GArSoft Update

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DUNE Near Detector Meeting

July 22, 2020

Progress Since Physics Week

- Bugfixes and tuning (many thanks to Leo Bellantoni for spotting many of the problems)
  - Drift electron cluster size bugfix (readout simulation step)
  - Zero-suppression algorithm (readout simulation step)
  - Hit Finder (reco)
  - TPC Cluster Finder (reco)
- New TrackTrajectory data product and event display uses it by default
- Day-One Tracker
  - Repurposing tracking code to work with the new proposed geometry
- Pandora integration by Eldwan Brianne

Drift Simulation Bugfix

- Diffusion modeled with finite samples from a Gaussian
- ALICE: simulate individual drifting electrons
- LArSoft – group them for speed and memory
- Had wanted 1 electron per sample, with a bug I got all electrons in a G4 step in a single random sample.
- Revert to 20 electrons per sample to save memory
- Bugfix expected to improve point resolution

Zero-Suppression

- Cartoon from the ICARUS NIM (parameters different for us)

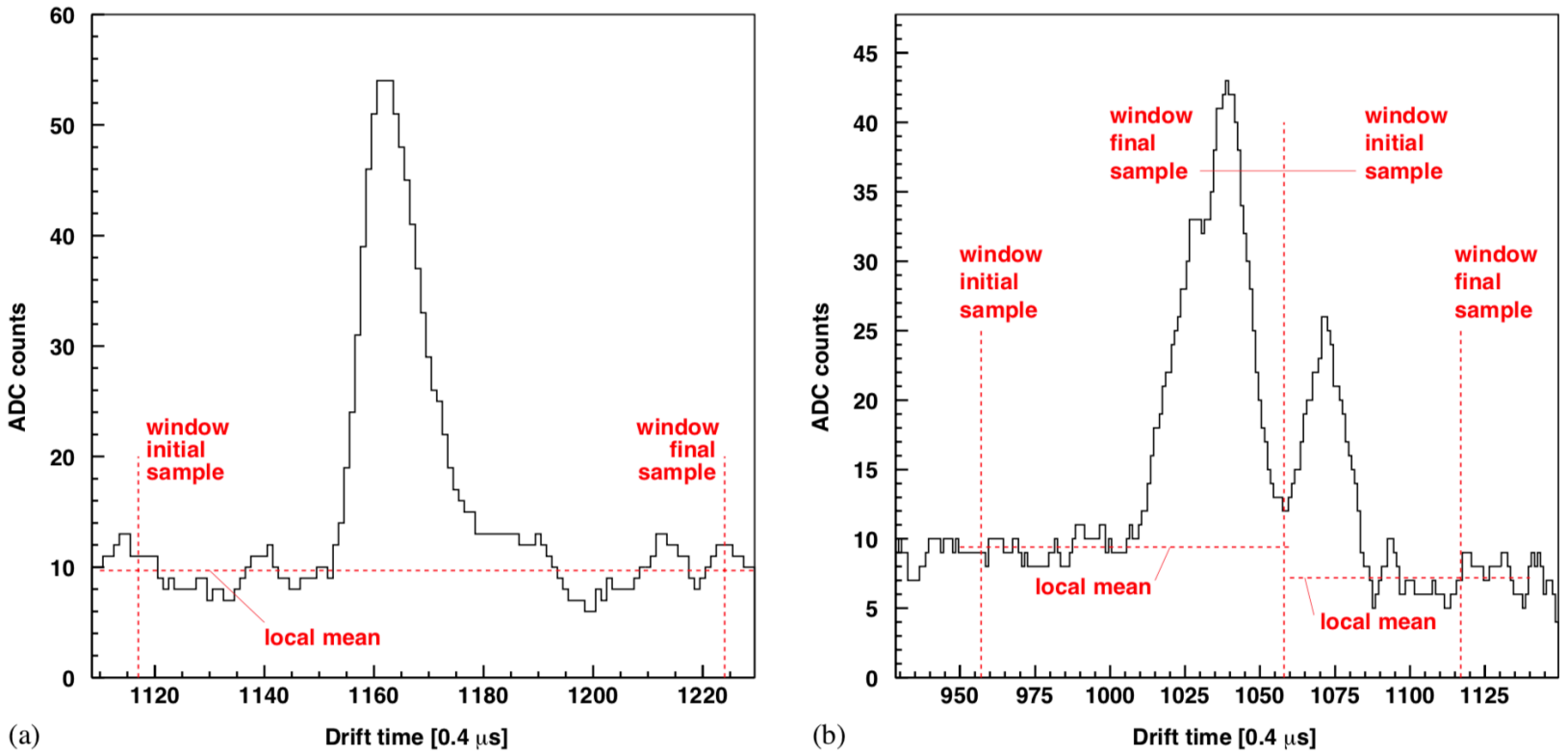


Fig. 70. Examples of computed local mean and hit windows for an isolated hit (left) and two close hits (right).

from the offline reconstruction section

GArSoft's Raw Waveform Zero-Suppression Algorithm

- Absolute positive ADC threshold applied. If an ADC value goes above 5, a snippet is sampled.
- Five ticks before the first sample to go over threshold and five ticks after the last over-threshold sample are included in the waveform snippet. "Front" and "Back" porches.
- Overlapping snippets get collected together (unlike ICARUS's offline hit cartoon)
- Thresholds and porches will need to be adjusted when we have noise and gain simulated

GArSoft's Raw Waveform Format

- Flag to indicate zero suppression is on or off
- Flat array of signed (!) integers per channel (one pad=one channel). Front-ends may do pedestal subtraction, or we may want to simulate that. (raw ADC's are unsigned).
- nticks in the total waveform
- number of snippets
- list of start ticks for each snippet
- list of lengths of snippets
- snippet data end to end

- LArPix/GArPix options would change the raw data format to a list of charge reset times.

GArSoft's Zero-Suppression Algorithm

- My implementation of this algorithm was buggy – it sometimes failed to make complete porches.
- Recoded from hard-to-understand state machine to a more conservative set of flags to indicate whether a tick is in a snippet or not.

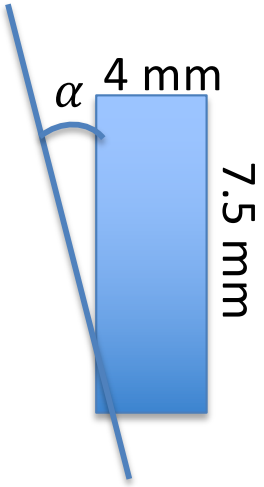
Hit Finder Fixes

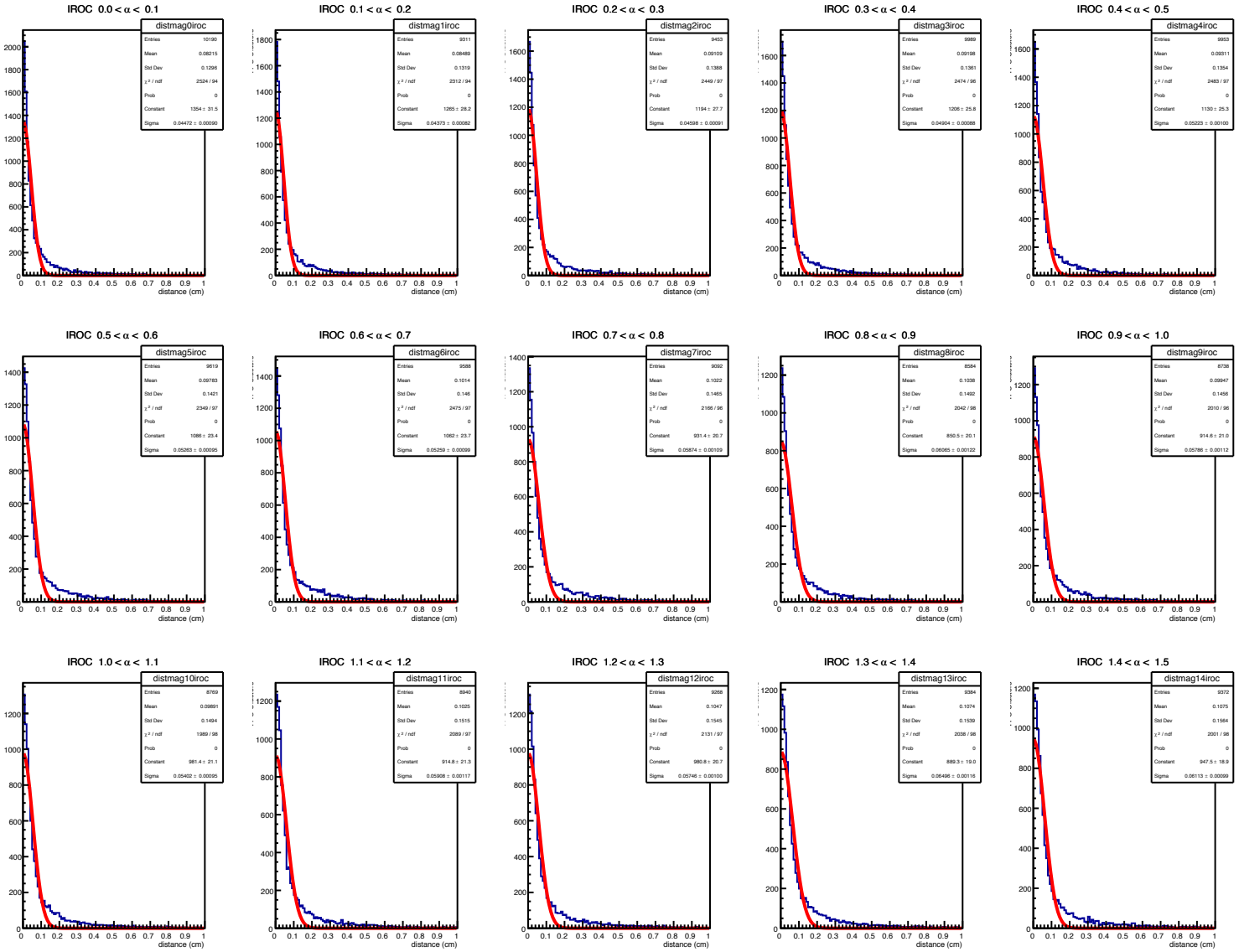
- ZS waveforms divided into hits. Long hits are split.
- Hit-splitting algorithm: If the ADC value falls to half of its peak, and rises up again to 1.3 times the trough, start a new hit at the trough.
- Several fixes after looking at Leo's spreadsheet of waveforms:
  - Last-hit-on-a-waveform-snippet-was-missing bug fixed before physics week
  - Off-by-one bug in begin and end times
  - Wrong peak ADC used if multiple hits on a snippet (just the first was used)
  - Some hits are only one tick long – change RMS parameter to 1/sqrt(12) ticks.
  - Still not perfect – the "Trough" is just where the ADC value falls to 0.5*max

