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Impact of low momentum PID on heavy flavor hadron reconstruction

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Previous setup

- Fast simulation for DIRC (η: -1 to 1) and dRICH (|η|: 1 to 3)
  - If particles can not reach DIRC @90cm: using 2r = ρ = p/(0.3B) ☛ p_T > 0.19GeV for 1.4T, 0.40GeV for 3T
  - If particles momentum is below the firing threshold for π/K/p, use the PID paramater matrix table below

Veto mode: if track momentum above pion threshold but not firing the detector, then it cannot be pion

True particle	Pion	Kaon	Proton
< pion firing: p < 0.13 (0.69)	prob(π/K/p) = 0.7, 0.2, 0.1		
< kaon firing: p < 0.47 (2.46)	prob(π/K/p) = 1, 0, 0	prob(π/K/p) = 0, 0.6, 0.4	
< proton firing: p < 0.88 (4.67)		prob(π/K/p) = 0, 1, 0	prob(π/K/p) = 0, 0, 1
p < 6 (50)			

DIRC dRICH

probability assigned according to multiplicity of different charged particles

Current setup

- Fast simulation for DIRC (η: -1 to 1) and dRICH (|η|: 1 to 3)
  - If particles can not reach DIRC @76cm: using 2r = ρ = p/(0.3B) ☛ p_T > **0.16GeV for 1.4T**, **0.19GeV for 1.7T**
  - Momentum/DCA_T resolution: from Ernst's fast sim (ePIC + 1.7T)
  - Update PID paramater matrix (more details here): because of the requirement of internal reflection, the actual detection threshold is higher than the firing threshold

Veto mode: if track momentum above pion threshold but not firing the detector, then it cannot be pion

True particle	Pion	Kaon	Proton
p < 0.25 (1)	prob(π/K/p) = 0.82, 0.11, 0.07		
p < 1.1 (3)	prob(π/K/p) = 1, 0, 0	prob(π/K/p) = 0, 0.62, 0.38	
p < 2.15 (5)		prob(π/K/p) = 0, 1, 0	prob(π/K/p) = 0, 0, 1
p < 6 (60)			

< pion firing

< kaon firing

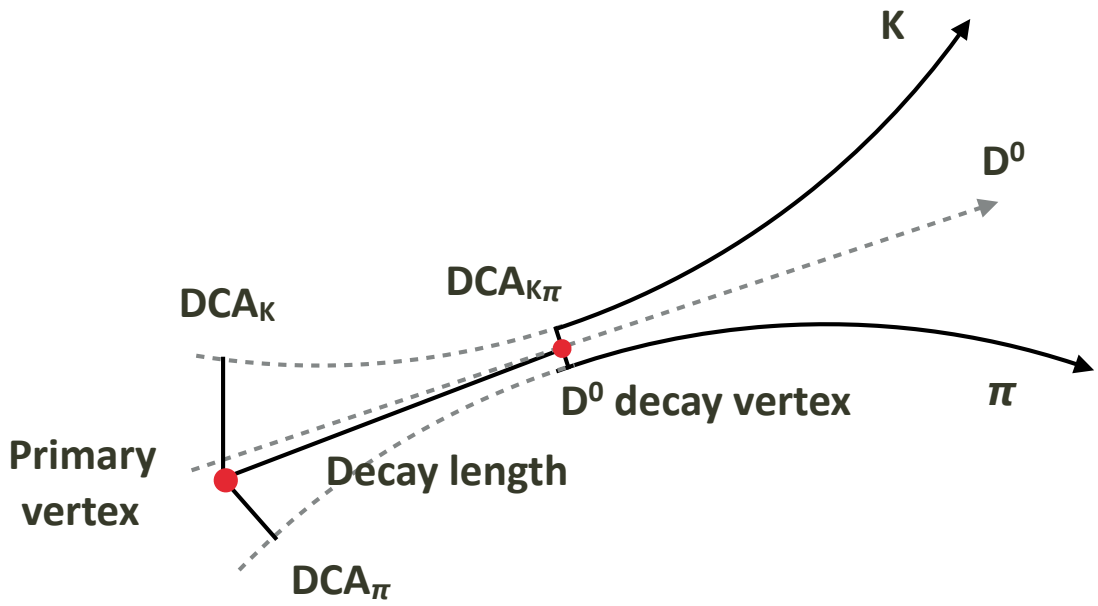
< proton firing

DIRC dRICH

probability assigned according to multiplicity of different charged particles

ePIC smearing and analysis selection

- Single track smearing using parameters from fast simuation with ePIC baseline tracking (assuming single pion resolution for all charged particles)
  - p (magnitude) smeared by p resolution along the true p direction
  - Vertex position smeared by $DCA_{r\varphi}$ and DCA_z
- No primary vertex smearing
- DIS event selection (2E8 events generated from pythia 6 e+p w/ 10x100GeV)
  - $Q^2 > 10\ GeV^2$ (event generated with $Q^2>10\ GeV^2$)
  - $0.05 < y < 0.8$
- D^0 selection
  - $p_T > 0.2GeV$
  - Pair identified Kπ tracks
  - $DCA_{pair} < 130\mu m$
  - Decay length > 40µm
  - $\cos\theta_{r\varphi} > 0.8$



All topological cuts in transverse plane, more details in arXiv: 2102.08337

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  - $Q^2 > 10\ GeV^2$ (event generated with $Q^2>10\ GeV^2$)
  - $0.05 < y < 0.8$
- Λ_c selection
  - $p_T > 0.2GeV$
  - Pair identified Kπ tracks
  - $DCA_{pair} < 300\mu m$
  - Decay length > 10µm
  - Λ_c DCA < 150um

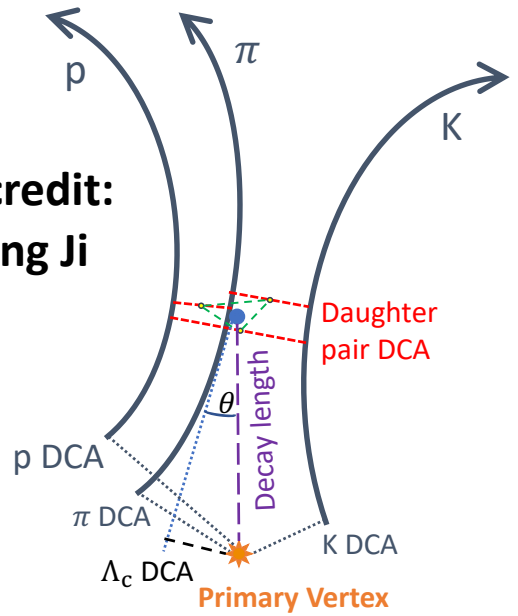


Figure credit: Yuanjing Ji

All topological cuts in transverse plane, more details in arXiv: 2102.08337

PID options

- For barrel: need to consider the momentum threshold reaching TOF detector
  - If using high enough p_T cut (e.g. 0.2GeV), then all charged particles can reach TOF and DIRC

- PID options
  - No PID
  - Detector Matrix (DM) PID: no low p cutoff (can be covered by TOF)
  - DIRC+dRICH: with low p cutoff (1.7T), including or excluding mis-identified particles
  - Caveat: assume perfect electron ID, ignore muons

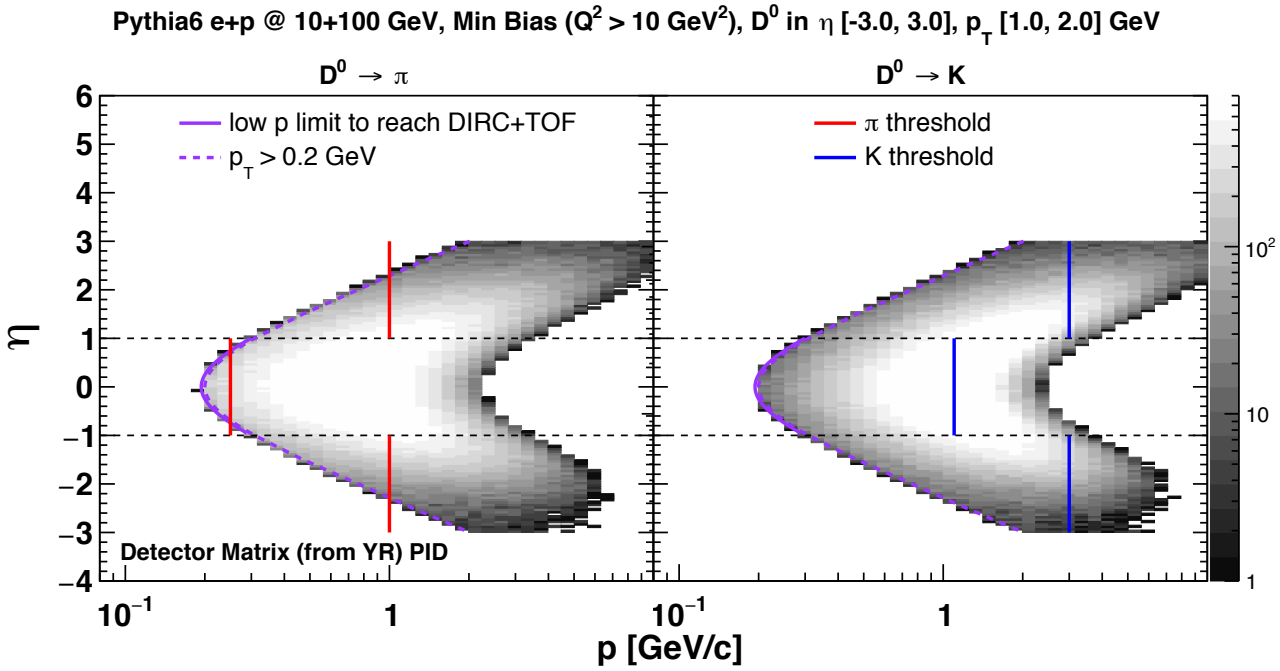


Table from the Yellow Report (YR)

