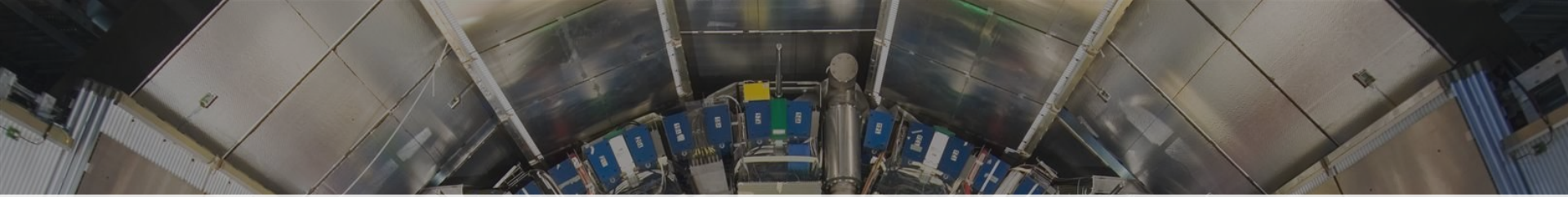


Study the potential of cell timing to improve cluster/jet calibration

2023, October 12

https://indico.slac.stanford.edu/event/8480/

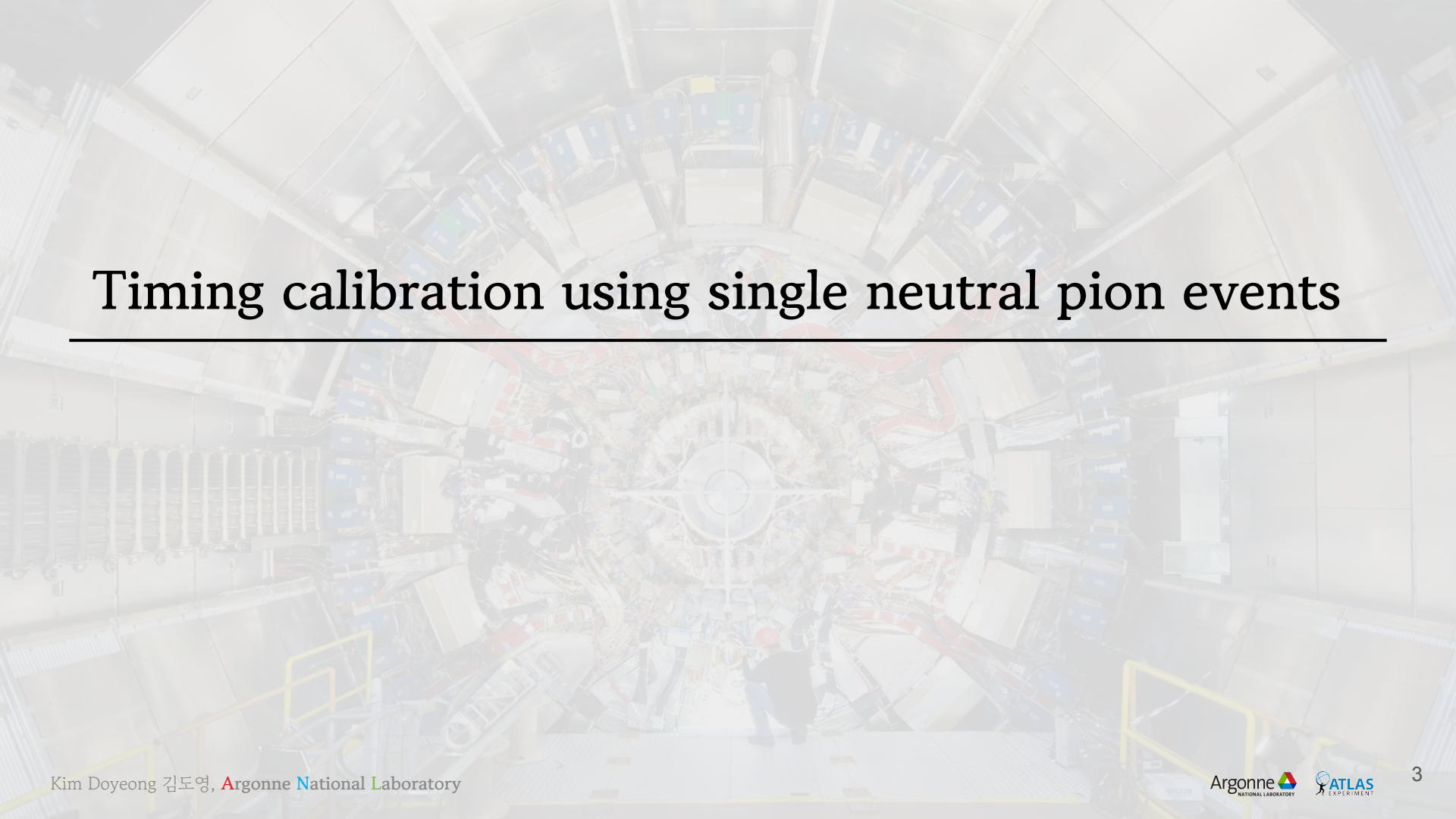
Kim Doyeong 김 도 영

Zahra Farazpay

Motivation

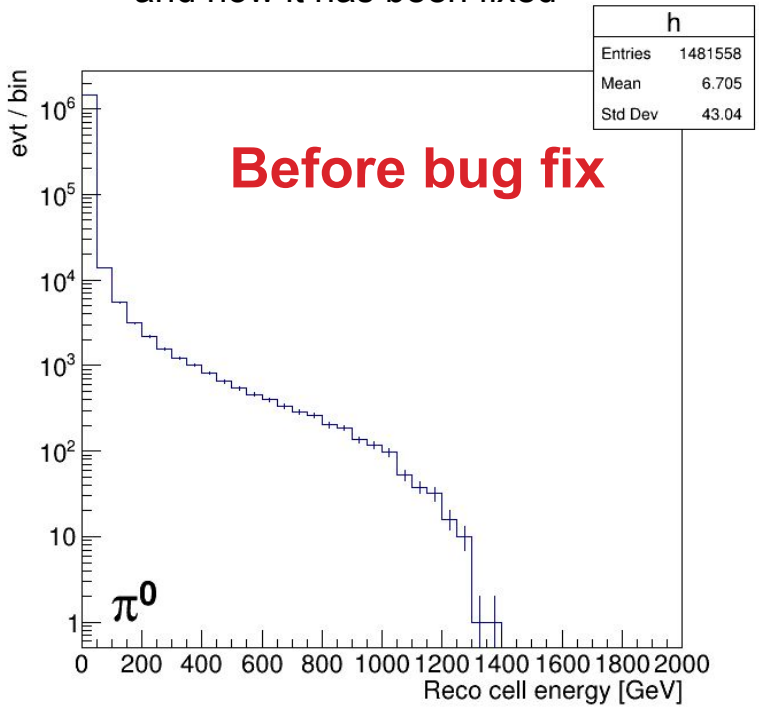
- Time information will enhance our understanding of jets
- Many physics program can be improved by using 5D calorimeter information
- ATLAS calorimeter systems measure time as well as energy, however, cell time information is hardly used
