GENERAL DEVELOPMENTS IN THE LOS ALAMOS NUCLEAR PHYSICS GROUP (T-16)

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Summary

Nuclear physics activities in support of nuclear data development by the newly formed "Nuclear Physics" group (T-16) at Los Alamos are summarized. Activities such as the development of a new Hauser-Feshbach/preequilibrium reaction theory code, improvements to and reissue of the existing GNASH reaction theory code, nuclear cross section evaluation in the context of ENDF/B-VI, development of a new medium-energy optical model potential, new fission neutron spectrum calculations with the Los Alamos model, and development of new 6-group delayed neutron constants for ENDF/B-VI are described.

Formation of New T-16 Group

A new group, "Nuclear Physics" (T-16), was formed in March at Los Alamos from the previous groups "Nuclear Theory and Applications" (T-2) and "Medium Energy Theory" (T-5). The new group has some 20 permanent scientific staff members and postdoctoral fellows, as well as a number of affiliates and consultants. For the present, activities of the new group are not expected to deviate much from those of the two previous groups.

Development of a New Hauser-Feshbach/Preequilibrium Code, McGNASH (Chadwick)

At LANL, significant progress has been made in developing a new and modern version of GNASH, known as McGNASH. The code is being written in a modular fashion, using Fortran90. Over 4000 lines have been written. Significant testing/validation has been accomplished, through checks against GNASH predictions. (This has also led to identifying and removing some approximations in GNASH too). In Hauser-Feshbach validation tests (we focused on 20 MeV n+58Ni, allowing n,p,d,t,α, γ ejectiles in sequential decay processes), we find agreement with GNASH to the better-than 0.2% level.

We have also completed a first version of a Hybrid Monte Carlo preequilibrium module. A collaboration with Oblozinsky at BNL has begun in this area.

Development of 150-MeV Libraries for ENDF/B-VI System (Chadwick)

New evaluations for incident neutrons and protons from 20 to 150 MeV were completed using the GNASH code, with the calculations optimized to available experimental data and systematics, especially for nonelastic cross sections. For the neutron evaluations experimental data were utilized for the total cross sections. The neutron evaluations were combined with existing ENDF/B-VI evaluations, and both the proton and neutron evaluations have been accepted for ENDF/B-VI and are included in Release 6. Target nuclei in the evaluations are: $^{1,2}H$, ^{12}C, ^{14}N, ^{16}O, ^{27}Al, $^{28,29,30}Si$, ^{31}P, ^{40}Ca, $^{50,52,53,54}Cr$, $^{54,56,57}Fe$, $^{58,60,61,62,64}Ni$, $^{63,65}Cu$, ^{93}Nb, $^{182,183,184,186}W$, $^{206,207,208}Pb$, and ^{209}Bi.

Modifications and Corrections of the Original GNASH Code (Young, Chadwick)

We are preparing to issue a new version of the original GNASH Hauser-Feshbach/preequilibrium code to the RSIC and NEA Data Bank code centers. The new code includes a number of minor improvements and one important correction in the way multiple reaction channels are buffered for high-energy calculations. The latter deficiency leads to inaccuracies of the order of 30% at 150 MeV in neutron production cross sections for structural materials but is substantially less important for heavy targets and decreases as the incident energy is lowered.

Light Element Studies with R-Matrix Theory (Hale)

Much of our light-element R-matrix activity has been directed to reactions of importance in astrophysics. We have been looking at important helium-burning reactions, such as $^{12}C(\alpha,n)^{16}O$ and $^{13}C(\alpha,n)^{16}O$, for the past several years. We are also beginning a systematic study of the big-bang nucleosynthesis reactions, starting with n+p capture. Astrophysical interests have also motivated us to investigate fully quantum-mechanical calculations of screened reaction rates. In keeping with the strong interest in the nature of fundamental hadronic interactions in our combined group, we have continued our studies of the lightest systems (A=3,4) with particular attention to evidence for three-body nuclear forces in the experimental data. We also anticipate that additional R-matrix work on the systems containing the light-element standard cross sections will begin soon in support of the newly proposed Standards CRP.

