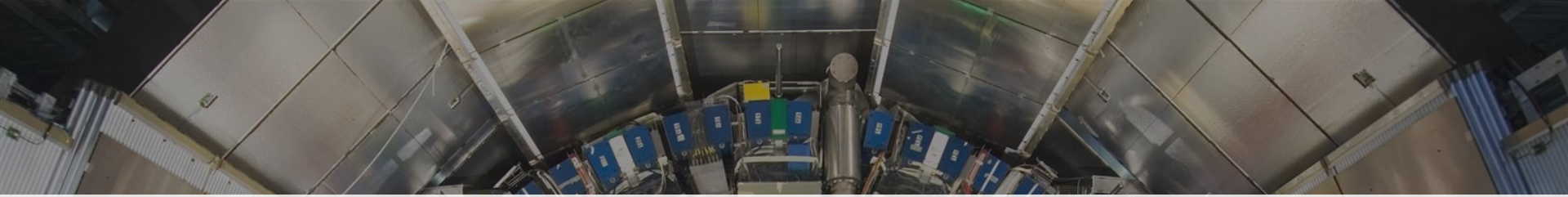

Timing calibration using single pion events

4D Tracking and 5D Calorimetry

https://indico.slac.stanford.edu/event/8722/

2024, Feb 14

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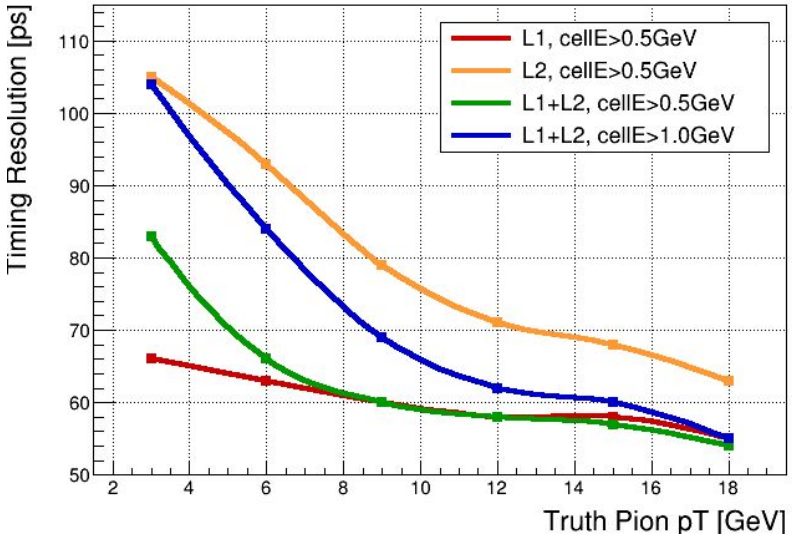
Primary task

- In order to check why layer 1 has better timing resolution, standard deviation of cell time after t0 calibration was checked inclusively, also in bins of #clusters in a pion
- Following slides have the plots made in the first and last truth pion pT bins (3~6 GeV, 18~20 GeV) in the below plot

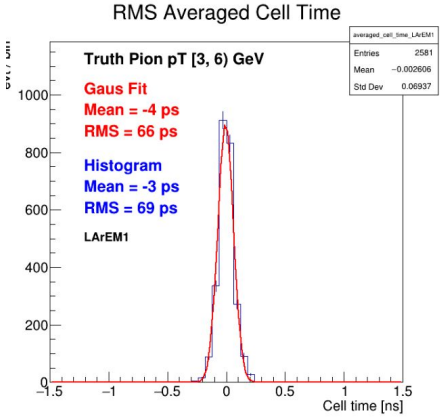
From slide3 of meeting on 24.01.17.

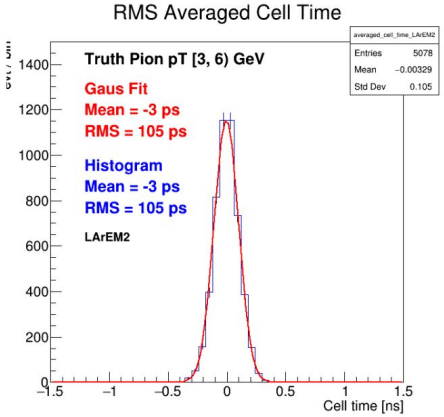


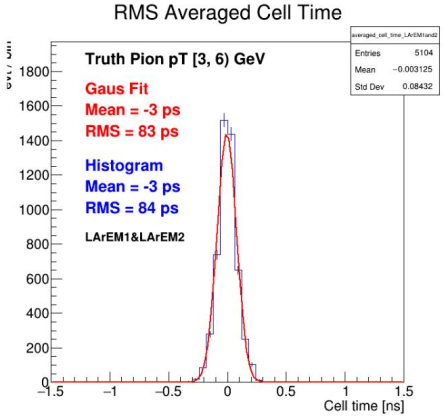
Timing resolution & Std. in different layers
3 GeV < truth pion < 6 GeV

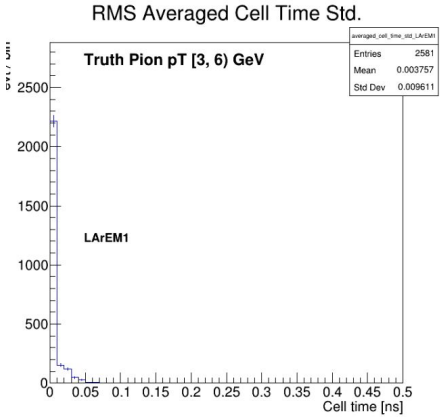
Neutral pion

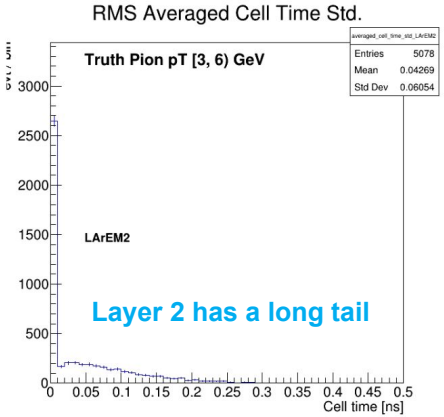
Timing resolution & Std. in different layers

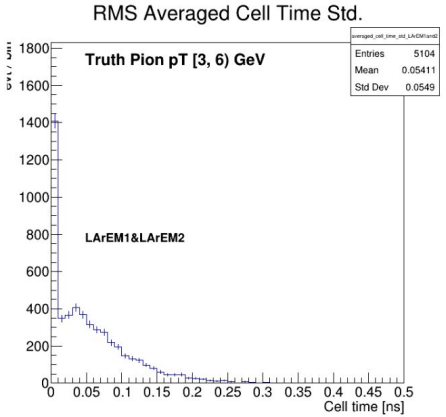






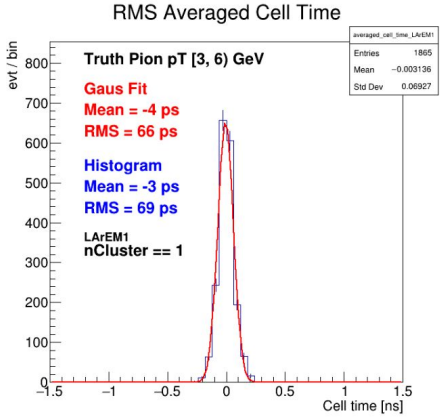


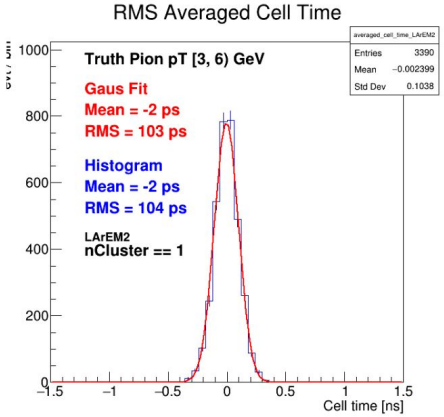


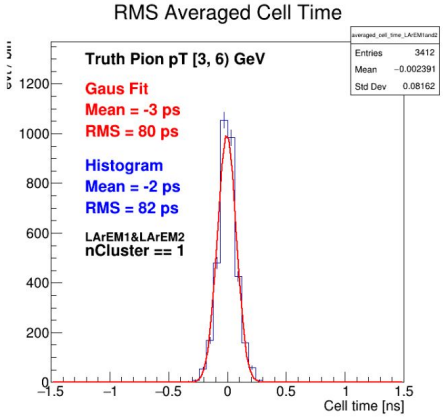


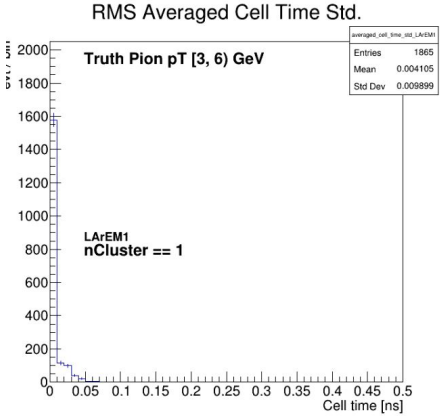
Neutral pion

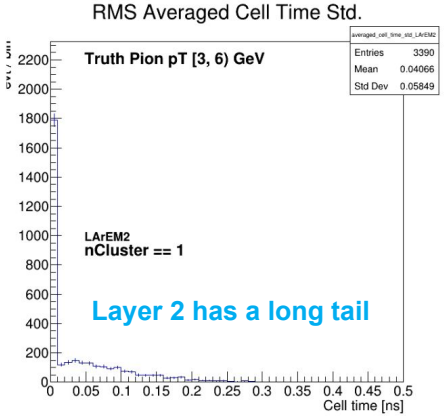
Timing resolution & Std. in different layers

