GArSoft Tracking Update

Tom Junk

DUNE ND Meeting

January 9, 2019

Updates Since Last Time

- Pattern recognition upgrade:

  - Very old – step in X, assign hits to tracks based on their (Y,Z) locations compared with the last hit on growing tracks.

  - Problem: Tracks near isochrony are not recognized well. Split into many little pieces. Even forming linear extrapolations near the growing ends of tracks didn't help here.

  - Now: Seek short track segments approximated by line segments

    - "Vector Hits", not a data product yet but we may need to display them to spot problems.

    - VH "position" is in the center of the VH.

    - 20 cm length cap on vector hit length (c.f. 4.5 – 7mm pad sizes).

    - Vector hits are chained together to form tracks.

Vector Hits

- These are just short clusters of hits that lie close to a line segment in 3D

- Finding them is meant to have isotropic efficiency. Not so for sorting hits in x. If a track goes along the (y,z) plane, then diffusion will just randomize hits when sorting by x.

- Match a hit to a vector hit if

  - it is close enough: within 10 cm of the center of existing VH

  - it lies close to the line – just use a cross product to evaluate. 2 cm perpendicular distance cut for now.

- Re-fit vector hit with all hits when a new one is added.

  - closed-form linear fits in (x,y) (y,z) and (x,z) planes. Do each twice, to get dy/dx, dy/dz, dz/dx, dx/dz, dx/dy, dz/dy and intercepts

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Vector hit Position and Direction

- ROOT Tutorial 3D line fit uses MINUIT, is slow, and sometimes fails.

- Find the coordinate (x, y, or z) so that the sum of the absolute values of the slopes (e.g. |dy/dx| + |dz/dx|) is smallest, and use those fits for the direction. Use the average position in that coordinate and the slopes to get the middle position of the vector hit.

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Vector Hit Matching

- Now that hits have been assigned to vector hits, we need to stitch them together to form tracks

- Grow clusters. Add a VH to a cluster of VH's if it matches one of the VH's already in it on all of these criteria

- Cut on

  - minimum distance between a VH and any other in a growing cluster (<60 cm)

  - Angle between the vector hit directions ($abs(cos) > 0.9$)

  - Distance between a VH center and the line of the other VH (<6 cm) (tightened from 10 cm)

  - eta = |(pos2 – pos1) x (dir2 + dir1)| / |dir2+dir1| (<1.6 cm).

    - Improvements since last time: divide by |dir2+dir1| to get a normalized average direction. And also compute with (dir2-dir1) in place of (dir2+dir1) in case one of them is flipped with respect to the other.

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Eta in pictures

- A pair of vector hits (blue) that should match up. They follow a helix (dashed black). The average direction is shown in red
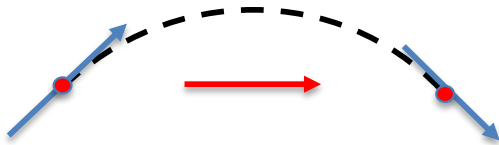
- A pair of vector hits that don't match up. The average direction is shown in red.

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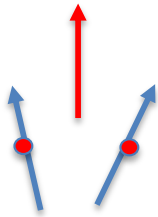
More pattern recognition updates

- If a vector hit is associated with two others, then attach the two groups together.

Jan 9, 2019   Tom Junk I GArSoft Update
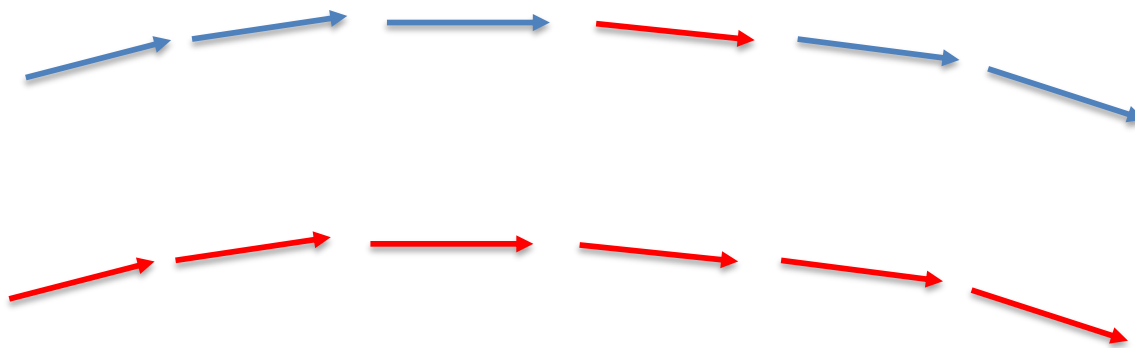
Hit Sorting for the Kalman fitter

- Initially hits were just sorted in *x*, which is parallel to E and B.

- Isochronous tracks got random sort orders, even if the hits were grouped into tracks properly.

- Want to sort hits "along a track" so they can be presented to the Kalman fitter.

- Kirsty Duffy suggested taking extreme points in X, Y, and Z (six in total) and endpoint candidates. Then find the summed distance of an endpoint candidate to all other hits and call the one with the largest sum the "endpoint".

- Initial sort was to "walk" along the track, finding the closest unsorted hit in 3D to the last one added, and add it. But that has a problem (next page)

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Naive Walking Sort Problem

Starting endpoint
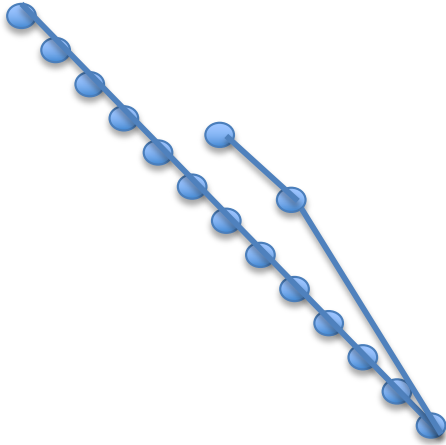
Walking sort will follow along a track and miss points on the side if there are closer ones.

It will then go back and pick them up because they are the closest.

Could put in a max distance cut to eliminate this problem.

Instead I sorted based only on distance from the endpoint hit. This works fine for long, gently curving tracks, but will fail for curlers.

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Removing Outer Hits

Field cage extends beyond the readout planes.

Charge drifting at larger radii than readout is simulated to land on the outer row of pads. (is this right?)

Ends up distorting track ends ("feet"). Solution – just cut them out.
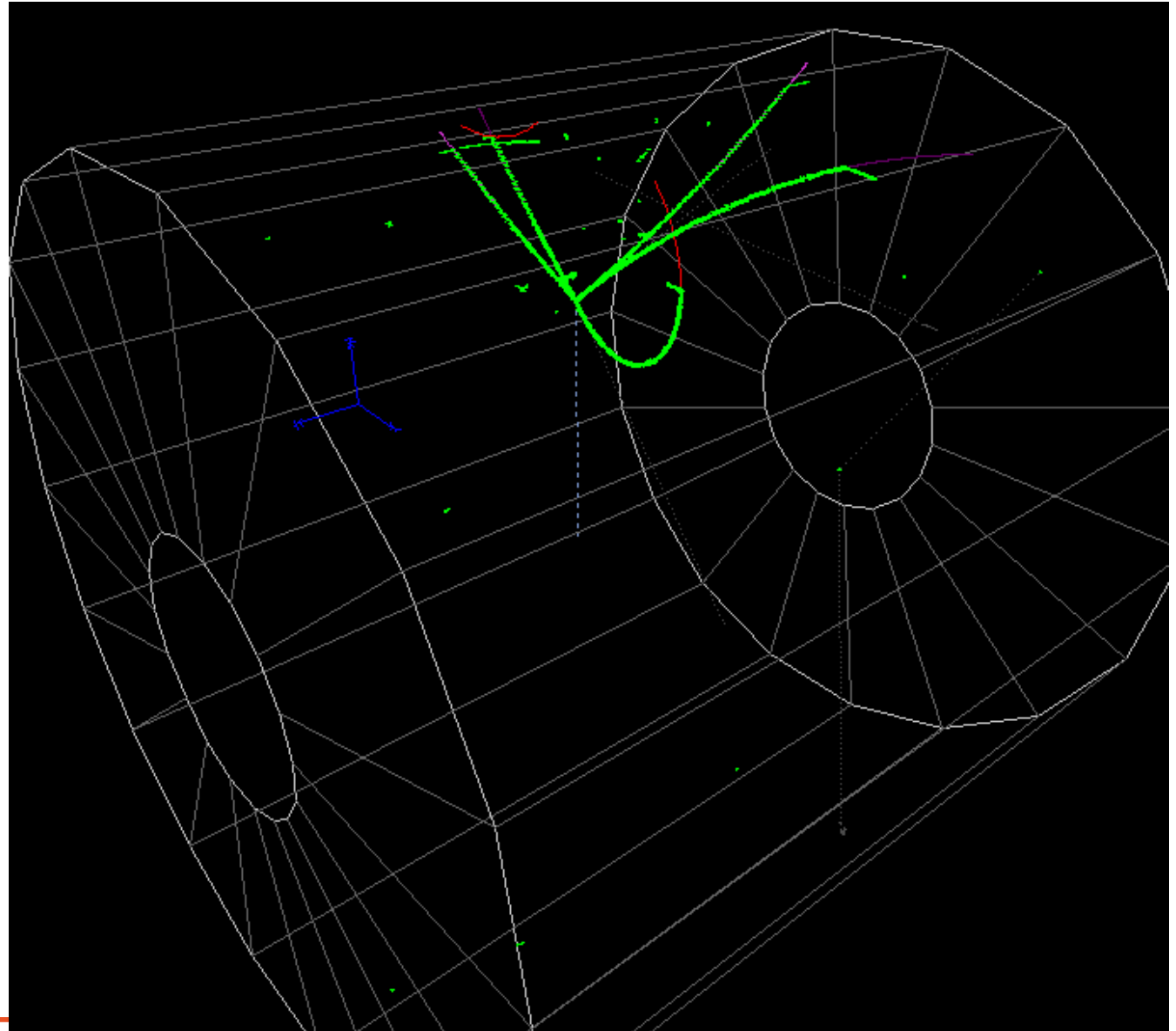
Fitter Updates

- Slope variable: $s = \mathrm{sqrt}(dy^2+dz^2)/dx$ diverges for isochronous tracks

- Replace functionality with lambda = ACot(s).
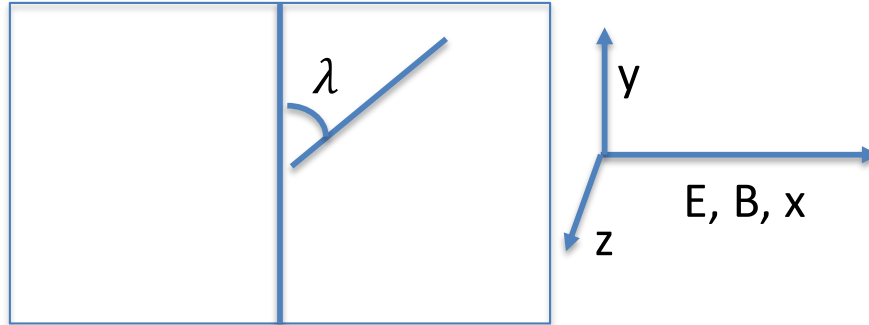
- lambda = 0 for tracks perpendicular to the fields, $\pm\pi/2$ for tracks parallel to the fields.

- Updates to: fitter, track parameter accessor methods, and event display.

- Event display still draws helices between x_{min} and x_{max}, so some tracks get extrapolated rather far by the event display.

