Pion and Kaon Form Factors at the EIC

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Exclusive, Diffractive, & Tagging Meeting

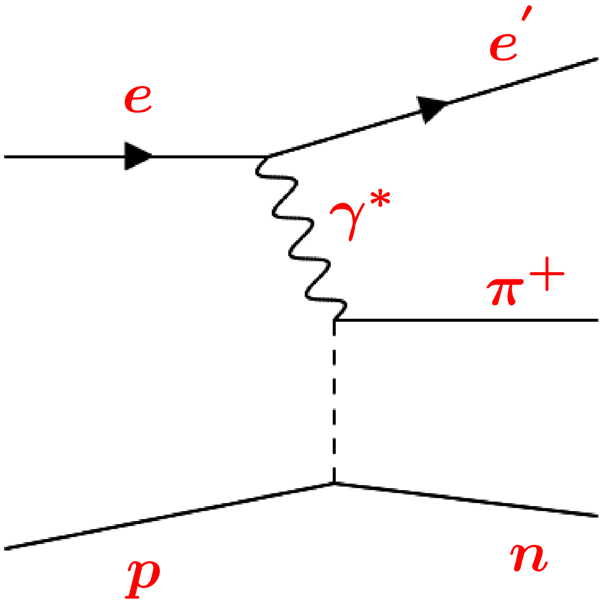
10/06/2024

ePIC simulations for exclusive reactions

- Feasibility studies of exclusive pion and kaon electroproduction reactions through ePIC simulations.
- Utilized DEMPgen to generate files for both reactions, passed π^+ files through the latest ePIC simulations.
- Begin with π^+ electroproduction reaction.

$$e + p \rightarrow e' + \pi^+ + n$$

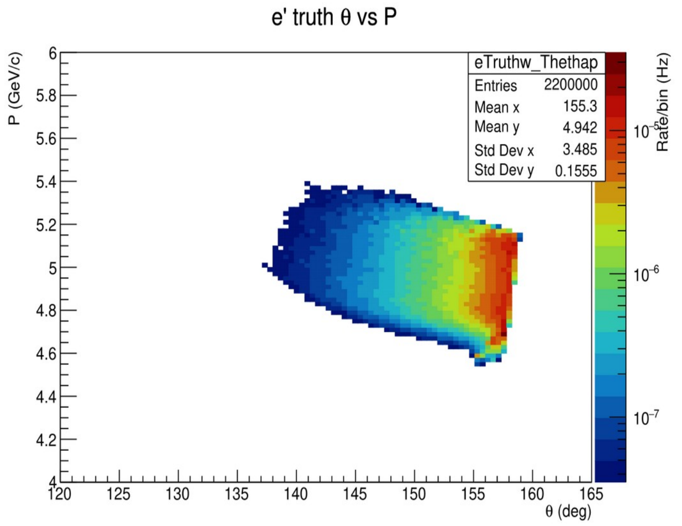
  - Indirectly use the "pion cloud" of the proton via the p(e,e' π^+ n) process.
- Identification involves reconstructing all final state particles.

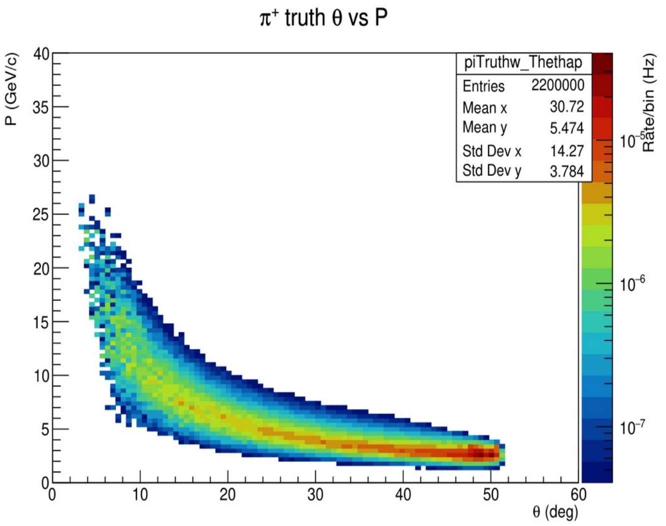


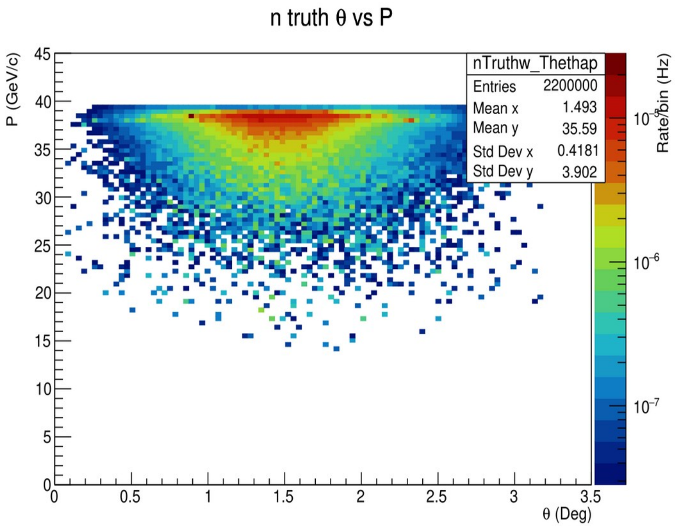
https://arxiv.org/abs/2403.06000

Spatial topology of weighted truth variables at ePIC detector

- Simulated 2200k events for 5(e) on 41(p) GeV collisions.
- e', π^+ hits the central detector, n hits far-forward detectors (mainly ZDC).





