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Impact of low momentum PID on heavy flavor hadron reconstruction

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ePIC HF/Jet WG meeting, 09/07/2022

- ▶ Fast simulation for DIRC (η : -1 to 1) and dRICH ($|\eta|$: 1 to 3)
 - ◆ If particles can not reach DIRC @90cm: using $2r = \rho = p/(0.3B) \rightarrow p_T > 0.19\text{GeV}$ for 1.4T, 0.40GeV for 3T
 - ◆ If particles momentum is below the firing threshold for $\pi/K/p$, use the PID parameter 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)	$\text{prob}(\pi/K/p) = 0.7, 0.2, 0.1$		
< kaon firing	$p < 0.47$ (2.46)	$\text{prob}(\pi/K/p) = 1, 0, 0$	$\text{prob}(\pi/K/p) = 0, 0.6, 0.4$	
< proton firing	$p < 0.88$ (4.67)		$\text{prob}(\pi/K/p) = 0, 1, 0$	$\text{prob}(\pi/K/p) = 0, 0, 1$
	$p < 6$ (50)			

DIRC dRICH probability assigned according to multiplicity of different charged particles

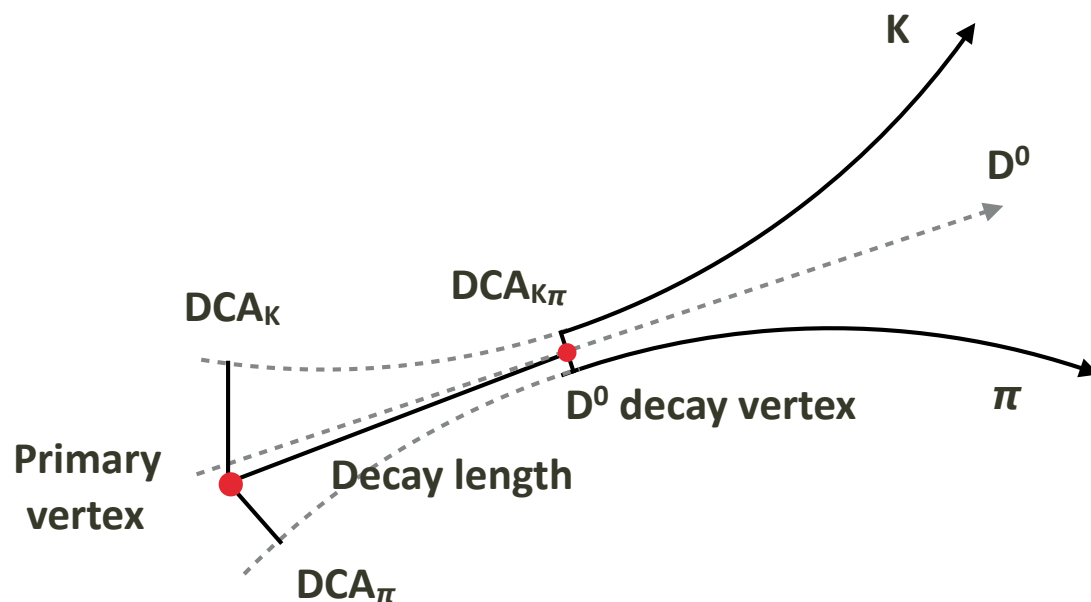
- ▶ Fast simulation for DIRC (η : -1 to 1) and dRICH ($|\eta|$: 1 to 3)
 - ◆ If particles can not reach DIRC @76cm: using $2r = \rho = p/(0.3B) \Rightarrow p_T > 0.16\text{GeV}$ for **1.4T**, **0.19GeV** for **1.7T**
 - ◆ Momentum/DCA_T resolution: from Ernst's fast sim (ePIC + 1.7T)
 - ◆ Update PID parameter 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
< pion firing	$p < 0.25$ (1)	$\text{prob}(\pi/K/p) = 0.82, 0.11, 0.07$		
< kaon firing	$p < 1.1$ (3)	$\text{prob}(\pi/K/p) = 1, 0, 0$	$\text{prob}(\pi/K/p) = 0, 0.62, 0.38$	
< proton firing	$p < 2.15$ (5)		$\text{prob}(\pi/K/p) = 0, 1, 0$	$\text{prob}(\pi/K/p) = 0, 0, 1$
	$p < 6$ (60)			

↑ DIRC ↑ dRICH probability assigned according to multiplicity of different charged particles

- ▶ Single track smearing using parameters from fast simulation 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)
 - ◆ $Q^2 > 10 \text{ GeV}^2$ (event generated with $Q^2 > 10 \text{ GeV}^2$)
 - ◆ $0.05 < y < 0.8$
- ▶ D^0 selection
 - ◆ $p_T > 0.2 \text{ GeV}$
 - ◆ Pair identified $K\pi$ tracks
 - ◆ $DCA_{\text{pair}} < 130 \mu\text{m}$
 - ◆ Decay length $> 40 \mu\text{m}$
 - ◆ $\cos\theta_{r\varphi} > 0.8$



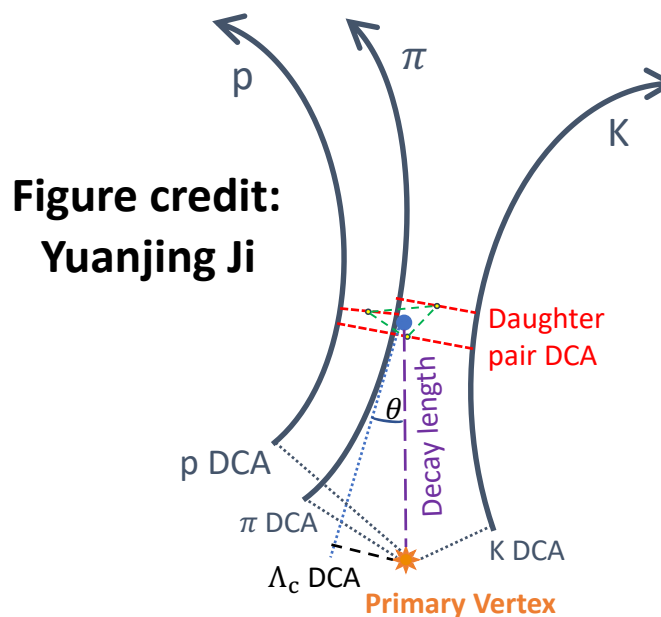
All topological cuts in transverse plane, more details in arXiv: 2102.08337

- ▶ Single track smearing using parameters from fast simulation 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 $DCA_{r\phi}$ and DCA_z

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- ▶ DIS event selection (2E8 events generated from pythia 6 e+p w/ 10x100GeV)
 - ◆ $Q^2 > 10 \text{ GeV}^2$ (event generated with $Q^2 > 10 \text{ GeV}^2$)
 - ◆ $0.05 < y < 0.8$

- ▶ Λ_c selection
 - ◆ $p_T > 0.2 \text{ GeV}$
 - ◆ Pair identified $K\pi$ tracks
 - ◆ $DCA_{\text{pair}} < 300 \mu\text{m}$
 - ◆ Decay length $> 10 \mu\text{m}$
 - ◆ $\Lambda_c \text{ DCA} < 150 \mu\text{m}$



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

- ▶ For barrel: need to consider the momentum threshold reaching TOF detector
 - ◆ If using high enough p_T cut (e.g. 0.2 GeV), 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

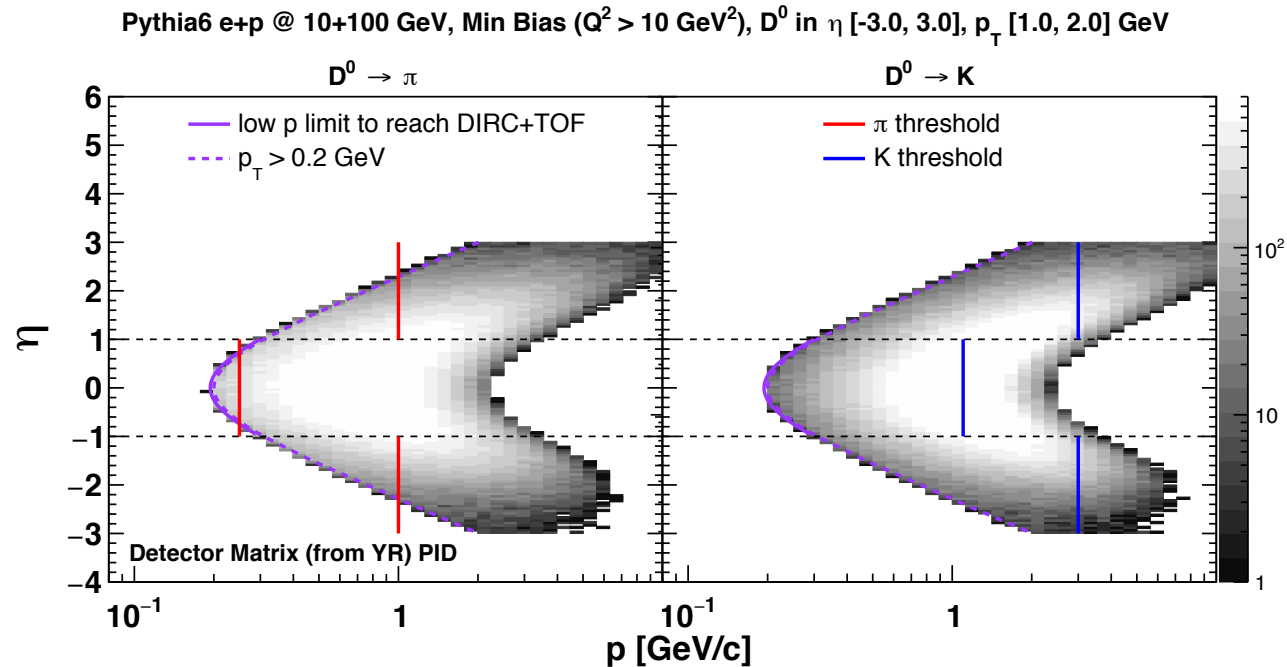
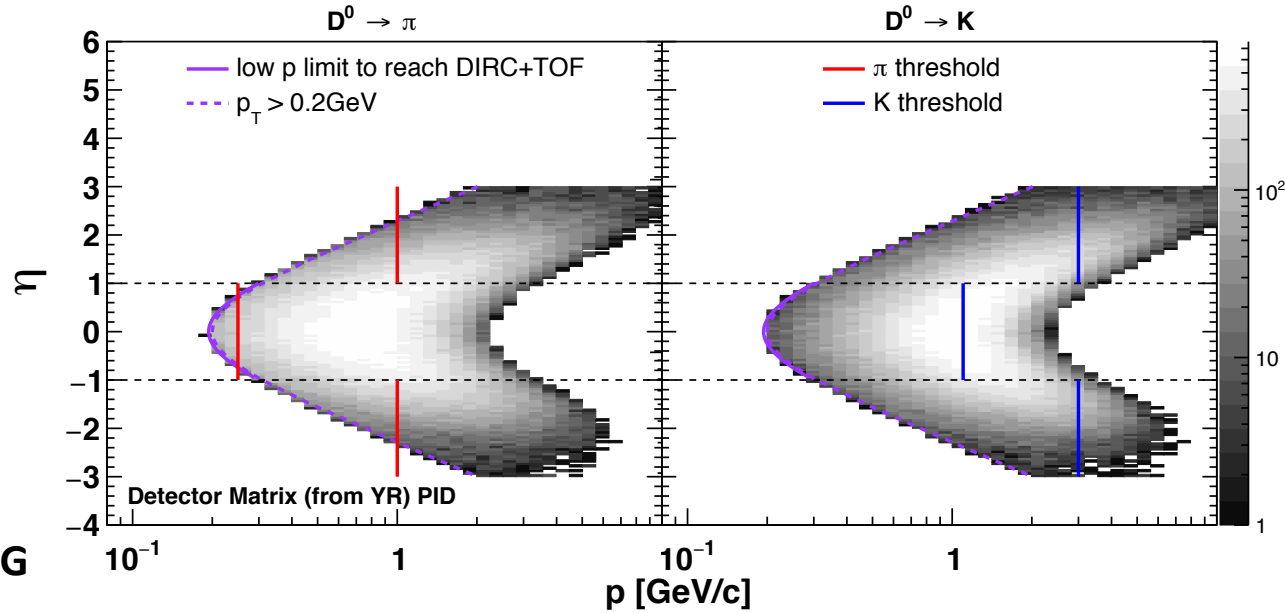


