X Latin American Symposium on Nuclear Physics and Applications

Edificio Polifuncional J.L. Massera
Universidad de la República
Montevideo, Uruguay, December 1-6, 2013

Book of Abstracts
PARALLEL SESSIONS
(Version Nov. 20, 2013)
Parallel Session 1 - Nuclear Structure (Room A21)  Chair: M. Gai

14:00 - 14:20  
*Experimental study of the resonant elastic scattering $^8$Li($p,p)^8$Li*
Alinka Lépine-Szily, Universidade de Sao Paulo, Brazil

14:20 - 14:40
*Measurement of charge-changing cross sections of neutron-rich boron isotopes*
Alfredo Estradé, Saint Mary’s University, Halifax, Canada and GSI Darmstadt, Germany

14:40 - 15:00
*Alpha-cluster model for $^{12}$C*
Roelof Bijker, ICN-UNAM, Mexico

15:00 - 15:20
*Alpha resonances excited in $^{13}$C and $^{16}$O by the ($^6$Li,$d$) reaction*
Thereza Borello-Lewin, Universidade de Sao Paulo, Brazil

15:20 - 15:40
*Self-Consistent Quantal Cranking Model for Monopole Excitations in Light Nuclei*
Parviz Gulshani, NUTECH Services, Canada
Experimental study of the resonant elastic scattering $^8\text{Li}(p,p)^8\text{Li}$

A. Lépine-Szily$^1$, E. Leistenschneider$^1$, P. Descouvemont$^2$, D. R. Mendes Jr.$^3$, R. Lichtenthäler$^1$, E. L. A. Macchione$^1$, V. Guimarães$^1$, R. P. Condori$^1$, V. Scarduelli$^1$, E. Rossi$^1$, J. Duarte$^1$, V. A. Zagatto$^1$, V. A. P. Aguiar$^1$, M. C. Morais$^1$, H. Santos$^1$, P. N. de Faria$^3$, V. Morcelle$^3$, K. C. C. Pires$^4$, T. Britos$^5$, and M. P. Assunção$^5$

$^1$Instituto de Física, Universidade de São Paulo, São Paulo, Brazil
$^2$Université Libre de Bruxelles, Brussels, Belgium
$^3$Universidade Federal Fluminense, Niterói, Brazil
$^4$Universidade Tecnológica Federal do Paraná, Cornélio Procópio, Brazil and
$^5$Universidade Federal de São Paulo, Diadema, Brazil

The resonant elastic scattering $^8\text{Li}(p,p)$ was measured at the Radioactive Ion Beams in Brazil (RIBRAS) Facility[1], which consists of two super-conducting solenoids of maximum magnetic field $B=6.5T$, coupled to the 8UD-Pelletron tandem Accelerator installed in the Pelletron Laboratory at the University of São Paulo Physics Institute. The aim of the experiment is to study resonances of the $^9\text{Be}$ compound nucleus close to the $^8\text{Li}+p$ threshold (16.8882MeV). These resonances have been observed and studied by our group in a previous experiment, through the $^8\text{Li}(p,\alpha)$ reaction [2].

The reaction was measured in inverse kinematics, at three incident energies: 15.8, 18.4 and 19.9 MeV, using the $^8\text{Li}$ secondary beam and a polyethylene $[\text{CH}_2]_n$ target. The thick target method was used, where the $^8\text{Li}$ beam is slowing down inside the target and the energetic protons emitted in the forward angles are detected. Their energy spectra yields the excitation function of the reaction. The experiment was realized using both superconducting solenoids of RIBRAS, with a $[\text{CH}_2]_n$ degrader between them, in order to eliminate most of the contaminant beams. The $^8\text{Li}$ beam purity was typically 97-99% in the scattering chamber installed after the second solenoid. The reaction products were measured at $\theta_{lab}=10^\circ$ using silicon detectors mounted as a $\Delta E - E$ telescope.

The simultaneous measurement of protons and $\alpha$-particles allows the attainment of the $^8\text{Li}(p,p)$ and $^8\text{Li}(p,\alpha)$ excitation functions between $E_{cm} = 0.3 - 2.2$ MeV, at the same time. The data will be presented together with R-matrix calculations [3], which allows the determination of excitation energies, spins, parities, total and partial widths of all observed resonances.


*This work was supported by Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP).
Measurement of charge-changing cross sections of neutron-rich boron isotopes

A. Estradé¹,²,∗ R. Kanungo¹, F. Ameil², J. Atkinson¹, Y. Ayyad³, D. Cortina-Gil³, I. Dillman², A. Evdokimov², F. Farinon², H. Geissel², G. Guastalla², W. Horiuchi⁴, R. Janik⁵, M. Kimura⁴, R. Knöbel², J. Kurcewicz², Y. Litvinov², M. Marta², M. Mostazo³, I. Muhka², C. Nociforo², H-J. Ong⁶, S. Pietri², A. Prochazka², C. Scheidenberger², B. Sitar⁵, P. Strmen⁵, Y. Suzuki⁷, M. Takechi², J. Tanaka⁶, I. Tanihata⁶, S. Terashima⁸, Y. Vargas³, H. Weick², and J. Winfield²

¹Department of Astronomy and Physics, Saint Mary’s University, Halifax, NS B3H 3C3, Canada
²GSI Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt, Germany
³Universidad de Santiago de Compostela, E-15706 Santiago de Compostella, Spain
⁴Hokkaido University, Sapporo, 060 0810, Japan
⁵Faculty of Mathematics and Physics, Comenius University, 84215 Bratislava, Slovakia
⁶RCNP, Osaka University, Mihogaoka, Ibaraki, Osaka 567 0047, Japan
⁷Niigata University, Niigata 950 2181, Japan and
⁸Beihang University, HaiDan District, Beijing 86-134-6633-8905, China

The large asymmetry between the proton and neutron numbers of unstable nuclei can lead to unusual nuclear matter distributions, which include the development of a neutron skin, or nucleon clusters and halo structures. Understanding these phenomena provides a valuable insight into the underlying nuclear structure features, such as the properties of the nuclear interaction and correlations between nucleons. We present results from a measurement of charge-changing cross sections for neutron-rich isotopes using the FRS fragment separator at GSI, in Germany. This is a sensitive method to determine the proton radius of unstable isotopes through a Glauber model analysis of the measured cross sections. We will describe the details of the experimental setup, and present new results for proton radii along the boron isotopic chain, up to the borromean nuclei ¹⁷B.

∗Present address: University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom
Recently there has been a lot of interest in the structure of $^{12}\text{C}$, especially the Hoyle state and its excitations [1-4]. The (collective) nature of the Hoyle state which is of crucial importance in stellar nucleosynthesis to explain the observed abundance of $^{12}\text{C}$, has presented a formidable challenge to nuclear structure calculations, such as shell model, cluster model or \textit{ab initio} lattice calculations. In order to determine the geometrical configuration of the three $\alpha$ particles it is crucial to identify the rotational sequences which have a characteristic pattern for triangular configurations [5] and another pattern for linear [6] or bent-arm configurations [7].

In this contribution, I discuss the spectroscopy of $^{12}\text{C}$ in the framework of the Algebraic Cluster Model in which the relative motion of the $\alpha$ clusters is described in terms of a $U(7)$ spectrum generating algebra [5]. In this approach the clusters are located at the vertices of an equilateral triangle (with $D_{3h}$ symmetry) which gives rise to a particular rotational sequence $J^P = 0^+, 2^+, 3^-, 4^+, 5^-, \ldots$.

Finally, I discuss how the ACM can be extended to four-body clusters with a possible application to $^{16}\text{O}$ as a configuration of four $\alpha$ particles at the vertices of a tetrahedron (with $T_d$ symmetry) [8].


\*This work was supported in part by grants from DGAPA-UNAM and CONACyT, Mexico
The investigation of α cluster correlations is the main purpose of the research program in progress, focusing on xα and xα + ν nuclei[1]. The reactions ⁹Be(⁶Li,d)¹³C and ¹²C(⁶Li,d)¹⁶O measured at the bombarding energy of 25.5 MeV, employing the São Paulo Pelletron-Enge-Spectrograph facility and the nuclear emulsion technique, were used to enhance α resonant states in ¹³C and ¹⁶O. An energy resolution of 20-40 keV was obtained and up to 15.5 MeV of excitation, in both nuclei, several resonances not previously measured, revealing a quasi-bound behavior, were detected. Focusing on ¹³C, the experimental angular distributions associated with the resonances just above the ⁹Be + α and 3α + ν thresholds[2] were compared with DWBA predictions. Seen at the ⁹Be + α threshold, a pure L = 4 transfer is indicated for each transition to the known ⁷/₂⁻ and (⁵/₂⁻) states instead of L = 2 obtained in the former fit[3] to the integrated contribution. The narrow resonance detected at 12.3 MeV of excitation, close to the 3α + ν threshold and populated by an L = 2 transfer, reveals a ⁹Be(G.S.) + α component for the ⁷/₂⁻ cluster state candidate, ¹²C(Hoyle) + ν, at this threshold. Considering the ¹⁶O, states were revealed around the 4α threshold (14.44 MeV) and the upper limit resonant widths were obtained. The resonance at 14.670 MeV was reached by an L = 5 direct transfer in agreement with the ⁵⁻ attribution. The upper limit width obtained, near the experimental resolution, is inconsistent with the usual experimental[4,5] and theoretical[6-7] interpretations of the ⁵⁻ state revealed as a broad resonance in the same excitation energy region and considered to be a member of the Kπ = 0⁻ band with the ¹²C(G.S.) + α structure. In the same excitation energy range, a narrow ⁵⁻ resonance decaying to ¹²C(2⁺₁), was predicted by Suzuki[6] using a comprehensive semi-microscopic alpha cluster calculation, in agreement with the present findings. Haigh et al.[8], in the investigation of the ¹²C decay products of the ¹⁶O ⁵⁻ resonance excited through the ¹²C(¹³C, ⁹Be)¹⁶O reaction, detected not only a ¹²C (G.S.), but also a small ¹²C(2⁺₁) contribution. The work is in progress.


* This work was supported in part by the brazilian funding agencies: FAPESP and CAPES.
Previously [1], we modeled collective monopole excitations in nuclei as oscillations in the nuclear radius in two dimensional space. By using a monopole-intrinsic product wavefunction and transforming the shell-model Schrödinger equation accordingly, we obtained a Schrödinger equation that is a sum of monopole and intrinsic parts and a term that couples these parts. Assuming the value of the monopole frequency, we obtained a solution of this equation using its underlying monopole $su(1,1)$ algebra and treating the monopole-intrinsic coupling term in a first order perturbation. The resulting calculated excitation energy of the first excited monopole state in light nuclei was found to be significantly lower than that determined experimentally.

We have now generalized this model to three dimensional space. To fully account for the coupling between the monopole and intrinsic motions, we have applied a constrained variational method to the monopole-intrinsic Schrödinger equation to resolve it into two coupled cranking-type Schrödinger equations, one for the monopole oscillations and another for the intrinsic motion. Each of these cranked equations contains its own cranking parameter and energy, which must be determined self-consistently by the solutions of the equation themselves.

The aforementioned self-consistency renders the two cranked equations time-reversal invariant unlike the conventional phenomenological Inglis-type cranking models [2,3]. The self-consistency also requires that the solutions of the equations be real in contrast to the unitary solutions of the conventional Inglis-type cranking models [3].

We determine the real solutions of the above-mentioned coupled cranking-type Schrödinger equations. These solutions are used to determine self-consistently the cranking and energy parameters in the equations. Using these solutions, an energy-weight sum rule, and the cranked equations, we determine the monopole frequency.

The impact of the monopole constraint on the intrinsic system is investigated using the first moment of the monopole constraint, a constrained variational method, and first order perturbation method. The excitation energy of the first excited $0^+$ state is calculated and compared with that observed experimentally in light nuclei. The presentation discusses the associated discrepancies and future developments to remedy them.

Tuesday December 3 (14:00 - 15:40)

Parallel Session 2 - Applications  (Room C12)  Chair: A. Hutton

14:00 - 14:20  Use of the FLUKA Monte Carlo code for Hadron Therapy Application
Andrea Mairani, CNAO Foundation, Italy and HIT, Heidelberg, Germany

14:20 - 14:40  Ongoing investigations on ion radiography and tomography
Lorena Magallanes, Heidelberg University Clinic and LMU Munich, Germany

14:40 - 15:00  RTHC a new proposal for radiation therapy
Rodolfo Figueroa, Universidad de La Frontera, Temuco, Chile

15:00 - 15:20  The $^9$Be($d$,n)$^{10}$B reaction as a neutron source for Boron Neutron Capture Therapy
María Eugenia Capoulat, CNEA, Universidad Nacional de San Martín, CONICET, Argentina

15:20 - 15:40  High-sensitivity radiation detector for low dose levels radiological applications
Mauro Valente, CONICET and Universidad Nacional de Córdoba, Argentina
Use of the FLUKA Monte Carlo code for Hadron Therapy Application

A. Mairani\textsuperscript{1,2}, G. Battistoni\textsuperscript{3}, T. T. Böhlen\textsuperscript{4}, F. Cerutti\textsuperscript{4}, A. Ferrari\textsuperscript{4}, T. Haberer\textsuperscript{2}, K. Parodi\textsuperscript{2}, V. Patera\textsuperscript{5}

\textsuperscript{1} Medial Physics Unit, CNAO Foundation, Pavia, Italy
\textsuperscript{2} Heidelberg Ion Beam Therapy Center, Heidelberg, Germany
\textsuperscript{3} Istituto Nazionale di Fisica Nucleare (I.N.F.N.), Milan, Italy
\textsuperscript{4} European Organization for Nuclear Research CERN, CH-1211, Geneva 23, Switzerland
\textsuperscript{5} Dipartimento di Scienze di Base e Applicate per l'Ingegneria, Sapienza Università di Roma, Rome, Italy

Monte Carlo (MC) codes are increasingly spreading in the hadrontherapy community due to their detailed description of radiation transport and interaction with matter. MC methods are being utilized at several institutions for a wide range of activities spanning from beam characterization to quality assurance and dosimetric/radiobiological studies. The suitability of a MC code for application to hadrontherapy demands accurate and reliable physical models for the description of the transport and the interaction of all components of the expected radiation field (ions, hadrons, electrons, positrons and photons). This becomes extremely important for correctly performing not only physical but also biologically-based dose calculations especially in cases where ions heavier than protons are involved. In addition, accurate prediction of emerging secondary radiation is of utmost importance in emerging areas of research aiming to in-vivo treatment verification.

This contribution will address the specific case of the general-purpose particle and interaction code FLUKA. Validations and applications at several experimental sites as well as proton/ion therapy facilities with active beam delivery systems will be presented:

- Generation of synchrotron accelerator library of proton/carbon ion beam energies and foci (i.e., lateral widths at the isocentre of the treatment unit).
- Physical database generation: laterally integrated depth-dose profiles, lateral-dose distributions at different depths, secondary fragments yields and fragment energy spectra at different depths.
- Forward MC re-calculations of physical/RBE-weighted dose distributions of proton and carbon ion treatment plans.
- MC-based treatment planning in proton therapy.

The satisfactorily agreement of FLUKA against several dosimetric/nuclear yields data indicates that the code already represents a valuable choice for supporting a large variety of applications in proton and ion beam therapy.
Ongoing investigations on ion radiography and tomography

L. Magallanes\textsuperscript{1,4}, I. Rinaldi\textsuperscript{1,4}, O. Jäkel\textsuperscript{1,2,3}, K. Parodi\textsuperscript{1,4}, M. Takechi\textsuperscript{5}, and B. Voss\textsuperscript{5}

1 Heidelberg University Clinic (Dep. radiation Therapy and Radiation Oncology) Heidelberg, Germany
2 Heidelberg Ion Therapy Center, Heidelberg, Germany
3 German Cancer Research Center, Heidelberg, Germany
4 Ludwig Maximilians University Munich, Garching, Germany and
5 GSI Helmholtz Center for Heavy Ion Research, Darmstadt, Germany

The major advantage of ion therapy is the conformal tumor-dose distribution characteristic of the inverted depth-dose profile and the well-defined range of ion beams (Bragg peak). However, the range in tissue is very sensitive to uncertainties. A significant shift of the Bragg peak’s distal dose fall-off may lead to underdosage of the tumor or overdosage of surrounding organs at risk.

To account for these range uncertainties, a novel imaging technique is investigated. Ion radiography and tomography use higher energy therapeutic ion beams that are detected after they exit the patient. This imaging technique is suitable to be applied at different stages of the treatment flow. During the planning phase, the distribution of relative stopping power in the patient can be reconstructed and introduced as input of the treatment planning system. This way, the uncertainty arising from the CT-HU to WEPL calibration can be minimized. Moreover, during the delivery phase, transmitted planar or volumetric images of the patient can be used in-vivo and prior to the treatment to monitor patient positioning and morphological changes as well as for range verification.

At the Heidelberg Ion Beam Therapy center\textsuperscript{[1]}, in cooperation with the GSI Helmholtz Center for Heavy Ion Research, a prototype detector system consisting of a stack of 61 parallel ionization chambers has been assembled to investigate the potential of radiographic and tomographic ion-based imaging\textsuperscript{[2, 3]}. The experiments carried out until now, especially using carbon ion beams, show promising images of phantoms of different complexity and composition\textsuperscript{[4]}.

A detailed characterization of the detector, namely setup and read-out electronics, has been done. It reveals the importance of further optimization of the actual detector system, data acquisition and image reconstruction methods towards an eventual clinical use. This contribution will present the status and on-going investigations of this transmission imaging technique in the frame of a joint project between the University Clinic in Heidelberg, the Ludwig Maximilians University in Munich, and the GSI Helmholtz Center for Heavy Ion Research.

RTHC a new proposal for radiation therapy*

R. Figueroa‡

Universidad de La Frontera, Temuco, Chile

RTHC (Radioterapia de Haz Convergente) is a new proposal technique for external radiotherapy based on a single convergent photons beam by means of a device capable to generate a single beam of convergent X photons. Previous studies [1] have shown that a primary beam of these characteristics provides excellent dosimetric results with a dose peak close to the isocenter, similar those used for hadron therapy treatment. To determine the physical and dosimetric characteristics of a device convergent X photons beam and its potential to be used in clinical treatments. Analytical developments plus software that allows determining the necessary fields (electrostatic and/or magnetic fields) for electrons trajectory control are used. Monte Carlo simulation code (PENELOPE) is applied to a specially designed geometry for the generation of a convergent photons beam. We determined the values of the magnetic and/or electric fields to handle the convergent beam device for an electrons’ energy range from 0.1 to 20 MeV. Angular distribution curves of the bremsstrahlung were determined for different thicknesses and incident electrons energies (0.4 to 6.0 MeV), plus the respective doses distribution in each case, characterized by a high dose concentration, close to the isocenter. We can conclude that the physical and dosimetric characteristics of convergent beam device radiotherapy have been determined. The achieved results show that it is possible to develop a convergent beam prototype of low and high energy as a single unit or to be adapted to an existing radiation-therapy LINAC, so this might be used either in the conventional mode or in the conventional one, depending on the case.


* This work was supported in part. Corfo – Innova Project 12IDL1-13124 and Universidad de La Frontera.

‡ Present address: Current Institution: Universidad de La Frontera, Temuco, Chile
The $^9\text{Be}(d,n)^{10}\text{B}$ reaction as a neutron source for Boron Neutron Capture Therapy

M.E. Capoulat$^{1,2,3}$‡, M.S. Herrera$^{1,2,3}$, D.M. Minsky$^{1,2,3}$ and A.J. Kreiner$^{1,2,3}$

$^1$Gerencia Investigación y Aplicaciones, CNEA, San Martín, Argentina
$^2$Escuela de Ciencia y Tecnología, Universidad Nacional de San Martín, San Martín, Argentina
$^3$CONICET, Buenos Aires, Argentina.

Boron Neutron Capture Therapy (BNCT) is a cancer therapy modality under development worldwide appearing as a promising alternative for diffuse, infiltrating and very radioresistant tumors. The therapy involves the selective accumulation of a $^{10}\text{B}$-carrying compound in tumor tissue followed by irradiation with a beam of thermal (for superficial tumors) or epithermal (for deep-seated tumors) neutrons. Neutrons are captured by $^{10}\text{B}$ present in tumor cells producing high LET and short-range radiation (an $\alpha$ particle and a $^7\text{Li}$ ion) that damages the targeted cells without harming the surrounding healthy tissue.

Several neutron-producing reactions have been thoroughly investigated as potential neutron sources for BNCT. Among them, the $^7\text{Li}(p,n)^7\text{Be}$ reaction is probably the optimal one from a neutronic point of view. However, the implementation of a $^7\text{Li}$ target constitutes a non-trivial challenge, mainly due to the difficulties related to power dissipation on the target material (which is $\sim$75 kW) and the presence of residual $^7\text{Be}$ radioactivity. In this context, the $^9\text{Be}(d,n)^{10}\text{B}$ reaction stands out as a potential alternative. First, metallic Be has more suitable thermal and mechanical properties compared to metallic Li, which allows reducing most of the target cooling requirements. Moreover, there is no residual radioactivity in the $^9\text{Be}(d,n)^{10}\text{B}$ reaction. Last but not least, the low deuteron energies involved in the $^9\text{Be}(d,n)$ reaction ($\sim$1.4 MeV) imply an advantage concerning voltage requirements, dimensions of the accelerator and costs compared to the $^7\text{Li}(p,n)$ reaction, which requires proton energies of $\sim$2.3 MeV.

In Argentina, a project aimed at the construction of a Tandem Electrostatic Quadrupole accelerator-based facility for BNCT is currently ongoing. A first prototype (which is in an advanced development stage) would be capable of delivering 30 mA of protons or deuterons of about 1.4 MeV, and it is intended to work in conjunction with the $^9\text{Be}(d,n)^{10}\text{B}$ reaction. In this context the potential use of the $^9\text{Be}(d,n)^{10}\text{B}$ reaction has been studied both for deep-seated and superficial tumors. Monte-Carlo simulations (including the treatment planning assessment of a real glioblastoma multiforme case) showed that treatment qualities comparable to those obtained with the optimal $^7\text{Li}(p,n)$-based neutron source are feasible. These results strengthen the prospects for an operative BNCT facility in the short-term.

* This work was supported in part by the National Atomic Energy Commission (CNEA), the National Scientific and Technical Research Council (CONICET) and the National University of San Martín (UNSAM)
‡ Present address: GlyA-CNEA, Av. Gral Paz 1499 (B1650KNA) San Martín, Argentina
High-sensitivity radiation detector for low dose levels radiological applications∗

M. Valente1,2, W. Molina3, and J. Vedelago2†

1 Instituto de Física Enrique Gaviola CONICET, Córdoba, Argentina
2 Facultad de Matemática, Astronomía y Física - Universidad Nacional de Córdoba, Córdoba, Argentina and
3 Venezuelan Institute of Scientific Research IVIC, Caracas, Venezuela

Radiation dosimetry by Fricke gel was largely used, generally focused and optimized for radiotherapy applications therefore involving relative high dose levels [1]. Many relevant advantages, like linear response, being dose rate and LET almost independent, tissue-equivalence and mainly continuous 3D dose mapping, suggest that its adaptation to low doser level radiological applications might constitute a valuable tool.

This work presents the characterization and performance of a novel dosimeter based on Fricke solution optimized for low dose levels [2]. Several chemical composition were studied to achieve satisfactory response for low dose levels, obtaining a modified Fricke solution consisting of suitable sulphuric acid, ferrous sulphate, Xylenol orange and benzoic acid concentrations that were optimized for assessing high sensitivity at low dose levels. Sample in standard spectrophotometric vials were irradiated with X-ray beams inside water-equivalent phantoms. solid-state CdTe detector was used to characterize radiation quality; whereas calibrated ionization chamber was used as reference to measure dose rates. Samples were analyzed by light transmission and absorbance before and after irradiation. Sensitivity for low dose levels was significantly improved by the developed system, which was benchmarked using typical setups for conventional radiography. Dosimeter vials were placed inside a water-equivalent phantom exposed to kilovoltage X-ray beam imaged (using long acquisition times) with a bi-dimensional digital detector, the integral beam line at Laboratorio de Investigaciones e Instrumentación en Física Aplicada a la Medicina e Imágenes por Rayos X (LIIFAMIRX), as it is customary in radiology.

Comparisons of dose values between Fricke gel dosimeter, ionization chamber and Monte Carlo simulations were performed for complex digital radiography setups. It should be remarked that the proposed method exhibits satisfactory reliability and high performance suggesting its potentiality as a promising low-level dosimetry system.


∗This work was supported in part by projects CONICET-PIP 11420090100398 SeCyT-UNC ISIDORA I and MsC. scholarship of IVIC-Venezuela
†Present address: Universidad Nacional de Córdoba - Medina Allende esquina Haya de la Torre Ciudad Universitaria, Córdoba, Argentina. Email: valente@famaf.unc.edu.ar
Tuesday December 3 (14:00 - 15:40)

Parallel Session 3 - Fundamental Interactions  (Room B11)  Chair: D. Melconian

14:00 - 14:20  The nuclear matrix elements of double beta decay in Pseudo-SU(4) model  
José Patricio Valencia, Universidad de Antioquia, Colombia

14:20 - 14:40  Neutron Electric Dipole Moment Search at the Paul Scherrer Institute  
Gilles Ban, ENSICAEN, France

14:40 - 15:00  Spin physics at COSY and beyond  
Alexander Nass, Forschungszentrum Jülich, Germany

15:00 - 15:20  Lorentz invariance violation in weak interaction: search for effects in beta decay of polarized neutrons  
Kazimierz Bodek, Jagiellonian University, Cracow, Poland

15:20 - 15:40  Toward a measurement of the Fierz interference term in $^6$He decay  
Oscar Naviliat-Cuncic, Michigan State University, USA
Due to the importance in determining the neutrino mass, the study of the neutrinoless double beta decay ($0\nu\beta\beta$) has gained much attention in recent years. In the perspective of nuclear structure the focus is the calculation of the nuclear matrix elements (NME) of the relevant nuclei. One way to tackle the problem is to study the NME of the corresponding $2\nu\beta\beta$. To this end, various models are explored, i.e. the Interacting Shell Model [1], the Interacting Boson Model[2], etc.

This work intends to calculate the NME of the $2\nu\beta\beta$ decay $^{76}\text{Ge} \rightarrow ^{76}\text{Se}$ in the framework of the pseudo-SU(4) × pseudo-SU(6) model [3], since the concept of pseudo-orbit and pseudo-spin describes well the strong mixing among the $\frac{p}{2} - \frac{p}{2} - f_{\frac{5}{2}}$ (or the $\tilde{d}s$) orbits. The shell model space of the two nuclei is decomposed into $\tilde{d}s$- and $g$-subshell. While for the $g$-subshell the seniority zero restriction applies [4], in the $\tilde{d}s$ subshell the SU(3) symmetry dominates [3,5], which reflects the strong interaction between proton- and neutron-sector.

For the nuclei $^{76}\text{Ge}$ and $^{76}\text{Se}$, the experimental occupation numbers [1] of different orbits provide constraints to the configurations $(N_\pi, N_\nu)$ and [$(M_\pi, M_\nu)$] in the $g$- and the $\tilde{d}s$-subshell, respectively. In the $g$-subshell it is reasonable to restrict the configuration to $(n_1, n_2)$ with $n_1 = 0, 2$ and $n_2 = 4, 6, 8$, respectively for both nuclei. The corresponding configurations in the $\tilde{d}s$-subshell are $[(4 - n_1), (16 - n_2)]$ for $^{76}\text{Ge}$ and $[(6 - n_1), (14 - n_2)]$ for $^{76}\text{Se}$, respectively. Through an algebraic analysis of the $\tilde{\text{SU}(4)} \times \tilde{\text{SU}(6)}$ model, taking into account the seniority-zero restriction for $g$-subshell, the two beta decays happen only either within the $g$-subshell or in the $\tilde{d}s$-subshell. Therefore there exist only two types of transition, i.e.

$$(n_1, n_2) \rightarrow ((n_1 + 2), (n_2 - 2)),$$

$$(m_1, m_2) \rightarrow [(m_1 + 2), (m_2 - 2)].$$

This feature greatly simplifies the calculation of NME of the $2\nu\beta\beta$. The amplitudes of the configurations are determined by fitting the nuclear properties of the two nuclei and then used in the calculation of NME of the $2\nu\beta\beta$ decay.


*This work was supported in part by CODI, Universidad de Antioquia, Medellin, Colombia
Search for Electric Dipole Moments (EDM) is a very powerful tool to probe physics beyond the Standard Model. In any Standard Model extension EDM can be calculated, these values can be compared to the experimental limits and therefore SM extensions can be validate. For the neutron electric dipole moment (nEDM) the current best limit has been set by the Sussex-Rutherford-ILL [1] at $|d_n| < 2.9 \times 10^{-26} \text{ cm (90\% CL)}$. This experimental limit is far away from the SM value, still extension of the SM give nEDM values which are in the range of new nEDM experiments. By using room temperature apparatus and ultra cold neutrons our collaboration is aiming at improving the current limit. At the Paul Scherrer Institute (PSI), Villigen, Switzerland, where a new ultra cold neutron source is running (2011), we have installed an improved RAL Sussex spectrometer and the collaboration aims to put a new limit on the nEDM: in the range of $10^{-26} \text{ e.cm at 95\% CL}$. We will present the experiment status, improvements and discuss the ongoing R&D effort on a new spectrometer schedule to run in 2017.

Spin physics at COSY and beyond

Alexander Nass\textsuperscript{1}\textsuperscript{*}

\begin{flushright}
\textsuperscript{1}Institut für Kernphysik, Forschungszentrum Jülich, Jülich, Germany
\end{flushright}

Hadron physics aims at a fundamental understanding of all particles and their interactions that are subject to the strong force. Experiments using hadronic probes bear the potential to shed light on open questions that address the structure of hadrons and their interaction, as well as the symmetries of nature. The COoler SYnchrotron COSY [1] at the Forschungszentrum Jülich accelerates protons and deuterons with momenta up to 3.7 GeV/c. In combination with internal polarized Hydrogen and Deuterium targets, the availability of electron and stochastically cooled polarized proton and deuteron beams allows for precision measurements.

This presentation highlights selected recent results from the ongoing spin physics programs at the COSY facility [2]. Spin physics projects reaching into the future, such as the quest for polarized antiprotons [3,4], the search for permanent electric dipole moments of protons and deuterons, and a test of time reversal invariance [5] using COSY, are presented as well.

\begin{enumerate}
\item R. Maier, Nuclear Instruments and Methods A390 (1997), 1-8
\item A. Kacharava and C. Wilkin, Nuclear Physics News, Vol. 23 No. 2 (2013)
\item W. Augustyniak, Physics Letters B 718 (2012), 64-69
\item D. Eversheim et al., Hyperfine Interact. 193 (2009), 335-339
\end{enumerate}

*Corresponding author - a.nass@fz-juelich.de
LORENZ INVARIANCE VIOLATION IN WEAK INTERACTION: SEARCH FOR EFFECTS IN BETA DECAY OF POLARIZED NEUTRONS

K. Bodek\textsuperscript{1}, G. Ban\textsuperscript{4}, A. Bialek\textsuperscript{2,}\textsuperscript{*}, A. Kozela\textsuperscript{2}, P. Gorel\textsuperscript{4,3,1,}\textsuperscript{*}, K. Kirch\textsuperscript{3,7}, St. Kistryn\textsuperscript{1}, M. Kuzniak\textsuperscript{1,2,}\textsuperscript{‡}, O. Naviliat-Cuncic\textsuperscript{4,8}, N. Severijns\textsuperscript{5}, E. Stephan\textsuperscript{5} and J. Zejma\textsuperscript{1}

\textsuperscript{1}Institute of Physics, Jagiellonian University, Cracow, Poland
\textsuperscript{2}Institute of Nuclear Physics, Polish Academy of Sciences, Cracow, Poland
\textsuperscript{3}Paul Scherrer Institute, Villigen, Switzerland
\textsuperscript{4} Universite de Caen Basse-Normandie, CNRS/IN2P3-ENSI, LPC, Caen, France
\textsuperscript{5} Katholieke Universiteit Leuven, Leuven, Belgium
\textsuperscript{6} Institute of Physics, University of Silesia, Katowice, Poland
\textsuperscript{7} Swiss Federal Institute of Technology, Zurich, Switzerland
\textsuperscript{8} Michigan State University, East-Lansing, MI 48824, USA

Lorentz Invariance (LI) belongs to the most basic principles underlying our understanding of nature. No compelling evidence for its violation has been found so far but various tests with increasing accuracy are ongoing motivated by the search for new physics. Among the four interactions, electromagnetism imposes the most stringent constraints while very little is known about the weak interaction in this context. Sidereal and daily modulations have been searched for in beta decay of free polarized neutrons. A sample of about 3 x10\textsuperscript{8} decay electrons distributed over a three month long data taking period were analyzed. Independent upper limits have been deduced for the coupling of the neutron spin and the electron momentum to an external field postulated as an exotic admixture to the weak interaction dominating in neutron decay [1]. Recently, a formalism was developed within the effective field theory approach including a tensor term in the W boson propagator which explicitly violates LI [2]. This formalism allows to interpret the investigated sidereal and daily modulations of the neutron beta decay observables from Ref. [1] in terms of the SME parameters [3]. The resulting upper limits for certain combinations of these parameters will be presented.


* Present address: University of Alberta, Edmonton, Canada.
‡ Present address: Department of Physics, Queen's University, Kingston, Ontario, Canada
Toward a measurement of the Fierz interference term in $^6$He decay

O. Naviliat-Cuncic$^{1,2}$, D. Bazin$^1$, A. Gade$^{1,2}$, X. Huyan$^1$, S. Liddick$^{1,3}$,
K. Minamisono$^1$, S. Noji$^1$, A. Simon$^1$ and D. Weisshaar$^1$

$^1$National Superconducting Cyclotron Laboratory, Michigan State University, East-Lansing, USA
$^2$Department of Physics and Astronomy, Michigan State University, East-Lansing, USA
$^3$Department of Chemistry, Michigan State University, East-Lansing, USA

Precision measurements of correlation observables in nuclear beta decay provide sensitive means to test the standard electroweak model (SM) and to search for new physics beyond. The presence of new physics would manifest itself in the correlation observables through phenomenological scalar or tensor couplings which are excluded by the SM.

In the beta decay of nuclei and in neutron decay, the Fierz interference term is one of the most sensitive parameters to such exotic couplings since it is linear in those couplings and provides therefore competitive constraints as compared to those obtained from high energy physics [1]. Stringent constraints on scalar couplings have been obtained from the contribution of the Fierz term to the $\mathcal{F}$-values in pure Fermi transitions [2] but the constraints on tensor couplings obtained from pure Gamow-Teller transitions are significantly weaker [1].

The Fierz term has rarely been measured directly in the past, mainly because of difficulties related with the back-scattering or out-scattering of electrons from detectors or with the control of possible dead-layers which induce distortions in the energy spectrum of beta particles.

We have performed an experiment at the National Superconducting Cyclotron Laboratory, using a high purity beam of $^6$He produced by fragmentation of $^{18}$O, with the purpose to explore the measurement of the Fierz term in a geometry where the beta particles do not have to cross any interface and where the detection system has no moving parts. The extracted $^6$He ions, with an initial energy of 77 MeV/nucleon, have first been degraded down to 46 MeV/nucleon and then implanted into CsI(Na) and NaI(Tl) scintillation detectors, at about 12 mm from the detector surface. Since the range straggling of the beam is about 2 mm and the range of 3.5 MeV electrons (end point of $^6$He decay) in these materials is about 6-7 mm, no beta particle can escape from the scintillators, depositing thereby their full energy in the detectors and eliminating the problems of partial energy deposition.

Particular attention has been devoted to identify possible beam contaminants as well background produced by beam induced reactions in the detectors.

This contribution will describe the experiment and present the status of the data analysis.


