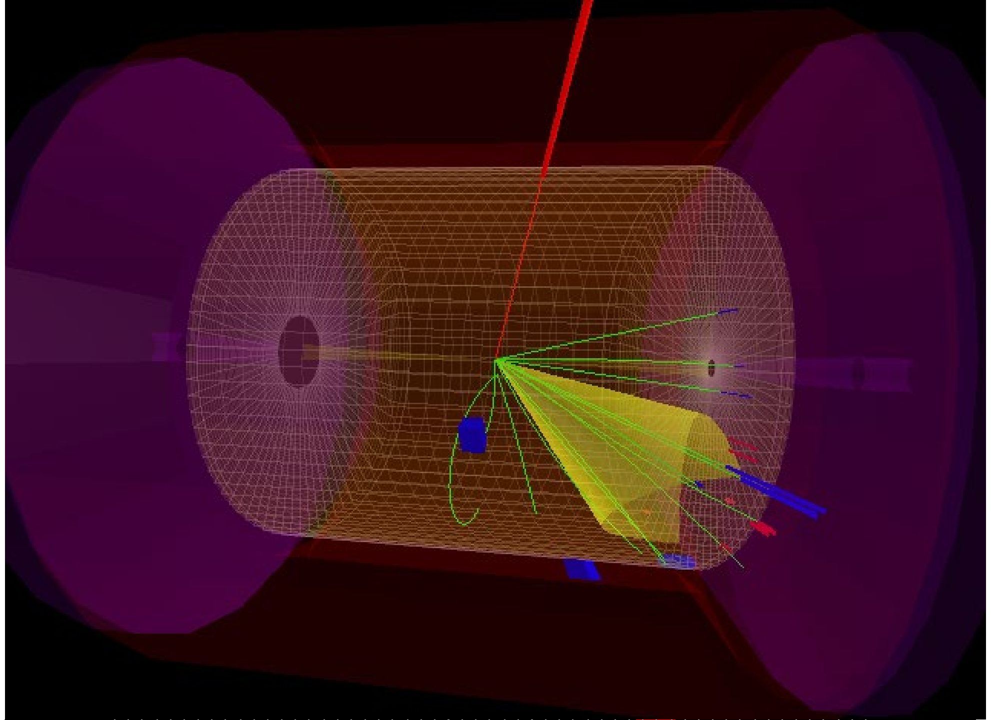
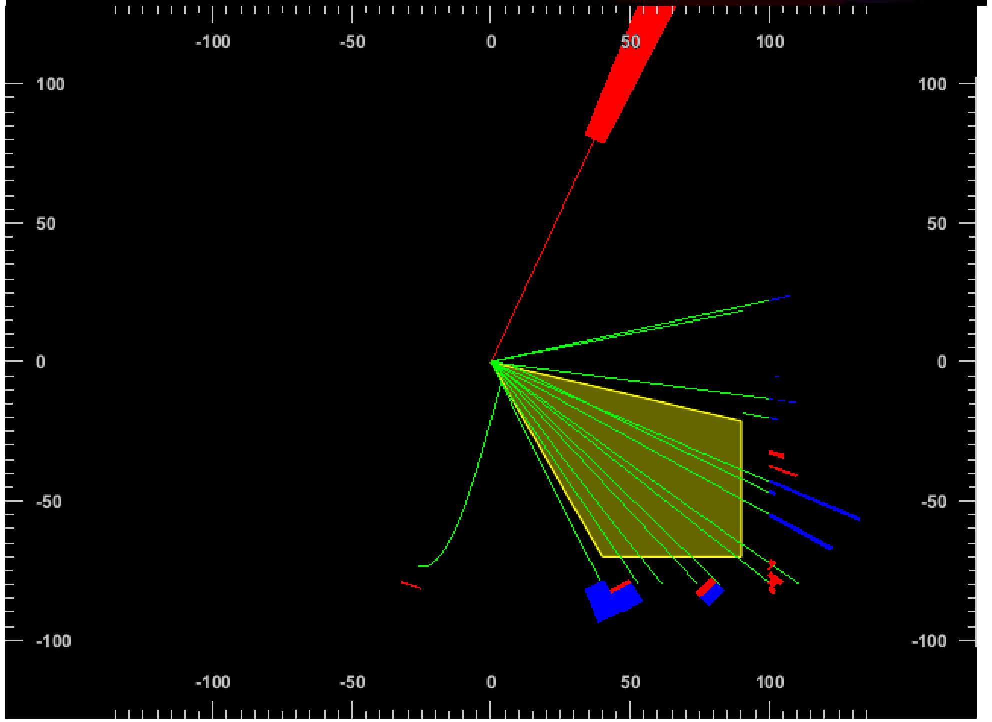
On the PID requirements of high-x, high-Q2 measurements (i.e jet measurements)

Miguel Arratia

UC RIVERSIDE

Jefferson Lab





Introduction

- I will describe motivations for high-Q2 jet measurements with PID and describe requirements.
- I will divide my presentation in three parts.

  1) Hadron-in-jet Collins asymmetry measurements
  2) Jet probes of cold-nuclear matter
  3) Charm-jet tagging in charged-current DIS

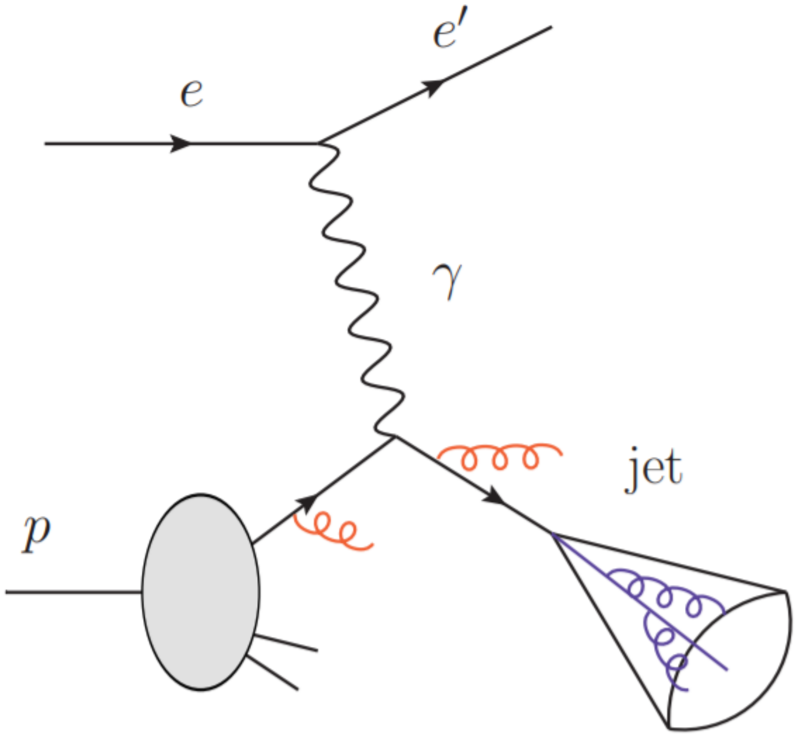
Jet-based measurements of Sivers and Collins asymmetries at the future Electron-Ion Collider

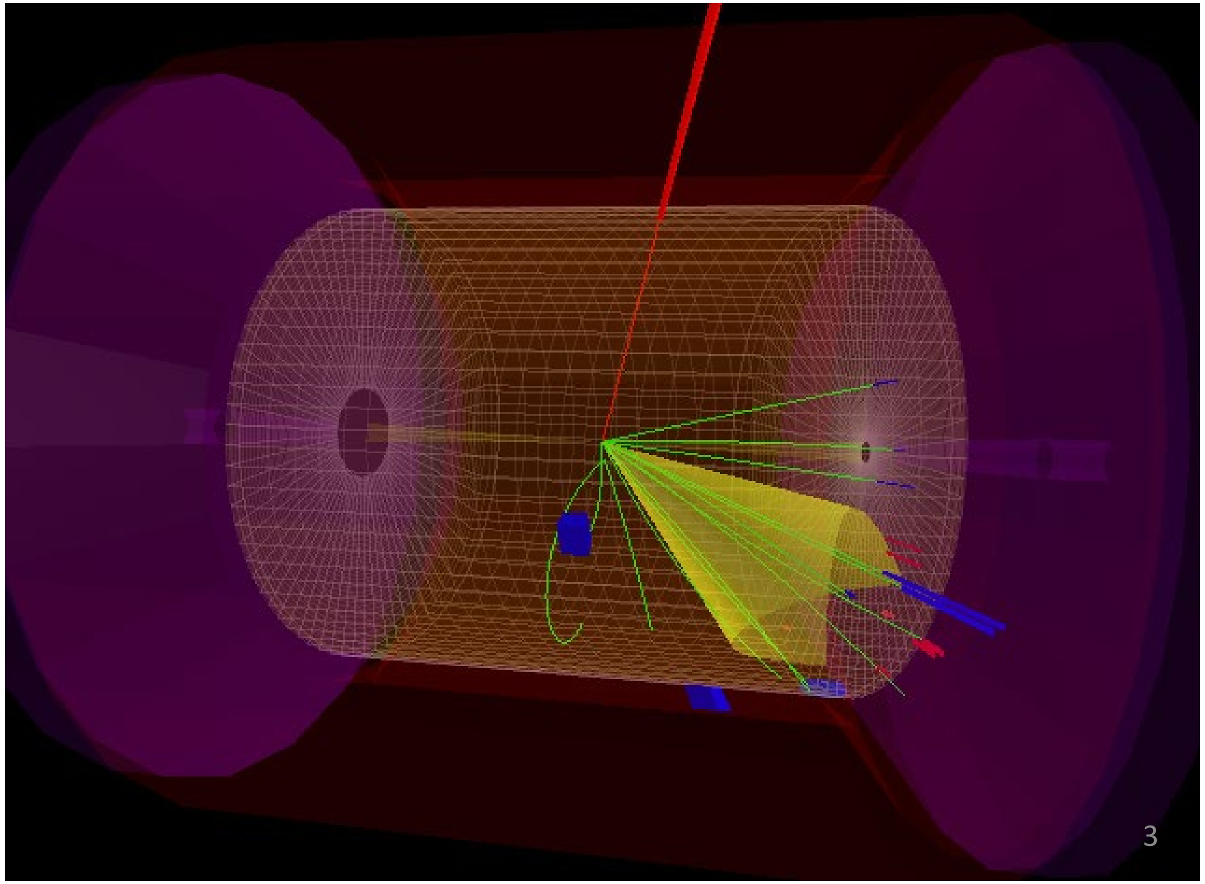
arXiv:2007.07281

Miguel Arratia,[1,2,*] Zhong-Bo Kang,[3,4,5,†] Alexei Prokudin,[6,2,‡] and Felix Ringer[7,8,§]

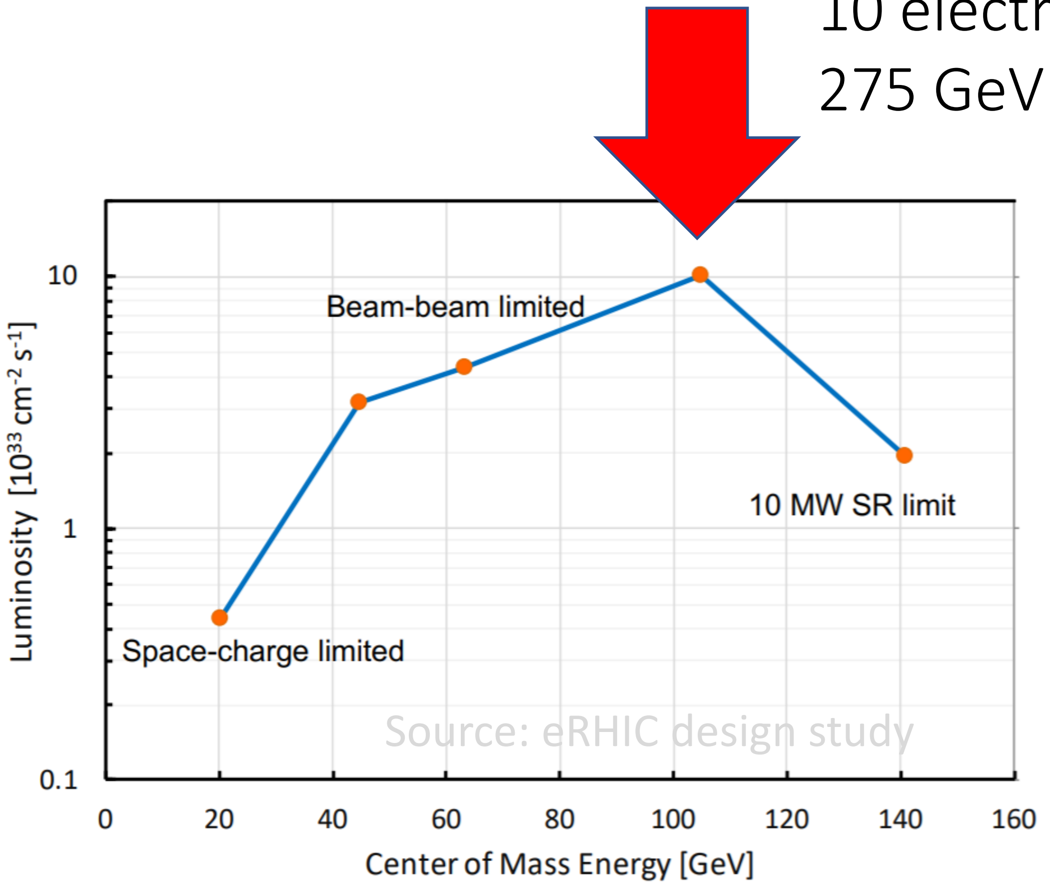
$$e + p(\vec{s}_T) \to e + (\text{jet}(\vec{q}_T)\, h(z_h, \vec{j}_T)) + X\,.$$

- Focuses on high Q2 region, to probe quark-TMDs, as well as their TMD evolution.





