Time-of-Flight Software Status

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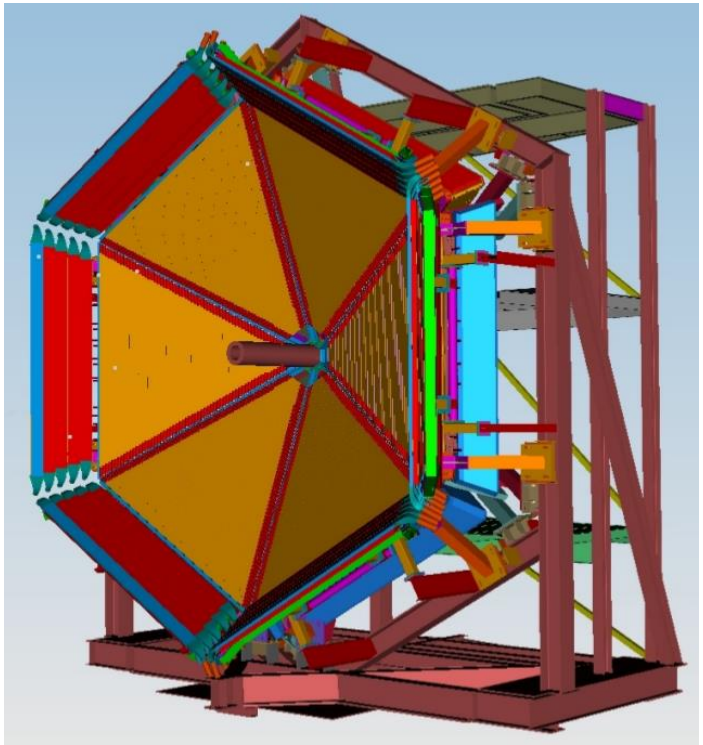

Outline:

- Motivation
- Time-of-Flight subsystem
- Status
- Validation results
- Timing resolution
- Summary

CLAS12 Workshop
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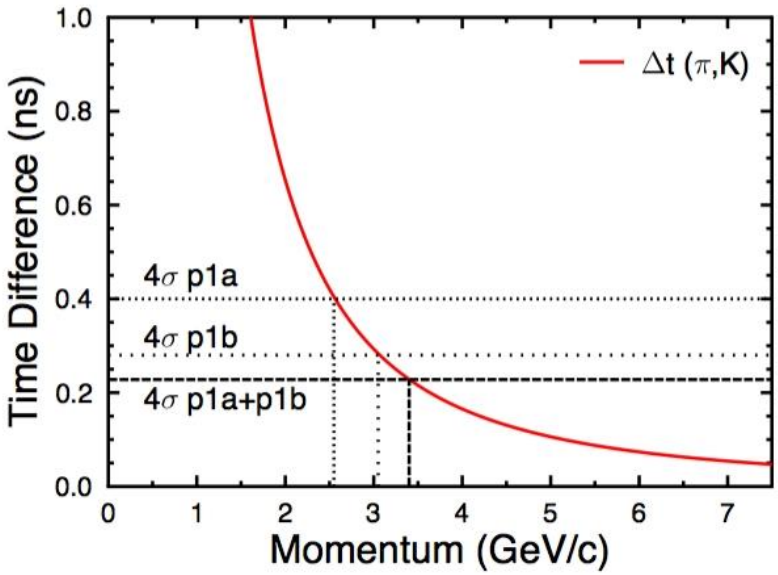
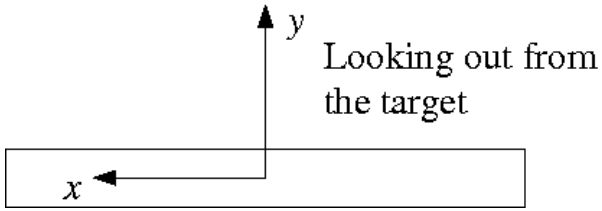
TOF Reconstruction

- Goal for FTOF: combined timing resolution in the range 35-80 ps.
  - → Main focus here.
- $\pi - K$ separation rises to p=3.4 GeV from 3.0 GeV.
- $\pi - p$ separation rises to p=6.6 GeV from 6.0 GeV.
- $K - p$ separation rises to p=5.8 GeV from 5.2 GeV.

