Combined charm cross section in pp collisions @ 5.02 TeV

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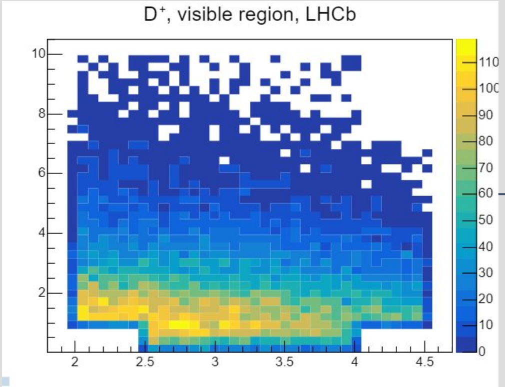
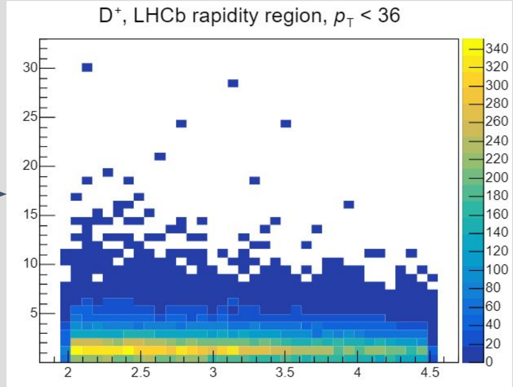
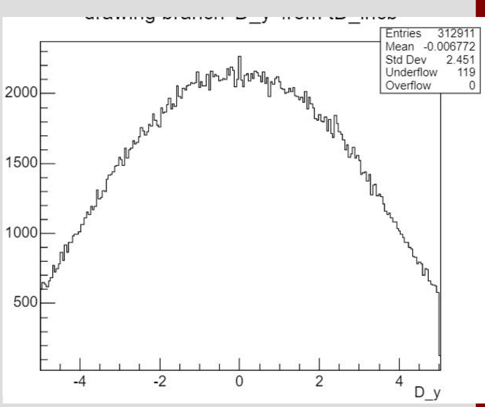
Reminder: Extrapolation strategy, updates from last HonexComb meeting

- Extrapolation of each hadron species (D^0, D^+, D^{*+}, Λ_c , Ξ_c) separately:
  - ➞ extrapolate measured points in each rapidity bin from visible range to $0 < p_T < 36$ GeV/c
  - ➞ Integrate experiment and multiply by Extrapolation factor: $\sigma_{\text{full pT}}^{\text{pyth}}(X)|_{y(\text{exp})}$ / $\sigma_{\text{visible}}^{\text{pyth}}(X)|_{y(\text{exp})}$: e.g.:







  - ➞ Then interpolate / extrapolate in y (up to y = 8)
  - ➞ Sum contributions from all species to obtain total cross section
- Extrapolation uncertainty: re-estimate full chain of extrapolation using alt. setting (different charm mass, **Monash tune**) and compare final cross section

- Experimental uncertainties propagated considering p_T-dependent correlations within each experiment
- Systematic uncertainty for possible contribution from Ω_c included (asymm. uncertainty, = cross-section of Ξ_c^+, same strategy as used by ALICE in PRD 105,L011103(2022)

Extrapolation uncertainties: The Monash tune

- Largest extrapolation is Λ_c , Ξ_c in rapidity due to no LHCb coverage at $\sqrt{s}$ = 5.02 TeV (factor ~7.3 in y), all other species factor ~1.8 in y (interpolating between mid- and forward rapidity)

```
Interpolation factors:  D0  1.85259
 D+  1.85614
 Ds  1.86184
 Lc  7.95966
 Xc  7.40202
```