Table from the Yellow Report (YR)

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

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

Pythia6 e+p @ 10+100 GeV, Min Bias ($Q^2 > 10 \text{ GeV}^2$), D^0 in η [-3.0, 3.0], p_T [1.0, 2.0] GeV

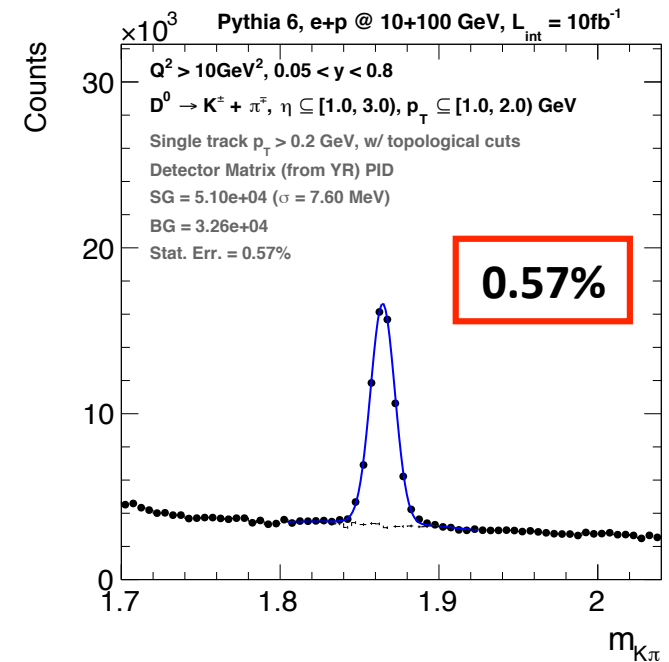
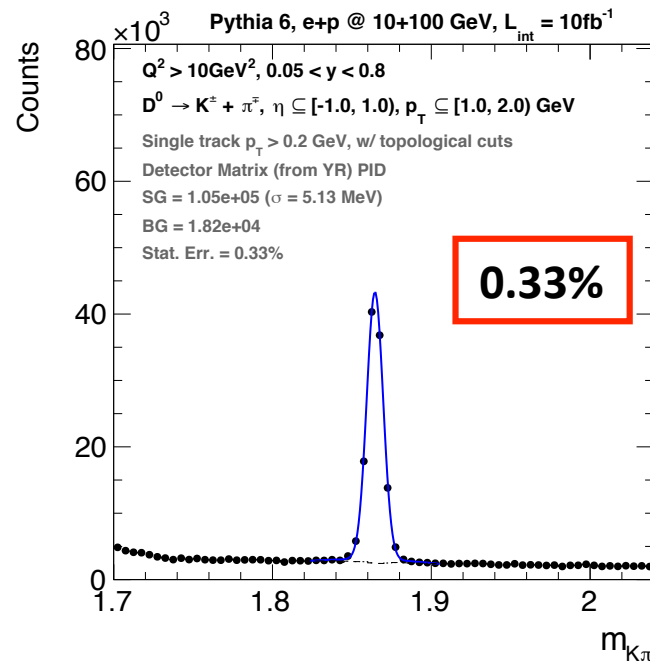
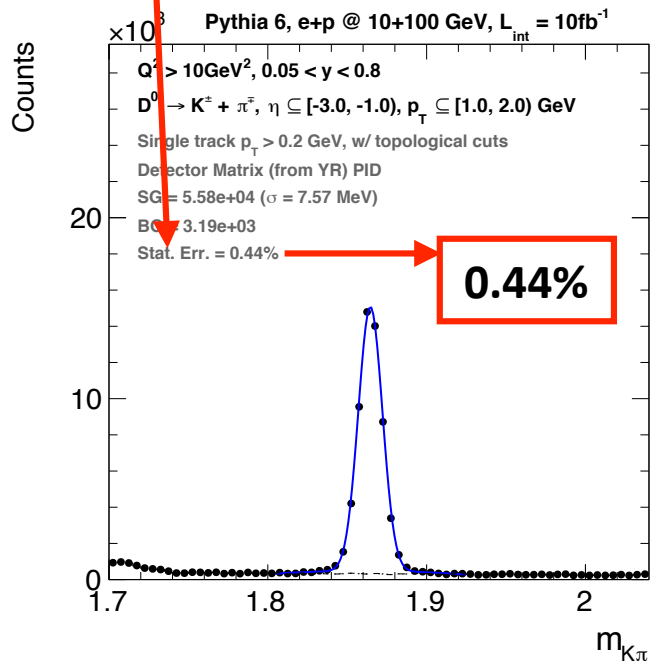


