Energy reconstruction in DUNE Dual Phase LAr TPC

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The Deep Underground Neutrino Experiment (DUNE)

- Next generation long-baseline neutrino experiment (beam in 2026)
- 1300 km baseline and beam power optimized for sensitivity to CP violation and mass hierarchy in a single experiment
- Far detector: four 10 kt Liquid Argon Time Projection Chamber (LArTPC)
  1. Single Phase (SP) design
  2. Dual Phase (DP) design

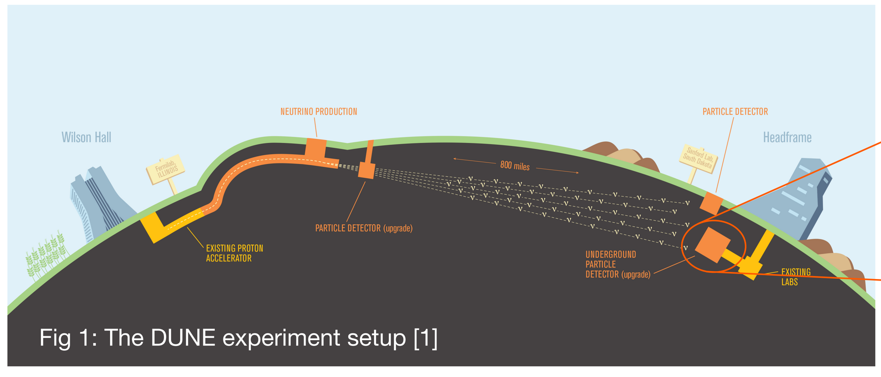


Fig 1: The DUNE experiment setup [1]

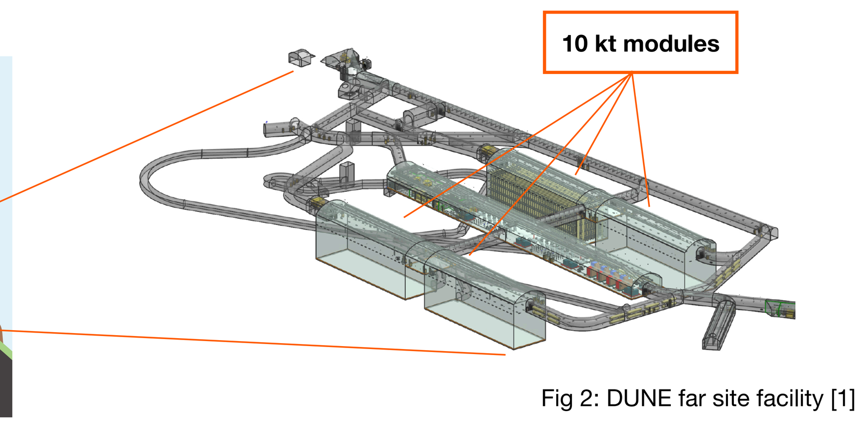


Fig 2: DUNE far site facility [1]

Dual Phase LArTPC

- Charged particles produce ionization charge and scintillation light
- An electric field drifts the charge upward, light is collected by PMTs
- Charge is extracted from the liquid to the gaseous argon
- A Large Electron Multiplier (LEM) amplifies the charge extracted
- The charge is collected at the anode shared equally on two perpendicular readout planes

