PID purity study on Hadron in jet production at the EIC

Xilin Liang, Miguel Arratia
University of California, Riverside

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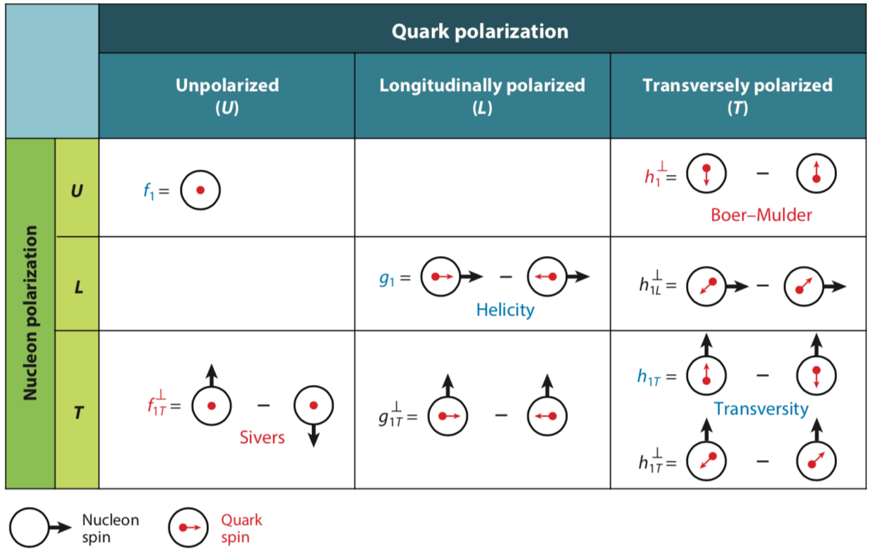
Outline

- Motivation
- Particle Identification (PID) performance check
- Hadron in jet PID purity study
- Conclusion and outlook

Motivation

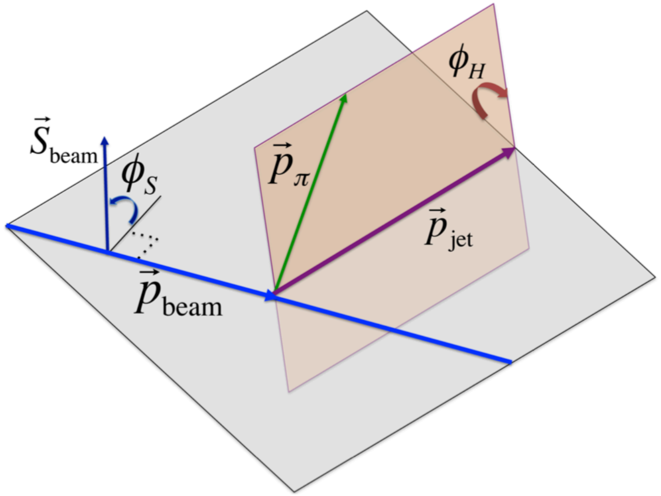
- Jets, which are collimated sprays of particles in high energy particle collision, are useful tools to study Quantum Chromodynamics(QCD).
- Jets can probe the 3D hadronic structure encoded in TMD PDFs and FFs*
  - In polarized collision, jets can probe Sivers effects and Collins effect.
- Jet substructure provides innovative advances to study these effects and explore 3D hadronic structure.

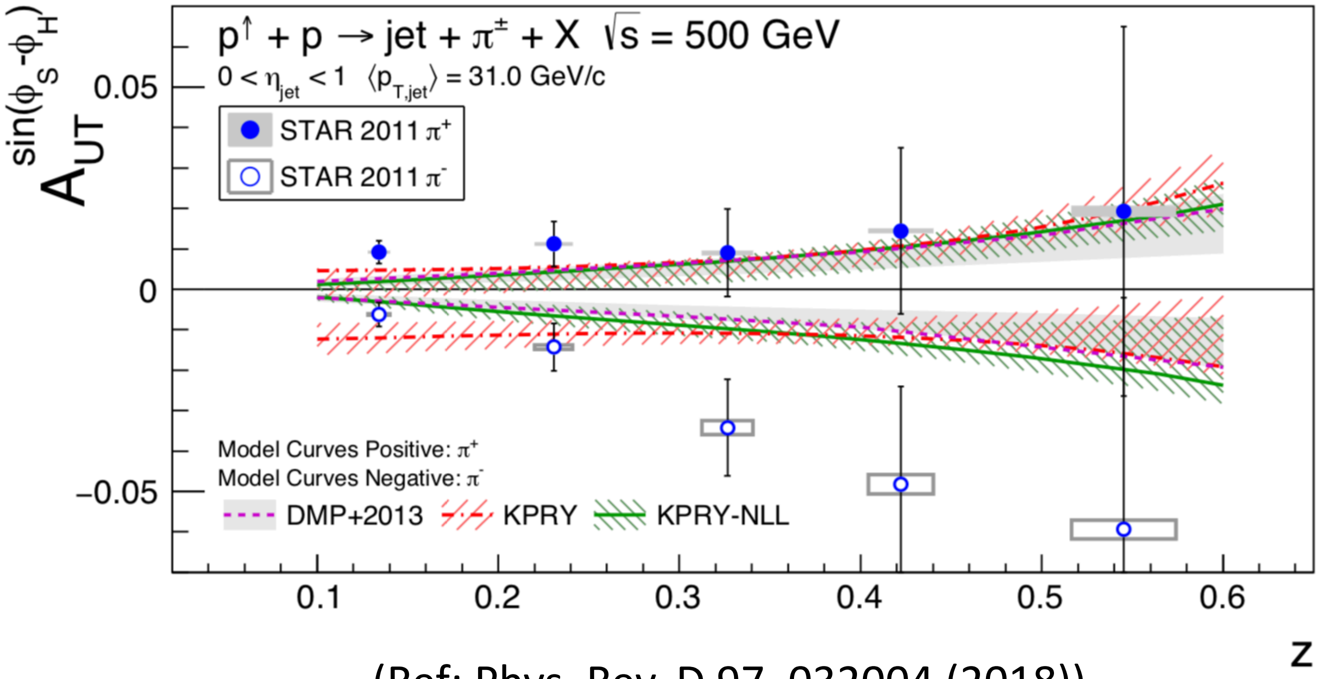


*TMD PDFs and FFs: Transverse Momentum Dependence Parton Distribution Functions and Fragmentation Functions

Motivation

- Collins effect with hadrons in jets. (Ref: Phys. Rev. D 97, 032004 (2018))
- For hadronic tracks in jets, high PID purity is critical for the measurement.
- At the EIC, we could expect to have a higher precision measurement.





