Jets and Heavy Flavor Detector Requirements Summary

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LBL YR Meeting

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Chapter 8.3 Overview

- Our detector requirements as they currently stand are all documented in YR Sec 8.3
- The section is not yet final, but as it stands gives a pretty complete picture of our studies

8.3.1 – Simulation and Detector Modeling
8.3.2 – Kinematics Summary
8.3.3 – Tracking
  Momentum Resolution
  Vertex Resolution
  Additional Considerations
8.3.4 – Particle Identification
8.3.5 – Calorimetry
  Electromagnetic Calorimetry
  Hadron Calorimetry
  Coverage Continuity

- Focus here on PID as this is where the largest tension with detector capability exists
- Briefly discuss some aspects of HCal requirements

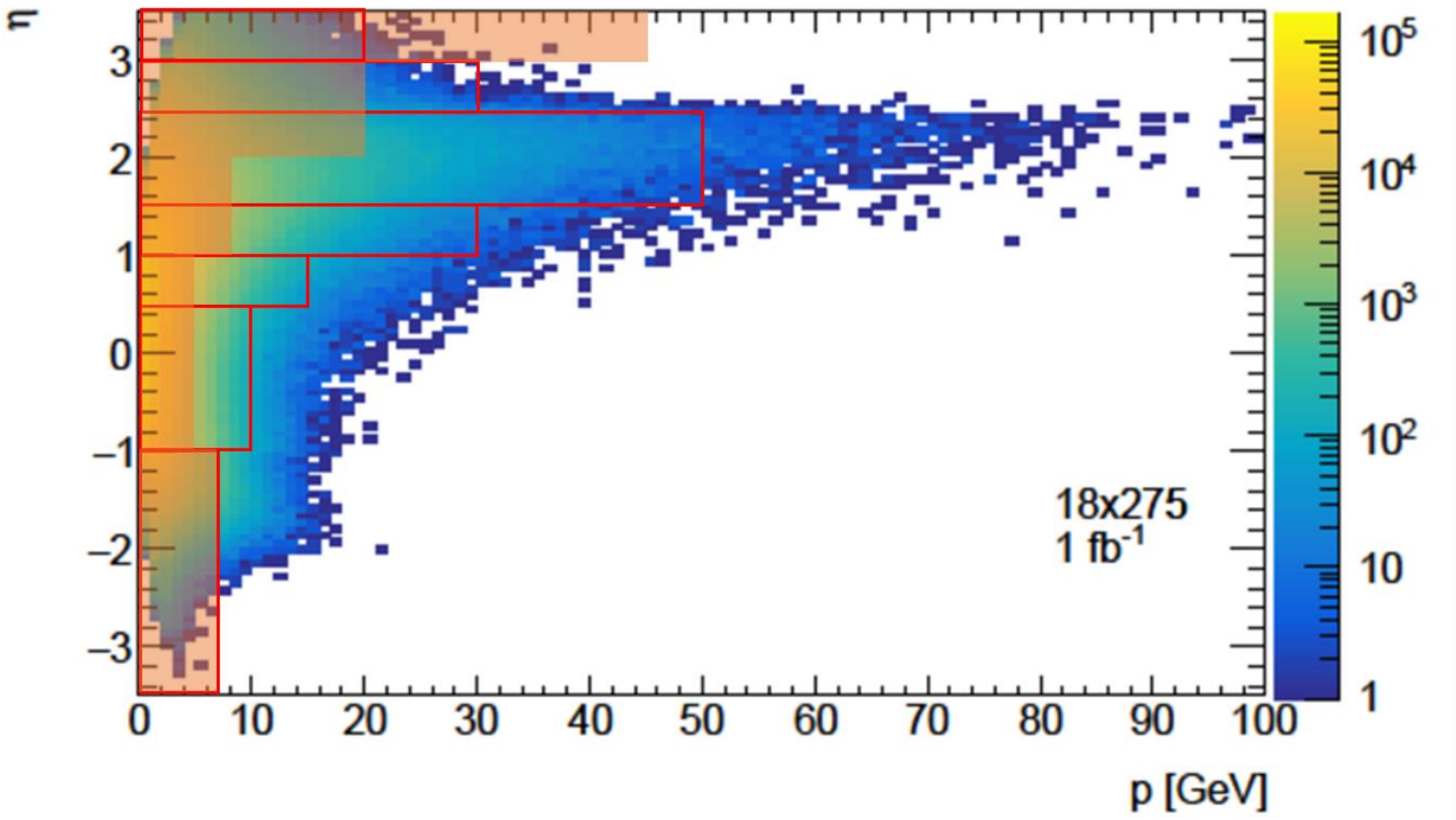
Our PID Requests: A Reminder

PID Momentum Coverage

Eta Range	Default Momentum Coverage	Requested Momentum Coverage
-3.5 < η < -1.0	≤ 7 GeV	Same
-1.0 < η < 0.0	≤ 5 GeV	≤ 10 GeV
0.0 < η < 0.5		
0.5 < η < 1.0		≤ 15 GeV
1.0 < η < 1.5	≤ 8 GeV	≤ 30 GeV
1.5 < η < 2.0		≤ 50 GeV
2.0 < η < 2.5	≤ 20 GeV	
2.5 < η < 3.0		≤ 30 GeV
3.0 < η < 3.5	≤ 45 GeV	Can tolerate ≤ ~20 GeV

- Plot of pseudorapidity vs momentum of pions found within jets
- Default PID ranges leave significant gaps in coverage
- Reduction of particle momenta at highest (and lowest) eta are due to jet radius

18x275



- Shaded boxes = default momentum coverage
- Red outlined boxes = requested momentum coverage