(*) This work was supported by the US National Science Foundation under grant number PHY-11-02511
Tuesday December 3 (16:00 - 17:40)

Parallel Session 4 - Applications (Room C12) Chair: A. Menchaca

16:00 - 16:20  Evaluation of high resolution detectors for table-top phase contrast enhanced Microradiography
Karla D. Palma-Alejandro, Czech Technical University, Prague, Czech Republic

16:20 – 16:40  Investigation of Ca and Mg in blood of dystrophic animal model using NAA
Sabrina Metairon, IPEN – CNEN, Sao Paulo, Brazil

16:40 – 17:00  A clinical study of contrast-enhanced digital mammography to correlate image descriptors with angiogenesis
María Ester Brandan, UNAM, Mexico

17:00 – 17:20  Dosimetry Optimization System and Integrated Software (DOSIS): a comparison against FLUKA code results over a standard phantom
Pedro Pérez, Agencia Nacional de Promoción Científica, Buenos Aires and Universidad Nacional de Córdoba, Argentina

17:20 – 17:40  Modelling of Computed Tomography filtration by Compton spectroscopy: Evaluation by Monte Carlo simulation
Stella Veloza, Universidad Nacional de Colombia, Bogota, Colombia
EVALUATION OF HIGH RESOLUTION DETECTORS FOR TABLE-TOP PHASE CONTRAST ENHANCED MICRORADIOGRAPHY*

Karla D. Palma-Alejandro, Franticek Krejci, Jan Zemlicka, Jan Dudak, Jan Jakubek, and Carlos Granja
Institute of Experimental and Applied Physics, Czech Technical University in Prague, Horska 3a/22, CZ 12800 Prague, Czech Republic

High resolution radiography is a powerful imaging technique for real time and nondestructive visualization of fine internal structure of materials and biomedical samples. X-ray imaging is based on attenuation, but this may be a difficult task for visualization of structures with similar elemental compositions. However, high performance electronic imagers are able to resolve these similarities in attenuation by utilising and improving their properties. In addition to conventional beam attenuation contrast imaging techniques, additional information may be further improved by X-ray diffraction techniques (phase-contrast) [1] which require either a coherent X-ray source (synchrotron accelerator) or a highly sensitive detector (Medipix [2]). This phase contrast is complementary to absorption contrast produced solely by attenuation. In this study radiographs of different samples were obtained using a microfocus X-ray tube, a hybrid semiconductor (silicon) pixel detector, Medipix2, and a commercial flat panel (scintillator-GOS) detector. High quality microradiographs were produced for biological samples such as a small fly, wasp and others. Phase-contrast enhanced images were acquired and evaluated. The analysis was performed regarding edge-enhancement relative to background, the contrast, and the signal-to-noise ratio (SNR) of the images acquired with both devices. The edge-enhancement was obtained from the image intensity profile using oversampling techniques [3]. Superior quality radiographs were obtained with the hybrid semiconductor pixel detector Medipix2, confirming that direct photon detection is preferable for high spatial resolution and contrast enhanced microradiography.


*This work was supported in part by the Institute of Experimental and Applied Physics in Czech Technical University in Prague and CONACYT-Mexico. Research performed in frame of the Medipix collaboration.
Investigation of Ca and Mg in blood of dystrophic animal model using NAA*

S. Metairon1, C.B. Zamboni1, M.F. Suzuki1, T.O. Andrade2, E.B. Cangussu2, C.R. Bueno Jr2, H.V.A. Caetano2, M. Zatz2

1 Instituto de Pesquisas Energéticas e Nucleares, IPEN – CNEN/SP
Av. Professor Lineu Prestes 2242
05508-000, São Paulo, SP, Brazil
metairon@live.com

2 Centro de Estudos do Genoma Humano, Instituto de Biociências, USP
Rua: do Matão, Travessa 13, 106
05508-090, São Paulo, SP, Brazil

In recent years, the Spectroscopy and Spectrometry Laboratory at IPEN – CNEN/SP (Brazil) has performed measurements related to the determination of inorganic elements in blood used in experimentation animals (rats, rabbits, mice) applying Neutron Activation Analysis technique (NAA) [1]. The advantage in using NAA to investigate blood is related to the fact that this analytic technique uses small quantity of blood (10 to 100 μL) when compared with the conventional clinical practices performed in serum (0.5 to 1.0 mL), resulting in an efficiency procedure for biochemical analysis mainly when the biological material is scarce. The success in these applications, with small and medium-sized animal models, has motivated us to study in more details the anomalies caused by Duchenne Muscular Dystrophy (DMD), an illness of hereditary character that affects approximately 1 in every 3,600 to 6,000 newborn boys in the world [2]. The DMD is the most severe and prevalent type of muscular dystrophy. The main characteristic of this genetic disease is instability of the membrane that involves the muscle fibers. However, in subject with DMD the dystrophin (a protein present in muscles) is altered causing critical muscular dysfunction causing a degeneration of the membrane that involves the muscular cell, leading its death. Nowadays, many promising therapeutic strategies have been developed in animal models with DMD. An animal model which has a phenotype similar to patients with DMD has been bred in Brazil: Golden Retriever Muscular Dystrophy dogs (GRMD). In these dogs, muscle degeneration and fibrosis are predominating, leading to a progressive loss of structure and muscle function, and resembling a human pathogenesis. In this study, elements of clinical relevance (Ca, Mg) were determined in blood of the GRMD using NAA at the IEA - R1 nuclear reactor. These data may help to evaluate the efficiency of new treatments as well as to show in more details the alterations that this disease may cause permitting to compare the advantages of different treatment schedules before performing tests in patients with DMD.


*This work was supported in part by CNPq
A clinical study of contrast-enhanced digital mammography to correlate image descriptors with angiogenesis

ME Brandon1, JP Cruz-Bastida1, I Rosado-Méndez1, Y Villaseñor2, L Benítez-Bribiesca3, P Sánchez-Suárez3, FE Trujillo-Zamudio4, HA Galván2, and H Pérez-Ponce1

1 Instituto de Física UNAM, Mexico City, Mexico
2 Instituto Nacional de Cancerología, Mexico City, Mexico
3 Hospital de Oncología, CMN SXXI, IMSS, Mexico City, Mexico
4 Hospital Regional de Alta Especialidad, Oaxaca, Mexico

Contrast-enhanced digital mammography (CEDM) is a technique based on the subtraction of images applying a contrast medium (CM), with the goal of eliminating the breast anatomical structure in the images. The CM generally contains iodine, due to the relatively high attenuation of X rays in iodine with respect to breast tissues. It is assumed that CEDM images enhance the visualization of the CM next to rapidly growing lesions as a consequence of angiogenesis, the formation of new microvessels.

This study is designed to investigate the possible correlation between iodine uptake in CEDM images and microvessel density in breast lesions. 19 patients, whose mammographies were classified as BIRADS 4-5, were included. A series of 6 images was acquired under one single breast compression, combining dual-energy and temporal acquisition. Low- and high-energy masks were acquired, CM was injected before the CM temporal sequence, a biopsy was obtained after the images, specific biomarkers for blood and lymphatic neo-microvessels were applied, and microvessel density was evaluated. In the processing, masks were subtracted from weighted CM images and the weight factor was a matrix obtained from the masks and contained pixel-by-pixel anatomical and radiological information[1]. Iodine uptake after the subtraction was quantified by contrast between the lesion and normal glandular tissue. Contrast was transformed into iodine mass thickness using calibrated samples.

11 lesions were malignant and 8, benign. The subtraction formalism severely reduced the anatomic noise in resulting images, compared with alternative techniques based on mean pixel values within regions-of-interest. Five types of time-intensity curves were identified, qualitatively similar to what is known for magnetic resonance images (MRI). Blood and lymphatic microvessel densities were correlated ($r=0.94$ $p<0.05$) and mean blood values in cancer were twice those in benign cases. No correlation was found between image contrast and microvessel density. The statistical distribution of uptake curves in benign and cancer cases, which resembles MRI, seems to be the most relevant parameter with a possible diagnostic value.


This work was supported in part by UNAM PAPIIT Grant IN105813 and CONACyT Salud 2009-01-112374.
Dosimetry Optimization System and Integrated Software (DOSIS): a comparison against FLUKA code results over a standard phantom

P. Pérez\(^1,2\), F. Botta\(^3\), M. Cremonesi\(^3\), M. Ferrari\(^3\), F. Guerriero\(^3\), F. Malano\(^3\), G. Pedroli\(^3\), I. Scarinci\(^2\), and M. Valente\(^2,4\)†

\(^1\) Agencia Nacional de Promoción Científica, Buenos Aires, Argentina
\(^2\) Facultad de Matemática, Astronomía y Física - Universidad Nacional de Córdoba, Córdoba, Argentina
\(^3\) European Institute of Oncology, Milan, Italy and
\(^4\) Instituto de Física Enrique Gaviola CONICET, Córdoba, Argentina

Dual-imaging facilities (PET-CT, SPECT-CT) allow obtainance of both mass and activity patient-specific distributions perfectly correlated, which may improve dose distributions estimations and radioimmunotherapy treatment planifications accuracy [1].

Calculation methods at voxel level require both quantitative and qualitative validation to obtain improvements in patient-specific dosimetry [2]. This work presents advances of a novel computational tool dedicated to 3D patient-specific dosimetry at voxel level.

Focusing on providing a dosimetric tool at voxel level, as well as the development of a platform based on full-stochastic methods for alpha-, beta- and gamma-emitters used in radiopharmaceutical applications. DOSIS is based on the Boltzmann radiation transport equation to realize energy delivering calculations. Procedures have been designed tacking into account MIRD formalism and standards [3]. Anatomic and metabolic images, and dose maps resulting of this calculations are analysed and processed by a special developed and designed software [4].

Finally, a dose calculation over a standard phantom is performed using DOSIS calculation code and FLUKA, validating the radiation transport code of DOSIS.


*This work was supported in part by projects CONICET PosDoc fellowship, ANPCyT PhD. scholarship and IEO
†Present address: Universidad Nacional de Córdoba - Medina Allende esquina Haya de la Torre Ciudad Universitaria, Córdoba, Argentina. Email: valente@famaf.unc.edu.ar
Modelling of Computed Tomography filtration by Compton spectroscopy: Evaluation by Monte Carlo simulation*

S. Veloza†‡, H.-U. Kauczor and W. Stiller
1 Universidad Nacional de Colombia, Bogota, D.C., Colombia
2 University Hospital Heidelberg, Heidelberg, Germany

A geometrical model of Computed Tomography filtration has been determined from Compton spectroscopy measurements of the X-ray spectra for a tube potential of 120kVp under a fan angle of 0° to 20° in steps of 2° and at 21° from the central ray, while the X-ray tube was kept at 3 o’clock position (Fig. 1). The spectrometer [1] consists of a scattering chamber, a low energy Germanium detector (active area of 200mm² and a thickness of 10mm) model GL0210 (Canberra GmbH, Rüsselsheim, Germany) and an optical feedback pre-amplifier (CANBERRA 2008B). For each fan angle the value of the X-ray path length was iteratively varied in the expression of the relative filter transmission and the computed values were used to estimate the shape of the aluminum filter as a function of the angle. To validate the model (Fig. 2), the filter was implemented in a Geant4 Monte-Carlo simulation of the Computed Tomography system. Resulting spectra of simulation and measurement are in good agreement with each other. The X-ray beam at the FOV border is extremely hardened and the photon fluence of the spectra is reduced to 3% in comparison to the photon fluence of the spectra at the center of the X-ray beam.


* This research project was funded by the German Federal Ministry of Education and Research (BMBF) within the collaboration project: “Innovative Methods for the Optimization of Radiological Applications in Biomedical Imaging”, grant number 02NUK008G.
†‡ Present address: Universidad Nacional de Colombia, Bogota, D.C., Colombia.
Tuesday December 3 (16:00 - 17:40)

**Parallel Session 5 - Nuclear Structure** (Room A21)  Chair: N.H. Medina

16:00 - 16:20  *Nuclei at the proton drip-line and their relevance to nuclear astrophysics*
*Lídia S. Ferreira*, Instituto Superior Técnico, Lisbon, Portugal

16:20 – 16:40  *Mirror (a)symmetry far from stability*
*Silvia M. Lenzi*, Università di Padova and INFN, Italy

16:40 – 17:00  *Structural changes observed in neutron rich A=108-122 nuclei*
*Akunuri Ramayya*, Vanderbilt University, USA

17:00 – 17:20  *Coulomb Breakup as a novel spectroscopic tool to probe directly the quantum numbers of valence nucleon of the exotic nuclei*
*Ushasi Datta Pramanik*, Saha Institute of Nuclear Physics, Kolkata, India

17:20 – 17:40  *$^{137}$Ba Double Gamma Decay Measurement with GAMMASPHERE*
*Edana Merchán*, University of Massachussets, Lowell, USA

17:40 – 18:00  *The $^{12}$C + $^{12}$C fusion reaction at low energies*
*Marlete Assunção*, Universidade Federal de São Paulo, Brasil
The determination of resonances in light nuclei, in the vicinity of the proton drip-line, is an important issue, to obtain the reaction rates in processes relevant for the energy production and element generation in nuclear astrophysics events.

As an example, we can consider the reaction $^{17}\text{F}(p,\gamma)^{18}\text{Ne}$, which plays a significant role in late nucleosynthesis of massive stars in the presupernovae phase where rp-process lead to the production of nuclei up to Cadmium. In inverse kinematics, the $^{17}\text{F}(p,\gamma)^{18}\text{Ne}$ is just the emission of a proton from an excited state of $^{18}\text{Ne}$. One and two proton emission from $^{18}\text{Ne}$ has been observed [1]. The excitation spectrum of $^{18}\text{Ne}$ presents some states that can be seen in the two-proton decay to the $^{16}\text{O}$ channel, but are suppressed in the one-proton decay to $^{17}\text{F}$. This seems to indicate that these $^{18}\text{Ne}$ states do not decay to the ground state of $^{17}\text{F}$, and consequently sequential decay of two successive protons from these states would be favoured. Microscopic calculations to interpret the data strongly rely in a solid nuclear structure description of the nuclei involved in the processes [2]. It is the purpose of this work to present a microscopic shell-model calculations for sequential two-proton decay from excited states in $^{18}\text{Ne}$, identifying the best candidates for decay. From decay observables, we were able to assign the angular momentum and parity of specific excited states in $^{18}\text{Ne}$, which can be relevant to interpret the formation of heavier elements.

Mirror (a)symmetry far from stability
Silvia M. Lenzi¹
¹ Dipartimento di Fisica e Astronomia, Università di Padova and INFN, Padova, Italy

The study of differences in excitation energy between analogue states in isobaric multiplets allows to verify the validity of isospin symmetry and independence as a function of the angular momentum. These differences are of the order of tens of keV and can be well reproduced by state-of-the-art shell model calculations. Several nuclear structure properties can be deduced from these data, such as the alignment of nucleons along rotational bands, the evolution of the nuclear radius and the identification of pure single particle excitations across two main shells. In addition, the isospin breaking of the nuclear interaction is suggested by the systematic comparison with data.

In the last years these studies have been extended from the nuclei in the $f_{7/2}$ shell to other mass regions due to the progress in the experimental techniques and the use of radioactive beams. From the theoretical side the research of the origin of the isospin breaking interaction is exploring different scenarios.

In this contribution, the latest experimental results together with the different ingredients that enter the calculation of the Coulomb energy differences between mirror nuclei will be presented and discussed.
Structural changes observed in neutron rich A=108-122 nuclei

Y. X. Luo\textsuperscript{1}, A.V. Ramayya\textsuperscript{1}, J. H. Hamilton\textsuperscript{1}, J.O. Rasmussen\textsuperscript{2}, S. J. Zhu\textsuperscript{3}, S. Frauendorf\textsuperscript{4}, J. K. Hwang\textsuperscript{1}, E. H. Wang\textsuperscript{1}, G. M. Ter-Akopian\textsuperscript{5}, Yu. Ts. Oganessian\textsuperscript{5}, Y. Shi\textsuperscript{6}, F.R. Xu\textsuperscript{6} and R. Donangelo\textsuperscript{7}

\textsuperscript{1}Department of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235 USA
\textsuperscript{2}Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA
\textsuperscript{3}Department of Physics, Tsinghua University, Beijing 100084, China
\textsuperscript{4}Department of Physics, Notre Dame University, Notre Dame, IN 46556, USA
\textsuperscript{5}Flerov Laboratory of Nuclear Reactions, JINR, Dubna, Russian Federation
\textsuperscript{6}Physics Department, Beijing University, Beijing 100871, China
\textsuperscript{7}Universidad de la Republica, Montevideo, Uruguay

Studies of prompt triple and four-fold $\gamma-\gamma$ coincidence data observed with Gammasphere following the spontaneous fission of $^{252}$Cf have significantly expanded our knowledge and identified new features of the variety of structures in several neutron-rich nuclei and traced their changes over long isotopic chains in Ru, Pd and Cd nuclei. For example, in Pd nuclei the wobbling motion of triaxial shape was observed and from the back bending properties and TRS calculations, a transition from prolate to oblate shape was deduced. Shape coexisting bands were observed in $^{115}$Pd. The evolution from triaxial softness to rigid triaxial shape is observed in going from $^{108}$Ru to $^{112}$Ru, with chiral doublet bands and wobbling bands in $^{112}$Ru. In $^{117-122}$Cd a shift to more slightly deformed structures are found where the excited level structures do not fit the long held picture of one, two and three phonon bands. Based on the systematic studies in the mass region, maximal triaxiality is reached in $^{112}$Ru and $^{114}$Pd, for N=68, 4 neutrons more than predicted in theoretical calculations.
Coulomb Breakup as a novel spectroscopic tool to probe directly the quantum numbers of valence nucleon of the exotic nuclei

U.Datta Pramanik for S306 collaboration

1 Saha Institute Of Nuclear Physics, Kolkata, India

100 years after discovery of the nucleus by Rutherford, the limits of the existence of the nuclei are still uncertain. Study of Nuclear Shell structure around drip line and validate theoretical prediction with the experimental data may provide important information on nucleon nucleon nucleon interaction. This may play key role in understanding of limits of existence of the nuclei i.e. drip line. To probe the nuclear shell structure of loosely bound nuclei, a number of experimental methods with different reaction mechanism are being used by scientists. However, very few methods can probe directly the ground state configuration of loosely bound nuclei. These methods are Coulomb Breakup, knockout, transfer reaction etc. with certain limitations.

Coulomb breakup is an exclusive tool for probing valence nucleon quantum states of loosely bound nuclei [1,2,3]. This method also solve many contradictory results of other method [3,4,5].

Recently, we have investigated the ground state properties of neutron-rich 'ISLAND of Inversion Nuclei' around N~20 using this method through kinematical complete measurement at GSI, Darmstadt [6]. In that experiment 40Ar beam with energy 525 A.MeV was fragmented and exotic neutron-rich nuclei Na(N=18, 19, 20), Mg (N=20, 21), Al (N=21, 22) were separated by FRS and transfer to CAVE C where kinematical complete measurement using LAND setup was performed. For first time, very clear evidence of p3/2 and f7/2 shell inversion has been observed through the data analysis of Coulomb breakup of 35Al (N=22). This results clearly point the breakdown of magic number N=28 and may be indication of new magic number as proposed by B.A. Brown which need further experimental verification. Ground state configuration of 33Mg is still in contradiction among various methods from different world leading laboratories [8,9]. I would like to report first Coulomb breakup results in that direction. Our new experimental results clearly demonstrate that Coulomb breakup is even successful if heavier nuclei (sd-pf shell). The limitation of this method is that the sensitivity of tail part of the wave function of valence nucleon. Hence this method is useful for valence nucleon occupying low-l orbital of loosely bound nuclei. It has been observed that for more deeply bound nuclei, final state of interaction is important. In this presentation, I want to discuss about this novel method and using this method what we have achieved in past and present new exciting results and what we can do in future using next generation RIB facilities.


* This work was Alexander Von Humboldt Foundation
The study of the electromagnetic moments, and decay probability, provides detailed information about nuclear wave functions. The well-know structure of the EM interactions are good for extracting information about the properties of the individual nucleons. However, the lowest multipoles are not always the only ones included in the decay process. It has been observed previously [1,2] in the case of a $0^+ \rightarrow 0^+$ transitions, where a single gamma transition is forbidden, the simultaneous emission of two $\gamma$-rays. A great opportunity to further investigate this phenomena is by using the standard $^{137}$Cs source populating via $\beta$-decay the isomeric state at 662 keV in $^{137}$Ba. In this case two photon process can have contributions from quadrupole-quadrupole or dipole-octupole multipolarities due to the high multipolarity of the decay, M4. Since the yield of the double gamma decay is around $10^{-6}$ orders of magnitude less than the first order transition very good statistics are needed in order to observe the phenomena. Using Gammasphere is ideal since its configuration allows a good coverage of the angular distribution and the Compton events can be suppressed. Nevertheless the process to understand and eliminate the Compton background is a challenge. Geant4 simulations were carried out to help correct for those factors. A new direct cascade via the low-lying $J^\pi = 1/2^+$ has been found.

The $^{12}\text{C}+^{12}\text{C}$ fusion reaction at low energies

M. Assunção¹, P. Descouvemont²

¹ Departamento de Ciências Exatas e da Terra, Universidade Federal de São Paulo, Campus Diadema, São Paulo, Brazil
² Physique Nucléaire Théorique et Physique Mathématique, C.P. 229, Université Libre de Bruxelles (ULB), B 1050 Brussels, Belgium

In the present work, we investigate the role of inelastic channels in the $^{12}\text{C}+^{12}\text{C}$ fusion reaction [1]. In particular we focus on the Hoyle state which is known to have a large radius. The $^{12}\text{C}+^{12}\text{C}$ system is described in a multichannel folding model.

The importance of the $^{12}\text{C}+^{12}\text{C}$ fusion in stellar nucleosynthesis[2] is well known and has been studied in several models [3,4]. However, our calculations were quite original in getting a more realistic model. Thus, we use the folding potential [5] in a multichannel approach involving the $^{12}\text{C}(0^+, 2^+, 0^+, 3^-)$ states.

For the nucleon-nucleon interaction, we use the DDM3Y density-dependent potential (see Ref. [6]) and the $^{12}\text{C}$ densities (including transition densities) are taken from the RGM calculation of Kamimura [7]. From the coupled-channel system, we determine the elastic and fusion cross sections simultaneously. The explicit presence of inelastic channels led us to consider that the imaginary part of the optical potential contains only a short-range absorption contribution [8]. When we vary the parameters of the optical potential we observe that the $S$-factor is not modified. For this reason, our model is free of any fitting parameter (see more details in Ref. [1]).

Wednesday December 4 (14:00 - 15:40)

Parallel Session 7 - Hadron Structure and Interactions (Room C21) Chair: M. Battaglieri

14:00 - 14:20  $\rho-\omega$ Interference in the Leptonic Decay Channel from Photoproduction off of a 1H target at JLab  
Dennis Weygand, Jefferson Lab, Newport News, USA

14:20 - 14:40  $\pi$ Polarization in Photoproduction with CLAS  
Jason Bono, Florida International University, USA

14:40 - 15:00  Study of the $K$-pp nuclear system via the $A(K_{\text{stop}} Ap)A'$ reaction  
Nevio Grion, Istituto Nazionale di Fisica Nucleare, Italy
**ρ−ω Interference in the Leptonic Decay Channel from Photoproduction off of a 1H target at JLab**

C. Djalali¹, M. Paolone², M. Kunkel³, D. Weygand⁴, M. Wood⁵ and the CLAS Collaboration

1 University of Iowa, Iowa City, IA, USA
2 Temple University, Philadelphia, PA, USA
3 The Old Dominion University, Norfolk, VA, USA
4 Thomas Jefferson National Accelerator Facility, Newport News, VA, USA
5 Canisus College, Buffalo, NY, USA

Although the phenomena of ρ−ω interference has been studied at great length in pionic decay channel over the past 50 years, a study of the interference in a purely electromagnetic production and decay channel has never been performed on an elementary proton target until now. Previous experimental studies of the leptonic decay channel were performed on Beryllium [1] and Carbon [2] targets, and published conflicting results of the ρ−ω interference phase. More recently, CLAS [3] and CBELSA/TAPS [4] have reported significantly different measurements of the ω absorption inside nuclear targets. An investigation of the ρ−ω interference on a Hydrogen target can help interpret these discrepancies. The ρ−ω interference parameters are obtained from preliminary fits to the dilepton spectrum (Fig.1). These results are compared to previous experimental data obtained on heavier targets and are discussed within the context of recent medium modification studies.

**FIGURE 1.** A preliminary fit to the dilepton event spectrum. The total fit, the ρ and the ω amplitudes are shown as solid lines, and the interference term is shown as a dashed lines.

Abstract

The weak decay of hyperons offers a valuable means of measuring their polarization, providing insight into their production mechanisms. Jefferson Lab’s CLAS collaboration has utilized this property of weak decays and has published the most precise polarization measurements of Λ to date in both photo and electroproduction. No such study however has been published for the Ξ baryon in either photo or electroproduction. High statistics CLAS data was collected in 2008 with a luminosity $68\text{pb}^{-1}$ using a circularly polarized photon beam with energies up to 5.45 GeV and a liquid hydrogen target. This dataset known as ”g12” is the world’s largest for meson photoproduction and provides a first time opportunity to study various aspects of the Ξ baryon in photoproduction.

By analyzing the angular distribution of the $\Xi^- \rightarrow \pi^- (\Lambda^0)$ decay in the $\gamma p \rightarrow K^+ K^+ \Xi^- \rightarrow K^+ K^+ \pi^- (\Lambda^0)$ reaction, the induced and transferred polarization of the Ξ can be measured. The data has a nearly background free signal with approximately 4500 events, a globally unprecedented yield for detecting $\Xi^- \rightarrow \pi^- (\Lambda^0)$ in photoproduction. Preliminary results displaying polarization as a function of beam energy and center of mass Ξ angle will be presented. Additionally basic features of the data and simulation will be shown including mass spectra and important aspects of the phase space.
Study of the $K^-pp$ nuclear system via the $A(K^-_{\text{stop}},\Lambda p)A'$ reaction

N. Grion\textsuperscript{1†}

\textsuperscript{1} Istituto Nazionale di Fisica Nucleare, Trieste, Italy

on behalf of the FINUDA Collaboration

The $A(K^-_{\text{stop}},\Lambda p)A'$ absorption reaction on light nuclei was studied to learn about the $K^-_{\text{stop}}pp \rightarrow [K^-pp]_{\text{bound}} \rightarrow \Lambda p$ process. The process is examined only on p-shell nuclei, i.e., $^6\text{Li}$, $^7\text{Li}$, $^9\text{Be}$, $^{13}\text{C}$, $^{16}\text{O}$. In fact, light nuclei limit the effects of $\Lambda(p)$ distortions while providing $pp$ targets. In addition, the measurement involves several nuclei since it is mandatory to investigate the influence of the nuclear structure on a $[K^-pp]_{\text{bound}}$ system.

The interest in studying bound nuclear clusters involving one or more kaons and two or more nucleons is surely grown in the last decade. In this realm, several models were developed able to predict the existence of a $[K^-pp]_{\text{bound}}$ nuclear system. Such a system is commonly characterized by a binding energy ($B_K$) and a width ($\Gamma_K$). Nevertheless, the values of $B_K$ and $\Gamma_K$ reported in the literature vary widely, so that $[K^-pp]_{\text{bound}}$ can be seen either as a weakly-bound or as a strongly-bound system. The model-dependent values of $B_K$ and $\Gamma_K$ motivated the starting of some measurements; however, the scarcity of results available nowadays is unable to indicate the right theoretical approach to the nature of $[K^-pp]_{\text{bound}}$. The experimental results that will be presented in this talk can help explaining the physics of the $[K^-pp]$ formation and decay. They can also provide valuable information on in-medium modification of the $\bar{K}N$ interaction.

The reaction final channel ($\Lambda p \rightarrow \pi^-pp$) was measured by means of the FINUDA spectrometer. The spectrometer allowed the $\pi^-$ and $p$ masses to be selectively identified from other particle masses. As well, $\pi^-$ and $p$ vector momenta were precisely analyzed over a $\sim 2\pi$ solid angle. A $\Lambda p$ event was finally selected only when a $\pi^-p$ vertex was reconstructed with a mass of $M_{\Lambda} \pm 3$ MeV/$c^2$. Several observables were then built, i.e., $p_p$, $p_\Lambda$, $\cos\Theta_{\Lambda p}$ and $M_{\Lambda p}$. Such observables were globally fit via a Monte Carlo model, which incorporates any single channel (up to 10) contributing to the kaon absorption reaction being measured, $A(K^-_{\text{stop}},\Lambda p)A'$. The results will explicitly be discussed for the $^9\text{Be}$ target; however, a table will summarize the results obtained for all the studied nuclei. Overall, they indicate the existence of a $[K^-pp]_{\text{bound}}$ system with $B_K \approx -70$ MeV/$c^2$ and $\Gamma_K \leq 50$ MeV/$c^2$.

\textsuperscript{*}This work was supported by the Istituto Nazionale di Fisica Nucleare (INFN) of Italy

\textsuperscript{†}Present address: INFN, Sez. di Trieste, via Valerio 2, 34078 Trieste, Italy

38
Wednesday December 4 (14:00 - 15:40)

Parallel Session 8 - Instrumentation and Facilities  (Room C22)  Chair: L. Sajo-Bohus

14:00 - 14:20  Development of a mobile modular system for the detection of Special Nuclear Material (MODES_SNM)
Giuseppe Viesti, Università di Padova, Italy

14:20 - 14:40  Position Sensitive Detectors for RBS/Channeling Experiments
Pedro Miranda, Universidade Técnica de Lisboa, Portugal

14:40 - 15:00  Study of interstrip gap effects and efficiency for full energy detection of Double Sided Silicon Strip Detectors
Domenico Torresi, INFN, Laboratori Nazionali del Sud, Italy

15:00 - 15:20  Research and Development in HPGe Detectors at LNL
Daniel Ricardo Napoli, Laboratori Nazionali di Legnaro, Italy

15:20 - 15:40  Position-Sensitive Coincidence Detection of Nuclear Reaction Products with Configurable Array of Timepix Detectors
Carlos Granja, Czech Technical University, Prague, Czech Republic
Development of a mobile modular system for the detection of Special Nuclear Material (MODES_SNM)

G. Viesti on behalf of the MODES_SNM Collaboration

Dipartimento di Fisica ed Astronomia dell’ Università di Padova, Padova, Italy

The project MODES_SNM, Modular DEtection System for Special Nuclear Material, is supported by the European Commission within the FP7[1]. Its main objective is the development of a mobile and modular detection system specially designed for SNM, i.e. highly enriched Uranium and weapon grade Plutonium, but with the capability of detecting all radioactive sources. The MODES_SNM prototype is defined as a Portable Radiation Scanner following the IAEA classification [2] that can be used in primary or secondary lines of control depending on the operational need as fixed or mobile system.

The MODES_SNM prototype makes use of a set of detectors based on high pressure cells using noble gas scintillators: $^4$He for fast neutrons and Xe for gamma rays. Moreover Li-lined $^4$He tubes have been developed to detect thermal neutrons. The technology of the high-pressure gas cells was developed by ARKTIS as a spin off of CERN based experiments [3]. The advantage in using $^4$He scintillation detectors in search for neutron sources is that the signal-to-noise ratio for fast neutron is much better respect to the one of typical detectors employing $^3$He proportional counters with polyethylene moderators. Moreover, energy windowing on the $^4$He light signal allow discriminating among different neutron sources. Finally the gamma ray sensitivity of such detectors is very low. The combination of separate measurements of fast and thermal component of the neutron spectrum offers the possibility of obtaining information about possible shielding of the neutron source.

Gamma ray Xe-based scintillation detectors have been also developed [4] with performances that are very interesting compared with standard NaI(Tl) detectors.

In the MODES_SNM prototypes different blocks of specialized detectors (fast neutrons, thermal neutrons and gamma-rays) will be connected with a block containing the front-end electronics, the DAQ and on board computer for on line data processing. The latter computer will communicate with operator devices (PC, tablets, smart-phones) via wireless communications allowing remote control and possibility of covered operations.

The detector read-out is performed in a fully digital fashion by using CAEN digitizers [5] with the possibility of performing on-line a pre-analysis of the events by using the FPGA embedded in the digitizers. This will allow transfer to the DAQ only filtered events for further data processing.

The basic R&D part of the project has been finalized and the prototypes will be integrated for the end of 2013. Laboratory tests as well as demonstration campaign are planned for the first half of 2014. Finally it should be mentioned that a specific research has been successfully completed to prepare a next generation of high-pressure detectors replacing the standard PMTs with silicon Multi-Pixel Photon Counting (MPPC).

The MODES_SNM project will be presented, discussing the major achievements in the detector development.

[1] see http://www.modes-snm.eu


[5] see www.caen.it
Position Sensitive Detectors for RBS/Channeling Experiments

P.A. Miranda¹,†, U. Wahl¹,², J.G. Correia¹,³, N. Catarino¹, E. Bosne¹, M.R. da Silva², and E. Alves¹

¹IST/ITN, Instituto Superior Técnico, Universidade Técnica de Lisboa, EN 10, 2696-953, Sacavém, Portugal
²Centro de Física Nuclear da Universidade de Lisboa, Avenida Prof. Gama Pinto 2, 1649-003 Lisboa, Portugal and
³ISOLDE Collaboration, Geneva, Switzerland

Position-sensitive detectors (PSD) has proven to be a very important tool in recent years, especially in its applications in material sciences, astronomy, medical imaging, and high-energy physics, among others [1-3]. In this work we present our first results on the use of two types of PSD’s in the field of materials science, particularly for lattice location studies using the RBS/Channeling technique in blocking geometry with a 0.5 mm collimated 2.0 MeV alpha-particle beam from a Van de Graaff accelerator. Also, some key features such as the maximum count rate, and both energy and position resolution of these detectors will be reported.

Firstly, a resistive-charge position sensitive detector was used to carry out lattice location studies in SiC:Fe, AlN:Er and Si:Ir implanted samples. The channeling and 2D blocking patterns were detected by means of measuring the angular distribution of scattered alpha particles around major crystallographic axes and planes using this type of detector. Furthermore, both the minimum yield and amorphous fraction of single-crystal samples were determined by fitting the normalized 2D patterns with Monte Carlo simulations. Currently, ongoing experiments are carried out in order to assess the suitability of a hybrid semiconductor pixel detector (Timepix) operated in the Time-over-Threshold mode (ToT) for lattice location and damage annealing studies in SrTiO₃ substrates.

So far, RBS/Channeling experiments performed in several single-crystal samples are showing that this type of detectors seem suitable for lattice location studies, particularly for heavy ion implantation (D \( \gtrsim \) 10\(^{15}\) at/cm\(^2\)) on light substrates. Additionally, after several experiments under ion beam conditions the performance of each detector does not show any noticeable deterioration due to radiation damage.


*This work was supported in part from the Portuguese Foundation for Science and Technology through CERN/FP/123585/2011 and PTDC/CTM/100756/2008 as well as the SPIRIT project, EC Grant agreement No. 227012-CP-CSA-Intra.

†Present address: Dept. of Physics, Fac. of Sciences, University of Chile. Santiago, Chile.
Study of interstrip gap effects and efficiency for full energy detection of Double Sided Silicon Strip Detectors

D. Torresi¹, L. Acosta¹, A. Di Pietro¹, P. Figuera¹, M. Fisichella¹, L. Grassi², V. Grilj², M. Jakšic², M. Lattuada¹, T. Mijatovic², M. Milin¹, L. Prepolec², N. Skukan², N. Soic², D. Stanko⁴, V. Tokić², M. Uroš⁵, M. Zadro²

¹INFN, Laboratori Nazionali del Sud, Catania, Italy
²Ruder Boškovic’ Institute, Zagreb, Croatia
³Dipartimento di Fisica e Astronomia, Università di Catania, Catania, Italy
⁴Department of Physics, University of Zagreb, Zagreb, Croatia.

Highly segmented double sided silicon detectors (DSSSD) are widely used in nuclear physics to perform accurate measurements of angular distributions, or to study reactions where coincidences of different particles are required to fully characterize the final state of the interaction process. It is well known that when a particle hits the SiO₂ insulating interstrip region, one can observe, in the two adjacent strips, signals with an amplitude which is different than the full energy one including opposite polarity signals [1-5]. For this reason, when analysing data gathered by using DSSSDs, it is very important to reject interstrip events by selecting only the ones producing the correct full energy signals. This results in an efficiency for full energy detection less than 100%.

For the first time, we performed [6] a systematic characterisation of DSSSDs response as function of the incident ion, energy, and polarization voltage, trying to identify an appropriate selection procedure of events which allows to maximize the efficiency for the full energy reconstruction. First tests, using ⁷Li and ¹⁶O beams at different energies, showed that the efficiency for full energy detection depends on the energy of the detected ion and on the applied bias voltage. Moreover, it was observed that the measured efficiency is different than the one extracted by simply considering the geometrical width of the SiO₂ zone. This means that the effective width of the inter-strip region is different than the geometric one declared by the manufacturer. In addition, systematic measurements of the effective width of the inter-strip gap were performed by scanning the front and back inter-strip regions using proton micro-beams at different energies and for different detector bias. Results show that both front and back effective inter-strip width can be much larger than the nominal geometric width of the SiO₂ zone and that both depend on the DSSSD type, and operating conditions.

In conclusion, the front and back effective interstrip width, which in turn is related to the DSSSD efficiency for full energy detection, depends on the DSSSD type, on its polarization voltage, and on the energy and charge of the detected ions. Therefore for those experiments aiming to measure, for instance, absolute cross-section with high precision, a complete characterization of the used DSSSDs is desirable.

Research and Development in HPGe Detectors at LNL

D. R. Napoli¹, G. Maggioni² and S. Carturan²
¹ INFN, Laboratori Nazionali di Legnaro, Legnaro, Italy
² University of Padova, Padova, Italy

Hiperpure Germanium Detectors continue to be a fundamental tool in nuclear gamma spectroscopy. New techniques for the tracking of the gamma interactions, inside the HPGe crystals, are opening a new era in the use of these detectors. In the present work we discuss results on the operation of the tracking techniques and new developments in HPGe detectors technologies.

