CALO – Endcap digitization problems!

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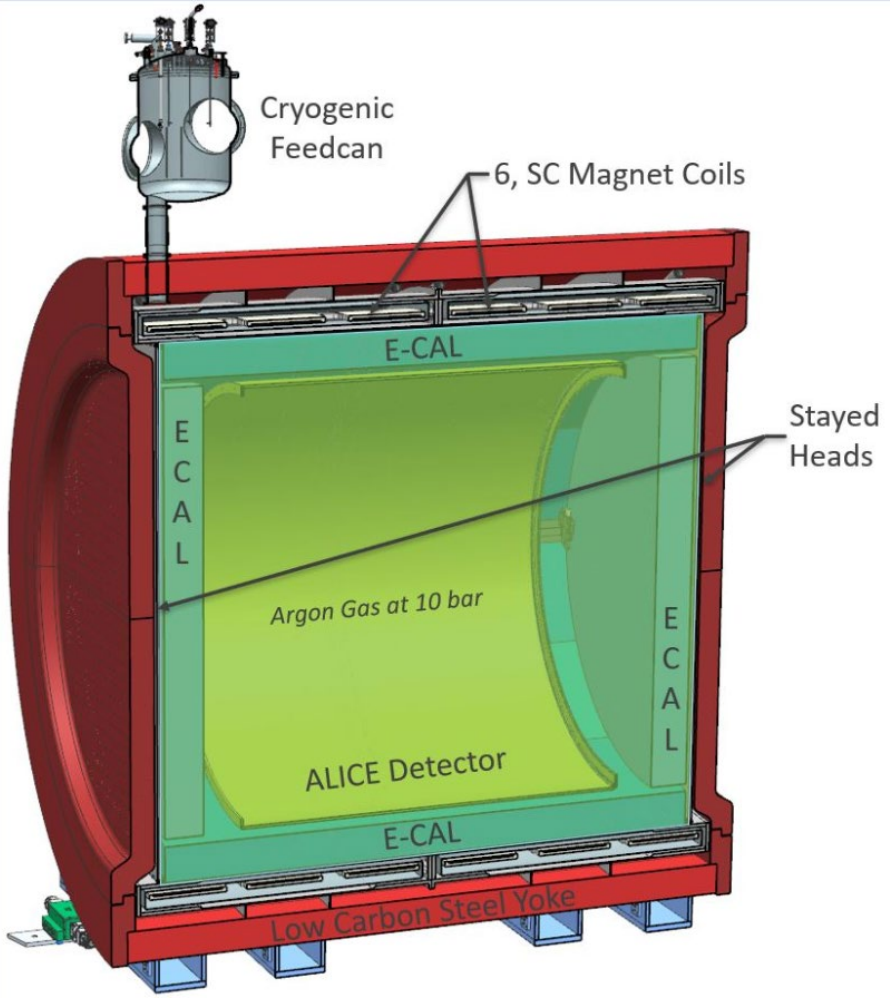
Many thanks to Leo for code fixes, Tom/Leo for software help, Eldwan Brianne for implementing the geometry

Latest Geometry

- New ECAL geometry –
  - 42 layers of Pb-Scintillator sandwich (~ 10.5 X_0) – tiles & strips
    - Barrel:
      - Scintillator: 8 layers - each 0.5 cm, and 34 layers - each 1 cm
      - Pb – 8 layers, each 0.7 mm thick, 34 layers, each 1.4 mm thick
    - Endcaps are 6 + 36 layers
  - Barrel has 12 fold symmetry
  - Newly optimized SPY magnet and cryostat as the pressure vessel
    - No extra material between the ECAL and TPC



TPCRadius = 273 cm, TPCLength = 259

TPCFidRadius = 222.5, cm TPCFidLength = 215

ECALInnerRadius = 278, ECALOuterRadius = 334 cm

ECALStartX = 328 , ECALEndX = 375 cm

Introduction

- Last year, I showed results with reconstructed information for neutrino events:
  - *About 9% of simulated hits in the endcap strips were being lost during digitization*
  - Leo fixed the problem, and we thought that was the end of it
    - "…traced the problem to somewhere in the guts of ROOT, *TGeoNavigator::FindNode(Double_t, Double_t, Double_t)* specifically. Looking at the release notes for the last 3 (minor) versions of ROOT, I don't see anything was done to this routine, but the real issue could be elsewhere. "

- This summer Reth and I have been studying Track-Cluster association, where we used single particle samples (positrons, photons, muons, etc.) and populated different parts of the CALO
  - The problem has reared its ugly head again!

From 2023: Missing DigiHits problem – how often SimHits are being discarded

	Barrel Tile	Barrel Strip	Endcap Tile	Endcap Strip
% failed before Leo's fixes*	0 out of 9K	0 out of 55K	0 out of 3.9K	~1000 out of 9K
% failed after Leo's fixes*	1 out of 22.7K	0 out of 81K	1 out of 3.6K	89 out of 10.3K

*Caveat – in the old sample, I had not saved Sim/Digi Layer numbers, so deciding what is tile/strip required cuts on X,Y,Z, of the hits

In the new samples, I simply use the layer numbers to decide whether the hit is in the tiles or in the strips

(I do need to use X, Y, Z to decide whether endcap or barrel, so there may be some edge effects)

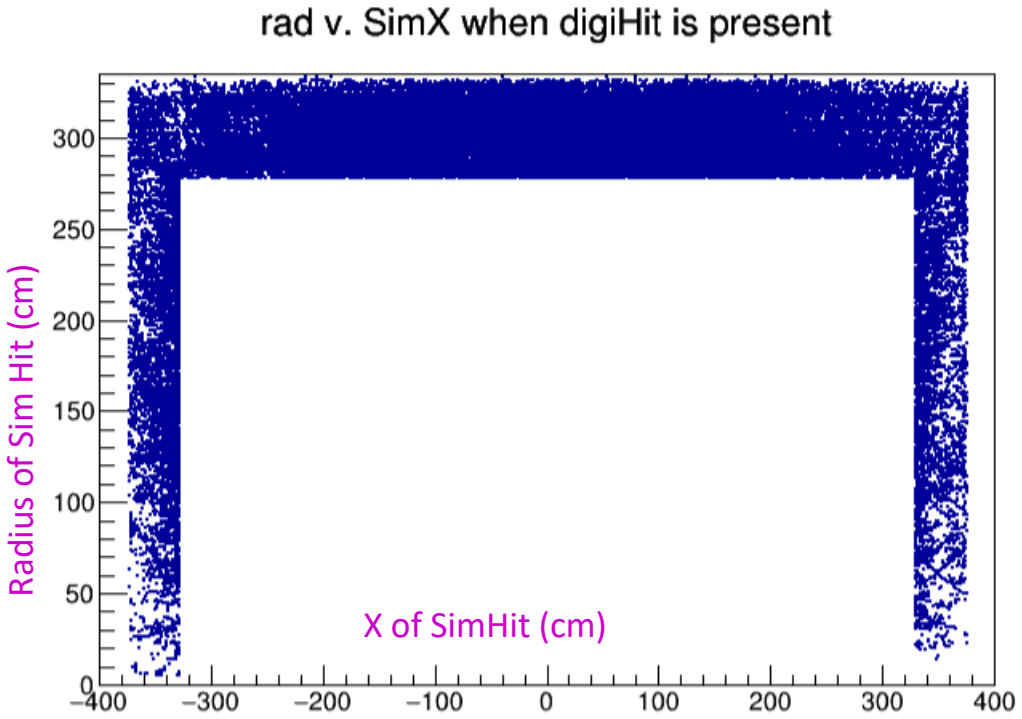
Background: the problem can be seen in CalculatePosition() in garsoft/ReadoutSimulation/ECALReadoutSimStandardAlg.cxx