  - So far, people use cuts on cell time to reject out-of-time PU but rigorous calibration hasn't been done yet
- **Our goals:**
  - Understanding cell timing in a single pion samples (charged, netral, w/wo PU)
  - Understanding cell timing in jets
  - Improve jet calibration - study with slow neutrons
  - Study of jet's time of arrival using calorimeters

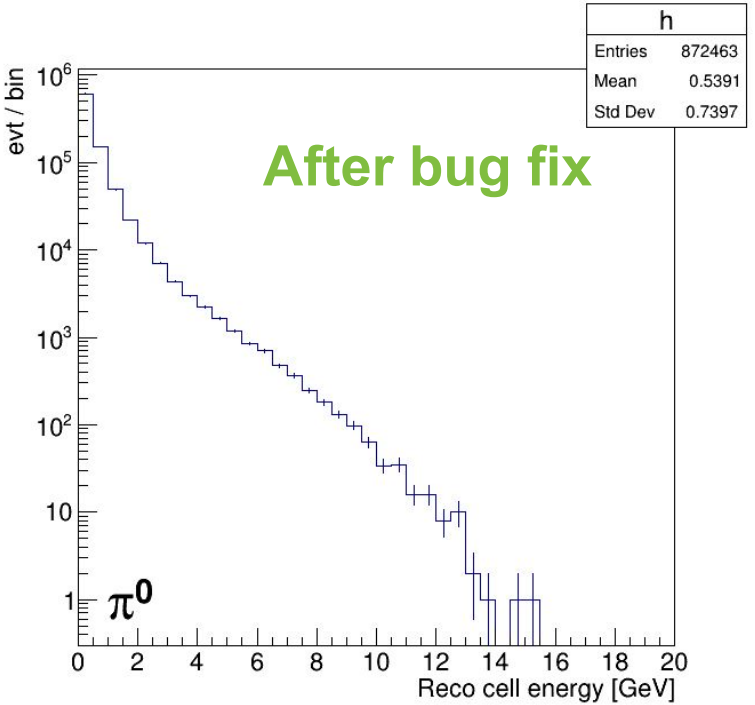
Timing calibration using single neutral pion events



