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ANALYZING POWER OF THE REACTION H($\vec{n}$,γ)D AT Tn = 180 AND 270 MeV

J.M. Cameron, C.A. Davis, H. Fielding, P. Kitching, W.J. McDonald, J. Soukup,
J. Uegaki, J. Wesick and H.S. Wilson
University of Alberta, Edmonton, Alta., Canada T6G 2N5
R. Abegg, D.A. Hutcheon and C.A. Miller
TRIUMF, 4004 Wesbrook Mall, Vancouver, B.C., Canada V6T 2A3
A.W. Stetz
Oregon State University, Eugene, OR 97403, USA
Y.M. Shin and N. Stevenson
University of Saskatchewan, Saskatoon, Sask., Canada S7N 0W0
I.J. van Heerden
University of the Western Cape, Bellville 7530, Rep. of South Africa,

(Presented by J. Uegaki)

Abstract

Angular distributions of the analyzing power of the reaction $n+p \rightarrow d+\gamma$ at 180 and 270 MeV incident neutron beam energy were measured with the TRIUMF polarized beam and a liquid hydrogen target. Our 180 MeV data are consistent with theoretical calculations either with or without meson exchange current. On the other hand, our 270 MeV analyzing power data show the need for meson exchange terms in the calculation.

Radiative neutron capture by protons is one of the simplest reactions to test models for nucleon-nucleon interactions. For more complicated radiative proton capture reactions on heavier targets, use of $n+p \rightarrow d+\gamma$ data is required for input to theoretical calculations in a quasi-deuteron model.

It is well established that meson exchange currents (MEC) and isobar configurations (IC) make an important contribution to the $n+p \rightarrow d+\gamma$ cross section at thermal energy where the M1 transition is dominant[1]), but that the calculation without MEC is successful at higher energy where the E1 transition is dominant[2]). At still higher energies near the pion production threshold, the MEC contribution could be important again because the contribution of the M1 and higher multipolarity transitions becomes larger.

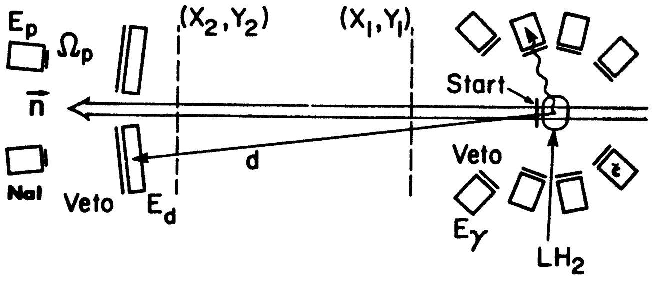
For a study of MEC effects at this energy, the analyzing power should be more sensitive than differential cross sections because of the presence of an E1-M1 interference term, and is easier to measure than the cross section if a polarized beam is available. We report here angular distributions of the analyzing power at neutron incident energies of 180 and 270 MeV.

The experiments were done on the TRIUMF neutron beam facility[3]), in which polarized neutrons of 180 and 270 MeV were produced by the (p,n) reaction in a 20 cm long liquid deuterium target by polarized proton beams of 195 and 285 MeV, respectively. A superconducting solenoid upstream of the LD_2 target precessed the spin direction of the polarized proton beam from vertical to transverse, so as to take advantage of the large spin transfer coefficient, r_t, for the quasi-free charge exchange reaction on deuterium.

The neutrons emitted at 9° laboratory angle passed through a collimator and two dipole magnets; one magnet had a vertical and the other a horizontal field, which were set to precess the spin of the neutron beam into the vertical. The neutron beam profile at the target was elliptical with a size of 9 cm horizontally, 7 cm vertically FWHM. The target was liquid hydrogen in a container with 0.25 mm thick mylar walls. Two LH_2 targets of thickness 0.3