10 electron +
275 GeV proton



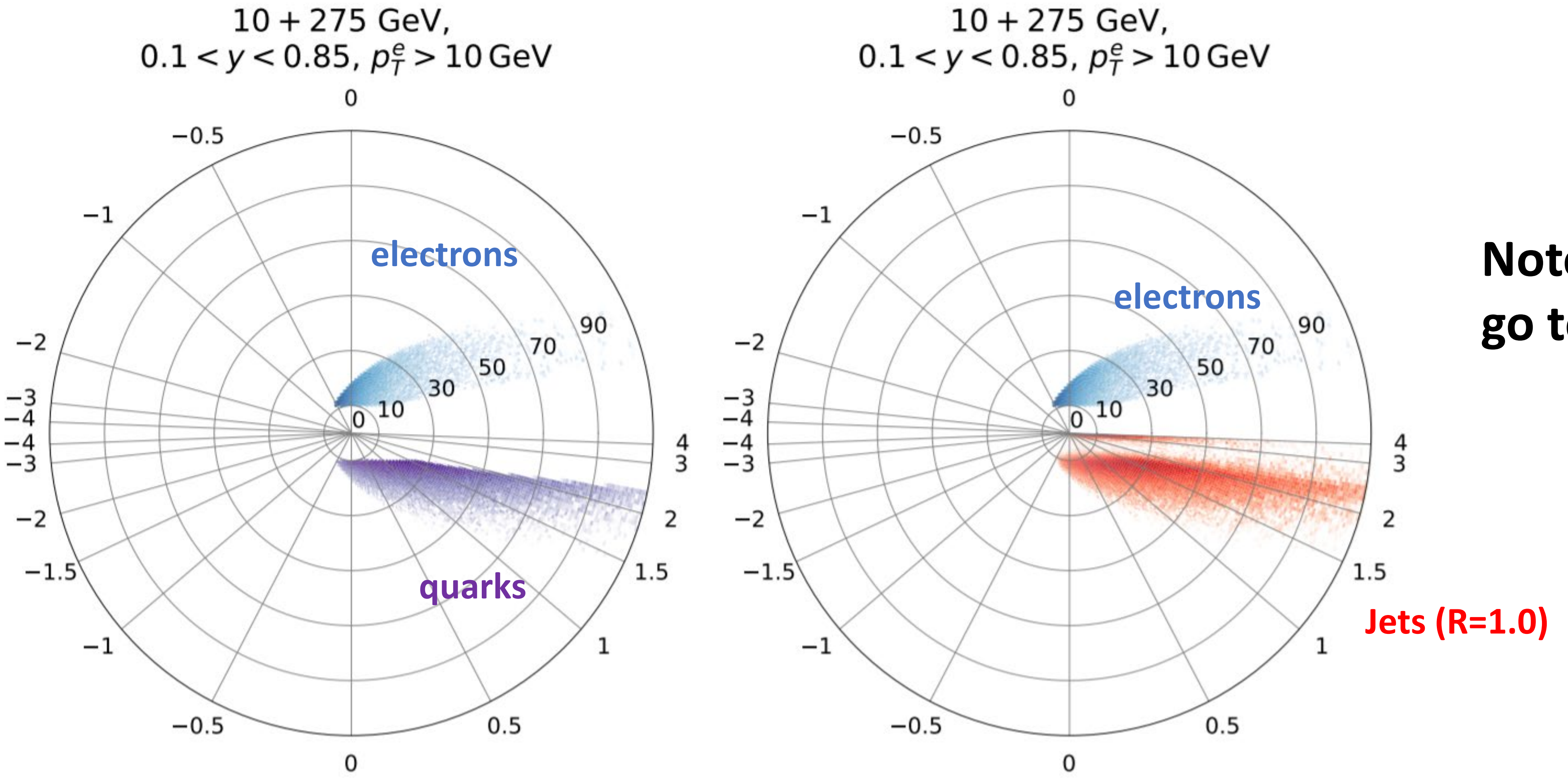
Concentrate on this beam configuration, as we need both high luminosity and high energy.

-Luminosity is required as it is a highly differential measurement, jet-Collins measurement has two more dimensions than traditional SIDIS (additional qT vector)

$$e + p(\vec{s}_T) \to e + (\mathrm{jet}(\vec{q}_T)\, h(z_h, \vec{j}_T)) + X\,.$$

-Energy is required to reach high Q2, crucial to constrain TMD evolution

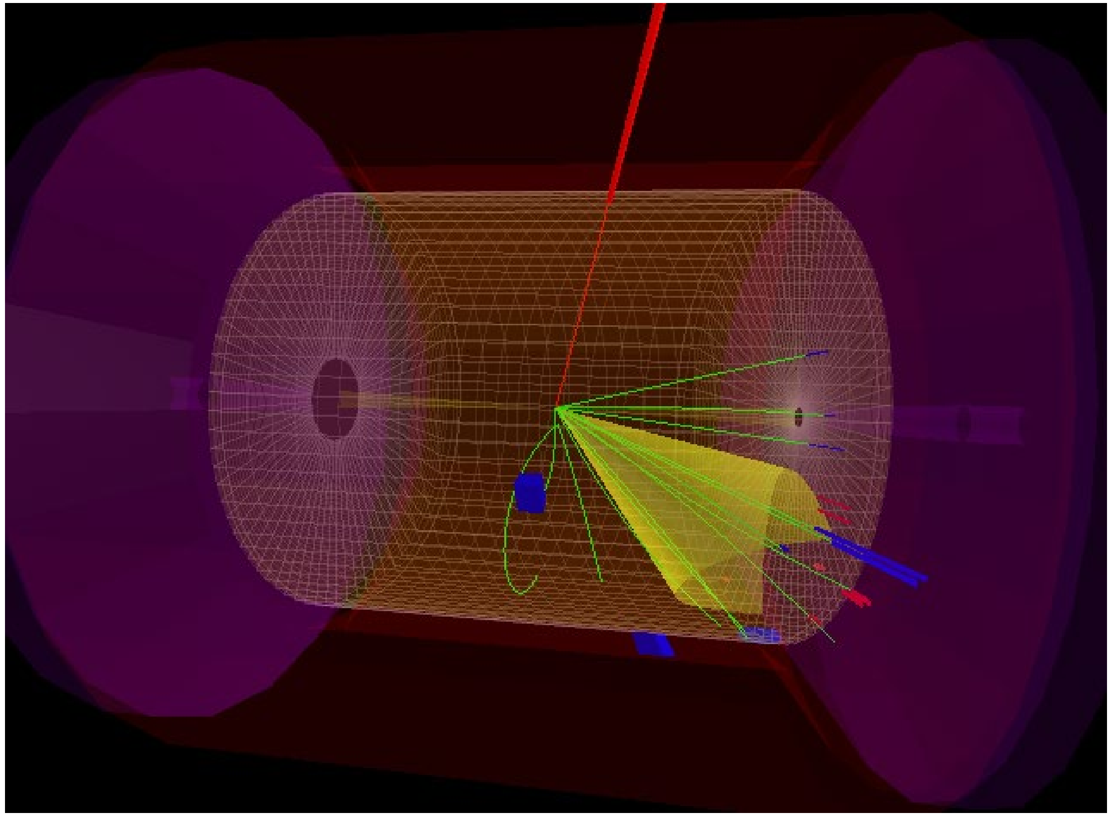
Jet kinematics for 275 GeV beam energy (most stringent PID)

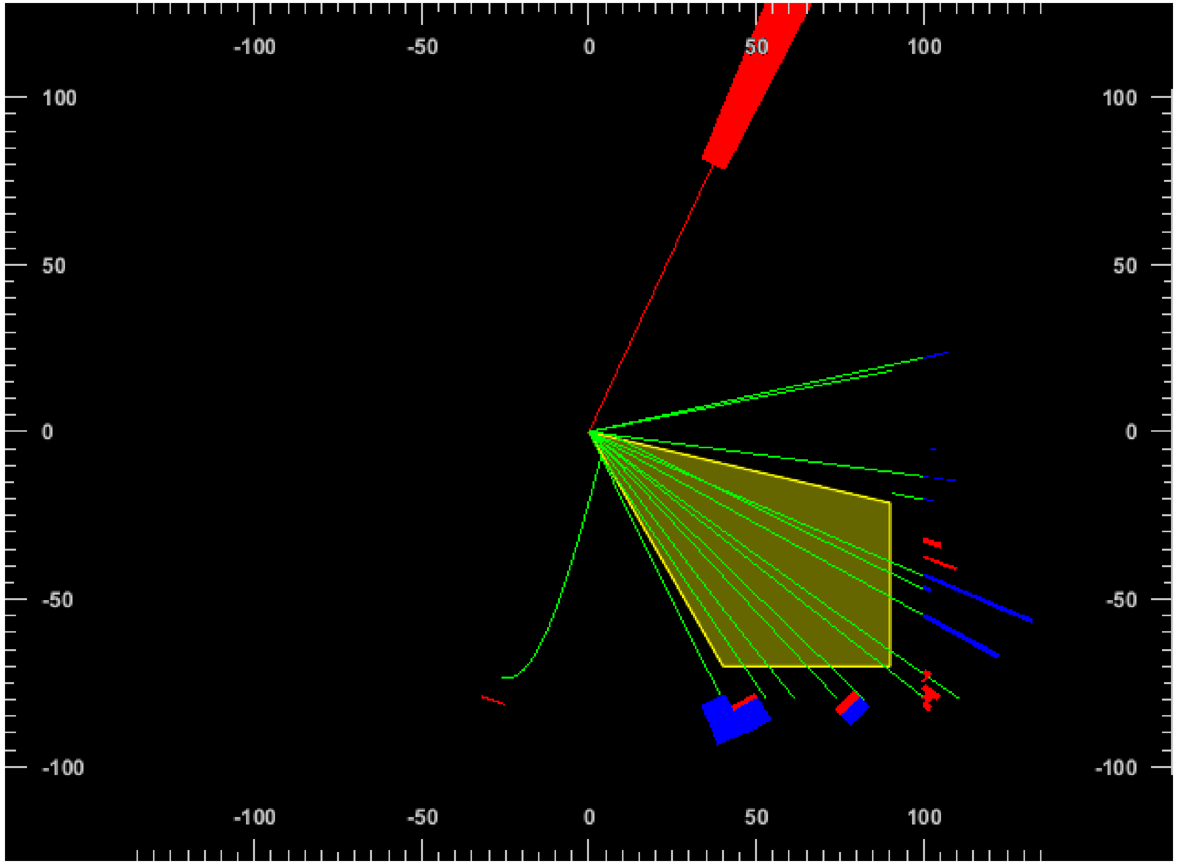


Note that most jets go to 1.0-2.5 eta

arXiv:2007.07281

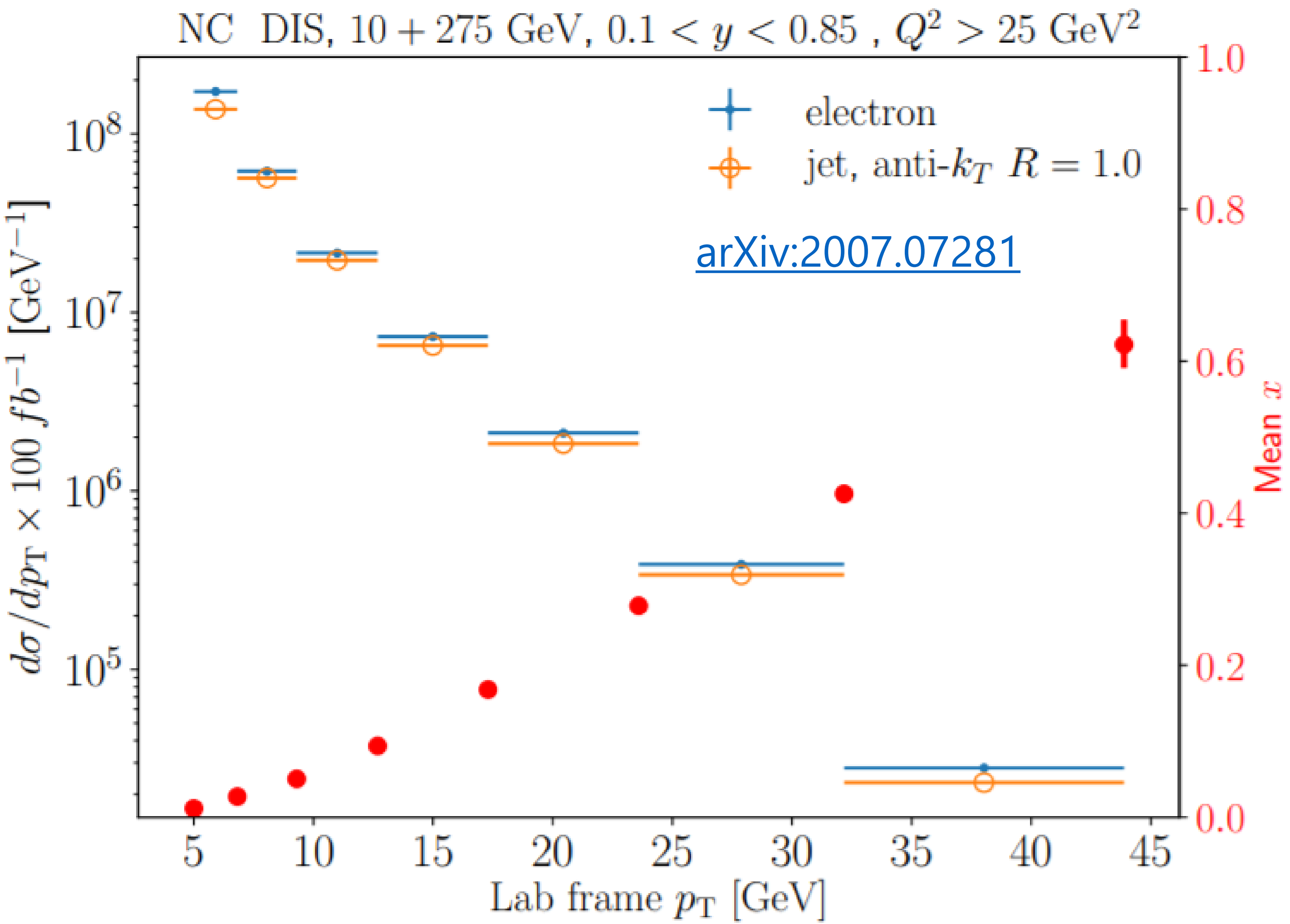
So most of the high Q2 events look like:





i.e. in the barrel-to-endcap transition.