- extrap factors in p_T (after "extrap")

```
visible LHCb D0 67865 full 68316 extrap 1.00665
upper mass 62097 full 62495 extrap 1.00641
lower mass 75110 full 75573 extrap 1.00616
Warning in <TCanvas::Constructor>: Deleting canvas with same name: c2
visible LHCb D+ 27063 full 30459 extrap 1.12548
upper mass 24626 full 27745 extrap 1.12665
lower mass 30571 full 34283 extrap 1.12142
Warning in <TCanvas::Constructor>: Deleting canvas with same name: c2
visible LHCb Ds 7686 full 11453 extrap 1.49011
upper mass 6975 full 10422 extrap 1.49419
lower mass 8474 full 12468 extrap 1.47132
```

```
visible ALICE Ds  5345 full 7136 extrap 1.33508
high ALICE Ds  4968 full 6579 extrap 1.32428
low ALICE Ds  6024 full 8005 extrap 1.32885
Warning in <TCanvas::Constructor>: Deleting canva
visible ALICE Lc  14654 full 20255 extrap 1.38222
high  ALICE Lc  13390 full 18451 extrap 1.37797
low ALICE Lc  16648 full 23334 extrap 1.40161
Warning in <TCanvas::Constructor>: Deleting canva
visible ALICE Xc  857 full 2320 extrap 2.70712
high  ALICE Xc  730 full 2045 extrap 2.80137
low ALICE Xc  909 full 2633 extrap 2.89659
```

→ Added Monash tune to give more realistic extrapolation uncertainties

Major difference between two options is fraction of Xi_c after extrap with Monash:

```
Fragmentation fractions:
D0: 0.395622
Dp: 0.162618
Ds: 0.0709345
Lc: 0.210113
Xc: 0.0803563
```

CR mode2

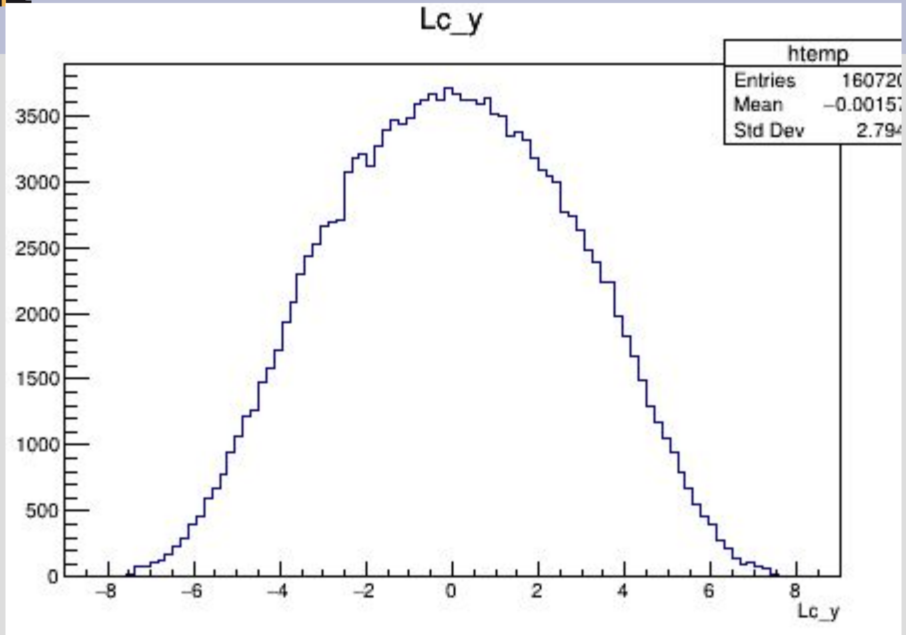
```
Fragmentation fractions:
D0: 0.419626
Dp: 0.171374
Ds: 0.0699354
Lc: 0.21997
Xc: 0.0595471
```

