Total charm cross-section in Au+Au 200GeV from STAR

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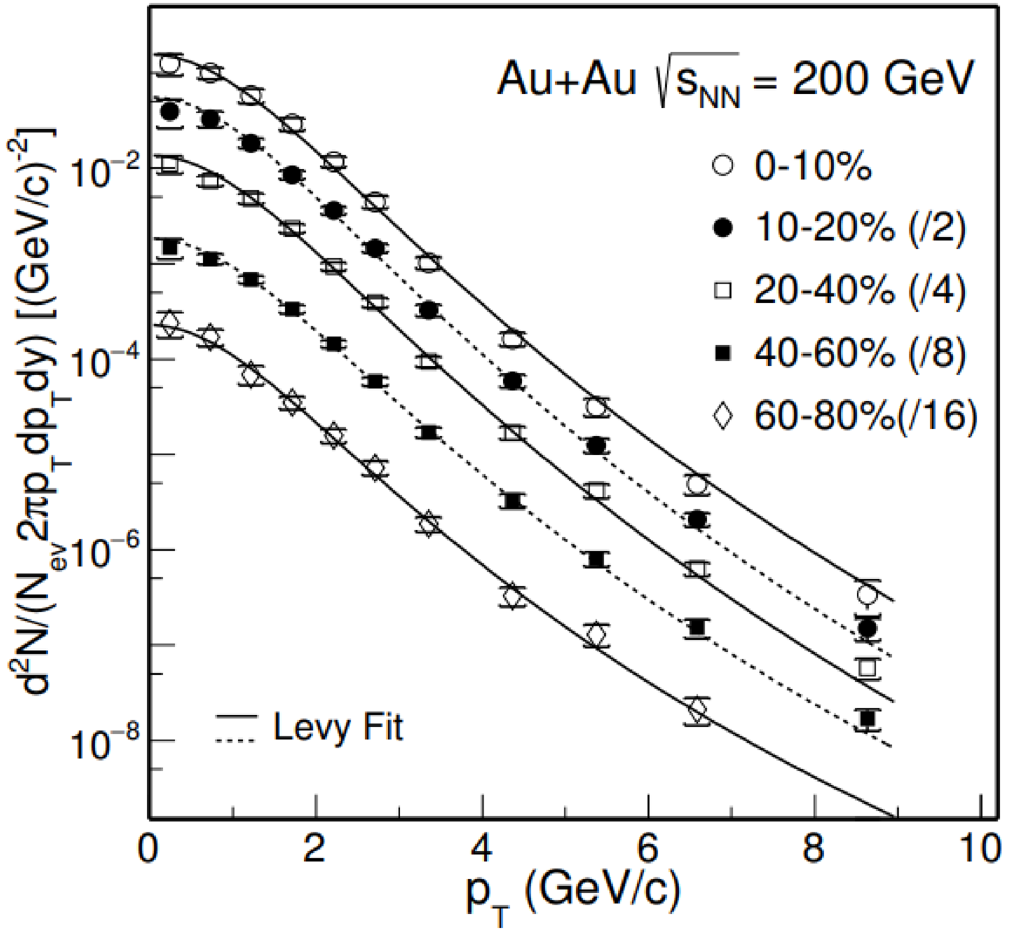
Charm hardon measurement at Au+Au 200GeV

Ground state charm hadrons production(with HFT) at Au+Au 200GeV from STAR:

- D0: run14 , published PhysRevC.99.034908 (2019)
- Lc: run14&run16, published Phys. Rev. Lett. 124, (2020) 172301
- Ds:run14&run16, published Phys. Rev. Lett. 127, (2021) 092301
- D±:run14&run16, https://www.star.bnl.gov/protected/heavy/vanekjan/Dpm_web/Home.html
- All primary Ground state charm hadrons are already published or in publish step. So we want to carry out a total charm production cross-section results in D± paper

Previous calculation by Xiaolong Chen
https://drupal.star.bnl.gov/STAR/system/files/charmCrossSection_190627.pdf

D^0 production cross-section:



Published D^0 data cover whole p_T range (0 GeV/c to 10 GeV/c)

$$\frac{d\sigma}{dy}|_{y=0} = \int \frac{d^2N}{dydp_T}|_{y=0}\, dp_T \ * \frac{\sigma_{pp}}{N_{collision}}$$

$\int \frac{d^2N}{dydp_T}|_{y=0}\, dp_T$ is calculated by sum all measured dN/dy in each p_T bin: $\int \frac{d^2N}{dydp_T}|_{y=0} dp_T = \sum_{p_T bin} \frac{dN_{measured}}{dy}|_{y=0}$

$\sigma_{pp} = 42\text{mb}$

$N_{collision}$ taking from run14&16 centrality calculation

(the σ_{pp} and $N_{collision}$ value will give an 8% uncertainty on all charm hardon cross-section calculation)

https://www.star.bnl.gov/protected/heavy/xgn1992/Centrality/Run2014/

D^0 production cross-section:

- For the uncertainty calculation, assuming the stat. err. in each pT bin are uncorrelated and sys. err. are fully correlated. The results shows in the table below:

Centrality:	$\frac{d\sigma}{dy}\Big\vert_{y=0}$ (μb)	Stat. Err.	Sys. Err.
0-10%	38.1894	1.1948	2.1799
10-40%	39.0188	0.5715	1.1132
40-80%	36.6356	0.6765	1.4079
0-80%	39.4365	0.4584	5.3178

$0.0 < p_T < 8.0$ GeV/c

- Considering both statics and consistence with other charm hadron measurement, we choose 10-40% centrality results **39.0 ± 0.6 (stat.) ± 1.1 (sys.)** to calculate the total charm cross-section

D^0 production cross-section: Fit to different model

- Using different model functions to describe D^0 p_T spectra in low pT range
- Function choosing:

Levy : $$\frac{d^2N}{2\pi p_T dp_T dy} = \frac{1}{2\pi}\frac{dN}{dy}\frac{(n-1)(n-2)}{nT(nT+m_0(n-2))}\left(1+\frac{\sqrt{p_T^2+m_0^2}-m_0}{nT}\right)^{-n}$$

Power-law: $$\frac{d^2N}{2\pi p_T dp_T dy} = \frac{dN}{dy}\frac{4(n-1)(n-2)}{2\pi(n-3)^2\langle p_T\rangle^2}\left(1+\frac{2p_T}{\langle p_T\rangle(n-3)}\right)^{-n}$$