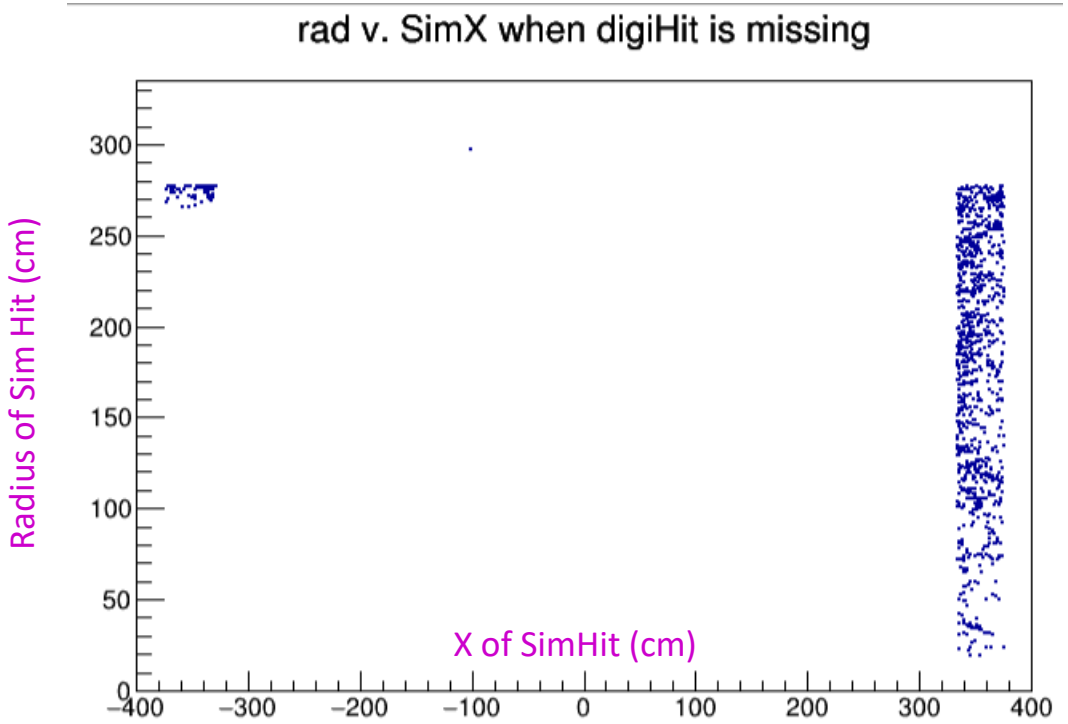
As far as Lorenz and I have understood, the "World" location of the SimHit is first transformed into a "Local" location. This "Local" position is then shifted to where the SiPM is located, and then the "new Local" position is transformed back into a "new World" position.

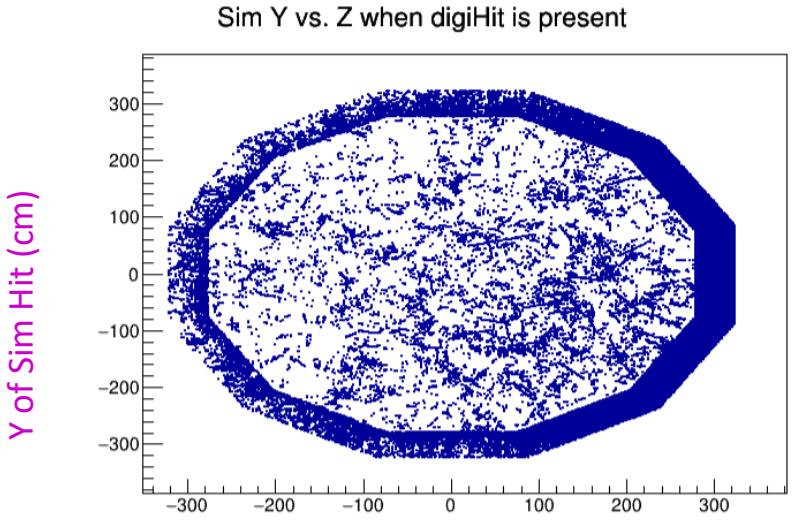
At this point, the nodenames of the old and new World locations are compared. If they are different, the hit is not digitized

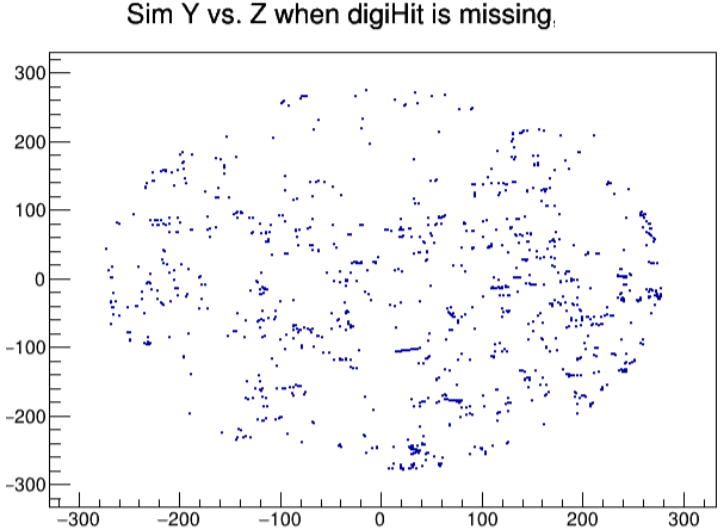
From 2023:

Plots of old sample, i.e., before Leo's fixes



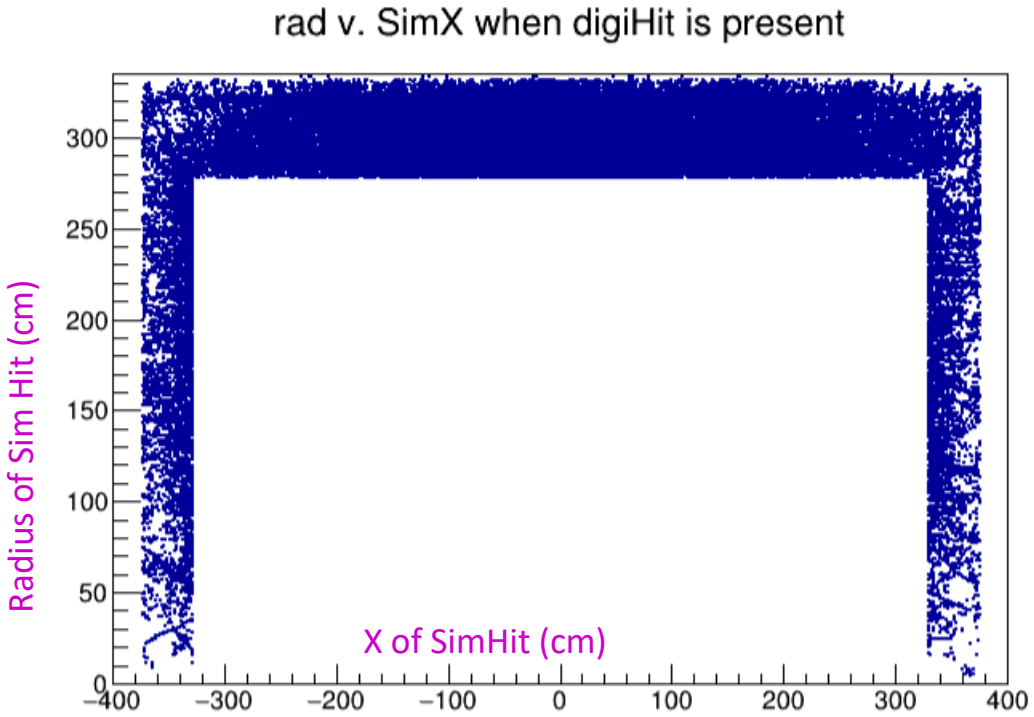


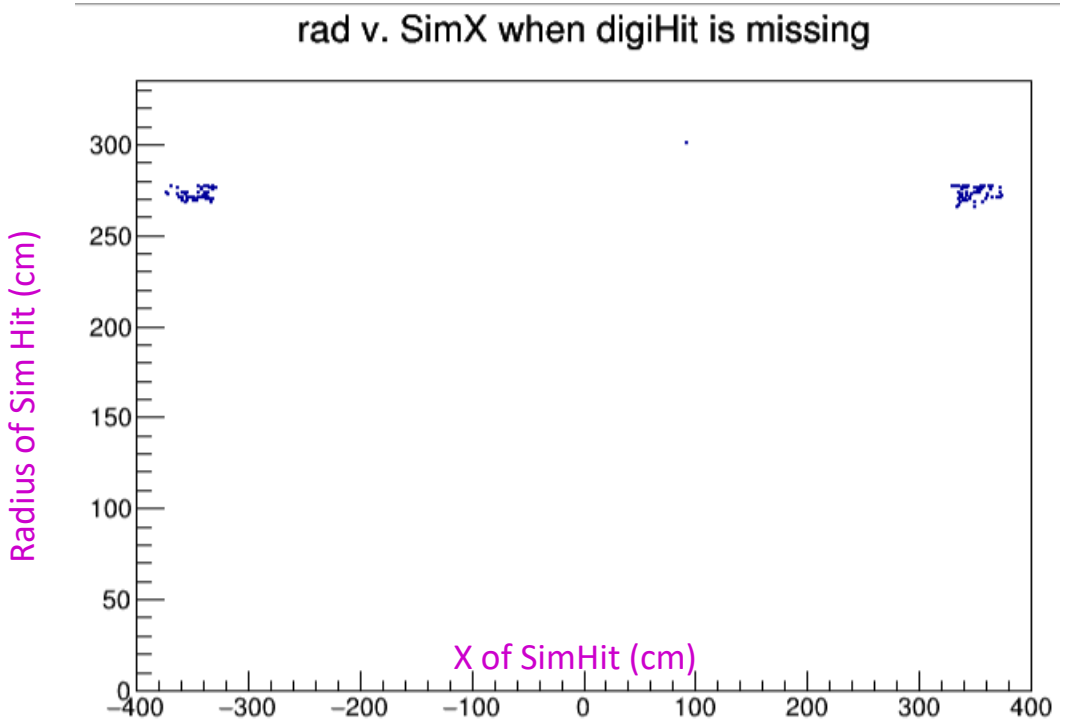


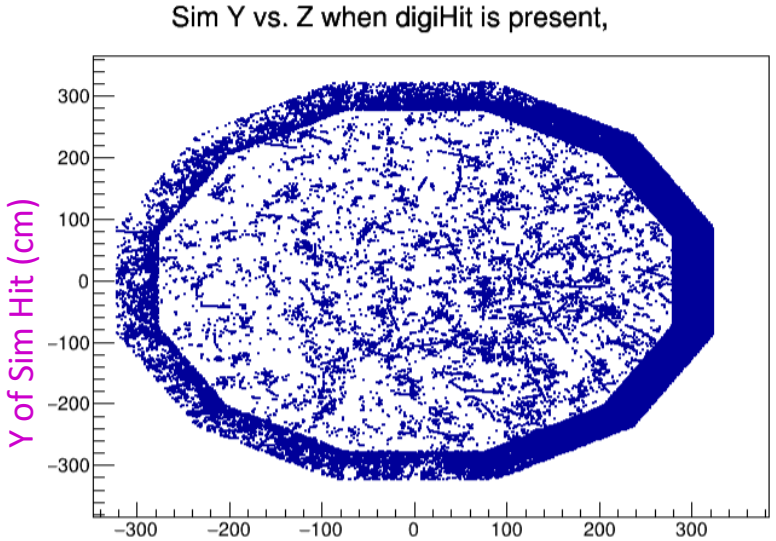


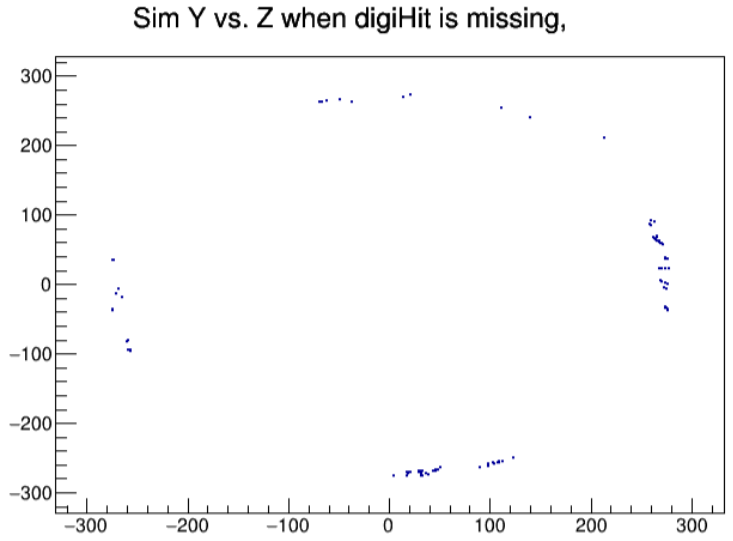
From 2023:

Plots of new sample, i.e., after Leo's fixes









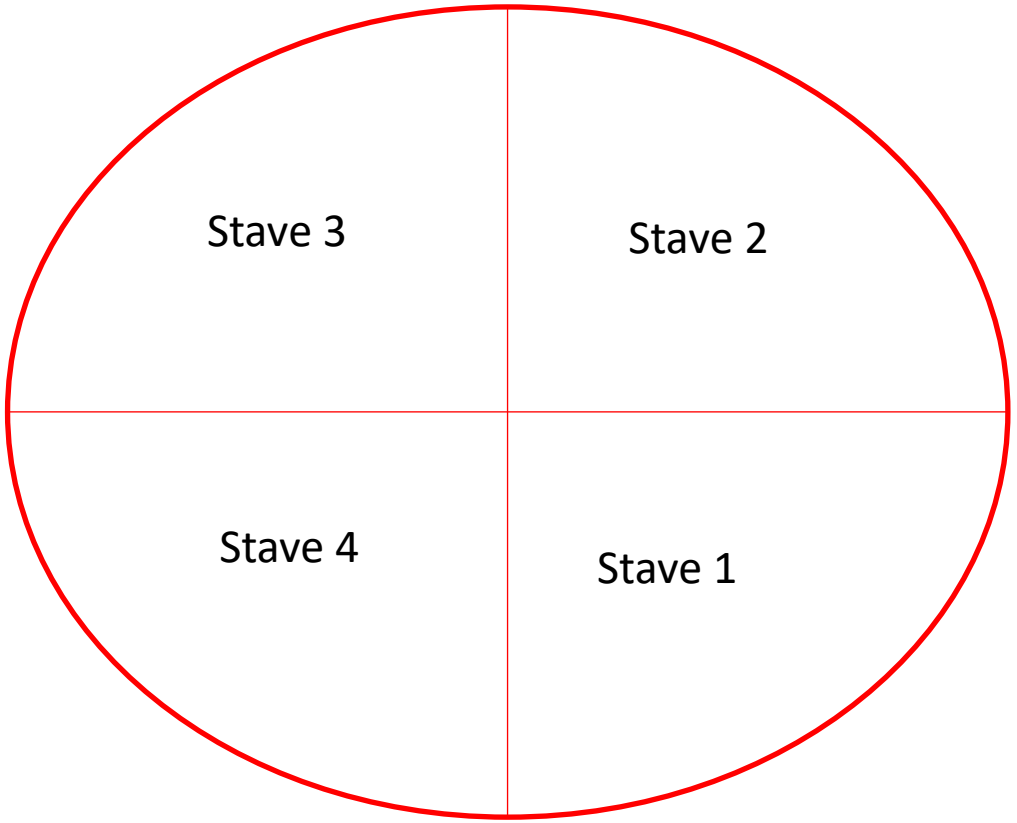
Leo: *'That's interesting. Might be in our GeoManager and the "IsEndcap" or "IsBarrel" methods. Might not!'*

Nomenclature

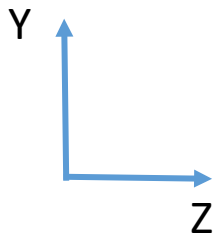
- ECAL is made up of detector id, staves, modules, slices and layers – these are used to encode the CellID (which is being used during digitization)
  - det_id = 1 (Barrel ECAL), = 2 (Endcap ECAL) [Yoke barrel appears to be 4]
  - Barrel ECAL: has 12 staves (as you go around in phi)
    - Module = 1 for Tile, = 2 for Strips
    - Slice = 1 for absorber, = 2 for Scintillator (for Tiles 3 is for PCB)
    - Layers go from 1 to 42 (first 8 are tiles, remainder are strips)
  - Endcap ECAL: has 4 staves, appear to match the four quadrants
    - Module: = 0 for negative X, = 3 for positive X. no distinction between strips/tiles??
    - Slice = 1 for absorber, = 2 for Scintillator
    - Layers go from 1 to 42 (first 6 are tiles, remainder are strips)
- Nodenames (in the code) look like
  - BarrelECal_stave10_module02_layer_21_slice2_vol_0
  - EndcapECal_stave02_module03_layer_13_slice2_vol_0

Staves in the Endcap – results based on hand scanning output in log file

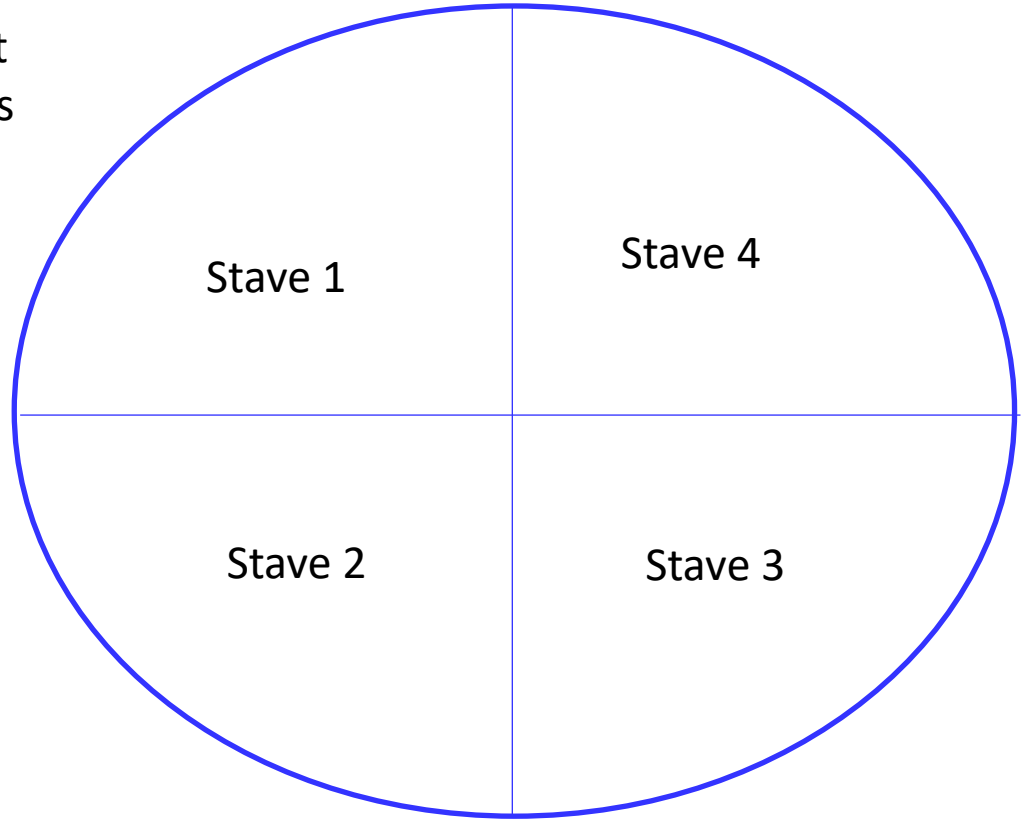
Module 0, i.e X < 0



Boundaries are not along the Y & Z axes
There is small amount of slop across the axes



Module 3, i.e X > 0



From 2023: Some examples of changed node names (since this is from debug statements in the code, there is NO fiducial volume cut on the neutrino vertex) – X,Y,Z measured relative to center of ND-GAr

- Based on 206 debug statements in log file . Mainly two kinds of isssues:

  - Nodename after is *volMPD* (106 out of 206 cases)
    - ND-GAr X,Y,Z 334.3 , -31.1 , 275.8
      - Before: EndcapECal_stave03_module03_layer_07_slice2_vol_0
      - After: volMPD_0 ????

