DVCS on ep Analysis Update

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Exclusive, Diffractive and Tagging PWG meeting

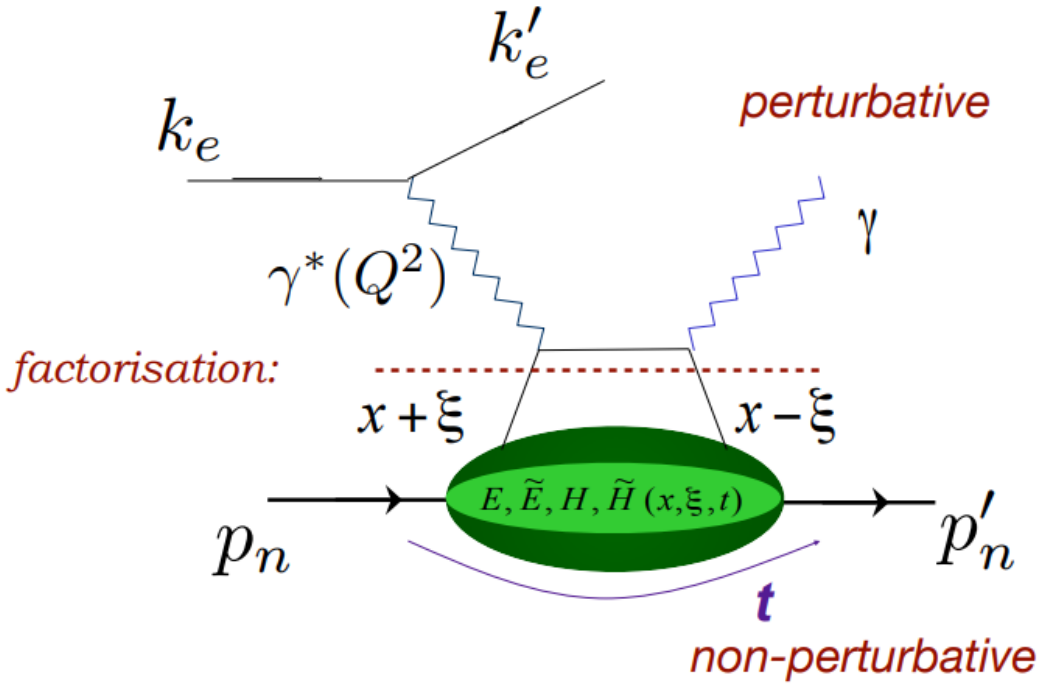
27/10/25

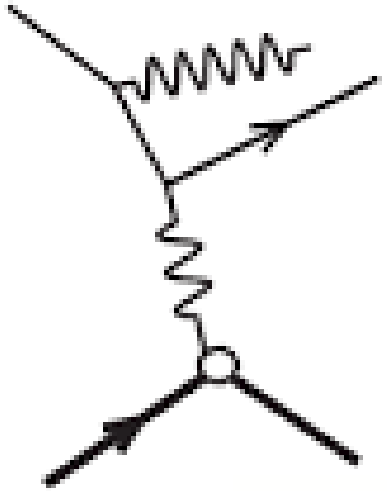
This presentation

- DVCS at ePIC
- Updates since last meeting (Physics Readiness Review, London).
  - Testing photon reconstruction fix
  - Other methods of calculating Mandelstam t?

Deeply Virtual Compton Scattering

Deeply Virtual Compton Scattering





- DVCS: electroproduction of a photon off a hadron target
- QM interference: Bethe-Heitler (e^- radiates final state photon.

Deeply Virtual Compton Scattering: kinematics

- Default kinematics:
  - $e(k) + p(p) \rightarrow e'(k') + p'(p') + \gamma$

- Inclusive kinematics: scattered electron only ("Electron method" in EICrecon)

$$Q^2 = -q^2 = -(k - k')^2 \qquad y = \frac{q.p}{k.p} \qquad x = \frac{Q^2}{2q.p} \qquad \xi = \frac{x}{2 - x} \approx \frac{x}{2}$$

- Mandelstam *t*: beam and scattered proton (BABE method in *tRECO* convention)

$$t = (p - p')^2$$

Photon reconstruction fix

Photon reconstruction issue

- Issue seen with photon reconstruction in 25.07.0 and 25.08.0 simulation campaigns.
  - Presented at the PRW in London (17-Sept-25).
- Reason: a bug in EICrecon being triggered by preparing the campaign files for background merging.
  - GitHub issue
- A fix for this was implemented almost immediately
  - Pull request for fix
  - Present in EICrecon release v1.30.0 (made public on 17-Oct-25)

Are we sure this has worked?

Testing ElCrecon photon fix

- Been asked to test this by PWG and Analysis coordinators.
- Spoke to Sakib on 03-Oct to figure out how to test this.
  - He said that he would run these tests.

- Test files finally prepared on 17-Oct with eic-shell container update.
- Brief analysis performed on 20-Oct.

Counting Sakib's test

- 5x41 full sample
- Compare 1 file to 25.06.1 campaign.

25.06.1

- MCParticles[genStatus == 1] = 7020
- MCParticles[gS == 1 && PDG == 22] = 2340
- RecoParticles = 4746
- RecoParticles[MC PDG == 22] = 2280

97% reconstruction

Sakib's test

- MCParticles[genStatus == 1] = 6435
- MCParticles[gS == 1 && PDG == 22] = 2145
- RecoParticles = 4307
- RecoParticles[MC PDG == 22] = 2087

97% reconstruction

Can be confident that EICrecon fix is successful.

Reconstructing Mandelstam t

Accounting for missing protons or poor t-resolution.