Blast-wave: $$\frac{dN}{p_T dp_T} = \frac{dN}{m_T dm_T} \propto \int_0^R r dr m_T I_0\left(\frac{p_T \sinh\rho}{T_{\rm kin}}\right)K_1\left(\frac{m_T \cosh\rho}{T_{\rm kin}}\right)$$

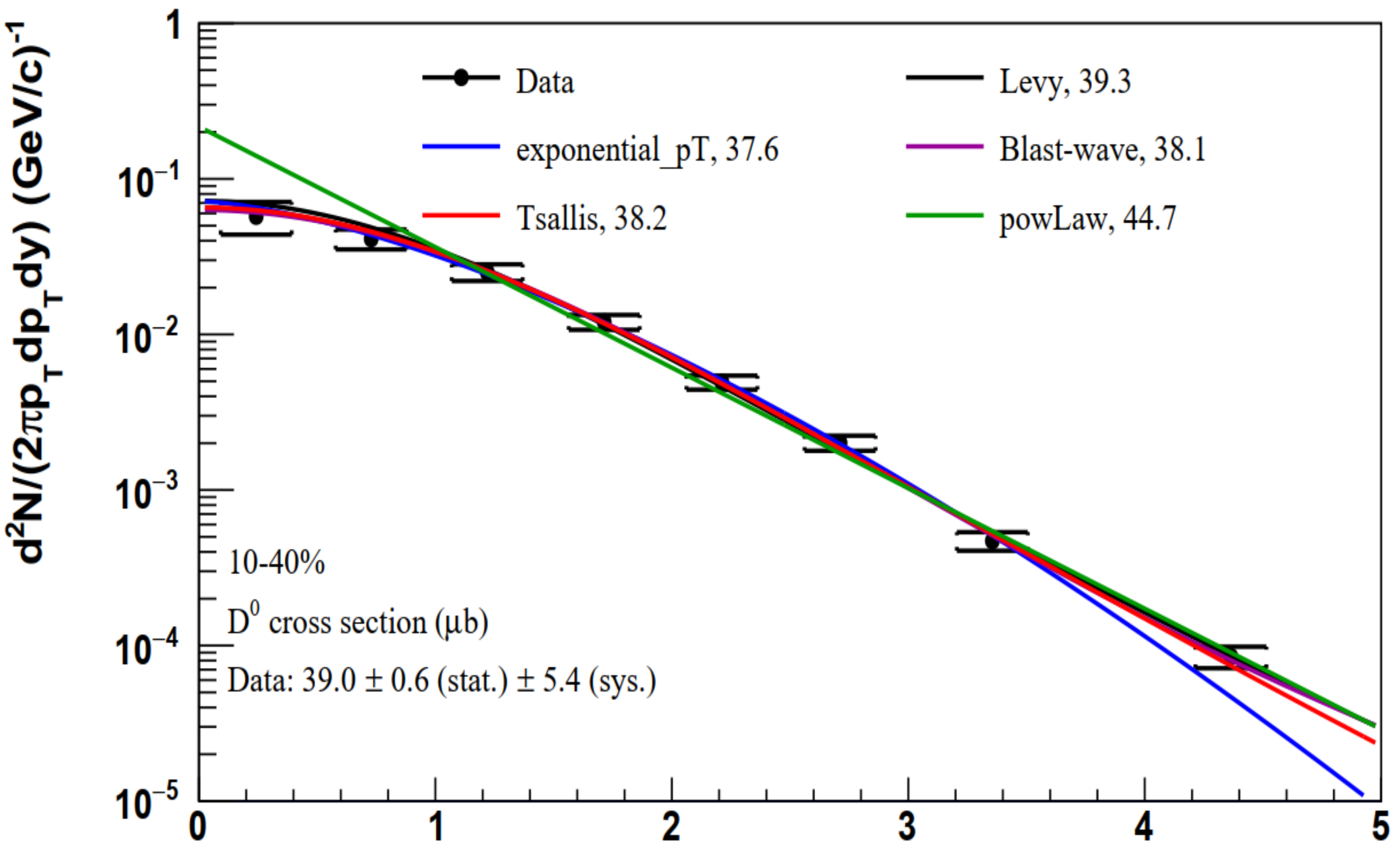
Tsallis: $$E\frac{d^3N}{dp^3} = gV\frac{m_T}{(2\pi)^3}\left[1+(q-1)\frac{m_T}{T_1}\right]^{-q/(q-1)}$$

Boltzmann: $$\frac{d^2N}{dp_T\, dy} \propto m_T \exp(-m_T/T)$$

exponential (pT,pT-Gaus,pT-trip): $$\frac{dN}{p_T\, dp_T} = c_{p_T^{1.5}} \exp\left(-\frac{p_T^{1.5}}{T_{p_T}^{1.5}}\right), \quad \frac{dN}{p_T\, dp_T} = c_{p_T^2} \exp\left(-\frac{p_T^2}{T_{p_T^2}^2}\right), \quad \frac{dN}{p_T\, dp_T} = c_{p_T^3} \exp\left(-\frac{p_T^3}{T_{p_T^3}^3}\right)$$

D^0 cross-section: Fit to different model

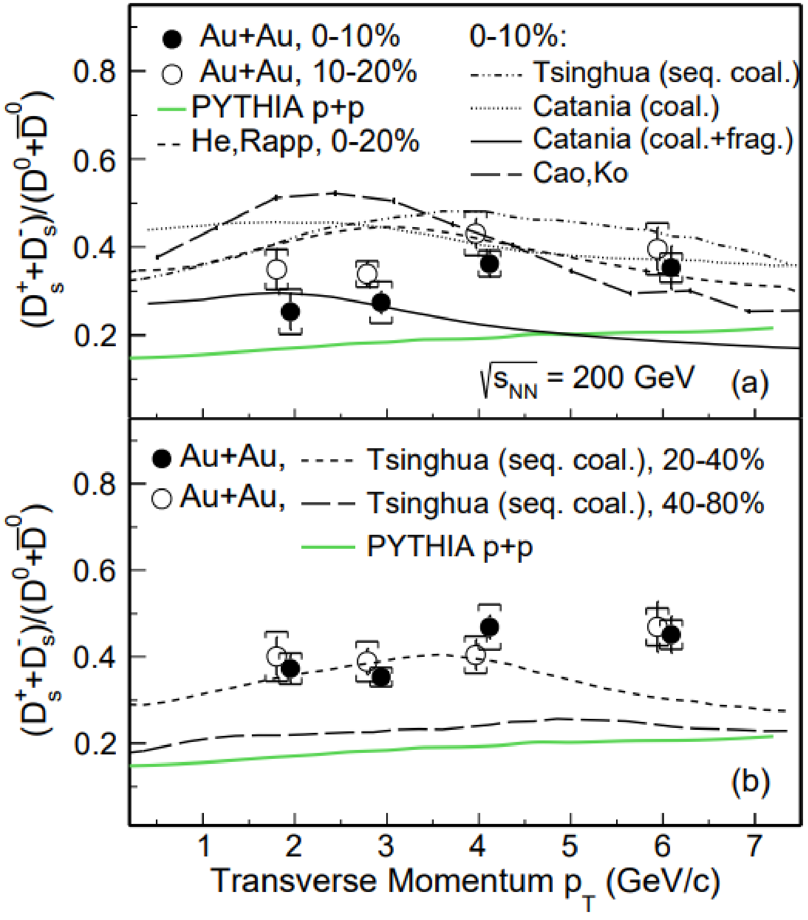
Number after function name means Integral cross-section in p_T(0.0-10.0 GeV/c)