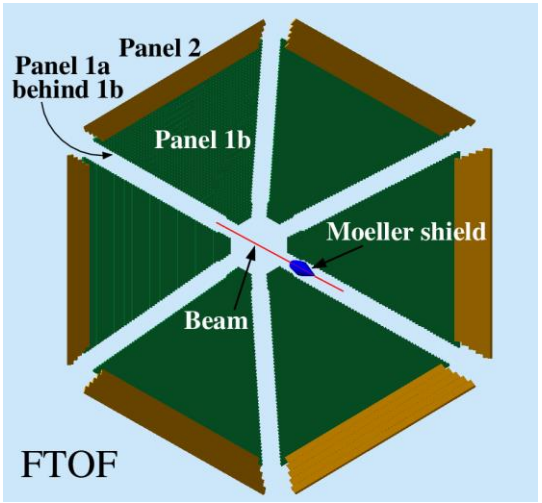


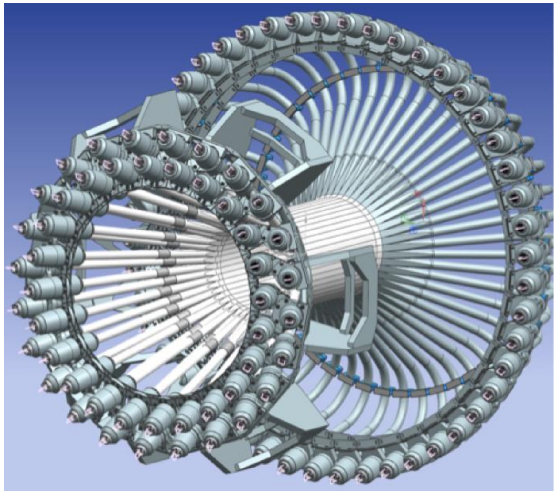
- Outputs
  - Times (T_L, T_R from TDCs)
  - Positions ($x_{cluster} = v_{eff}(T_L - T_R)/2$, $y_{cluster}$ depends on cluster size)
  - Hit times (T_{hit} from $(T_L + T_R)/2$)
  - Deposited energy (E_{dep} from ADCs)



TOF Reconstruction

- Forward Time-of-Flight (FTOF)
  - 6 sectors, double-sided PMT readout.
  - Paddles:
    - Panel 1a - 23, 15-cm wide, 70-130 ps timing requirement.
    - Panel 1b - 62, 6-cm wide, 40-100 ps timing requirement.
    - Panel 2 – 5, 15-cm wide, 140-165 ps timing requirement .
- Central Time-of-Flight (CTOF)
  - 48 paddles, double-sided PMT readout.
  - form hermetic barrel around target.
  - 60-ps timing resolution requirement.





FTOF Software Status

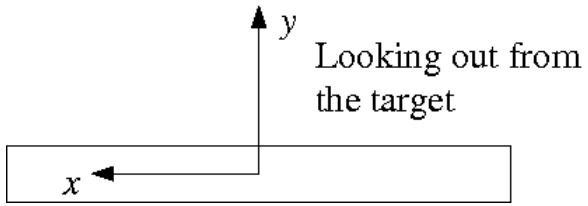
- First version of standalone TOF reconstruction code (CLAS-NOTE 2014-003) ported to coatjava.
- Results of DC reconstruction used to extrapolate track to FTOF panels.
- Geometry obtained from Java package for FTOF reconstruction and gemc.
- Updated to latest versions of Common Tools.
- Part of upcoming Common Tools 2.5 release.
- Validation studies on going (results below).