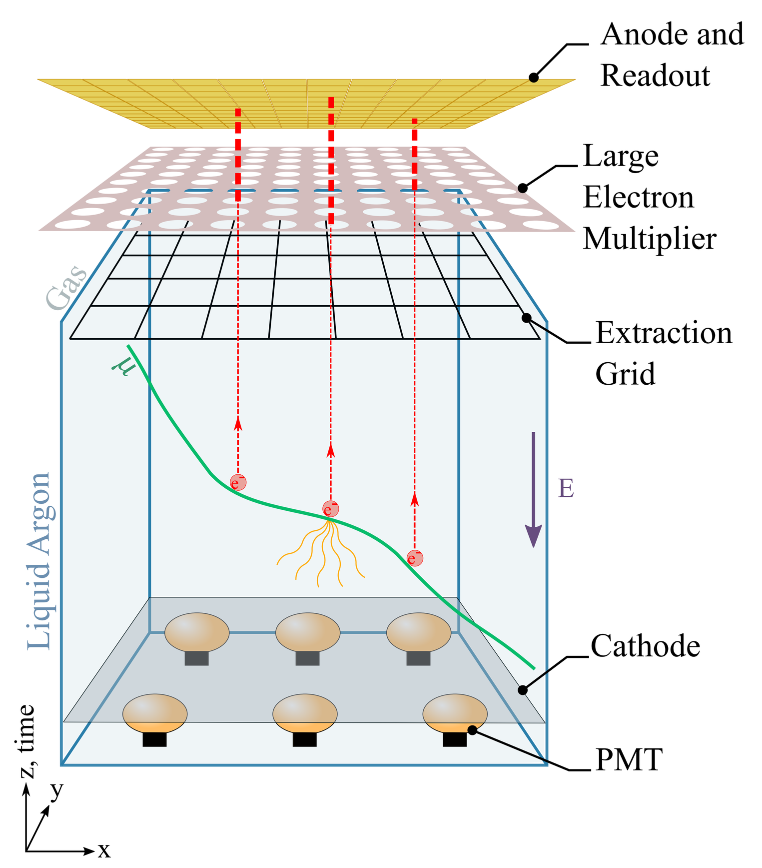


Fig 3: Sketch of a Dual Phase LArTPC [3]

Features of the DP design:

✓Fully active volume

✓Tunable Signal to Noise Ratio

✓High granularity (3 mm/view)

➡Never tested on large scale

Total drift	12 m
Length x Width	12x60 m²
Electric drift field	0.5 keV
Gas phase gain	20
Signal/Noise after drift	9:1

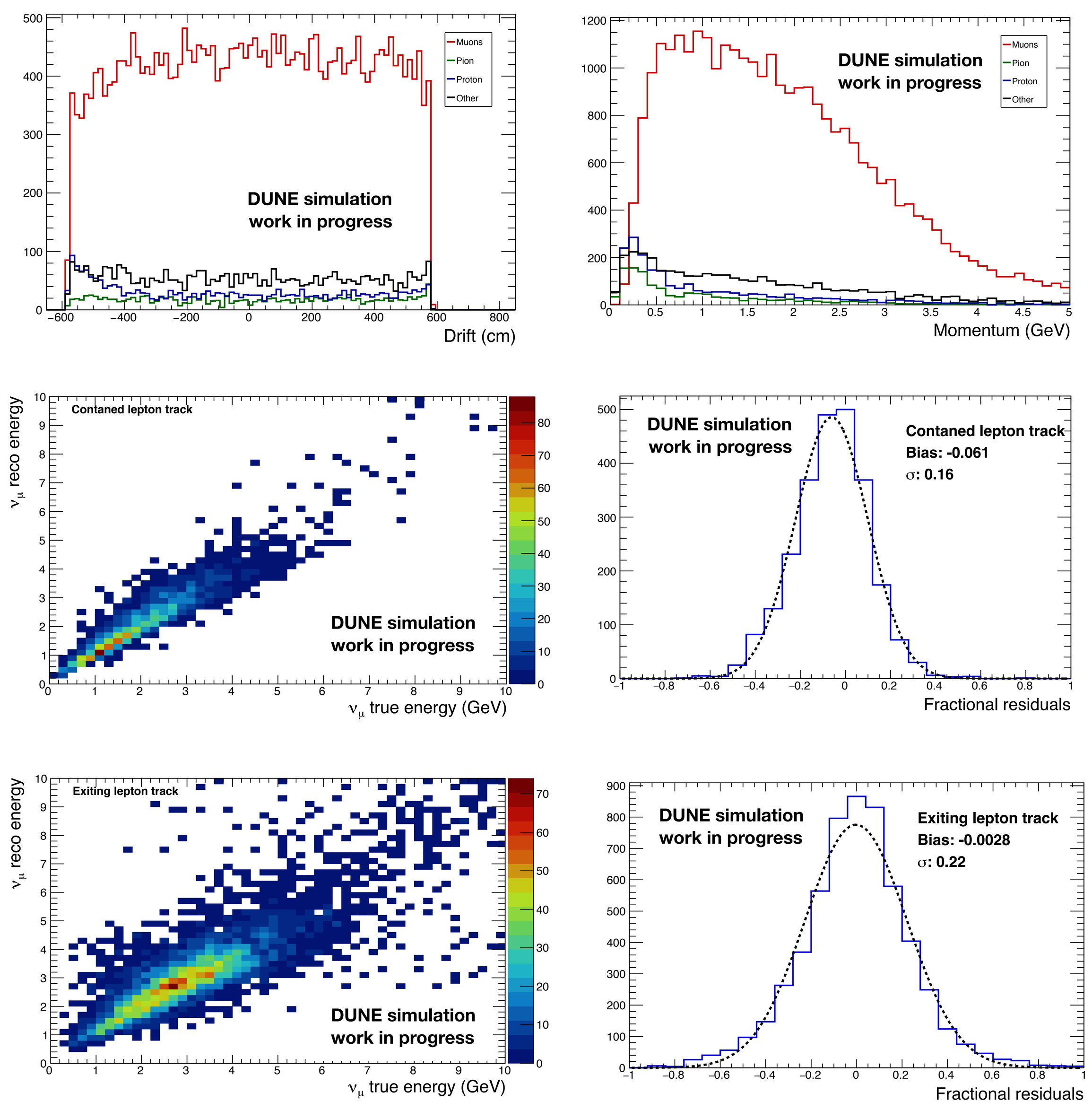
Tab 1: DUNE Dual Phase design specification parameters [1]