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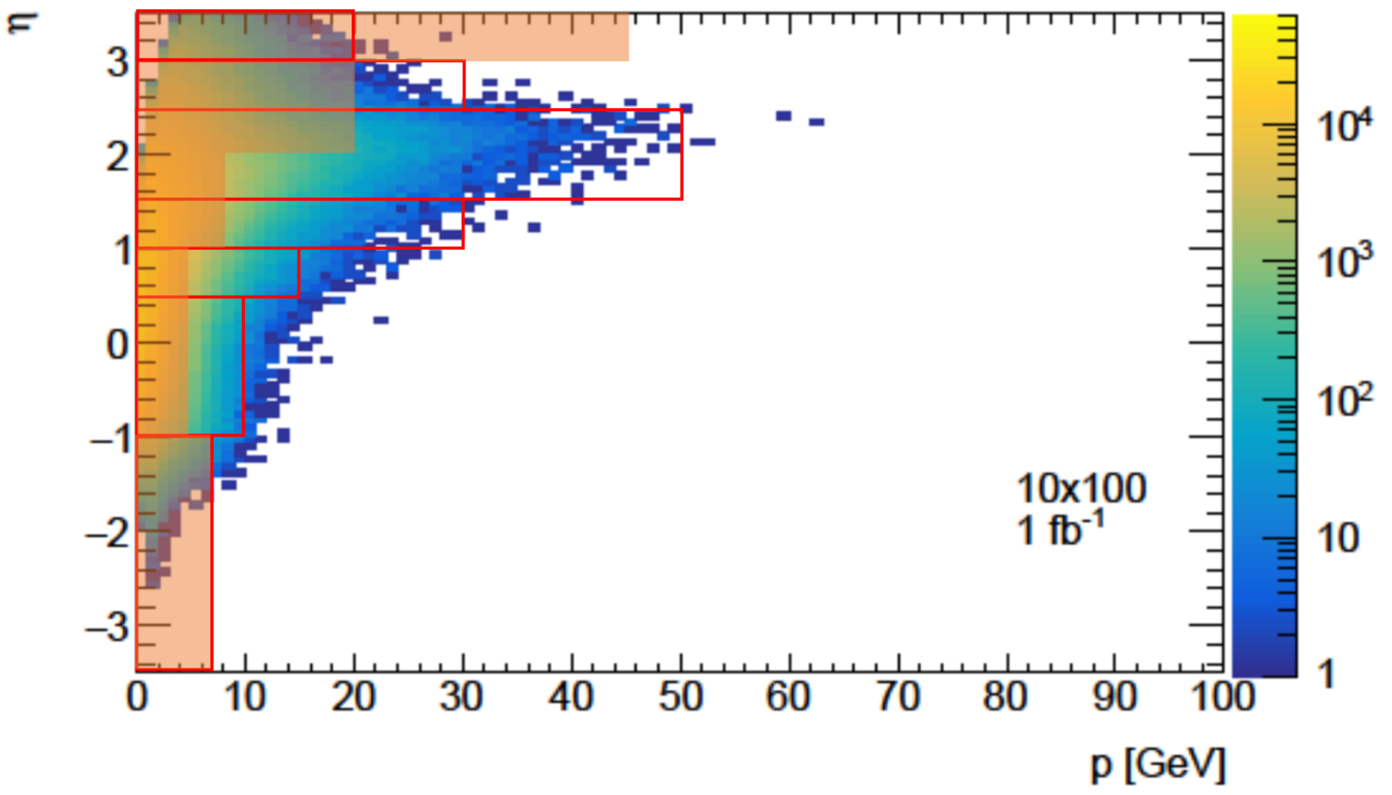
- Even at low COM energy, where particle momenta are lower, default values leave a lot of particle momentum range uncovered

10x100



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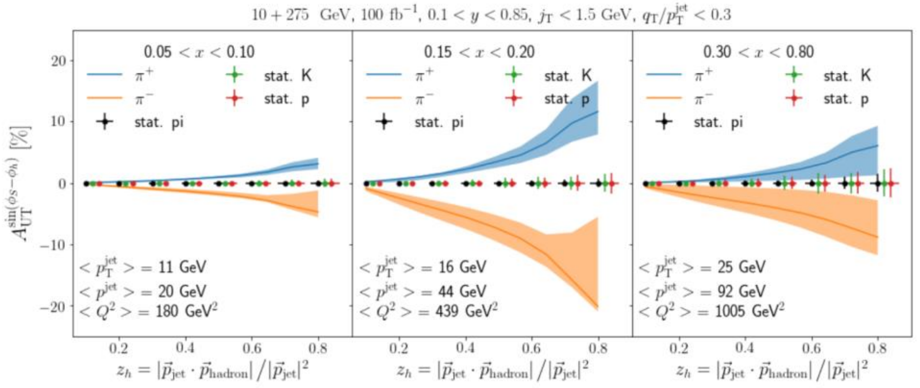
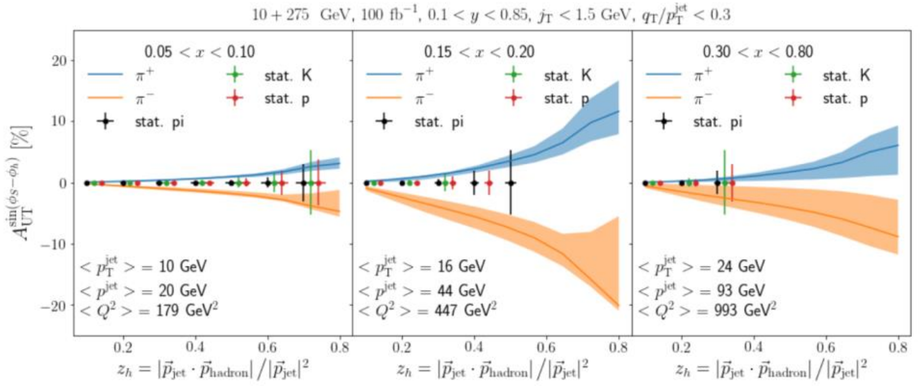
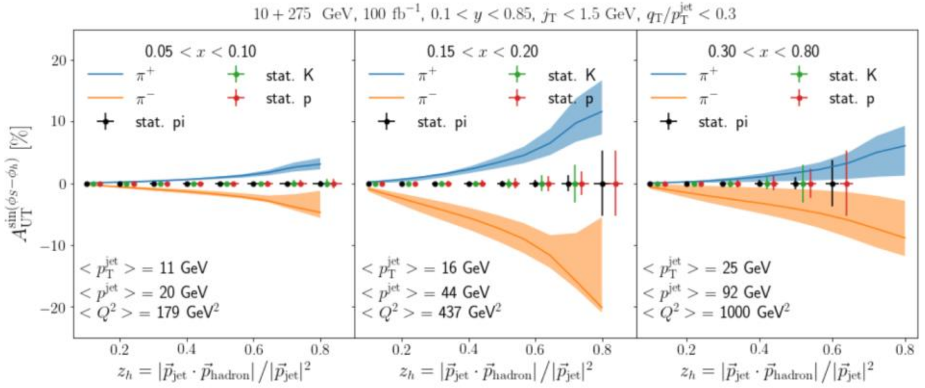
PID Coverage Impact