Boltzmann, Exponential p_T-Gaus, Exponential p_T-triple are failed to describe data.

Levy , Blast-wave, Tsallis and Exponential p_T and Power-Law functions can fit to the low p_T spectra, but Power-Law function overestimate 0-1 GeV yields.

D_s cross-section: extrapolate from D_s/D^0 ratio



D_s measurement for 10-40% cover p_T 1.0 to 8.0 GeV/c,

Using the same method as L_c to do the extrapolation down to 0 p_T:

$$\frac{dN(D_s)}{dp_T dy}(p_T) = \frac{dN(D^0)}{dp_T dy}(p_T) \times C_1 \frac{D_s}{D^0}(p_T)$$

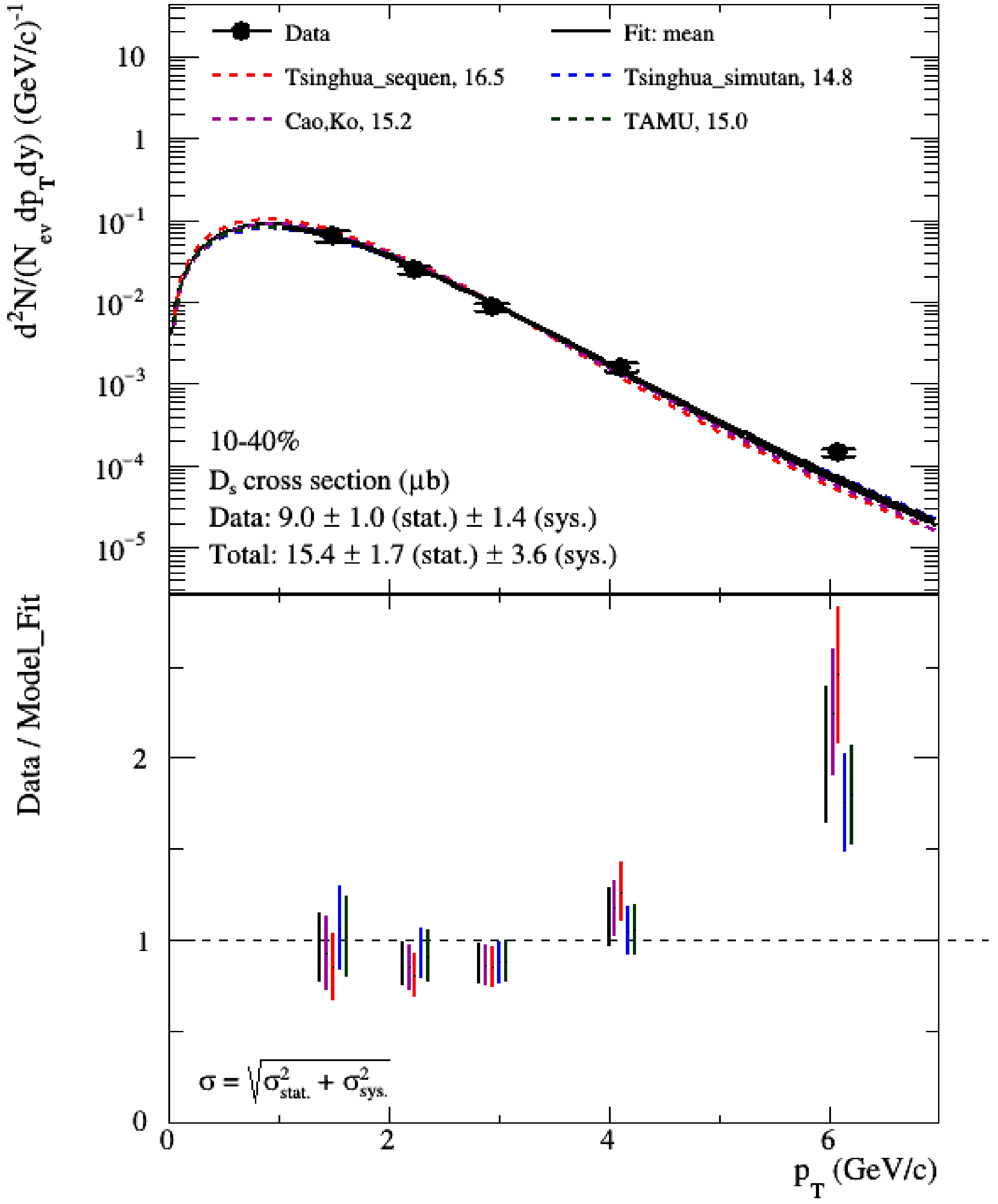
$\frac{dN(D^0)}{dp_T dy}(p_T)$ is getting from levy fitting of D^0 10-40% centrality data

(p_T 0-10 GeV/c).

$\frac{D_s}{D^0}(p_T)$ are getting from different model calculation

C_1 is a free parameter which allow the overall D_s/D^0 ratio could

change



All model curves are using 10-40% results, expect for TAMU, which only have 0-20% centrality.

