Angle and energy reconstruction of atmospheric neutrinos in DUNE

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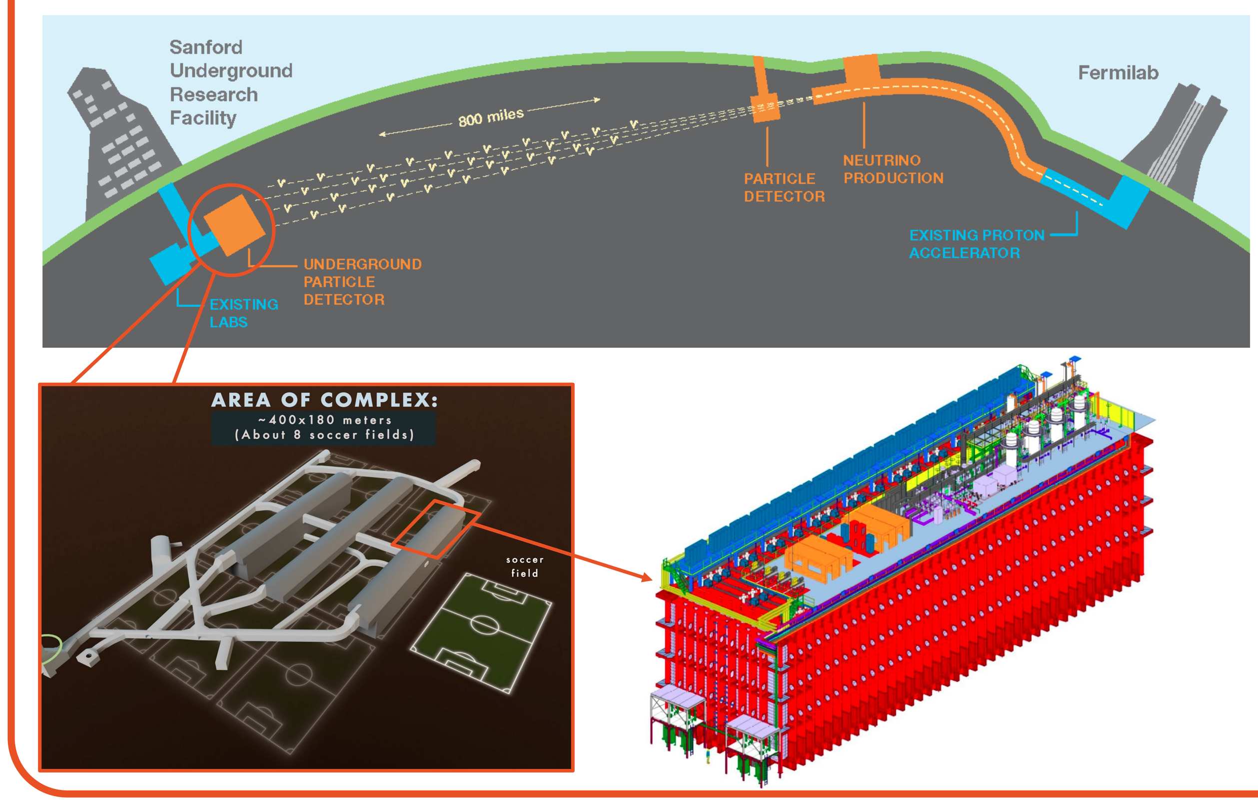
Motivation

Deep Underground Neutrino Experiment (DUNE)