(Ref: Phys. Rev. D 97, 032004 (2018))

Part I: PID performance check

- PID performance check for the PID systems
- PID performance check with hadronic track in the jet

Basic idea for Particle Identification (PID) hypothesis

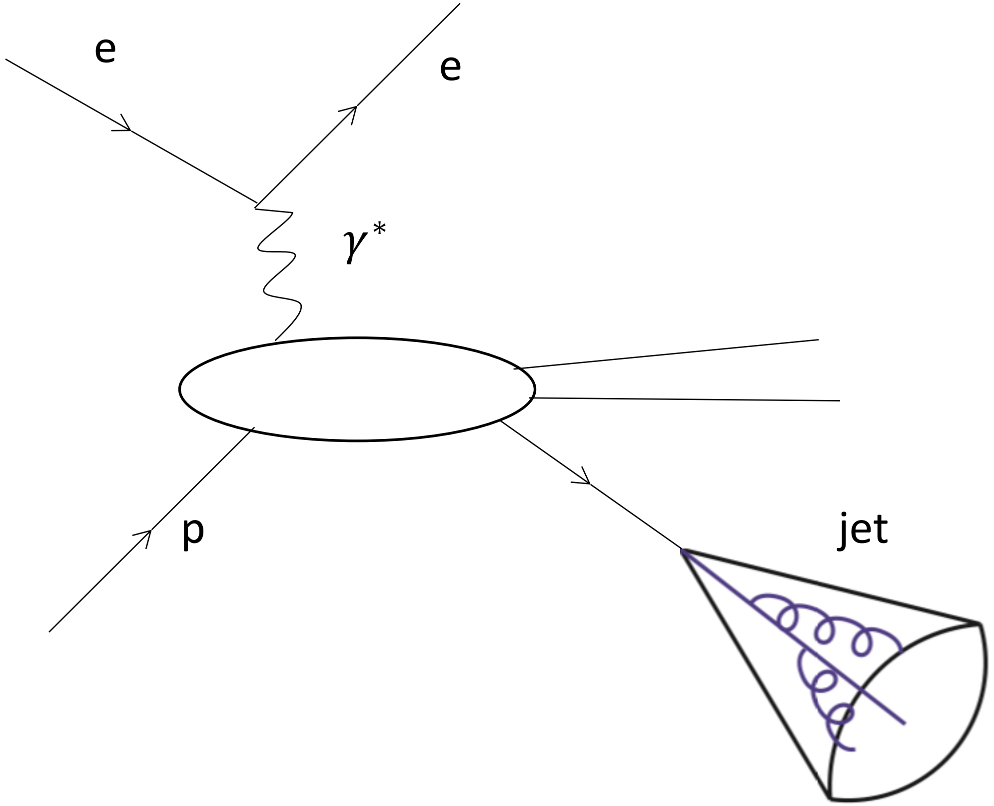
- For tracks, they are given the PID value for particles to indicate their particle species.
- The particle identification systems are implemented in Delphes simulation as identification maps which encode the efficiency that a track with truth identity A will be identified as PID hypothesis B.
- The PID hypothesis is based on assumption that two species should separate by "n sigma", which comes from EICUG PID group and Yellow Report.
  - Track pseudorapidity, momentum serve as the main aspect in PID hypothesis for hadrons.
- Check for Pion, Kaon and Proton tracks.
- Check for 3 different PID system

PID system	Pseudorapidity Range	Momentum Range
	$-3.5 < \eta < -1.0$	$\leq 7\,\mathrm{GeV}/c$
1. barrelDIRC	$-1.0 < \eta < 0.5$	$\leq 10\,\mathrm{GeV}/c$
1. barrelDIRC	$0.5 < \eta < 1.0$	$\leq 15\,\mathrm{GeV}/c$
2. dualRICH_aerogel / 3. dualRICH_c2f6	$1.0 < \eta < 1.5$	$\leq 30\,\mathrm{GeV}/c$
2. dualRICH_aerogel / 3. dualRICH_c2f6	$1.5 < \eta < 2.5$	$\leq 50\,\mathrm{GeV}/c$
2. dualRICH_aerogel / 3. dualRICH_c2f6	$2.5 < \eta < 3.0$	$\leq 30\,\mathrm{GeV}/c$
2. dualRICH_aerogel / 3. dualRICH_c2f6	$3.0 < \eta < 3.5$	$\leq 20\,\mathrm{GeV}/c$

Requested PID momentum coverage for 3σ pion/kaon separation.
Ref: EIC Yellow Report arXiv:2103.05419