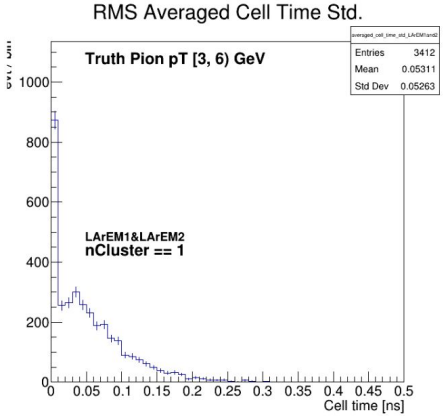






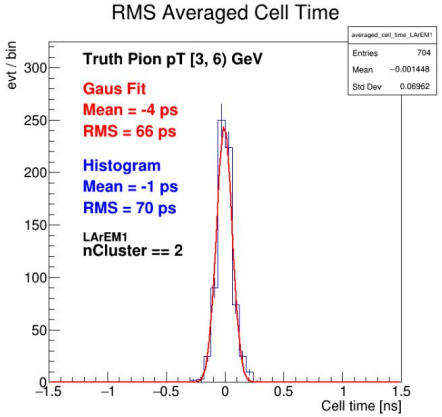


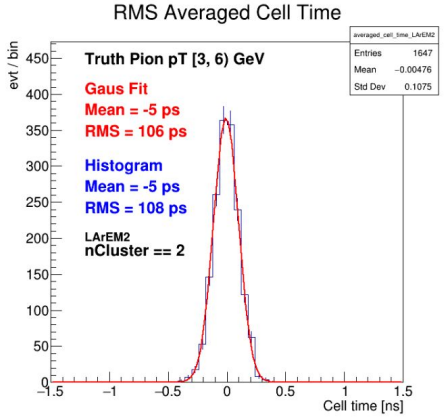


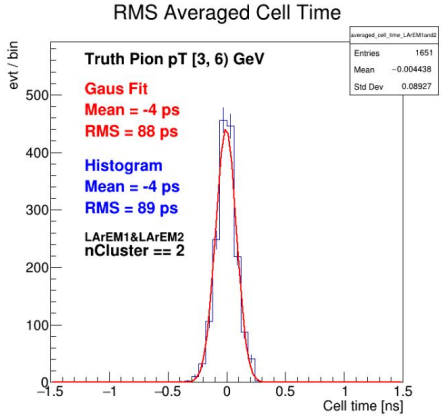


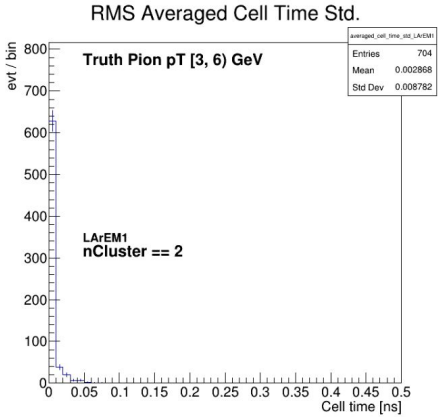
Neutral pion

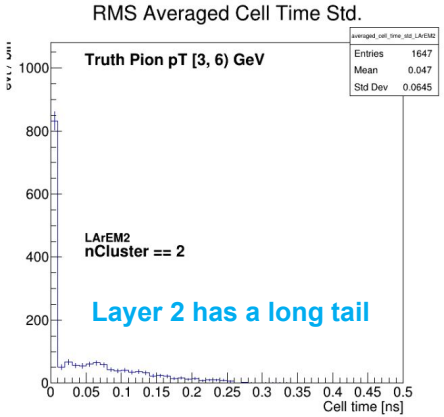
Timing resolution & Std. in different layers

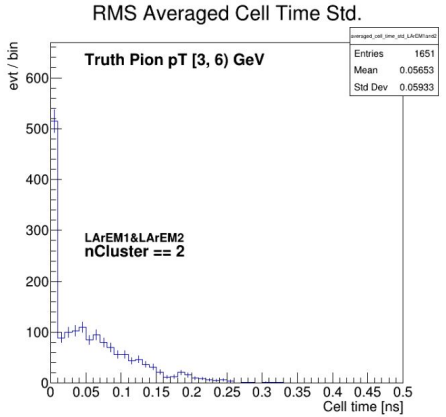






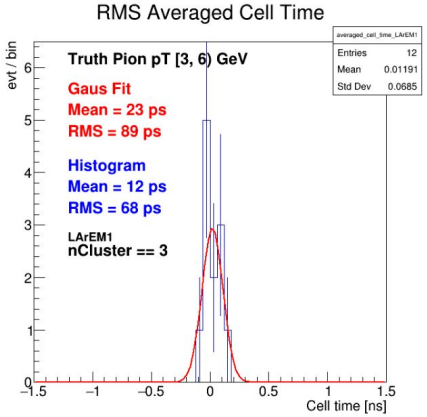


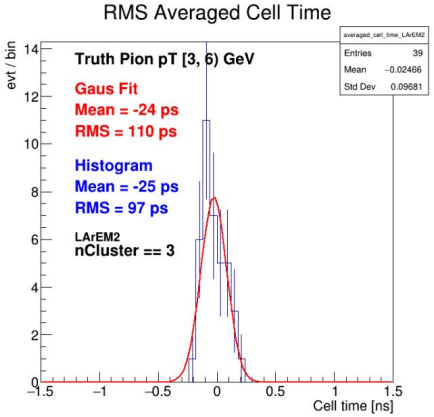


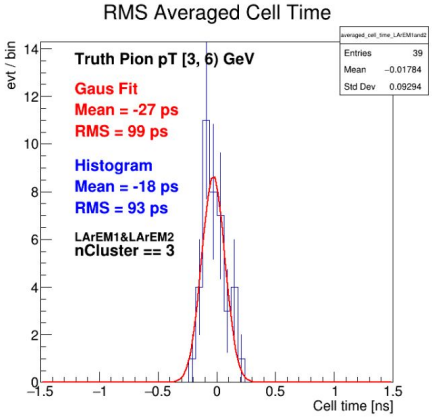


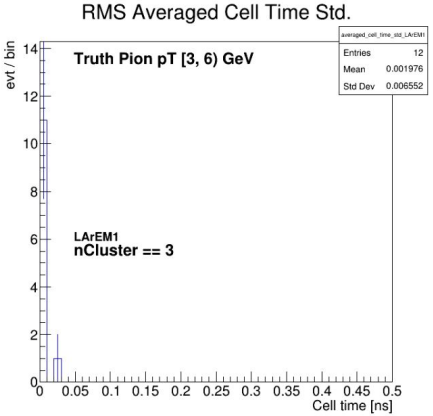
Neutral pion

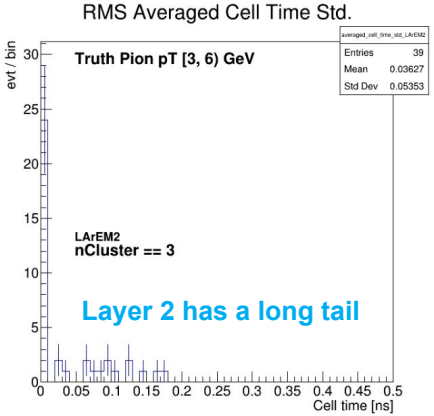
Timing resolution & Std. in different layers

