Charged Current in unpolarized ep collisions

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2nd EIC YR workshop

Outline

- Impact study of EIC charged current data on Proton PDFs constraint.
- Radiative effect on the measurement of cross section.
- Detector requirement:
  - PID impact: final state hadrons and photon identification.
  - Detector acceptance effect on kinematics reconstruction.
  - EIC-smear study.

Charged current kinematics region at EIC

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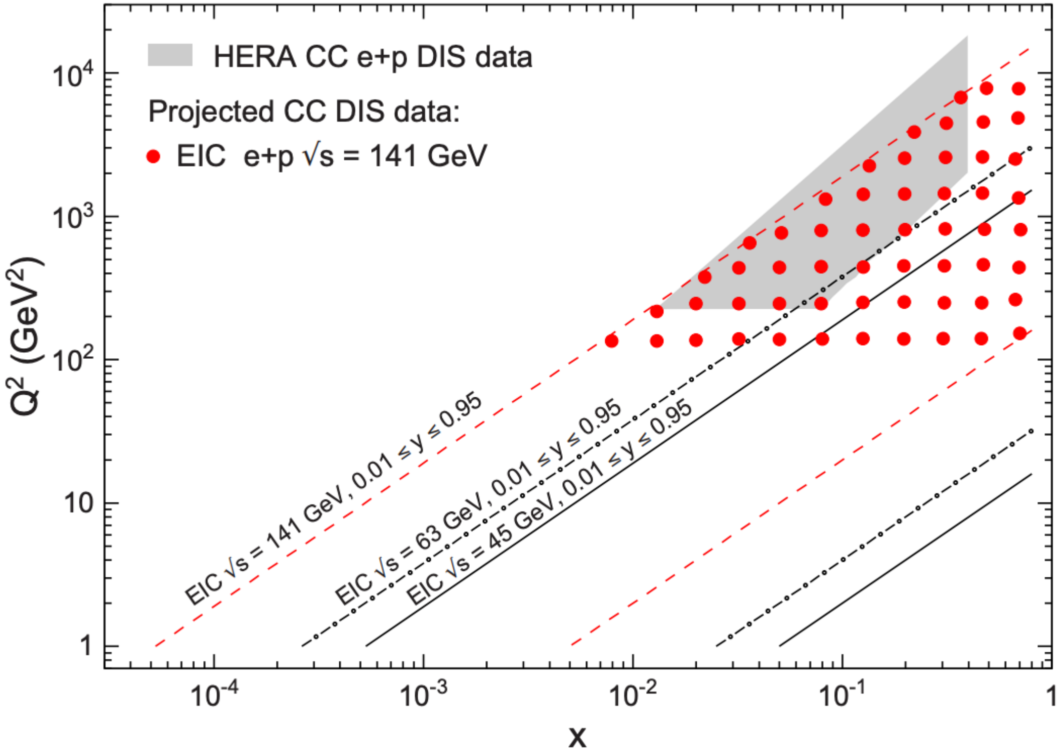
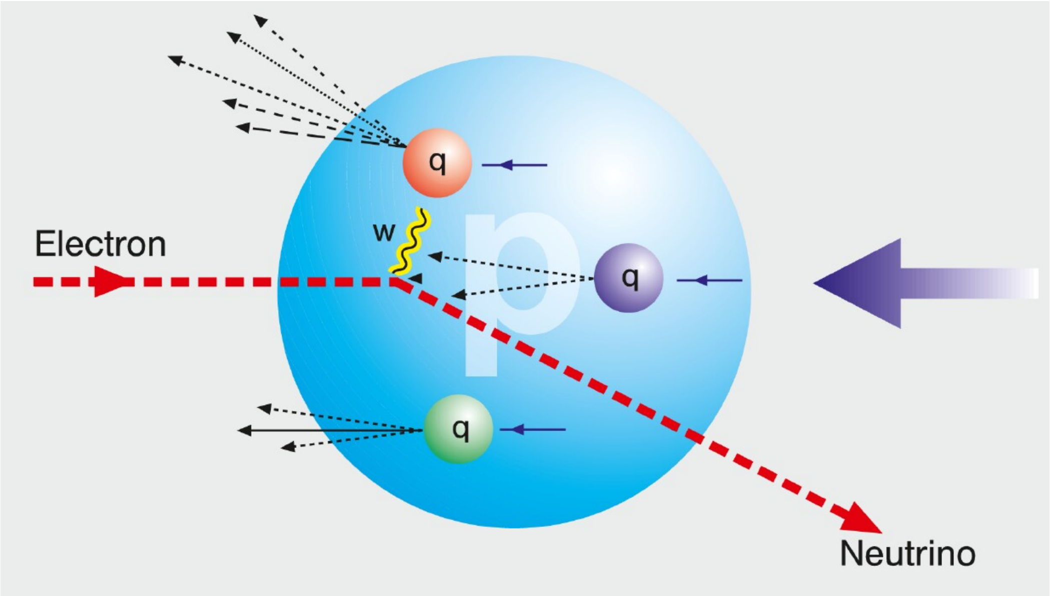


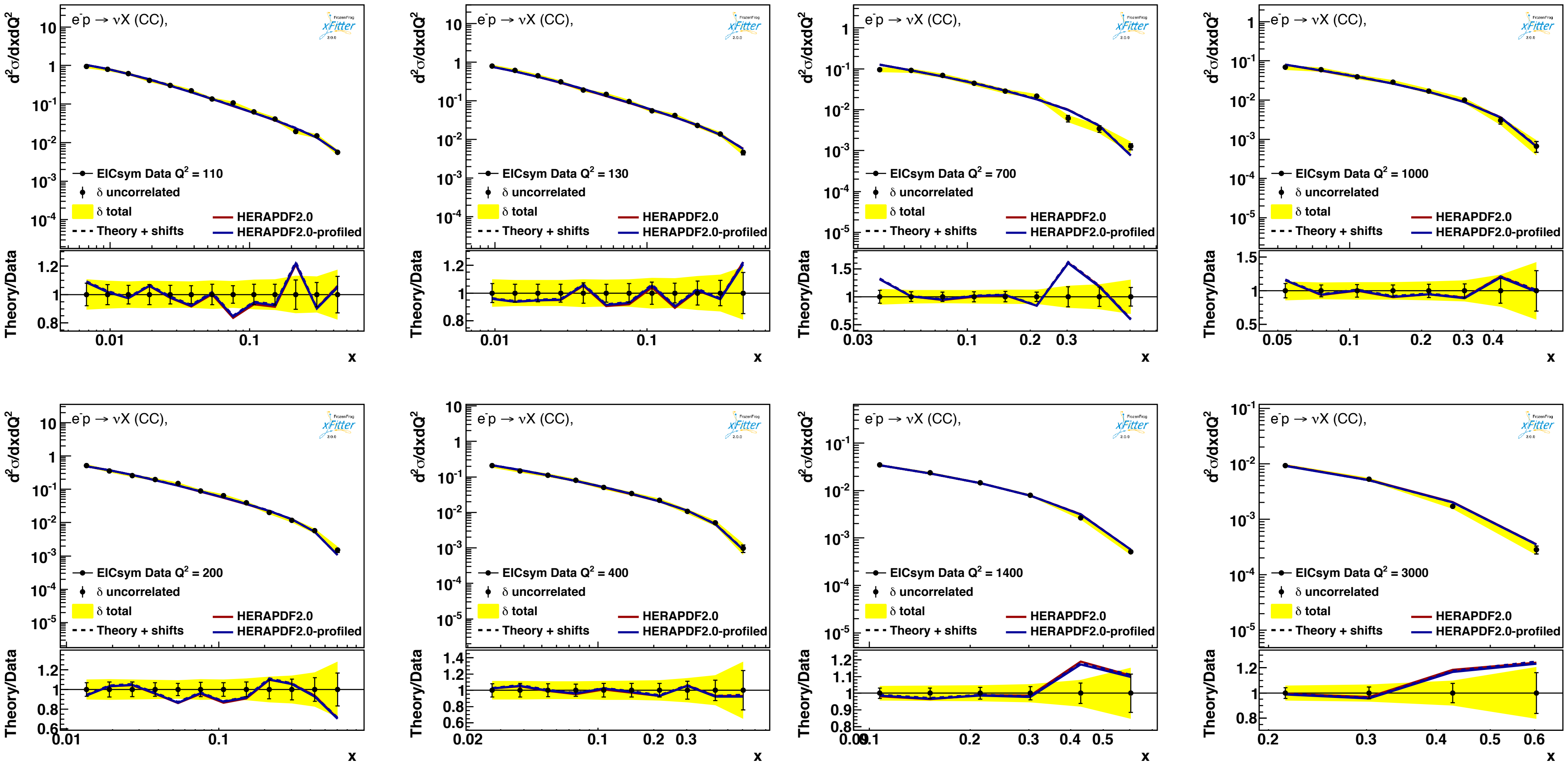


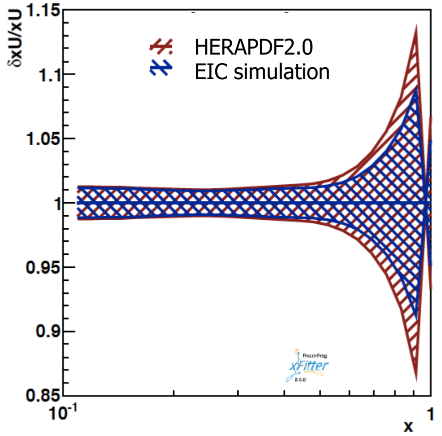
High energy is required in CC channel. Data sample are simulated from Djangoh: 18x275 GeV with radiative correction included.

Kinematics:

- True level: trueQ^2, used to do impact study.
- Radiative level: Q^2. They are calculated from neutrino. Radiative effect is included.
- Reconstructed level: Q^2 rec. Use Jacquet-Blondel method on hadronic final state to reconstruct kinematics.