Perfect

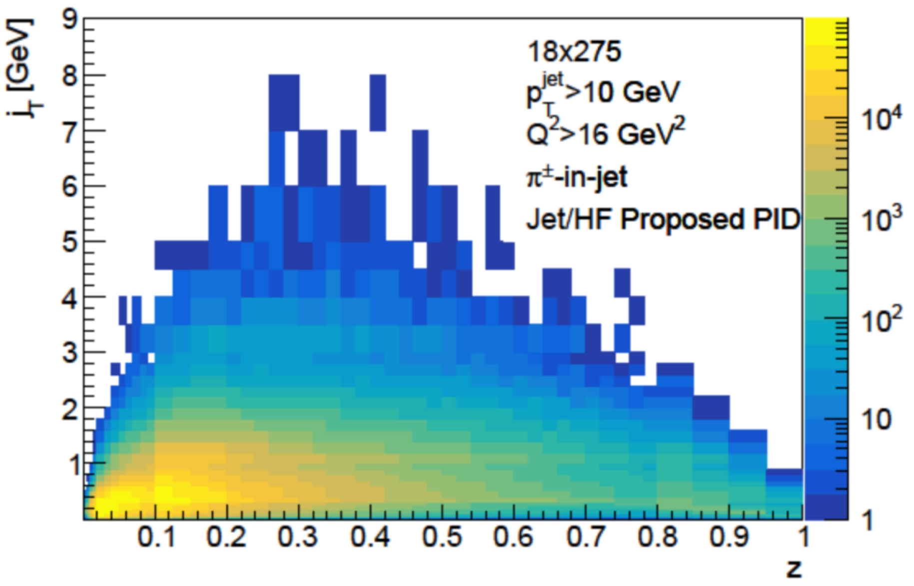


Default

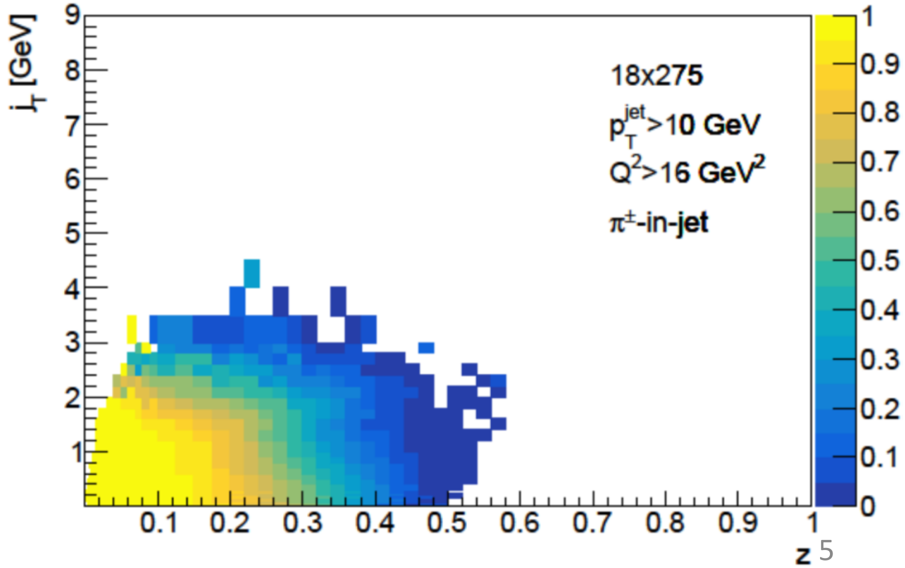


Requested

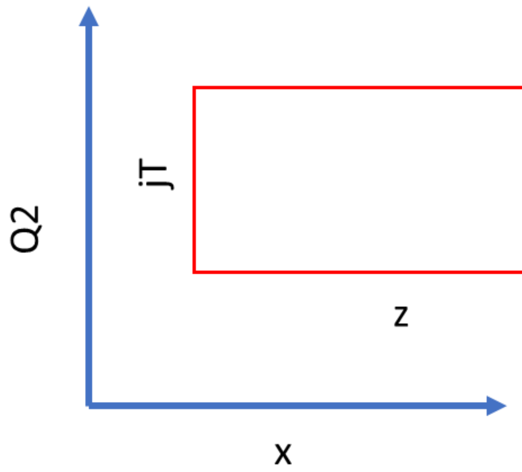
Requested Coverage: j_T Vs z



Default / Requested Ratio

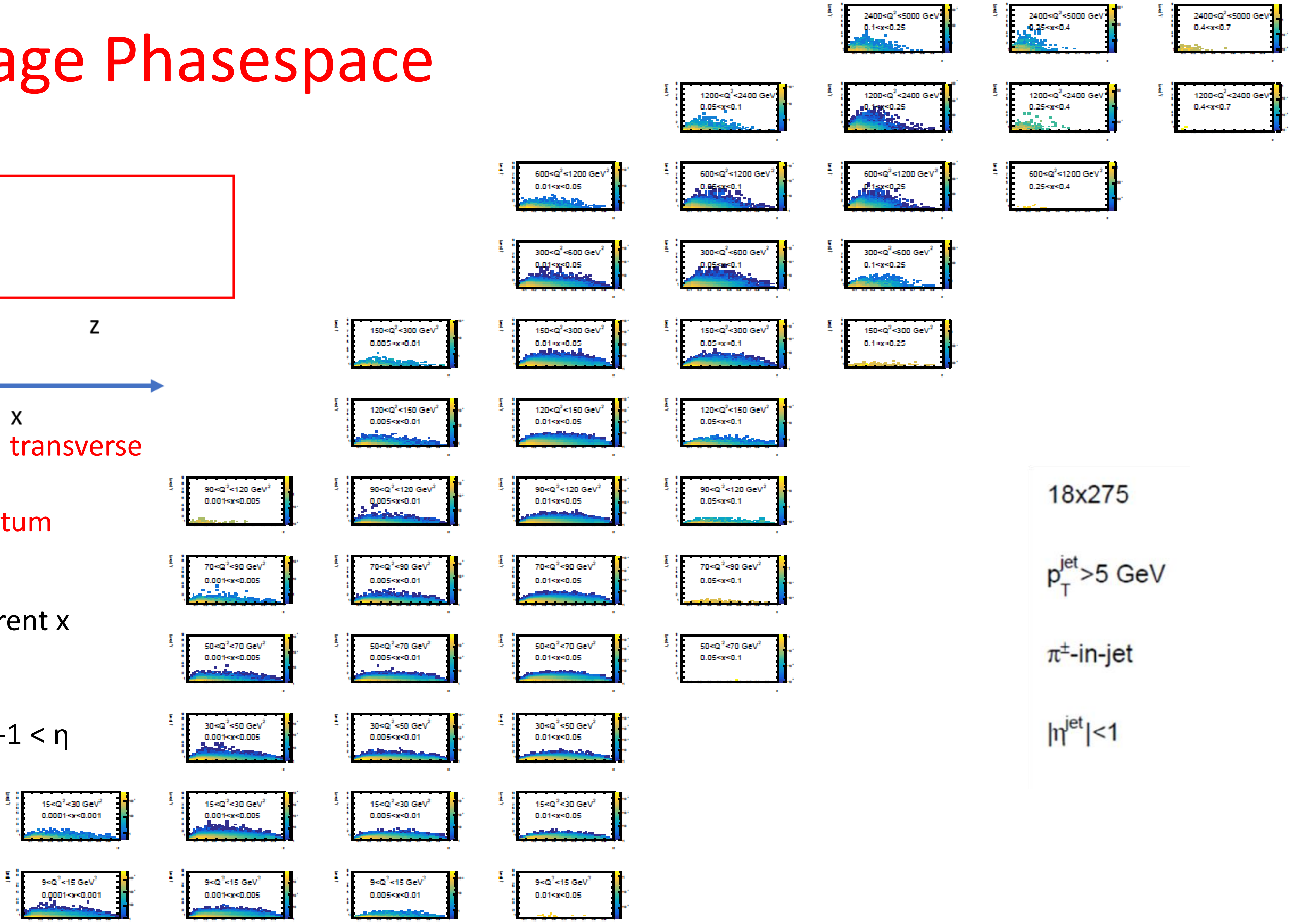


PID Coverage Phasespace



jT = particle momentum transverse to jet axis
z = particle / jet momentum

- Coverage in j_T vs z for identified pions in different x and Q2 bins
- Top energy and Barrel (-1 < η < 1) region only
- Jet p_T down to 5 GeV



