Update on **t** reconstruction studies for DEMP events with SiPM-on-tile ZDC

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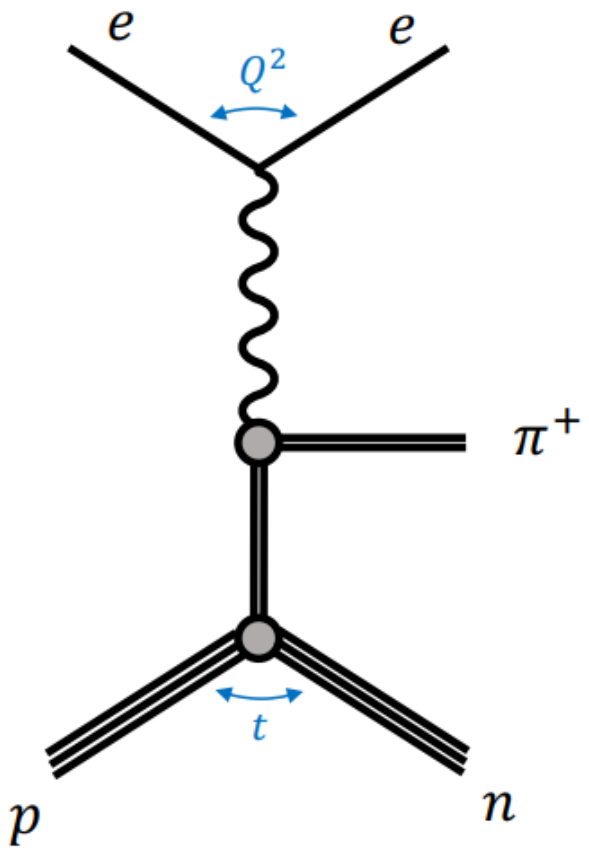
Motivation