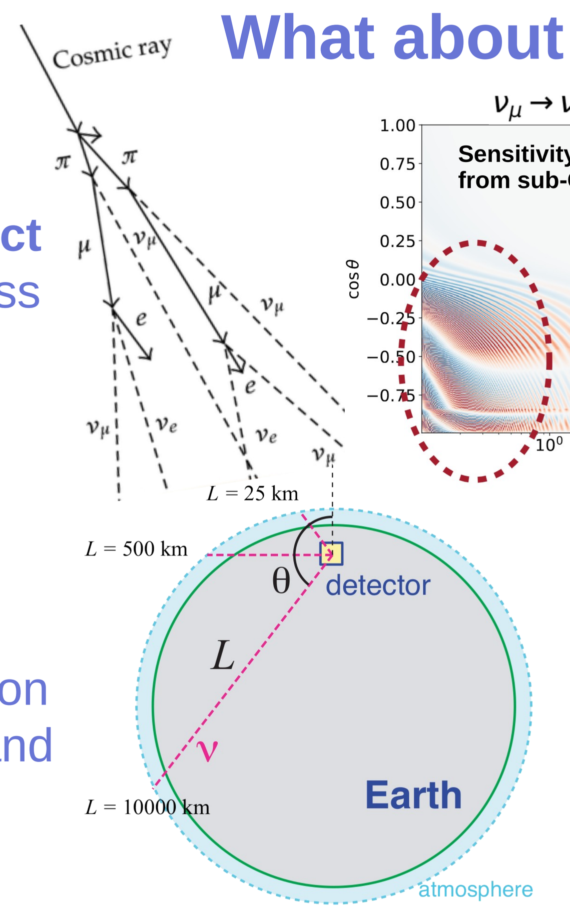


Intense beam (2 MW), **ν_μ and $\bar{\nu}_\mu$ modes, energy from 0.1 to 10 GeV**

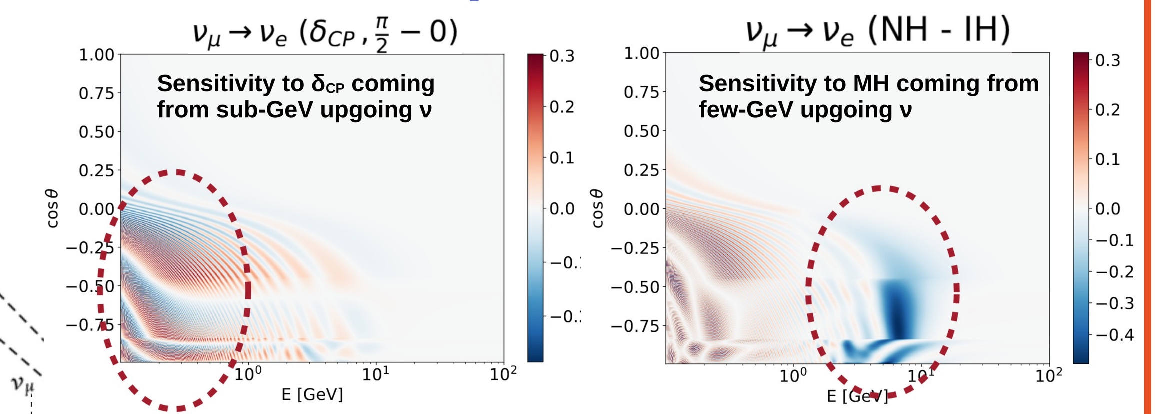
Baseline of 1300 km will explore **matter effect** and break degeneracies between δ_{CP} and mass hierarchy

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 ?



