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Update on energy reconstruction in DP

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Introduction

For the TDR we would like to have a complete reco chain for the DP detector and we would like to be able to produce some spectra

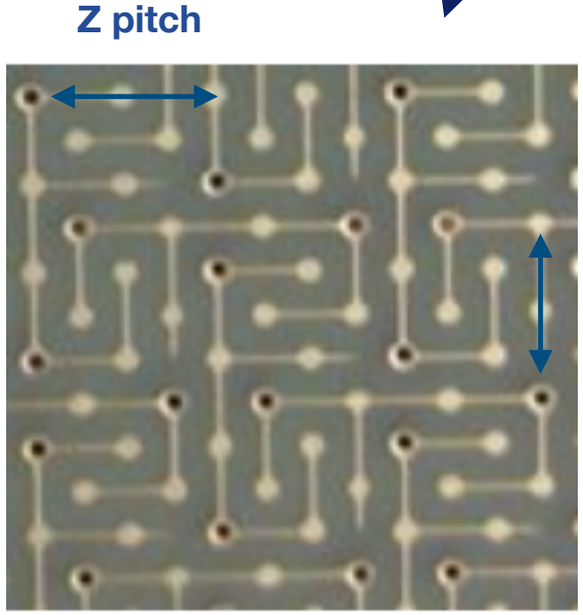
- Testing, tuning and improving the reconstruction machinery already in place
- Energy reconstruction for DP and study of DP specific impact on the detector resolution

Today:

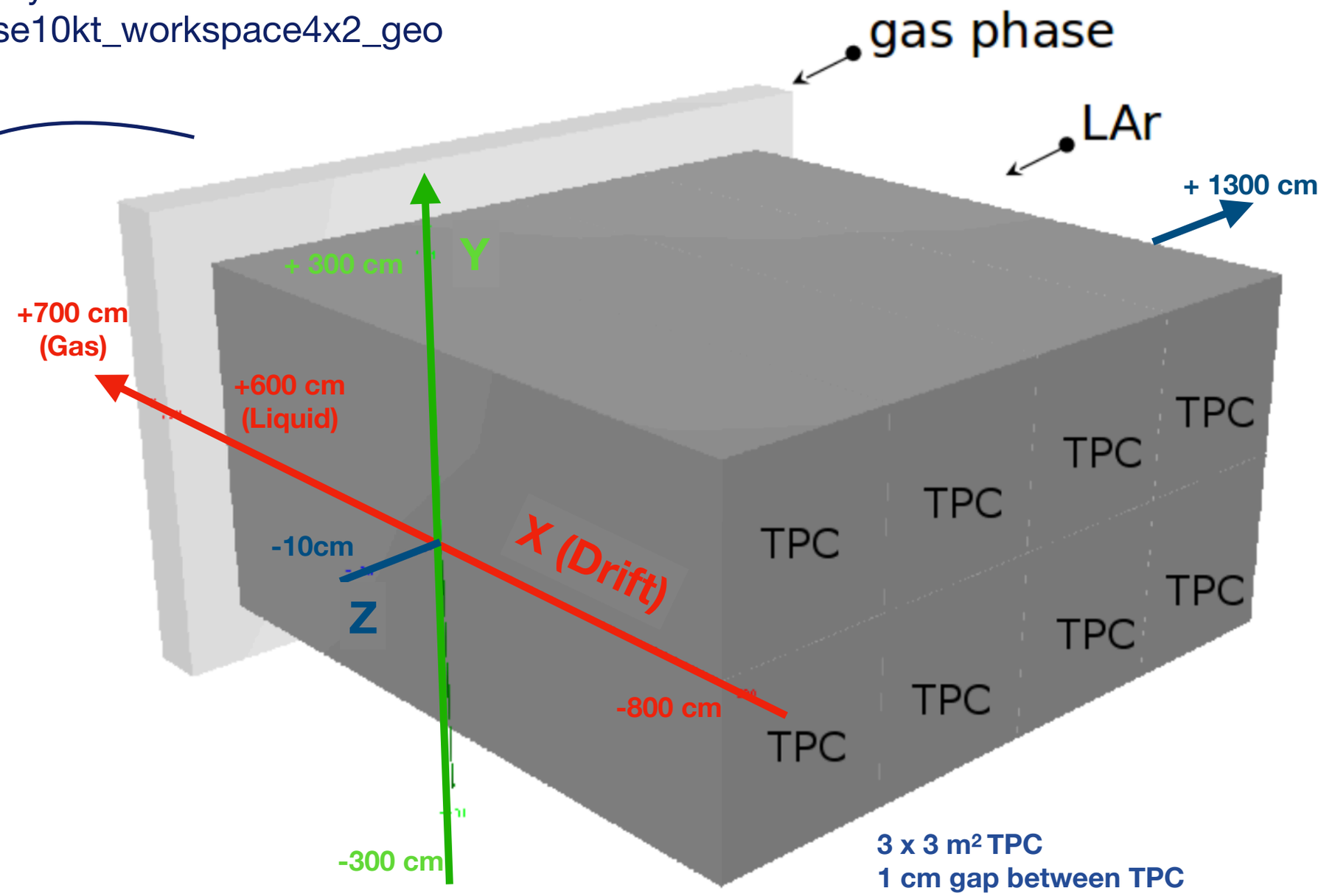
- Introduction on Dual Phase
- Issues with the reconstruction
- ν_μ CC energy reconstruction

Far detector geometry

Use of workspace geometry to have a similar fid.
Volume to SP: dunedphase10kt_workspace4x2_geo



Anode 50x50 cm² module



3 x 3 m² TPC
1 cm gap between TPC

From the Jan. 2018 collab. meeting: https://indico.fnal.gov/event/14581/session/6/contribution/172/material/slides/0.pdf

Dual-Phase specificities

Drift length (fiducial volume)	12 m	Electron lifetime and diffusion, reduce image quality
Drift Field	0.5 kV/cm	
Wire pitch	3 mm	Higher granularity
Pich direction	Z and Y	Topologically problematic for the far detector neutrino events
# of Planes	2	Ambiguities in reconstruction unresolved
Plane type	Collection	Larger image quality (no double pulse)
Gain	Minimal CDR requirement is 20.	Is supposed to compensate for all the flawns from the longer drift
Liquid-Gas interface	/	Effect of electron extraction on the signal waveform -> Detector resolution
Space charge	/	In liquid and at the liquid gas interface

- Because of gain, one might expect different performances between DP and SP in the energy reconstruction: → **Impact of gain on the energy resolution**
- Smaller pitch might improve patter recognition
- Hard event topology and absence of a third plance could make reconstruction harder → **Find an estimate of that and solution to improve it**
- Sensitivities for DUNE → **DP dedicated studies have never been completed (as far as I know)**

FD Simulation

Neutrino samples: overview

Ready to get analysed!

- 1 million ν_e (up to hit finding)
- 1 million ν_μ (up to hit finding)
- 1 million ν_τ (up to hit finding)
- 1 million $\bar{\nu}_e$ (up to hit finding)
- 1 million $\bar{\nu}_\mu$ (up to hit finding)
- 1 million $\bar{\nu}_\tau$ (up to detsim)

people involved so far:

Christoph Alt, Dominic Brailsford, Zahra Ghorbani, Alex Radovic, Andrea Scarpelli, **Dorota Stefan**, Robert Sulej and Leigh Whitehead

- file location (reco): /pnfs/dune/persistent/users/dstefan/v06_59_00/
- everyone is invited to get involved!

From the Jan. 2018 collab. meeting: https://indico.fnal.gov/event/14581/session/6/contribution/172/material/slides/0.pdf

Moving forward: reconstruction

Standard approach for reconstruction so far:

✓Hit finder: raw hit finder fitting

✓Clustering: linecluster

✓Tracking: pmalg

Not yet in place, but planned:

- Clustering using Trajcluster
- CNN hit feature labelling
- Shower reconstruction: emshower

A long shot:

- Pandora …

ν_μ energy reconstruction

Following the approach of the SP by N. Grant and T. Yang

- See the internal note https://docs.dunescience.org/cgi-bin/private/RetrieveFile?docid=2278&filename=NuEnergyReco_v2.pdf&version=2

Event	Topology	Reco feature	Observable
ν_μ CC	**μ contained**	**Longest track contained**	**Momentum from track length**
ν_μ CC	**μ not contained**	**Longest track not contained**	**Momentum from MCS**
ν_e CC	all	Em shower with largest charge	Cal. energy from charge
Hadronic	all	Charge collected	Cal. energy from charge

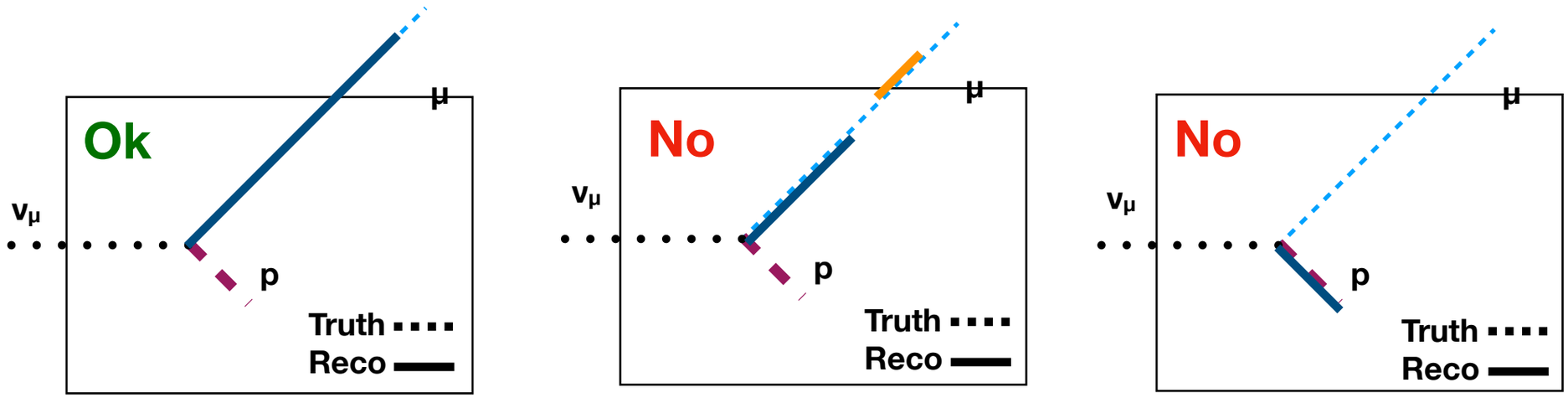
Efforts to improve ν_μ CC events reconstruction:

- **Correct longest track identification and reconstruction**

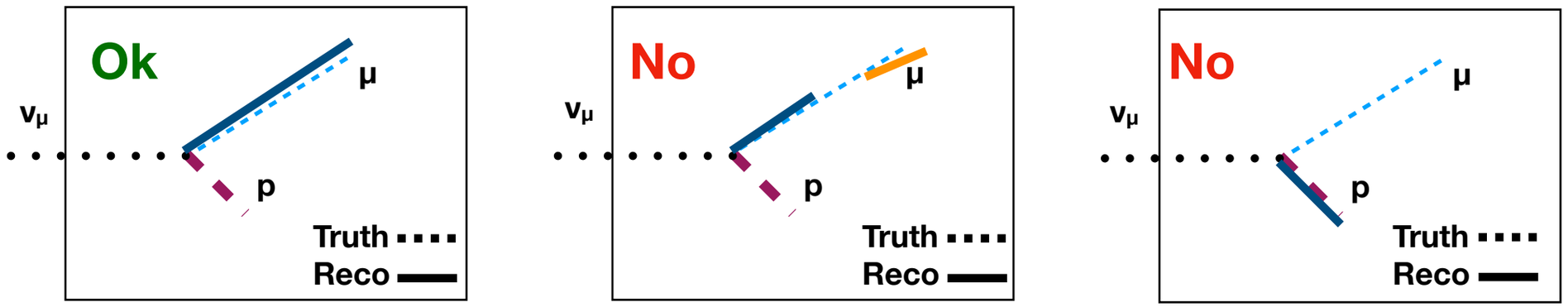
Troublesome reconstruction

Main problem in ν_μ CC events leading muon track reconstruction:

Case: Not contained

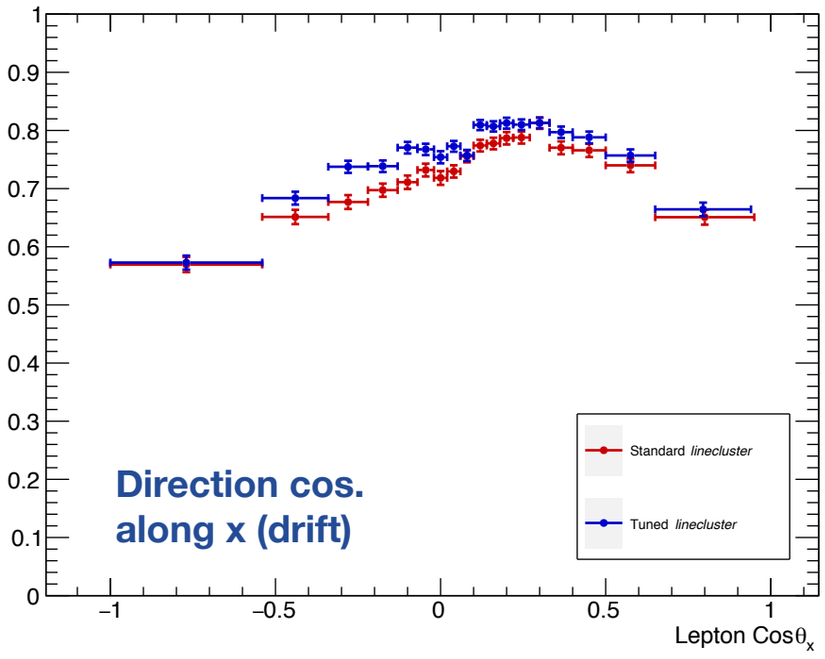


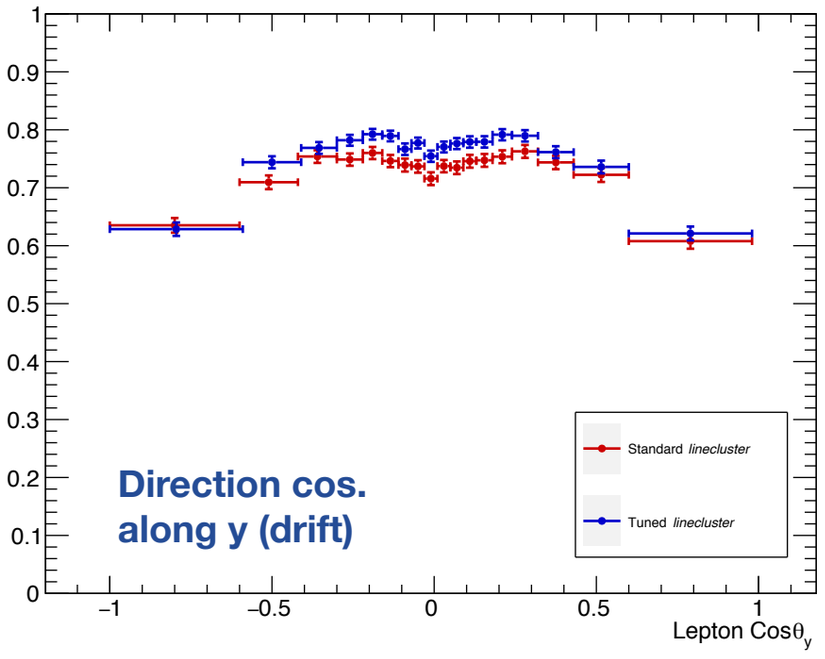
Case: Contained

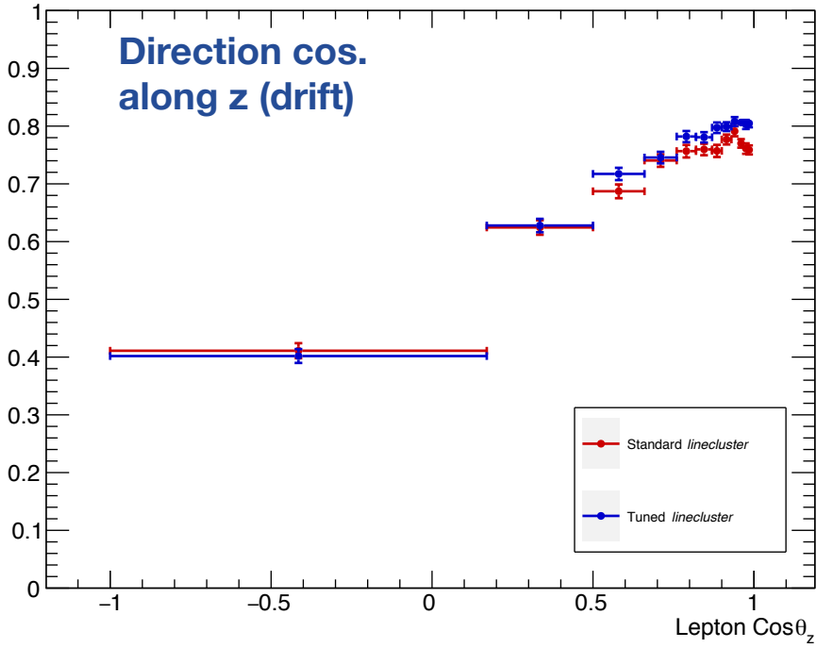


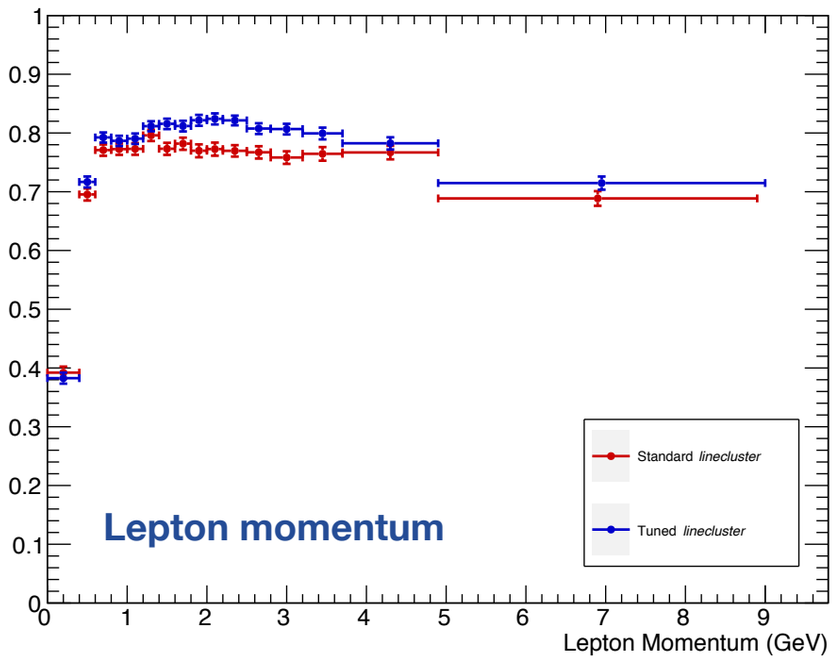
Use completeness and truth info to identify correctly reconstructed tracks and have an idea of the reconstruction efficiency

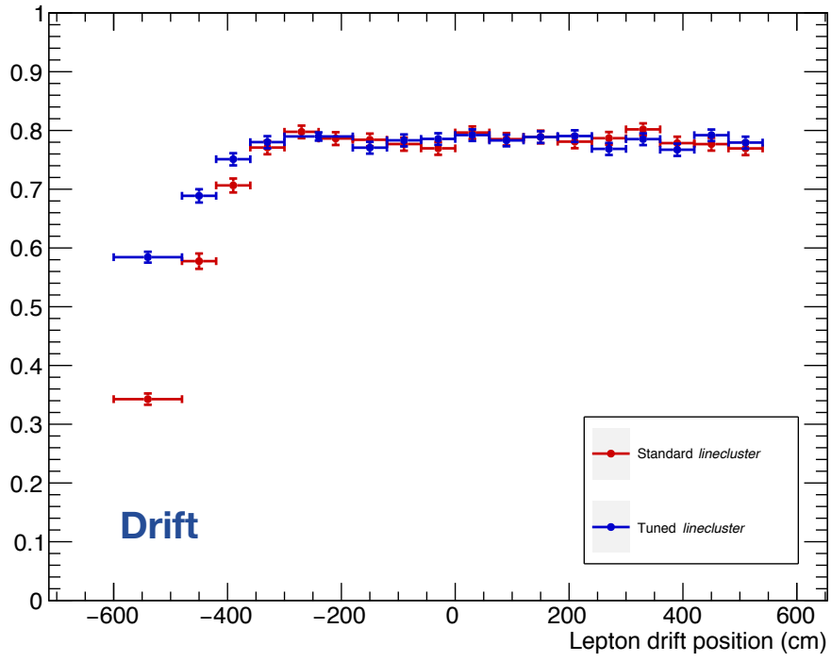
Reconstruction efficiencies (preliminary)