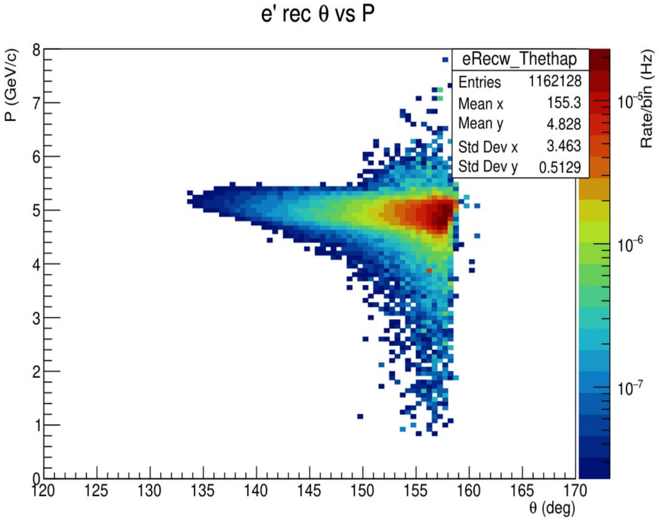


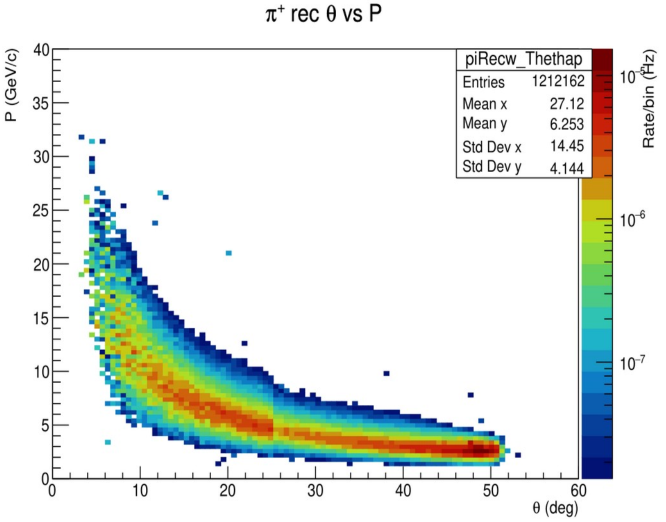
Spatial topology of weighted rec variables at ePIC detector

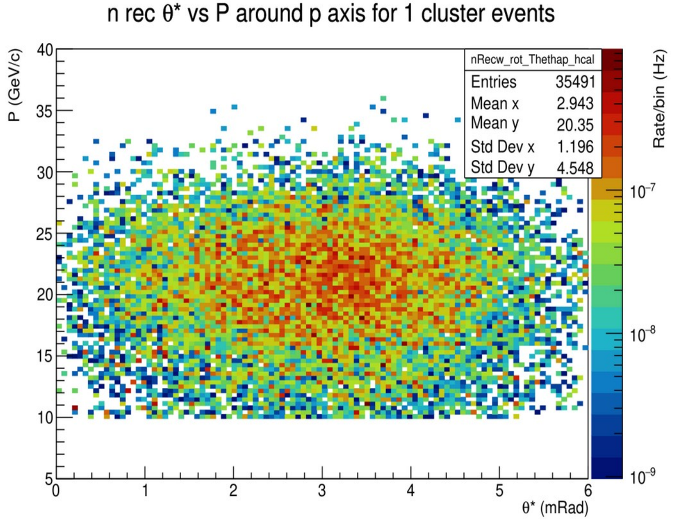
- Simulated 2200k events for 5(e) on 41(p) GeV collisions.
- e', π^+ hits the central detector, n hits far-forward detectors (mainly ZDC).

Reconstruction efficiency for e', π^+ drops significantly compared to january simulated files.

[1 cluster events with E>10 GeV, θ^*<6.0 mRad]







~47% Events lost

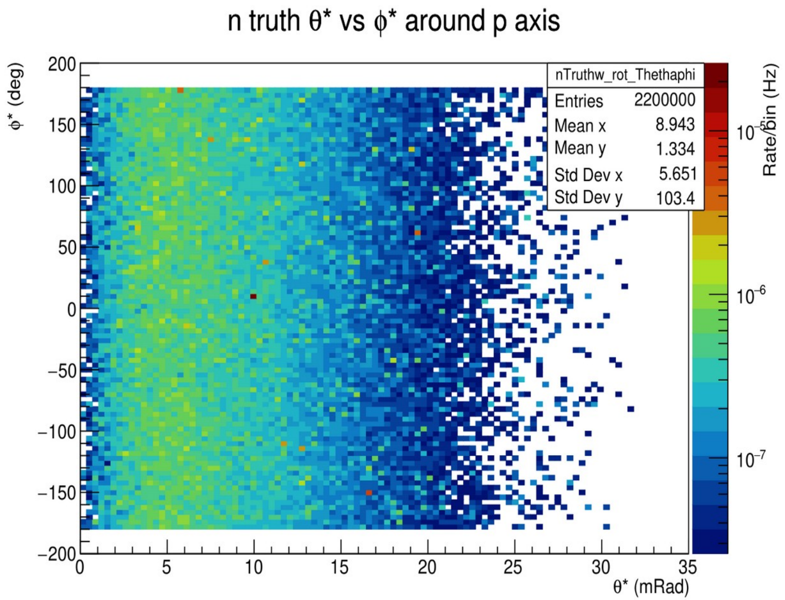
~45% Events lost

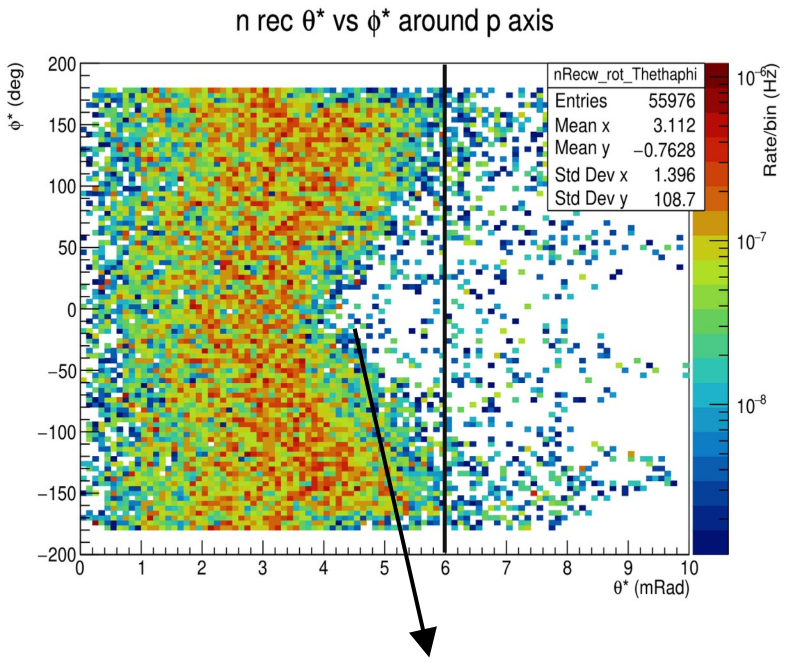
[Using HcalFarForwardZDCClusters]

θ^* is the rotation by 25 mRad around proton axis

Neutrons truth vs rec distribution

- Reconstructed neutrons using newly merged branch ReconstructedFarForwardZDCNeutrons.