All D_s/D^0 model are underestimated the 5.0-8.0 GeV data point

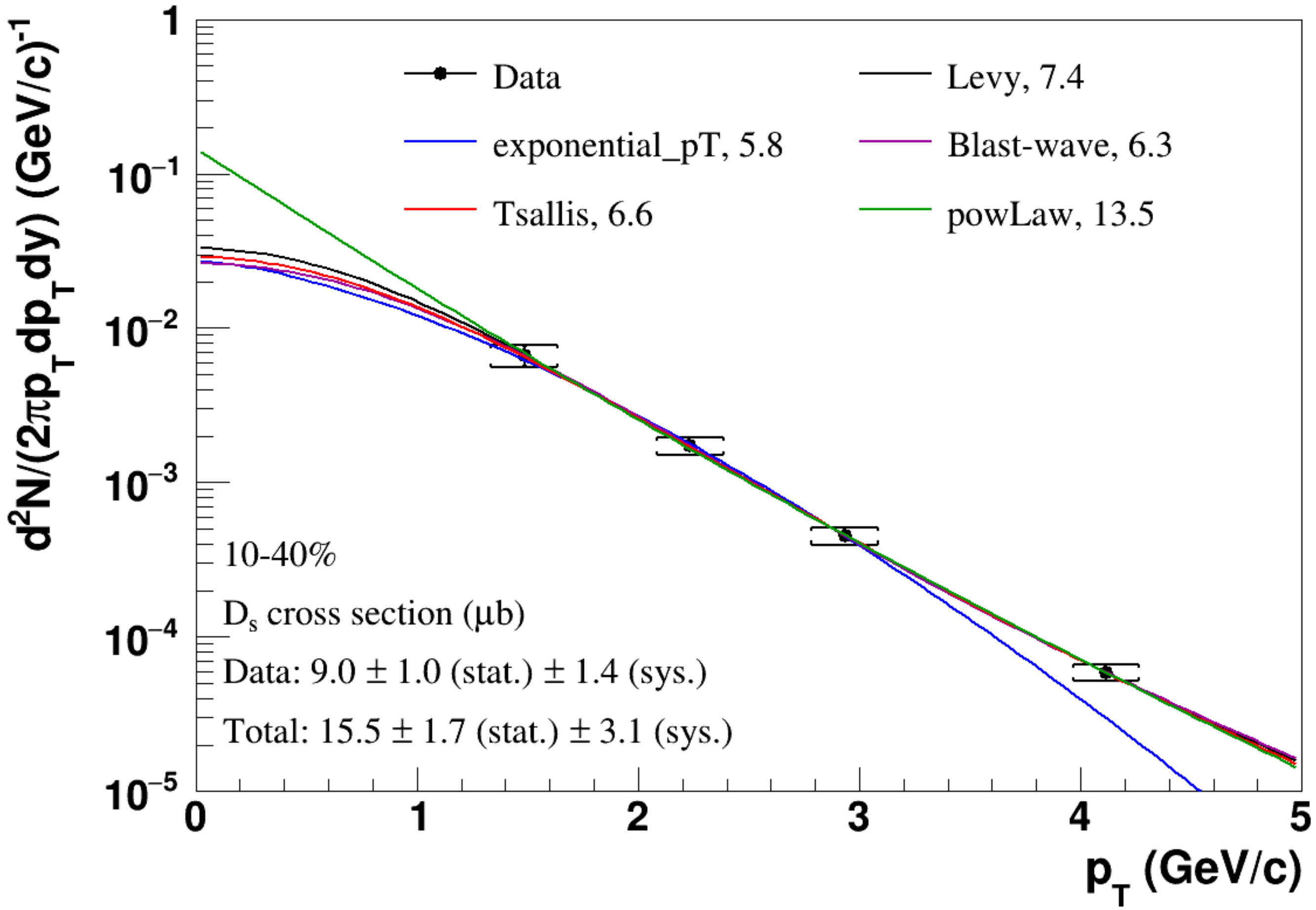
The final results are using the average between these four-model extrapolation (0-1 GeV) plus data (1-8.0 GeV). And the differences between models are quote as systemic errors.

Ds (10-40%) Total cross-section using this method is:

15.4 ± 1.7 (stat.) ± 3.6(sys.) $0.0 < p_T < 8.0$ GeV/c

D_s cross-section: extrapolate from p_T spectra

Number after function name means Integral cross-section in pT(0.0-1.0 GeV/c)



Boltzmann, Exponential p_T-Gaus, Exponential p_T-triple are failed to describe data.

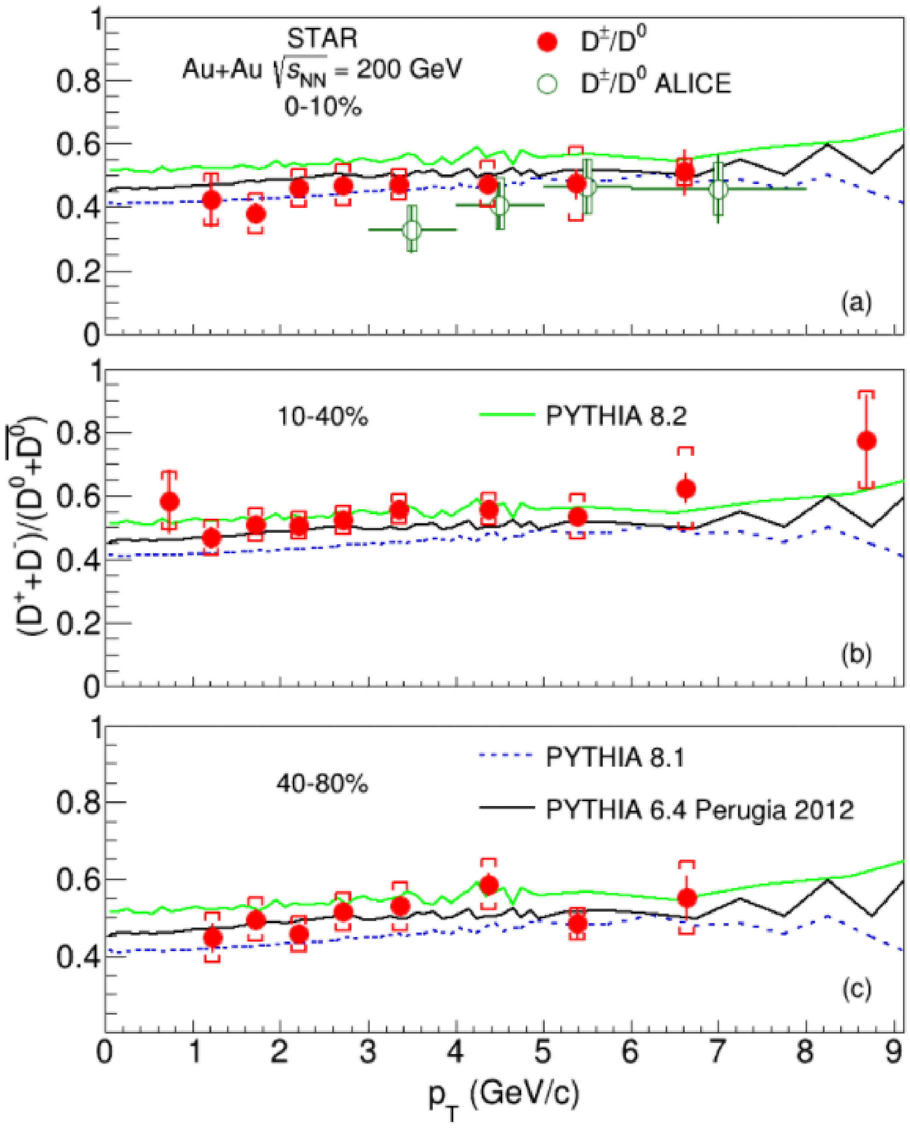
Power-Law overestimate low p_T cross-section.

