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Measurements of the Spin Rotation Function in 200-MeV Proton Elastic Scattering

E.J. Stephenson, A.D. Bacher, J.D. Brown, M.S. Cantrell, J.R. Comfort,† V.R. Cupps, D.L. Friesel, J.A. Gering, W. P. Jones, D.A. Low, R.S. Moore, C. Olmer, A.K. Opper, P. Schwandt, J.W. Seubert,†† A. Sinha, S.W. Wissink

Indiana Universiy Cyclotron Facility, Bloomington, IN 47405 U.S.A.
†Arizona State University, Tempe, AZ 85281 U.S.A.
††Indiana University-Purdue University at Indianapolis, Indianapolis, IN 46202 U.S.A.

We have recently completed measurements of the spin rotation function Q for 200-MeV protons elastically scattered from ^{12}C, ^{16}O, ^{40}Ca, and ^{48}Ca. These new data extend previously existing cross section and analyzing power angular distributions[1-3] for ^{12}C, ^{16}O, and ^{40}Ca. Measurements have also been made of the cross section and analyzing power for ^{48}Ca. The measurements shown here are preliminary.

Proton elastic scattering measurements are most often described by an optical potential. Two distinct approaches are now in use, one employing modest attractive central and spin-orbit terms in a Schroedinger equation, and another using strong cancelling vector and scalar potentials in a Dirac equation. Ray and Hoffmann[4] have reviewed both types of calculation using potentials from an intermediate energy impulse approximation. They pointed out that the non-relativistic approach has difficulty at most intermediate energies. At the same time, the relativistic impulse approximation works well near 500 MeV, but also has increasing difficulty as the energy is lowered.

Recent work on the RIA indicates that these problems arise from the treatment of pion exchange in nucleon-nucleon scattering.[5,6] Calculations that use a pseudoscalar πNN vertex diverge at zero bombarding energy, creating potentials at 200-MeV that are substantially larger than those obtained phenomenologically. This divergence is controlled when a pseudovector form of the πNN vertex is used. Two groups[5,6] have generated improved RIA potentials, whose calculations of the spin-dependent observables for ^{40}Ca are shown in Fig. 1. Both calculations provide a satisfactory description of the measurements, even though there are differences between the theoretical developments. Tjon and Wallace[5] include contributions from a broad range of relativistic invariants and amplitudes, while Horowitz and Murdock[6] include a density-dependent correction for Pauli blocking.

Relativistic optical model calculations now employ only vector and scalar potentials, even though a tensor potential is allowed. The tensor density of a nucleus measures the interference between positive and negative energy components, and is largest for nuclei such as ^{48}Ca where the filled $f_{7/2}$ neutron shell has no $f_{5/2}$ companion. Because the amplitudes come from a meson-exchange model of nucleon-nucleon scattering, the impulse approximation can provide an estimate of the size of the tensor potential. Calculations from Ref. 6 are shown in Fig. 2 with and without the tensor potential. While the effects show up most strongly in Q, they are still too small to matter at the present level of agreement between theory and experiment.

Additional calculations from Ref. 6 for ^{12}C and ^{16}O are shown in Fig. 3. The agreement becomes worse with decreasing mass, probably as a result of less precise ground state densities and the neglect of recoil corrections. Nevertheless, the Q measurements for all targets exhibit very similar features which the calculation is capable of describing.

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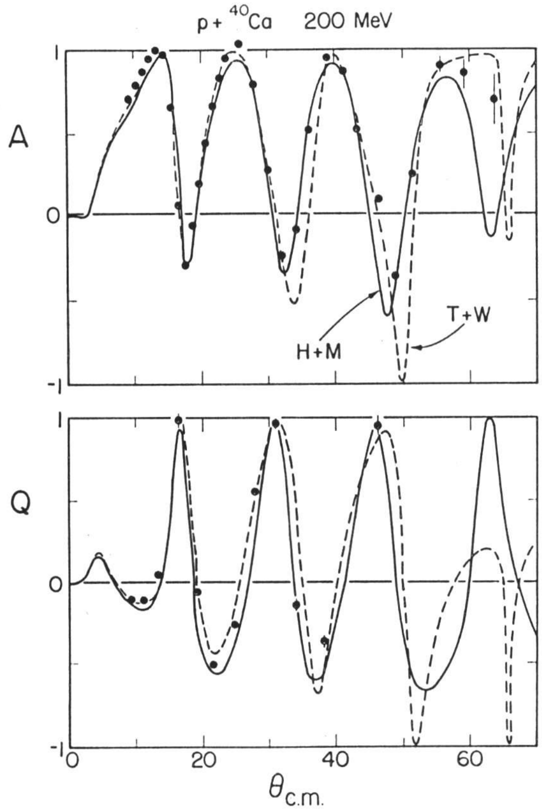