Stat. Err. = sqrt(SG+BG)/SG

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

▶ decrease with increasing SG

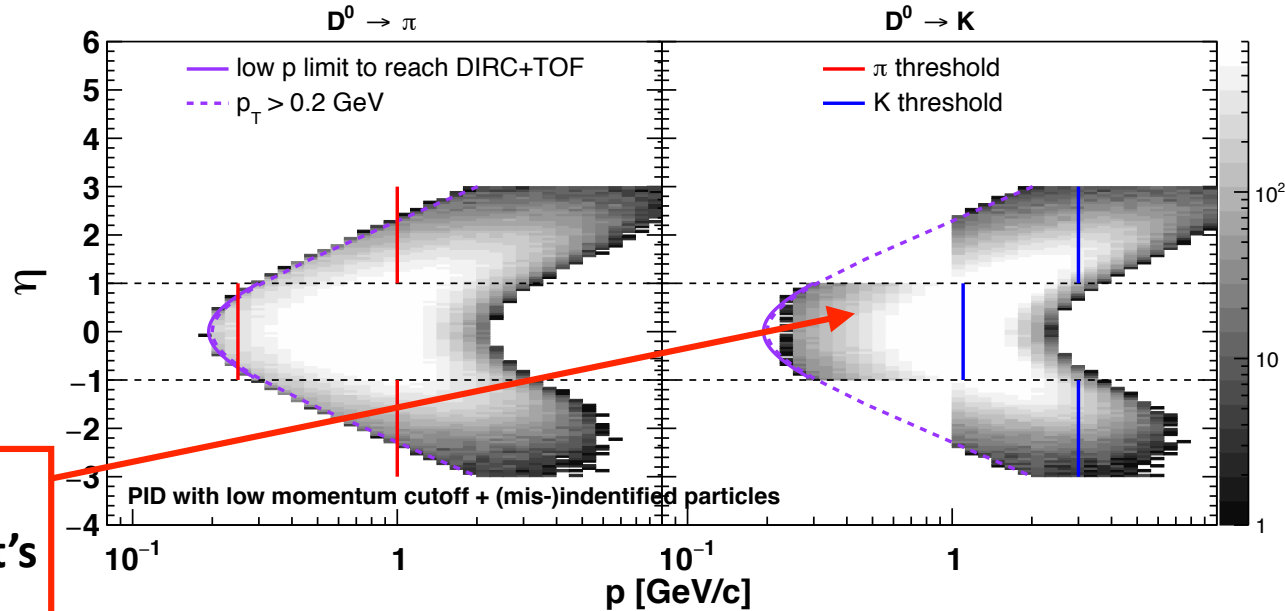
▶ decrease with decreasing BG



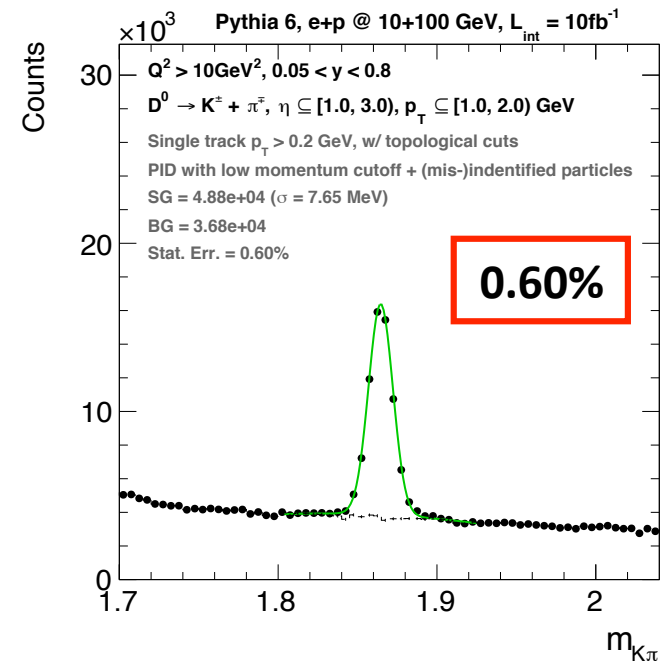
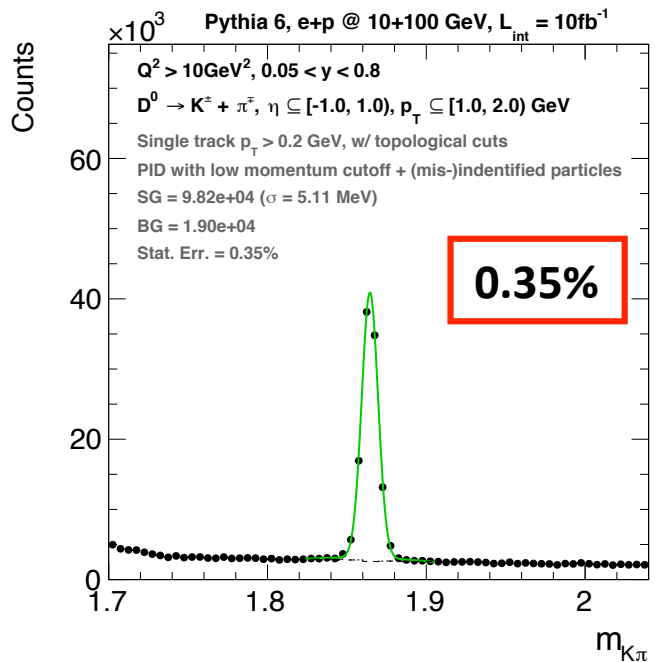
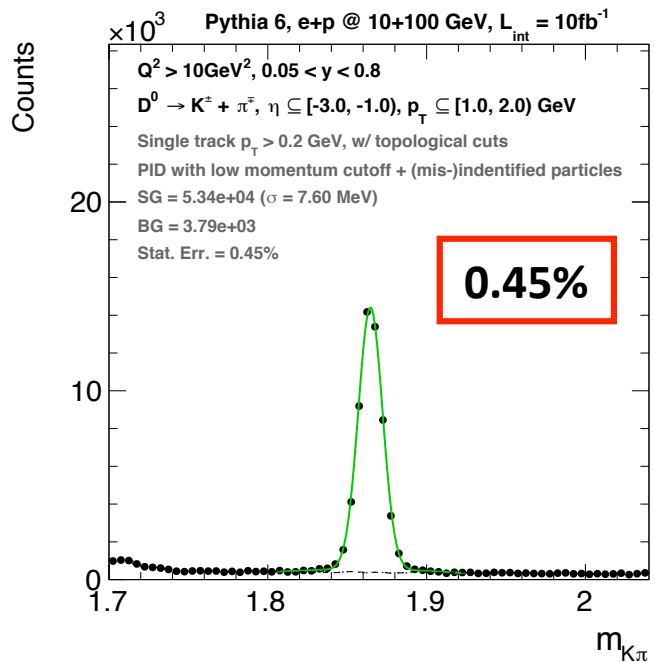
- ▶ PID with only Cherenkov detectors: w/ low momentum cutoff and some mis-identified particles

◆ $\text{prob}(\pi) > 0.7, \text{prob}(K) > 0.5$

Pythia6 e+p @ 10+100 GeV, Min Bias ($Q^2 > 10 \text{ GeV}^2$), D^0 in η [-3.0, 3.0], p_T [1.0, 2.0] GeV



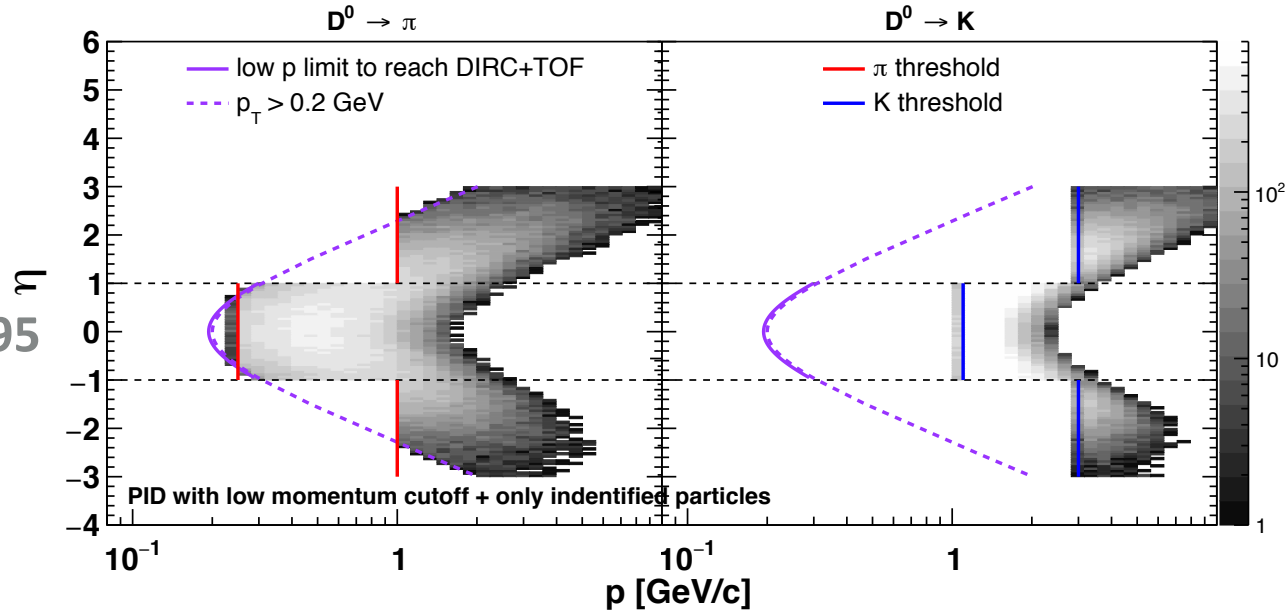
Using veto mode for particles beyond pion detecting threshold: if not pion, it's either kaons (0.62) or protons (0.38)



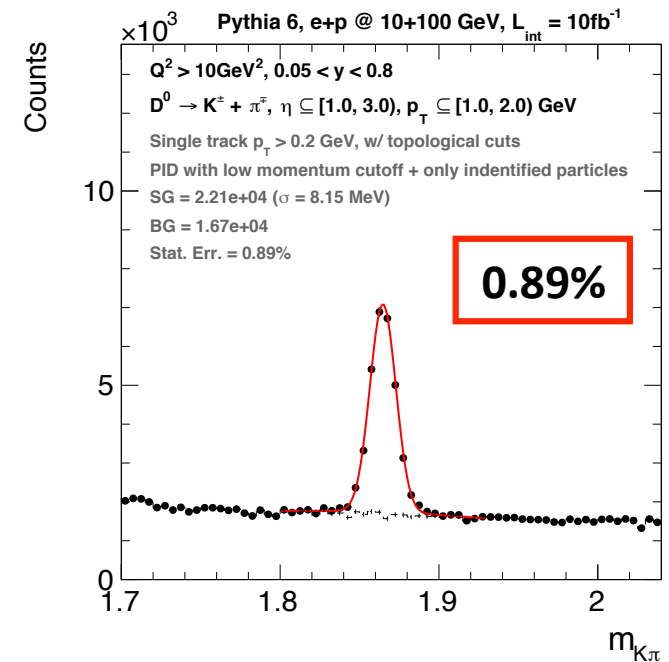
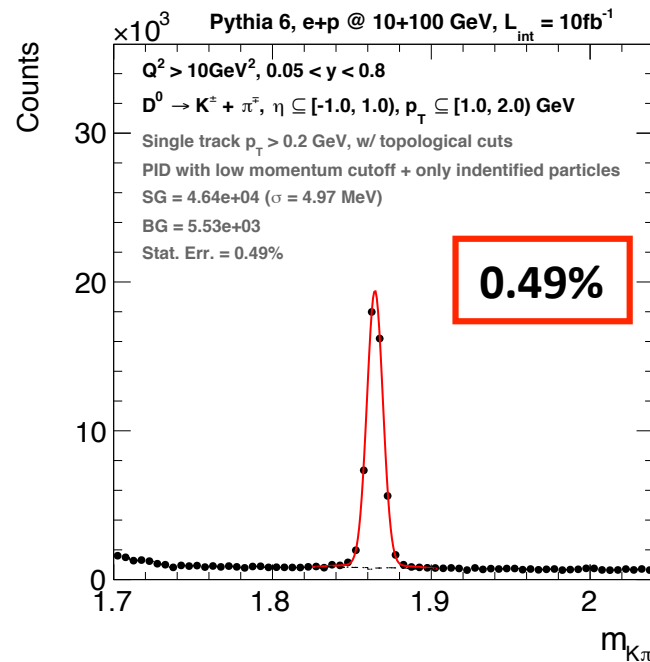
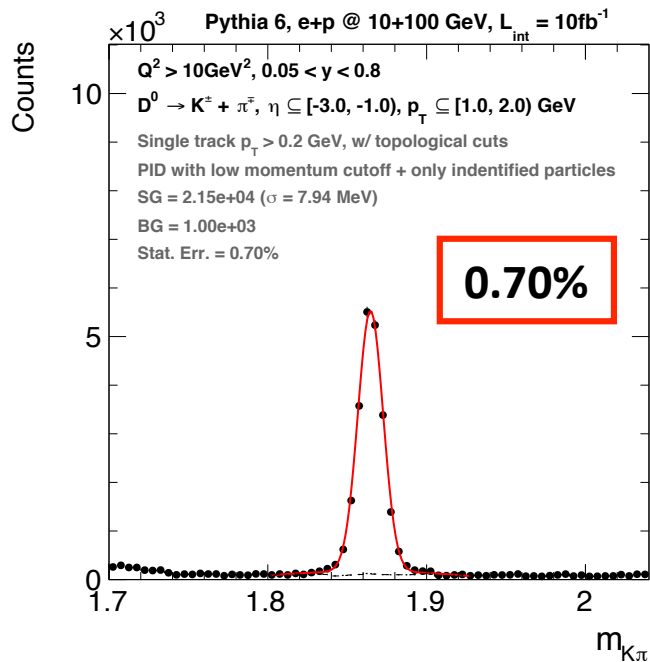
- ▶ PID with only Cherenkov detectors: w/ low momentum cutoff and only identified particles

