Optical model calculation of elastic and charge exchange scattering of protons from trinucleons

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(Received 28 May 1985)

Elastic and charge exchange scattering of intermediate energy protons from ^{3}He and tritium is calculated with a microscopic, momentum space optical potential. Full spin dependences, form factors derived from realistic three-body calculations, and off-shell kinematics are included. High sensitivity is found to the removal of meson exchange currents from nuclear densities and to the choice of input NN phase shifts.

I. INTRODUCTION

Proton scattering from ^{3}He is interesting but difficult to calculate well. Its interest arises from the large spin effects present when one third of the nucleons in a target have unpaired spin, and from being able to study a nucleus whose structure can be determined from first principles. The difficulty arises from being in somewhat of a no man's land at intermediate energies: it is too high an energy for resonating group or variational calculations to be practical, yet too low an energy for diffractive models to be applicable at large angles; it is too small a system for the phenomenological optical potential to work well, yet too large a system for an exact solution of the four-body problem.

The interest and challenge of this problem is further heightened by the complete angular distributions now being accumulated at many energies[1] and the extensive knowledge of the structure of the three-nucleon (3N) system. Part of the challenge in using that structure information arises from the 3N electromagnetic form factors containing large contributions from meson exchange currents (MEC's) (Ref. 2) which should be removed before they can be used to construct a theory for hadron scattering. These currents are interesting because they require us to view the nucleus as more than a collection of nucleons. They are also relevant to the recent Dirac equation studies of proton scattering[3,4] since the negative energy states of the projectile nucleon are a crucial addition of the Dirac approach,[4] whereas negative energy states of the bound nucleon are included in the "meson" current corrections to the form factors.[2]

A fascinating aspect of proton scattering from light nuclei is the presence of back angle peaks that appear and disappear as a function of energy. While it has long been appreciated that these peaks have their origins in an exchange mechanism of some sort, our previous study[5] was a definitive indication that much of the peaking arises from antisymmetry at the nucleon-nucleon (NN) level. Additional, fundamental calculations of these mechanisms at medium energies are just now being attempted and it is important to perfect these calculations in order to unravel some of the interesting physics that occurs at large momentum transfers.

In this paper we extend our earlier study of proton-^{3}He scattering at intermediate energies using a momentum space optical potential.[5,6] We examine the sensitivity of using different sets of NN phase shifts and improved nuclear form factors with MEC's removed. We also report on our study of the isospin related reactions, elastic and charge exchange scattering from tritium.

The starting point in our calculations is still the first order optical potential, Eq. (1), and our aim is still to determine how accurate a description is provided by a realistic and careful evaluation of that potential. Essentially, our calculation is a parameter-free evaluation of the "impulse approximation" with the Lippman-Schwinger equation used to generate higher orders of multiple scattering. Since the nucleon-nucleon amplitudes are antisymmetrized, they inherently include some "exchange" effects. This calculation should be contrasted with others of medium energy proton-helium scattering which employ: a phenomenological potential (strengths and/or sizes adjusted to data)—sometimes with the contribution from additional exchange diagrams added in as separate terms;[7] direct application of a simplified form of the impulse approximation;[8] or a diffractive model whose utility at medium energies is questionable.

While it appears reasonable to first study the simple "t-ρ" approximation to U before undertaking complicated calculations of correlation and many-body effects, the reader should keep in mind that higher order corrections are expected to be large for light nuclei and so our theory is not complete. For example, many-body effects are crucial at low energies where resonating group and variational calculations succeed in reproducing the data,[9] a similar model to ours is not truly precise for even small angle scattering from heavier nuclei,[10] and there are corrections on the order of 20% in p-^{4}He scattering at 1 GeV from higher order effects which we ignore.[11] Thus, while we are encouraged that our investigation shows that a relatively simple, microscopic model can be used to understand at least the grosser features of high momentum transfer proton scattering from light nuclei, further extension will be necessary before rigorous conclusions can be drawn.

II. THEORY

A. First order optical potential

We describe p-^{3}He scattering with the momentum space optical potential:

$$
\begin{aligned}
U^{(1)}(\mathbf{k}',\mathbf{k};E)&=\langle\psi_A\,|\,t^{\mathrm{pN}}_{(\omega)}\,|\,\psi_A\rangle\\
&\approx N\{t^{\mathrm{pn}}_{A+B}\rho^{\mathrm{n}}_{\mathrm{matter}}(q)+[t^{\mathrm{pn}}_{A-B}\sigma_{\mathrm{p}}\cdot\hat{\mathbf{n}}\sigma_{\mathrm{n}}\cdot\hat{\mathbf{n}}+t^{\mathrm{pn}}_{E}\sigma_{\mathrm{n}}\cdot\hat{\mathbf{n}}+t^{\mathrm{pn}}_{C+D}\sigma_{\mathrm{p}}\cdot\hat{\mathbf{m}}\sigma_{\mathrm{n}}\cdot\hat{\mathbf{m}}+t^{\mathrm{pn}}_{C-D}\sigma_{\mathrm{p}}\cdot\hat{l}\sigma_{\mathrm{n}}\cdot\hat{l}\\
&\quad+t^{\mathrm{pn}}_{CD}(\sigma_{\mathrm{p}}\cdot\hat{\mathbf{m}}\sigma_{\mathrm{n}}\cdot\hat{l}+\sigma_{\mathrm{p}}\cdot\hat{l}\sigma_{\mathrm{n}}\cdot\hat{\mathbf{m}})]\rho^{\mathrm{n}}_{\mathrm{spin}}(q)+t^{\mathrm{pn}}_{E}\sigma_{\mathrm{p}}\cdot\hat{\mathbf{n}}\rho^{\mathrm{n}}_{\mathrm{matter}}(q)\}+\begin{Bmatrix}N&\to&Z\\ \mathrm{n}&\to&\mathrm{p}\end{Bmatrix}\,. \qquad (1)
\end{aligned}
$$

