

Angle and energy reconstruction of atmospheric neutrinos in DUNE

XXXI International Conference on Neutrino Physics and Astrophysics

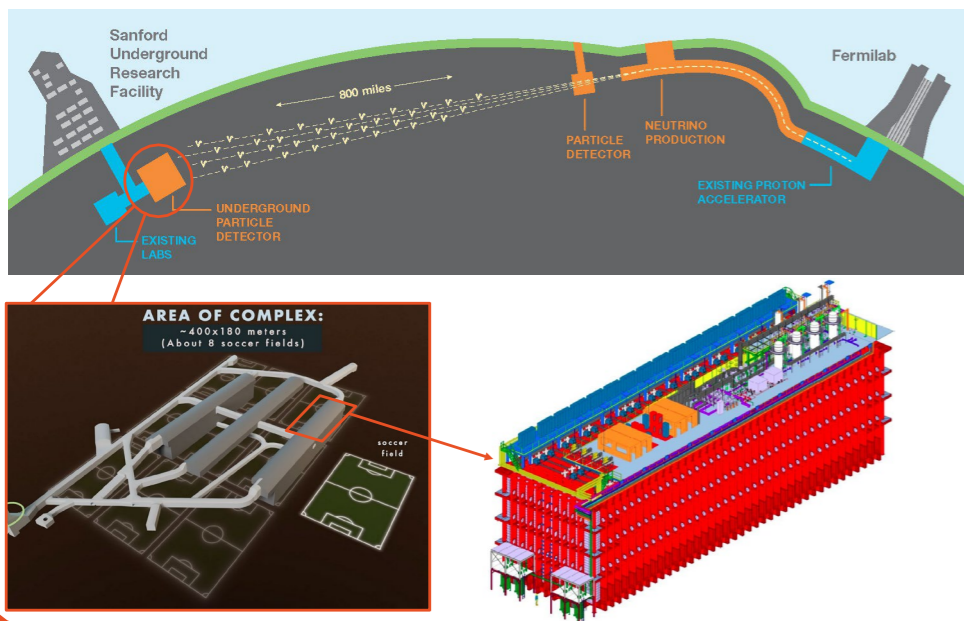
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Motivation

Deep Underground Neutrino Experiment (DUNE)



Intense beam (2 MW), ν_μ and $\bar{\nu}_\mu$ modes, energy from 0.1 to 10 GeV

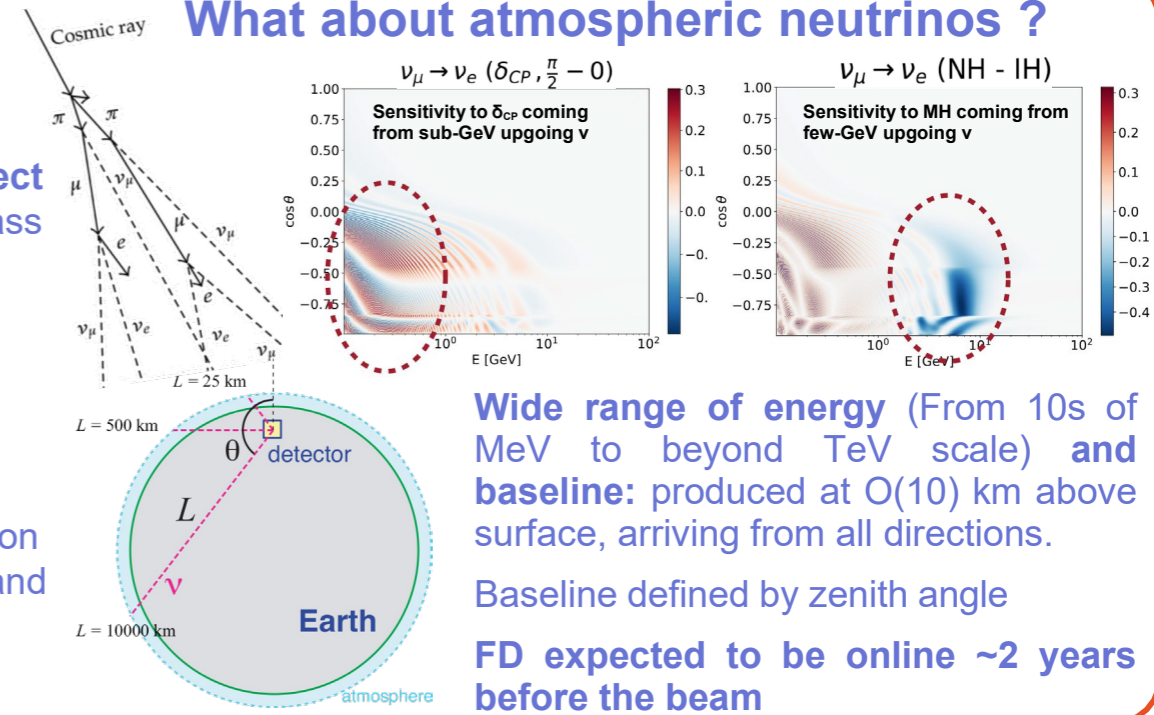
Baseline of 1300 km will explore matter effect and break degeneracies between δ_{CP} and mass hierarchy

