

Timing calibration using single neutral pion events

2023, October 13

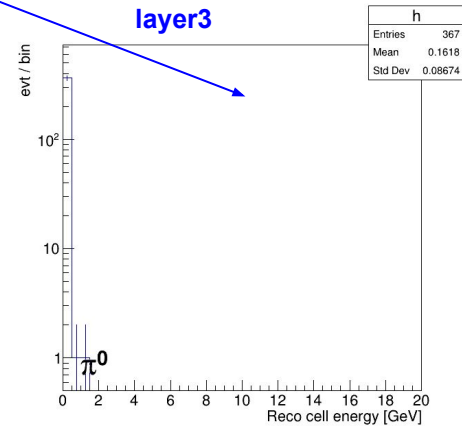
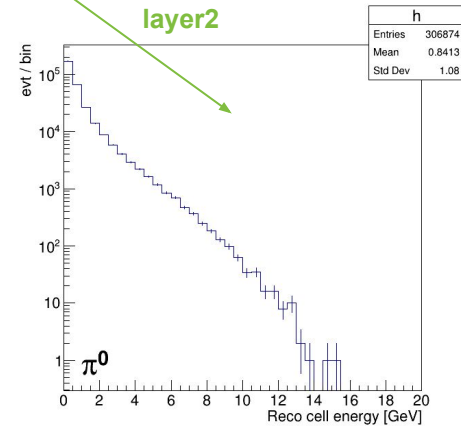
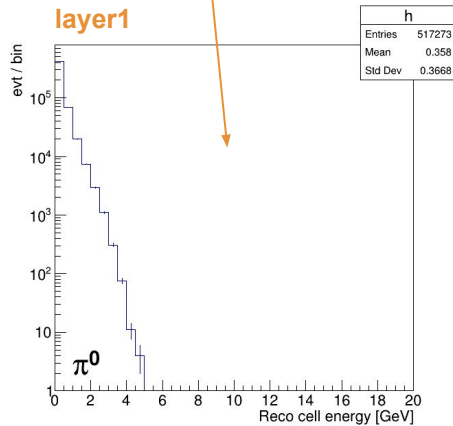
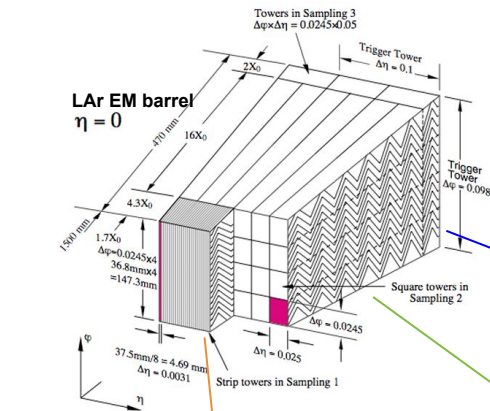
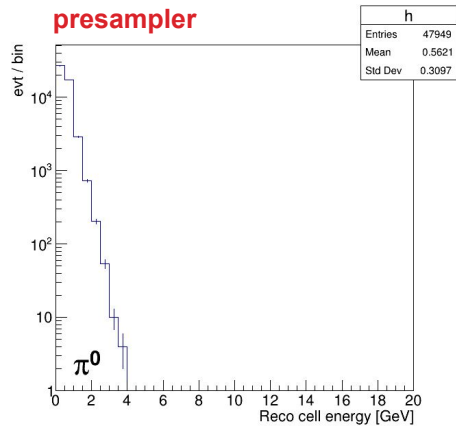
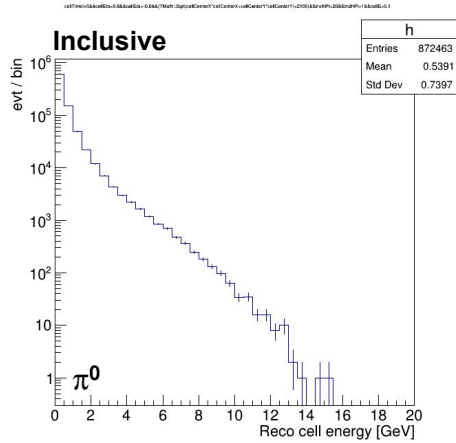
<https://indico.slac.stanford.edu/event/8480/>