Reduced cross section at true level with xfitter

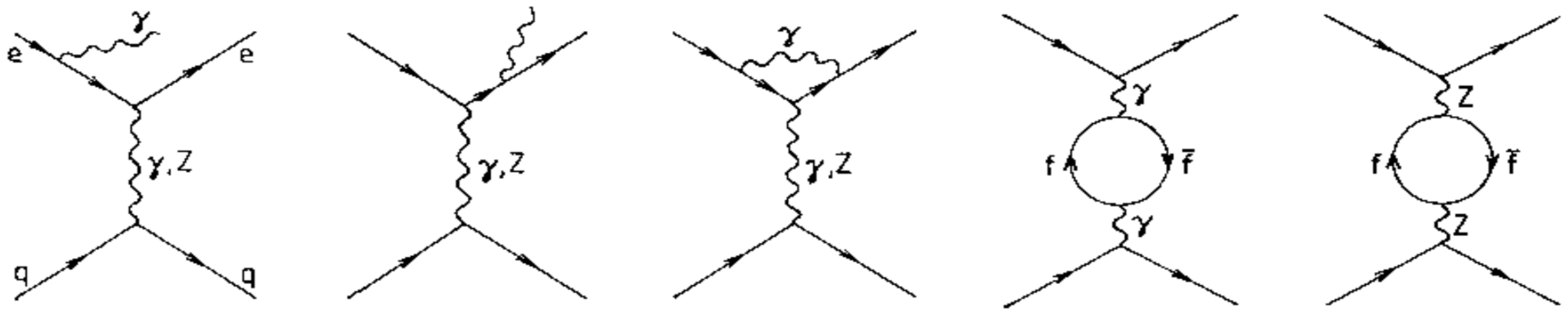




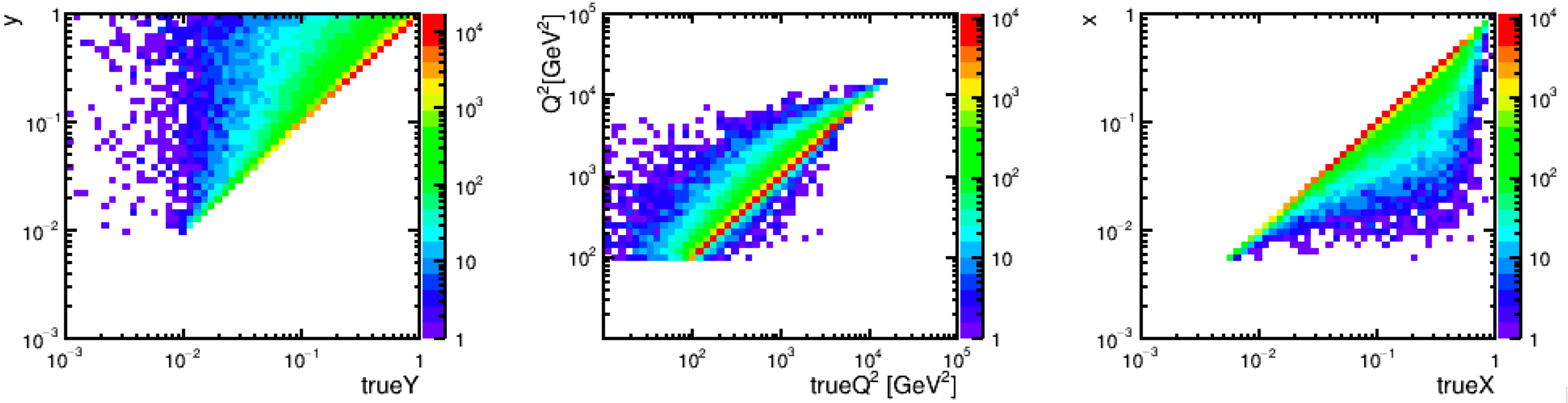
- CC reduced cross sections measured at EIC agree with theory predictions and HERAPDF.
- Reduced cross sections on true level are used for impact study. EIC CC data reduce uncertainty of U at high x.

Kinematics with radiative effect

Data sample : Int L = 10 fb^{-1}, Kinematics settings: $0.01<y<0.95$, 10^2 GeV^2 $<Q^2<10^5$ GeV^2

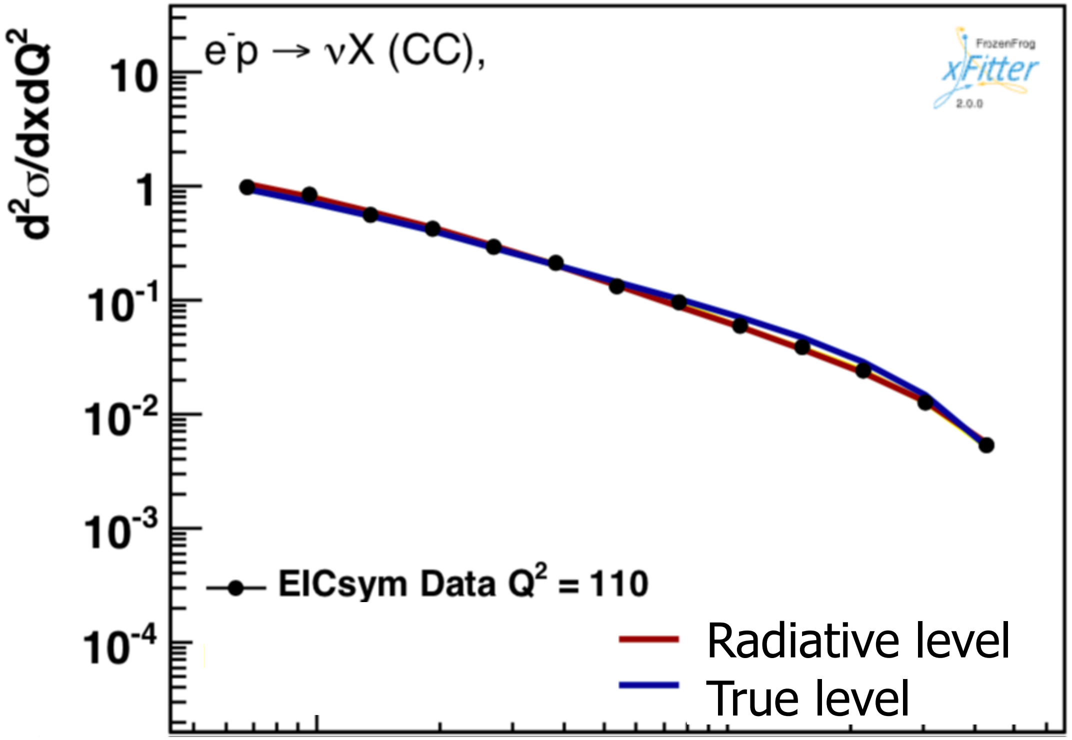


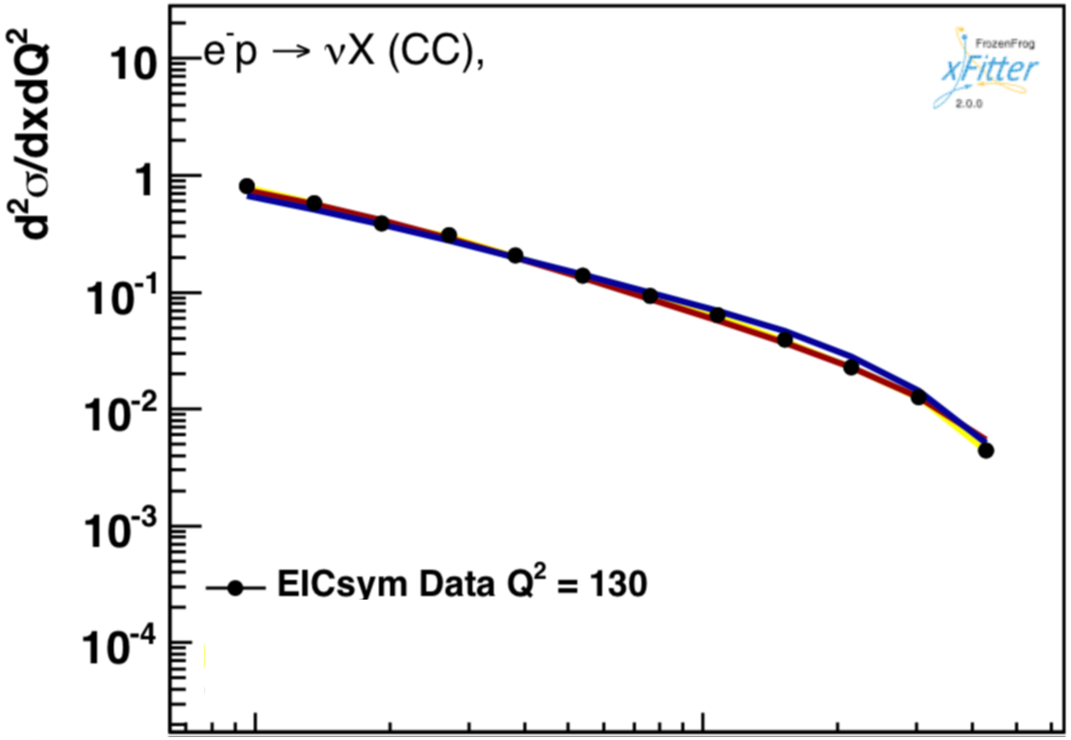
initial **final** **vacuum** **loops**



- **Djangoh is used to simulate charged current deep-inelastic scattering including radiative effects.**
- **Kinematics are smeared after including radiative corrections.**