FTOF Software Validation Studies

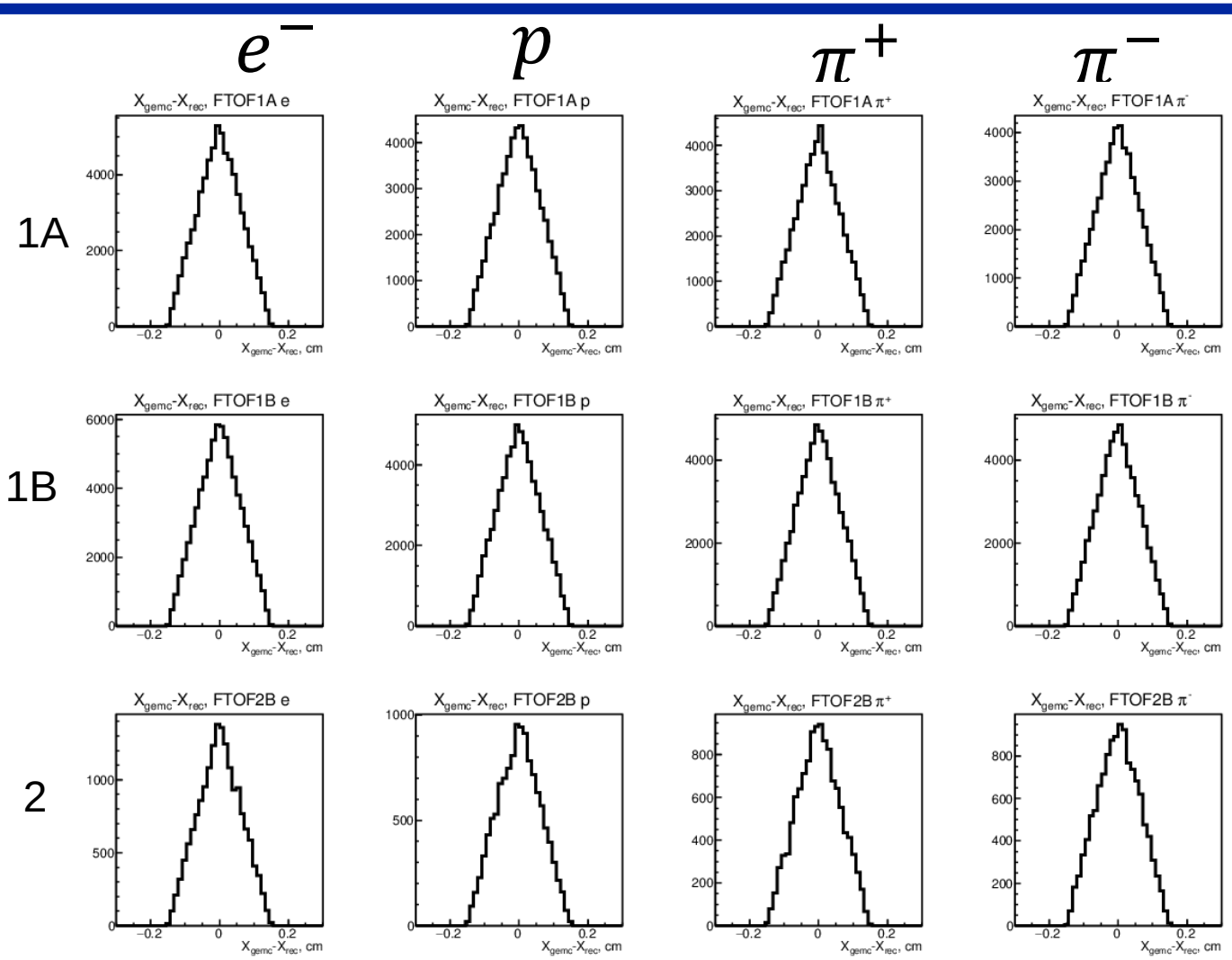
- Run Conditions:

JLab software v1.2	gemc v2.2
coatjava 2.0	Single paddle hits.
Event generators – uniform distributions	$ep \rightarrow e'p$ $ep \rightarrow e'\pi^+\pi^-$
Magnetic fields off	

- Studies
  - Particles: e', p, π^+, π^-
  - Quantities: $\Delta X = X_{gemc} - X_{recon}$
    $\Delta Y = Y_{gemc} - Y_{recon}$
    $\Delta T = T_{gemc} - T_{recon}$
    Y_{recon} versus X_{recon}
    $E_{dep}, \ ADCL, \ ADCR$
    $TDCR, TDCL$