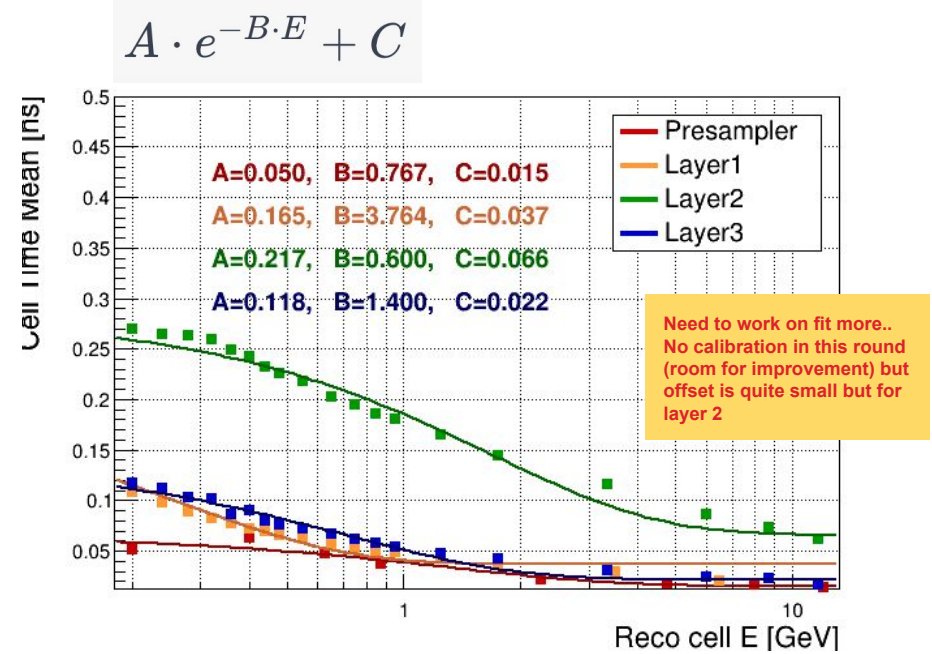
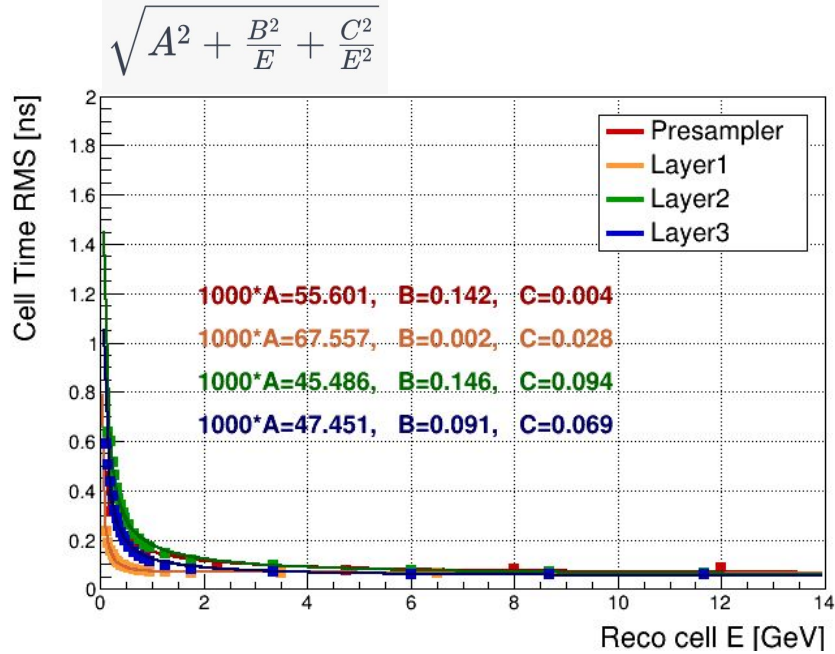
Kim Doyeong 김도영

Zahra Farazpay

Timing calibration using single neutral pion events

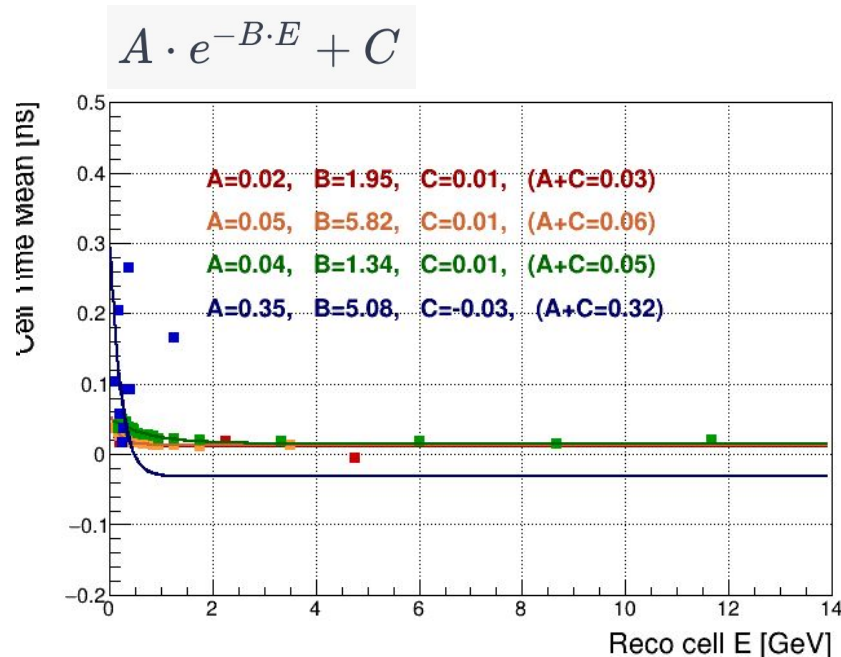
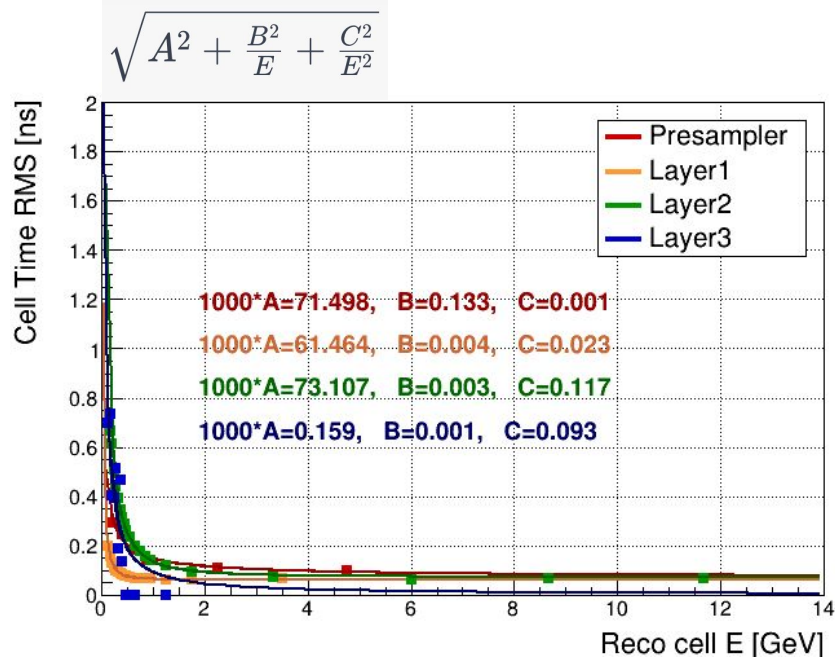


- Check reco cell E range within the region of our interest
- There is no cell which has more than 16 GeV



