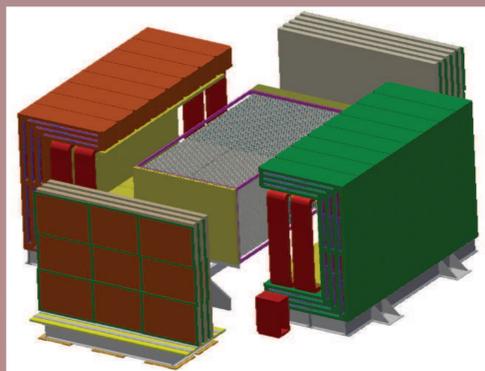


# Fine-Grained Tracker as a Near Detector for LBNE

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## Introduction

The reference design of the near detector for the LBNE experiment is a Fine-Grained Tracker (FGT) capable of precisely measuring all four species of neutrinos:  $\nu_{\mu}$ ,  $\nu_e$ ,  $\bar{\nu}_{\mu}$ , and  $\bar{\nu}_e$ . The FGT is composed of a Straw-Tube Tracker (STT) with transition-radiation capability surrounded by a high resolution electromagnetic calorimeter (ECAL) and embedded in a dipole magnet. Muon-ID detectors instrument the iron-yoke of the magnet and the downstream and upstream stations outside the magnet. The STT is instrumented with Ar and other nuclear targets. The goal of the FGT is to constrain systematic errors below the statistical error in all oscillation studies in the far detector. The FGT will also conduct a panoply of precision measurements and searches.



## International Collaboration

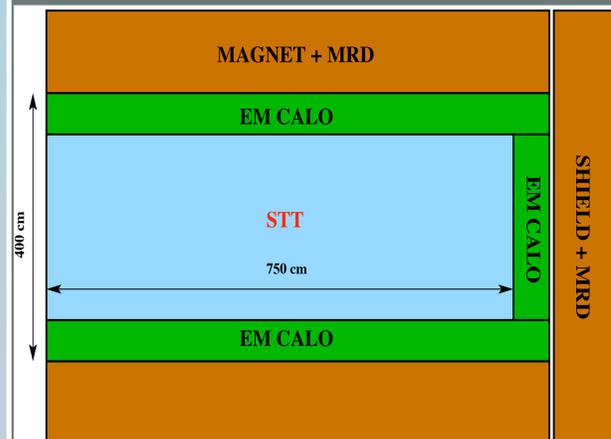
Indian institutions have proposed to prototype, develop, and fabricate the Fine-Grained Tracker (FGT), in collaboration with the US institutions, as the LBNE Near Detector. The proposal (DPR) was submitted to the Indian funding agencies, DAE and DST, in Dec., 2012.

- STT: Panjab University with some contributions from US groups
- ECAL: India Institute of Technology (Guwahati) and Delhi University
- Magnet: Bhabha Atomic Research Centre, Trombay, Mumbai
- RPC: Variable Energy Cyclotron Centre
- Simulation & Sensitivity study: University of South Carolina

## Physics Goals

- Constrain the systematic uncertainties in the oscillation studies
- Conduct precision measurements of neutrino interactions, including cross-sections, exclusive processes, electroweak and isospin physics, structure of nucleons and nuclei etc.
- Conduct searches for new physics covering unexplored regions, including heavy (sterile) neutrinos, large  $\Delta m^2$  neutrino oscillations, light Dark Matter candidates etc.

## FGT Sub-detectors



## FGT Requirements

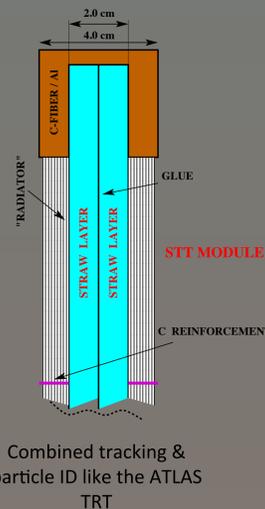
Item	Requirement	Performance Metric	FGT
Inner Magnetic Volume	4.5m×4.5m×8.0m	Straw Tube Detector Mass	8 tons
Tracking Detector	3.5m×3.5m×7.04m, 88 modules, 123,904 straws	Vertex Resolution	0.1 mm
Targets	1.27 cm thick argon, water, and other nuclear targets	Angular Resolution	2 mrad
Transition Radiation Radiators	2.5 cm thick radiators	$E_e$ resolution	5%
ECAL	$X_0=10$ barrel, 10 backward, and 18 forward, 32,320 scintillator bars	$E_{\mu}$ resolution	5%
Dipole Magnet	0.4 T, 2.4 MW, 60 cm thick steel	$\nu_{\mu}/\nu_{\mu}$ ID	Yes
Magnetic Field Uniformity	<2% magnetic field variation over inner volume	$\nu_e/\nu_e$ ID	Yes
MuID	32 RPC planes interspersed between 20 cm thick layers of steel	$N\bar{C}\pi^0/CCe$ Rejection	0.1%
		NCY/CCe Rejection	0.2%
		CC $\mu$ /CCe Rejection	0.01%

