PID PERFORMANCE AT EPIC

Lorenzo Polizzi – University and INFN of Ferrara

DIS2026 | WG6 | Flash talk

Work-in-progress study of detector performance in multi-dimensional Semi-Inclusive DIS for the ePIC pre-TDR.

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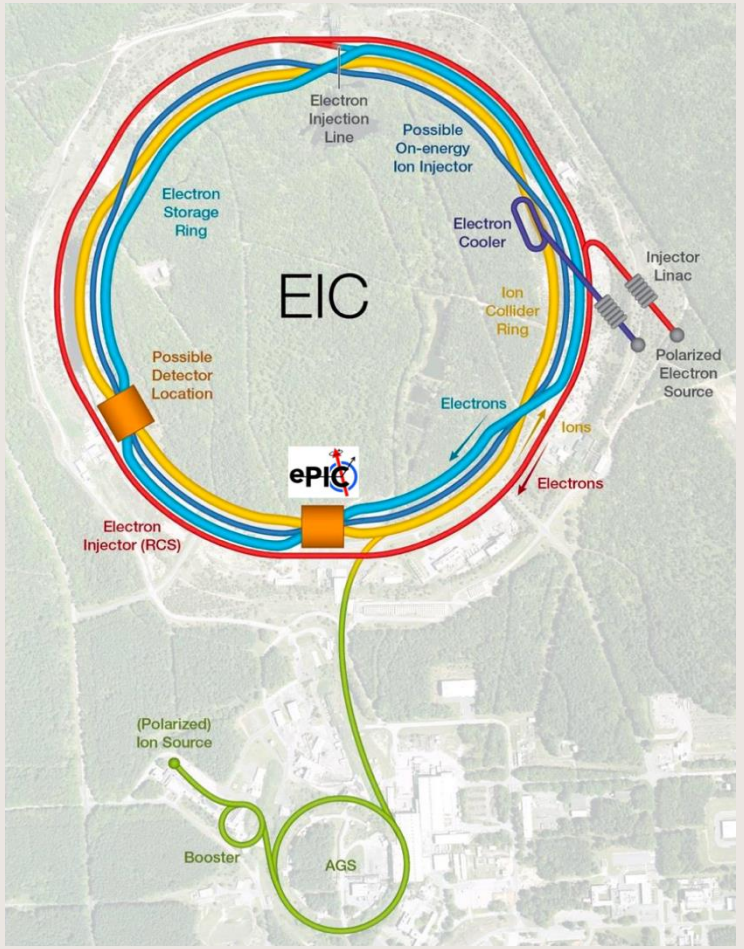
EIC AND EPIC EXPERIMENT

The **Electron-Ion Collider** (EIC) is the future collider that will take place at the **Brookhaven National Laboratory** (BNL).

It will be the first of its kind:

- Highly polarized beam: $\sim 70\%$ $(e^-, p,\ ion)$.
- CME: $\sim 28 - 140$ GeV.
- Luminosity: $\sim 10^{33-34} cm^{-2} s^{-1}$.
- ePIC will be the first detector of the experiment.
- Plans to be operative in the early 2030s.



EIC AND EPIC KEY POINT

- **Untangle the Proton Spin Puzzle**

  Disentangle the contributions of quark spin, gluon spin, and orbital angular momentum to the proton spin.

- **Origin of the Proton Mass**

  Probe the role of the QCD trace anomaly in mass generation. Exclusive processes will access the underlying gluonic structure.

- **3D Imaging of the Nucleon Structure**

  Multidimensional mapping of quarks and gluons: spatial distributions, momentum distributions, and spin–momentum correlations.

- **Appearance of Hadronic Matter**

  How confined hadrons arise to understand the transition from partonic to hadronic regime.

- **Gluon Saturation and High-Density QCD**

  Explore the non-linear QCD regime and the onset of gluon saturation at small Bjorken-x.

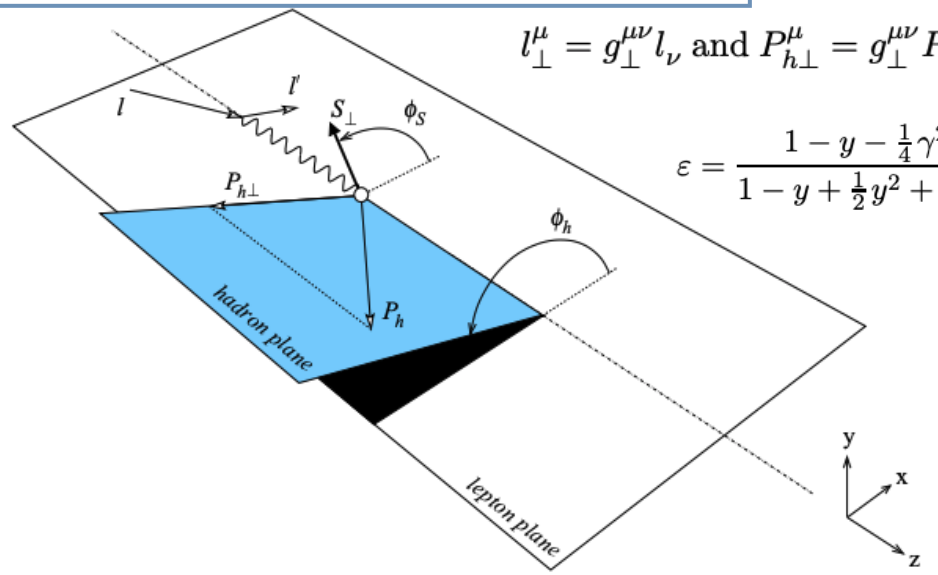
SIDIS CROSS-SECTION

$$\ell(l) + N(P) \to \ell(l') + h(P_h) + X,$$

$$q = l - l'$$

$$Q^2 = -q^2$$

$$x = \frac{Q^2}{2\,P\cdot q}, \qquad y = \frac{P\cdot q}{P\cdot l}, \qquad z = \frac{P\cdot P_h}{P\cdot q}, \qquad \gamma = \frac{2Mx}{Q}.$$



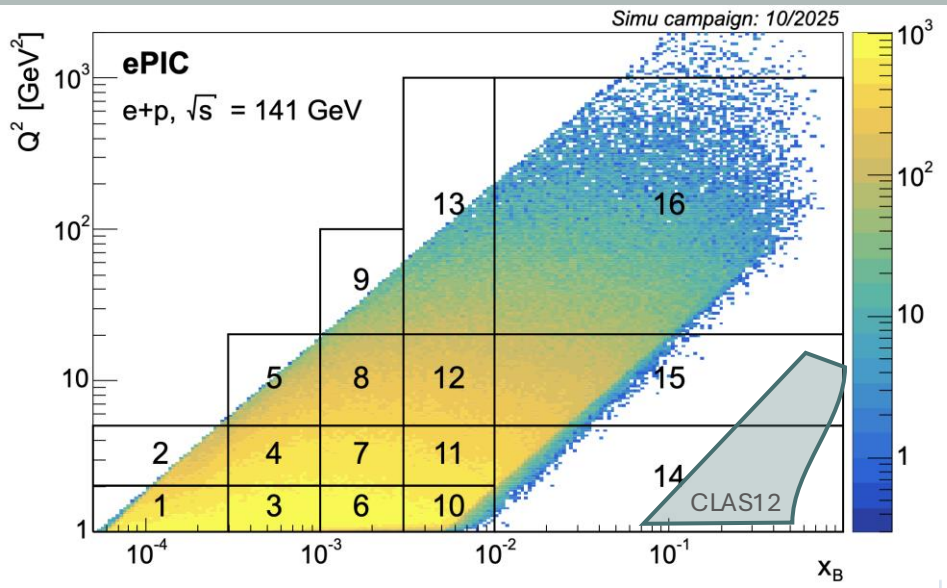
$$l^\mu_\perp = g^{\mu\nu}_\perp l_\nu \text{ and } P^\mu_{h\perp} = g^{\mu\nu}_\perp P_{h\nu}$$

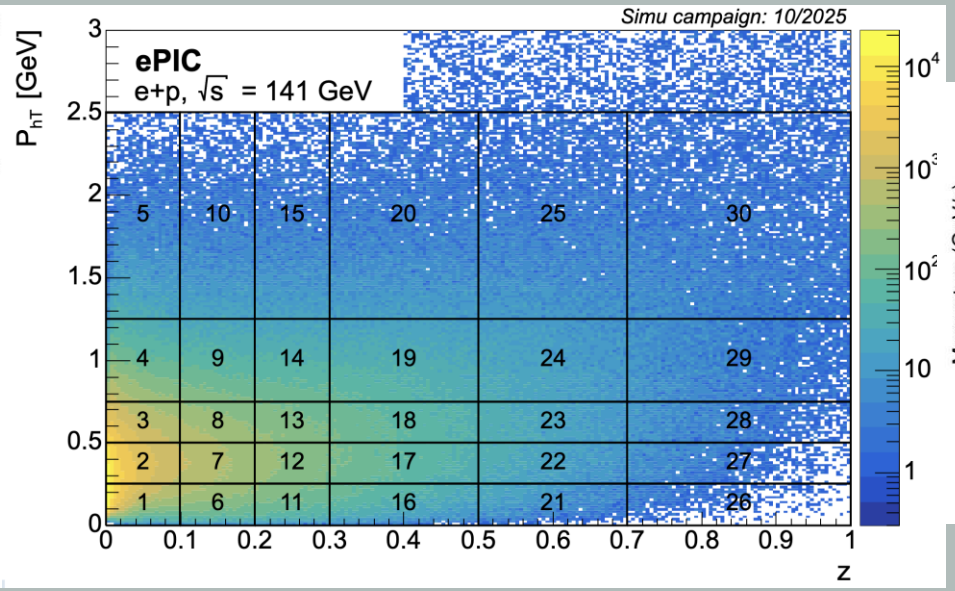
$$\varepsilon = \frac{1 - y - \frac{1}{4}\gamma^2 y^2}{1 - y + \frac{1}{2}y^2 + \frac{1}{4}\gamma^2 y^2},$$