Deterctor Matrix	
Barrel	< 6 GeV
Forward	< 10 GeV
Backward	< 50 GeV

PID options — No cutoff

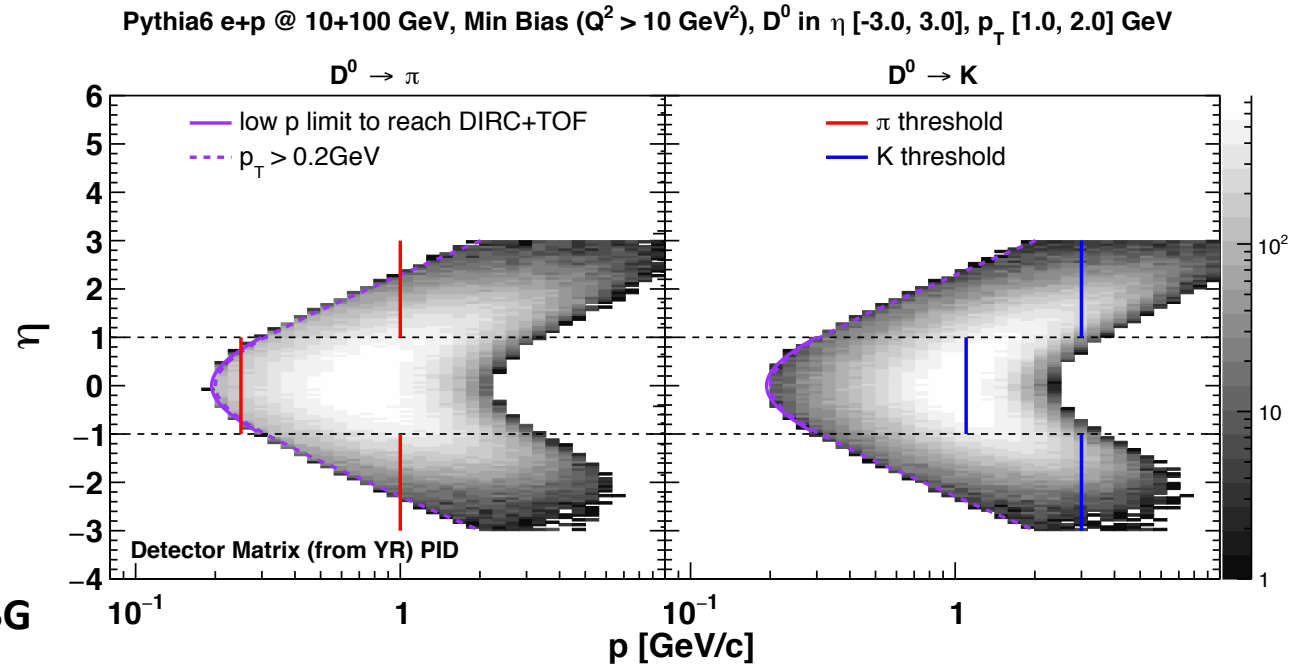
- Detector matrix from YR: no low momentum cutoff or equivalent to if TOF are implemented

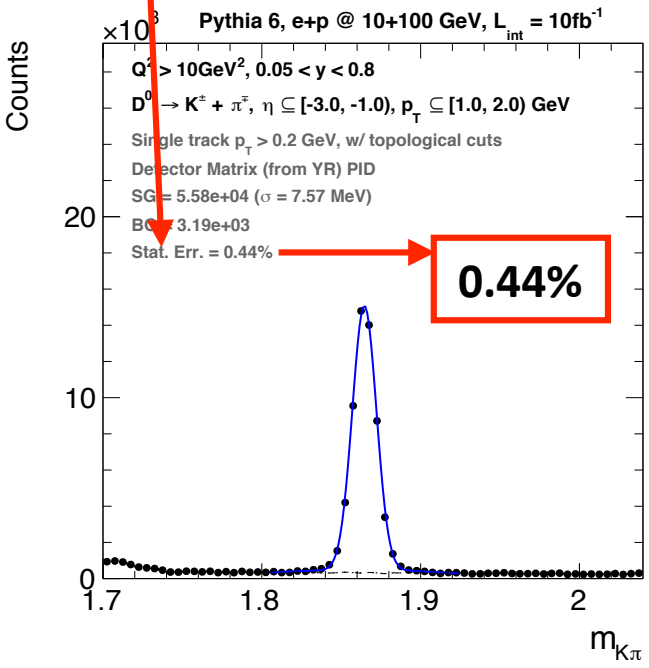
Stat. Err. = sqrt(SG+BG)/SG

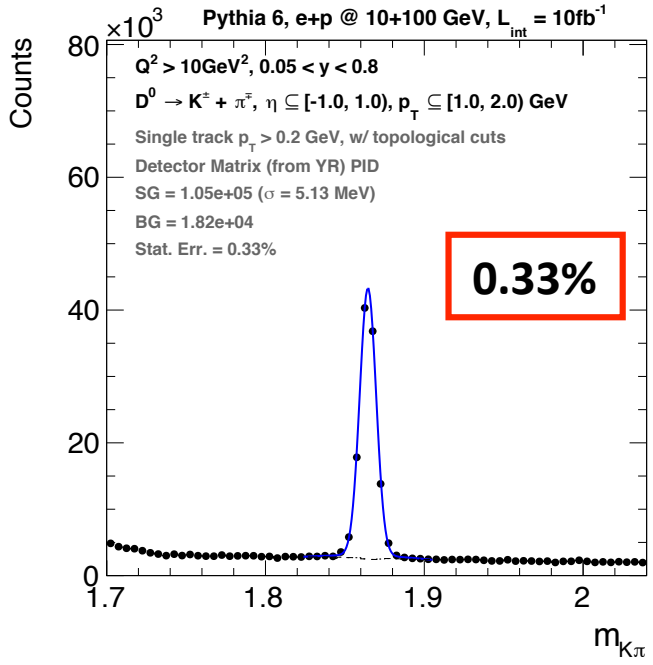
= sqrt(1+BG/SG)/sqrt(SG)

