

STUDY OF (n,p) REACTIONS BETWEEN 100 AND 200 MeV

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Charge-exchange reactions are very important probes for the study of giant resonances and spin-flip states in nuclear physics. In conjunction with (γ, X), (e, e') and (p, p') reactions, charge exchange reactions can be used to isolate isovector from isoscalar transitions. The (p, n) reaction has been studied systematically¹ since the late 1970's. This report describes an experiment performed at the Indiana University Cyclotron Facility (IUCF) for the study of neutron-induced-charge exchange reactions.

A neutron facility for (n, p) studies was constructed in the late 1970's at the Crocker Nuclear Laboratory at the University of California at Davis.² The energy resolution of the neutron beam, less than 1 MeV FWHM, has made possible many significant (n, p) studies, but the low neutron energy, limited to 67 MeV, precludes strong excitation of important Gamow-Teller and other spin flip resonances.

Three targets are the leading candidates for producing neutron beams from proton beams: ${}^7\text{Li}$, ${}^3\text{H}$, and ${}^2\text{H}$; for technical simplicity we chose ${}^7\text{Li}$ for the initial facility. The intrinsic neutron energy spread in the ${}^7\text{Li}(p, n){}^7\text{Be}$ reaction is due to the excitation of the first excited state of ${}^7\text{Be}$ at 0.43 MeV. At 120 MeV a 300 mg/cm² target of ${}^7\text{Li}$ contributes about 1.6 MeV to give a total width of the neutron beam of about 1.7 MeV which is acceptable for initial nuclear structure studies. In order to achieve the desired monochromaticity of the neutron beam the (n, p) target was placed ~ 2 m from the neutron production target so

that effectively all degraded neutrons could be removed from the beam by a time-of-flight requirement.

An important feature of the setup is that the reaction products [principally protons from the (n, p) reaction] are measured with high purity Ge telescopes. A HPGe detector has an energy resolution of approximately 60 keV for energetic protons. As the neutron flux is not large, counting rate considerations dictate the use of relatively thick (n, p) targets. Therefore, the overall energy resolution is determined by the thicknesses of the two targets: the production and the (n, p) target. The ideal situation is for the production target and the (n, p) target to make equal contributions to the resolution.

Figure 1 shows the experimental setup. The primary proton beam from the IU Cyclotron strikes the ${}^7\text{Li}$ production target mounted on a target ladder inside a suitable target chamber. After passing through the self-supporting target, the proton beam is swept by a magnet into a beam pipe leading to a beam stop some 5.5 m beyond the target. This beam dump provides an effective Faraday cup for collecting the beam. A concrete wall, 178 cm thick, separates the production area from the (n, p) experimental area.

A collimator mounted in this wall delineates the neutron beam. The neutron collimator consists of a steel cylinder filled with lead in which a section of copper waveguide is embedded. This assembly in turn is embedded in the concrete shielding wall. The waveguide which serves to collimate the neutrons has a

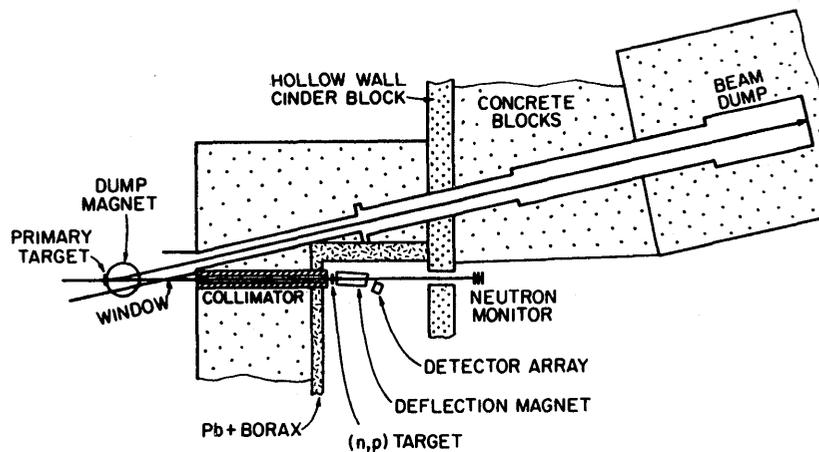


Figure 1. Schematic drawing of the experimental setup for (n,p) measurements at IUCF.

rectangular aperture 2.22 cm wide by 3.33 cm high. The collimator is sealed by mylar at both ends and kept evacuated to about 10^{-3} Torr. When a neutron beam is produced a lead slab 19 mm thick is placed over the entrance to the collimator to absorb protons scattered by the production target. At a distance of ~ 1.7 m behind the (n,p) target a neutron monitor³ is set up to measure the intensity and energy spectrum of the neutron beam.