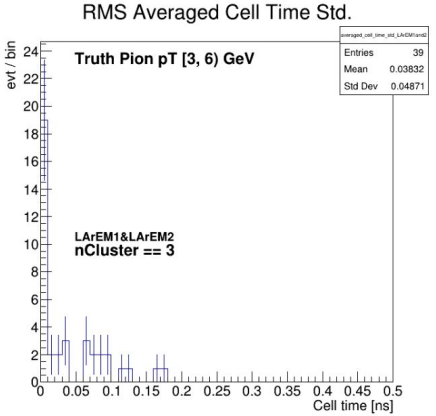








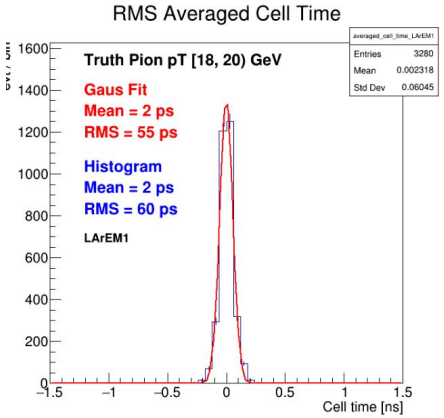


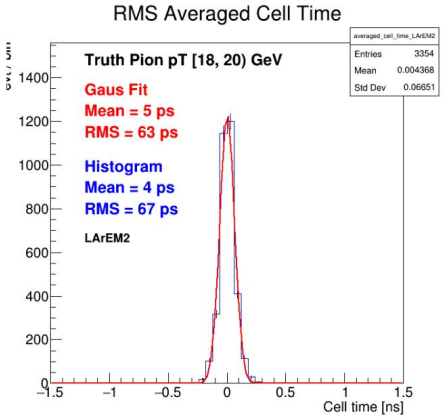


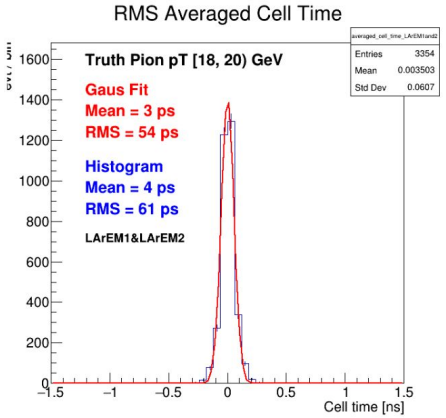
Timing resolution & Std. in different layers
18 GeV < truth pion < 20 GeV

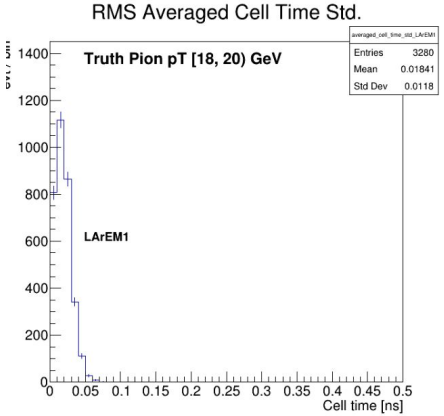
Neutral pion

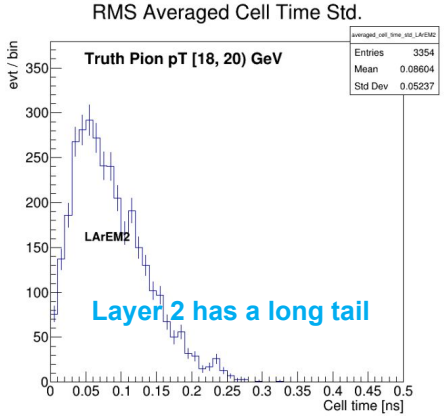
Timing resolution & Std. in different layers

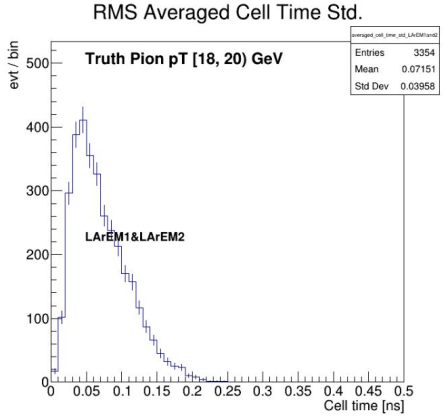






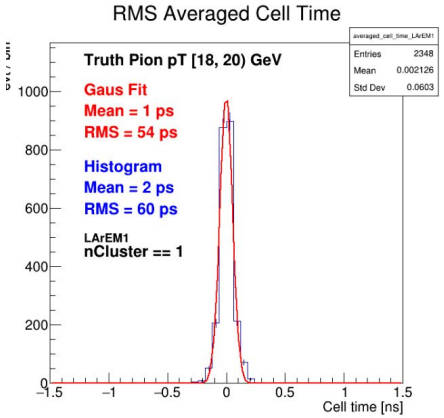


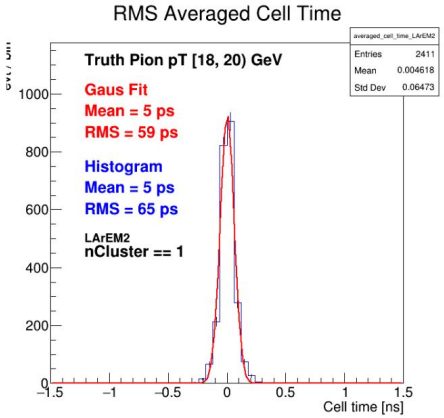


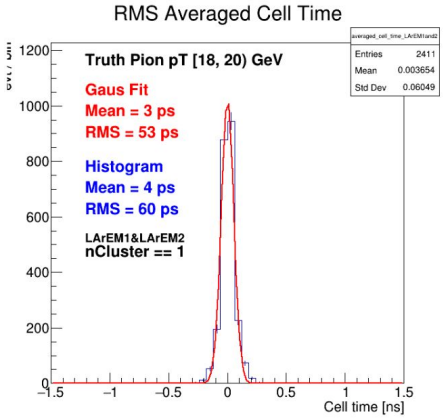


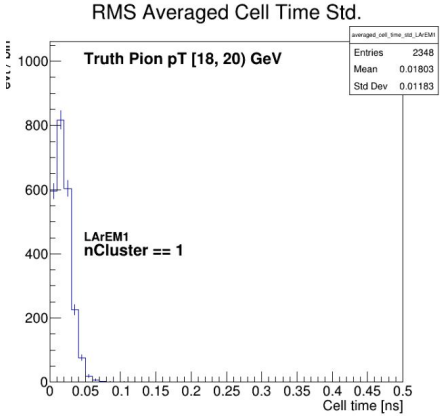
Neutral pion

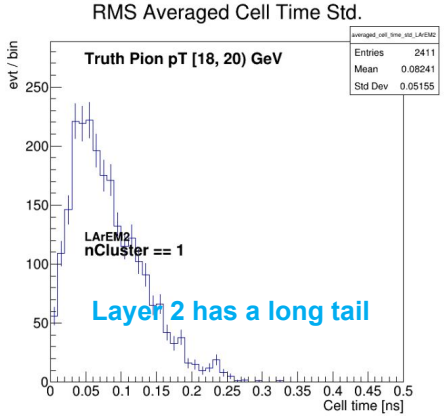
Timing resolution & Std. in different layers