The final results are using the average between Levy , Blast-wave, Tsallis and Exponential p_T. And the differences are quote as systemic errors.

Ds (10-40%) Total cross-section using this method is: **15.5 ± 1.7 (stat.) ± 3.1 (sys.)**

The difference of the total cross-section between this and the previous method is very small

$D^{\pm}$ cross-section: extrapolate from $D^{\pm}/D^0$ ratio



$D^{\pm}$ measurement for 10-40% cover p_T 0.5 to 10.0 GeV/c,

Using the same method as L_c to do the extrapolation down to 0 p_T:

$$\frac{dN(D^{\pm})}{dp_T dy}(pT) = \frac{dN(D^0)}{dp_T dy}(pT) \times C_1 \frac{D^{\pm}}{D^0}(p_T)$$

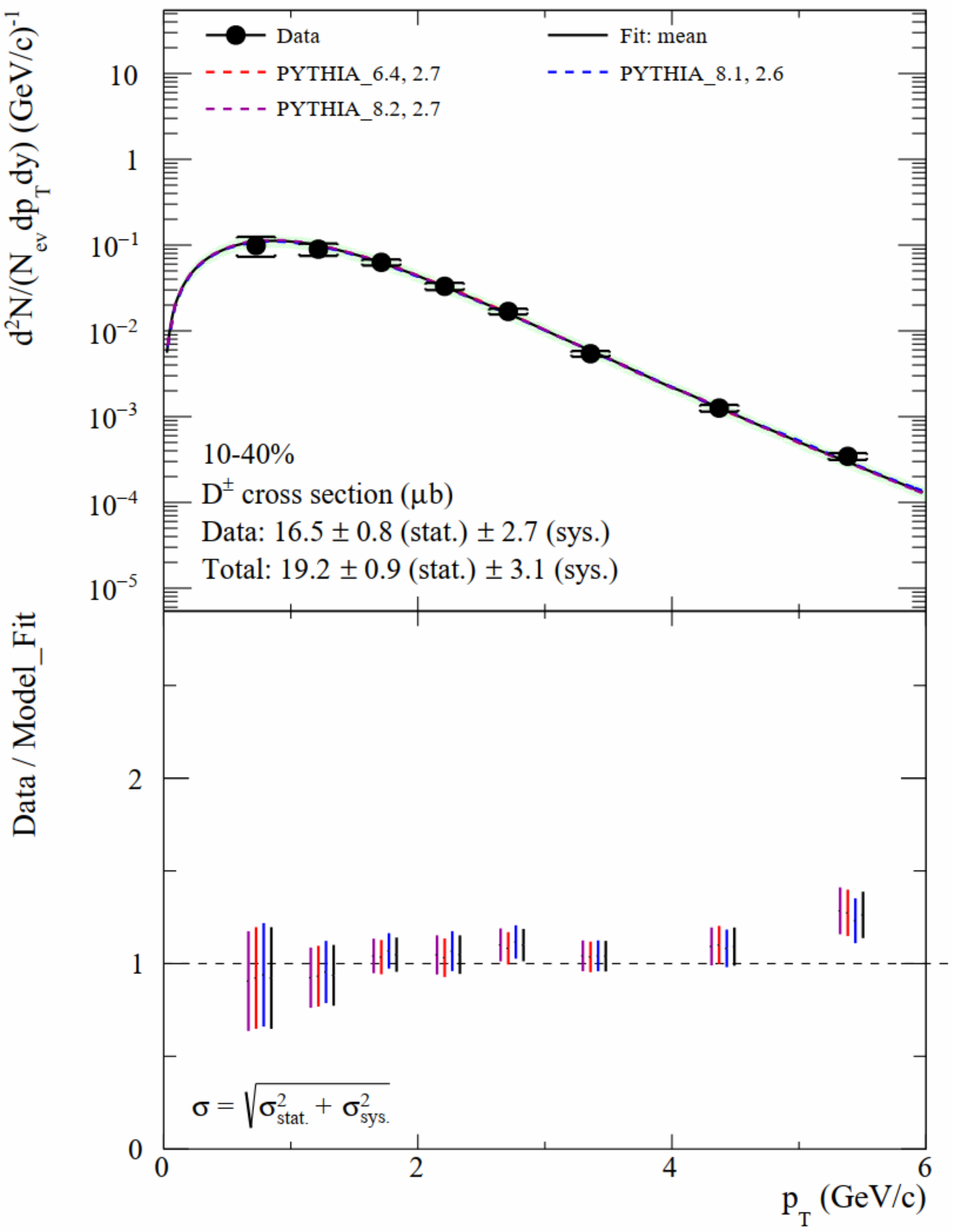
$\frac{dN(D^0)}{dp_T dy}$ (pT) is getting from levy fitting of D^0 10-40% centrality data

(p_T 0-10 GeV/c).

$\frac{D^{\pm}}{D^0}$ (p_T) are getting from different version of PYTHIA calculation

C_1 is a free parameter which allow the overall $D^{\pm}/D^0$ ratio could change

Number after function name means Integral cross-section in pT(0.0-0.5 GeV/c)



The final results are using the average between PYTHIA predictions and extrapolation to 0-0.5 GeV p_T range, then plus data 0.5 to 8.0 GeV p_T range. And the differences between models are quote as an additional systemic errors.

