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PROPOSED LETTER TO THE EDITOR

EFFECTS OF NUCLEAR STRUCTURE ON THE SCATTERING OF POLARIZED PROTONS

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A thorough understanding of the nuclear scattering process must necessarily include a description of the spin polarization induced by it. The current standard theory of elastic scattering, the optical model, has yet to be tested extensively against polarization data and so many of its spin-dependent features remain arbitrary or obscure. For example, Rosen[1] and co-workers have found that the polarization of protons in elastic scattering varies rapidly at large angles as a function of A (mass number) whereas the optical model predicts a smooth dependence. They have suggested that the spin-orbit potential may depend on the closing of shells or have an isospin dependence as does the central potential. The present experiment was designed to explore any such structural effect on the polarization for the A^{40} - Ca^{40} pair and to extend some of Rosen's measurements on other nuclei to the 16- to 21 MeV range.

The polarization was determined by measuring the right-left asymmetry in the scattering of a polarized proton beam. Six scintillation telescopes, three on each side, were used to detect the scattered protons. The well-known proton-helium scattering was used to polarize the protons. A suitable proton beam was formed by scattering a 40 MeV alpha beam in a hydrogen gas target and collecting the protons recoiling at 25° with a single quadrupole lens. The energy of the proton beam was 19 MeV, but it could be increased to 21 MeV by reducing the recoil angle to 18° or decreased by degrading the alpha beam in the hydrogen target. The energy spread due to the beam and target was maintained between 500 and 1000 KeV, resulting in an overall energy resolution of 6%. This gave a clean separation of the elastic and inelastic peaks.

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Comparisons of the polarizations produced by A^{40} and Ca^{40} at several different bombarding energies are shown in Fig. 1. Systematic differences over a large angular range are seen in the back hemisphere at all energies, but they are especially pronounced (> 30%) between 16.6 and 18.2 MeV. K^{39} was also measured at 18.2 and 21.0 MeV and found to give results intermediate to Ca^{40} and A^{40}. The data appear to reflect a true nuclear structure effect since most other causes can be ruled out; i.e., the effect is present at several energies, the nuclear radii are the same, the (p,n) threshol is exceeded by at least 4 MeV (at E_p = 18.2 MeV), and no inelastic state appears to be so strongly excited as to unduly perturb the elastic scattering.[2] The exact changes in the optical parameters required to explain these differences have not been established; however, a preliminary analysis of the 18.2 MeV data by H. Volkin[3] indicates that for Ca^{40} the radius of the spin-orbit potential (a derivative form was used) must be less than that of the central potential, but K^{39} requires less of this adjustment and A^{40} none at all. He suggests that the spin-orbit potential is centered on the nuclear matter radius for doubly magic nuclei* and that it moves out to the central potential radius as holes or particles are added. The predicted cross section is insensitive to the radius of the spin-orbit force.

A number of other pairs of neighboring nuclei were measured in an effort to find additional structural effects, but only Sn^{116} -Sn^{122} produced significant differences at our energy. These results are shown in Fig. 2 along with those from the Co^{59} -Ni^{58} pair, which shows differences at 14.5 MeV (and at 28 MeV[4]) but not at 20.9 MeV. It is difficult to say whether structural effects are present in either of these pairs since in the tin isotopes there are significant differences in the nuclear radii, while in

Co and Ni there are strong couplings to the first excited states. The lead isotopes, 206 and 208, and the elements Sr and Zr (natural mixtures) were also studied but no significant differences were found.

The energy dependence of the above results is in itself interesting. A pair of neighboring nuclei that show large differences in their polarizations at one energy may show very little at another. A possible explanation of this behavior can be found in the overall mass and energy dependence of the polarization. Survey measurements[1,5] have shown that the number of oscillations of the polarization between 0^{o} and 180^{o} increases as the mass or energy increases and that the transitions from n to n+1 oscillations always occur at approximately integral KR (where K is the wave number of the proton and $R = 1.25A^{1/3}$). In Fig. 1 such a transition occurs for Ca^{40} and A^{40} near 17 MeV, while in Fig. 2 one occurs for Co^{59} and Ni^{58} near 14.5 MeV. In both cases the large differences in the polarizations occur at these transition energies and near KR = 4. Since KR is an index of the number of partial waves being scattered, this suggests that the enhanced sensitivity of the polarization to structure is associated with the entry of a new partial wave into the scattering.