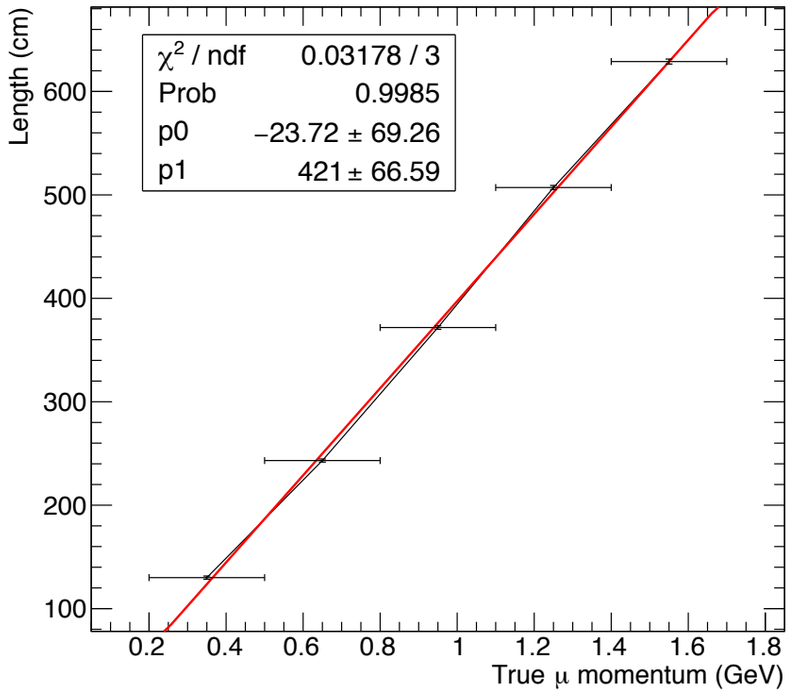


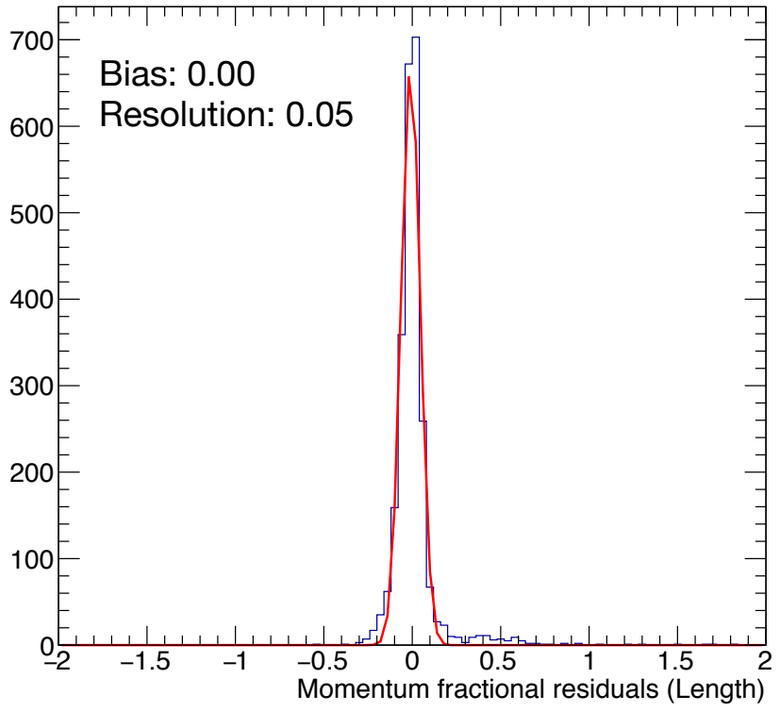




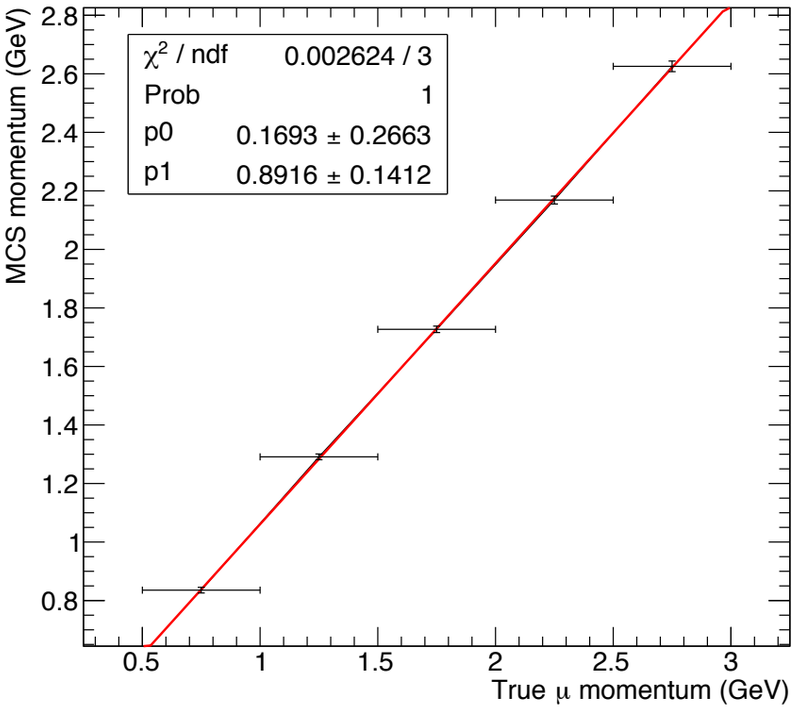
Possible efficiency degradation related to the direction due to momentum-direction correlation