Here the ρ's describe the matter and spin distributions for n's and p's, and the t's are off-energy-shell NN T matrices in the NN center of mass (c.m.). The general form for the p-^{3}He and NN amplitude is

$$M=\tfrac{1}{2}[(A+B)+(A-B)\sigma_1\cdot\hat{\mathbf{n}}\sigma_2\cdot\hat{\mathbf{n}}+(C+D)\sigma_1\cdot\hat{\mathbf{m}}\sigma_2\cdot\hat{\mathbf{m}}+(C-D)\sigma_1\cdot\hat{l}\sigma_2\cdot\hat{l}+E(\sigma_1+\sigma_2)\cdot\hat{\mathbf{n}}+F(\sigma_1-\sigma_2)\cdot\hat{\mathbf{n}}], \qquad (2)$$

where $\hat{\mathbf{n}}$, $\hat{\mathbf{m}}$, and $\hat{l}$ are the unit vectors,

$$
\begin{aligned}
\hat{\mathbf{n}}&=\frac{\mathbf{k}_i\times\mathbf{k}_f}{|\,\mathbf{k}_i\times\mathbf{k}_f\,|}\,,\\
\hat{l}&=\frac{\mathbf{k}_i+\mathbf{k}_f}{|\,\mathbf{k}_i+\mathbf{k}_f\,|}\,,\\
\hat{\mathbf{m}}&=\frac{\mathbf{k}_f-\mathbf{k}_i}{|\,\mathbf{k}_f-\mathbf{k}_i\,|}\,,
\end{aligned}
\qquad (3)
$$

$(\mathbf{k}_i,\mathbf{k}_f)$ is the (initial, final) c.m. momentum, and the amplitudes $A-F$ are functions of $\mathbf{k}_f$ and $\mathbf{k}_i$ but not spin. For identical particles (e.g., two nucleons) the F term vanishes via the generalized Pauli principle. Details related to constructing this optical potential and solving the spin-coupled Lippman-Schwinger equations are found in Ref. 5. Physically, our potential is microscopic, and includes the full spin structure for spin $\frac{1}{2}\times\frac{1}{2}$ scattering, antisymmetrized NN amplitudes, and realistic nuclear form factors. Since we work in momentum space we are also able to employ a three-body model for the energy variable ω in the optical potential and thus incorporate unitarity, nucleon binding, and recoil effects.

The T matrices in $U(\mathbf{k}',\mathbf{k}';E)$ are determined from phase shifts for the on-energy-shell behavior, and from a nonlocal separable potential model for the off-shell behavior. This off-shell behavior, while not unique, does incorporate the important constraints of a finite ranged NN force. The T matrices are transformed to the p-nucleons c.m. with a covariant, "optimal" impulse approximation that incorporates the full angular and nonlocal nature of the kinematics. We have used this transformation successfully in preceding pion, kaon, and nucleon calculations,[12] and note that it is equivalent to the newfound, but misnamed, use of "Breit frame" kinematics. With these nonlocalities, energy, spin, angle, and momentum dependences included, we are able to determine all the p-3N spin observables predicted by the optical potential (1).

B. Improved form factors

To describe the matter and spin distributions of n's and p's, the optical potential (1) requires four form factors. In our original work,[12] we were able to solve for these four in terms of the three, electromagnetic form factors [$F_{\mathrm{ch}}(^3\mathrm{He})$, $F_{\mathrm{ch}}(^3\mathrm{H})$, and $F_{\mathrm{mag}}(^3\mathrm{He})$], by approximating some small terms. Since the momentum transfers for proton scattering can be large, and since small corrections have now been noted (even for pion scattering[13]), we need to improve our model. Part of this improvement is the removal of MEC contributions in these form factors to produce pure "nucleonic" ones. It is important to make this

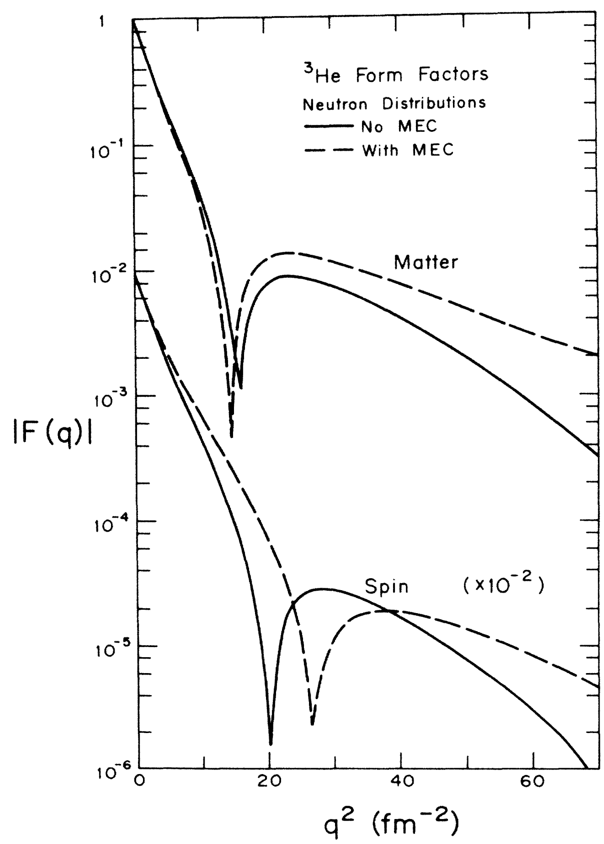


FIG. 1. The neutron matter and spin form factors for ^{3}He deduced from results of the three-body calculations of Ref. 2. The dashed curves contain (spurious) contributions from electromagnetic meson exchange currents, the solid curves do not.

removal since the electromagnetic MEC contributions are for photon coupling not hadronic scattering; MEC corrections to proton-nucleus scattering are presumably included in the pN T matrices.