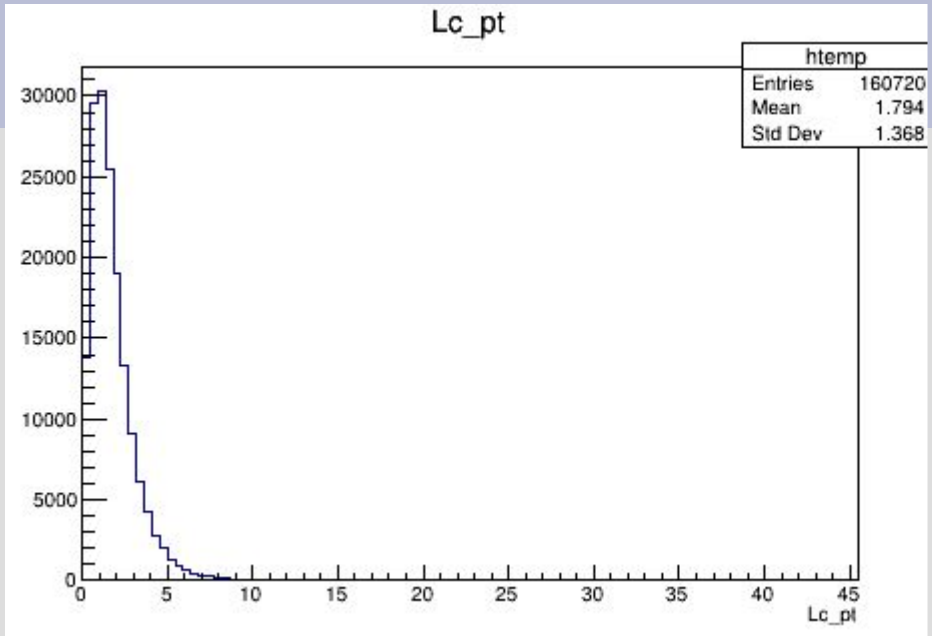
Monash

⇒ 8% lower total cross section with Monash extrapolation than central CR2

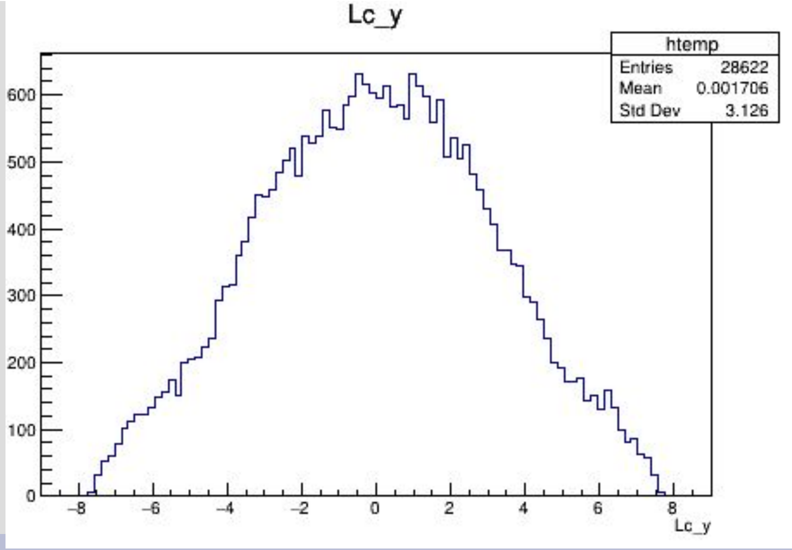
→ Some effects visible on baryon distributions using Monash (see next slides)