$D^{\pm}$(10-40%) Total cross-section using this method is:

19.2 ± 0.9 (stat.) ± 3.1 (sys.) $0.0 < p_T < 8.0$ GeV/c

Λ_c production cross-section:

Λ_c measurement cover p_T 2.0 to 8.0 GeV/c

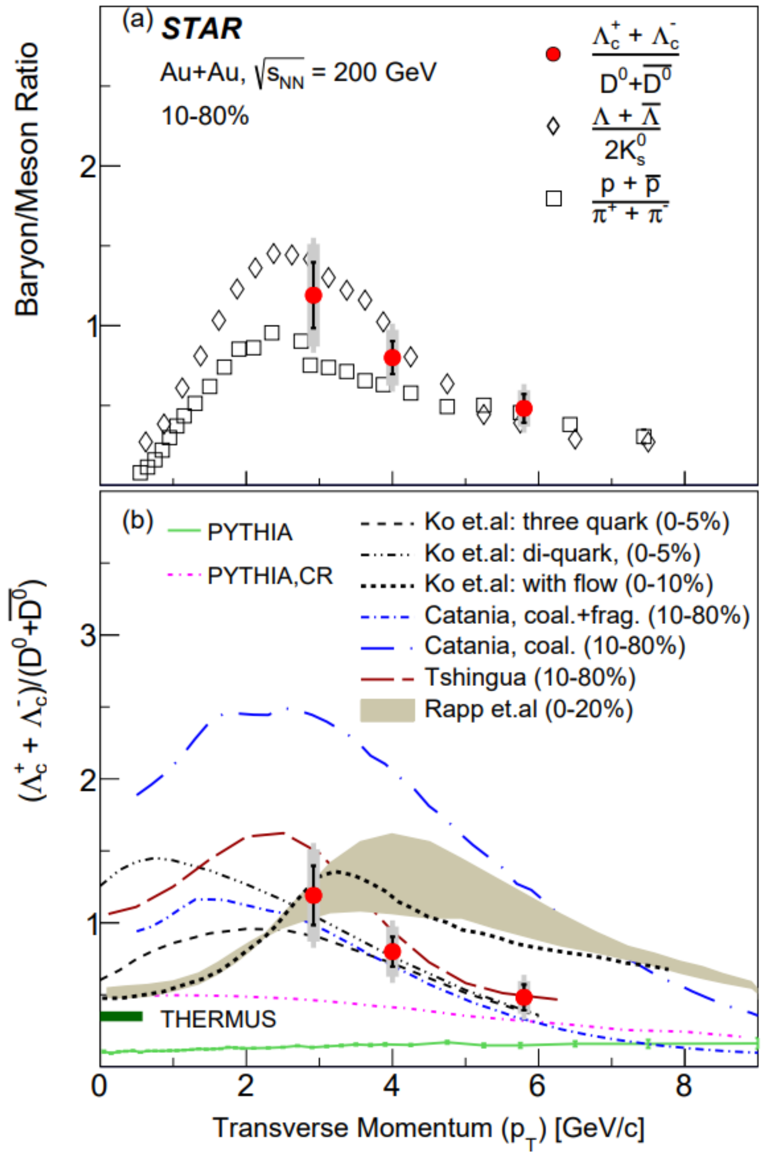
Using the measured Λ_c/D_0 ratio and D_0 spectra to do the extrapolation down to 0 p_T:

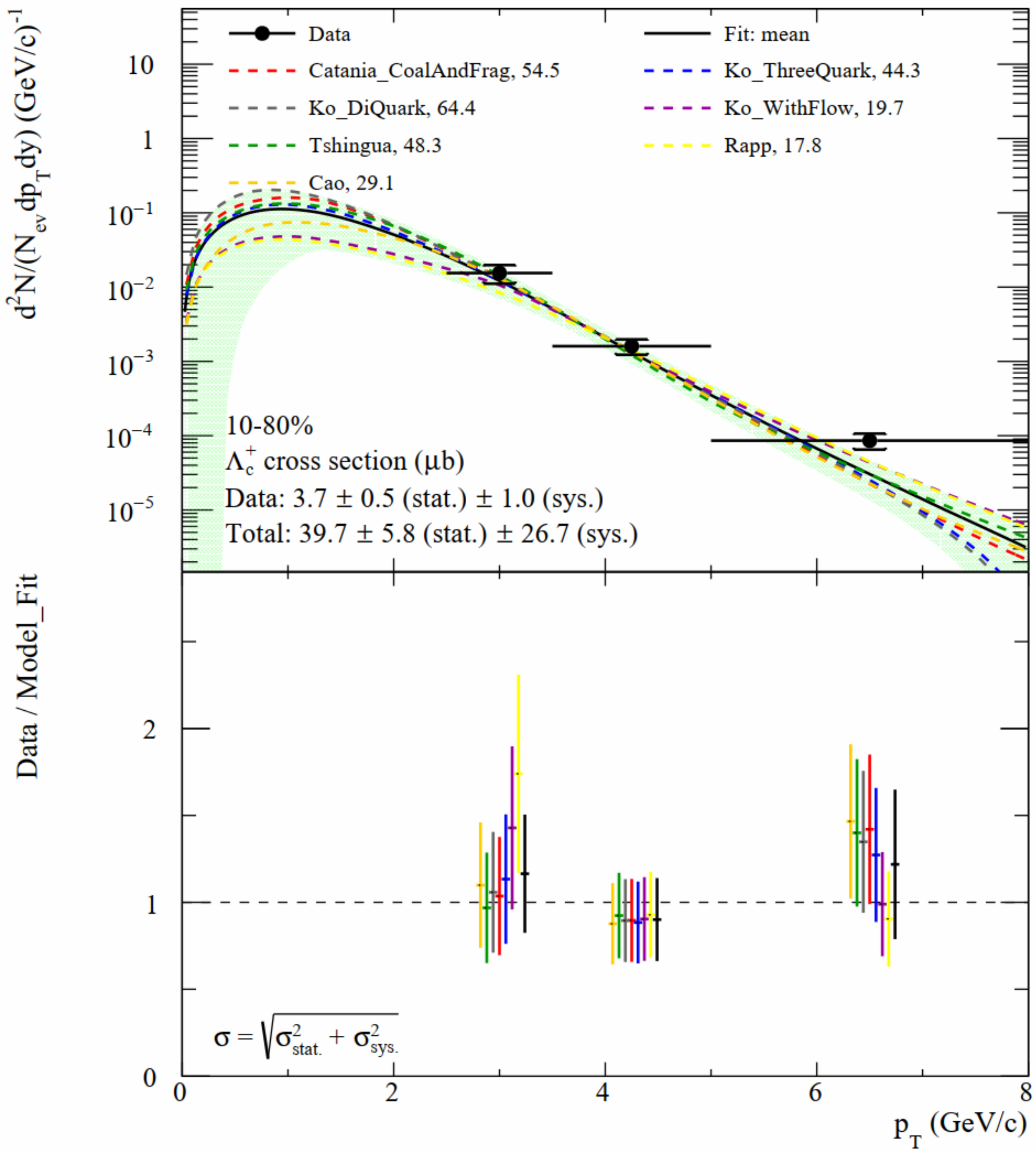
$$\frac{dN(\Lambda_c)}{dp_T dy}(pT) = \frac{dN(D^0)}{dp_T dy}(pT) \times C_1 \frac{\Lambda_c}{D^0}(p_T)$$

