On the PID requirements of jets for 3D imaging

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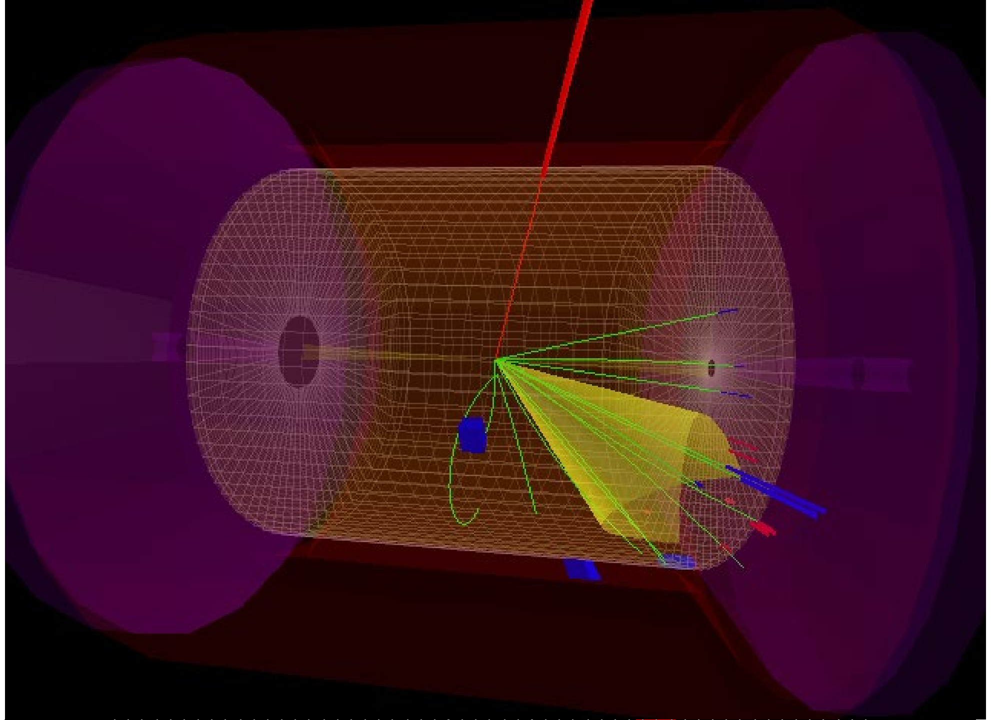
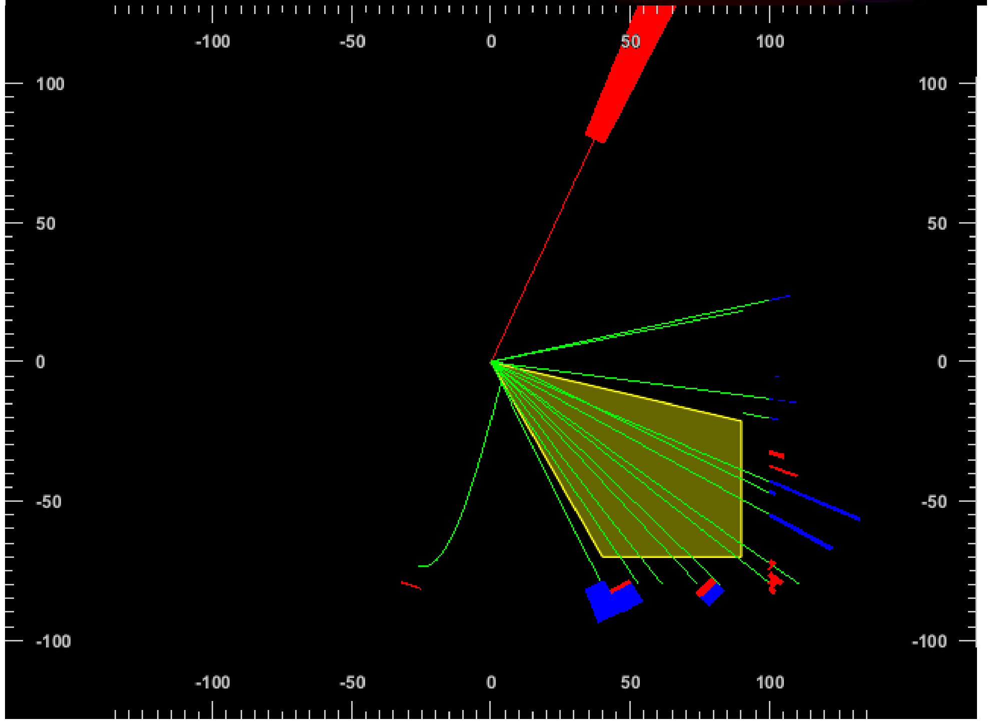
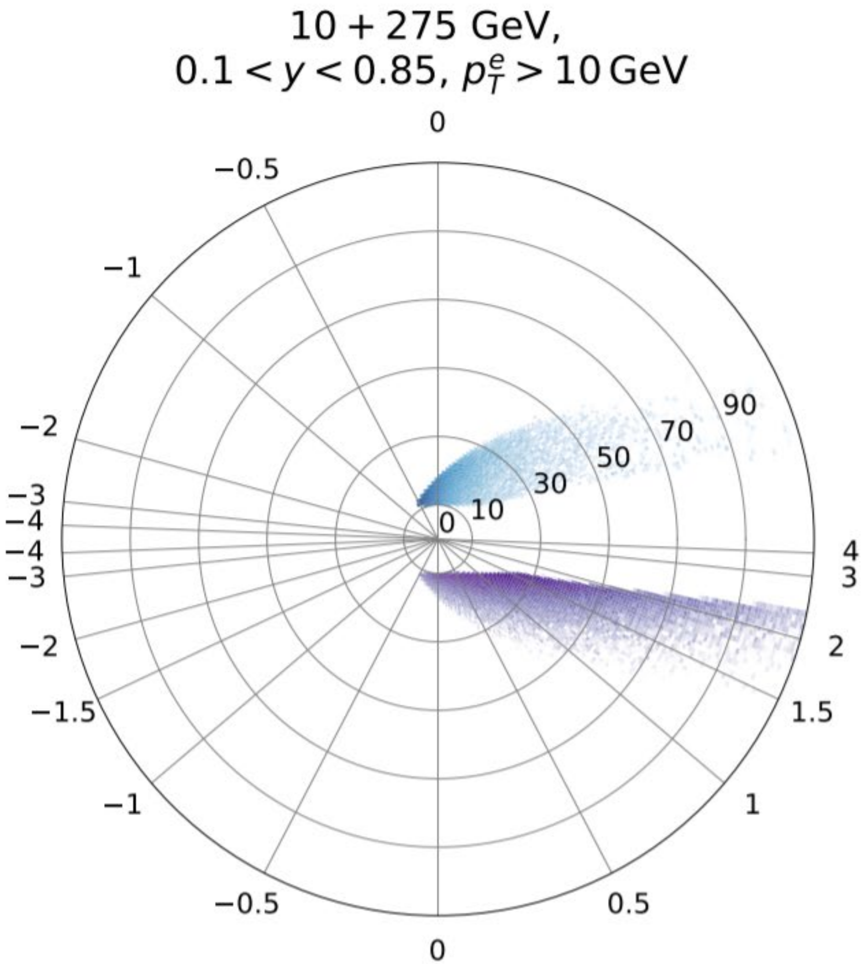