Reco cell E before/after bug fix

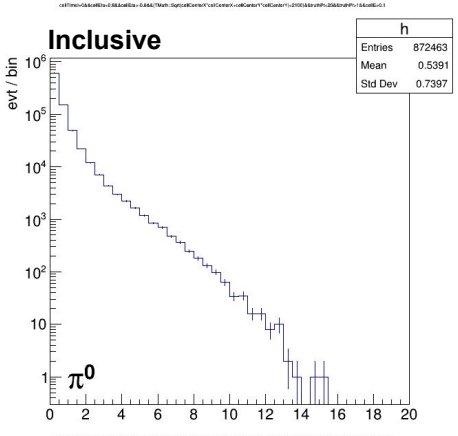
Bug: With 1GeV < Truth pion pT < 20GeV, there are cells which has cellE >> 20GeV
This is because of mismatch btw cell index and cluster index at the Ntuple level, and now it has been fixed

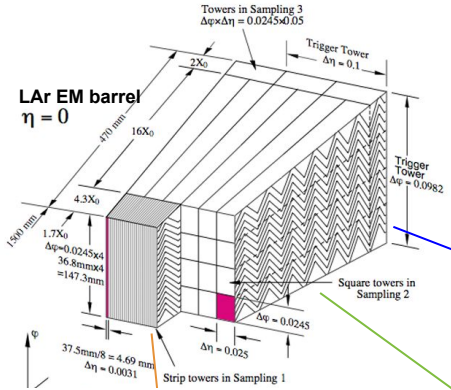




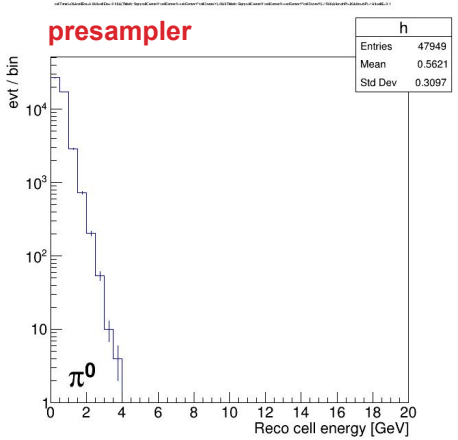
5D Calorimeter

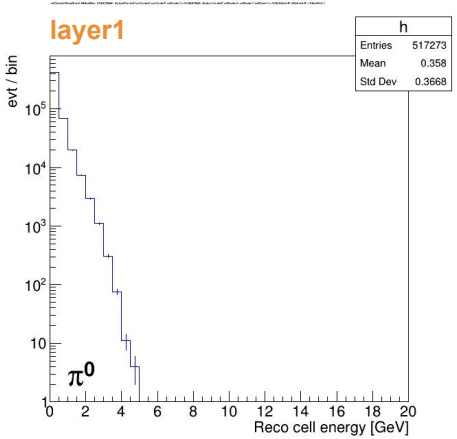
Reco cell E per layer (1 GeV < truth pion p_T < 20 GeV)

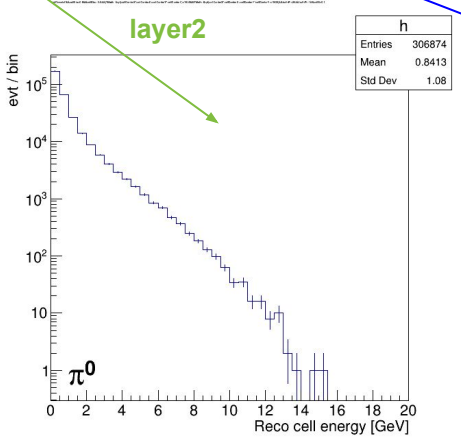


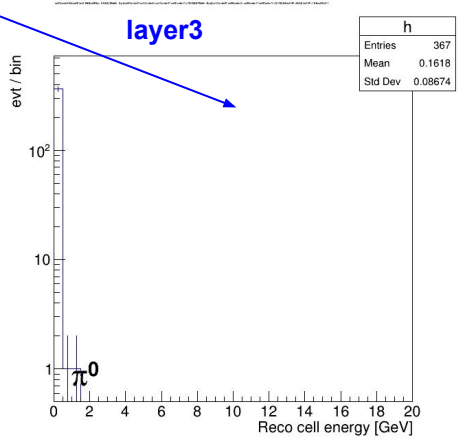


- Check reco cell E range within the region of our interest
- There is no cell which has more than 16 GeV





