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THE 3rd NORDIC MEETING ON HIGH ENERGY REACTIONS IN NUCLEI

GEILO SPORTELL, Geilo, Norway

January 8 - 12, 1979

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Organizing Committee:	A M Green, University of Helsinki
	S Kullander, The Gustaf Werner Institute, University of Uppsala
Advisory Committee:	T E O Ericson, E Nyman, I Otterlund, E Pietarinen, H Pilkuhn, A Reitan and E Uggerhöj
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Preface

The Third Nordic Meeting on High Energy Reactions in Nuclei was held at Geilo Sportell, Geilo, Norway, January 8-12 1979. The meeting was the third in a series of meetings initiated in 1975 and continued in 1977. The main topic of these meetings is the hadronic structure of nuclei and its interaction with radiation produced at accelerators with energies above what is typically used in low-energy nuclear physics. The method used, instrumental as well as theoretical, resemble what is used in elementary particle physics, whilst the main aim of the research is to obtain more information about atomic nuclei.

The meeting was sponsored by NORDITA and by Nordisk Samarbeidskomitê for Acceleratorbasert Forskning. The talks were organized in five morning sessions each of three hours, five afternoon sessions each of two hours, and three evening lectures. In the evening lectures topics of a more general character were discussed.

A major emphasis was placed on the NN and $\overline{N}N$ interaction in bound and unbound systems. Four of the ten sessions were devoted to this subject. Two sessions contained lectures and seminars on "Isobars in nuclei", two were devoted to hadron-nucleus reactions, one to high-energy heavy-ion reactions and one to new developments of experimental tools. This latter session had two talks, one about channeling with GeV particles and the other about the planned low-energy antiproton facility LEAR at CERN. Talks of more general character were "The experimental programme at the CERN SC", "Accelerator produced nuclear fuel?" and "The upsilons, a new family of quark-antiquark bound state".

During the conference discussions on the relevance of these conferences in Nordic physics were held with the participants and with a group of past organizers and the advisory committee. There are Nordic conferences in Nuclear Physics every second year and in Elementary Particle Physics also every second year. There was however a unanimous support for the presend kind of conference to continue. Firstly the Elementary Particle Physics conferences nowadays contain mostly quark and lepton physics and secondly the Nuclear Physics conferences concentrate on the collective aspects and the many body problems of the nucleus. The present conferences, intermediate in object and method, are more topical than the others and also attract comparatively more scientists from the international community. They are thus motivated internationally being at the same time a meeting place for Nordic physicists in the field.

A suggestion from the nuclear physicists that one or two informative sessions should be held on Nuclear Physics or Elementary Particle Physics with the aim of increasing the contacts between Nordic physicists was favourably received. In conclusion it was thus felt that these conferences should continue and the next conference was proposed to be in January 1981. New organizers, G. Fäldt, Stockholm, and I. Otterlund, Lund, were also appointed.

This collection of abstracts has been provided by the authers, who have not had the opportunity to read the final versions.

The smooth running of the conference would not have been possible without the efficient administrative help of Mrs Birgitta Olsson. We want to thank her as well as the sponsors.

Anthony M Green　　　　Sven Kullander

Organizers

PROGRAMME

Hours:	Morning Sessions	08.30-11.30
	Afternoon	16.00-18.00
	Evening	20.00-21.00

Monday

Morning	Chairman: A.M. Green
D. Bugg	NN elastic scattering up to 800 MeV/I
G. Tibell	The experimental programme at the CERN SC
W. Grein	Dispersion analysis of NN toward scattering amplitudes
Afternoon	Chairman: S. Kullander
H.J. Weber	Correlations at medium range and isobar configurations
H. Arenhövel	Virtual isobars in nuclei and electromagnetic effects
K. Holinde	The effect of Δ-isobars in the two-nucleon problem

Tuesday

Morning	Chairman: P. Radvanyi
H.J. Weber	N^* spectator experiments
A. Hallgren	Isobar knock-out from helium with 5 GeV pions
G. Fäldt	Interpretation of N^* knock-out reactions
Afternoon	Chairman: L. Kok
R. Vinh Mau	The nucleon-nucleon potential
J.M. Richard	Some problems in the nuclear approach of baryonium
D. Bugg	NN elastic scattering up to 800 MeV/II
Evening	
T.E.O. Ericson	Accelerator produced nuclear fuel?

Wednesday

Morning	Chairman: H. Verheul
K. Kilian	Past and future experiments with antiprotons
F. Myhrer	Short range nuclear forces and the quark model
K. Fransson	Further exploration of the strongly bound states of the $\bar{p}p$ system
Afternoon	Chairman: J. Thirion
I. Otterlund	Review of high-energy heavy-ion reactions
A. Oscarsson	Properties of participants and spectators in non-peripheral ^{56}Fe induced reactions at 1.7 A GeV
L. Bergström	Some models for particle production in very high energy hadron nucleus collisions
Evening	
R. Vinh Mau	The nucleon-nucleon potential

Thursday

Morning	Chairman: G. Bruge
B. Tatischeff	The experimental situation of the $A(p,\pi^+)B$ reaction
M. Dillig	Survey on the theory of exclusive stripping processes on nuclei - in particular for the (p,π) reaction - at medium energies
H. Pilkuhn	How accurately can one determine neutron distributions from pion-nucleus scattering
Afternoon	Chairman: P. Barnes
H. Högaasen	The sixquark S-wave state and its relevance for the NN system
K. Klingenbeck	A^* resonances in π-nucleus scattering
Evening	
H. Schroeder	The Upsilons, a new family of qark-antiquark bound states

Friday

Morning	Chairman: H. Nielsen
M. Ericson	Nuclear critical opalescence
K. Shimitzu	Rescattering effects in bound pion absorption
M. Uhrmacher	New results in the (K^-,π^-) strangeness exchange reaction on nuclei
Afternoon	Chairman: B. Sundqvist
K. Kilian	Phase space cooling as a mean to obtain high intensity $\bar{p}$ beams
E. Uggerhöj H. Nielsen	Channeling with GeV particles

NN elastic scattering up to 800 MeV.

