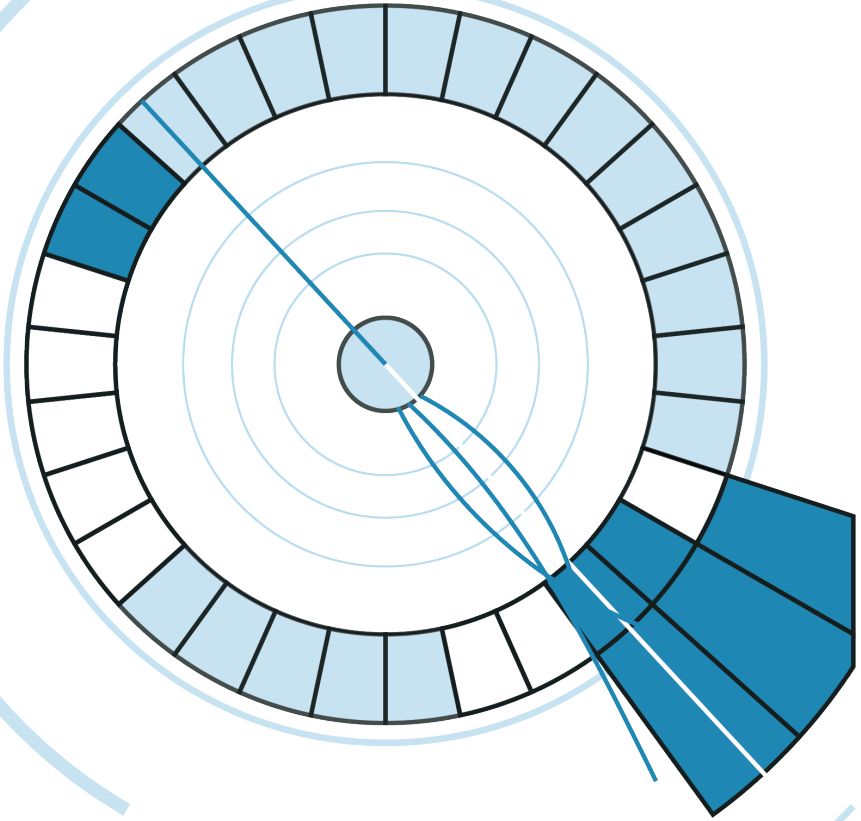
Jets for 3D imaging

Miguel Arratia

UNIVERSITY OF CALIFORNIA
UC RIVERSIDE

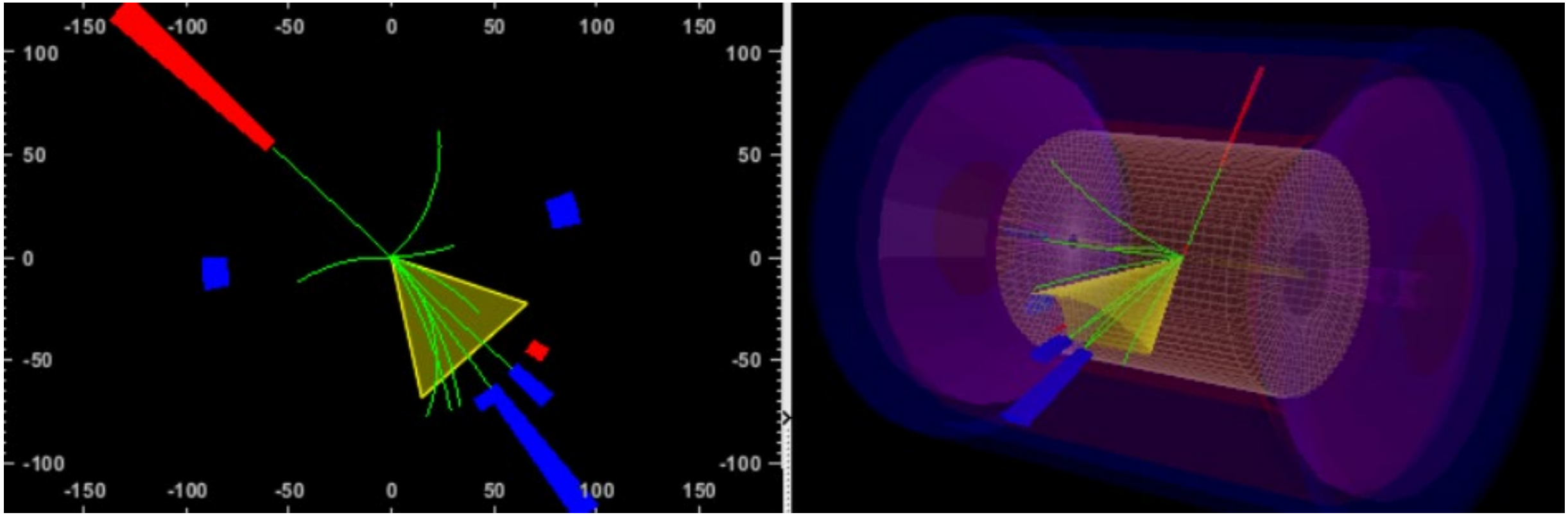
YR Jet/heavy quark group, 05/04/20



Outline

- Hadron-in-jet Collins angle resolution
- Neutrino-jet Sivers angle resolution
- CC DIS performance