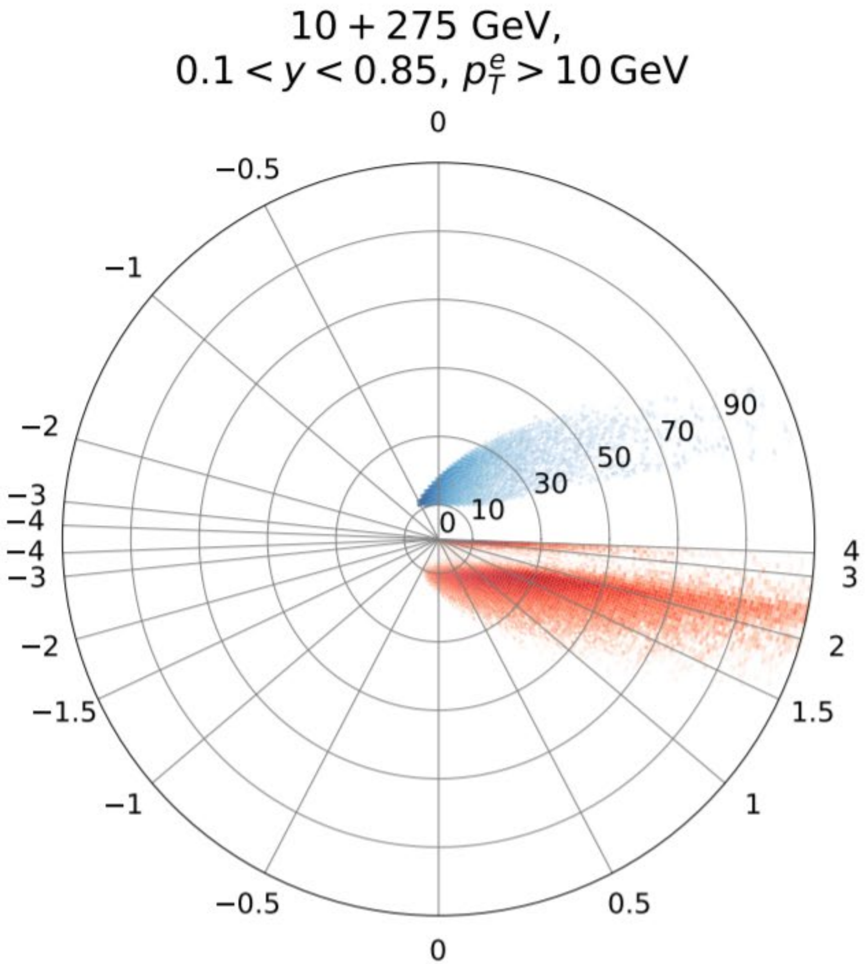


Intro

- 5 minutes is not enough to summarize requirements on PID, tracking, and calorimetry.
- So, in this presentation I will focus on PID.
- You can find much more details in our manuscript:
  "Jet-based measurements of Sivers and Collins asymmetries at the future Electron-Ion Collider" Miguel Arratia, Zhong-Bo Kang, Alexei Prokudin, Felix Ringer
  arXiv:2007.07281