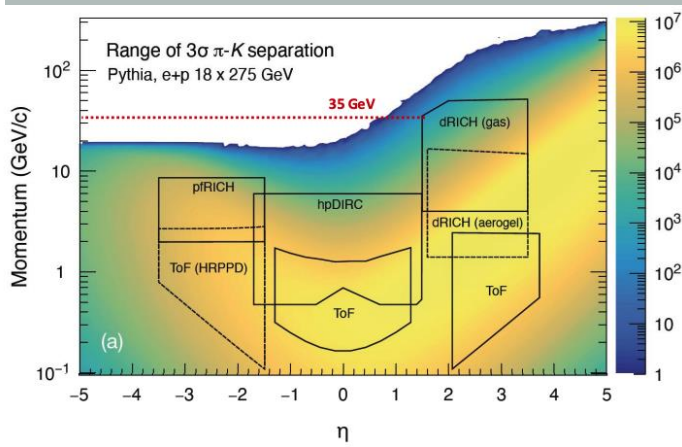
$$\begin{aligned}
\frac{d\sigma}{dx\,dy\,d\psi\,dz\,d\phi_h\,dP_{h\perp}^2} = {} & \\
& \frac{\alpha^2}{xyQ^2}\,\frac{y^2}{2\,(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\Big\{F_{UU,T} + \varepsilon F_{UU,L} + \sqrt{2\,\varepsilon(1+\varepsilon)}\,\cos\phi_h\,F_{UU}^{\cos\phi_h} \\
& + \varepsilon\cos(2\phi_h)\,F_{UU}^{\cos 2\phi_h} + \lambda_e\sqrt{2\,\varepsilon(1-\varepsilon)}\,\sin\phi_h\,F_{LU}^{\sin\phi_h} \\
& + S_\parallel\left[\sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin\phi_h\,F_{UL}^{\sin\phi_h} + \varepsilon\sin(2\phi_h)\,F_{UL}^{\sin 2\phi_h}\right] && \text{Beam-Spin Ass.} \\
& + S_\parallel\lambda_e\left[\sqrt{1-\varepsilon^2}\,F_{LL} + \sqrt{2\,\varepsilon(1-\varepsilon)}\,\cos\phi_h\,F_{LL}^{\cos\phi_h}\right] && \text{Helicity} \\
& + |\boldsymbol{S}_\perp|\Big[\sin(\phi_h-\phi_S)\left(F_{UT,T}^{\sin(\phi_h-\phi_S)} + \varepsilon\,F_{UT,L}^{\sin(\phi_h-\phi_S)}\right) && \text{Sivers} \\
& \quad + \varepsilon\,\sin(\phi_h+\phi_S)\,F_{UT}^{\sin(\phi_h+\phi_S)} + \varepsilon\,\sin(3\phi_h-\phi_S)\,F_{UT}^{\sin(3\phi_h-\phi_S)} && \text{Collins} \\
& \quad + \sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin\phi_S\,F_{UT}^{\sin\phi_S} + \sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin(2\phi_h-\phi_S)\,F_{UT}^{\sin(2\phi_h-\phi_S)}\Big] \\
& + |\boldsymbol{S}_\perp|\lambda_e\Big[\sqrt{1-\varepsilon^2}\,\cos(\phi_h-\phi_S)\,F_{LT}^{\cos(\phi_h-\phi_S)} + \sqrt{2\,\varepsilon(1-\varepsilon)}\,\cos\phi_S\,F_{LT}^{\cos\phi_S} \\
& \quad + \sqrt{2\,\varepsilon(1-\varepsilon)}\,\cos(2\phi_h-\phi_S)\,F_{LT}^{\cos(2\phi_h-\phi_S)}\Big]\Big\}, \qquad (2.7)
\end{aligned}$$

KINEMATIC REGION

SIDIS processes of $\pi^{\pm}$ and $K^{\pm}$ in the final state. The data analysed are from the 25.10.0 campaign, focusing on two different configuration: 10 × 100 GeV and **18 × 275 GeV**.

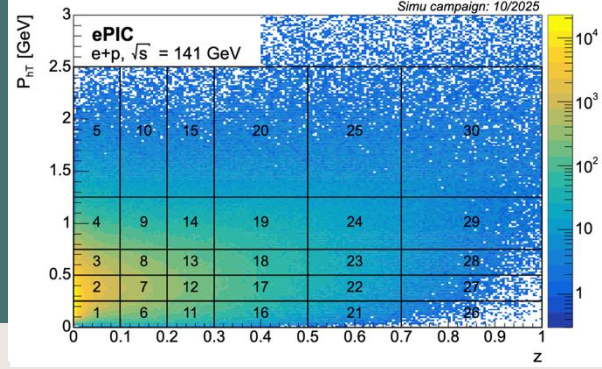




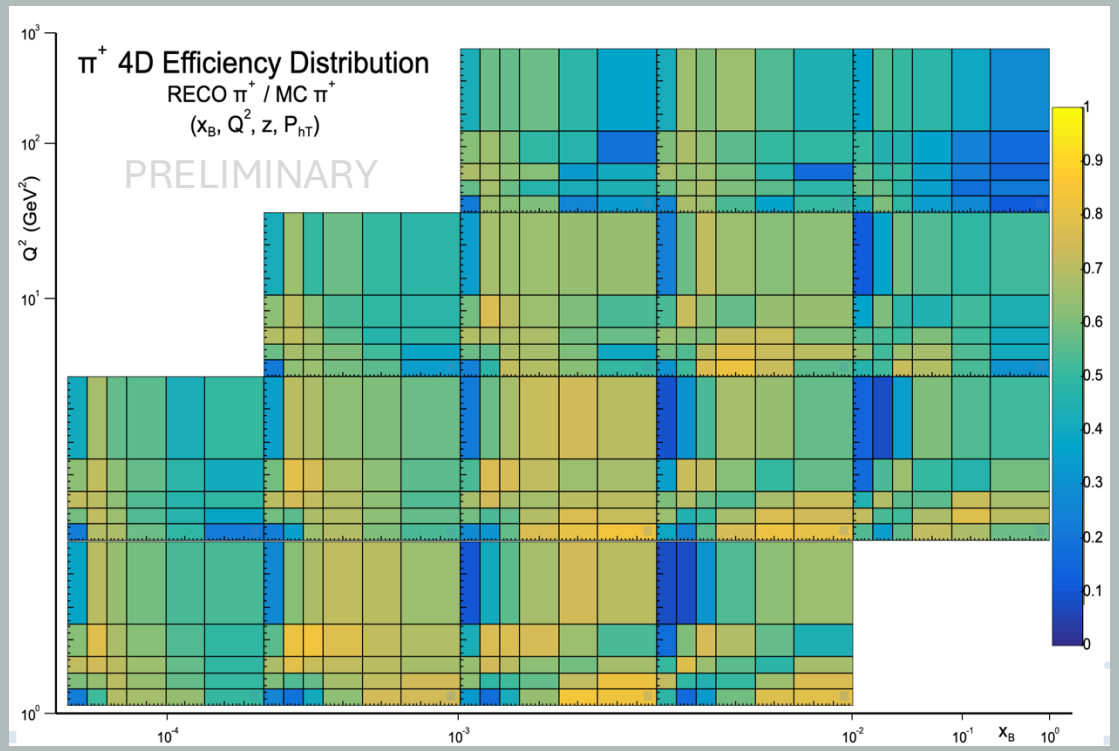


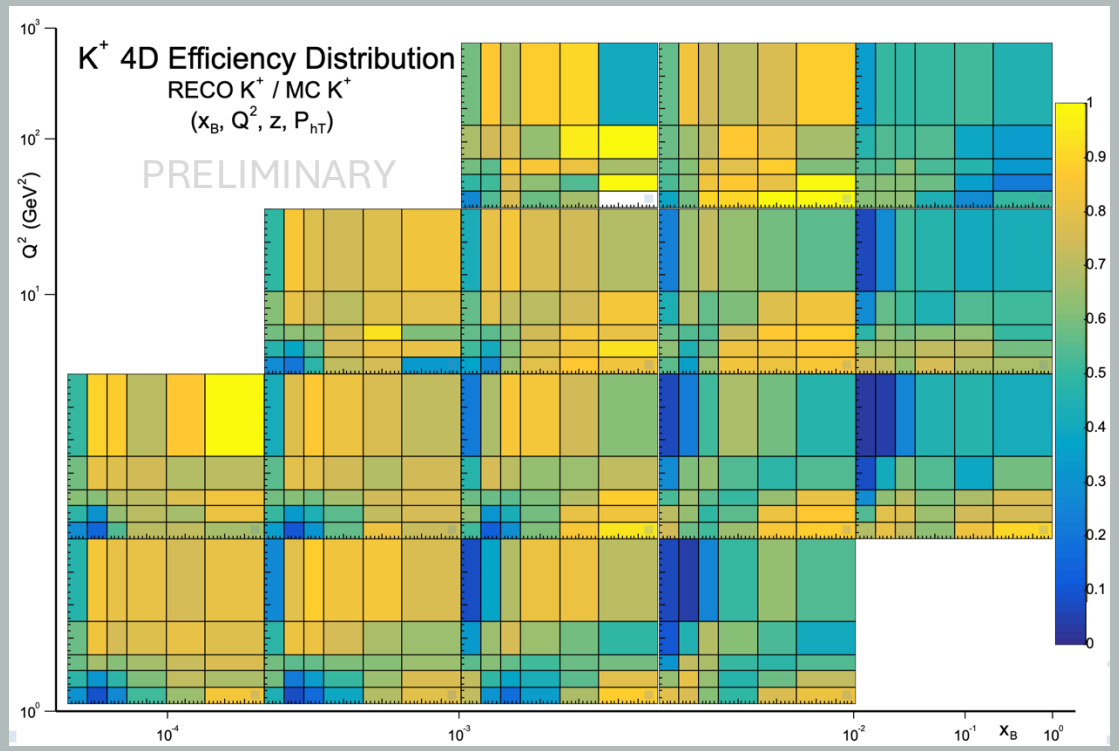
ePIC PID detector with their pseudorapidity and momentum coverage.