Data set

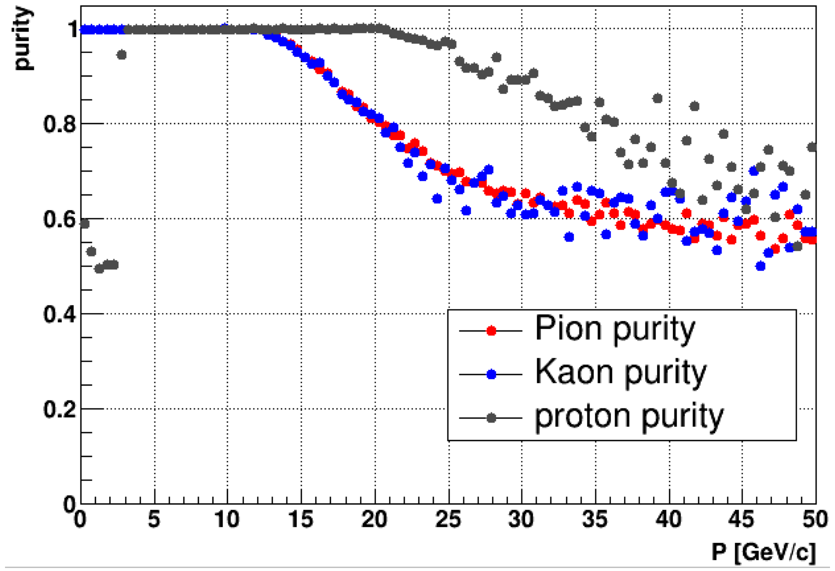
- Use Pythia8 to simulate Deep Inelastic Scattering (DIS) process
- Use Delphes to do the EIC detector respond simulation
  - Delphes card: **ATHENA.tcl** , where PID hypothesis is implemented for calorimeter systems.
- Number of event generated: 1 M
- E_{proton} = 275 GeV
- $E_{electron}$ = 10 GeV
- Q^2 > 25 GeV
- Jet finding algorithm:
  - Anti-kT , R=1.0 , P_T > 3 GeV



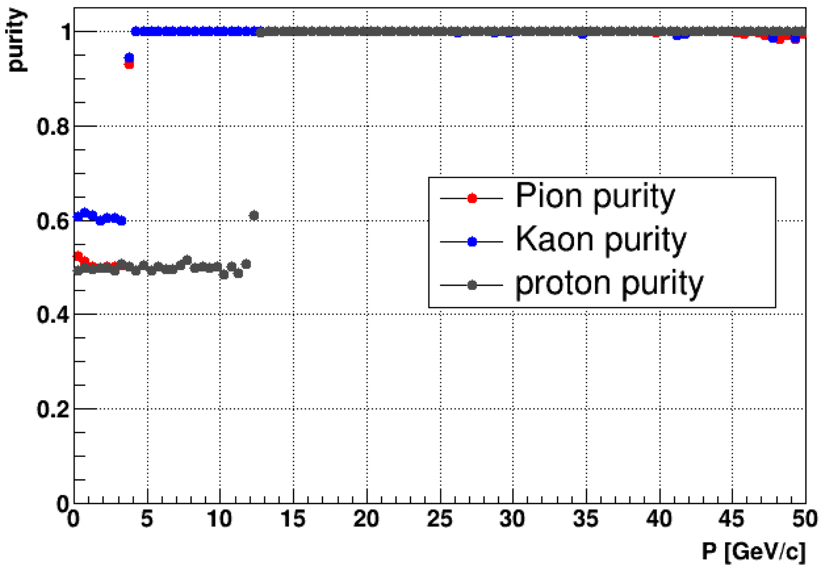
PID performance check for the PID systems

- Particle type: Pion, Kaon, proton
- PID purity: $\frac{number\ of\ correctly\ identified\ tracks\ in\ PID\ system\ for\ each\ tyoe}{number\ of\ all\ \color{red}{true\ level\ tracks}\ in\ PID\ system\ coverage\ for\ each\ type}$
  - π purity = $\frac{n(\pi\to\pi)}{n(\color{red}{\pi}\to\pi)+n(\color{red}{\pi}\to K)+n(\color{red}{\pi}\to Pr)}$