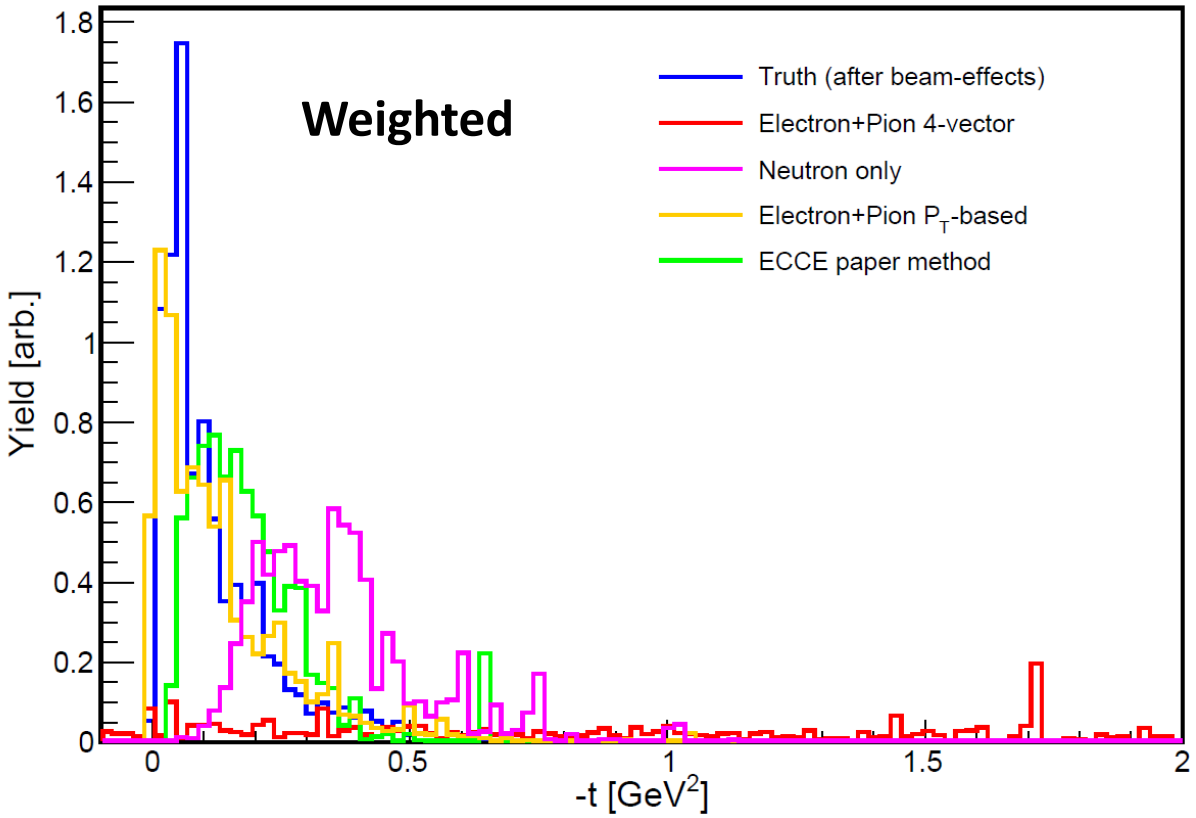
$e^- + p^+ \rightarrow e^- + pi^+ + n$



- On Nov. 21st, we showed studies (here) of **t** reconstruction for Deep Exclusive Meson Production (DEMP) events.
- We were asked to investigate two things in more detail:
  1. Different **t** reconstruction methods that had been used in prior studies
  2. Influence of the beam effects afterburner on the truth **t** calculation

t reconstruction

5x100 GeV – 10k events simulated



Electron+Pion 4-vector:

$$t = (p_e - p_{e\prime} - p_\pi)^2$$

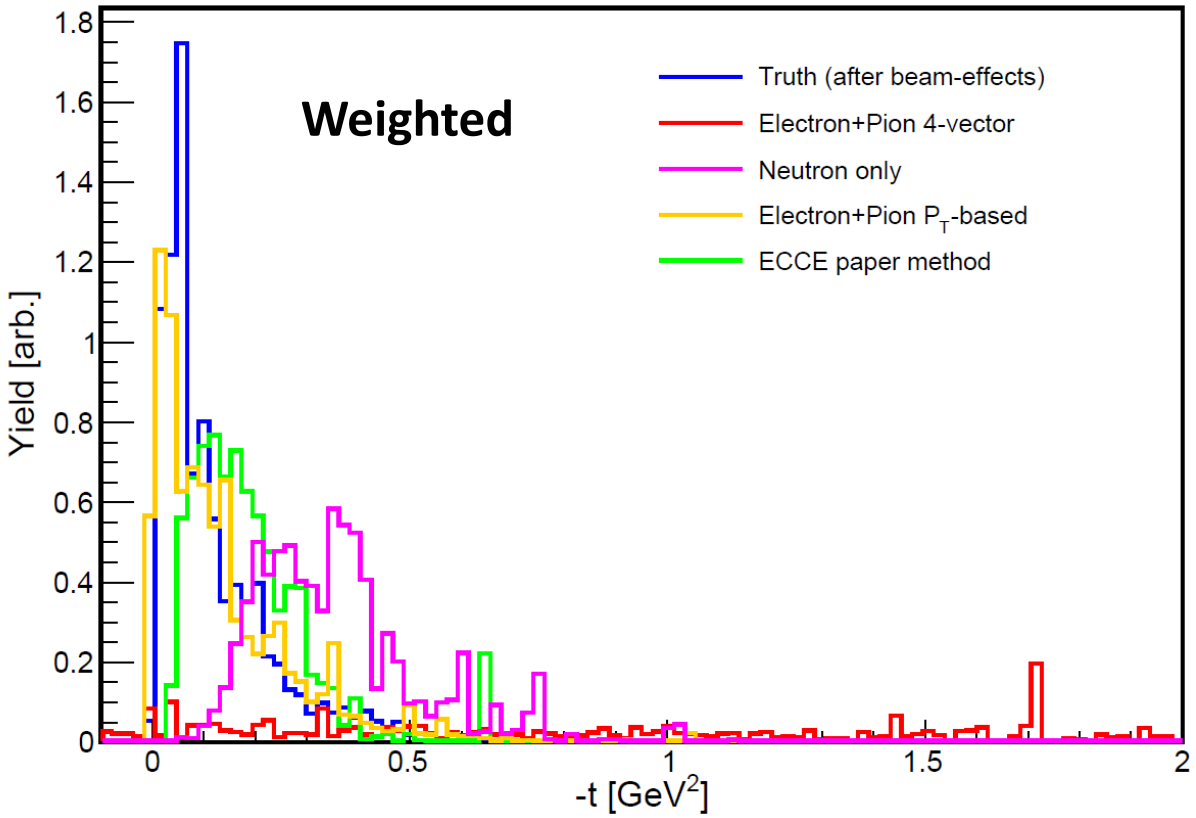
$$p_e = (0,0,-5,5)\ \text{GeV/c}$$

Method 2 in Probing short-range correlations in the deuteron via incoherent diffractive J/ψ production with spectator tagging at the EIC

