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TITLE: ADAPTATION OF A NUCLEON-NUCLEUS ELASTIC SCATTERING MODEL FOR LAHET^{TM}

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Adaptation of a Nucleon-Nucleus Elastic Scattering Model for LAHET^{TM}

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Introduction

The LAHET[1] Monte Carlo code for the transport and interaction of nucleons, pions, muons, light ions, and antinucleons has been upgraded by the addition of an elastic scattering model for neutrons above 15 MeV and protons above 50 MeV. Earlier elastic scattering in LAHET has been limited to neutrons below 100 MeV, using a library of elastic optical-model cross sections generated using the Bechetti-Greenlees potential. The new methodology has been adapted from the HERMES[2] code. However, the sampling algorithm for the center-of-mass scattering angle has been completely rewritten, and the elastic cross section data has been replaced below 400 MeV.

The new method is viewed as an intermediate step in the effort to provide a library of both elastic and non-elastic cross sections from a global optical-model potential for LAHET usage.

Nucleon Elastic Scattering Cross Sections from 50 MeV to 400 MeV

The tabulated elastic scattering cross sections were generated with an interim[3] global medium-energy nucleon-nucleus phenomenological optical-model potential. The potential is based upon a relativistic Schrödinger representation and is applicable to neutron and proton incident energies in the range 50 – 400 MeV and a target mass range of 20

– 220. The starting point for this work was the proton optical potential of Schwandt et al.[4] based upon measured elastic proton scattering observables in the range 80 – 180 MeV. This potential was modified to optimally reproduce experimental proton total reaction cross sections as a function of energy, while allowing only minimal deterioration in the fits to other elastic proton scattering observables. Further modifications in the absorptive potential were found necessary to extrapolate the modified potential to higher energies. At this point explicit isospin was introduced and the potential was converted to a neutron-nucleus potential by use of standard Lane model assumptions and by accounting approximately for the Coulomb correction, and comparing predicted and measured neutron total cross sections. Final comparisons of predicted and measured elastic scattering observables for both protons and neutrons were made for ^{27}Al, ^{56}Fe, and ^{208}Pb. The results were generally good.

The neutron and proton elastic cross sections so generated are tabulated for 9 mass values and 19 energies between 50 MeV and 400 MeV. Above 400 MeV, the tabulations from HERMES are used. The HERMES neutron elastic cross section tabulation below 50 MeV has been extended to lower and higher masses to minimize mass extrapolation error; the neutron elastic optical-model cross sections currently used by LAHET below 50 MeV are used for this purpose. Proton elastic scattering vanishes below 50 MeV in this implementation.

Sampling Algorithm for the Angular Distribution

The current model[2] for the COM scattering angle is given by

$$\frac{d\sigma}{d\Omega} \sim \left(\frac{J_1(x)}{x}\right)^2 \text{ for } x = 2R\sin(\theta/2)/\bar{\lambda}, \; R = (1.4\text{fm})A^{1/3} + \bar{\lambda}$$

which, since $\cos\theta = 1 - \bar{\lambda}^2 x^2/2R^2$, provides a probability distribution for x^2 or $\cos\theta$. The implementation is by a table of 98 equally-probable (1%) bins in the variable x^2, with an approximate asymptotic distribution for the last 2% of the distribution. In practice, the sampling range is always restricted by $\cos\theta \geq -1$.

In figure 1, a test calculation for $p(\cos\theta)$ vs. θ is shown for the COM angular distribution for 84 MeV neutrons scattered by ^{27}Al using 10^8 random samples of the algorithm.

Summary

The elastic scattering model discussed above employs cross sections generated from a physically based optical-model potential appropriate to the energy range in which they are applied in LAHET and broadens considerably the mass range for the tabulated cross sections at low energies. The algorithm for sampling for the scattering angle provides a more complete and accurate representation of the assumed distribution than that originally proposed for HERMES. Taken together, the LAHET implementation is an interim step in the long-range objective of determining elastic and nonelastic reaction rates through cross sections obtained by a global nucleon-nucleus optical potential for

the energy range 20 MeV to 2 GeV.

1. Richard E. Prael and Henry Lichtenstein, "User Guide to LCS: The LAHET Code System", LA-UR-89-3014, Los Alamos National Laboratory (September 1989).

2. P.Cloth *et al.*, *HERMES - A Monte Carlo Program System for Beam-Materials Interaction Studies*, Kernforschungsanlage Jülich GmbH, Jül-2203, May 1988.