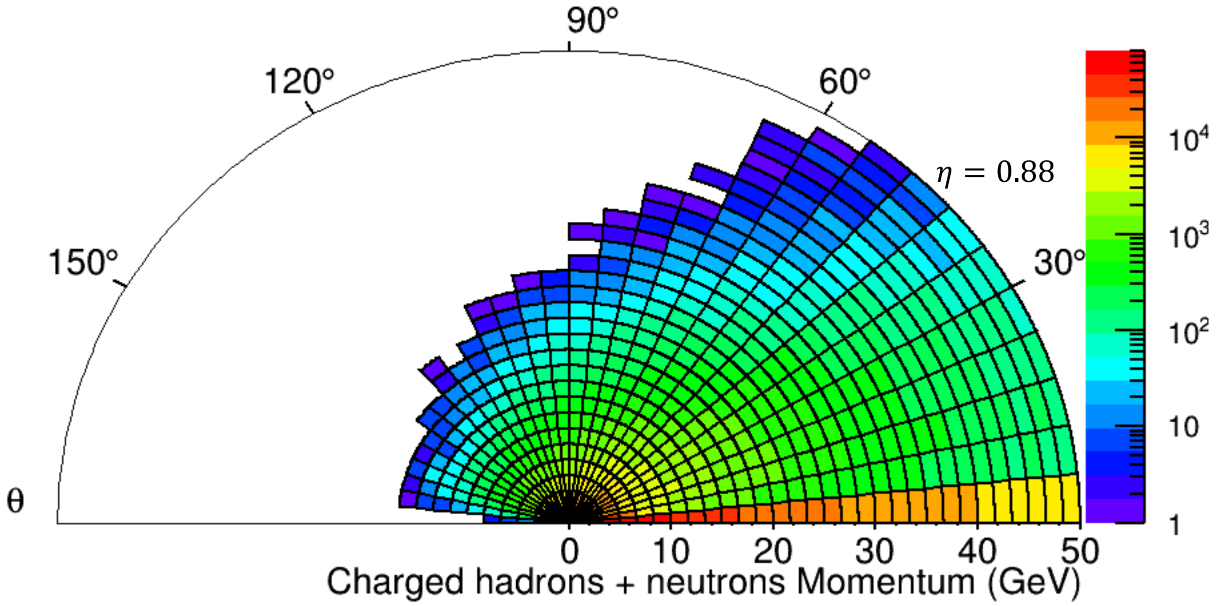
Radiative effect

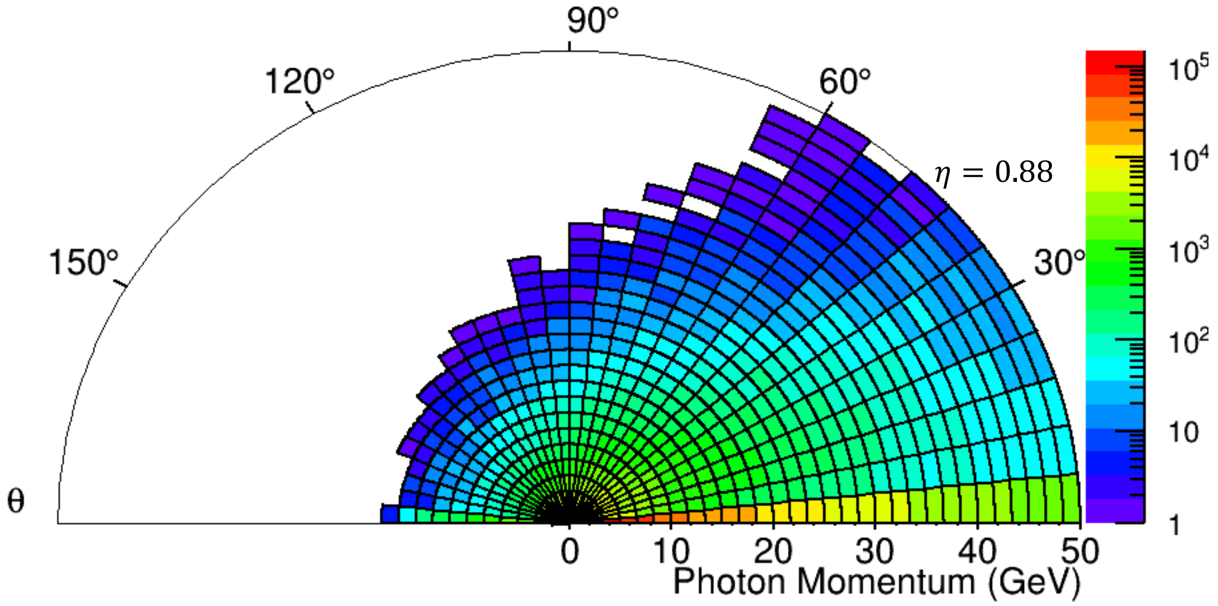




Radiative effect is significant.

Final state particles Hit Map

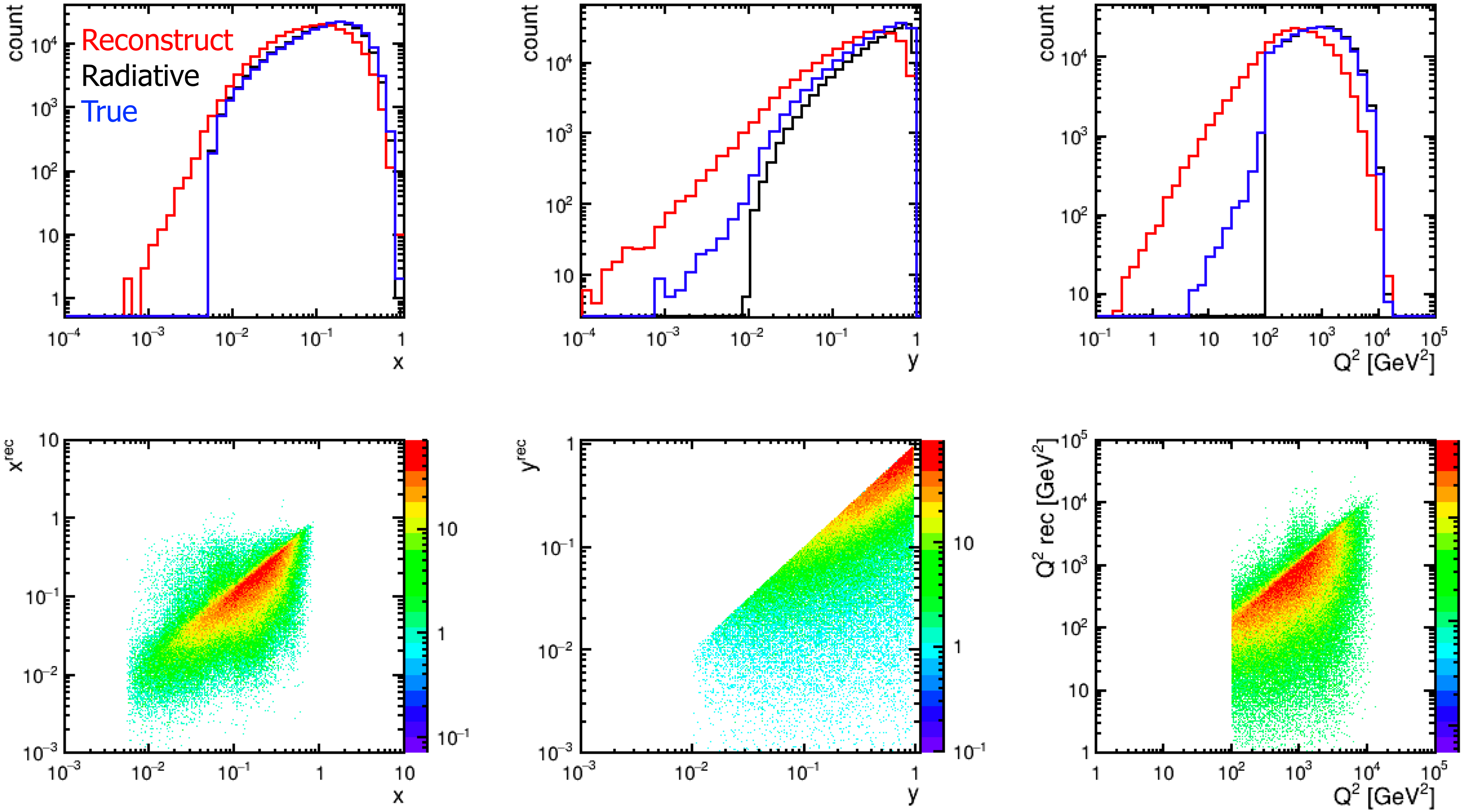




- **Final state particles are mainly detected in middle and forward direction.**
- **Very forward particles with high momentum are produced from proton beam remnant.**

PID impact: final hadrons with full acceptance

$$x^{rec} = \frac{Q^2_{JB}}{s y_{JB}}; \quad y^{rec} = \frac{(E - p_z)_h}{2E_e}; \quad recQ^2 = \frac{p^2_{t,h}}{1 - y_{JB}}$$



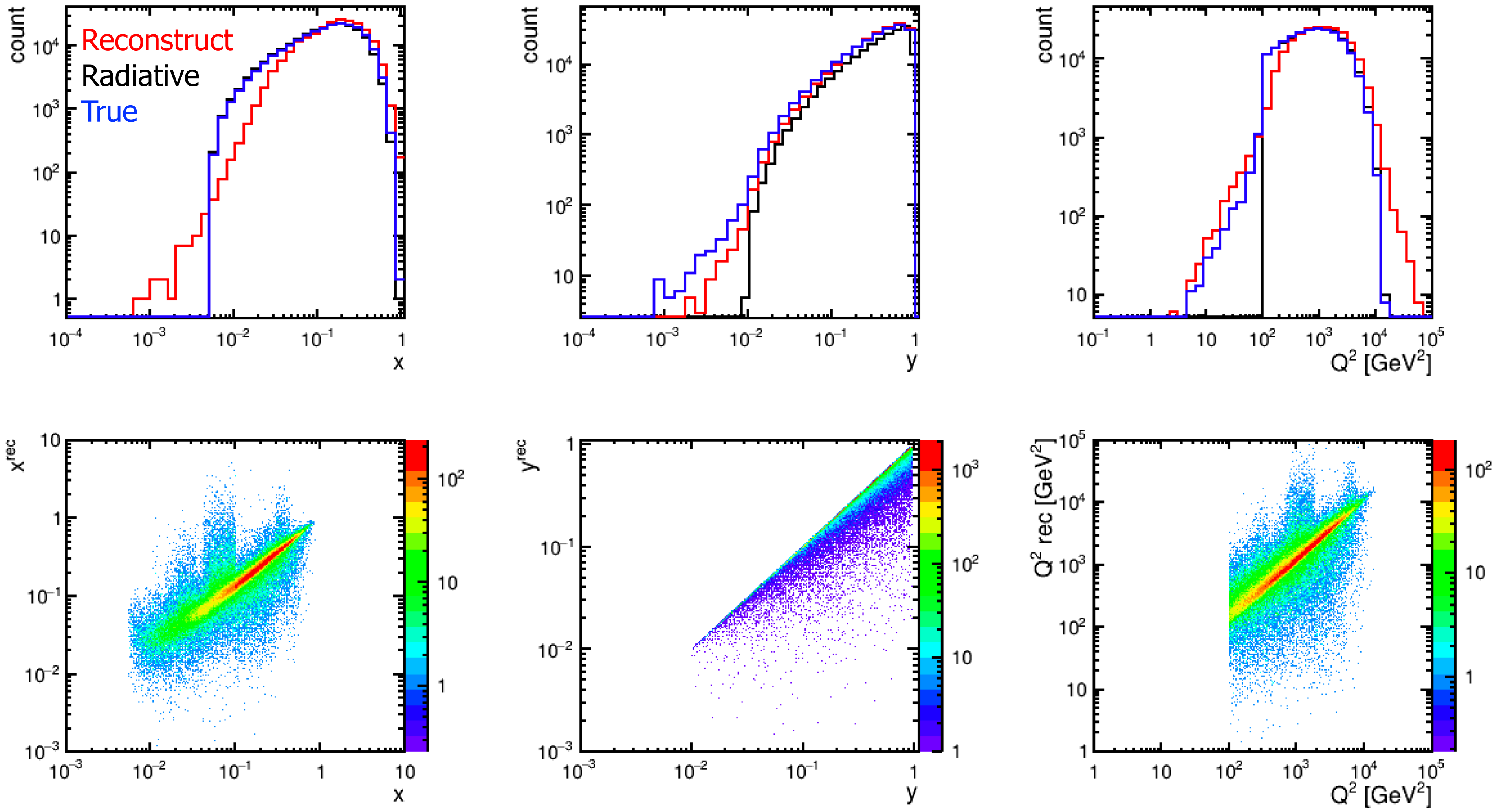
$$p^2_{t,h} = \left(\sum_h p_{x,h}\right)^2 + \left(\sum_h p_{y,h}\right)^2$$

$$(E - p_z)_h = \sum_h \left(E_h - p_{z,h}\right)$$

y^{rec} is smaller, due to losing contribution from not detected particles.