TPC Cluster Finder Fix

- TPC Cluster algorithm finds nearby hits and
  - sums the hit charges
  - finds the charge-weighted centroid position
  - calculates width (along time axis, but need to do this in Y and Z too)
- Bugfix – wrong hit charge was used in the centroid calculation – was always using the first hit's charge, so all hits got weighted equally. Easy to fix.
- Added covariance matrix to give size and rough shape of cluster
- Tuning – how far in X, Y, and Z to go to add hits to a TPC cluster. ALICE just does clustering within a pad row, but this results in inhomogeneity for us.
  - New parameters – look ±1 cm in X and ±2 cm in Y and Z. Was ±0.5 cm and ±1 cm. (didn't include the next pad row in the OOROC).
  - Consequence: fewer TPC Clusters but better-measured ones.

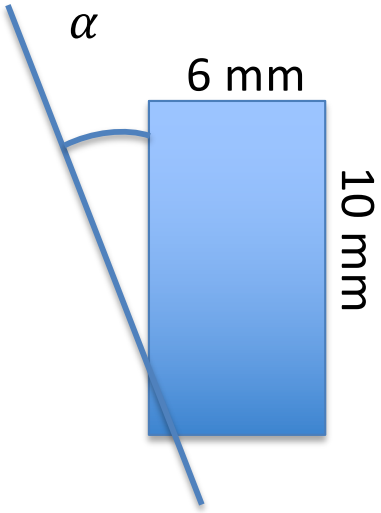
TPC Cluster Residuals: IROC

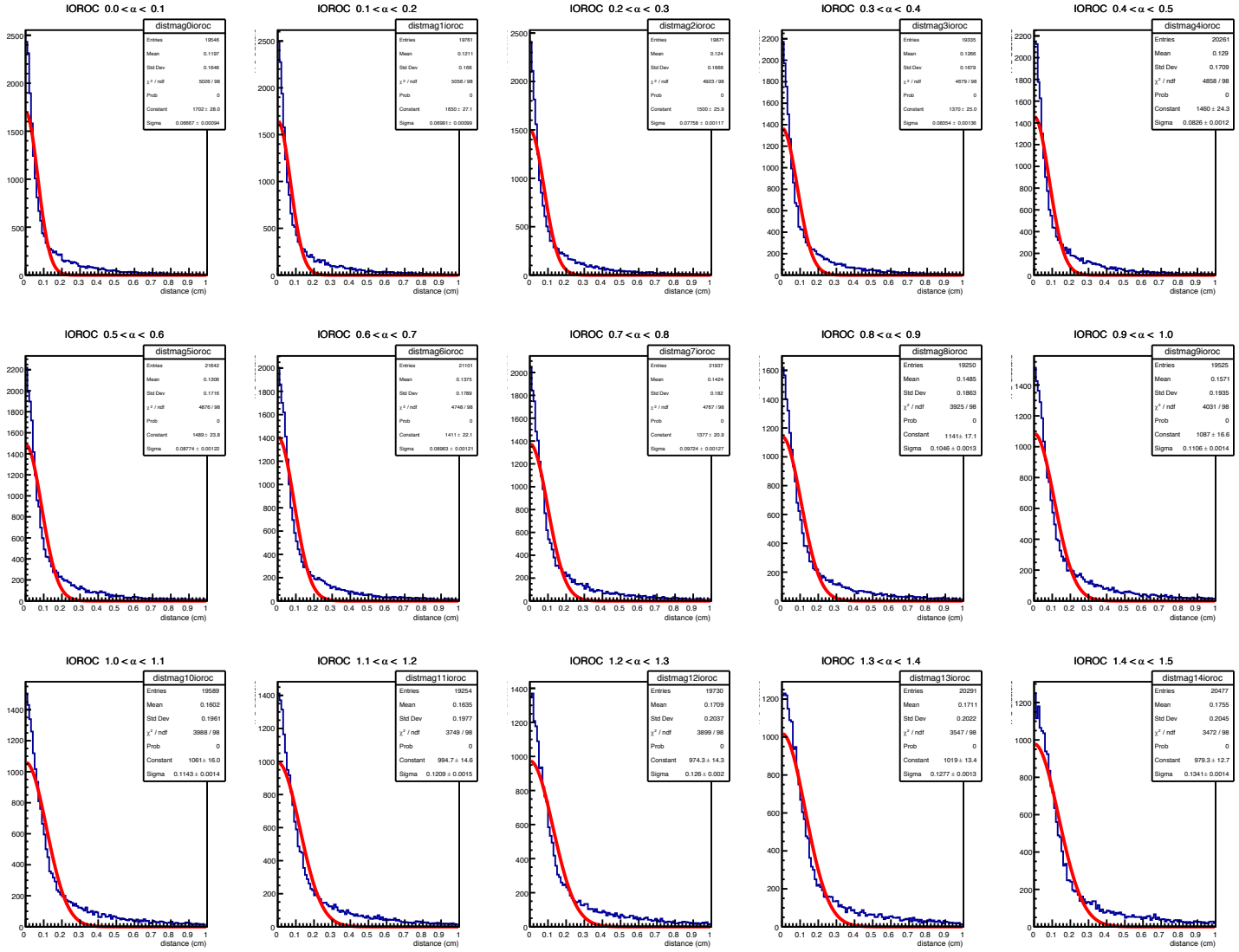




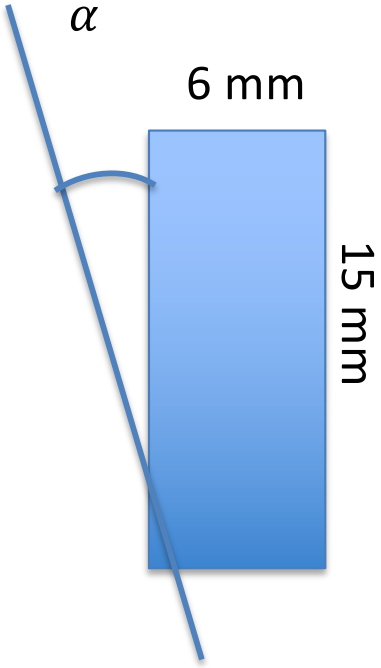
Fermilab DUNE

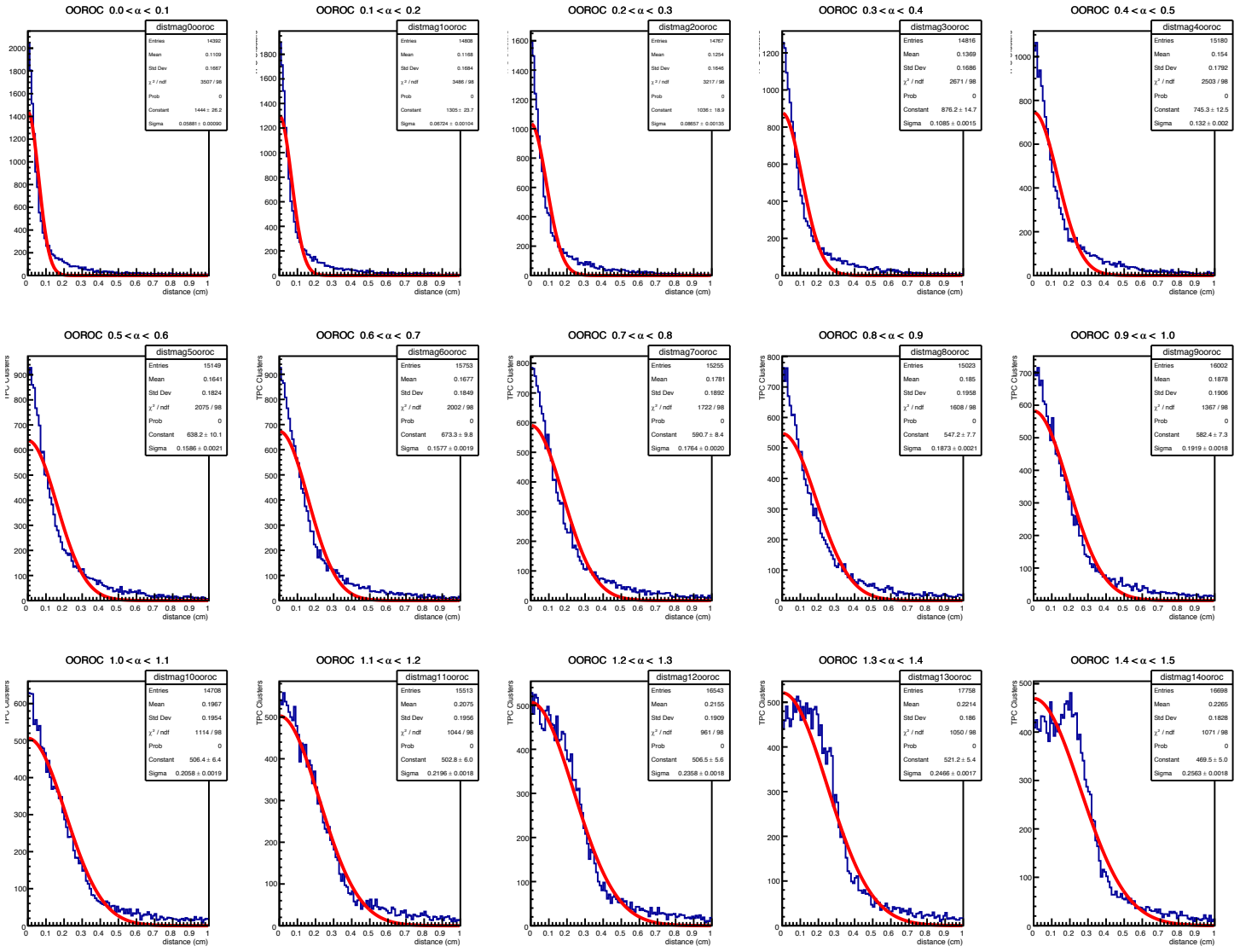
TPC Cluster Residuals: IOROC



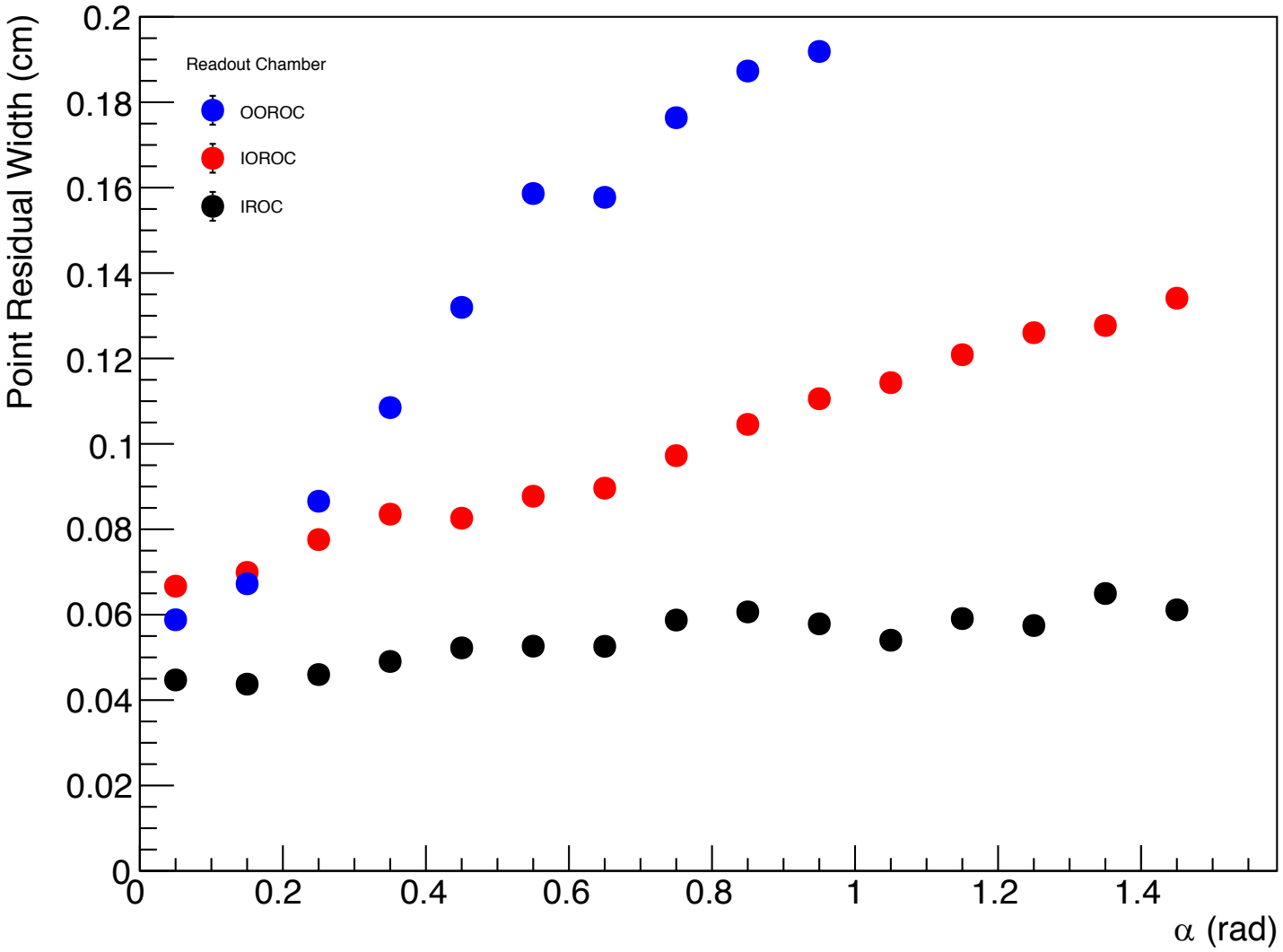


TPC Cluster Residuals OOROC