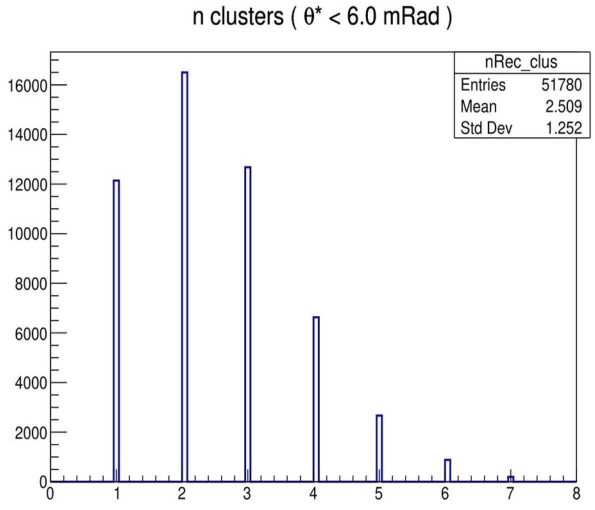
~42% Events lost within $\theta^* < 6.0$ mRad.

Is this cut determined by the clustering algorithm?

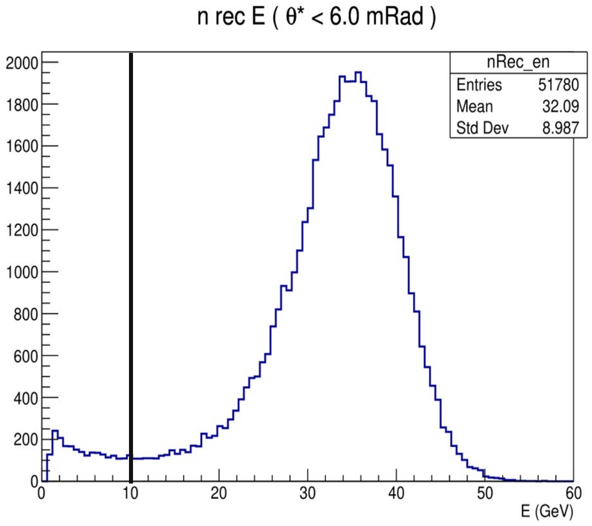
θ^* , ϕ^* is the rotation by 25 mRad around proton axis

Spatial topology of weighted rec neutrons at ePIC detector

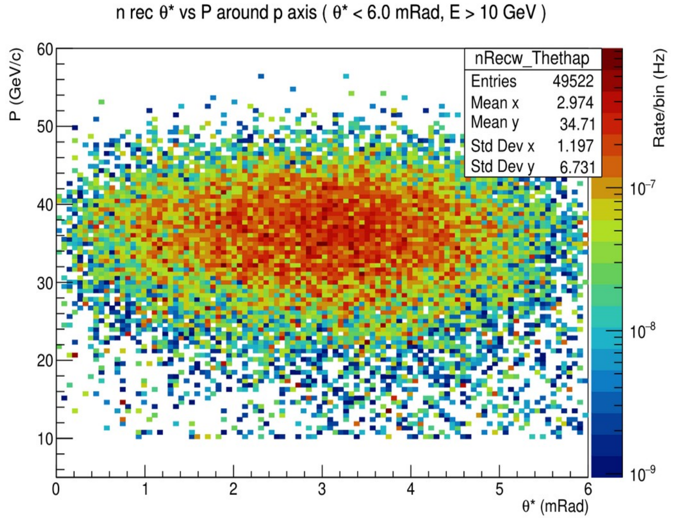
- Reconstructed neutrons using newly merged branch ReconstructedFarForwardZDCNeutrons.



[Most neutrons have 2+ clusters]

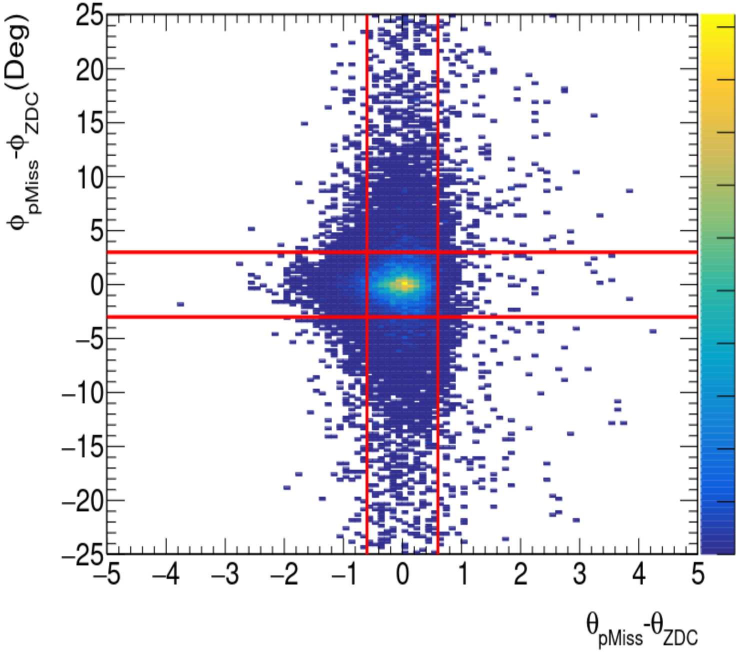


[Apply > 10 GeV cluster cut]

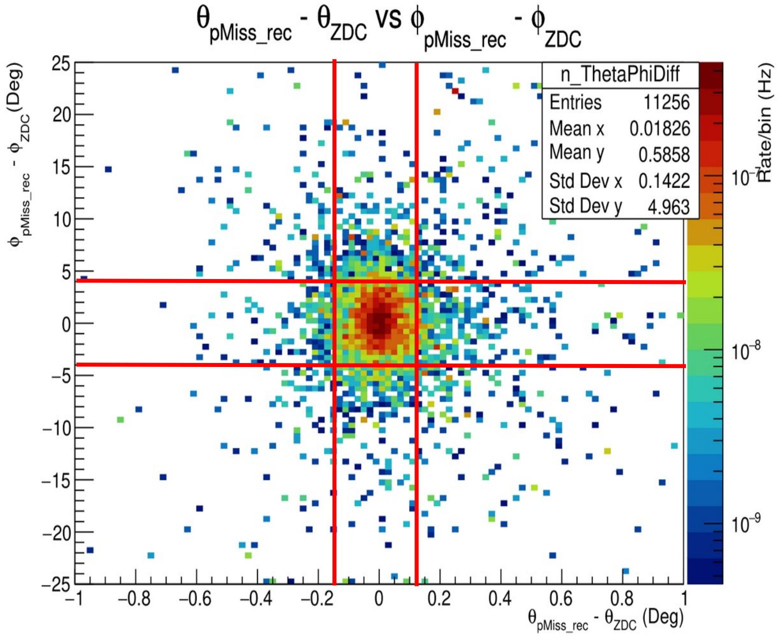


Diff. b/w rec & detected simulated angles for the neutrons

For 5(e) on 100(p) GeV collisions from ECCE simulations.



