ν energy reconstruction based on Pandora And Interface for RegCNN

DUNE Reconstruction Workshop

Wenjie Wu

University of California, Irvine

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Motivation

- UCI group is developing Convolutional Neural Networks for neutrino energy reconstruction
  - Both ν_e and ν_μ energy can be reconstructed by CNN models
- In order to make "apple to apple" comparisons, we also reconstructed neutrino energy by the traditional method (kinematics-based method, *DUNE-doc-2278 by Nick Grant et al.*)
  - Some preliminary results show that CNN models can outperform the traditional method for both ν_e and ν_μ energy reconstruction (*DUNE-doc-13885 by Ilsoo Seong et al.*)
  - The traditional method relies on reconstructed showers and tracks. Currently, default track and shower results come from *pmtrack* and *emshower* module
  - *pandoraTrack* and *pandoraShower* maybe more well-maintained modules for track and shower reconstruction
- This report basically repeated the procedures in *DUNE-doc-2278* and focused on ν_μ energy reconstruction

Kinematics-based method

$$E_\nu = E_{\rm lep}^{\rm cor} + E_{\rm had}^{\rm cor}$$

- ν_e CC energy: divide event into reconstructed shower with highest charge and hadronic energy
- ν_μ CC energy: divide event into longest reconstructed track and hadronic energy
- Hadronic/Electron energy: electron lifetime (wire-by-wire) and recombination (constant) corrected calorimetric energy

Kinematics-based method

Electron shower energy

Calorimetric energy calibrated with MC

Muon momentum (Longest track contained)

By track range, calibrated by MC

Muon momentum (Longest track exiting)