3. D. G. Madland, *Proceedings of a Specialist's Meeting on Preequilibrium Reactions, Semmering, Austria, February 10–12, 1988*, Edited by B. Strohmaier (OECD, Paris, 1988), p. 103–116.

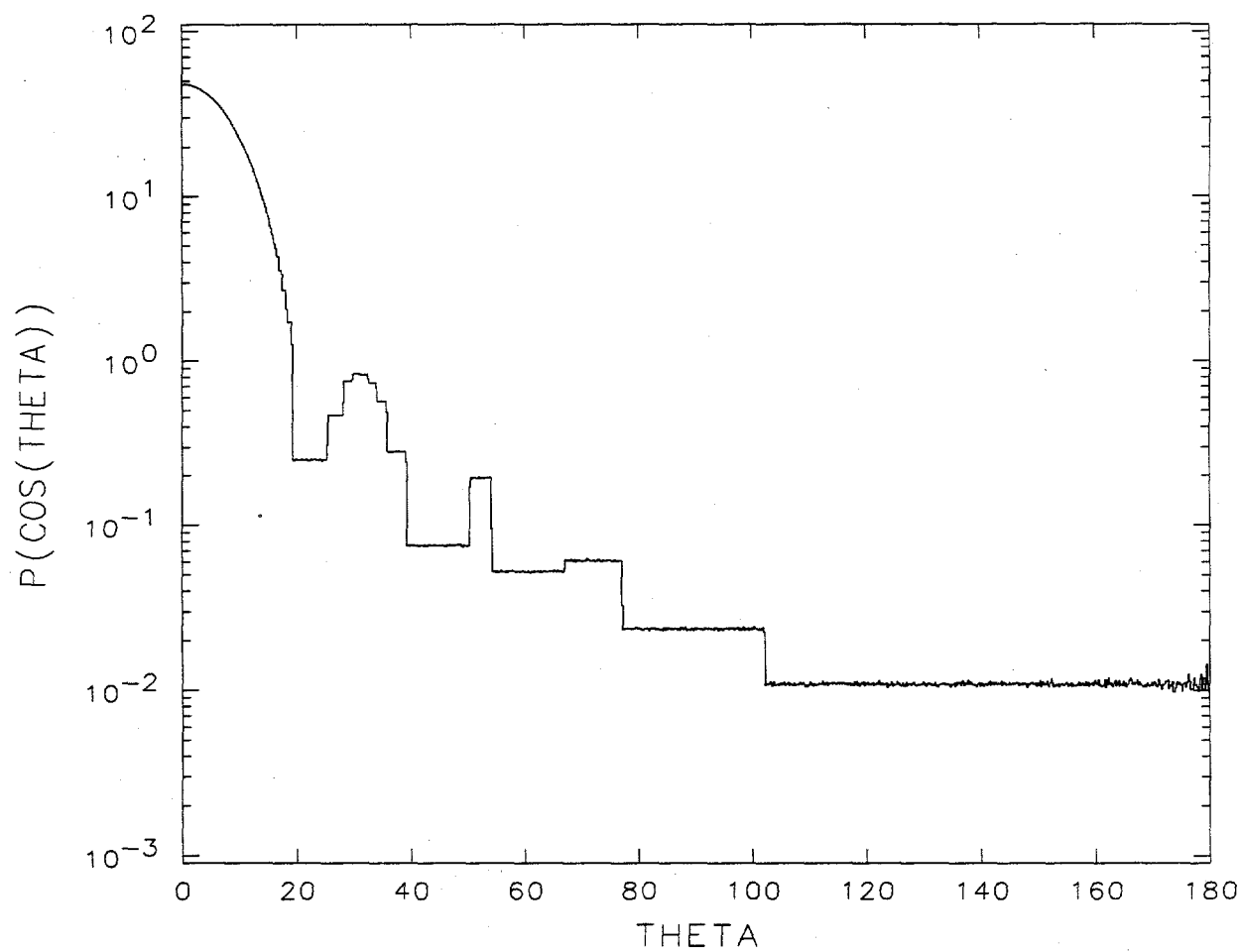4. P. Schwandt *et al.*, Phys. Rev. C **26**, 55 (1982).

Figure 1: Calculated center of mass angular distribution for 84 MeV neutrons scattered by ^{27}Al obtained from sampling algorithm.