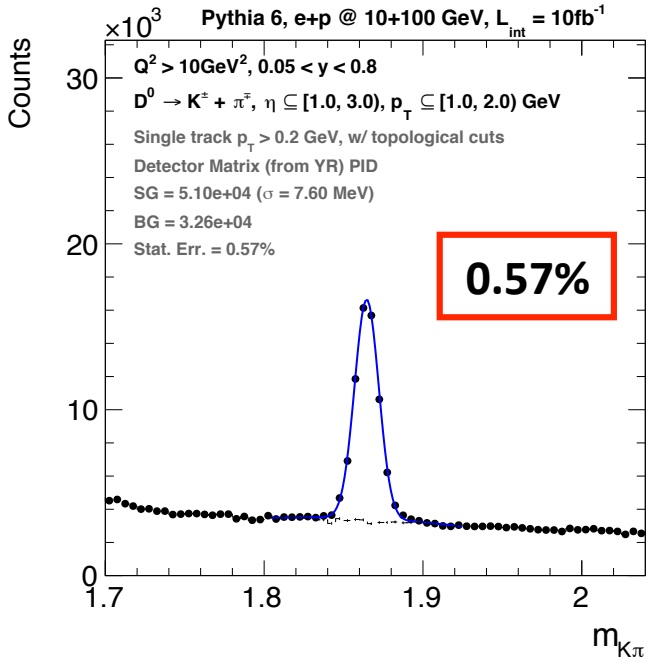
☛ decrease with increasing SG

☛ descrease with descreasing BG





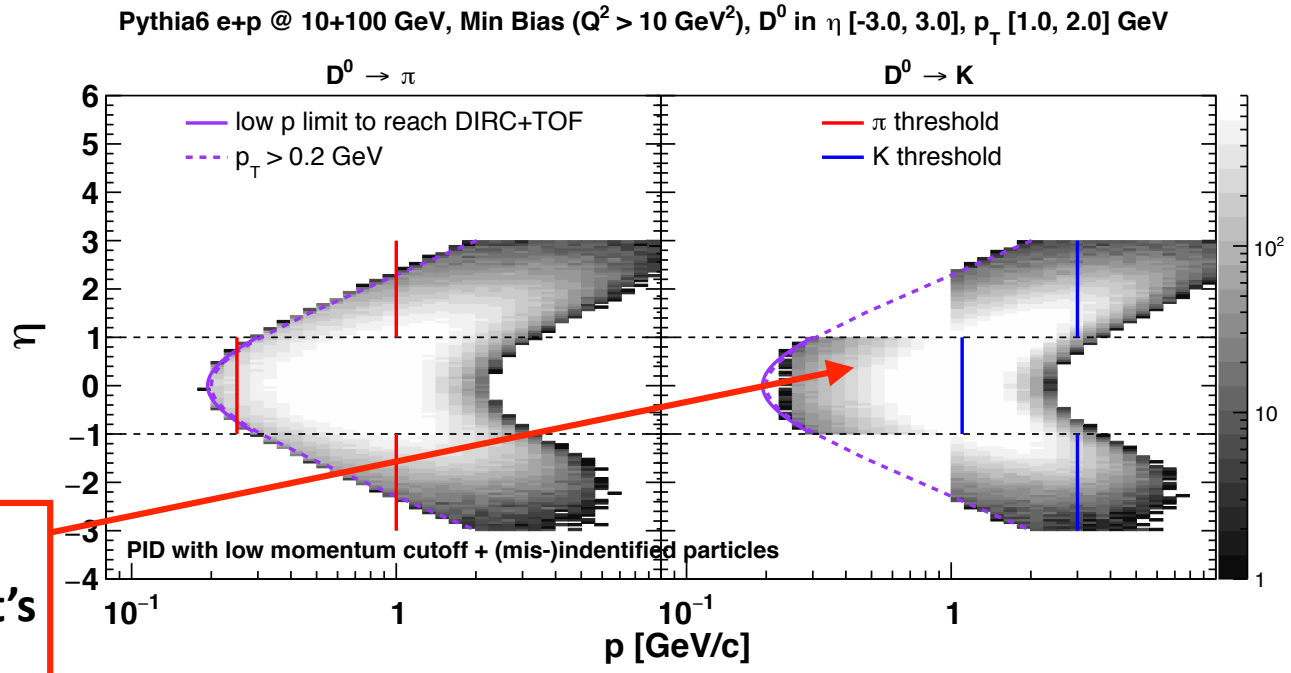


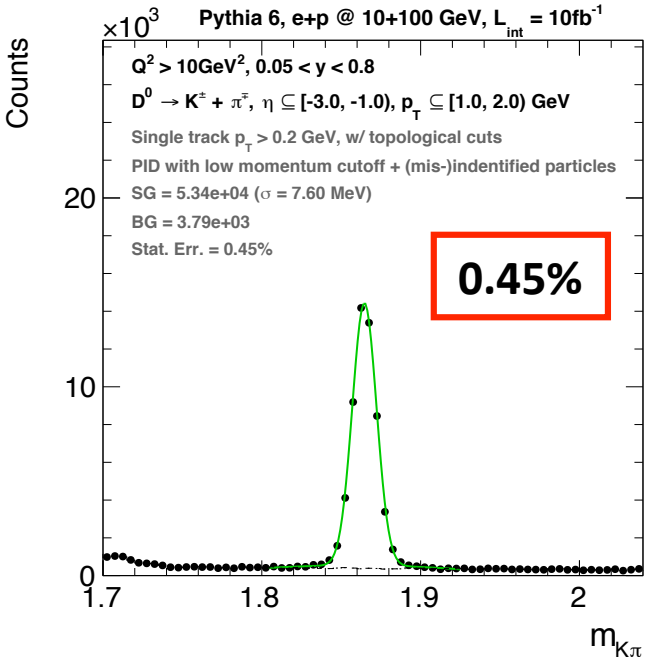


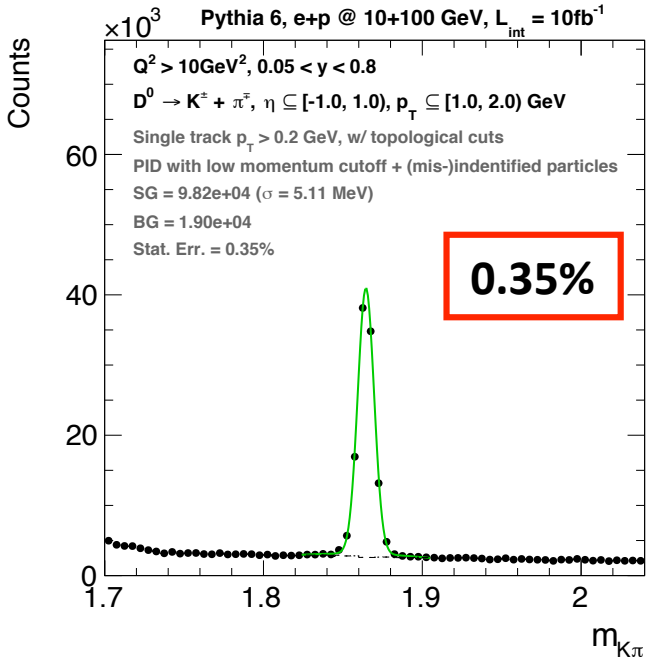
PID options — Cutoff

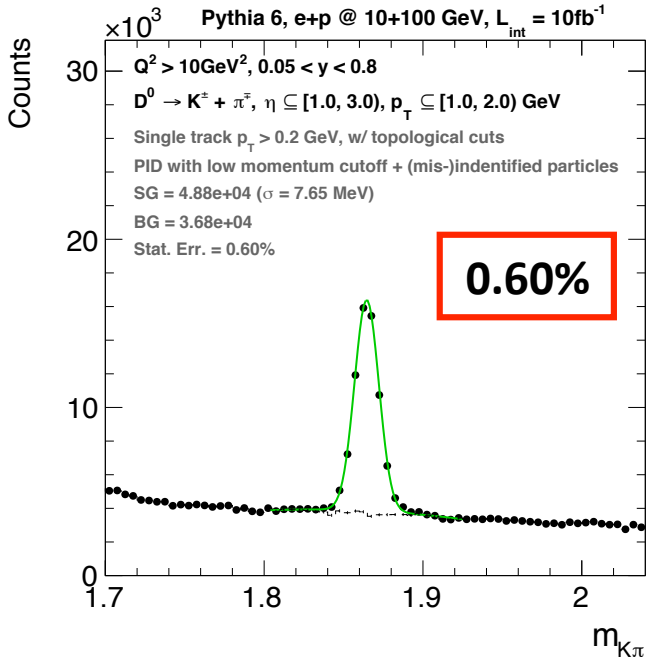
- PID with only Cherenkov detectors: w/ low momentum cutoff and some mis-identified particles
  - prob(π) > 0.7, prob(K) > 0.5

Using veto mode for particles beyond pion detecting threshold: if not pion, it's either kaons (0.62) or protons (0.38)



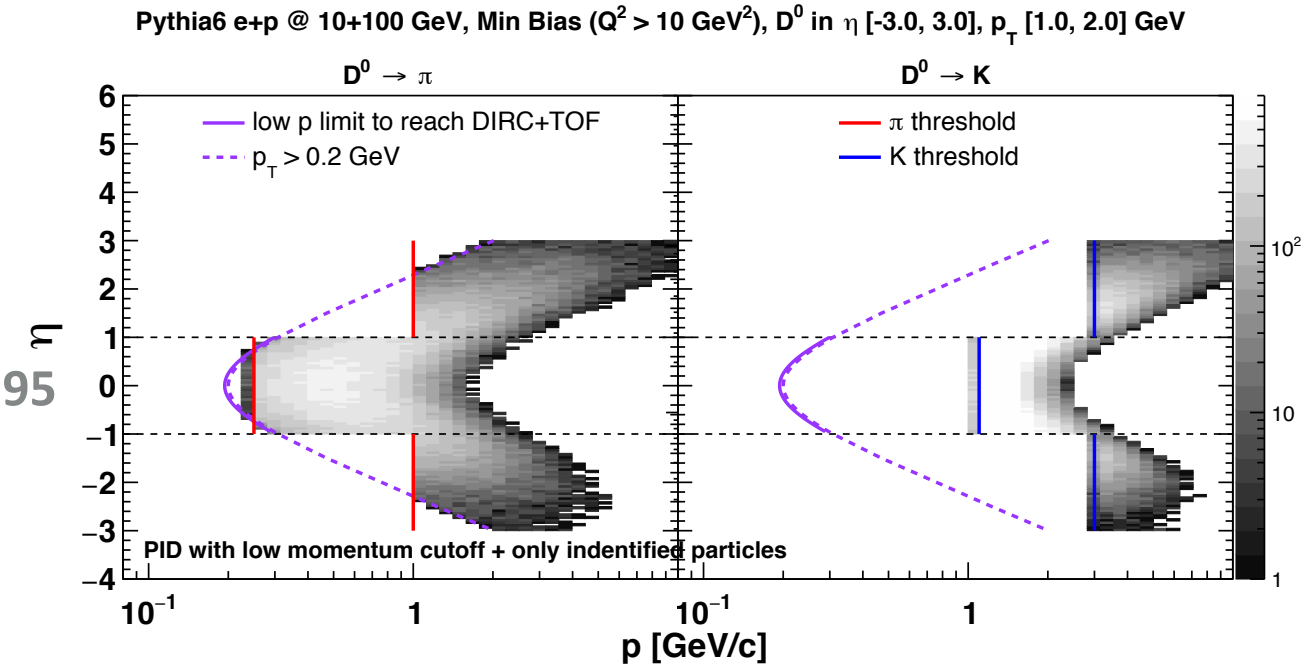


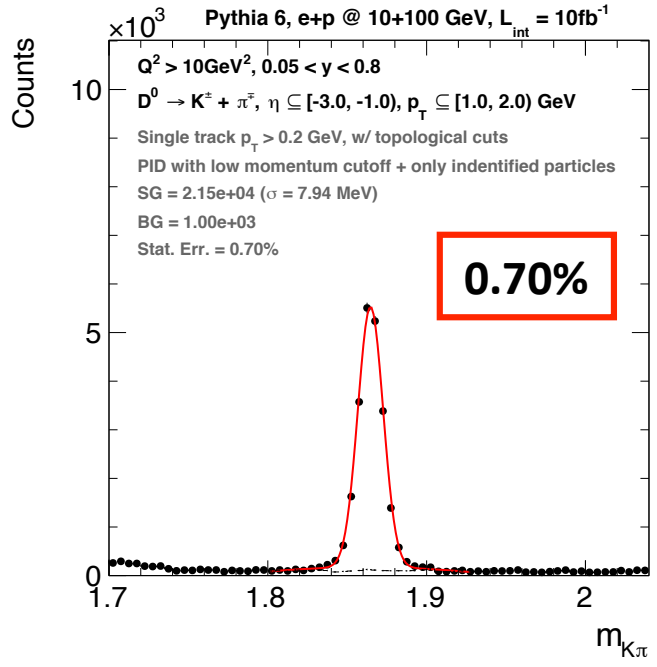


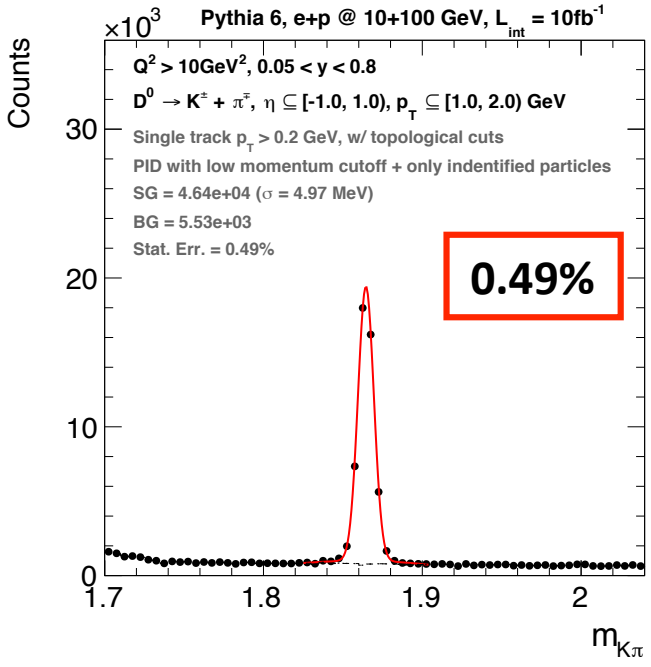


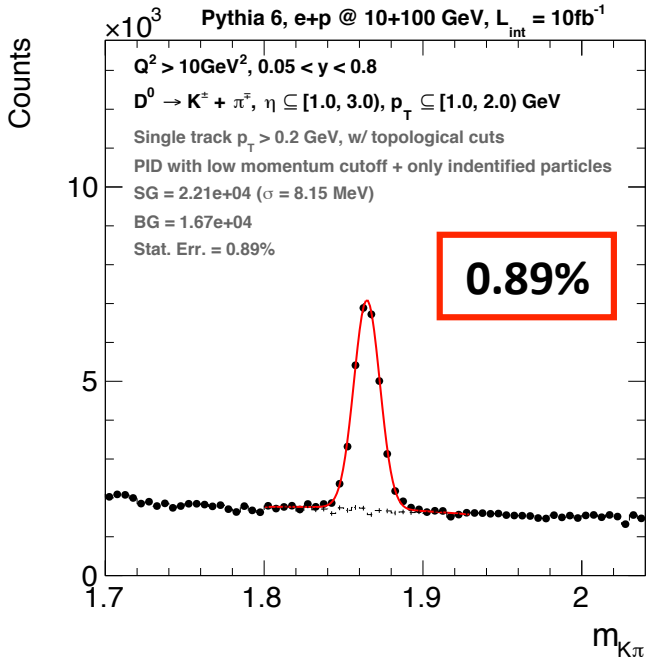
PID options — All identified

- PID with only Cherenkov detectors: w/ low momentum cutoff and only identified particles
  - prob(π) > 0.95, prob(K) > 0.95