Reconstructing Mandelstam t

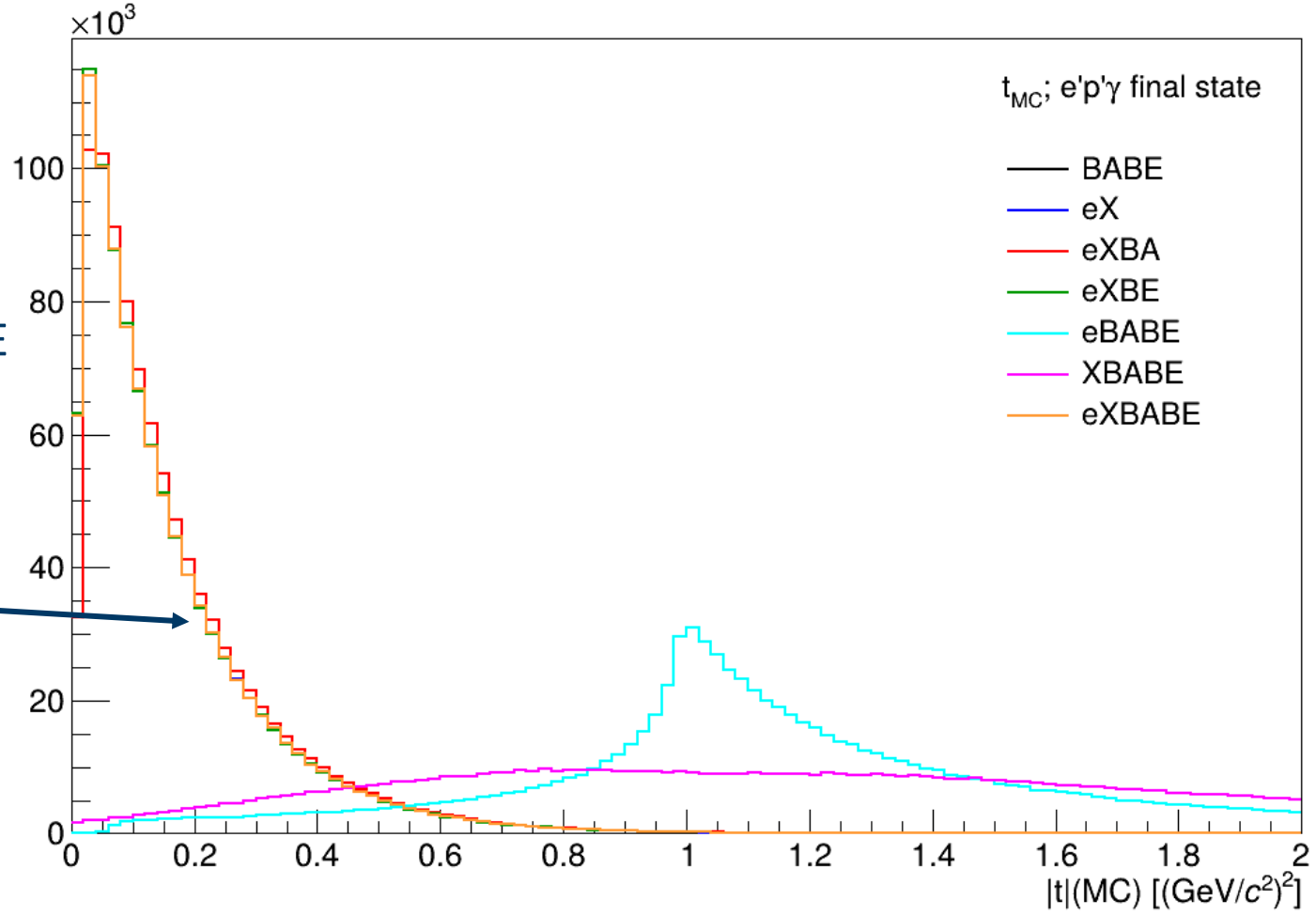
- Discussion from the PRW: want to find a way to reconstruct t for
  - Missing scattered p.
  - Poor t-resolution.

- Need some method to reconstruct t *without* the detection of the scattered proton.
  - Using tRECO convention note, 2 methods exist: eX / eXBE.
  - ‘e’ – Scattered/DIS electron
  - ‘X’ – Rest of final state *without the scattered baryon* (i.e. DVCS γ)
  - ‘BE’ – “Beam” hadron

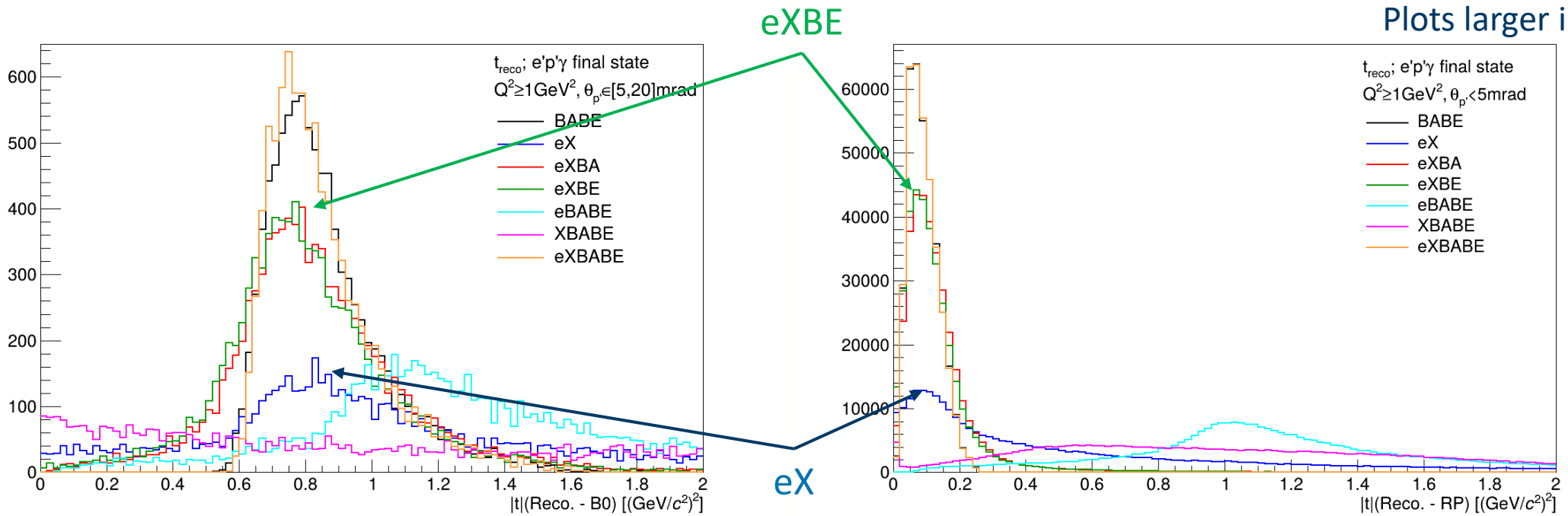
MC t calculations

Cannot distinguish between eX and eXBE from MC alone.

Lie on top of each other.



Reco. t calculations



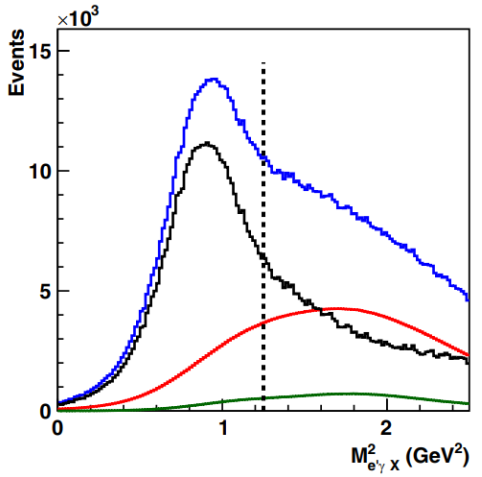
- Calculations using fully exclusive e'p'γ events, separating B0 protons from RP protons.
- eX method (dark blue) shows clear poor performance w.r.t other tRECO methods.
  - Best choice of method: eXBE
  - (eXBE also shows smearing, but to a lesser extent).