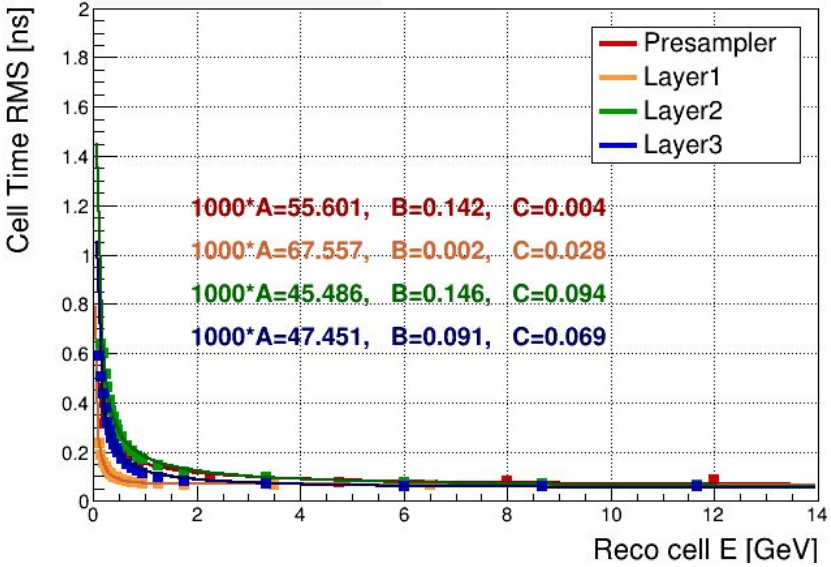




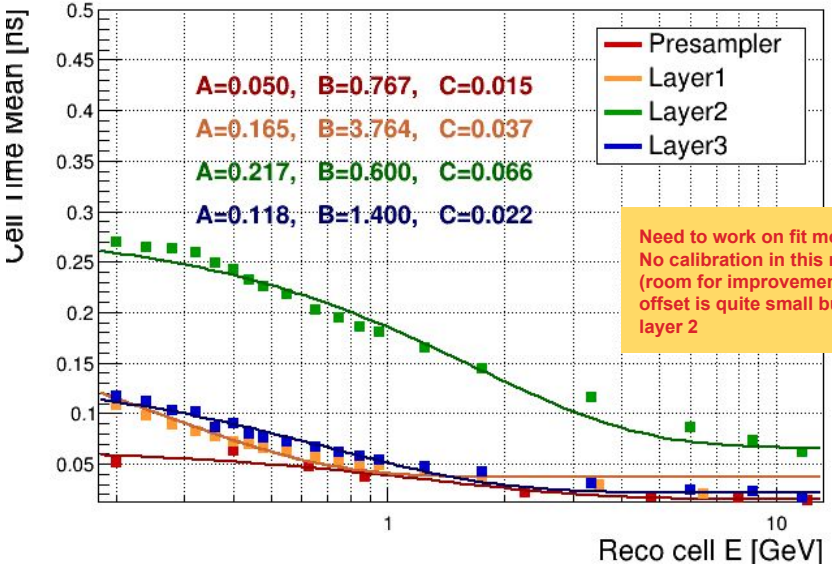
5D Calorimeter

RMS vs Reco cell E per EM LAr Barrle layer

$$\sqrt{A^2 + \frac{B^2}{E} + \frac{C^2}{E^2}}$$



$$A \cdot e^{-B \cdot E} + C$$



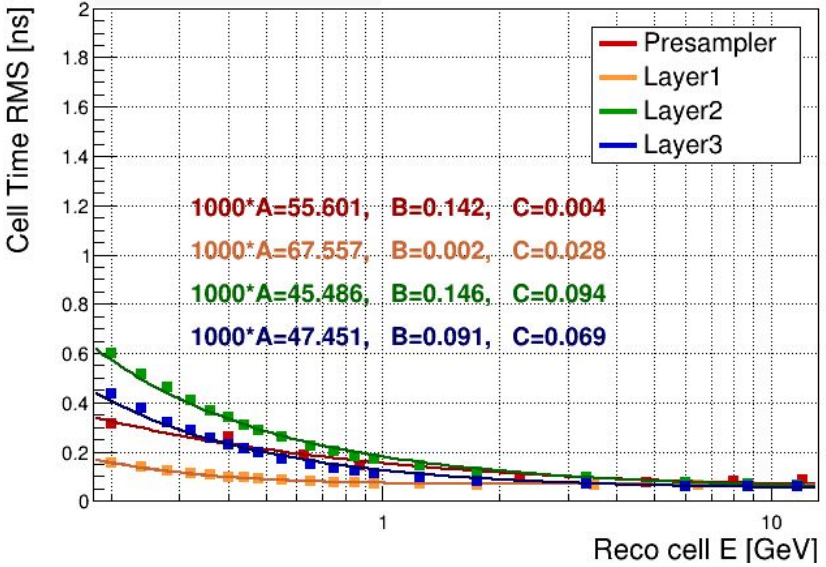
Need to work on fit more..
No calibration in this round (room for improvement) but offset is quite small but for layer 2