By multi-Coulomb scattering, calibrated by MC

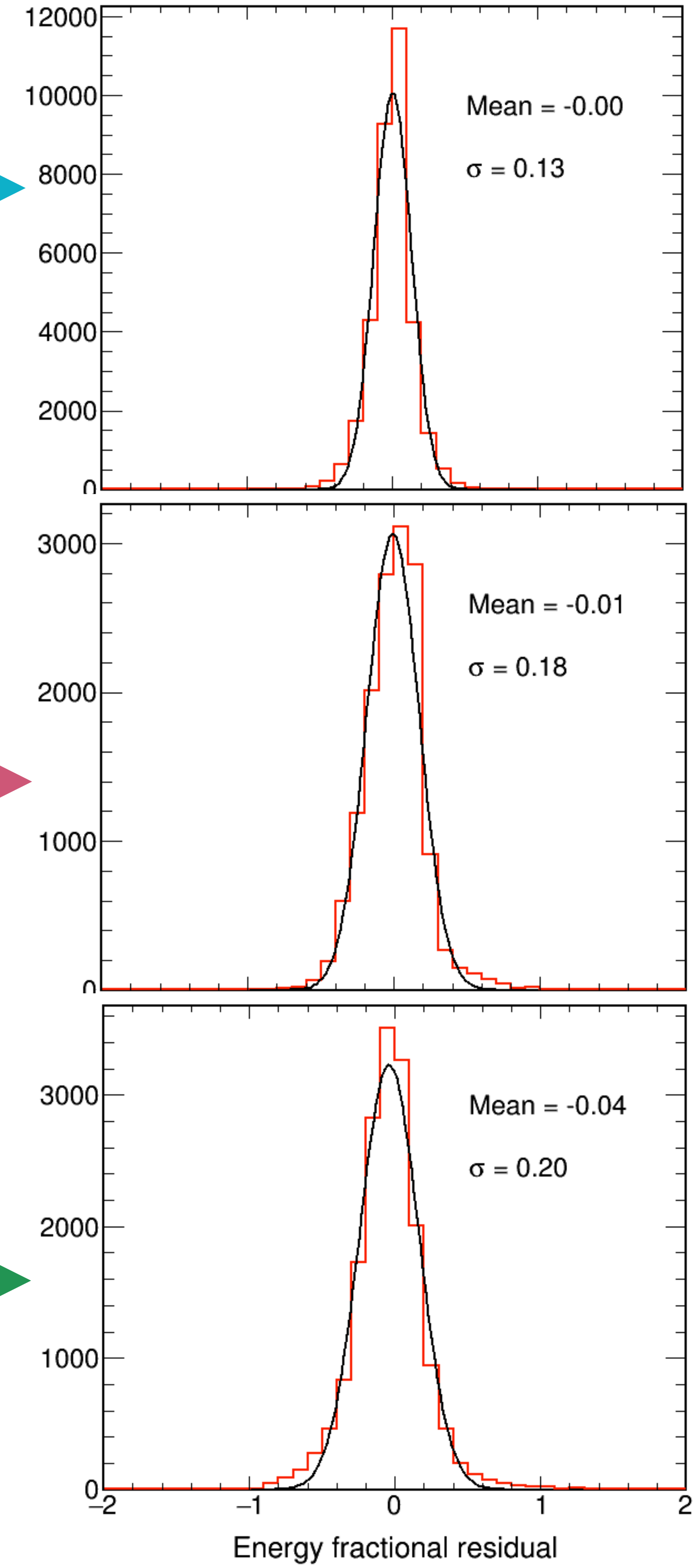
Hadronic energy

By reconstructed hits not in the muon track or electron shower, calibrated by MC

ν_e CC

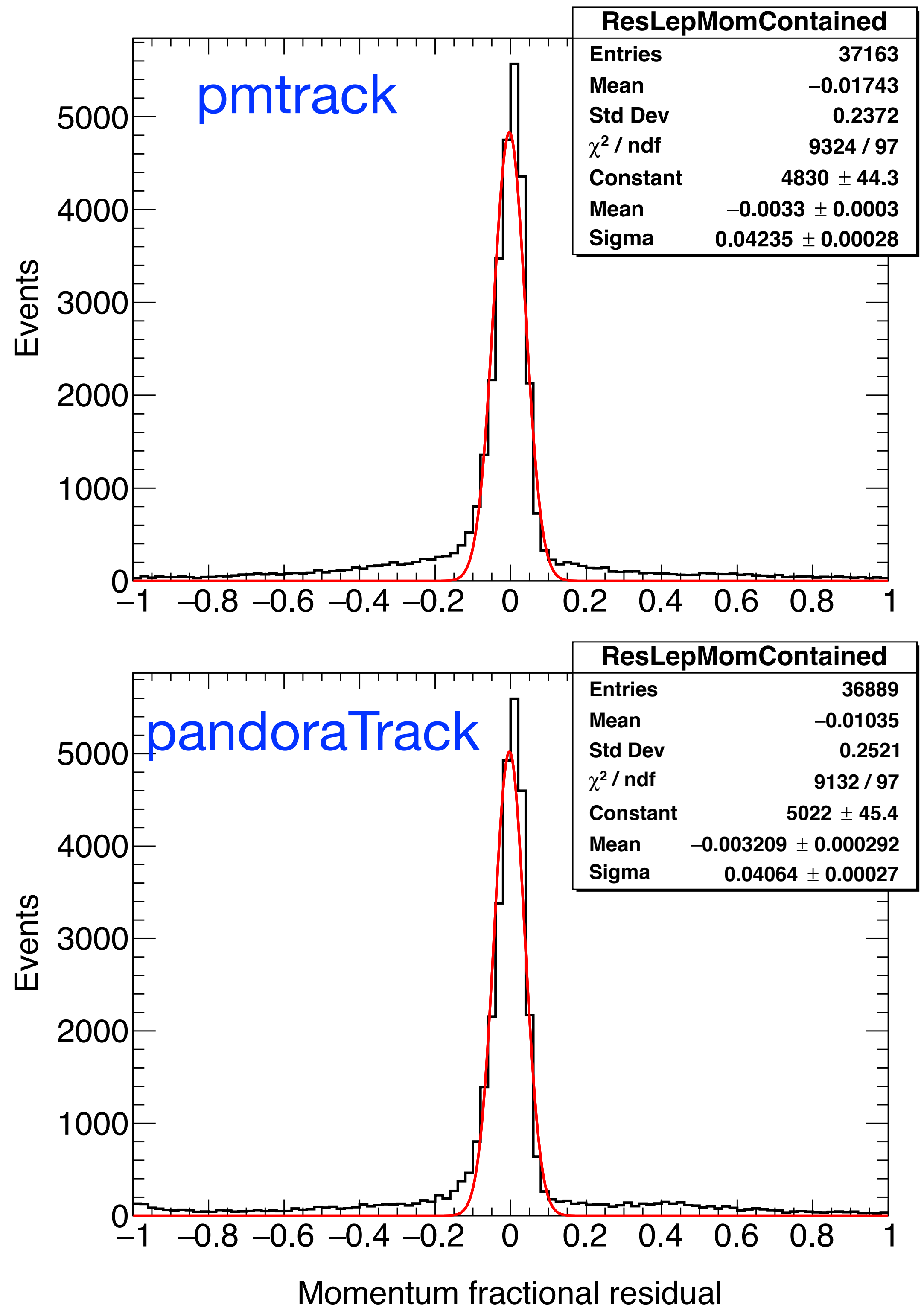
Contained ν_μ CC

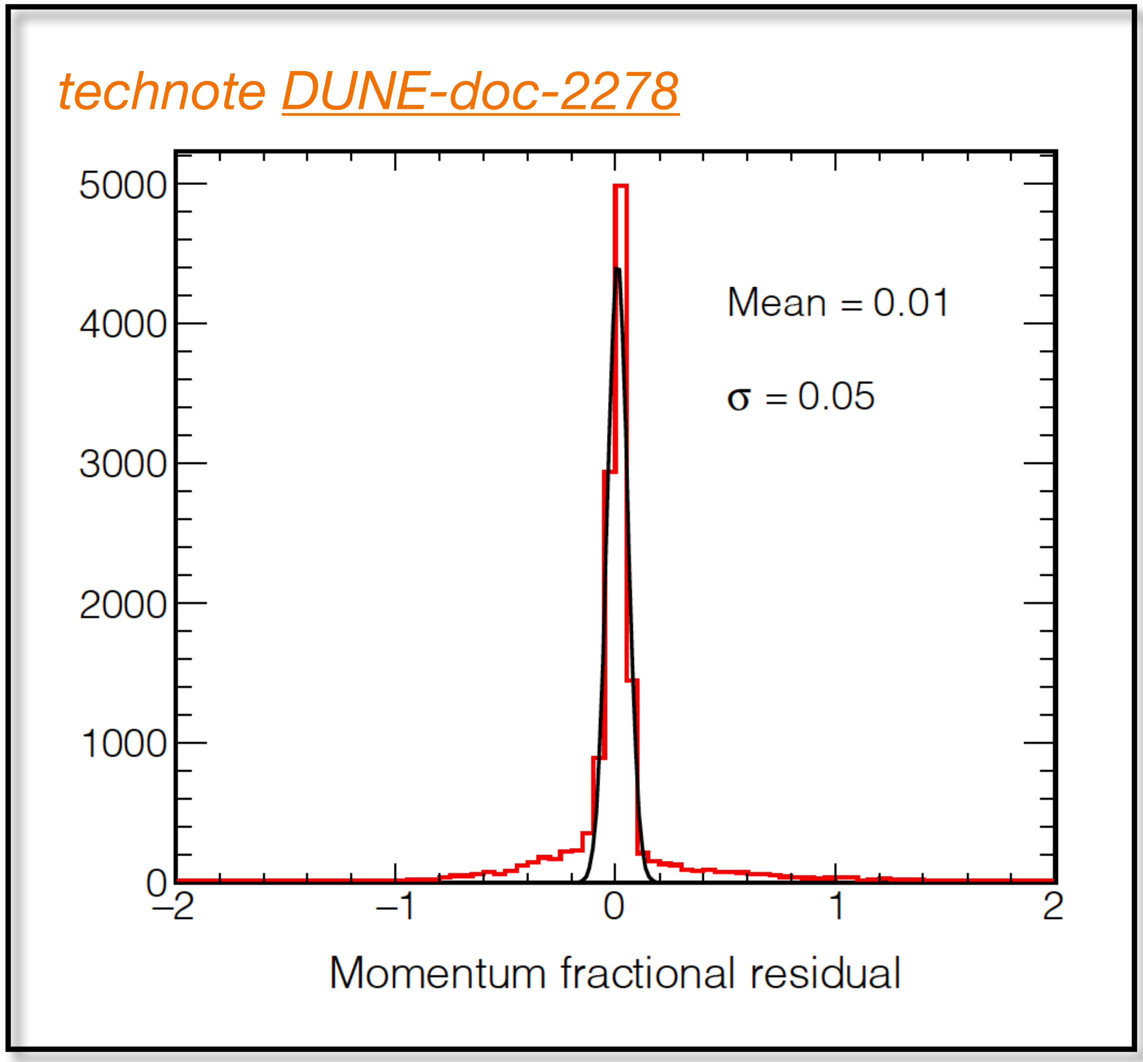
Exiting ν_μ CC



For events with contained tracks

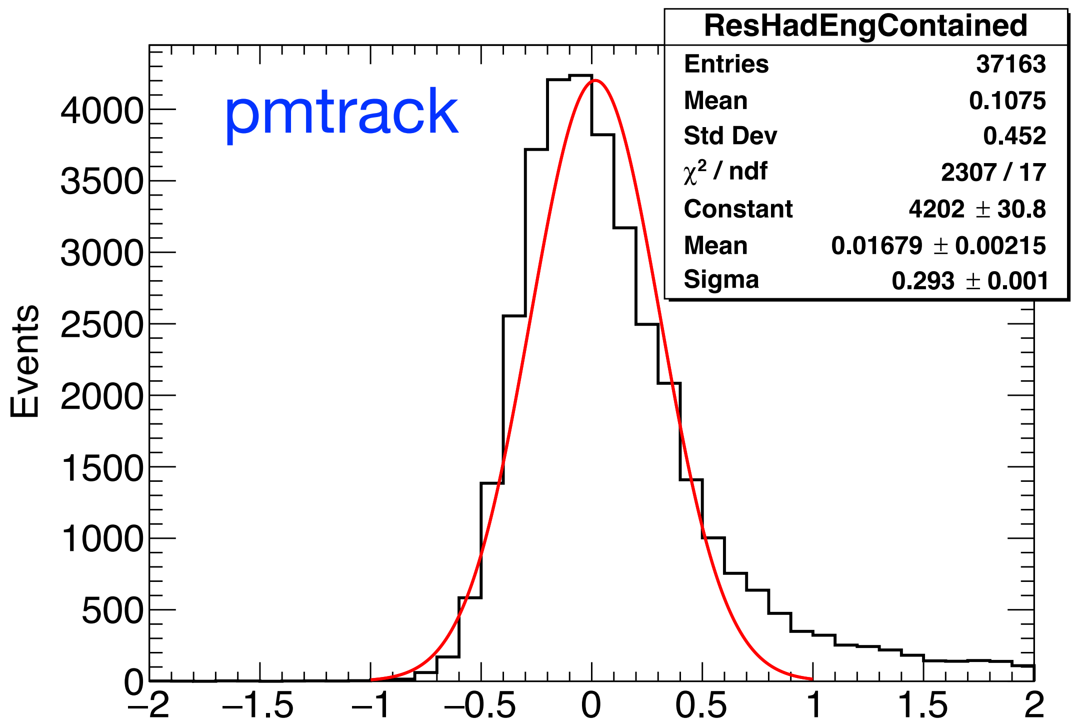
Lepton P

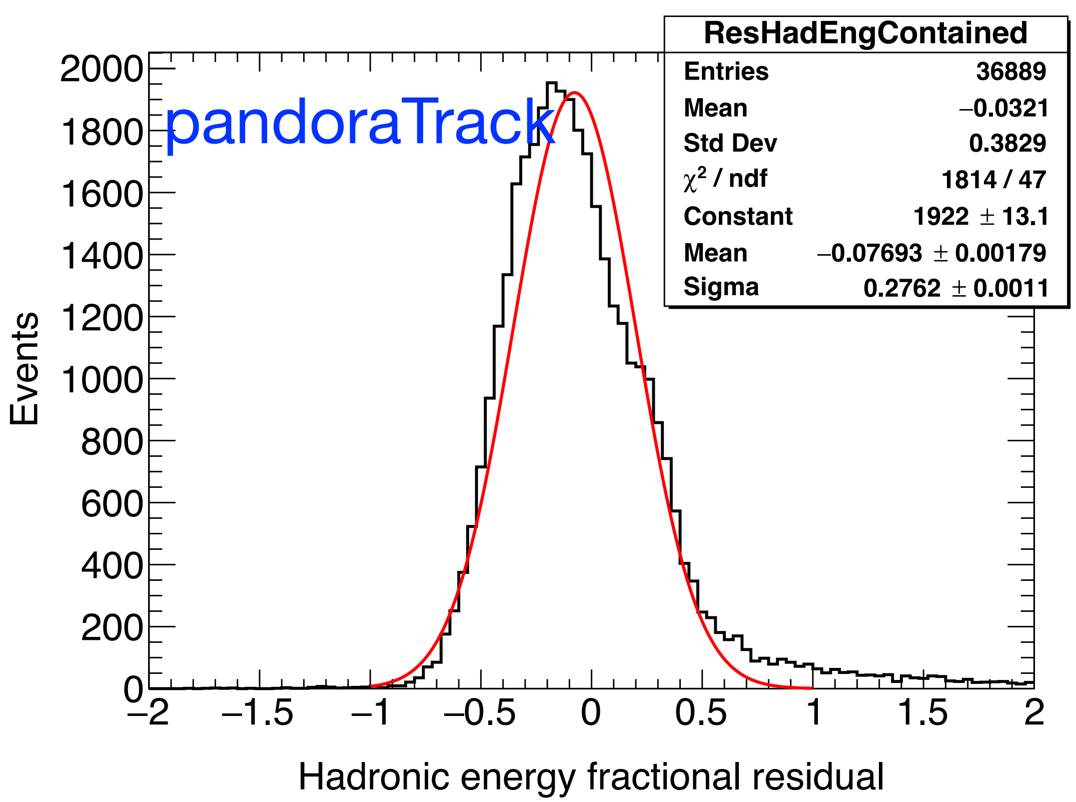


