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Electron Detection in the Reference Near Detector for DUNE and Constraints on the Anti-Electron-Neutrino Normalization

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The DUNE experiment is a proposed next generation long-baseline neutrino oscillation experiment designed to solve mass hierarchy and CP-violation problems by measuring $\nu_\mu/\bar{\nu}_\mu$ to $\nu_e/\bar{\nu}_e$ oscillation in one single experiment. It is therefore critical for DUNE to measure the electrons and positrons precisely. The DUNE Near Detector, located at Fermilab, will provide a precise determination of the electron/positron identification, momentum, and energy, and the anti-electron neutrino content of the beam

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1. Introduction

DUNE is the next generation long-baseline neutrino oscillation experiment aiming to solve the mass hierarchy and CP-violation problems by measuring $\nu_\mu/\bar{\nu}_\mu$ to $\nu_e/\bar{\nu}_e$ oscillation [1]. DUNE will use a new neutrino beam proposed at Fermilab. The neutrino spectrum will be measured by the near detector (ND) at Fermilab, and the far detector at Sanford Underground Research Facility in South Dakota.

A highly capable near detector will be important for DUNE to fulfill its scientific goals. It provides constraints on the systematic uncertainties to the oscillation measurement, and also offers physics by itself. This talk focuses on the reference design for the DUNE ND, the Fine-Grained Tracker (FGT) detector, and its ability of electron/positron measurement.

2. Fine-Grained Tracker

The central part of the Fine-Grained-Tracker (FGT) detector is a Straw Tube Tracker (STT), surrounded by 4π coverage of Electromagnetic-Calorimetors (ECAL) and Muon Detectors (Figure 1). The detector complex is in a dipole magnetic field of 0.4 T which makes possible the measurement of particle charge and wrong-sign contamination in the (anti)neutrino beam. The target is pressurized Ar gas which provides 10 times of the far detector statistics. It is also possible to add additional target materials such as carbon and calcium to study the nuclear effect. The detector is low-density ($0.1g/cm^3$), with long radiation length (6m), optimized for tracking of charged leptons and hadrons. The FGT detector provides excellent resolution for the electron and muon energy and angle measurement, as well as the high-efficiency background rejection. The detailed performance of FGT is summarized in Table 1.

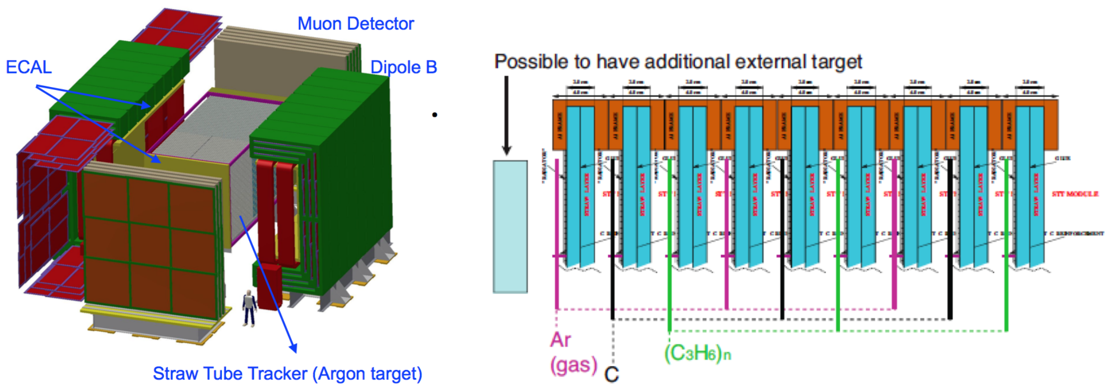

Figure 1: The reference DUNE near detector design, Fine-Grained Tracker detector (left), and the possible nuclear target might be used (right).

3. Electron/Positron Measurement

Figure 2 shows a $\bar{\nu}_e$-CC candidate events in a FGT detector. Electrons/positrons make tracks in the FGT, and so are the hadrons, thanks to the low-density detector material used. We are

Table 1: FGT performance.

