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TITLE FINAL STATE INTERACTIONS IN THE ELECTROMAGNETIC DISINTEGRATION OF ^{3}He

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FINAL STATE INTERACTIONS IN THE ELECTROMAGNETIC DISINTEGRATION OF ^{3}He

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ABSTRACT

The importance of final-state interactions in the electrodisintegration and photodisintegration of ^{3}He are emphasized utilizing results of Faddeev calculations based upon schematic NN force models.

The shell model is but a mean field approximation of the nucleus. It should come as no surprise that higher energy and momentum transfer experiments at Bates reveal the shortcomings of this model inspired by early measurements of ground state and low energy excitations of the nucleus. That it has worked so well is the surprise.

Inclusive electron scattering experiments, in which one sums over hadronic degrees of freedom, test primarily those average properties of the nucleus which are summarized in the Fermi gas model on shell model pictures. We propose to do more in terms of exploring the nucleus with coincidence measurements, where the explicit hadronic degrees of freedom become all important to our understanding of the physics.

It is in this regime that one can appreciate that few-nucleon systems have come to play a special role in nuclear physics. Our ability to perform exact three-body calculations for mass 3 opens the possibility of testing our models of nuclear forces as well as our understanding of electromagnetic currents. Faddeev calculations of ^{3}H and ^{3}He with realistic potential models have established the scaling of such observables as radii and asymptotic normalization constants with binding energy.[1] Furthermore, the spin-doublet, zero energy Nd scattering lengths and thermal nd radiative capture cross section also scale with binding energy of the corresponding mass 3 system.[2] Our best theoretical predictions of these observables come, in fact, from interpolation of the scaling plots for model results, as is illustrated in Fig. 1 for the rms radii. The predictions for radii, D/S asymptotic normalization constant ratio, Coulomb energy of ^{3}He, and Nd spin-doublet scattering lengths agree well with experiments in all cases except for the pd scattering lengths where curvature in the low energy effective range expansion likely invalidates present experimental estimates.

Where does the model fail? The charge form factor of ^{3}He (and ^{3}H) is reasonably described at low momentum transfer (which determines the size of the system), but the model fails to reproduce the position of the diffraction minimum and the magnitude as well as position of the secondary maximum in impulse approximation,[3] as is illustrated in Fig. 2. The difficulty is reflected in the charge density if one Fourier transforms the charge form factor data (the impulse approximation). This

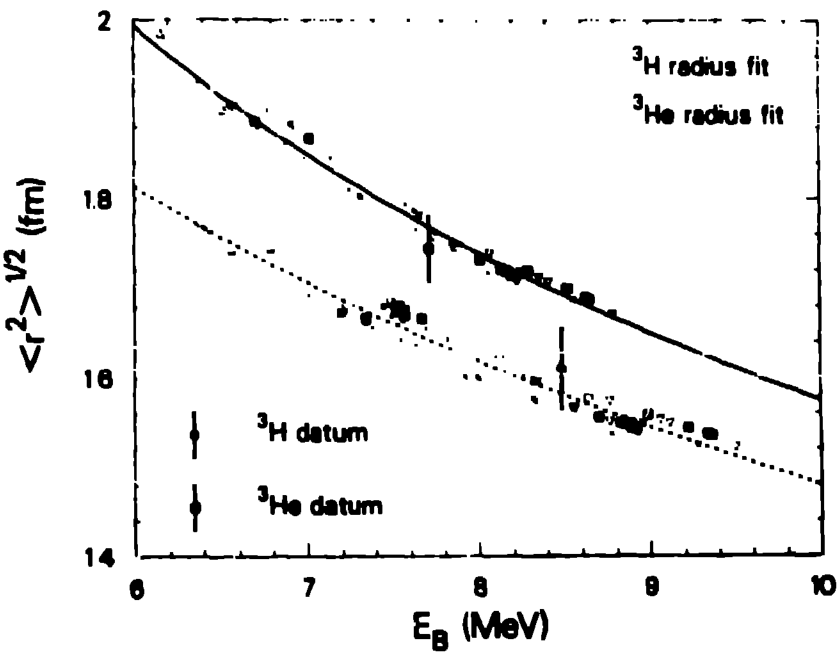

Figure 1. Theoretical ^{3}H and ^{3}He rms radii results plotted as a function of model binding energy compared with experimental estimates.