4 Far Detector (FD) modules 17 kt of liquid argon each

Liquid Argon TPC

- Excellent 3D imaging with millimeter resolution
- Particle identification through dE/dx , range and topology
- Excellent calorimetric measurements

What about atmospheric neutrinos ?



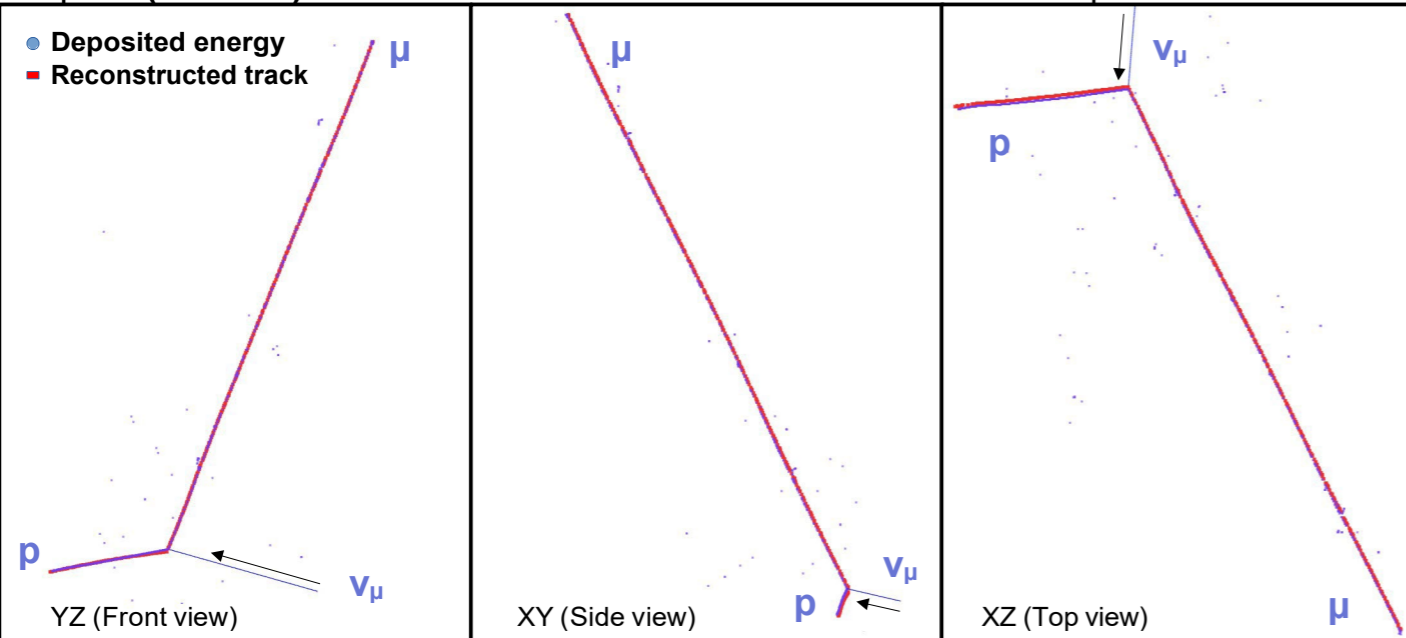
Angle reconstruction



Methods

ν_μ CC (1.4 GeV)

