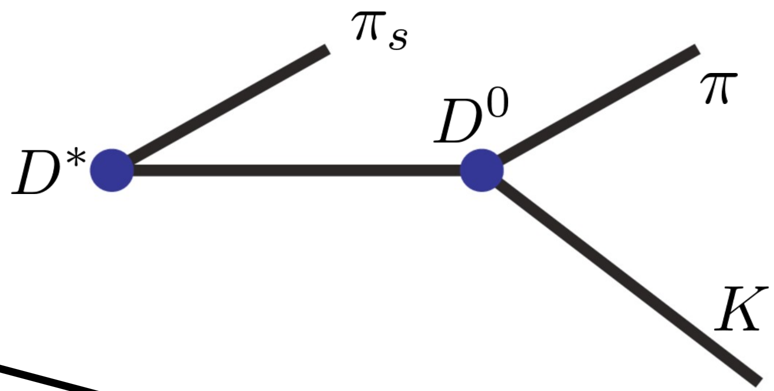
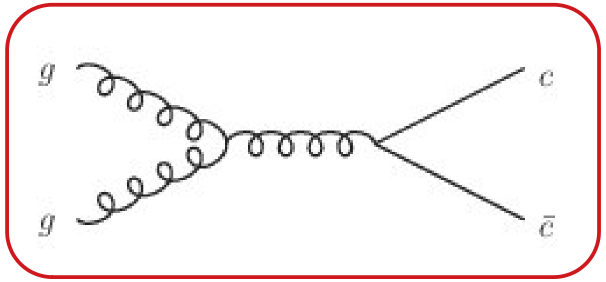
D* cross sections at 5 TeV

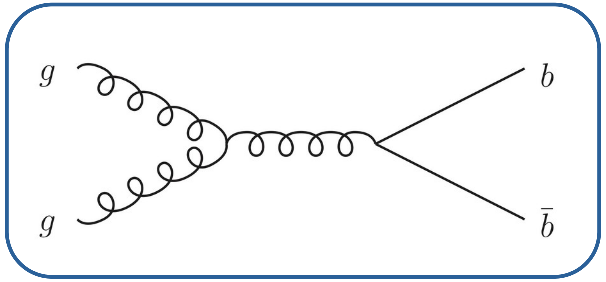
DESY Hamburg: Josry Metwally, Achim Geiser, Nur Zulaiha Jomhari - 3.2021

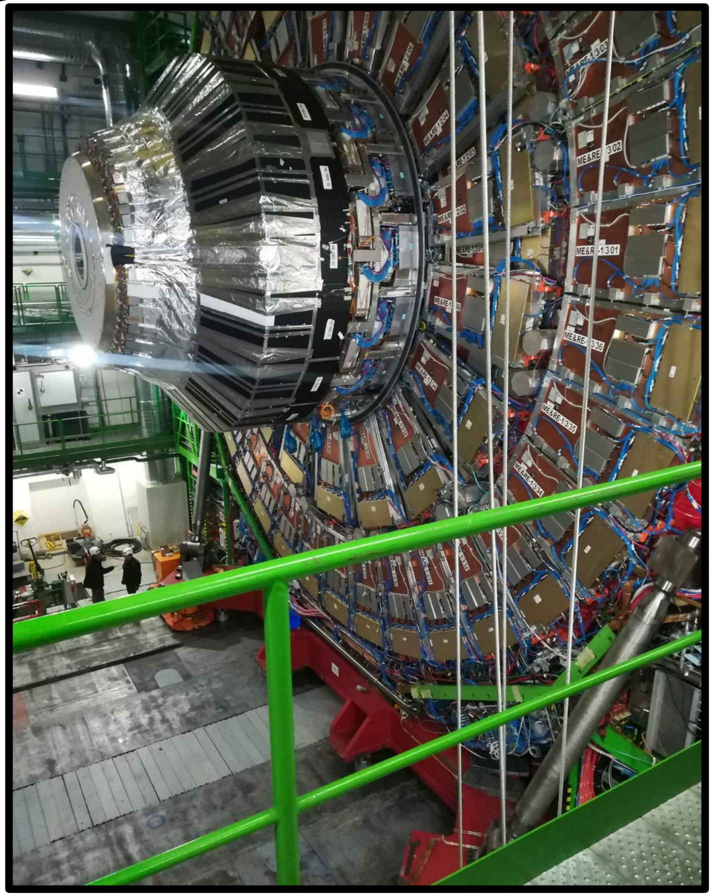
Introduction to our D meson analysis



- We reconstruct $D^{*\pm} \rightarrow D^0\pi_s^\pm \rightarrow K^\mp\pi^\pm\pi_s^\pm$
- Measure D* cross sections in full phase space in CMS of prompt D mesons and D mesons from b hadron decays in small bins in p_T and |y| (rapidity) and integrate







- **Today**:
  - **5 TeV D* cross sections** for old and new D* selection (see preselection cuts for D* meson analyses, by Achim)
  - Compare **7 TeV** and **5 TeV D* cross sections**

old/new cuts for D* selection

$D^{*\pm} \rightarrow D^0\pi_s^\pm \rightarrow K^\mp\pi^\pm\pi_s^\pm$

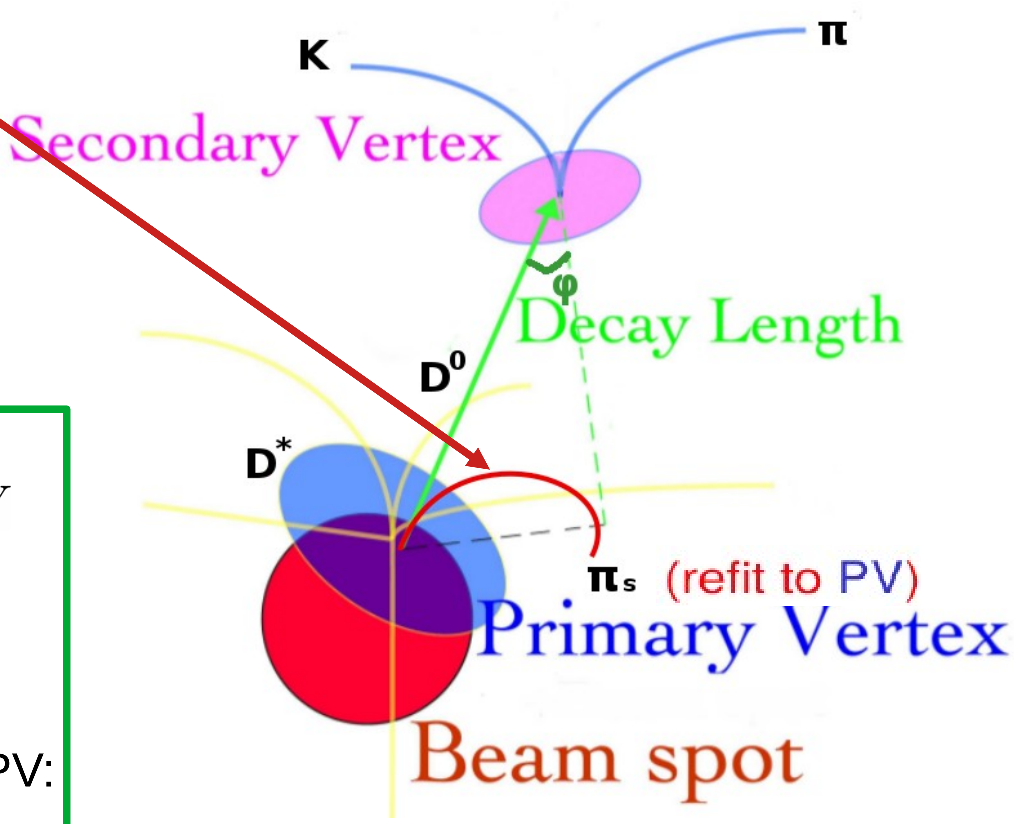
the D^* system	
right charge $K^\mp\pi^\pm\pi_s^\pm$ with a real D⁰	wrong charge $K^\mp\pi^\mp\pi_s^\pm$ comb bg
use both to extract the signal	

- Track p_T cut: none for slow pion π_s
- D^0 mass cut: $1.836 < m_{D^0} < 1.892\ GeV$
- We define our cuts in two p_T regions differently:

- in the **higher** p_T region $p_T^{D^*} > 3.5\ GeV$

- in the **lower** p_T region $p_T^{D^*} < 3.5\ GeV$

explicit cuts see backup



Old D* selection:

- Track p_T cut: $p_T^{K,\pi} > 0.5\ GeV$
- No cut on dEdx
- Cut on max distance form PV: dz cut 0.1 cm

New D* selection:

- Track p_T cut: $p_T^{\pi} > 0.5\ GeV$
- Cut on dEdx for Kaon
- Cut on max distance from PV: loosen dz cut to 0.5 cm

more details see preselection cuts for D* meson analyses, by Achim

Information about used data and MC for 2015 5 TeV

data

Sample	#Events	w. JSON	(N)MB
/MinimumBias1/Run2015E-PromptReco-v1/AOD	126,809,757	111,413,194	
/MinimumBias2/Run2015E-PromptReco-v1/AOD	126,998,875	111,600,855	
/MinimumBias3/Run2015E-PromptReco-v1/AOD	126,853,017	111,502,472	
/MinimumBias4/Run2015E-PromptReco-v1/AOD	127,250,025	111,851,720	
/MinimumBias5/Run2015E-PromptReco-v1/AOD	127,169,537	111,772,459	
/MinimumBias6/Run2015E-PromptReco-v1/AOD	127,256,729	111,859,378	
/MinimumBias7/Run2015E-PromptReco-v1/AOD	127,256,692	111,858,963	
/MinimumBias8/Run2015E-PromptReco-v1/AOD	127,239,988	111,841,797	
/MinimumBias9/Run2015E-PromptReco-v1/AOD	127,222,974	111,826,347	
/MinimumBias10/Run2015E-PromptReco-v1/AOD	127,220,628	111,822,249	
/MinimumBias11/Run2015E-PromptReco-v1/AOD	126,325,160	111,857,169	
/MinimumBias12/Run2015E-PromptReco-v1/AOD	127,207,059	111,808,958	
/MinimumBias13/Run2015E-PromptReco-v1/AOD	125,206,184	109,958,587	
/MinimumBias14/Run2015E-PromptReco-v1/AOD	126,522,737	111,602,374	
/MinimumBias15/Run2015E-PromptReco-v1/AOD	126,753,153	111,602,223	
/MinimumBias16/Run2015E-PromptReco-v1/AOD	127,128,323	111,872,629	
/MinimumBias17/Run2015E-PromptReco-v1/AOD	126,280,043	111,105,435	
/MinimumBias18/Run2015E-PromptReco-v1/AOD	126,542,929	111,311,694	
/MinimumBias19/Run2015E-PromptReco-v1/AOD	126,373,548	111,214,484	
/MinimumBias20/Run2015E-PromptReco-v1/AOD	127,031,373	111,633,897	
Total	2,536,648,731	2,231,316,884	1,853,304,000
effective luminosity (see section 5.1)		40.17 nb^{-1}	40.17 nb^{-1}

MC

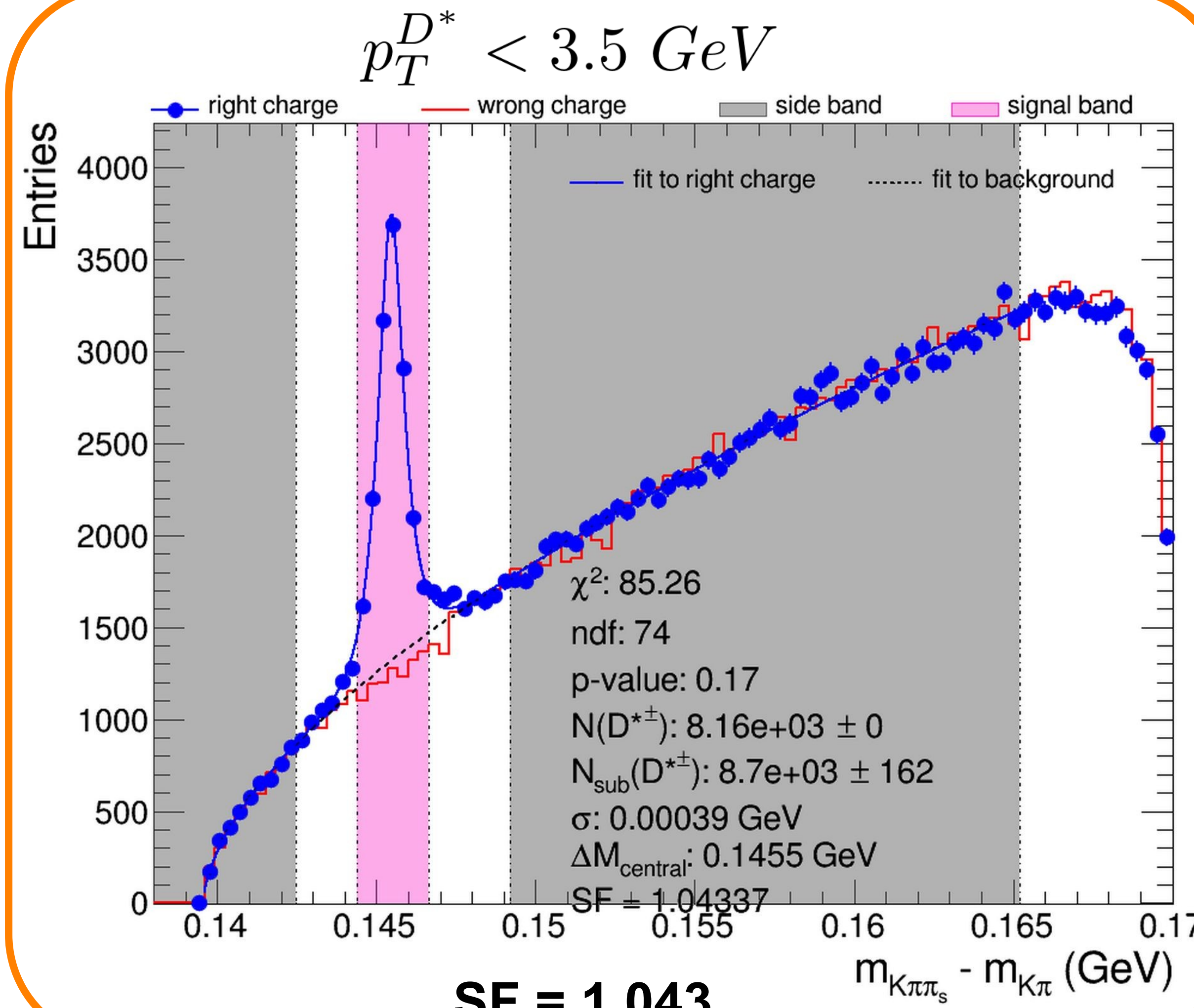
/D0Kpi_pT0toInf_TuneCUEP8M1_5TeV_pythia8-evtgen/ HINppWinter16DR-75X_mcRun2_asymptotic_ppAt5TeV_v3-v3/AODSIM	12,077,624	40.4 nb^{-1}

more in AN-20-050 and AN-18-284

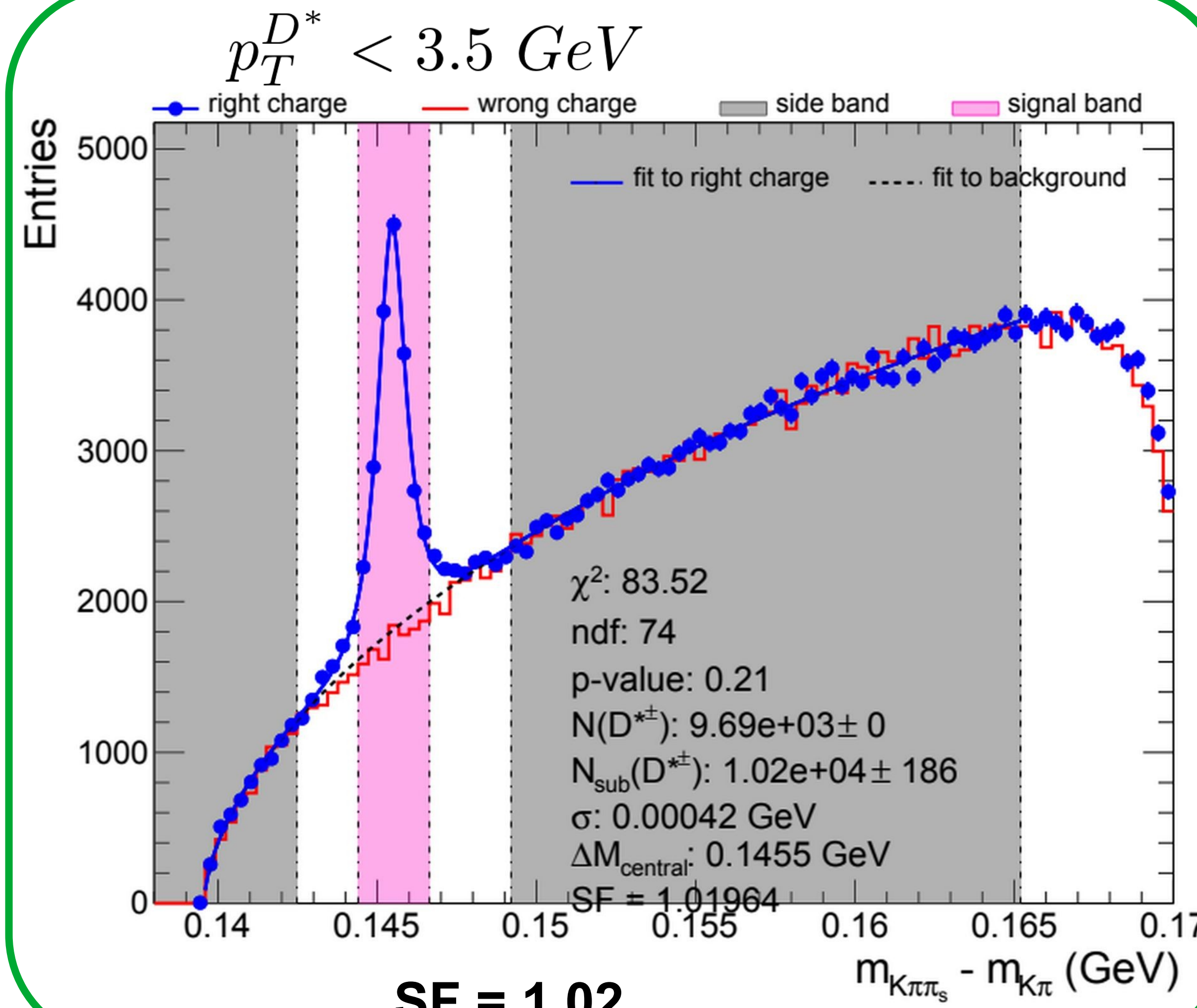
Signal extraction on 5 TeV 2015 data old vs new

right charge $K^{\mp}\pi^{\pm}\pi_s^{\pm}$ with a real D^0	wrong charge $K^{\mp}\pi^{\mp}\pi_s^{\pm}$ comb bg
use both to extract the signal	