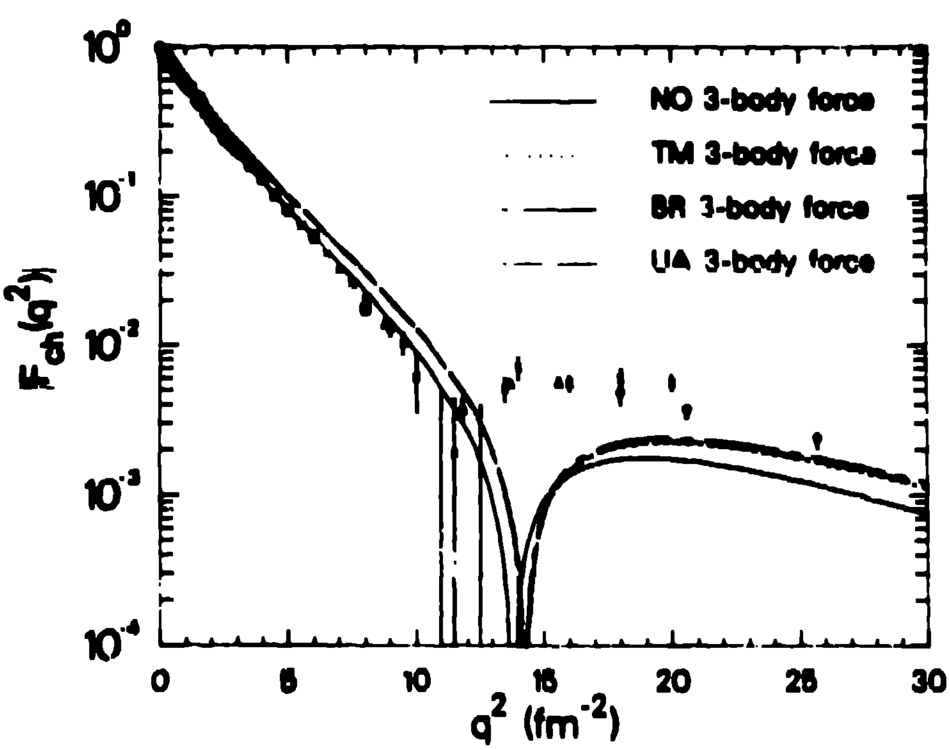

Figure 2. The ^{3}He charge form factor data compared to RSC model calculations with and without three-body forces.

"experimental charge density" exhibits a minimum at small radii due to the large (negative) secondary maximum at high momentum transfer, which the theoretical charge densities do not possess.

How can one improve the model? One direct approach is through the electromagnetic disintegration of ^{3}He, taking the nucleus apart one nucleon at a time. This was pioneered by Johansson[4] in an experiment which looked at ^{3}He$(e, e'p')d$ and ^{3}He$(e, e'p)nn$ in kinematics which corresponds to quasifree proton knockout. A comparison of Faddeev results[5] for two schematic NN force models with the data is made in Fig. 3.

In both model calculations the final state interaction (FSI) effects are less than 10% . The Malfliet-Tjon potential model [6] with realistic short range repulsion [$E_b(^3\text{H}) \approx 8.5$ MeV] provides a semi quantitative representation of the reanalyzed data, whereas the Yamaguchi potential model[6] which has no repulsion [$E_b(^3\text{H}) \approx 11$ MeV] does not. That is, one finds scaling with trinucleon binding even in these results, because the momentum distribution function ρ_2 has a normalization at $|\vec{p}| = 0$ which directly reflects the size (and therefore binding energy) of the system.

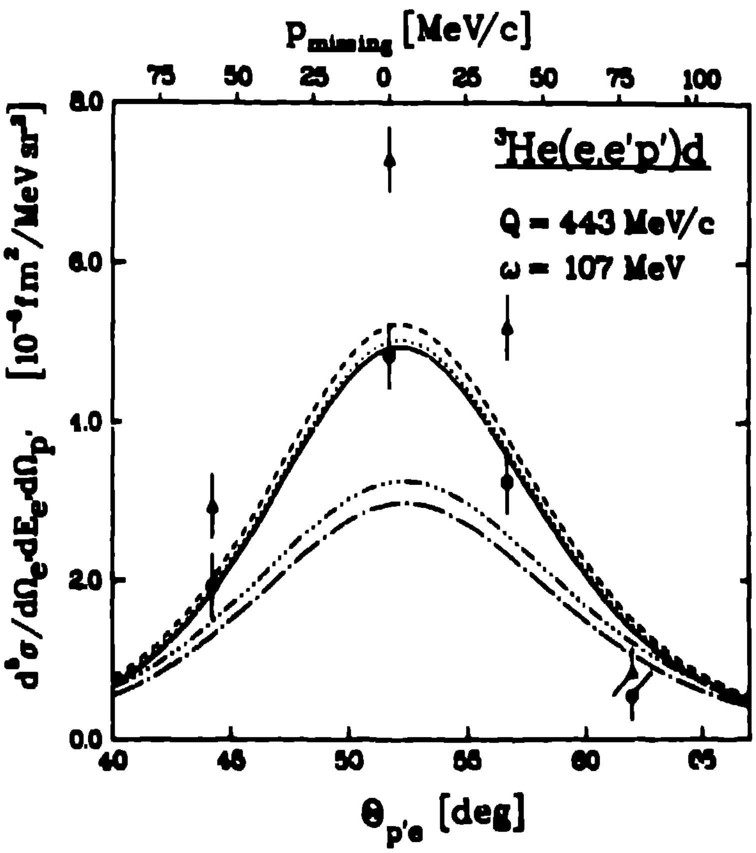

Figure 3. Coincidence data for quasifree proton knockout kinematics compared to MT I-III model results [PWIA - - -, Born + FSI ---, and unitary pole approximation · · ·] for the upper curves and Yamaguchi separable potential model results [PWIA - - - - and Born + FSI ·] for the lower curves.