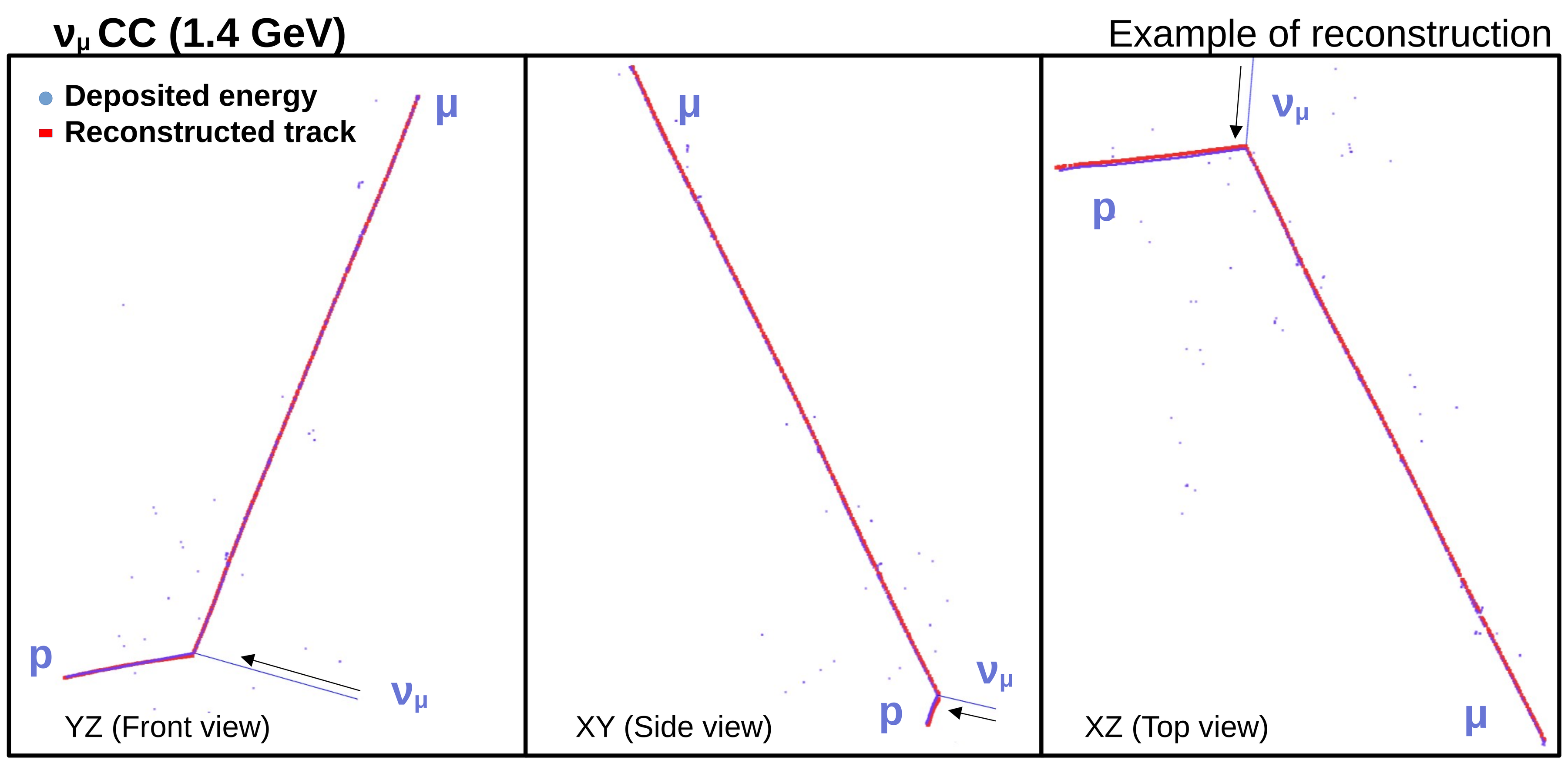
Wide range of energy (From 10s of MeV to beyond TeV scale) **and baseline:** produced at O(10) km above surface, arriving from all directions.