Method E in On the Calculation of t in Diffractive VM production and DVCS

t reconstruction

5x100 GeV – 10k events simulated



Neutron only:

$$t = (\, p_p - p_n \,)^2$$

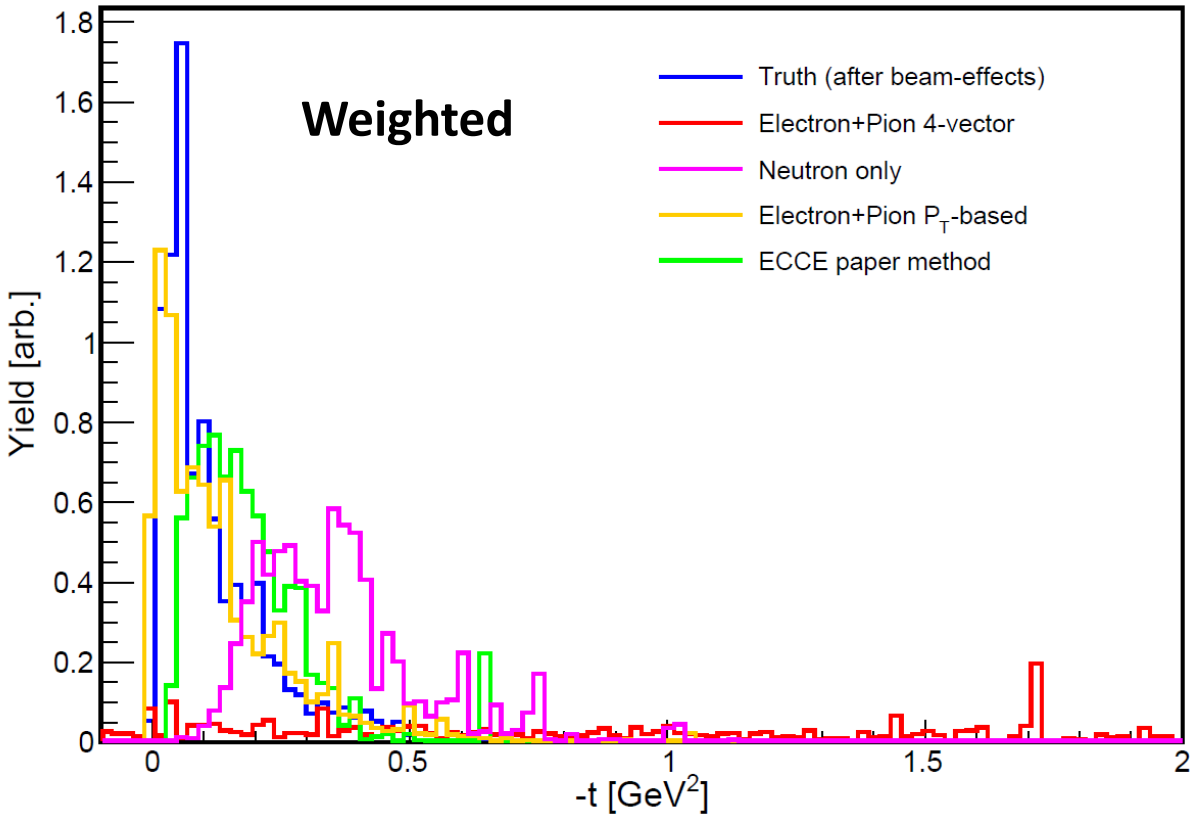
$$p_p = 100 \times (\sin(\theta), 0, \cos(\theta), 1) \text{ GeV/c}$$

Method 1 in Probing short-range correlations in the deuteron via incoherent diffractive J/ψ production with spectator tagging at the EIC