- Timing resolution and mean are parametrized by cell E (E)
- The constant term (i.e. **A**) depends on **layer** (range from 45.5 ~ 67.6 ps)
- Cell time resolution = 73.1 ps at layer 1 for 1GeV cell, 67.6 ps at layer 1 for 10GeV cell
  179. ps at layer 2 for 1GeV cell, 65.4 ps at layer 2 for 10GeV cell
  124. ps at layer 3 for 1GeV cell, 55.9 ps at layer 3 for 10GeV cell

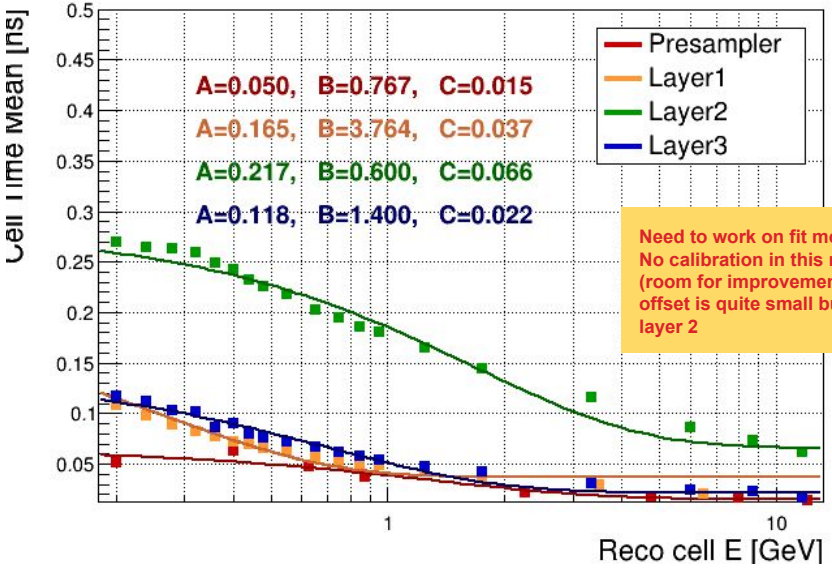
RMS vs Reco cell E per EM LAr Barrle layer

$$\sqrt{A^2 + \frac{B^2}{E} + \frac{C^2}{E^2}}$$

Log scale X-axis



$$A \cdot e^{-B \cdot E} + C$$



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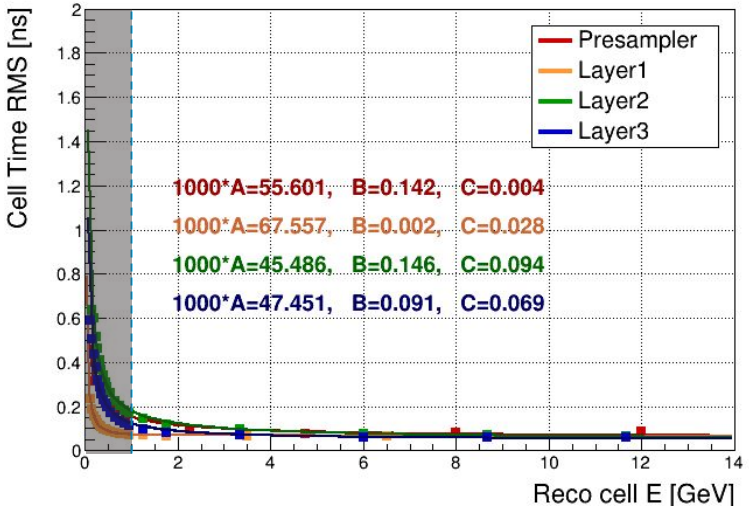
  179. ps at layer 2 for 1GeV cell, 65.4 ps at layer 2 for 10GeV cell
  124. ps at layer 3 for 1GeV cell, 55.9 ps at layer 3 for 10GeV cell

Event selections

To have a same set of pions for comparison, the following selections are applied

- 1 GeV < Truth pion pT < 20 GeV
- Only non-zero cell time cells
- LAr EM Barrel (|eta| < 0.8)
- Pre-sampler is excluded

Up to this selection, 88508 pions



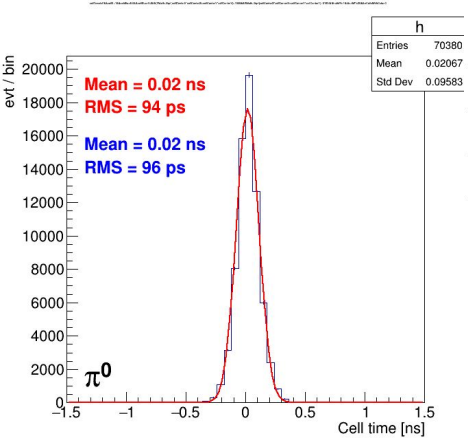
- **At least one cell in a pion has reco cell E > 1 GeV**

→ 37926 pions (88508/37926 = 42.9%)