PID impact: photons included

$$x^{rec} = \frac{Q^2_{JB}}{s y_{JB}}; \quad y^{rec} = \frac{(E - p_z)_h}{2E_e}; \quad recQ^2 = \frac{p^2_{t,h}}{1 - y_{JB}}$$



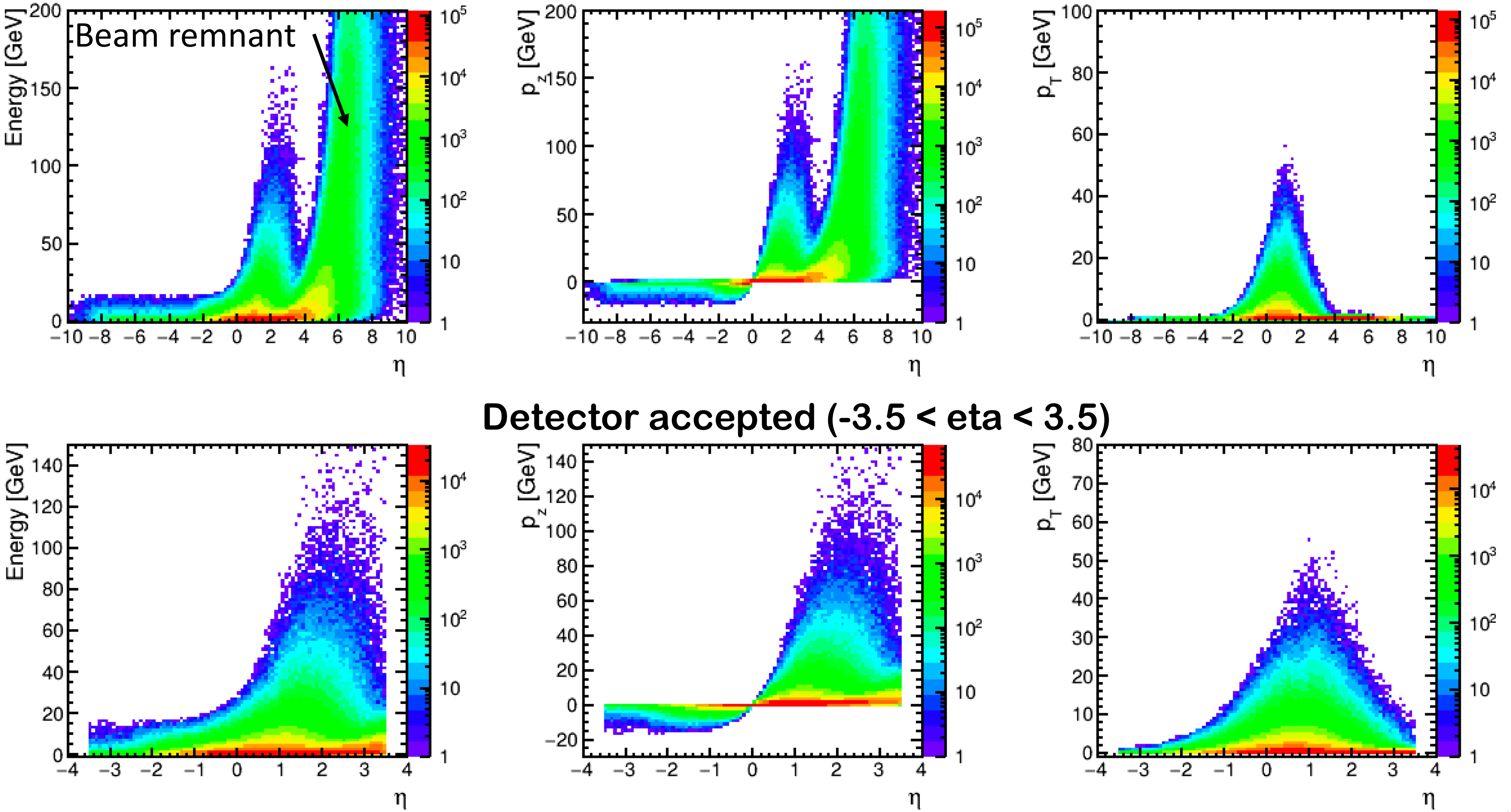
- **Final photons are important.**
- **What HERA did: https://arxiv.org/pdf/hep-ex/9606014.pdf, Sum over all EMC (HAC) cells with energy deposits above 60 MeV (110 MeV).**
- **Those energy threshold would affect the measurement too.**

Detector acceptance effect

$$x^{rec} = \frac{Q^2_{JB}}{s y_{JB}}; \quad y^{rec} = \frac{\boxed{(E - p_z)_h}}{2E_e}; \quad recQ^2 = \frac{\boxed{p^2_{t,h}}}{1 - y_{JB}}$$

Perfect detector

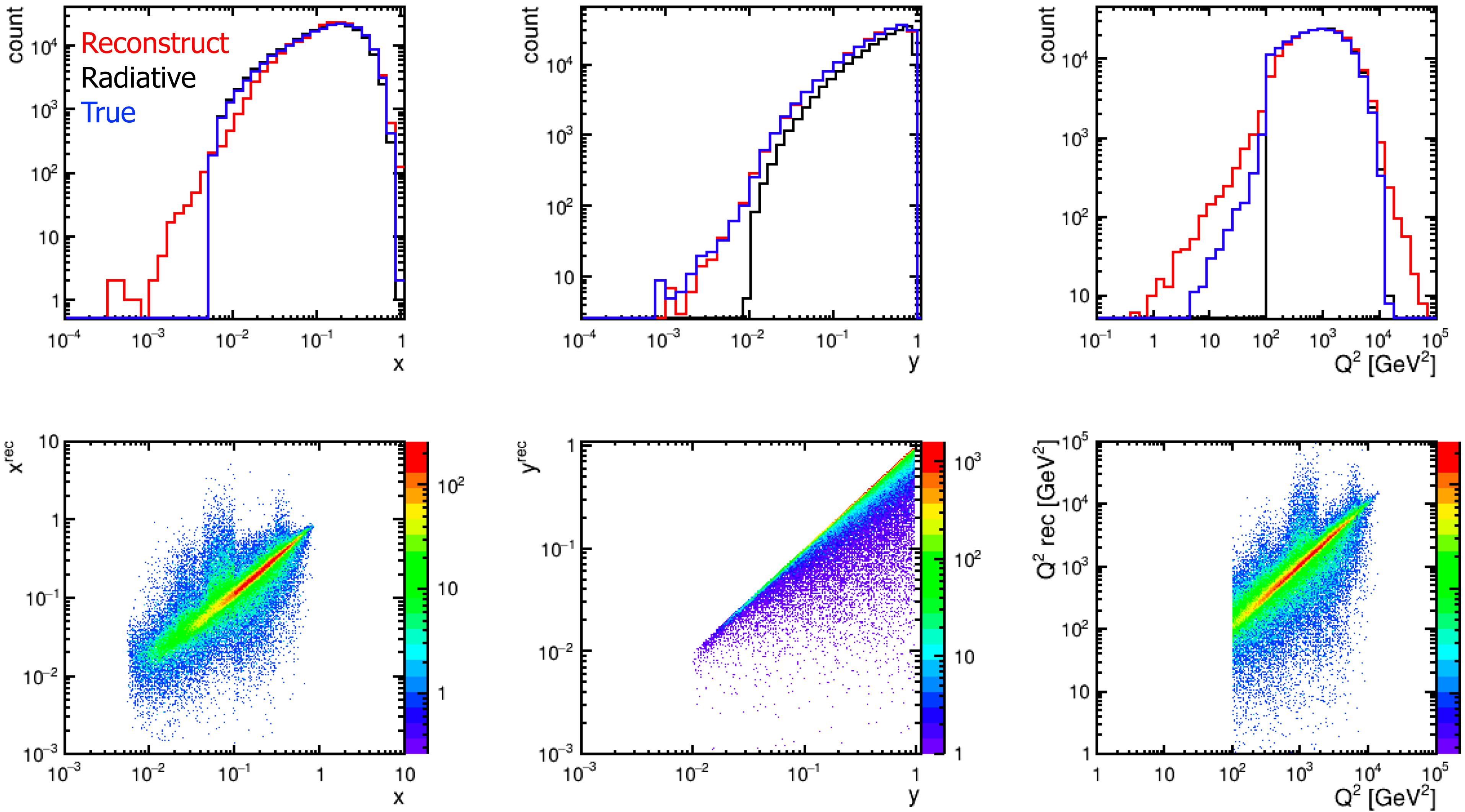
Detector accepted (-3.5 < eta < 3.5)



Detector acceptance effect on kinematics

$$x^{rec} = \frac{Q^2_{JB}}{s y_{JB}}; \quad y^{rec} = \frac{(E - p_z)_h}{2E_e}; \quad recQ^2 = \frac{p^2_{t,h}}{1 - y_{JB}}$$