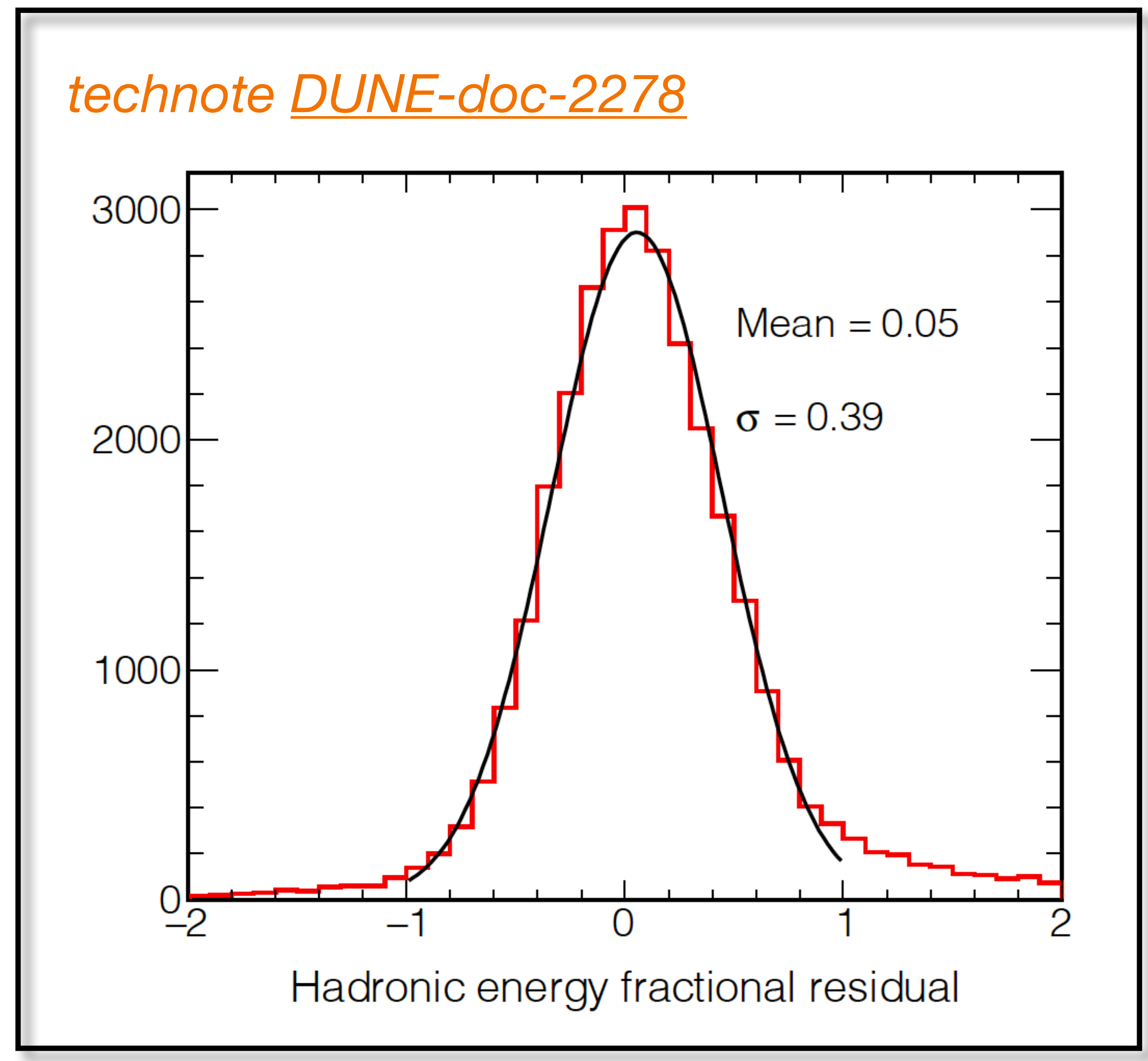


For events with contained tracks

Hadronic E

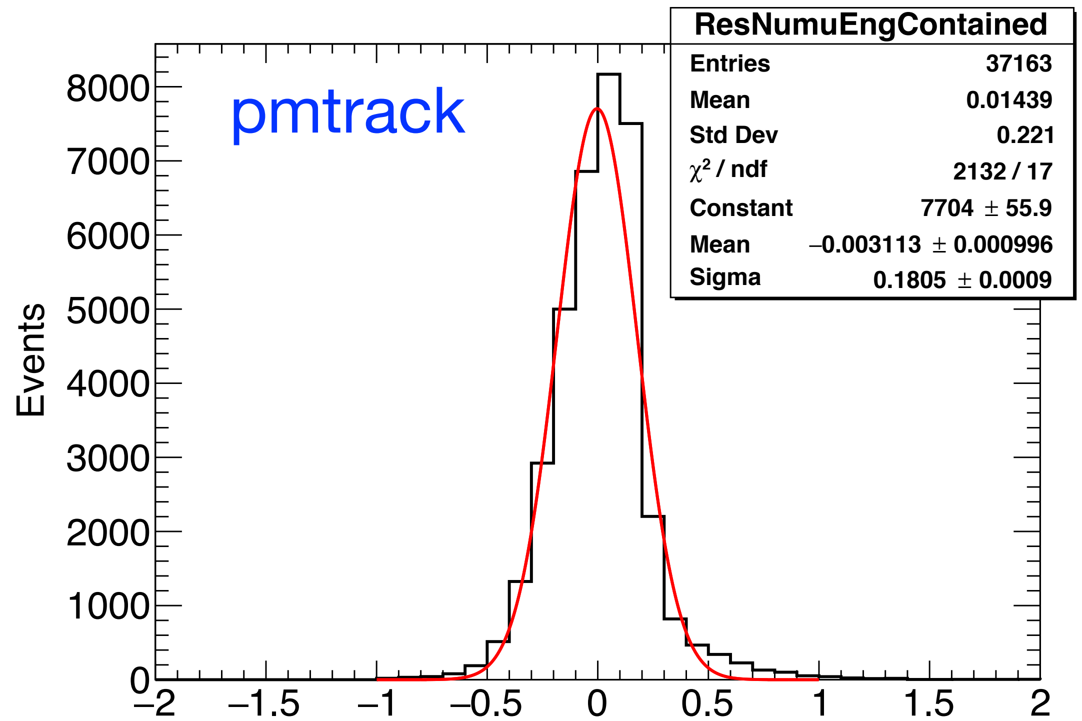


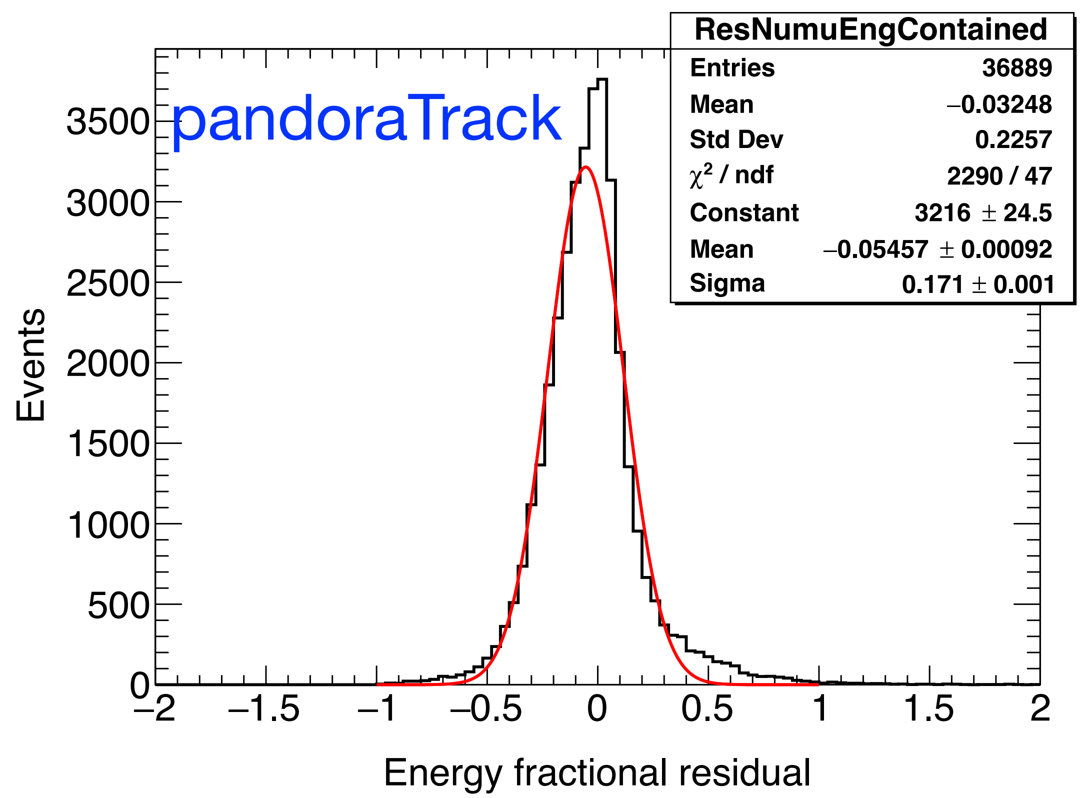




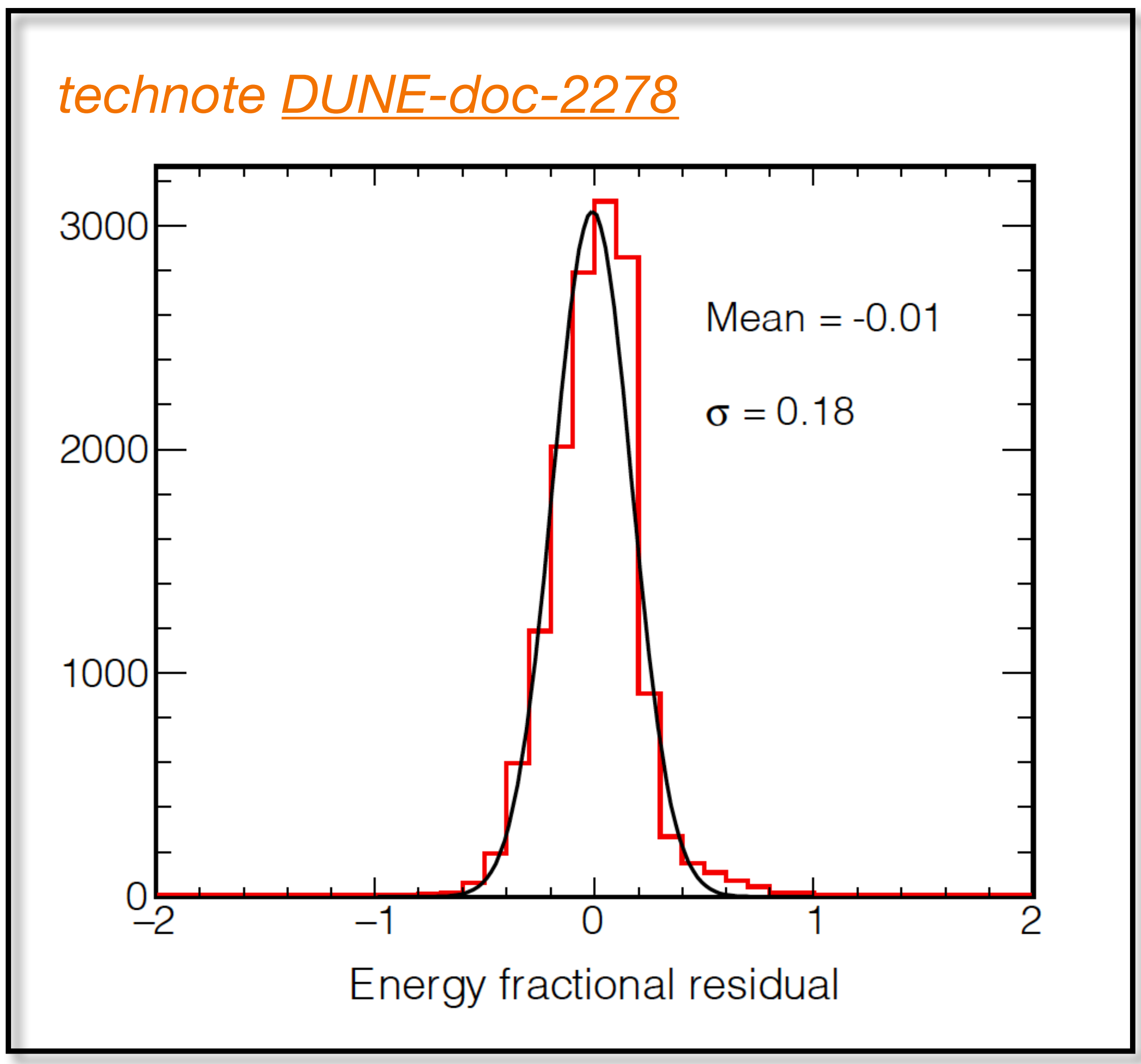
For events with contained tracks

Numu E





- Result for contained tracks in the tech note is re-produced
- pmtrack and pandoraTrack have similar performance on contained events