Method shown on slide 3 in On the Calculation of t in Diffractive VM production and DVCS

t reconstruction

5x100 GeV – 10k events simulated



Electron+Pion P_T-based:

$$t = -(\overrightarrow{p_{T,e'}} + \overrightarrow{p_{T,\pi}})^2$$

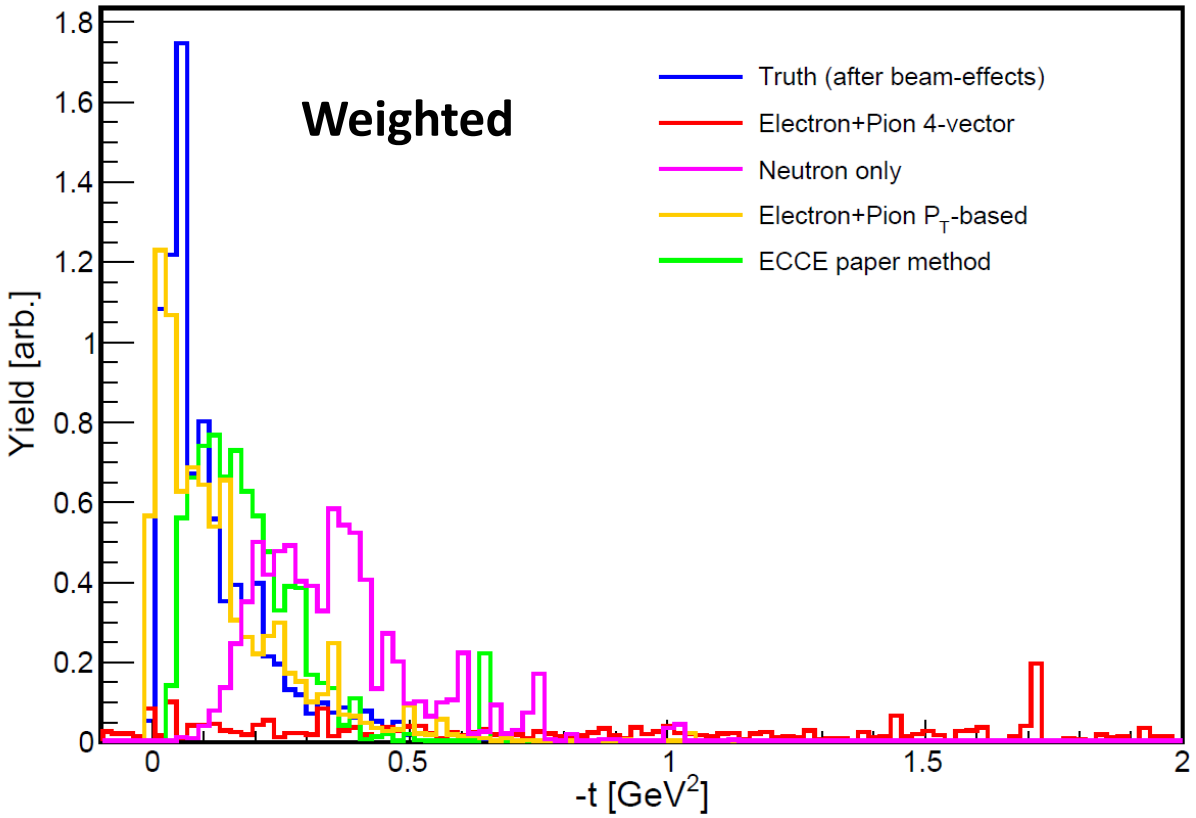
We use transverse momenta defined in lab frame with respect to proton beam direction. Is this correct?

Method 3 in Probing short-range correlations in the deuteron via incoherent diffractive J/ψ production with spectator tagging at the EIC

Method A in On the Calculation of t in Diffractive VM production and DVCS

t reconstruction

5x100 GeV – 10k events simulated



ECCE paper (here) method:

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

$$p_e = (0,0,-5,5)\ \text{GeV/c}$$

$$p_p = 100\ \times (\sin(\theta), 0, \cos(\theta), 1)\ \text{GeV/c}$$

Replace the angles in p_{miss} by the reconstructed neutron angles and set the mass of the 4-momentum to the neutron mass → p_{neut}^{opt}

$$t = (\, p_p - p_{neut}^{opt})^2$$

Some conceptual similarity to method L in On the Calculation of t in Diffractive VM production and DVCS