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Old Tracking Performance for muons in numuCC events

Late November,
Vector Hits, but
no post-VH association
hit sorting.
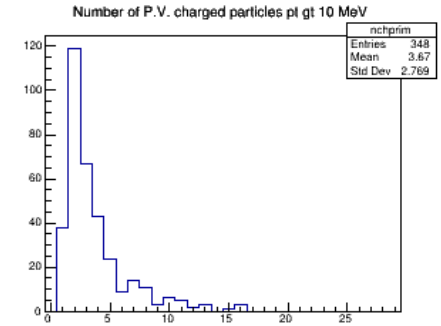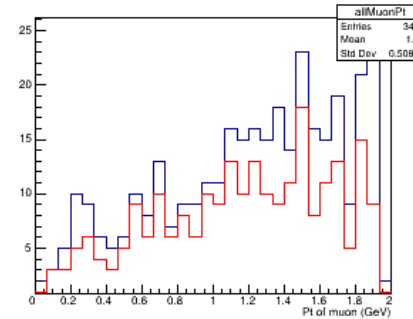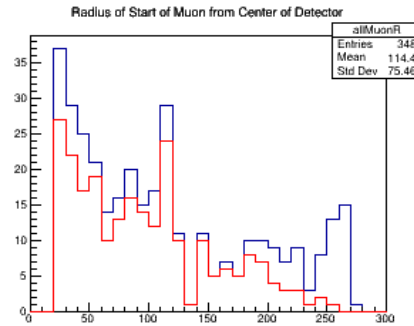
Still a hole in the
tracking efficiency
perpendicular to the
fields
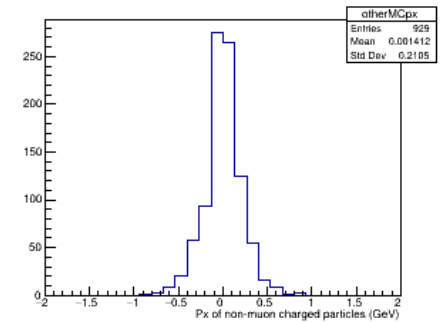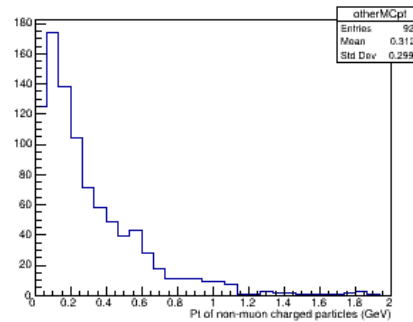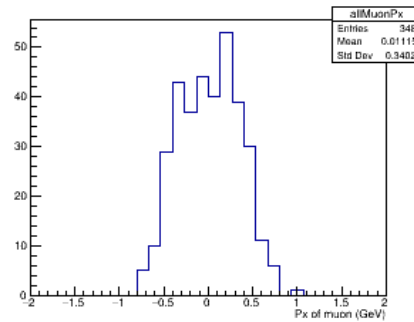
Single isochronous
particles found to
be poorly reconstructed
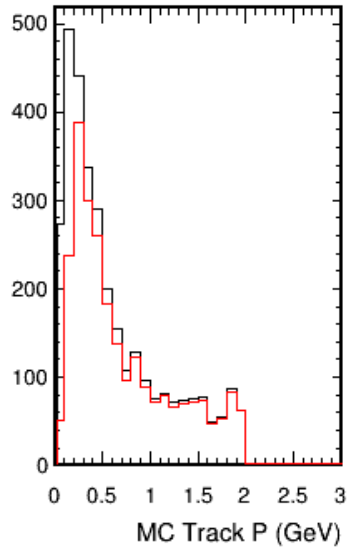by looking at event
display
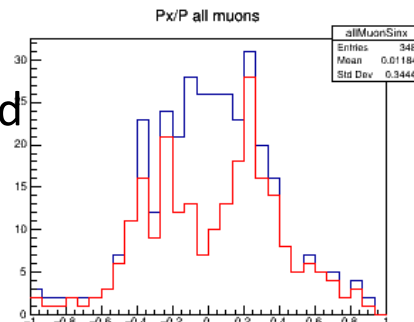
Current Tracking Performance: Muons

Performance
for muons
in numuCC
events
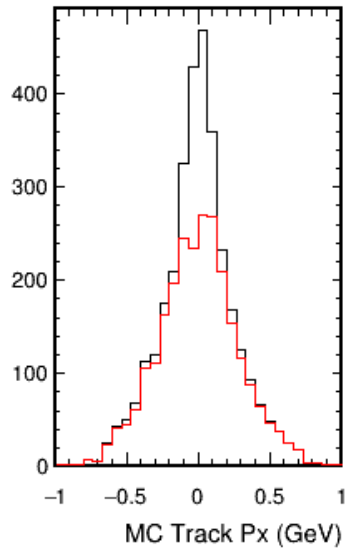(Enu = 2 GeV)