For 5(e) on 41(p) GeV collisions from ePIC simulations.



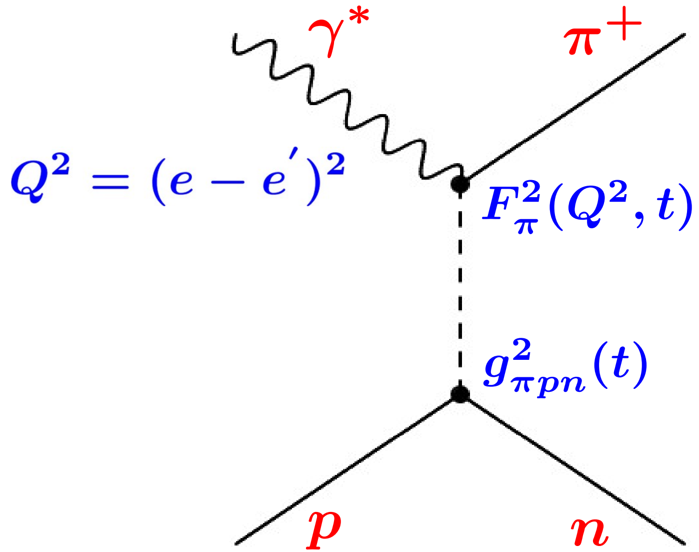
Accessing form factor through π^+ electroproduction

- Measure $e'\pi^+n$ triple coincidence events.
- At small -t, the pion pole process dominates σ_L.
- In the Born model, F_π^2 appear as [In practice one uses a more sophisticated model]

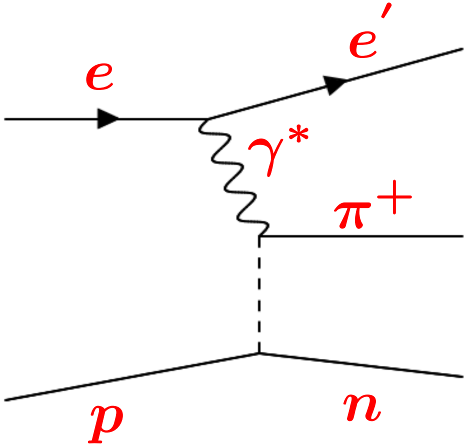
$$\frac{d\sigma_L}{dt} \propto \frac{-tQ^2}{(t-m_\pi^2)^2} g_{\pi pn}^2(t) F_\pi^2(Q^2,t)$$

- Q^2, -t reconstruction resolution is crucial for extracting F_π^2 from the measured cross section.
- Different approaches tried to reconstruct -t.

$$e + p \rightarrow e' + \pi^+ + n$$

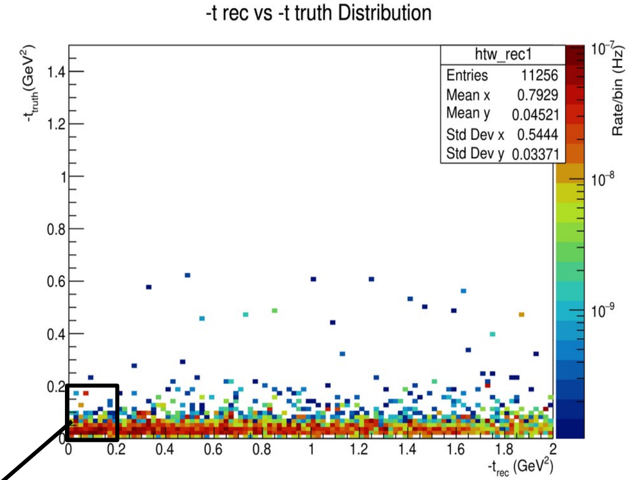


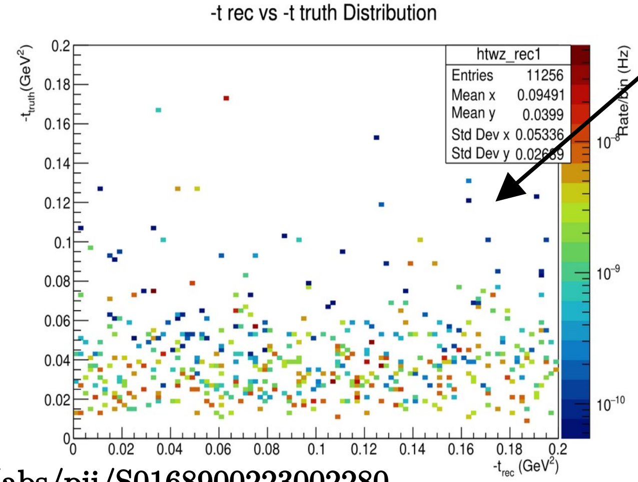
-t reconstruction using lepton-meson vertex (Method - 1)