## FGT Performance

## Straw Tube Tracker (Panjab U.)

Proven design and technology

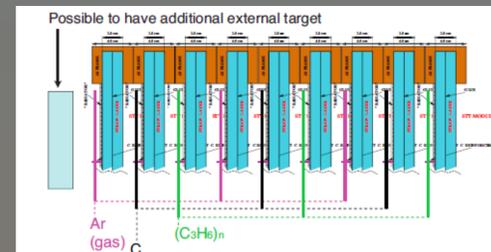
- Straw Inner diameter :  $9.530 \pm 0.005$  mm
- Operate with 70%/30% Xe/CO<sub>2</sub> gas mixture
- Radiator/target thickness ~ 20mm with 75 (C3H6)<sub>n</sub> foils (40  $\mu$ m) for transition radiation and tulle spacers
- Straws arranged in double layers glued together inserted within C-fiber/Al composite frames
- 166 modules arranged by alternating vertical and horizontal orientation with total length of 7 m
- Mass of the active target dominated by the radiators (82.6% of total mass) can be tuned to achieve desired events and momentum resolution



Combined tracking & particle ID like the ATLAS TRT

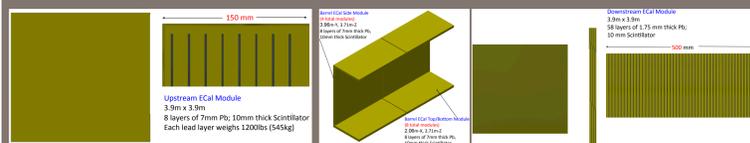
## Radiators/Nuclear Targets (US)

Use statistical subtraction of different target materials



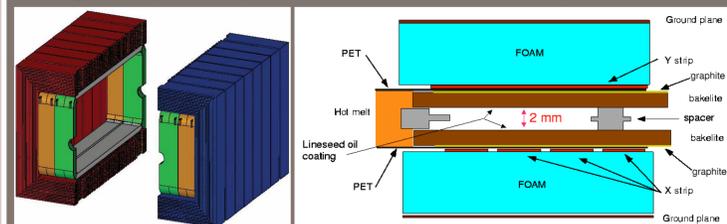
- Al tubes filled with pressurized Ar gas to provide same target as in FD (LANL)
- Radiators (C3H6)<sub>n</sub> and C targets for flux and precision measurements (Carolina)
- Develop Ca target for FD oscillation analysis and isospin physics (Carolina)
- Steel target (Fe) for INO experiment

## Electromagnetic Calorimeter (IIT,Guwahati & Delhi U.)



- Lead-scintillator based on the T2K-ECAL, embedded inside the 0.4 T dipole magnet
- 58 layers of alternating horizontal/vertical scintillator strips per 1.75 mm Pb along the z-direction
- Plastic Scintillator bars: 4m×2.5cm×1.0cm, 160 bars/layer, 9,280 bars in total
- Two sided readout

## Magnet (BARC) and Muon-ID (VECC)

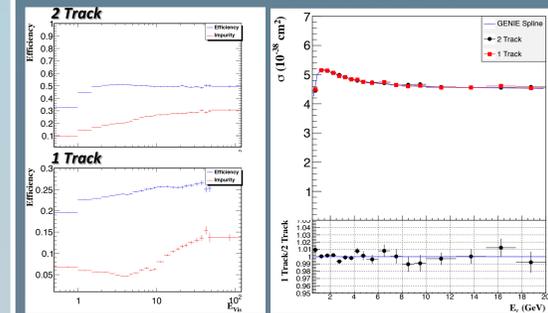


- 4.5m×4.5m×8.0m inner dimensions
- <2% magnetic field variation over inner volume
- 0.4 T magnetic field
- Muon Range Detector – identify muons at low momenta exiting the sides of the detector.
- External Muon Identifier – identify high-energy forward muons

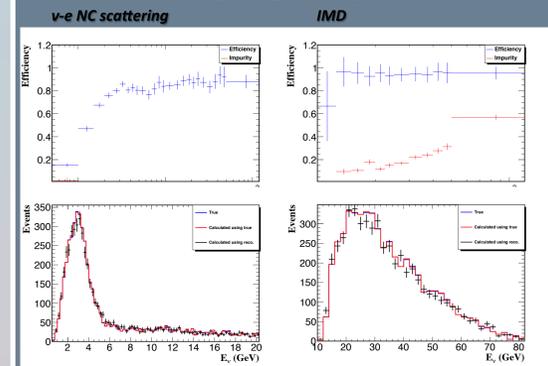
## Sensitivity Study using Fast MC (Carolina)<sup>1</sup>

CCQE 1 & 2 Track<sup>2</sup>

Constraints nuclear effects : initial state pair wise correlations and final state interactions



$\nu$ -e NC scattering & Inverse Muon Decay  
Constraints neutrino flux



1. The LBNE Fast Monte Carlo - Poster 195
2. Sensitivity of Quasi-Elastic Scattering in the LBNE Near Detector - Poster 232

## Geant4 Simulation (Carolina)

HiResMv Software (HiSoft/hisoft)

### Framework

- Based on ART framework
- Using Git/mrb

### Geometry

- Under development
- Python based script
- Straw Tube Tracker and radiators/targets are in place