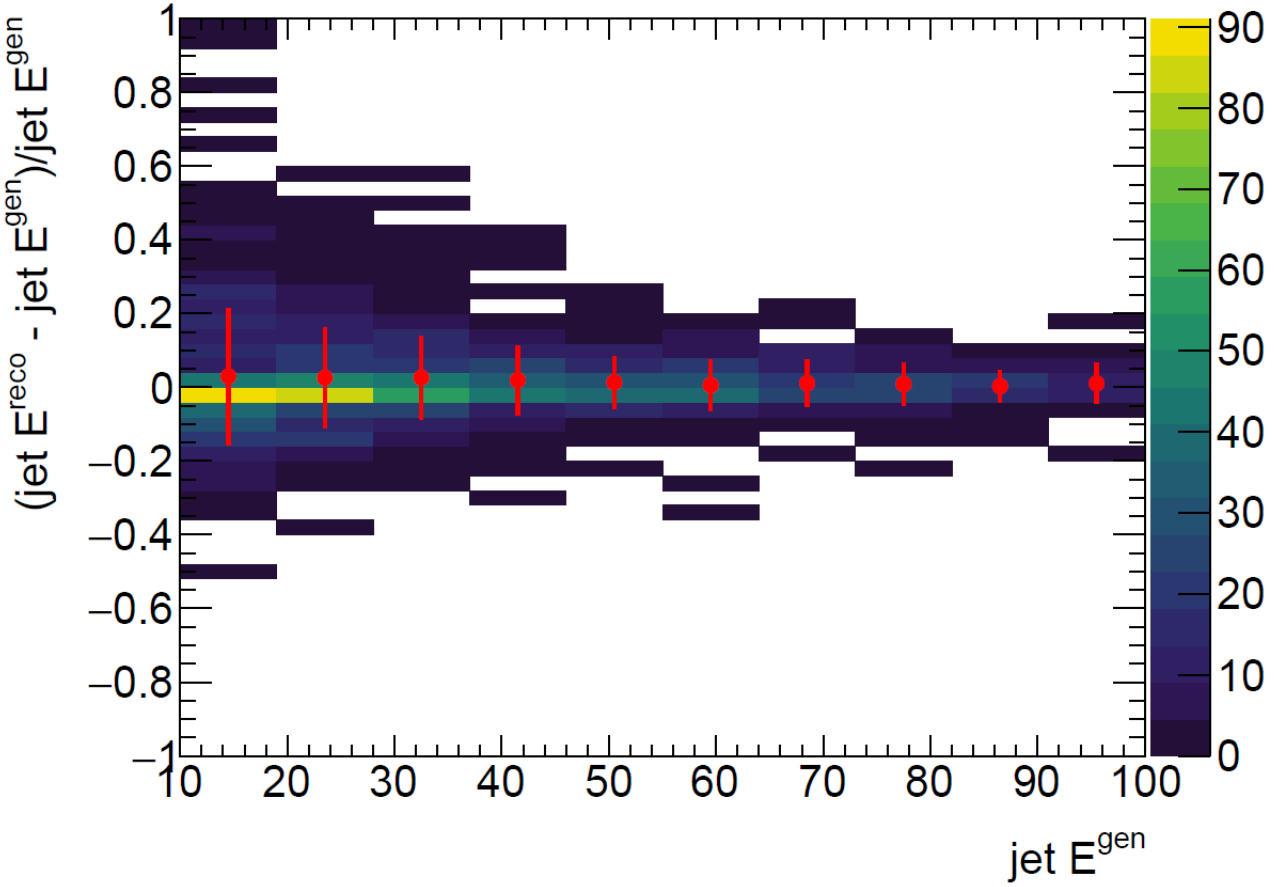
Electron-jet channel

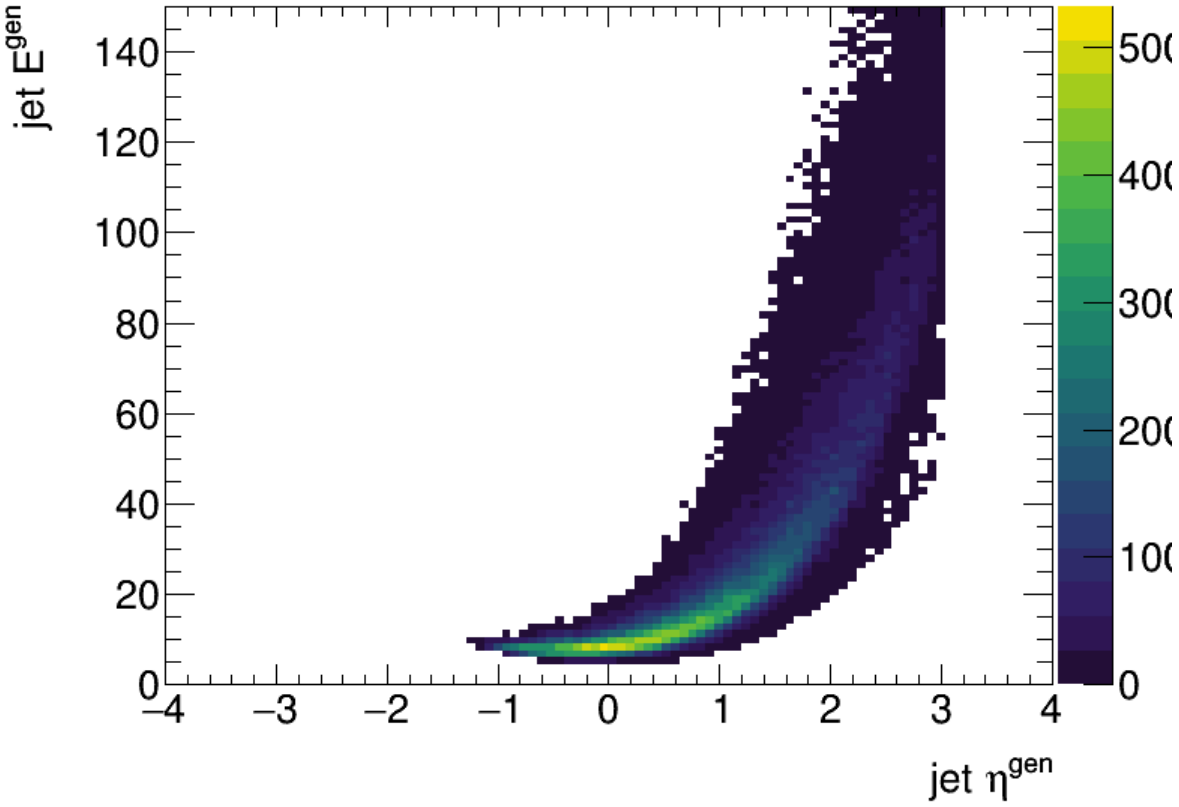


Delphes fast simulation of an EIC detector and Pythia8 neutral-current DIS event

Jet performance

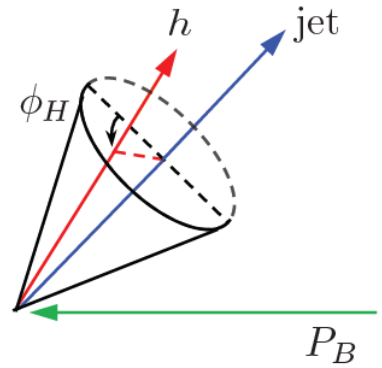
anti-kT R=1.0, particle-flow



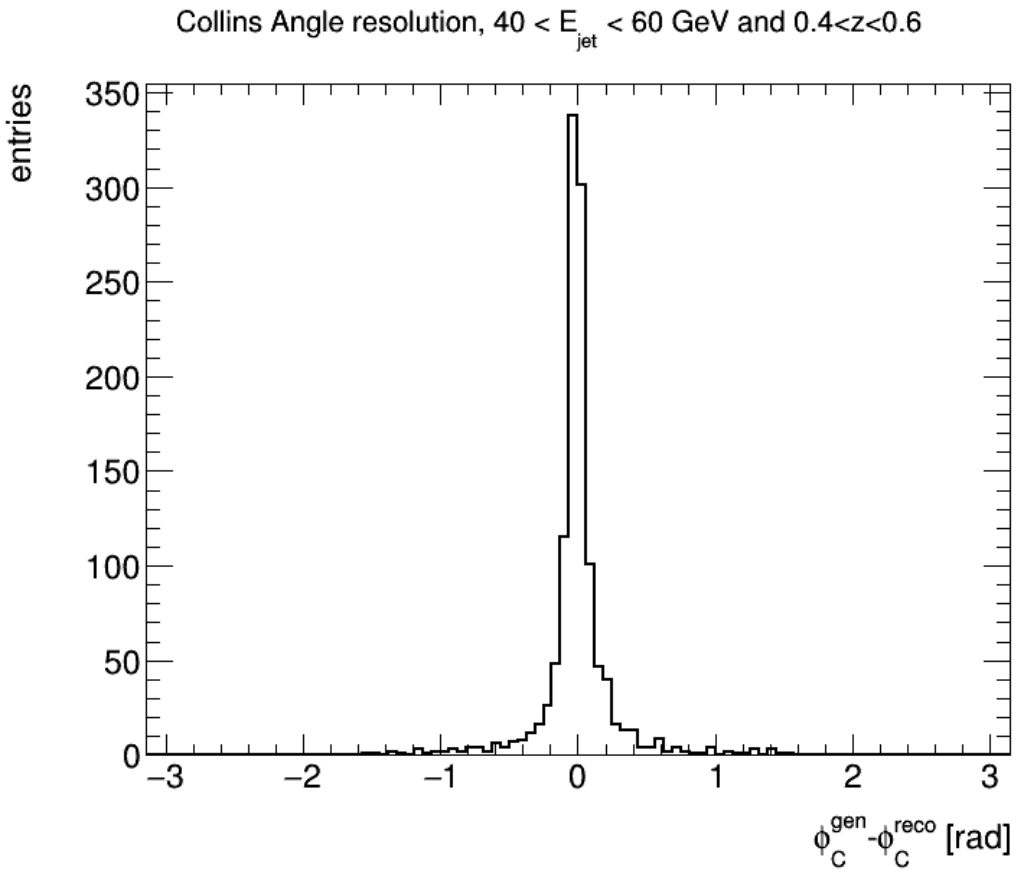


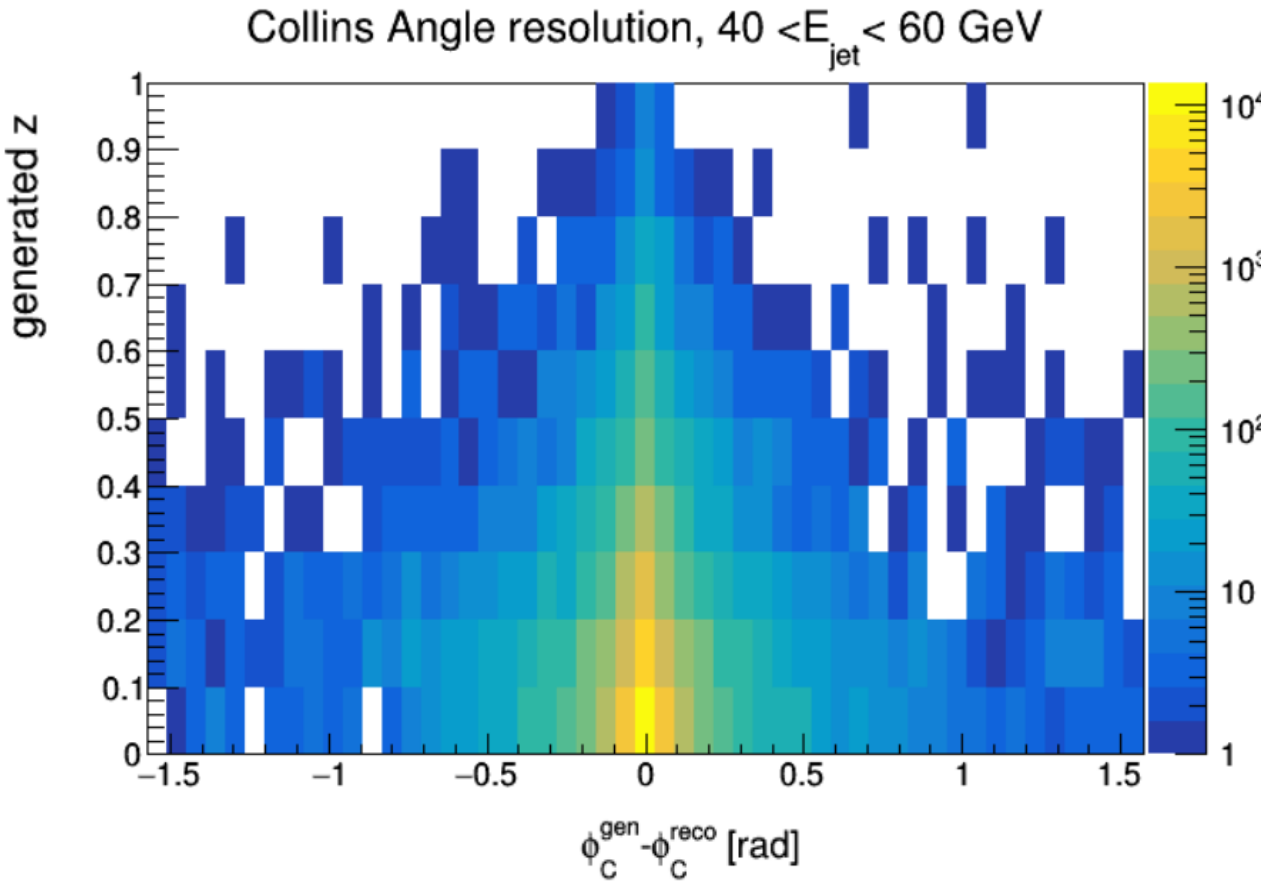
~20% at 10 GeV, ~10% at 50 GeV

Collins Angle resolution



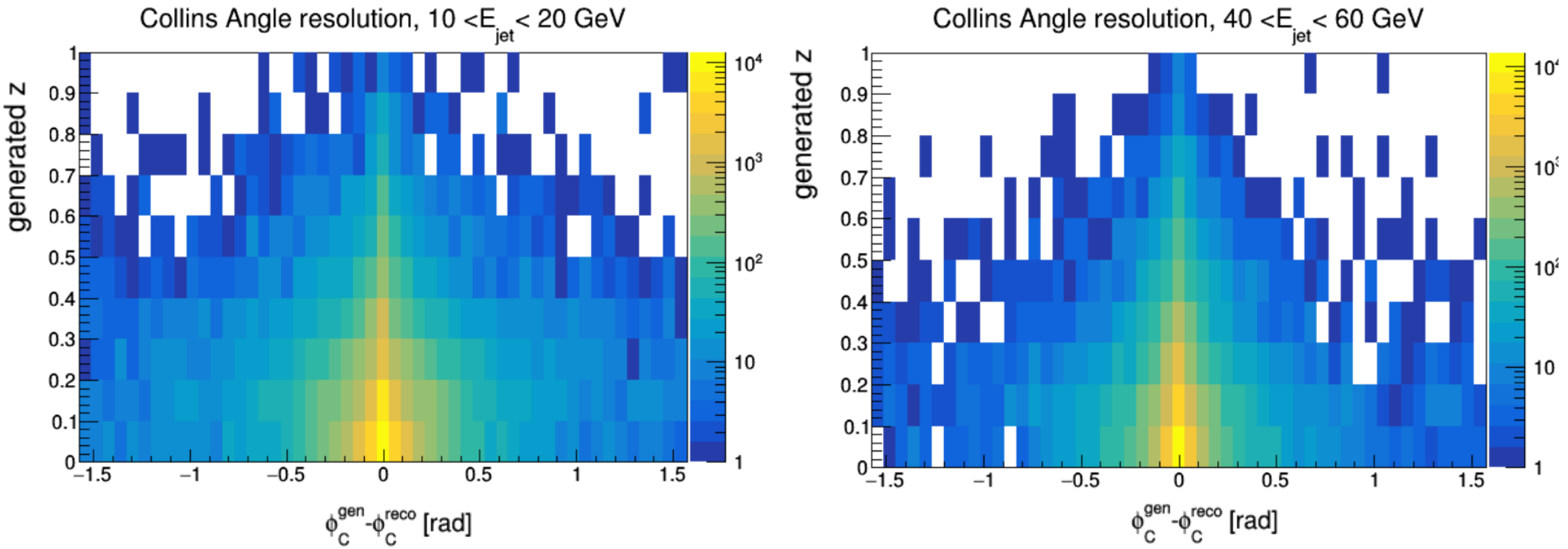
Charged-pion





- Calculation on how this propagates to “asymmetry dilution” ongoing

Jet-energy dependence of Collins Angle resolution



- There is an interplay between energy resolution for jet (improves with energy) and momentum resolution for hadron (degrades)

Collins angle resolution at STAR

J. Kevin Adkins, STAR Thesis 2019
https://arxiv.org/abs/1907.11233

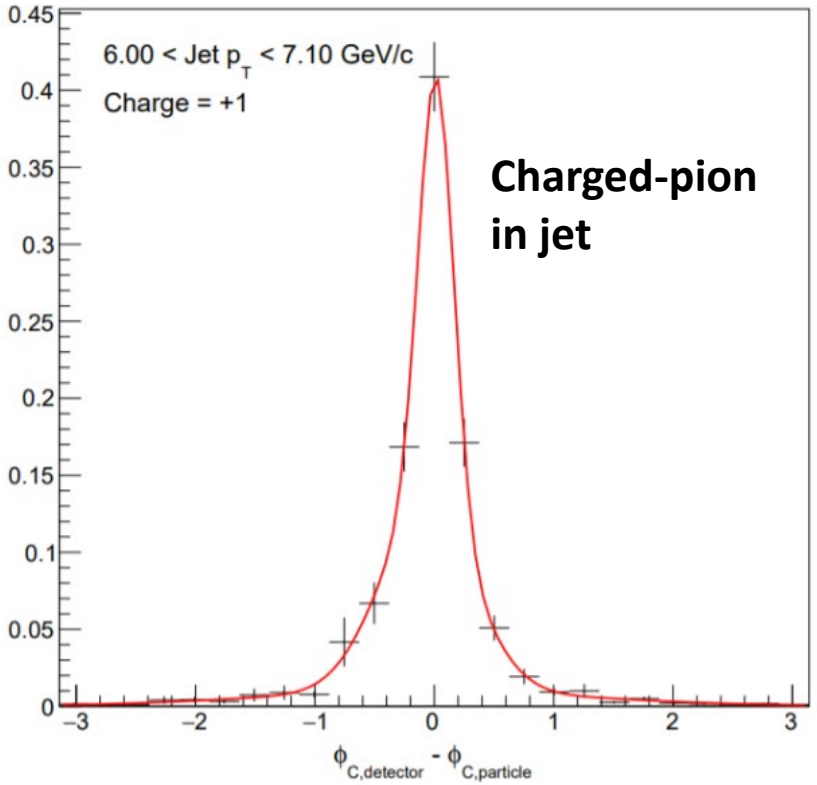
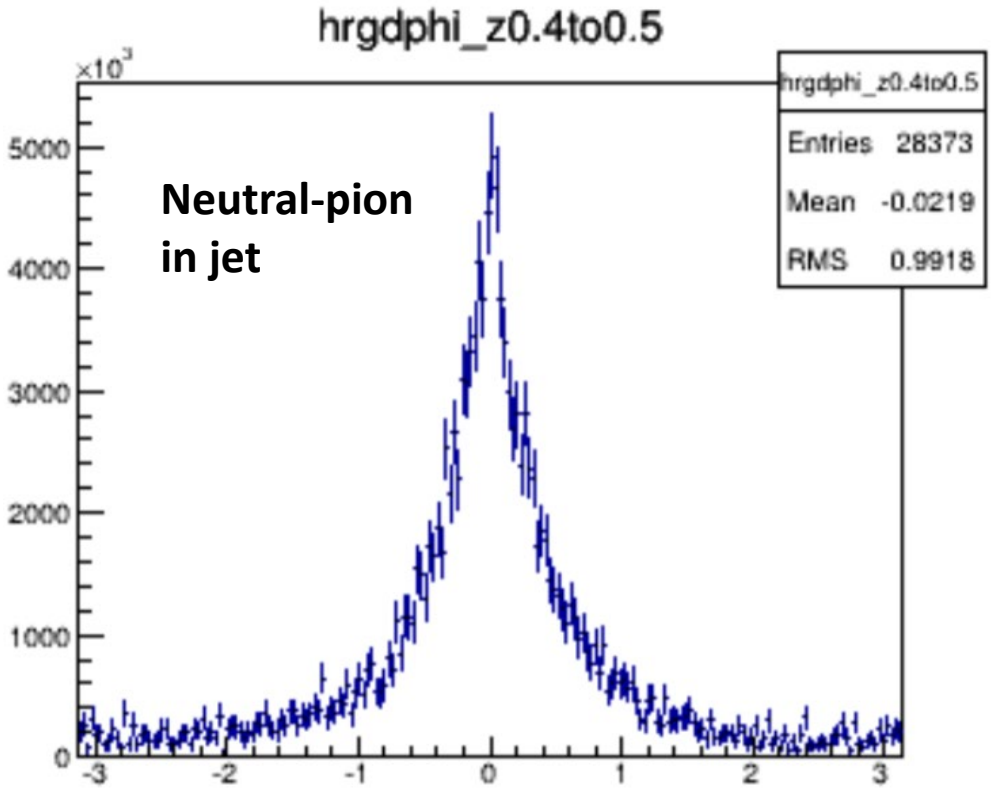
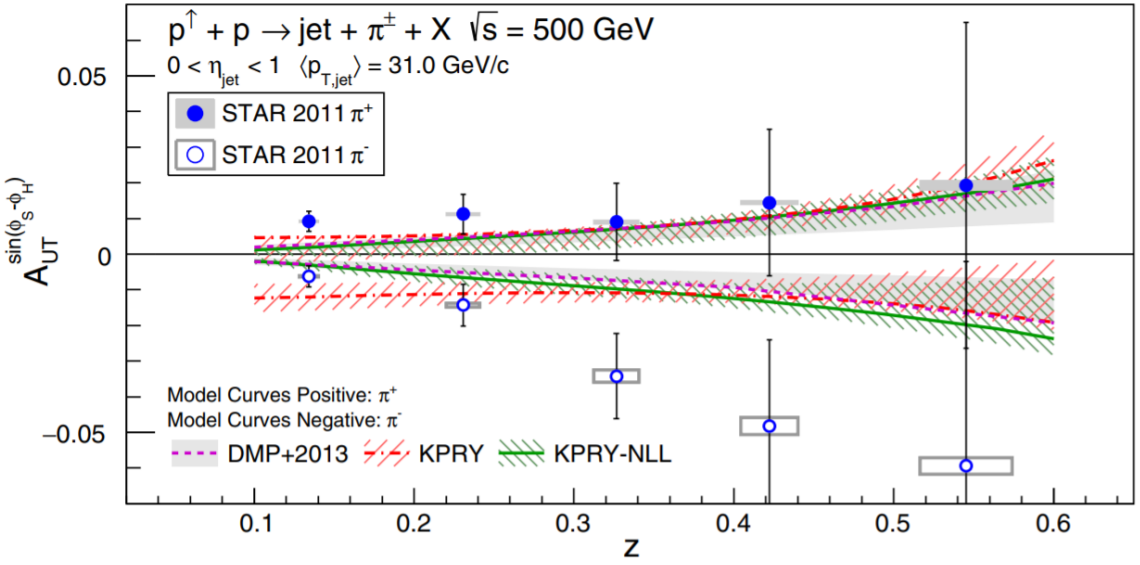


Figure 6.12: ϕ_C **Resolution Example Fit** - A triple Gaussian fit to the spread in detector minus particle level ϕ_C values.