The removal of MEC's is an old concern for nuclear theory. While some of the elementary techniques to do it were already spelled out in the key papers of Gibson and Schiff,[14] the problem is that unless the electromagnetic form factors are reproduced accurately with a theory including MEC, there is no reliable way to "turn off" the MEC contributions. Fortunately, recent calculations of Hadjimichael, Goulard, and Bornais[2] reproduce all of the 3N form factors out of $q^2 \simeq 80$ fm^{-2} with a basis of nucleons, isobars, and mesons, and find that beyond $q^2=20$ fm^{-2} , much of the electromagnetic form factors arise from MEC. We now use their pure nucleonic wave functions in our calculation.

If we again start with the analyses of Gibson and Schiff,[14] we obtain our previous expressions for the matter form factors:

$$\rho^{p}_{matter}(q)=F_{ch}(^3\mathrm{He})/f^{p}_{ch} \ , \tag{4}$$

$$\rho^{n}_{matter}(q)=F_{ch}(^3\mathrm{H})/f^{p}_{ch} \ . \tag{5}$$

Here the form factors are pure nucleonic, f^{p}_{ch} is the elementary proton's charge form factor, and we have assumed $f^{n}_{ch}=0$. For the spin form factors we obtain

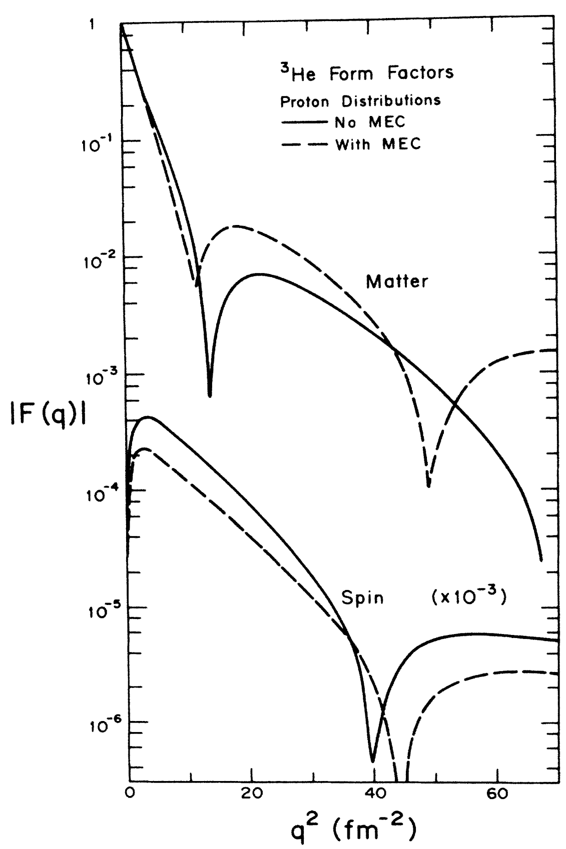


FIG. 2. Same as Fig. 1, only now for the distribution of protons.

$$\rho^{n}_{spin}(q)=\{\mu_p[\mu_{^3\mathrm{H}}F'_m(^3\mathrm{H})-Y(^3\mathrm{H})] -\mu_n[\mu_{^3\mathrm{He}}F'_m(^3\mathrm{He})-Y(^3\mathrm{He}]\}/[f^{p}_{ch}(\mu_p^2-\mu_n^2)] \ , \tag{6}$$

$$\rho^{p}_{spin}(q)=\{\mu_p[\mu_{^3\mathrm{He}}F'_m(^3\mathrm{He})-Y(^3\mathrm{He})] -\mu_n[\mu_{^3\mathrm{He}}F'_m(^3\mathrm{H})-Y(^3\mathrm{H})]\}/[2f^{p}_{ch}(\mu_p^2-\mu_n^2)] \ , \tag{7}$$

where μ_i is the magnetic moment of particle "i" and Y is the MEC correction. If we make the MEC correction and replace the static nuclear magnetic moments by nucleon values, we obtain form factors with the normalization,

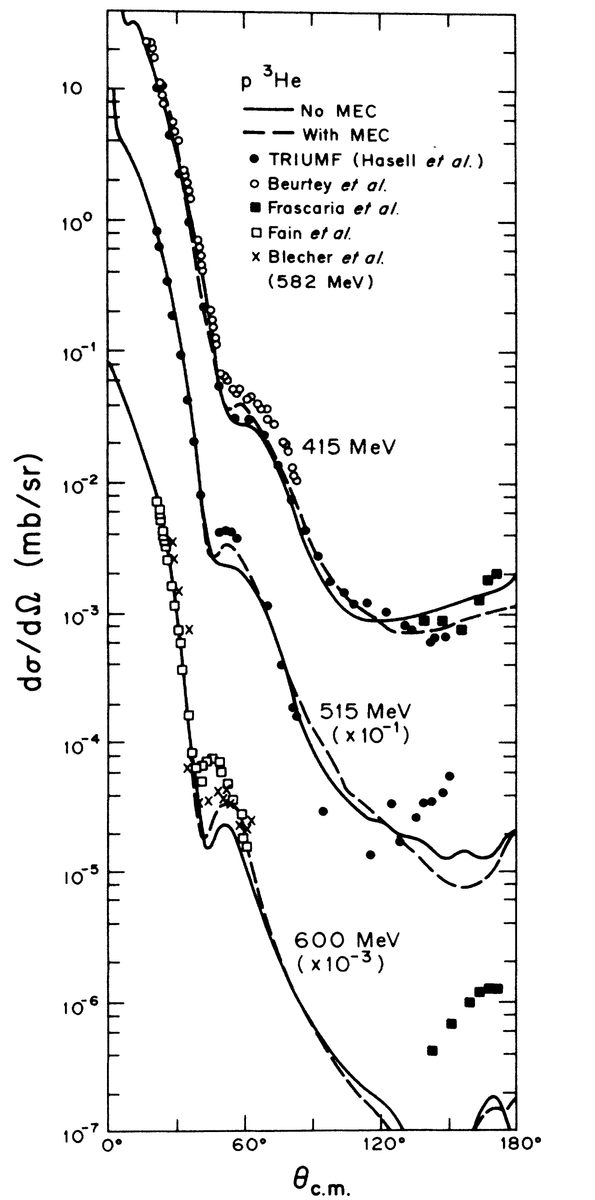


FIG. 3. p-^{3}He differential cross sections for 415, 515, and 600 MeV proton scattering. The dashed curves are calculated with form factors that contain (spurious) contributions from electromagnetic MEC's, the solid curves are not. The data are from Refs. 1 and 15–18.