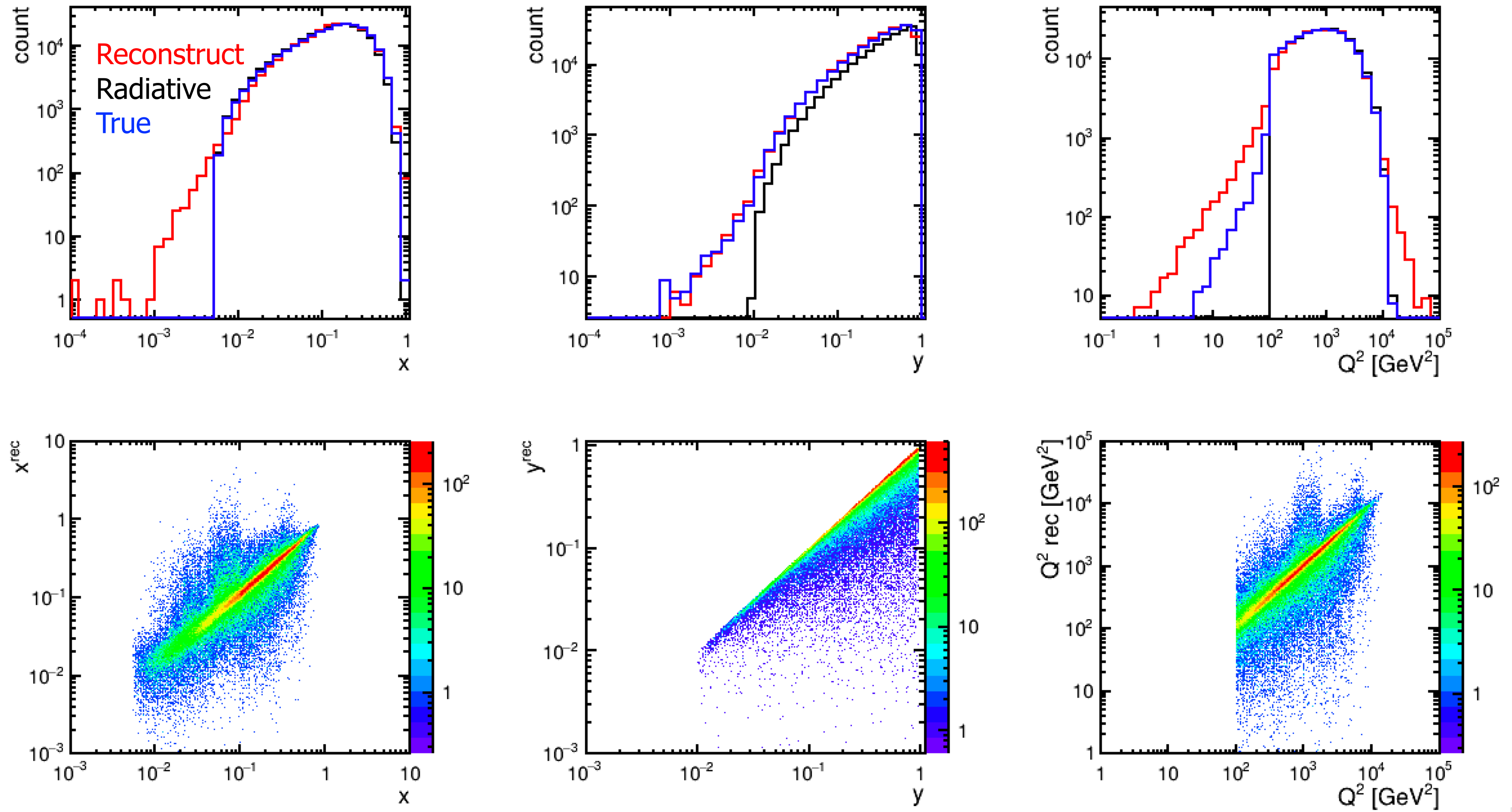
-3.5<eta<3.5



Energy threshold impact

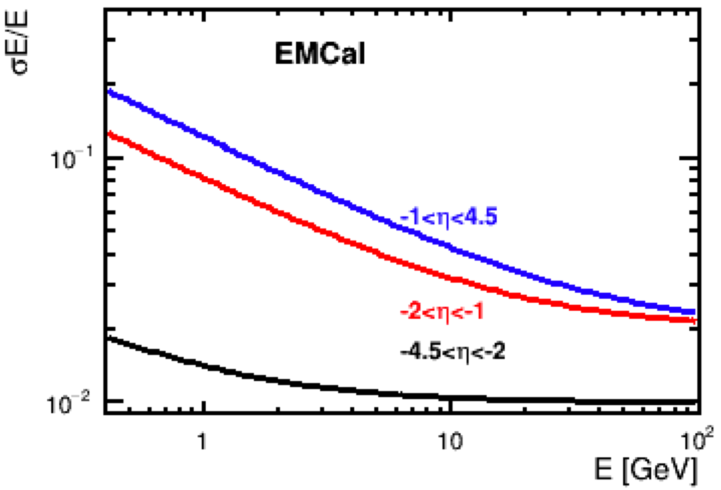
1. Photon E>100 MeV, Hadron E>250MeV, -3.5<eta<3.5
2. Photon E>250 MeV, Hadron E>500MeV, -3.5<eta<3.5, shown below.

$$x^{rec}=\frac{Q^2_{JB}}{s\,y_{JB}};\quad y^{rec}=\frac{(E-p_z)_h}{2E_e};\quad recQ^2=\frac{p^2_{t,h}}{1-y_{JB}}$$



EIC Smear: detectors smear input

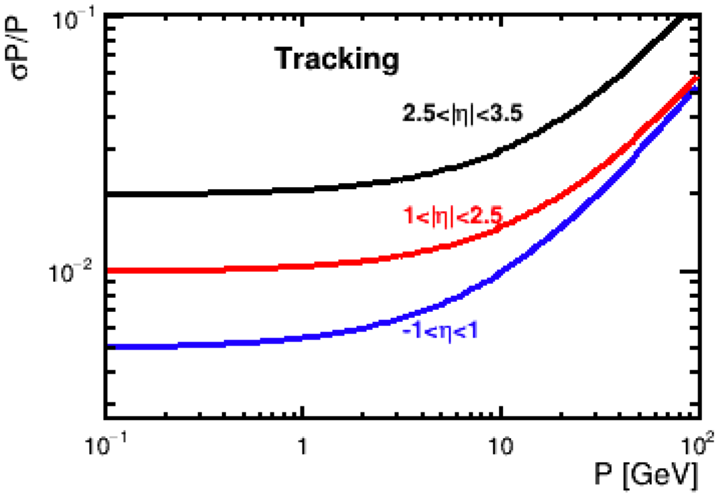
Photons



EMcal: -4.5 < eta < 4.5

eta = -4.5 – -2: sigma_E~sqrt(pow (0.01*E,2) + pow(0.01,2)*E)
eta = -2 – -1: sigma_E~ sqrt(pow (0.02*E,2) + pow(0.08,2)*E)
eta = -1 – 4.5: sigma_E~ sqrt(pow (0.02*E,2) + pow(0.12,2)*E)

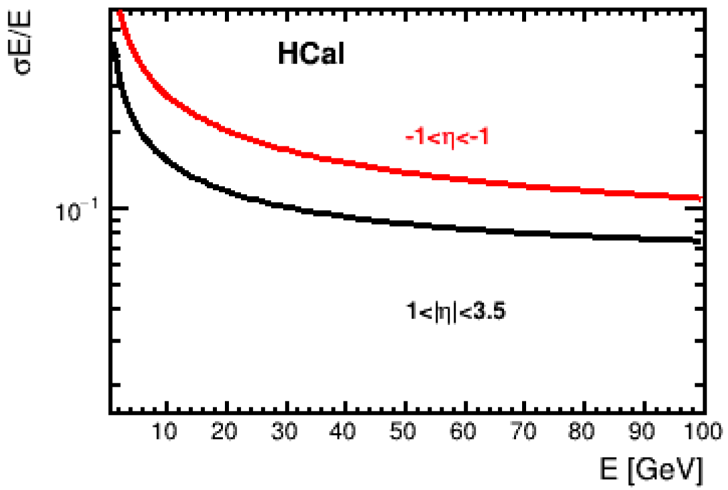
Charged hadrons



Tracking: -3.5 < eta < 3.5

eta = -3.5 – -2.5: sigma_p/p ~ 0.1% p+2.0%
eta = -2.5 – -1: sigma_p/p ~ 0.05% p+1.0%
eta = -1 – +1: sigma_p/p ~ 0.05% p+0.5