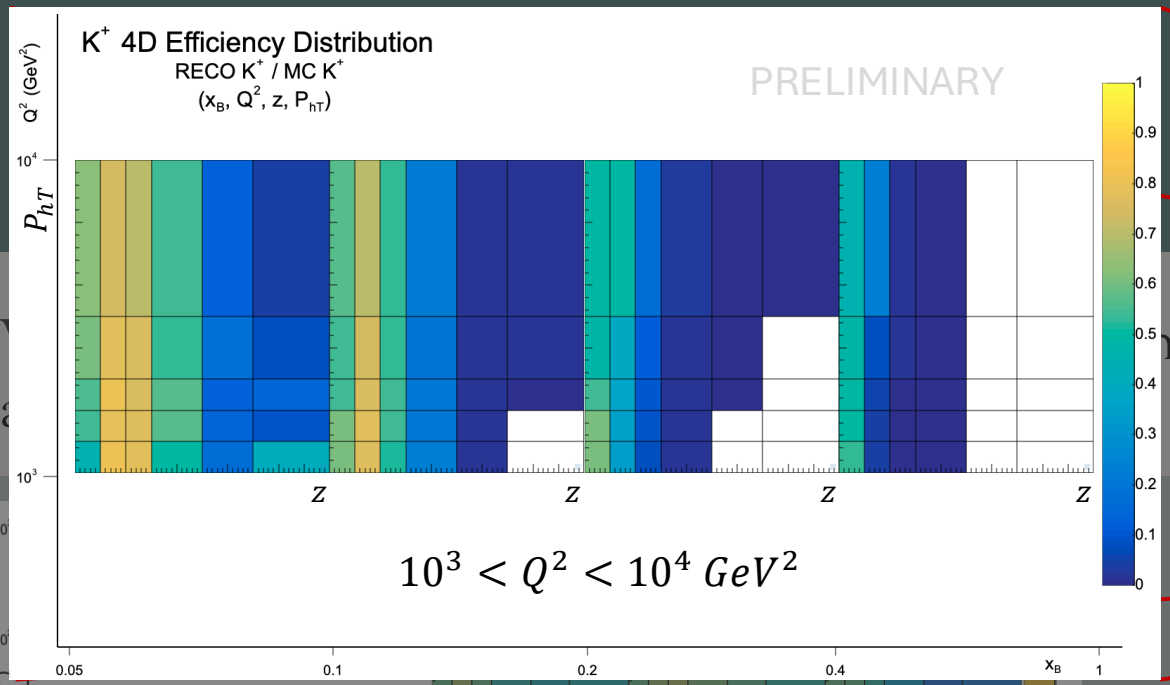
EFFICIENCY



We defined the efficiency as: $\varepsilon = h_{RECO}/h_{MC}$ using the same fiducial cut, such as $-3.5 \leq \eta \leq 3.5$ and $0.01 < y < 0.95$. Each $z - P_{hT}$ bin grid in the $x_B - Q^2$ lattice.







$10^3 < Q^2 < 10^4\ GeV^2$

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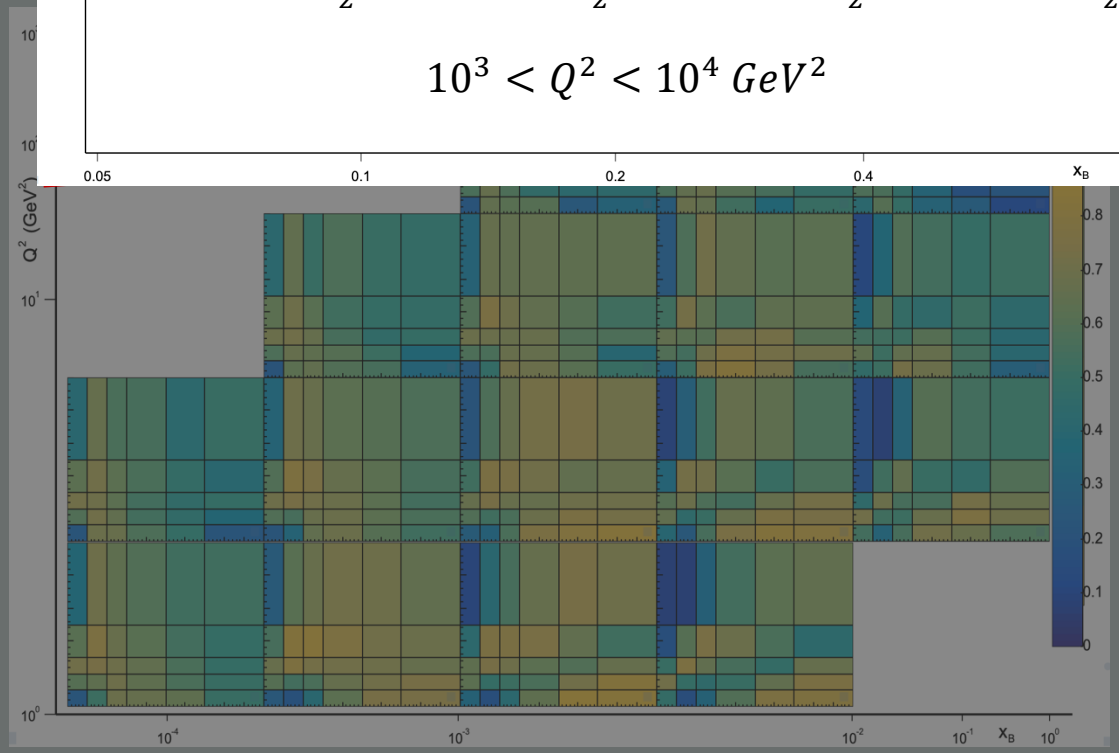
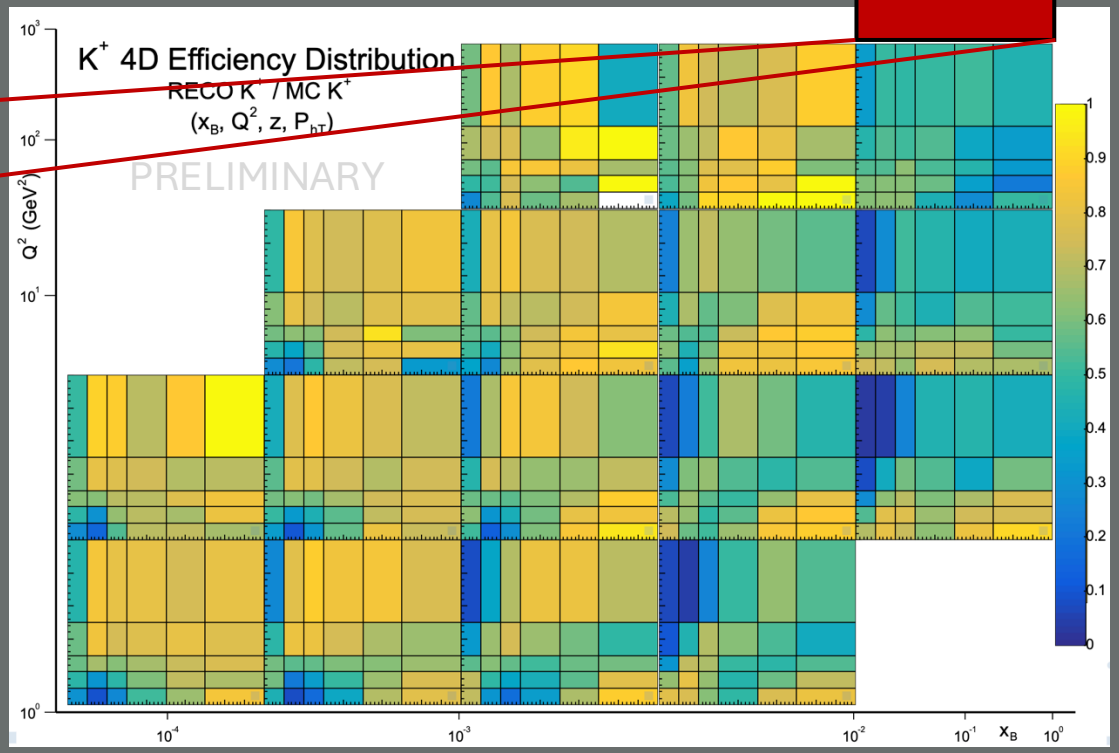
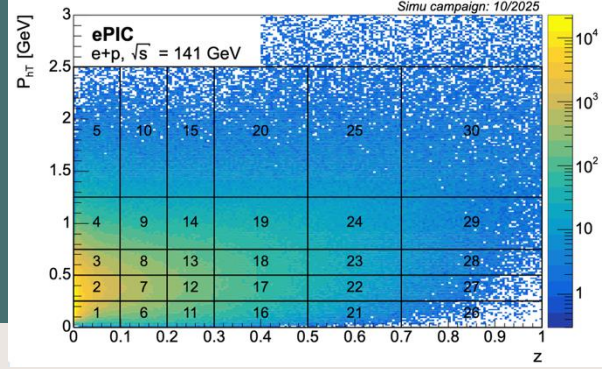
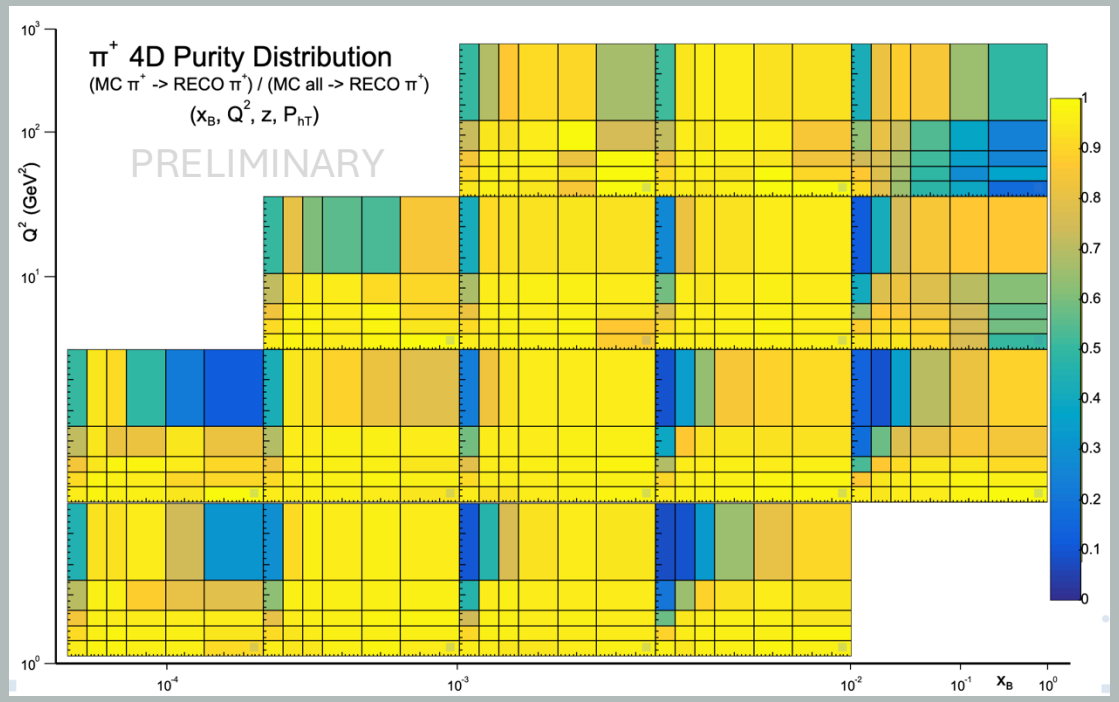


