ATHENA Barrel HCal Update

Henry Klest

Calo WG Meeting 10/11/21
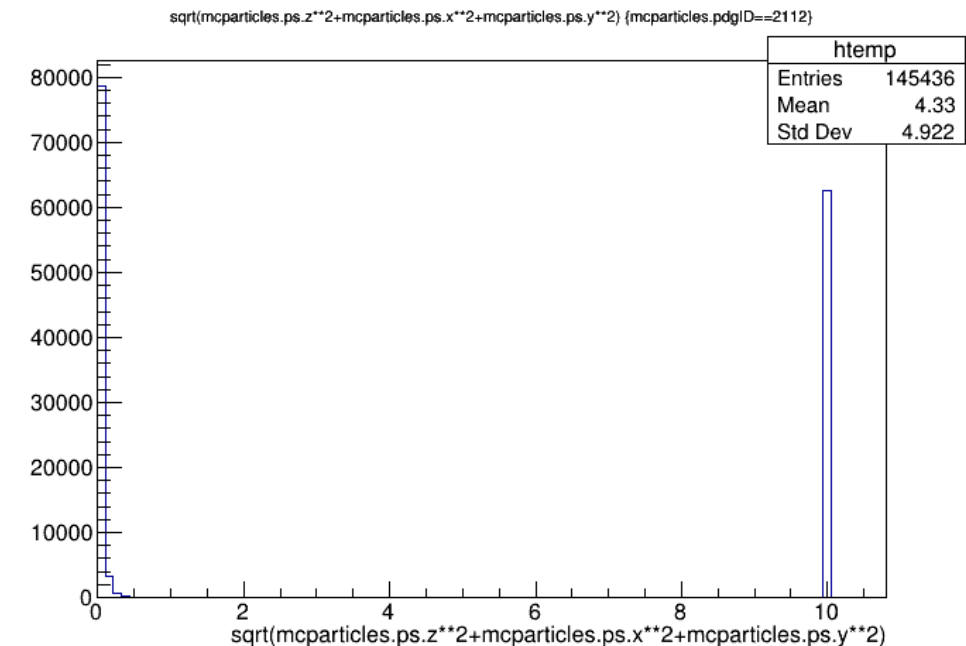
Preface: Neutron Event Sample

Note: Magnet in the iteration I'm analyzing is ~2.2 λ, surprisingly no improvement in clustering efficiency seen, still 8% for 10 GeV n

- In 10 GeV neutron barrel sample, some non-neutrons, some particles with small momenta

- Need to put in some qualifiers to make sure that particles I'm looking at are actually 10 GeV neutrons

- Possible that this is somehow biasing things, not sure what else I can do to make sure I'm looking at the right particles

sqrt(mcparticles.ps.z**2+mcparticles.ps.x**2+mcparticles.ps.y**2) {mcparticles.pdgID==2112}

htemp	
Entries	145436
Mean	4.33
Std Dev	4.922

sqrt(mcparticles.ps.z**2+mcparticles.ps.x**2+mcparticles.ps.y**2)