- Deposited energy
- Reconstructed track

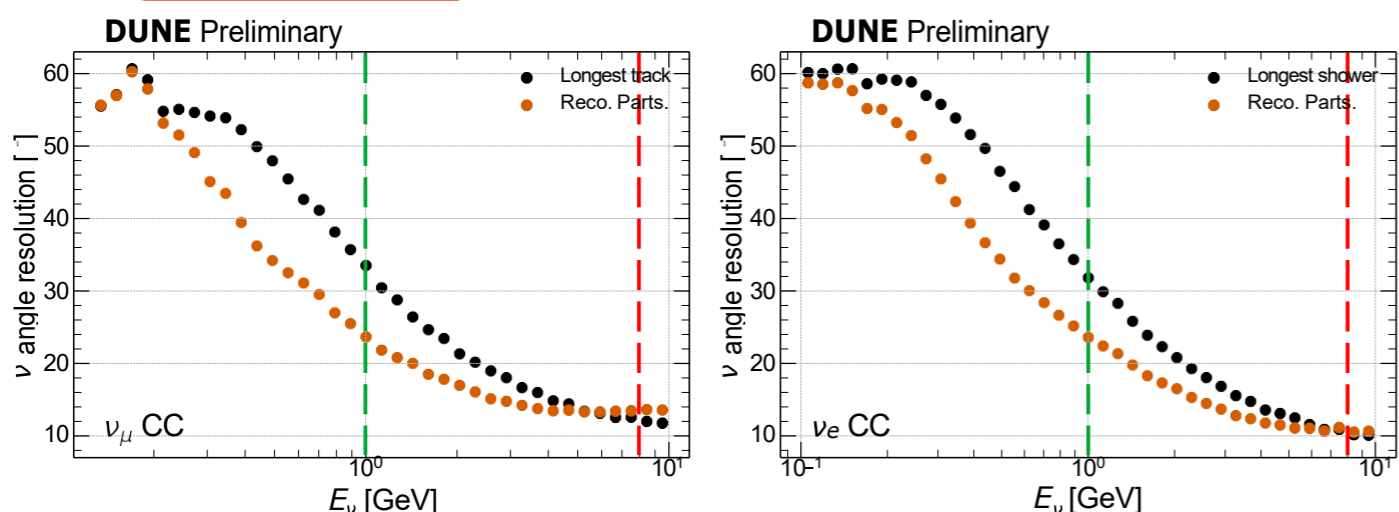


Example of reconstruction

Two different methods:

- Assuming lepton direction as neutrino direction
 - ▶ Simplified approach best suited for events with $E > 3$ GeV
 - ▶ For ν_μ events, select reconstructed longest track as muon
 - ▶ For ν_e events, select shower with highest charge as electron
- Use all reconstructed particles
 - ▶ More sophisticated method: use our best knowledge of all Final State charged particles
 - ▶ For Shower-like events:
 - Shower with highest charge assumed to be electron (ν_e events)
 - Longest track assumed to be muon (ν_μ events)
 - ▶ Use Particle Identification (PID) to decide between protons and pions
 - ▶ Computes momentum for track and shower-like particles
 - ▶ Unavailable information:
 - Neutron carried momentum
 - Nuclear effects: Fermi motion, final state interactions

Results



The plotted resolutions correspond to 1 sigma around 0 of the true minus reconstructed angle distribution along zenith angle.

