Analysis of proton-^{9}Be scattering observables using most accurate spin orbit potential

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Introduction

Microscopic calculation of a nucleon-nucleus interaction has been one of the important aims in nuclear reaction theory. This many-body interaction can be approximated by a complex one-body potential called the optical potential. The optical potential is an important ingredient in the evaluation of elastic, inelastic nucleon scattering, charge exchange, transfer, breakup reactions, and applications to the scattering of exotic nuclei from hydrogen through inverse kinematics. The Brueckner-Hartree-Fock (BHF) theory is one of the most widely used for obtaining the microscopic nucleon-nucleus optical potential by folding the nucleon-nucleon (*NN*) reaction matrix (effective interaction).The effective interaction (*t* matrix) is obtained by solving the Bethe-Goldstone integral equation for a nucleon-nucleon interaction in nuclear matter. The *t* matrix depends on the incident energy of the nucleon and density of the nuclear matter. This *t* matrix is then folded over the nucleon density in the target using local-density approximation to obtain the nuclear optical potential. There are only two inputs in the BHF: the realistic nucleon-nucleon interaction and the nucleon density distribution in the target nucleus. The microscopic optical potential thus obtained is nonlocal due to exchange even if the *NN* interaction is local. Hence to obtain scattering observables one would have to solve the integral equation. Furthermore, the application of a nonlocal potential would be quite difficult in certain reactions. In order to simplify the calculations, Brieva and Rook (BR) proposed [1] an approximate form of the equivalent local potential. The direct part of the nucleon-nucleus spin-orbit potential in the folding model approach obtained by BR is:

$$U_{SO}^{D,p}(r_1,E)=\frac{\pi}{3r_1}\Big[\frac{d\rho_p(r_1)}{dr_1}\int \boldsymbol{t}_{SO}^{D,pp}\Big(x;\rho_T\Big(\frac{|\boldsymbol{r}_1+\boldsymbol{r}_2|}{2}\Big),E\Big)x^4dx+ \frac{d\rho_n(r_1)}{dr_1}\int \boldsymbol{t}_{SO}^{D,pn}\Big(x;\rho_T\Big(\frac{|\boldsymbol{r}_1+\boldsymbol{r}_2|}{2}\Big),E\Big)x^4dx\Big]$$

We had been able to avoid the BR approximation and obtain an exact expression for both the direct and a local equivalent to the exchange parts of the spin-orbit potential. The detailed numerical calculations and results have been reported in our latest paper [2]. Here due to constraint in space we present the final equation obtained after removing the BR approximation.

$$U_{SO}^{D,p}(r_1,E)=-\frac{1}{2r_1}\Big[\int\rho_p(|\boldsymbol{r}_1+\boldsymbol{x}|)\,\boldsymbol{t}_{SO}^{D,pp}\cos(\theta)xd^3x+ \int\rho_n(|\boldsymbol{r}_1+\boldsymbol{x}|)\,\boldsymbol{t}_{SO}^{D,pn}\cos(\theta)xd^3x\Big]\,\boldsymbol{l_1}.\boldsymbol{s_1}$$

Results and Discussions

Employing this exact spin orbit potential in Brueckner-Hartee-Fock (BHF) approach we have analyzed the differential cross section of ^{9}Be at various energies where we have the available experimental data. Earlier the BHF approach has been successfully employed to study normal as well as a broad range of exotic nuclei. The required nuclear density distributions employed here are obtained using the semi-phenomenological model for nuclear density distributions [3]. Fig. 1 shows the proton and neutron density profile of ^{9}Be.The resulting optical potential with these two inputs is used to calculate the physical observables. Thus there are no free parameters in this microscopic approach for obtaining the nuclear optical potential.

In Fig. 2 we present the calculated new spin orbit potential at various energies obtained after removing the Brieva and Rook [BR]approximation. We observe that the spin orbit potential depends mildly on energy.

In Fig. 3, Solid lines represent our results for differential cross section using modified spin orbit potential and the solid black dots are the experimental data. We conclude that there is a reasonably good agreement between our results and the experimental data [4-9].