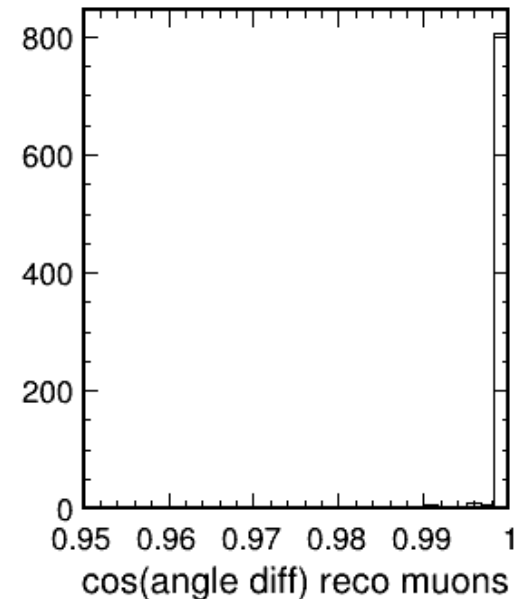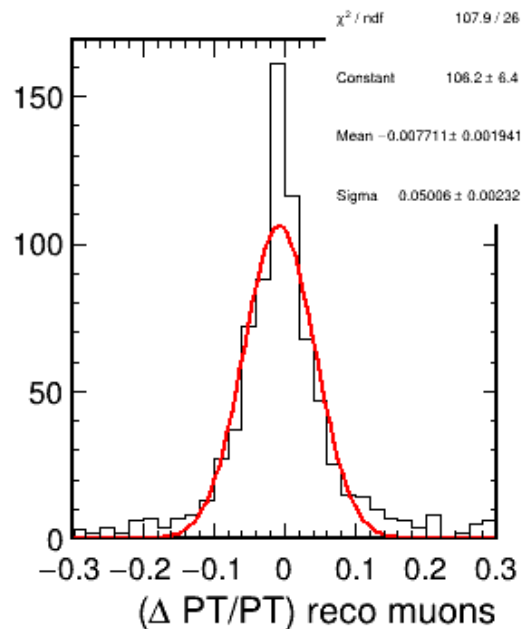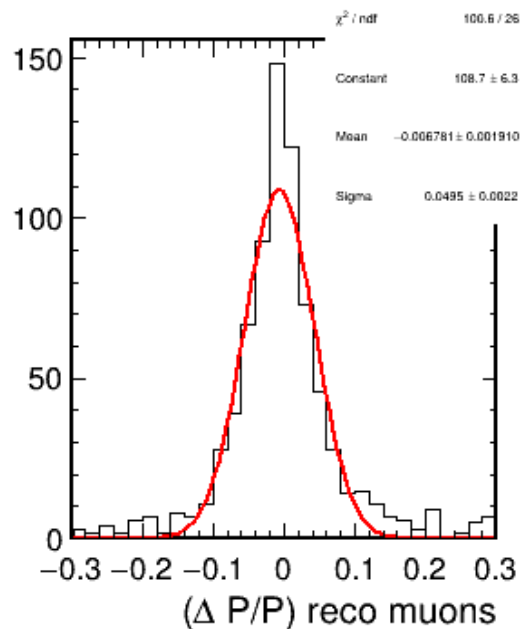I also cut out
vertices within
50 cm of the
wall.
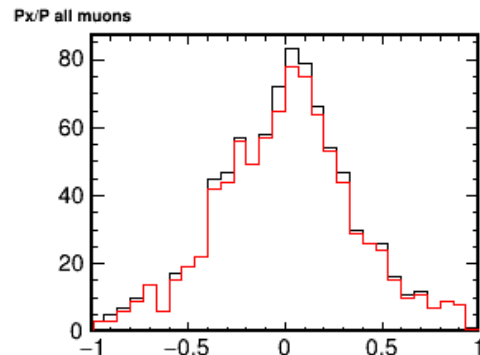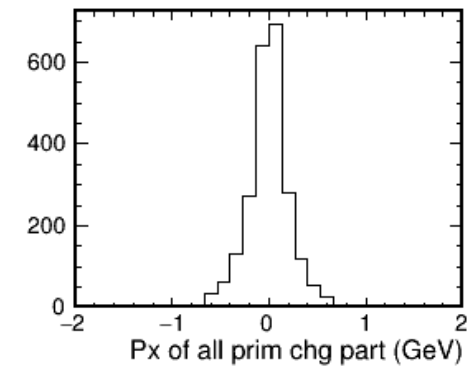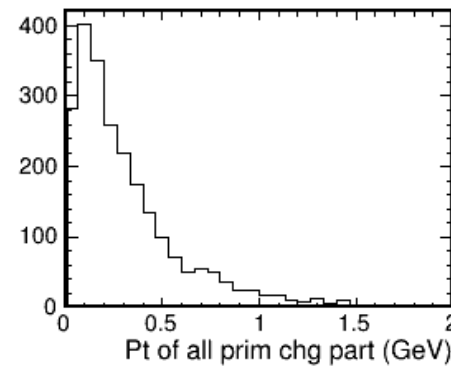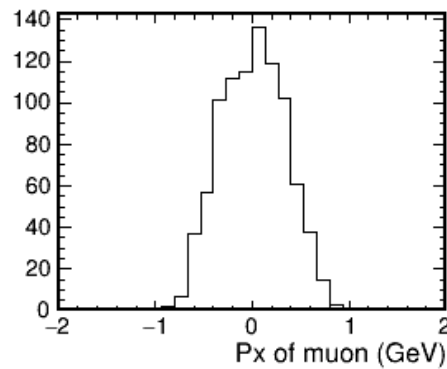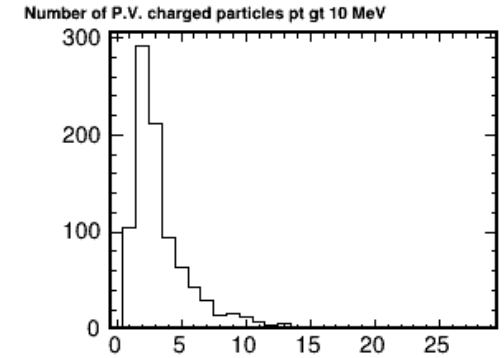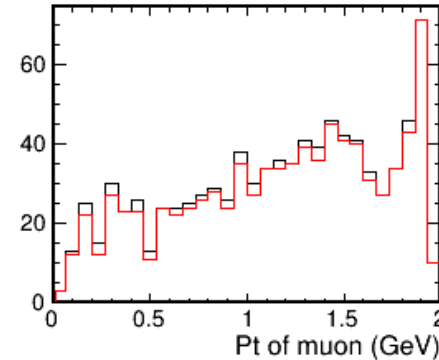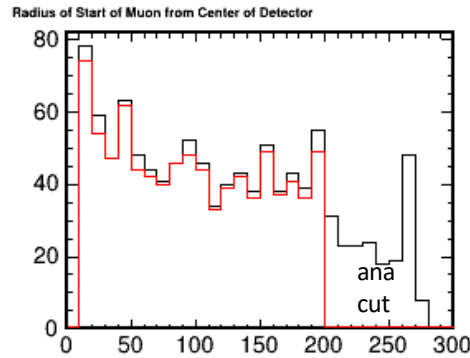
Lower efficiency at lower momentum ~90% efficiency down to 200 MeV however!
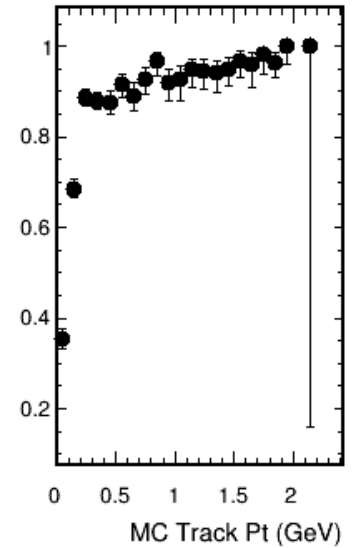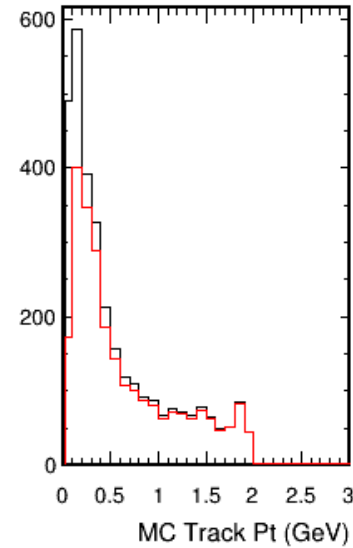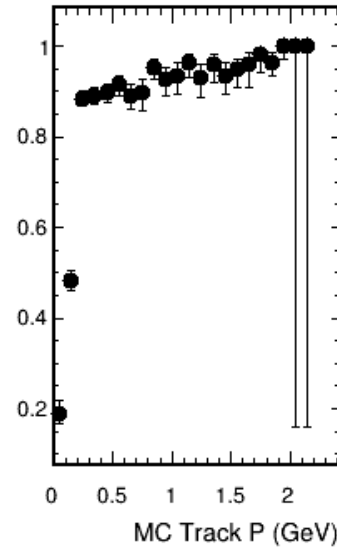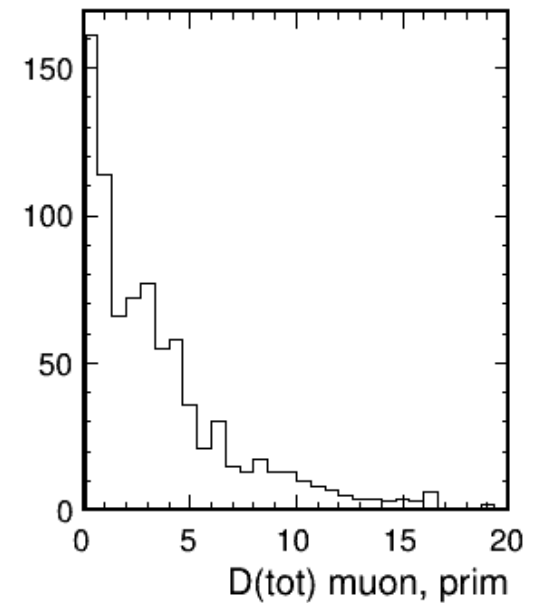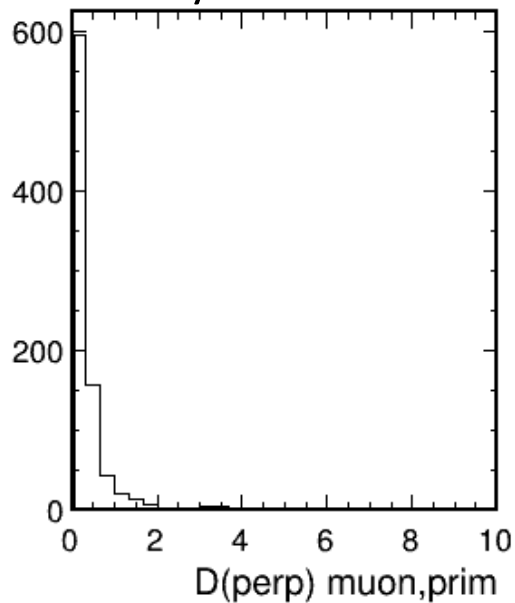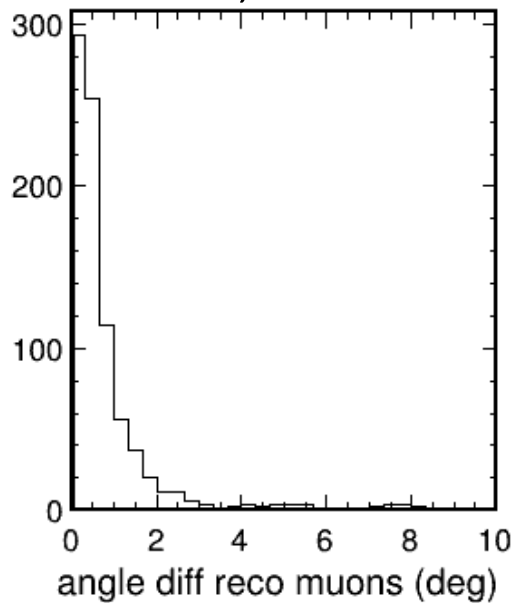
Generally low-momentum protons – need to work on these!
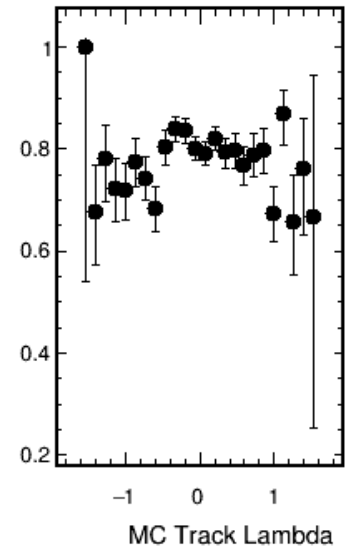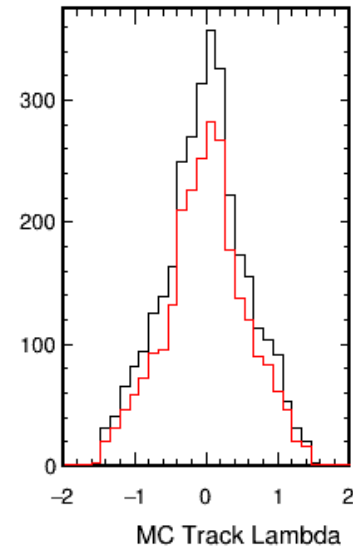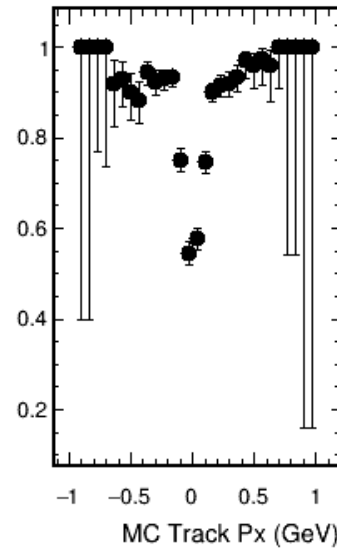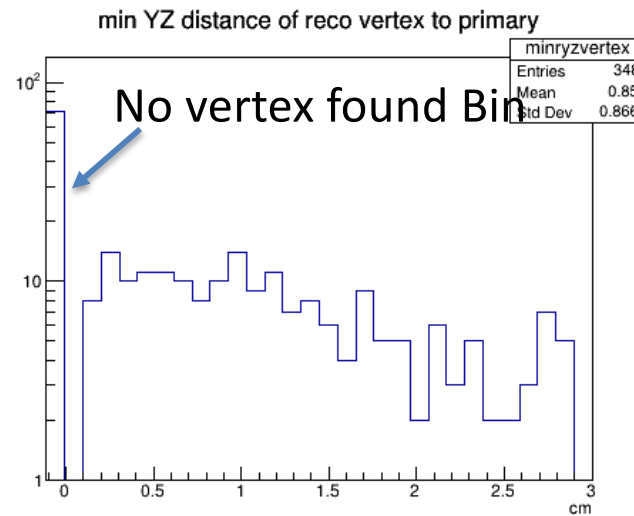
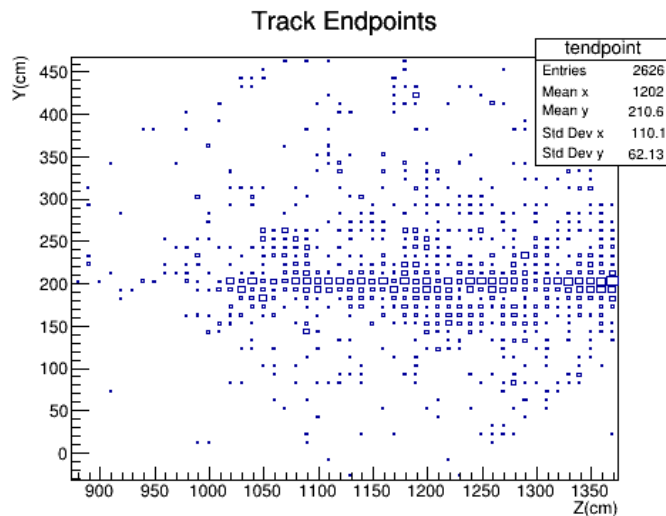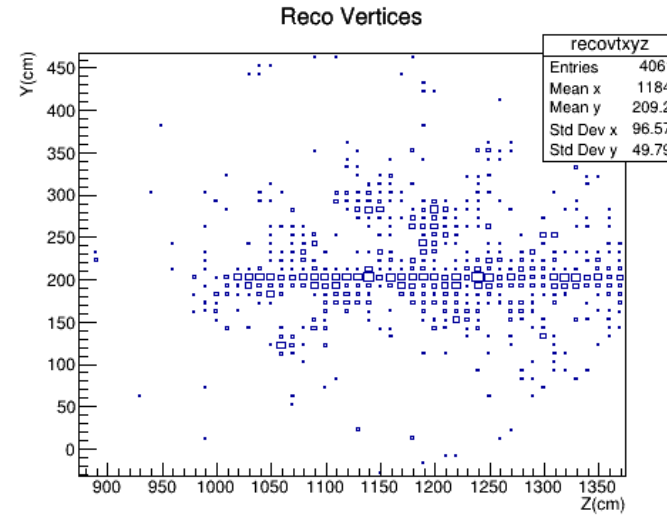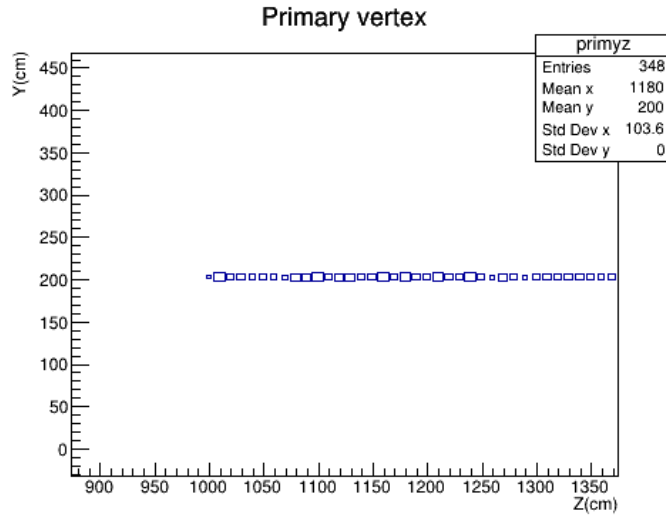# Momentum, Angle, and Position Resolution of Muons

±5% momentum resolution

work to be done, and verification with analytical estimates to be done

Old Vertexing Performance: 2 GeV numuCC

Old
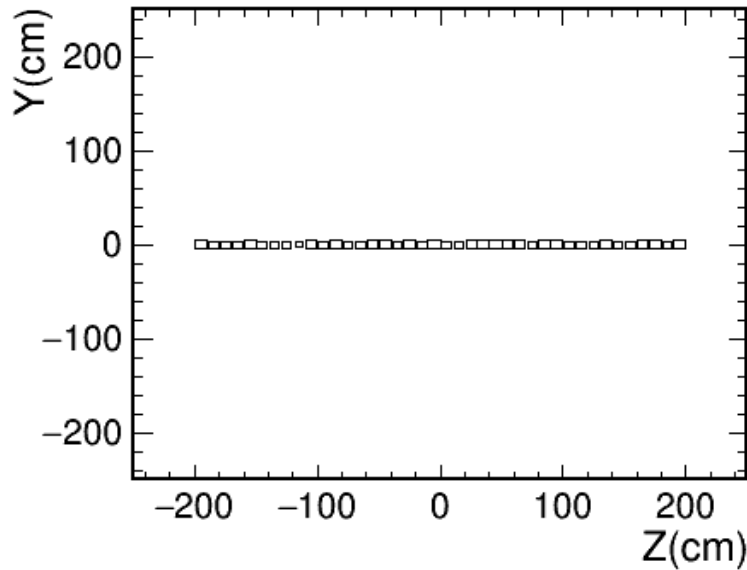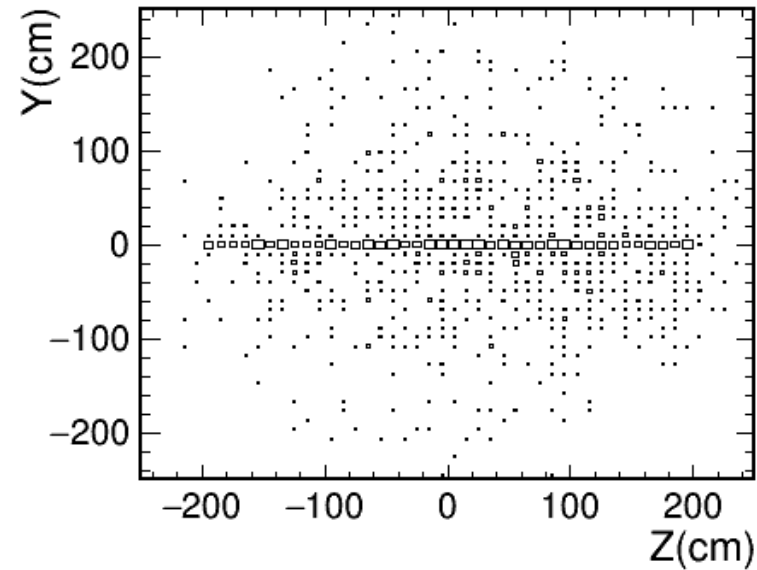VH patrec

Vertex
finder has
endedness
bug.