Radiator Mass	7 tons
Other Nuclear Target Mass	1-2 tons
Vertex Resolution	0.1 mm
Angular Resolution	2 mrad
Electron Energy Resolution	$6\%/\sqrt{E}$ (4% at 3 GeV)
Muon Energy Resolution	3.5%
$\nu_\mu/\bar{\nu}_\mu$ ID	Yes
$\nu_e/\bar{\nu}_e$ ID	Yes
π^+/π^- ID	Yes
$\pi^+/p/K^+$ ID	Yes
NC π^0 Rejection	0.1%
NC γ Rejection	0.2%
CC μ Rejection	0.01%

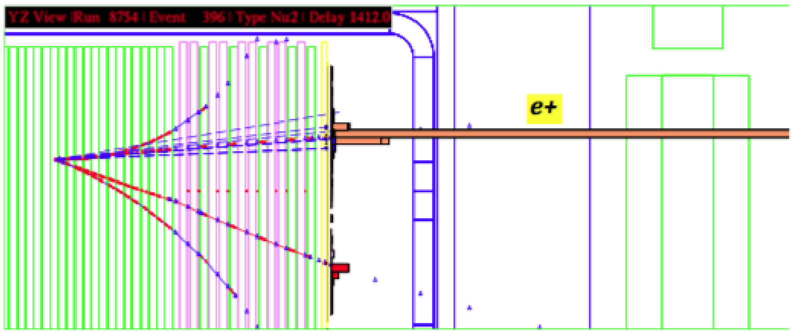

Figure 2: A $\bar{\nu}_e$-CC candidate events in a FGT detector.

therefore able to measure lepton and hadron momentum vectors with high precision, by using the track curvature in the dipole magnetic field for the momentum measurement, and ECAL for more precise energy measurement. The combined e^+/e^- momentum resolution ~3.5% (at ~3 GeV).

The FGT detector also has excellent performance in selecting electron/positrons. Information that can be used for identification of electron includes transition radiation (TR) measurement in the Staw Tube Tracker (STT), longitudinal and transverse energy deposition pattern in the ECAL, and pattern of energy loss (helical track-fit) in STT. The dipole magnetic field allows distinguishing e^+ from e^-, and therefore a measurement of anti-electron-neutrino content in the beam.

STT and ECAL prototypes in a test beam have been proposed to calibrate the detector's respond to electron/positron. In addition, we can also use e^+/e^- from γ-conversion events in STT to calibrate the electron identification efficiency and energy scale.

4. Summary

A Fine-Grained Tracker ND for DUNE is able to precisely identify and measure electrons and positions. The particle identification involves measurements of the transition-radiation in the high-resolution straw tube tracker (STT) and the profile of the energy deposition in the ECAL;

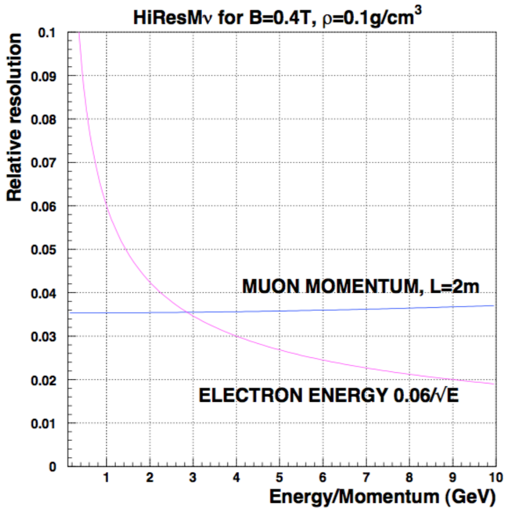

Figure 3: Muon momentum resolution, by using track curvature in STT (blue), and electron energy resolution in the ECAL (megenta).

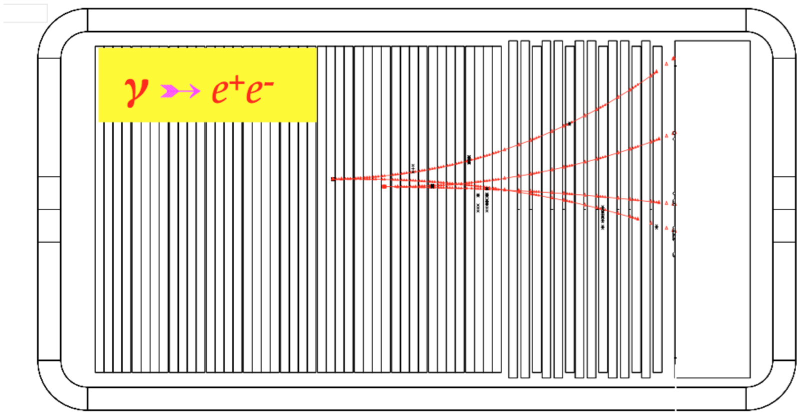

Figure 4: A π^0 event where both photons from the π^0 decay convert to electron/positron pairs in the STT.

the momentum is determined from the track reconstruction in the STT within a dipole B-field. The ability to reconstruct the electron/positrons and the hadrons from the anti-electron neutrino interactions permits an accurate determination of the anti-electron neutrino content of the beam.

References

[1] R. Acciarri *et al.* [DUNE Collaboration], arXiv:1601.05471 [physics.ins-det].