Residual Widths by ROC



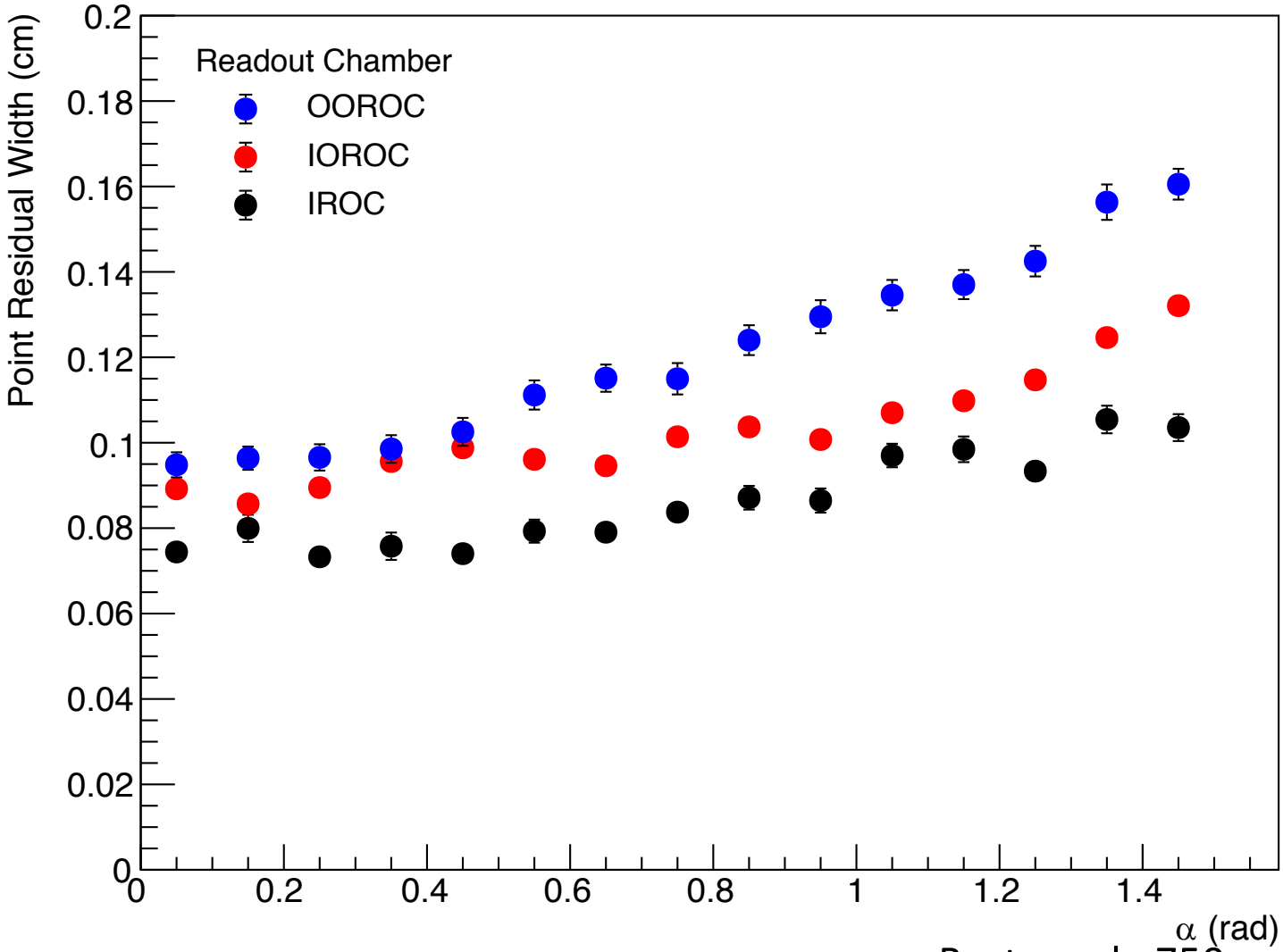
siduals perp
track, not just

ew default
cm Y,Z
uster window

Best resol,
440 µm

Fermilab DUNE

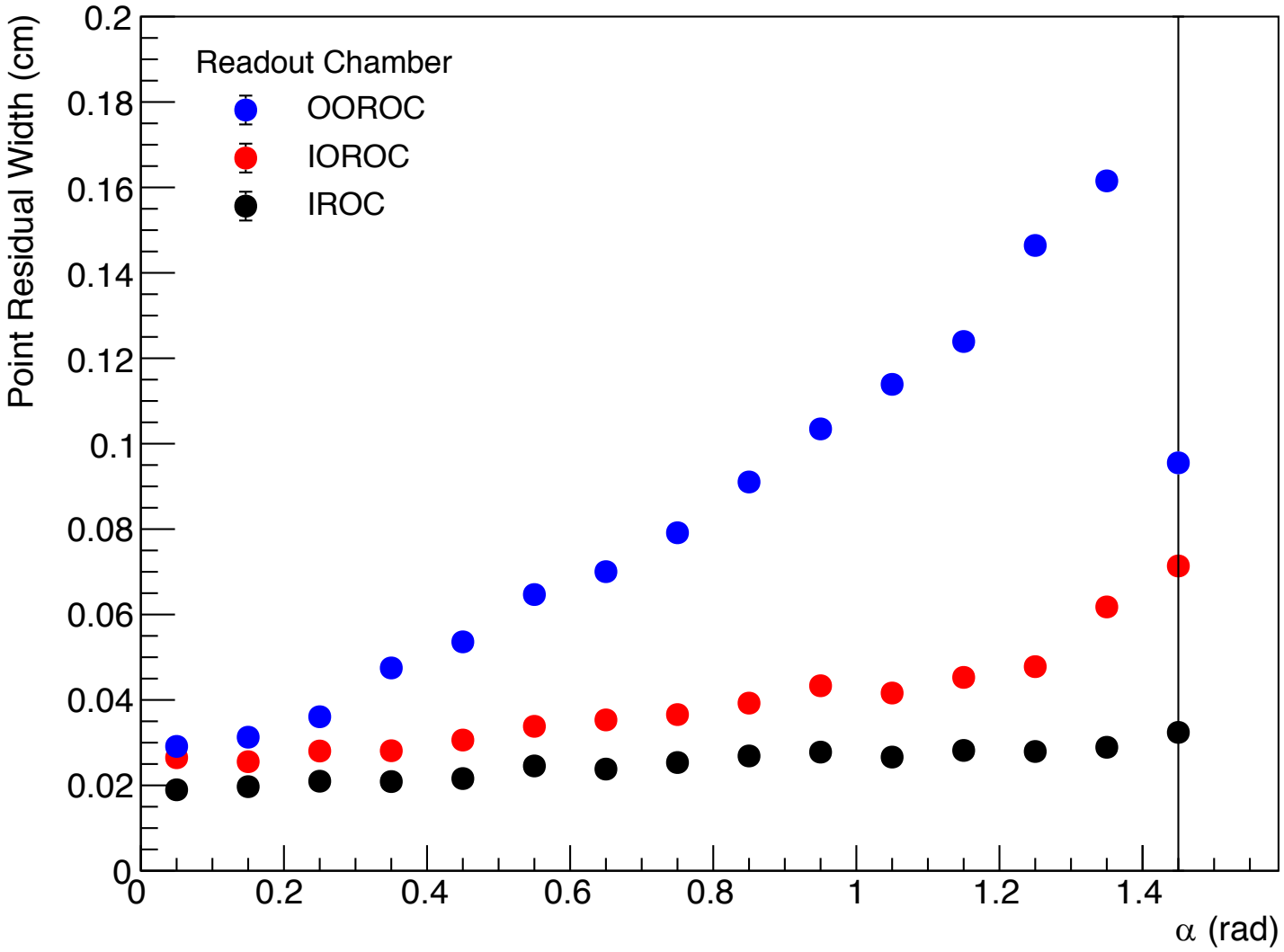
For Comparison CDR Resolutions



N.B. for this plot,
I extended the TPC cluster window to ±4 cm in Y and Z

Best resol: 750 µm. With fixes, 450 µm

New TPC Cluster Resolutions with 4x4 cm Clusters



More apples-to-apples comparison

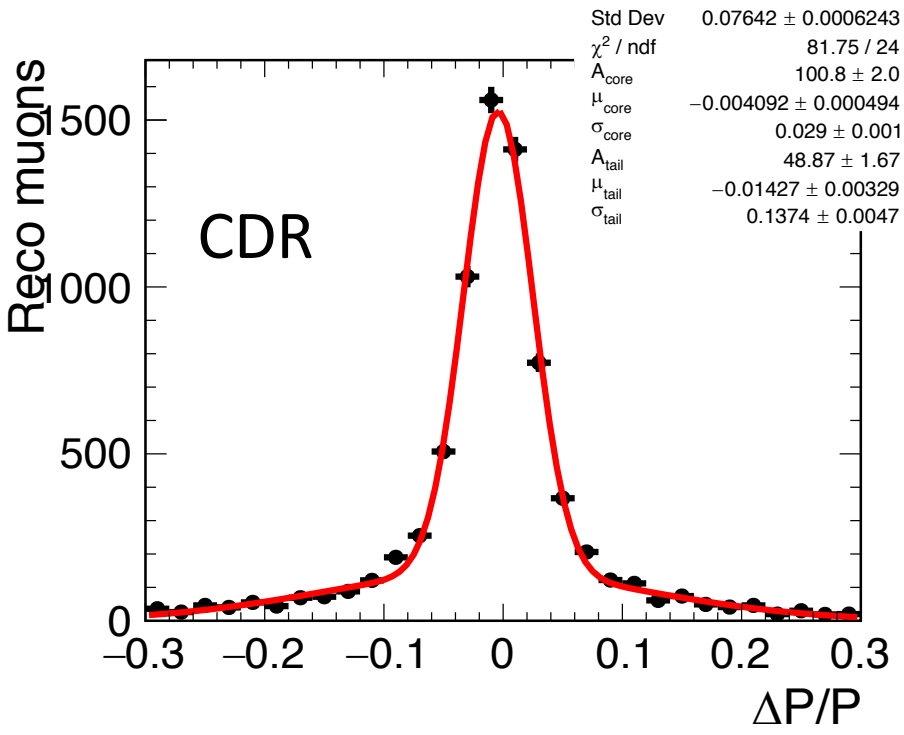
For isolated tracks, we can do well with resolution; ~200 µm