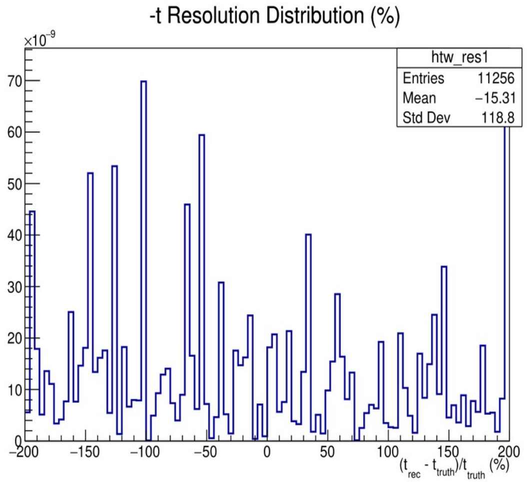


$$-t_{truth} = -(\gamma^* - \pi^+)^2$$

$$-t_{rec} = -(\gamma^* - \pi^+)^2$$

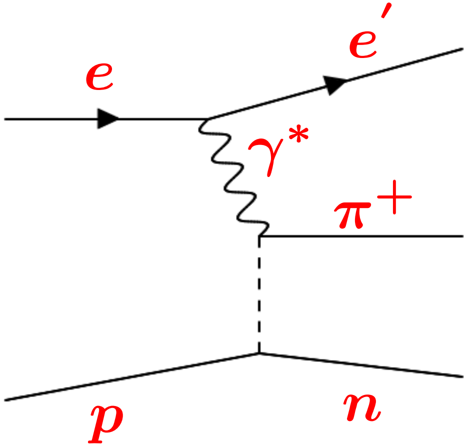






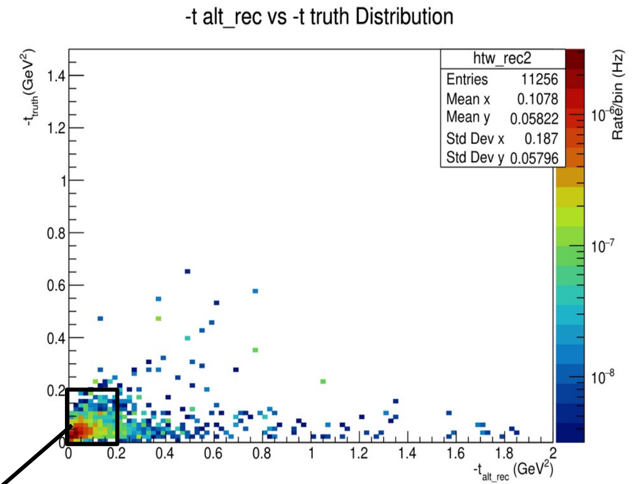
https://www.sciencedirect.com/science/article/abs/pii/S0168900223002280

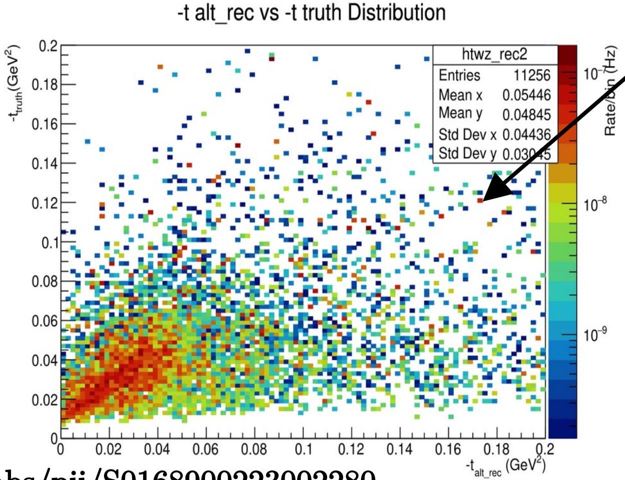
-t reconstruction using proton-baryon vertex (Method - 2)

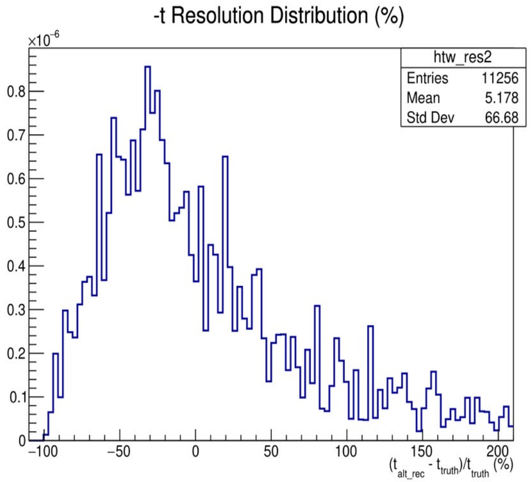


$$-t_{truth} = -(\gamma^* - \pi^+)^2$$

$$-t_{alt\_rec} = -(p - n)^2$$







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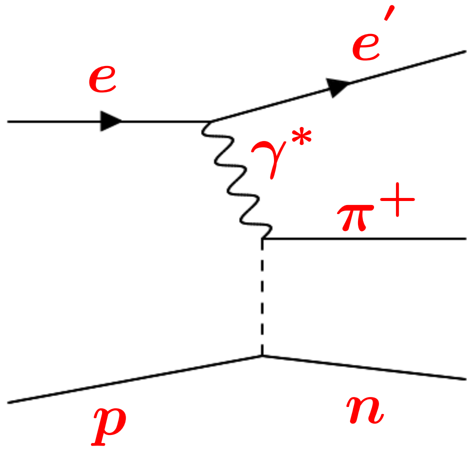
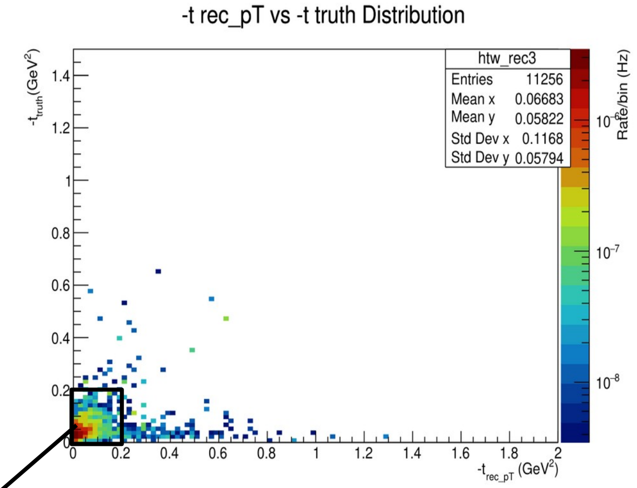
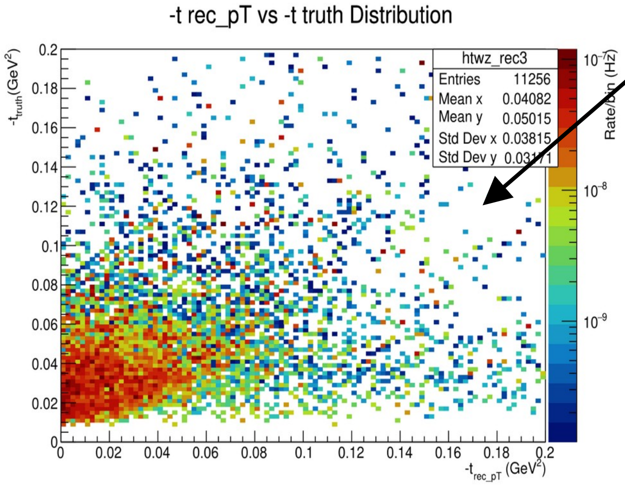
-t reconstruction using pT of e' and π^+ (Method - 3)