Yuxi Pan, STAR Thesis, 2015

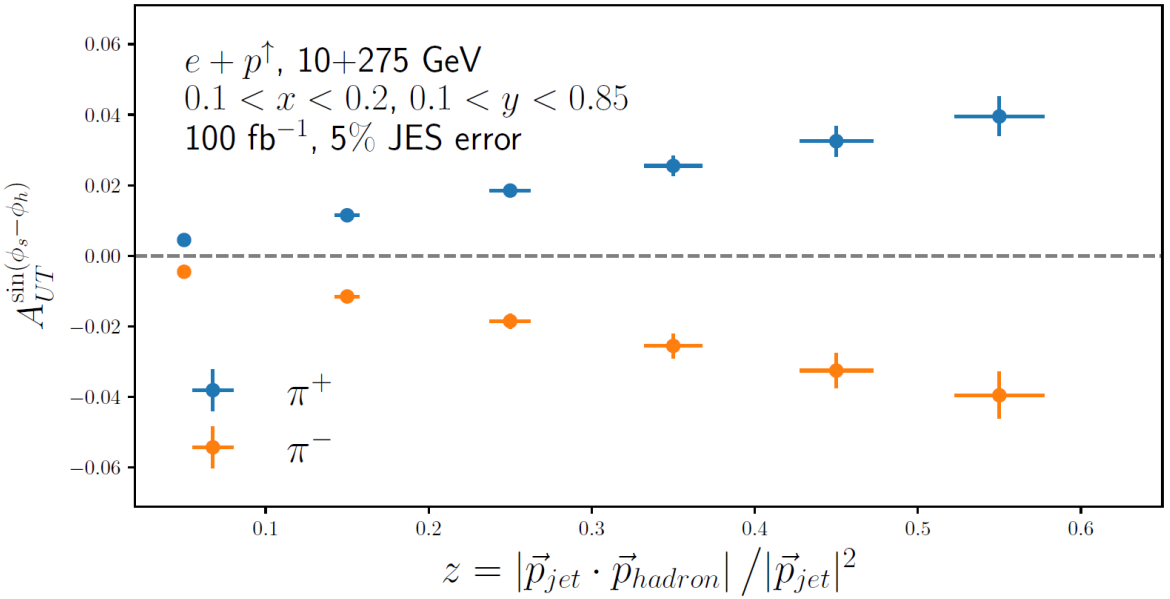


pp at RHIC



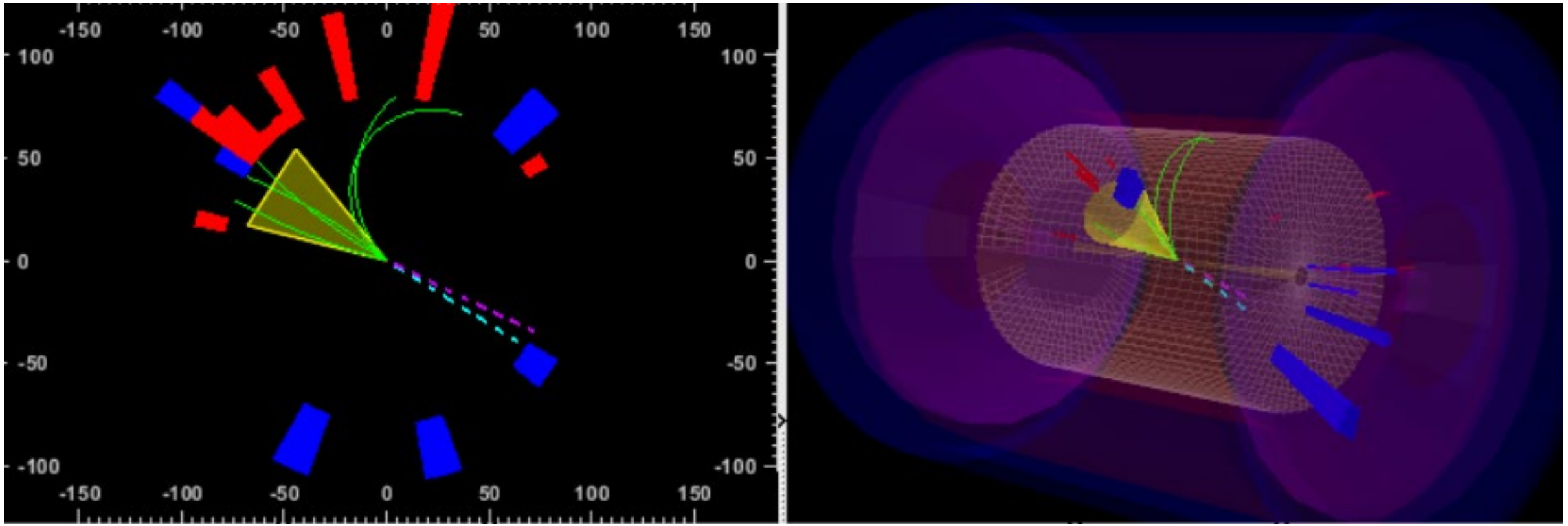
Phys. Lett. B 774, 635 (2017)