D. Bugg
Queen Mary College, Physics Department, London, England

Abstracts:

I

New data on pp and np elastic scattering from TRIUMF, SIN, LAMPF and Argonne are reviewed, and experiments at TRIUMF are described in detail. The pp data have refined the accuracy of pp phase shifts, which are now unique at 25, 50, 95, 150, 210, 325, 380, 625, 515 and 580 MeV; they are in excellent agreement with theoretical models, for example that of Vinh Mau et al. A large step forward has been the measurement of np Wolfenstein parameters D_t, R_t and A_t at TRIUMF. These data allow, for the first time, unique and accurate determination of I = 0 phase shifts at 210, 325, 625 and 515 MeV. Resulting values of $\bar{\varepsilon}_1$ are in good agreement with the Hamada-Johnston potential and values of $\bar{\varepsilon}_3$ agree well with the Paris potential. However, central, tensor and spin-orbit combinations of D waves (and G waves) deviate systematically by large amounts from published predictions of the Paris group. A reshuffle of coupling constants appears to be needed.

II

Values of $\Delta\sigma_L$ for pp scattering measured at Argonne cause problems in phase shift analyses between 425 and 580 MeV. Elastic data determine well the real parts of the phase shifts; the elastic component of $\Delta\sigma_L$ shows no structure in this energy range. If the structure in $\Delta\sigma_L$ is to be accomodated in the inelastic cross section, elasticity parameters y are required which are in gross disagreement with predictions of Green and Sainio, based on NN → NΔ via π and ρ exchange. This is worrying, since that model gives a good fit to $d\sigma/d\Omega$ and P in $pp \to d\pi^+$, which is 50 % of the inelastic cross section at these energies. To fit $\Delta\sigma_L$ below 580 MeV $\geq$ 70 % of the inelasticity must be in $^1D_2$ and very little in $^3P_1$ or $^3F_3$. However, it then becomes impossible to fit $P(pp \to d\pi^+)$. Further evidence of the difficulty with $\Delta\sigma_L$ is that values of Re F_3, calculated from the forward dis-

persion relation, are in serious disagreement with the phase shift analysis at 325, 380 and 425 MeV. Recent Argonne data on $\Delta\sigma_L$(dp), indicating strong singlet resonance within the elastic range, are also difficult to accomodate.

The Experimental Programme at the CERN SC

G. Tibell
EP Division, CERN, CH-1211 Genève 23*), Switzerland

Abstract:

The CERN Synchro-cyclotron Programme has been running during 1978 with an average of 15 experiments active (in preparation or taking data). An important addition to the beam facilities (primary 600 MeV protons or secondary pion and muon beams) consists of a 910 MeV ^{3}He-beam which can be extracted from the accelerator and used externally. During 1979 another addition is expected to become operational: A beam of ^{12}C ions with an energy of 86 MeV per nucleon.

This report will give some examples of the results obtained with the different beams in the course of last year. The emphasis will be put on some experiments performed in muon and pion beams in the so called neutron room, one of the experimental areas outside the cyclotron hall.

*) On leave from The Gustaf Werner Institute, University of Uppsala, Uppsala, Sweden

Dispersion analysis of NN forward scattering amplitudes.

W. Grein
University of Karlsruhe, Germany

Abstract:

We present a complete analysis of all non-vanishing helicity amplitudes for pp and pn forward scattering based on dispersion relations. The experimental input - total cross section data (in pure spin states and spin averaged) and phase shift analyses - are briefly reviewed. We discuss the evidence for dibaryon resonances following from our analysis. The physical cut discontinuity is studied in detail by the discrepancy function method.

We calculate the two-pion exchange part of the discontinuity from $\pi\pi \rightarrow N\bar{N}$ partial wave amplitudes, check their consistency with NN scattering data and determine a variety of meson-NN coupling constants.

N^* spectator experiments

H.J. Weber
University of Virginia, Dept of Physics, Virginia, U.S.A.

Abstracts:

1. Correlations at medium range and isobar configurations.

Several reactions such as (e,e'p),(p,2p) ,(p,d) and deuteron disintegration processes are reviewed at medium energies and momentum transfers. The systematic break-down of the low-energy mechanisms at a critical nucleon spectator momentum between the Fermi momentum p_F and $2p_F$ is related to the qualitative change of the nucleon momentum distribution in nuclei from a purely single-particle character (Slater determinant) to a dominant nucleon pair correlation content. The interaction of a projectile with a nucleon pair is described in terms of medium and short range correlations and initial final-state interactions (plane wave distortions).

