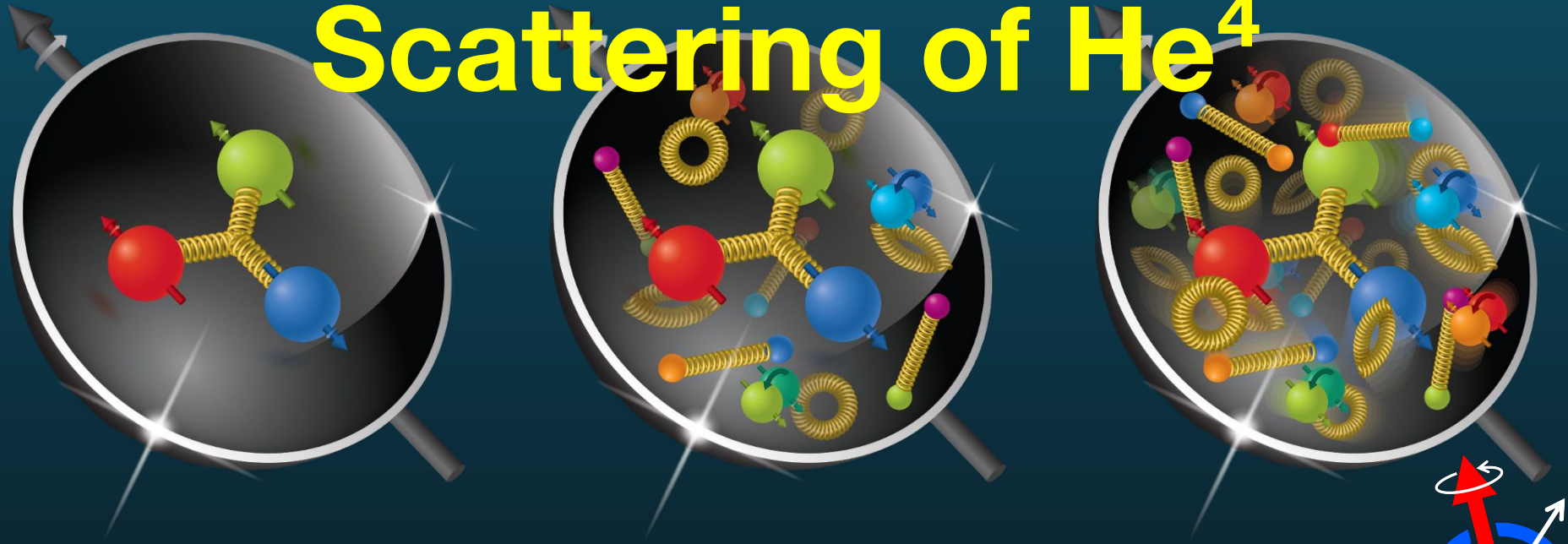
Deeply Virtual Compton Scattering of He^4



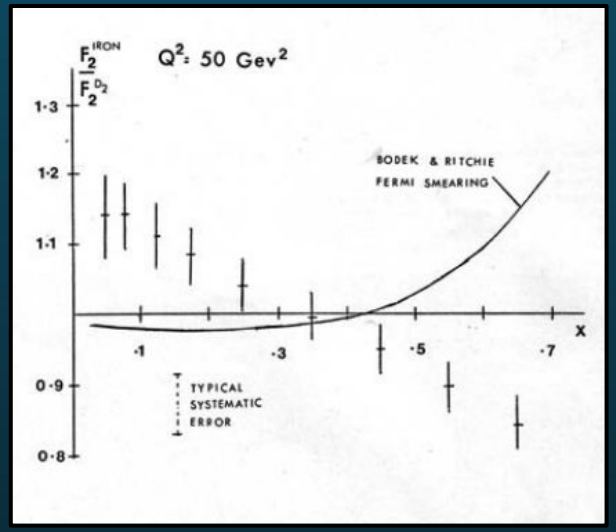
University of Glasgow

Gary Penman
01.03.24

ePIC

History of DVCS and DIS

- Measurements of F_2^{Fe}/F_2^{D2} in DIS at CERN, 1982
- Binding Energy of Nucleus << Typical momentum transfer
- Expect almost constant plot with minor corrections
- Instead, see clear downward gradient!
- Dubbed: ‘EMC Effect’

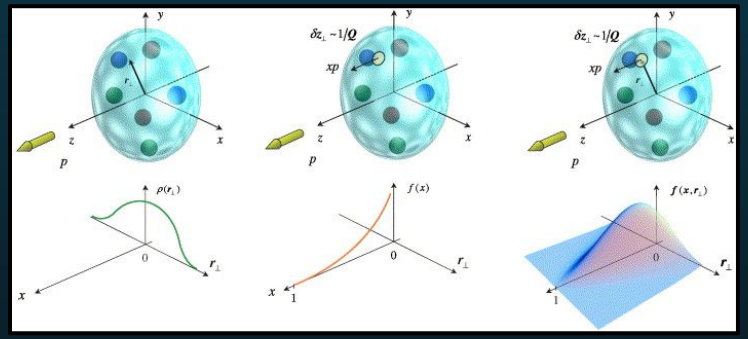


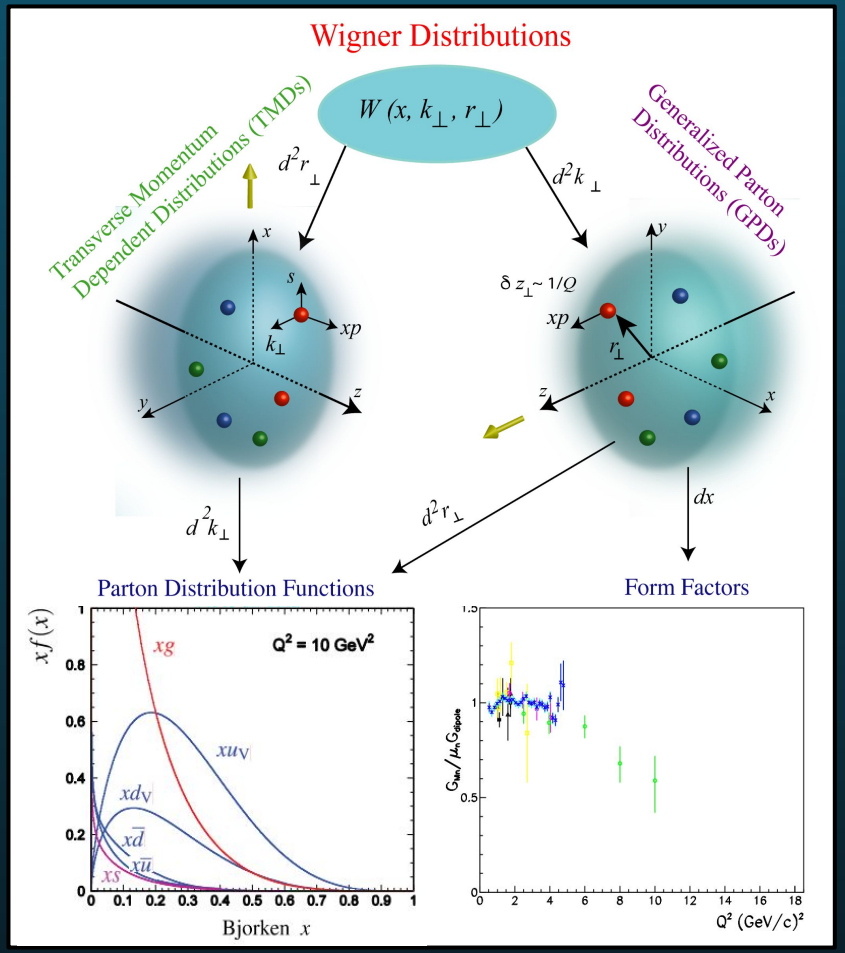
EMC Data, CERN Courier 1982.

https://cds.cern.ch/record/1734943/files/vol53-issue4-p035-e.pdf

Hard Exclusive Processes and 3D Imaging

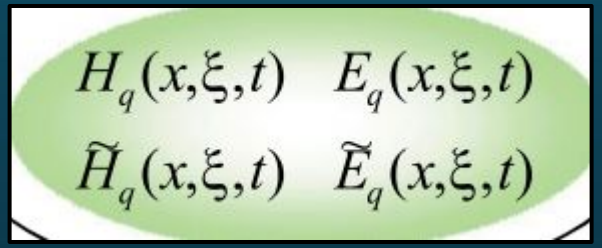
- FFs describe 1D transverse distribution, PDFs describe 1D longitudinal momentum, but no correlation!
- GPDs directly correlate longitudinal momentum and transverse position of partons.





Generalized Parton Distributions

- DVCS / TCS allow access to 1+2D GPDs through CFFS.
- Many ep studies and experiments so far.
- Recent publication of 12 GeV e-p results, end (e`,d) approved at PAC50
- However only current e-^{4}He data from CLAS6!
  M. Hattaway, R. Dupre et al.
  https://arxiv.org/abs/2102.07419



Combine differently depending on polarization of beam and target (BSA, ITSA, BITSA, tTSA).