Baseline defined by zenith angle

FD expected to be online ~2 years before the beam

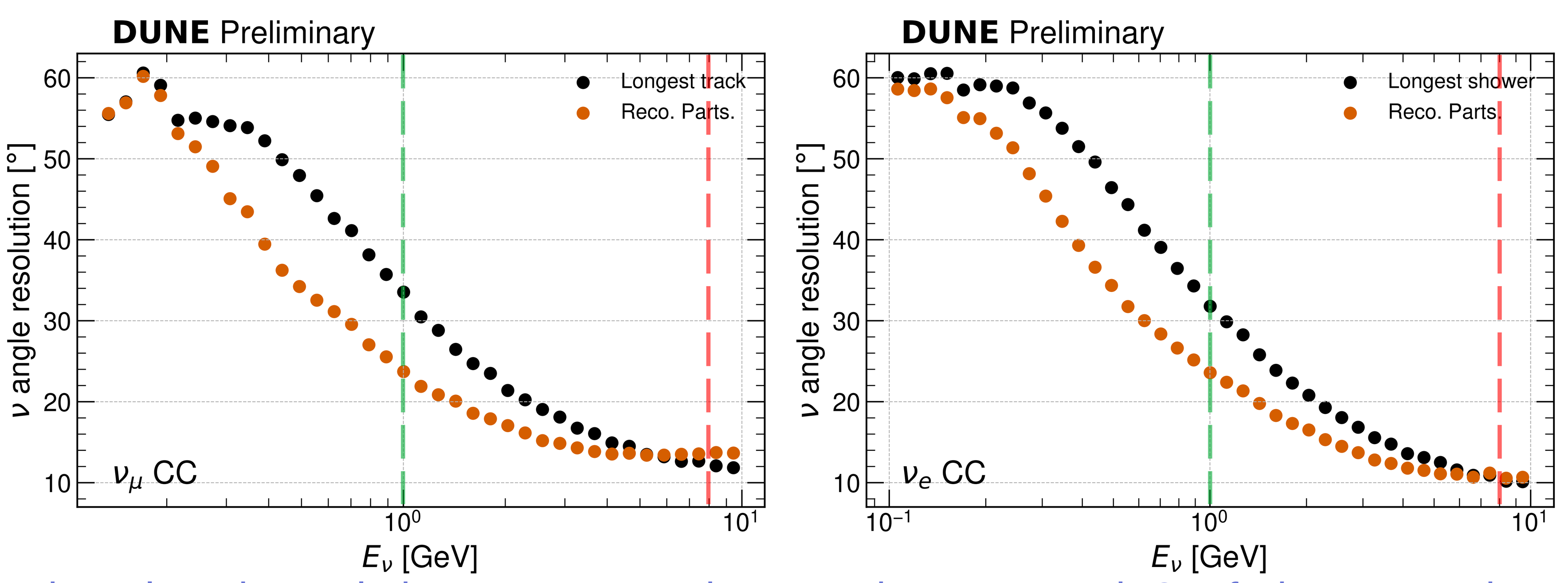
Angle reconstruction

Methods



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)
  - For track-like 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

