

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

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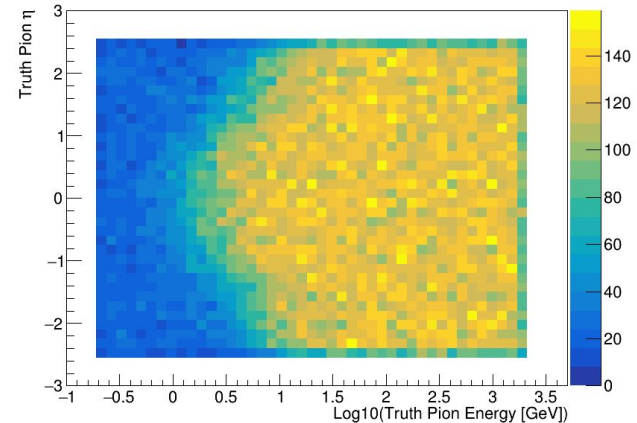
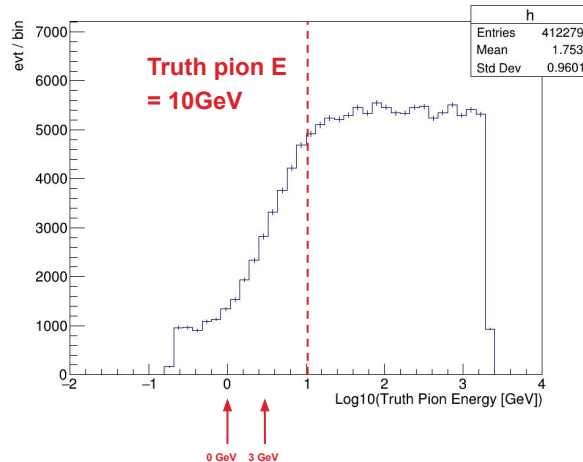
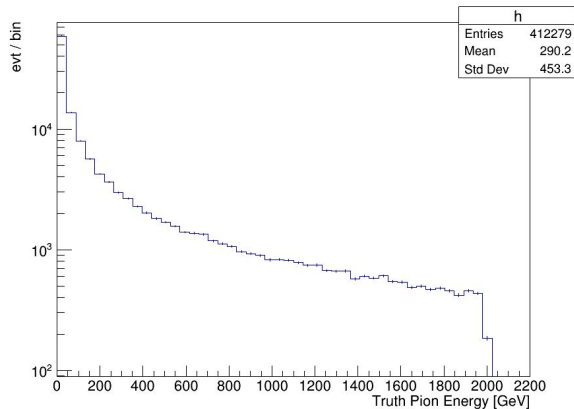
- Time information will enhance our understanding of jets
- Many physics program can be improved by using 5D calorimeter information
- ATLAS calorimeter systems measure time as well as energy, however, cell time information is hardly used
  - So far, people use cuts on cell time to reject out-of-time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

- How the Ntuple generated:

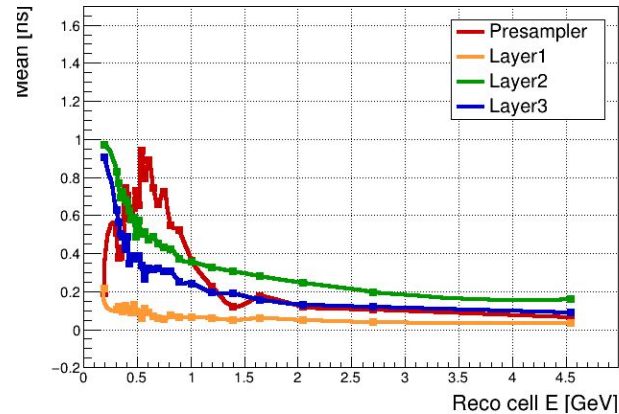
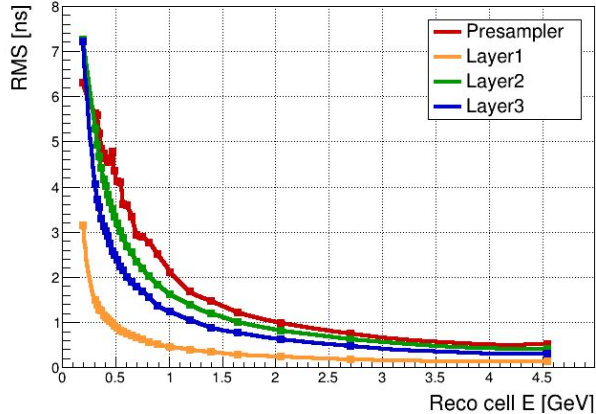
Generated with the logarithm of their energies sampled uniformly, also the showers are distributed uniformly at random  $\eta$