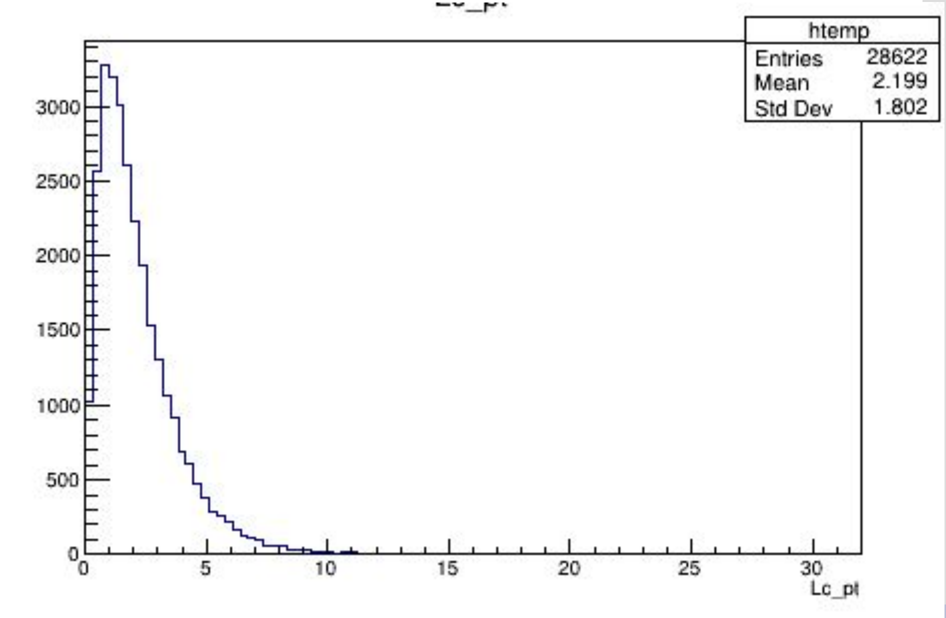
PYTHIA Lc baryon spectra





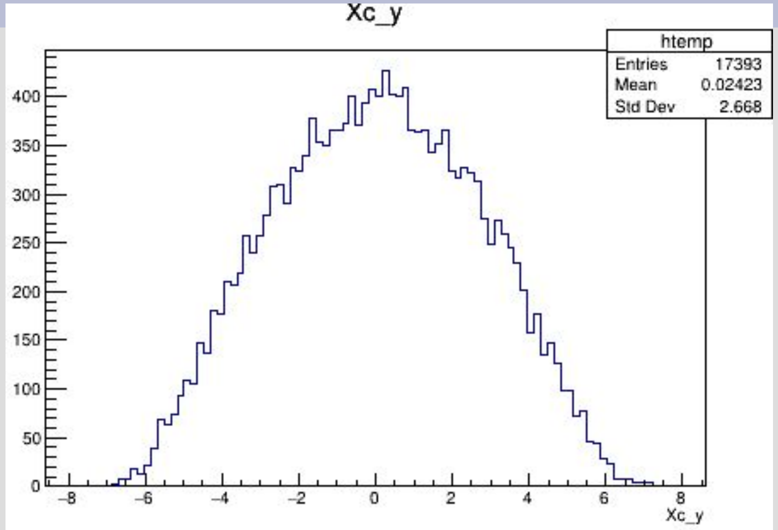
CR mode2

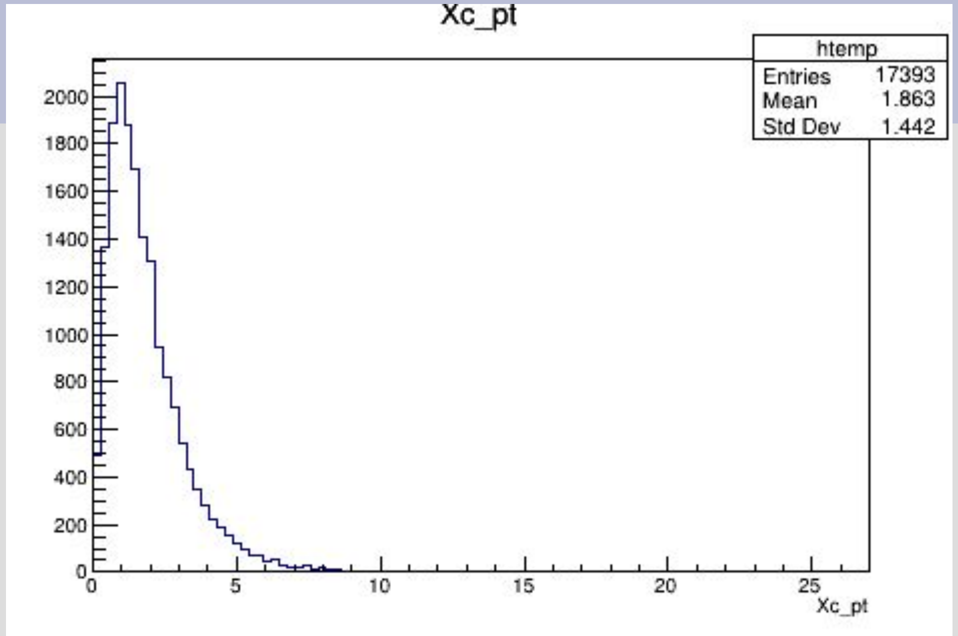




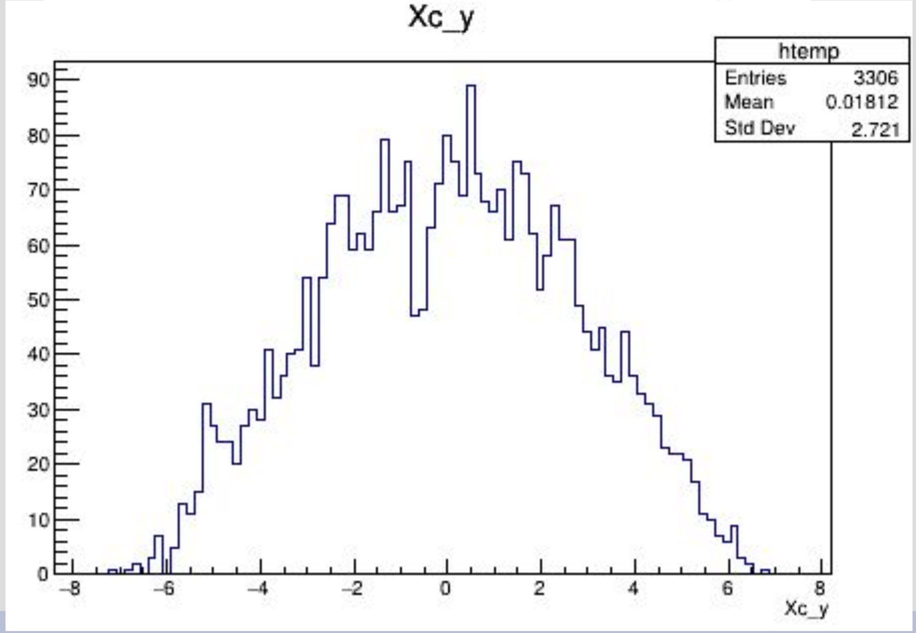
Monash

PYTHIA Xic baryon spectra