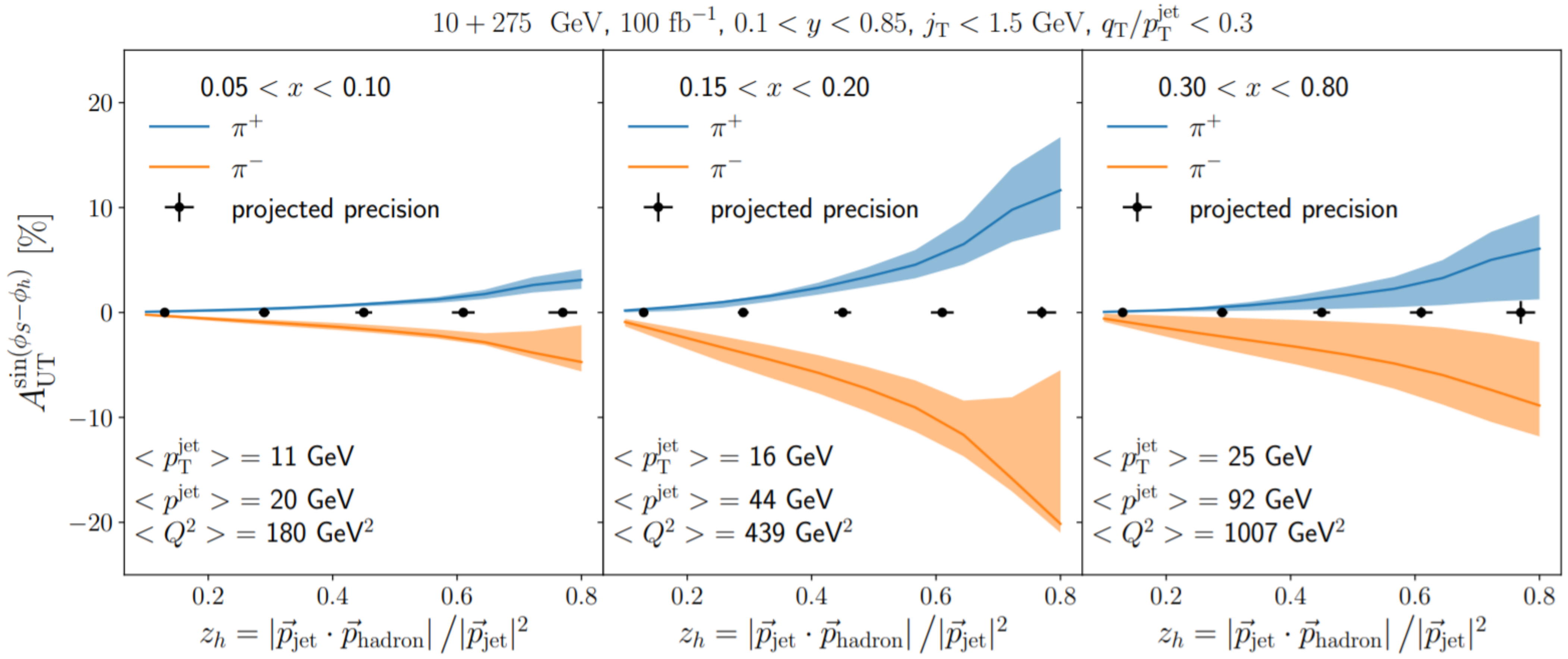
Cross-section

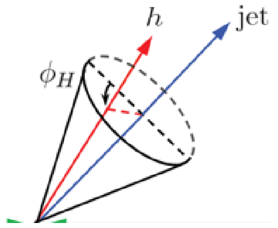


- We expect plenty of yield, even up to pT ~ 40 GeV (~150 GeV momentum)
- A key goal is to explore valence region at high Q2. x ~0.2 probed at pT~20 GeV

Hadron-in-jet Collins asymmetries

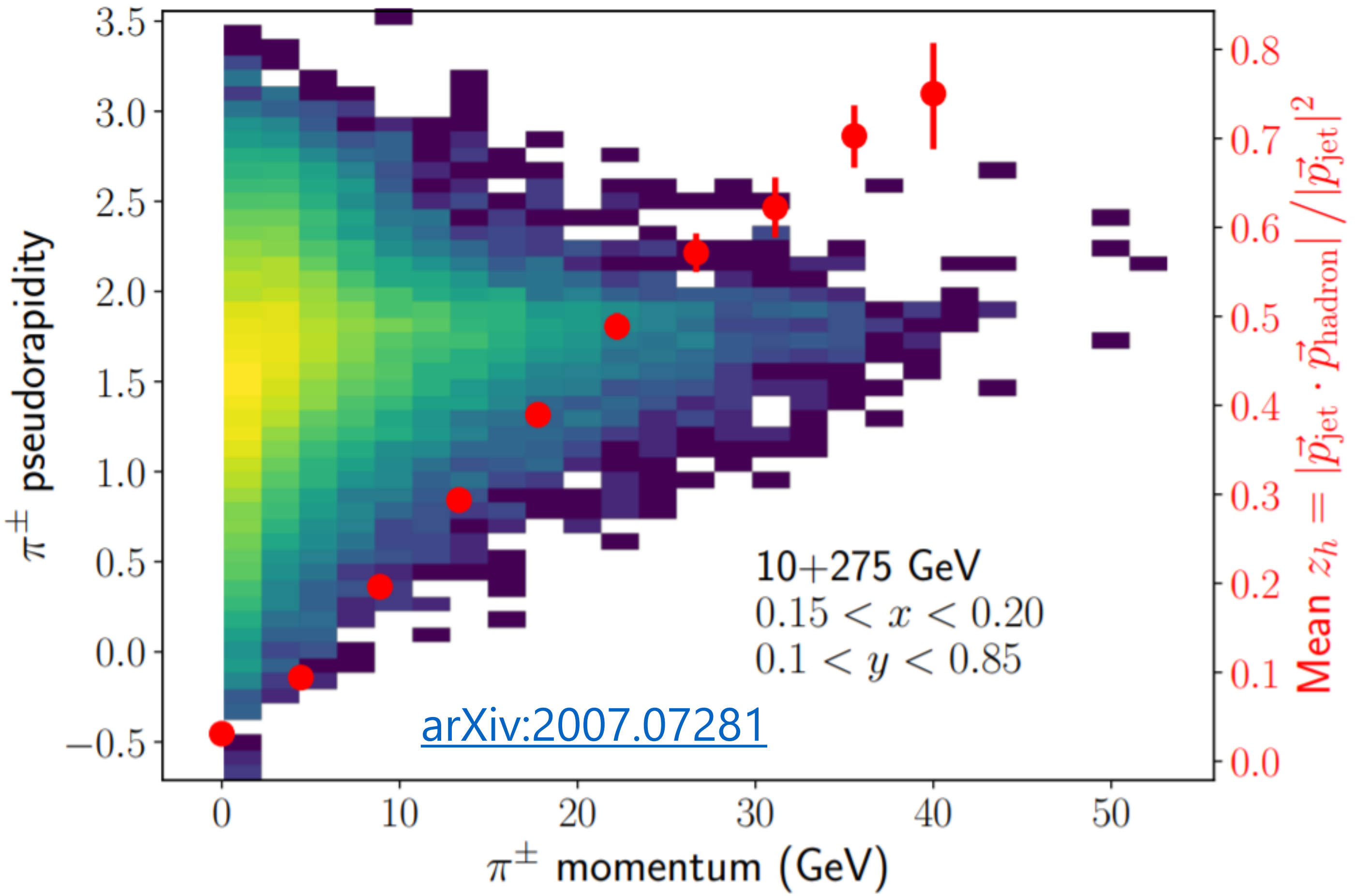
arXiv:2007.07281

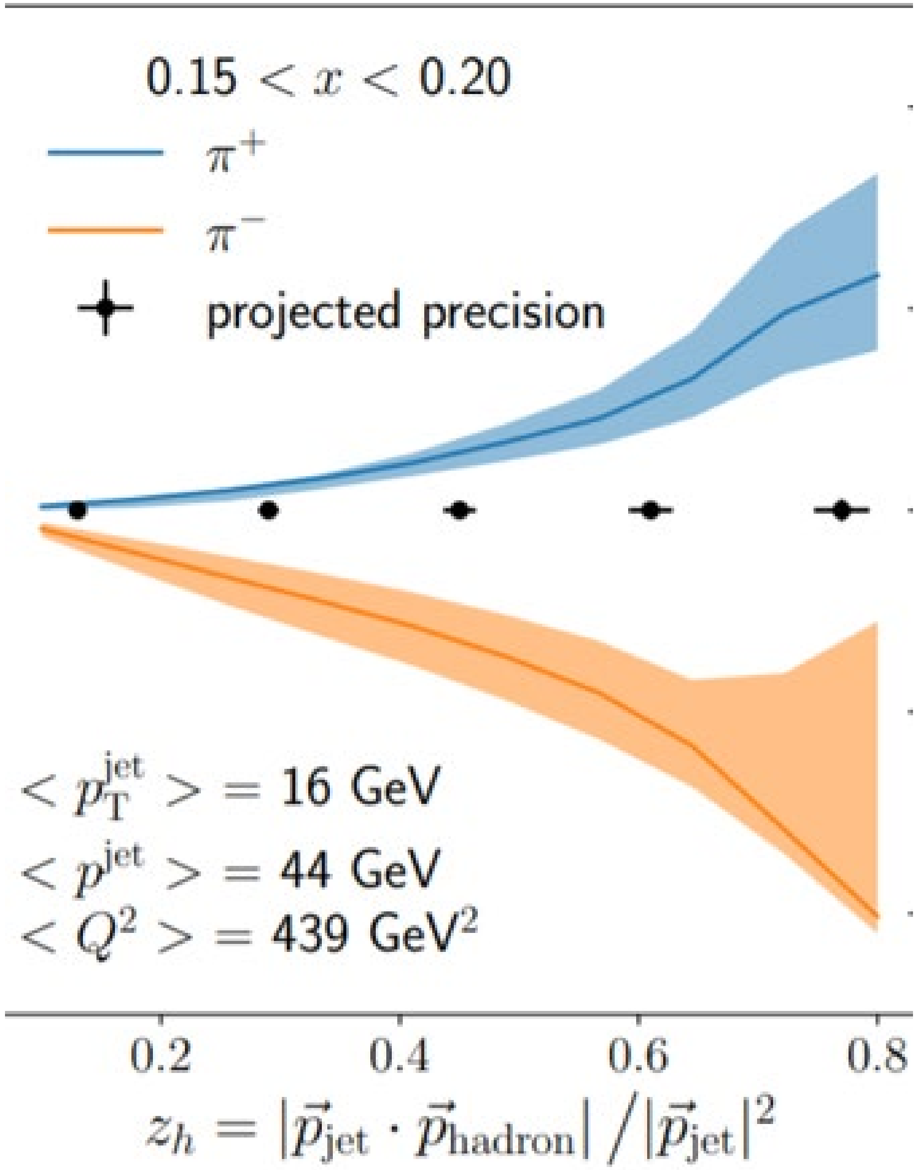




- Note that we want to sample high-z region as well as high-x region, where jet momentum reaches ~100 GeV momentum on average
- Obviously, we also want kaons, predictions not shown because Collins FF is unknown

