TMS Issues and Oddities

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Outline

- Issues with MC Truth
- Issues with Reconstruction
- Issues with Combining them

- Data sample:
  MiniProdN1p2_NDLAr_1E19_RHC.spill.00001.
  EDEPSIM_SPILLS_TMS_RecoCandidaes_Hough_Cluster1.root
- Code: Snapshot as of 11-Mar-2024

MC Truth

- Sample composition.
  - Half (54%) neutrinos and half (46%) antineutrinos
    - This is supposed to be a RHC sample, so that makes sense
  - A few percent of elecyton neutrinos and anti neutrinos
    - Corresponds to a decay pipe of a few hundred meters, so that makes sense.
  - Half (56%) negative muons and half (44%) positive muons
    - But there is little correlation between neutrino flavor and lepton charge!

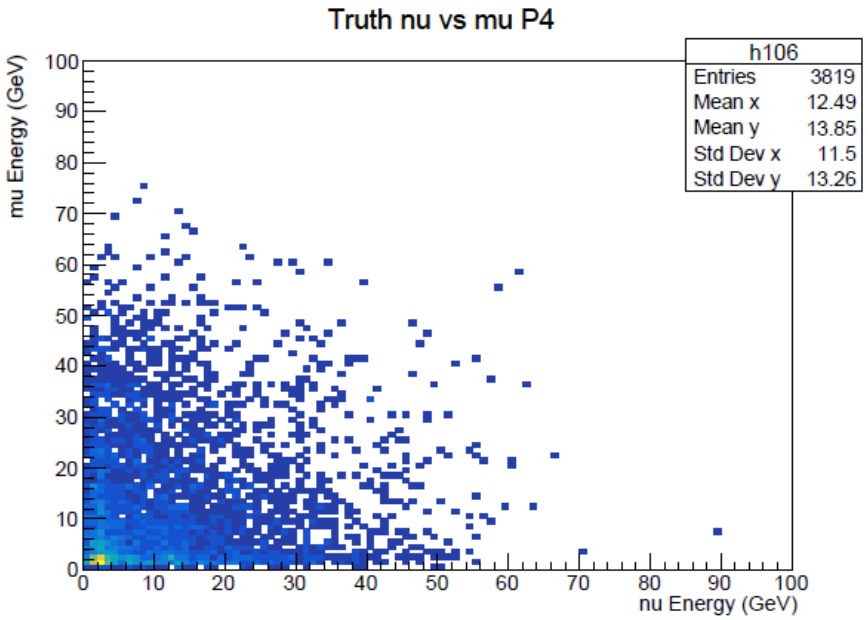
	Neutrino	Antineutrino
Negative muon	1068	986
Positive muon	925	658

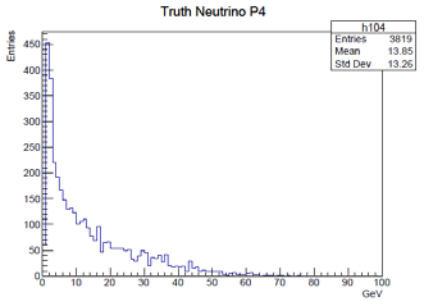
A χ^2 test shows the two are correlated (P = 0.3%). However, the correlation goes the wrong way.

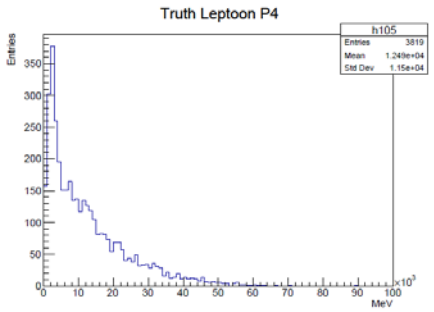
- Also, a large number of events with PDG code 0. They have trajectories (!), but seem not to give rise to muons.
  - Hypothesis – no interaction, but the trajectories from a previous interaction were not cleared

More MC Truth

- Plotted the parent neutrino energy vs. daughter muon energy
  - Vittorio Paolome was the first to make this plot.