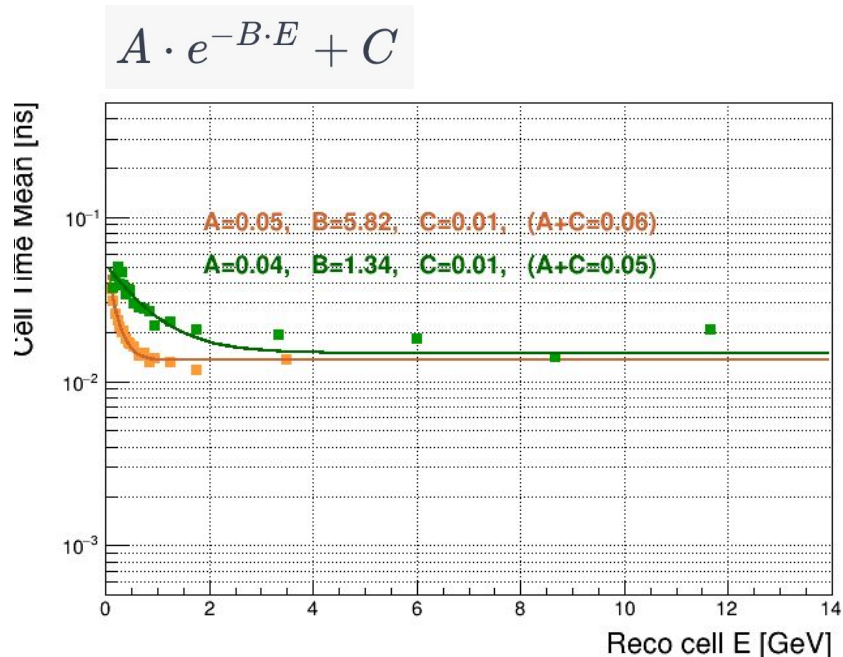
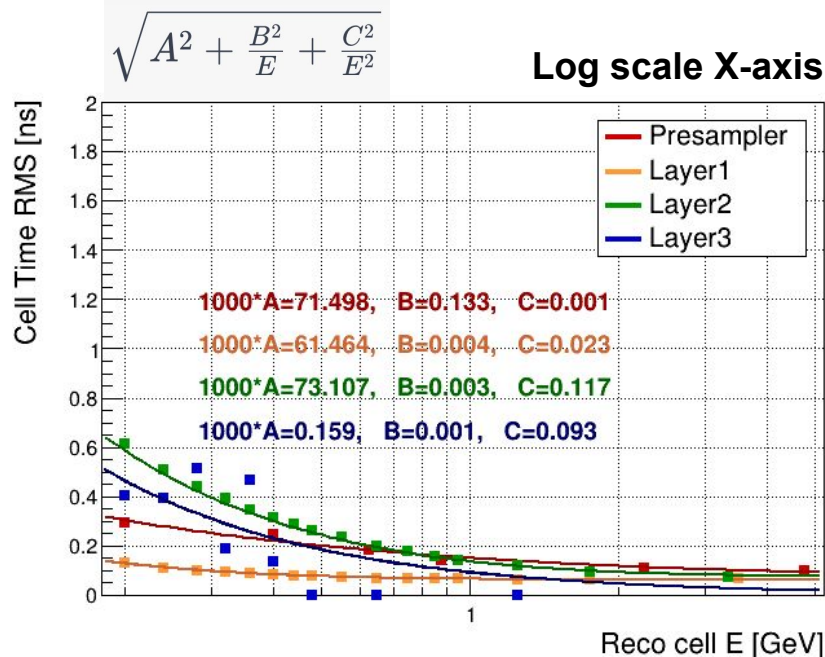
- Timing resolution and mean are parametrized by cell E (E)
- The constant term (i.e. A) depends on **layer** (range from 45.5 ~ 67.6 ps)
- Cell time resolution =

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



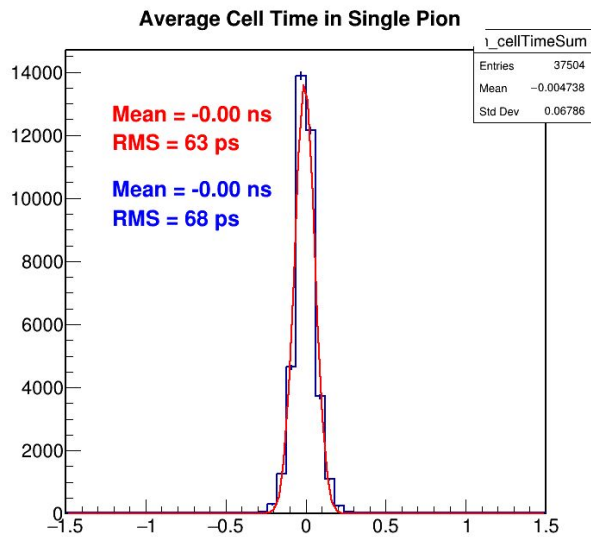
- Timing resolution and mean are parametrized by cell E (E)
- The constant term (i.e. A) depends on layer (range from 61.5 ~ 73.1 ps)

Only layer 1 and layer 2 will be considered in this study

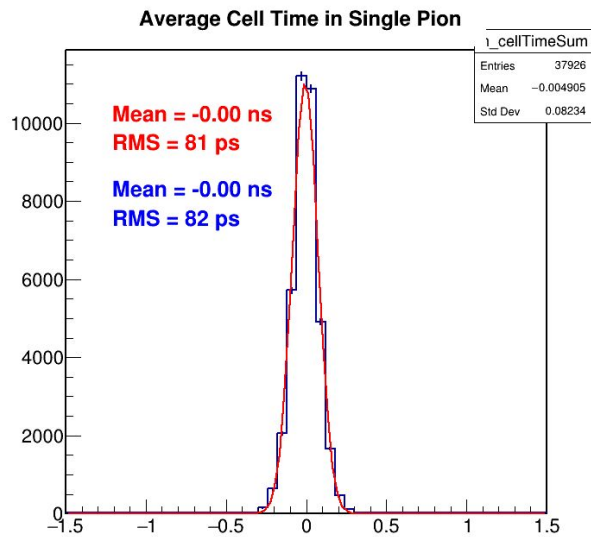


- Timing resolution and mean are parametrized by cell E (E)
- The constant term (i.e. A) depends on **layer** (range from 61.5 ~ 73.1 ps)

