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3.48 Measurement of the Vector and Tensor Analyzing Powers $A_y(\theta)$ and $A_{yy}(\theta)$ in the $^2H(\vec{d},\gamma)^4He$ Reaction for E_d = 10 MeV

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Much interest has been expressed recently in the measurement of analyzing powers in the $^2H(\vec{d},\gamma)^4He$ reaction as a tool to study D-state effects in the four nucleon system. Weller et al.[1] published the first measurement of the tensor analyzing power $T_{20}(\theta)$, along with a measurement of the differential cross section for this reaction at an incident energy of 9.7 MeV. They concluded that, within the accuracy of their measurement, T_{20} is isotropic. Seyler and Weller[2] have given a detailed proof that T_{20} and T_{22} must be isotropic if one assumes pure E2 radiation and if one neglects terms which are products of two channel-spin s=2 amplitudes. In another recent paper, Santos et al.[3] have argued that the vector analyzing power $iT_{11}(\theta)$ must be small since it arises from interference terms between the dominant E2 amplitudes and either E1 or M2 amplitudes, both of which are thought to be strongly suppressed.

The present measurement was performed using a polarized deuteron beam from the University of Wisconsin colliding beam polarized ion source[4] and tandem Van de Graaff accelerator. The target was a gas cell 3.65 cm in diameter cooled to liquid nitrogen temperature and filled with D_2 at a pressure of 200 kPa. Entrance and exit foils for the gas cell were made of 3 μm rolled tungsten, chosen for its high tensile strength and low γ-ray background. The beam energy at the center of the target was 10.0 MeV, and the γ-rays produced were detected in an anticoincidence shielded 25 × 25 cm NaI spectrometer collimated with lead to subtend a solid angle of 31.1 msr. Paraffin shielding was used between the target and detector to reduce the flux of neutrons (mostly from the $^2H(d,n)^3He$ reaction) in the spectrometer. The beam current on target was varied from about 150 nA to 350 nA in order to keep the singles rate in the spectrometer roughly constant for different laboratory scattering angles, thus keeping the detector deadtime (~15%), pileup and anticoincidence rejection efficiency (~97.5%) as constant as possible. The target itself could be rotated out of the beam path in order to measure the beam polarization in a ^3He polarimeter[5] located in the same beamline.

The beam polarization was changed by switching the rf transitions at the source at one second intervals in order to produce four different spin states corresponding to $p_{yy} \approx \pm 0.9$ and $p_y \approx \pm 0.3$. Data were stored independently for each of the four spin states. The spin orientation axis was perpendicular to the beam momentum axis (in the y-direction according to the Madison convention). The four different beam polarizations result in four equations for the measured yields at each angle:

$$Y^i(\theta) = Y^u(\theta)\left[1 + \tfrac{3}{2}p_y^i A_y(\theta) + \tfrac{1}{2}p_{yy}^i A_{yy}(\theta)\right] , \quad i=1,4 \qquad (1)$$

containing three unknowns: the unpolarized yield, Y^u, and the analyzing powers A_y and A_{yy}. Data were taken at laboratory angles of 35°, 45°, 55°, 70°, 90°, 110°, 125°, 135° and 145°.

In order to extract relative differential cross sections, the product of beam current and target thickness was monitored using a plastic scintillator detector placed at 0° (after the end of the beamline) which measured neutrons from the $^2H(d,n)^3He$ reaction. The results of the differential cross section measurement show a $\sin^2(2\theta)$ behavior, as would be expected from pure E2 radiation.

The measured vector analyzing powers $A_y(\theta) = (2/\sqrt{3})iT_{11}(\theta)$ and tensor analyzing powers $A_{yy}(\theta) = -T_{20}(\theta)/\sqrt{2}-\sqrt{3}T_{22}(\theta)$ are shown in Fig. 1. The error bars reflect primarily counting statistics, but also include errors due to background subtraction and uncertainties in the beam polarizations.

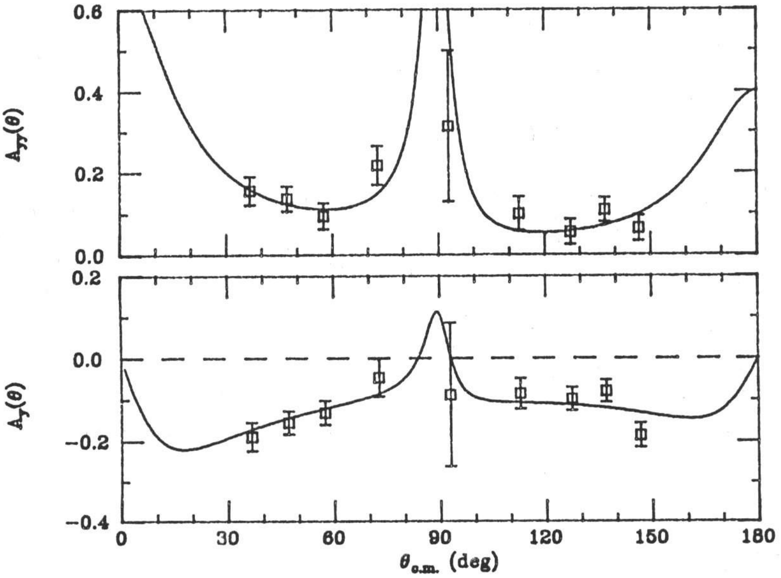

Figure 1. Vector and Tensor Analyzing Powers for $^{2}H(\vec{d},\gamma)^{4}He$ at 10 MeV

Information about the multipolarity of a transition may be obtained by examining an expansion of $\sigma(\theta)A(\theta)$ in terms of associated Legendre polynomials. The solid lines in Fig. 1 are the result of least-squares fits to $\sigma(\theta)A(\theta)$ and to $\sigma(\theta)$. Significantly, both $\sigma(\theta)A_y(\theta)$ and $\sigma(\theta)A_{yy}(\theta)$ require the inclusion of odd-order terms in order to fit the data. This is direct evidence that the transition is not purely E2, for, as pointed out in ref. [2], due to the symmetry conditions imposed by the identity of the (incident and target) deuterons, the assumption of pure E2 radiation forces all odd-order Legendre terms in the product of the cross section with t'e analyzing powers to vanish.

Further evidence for the existence of amplitudes other than E2 comes from the fact that the vector analyzing power is not small, but is in fact comparable in magnitude to the tensor analyzing power. Following the arguments presented in ref. [3], the vector analyzing power can only arise from the interference of E2 with either E1 or M2 amplitudes, which must, in this case, be substantial.

Thus, although the angular distribution of the differential cross section for this reaction displays the characteristic form of E2 radiation, both the vector and tensor analyzing powers indicate the admixture of other multipoles.

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