Only 1 Chiral even GPD needed to parameterize structure of spinless nuclei:

$$H_A(x,\xi,t)$$

DVCS of ^{4}He

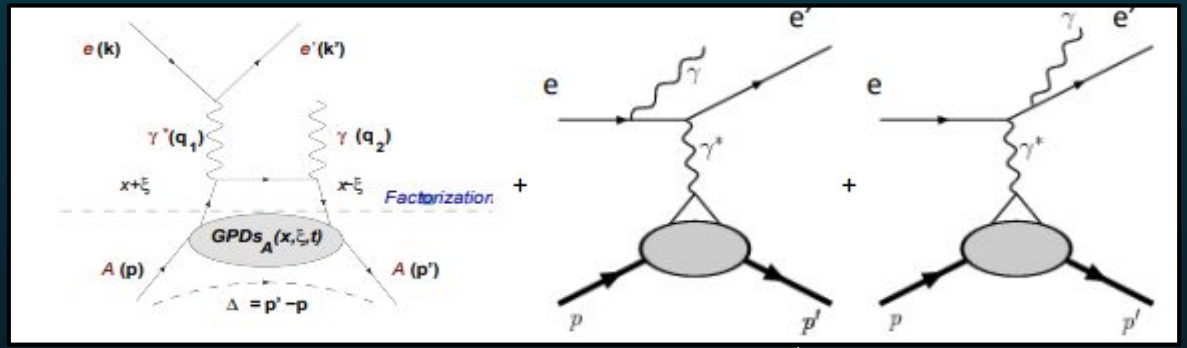
- Process which can give understanding of EMC effect, and tomographic view of nucleons.
- Pure DVCS reaction illustrated by 'Handbag Mechanism'.
- At leading twist order full picture DVCS + Bethe-Heitler:

$Q^2 = -q^2 = -(k'- k)^2$, the virtuality of γ^*

$x_B = Q^2/2M\nu$

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

ϕ_h = angle between leptonic and hadronic scattering planes.



Handbag approximation of coherent DVCS of ^{4}He
https://arxiv.org/pdf/1910.07458.pdf