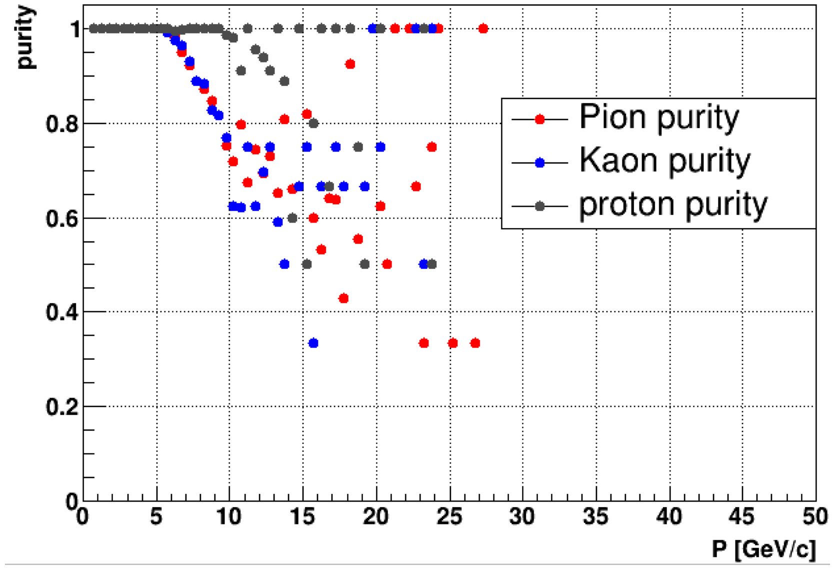
dualRICH_aerogel



dualRICH_c2f6



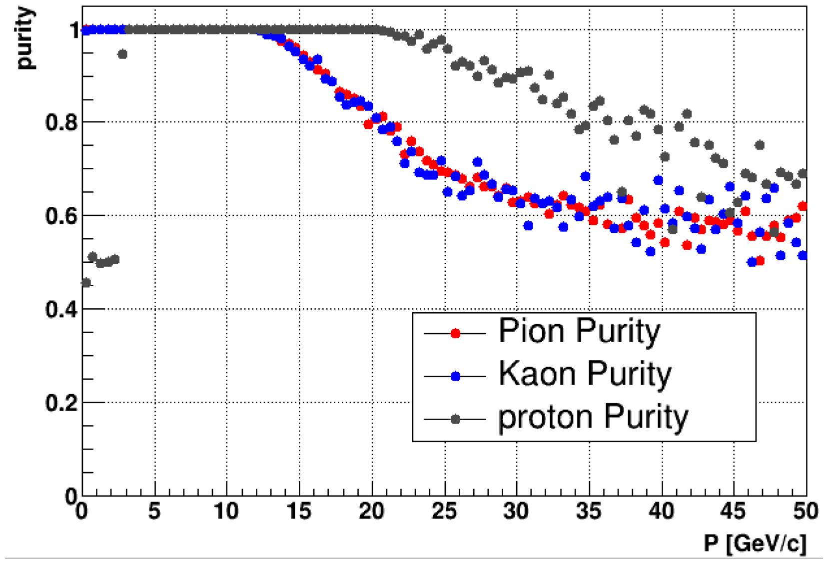
barrelDIRC



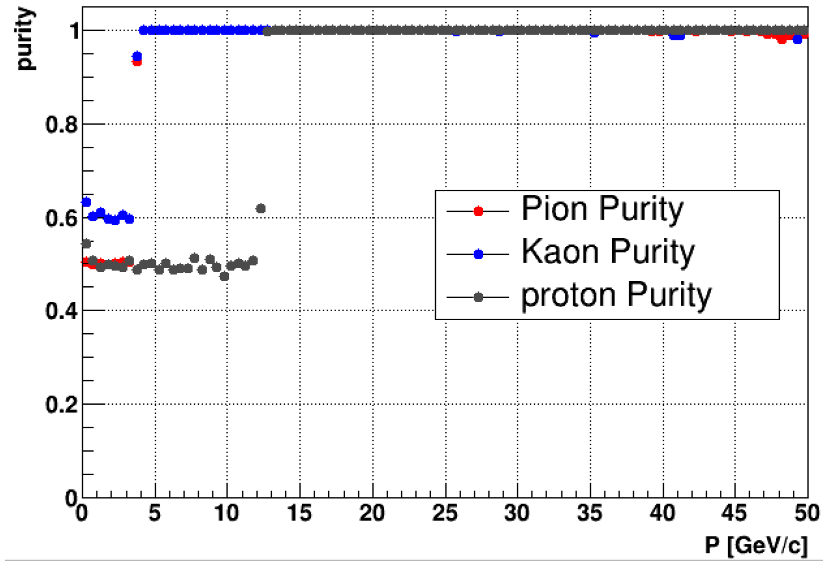
Hadronic track in jet PID purity result

- purity: $\frac{number\ of\ correctly\ identified\ tracks\ in\ PID\ system}{number\ of\ all\ tracks\ in\ jet\ within\ PID\ system\ coverage}$
  - “Correctly identified track”: PID value for track in jet is same as the PID value for the corresponding track in PID system hypothesis.
- The purity results distributions look similar with the purity in the PID performance check.