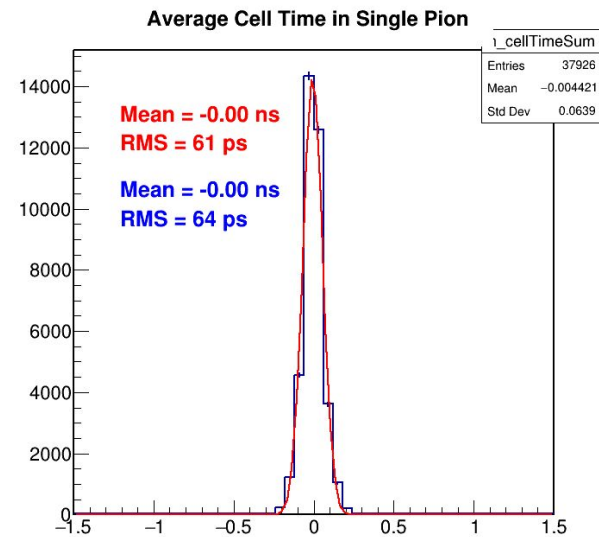
Only layer 1 and layer 2 will be considered in this study



Layer 1 only



Layer 2 only



Layer 1+2

- **Calibration** is well done and distributions are centered at 0 in each layer and inclusively
Where calibration means 'cell time \rightarrow cell time - $f_{\text{mean}}(\text{cell E})$ '
 $f_{\text{mean}}(\text{cell E})$ is fit functions on slide 5



Draw cell time with one cell

Why it does not follow $1/\sqrt{N}$ rule?

After given selection,
we have (reco cell E, cell time) pair that is **sorted by reco cell E** for each pion

0	celle = 1.0374	cellTime =	2.3166
1	celle = 0.36766	cellTime =	1.9161
2	celle = 0.3251	cellTime =	-0.24404
3	celle = 0.25441	cellTime =	-0.64209
4	celle = 0.22627	cellTime =	3.5027
5	celle = 0.2012	cellTime =	-3.9121
6	celle = 0.16394	cellTime =	12.035
7	celle = 0.16394	cellTime =	12.035
8	celle = 0.12405	cellTime =	9.5905
9	celle = 0.10802	cellTime =	-1.4767

If we average cell time from all cells that passed the selection criteria,

0	celle = 1.0374	cellTime =	2.3166
1	celle = 0.36766	cellTime =	1.9161
2	celle = 0.3251	cellTime =	-0.24404
3	celle = 0.25441	cellTime =	-0.64209
4	celle = 0.22627	cellTime =	3.5027
5	celle = 0.2012	cellTime =	-3.9121
6	celle = 0.16394	cellTime =	12.035
7	celle = 0.16394	cellTime =	12.035
8	celle = 0.12405	cellTime =	9.5905
9	celle = 0.10802	cellTime =	-1.4767

deno = 10

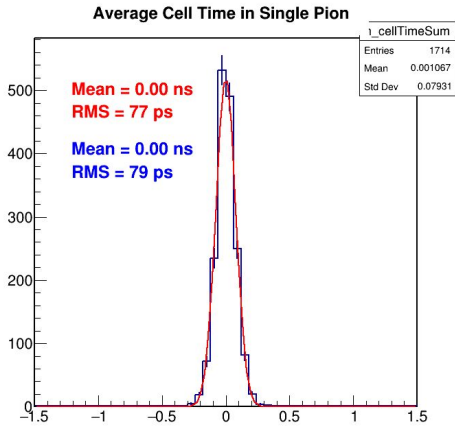
avg. = 3.5121

If we average cell time from only leading cell,

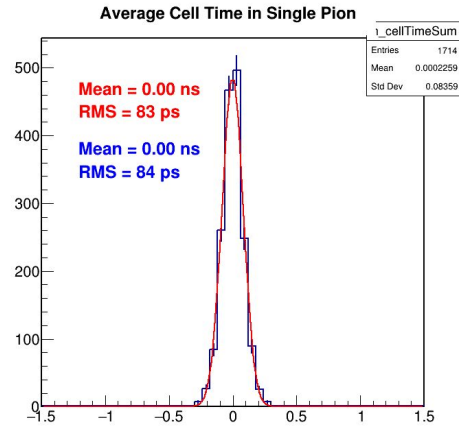
0	celle = 1.0374	cellTime =	2.3166
1	celle = 0.36766	cellTime =	1.9161
2	celle = 0.3251	cellTime =	-0.24404
3	celle = 0.25441	cellTime =	-0.64209
4	celle = 0.22627	cellTime =	3.5027
5	celle = 0.2012	cellTime =	-3.9121
6	celle = 0.16394	cellTime =	12.035
7	celle = 0.16394	cellTime =	12.035
8	celle = 0.12405	cellTime =	9.5905
9	celle = 0.10802	cellTime =	-1.4767

deno = 10

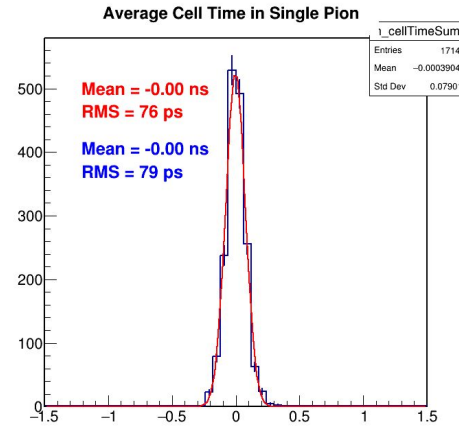
avg. = ~~3.5121~~ → avg. cell time = 2.3166 ns