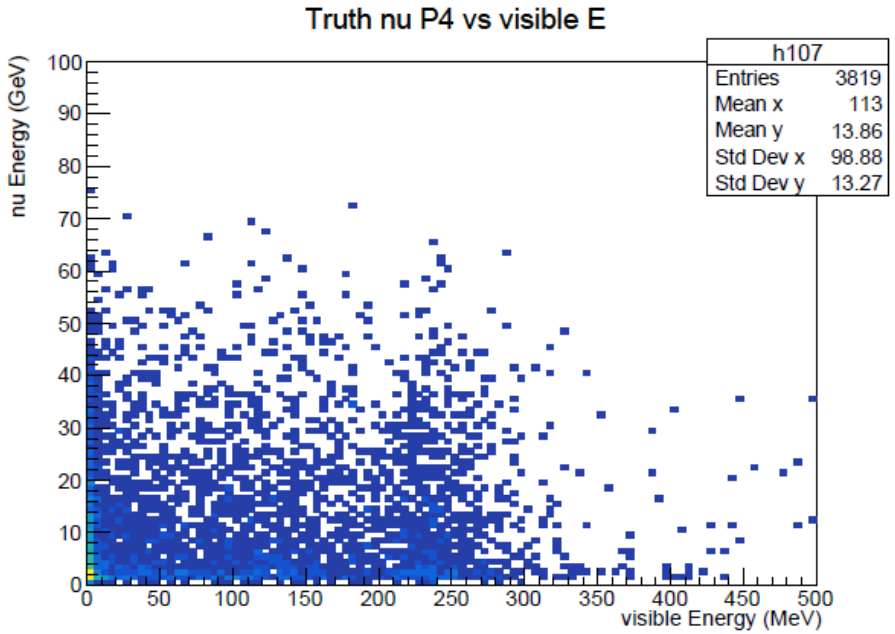


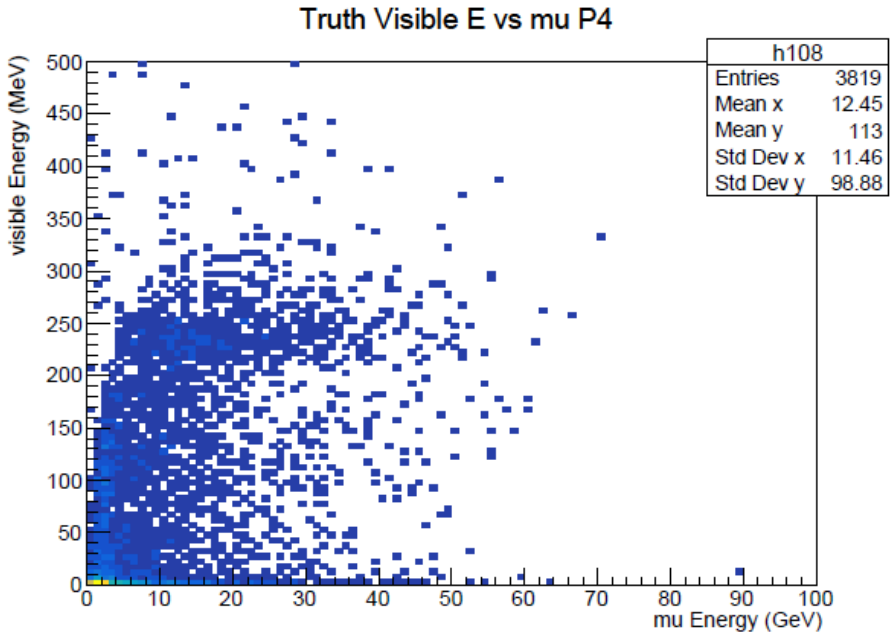


- Golly!
  - There is no correlation between these energies
  - If this is a 120 GeV beam these high energy events are unlikely
  - If this is a 60 GeV beam, these high energy events are impossible
  - Regardless, 1 GeV neutrinos do not give rise to 70 GeV muons

MC Truth – Which is Right?