* This work was supported in part by...
‡ Present address: Current Institution (name, city, country)
Position-Sensitive Coincidence Detection of Nuclear Reaction Products with Configurable Array of Timepix Detectors*

C. Granja\textsuperscript{1,‡}, V. Pugatch\textsuperscript{2}, A. Okrymenko\textsuperscript{2}, V. Kraus\textsuperscript{1}, and S. Pospisil\textsuperscript{1}

\textsuperscript{1} Institute of Experimental and Applied Physics, Czech Technical University, Prague, Czech Republic
\textsuperscript{2} Institute for Nuclear Research KINR, Nat. Ac. of Sciences, Kiev, Ukraine

In low-energy nuclear reactions of astrophysical interest or fusion studies the spatial- and time-correlated detection of two and more reaction products can be a useful tool to discern reaction channels, extract correlated angular distributions and partial reaction widths. For this purpose we assembled a configurable array of Timepix detectors extendable to silicon diodes and dE detectors triggered and synchronized by a custom-made coincidence unit. The technique was demonstrated on p+p elastic scattering (see Fig.1), neutron induced reactions on B and Li doped targets as well as fission and was used for measurements of the reaction \(^{11}\text{B}(p,\alpha)\alpha\) at the VdG accelerator in Prague and the Tandem VdG accelerator of the KINR in Kiev.

* Research carried out in frame of the Medipix Collaboration. Work supported by Grant 149/120006M of the Ministry of Education, Health and Sports of the Czech Republic.

‡ Corresponding author: carlos.granja@utef.cvut.cz

Fig. 1. Spatial-and time-correlated detection of elastic scattered proton and recoiled proton from a 2.65 MeV proton beam onto a CH\textsubscript{2} target. Single events are registered in two pixel detectors apart at 90 deg (top) operated in time-of-arrival mode (shown in color) providing event time stamps which can be plotted in correlated time spectra (bottom). A coincidence pair is indicated by the arrows. Frames shown collected in 1 ms exposure time. The spatial information, given by the 256 × 256 pixel matrix of each detector, is coupled to the time-correlated information given by the color scale shown in the range 0–1000 µs.
Wednesday December 4 (14:00 - 15:40)

Parallel Session 9 - Nuclear Reactions (Room A21) Chair: R. Lichtenthaler

14:00 - 14:20  \textit{J/\psi} measurements with the ALICE experiment at the LHC
\textbf{Edmundo Garcia-Solis}, Chicago State University, Chicago, USA

14:20 - 14:40  Weak pion production on nuclei
\textbf{Alejandro Mariano}, Universidad Nacional de La Plata, Argentina

14:40 - 15:00  Coexisting single-particle solutions in low-density symmetric nuclear matter
\textbf{Hugo Arellano}, University of Chile, Santiago, Chile

15:00 - 15:20  Nuclear matter and $\nu$ properties from $\pi$ induced reactions and decay
\textbf{Ivan Gnesi}, Università di Torino, INFN and Centro Studi e Ricerche E. Fermi, Roma, Italy

15:20 - 15:40  Recent developments in Multi-Channel Algebraic Scattering calculations
\textbf{Luciano Canton}, Istituto Nazionale di Fisica Nucleare, Padova, Italy
**J/ψ measurements with the ALICE experiment at the LHC**

E. Garcia-Solis¹, for the ALICE Collaboration

¹Chicago State University, Chicago, USA

The hot and dense nuclear matter created in nuclear collisions at relativistic energies consists of plasma of deconfined quarks and gluons. The suppression of quarkonium production in high energy nuclear collisions relative to proton-proton collisions, due to the Debye screening of the quark-antiquark potential, was proposed as a signature of the formation of Quark-Gluon Plasma. However, there are other effects that may impact the observed quarkonia production such as cold nuclear matter effects and statistical coalescence of quark-antiquark pairs. Studies of the production of various quarkonium states in heavy-ion collisions can provide insight into the properties of the hot and dense medium created at the Large Hadron Collider (LHC) energies. In addition, systematic measurement of the quarkonia production for different colliding systems, centralities and collision energies may help to understand the quarkonium production mechanisms as well as the medium properties.

The ALICE experiment at the LHC can measure the J/ψ down to very low transverse momentum in the di-muon and di-electron channels. We will discuss the results on charmonium obtained by ALICE and will provide comparisons with other experimental results and with theoretical calculations [1].

[1] This material is based upon work supported by the National Science Foundation under Grant No NSF-PHY-0968903.
Weak pion production on nuclei

A. Mariano\textsuperscript{1,2} and C. Barbero\textsuperscript{1,2}

\textsuperscript{1}Departamento de Física, Universidad Nacional de La Plata (UNLP), cc.67 La Plata(1900), Argentina and
\textsuperscript{2}Instituto de Física La Plata (IFLP), 49 y 115 La Plata(1900), Argentina

Neutrino oscillation experiments search a distortion in the neutrino flux at a detector positioned far away (L) from the source. By comparing near and far neutrino energy spectra, one gains information about the oscillation probability $P(\nu_i \rightarrow \nu_j) = \sin^2 2\theta_{ij} \sin^2 \frac{\Delta m_{ij}^2 L}{2E_\nu}$, and then about the $\theta_{ij}$ mixing angles and $\Delta m_{ij}^2$ mass squared differences. In this moment new high quality data are available from MiniBoone [1], Sciboone [2] and becoming from Minerva [3] experiments, full dedicated to measure cross sections. Charged current quasielastic scattering (CCQE) reaction $\nu_n n \rightarrow l^- p$ on a single nucleon in the nucleus target is used as signal event. The neutrino energy is not directly measurable but has to be reconstructed from the reactions products through two body kinematics (exact only for free nucleons). However, competition with another processes could lead to a possible misidentification of the arriving neutrinos. In fact:

- Disappearance searching experiments $\nu_\mu \rightarrow \nu_\mu$ (like Sciboone) use $\nu_\mu n \rightarrow \mu^- p$ CCQE reaction to detect an arriving neutrino and reconstruct its energy. Nevertheless, $E_\nu$ determination could be wrong for a fraction of background events $\nu_\mu p \rightarrow \mu^- p\pi^+$ (CC1\pi+) that can mimic a CCQE event if the pion is absorbed in the target and/or not detected.

- In $\nu_\mu \rightarrow \nu_e$ appearance experiment (like MiniBooNE) one detects $\nu_e$ in an (almost) $\nu_\mu$ beam. Signal event $\nu_e n \rightarrow e^- p$ is dominated by a $\nu_\mu N \rightarrow \nu_\mu N\pi^0$, $N = n, p$ (NC1\pi0) background, and as the detector can not distinguish between $e^-$ and $\pi^0$ if one of both photons from the $\pi^0 \rightarrow \gamma\gamma$ decay escapes, a misidentification is present.

A precise knowledge of the cross sections of these elementary 1\pi charged (CC) neutrino-nucleon, neutral current (NC) scattering processes and the inclusion of the several nuclear effects, is a prerequisite for the proper interpretation of the experimental data. This will allow to make simulations in event generators to eliminate fake events coming from 1\pi processes to get more realistic QE countings.


\*UNLP and IFLP
Coexisting single-particle solutions in low-density symmetric nuclear matter

H. F. Arellano$^1$ and J.-P. Delaroche$^2$

$^1$Department of Physics-FCFM, University of Chile, Santiago, Chile. and
$^2$CEA, DAM, DIF, F-91297 Arpajon, France.

The only two-nucleon bound state system occurring in free space is the deuteron, constituted by a proton-neutron pair. Although the neutron-neutron interaction is attractive, its strength is not deep enough to allow for a bound state in the form of a dineutron. However, this picture changes drastically when the interacting neutrons are submerged in nuclear matter. In this contribution we address dinucleon properties as implied by the Brueckner-Hartree-Fock approximation for infinite symmetric nuclear matter at zero temperature [1]. Special emphasis is given to dinucleon formation in the search of self-consistent single-particle fields, leading to novel features for low-density nuclear matter, i.e. mass densities of the order of $10^{11-12}$ g cm$^{-3}$. Searches have been carried out at Fermi momenta in the range $0 < k_F \leq 1.75$ fm$^{-1}$ using the Argonne $v_{18}$ bare nucleon-nucleon potential. As a result, two distinct solutions meeting self-consistency are found with overlapping domains in the interval $0.130$ fm$^{-1} \leq k_F \leq 0.285$ fm$^{-1}$. Effective masses as high as three times the nucleon mass are found in the coexistence domain, in resemblance to heavy Fermions in strongly correlated systems. Properties of dinucleon bound state solutions and possible implications shall be discussed.


*Work supported in part by FONDECYT under grant No 1120396.
Nuclear matter and $\nu$ properties from $\pi$ induced reactions and decay

I. Gnesi$^{1,2,3}$ on behalf of PAINUC Collaboration$^*$

1 Dipartimento di Fisica Generale “A. Avogadro”, Università di Torino, Italy
2 INFN, Sezione di Torino and
3 Centro Studi e Ricerche “Enrico Fermi”, Roma, Italy

PAINUC experiment obtained the first experimental evidence for the presence of a radiative interaction channel in $\pi^4$He interaction: $\pi^\pm 4$He$\rightarrow \pi^\pm 4$He$\gamma$. The main physical feature of the channel is the good agreement of the $\gamma$s energy distributions with the radiation distributions of a Planck blackbody at $T\sim 16$ MeV. Besides, the first experimental observation of the excitation of the $\Delta^-$ resonance, below the threshold energy for pion production, has been obtained. The resonant invariant mass of the $\pi^-n$ system has been measured at $M_{\pi n}=(1157\pm 14)$ MeV/c$^2$ with a width $\Gamma =(38\pm 2)$ MeV/c$^2$, thus shifted with respect to the free nucleon $\Delta$ values. The kinematical features of the resonance suggest the involvement of more than one nucleon.

The positive pion absorption reaction ($\pi^+ 4$He $\rightarrow$ 3pn) in the $\Delta$ resonance energy region shows strong angular correlations and weak Final and Initial State Interactions (FSI/ISI) among final state nucleons, for all the different two-nucleons and three-nucleons systems. On the basis of model-independent kinematical arguments the branching ratio of pion absorption on systems of three or four nucleons has been evaluated to be $\sim 14\%$; even if signatures of pd absorption are observed, where the slow proton is just a spectator, interesting signatures of pure 3-4 nucleon absorption are also present, supporting the hypothesis of the excitation of a nuclear collective resonance. According to the experimental findings, the physical features of the $\pi$ induced collective resonance have been extracted, according to a two parameters semi-empirical model, by fitting data from a collection of resonant $\pi A$ elastic scattering cross sections. The contributions to the total binding energy per each additional nucleon has been found to be $E_B >50$ MeV, being 7 times more than the binding energy per nucleon in $^4$He; the interaction strength with the surrounding nuclear medium seems to steeply fall within a range of 1 fm [1].

The direct measurement of the muon neutrino mass is also being studied at PAINUC since the most accessible channel for its direct study is the pion decay. A high precision simulation has been performed, studying the limits on $m_\nu$ imposed by $\pi/\mu$ momentum resolutions and masses. The required resolution for resolving a 1 keV/c$^2$ neutrino is 1 meV/c: this value can be reached in a near future. The poor pion mass resolution, 350 eV, constrains the accessible $m_\nu$ sector above 419 keV/c$^2$. Finally, from a set of $\pi^\pm$ decays, collected at PAINUC, new upper limits of the muon (anti)neutrinos have been extracted.

[1] I. Gnesi et al., EPJA 47:3 (2011);

$^*$Present address: Università di Torino, Torino, Italy
Recent developments in Multi-Channel Algebraic Scattering calculations

L. Canton\textsuperscript{1}, K. Amos\textsuperscript{2}, S. Karataglidis\textsuperscript{3}, P.R. Fraser\textsuperscript{1}, J.P. Svenne\textsuperscript{4}, and D. van der Knijff\textsuperscript{2}

\textsuperscript{1}Istituto Nazionale di Fisica Nucleare, Padova, Italy
\textsuperscript{2}School of Physics, University of Melbourne, Victoria 3010, Australia
\textsuperscript{3}Department of Physics, University of Johannesburg, South Africa and
\textsuperscript{4}Department of Physics and Astronomy, University of Manitoba, Winnipeg, Manitoba, Canada

A multi-channel algebraic scattering (MCAS) method has been developed to calculate spectra (bound/resonance) and scattering aspects of a number of light-mass nuclei, which are treated as a two-cluster system; specifically, nucleon plus core-type. To date, collective models have been used to specify the interactions between the nucleon and low-lying states of the nucleus that form the compound. An outline of the main characteristics of the MCAS method will be given.

For the case of the carbon isotopes, these studies have been complemented by sufficiently complex and complete shell-model calculations. Comparisons with the multi-$\hbar \omega$ shell-model results provide new insights into the validity of those from MCAS.
Thursday December 5 (14:00 - 15:40)

Parallel Session 10 - Instrumentation and Facilities  (Room C22)  Chair: C. Granja

14:00 – 14:20  Neutron-gamma ray attenuation gauge for sulphur content and multiphase petroleum Monitoring
Laszlo Sajo-Bohus, Universidad Simon Bolivar, Caracas, Venezuela

14:20 - 14:40  Novel dual single sided silicon strip detector chip for radiotherapy verification
Marcos Alvarez, Universidade de Sao Paulo, Brazil and Universidad de Sevilla, CNA Sevilla, Spain

14:40 - 15:00  Design and development of an integral high-resolution radiation dosimetry system for medical applications
Mauro Valente, Universidad Nacional de Córdoba and CONICET, Argentina

15:00 - 15:20  Supersonic gas jet target for nuclear physics experiments
Francisco Favela, Instituto de Física, Mexico

15:20 - 15:40  Beam Thermalization Facility at the NSCL
Chandana Sumithrarachchi, National Superconducting Cyclotron Laboratory, USA
Neutron-gamma ray attenuation gauge for sulphur content and multiphase petroleum monitoring

L. Stevanato\textsuperscript{2}, D. Cester\textsuperscript{2}, F. Pino\textsuperscript{1}, H. Barros\textsuperscript{1}, L. Sajo-Bohus\textsuperscript{1}, A. Vidal\textsuperscript{1}, G. Nebbia\textsuperscript{3}, G. Viesti\textsuperscript{2}

\textsuperscript{1}Universidad Simon Bolivar, Ado 89000, 1080A, Caracas, Venezuela
\textsuperscript{2}Dipartimento di Fisica ed Astronomia dell’ Università di Padova, Via Marzolo 8, I-35131 Padova, Italy
\textsuperscript{3}Istituto Nazionale di Fisica Nucleare, Sezione di Padova, Via Marzolo 8, I-35131 Padova, Italy

The knowledge of the sulphur content and the multi-phase flow parameters are important for the petroleum industry, specifically during the transport in pipelines and network related to exploitation’s wells. The development of new technologies that help in controlling the flow of oil in real time is the goal of a collaboration project between the University Simon Bolivar in Caracas and the University of Padova [1]. A new system based on the attenuation measurements of gamma rays and neutron from a $^{252}$Cf source is developed [2]. This technique is based on the measure of the factor R between attenuation of gamma ray and neutrons. It has been demonstrated that the factor R is a function of the average atomic number of the material and therefore changes when some other material is added to oil. Laboratory measurements were performed to verify the possibility of a) monitor the sulphur content in oil and b) monitor the presence of gas, water and solid material in the pipeline. As far as the sulphur monitoring, the results obtained are presented in Fig.1 where the measured factor R is reported as a function of the sulphur content in oil (% in weight). Moreover in Table 1 measured R values for sand, oil and water are also reported. The sensitivity of the present system to monitor the transport of multi-phase material will be studied in the near future. In this talk the experimental methodology will be presented and the results discussed.

![Graph showing sulphur weight percent vs. R values](image)

<table>
<thead>
<tr>
<th>Material</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>sulphur</td>
<td>0.98</td>
</tr>
<tr>
<td>sand</td>
<td>1.14</td>
</tr>
<tr>
<td>oil</td>
<td>3.40</td>
</tr>
<tr>
<td>water</td>
<td>3.31</td>
</tr>
</tbody>
</table>

Table 1

Novel dual single sided silicon strip detector chip for radiotherapy verification


1 Instituto de Física da Universidade de Sao Paulo (IFUSP), 05508-090, Sao Paulo, Brazil.
2 Departamento de Física, Atómica, Molecular y Nuclear (FAMN), Universidad de Sevilla, 41012 Seville, Spain.
3 Centro Nacional de Aceleradores (CNA), 41092 Seville, Spain.
4 Hospital Universitario Virgen Macarena, 41009 Seville, Spain.
5 Escuela Superior de Ingenieros, 41092 Seville, Spain.
6 Micron Semiconductor Ltd., Sussex BN1 5BN, England, United Kingdom.

A novel dual single sided silicon strip detector (SSSSD) chip was designed to attend clinical requirements in radiotherapy verification. Within this aim, the available double sided (DS) BB7 design, from Micron Semiconductor Ltd., was adapted [1]. A 64 x 64 mm² dual SSSSD chip was packed by kapton printed circuit board (PCB), instead of using the conventional FR4 material. The 32 x 32, 2 mm width, 500 μm thick, silicon strips were connected to an in-house developed electronics by kapton based cables. The two independent SSSSD were separated by a 500 μm kapton dielectric film, with the same silicon wafers dimensions, avoiding air gaps in between them. Thus, we optimize the homogeneity of detector surroundings, by using kapton material, which densities are close to the water (main component of human tissue) one. The dual SSSSD chip was mounted in a back to back perpendicular configuration in order to allow 2D dose measurements, improve spatial resolution and make radiotherapy treatment verification faster. Parameters and performance of the novel detector are presented and compared to the commercial W1-SS 500 design, which was previously used to carry out the feasibility study of applying these detectors for radiotherapy verification [2, 3].

Design and development of an integral high-resolution radiation dosimetry system for medical applications∗

J. Vedelago† and M. Valente†,

1 Facultad de Matemática, Astronomía y Física - Universidad Nacional de Córdoba, Córdoba, Argentina and
2 Instituto de Física Enrique Gaviola CONICET, Córdoba, Argentina

Requirements for overall high performance of dosimetry systems increases due to the growing complexity of medical treatments. Non conventional treatment modalities like Boron Neutron Capture Treatment (BNCT) and hadrontherapy, as well as conventional modern methods like IMRT, tomotherapy might significantly improve diseases control. The Fricke gel dosimetry is a valuable method for in-phantom dose measurements in complex irradiation modalities like IMRT and BNCT [1], [2]. Implementation of this technique requires dedicated instruments capable of measuring and further analysis immediately in situ at the radiation facility.

This work presents a novel and integral dosimetry system aimed to attain portability requirements [3]. It is based on Fricke gel dosimeter optically analyzed offering several specific advantages like tissue-equivalence and continuos 3D dose mapping [2]. Moreover, the versatilitie of Fricke gel dosimetry about different chemical and isotopic compositions allows its application on different high performance conventional and non conventional radiation procedures [2], [4].

Specific radiation transport models were developed with the aim of enabling relative simple optical technique for sample analysis. Theoretical approaches are supported by analytical solution of Boltzmann’s equation of radiation transport. Instrumentations design and construction were completely realized at the facilities of the Laboratorio de Investigaciones e Instrumentación en Física Aplicada a la Medicina e Imágenes por Rayos X - LIIFAMIR⃝). The developed integral dosimetry system includes dedicated software for data acquisition and further processing in order to employ the system set up for direct in situ measurements for routine clinical scopes [2], [3].


∗This work was supported in part by projects CONICET-PIP 11420690100398 SeCyT-UNC ISIDORA I along with a CIN undergraduation scholarship.
†Present address: Universidad Nacional de Córdoba - Medalla Allende esquina Haya de la Torre Ciudad Universitaria, Córdoba, Argentina. Email: valente@famaf.unc.edu.ar.
Supersonic gas Jet target for nuclear physics experiments.∗

F. Favela1, E. Chávez1, M.E. Ortíz1, E. Andrade1,
O. de Lucio1, A. Huerta1, and D. Shapira2

1Instituto de Física (IF, Mexico City, Mexico) and
2Oak Ridge National Laboratory (ORNL, Oak Ridge Tennessee, United States)

A supersonic gas jet target for nuclear physics experiments was designed and constructed at the Institute of physics in Mexico City. Systems like this have been developed and successfully performed in the past [1], [2]. Such a target is indestructible regardless of the accelerator’s beam intensity, this target best resembles an ideal one, it has a high density in a well defined space region, taking all the beam an accelerator can give without changing the target. This allows for low count rate experiments (such as astrophysical ones [3],[4]) to be performed in a reasonable amount of time and also experiments with gases that cannot be conveniently mixed into a solid and placed inside a scattering chamber, such as in the case of noble gases. A gas cell would make the beam interact with the cell’s windows, which can get damaged or destroyed under high accelerator’s current and introduce spurious reactions from the window’s material, making some experiments unpractical. The design itself allows for it to be continually upgraded while keeping it functional, allowing us to perform more ambitious experiments in the future. Details on the design and construction of the system and the on first performed experiments (Air, Nitrogen and Argon) will be given.


∗This work was supported in part by PAPIIT: IN118310 and CONACYT: 82692.
Beam Thermalization Facility at the NSCL

C. S. Sumithrarachchi¹, K. Cooper¹, B. Barquest¹, D. J. Morrissey¹, J. A. Rodriguez², G. Savard³, S. Schwarz¹ and S. Williams¹

¹ National Superconducting Cyclotron Laboratory, East Lansing, USA
² Facility for Rare Isotope Beams, East Lansing, USA
³ Argonne National Lab, Argonne, USA

Beam thermalization provides access to low-energy ion beams at projectile fragmentation facilities. The thermalization process includes slowing down the fast exotic beams in solid degraders after having appropriate momentum compression, and dissipating the rest of kinetic energy by collisions with the buffer gas [1]. The beam thermalization area at the National Superconducting Cyclotron Laboratory (NSCL) was reconfigured recently to accommodate momentum compression beam lines, a large Radio-frequency (RF) gas catcher constructed by Argonne National Lab (ANL) [2] and a low-energy beam transport system. The exotic isotopes produced by A1900 fragment separator at the NSCL were thermalized in 1.2 m long gas catcher operates at 100 mbar Helium gas pressure. The ions were guided to an extraction nozzle with a combination of electrostatic and RF potentials, and were exited by the gas flow. The RF ion guide was used for a low-velocity transport of the ions into ultrahigh vacuum. Finally, the ions were modestly accelerated for their further transport. The status of the commissioning of beam thermalization facility at the NSCL will be presented.

Thursday December 5 (14:00 - 15:40)

Parallel Session 11 - Nuclear Reactions  (Room A21)  Chair: A. Pacheco

14:00 - 14:20  Nuclear and Coulomb breakup of Li at near barrier energies, their interferences and their effect on fusion  
Paulo Gomes, Universidade Federal Fluminense, Niteroi, Brazil

14:20 - 14:40  Continuum Discretized Coupled Channels Calculations for reactions of $^6$Li with several targets. Effect of resonances of $^6$Li on elastic scattering Angular Distributions  
Arturo Gómez Camacho, Instituto Nacional de Investigaciones Nucleares, Mexico

14:40 - 15:00  Preliminary Results from the First EXL Experiment with a Stored Radioactive Beam  
Juan Carlos Zamora, Technische Universität Darmstadt, Germany

15:00 - 15:20  Complete and incomplete fusion of weakly bound nuclei  
Raúl Donangelo, Facultad de Ingeniería, Montevideo, Uruguay and Universidade Federal do Rio de Janeiro, Brasil

15:20 - 15:40  Coulomb effects in cold fission from $^{233}$U($n_{th}$, f), $^{235}$U($n_{th}$, f) and $^{239}$Pu($n_{th}$, f)  
Modesto Montoya, Instituto Peruano de Energía Nuclear, Lima, Peru
Nuclear and Coulomb breakup of $^6$Li at near barrier energies, their interferences and their effect on fusion*

P. R. S. Gomes¹, D. R. Otomar¹, J. Lubian¹, L. F. Canto² and M. S. Hussein³

¹ Instituto de Física, Universidade Federal Fluminense, Niterói, Brazil
² Instituto de Física, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil
³ Instituto de Física and Instituto de Estudos Avançados, Universidade de São Paulo, São Paulo, Brazil

We present results of CDCC calculations for the nuclear, Coulomb and total breakups of $^6$Li on different targets, at energies below and above the Coulomb barrier, aiming to investigate the relative importance of nuclear and Coulomb breakup on the target mass and/or charge, and their interferences. The calculations have no free parameter and were in very good agreement with elastic scattering data for all systems investigated. The interference between the two kinds of breakup was found to be strongly destructive, especially at low energies, where the total breakup cross section is smaller than the pure Coulomb breakup. We show the scaling laws obtained as a function of mass and/or charge of the target and the theoretical derivation of those scaling laws. We also compare the predictions for the integrated total breakup cross sections with experimental fusion cross sections at the same energy range. Finally, we investigate the possible effect of the breakup on the fusion cross section by deriving the total breakup cross section integrated up to partial waves corresponding to those which may contribute to fusion. Parts of the results of this contribution were published recently [1] and some others are original.


• This work was supported in part by CNPq, Capes, FAPERJ, FAPESP and the Pronex
Continuum Discretized Coupled Channels Calculations for reactions of $^6$Li with several targets. Effect of resonances of $^6$Li on elastic scattering Angular Distributions.∗

A. Gómez Camacho$^1$ and A. Díaz Torres$^2$

$^1$Departamento del Acelerador, Instituto Nacional de Investigaciones Nucleares, México and
$^2$European Center of Theoretical Nuclear Physics and Related Areas, Trento, Italy

Nuclear reactions with weakly bound projectiles, important in nuclear astrophysics, have been the subject of intense research in recent years. In particular, reactions with the weakly bound $^6$Li have been both theoretically and experimentally studied and a large amount of data are available for several reaction mechanisms. The weakly bound $^6$Li easily breaks up ($E_{th} = 1.47$ MeV) into fragments, deuteron and alpha particles. In reactions with a given target, among other nuclear mechanisms, the fragments can fly apart feeding the continuum. In CDCC calculations[1,2], this continuum energy space is represented by a discretized space as fine and extensive as necessary for each nuclear system and bombarding energy. Continuum wave functions are represented by a normalized superposition of scattering states in which resonant states can be adequately considered. In this descriptive talk, a presentation is made of the effects on elastic scattering cross section angular distributions of $^6$Li with various targets $^{28}$Si, $^{58}$Ni, $^{144}$Sm and $^{208}$Pb due to the resonances $l = 2$ ($J = 3^+, 2^+$ and $1^+$) of $^6$Li. The model of Coupled Channels in the continuum is used to calculate these effects. In this three-body problem, nuclear potentials among fragment-target are taken from systematic studies. That is, double folding Sao Paulo potential[3,4] for the $\alpha+$target interaction with adequate mass densities for the $\alpha$ particle. The systematic Woods-Saxon deuteron+target potentials of Ref.[5] and as for the $d + \alpha$, the potential of Ref.[6], that correctly reproduces the resonant states and widths of $^6$Li. For all the nuclear sistem studied in this work, close agreement to the data is obtained whenever data for elastic scattering angular distributions exist. Also, by modifying the resonant discrete energy space, the effects of any or any group of resonant states of $^6$Li can be separately determined.


∗This work was supported in part by CONACYT, México
Preliminary Results from the First EXL Experiment with a Stored Radioactive Beam

J.C. Zamora\textsuperscript{1}, S. Bagchi\textsuperscript{2}, S. Böning\textsuperscript{1}, M. Cstatlós\textsuperscript{3}, I. Dillmann\textsuperscript{4}, C. Dimopoulou\textsuperscript{4}, P. Egelhof\textsuperscript{5}, V. Eremin\textsuperscript{5}, T. Furuno\textsuperscript{6}, H. Geissel\textsuperscript{4}, R. Gernhäuser\textsuperscript{7}, M. N. Harakeh\textsuperscript{2}, A.-L. Hartig\textsuperscript{1}, S. Ilieva\textsuperscript{1}, N. Kalantar-Nayestanaki\textsuperscript{2}, O. Kiselev\textsuperscript{4}, K. Kollmus\textsuperscript{3}, C. Kozhuharov\textsuperscript{4}, A. Krasznahorkay\textsuperscript{3}, T. Kröll\textsuperscript{1}, M. Kuilman\textsuperscript{2}, S. Litvinov\textsuperscript{4}, Yu. A. Litvinov\textsuperscript{4}, M. Mahjour-Shafiei\textsuperscript{2,8}, M. Mutterer\textsuperscript{4}, D. Nagae\textsuperscript{9}, M. A. Najafi\textsuperscript{2}, C. Nociforo\textsuperscript{4}, F. Nolden\textsuperscript{4}, U. Poop\textsuperscript{4}, C. Rigollet\textsuperscript{2}, S. Roy\textsuperscript{2}, C. Scheidenberger\textsuperscript{4}, M. von. Schmid\textsuperscript{1}, M. Steck\textsuperscript{4}, B. Streicher\textsuperscript{2,4}, L. Stuhl\textsuperscript{3}, M. Thürauf\textsuperscript{1}, T. Uesaka\textsuperscript{10}, H. Weick\textsuperscript{4}, J. S. Winfield\textsuperscript{4}, D. Winters\textsuperscript{4}, P. J. Woods\textsuperscript{11}, T. Yamaguchi\textsuperscript{12}, K. Yue\textsuperscript{1,4,13}, and J. Zenihiro\textsuperscript{10}

\textsuperscript{1}Institut für Kernphysik, Technische Universität Darmstadt, Germany
\textsuperscript{2}KVI, Rijksuniversiteit Groningen, Netherlands
\textsuperscript{3}ATOMKI, Institute of Nuclear Research, Debrecen, Hungary
\textsuperscript{4}GSI Helmholtz Centre for Heavy Ion Research, Darmstadt, Germany
\textsuperscript{5}Physical-Technical Institute of Russian Academy of Sciences, St. Petersburg, Russia
\textsuperscript{6}Division of Physics an Astronomy, Kyoto University, Kyoto, Japan
\textsuperscript{7}Physik-Department, Technische Universität München, München, Germany
\textsuperscript{8}Department of Physics, University of Tehran, Tehran, Iran
\textsuperscript{9}Department of Physics, University of Tsukuba, Tsukuba, Japan
\textsuperscript{10}RIKEN Nishina Center, Wako, Saitama Japan
\textsuperscript{11}Institute for Particle and Nuclear Physics, University of Edinburgh, Edinburgh, United Kingdom
\textsuperscript{12}Department of Physics, Saitama University, Saitama, Japan and
\textsuperscript{13}Institute for Modern Physics, Lanzhou, China

EXL (EXotic nuclei studied in Light-ion induced reactions at the NESR storage ring) is a project within NUSTAR at FAIR. Its objective is the investigation of light-ion reactions in inverse kinematics with radioactive beams in the New Experimental Storage Ring (NESR), using a universal detector system which provides high resolution and large solid angle coverage in kinematically complete measurements.

In a recent experiment at the present ESR storage ring, the collaboration has performed feasibility studies and first experiments by using a dedicated detector setup including UHV capable DSSDs and PIN diodes for the detection of target like recoil ions, and beam like reaction products, respectively. With this setup the interaction of $^{56,58}$Ni beams with internal hydrogen and helium gas-jet targets was investigated. Some preliminary results from this experiment will be presented, together with simulations employed to understand the different reaction channels observed. This work is supported by BMBF (06DA9040I and 05P12RDFN8) and HIC for FAIR.

\textsuperscript{*}Electronic address: jczamorac@ikp.tu-darmstadt.de
Complete and incomplete fusion of weakly bound nuclei

H.D. Marta$^{1,*}$, L.F. Canto$^2$, and R. Donangelo$^{1,2}$

$^1$Instituto de Física, Facultad de Ingeniería, C.C. 30, 11000 Montevideo, Uruguay and
$^2$Instituto de Física, Universidade Federal do Rio de Janeiro, C.P. 68528, 21941-972 Rio de Janeiro, Brazil

The influence of the breakup channel in fusion reactions of weakly bound nuclei with heavy targets has been a matter of theoretical controversies in the last years. In a previous work [1] we have presented a semiclassical treatment of breakup reactions and verified that the results are in agreement with complete quantum mechanical calculations and experimental data. Here we extend that work to consider the simultaneous treatment of breakup and fusion.

Several possibilities are considered for the reaction. The projectile does or does not undergo a breakup process. In the second case, it either fuses with the target, and we have the direct complete fusion process, or scatters quasi-elastically. If breakup occurs, none, one or both of the fragments may fuse with the target, and we have pure breakup, incomplete fusion or sequential complete fusion reactions, respectively. Note that this last process cannot be calculated employing quantum Coupled Channels codes.

In our calculations the breakup probability as well as the energy and angular distributions of the breakup fragments are obtained by the semiclassical model proposed in [1]. We have verified in those calculations that the breakup occurs predominantly at the point of closest approach. Thus, we end the breakup calculation at this point, and, using the breakup amplitudes, we calculate the momentum distribution of the breakup products. From them we calculate the fusion probabilities of the fragments. Preliminary results for the complete and incomplete fusion for the $^6\text{Li}+^{209}\text{Bi}$ system are encouraging when compared with available measurements [2].


*This work was supported in part by the Programa Sul Americano PROSUL, Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), MCT/CNPq (PRONEX), under contract 41.96.0886.00, Fundação de Amparo à pesquisa do Estado de Rio de Janeiro, and PEDECIBA and ANII (Uruguay)

$^*\text{Deceased}$
Coulomb effects in cold fission from $^{233}\text{U}(n_{th}, f)$, $^{235}\text{U}(n_{th}, f)$ and $^{239}\text{Pu}(n_{th}, f)$

M. Montoya
Instituto Peruano de Energía Nuclear, Lima, Peru
Universidad Nacional de Ingeniería, Lima, Peru

The maximal value of fragment kinetic energy in the cold region [1] of the thermal induced fission of $^{233}\text{U}$, $^{235}\text{U}$ and $^{239}\text{Pu}$ is interpreted in terms of Coulomb energy [2] interaction between complementary fragments at scission.

To describe “Coulomb effect” let’s first define the following curves depending of $A$: i) $\bar{Q}$, the smoothed curve referred to maximal value of available energy of the reaction ($Q$), as a linear curve in the mass region from the lightest $A$ to that at which ends the linear trend and, for higher mass numbers, a curve following the approximately horizontal trend of $Q$; ii) $C$, the electrostatic interaction energy between complementary spherical fragments corresponding to $Z_\theta$ with surfaces separated by 2 fm (the result is a step function of mass number); and iii) $K$, the maximal value of total kinetic energy, as the lowest of the ten highest values of total kinetic energy.

Now let’s define the smooth excess of electrostatic energy, as a function of $A$, by the relation $\delta C = C - \bar{Q}$, and the smoothed values of minimal excitation energy, as a function of $A$, by the relation $X = \bar{Q} - K$.

The fluctuations of $K$ are interpreted as effects of the step variation of the electrostatic energy as a function of $Z_\theta$. It is found that the smoothed values $\delta C$ and $X$ are correlated. This result suggests that, at scission, a higher excess of electrostatic interaction energy produces a higher deformation of fragments, therefore a higher $X$ and a then lower $K$-values. It was also found that the fluctuations of $\delta C$ and $X$ curves increase with the asymmetry of fragmentation. See Fig. for the case of the thermal induced fission of $^{233}\text{U}$. Results from several experiments in cold fission suggest that scission explore all configurations permitted by the $Q$-value.

Thursday December 5 (14:00 - 15:40)

Parallel Session 12 - Nuclear Structure (Room B11) Chair: D. Rudolph

14:00 - 14:20 Measuring neutron recoil polarization in the photoproduction off deuterium
Svyatoslav Tkachenko, University of Virginia, USA

14:20 - 14:40 Experimental study of the Neutron-rich Nuclei near the N=82 Closed Shell using the Reaction$^{96}$Zr + $^{124}$Sn at 530 MeV with GASP and PRISMA-CLARA arrays
Wilmar Rodriguez, Universidad Nacional de Colombia, Bogota, Colombia

14:40 - 15:00 Identification of neutron-rich Zr and Sr isotopes populated through a heavy-ion fission reaction
Cesar Lizarazo, Universidad Nacional de Colombia, Bogota, Colombia

15:00 - 15:20 Spectroscopy and GEANT4 Simulations of Element 115 Decay Chains
Luis Sarmiento, Lund University, Sweden
Measuring neutron recoil polarization in the photoproduction off deuterium

S. Tkachenko
University of Virginia (Charlottesville, VA, USA)

Understanding the deuteron, the simplest nucleus, is a cornerstone of understanding nuclear physics. While a fairly good handle on unpolarized reactions involving the deuteron has been developed, the advent of polarization measurements, capable of constraining deuteron models even further, demonstrated some deficiencies in our knowledge.