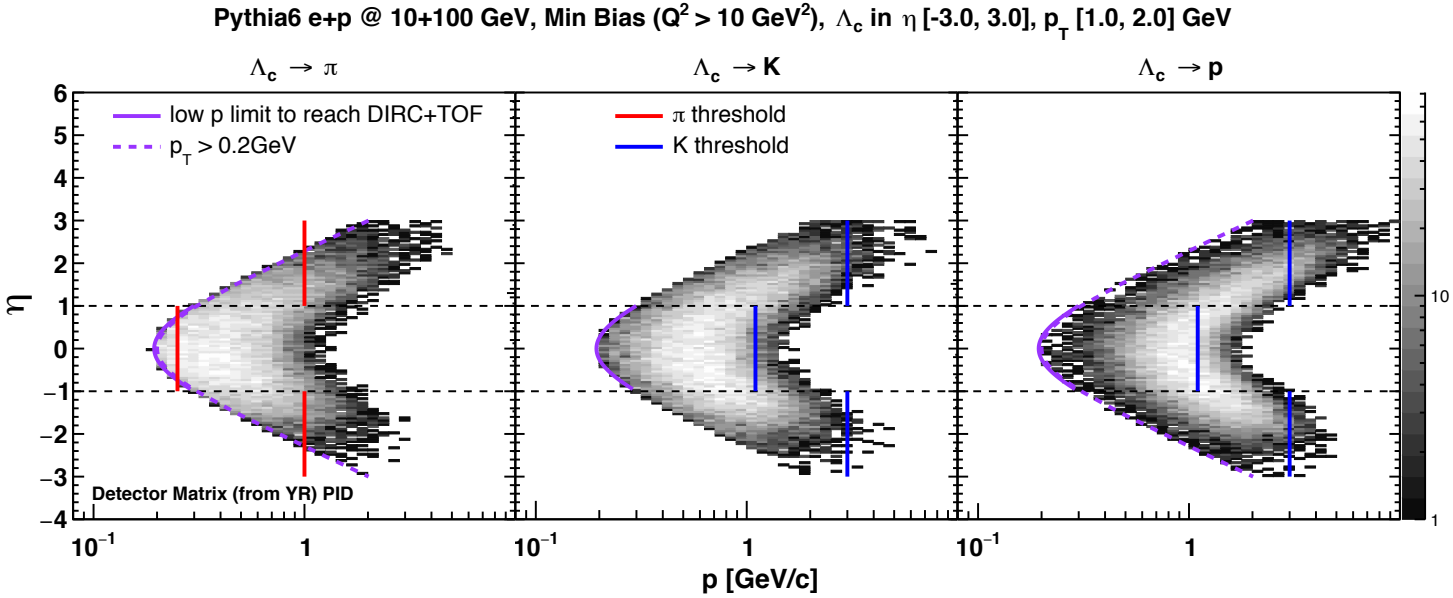


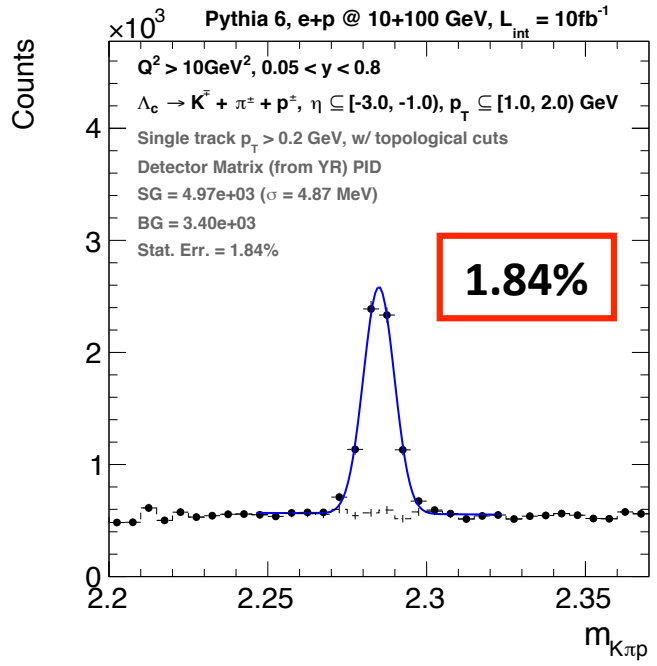


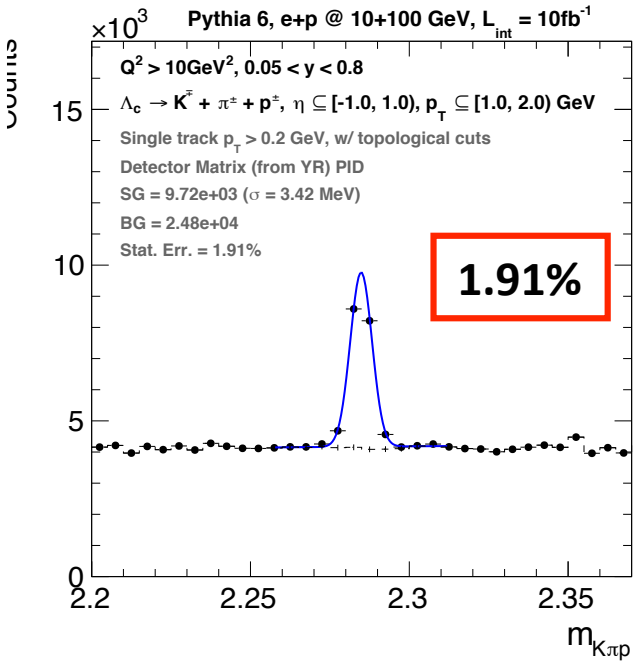


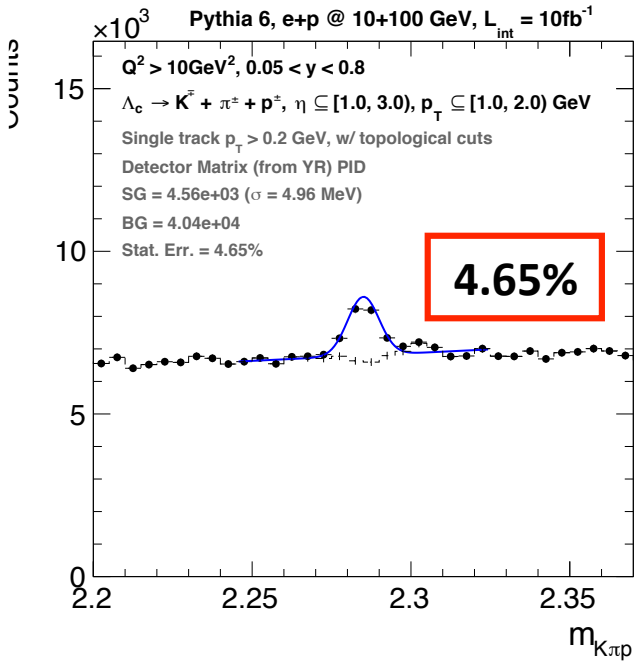
PID options — No cutoff

- Detector matrix from YR: no low momentum cutoff or equivalent to if TOF are implemented