The origin of these medium range correlations in the two-pion exchange part of the nucleon-nucleon interaction is reviewed, first using the dispersion theoretical method and then the transition potential approach. The resulting isobar configurations which represent an important part of these correlations are discussed and contrasted with the Jastrow correlation method for generating momentum components at medium range in such observables as charge form factors and pionic deuteron disintegration processes.

2. N^*-spectator experiments.

Several $\Delta(1232)$ spectator experiments are briefly reviewed, in particular M. Goldhaber's $\pi d \to \pi\Delta^{++}\Delta^-$ at 12 GeV/c, the inclusive DESY experiment $\gamma d \to \Delta^{++}x$ at 5.5 GeV photonenergy and the Virginia-Saclay-SIn collaboration on $\pi^- d \to p\Delta^-$ at 1.1 GeV/c. Different methods to separate the N^*-spectator signal from the background are discussed, in particular the crucial cut-off of nucleon spectators at low momentum.

In the remainder of the talk the main emphasis is on presenting the recent CERN N^*-knockout experiment from ^4He, $\pi^{-4}He \to \pi^{-3}H\,x$ at 5 GeV/c.

The theoretical and experimental consequences of measuring a recoil triton in the momentum range $.3 < p_R < .7$ GeV/c in the final state are discussed in detail. Wave functions for the N^*-^3H configuration are constructed. In a 2N-exchange model for the transition potential, the N^*-^3H momentum density is related to that of the N^*N configuration and overlap integrals recursively. The overlap integrals shift the maximum of the N^*N distributions at $\sim$ 750 MeV/c down to 300 MeV/c. The same happens in a OBE model where the N^*N transition potential is multiplied by the elastic ^3H form factor. As a result, N^*'s in high (πN) partial waves have negligible N^*-^3H probability, whereas (πN) S-wave resonances at 1535, 1700 MeV/c^2 have $\sim$.2 % per nucleon each. Theoretical uncertainties are discussed pertaining to double counting in high-momentum components of effective nucleonic wave function, retardation effects and the inclusion of the N^* mass distribution.

Virtual isobars in nuclei and electromagnetic effects.

H. Arenhövel
University of Mainz, Mainz, Germany

Abstract:

Electron scattering provides a very useful tool to investigate the electromagnetic structure of nuclei and to study interaction effects such as meson exchange currents (MEC) and nuclear isobar configurations (IC). These interaction effects can be most reliably calculated for the two nucleon system. Therefore the electro-disintegration of deuterium has been investigated. In the one-photon-exchange the coincidence cross section d(e,e'p)n is determined by four structure functions which reduce to two form factors (longitudinal and transverse) for d(e,e'). The structure functions and form factors contain the information on the electromagnetic structure and are calculated by making a multiple expansion of the transition current matrix element. The final state interaction is properly taken into account by using various realistic NN-potentials. The IC are calculated in the impulse approximation and for MEC we have included contributions from π, ρ and ω exchange. No relativistic corrections are included. In general the longitudinal structure functions and form factors are little affected by MEC and IC. However, the transverse functions and the form factor are sensitive to interaction effects. Near the quasi-elastic ridge the effects are small ($\sim$ 3 %). Near the threshold region large contributions from MEC for increasing momentum transfer are observed. They can amount up to 300 % since the dominating M1 form factor has a minimum. On the other side of the quasielastic ridge for increasing excitation energy but lower momentum transfer the IC become important, in particular for the transverse structure functions. Existing experimental data on d(e,e') especially near threshold can be well described only if the dominating contributions from MEC are added. This constitutes the up to now most convincing evidence for MEC and to a lesser extent for IC.

The effect of Δ-isobars in the two-nucleon problem.

K. Holinde and R. Machleidt
Institut für Theoretische Kernphysik der Universität Bonn,
West Germany

Abstract:

The fourth-order iterative diagrams involving NΔ- and ΔΔ-intermediate states and including π^- as well as ρ-exchange are calculated in momentum space without any approximation. It is shown that the use of the static limit in the propagators overestimates such contributions by roughly a factor of 3. On the other hand, the static limit at the vertices leaves the contribution arising from NΔ-states nearly unaltered, but reduces the corresponding ΔΔ-contribution by roughly a factor of 3. Thus the consistent use of the static limit (i.e. in the propagator as well as in the vertices) overestimates the contribution from NΔ-intermediate states by nearly a factor of 3, but is a good approximation for the contribution of ΔΔ-intermediate states. This is the reason why our result for the ΔΔ-probability in the deuteron, $P_{\Delta\Delta} \simeq 0.5$ %, is in reasonable agreement with former results using the static limit consistently.

NN-scattering phase shifts and deuteron isobar wave functions are calculated using these diagrams together with a suitably modified one-boson-exchange potential, likewise derived from non-covariant perturbation theory. It turns out that, in spite of having more or less the same $P_{\Delta\Delta}$ as current static models, the corresponding isobar wave functions have much more high-momentum components, which can be traced back to retardation effects in our (relativistic) propagators.

Isobar knock-out from helium with 5 GeV/c pions

Allan Hallgren
The Gustaf Werner Institute, Uppsala Sweden

Abstract:

In order to obtain information on the possible existence of isobar-triton states in helium, the reactions $\pi p \rightarrow \pi x$ and $\pi^4He \rightarrow \pi^3Hx$ have been studied using 5 GeV/c pions. The triton momentum was in the range 0.25-0.60 GeV/c and the mass of x from 0.9 to 1.8 GeV/c^2.