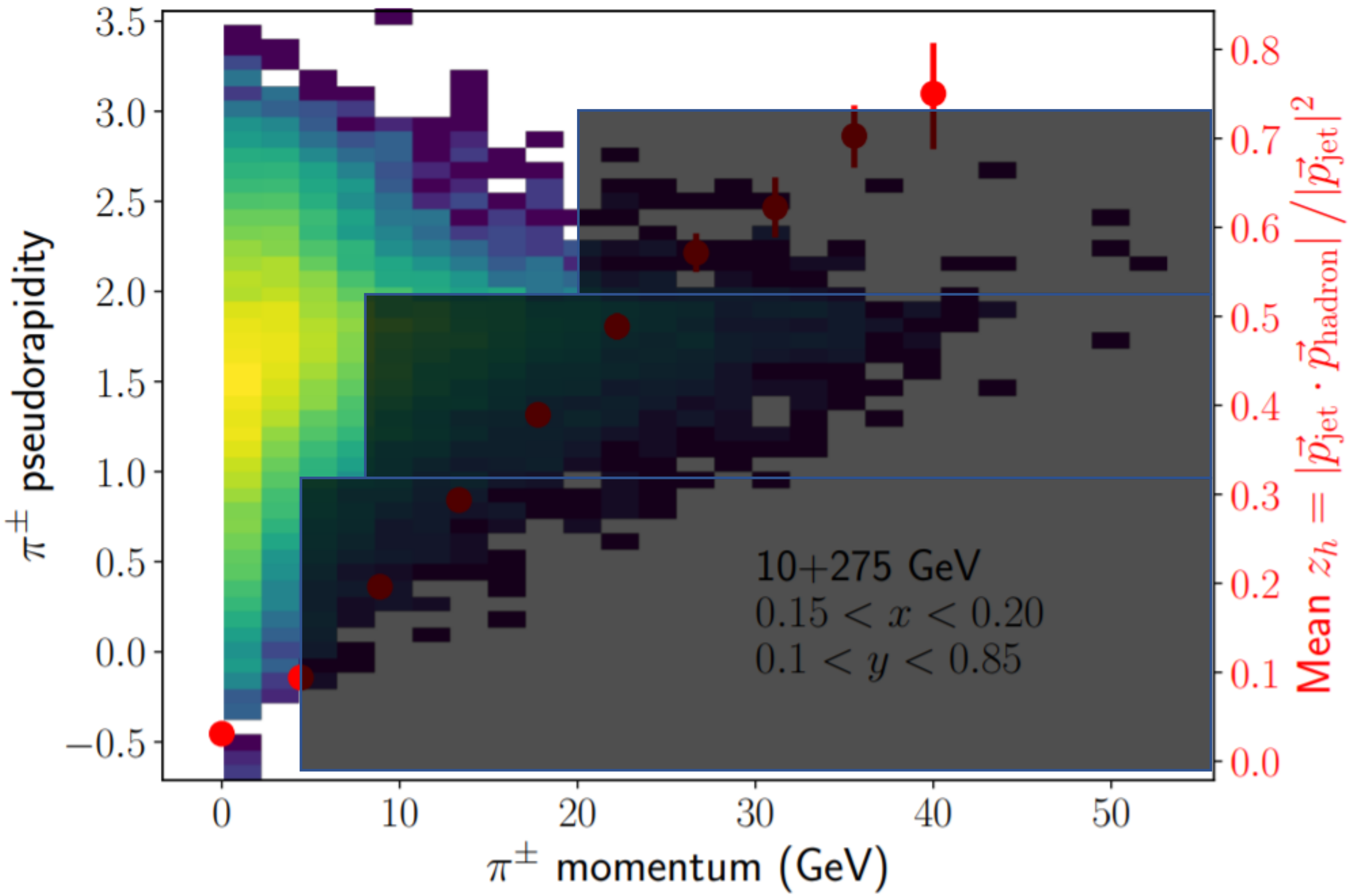
PID requirements





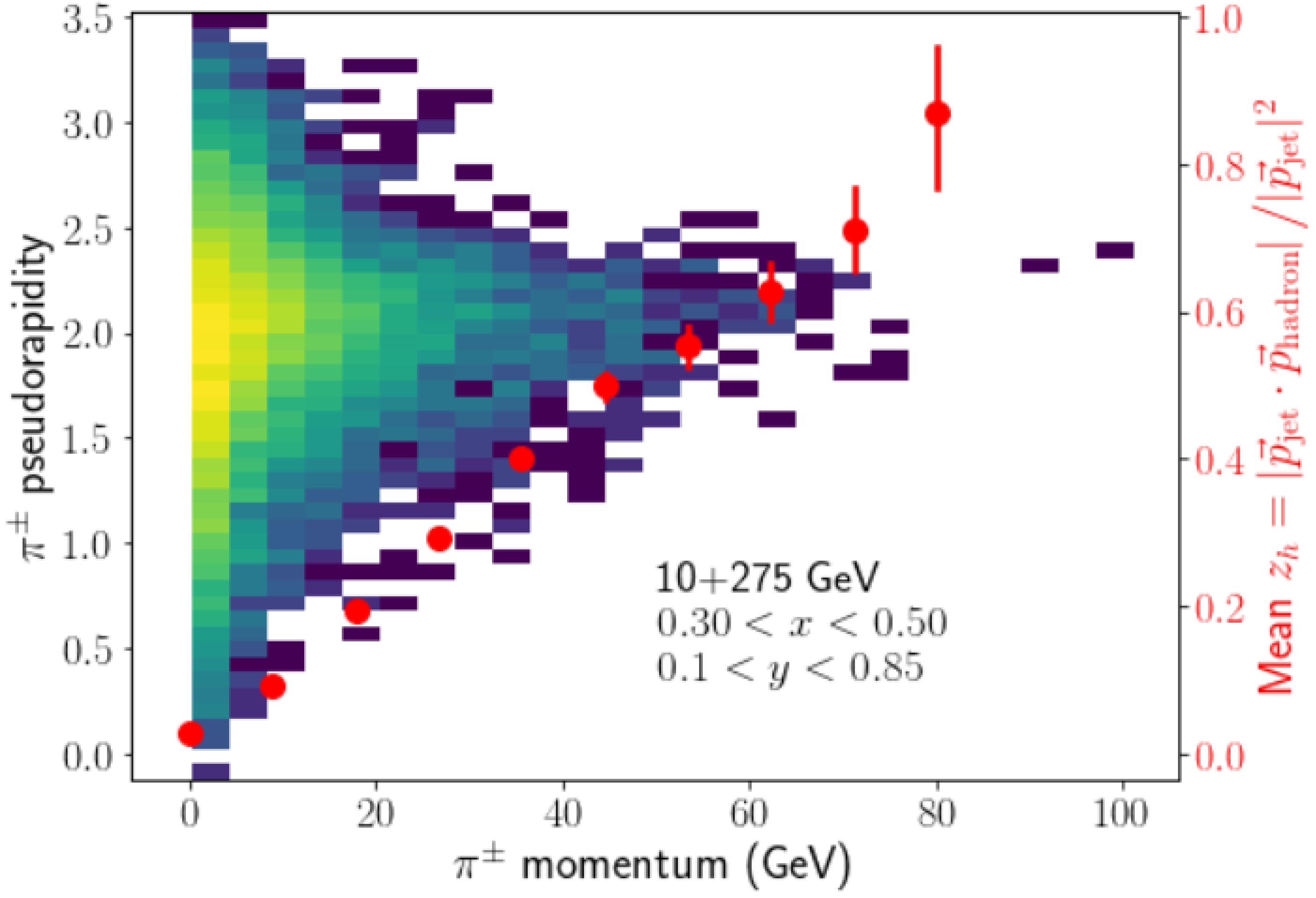
The current matrix has a pi/k/p separation up to 8 GeV in the eta region 1.0-2.0. That is totally inadequate for this measurement

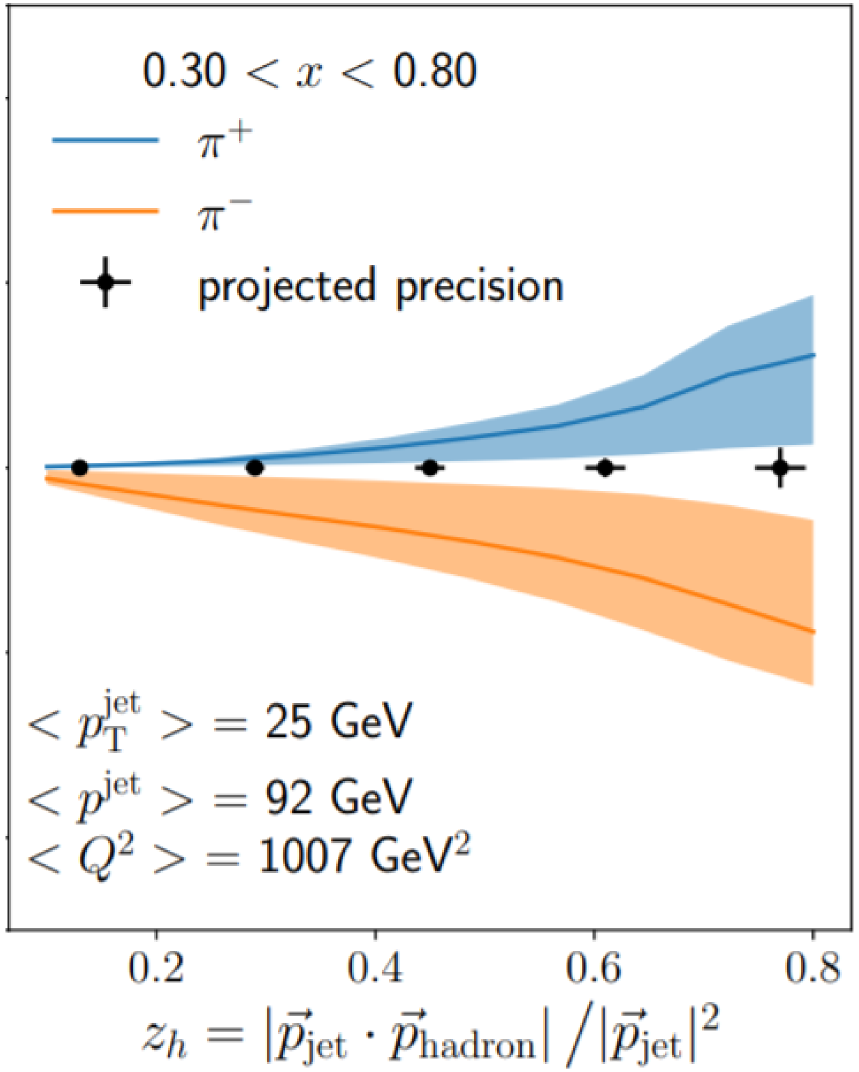
Currently in the detector matrix, “pi/K/p separation”



-1.0 to 1.0	< 5 GeV
1.0 to 1.5	≤ 8 GeV/c
1.5 to 2.0	
2.0 to 2.5	≤ 20 GeV/c
2.5 to 3.0	
3.0 to 3.5	≤ 45 GeV/c

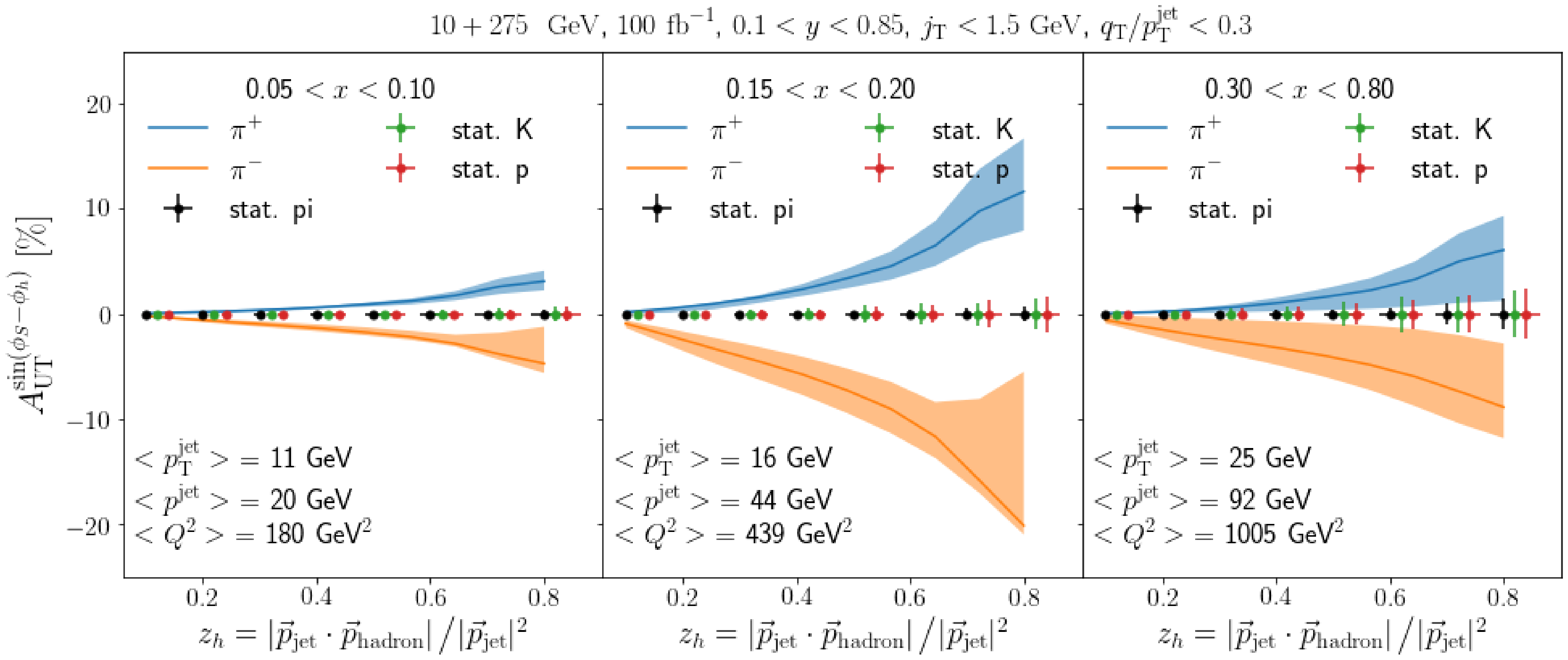
Beyond x =0.3 (no data currently exists)