ep at EIC



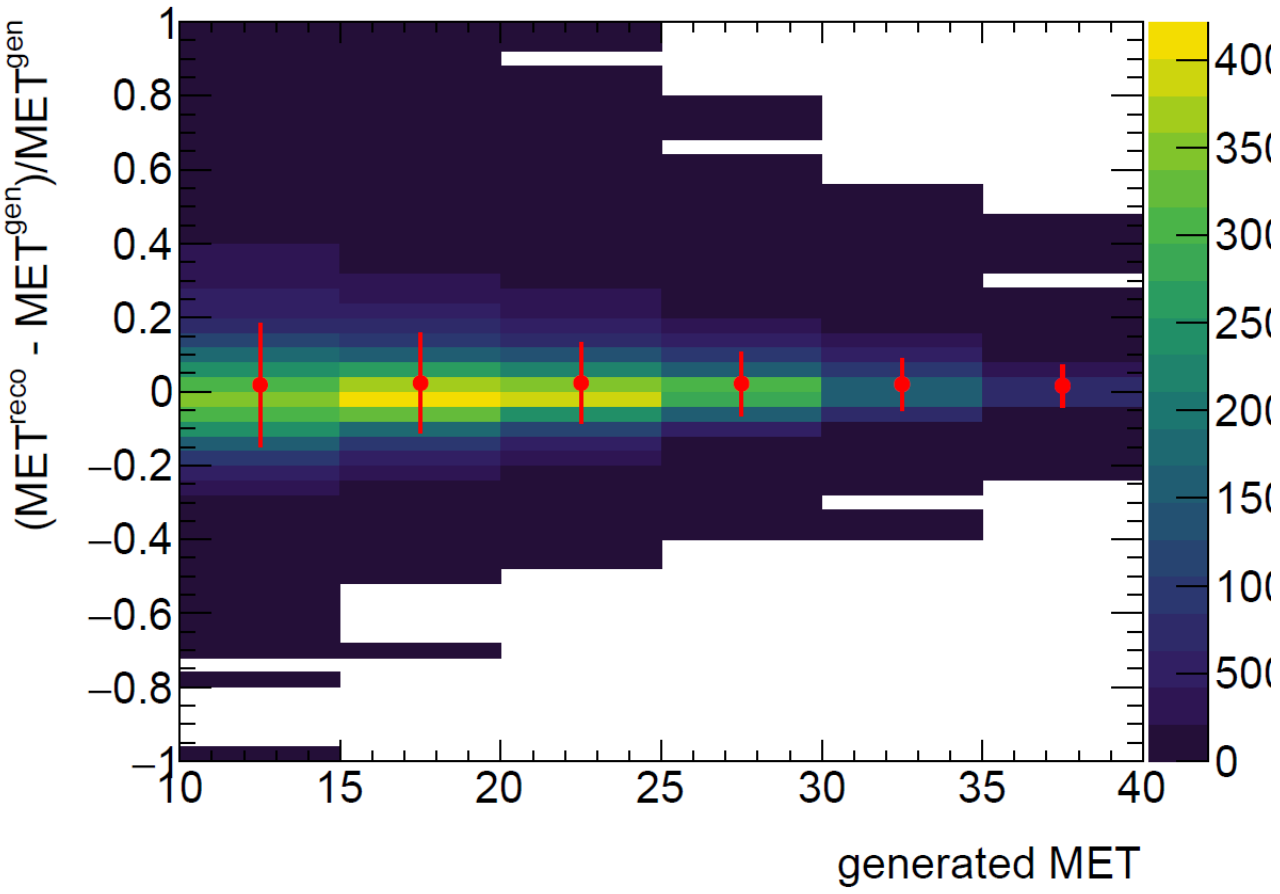
This would be a nice YR money plot…

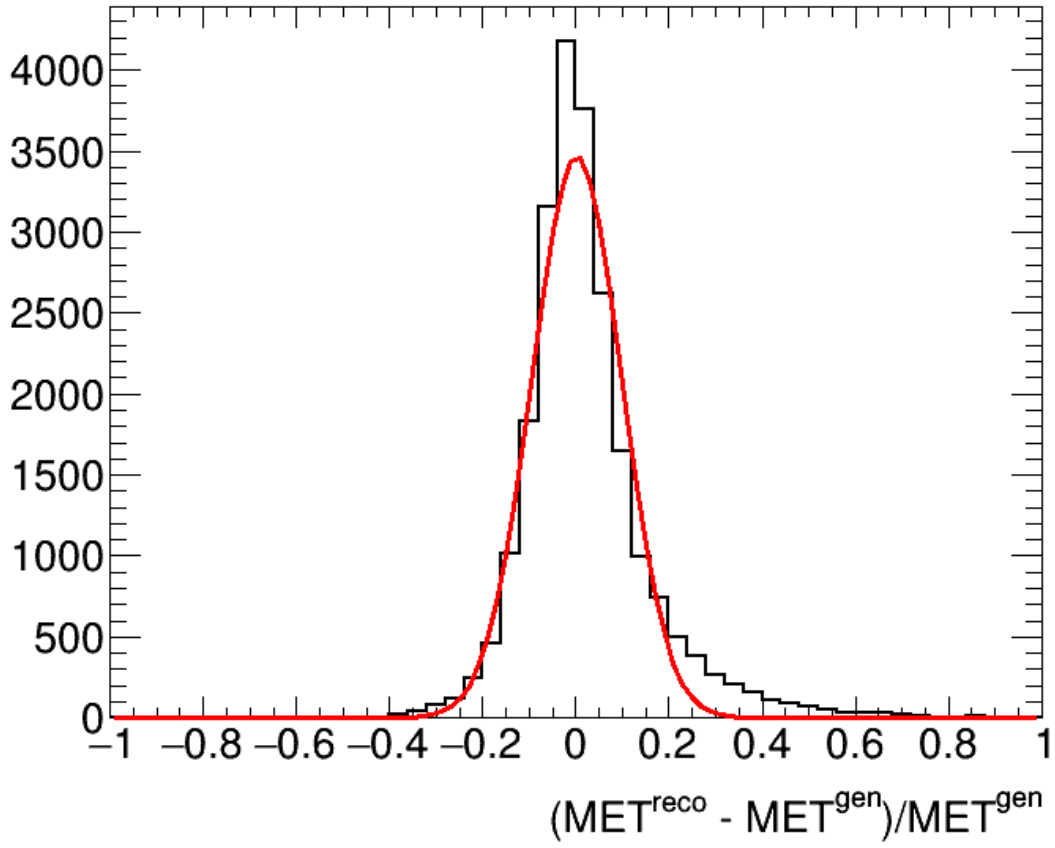
Charged-current DIS at the EIC



Delphes fast simulation of an EIC detector and Pythia8 charged-current DIS event

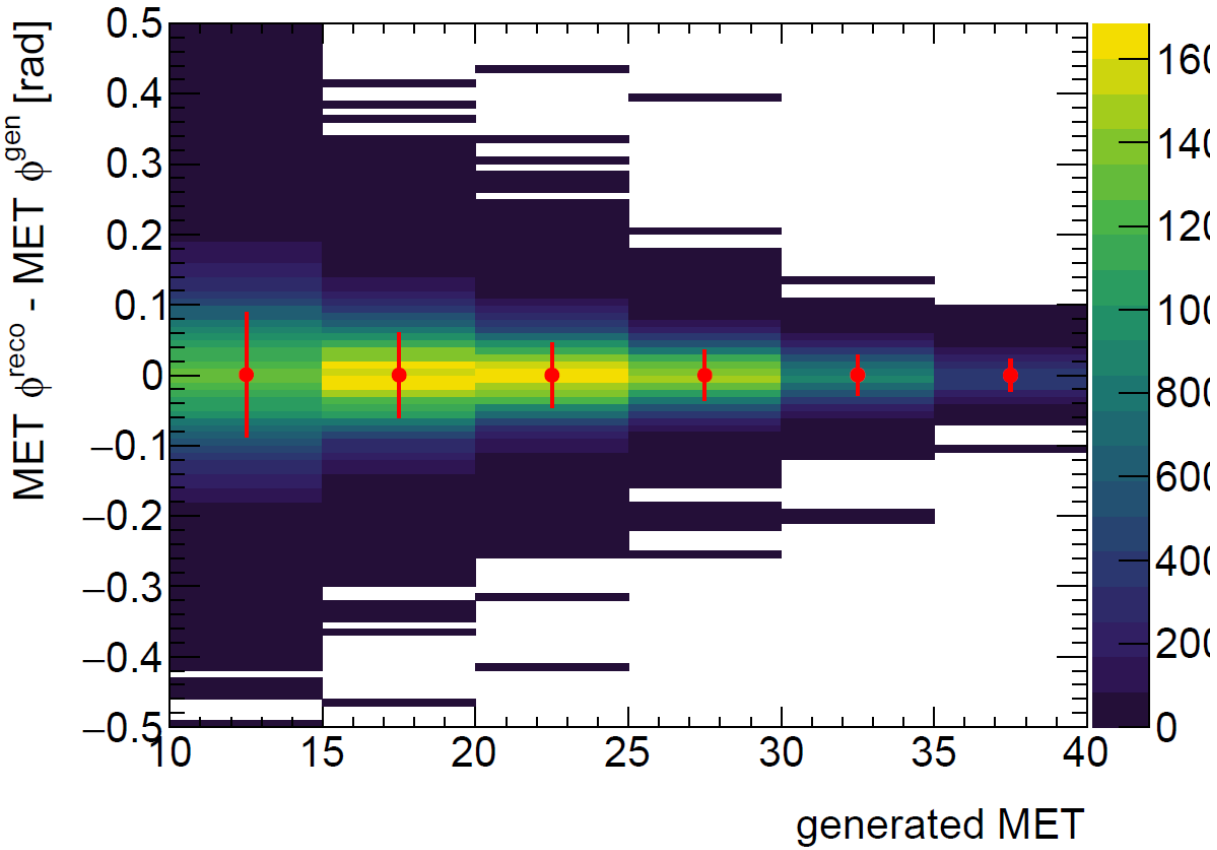
Neutrino pT

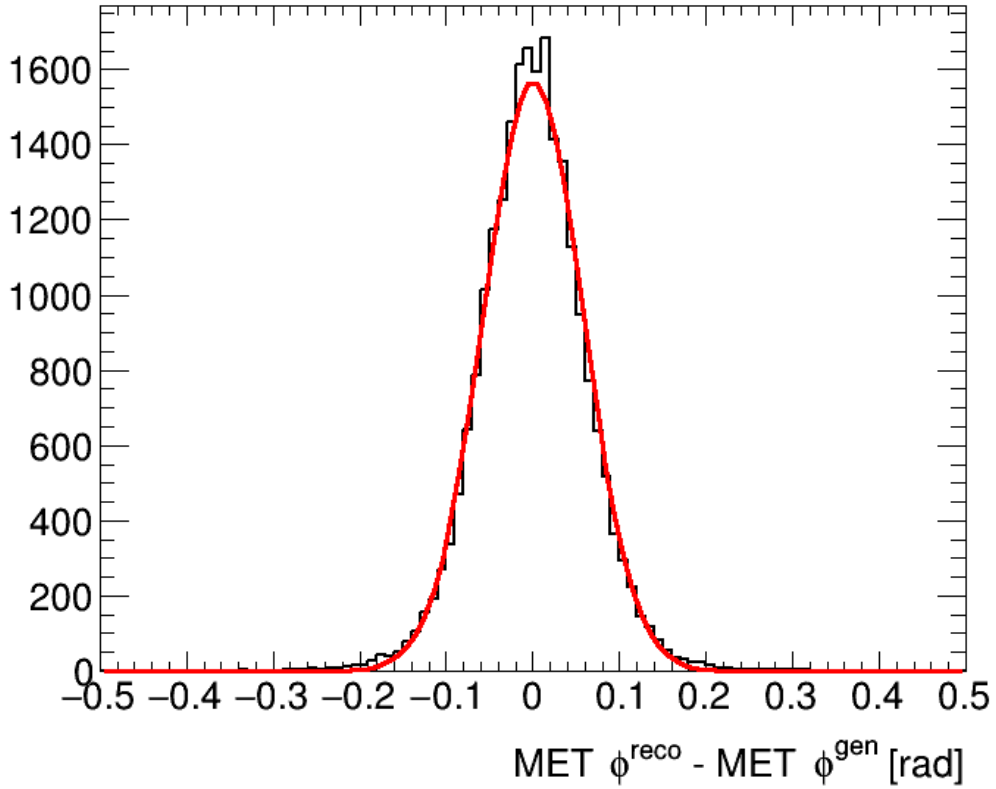




~20% at 10 GeV , ~10% at 25 GeV, but non-Gaussian response

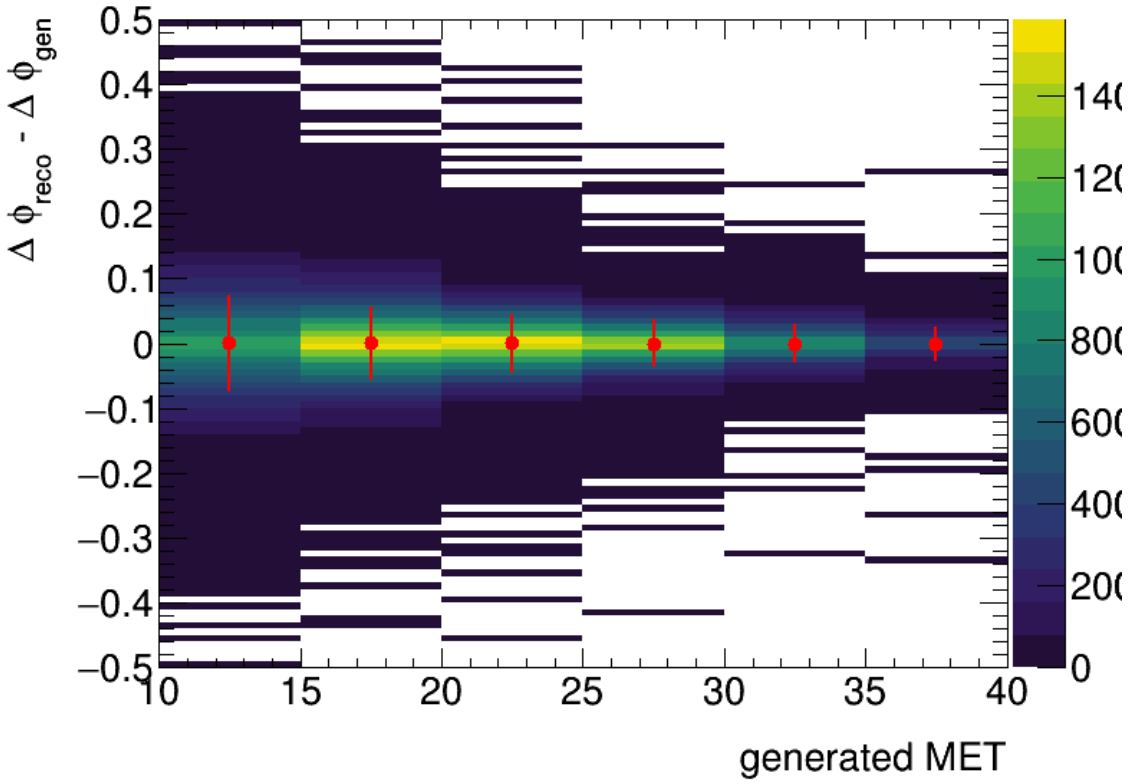
Neutrino azimuthal angle

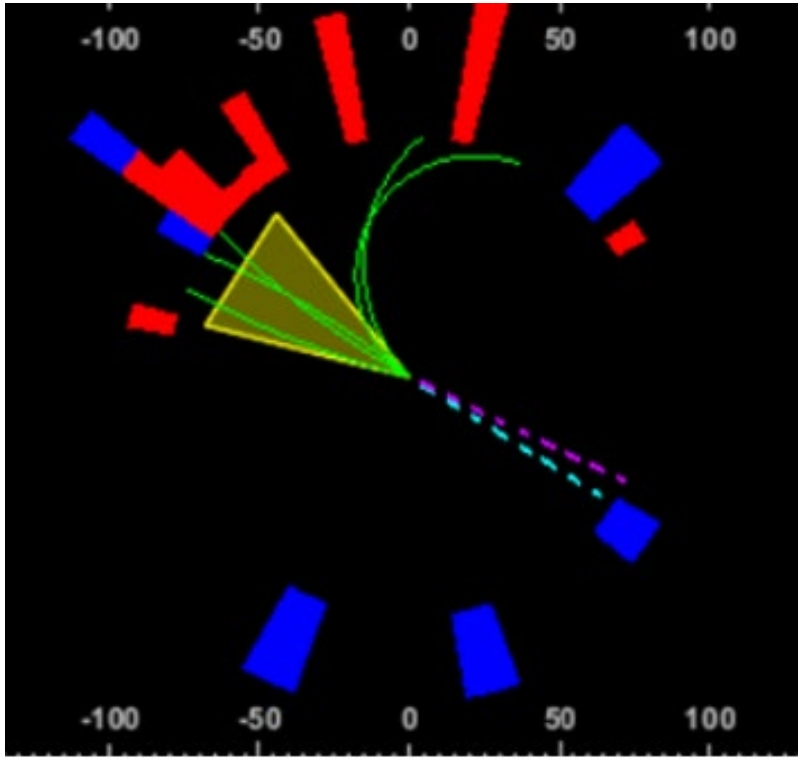




~ 0.10 rad at 10 GeV, ~0.05 rad at 30 GeV

Resolution for Neutrino-jet opening angle



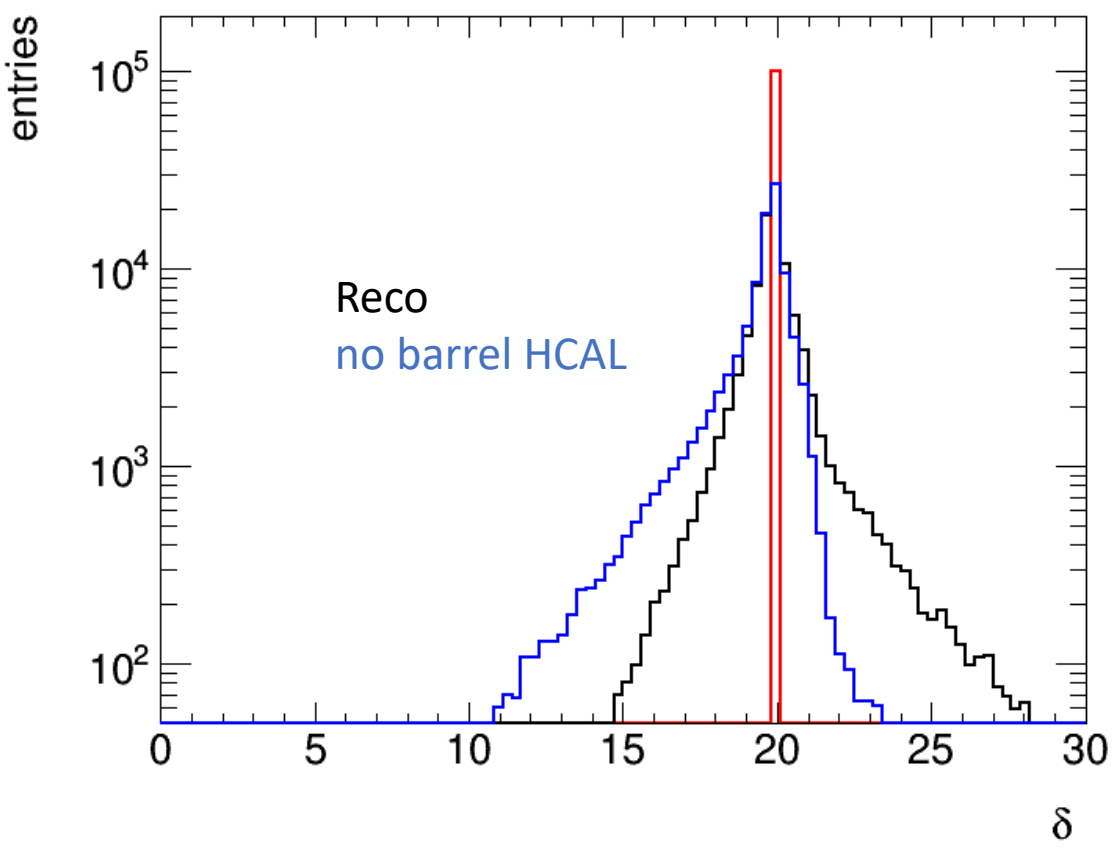


Dominated by MET resolution, ~0.1 rad RMS.
Feasibility studies still ongoing, but looking promising!
(comparable RMS to dijet at RHIC Phys. Rev. Lett. **99**, 142003)

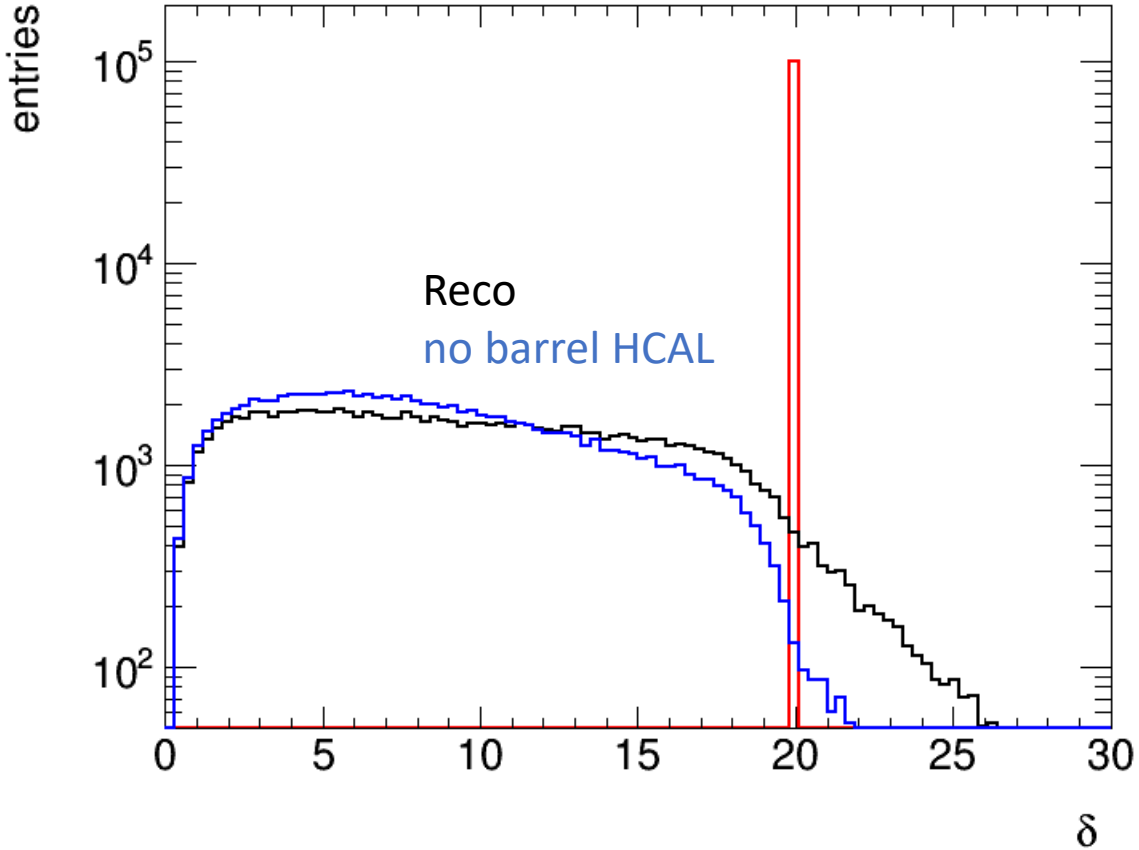
Background rejection to NC DIS:

$$\delta = \sum_i E_i(1 - \cos\theta_i)$$

NC DIS

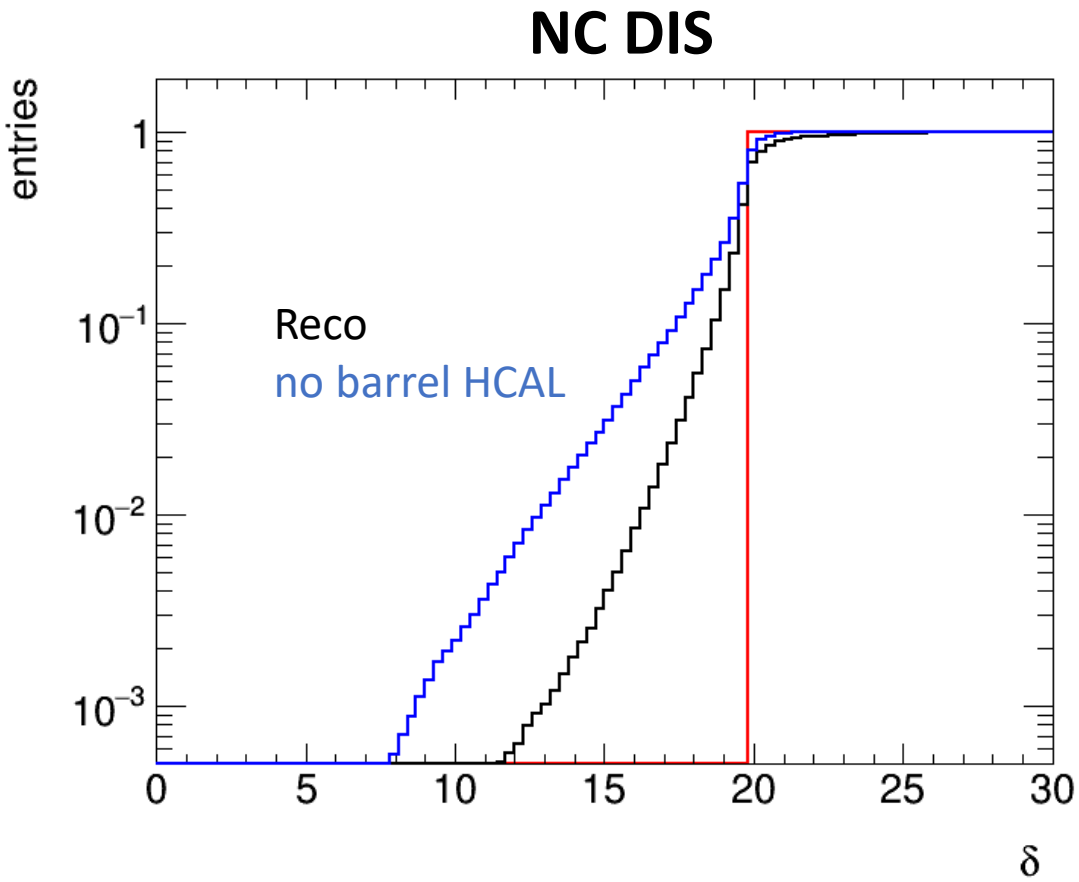


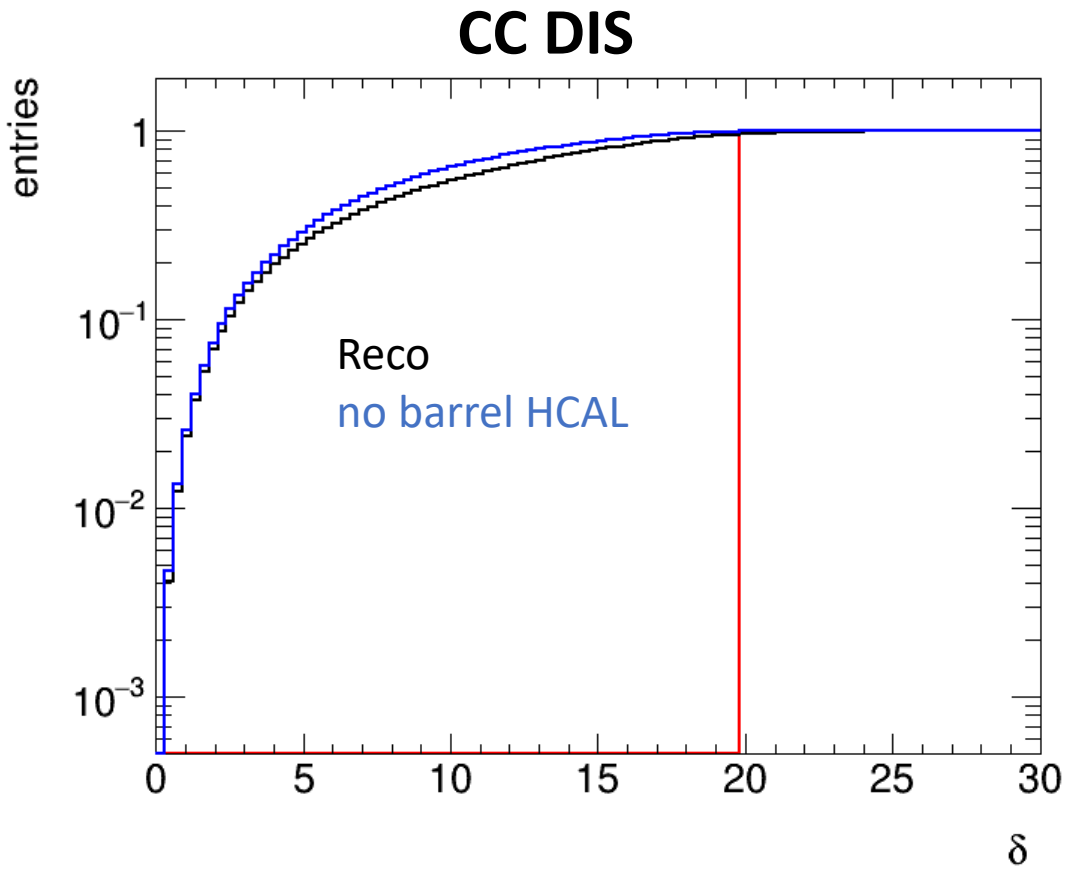
CC DIS



- If one misses track of electron but measures cluster (or viceversa), delta-cut useful to veto NC DIS.
- Further suppression can be obtained by vetoing “isolated-clusters”

Background rejection to NC DIS:



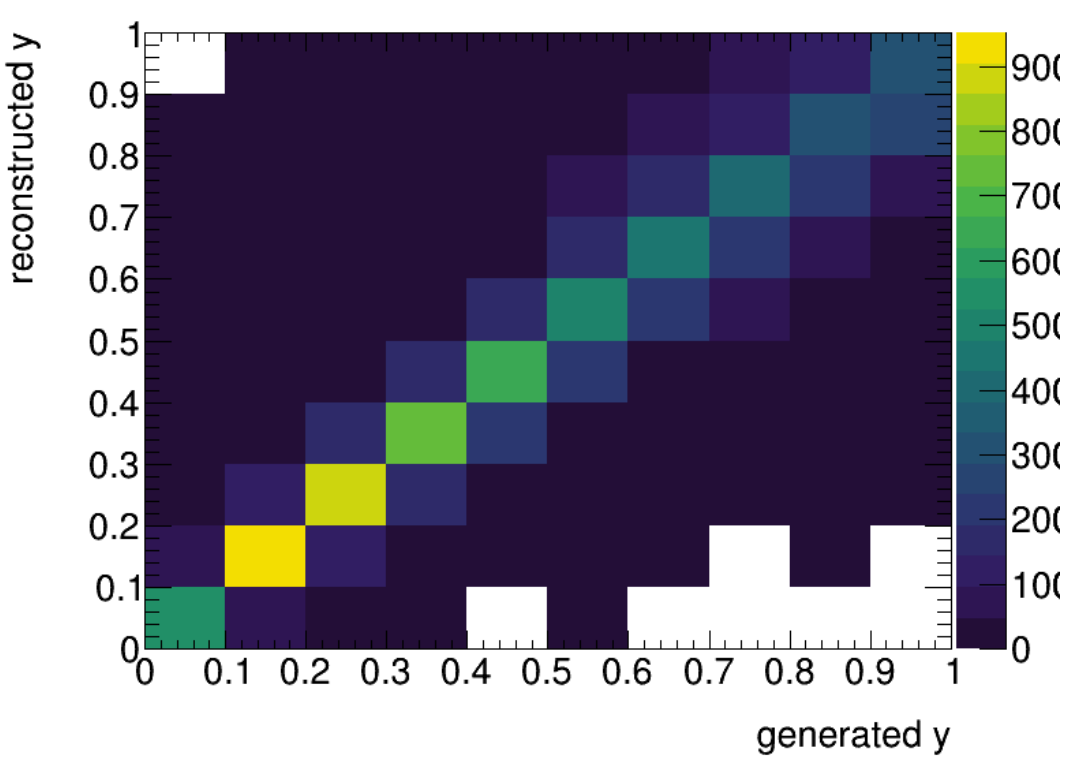


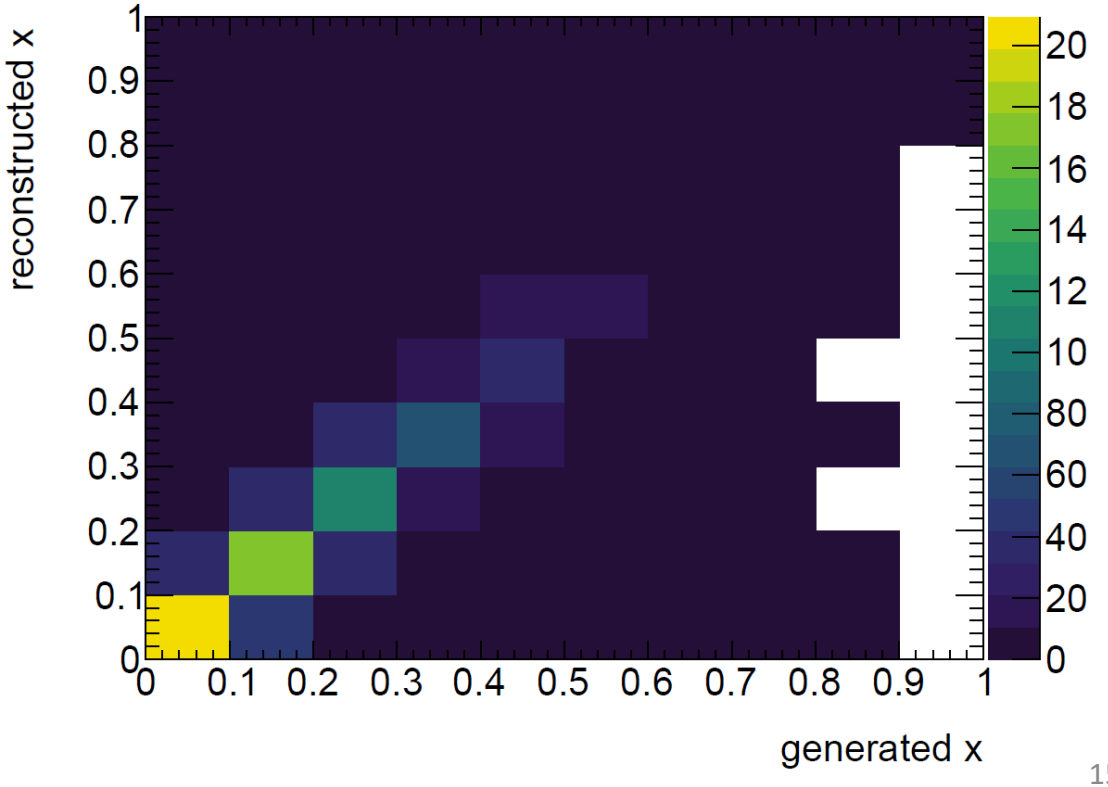
- Studies still ongoing, need to factor in electron inefficiency and cross-sections to obtain a signal-to-noise ratio as a function of delta

Jacquet-Blondel performance

(which is very related to MET performance)

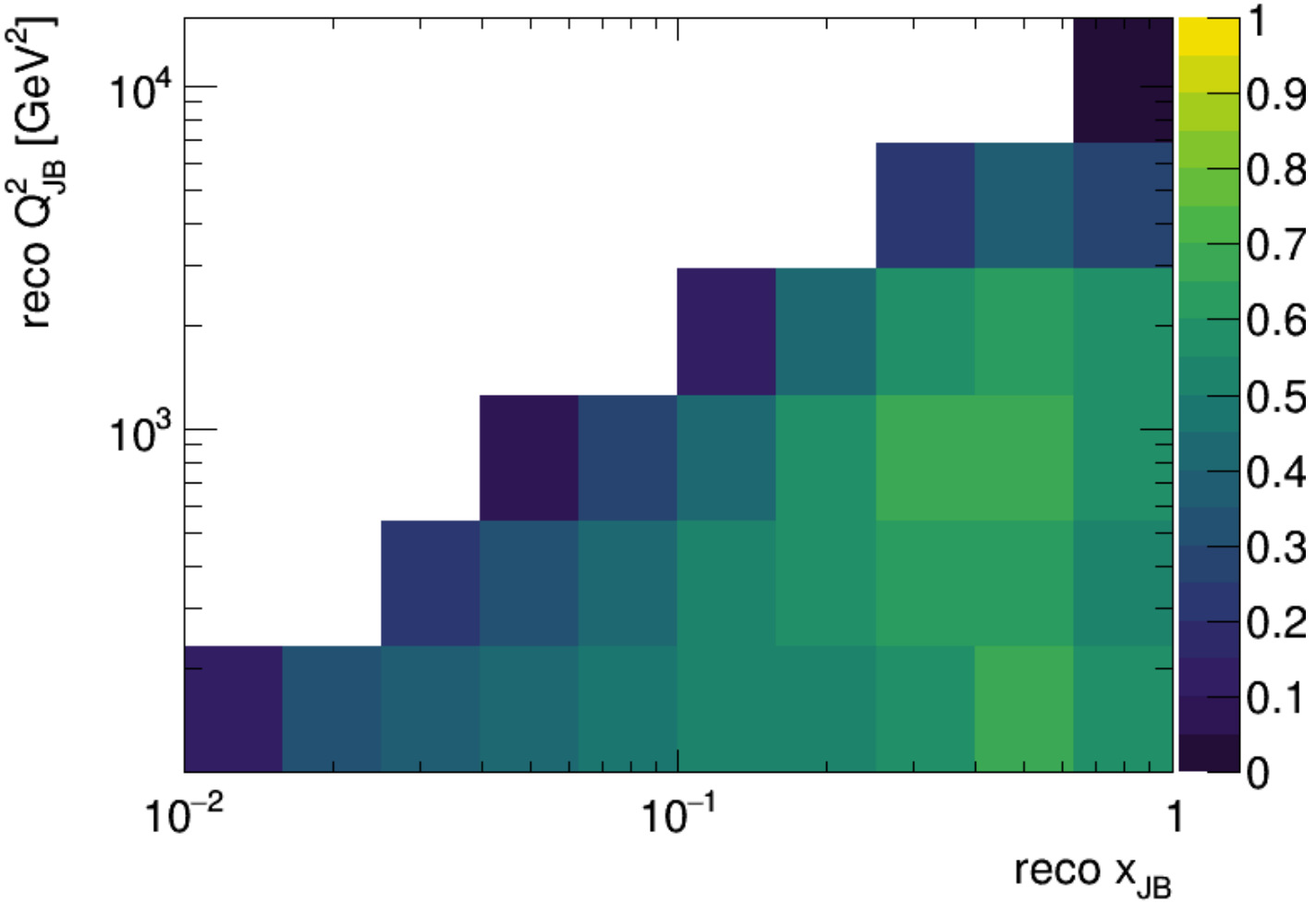
$$y_{\mathrm{JB}} = \frac{\sum_i (E_i - p_{Z,i})}{2\ E_e}, \qquad Q^2_{\mathrm{JB}} = \frac{(p_T^{\mathrm{miss}})^2}{1 - y_{\mathrm{JB}}} \qquad \text{and} \qquad x_{\mathrm{JB}} = \frac{Q^2_{\mathrm{JB}}}{s\ y_{\mathrm{JB}}},$$





