

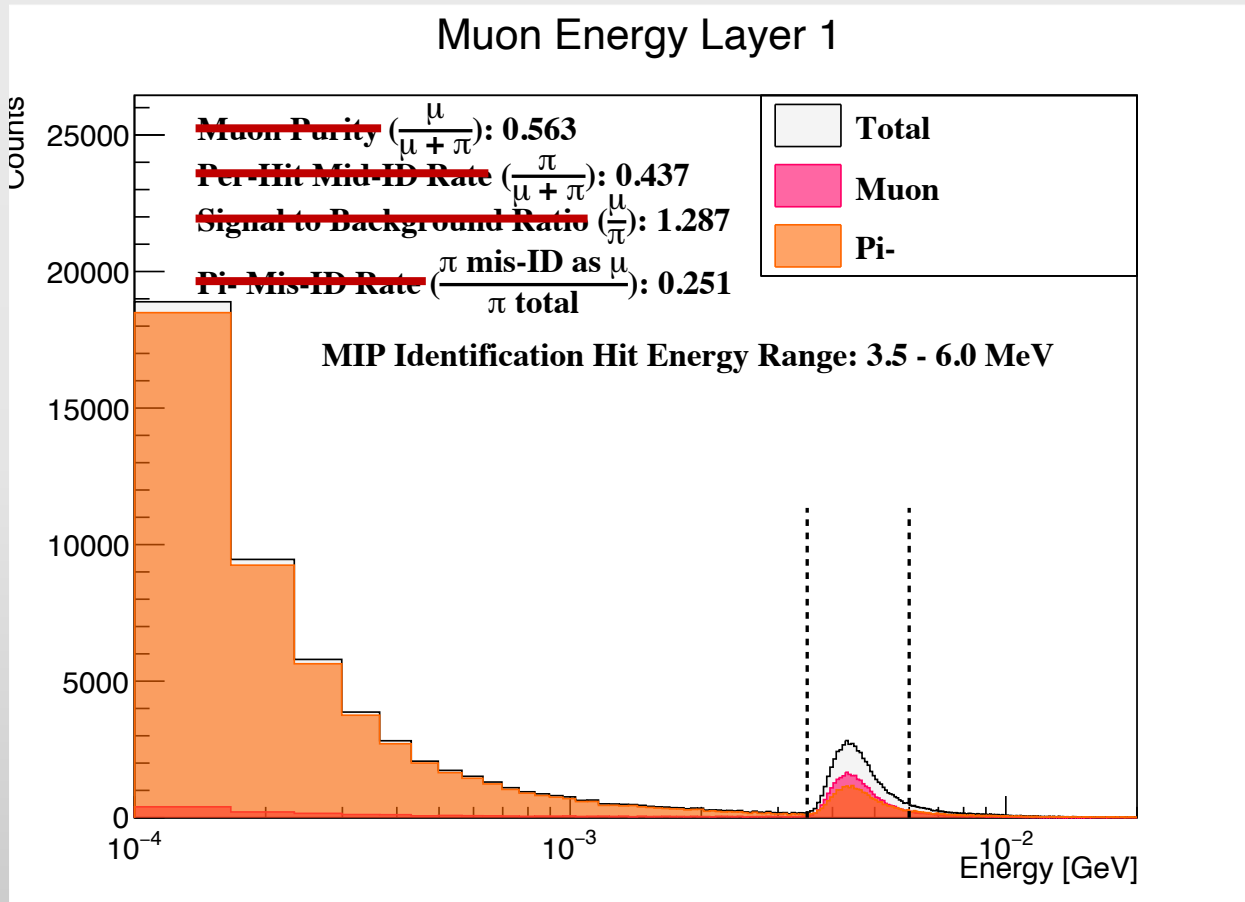
# Low Energy Hits in nHCal

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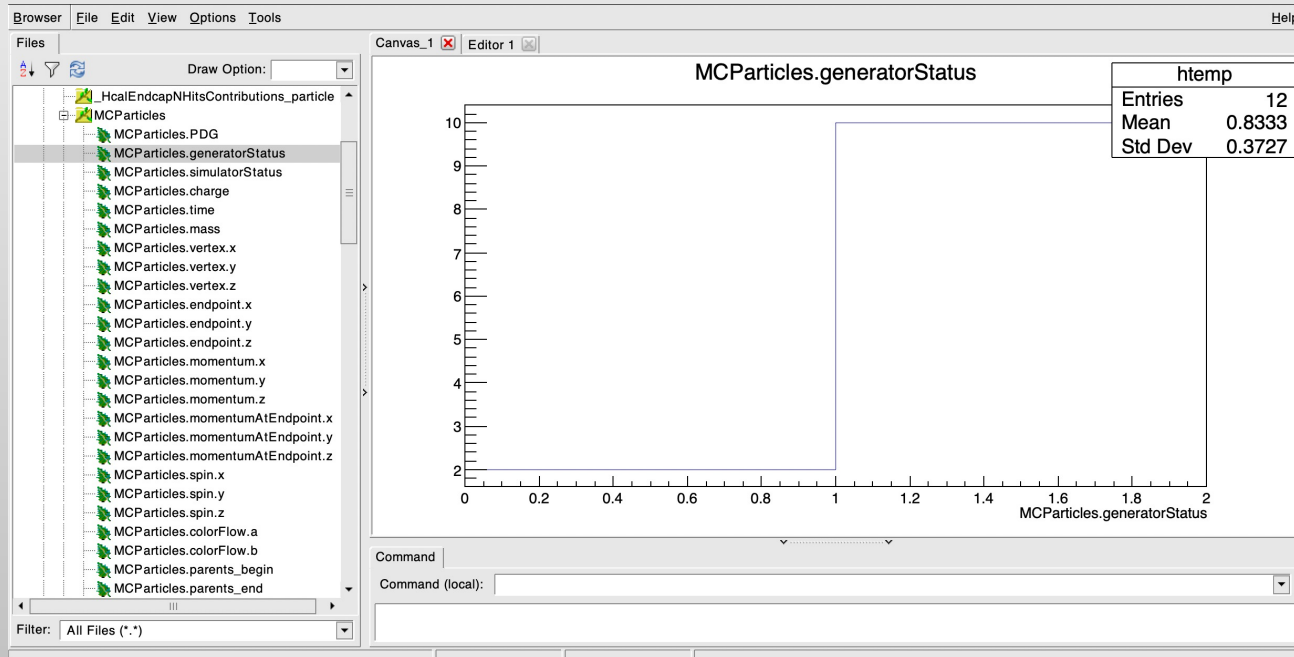
# Hit energy distributions



- Last week, we noted that there are hits with energy smaller than the MIP peak energy in nHCal.
- These appear with particle guns of hadrons much more than leptons.
- What is going on?

# What does npsim give us?

```
npsim --compactFile ../epic/install/share/epic/epic_nhcal_opt_10_layers_4p0cm_abs_2p4cm_sci.xml \
-N 10 \
--enableGun \
--gun.particle=pi- \
--gun.energy 1*GeV \
--gun.thetaMin 145*deg \
--gun.thetaMax 145.5*deg \
--gun.distribution uniform \
--part.enableDetailedHitsAndParticleInfo \
--part.keepAllParticles=true \
--part.minimalKineticEnergy=1*MeV \
--outputFile 1gev_pimin_keepallparticles.root
```



- See this npsim command with options for additional output
- Even with this, it doesn't give detailed info on secondaries.
- Npsim only writes secondary to a file in some specific scenario (about 700 secondaries/50000 gun particles)