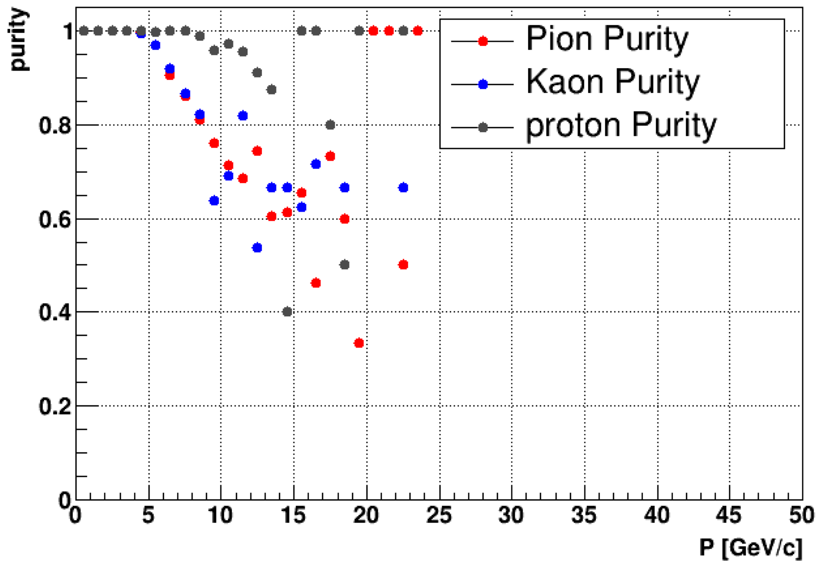
dualRICH_aerogel



dualRICH_c2f6



barrelDIRC

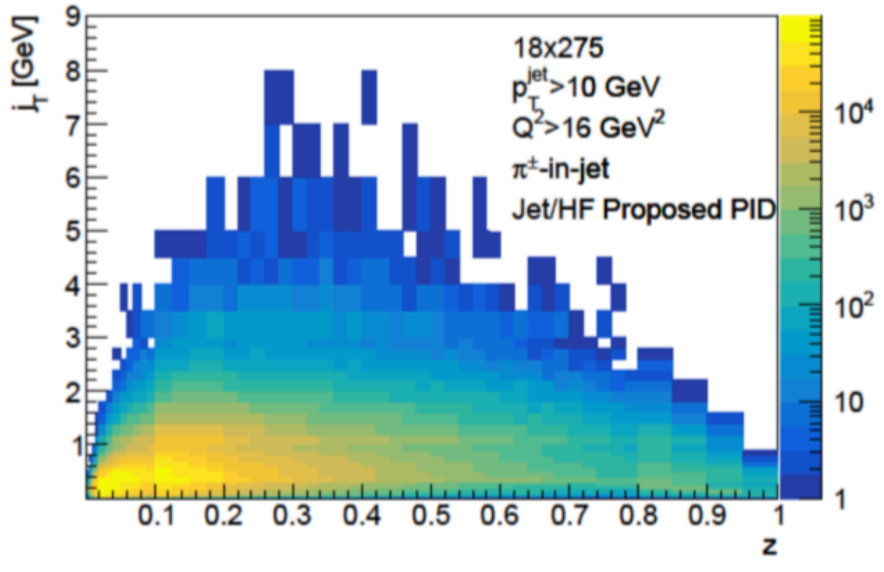


PID purity for hadronic track in the jet

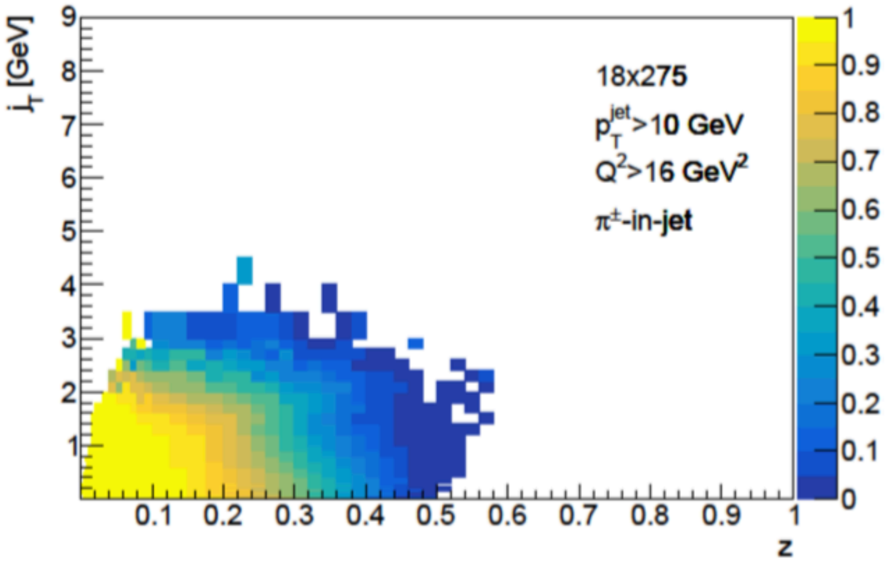
- Investigate PID purity as the function of track longitudinal momentum fraction (z) from the jet.
  - $\mathrm{z} = \frac{\vec{p}_{track} \cdot \vec{p}_{jet}}{\vec{p}_{jet}^{2}}$

Motivation on PID purity with limited phase space

- The restricted momentum coverage (right plot) taken based on pseudorapidity range will limit the phase space and cause the high z range to be inaccessible.
  - The restricted momentum coverage is based on expected performance range.



(a)

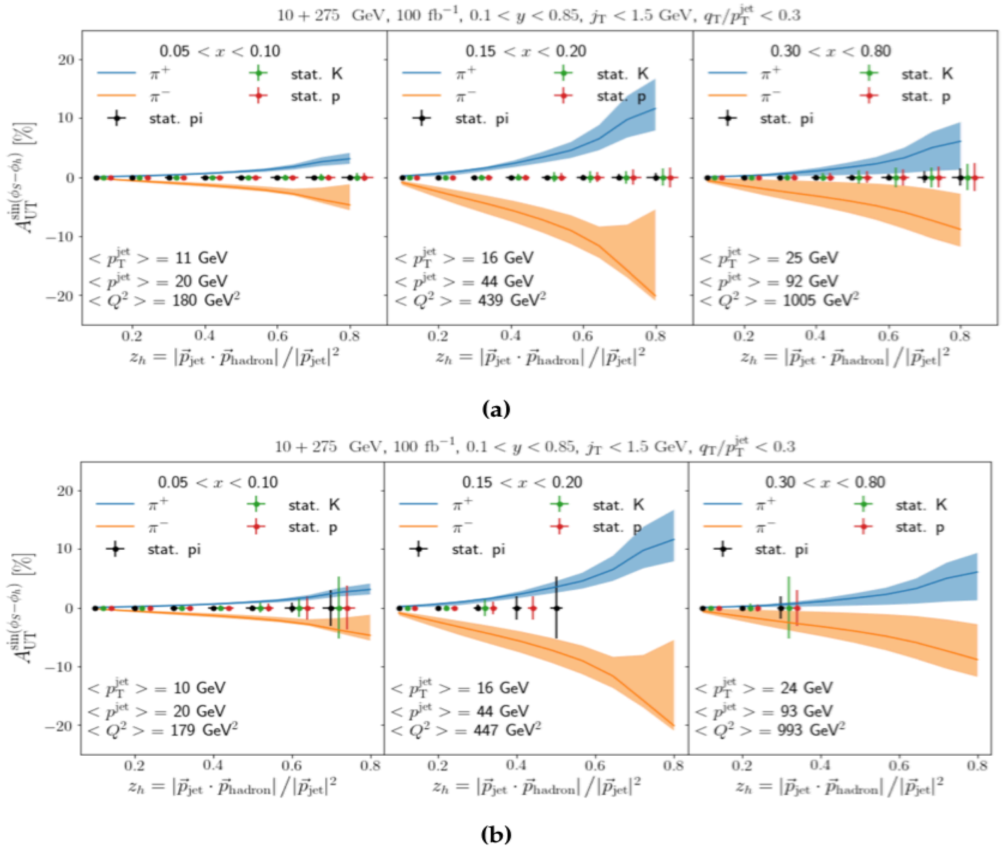


(b)

Ref: EIC Yellow Report arXiv:2103.05419

Impact on physics measurement with restricted momentum coverage

- Top row plots are Collins asymmetry with hadrons in perfect expected PID.
- Bottom row plots are Collins asymmetry with hadrons in restricted momentum reach PID.
- Our ongoing step is to investigate how the PID purity change in limited phase space by choosing different (x,Q^2).