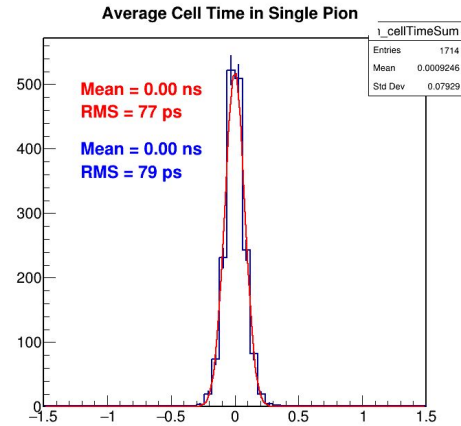
Averaged all cells
after the selection



Averaged 1 cell
after the selection



Averaged 4 cell
after the selection



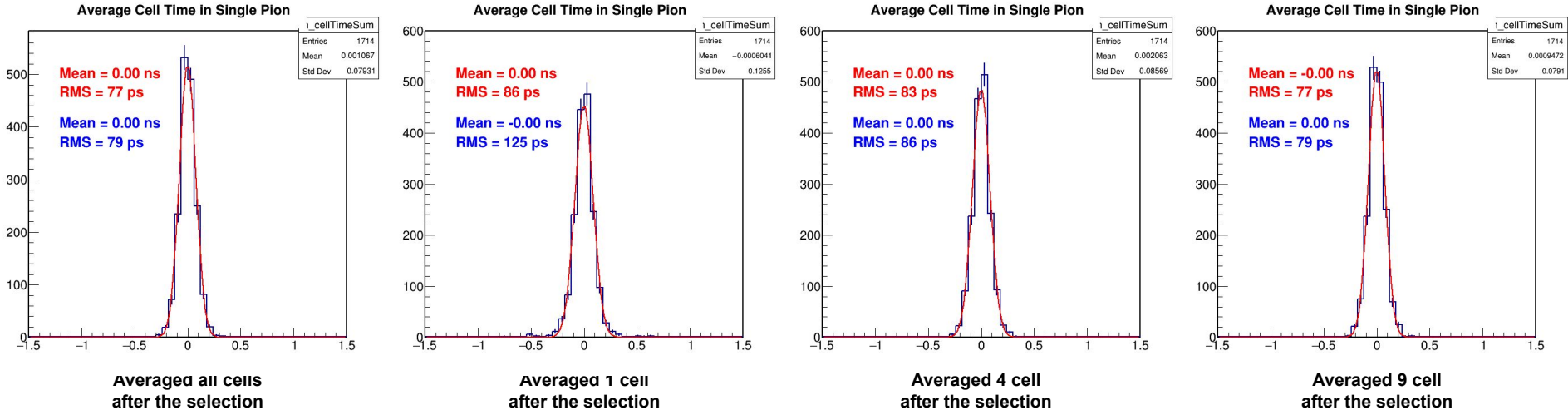
Averaged 9 cell
after the selection

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

- $1 \text{ GeV} < \text{Truth pion } p_T < 20 \text{ GeV}$
- Only non-zero cell time cells
- LAr EM Barrel ($|\eta| < 0.8$)
- Only layer2(where most of the energy is deposited) is considered
- After the above selection #cell in a pion ≥ 9
- At least one cell in a pion has reco cell $E > 1 \text{ GeV}$

$1/\sqrt{N}$ 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

All distributions are sorted by cellE after selection, then $1/\text{RMS}^2$ weighted average without calibration



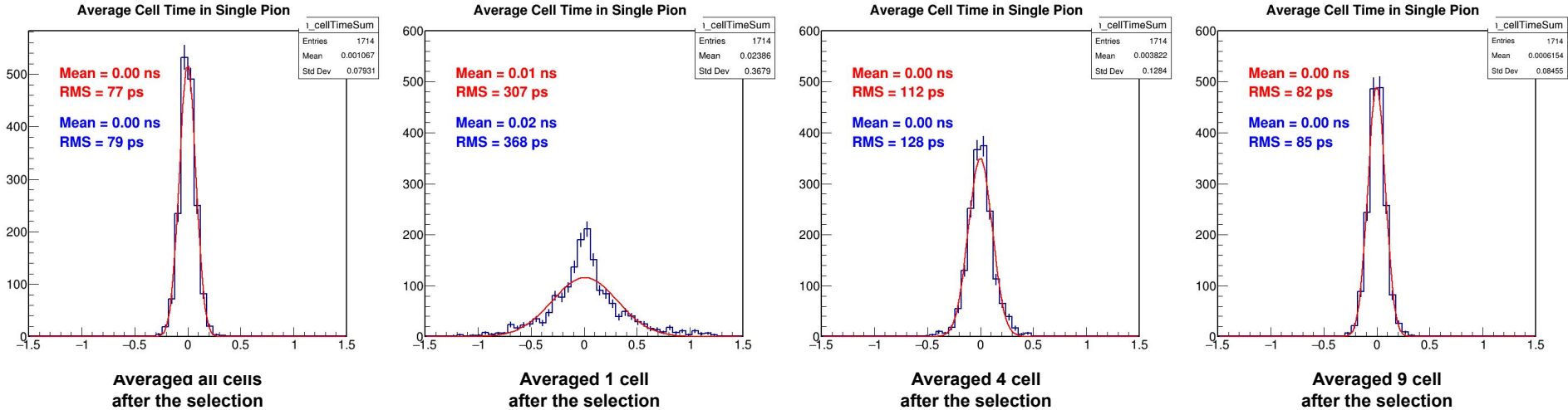
To have a same set of pions for comparison, the following selections are applied

- 1 GeV < Truth pion p_T < 20 GeV
- Only non-zero cell time cells
- LAr EM Barrel ($|\eta| < 0.8$)
- Only layer2(where most of the energy is deposited) 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 $1/\text{RMS}^2$ weighted average without calibration (cells are ordered at Ntuple level)

```
root [4] CellTree->Scan("cellE:eventNumber")
*****
*   Row   *   cellE * eventNum *
*****
*     0 * 0.8483136 *     837 *
*     1 * 0.0939839 *     837 *
*     2 * 0.5843032 *     837 *
*     3 * 0.1696579 *     837 *
*     4 * 0.0289775 *     837 *
*     5 * 0.0239537 *     837 *
*     6 * 0.0160578 *     837 *
*     7 * 0.1386839 *     837 *
*     8 * 0.0460442 *     837 *
*     9 * 0.0588638 *     837 *
*    10 * 0.2087058 *     837 *
*    11 * 0.5918792 *     837 *
*    12 * 0.3367217 *     837 *
*    13 * 0.1200660 *     837 *
*    14 * 0.0588638 *     837 *
*    15 * 0.0470919 *     837 *
*    16 * 0.0588638 *     837 *
*    17 * 0.0099955 *     837 *
*    18 * 0.9332099 *     837 *
*    19 * 0.0460442 *     837 *
*    20 * 0.0219919 *     837 *
*    21 * 0.0090269 *     837 *
*    22 * 0.0099955 *     837 *
*    23 * 0.0289775 *     837 *
*    24 * 0.0010085 *     837 *
Type <CR> to continue or q to quit ==>
```