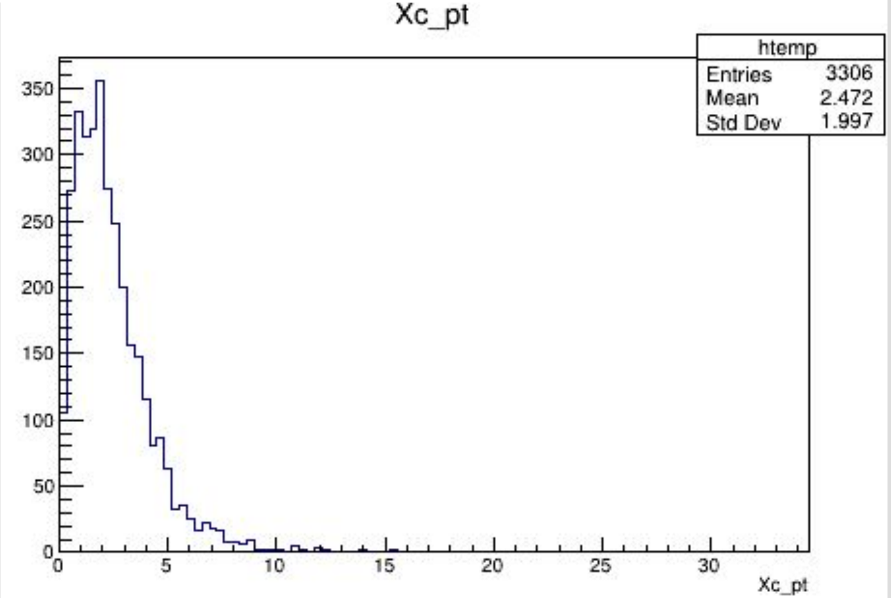




CR mode2



Monash



Extrapolation results

- Result (orange) compared with full FONLL uncertainty band for bare ccbar production in same rap. region (black)
