MEASUREMENT OF THE FORWARD CROSS SECTION OF p(n,d)γ AT 190 MEV

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The forward angle cross section for deuteron photodisintegration, d(γ,p)n, measured for E_γ between 20 and 120 MeV[1] has been found at variance with standard theoretical predictions[2] using various NN potentials. At the lower energy, the experimental finding has been confirmed using the time-reversed reaction p(n,d)γ with E_n=72 MeV.[3]

In this experiment we are investigating the forward angle cross section for radiative capture p(n,d)γ at E_n=190 MeV. This is equivalent to E_γ=95 MeV in the inverse reaction. Since the experimental status report in the 1981 IUCF Annual Report, several important improvements have been made, additional hardware and electronics changes have been tested, and in December 1982 the experiment reached the production stage. In January of 1983 a long data run was completed. First results are expected by mid-1983.

The final experimental set-up is shown in Fig. 1 and discussed below. The primary proton beam, E_p=190 MeV, strikes a 2g/cm^2 natural lithium target (2) which serves as the neutron source. The lithium target is immediately followed by a heavy copper collimater (not shown) which serves to stop scattered protons. The primary proton beam is then deflected into a shielded beam dump (4) by passing through the gap of a large magnet (3). This magnet is the final magnet of the IUCF beam swinger assembly which is normally used for (p,n) studies. Because of the high energy and nonstandard path of the primary proton beam, shims are required in the magnet gap to produce the necessary field for deflecting the particles.

The neutron beam emerges from the lithium target (2), passes through a collimater (5), and strikes the liquid hydrogen target (6). The latter is an 11 cm

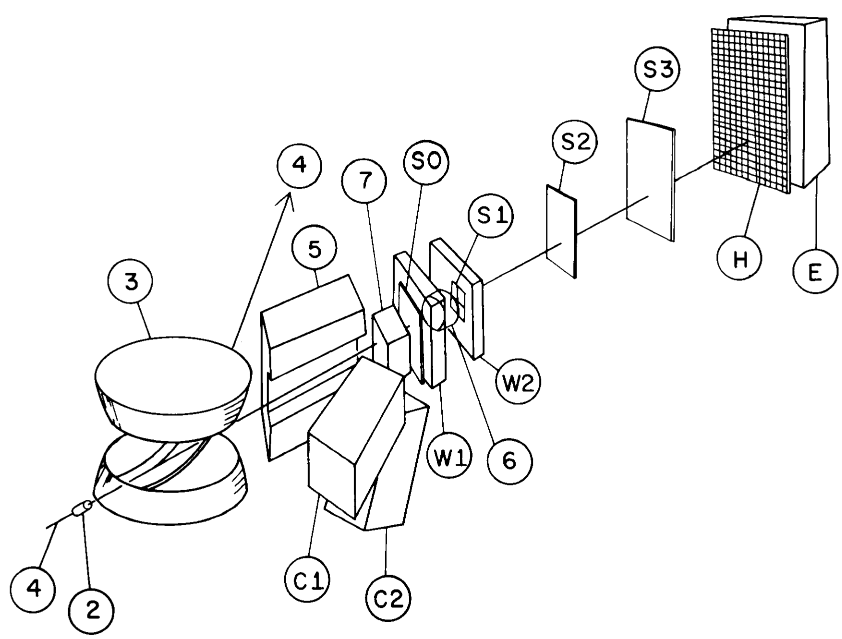

Figure 1. Experimental layout to measure p(n,d)γ at angles near 0°. A detailed description is provided in the text.

diameter by 6.4 cm thick stainless steel cylinder capped at both ends by 0.025 mm thick stainless steel windows through which the neutron beam and recoil particles pass. This cell holds 0.6 liters of liquid hydrogen (0.45 g/cm^2) and resides in a vacuum vessel which also has 0.025 mm thick stainless steel windows for the passage of the neutron beam and particles.

The incoming neutron path to the target is obstructed by a 7 cm thickness of lead which serves to stop charged particles which may also be incoming. A thin scintillator (S0) serves to detect those charged particles that do impinge on the target from upstream. Outgoing protons and deuterons are tagged by a set of thin scintillators (S1,S2,S3), their energies measured in a thick (7.6 cm) scintillator (E), and their directions determined by use of a scintillator hodoscope (H) which has an area resolution of 15×25 two centimeter square cells. Scintillator S1 is segmented into 4 two centimeter square cells for additional accuracy in determining the direction of the particles.