Primary vertex

primyz	
Entries	348
Mean x	1180
Mean y	200
Std Dev x	103.6
Std Dev y	0

Reco Vertices

recovtxyz	
Entries	4061
Mean x	1184
Mean y	209.2
Std Dev x	96.57
Std Dev y	49.79

Track Endpoints

tendpoint	
Entries	2626
Mean x	1202
Mean y	210.6
Std Dev x	110.1
Std Dev y	62.13

min YZ distance of reco vertex to primary

minryzvertex	
Entries	348
Mean	0.85
Std Dev	0.866

No vertex found Bin

2D
dist perp
to B field

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Vertexing Performance Now

Primary vertex

Reco Vertices

Track Endpoints
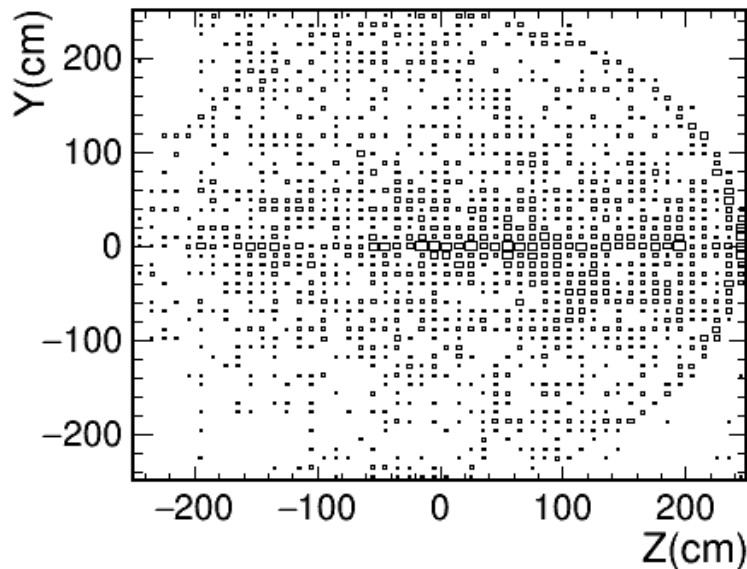
min 3D distance of reco vertex to primary

No vertex found Bin
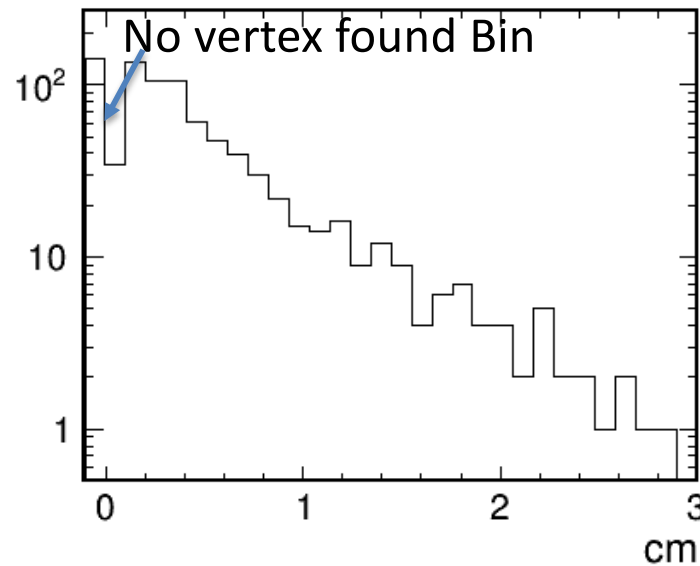
now quoting 3D dist.

3x more events

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Comparison old Patrec, New Fit
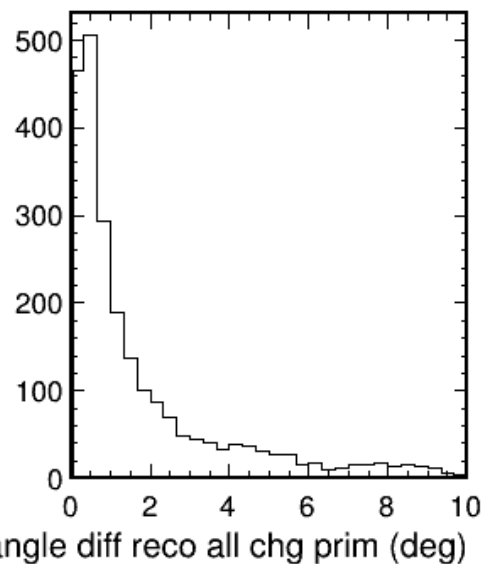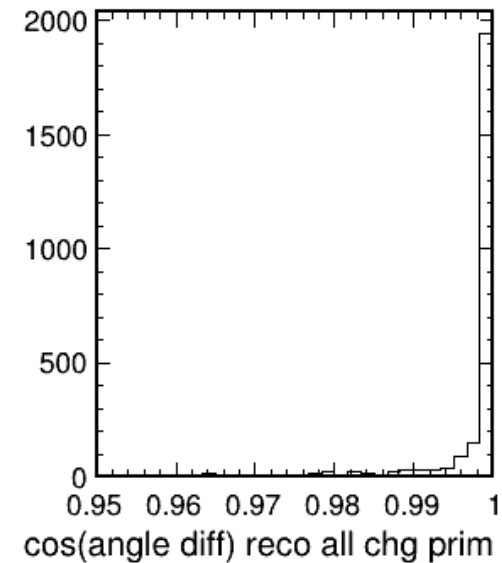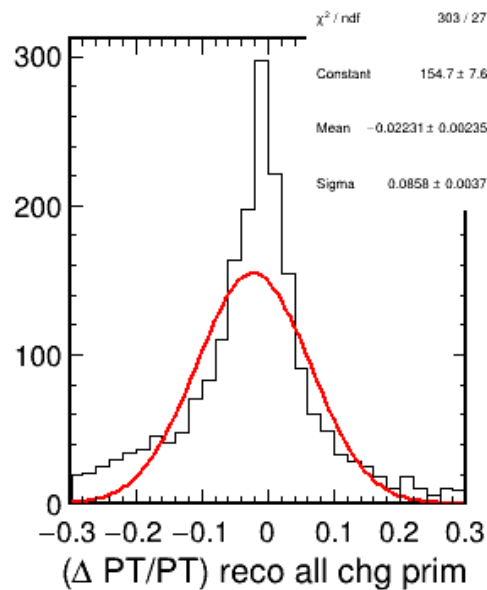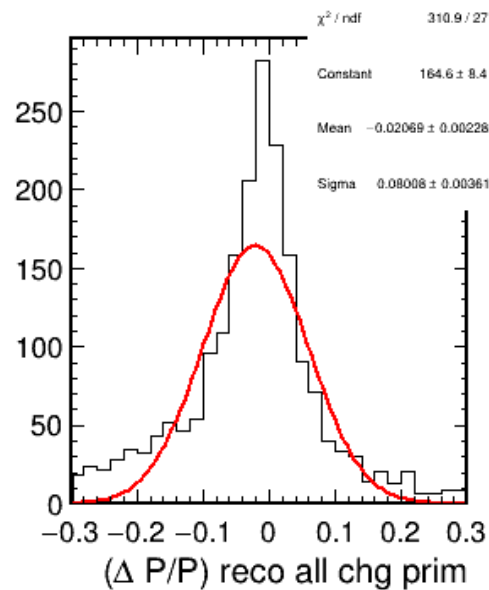
- Old patrec: sort hits in X, cluster in Y and Z. Now re-sort hits along track before fitting, and use lambda instead of slope.

- Maybe the old patrec can help with low-momentum tracks?

- Still very inefficient at lambda=0

- new fiducial cut
  is in place here.
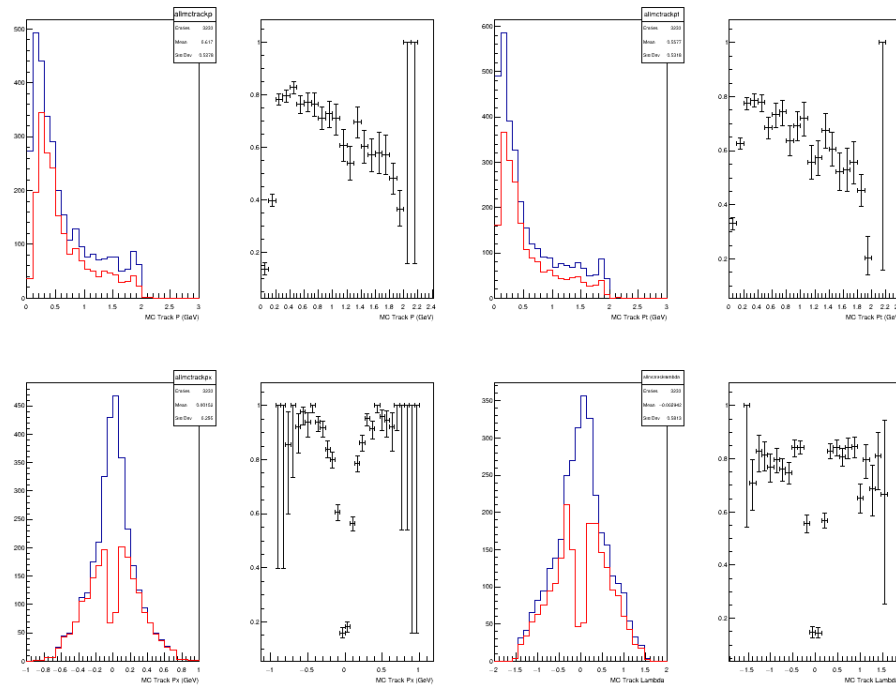
All particle position, momentum, and angle resolutions in numuCC events
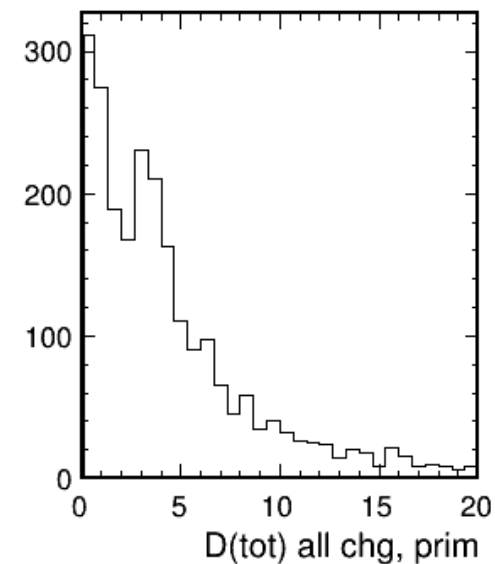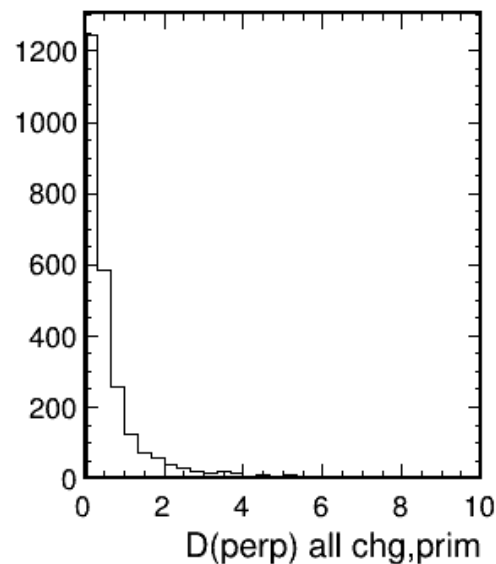
Other updates

- Updated to *art* v3_00_00

    - It has multithreading capability – more than 1 event processed simultaneously

    - We don't (yet) need this functionality, and can't even turn it on yet, as some services need some thought, but at least the program works with the new version of art.