PID options — Cutoff

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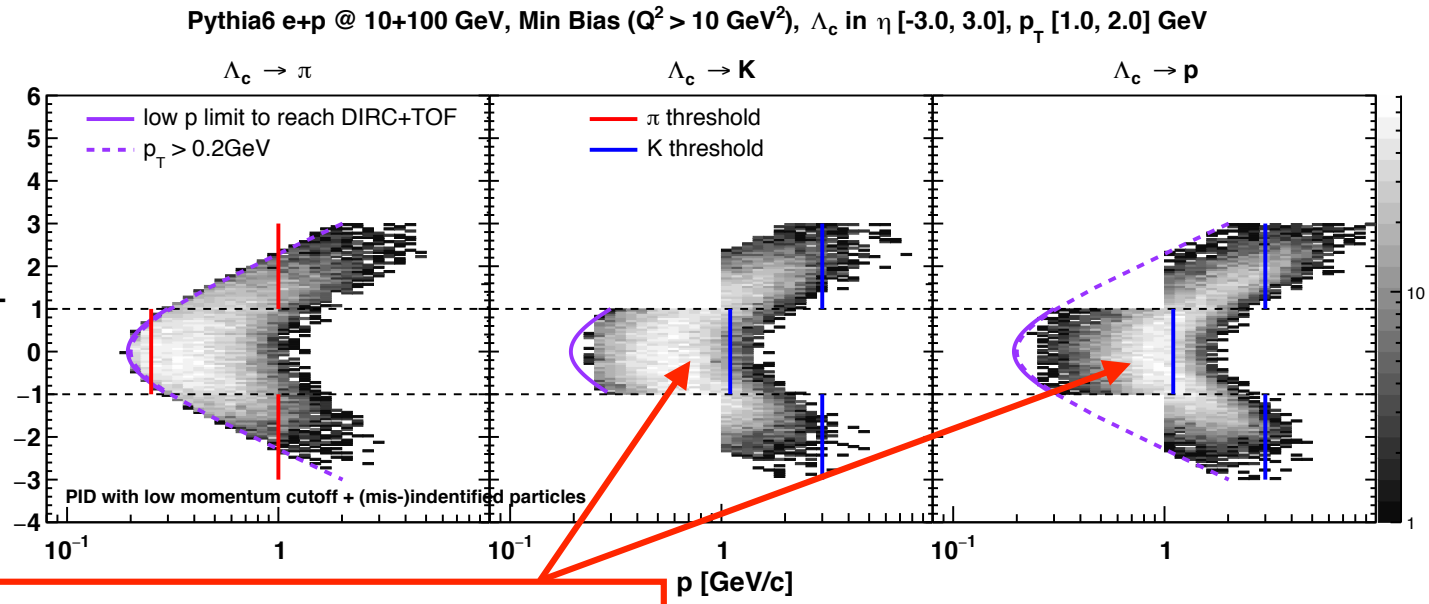
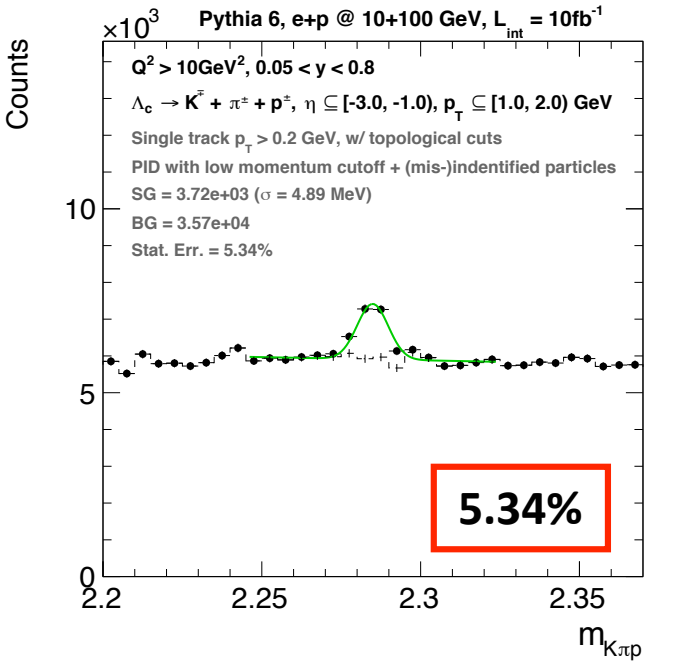
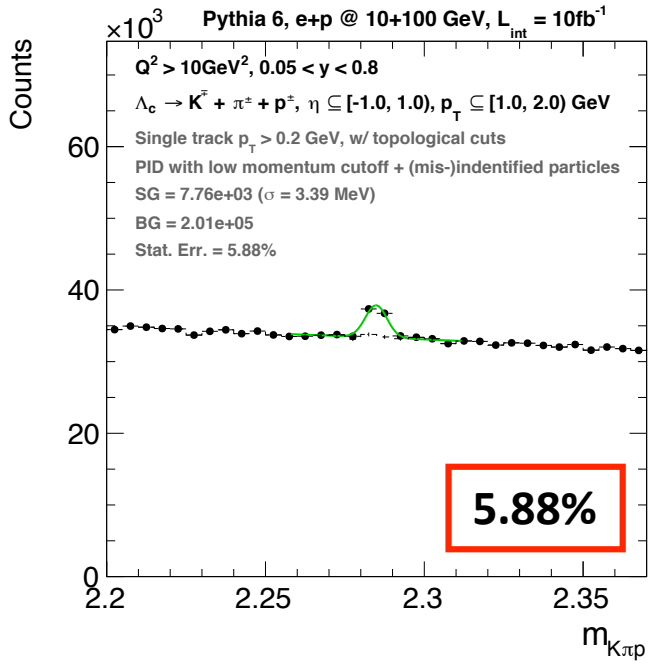
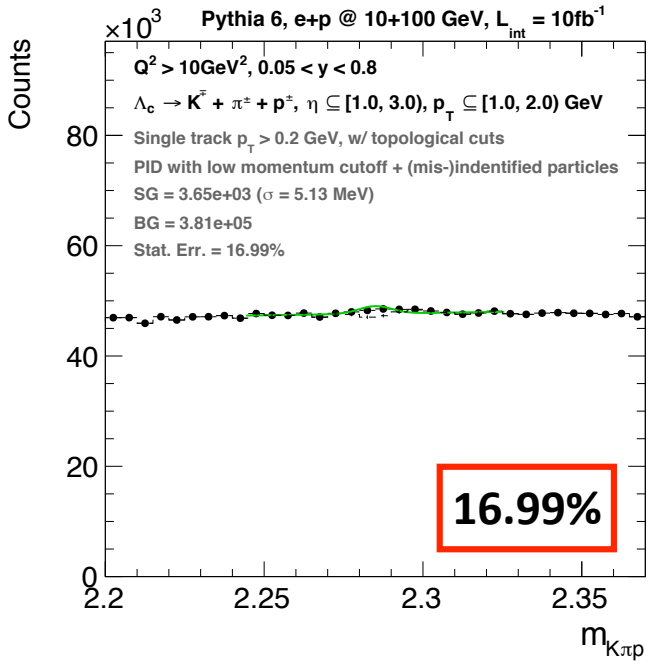
  - prob(π) > 0.7, prob(K) > 0.5, prob(p) > 0.1



Using veto mode for particles beyond pion detecting threshold: if not pion, it's either kaon (0.62) or proton (0.38)



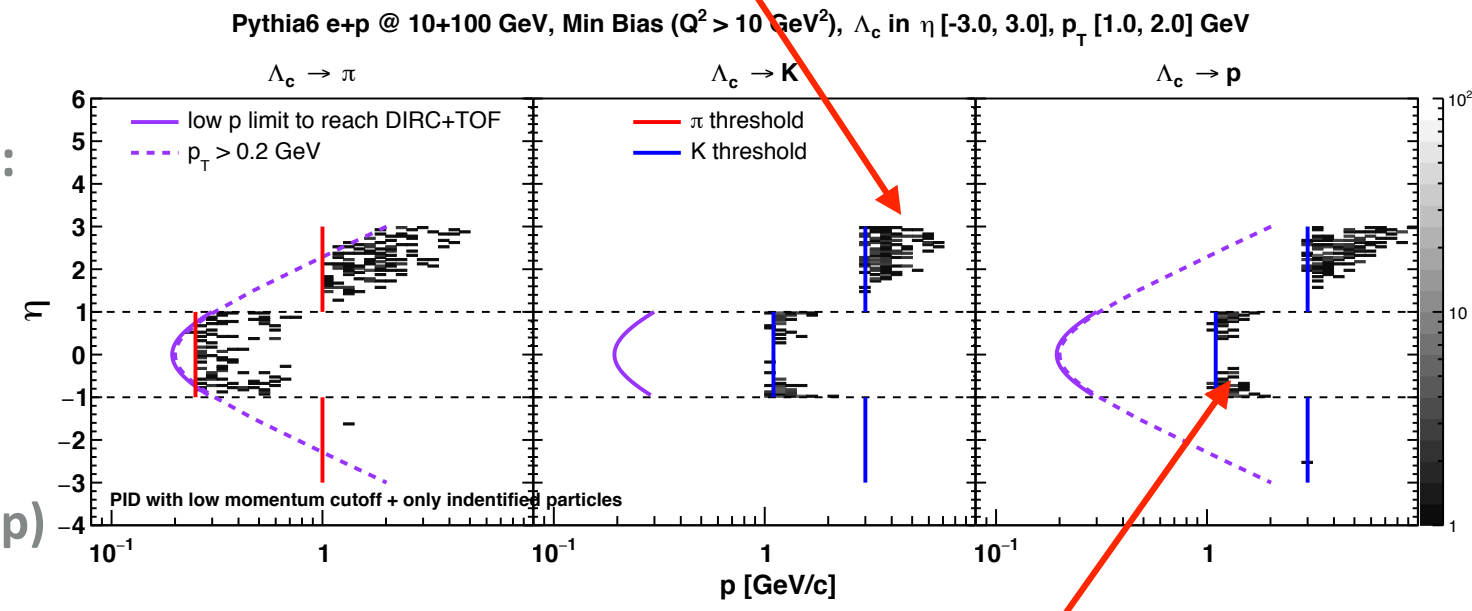




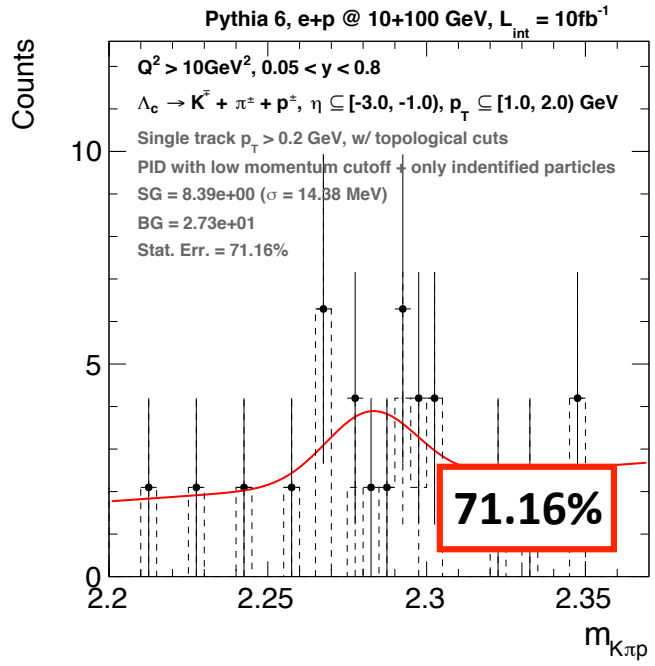
PID options — All identified

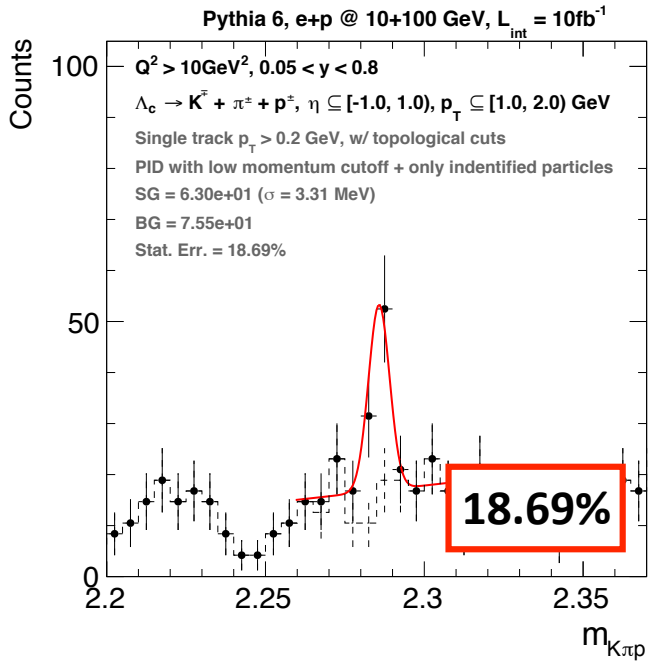
Requiring identified K throw away a lot of signals

