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FINAL STATE INTERACTION IN THREE NUCLEON SYSTEM

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FINAL STATE INTERACTION IN THREE NUCLEON SYSTEM*

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Vector to vector spin-transfer parameters for slightly inelastic p-d scattering are discussed in the context of recent theoretical and experimental developments.

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*Work supported by the U. S. Atomic Energy Commission.

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INTERACTION A L'ETAT FINAL DANS LE SYSTEME A TROIS NUCLEONS*

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Les paramètres de transfert vectoriel de spin pour la diffusion p-d faiblement inélastique seront discutés dans le contexte de récents développements théoriques et expérimentaux.

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The dynamics of three-nucleon system, as well as the interaction between the particles on and off the energy shell can be studied by the processes leading to three nucleons in the final state. There are several approximate descriptions of the three-nucleon breakup process which are often used. Each is useful in providing an understanding of and insight into the qualitative features of the breakup process in a limited part of phase space. The final state interaction (FSI) mechanism is appropriate for understanding that part of the breakup spectrum in which one of the three outgoing pairs of nucleons has a low relative energy. Typically, the cross sections are enhanced. The FSI theory of Watson and Migdal is often used to describe these enhancements. Theoretical calculations[1)] based on separable S-wave potentials give results in good agreement with the Watson-Migdal form of the final state peak. These calculations also predict a rather complex angular dependence of the FSI which may prove to be sensitive to the energy shell behavior assumed in the model.

Several attempts[2-5)] have been made to estimate the size of model dependent effects in N-d breakup reactions. The recent results of Brayshaw[4)] and of Haftel and Peterson[5)] (HP) are of particular interest because these estimates were based on comparison of models which gave identical on-shell two-nucleon scattering. For $E_{cm} \leqslant 20$ MeV Brayshaw and HP have found that significant model dependent variations were restricted to three-body ^{2}S-waves. They also found that if it is required that the N-d doublet scattering length, a_2, is held fixed the remaining variability is much reduced. Brayshaw believes that his analysis indicates that the two nucleon observables and a_2 determine the low energy trinucleon reactions to high precision for any plausible interaction. It would be significant if this expectation were to be experimentally verified. The conclusions of HP are different from that of Brayshaw while they provide a basis for selecting experiments. HP have found substantial variability in the ^{2}S partial wave even with a fixed doublet scattering length. The sensitive region is concentrated where singlet FSI dominates. The variability in the amplitudes results in variations of the FSI angular distributions and spectra which are of sufficient magnitude to be significant experimentally. In regard to these HP expectations the experiment and analysis of Brückman et al.[6)] (BKMSW) should be particularly valuable. They found that the breakup cross section in the np FSI region could be fitted very accurately by

$$\frac{d\sigma}{dS d\Omega_3 d\Omega_4} = \left[X^s_{np}(\theta_3) F^s_{np}(E_{45}) + X^t_{np}(\theta_3) F^t_{np}(E_{45})\right] \rho_S(E_3,E_4) \quad ,$$

where F^s_{np} and F^t_{np} are the singlet and triplet Watson-Migdal enhancement factors. Empirically BKMSW have found that the triplet FSI angular distribution, $X^t_{np}(\theta_3)$, was the same as the experimental d-p elastic angular distribution and that the magnitude of the triplet FSI cross section could be successfully related to the elastic cross section. Their application of the Watson-Migdal analysis shows internal consistency with the np low-energy parameters. Other experiments which should be particularly valuable in isolating the np singlet FSI are the measurements of the vector to vector spin transfer parameters $K^{y'}_y$ in $^1H(\vec{d},\vec{p})$ and $^2H(\vec{p},\vec{p})$ for slightly inelastic p-d scattering. These experiments when combined with kinematically incomplete cross section measurements should allow one to extract $X^s_{np}(\theta_3)$. Assuming the validity of the Watson-Migdal analysis,

$$K_y^{y'} = \frac{{}^sK_y^{y'}\; X_{np}^s(\theta_3)\; F_{np}^s(E_{45}) + {}^tK_y^{y'}\; X_{np}^t(\theta_3)\; F_{np}^t(E_{45})}{X_{np}^s(\theta_3)\; F_{np}^s(E_{45}) + X_{np}^t(\theta_3)\; F_{np}^t(E_{45})}$$

where ${}^sK_y^{y'}$ and ${}^tK_y^{y'}$ are the spin-transfer parameters for the singlet and triplet components respectively. Using the simplified structure of the breakup amplitudes,[7] characteristic of the Amado model, it is easy to show that

$${}^sK_y^{y'} = 1 \qquad \text{for } {}^1H(\vec{d},\vec{p})$$

$${}^sK_y^{y'} = -\frac{1}{3} \qquad \text{for } {}^2H(\vec{p},\vec{p}) \quad .$$

${}^tK_y^{y'}$ will depend on angle and energy but an implication of BKMSW is that ${}^tK_y^{y'}$ is nearly the same as the $K_y^{y'}$ parameters for elastic scattering. However in terms of the breakup amplitudes[7]

$${}^tK_y^{y'} = \frac{\frac{5}{3}|q|^2 - \frac{1}{12}|d_1|^2 - \frac{1}{4}|d_2|^2 - \frac{2}{3}\,\mathrm{Re}q^*d_1 + \sqrt{\frac{4}{3}}\,\mathrm{Re}q^*d_2 + \sqrt{\frac{1}{12}}\,\mathrm{Re}d_1^*d_2}{2|q|^2 + \frac{1}{4}|d_1|^2 + \frac{3}{4}|d_2|^2 - \sqrt{\frac{3}{4}}\,\mathrm{Re}d_1^*d_2} \qquad \text{for } {}^1H(\vec{d},\vec{p})$$

$${}^tK_y^{y'} = \frac{\frac{1}{9}|q|^2 + \frac{1}{36}|d_1|^2 + \frac{1}{12}|d_2|^2 + \frac{8}{9}\,\mathrm{Re}q^*d_1 - \sqrt{\frac{64}{27}}\,\mathrm{Re}q^*d_2 - \sqrt{\frac{1}{108}}\,\mathrm{Re}d_1^*d_2}{3|q|^2 + \frac{1}{4}|d_1|^2 + \frac{3}{4}|d_2|^2 - \sqrt{\frac{3}{4}}\,\mathrm{Re}d_1^*d_2} \qquad \text{for } {}^2H(\vec{p},\vec{p}),$$

where q is the amplitude for breakup in the quartet state ($S = 3/2$), and d_1 and d_2 are the doublet-state ($S = 1/2$) amplitudes in which the two identical nucleons are coupled to spin 1 or 0, respectively.

To a first approximation the slightly inelastic $K_y^{y'}$ parameters can be computed on the basis of a decomposition of the breakup cross section similar to that of BKMSW and a measurement of the corresponding $K_y^{y'}$ for elastic scattering. Thus a measurement of the $K_y^{y'}$ parameters have additional interest in that they provide additional checks of the final state interaction theory. We are currently working on the theoretical predictions using a computer code which solves the three particle Faddeev equation for separable spin dependent s-wave nucleon nucleon interactions.[8]

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