HCal Hits – Info from Oleg/Calo Readout Table

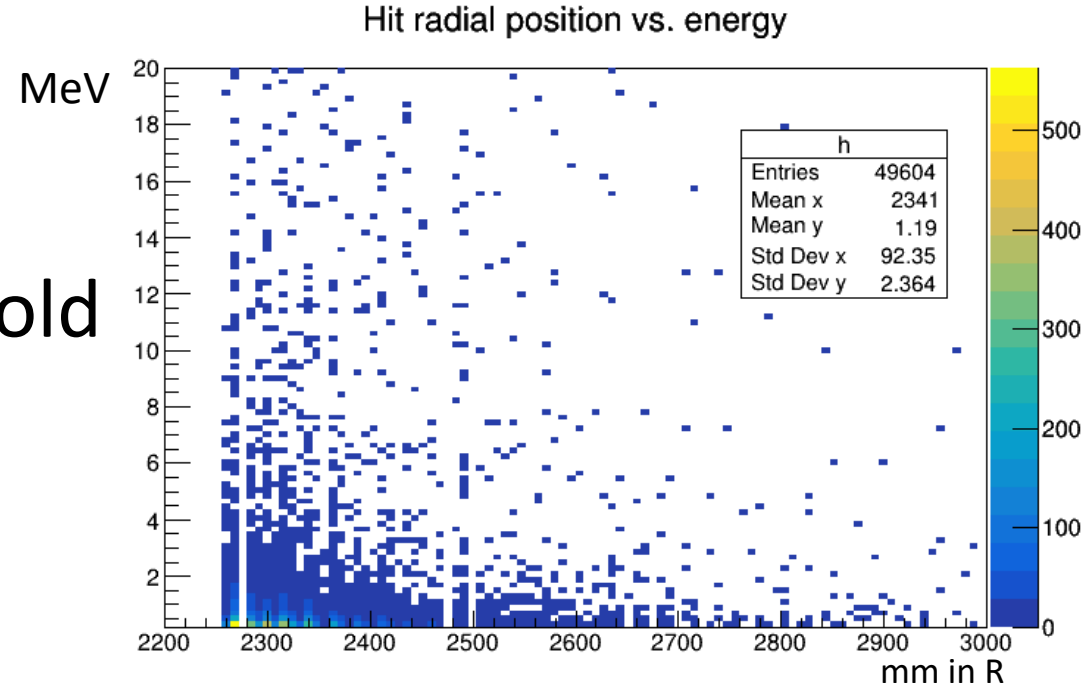| Detector	Sub-system	Readout Unit	GEANT Max Energy Deposition	ADC Resolution	Pedestal (ADC counts)	Pedestal Sigma (ADC Counts)	Threshold (ADC counts)
	n-EMCal PWO	Tower	20 GeV	14 bit	100	1	3
	n-EMCal SC Glass	Tower	20 GeV	14 bit	100	1	3
	n-Hcal (KLM type) (10 la	Scint. Tile (individual til	20 MeV	8 bit	20	0.3	2
	p-EMCal	Tower (sum 796 fibers)	3 GeV	14 bit	100	0.7	1
	p-Hcal	Tower (sum 51 tiles)	3.6 GeV	10 bit	20	0.8	3
	b-Hcal (KLM Type) (5 lay	Scint. Tile (individual til	20 MeV	8 bit	20	0.3	2
	b-Ecal (ScFI part)	Sub-Layer (one light gui	750 MeV	14 bit	20	0.5	1
	b-Ecal (Si layers)	Pixel					

- 5 layers of scintillating tiles, 10 cm x 10 cm squares
- 8-bit ADC: 256 counts
  - Pedestal is 20 ADC counts, $\sigma_{Ped.} \approx 0.3$ ADC units
  - Threshold is 2 ADC counts
- GEANT maximum energy deposition in one tile is 20 MeV
  - Say ~230 available ADC counts to span range of 0-20 MeV, One ADC count is ~0.09 MeV
- Minimum energy is = 2 ADC counts ~ 0.18 MeV

HCal Hits

- Event sample is 49k 10 GeV neutrons
  - **Multiple hits allowed per event**
  - Couldn't figure out a good way to access N_{hits} per particle thrown

- 17% is maximum possible hit above threshold rate, if only 1 hit/event
  - Reco clusters were roughly correct?

- Peak energy deposit is at very beginning of Hcal

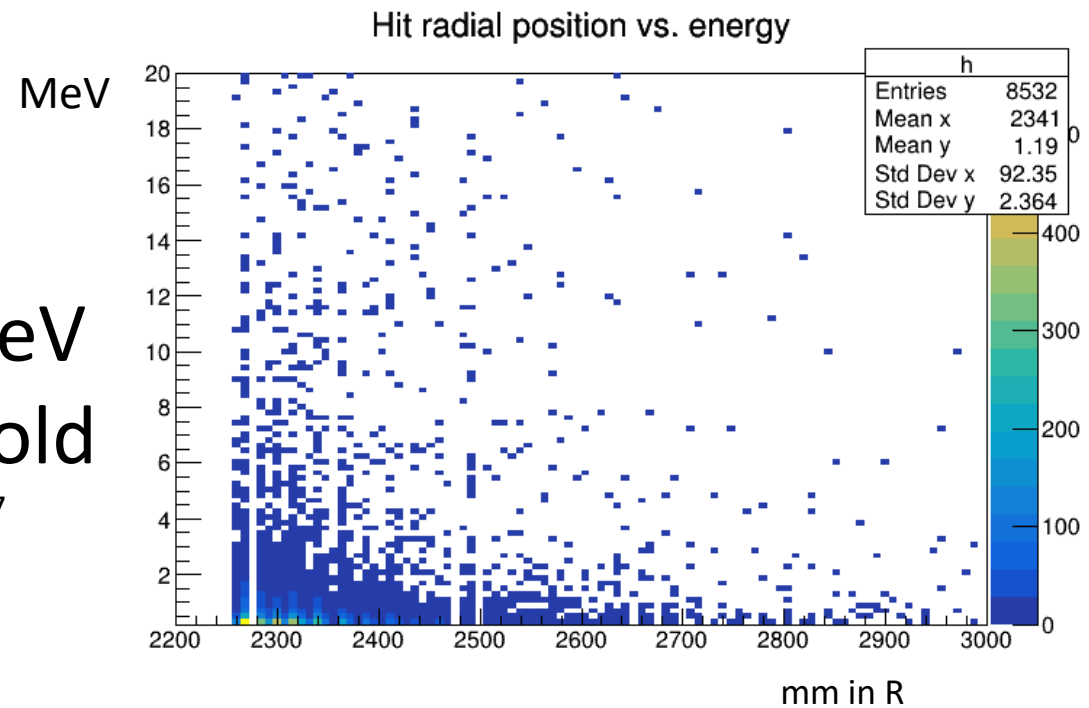- Number of hits seems low based on prior study of reco-level clusters