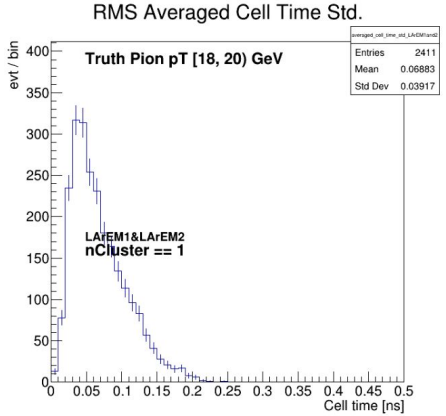






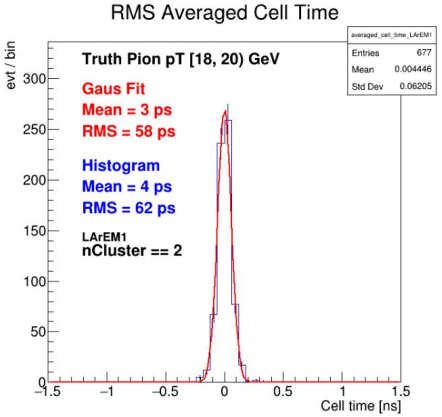


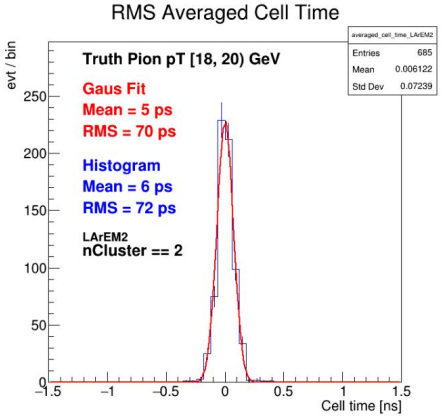


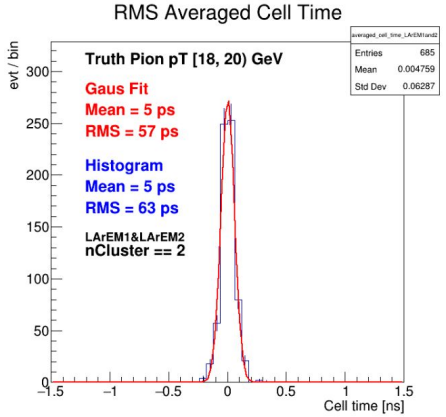


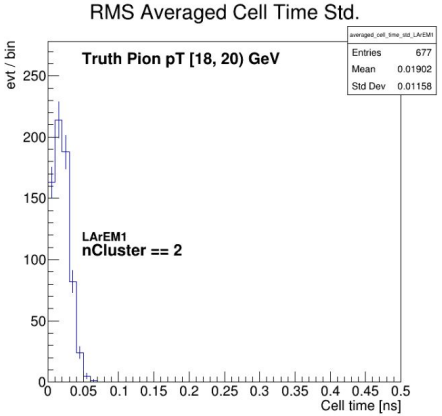
Neutral pion

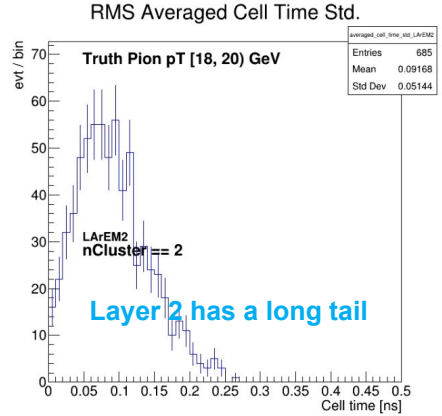
Timing resolution & Std. in different layers

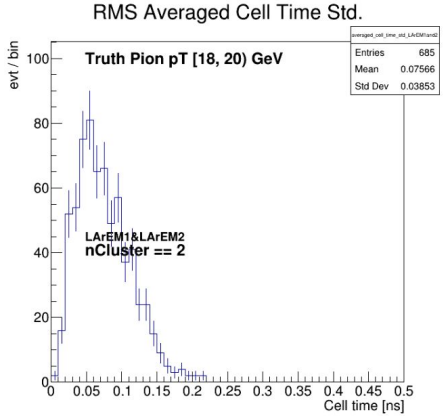






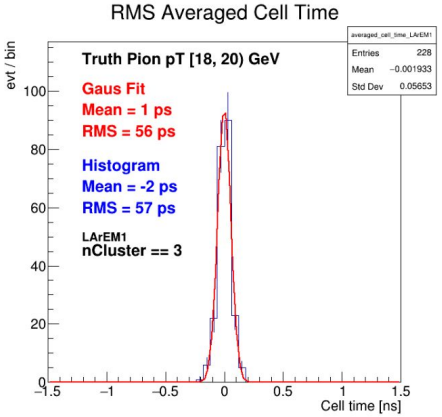


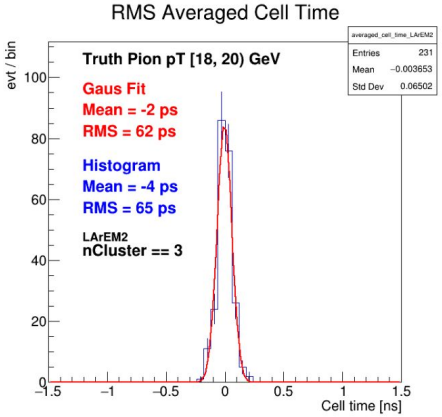


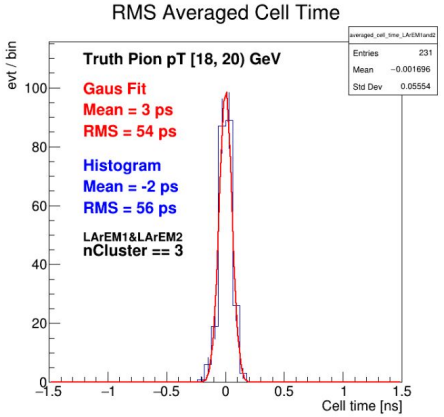


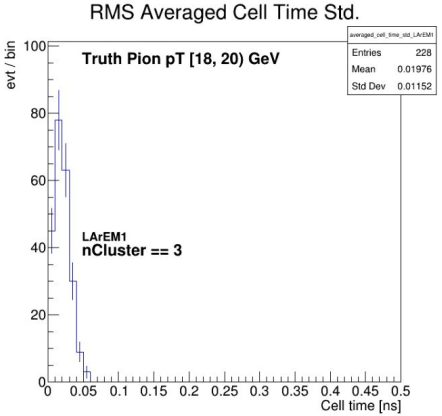
Neutral pion

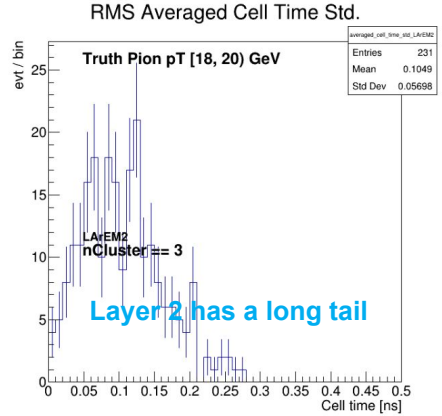
Timing resolution & Std. in different layers

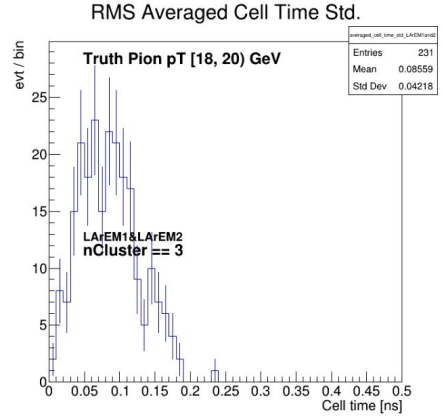












What are in a single pion?

Neutral pion

Cells in a pion #1

```
------------------------------------------------------------------------
event number              : 1992999
weighted_avg_cellTime     : -0.0334 ns
weighted_avg_cellTime_std: 0.0353 ns
========================================================================
cellE         cellTime(calibed)              distance R
3.325 GeV     -0.028 ns    weight: 176.32    1760.50 mm
1.861 GeV     -0.138 ns    weight: 100.33    1760.44 mm
1.691 GeV      0.001 ns    weight:  89.85    1760.16 mm
2.458 GeV     -0.040 ns    weight: 134.45    1760.10 mm
1.146 GeV     -0.018 ns    weight: 258.79    1545.09 mm
1.240 GeV     -0.031 ns    weight: 262.89    1545.03 mm
0.516 GeV     -0.023 ns    weight: 182.21    1544.97 mm
0.692 GeV     -0.033 ns    weight: 218.26    1544.90 mm
1.287 GeV     -0.030 ns    weight: 264.65    1544.83 mm
0.521 GeV     -0.034 ns    weight: 183.57    1544.76 mm
------------------------------------------------------------------------
Layer 1 only
weighted_avg_cellTime     : -0.0281 ns
weighted_avg_cellTime_std: 0.0056 ns
------------------------------------------------------------------------
Layer 2 only
weighted_avg_cellTime     : -0.0480 ns
weighted_avg_cellTime_std: 0.0525 ns
------------------------------------------------------------------------
Layer 1+2 but for cell(s) with the outlier cell time
weighted_avg_cellTime     : -0.0262 ns
```

Layer 2

Layer 1

- In layer 2, outlier cells are often observed, which has cell time far away from the mean
- Without the outliers, |weighted average time| gets smaller significantly