Normalize red to the blue (in grey area) leads to an scale factor (SF), apply it to red and subtract then red in the signal region (pink) from blue to get the signal



SF = 1.043



SF = 1.02

a bit more signal

Signal extraction on 5 TeV 2015 data old vs new

right charge $K^{\mp}\pi^{\pm}\pi_s^{\pm}$ with a real D⁰	wrong charge $K^{\mp}\pi^{\mp}\pi_s^{\pm}$ comb bg
use both to extract the signal	

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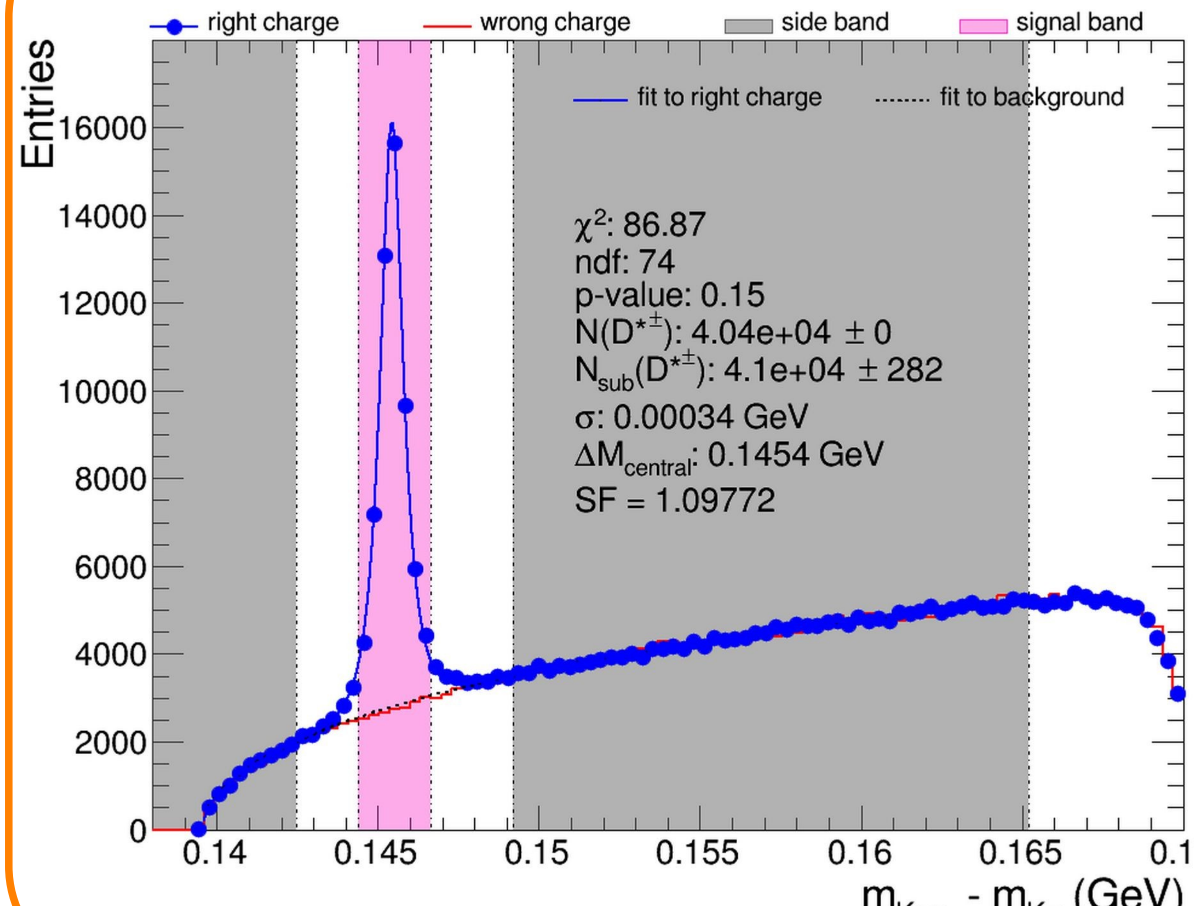
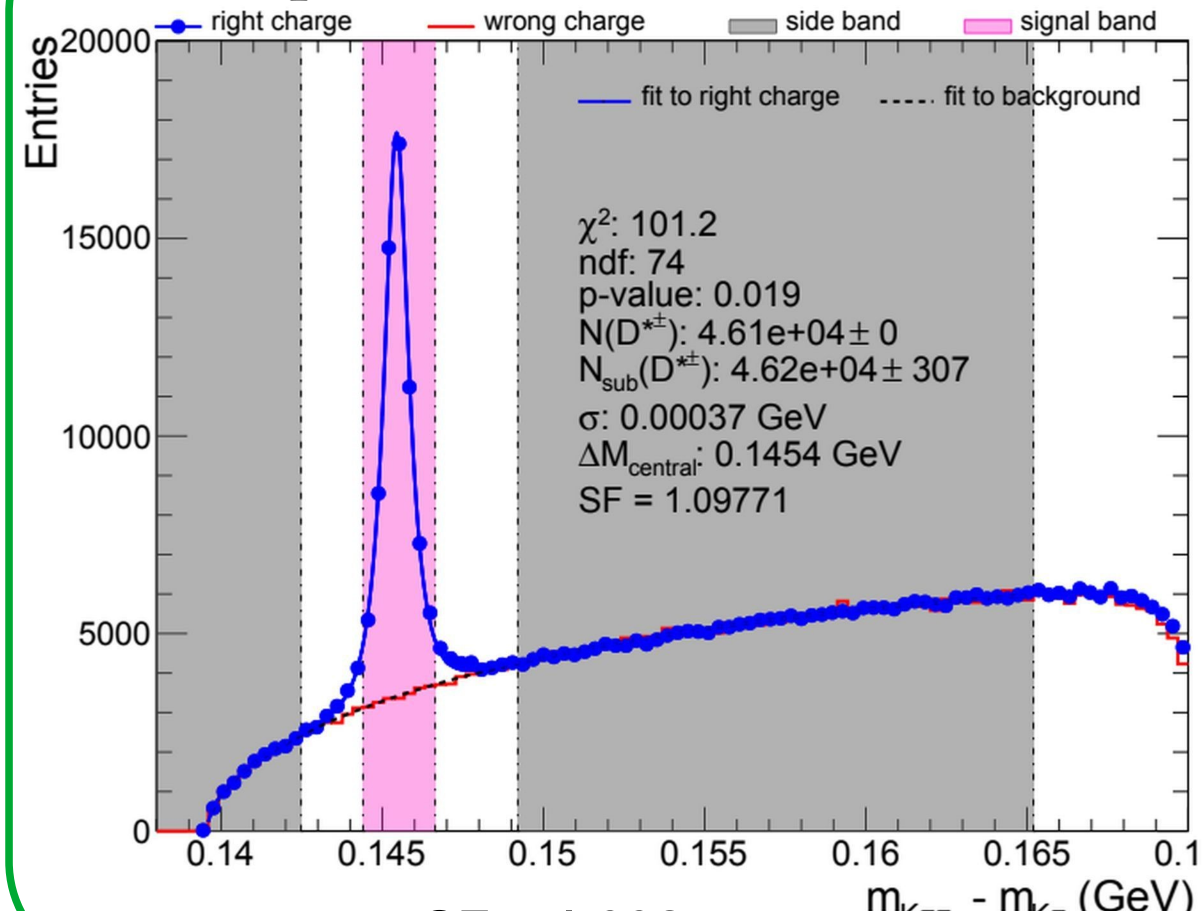
$p_T^{D^*} > 3.5\ GeV$



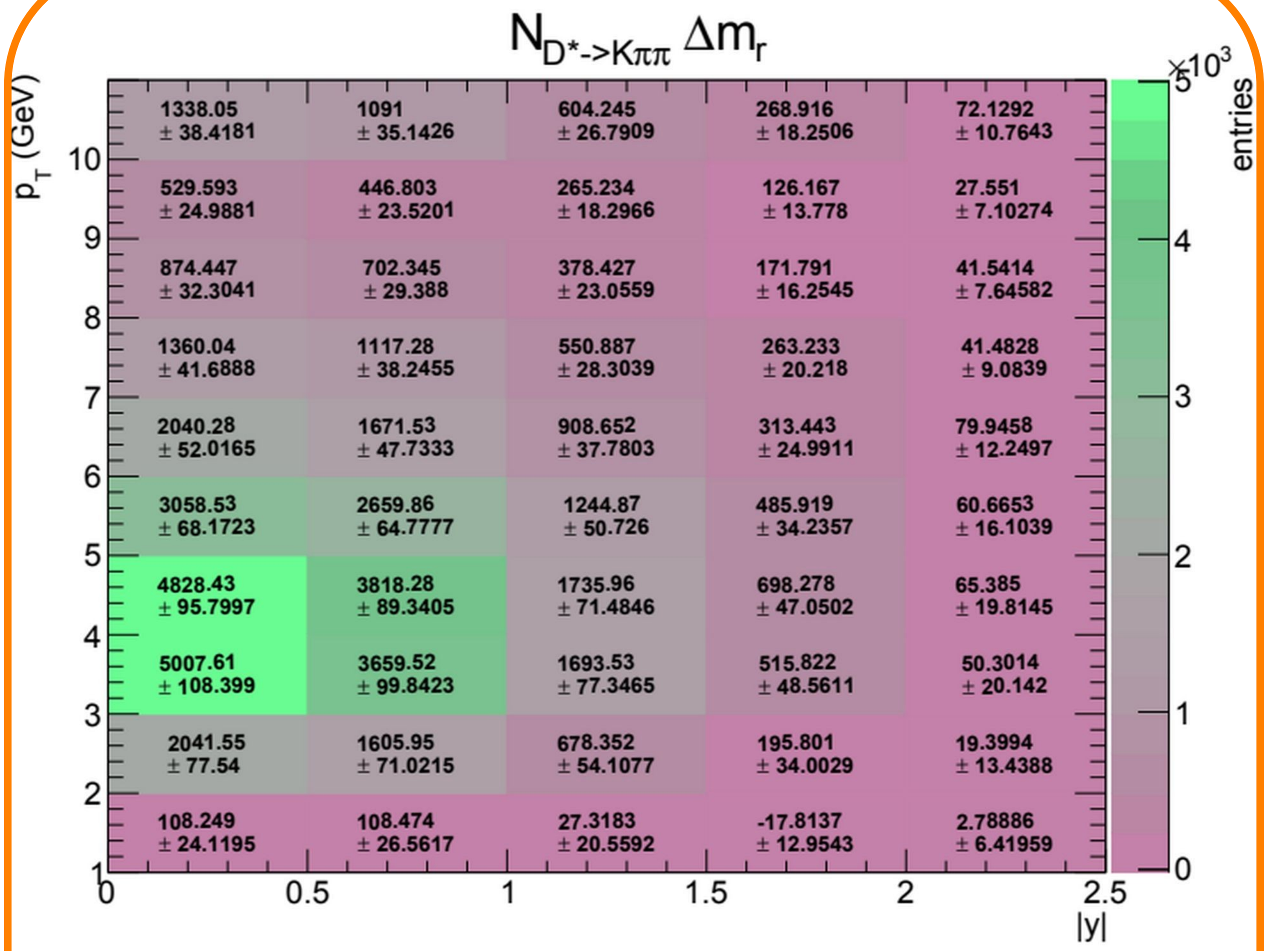
SF = 1.098

$p_T^{D^*} > 3.5\ GeV$

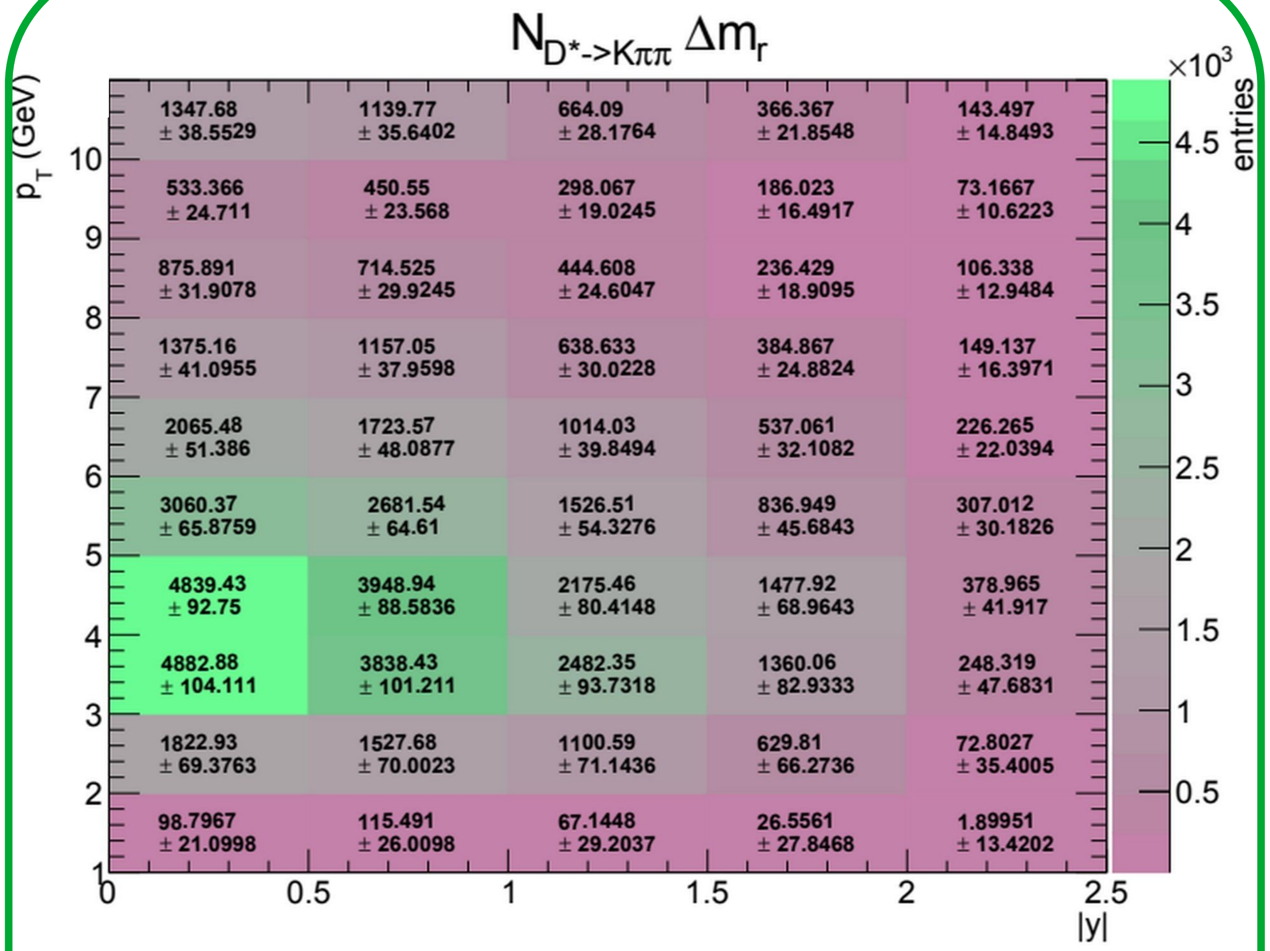


SF = 1.098

Double differential signal table for D* old vs new

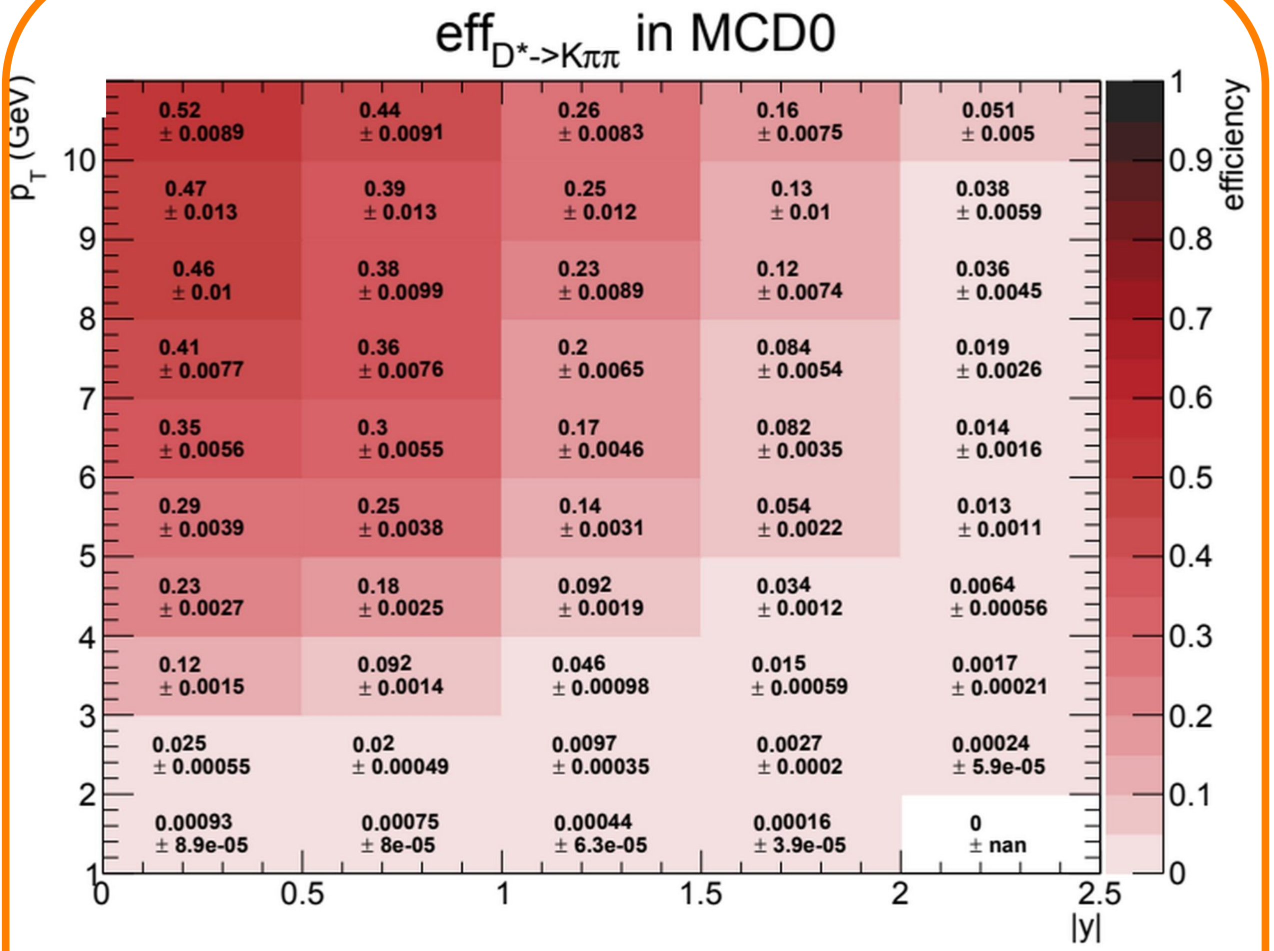


- Signal number and its uncertainty in small bins in p_T and |y| for $D^{*\pm} \to D^0\pi_s^\pm \to K^\mp\pi^\pm\pi_s^\pm$

