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DETECTOR DEVELOPMENT FOR THE $pp \rightarrow pn\pi^+$ EXPERIMENT (CE03)

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• Introduction

The kinematically complete determination of the three-body final state of the $p + p \rightarrow p + n + \pi^+$ reaction requires the measurement of five degrees of freedom of the outgoing particles. The five quantities which may be measured most accurately are the outgoing angles of both nucleons and the energy of the proton. This will be accomplished at the T-site of the Cooler, where a specially-constructed magnet will serve to separate the incident beam from the reaction nucleons and pions. The reaction neutrons will emerge from the target in a narrow cone near threshold and be detected in a neutron hodoscope 3-7 meters (depending on the beam energy) downstream, while the reaction protons will be bent out of the projectile beam and will be detected by two wire chambers and a ΔE-E scintillator assembly. At this time, the neutron hodoscope has been completed, as has one of the wire chambers and a portion of the ΔE-E assembly. These components have been tested in the Cooler beam; a partial offline analysis will be discussed here.

• Neutron Hodoscope

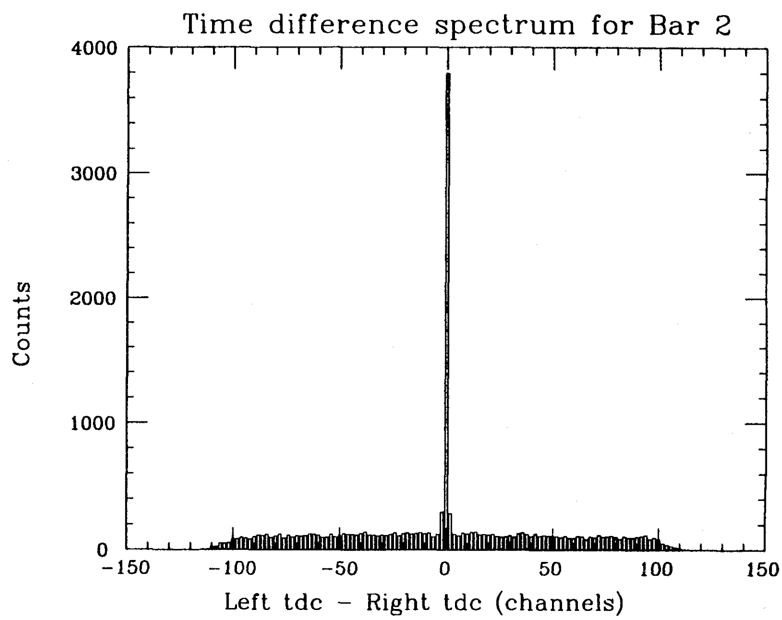
The neutron hodoscope consists of fourteen bars of BC 408 plastic scintillator fitted with fast phototubes at each end. When a scintillation event occurs in a given bar, the time difference between the arrival of the signals at the phototube gives the position of the scintillation along the bar while the position in the perpendicular direction is given by noting which bar fired. Timing and energy calibrations are obtained from pulses fanned out to the scintillator bars from a pulsed ultraviolet laser through quartz fiber optics which also feeds signals to the other scintillators in the system. Neutron time of flight will provide a check on the more precisely measured quantities.

The overall dimensions of the hodoscope are 70 $\times$ 120 cm, with a depth of 15 cm. Each bar is 5 cm tall, which gives the basic limitation on the vertical resolution. The detector will be mounted on a movable support with an axle about which the entire detector can rotate 90° for increased flexibility, allowing the detector to be located very close to the beam pipe when needed. Since the proton beam is bent to $-6°$ by the 6° magnet, the measurement of neutron scattering angles from $-3°$ to $+25°$ is possible at the T-site. In the final experiment, neutron angles will be determined to within an error of $\pm 0.25°$ when the detector is placed 3 m from the target (its closest anticipated position). In this position the vertical acceptance of the hodoscope is 13° and the horizontal acceptance is 22°, which will cover all angles of interest in the measurements near the pion threshold.