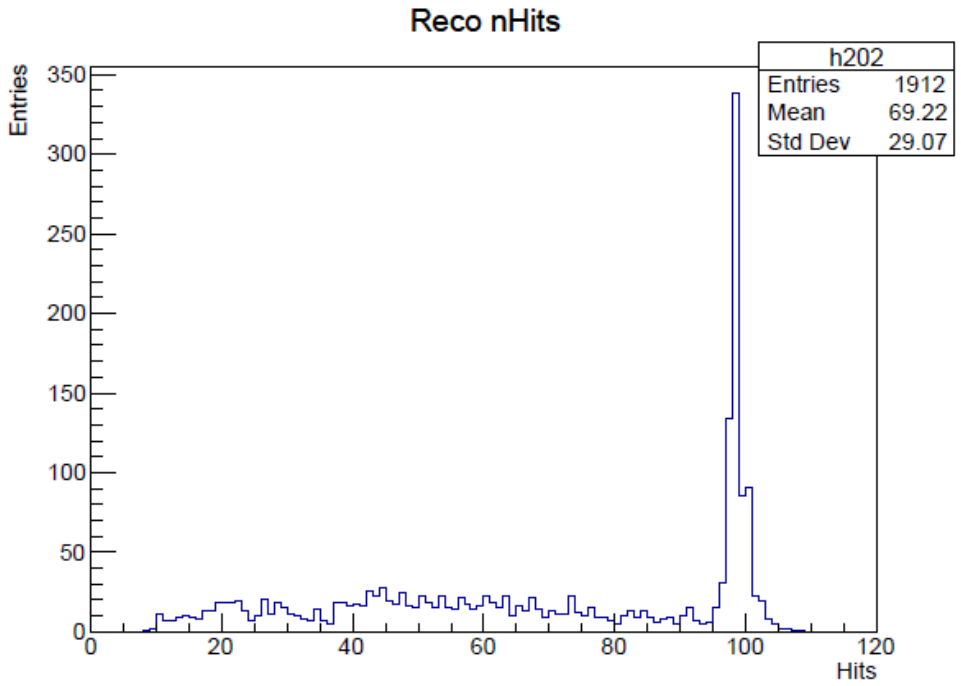
- Plot vs. the “visible energy” (presumably what was deoisted in the active region)

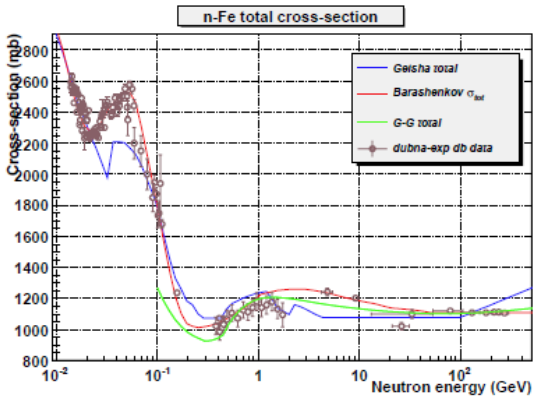




- Both look terrible, but at least the muon energy shows some structure
  - 200-250 MeV is about what we expect for muons that hit all 100 layers