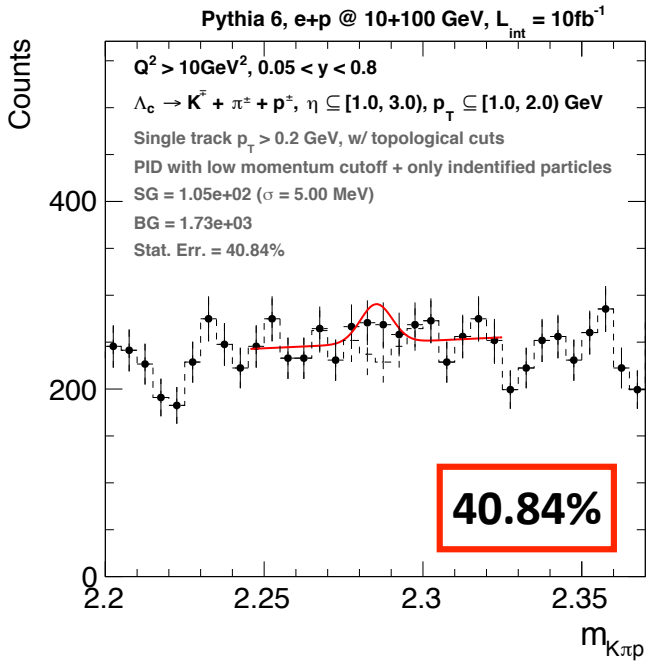
- PID with only Cherenkov detectors: w/ low momentum cutoff and only identified particles
  - prob(π) > 0.95, prob(K) > 0.95, prob(p) > 0.95



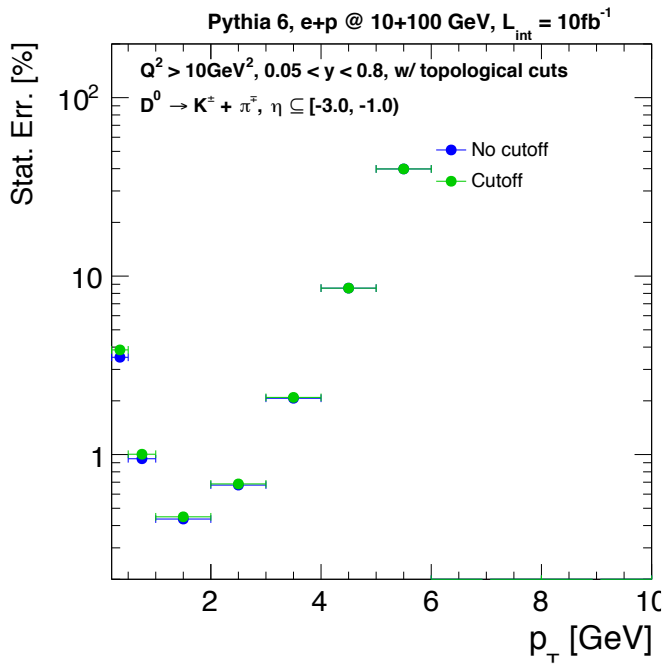
Veto mode for proton: if above kaon threhold and not firing, it has to be proton