The ultraviolet laser produces pulses 300 ps in width which are fed into a fiber-optic bundle and distributed to each scintillator in the entire detector system. The optical fibers connected to the hodoscope terminate in small patches of scintillator material which are precisely positioned in the x center of each of the hodoscope bars; this results in a light pulse originating at a symmetry point and yielding equal and calibrated amounts of light in each photomultiplier. This can be used in a number of ways to cross-check timing and energy data, including gain stabilities. Similar couplings to the other scintillators are planned. In Fig. 1 a raw position spectrum for bar number 2 is shown. The continuum covers the entire active area of the bar and is due to cosmic rays and to a small number of reaction protons, while the sharp peak in the center is due to the laser pulses.

In earlier tests done in an accelerator beam, horizontal position resolutions of 2.5 cm have been obtained for collimated neutrons up to 90 MeV; this corresponds to 300 ps timing resolution. In these tests instantaneous counting rates of up to 800,000 counts per

Figure 1. The raw position spectrum for bar number 2 of the neutron hodoscope. The continuum covers the active area of the bar and is due to cosmic rays and to a small number of reaction protons, while the sharp peak is due to the laser pulses.



second were used without significant resolution deterioration. The response of the detector has been found to be linear along the full length of the scintillator bar.

In February 1990 the hodoscope was used in conjunction with one wire chamber and the partially-completed ΔE-E assembly (the proton arm) in a test run using proton-proton elastic scattering at the Cooler T- site. By detecting the scattered protons on both sides of the beam, the final state is overdetermined. The results of this run are presented elsewhere in this report. Fig. 2 is a schematic drawing of the hodoscope on which is superimposed a position spectrum after cuts on ejectile energies of 60 - 62 MeV and 75 - 77 MeV in the proton arm. The x bands associated with each energy cut are clearly separated and the expected cutoffs due to the geometry of the test setup (the proton arm solid angle was smaller) are seen in the bars near the top and the bottom.

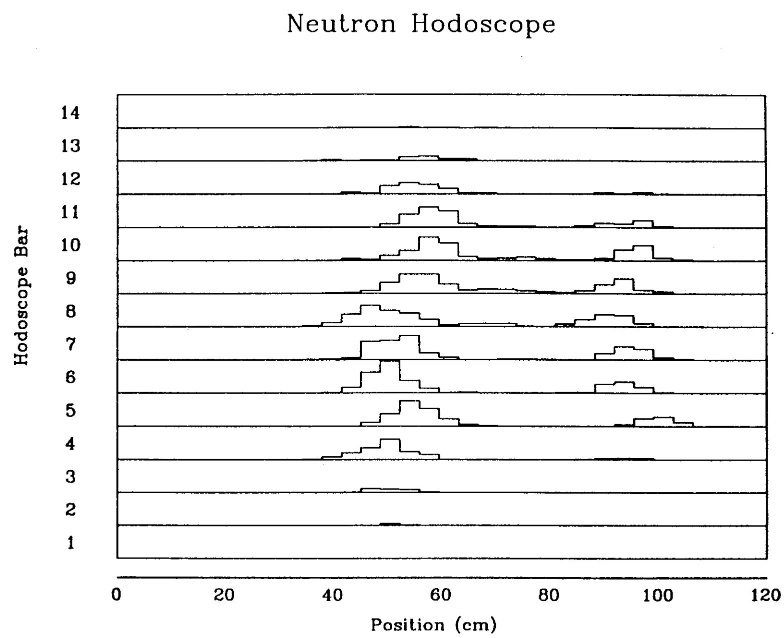


Figure 2. A schematic drawing of the hodoscope on which is superimposed a position spectrum after cuts on ejectile energies of 60-62 MeV and 75-77 MeV in the proton arm.

