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NUCLEAR PHYSICS

Elastic α-Nucleus Scattering at 36 to 60 Mev/Nucleon

M. A. Alvi · M. A. Abdulmomen · Jamal H. Madani ·
R. J. Peterson

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Abstract Working within the framework of the Coulomb modified Glauber model and using the optical limit approximation to evaluate the elastic S-matrix, we use a parameterized effective nucleon-nucleon phase shift function instead of the frequently applied Gaussian parameterization of the nucleon-nucleon scattering amplitude to compute elastic differential cross sections for alpha particles. Our phenomenological ansatz contains three parameters which are adjusted in order to reproduce the alpha nucleus elastic scattering data for one nucleus at each of three beam energies. It is found that once the nucleon-nucleon phase shift function is so calibrated, our model very nicely reproduces elastic alpha scattering data on other nuclei at the same energy.

Keywords Optical and diffraction models · Alpha elastic scattering · Nucleon–nucleon phase shift

1 Introduction

The first "heavy ion" scattering data on complex nuclei were obtained with alpha particles (^{4}He). At energies near 10 MeV per nucleon, these elastic scattering data showed striking diffractive oscillations, indicating a black nucleus with a very short mean free path for the alpha particles within the nuclei. These oscillations could be fitted by assuming a sharp cutoff in the partial wave amplitudes [1]. The oscillations with angle were similar to those from optical Fraunhofer diffraction, and the minima could be matched with a simple Bessel function. The details of the oscillations could give a sensitive measure of a nuclear radius parameter [2].

At higher beam energies, the deep diffraction minima are filled in, reflecting a longer mean free path for the ion beam in complex nuclei. These and other data have been addressed with a wide range of computational methods. The availability of precise data and the use of these models can give insights into the fundamental nucleon–nucleon interaction within the nuclei, where it might differ from that in free space. In this sense, the alpha particle scattering at suitable beam energies can be used as the model for other reactions seeking to investigate the issue of "medium" modifications. It is of value to investigate a wide range of theoretical models, since the strong absorption may lead to ambiguities of parameter choices made, for instance, with optical model methods. The use of models which enable specific insights into the sensitivities of the assumptions can be particularly valuable.

Generally, two approaches have been used for analyzing α-nucleus elastic scattering differential cross section data. One often used at low and medium energies is the phenomenological optical model potential. At these energies, the behavior of α-nucleus scattering cross sections is dominated by strong absorption in the nuclear surface region. More explicitly, the cross section depends mainly on a small number of phase shifts (δ_l), i.e., to those where l values correspond to impact parameters in the region of the nuclear surface. Since a different interior wave function can generate the same phase shifts, the optical model parameterization of the interaction, as has been explained above, leads to ambiguous information regarding the optical potential. This has been found to give the existence of discrete and continuous ambiguities as well as significant uncertainty in the general shapes of the real and imaginary potentials [3–8].

The other approach which has frequently been used is the eikonal approximation of the Glauber multiple scattering theory [9], which provides us with an excellent framework to describe reactions at high and intermediate energies in various fields of

R. J. Peterson
Department of Physics, University of Colorado,
Boulder, CO 80309–0390, USA

M. A. Alvi (✉) · M. A. Abdulmomen · J. H. Madani
Department of Physics, King Abdul Aziz University,
Jeddah, Saudi Arabia
e-mail: alveema@hotmail.com