18x275

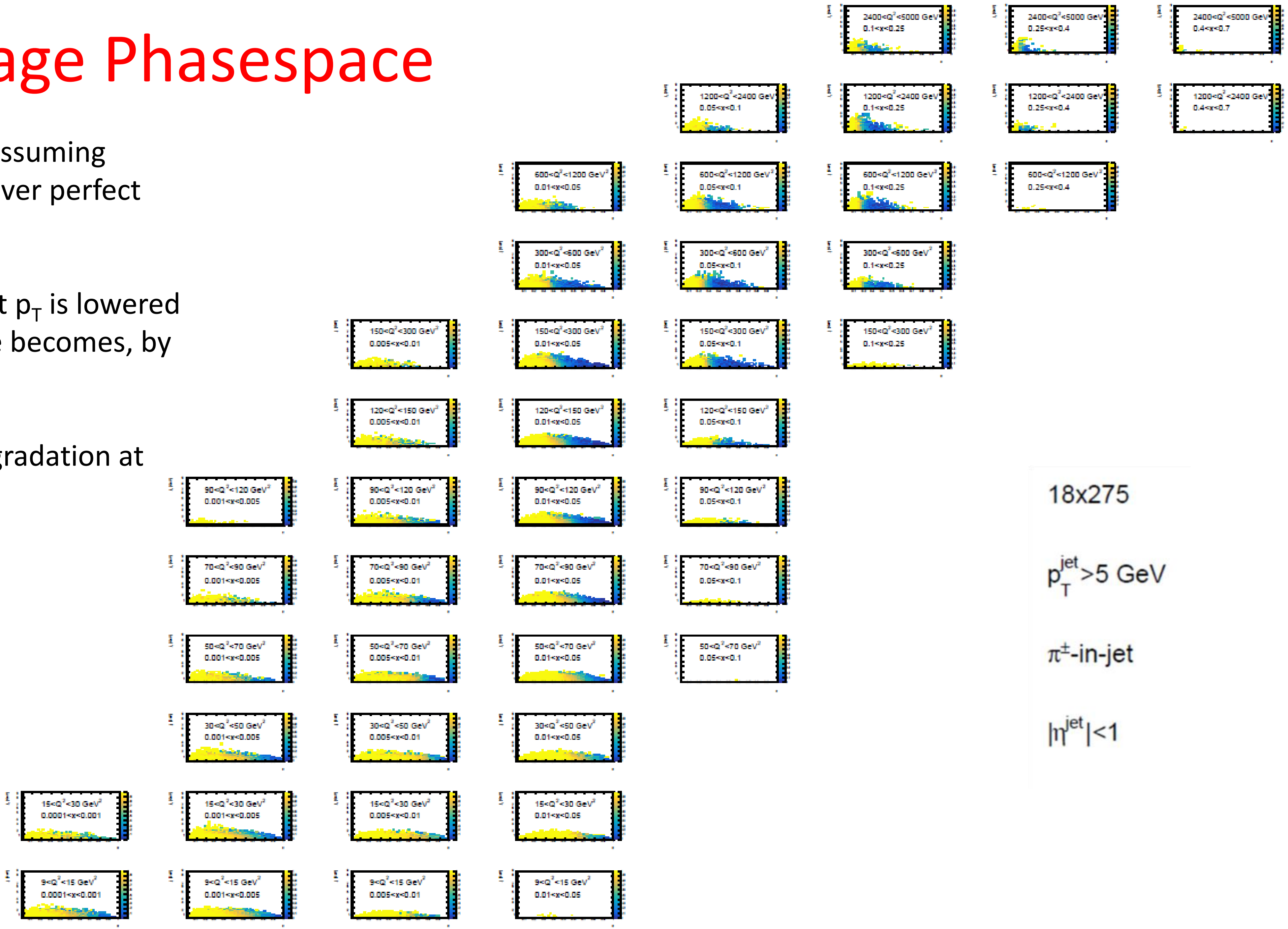
p_T^{jet}>5 GeV

$\pi^{\pm}$-in-jet

$|\eta^{jet}|<1$

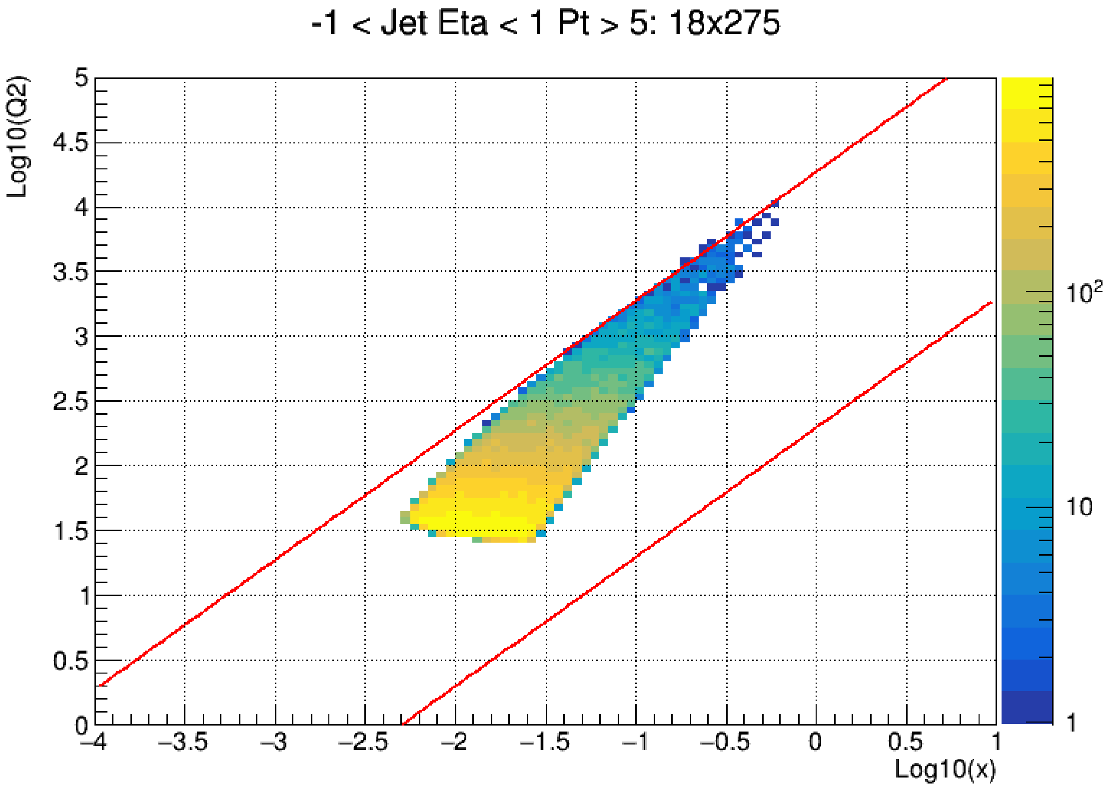
PID Coverage Phasespace

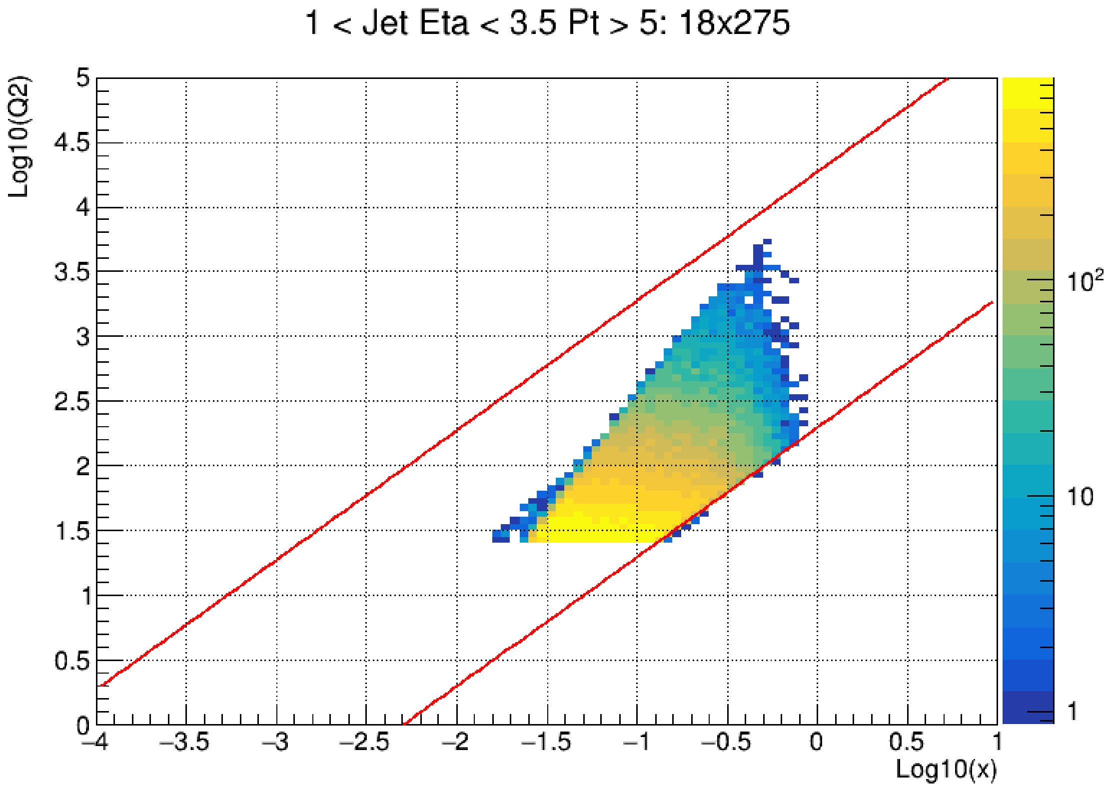
- Ratio of acceptances assuming default PID coverage over perfect coverage
- Note that minimum jet p_T is lowered to 5 GeV so z coverage becomes, by definition, better
- Still see significant degradation at high-x / high-Q^2



What about Lower Energies?

- Here “jet” is actually just the struck quark in the LO DIS process – no jet finding is performed