Jacquet-Blondel Purity

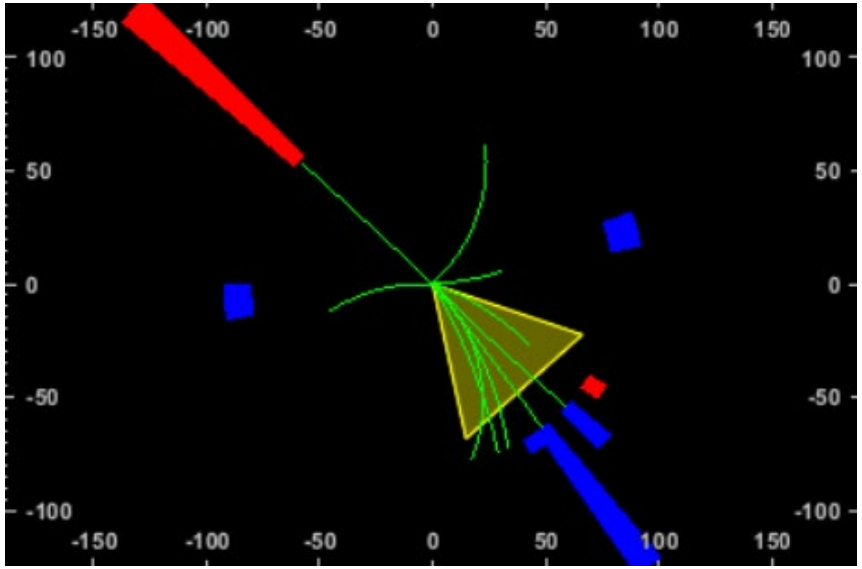
$$\text{purity} = (N_{gen} - N_{out}) / (N_{gen} - N_{out} + N_{in})$$

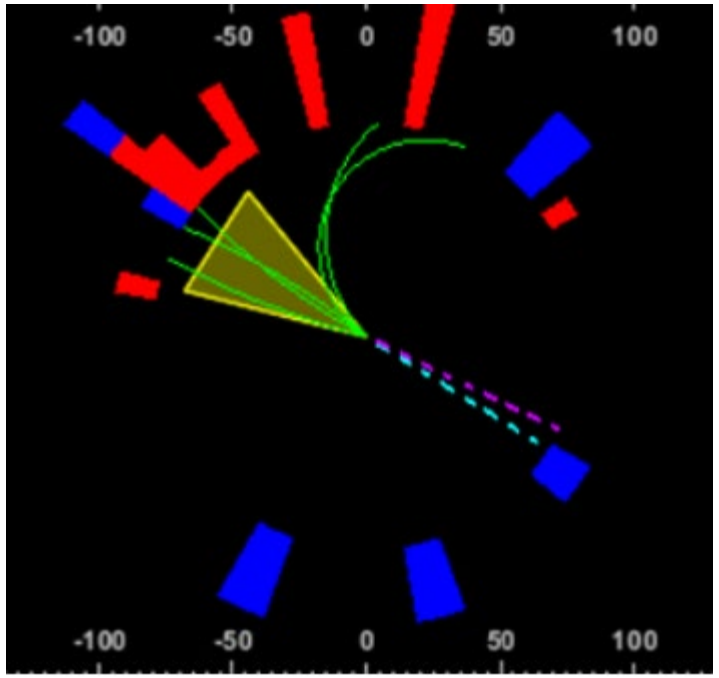


- Reasonable purity reached at high-x and high Q2. (similar conclusion reached in Aschenauer et al. Phys. Rev. D 88, 114025 (2013))
- This is one figure of merit, but one should not forget to consider non-Gaussian tails in response…

Summary

- Hadron-in-jet Collins angle resolution with baseline parameters seems enough.
- Sivers measurement in neutrino channel seems feasible.
- Background rejection studies for CC ongoing, need to include photoproduction as well.
- Double-differential measurements in CC DIS seem feasible.





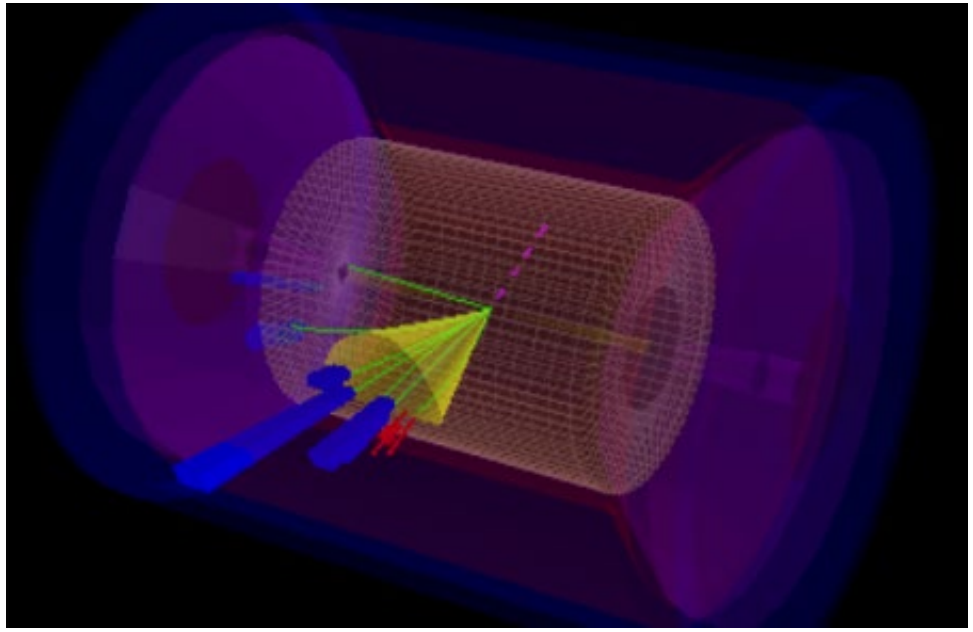
Backup

EIC detector in Delphes

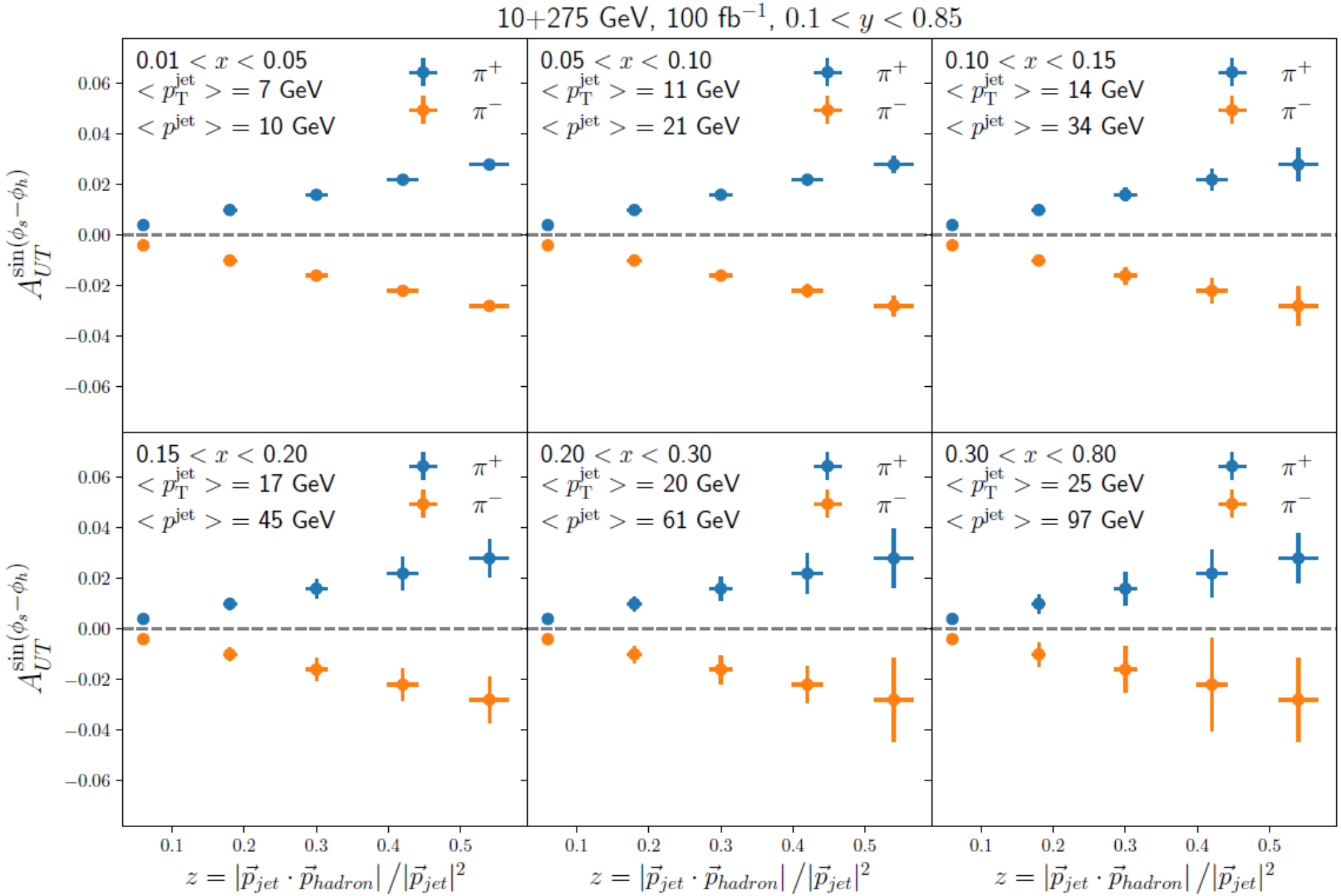
https://github.com/miguelignacio/delphes_EIC/blob/master/delphes_card_EIC.tcl

Tracking resolution, EMCAL resolution and HCAL resolution as in detector handbook.

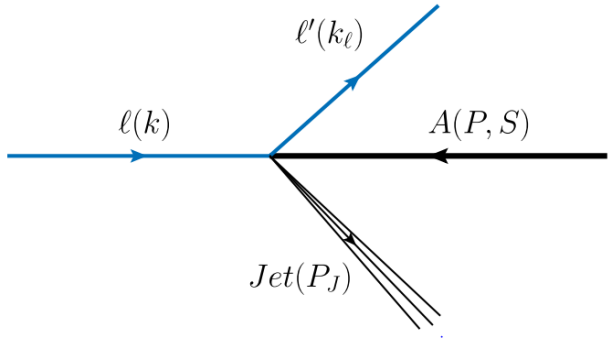
In addition:

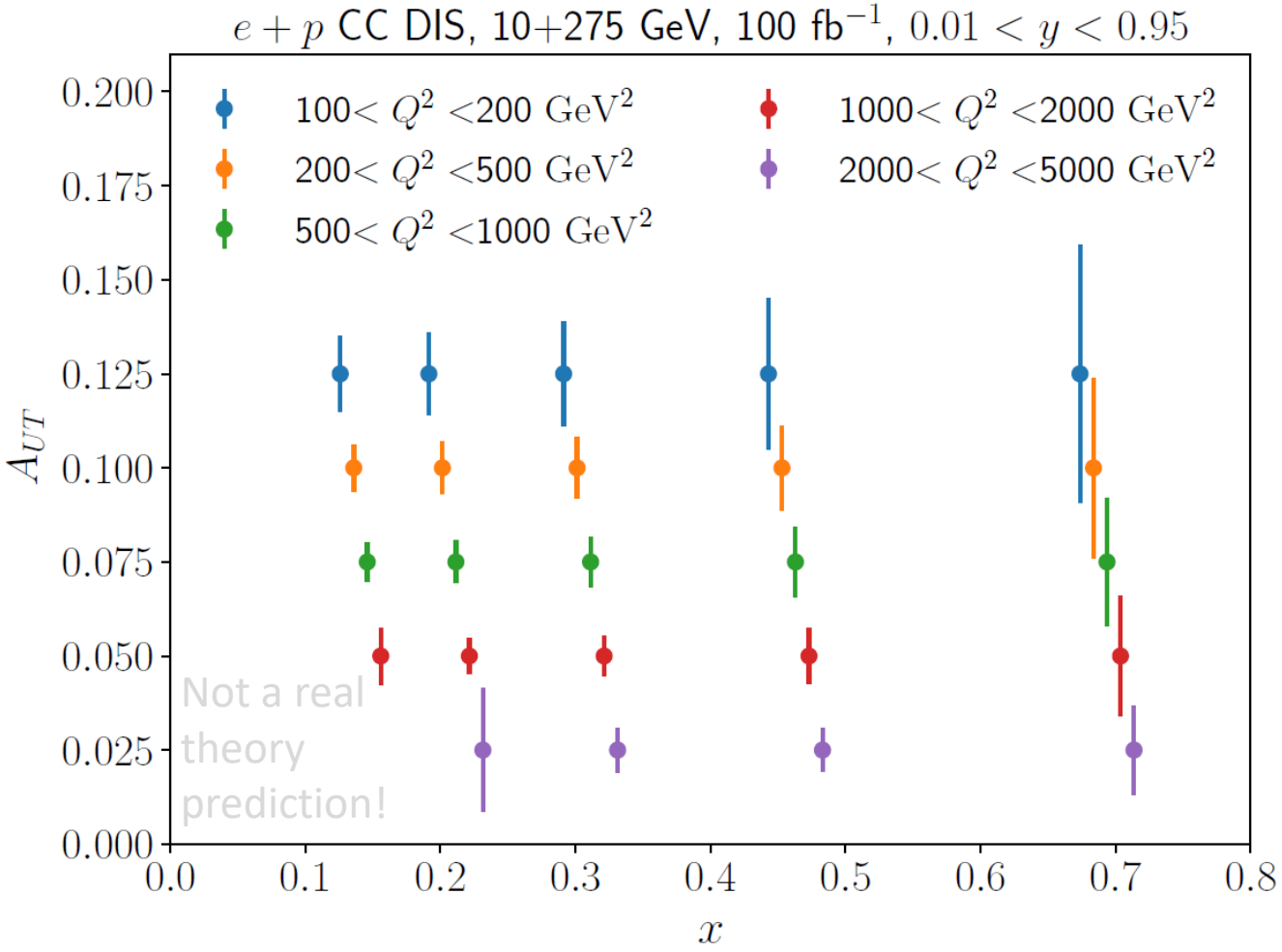


- B=1.5 T, R=0.80 m, L = 1 m
- EMCAL granularity (dphi x deta):
  0.02 x 0.02 for |eta|<3.5
- HCAL granularity (dphi x deta):
  0.1 x 0.1 for |eta|<1.0
  0.025 x 0.025 for 1.0 |eta|<4.0
  (10x10 cm2 at 3.6 m, suggested by O. Tsai)
- HCAL resolution:
  100%/sqrt(E) + 10% in barrel (0.0—1.0)
  50%/sqrt(E) + 10% in encap (1.0—4.0)
- Tracking threshold 100 MeV pT;
  EMCAL threshold of 200 MeV; (noise ~ 30 MeV per tower)
  HCAL threshold of 500 MeV; (noise ~100 MeV per tower)
- No PID yet, but it can be included (LHCb is in Delphes).
  Need parametrization of efficiency and mis-identification matrix


10+275 GeV, 100 fb^{-1}, $0.1 < y < 0.85$
$0.01 < x < 0.05$
$< p_T^{jet} > = 7$ GeV
$< p^{jet} > = 10$ GeV
$0.05 < x < 0.10$
$< p_T^{jet} > = 11$ GeV
$< p^{jet} > = 21$ GeV
$0.10 < x < 0.15$
$< p_T^{jet} > = 14$ GeV
$< p^{jet} > = 34$ GeV
$0.15 < x < 0.20$
$< p_T^{jet} > = 17$ GeV
$< p^{jet} > = 45$ GeV
$0.20 < x < 0.30$
$< p_T^{jet} > = 20$ GeV
$< p^{jet} > = 61$ GeV
$0.30 < x < 0.80$
$< p_T^{jet} > = 25$ GeV
$< p^{jet} > = 97$ GeV
π^+
π^-
$A_{UT}^{\sin(\phi_s - \phi_h)}$
$z = |\vec{p}_{jet} \cdot \vec{p}_{hadron}| / |\vec{p}_{jet}|^2$