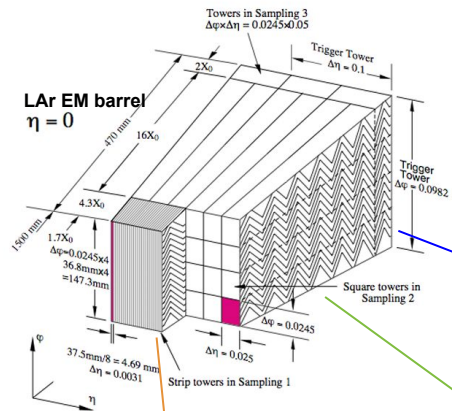
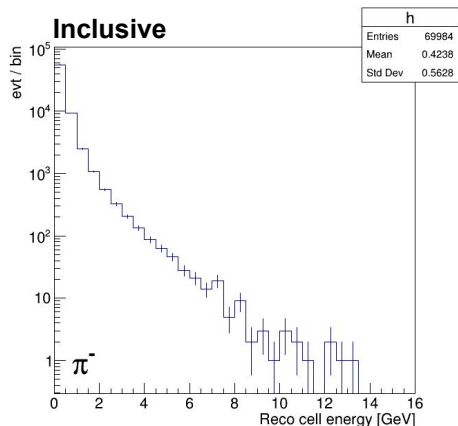
- Additional information on the Ntuple:

- Min truth pion E = 0.2000181 GeV, Max truth pion E = 1999.7366 GeV
- Log10(E) distribution &  $\eta$  distributions are uniform only when it is greater than  $\sim 1$  (i.e. Truth pion E = 10GeV)
- In this Ntuple, the cell time is a reconstructed feature with truth particles generated at  $t = 0$

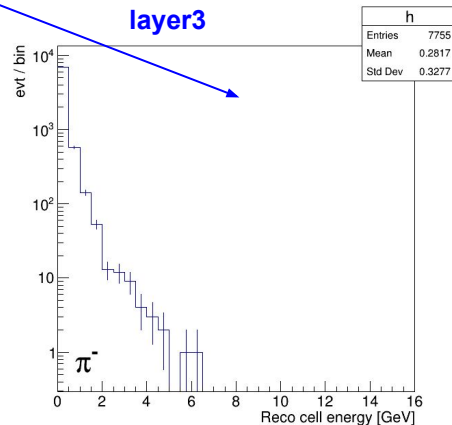
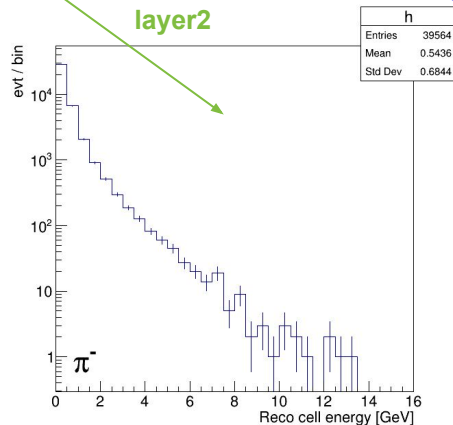
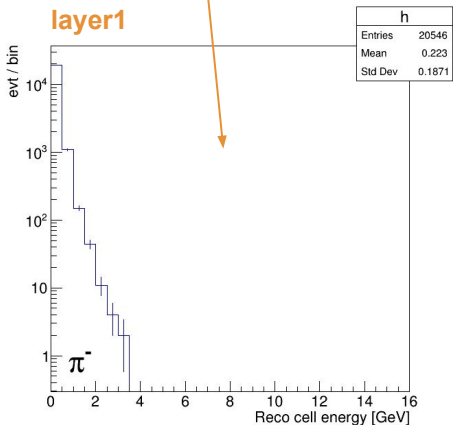
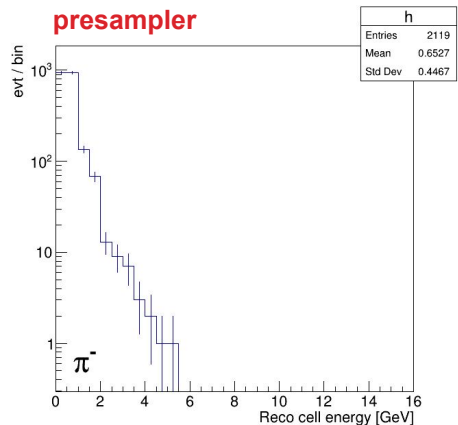