Comment on neutron reconstruction

- Previously, we performed the neutron reconstruction by running the HEXPLIT algorithm in our analysis code on the **ZDCRecHits** collection.
- Now we can use the **ZDC_HEXPLITClusters** collection directly.

```
ZDC_HEXPLITClusters = (vector<edm4eic::ClusterData>*)0x1424e1a0
ZDC_HEXPLITClusters.type = 0
ZDC_HEXPLITClusters.energy = 81.182350
ZDC_HEXPLITClusters.energyError = 0.000000
ZDC_HEXPLITClusters.time = 120.842834
ZDC_HEXPLITClusters.timeError = 0.000000
ZDC_HEXPLITClusters.nhits = 0
ZDC_HEXPLITClusters.position.x = -791.101501
ZDC_HEXPLITClusters.position.y = -42.365356
ZDC_HEXPLITClusters.position.z = 36226.386719
ZDC_HEXPLITClusters.positionError.xx = 0.000000
ZDC_HEXPLITClusters.positionError.yy = 0.000000
ZDC_HEXPLITClusters.positionError.zz = 0.000000
ZDC_HEXPLITClusters.positionError.xy = 0.000000
ZDC_HEXPLITClusters.positionError.xz = 0.000000
ZDC_HEXPLITClusters.positionError.yz = 0.000000
ZDC_HEXPLITClusters.intrinsicTheta = 0.000000
ZDC_HEXPLITClusters.intrinsicPhi = 0.000000
ZDC_HEXPLITClusters.intrinsicDirectionError.xx = 0.000000
ZDC_HEXPLITClusters.intrinsicDirectionError.yy = 0.000000
ZDC_HEXPLITClusters.intrinsicDirectionError.xy = 0.000000
```

HepMC files on S3

S3/eictest/EPIC/EVGEN/EXCLUSIVE/DEMP/5on100/eic_DEMPGen_5on100_ip6_pi+_1B_1.hepmc

```
A ab_afterburner_is_used 1
A ab_crossing_angle 0.025
A ab_hadron_beta_crab_hor 500000
A ab_hadron_beta_star_hor 610
A ab_hadron_beta_star_ver 55
A ab_hadron_divergence_hor 0.000206
A ab_hadron_divergence_ver 0.000206
A ab_hadron_rms_bunch_length 70
A ab_hadron_rms_emittance_hor 2.6e-05
A ab_hadron_rms_emittance_ver 2.3e-06
A ab_lepton_beta_crab_hor 150000
A ab_lepton_beta_star_hor 780
A ab_lepton_beta_star_ver 71
A ab_lepton_divergence_hor 0.00016
A ab_lepton_divergence_ver 0.00016
A ab_lepton_rms_bunch_length 7
A ab_lepton_rms_emittance_hor 2e-05
A ab_lepton_rms_emittance_ver 1.8e-06
A ab_use_beam_bunch_sim 1
E 0 1 5 @ -5.5270989698305503e-02 -3.4184489514529101e-03 9.2400434587506002e+00 -1.2210289059169902e+01
U GEV MM
A 0 weight 0.000495402
P 1 0 11 9.3822153510404738e-04 -1.3923773484238392e-03 -4.9995943299398453e+00 4.9995946118601431e+00 5.1099999999999995e-04 4
P 2 0 2212 -2.5286097026826884e+00 2.3338502715787763e-02 9.9991886598796910e+01 1.0002785518694716e+02 9.3827000000000005e-01 4
V -1 0 [1,2] @ -5.5270989698305503e-02 -3.4184489514529101e-03 9.2400434587506002e+00 -1.2210289059169902e+01
P 3 -1 11 -2.3352746752187579e+00 5.4161533649472282e-01 -4.5546191010509229e+00 5.1469778437014160e+00 5.1099999999999995e-04 1
P 4 -1 211 1.8670699700915940e+00 -4.1359670537440302e-01 5.8428628263162263e+00 6.1494253309933304e+00 1.3957000000000000e-01 1
P 5 -1 2112 -2.0594704286934160e+00 -1.0607250754029605e-01 9.3704078566628965e+01 9.3731466636879958e+01 9.3957000000000002e-01 1
```