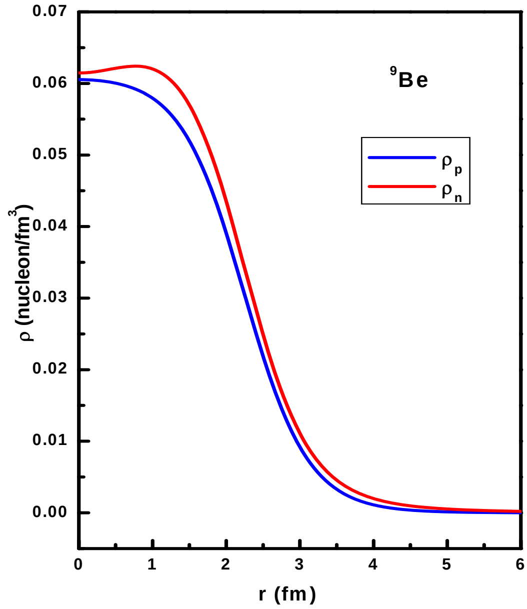

Fig.1 Semi-phenomenological proton and neutron density distributions of ^{9}Be.

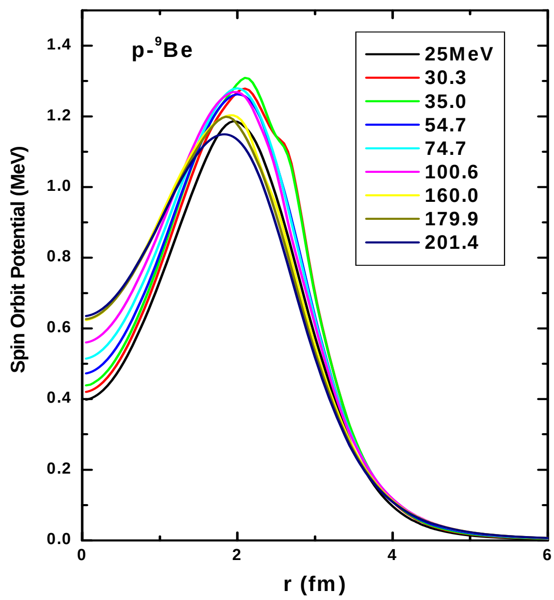

Fig. 2 Proton-nucleus spin orbit potential for ^{9}Be at various energies

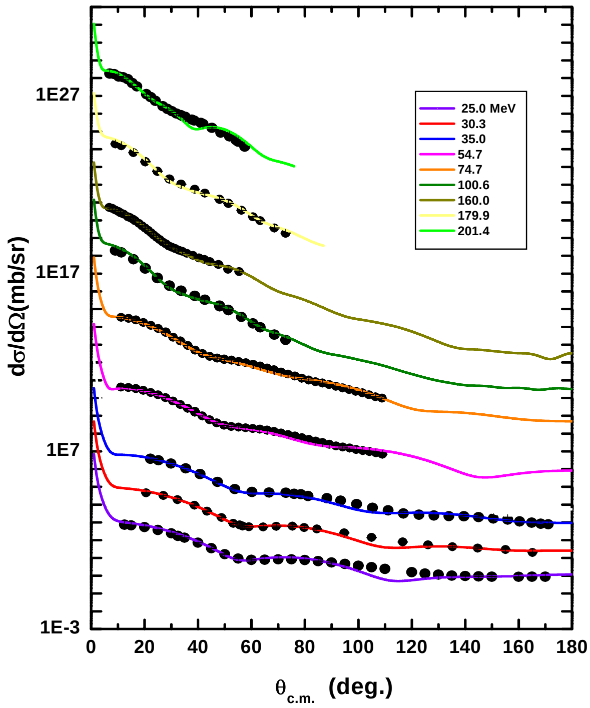

Fig.3. Differential cross section for p-^{9}Be elastic scattering at different energies.

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