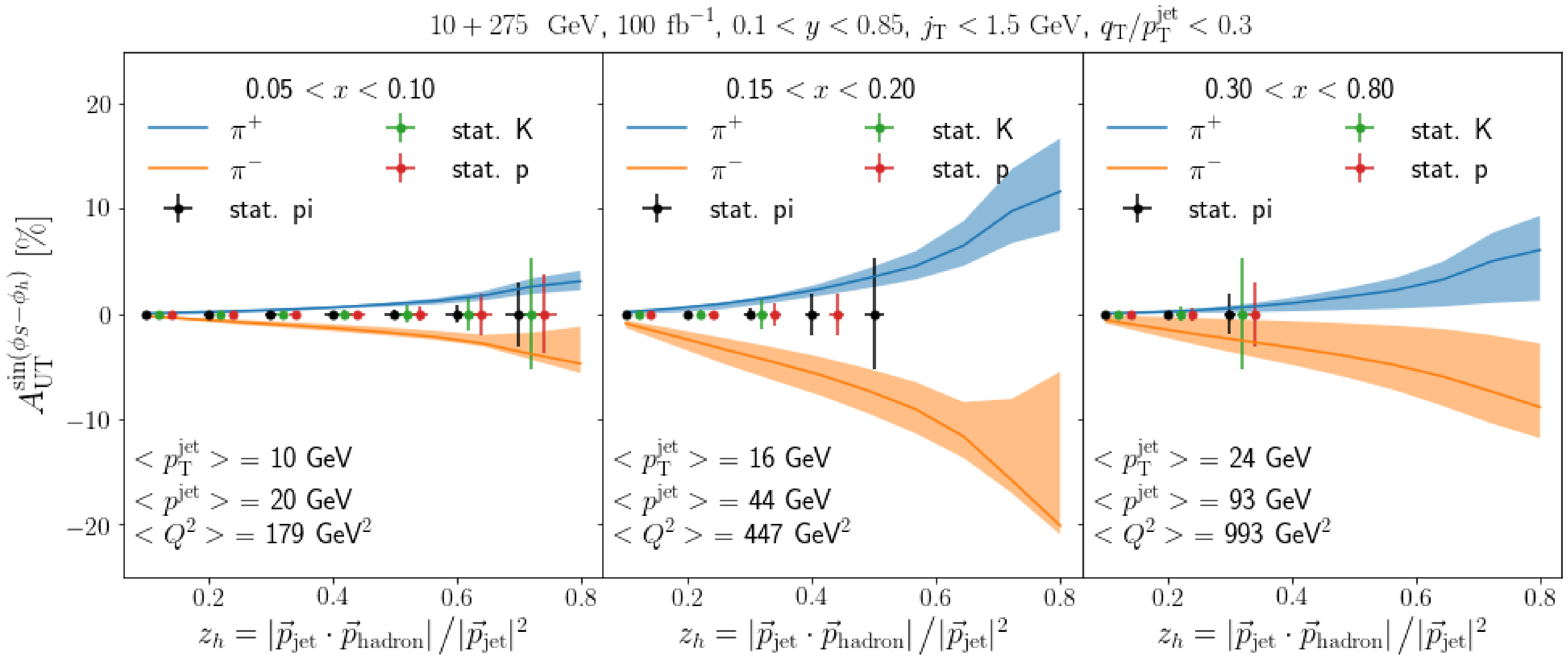


Even more stringent, up to 50 GeV for 1.5-2.0

Ideal PID coverage

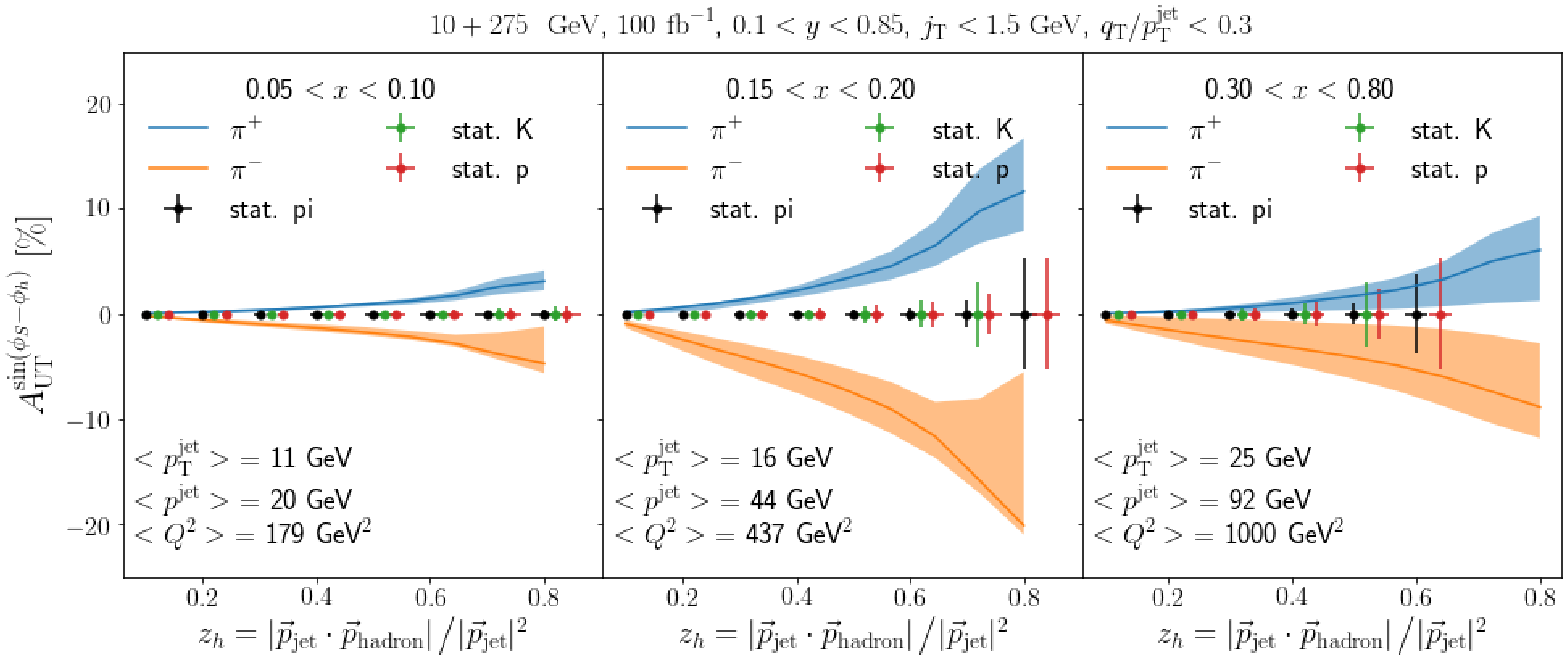


Detector Matrix as it is now



This shows data unbinned in Q2, so is biased towards the lowest Q2,
-> the least demanding

With proposed PID coverage

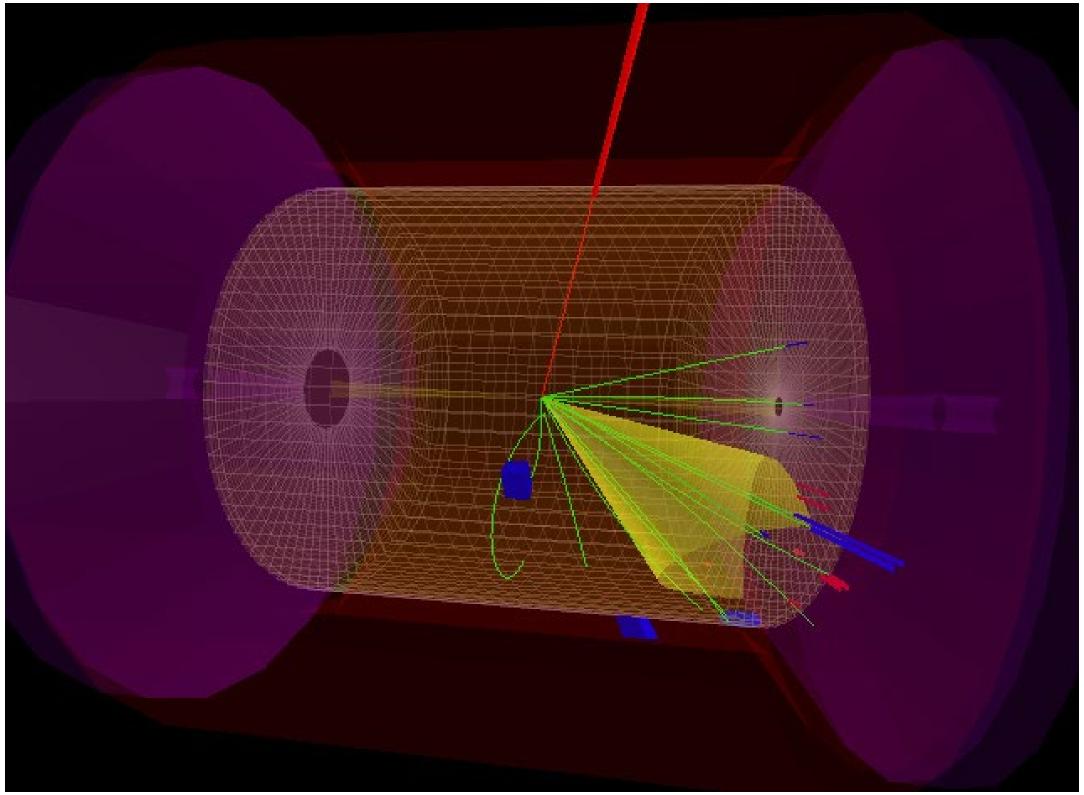


This shows data unbinned in Q2, so is biased towards the lowest Q2,
-> the least demanding

Take-home message

For the hadron-in-jet Collins measurements, which probe mid-to-large x and mid-to-large Q2, (i.e roughly x>0.01 and Q2>100 GeV2) we would need the PID up to ~50 GeV already at eta=+1.0 to +2.0. No very stringent requirement beyond eta = +2.5.

Note this is vastly different from low Q2 SIDIS measurements. Perhaps this is an opportunity for detector complementarity. Perhaps one can optimize a PID system for low-Q2 SIDIS and another for high-Q2 jets.

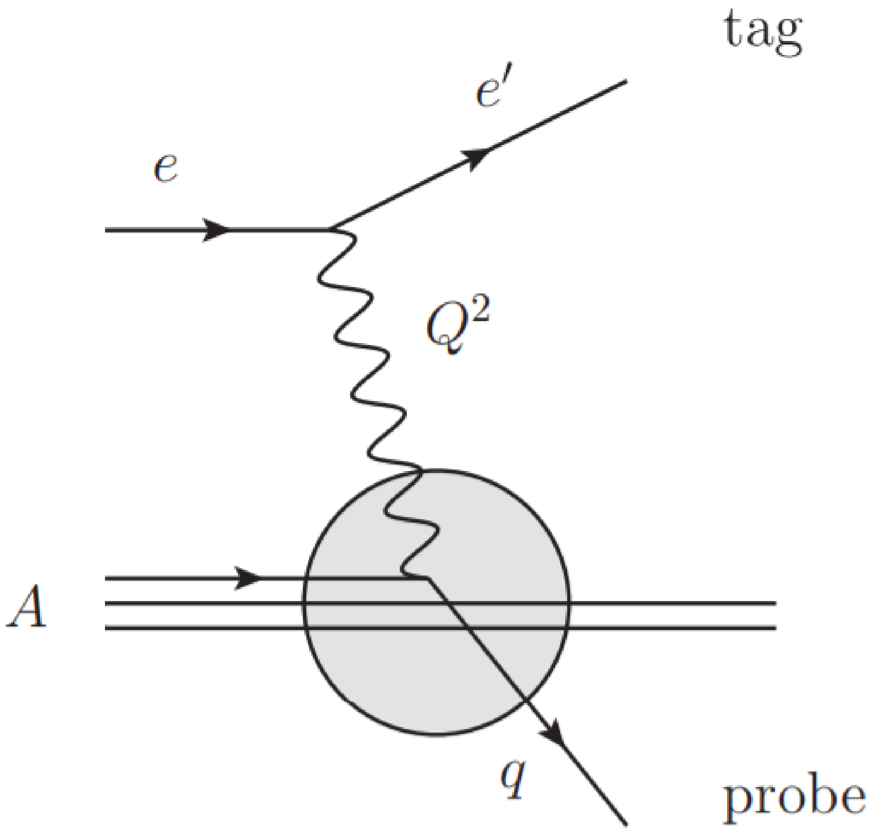


“Why can’t you do this with lower beam energies, which have less stringent PID requirements?” “Why can’t you pursue this physics with low-Q2 SIDIS?”

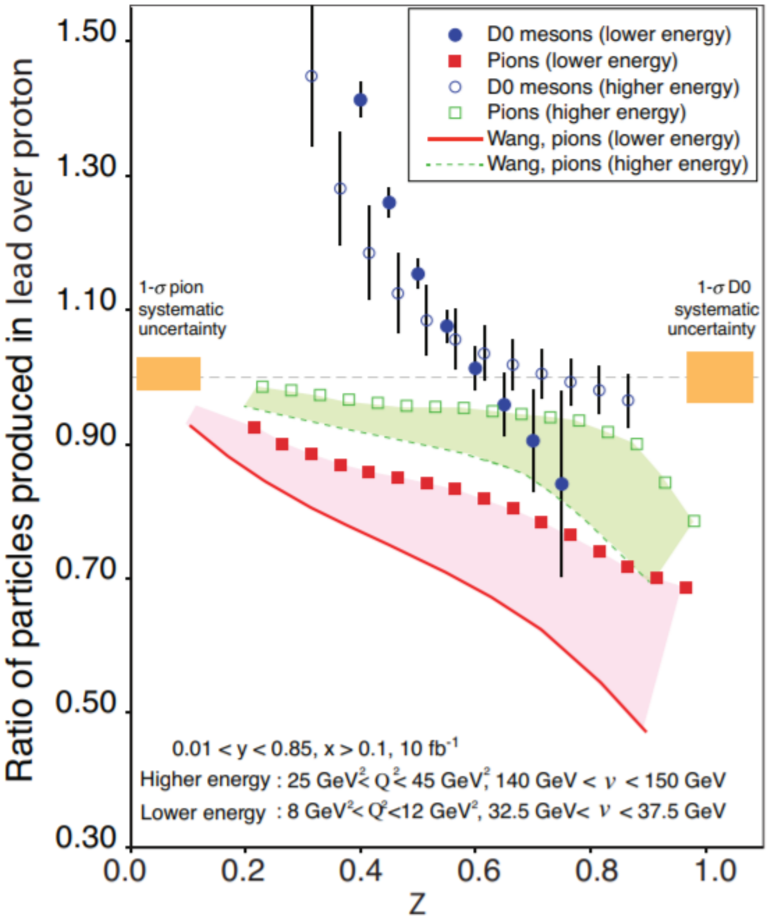
- We need to make sure that we can probe highest Q2 available at EIC, which come at the highest proton-beam energies.
- We need to probe the entire x, Q2 phase space available (imagine a detector optimized for inclusive DIS for only Q2<10 GeV2)
- Jets at high Q2 allow us to cleanly separate TMD PDF and TMD FF. (see https://arxiv.org/abs/2007.07281)
- Constrain TMD evolution requires low and high Q2 EIC data.
- Test universality and factorization by comparing to RHIC jet measurements at similar kinematics.
- Benefit from jet-substructure advances for spin/TMD physics.