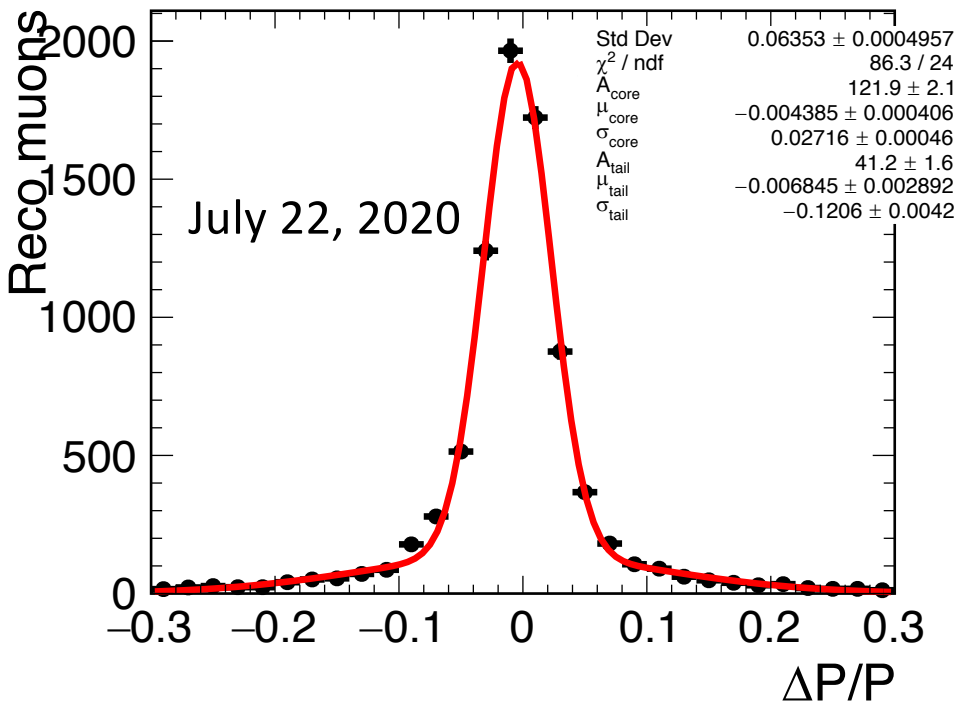
CROC gets ~230 µm

Resolution vs. pattern recognition tradeoff

Muon Momentum Resolution

Beam ν_μCC events

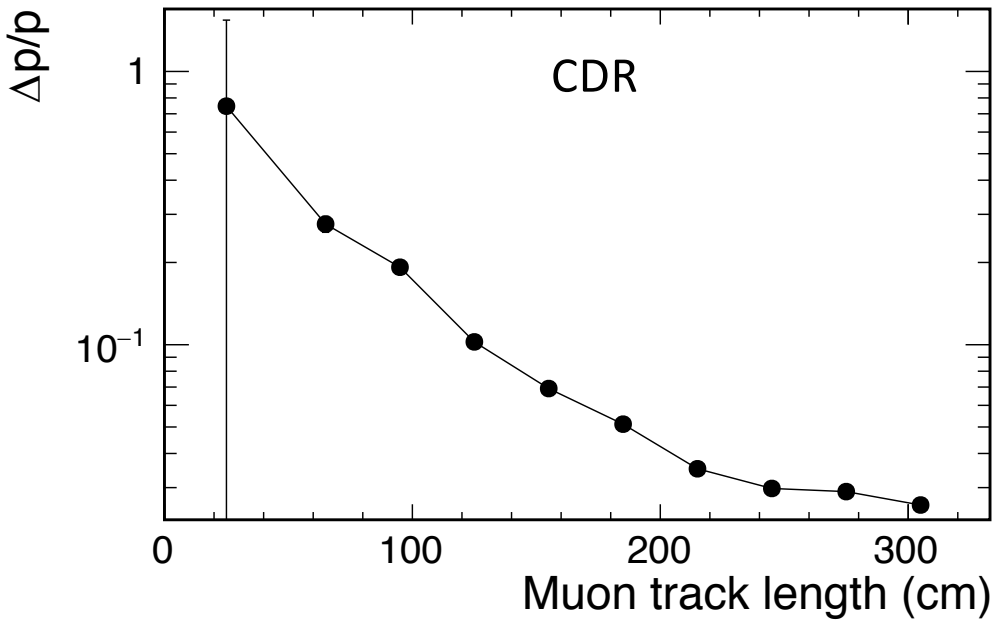


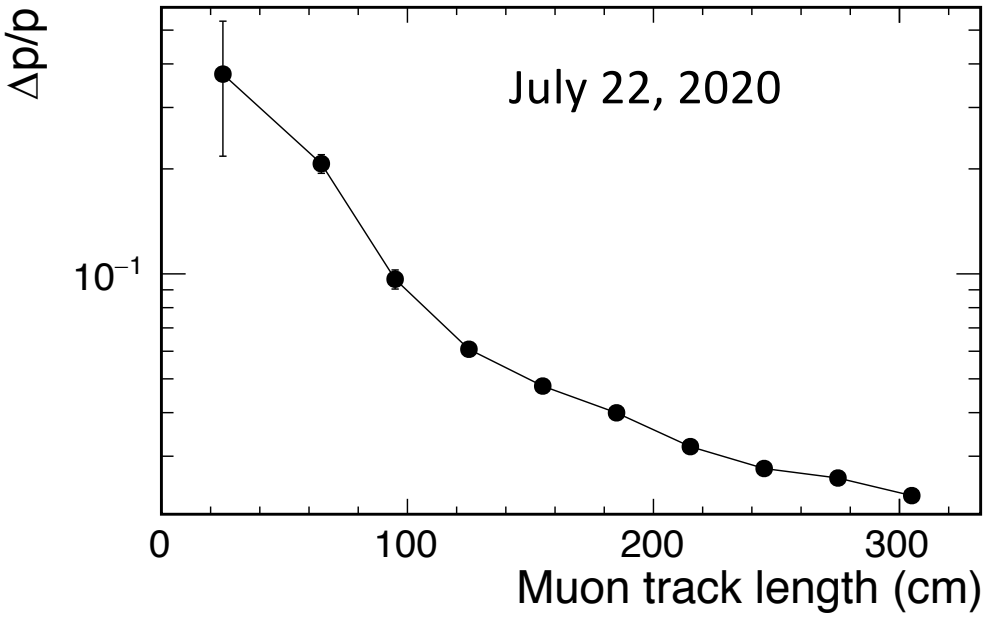


Cheated Patrec:
tracks have all the right
TPC clusters assigned.

Fit to a sum of two Gaussians.
The A parameter is proportional to area
Core width went from 2.9% to 2.7%
Tail fraction went from 33% to 25% of the total.
Tail width went from 13.7% to 12.1%