Reconstruction – Number of Hits

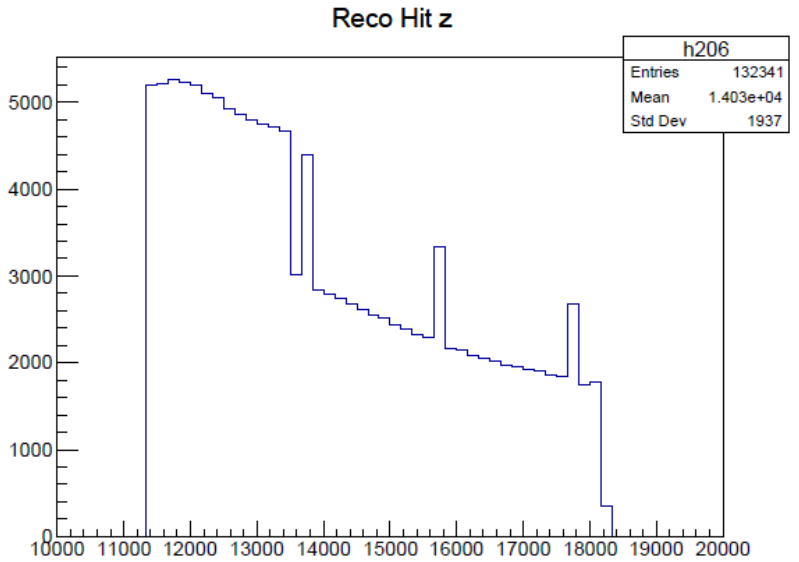




Apostolaiks et al.
EUDET-Memo-2007-15

- Way too many muons go all the way through.
- The events with >100 hits contain a diffuse collection of hits, well-separated from the muon
  - I suspect neutrons. It will well known iron becomes largely transparent to neutrons in a region just below 1 GeV

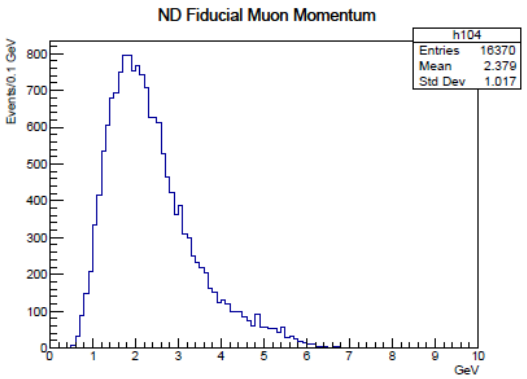
Reconstruction – z Hit Distribution



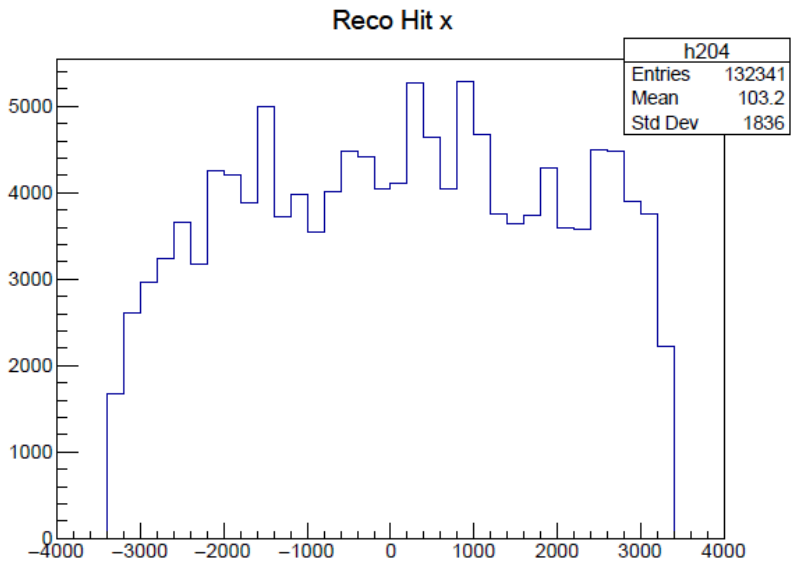
Ignore the spikes – this is a stubborn binning artifact. (Essentially a Moire pattern)

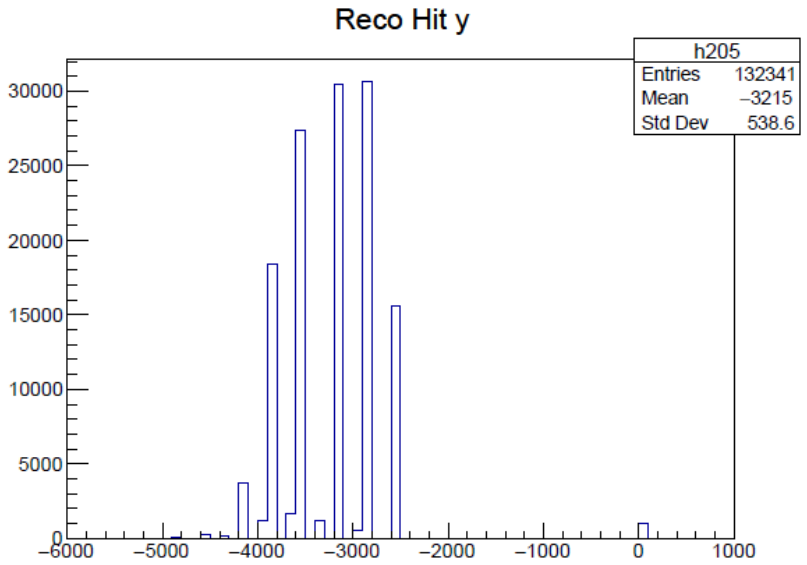
- The jump is because this is z, not plane number
  – the density of planes (and therefore hits) is higher in the front.
- The exponentials look approximately right.
- Way too many muons make it all the way through – should eb a few %