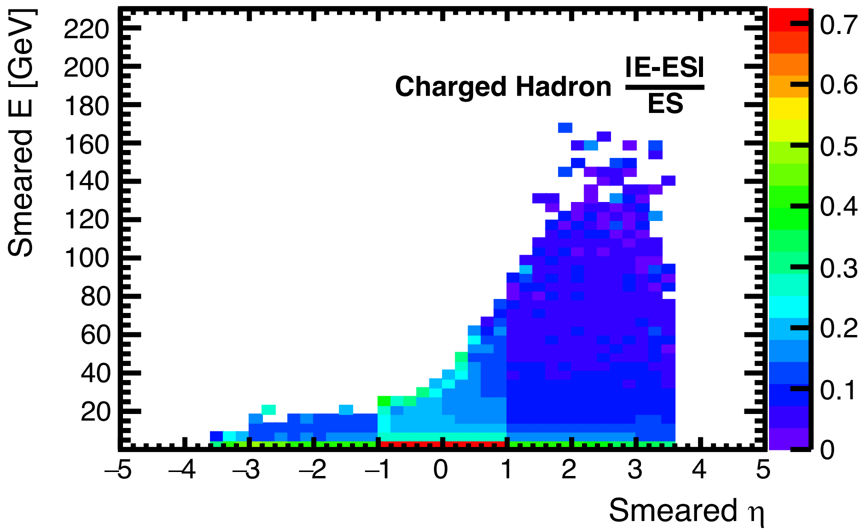
Charged hadrons+neutrons

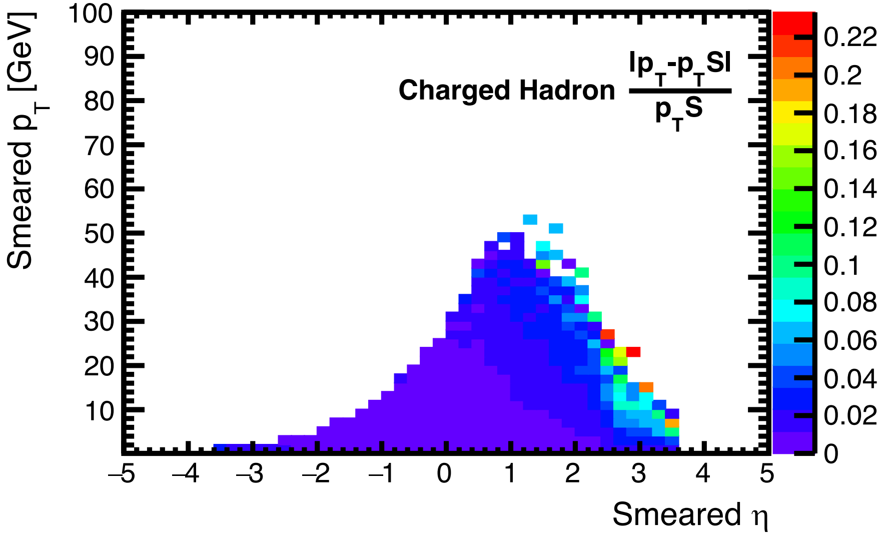


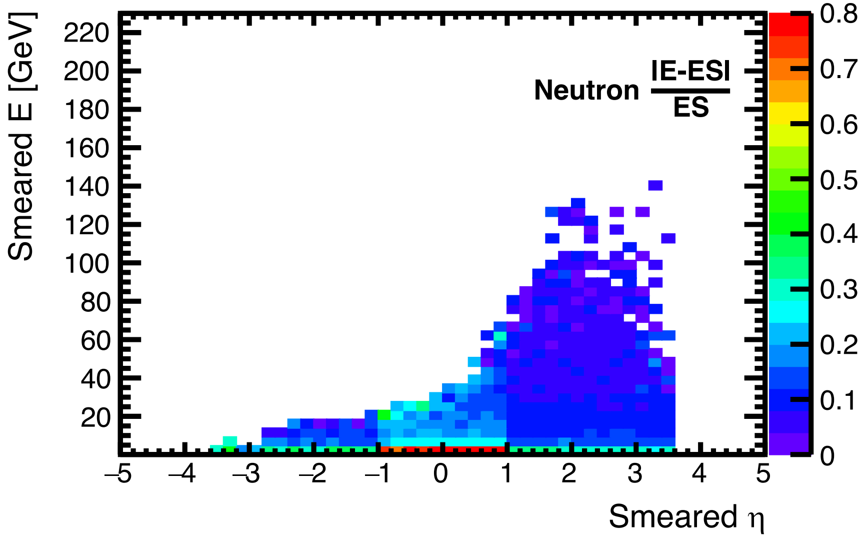
Hcal is -3.5 < eta < 3.5

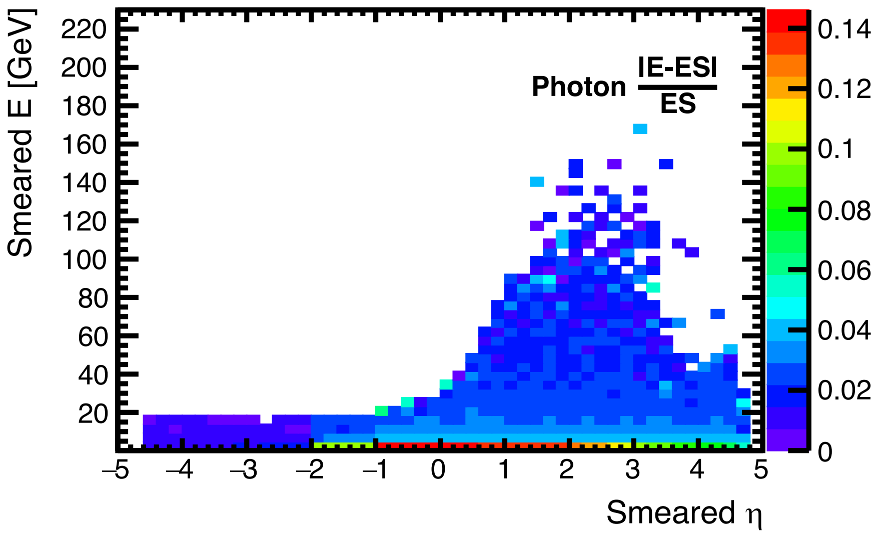
eta = -3.5 – -1: sigma_E ~sqrt(pow(0.06*E, 2) + pow (0.45,2) *E
eta = -1 – 1: sigma_E ~ sqrt(pow(0.07*E, 2) + pow(0.85, 2)*E)

Resolution map



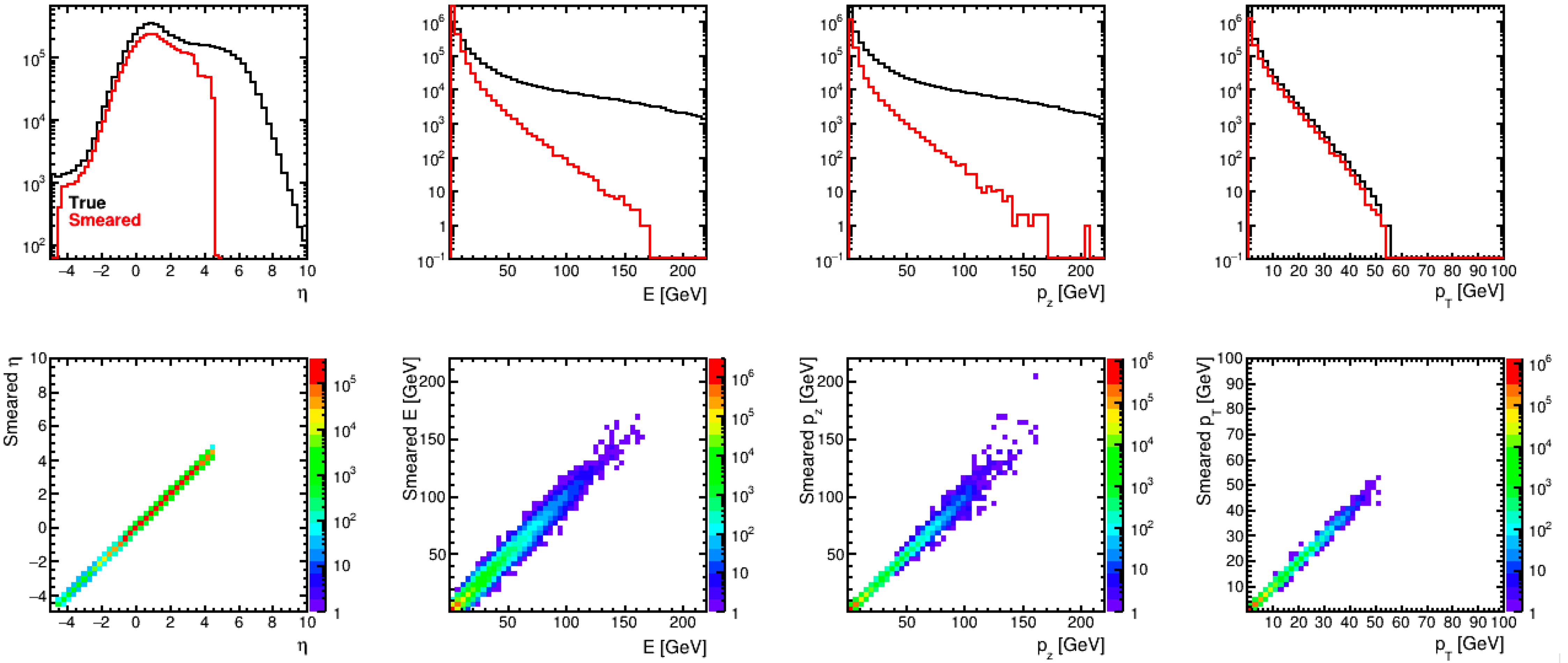






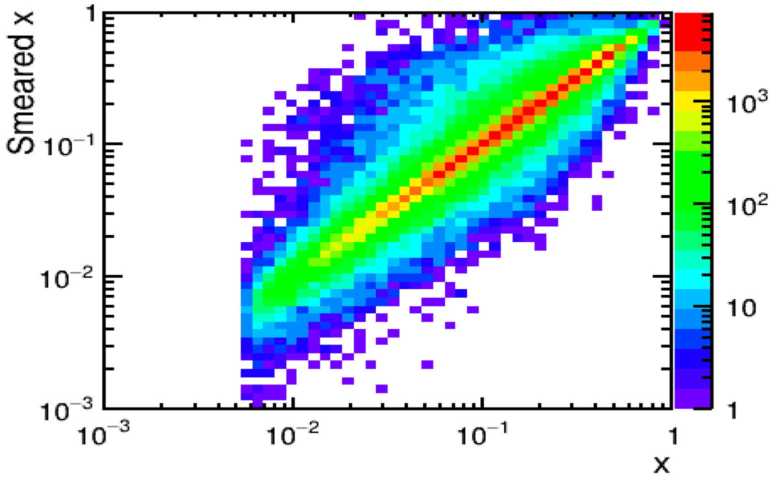
EIC Smear: final particles kinematics

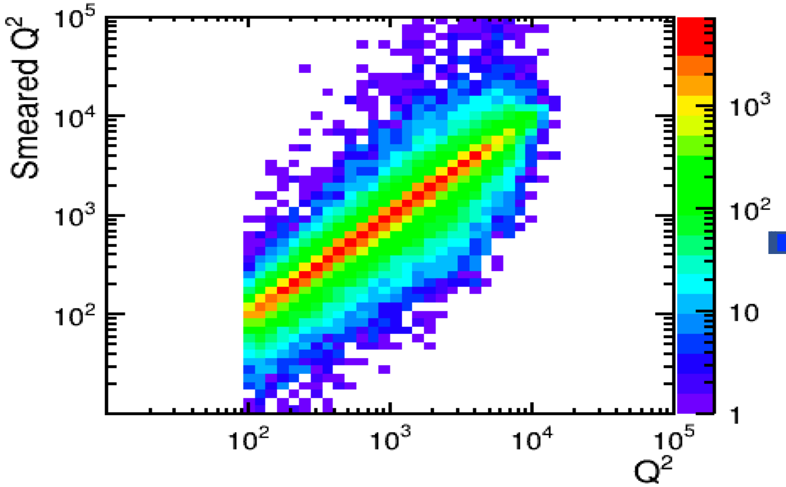
$$x^{rec} = \frac{Q^2_{JB}}{s y_{JB}}; \quad y^{rec} = \frac{(E - p_z)_h}{2E_e}; \quad recQ^2 = \frac{p^2_{t,h}}{1 - y_{JB}}$$

