MEDIUM EFFECTS IN THE NORMAL COMPONENT POLARIZATION OBSERVABLES FOR THE $^{13}C(\vec{p},\vec{p}')^{13}C$, $1/2^- \rightarrow 9/2^+$ REACTION AT 200 MeV

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Free nucleon-nucleon scattering can be described by the following t matrix:[1,2]

$$t_{free} = t_0^C + t_\sigma^C \vec{\sigma}_1 \cdot \vec{\sigma}_2 + t^{SO} (\vec{\sigma}_1 + \vec{\sigma}_2) \cdot \hat{n} + t^{TD} S_{12}(\hat{q}) + t^{TX} S_{12}(\hat{Q}),$$

where the five individual amplitudes represent the central spin-independent, central spin-dependent, spin-orbit, tensor-direct and tensor-exchange parts of the interaction. Each of the amplitudes are also functions of the scattering kinematics as well as the total two-body isospin. However, when nucleons interact inside the nuclear medium, this fundamental interaction may be modified due to effects of the strong nuclear field environment. This would lead to a nucleon-nucleon interaction that would depend on the nuclear density. Indeed, it has already been proposed, based on QCD sum rule techniques, that the short ranged repulsive core becomes stronger with increasing density.[3] Similar results also arise in other theoretical treatments.[4,5] Therefore, detailed knowledge of this interaction as a function of the nuclear density is important for our understanding of the properties of nuclear matter.

One way to probe such modifications experimentally is through $(\vec{p},\vec{p}')$ measurements from nuclear targets. Within an impulse approximation framework,[6] the three main ingredients for a calculation of a nucleon-nucleus scattering observable are: 1) the structure of the transition under study, 2) distortions, and 3) the effective nucleon-nucleon interaction. By using (e,e$'$), (π,π'), and proton elastic scattering measurements,[7–10] it is possible to constrain the transition formfactor and the optical model distortions in a way independent of the $(\vec{p},\vec{p}')$ data. With the uncertainties in structure and distortions at a minimum, detailed knowledge about the in-medium nucleon-nucleon interaction can be obtained. One effect known to modify this interaction is Pauli blocking, which inhibits scattering to states below the Fermi momentum. The purpose this experiment, E379, was to obtain information about the isoscalar component of the effective interaction. This information will then be included in a global analysis with other IUCF data[11,12] to define the effective interaction at 200 MeV.

The collaboration measured the normal component spin observables, A_y, P and $D_{nn'}$, and cross section, $d\sigma/d\Omega$, for the reaction $^{13}C(\vec{p},\vec{p}')^{13}C$ to the "stretched" $9/2^+$ state at $E_{\rm exc} = 9.50$ MeV in the range $\theta_{cm} = (20° - 80°)$ at 200 MeV bombarding energy. Cross sections and analyzing powers were measured in 3° steps while P and $D_{nn'}$ were observed

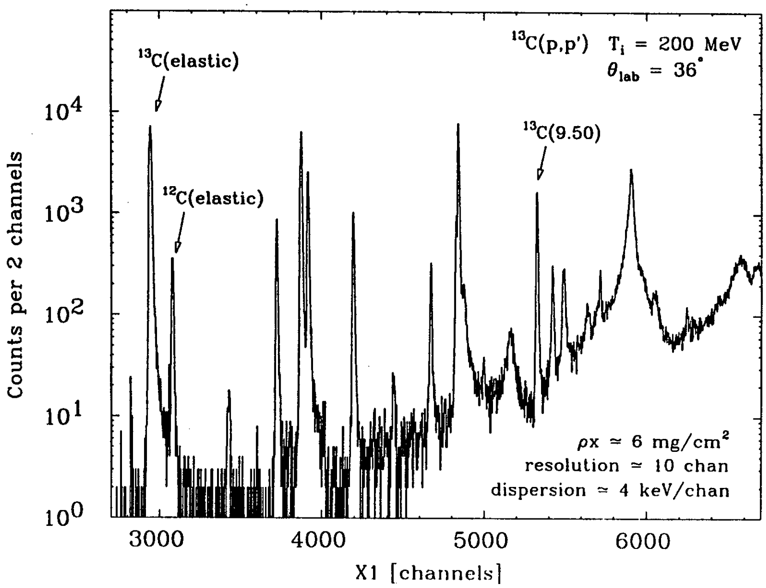

Figure 1. An online spectrum of scattered protons from ^{13}C for a proton bombarding energy of 200 MeV and a spectrometer angle of 36°. The state of interest for this experiment is labeled as ^{13}C(9.50) and is shown cleanly separated from the neighboring states with a resolution of the order of 40 keV (FWHM) (with a 6 mg/cm^2 target thickness).