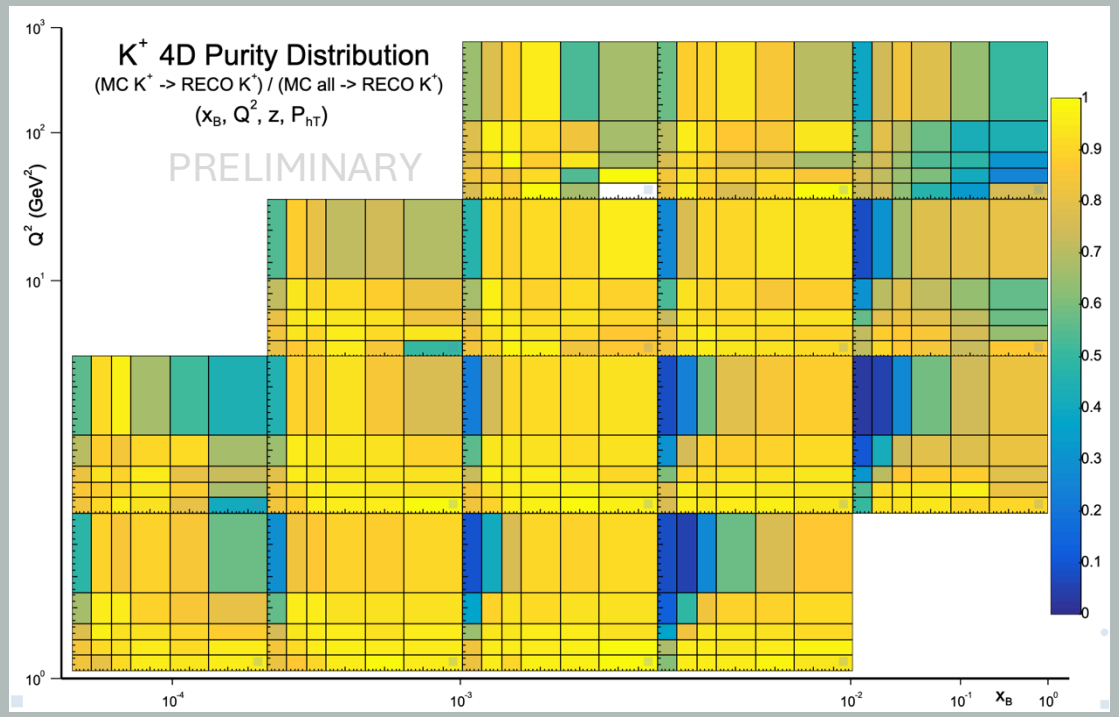


PURITY



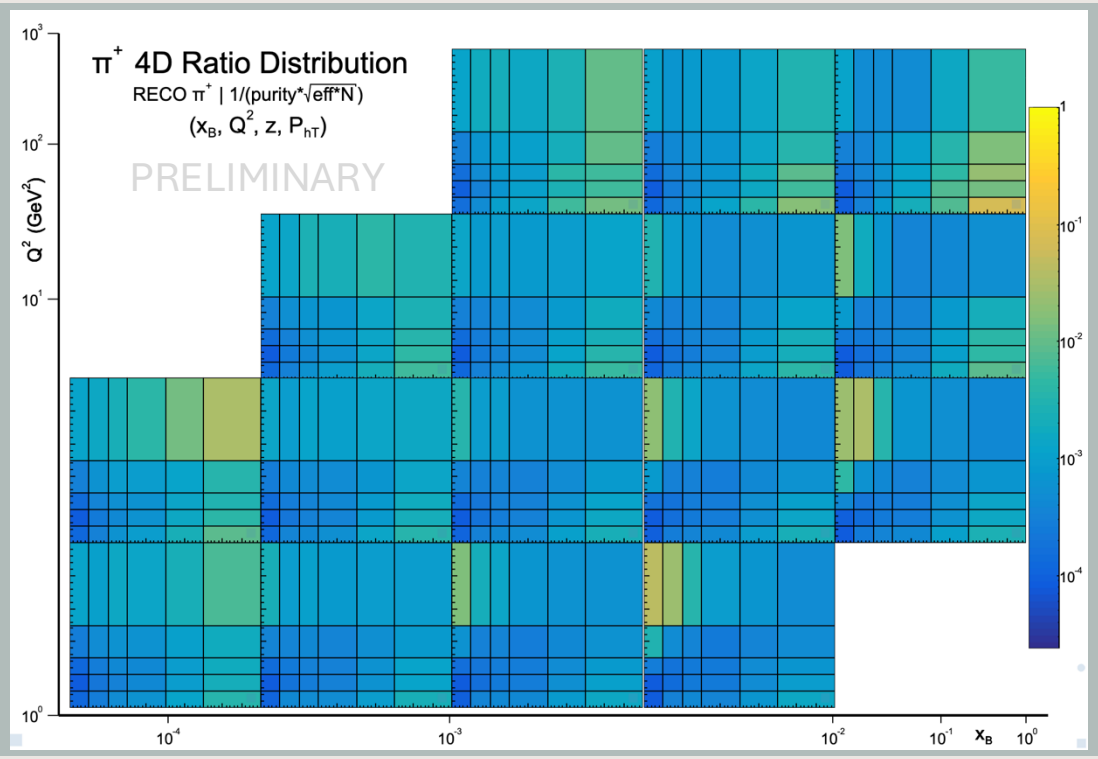
We defined the purity as: $p^{\pi^+} = N^{\pi^+ \to \pi^+}_{mc \to reco} / N^{h \to \pi^+}_{mc \to reco}$.

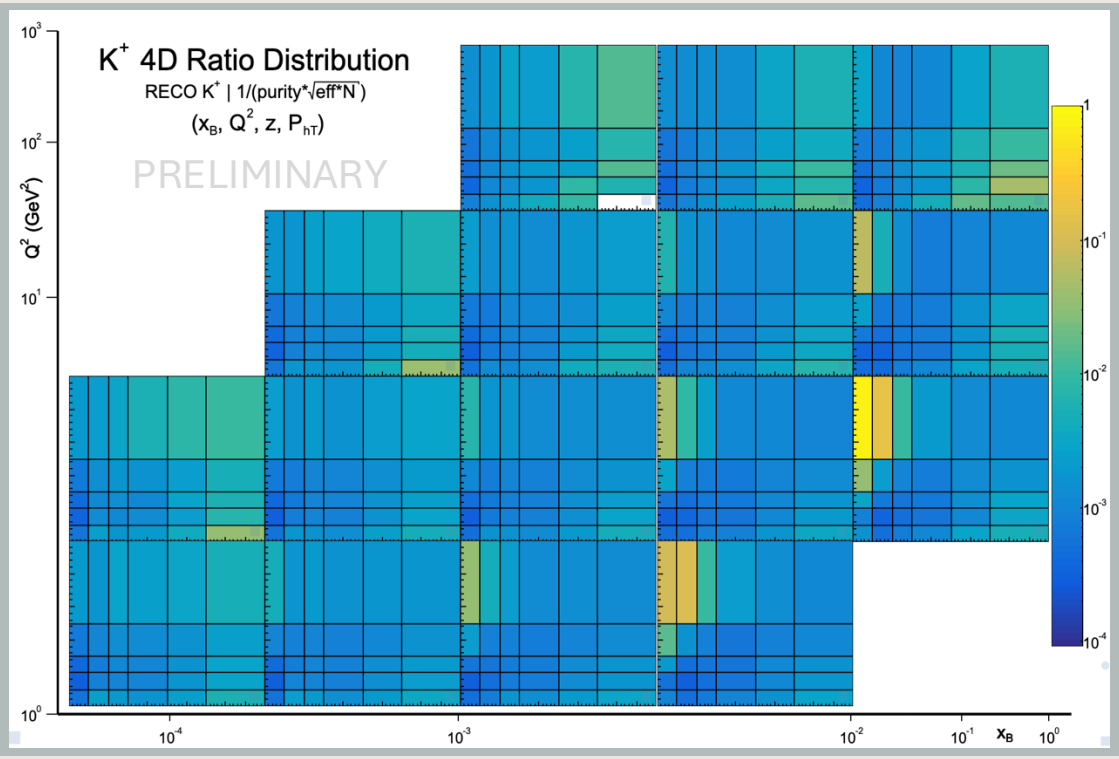




PROJECTED STATISTICS UNCERTAINTY

We also calculate the ratio defined as: $r = \frac{1}{p\sqrt{\varepsilon N_{proj}}}$, with N_{proj} the statistics projected to the expected luminosities of $10\ fb^{-1}$.





