

A Hybrid Emulsion Detector

For

Direct Observation of ν_τ

The DONUT Collaboration

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Abstract

An experimental apparatus, designed primarily for direct observation of the tau neutrino, has been constructed and made operational by the DONUT Collaboration for the Fermilab E872 experiment. It consists of a nuclear emulsion target, a scintillating fiber tracker system with optoelectronic readout, an air-core analysis magnet, trigger counters, drift chambers, an electromagnetic calorimeter, and a muon identification system. The design, construction and performance of the entire apparatus and of the various detectors are described.

1. Introduction

There is compelling theoretical justification and experimental evidence that the tau neutrino (ν_τ) exists as a unique lepton [1, 2]. Experimental evidence to date indicates that the couplings of the ν_τ are consistent with predictions of the Standard Model [3, 4]. However, direct interactions of ν_τ in the manner observed for ν_e and ν_μ have yet to be seen. Experimental observation of charged-current events requires high beam intensity combined with very good detector resolution. These requirements are met by the 800 GeV primary proton beam from the Fermilab Tevatron combined with a hybrid emulsion spectrometer. The hybrid emulsion spectrometer consists of a nuclear emulsion target and ancillary detectors for event location. This same technique has been used successfully in other experiments [5, 6, 7].

Recent experimental data [8] indicate that the atmospheric neutrino anomaly might be due to neutrino flavor oscillations of the type $\nu_\mu \rightarrow \nu_\tau$. In addition to the experiments of references 5 and 7, other oscillation experiments, both short-baseline and long-baseline, have considered the use of high resolution emulsion targets to detect neutrino oscillations through the direct observation of ν_τ from a beam initially comprised of ν_μ [9, 10, 11]. The E872 experiment is, therefore, an important step in addressing the question of neutrino mass and mixing.

The E872 experiment tested the detector components early in the Tevatron 1996-97 fixed target run and collected physics data from 13 April, 1997, when the first two emulsion modules were installed, to 3 September, 1997. Altogether, a total of seven emulsion modules were used, although no more than four were used at any given time.

We describe the experimental apparatus in this paper, with particular emphasis on the design, construction and performance of the various detector subsystems. The prompt neutrino beam is presented in Reference .

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