  - Hit moves from *endcap* to *Barrel* (99 out of 206 cases) – new position is usually in the tile - layer 1 (27 times), 4 (43 times), or 7 (15 times), but in 14 cases it moved to layer 9, i.e., a strip layer

    - ND-GAr X,Y,Z -354.984 , -69.4758 , -269.161 (radius = 278 cm)
      - Before: EndcapECal_stave04_module00_layer_25_slice2_vol_0
      - After: BarrelECal_stave05_module01_layer_09_slice2_vol_0

  - Third kind (just came once)
    - ND-GAr X,Y,Z 91.7, 212.4, 213.2
    - Before: BarrelECal_stave11_module02_vol_0 (why isn‘t there a layer/slice number??)
    - After: BarrelECal_stave11_module02_layer_23_slice2_vol_0

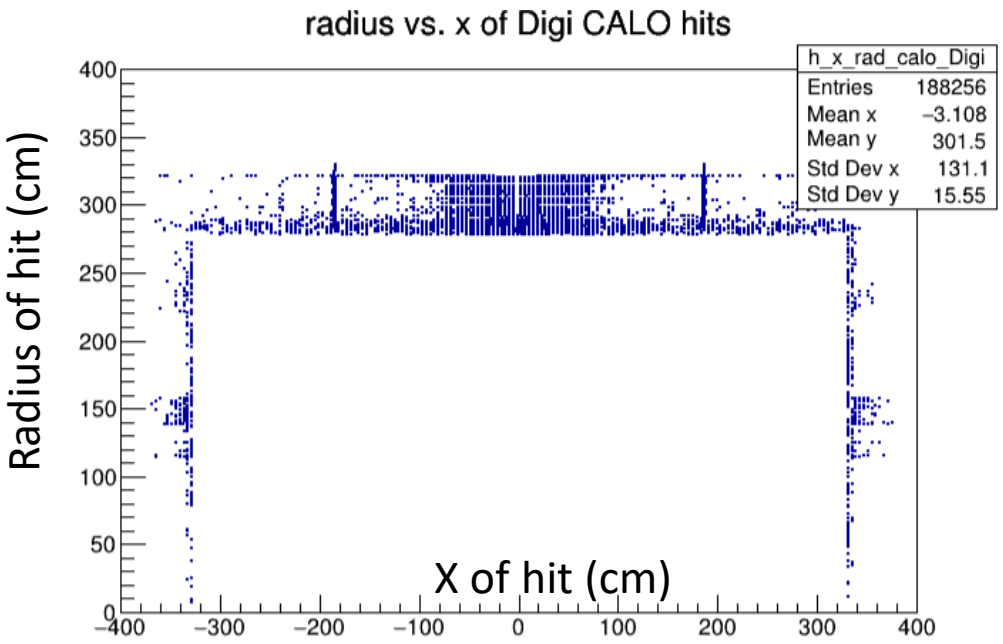
From 2023: Preliminary conclusions for the digitization problem

- Less of an issue than in the past, but it may be pointing to a problem in how the geometry is being done, either in the gdml file or in Geant
  - From Leo: *"The problem is that this information is in the gdml file, and Eldwan kept changing conventions as he tried different geometries."*

New Information – Summer'24

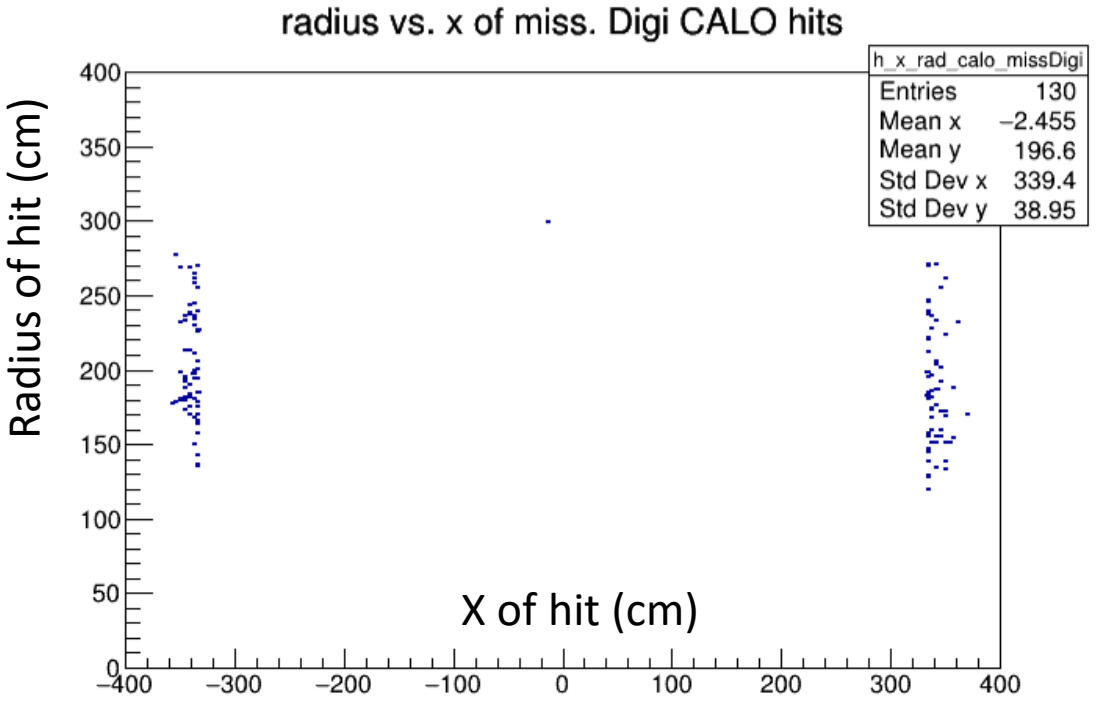
- Using single positron samples
  - They start at the center of the TPC, with momentum distributed between either 0-6 GeV or 3±1 GeV
  - We shoot them at different parts of CALO:
    - Downstream barrel – along the beam direction
    - Endcap – illuminate the entire (positive) endcap –
      - Not very careful in setting the angular distribution of the positrons and about ~ 20% of hits are in the barrel