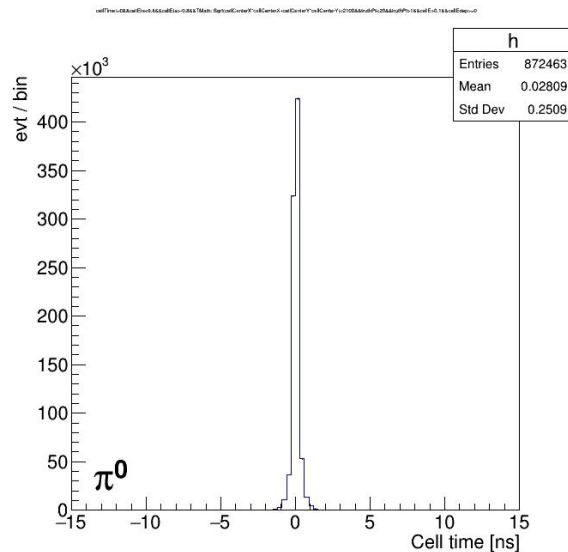
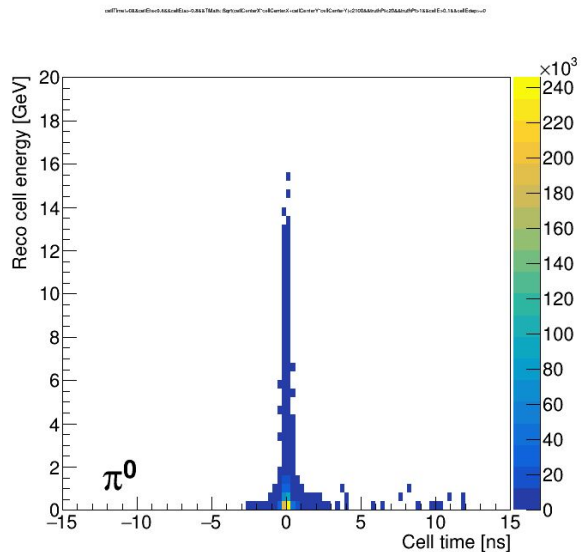
Ntuple is not ordered in cellE, but somehow correlated...
(can look it up)



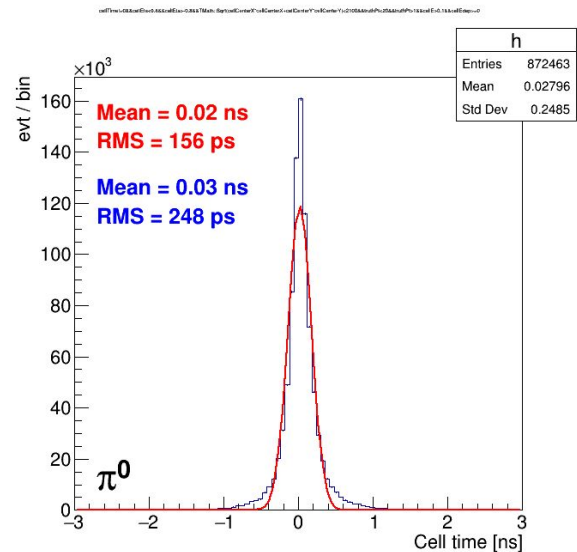
To have a same set of pions for comparison, the following selections are applied

- $1 \text{ GeV} < \text{Truth pion } p_T < 20 \text{ GeV}$
- Only non-zero cell time cells
- LAr EM Barrel ($|\eta| < 0.8$)
- Only layer2(where most of the energy is deposited) is considered
- After the above selection #cell in a pion ≥ 9
- At least one cell in a pion has reco cell $E > 1 \text{ GeV}$

All distributions are randomly mixed after selection, then $1/\text{RMS}^2$ weighted average without calibration



Projection to ctle time,
with the same binning&range



Projection to ctle time,
with different binning&range
+ Gaussian fit

Timing resolution of neutral pion with various average methods

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

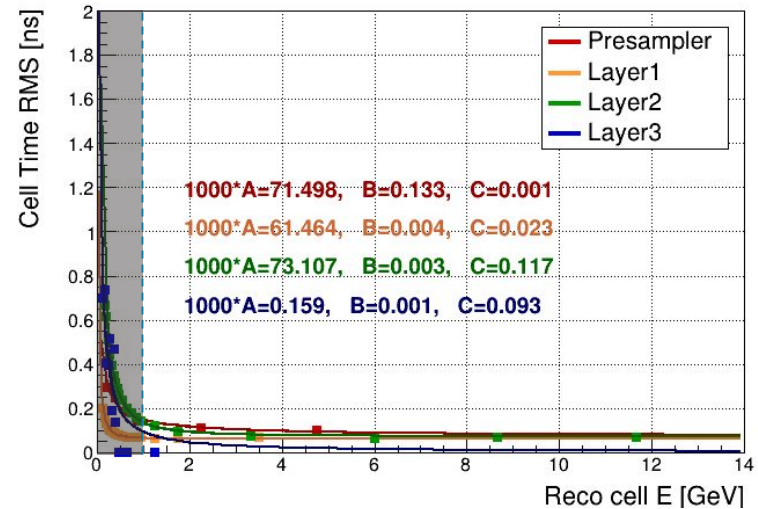
- $1 \text{ GeV} < \text{Truth pion } p_T < 20 \text{ GeV}$
- Only non-zero cell time cells
- LAr EM Barrel ($|\eta| < 0.8$)
- Pre-sampler is excluded