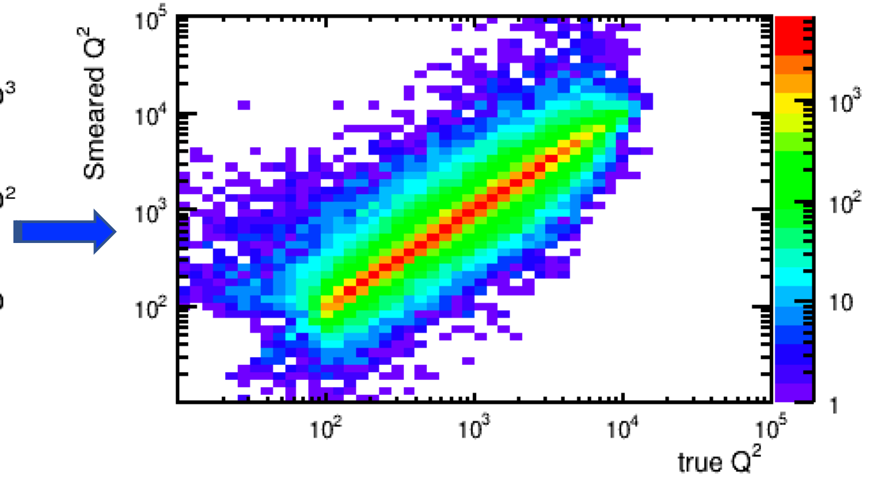


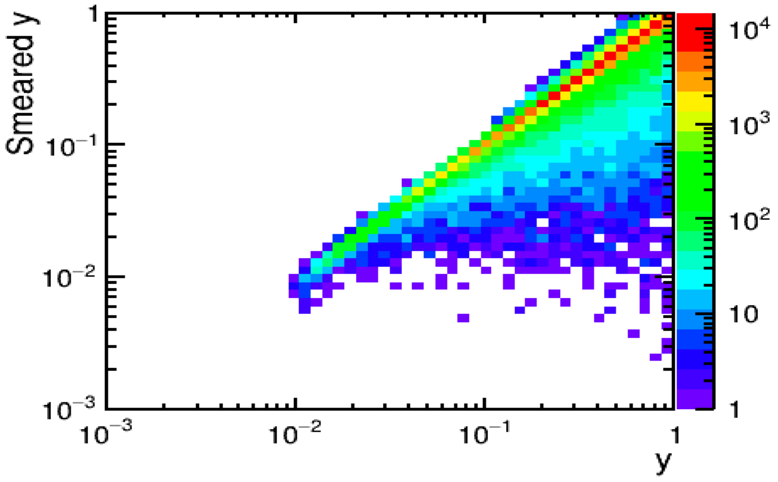
Smeared final particles kinematics: all final photon, pion, proton, neutron and kaon are included.

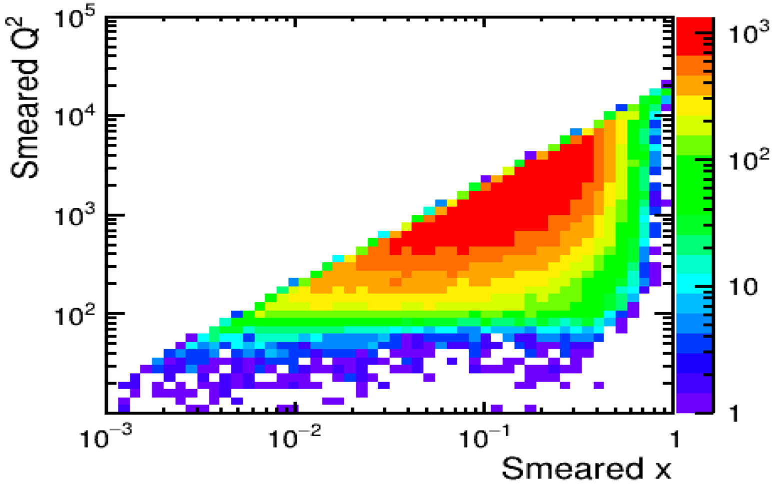
Smeared kinematics











- **Smear effect: Correlations between the reconstructed kinematic variables including detector and radiative effects and the radiative level.**
- **Smear+Radiative effect: Correlations between the reconstructed Q^2 the trueQ^2.**

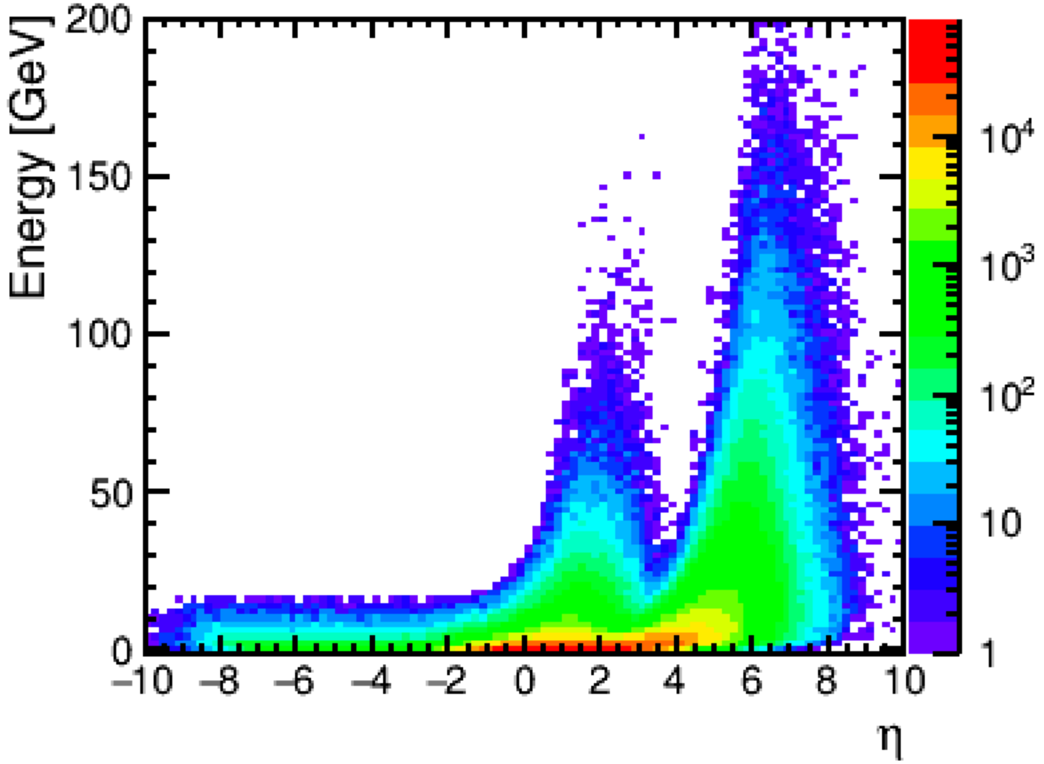
Summary

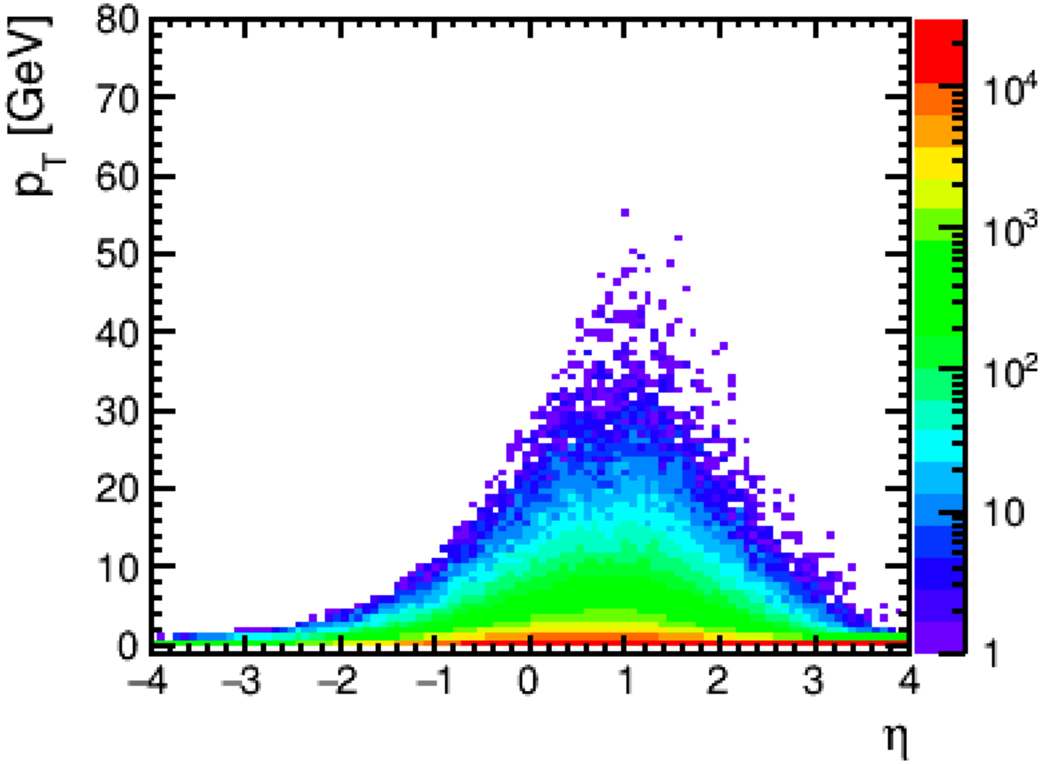
Charged current channel: final hadronic state

1. EIC CC data at true level can improve U constraint at large x.
2. Significant Radiative effect is required to be corrected in impact study.
3. PID requirement: detection of final state charged hadrons, neutrons, photons is required in reconstructing kinematics.
4. Energy resolution: E hadron>500 MeV, E photon>250 MeV.
5. Detector acceptance is studied.
6. EIC-smear study is on-going.