$\frac{dN(D^0)}{dp_T dy}$ (pT) is getting from D^0 10-40% centrality data (p_T 0-10 GeV/c).

$\frac{\Lambda_c}{D^0}(p_T)$ are getting from different model prediction

C_1 is a free parameter which allow the overall Λ_c/D^0 ratio could change, and fitted to L_c spectra





Λ_c dσ/dy in p_T 2.0 to 8.0 GeV/c are calculated by data and p_T 0.0 to 2.0 GeV/c are using the integrated average between these four-model. And the differences between models are quote as an additional systemic errors.

The bottom plot shows the ratio between Lc dσ/dy data and model in 2.0 to 8.0 GeV/c

Lc (using 10-80% data) Total cross-section is:

39.7 ± 5.8(stat.) ± 26.7 (sys.) 0.0 < pT < 8.0 GeV/c

Total charm cross-section:

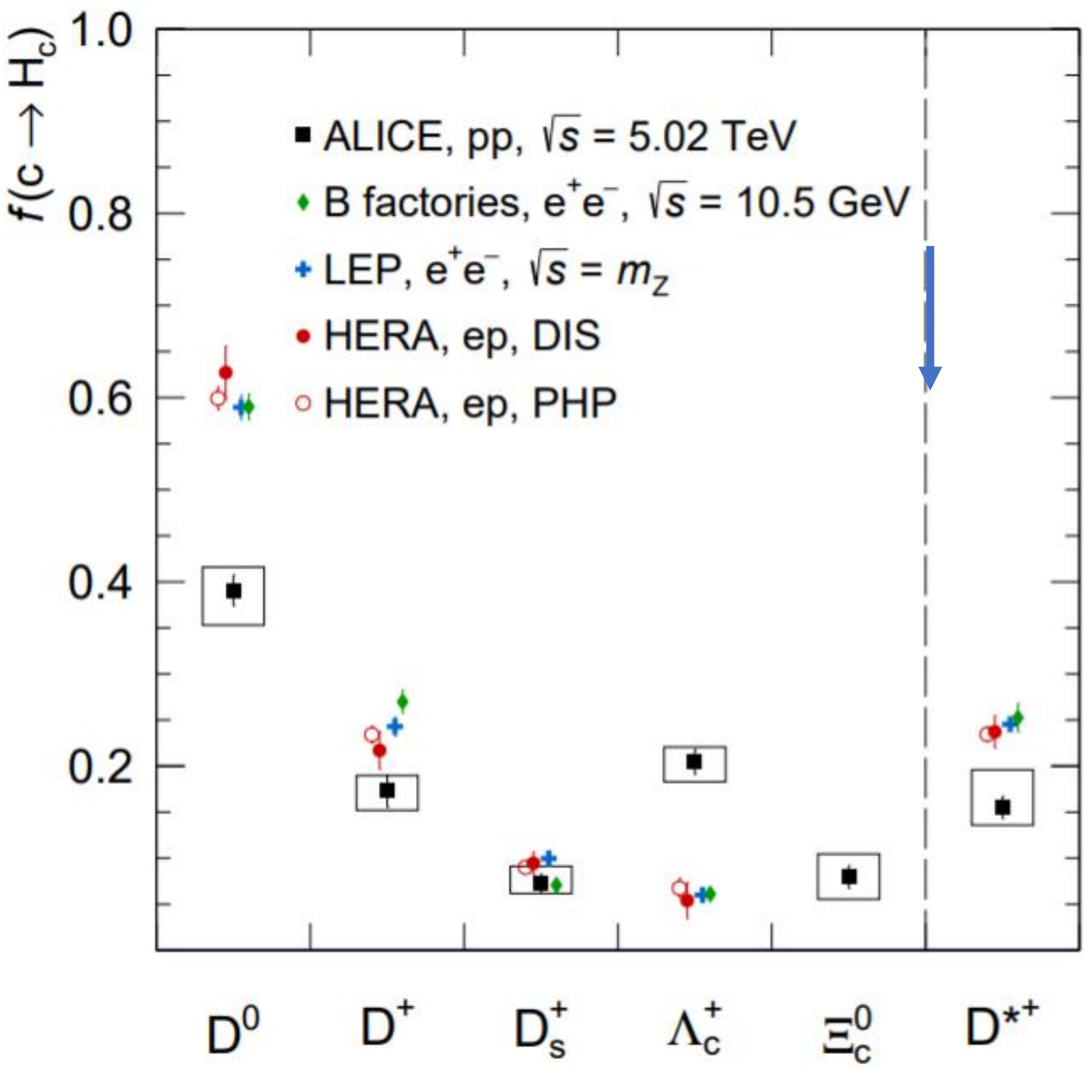
Collision System	Charm Hardon	Cross-section $\frac{d\sigma}{dy}\|_{y=0}$ (μb) (per nucleon-nucleon collision)
Au+Au 200 GeV (10-40% p_T 0-8 Gev/c)	D^0	39.0 ± 0.6 (stat.) ± 1.1 (sys.)
	$D^{\pm}$	19.2 ± 0.9 (stat.) ± 3.1(sys.)
	D_s	15.4 ± 1.7 (stat.) ± 3.6(sys.)
	Λ_c *	39.7 ± 5.8 (stat.) ± 26.7 (sys.)
	Total	113.3 ± 6.2 (stat.) ± 27.2 (sys.) *
P+P 200 GeV	Total	130 ± 30 (stat.) ± 26 (sys.)

