STUDY OF THE 3-NUCLEON SYSTEM: d+p BREAKUP MEASUREMENTS AT E_d = 80 MeV

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Studies of the proton-deuteron interaction are of fundamental interest since the 3-nucleon system is the simplest many-body system in which one can test "realistic" effective (i.e., medium-modified) off-shell NN forces, and one which (in principle) is exactly calculable using Faddeev theory. Extension of these studies to a new, higher-energy regime of several tens of MeV nucleon lab energy will allow us to test the quality of the assumed "realistic" NN interaction (particularly the parameterization of the tensor force) as well as the various computational approaches to the Faddeev calculations (e.g., separable-interaction representations for all partial waves vs. perturbation treatment of higher partial waves). At the same time, measurement at higher energies of the tensor polarization effects in the breakup reaction d+p→p+p+n in particular is experimentally advantageous because of the large size predicted for these effects, in contrast to the situation at low energies.

With these motivations, preliminary measurements of the tensor analyzing power A_{yy} were made for the kinematically complete d+p breakup reaction at E_d = 80 MeV in which the outgoing protons were detected in coincidence at four non-coplanar symmetric angle pairs (θ,ϕ). These measurements are part of an ongoing experimental program at IUCF to determine primarily the tensor observables A_{xx} and A_{yy} in a very specific non-coplanar breakup geometry, namely that corresponding to the symmetric constant relative energy (SCRE) condition $|k_1|=|k_2|=|k_3|$, $\sphericalangle(k_i,k_j)=120°$ where the k_i are the c.m. momenta of the final-state nucleons. By varying the laboratory angles (θ,ϕ) and $(-\theta,\pi-\phi)$ of the detected protons under the fixed SCRE condition, the observables are measured as a function of the angle α of rotation of the c.m. momentum triangle (vertices k_1,k_2,k_3) about an axis perpendicular to the incident deuteron momentum [specifically, $\alpha = \sphericalangle(-k_d,k_n)$]. This SCRE kinematic configuration is of interest because it is believed to sample most effectively the I=1/2, S_{pp}=0 amplitude of the 3-nucleon final state which, in turn, should be most sensitive to details of the assumed NN interaction at short range in a Faddeev calculation of this breakup process. Experimentally, of course, for a given α one obtains distributions of the observables along the whole kinematic energy locus (E_{p1} vs. E_{p2}), not just at the SCRE point ($E_{p1} = E_{p2}$).

The preliminary experiment was carried out using the newly-developed rotating detector platform system in the IUCF γ-cave.[1] Two symmetric ΔE-E detector telescopes consisting of 0.5 mm Si + 10 mm hyper-pure Ge detectors in LN_2 cryostats were used in conjunction with CH_2 targets (~10 mg/cm^2) and the tensor-polarized deuteron beam. Unfortunately, the use of hydrocarbon targets caused a serious and unforeseen problem in the August run: the much larger-than-estimated yield of continuum protons from ^{12}C gave rise to unacceptably high accidental coincidence yields at the planned beam intensity, forcing us to acquire data at considerably reduced beam currents (~ 5nA, instead of the 25nA anticipated). Consequently, both the quantity and quality of the data obtained in the available beam time suffered: data were obtained at only 4 angles (α = 75°, 120°, 142° and 150°) and the statistical error of the A_{yy} measurements (typically ±0.1) was about twice what is needed in order for the data to provide a meaningful test of theoretical calculations. Partial results extracted from these measurements are presented in Figs. 1 and 2. In Fig. 1, the A_{yy} results for the SCRE point on the kinematic locus are shown in comparison with a Faddeev calculation by Stolk and Tjon[2] (dash-dot curve). The agreement is remarkably good but hardly constitutes a verification of the theory. The solid curve is a similar calculation of A_{xx}, still to be measured. Figure 2 displays the relative-energy distributions of the α=150° measurements along the kinematic locus on either side

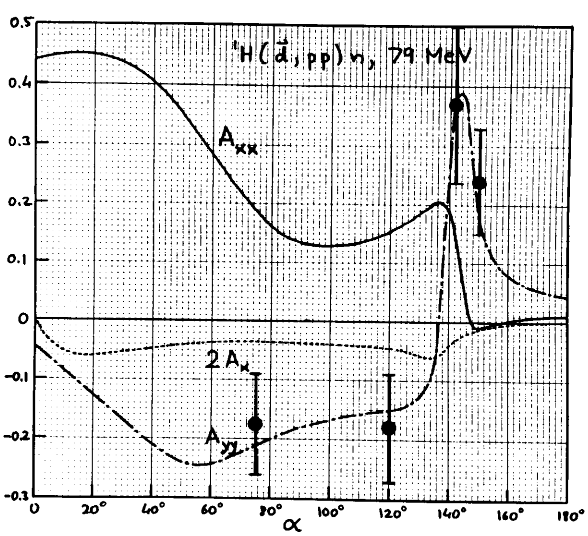

Figure 1. Preliminary experimental results for the tensor parameter A_{yy} at the SCRE point on the kinematic loci corresponding to α=75°, 120°, 142°, and 150°. The curves are predictions of Faddeev calculations in the variational approach of Stolk and Tjon.