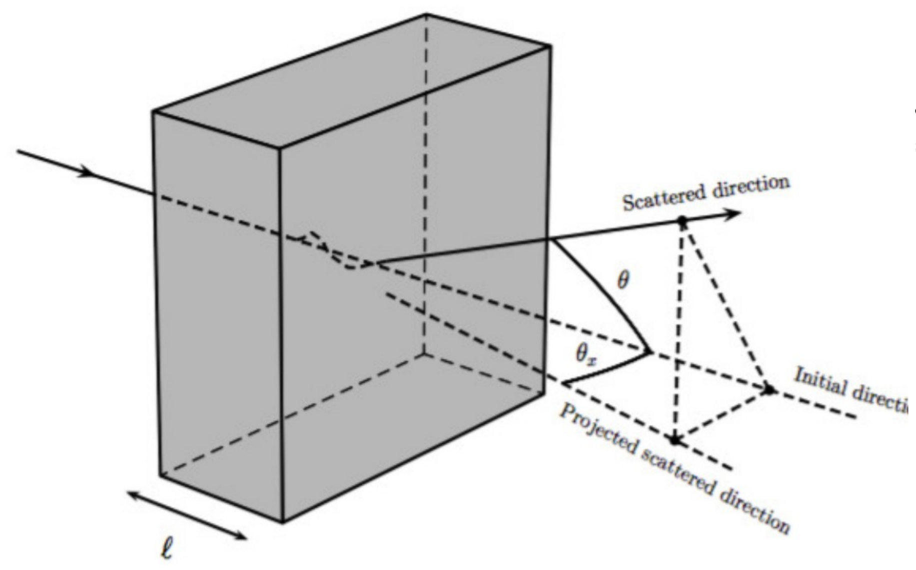


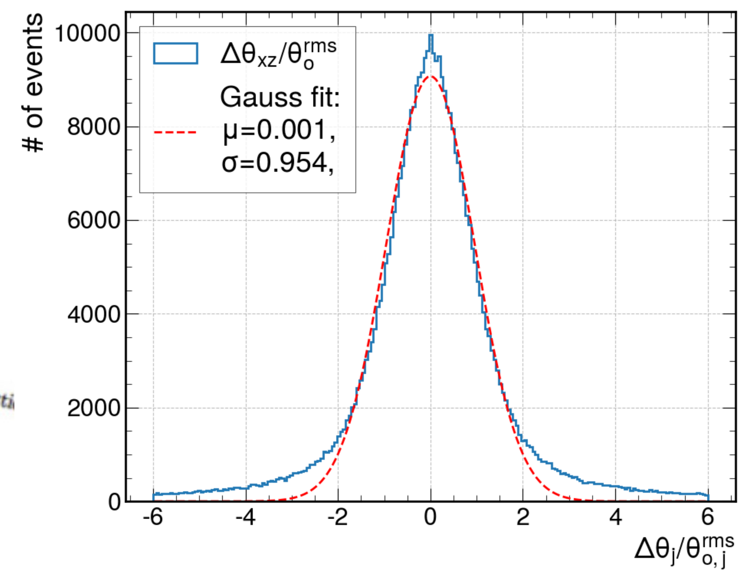
The plotted resolutions correspond to 1 sigma around 0 of the true minus reconstructed angle distribution along zenith angle.
- **For energies < 1 GeV**, resolution dominated by Fermi motion and other nuclear effects. Studies (not shown in this poster) have shown that an improved proton reconstruction 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