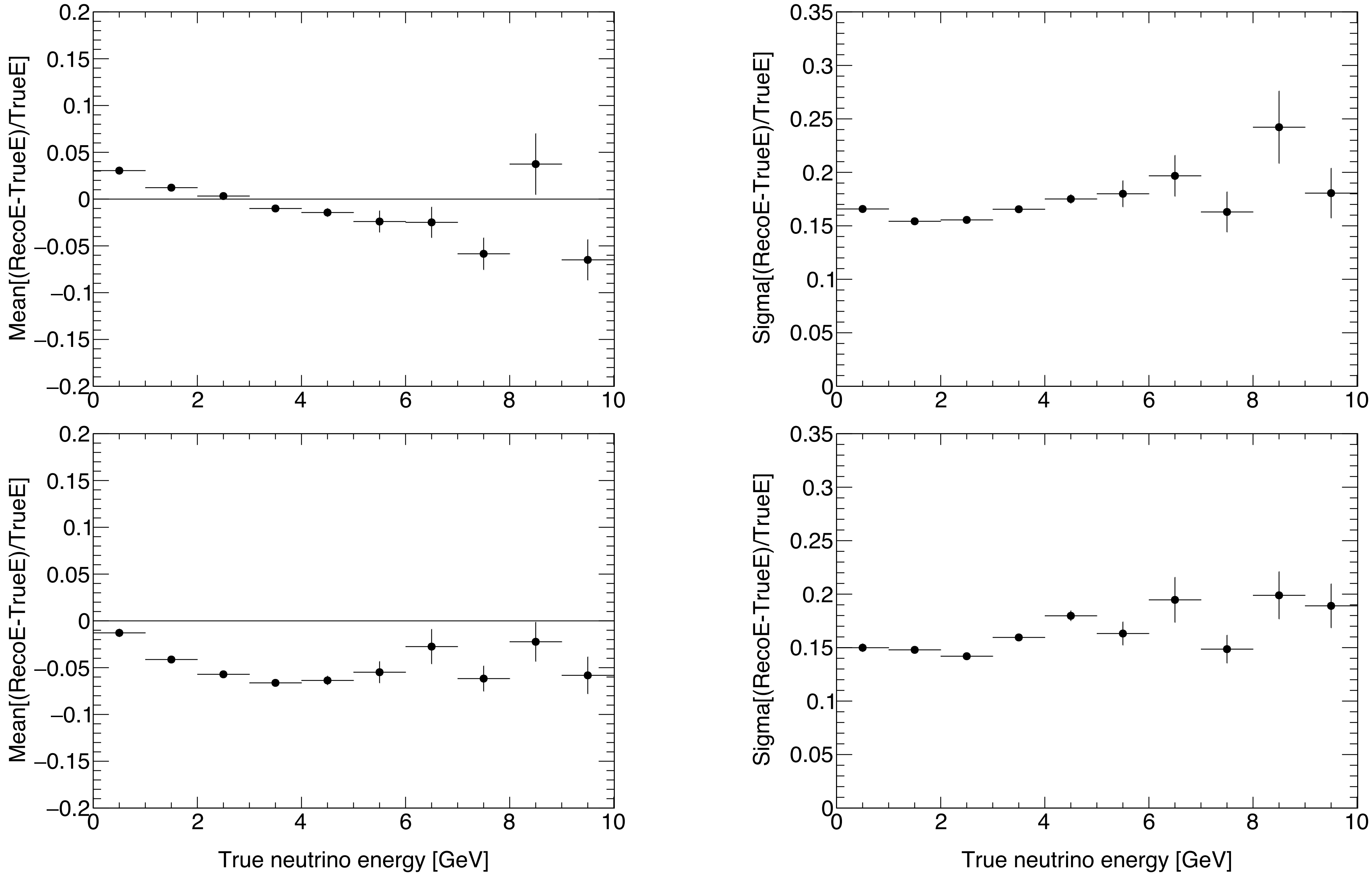


For events with contained tracks

Numu E: energy dependency of energy resolution

pmtrack

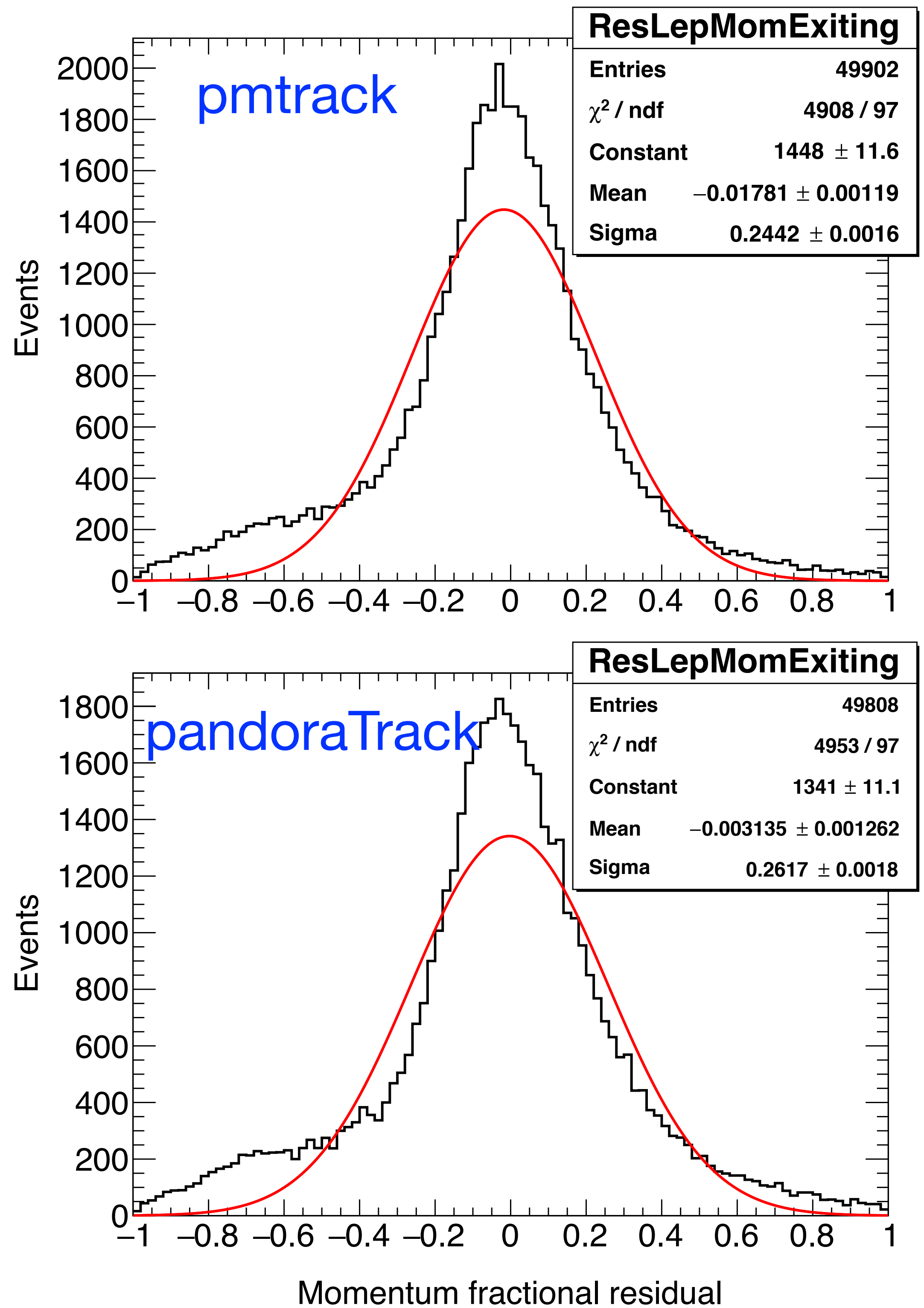
pandoraTrack

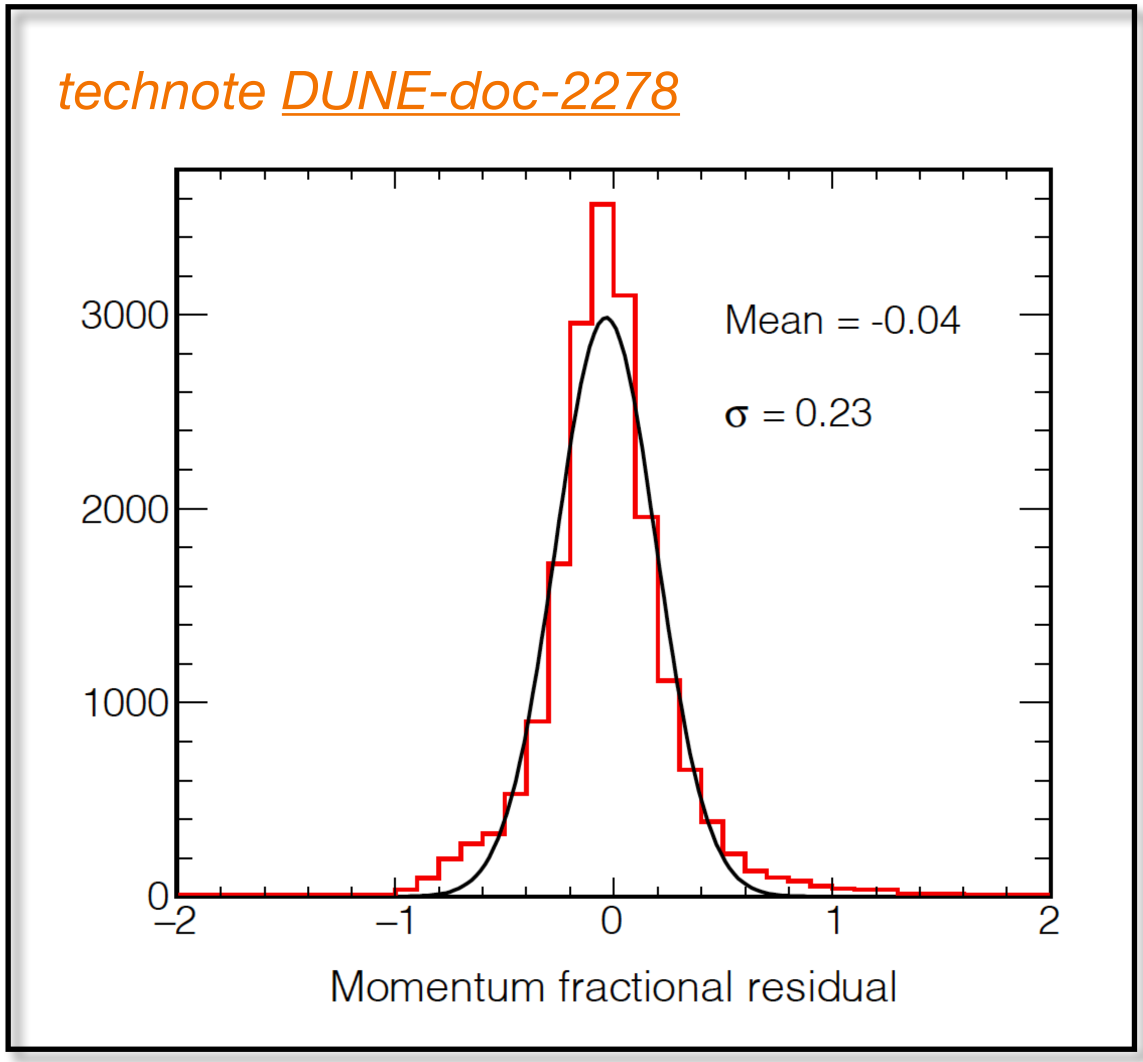


- Fit a gaussian to the resolution distribution for each energy bin
- pandoraTrack tends to have lower Reco. E for all energies, may be further improved by fine tune the calibration parameters