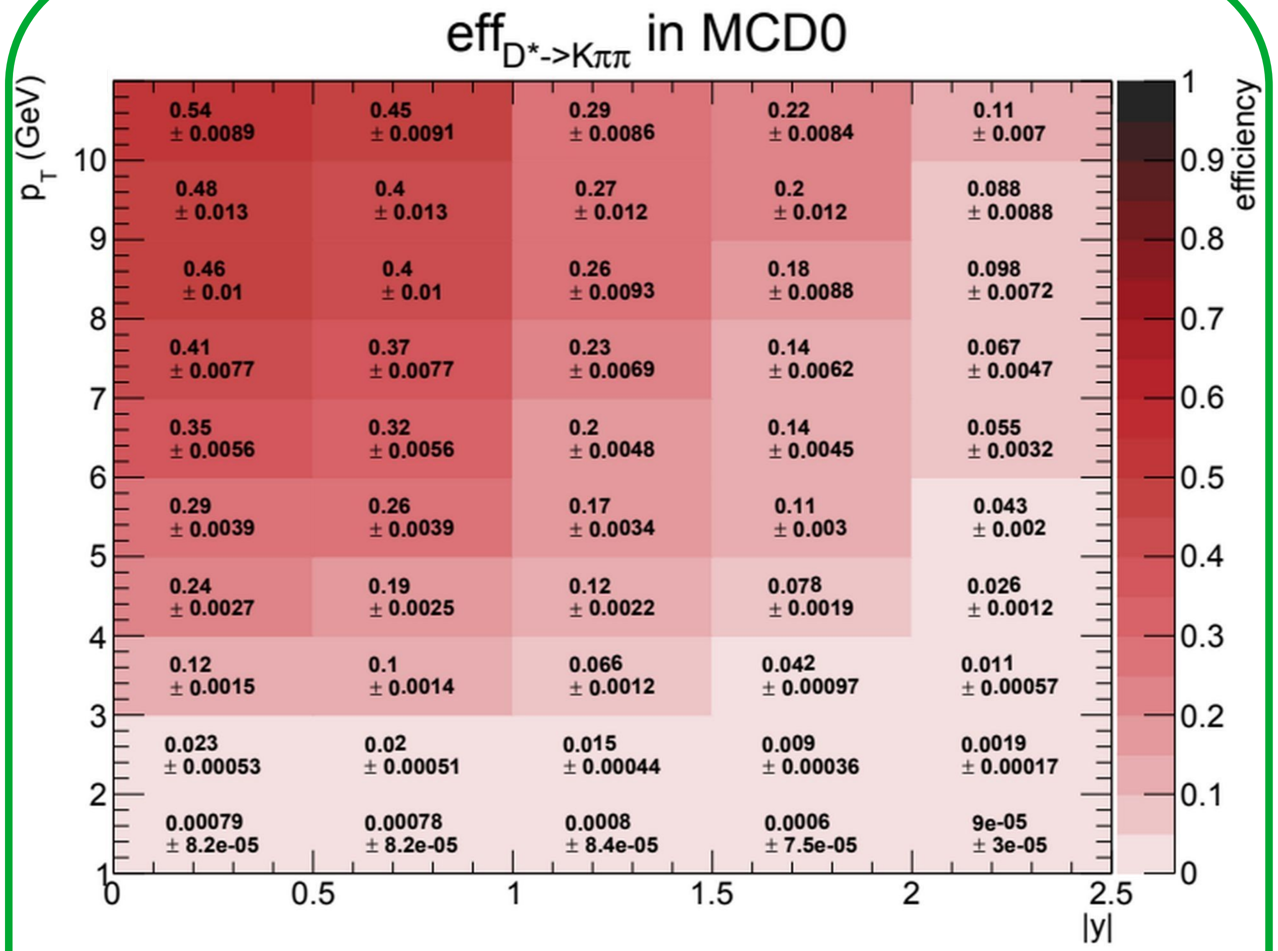


- Signal number and its uncertainty in small bins in p_T and |y| for $D^{*\pm} \to D^0\pi_s^\pm \to K^\mp\pi^\pm\pi_s^\pm$

Double differential efficiency table for D* old vs new

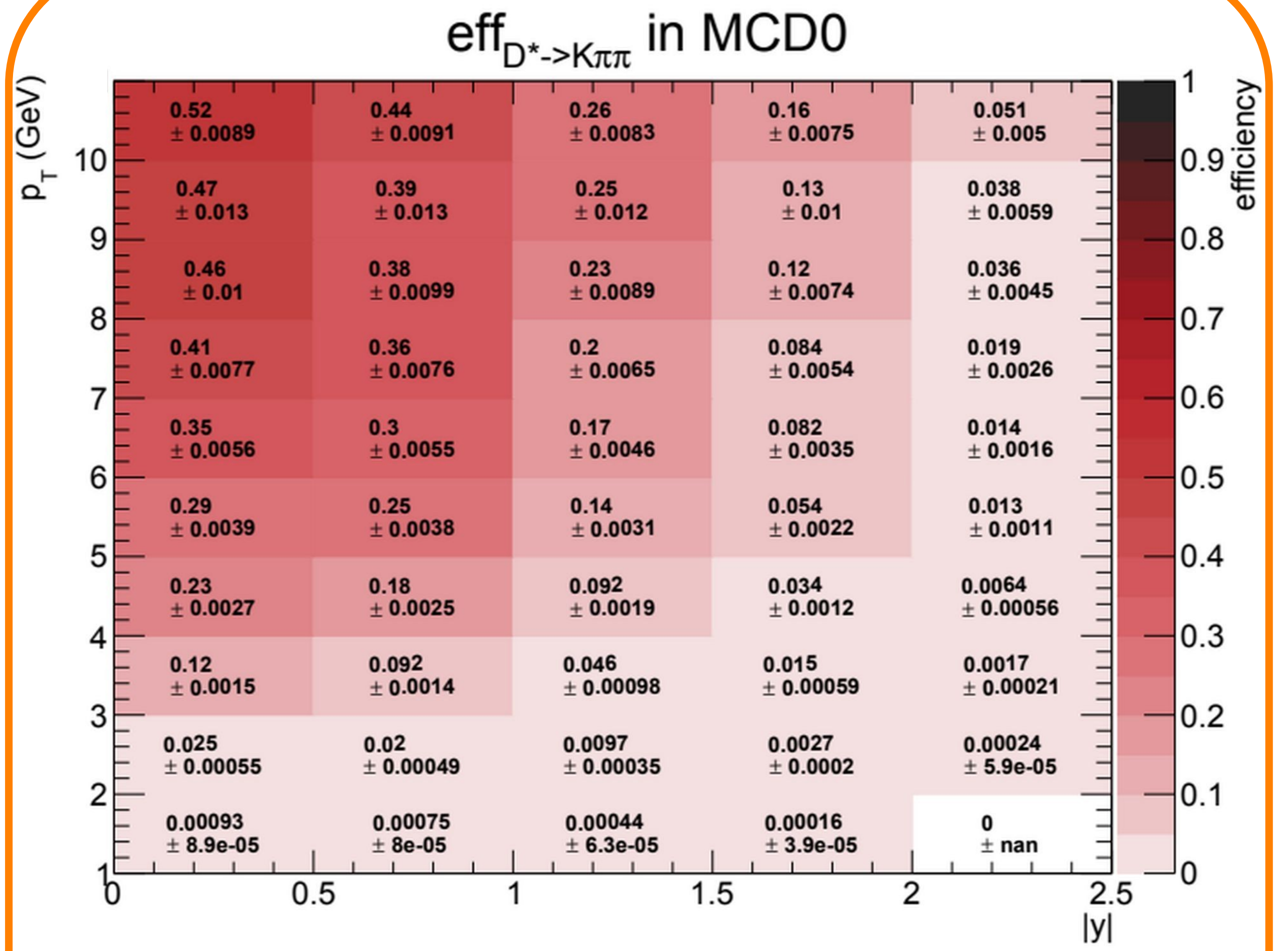


- Efficiency and its uncertainty in small bins in p_T and |y| for $D^{*\pm} \to D^0\pi_s^\pm \to K^\mp\pi^\pm\pi_s^\pm$



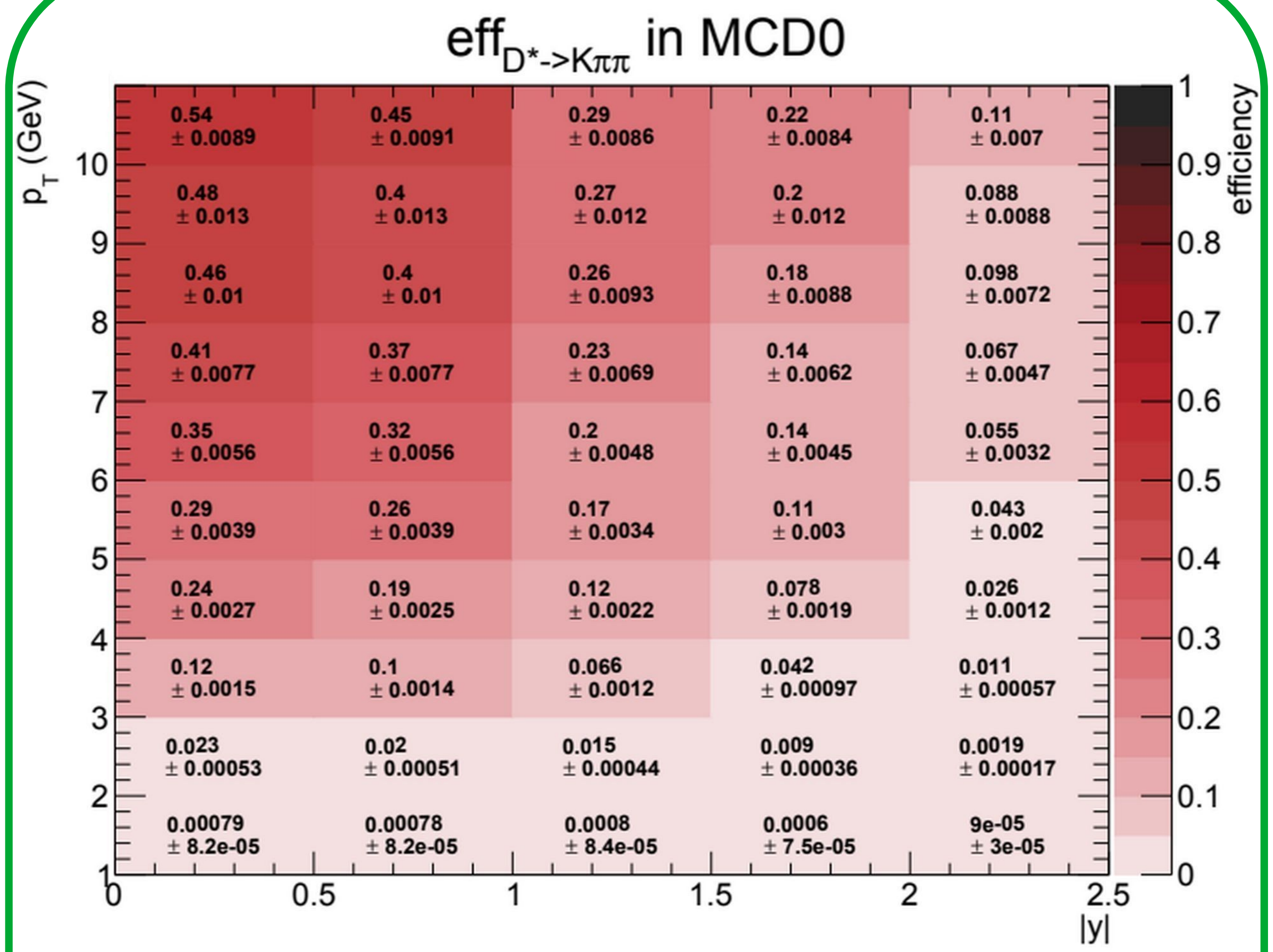
- Efficiency and its uncertainty in small bins in p_T and |y| for $D^{*\pm} \to D^0\pi_s^\pm \to K^\mp\pi^\pm\pi_s^\pm$

Double differential efficiency table for D* (old selection)



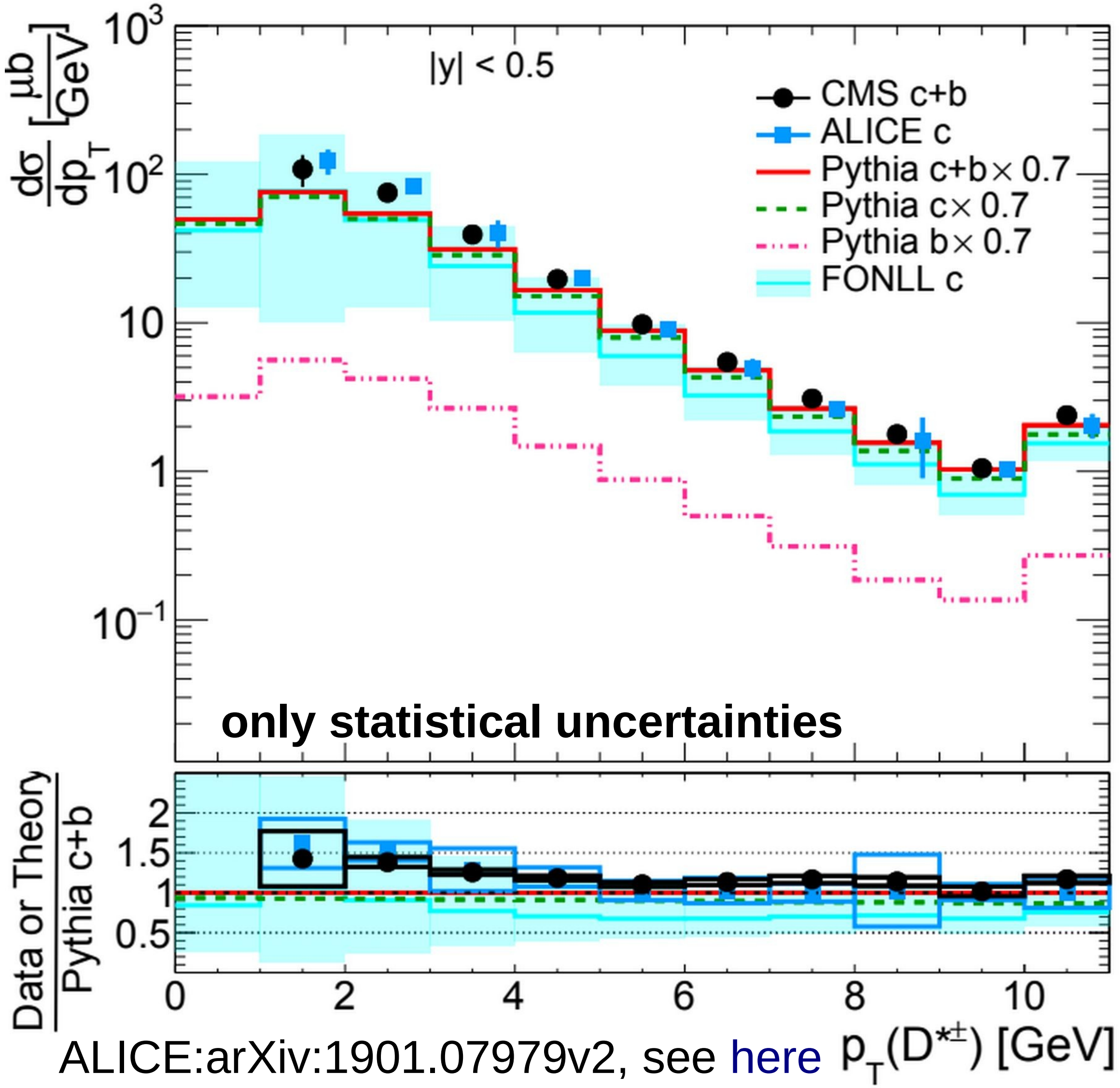
- Efficiency and its uncertainty in small bins in p_T and |y| for $D^{*\pm} \rightarrow D^0\pi_s^\pm \rightarrow K^\mp\pi^\pm\pi_s^\pm$