CONCLUSION

- The **ePIC experiment** at the **EIC** will enable **precision studies** of **hadronic structure** over a **broad kinematic range**.
- **Efficiency** and **Purity** studies are essential to optimize the PID performances.
- The **hadronic PID** system is expected to provide **strong particle separation** up to **~55 GeV** thanks to the complementary PID detectors.
- Projected statistics measurements highlight the possibility to have uncertainties at sub-percent level under ideal conditions.
- The wide kinematic coverage enables access to key regions for **hadron structure, hadronization, and flavor dynamics**, beyond inclusive **Deep Inelastic Scattering**
- Further studies, including **systematic uncertainties**, **background** implementation, **early-science** conditions, and so on, are ongoing.

THANKS

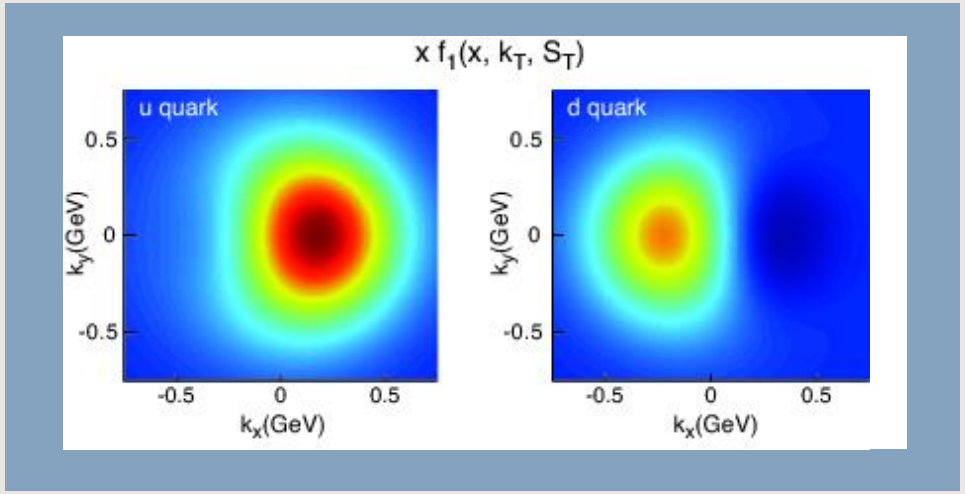
BACKUP

DEEP INELASTIC SCATTERING

Polarized DIS gives access to the 1D (collinear) spin structure, encoded in the Parton Distribution Functions (PDFs).

Semi-Inclusive DIS opens the door to the 3D nucleon structure, described by Transverse Momentum Dependent distributions (TMDs).

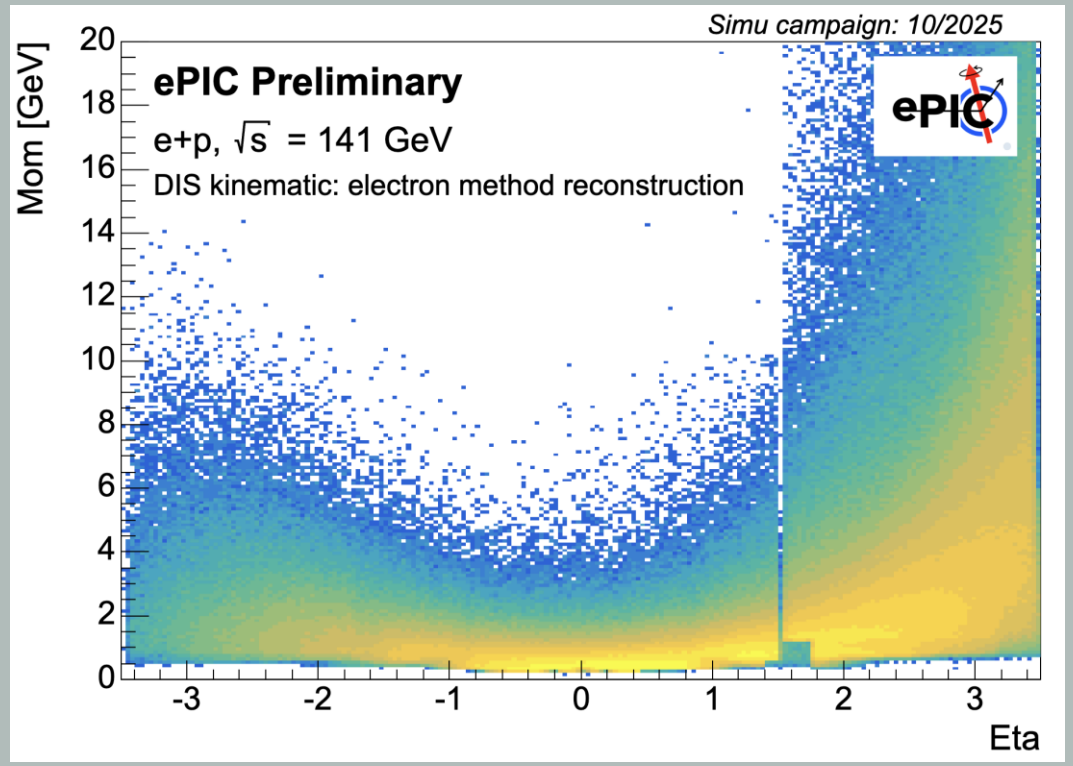
Spin asymmetries in SIDIS are direct manifestations of the underlying PDFs and TMDs. They appear as angular modulation in the differential cross-section.



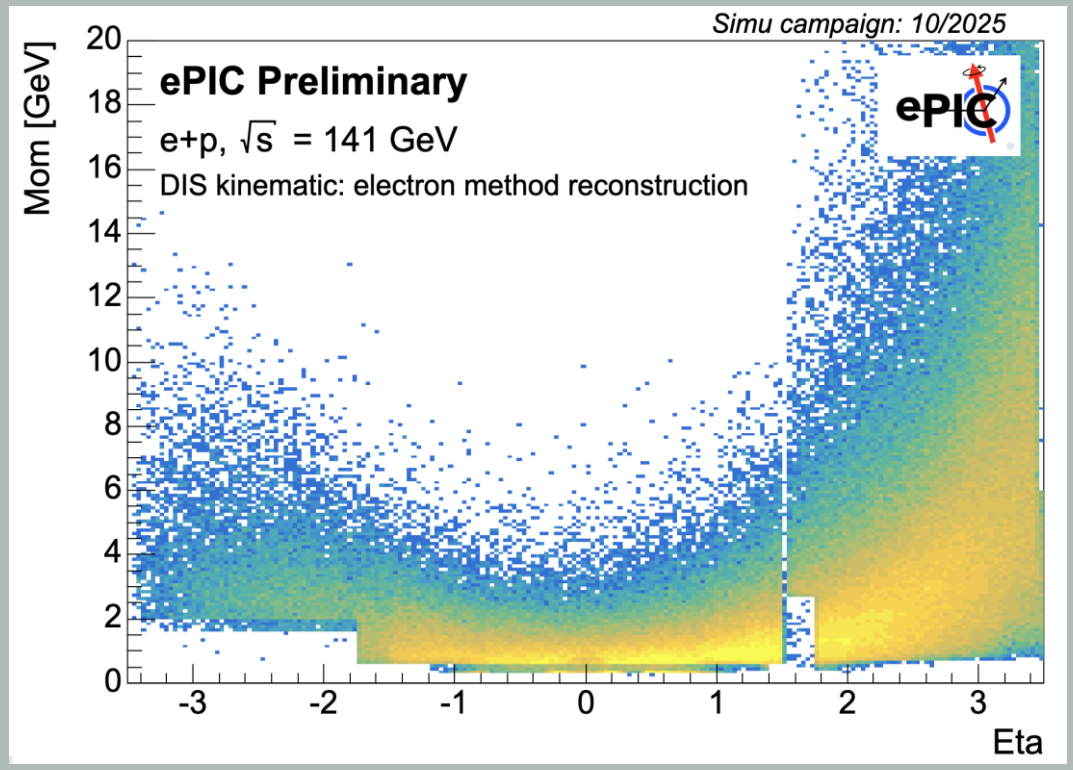
Transverse-momentum distribution (Sivers effect)
DOI: https://doi.org/10.48550/arXiv.1212.1701