The theoretical analysis includes multiple scattering and final state interactions. Different proton-triton wave functions are tested on the experimental distributions. It is found that a modified Hulthên type wave function gives the best fit. With this wave function a considerably better agreement is obtained for masses above 1.32 GeV/c^2 if 0.5 % of the isobar-triton configuration is added to the conventional proton-triton single-particle wave function.

Interpretation of N* knock-out reactions.

G. Fäldt
University of Stockholm, Stockholm, Sweden

Abstract:
The theoretical description of the two reactions $\pi^-+{}^4He \rightarrow \pi^-+{}^3H+p$ and $\pi^-+{}^4He \rightarrow {}^3H+x$ (anything) are discussed. The aim of the experimental study was to investigate the existence of pre-exising N* components in the ${}^4He$ wave function.

For the interpretation of tha quasi-elastic eaction a proton-triton cluster wave function is used. In the Glauber theory the amplitude has two single scattering terms and two double scattering terms. This model overestimates the experimental cross section by a factor 10-20. We show that this inadequacy is due to the assumption of plane wave motion for the relative proton-triton system in the final sate. An improved description can be obtained by using the relevant scattering wave function. It is derived from a separable S-wave proton-triton interaction which in turn is derived from the bound state wave function. When this improvement is done the theoretical result overestimates the experimental cross section by a factor of two. However, it is very important that we are able to conclude that the bound state wave function must necessarily be positive.

The interpretation of the N* production is more complicated. Here we have three independent contributions: i) production by the proton, ii) production by the triton and iii) knock-out of pre-existing N*. The production by the proton is described by diagrams simply related to those for quasi-elastic scattering. The diagrams where the produced N* undergoes a subsequent collision on the triton are especially important when the fast pion and triton are scattered to different sides. The production by the triton is particularly important for forward scattering. This gives a kind of faked N* contribution.
At last we have the knock-out of pre-existing N*. They are assumed to amount to about 1 % of the initial helium wave function. In the N* experiment their contribution can only be seen when the fast pion and triton are scattered to the same direction. Then they constitute a major fraction of the theoretical cross section. Agreement with experiment, however, requires that pre-existing N*:s are present also

in the low mass region. With this interpretation the total fraction of pre-existing N^* in the observed mass region is 1-2%.

The nucleon-nucleon potential

R. Vinh Mau
Laboratoire de Physique Théorique des Particules Elémentaires
et Institut de Physique Nucléaire, Paris, France

Abstract:

The survey is given of recent progress in the construction of a realistic nucleon-nucleon potential in which the degrees of freedom of mesons and isobars are taken into account as completely and as carefully as possible. Applications to various nuclear physics calculations (e.g. nuclear matter, three body systems etc.) are also reported.

Some problems in the nuclear approach of baryonium.

Jean-Marc Richard, Laboratoire de Physique Théorique des Particules Elémentaires et Institut de Physique Nucléaire, Paris, France

Abstract:

$\bar{N}N$ spectrum in potential models is shown to exhibit some typical level ordering. In particular, there is a strong isospin dependence which contrasts with the almost isospin degenerate spectra one gets in the quark models of baryonium.

The problem of elastic and inelastic widths of $\bar{N}N$ states is also discussed. It is shown in particular that the potential model cannot reproduce a narrow resonance at m = 1932 MeV with $J^{PC} = 2^{++}$ and I = 1. There is however the possibility of narrow structures close to the threshold.

Accelerator produced nuclear fuel?

T.E.O. Ericson
CERN, Genêva, Switzerland

Abstract:

A high energy proton produces a large number of protons and much heat in a thick target. As an example a 1 GeV proton in a thick ^{218}U target produces 60 neutrons and 4 GeV of heat. The number of neutrons and the heat increases in proportion to the power delivered by the accelerator (whether by current or energy increase). If the neutrons are allowed to transform ^{232}Th or ^{238}U into fissile nuclei 170 MeV can be gained from each neutron. A 1 GeV proton can then be made to give 14 GeV; with a 50 % efficient accelerator and a 1/3 conversion factor one can then obtain about 2.5 GeV electric power from each proton. While this is an energyproducing cycle the efficiency is only about 15-20 % of the circulating power which is rather low. The role of the process must therefore be as part of an energy system.

An interesting possibility is the following. The isotope ^{233}U has $\eta = 2.24$ in the thermal region, which means that it is marginally possible to use it for a thermal breed reactor. It lacks the drawbacks of ^{239}Pu and the safety record of thermal reactors is impressive. In reality it is more reasonable to consider it in thermal convector reactors with a breed factor of 0.90 or above. This means that for 1 ton material burned ($1000MW_{electric/year}$) the fuel is reduced by 100 kg which must be furnished externally. Industrially designed reactors of this type exist. An accelerator producing 100 kg ^{233}U a year must furnish 400 moles of neutrons/year, which means an average nominal power of 30 MW, i.e. for example 30 mA at 1 GeV. Industrially interesting accelerators must have at least this power or even a magnitude larger. The target region of such an accelerator will liberate several 100 $MW_{thermal}$ including the burning of some of the produced fissile material. It will therefore ressemble an undercritical fast reactor assembly in technology, complexity and cost. The fissile material can be produced in a blanket surrounding this system; it may be possible to directly produce reactor usable rods by irradiating with % content of ^{233}U or ^{233}Pu which would permit bypassing chemical processing altogether.