Reconstructing Mandelstam t (2)

- With the eXBE method being chosen, is that good enough?

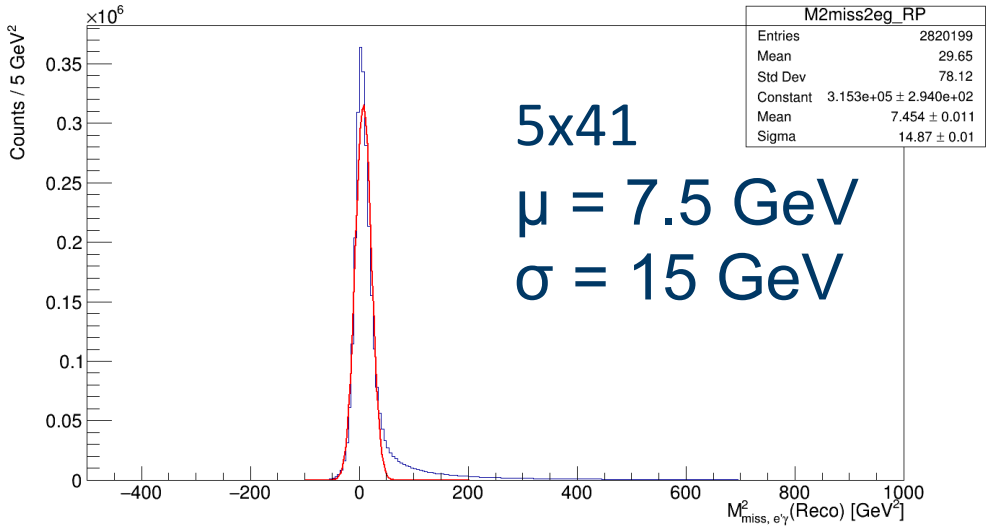
- Could just rely on known particles in DVCS simulations…
  - Would create a lot of background when comparing to other samples.

- What to use as extra cuts?
  - First test: M_{miss}^2 (as CLAS does)
  - Expected to be m_p^2 for true DVCS event

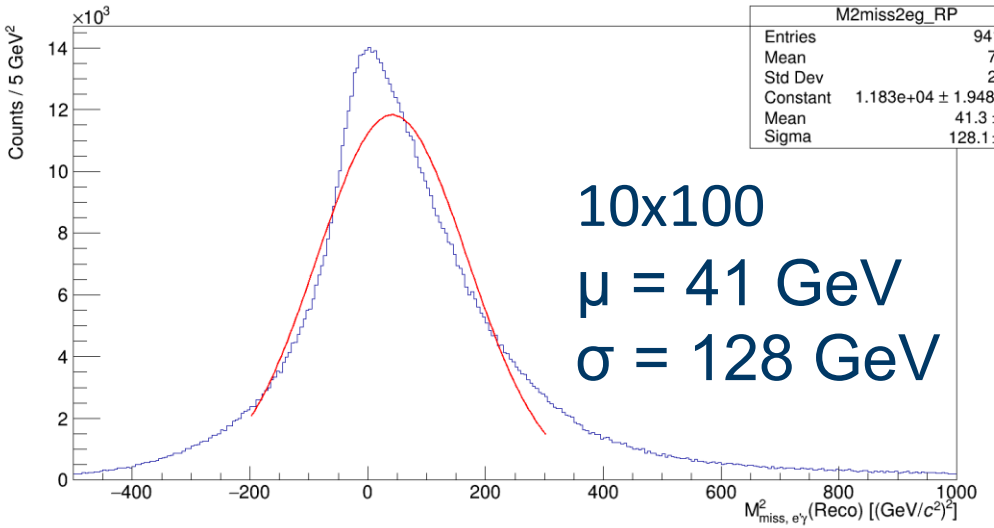


PRL **130**, 211902, May '23

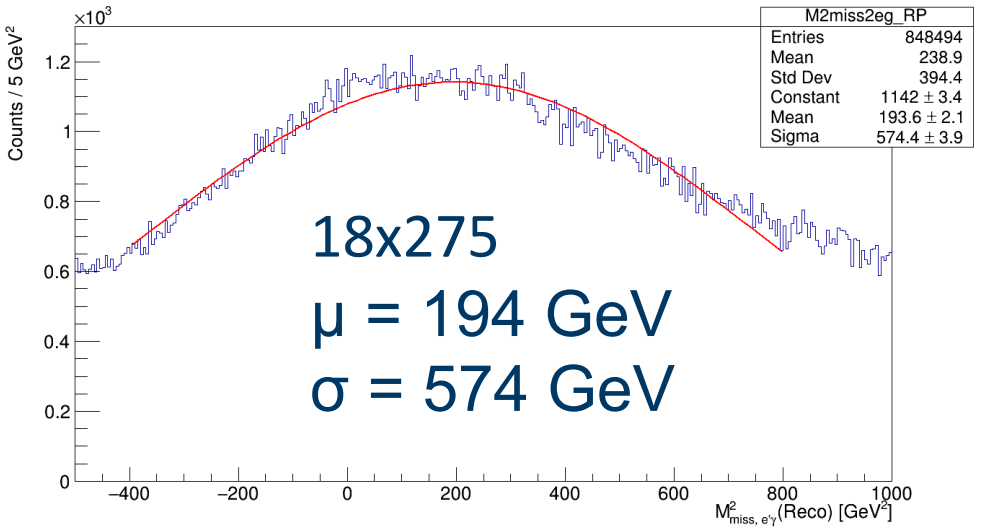
Missing mass squared at ePIC



5x41
μ = 7.5 GeV
σ = 15 GeV



10x100
μ = 41 GeV
σ = 128 GeV



18x275
μ = 194 GeV
σ = 574 GeV

Reconstructing Mandelstam t (3)

- Okay, so can't use MM2 as a viable cut here.
- Why?
  - Not due to detector resolutions (plots in backup).
    - Energy/momentum resolution around ~3-4%
  - Kinematic factors.

- What else to use as a cut?
  - Other missing kinematics.
  - Missing momentum of e'γ system (expect to be ~beam momentum).
    - Choose this as detector momentum is what goes into 4-vectors.

Best choice of p_{miss} cut?

- Know that expected 2-body p_{miss} should be roughly equal to hadron beam momentum for pure DVCS event.

- But where is the bast place to actually *put* a cut?
  - Compare signal and background events, cutting around proton beam momentum.
  - Using S. Maple's DIS file (10x130) for this.