DVCS He^4 with ePIC

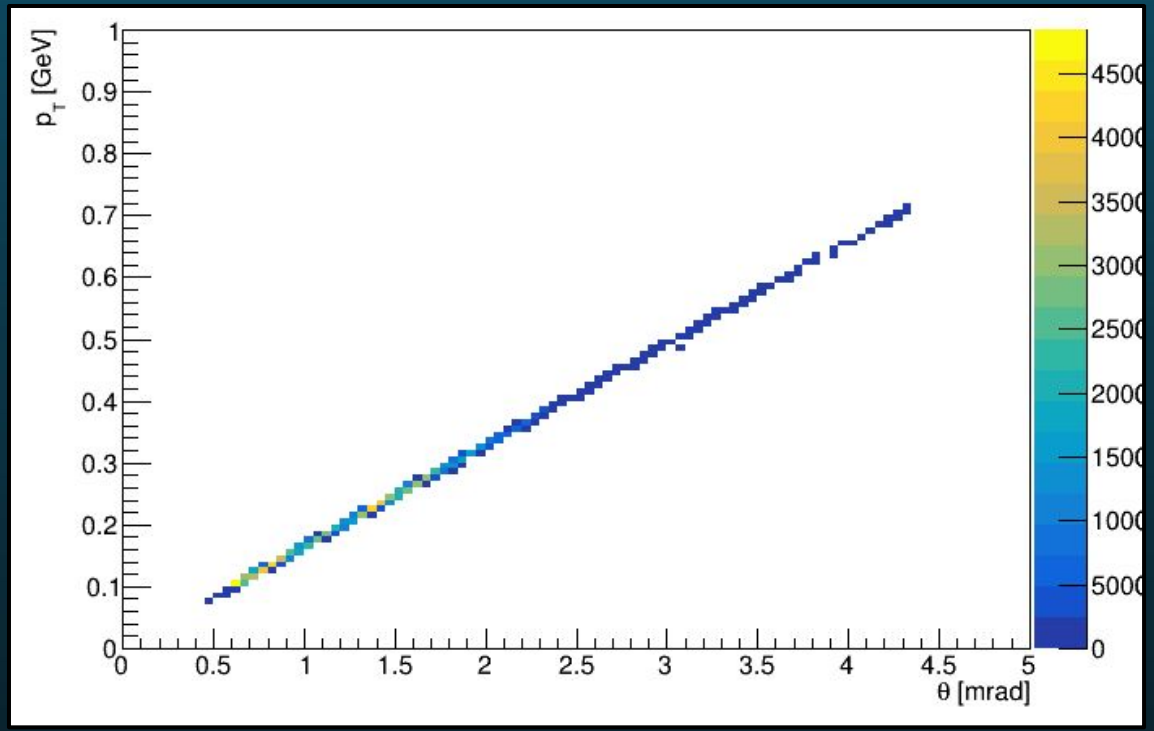
Setup

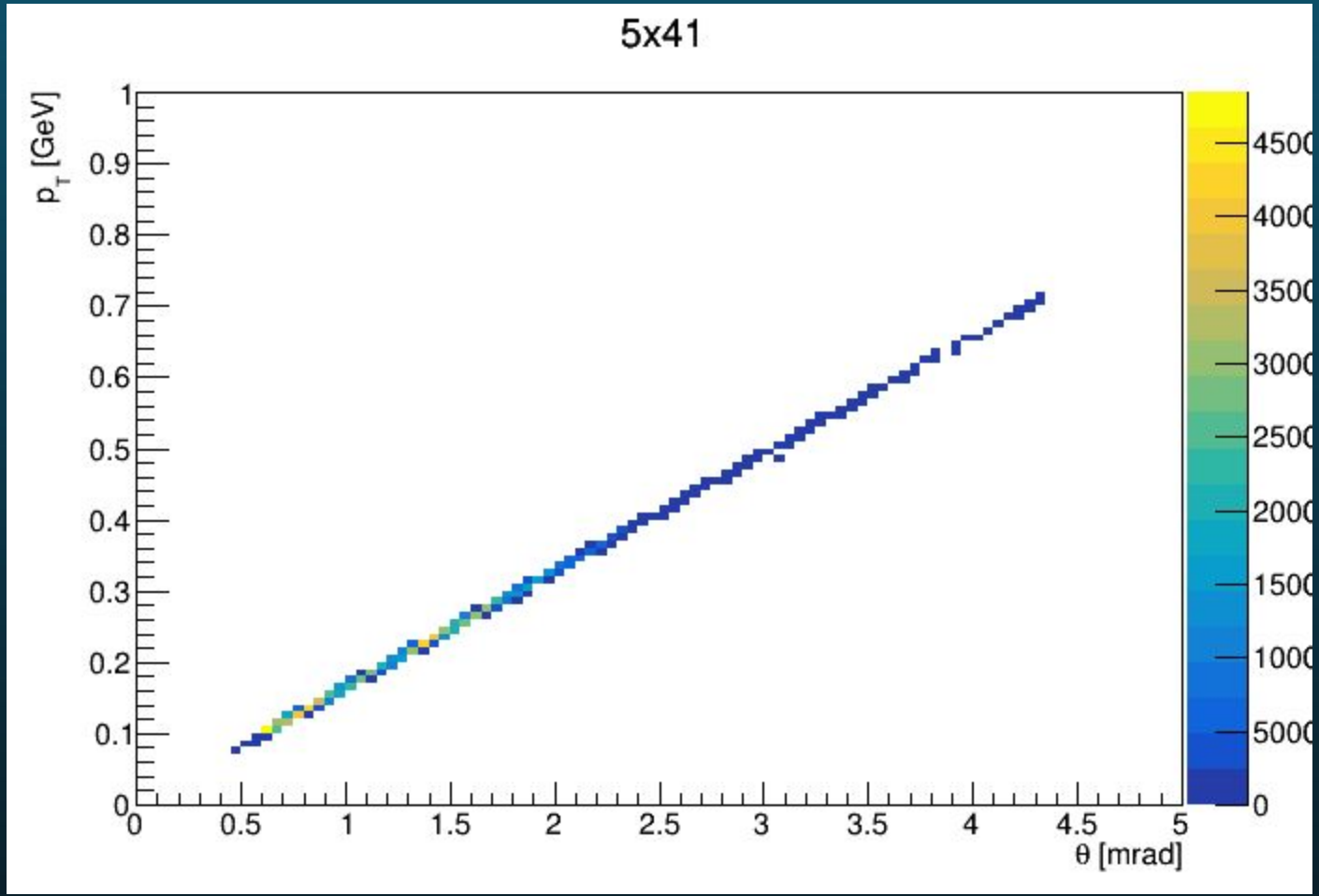
- Topeg Generator

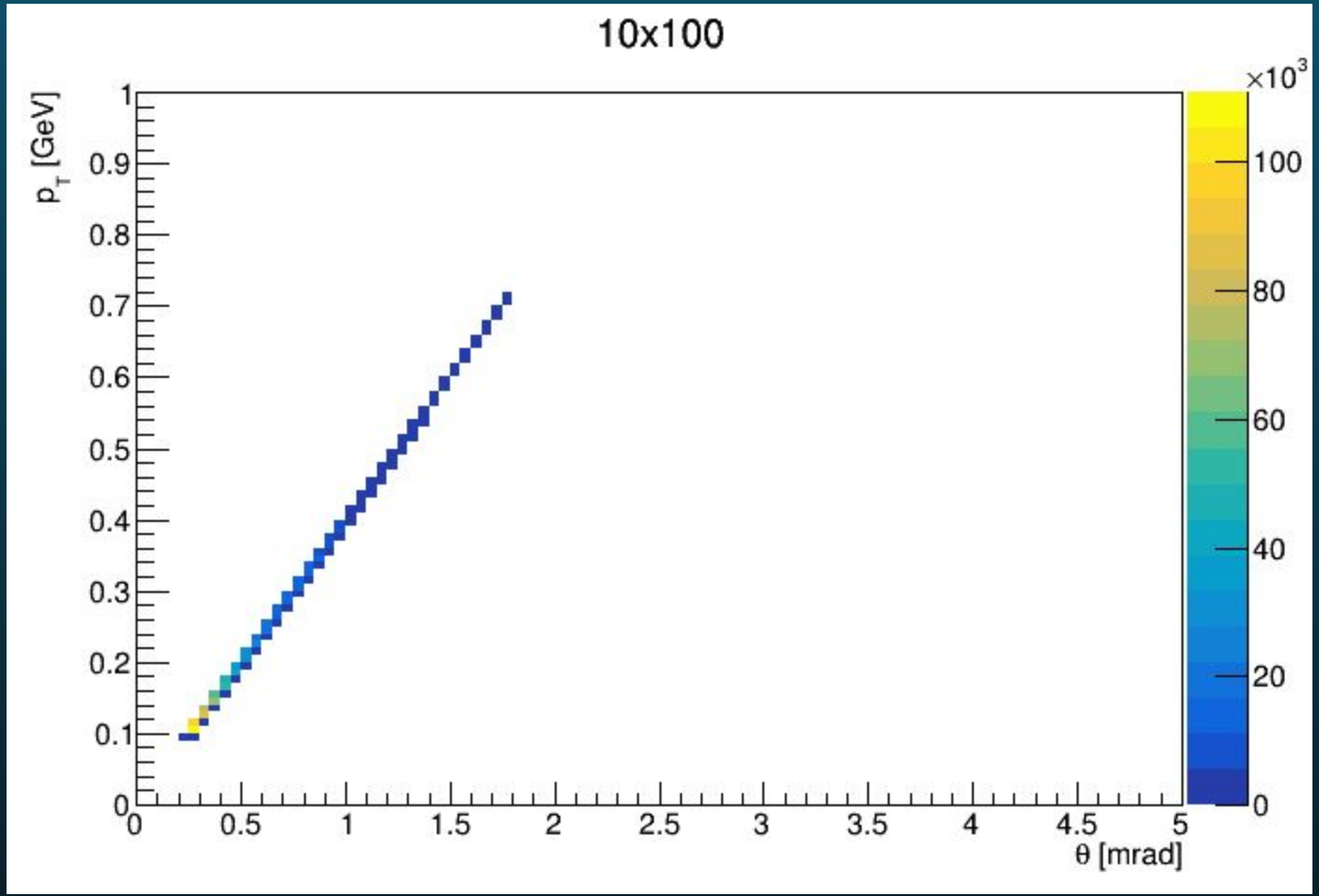
  https://gitlab.in2p3.fr/dupre/nopeg

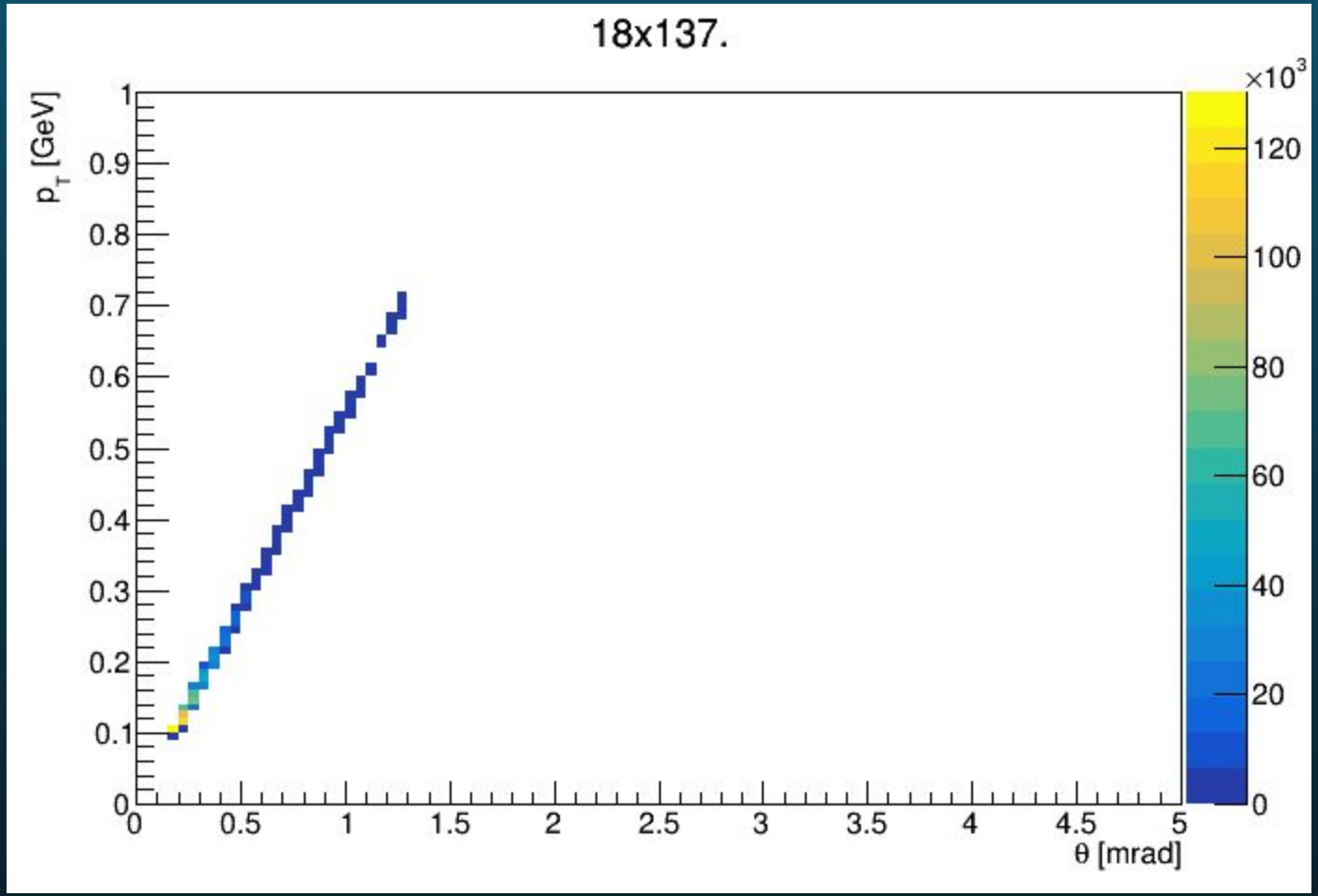
- 5 GeV e^-
- 41 GeV/u = 164 GeV He^4
- 1M events generated