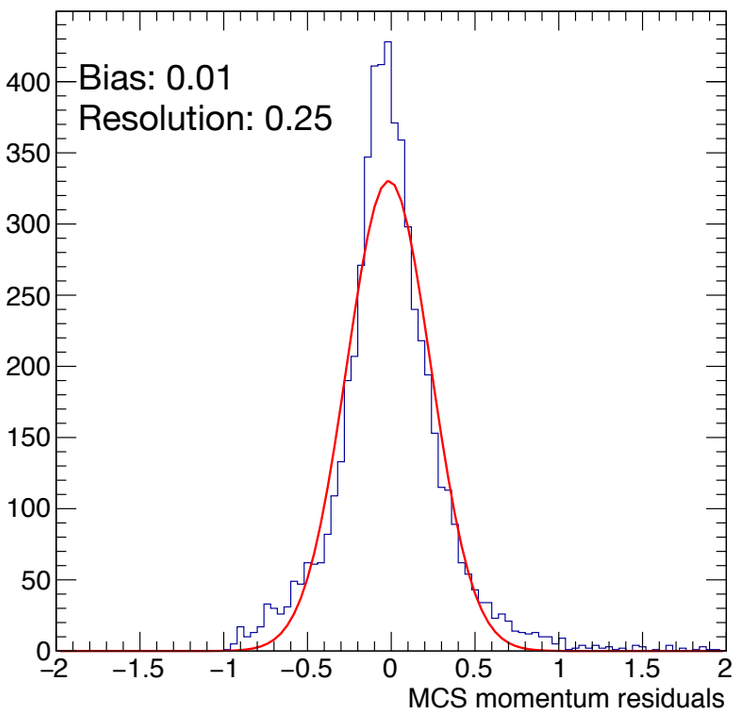
Longest track momentum





- **Contained tracks**

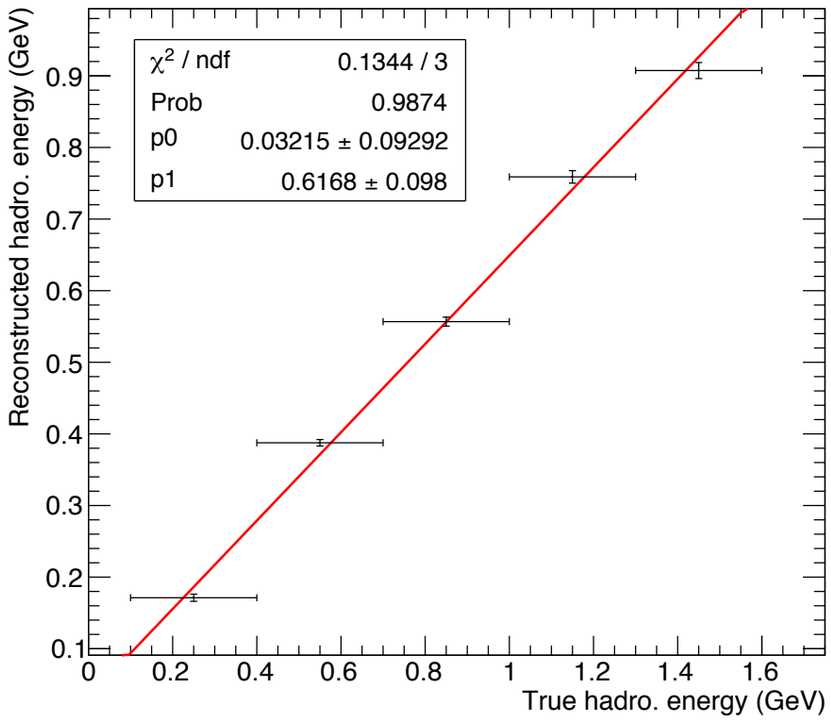


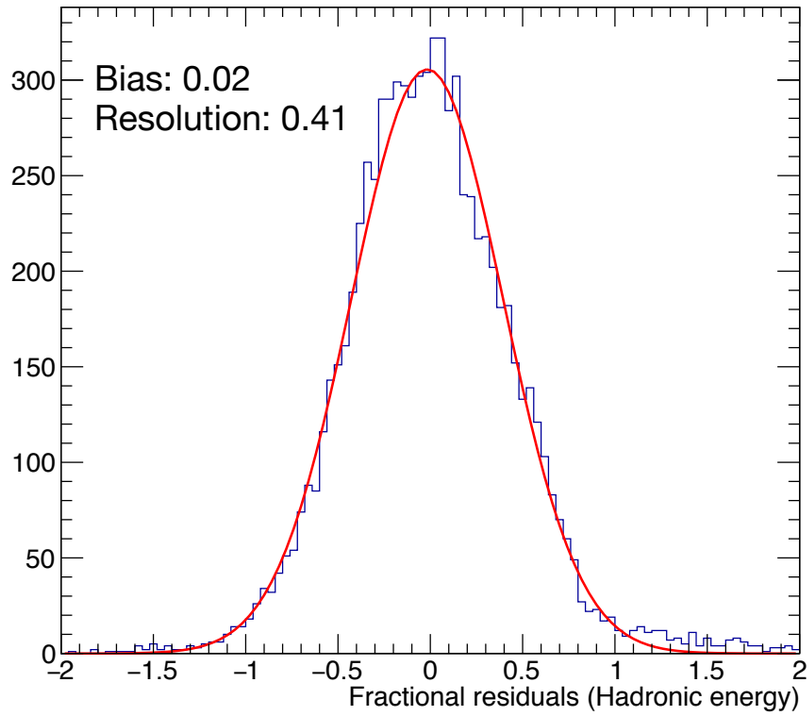


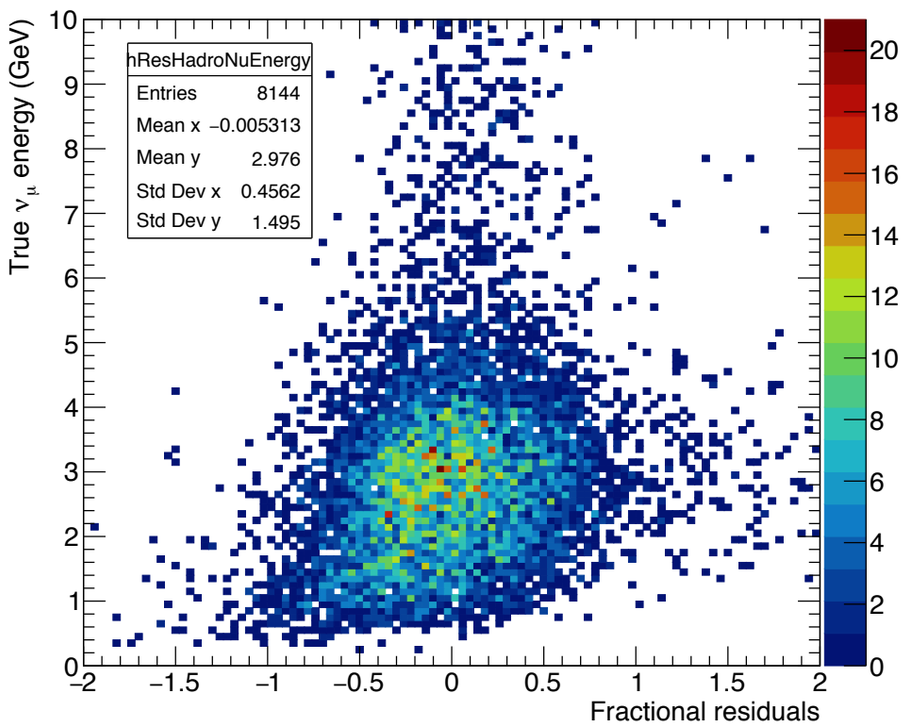
- **Exiting tracks**

Hadronic energy

Simple hit energy sum and correction for the invisible energy

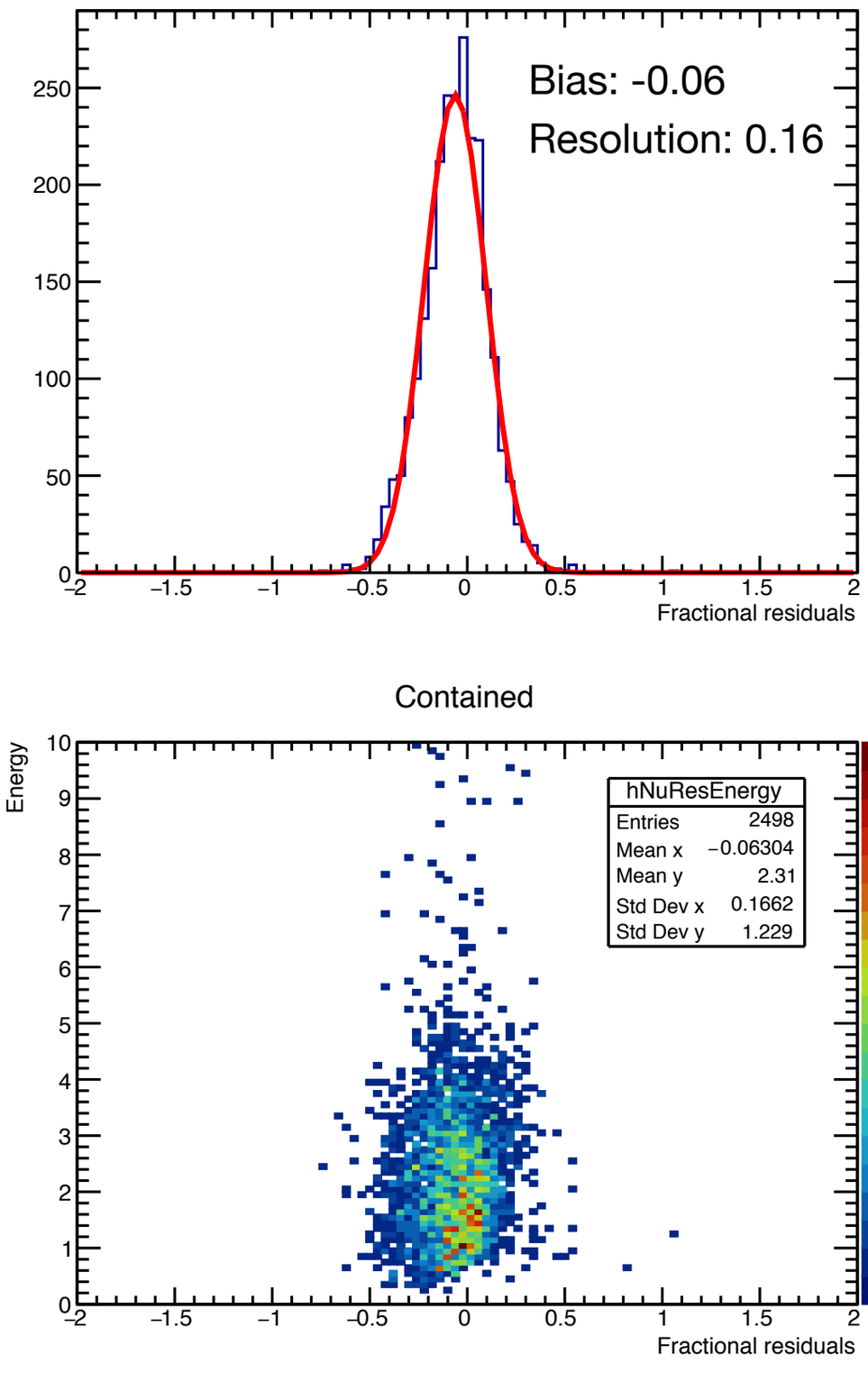


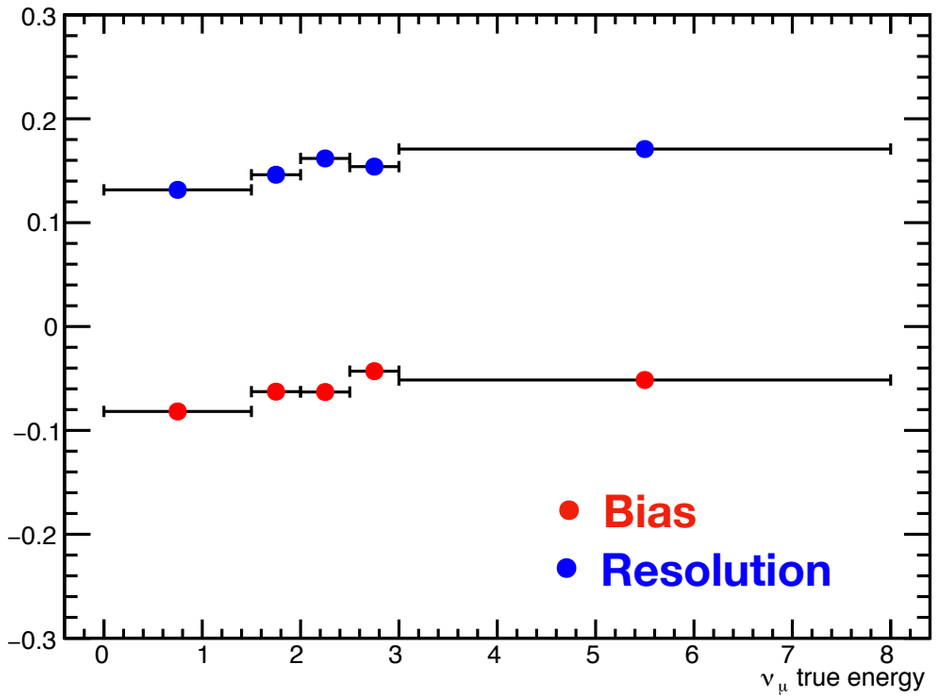


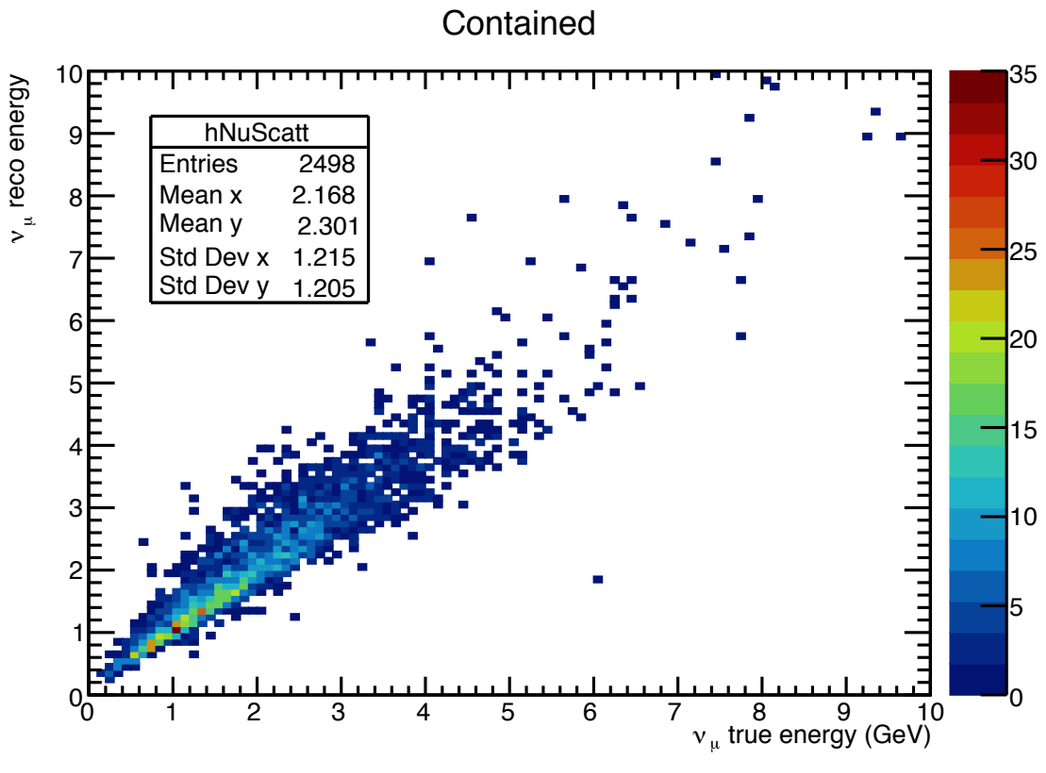


- **Hadronic energy**
  - Assume linear dependence on the true energy, while it is not.
  - Ad hoc tweak to correct the resolution and bias energy dependence..