No Threshold

$N_{hits}/N_{thrown} \sim 1$

0.18 MeV Threshold

$N_{hits}/N_{thrown} \sim .17$

Hit radial position vs. energy

h	
Entries	49604
Mean x	2341
Mean y	1.19
Std Dev x	92.35
Std Dev y	2.364

Hit radial position vs. energy

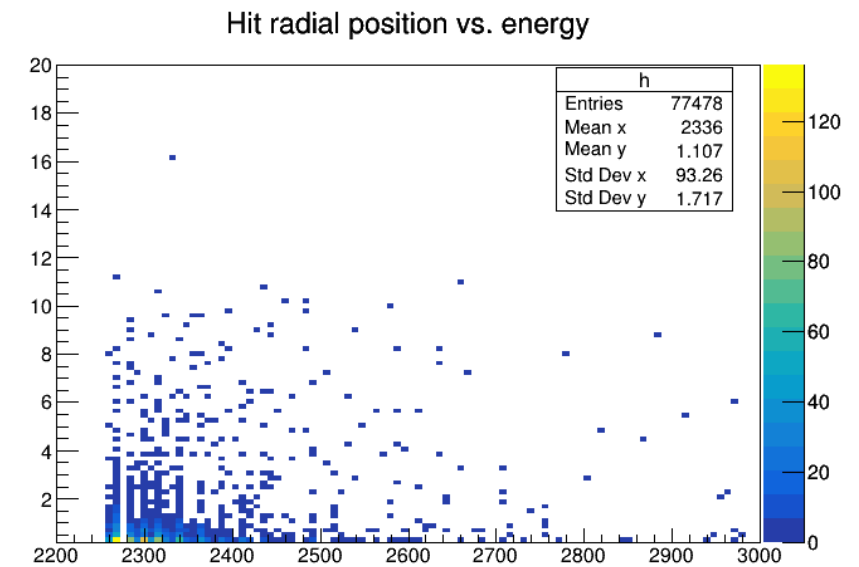| h	
Entries	8532
Mean x	2341
Mean y	1.19
Std Dev x	92.35
Std Dev y	2.364

HCal Hits

- Event sample is 110k 2 GeV neutrons

- Fewer hits observed, as expected
  - Not so much less

- After magnet shift, forward angles now open for "barrel" neutrals to hit HCal more directly?