Right: MC p_T vs polar θ of scattered He4

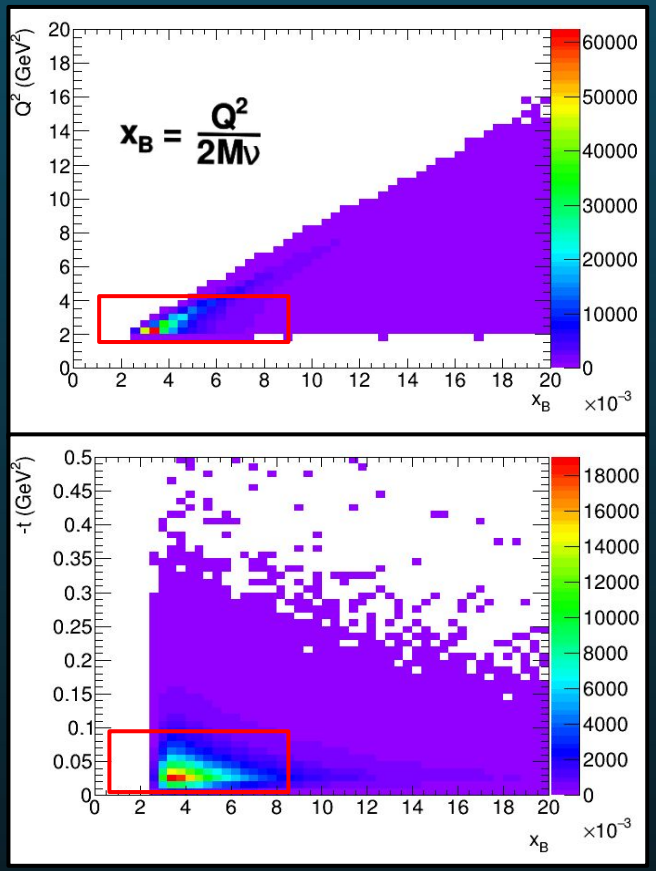


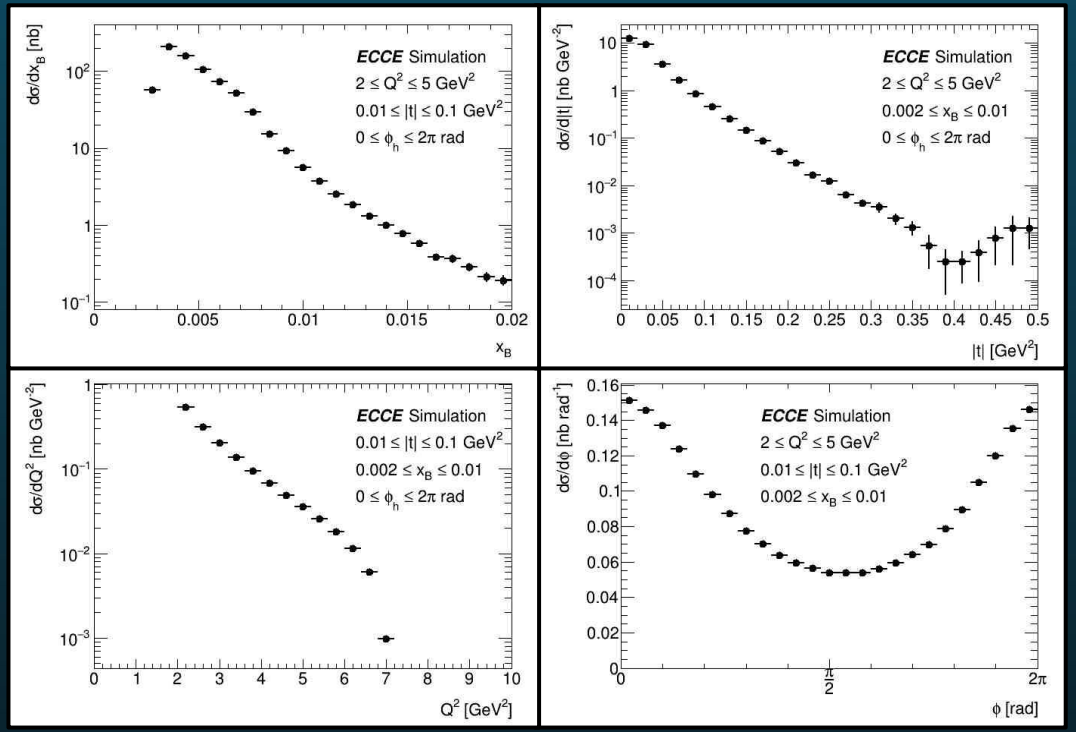

5x41
p_T [GeV]
θ [mrad]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
4500
4000
3500
3000
2500
2000
1500
1000
5000
0


10x100
p_T [GeV]
θ [mrad]
×10^3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
20
40
60
80
100

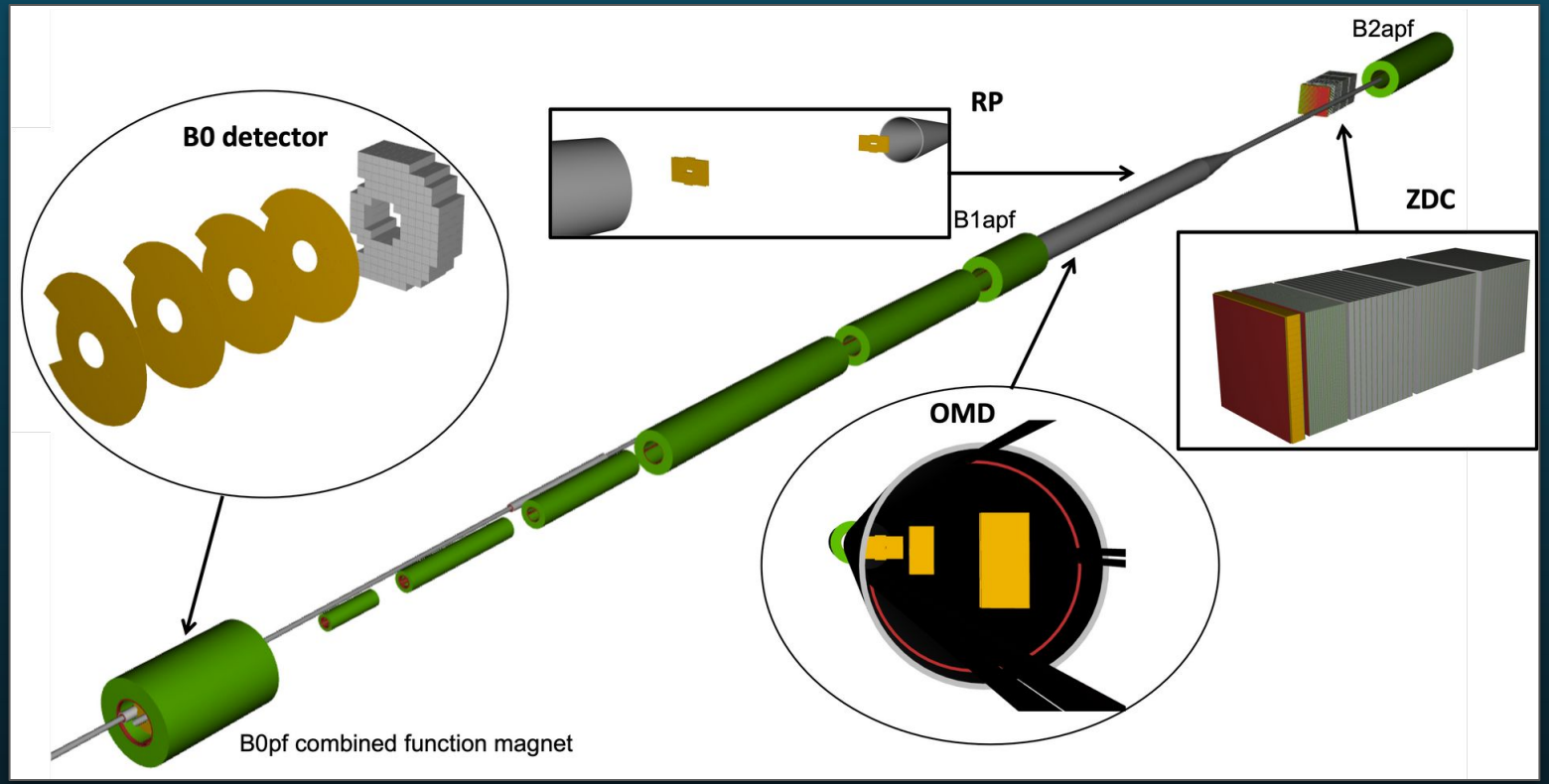

18x137.
p_T [GeV]
θ [mrad]
×10^3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
20
40
60
80
100
120

ECCE Results





Forward Detection for Exclusive Channels



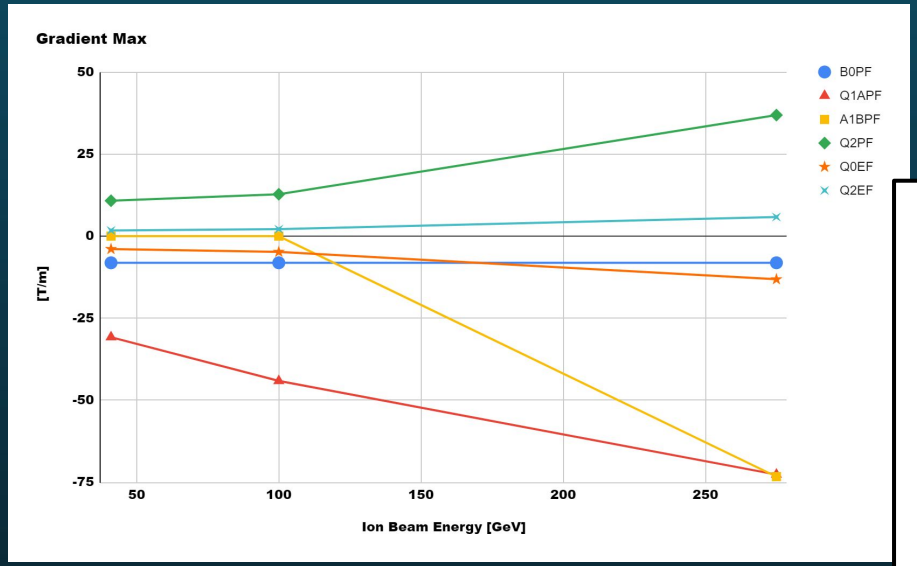
Scaling Forward Magnets to 41GeV/u He4

Need to correctly steer the ion beam through the beam pipe and centre of forward detectors (B0 Calorimeter, Roman Pots).