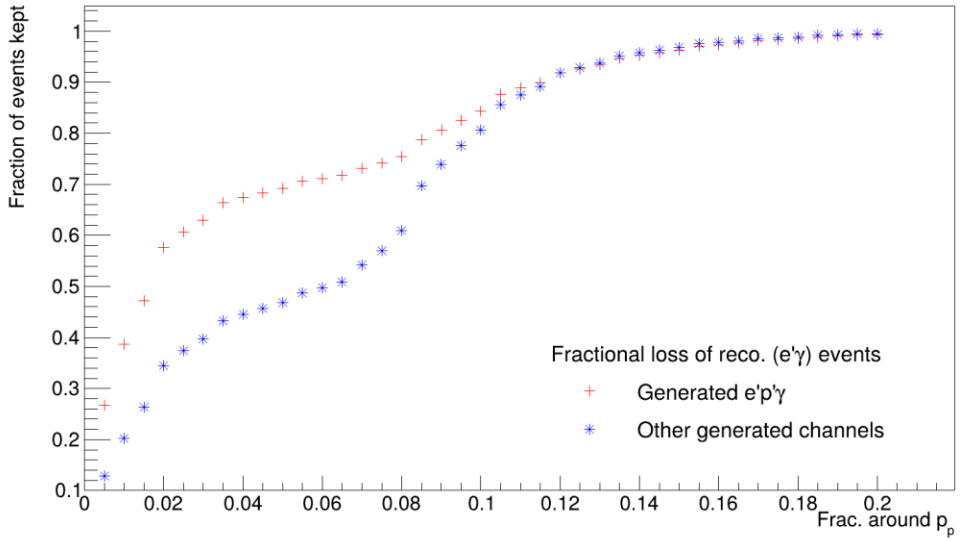
Best choice of p_{miss} cut? (2)

- Plot p_{miss} for all events with at least 1 reconstructed final state electron and photon (using MC matching for PID).

- Place limits around hadron beam momentum (± X% around 130 GeV) and count events within window.
  - Go from ±0.5% to ±20% around beam momentum, in steps of 0.5%.

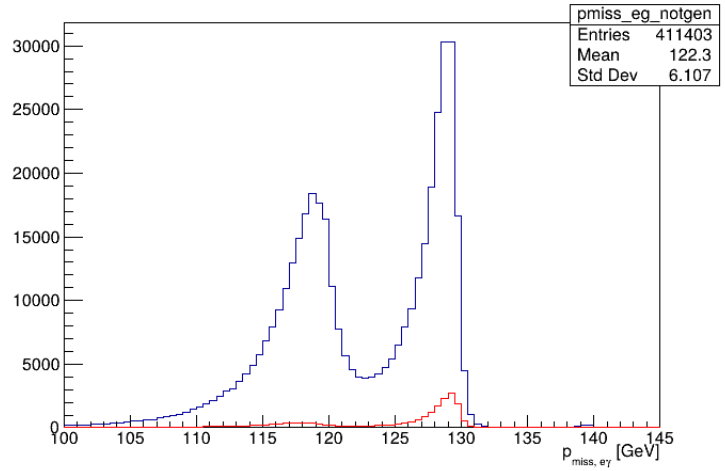
- Method: maximise significance, $\sigma = \frac{S}{\sqrt{S+B}}$
  - S – signal events (from known generated e'p'γ events)
  - B – background events (from known non-e'p'γ events with $n_{rec}(e', \gamma) \geq 1$)

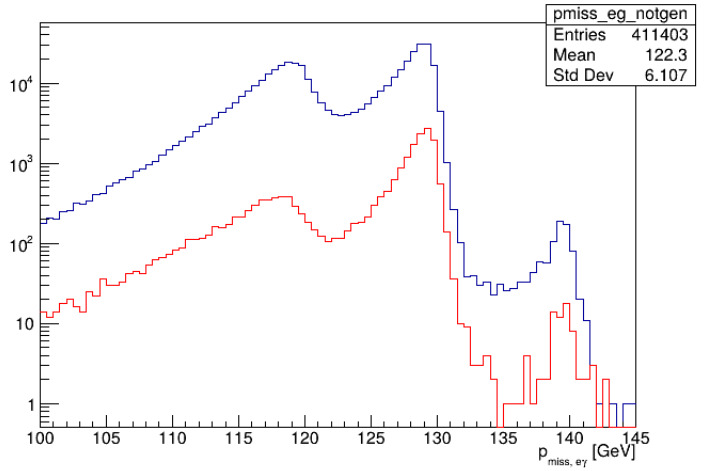
Best choice of p_{miss} cut? (3)



- Maximum significance at 5% around beam momentum.
- Corresponding count losses:
  - Signal – 30.7%
  - Background – 53.2%

(Blue – background; red – signal)



