Comment on "High-Spin-State Spectroscopy with the Reaction $^{88}Sr(p_{pol}, \pi^-)^{89}Zr$"

Recent publications[1,2] on the (p, π^-) reactions with medium-heavy nuclei ($A \sim 48$ and 90) have demonstrated the strong high-spin selectivity of the (p, π^-) reactions. The accompanying theoretical studies[1,3] in terms of the simple shell model with the again simple (p, π^-) reaction model have explained the energy spectra at low excitation energies and the angular distributions of a few dominant transitions. On the other hand, the analyzing power distributions for the stretched states seem to show a common, simple, generally positive pattern irrespective of nuclei, which is yet to be understood.[1] We comment here on a simple theoretical account of the analyzing power distributions and further implications of the (p, π^-) reactions.

As is well known, pion absorption and production need a large momentum transfer (short-range interaction) between two nucleons and therefore the two nucleons in the initial state for pion absorption and in the final state for pion production have to be in the relative s state. Hence, limiting our discussion to the (p, π^-) reactions, the final two protons have to be in the spin singlet state ($S=0$, $T=1$, $L_{rel}=0$).[4] On the other hand, the pseudoscalar character of the outgoing pion requires the nuclear spin operator, and hence the initial nucleon pairs in the spin triplet state. Furthermore, the high momentum transfer requires that the target nucleon with which the incoming proton interacts move towards the incoming proton with large momentum. If such a nucleon (neutron) is in the stretched state ($j = l + \frac{1}{2}$) as in the case considered here, an incoming proton at the upper side should have spin up with respect to the reaction plane, while one at the lower side should have spin down as shown in Fig. 1. Note that the large angular momentum of the final state makes the initial proton interact at the far side of the target nucleus. A pion produced at the upper side goes out almost freely in the direction of the positive scattering angle, while one at the lower side has to go through the nuclear medium. Hence, an asymmetry is caused in the (p, π^-) cross section: $A_y = (\sigma_\uparrow - \sigma_\downarrow)/(\sigma_\uparrow + \sigma_\downarrow)$. Using a simple spherical geometry with the radius R and the pion mean-free-path λ, we can relate $\sigma_\downarrow$ with $\sigma_\uparrow$ simply taking account of the attenuation consideration; $\sigma_\downarrow = \sigma_\uparrow \times \exp(-2R \sin\theta/\lambda)$ with θ being the scattering angle. We show in Fig. 2 the result of the (p, π^-) asymmetry distributions thus obtained together with the experimental data. The $(\mathbf{l} \cdot \mathbf{s})$ distortion on the incoming proton should act to reduce the asymmetry due to flip of the incident spin and also produce a small negative asymmetry at forward angles.

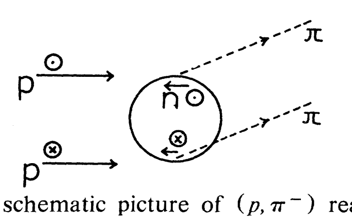

FIG. 1. A schematic picture of (p, π^-) reactions. The kinematical constraints (see text) require the spin-up incoming proton to interact with a spin-up neutron moving towards the proton around the upper edge, while that of spin down to interact with a spin-down neutron around the lower edge. The π^- produced around the lower edge suffers nuclear attenuation.

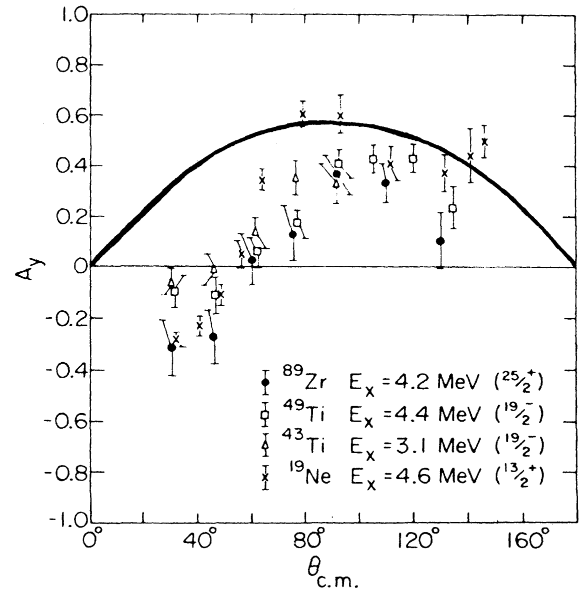

FIG. 2. The solid line for the asymmetry A_y as a function of the scattering angle θ is obtained with the parameters for the shadowing effect: $R = 0.9A^{1/3}$ fm (Ref. 2) and $\lambda = 6$ fm. Experimental data are taken from Ref. 2.

In conclusion, our simple consideration of the asymmetry should encourage a quantitative study of the asymmetry for the (p, π^-) reaction, where the short-range nature of the interaction together with the pion distortion are the necessary ingredients for the asymmetry. We expect, further, strong (p, π^-) strengths due to the $(g_{7/2} g_{9/2} g_{9/2}^{-1})$ configurations in the continuum of the (p, π^-) spectra, which are about a factor of 4 larger than those from the $(g_{9/2} g_{9/2} g_{9/2}^{-1})$ configuration, from consideration of the $9j$-coefficient.

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