

# Development of a Large Tracking Detector for Neutral Particle Detection

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## Introduction

A detector has been designed to reconstruct the tracks of protons of 100-500 MeV kinetic energy produced in neutral-current interactions by approximately 1 GeV neutrinos. This would open the possibility of a measurement of the strange-quark contribution to the spin of the nucleon [1]. This is a challenging task as the signature of these neutral-current interactions is a single low-energy proton of typically 100 MeV kinetic energy with a range in liquid scintillator of only 10 cm.

A typical, accelerator-generated neutrino flux is  $\Phi = 10^6 \nu/\text{cm}^2/\text{s}$ , and a typical neutrino-induced reaction cross section is  $\sigma \sim 10^{-38} \text{ cm}^2$ . Thus, to observe just a few events per second, a target with  $10^{30}$  to  $10^{31}$  nuclei is required. This corresponds to an active target of about 10 tons of material.

One possible approach to provide charged-particle track information is to use a array of long scintillator bars, either solid, or liquid-filled tubes, arranged crosswise in a stack. The disadvantage of this scheme is that the tracking resolution is determined by the bar dimension and by the precision with which the bars are manufactured and assembled. Also, there is no information on tracks that run nearly parallel to the bars, causing directional blind spots. The scheme that we have avoids these disadvantages.

The proposed detector consists of a light-tight container, filled with a mineral-oil-based, liquid scintillator. Wavelength-shifting fibers that are submersed in the oil collect the scintillation light and guide it to photomultipliers. There are three sets of fibers that are mutually orthogonal to each other. Each set intercepts the wall of the container at the crossings of a quadratic grid. The resulting arrangement is thus invariant with respect to a rotation by  $90^\circ$  in any direction. The light collected by an individual fiber depends on the distance to the particle track. Combining the response of fibers near the track makes it possible to reconstruct its parameters. The symmetrical fiber arrangement ensures that the reconstruction can be done for tracks at any angle within the detector.

## Proof-of-Principle Tests

To demonstrate that this technique is sound, we have constructed a small prototype (shown in Fig. 1) and tested it with 200-MeV protons from the IUCF cyclotron. The device consists of a tank with inside dimensions  $30 \times 14 \times 13 \text{ cm}^3$  made from 6.4-mm thick black-anodized aluminum. Wavelength-shifting fibers of 1.50-mm diameter penetrate the wall of the chamber through oil-tight o-ring seals. The fibers are spaced by 2 cm from each other and arranged in a six by five rectangular grid. One end of the fibers is routed to one of two multi-anode

photomultipliers, while the other end is polished and ends in a dark space. The entire assembly is made light-tight with a black aluminum cover.

Several interesting results were obtained in the tests of this device with 200-MeV protons. A report on this work has been completed [2] and submitted to Nuclear Instruments and Methods. The main results are that a particular combination of ultraviolet  $\rightarrow$  blue wavelength shifting fibers combined with a liquid scintillator without wavelength shifter works well in this detector. It has been determined that this configuration yields  $22 \pm 2$  detected photoelectrons for proton tracks passing near the fiber. This is an ample amount of light that may be used to form particle tracks. The position and angular resolution for tracks reconstructed in this device was measured to be 0.3 cm and  $3.5^\circ$  respectively. These results were reproduced in a simulation indicating that the light production/propagation/detection processes are adequately understood. We are currently seeking support to build a  $(50 \text{ cm})^3$  device with fibers oriented in all 3 directions. This is this next step towards demonstrating that this device is an excellent neutrino detector and may be used for neutron detection as well.

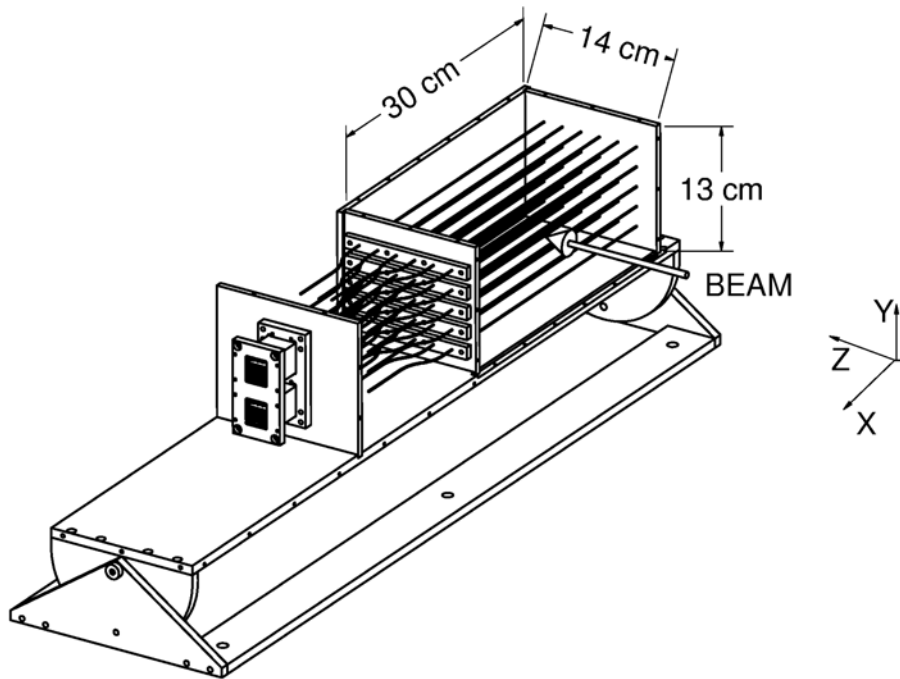


Figure 1: Assembly drawing of the prototype detector. There are 5 rows of 6 fibers for a total of 30 wavelength-shifting fibers.

1. L. Bugel *et al.*, arXiv:hep-ex/0402007.
2. R. Tayloe *et al.*, submitted to Nucl. Instrum. Methods; see also (<http://www.iucf.indiana.edu/~rex/scibath.pdf>).