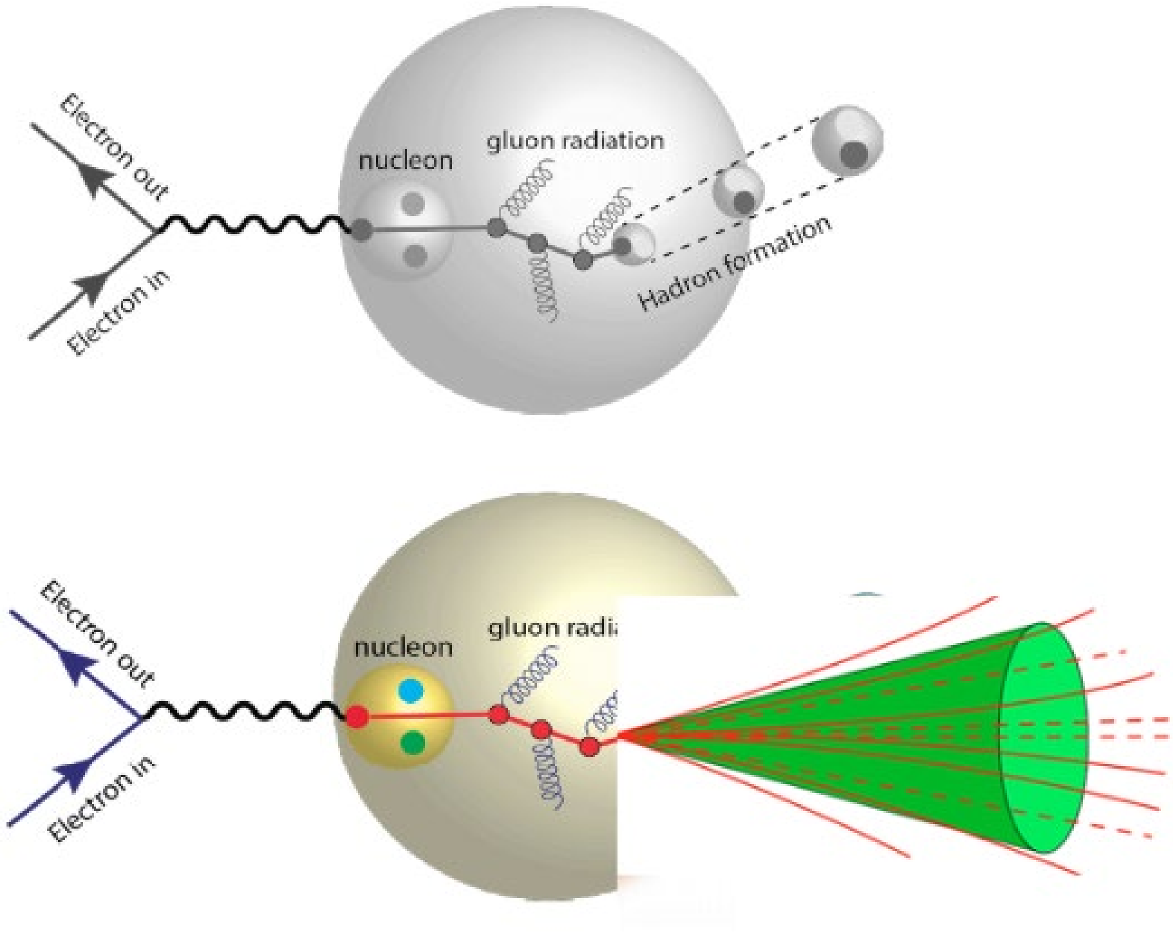
PHYSICAL REVIEW C **101**, 065204 (2020)

Jets as precision probes in electron-nucleus collisions at the future Electron-Ion Collider



We need high Q2 jet measurements, not just low-Q2 hadron measurements

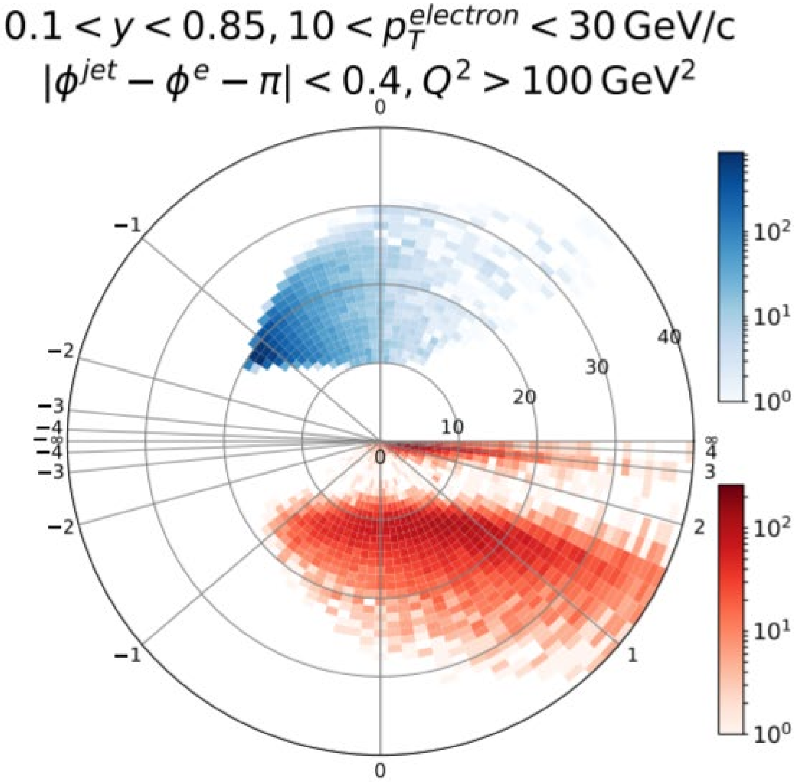




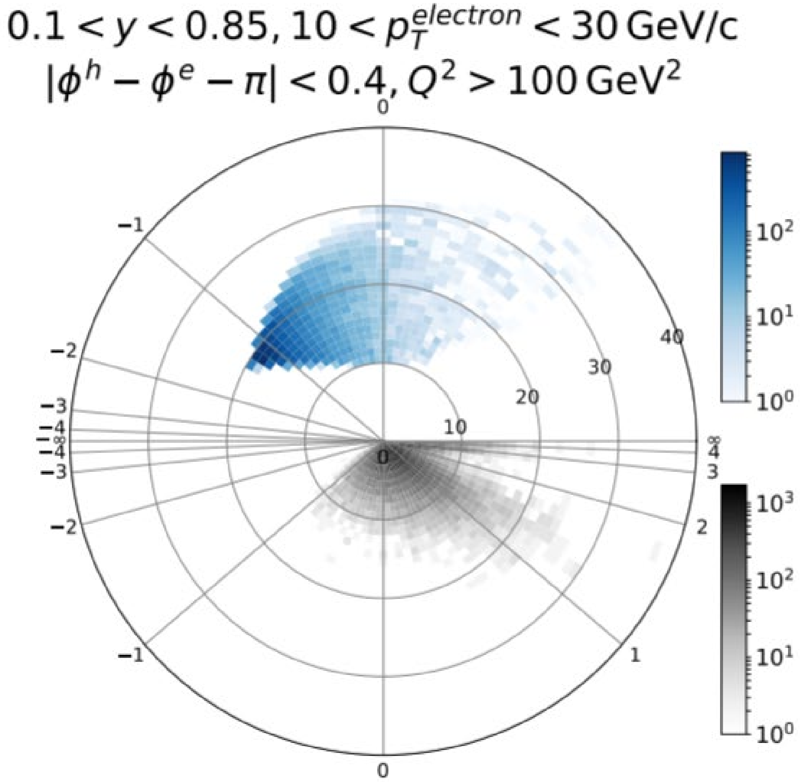
PID critical for cold-nuclear matter studies with light-,strange-, and charm-jets; jet fragmentation and other substructure studies; and nuclear TMDs!

For 100 GeV nucleon beam (highest for e-A) the barrel region is critical

Phys. Rev. C 101, 065204 (2020)



Jets, R=1.0



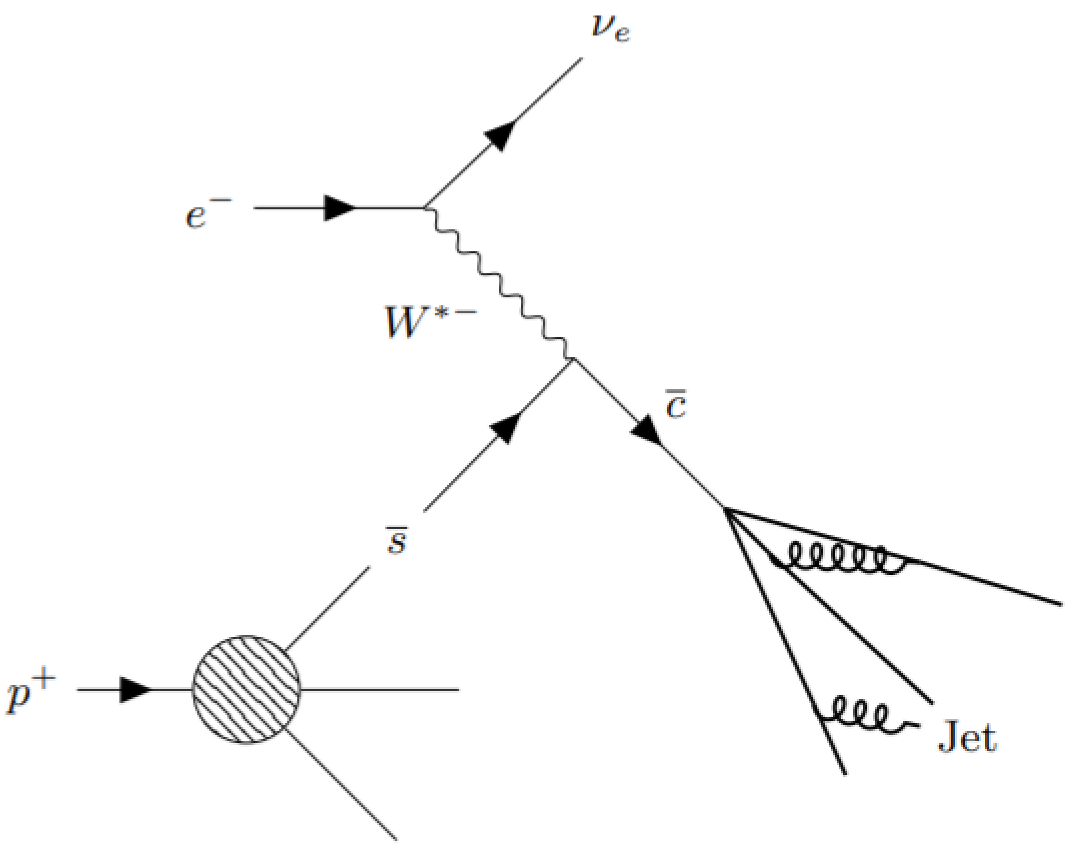
Hadrons

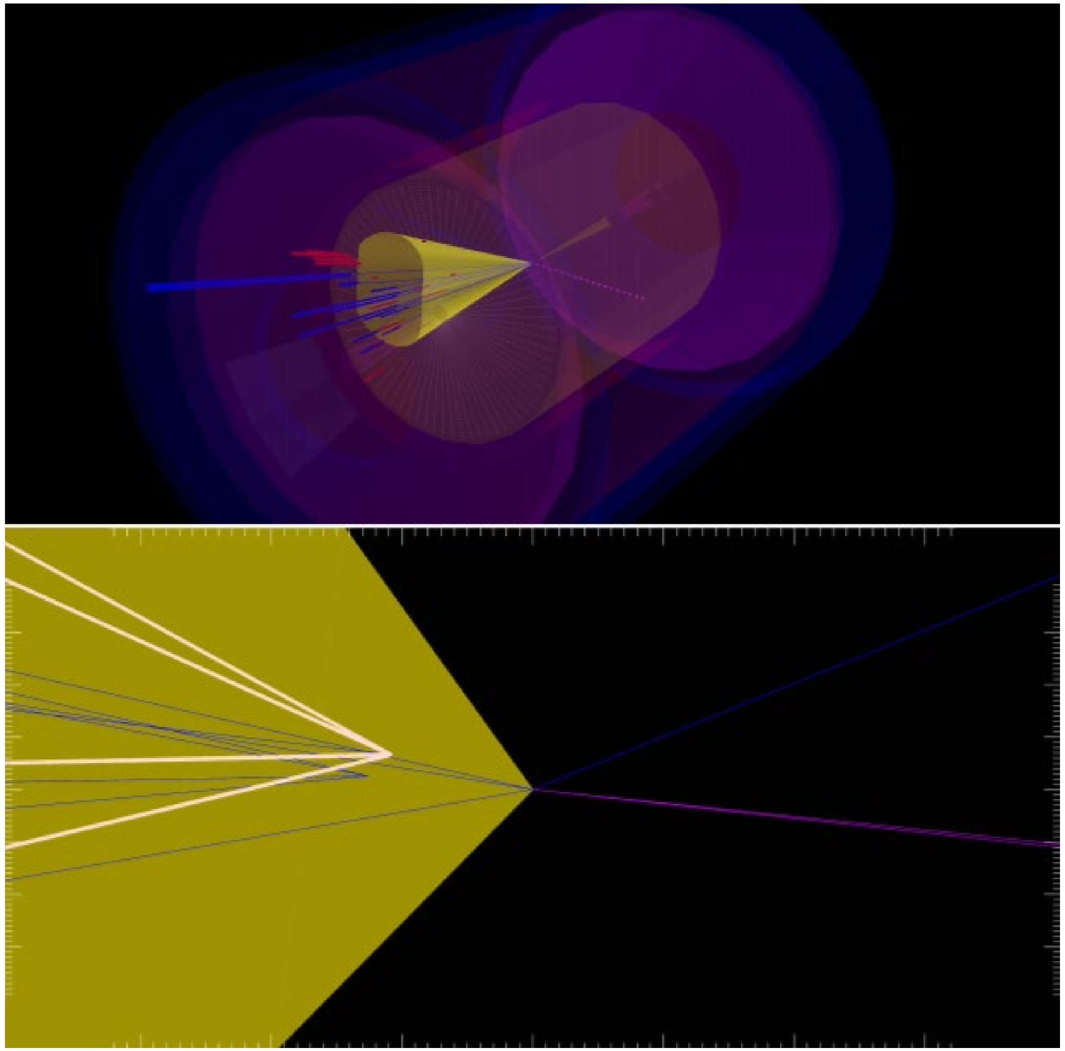
Current detector matrix goes to 5 GeV up to eta=+1.0, but jets go to 30 GeV.