In conclusion, we have definitely found that the structure of the nucleus affects the elastic, proton polarization at A = 40. The results on heavier nuclei are not yet clear due to complications, but the influence of nuclear structure appears to decrease with increasing A as expected. The sensitivity of the polarization to structure has a dependence on the proton energy that seems to be understandable on the basis of potential scattering.

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*Volkin as found evidence for this in O^{16} as well.

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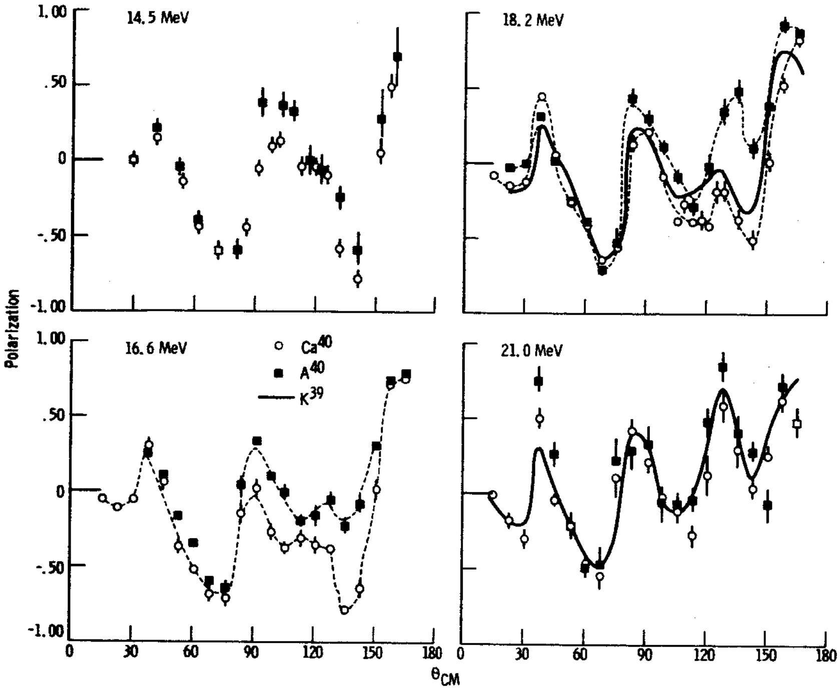

Figure 1

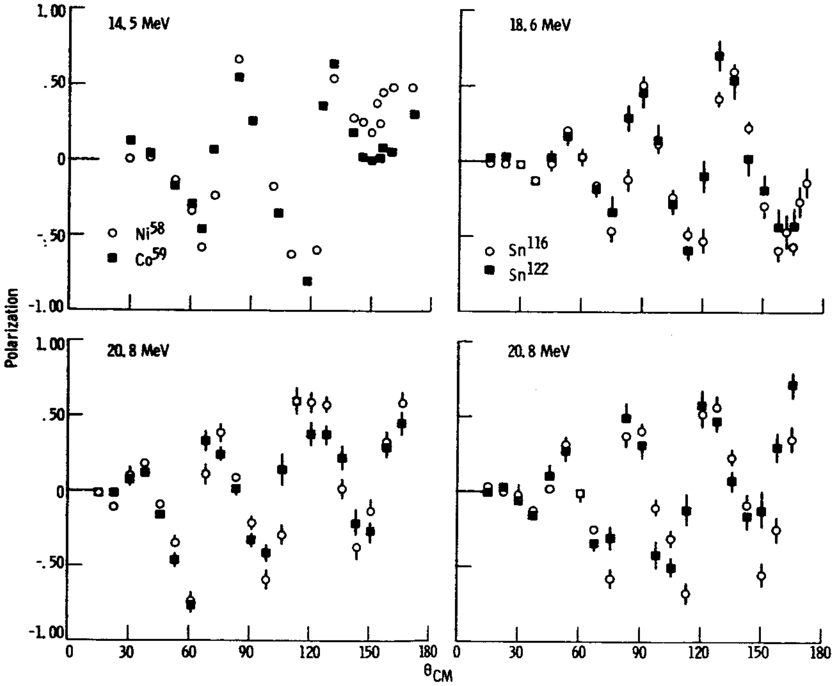

Figure 2