- When we average cell time per each pion, timing resolution was not improved after averaging.
- It turned out that, there are dependency on EM calo layer
  - Is there any dependency on truth pion  $p_T$ ?
  - Fit the distributions for calibration

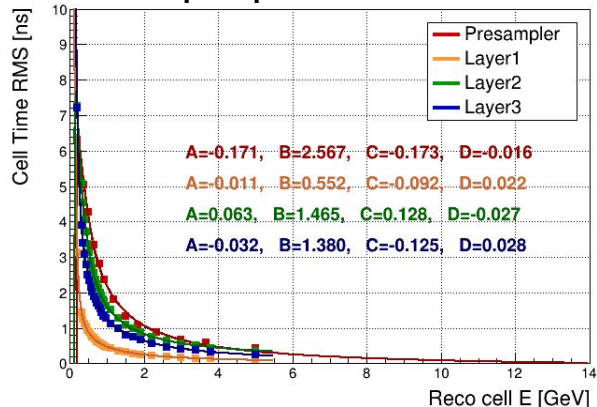




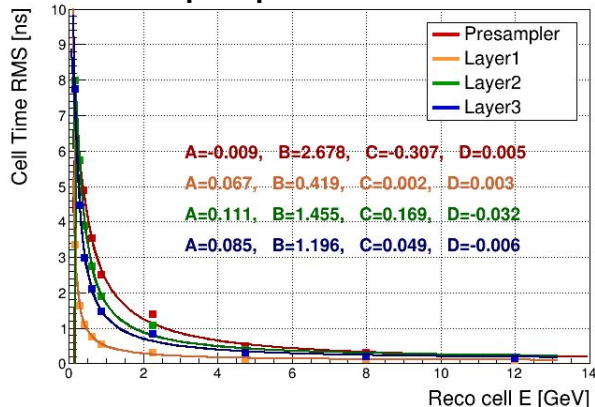
- Check reco cell E range within the region of our interest
- There is no cell which has more than 14 GeV



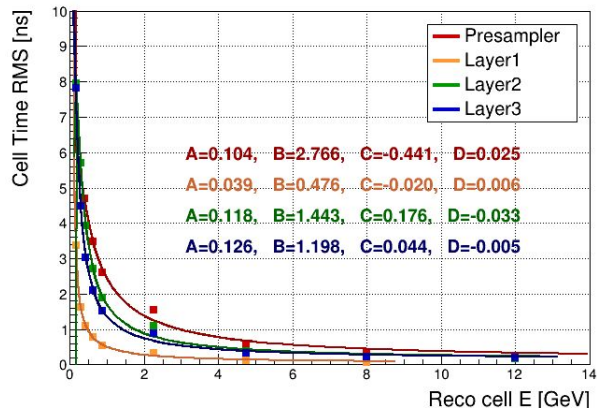
1 GeV < pion pT



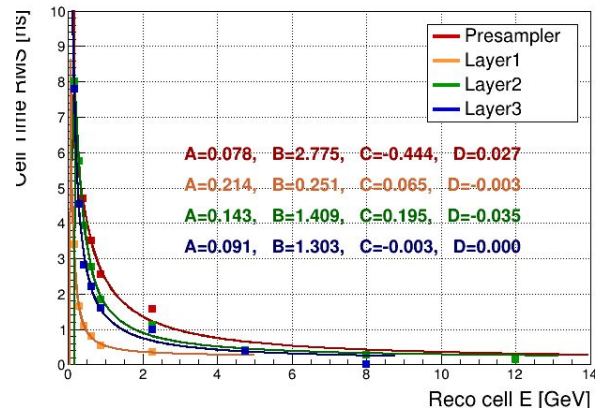
1 GeV < pion pT < 500 GeV



1 GeV < pion pT < 50 GeV



1 GeV < pion pT < 20 GeV



- Timing resolution is parametrized by cell E (E)