The (n,p) protons are bent out of the neutron beam by a dipole magnet. The maximum field is ~ 0.8 T at a current of ~ 500 A. The effective length of the field is 47.6 cm. With this magnet, protons of 110 MeV emitted at 0° can be bent at an angle of about 12° . This arrangement introduces a correlated variation of momentum and reaction angle at any given detection angle. A detector 2.5 cm in diameter selects a momentum bite of 19% and an angle bite of 1.8° .

The protons are detected simultaneously in three telescopes each composed of three hyperpure Ge detectors. The telescopes are mounted and cooled to liquid nitrogen temperature inside an evacuated cryostat. They are arranged so as to accept protons emitted typically at 7.5° , 12.5° and 17.5° when the

deflecting magnetic field is turned off. Analog signals from each HPGe detector are first amplified in a specially modified Ortec 142B preamplifier, which drives a short cable leading to a standard timing filter amplifier. This in turn drives a cable about a hundred meters long. The pulses are eventually digitized in a peak sensing ADC and signals from the three elements of a telescope are summed in software to obtain the proton energy spectrum. The preamplifier modification consists simply of reducing the feedback resistor value by a factor of ~ 2000 which permits operation at counting rates up to 10^6 sec^{-1} .

In addition to the shielding discussed above, a shield was provided for the Ge telescopes. The detector shield consists of an outer layer of 3.9 cm thick Pb, and an inner layer of $^6\text{Li}_2\text{CO}_3$ powder 5 mm thick. The ^6Li nuclei absorb thermal neutrons without producing gamma rays. Background measurements showed that this shield lowers the ungated counting rate in the Ge detectors by a factor of about five under typical running conditions. Copper collimators inserted into the Pb shield reduce the Ge detector apertures to 20 mm to exclude particles which would leave the telescopes before stopping.

In front of each Ge telescope of 1 mm thick ΔE plastic scintillator is placed to provide a fast trigger in coincidence with the signals in the first detector of the corresponding telescope. Particle timing information is obtained by starting a TDC on a valid fast trigger pulse and stopping it on a phase-stabilized beam pickoff signal. In addition, the timing difference between ΔE 's and Ge detectors is recorded and monitored. Constant fraction discriminators are used to generate all fast logical pulses.

The data acquisition and analysis were performed using the XSYS code (written at TUNL, modified at IUCF) on VAX computers. Proton spectra were obtained from those events which satisfied cuts on ΔE timing vs. total energy E , ΔE vs. E , and E_1 vs. E , where ΔE and E_1 are energies deposited in the ΔE detector and the first detector in a given telescope, respectively.

The overall performance of the whole setup is illustrated in Fig. 2 which shows a typical $^1\text{H}(n,p)$ spectrum obtained with a 98 mg/cm² CH₂ target and a correspondingly thin (100 mg/cm²) ^7Li primary target. The observed energy resolution, ~ 1.4 MeV FWHM, is approximately consistent with the target thicknesses and the kinematic broadening.

Measurements of (n,p) cross sections have been performed with ^6Li , ^7Li and ^{13}C targets. Preliminary $^6\text{Li}(n,p)$ results are presented in a companion paper in this annual report. Experience with the latter two targets indicates that further improvement of the neutron beam purity would be needed for measurements of medium and heavy targets with smaller cross sections. This could be achieved by inserting an additional sweeping magnet over a portion of the collimator, and by setting up thin (perhaps MWPC) veto counters with low or no hydrogen content at the exit of the

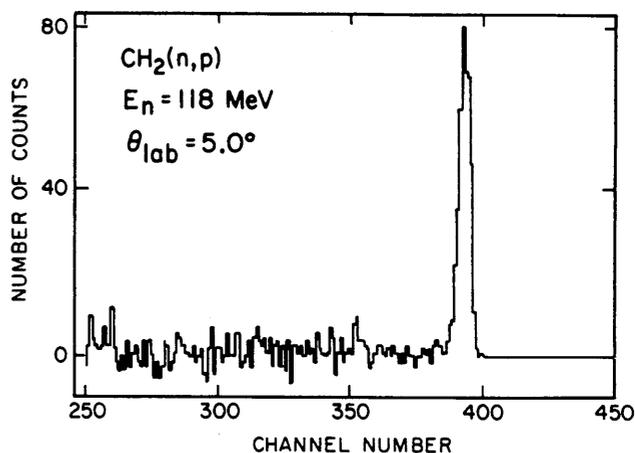


Figure 2. A typical (n,p) spectrum from a CH₂ target. Target thicknesses: ^7Li (primary) - 100 mg/cm²; CH₂ (secondary) - 98 mg/cm².

collimator. Additional MWPC's near the proton telescopes would complete a ray-tracing system which would provide improved definition of the proton telescope acceptances and target in/out ratios. Further desirable improvements include a new deflection magnet with enhanced maximum field to permit measurements at higher energy, and better telescope geometry (larger HPGe detectors for higher acceptance).

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