only in steps of 9°. This measurement was performed on the K600 magnetic spectrometer at IUCF and utilized the existing medium-dispersion port focal plane detection system to detect the scattered protons and the focal plane polarimeter to determine their polarization. The targets were fabricated at IUCF by Bill Lozowski of enriched carbon with isotopic purities better than 99%, and ranged in thickness from 3.6 mg/cm^2 to 16 mg/cm^2. With the K600 dispersion-matching system, resolutions ranged from 40 keV (FWHM) at best to 80 keV (FWHM) for the thickest targets at large angles. Data were also obtained for elastic scattering $^{13}\mathrm{C}(\vec{\mathrm{p}},\vec{\mathrm{p}})^{13}\mathrm{C}$, and the analyzing powers extracted online agreed well with a previous measurement by H.O. Meyer *et al.*[10] at IUCF.

Shown in Fig. 1 is an online spectrum of scattered protons from a ^{13}C target of thickness $\simeq$ 6 mg/cm^{2}measured at a spectrometer angle of 36°. The elastic peaks from ^{13}C and ^{12}C are identified, as well as the ^{13}C peak of interest at $E_{\rm exc} = 9.50$ MeV with $J^{\pi} = 9/2^{+}$. The resolution obtained for the state was of the order of 40 keV (FWHM) and its peak was cleanly separated from the peaks of the two nearby states, the ^{13}C(8.86) $1/2^-$ and ^{13}C(9.90) $3/2^-$. For all other angles the 9.50 MeV state was cleanly isolated except for spectrometer angles near 72°, where the scattering peaks from the ^{12}C(7.65) state and ^{13}C(9.50) state cross through each other.

Plotted in Fig. 2 as the open circles are the online differential cross sections for the reaction $^{13}\mathrm{C}(\mathrm{p},\mathrm{p}')^{13}\mathrm{C}$, $1/2^- \rightarrow 9/2^+$ at $E_{\rm exc} = 9.50$ MeV. The normalizations for these measurements were checked by comparing the ^{13}C elastic measurements with published data.[10] For all but the two largest angle points, the differences were within expected normalization uncertainties of 20%. The origin of the large normalization error is not known, but could have arisen if part of the beam spot, which was wide to facilitate dispersion

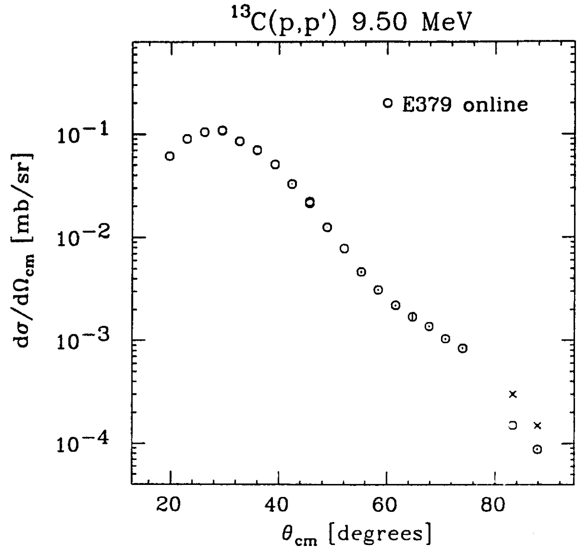

Figure 2. Online results for the $1/2^- \rightarrow 9/2^+$ differential cross section are plotted as open circles. The two points indicated by crosses were corrected for an apparent normalization problem by comparing the ^{13}C elastic scattering measurements with published data.[10]

matching, missed the target. Using the ^{13}C elastic measurements to normalize these points yielded the results indicated by crosses.