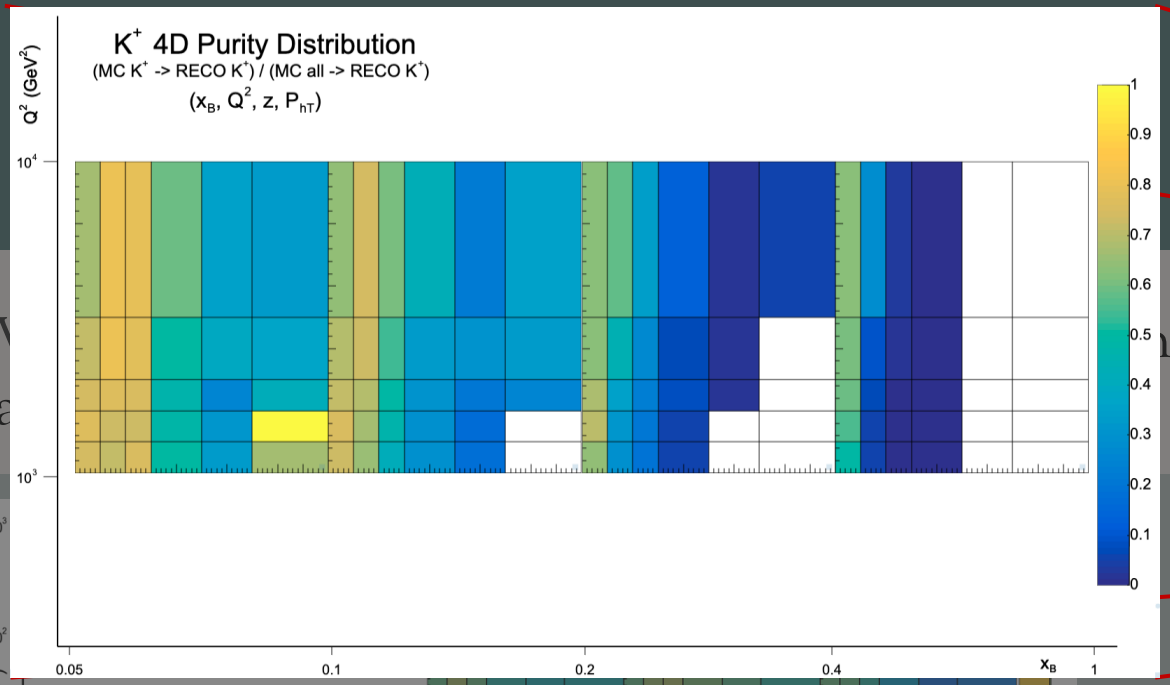
PSEUDORAPIDITY

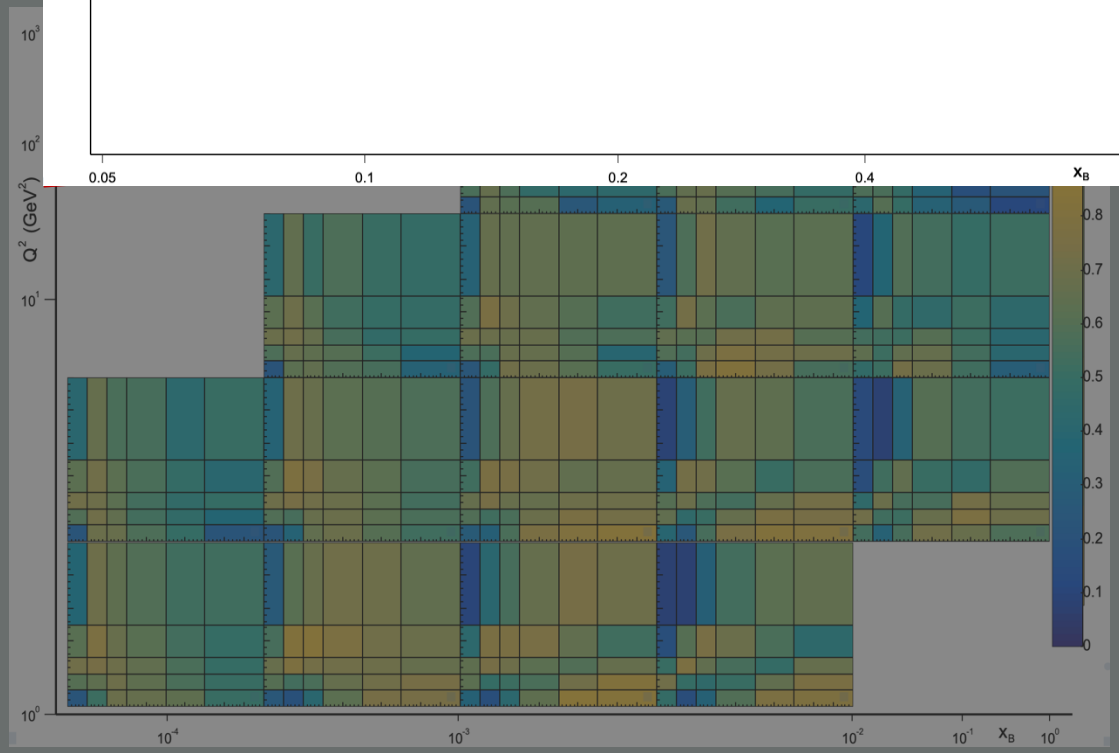
π^+



K^+




K+ 4D Purity Distribution
(MC K+ -> RECO K+) / (MC all -> RECO K+)
(xB, Q2, z, PhT)
Q2 (GeV2)
xB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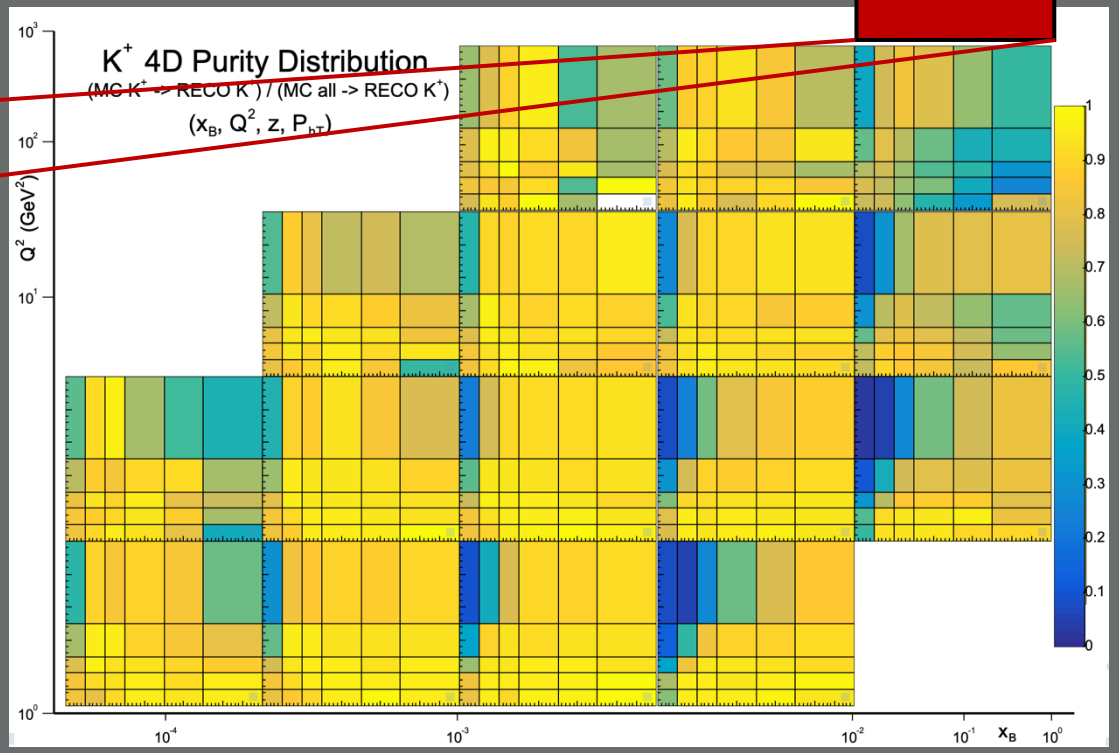
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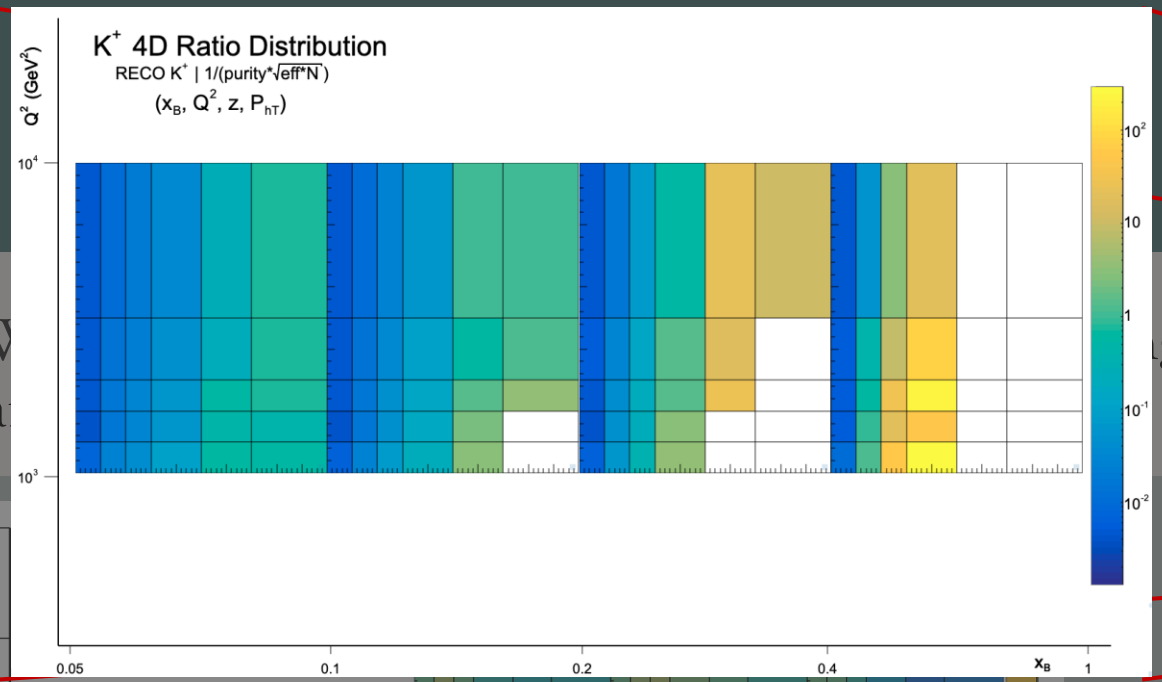
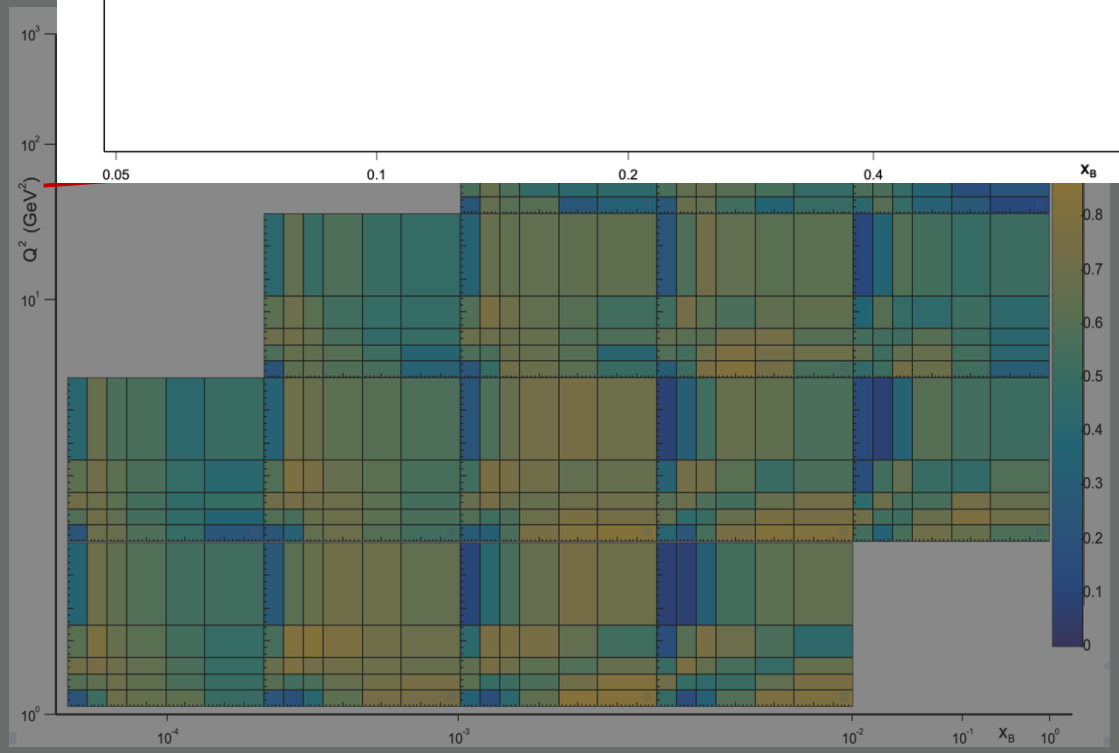
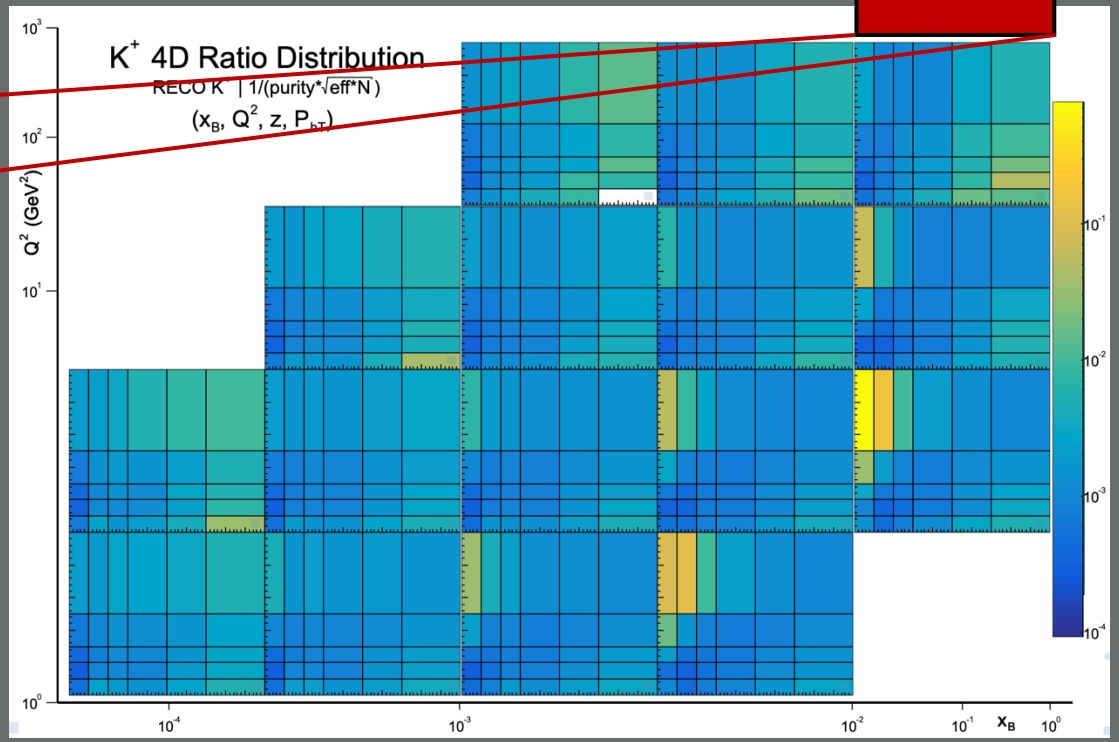
a