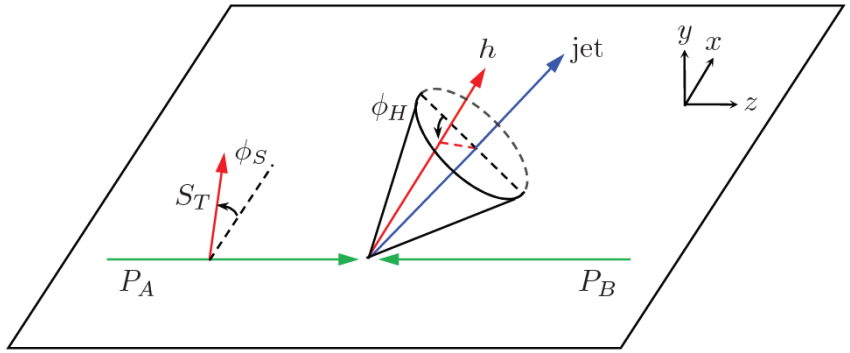
u-quark Sivers with neutrino-jet correlations

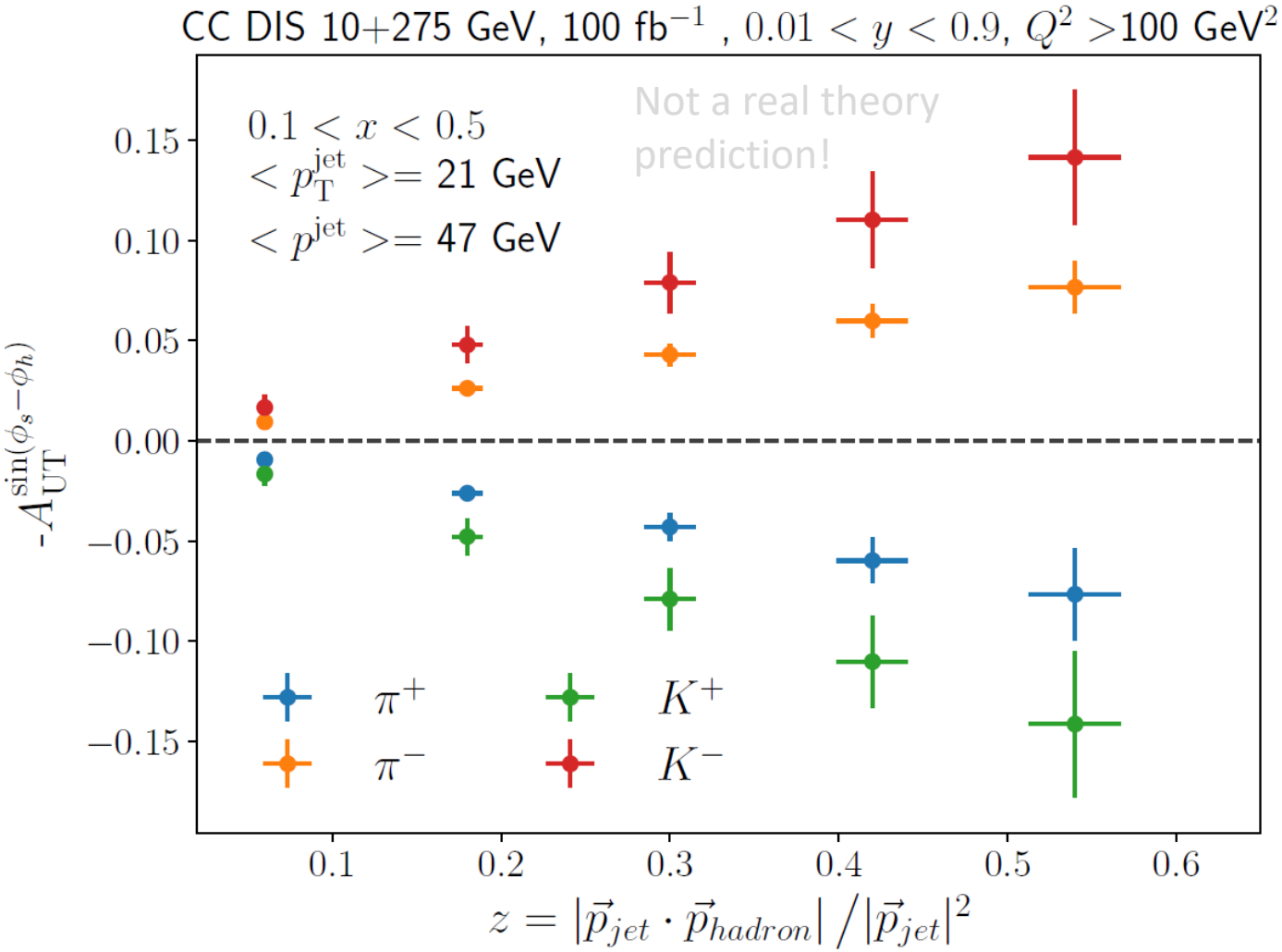




- Statistical projections assume 100 fb-1, 70% polarization, 50% overall efficiency.
- Most systematic cancels in the ratio.
- Needs measurement of neutrino, i.e. missing energy, azimuthal angle.
  [This requirement is intrinsic to CC DIS, and for Jacquet-Blondet method for NC DIS]
- Binning inspired in PRD 88, 114025 (2013)

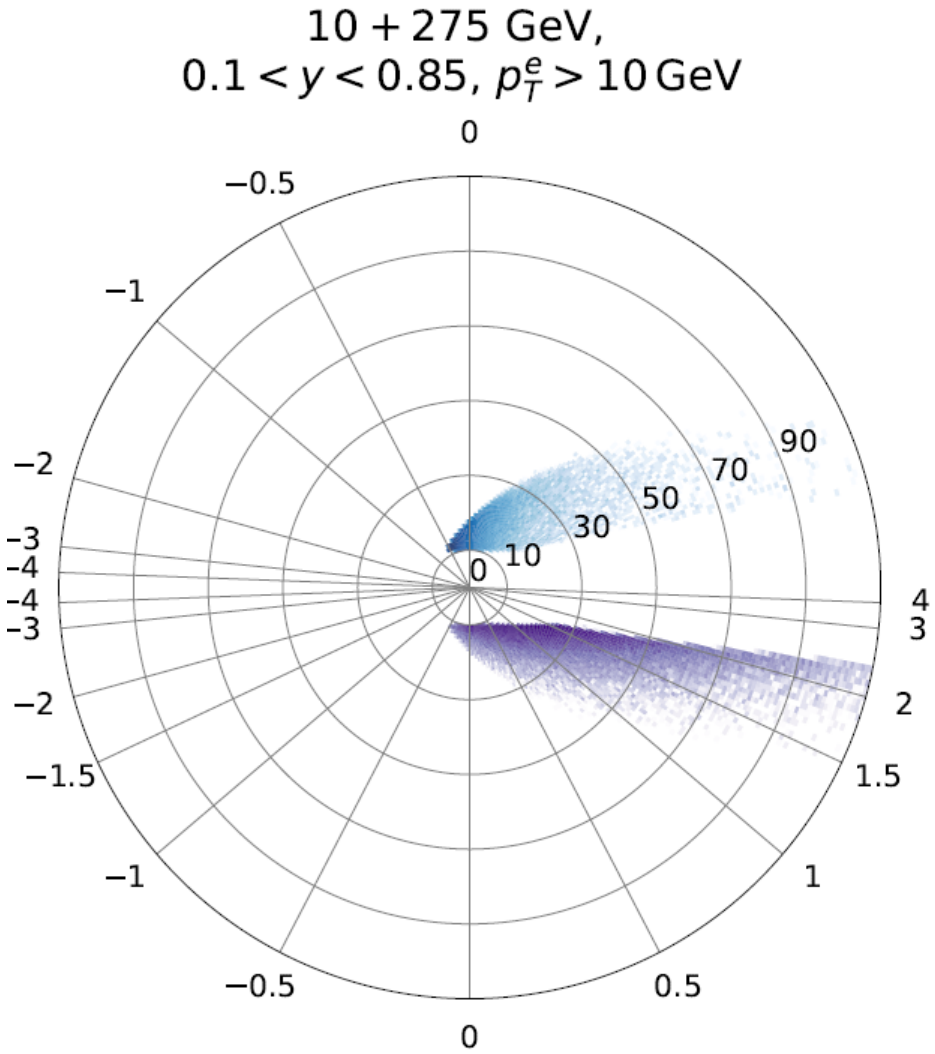
u-quark Transversity in charged-current DIS

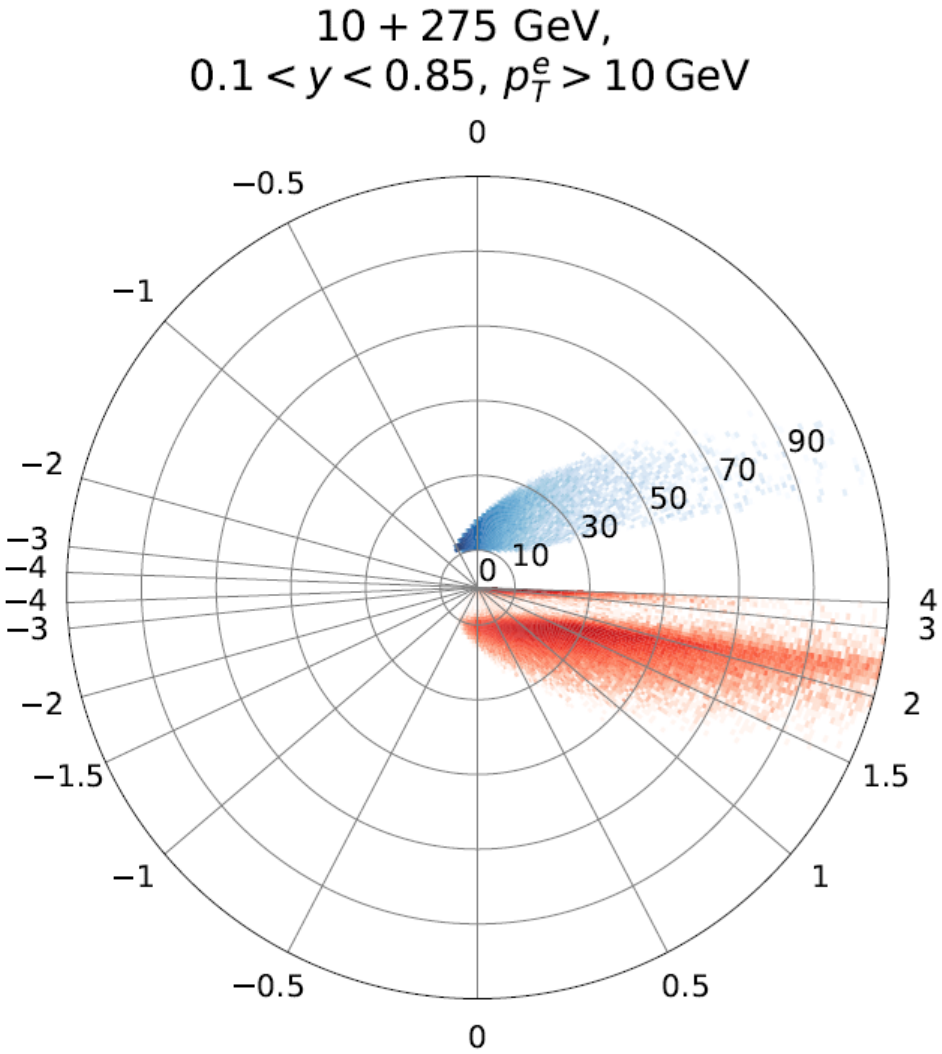




- Decent statistics, specially for pions.
- Flavor specific
  (u-quark for electrons;
  d-quark for positrons)
- Non-cancellation of u/d transversity will lead to larger asymmetries.

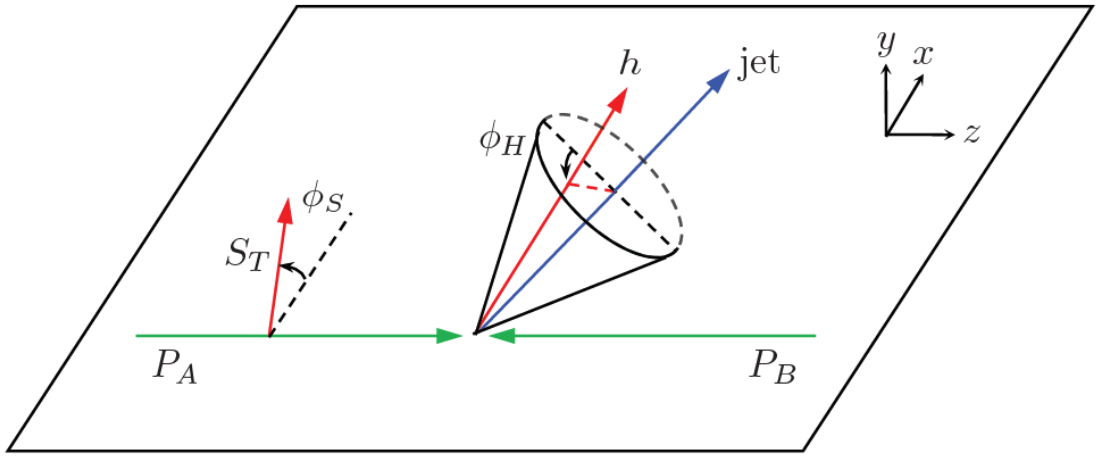
Kinematics


10 + 275 GeV,
0.1 < y < 0.85, p_T^e > 10 GeV
0
−0.5
−1
−2
−3
−4
−4
−3
−2
−1.5
−1
−0.5
0
0.5
1
1.5
2
3
4
10
30
50
70
90