# What does npsim give us?

```
+++ Hit: Cell: FFED001101810271 Pos:( -1.7e+03, -1.9e+03, -4.07e+03) [mm] E: 5.4 MeV #Contributions: 5
Contribution # 0 TrackID: 66 PDG: 2112 0.0465 MeV 40.9 ns
Contribution # 1 TrackID: 66 PDG: 2112 0.0386 MeV 41.5 ns
Contribution # 2 TrackID: 66 PDG: 2112 0.000488 MeV 45.4 ns
Contribution # 3 TrackID: 66 PDG: 2112 0.0114 MeV 52.8 ns
Contribution # 4 TrackID: 46 PDG: -211 5.3 MeV 16.3 ns
```

```
+++ Hit: Cell: FFED001101810271 Pos:( -1.6e+03, -1.9e+03, -4.07e+03) [mm] E: 0.199 MeV #Contributions: 12
Contribution # 0 TrackID: 130 PDG: 2112 0.0272 MeV 37.1 ns
Contribution # 1 TrackID: 130 PDG: 2112 0.0037 MeV 42 ns
Contribution # 2 TrackID: 130 PDG: 2112 0.0119 MeV 45.7 ns
Contribution # 3 TrackID: 130 PDG: 2112 0.00273 MeV 53.5 ns
Contribution # 4 TrackID: 130 PDG: 2112 0.000283 MeV 72.8 ns
Contribution # 5 TrackID: 130 PDG: 2112 0.000133 MeV 111 ns
Contribution # 6 TrackID: 139 PDG: 2212 0.0103 MeV 39.8 ns
Contribution # 7 TrackID: 139 PDG: 2212 0.000645 MeV 39.8 ns
Contribution # 8 TrackID: 138 PDG: 2212 0.0587 MeV 25 ns
Contribution # 9 TrackID: 201 PDG: 2112 0.0202 MeV 31.1 ns
Contribution # 10 TrackID: 201 PDG: 2112 0.0564 MeV 32.7 ns
Contribution # 11 TrackID: 212 PDG: 1000060120 0.00712 MeV 31.9 ns
```

```
+++ Hit: Cell: FFED001101818271 Pos:( -1.7e+03, -1.9e+03, -4.13e+03) [mm] E: 0.157 MeV #Contributions: 10
Contribution # 0 TrackID: 130 PDG: 2112 0.000122 MeV 430 ns
Contribution # 1 TrackID: 130 PDG: 2112 0.00018 MeV 450 ns
Contribution # 2 TrackID: 130 PDG: 2112 3.69e-06 MeV 472 ns
Contribution # 3 TrackID: 130 PDG: 2112 1.4e-05 MeV 497 ns
Contribution # 4 TrackID: 130 PDG: 2112 9.95e-06 MeV 530 ns
Contribution # 5 TrackID: 157 PDG: 2112 0.0553 MeV 28.9 ns
Contribution # 6 TrackID: 157 PDG: 2112 0.0528 MeV 32.3 ns
Contribution # 7 TrackID: 162 PDG: 2212 0.00888 MeV 27 ns
Contribution # 8 TrackID: 162 PDG: 2212 0.000756 MeV 27 ns
Contribution # 9 TrackID: 161 PDG: 2212 0.0387 MeV 26.1 ns
```

```
+++ Hit: Cell: FFED001101820271 Pos:( -1.7e+03, -2e+03, -4.2e+03) [mm] E: 0.46 MeV #Contributions: 14
Contribution # 0 TrackID: 130 PDG: 2112 1.89e-05 MeV 1.97e+03 ns
Contribution # 1 TrackID: 140 PDG: 11 0.0435 MeV 16.9 ns
Contribution # 2 TrackID: 140 PDG: 11 0.065 MeV 16.9 ns
Contribution # 3 TrackID: 140 PDG: 11 0.00109 MeV 16.9 ns
Contribution # 4 TrackID: 140 PDG: 11 0.014 MeV 16.9 ns
Contribution # 5 TrackID: 140 PDG: 11 0.0234 MeV 16.9 ns
Contribution # 6 TrackID: 140 PDG: 11 0.0146 MeV 16.9 ns
Contribution # 7 TrackID: 140 PDG: 11 0.0086 MeV 16.9 ns
Contribution # 8 TrackID: 140 PDG: 11 0.0201 MeV 16.9 ns
Contribution # 9 TrackID: 140 PDG: 11 0.0179 MeV 16.9 ns
Contribution # 10 TrackID: 140 PDG: 11 0.0221 MeV 16.9 ns
Contribution # 11 TrackID: 140 PDG: 11 0.0392 MeV 16.9 ns
Contribution # 12 TrackID: 140 PDG: 11 0.0545 MeV 16.9 ns
Contribution # 13 TrackID: 140 PDG: 11 0.136 MeV 16.9 ns
```

```
+++ Hit: Cell: FFED001101818271 Pos:( -1.7e+03, -1.8e+03, -4.13e+03) [mm] E: 0.0329 MeV #Contributions: 9
Contribution # 0 TrackID: 157 PDG: 2112 0.0046 MeV 35.3 ns
Contribution # 1 TrackID: 157 PDG: 2112 0.000799 MeV 36.8 ns
Contribution # 2 TrackID: 157 PDG: 2112 0.00146 MeV 38.3 ns
Contribution # 3 TrackID: 157 PDG: 2112 0.0235 MeV 39.5 ns
Contribution # 4 TrackID: 157 PDG: 2112 0.00087 MeV 49.5 ns
Contribution # 5 TrackID: 157 PDG: 2112 0.00149 MeV 64 ns
Contribution # 6 TrackID: 157 PDG: 2112 6.16e-05 MeV 66.3 ns
Contribution # 7 TrackID: 157 PDG: 2112 5.39e-05 MeV 107 ns
Contribution # 8 TrackID: 157 PDG: 2112 5.19e-05 MeV 108 ns
```

```
+++ Hit: Cell: FFED001101820271 Pos:( -1.7e+03, -1.9e+03, -4.2e+03) [mm] E: 4.86e-06 MeV #Contributions: 4
Contribution # 0 TrackID: 157 PDG: 2112 2.9e-06 MeV 3.14e+03 ns
Contribution # 1 TrackID: 157 PDG: 2112 1.76e-06 MeV 3.81e+03 ns
Contribution # 2 TrackID: 157 PDG: 2112 1.95e-07 MeV 5.01e+03 ns
Contribution # 3 TrackID: 157 PDG: 2112 5.53e-09 MeV 6.17e+03 ns
```