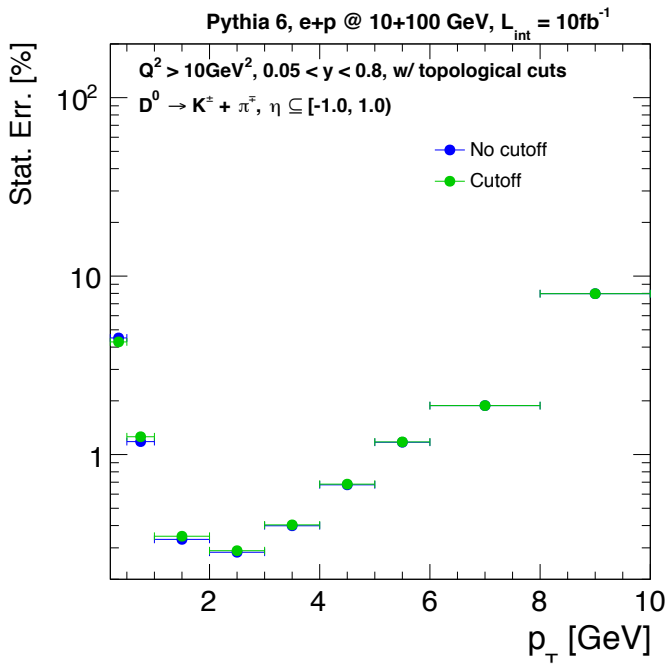


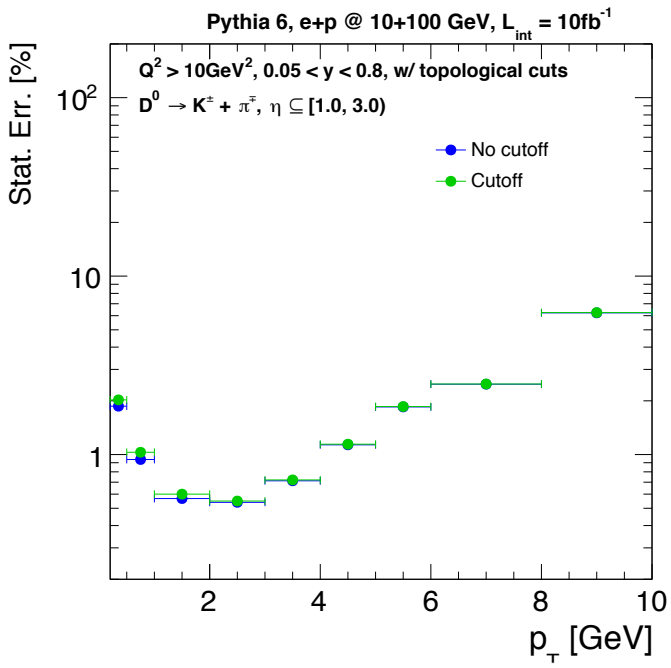


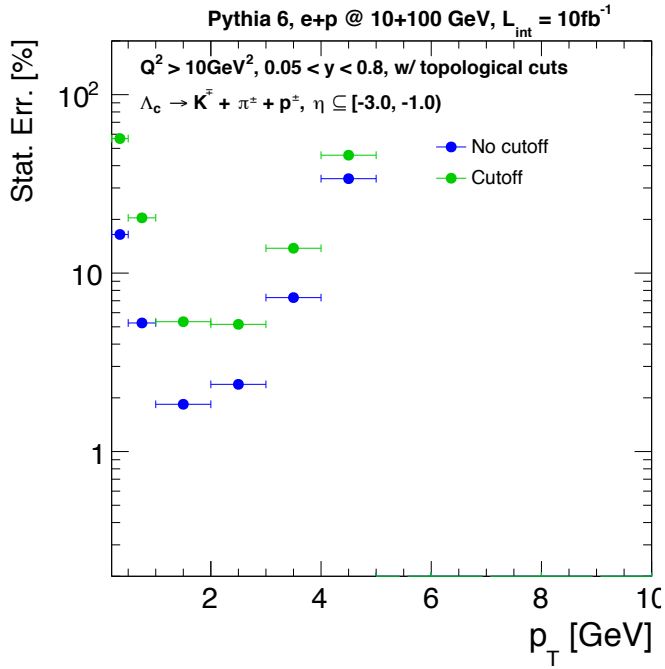


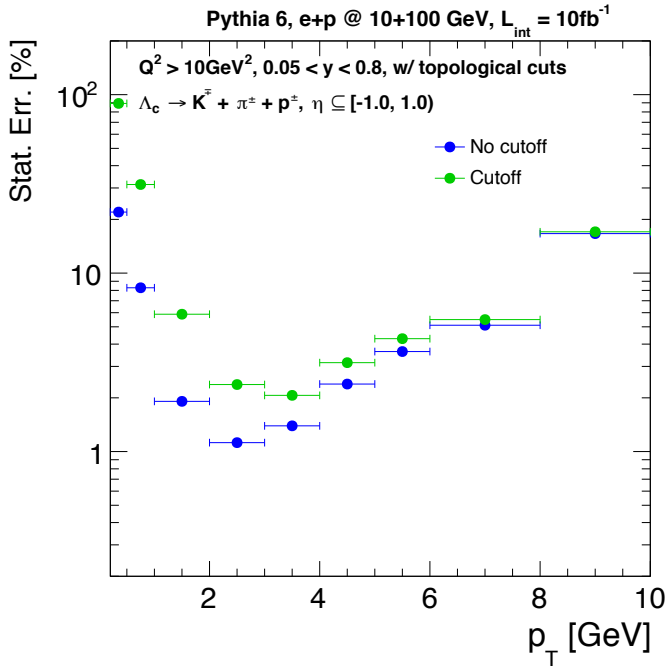
Stat. Err. at different η and p_T

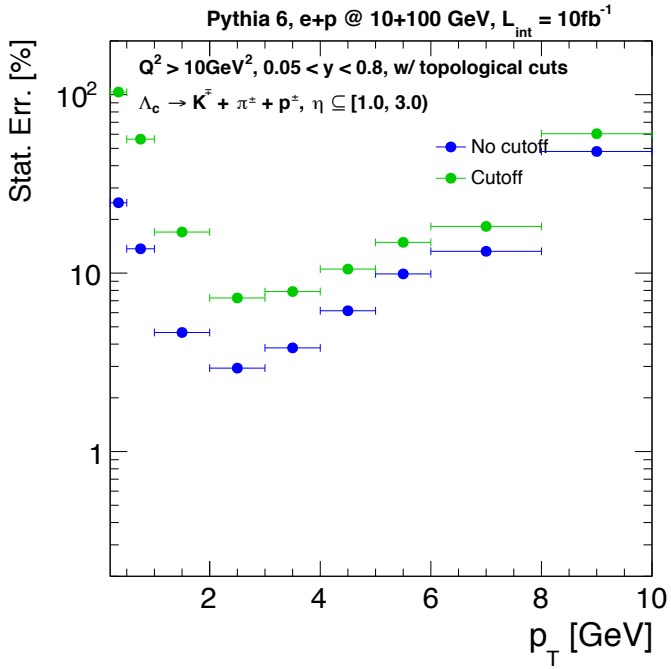




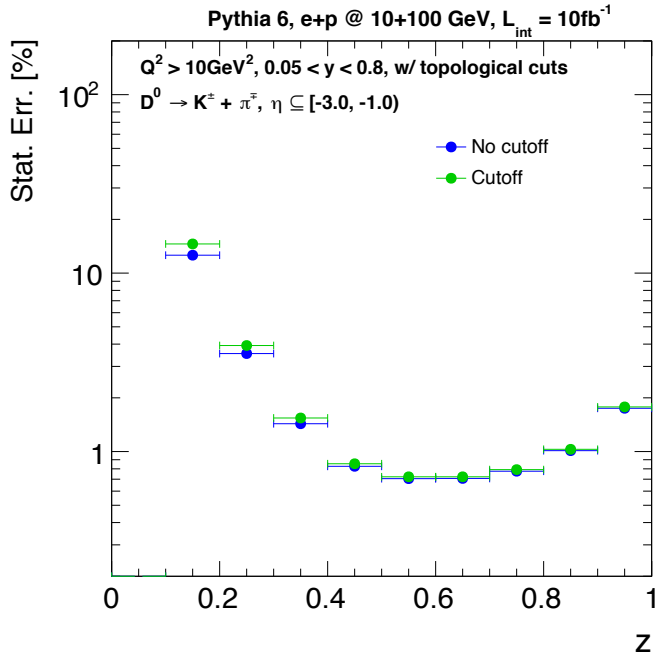


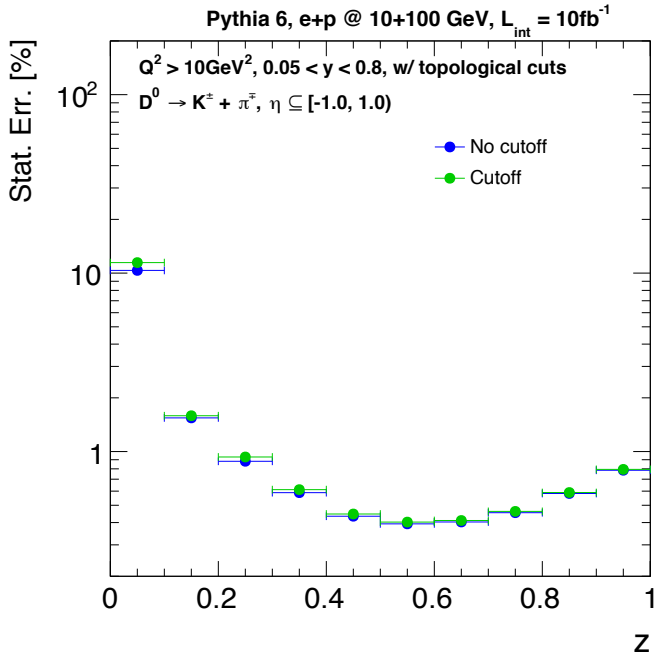


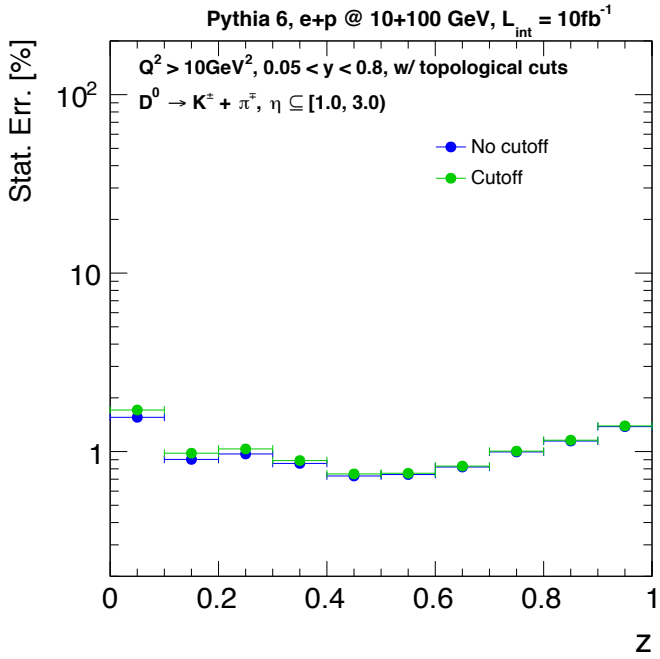


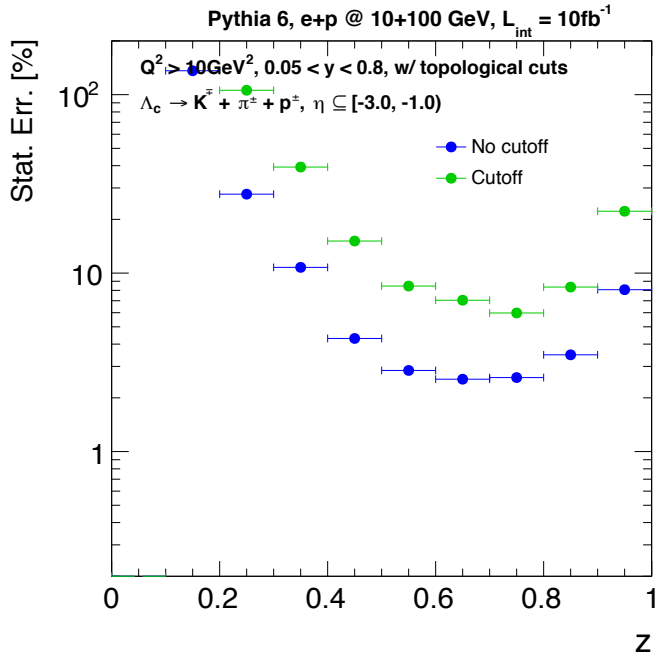


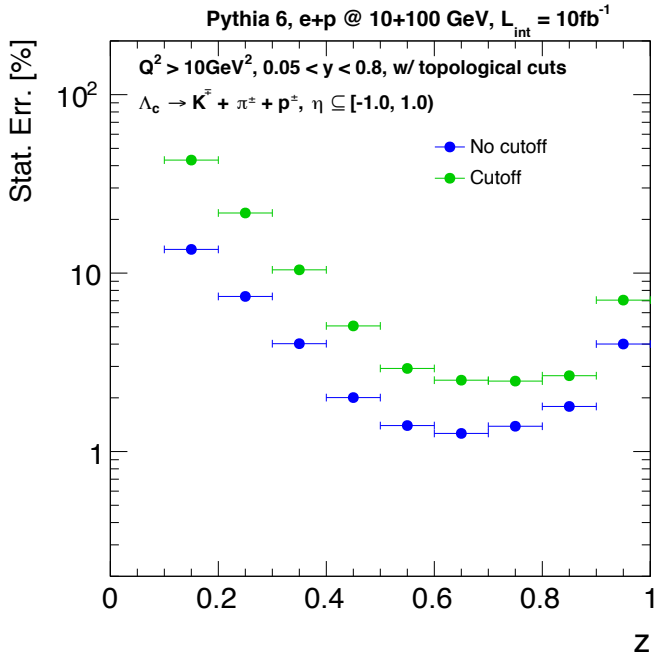
Stat. Err. at different η and z

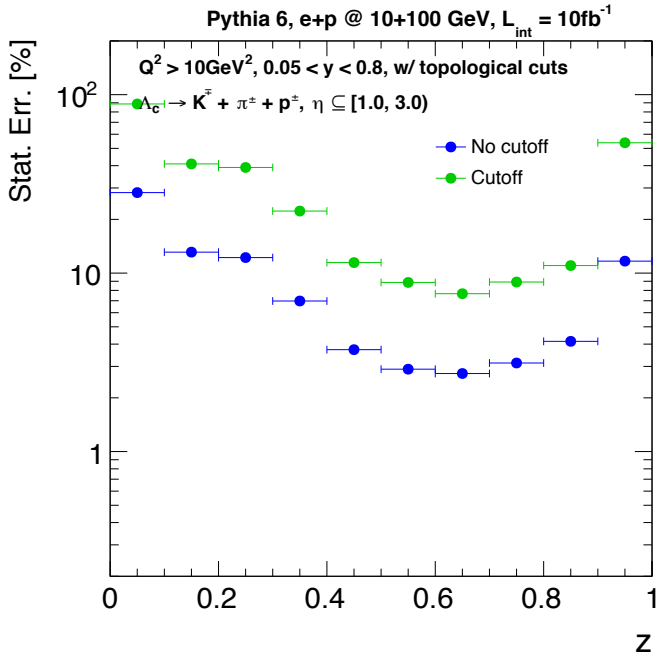












Take away message — w/ or w/o low momentum PID

- Negligible impact on D^0 meson
- Larger impact on Λ_c baryon

Physics impact

- Negligible impact on D^0 meson
  - Charm F_2, gluon helicity, gluon TMD measurements via D^0 <u>will not</u> be affected
- Larger impact on Λ_c baryon

arXiv: 2107.05632

arXiv: 2110.04489

arXiv: 2102.08337

Figure from ATHENA proposal (credit: Matt Kelsey)