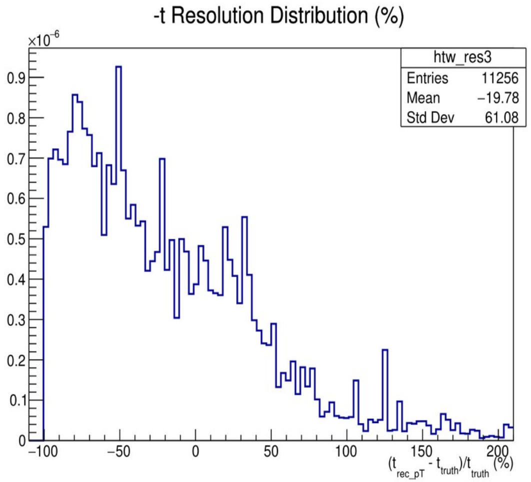


$$-t_{truth} = -(\gamma^* - \pi^+)^2$$

$$-t_{rec\_pT} \approx -(p_{T,\pi^+} + p_{T,e'})^2$$



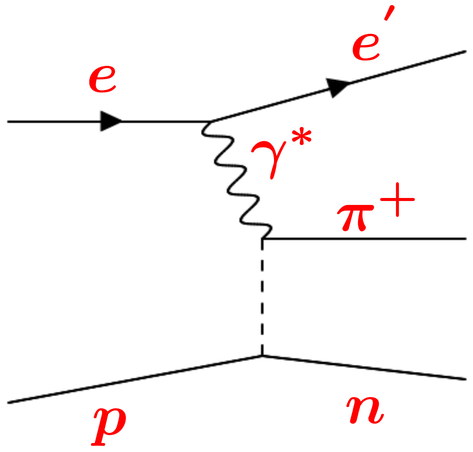




Valid for small -t and small Q^2.

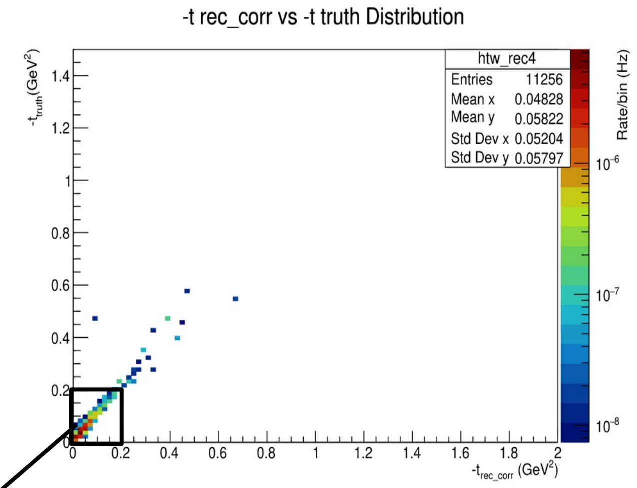
https://arxiv.org/pdf/2005.14706.pdf

-t reconstruction using corrected n track (Method - 4)



$$-t_{truth} = -(\gamma^* - \pi^+)^2$$

$$-t_{rec\_corr} = -(p - n_{corr})^2$$

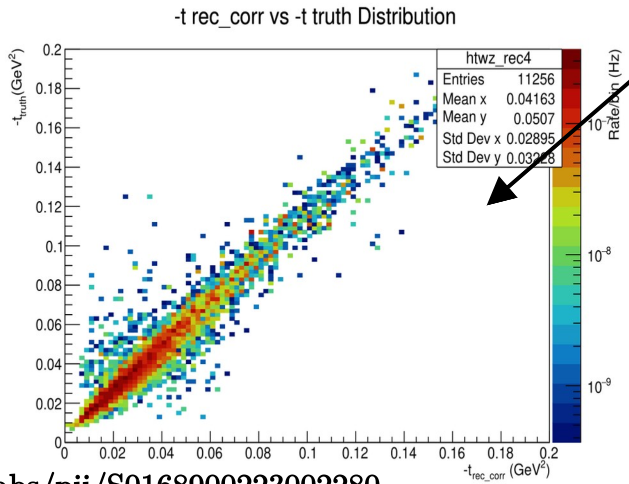


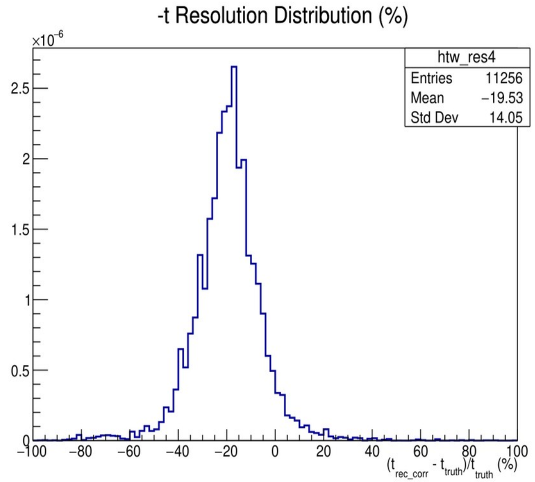
Reconstructed n_corr:

Using missing momentum information,

$$p_{miss} = |\vec{p_e} + \vec{p_p} - \vec{p_{e'}} - \vec{p_{\pi^+}}|$$

And replaced θ_{Miss}, ϕ_{Miss} with θ_{ZDC}, ϕ_{ZDC}, and fixed the neutron mass.