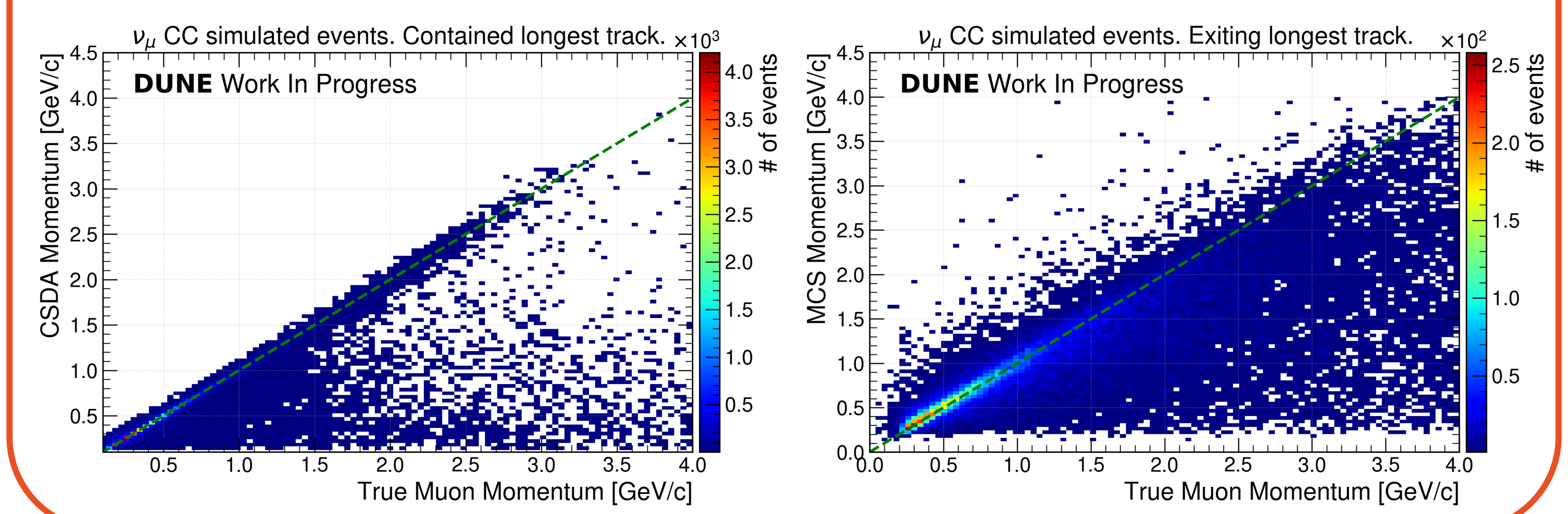
Methods

The muon energy is estimated in two ways.
- For **Contained** tracks:
  - **Constant Slow Down Aproximation (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.

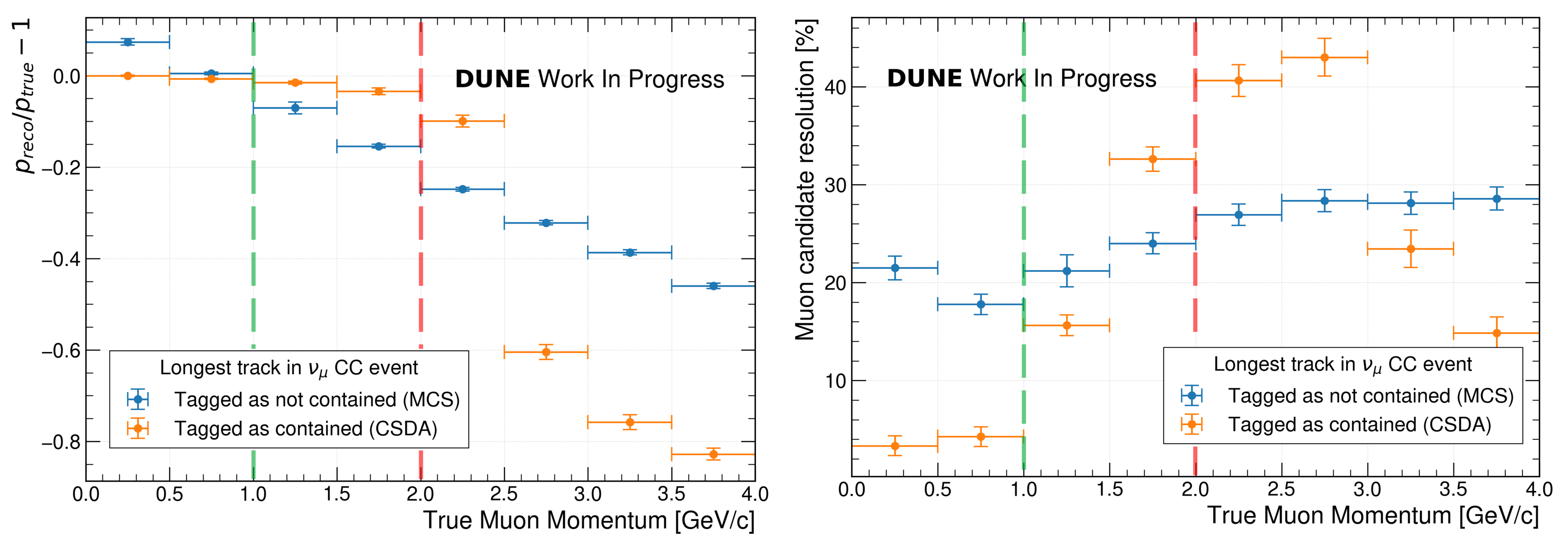




The energy lost is computed for each segment (ℓ = 10 cm) from the stopping power. A correction is added to the scatter angles to account for the fitting of the tracks. The following plots show the energy reconstruction for longest tracks as muon candidate in ν_μ CC events inside a 6x7x14 m^3 scaled LArTPC 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.

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[1] - P. Abratenko et al 2017 JINST 12 P10010