Successful description of elastic scattering of ^{3}He particles at 150 MeV/nucleon with the single folding potential model

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Elastic scattering of ^{3}He particles from ^{90}Zr and ^{208}Pb was measured at 150 MeV/nucleon. The data were well reproduced by the single folding potential model without an anomalously large reduction for the potential depth.

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The description of interaction between two nuclei is an interesting subject in nuclear physics. For the composite projectile-nucleus interaction one of the simplest models for it is the single folding potential (SFP) [1], in which a phenomenological optical potential that describes elastic scattering of a nucleon from a target nucleus is folded into the ground state density of the projectile. This potential model has such characteristic features that no free parameter is needed in calculations and an imaginary potential is automatically introduced.

This model has been applied to the description of the elastic scattering mainly at incident energies lower than 20 MeV/nucleon [1–4]. From these studies it has been found that an anomalously large (80–50 %) reduction (renormalization factor of 0.2–0.5) have to be artificially introduced on the potential depth to reproduce the experimental cross sections [1–4]. Consequently, serious doubt has been cast on the physical validity of this model. One of the explanations for this reduction is that the potential between a constituent nucleon of the projectile and target nucleus may be different from that between a free nucleon and the target nucleus due to a medium effect in the projectile [1].

At higher incident energies, e.g., typically 100 MeV/nucleon, the medium effect is suggested to become less important [5,6]. Thus, we expect that the SFP picture manifests its validity at such higher incident energies. Indeed, the analyses of the elastic scattering of deuterons at 200 and 350 MeV/nucleon [6–8] and of α particles at 340 MeV/nucleon [7] stimulate the above expectation: The single folding calculations seem to reproduce the absolute magnitude of the experimental cross sections. However, experimental data and their analyses of the elastic scattering at the high incident energies, so far, are limited to only these deuterons and α-particle cases. In order to establish the validity of the SFP picture, further study seems to be necessary at the high incident energy with different projectiles.

In the present work, we measured the elastic scattering of ^{3}He particles at an incident energy of 150 MeV/nucleon from ^{90}Zr and ^{208}Pb, the typical nuclei in medium and heavy mass regions. The data were analyzed with the single folding potential model. Until now, to our knowledge, no single folding calculation with a phenomenological potential has been found in the literature for mass-3 projectiles. This is the first analysis of the ^{3}He elastic scattering at a high incident energy with the single folding potential model.

The elastic scattering data were taken with the 450 MeV ^{3}He beams extracted from the $K = 400$ MeV ring cyclotron of the Research Center for Nuclear Physics, Osaka University [9]. The targets were self-supporting metallic foils of enriched ^{90}Zr (11.3 mg/cm^2) and ^{208}Pb (8.6 and 58.0 mg/cm^2) isotopes.

Scattered ^{3}He particles were analyzed with the magnetic spectrograph "Grand Raiden" [10], and were detected by the focal-plane detector system [11], consisting of two two-dimensional position-sensitive multiwire drift chambers and two ΔE plastic scintillators. A typical energy resolution was 400 keV. The uncertainty for the absolute values of the cross sections was estimated to be about 15% which was mainly due to the uncertainty of the target thickness and the beam integration efficiency. Cross sections were derived by sorting events in an angular range of every 0.5°. Figure 1 shows measured angular distributions of the elastic scattering from ^{90}Zr and ^{208}Pb. Error bars show only statistical ones.

In the calculation with the single folding model we used the proton-nucleus optical potentials derived at an incident energy of 160 MeV [12]. These potential sets were based upon the standard Schrödinger phenomenology. A spin-orbit potential was not included in the present calculations, since its contribution to the differential cross sections was expected to be not so large [13]. The radial dependence of the ^{3}He density was assumed to have a Gaussian shape distribution. The width of this distribution was determined so as to reproduce the root-

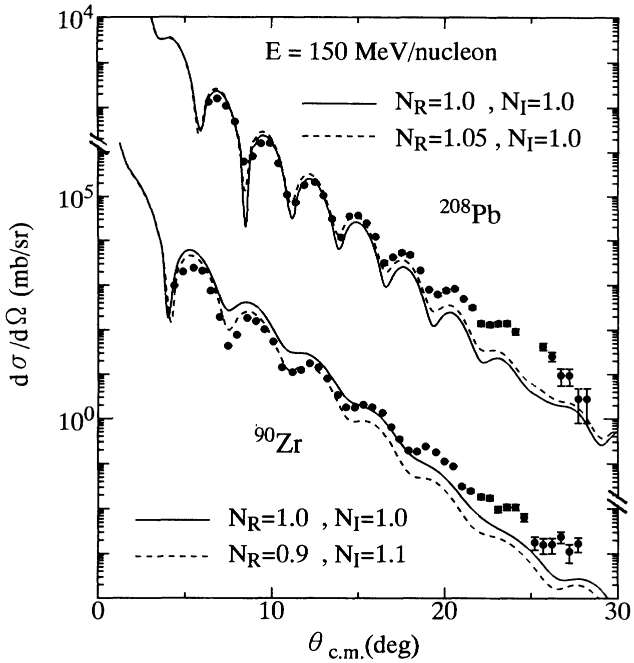

FIG. 1. Experimental and calculated angular distributions of differential cross sections for elastic scattering of ^{3}He particles at 150 MeV/nucleon on ^{90}Zr and ^{208}Pb. Solid curves show the calculated results with $N_R = N_I = 1$ and dotted curves with $N_R = 0.9$ and $N_I = 1.1$ for ^{90}Zr and $N_R = 1.05$ and $N_I = 1.0$ for ^{208}Pb.

mean-square radius of the ^{3}He observed by the electron scattering [14]. Volume integrals per nucleon of the present folding potentials were, respectively, $J_R = 216$ and $J_I = 93$ MeV fm^3 for ^{90}Zr and $J_R = 197$ and $J_I = 97$ MeV fm^3 for ^{208}Pb.

Solid curves in Fig. 1 show the calculated angular distributions of differential cross sections without the renormalization for the folding potentials ($N_R = 1.0$ for the real potential and $N_I = 1.0$ for the imaginary potential). It is found that not only the absolute magnitude but also characteristic diffraction patterns and gradients of the experimental angular distributions are well reproduced.

For better fitting of the calculated angular distributions with the experimental ones, especially at a forward angular region, the renormalization factors were varied from $N_R = N_I = 1.0$. The best fit (dotted curves in Fig. 1) was obtained only with at most 10% changes in the renormalization factors. This suggests that the single folding model essentially describes elastic scattering of ^{3}He particles at the present energy. This is in sharp contrast to the case at the lower incident energies, where an anomalously large reduction of the potential depth is necessary [1].

At a backward angular region, the calculation seems to slightly underestimate cross sections compared with experimental values. A specific nature of an employed type (Schrödinger phenomenology) of the optical potential for protons may cause some part of this discrepancy [6].

In summary, the single folding potential model well described the elastic scattering of the ^{3}He particles at 150 MeV/nucleon, as a whole, without introducing a large reduction for the potential depth. This suggests that at an incident energy higher than at least 150 MeV/nucleon the potential between a free nucleon and a target nucleus becomes a good approximation of that between a nucleon in the projectile and the target nucleus.

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