The cost of fissile material from such a system using commercial calculations (10 % interest + 10 % amortization) will be a few hundred $/g fissile. This cost is dominated by the target system, which is energy producing; cost can then be calculated simply from the power used by the accelerator. Even extremely liberally calculated costs for the accelerator proper will not dominate costs. The cost for fissile material produced in this way is few times higher than present commercial prices. However, since nuclear power costs are dominated by capital costs rather than by fuel costs, the use of accelerator produced fuel both in the reactor invectory as well as for supplementing a converter would only increase nuclear electricity costs by less than 30 %.

Accelerator breeding is a politically interesting alternative for countries without national uranium supplies and wanting to avoid plutonium economy. A 300 mA 1 GeV accelerator would be able to cover the entire nuclear fuel needs of Sweden. The drawback of the accelerator system is the coupling of two advanced (although reliable) technical systems. It also necessitates the developments of highly reliable accelerators of more than 30 times higher intensity than now in use.

Past and future experiments with antiprotons.

K. Kilian
CERN, Genève, Switzerland

The interest in $\bar{p}$ physics has focused on the problem of baryonium states. These objects appear to be preferentially coupled to $\bar{B}B$ channels either in the incoming or outgoing channels. Probably the best evidence for a narrow baryonium state exists at 1.935 GeV ($\Gamma \sim 4$MeV) which is seen in different formation experiments. Other formation- as well as production experiments showed baryonium candidates up to a mass of 2.95 GeV. Recently in a $\bar{p}_{stop} + p \rightarrow M + \gamma$ experiment also baryonium below the $2\,m_p$ threshold may have been found. Very exciting models in the quark picture and in terms of nuclear physics potentials have been developed. Quantum numbers of baryonium states have to be unambiguosly determined in the coming experiments at CERN and BNL. There is a chance to improve the knowledge of the internal structure of hadrons.

Short range nuclear forces and the quark model.

F. Myhrer (with C. Carlsson and G. Brown)
Nordita, Copenhagen, Switzerland

Abstract:

Using the MIT quark bag we try to understand the short range forces between nucleons. Our considerations are based on the extensive calculations of a deformed six quark bag by De Tar. We find that the repulsion between two clusters of three quarks each can be understood by colour Coulomb exchange forces. We argue about a possible connection between this force and the one-boson-exchange forces which act at long internucleon distances.

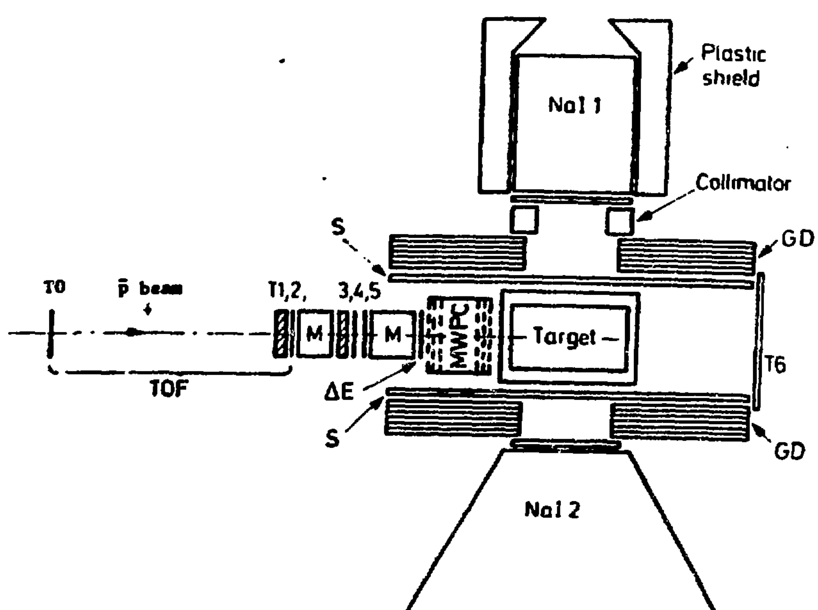
Further exploration of the strongly bound states of the $\bar{p}p$ system.

L. Adiles, G. Backenstoss, I. Bergström, P. Blüme, K. Fransson,
R. Guigas, M. Izycki, A. Kerek, A. Kiriakidis, H. Koch, M. Meyer,
P. Pavlopoulos, H. Poth, B. Richter, M. Suffert, L. Tauscher,
H. Ullrich, K. Zioutas.
Research Institute of Physics, Stockholm, Sweden

Abstract:

In a test experiment at CERN in 1976 we were able to find strong evidence for three narrow states in the $\bar{p}p$ system[1,2], several hundred MeV below the threshold. Indications of some broader structures were also present. As the experiments were performed only in a parasitic mode, the experimental set-up was not optimized for this experiment, and the beam time available was too short to achieve high confidence levels. Furthermore, owing to the high background, the γ-energy range was limited to energies above 100 MeV. To further explore these states the steps now to be taken are as follows:

a) Confirmation of the results in the $\bar{p}p$ system. Search for broadened structures in the γ-ray spectra. Extension of the γ-energy range below 100 MeV.