Double differential efficiency table for D* (new selection)

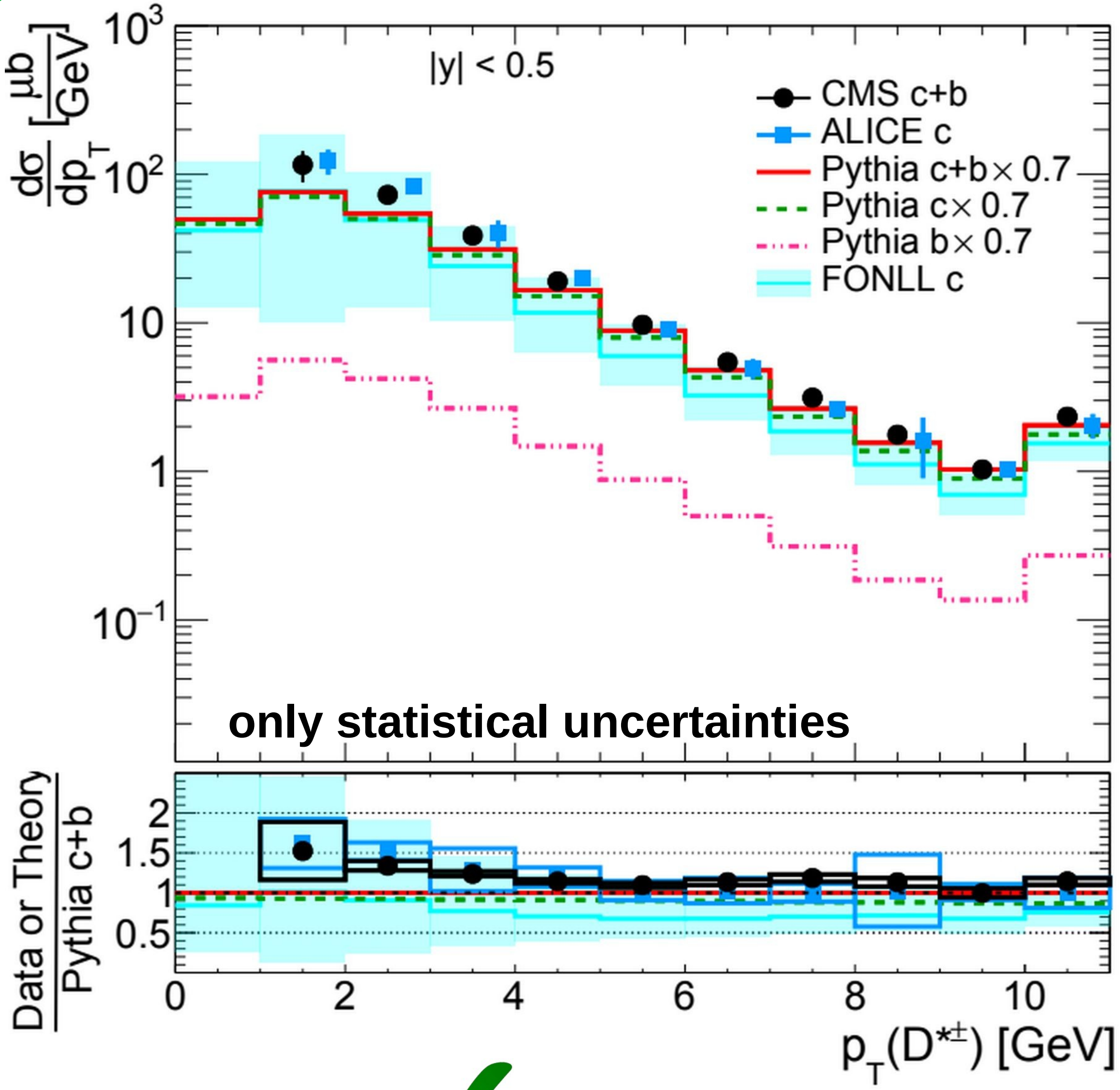


- Efficiency and its uncertainty in small bins in p_T and |y| for $D^{*\pm} \to D^0\pi_s^\pm \to K^\mp\pi^\pm\pi_s^\pm$

Differential cross section for D* in bins of rapidity

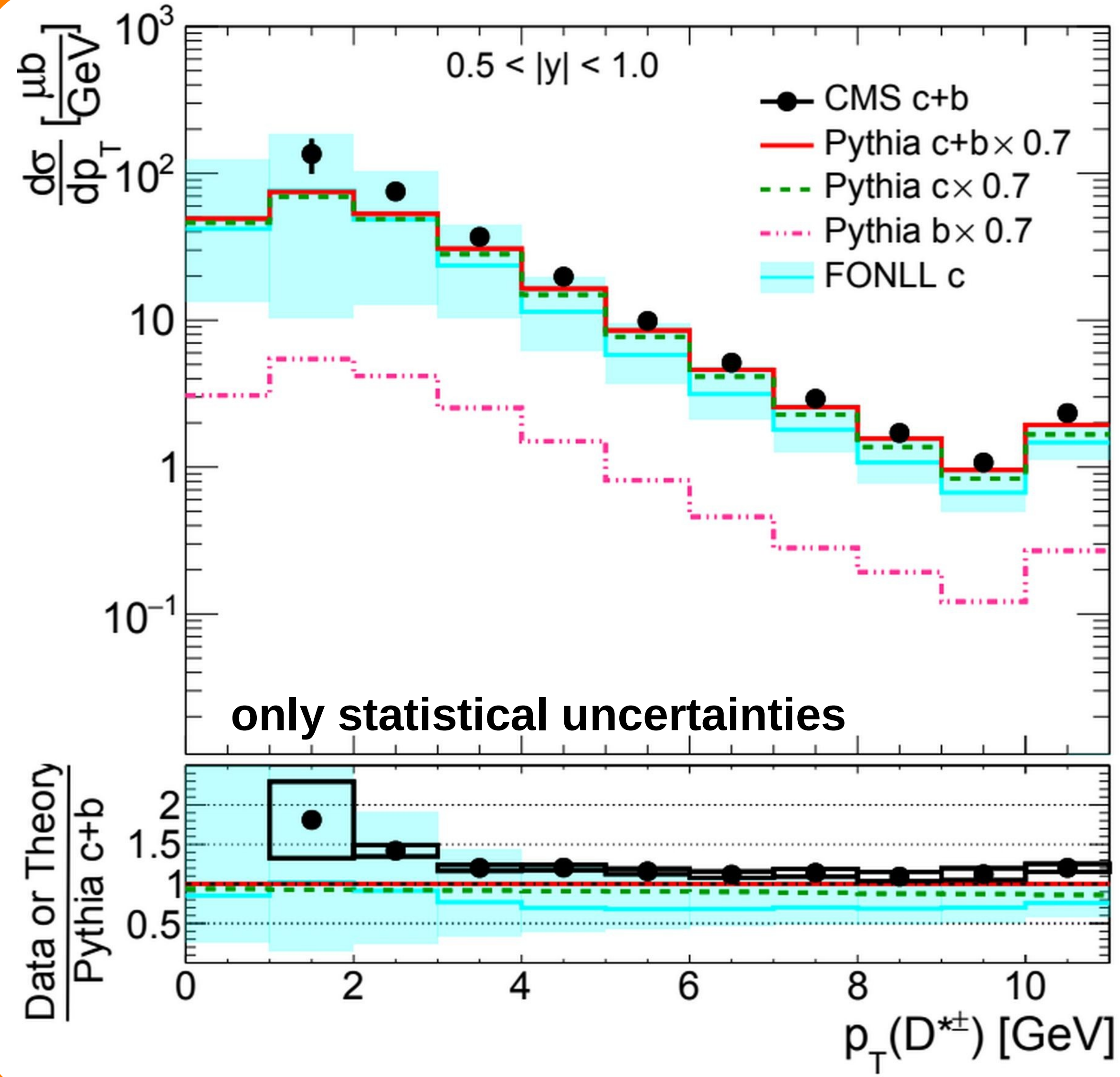


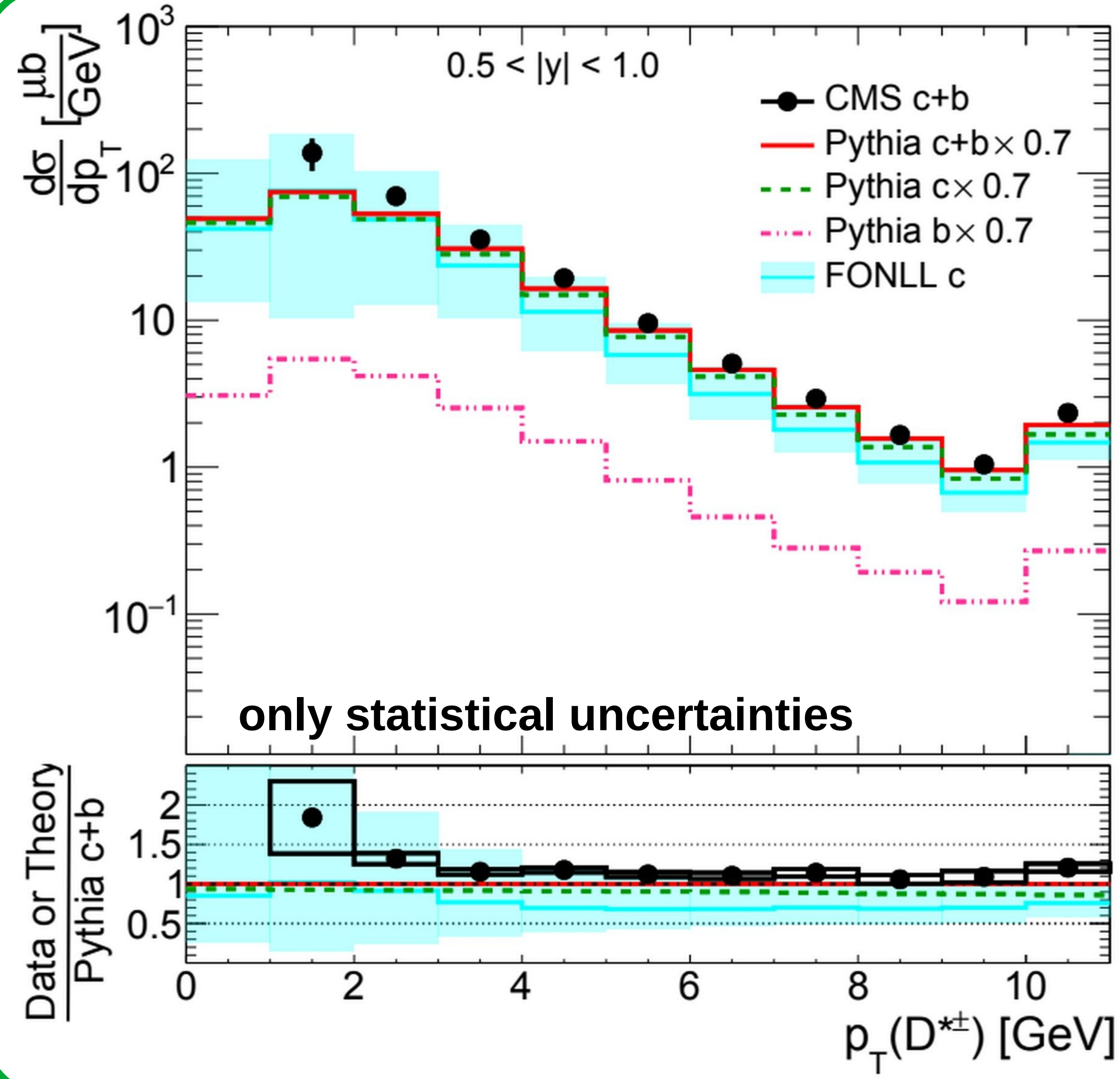
ALICE:arXiv:1901.07979v2, see here



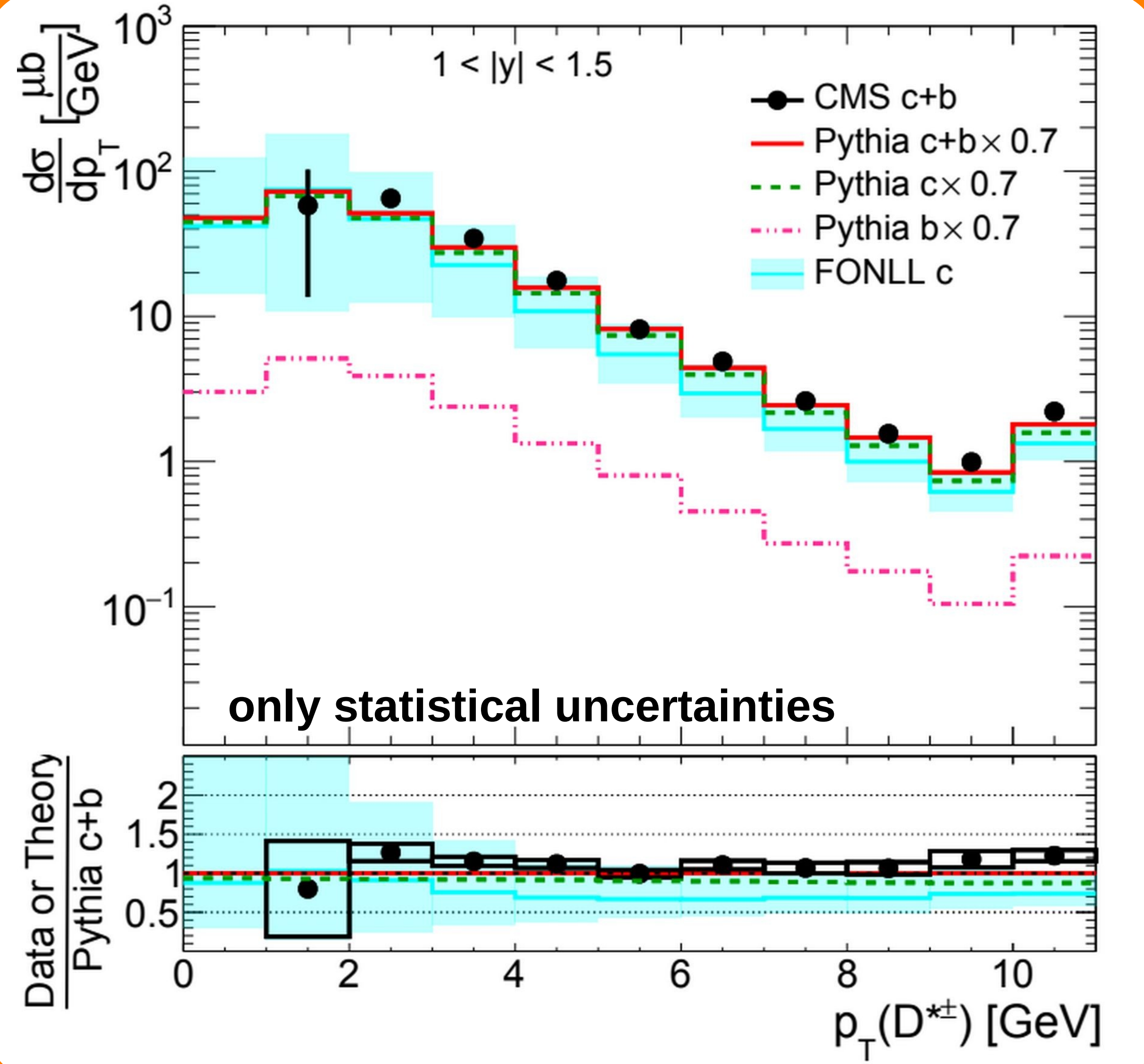
CMS and ALICE results agree ✓

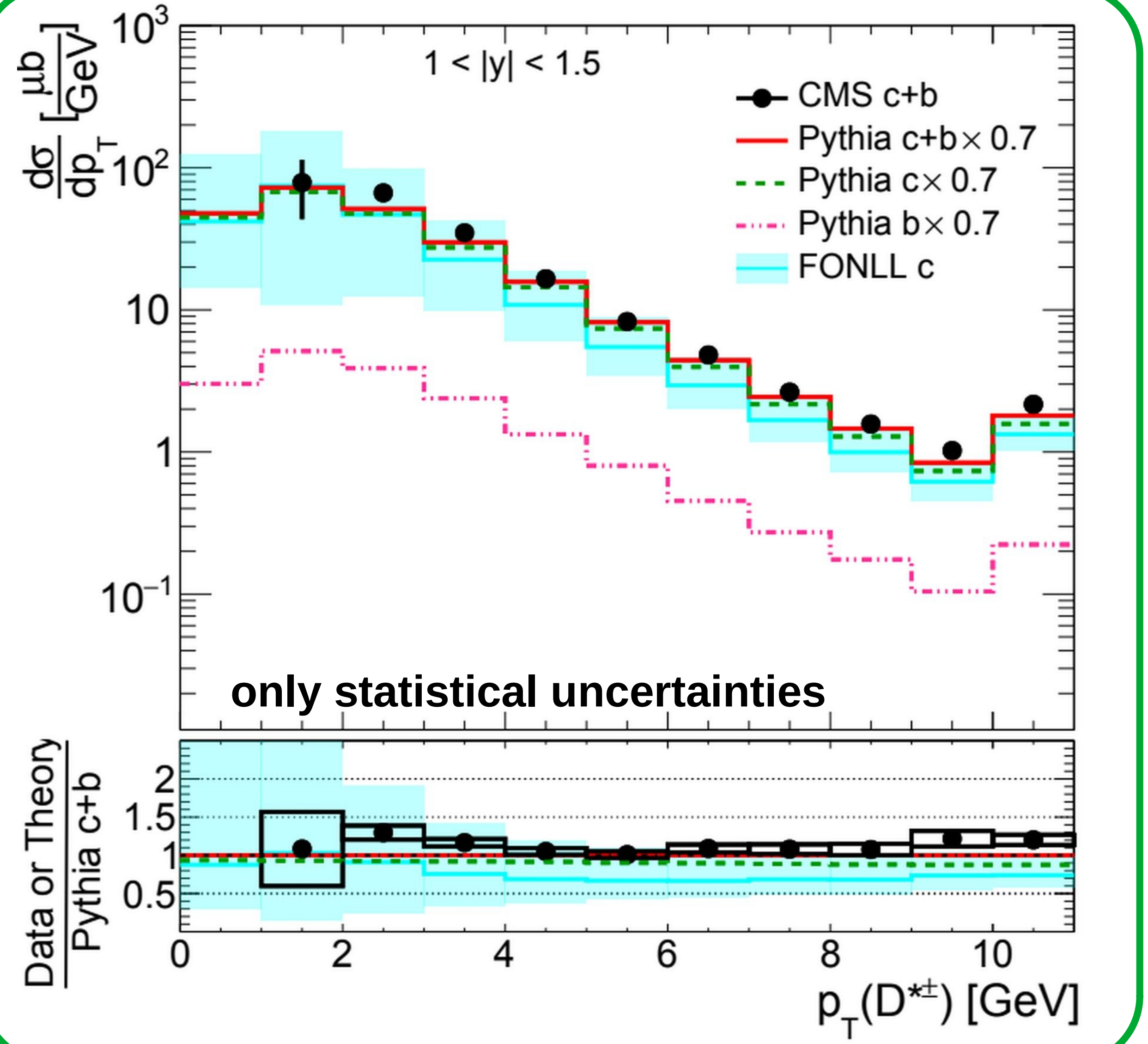
Differential cross section for D* in bins of rapidity