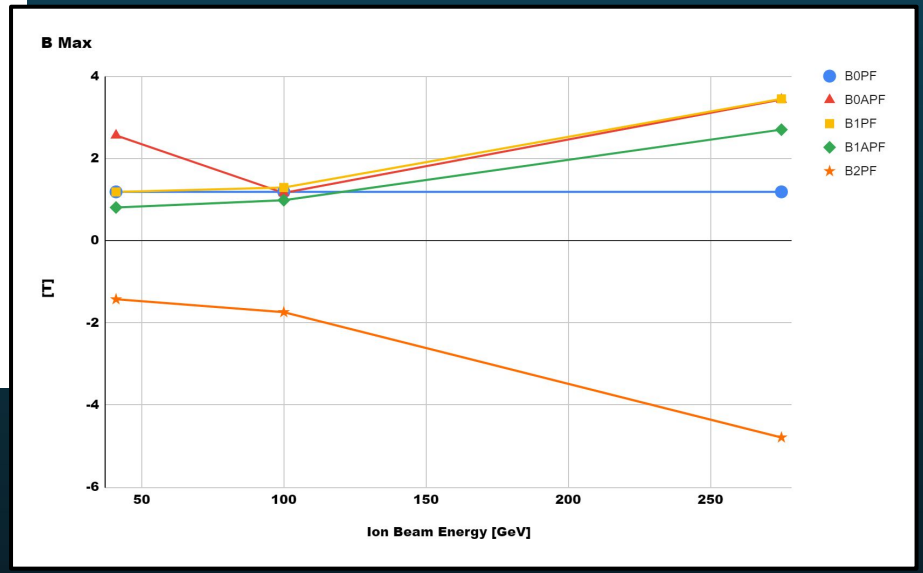
“Effective” scaling of 82 GeV required - 2 protons in He4!

Initial attempts were unsuccessful, but most recent attempt looks to be working.

Default Far Forward Field Gradient and BMax values



Forward steering values show near linear interpolation between kinematic settings.

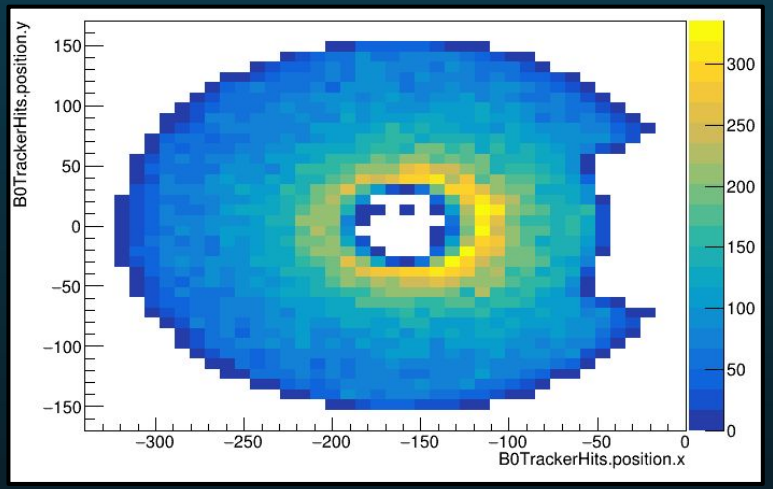


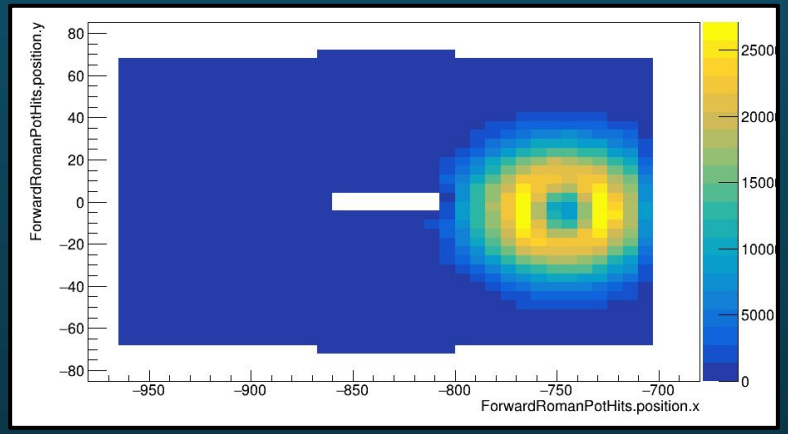
ePIC 41GeV Steering He4

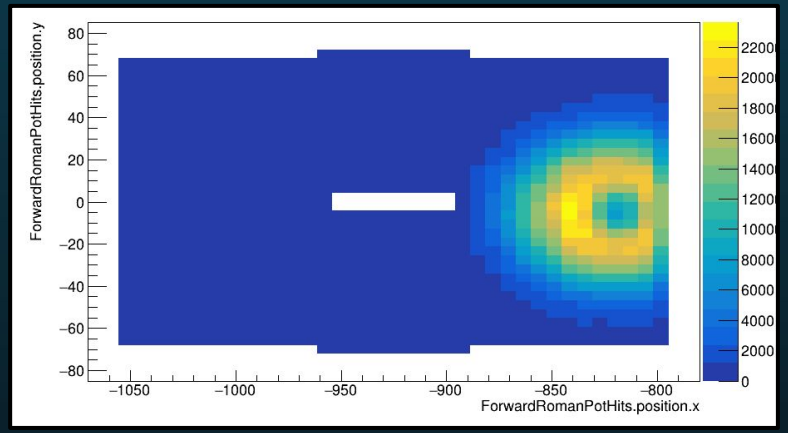
Config: epic_5x41 (default)

Version: epic-nightly

Build date: June 28-30 2023





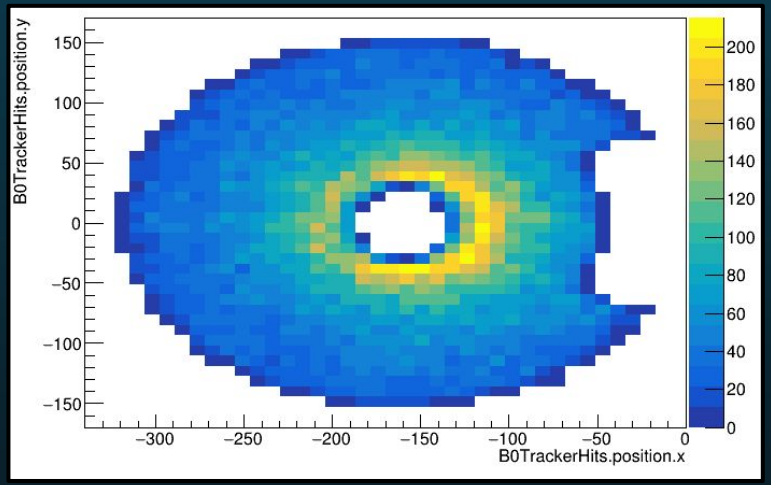


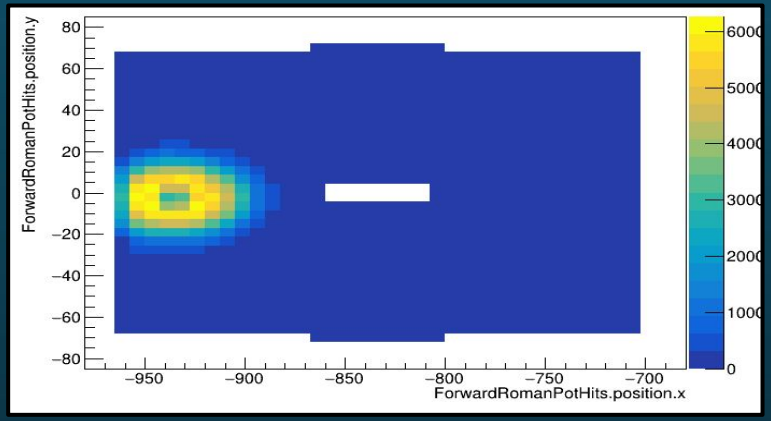
ePIC 82GeV Steering He4

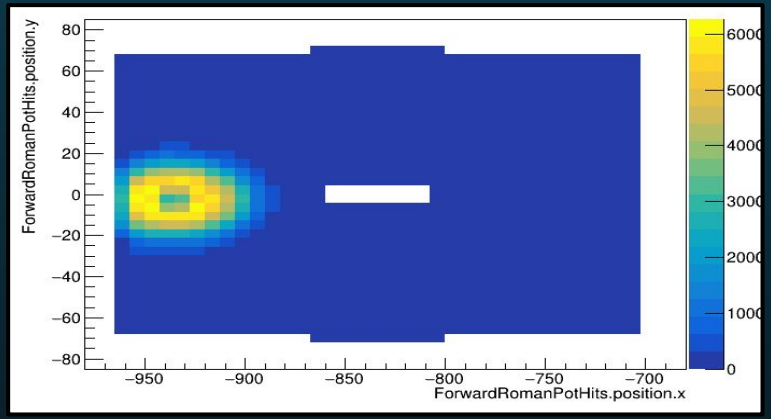
Config: epic_5x164 (custom - 5x100 with forward magnets scaled by 0.82)

