Update on FGT Electromagnetic Calorimeter (ECAL)

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DUNE Near Detector Working Group Meeting

February 24, 2016
DUNE FGT Near Detector

Current CDR reference design. Four components detector:

- An active low density **straw tube tracker** (STT) in a 0.4 T magnetic field with embedded high pressure argon gas targets.

- The STT will be surrounded by a \( 4\pi \) **lead-plastic scintillator Electromagnetic Calorimeter**. *This Talk.*
  - Will consist of a Downstream, Barrel and Upstream part.
  - With transverse and longitudinal segmentation.
  - Enables complete detection of particles, such as photons, neutrons, electrons etc. produced in \( \nu \) interactions.
  - Energy resolution: \( 6\%/\sqrt{E} \) for downstream ECAL; Time resolution: 1 ns for \( E > 100 \text{ MeV} \)

- The tracking detector and ECAL modules will reside inside a **0.4 T dipole magnet** with inner dimensions of 4.5 m wide by 4.5 m high by 8 m long.

- Surrounding the dipole magnet and also downstream of the magnet, there is a **4\( \pi \) muon-ID detector made of RPC** to detect high energy forward muon tracks.
DUNE FGT Near Detector Layout
**DUNE FGT Near Detector Layout**

- Best performance among the 4-options
- $3.5m \times 3.5m \times 7.5m$ STT ($\rho=0.1$ gm/cm$^3$)
- $4 \pi$ -ECAL in a Dipole-B-Field (0.4T)
- $4 \pi$ -$\mu$-Detector (RPC) in Dipole and Downstream
- Pressurized Ar Target ($\approx 5$ FD-Stat) $\Rightarrow$ LAr-FD

Transition Radiation $\Rightarrow$ e-/e+ ID $\Rightarrow$ $\gamma$

dE/dx $\Rightarrow$ Proton, $\pi^{+/-}$, $K^{+/-}$
Magnet/Muon Detector $\Rightarrow$ $\mu^{+/-}$

$\{\nu-e \Rightarrow \text{Absolute Flux measurement}\}$
The 4π lead-plastic scintillator electromagnetic calorimeter has three components:

- **Downstream ECAL**: 60 layers of alternating horizontal/vertical extruded plastic scintillator strips per 1.75 mm of lead along the z-direction. The dimension of each scintillator bar is 3.2 m x 2.5 cm x 1 cm. 128 bars per layer and 7680 scintillator bars in total. Two sided readout via extruded WLS fiber and SiPM. $20 \ X_0$.

- **Barrel ECAL**: Will surround the sides of the STT. 16 layers of plastic scintillator bars (horizontal along the axis of the magnet) per 3.5 mm of Pb along the z-direction. Same dimensions of the scintillator bars as in the downstream ECAL. 128 bars per scintillator plane and 16,384 scintillator bars in total. Total of 8 modules for the top/bottom and the sides. $10 \ X_0$.

- **Upstream ECAL**: 16 layers of alternating horizontal/vertical scintillator strips per 3.5 mm Pb along the z-direction. Same scintillator bar dimensions. 128 bars per scintillator plane and 2048 scintillator bars in total. $10 \ X_0$. 
ECAL Assembly

Need space for electronics and services (cooling for the electronics, cabling etc. Current assumption is about 10 cm.

Assembly Reference Plate ~ 12.7mm thick

"Y" scintillator slats

"X" scintillator slats

Lead Sheet 1.75 mm thick
ECAL Assembly

Forward Calorimeter

32 channel front end boards servicing array of 4 x 8 SiPMs
The electromagnetic calorimeter will be designed and constructed in two phases:

- **R & D and Prototyping Phase:**
  - Construct a 2 m x 2 m downstream ECAL with about 10 radiation length.

- **Final ECAL design and assembly**
  - Assembly hall for the final ECAL will be setup at IIT Guwahati during the prototyping phase.