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



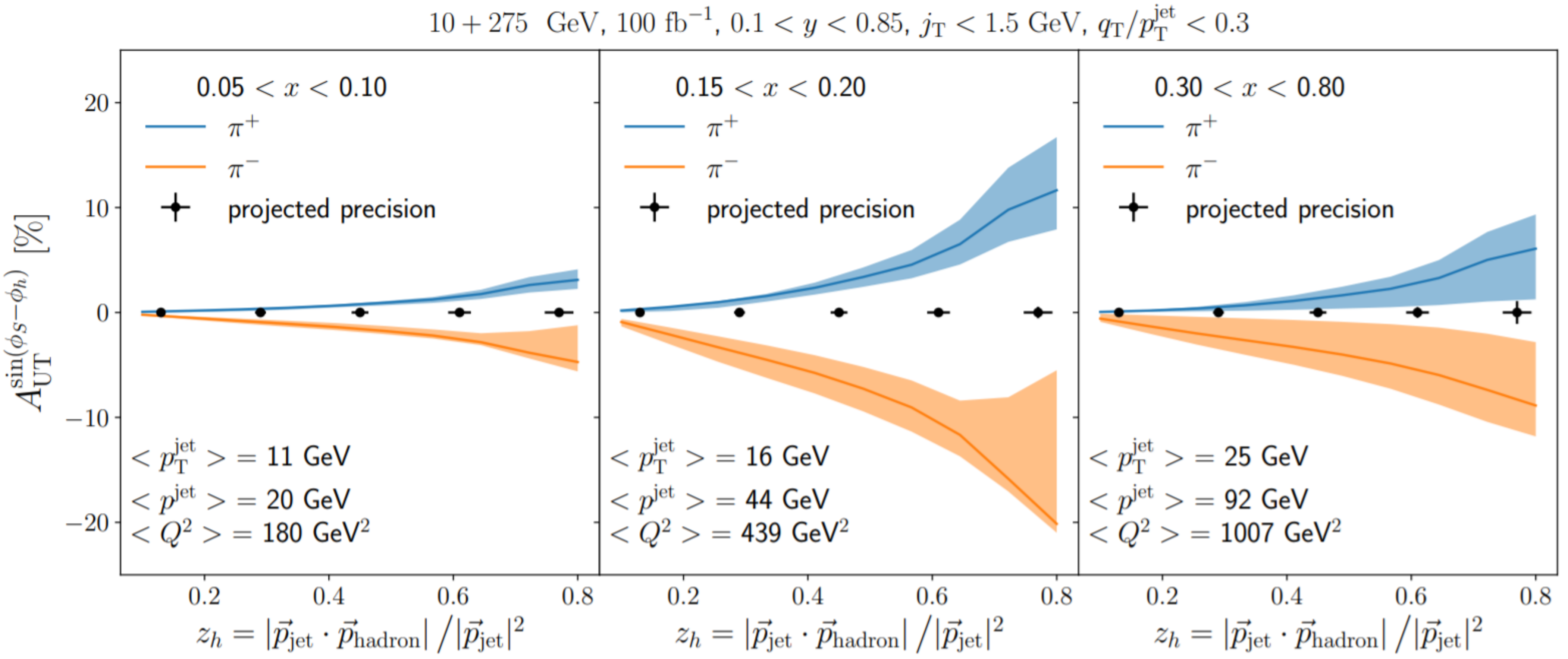


Note that most jets go to 1.0-2.5 eta

https://arxiv.org/abs/2007.07281

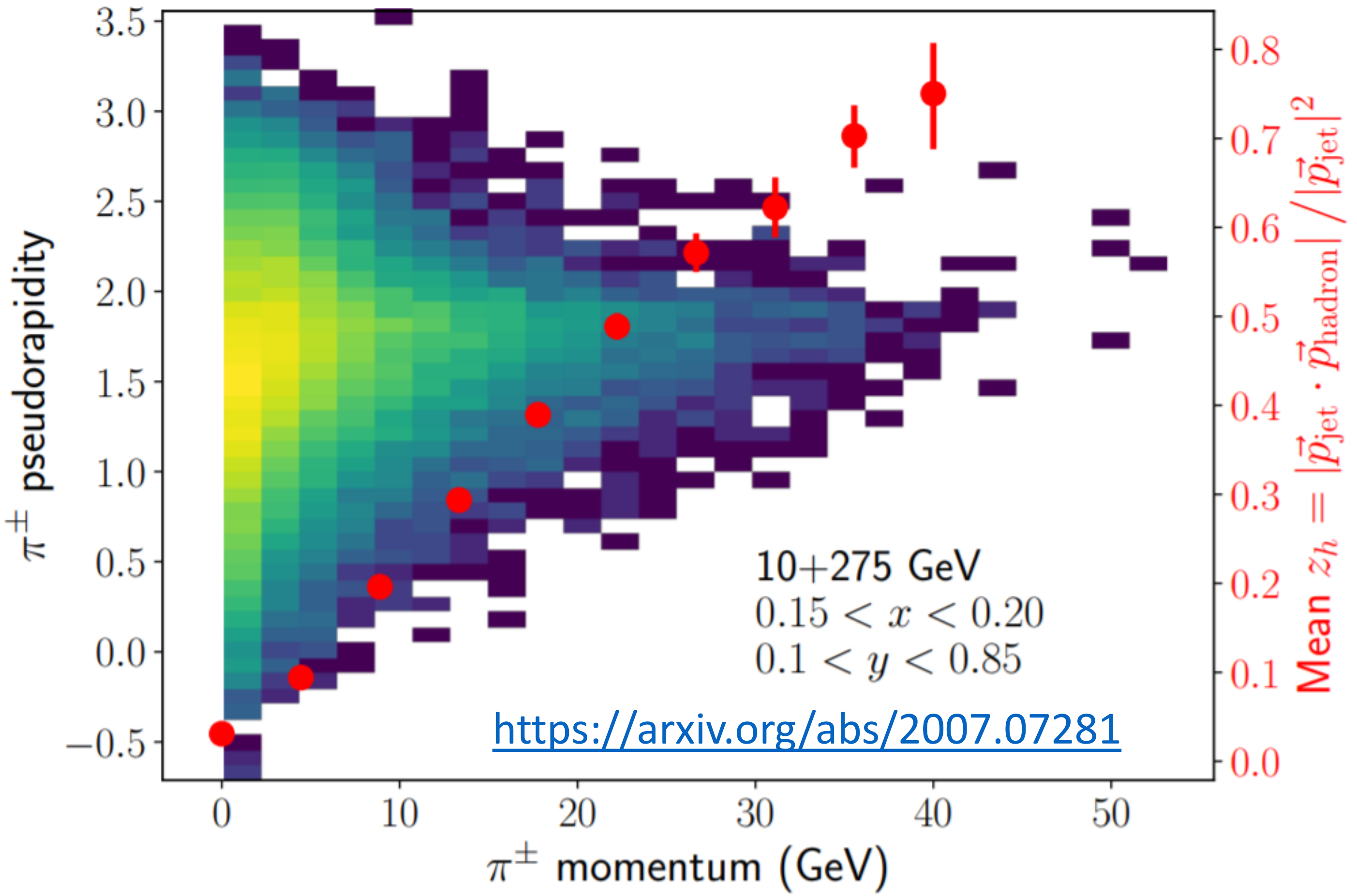
Driver channel:
Collins asymmetries for charged pions to access quark transversity and other TMDs

