THE E358 HIGH RESOLUTION NEUTRON DETECTOR

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IUCF experiment E358 represents a study of scattering observables for the exclusive quasifree reaction ^{40}Ca(p,np) detecting the scattered neutrons in coincidence with the associated protons. In the experiment sufficient resolution is required to be able to distinguish neutron knockout from the valence shell-model orbitals of ^{40}Ca which represent the major contribution to the quasifree scattering yield. A large portion of the groundwork for this experiment, covering a period of about six months, has gone into the development and construction of a new high-energy resolution neutron detector.

The neutron four-momentum and kinetic energy are measured by letting the neutron undergo np elastic scattering in a slab of hydrogenous material and detecting this second scattered proton in an array of NaI. The neutron detector consists of ten 2.3 mm thick sheets of polyethylene alternated with nine X and nine Y multiwire proportional chambers (MWPC's) operated as horizontal drift chambers, each with an active area of 39.1 cm × 23.4 cm (Fig. 1).

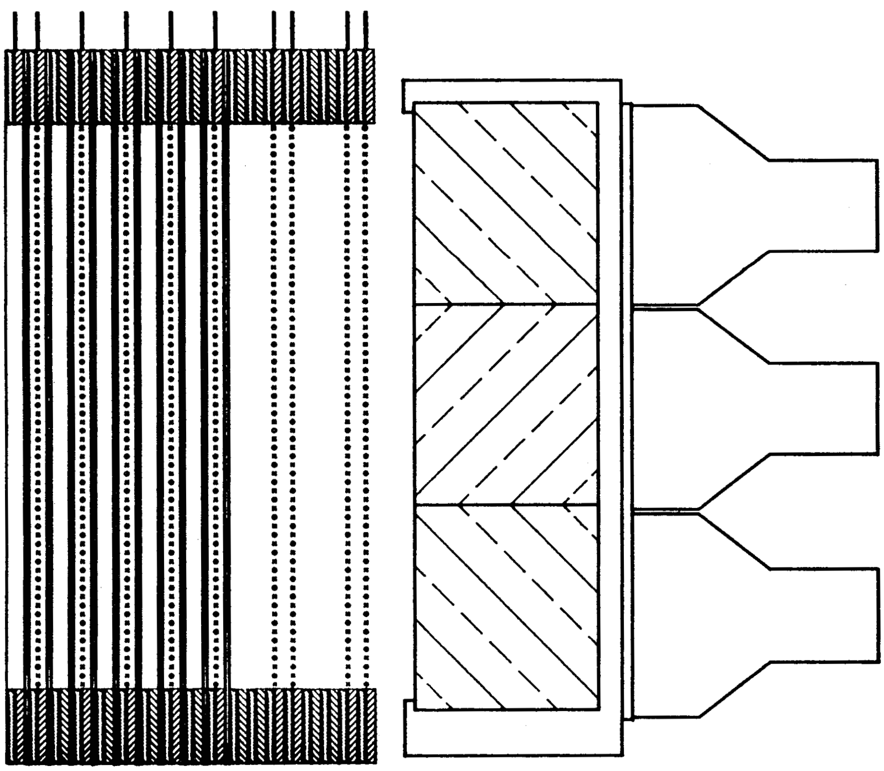

Figure 1. Top view of the E358 neutron detector showing the stacking arrangement of the 18 MWPC's followed by the 3×2 array of sodium iodide.

The central motivation in going to a design in which thin slabs of converter material are alternated with horizontal drift chambers is to maintain the resolution in the proton tracking. This resolution is a strong function of the relative angle between the incident neutron and the scattered proton. From the np free-scattering energy relation, the uncertainty in the neutron kinetic energy is given approximately by

$$\frac{\Delta T_n}{T_n} = \sqrt{\frac{\Delta T_p^2}{T_p^2} + (2\tan\Theta_{np}\cdot\Delta\Theta_{np})^2}$$

The segmented design of the detector allows determination of the proton trajectory before the Coulomb multiple scattering blurs the information, and hence, increases the neutron energy uncertainty. From the kinematics for the neutron energies of interest in the experiment (80 MeV $\rightarrow$ 150 MeV), np free scattering can be distinguished from the ^{12}C(n,p)X background out to an angle of $\Theta_{np} \approx 25°$. This threshold is due to the difference in the Q values for these reactions (Fig. 2). In order to define this threshold and to provide redundant information about our kinematics, a crude time-of-flight cut is imposed on the neutrons. The placement of the NaI array with respect to the neutron detector is dictated by being able to detect protons from np free scattering within the converter within this angular range. Thus the solid angle of the wire chambers has been matched to that of the existing NaI array (3×2 matrix of $5'' \times 5'' \times 5''$ optically isolated crystals). Furthermore this solid-angle matching has gone hand in hand with attempts to minimize the number of readout channels required for the drift chambers. To this end, two designs were included (X and Y) employing two slightly different drift cell sizes. In the X dimension the anode-cathode separation is 6 mm (yielding a square drift cell), while in the Y dimension, the anode-cathode separation is 7 mm (yielding a rectangular drift cell). This design then includes 32 sense wires for the X chambers and 16 sense wires for the Y chambers. Each MWPC was designed to be a stand-alone detector consisting of a single aluminum jig plate (1/4$''$ thick) and a single G10 board (1/4$''$ thick) supporting the guard and sense wires. The cathode foils and gas barriers are constructed from 1/2 mil mylar to reduce the wire chamber contribution to the multiple scattering. The printed circuit boards allow for separate biasing of both the anode and the cathode wires (nominal plateau biases $V_A = 2200$ V, $V_C = -500$ V) with the cathode foils at ground. This permits maximum flexibility in shaping the electric field to simplify the relationship between drift time and drift distance.