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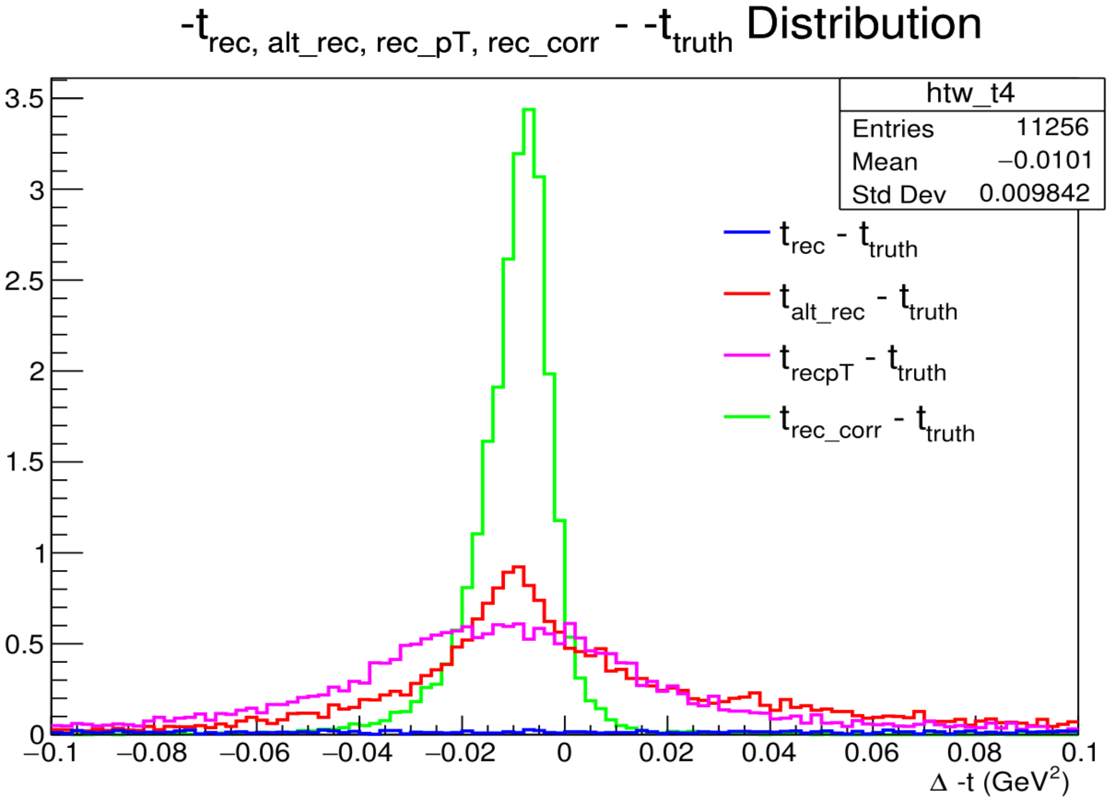
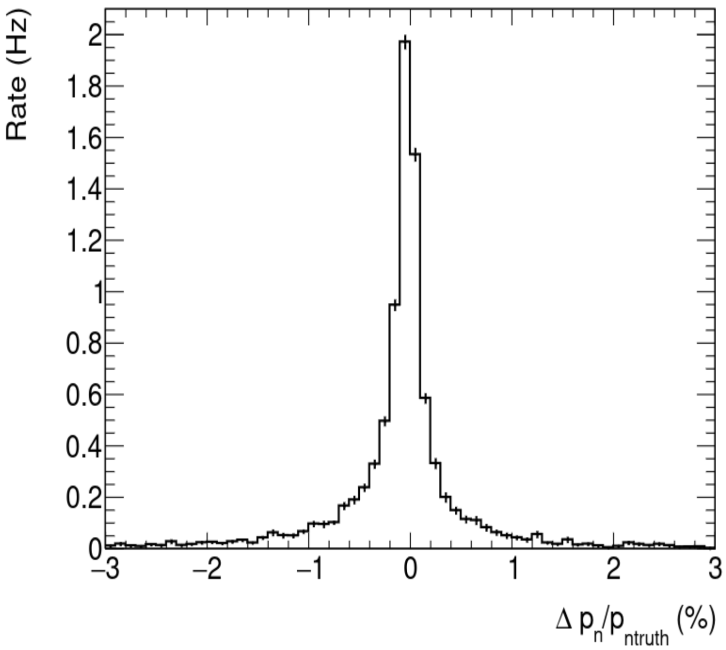
Comparison of Δ -t from various methods

- All methods reconstruct -t slightly shifted from true -t, which would need to be understood and corrected for in the actual physics analysis.

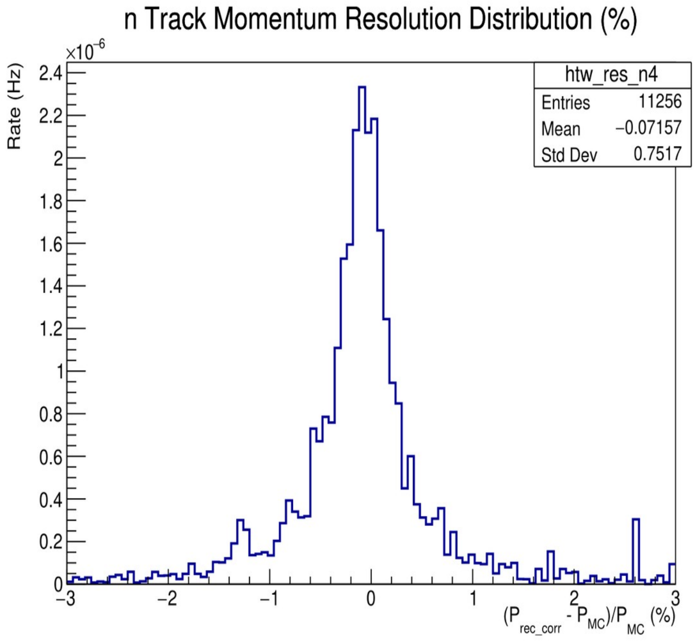


Neutron track momentum resolution

For 5(e) on 100(p) GeV collisions from ECCE simulations.



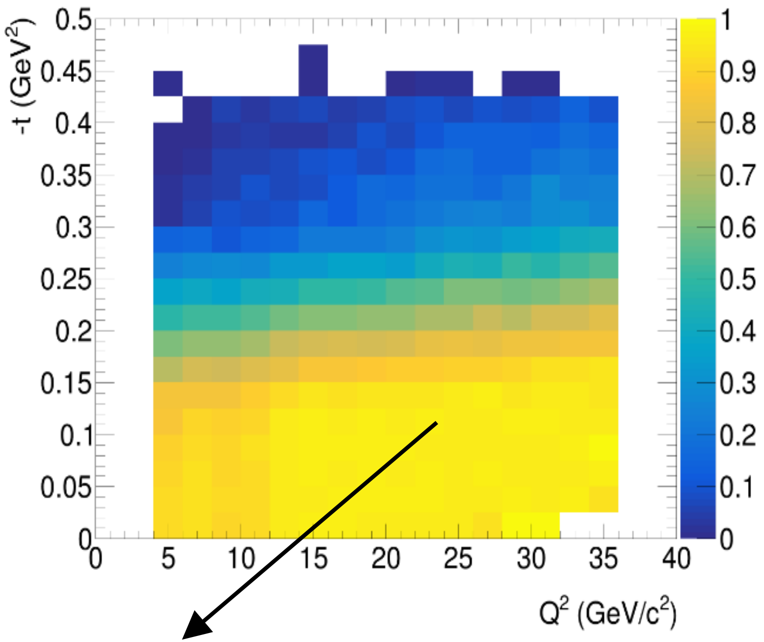
For 5(e) on 41(p) GeV collisions from ePIC simulations.