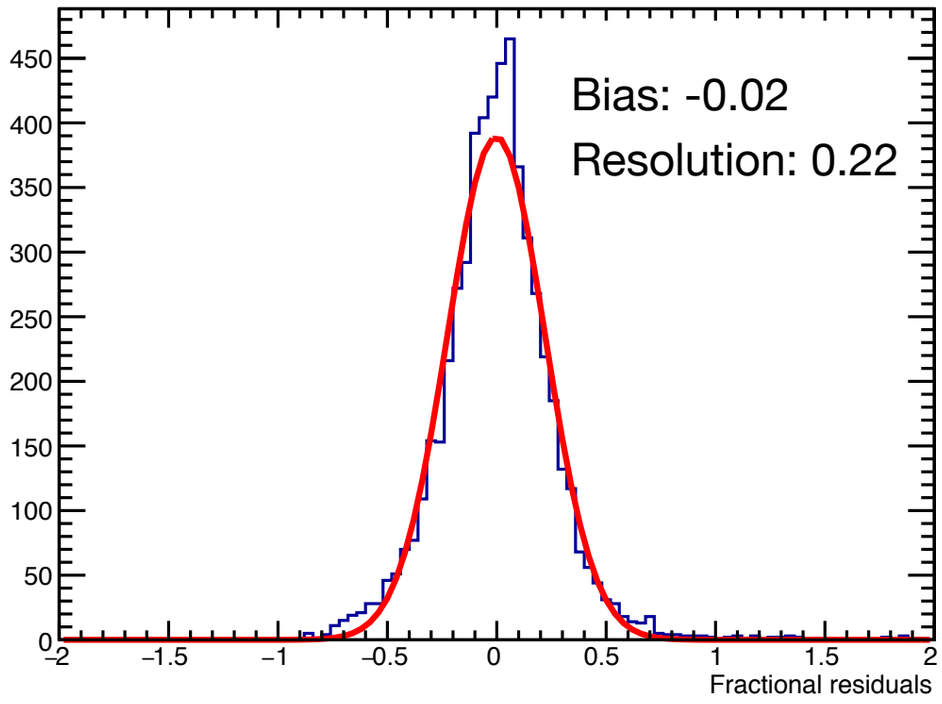
ν_μ energy (contained)

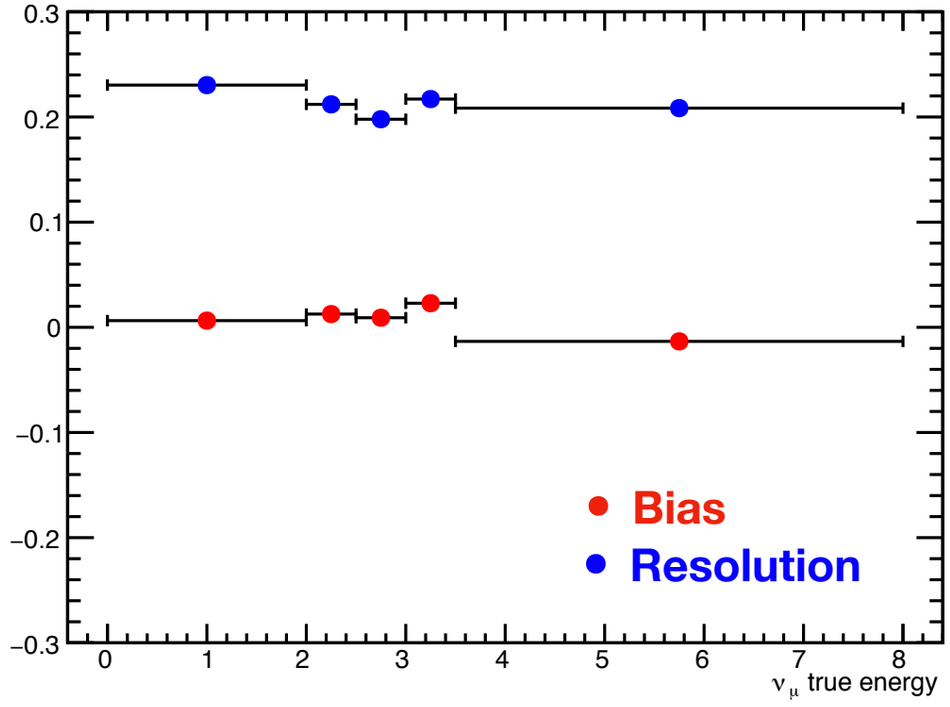


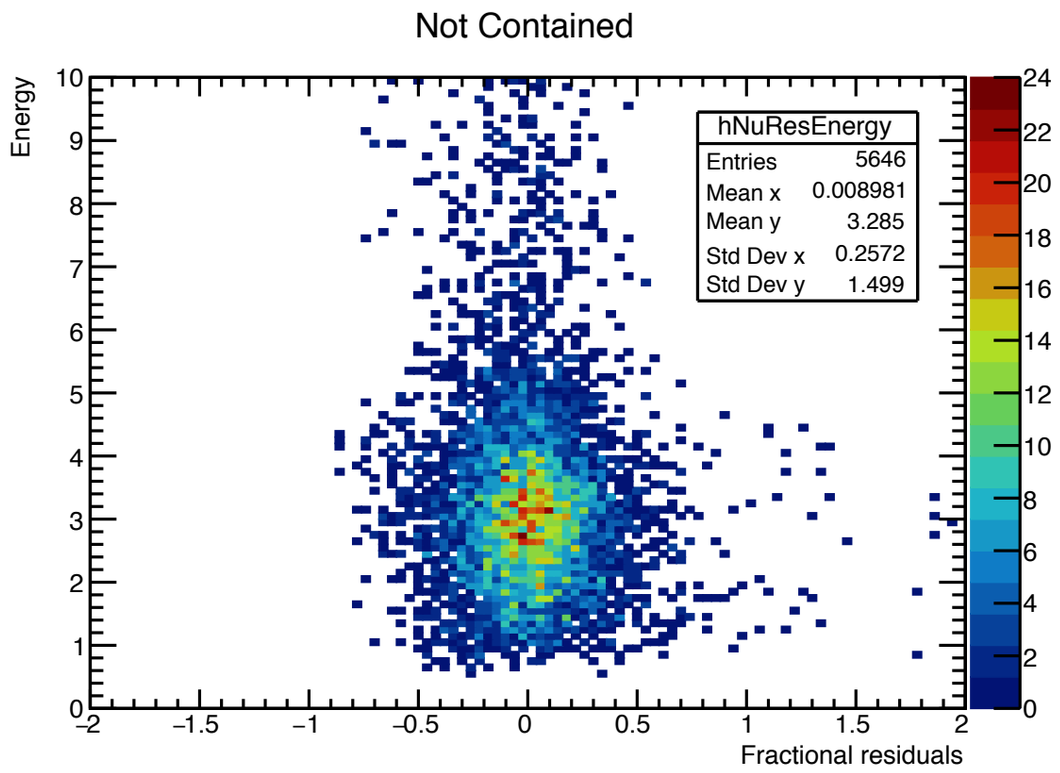


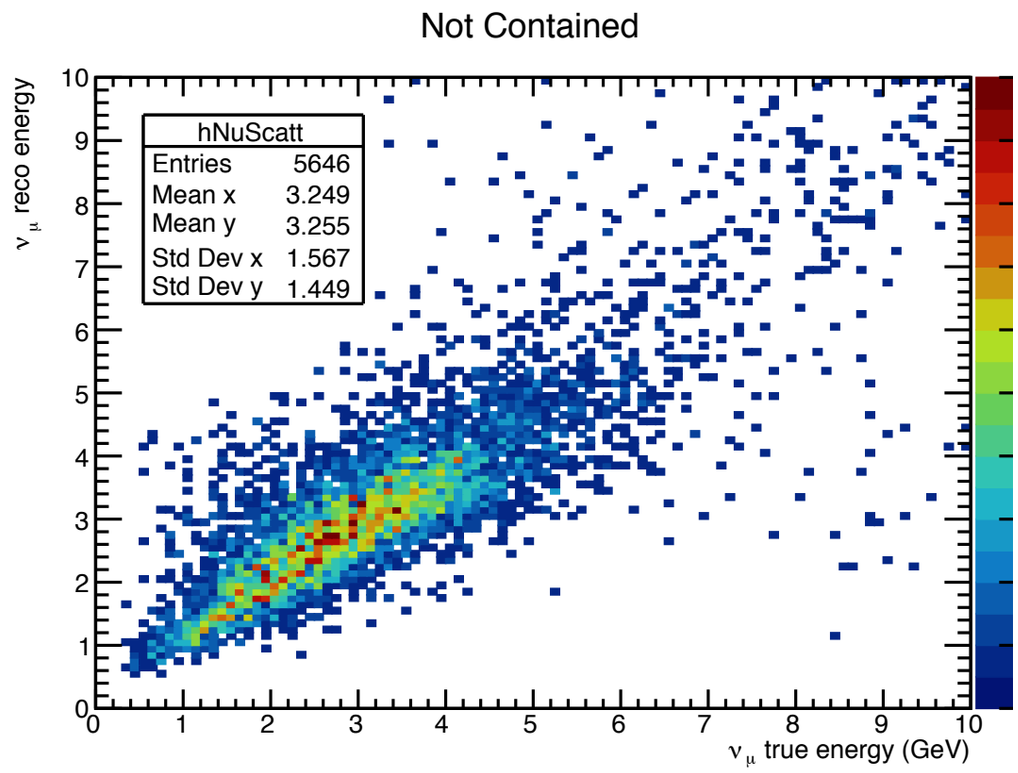


ν_μ energy (not-contained)









Energy reco performances

Event	Topology	Resolution SP*	**Resolution DP** (at gain = 20)
ν_μ CC	μ contained	Track length: 5% Hadronic part: 39% **Overall: 18%**	Track length: 5% Hadronic part: **Overall: 16%**
ν_μ CC	μ not contained	Track MCS: 23% Hadronic part: 39% **Overall: 20%**	Track MCS: 25% Hadronic part: 41% **Overall: 22%**