$$\rho^{\mathrm{n}}_{\mathrm{spin}}(0)=1,\ \ \rho^{\mathrm{p}}_{\mathrm{spin}}(0)=0\ , \tag{8}$$

and explicit form:

$$\rho^{\mathrm{n}}_{\mathrm{spin}}(q)=[\mu_{\mathrm{p}}^2F_m({}^3\mathrm{H})-\mu_{\mathrm{n}}^2F_m({}^3\mathrm{He})]/[f^{\mathrm{p}}_{\mathrm{ch}}(\mu_{\mathrm{p}}^2-\mu_{\mathrm{n}}^2)], \tag{9}$$

$$\rho^{\mathrm{p}}_{\mathrm{spin}}(q)=\mu_{\mathrm{p}}\mu_{\mathrm{n}}[F_m({}^3\mathrm{He})-F_m({}^3\mathrm{H})]/[2f^{\mathrm{p}}_{\mathrm{ch}}(\mu_{\mathrm{p}}^2-\mu_{\mathrm{n}}^2)]\ . \tag{10}$$

These form factors are presented in Figs. 1 and 2. The solid curves are purely nucleonic, the dashed curves contain (spurious) MEC contributions. The MEC contributions are very large and tend to raise the form factors at large q values (where they differ significantly from our previous form factors).

It is important to note that our "removal" of MEC effects from the form factors does not provide a consistent relativistic theory; clearly there are also relativistic corrections to be made to the NN amplitudes, to the three-body wave functions, and to the scattering equations and optical potentials themselves. Indeed, we are working on some of these improvements now. Seeing the importance of the removal of MEC effects from the form factors will, however, indicate whether this one type of relativistic effect is important and whether it should be included in more complete calculations in the future.

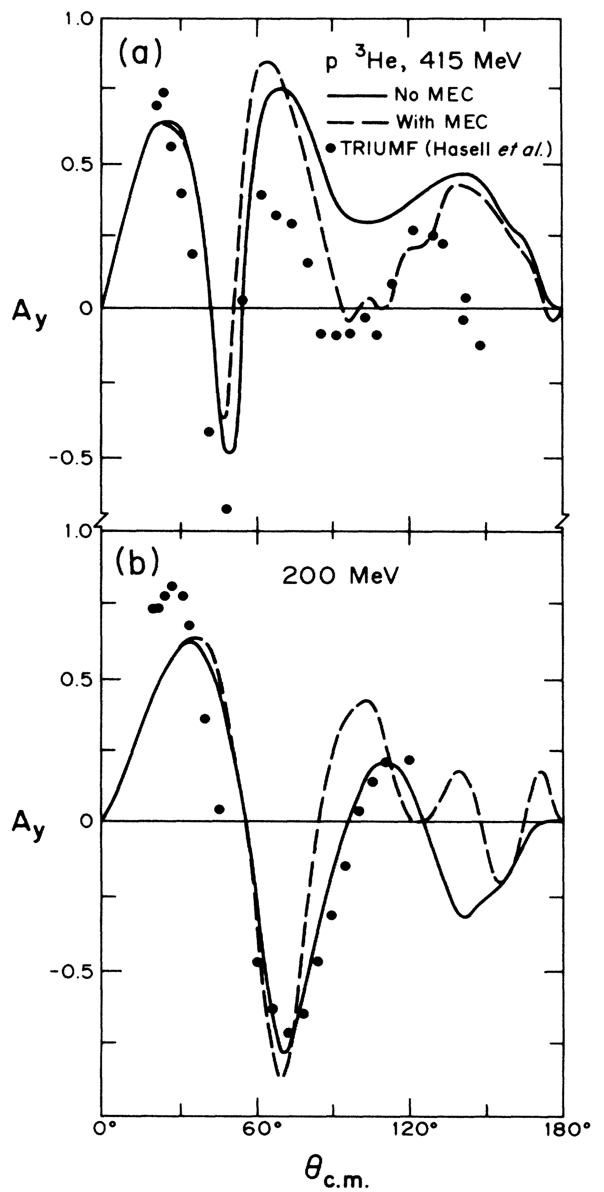


FIG. 4. p-^{3}He analyzing powers at 200 and 415 MeV are compared with calculations including and removing MEC's in the nuclear density. The data are from Ref. 1.

III. p-^{3}He RESULTS AND DISCUSSION

A. MEC removal

In Fig. 3 we show the effect of MEC removal on predicted differential cross sections for 415, 515, and 600 MeV proton scattering from ^{3}He. The data are from Hasell *et al.*,[1] Beurtey *et al.*,[15] Fain *et al.*,[16] and Blecher *et al.*[17] In Fig. 4 an analogous comparison is made for the analyzing power. Improved numerical techniques make these curves smoother than those in Ref. 5. The effect of MEC removal on $d\sigma/d\Omega$ is significant but still smaller than the scatter in the data. The effect on A_y is larger.