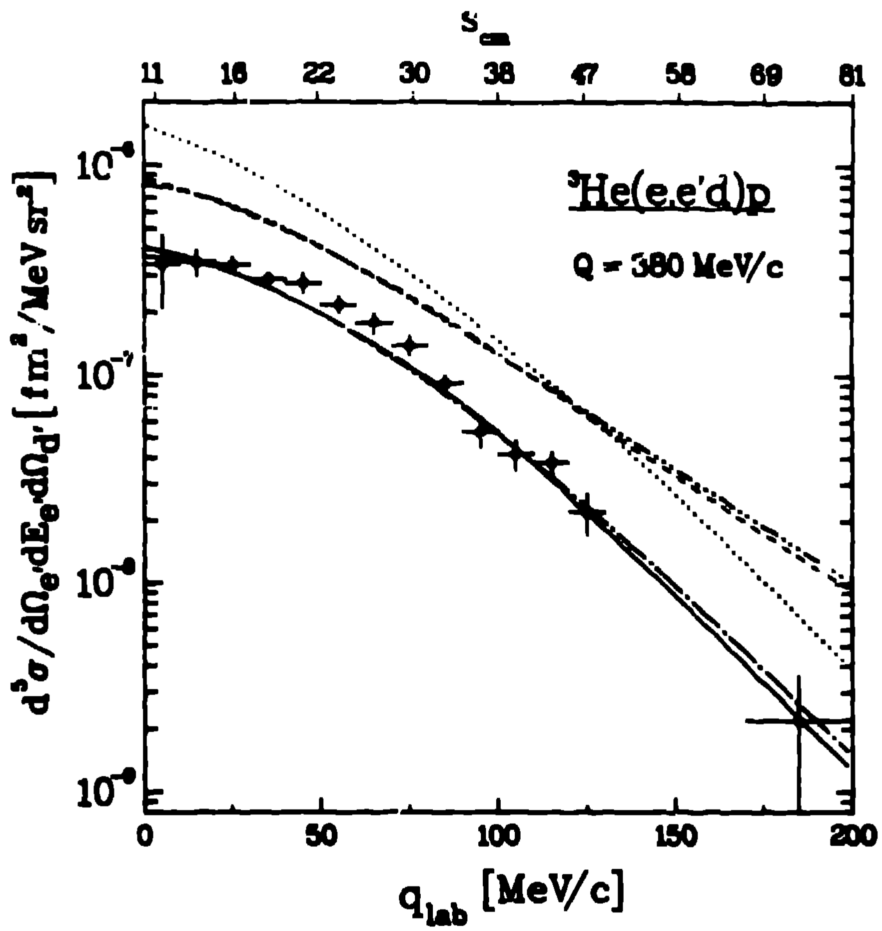

Figure 4. Coincidence data at fixed momentum transfer for deuteron knockout kinematics compared to MT I-III model results [Born - - -, Born + FSI —, and Born + lowest order rescattering ···] and unitary pole approximations [Born -- - - - and Born + FSI — - —].

Final-state interaction effects are small in the case of quasifree proton knockout in Fig. 3, but more generally this is not the case. A pertinent example comes from the data of Keizer, *et al.*,[7] in which the "antiparallel" kinematics of the measurement corresponds to deuteron knockout. A comparison of these data with van Meijgaard's[5] calculations in Fig. 4 clearly establishes that the Born approximation can be an order of magnitude too large.

Adding first order rescattering does not improve the overall description of the data. The full FSI calculation is required to provide a reasonable representation of the data.

Treating the knocked out deuteron as an elementary particle with its own dipole moment is a poor approximation, because the important coupling via rescattering of the $^1S_0\,np$ pair into a $^3S_1$ deuteron is neglected.[5] This important rescattering (FSI) effect was first observed[8] in low energy ($E\gamma \leq 50$ MeV) photodisintegration of ^{3}He and ^{3}H. There, near the peak in the deuteron channel cross section, 90% of the $T = 1/2$ three-body breakup channel strength is actually transferred to the two-body (deuteron) breakup channel due to FSI effects. At higher energies, the transfer occurs in the inverse direction.

Thus, FSI effects are non-negligible unless kinematically suppressed as, for example, in the quasifree proton knockout example. In particular, the np interactions are expected to dominate. We know that in ^{3}He (and ^{4}He), the $T = 1$ One-Pion-Exchange potential $< V_{OPE} >$ accounts for some 80% of the total potential energy of the system.[9] That is, $V_{np} >> V_{pp}$ (or V_{nn}) in terms of its effect, even though σ_{np} is no more than a factor of 2 greater than σ_{nn}. Because of the strong np force, the quasi-deuteron model appears to work, and we should not be surprised that

$$\frac{\sigma(\gamma, np)}{\sigma(\gamma, pp)} \geq 10$$

and that np FSI effects dominate pion absorption in nuclei.

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