No Threshold

$N_{hits}/N_{thrown} \sim .7$

0.18 MeV Threshold
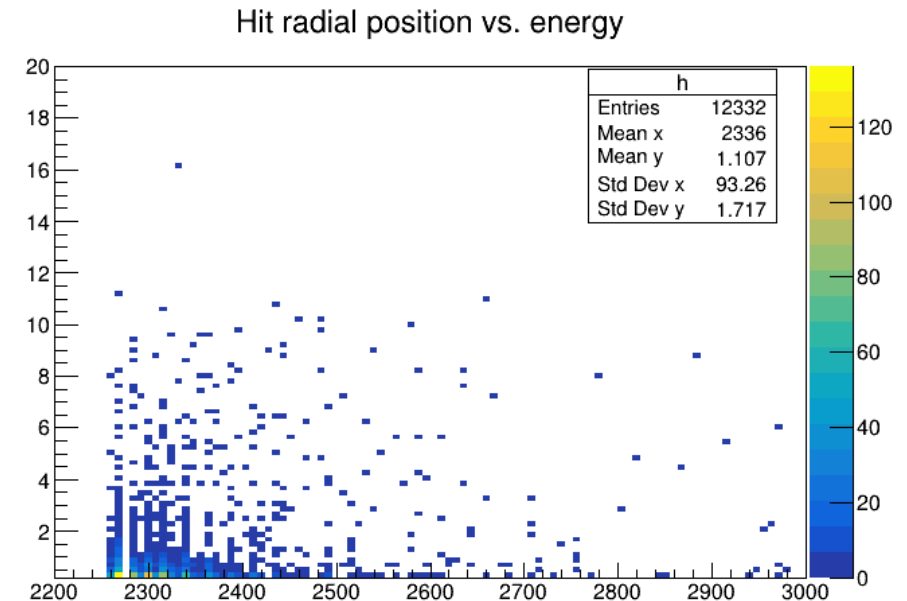