✳ See the internal note https://docs.dunescience.org/cgi-bin/private/RetrieveFile?docid=2278&filename=NuEnergyReco_v2.pdf&version=2

- At gain 20 and selecting well-reconstructed tracks , SP and DP perform alike (as predicted from CDR minimal requirement)
- A Gain increase might impact the hadronic component, yielding a better estimate of the overall energy

Conclusion

First look on reconstruction highlight major problems

- Better tuning of the existing algorithms
- Implement CNN to solve possible ambiguities

First look on energy

- Energy calibration and reconstruction for $\nu_{\mu\ CC}$ events was done selecting nicely reconstructed events

Outlook

- Improvement of the reconstruction
- Using truth info try to evaluate the impact of gain, purity and electric field on the energy resolution (and event selection (?))
- Export the results for physics studies

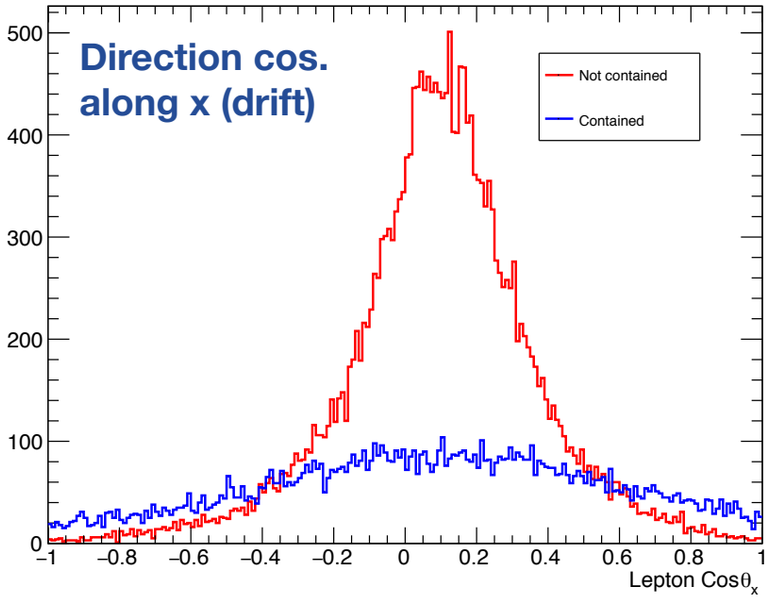
Questions, tips or feedbacks?

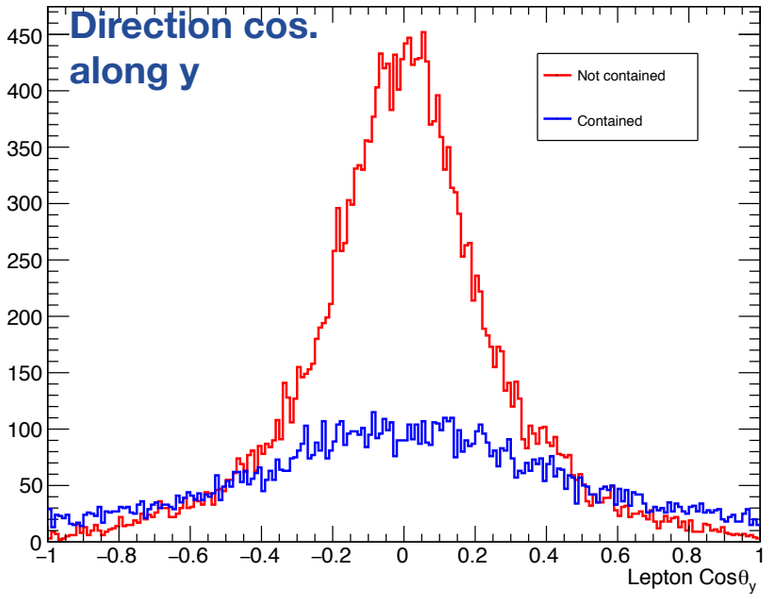
Thank you!

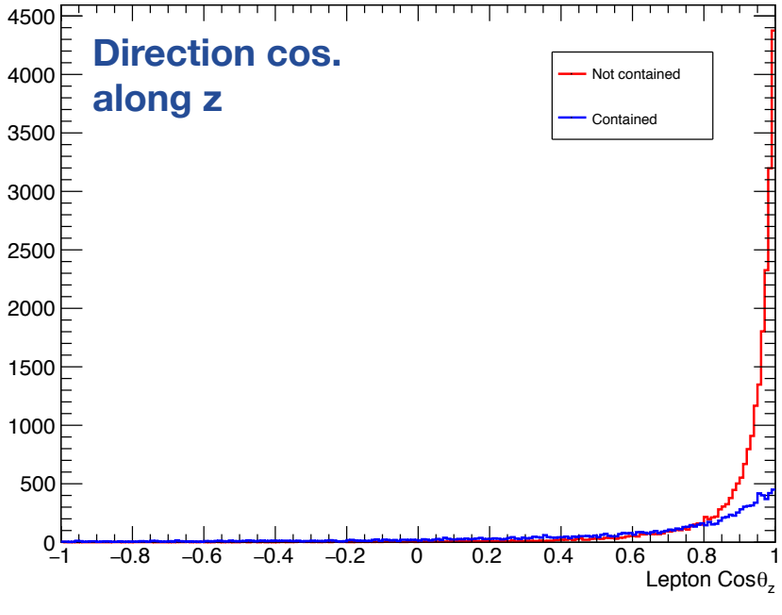
Topology of the events

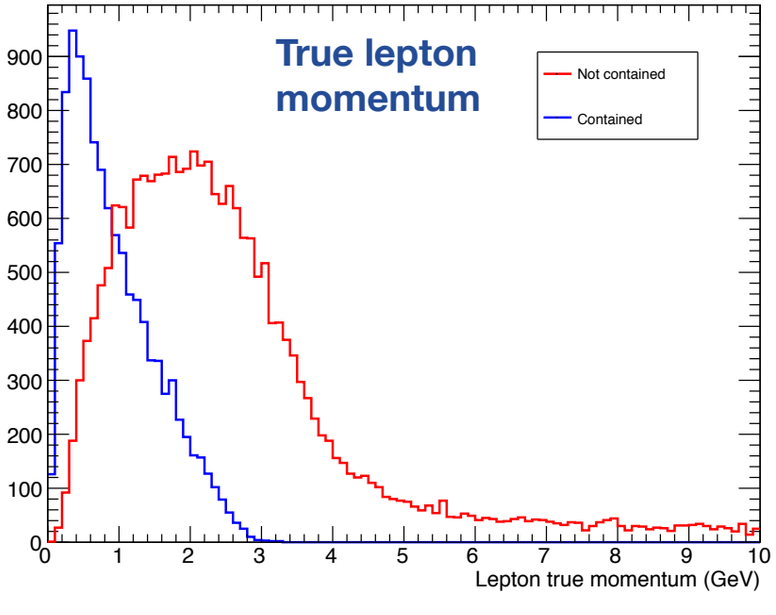
CRP wires in DP are oriented towards **difficult directions in z**