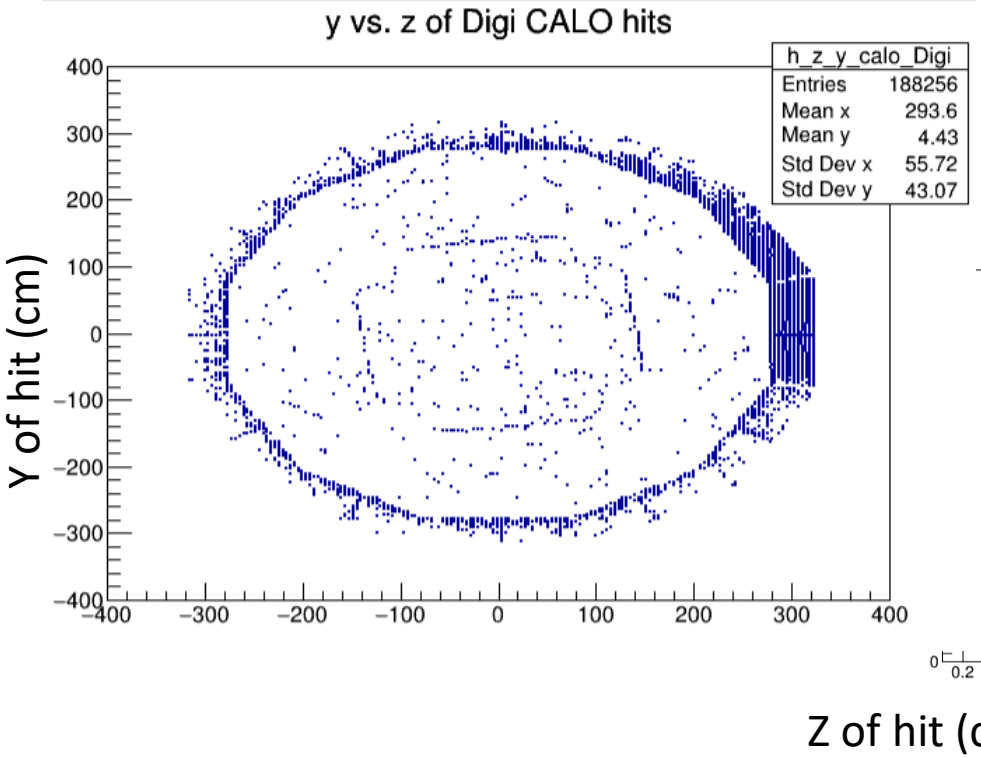
- Plot location of found DigiHits and when they are missing use locations of SimHits

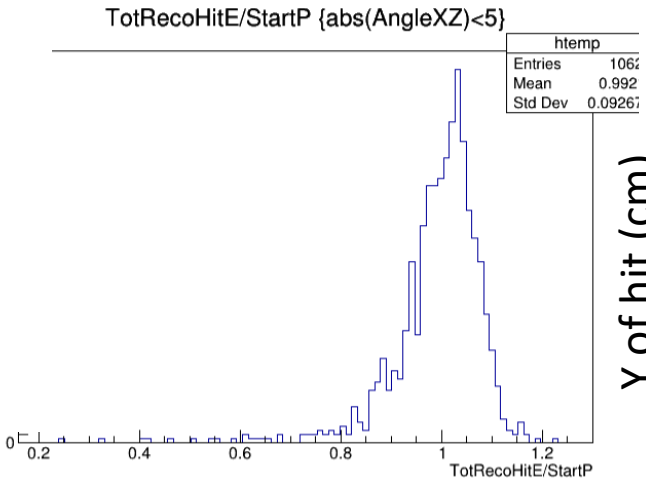


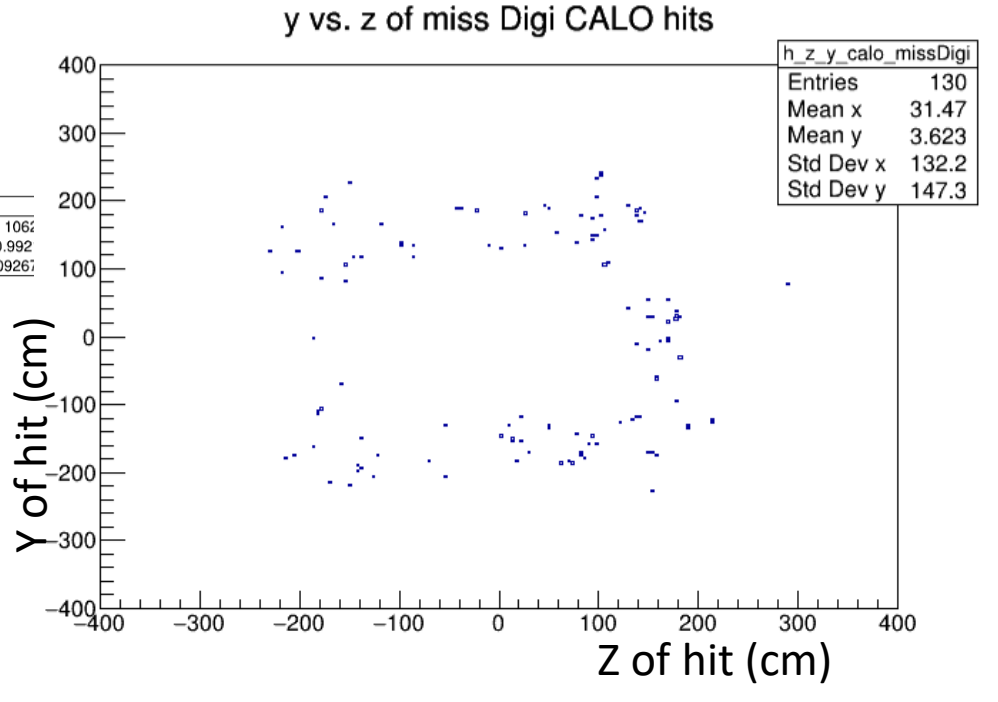
Positrons shot at downstream barrel along beam direction

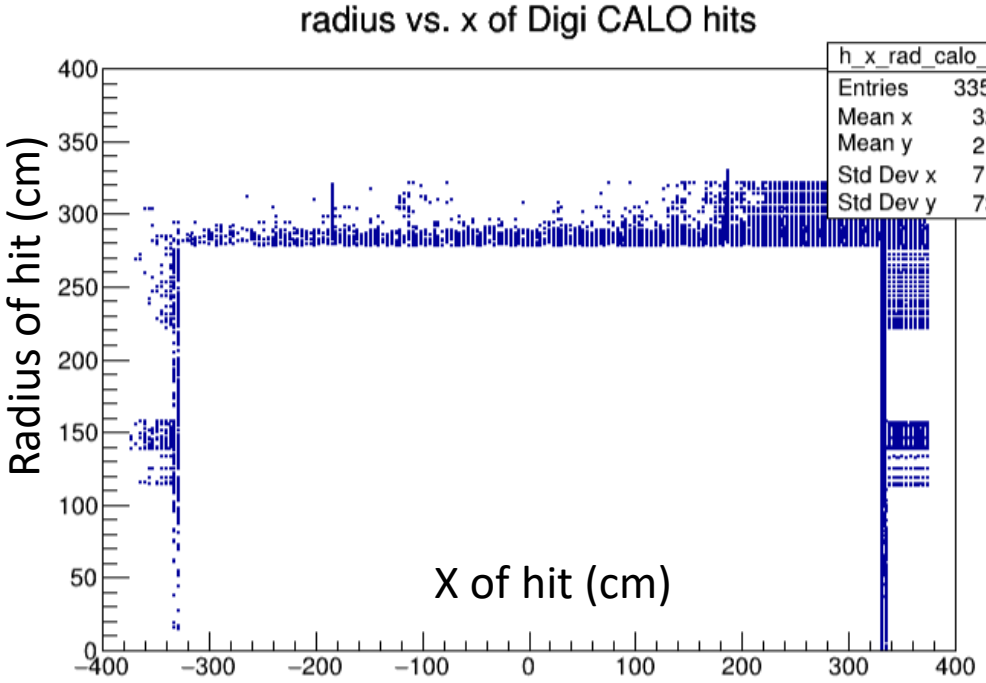
Barrel looks fine:
Missing DigiHits
Are all in Endcap