Position Studies- 1



$$\Delta X = X_{gemc} - X_{recon} \quad (\pm 3\ mm)$$

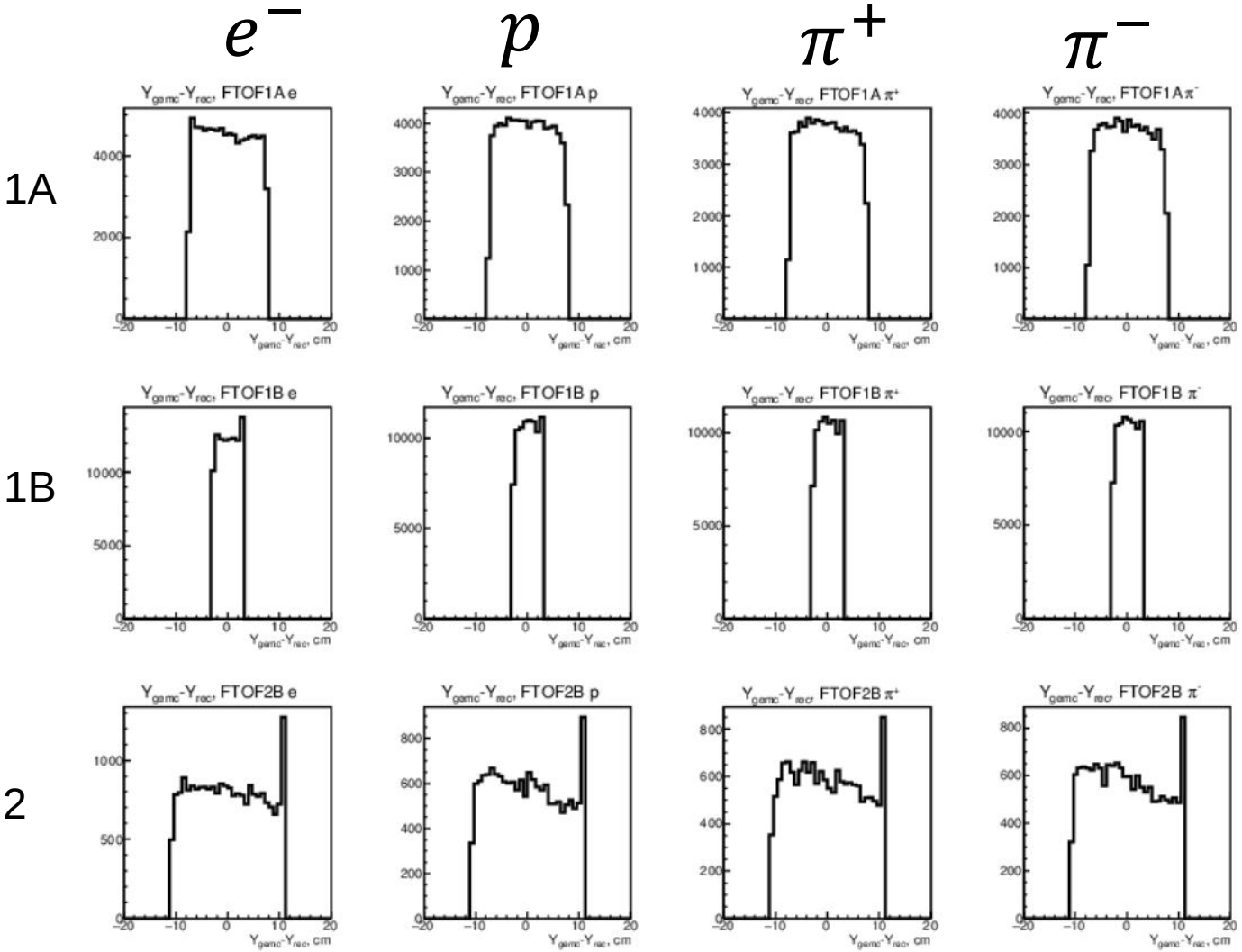
Magnetic fields set to zero.

Panel widths:
1A – 15 cm
1B – 6 cm
2 – 22 cm

Histograms show difference between simulation and reconstruction parameters.

Geometry used in coatjava 2.0 from same database used by gemc.