    - We still benefit from bugfixes and updates to *art*, instead of being stuck in the past.

- Some bugfixes: a channel map problem caused some failures if a track hit one of the 18 corners between the circle and IROC sectors. May have been the source of Thomas Campbell's odd distributions.

- Bugfix in vertex finder – mixup in track endpoints fixed.

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To Do

- Make momentum and angular resolution plots – got a start on this

- Figure out how to keep the pattern recognition from stitching tracks across the primary vertex

- Look at split tracks – tracks with gaps and kinks, and delta rays can split tracks.

- Use the backtracker to make track completeness and purity metrics. Expect completeness to be more of an issue, perhaps purity for very short stubs at the vertex.

- Address curlers. Maybe use the original patrec as a second pass. Initial try – doesn't look so good.

- Address low-momentum tracks near the vertex.

- Vertex finding measurement uncertainties

- Event display updates – vector hits, pickability, truth labels, etc.

- Extrapolate to ECAL

- Try with more complex events (pileup with particles coming from ECAL)

- Look at performance of hit clustering algorithm

- Write technote

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Extras

Fit Tuning

- Kalman filter inter-step error parameters were stiffened last time. 1E-9 error squared contributions per hit
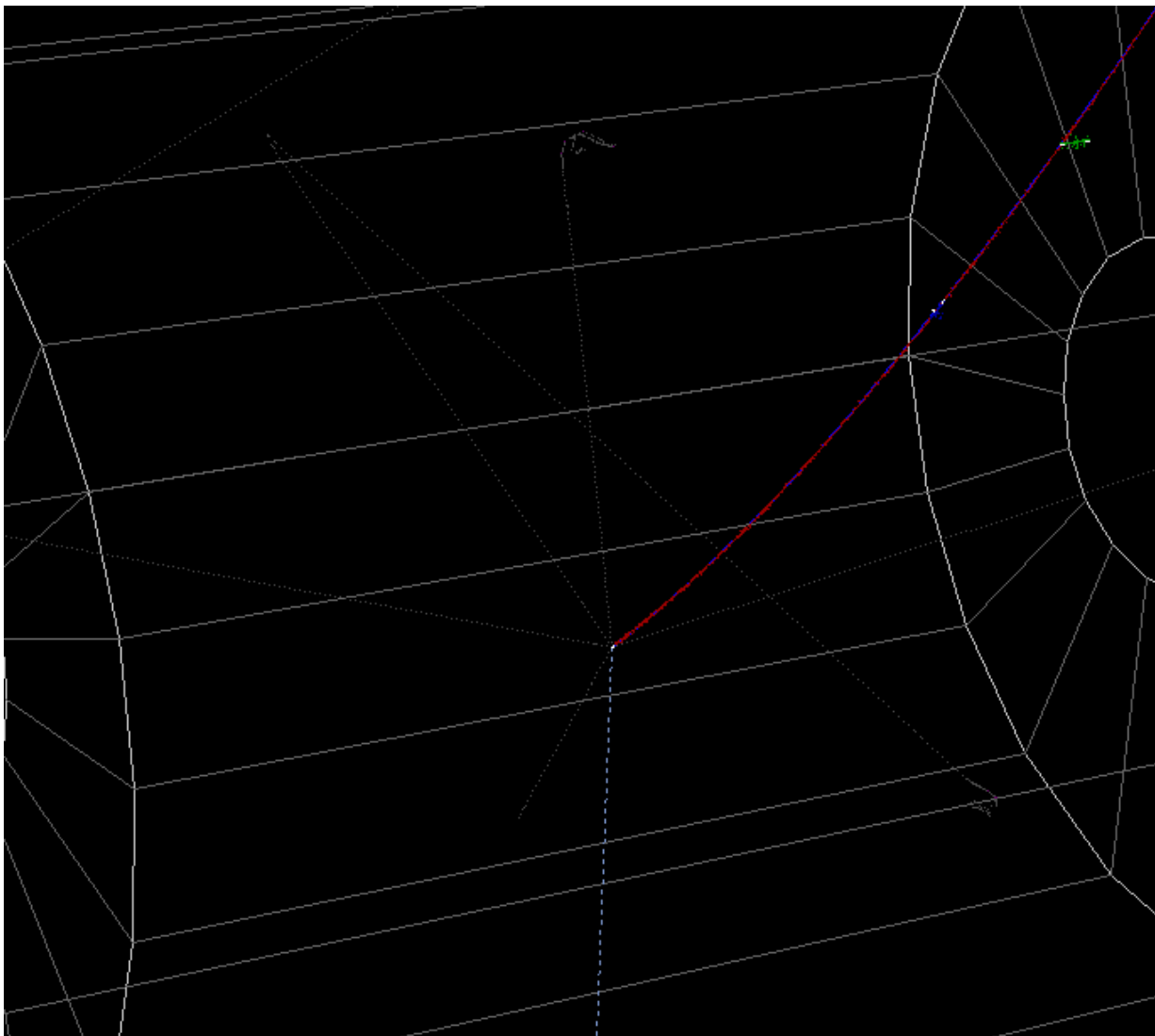
Event Display 1: GENIE (nue,numu) Events
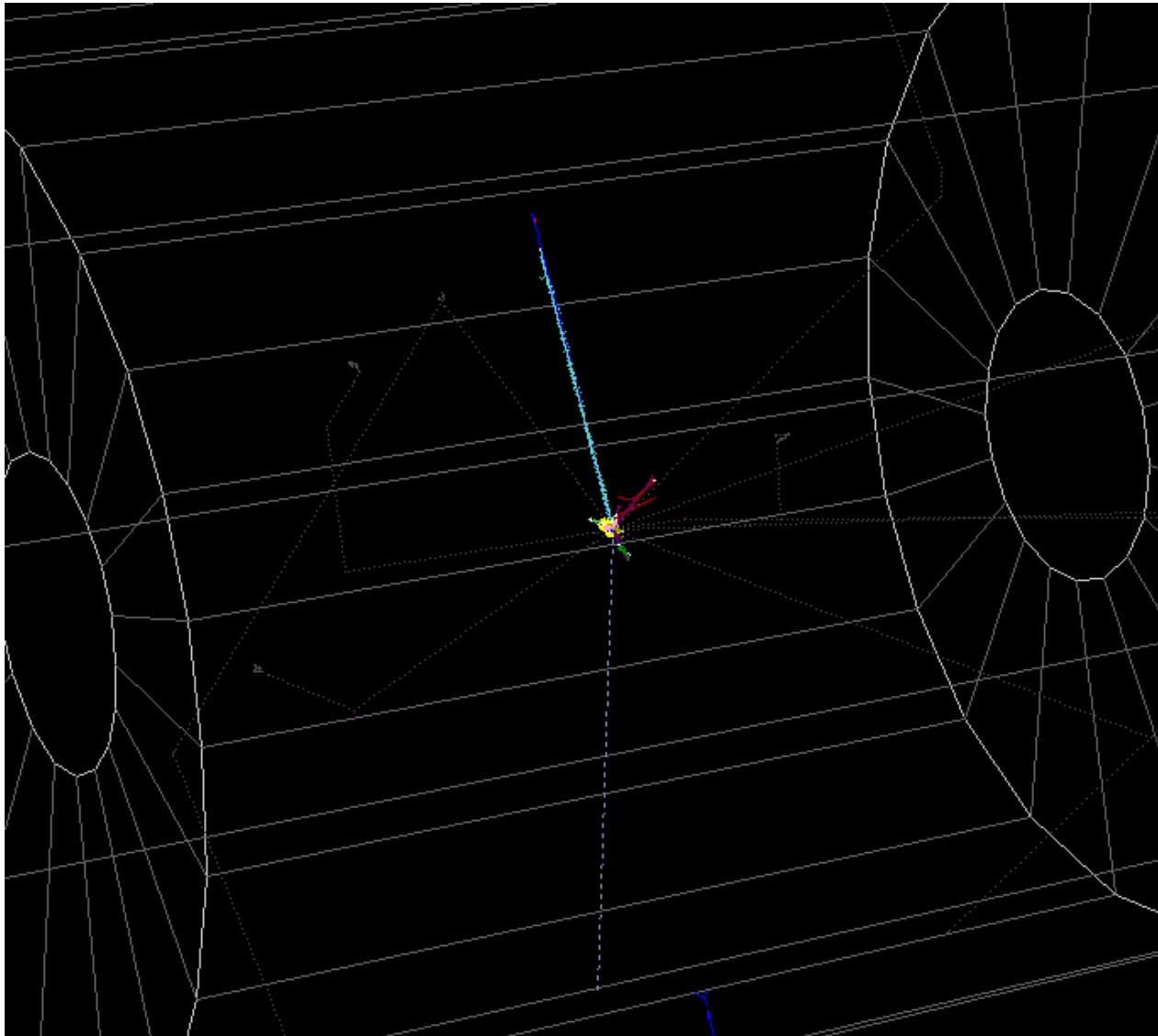
Still not perfect
for short tracks,
but getting the
long tracks is
better.

MC:
blue: muons
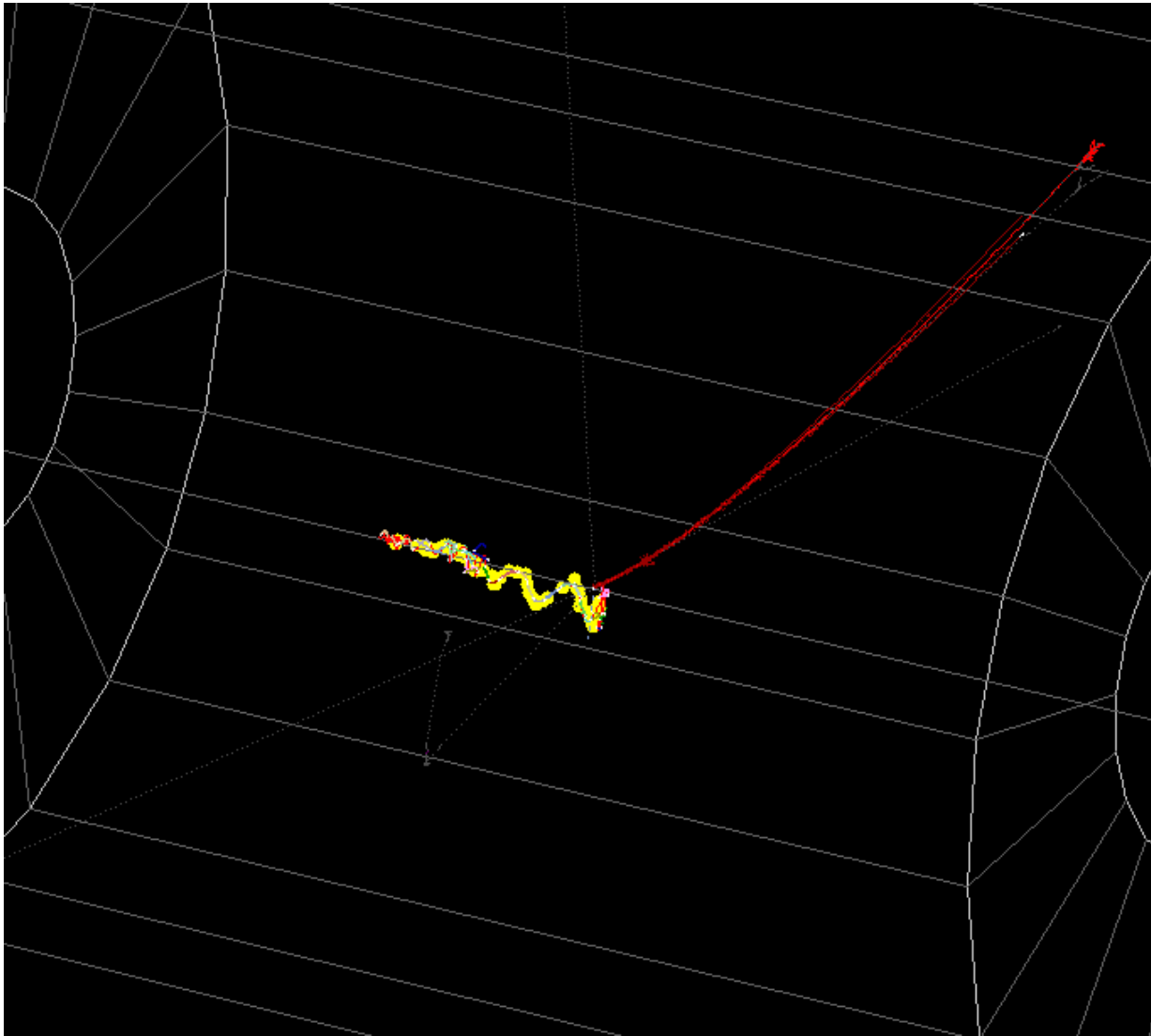red: electrons
purple: protons
dashed blue: neutrino