HepMC files on S3

S3/eictest/EPIC/EVGEN/EXCLUSIVE/DEMP/5on100/eic_DEMPGen_5on100_ip6_pi+_1B_1.hepmc

```
A ab_afterburner_is_used 1
A ab_crossing_angle 0.025
A ab_hadron_beta_crab_hor 500000
A ab_hadron_beta_star_hor 610
A ab_hadron_beta_star_ver 55
A ab_hadron_divergence_hor 0.000206
A ab_hadron_divergence_ver 0.000206
A ab_hadron_rms_bunch_length 70
A ab_hadron_rms_emittance_hor 2.6e-05
A ab_hadron_rms_emittance_ver 2.3e-06
A ab_lepton_beta_crab_hor 150000
A ab_lepton_beta_star_hor 780
A ab_lepton_beta_star_ver 71
A ab_lepton_divergence_hor 0.00016
A ab_lepton_divergence_ver 0.00016
A ab_lepton_rms_bunch_length 7
A ab_lepton_rms_emittance_hor 2e-05
A ab_lepton_rms_emittance_ver 1.8e-06
A ab_use_beam_bunch_sim 1
E 0 1 5 @ -5.5270989698305503e-02 -3.4184489514529101e-03 9.2400434587506002e+00 -1.2210289059169902e+01
U GEV MM
A 0 weight 0.000495402
P 1 0 11 9.3822153510404738e-04 -1.3923773484238392e-03 -4.9995943299398453e+00 4.9995946118601431e+00 5.1099999999999995e-04 4
P 2 0 2212 -2.5286097026826884e+00 2.3338502715787763e-02 9.9991886598796910e+01 1.0002785518694716e+02 9.3827000000000005e-01 4
V -1 0 [1,2] @ -5.5270989698305503e-02 -3.4184489514529101e-03 9.2400434587506002e+00 -1.2210289059169902e+01
P 3 -1 11 -2.3352746752187579e+00 5.4161533649472282e-01 -4.5546191010509229e+00 5.1469778437014160e+00 5.1099999999999995e-04 1
P 4 -1 211 1.8670699700915940e+00 -4.1359670537440302e-01 5.8428628263162263e+00 6.1494253309933304e+00 1.3957000000000000e-01 1
P 5 -1 2112 -2.0594704286934160e+00 -1.0607250754029605e-01 9.3704078566628965e+01 9.3731466636879958e+01 9.3957000000000002e-01 1
```

Incoming electron and proton beam with crossing angle plus energy and angle smearing applied.

HepMC files on S3

S3/eictest/EPIC/EVGEN/EXCLUSIVE/DEMP/5on100/eic_DEMPGen_5on100_ip6_pi+_1B_1.hepmc

```
A ab_afterburner_is_used 1
A ab_crossing_angle 0.025
A ab_hadron_beta_crab_hor 500000
A ab_hadron_beta_star_hor 610
A ab_hadron_beta_star_ver 55
A ab_hadron_divergence_hor 0.000206
A ab_hadron_divergence_ver 0.000206
A ab_hadron_rms_bunch_length 70
A ab_hadron_rms_emittance_hor 2.6e-05
A ab_hadron_rms_emittance_ver 2.3e-06
A ab_lepton_beta_crab_hor 150000
A ab_lepton_beta_star_hor 780
A ab_lepton_beta_star_ver 71
A ab_lepton_divergence_hor 0.00016
A ab_lepton_divergence_ver 0.00016
A ab_lepton_rms_bunch_length 7
A ab_lepton_rms_emittance_hor 2e-05
A ab_lepton_rms_emittance_ver 1.8e-06
A ab_use_beam_bunch_sim 1
E 0 1 5 @ -5.5270989698305503e-02 -3.4184489514529101e-03 9.2400434587506002e+00 -1.2210289059169902e+01
U GEV MM
A 0 weight 0.000495402
P 1 0 11 9.3822153510404738e-04 -1.3923773484238392e-03 -4.9995943299398453e+00 4.9995946118601431e+00 5.1099999999999995e-04 4
P 2 0 2212 -2.5286097026826884e+00 2.3338502715787763e-02 9.9991886598796910e+01 1.0002785518694716e+02 9.3827000000000005e-01 4
V -1 0 [1,2] @ -5.5270989698305503e-02 -3.4184489514529101e-03 9.2400434587506002e+00 -1.2210289059169902e+01
P 3 -1 11 -2.3352746752187579e+00 5.4161533649472282e-01 -4.5546191010509229e+00 5.1469778437014160e+00 5.1099999999999995e-04 1
P 4 -1 211 1.8670699700915940e+00 -4.1359670537440302e-01 5.8428628263162263e+00 6.1494253309933304e+00 1.3957000000000000e-01 1
P 5 -1 2112 -2.0594704286934160e+00 -1.0607250754029605e-01 9.3704078566628965e+01 9.3731466636879958e+01 9.3957000000000002e-01 1
```