From a 2-year old Truth-level study



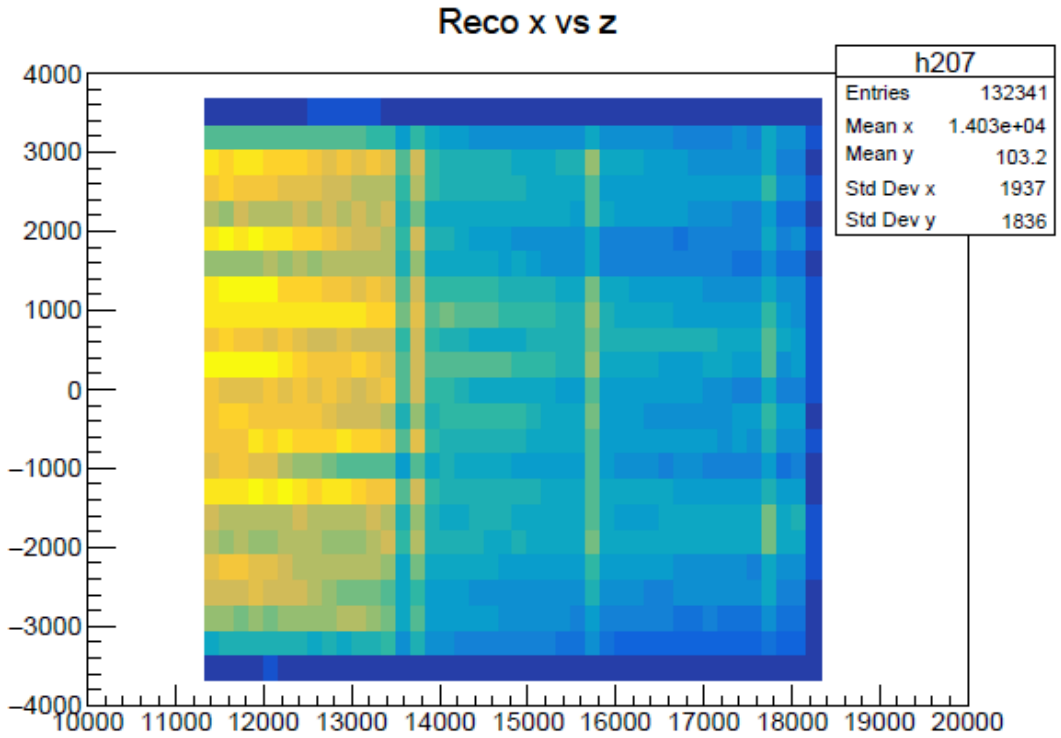
Reconstruction – x and y Hit Distribution