$$A + \frac{B}{E} + \frac{C}{E^2} + \frac{D}{E^3}$$

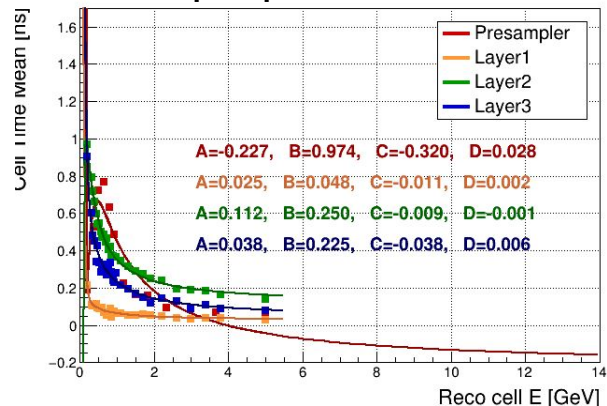
- The constant term (i.e. A) depends on layer and pion pT  
It amounts to

- 11 ~ 214 ps at layer 1
- 63 ~ 143 ps at layer 2
- 32 ~ 125 ps at layer 3

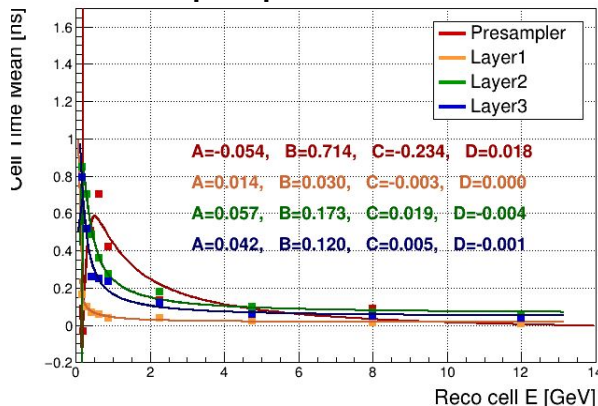
Note: Fits with the following parametrization diverge often

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

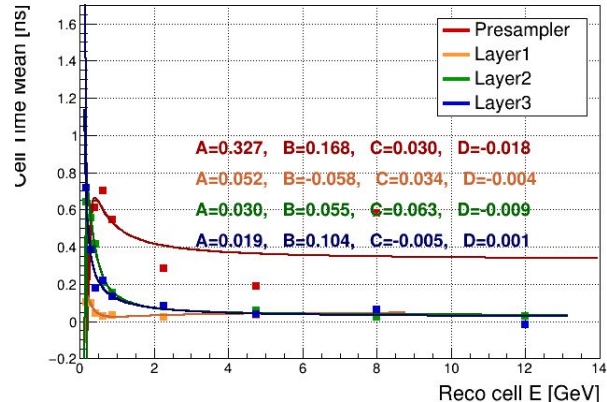
1 GeV < pion pT



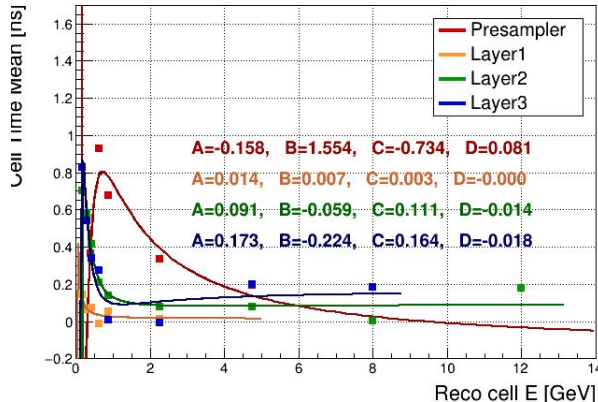
1 GeV < pion pT < 500 GeV



1 GeV < pion pT < 50 GeV



1 GeV < pion pT < 20 GeV



- Mean values of the cell time is parametrized by cell E (E)

