0 Abstract

The primary purpose of the Fermilab Experiment E-872 was to make the first direct observation of the charged current interaction of the tau neutrino. Additionally, there are several other physics measurements which we will attempt to extract from the data sample.

The purpose of the following outline is to provide a road map through the experiment, taking the user from the early conceptual design of the project through its completion. This master outline (when used in its hyperlinked format) provides an organized repository for the results of the experiment's design, data analysis, Monte Carlo studies, physics calculations, and finally documentation of each of these.

1 Introduction

2 Physics Motivation

2.1 *The THIRD Neutrino*

2.1.1 What we know about the ν_τ

2.1.2 What we don't know about ν_τ

2.2 *Neutrino Oscillations*

2.2.1 ν_τ appearance experiments

2.2.2 Other methods of inferring ν_τ

3 Physics Calculations

3.1 *Production of Prompt Neutrinos*

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3.1.1.1 ν_μ, ν_e

3.1.1.2 ν_τ

3.1.1.3 Charm Production

3.1.1.3.1 Cross sections

3.1.1.3.2 A dependence

3.1.1.4 $D_s \rightarrow \tau\nu$ Branching Fraction

3.1.2 Secondary Sources

3.2 *Weak Interactions and Neutrinos*

3.2.1 Charged Current Interactions

3.2.1.1 Neutrino/anti-neutrino average

3.2.1.2 ν_τ threshold

3.2.2 Neutral Current Interactions

3.3 *Expected Rates*

3.3.1 General Formulation

3.3.2 Solid Angle Acceptance

3.3.3 Target Masses (refer to 5.4.1)

3.3.4 Protons on target

3.3.4.1 SEM Calibration

3.3.4.2 Live time correction

3.3.5 Detection Efficiency (Refer to 5.5.1, 7.3 and 7.4)

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3.3.5.2 Candidate Event Selection

3.3.5.3 Emulsion Scanning

3.3.5.4 Trigger

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3.3.5.6 Emulsion Scanning

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4.1 *Design Requirements*

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- 4.1.2 Backgrounds
  - 4.1.2.1 Muons
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  - 4.1.2.3 Electron/gammas

4.2 *Concept*

- 4.2.1 Primary Proton Beam
- 4.2.2 Target
  - 4.2.2.1 A dependence
  - 4.2.2.2 Density (full and half)
- 4.2.3 Muon Sweeping
  - 4.2.3.1 Prompt Muon Production
  - 4.2.3.2 Secondary Sources
  - 4.2.3.3 Design Strategy
    - 4.2.3.3.1 Primary
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4.3 *Engineering Designs*

- 4.3.1 Primary Proton Beam
- 4.3.2 Target (Beam Dump)
- 4.3.3 Muon Sweeping
  - 4.3.3.1 Primary
  - 4.3.3.2 Supplemental
  - 4.3.3.3 Primary (SELMA)
  - 4.3.3.4 Secondary (MuSweep)
- 4.3.4 Muon Absorption
- 4.3.5 Soft Component Shielding