* Λ_c^+ results are using 10-80% centrality

* 8% uncertainty on σ_{pp} and $N_{collision}$ are not included

Back up

Charm fragmentation at ALICE



Arxiv 2105.06335

Ground state charm hadron:

D^0 , D^+, D^+_s , Λ_c , Ξ^0_c, Ξ^+_c, Ω_c, J/ϕ

$f(c\text{->}H_c) = \sigma(H_c) / \sigma_{all}$

HERA: $\sigma_{all} = \sigma(D^0) + \sigma(D^+) + \sigma(D_s) + \sigma(\Lambda_c) \cdot 1.14$

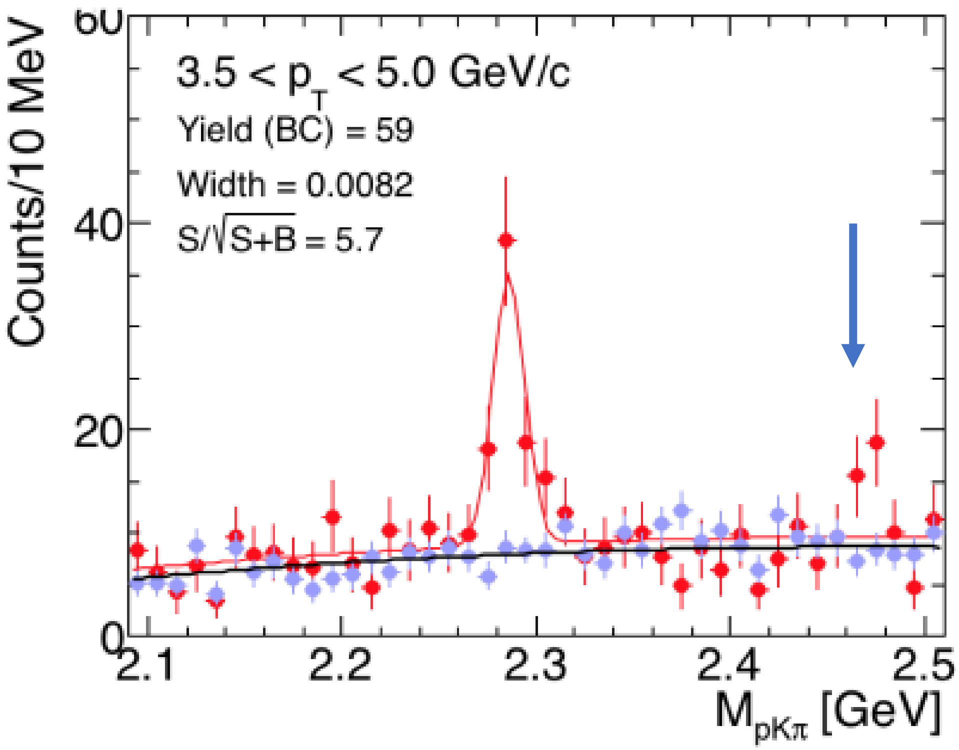
ALICE: σ_{all} $(d\sigma_{cc}/dy||y|<0.5)$

$= C^*[\sigma(D^0) + \sigma(D^+) + \sigma(D_s) + \sigma(\Lambda_c) + 2^*\sigma(\Xi^0_c)]$

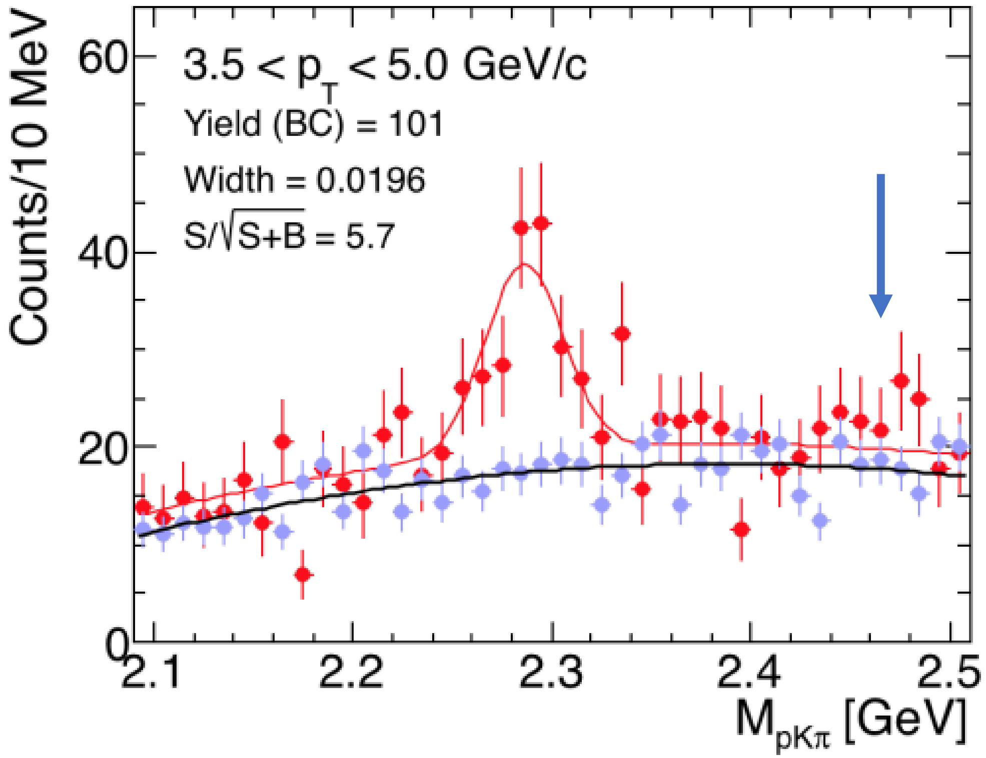
- Ξ_c^0 have a ~10% contribution at ALICE and can not be measured at STAR due to low statistics

possible Ξ_c^+ contribution at STAR

Star run14 AuAu 200 GeV



Star run16 AuAu 200 GeV



Ξ_c^+ Mass 2467.71$\pm$0.23 MeV Ξ_c^+ -> p K π B.R. $6.2\pm3.0\times10^{-3}$