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THE  $^{12}\text{C}(p,p')^{12}\text{C}$  REACTION AT MEDIUM ENERGIES: LARGE MOMENTUM TRANSFER AND DENSITY DEPENDENT FORCES

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In recent years efforts have been made to deduce a self-consistent, density-dependent, effective nucleon-nucleon (NN) interaction in the nuclear medium.<sup>1</sup> The success of this program became evident when it was possible to correctly predict the qualitative shape and energy dependence of the optical potential describing medium energy elastic scattering<sup>2-5</sup> and when it was shown that the use of a density dependent interaction improves the description of the transition between nuclear states in proton inelastic scattering.<sup>6</sup>

We have measured proton inelastic scattering from  $^{12}\text{C}$  to the first excited  $2^+$  state in  $^{12}\text{C}(E_x=4.44 \text{ MeV})$ . Except for the measurements at forward angles at 122 and 200 MeV<sup>7,8</sup>, the data are a by-product of an investigation of proton elastic scattering from  $^{12}\text{C}$ .<sup>3-5</sup> They constitute the most complete set of measurements on an inelastic proton scattering transition available at medium energy at present. The experiment was performed at incident lab energies of 121.9, 159.6, and 200.0 MeV using a magnetic spectrometer (QDDM). Both natural and enriched self-supporting  $^{12}\text{C}$  targets were employed, ranging in thickness from 2 mg/cm<sup>2</sup> to 132 mg/cm<sup>2</sup>. The angular range covered was from 6° to 154° in the laboratory which, e.g., at 160 MeV corresponds to a range of transferred momentum  $q$  of 50 to 1000 MeV/c.

Three ingredients enter calculations of  $(p,p')$  in the distorted-wave t-matrix approximation (DWTA): the optical potential for generating the distorted waves, the wavefunction (or the transition density) for the excited state and the effective interaction between projectile and target nucleons.

In order to study the influence of the potential generating the distorted waves on the inelastic scattering results, we have compared calculations using a standard Woods-Saxon potential with the results obtained if a non-standard shape is assumed. Here, two modifications to the conventional Woods-Saxon form have been introduced: The real central potential is given as a sum of two Woods-Saxon terms yielding a depression in the center, as predicted by microscopic theories.<sup>1</sup> Secondly, the spin-orbit potential (both real and imaginary parts) involves the derivative of the ground-state density distribution (obtained, e.g., from elastic electron scattering) instead of the conventional derivative of a Woods-Saxon form factor. The parameters for both these types of optical potentials are given in Ref. 5.

Since we also wanted to test the sensitivity of the results of our calculations to the transition form factor we have compared two different wave functions which are both commonly accepted. These are, on one hand, the shell-model wave function calculated

by Cohen and Kurath<sup>9</sup> and, on the other hand, the random-phase-approximation (RPA) wave function obtained by Gillet and Vinh Mau.<sup>10</sup> A correction factor for the Cohen-Kurath wave functions taking core polarization effects into account can be determined experimentally from elastic electron scattering and leads to a renormalization factor of 2.0 for the cross section. In contrast to the Cohen-Kurath result, core polarization is included in the RPA wave functions. In the present case, all shells up to the (2p,1f)-shell were taken into account for the particle-hole excitation.

Compared to earlier work (e.g., Refs. 7,8) the most important new theoretical ingredient is represented by the choice of the effective force between projectile and target nucleon. In contrast to a force which is based on the free NN t-matrix, we use a density-dependent force obtained by solving a Bethe-Goldstone equation as outlined in Ref. 1. At present, two different numerical tabulations of the t-matrix representing the effective NN interaction are available for practical calculations. In the first (F1),<sup>11</sup> the Hamada-Johnston potential has been used to parametrize the free NN interaction while the second (F2)<sup>12</sup> is based on the more recent Paris potential.

Only the central scalar-isoscalar, the spin-orbit isoscalar and the tensor-isoscalar parts contribute significantly to a transition from the ground state to the first excited state in <sup>12</sup>C (a natural-parity isoscalar transition). Preliminary calculations with the force based on the Paris potential showed in addition that the tensor interaction contributes only very weakly. It was thus omitted in all calculations. In all cases the exchange contributions have been treated exactly. In Fig. 1 we present experimental

cross sections and analyzing powers for <sup>12</sup>C( $E_x=4.44$  MeV), measured at lab energies of 122, 160, and 200 MeV. The analyzing power data in particular are characterized by pronounced structure persisting to large momentum transfers, while the cross section data exhibit notable angular structure only beyond  $q \sim 750$  MeV/c. In Fig. 1 the data points are compared with two DWTA calculations, differing in the underlying effective NN interaction, namely the Hamada-Johnston potential (F1) and the Paris potential (F2). In both cases Cohen-Kurath wave functions and the non-standard double Woods-Saxon distorting potential have been used. The fact that the data are available up to large momentum transfers (1100 MeV/c) is important since calculations with the two interactions, because of their difference in off-shell behavior, are expected to differ mainly at large momentum transfer.

In summary, the calculations presented here represent a good description of the data up to  $q=400-500$  MeV/c. The introduction of a density-dependent interaction provides a very significant improvement over earlier calculations.

We present evidence that it is important to acquire (p,p') data to as high a momentum transfer as is technically feasible: only this information allows us to test the off-shell behavior of the effective interaction, with the proviso, of course, that more care will be devoted to the description and test of the high-momentum components of the nuclear wave functions. It is also clear that the availability of the analyzing power measurements is crucial.