RECO:
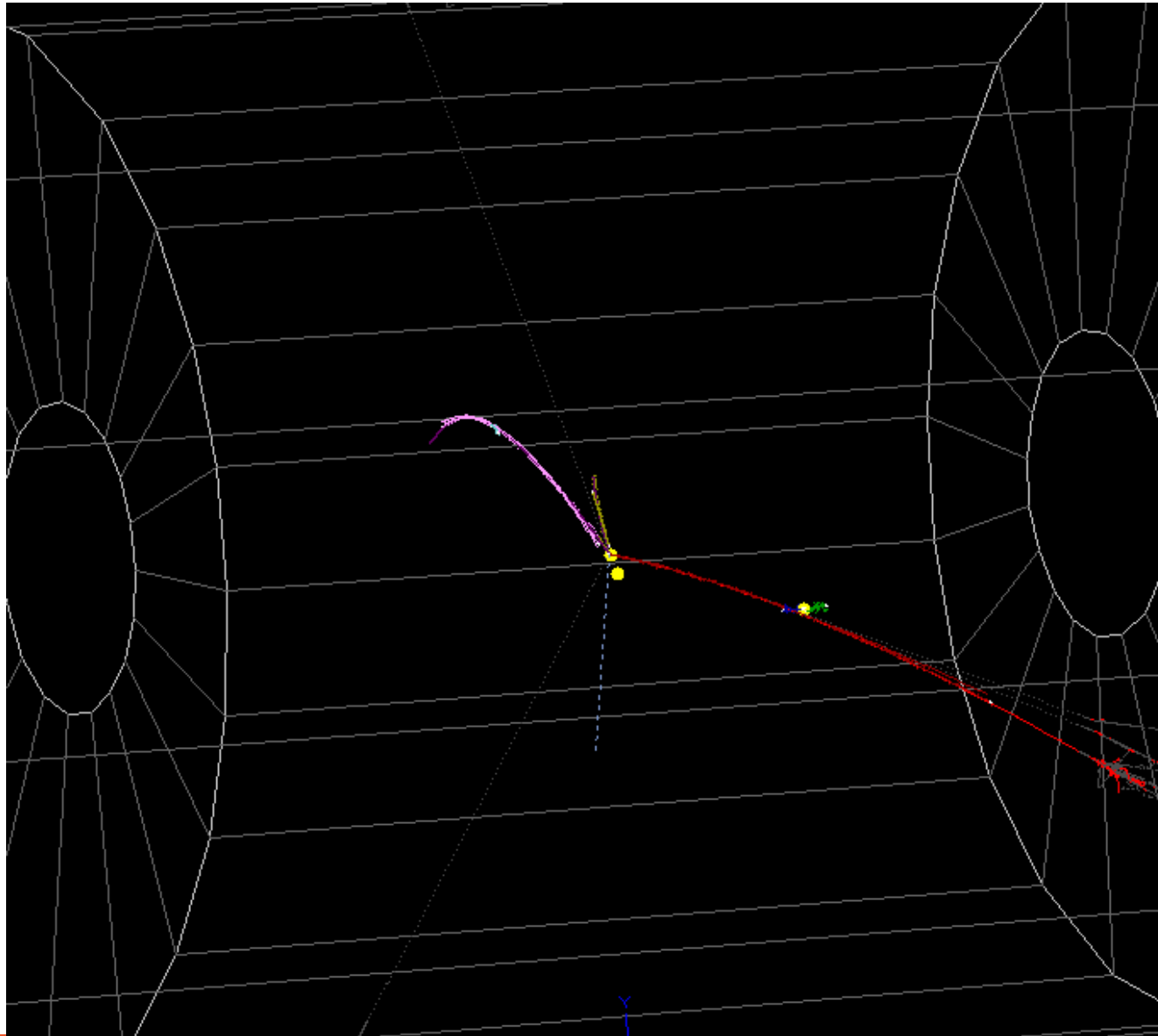arbitrary colors

Event Display #2
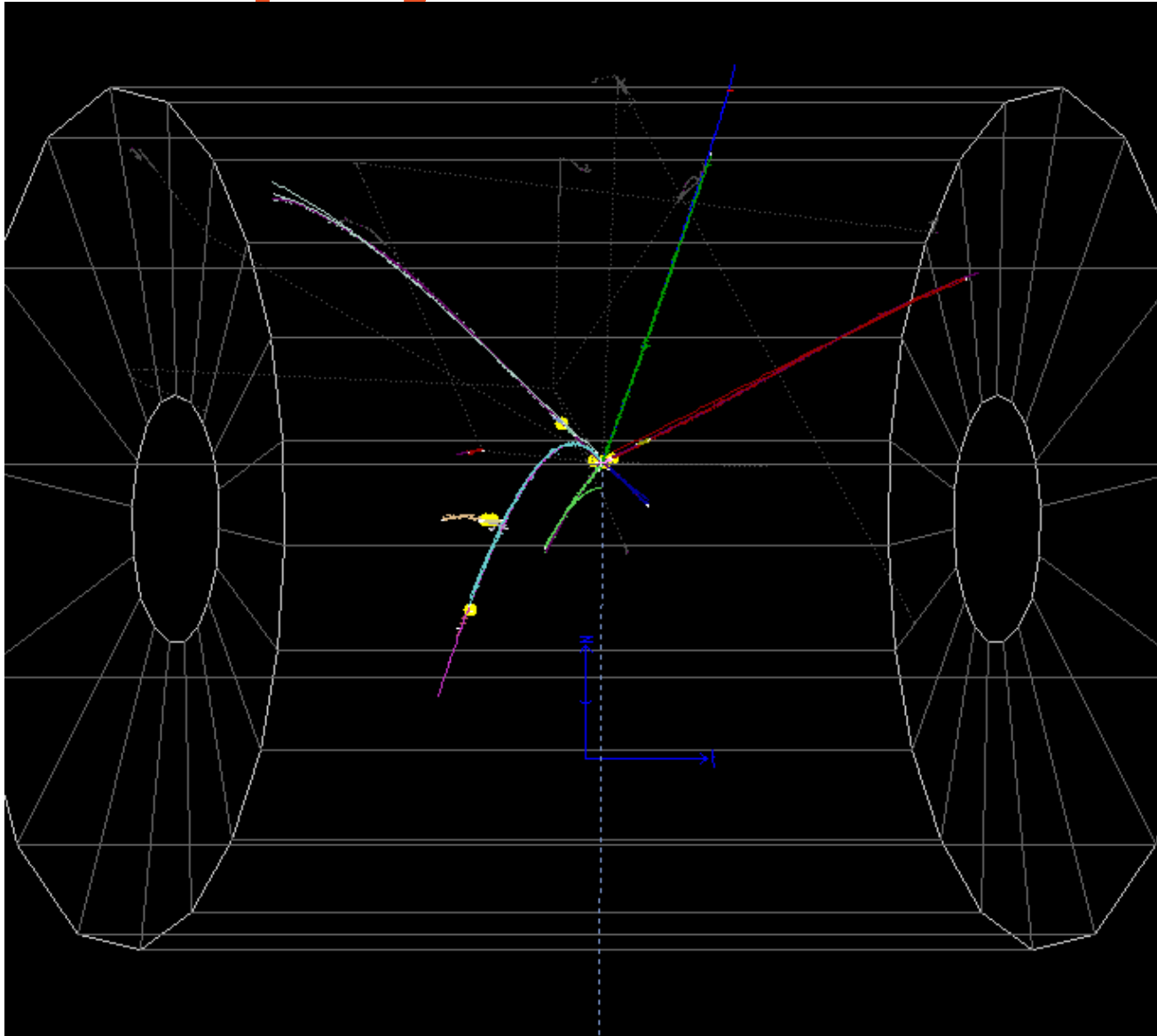

Single muon

Event Display #3

Didn't work so well on the corkscrew.

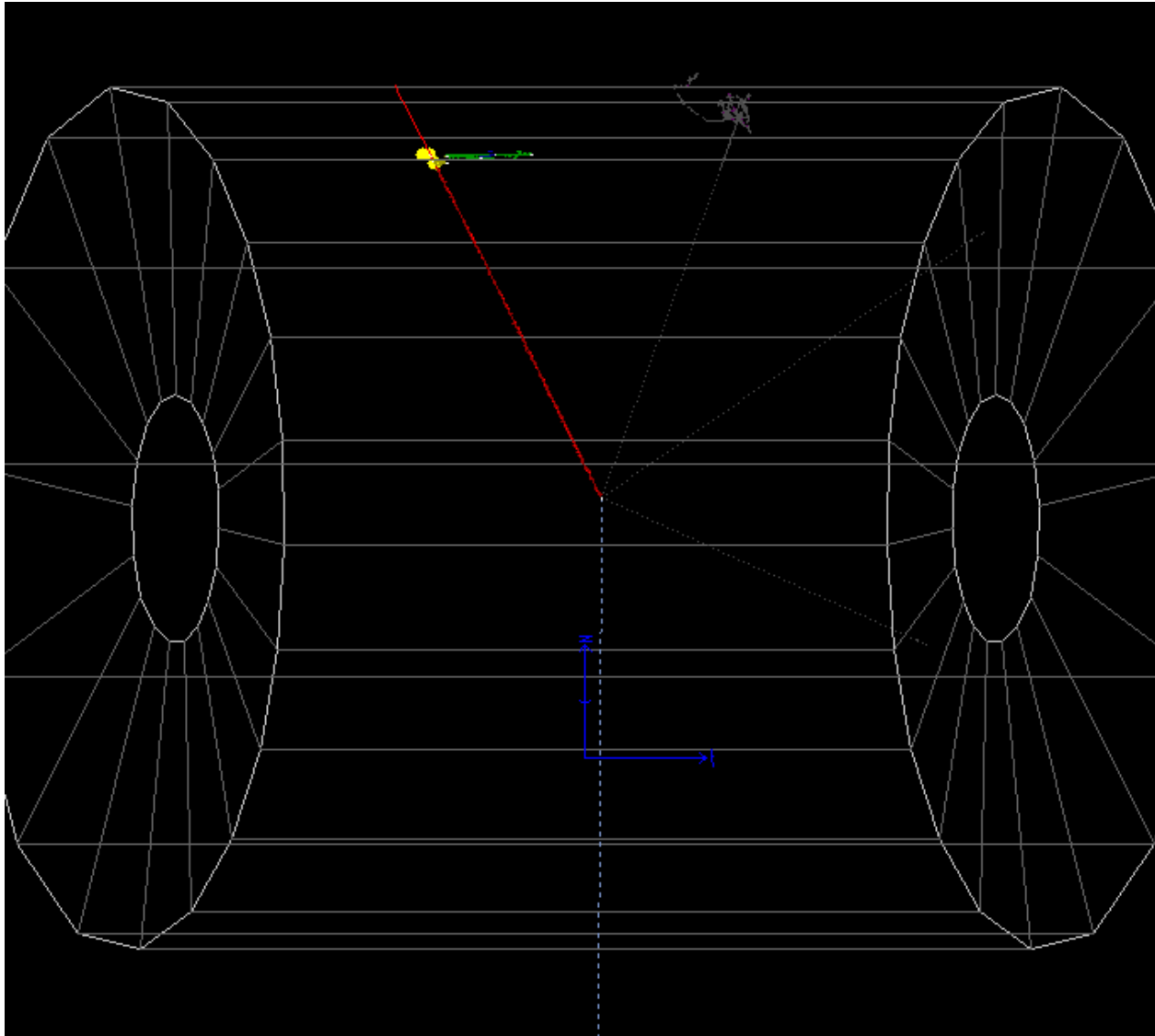Maybe go back to the previous pattern recognition to get low-energy spirals