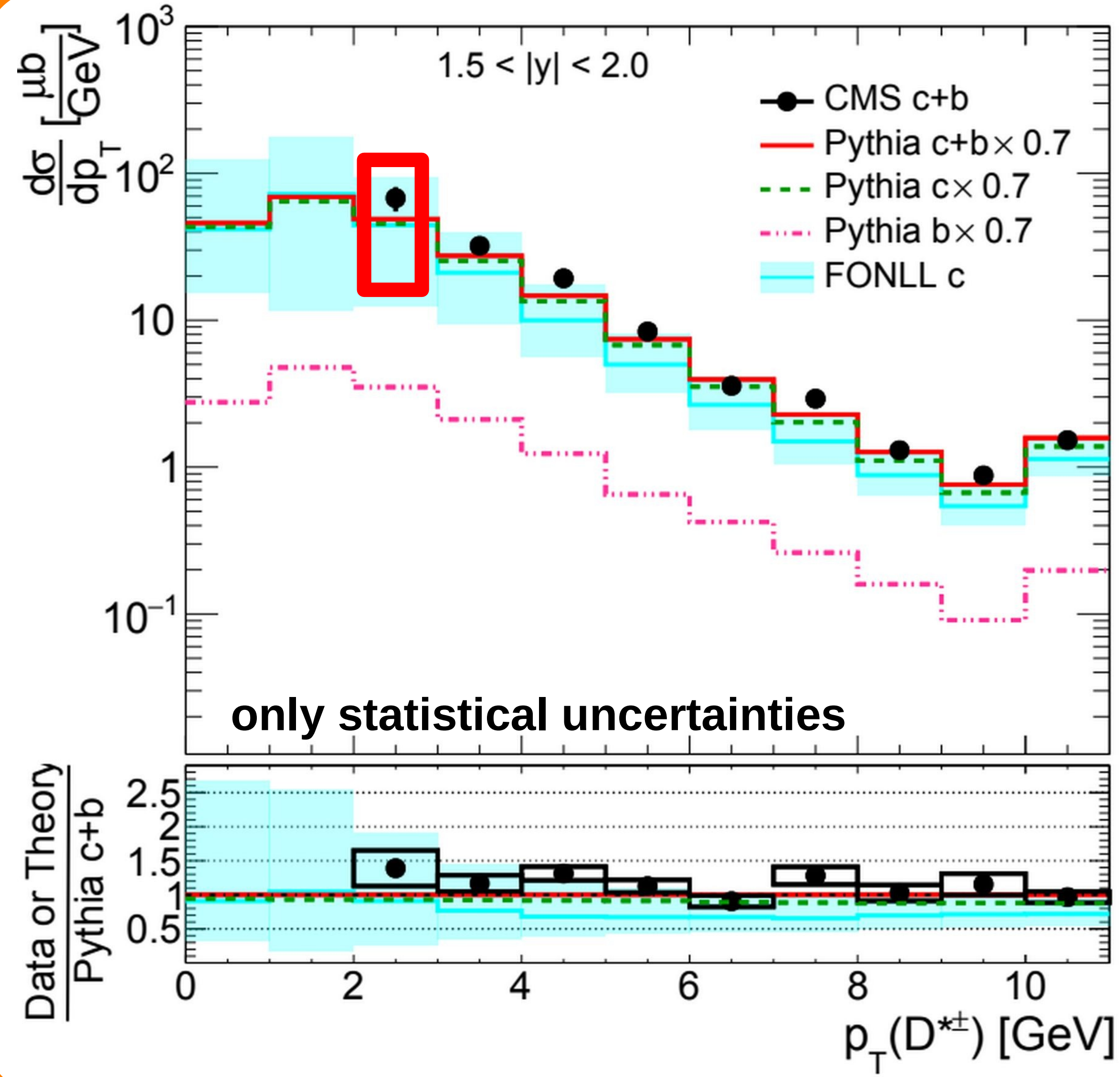


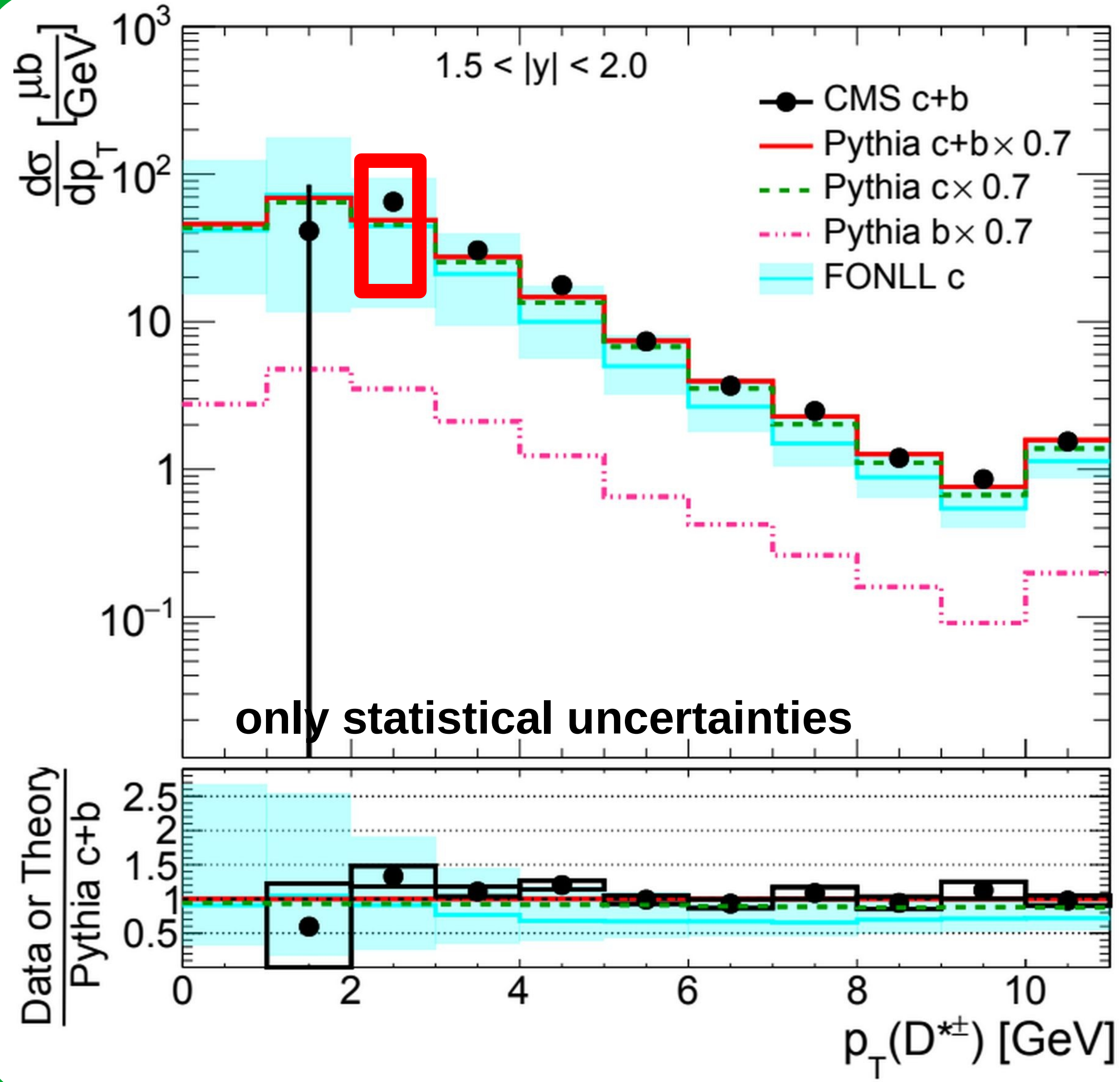
Differential cross section for D* in bins of rapidity





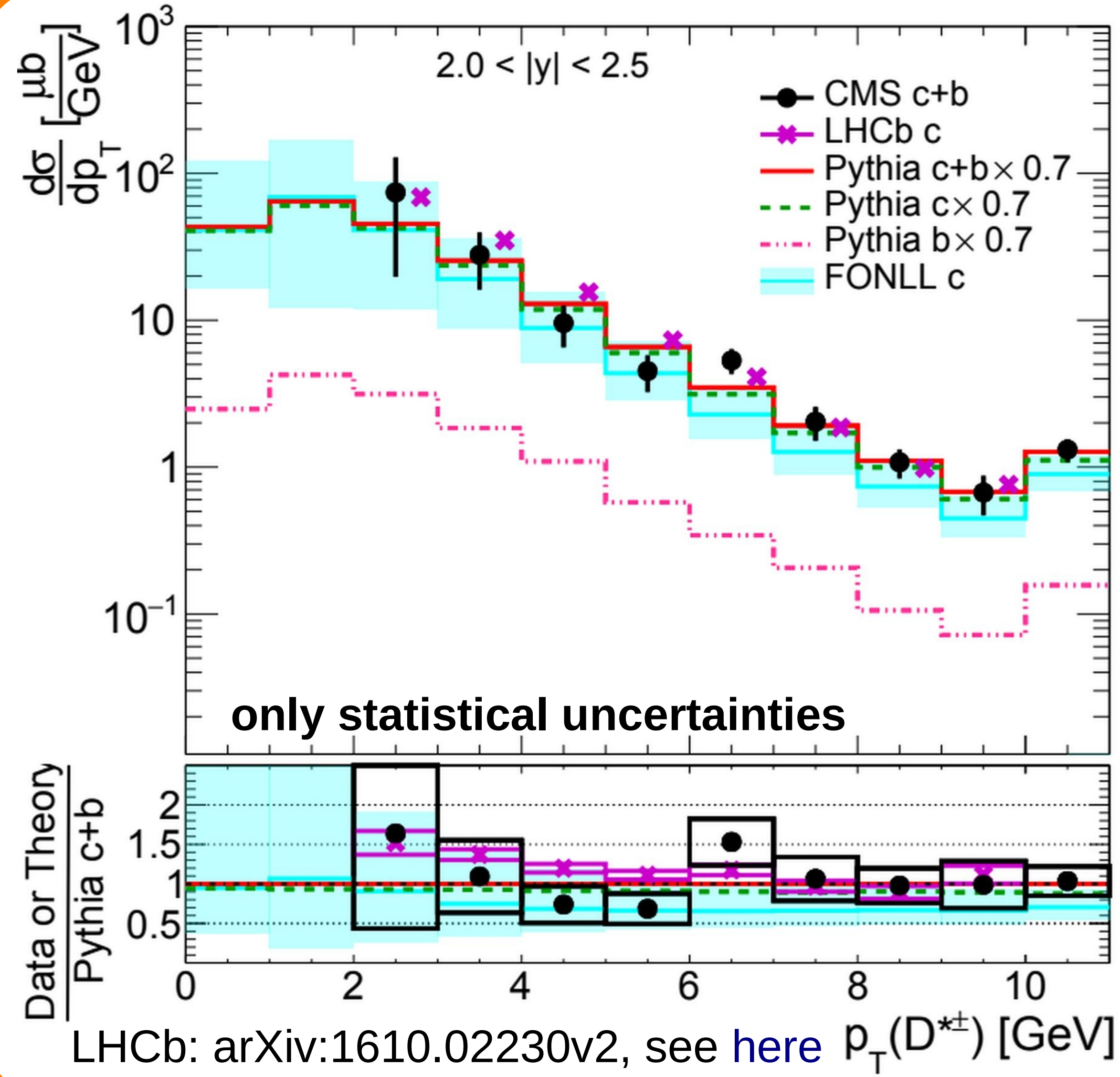
Differential cross section for D* in bins of rapidity