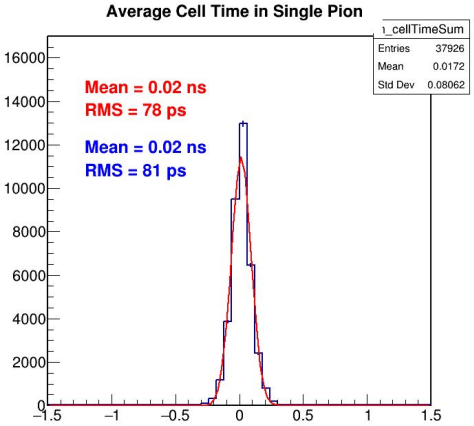
FYI, this fraction was **8.65%** in case of charged pion due to higher cell E cut (2GeV)
so neutral pion seems much more promising

5D Calorimeter

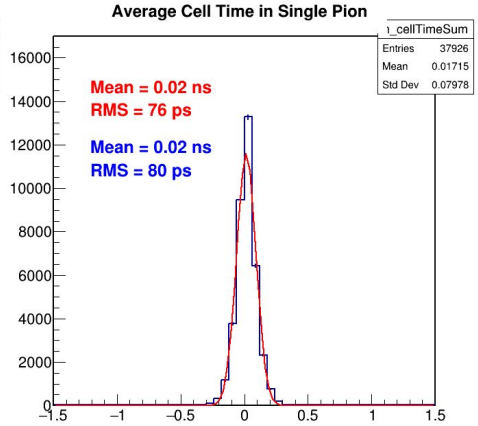
Various way to average (average only reco cell E > 1 GeV)



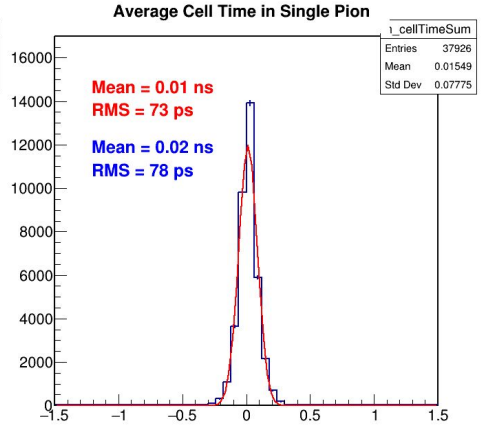
Individual cell time



Arithmetic mean

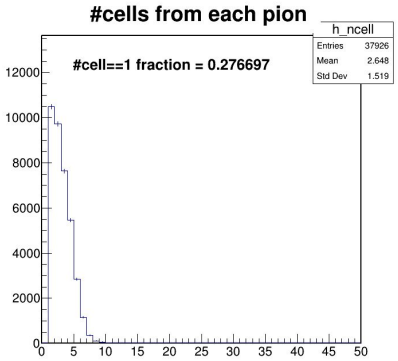


Cell E weighted

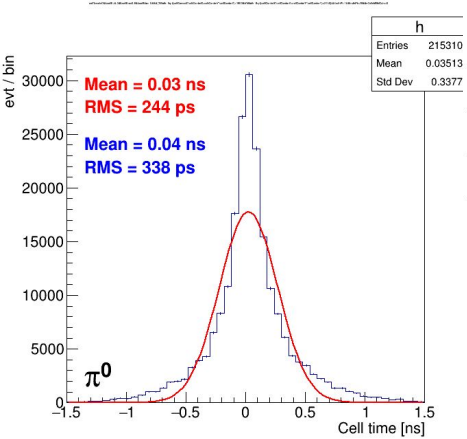


1/RMS² weighted (no calibration)

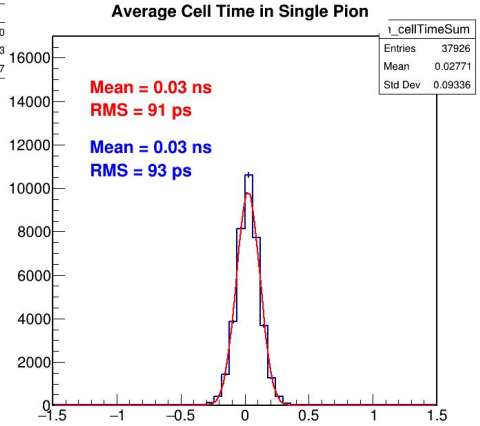
- Average only cells with **reco cell E > 1 GeV**
- Single cell faction in averaged distributions = 27.7 %



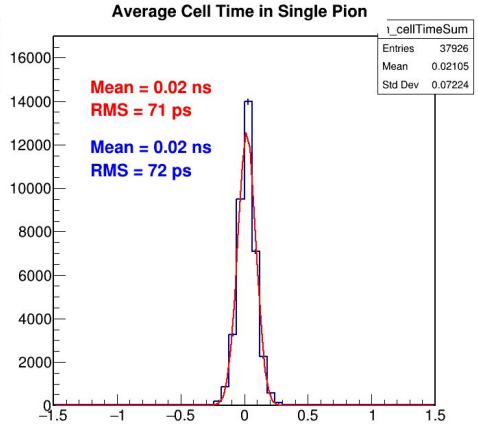
Various way to average (average only reco cell E > 0.1 GeV)