Neutrino energy reconstruction @DUNE

- Extracting oscillation parameters from spectral information demands outstanding energy resolution over a broad range (0.5-5 GeV)
- Thanks to the tracking capacity of LArTPCs, topological features of the event can be used to reconstruct the primary lepton energy
- The hadronic (and electromagnetic) contribution to the total neutrino energy is estimated using calorimetric information
- We present estimates of DUNE DP far detector energy resolution, using full simulation for the first time

ν_μ CC events:

- Momentum of the primary lepton can be reconstructed the longest track in the event:



Correct association between the primary μ and the longest track:

- For contained μ: 83%
- For not contained μ: 98%

Mismatch is more probable at lower muon momentum, while not affected by drift distance

Contained longest track:

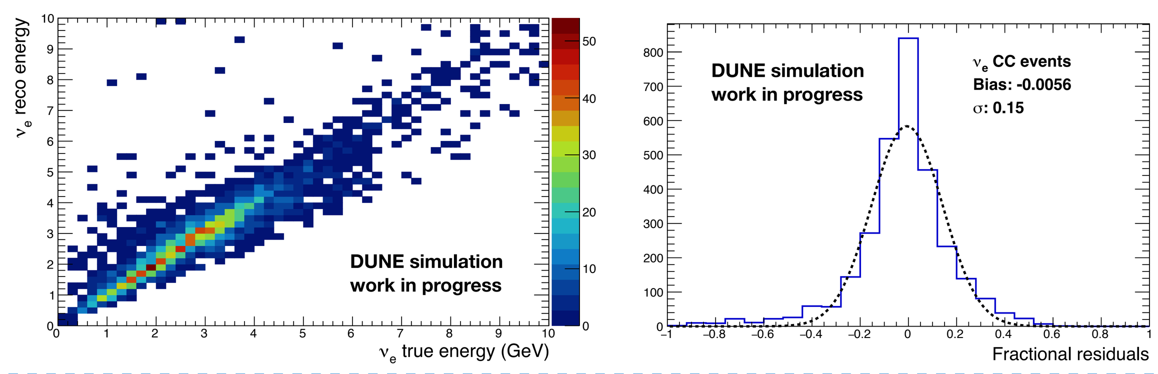
- Momentum of the lepton from the track range
- Due to the high inelasticity a large fraction of the energy goes in the hadronic part
- Invisible energy due to neutral particles spoils resolution on the hadronic part

Exiting longest track:

- Momentum from multiple coulomb scattering
- Track momentum resolution for this events is important due to the low inelasticity

ν_e CC events:

- select em shower with the largest charge



Selection of the largest electromagnetic shower from the primary vertex (use truth for shower selection):

- Main background from resonant π0 production in νNC interactions
- Preliminary results