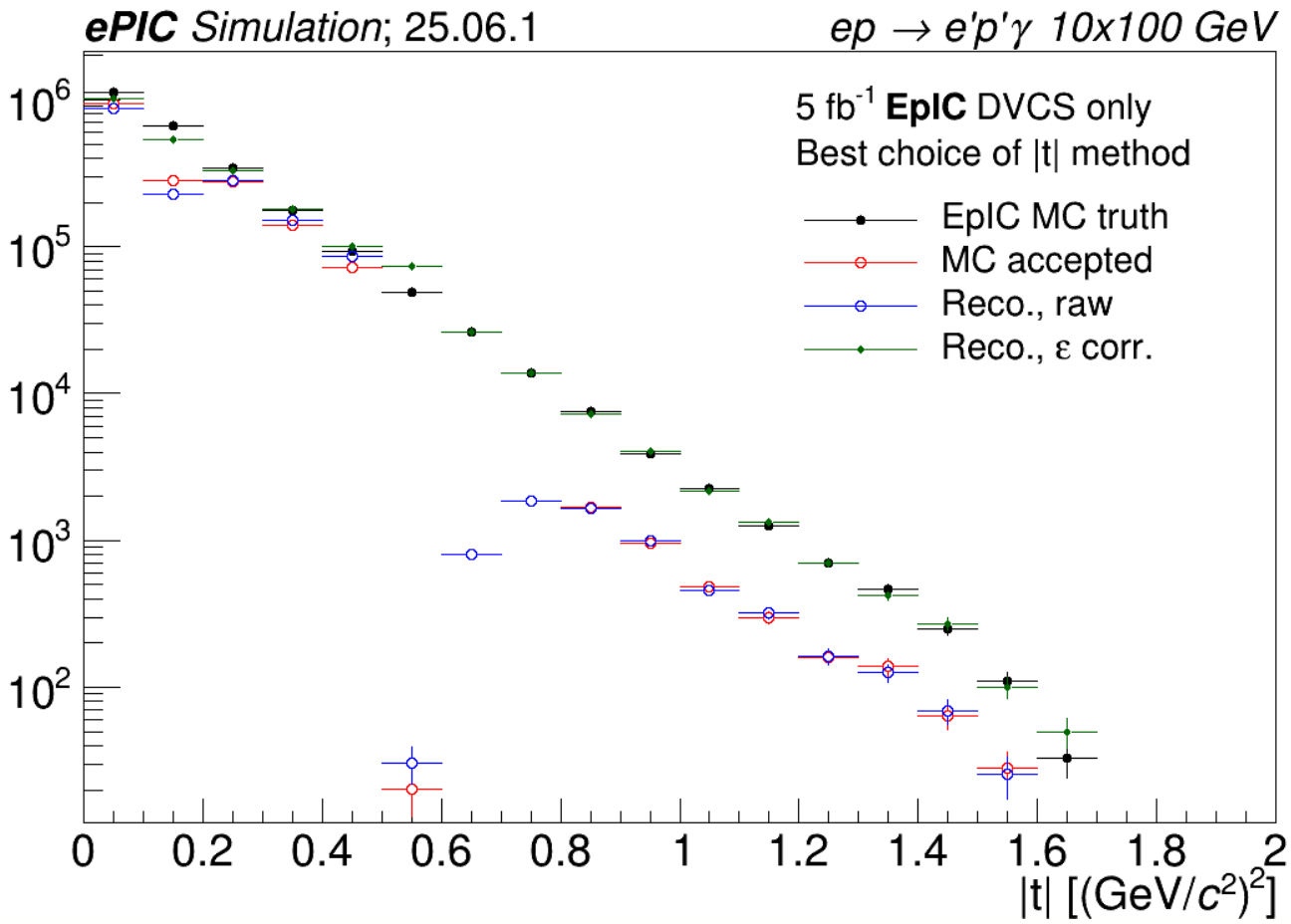


Validity of method?

- Plot t from eXBE method for all events with the following selection:
  - Single scattered electron
  - Single real photon
  - 2-body missing momentum within 5% of beam proton momentum.
    - For case shown (10x100): 95 GeV ≤ $p_{miss,e'\gamma}$ ≤ 105 GeV

- This test:
  - Compare bin-by-bin in t.
  - Choose 1 reconstruction method for each bin – fully exclusive BABE or semi-inclusive eXBE.
  - Note: have reduced t-bin size to 0.1 GeV^2 (rough worst t-resolution).

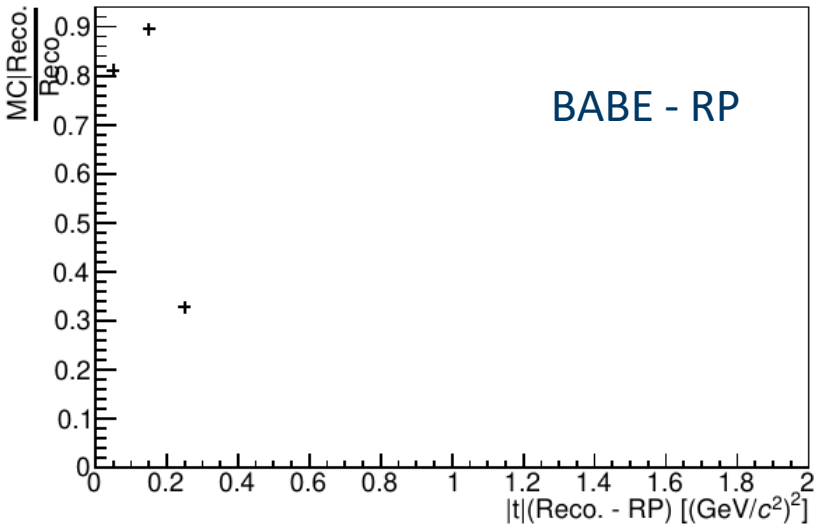
Result

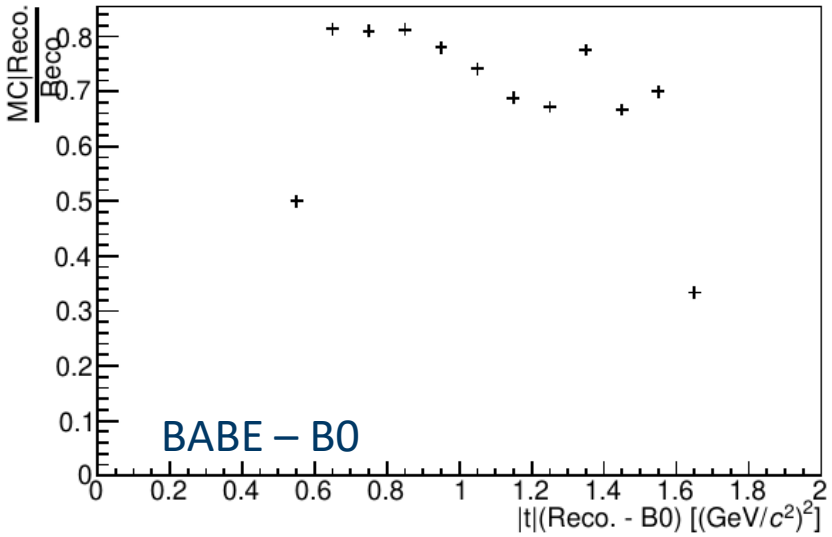


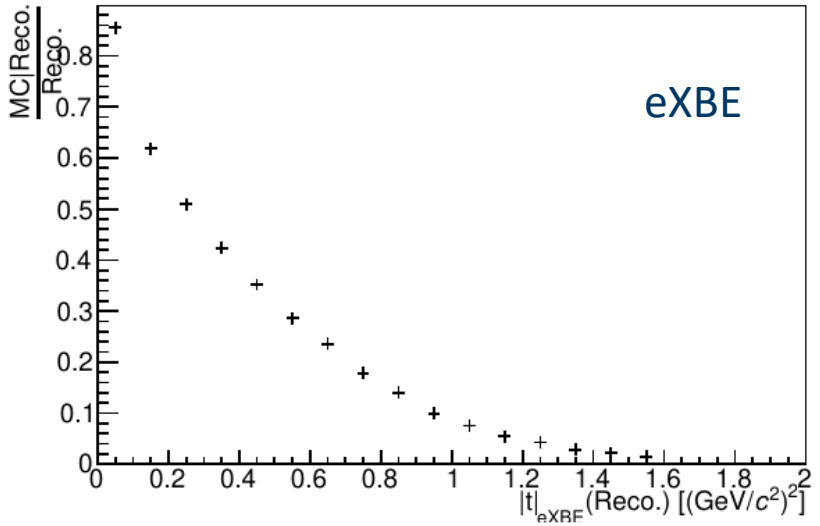
- No severe fluctuations as seen for BABE method alone.
- Selection seems to overcorrect raw reco. distribution (not massively, but consistently – perhaps ~10%).
- Concern: purity of t-reconstruction methods is lower than ideally considered.

Purity of t-reconstruction

- Reduced t-bin width to 0.1 GeV^2 (rough worst t-resolution seen).







- Even when the best purity, eXBE purity is not >75%.
  - Problem?

Concluding remarks

Summary of this update

- Can be confident that fix put into EICrecon has addressed loss of photon reconstruction.