Considered 34421 numu events: **11125 contained**, **23296 not contained**



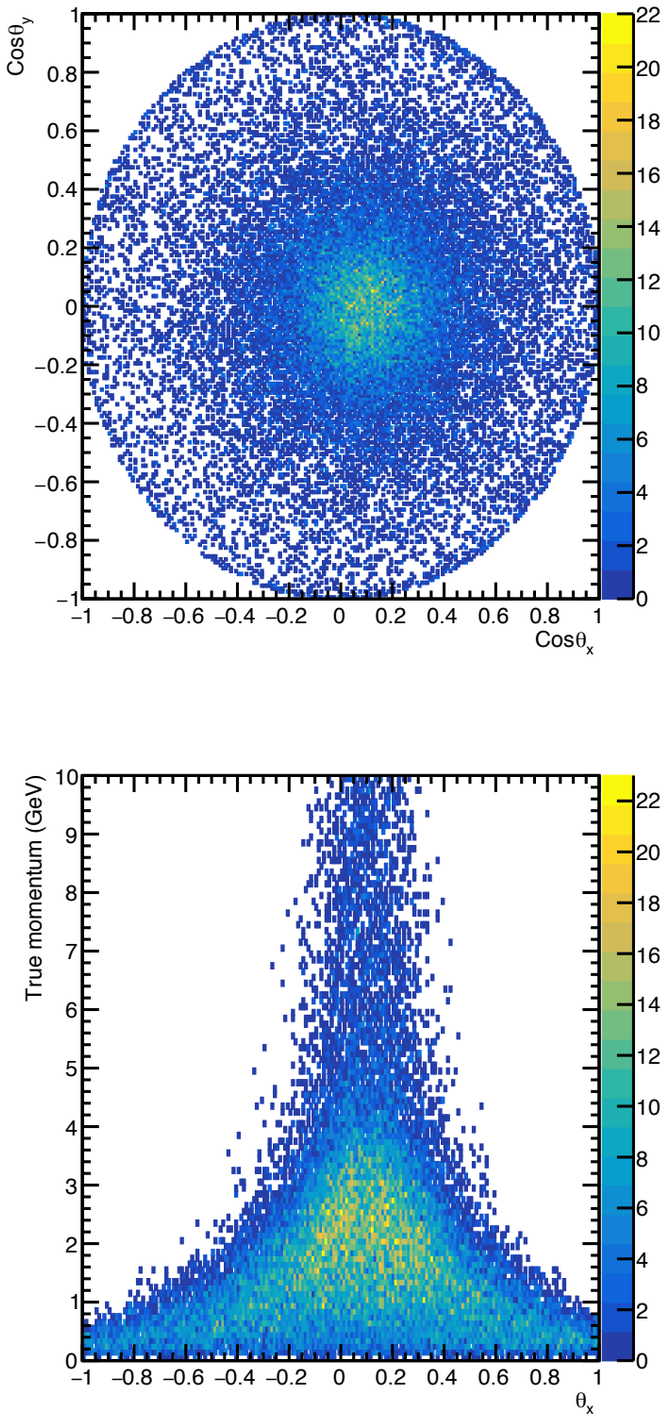


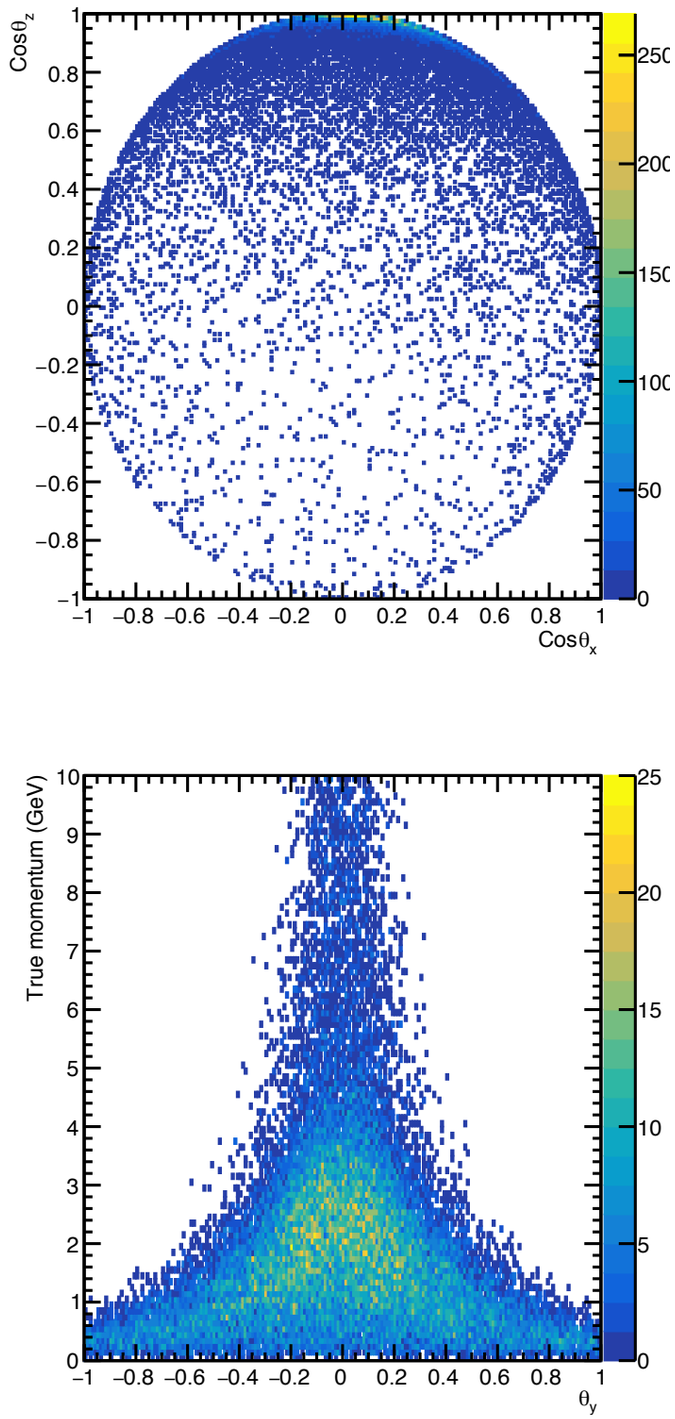


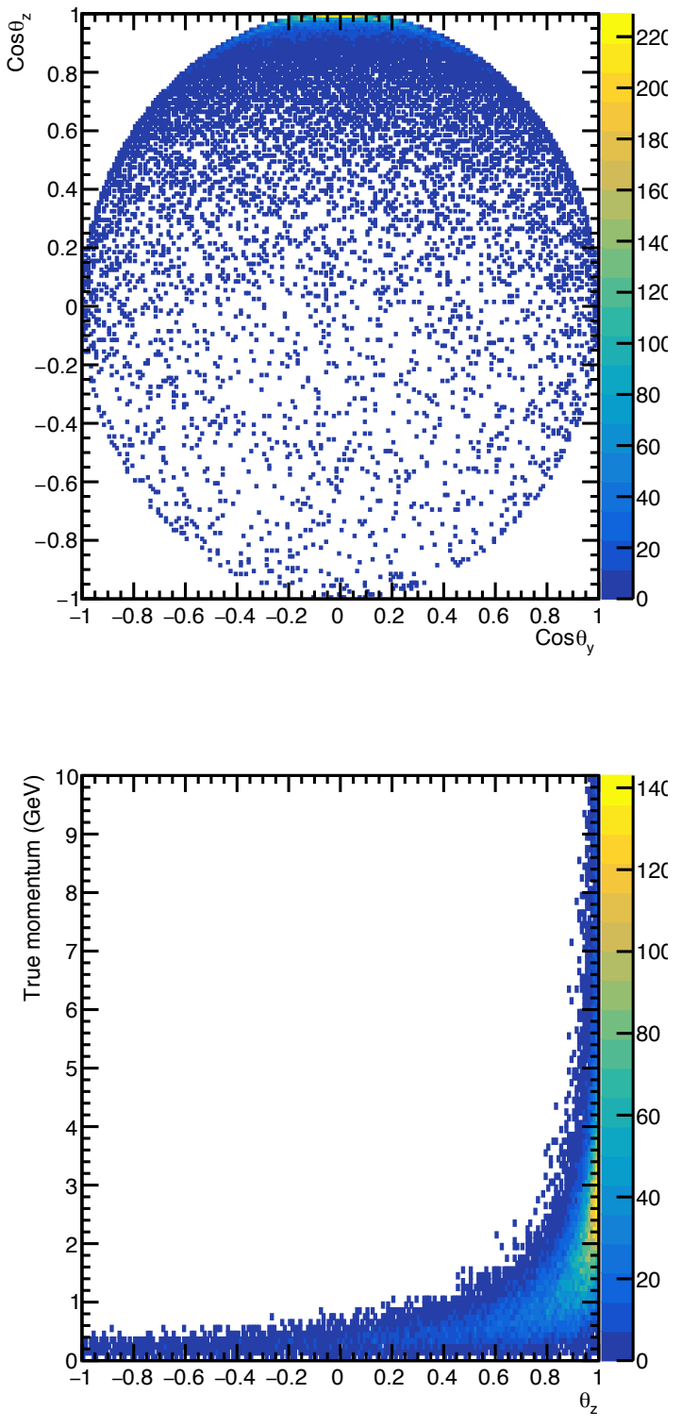


Topology of the events - 2D

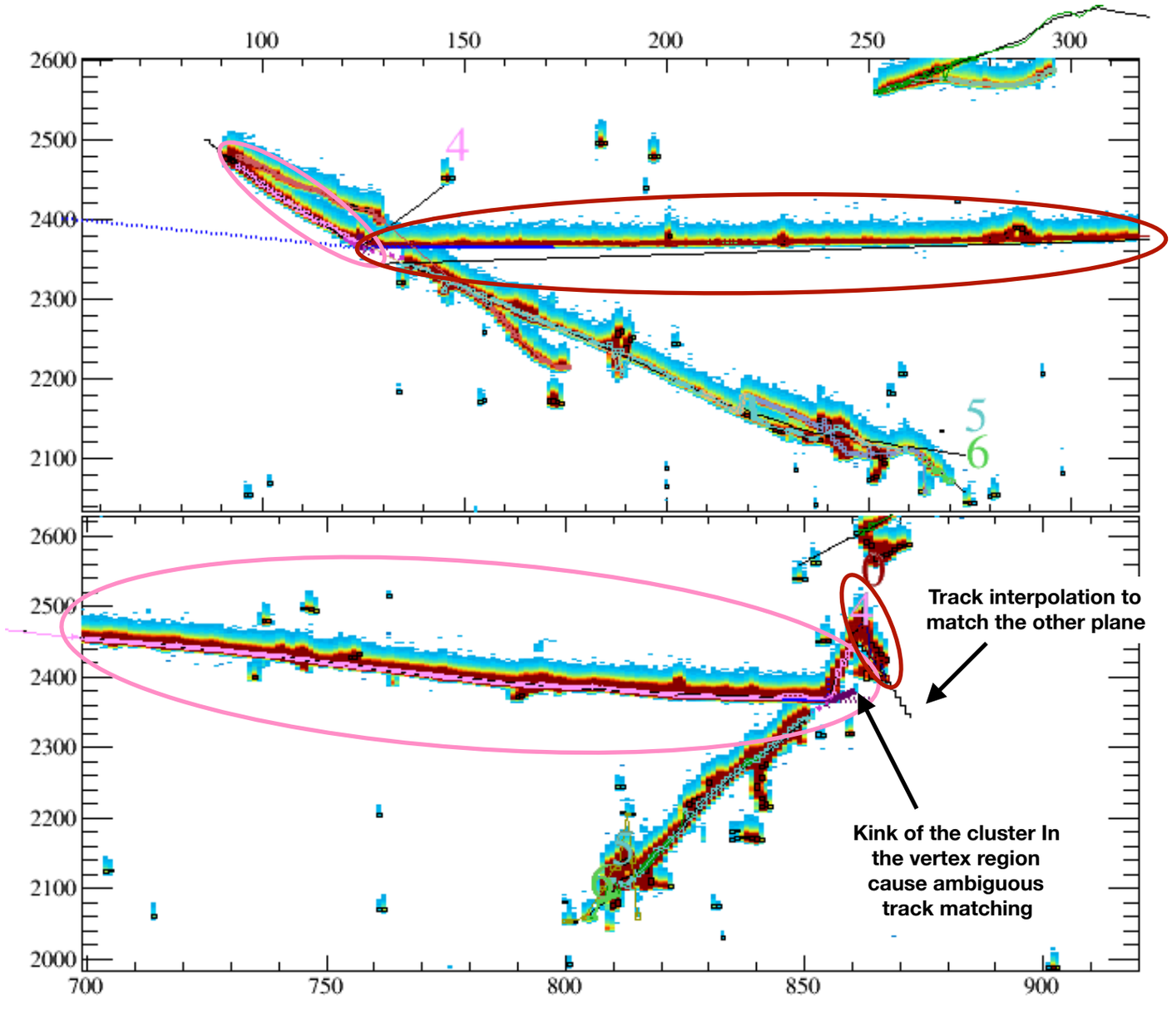
Observe correlations between directions and momentum