Momentum Resolution vs. Track Length

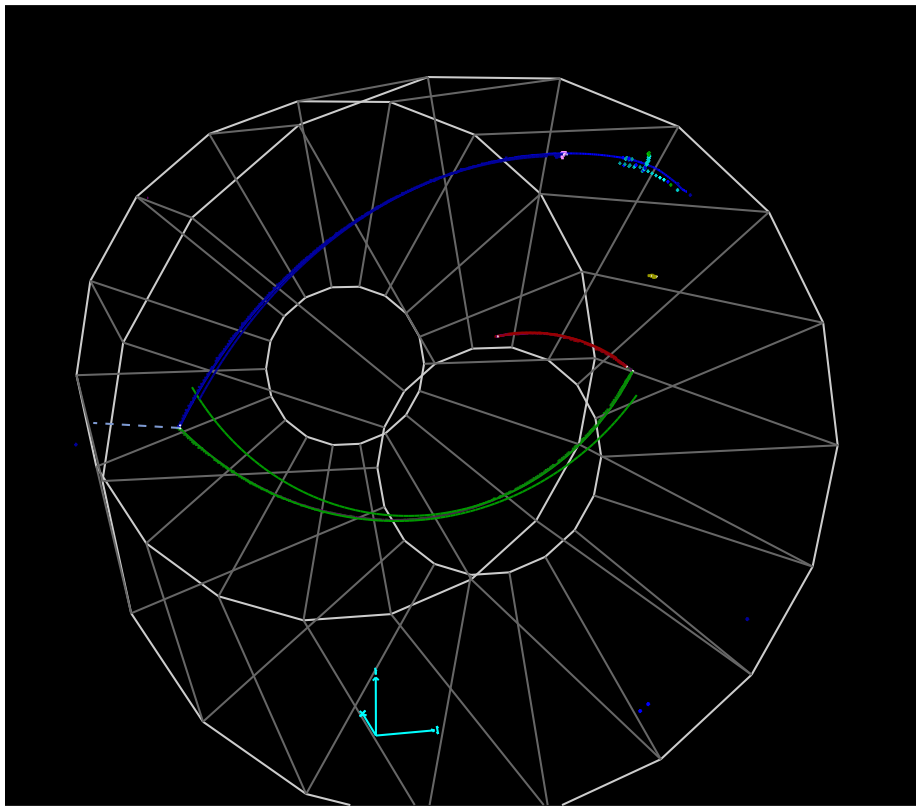


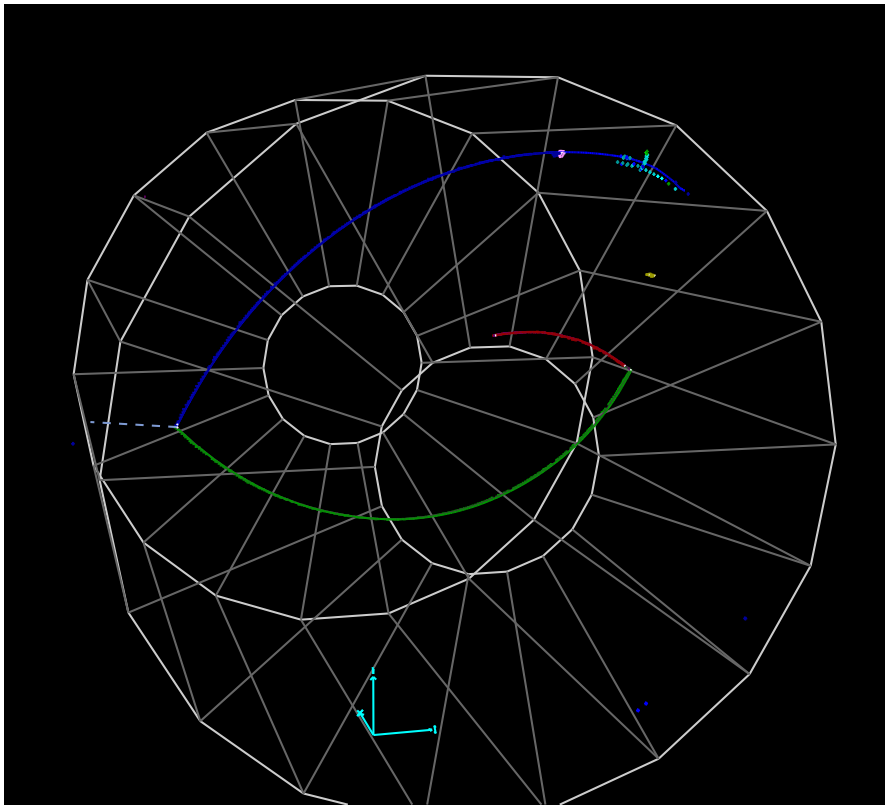


New Data Product: TrackTrajectory

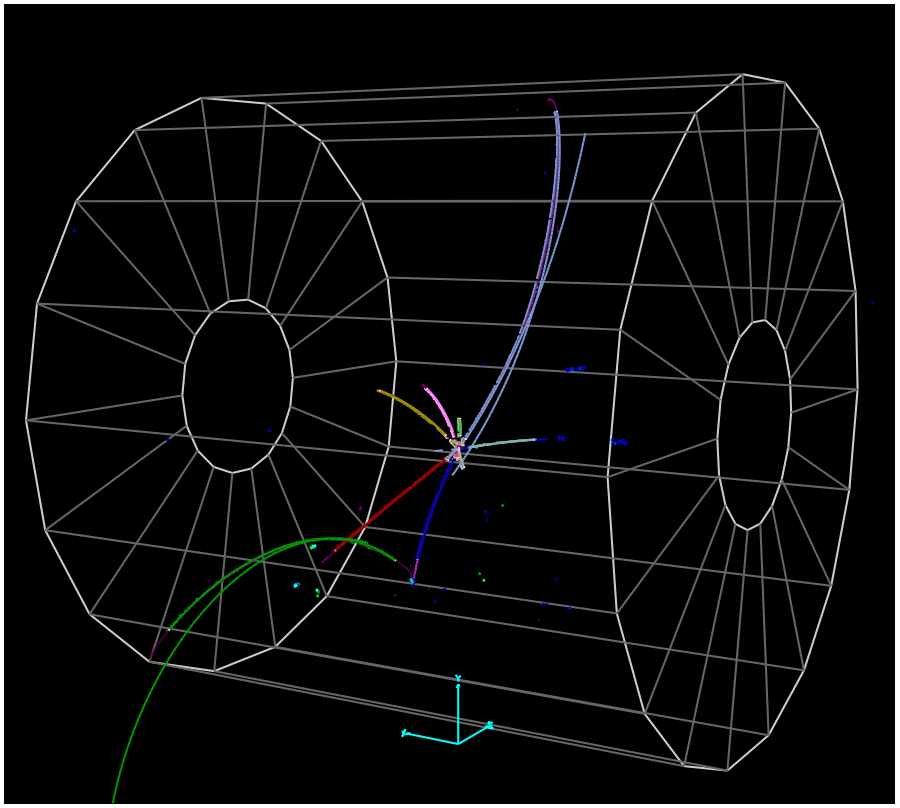
- One item per track.
- Vector of TVector3's (floats).
- Filled by the track fitter on each step of the Kalman filter
- Why we need it: Tracks spiral as they lose energy. Event display drew two helices using track parameters on either end.
- Momentum and direction were different, so these helices didn't match the measured points or each other.
- Needed something in the event display to debug attempts at reconstructing low-energy curlers.
- I tried resurrecting the X-sorting patrec to work on low-energy curlers, but need to work on the hit sorting. Fixed bugs in sim and hit finding may be a good reason to revisit this.

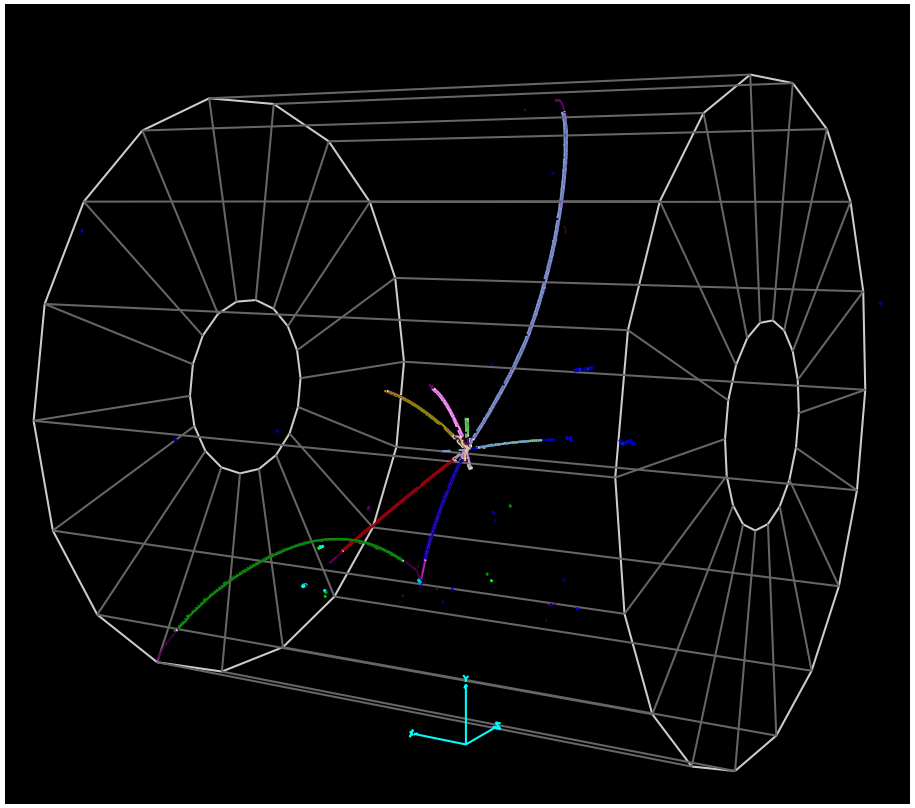
Event Display Drawn with Helices and Trajectories





Another Example





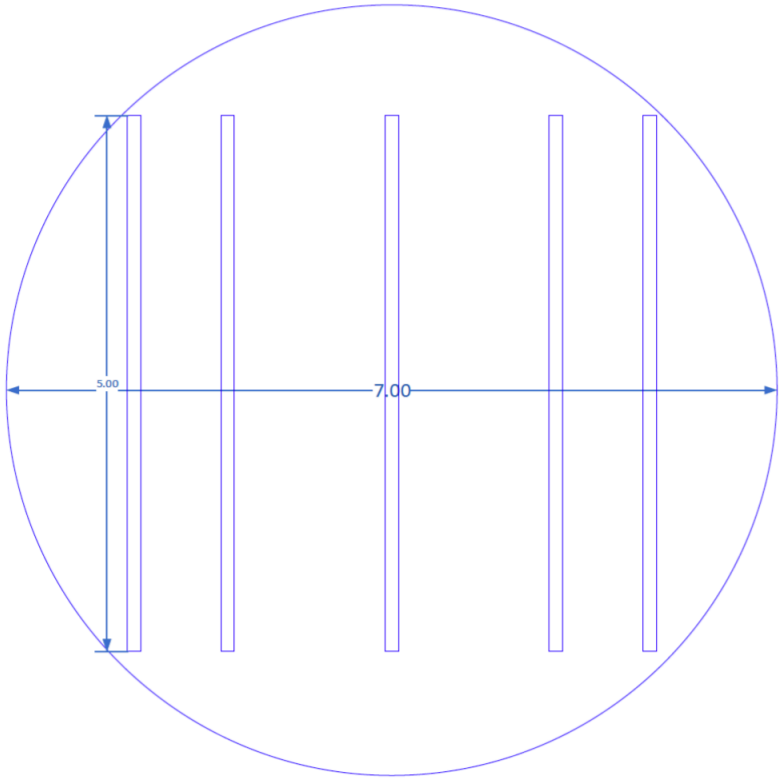
Sometimes the helices would be extrapolated beyond the end of the track

Day-One Tracker Geometry (from Eldwan Brianne)

The detector geometry.