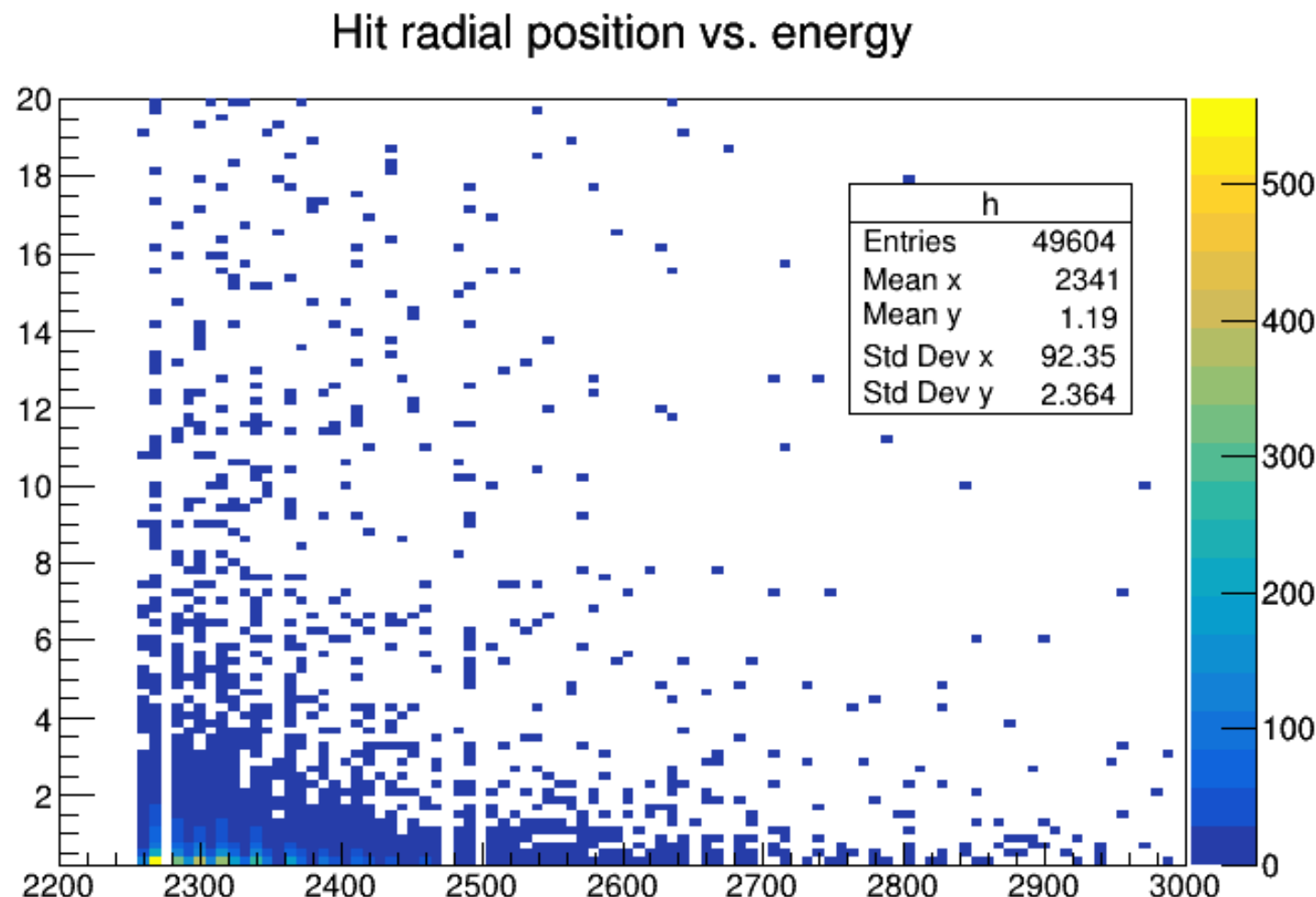
$N_{hits}/N_{thrown} \sim .11$
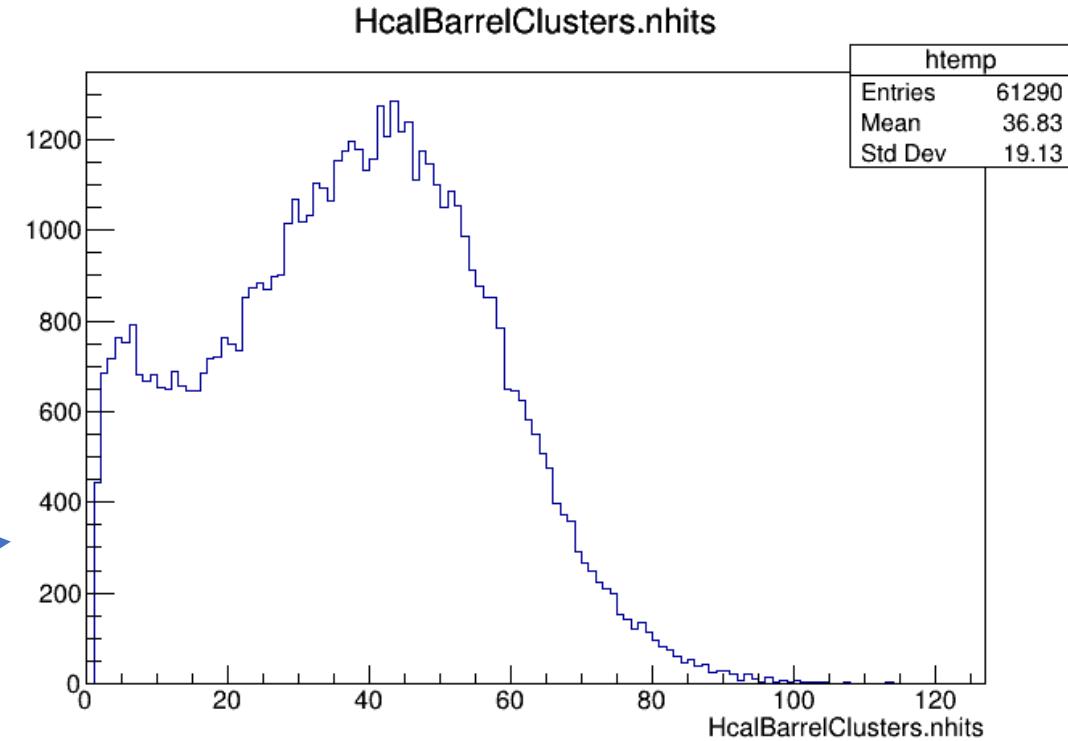
Dynamic Range