- stat. uncertainty as bar; syst. as orange box; extr. unc in red

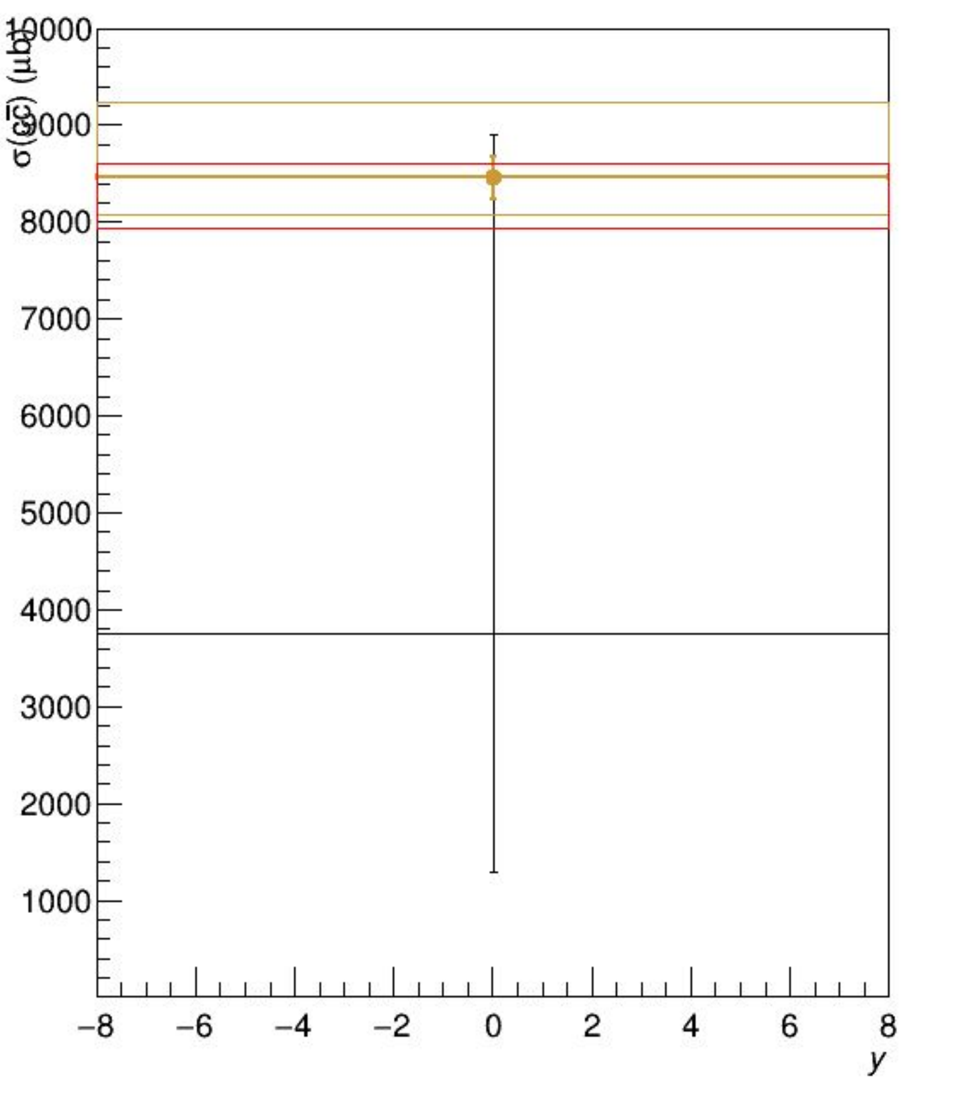
$$8460.99 \pm 220.053\,(\text{stat.})\,^{+379.762}_{-379.868}\,(\text{syst.})\,^{+136.454}_{-519.46}\,(\text{extr.})\,+679.894\,(\Omega_c)$$