For events with exiting tracks

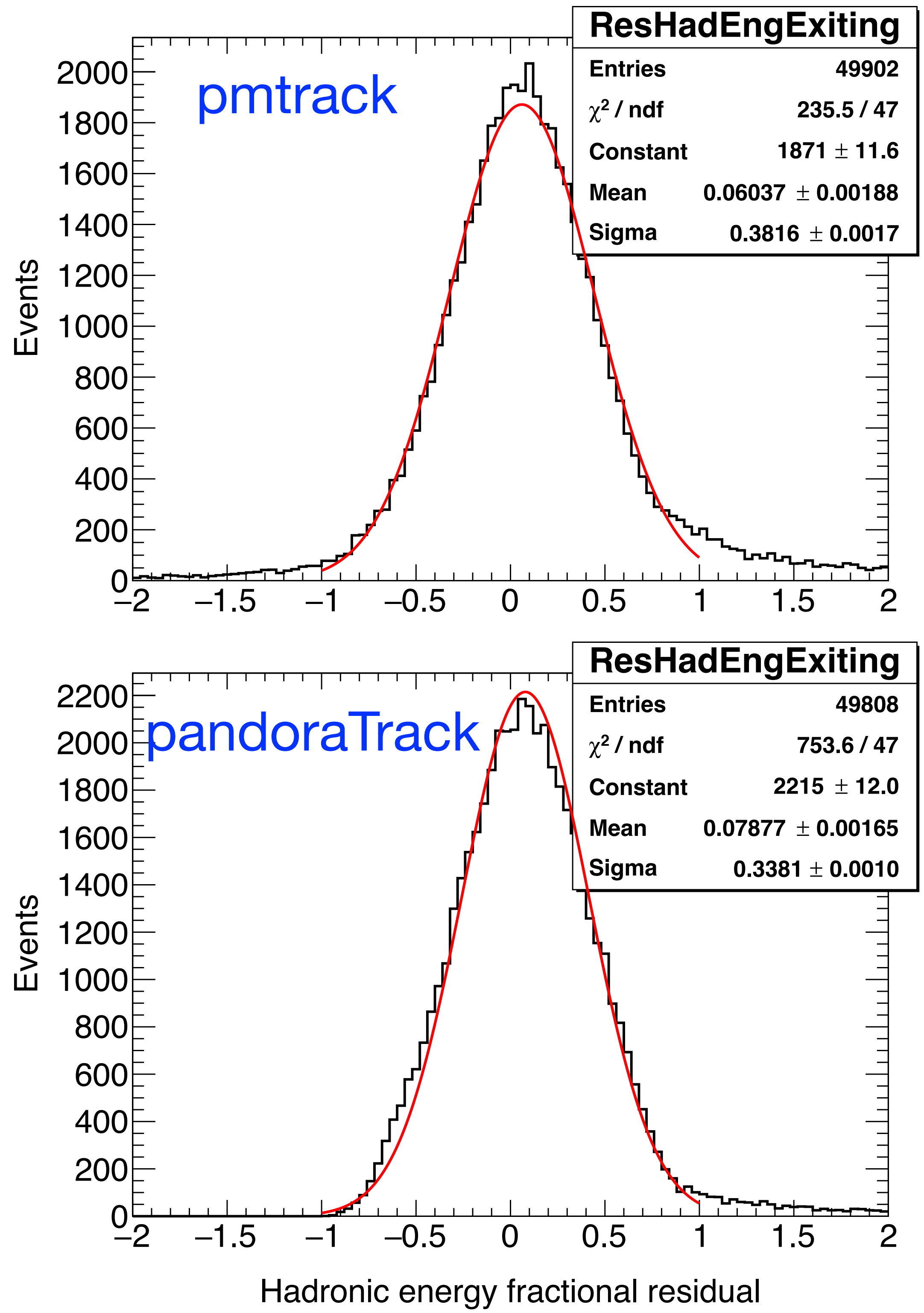
Lepton P

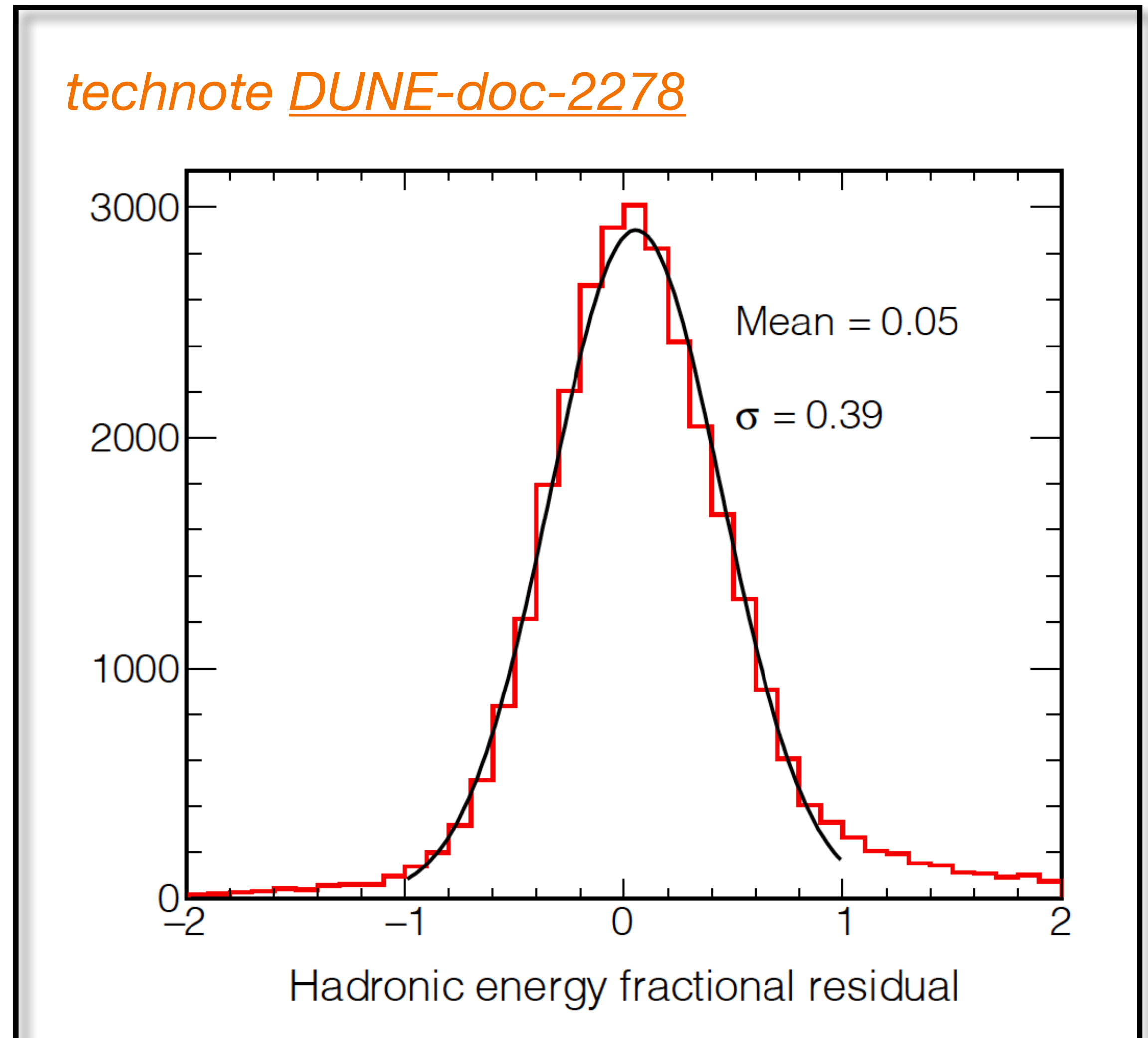




For events with exiting tracks

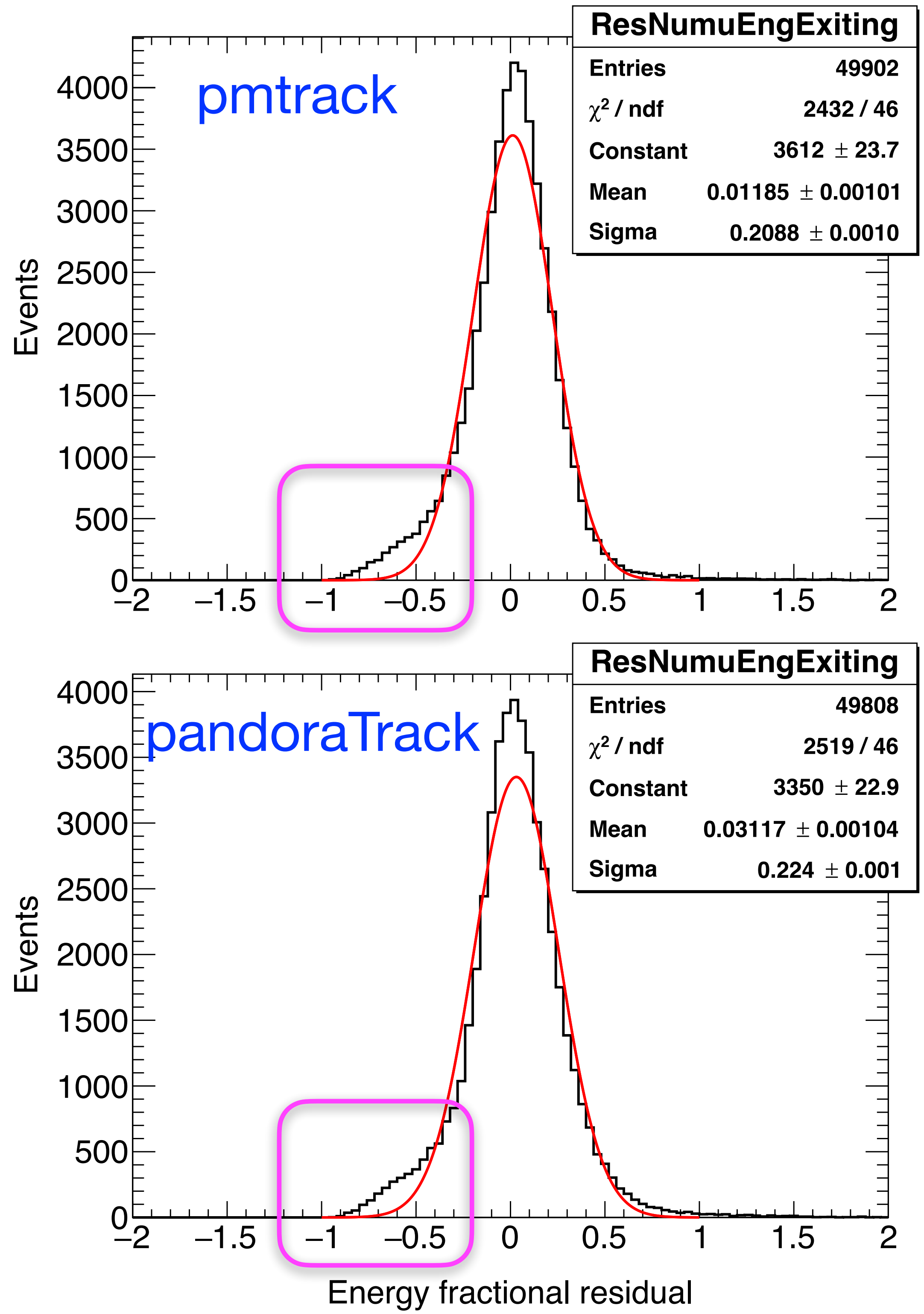
Hadronic E



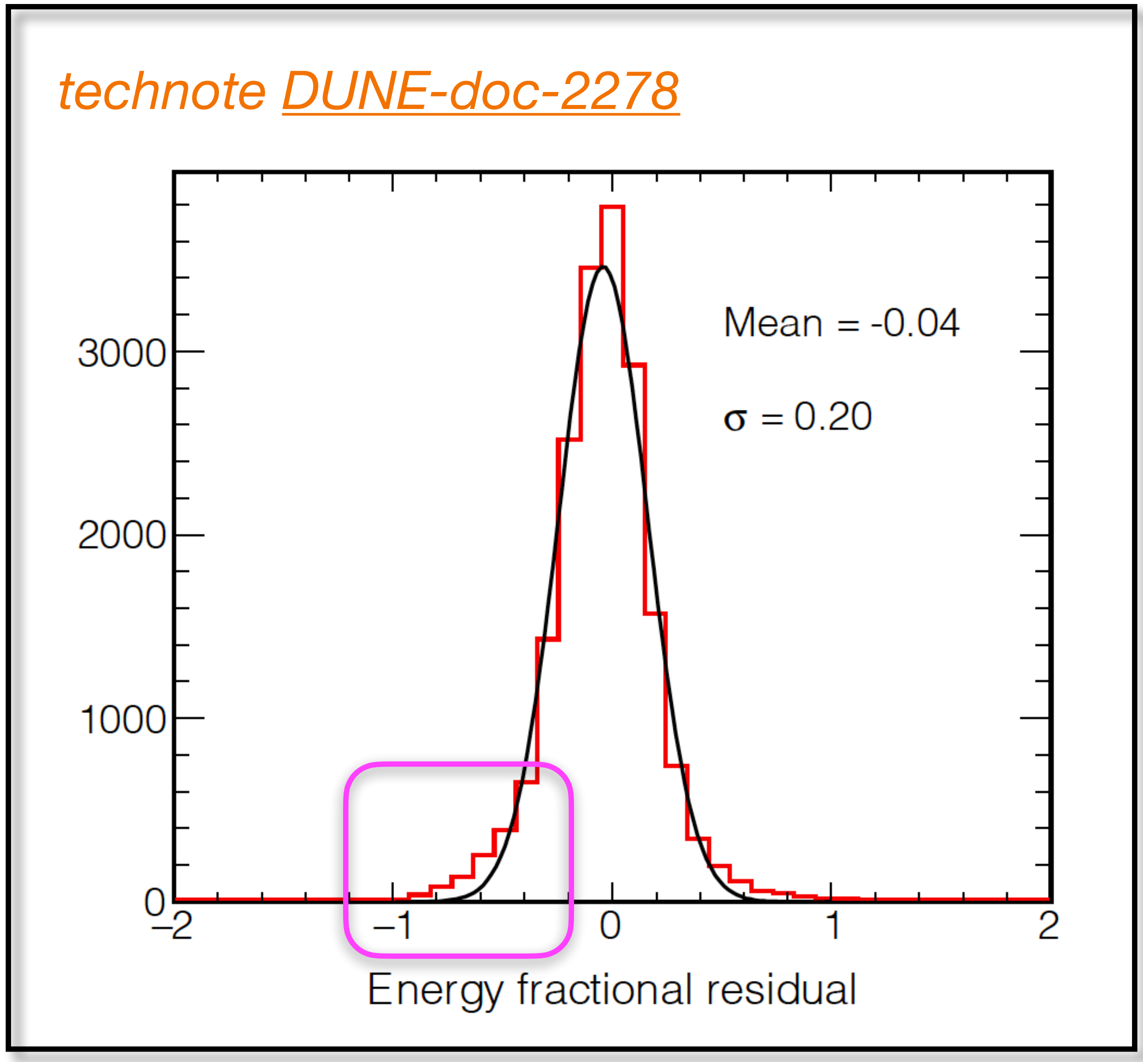


For events with exiting tracks

Numu E

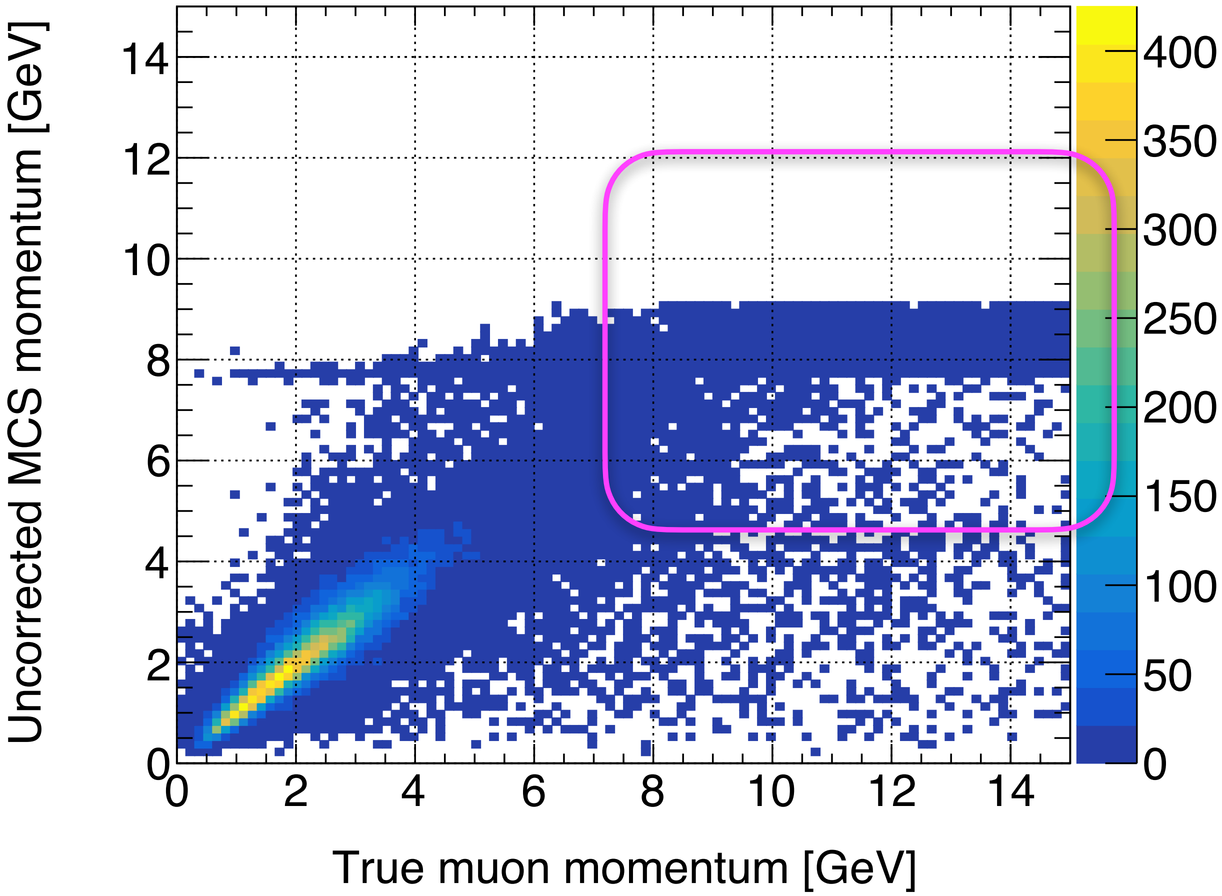


- Result for contained tracks in the tech note is re-produced
- There is an obvious tail on the negative side which diminishes the resolution