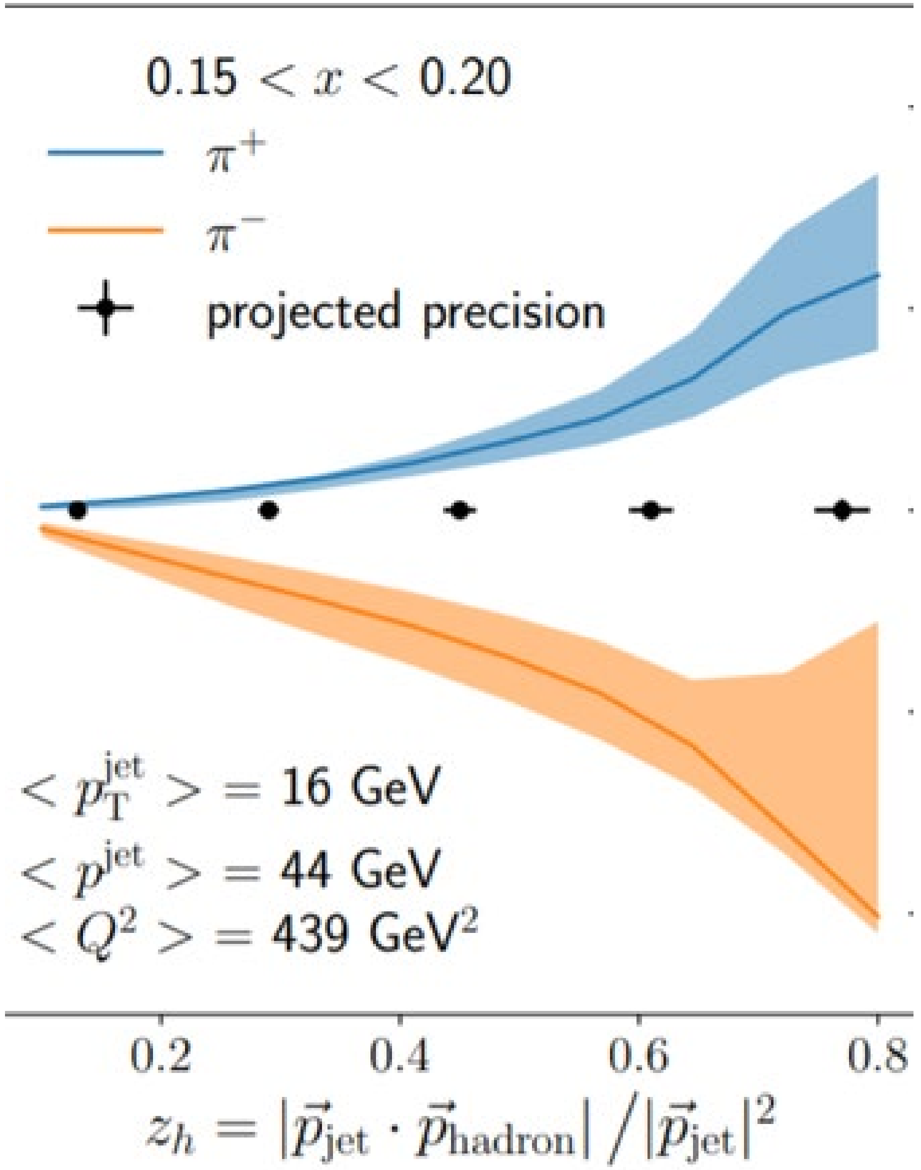
https://arxiv.org/abs/2007.07281



- 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

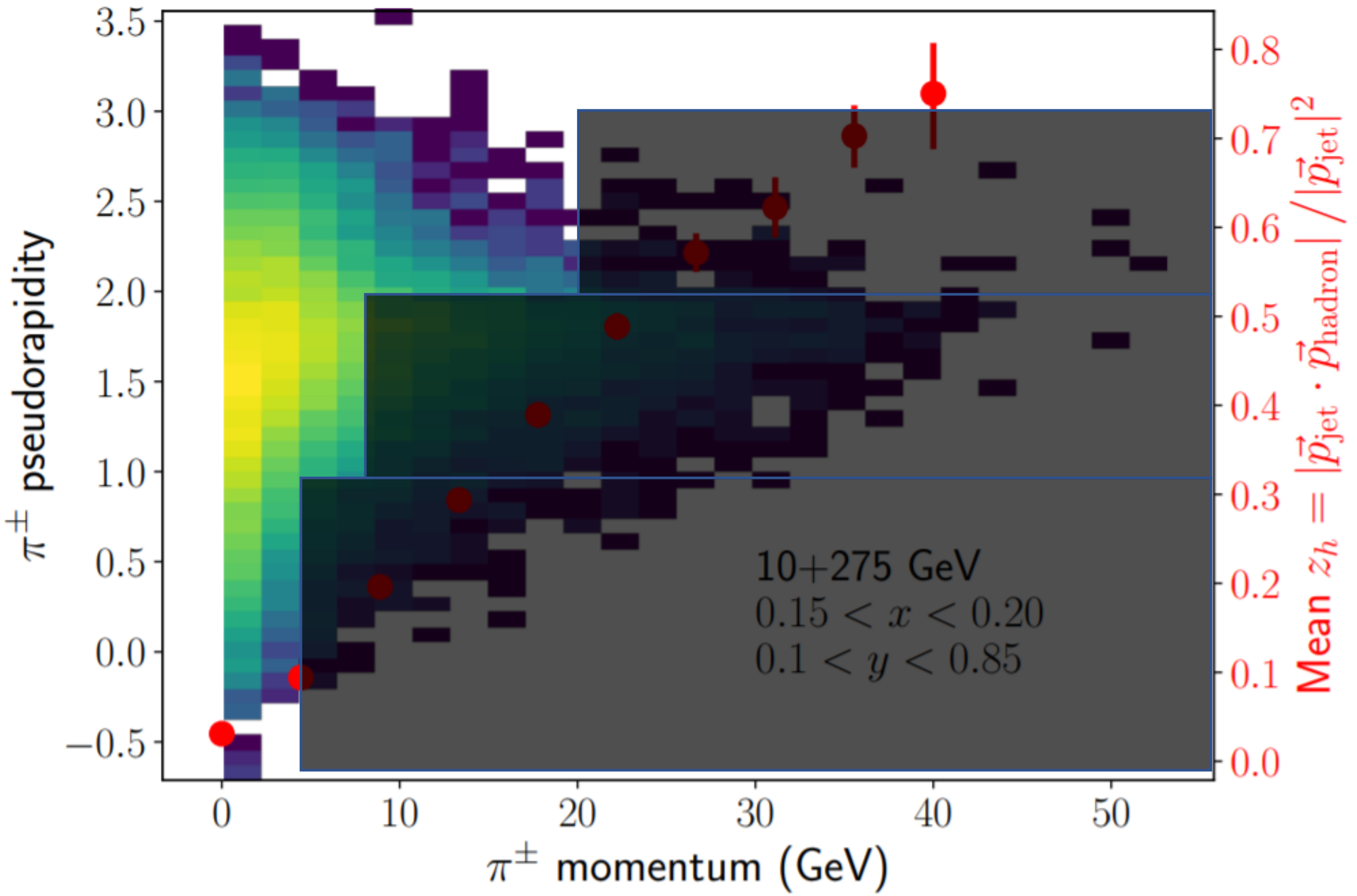
PID requirements





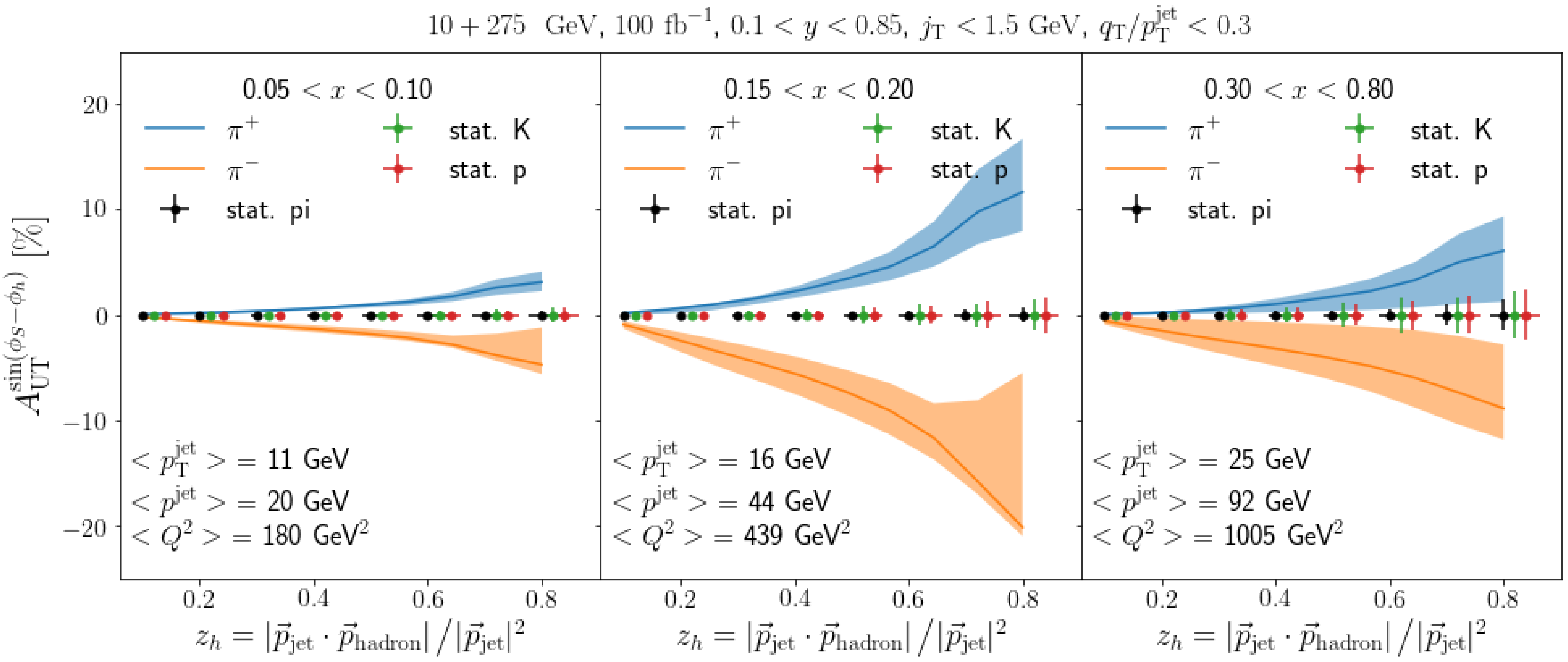
The current matrix has a pi/k/p separation up to 8 GeV in the eta region 1.0-2.0. That is totally inadequate for this measurement