Cells in a pion #2

```
------------------------------------------------------------------------
event number              : 1986411
weighted_avg_cellTime     : 0.0394 ns
weighted_avg_cellTime_std: 0.1184 ns
========================================================================
cellE         cellTime(calibed)              distance R
7.297 GeV     0.050 ns     weight: 289.59    1742.62 mm
0.607 GeV     -0.271 ns    weight: 21.16     1742.72 mm
1.586 GeV     0.134 ns     weight: 83.25     1742.52 mm
0.829 GeV     -0.004 ns    weight: 34.42     1743.28 mm
0.716 GeV     0.130 ns     weight: 27.47     1740.49 mm
1.396 GeV     0.013 ns     weight: 268.11    1539.13 mm
1.820 GeV     0.035 ns     weight: 276.61    1539.04 mm
1.447 GeV     0.049 ns     weight: 269.51    1538.71 mm


------------------------------------------------------------------------
Layer 1 only
weighted_avg_cellTime     : 0.0327 ns
weighted_avg_cellTime_std: 0.0148 ns
------------------------------------------------------------------------
Layer 2 only
weighted_avg_cellTime     : 0.0513 ns
weighted_avg_cellTime_std: 0.1485 ns
------------------------------------------------------------------------
Layer 1+2 but for cell(s) with the outlier cell time
weighted_avg_cellTime     : -0.0358 ns
```

Layer 2

Layer 1

- In layer 2, outlier cells are often observed, which has cell time far away from the mean
- Without the outliers, |weighted average time| gets smaller significantly

Cells in a pion #3

```
------------------------------------------------------------------------
event number              : 1995832
weighted_avg_cellTime     : 0.0882 ns
weighted_avg_cellTime_std: 0.0885 ns
========================================================================
cellE         cellTime(calibed)              distance R
4.955 GeV     0.039 ns     weight: 234.89    1740.40 mm
1.564 GeV     0.245 ns     weight: 81.85     1740.33 mm
0.637 GeV     0.312 ns     weight: 22.84     1740.46 mm
1.623 GeV     0.156 ns     weight: 85.58     1742.52 mm
2.042 GeV     0.060 ns     weight: 279.20    1538.37 mm
0.507 GeV     0.084 ns     weight: 179.92    1538.29 mm
1.007 GeV     0.063 ns     weight: 250.91    1538.03 mm
0.711 GeV     0.119 ns     weight: 221.16    1537.95 mm
0.690 GeV     0.069 ns     weight: 217.93    1538.45 mm

------------------------------------------------------------------------
Layer 1 only
weighted_avg_cellTime     : 0.0777 ns
weighted_avg_cellTime_std: 0.0216 ns
------------------------------------------------------------------------
Layer 2 only
weighted_avg_cellTime     : 0.1166 ns
weighted_avg_cellTime_std: 0.1024 ns
------------------------------------------------------------------------
Layer 1+2 but for cell(s) with the outlier cell time
weighted_avg_cellTime     : 0.0709 ns
```

Layer 2

Layer 1

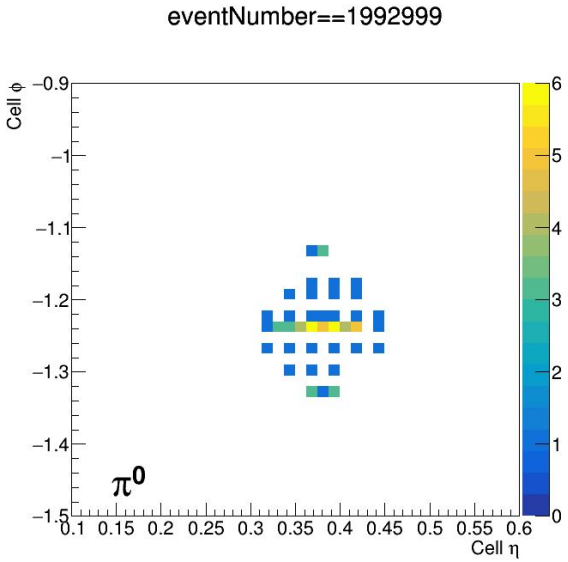
- In layer 2, outlier cells are often observed, which has cell time far away from the mean
- Without the outliers, |weighted average time| gets smaller significantly

Event display of the three pions

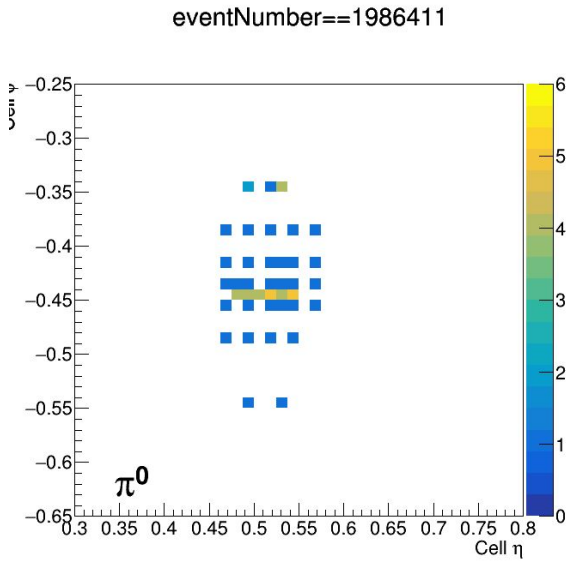
Neutral pion

All clustered cells

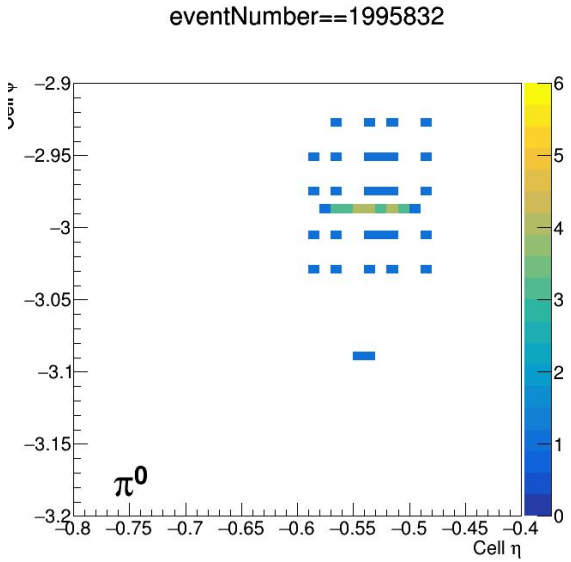
You can swap slides 18 to 23 to compare



Pion #1



Pion #2

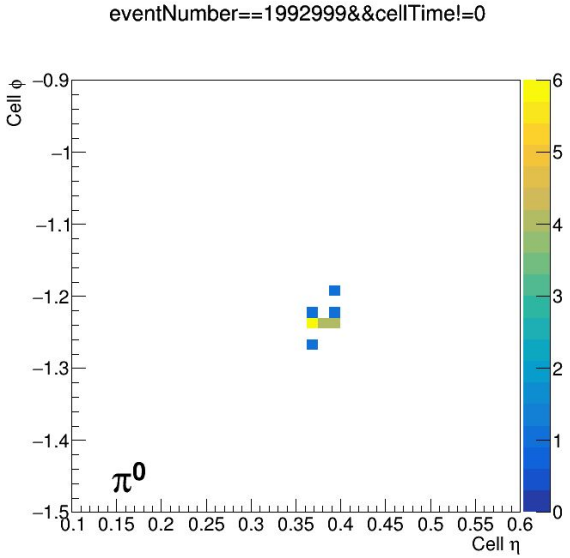


Pion #3

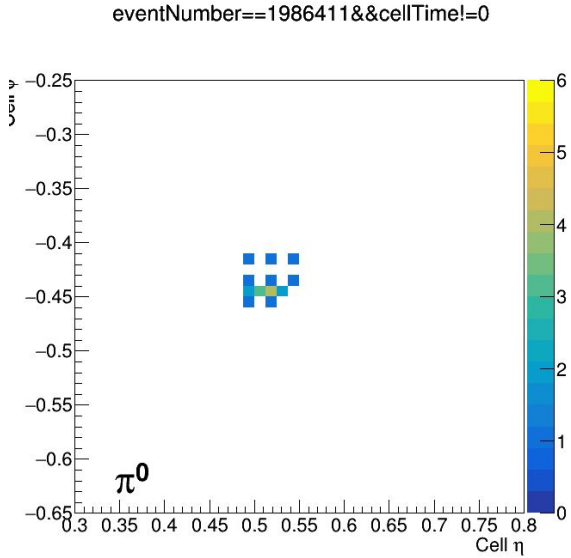
in the slides with tables (slides 15~17)