Scale 1:10

FIGURE 1

T0,.. T6:	Telescope counters
ΔE:	High resolution ΔE-counter
S:	Cylindrical scintillation counter, divided into 30 strips
GD:	Cylindrical γ-ray detector, divided into 30 sections
MWPC:	Multiwire proportional chambers
M:	Moderator
NaI 1:	12" × ⌀10"
NaI 2:	Detector consisting of 54 prismatic segments, each with its own PM tube (part of a "crystal ball")

b) Better measurements of the widths of the states.

c) Determination of the annihilation channels of the bound states.

d) Extension of the experiments to few-nucleon systems such as deuterium.

We are now back in the PS beam at CERN (proposal S 161) with an experimental set-up (see Fig. 1) designed to meet these requirements. Its geometrical configuration was optimized according to extensive Monte Carlo calculations of the interesting reactions, which allowed a complete simulation of the proposed experiments.

References

1. Pavlopoulos et al. Phys.Lett. 72B (1978) 415.
2. Pavlopoulos et al. 2nd int.Conf. on Nucleon-Nucleon Interaction. Vancouver, June 27-30, 1977.

Review of high energy heavy ion reactions.

I. Otterlund
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Abstract:

Recent development in the field of high energy heavy ion reactions is reveiwed. Starting at energies where the transition between low and high energy phenomena occurs, the talk will end at cosmic ray energies.

A rapid transition between low-energy deeply inelastic processes, and high-energy abrasion or fragmentation phenomena takes place already between 10-20 MeV/nucleon. This has been observed in studies of the isotopic field and momentum distributions produced in peripheral collisions of ^{16}O on heavy targets as a function of energy from 5 MeV/nucleon to 2.1 GeV/nucleon. Preliminary element production cross section for Be-Ar in ^{40}Ar + ^{232}Th reactions do not change significantly between 9.7 and 1800 MeV/nucleon.

High energy heavy ion accelerators provide a unique possibility to study exotic nuclei. To shift out the exotic species, a sophisticated particle identification scheme has been used at Berkeley to determine Z and N in a solid state counter telescope placed at the focal plane of a magnetic spectrometer. The isotopes ^{28}Ne and ^{35}Al have been observed for the first time.

The fireball model and the firestreak model will be discussed. The firestreak calculations fit the new proton energy data obtained in ^{20}Ne + U reactions at 250 MeV/nucleon and 400 MeV/nucleon by the Paskanger/Gutbrod group fairly well at 90^o and more backward angles. However, at forward angles it predicts too much yield at low energies. It has been suggested that the expansion of the compressed fireball has to be considered. This effect appears to be in the right direction to bring better agreement with the data. Intranuclear cascade calculations and two-fluid hydrodynamical calculations are in good agreement with the energy and angular distributions.

Pion multiplicities and pseudo-rapidity distributions in central heavy ion reactions at very high energies (~300 GeV/nucleon) will be discussed in the framework of a model which is an expansion of independent particle models for hadron-nucleus interactions. In this model the limited space time development of nuclear collisions is considered.

Properties of participants and spectators in nonperpheral ^{56}Fe induced reactions at 1.7 A GeV.

K.B. Bhalla, S. Hertzman, A. Oskarsson and I. Otterlund.
Dept of Cosmic and Subatomic Physics, University of Lund, Sweden.

Abstract:

We present the first results from an investigation of small impact parameter ^{56}Fe induced reactions in emulsion. Large multiplicity events for the CNO and AgBr target groups respectively, have been isolated and all emission angles were measured. We compare the experimental angular distributions with a participant-spectator model, based on the idea of clean geometrical cuts out of hard sphere nuclei. The participant (overlap region) is treated according to the concepts of the nuclear fireball model, while the spectators are assumed to decay the same way as spectators do in peripheral collisions, i.e. a simple fragmentation process, only reflecting the internal motion of the nucleons inside the nucleus.

The collisions ^{56}Fe-CNO are favourable when studying the spectator breakup since there is always a large projectile spectator left. We observe that the emission of particles from nonoverlapping parts of the interacting nuclei in collisions with a substantial amount of overlapping nuclear matter, can not be regarded the same way as the spectator breakup in perpheral collisions, neither in the angular distribution of the emitted particles nor in their mass distribution.

Some models for particle production in very high energy hadron-nucleus collisions.

Lars Bergström
Royal Institute of Technology, Dept of Theoretical Physics, Stocholm
Sweden

Abstract:

The field of high energy particle production on nuclei is rapidly growing in interest among particle physicists, since these processes may give unique information on the structure of nucleons and mesons. The significance of this for quark-parton models of hadrons is discussed. Also, connections with collective behaviour of struck nucleons are treated. In particular, features of the collective tube model (CTM) are discussed.

The experimental situation of the $A(p,\pi^+)B$ reaction.

Boris Tatischeff
Inst Physique Nucléaire, Orsay, France

Abstract:

This review talk summarizes the experimental situation occurring around different accelerators, compares the properties of the spectrometers used and reminds the experimental programs when they are known.