DUNE Dual Phase prototypes at CERN

3x1x1 m³ (2017)

- Small scale prototype: ~$\mathcal{O}$(1 m) drift, 4t LAr fiducial volume
- **Aim**: foreseen technical challenges for larger detectors
- Detector operated in different configurations allowing an extensive scan of extraction and amplification field
- 400k triggers of cosmic ray data collected during Summer-Fall 2017
- First test for noise filtering and track reconstruction strategies
- Analysis is ongoing to assess detector response, gain

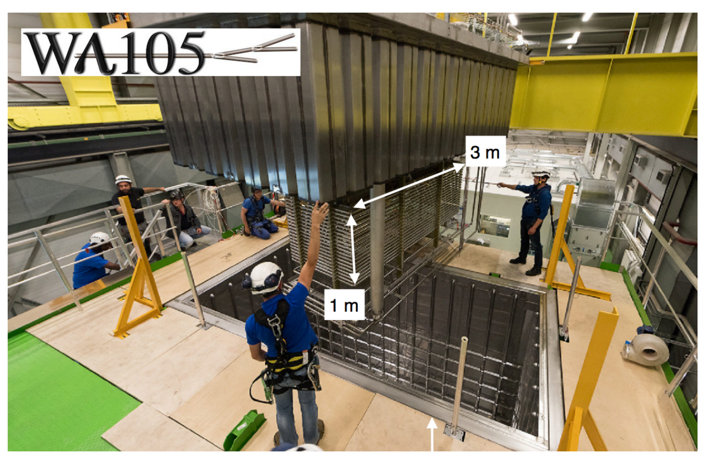


Fig 4: Field cage installation in the 10 t prototype at CERN [4]

Fig 5: Cryostat of ProtoDUNE DP

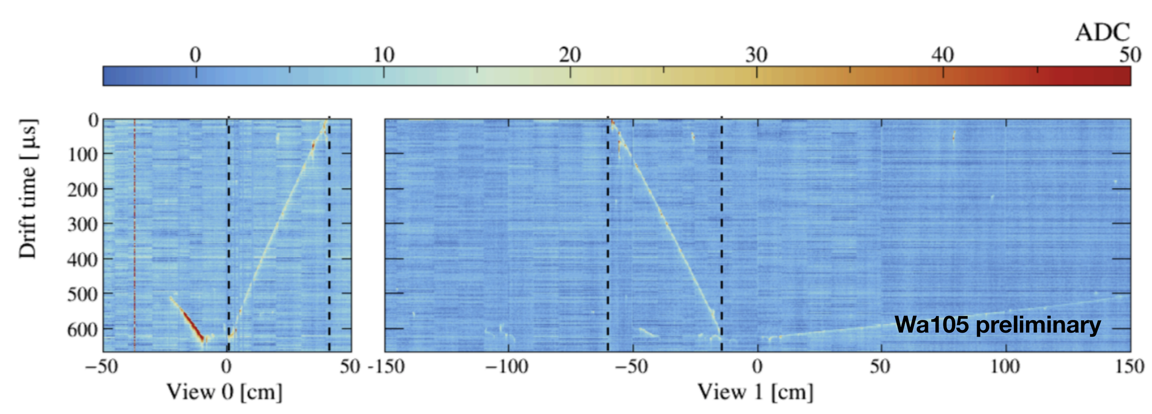


Fig 6: Example of a muon crossing the TPC of the 10 t prototype

6x6x6 m³ – ProtoDUNE – DP (2018)

- Large scale prototypes meeting DUNE requirements ~$\mathcal{O}$(10 m) drift, 300 t LAr fiducial volume
- **Aims**:
  - Design validation and optimization
  - Anticipate FD construction and commissioning challenges
  - Validation of detector full simulation
  - Measure impact of space charge effects and test light collection system
  - Test for reconstruction and analysis techniques

References

[1]. R. Acciarri et al. https://arxiv.org/abs/1601.05471

[2] L. Agostino et al., https://arxiv.org/abs/1409.4405

[3] L. Zambelli, http://vietnam.in2p3.fr/2017/neutrinos/program.php

[4] S. Murphy, https://indico.cern.ch/event/649662/

DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT

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