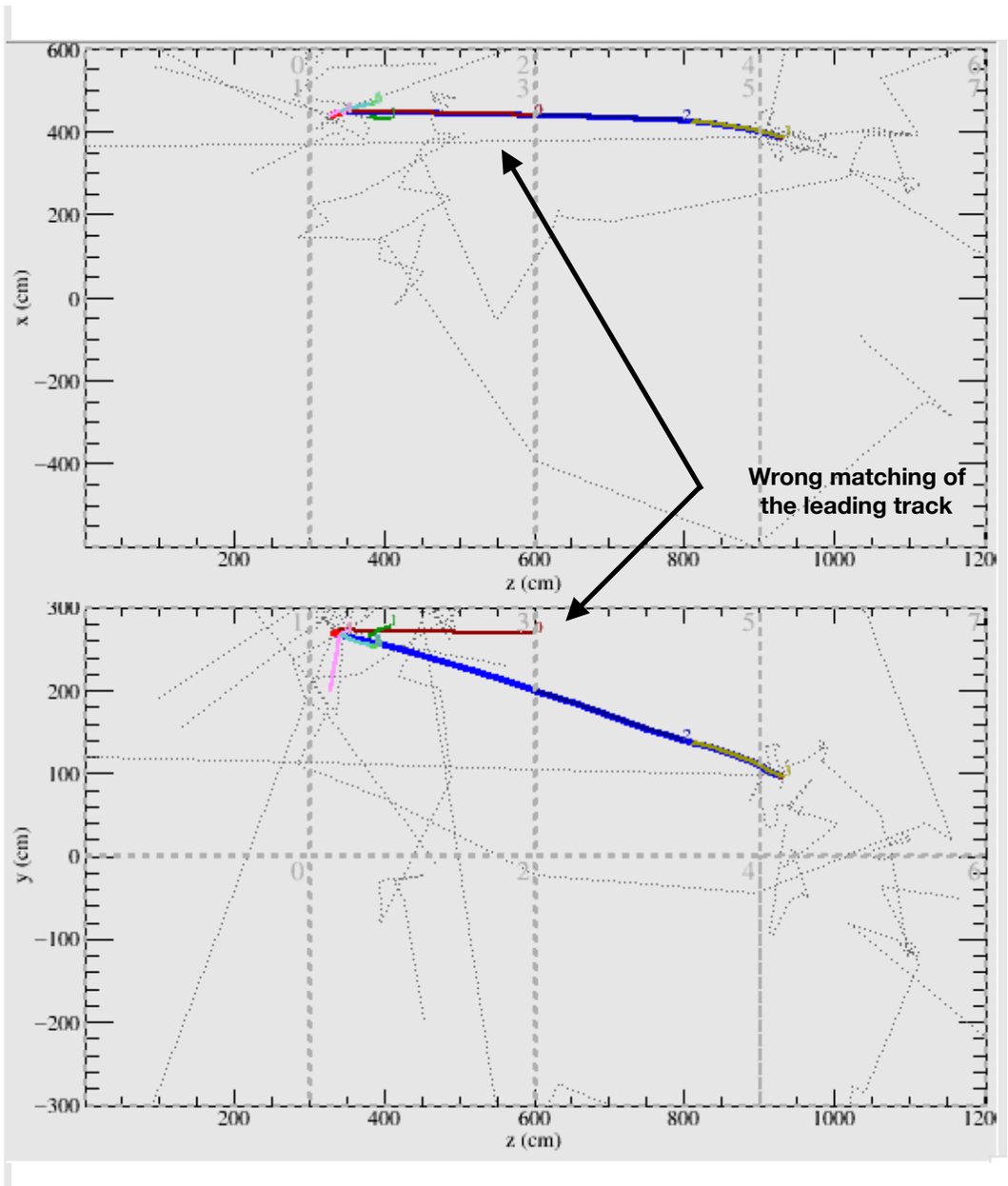






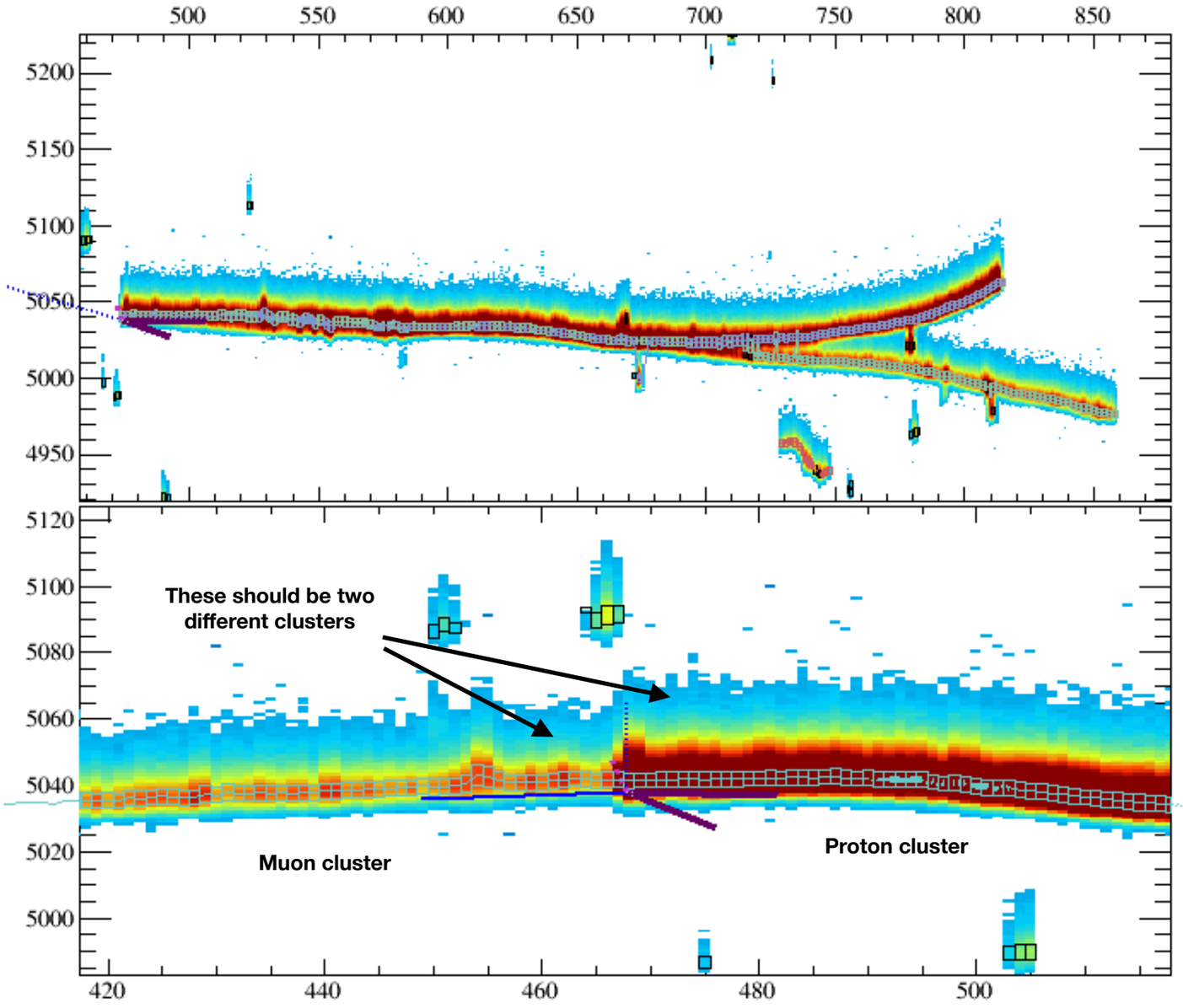
Issues with the FD Reconstruction - evd 1

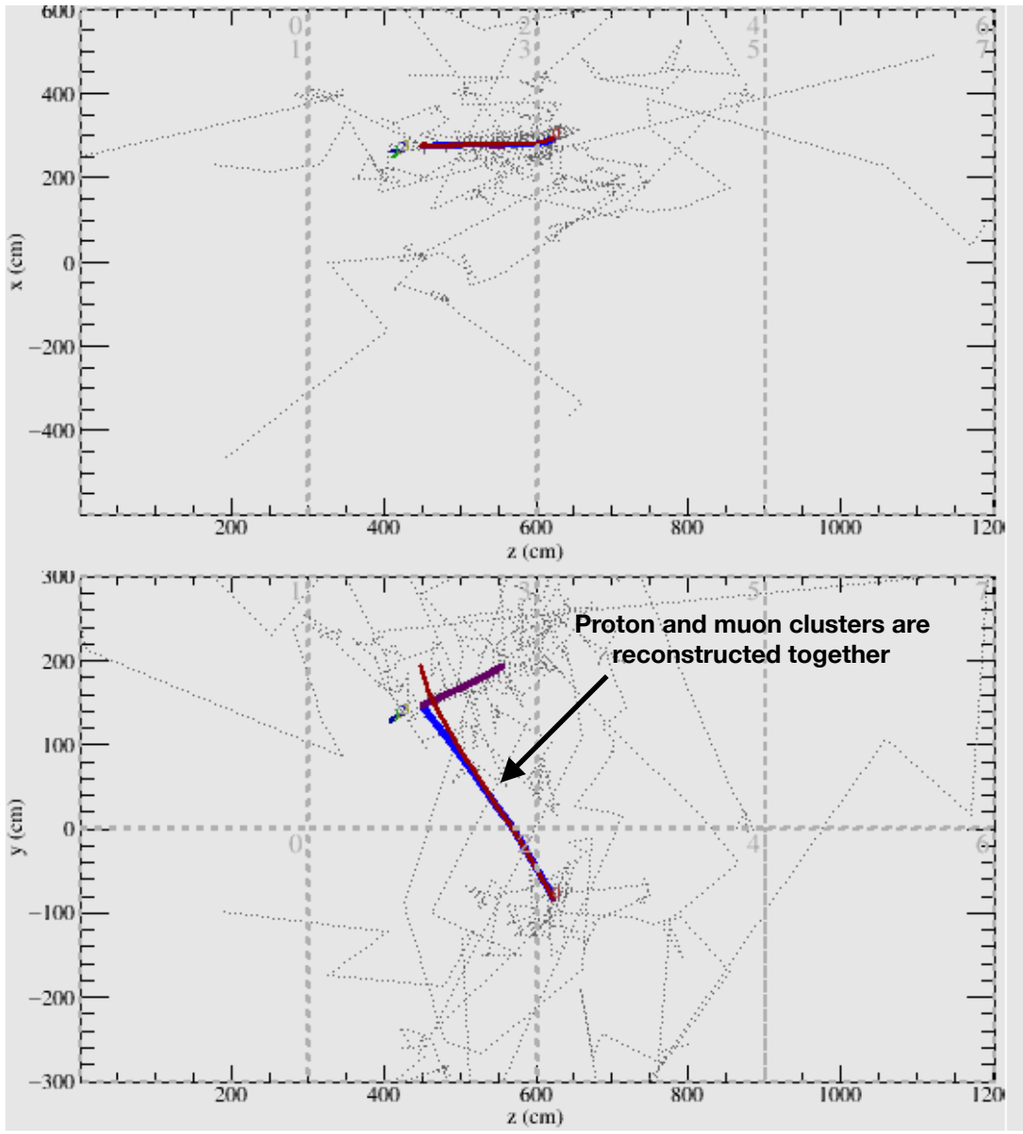




Ambiguities are produced by long clusters kinks in the vertex region, causing ambiguous track matching within the TPC.

Issues with the FD Reconstruction - evd 2





Rather common issue: two almost collinear clusters should be separated from their different charge, but they are not.