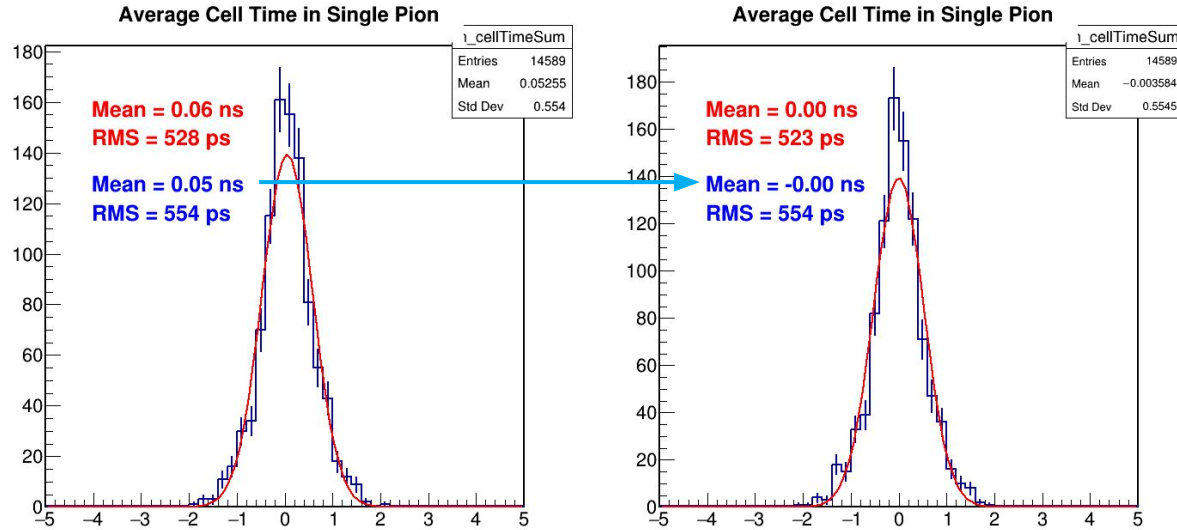
$$A + \frac{B}{E} + \frac{C}{E^2} + \frac{D}{E^3}$$

- The constant term (i.e. A) depends on layer and pion pT

\* Looks like sensitive to binning :(

→ Having reliable constant term is very challenging for low pT pions

→ Offset does depends on pion pT



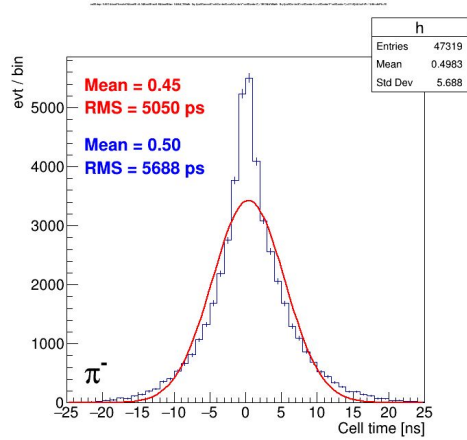
**1/RMS<sup>2</sup> weighted  
Reco cell E > 2GeV  
Layer 1 only**

**1/RMS<sup>2</sup> weighted  
Reco cell E > 2GeV  
Layer 1 only  
Offset( $t_0$ ) subtracted**

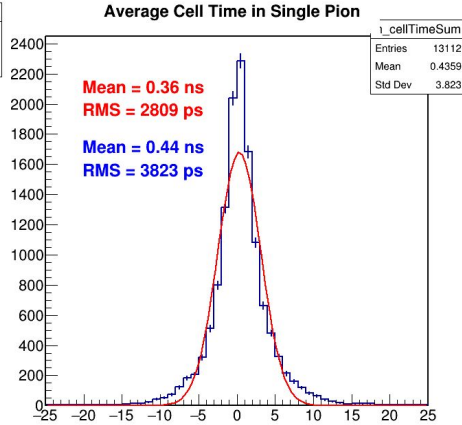
$$\frac{\sum_i (w_i \cdot (t_i - t_0))}{\sum_i w_i}$$

**Used weighted average,  
where  $w = (1/\text{RMS}^2)$**

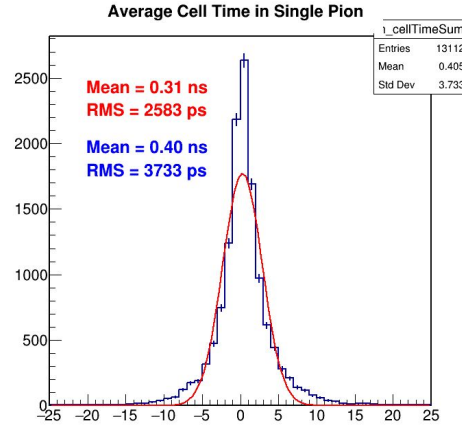
- Fittings with '1 GeV < pion pT < 50 GeV' are applied to events with '1 GeV < pion pT < 20 GeV'
- After calibration, mean value centers at 0ns