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

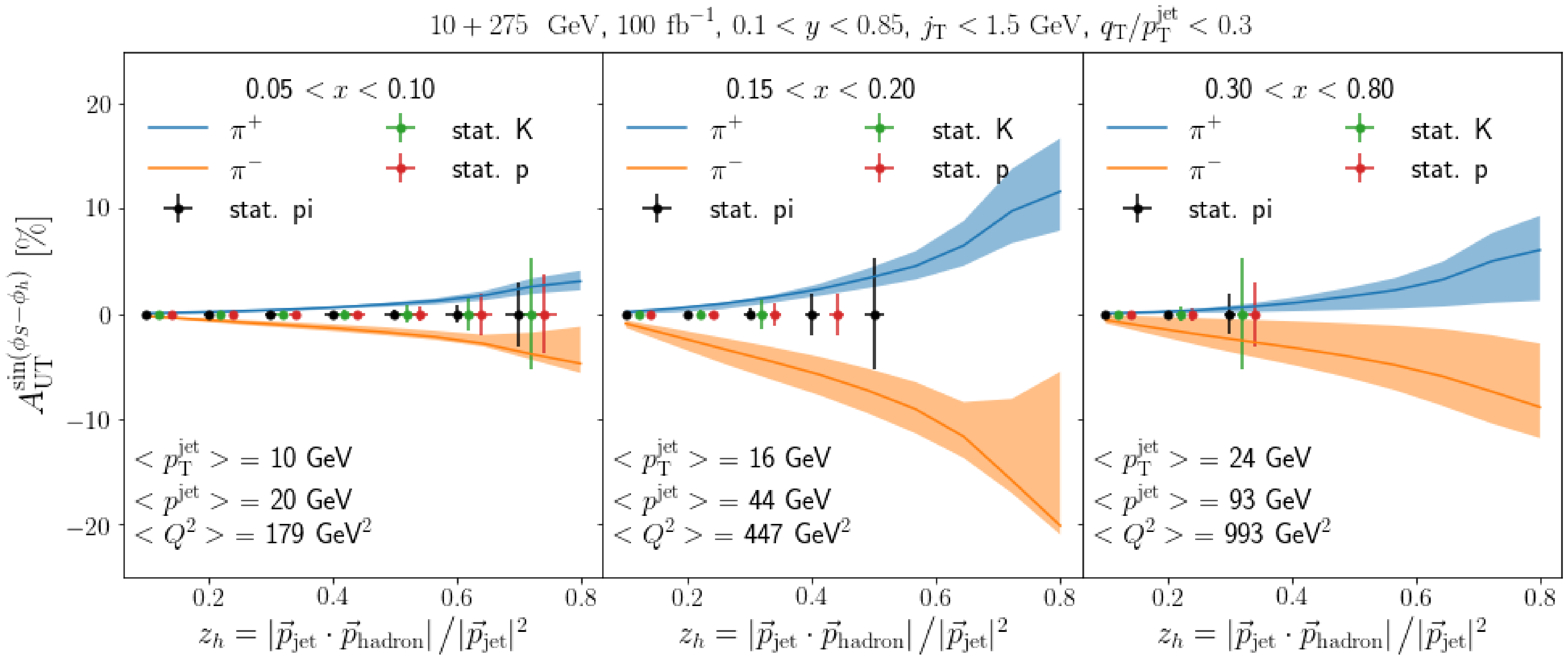


-1.0 to 1.0	< 5 GeV
1.0 to 1.5	≤ 8 GeV/c
1.5 to 2.0	
2.0 to 2.5	≤ 20 GeV/c
2.5 to 3.0	
3.0 to 3.5	≤ 45 GeV/c