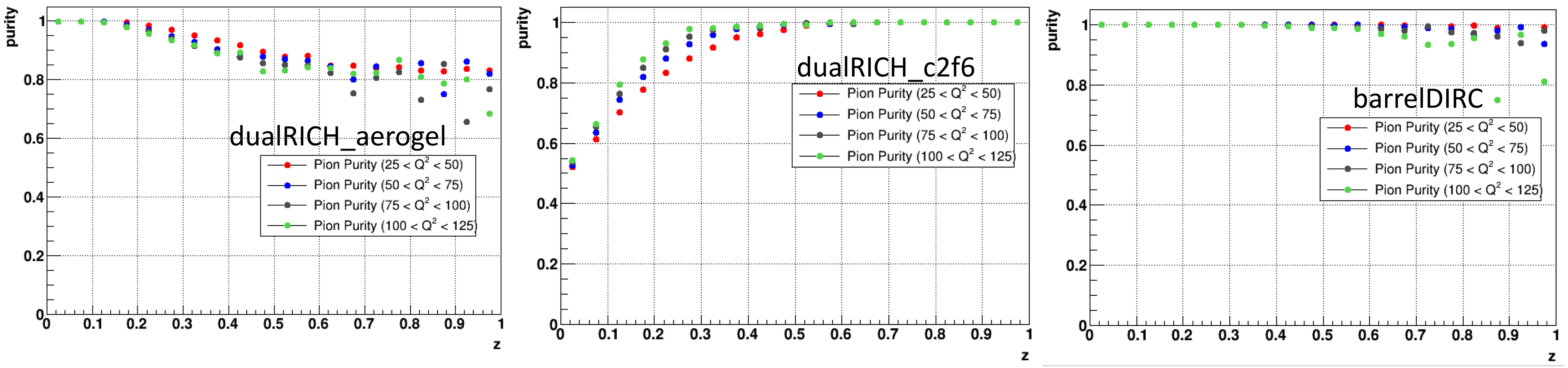


Ref: EIC Yellow Report, arXiv:2103.05419
M. Arratia, Z. Kang, A. Prokudin, F. Ringer Phys.Rev.D 102 (2020) 7, 074015

Pion track purity result for different z

- purity: $\dfrac{number\ of\ correctly\ identified\ tracks\ in\ PID\ system}{number\ of\ all\ tracks\ in\ jet\ within\ PID\ system\ coverage}$
  - "Correctly identified track": PID value for track in jet same as the PID value for the corresponding track in PID system hypothesis.
  - Z: track longitudinal momentum fraction from the jet
  - Try to look at the pion track purity with the change of Q^2.

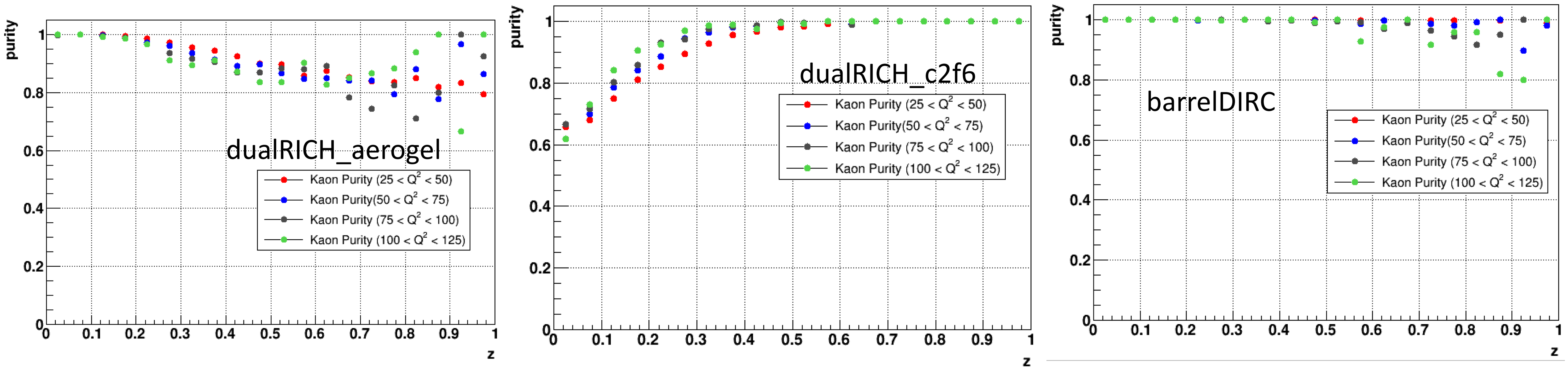
$$z = \frac{\vec{p}_{track} \cdot \vec{p}_{jet}}{\vec{p}_{jet}^{\,2}}$$



Kaon track purity result for different z

- purity: $\frac{number\ of\ correctly\ identified\ tracks\ in\ PID\ system}{number\ of\ all\ tracks\ in\ jet\ within\ PID\ system\ coverage}$
  - "Correctly identified track": PID value for track in jet same as the PID value for the corresponding track in PID system hypothesis.
  - Z: track longitudinal momentum fraction from the jet

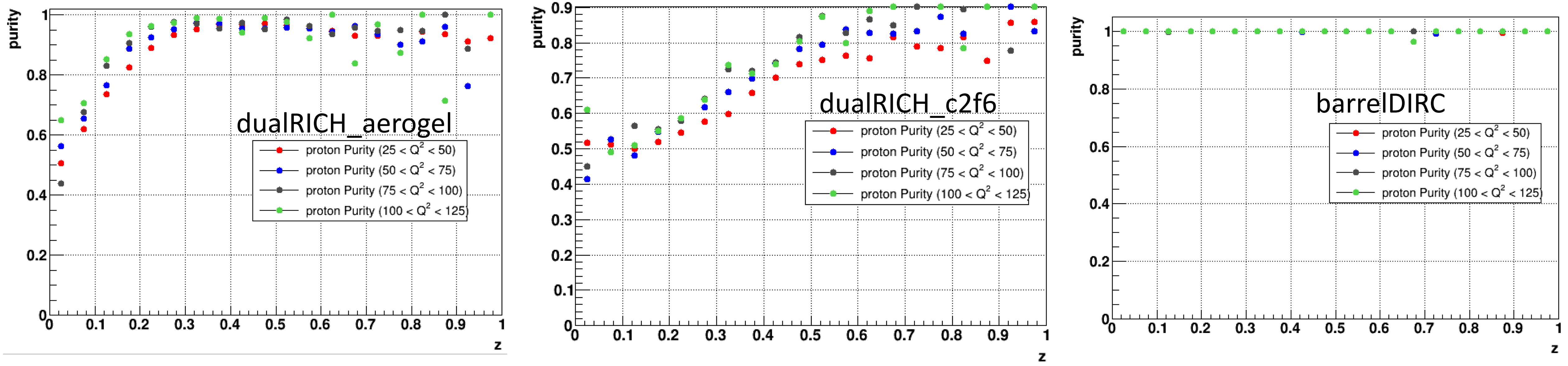
$$z = \frac{\vec{p}_{track} \cdot \vec{p}_{jet}}{\vec{p}_{jet}^{\,2}}$$