Position Studies- 2



$$\Delta Y = Y_{gemc} - Y_{recon} \quad (\pm 20\ cm)$$

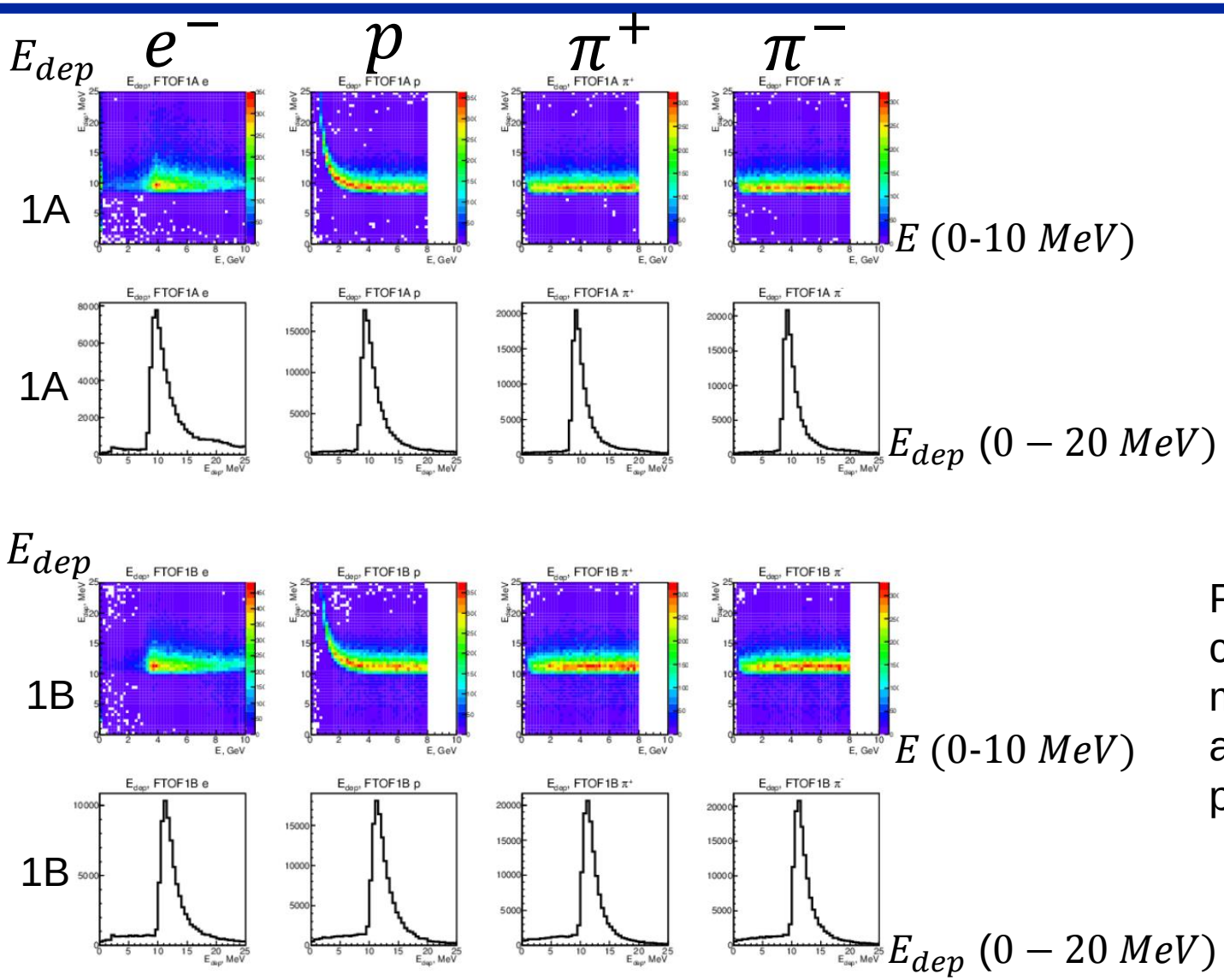
Magnetic fields set to zero.

Panel widths:
1A – 15 cm
1B – 6 cm
2 – 22 cm

Widths reflect geometry of each paddle.

Spike in panel 2 and a wee bit in panel 1b likely due to hit in neighboring counter. Under investigation.