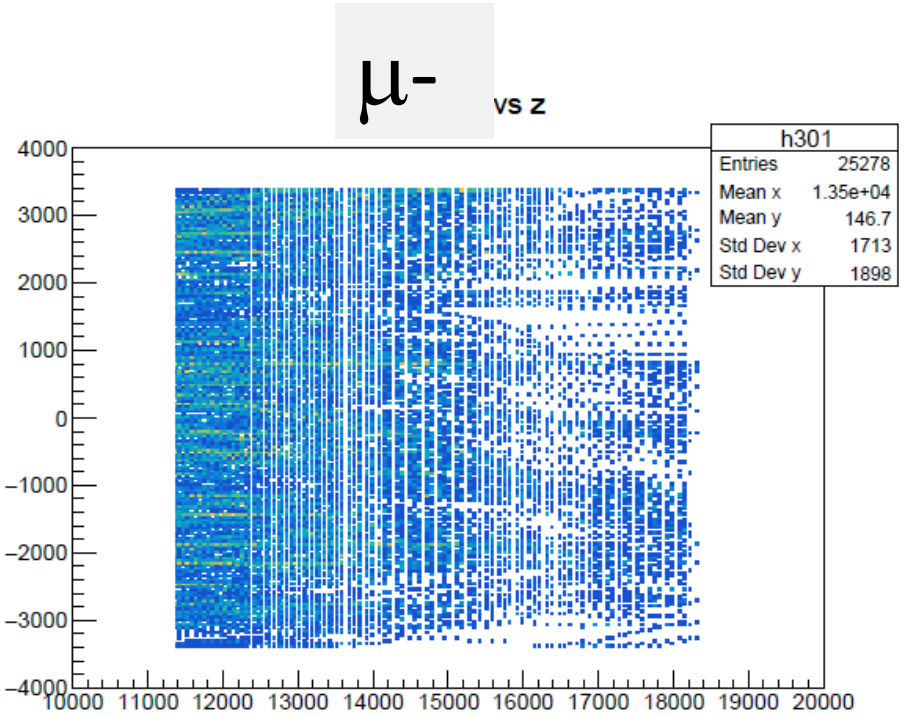
- The x-distribution looks OK
- The y-distribution is pre-Asa's latest update so shouldn't be there at all. Certainly not ***underneath*** the TMS.