Version: epic-nightly

Build date: June 15/16 2023





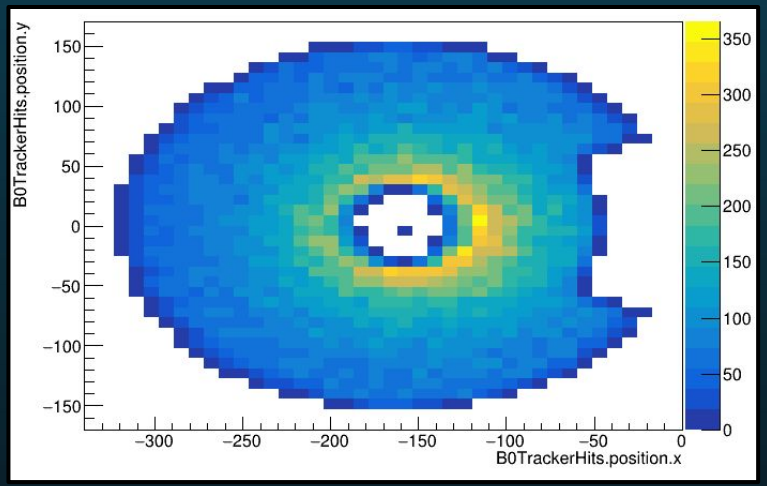


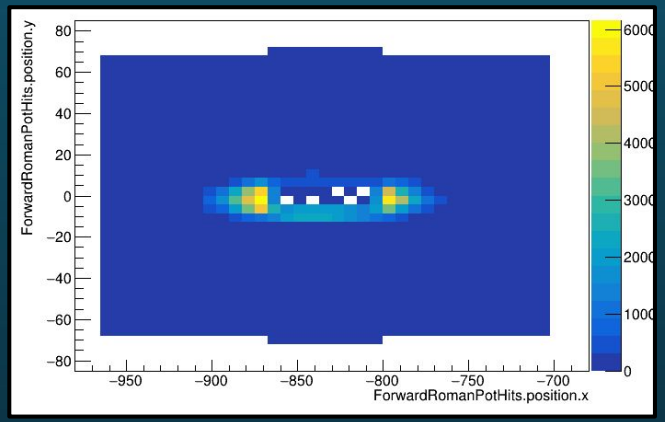
New 82GeV Steering He4

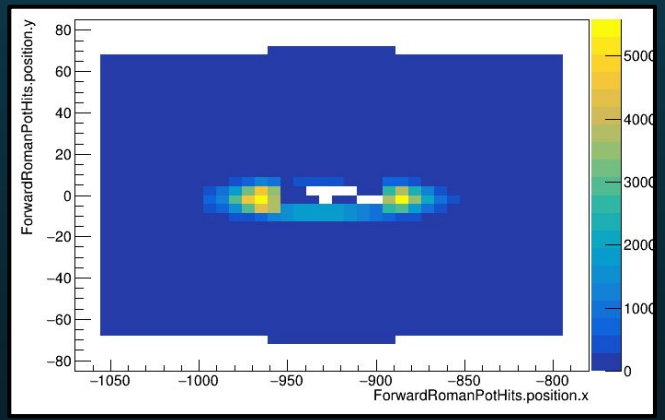
Config: epic_5x164 (custom - 18x275 with forward magnets scaled by 82/275)

Version: epic-nightly

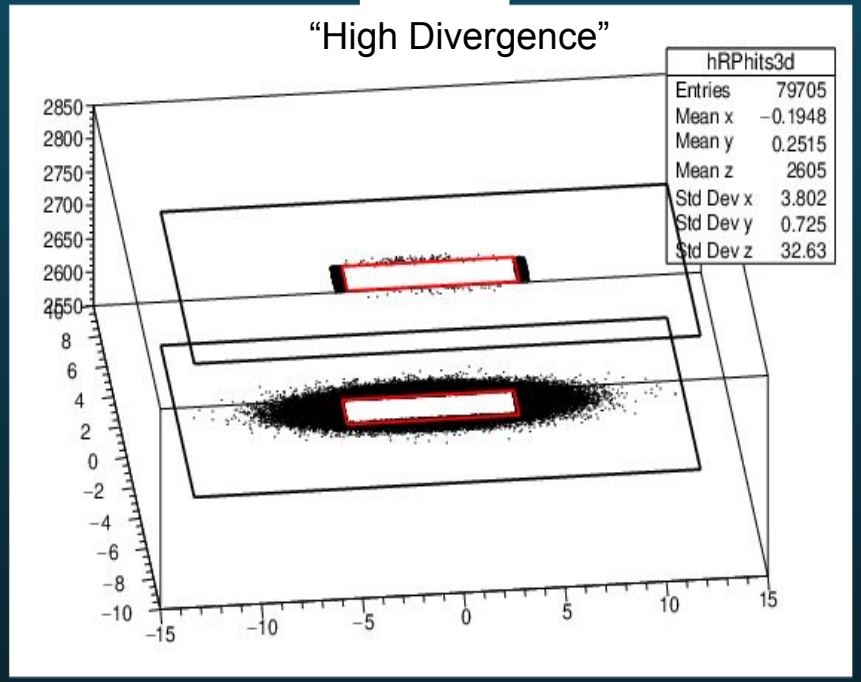
Build date: July 3rd/4th 2023

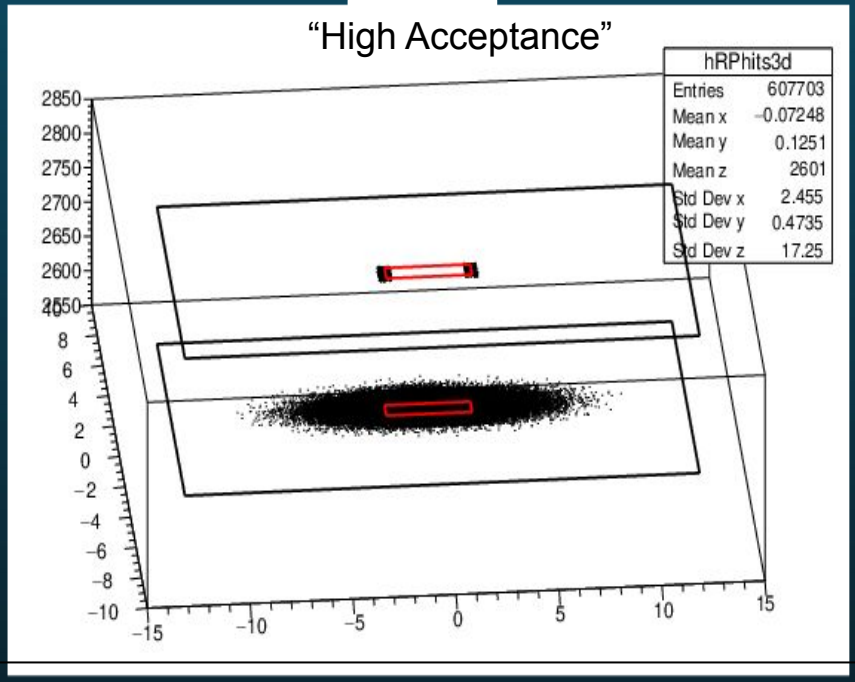






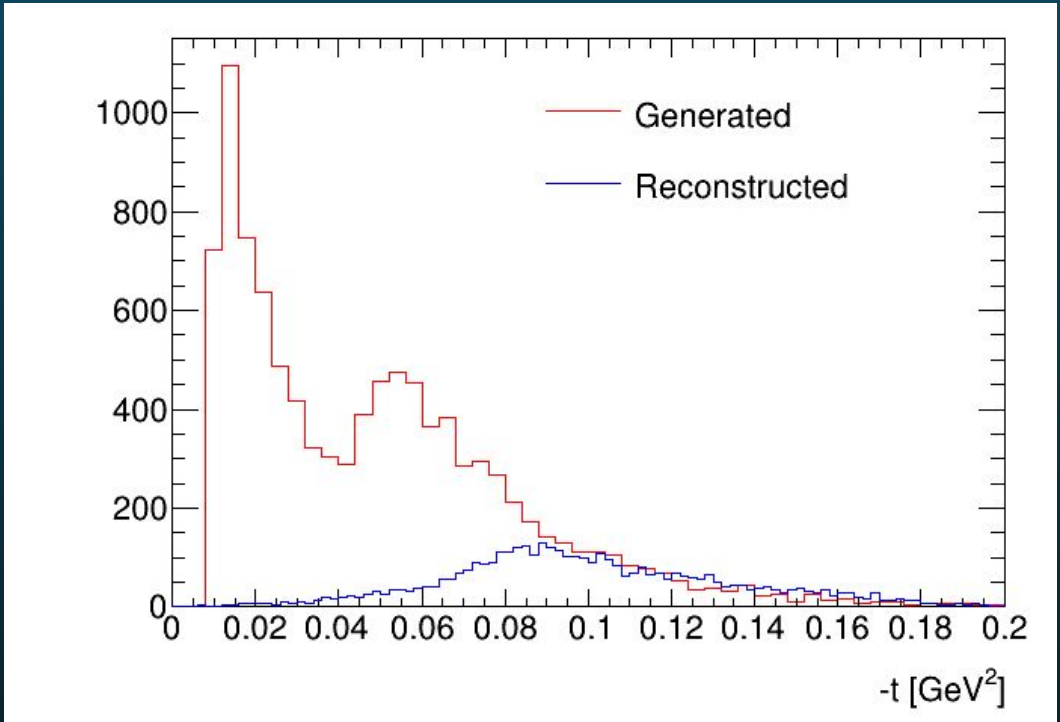
c.f. Old ECCE Results





Actual simulation parameterisations were identical at this point. The size of central hole was changed to simulate as close to the 2 as possible.