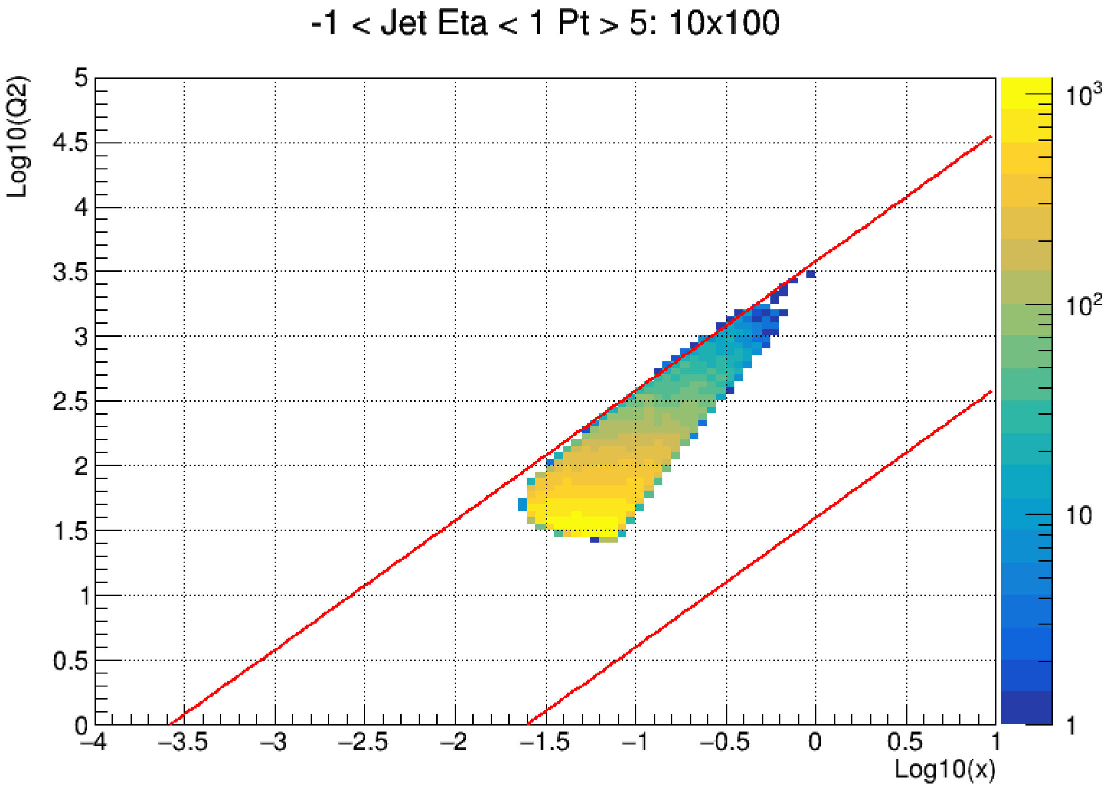


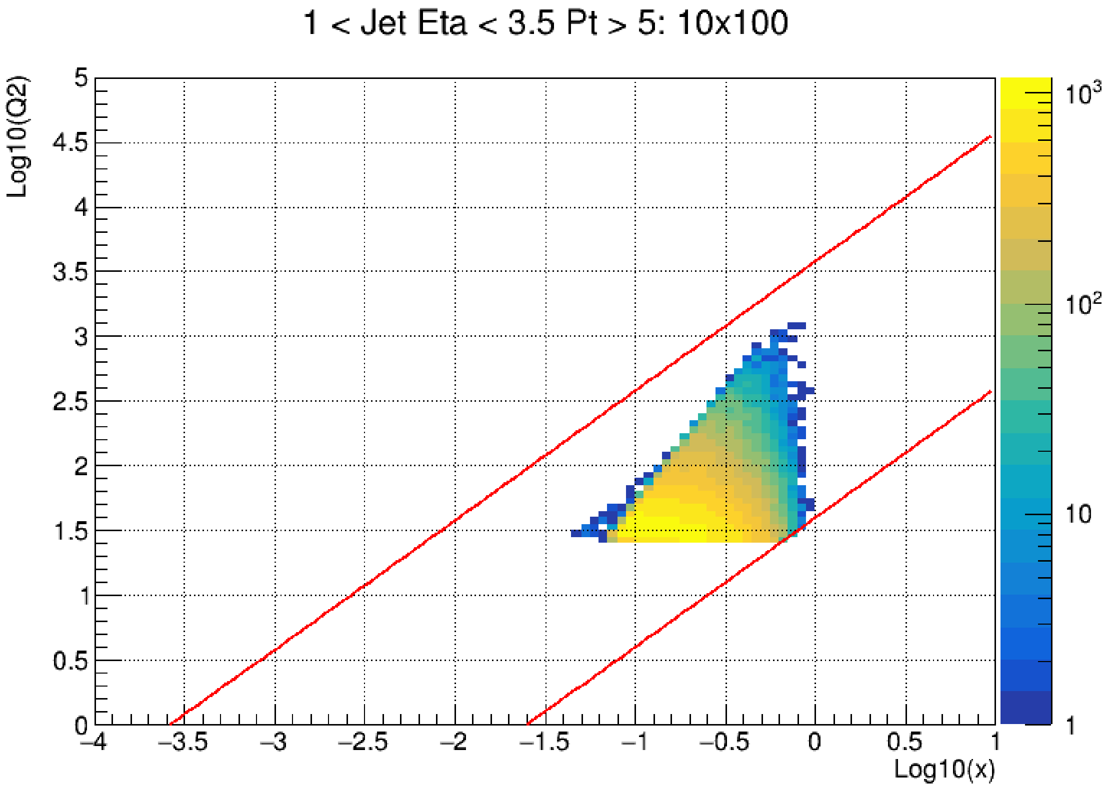
- Look at x-Q2 of “jets” with pseudorapidity in the barrel and endcap for different energies
- Require “jet” to have pT > 5 GeV
- Cut on y: 0.01 < y < 0.95 (red lines)

❑ Minimum Q2 = 10 GeV2

What about Lower Energies?

- As COM energy is lowered, jet distributions move to lower Q2 and higher x – as expected (gain some x-Q2 coverage in endcap)





- In the barrel, phase space probed by jets is almost orthogonal between energies
- x-Q2 probed by jets in barrel at 10x100 is completely covered by jets in the endcap at 18x275

- Lowering COM energy will bring jets at a given x-Q2 from the endcap toward the barrel (where presumably PID coverage is worse) – hard to see the advantage

What about < 3σ Separation?

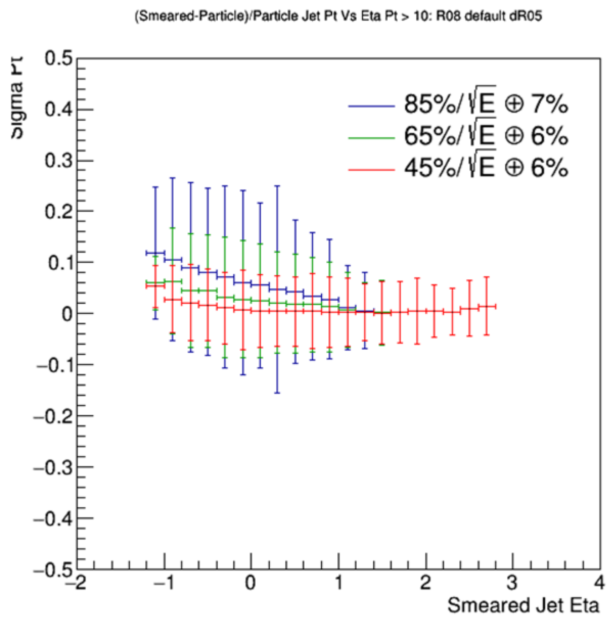
- PID coverage is not a theta function at some critical momentum value, there will be some smooth drop-off in performance
- What is the tradeoff between higher momentum coverage and lower separation power?
- Studies ongoing to quantify pion/kaon efficiency and purity assuming >3σ separation over full particle momentum range and assuming a realistic separation as a function of momentum
- Due to much lower yield, can assume lowering separation power will greatly effect kaon measurements due to pion contamination

Calorimetry: Hadronic

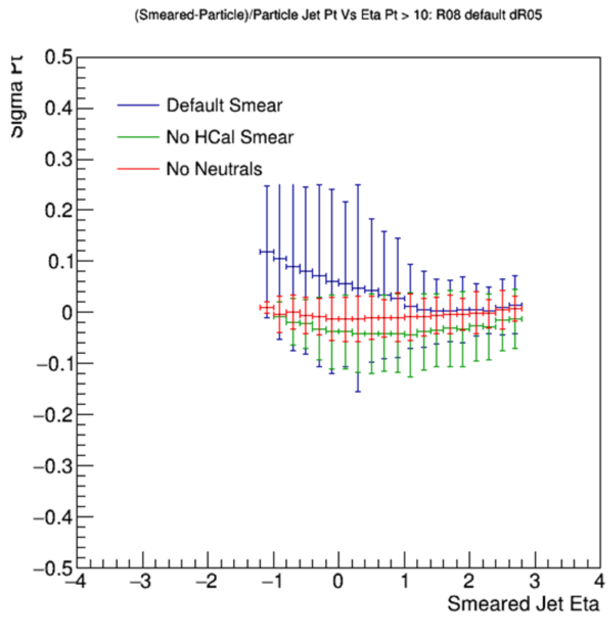
HCal Energy Resolution

Eta Range	Default Resolution (σE/E)	Requested (σE/E)
-3.5 < η < -1.0	50%/√E	Same (~10% constant term is acceptable)
-1.0 < η < 1.0	N/A	85%/√E + 10%
1.0 < η < 3.0	50%/√E	50%/√E + 10%
3.0 < η < 3.5		50%/√E + 5%
3.5 < η < 4.0	N/A	