To cover up to z~0.6 we would need PID up to ~8 GeV from 0 to +1.0, and up to ~15 GeV from 0.75 to +1.0

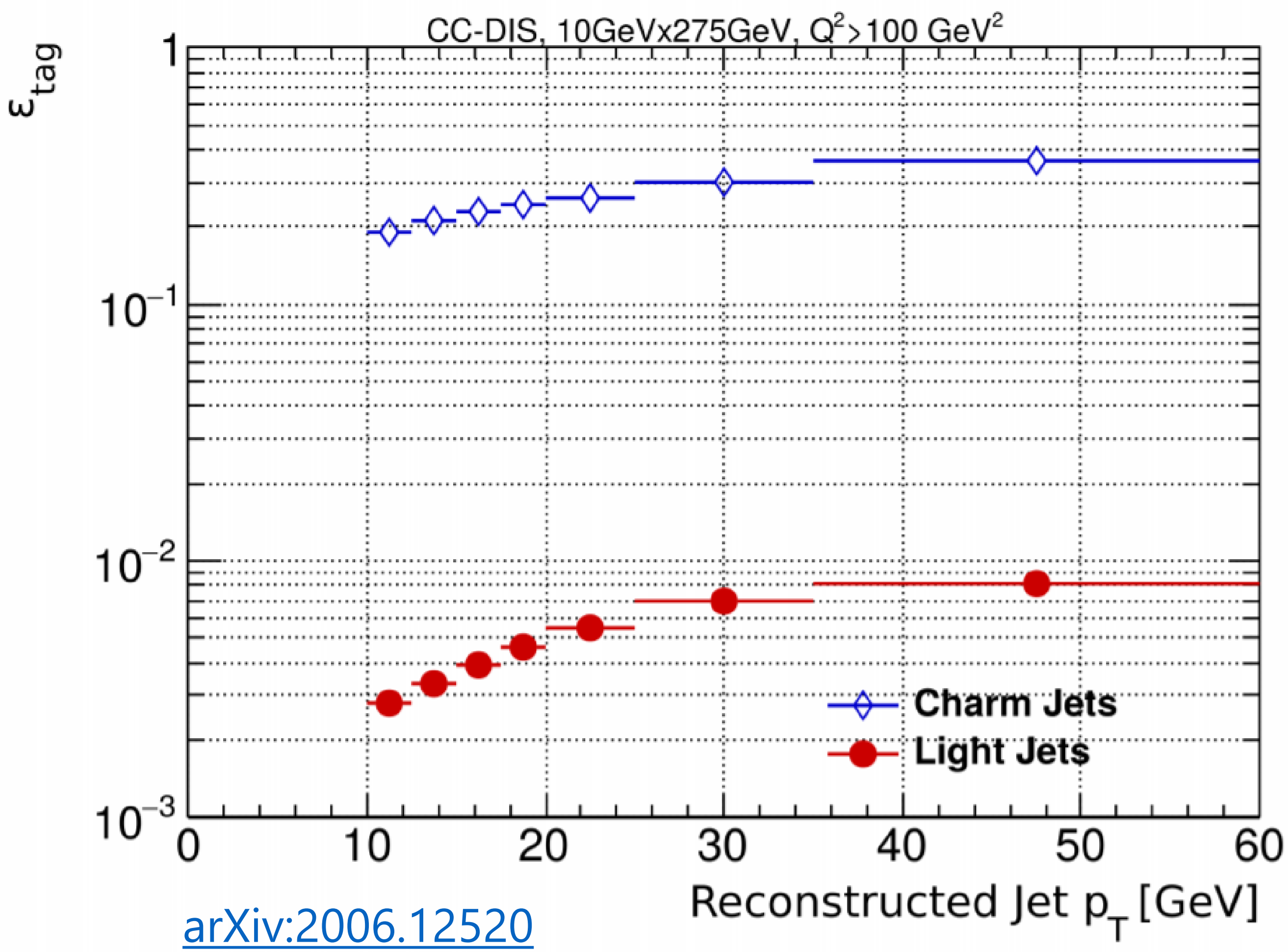
Charm jets as a probe for strangeness at the future Electron-Ion Collider

Miguel Arratia,[1,2] Yulia Furletova,[2] T. J. Hobbs,[3,4] Fredrick Olness,[3] and Stephen J. Sekula[3,*]





PID, Kaons in particular, can help improve charm-tagging efficiency significantly

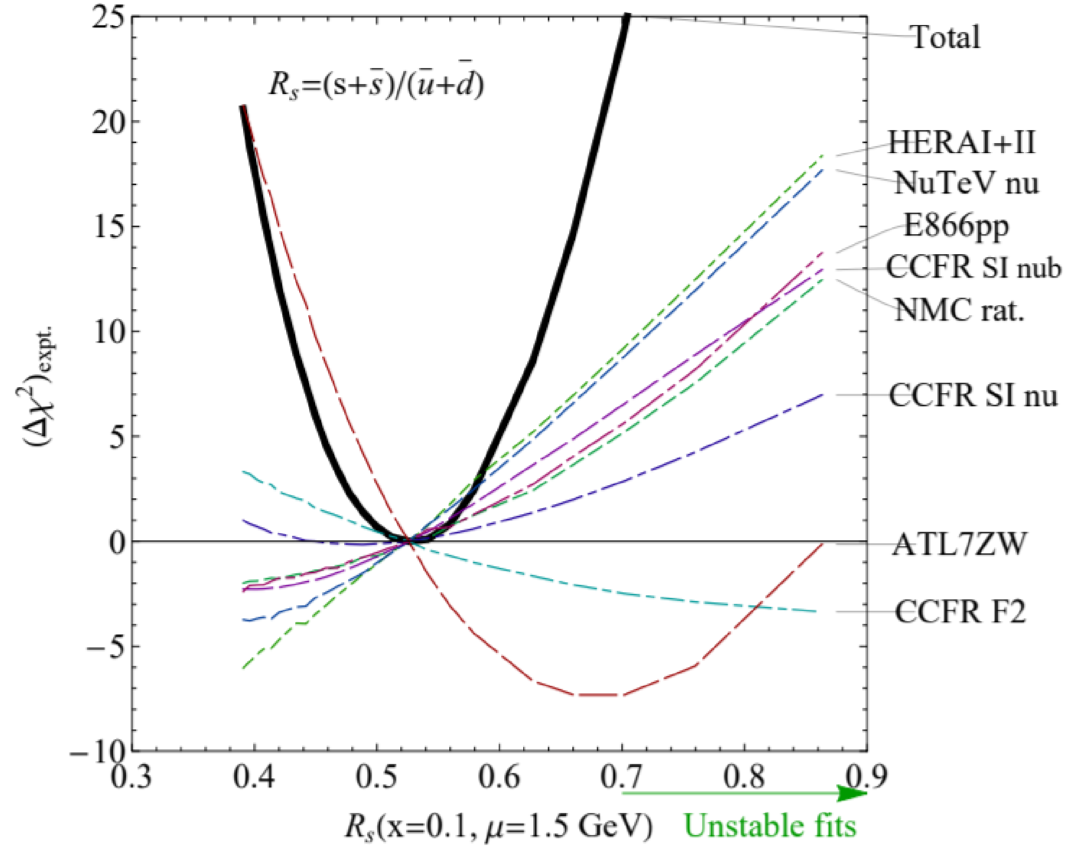


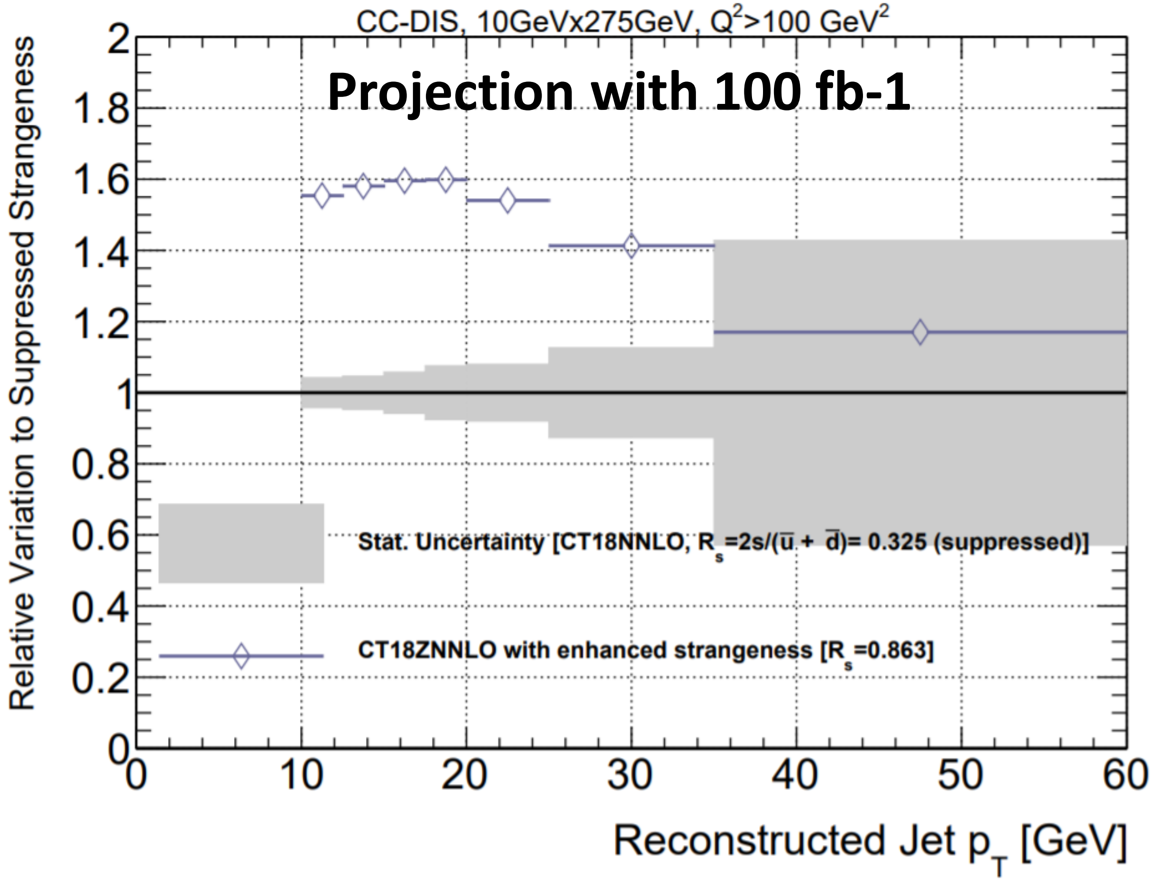
arXiv:2006.12520

We show in arXiv:2006.12520
That adding PID increases tagging from ~20% (purely displaced vertex) to ~30%.
Multi-variate approaches would likely bring that number to ~40-50%