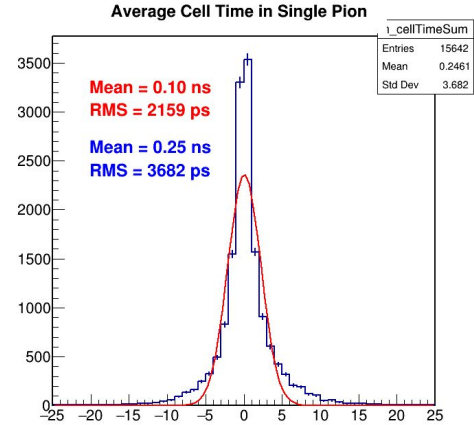
**Individual cell time**  
No presampler



**Arithmetic mean**  
Reco cell E > 0.1GeV  
No presampler

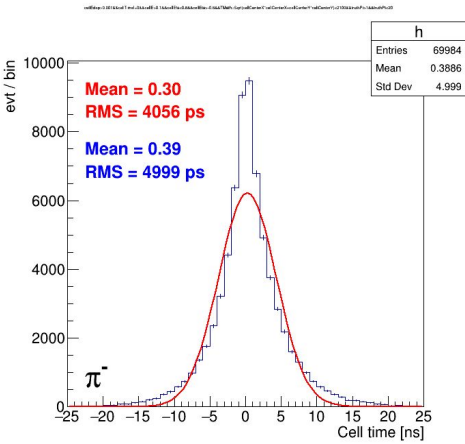


**Cell E weighted**  
Reco cell E > 0.1GeV  
No presampler



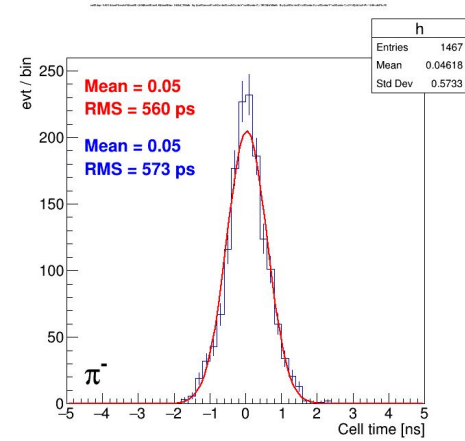
**1/RMS<sup>2</sup> weighted**  
Reco cell E > 0.1GeV  
No presampler  
Calibrated

- Weighted average distributions have enhanced RMS, and mean is closer to 0 after calibration
- Non-gaussian tails (from low gain cells) are still remain
- Calibration is still not perfect

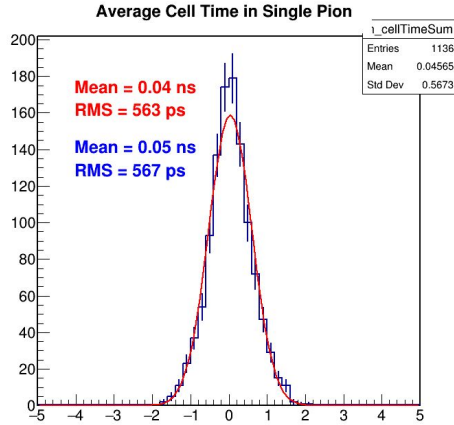


Individual cell time

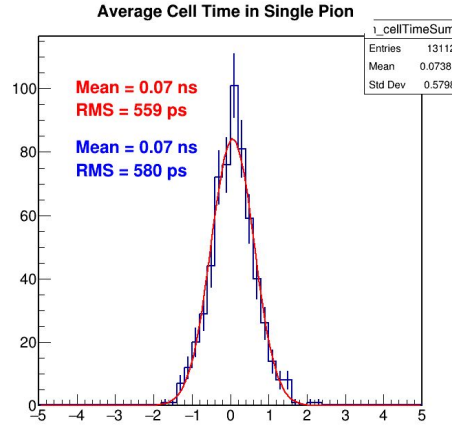
- This slide is just for reference with/without presampler before averaging