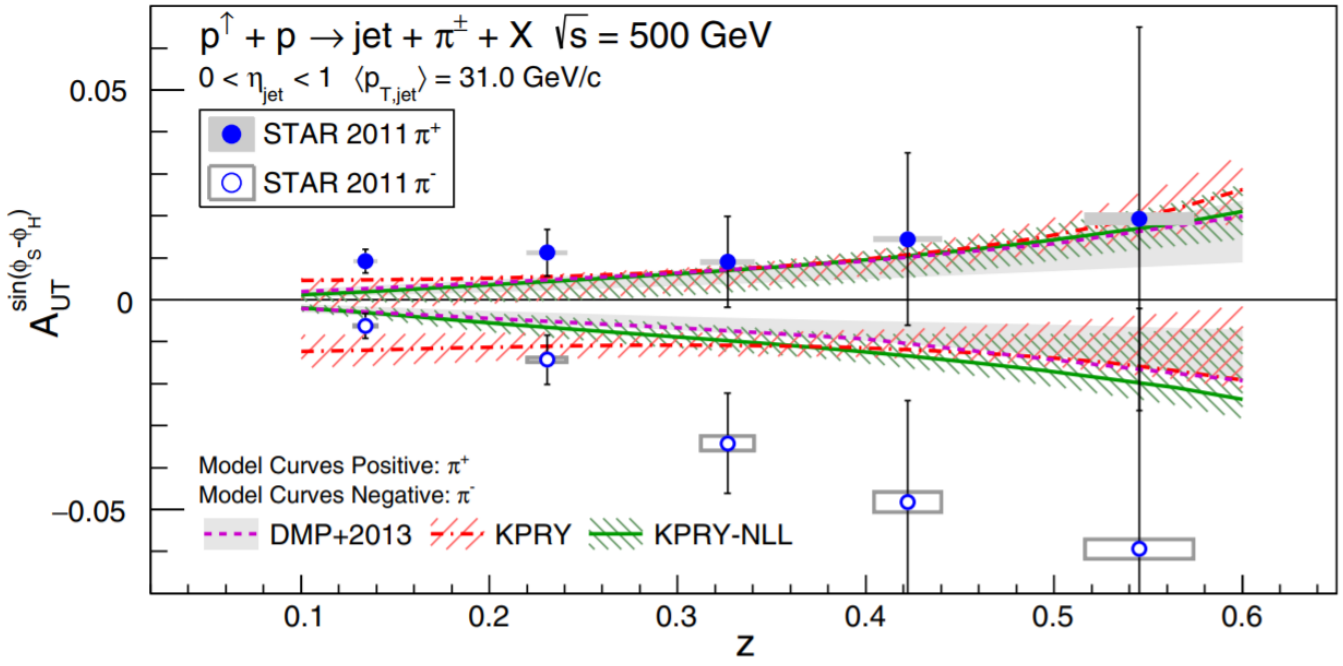

10 + 275 GeV,
0.1 < y < 0.85, p_T^e > 10 GeV
0
−0.5
−1
−2
−3
−4
−4
−3
−2
−1.5
−1
−0.5
0
0.5
1
1.5
2
3
4
10
30
50
70
90

Transversity with jets

distribution of transversely polarized quarks inside a transversely polarized nucleon



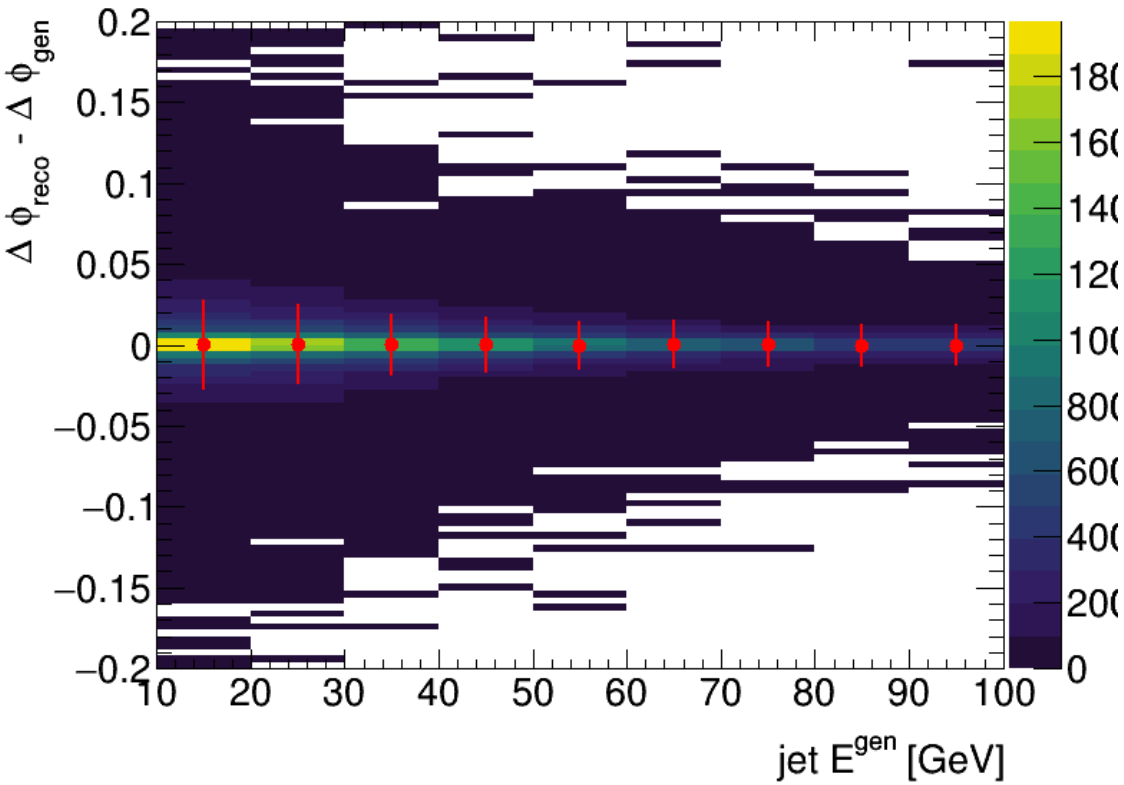
STAR Collaboration, Phys. Rev. D 97, 032004 (2018)

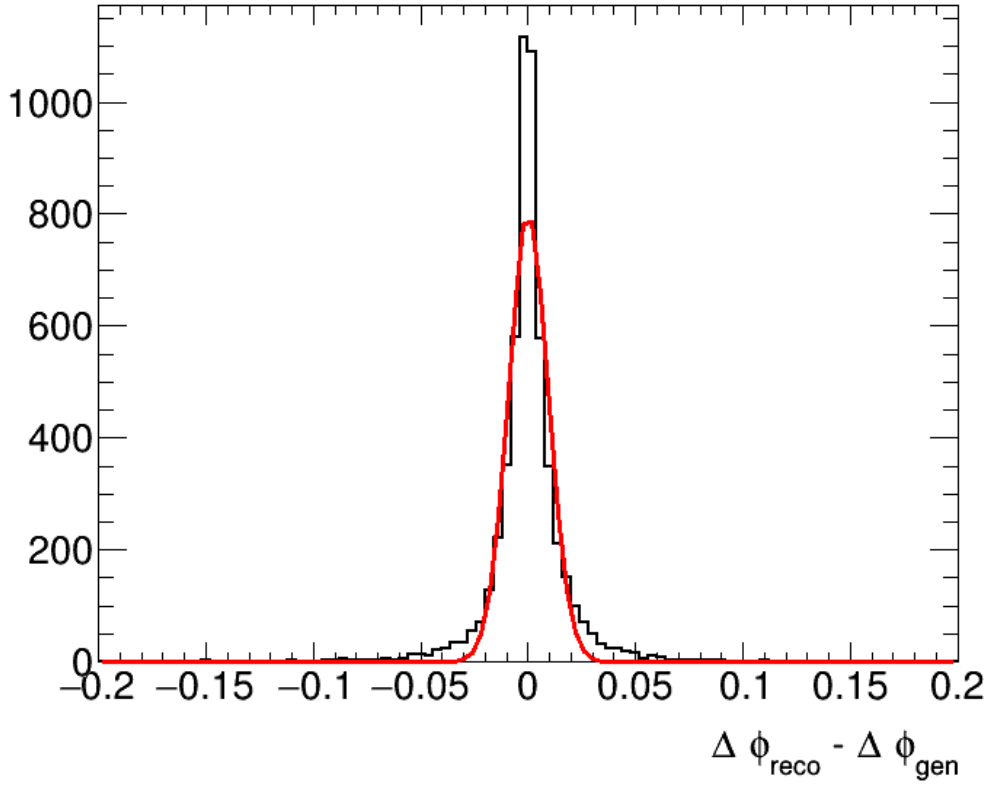


"Collins azimuthal asymmetries of hadron production inside jets
Phys. Lett. B 774, 635 (2017), Kang et al.
"The transverse momentum distribution of hadrons within jets"
JHEP 1711 (2017) 068, Kang et al.

- Jet measurement crucial to factorize initial and final state TMD effects.
- At EIC, we could explore this observable with much higher precision, kinematic control. Tests of TMD evolution & universality; complements di-hadron measurements.

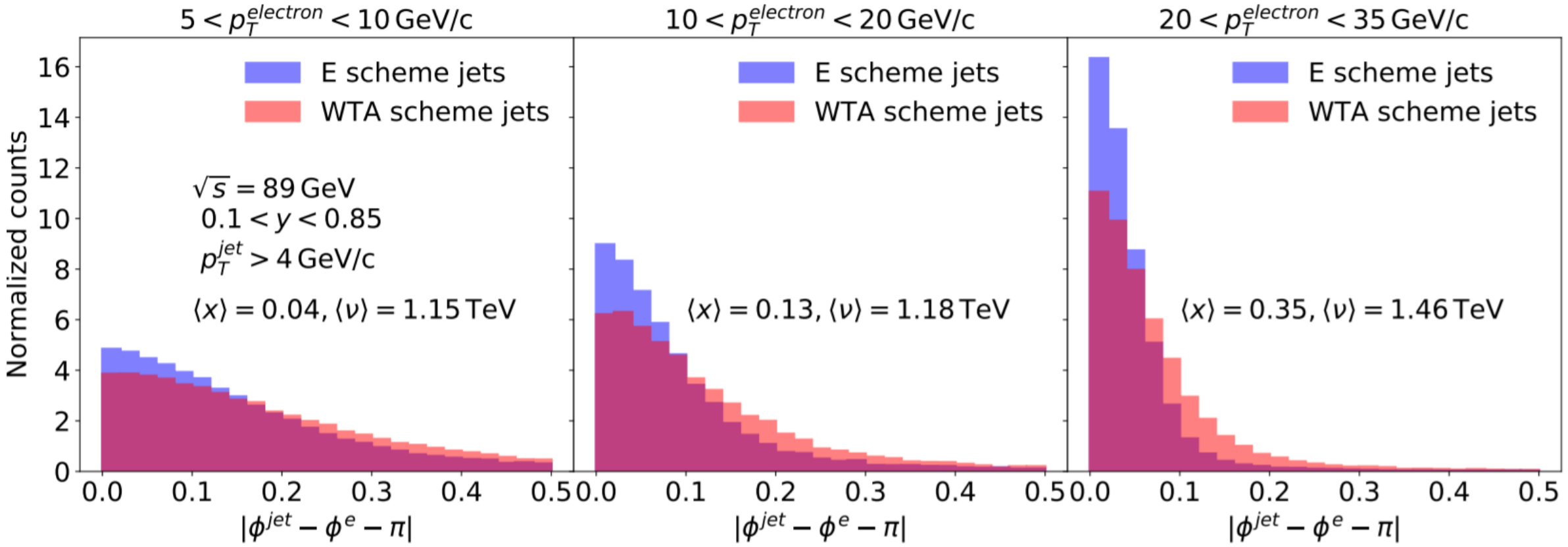
Electron-jet opening angle resolution





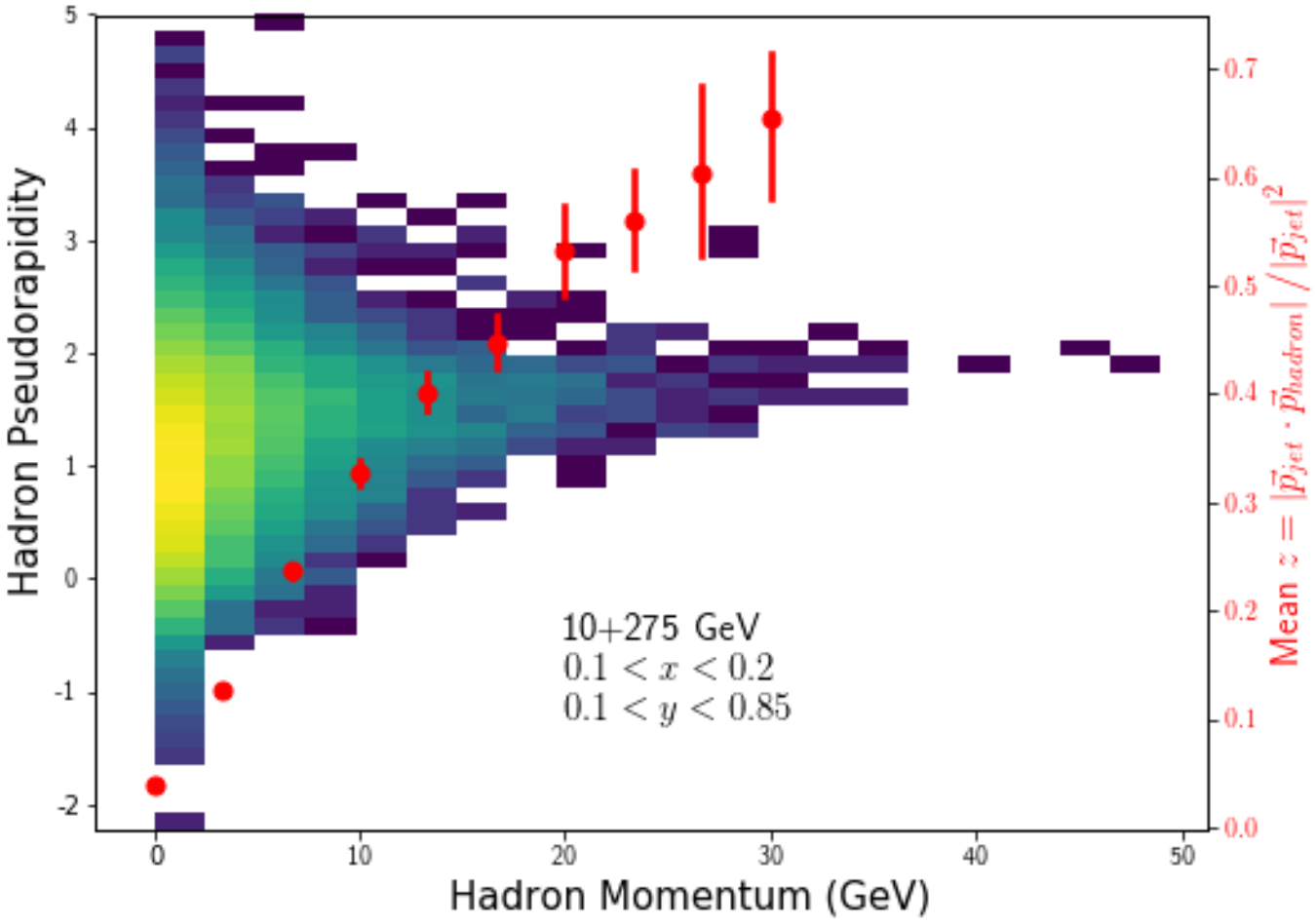
- 0.01 radians RMS, with non-Gaussian tails

Resolution much smaller than "intrinsic width"



Arratia et al. https://arxiv.org/abs/1912.05931

PID requirements:



- Charged pions separation from Kaons and protons up to ~30 GeV