- Alternate methods of $|t|$ reconstruction – best reconstruction from eXBE method.
  - Both in region where proton is detected by Roman Pots (will likely change with new RP algorithm), and when proton is missed.
- Current test of eXBE reconstruction looks alright, but unsure of details currently being used.

Next steps

- Admin:
  - Waiting on 25.10.1 simulation campaign for pre-TDR plots.
  - Redo current plots with official ePIC style.
- Analysis:
  - Redo current analysis to use electron finder (will need complete edm4eic-based rewrite).

- Questions:
  - Is the *t* reconstruction purity a problem?
  - Is the method described the best way of selecting *t* reconstruction? Would it be better to plot missing p' events separately and combine afterwards?

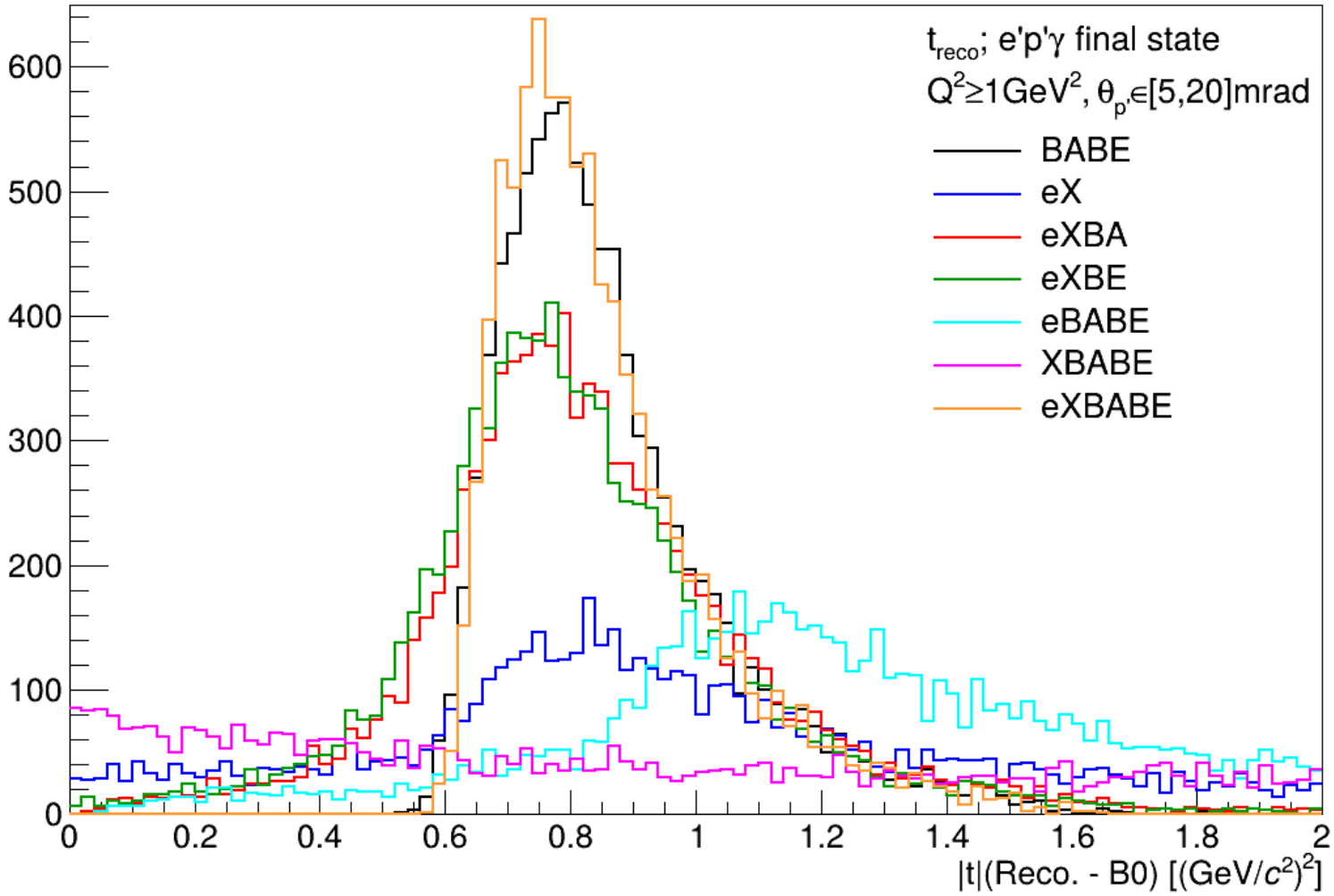
Thank you for listening!

Any questions?

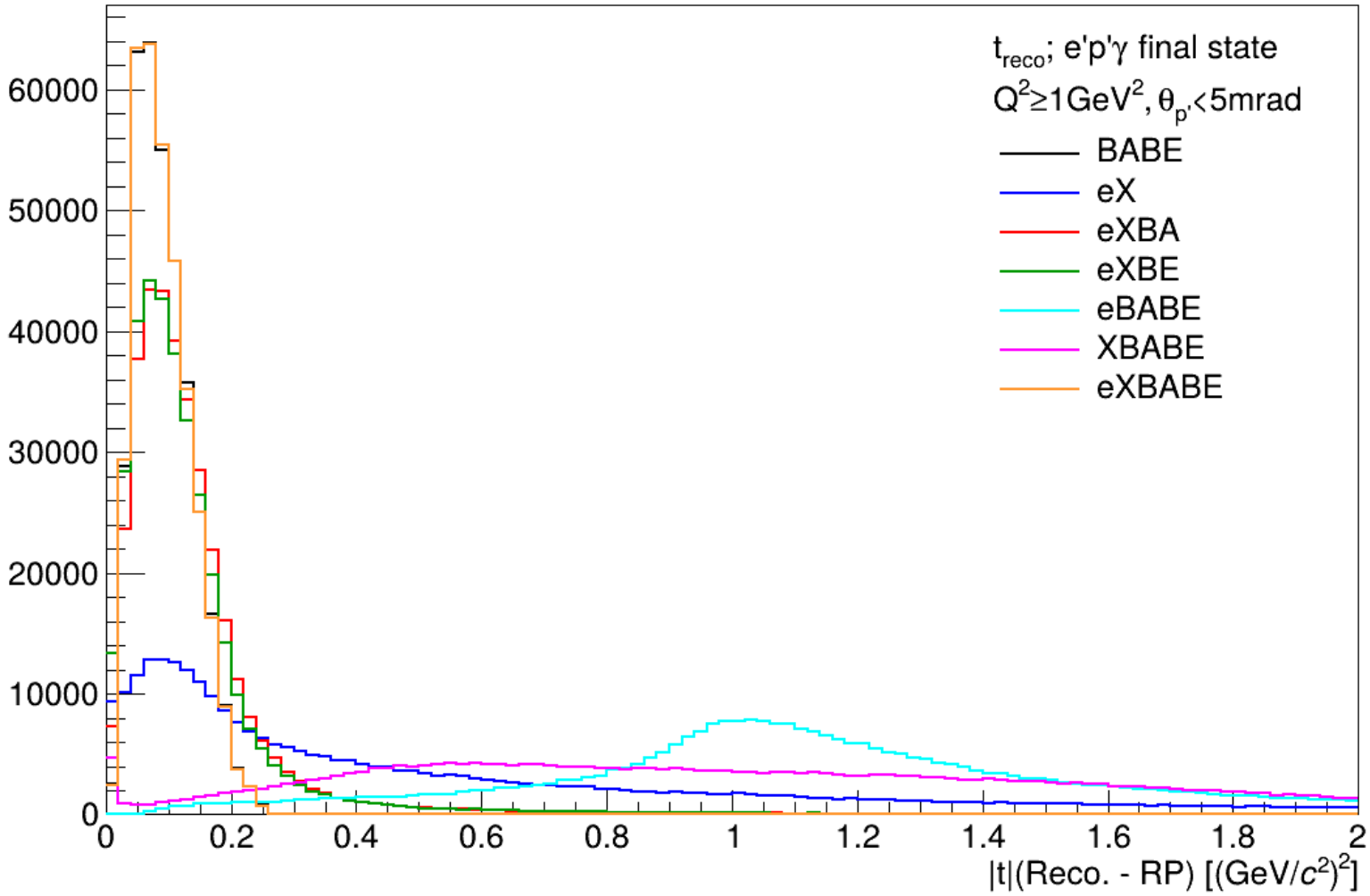
Offline questions? Ping me an email!