For example, the dependence on the photon energy of the neutron recoil polarization $P_y'$ in the inclusive polarized photoproduction off the deuteron, $d(\vec{\gamma}, \vec{n})X$, is not well-understood. The only comprehensive measurement by Nath et al. lines up with both potential and effective field theory models up to a photon energy of about 12 MeV and then abruptly departs, indicating the possibility of a new channel opening. The $P_y'$ dependence on the neutron scattering angle is not known well either, with the few existing measurements having large uncertainties.

We will measure $P_y'$ for a range of photon energies and neutron scattering angles, covering the kinematic region in which the discrepancy between data and theory exists. The measurements will be performed at the High Intensity Gamma Source (HI-$\gamma$S) facility located at Duke University. The HI-$\gamma$S photon beam, produced by Compton backscattering, has a polarization of nearly 100%. A heavy water target in conjunction with a set of analyzer/scintillator-cell assemblies will provide polarization analysis of the ejected neutrons. The experiment will take place in 2014, with physics results expected in 2014-2015.
Experimental study of the Neutron-rich Nuclei near the N=82 Closed Shell using the reaction \( ^{96}_{40}\text{Zr} + ^{124}_{50}\text{Sn} \) at 530 MeV with GASP and PRISMA-CLARA arrays

W. Rodriguez, D.A. Torres, and F. Cristancho  
*Universidad Nacional de Colombia, Bogota, Colombia.* and  
*Centro Internacional de Fisica, Bogota, Colombia.*

R. Chapman, J. F. Smith, D. Mengoni, V. Truesdale, L. Grocutt, and K. Mulholland  
*School of Engineering and Science, University of the West of Scotland, Paisley, PA1 2BE, U.K.*

C. A. Ur, E. Farnea, S. M. Lenzi, L. Capponi, and C. Michelangnoli  
*Dipartimento di Fisica dell’Università di Padova, Padova, Italy.*

D. Napoli  
*INFN, Laboratori Nazionali di Legnaro, Legnaro (Padova), Italy.*

N. Medina  
*Departamento de Fisica Nuclear, Universidade de Saõ Paulo, Brazil.*

The region approaching \( N \geq 50 \) and \( Z \approx 40 \) is a very interesting region for both, nuclear structure and nuclear astrophysics, due to the possibility to study shell closures and sub-closures in the neutron-rich region, and for the opportunity to increase our knowledge on nuclei in the path of the \( r \)-process nucleosynthesis, respectively. During the last decade experimental studies of neutron-rich nuclei have been conducted using deep inelastic reactions using dedicated experimental arrays, such as the PRISMA-CLARA array at Legnaro National Laboratory, Italy. Due to the large acceptance of the PRISMA magnetic spectrometer, and its use in conjunction with the high-resolution gamma-ray detector array CLARA in thin target experiments, a clear and identification of the sub-products of the reaction is possible. A more detailed spectroscopy information can be obtained if partner thick target experiments are performed using highly efficient gamma-ray arrays, such as GASP. The latter may allow to obtain pivotal information for a complete characterization of the nuclear states.

Here we present an experimental study of the reaction \( ^{96}_{40}\text{Zr} + ^{124}_{50}\text{Sn} \) using the GASP and PRISMA-CLARA arrays. The experiment populates a wealth of projectile-like and target-like binary fragments, in a large neutron-rich region around \( N \geq 50 \) and \( Z \approx 40 \), using multinucleon transfer reactions. Preliminary results on the study of the yrast and near-yrast states for some neutron-rich isotopes with \( Z < 50 \) will be presented, along with a comparison of the experimental yields obtained in the experiments.
The study of neutron-rich nuclei is currently one of the most active research fields in nuclear physics. These nuclei contain an excess of neutrons when compared with stable nuclei, that feature leads to new phenomena such as the re-arrangement of nuclear shells which consequently causes deformations of the nuclear shape. In the last decades, neutron-rich nuclei with around 38 protons have gained attention due to the behavior of their shape deformation as a function of the number of neutrons. A remarkable case is exhibited by the Zirconium isotones, where the deformation of the nuclear shape changes from a low deformed structure for the $^{96}\text{Zr}$, to a highly prolate deformation as in the case of $^{104}\text{Zr}$ [1]. Nevertheless, a full study is far from being completed. The production of these isotopes, with statistics high enough to allow for a good performance of gamma spectroscopy, is a challenge only recently tackled thanks to improvements to the latest experimental facilities. At the LNL laboratory in Legnaro, Italy, neutron-rich nuclei in the $Z\sim38$ region were populated by the fission reaction of a $^{136}\text{Xe}$ projectile colliding against a $^{238}\text{U}$ target, at a beam energy of 1 GeV. In order to detect the nuclear species produced and the gamma rays associated with them, the modern AGATA-PRISMA setup was used. In this work, the partial analysis of the data for this experiment will be shown; in particular, the mass production of Zirconium and Strontium isotopes. Also, the yield of production of the reaction is estimated, allowing to obtain a criteria for its suitability with regards to populating these neutron-rich nuclei of interest.

During the past decade, correlated α-decay chains, which all terminate by spontaneous fission, have been observed in several independent experiments using 48Ca-induced fusion-evaporation reactions on actinide targets [1]. These are interpreted to originate from the production of isotopes with proton numbers $Z = 113-118$. However, neither their mass, $A$, nor their atomic number, $Z$, have been measured directly.

In November 2012, a three-week experiment was conducted at the GSI Helmholtzzentrum für Schwerionenforschung GmbH in Darmstadt, Germany, using high-resolution α, electron, X-ray, and γ-ray coincidence spectroscopy to observe α-X-ray events to identify uniquely atomic numbers of isotopes with $Z = 115$ decay chains. The reaction $^{48}$Ca+$^{243}$Am was used, with fusion-evaporation products being focused into the TASISpec set-up [2], which was coupled to the gas-filled separator TASCA [3].

A beam integral of roughly $6 \times 10^{18}$ $^{48}$Ca particles led to the observation of 30 correlated α decay chains with characteristics similar to those previously published [4,5]. More importantly, decay schemes arising from high-resolution spectroscopic coincidence data, in conjunction with comprehensive Monte-Carlo simulations [6], open the door for direct nuclear structure insights of these heaviest man-made atomic nuclei.

Thursday December 5 (16:00 - 17:40)

Parallel Session 13 - Applications  (Room C22)  Chair: M. Valente

16:00 - 16:20  Technical applications of an imaging Gamma-ray Compton Backscattering device and simulation using GEANT4  
David Flechas, Universidad Nacional de Colombia, Bogota, Colombia

16:20 – 16:40  The effect of wetting and drying cycles on soil chemical composition and their impact on bulk density evaluation  
Lulz Pires, State University of Ponta Grossa, Brazil

16:40 – 17:00  CAB Models for Water: new models for the interaction of thermal neutrons in water  
José Ignacio Márquez Damián, Centro Atómico Bariloche, Argentina
Technical applications of an imaging Gamma-ray Compton Backscattering device and simulation using GEANT4∗

D. Flechas1,†, L.G. Sarmiento1,‡, F. Cristancho1, and E. Fajardo2
1Universidad Nacional de Colombia, Bogotá, Colombia and
2Centro Internacional de Física, Bogotá, Colombia

The γ-backscattering imaging techniques are alternative methods to the transmission techniques to determine the amount and distribution of matter in objects. These are very useful techniques when the access to both sides of the sample, unlike in the transmission case, is not possible. A γ-backscattering imaging device dubbed Compton Camera, developed at GSI (Darmstadt, Germany) and studied and modified by the Nuclear Physics Group of National University in Bogotá, uses the so called Compton Gamma-ray Backscattering (GCB) technique, which has been successfully tested [1-3] in different situations. The Compton Camera makes the most of back-to-back emission of two γ-rays, from positron annihilation, to construct a bi-dimensional image representing the distribution of matter of the sample in the field-of-view of the camera. The backscattering imaging method can be used to identify and study structural defects, to help finding hidden objects, to name just two cases.

In this work, the images resulting from different experimental conditions in the study and analysis of metallic surfaces will be shown. Furthermore, some experimental limits of the actual prototype are set. In order to increase the understanding of the image formation process and to assist in the data analysis, a simulation of the camera was developed using the GEANT4 [4] simulation toolkit. The simulated images and their comparison with the experimental ones suggest already methods to improve the present experimental device.


∗This work was supported in part by Universidad Nacional de Colombia DIB 13440 and Colciencias 110152128824
†E-mail address: dcflechas@unal.edu.co (D.Flechas)
‡Present address: Lund University, S-22100 Lund, Sweden
The effect of wetting and drying cycles on soil chemical composition and their impact on bulk density evaluation*

L.F. Pires

*Department of Physics, State University of Ponta Grossa, Ponta Grossa, PR, Brazil

The gamma-ray attenuation technique has been applied successfully in several areas of knowledge such as medicine, industry, chemistry, biology, agriculture and so on. Before the technique application it is important to know the probability of gamma photons interaction with the matter. The linear attenuation coefficient (k) measures the probability per unit length of a photon to be absorbed or scattered while interacting with a sample. k represents the sum of several individual attenuation coefficients due mainly to the photoelectric absorption, coherent and incoherent scatterings and pair production [1]. Soil is characterized as a three phase system composed by solid, liquid and gaseous phases. It is known that for a given photon energy the mass attenuation coefficient (µ) is directly related to the chemical composition of the soil [2]. As a consequence by using the mixture rule, in which µ is calculated by adding the products of mass attenuation coefficients and the contents of the chemical components of the soil, it is possible to obtain a theoretical µ value [3]. A possible cause of chemical composition changes in soil is the application of repeated wetting and drying (W-D) cycles. Another consequence of these changes in the chemical composition of the soil can be alterations in its µ. This result can affect how well the gamma-ray attenuation or computed tomography (CT) techniques can determine soil bulk density (d_s) or porosity (φ) when samples are submitted to W-D cycles. In this work the soil elemental (oxides) composition variation of three Brazilian soils submitted to the application of W-D cycles was measured in order to evaluate possible changes in the calculated µ as a function of the cycles. Measurements of µ by using radioactive sources of $^{241}$Am and $^{137}$Cs were also performed. Gamma-ray CT was used as a tool to evaluate the impact of changes in µ induced by the cycles in determinations of d_s. The measured and calculated values of µ presented good agreement. Significant modifications were not observed in the total elemental composition of the soils after the application of W-D cycles. As a consequence only slight changes in µ were observed. However, the use of CT allowed concluding that even small changes in µ can cause some change in d_s.


* This work was supported in part by the Brazilian Agencies CNPq and Fundação Araucária.
‡ Present address: Department of Physics, State University of Ponta Grossa, Ponta Grossa, Brazil
CAB Models for Water: new models for the interaction of thermal neutrons in water.*

J.I. Márquez Damián†, J.R. Granada†, and D.C. Malaspina

Departamento Física de Neutrones and Instituto Balseiro,
Centro Atómico Bariloche, Bariloche, Argentina and
Computation, Modeling & Bioinformatics Center,
Northwestern University, Evanston, IL, USA

During the past few years we have been working at the Department of Neutron Physics at Centro Atómico Bariloche on an update of evaluation of the thermal neutron scattering law for light and heavy water. We based our approach on combining the best available experimental data with molecular dynamics simulations [1]. With this methodology we produced a set of new thermal neutron scattering files in ENDF-6 format, that result an improvement over existing evaluations[2].

In this talk we will present the models, a brief summary of the validation and some applications to nuclear reactor calculations.

http://dx.doi.org/10.1063/1.4812828


*This work was supported in part by CONICET (J.I.M.D.) and the National Science Foundation (D.C.M.).
†Also at CONICET
Thursday December 5 (16:00 - 17:40)

Parallel Session 14 - Nuclear Reactions (Room A21) Chair: W. Lynch

16:00 - 16:20  Study of binary fragmentation and compound nucleus fission in the fusion reaction $^{50}$Ti + $^{208}$Pb
Marco Cinausero, Laboratori Nazionali di Legnaro, Italy

16:20 – 16:40  Fusion cross sections of carbon isotopes obtained with an ionization chamber in active target mode
Patricio Carnelli, Laboratorio TANDAR, CONICET, UNSAM, Argentina

16:40 – 17:00  Pre-equilibrium α-particle emission as a probe to study α-clustering in nuclei
Daniela Fabris, INFN Sezione di Padova, Italy

17:00 – 17:20  α-clustering effects in $^{12}$C + $^{12}$C and $^{14}$N + $^{10}$B reactions at 2.6 A.MeV excitation energy
Luca Morelli, Universita di Bologna and INFN Sezione di Bologna, Italy
Study of binary fragmentation and compound nucleus fission in the fusion reaction $^{50}\text{Ti} + ^{208}\text{Pb}$


$^1$INFN, Laboratori Nazionali di Legnaro, Legnaro (Padova), Italy
$^2$Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai, India
$^3$INFN and Dipartimento di Fisica e Astronomia, Università di Padova, Padova, Italy
$^4$Inter-University Accelerator Centre, New Delhi, India
$^5$Department of Physics, Panjab University, Chandigarh, India
$^6$INFN and Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy
$^7$INFN and Dipartimento di Fisica, Università di Firenze, Firenze Italy
$^8$Nevsehir University, Turkey
$^9$Universidad Simon Bolivar, Caracas, Venezuela and
$^{10}$INFN and Dipartimento di Fisica, Università “Federico II”, Napoli, Italy

The synthesis of super-heavy elements (SHEs) continues to be one of premiere frontiers of nuclear physics. There have been several reports on the production of super-heavy nuclei using different target-projectile combinations using cold fusion reactions by the observation of evaporation residues [1]. However, the fission path in these reactions has not been investigated in full detail. The fission characteristics of the super-heavy nuclei can be studied through binary fragmentation reactions in the exit channel of suitably selected heavy ion reactions, provided that the binary fragmentations resulting from the fission of compound nucleus can be separated from those resulting from non-compound processes. Further recent experimental data on cold fusion reactions leading to the formation of super-heavy nuclei with $Z \leq 113$ shows a strong dependence on coulomb parameter [2]. In order to further investigate the dynamics of binary fragmentation and fusion-fission of super-heavy systems, we carried out detailed investigation of fragment mass vs total kinetic energy distribution and neutron emission in the 294 MeV $^{50}\text{Ti} + ^{208}\text{Pb}$ reaction, leading to the formation of the super-heavy nucleus $^{258}\text{Rf}$, for which residues have been experimentally observed [1, 2]. Two Time of Flight arms based on position sensitive MCP detectors were used to catch the two complementary fragments providing a full kinematics reconstruction of the event. The emitted neutrons were detected by using an array of BC501 liquid scintillators. The neutron energy was determined by measuring the time-of-flight (TOF) with respect to the MCP start signal. A custom digital acquisition system was used. Preliminary results will be presented and discussed.

Fusion cross sections of carbon isotopes obtained with an ionization chamber in active target mode*

P. F. F. Carnelli\textsuperscript{1,2,3}, S. Almaraz Calderón\textsuperscript{4}, D. Henderson\textsuperscript{4}, K. E. Rehm\textsuperscript{4}, M. Albers\textsuperscript{4}, A. Arazi\textsuperscript{1,2}, M. Alcorta\textsuperscript{4}, P. F. Bertone\textsuperscript{4}, H. Esbensen\textsuperscript{4}, J. O. Fernández Niello\textsuperscript{1,2,3}, C. L. Jiang\textsuperscript{4}, S. T. Marley\textsuperscript{4,5}, O. Nusair\textsuperscript{4}, T. Palchan Hazan\textsuperscript{4}, R. C. Pardo\textsuperscript{4} and M. Paul\textsuperscript{6}

\textsuperscript{1}Laboratorio TANDAR, Buenos Aires, Argentina
\textsuperscript{2}CONICET, Buenos Aires, Argentina
\textsuperscript{3}UNSAM, San Martín, Buenos Aires, Argentina
\textsuperscript{4}Argonne National Laboratory, Argonne, IL, USA
\textsuperscript{5}Western Michigan University, Kalamazoo, MI, USA
\textsuperscript{6}Hebrew University, Jerusalem, Israel

Carbon fusion has provided questions to both physicists and astronomers for at least the last 50 years. From fundamental nuclear structure to recent discoveries in stellar phenomena there are still open topics. Fusion in the \textsuperscript{12}C + \textsuperscript{12}C system show oscillations that are not present in neighboring systems and are yet not completely understood \cite{1}. Unexplained behavior in the threshold between \textit{1p} and \textit{2s1d} shells is seen as fusion cross sections show significant changes in systems which differ by only a nucleon \cite{1}. A new type of stellar explosions, called \textit{superbursts}, in X-ray binaries were recently observed and are thought to require fusion of radioactive carbon isotopes for an explanation, opening new paths for stellar nucleosynthesis \cite{2, 3}. These are a few interesting examples that motivated the development of a new measurement technique, which comprises a MUlti-Sampling Ionization Chamber (MUSIC) operated in active target mode, with methane gas (CH\textsubscript{4}) as both counting gas and reaction target. This offers a high efficiency detection method where excitation functions can be sampled, using a single beam energy, in a range determined by the ionization gas pressure. This is a great advantage since it drastically reduces the measurement time and the data are automatically normalized. The high efficiency of the detector makes it ideal for experiments where the reaction cross section and/or the beam intensity are low, i.e. for processes involving radioactive nuclei.

Using the MUSIC, fusion cross sections in systems with carbon isotopes of mass numbers \textit{A} = 10, 12, 13, 14, 15 impinging on a carbon-12 target have been measured. Beam energies of about 3 MeV/\textit{A} were used for obtaining fusion excitation functions in the center of mass energy range between 10 and 20 MeV.

In this contribution, the operation principle of the MUSIC is discussed. Then, the experimental excitation functions are presented and compared with previous data (when available) and different theoretical models.


* This work was supported in part by the U.S. DOE ONP DE-AC02-06CH11357 (ANL) and the Universidad Nacional de San Martín, Argentina, grant SJ10/39 (TANDAR)
Pre-equilibrium $\alpha$-particle emission as a probe to study $\alpha$-clustering in nuclei


$^1$Institute for Nuclear Research, Moscow, Russia
$^2$Laboratori Nazionali di Legnaro, Legnaro (PD), Italy
$^3$Dipartimento di Fisica, Universita’ di Padova and INFN sezione di Padova, Padova, Italy
$^4$Dipartimento di Fisica, Universita’ di Bologna and INFN sezione di Bologna, Bologna, Italy
$^5$Dipartimento di Fisica, Universita’ di Firenze and INFN sezione di Firenze, Firenze, Italy
$^6$Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow, Russia
$^7$University of Nevsehir, Science and Art Faculty, Physics Department, Nevsehir, Turkey
$^8$Dipartimento di Fisica Universita Federico II di Napoli and INFN sezione di Napoli, Italy

The study of nuclear states built on clusters bound by valence neutrons in their molecular configurations is a field of large interest. In particular clustering will become important at the drip–line, where weakly bound systems will prevail [1]. In the case of light nuclei clustering might actually be the preferred structural mode [2]. Presently these structures are still mainly described by theory and must be experimentally verified at the new generation of radioactive beam facilities. In this regard, it is particularly interesting to confirm the existence of alpha clusterization in nuclei through a new generation experiments. In the past we have studied the reactions 250 and 130 MeV $^{16}$O + $^{116}$Sn with the GARFIELD + HECTOR apparatus at Legnaro National Laboratories [3,4]. A significant increase has been observed in the yield of the secondary alpha particles, emitted at small angles, in the pre-equilibrium part of spectra. This pronounced production is linked to secondary $\alpha$-particles emitted during non-equilibrium stage in fusion nuclear reactions and can be ascribed to the presence of $\alpha$-cluster in the $^{16}$O projectile nucleus.

A confirmation of this effect can be obtained comparing the secondary alpha particles emitted in fusion reactions where a clustering projectile ($^{16}$O) and projectile without alpha clusterization ($^{19}$F) are used. In a new experiment the two reactions $^{16}$O + $^{65}$Cu and $^{19}$F + $^{62}$Ni, leading to the same compound system $^{81}$Rb, at the same beam energy per nucleon (16 MeV/u) $E_O = 256$ MeV, $E_F = 304$ MeV have been studied using GARFIELD [5] and RCo [7] multi-detection system at LNL. Angular distributions and light charged particles emission spectra in coincidence with evaporation residues have been measured. The experimental setup and preliminary results of data analysis will be presented.

$\alpha$-clustering effects in $^{12}\text{C}+^{12}\text{C}$ and $^{14}\text{N}+^{10}\text{B}$ reactions at 2.6 A. MeV excitation energy.


$^1$ Dipartimento di Fisica e Astronomia dell'Universitá and INFN, Sezione di Bologna, Bologna, Italy.
$^2$ Dipartimento di Fisica dell'Universitá and INFN, sezione di Pavia, Pavia, Italy.
$^3$ CNRS, UMR6534, LPC, Caen, France and ENSICAEN, UMR6534, LPC, Caen, France.
$^4$ INFN, Laboratori Nazionali di Legnaro, Legnaro (Padova), Italy.
$^5$ University of Nevsehir, Science and Art Faculty, Physics Department, Nevsehir, Turkey.
$^6$ INFN, Sezione di Padova., Padova, Italy. and
$^7$ Dipartimento di Fisica dell'Universitá and INFN, Sezione di Firenze, Firenze, Italy.

An experimental campaign has been undertaken at Laboratori Nazionali di Legnaro (LNL INFN), Italy, in order to progress in our understanding of the statistical properties of light nuclei at excitation energies above particle emission threshold, by measuring exclusive data from fusion-evaporation reactions. These properties notably include the excitation energy dependence of the nucleon effective mass, symmetry energy and pairing correlations. In particular, the determination of the nuclear level density in the A $\sim$ 20 region, the understanding of the statistical behaviour of light nuclei with excitation energies $\sim$3 A.MeV, and the measurement of observables linked to the presence of cluster structures of nuclear excited levels [1] are the main physics goals of this work. On the experimental side, a first reaction: $^{12}\text{C}+^{12}\text{C}$ at 95 MeV beam energy has been measured, using the GARFIELD + Ring Counter (RCo) apparatuses [2,3]. Fusion-evaporation events have been exclusively selected out of the entire data set. The comparison to a dedicated Hauser-Feshbach calculation [4] allows us to give constraints on the nuclear level density at high excitation energy for light systems ranging from C up to Mg. Out-of-equilibrium $\alpha$ emission has been evidenced and attributed both to an entrance channel effect (favoured by the cluster nature of reaction partners), and, in more dissipative events, to the persistence of cluster correlations well above the $^{24}\text{Mg}$ threshold for 6 $\alpha$’s decay [4]. In order to study the same $^{24}\text{Mg}$ compound nucleus at similar excitation energy with respect to this first reaction a new measurement, $^{14}\text{N}+^{10}\text{B}$ at 5.7 A.MeV, was performed at LNL laboratories with the same experimental setup. The comparison between the two systems would allow us to further constrain the level density of light nuclei in the mass-excitation energy range of interest. Deviations from a statistical behaviour can be used as a tool to get information on nuclear clustering, both in the ground-state for projectile and target and in the hot source formed in the collision.

Thursday December 5 (16:00 - 17:40)

Parallel Session 15 - Hadron Structure and Interactions  (Room B11)  Chair: W. Brooks

16:00 - 16:20  Strongly interacting matter under intense magnetic fields
Norberto Scoccola, Comisión Nacional de Energía Atómica, CONICET and Universidad Favaloro, Argentina

16:20 – 16:40  Valence and sea quarks in the nucleon
Roelof Bijker, ICN-UNAM, Mexico

16:40 – 17:00  On the couplings in ELA for eta-meson photoproduction
Huachuan Wu, Universidad de Antioquia, Medellín, Colombia
The phase structure of magnetized quark matter is analyzed in the framework of the two-flavor Nambu-Jona-Lasinio models paying special attention to its dependence on the model parameters as different values within the phenomenological allowed range are considered. We first discuss the simpler chiral limit case, and then the more realistic situation of finite current masses. We show that in spite of the difference in the nature of some transitions, at low temperatures both cases are alike and exhibit a rather rich phase structure for a significant range of acceptable parameters. A simplification of the phase structure is obtained as parameters leading to larger values of the dressed quark mass in the vacuum are considered. Finally, we consider the so-called “inverse catalysis effect” showing that in some phases it implies an actual decrease of the order parameter as the magnetic field increases.
Valence and sea quarks in the nucleon

Roelof Bijker

ICN-UNAM, AP 70-543, 04510 Mexico DF, Mexico

The constituent quark model (CQM) describes the nucleon as a system of three constituent, or valence, quarks. Despite the successes of the CQM (e.g. masses, electromagnetic coupling, magnetic moments), there is compelling evidence for the presence of sea quarks from the measurement of the flavor asymmetry of the proton and the so-called proton spin crisis.

In this contribution, we present the unquenched quark model which is an extension of the CQM that includes the effects of sea quarks via a $^3P_0$ quark-antiquark pair-creation mechanism. As an application, we review the results for baryon magnetic moments and the flavor and spin content of baryons [1,2], as well as the strange magnetic moment and the strangeness radius of the proton [3].


*This work was supported in part by grants from DGAPA-UNAM and CONACyT, Mexico
In recent decades there has been substantial progress in the study of η-meson photoproduction, which is motivated by the special role of η-meson in identifying new resonances which are weakly coupled to the πN channel. Experimentally new accelerator facilities and the state-of-art detectors have facilitated the production of high-precision data [1]. On the theory side the Effective Lagrangian Approach (ELA) has shown its effectiveness and relative simplicity in interpreting data. However, in the application of ELA there exists an uncertainty in choosing the couplings: while some authors use the pseudo-scalar (PS) coupling only [2], the others employ both the pseudo-vector (PV) and the PS couplings [3]. The two types of choice can explain data fairly well, which seems somewhat puzzling and thus an in-depth study is needed for revealing the characteristics of the two couplings. 

For the resonances S11 and P11 we derive analytical formulas for the difference between the PS and PV couplings. A prominent feature is found that for these resonances the imaginary parts of the PS and PV couplings are almost equal, while the real parts of the two couplings are passing through zero at resonance point and the difference between them increases moderately when deviating from there. The imaginary part has its peak value at the resonance point while the other contributions are relatively small, thus an approximate equivalence between the PS and PV couplings occurs in an energy region around the resonance point, which is in agreement with our previous study [4]. The difference between the real part of the PS and PV couplings increases monotonously while going away from the resonance point, therefore, it can be compensated with a properly chosen form factor and an approximate equivalence between the PS and PV couplings can be reached for an extended energy region.

Recent high-precision data [1] provide a good opportunity to further check the couplings. The energy dependence of the cross section has a very different behavior for different angles. For example, the E-dependence curve for small angle (say, \( \theta = 20^\circ \)) has a big dip at c.m. energy \( \approx 1.65 \) GeV, whereas the curve becomes smooth when \( \theta \) is larger than 100 °. An interference between the S11 and P11 resonances in the energy region is also employed to explain this difference.


---

*This work was supported in part by SUI, Universidad de Antioquia, Medellin, Colombia
X Latin American Symposium on Nuclear Physics and Applications

Edificio Polifuncional J.L. Massera
Universidad de la República
Montevideo, Uruguay, December 1-6, 2013

Book of Abstracts
PLENARY SESSIONS
(Version Nov. 17, 2013)
Monday December 2
Plenary Session 1 (Anfiteatro) Chair: A. Kreiner

9:00 - 9:30 Opening Session

9:30 - 10:00 Use of molecular imaging to guide and assess radiation therapy
Robert Jeraj, University of Wisconsin, USA

10:00 - 10:30 Accelerator technology and SPECT developments for BNCT
Alejandro Valda, CNEA Buenos Aires and Universidad Nacional de San Martín, Argentina

10:30 - 11:00 Coffee Break

11:00 - 11:30 Use of $^{67}$Ga-chloride for pharmacokinetic studies of coral snake neurotoxin by SPECT/CT
Luis Alberto Medina, Universidad Nacional Autónoma de México, México and Cuernavaca, Mexico

11:30 - 12:00 Status report on the detection of illicit materials in cargo containers by using neutron beams
Giuseppe Viesti, University of Padova, Italy

12:00 - 12:30 Innovative nuclear reactors: the future of nuclear reactor technology towards sustainable development
Paulo A. B. de Sampaio, Instituto de Engenharia Nuclear, CNEN, Rio de Janeiro, Brazil
Use of molecular imaging to guide and assess radiation therapy
Robert Jeraj
University of Wisconsin, Madison

Imaging is intimately associated with radiation therapy (RT). Anatomical imaging is the standard of care for crucial components of the RT process such as tumor localization, treatment planning, and positioning verification. However, as disease progression and treatment response at the molecular and cellular level precede visible structural changes to tissue, applications of functional and molecular imaging are becoming increasingly more important.

Use of molecular imaging in RT can be divided into three phases:

1. Imaging for diagnosis and staging, performed during the initial phases of RT to establish the presence and progression of disease
2. Imaging for target definition, performed prior to RT in order to determine the spatial extent of the tumor and the position of normal tissue
3. Imaging for treatment response assessment, performed during or after RT to establish effectiveness, predict outcome, and potentially modify therapy

Following diagnosis and staging molecular imaging can help to define which type of therapy should be used, as well assess the spatial extent of the tumor, thus providing grounds for more reliable target definition. Molecular imaging has been shown to significantly reduce large inter-observer variability in target definition compared to anatomical imaging. This reduction leads to significant reduction in treatment margin, thereby enabling more accurate and precise tumor targeting. Furthermore, molecular imaging has the potential to characterize biological heterogeneity within tumors, providing foundations for so-called biologically conformal radiotherapy, or dose painting. Early treatment response assessment refers to the use of molecular imaging during the course of therapy, and late treatment response assessment refers to the use of molecular imaging after the therapy has been completed. While late assessment enables prediction of treatment outcome, early assessment, in addition, enables treatment adaptation.
Accelerator technology and SPECT developments for BNCT*

J. Bergueiro1, M. Baldo1, D. Cartelli1,2, W. Castell1, J. Gómez1, J. Padulo1, J. C. Suarez Sandín1, M. Igarzábal1, J. Erhardt1, D. O. Mercuri1, D. M. Minsky1,2, A. A. Valda1,2, J. M. Kesque1, M. E. Capoulat1,3, M. S. Herrera1,3, S. González1,3, H. Somacal1,2, M. E. Debray1,2, M.F. del Grosso1,2, L. Gaggetti1,3, M. Suárez Anzorena1, O. García Carranza1, N. Canepa1, S. Girola1,2, M. Gun4, L. Rogulich1,2, A. J. Kreiner1,3

1 Accelerator Technology and Applications, CNEA, Buenos Aires, Argentina
2 School of Science and Technology, Universidad Nacional de San Martín, San Martín, Argentina
3 CONICET, Buenos Aires, Argentina
4 Faculty of Engineering, University of Buenos Aires, Buenos Aires, Argentina

Accelerator-Based BNCT (AB-BNCT) is establishing itself worldwide as the future modality to start the phase of in-hospital facilities. There are projects in Russia, UK, Italy, Japan, Israel, and Argentina to develop AB-BNCT around different types of accelerators. They will be briefly mentioned. In particular, the present status and recent progress of the Argentine project will be presented. The topics will cover: high power ion sources, power and voltage generation systems for a Tandem-Electrostatic-Quadrupole (TESQ) accelerator, acceleration tubes, transport of intense beams, beam diagnostics, control systems, high power targets, the 9Be(d,n) reaction as a possible neutron source, Beam Shaping Assemblies (BSA’s), treatment room design, treatment planning assessment of clinical cases, etc. A complete test stand has been built and commissioned for intense proton beam production and characterization. Beams of 10 to 30 mA have been produced and transported during variable periods of operation by means of a pre accelerator and an electrostatic quadrupole doublet to a suppressed Faraday cup. The beam diagnostics has been performed through the observation with digital cameras of induced fluorescence in the residual gas. A 200 kV TESQ accelerator prototype has been constructed and tested and a 600 keV prototype is under construction. Selfconsistent space charge beam transport simulations have been performed and compared with experimental results. In addition to the traditional 7Li(p,n)7Be reaction, 9Be(d,n)10B using a thin Be target has been thoroughly studied as a candidate for a possible neutron source for deep seated tumors, showing a satisfactory performance. BSA’s and production targets and a treatment room complying with regulations have also been designed. Realistic clinical treatment planning cases for AB-BNCT have been studied showing very good results. Finally we will present advances in the development of a Single Photon Emission Computed Tomography (SPECT) system for online dosimetry during a BNCT treatment.

* This work was supported in part by CONICET and Universidad Nacional de San Martín.
Use of $^{67}$Ga-chloride for pharmacokinetic studies of coral snake neurotoxin by SPECT/CT*.

LA Medina$^{1,3}$, I Vergara$^{2}$, ME Romero-Piña$^{3}$, A Alagon$^{2}$

$^{1}$Instituto de Física, UNAM (Mexico City, Mexico)
$^{2}$Instituto de Biotecnología, UNAM (Cuernavaca City, Mexico)
$^{3}$Unidad de Investigación Biomédica en Cáncer, INCan-UNAM (Mexico City, Mexico)

The gamma emitting radionuclides have been widely used in the radiolabeling of biomolecules due to their suitable physical properties, including half-life, gamma energy, suitable chemistry, etc. There are several papers reporting the pharmacokinetics of radiolabeled toxic proteins of animal poisonous with $^{125}$I; the data show that the toxins do not lose its toxicological effect after radiolabeling [Pepin et al., 1995; Riviere et al., 1996]. Unfortunately, this radionuclide is not available in Mexico and the radiolabeling of toxins to perform pharmacokinetics studies that will help in the development of antivenom therapies need to be evaluated with other kind of gamma-emitters radionuclides. Beside $^{67}$Ga is no longer commonly used in clinical practice it still has potential to perform pharmacokinetics studies of biomolecules of medical interest. $^{67}$Ga (half-life 78 h) is a gamma-emitting isotope (the gamma emitted immediately after electron-capture) which main energies of emission are 184.6, 93.3, and 300.2 keV.

In this work, we show the results of the radiolabeling and pharmacokinetics of a neurotoxin of coral snake venom with $^{67}$GaCl$_3$. The pharmacokinetics was evaluated in rats, after subcutaneous injection in its foot pad, using a microSPECT/CT system (Albira ARS). The determination of neurotoxin pharmacokinetics is very important for the optimization of antivenom therapy. Monitoring the neurotoxin biodistribution in organs and tissues using SPECT/CT technique could provide important findings about the envenomation development.


* This work was supported in part by a research grant from CONACyT-Mexico and PAPIIT-UNAM.
Non-intrusive inspection of cargo containers has become a key issue in the fight against terrorism. Indeed, shipping of cargo container between seaports represent today one of the more important way of the international trade. After 9/11, the Cargo Security Initiative started setting standards for the cargo containers inspections in the trading between US and other countries, as the ones in the European Union (EU). US are now aiming at 100% scanning of cargo containers shipped towards the American ports.

At present time, controls are mainly based on X- or gamma-ray scanners, which provide mainly the shape and density of the transported goods. Fast neutrons can be additionally employed to deduce information about their elemental composition. Neutrons have been selected mainly thanks to their capability of penetrating materials and the availability of different type of neutron sources.

Neutron transmission measurements or the detection of characteristic gamma-rays emitted following neutron induced reactions have been proposed to characterize carbon, oxygen and nitrogen, which are major components of explosives or narcotics, with the goal of discriminating illicit from “benign” materials. Several systems have been validated under laboratory conditions demonstrating that such technologies are capable of providing material specific information and few of them have been fielded. However, the use of neutron based tools depends not only on the intrinsic capability of the method, as explored in laboratory conditions, but also on some major issues:

1) the possibility of solving logistics and licensing problems;
2) the possibility of constructing systems that are operated directly by end-users;
3) the effective integration of the neutron based system in current customs procedures.

In this talk, the general capability of neutron sources to be used in a cost effective way to detect illicit materials inside cargo containers will be discussed looking also to the latest technical development in the field of neutron generators, detectors and associated front-end electronics. Moreover, some of the systems that have been fielded so far will be discussed comparing their distinctive technical characteristics with explicit reference to the FP6 project EURITRACK and the Italian, recently developed system called SMANDRA.
Innovative Nuclear Reactors: the future of nuclear reactor technology towards sustainable development

P. A. B. de Sampaio
Instituto de Engenharia Nuclear/CNEN, Rio de Janeiro, Brazil

Between a third and a quarter of human population does not have access to electricity, relying on burning wood as its only energy source. On the other hand, the developed countries, which consume most of the energy generated in the world, have an energy matrix based on the use of fossil sources. Such an energy matrix, if extended at the same level of demand for the whole mankind, would render human life unviable. Thus, promoting the development of third world countries, seeking equity and a better wealth distribution, is a challenge that impacts the survival of mankind.

A particularly concerning issue is the increase of green house gas emissions (GHG) resulting from burning fossil fuels and the climatic consequences of such emissions. According to the Intergovernmental Panel on Climate Change (IPCC), through its most recent Synthesis Report of 2007 (a new one is due shortly), there are strong evidences that anthropogenic causes, and in particular CO2 emissions, are among the main driving forces of global warming [1].