Neutral pion

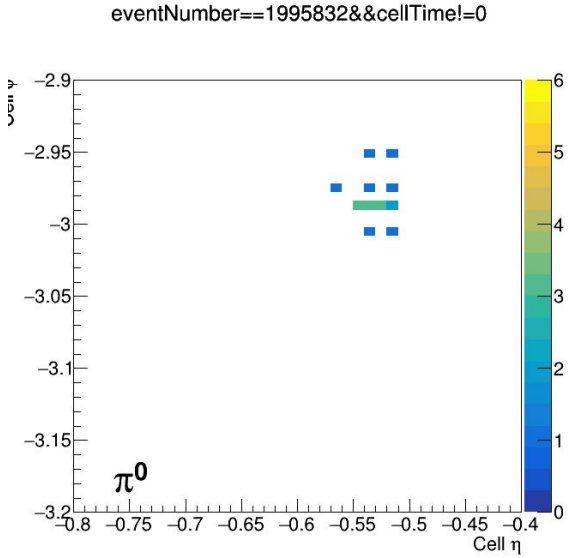
All clustered cells with cellTime!=0



Pion #1



Pion #2



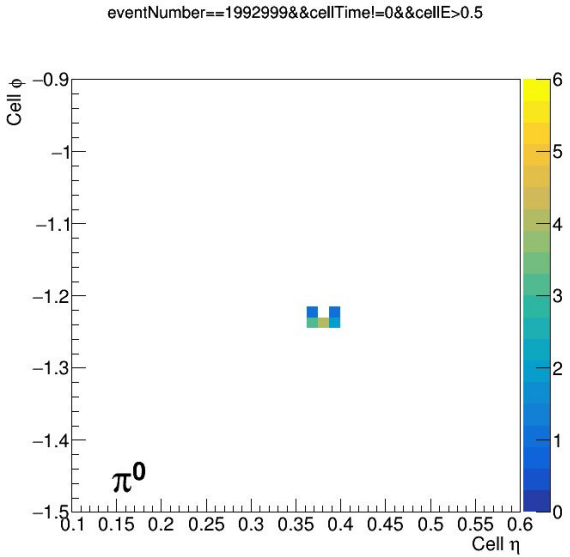
Pion #3

in the slides with tables (slides 15~17)

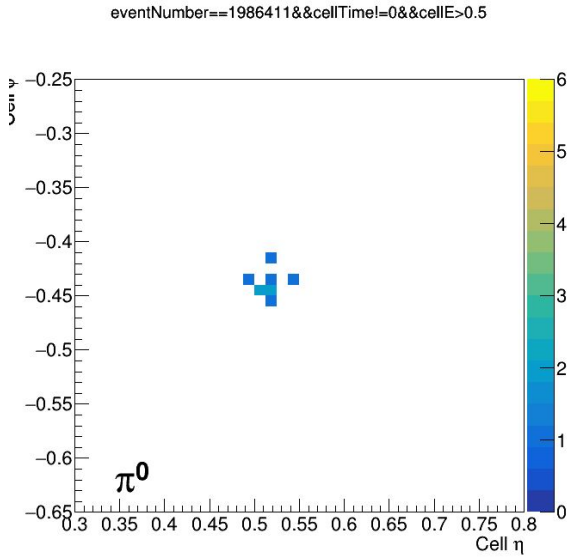
Neutral pion

All clustered cells with cellTime!=0, cellE>0.5GeV

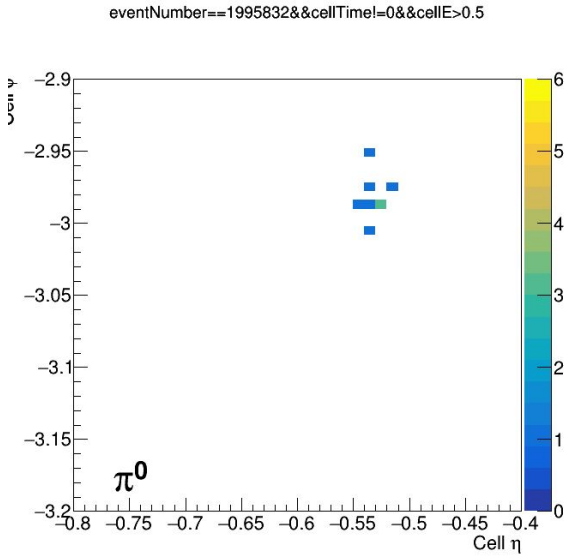
You can swap slides 18 to 23 to compare



Pion #1



Pion #2



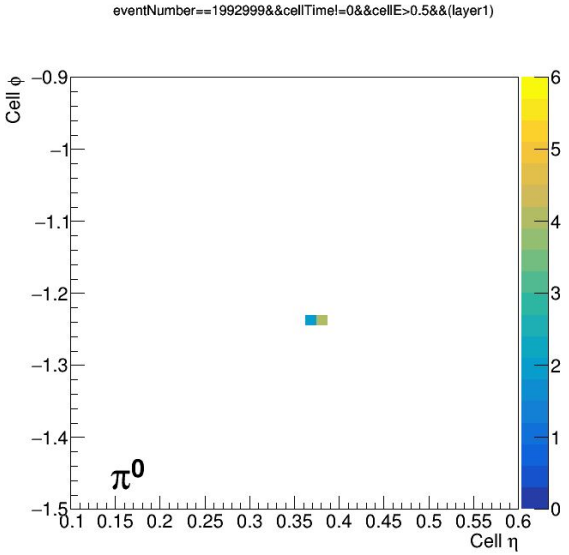
Pion #3

in the slides with tables (slides 15~17)

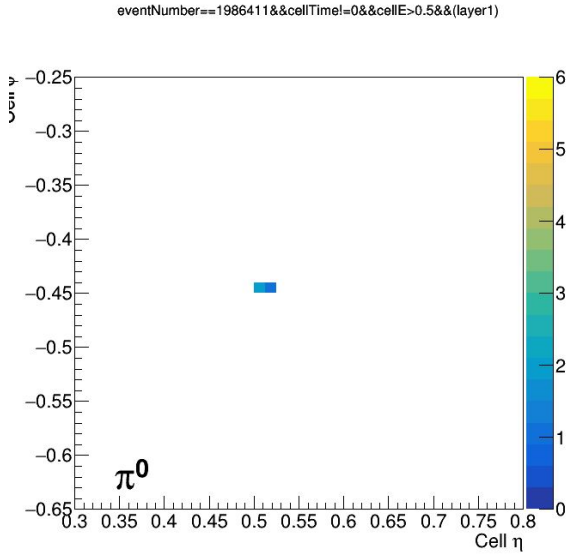
Neutral pion

All clustered cells with cellTime!=0, cellE>0.5GeV (layer1)

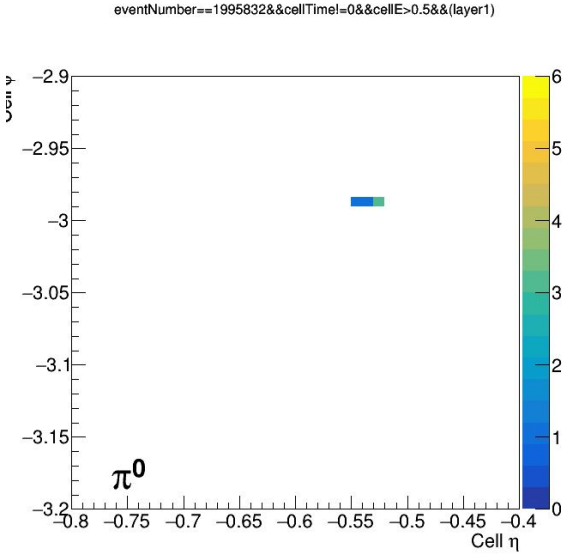
You can swap slides 18 to 23 to compare



Pion #1



Pion #2



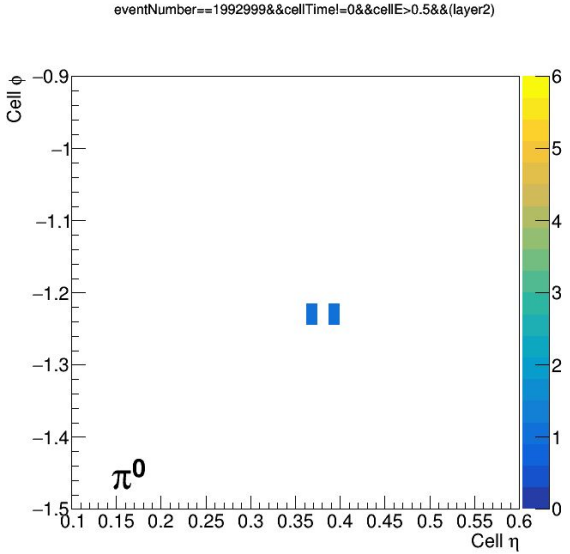
Pion #3

in the slides with tables (slides 15~17)