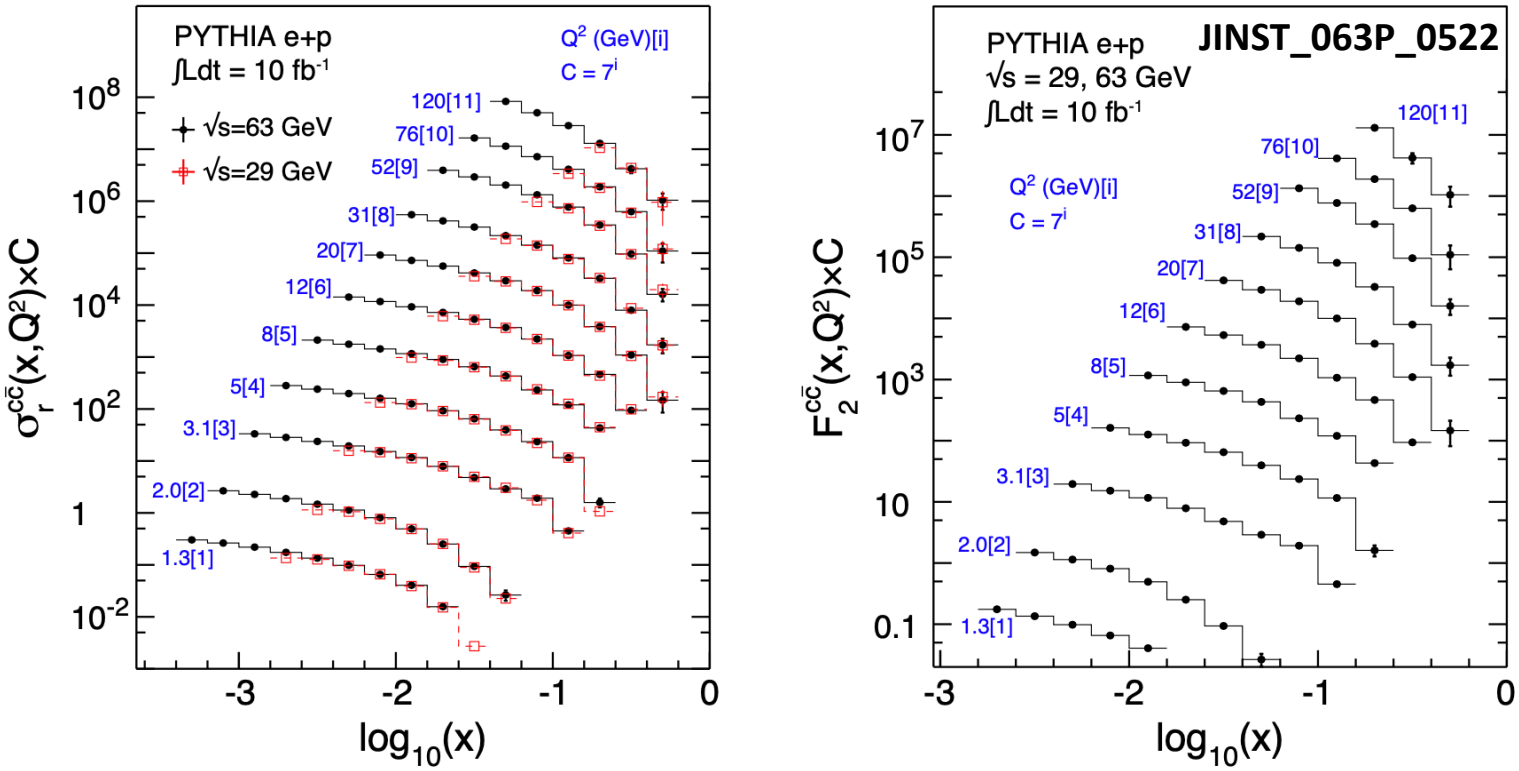
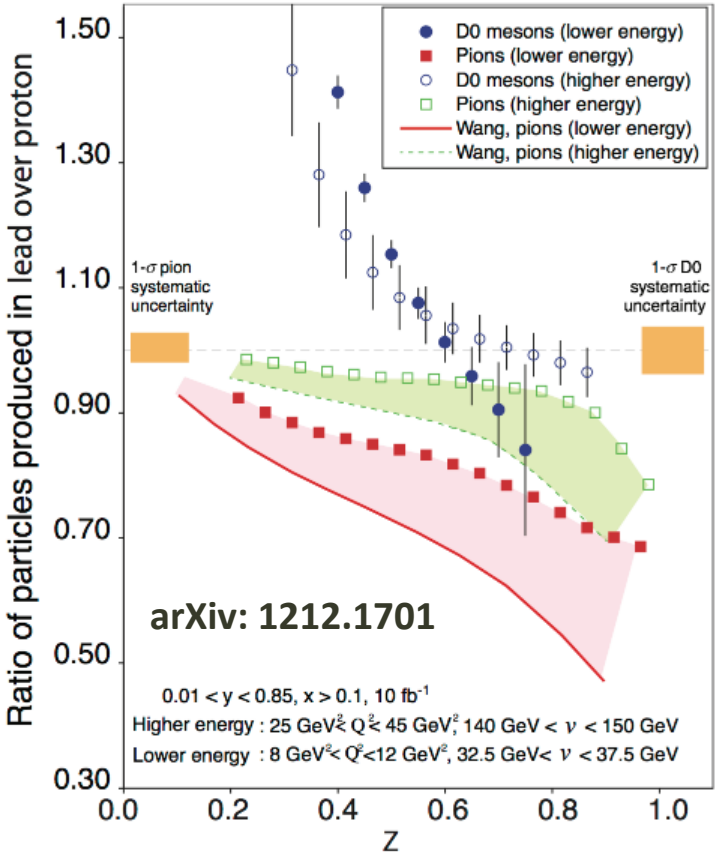
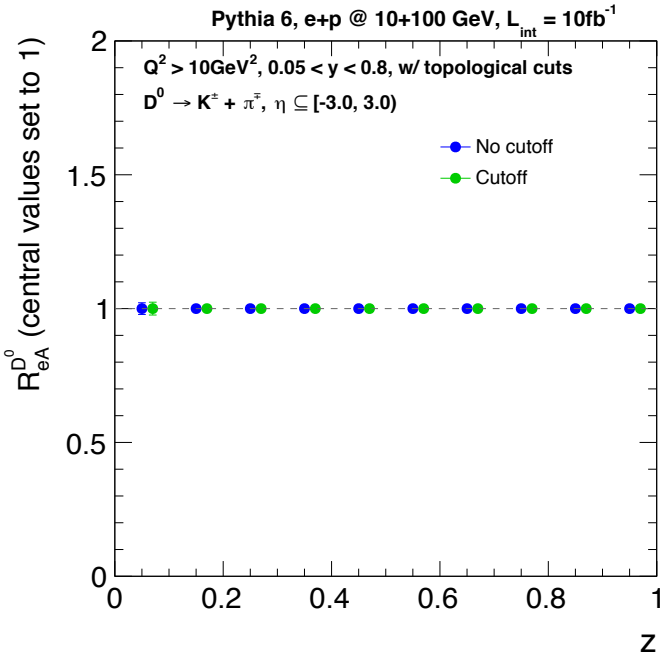


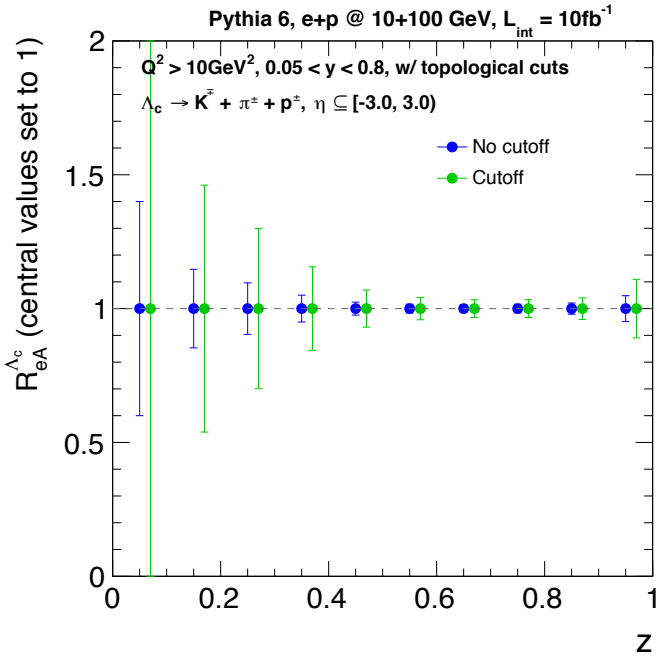
Figure 3.22: The reduced charm cross section $\sigma_r^{c\bar{c}}$ (left) and corresponding structure function $F_2^{c\bar{c}}$ (right) in intervals in Bjorken-x for different values of Q^2 from PYTHIA simulations and ATHENA response for $e + p \to e' + D^0 + X$ at the indicated center-of-mass energies for an integrated luminosity of $10\,\mathrm{fb}^{-1}$. The vertical values for different Q^2 values are scaled as indicated (FastSim).

Physics impact

- Negligible impact on D^0 meson
  - Charm F_2, gluon helicity, gluon TMD measurements via D^0 will not be affected
- Larger impact on Λ_c baryon
  - Charm hadron double ratio R_{eA}: negligible impact on D^0 meson, about a factor of 2 stat. err. increase for Λ_c







Physics impact

- Negligible impact on D^0 meson
  - Charm F_2, gluon helicity, gluon TMD measurements via D^0 will not be affected
- Larger impact on Λ_c baryon
  - Charm hadron double ratio R_{eA}: negligible impact on D^0 meson, about a factor of 2 stat. err. increase for Λ_c
  - Λ_c/D^0 ratio to study hadron chemistry: increasing impact at low p_T range and forward rapidity

Figure from ATHENA proposal (credit: Yuanjing Ji)

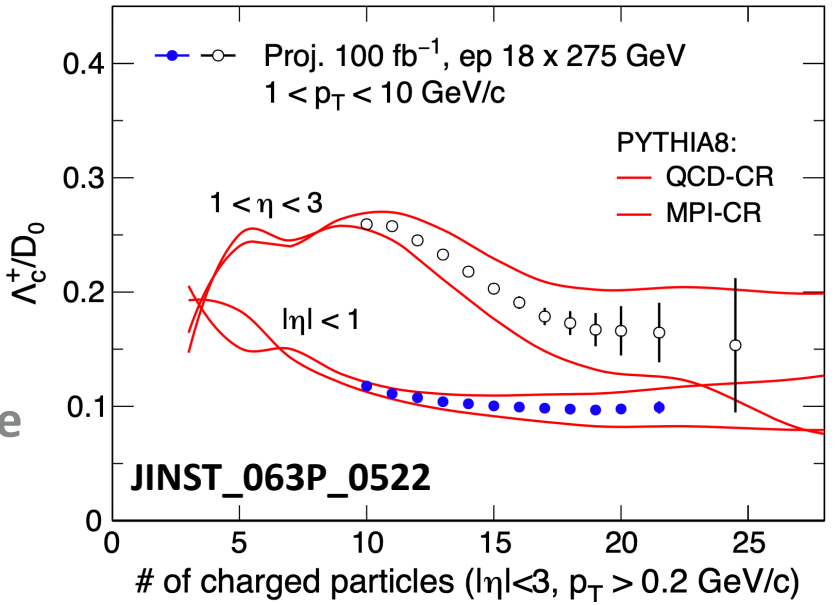


Figure 3.28: Projections for ATHENA measurements of the heavy-quark Λ_c^+ to D^0 baryon-to-meson ratio as a function of the charged track multiplicity (FastSim).