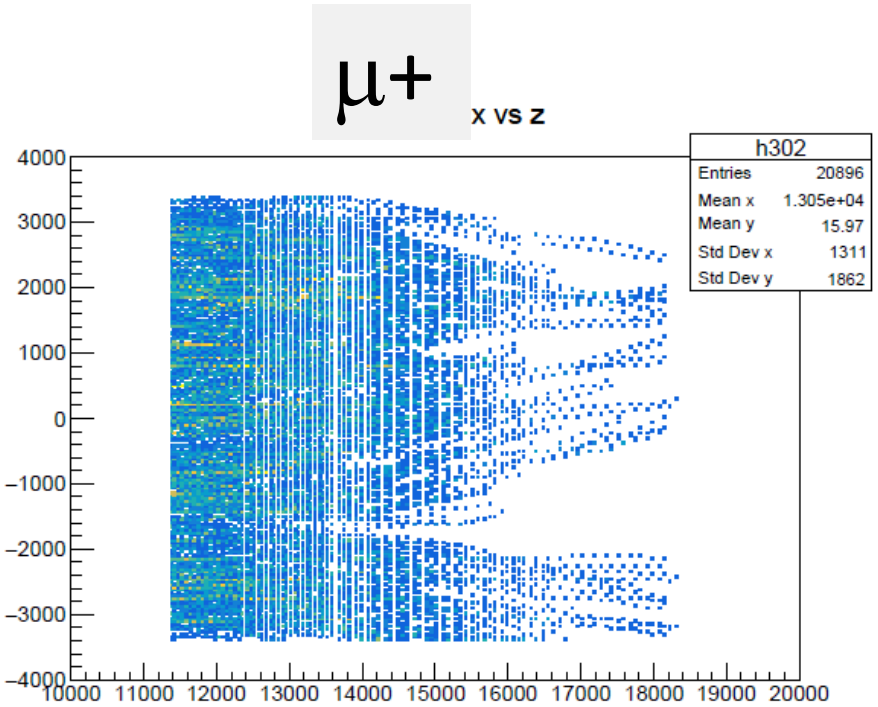
Reconstruction – x vs . z



- This shows the occupancy – same basic features as the 1D plots

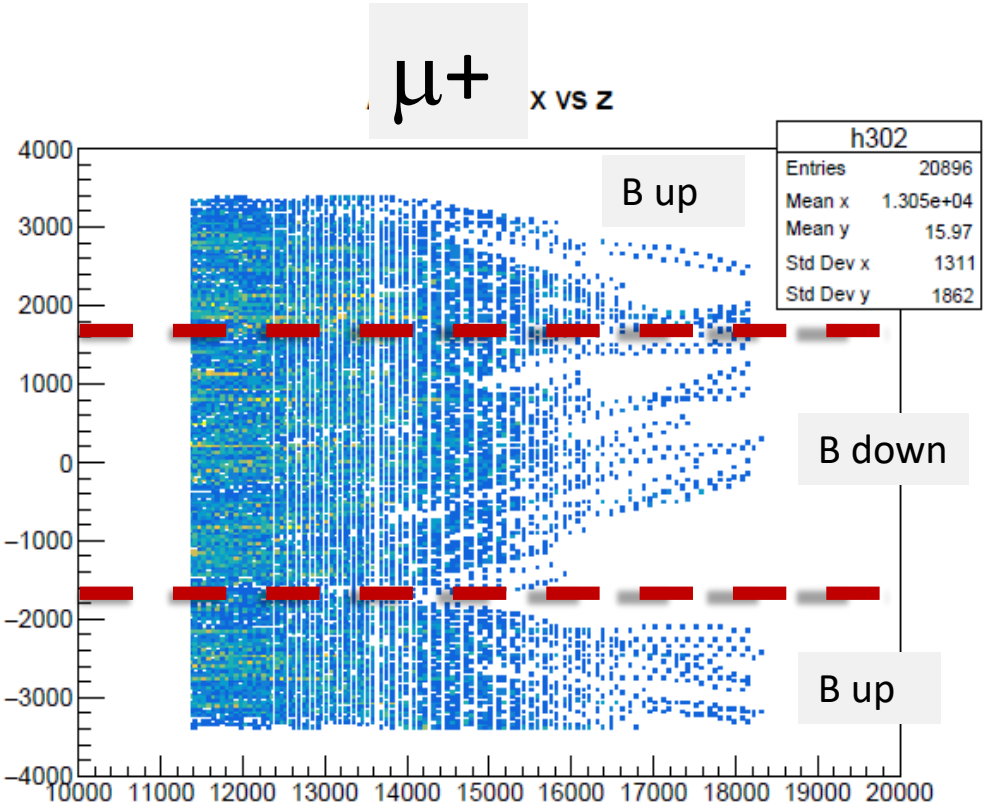
Reconstruction + Truth – x vs . z vs. muon charge





- Require muon to stop in TMS (fewer than 95 hits)
- Occupancy looks different based on muon charge – see next slide.

Reconstruction + Truth – x vs . z vs. muon charge



The magnetic field focuses the muons of a given charge onto the field reversal lines. (TMS is actually a "muon trap")

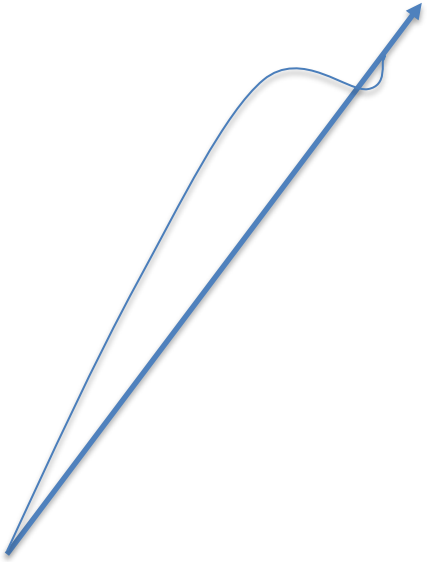
Positive muons go to the south line, negative muons go to the north line.

For RHC this mostly averages out; for FHC it will not and occupancy will have an asymmetry.

We have not been able to make this plot for maybe a year – this is good news.