Deposited Energy and ADCs

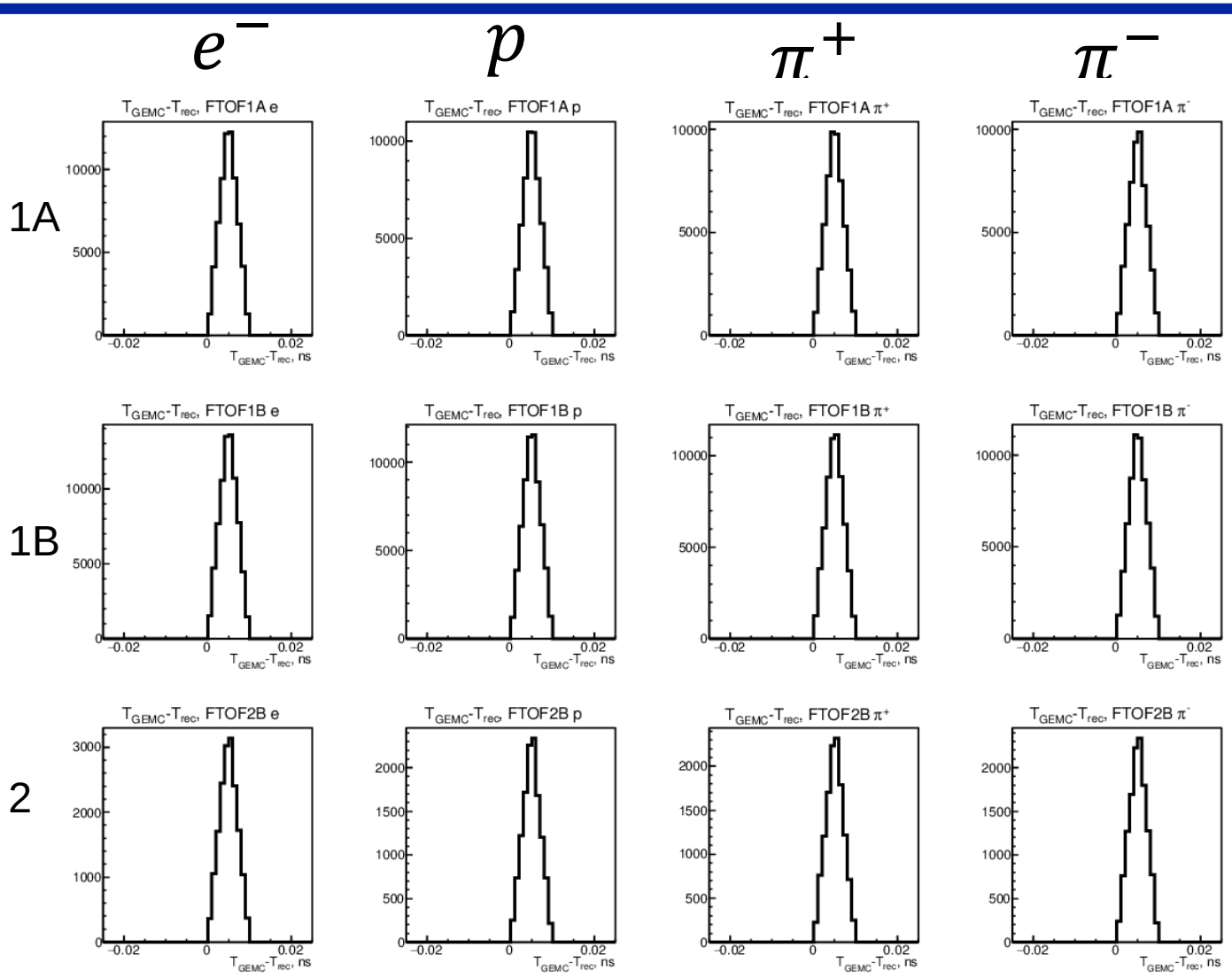


Magnetic fields set to zero.

Panel thickness:
1A – 5 cm
1B – 6 cm
2 – 5 cm

Position of E_{dep} peak consistent with past measured response and thickness of the paddle.

Timing



Timing resolutions

Panel 1a: 70-130 ps
Panel 1b: 40-100 ps
Panel 2: 140-165 ps.