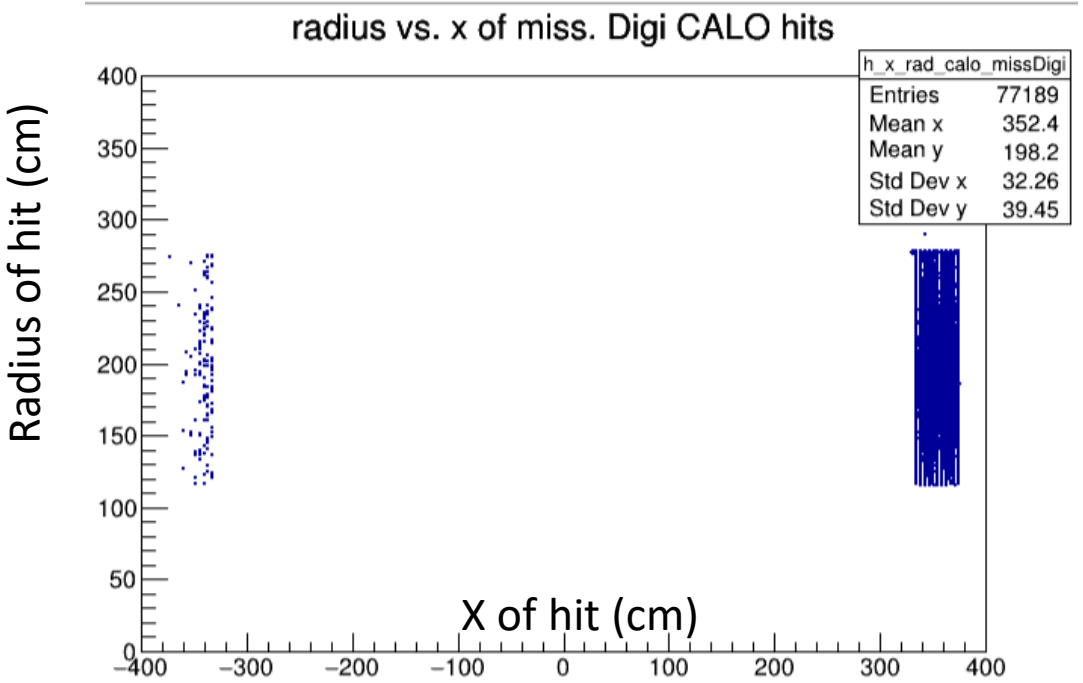


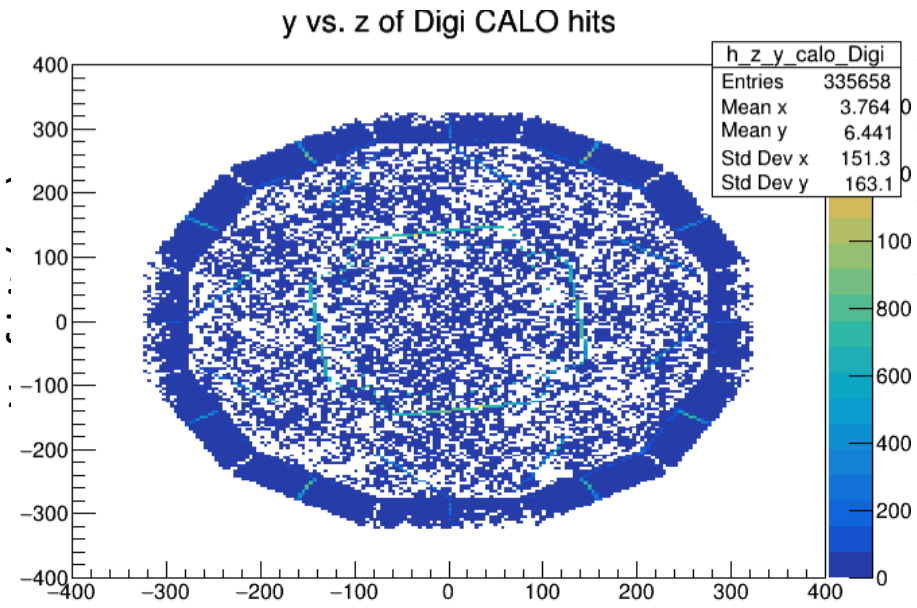


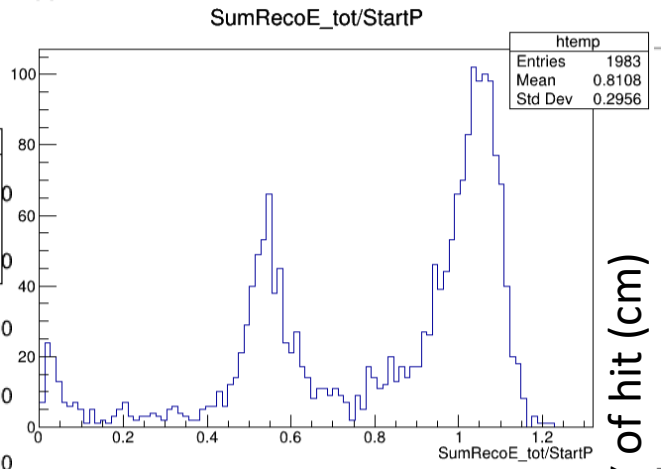


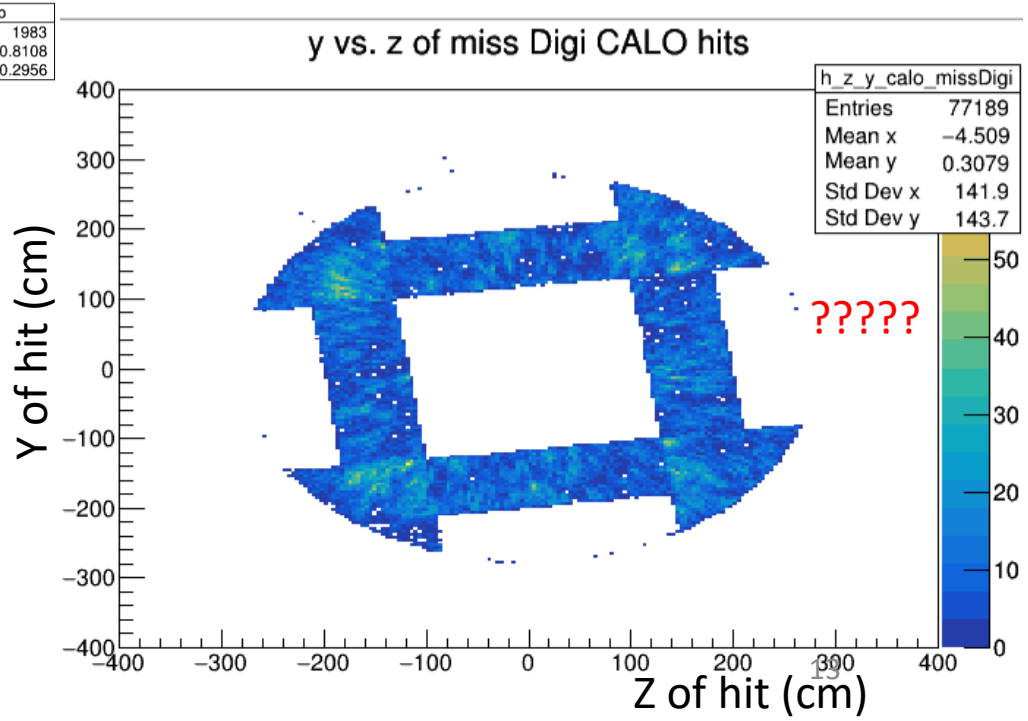
Positrons shot at Positive Endcap

Barrel looks fine:
Missing DigiHits
Are all in Endcap









Here two hits are close by, but end up differently

- Put in some debug statements in the ReadoutSim code
- CalculatePosition() <------ Dropping the hit
- ND-GAr X/Y/Z 334.64, -24.58, -140.08
- isTile 0
- Strip length 236.441
- Local Point before new position (6.086, 142.09, -0.432) in node EndcapECal_stave02_module03_layer_*08*_slice2_vol_0
- Local Point after new position (-214.85, 142, 0) in node EndcapECal_stave01_module03_layer_08_slice2_vol_0

- CalculatePosition() ----> Found the hit
- ND-GAr X/Y/Z 335.82, -24.82, -139.91
- isTile 0
- Strip length 238.75
- Local Point before new position (6.343, 141.95, -0.394) in node EndcapECal_stave02_module03_layer_*09*_slice2_vol_0
- Local Point after new position (6, 139.0, 6.9528e-310) in node EndcapECal_stave02_module03_layer_09_slice2_vol_0

CalculatePosition() <------ Dropping the hit

ND-GAr X/Y/Z 336.876, 67.0224, 109.744
isTile 0
Strip length 252.607
Local Point before new position (52.1275, 117.554, -0.479176) in node EndcapECal_stave04_module03_layer_10_slice2_vol_0
Local Point after new position (-13.8559, 118, 0) in node EndcapECal_stave03_module03_layer_10_slice2_vol_0

CalculatePosition() ----> Found the hit

ND-GAr X/Y/Z 347.149, 72.9773, 95.1628