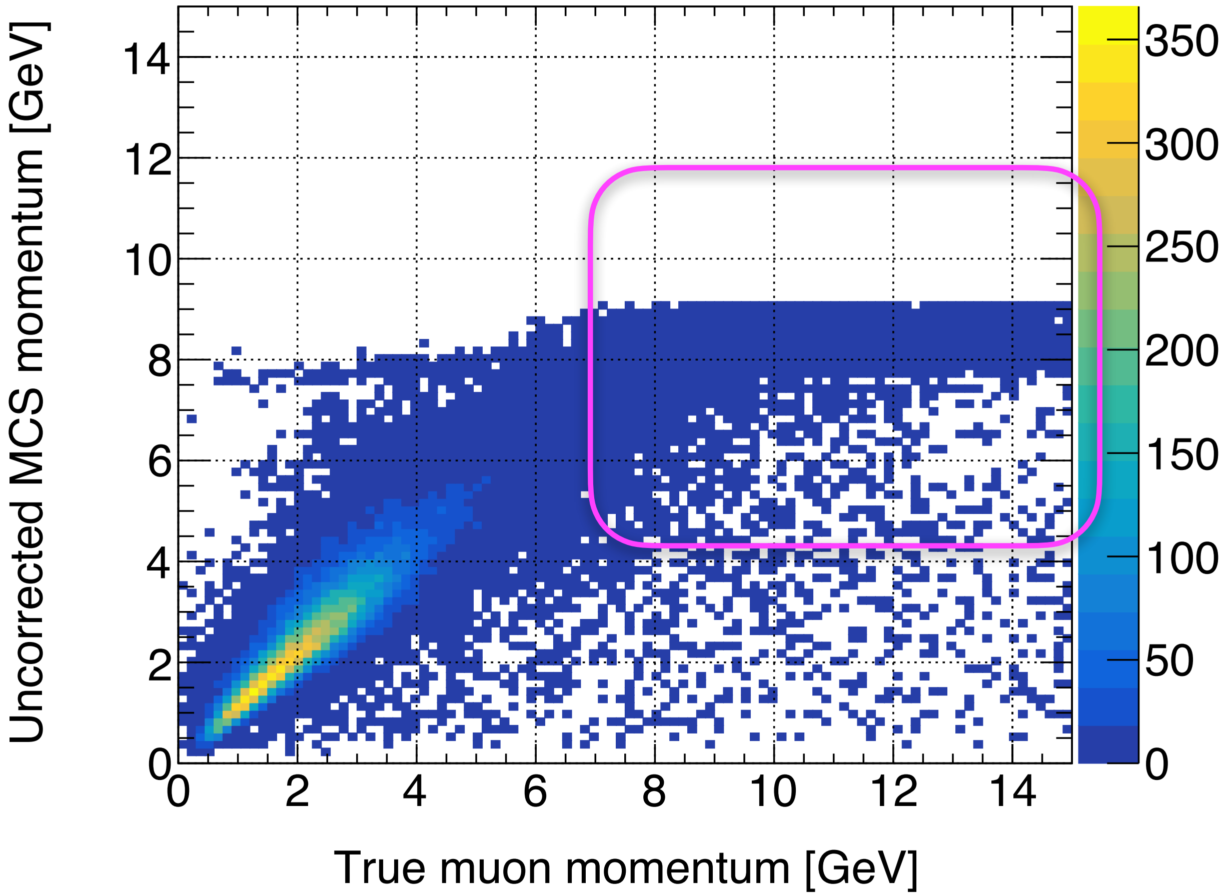


For events with exiting tracks

pmtrack



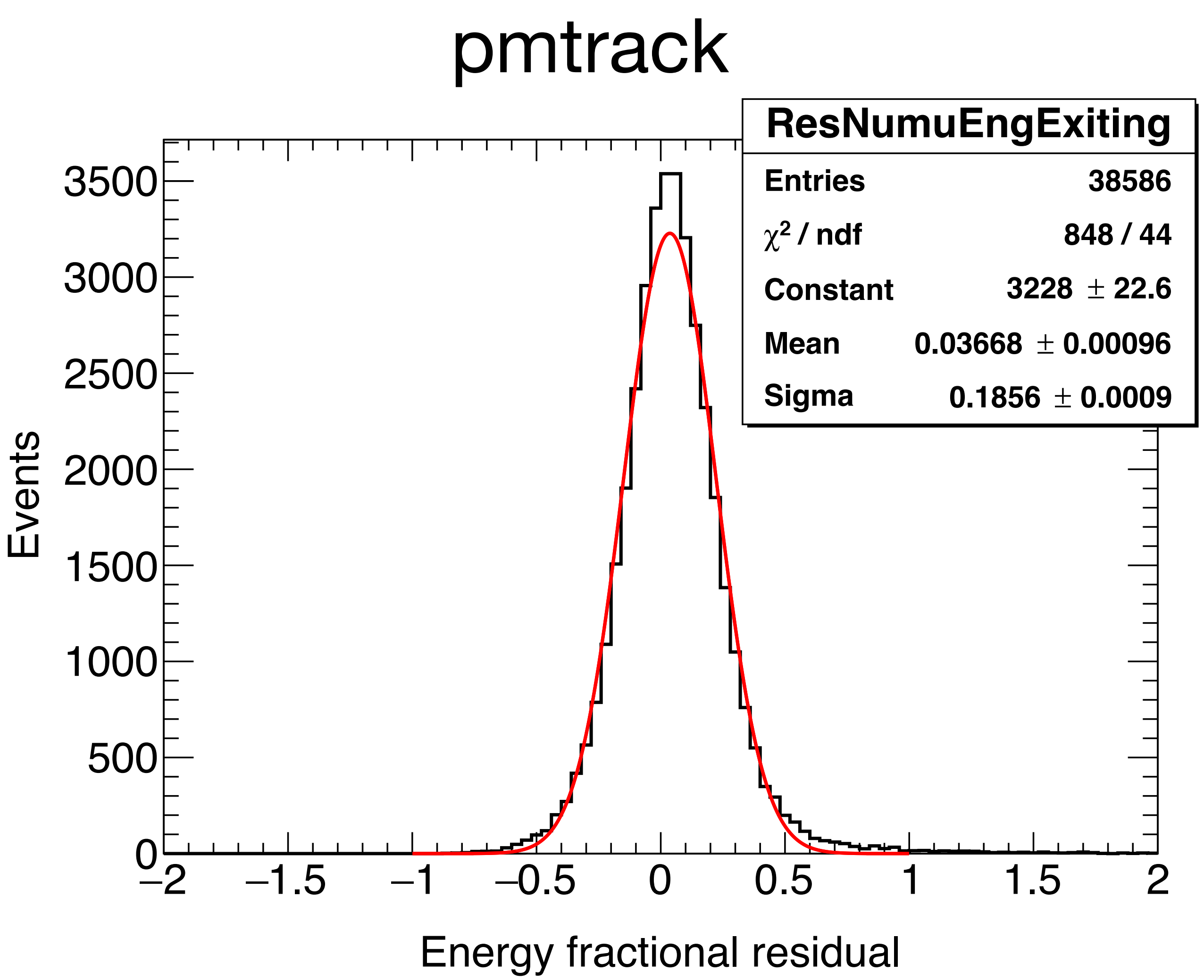
pandoraTrack

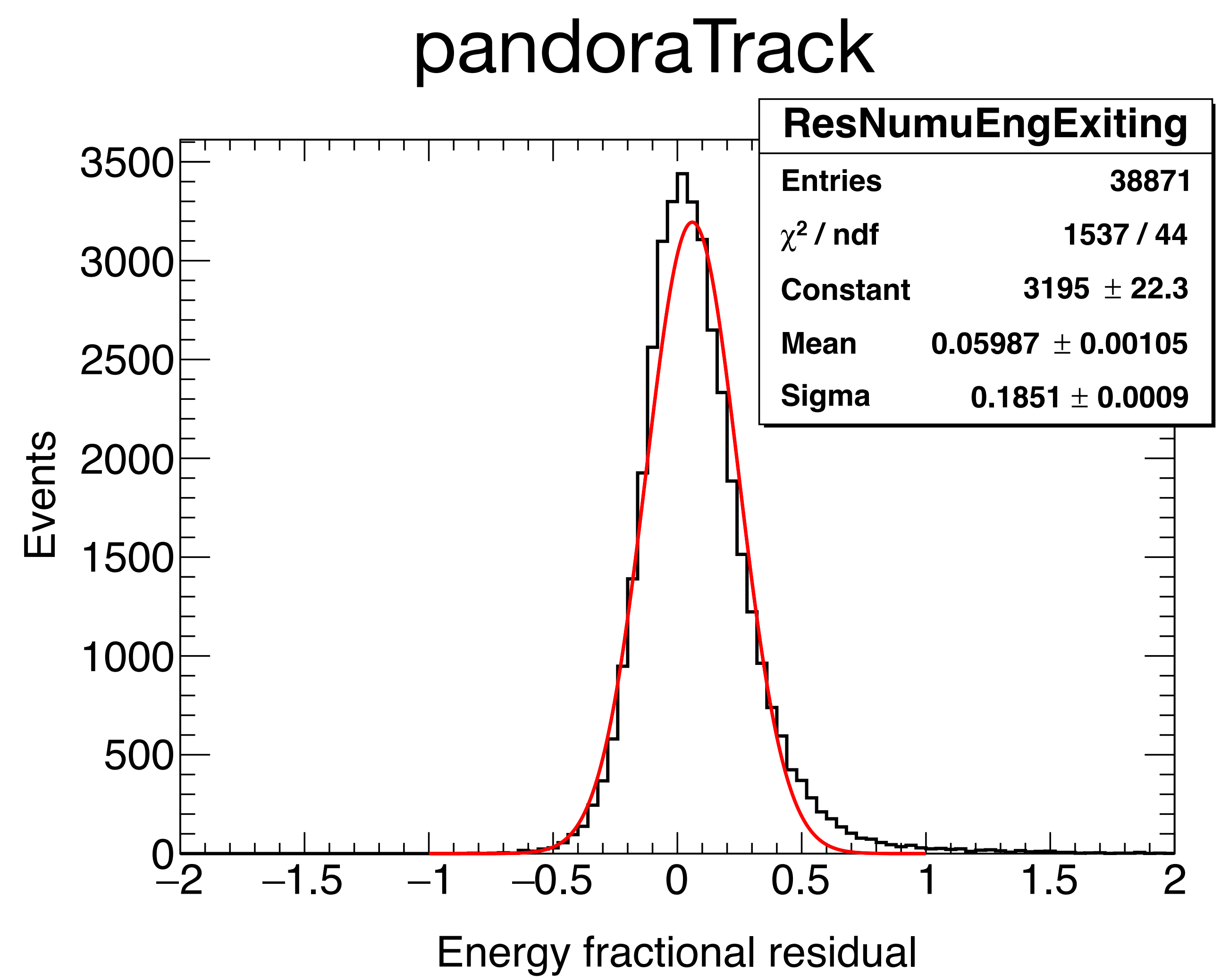


- For large momentum muons, the MCS method fails to calculate the momentum and always give a value smaller than the true momentum
- Those events will fall into the negative region of the resolution distribution

For events with exiting tracks

➤ If we only interested on events with energies below 10 GeV