SPY + Minerva-like Sc layers

- The temporary MPD (soon new name) is as the following
  - The magnet as the SPY
    - 10 cm Al solenoid
    - an iron return yoke about 30 cm thick, integrating a muon id system ➠ (3 layers 10 cm iron, 1.67 cm Sc)
    - an open window in front of the LAr
    - 7 m in diameter maximum
  - Inside, 5 scintillator layers (6 m x 5 m) of 4 cm thickness segmented Minerva-like (triangles)
    - ➠ distance between layers is to be optimised for better tracking

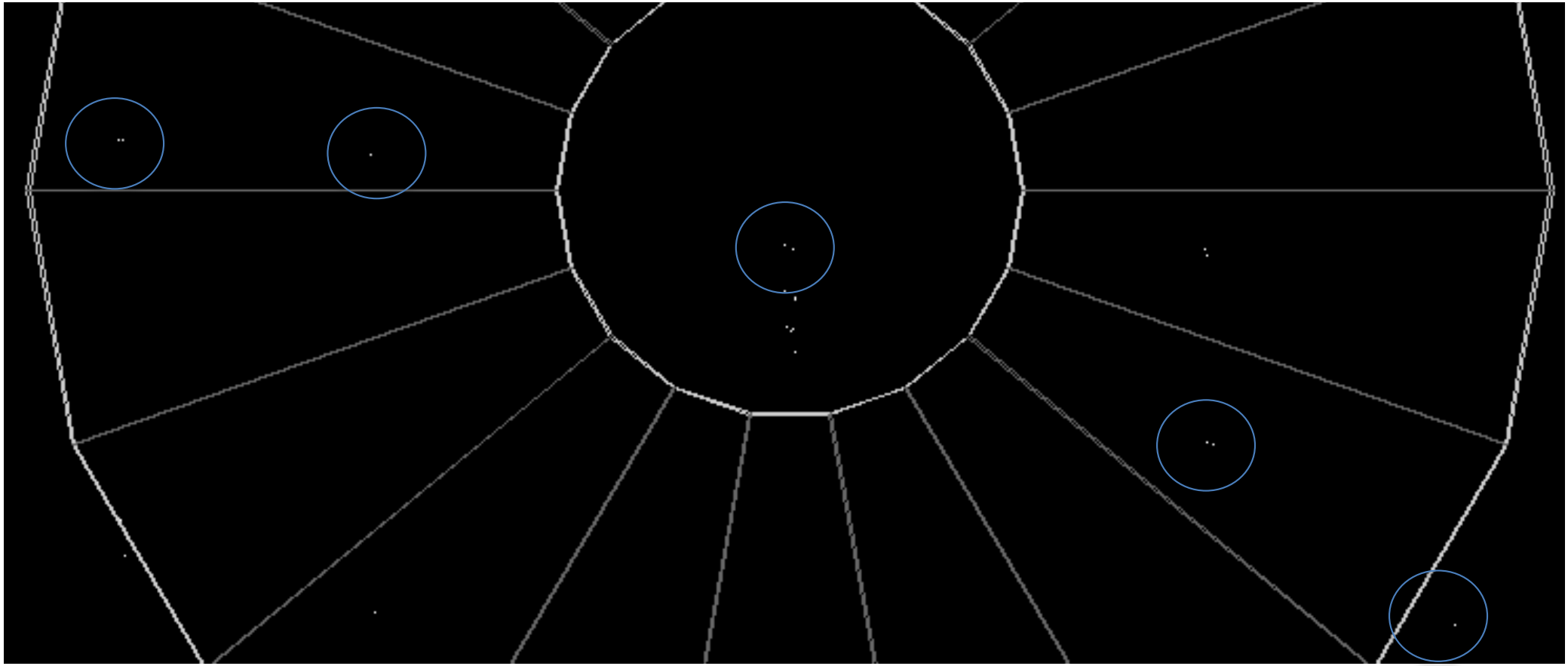


D1T Expedients

- Eldwan produces CaloDeposit data for the scintillator-plane hits
- Matching between the X and Y planes gives 3D CaloDeposit measurements
- Convert these directly to TPCClusters
- Vector Hit pattern recognition won't work with these
- Wrote a quick and dirty circle test – look for triplets of hits, each on a different plane, and find the circle with the most candidate hits on a ±5 cm road (may want to tighten this, but there may be scattering)
- Pileup – timing is our friend here – assume no pileup for now.
- Need at least three hits to measure momentum!

A 1 GeV/c Muon in the D1T

end-on view



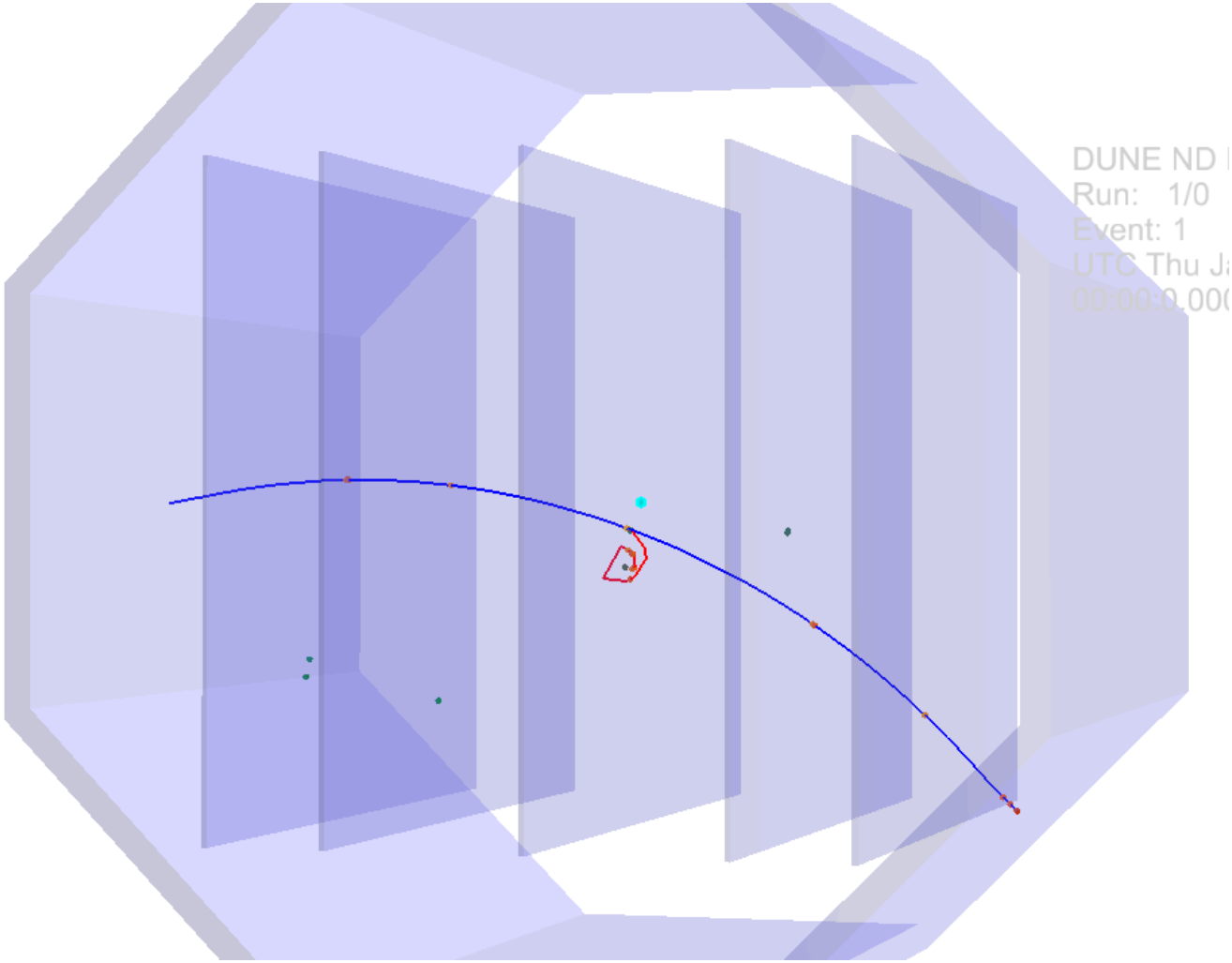
Plus some extras not directly on the track

Eldwans' EVD of this event

Hits associated with the same track will arrive at similar times

Sub-ns timing may help with TOF

Hit charge as a discriminant? Not yet used.



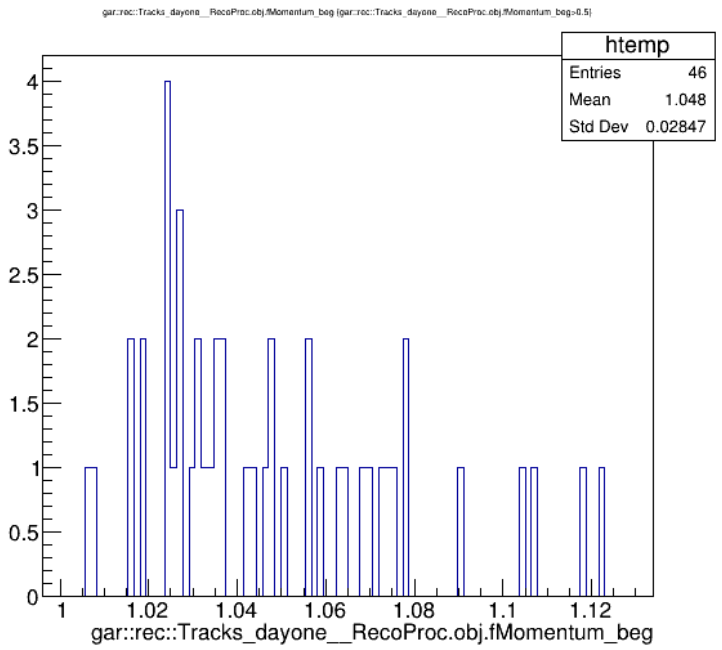
Delta ray plus additional hits (bremsstrahlung+Compton or other processes)

Fifty 1 GeV Muons from Eldwan

- I asked Eldwan to simulate 50 1 GeV muons – he randomized them in a 20 degree cone.
- Converter, event display and initial patrec work. Fitter needs some work though.
- Patrec produces a track candidate with three hits and a dip angle – momentum.