Ideal PID coverage

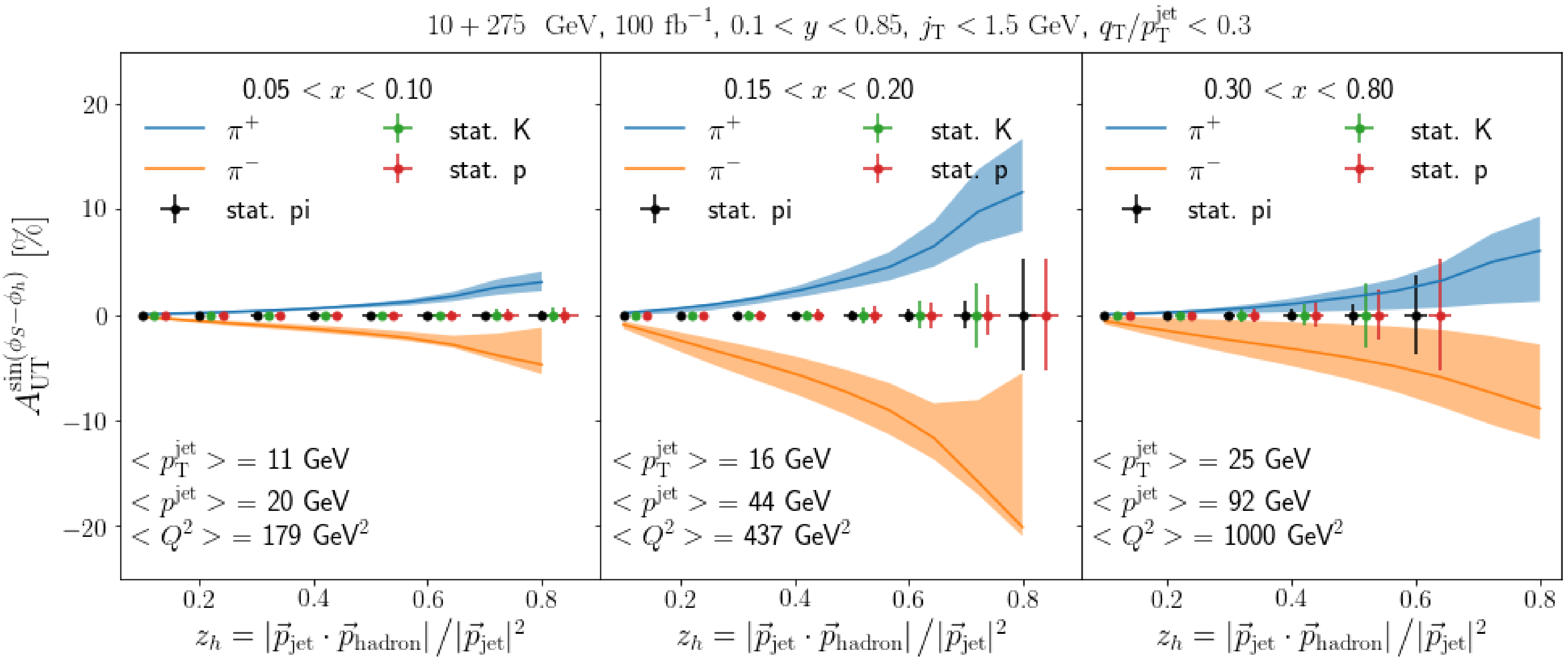


Detector Matrix as it is now



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

With proposed PID coverage

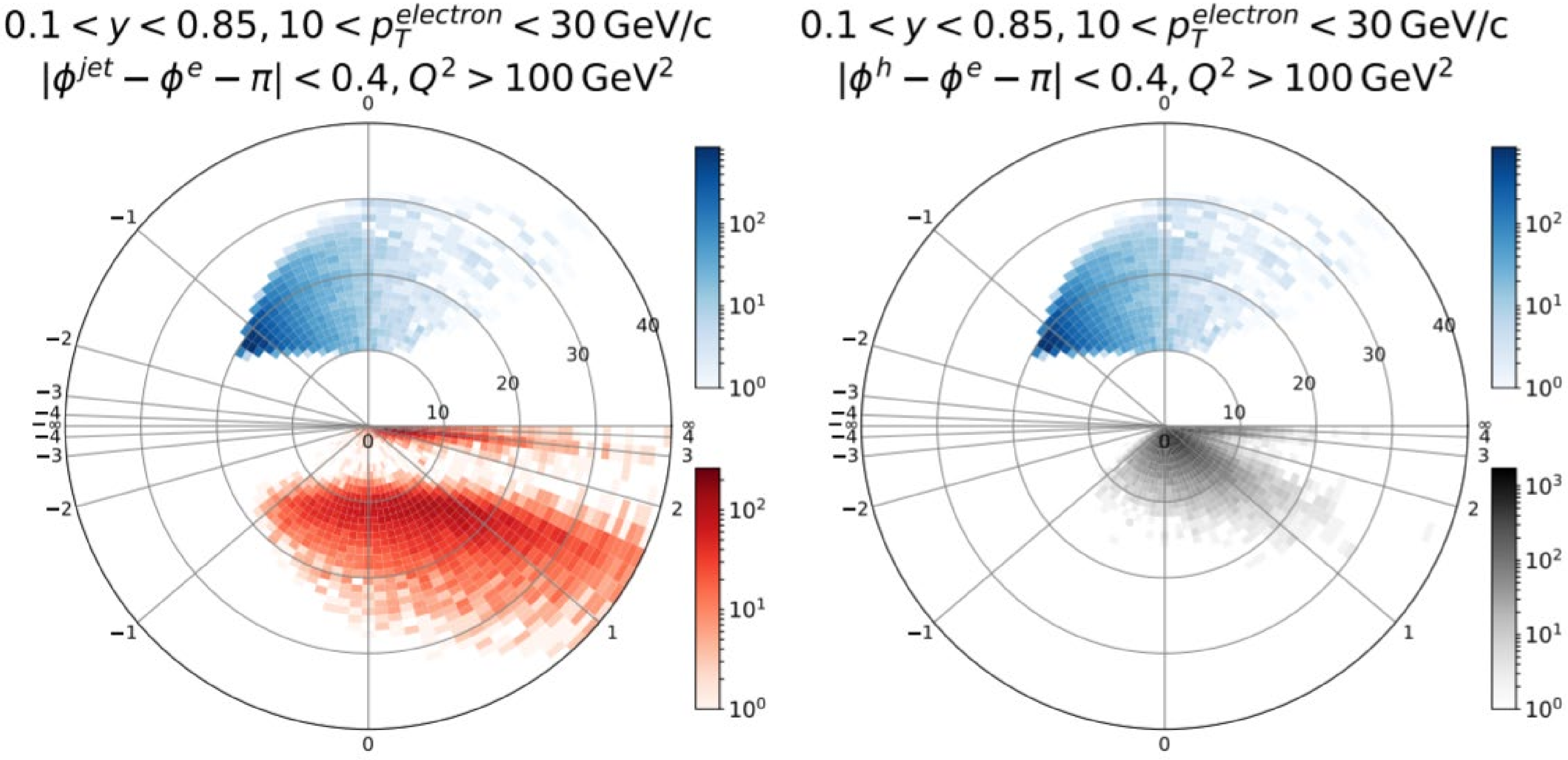


This shows data unbinned in Q2, so is biased towards the lowest Q2,
-> the least demanding

For 100 GeV (highest e-A) , barrel region is critical

PID critical for cold-nuclear matter studies with light-,strange-, and charm-jets. Jet fragmentation studies

Phys. Rev. C 101, 065204 (2020)



Jets, R=1.0 **Hadrons**

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

~8 GeV from 0 to +1.0,
~15 GeV from 0.5 to +1.0

Nutshell:

In summary, without PID coverage eta region +1.5 to +2.0 up to ~40-50 GeV and in the eta region 1.0-1.5 up to ~25-30 GeV, we would totally compromise measurements of Collins asymmetries with hadron-in-jets at Q2>100 GeV2, x>0.01

Not having such PID would also limit other jet-substructure measurements like the sea-tagged jet-Sivers measurement and many others yet to be invented.

~~Note that these requirements differ from those expressed by the SIDIS group, which seem to be focusing on low Q2 region/low beam energies.~~

Note that these requirements are like those being expressed by SIDIS group, unsurprisingly since high Q2 SIDIS = jets.