The discussion of the recent experimental results - often unpublished - is presented according to the analysis which has been done, going from phenomenology to microscopy,(the former models being in better agreement with various data). The often used discription with $M_{\pi NN}$ hamiltonian and DWBA suffers of several difficulties. The knowledge of the importance of the recoil term in the hamiltonian remains uncertain. The results of the analyzing powers are reminded and the need for a microscopic calculation for cross sections and analyzing powers for different energies and different targets is stressed.
The data available from (p,π^-) reactions are discussed, then a comparison between (p,π^+) and (d,p) reactions is presented and a suggestion to compare $(\vec{p},\pi^+)$ with $(\vec{d},p)$ reactions is emphasized. The plot of $d\sigma/dt$ versus t suggests different reaction mechanisms for forward and backward parts of the spectrum. Finally coherent pion production by mean of composite particles is shortly discussed.

Survey on the theory of exclusive stripping processes on nuclei - in particular for the (p,π) reaction - at medium energies.

M. Dillig
Institute for Theoretical Physics, University of Erlangen-Nürnberg
Erlangen, Germany

Abstract:

With a large amount of data obtained in the last two years on stripping processes with a two-body final state, i.e.

$$A(x,y)B$$

such as $(p,\pi^{\pm})$, (p,γ), (d,p) etc. at large momentum transfers (for recoil momenta of typically $Q_R \gtrsim 500$ MeV/c), it has become possible to test various theoretical models for the description of such processes.

The outcome of quite a variety of investigations may be summarized as follows:

- the data clearly point out that the cross section is in general dominated by the single rescattering contribution (in the multiple scattering expansion), yielding for (p,π^+) and (p,γ)

$$\frac{d\sigma}{d\Omega} \propto |< H(pN \to NN\pi(\gamma)) >|^2 \ \psi(Q_R/3)|^2$$

  where $|\psi(q)|^3$ represents schematically the three wave functions of the interacting nucleons (i.e. the projectile and a target nucleon),

- In contrast, the contribution from the direct one-particle stripping amplitude, which yields for the cross section

$$\frac{d\sigma}{d\Omega} \propto |< H_{\pi(\gamma)NN} >|^2 \ \psi(Q_R)|^2$$

- seems to be strongly suppressed for $Q_R \gtrsim 500$ MeV/c.

As a consequence, high momentum transfer stripping processes are in general a nice tool to study the reaction mechanism - which is strongly dominated by π and ρ exchange, combined with isobar $\Delta(1236)$ excitation - while information about high momentum components in the wave function of a bound nucleon - lacking presently a quantitative understanding of the rescattering

model - can only be extracted in particular kinematical situations, such as from the (p,γ) process at $Q_R \sim$ 300-500 MeV/c or from near threshold π-production in (p,π) with $T_p \lesssim$ 160 MeV.

For a more detailed understanding of medium energy stripping processes

- an extension of the conventional models towards a nonpertubative evaluation of the multiple scattering series and
- a consistent analysis of a wide class of data from different processes, though in kinematically overlapping regions

is needed. Such a kind of investigations, using either the coupled channel formation or the isobar doorway approach, are in progress.

How accurately can one determine neutron distributions from pion-nucleus scattering?

H. Pilkuhn, University of Karlsruhe, Germany

Abstract:

The large difference between $\pi^- n$ and $\pi^- p$ scattering in the Δ resonance region has been used to determine the distribution of the extra neutrons in ^{18}O in comparison with ^{16}O. A quantitative analysis requires knowledge of all isospin-breaking effects. In addition to the pure Coulomb amplitude and a possible Δ mass splitting, one must include graphs in which the Coulomb force plays the role of initial and final state distortions of the strong interactions. In phenomenological approaches to the scattering amplitude, this has been included as a WKB shift of the pion momentum at the nuclear site, with a corresponding energy shift (which plays a role because of the resonance structure). I wish to demonstrate from the Bethe-Salpeter-equation that the pion energy is practically not shifted. Instead, the pion is virtual when it reaches the nucleus. A treatment of pion-nucleus scattering which includes this property will be proposed.

The sixquark S-wave state and its relevance for the NN system

H. Högaasen, University of Oslo, Oslo, Norway

Abstract:

After an introduction to the nature of the colourdynamic forces that bind quarks together, the general properties of 6q s-wave states are deduced. We then propose a model of the deuteron where the quark fields are taken as elementary for small distances. The electromagnetic form factor at great momentum transfers, the ΔΔ space wave function and the spectator Δ production in exclusive reactions are all determined by the choice of one parameter.

A* resonances in π-nucleus scattering

K. Klingenbeck
Institute for theoretical physics, University of Erlangen, Germany

Abstract:

The excitation of N* resonances in the nucleus leads to a coupling between internal and external degrees of freedom of the A baryon system. As a consequence we obtain resonances of the whole A baryon system (A* resonances), which are characteristic for the many body system. The A* resonances, corresponding to the Δ excitation, are most easily excited in π nucleus scattering in the region of the elementary resonance. With this reaction mechanism we described elastic scattering for several nuclei (d, ^{4}He, ^{12}C, ^{16}O). We obtain a reasonable and systematic description of the experimental data. As a further test we have calculated inelastic scattering for the 2^+, 3^- and 1^+(15.11 MeV) excitation of ^{12}C.

Altogether this applications indicate that a complex nucleus has various isobaric resonances of different multipolarity in this energy range. The corresponding distribution of the multipole excitation strength has been studied for the above nuclei. Moreover we have found that each multipolarity is dominated by a few collective resonances, which carry almost all the (elastic) transition strength. This leads to simplified a transparent description of the A* reaction mechanism.