TDC digitization in gemc needs to be made more realistic – DONE!

Required timing resolution is in the range 35-80 ps for combined panels 1a and 1b.

$$\Delta T = T_{gemc} - T_{recon} \quad (\pm 20\, ps)$$

Time Resolution - 1

1. Start with ‘gold’ events first: single hits in panels 1a and 1b, all signals present.
2. Cluster coordinates:

$$x_{cluster} = \frac{v_{eff}}{2}(TDC_L - TDC_R) \qquad y_{cluster} = \text{middle of counter}$$

3. Cluster matching within a panel

$x^{1a}_{cluster} - x^{1a}_{track} < parm^{x}_{1a}$ Panel 1a $\qquad x^{1b}_{cluster} - x^{1b}_{track} < parm^{x}_{1b}$ Panel 1b

$y^{1a}_{cluster} - y^{1a}_{track} < parm^{y}_{1a} \qquad y^{1b}_{cluster} - y^{1b}_{track} < parm^{y}_{1b}$

4. Cluster matching across panels.

$$(x^{1a}_{cluster} - x_{corr}) - x^{1b}_{cluster} < parm^{x}_{1ab}$$

$$(y^{1a}_{cluster} - y_{corr}) - y^{1b}_{cluster} < parm^{y}_{1a}$$

where x_{corr}/y_{corr} is an extrapolation back to the panel 1b hit location and the $parm^{j}_{i}$ are to be determined.

Time Resolution - 2

5. Compute correct hit time using

$$t_{corr} = \frac{\frac{t_{cluster}^{1b}}{1/\sigma_{1b}^2} + \frac{t_{cluster}^{1a} - \Delta r/\beta}{1/\sigma_{1a}^2}}{\frac{1}{\sigma_{1b}^2} + \frac{1}{\sigma_{1a}^2}}$$

where the σ_{1a} and σ_{1b} are the counter time resolutions. The times $t_{cluster}^{1a}$ and $t_{cluster}^{1b}$ are the hit times relative to the RF. The term $\Delta r/\beta$ accounts for the path length difference between the panel 1b cluster hit coordinate and the panel 1a one (depends on tracking).

6. Study time resolutions by comparing the widths of the distributions:

$$\sigma\left[(t_{1b} - t_{RF}) - t_{1b}^{hit}, p\right], \sigma\left[(t_{1a} - t_{RF}) - t_{1a}^{hit}, p\right], \sigma\left[(t_{corr} - t_{RF}) - t_{1b}^{hit}, p\right]$$

which are also functions of momentum.

Time Resolution - 3

7. Use ‘silver’ events: multiple paddle hits in panels 1a and 1b, all signals present.

$$x_{cluster} = \frac{\sum_{i=1}^{nhits} \frac{x_{hit}^{i}}{E_i^2}}{\sum_{i=1}^{nhits} E_i^2} \qquad y_{cluster} = \frac{\sum_{i=1}^{nhits} \frac{y_{hit}^{i}}{E_i^2}}{\sum_{i=1}^{nhits} E_i^2}$$

$E_i \equiv$ deposited energy
$nhits \equiv$ cluster size

8. Cluster matching – same as above for gold events.
9. Hit time for cluster

$$t_{cluster}^{1b} = \frac{\sum_{i=1}^{nhits} \frac{t_{1b}^{i}}{1/\sigma_{1b}^2}}{\sum_{i=1}^{nhits} 1/\sigma_{1b}^2} \qquad t_{cluster}^{1a} = \frac{\sum_{i=1}^{nhits} \frac{t_{1a}^{i}}{1/\sigma_{1a}^2}}{\sum_{i=1}^{nhits} 1/\sigma_{1a}^2}$$

10. Corrected hit time – same as above for gold events.
11. Time resolutions – same as above for gold events.
12. Bronze/broken-beer-bottle events – single paddle hits, one signal missing.

Summary

1. Standalone TOF reconstruction software updated and in coatjava 2.5.
2. Matching between DC track and FTOF hits done.
3. FTOF and gemc getting calibration constants from the same source.
4. Validation studies ongoing.
5. Timing resolution studies starting.