The qualitative agreement between the predicted A_y and experiment is reasonable for a parameter-free, microscopic calculation, yet the quantitative agreement is not good. The important point in this comparison is the significant changes in A_y when spurious MEC's are removed from nuclear densities. Since standard optical model calculations often use uncorrected electron scattering charge densities (the MEC contributions have not been calculated for heavier nuclei), not removing MEC's can be an important source of error.[19] This is also an important point to keep in mind when constructing relativistic optical potentials with Dirac wave functions. If the Dirac wave functions for the nucleons bound in the nucleus have been fit to experimental electromagnetic form factors, it may be difficult to remove the MEC's from them consistently since these currents also contain antinucleon degrees of freedom.

B. NN phase shift sensitivity

The optical potential (1) incorporates the full spin structure of the NN and N-^{3}He amplitude. It is conceivable, therefore, that a measurement of the differential cross section and some spin observables in p-^{3}He scattering may serve as a test of the NN amplitudes if the reaction theory and nuclear structure are understood adequately.

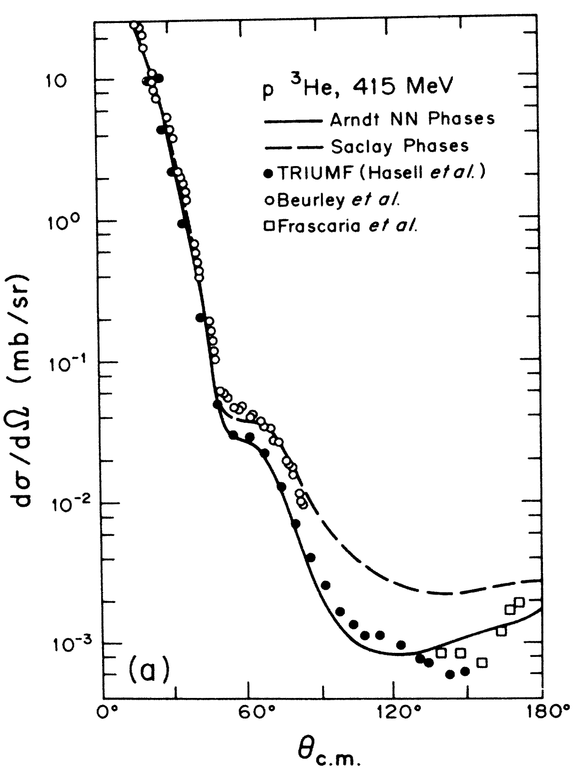
Since we are using a separable potential model for only the off-shell behavior of the NN T matrix, we have the flexibility of comparing predictions with different phase shifts used for the on-shell amplitudes. In Fig. 5 we present differential cross sections, and in Fig. 6 analyzing powers for p-^{3}He scattering using NN phases from (energy-averaged) "Saclay" (Bystricky *et al.*[20]) and Arndt[21] analyses. In all cases we employ pure nucleonic form factors.

The on-shell sensitivity is surprisingly high, especially at large scattering angles. To uncover the cause of this sensitivity we have examined the individual terms in the input NN amplitudes [the A's, B's, etc. used to construct the $U(\mathbf{k}',\mathbf{k})$ in Eq. (1)], and as shown in Fig. 7, find only small differences—even at 415 MeV where the p-^{3}He differences are largest. This suggests that the high sensitivity arises from interference among the six amplitudes combined to form the p-^{3}He scattering observables.

The sensitivity shown in Figs. 5 and 6 is consistent with the Glauber model calculations of Bizard *et al.*[22] and Bizard and Osmont[23] that compared the Saclay phases with the older MAW version of Arndt. This sensitivity would be large enough for p-^{3}He scattering to serve as a test of different NN phase shift sets—if the theory were more reliable and there were smaller systematic differences in the experimental p-^{3}He data. We call on our theoretical and experimental colleagues to improve this situation.

We have not thoroughly examined the off-shell sensitivity of our calculation, i.e., how our predictions would change if different potential or phenomenological models were used for the NN amplitudes. It seems likely that the off-shell effects would be the same size as the on-shell effects shown in Figs. 5 and 6. A comparison with other separable potential models (found by varying the parameters in the ones we use) produces small variations. A comparison with popular phenomenological models would be interesting but probably inconclusive since they have different on-shell behavior and do not include the finite range of the NN interaction with the same accuracy as the potential models.

The importance of kinematic and higher order multiple scattering effects have already been indicated in Ref. 5 where we generally found them to be smaller than the on-shell effects displayed here. Glauber model calculations[22–24] find relatively large "multiple scattering" corrections for large angle scattering at 600 MeV. However, since the summation of the multiple scattering series used in the present work appears to converge rapidly, and since the structure and agreement with data in the two approaches are so different, it does not seem reasonable to