Backup

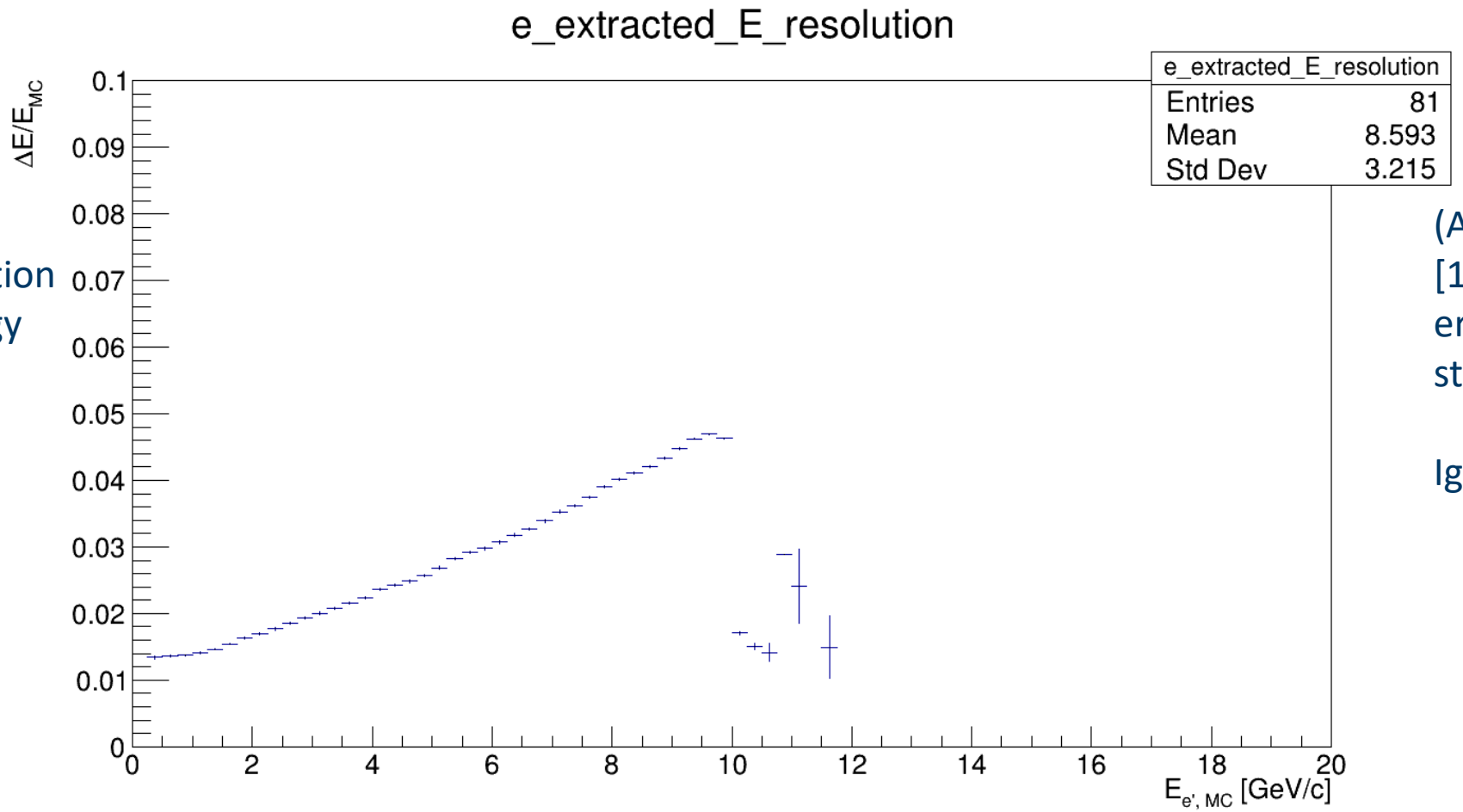
Reco. t calculations (B0 protons)



Reco. t calculations (RP protons)



Energy resolution (e’)