◆ $\text{prob}(\pi) > 0.95, \text{prob}(K) > 0.95$

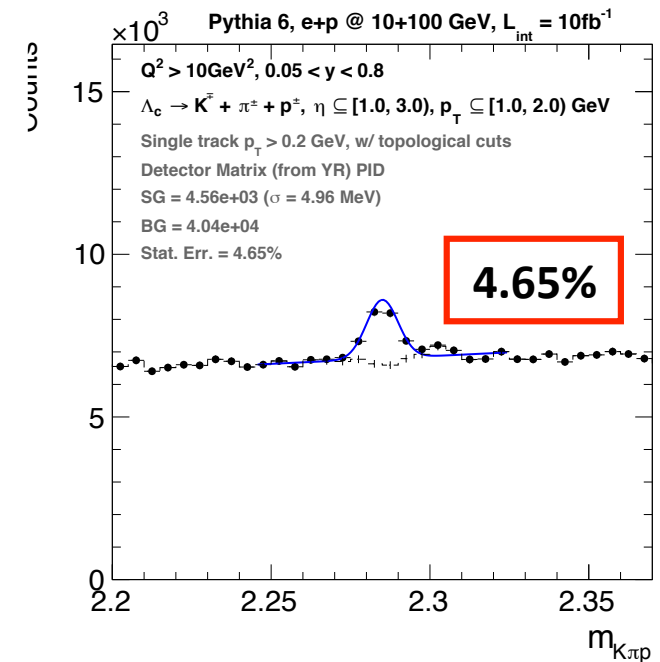
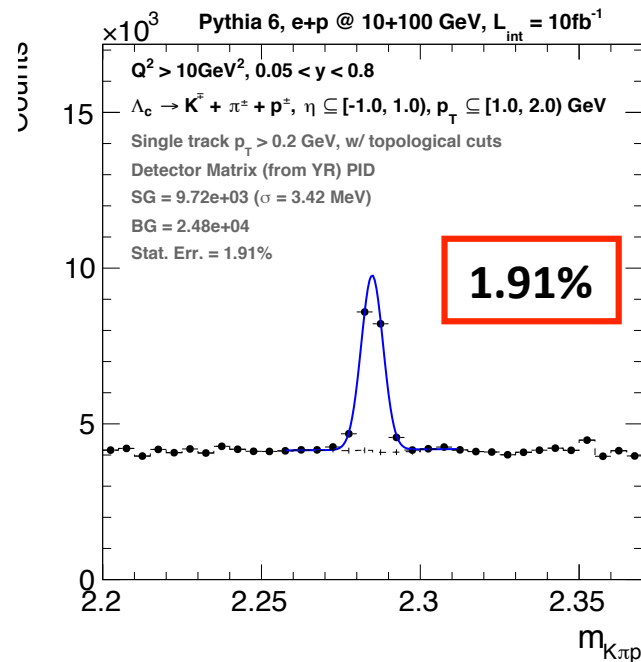
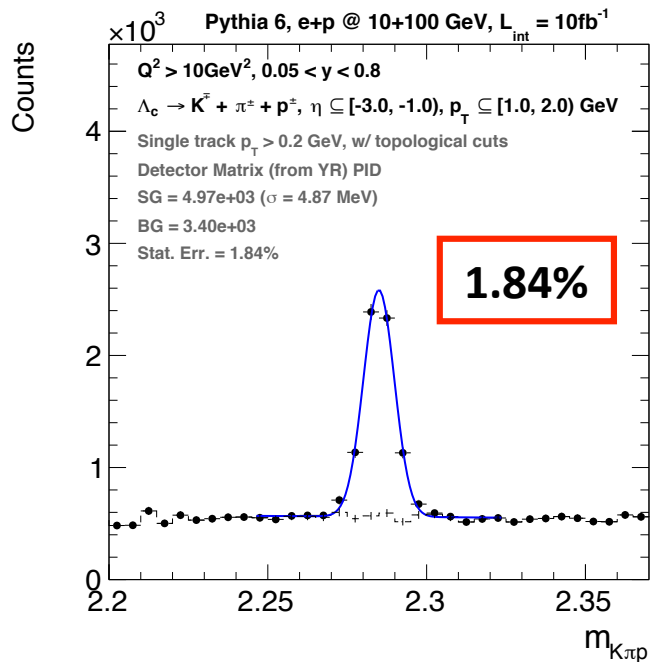
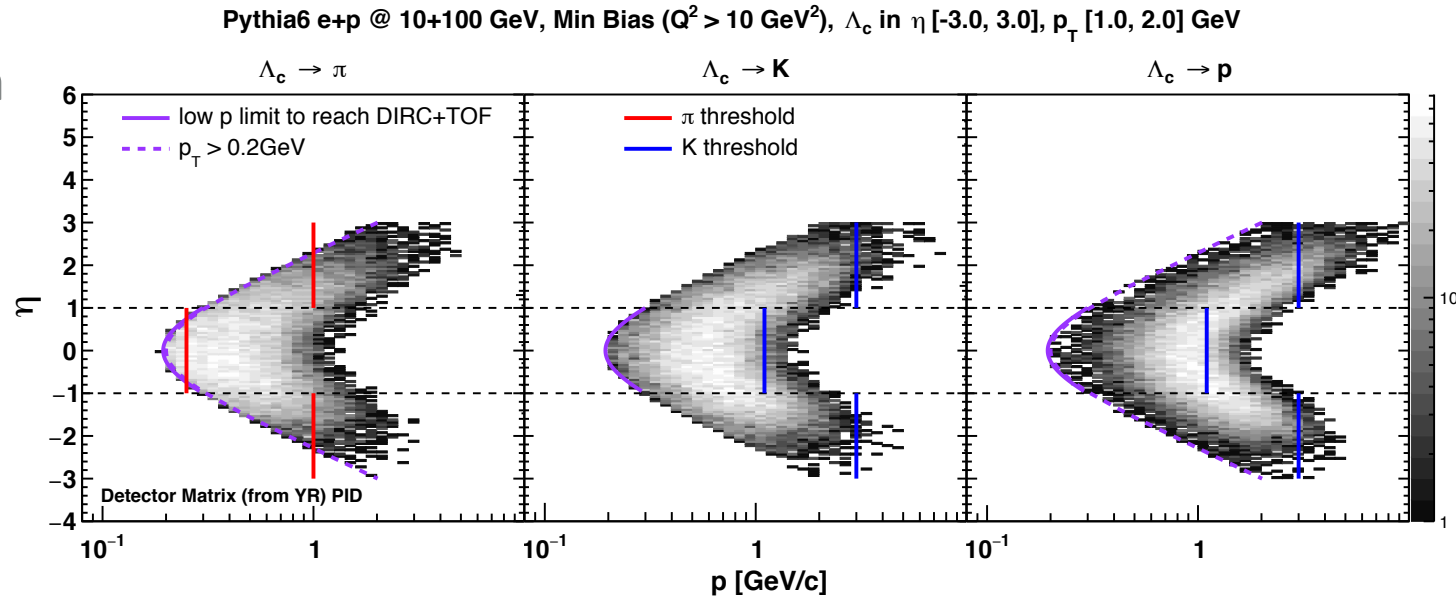
Pythia6 e+p @ 10+100 GeV, Min Bias ($Q^2 > 10 \text{ GeV}^2$), D^0 in $\eta [-3.0, 3.0]$, $p_T [1.0, 2.0] \text{ GeV}$



PID with low momentum cutoff + only identified particles

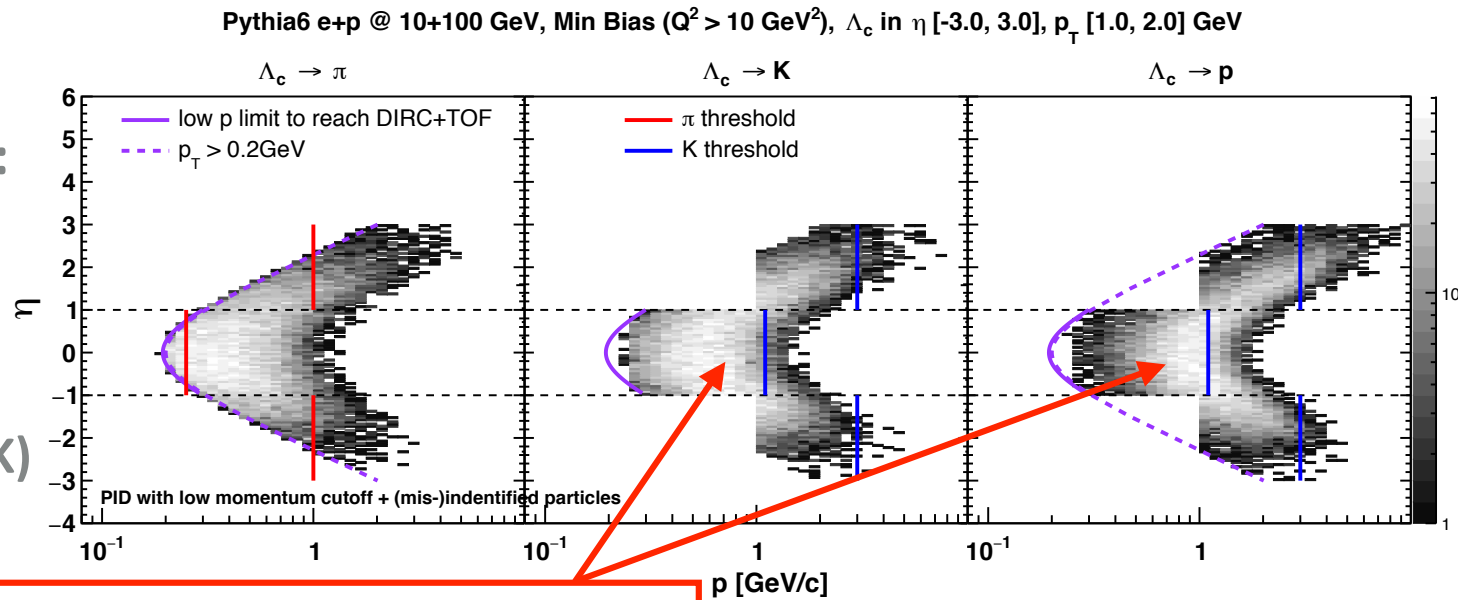


- ▶ Detector matrix from YR: no low momentum cutoff or equivalent to if TOF are implemented