Can likely live with 10%, but it is limiting factor for high E jets



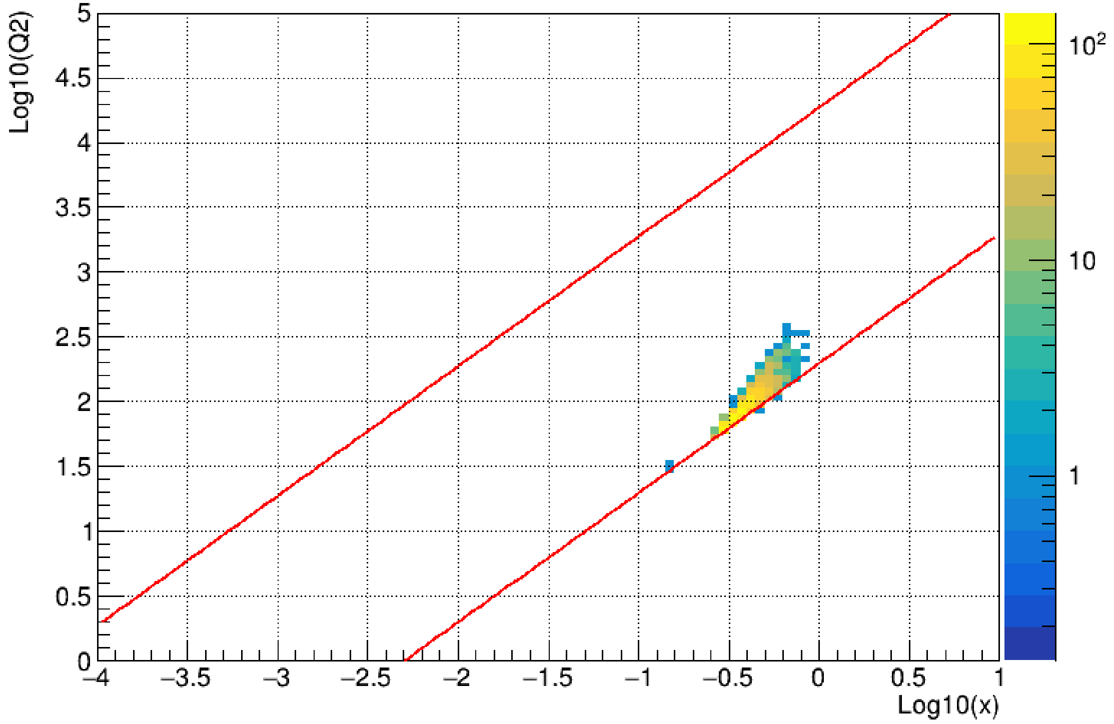
- Barrel HCal requested for missing transverse energy measurements in CC events (also for Jaquet-Blondel), measurement of neutral hadrons
- 100%/√E sufficient for missing energy, but seen that better resolution needed for accurate jet reconstruction toward smaller eta values
- No longer believe we need calorimeter coverage to eta of 4 because same x-Q2 space can be recovered at smaller pseudorapidity for lower hadron beam energies
- More study of position resolution / potential cluster separation needed as being able to select jets with no neutral hadron shows possibility of greatly improving jet energy resolution, especially at low eta / p_T / x



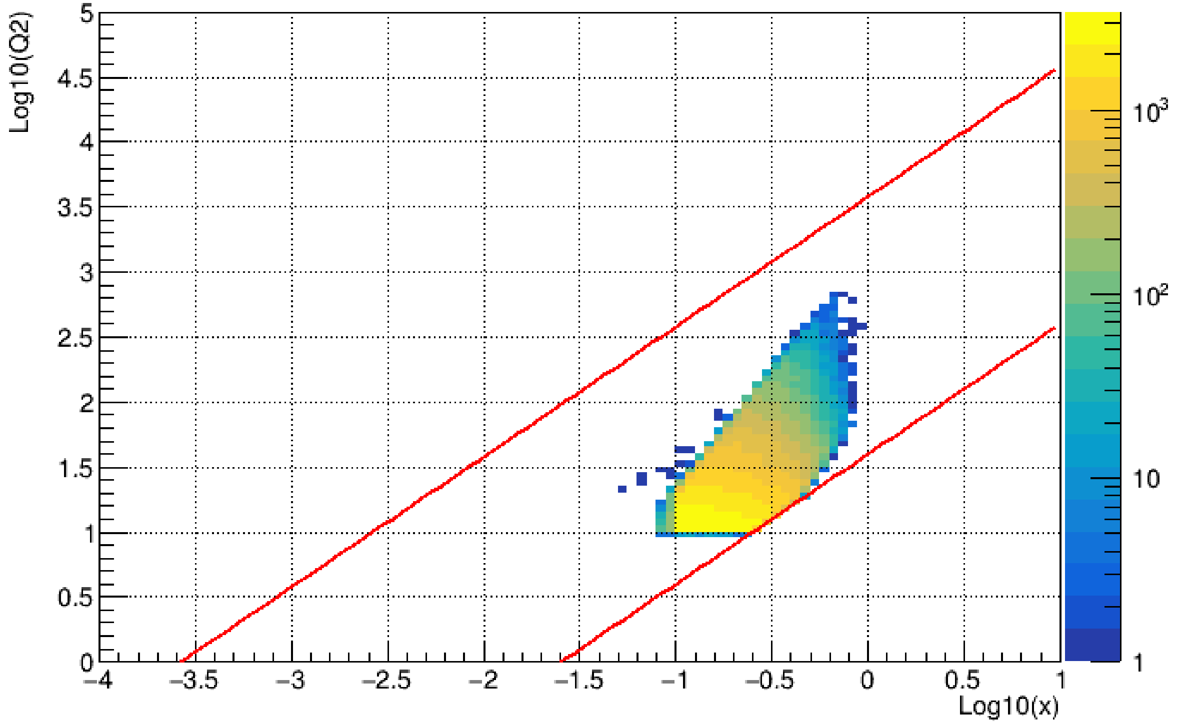
Calorimeter Coverage

- It has been proposed that calorimeter coverage should only extend to eta = 3.5
- What phase space coverage do we lose, and can it be recovered?

18x275: 3.0 < Quark Eta < 3.5



10x100: 1.5 < Quark Eta < 3.0



- Phase space lost at top energy if calorimeter coverage is restricted to eta < 3.5 instead of 4.0 (assume jet R = 0.5)
- Lost coverage in x-Q2 at top energy can be recovered by moving to lower pseudorapidity at lower hadron beam energies