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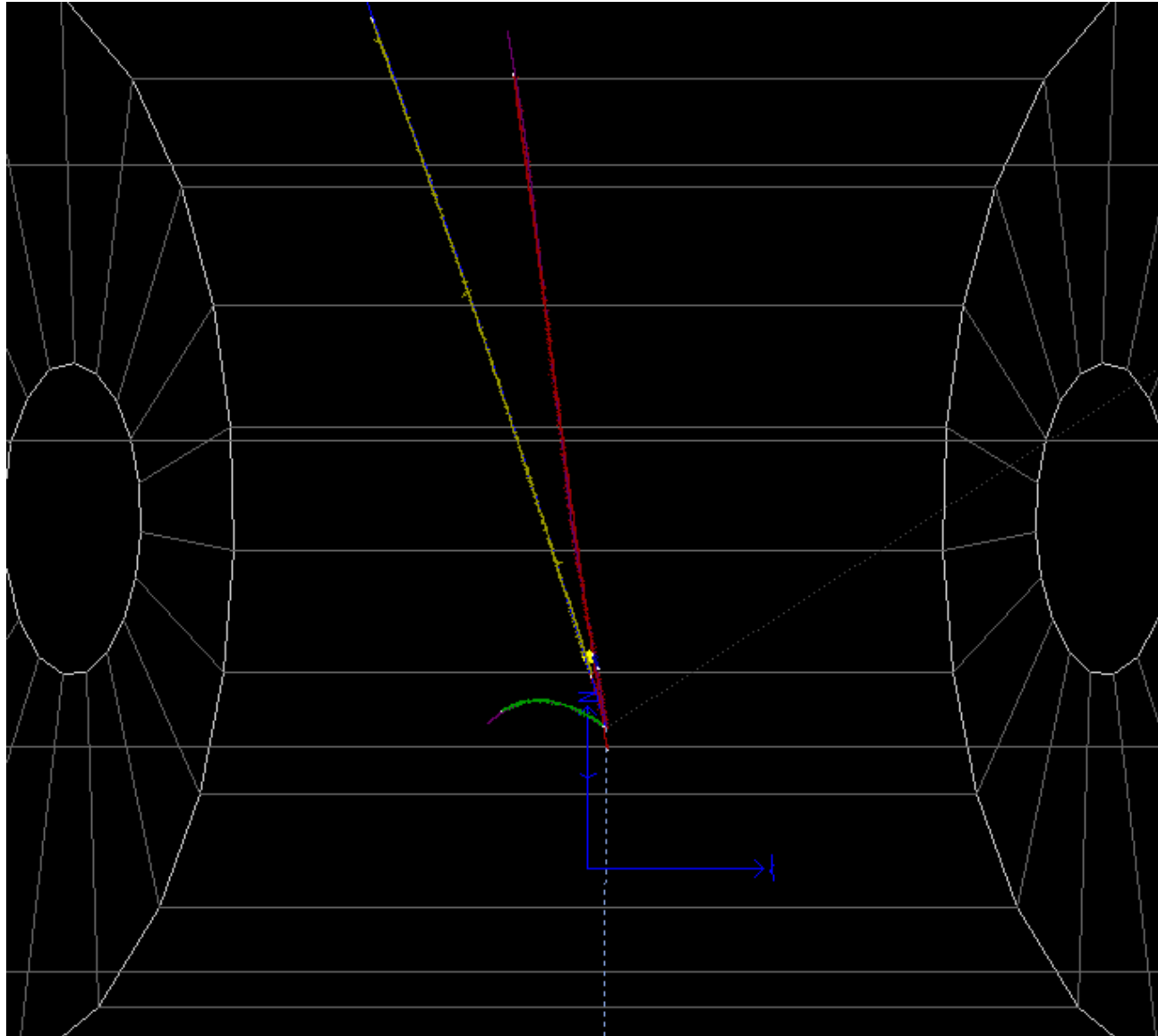# Event Display #4