Studies such as those of IPCC indicate that nuclear energy will have an important role as a key mitigation technology for containing CO2 emissions in the next decades [1], [2]. Nonetheless, the effective contribution of nuclear energy will depend on various factors related to economics, safety and security, public acceptance and sustainability.

There are two important initiatives regarding the discussions on the future of nuclear reactor technology. One of those is co-ordinated by the International Atomic Energy Agency (IAEA) and is known as “International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)”. The other is lead by the Department of Energy of the United States and is known as “Generation IV (GIF)

Indeed, the challenge facing the development of Innovative Nuclear Reactors is, through comprehensive R&D programs, to establish technological breakthroughs that overcome seemingly contradictory objectives of economy, safety and security, public acceptance and sustainability.

Plenary Session 2 (Anfiteatro)  Chair: G. González-Sprinberg

14:00 - 14:30  Challenges for high power superconducting linacs  
Andrew Hutton, Jefferson Lab, Newport News, Virginia, USA

14:30 - 15:00  Status of the rare isotope reaccelerator facility ReA at NSCL  
Fernando Montes, Michigan State University, East Lansing, Michigan, USA

15:00 - 15:30  Evidence for a triangular $D_{3h}$ symmetry in $^{12}$C  
Moshe Gai, University of Connecticut, Groton, Connecticut, USA

15:30 - 16:00  Coffee break

16:00 - 16:30  Dynamical exploration of complex states of matter in neutron stars crusts  
Virginia de la Mota, SUBATECH and Université de Nantes, France

16:30 - 17:00  Nuclear astrophysics with radioactive beams  
Carlos A. Bertulani, Texas A&M University, USA

17:00 - 17:45  Astroparticles in Latin America: current status and outlook  
Ivan Sidelnik, CNEA, CONICET and Instituto Balseiro, Bariloche, Argentina
Challenges of High Power Superconducting Linacs *

A. Hutton
Jefferson Lab, Newport News, USA

Superconducting linear accelerators have been operating for well over 40 years, initially with heavy ions in the ATLAS facility at ANL in 1977, and then with electrons in the CEBAF facility at Jefferson Lab in 1995. CEBAF was the first megawatt-class superconducting linear accelerator, and this was followed by the SNS facility at ORNL in 2003, which has now accelerated a megawatt H* beam to produce spallation neutrons.

Superconducting linacs are considered to be the best way of producing megawatt beams at GeV energies; this is the domain of spallation neutron sources (ESS in LUND, Sweden), and Accelerator Driven Systems (ADS) for transmutation of nuclear waste and driving sub-critical reactors for nuclear energy (MYRRHA in Mol, Belgium; C-ADS in Shandong Province, China; and the proposed facility in Visakhapatnam, India).

Superconducting linacs should also be the technology of choice for low-energy, high-current linacs for isotope production, security screening, and inverse Compton X-Ray sources. However, this requires considerable progress in minimizing the cryogenic requirements, primarily through operation at 4.2K.

Many laboratories around the world are developing the technologies needed for high-power CW superconducting linacs. This paper will present an overview of the challenges, with examples of partial and full solutions. Future areas of R&D will be highlighted, with particular focus on the areas suitable for university research.

* This work was supported by Jefferson Science Associates, LLC under U.S. DOE Contract No. DE-AC05-06OR23177
Status of the rare isotope reaccelerator facility ReA at NSCL*

F. Montes\textsuperscript{1,2}

\textsuperscript{1}NSCL, Michigan State University, East Lansing, MI 48824, USA and
\textsuperscript{2}Joint Institute for Nuclear Astrophysics, Michigan State University, E. Lansing, MI 48824, USA

Nucleosynthesis processes in novae, supernovae and X-ray bursts often involve unstable ions and reactions that are currently unavailable or chemically difficult to obtain at the relevant energies in rare beam facilities. The ReAccelerator facility (ReA) at Michigan State University will provide heavy ion beams with energies well suited for astrophysically motivated nuclear studies. The possibility to measure direct measurements of capture reactions, transfer reactions and/or scattering reactions measurements, among others, will provide exciting science opportunities. An overview and status of the ReA facility along with results of the ongoing beam commissioning and experimental plans will be presented.

* This work was supported by the National Science Foundation under Cooperative Agreement PHY1102511 and Michigan State University
Evidence for a Triangular $D_{3h}$ Symmetry in $^{12}\text{C}$

M. Gai$^1$, M. Freer$^2$, T. Kokalova$^2$, D.J. Marin-Lambarri$^2$, C. Wheldon$^2$

1. LNS at Avery Point, University of Connecticut, Groton, CT 06340-6097, USA and WNSL, Dept of Physics, Yale University, New Haven, CT 06520-8124
2. School of Physics and Astronomy, University of Birmingham, Birmingham B15 2TT, UK

Geometrical equilateral triangular configuration [1] have been identified in Molecular Physics [2] and in the structure of the proton [3] where the predicted spectrum of an oblate spinning top with a $D_{3h}$ symmetry was observed. It was suggested [1] that the three alpha-particle system of $^{12}\text{C}$ should lead to similar structure. Specifically the ground state rotational band of $^{12}\text{C}$ was predicted [1] to include the most unusual sequence of states: $0^+, 2^+, 3^-, 4^\pm$ and $5^-$. A new high spin state reported by the Birmingham group [4] as well the previously published $4^+$ and $4^- [5,6,7]$ states lead to a $J(J+1)$ trajectory as predicted by the U(7) model including the nearly degenerated $4^-$ and $4^+$ states.

In addition this U(7) model predicts [1] the Hoyle state at 7.65 MeV in $^{12}\text{C}$ to be the first vibrational breathing mode of the three alpha-particle equilateral configuration leading to the same rotational structure albeit with a larger moment of inertia (by a factor of 2). Recent measurements revealed the $2^+$ [8,9,10,11] and $4^+$ [5] members of the predicted Hoyle rotational band and we are currently searching [12] for the $4^-$ predicted to be nearly degenerated with the $4^+$ state and the $3^-$ (broad) state that was suggested to lie between 11 and 14 MeV [6].

The U(7) model also predicts the $1^-$ state at 10.84 MeV to be the vibrational bending mode with a rotational band including the $1^-$ and a degenerate $2^\pm$ states. We are searching for the third $2^+$ of $^{12}\text{C}$ that is predicted by the U(7) model to lie near the observed $2^-$ state at 11.8 MeV.

[12] A $^{12}\text{C}(e,e')$ experiment in progress at Darmstadt; P. von Neumann-Cosel et al.

*Work Supported by U.S. Department of Energy, grant number DE-FG02-94ER40870.
Dynamical exploration of complex states of matter in neutron stars crusts*

V. de la Mota and M. Novak

Institution1 (SUBATECH, Nantes, France)

Modern nuclear physics as well as many-body theories are valuable tools which may allow us to improve our understanding of the physics of compact objects. The interest is twofold: on one side, learning about stellar matter properties as its transport coefficients, may have important astrophysical consequences. On the other side, probing the equation of state to which the occurrence of exotic structures in neutron stars crusts is expected to be sensitive, is in direct connexion with heavy ion reactions aspects as the processes leading to fragment formation. We investigate the occurrence of exotic structures in the outermost layers of neutron stars within the framework of a microscopic model [1] describing the nucleonic dynamics through a time-dependent mean field approach at around zero temperature. In this model starting from an initial crystalline lattice of nuclei at subnuclear densities the system evolves and self-organizes in various low-lying energy structures without assumption of final shapes [2]. The effect on the behavior of these structures due to different lattice symmetries, densities, nuclear composites and lattice perturbations are analyzed. We investigate their sensitivity to the equation of state (in particular to the isospin-dependent part of the effective force) and propose a general treatment of transport phenomena in the nuclear medium of the crust.


*This work was supported in part by IN2P3 (CNRS), Universite de Nantes and Ecole des Mines de Nantes
Eighty years of nuclear science has allowed us to infer the origin of the chemical elements out of which our bodies and the Earth are made. We now believe that the lightest elements were created in nuclear reactions in the first three minutes after the big bang, and all the rest were made in nuclear reactions inside the stars and distributed throughout interstellar space via stellar winds and giant stellar explosions. I will show how a new generation of theoretical developments and experiments can shed light on the complex nuclear processes that control the evolution of stars and stellar explosions [1-3].

Astroparticles in Latin America: Current Status and Outlook

I. Sidelnik

1Centro Atómico Bariloche (CNEA y CONICET) e Instituto Balseiro, Av. Bustillo km 9.5, San Carlos de Bariloche, Río Negro, Argentina

The successful installation and operation of the Auger Observatory in Argentina has been a milestone in Astroparticle research in Latin America [1-2], generating new regional research opportunities in the field. In this context, the LAGO (Large Aperture Gamma ray Burst) Observatory [3-4], began in 2005 with the aim of studying the high-energy component of the gamma ray bursts (GRBs) [5]. The observatory consists of different arrays of water Cherenkov detectors installed in high altitude mountains throughout Latin America [6]. Recently, it has been demonstrated the feasibility of conducting studies on the solar modulation of the galactic cosmic ray flux [7]. Currently more than 80 scientists and students from Mexico, Guatemala, Colombia, Venezuela, Ecuador, Peru, Bolivia and Argentina are integrated into the LAGO Collaboration. The high level of regional integration in the scientific community reached thanks to this kind of major projects, has led to the recent formation of the CLES (Consortio Latinoamericano de Experimentos Subterráneos) [8]. This organization promotes the creation and installation of the ANDES Underground Laboratory [8] to be built inside the projected International Agua Negra tunnel between Argentina and Chile. The ANDES laboratory with over 1750 meters of rock cover, will be the first laboratory of its kind to be installed in the Southern Hemisphere [9].

In this talk I will describe the current status of these enterprises in our region and its future possibilities.

Tuesday December 3
Plenary Session 3 (Anfiteatro)  Chair: O. Naviliat-Cuncic

9:00 - 9:30  The Qweak experiment
Juan Carlos Cornejo, College of William and Mary, Williamsburg, Virginia, USA

9:30 - 10:00  Precision measurements of β-decay correlation parameters from trapped atoms and ions
Dan Melconian, Texas A&M University, College Station, Texas, USA

10:00 - 10:30  Isobar separation and precision mass spectrometry of short-lived nuclides with a multi-reflection time-of-flight analyzer
Lutz Schweikhard, University of Greifswald, Greifswald, Germany

10:30 - 11:00  Coffee Break

11:00 - 11:30  Low energy-neutrons in the study of the hadronic weak Interaction: The NPDGamma experiment
Libertad Barrón Palos, Universidad Nacional Autónoma de México, México, Mexico

11:30 - 12:00  Precision measurements in nuclear beta-decay with LPCTrap
Xavier Fléchard, Laboratoire de Physique Corpusculaire de Caen, Caen, France

12:00 - 12:30  Using cosmic muons to search for cavities in the Pyramid of the Sun, Teotihuacan: preliminary results
Arturo Menchaca-Rocha, Universidad Nacional Autónoma de México, México, Mexico
The Q_{weak} experiment measured the parity-violating asymmetry from elastic electron-proton scattering at \( Q^2 = 0.025 \text{ (GeV/c)}^2 \). Using a 1.155 GeV/c 89% longitudinally polarized electron beam current of up to 180 \( \mu \text{A} \) incident on a 34.4 cm long high-powered liquid \( \text{H}_2 \) cryotarget and a 9000 A torodial magnet selected out elastically scattered electrons that were then detected on an array of eight symmetrically placed Čerenkov detectors. The results from our commissioning period, which constitute approximately 4% of our data, have been published, where we report a parity violating asymmetry of \( A_{ep} = -279 \pm 35 \) (statistics) \( \pm 31 \) (systematics) ppm. By combining the results of other Parity Violating Electron Scattering (PVES) experiments, we have precisely determined the weak charge of the proton \( (Q_w^p) \), and inclusion of Atomic Parity Violating Experiments (APV) allows for a determination of the neutron’s weak charge. During this talk I will detail the advantages of a PVES experiment, as well as the challenges we faced. I will also discuss our published results and what we expect to achieve after the analysis of our complete dataset.
Precision measurements of $\beta$-decay correlation parameters from trapped atoms and ions

D. Melconian
Cyclotron Institute and Department of Physics & Astronomy, Texas A&M University, College Station, TX USA

Precision measurements in the low-energy frontier of nuclear physics provide an elegant way to complement searches at colliders for physics beyond the standard model of particle physics. The momenta of the leptons and daughter nucleus following $\beta$ decay immediately probe physics at the scale of the mass of the $W$ boson mediating the transition. If so-far unseen mediators were to weakly participate in $\beta$ decay (for example a right-handed $W$ boson), they would affect the angular distribution of the decay; precision measurements of the correlation parameters, on the order of 0.1% of their value, would be sensitive to (or meaningfully constrain) new physics.

By combining neutral atom trapping techniques with optical pumping methods, the TRINAT collaboration at TRIUMF has the ability to highly-polarize ($\gtrsim 99\%$) a very cold ($\lesssim 1$ mK), localized ($\lesssim 1$ mm$^3$) source of short-lived ($\sim 1$ s) $^{37}$K atoms. This is an ideal source of radioactive atoms which allows unprecedented precision in measuring the polarized observables of beta decay.

Although known predominantly for their incredible mass-measurement abilities, ion traps are another technology that can provide a clean, localized source of short-lived nuclei for precision $\beta$-decay experiments. TAMUTRAP is a new Penning trap facility being constructed at the Cyclotron Institute at Texas A&M University. At the heart of this facility is a large-bore 7-Tesla magnet which will house a cylindrical Penning trap with an inner diameter of 180 mm. The unprecedented open-area of TAMUTRAP is ideal for $4\pi$ collection of the delayed protons following the superallowed $\beta$ decays of $T = 2$ nuclei.

In this talk I will give an overview of the TRINAT and TAMUTRAP facilities and their experimental programs. Preliminary results and lessons learned from a recent test run at TRIUMF measuring the $\beta$ asymmetry parameter, $A_\beta$, will be presented. The status and progress in constructing TAMUTRAP will also be presented.

*This work was supported by DOE ER41747 and ER40773
Isobar separation and precision mass spectrometry of short-lived nuclides with a multi-reflection time-of-flight analyzer

Lutz Schweikhard\textsuperscript{1} for the ISOLTRAP collaboration\textsuperscript{2}

\textsuperscript{1}Institute of Physics, University of Greifswald, 17487 Greifswald, Germany
\textsuperscript{2}http://isoltrap.web.cern.ch/isoltrap/

Multi-reflection time-of-flight (MR-ToF) analyzers are low-energy (i.e. keV) table-top ion-beam devices that can achieve mass resolving powers $R = m/\Delta m$ exceeding 100,000 on millisecond timescales. A dedicated device \cite{1} was built in Greifswald and implemented in the precision Penning-trap mass spectrometer ISOLTRAP \cite{2} at the online isotope-separator ISOLDE at CERN/Geneva. It was installed between the rf quadrupole ion trap for capturing and bunching of ISOLDE’s continuous 60-keV ion beam and the first of ISOLTRAP’s two Penning traps. The MR-ToF analyzer (Fig. 1) consists of two electrostatic ion mirrors between which the ions are repeatedly reflected. The ions are captured and ejected by pulsing the potential of an “in-trap lift” electrode \cite{3}.

![Fig. 1: Sketch of ISOLTRAP MR-ToF mass analyzer in combination with an ion detector (top right) or a Bradbury-Nielsen gate (bottom right) \cite{1c}.](image)

As indicated in the figure (top right), a detector behind the MR-ToF analyzer can record ToF spectra for precision mass spectrometry. Alternatively, it can be combined with a Bradbury-Nielsen gate \cite{4} for ion selection, i.e. for ion-beam purification. For the first direct mass measurement of the short-lived \textsuperscript{82}Zn \cite{5}, the latter mode was used to remove the abundant isobaric rubidium contamination. In the mass spectrometer mode, the new device allowed precision mass measurements of the low-yield – and so far unreached – exotic calcium isotopes \textsuperscript{53,54}Ca. The resulting nuclear binding energies were decisive in confirming $N=32$ as a magic neutron number \cite{6}. In addition, the MR-ToF’s fast high-resolution mass analysis is an important tool for ISOLDE target and ion source developments \cite{1c}.

\begin{thebibliography}{9}
\bibitem{3} R.N. Wolf \textit{et al}., Int. J. Mass Spectrom. 313 (2012) 8
\bibitem{4} N. Bradbury and R. Nielsen, Phys. Rev. 49 (1936) 388
\bibitem{6} F. Wienholtz \textit{et al}., Nature 498 (2013) 346
\end{thebibliography}
Low energy-neutrons in the study of the Hadronic Weak Interaction: The NPDGamma Experiment

L. Barrón-Palos

Instituto de Física, Universidad Nacional Autónoma de México, México D.F., México

The study of the Hadronic Weak Interaction, and particularly of the stangeness-conserving HWI between nucleons, is of interest for several reasons: The fact that the QCD symmetries cannot explain some properties observed in the strangeness-changing HWI [1] opens the possibility for a non-trivial QCD dynamical process that either is related to the presence of the strange quark, or is a more general process that affects light quarks as well; measurement of weak amplitudes in the $\Delta S = 0$ sector could discriminate between the two possibilities. The $\Delta S = 0$ HWI is also perhaps the only via to study weak neutral currents at low energies [2], and constitutes a probe for quark-quark correlations in nucleons. At low energies, using an Effective Field Theory (EFT) approach, the nucleon-nucleon (NN) HWI can be parameterized in terms of five weak transition amplitudes involving $S$ and $P$ waves [3]. There is a program to determine these weak amplitudes through the measurement of Parity Violating (PV) observables in few-nucleon systems in experiments that make use of low-energy neutron beams at the ORNL Spallation Neutron Source (SNS) and the NIST Center for Neutron Research (NCNR). Some of the experiments of this program will be presented, with emphasis on the NPDGamma experiment [4], currently measuring at the SNS the PV asymmetry in the spatial distribution of the gamma rays emitted in the $\vec{n} + p \rightarrow d + \gamma$ nuclear reaction ($A_{\gamma}$), which occurs through the $\Delta I = 1 \ 3S_1 - 3P_1$ transition, dominated by long-range pion exchange. The goal of the experiment is to measure $A_{\gamma}$ to a precision of $10^{-8}$. Preliminary results will be discussed.


---

*This work was supported in part by PAPIIT-UNAM IN111913
†For the NPDGamma Collaboration
Precision measurements of the beta-neutrino angular correlation coefficient, \( a \), in nuclear beta-decay constitute sensitive tools to search for exotic couplings presently excluded by the V-A theory of the weak interaction. The study of pure Gamow-Teller (GT) transitions enables to probe tensor type couplings, while pure Fermi (F) transitions are sensitive to scalar-type interactions. In addition, precise measurements in mirror transitions provide experimental values of the mixing ratios, \( \rho \), between the GT and F contributions. They thus enrich the database of nuclear transitions used for the determination of the \( V_{ud} \) element of the CKM matrix [1].

For beta-neutrino correlation measurements, the most relevant observable is the energy of the recoiling daughter nucleus. The LPCTrap device, installed at GANIL, makes use of a Paul trap to confine the radioactive nuclei. The detection of the recoil ions and beta particles in coincidence provides the recoil-ion energies by time of flight measurements [2]. The Paul trap is chemically unselective and enables therefore the confinement of any radioactive specie. Correlation measurements have so far been performed in the pure GT transition of \(^6\text{He}^+\) and in the mirror transition of \(^{35}\text{Ar}^+\) and a new measurement will be carried out in the mirror decay of \(^{19}\text{Ne}^+\). The collected data have provided relative statistical precisions on \( a \) better than 0.5%. Particular attention is now being devoted to the study of systematic effects.

The detection set-up enables simultaneous measurements of both the charge-state and the energy of the recoil-ions. Fundamental atomic processes such as electron shakeoff (SO) resulting from the sudden change of the central potential will thus also be discussed [3].


*Present address: Physics Division, Argonne National Laboratory, Argonne, IL 60439, USA
†Present address: RIKEN Advanced Science Institute, Hirosawa, Wako, Saitama 351-0198, Japan
Using cosmic muons to search for cavities in the Pyramid of the Sun, Teotihuacan: preliminary results.

S. Aguilar¹, R. Alfarò¹, E. Belmont¹, V. Grabski¹, T. Ibarra¹, V. Lemus¹, L. Manzanilla², A. Martínez-Dávalos¹, M. Moreno¹, R. Núñez¹, A. Sandoval¹, and A. Menchaca-Rocha¹.

¹Instituto de Física, Universidad Nacional Autónoma de México, México
²Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México, México

Over the last two years the Pyramid of the Sun, at Teotihuacan, Mexico, has been searched for possible hidden chambers by means of muon attenuation measurements inside the monument’s volume. The experimental method is based on the use of a muon tracker [1] placed in a chamber at the end of a tunnel, which runs below the base, and ends close to the symmetry axis of the pyramid. The accumulated experimental data, when compared to physics simulations using GEANT4 [2], already show identifiable known features of the external shape of the pyramid. Experimental results of the relative density distribution inside the pyramid are presented and compared to the aforementioned Monte Carlo simulations.

Fig 1. External shape of the Pyramid of the Sun. Outlined in dark blue is the projected detector field of view. The prehispanic tunnel location is shown in red.

Wednesday December 4
Plenary Session 4  (Anfiteatro)  Chair: R. Bijker

9:00 - 9:30  *Collinear Structure Functions of the Nucleon: Status and Future*
*Sebastian E. Kuhn*, Old Dominion University, Norfolk, Virginia, USA

9:30 - 10:00  *Hadron spectroscopy at CLAS and CLAS12*
*Marco Battaglieri*, INFN Sezione di Genova, Genova, Italy

10:00 - 10:30  *Meson Spectroscopy at GlueX*
*Carlos Salgado*, Norfolk State University and JLab, Virginia, USA

10:30 - 11:00  Coffee Break

11:00 - 11:30  *The ALICE experiment at the LHC*
*Gerardo Herrera Corral*, CINVESTAV, México, Mexico

11:30 - 12:00  *The emergence of hadrons from color charge in QCD*
*William Brooks*, Universidad Técnica Santa María, Valparaiso, Chile

12:00 - 12:30  *Status and Science of the Facility for Rare Isotope Beams*
*Brad Sherrill*, FRIB, Michigan State University, East Lansing, Michigan, USA
Collinear Structure Functions of the Nucleon: Status and Future

S.E. Kuhn

1Old Dominion University, Norfolk/Virginia, USA

While our ultimate goal is a complete three-dimensional picture of the nucleon in terms of its fundamental constituents, there are still important lessons to be learned about its “one-dimensional” collinear parton distribution functions (PDFs) like $f_1(x)$ and $g_1(x)$. There are rigorous proofs for factorization [1] and universality (process independence) which make these PDFs fundamental. They also appear as limits of Generalized Parton Distributions (GPD) and as integrals of transverse momentum-dependent (TMD) parton distribution functions.

Experimentally, the unpolarized structure functions $F_1(x, Q^2), F_2(x, Q^2)$ have been studied over a huge kinematic range in both variables. Information on the polarized structure functions $g_1(x, Q^2), g_2(x, Q^2)$ is somewhat more limited, both in kinematics and in statistical precision. In both cases, much less is known about the neutron than the proton, due to the absence of a free neutron target. Accessing these structure functions at large $x$ (where valence quarks dominate) has been challenging due to the high luminosity and the high resolution required. Finally, much information can be extracted from studying higher twist contributions to these structure functions and the connection between the DIS limit and the region where nucleon resonance excitation dominates.

In my talk, I will present an overview of recent experimental results (with special emphasis on the valence region and the transition from quark to hadronic degrees of freedom). I will also give an outlook on the next round of experiments coming online with the energy-upgraded Jefferson Lab electron beam, and future projects like the Electron Ion Collider.


*This work was supported by the U.S. Department of Energy
The known hadron matter is made of two possible configurations: baryons, combination of 3 quarks and mesons, made by a quark and an anti-quark pair. QCD, the fundamental theory of strong interaction does not exclude the existence of states made by different combination of quarks and gluons: tetra-quarks, exotic and hybrid mesons, glue-balls. Precise determination of the hadron spectrum as well as finding evidence for such configurations would help in understanding one of the main open question in hadron physics: how the quark are confined within hadrons. In spite of a several decades of investigation, the experimental proof of the existence of such states is still under debate and the excited spectrum of mesons and baryons produced with different beams represent one of the main topic in the research programs of many existing (CERN, SLAC, BES, JLab ..) and future (JLAB12, FAIR ...) facilities. In my talk I will present the the results obtained at Jefferson Lab with the CLAS detector and the physic program that will be pursued in the Hall-B using the CLAS12 detector and the energy-upgraded beam of JLab. The physic case as well as the quasi-real photon tagger facility proposed for that experimental Hall will be described and some expected results will be shown.
Meson Spectroscopy at GlueX*

Elton S. Smith\textsuperscript{1} for the GlueX Collaboration
\textsuperscript{1} Jefferson Lab, Newport News, VA 23606 USA

The goal of the GlueX experiment [1] is to provide critical data to help understand the soft gluonic field responsible for binding quarks in hadrons. Hybrid mesons, and in particular exotic hybrid mesons, provide the ideal laboratory for testing QCD in the confinement regime since these mesons explicitly manifest the gluonic degrees of freedom. Photoproduction is expected to be particularly effective in producing exotic hybrids but there is little data on the photoproduction of light mesons. GlueX will use the new 12-GeV electron beam at Jefferson Lab to produce a 9-GeV beam of linearly polarized photons using the technique of coherent bremsstrahlung. A solenoid-based hermetic detector is under construction, which will be used to collect data on meson production and decays. These data will also be used to study the spectrum of conventional mesons, including the poorly understood excited vector mesons. This talk will give an update on the experiment as well as describe the latest theoretical developments [2] to help understand how the data of hybrid mesons can provide insights into the fundamental theory of strong interactions.


* This manuscript has been authored by Jefferson Science Associates, LLC under Contract No. DE-AC05-06OR23177 with the U.S. Department of Energy.
The ALICE experiment at the LHC

Gerardo Herrera Corral
(on behalf of the ALICE Collaboration)
Physics Department, CINVESTAV, México D.F., Mexico

ALICE is one of the four large experiments at the LHC. It focuses on the study of ultra-relativistic heavy ion collisions. Its main goal is to study in great detail the properties of matter under extreme energy densities. We discuss some aspects of the ALICE research program, the experiment future plans as well as some general items of the ALICE upgrade. After a summary of the main results we discuss briefly recent activities on diffractive physics. A proposal to install detectors in the forward region is also presented. These new detectors would allow one to study processes with rapidity gaps larger than those presently covered.
The Emergence of Hadrons from Color Charge in QCD

W.K. Brooks and H. Hakobyan

Universidad Técnica Federico Santa María, Valparaíso, Chile

The propagation of colored quarks through strongly interacting systems, and their subsequent evolution into color-singlet hadrons, are phenomena that showcase unique facets of Quantum Chromodynamics (QCD). Medium-stimulated gluon bremsstrahlung, a fundamental QCD process, induces broadening of the transverse momentum of the parton, and creates partonic energy loss manifesting itself in experimental observables that are accessible in high energy interactions in hot and cold systems. The formation of hadrons, which is the dynamical enforcement of the QCD confinement principle, is very poorly understood on the basis of fundamental theory, although detailed models such as the Lund string model or cluster hadronization models can generally be tuned to capture the main features of hadronic final states. With the advent of the technical capability to study hadronic final states with good particle identification and at high luminosity, a new opportunity has appeared. Study of the characteristics of parton propagation and hadron formation as they unfold within atomic nuclei are now being used to understand the coherence and spatial features of these processes and to refine new experimental tools that will be used in future experiments. Fixed-target data on nuclei with lepton and hadron beams, and collider experiments involving nuclei, all make essential contact with these topics and they elucidate different aspects of these same themes. In this talk, a survey of the most relevant recent data and its potential interpretation will be followed by descriptions of planned experiments at Jefferson Lab following the completion of the 12 GeV upgrade, and feasible measurements at a future electron-ion collider.

*This work was supported in part by the Chilean CONICYT
Unanswered questions include how the elements heavier than iron were formed in nature and what are the limits of atomic nuclei both in atomic number and in neutron number. Up to the present, claims for the synthesis of element 118 [1] have been made and new searches are underway. How many more elements might ultimately be found is unknown. Equally unknown for all but the very lightest elements is the limit to the number of isotopes [2]. These mysteries are a reflection of our poor understanding of how to model the interactions at play in atomic nuclei. Another manifestation of our lack of understanding is the uncertainties in modeling astrophysical processes involving nuclei [3]. The nuclear processes that drive stars, stellar evolution, and stellar explosions are central to understanding the cosmos, yet most are not known to sufficient accuracy.

Answers to the questions and solutions the challenges mentioned above require production and study of rare isotopes. The major project in the USA in isotope beam production is the Facility for Rare Isotope Beams, FRIB. FRIB will use heavy-ion beams and in-flight separation following projectile fragmentation or fission to produce beams of a large fraction of all possible isotopes. To do this, FRIB will accelerate all stable ions up to at least 200 MeV/u at beam powers of 400kW. Experimental facilities will include fast, stopped and reaccelerated beam capabilities. The talk will describe the plans for FRIB, the expected performance, and outline the expected science program.


* Work supported by US DOE Cooperative Agreement DE-SC0000661 and by Michigan State University.
Thursday December 5
Plenary Session 5 (Anfiteatro)  Chair: R. Donangelo

9:00 - 9:30  *Experiments with the double solenoid system RIBRAS*
Rubens Lichtenthäler, Universidade de São Paulo, São Paulo, Brazil

9:30 - 10:00  *Rainbow-like scattering in absorptive nuclear systems*
José R.B. Oliveira, Universidade de São Paulo, São Paulo, Brazil

10:00 - 10:30  *Experimental study of non-capture breakup reactions at the TANDAR laboratory*
Alberto J. Pacheco, Laboratorio TANDAR, CNEA, San Martín, Argentina

10:30 - 11:00  Coffee Break

11:00 - 11:30  *Fusion reactions induced by halo and weakly bound nuclei around the Coulomb barrier: results and experimental problems*
Pierpaolo Figuera, INFN, Laboratori Nazionali del Sud, Catania, Italy

11:30 - 12:00  *Probing the density and momentum dependent symmetry energy*
William G. Lynch, Michigan State University, East Lansing, Michigan, USA

12:00 - 12:30  *The ISOLDE Facility: recent highlights and the HIE-ISOLDE project*
Maria José G. Borge, ISOLDE, CERN, Switzerland and Instituto de Estructura de la Materia, Madrid, Spain
Experiments with the double solenoid system RIBRAS

R. Lichtenthäler

1 Institute of Physics (University of São Paulo, São Paulo, Brazil)

The Radioactive Ion Beams in Brasil (RIBRAS) system is, so far, the only equipment in South America capable of delivering secondary beams of exotic nuclei. Since its inauguration in 2004 a research program has been developed which consists in the investigation of elastic scattering and reactions induced by light exotic projectiles such as $^6$He, $^8$Li on different targets. This research allows the study of the nuclear force in exotic systems and provides information of the total reaction cross section. Exotic projectiles such as $^6$He are systems which present a cluster structure formed by a stable core (alpha particle) plus two weakly bound neutrons which form a kind of halo whose density is much lower than the normal nuclear matter and extends over large distances from the core. In addition to the neutron halo, $^6$He present other remarkable features such as its 3-body structure. $^6$He is a 3-body system which is bound only if its 3 components (the two neutrons and the alpha particle) are present. Thus $^5$He in unbound and so is the di-neutron system. The strong coupling between the elastic scattering and the breakup channel allows the observation of interesting 3-body effects which are seen in the elastic angular distributions.

In this talk we will present some results of the research developed in RIBRAS over the last years.

Rainbow-like scattering in absorptive nuclear systems


1Departamento de Física Nuclear, Instituto de Física da Universidade de São Paulo, São Paulo, SP, Brazil.
2Dipartimento di Fisica e Astronomia Universita di Catania, Catania, Italy.
3INFN, Laboratori Nazionali del Sud, Catania, Italy.
4INFN - Sezione Catania, Catania, Italy.
5Instituto de Física da Universidade Federal Fluminense, Niterói, RJ, Brazil.

Nuclear rainbow phenomena is known to occur in nuclear scattering of weakly absorbing systems such as $^{12}$C + $^{12}$C, $^{12}$C + $^{16}$O, $^{16}$O + $^{16}$O, and $\alpha$ projectiles in various target nuclei. Following theoretical predictions [1] based on the São Paulo Potential (SPP), the $^{16}$O+$^{27}$Al elastic and inelastic scattering was measured at two beam energies (namely, 100 and 280 MeV) with the MAGNEX spectrometer at the LNS, Catania [2,3]. The results show rainbow-like characteristics at the largest scattering angles, even in this system for which absorption is stronger and surface reflection tends to dominate the elastic scattering angular distribution. The coupling to the inelastic channels appears to be fundamental for the possibility of some refractive scattering, according to the theoretical calculations, which is essential for nuclear rainbow formation. This can be best appreciated in a near-far decomposition of the angular distributions [4]. Although the cross sections are very small, the large scattering angle region can provide important information from the inner parts of the nucleus-nucleus potential, which is practically inaccessible otherwise.


*We acknowledge support from INFN (Italy); FAPESP, CNPq, FAPERJ, and CAPES (Brazil)
Experimental study of non-capture breakup reactions at the TANDAR Laboratory

A. J. Pacheco$^{1,2}$, D. Martinez Heimann$^2$, A. Arazi$^{1,2}$, C. Balpardo$^1$, O. A. Capurro$^1$, M. A. Cardona$^{1,2}$, P. F. F. Carnelli$^2$, E. De Barbará$^1$, D. Hojman$^{1,2}$, J. Fernández Niello$^{1,2,3}$, G. V. Martí$^1$, A. Negri$^2$, D. Rodrigues$^2$

$^1$Laboratorio TANDAR, CNEA, San Martín, Argentina, 
$^2$Conicet, Buenos Aires, Argentina 
$^3$UNSAM, San Martín, Argentina

Breakup reactions play a distinctive role among the processes that occur in nuclear collisions induced by weakly bound projectiles. The motivation for the study of these reactions recognizes various origins, that range from their usefulness as an indirect tool to determine cross sections of the corresponding inverse capture processes of astrophysical interest, to the questions that arise from their connection to other reaction channels such as complete and incomplete fusion. For the investigation of these and other aspects it is desirable to have a detailed experimental knowledge of the process and of the underlying mechanisms. In this talk we will review the details and main results of the experiments that are being carried on at the TANDAR Laboratory for the investigation of non-capture breakup reactions, i.e., those for which the breakup products manage to escape from being subsequently absorbed by the target-like nucleus. The measurements involve the coincident detection of the emitted light particles, from which one can obtain an unambiguous and complete characterization of the reaction by means of the identification of the fragment that undergoes breakup (either the projectile or a projectile-like transfer product) and the determination of the total Q value, relative energy of the breakup products, and the angular distribution of their emission in the relevant rest frame. We will describe the tools that are used for the discrimination of resonant processes from those presumably originated in the direct population of the continuum and the conditions for their application. The absolute differential and total cross sections of breakup reactions that have been obtained for $^6$Li + $^{144}$Sm will be presented and discussed, taking as a reference for comparison the corresponding cross sections of competing channels in the same system.
Fusion reactions induced by halo and weakly bound nuclei around the Coulomb barrier: results and experimental problems.

P. Figuera

1 INFN- Laboratori Nazionali del Sud, Catania, Italy

The study of nuclear collisions involving halo or weakly bound nuclei, at energies around the Coulomb barrier, had a considerable interest in the last decade since the peculiar structure of such nuclei can deeply affect the reaction dynamics (see e.g.[1-5]). One expects that direct processes like breakup or transfer become important due to the halo and cluster structure of the weakly bound projectiles. Coupling to continuum effects are also expected to have an important role on elastic scattering and fusion around the barrier. In addition, the study of fusion reactions is complicated by the fact that, together with complete fusion (CF), one may have incomplete fusion processes (ICF) following the breakup of the weakly bound projectile.

In this contribution we will discuss some of the experimental problems related with low energy fusion cross section measurements with halo and weakly bound beams, showing that the drawbacks of some used experimental techniques were not fully discussed despite the large number of experiments performed. In addition, by comparing our experimental results, using beams of $^6$He, $^{13}$N, $^6$Li and $^7$Li on different targets [e.g. 6-9], with the ones of other authors we will try to summarize our present understanding of the discussed topic, underlining the need of new better quality data, both with stable and radioactive beams, and the related experimental challenges.

Probing the density and momentum dependent symmetry energy *

W.G. Lynch

NSCL and the Department of Physics and Astronomy, Michigan State Univ. E. Lansing, MI USA.

The density and momentum dependencies of the symmetry energy play an important role in the masses, isobaric analog states, low-lying E1 strength functions, neutron skins and giant resonances of neutron rich nuclei. It also governs the internal structure of neutron stars, influences their radii and cooling rates as well as neutrino transport in core-collapse supernova. This talk will discuss some current experimental constraints on the density and momentum dependence of the symmetry energy.