Key channel to constrain strange at EIC

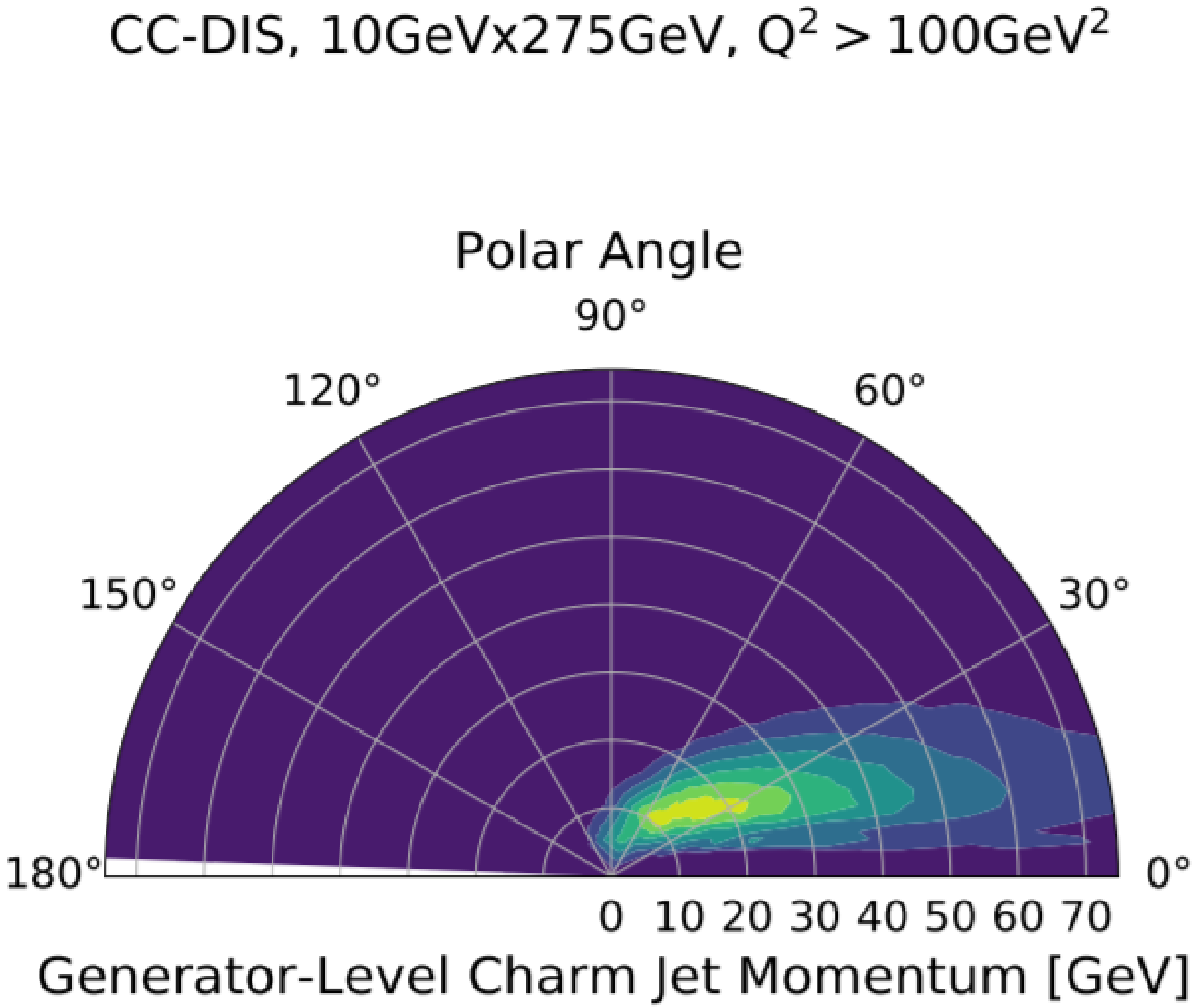
arXiv:2006.12520 CT18Z NNLO





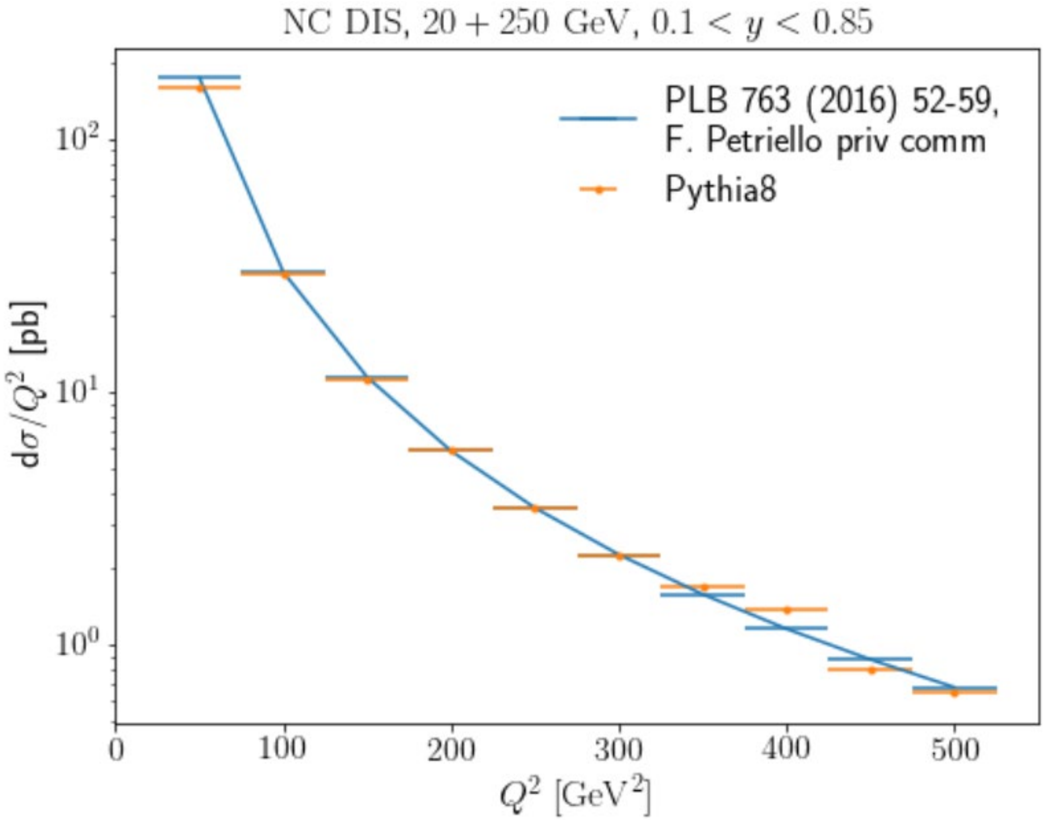
Luminosity hungry measurement, significantly higher efficiency with PID would enable a significant measurement with less beam time (potentially a factor of of ~2)

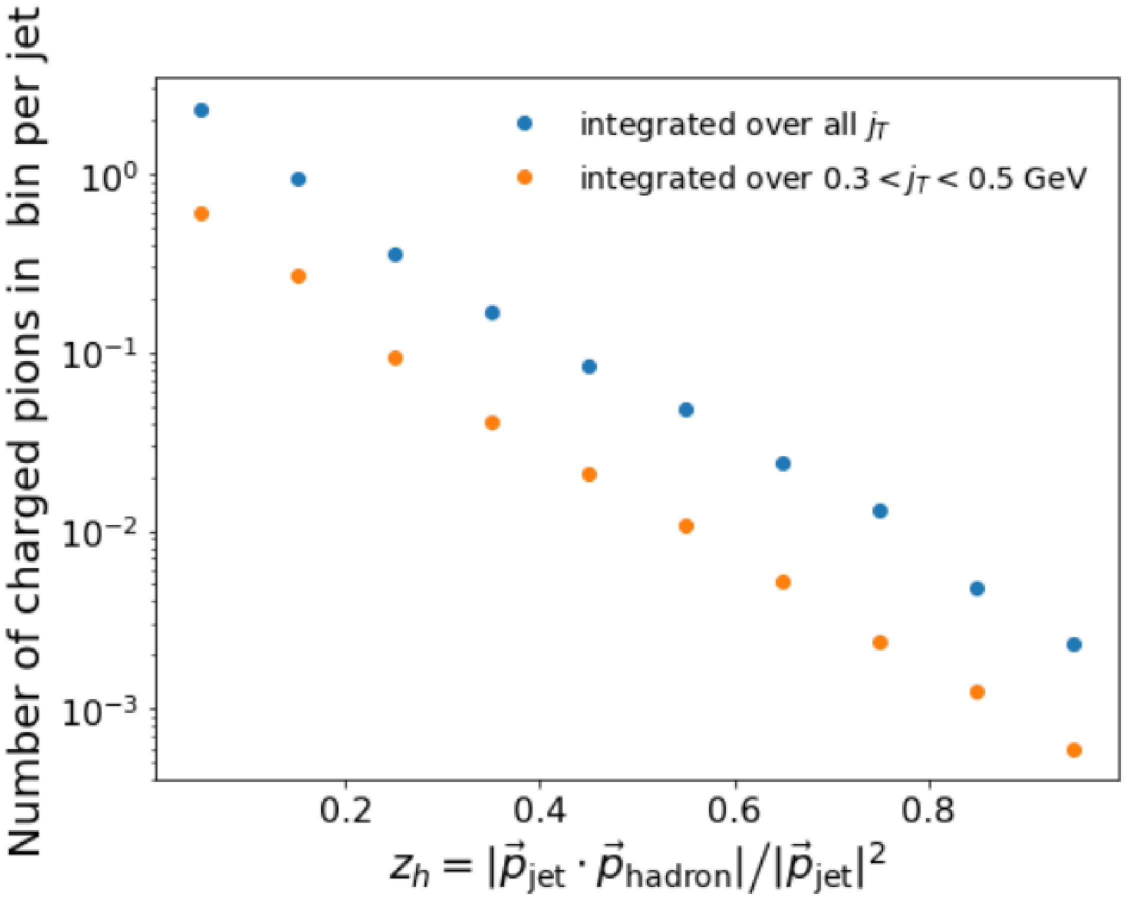
Jet kinematics are similar to those in NC DIS



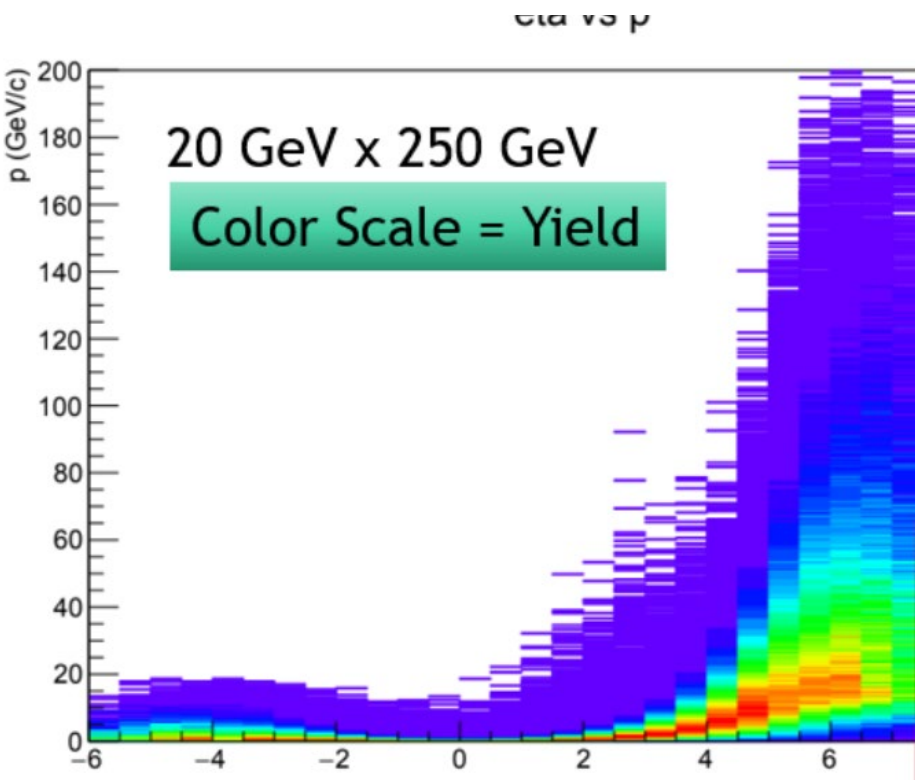
arXiv:2006.12520

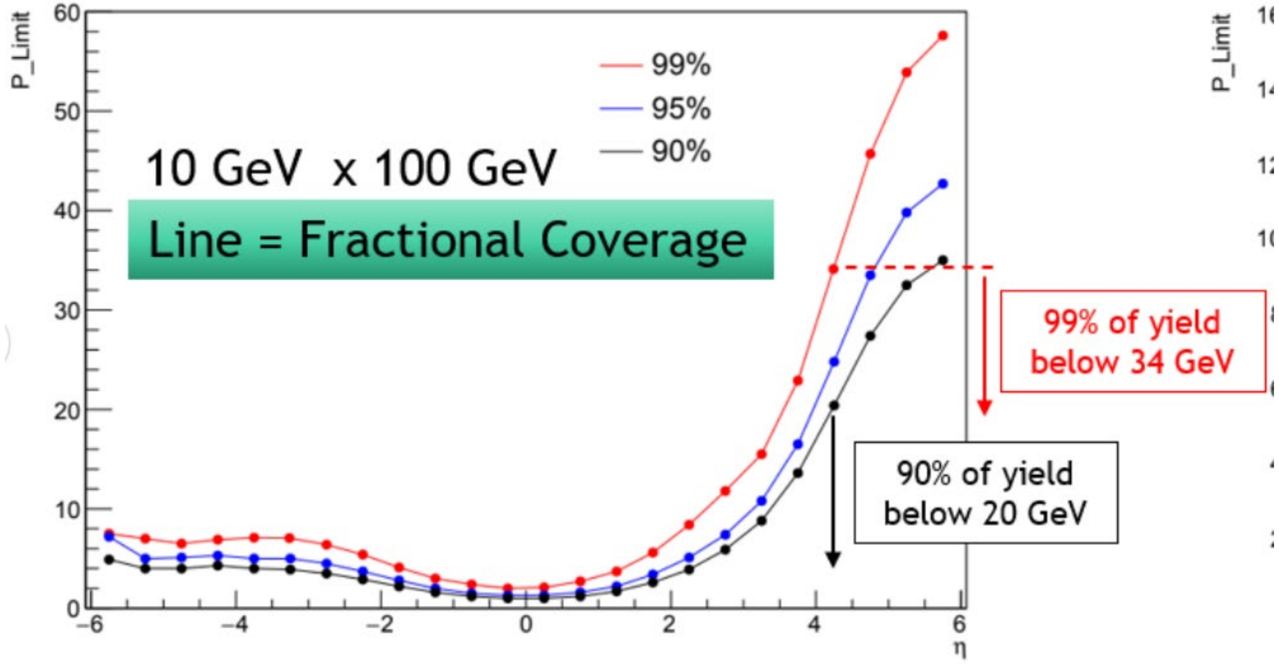
Cross-sections drops fast in Q2 and z…





So I think your proposed fractional coverage metric requires binning in Q2 AND x AND z

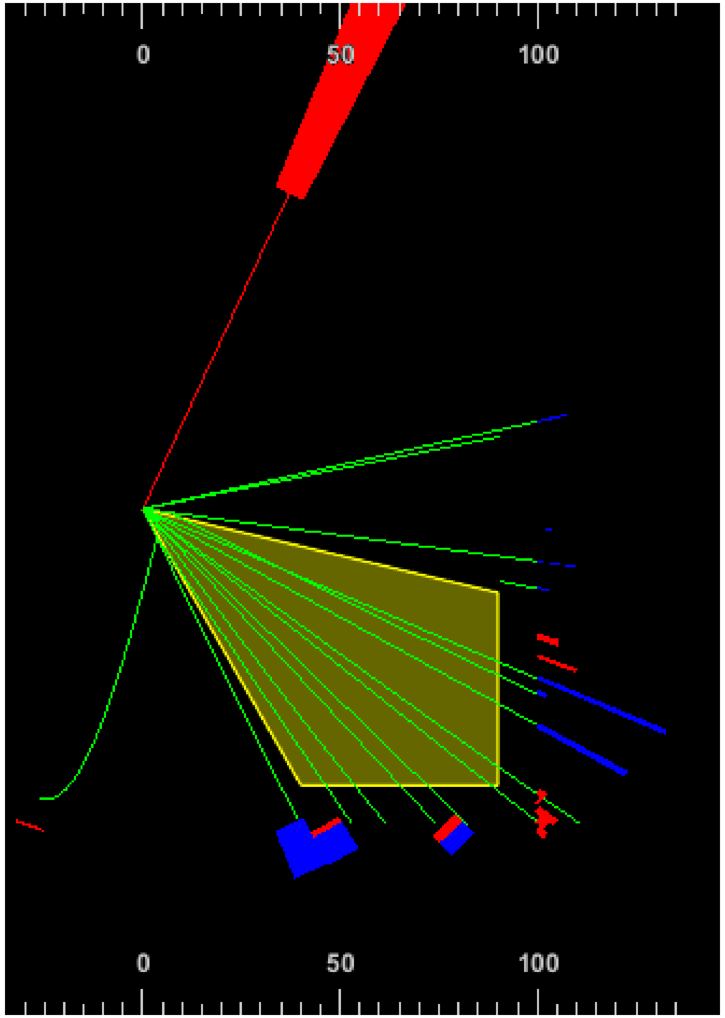




Otherwise one is completely dominated by low Q2, and low z region.

Conclusions

- PID requirements for high Q2 events (= jet events) are more demanding toward more central region of the detector. The barrel-to-endcap region is critical, the very forward region is not so important.
- There are plenty of good reasons to aim for PID for high Q2, including but not limited to hadron-in-jet Collins, strange-tagged jet-Sivers, strange PDF,
  jet fragmentation in cold nuclear matter, etc.
- If one cannot optimize for entire eta range, this might offer a possibility of complementarity: one detector optimized for Q2>100 GeV2 and another for Q2<100 GeV2
  i.e a PID system for a jet detector and another for a SIDIS detector



$0.5 < \eta < +1.0 < 10\text{–}15$ GeV
$+1.0 < \eta < +1.5 < 25$ GeV
$+1.5 < \eta < +2.0 < 50$ GeV
$+2.0 < \eta < +2.5 < 20$ GeV