Initial Look at ePIC acceptance

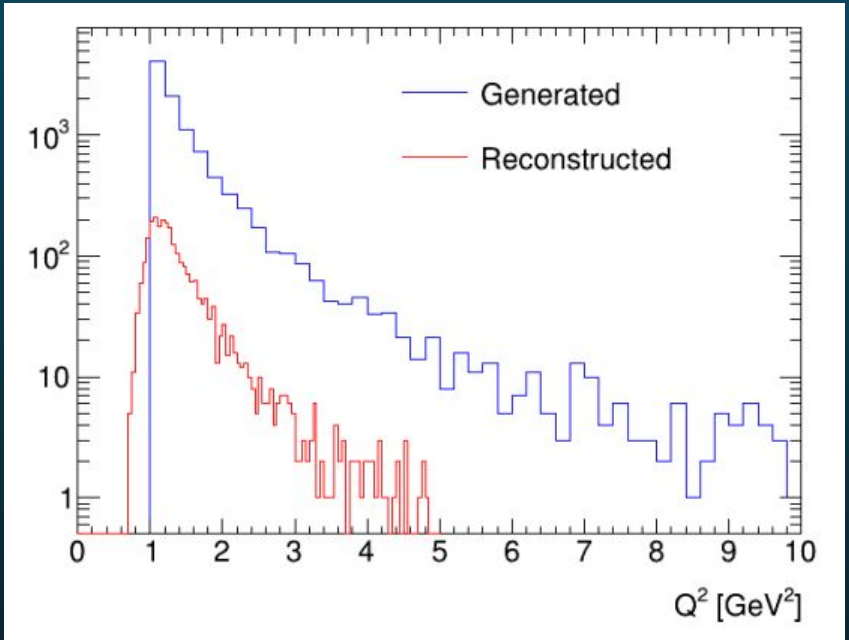


Very early look at ePIC reconstruction (10K events).

Current efforts focused on developing correct optics model for He4.

Reconstruction currently performed with proton model.

Scattered Electron Selection



Reconstructed Charged Particles branch of eicrecon / ddsim

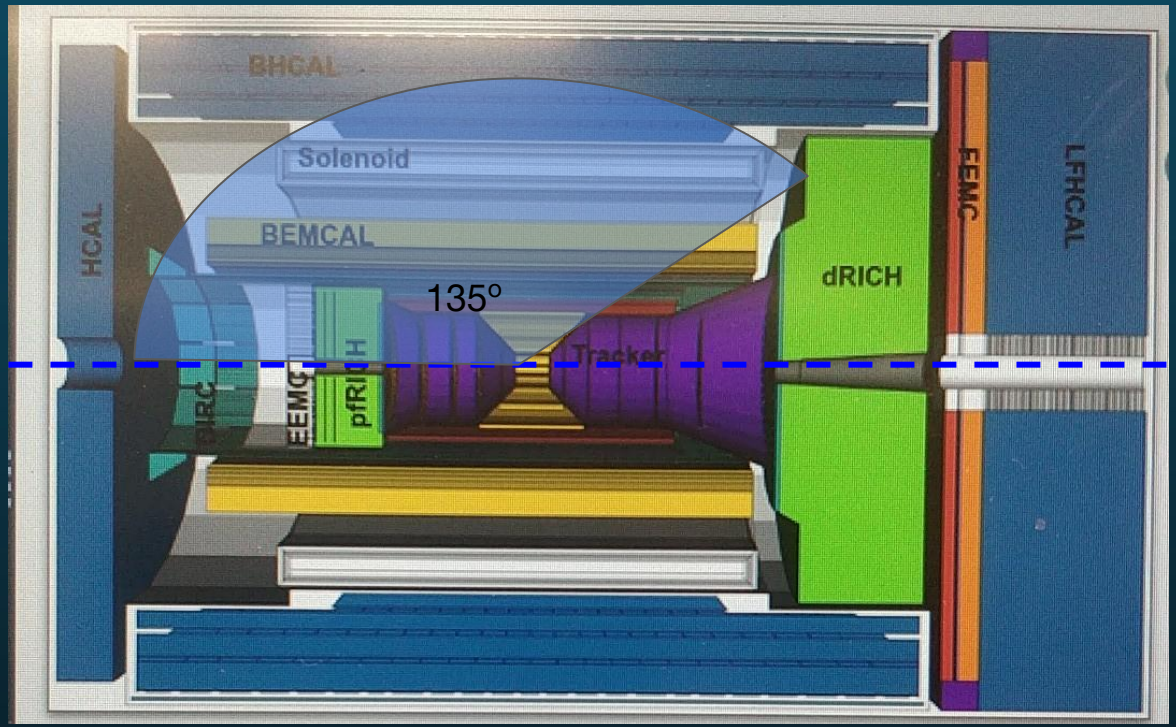
Uses tracker + calorimeter information

Use PDG and PID cuts to ensure electron.

$Q^2 = -q^2 = -(k' - k)^2$

Observing low Q^2 smearing

DVCS Electron & Photon Selection



Expect most/all photon and electron clusters in EEMC, BEMCAL (-3 ~< eta ~< 1).

As expected only low energy noise in all 3 HCals.

Forward EMC empty.

Need to separate charged and neutral clusters with track matching.

Exclusive Analysis Status

Global Cuts

- Roman Pot Tracks > 0
  (He^4 condition)
- Reconstructed Charged Particles > 0
  (e^- condition)
- EEMC + BEMC clusters > 0
  (photon condition)

26% of 10K events pass these 3 cuts.

Identification of correct photon cluster and calibration of energy is one of the next steps

Neutral particle reconstruction discussed at collaboration meeting in August. Need to revisit the recon code written since.

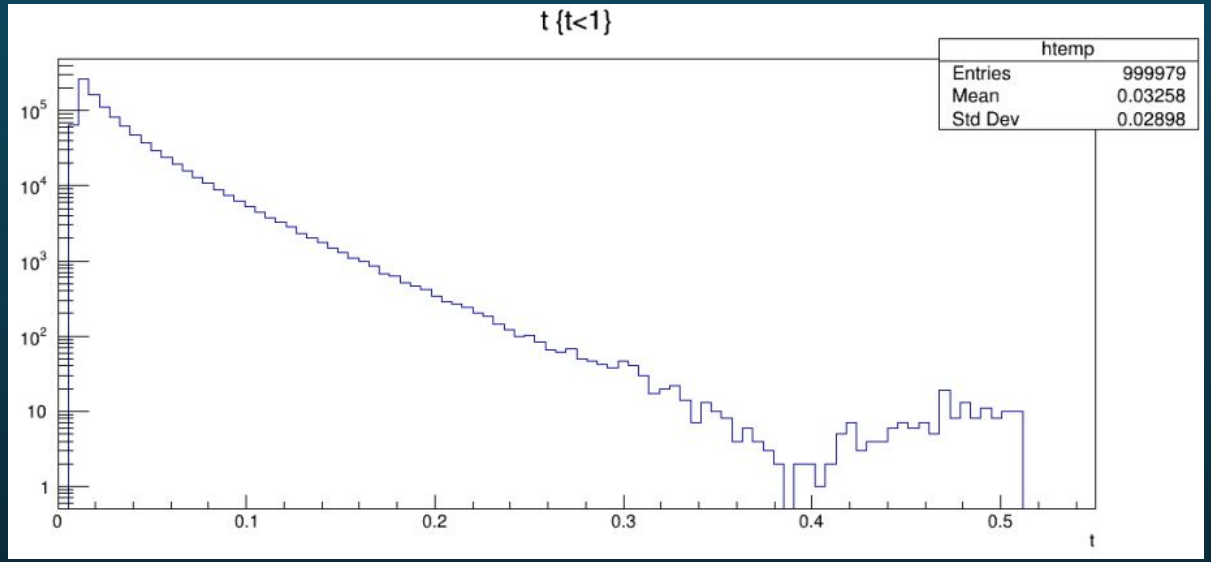
Summary and Ongoing Work

- DVCS on He4 is an interesting channel but little data exists so far.
  - EIC is an excellent opportunity to study it further
- ePIC detector looks to be well suited to the channel
- Lots of (ongoing) work for intermediary analysis steps:
  - Afterburner non-nominal beam energy debugging
  - Determine correct forward optics model for He4.
  - Benchmark Script for EDT Processes
  - Overlapping benchmarks with working group.
  - ePIC Physics comparison plots
  - Background studies

THANKS!