* This work was supported in part by...
‡ Present address: Current Institution (name, city, country)
The ISOLDE Facility: Recent Highlights and the HIE-ISOLDE project

M.J.G. Borge$^{1,2}$

$^1$ ISOLDE-PH Department, CERN, 1211 Geneve-23, Switzerland
$^2$ Instituto de Estructura de la Materia, IEM-CSIC, Serrano 113bis, 28006-Madrid, Spain

The On-Line Isotope Mass Separator ISOLDE at the CERN Proton-Synchrotron Booster (PSB) is a facility dedicated to the production of a large variety of radioactive ion beams for many different experiments in the fields of nuclear and atomic physics, materials science and life sciences. The facility has garnered unique expertise in radioactive beams over the last 45 years.

The nuclear physics studies focused at first on fundamental properties (mass, spin, magnetic moments, decay modes...) of exotic nuclei using low energy beams of 30-60 keV. New fields of research opened up in 2001 when the Radioactive beam EXperiment, REX, started operation and allowed reaction experiments to be carried out up to 3 MeV/u. Unique feature of REX-ISOLDE is that essentially all isotopes produced can be charge-bred and accelerated further. In a decade of physics with post-accelerated beams beautiful results have been obtained exploring, by Coulomb excitation with the Miniball HPGe-array the shape transitions in extreme neutron rich middle mass nuclei [1].

The HIE ISOLDE upgrade (HIE stands for High Intensity and Energy), intends to improve the experimental capabilities at ISOLDE over a wide front [2]. The main feature are to boost the energy of the beams, going in steps from currently 3 MeV/u via 5.5 MeV/u to finally 10 MeV/u, and to accommodate a roughly fourfold increase in intensity. In addition improvements in several aspects of the secondary beam properties such as purity, ionization efficiency and optical quality are addressed. Presently the facility and the experimental equipment undergo extensive transformation to commit to the new physics challenges [3].

In this presentation recent ISOLDE highlights, the HIE-ISOLDE project and the day one proposed experiments will be discussed.

Friday December 6
Plenary Session 6 (Anfiteatro)  Chair: A. Lepine-Szily

9:00 - 9:30  *In-beam γ-ray spectroscopy at relativistic energies: first results from the PRESPEC-AGATA campaign*
**Dirk Rudolph**, Lund University, Lund, Sweden

9:30 - 10:00  *Nuclear structure studies at Institut Laue-Langevin*
**Ulli Köster**, Institut Laue-Langevin, Grenoble, France

10:00 - 10:30  *GRETINA: The physics campaign at NSCL and future plans*
**Dirk Weisshaar**, Michigan State University, East Lansing, Michigan, USA

10:30 - 11:00  Coffee Break

11:00 - 11:30  *Nuclear structure aspects via g-factor measurements: pushing the frontiers*
**Diego A. Torres Galindo**, Universidad Nacional de Colombia, Bogotá, Colombia

11:30 - 12:00  *Recent advances in the nuclear shell model*
**Frédéric Nowacki**, Institut Pluridisciplinaire Hubert Curien, Strasbourg, France

12:00 - 12:30  *The role of the g_{9/2} orbital in the odd-odd gallium isotopes*
**Nilberto H. Medina**, Universidade de São Paulo, São Paulo, Brazil
In-beam $\gamma$-ray spectroscopy at relativistic energies: First results from the PRESPEC-AGATA campaign

D. Rudolph\(^1\) and on behalf of the PRESPEC-AGATA Collaboration

\(^1\)Department of Physics, Lund University, Lund, Sweden

Contemporary nuclear structure experiments target exotic nuclei at the outskirts of the nuclear landscape to provide information on relevant observables probing modern theoretical parametrisations of the nuclear hamiltonian. One production mechanism for nuclei far from the line of stability are fragmentation reactions at relativistic energies, while $\gamma$-ray spectroscopy has proven invaluable when deriving precise and reliable information from the decay of excited nuclear states.

The talk presents first results from the ongoing, pan-European PRESPEC-AGATA campaign conducted at the GSI Helmholtzzentrum für Schwerionenforschung at Darmstadt, Germany. Following an initial fragmentation reaction, the GSI Fragment Separator (FRS) \(^1\) selects a user-defined relativistic radioactive ion beam and delivers it to a secondary target station. Here, secondary nuclear reactions are induced. The outgoing reaction products are characterized using the Lund-York-Cologne CAlorimer (LYCCA) \(^2\). The European Advanced GAmmma-ray Tracking Array (AGATA) \(^3\) denotes the core of the set-up; some 20+ AGATA modules, i.e individually encapsulated 36-fold segmented HPGe crystals, are being used. In fact, it is AGATA’s intrinsic position resolution of $\gamma$-ray interaction points combined with precise tracking information of incoming and outgoing beams, which allows for high-resolution in-beam $\gamma$-ray spectroscopy of relativistic ions: Coulomb excitation of a band-terminating high-spin isomer in neutron-deficient $^{52}$Fe, low-lying $E1$ strength in neutron-rich $^{64}$Fe, and the evolution of both nuclear shapes of heavy Zr isotopes as well as collectivity in the vicinity of $^{208}$Pb are under investigation.

Besides its own physics right but because of its R&D of technology and techniques, the PRESPEC-AGATA campaign can be considered a pre-runner of the anticipated HIgh-resolution in flight SPECtroscopy (HISPEC) experiment at the international Facility for Antiproton and Ion Research (FAIR), which is currently under construction at Darmstadt, Germany.

---

Nuclear structure studies at Institut Laue-Langevin

U. Köster¹, A. Blanc¹, H. Faust¹, G. de France², M. Jentschel¹, P. Mutti¹, J.M. Regis³, G.S. Simpson⁴, T. Soldner¹, C. Ur⁵, W. Urban¹

¹ Institut Laue-Langevin, Grenoble, France
² GANIL, Caen, France
³ IKP Cologne, Germany
⁴ LPSC Grenoble, France
⁵ INFN Padova, Italy

The high-flux reactor of Institut Laue-Langevin in Grenoble provides intense neutron beams with capture fluxes up to $2 \times 10^{10}$ n.cm$^{-2}$s$^{-1}$, as well as in-pile positions reaching capture fluxes up to $1.5 \times 10^{15}$ n.cm$^{-2}$s$^{-1}$. Most of these cold, thermal and hot neutron beams serve instruments for neutron scattering applications, but three prominent instruments are also devoted to nuclear structure studies:

1. The fission fragment separator LOHENGRIIN exploits an in-pile position where thin fissile or fertile targets are exposed to a thermal neutron flux of $5 \times 10^{14}$ n.cm$^{-2}$s$^{-1}$. The recoiling, highly ionized fission fragments are separated by a magnetic dipole and an electrostatic dipole according to their mass over ionic charge and kinetic energy over ionic charge ratios. Thus, mass separated beams of neutron-rich isotopes between mass 80 and 160 become available for nuclear spectroscopy studies in the focal plane. The flight time to the focal plane is about 1.4 to 2 μs, thus giving access to a large variety of microsecond isomers with half-lives as short as 0.5 μs. So far over 70 different microsecond isomers and various beta-decaying isotopes have been observed and studied by gamma, conversion electron and delayed-neutron spectroscopy at LOHENGRIIN.

2. Also the crystal spectrometer GAMS uses an in-pile position where stable targets are exposed to a thermal neutron flux of $5 \times 10^{14}$ n.cm$^{-2}$s$^{-1}$. The gamma rays emitted upon neutron capture or subsequent beta decay are analyzed by diffraction with a curved crystal spectrometer or a double-flat-crystal spectrometer respectively. The former has better energy resolution than Ge detectors (in a third order reflection about 10 eV at 100 keV gamma ray energy and 1 keV for 1 MeV gammas), but even more importantly a very wide dynamic range of up to five orders of magnitude. Thus, weak gamma rays can be cleanly separated from neighboring intense background. Single and multi-neutron capture on stable target isotopes provides access to excited states in about 300 stable and slightly neutron-rich isotopes. When equipped with flat crystals, the energy resolution is further improved to the eV range enabling accurate measurements of the gamma ray energy and the observation of line broadening due to gamma ray induced Doppler broadening. The latter enables direct measurements of sub-picosecond lifetimes of excited states.

3. Coincidence measurements of prompt gamma rays from short-lived excited states populated in neutron-induced reactions are possible with detector setups placed at the external cold neutron beam PF1B finely collimated to a halo free pencil beam of ≈1 cm diameter. Recently three dedicated campaigns were performed with γ ray detector arrays consisting of Ge detectors, partially complemented by LaBr₃:Ce detectors for fast timing studies. In 2012 and 2013 the EXILL campaign used a combination of EXOGAM, GASP and ILL Ge detectors with up to 46 Compton suppressed Ge crystals and 16 LaBr₃:Ce detectors of the FATIMA collaboration for fast timing measurements. A wealth of new nuclear structure data became available by these campaigns that employed $^{235}$U and $^{241}$Pu targets to populate neutron-rich nuclei in fission and over two dozen stable target isotopes for detailed (n,$\gamma$) spectroscopy.
GRETINA [1] is a first implementation of a gamma-ray spectrometer which is capable of tracking gamma-rays through its active detector volume. This new technology is based on segmenting the outer contact of large-volume HPGe crystals to locate the individual scattering sites in the detector by analyzing both net and induced signals. The characteristics of the Compton and pair-production processes are then used to group and sequence the interactions points and determine the scattering path of the original gamma-rays. This ability to track gamma-rays accurately is crucial in building high-efficiency, closely-packed Ge arrays.

GRETINA consists of seven, four-crystal modules (6x6 segments). Each crystal is individually encapsulated with all four capsules sharing a common cryostat. The irregular, tapered hexagonal crystals pack into a spherical shell with the seven modules spanning 1π solid angle. GRETINA was constructed and commissioned at LBNL and just completed its first physics campaign at NSCL/MSU.

In this talk, I will discuss some technical aspects of the device and present an overview of the experimental program carried out at NSCL. Future plans for enhancements of GRETINA as well as its possible evolution into a full 4π-coverage array, GRETA, will also be discussed.

During the past decades systematic studies of the magnetic moments of the $2_{1}^{+}$ states in even-even nuclei have been performed by several groups around the globe, providing valuable tests of theoretical models of nuclear structure. Such measurements have unveiled important features of the interplay between single-particle and collective excitation degrees of freedom [1]. It is widely accepted that the possibility to distinguish between single-particle and collective behaviors in nuclear states, thanks to the microscopic description of the states under study, is one of the greatest achievements of the research in nuclear magnetic moments. Experimentally much progress has been achieved by using the transient field technique in inverse kinematics. However, the challenges arise from the difficulty to extend these measurements to $4_{1}^{+}$, $2_{2}^{+}$, and ever higher excited states, and the use of low intensity radioactive beams.

In recent years, the use of alpha-transfer reactions has become an active area of research which allows the production of states in radioactive species that otherwise will only be produced in future radioactive beam facilities [2,3,4,5,6]. A hindrance to the use of the alpha-transfer mechanism is that the alignment of the nuclear spin, necessary to observe a precession of the magnetic moment in an external or a hyperfine magnetic field, is much reduced compared to that observed in experiments using traditional Coulomb excitation reactions.

In this talk, a review of recent magnetic moments ($g$ factors) measurements, using the transient field technique, will be presented. The results are evaluated in the context of the systematics of $g$ factors in several mass regions. Large-scale shell-model calculations and interacting boson model IBA-II predictions are utilized to interpret the experimental results, and to explore the existence of shell closures for protons and neutrons at $N = 38, 40$ and $Z = 38$. Future uses of transfer reactions to expand the frontiers of $g$-factor measurements will be discussed. Recent experiments to measure $g$ factor values for the excited states of $^{90}$Sr and $^{82}$Sr will be presented.

Recent advances in the nuclear shell model

F. Nowacki

Institut Pluridisciplinaire Hubert Curien, Strasbourg, France

In this presentation, we will expose some of the last developments in microscopic nuclear structure calculations for exotic nuclei. In a first part we will expose the basic ingredients of nuclear structure calculations with the nuclear shell model framework. In a second step we will expose recent study on the development of collectivity in neutron-rich nuclei around $N=40$, where experimental evidence suggest a rapid change from the spherical to rotational regime, in analogy to the island of inversion known at $N=20$ [1]. Theoretical calculations are performed within the interacting shell model framework using an enlarged model space outside $^{48}$Ca core comprising $pf$ shell for the protons and $(f_{5/2} p_{3/2} p_{1/2} g_{9/2} d_{5/2})$ orbits for neutrons. The effective interaction is based on realistic two-body matrix elements which are corrected empirically in its monopole part.

We find a very good agreement between theoretical results and available experimental data. We predict different development of deformation in various isotopic chains, with the maximum of collectivity occurring in the chromium isotopes. The shell evolution responsible for the observed shapes will be discussed in details, in parallel with the $N=20$ case. Finally the stability of the waiting point nucleus $^{78}$Ni and persistence of spin-orbit shell gaps will be discussed as the impact of 3N forces in medium-mass nuclei [2].

The role of the g9/2 orbital in the odd-odd gallium isotopes

N. H. Medina¹, P.R.P. Allegro¹, S. M. Lenzi², J.R.B. Oliveira¹, V.A.P. Aguiar¹, R.V. Ribas¹, D.L. Touffen¹-³, W.A. Seale¹, V.A.B. Zagatto¹, F. Genezini⁴, G. Zahn⁵, M.A.G. Silveira⁵, S.L. Tabor⁵, P. Bender⁶, V. Tripathi⁶, L.T. Baby⁶, R. Dungan⁶, A. Kuchera⁶, J. Von Mass⁶, S. Miller⁶, and D. Moerland⁶.

¹ Instituto de Física, Universidade de São Paulo, São Paulo, Brazil.
² INFN and Università di Padova, Padova, Italy
³ Instituto Federal de Educação, Ciência e Tecnologia, Guarulhos, Brazil
⁴ Instituto de Pesquisas Energéticas e Nucleares, São Paulo, Brazil.
⁵ Centro Universitário da FEI, São Bernardo do Campo, Brazil.
⁶ Florida State University, Tallahassee, USA.

In this work a systematic study was performed to determine the role of the g9/2 orbital in the description of excited states of odd-odd ⁶⁴,⁶⁶,⁶⁸,⁷⁰Ga. Nuclear properties of ⁶⁴,⁶⁶,⁷⁰Ga and ⁶⁷Ge nuclei, such as the energy of the excited states, spins and isomeric state lifetimes were measured at University of São Paulo, Brazil, and at Florida State University, USA. To populate the high spin states of these nuclei ⁵⁸Ni(ⁱ²C, xpnzα)⁶⁴Ga, ⁵⁵Mn(ⁱ⁸O, xpnzα)⁶⁶,⁷⁰Ga, ⁵⁸Ni(ⁱ¹B, ⁲pn)⁶⁶Ga and ⁵¹V(⁰¹F, p⁴n)⁶⁶Ga fusion-evaporation reactions were used. In-beam gamma-ray spectroscopy techniques were applied with SACI-PERERE [1], SISMEI [2] and FSU Clover Array spectrometer [3]. The experimental results for those nuclei and the known nuclear structure of ⁶⁸Ga and odd-mass Zn, Ga, Ge nuclei were compared with the results of Large Scale Shell Model calculations using the Antoine code [4] with the residual interactions: JUN45 [5] and FPG [6]. Large Scale Shell Model is one of the most reliable models to describe nuclei and has reproduced, with very good accuracy, detailed nuclear properties in several mass regions [7]. Shell Model calculations indicated that negative parity excited states of the non-natural parity states in odd-odd gallium isotopes were formed by the excitation of one neutron to the 1g9/2 orbital.


* This work was supported in part by FAPESP, CNPq, USP, FSU and NSF.
X Latin American Symposium on Nuclear Physics and Applications

Edificio Polifuncional J.L. Massera
Universidad de la República
Montevideo, Uruguay, December 1-6, 2013

Book of Abstracts

POSTER CONTRIBUTIONS

(Version Nov. 17, 2013)
Wednesday, December 4
16:00 Poster session (Hall)

1. **Gamma transitions from the $\beta^-$ decay of $^{131m}Te**

2. **Systematics in the decay pattern of even mass Zr isotopes**
   G. Kaur, Rajni, M.K. Sharma

3. **Microscopic description of even-even ytterbium nuclei**
   C.E. Vargas, V.M. Velázquez-Aguilar, S. Lerma, C. Campuzano

4. **Isovectorial pairing plus quadrupole model in the framework of SU(3) scheme**
   A. Lozano-Torres, S. Lerma-Hernández, C. Vargas-Madrazo

5. **Shell effects in Duflo-Zuker inspired mass formulas: a status report**
   C. Barbero, J. Hirsch, A. Mariano

6. **Measurements of the $^6He+p$ Resonant Scattering**

7. **Entrance channel effect using stable and radioactive Sn-beams**
   R. Kumar, D. Jain

8. **Compound nucleus decay: comparison between saddle point and scission point barriers**
   T.J. Santos, B.V. Carlson

9. **Study of $\omega \rightarrow \pi^+\pi^-\pi^0$ decay**
   A. Melo

10. **Estimate of Photoneutrons Generated by 6-18 MV X-Ray Beams for Radiotherapy Techniques**
    R. Castillo, J. Dávila, L. Sajo-Bohus

11. **A network for neutron physics research in Chile**

12. **Silver activated counter detector for measurements of high intensity fast neutron burst**
    A. Tarifeño-Saldivia, A. Llanquihuen-Martínez, L. Soto

13. **Modelling moderated proportional neutron counters using the Geant4 toolkit and the application to detection of fast neutron burst**

14. **Module development DDHMS the code EMPIRE reactions for applications in reactions induced by nucleons**
    L.Brito, B. Carlson
15. Detecting capabilities of the boron loaded liquid scintillator EJ-339A  
F. Pino, L. Stevanato, D. Cester, G. Nebbia, L. Sajo-Bochus, G. Viesti

16. Using the Bayes' theorem of conditional probabilities to obtain the neutron flux of the RECH-1  
experimental nuclear reactor at CCHEN  
F. Molina, P. Aguilera, M. Zambra, J.R. Morales, C. Henríquez

17. Design and construction of a stable 30 keV proton accelerator for detection efficiency studies  
A. Salas-Bacci, S. Baefsler, A. Ross, N. Roane, R. Slater, C.J. Whitaker

18. Improved heat transfer for SPIRAL2 target driver  
G. Acosta, J. Bermúdez, L. B. Tecchio, E. Udup, L. Sajo-Bohus

19. \(^{222,220}\text{Rn}\) Exhalation rate of materials used at UNEFM  
H.P. Santiago, L. Sajo-Bohus, D. Palacios, H. Barros, L. Loaiza

20. Effect of high dose of rays-X on the parasitic action of Plasmodium berghei  
L. Spencer, C. Nava-Lausón, J. Davila, L. Sajo-bohus

21. An improved formula for stopping power at low incident energy  
A. Ochoa, H.C. Wu

22. Natural activity of \(^{40}\text{K}\) in some Chilean building materials  
M. Sepúlveda, R. Barriga, P. Ortiz, P. Miranda, J.R. Morales

23. Image formation in a gamma ray Compton Backscattering device  
N. González, F. Cristancho

24. The use of portable X-ray Fluorescence Spectrometry (PXRFs) for clinical practices  
C.B. Zamboni, S. Metairon, M.A. Rizzutto, S. Bernardes

25. An application of Accelerator Mass Spectrometry to geology  
D. Rodrigues, A. Arazi, G. Marti, P. Steier, A. Negri

26. Very high dose dosimetry using TL behaviour of jadeite and beryl minerals  
L.S. do Carmo, S. Watanabe, N.F. Cano, R.F. Barbosa

27. Contribution of \((n,\gamma)\) Reaction in the Out-of-Field Absorbed Dose for Patients under Radiotherapy  
Treatments with High MV Linear Accelerators  
R. Martín-Landrove, L. Sajo-Bohus, L. Spencer, D. Palacios, J. Dávila

28. Nuclear Radiation as probe to investigate some of the physical properties of Willemite  
R. M. Ferreira, S. Watanabe, N.F. Cano

29. Use of the FLUKA Monte Carlo code for 3D patient-specific dosimetry on PET-CT and SPECT-CT images  
30. *Titanium Extraction from Waste NORM*

31. *Radiation Effect Mechanisms in Electronic Devices*

32. *Preliminary results on the neutron energy distribution measurements at the RECH-1 reactor core*
P. Aguilera, F. Molina, J.R. Morales, M. Zambra, C. Henríquez

33. *Monitor unit calculation for radiotherapy treatments using the Monte Carlo method*
H. Laulate, A.F. Menezes, J.P. Reis Junior, A.X. Silva

34. *Calculation of minor actinides transmutation in ADS reactors*
P.K. Taipe, F.C. Silva, A.C.M. Alvim

35. *Environmental applications of nuclear techniques: Inter-hemispheric exchange of tropospheric air masses*
A.E. Negri, J. Fernández Niello, A. Arazi

36. *Design of a detection system to obtain 2D dose maps for complex radiation therapy treatment verification*

37. *Characterization of a polymer gel dosimetry system based on N-isopropylacrylamide and N-N’ methylenebisacrylamide*
F. Mattea, M. C. Strumia, M. Valente

38. *Near-threshold $^7$Li$(p,n)^7$Be reaction for Boron Neutron Capture Therapy*
D.M. Minsky, A.J. Kreiner

39. *Internal dosimetry for alpha emitters radiopharmaceuticals in biological tissue studied with the FLUKA code*
M. Valente

40. *Energy deposition in biological tissues by $^7$Li and $^4$He due to neutron capture calculated with the FLUKA code*
S. Triviño, D. Graña, M. Valente

41. *Quantum Dosimetry and Directional Visualization of Space Radiation with Miniaturized Timepix Payloads Onboard the International Space Station (ISS) and ESA Proba-V Satellite*
C. Granja, Z. Vykydal, D. Turecek, S. Polansky, S. Pospisil, J. Jakubek, V. Kraus, M. Holik, A. Owens, L. Pinsky, Z. Kozacek

42. *Beryllium Target for Accelerator-Based Boron Neutron Capture Therapy*
M. Suarez Anzorena, L. Gagetti, M.F. del Grosso, A.J. Kreiner
43. Application of the spatial efficiency $\varepsilon(r)$ of a HpGe detector to determine the specific activity of radioactive material in cylindrical extended sources
P. Ortiz, J.R. Morales

44. Procedures for the verification of the self-shielding of Cyclotron PETtrace
H.S. Videira, B.M. Pássaro, J.A. Gonzalez, J.S. Santos, M.I.C.C. Guimarães

45. Adaptative segmentation for phase-contrast X-Ray imaging
I. Domínguez, G. Herrera, A. Ramírez, R.E. Sanmiguel

46. Dose Point Kernel calculation and modelling with nuclear medicine dosimetry purposes
I. Scarinci, M. Valente, P. Pérez

47. Study of dose deposition of $^{125}$I brachitherapy seeds in a solid water phantom
L.C. Tomaz, A.P. Mourão, S.E. Grynberg

48. The frequency analysis in Gamma-ray Compton Backscattering imaging
F. Cristancho, D. Flechas

49. Study of the buildup factor in monoelemental materials with $\gamma$-rays
C. Garzón, F. Cristancho

50. Optimization of the slow neutron detector array in the Thermal Neutron Backscattering Technique
J. Gómez-Muñoz, A. Cruz, F. Cristancho

51. Periglacial shallow lakes offer information about climate change? Preliminary results, King George Island
H. Barros, M. Bezada, D. Palacios, A. Ojeda, S. Hurtado
**Gamma transitions from the $\beta^-$ decay of $^{131m}\text{Te}$**

J. C. Ruivo$^1$, C. B. Zamboni$^1$, N. H. Medina$^2$ and J. R. B. Oliveira$^2$

$^1$Instituto de Pesquisas Energéticas e Nucleares, IPEN/CNEN – SP, Brazil
$^2$Laboratório Pelletron, Universidade de São Paulo, IFUSP - SP, Brazil

Tellurium isotopes are the focus of studies at Laboratório de Espectroscopia e Espectrometria das Radiações (LEER)/IPEN in partnership with the Laboratório Pelletron, IFUSP. The purpose of this work is to investigate the excited states in $^{131}\text{I}$ by $\beta^-$ decay of $^{131m}\text{Te}$ to obtain complementary experimental information to elucidate the population of low - energy levels ($< 3\text{MeV}$). This includes an extensive $\gamma$-ray measurement, using high resolution detectors, with high statistics in the region from 100 keV to 2.5 MeV. According to the last compilation by NDS [1] basically, the results of two studies [2,3] established the features of the $\beta^-$ decay scheme of $^{131m}\text{Te}$. Analyzing these works there is some controversy regarding the presence of $\gamma$ transitions in the level scheme, when the data from beta decay are compared with nuclear reactions studies [1]. Moreover, a number of $\gamma$ transitions must be confirmed as well as the intensities. In an attempt to propose a well established decay schema of $^{131}\text{Te}$ motivated us to perform an investigation of excited levels in $^{131}\text{I}$. Radioactive sources of $^{131}\text{Te}$ were obtained using $^{130}\text{Te}(n,\gamma)^{131}\text{Te}$ nuclear reaction. Approximately 5 to 20 mg of natural tellurium was irradiated with a thermal neutron flux of about $3.2 \times 10^{12}$ n/cm$^2$s, during few minutes, in the IEA-R1 Nuclear Reactor at IPEN/CNEN-SP. The singles spectra were investigated using two independent $\gamma$-spectrometers consisting of a 196 cm$^3$ and 89 cm$^3$ HPGe coaxial detectors, both coupled to a MCA (ORTEC Model 919E) and a PC were used. The spectrometers were calibrated for energy through the measurement of standard sources of $^{56}\text{Co}$, $^{137}\text{Cs}$ and $^{152}\text{Eu}$ [4]. The areas of the gamma rays were evaluated by using the IDF computer code [5]. These results were compared with those published [2,3] and our gamma-rays energies are given more accurate values.


* This work was supported in part by CNPq
The decay pattern of compound nucleus provides useful information regarding nuclear reaction dynamics and associated properties such as nuclear structure, nuclear deformations and orientations, shell closure effects, isotopic effects etc. In view of this, we have calculated the decay cross-sections for Zr isotopes formed in $^{16}$O + $^{70,72,74,76}$Ge reactions at energies lying across the Coulomb barrier using dynamical cluster-decay model (DCM) [1]. The calculations are done in reference to the measured fusion excitation functions for $^{86,88,90,92}\text{Zr}^*$ isotopes [2] and the cross-sections have been estimated for evaporation residues (ER; ($A_2 \leq 4$)), intermediate mass fragments (IMFs; ($5 \leq A_2 \leq 20$)), and fission fragments with the inclusion of quadrupole ($\beta_2$) deformations having optimum orientations ($\theta_{opt}$). It is relevant to note that, DCM adequately differentiates between these decay processes and suggests ER to be the dominant decay mode with negligible contribution of the IMF and fission cross-sections in agreement with [2]. The fragment mass distribution is observed to be symmetric for all isotopes of $Z=40$ nucleus. The comparative analysis of the fragmentation profile of Zr isotopes shows that at $\ell=0h$, the potential energy surfaces behave almost similarly. However at $\ell=\ell_{max}$, the decay pattern in fission region shows systematic increase in the magnitude of fragmentation potential, being least for $^{86}\text{Zr}^*$ (filled square in Fig.1) and increasing with addition of two successive neutrons. In ER and IMF region $^{86}\text{Zr}^*$ again shows lowest fragmentation potential whereas other isotopes do not follow the systematics of fission region. Although the $\alpha$-nucleus structure persists for all the nuclei, its emergence is more prominent in case of lighter isotope. Further investigations regarding isotopic analysis of Zr isotopes are underway.

References

FIG. 1: Variation of fragmentation potential for the decay of $^{86,88,90,92}\text{Zr}$ isotopes at $E_{c.m.} \sim 31$ MeV.

*Email:gurvinderkaur.phd@thapar.edu
Microscopic description of even-even ytterbium nuclei

C.E. Vargas\textsuperscript{1}, V.M. Velázquez-Aguilar\textsuperscript{2}, S. Lerma\textsuperscript{1}, and C. Campuzano\textsuperscript{1}

\textsuperscript{1} Departamento de Física, Universidad Veracruzana, Lomas del estadio S/N, CP 91000, Xalapa, Ver. México and
\textsuperscript{2} Facultad de Ciencias, Universidad Nacional Autónoma de México, Apartado Postal 70-542, 04510 México Distrito Federal, México

Microscopic studies in rare-earth nuclei are complicated due to large valence spaces involved. This computational problem can be avoided using symmetry-based models. In this work, ground-state, $\gamma$ and $\beta$ bands, and their B(E2) transition strengths in $^{168-178}$Yb isotopes are studied in the framework of the pseudo-SU(3) model, which includes the preserving symmetry $Q \cdot Q$ term and the symmetry-breaking Nilsson and pairing terms, systematically parametrized. Additionally, three rotor-like terms are considered, whose free parameters are used to fine tune the moment of inertia of rotational bands and the band head of $\gamma$ and $\beta$ bands. The model successfully describes in a systematic way rotational features in these nuclei and allows to study the shape associated to these bands. The results presented show that the ground state and $\gamma$ bands in $^{174}$Yb, $^{176}$Yb and $^{178}$Yb nuclei have prolate shape while the first $0^+$ excited band is triaxial.
An extended pairing plus quadrupole model, in the framework of Elliot SU(3) scheme, is used to study the combined effects of the quadrupole-quadrupole, pairing and spin-orbit interactions on energy spectra and deformation in the yrast band of even-even nuclei in the sd and fp shells. The pairing interaction contains the three components of the isovectorial pairing $T_z = 0, \pm 1$ and the results were obtained for a reasonable choice of the interaction parameter strengths. After a general review of the pairing effects on deformations, the backbending phenomenon of $^{48}$Cr was reproduced in a highly truncated Hilbert space by renormalizing the pairing strength to compensate the effective suppression of paring correlations caused by the the truncation. Likewise The backbending phenomenon in $^{50}$Cr and $^{52}$Fe is reproduced by using this method.

*This work was supported in part by CONACyT.
Shell effects in Duflo-Zuker inspired mass formulas: a status report

C. Barbero\textsuperscript{1,2}, J. Hirsch\textsuperscript{3}, and A. Mariano\textsuperscript{1,2}

\textsuperscript{1} Departamento de Física, Universidad Nacional de La Plata, C. C. 67, 1900 La Plata, Argentina
\textsuperscript{2} Instituto de Física La Plata, CONICET, 1900 La Plata, Argentina and
\textsuperscript{3} Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, 04510 México, DF, México

We discuss different ways to introduce shell effects in Duflo-Zuker inspired mass formulas through the term containing the information about monopole interaction, usually known as the ‘master term’. We compare the fits performed using different dependence of the master terms with shell degeneracies. Interesting results are obtained and discussed.

\textit{Keywords}: Nuclear masses; Binding energies; Mass models; Duflo-Zuker

*This work was supported in part by CONICET, Argentina
\textsuperscript{1}email address: barbero@fisica.unlp.edu.ar
Measurements of the $^6$He+p Resonant Scattering∗

R. Pampa Condori1, R. Lichtenthäler1, A. Lépine-Szily1, L.R. Gasques1, V.B. Scarduelli1, M.C. Morais1, J.A. Alcántara-Núñez1, E. Leistenschneider1, P.N. de Faria2, D.R. Mendes Junior2, K.C.C. Pires3, J.M.B. Shorto4, and M. Assunção5

1Departamento de Física Nuclear, Instituto de Física da Universidade de São Paulo, P.O.Box 66318, São Paulo, SP, Brazil
2Universidade Federal Fluminense, Centro de Estudos Gerais, Instituto de Física, Niterói, RJ, Brazil
3Universidade Tecnológica Federal do Paraná, Campus Cornélio Procópio, PR, Brazil
4Instituto de Pesquisas Energeticas e Nucleares, IPEN/CNEN, Brazil and
5Universidade Federal de São Paulo, Campus Diadema, São Paulo, SP, Brazil

The spectroscopy of light nuclei such as $^6$Li, $^7$Li, and others is still a relatively unexplored field and the ability to produce these nuclei in reactions induced by exotic nuclei is motivating. In particular the $^7$Li has an excited state at 11.24MeV $J^\pi = 3/2^+ T = 3/2$ which is the Isobaric Analog State of the $^7$He ground state. We present results of an experiment $^6$He+CH$_2$ performed in the RIBRAS[1] double solenoid system. The $^6$He secondary beam was produced by the $^9$Be($^7$Li,$^6$He) reaction at incident $^7$Li energy of 24MeV. A thick 12mg/cm$^2$ CH$_2$ foil was used as a secondary target and as absorber in the midway scattering chamber between the two solenoids. We observed the protons, deuterons, tritons and $\alpha$ particles produced in reactions of the $^6$He beam and the CH$_2$ target. Measurements of the elastic scattering p($^6$He,p) have been performed at three different angles, namely 0, 20, and 25 degrees in the laboratory system, to observe states of the $^7$Li[2] around excitation energies of $E_{^7Li}^{exc} = 10.4 - 11.8$MeV. Excitation functions have been obtained for those angles which correspond to 180, 140, and 130 degrees in the center of mass system. We have fitted those excitation functions using the Breit-Wigner function. We also compare the obtained excitation functions with predictions of the R-matrix calculations[3].


∗This work was supported by FAPESP(proc. n 2011/08781-6) and CNPq(CLAF)(proc.n 141635/2008-8)
Entrance channel effect using stable and radioactive Sn-beams

Raj Kumar\textsuperscript{1} and Deepika Jain\textsuperscript{2}

\textsuperscript{1}Department of Physics and Astronomy, University of Padova, Padova, Italy
\textsuperscript{2}School of Physics and Materials Science, Thapar University, Patiala, India

One of the interesting puzzles in nuclear physics is whether the decay of excited compound nucleus (CN) depends on its mode of formation or not. Recently, an experiment was performed to produce CN \(^{172}\text{Yb}^*\)\textsuperscript{[1]} formed from stable \(^{124}\text{Sn}\)- and radioactive \(^{132}\text{Sn}\)-beams on target \(^{48}\text{Ca}\) and \(^{40}\text{Ca}\) respectively. This offers an opportunity to study the entrance channel effect on the decay of \(^{172}\text{Yb}^*\) by using dynamical cluster-decay model (DCM) \textsuperscript{[2]}. The DCM has been used to address various nuclear structure properties like the role of shell effects, barrier modification, fine or substructure of fission fragments, and entrance channel effects for a variety of nuclear reactions during last few years. In this work, we studied the entrance channel effect through the fragmentation potential and pre-formation probability behavior. In order to made a comparison between the decay pattern of the two incoming channels, calculations are done at the approximately similar center-of-mass energy (\(E_{\text{c.m.}}\)) i.e. 123.9 MeV and 124.01 MeV for \(^{40}\text{Ca}+^{132}\text{Sn}\) and \(^{40}\text{Ca}+^{124}\text{Sn}\) channels respectively.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fragmentation_potential.png}
\caption{Fragmentation potential as a function of mass number for two different entrance channels at comparable \(E_{\text{c.m.}}\) values and respective parameters.}
\end{figure}

In DCM, each possible combination of fragments for the decay of \(^{172}\text{Yb}^*\) is worked out in order to calculate the fragmentation and pre-formation probability of each combination minimized in charge. The effect of deformation and optimum orientation is also included. Fig. 1 shows the variation of fragmentation potential as function of mass number for two different entrance channels at comparable \(E_{\text{c.m.}}\) values. The neck-length parameter of DCM is within the range of nuclear proximity (-2 fm). It is observed that despite the large difference in Q-value and hence temperature, there is no significant change in the decay pattern except magnitude. The maximum value of angular momentum differs by few units. Thus it is clear that decay of CN \(^{172}\text{Yb}^*\) is independent of mode of its formation with the use of stable or radioactive beam in the entrance channel.

\textsuperscript{[1]} D. Jain et al. Phys. Rev. C 87, 044612 (2013) and earlier references there in.
Compound nucleus decay: comparison between saddle point and scission point barriers

T. J. Santos and B. V. Carlson

1 Instituto Tecnológico de Aeronáutica, São José dos Campos SP, Brazil

One of the principal characteristics of nuclear multifragmentation is the emission of complex fragments of intermediate mass. The statistical multifragmentation model furnishes a fairly good description of this emission [1-4] but cannot be considered a true statistical decay model, as it contains no decay widths or lifetimes. A consistent extension of the model to a decay one has been developed, in which it becomes the near simultaneous limit of a sequential decay model. [5] In this extension, intermediate mass fragment emissions are described by expressions almost identical to those of light particle emission. [6] At lower temperatures, similar expressions have been shown to furnish a good description of very light intermediate mass fragment emission [7] but not of the emission of heavier fragments, which seems to be determined by the transition density at the saddle-point rather than at the scission point. [8,9] Here, we compare these different formulations of intermediate fragment emission and analyze the barrier height using Sierk's saddle point barriers [10] and the São Paulo potential [11] scission point barriers as a function of mass and atomic number.