EFFICIENCY (NEGATIVE)

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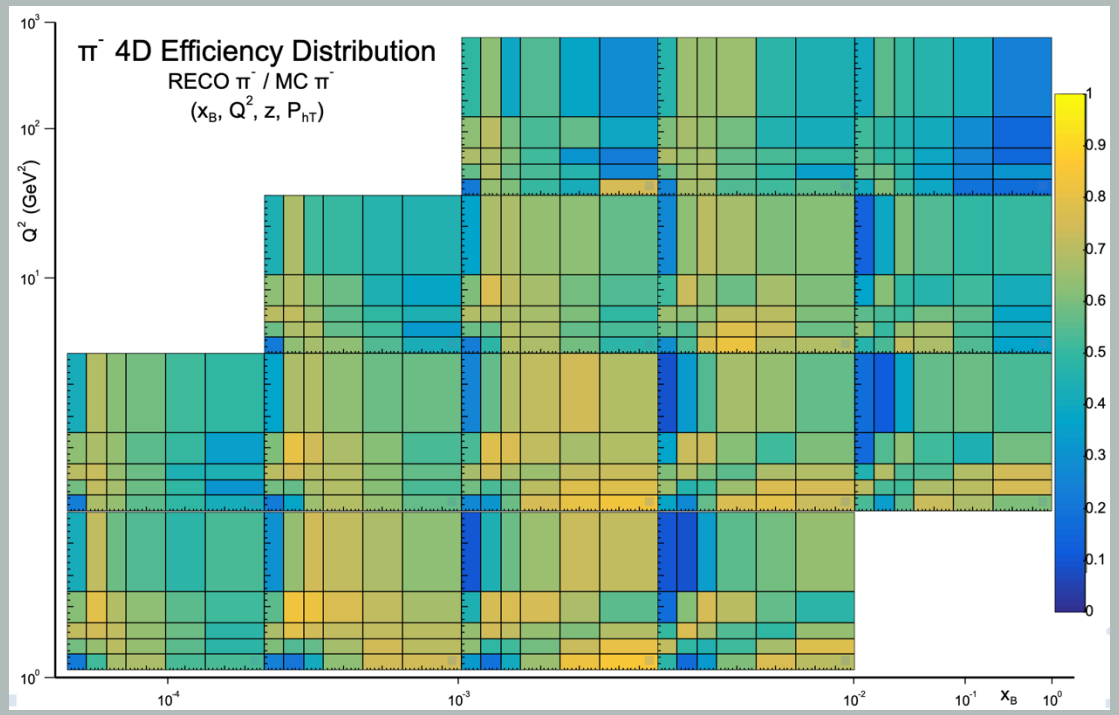