Miscellaneous Evaluation Work (Young)

New evaluations have been completed for neutron-induced reactions on ^{16}O, ^{35}Cl and ^{37}Cl. The ^{16}O evaluation spans the energy range 10^{-5} eV to 30 MeV, where it is joined with the existing 150-MeV evaluation. New measurements of $^{16}O(n,x\gamma)$ discrete γ-ray angular distributions for $E_n = 4 - 200$ MeV were available from LANSCE and provided a major new evaluation input. The new data permit much more reliable determination of (n,n') cross sections [not to mention (n,xγ) cross sections] than was previously possible.

The ^{35}Cl and ^{37}Cl evaluations extend to 20 MeV and are based largely on GNASH calculations matched to the available experimental data, with resonance parameters and inelastic angular distribution taken from JENDL evaluations. New evaluations by Frankle and Reedy of thermal-neutron radiative capture photon production data were incorporated into the ^{35}Cl and ^{37}Cl evaluations. Additionally, the new evaluations by Frankle and Reedy of thermal-neutron photon production have been incorporated into existing ENDF/B-VI evaluations for ^{9}Be, ^{14}N, ^{19}F, ^{23}Na, ^{27}Al, ^{45}Sc, $^{50,52,53,54}Cr$, ^{55}Mn, $^{54,56,57,58}Fe$, $^{58,60,61,62}Ni$, $^{63,65}Cu$, and natural K and Mg. These results will be made available for a future update of the ENDF/B-VI file.

New Medium-Energy Nucleon-Nucleus Optical Model Potential (Madland, Sierk)

A global medium-energy nucleon-nucleus optical model potential is under development. The objective is to construct a potential with the following properties: (1) applicable to spherical (or approximately spherical) nuclei in the mass number range $16 \leq A \leq 209$; (2) simultaneous treatment of proton and neutron projectiles (explicit isospin dependence): (3) energy range of (perhaps) 20 MeV $\leq E_{proj} \leq$ 2000 MeV; (4) predict very accurate integral observables: σ_R, σ_{tot}; and, (5) phenomenological approach guided by results/conclusions from microscopic approaches. The two formalisms that are being use are the relativistic Schrödinger formalism and a Dirac formalism. With the relativistic Schrödinger formalism, a second-order reduction of the Dirac equation is formally identical with the non-relativistic Schrödinger equation provided the potential is multiplied by a momentum-dependent factor. In the Dirac formalism, an extended Walecka model is applied in the mean field approximation. The "extended" here means the introduction of isospin and corresponding isovector-scaler and isovector-vector mean fields in addition to the two isoscalar fields. This approach yields a relativistic generalization of the Lane model to allow simultaneous treatment of proton and neutron scattering.

Fission Neutron Spectra Calculations (Madland)

The Los Alamos model has been used to calculate a new prompt fission neutron spectrum matrix for the n + ^{235}U system. Energy-dependent compound-nucleus formation cross sections for the inverse process were used throughout. The matrix includes first-, second-, and third-chance fission components and also includes the neutrons evaporated prior to fission in second- and third-chance fission. It has been calculated for 19 incident neutron energies ranging from 0 to 15 MeV. The nuclear level-density parameters used in the calculations were determined in least-squares adjustments to the measured differential spectra assembled by N. Kornilov and P. Staples. The matrix is considered complete except for the following: the measurements of the thermal-neutron-induced spectrum are not in agreement. This means that the calculated thermal spectrum depends upon which measurement, or measurements, is used to determine the nuclear level-density parameter for this case. Fortunately, 30 integral cross section measurements have been made in the thermal field. These measurements will assist in determining the correct thermal spectrum.

Fission Product and Decay Data (Wilson, England)

Delayed neutron group parameters have been recalculated with the CINDER'90 code using revised decay data and improved fission yields, with the eventual goal of replacing the values currently in ENDF/B-VI. Beta decay spectra, Pn values, and other decay data are greatly improved relative to those used earlier for ENDF/B-VI, and 60 new fission-yield data sets have replaced the 50 older sets used in the previous calculations. As part of this work, the use of 8 groups with constant exponential (lambda) values for all fission nuclides was compared to the traditional use of 6 groups with lambdas determined by a least squares fitting code. No advantage was observed in the use of 8-group fits with fixed lambdas relative to conventional 6-group fits with variable lambdas. This outcome is important because it means that reactor codes that have traditionally been used do not need to be modified.