- Back up

Final state photons

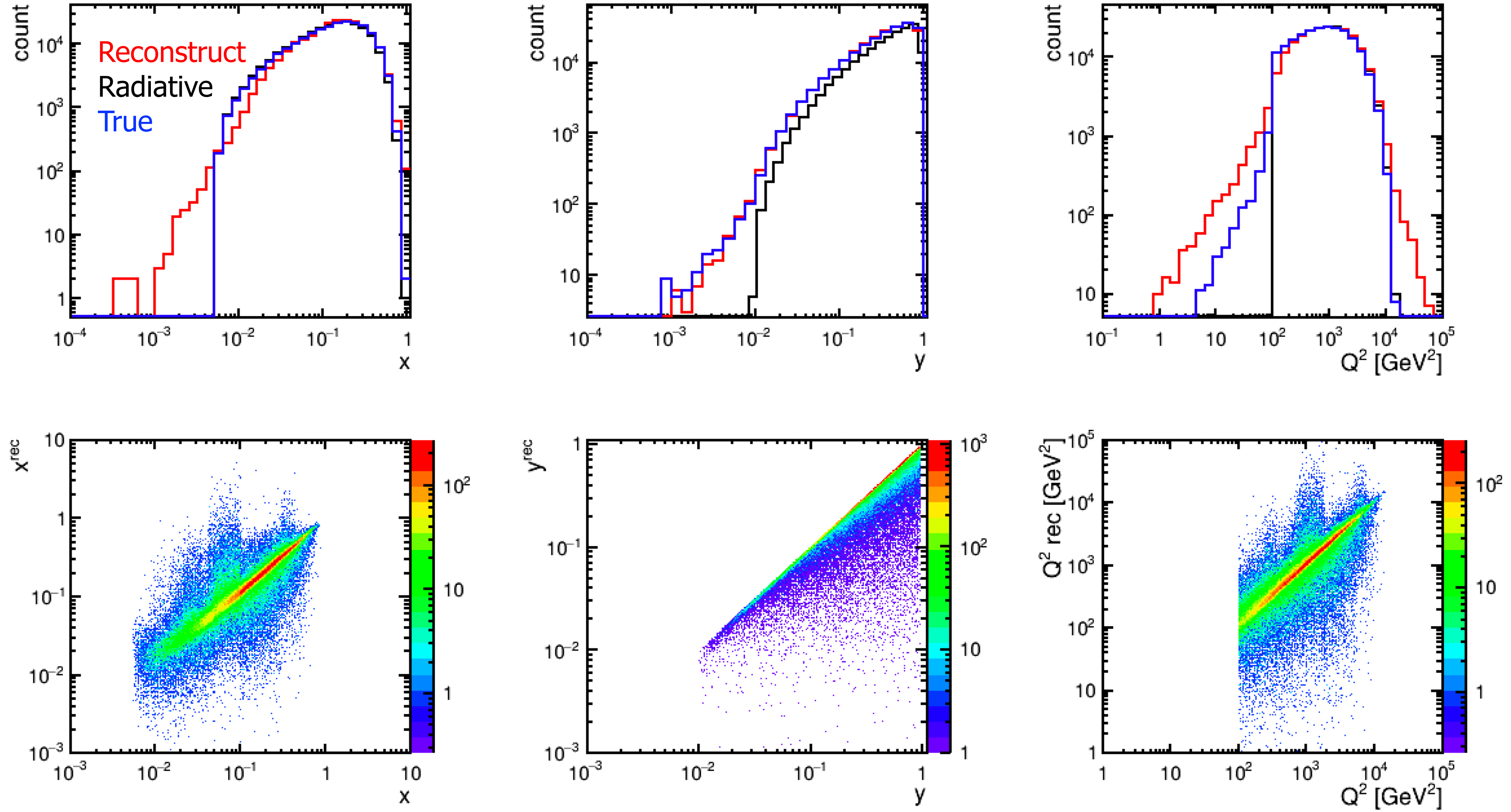




Energy threshold impact (1):

EMcal E>100 MeV, Hcal E>250MeV, -3.5<eta<3.5

$$x^{rec} = \frac{Q^2_{JB}}{s y_{JB}}; \quad y^{rec} = \frac{(E-p_z)_h}{2E_e}; \quad recQ^2 = \frac{p^2_{t,h}}{1-y_{JB}}$$

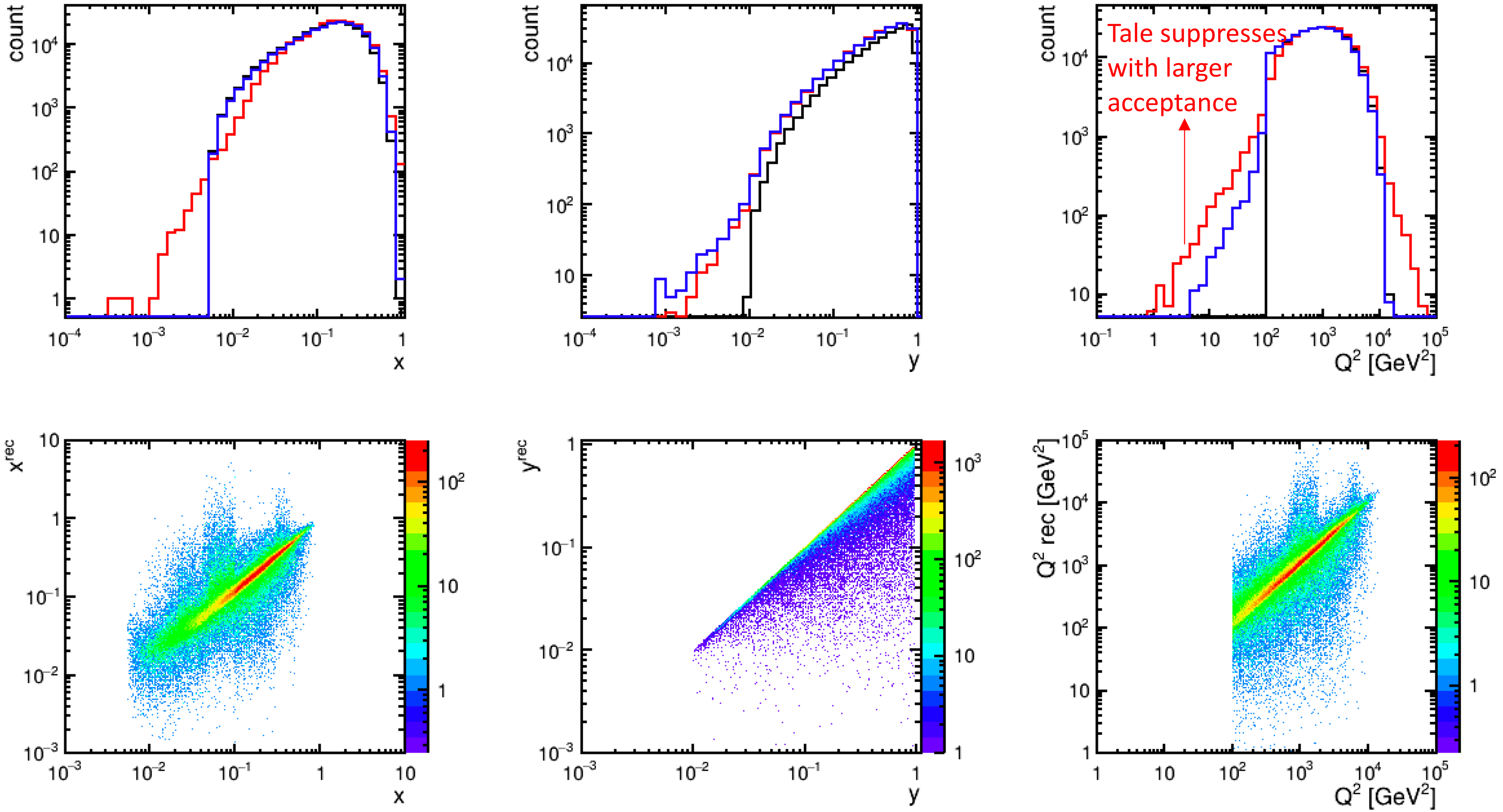


Detector acceptance effect on kine

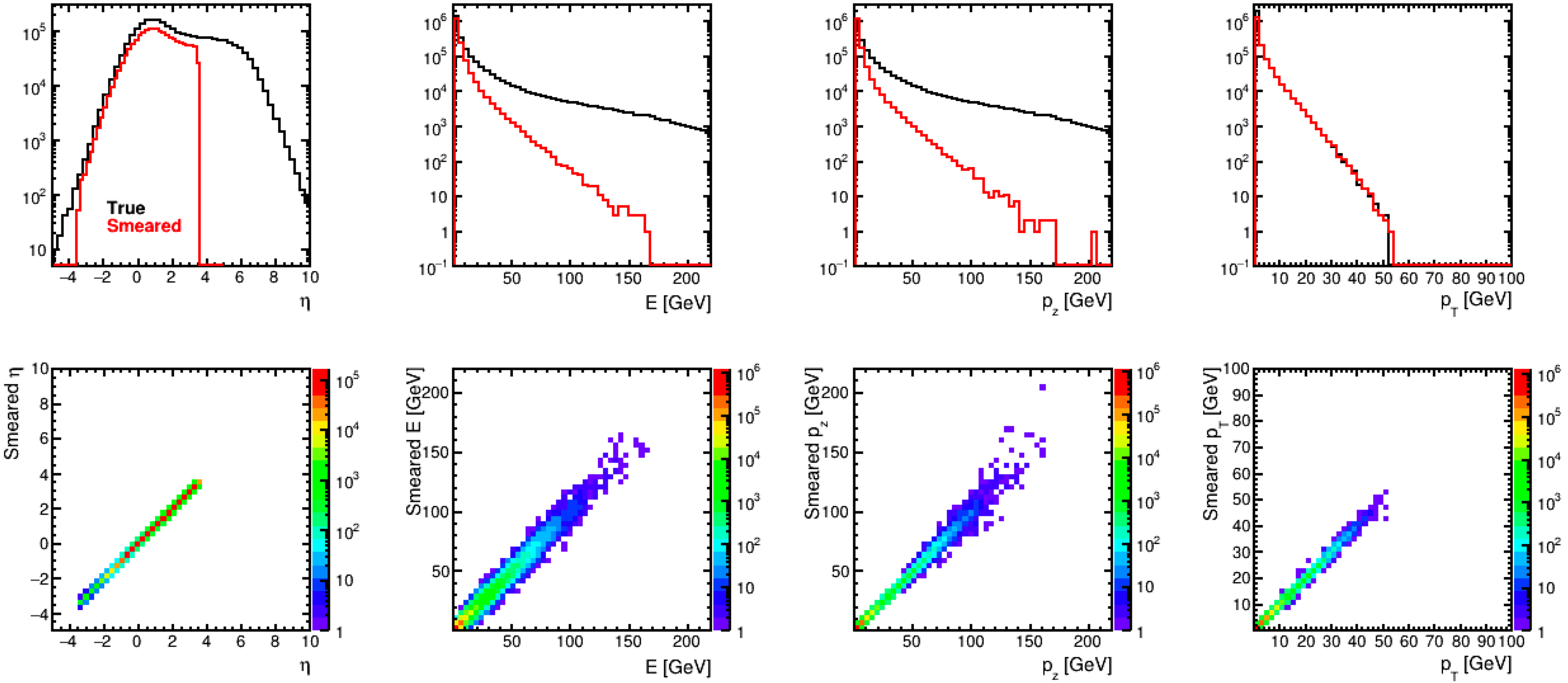
$$x^{rec} = \frac{Q^2_{JB}}{s y_{JB}}; \quad y^{rec} = \frac{(E - p_z)_h}{2E_e}; \quad recQ^2 = \frac{p^2_{t,h}}{1 - y_{JB}}$$

Detector accepted: all final photon, pion, proton, neutron are included, -4<eta<4

True level, radiative



EIC Smear: final charged hadron kinematics



Smeared final particles kinematics: **all final pion, proton and kaon are included.**