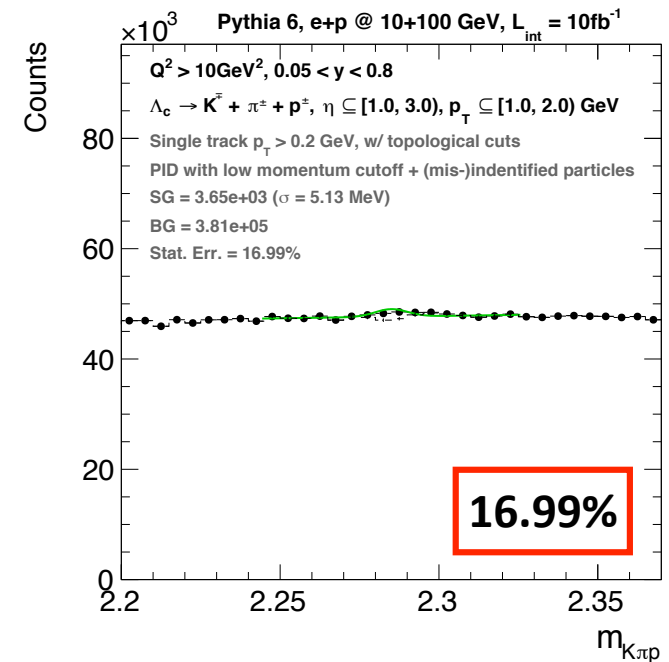
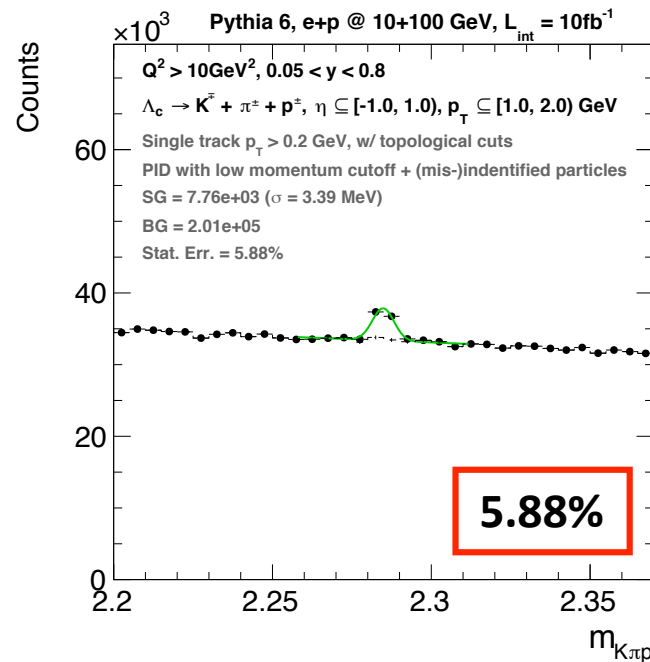
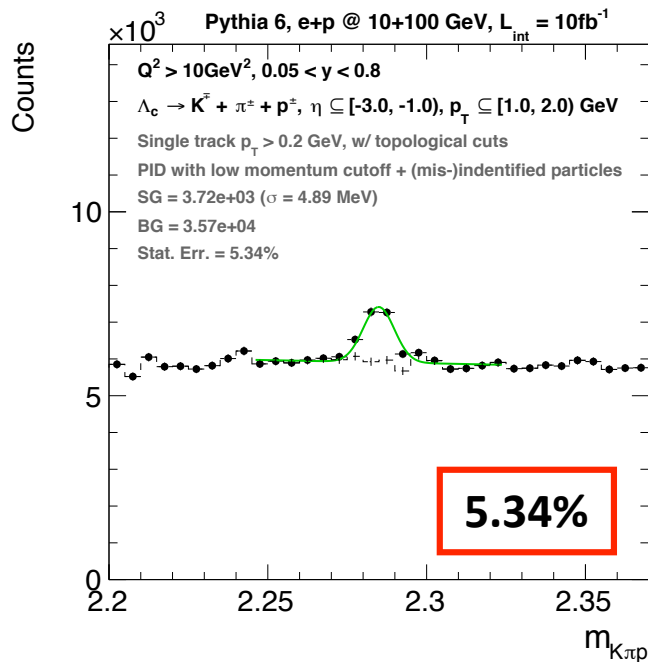


- ▶ PID with only Cherenkov detectors: w/ low momentum cutoff and some mis-identified particles

- ◆ $\text{prob}(\pi) > 0.7$, $\text{prob}(K) > 0.5$, $\text{prob}(p) > 0.1$



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

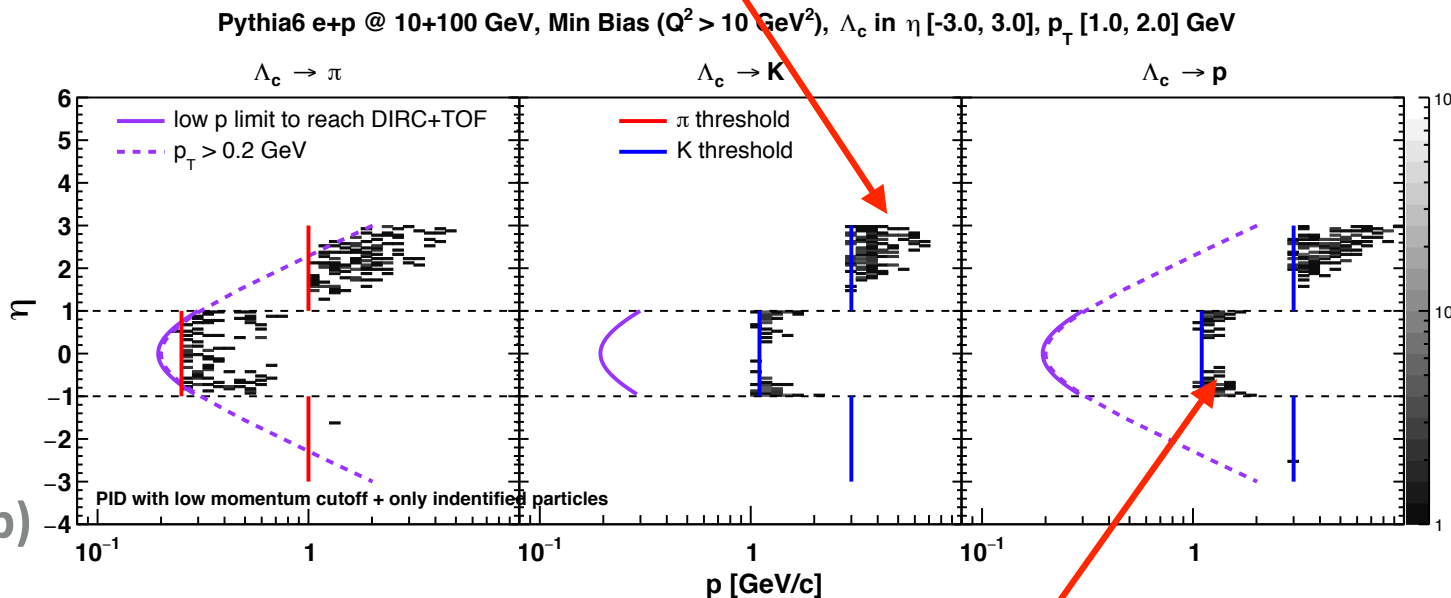


PID options — All identified

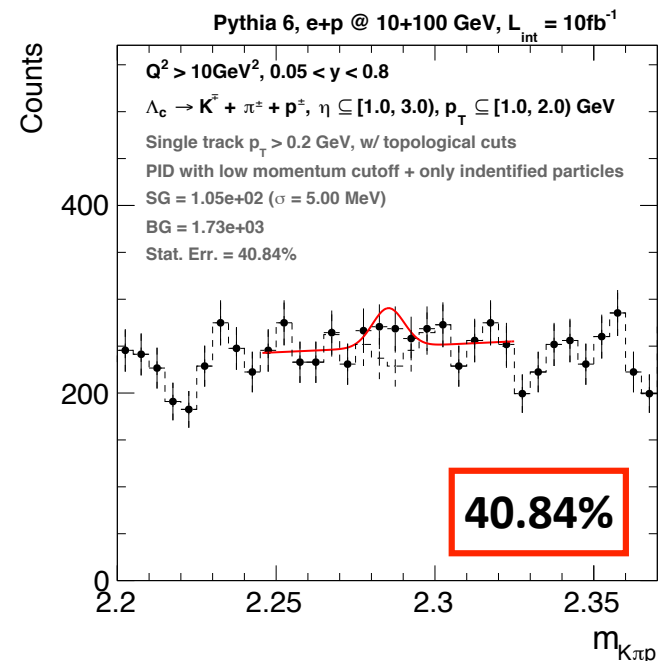
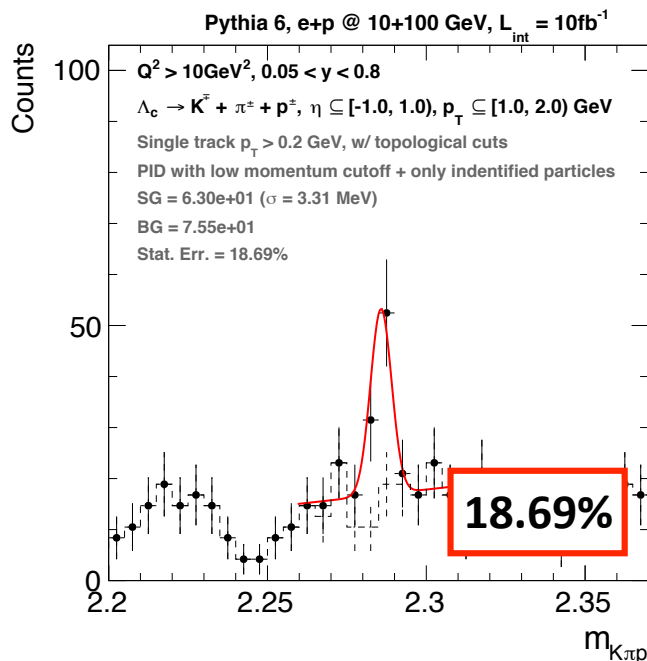
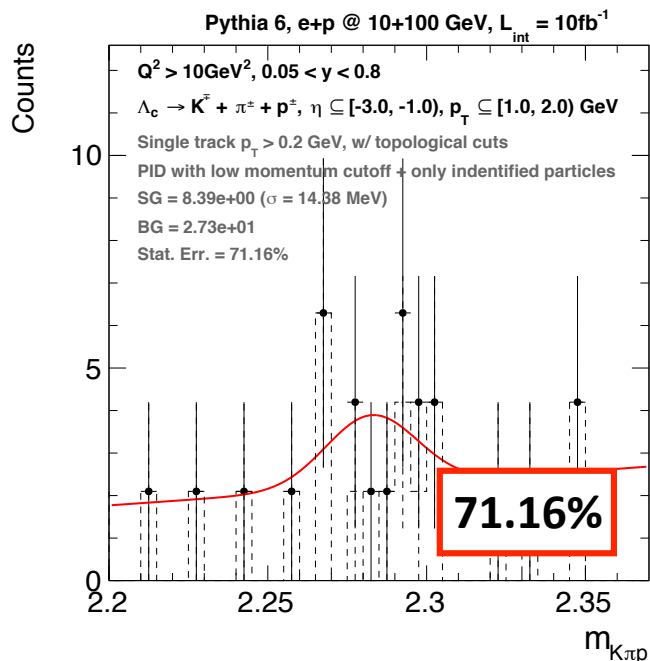
Requiring identified K throw away a lot of signals