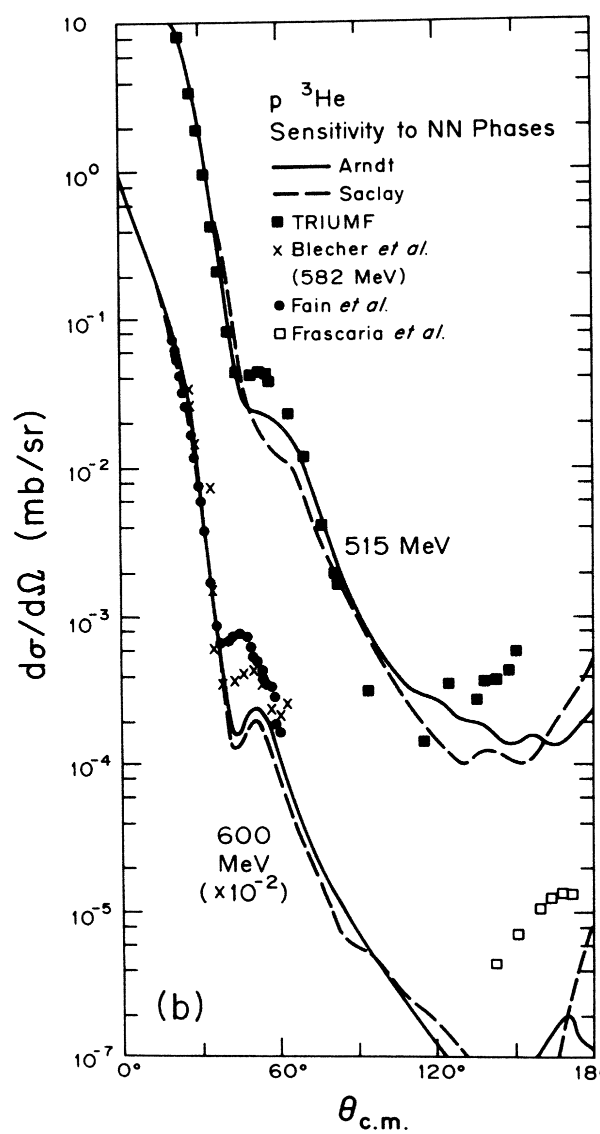


FIG. 5. Sensitivity of p-^{3}He differential cross sections to the use of the Saclay (Ref. 20) and Arndt (Ref. 21) fits to the NN phase shifts, (a) 415 MeV, (b) 515 and 600 MeV. The data are from Refs. 1 and 15—18.

extend their conclusions to our calculation. Although the Glauber approach is simpler, we must question its reliability at these low energies and large scattering angles; indeed, a strength of the present calculation is its careful inclusion of the kinematics, antisymmetries in the NN amplitudes, and nonlocalities that are crucial to describing large angle scattering.

IV. ELASTIC SCATTERING FROM TRITIUM

A unique aspect of the scattering from the three-nucleon system is the full determination of the scattering amplitude by measuring three "elastic" reactions:

$$p+{}^3\mathrm{He}\rightarrow p+{}^3\mathrm{He},$$

$$p+{}^3\mathrm{H}\rightarrow p+{}^3\mathrm{H},$$

$$p+{}^3\mathrm{H}\rightarrow n+{}^3\mathrm{He}.$$

Indeed, if isospin is a good symmetry, only isospin 0 and 1 amplitudes are needed to describe elastic scattering of the isodoublet N from isodoublet 3N:

$$\langle p^3\mathrm{He} \mid T \mid p^3\mathrm{He}\rangle = T_1 = \langle n^3\mathrm{H} \mid T \mid n^3\mathrm{H}\rangle, \tag{11}$$

$$\langle p^3\mathrm{H} \mid T \mid p^3\mathrm{H}\rangle = (T_1+T_0)/2 = \langle n^3\mathrm{He} \mid T \mid n^3\mathrm{He}\rangle, \tag{12}$$

$$\langle p^3\mathrm{H} \mid T \mid n^3\mathrm{He}\rangle = (T_1-T_0)/2 = \langle p^3\mathrm{He} \mid T \mid p^3\mathrm{He}\rangle - \langle n^3\mathrm{He} \mid T \mid n^3\mathrm{He}\rangle . \tag{13}$$

The charge exchange reaction (13) is just elastic, isospin flip scattering between two analog states. Fortunately, we can obtain a complete set of measurements at both 415 and 600 MeV if we combine the data of Bizard *et al.*,[22]