Table 1: Channels listed are increasingly demanding. For every row consider all requirements above as well. The (x, Q^2) dependence of the observables is omitted for brevity. These measurements mostly focus on high Q^2 region, high-x (> 50–100 GeV^2, $x > 0.01$). Date: August 17, 2020, Miguel Arratia

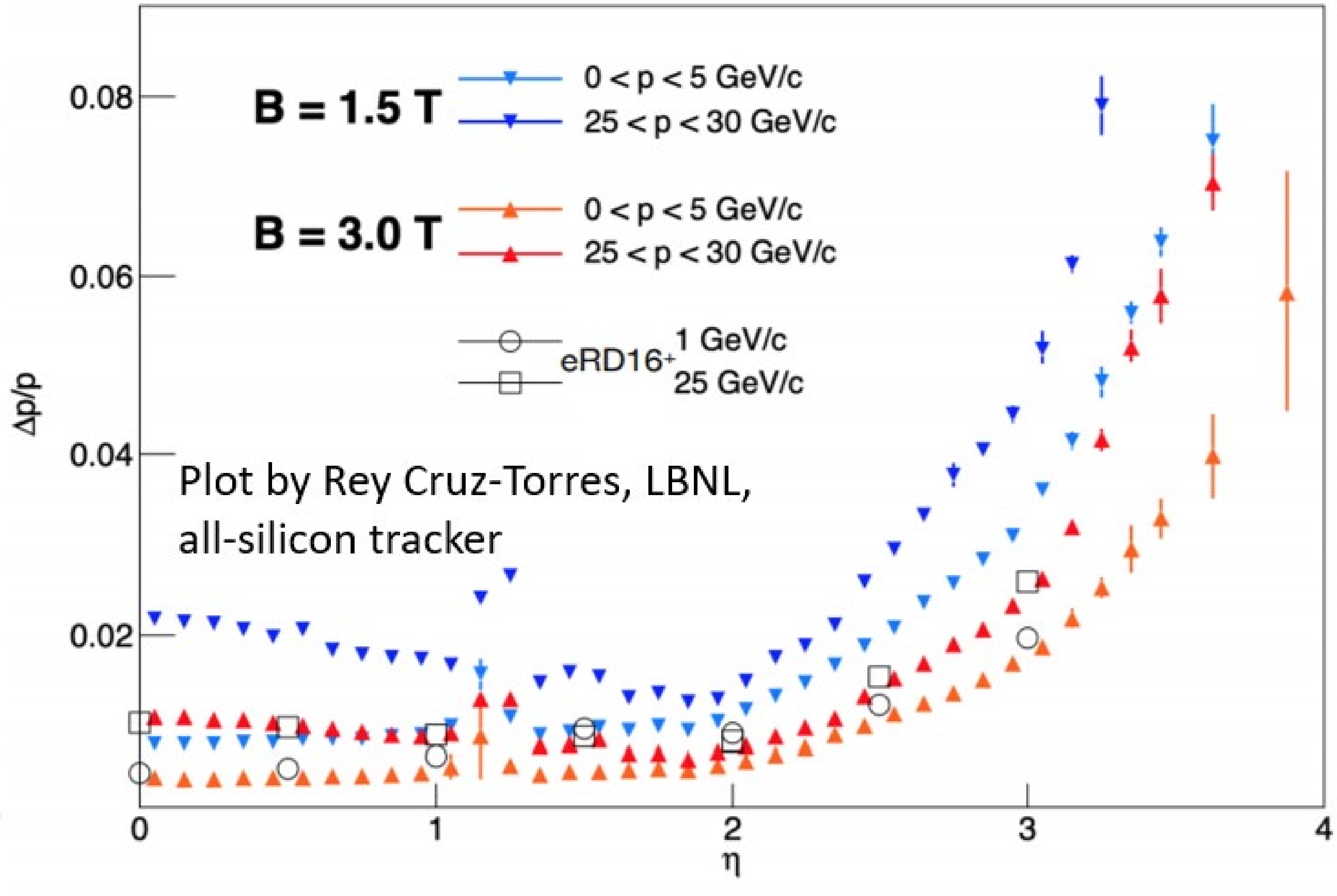
Channel	Observable	Goal	Physics-driven requirement	Category	numbers
e-jet (NC) 100 fb^{-1}	$d\sigma$, $A_{UT}(q_T)$ $A_{UT}(\Delta\phi)$	k_T-dependence of quark Sivers	$\sigma(q_T) << $ intrinsic width $\sigma(q_T) < 0.5$ GeV $\sigma(\Delta\phi) <<$ intrinsic width $\sigma(\Delta\phi) < 0.02$ rad $R = 1.0 \rightarrow$ had. corr. $O(1)\%$ energy-flow reco	Jet energy res. Acceptance Granularity	ECAL&HCAL $dE/E < 60\%/\sqrt{E}$ + energy flow 2π, $-1.0 < \eta < +4.0$ HCAL and ECAL endcap $\Delta\phi \times \Delta\eta \leq 0.05 \times 0.05$
h-in-jet (NC) 100 fb^{-1}	$d\sigma$, $A_{UT}(z_h, j_T)$	q-transversity	dp/p at high $z <$ jet dE/E $\pi/K/p$ separation	Tracker PID (3-σ)	$dp/p < 5\%$ at $p = 50$ GeV, up to $\eta = +2.5$ $-1.0 < \eta < +1.0 < 8$ GeV $+1.0 < \eta < +1.5 < 25$ GeV $+1.5 < \eta < +2.0 < 50$ GeV $+2.0 < \eta < +2.5 < 20$ GeV
ν-jet (CC) 100 fb^{-1}	$d\sigma$, A_{UT}	u Sivers	$\Delta\phi << 0.3$ rad E_T^{miss} down to 10 GeV Bkg. rej. to phot and NC >70% survival prob. for 5 bins per-decade in x, Q^2	E_T^{miss} res. Acceptance Jet/E_T^{miss} res.	$dE_T^{miss}/E_T^{miss} < 15\%$ 2π, $-1.0 < \eta < +4.0$ HCAL and ECAL E>100 MeV thres. ECAL E>400 MeV thres. HCAL $p_T > 100$ MeV tracker $dx/x < 20\%$, $dE_T^{miss}/E_T^{miss} < 15\%$
h-in-jet (CC) 100 fb^{-1}	$d\sigma$, $A_{UT}(z_h, j_T)$	u-transversity	—	—	—
c-jet (CC) 100 fb^{-1}	$d\sigma$, A_{LL}	s PDF& helicity	charm-jet tagging $\epsilon > 30\%$ (<0.5% mis-tagging)	Tracker PID	$\sigma(d_0)$ and $\sigma(z_0) < 20$ μm in $-1.0 < \eta < +3.0$ $\approx 100\%$ tracking eff. Same as hadron-in-jet
h-in-c-jet (CC) 100 fb^{-1}	$d\sigma$, $A_{UT}(z_h, j_T)$	s-transversity	—	—	—
c-jet (e^+ CC) 100 fb^{-1}	$d\sigma$, A_{LL}	$s/\bar{s}$ asymmetry	positrons	—	—

Backup slides

"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.