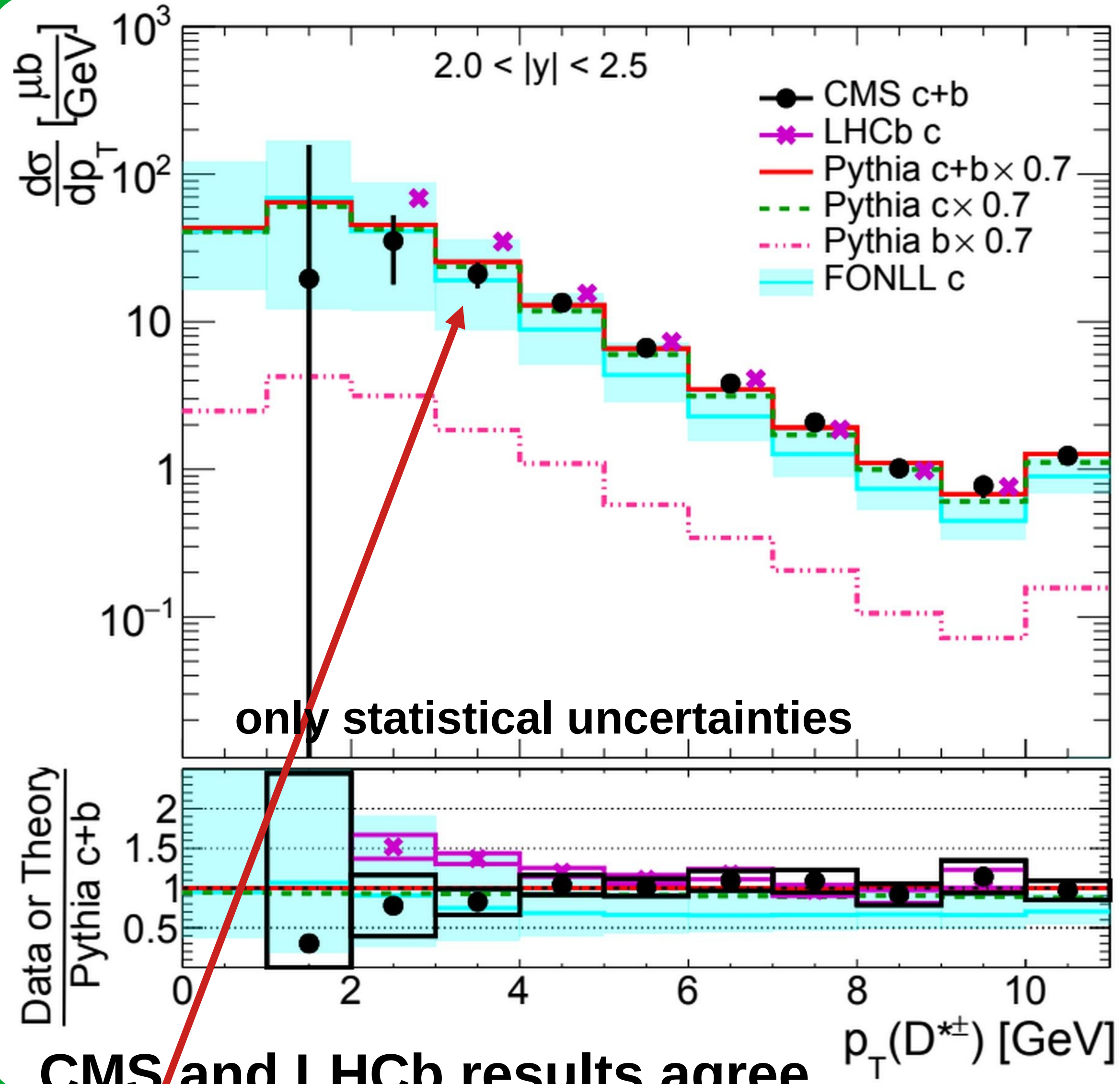


uncertainty decreases

Differential cross section for D* in bins of rapidity



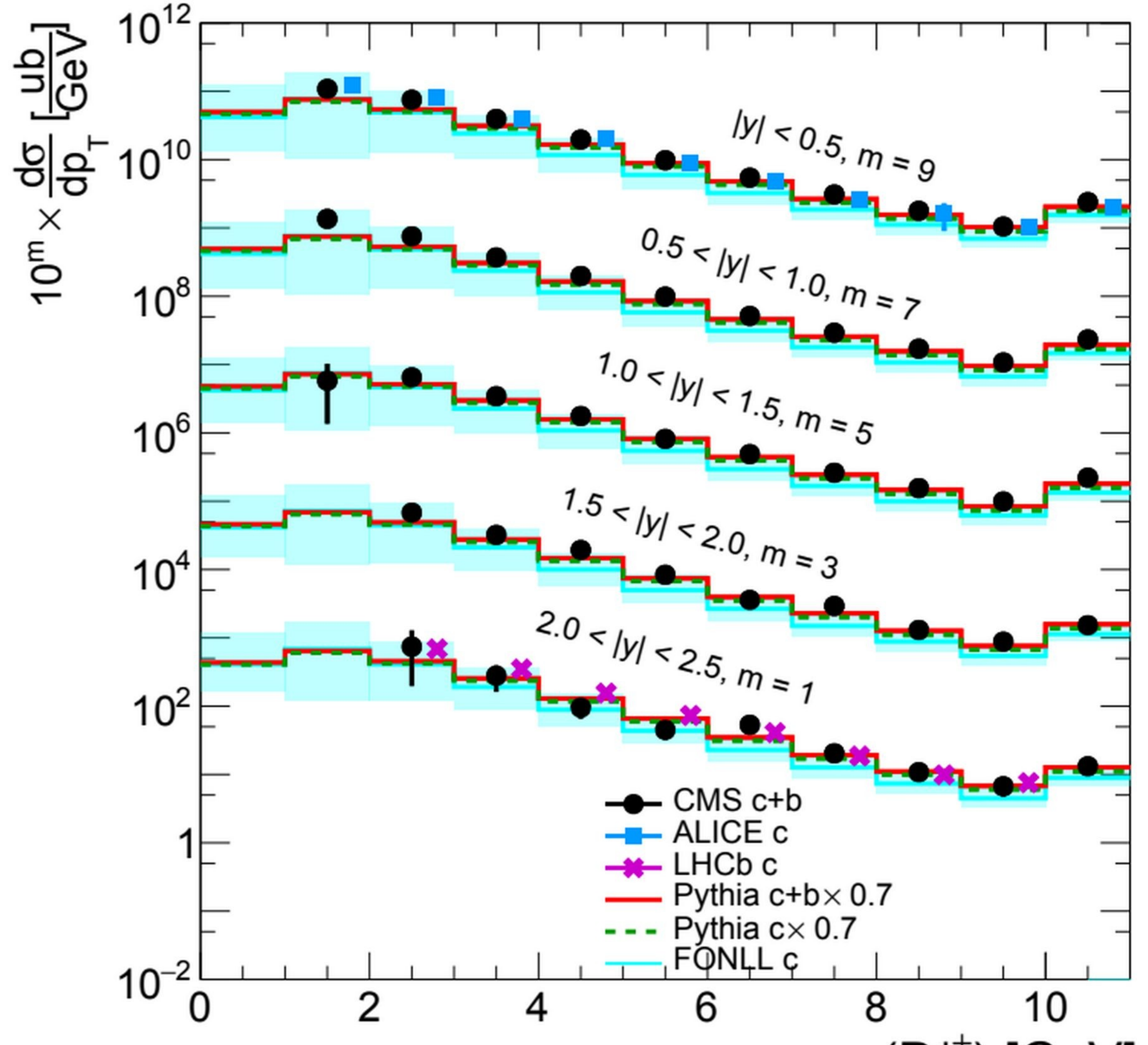
LHCb: arXiv:1610.02230v2, see here



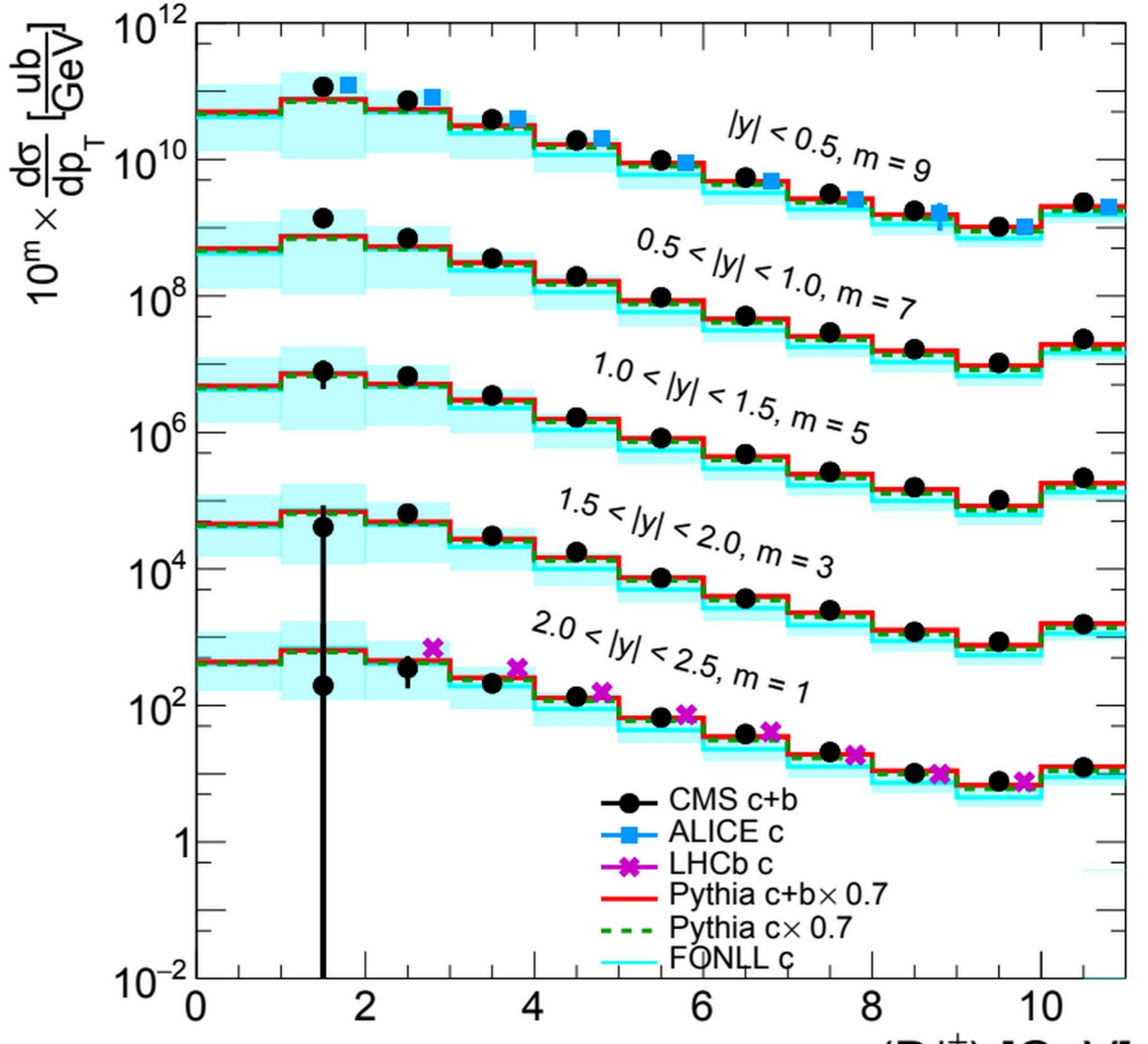
CMS and LHCb results agree

uncertainty decreases

Differential cross section for D* in bins of rapidity

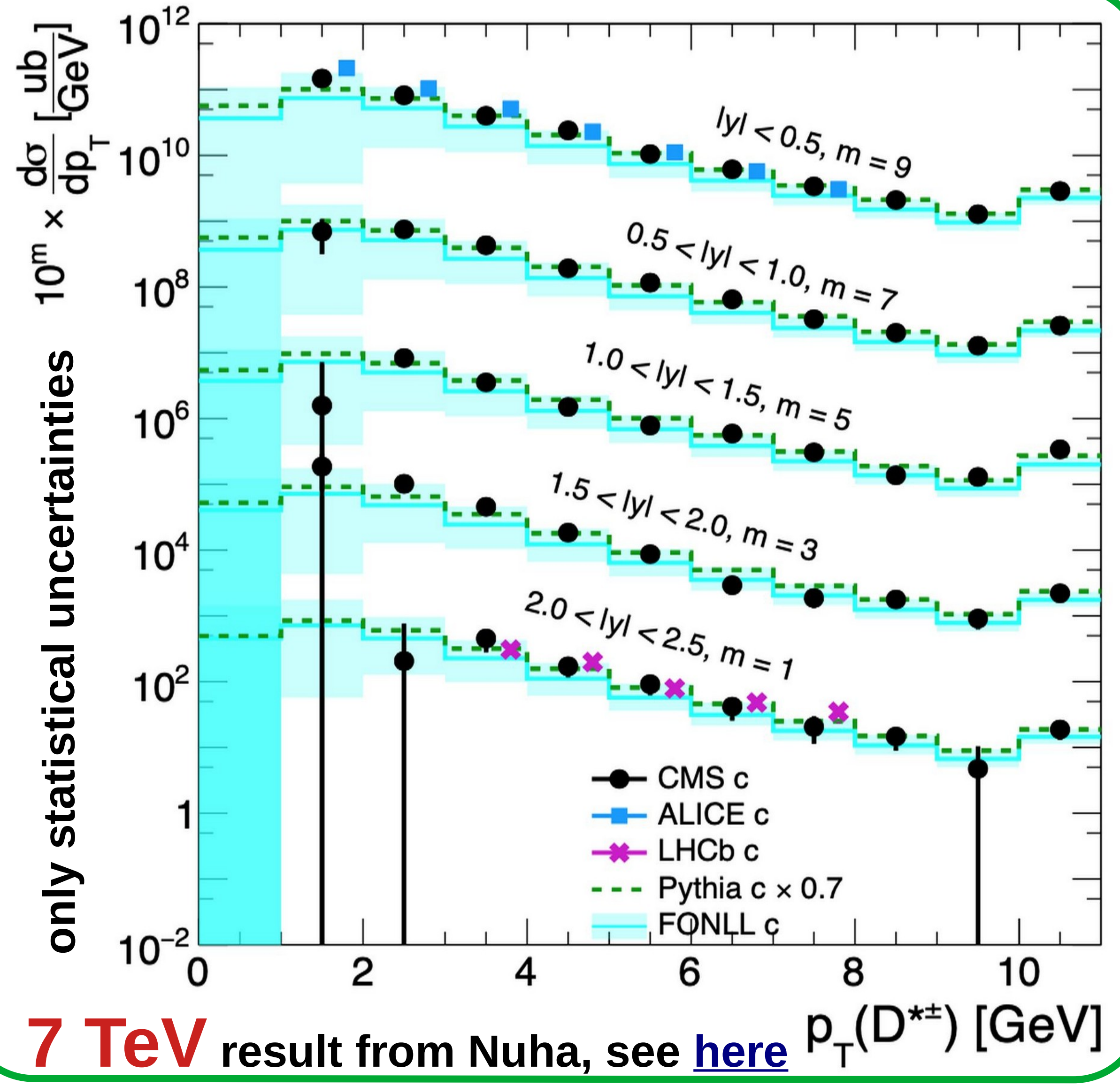


only statistical uncertainties

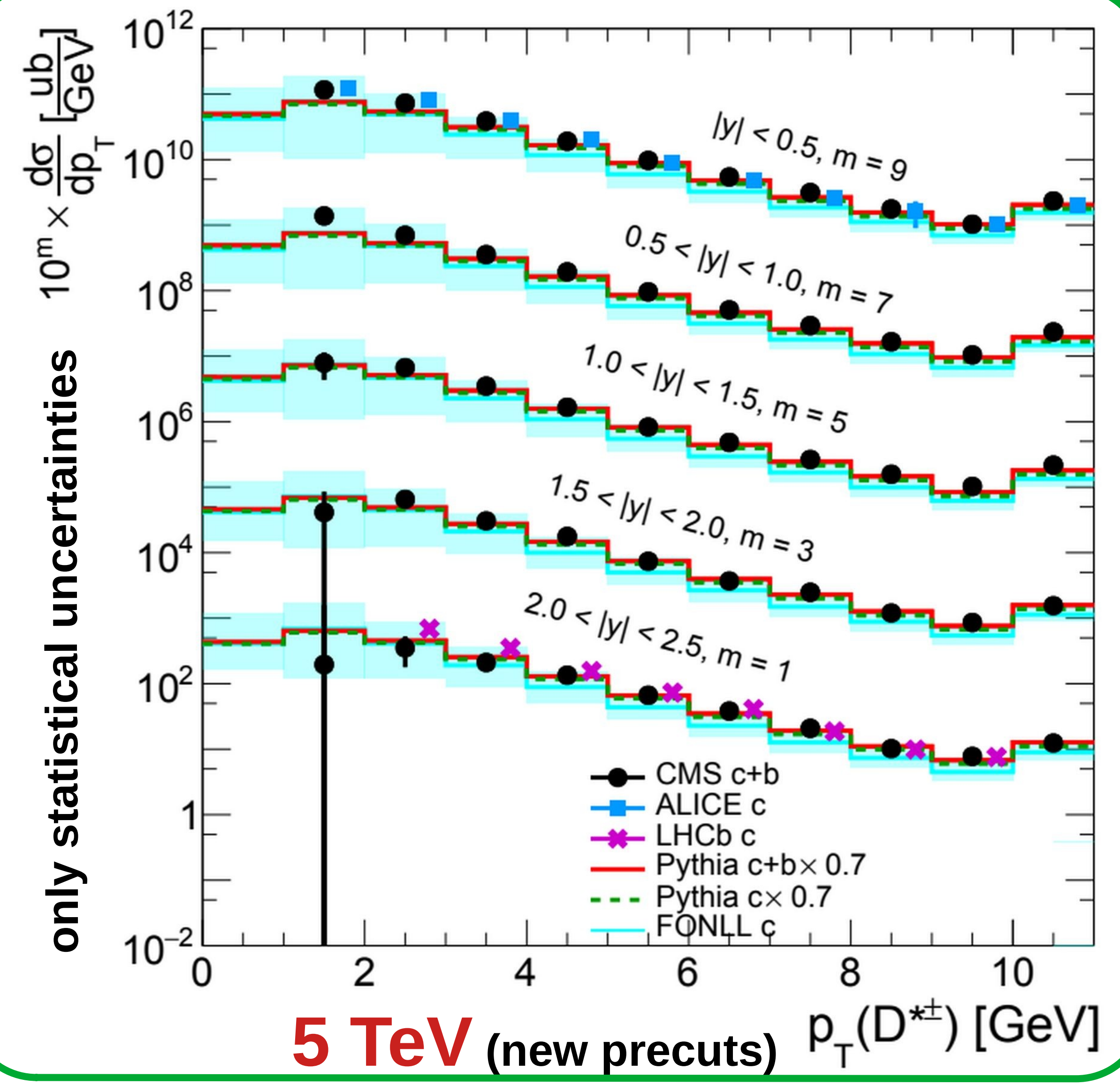


only statistical uncertainties

Differential cross section for D* at 7 TeV and 5 TeV with new cuts



7 TeV result from Nuha, see [here]



5 TeV (new precuts)

Summary

- Measured D mesons $D^{*\pm} \rightarrow D^0 \pi_s^\pm \rightarrow K^\mp \pi^\pm \pi_s^\pm$
- With new cuts we have more signal but also more background
- For some bins in p_T and |y| for instance for 1.5 < |y| < 2.0 we got a measurement (but with large uncertainty) compared to the results with the old cuts

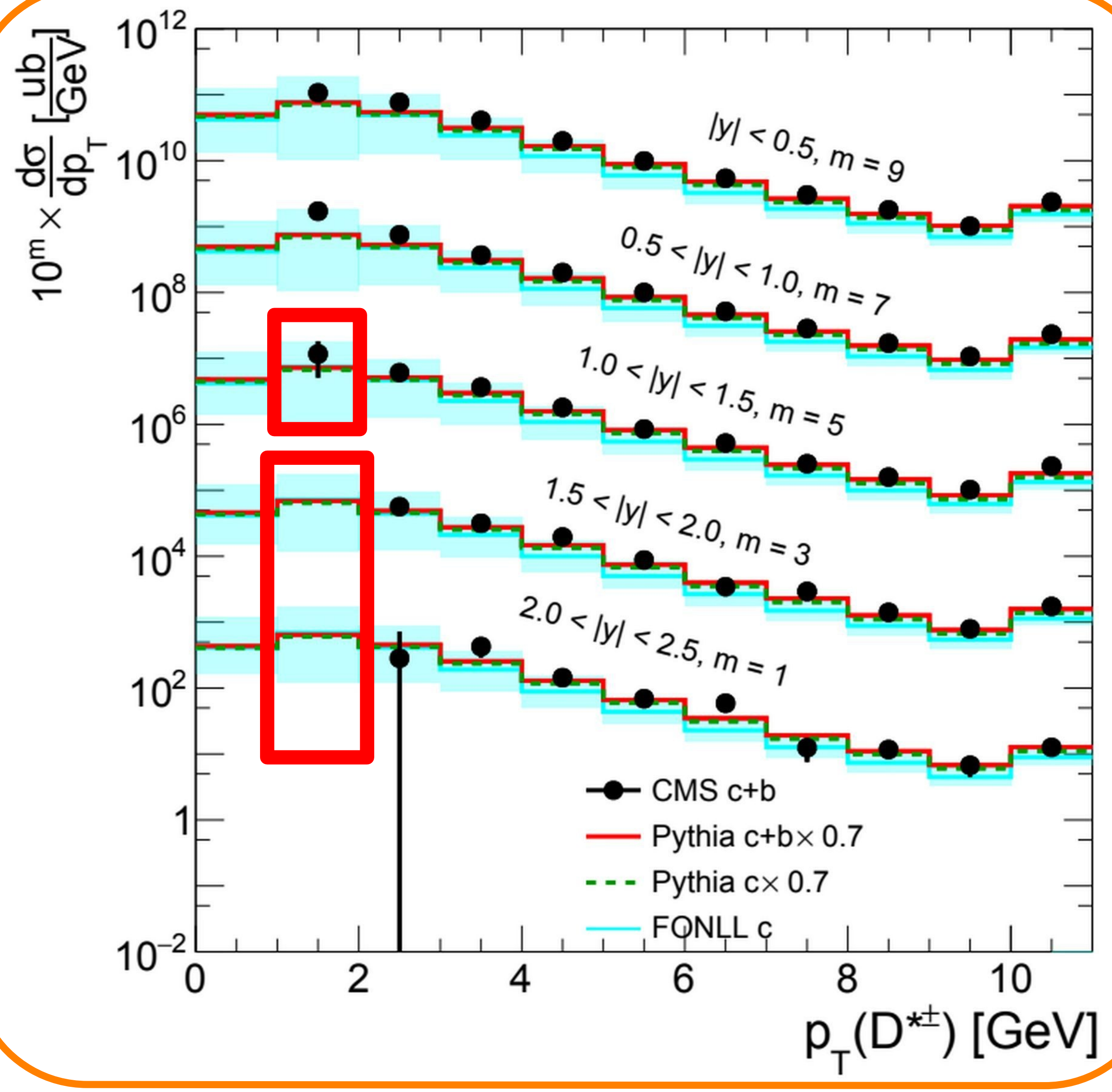
- Agreement with other experiments (ALICE and LHCb) and with theory
- D* cross sections for **5 TeV** and **7 TeV** in agreement