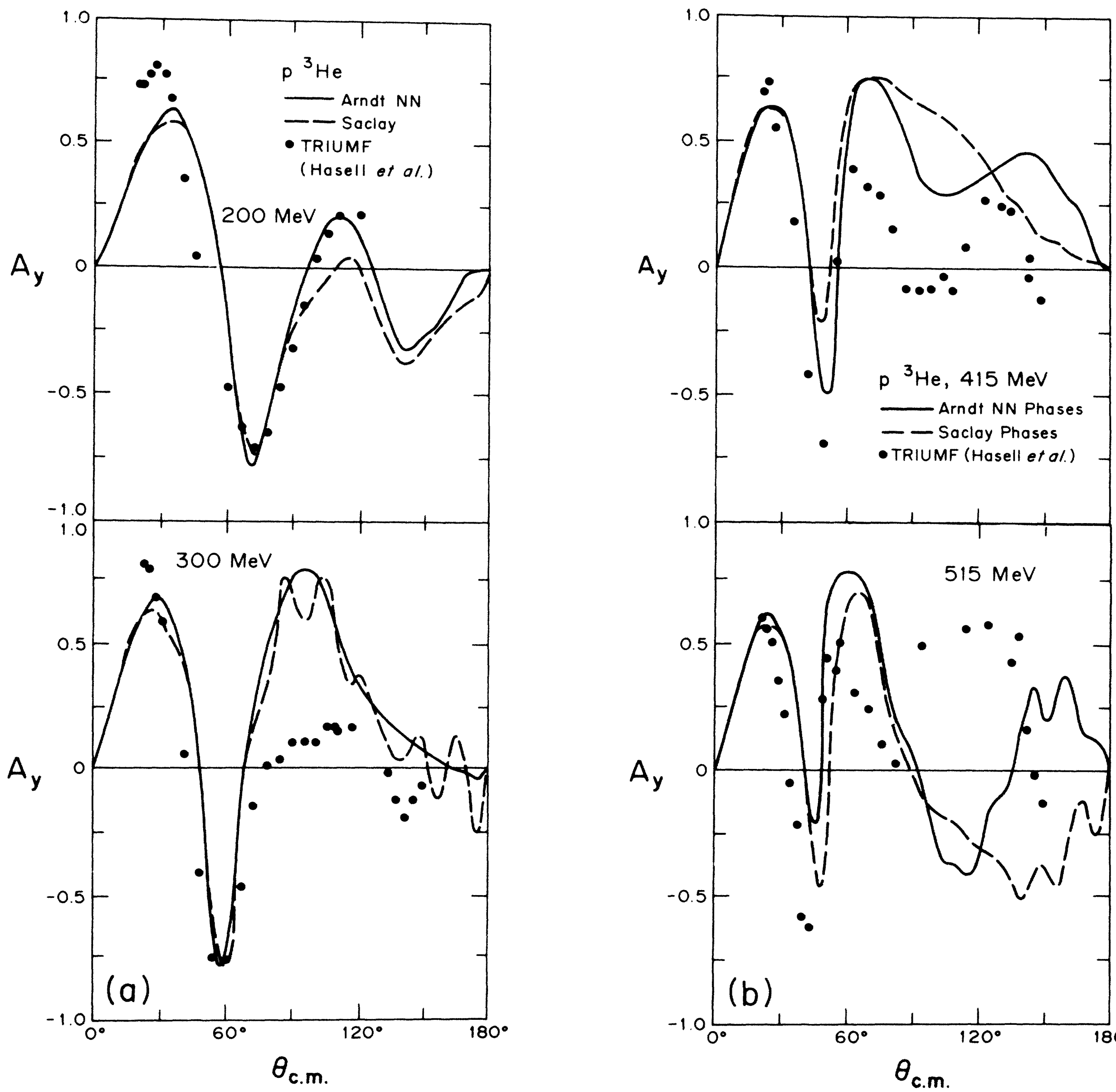


FIG. 6. Sensitivity of p-^{3}He analyzing powers to the input NN phase shifts, (a) 200 and 300 MeV, (b) 415 and 515 MeV. The data are from Ref. 1.

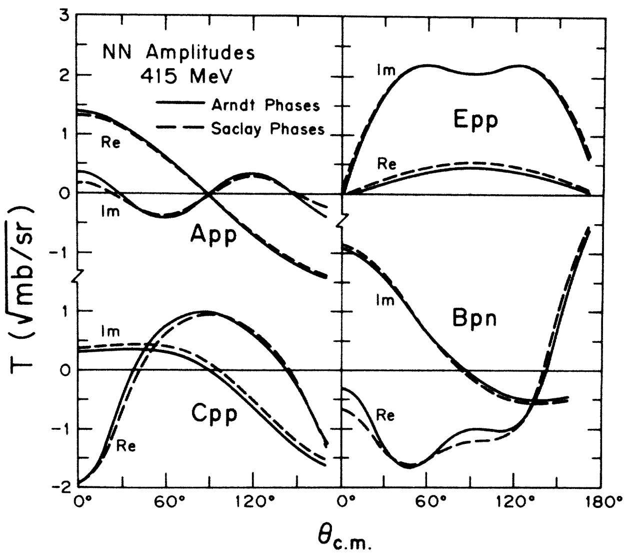


FIG. 7. The real and imaginary parts of the elementary NN amplitudes at 415 MeV as calculated with the Saclay (Ref. 20) and Arndt (Ref. 21) phases.

Fain *et al.*,[16] Hasell *et al.*,[1] and Boschitz *et al.*[25]

To extend our calculation to charge exchange and elastic scattering a tritium target, we invoke isospin symmetry to relate the nuclear form factors and the NN amplitudes:

$$\rho_p(^3\mathrm{H})=\rho_n(^3\mathrm{He}),\ \ \rho_n(^3\mathrm{H})=\rho_p(^3\mathrm{He}), \tag{14}$$

$$t_{nn}=t_{pp}\ . \tag{15}$$

Since these form factors are multiplied by the appropriate elementary T matrices, they are weighted differently in the helium and tritium optical potentials, and we expect similar—but not identical—elastic scattering from these two nuclei. The charge exchange amplitude (13), on the other hand, is the difference between two nearly equal amplitudes, and we expect a smaller and qualitatively different cross section than the elastic ones.

A. p-tritium elastic scattering

In Fig. 8 we show some results on the simplest of these auxiliary reactions, proton elastic scattering from tritium. Aside from our inclusion of the Coulomb amplitude, this is the same calculation as n scattering from ^{3}He. The cross sections are similar to p-^{3}He with the major theoretical difference being a higher secondary maximum for p-^{3}H. The experimental data[22,16] show an opposite trend.

The agreement of our theory with the p-tritium data is better in the forward direction than beyond the first minimum. As found for helium, the sensitivity to input phase shifts and MEC removal is also high at large angles. Surprisingly, the Arndt NN phases that produced good agreement with the 415 MeV helium data from TRIUMF,[1] do not produce equally good agreement with the 415 MeV tritium data of Bizard *et al.*[22] This may be caused by inadequacies in the description of the three-nucleon wave function or inaccuracies in the data (or both). More consistent p-3N data would be helpful here.

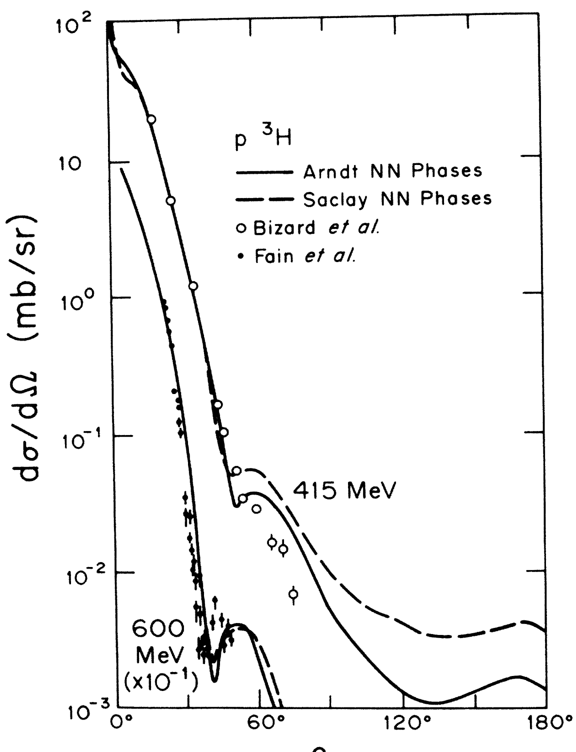


FIG. 8. p-tritium differential cross sections showing input phase shift sensitivity at 415 and 600 MeV. The data are from Refs. 16 and 22.