4.4 *Performance*

- 4.4.1 Muon backgrounds
- 4.4.2 Neutron Backgrounds
- 4.4.3 Soft e,γbackgrounds

5 Hybrid Emulsion Spectrometer

5.1 *Methods of DetectingTau Neutrino Interactions*

5.1.1 Indirect (kinematic) Method

5.1.2 Direct (decay length) Method

5.2 *Historical Background*

5.2.1 Philosophy (Method)

5.2.2 Neutrino Production of Charm (E531, WA??)

5.2.3 Fixed Target b-production (E653)

5.3 *Conceptual Design*

5.3.1 Resolution Requirements

5.3.2 Particle ID

5.3.3 Energy/momentum measurements

5.4 *Components*

5.4.1 Emulsion Targets

5.4.1.1 Material Description

5.4.1.2 ECC Module Composition

5.4.1.3 Bulk Module Composition

5.4.1.4 ECC/Bulk Hybrids

5.4.2 Trigger Counters

5.4.2.1 Veto Wall

5.4.2.2 T1, T2 Fiber Counters

5.4.2.3 T3 Trigger Wall

5.4.2.4 Trigger Logic

5.4.3 Scintillating Fiber System

5.4.3.1 Fiber Planes

5.4.3.2 Image Intesifiers

5.4.3.3 CCD Readout

5.4.4 Magnetic Field

5.4.5 Drift Chambers

5.4.5.1 Vertex Drift Chambers

5.4.5.2 Magnet Chambers

5.4.5.3 Downstream Chambers

5.4.6 Electromagnetic Calorimeter

5.4.7 Muon ID System

5.4.7.1 Gas Proportional Tubes

5.4.7.2 Scintillator Strips

6 Data Taking

6.1 *Calibration with PW5 Muons*

6.2 *Neutrino Interaction Triggers*

6.2.1 Trigger Rate

6.2.2 Data Acquisition

6.2.3 On-line Analysis

7 Data Analysis

7.1 *Emulsion Processing*

7.2 *Alignment and Calibration*

7.2.1 Emulsion

7.2.1.1 ECC's

7.2.1.2 Bulk

7.2.1.3 Changeable Sheets

7.2.2 Fiber Tracker

7.2.3 Trigger Counters

7.2.4 Drift Chambers

7.2.4.1 VDC

7.2.4.2 KSU

7.2.4.3 Monster

7.2.5 Muon ID

7.2.5.1 Gas Tubes

7.2.5.2 Scintillators

7.2.6 EM Calorimeter

7.2.7 Magnetic Field

7.3 *Performance*

7.3.1 Trigger Efficiency

7.3.2 Tracking efficiency

7.3.3 Position Resolution

7.3.4 Momentum resolution

7.3.5 Energy resolution

7.3.6 Particle ID

7.4 *Event Location (Spectrometer)*

7.4.1 Raw Data Processing

7.4.2 Pass 1 Stripping

7.4.3 Visual Scan Selection

7.4.4 Track Finding

7.4.5 Vertex Prediction

7.4.6 Refitting

7.5 *Event Location (Emulsion)*

7.5.1 Introduction

7.5.2 Scanning Hardware

7.5.3 Scanning Methods

7.5.3.1 CS Scan

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7.5.4 Results

7.5.4.1 Vertex Location

7.5.4.2 Decay Search
7.5.4.3 Preliminary Event ID
7.6 *Event Analysis*
7.6.1 Event Distributions
7.6.1.1 Vertex Distributions
7.6.1.1.1 Transverse (U,V)
7.6.1.1.2 Longitudinal (Z)
7.6.1.2 Calorimeter Energy
7.6.1.3 Muon momentum
7.6.1.4 Angular Distribution of Tracks
7.6.2 Determination of Event Parameters
7.6.3 Event type likelihood analysis

8 Monte Carlo Analysis

8.1 *Neutrino Event Generator*

8.1.1 Deep Inelastic (Lepto 6.1)

8.1.2 Quasi-elastic events

8.2 *Generated Distributions*

8.2.1 Neutrino Types

8.2.2 Energy Spectra

8.2.2.1 Primary Neutrino

8.2.2.2 Lepton in CC interactions

8.2.2.3 Total Visible Energy

8.2.3 Tau Lepton Distributions

8.2.3.1 Decay Length

8.2.3.2 Decay Kink Angle

8.2.3.3 Daughter Momentum

8.3 *Hybrid Emulsion Spectrometer Simulation (Geant)*

8.3.1 Descriptions

8.3.1.1 Emulsion Targets

8.3.1.2 Scintillating Fiber Tracker

8.3.1.3 Trigger Counters

8.3.1.4 Tracking Chambers

8.3.1.5 EM Calorimeter

8.3.1.6 Muon ID

8.3.2 Distributions (Comparison to Data)

8.3.2.1 Scintillating Fiber Tracker

8.3.2.2 Trigger Counters

8.3.2.2.1 Veto Wall

8.3.2.2.2 T1, T2

8.3.2.2.3 T3

8.3.2.3 Tracking Chambers

8.3.2.3.1 VDCs

8.3.2.3.2 KSU

8.3.2.3.3 Monster

8.3.2.4 EM Calorimeter

8.3.2.5 Muon ID

9 Physics Results

9.1 *Composition of the Prompt Neutrino Beam*

9.1.1 Measured ν_μ and ν_e events rates

9.1.2 Acceptance corrections

9.2 *NuTau Interactions in Bulk Emulsion*

9.2.1 Measured Event Rates

9.2.2 Measured Event Distributions

9.2.3 Acceptance Corrections

9.2.4 Comparison to Predictions

9.3 *NuTau Interactions in ECC Targets*

9.3.1 Measured Event Rates

9.3.2 Measured Event Distributions

9.3.3 Acceptance Corrections

9.3.4 Comparison to Predictions

9.4 *Neutrino Production of Charm in Emulsion Targets*

9.4.1 Measured Event Rates

9.4.2 Measured Event Distributions

9.4.3 Acceptance Corrections

9.4.4 Comparison to Predictions

9.5 *Determination of* $\sigma_{charm}(x_\beta, p_t)$

9.5.1 Measured Muon Energy Spectrum

9.5.2 Determination of Neutrino Spectrum

9.6 *Measurement of the* ν_τ *magnetic moment*

9.6.1 Present Limits

9.6.2 Signature of the Process

9.6.3 Improved Limits