isTile 0
Strip length 259.535
Local Point before new position (59.9347, 103.875, -0.484471) in node EndcapECal_stave04_module03_layer_19_slice2_vol_0
Local Point after new position (58, 139.005, 6.9528e-310) in node EndcapECal_stave04_module03_layer_19_slice2_vol_0

More from debug statements

- One of the local coordinates changes a lot, and that screws up the nodename:
  - CalculatePosition() <------ Dropping the hit

  ND-GAr X/Y/Z 338.044, -83.4927, 132.569

  isTile 0

  Strip length 261.844

  Local Point before new position (120.538, 100.079, -0.452597) in node EndcapECal_stave03_module03_layer_11_slice2_vol_0

  Local Point after new position (118, -13.8559, 6.9528e-310) in node EndcapECal_stave04_module03_layer_11_slice2_vol_0

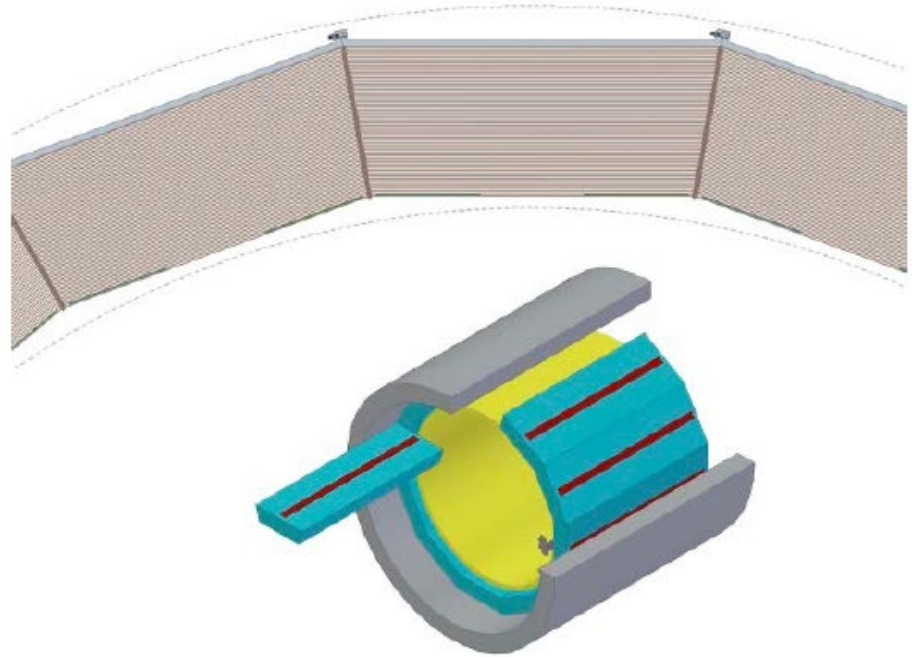
Summary

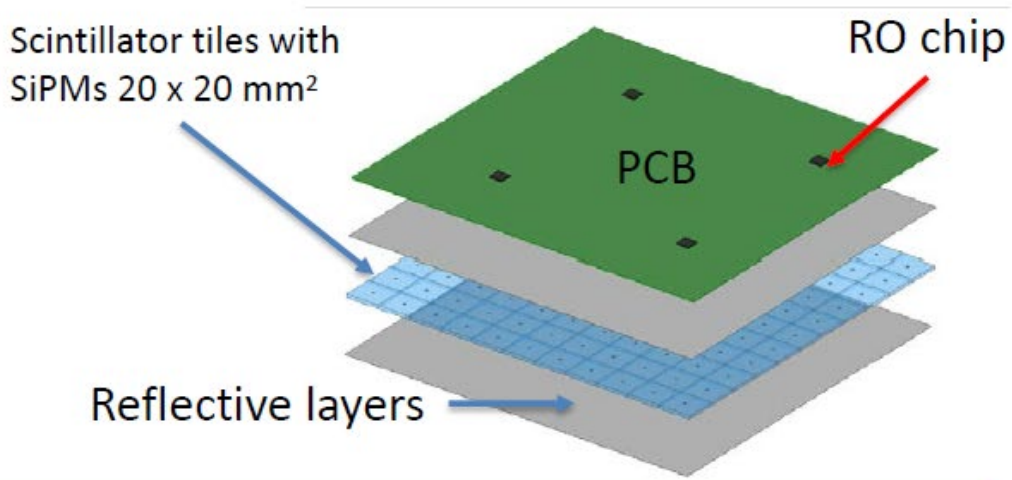
- Clearly there is a problem
  - I am not a Geometry expert
    - Tom J. had sent me an e-mail about it a while back, and it has been on my to-do
- Will generate samples where we fully illuminate the downstream and upstream barrels, and see if there are other “problem areas”

Extra –

ECAL: Engineering status

- Based on the ILD design
- Preliminary designs
  - Check ECAL space between TPC/Magnet and put in realistic tolerances.
  - First ideas on how to fix the ECAL
    - Self-supporting
    - Individual rails
  - Module/Layer design: Lead too soft/toxic - most likely in a super-module" made in carbon fiber





From a talk by either Alan or Eldwan