- The plan is in accordance with the DPR submitted to the Department of Atomic Energy and Department of Science and Technology, India.
  - The execution of this project is subject to release of the requested fund.
Laboratory Infrastructure for the ECAL assembly

32 m x 12 m laboratory space at IIT Guwahati:
FGT ND-ECAL Simulation Status

- Simulate and optimize the ECAL in the HiSoft framework.
  - Now has a new repository called dunefgt created by Tyler Alion.

- GDML geometry of the DUNE-FGT has been prepared and initialized.
  - Used duneggd, based on “gegede” to develop the DUNE FGT geometry.

- Initial goal is to determine the energy resolution of the downstream, upstream and barrel ECAL for various energy range of incoming electrons from 50 MeV to about 10 GeV using G4 energy depositions.

Soumya Ranjan Das, IITG
DUNE FGT Near Detector Simulation

Soumya Ranjan Das, IITG
DUNE FGT Near Detector Simulation: Barrel ECAL

Soumya Ranjan Das, IITG
Upstream/Downstream ECAL

10X₀

16 layers
3.5mm Pb

20X₀

60 layers
1.75mm Pb

Soumya Ranjan Das, IITG
Simulation level Energy Resolution

HiResMν for $B=0.4T$, $\rho=0.1g/cm^3$

Relative Resolution (Downstream ECAL)

Electron Energy (GeV)

Resolution from simulation
Parametric Resolution

Soumya Ranjan Das, IITG
Simulation level Energy Resolution

Energy resolution vs input energy of electrons incident normally on each ECAL

$\sigma_E/E_{\text{avg}}$ (%) vs $E_{\text{beam}}$ (GeV)

- [ ] Downstream ECAL
- [ ] Barrel ECAL
- [ ] Upstream ECAL

Preliminary

Soumya Ranjan Das, IITG
Energy Response

Downstream ECAL:
Electrons are fully contained up to 10 GeV

Soumya Ranjan Das, IITG
Fast MC Simulation of Photon Transport in Scintillator Bar

- Fast simulation of photon transport in a scintillator bar without WLS fiber to study attenuation in ECAL. Side Reflectivity and End Transmittivity taken to be 0.9.
- Significant attenuation noticed for photons generated isotropically around the middle of the bar. Light yield is only noted for photons generated at the ends.
- Determine the effect of attenuation by introducing WLS fiber.
Attenuation for one scintillator bar without the WLS fiber

Probability of detection of photons from both ends of the scintillator bar

- Average Probability (in log scale)
- Length of the scintillator bar (in cm)

- Blue line: Bottom face of the scintillator bar
- Red line: Top face of the scintillator bar

Soumya Ranjan Das, IITG
ECAL Readout Electronics Concept

90mm x 165mm front end board with 32 channel TRIP-T chip (blue) and a placeholder FPGA chip

The board size may be able to grow a bit in length but not in height => custom board
**ECAL Readout Electronics Concept**

- Study of MPPCs & preliminary simulations being done with Trip-T chip in focus
- This is done to understand and estimate the MPPC output, capacitative division of the said output, role of integrating preamplifier, amplifiers and ADC electronics.
- In the near future testing out the complete design for a single channel using simulations and actual hardware is the primary objective.

**Attempts to simulate the SiPM output when one cell of APD array is fired**

Very preliminary results for integrating preamplifier

Maharnab Bhattacharjee, IITG
Coupling of the WLS fiber with SiPM

- AUTOCAD design for the coupler to hold the WLS fiber and the SiPM together. Alternate design ideas are also explored.

Dibyajyoti Kalita, IITG
Summary

- **Focus on:** ECAL geometry optimization, simulation of the readout electronics and the design of the coupler to couple the fiber with the SiPM.

  - Require “go ahead” from the funding agency to develop the infrastructure at IIT Guwahati for the detector assembly. Detailed plan is already developed.

  - Focus on building the 2 m x 2 m downstream ECAL prototype in three years once the funding becomes available.

  - JINR, Dubna to collaborate on the r&d of the ECAL at IITG.