Event Display #5
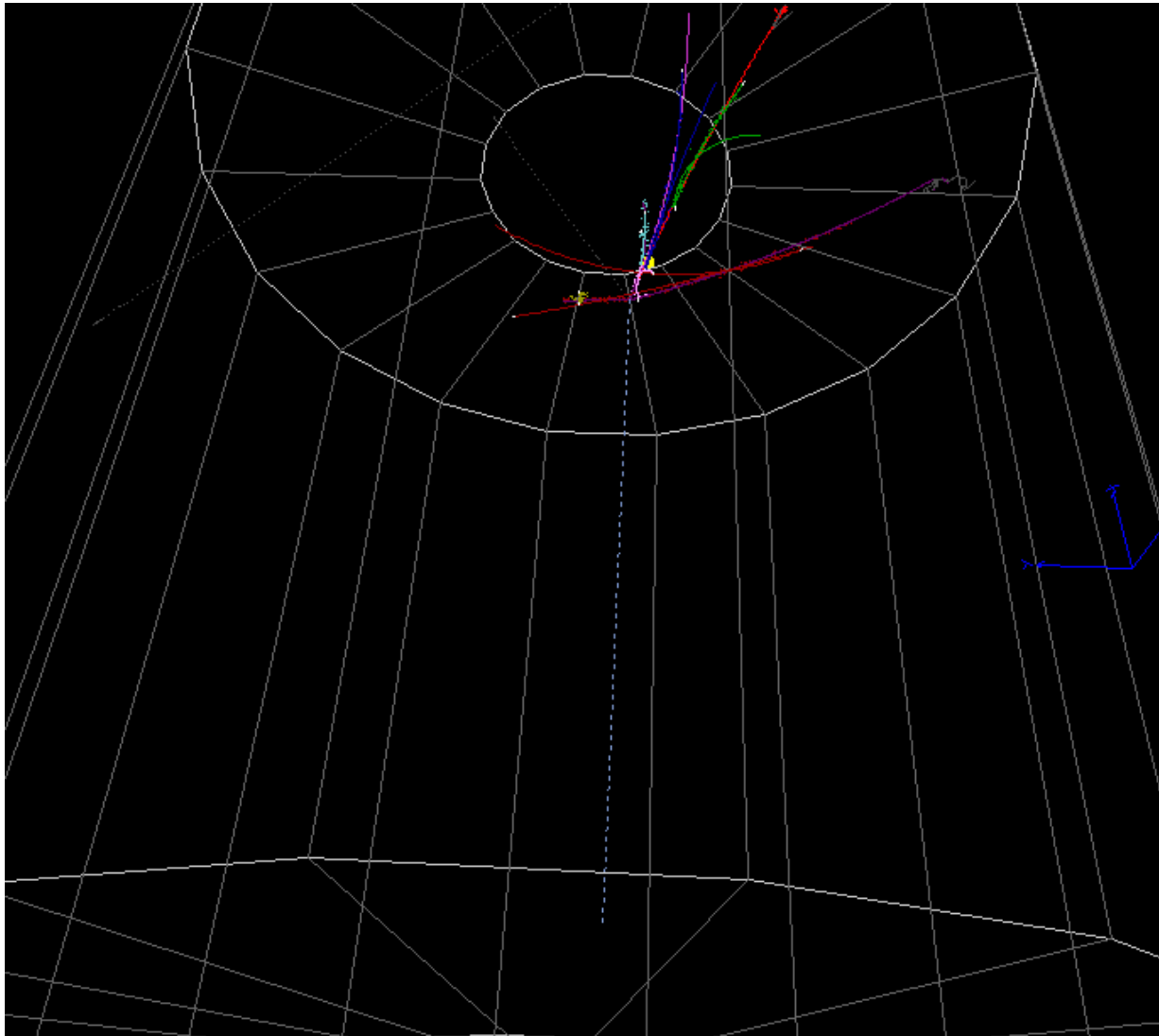
Event Display #6

Our famous
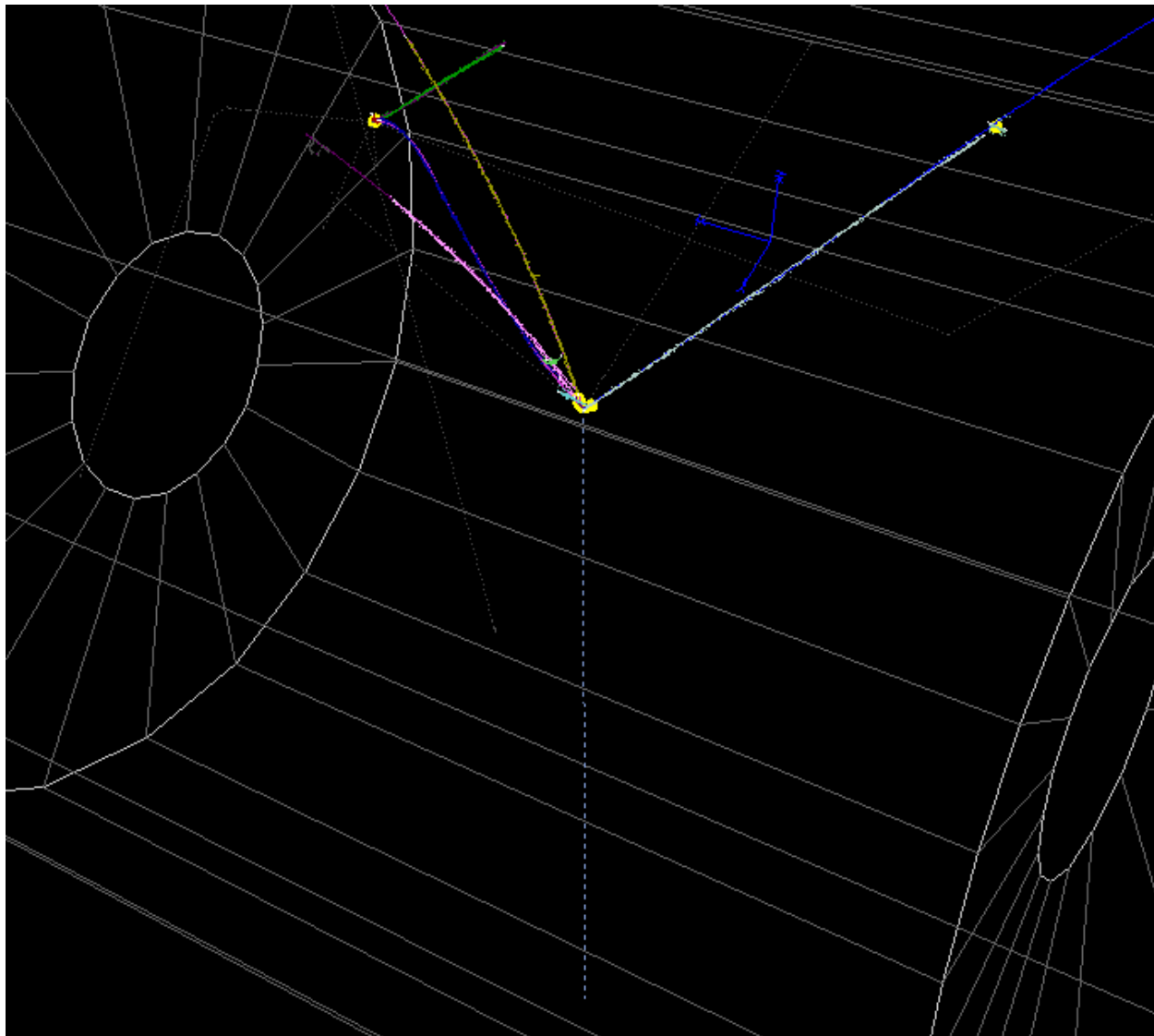no-Primary
Vertex Example

Event Display #7

Vertex
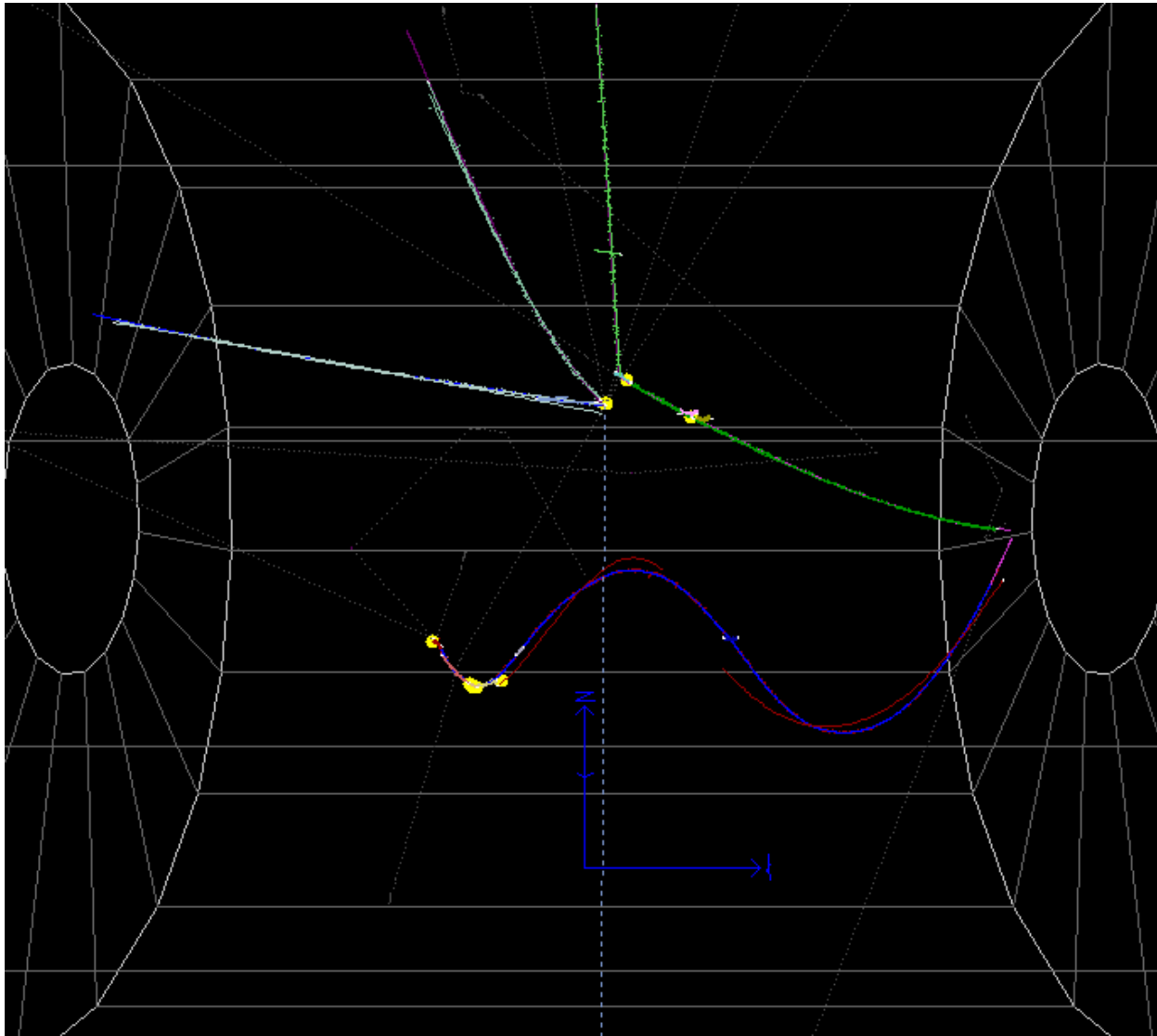is a little off

Event Display #8

Near the side wall
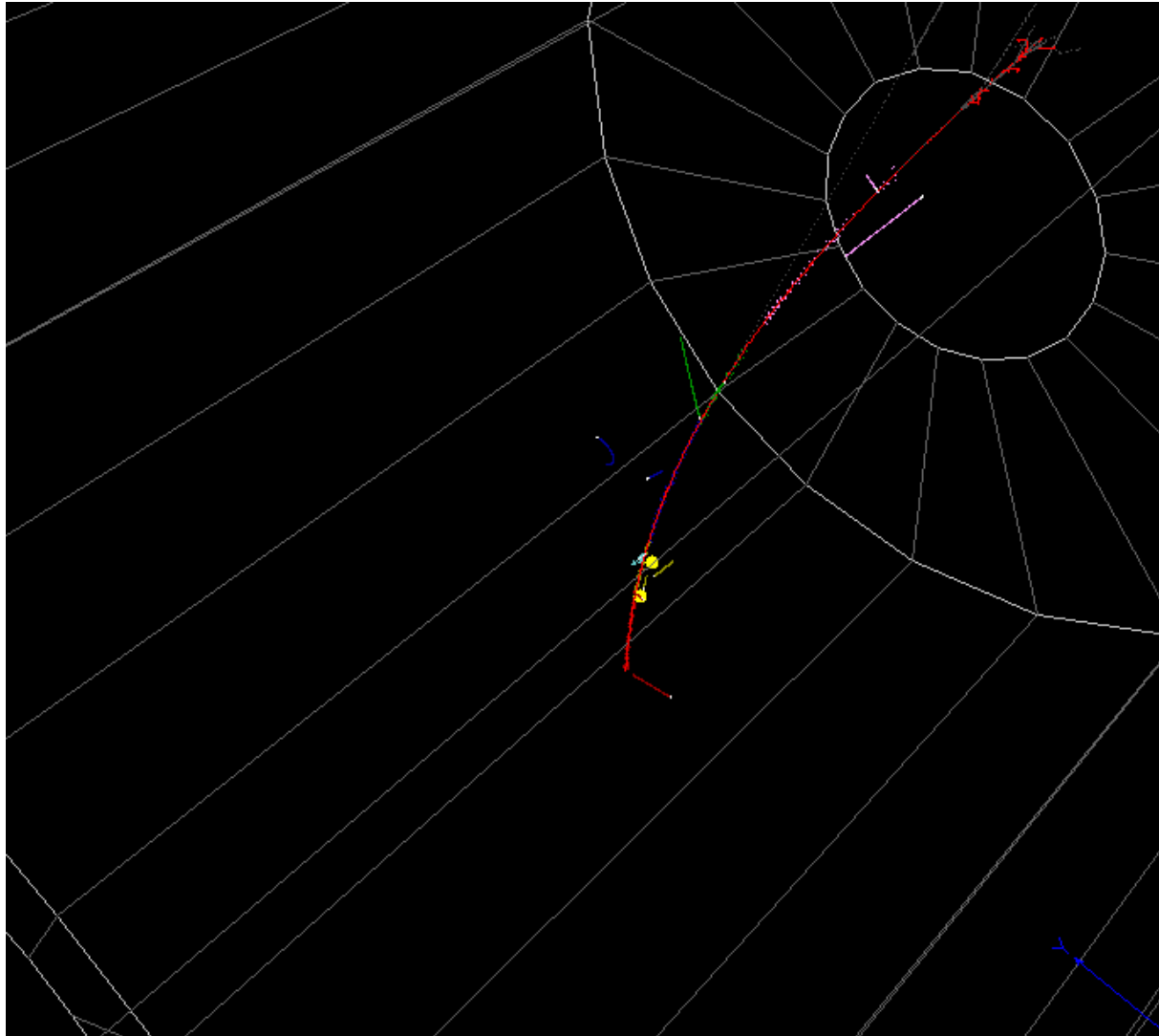
Event Display #9

Event Display #12

10 was empty
11 was boring

This one has a
corkscrew that
was sort of followed.

Single muon, 1 GeV, going along Z

Isochronous tracks

- Sorting hits in X is not a good idea for tracks that go in the (y,z) plane.

- Problem is, the fit marched along tracks using X as the independent variable.

- Even if we find the patterns properly, the fit will not be as stable for these tracks.

- May need to make the fitter more isotropic.

- Track parameters: x,y,z,curvature,slope,phi.

- Isocrhonous tracks: slope = infinity. Perhaps a poor choice. Corkscrews have slope=0. Expect lots of corkscrews.

- May need to move slope variable to theta instead

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Tracking Efficiency for Primary Muons: Nov 16

A bit better than last time!

Blue: MC
Red: reco
(only two plots show reco here)
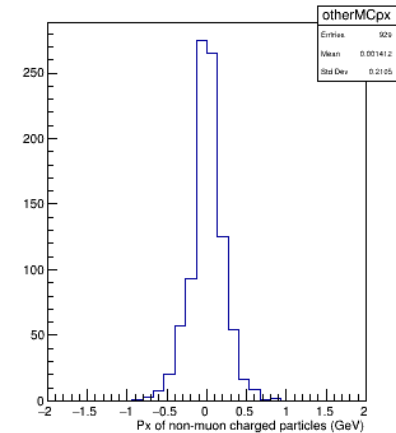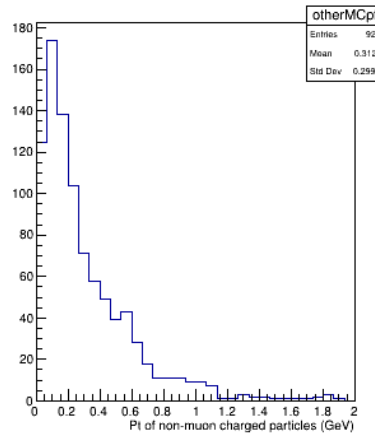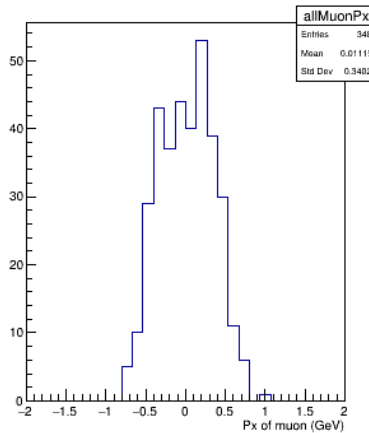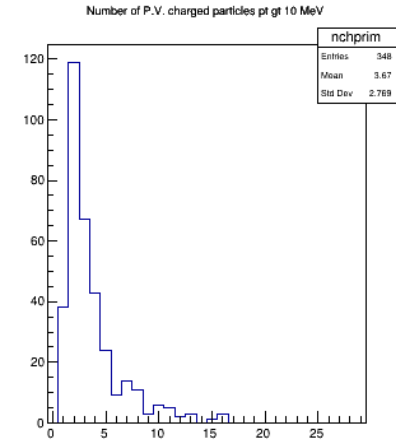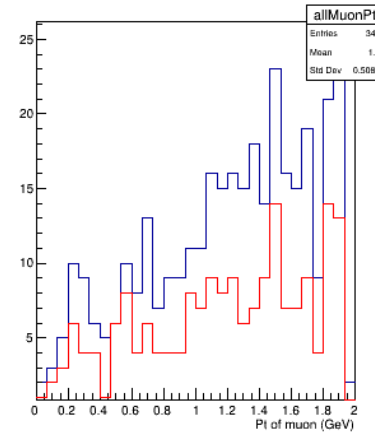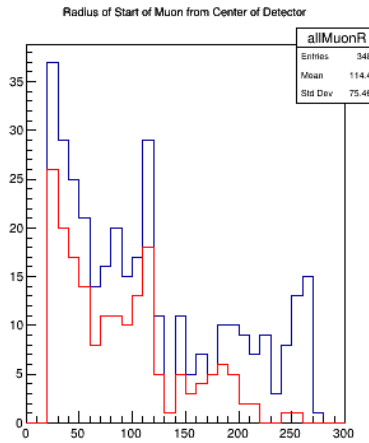
Vertexing Plot: Nov. 16

Finding
more primary
vertices!

Was: 190 or so
out of 348 missed.
Now around
130.