➤ We can achieve comparable resolution as contained events for exiting events with energies smaller than 10 GeV

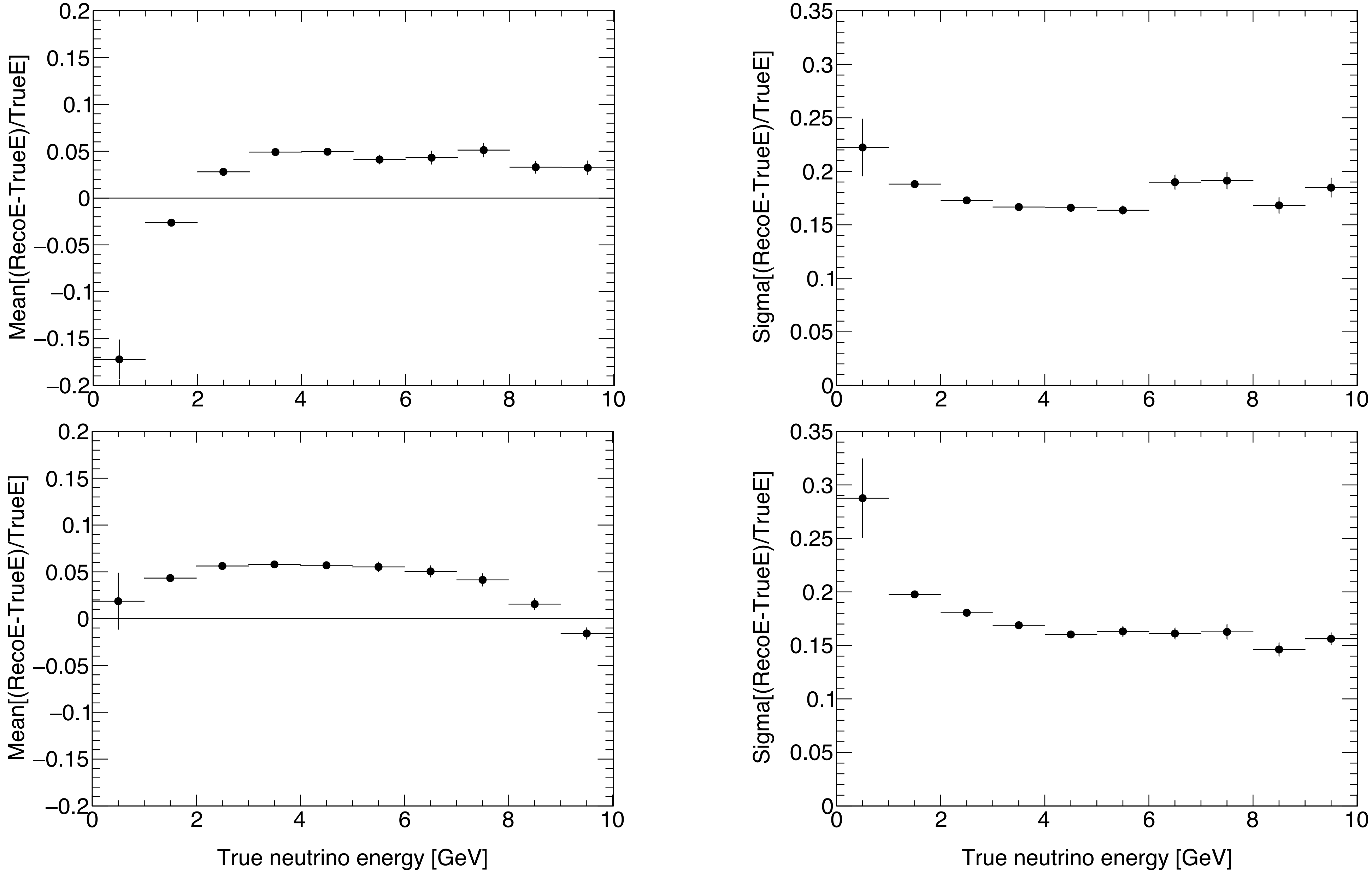
➤ pmtrack and pandoraTrack have similar performance

For events with exiting tracks

Numu E: energy dependency of energy resolution

pmtrack

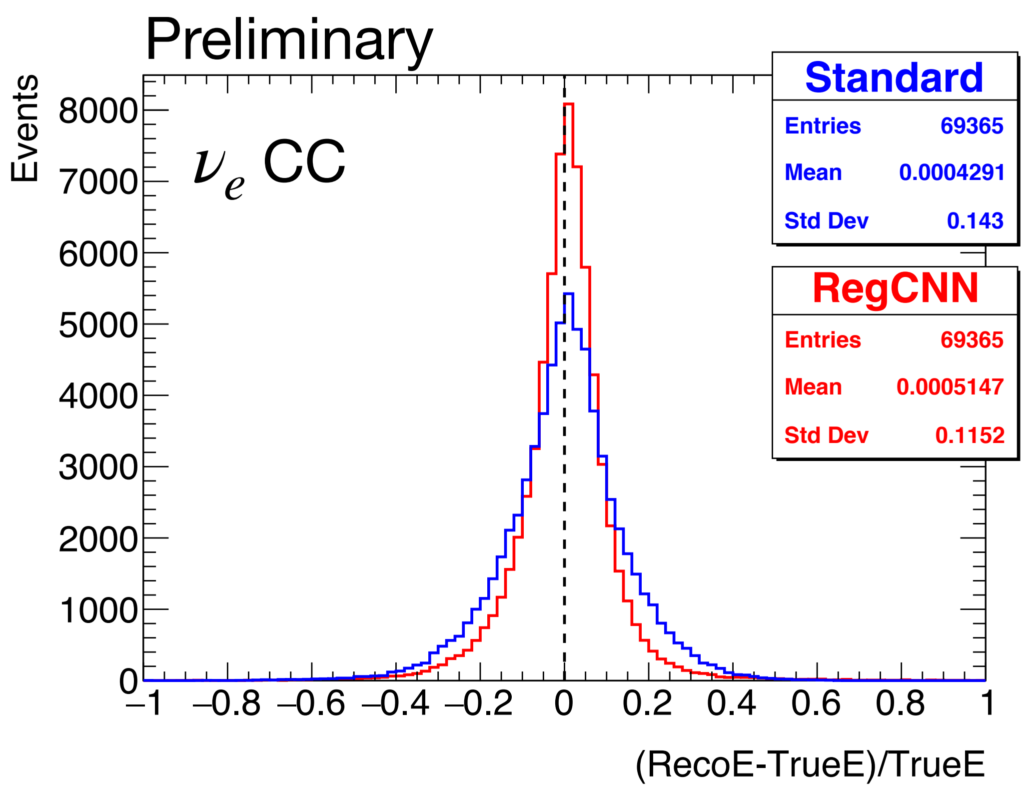
pandoraTrack

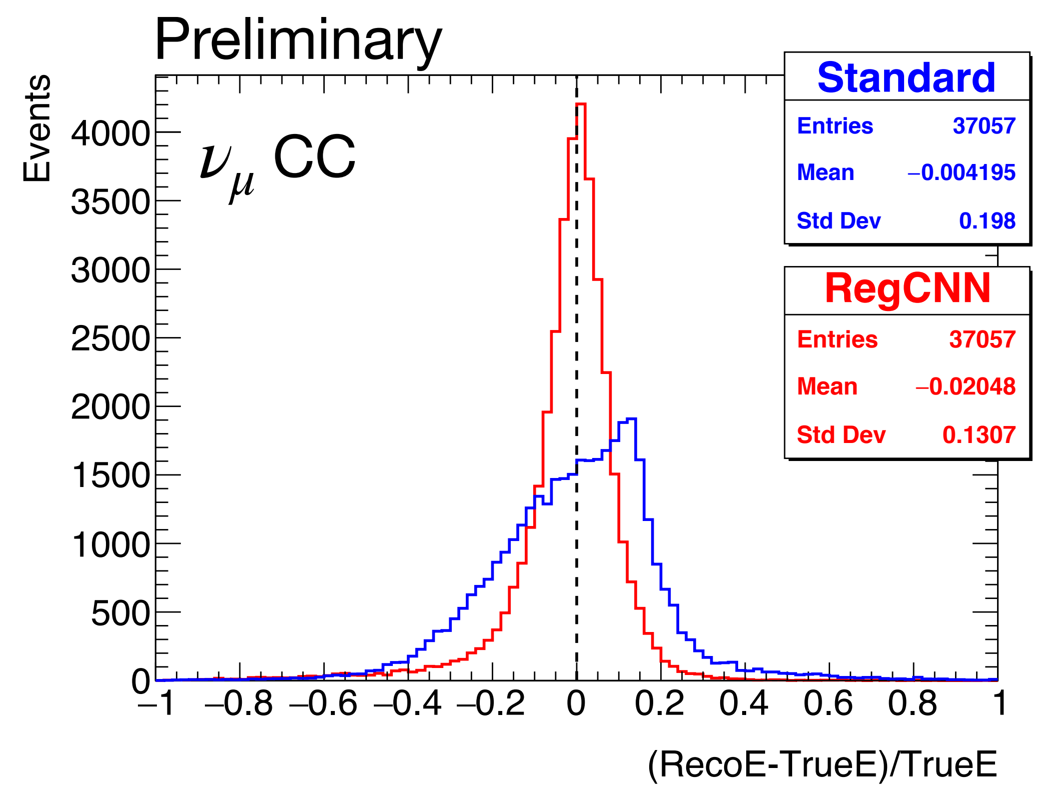


- Fit a gaussian to the resolution distribution for each energy bin
- Similar performance for pmtrack and pandoraTrack