⇒ lower bound of extrap. uncertainty comparable with systematics from data

⇒ Ω_c contribution plotted as part of systematic band but quoted separately in text

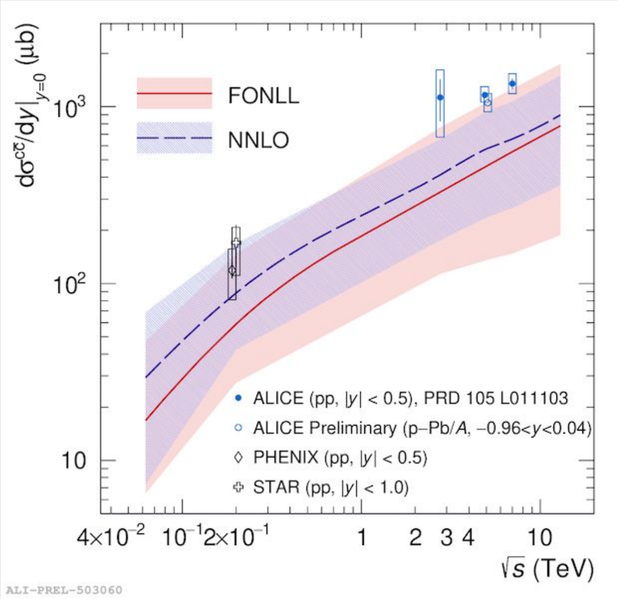
⇒ Hadronisation ratios remain consistent with published values from ALICE at mid-rapidity for all species