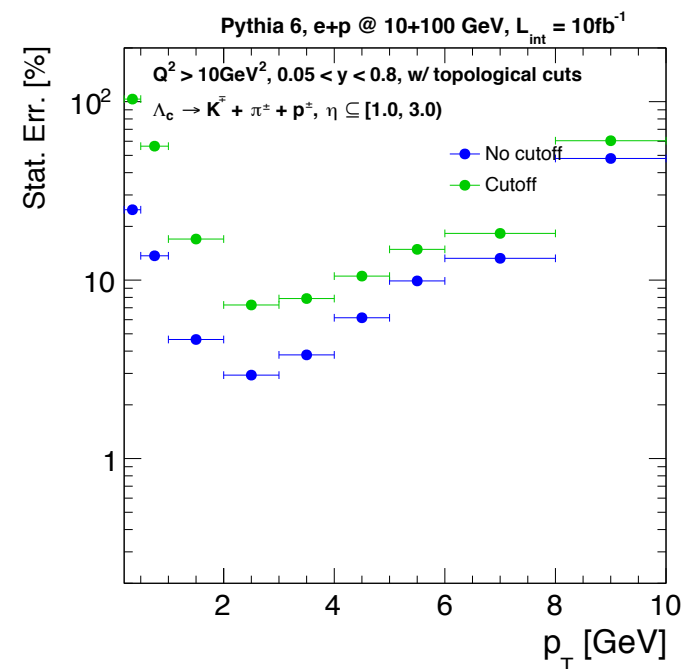
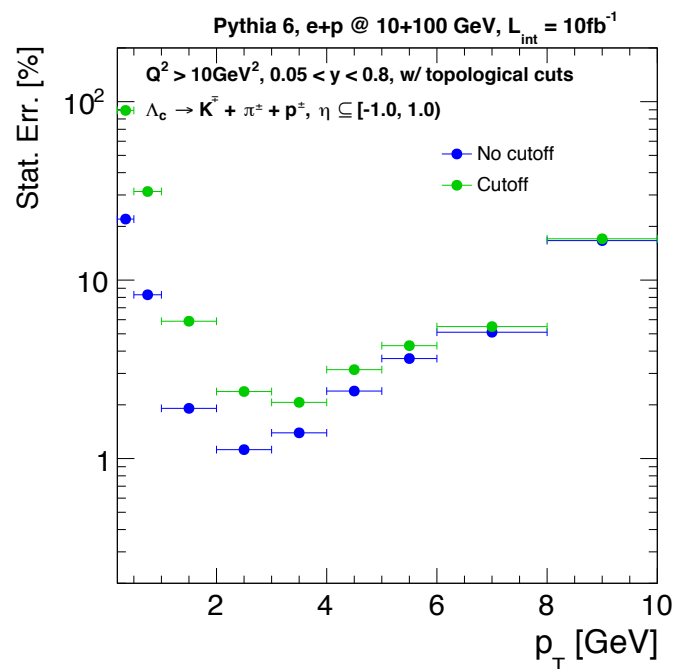
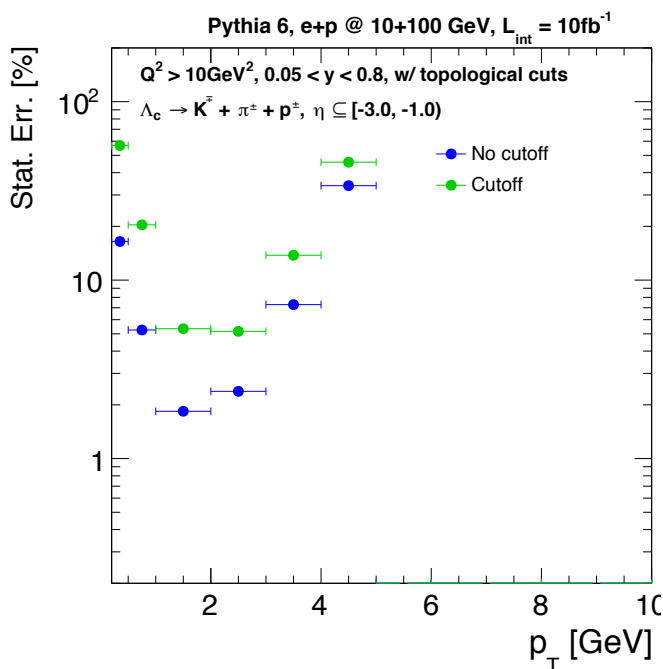
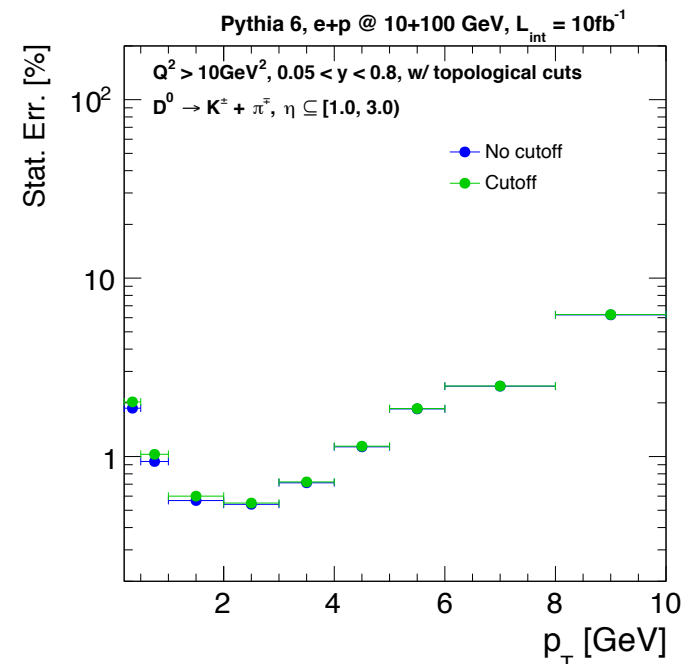
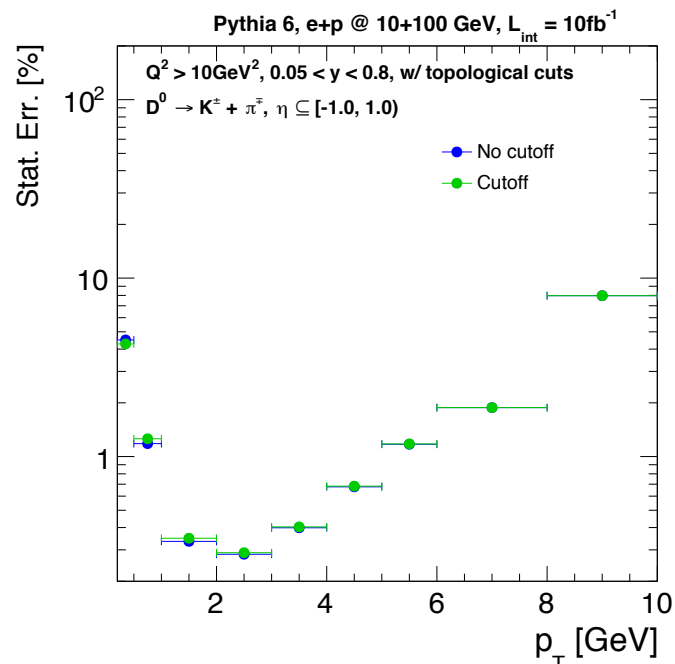
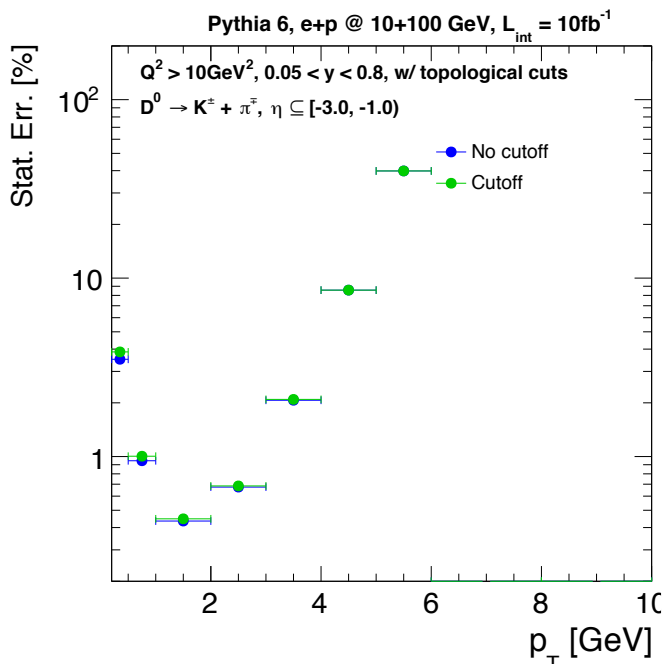
- ▶ PID with only Cherenkov detectors: w/ low momentum cutoff and only identified particles