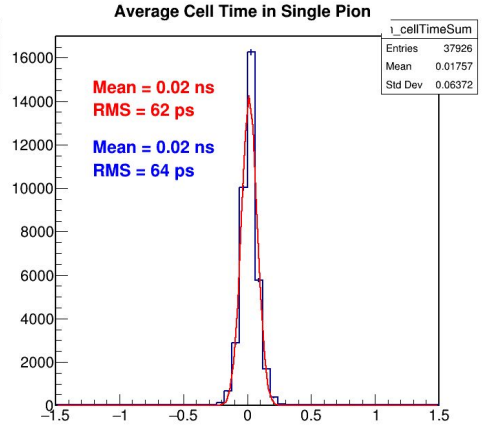
Individual cell time



Arithmetic mean



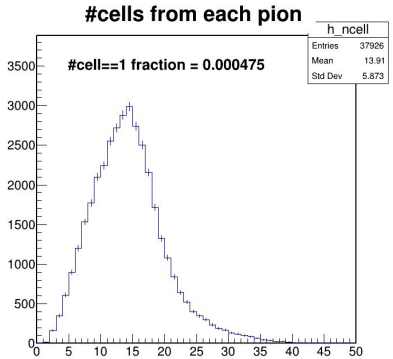
Cell E weighted



1/RMS² weighted (no calibration)

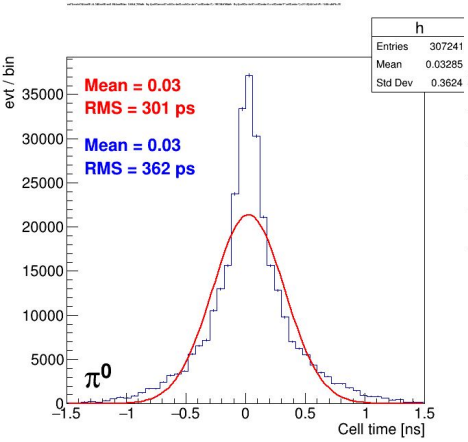
- Average only cells with **reco cell E > 0.1 GeV**
- Single cell faction in averaged distributions = 0.05 %

→ Using pions with at least one energetic cell, we can achieve a very decent timing resolution with **neutral pions**, which can complement the timing information for charged particles obtained from the timing detector (we still even have a room for improvement with proper calibration)

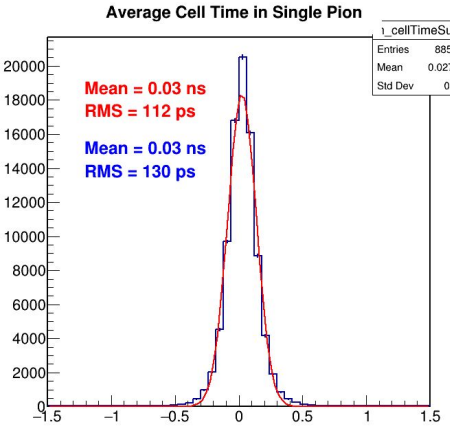


5D Calorimeter

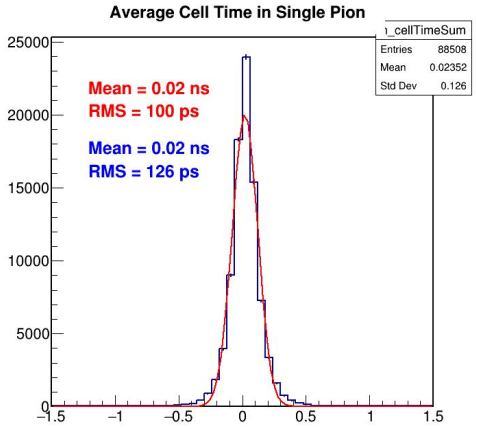
Various way to average (average only reco cell E > 0.1 GeV)