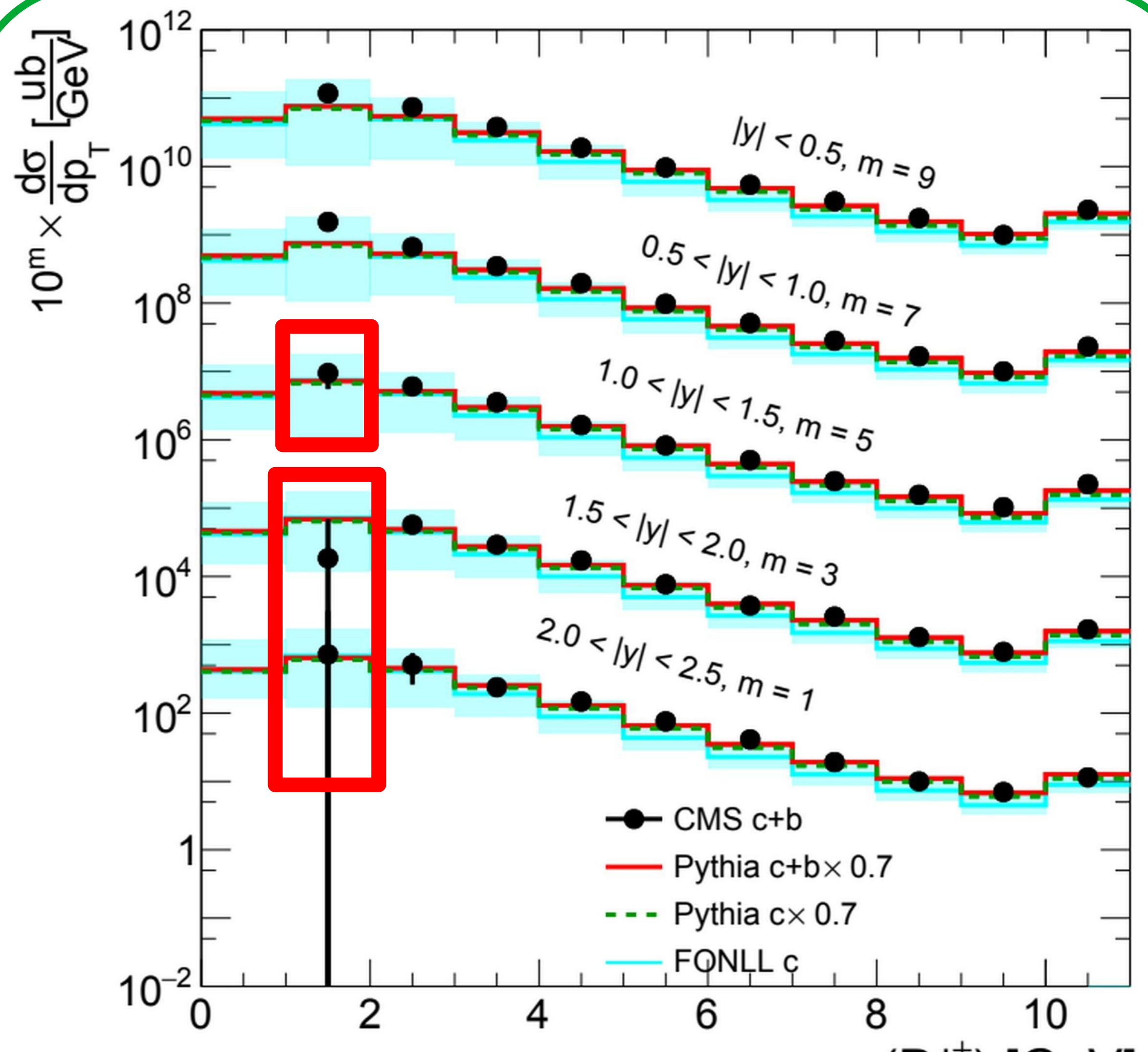
- **Outlook**: separation of prompt/nonprompt D* is in progress

Backup

Now for deltam

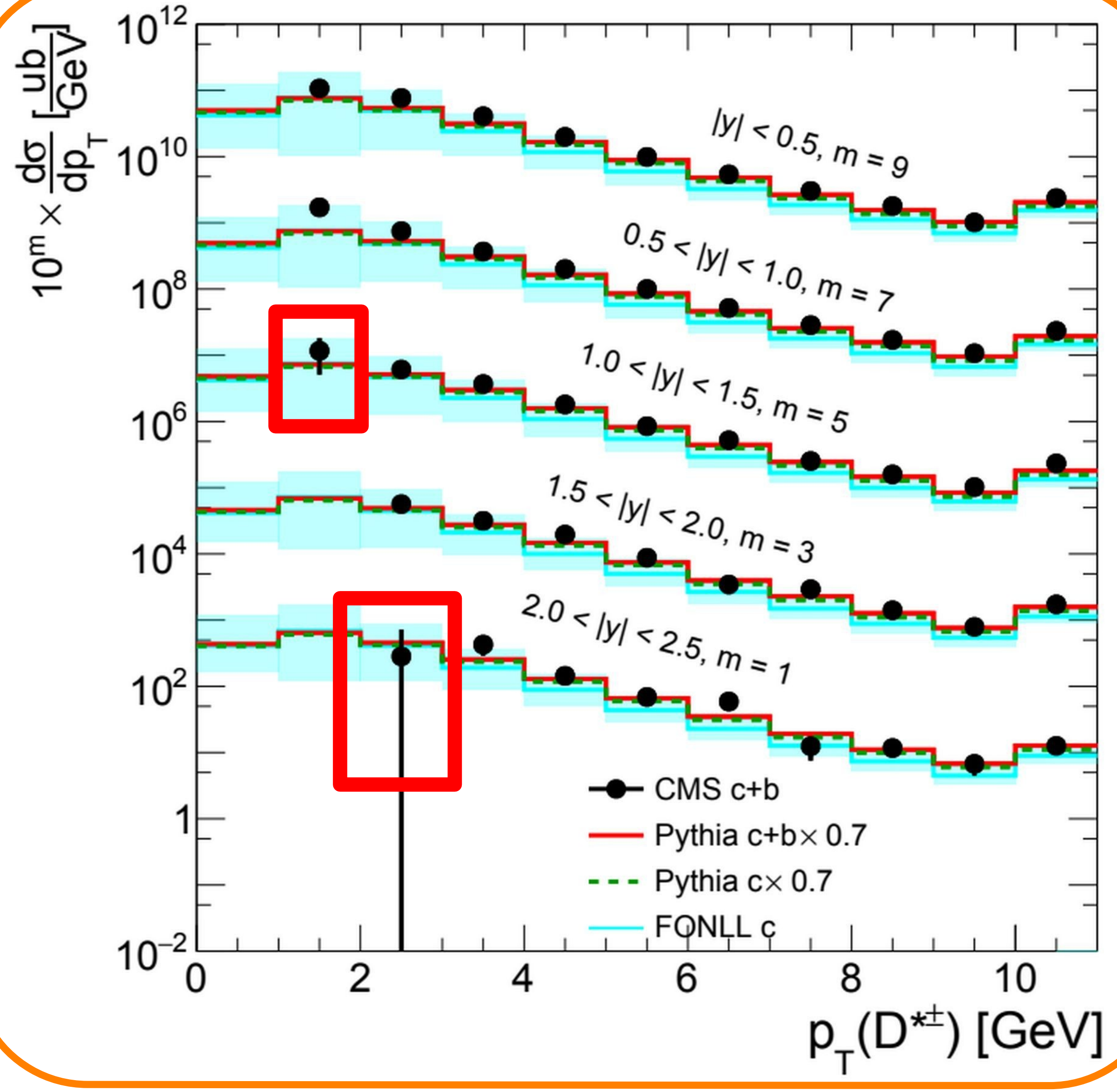
Diff. xsec for D* in bins of rapidity for old/new cuts for deltam

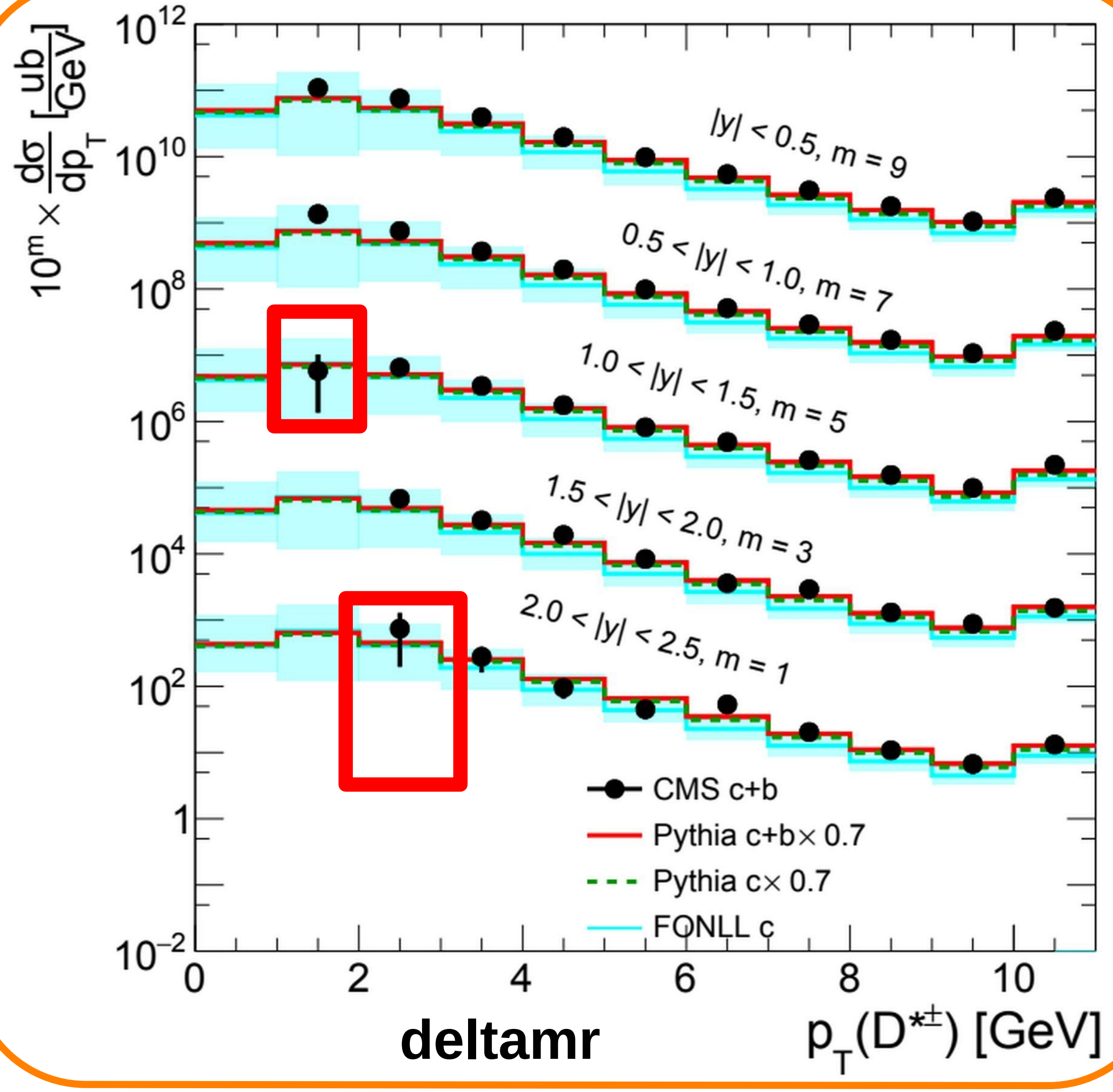




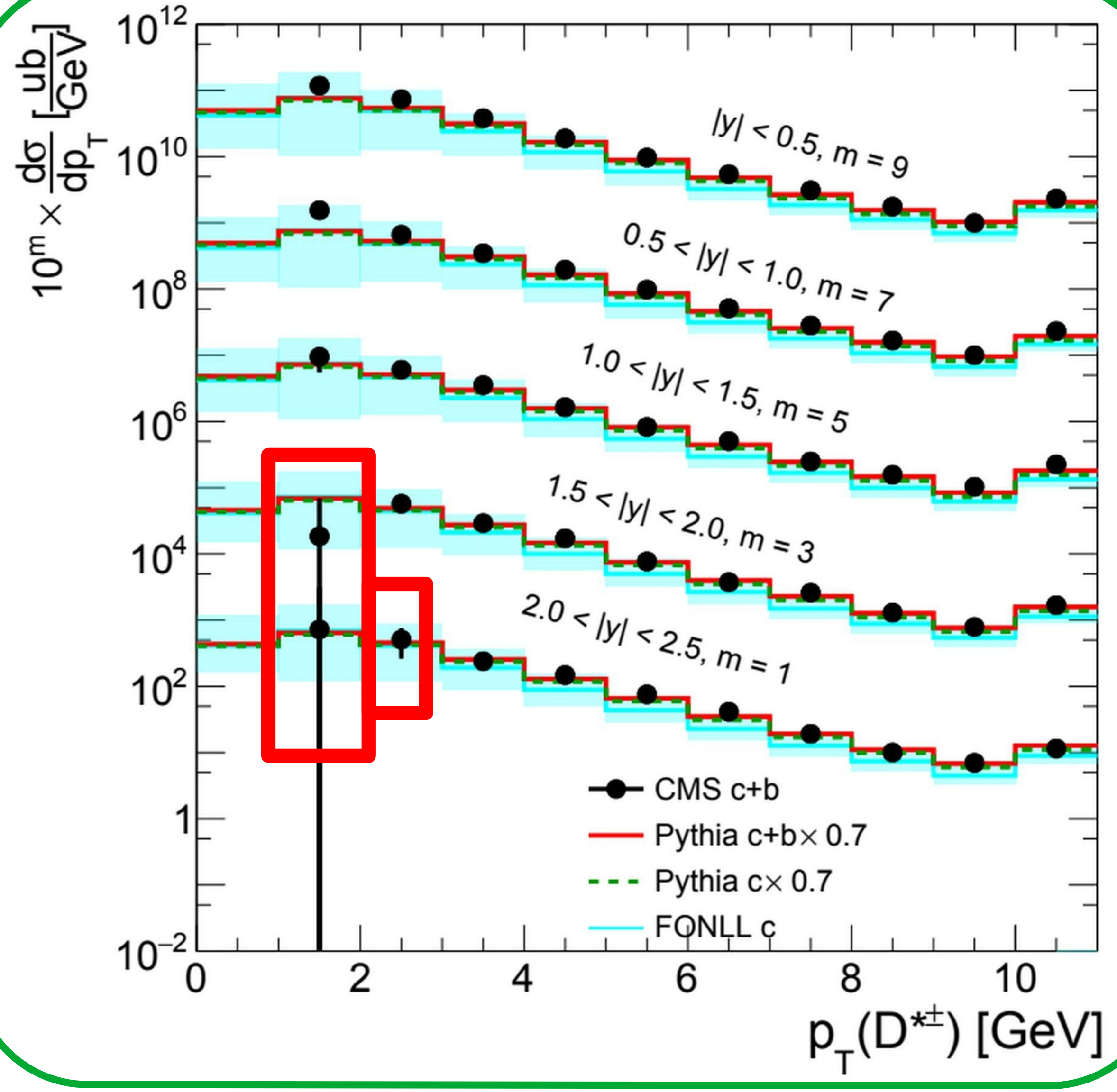
new cuts

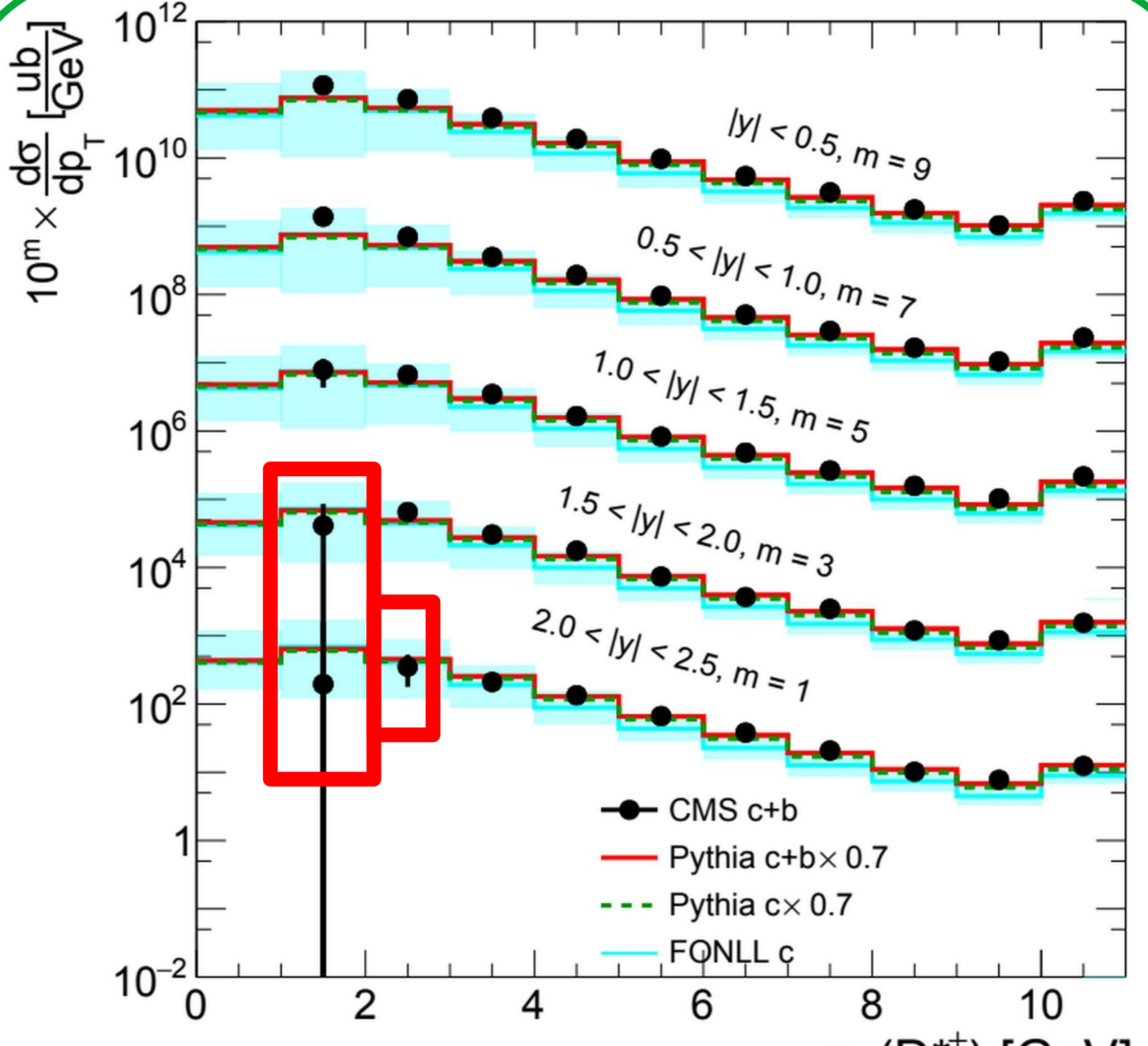
Diff. Xsec for D* in bins of rapidity - old cuts deltam VS deltmar