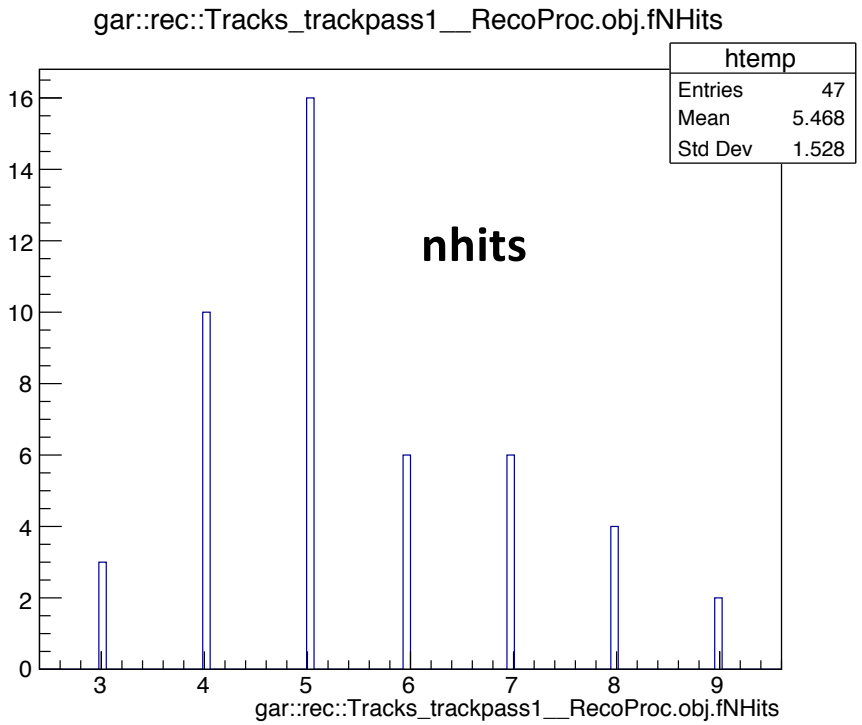
A little biased. One additional track was reconstructed at 200 MeV. Efficiency only 92% for now.
Core of distribution is nice and sharp however.

Could be the road is too wide.

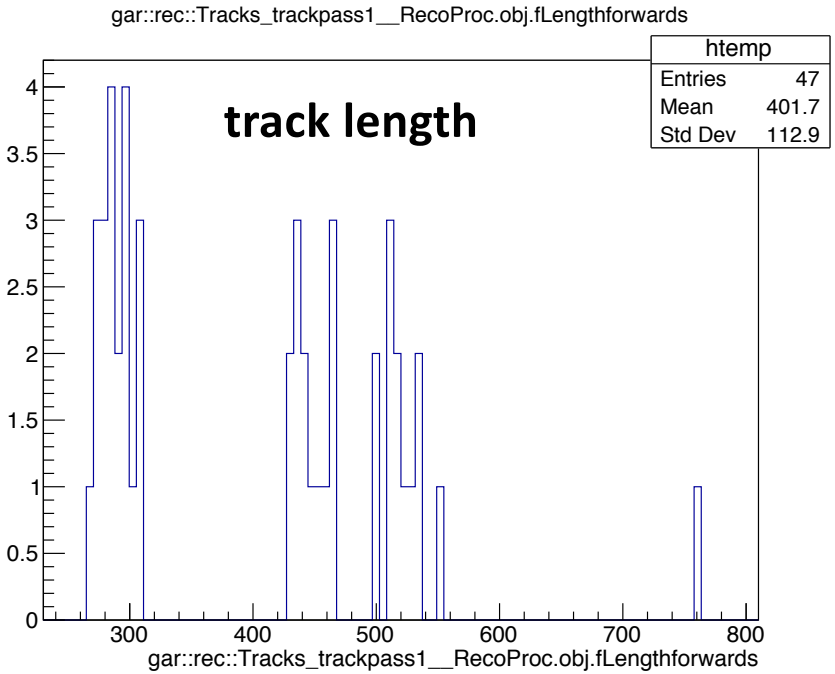


Momentum from just the triplet circle solutions

nhits and track length– 10 per track for a muon crossing all planes



Many tracks in the sample bent away and did not hit the last few planes

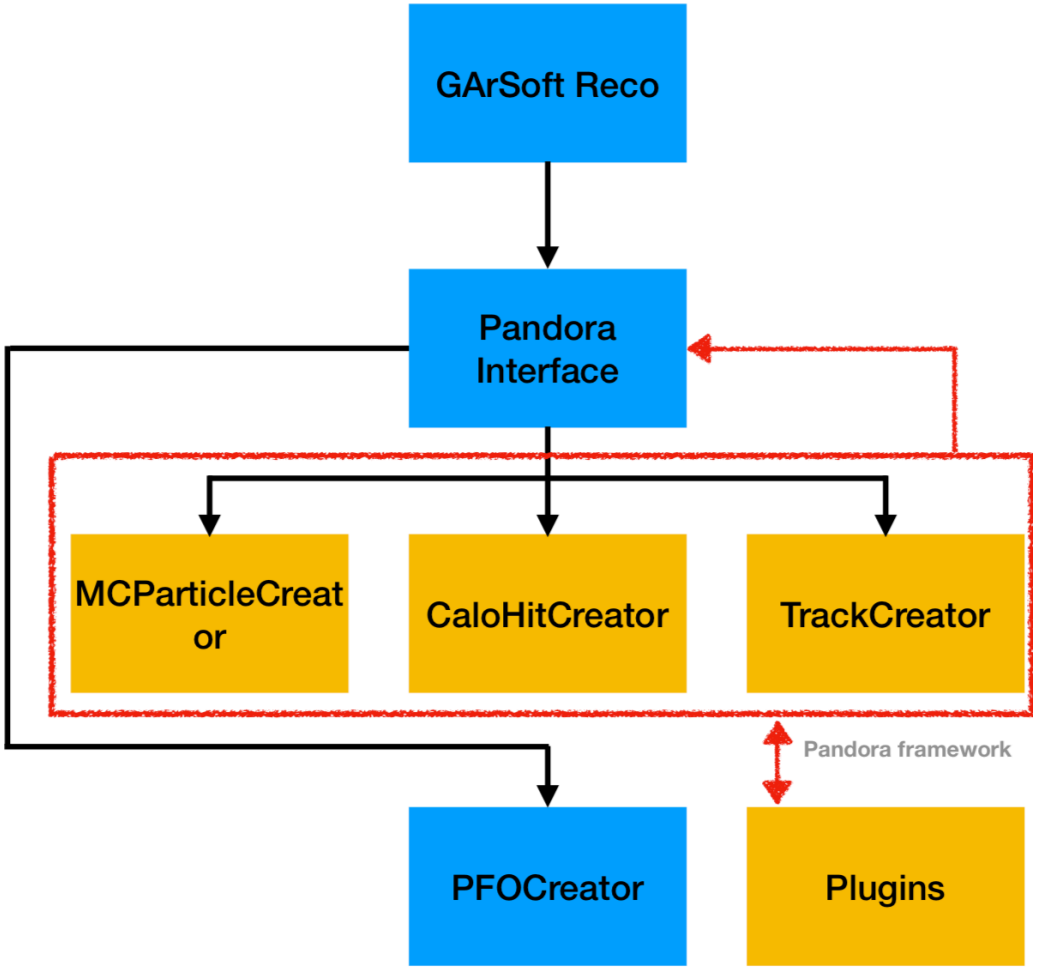


Pandora Integration – Eldwan Brianne

The actual implementation.

A mix between LC and LAr code

- Very similar to ILC implementation for the interface
  - Plugins
    - BField: Get GArSoft BField service and pass BField the value to Pandora
    - PseudoLayer: Similar to layer but avoid “hard” breaks between detector modules
  - Translators
    - MCParticleCreator: Translates art MCTruth and MCParticle into Pandora MC objects
    - CaloHitCreator: Translates art CaloHits (for now ECAL) into Pandora hits
    - TrackCreator: Translates art Tracks (from TPC) into Pandora tracks (very simple implementation for now)
    - PFOCreator: Translates Pandora Clusters/PFOs into art Clusters and PFParticles (output)



Slide from https://indico.fnal.gov/event/44499/contributions/191847/attachments/131632/161243/ND_GAr_20.07.20.pdf

We requested Pandora LC Content to be added to the larsoft pandora UPS product and are upgrading GArSoft to use it.

Extras

Working on a Fitter for the D1T

- The existing fitter didn't work out of the box
  - Independent variable was X and it needs to be Z
  - More importantly, the track step update was linearized for the short steps in the TPC fit. Big steps require a helix extrapolation. May be useful to do this for the short steps too.
  - Need to pick the right ambiguity – a helix crosses a plane multiple times.
- Work on the patrec and fitter illustrates some challenges associated with the day one design.
  - Need to swim particles through a nonuniform field without measurements to see where they land on the next plane – lack in situ test of field nonuniformity
  - Particles may miss planes, angle or if they have low momentum – possibly lower the field? Multiple scattering is not as much of an issue as with the HP gas. We are no longer as interested in neutrino scatters in the tracking volume.