Pion single-charge-exchange reaction on ^{14}C above the delta resonance

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Above the delta resonance, the pion-nucleon interaction becomes weaker than that around the delta resonance and the multiple scattering series for pion-nucleus interaction is believed to converge rapidly. Various pion-nucleus reactions for these energies have been studied both experimentally and theoretically. For the elastic scattering, the theoretical calculation based on the Glauber theory or the optical model slightly underestimate the experimental data. The single-charge-exchange reactions (SCX) have been studied also above the delta resonance[1]-[3]. The theory overestimate the experiment forward cross section by about a factor 1.7 around the incident energy region 400–600 MeV [2]. Oset and coworkers [3] calculeted the polarization effect in nuclear matter introducing the energy gap Δ for a minimum particle-hole excitation energy. They incorporate the polarization effect under the local density approximation and it leads to the isovector renomarization of the charge exchange pion-nucleus amplitude and the forward cross section is reduced in conformity with the experiment.

In the present work, we reanalyzed the excitation function for the reaction $^{14}\mathrm{C}(\pi^+,\pi^0)^{14}\mathrm{N(IAS)}$ including the first-order core polarization effects in the shell model calculations. We adopt the distorted-wave impluse approximation in momentum space to calculate the SCX amplitude. The pion-nucleus scattering amplitude is given by

$$\begin{aligned} f(\theta) &= \frac{1}{2\sqrt{6\pi}} \sum_l (2\ell+1) P_l(\cos\theta) \sum_{\lambda,\ell_1} \frac{2\ell_1+1}{2\lambda+1} F_\lambda(k_0) (\ell\ell_1 00|\lambda 0)^2 \\ &\times \int r^2 dr [\int j_{\ell_1}(kr)\phi_\ell(k) g_\lambda(k) k^2 dk]^2 \rho_V(r) \end{aligned}$$

where $\rho_V(r)$ is the nuclear isovector density

$$\rho_V(r) = <^{14}\mathrm{N}|\hat{O}|^{14}\mathrm{C}> \quad , \qquad \hat{O} = \sqrt{3}\sum \frac{\delta(r-r_j)}{r^2}\tau_j^+ .$$

We adopt the pion-nucleon phase shifts given in ref.[4] and take the partial waves up to $\lambda = 6$. The pion-nucleus distorted waves are generated with the Klein-Gordon equation in momentum space. We calculate the forward SCX cross section with the Cohen-Kurath p-shell wave function with (8–16) POT matrix element[5]. The core polarization effects are incorporated with the first order perturbation

$$\begin{aligned} \rho_V(r) &= < f|\hat{O}|i> \\ &+ < f|\hat{O}\frac{1}{E_f - H_0}(V_{res}-U)|i> + < f|(V_{res}-U)\frac{1}{E_i - H_0}\hat{O}|i> . \end{aligned}$$

As a residual two-body interaction the Yukawa form with Rosenfeld mixture is used for the central part, and as a noncentral part we adopt the tensor force of Hamada-Johnstone nucleon-nucelon interaction with the cutoff radius $r_c = 0.7$ fm. As the intermediate states we include the configurations up to $12\hbar\omega$ excitation energies. The results with and without polarization effect are shown in Fig. 1. It enhances the forward cross section about 10-20 % and the theory overestimate the cross section by about 1.2-2.2 for the energy region considered here.

In ref. [3], the medium polarization calculated in nuclear matter is incorporated with the local density approximation and then the isovector density is reduced with the medium polarization and the SCX cross section decreases at all angles [3]. The polarization effect pushes the density outward due to the effect of higher configurations. Because of this, the polarization effect cannot be expressed as a simple renormalization effect. The angular distributions of the SCX cross section are shown in Fig. 2. As seen, the forward cross section is enhanced slightly. If we neglect the pion distortion, the polarization effect is absent for the forward cross section. The forward cross section is expected to be sensitive to the nuclear isovector density around the nulcear surface. Further experiments including the angular distribution are necessary to clarify the mechanism of the SCX reactions at these energies.

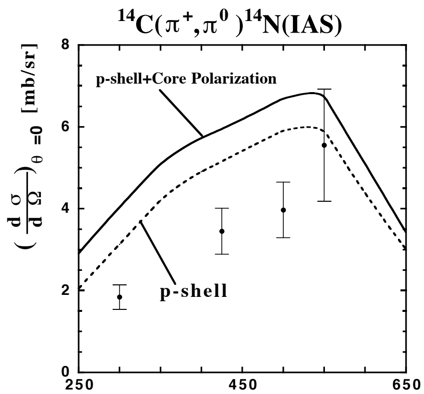

Fig. 1

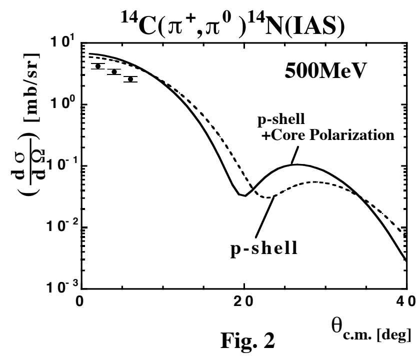

Fig. 2

References

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