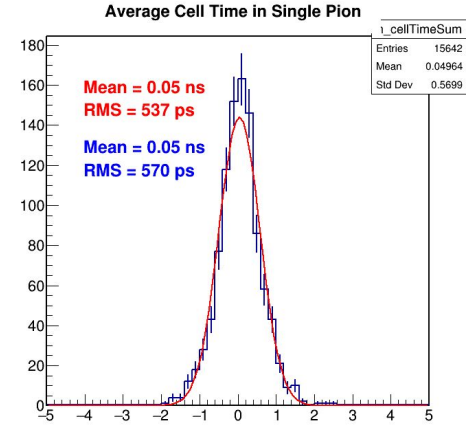
**Individual cell time**  
**Reco cell E > 2GeV**  
**No presampler**



**Arithmetic mean**  
**Reco cell E > 2GeV**  
**No presampler**

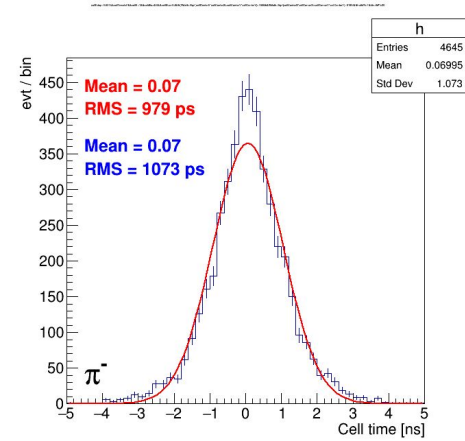


**Cell E weighted**  
**Reco cell E > 2GeV**  
**No presampler**

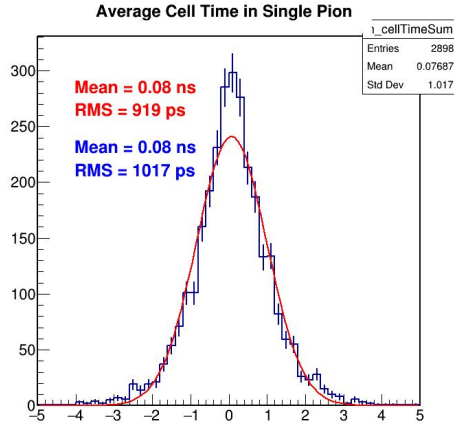


**1/RMS<sup>2</sup> weighted**  
**Reco cell E > 2GeV**  
**No presampler**

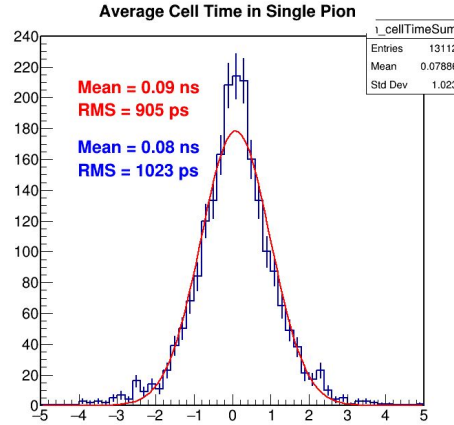
- With high reco cell E cut (2 GeV, where RMS converges btw layers), weighted average distributions doesn't play much role
- For 97.1% of pion, single cell survived after this hard cut



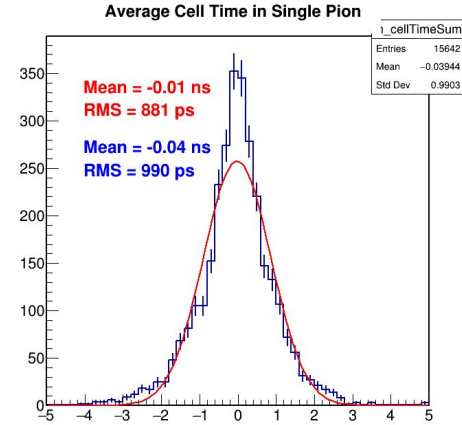
Individual cell time  
Reco cell E > 1GeV  
No presampler



Arithmetic mean  
Reco cell E > 1GeV  
No presampler



Cell E weighted  
Reco cell E > 1GeV  
No presampler



1/RMS<sup>2</sup> weighted  
Reco cell E > 1GeV  
No presampler

- With high reco cell E cut (1 GeV), RMS weighted average distribution has 8% enhanced timing resolution wrt individual cell time distribution
- For 84.9% of pion, single cell survived after this hard cut

- E resolution for validation purpose
- Pi zero sample (w/o pileup) has ridiculous cell E
  - Under investigation...