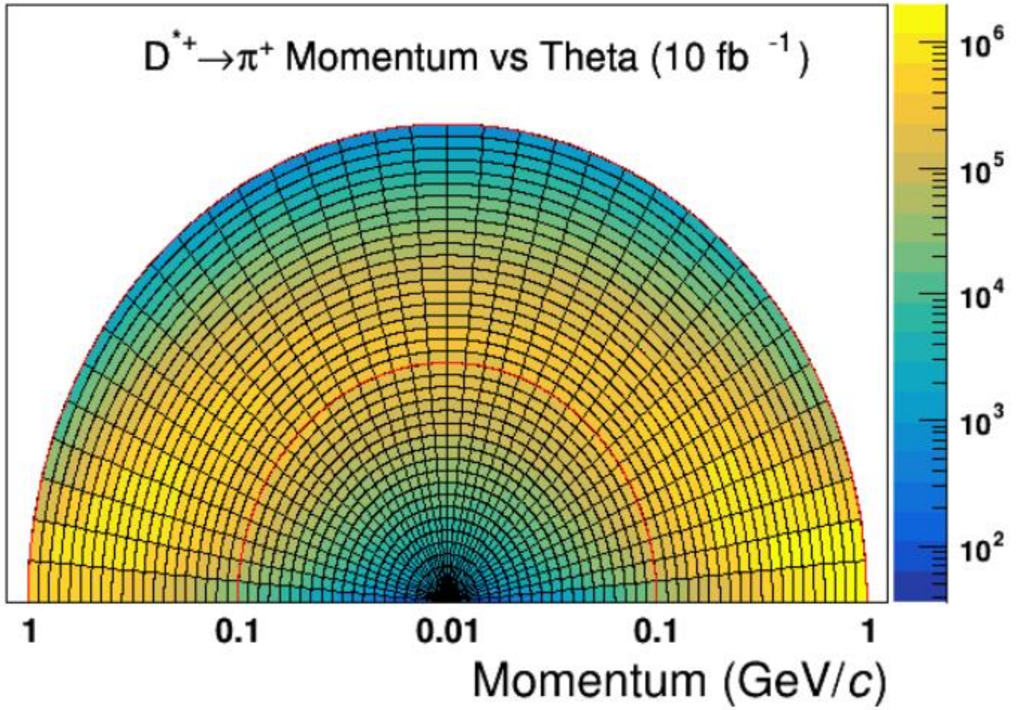
Tracking: Momentum Resolution

Assumed Resolution

Eta Range	Resolution (σP/P)%
-3.5 < η < -2.5	0.1%*P + 0.5%
-2.5 < η < -2.0	0.1%*P + 0.5%
-2.0 < η < -1.0	0.05%*P + 0.5%
-1.0 < η < 1.0	0.05%*P + 0.5%
1.0 < η < 2.5	0.05%*P + 1.0%
2.5 < η < 3.5	0.1%*P + 2.0%

- Most studies assumed the track momentum resolutions listed above (original detector matrix)
- Found to lead to reasonable jet energy resolutions
- Potential new parameterizations need to be run through the various analyses – can correlate change in tracking resolution to change in jet energy resolution

- We request a minimum track transverse momentum of 100 MeV – Driven by detection of soft pion from D* decay
- Will also be relevant for substructure / global event shape measurements and jet energy scale

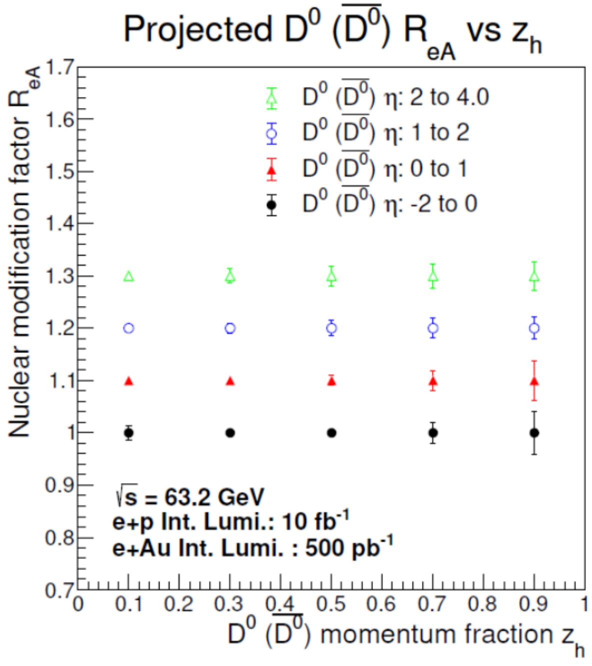


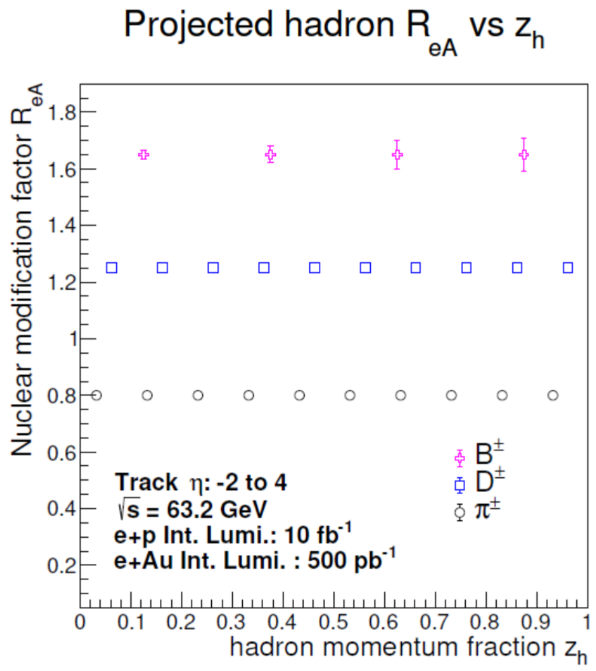
Tracking: Vertex Resolution

Vertex Resolution

Eta Range	Default Resolution	Requested Resolution
$-3.5 < \eta < -3.0$	TBD	N/A
$-3.0 < \eta < -2.5$		$\sigma_{xy} = 30/p_T + 40$ μm
$-2.5 < \eta < -1.0$		$\sigma_{xy} = 30/p_T + 20$ μm
$-1.0 < \eta < 1.0$	σ_{xyz}~20μm, $\sigma_{xy} \sim \sigma_z \sim 20\mu m/p_T + 5\mu m$	Same
$1.0 < \eta < 2.5$	TBD	$\sigma_{xy} = 30/p_T + 20$ μm
$2.5 < \eta < 3.0$		$\sigma_{xy} = 30/p_T + 40$ μm
$3.0 < \eta < 3.5$		$\sigma_{xy} = 30/p_T + 60$ μm

- Vertex resolution driven by need to reconstruct charmonium and bottomonium states
- Resolutions listed above enable the high statistics measurements of ReA shown to the right for D and B mesons over a wide pseudorapidity range
- Enhancing (degrading) resolutions will improve (decrease) signal significance and decrease (increase) integrated luminosity needed to reach a given precision





Calorimetry: Electromagnetic

EMCal Energy Resolution

Eta Range	Default Resolution (σE/E)	Requested (σE/E)
$-4.5 < \eta < -2.5$	2%/√E	Same (1-3% constant term acceptable)
$-2.5 < \eta < -2.0$	2%/√E	Same (1-3% constant term acceptable)
$-2.0 < \eta < -1.5$	7%/√E	Same (1-3% constant term acceptable)
$-1.5 < \eta < -1.0$	7%/√E	Same (1-3% constant term acceptable)
$-1.0 < \eta < 4.5$	10-12%/√E	Same (1-3% constant term acceptable)

- Most analyses used the above ECal parameterizations, including a 1-3% constant term depending on eta
- Found to result in acceptable jet energy resolutions
- New parameterizations will need to be run through analyses – correlate changes in parameters to jet energy resolution
- Many analyses assumed minimum energy threshold of 100 MeV

- Also looked at the effect of a service gap (eta = 0.1 or 0.3) on jet reconstruction
- Advocate for the most complete coverage possible