* This work was supported in part by CAPES, CNPq and FAPESP
‡ Instituto Tecnológico de Aeronáutica, São José dos Campos-SP, Brazil
Study of $\omega \to \pi^+\pi^-\pi^0$ decay.

A. Melo

Facultad de Ciencias - Universidad de la República, Montevideo, Uruguay

In the present work the reaction $p\gamma \to p\pi^+\pi^-\pi^0$ is analyzed with the largest statistical data available today for the $\omega$ meson decay into 3 pions. The data was obtained at the Thomas Jefferson National Accelerator Facility. The reaction was modeled with the production of a resonance $R (p\gamma \to pR)$, followed by a decay into 3 pions ($R \to \pi^+\pi^-\pi^0$). This decay was modeled with an Isoabar, that makes it sequential in pairs ($R \to I\pi$; $I \to \pi\pi$). Data selection is completed and work is in progress.
Photoneutron production was investigated on Varian Clinac accelerator operating in the 10-18 MV range. Neutrons were measured at the surface and isocenter of a PMMA phantom realted to prostate treatment plans. Three treatment approaches were assessed: 18-MV conventional three-dimensional conformal technique (3D-CRT); 18-MV intensity-modulated radiation therapy technique (IMRT); and 10-MV volumetric modulated arc therapy technique (VMAT). Etched-track detectors with boronated converters and paraffin wax moderators were employed in this study [1]. The isotope $^{10}$B was employed due to its high thermal neutron capture cross section (3832 b), nuclear characteristics, being a non-radioactive element and available with 98% isotope enrichment [2]. Latent track chemical etching was performed using 6N NaOH solution at 70 °C. Etche tracks were visualized using an optical transmission microscope, their analysis was made by MORFOLM software (developed at AEKI Budapest Hungary) and the number of tracks/cm$^2$ were determined for each treatment approach. The relationship between tracks density per UM, distance from the treatment field, and depth in the phantom were studied. The tracks density obtained at isocenter was about 2 times the tracks density on the surface of phantom and these decreased with distance from the treatment field. For an IMRT treatment the number of tracks/cm$^2$ UM is comparable to the number of tracks/cm$^2$ UM for a 3D-CRT treatment and as expected no neutron contribution was seen in below 10-MV VMAT treatment. Paraffin wax and boric acid decreased the tracks density at isocenter for 18-MV IMRT and 3D-CRT techniques.

Financially supported by national science fundation FONACIT No.2940749-2269

Scientists from the University of Chile (UCh) and the Chilean Nuclear Energy Commission (CCHEN) have started a research program on neutron physics and applications. The main goal is to perform basic and applied research at the existing experimental facilities in both institutions. At CCHEN a 5 MW pool-type research reactor, RECH-1, is operative. This reactor provides maximum neutron fluxes of $7 \times 10^7$ n/cm$^2$s (thermal) and $5 \times 10^7$ n/cm$^2$s (fast) in steady state. Furthermore, plasma focus (PF) devices produce fast neutrons bursts from D-D fusion reactions [1]. These devices exist from table top size (low energy PF) to medium size (SPEED2). The neutron burst intensity ranges from $10^2$ up to $10^{11}$ n/burst. Additionally, a Secondary Reference Standards Laboratory, including neutron metrology, is under construction. At UCh, the KN 3575 High Voltage Van de Graaff accelerator is operated by the Center for Experimental Physics (CEFEX)[2]. An important upgrade is under design to obtain fast neutrons by means of proton- and deuteron-induced reactions. The upgrade aims to deliver up to $10 \mu$A charged particle beam intensity into a 10 m-diameter bunker, where specific targets can be placed. The CNNPA aims to count on a wide neutron energy range from reactor, fusion plasmas, isotopical and accelerator sources, to be used for basic research and applications. Both experimental and theoretical researchers from local and foreign institutions are invited to collaborate.

Silver activated counter detector for measurements of high intensity fast neutron burst*

A. Tarifeño-Saldivia\textsuperscript{1,2,4}, A. Llanquihuen-Martínez\textsuperscript{3} and L. Soto\textsuperscript{1,2,4}

\textsuperscript{1}Comisión Chilena de Energía Nuclear, Chile
\textsuperscript{2}Center for Research and Applications in Plasma Physics and Pulsed Power, P4, Chile
\textsuperscript{3}Universidad Andrés Bello, Facultad de Ciencias Exactas, Departamento de Ciencias Físicas, Republica 220, Santiago, Chile
\textsuperscript{4}Chilean Network for Neutron Physics and Applications (CNNPA), Chile.

In fusion facilities, such as Z-pinch, plasma focus or laser driven experiments, fast neutrons are produced in the form of a burst of radiation. For these kinds of sources, moderation of the neutron energy and silver activation is one of the most common techniques for measurement of the neutron yield [1, 2]. In the recent years, the study of this detection system has been revisited in order to improve the calibration methodologies [3], and to study the effects of moderator geometry for measurements in low intensity burst neutron sources [4]. In this work, the design, construction and characterization of a silver activated neutron counter for measurements in high intensity neutron burst sources are reported. For such sources ($Y_{4\pi} > 10^9$ n/burst), the effects of moderator geometry, as well as, the systematic effects introduced in the measurement by dead time, after irradiation of the detector by a burst of neutrons, are discussed and included in the measurement methodology.


* This work was supported in part by Conicyt grant ACT-1115
Modelling moderated proportional neutron counters using the Geant4 toolkit and the application to detection of fast neutron burst*

A. Tarifeño-Saldivia$^{1,3,4}$, F. Molina$^{1,3,4}$, J. L. Tain$^2$, D. Jordan$^2$ and L. Soto$^{1,3,4}$

$^1$Comisión Chilena de Energía Nuclear, Chile.
$^2$Instituto de Física Corpuscular, CSIC – Univ. Valencia, Valencia, Spain.
$^3$Center for Research and Applications in Plasma Physics and Pulsed Power, P4, Chile.
$^4$Chilean Network for Neutron Physics and Applications (CNNPA), Chile.

Geant4 is a toolkit for Monte Carlo simulation of the passage of particles through matter. It is widely used in high energy, nuclear and accelerator physics, as well as studies in medical and space science [1, 2]. In the recent years, the Geant4 collaboration community has been doing efforts in order to improve the toolkit capabilities for the modelling of hadronic processes, in particular for neutrons at low energies. Thus, benchmarking with experimental results and validated codes, e.g. MCNP, are important activities. In this work, the modelling with the Geant4 toolkit of moderated $^3$He filled proportional neutron counters is studied. The energy deposition spectra by the neutron capture products in the gas counter is compared with experimental results. On the other hand, efficiency calculation for polyethylene moderated proportional counters are compared with experimental and MCNP results [3]. Finally, the application of the Geant4 toolkit to the study of the temporal response of moderated proportional neutron counters to detection of bursts of fast neutrons is presented.


* This work was supported in part by Conicyt grant ACT-1115
Module development DDHMS the code EMPIRE reactions for applications in reactions induced by nucleons

L.Brito, B. Carlson

*Instituto Tecnológico de Aeronáutica-ITA (ITA, S.J. Campos, Brasil)*

Blann proposed the hybrid Monte Carlo simulation model (HMS), [1] which uses only the densities of available states for creation and decay of single particle-hole pairs, in response to doubts concerning the partial equilibration of particle-hole configurations in the exciton [2] and hybrid [3] models. The HMS model was later extended, in collaboration with Chadwick, to the double-differential HMS (DDHMS) model [4]. This extension is based on Chadwick and Oblozinsky’s prescription for approximating the energy-angular distribution of available two-particle-one-hole states. [5, 6] Here, we compare the double differential cross sections obtained using several different expressions for the 1p->2p1h transition densities of the DDHMS: 1) exciton densities with the Chadwick-Oblozinsky prescription; 2) Fermi gas densities with the Chadwick-Oblozinsky prescription; 3) exact nonrelativistic Fermi gas densities [7] and 4) exact relativistic Fermi gas densities[8]. We perform the comparison using the DDHMS module in the EMPIRE-3.1 reaction code. [9]

Refs.

\(\text{sc EMPIRE-3.1},\) available online at http://www.nndc.bnl.gov/empire/.
Detecting capabilities of the boron loaded liquid scintillator EJ-339A.

F. Pino¹, L. Stevanato², D. Cester², G. Nebbia³, L. Sajo-Bochus¹, G. Viesti²

¹ Laboratorio de Física Nuclear, Universidad Simón Bolívar, Apartado 89000, 1080A Caracas, Venezuela
² Dipartimento di Fisica ed Astronomia dell'Università di Padova, Via Marzolo 8, I-35131 Padova, Italy
³ INFN Sezione di Padova, Via Marzolo 8, I-35131 Padova, Italy

A commercial boron-loaded liquid scintillator EJ-339A (4.6 % of $^{10}\text{B}$) has been studied in order to verify the capability of detecting photons and neutrons in an extended energy range i.e. both fast and thermal components of the neutron spectrum [1]. In particular, the possibility of recognizing boron capture events to obtain the thermal neutrons yield is hereby studied in details. From the experimental point of view, a weak $^{252}\text{Cf}$ neutron source (~ 8000 neutron/s) was placed at 17 cm front face of two liquid cells (EJ-301 and EJ-339A for comparison) to determine in detail the neutron induced reaction on the $^{10}\text{B}$ nuclei. The PMT anode signals were directly fed into a CAEN V1720 12bit 250 MS/s Digitizer. Thermal neutrons were produced by placing a variable number of polyethylene bricks between the $^{252}\text{Cf}$ source and the mentioned detectors. It is found that the signals from the neutron induced reactions on $^{10}\text{B}$ suffer a large quenching and correspond to about 50 keVee. Moreover they are mainly mixed with gamma-ray events when the PSD technique is applied [2,3]. These measurements provide us the possibility of study the shielding effect in the detector's responses. The number of the detected thermal neutrons was estimated by comparing the response of the two detectors with and without $^{10}\text{B}$ load. An interesting correlation between the ratio thermal neutron events to fast neutron events (>100 keV) and the polyethylene thickness was found. Also, Monte Carlo simulations of the experimental set up were performed with GEANT4.9.6, finding excellent correspondence with the experimental results. The correlation might be used to extract an information about the shield around a fission neutron source.

We have also studied the possibility of discriminating the low energy peak at about 50 keVee due to the thermal neutron signals to events having a close energy (59 keV) but associated to gamma ray sources as $^{241}\text{Am}$. The use the the EJ-339A scintillator as a neutron detector in a wide energy range is discussed.

Using the Bayes’ theorem of conditional probabilities to obtain the neutron flux of the RECH-1 experimental nuclear reactor at CCHEN∗

F. Molina1,3, P. Aguilera1,2,3, M. Zambra1,3, J.R. Morales2,3, and C. Henríquez1

1Comisión Chilena de Energía Nuclear (CCHEN), P.O. Box 188-D, Santiago, Chile
2Departamento de Física, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile and
3Chilean Network for Neutron Physics and Applications (CNNPA), Chile

The Bayes’ theorem of conditional probabilities is shown as an alternative to unfold the neutron flux energy distribution, Φ(E), from neutron activation measurements of different target material, A∞i, at RECH-1 reactor core at CCHEN and the corresponding tabulated cross sections σi, since A∞i = ∫0∞ σi(E)Φ(E)dE, → A∞i = ∑nj=1 σijΦj. The unfolding algorithms used in the analysis of target activation to obtain the neutron flux energy spectrum of a nuclear reactor core in similar devices worldwide, need an a priori knowledge of the spectrum shape to solve the inverse problem of obtaining Φj [1-3]. The advantage of using the Bayes based unfolding iterative algorithm is that an a priori knowledge of the neutron flux spectrum is not needed to obtain the experimental spectrum. In fact it is possible to start iterating with an uniform distribution [4]. This unfolding algorithm have been used recently to solve analogue problems in nuclear physics such obtaining feeding probabilities in total gamma spectroscopy beta decay measurements [5], and to obtain the neutron energy background at Canfranc Underground Laboratories using 3He detectors embedded in individual polyethylene blocks of different sizes [6]. Furthermore, using this algorithm to obtain neutron energy spectrum from a nuclear reactor is a novel work, extending the applicability of the method. In this work, due the activation measurements have not been done yet, an analysis of the unfolding algorithm is presented using real tabulated cross sections and starting the iterations from an uniform flux distribution.


∗This work was supported in part by Proyecto Bilateral Argentina-Chile ANPCyT-CONICYT, ACE-01
We have designed and constructed a stable, low current, 30 keV, ion source and proton accelerator at the University of Virginia. The accelerator is needed for angular detection efficiency studies with a large area, thick, and 127-hexagonal segmented silicon detector for the neutron beta decay experiment “Nab” that will be carried out at SNS, Oak Ridge National Laboratory in search of physics beyond the standard model.

We will present the design, simulations, operation, and detection of 30 keV H\(^+\) and H\(_2\)^+ as well as our efforts to gain beam stabilization and correlation of both ion currents.
Improved heat transfer for SPIRAL2 target driver

G. Acosta\textsuperscript{a,c}, J. Bermúdez\textsuperscript{a}, L. B. Tecchio\textsuperscript{a}, E. Udup\textsuperscript{a,b}, L. Sajo-Bohus\textsuperscript{c}

\textsuperscript{a}INFN Laboratori Nazionali di Legnaro, 35020 Legnaro, Italy.
\textsuperscript{b}Horia Hulubei National Institute of Physics and Engineering, Bucharest, Romania.
\textsuperscript{c}Universidad Simón Bolívar. Nuclear Physics Laboratory. Caracas, Venezuela.

Nucleus with an "extraordinary" density constitutes the heart of supernovae and neutron stars. This kind of matter will be reproduced by SPIRAL2 ongoing project [1], which will be operative few years from now. Results expected from this powerful neutron source will provide information on the governing forces mainly for neutron-rich nuclei. SPIRAL2 will be the most powerful, fast neutron source in the world, and it is expected to keep this rank for a decade or more to come. The core for this technological marvel is the neutron converter and its coupled motor driver. The neutron converter is conceived as a high speed rotating target made of natural graphite; an artistic view of the high speed rotating target and the complete assembly are given. In this study a new cooling system for the neutron converter driver is given in order to improve its performance. The configuration for 1kW electrical motor driver is studied with ANSYS Workbench CFX software. Temperature gradients of all over the motor surfaces were simulated to establish the behavior of a new arrangement respect to the proposed one for SP2 neutron source [2]. Results indicate that a cooling system for the neutron converter motor driver was necessary. The helical cooling coil around the case is a convenient approach for heat removal from an enclosed motor. The improvement held low level temperature so its operational lifetime could be extended for a longer time. We found, also by simulation, that the water cooled motor is the best solution for the target driver of the Neutron Converter Module assembly, in compliance with SPIRA2 target driver characteristics, including radiation damage.

\textbf{222, 220}Rn EXHALATION RATE OF MATERIALS USED AT UNEFM \\

Santiago H., P.\textsuperscript{1,2}, Sajo-Bohus L.\textsuperscript{2}, Palacios D.\textsuperscript{2}, Barros H.\textsuperscript{2} and Loaiza L.\textsuperscript{1} \\

\textsuperscript{1}Universidad Francisco de Miranda-Basic Sciences Research Center, Coro-Venezuela \textsuperscript{2}Universidad Simón Bolívar Nuclear Physics Laboratory, Caracas-Venezuela \\

Radon gas \textsuperscript{222}Rn spreads from the surface and from materials containing, NORM such as \textsuperscript{226}Ra. It is expected that radioactive elements are also exhaled from the materials in the buildings of the National Experimental University “Francisco de Miranda”, located in Coro city, Falcon State (UNEFM) and, therefore they can accumulate in the interior and different spaces frequented by students and workers alike. It is well known that depending on the inhalation doses it is possible to develop lung cancer. For that reason it is indispensable to know the exposition rates due to radon gas and eventually evaluate the radiological impact in the population. In this study case, the exhalation rate was determined for a set of building materials used in the constructions of UNEFM. The method consists of the utilization of passive detectors LR-115 exposed for a month using the diffusion chamber technique. The radon concentration measurements in the interiors due to the emanation of brick walls, marble shelves, granite floors and concrete blocks vary from $105 \pm 4$ a $130 \pm 4$ Bqm$^{-3}$, $210 \pm 7$ a $320 \pm 11$ Bqm$^{-3}$, $138 \pm 5$ a $176 \pm 6$ Bqm$^{-3}$, and, $71 \pm 3$ a $95 \pm 3$ Bqm$^{-3}$ respectively. The radon average exhalation rate in the interiors due to the emanation of brick walls, marble shelves, granite floors and concrete bricks is between $0.234 \pm 0.009$ y $0.132 \pm 0.009$ Bqm$^{-2}$ h$^{-1}$ respectively. In the brick blocks and concrete bricks is $0.098 \pm 0.003$ y $0.130 \pm 0.004$ Bqm$^{-2}$ h$^{-1}$ respectively. The values obtained in seven rooms were relatively low and within the range recommended by the International Commission of Radiological Protection (ICRP).
Effect of high dose of rays-X on the parasitic action of *Plasmodium berghei*

Spencer, L.¹, Nava-Lausón, C.¹; Davila, J.²; Sajo-bohus, L.¹

¹ Universidad Simón Bolívar Valle de Sartenejas Apdo 89000, Caracas 1080A, Venezuela.
² Centro Medico Docente La Trinidad, Servicio de Radioterapia, Caracas-Venezuela.

Malaria is responsible for millions of clinical cases and approximately for 655,000 deaths annually. Therefore, the development of strategies for the design of an effective vaccine has become a priority for the Parasitologists worldwide. The aim of the present study was the evaluate the effect of irradiation with X-rays on the merozoite stage of *Plasmodium berghei* using the BALB/c mice as experimental model. We used doses of ionizing radiation between 80 and 350 Gy in parasitized red blood cells (GRP) from *Plasmodium Berghei* to determine its effect on merozoite parasites, because in previous research we showed that 50 Gy was still not sufficient to attenuate the parasite [1]. The parasitemia was monitored daily by Giemsa stain and the effect of high dose was evaluated by indirect immunofluorescence (IFI) immunological test. Our results show that, with 120 Gy dose, 50% of individuals manage to control the infection entirely and survive. For higher dose it is observed the death of individuals even without producing significant levels of parasitemia in blood (less than 5%). IFI assay showed that for the treatments with 250, 300 and 350 Gy parasites are outside red blood cells even in the 10 day post-infection. X-ray radiation dose exceeding the 250 Gy on GRP with *P. berghei*, diminish the ability of the parasite to invade the red blood of the host. However, the radiation has an adverse effect that causes the death of individuals for reasons unrelated to infection by malaria. Doses of radiation around 120 Gy achieve attenuation parasitic to achieving a percentage of survival of 50% in BALB/c mice.


Financially supported by national science fundation FONACIT No.2940749-2269
An improved formula for stopping power at low incident energy

A. Ochoa and H.C. Wu

Instituto de Física, Universidad de Antioquia, Medellin, Colombia

The theory of Bohr [1] on the energy loss of heavy charged particle passing through matter is a good start for the study of stopping power. In the Bohr’s theory, the electrons inside the matter are assumed to be at rest, and their interaction with the projectile is treated according to the distance between the electron and the projectile. The electrons in the “close zone” make Coulomb collision with the projectile, whereas those in the “distant zone” interact through electric field. This theory works well for incident energy above 1 MeV, whereas it collapses at incident energy around 0.1 MeV. There have been attempts to repair the theory at low-energy limit. For example, P. Sigmund [2] takes the equality of the contributions from the distant- and close-zone as the criterion to determine the boundary between the two zones, and thus a collapse of Bohr’s formula at around 0.1 MeV is avoided. However, the physical basis of the criterion is unclear.

In this work we modify the Bohr’s theory by considering the motion of electrons in the matter. When a projectile passes through the matter, the electrons in the distant zone can move into the close zone and consequently results in an enlargement of close zone. While this enlargement is insignificant for projectiles with higher energy, it makes substantial difference for protons at low-energy limit. With a phenomenological formula for the boundary between the close- and distant-zone, the stopping power is calculated. Fig 1 shows an excellent agreement between calculated and experimental (NIST [3]) stopping power for proton passing through Aluminum with incident energy between 0.001-300 MeV. Such a good agreement also exists for a big variety of matters.


*This work was supported in part by CODI of the University of Antioquia
Natural activity of $^{40}$K in some Chilean building materials

M. Sepúlveda$^1$, R. Barriga$^1$, P. Ortiz$^1$, P. Miranda$^1$, and J.R. Morales$^1$

$^1$Departamento de Física, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile.

Knowledge of the natural level of radioactivity is important to assess the influence of gamma radiation exposure in building materials. The main sources of external radiation exposure in buildings are members of the uranium and thorium decay chains and $^{40}$K [1] occurring naturally in building materials, which emit gamma rays.

The specific activity of building materials has been reported for many countries. However, for Chilean building materials no such data are available. A study of $^{40}$K specific activity on building materials was carried out with gamma-spectrometric system based on high-purity germanium detector. The $^{40}$K activity was measured directly by its own gamma-ray line at 1460.8 keV. Samples of gypsum, cement, brick and cement and gravel mixture, widely used in Chile, were used on this work.

The samples were corrected by moisture content and the geometrical conditions has been normalized to avoid volumetric corrections [2]. All preliminary results are below the world average of 500 Bq/kg for building materials reported by UNSCEAR.


*Present address: msepulveda@gnm.cl
Image formation in a gamma ray Compton Backscattering device.

N. González¹,² and F. Cristancho¹,²‡
¹Departamento de Física, Universidad Nacional de Colombia, Bogotá, Colombia.
²Centro Internacional de Física, Bogotá, Colombia.

The Compton Camera is a backscattering device that allows us to obtain images of hidden objects. The device includes a $^{22}$Na source placed in a conical lead shielding and two geometrically opposing CsI detectors, one position sensitive detector in charge of building the image and a backscattering detector in charge of triggering the recollection of data.

In order to study the image formation in the device we developed a theoretical approximation to evaluate the backscattered intensity as a function of depth. We have performed backscattering experiments to analyze the number of single and multiple backscattered photons as a function of thickness and to compare the experimental results with the theoretical model. The results of this comparison show that Multiple Compton events have a detrimental effect on the quality of the image and the Single Compton events build the image. We have evaluated the differences in backscattered intensity between two different materials to study the contrast in the image obtained.

‡Departamento de Física, Universidad Nacional de Colombia, Bogotá, Colombia.
The use of portable X-ray Fluorescence Spectrometry (PXRFS) for clinical practices*

C. B. Zamboni¹, S. Metairon¹, M. A. Rizzutto², S. Bernardes²
¹ Instituto de Pesquisas Energéticas e Nucleares, IPEN/CNEN, SP, Brasil
² Universidade de São Paulo, IFUSP, SP, Brasil

In the last years X-Ray Fluorescence (XRF) technique has been applied to clinical finality at IPEN/CNEN-SP, in collaboration with blood banks and research centers from Brazil [1,2]. The major advantage for using this analytic technique for chemistry clinical is the viability to use small quantities of blood (25 to 100μL) comparatively to conventional analyses preformed using serum (at least 500μL to 10 mL). Besides, the execution is faster and the procedure is not destructive. Now, we intend to check the viability of using a portable X-Ray Fluorescence Spectrometry (PXRFS) for clinical blood examination. In this study the biological samples came from Blood Banks of São Paulo city (Brazil). Each sample was collected in a vacuum plastic tube (without anticoagulants) attached to the donor’s arm and, immediately after the collection exactly, 100μL of whole blood was transferred to the filter paper (Whatman, n°41) using a calibrated micropipette and it was dried for few minutes using an infrared lamp. Samples were prepared in duplicate. The XRF analysis was performed using MINI X spectrometer from Amptek, model X-123 SDD with Ag X-ray tube. The characteristics X-ray fluorescent intensities (Kα lines) were measured with a Si detector (Si Drift 25 mm² x 500μm / 0.5 mil) Be (window / 1.5”) and biological samples were irradiated for 300s using 30 kV and 5 μA excitation. The quantitative analysis was performed using WINAXIL software program. We intend to stimulate the use of this small spectrometry as an alternative for diagnostic of the clinical diseases that have high prevalence in Brazilian population.


* This work was supported in part by CNPq
An application of Accelerator Mass Spectrometry to geology

D. Rodrigues\textsuperscript{1,2}, A. Arazi\textsuperscript{1,2}, G. Marti\textsuperscript{1}, P. Steier\textsuperscript{3}, and A. Negri\textsuperscript{1,2}

\textsuperscript{1} Laboratorio Tandar, Comisión Nacional de Energía Atómica, Buenos Aires, Argentina
\textsuperscript{2} Consejo Nacional de Investigaciones Científicas y Técnicas, Buenos Aires, Argentina and
\textsuperscript{3} Vienna Environmental Research Accelerator.

The radionuclide $^{10}$Be is produced in the atmosphere by fragmentation reactions induced by the impact of high energy cosmic protons on N$_2$ and O$_2$ molecules [1]. It arrives to the oceans through wet precipitation and it is then accumulated in deep-sea sediments. Therefore, the presence of $^{10}$Be in volcanic rocks [2] provides clear evidence that the sediments are being incorporated beneath arcs during the subduction process of the tectonics plates, since the half-life of $^{10}$Be is too short (1.39 Myr, [3]) to be present in the mantle.

Accelerator Mass Spectrometry (AMS) is the most sensitive technique for the detection of long-lived radioisotopes (or even stable nuclides), being capable of detecting one radioactive atom among $10^{15}$ of its stable isotope.

The improvement of AMS over the conventional Mass Spectrometry (MS) relies on the use of the tandem accelerator, which ensures the destruction of isobar molecules at the stripper and provides high energy for the discrimination of isobar nuclides.

With the purpose of estimate the amount of sediments involved in the subduction process a simplified model was used and the isotopic ratio $^{10}$Be/$^9$Be have been measured by AMS in ash samples of three different volcanoes of South America.

The measurements were performed in a 3 MV accelerator at VERA (Vienna Environmental Research Accelerator) [4] by using a 500 nm silicon nitride foil like passive absorver togheter with a switching magnet in order to reduce the isobaric interference of $^{10}$B. Besides, an ionization chamber with segmented anode at the end of the line allowed the discrimination of other interfering particles.

The ratios found ($^{10}$Be/$^9$Be $\sim 10^{-10}$) are one order of magnitude higher than the reported values in volcanic rocks. It could be due to atmospheric contamination of the samples with $^{10}$Be during the eruption. New measurements with samples leached with weak acids are planed to carried out using the TANDAR accelerator.

Very high dose dosimetry using TL behaviour of jadeite and beryl minerals*

L.S. do Carmo¹, S. Watanabe¹, N.F. Cano¹ and R.F. Barbosa²

¹ Institute of Physics (University of São Paulo, São Paulo, Brazil)
² Department of Sea Sciences (Federal University of São Paulo, Santos, Brazil)

The low dose dosimetry has been well developed due to its usefulness in radiotherapy, nuclear medicine and other applications in medicine. However, although there are nuclear applications in industry involving high radiation dose, there are not many high dose dosimetry works published. Here, we investigated two silicate minerals, jadeite and beryl for very high dose dosimetry. Jadeite is a member of Pyroxene Group and beryl of Ring Group. The white variety (WJ) of jadeite presented TL peaks at 120, 190 and 230 °C peaks. The 190 °C peak grows linearly with dose up to about 10 kGy, beyond that it saturates. The green variety (GJ) has TL peaks at 140, 210, 250 and 330 °C. The 250 °C peak grows up to about 250 kGy and then decreases, but at 2500 kGy its TL reading is still relatively high. The green variety of jadeite can, thus, be used for very high dose dosimetry.

The uncolored variety of beryl is called goshenite (GB) and blue-green variety, aquamarine (AB). The 180 °C peak in GB grows up to about 1250 kGy and then decreases, while in AB the high temperature peak grows up to 250 kGy and then decreases. Both GB and AB can be used for very high dose dosimetry.

* This work was supported by FAPESP.
† Present address: Institute of Physics (University of São Paulo, São Paulo, Brazil)
Contribution of $(n,\gamma)$ Reaction in the Out-of-Field Absorbed Dose for Patients under Radiotherapy Treatments with High MV Linear Accelerators

R. Martín-Landrove$^1$, L. Sajo-Bohus$^2$, L. Spencer$^2$, D. Palacios$^2$ and J. Dávila$^{1,3}$

$^1$Universidad Central de Venezuela, Caracas-Venezuela
$^2$Universidad Simón Bolívar, Laboratorio de Física Nuclear, Baruta Caracas-Venezuela
$^3$Física Médica C. A. Caracas, Venezuela

Although radiotherapy treatments at high energy offer important benefits for patients with several forms of cancer, there was a concern related to generation of neutrons through photonuclear reactions and their contribution to the delivered radiation dose. The debate about health hazards for patients reached a critical point when a recommendation for deterrence in the use of high energy beams was issued [1]. More recent Monte Carlo simulations [2-4] lead to much lower neutron dose equivalent and risk estimations with large uncertainties. In this work an alternative approach which is based on transport theory and neutron mean free paths for different tissues provides an upper bound of 1 MeV for the relevant energy range related to 15 MV linear accelerators.

In that energy range there are just two processes to be considered, namely, elastic scattering and $(n,\gamma)$ reactions. The contribution of the $(n,\gamma)$ reactions to the out-of-field absorbed dose is evaluated in detail for several tissues by taking into account gamma rays and beta emission decay chain for every nuclide. In the same way the enhancement effect on the absorbed dose which is produced by multiple scattering is evaluated through transport theory considerations. The resultant absorbed dose does not pose any significant health hazard. Financially supported by national science fundation FONACIT No.2940749-2269

Nuclear Radiation as probe to investigate some of the physical properties of Willemite*

R. M. Ferreira I‡, S. Watanabe I and N.F. Cano I

1 Institute of Physics (University of São Paulo, São Paulo, Brazil)

A radiation is frequently used to explore the physical properties of materials. Here, we investigated the thermoluminescence (TL) and electron paramagnetic resonance (EPR) properties of the willemite, a silicate mineral, under γ-irradiation. Electron irradiation is also under way.

Willemite, of chemical formula Zn$_2$SiO$_4$, is a silicate mineral of the Olivine Group, together with fayalite (Fe$_2$SiO$_4$), forsterite (Mg$_2$SiO$_4$) and phenakite (Be$_2$SiO$_4$). A sample of willemite of mexican origin purchased from a local stone dealer is a bunch of about 35-40 small crystals of size 2-3 mm, glued on another mineral called limonite. X ray fluorescence analysis indicated besides SiO$_2$ and ZnO, basic components of willemite, Al$_2$O$_3$ and Fe$_2$O$_3$ as main impurities in both minerals. This analysis has shown that limonite is a solid solution of willemite and fayalita. Willemite presented 160, 230 and 320 °C TL peaks that irradiated with gamma-rays grows in intensity with the radiation dose up to about 2000-2500 Gy, saturating beyond. The limonite has only 160 and 270 °C peaks; they also grow in intensity with radiation dose up to about 5000 Gy. These results indicate that these minerals can be used for high dose dosimetry. Since limonite has large concentration of iron (about 11,1 weight %) its EPR spectrum dominated by a strong signal at g = 2,0. But willemite presented signals due to peroxy-canter that grows with radiation dose. Effects of electron irradiation will be presented at the meeting.

* This work was supported by FAPESP.
‡ Present address: Institute of Physics (University of São Paulo, São Paulo, Brazil)
Use of the FLUKA Monte Carlo code for 3D patient-specific dosimetry on PET-CT and SPECT-CT images

A Mairani\textsuperscript{1,2}, F Botta\textsuperscript{3}, R F Hobbs\textsuperscript{4}, A Vergara Gil\textsuperscript{5}, M Pacilio\textsuperscript{6}, K Parodi\textsuperscript{2}, M Cremonesi\textsuperscript{3}, A Di Dia\textsuperscript{3}, M Ferrari\textsuperscript{3}, F Guerriero\textsuperscript{3}, G Battistoni\textsuperscript{7}, G Pedroli\textsuperscript{3}

\textsuperscript{1} Medial Physics Unit, CNAO Foundation, Pavia, Italy
\textsuperscript{2} Heidelberg Ion Beam Therapy Center and Department of Radiation Oncology, Heidelberg, Germany
\textsuperscript{3} Medical Physics Unit, European Institute of Oncology, Milan, Italy
\textsuperscript{4} Department of Radiology, Johns Hopkins University, School of Medicine, Baltimore MD, USA
\textsuperscript{5} SSDL, Center for Radiation Protection and Hygiene, Havana, Cuba
\textsuperscript{6} Medical Physics Department, S.Camillo Forlanini Hospital, Rome, Italy
\textsuperscript{7} Istituto Nazionale di Fisica Nucleare (I.N.F.N.), Milan, Italy

Patient specific absorbed dose calculation for nuclear medicine therapy is a topic of increasing interest. 3D dosimetry at the voxel level is one of the major improvements for the development of more accurate calculation techniques, as compared to the standard dosimetry at organ level.

This study aims to use FLUKA Monte Carlo code to perform patient specific 3D dosimetry through direct Monte Carlo simulation on PET-CT and SPECT-CT images. To this aim dedicated routines were developed in the FLUKA environment.

Two sets of simulations were performed on model and phantom images. Firstly, the correct handling of PET and SPECT images was tested under the assumption of homogeneous water medium by comparing FLUKA results with those obtained with the voxel kernel convolution method and with other Monte Carlo-based tools developed to the same purpose (the EGS-based 3D-RD software and the MCNP5-based MCID). Afterwards, the correct integration of the PET/SPECT and CT information was tested, performing direct simulations on PET/CT images for both homogeneous (water) and non-homogeneous (water with air, lung and bone inserts) phantoms. Comparison was performed with the other Monte Carlo tools performing direct simulation as well.
The absorbed dose maps were compared at the voxel level. In case of homogeneous water, by simulating $10^8$ primary particles a 2% average difference with respect to the kernel convolution method was achieved; such difference was lower than the statistical uncertainty affecting the FLUKA results. The agreement with the other tools was within 3-4%, partially ascribable to the differences among the simulation algorithms. Including the CT-based density map, the average difference was always within 4% irrespectively of the medium (water, air, bone), except for a maximum 6% value when comparing FLUKA and 3D-RD in air.

The results confirmed that the routines were properly developed, opening the way for the use of FLUKA for patient-specific, image-based dosimetry in nuclear medicine.
Titanium Extraction from Waste NORM

B. R. Pereira¹, P. S. R. Santos¹, G. Fontana¹, N. H. Medina², M. A. Rizzutto²,
A. T. Silveira Junior³ and M. A. G. da Silveira¹.
¹Centro Universitário da FEI, São Bernardo do Campo, Brazil
²Instituto de Física da USP, São Paulo, Brazil
³Instituto de Química da USP, São Paulo, Brazil

The constantly growing of global agricultural production depends on the development of a whole production to be lasting and sustainable. The phosphoric acid production is directly related to the production of fertilizers, but its production process requires several steps which generates a lot of wastes. There are several elements in some of these wastes that are very valuable and important for economy and for technological development. An example is a residue derived from a step of physical handling of the phosphate rock, containing about 30% of titanium in its composition. Titanium can be used in various applications, such as a component in high-tech metallic alloys, or, in the form of titanium dioxide, which is the form that presents the greatest value in industry. This study focus on the extraction of titanium oxide present in a residue from the phosphoric acid production, by attacking the material chemically. The concentration analyses were done by X-ray Fluorescence. This waste is a Naturally Occurring Radioactive Material (NORM), since there are natural radioisotopes in the residues. In order to verify the natural radionuclide concentration, gamma ray spectrometry was also used [1,2].

This study would contribute to economic and environmental issues, since in the phosphoric acid production process it is possible to transform an unused waste in a high value product. The methodology to concentrate titanium oxide was based in industrial extraction of titanium ores and consists of solubilizing the impurities present in the sample by means of chemical attack [2]. In the Figure liquid and solid phase X-ray fluorescence spectra are shown. It is possible to observe that in the liquid phase, after the acid attack, does not present titanium ions dissolved, as the characteristic peak of titanium is not present in the spectrum of this phase. This shows that titanium, as well as zirconium and niobium, were concentrated in the solid phase.

This work was supported in part by Centro Universitário da FEI, CNPq and FAPESP.
Radiation Effect Mechanisms in Electronic Devices.