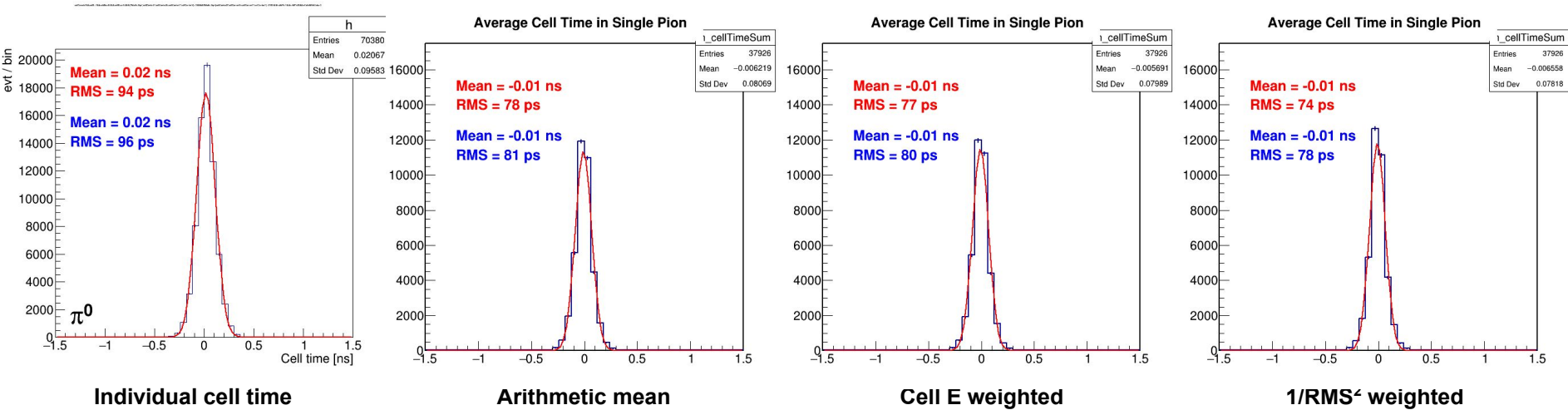
Up to this selection, 88508 pions

- At least one cell in a pion has reco cell E $> 1 \text{ GeV}$

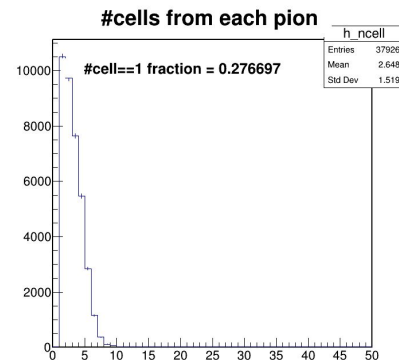
→ 37926 pions (88508/37926 = 42.9%)

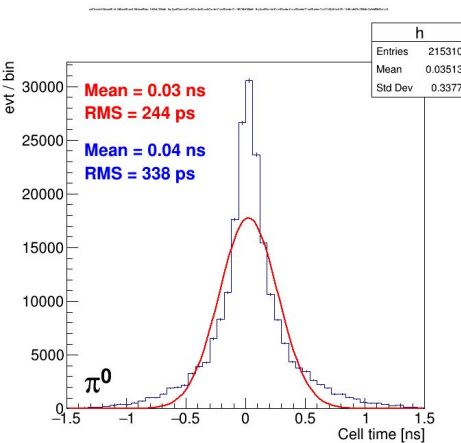
FYI, this fraction was 8.65% in case of charged pion due to higher cell E cut (2GeV)
so neutral pion seems much more promising



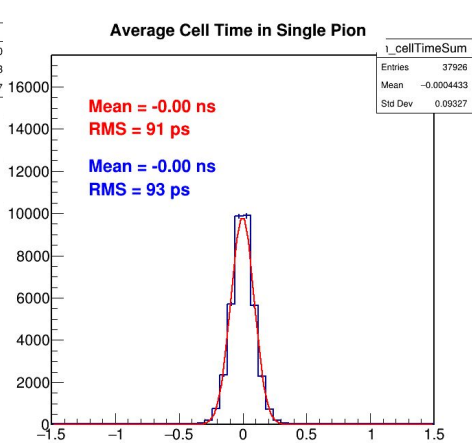


- Average only cells with reco cell E > 1 GeV
- Single cell fraction in averaged distributions = 27.7 %
- All averaged distributions are calibrated