- Small sample size here, but not so many hits out to 20 MeV
  - Large majority of hits < 1 MeV
    - Majority < 0.18 MeV Threshold
- Decrease 20 MeV maximum?

Sub-system	GEANT Max Energy Deposition
n-EMCal PWO	20 GeV
n-EMCal SC Glass	20 GeV
n-Hcal (KLM type) (10 la	20 MeV
p-EMCal	3 GeV
p-Hcal	3.6 GeV
b-Hcal (KLM Type) (5 lay	20 MeV
b-Ecal (ScFi part)	750 MeV
b-Ecal (Si layers)	

Hit radial position vs. energy

h	
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Mean y	1.19
Std Dev x	92.35
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Reco to Full Comparison

HcalBarrelClusters.nhits

htemp	
Entries	61290
Mean	36.83
Std Dev	19.13

- RECO: 596679 10 GeV neutrons fired, 48025 clusters reconstructed
    - ~8% cluster reconstruction rate
    - ~40 hits/cluster?
    - How is a "hit" defined in reco files?

- FULL: 49622 10 GeV neutrons fired, 49604 total hits measured
    - 8532 hits above threshold, max of 17% in 1 hit/event limit

- Has Hcal readout been updated yet?
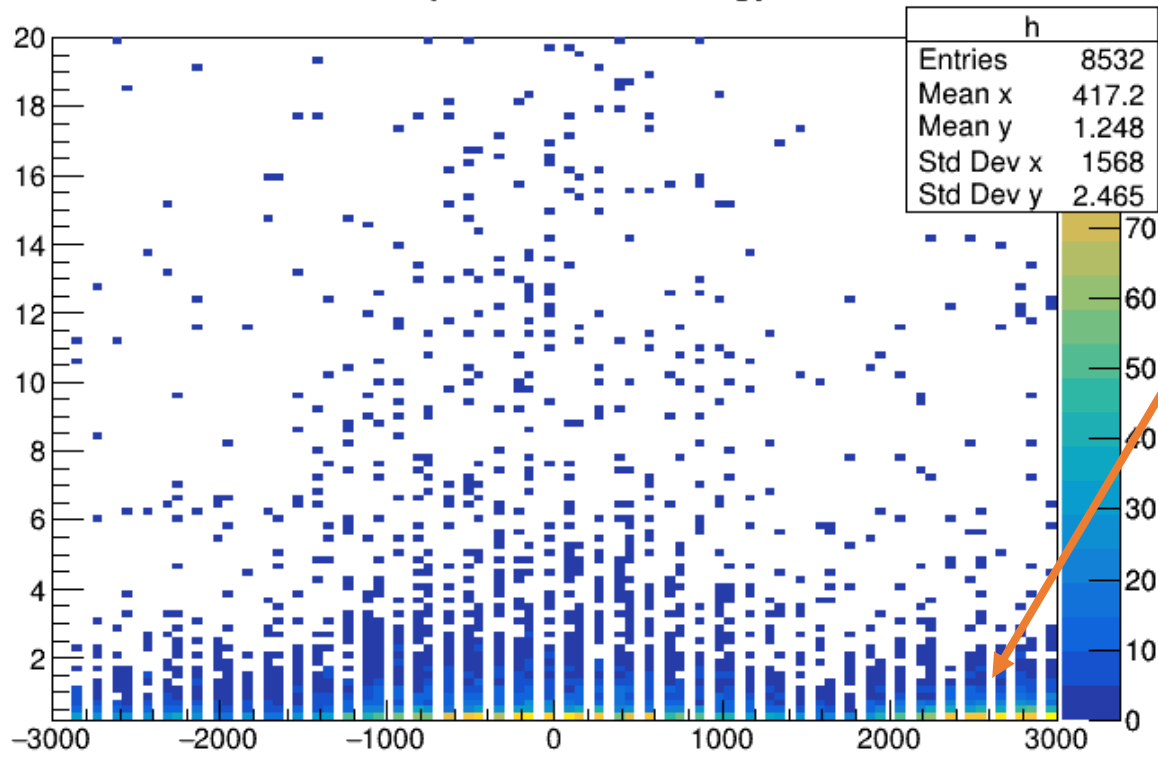
```
# Central Barrel Hcal
cb_hcal_daq = dict(
        dynamicRangeADC=50.*MeV,
        capacityADC=32768,
        pedestalMean=400,
        pedestalSigma=10)
```