Fig. 1. Measurements of A and Q for ^{40}Ca. The RIA calculations are from Tjon and Wallace[5] (T+W) and Horowitz and Murdock[6] (H+M).

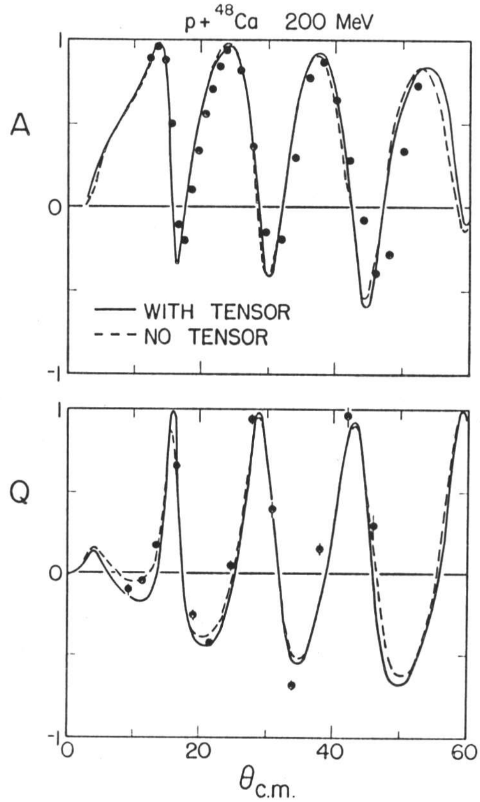

Fig. 2. Measurements of A and Q for ^{48}Ca. The calculations from Ref. 6 were made with (solid) and without (dashed) a tensor potential.

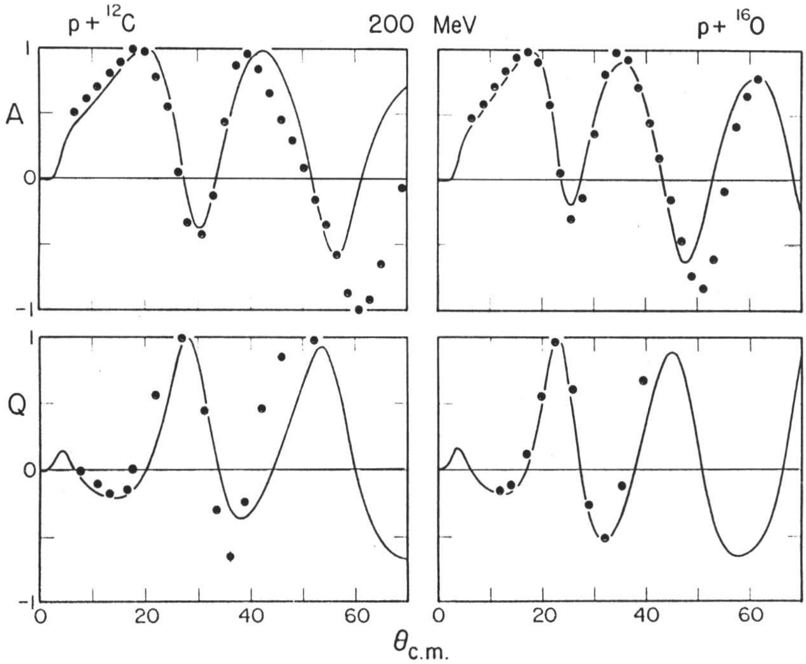

Fig. 3. Measurements A and Q for ^{12}C and ^{16}O, with calculations from Ref. 6.