Backup

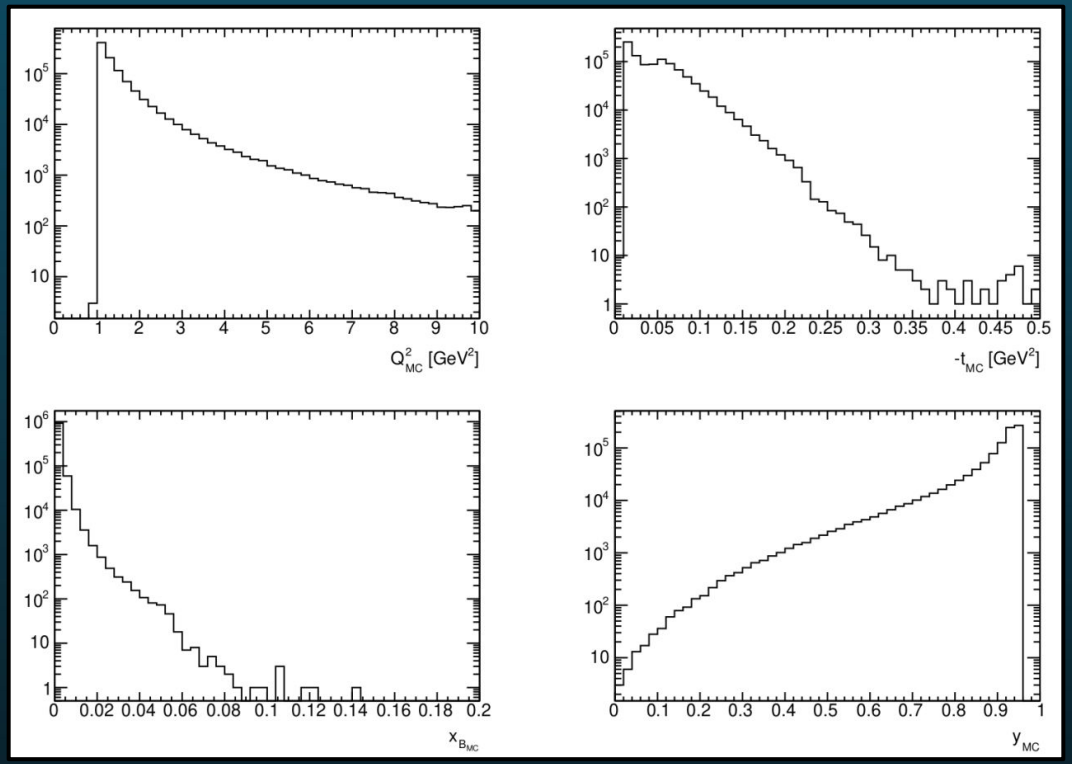
New Problem: -t Curve Shape!



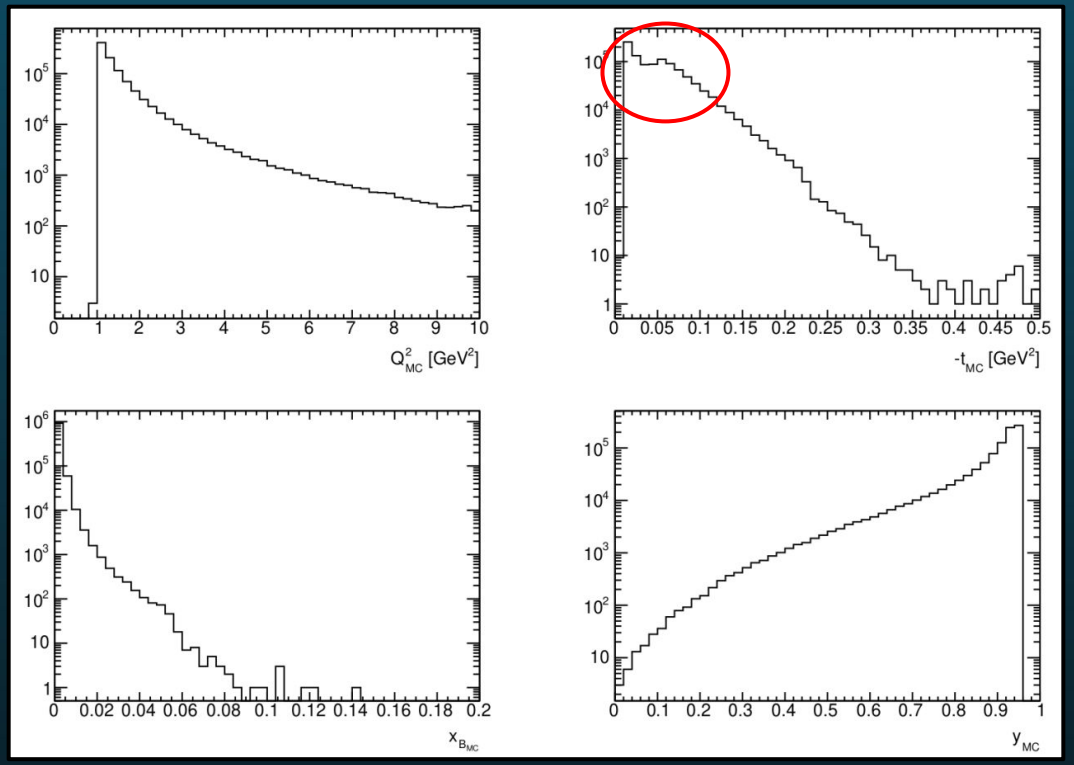
TOPEG: Generator Level |t| curve. Note minima around 0.4

C.f. ePIC results, minima around 0.04, drop off at 0.2. Statistical or recon issue?

DDSIM “MCParticles” Kinematics



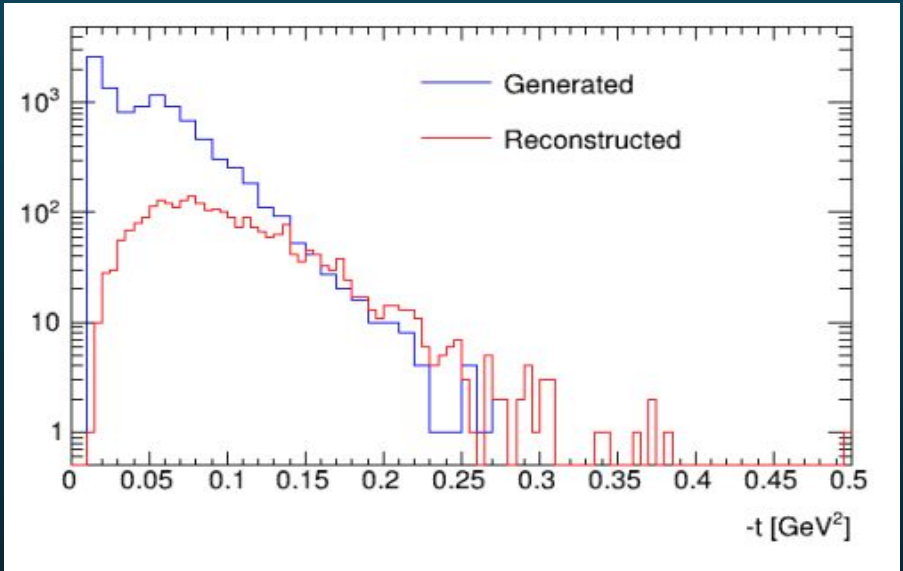
DDSIM “MCParticles” Kinematics



Minima slightly visible with current binning

DDSIM Beam Values

```
Ebeam: 0.000267995, 0.000772889, -4.99961
Hbeam: -4.09861, 0.000514387, 163.974
```

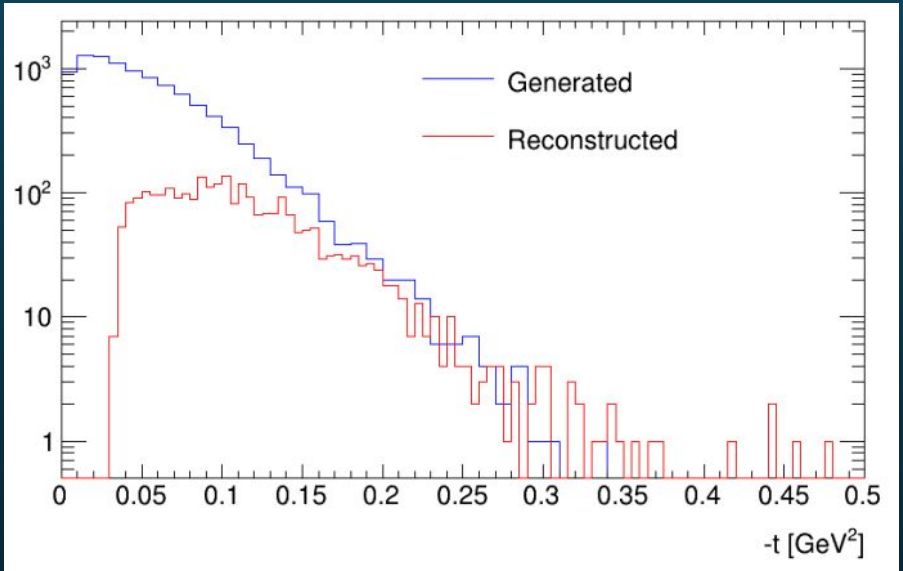


Beam has a px component due to crossing angle.

t is invariant, so scattered particle 4vector need not be

Only reconstructed He4 4vector corrected for crossing angle.

Generator Beam Values




```
Ebeam: 0, 0, -5
Hbeam: 0, 0, 163.958
```

Reverse:

By resetting beams px py to 0, we effectively correct the crossing angle. Hence, the scattered particle now needs to be corrected, but the reconstructed particle does not.

These should be equivalent techniques, and yet the distributions are different!