Shown in Fig. 3 are the online results for the normal component spin observables for this transition. The top panel plots the analyzing power A_y, the middle panel the induced polarization P, and the bottom panel the normal component spin transfer coefficient $D_{nn'}$ as functions of the center of mass scattering angle θ_{cm}. Plotted along with the data are curves from a DWBA calculation using structure and distortion effects from published (e,e′) and (p,p′) data for this transition.[7,8,10] The solid curve is the calculation using the free nucleon-nucleon t-matrix derived from the SM93 phase shift solution of Arndt.[13] This result only qualitatively describes the features present in the data. The dashed curve includes a modification of the free interaction due to Pauli blocking in the medium.[14] It, too, is not able to describe the data quantitatively. We expect these measurements over a broad range of momentum transfer will give us a clearer picture of the effective interaction at 200 MeV. A full analysis of these data is underway at IUCF.

1. W.G. Love and M.A. Franey, Phys. Rev. C **24**, 1073 (1981).
2. M.A. Franey and W.G. Love, Phys. Rev. C **31**, 488 (1985).
3. T. Hatsuda and S. Huong Lee, Phys. Rev. C **46**, R34 (1992).
4. G.E. Brown and M. Rho, Phys. Lett. **B237**, 3 (1990).
5. G.E. Brown and M. Rho, Phys. Rev. Lett. **66**, 2720 (1991).
6. A.K. Kerman, H. McManus and R.M. Thaler, Ann. Phys. **8**, 551 (1959).
7. R.S. Hicks, *et al.*, Phys. Rev. C **34**, 1161 (1986).
8. R.S. Hicks, *et al.*, Phys. Rev. C **36**, 485 (1987).
9. S.J. Seestroom-Morris, *et al.*, Phys. Rev. C **26**, 594 (1982).

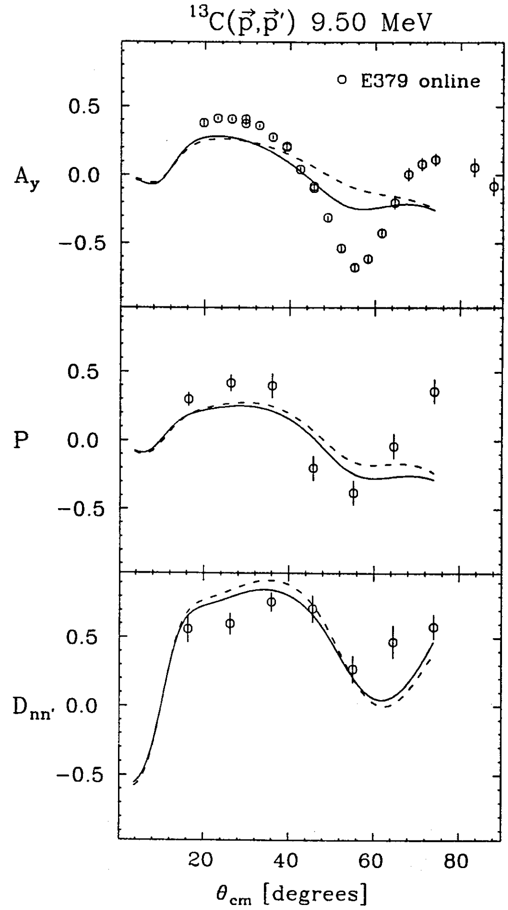

Figure 3. Online results for the normal component polarization observables, A_y, P and $D_{nn'}$. The solid curve is a DWBA calculation using the free nucleon-nucleon t matrix, t_{free}, for the interaction. The dashed curve includes the modification to the free interaction due to Pauli blocking.

10. H.O. Meyer, *et al.*, Phys. Rev. C **23**, 616 (1981).
11. H. Baghaei, *et al.*, Phys. Rev. Lett. **69**, 2054 (1992).
12. S. Chang, *et al.*, IUCF Sci. and Tech. Rep., May 1992 – April 1993, p. 16.
13. R. Arndt, private communication.
14. K. Nakayama and W.G. Love, Phys. Rev. C **38**, 51 (1988).