The present calculations are shown to depend quantitatively on all input parameters. On this level, valid conclusions about any one of them are possible only after a careful scrutiny of all others, a task

which may be facilitated by selecting certain transitions with a particularly simple spin-isospin configuration and with supporting data, such as (e,e')

and (p,p') available over the whole range of momentum transfers investigated, which should be as large as is feasible.

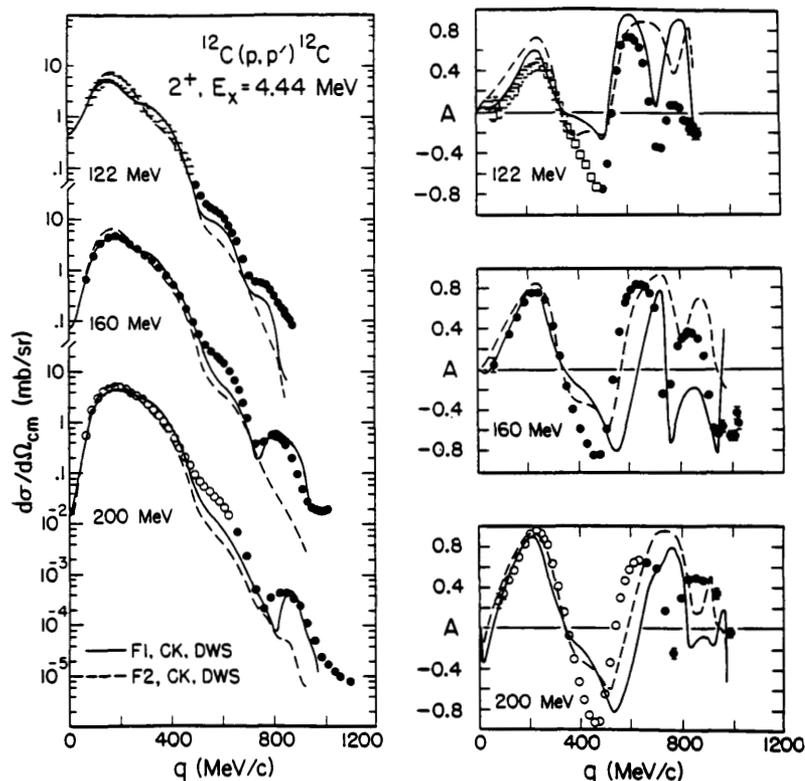


Figure 1. Cross section and analyzing powers for the  $^{12}\text{C}(p,p')^{12}\text{C}$  ( $2^+, E_x=4.44$  MeV) reaction at 122, 160, and 200 MeV. The solid dots are from the present work, the open squares from Ref. 7 and the open circles from Ref. 8. Both calculations shown are with the Cohen-Kurath wave functions (CK) and the non-standard distorting potential (DWS). The solid line was obtained using the effective force F1 (based on the Hamada-Johnston potential); the dashed line corresponds to force F2 (based on the Paris potential).

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FRAGMENTATION OF HIGH-SPIN PARTICLE-HOLE STATES IN  $^{26}\text{Mg}$

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Systematic information is now being obtained on the excitation of spin-flip degrees of freedom throughout the periodic table from inelastic scattering and charge exchange reactions. A systematic quenching of the isovector spin-flip strength has been identified,<sup>1</sup> though the quenching mechanism is not understood. Inelastic proton and pion scattering reactions also indicate a large quenching for isoscalar spin-flip excitations, but the systematics of this effect are less well-established.<sup>2,3</sup>

Several theoretical explanations have been offered for this reduction in the spin-flip strength. The explanations include: fragmentation of the single-particle strength,<sup>4</sup> mesonic renormalization of the spin current,<sup>5</sup> and the explicit inclusion of  $\Lambda(1232)$  isobar-hole states.<sup>6</sup> It appears that it may be possible to separate these mechanisms by studying the inelastic transition strengths as a function of single-particle occupation probability and as a function of angular momentum. The deformed nuclei in the s-d shell seem to be excellent candidates for such a study. The single particle occupation probabilities

as determined by single nucleon transfer reactions change rapidly as the ground-state deformation changes. Also, several high-spin,  $6^-$ , and low-spin,  $1^+$ , states are known from previous work.<sup>2,3,7</sup>

We have measured the angular distributions and analyzing powers for polarized proton scattering from  $^{26}\text{Mg}$  at 135-MeV incident energy. Angular distributions were measured in  $5^\circ$  steps from a laboratory angle of  $10^\circ$  to  $60^\circ$  for states in the excitation energy range from 0 to 20 MeV. A typical spectrum is shown in Fig. 1. Based on the angular distributions of the cross sections and analyzing powers, five  $6^-$  states at excitation energies of  $9.18 \pm 0.03$  MeV,  $11.98 \pm 0.05$  MeV,  $12.48 \pm 0.05$  MeV,  $12.85 \pm 0.05$  MeV and  $18.0 \pm 0.1$  MeV have been identified. The 18-MeV level is believed to be a T=2,  $6^-$  state.

Further analysis is in progress to improve the knowledge of the energy calibration.

DWIA calculations are being performed to extract the transition strengths for each state. Preliminary calculations indicate that the yield to the  $6^-$ , T=2