- Wire Chambers

A total of two drift chamber assemblies will be used in the final measurements near pion production threshold. The smaller of the two chambers has an active area of 22 $\times$ 40 cm, and the larger has an active area of 35 $\times$ 65 cm. Amplification and discrimination of pulses is performed by LeCroy 2735DC cards. Each assembly has a pair of x planes and a pair of y planes so that the particle position and direction will be accurately determined. Currently, one of the two wire chambers is completed. The second wire chamber is being assembled and is nearly finished; it will be bench-tested and tested in-beam during the summer of 1990. Data obtained in a Cooler run in February 1990 using the first wire chamber are presented elsewhere in this report.

- Charged Particle Scintillators

The E scintillator is made up of three to five rectangular plastic scintillator bars which may be oriented so that the particle traverses either the width or the depth of each bar, allowing the volume of the detector to be adjusted for the maximum energy of the detected particles. They will range from approximately 70 to 140 MeV in the three planned measurements near production threshold. Each bar is viewed on one end by a single 3 inch photomultiplier. Two of the five bars were used in the February run. In an earlier beam test with 90 MeV deuterons the energy resolution was measured to be 2.0 to 2.2% (depending on position). Since the results from the current design were quite satisfactory the final three bars use an identical design.

The ΔE scintillator was designed to give the primary timing benchmark for the final experiment. Very fast phototubes (Amperex XP2020) have been purchased toward this end, with a design goal of 250 ps timing for the detector overall. This detector is currently under assembly and will be ready in summer 1990.

PROGRESS ON T-SITE CONSTRUCTION FOR EXPERIMENT CE03

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Preparation of the T-site of the Cooler ring for experiment CE03, to study the reaction $p+p \rightarrow p+n+\pi^+$, involves replacement of two three-degree bending magnets with a new six-degree magnet. This magnet will be used as a ring bending magnet and to separate charged particles of low magnetic rigidity and neutral particles from the circulating beam. It is also designed to be used as a spectrometer to detect recoiling residual nuclei and scattered particles over a wide range of scattering angles and momenta with high accuracy.

Fig. 1 shows a top view of the new T-site magnet. The rays of the circulating beam,

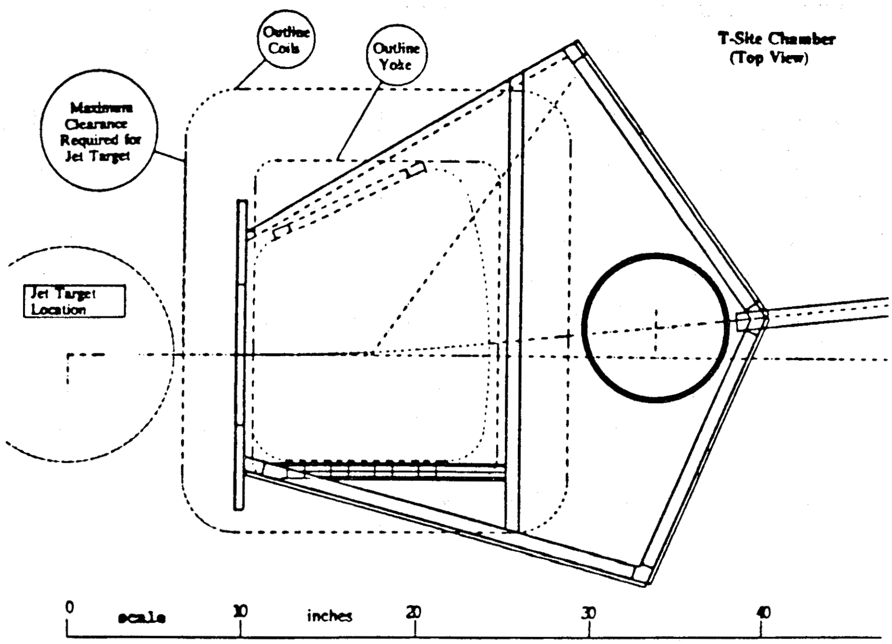

Figure 1. Top view of the new T-section magnet. The outline of the yoke, coils, and pole tips are shown together with the vacuum chamber assembly.