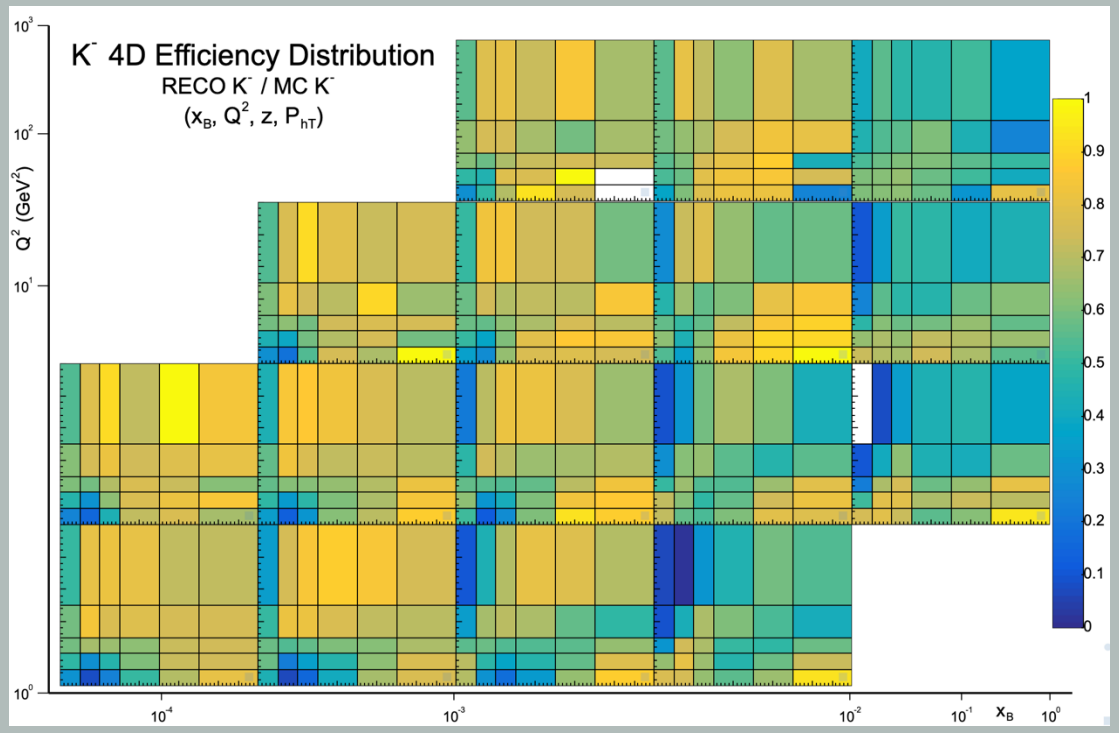

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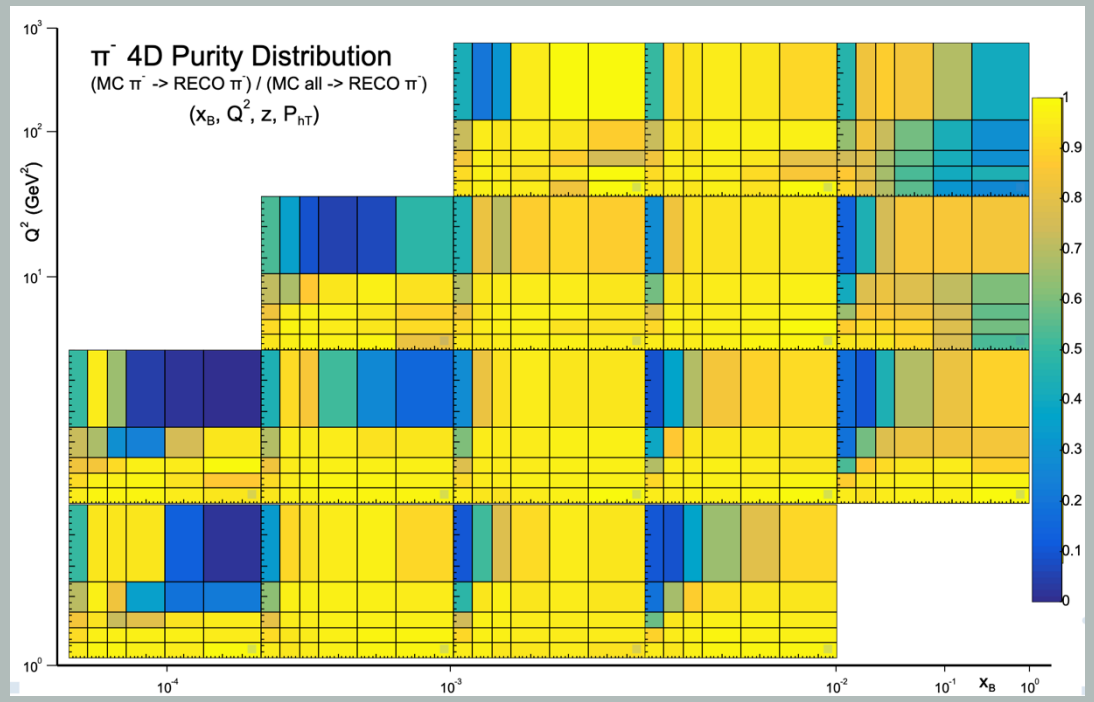

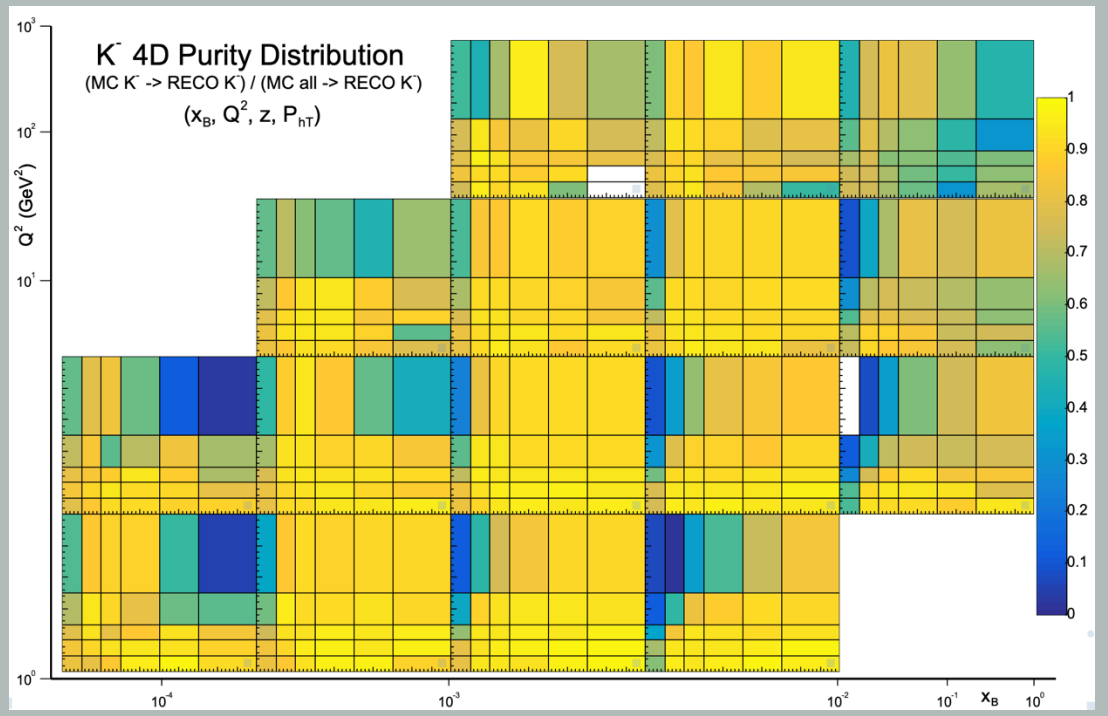

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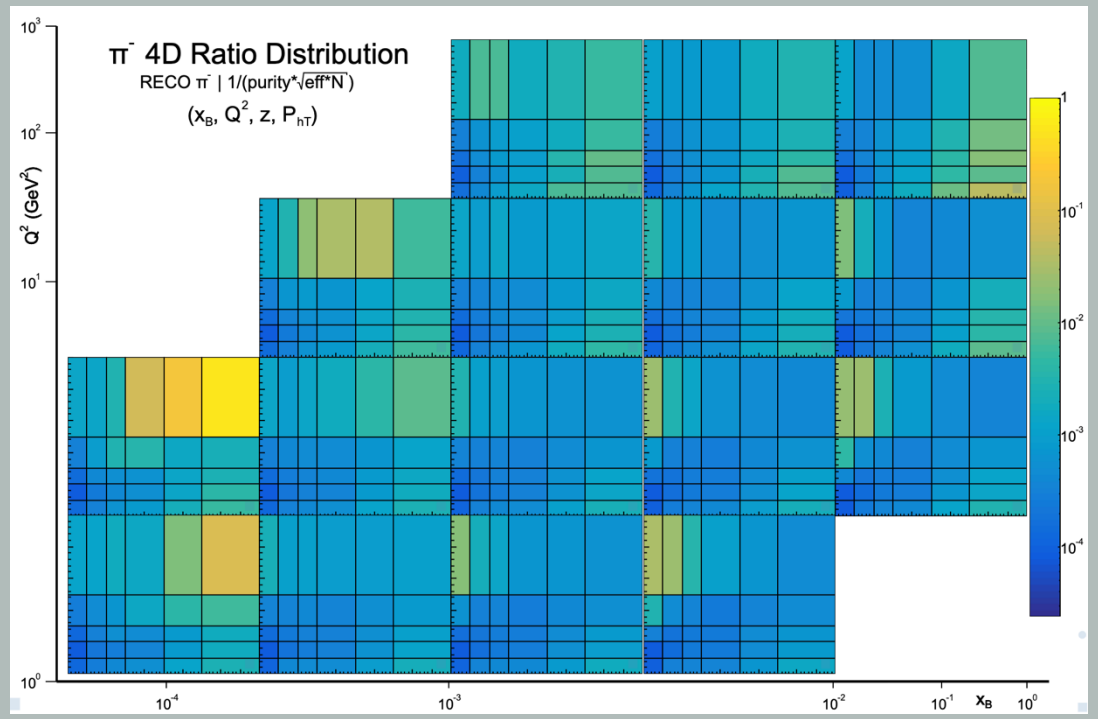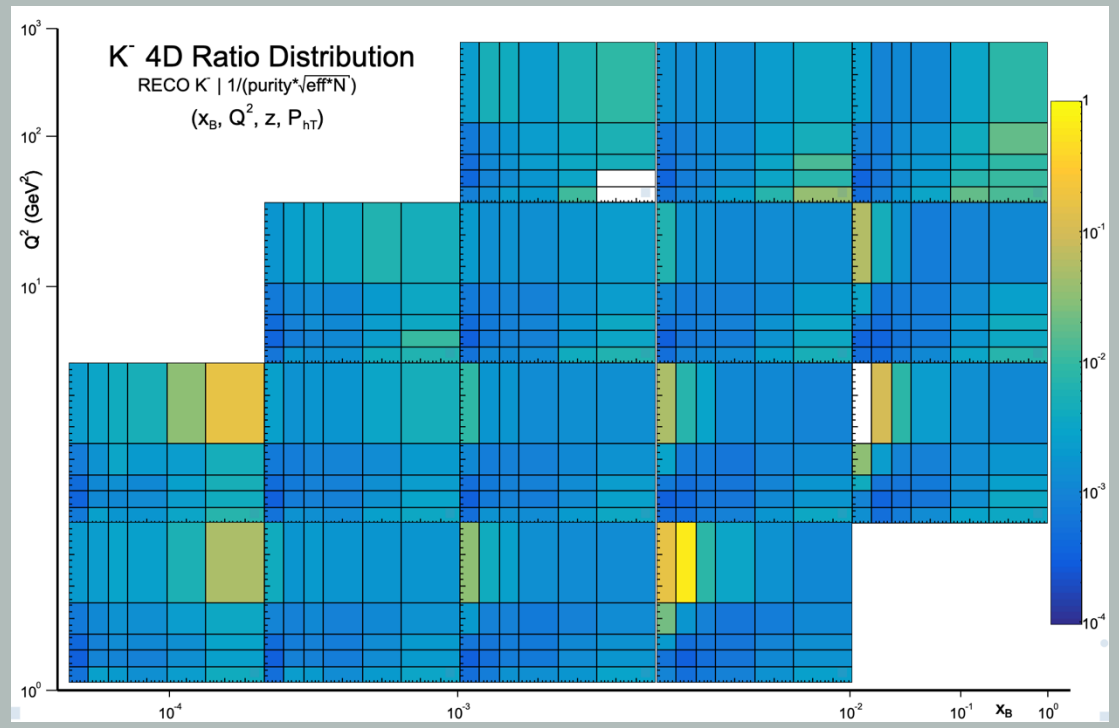
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