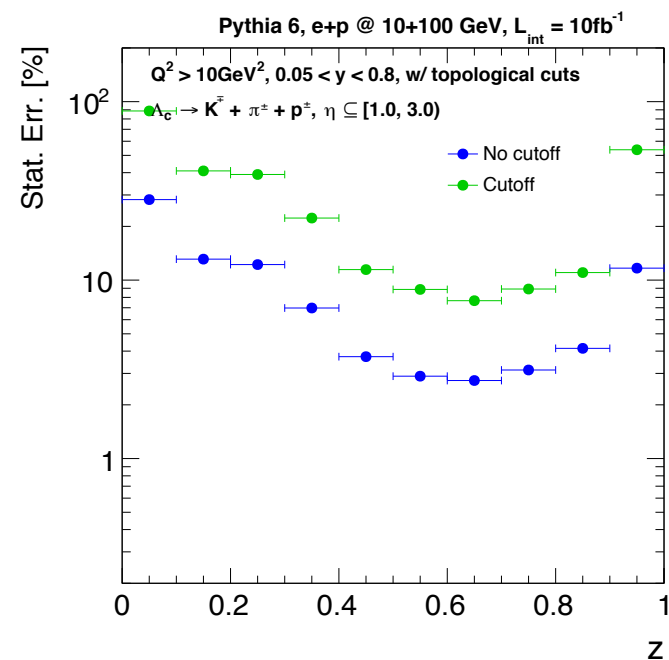
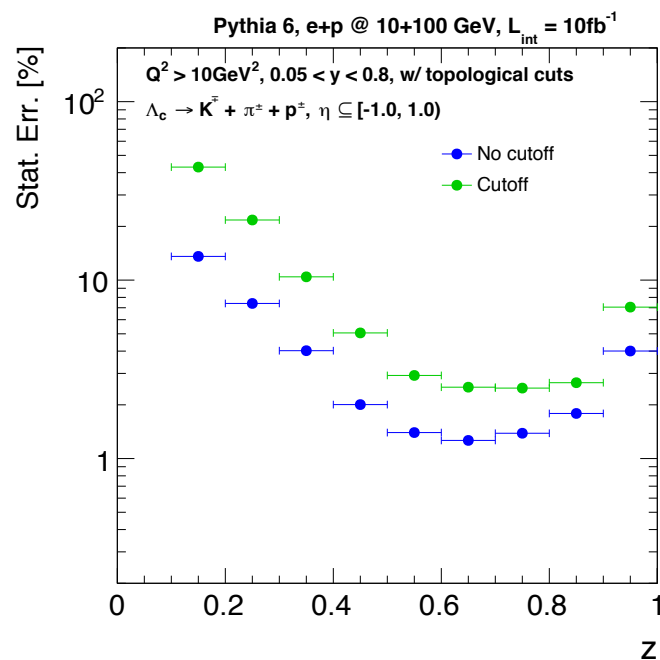
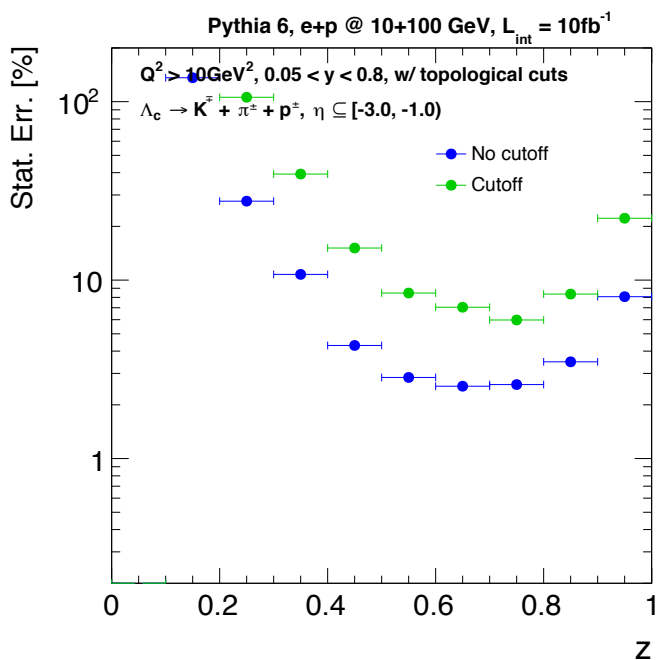
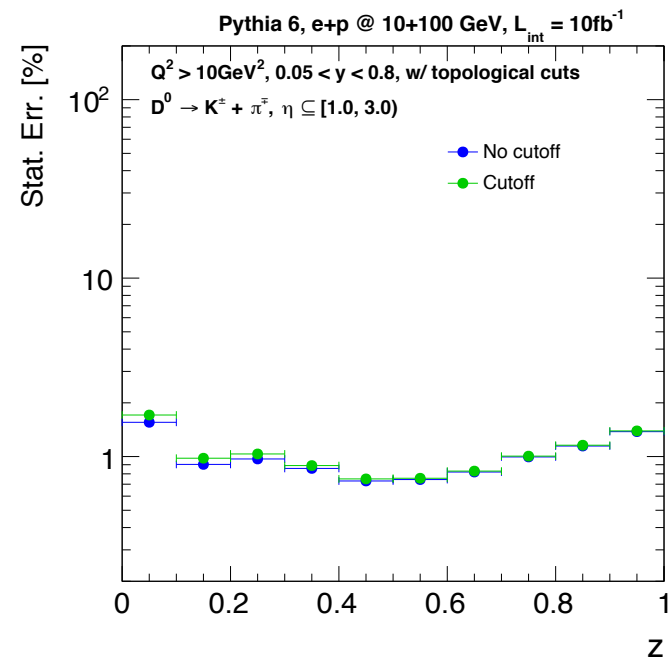
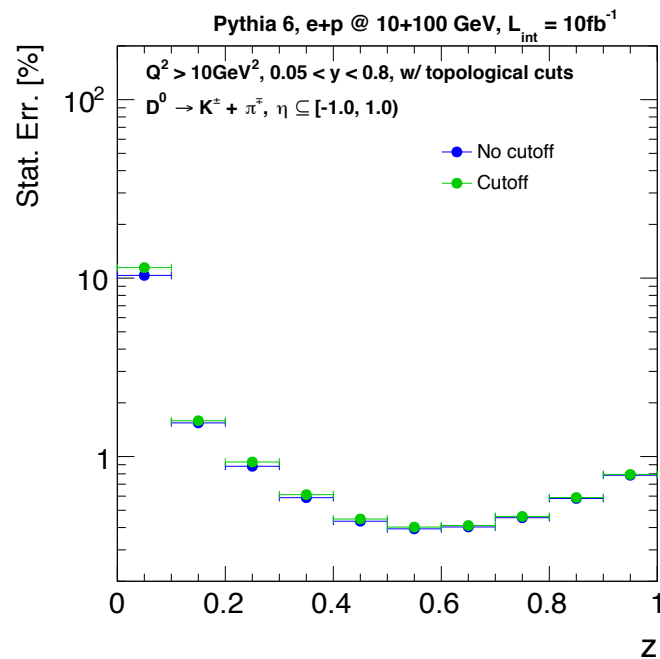
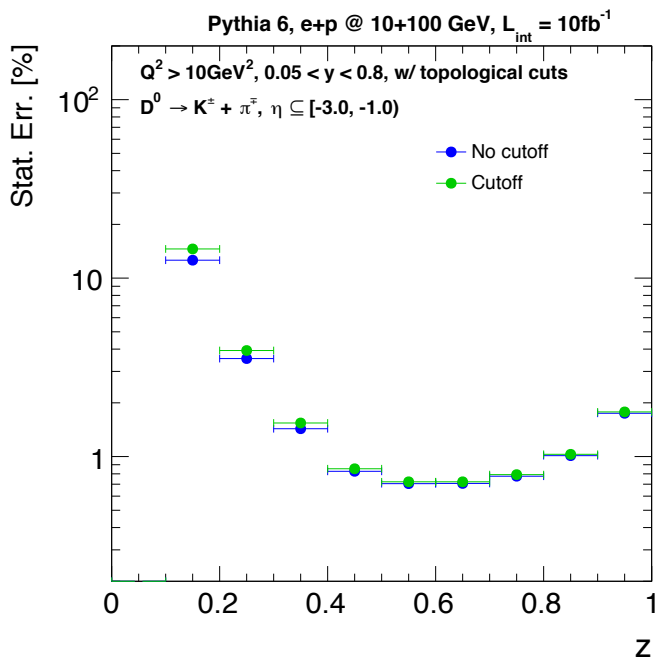
- ◆ $\text{prob}(\pi) > 0.95$, $\text{prob}(K) > 0.95$, $\text{prob}(p) > 0.95$



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







- ▶ Negligible impact on D^0 meson

- ▶ Larger impact on Λ_c baryon

- ▶ 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

[arXiv: 2107.05632](https://arxiv.org/abs/2107.05632)

[arXiv: 2110.04489](https://arxiv.org/abs/2110.04489)

[arXiv: 2102.08337](https://arxiv.org/abs/2102.08337)

Figure from ATHENA proposal (credit: Matt Kelsey)