and 0.7 g/cm^2 were used in the experiment. Both cells were 15 cm in diameter which was larger than the neutron beam size. Our detector arrangement is shown in fig. 1. The entire detector system was always arranged to be left-right symmetric for the various configurations of detector angles which were used. The proton beam spin direction was reversed every 3 minutes so that the systematic asymmetry caused by unequal detector efficiencies was cancelled to first order. Altogether eight lead-glass Cerenkov counters were used for γ-ray detection, each with a plastic veto counter in front to reject charged particles. Two plastic scintillators of size 10 cm thick × 30 cm wide × 35 cm tall, which were followed by plastic veto counters to reject passing charged particles, were used for deuteron detection. Pulse height and time information of all events within the 120 ns wide coincidence between d and γ counters were recorded on magnetic tape, and all other background elimination was done by off-line analysis. The start counter in fig. 1 was a 1.6 mm thick plastic scintillator located 0.3 m downstream of the LH_2 target and determined deuteron time of flight over a 1.7 m path. The combination of the TOF and the pulse height of the deuteron detector cleanly separated deuterons from protons. Broken lines shown in fig. 1 were multiwire delay-line chambers which allowed determination of deuteron trajectories. Additional cuts on Cerenkov detector pulse heights, cyclotron RF phase, deuteron-gamma time differences, and deuteron trajectories gave very clean identification of H(n,γ)D events. We also used NaI detectors with solid-angle defining plastic scintillators in front for detecting protons from the charge exchange reaction at the LH_2 target. These were used for monitoring the incident neutron beam intensity, but not for monitoring the neutron polarization. The neutron beam polarization was calculated from measured proton beam polarization using the spin transfer coefficient $r_t = -0.85$ at both energies; this value of r_t was taken from the results of previous measurements at TRIUMF[4]). The typical neutron beam intensity was 1.5×10^6 neutrons per second with 60% polarization, from a 250 nA proton beam with 70% polarization. The effect of the LH_2 target container was measured by replacing the LH_2 with cold hydrogen gas, and subtracted from the data - typically the empty/full ratios were 1 to 10 in count rate for the 270 MeV case and much less at 180 MeV.

Fig. 1. Experimental arrangement (top view).



The results are shown in figs. 2 and 3 for 180 and 270 MeV neutron energy, respectively. The error bars are statistical only and we estimate possible scale errors to be at most 5%, mostly due to the uncertainty in the polarization transfer coefficient. The solid lines are approximation I of Partovi[2]) which includes terms up to dipole-octupole interference but with no MEC. The dotted and dashed curves are calculations of Rustgi and Vyas[5]) (for a super-soft-core potential); the dotted one is without MEC with multipolarity up to M1 and E2, and the dashed one is with MEC. The upper triangles at 60° are the results of Arenhövel, Fabian and Miller[6]) without MEC, the lower triangles with MEC. The calculations with MEC are in accord with our data at 180 MeV, although there is a tendency for our points to be at more positive

Fig. 2. Analyzing power at Tn = 180 MeV.

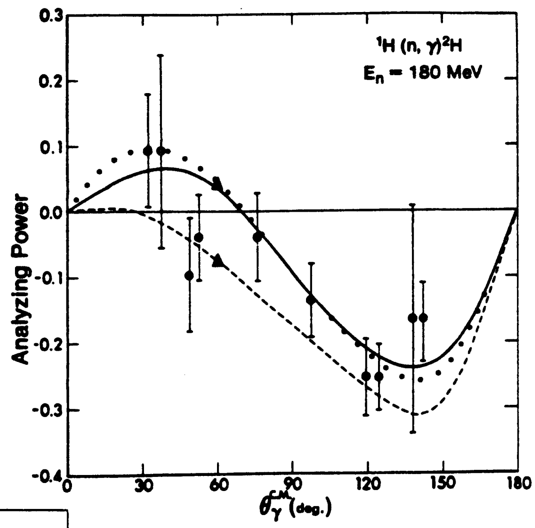
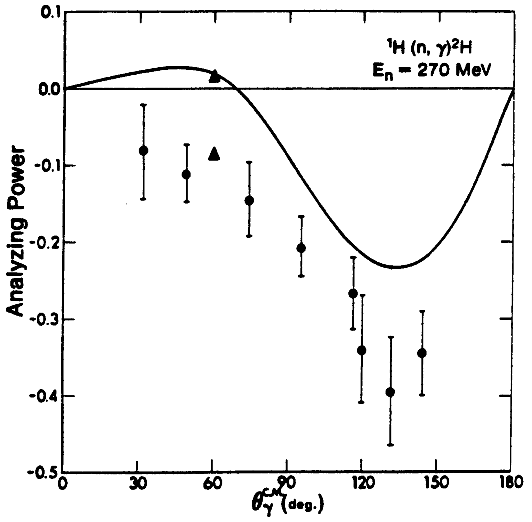


Fig. 3. Analyzing power at Tn = 270 MeV.



A_y. At 270 MeV our data agree with the calculation for 60° by Arenhövel, Fabian and Miller; the calculation without MEC clearly is inconsistent with our data. At 180 MeV the experimental and theoretical angular distributions are of similar shape. If this similarity persists at 270 MeV, we would expect agreement at other angles between our data and the calculations with MEC and IC. Our data do not indicate any need of additional mechanisms (such as quark degrees of freedom as proposed by Hadjimichael^7) to explain low energy deuteron photo-disintegration data), although a calculation must be made to confirm agreement over the complete angular range at 270 MeV.

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