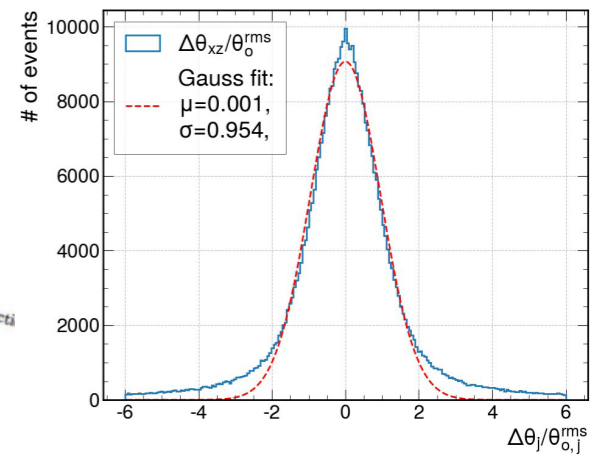
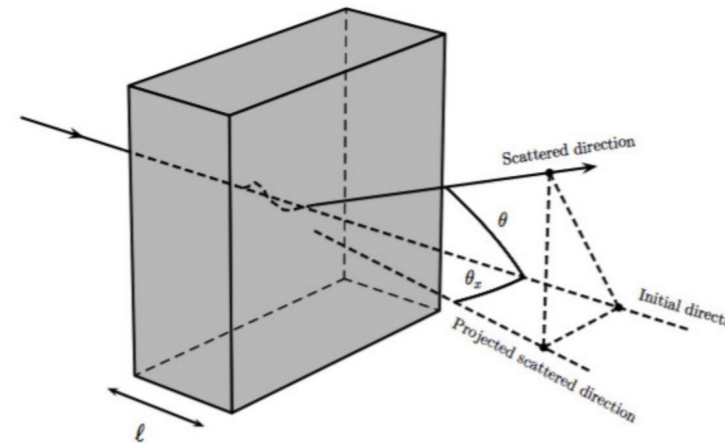
- For energies < 1 GeV, resolution dominated by Fermi motion and other nuclear effects. Studies (not shown in this poster) have shown that an improved proton reconstruction would have a positive impact on the resolution.
- From 1 to 8 GeV, angular resolution close to the best theoretical performance. Momentum reconstruction seems to be where most of the possible improvements lie.
- $E > 8$ GeV, Limited reconstruction accuracy. Improving the tracks/showers reconstruction could provide large improvements.

Energy reconstruction

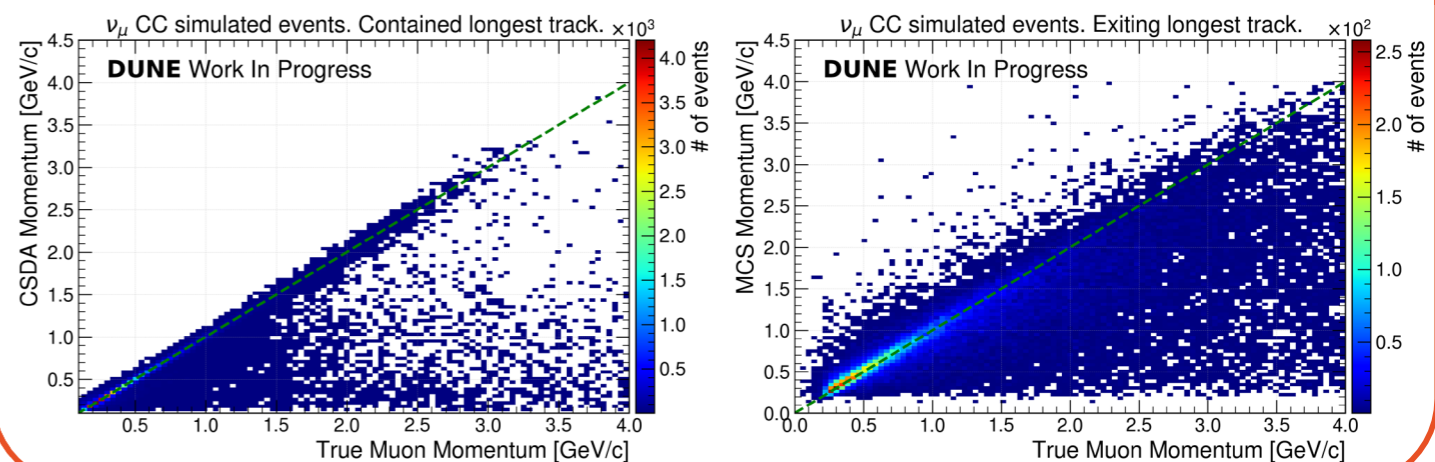
Methods

The muon energy is estimated in two ways.