From:
https://eicweb.phy.anl.gov/EIC/benchmarks/reconstruction_benchmarks/-/blob/master/benchmarks/clustering/options/full_cal_reco.py
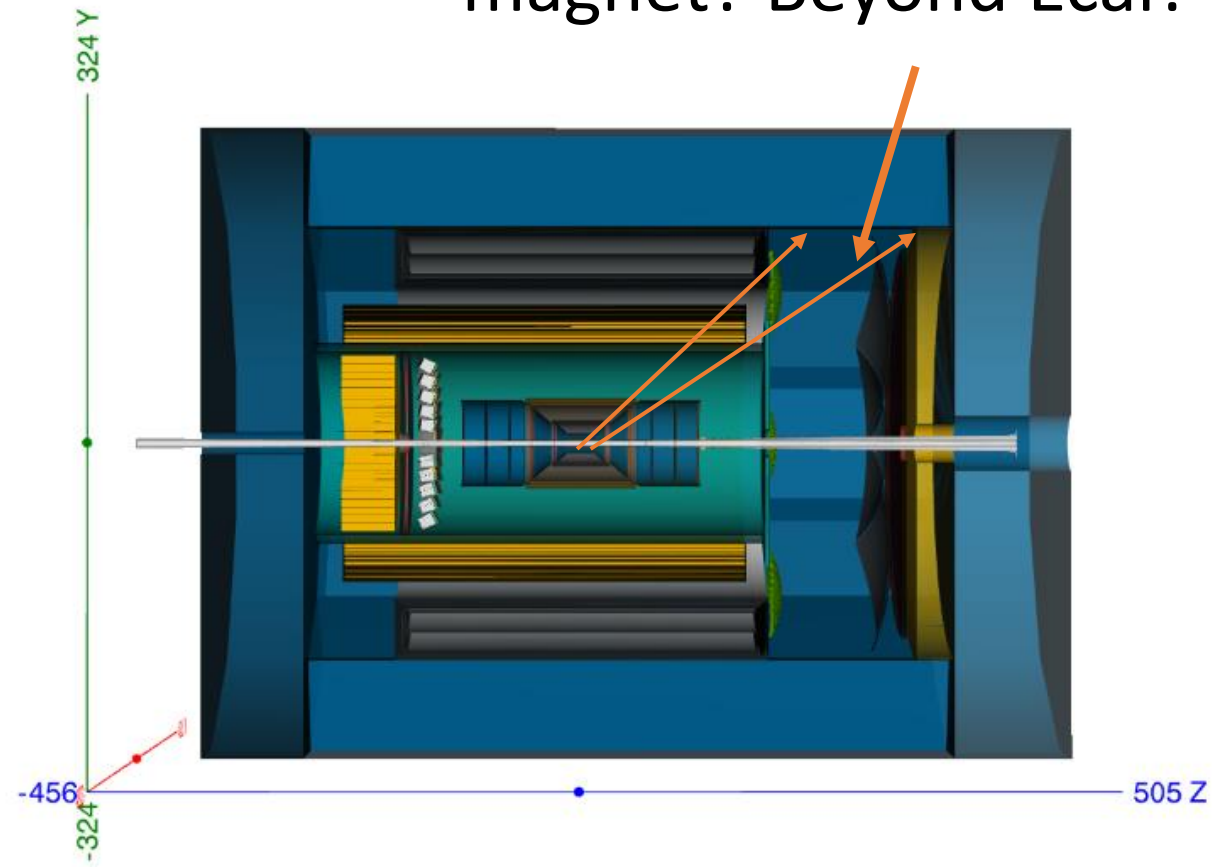
Hit z position vs. energy

h	
Entries	8532
Mean x	417.2
Mean y	1.248
Std Dev x	1568
Std Dev y	2.465

10 GeV Neutrons

0.18 MeV Threshold

$N_{hits}/N_{thrown} \sim .17$

Increase in N_{hits} to high Z, but not low Z

From angle beyond magnet? Beyond Ecal?

Summary

- Based on hit data, seems like the cluster data for the barrel HCal is in the right order of magnitude
  - Still needs some double checking
- Some inconsistency between reco and full sim, namely N_{hits} in a cluster
  - Lower threshold?
- With magnet movement, forward angles should now have better HCal efficiency for neutrals, including lower energy neutrals

Backup

"Efficiency" (Fraction with > 0 Clusters)

- Neutron efficiency even lower than K_L except at 20 GeV
  - Less likely to interact in the Ecal at lower energies
  - K_L Decays easier to detect

- Sanity Check: $e^{-4} \sim .02$, $e^{-2} \sim .14$
  - Showers in magnet can still leave energy in Hcal
  - If a shower can longitudinally extend by 2 λ_0, then results are sensible
  - Would naively expect even less coming out of magnet than seen here

Species	Hcal	Ecal SciFi	Ecal Imaging	Hcal+SciFi	SciFi+ Imaging	Total fraction with > 0 clusters
500 MeV neutron	0.00001	0.14	0.0004	0	0.000006	0.140394
1 GeV neutron	0.0016	0.393	0.001229	0.00001	0.000678	0.395141
5 GeV neutron	0.028	0.76	0.1	0.078	0.1	0.71
10 GeV neutron	0.08	0.79	0.25	0.031	0.25	0.839
20 GeV neutron	0.175	0.81	0.31	0.087	0.31	0.898

Low energy hadrons are surprising