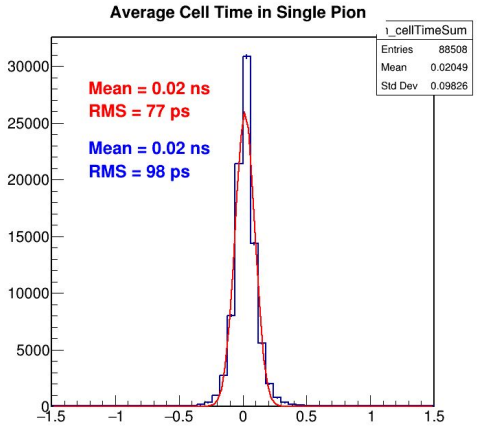
Individual cell time



Arithmetic mean

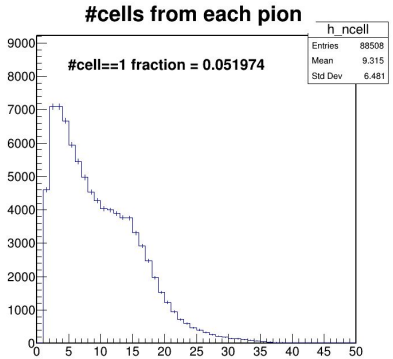


Cell E weighted



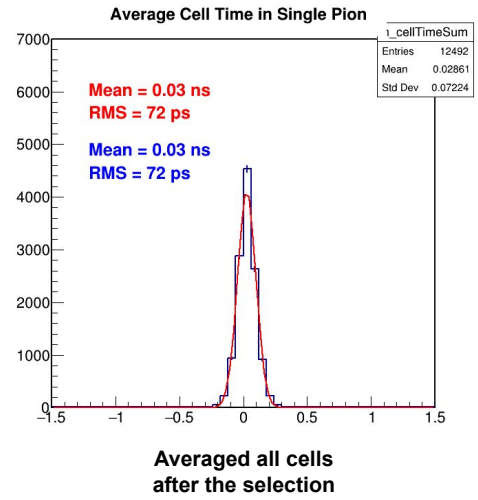
1/RMS^2 weighted (no calibration)

- Average only cells with **reco cell E > 0.1 GeV**
- Single cell faction in averaged distributions = 5.20 %
- **At least one cell in a pion has reco cell E > 1 GeV (removed)**

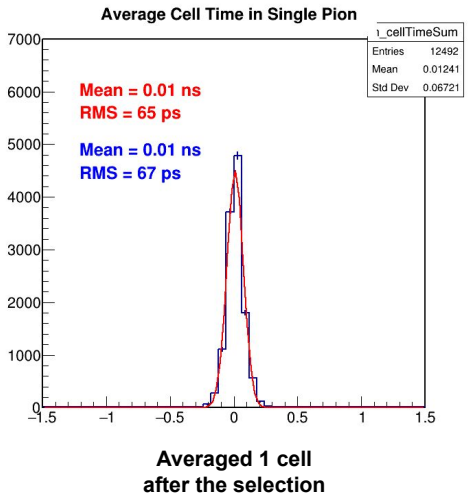


5D Calorimeter

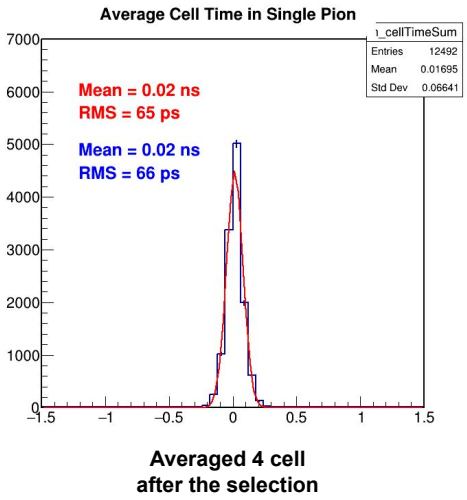
Checking stat error change with different sample size



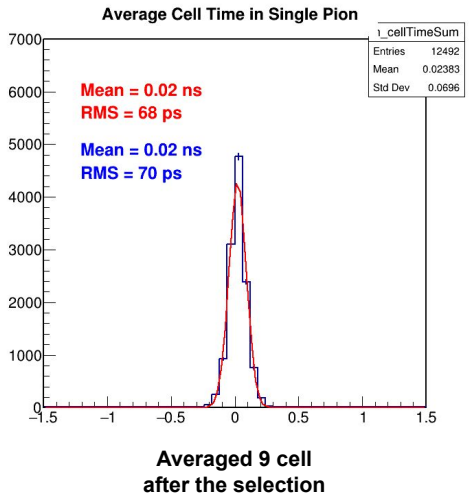
Averaged all cells after the selection



Averaged 1 cell after the selection



Averaged 4 cell after the selection



Averaged 9 cell after the selection

To have a same set of pions for comparison, the following selections are applied

- 1 GeV < Truth pion pT < 20 GeV
- Only non-zero cell time cells
- LAr EM Barrel (|eta| < 0.8)
- Only layer1 is considered
- After the above selection #cell in a pion >= 9
- At least one cell in a pion has reco cell E > 1 GeV

All distributions are $1/RMS^2$ weighted average without calibration

1/sqrt(N) is generally applicable when we are dealing with simple arithmetic averages of independent and identically distributed random variables, so we don't see that effect here

Cell time vs reco cell E