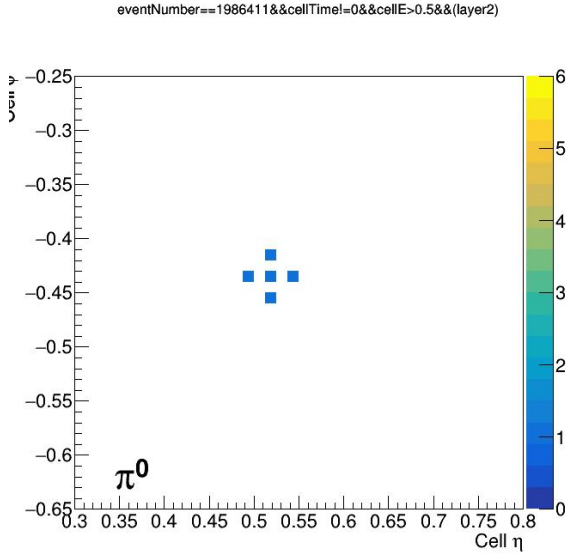
Neutral pion

All clustered cells with cellTime!=0, cellE>0.5GeV (layer2)

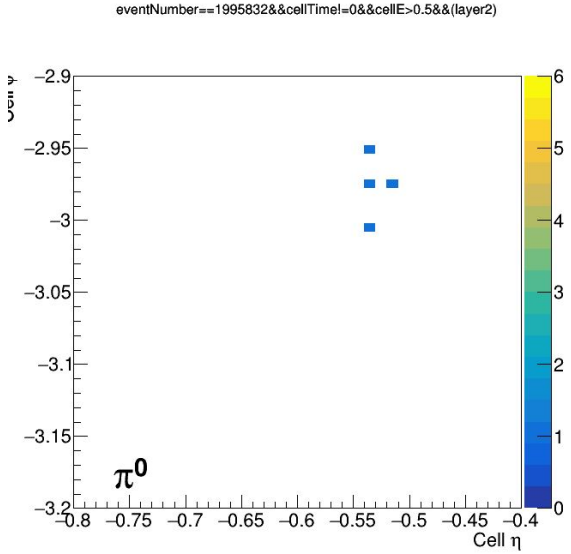
You can swap slides 18 to 23 to compare



Pion #1



Pion #2



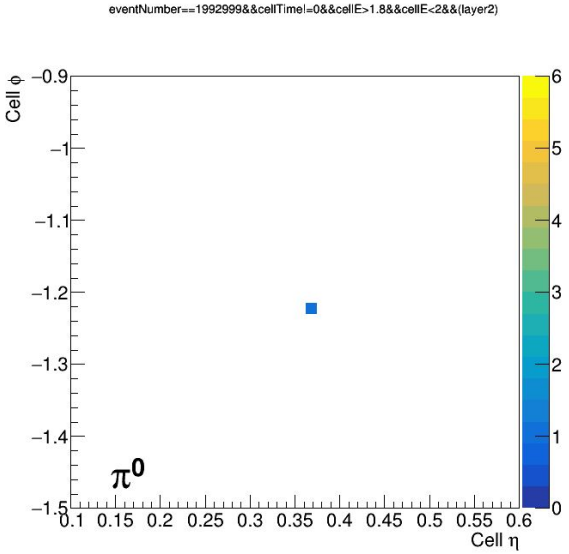
Pion #3

in the slides with tables (slides 15~17)

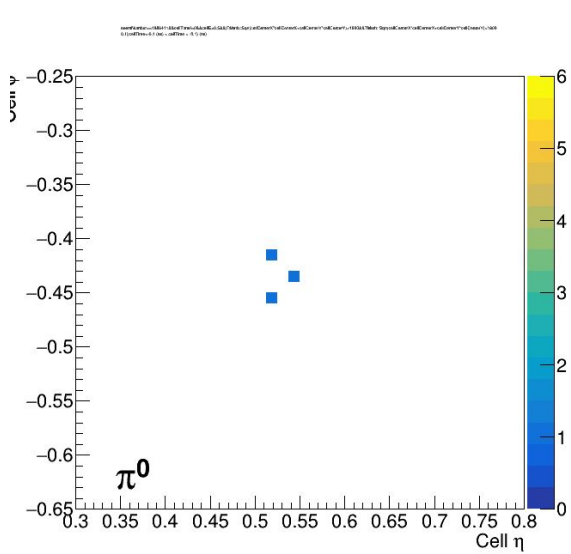
Neutral pion

All clustered cells with cellTime!=0, cellE>0.5GeV (layer2)

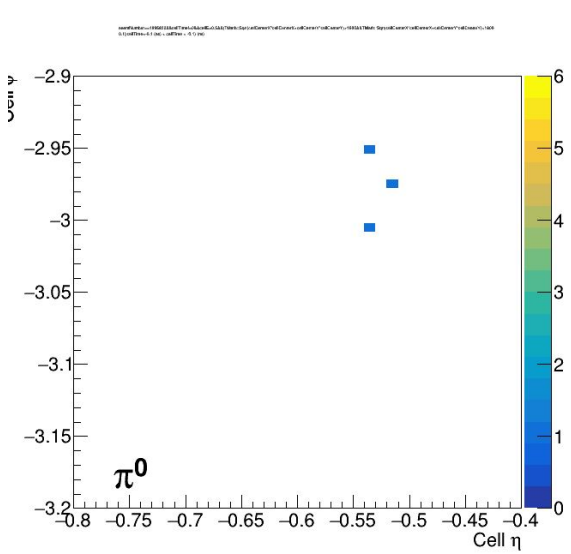
Only the big std cells left in these plots
Somehow, hits around the most energetic cell in the pion have very slow hits



Pion #1



Pion #2



Pion #3

in the slides with tables (slides 15~17)

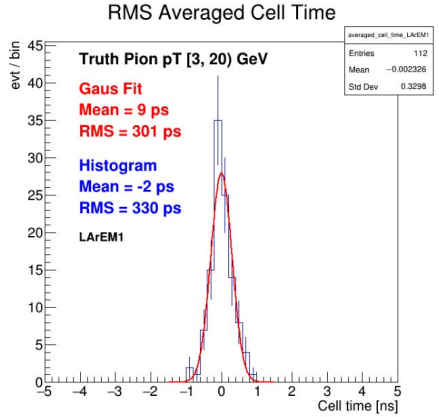
Summary & Plan

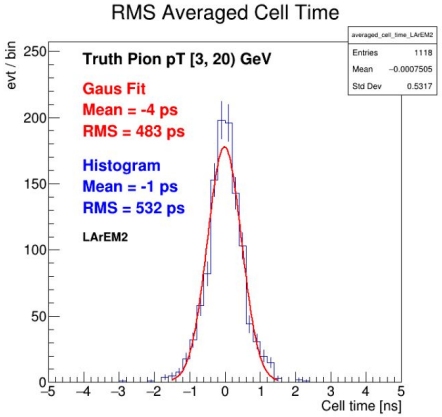
- The standard deviation of the t0 offset calibrated cell time within a pion is larger in layer 2 than in layer 1
- Technically, we can suppress them by rejecting cells with more than 3 sigma, for example
- Given that the slow hits have a unique geometrical feature in the event display (slide22 vs slide 23), and R distances (slides 14, 15, and 16) are very close to the most energetic cell, I wonder if there is any actual physics going on

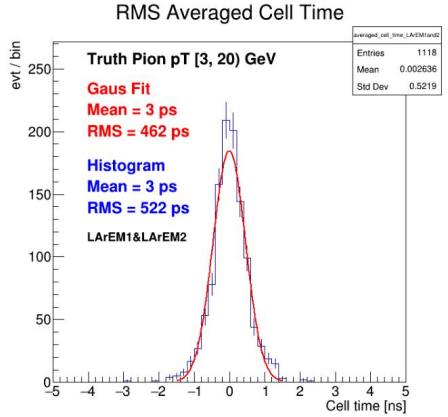
Sanity check with charged pion

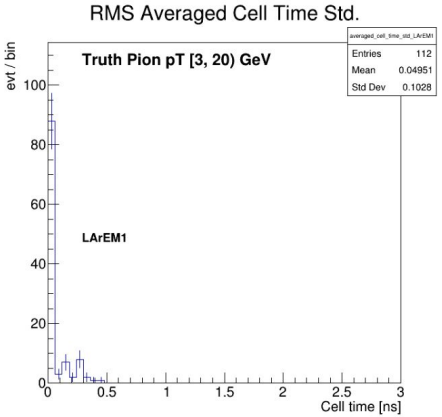
Charged pion

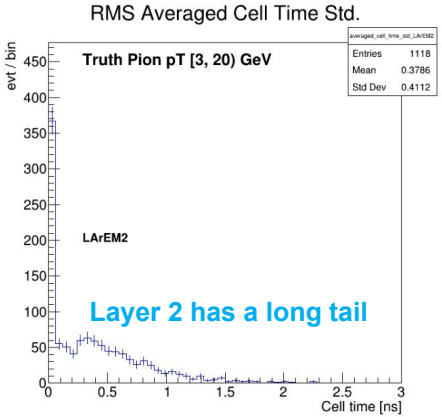
Timing resolution & Std. in different layers