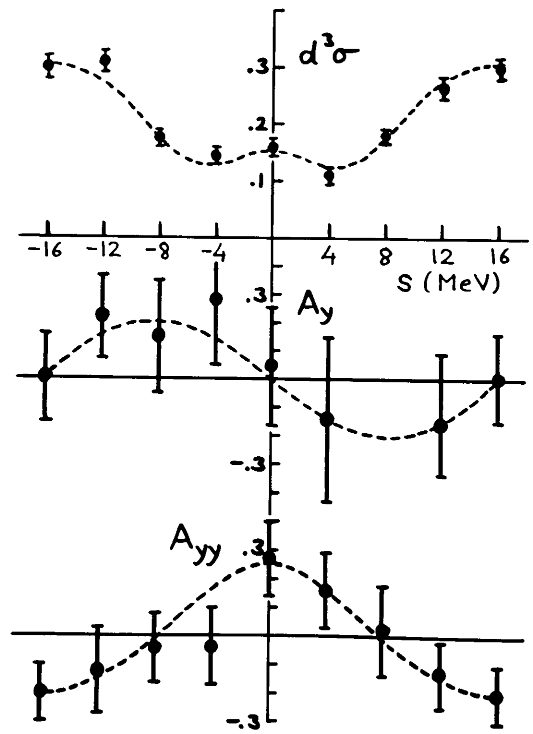

Figure 2. Preliminary experimental results for $d^3\sigma/d\Omega_2 dE_{12}$ (in mb/sr^2-MeV) and vector and tensor analyzing powers A_y, A_{yy} as function of arc length S(MeV) along the kinematic locus for α=150°. The smooth curves drawn through the points are only meant to emphasize the expected symmetry character of the data about the SCRE point 5=0.

of the SCRE point (origin of arc length S). Measurements with 3 polarization states of the deuteron beam (unpolarized, +tensor-vector, -tensor-vector) allowed determination of the vector analyzing power A_y (with larger uncertainties, owing to the small vector beam polarization) and the triple differential cross section $d^3\sigma/d\Omega_1 d\Omega_2 dE_{12}$ in addition to A_{yy}. The symmetric character of $d^3\sigma$ and A_{yy} and antisymmetric behavior of A_y about the SCRE point (required by fundamental reaction symmetry considerations) is readily apparent (the dashed curves are intended to prejudice the eye towards this conclusion). These results give us confidence that the sources of systematic errors are sufficiently under control to permit us to obtain more and better data (with the desired precision of ±0.05 in A_{yy} and A_{xx} for data bins of about 4 MeV relative energy) with improved experimental techniques, principally involving the use of an elemental hydrogen target in the form of a high-pressure and/or LN-cooled gas cell. In a 13-shift run requested for April, 1983, we propose to measure (1) A_{yy} at about 6 non-coplanar angle pairs (θ,ϕ) covering the range in rotation angle α of the momentum triangle between 45° and 150° and (2) A_{xx} at perhaps 3 non-coplanar angle pairs corresponding to $\alpha \simeq 45°$, 90° and 135°. Since the spin quantization axis for the IUCF polarized beams is vertical in the lab, the A_{yy} and A_{xx} measurements involve orthogonal experimental configurations in the sense of horizontal and vertical scattering planes, respectively.

Meanwhile, additional Faddeev calculations for this reaction are underway using the Doleschall separable-interaction code[3] at the Los Alamos National Laboratory. Comparison of predicted observables from these calculations with those of the older, Stolk and Tjon variational-method calculations[2] (shown in Fig. 1) will determine the optimum quantity and precision of the data to be measured. Variation of the NN tensor force parametrization in particular will be explored in future calculations in the Doleschall approach since one expects the tensor analyzing powers in the d+p breakup reaction to be sensitive to details of this force.

1) see p. 210 of this report.

2) C. Stolk and J.A. Tjon, Nucl. Phys. A295, 394 (1978).

3) P. Doleschall, Nucl. Phys. A220, 491 (1974); ibid. A201, 264 (1973).