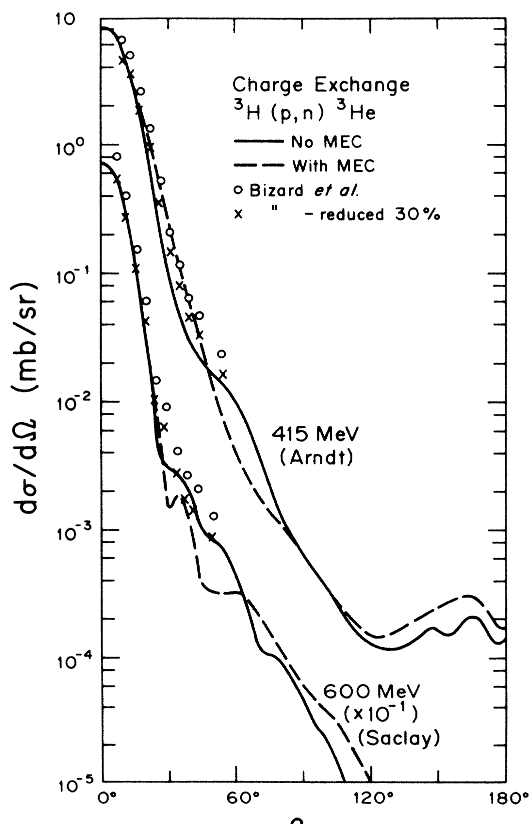


FIG. 9. Differential cross sections for p-tritium charge exchange, ^{3}H(p,n)^{3}He, showing sensitivity to removal of MEC's from nuclear densities. The data are from Refs. 16 and 22.

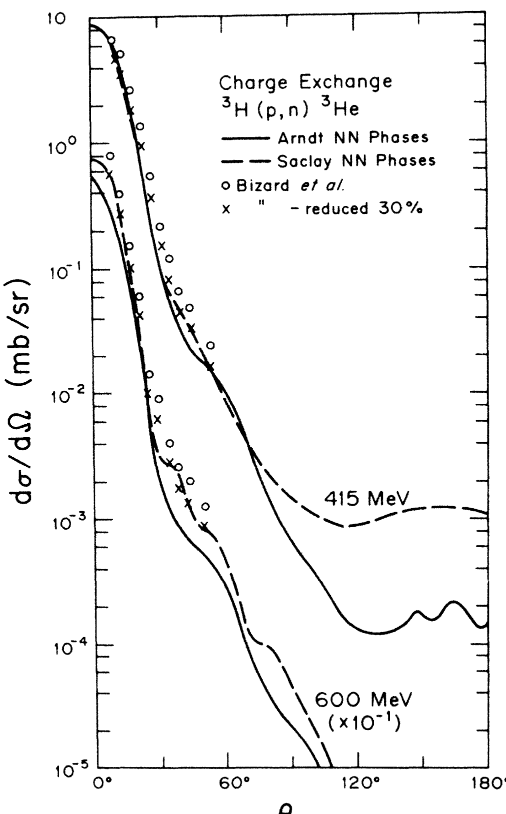


FIG. 10. Same as Fig. 9, only now showing sensitivity to input NN phase shifts.

B. Charge exchange from tritium

In Figs. 9 and 10 we show some results on charge exchange from tritium, ^{3}H(p,n)^{3}He, which, as expected, are quite different from elastic scattering; they are an order of magnitude smaller with more of a forward peak. Here too, backward peaking is predicted to occur, its origin being the use of antisymmetrized NN amplitudes in constructing the optical potential. The sensitivity to MEC removal and NN phase shifts is higher than for elastic scattering, as expected.

Very good agreement with the charge exchange data of Bizard *et al.*[22] is obtained if we lower the data's normalization by 30%. We can justify the renormalization by the $\pm 11\%$ uncertainty in beam intensity, the absence of an overall normalization measurement (it was fixed by comparison to pn$\rightarrow$np data), and of course uncertainties in the theory.

Bizard *et al.*[22] and later Bizard and Osmont[23] interpreted these same data with a Glauber model employing a diffractive model for the NN amplitude and a supplementary one-pion exchange amplitude to generate the steep forward peak. They found an improvement but still not good agreement when they extended their model to include spin effects.

We agree with Bizard and Osmont that spin effects, the on-shell NN parametrization, and the nuclear structure description are important. We find no need for a supplementary pion exchange tail to generate the forward peak, however.

V. CONCLUSIONS

We appear to have some elements of a description of intermediate energy proton scattering from light nuclei that promises to yield interesting physics—particularly for large angle scattering. This momentum space description is an improvement upon conventional proton studies in its use of realistic form factors, antisymmetrized amplitudes, finite range forces, accurate off-shell kinematics, and other nonlocal effects. With improvements, it may be possible to use this description to extend our knowledge of the nucleon, meson, and quark "structure" of the three-nucleon system, within both Schrödinger and Dirac pictures.

Before conclusions can be drawn on new physics, however, it is necessary to clear up some relevant problems that other researchers may care to examine. Firstly, medium energy protons scattering from ^{3}He displays a high sensitivity to the choice of phase shift parametrization used to describe the NN amplitudes. If both the Saclay and Arndt phases are equally good representations of the NN data (a question to be answered), then we have the promise of a means to choose between them. However, a better theory and more consistent p-^{3}He data must be obtained to accomplish this. Secondly, in our limited system we have been able to "turn on" and "off" the meson exchange current contributions normally buried in the nucleon densities, and found large effects in the analyzing powers. This raises the interesting question of the best approach to construct a relativistic optical potential. That potential should contain contributions from negative energy bound nucleons but not from the other meson exchange currents present in the electromagnetic form factor to which the nuclear densities are fit.

This work was supported in part by the Department of Energy, Contract No. DE-AT06-7910405, and Oregon State University for acquisition of the Ridge-32 computer.

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