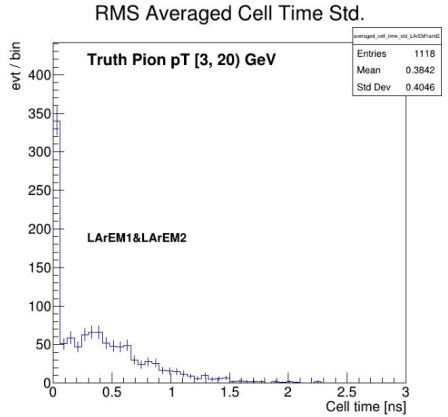






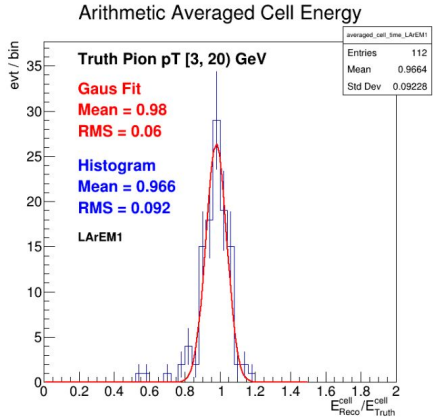


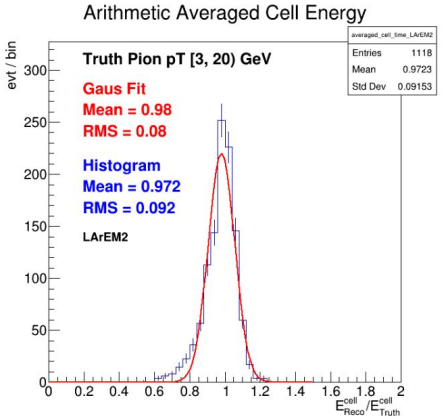


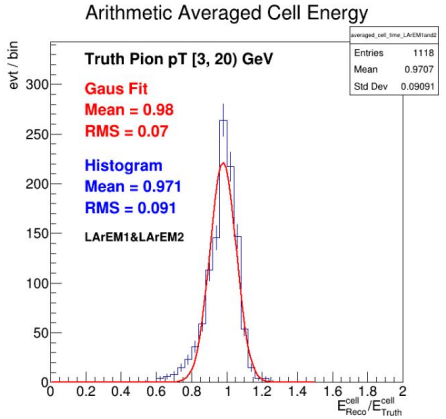


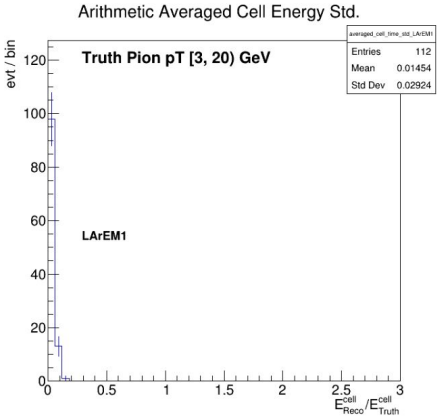
Charged pion

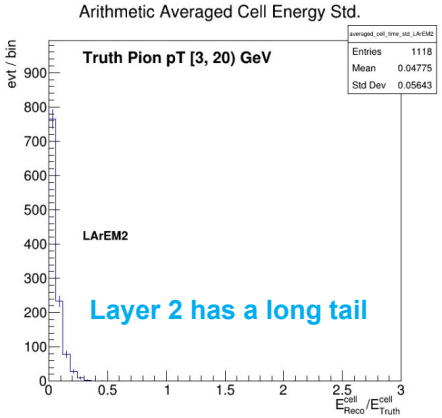
Timing resolution & Std. in different layers

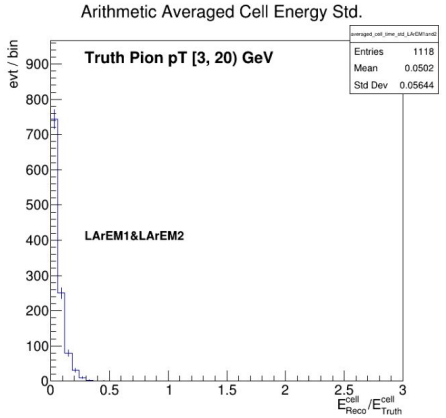








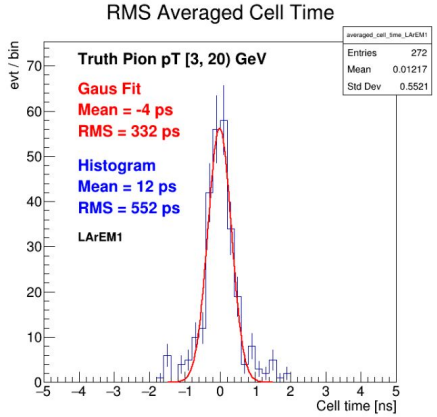


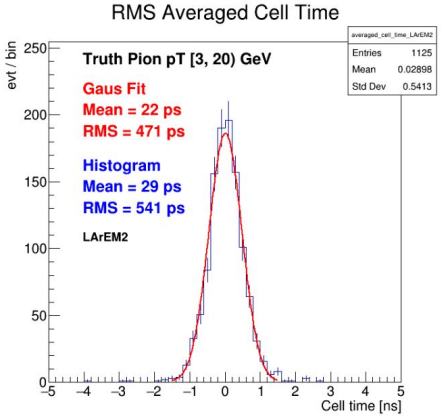


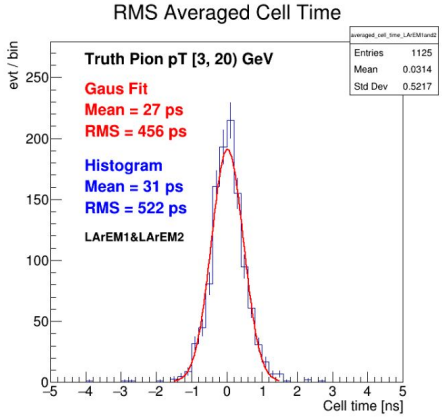
Backup

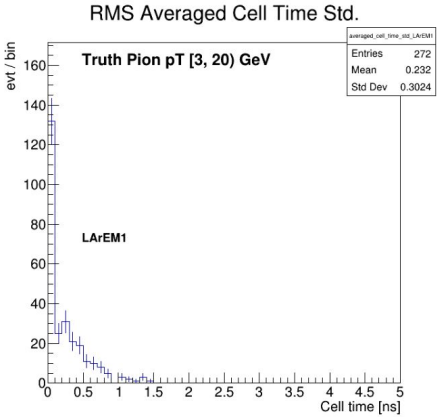
Charged pion

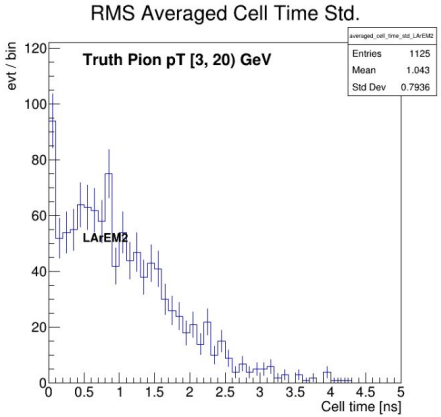
Timing resolution & Std. in different layers

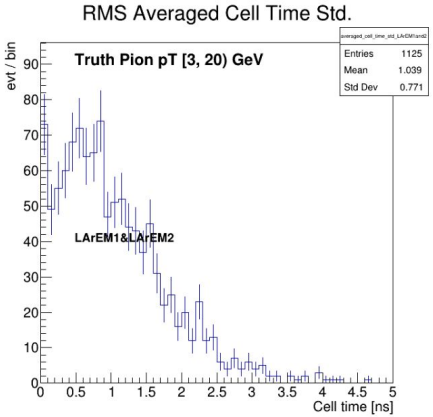












Charged pion

Timing resolution & Std. in different layers