Two small multiwire chambers (W1,W2) are inserted between S0 and the target and between the target and S1 to reject deuterons produced by (n,d) reactions in these scintillators. Two large volume lead-glass detectors (C1,C2) are used to detect the gamma rays from some of the (n,d)γ reactions. Using these detectors we obtain an almost background-free sample of p(n,d)γ deuterons. These events are restricted in space at the hodoscope and form an invaluable reference sample for later off-line analysis of the collected data.

The trigger to the computer for an event is provided by an $\overline{S0}\cdot S1\cdot S2\cdot S3\cdot E$ coincidence. For each event the energy signals from all detectors, coincidence bits from the elements of the hodoscope and S1, and the time of the signals in each of the detectors and the cyclotron RF signal relative to that from S1 are recorded by the computer and stored in event mode on tape.

The relative timing of RF-S1 allows us to discriminate against low energy neutrons produced in the lithium target. The time-of-flight, S1-E, together with the energy deposited in E, allows us to cleanly distinguish protons from deuterons. An integrator triggered pulser event gives us a measure of the system deadtime and the accidental responses of the detectors.

The absolute normalization of the cross section to be measured depends on the neutron flux across the sensitive area of the target volume and the thickness and density (boiling) of the target. Because the uncertainties in the above are common to both p(n,d)γ and p(n,p)n which we measure simultaneously, we will determine our results relative to the known p(n,p)n elastic scattering cross section. To conserve event tapes we only sample the high energy proton events for about 5% of the time throughout the course of the experiment.

The maximum allowed beam current is determined by the performance of the wire chambers and other detectors and is normally chosen to be 40-50 na. Under the above conditions about 600 deuterons from p(n,d)γ are detected each hour in the above apparatus (Fig. 1). To achieve a statistically significant measurement of just the zero degree cross section of p(n,d)γ, about 80-100 hours of beam on target are required. We expect that the run of January 1983 combined with the shorter run in December of 1982 should supply the necessary data.

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PROTON RADIATIVE CAPTURE BY DEUTERIUM AT MEDIUM ENERGIES

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In an attempt to learn more about reaction mechanisms for (p,γ) at medium energies, we have designed and executed an experiment investigating $^2H(p,\gamma)^3He$ in the proton energy range of 100-200 MeV. Eight point angular distributions, at angles ranging from 17° to 150° in the lab, have been obtained for the differential cross section and analyzing power at energies of 100, 150, and 200 MeV.

In order to obtain good event definition and reduce background, the emitted ^3He and γ were detected in coincidence. The recoil particles were detected using a plastic scintillator range telescope. The high energy photons were detected using lead glass Cerenkov detectors whose solid angles were defined with lead collimators. In order to obtain high efficiency, simultaneous measurements were made at eight angles ranging from θ_γ=17° to 150° in the lab. This was done by using an array of eight independent photon detectors and a plastic scintillator range telescope covering an extended angular range (2.5°-16°). The range telescope was segmented to reduce the rate in each of its elements and also to provide a measure of the angle at which the detected particle was emitted.

Production runs were made using CD_2 targets. The deuterium and carbon content of the targets was monitored continuously using a plastic scintillator - NaI telescope. Background checks were made repeatedly using CH_2 targets. We generally found the background everywhere to be less than 5%.

The high efficiency and effectiveness of the apparatus has yielded data of high statistical quality. Although the data analysis is still in its preliminary stages, we should be able to extract analyzing powers with uncertainties of ±0.02, or less, at all energies and angles. We should be able to extract differential cross sections with absolute uncertainties less than 15%. The experiment has made it clear that with only a few minor modifications to the apparatus and with a little more time spent investigating systematic effects, we should be able to make absolute measurements of the cross section to better than ~5%.

The small relative uncertainties in the extracted analyzing powers and cross sections will permit a more significant study of the energy dependence of these quantities. We hope that the existence of these measurements will eventually lead to an increase in our understanding of mechanisms for radiative capture at intermediate energies.