Proton track purity result for different z

- purity: $\frac{number\ of\ correctly\ identified\ tracks\ in\ PID\ system}{number\ of\ all\ tracks\ in\ jet\ within\ PID\ system\ coverage}$
  - "Correctly identified track": PID value for track in jet same as the PID value for the corresponding track in PID system hypothesis.
  - Z: track longitudinal momentum fraction from the jet.

$$z = \frac{\vec{p}_{track} \cdot \vec{p}_{jet}}{\vec{p}_{jet}^{\,2}}$$



Conclusion and outlook

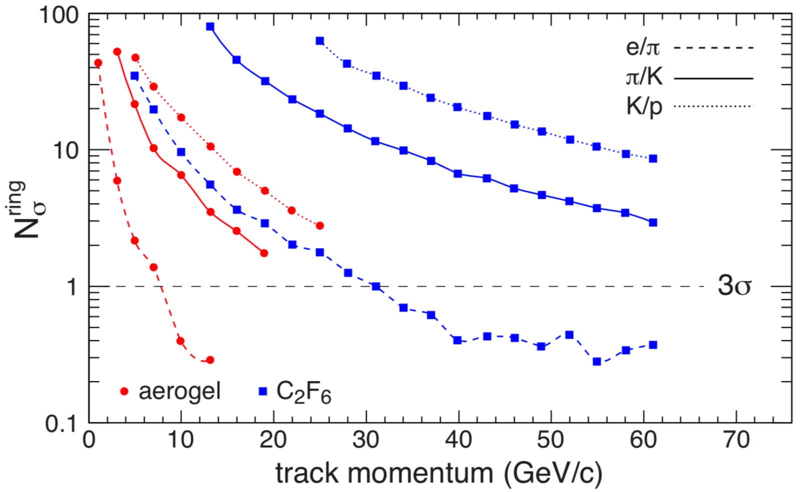
- At EIC, we would expect to explore TMD and probe hadronic structure with higher precision.
  - High PID purity for tracks in jet plays an essential role.
- The PID purity for dualRICH_aerogel, dualRICH_c2f6 system and barreDIRC system works well in the simulation and match with the expectation from EIC design.
- The PID purity for tracks in jets looks reasonable and we will continue to work with different (x,Q^2) ranges to explore the PID purity with the limited phase space.

Thank you!

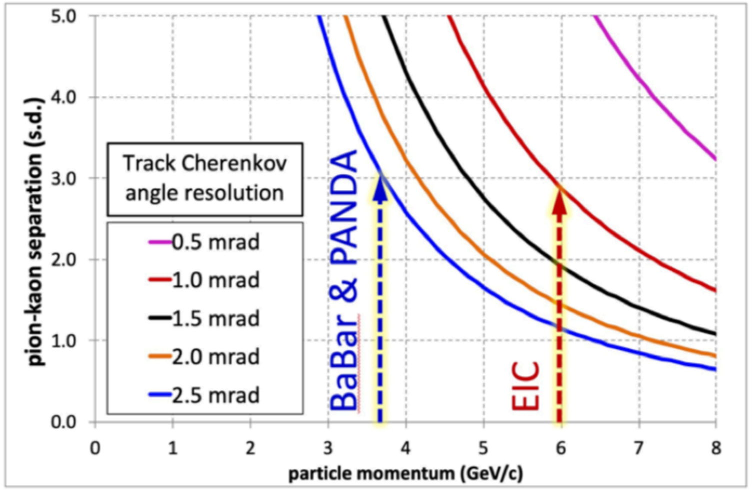
Back up

PID ability for dualRICH and barrelDIRC system

- **Dual RICH** system utilize two different radiator:
  - Aerogel radiator and gas radiator (C_2F_6)
- dualRICH system coverage for PID ability is $1 < \eta < 3.5$
- Two different radiator have different particle species separation ability for track momentum.



- **Barrel DIRC** system is based on Detection of Internally Reflected Cherenkov light (DIRC).
- Coverage for PID ability is $-1 < \eta < 1$
- To satisfy the physics goals for EIC, π/K identification are required up to 5 – 7 GeV/c.