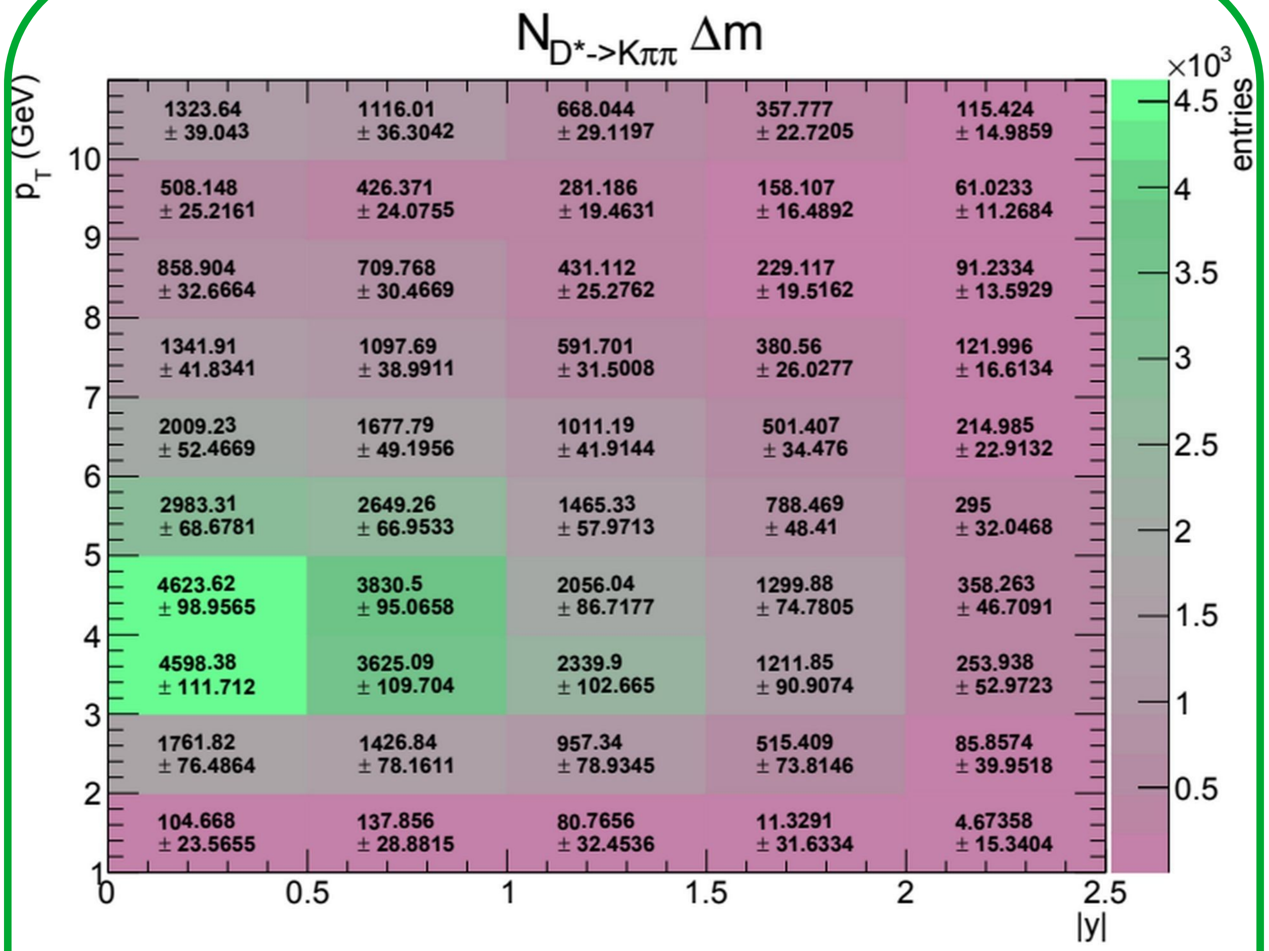
Diff. Xsec for D* in bins of rapidity - new cuts deltam VS deltmar



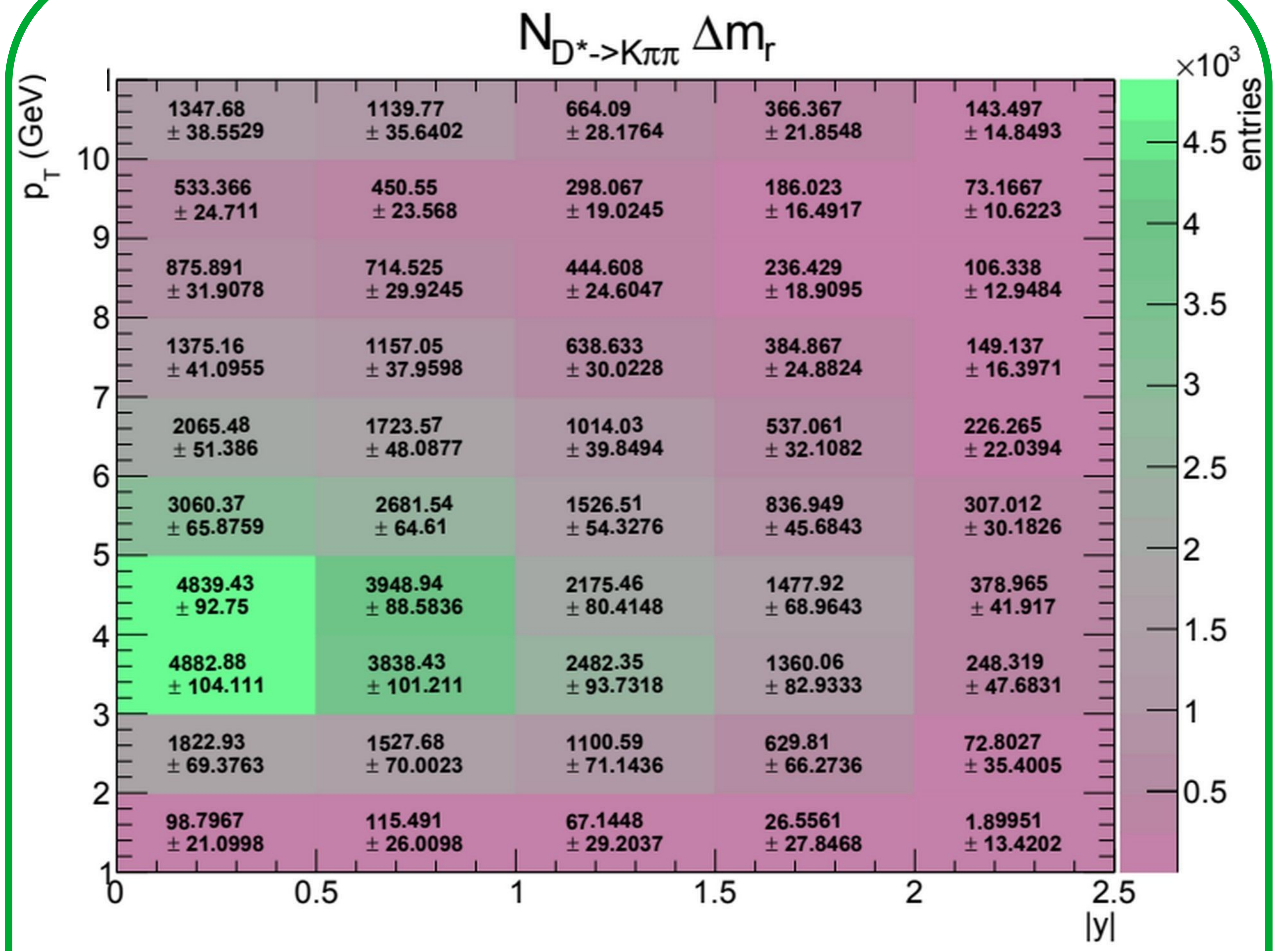


deltamr

Double diff. Signal table for D* - for new cuts deltam VS deltamr



- Signal number and its uncertainty in small bins in p_T and |y| for $D^{*\pm} \to D^0\pi_s^\pm \to K^\mp\pi^\pm\pi_s^\pm$



- Signal number and its uncertainty in small bins in p_T and |y| for $D^{*\pm} \to D^0\pi_s^\pm \to K^\mp\pi^\pm\pi_s^\pm$

Used cuts for the selection of $D^{*\pm} \rightarrow D^0\pi_s^\pm \rightarrow K^\mp\pi^\pm\pi_s^\pm$

the D^* system

right charge	wrong charge
$K^\mp\pi^\pm\pi_s^\pm$	$K^\mp\pi^\mp\pi_s^\pm$
with a real D⁰	comb bg

use both to extract a very clear signal

- Track p_T cut: $p_T^{K,\pi} > 0.5\ GeV$ none for slow pion π_s
- D^0 mass cut: $1.836 < m_{D^0} < 1.892\ GeV$
- We define our cuts in two p_T regions differently:
  - in the **higher** p_T region $p_T^{D^*} > 3.5\ GeV$

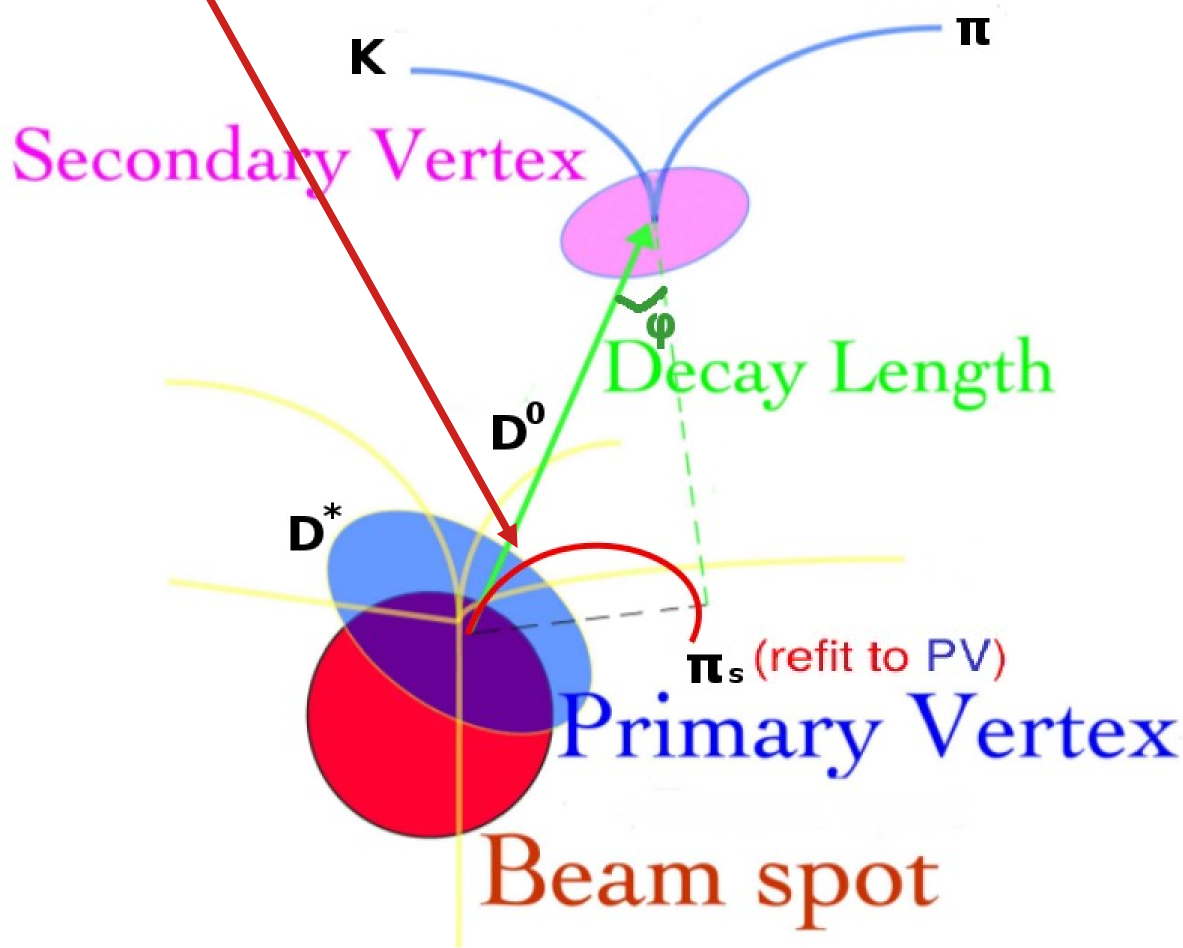
$$\left(dl_{sig}^{D^0} > 0\ \ \&\ \ pt_{Tfrac}^{D^*} > 0.15\ \ \&\ \ \cos(\phi) > 0.8\right)\ or\ dl_{sig}^{D^0} > 2$$

  - in the **lower** p_T region $p_T^{D^*} < 3.5\ GeV$

$$\mathrm{pt}_{Tfrac}^{D^0} > 0.1\ \ \&\ \ \cos(\phi) > 0.8\ \ \&$$

$$\left\{\left(dl_{sig}^{D^0} > 1.5\ \&\ pt_{Tfrac}^{D^*} > 0.15\right)\ or\ \left(dl_{sig}^{D^0} > 2\ \&\ \cos(\phi_{D^0}) > 0.995\right)\ or\ dl_{sig}^{D^0} > 3\right\}$$

- With: $p_{Tfrac} = \dfrac{p_T\ of\, D\, meson}{p_T\ of \Sigma_{\text{at respective PV}}^{\text{all tracks}}}$ $\qquad dl_{sig}^{D^0} = \dfrac{dl^{D^0}}{dl_{err}^{D^0}}$



Fixed Order Next to Leading Log

- We used FONLL for the prediction of heavy quark production and chose D* as hadronic final state
- We used the following set of parameters for charm production
  - the fragmentation factor for charm $f_c = 0.236$
  - the PDF set CTEQ6.6 (PDF uncertainty summed in quadrature to mass und scale uncertainty)
  - central value for mass $m_c = 1.5$ GeV (mass uncertainty $m_c = 1.3$, 1.7 GeV summed in quadrature to scales uncertainties)
  - central value $\mu_R = \mu_F = \mu_0 = \mathrm{sqrt}(m^2 + p_T^2)$
  - scale uncertainties: $\mu_0/2 < \mu_R$ and $\mu_F < 2\mu_0$ with $1/2 < \mu_R/\mu_F < 2$
- We variate the mass, PDF, renormalisation and factorization scale

  and got an uncertainty band by the lower and upper values of

  this variation

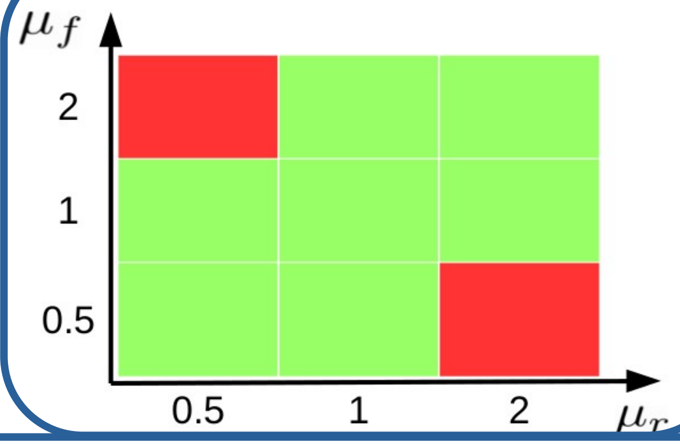


Illustration of the seven combinations of the variation of the renormalisation scale μ_r and factorization scale μ_f