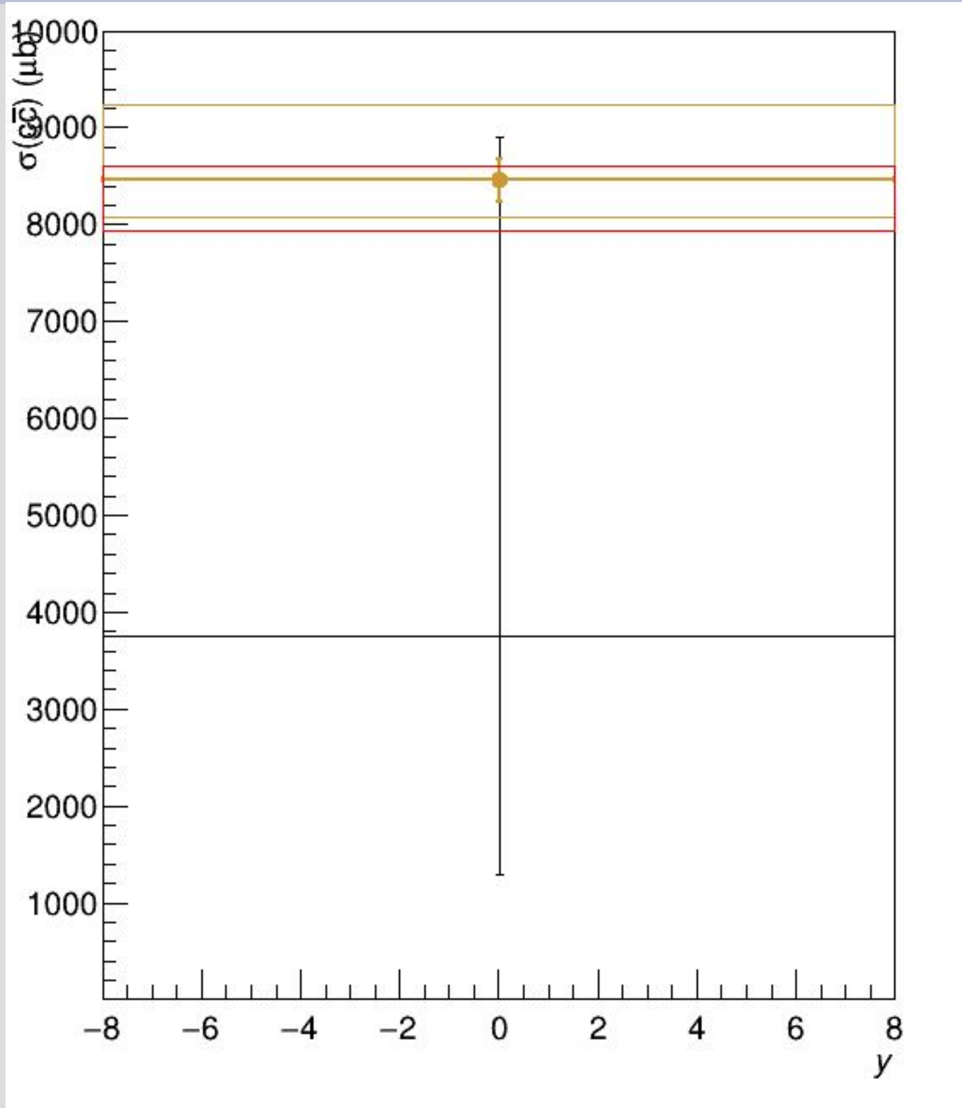
H_c	ALICE (published, |y| < 0.5)	Honexcomb (extrap., |y| < 8)
D^0	$39.1 \pm 1.7\,^{+2.5}_{-3.7}$%	39.7 %
D^+	$17.3 \pm 1.8^{+1.7}_{-2.1}$%	16.4 %
D_s^+	$7.3 \pm 1.0^{+1.9}_{-1.1}$%	7.03 %
Λ_c^+	$20.4 \pm 1.3^{+1.6}_{-2.2}$%	20.8 %
Ξ_c^0	$8.0 \pm 1.2^{+2.5}_{-2.4}$%	7.9 %



Extrapolation results

- Result (orange) compared with full FONLL uncertainty band for bare ccbar production in same rap. region (black)
- As expected from general results of cross section vs $\sqrt{s}$ from multiple experiments, extrapolated cross section is far into the upper band of FONLL calculations





Publication status

- First draft close to complete
  - → Explanation of datasets, fitting of central mass value for PYTHIA calculations, discussion of extrapolation strategy and comparison of final result with pQCD
  - → Some extrapolation details + final results to be added, plus plotting style for final results (possible comparison with general σ_{cc} vs $\sqrt{s}$ plot from ALICE)
  - → General editing pass to be done
  - → Plan to submit early in New Year

Combination of charm measurements from the ALICE, CMS and LHCb experiments in *pp* collisions at $\sqrt{s} = 5.02$ TeV

Abstract

Open charm production in proton-proton collisions represents an important tool to investigate some of the most fundamental aspects of Quantum Chromodynamics, from the partonic mechanisms of heavy-quark production to the mechanisms of heavy-quark hadronisation. Over the last decade, the measurement of the production cross sections of charmed mesons and baryons in proton-proton collisions was at the centre of a wide experimental effort at the Large Hadron Collider. Thanks to the complementarity of the different LHC experiments, the production of charmed hadrons was measured over a wide transverse momentum region and at different rapidities. In this paper, the measurements of five of the most abundant charmed hadrons D^0, D^*, D^+, D_s^+ and Λ_c^+ performed by ALICE, CMS and LHCb at the centre-of-mass