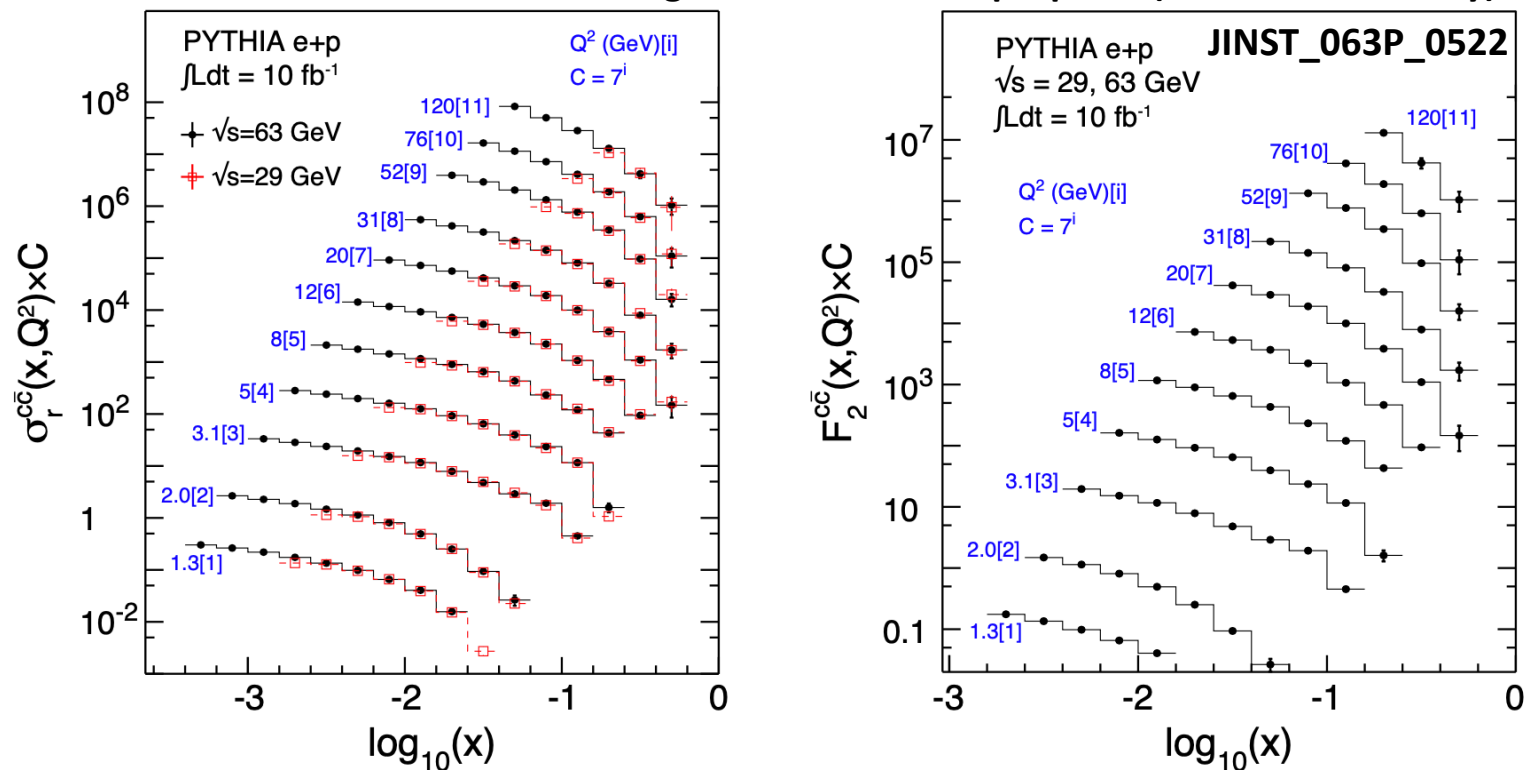
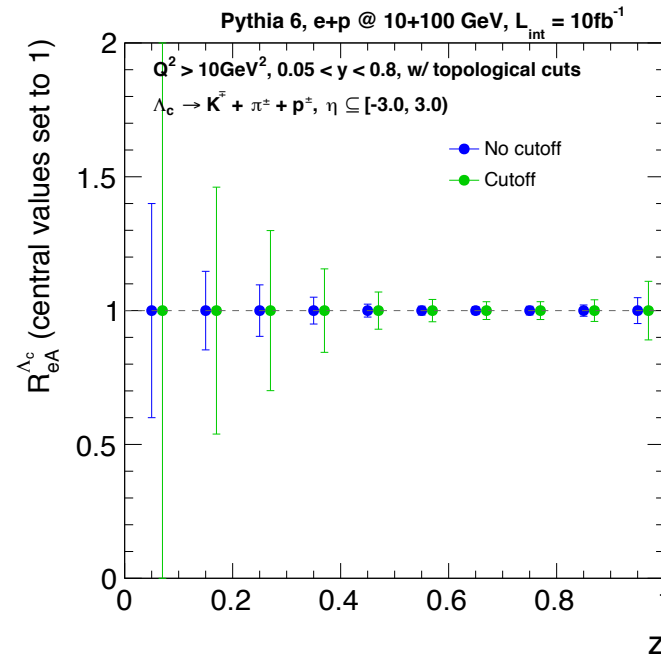
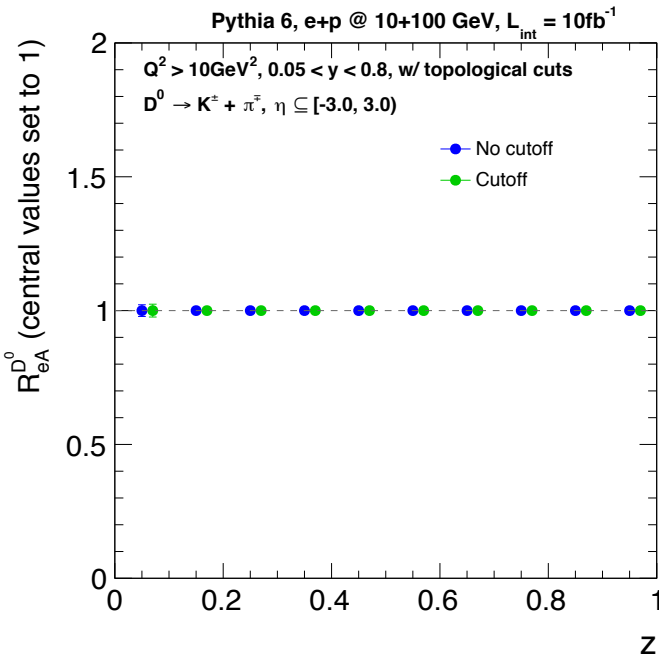
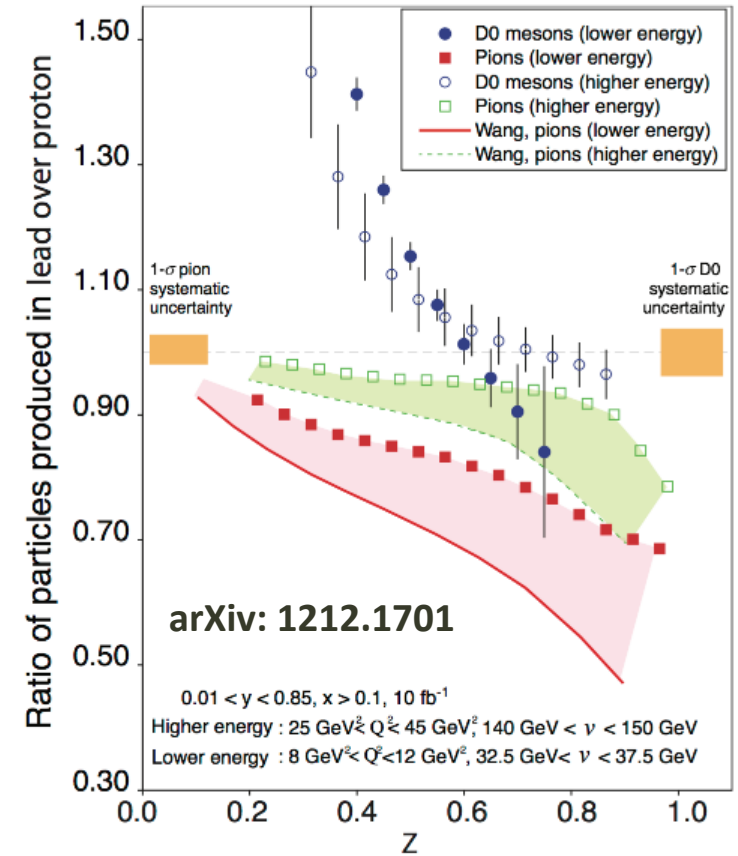


Figure 3.22: The reduced charm cross section $\sigma_r^{c\bar{c}}$ (left) and corresponding structure function $F_2^{c\bar{c}}$ (right) in intervals in Bjorken- x for different values of Q^2 from PYTHIA simulations and ATHENA response for $e + p \rightarrow e' + D^0 + X$ at the indicated center-of-mass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



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 - ◆ 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)

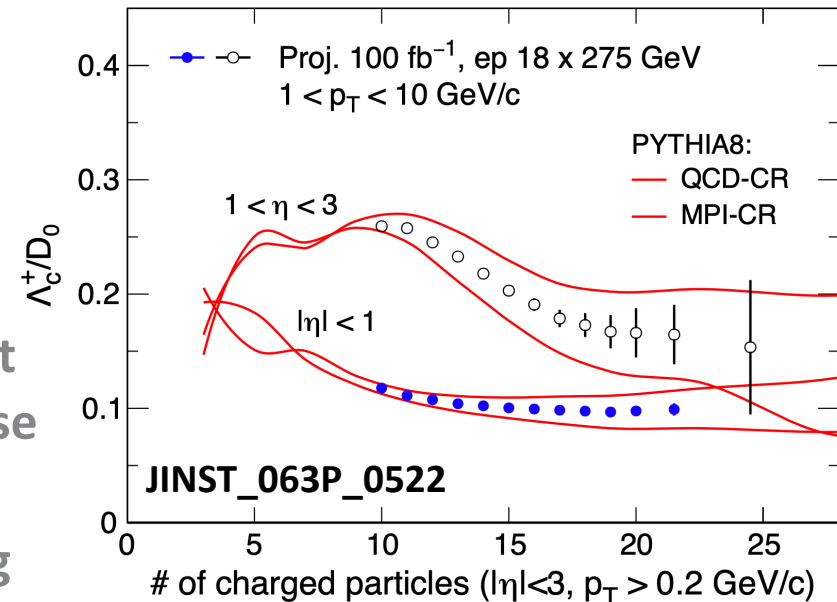


Figure 3.28: Projections for ATHENA measurements of the heavy-quark Λ_c^+ to D^0 baryon-to-meson ratio as a function of the charged track multiplicity (FastSim).