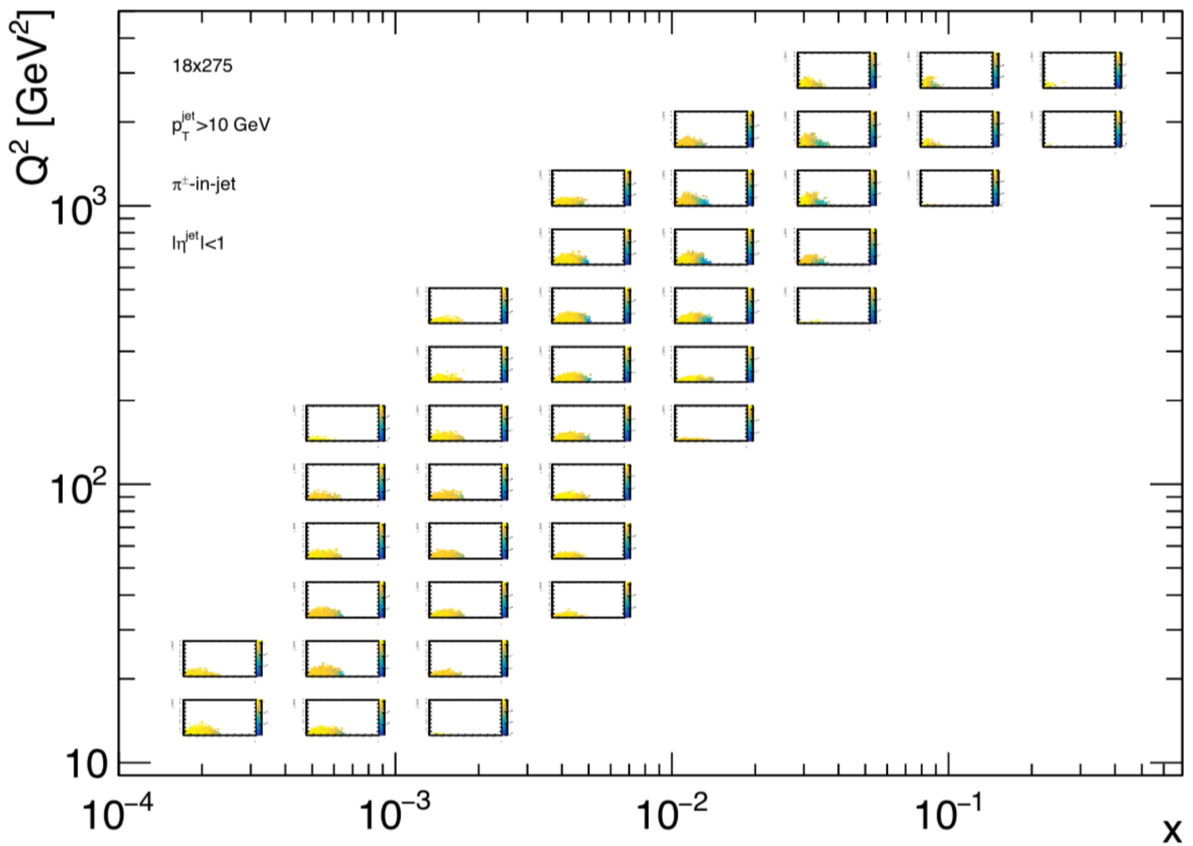
Ref: EIC Yellow Report arXiv:2103.05419

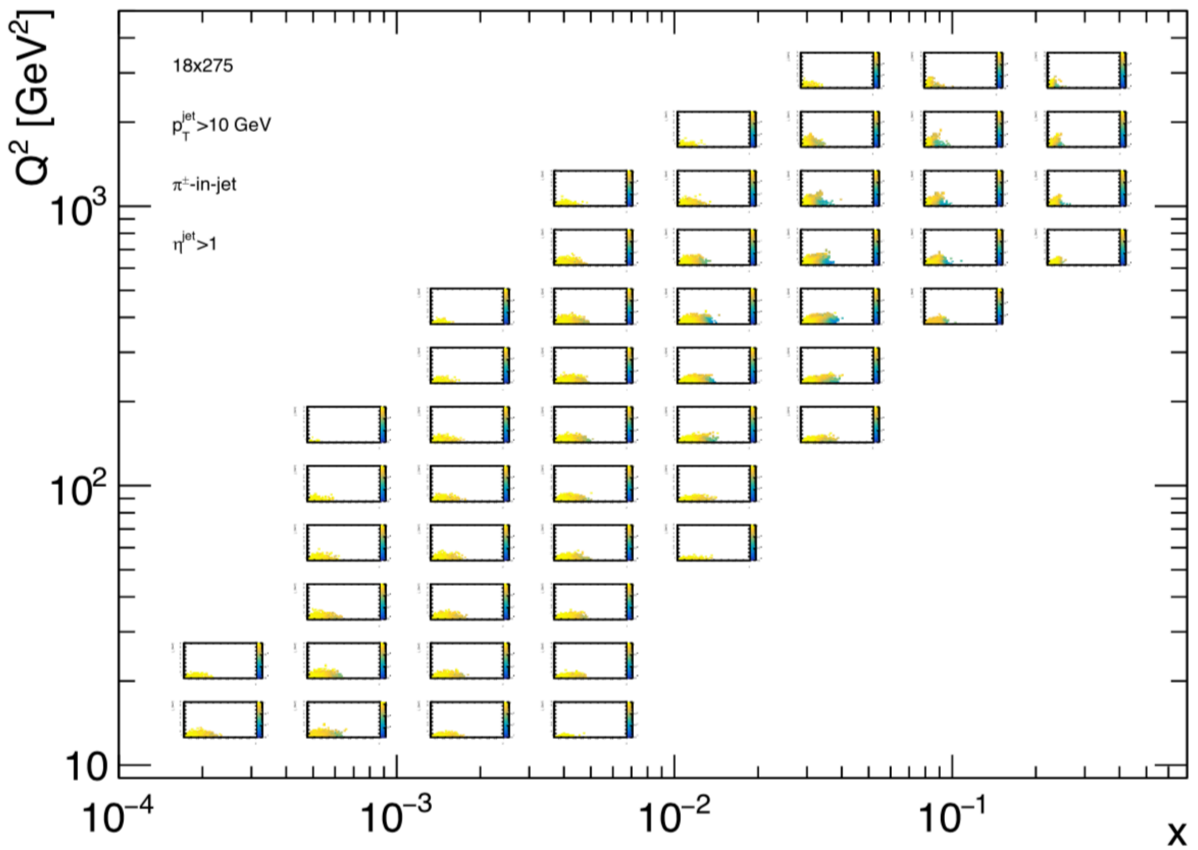
The restricted momentum coverage values

Pesudorapidity range	restricted momentum coverage
$-1.0 < \eta < 1.0$	<= 5 GeV/c
$1.0 < \eta < 2.0$	<= 8 GeV/c
$2.0 < \eta < 3.0$	<= 20 GeV/c
$3.0 < \eta < 3.5$	<= 45 GeV/c

Effects on restricted momentum limit coverage on phase space

- Barrel region jets (left plot) and forward region jets (right plot).





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Track PID purity study from jet

- Goal: check PID purity for tracks in jets with different track momentum and the track longitudinal momentum fraction (z) from the jet.
  - Check PID purity with changing different (x,Q^2) as the next step.
  - Track longitudinal momentum fraction (z) from jet : $\mathrm{z} = \frac{\vec{p}_{track} \cdot \vec{p}_{jet}}{\vec{p}_{jet}^{\,2}}$
- Check for 3 PID system:
  - dualRICH_aerogel: $1 < \eta < 3.5$
  - dualRICH_c2f6: $1 < \eta < 3.5$
  - barrelDIRC: $-1 < \eta < 1$
- Check for Pion, Kaon and Proton tracks.

Jet finding algorithm:

Anti-kT , R=1.0 , P_T > 3 GeV