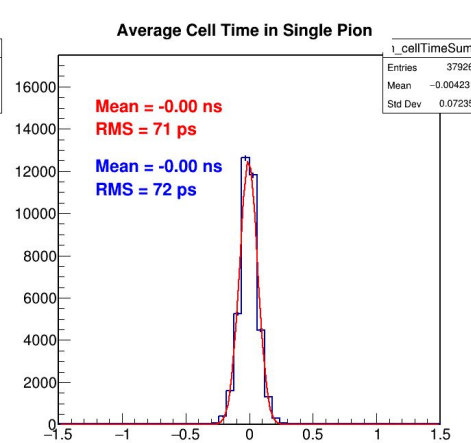




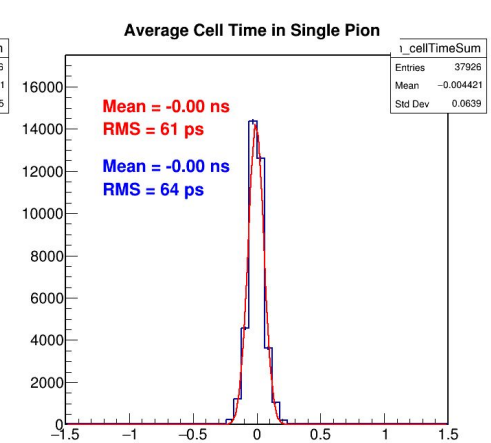
Individual cell time



Arithmetic mean



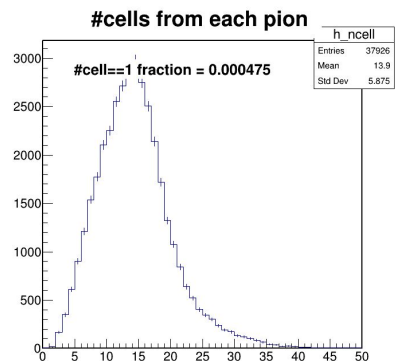
Cell E weighted

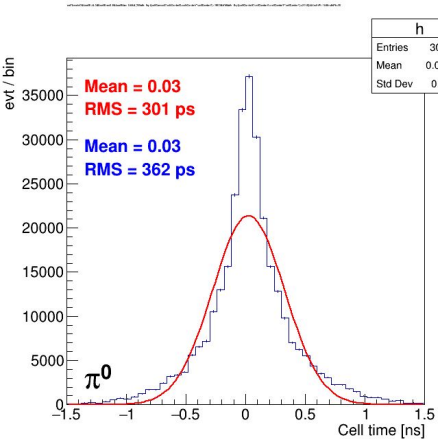


1/RMS² weighted

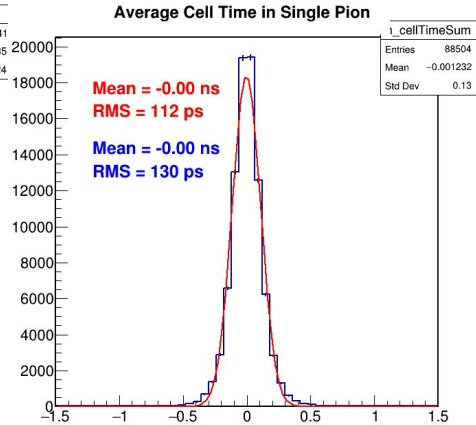
- Average only cells with reco cell E > 0.1 GeV
- Single cell fraction in averaged distributions = 0.05 %
- All averaged distributions are calibrated

→ 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)

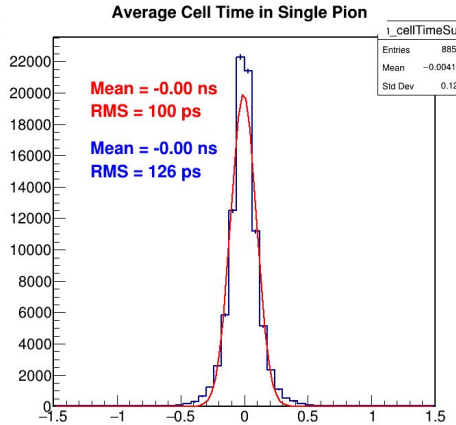




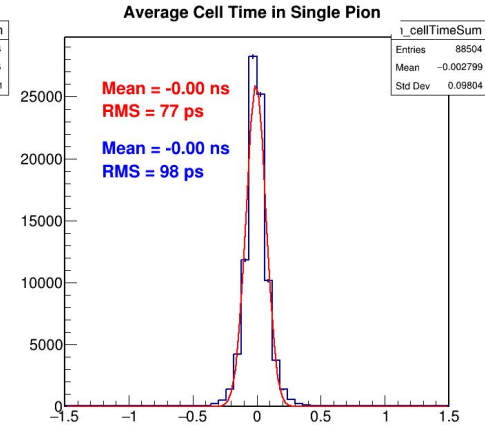
Individual cell time



Arithmetic mean

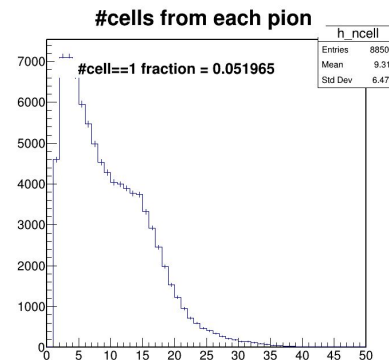


Cell E weighted



1/RMS² weighted

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

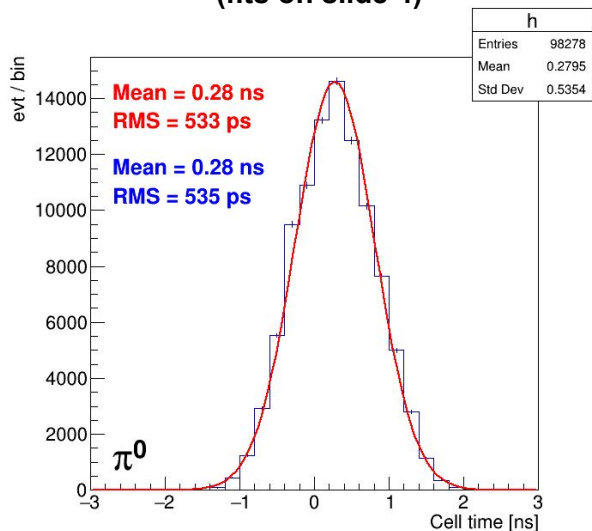


Backup

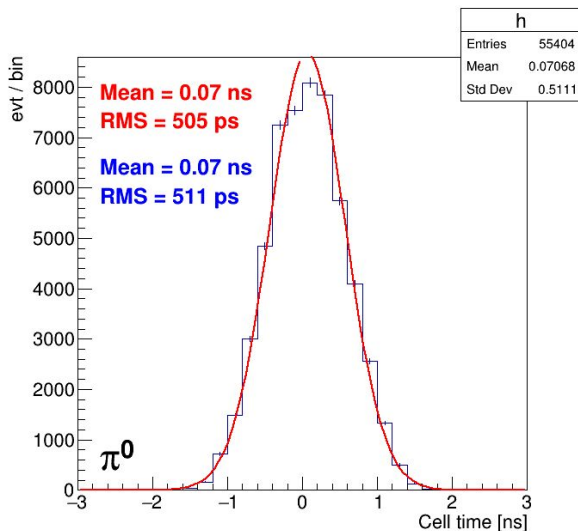
Old fits are made of Ntuple with bug (mistakenly used a wrong file, sorry about the confusion)

Three plots below are made with the same selection using $0.22 \text{ GeV} < \text{reco cell E} < 0.26 \text{ GeV}$ but for

**1 < GeV Truth pion pT < 50 GeV
With buggy Ntuple
(fits on slide 4)**



**1 < GeV Truth pion pT < 50 GeV
Without buggy Ntuple**



**1 < GeV Truth pion pT < 20 GeV
Without buggy Ntuple
(fits on slide 5)**