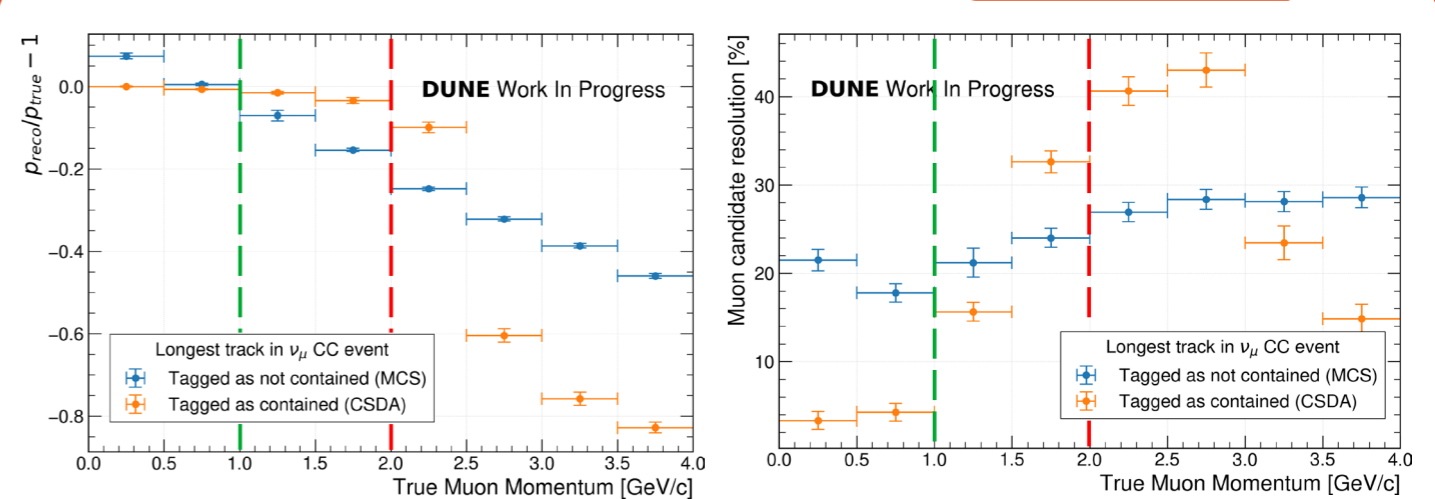
- For Contained tracks:
 - ▶ Constant Slow Down Approximation (CSDA)
 - ▶ Uses the Stopping Power to estimate the muon momentum via track range.
- For Not Contained tracks:
 - ▶ Multiple Coulomb Scattering (MCS).
 - ▶ The method I've implemented is based on the MicroBooNE [1] studies.



The energy lost is computed for each segment ($\ell = 10$ cm) from the stopping power. A correction is added to the scatter angles to account for the fitting of the tracks. The following plots show the energy reconstruction for longest tracks as muon candidate in ν_μ CC events inside a $6 \times 7 \times 14$ m³ scaled LArTPC with Horizontal Drift technology of DUNE.



Results



Bias (left) and resolution (right) of the reconstructed momentum. The bias is retrieved as the median, while the resolution corresponds to 1 sigma of the distribution. The minimum track length for MCS method was set to 50 cm.

- Longest track tagged as contained, the CSDA recovers muon momentum with negligible ($< 5\%$) bias below 2 GeV and resolution below 5% for $E < 1$ GeV. The resolution is below 30% except for energies > 2 GeV, caused mostly by the longest track not corresponding to the muon.
- Longest track tagged as not contained, the MCS has resolution below 30% for energies higher than 500 MeV. However, the bias starts to be significant ($> 20\%$) for energies above 2 GeV.