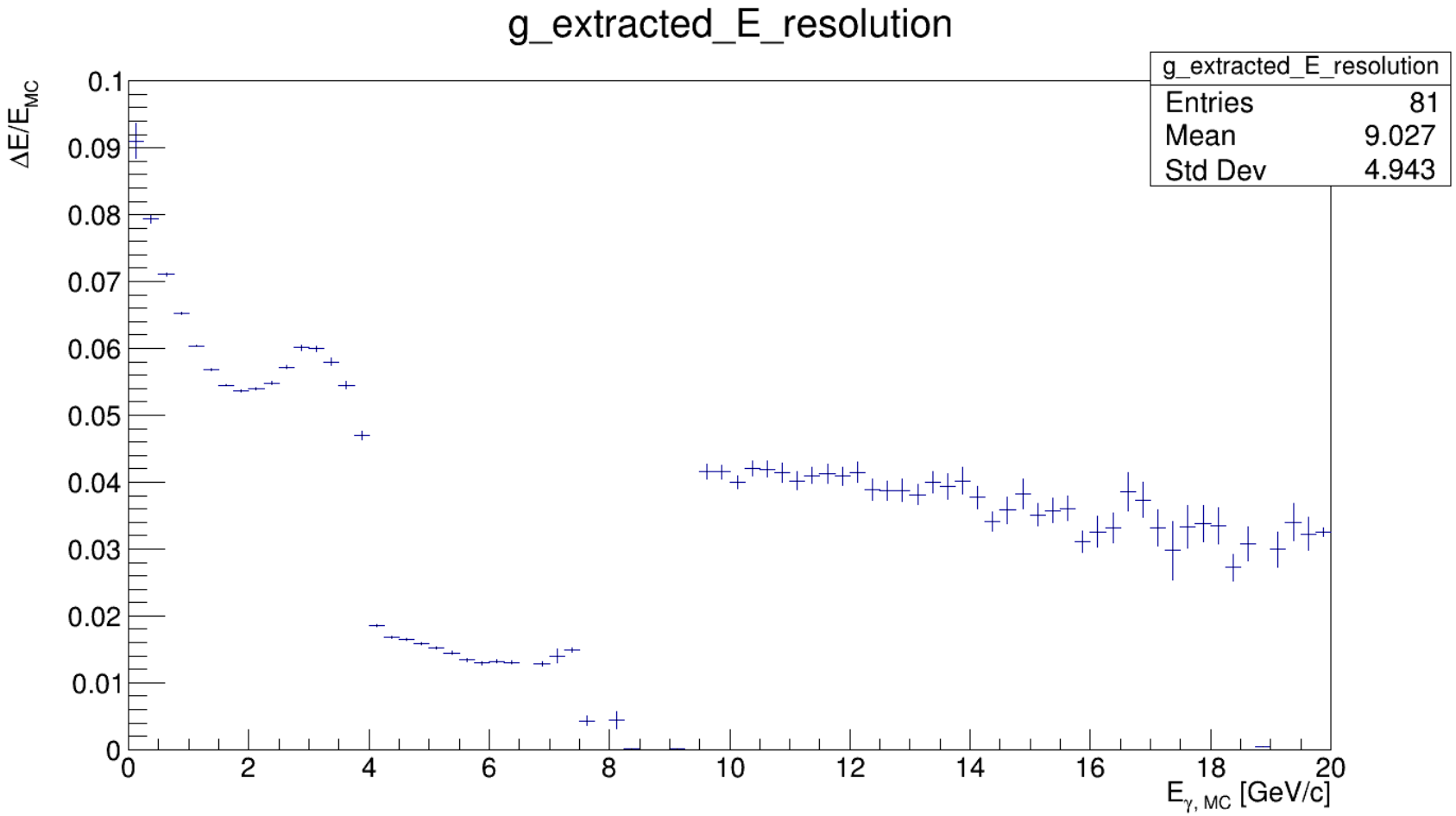
Basically just momentum resolution from tracker (energy calculated from momentum and mass).

Resolution ~few %.

(Actually a point at [11.25, 0.9]; v. high errors due to poor statistics)

Ignored them for now.

Energy resolution (γ) – being generous

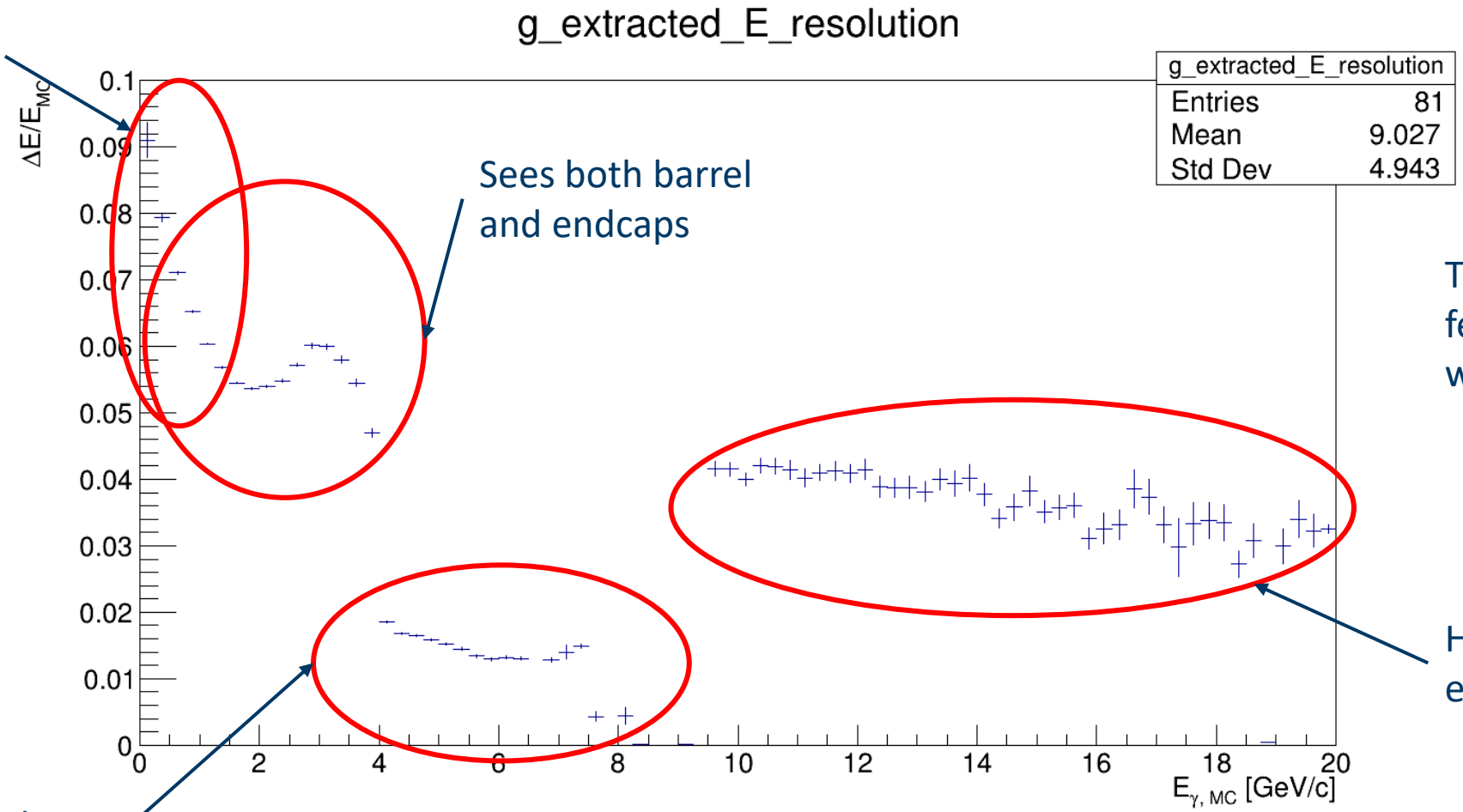


Energy resolution (γ) – being generous

Affected by edge effects at high |η|

Energy purely from calorimeters.

(Most) resolution ~3/4%



Sees both barrel and endcaps

This zoom ignores a few points at 30% or worse resolution…

Hadron endcap only

Both endcaps

Mandelstam t resolution

Yes, technically 10x130, but works as close approximation of 10x100 (as shown in main).