M. A. G. Silveira¹, N. H. Medina², R. B. B. Santos³, F. Leite¹, F. Cunha¹, K. H. Cirne¹, A.P. Aguiar² and N. Added².

¹ Centro Universitário da FEI, São Bernardo do Campo, S.P., Brazil
² Instituto de Física da USP, São Paulo, S.P., Brazil

The development of the electronics industry worldwide achieved great advances from the 70s, with studies on oxidation process in field effect silicon transistors. Thus, there was a need for knowledge of the mechanisms that are present in oxides and interfaces between silicon and silicon oxides, as well as other compound semiconductors due to critical differences between the properties of silicon [1,2]. Against this background, many studies have been performed to understand reliability and ionization radiation effects on electronic devices. Reliability problems and effects of ionizing radiation on electronic devices are critical, depending on the environment in which the devices are exposed. This is the case of space, avionics, particle accelerators, nuclear reactors. This research area is strategic for space and defense areas [1-4]. Thus, it is of fundamental importance to conduct tests to qualify electronic devices submitted to irradiation, based on Total Ionizing Dose (TID), Single Event Effects (SEE) and Displacement Damage (DD). This work shows tests using X-ray and ion beams to test commercial MOSFET (Metal Oxide Semiconductor Field Effect Transistor). The integrated circuits, CD4007, were exposed to 60 MeV $^{35}$Cl ion beams using the São Paulo 8UD Pelletron Accelerator and 10 keV X-ray radiation using a Shimadzu XRD-7000. The total dose effects due to ionizing radiation in MOSFET devices can lead to trapping of charges in the oxide and at the interface Si/SiO$_2$, which increases or decreases the transistors off-current and leakage currents, and shifts the threshold voltage. Characteristic curves of current as a function of gate voltage, in different irradiation conditions, for p and n-MOSFET transistors, which compose the commercial device, were studied. In Figure 1 it is possible to note different behaviors of the devices as a function of radiation dose due to X-ray radiation and the incidence a 60 MeV $^{35}$Cl ion beam.


This work was supported in part by Centro Universitário da FEI, CNPq, FAPESP and FINEP.
Preliminary results on the neutron energy distribution measurements at the RECH-1 reactor core

P. Aguilera\textsuperscript{1,2,3}, F. Molina\textsuperscript{1,3}, J. R. Morales\textsuperscript{2,3}, M. Zambra\textsuperscript{1,3}, and C. Henríquez\textsuperscript{1}

\textsuperscript{1}Comisión Chilena de Energía Nuclear (CCHEN), P.O. Box 188-D, Santiago, Chile

\textsuperscript{2}Departamento de Física, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile and

\textsuperscript{3}Chilean Network for Neutron Physics and Applications (CNNPA), Chile.

The RECH-1 is a 5 MW pool-type experimental nuclear reactor. The RECH-1 neutron energy flux have been measured at the end of the experimental lines at three energy regions: thermal, epithermal and fast [1]. It is important to obtain a precise experimental measurement of the neutron energy distribution to validate MCNPX codes and have an accurate characterization of the device for future basic research in neutron physics. Furthermore, the measurement of the neutron energy distribution provides a key information to enhance calculations of many applied nuclear physics problems as neutron dosimetry, isotope production and radiation damage.

The experimental measurements are based on neutron activation of different target materials [2,3], obtaining the saturation activity $A_i^\infty$ by gamma spectroscopy of the decaying daughter nuclei produced. Using the tabulated cross section values and the saturation activity it is possible to unfold the neutron energy flux distribution [4].

Preliminary experimental results of neutron activation, gamma efficiency and unfolding method tests will be presented.

[1] C. Henríquez et al, Mediciones de flujo neutrónico en un núcleo configurado por elementos combustibles de bajo enriquecimiento. CCHEN internal publication.


Monitor unit calculation for radiotherapy treatments using the Monte Carlo method

H. Laulate¹, A. F. Menezes¹, J. P. Reis Junior¹ and A. X. Silva¹
¹ Programa de Engenharia Nuclear, COPPE/ UFRJ, Rio de Janeiro, Brazil

This study aims to develop a methodology to quantify and assess the monitor unit (MU) for a radiotherapy treatment simulation using the Monte Carlo method. For this study was reproduced two standard treatments considering that the patient has low or high risk prostate cancer. In low risk prostate cancer, the Clinical Target Volume (CTV) should be restricted to the prostate only and the Planning Target Volume (PTV) was considered 1 cm beyond the CTV. An additional 0.6 cm margin is added to account for penumbra. In the high risk prostate cancer, we use Whole Pelvic Radiotherapy (WPRT). Here we consider bony landmarks to determine the field size. In both treatments we use 15 MV photons, the four-field box technique and 2 Gy daily fractions.

The irradiations were performed using the Siemens Oncor Expression linear accelerator belonging to the service of the Clinicas Oncologicas Integradas (COI/RJ), modeled and validated using the MCNP code.
Calculation of minor actinides transmutation in ADS reactors

P. K. Taipe¹, F. C. Silva¹ and A. C. M. Alvim¹
¹Programa de Engenharia Nuclear – COPPE/UFRJ, Rio de Janeiro, Brazil

One of the points in debate and therefore of mistrust about the use of nuclear energy as a source of electricity generation is what to do with spent fuel elements. These fuel elements have several radionuclides (fission products long-lived and minor actinides) that turns them into a system with very high radiotoxicity. One possibility to solve this issue is to repackage them into suitable geological repositories. But studies are underway to investigate the possibility of incinerating long-lived fission products and transmute minor actinides, that are the main contributors to radiotoxicity, in ADS reactors. The transmutation of minor actinides in ADS reactors greatly diminishes this radiotoxicity. But ADS are subcritical reactors guided by a source and transmutation of minor actinides requires high fluxes in the region where these actinides are. Therefore, studies are underway to determine the appropriate intensity of the source and neutron fluxes for a chosen level of subcriticality. In this paper we present results of studies in order to show the efficiency of an ADS reactor type to decrease this radiotoxicity, considering different levels of subcriticality and different intensities of the source and neutron fluxes, that is, a sensitivity study was made for this purpose.
Environmental applications of nuclear techniques: 
Inter-hemispheric exchange of tropospheric air masses

A. E. Negri¹, J. Fernández Niello¹,² and A. Arazi¹
¹ Laboratorio TANDAR - CNEA, Buenos Aires, Argentina
² Universidad Nacional de San Martín, San Martín, Argentina

Since the coming of the nuclear era a large variety of radionuclides were introduced to the environment, which could be used as tracers of different transport processes. Actually, also natural radioisotopes are used for tracing atmospheric, oceanic or biological mechanisms. In particular, the experimental study of the atmospheric dynamics [1] can be aided by the high-sensitive detection of radionuclides such as ³H, ⁷Be, ¹⁴C, ³⁶Cl, ⁹⁰Sr, ¹²⁹I, and ¹³⁷Cs. Several techniques and methods have been applied in order to detect and follow these radionuclides, like accelerator mass spectrometry, gamma detection, neutron activation, etc. In this contribution we analyze the transport of radionuclides released into the environment due to atmospheric nuclear weapon tests, power plant accidents and nuclear fuel reprocessing plants [2]. We focus our study on the information that can be obtained about the exchange of tropospheric air masses between the northern and southern hemisphere and on the constrains that the sensitive measurements of these radionuclides can pose on well-accepted atmospheric models [3].

Design of a detection system to obtain 2D dose maps for complex radiation therapy treatment verification


1 Instituto de Física da Universidade de Sao Paulo (IFUSP), 05508-090, Sao Paulo, Brazil.
2 Departamento de Física, Atómica, Molecular y Nuclear (FAMN), Universidad de Sevilla, 41012 Seville, Spain.
3 Centro Nacional de Aceleradores (CNA), 41092 Seville, Spain.
4 Hospital Universitario Virgen Macarena, 41009 Seville, Spain.
5 Departmento de Ingeniería electrónica, Universidad de Sevilla, 41092 Seville, Spain.

The Project “Design of a detection system to verify 2D dose maps for Intensity Modulated Radiation Therapy (IMRT) treatment” is one of the 22 sub-projects of the “optimization of Particle Accelerator” (oPAC) European network. This work is part of a wide scientific collaboration established under the name RADIA. It involves the Department of Atomic, Molecular and Nuclear Physics and the Department of Electonical Engineering of the University of Seville, the National Accelerator Centre (CNA) and also the Virgen Macarena University Hospital. Such a work aims to produce a novel optimized online readout system to obtain 2D dose maps at axial planes for radiotherapy treatment verification, based on silicon technology. This system is being developed following clinical requirements and couples a novel dual single sided silicon strip detectors (SSSSD) chip, designed and developed in collaboration with the company Micron Semiconductor Ltd., to its in-house developed electronics, mechanical phantoms, data acquisition and analysis systems. First measurements have been performed at the Virgen Macarena Hospital in Seville by using a slab phantom (made out of polyethylene, similar in density to human tissue), designed in order to house the detector. Such system has been irradiated with a 6MV photon beam produced by a Siemens linac. This setup has been used to determine important parameters related to the required quality assurance (QA) protocols such as: linearity of the detector response, reproducibility, penumbra, output factors, percent depth dose (PDD). The goodness of these results is compared to a feasibility study that was carried out by employing a commercial W1-SS 500 detector, for complex radiotherapy treatment verification [1, 2].

Data acquisition and processing software is also being developed in order to obtain a system that could be directly operated by the medical staff.

Bibliography


Characterization of a polymer gel dosimetry system based on N-isopropylacrylamide and N-N’-methylenebisacrylamide.

F. Mattea1,2, M. C. Strumia1,2, and M. Valente3,4
1 Instituto de Investigaciones Físico-Químicas de Córdoba, CONICET-UNC, Córdoba, Argentina
2 Facultad de Ciencias Químicas - Universidad Nacional de Córdoba, Córdoba, Argentina
3 Instituto de Física Enrique Gaviola CONICET, Córdoba, Argentina
4 Facultad de Matemática, Astronomía y Física - Universidad Nacional de Córdoba, Córdoba, Argentina

Diagnostic radiology and radiotherapy are the most used techniques to detect and treat several pathologies like tumor and cancer diseases. According to available evidence [1] at least 52% of cancer patients should receive radiotherapy during their treatment. The process of radiotherapy is complex and involves understanding of the principles of medical physics, radiobiology, radiation safety, dosimetry, radiotherapy planning, simulation and interaction of radiation therapy with other treatment modalities. One of the key aspects of radiotherapy is to determine the real dose an organ or tissue is exposed. For that purpose, if the irradiation conditions are well defined and known in relation to the anatomy of the patient, Monte Carlo simulations of the energy deposition can be performed. However, if those conditions are not fulfilled, it is also possible to measure the organ dose directly with the use of suitable phantoms and dosimeters [2]. Among the different types of dosimeters, polymeric ones are of great interest because of their capability to mimic soft-tissue while maintaining a specific shape presenting high dose sensitivity and the ability to retain 3D spatial dose distribution for long periods of time after being exposed [3]. A typical polymer gel dosimeter is a complex aqueous composition of physical gel-forming agent, monomers, and oxygen scavengers. The concentration of each component affects the sensitivity and the response of the dosimeter to radiation. Therefore, an in-depth study on the preparation methodology is essential for the development of new dosimeters.

In this work the preparation and characterization of a polymeric dosimeter based on the monomers N-isopropylacrylamide (NIPAM), N-N’-methylenebisacrylamide (BIS) and an aqueous gelatin matrix containing Tetrakis(hydroxymethyl)phosphonium chloride (THPC) as oxygen scavenger is studied. Different characterization techniques, such as X-ray Raman spectroscopy, confocal and scanning electronic microscopy, and absorbance/transmittance analysis of the different dosimeters after being irradiated are presented and analyzed from a physical and chemical point of view, in the interest of proposing new materials for specific treatment purposes.

Near-threshold $^7\text{Li}(p,n)^7\text{Be}$ reaction for Boron Neutron Capture Therapy

D.M. Minsky$^{1,2,3\dagger}$ and A.J. Kreiner$^{1,2,3}$

$^1$Gerencia Investigación y Aplicaciones, CNEA, San Martín, Argentina
$^2$Escuela de Ciencia y Tecnología, Universidad Nacional de San Martín, San Martín, Argentina
$^3$CONICET, Buenos Aires, Argentina.

Boron neutron capture therapy (BNCT) is a radiation therapy under development for the treatment of some types of cancers like melanoma and glioblastoma multiforme. It is performed in two steps: first, a stable isotope of boron ($^{10}\text{B}$) is administered to the patient via a carrier drug and then the patient is irradiated with an epithermal neutron beam. The neutrons are moderated as they penetrate in the patient’s tissues and reach the tumor with thermal energy. $^{10}\text{B}$ has a high thermal neutron capture cross section ($3840\text{ b}$) leading to the $^{10}\text{B}(n,\alpha)^7\text{Li}$ reaction. The emitted charged particles have a high linear energy transfer (LET) and they deliver all their energy ($1.47\text{ MeV}$ for the $\alpha$ particle and $0.84\text{ MeV}$ for the $^7\text{Li}$) only to the cells in close proximity to the reaction point with a lethal effect. The range of the emitted particles are of the order of the cell radius so the effect is very localized.

The success of BNCT depends both on the selectivity of the boron carrier drug and the neutron field quality. Until now, all clinical trials have been carried by using nuclear reactors as neutron sources. However, there is a significant level of consensus internationally that advancement of BNCT requires neutron sources suitable for installation in hospital environments. Ion accelerators can fulfill this requirement and in principle can also provide better treatment qualities by choosing adequate nuclear reactions with softer primary neutron energies, which are closer to the ideal epithermal spectrum than those produced by nuclear reactors.

In our group, a dedicated Tandem Electrostatic Quadrupole accelerator devoted to Accelerator-Based BNCT (AB-BNCT) is under development and construction. The accelerator will be capable of delivering $30\text{ mA}$ of protons and deuterons of energies up to $2.4\text{ MeV}$. Several reactions have been studied, in particular $^7\text{Li}(p,n)^7\text{Be}$. This is an endothermic reaction, so the energy of the neutrons can be as low as desired at the expense of yield. In previous work we have studied the regime of proton energies about that of the resonance ($\sim2.3\text{ MeV}$). In this regime a Beam Shaping Assembly (BSA) is needed in order to moderate and direct the neutrons. Several configurations have been obtained with good treatment qualities.

In this work we explore the $^7\text{Li}(p,n)^7\text{Be}$ neutron production reaction but in a different regime: bombarding proton energies near the reaction threshold. In this regime, neutrons are produced with energies much nearer to the optimal for the treatment and thus no BSA is required. Less unnecessary radiation is produced and the low yield is compensated with the lack of losses in the BSA.

$\dagger$ Present address: GIyA-CNEA, Av. Gral Paz 1499 (B1650KNA) San Martín, Buenos Aires, Argentina
Internal dosimetry for alpha emitters radiopharmaceuticals in biological tissue studied with the FLUKA code

M. Valente\textsuperscript{1,2}\textsuperscript{*}\textsuperscript{†}

\textsuperscript{1} Instituto de Física Enrique Gaviola CONICET, Córdoba, Argentina and
\textsuperscript{2} Facultad de Matemática, Astronomía y Física - Universidad Nacional de Córdoba, Córdoba, Argentina

Clinical practices for neoplastic disease diagnose and treatment are based on the incorporation of \(\alpha\), \(\beta\) and \(\gamma\) radiotracers and radiopharmaceuticals, which might be associated with potential damage. Thus, being necessary accurate dosimetry strategies. \textit{In vivo} absorbed dose appears as an ideal solution. However, its implementation in clinics does not attain enough reliability. On the other hand, different approaches were proposed for internal dosimetry calculations. Some specific analytical methodologies were developed by the Committee on Medical Internal Radiation Dose (MIRD) to assess organ-level dose values in nuclear medicine [1]. Improvements in informatics achieve better computation performance, but Monte Carlo approaches for patient-specific dosimetry are sometimes high time-consuming limiting its use in routine clinical practices.

Analytical approaches introduce kernel convolution techniques aimed to patient-specific dosimetry. Although scattering effects are not accurately handled, these methods are capable of fast dosimetry computation based on photon Energy Deposition Kernel (EDK) and particle Dose Point Kernel (DPK) assessed for radionuclides in order to perform further dosimetry calculations. EDK and DPK are obtained according to specific source emission. It was considered a point source isotropically emitting within an homogeneous medium, so that radiation transport is accounted as uniformly distributed over concentric spherical regions by shell tally.

Dedicated Monte Carlo simulations were performed by a subroutine adapted from the FLUKA code [2, 3]. In-water EDK were evaluated at different photon energies and some typical \(\gamma\)-emitters radiopharmaceuticals; whereas DPK were obtained for both \(\alpha\)- and \(\beta\)- emitters. Additionally, EDK and DPK were calculated for several biological tissues. Obtained results agree with energy loss from stopping power calculated by Bethe-Barkas-Bloch theory in the continuous slowing down approximation.

[1] W. Snyder et al. MIRD Pamphlet Number 12 Society of Nuclear Medicine, (1977)

\textsuperscript{*}This work was supported in part by project CONICET-PIP 11420090100398 and CONICET PosDoc fellowship
\textsuperscript{†}Present address: Universidad Nacional de Córdoba - Medina Allende esquina Haya de la Torre Ciudad Universitaria, Córdoba, Argentina. Email: valente@famaf.unc.edu.ar
Energy deposition in biological tissues by $^7\text{Li}$ and $^4\text{He}$ due to neutron capture calculated with the FLUKA code

S. Triviño\textsuperscript{1,2}, D. Graña\textsuperscript{1,3}, and M. Valente\textsuperscript{1,4}\textsuperscript{†}

\textsuperscript{1} Facultad de Matemática, Astronomía y Física - Universidad Nacional de Córdoba, Córdoba, Argentina
\textsuperscript{2} Reactor Nuclear RA-0 UNC-CNEA, Córdoba, Argentina
\textsuperscript{3} Instituto de Astronomía Teórica y Experimental, Observatorio Astronómico Córdoba CONICET-UNC, Córdoba, Argentina and
\textsuperscript{4} Instituto de Física Enrique Gaviola CONICET, Córdoba, Argentina

Boron Neutron Capture Therapy (BNCT) is a promising cancer therapy, currently being investigated and optimized, relying on the high thermal neutron capture cross section of the $^{10}\text{B}$ nuclide, which undergoes the reaction $^{10}\text{B}(n,\alpha)^7\text{Li}$ [$Q = 2.79\text{MeV} \sigma = 3837 \cdot 10^{-24} \text{cm}^2$]. $Q$ is mostly converted into kinetic energy shared between the reaction products $^7\text{Li}$ and $\alpha$ particles releasing energy in tissue in a range around $10\mu\text{m}$, approximately typical cell dimensions. Thereby, converting BNCT into a therapy capable of quite selectively targeting cancer at a cellular level. Neutrons are themselves not directly ionizing particles and the mechanisms through which energy is lost and further release in a medium are very complex. Different types of secondary radiation carry out specific \textit{Linear Energy Transfer - LET} and \textit{Radiobiological Effectiveness - RBE} thereby being necessary to separate dose components. Relative contributions to the total dose arising from secondary components are dependent on neutron energy spectrum, beam geometry as well as irradiated material, its size and dimensions.

Quite uniform absorbed dose spatial distribution within the whole volume of the treated organ constitutes the main goal requiring accurately evaluations of both therapeutic dose and deposition in healthy tissues. However, dose components, like photons and protons generated in marginal reactions have to be accounted therefore affecting and distorting the desired therapeutic dose distribution.

The present work presents a study aimed to characterize energy deposition due to $^7\text{Li}$ and the $\alpha$ as well as corresponding pathlengths through different biological tissues. Simplified expressions for energy loss are described by the Bethe theory thus energy deposition and particle range are compared with theoretical models of the FLUKA Monte Carlo code \cite{1,2} by subroutines adapted at the \textit{Laboratorio de Investigaciones e Instrumentación en Física Aplicada a la Medicina e Imágenes por Rayos X - LIIFAMIR\textsuperscript{®}}.


\textsuperscript{‡} This work was supported in part by projects CONICET-PIP 11420090100398 and SeCyT-UNC ISIDORA I

\textsuperscript{†} Present address: \textit{Universidad Nacional de Córdoba - Medina Allende esquina Haya de la Torre Ciudad Universitaria, Córdoba, Argentina. Email: valente@famaf.unc.edu.ar

47
Quantum Dosimetry and Directional Visualization of Space Radiation with Miniaturized Timepix Payloads Onboard the International Space Station (ISS) and ESA Proba-V Satellite*

C. Granja1,‡, Z. Vykydal1, D. Turecek1, S. Polansky1, S. Pospisil1, J. Jakubek1, V. Kraus1, M. Holík1, A. Owens2, L. Pinsky3, Z. Kozáček4

1 Institute of Experimental and Applied Physics (IEAP), Czech Technical University (CTU), Prague, Czech Republic
2 European Space Research & Technology Centre (ESTEC), European Space Agency (ESA), Noordwijk, The Netherlands
3 University of Houston, Houston, Texas, USA
4 Czech Space Research Center (CSRC), Brno, Czech Republic

Highly integrated light weight payloads based on the semiconductor pixel detector Timepix deployed onboard the ISS and in open space in a ESA satellite provide high sensitivity dosimetry, monitoring and directional visualization of the charged particle field (Figure 1). Description and first results will be presented.

Fig. 1. Highly integrated pixel detector Timepix in the LITE architecture (a) plugged into a NASA laptop (b) inside the ISS. Earth mappings of particle flux above the northern (c) and southern (d) hemispheres showing the region over Europe and northern Africa (c) and South America with the Earth radiation belt South Atlantic Anomaly (d).

* Research carried out in frame of the Medipix Collaboration. Work funded by Grant 641-120004M by ESA-ESTEC.
‡ Corresponding author: carlos.granja@utef.cvut.cz

48
Beryllium Target for Accelerator - Based Boron Neutron Capture Therapy

M. Suarez Anzorena¹, L. Gagetti¹,²,³, M. F. del Grosso¹,³ and A.J. Kreiner¹,²,³

¹ CNEA, Gerencia de Investigación y Aplicaciones (Buenos Aires, Argentina)
² UNSAM, Escuela de Ciencia y Tecnología (Prov. De Buenos Aires, Argentina)
³ CONICET (Buenos Aires, Argentina)

This work is part of a project for developing Accelerator-Based Boron Neutron Capture Therapy (AB-BNCT) for which the generation of neutrons through nuclear reactions like \(^9\text{Be}(d,n)^{10}\text{B}\) is necessary [1]. In this paper first results of the design and development of such neutron production targets are presented.

For this purpose, the neutron production target has to be able to withstand the mechanical and thermal stresses produced by intense beams of deuterons (of 1.4 MeV with a total current of about 30mA). In particular, the target should be able to dissipate an energy density of up to 1 kW/cm\(^2\) and preserve its physical and mechanical properties for a sufficient length of time under irradiation conditions and hydrogen damage. The target is proposed to consist of a thin Be deposit (neutron producing material) on a thin W or Mo layer to stop the beam and a Cu backing to help carry away the heat load.

To achieve the adhesion of the Be films on W, Mo and Cu substrates, a powder blasting technique was applied with quartz and alumina microspheres. On the other hand, Ag deposits were made on some of the substrates previously blasted to favor the chemical affinity between Beryllium and the substrate thus improving adhesion [2].

Be deposits were characterized by means of different techniques including Electron Microscopy (SEM) and XR Diffraction. Roughness and thickness measurements were also made.

To satisfy the power dissipation requirements for the neutron production target, a microchannel system model is proposed [3]. The simulation based on this model permits to determine the geometric parameters of the prototype complying with the requirements of a microchannel system. Results were compared with those in several publications [3,4,5] and discrepancies lower than 10% were found in all cases.

A prototype for model validation is designed here for which simulations of fluid and structural mechanics were carried out and discussed.

Application of the spatial efficiency $\epsilon(\vec{r})$ of a HpGe detector to determine the specific activity of radioactive material in cylindrical extended sources.*

P. Ortiz$^1$ and J. R. Morales$^1$

$^1$Departamento de Física, Facultad de Ciencias, Universidad de Chile, Santiago, Chile

In the present work, the intrinsic efficiency for a high-resolution spectroscopy gamma system as a function of the source-detector position, i.e. $\epsilon(\vec{r})$, and the specific activity for a radioactive homogeneous extended source in cylindrical geometry, for an energy of 661.65 keV ($^{137}$Cs), were determined.

Mathematical expressions for the intrinsic spatial efficiency and the specific activity of a volumetric cylindrical sample were obtained from basic concepts of solid angle and gamma attenuation [1].

In order to determine the intrinsic spatial efficiency, a $^{137}$Cs source of known activity was positioned at different source-detector position. This efficiency was used to establish the specific activity for different reference materials.

This methodology allows us to determine the specific activity of radioactive species present in volumetric samples, such as soil, water and construction materials samples [2-4], without the direct use of reference materials for quantification of radiation levels. The reference material was only used to validate the method.

The advantage of this method is that allows specific activity determination without the need of making matrix effect corrections (shape and size of the sample, sample density, self-attenuation and moisture), which are the principal error sources in this type of measurement.


*This work was supported in part by Center for Experimental Physics (CEFEX), University of Chile.
Procedures for the verification of the self-shielding of Cyclotron PETtrace

H. S. Videira¹, B. M. Pássaro², J. A. Gonzalez², J. S. Santos², M.I.C.C.Guimarães²
¹ CYCLOPET Radiofarmacos LTDA., Curitiba, Brazil.
² Centro de Medicina Nuclear do InRad-HCFM-Universidade de São Paulo, São Paulo, Brazil.

According to the literature, shielding can be defined as "a physical entity interposed between the ionizing radiation source and an object to be protected so that the level of radiation is reduced in the position where the object is" (Chilton et al., 1984).

Regarding shielding, cyclotrons can be self-shielded or not. The first type has a heavy armor built around it, while the bunker-type cyclotron must have additional structural shields. Those are required to reduce the radiation levels within safety limits, according to regulatory agencies.

Therefore, it is important that the shielding is properly designed and installed, since corrections or additions are generally expensive after the installation is complete. For the same reason, planning should also take into account possible future modifications. For instance, use of higher radiation energies, the increasing of the beam intensity, use of different types of accelerated particles, and an increase in work load (NCRP No. 144, 2005).

The objective of this study consists of verifying the effectiveness of shielding of borated water built for a self-shielded cyclotron accelerator PETtrace 860.

The self-shielding of PETtrace cyclotron is composed of eight tanks. Each tank was filled with a mixture of water with 3.5% of boron and locally coated with lead plates and bricks. In the end of the preparation of each mixture the indication of the solution pH was measured to ensure that it was a neutral pH.

Shielding verification was performed by using the radiometric survey provided with the condition of an irradiation of 40 uA of protons in a target of H2O18 (98% purity), with a neutron and gamma detector. Measurements were taken at different points around the shielding and through the radiometric survey around the installation. Due to sky shine phenomenon, verification was also performed with gamma and neutron monitors in the condition of simultaneous irradiation of two targets of H2O18 (98% purity) with 50 uA of protons on each of the targets for a 2-hours period.

Radiometric survey results in the surroundings of cyclotron's self-shielding with irradiation of H2O18 target with 40 uA for production of F18 for the two targets and in the condition of 50 uA, showed that radiation levels were below the limits set by the manufacturer. This certifies the shielding effectiveness for the proposed practice.

* This work was supported in part by: CYCLOPET Radiofarmacos LTDA; Street Ferdinando Dias Paredes, 367, Curitiba, Paraná, Brazil.
Adaptative segmentation for phase-contrast X-Ray imaging.

I. Domínguez, G. Herrera, A. Ramírez and R.E. Sanmiguel
Center for Research and Advanced Studies (CINVESTAV), Mexico City, México.

A set-up for X-Ray Imaging was mounted using a microsource X-ray generator, a Shad-O-Box detector and a X-ray Imaging Plate System. We implemented the in-line phase contrast technique in our laboratory. Phase contrast imaging is an emerging X-ray imaging technique capable of improving the conspicuity of fine detail in an image, including some detail which are not visible with conventional techniques [1][2]. The application of phase contrast imaging techniques to medical diagnostics (e.g. mammography) and the new segmentation adaptative algorithms based in entropy has opened new horizons for X-ray based imaging.

The ROI (Region Of Interest) extraction is an important step in de X-ray imaging processing, because it reduces the computational cost. The classical spatial filters used in image segmentation show different results when the dimension of an image changes, this implies modifying the algorithm and it takes longer.

The phase contrast technique shows better detail information [3]. In order to avoid different results on images with variable dimensions, we used the non–extensive systems concept [5] applied to images through Tsallis entropy that assumes subsets of probabilities for different regions [6] in the X-ray image. The ROI extraction based on Tsallis entropy and phase contrast X-ray images offers high quality region extraction and therefore more accurate diagnoses.

Dose Point Kernel calculation and modelling with nuclear medicine dosimetry purposes

I. Scarinci, M. Valente, and P. Pérez

1 Facultad de Matemática, Astronomía y Física - Universidad Nacional de Córdoba, Córdoba, Argentina
2 Instituto de Física Enrique Gaviola CONICET, Córdoba, Argentina
3 Agencia Nacional de Promoción Científica, Buenos Aires, Argentina
4 Secretaria de Ciencia y Tecnología - Universidad Nacional de Córdoba, Córdoba, Argentina

Monoclonal labeled antibodies administration with radioimmunotherapy purposes in nuclear medicine procedures is performed by depositing specific radioactivity concentrations on tumoral regions with the aim of hurt tumoral tissue. Kinetic characteristics of this antibodies produce a non-uniform activity distribution over the patient body and it is assumed uniformly to simplify quantification on internal dosimetry [1].

Treatment planification requires the estimation of the radionuclide’s delivered dose distribution that can be approximated by numeric or analytic methods [2]. Numerically, through Monte Carlo methods; while analitically, by an activity distribution convolution using Dose Point Kernels [3].

Monte Carlo method provides the calculation capacity and presicion that can not be achieved by analytic approximations. So they result in an important tool for the radiation transport study over soft tissues[4].

This work is focused on the utilization of the Monte Carlo method with the aim of performing Dose Point Kernels calculations over complex systems that involve biologic media in finite dimensions. This results will be used to perform an hybrid dose delivery calculation considering a real activity distribution as a non-homogeneous kernels distribution, in a patient-specific media distribution [5].

Currently, many kinds of radioactive sources are used in brachytherapy for cancer treatment. The $^{125}$I seed used in this work is the model OncoSeed 6711, produced by Oncura, which is ranked among the best options for treating prostate cancer. This source emits gamma photons with average energy of 28 keV and has a half-life of 59.4 days. After the implants, the natural movement of the organ can cause the seeds undergo slight displacements relative to the position originally planned, which can cause changes in dose distribution in the tumor volume. This work seeks to compare the dose distribution in a solid water phantom of two symmetrical, but different arrangements of four seeds. For this study, the phantom was machined to accommodate the seeds and TLD-100 LiF rod type dosimeters. The study, using TLD dosimeters, was conducted up to 4 cm of the settings. In addition, an EBT Gafchromic radiochomic film was positioned over the two configurations during a period of time enough for 1 Gy deposition on it, to observe possible changes in the shape of the isodose curves. The TLD results showed a difference up to 35.8% of the dose deposited in the center of the configurations and different doses were deposited at distances corresponding to 1 and 2 cm radius from the symmetrical seeds arrangements. After 3 cm radius, the dose discrepancy is no longer significant. Another important point is that despite the configurations are symmetrical, different dose values were deposited at symmetrical points. The isodose qualitative curves shown by the films showed a difference in the shape of that curves. Thus, the different positions of the seeds proved decisive in dose deposition and this fact should be taken into consideration in planning treatment.

The frequency analysis in Gamma-ray Compton Backscattering imaging

F. Cristancho† and D. Flechas
Universidad Nacional de Colombia, Bogotá, Colombia

The Gamma-ray Compton Backscattering technique [1] has proved to be an effective imaging technique. We have shown that with essentially no additional image processing it is possible to make a photography of a lead object immersed up to around 3 cm in sand [2]. However, if the scattering properties of matrix and object are too similar, as in the case shown in the top part of Fig. 1, no distinction between matrix and object is obtained. A frequency analysis, however, shown in the bottom part of Fig. 1, shows that even in the case of near equality, the three images contain properties that can be used to distinguish them. Experiments with different materials combinations, the corresponding Monte Carlo simulations and the application of a recently developed theoretical approximation [3] show that this feature can be used as an additional procedure to characterize physically the sample inspected by the Compton Camera.


FIG. 1: Top: Iron object buried in sand at the depths labeled. Visually there is no distinction between the three images. Bottom: The frequency analysis, shows, however distinctive histogram composition.

---

---

*This work was supported in part by Universidad Nacional de Colombia DIB 13440 and Colciencias 110152128824.
†E-mail address: lfcristanchom@unal.edu.co
Study of the buildup factor in monoelemental materials with γ-rays∗

C. Garzón† and F. Cristancho
Universidad Nacional de Colombia. Bogotá, Colombia.

When a monoenergetic beam of γ-rays of intensity $I_0$ passes through a sample of thickness $z$, the beam intensity decreases following the known exponential relation $I(z) = I_0 \exp(-\mu z)$. This expression, however, does not account for the photons that do not traverse the sample following a straight line but performing Single Compton Scattering (SS) or Multiple Compton Scattering (MS) before reaching the other side of the sample. The total γ-intensity at a point along the beam direction is then $I(z) = I_0 B(z) \exp(-\mu z)$, with $B(z)$ a factor known as buildup that includes these photons. Buildup is a very important quantity in radioprotection, in γ-rays applications in industry and in specific experimental setups in basic research. These two aspects has led us to undertake its systematic investigation [1,2]. We devise γ-ray transmission experiments with geometrically very simple arrays involving, for the sake predictability, only monoelemental metallic materials. Disagreement between experiment and theory may point to wrong electronic settings or wrong use of the theory. The first theoretical approximation is given by the application of the Klein-Nishina cross section, useful if only Single Scattering is important. The comparisons experiment-theory may show when Multiple Scattering becomes important and provide also a first approach to its theoretical description.

Experiments, their corresponding Monte Carlo simulations and theoretical analyses for the iron and aluminum cases are shown.


∗This work was supported in part by Universidad Nacioonal de Colombia DIB 13440 and Colciencias 110152128824.
†E-mail address: cmgarzonf@unal.edu.co
Optimization of the slow neutron detector array in the Thermal Neutron Backscattering Technique

J. Gómez-Muñoz, A. Cruz, and F. Cristancho
Universidad Nacional de Colombia, Bogotá D.C., Colombia and Centro Internacional de Física, Bogotá D.C., Colombia

The Thermal Neutron Backscattering Technique (TNBT) is used to locate buried hydrogen-rich objects. It consists of a fast neutron source and an array of $^3$He neutron detectors. TNBT has been used in controlled conditions with arrays comprising more than two detectors, in different types of soil and varied soil water content [1,2]. The use of TNBT in field conditions requires the miniaturization of electronic modules and experimental setup. The geometrical location of the detectors is important for the optimal technique development. Experiments and Geant4 simulations are performed to study different possibilities of the array configuration, number of detectors, dependence with different soils and the best performance in data analysis.

Available online: http://www.gfnun.unal.edu.co/prodGrupo/AngelC_TM.pdf
Periglacial shallow lakes offer information about climate change? Preliminary results, King George Island*

H. Barros1,4, M. Bezada2, D. Palacios1, A. Ojeda3 and S. Hurtado4

1 Universidad Simón Bolívar, Laboratorio de Física Nuclear, Caracas-Venezuela
2 Universidad Pedagógica Experimental Libertador, Dpto. Cs. de la Tierra, Caracas-Venezuela
3 Universidad Central de Venezuela, I. Zoología y Ecología Tropical, Caracas-Venezuela
4 Universidad de Sevilla, CITIUS, Servicio de Radioisótopos, Sevilla-España.

South Shetland Islands (northern Antarctic Peninsula) represent one of the world’s areas most affected by the retreat of glaciers due to global warming. As pointed by Ingólfsson [1], during the last 100 years the climatic development in the western Antarctic Peninsula region has moved from a relatively cold regime to an increasingly warm regime. A large number of evidences indicate that melt water and sediment transport have increased during the past 50 years. The King George Island (KGI) ice cap, its high sensitivity to climate changes, thermal regime, ablation rates, distribution, etc. and its relation with the relative sea level, have been deeply studied and this behavior is generally extensive to the South Shetland Islands ice caps [2]. However, there are not many recent dating studies in this area. Radiometric dating is the main way to quantify (retrospectively) the rates of various geo-hydro-environmental processes of interest and further work is necessary to constrain timescales of these processes affected by recent climate changes. The few available dating studies of lacustrine sediments are restricted to lakes of sufficient size and depth [3, 4, 5], which are not widespread and have a very uneven spatial distribution. On the other hand, there are many small shallow periglacial lagoons having a better spatial distribution, especially with respect to the fronts of receding glaciers. These lagoons are typically discarded for recent dating studies, due to a number of technical reasons. In this paper, for the first time, we present the preliminary results of a recent radiometric dating (210Pb and 137Cs) from a periglacial shallow lagoon on Fildes Peninsula (KGI) and discuss the results in the context of the local geology and climatic conditions during the last century. The lagoon is located near the Collins Glacier retreat border and the results indicates that besides the upper sediment layers may be frozen during winter time, the stratigraphic information is still preserved and temporal information on the sedimentation process can be extracted.


* We acknowledge the partial support of this work by: The IAEA TC Projects VEN/8/020 and VEN/7/007 and the Venezuelan Antarctic Program.