Detection efficiency per (Q^2,t) bin

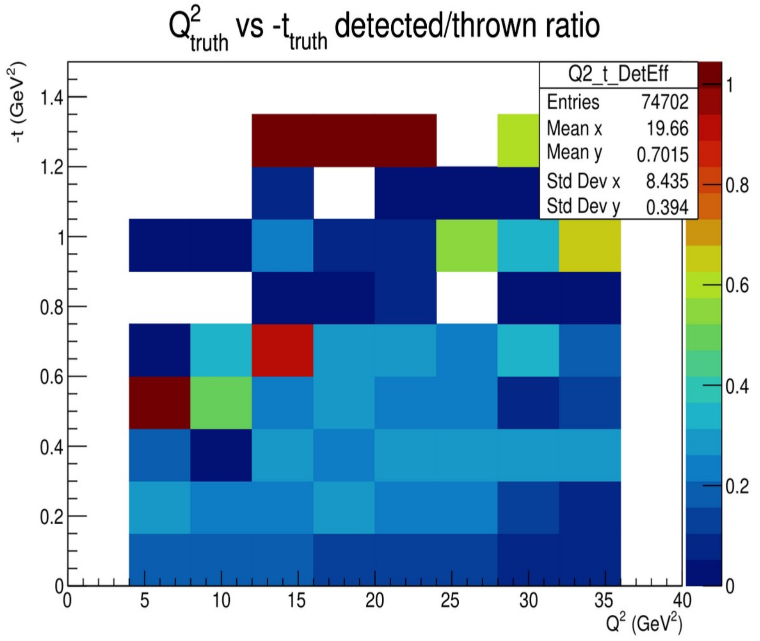
- Distribution has expected shape, but is lower than expected, due to a low no. of reconstructed neutrons and lower than anticipated e', π^+ reconstruction.

For 5(e) on 100(p) GeV collisions from ECCE simulations.



Detection efficiency best in crucial low -t region

For 5(e) on 41(p) GeV collisions from ePIC simulations.



Summary

- Number of reconstructed e', π^+ drops significantly, which in turns affects the coincidence events.
- Used newly merged ReconstructedFarForwardZDCNeutrons branch to reconstruct neutrons.
- Except ~50 % drop of e', π^+, everything looks optimistic.
- Plan to determine the $F_\pi(Q^2)$ projections for the TDR.
- Reconstruction is considerably challenging for the kaon electro-production reaction.
- Main issue is to separate photons from the low-energy neutrons in the both ZDC – EMCAL & HCAL.
- Will update the status in the upcoming meetings.

Thank you !

EIC-Canada

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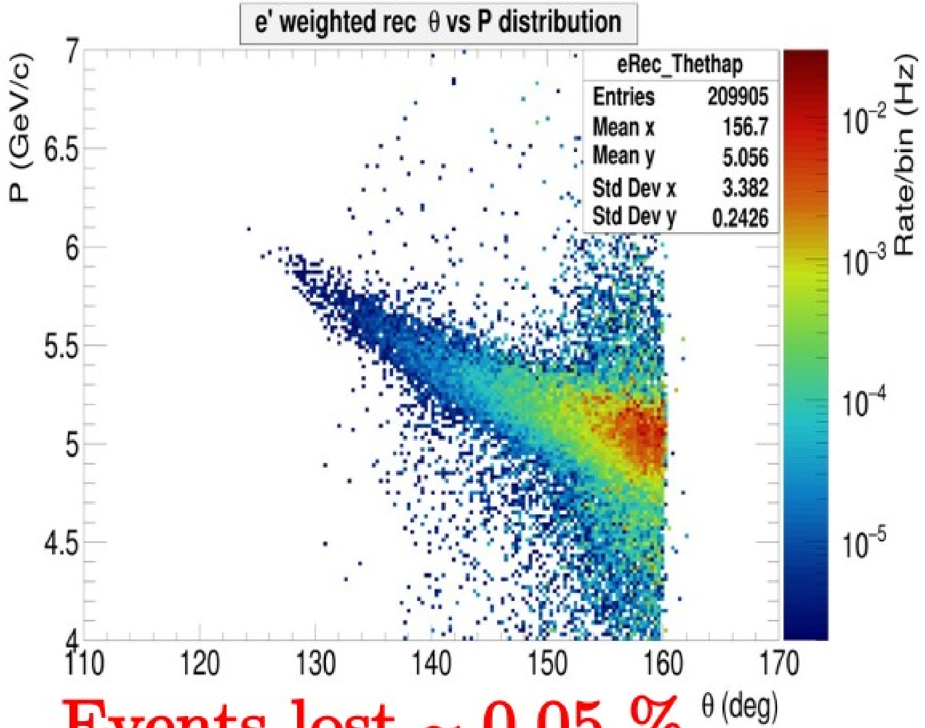
Tests

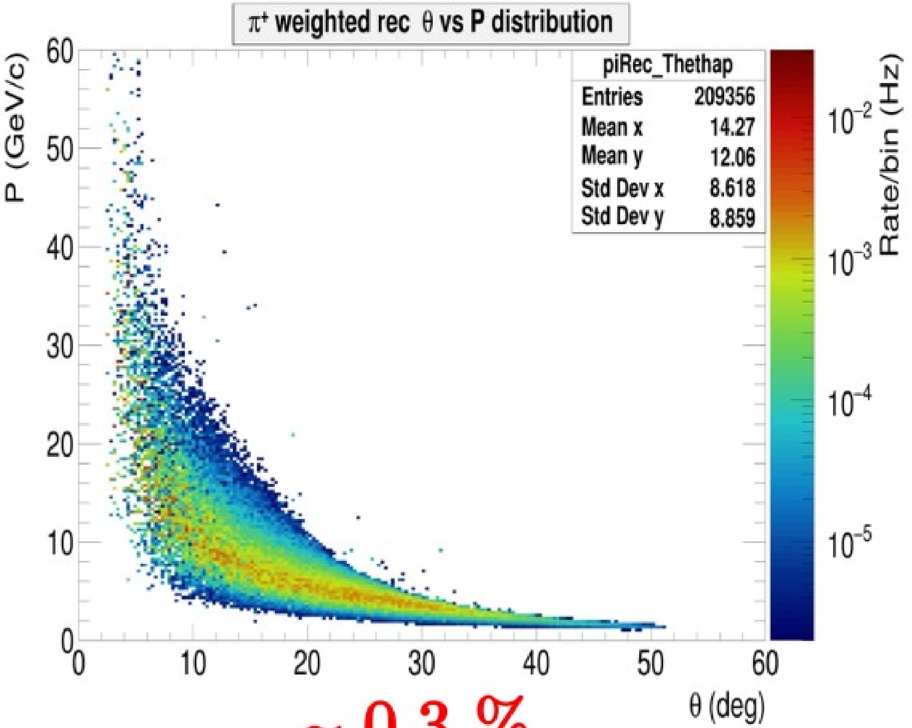
- Absolute value of the PDG resulted an expected no. of e' and π^+.
- No increase in the number of coincidence events,
- Events correspond to e^+ and π^- with different P vs. θ distribution.

January simulations results

- For 5(e) on 100(p) GeV collisions from ePIC simulations.



Events lost ~ 0.05 %



~ 0.3 %