Interface for RegCNN in LArSoft

- We developed an interface for RegCNN in LArSoft
  - Neural networks for ν_e and ν_μ CC events are implemented





- The implementation for 3D CNN is ongoing
  - For direction reconstruction

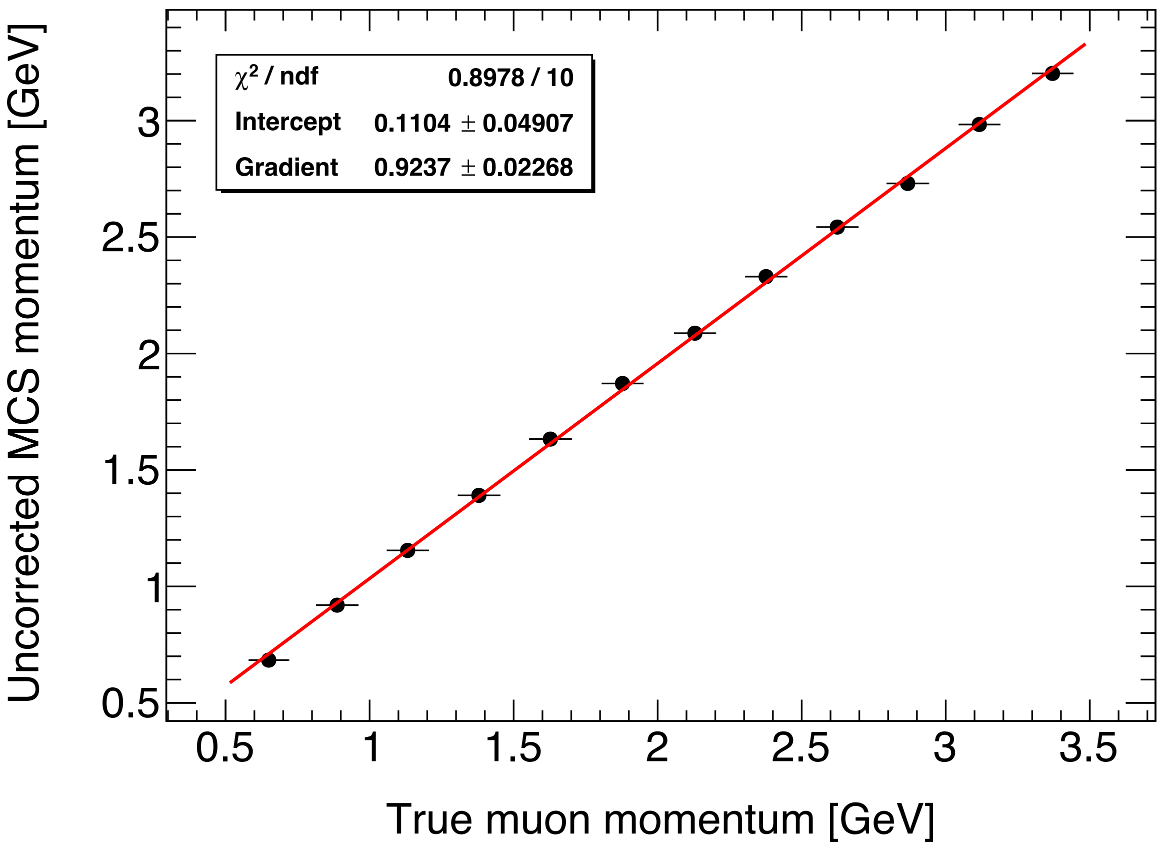
Summary and prospect

- We evaluated the effect of different track reconstruction methods on the neutrino energy resolution
  - pmtrack and pandoraTrack give similar performance for both contained events and exiting events
  - pandoraTrack may be more well-maintained
- MCS method fails for high energy muon tracks, may need further investigation on this method
- The interface for CNN models for estimating ν_e and ν_μ energy in LArSoft have been implemented
  - The interface for 3D CNN models is currently ongoing

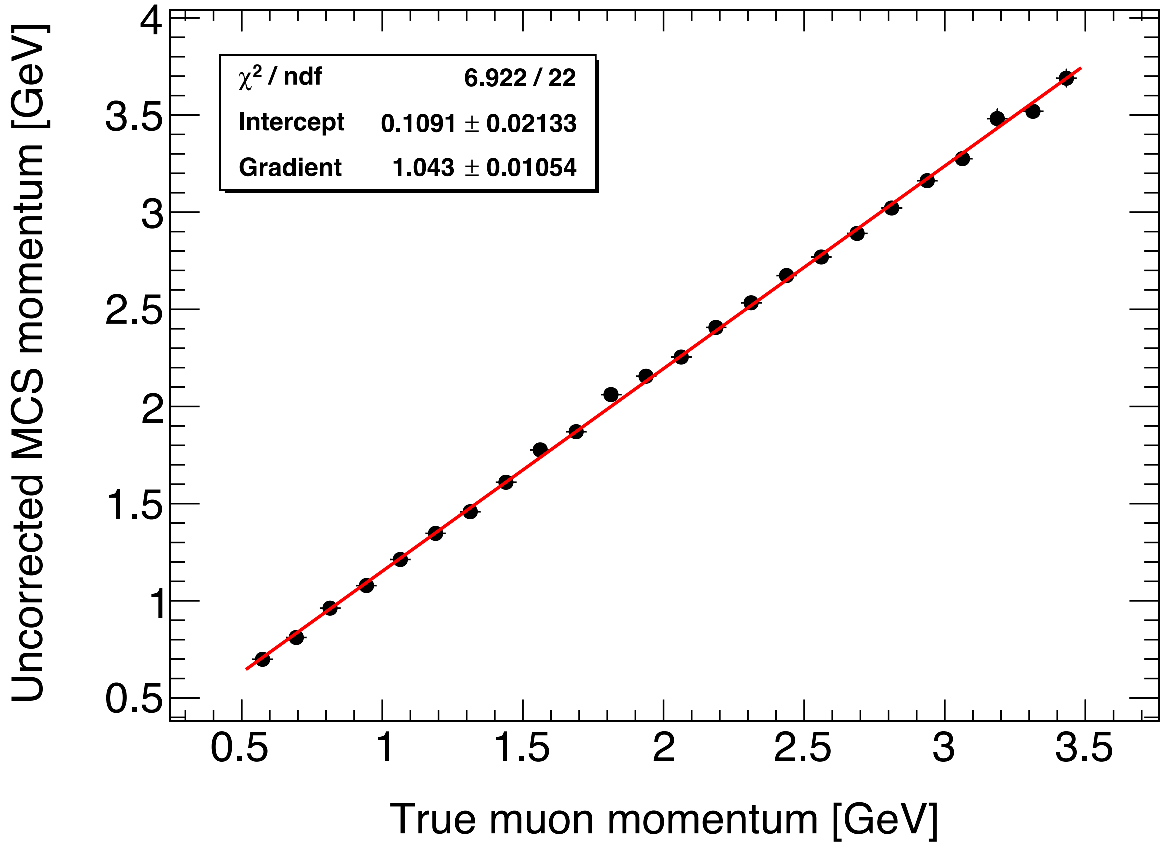
Backup

Calibration: MCS momentum

pmtrack

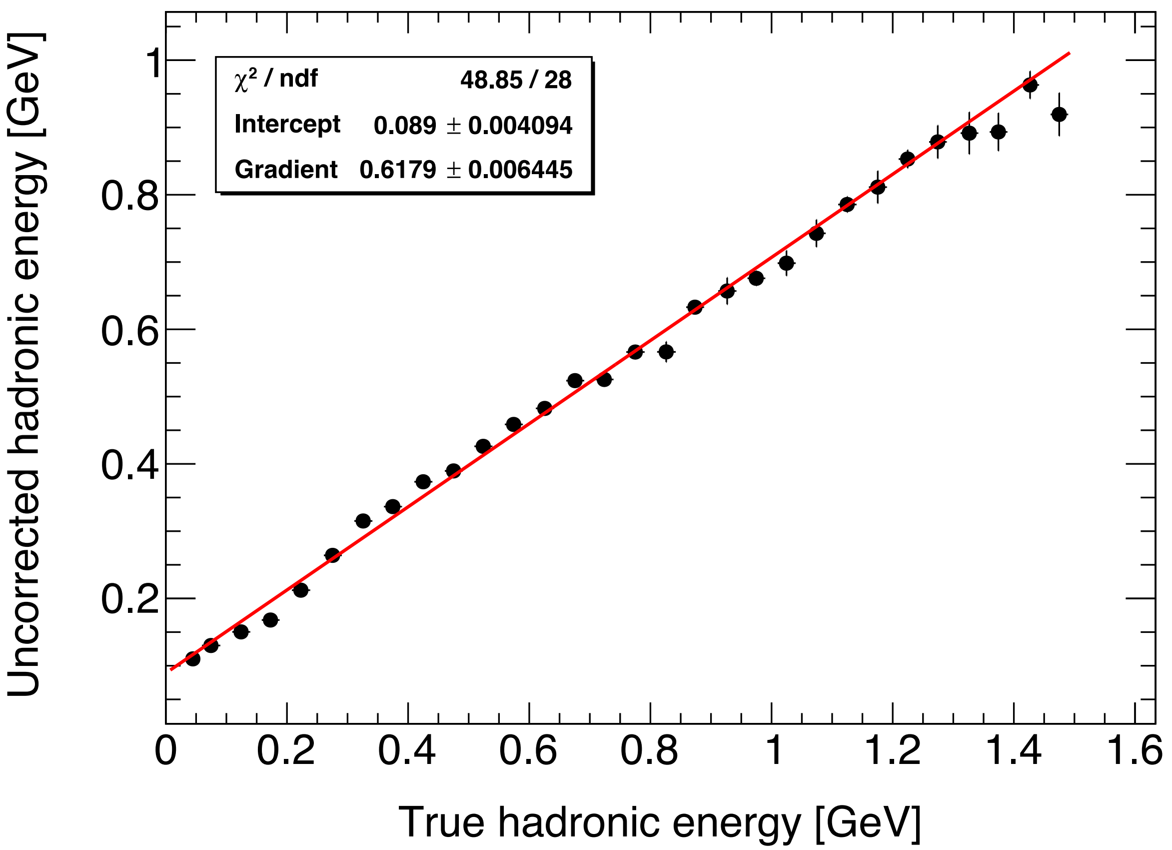


pandoraTrack



Calibration: hadronic E with exiting tracks

pmtrack



pandoraTrack