Ref. K. Klingenbeck et al., Phys. Rev. Lett. 41 (1978) 387.

The Upsilons, a new family of quark-antiquark bound states.

H. Schröder, DESY-F15, Hamburg, Germany

Abstract:

The experimental observation of two narrow states formed in e^+e^--annihilation around 10 GeV is described. Their properties are presented and the implications on the nature of strong interactions are discussed.

Nuclear critical opalescence

Magda Ericson, CERN, Genève

Abstract:

Nuclear matter when compressed undergoes a phase transition, called pion condensation. It is a magnetic transition where the nucleonic spins get partially aligned along a cerntain pattern. The critical density for this phase transition is not known precisely but it is believed to be well above the ordinary nuclear density.

This phase transition is a second order one and as such has precursor phenomena in the normal phase: namely the existence of a short-range order in the nucleonic spins which produces an enhancement of the virtual pion field around a critical momentum. It is the critical opalescence phenomenon analogous to the one observed for magnetic transitions.

Rescattering effect in a bound pion absorption.

K. Shimizu and A. Faessler, IKP, KFA Jülich, West Germany

Abstract:

The p-wave bound pion absorption leading to two nucleon emission in ^{16}O is studied in detail. The nucleon-nucleon correlations are treated by using the Brueckner theory for initial state and by solving the Lippmann-Schwinger equation for final state with the Reid soft core potential. First we investigate the effect of short range correlations on the single nucleon absorption term. The dominant correlations turn out to be tensor correlations (T=0). Hence the initial correlation is important for n-n emission while the final state correlation is important for n-p emission. Since the matrix elements of these terms are almost the same, we obtain the ratio of n-n to n-p emission R=W(nn)/W(np) $\sim$ 1 which is far below the experimental value $R_{exp} \geq 4$. In order to solve this discrepancy, we introduce the so called rescattering term, whose main terms are via Δ-resonance in the intermediate state. Again the main contributions are shown to come from a tensor part of NN-NΔ interaction (due to π and ρ exchange). Due to the mass difference between nucleon and Δ-isobar, we found that direct absorption and rescattering terms contribute coherently for W(nn) and hence W(nn) increases. As for W(np), they contribute destructively and so W(np) decreases. Consequently the ratio R is increased by including the rescattering terms. The numerical results are as follows: W(nn) = 1.5 [$10^{15}sec^{-1}$], W(np) = 0.37, R = 4.1. The total absorption rate is W = 1.87.

New results in the (K^-,π^-) strangeness exchange reaction on nuclei.

T. Ketel, K. Kilian and M. Uhrmacher
CERN, Geneva , Switzerland

Abstract:

In the strangeness exchange reaction (K^-,π^-) *on different nuclei* the most prominent transitions to hypernuclear states produced in recoil-less and quasifree Λ production have been identified. The analysis of the spectra shows that in the Λ nucleus interaction the spin orbit coupling is at least one order of magnitude smaller than for the nucleon-nucleus interaction. In the first approximation the Λ particle in a nucleus behaves like a "spinless" particle in a harmonic oscillator potential.

New results in the (K^-,π^-) strangeness exchange reaction on nuclei.

H. Catz, T.J. Ketel, K. Kilian and M. Uhrmacher
CERN, Geneva, Switzerland

Abstract:

In the strangeness exchange reaction on different nuclei the most prominent transitions to hypernuclear states produced in recoilless and quasifree Λ production have been identified. The analysis of the spectra shows that in the Λ-nucleus interaction the spin orbit force is in first order negligible. Spectra of hypernuclei with higher masses (around A=40) give a complete set of shells in the Λ-potential. These levels are about equidistant so that the Λ-particle in the nucleus behaves like a particle moving in a harmonic oscillator, not affected by any spin-orbit force.

Phase space cooling as a mean to obtain high intensity $\bar{p}$ beams.

K. Kilian
CERN, Genêva, Switzerland

Most problems in low energy $\bar{p}$ experiments are due to the very poor phase space density and the high pion contamination of the available $\bar{p}$ beams. One can improve the situation by decelerating the $\bar{p}$ obtained at the production maximum ($\sim$3.5 GeV/c) in a storage synchrotron. Many orders of magnitude in phase space density can be gained in addition, by application of phase space cooling techniques. "Heat exchange" of a proton beam with a high quality electron beam was successfully tested in Novosibirsk. This electron cooling can provide $\bar{p}$ beams in the energy range and with the quality of a tandem accelerator. Stochastic cooling recently developed at CERN uses high frequency feedback techniques on the circulating particles. An antiproton accumulator using stochastic cooling will be operative end of 1981 at CERN as part of a big SPS experiment. Adding a low energy stretcher ring to this installation will allow experiments with $\lesssim 10^7$ $\bar{p}$/sec in a range of 0.1-1.7 GeV/c.

Channeling with GeV particles.

E. Uggerhöj and H. Nielsen
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Abstract:

A short review is given of the present state of the art in High Energy Channeling physics but with particular emphasis on the results of the 1976 Aarhus-CERN-Strasbourg experiment with 2-15 GeV/c protons and pions where it was found that channeling has a drastic influence on energy loss, scattering phenomena and also nuclear interactions. A brief description of the ideas behind the next channeling experiment at CERN is also presented, and finally the possibility of using the channeling effect to measure the lifetime of the η-meson will be touched.