In order to minimize the neutron energy uncertainty from the measurements we must successfully resolve the left/right drift chamber position ambiguities incurred during the proton track reconstruction. These ambiguities arise in all horizontal drift chambers due to the fact that the drift-time information is insufficient to directly infer on which side of the sense wire the event passed. Hence there is a need for track reconstruction using multiple wire chambers. Furthermore to aid in the traceback procedure two additional features have been allowed for within the neutron detector. First the chambers are designed such that neighboring detectors are offset by one wire spacing, and secondly XX YY chamber pairs are placed after the ten interleaved converter sheets to ensure that the traceback resolution

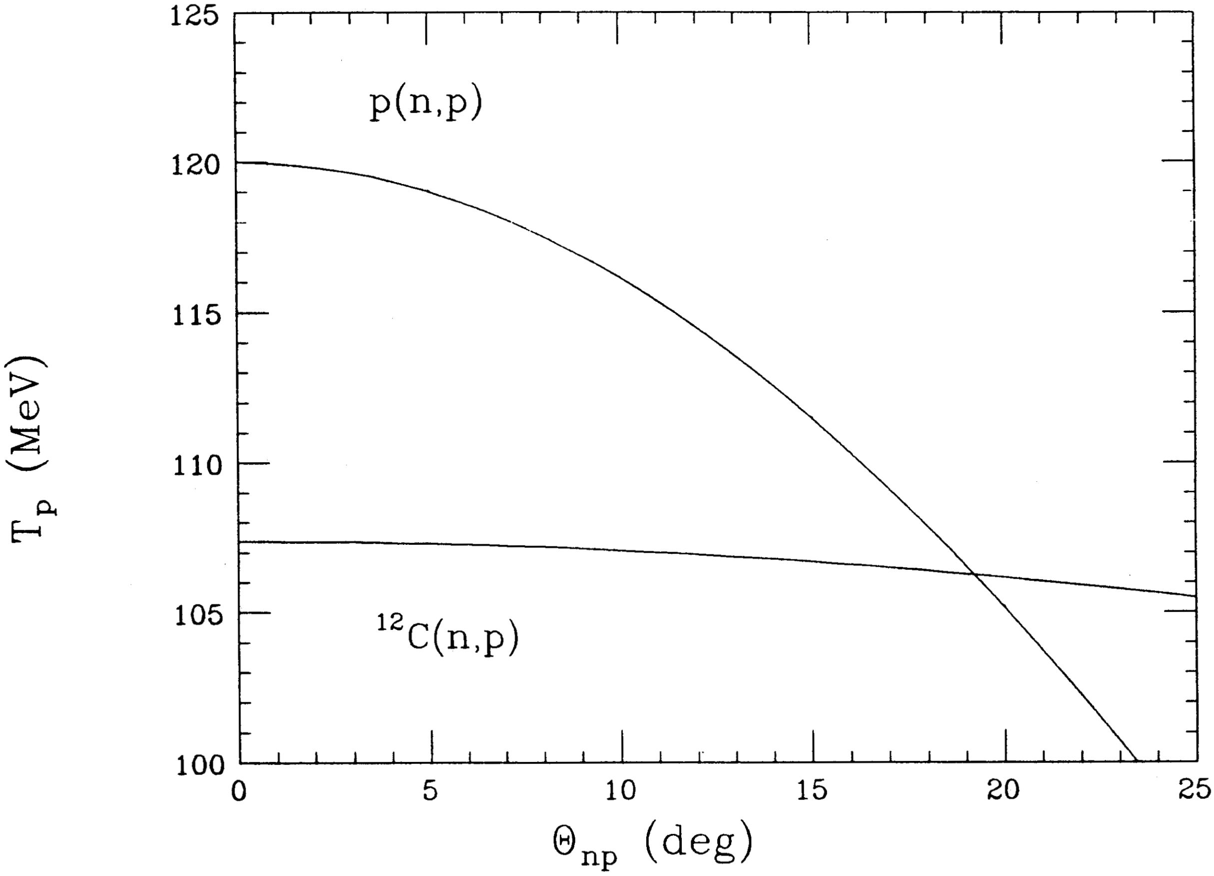

Figure 2. Proton kinetic energy vs. np relative angle for the primary np free scattering reaction and the n + ^{12}C competing background reaction at $T_n = 120$ MeV. The threshold is due to the difference in Q values for these processes.

is independent of the location of the n→p conversion. To obtain sufficient energy resolution each point in the track of the charged particle must be determined to better than 300 μm.

The chambers were designed to be placed onto a support stand which also serves as an alignment table. To ensure that the relative alignment of each chamber with respect to its neighbors is accurately known, alignment fiducials have been included directly onto the printed circuit boards. As the chambers are placed onto the alignment table, they are then sighted with respect to these flags. The design has been shown to be reproducible such that a sighted chamber can be taken off the table and replaced back into its original location without affecting its alignment or that of other members of the detector. The entire stack of chambers, once placed onto the table, is stabilized by four rods which are inserted through the stack of chambers at each of the corners and secured.

These wire chambers were also designed and built such that once E358 is completed, the full complement of chambers (18 + 2 spares) will be entered into the wire chamber laboratory equipment pool and be available for general purpose usage.