Realistic simulations show tracking performance deteriorates fast beyond eta = 3.0



Realistic simulations show tracking performance deteriorates fast beyond eta = 3.0, but currently the detector matrix states:

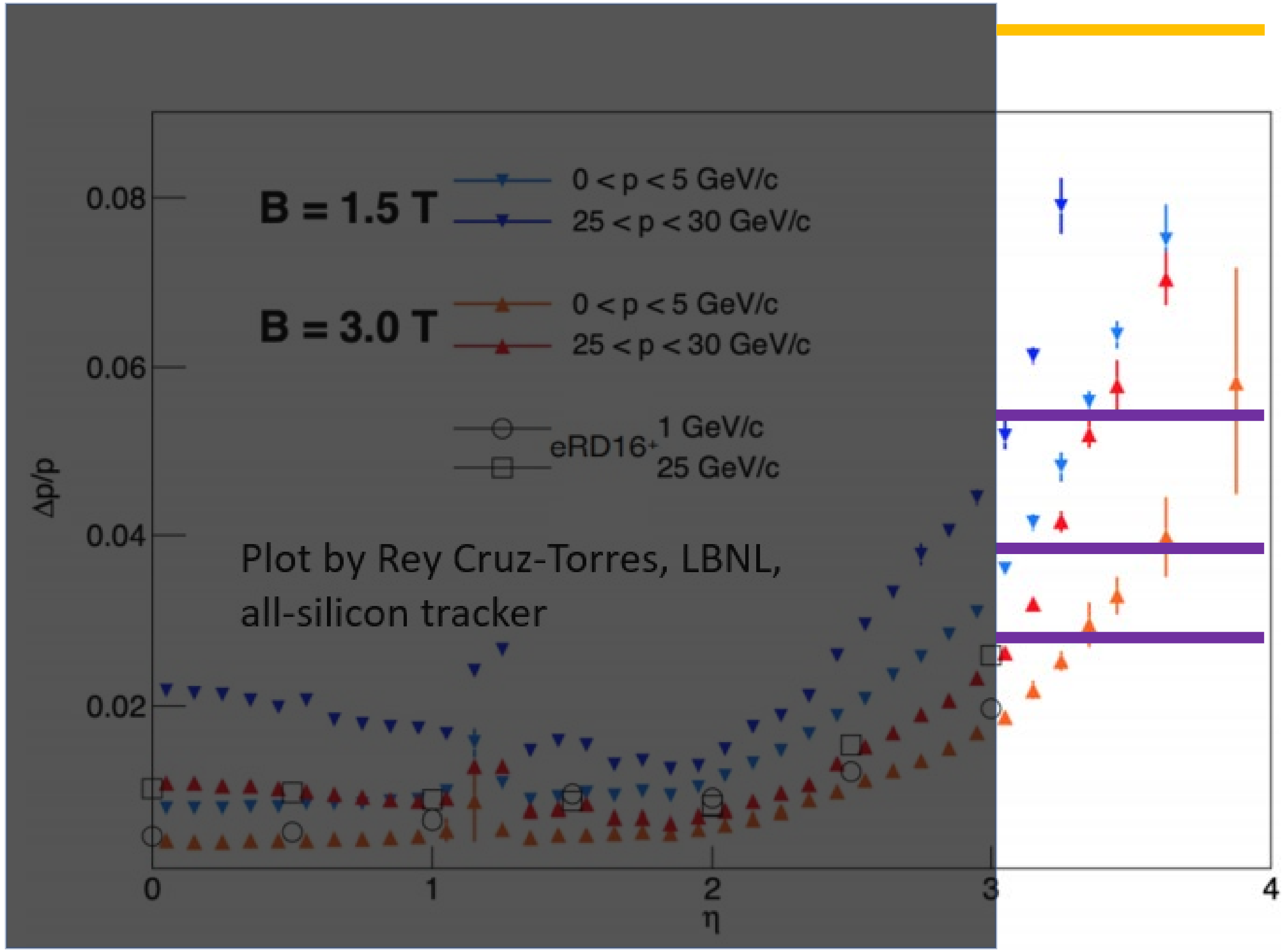
16	1.0 to 1.5			Forward Detectors	σp/p ~0.05%×p+1.0%
17	1.5 to 2.0				
18	2.0 to 2.5				
19	2.5 to 3.0				σp/p ~ 0.1%×p+2.0%
20	3.0 to 3.5				

Totally unrealistic requirements in detector matrix?

- Are we misleading ourselves to wrongly conclude HCAL has little impact on jet and missing-energy measurements beyond eta=3.0?
- Given realistic performance, can PID even work beyond 3.0 up to 50 GeV, as currently stated in matrix?.

HCAL with 50%/sqrt(E) + 10%
at E=30 GeV

at E>50 GeV



HCAL with 40%/sqrt(E)

at E = 50 GeV

at E = 100 GeV

at E = 200 GeV

HCAL forward calorimeter performance limited by **space** and **material in front.**

Table shown by A. Bazilevsky,
Pavia meeting

shown)

Detector Matrix for the calorimeters

η	Nomenclature	EmCal						HCal			
		Energy resolution %	Spatial resolution mm	Granularity cm^2	Min photon energy MeV	PID e/π πsuppression	Technology solution	Energy resolution %	Spatial resolution mm	Granularity cm^2	Technology solution
-3.5 : -2	backward	2/√E ⊕ 1	3/√E ⊕ 1	2x2	50	100	$PbWO_4$	50/√E⊕10	50/√E ⊕ 30	10x10	Fe/Sc
-2 : -1	backward	7/√E ⊕ 1.5	3(6)/√E ⊕ 1	2.5x2.5 (4x4)	100	100	DSB:Ce glass; Shashlik; Lead glass	50/√E⊕10	50/√E ⊕ 30	10x10	Fe/Sc
-1 : 1	barrel	(10-12) /√E ⊕ 2	3/√E ⊕ 1	2.5x2.5	100	100	W/ScFi	100/√E⊕ 10	50/√E ⊕ 30	10x10	Fe/Sc
1 : 3.5	forward	(10-12) /√E ⊕ 2	3/√E ⊕ 1	2.5x2.5 (4x4)	100	100	W/ScFi Shashlyk, glass	50/√E⊕ 10	50/√E ⊕ 30	10x10	Fe/Sc

Technology selection depends on the space available
Several other technologies are under consideration
Material in front will affect the resolution

★

Note 10% constant term matches stochastic term at E= 25 GeV. Not great for a beam energy of 275 GeV…