Scattered electron, positive pion, and neutron

HepMC files on S3

S3/eictest/EPIC/EVGEN/EXCLUSIVE/DEMP/5on100/eic_DEMPGen_5on100_ip6_pi+_1B_1.hepmc

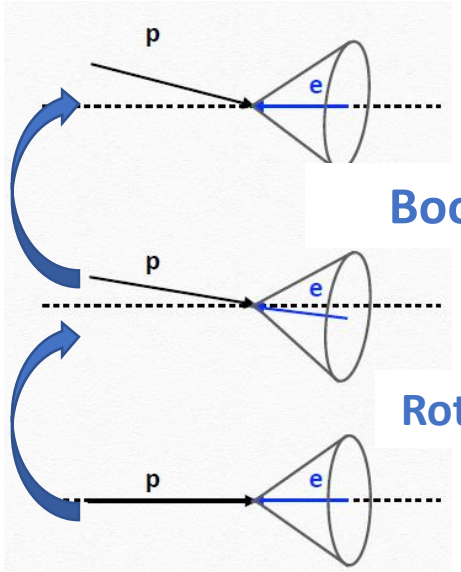
```
A ab_afterburner_is_used 1
A ab_crossing_angle 0.025
A ab_hadron_beta_crab_hor 500000
A ab_hadron_beta_star_hor 610
A ab_hadron_beta_star_ver 55
A ab_hadron_divergence_hor 0.000206
A ab_hadron_divergence_ver 0.000206
A ab_hadron_rms_bunch_length 70
A ab_hadron_rms_emittance_hor 2.6e-05
A ab_hadron_rms_emittance_ver 2.3e-06
A ab_lepton_beta_crab_hor 150000
A ab_lepton_beta_star_hor 780
A ab_lepton_beta_star_ver 71
A ab_lepton_divergence_hor 0.00016
A ab_lepton_divergence_ver 0.00016
A ab_lepton_rms_bunch_length 7
A ab_lepton_rms_emittance_hor 2e-05
A ab_lepton_rms_emittance_ver 1.8e-06
A ab_use_beam_bunch_sim 1
E 0 1 5 @ -5.5270989698305503e-02 -3.4184489514529101e-03 9.2400434587506002e+00 -1.2210289059169902e+01
U GEV MM
A 0 weight 0.000495402
P 1 0 11 9.3822153510404738e-04 -1.3923773484238392e-03 -4.9995943299398453e+00 4.9995946118601431e+00 5.1099999999999995e-04 4
P 2 0 2212 -2.5286097026826884e+00 2.3338502715787763e-02 9.9991886598796910e+01 1.0002785518694716e+02 9.3827000000000005e-01 4
V -1 0 [1,2] @ -5.5270989698305503e-02 -3.4184489514529101e-03 9.2400434587506002e+00 -1.2210289059169902e+01
P 3 -1 11 -2.3352746752187579e+00 5.4161533649472282e-01 -4.5546191010509229e+00 5.1469778437014160e+00 5.1099999999999995e-04 1
P 4 -1 211 1.8670699700915940e+00 -4.1359670537440302e-01 5.8428628263162263e+00 6.1494253099333304e+00 1.3957000000000000e-01 1
P 5 -1 2112 -2.0594704286934160e+00 -1.0607250754029605e-01 9.3704078566628965e+01 9.3731466636879958e+01 9.3957000000000002e-01 1
```

Truth t distribution is above plots calculated using lines below:

$$t_{true} = (p_p - p_n)^2$$

Weight is applied for each event

HepMC files before afterburner



S3/eictest/EPIC/EVGEN/EXCLUSIVE/DEMP/eic_DEMPGen_5on100_1B_1_100.hepmc

```
E 0 1 6
U GEV MM
P 1 0 11 6.1232300000000001e-16 0.0000000000000000e+00 -5.0000000000000000e+00 5.0000000000000000e+00 0.0000000000000000e+00 21
P 2 0 2212 0.0000000000000000e+00 0.0000000000000000e+00 1.0000000000000000e+02 1.0000399780273438e+02 8.9419043234744078e-01 21
P 3 0 22 -1.5014300000000000e+00 -2.9472200000000002e+00 -7.5489600000000001e-01 -3.8157001137733459e-01 -3.3711526323400878e+00 21
P 4 0 11 1.5014300000000000e+00 2.9472200000000002e+00 -4.2450999999999999e+00 5.3815698623657227e+00 4.7328873876336490e-03 1
P 5 0 2112 -7.6801800000000003e-02 -2.4961500000000000e-01 8.6905199999999994e+01 8.6910697937011719e+01 9.4203115329907905e-01 1
P 6 0 211 -1.4246200000000000e+00 -2.6976100000000001e+00 1.2339900000000000e+01 1.2712100028991699e+01 1.3309124911411238e-01 1
E 0 1 6
U GEV MM
P 1 0 11 6.1232300000000001e-16 0.0000000000000000e+00 -5.0000000000000000e+00 5.0000000000000000e+00 0.0000000000000000e+00 21
P 2 0 2212 0.0000000000000000e+00 0.0000000000000000e+00 1.0000000000000000e+02 1.0000399780273438e+02 8.9419043234744078e-01 21
P 3 0 22 2.3812799999999998e+00 1.3961900000000000e+00 -6.6133200000000003e-01 -1.4236100018024445e-01 -2.8349487322263309e+00 21
P 4 0 11 -2.3812799999999998e+00 -1.3961900000000000e+00 -4.3386699999999996e+00 5.1423602104187012e+00 -5.4579943685371573e-03 1
P 5 0 2112 6.4095700000000000e-01 -1.2139400000000000e-01 9.4416200000000003e+01 9.4423103332519531e+01 9.3704755726459565e-01 1
P 6 0 211 1.7403200000000001e+00 1.5175799999999999e+00 4.9225099999999999e+00 5.4389700889587402e+00 1.3974322769940900e-01 1
```

HepMC files before afterburner

Two issues:

1. Events don't seem to match the events in the post-afterburner file. For example, the scattered electron momentum in event 1 is very different in the two files.
2. Trying to run the beam effects afterburner on this file causes a crash on the first event (due to no defined vertices). Can contact exclusive/diffractive/tagging group about this.

S3/eictest/EPIC/EVGEN/EXCLUSIVE/DEMP/eic_DEMPGen_5on100_1B_1_100.hepmc

```
E 0 1 6
U GEV MM
P 1 0 11 6.1232300000000001e-16 0.0000000000000000e+00 -5.0000000000000000e+00 5.0000000000000000e+00 0.0000000000000000e+00 21
P 2 0 2212 0.0000000000000000e+00 0.0000000000000000e+00 1.0000000000000000e+02 1.0000399780273438e+02 8.9419043234744078e-01 21
P 3 0 22 -1.5014300000000000e+00 -2.9472200000000002e+00 -7.5489600000000001e-01 -3.8157001137733459e-01 -3.3711526323400878e+00 21
P 4 0 11 1.5014300000000000e+00 2.9472200000000002e+00 -4.2450999999999999e+00 5.3815698623657227e+00 4.7328873876336490e-03 1
P 5 0 2112 -7.6801800000000003e-02 -2.4961500000000000e-01 8.6905199999999994e+01 8.6910697937011719e+01 9.4203115329907905e-01 1
P 6 0 211 -1.4246200000000000e+00 -2.6976100000000001e+00 1.2339900000000000e+01 1.2712100028991699e+01 1.3309124911411238e-01 1
E 0 1 6
U GEV MM
P 1 0 11 6.1232300000000001e-16 0.0000000000000000e+00 -5.0000000000000000e+00 5.0000000000000000e+00 0.0000000000000000e+00 21
P 2 0 2212 0.0000000000000000e+00 0.0000000000000000e+00 1.0000000000000000e+02 1.0000399780273438e+02 8.9419043234744078e-01 21
P 3 0 22 2.3812799999999998e+00 1.3961900000000000e+00 -6.6133200000000003e-01 -1.4236100018024445e-01 -2.8349487322263309e+00 21
P 4 0 11 -2.3812799999999998e+00 -1.3961900000000000e+00 -4.3386699999999996e+00 5.1423602104187012e+00 -5.4579943685371573e-03 1
P 5 0 2112 6.4095700000000000e-01 -1.2139400000000000e-01 9.4416200000000003e+01 9.4423103332519531e+01 9.3704755726459565e-01 1
P 6 0 211 1.7403200000000001e+00 1.5175799999999999e+00 4.9225099999999999e+00 5.4389700889587402e+00 1.3974322769940900e-01 1
```

Summary

- Continued studies of **t** reconstruction for DEMP events. Studied additional methods guided by prior work.
- Began comparison of DEMP events before and after application of the beam-effects afterburner.