Charge ID

- Draw a line from the start to the end of the track
- Compare the area between the track and the line left of the line and right of the line.
- The side with the most area determines the charge



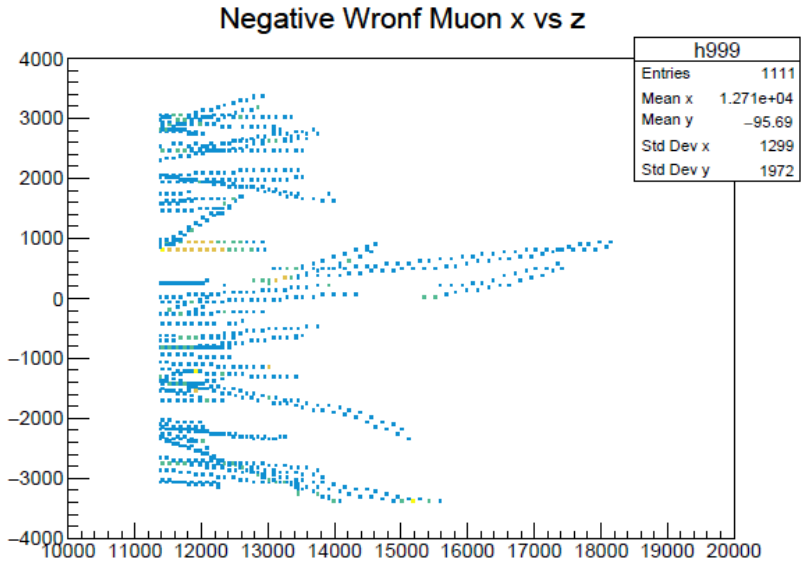
- Complexities
  - Invert the weighting if the trajectory crosses the B-field sign reversal boundary
  - Looked at summing the squared distance rather than the distance
    - Only in 13 cases do they differ – not worth it for now

More on Charge ID

	Right Sign	Wrong Sign
Positive muons	987	144
Negative muons	462	37

- Charge ID is wrong ~15% of the time – seens too high
- After requiring muos (PDG ±13) and fewer tha 95 hits, the charge balance changed from 1:1 to 2:1
- Charge mis-ID depends on charge (it shouldn't) at P < 0.2%.
- Wouldn't the algorithm do better if you squared the residuals? Probably, but only 13 events change (deternined) sign.

What's Going Wrong with Charge ID



- Not dominated by "swimmers" (although there may be some)
- Most tracks don't even curve at all!
- Suspicion – muons exiting before they have a chance to curve – another synotom of a spectrum that is too hard.

Comment on Code

- I am not ROOT's biggest fan. But if we are going to use it, we should use it in a ROOTy way.
- In particular, MC Truth and Reconstruction are different TTrees
  - They should be two branches of the same Ttree
  - "Why? We can always write code to merge them?"
    - Yes, but this way you don't have to.
    - Writing unnecessary code means an unnecessary risk of errors.
    - Merging the TTree ourselves takes $O(n^2)$ time with a loop, O(n log n) with an index, but O(n) if in a single TTree.
      - n.b. This file has exactly the same entries in both TTrees, which allows for a fast merge. But this is not guaranteed. Another potential source of error.

Next Steps?

- Did I use the Time Slicer?
  - I have no idea.
  - This indicates a problem with the provenance of the data sets we are looking at. It would be useful if we had the ability to make short runs of known configuration to test these sorts of things. Probably outside of Production – we want fast turnarounds for these tests.

- Why did you do this?
  - I see this as a start of a validation effort – before making design decisions based on Monte Carlo, we should check that the low-level qunatities look right.
  - Advice from a blind and crippled old coor: before looking at a 2D plot, look at a 1D plot. Before looking at a 1D plot, look at an event display. Before looking at an event display, look at an oscilloscope.

Summary and Conclusions

- Issues with MC Truth
  - Truth four-momenta seem problematic
  - PDG Codes for at least the parent neutrino seem not always correct
- Issues with Reconstruction
  - Too many long tracks – possibly a consequence of MC Truth issues
  - The y-distribution makes no sense, and probably shouldn't be there at all.
- Issues with Combining them
  - Despite the above problems, at least some times this works.

I trust what we have to tune up our code – but not to make design decisions.