- **BUT:**  
enableDetailedHitsAndParticleInfo option gives us much more detailed output
- First example: gun pi- acts like a MIP, deposits a few MeV, while protons deposit much less energy
- Other examples: small energy deposits from mostly protons, some electrons.
- Electrons/protons knocked off from atoms in scintillator?

Tell me to zoom in if I forget!

# Summary

- The low energy hits are mostly from low energy protons (dissociated from nuclei?)
- Still, shouldn't low energy charged particles deposit more energy than a MIP?
- Well:  $dE/dx$  is higher at an energy lower than the MIP energy
  - But, very low energy particles  $\rightarrow$  very short range before stopping  $\rightarrow$  small total energy deposited.
  - Need to find a way (in npsim or otherwise) to check average KE or p of these protons.

# Additional notes on npsim file output

- It does not (as far as I can tell) save detailed shower information.
- Instead, all hit contributions in a hit are attributed to the MCParticle (usually gun particle).
- Sometimes, a secondary is added to the MCParticle list.
  - I suspect this only happens when the parent particle is stopped and there is a particularly high energy secondary still traversing the detector
- In 50000 events, there are none where different particles (by MC index) give hits in the same layer.
- Most commonly, a handful of active tiles (=number of hits) per layer. Typically, the leading energy hit carries a large fraction of the total energy in that layer.