Measurements of open charm production with LHCb

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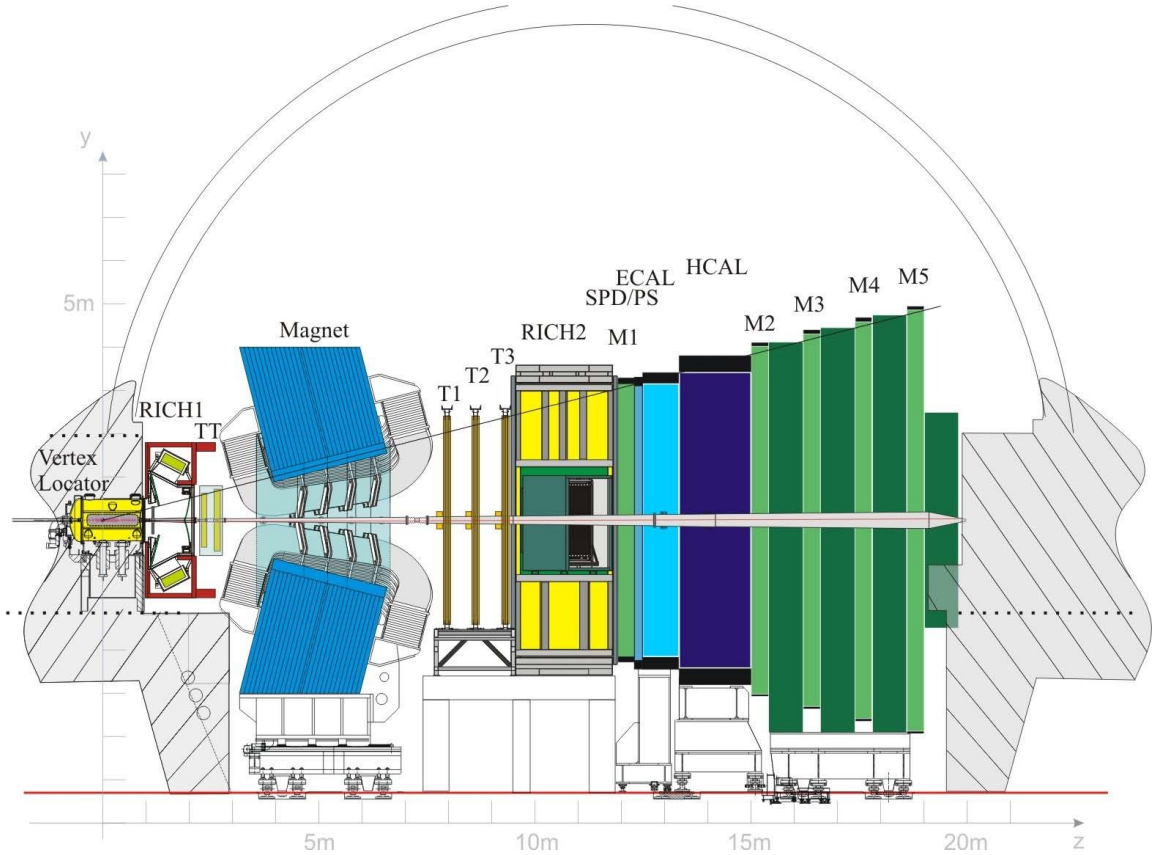
Outline

Introduction

- measurement of prompt[1] open charm cross section
- in pp collisions at $\sqrt{s} = 7$ TeV
- species: D^0, D^+, D^{*+} and D_s^+, including anti-particles
- kinematic range is
  transverse momentum: $(0 < p_T < 8)$ GeV
  rapidity: $2 < y < 4.5$
- in bins of y and p_T

[1] direct production or via non-weak decay

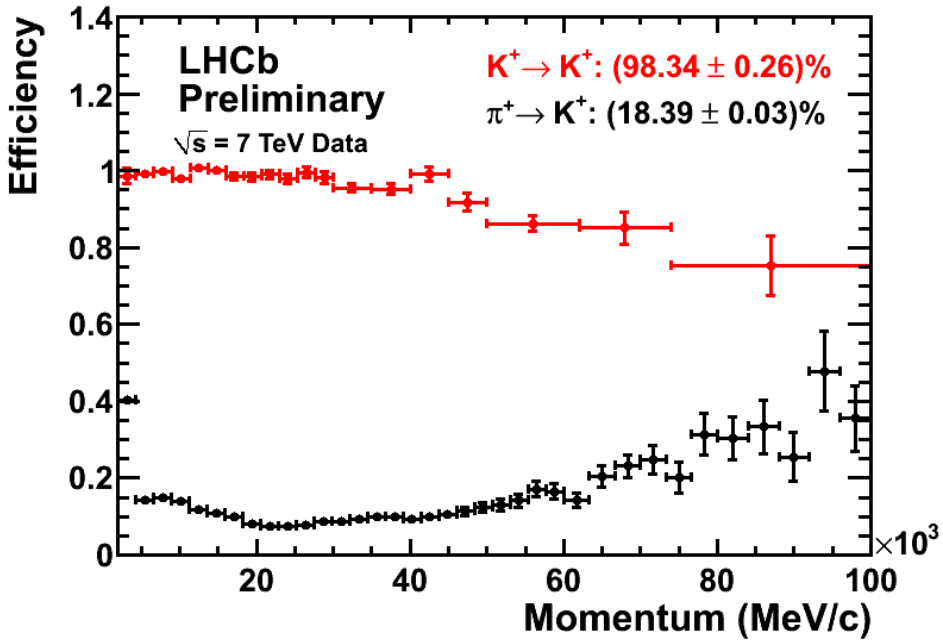
The LHCb detector



- precise measurements of CP violation and rare decays
- forward spectrometer $\rightarrow$ unique kinematic range at LHC
- excellent vertex resolution & particle identification (PID)

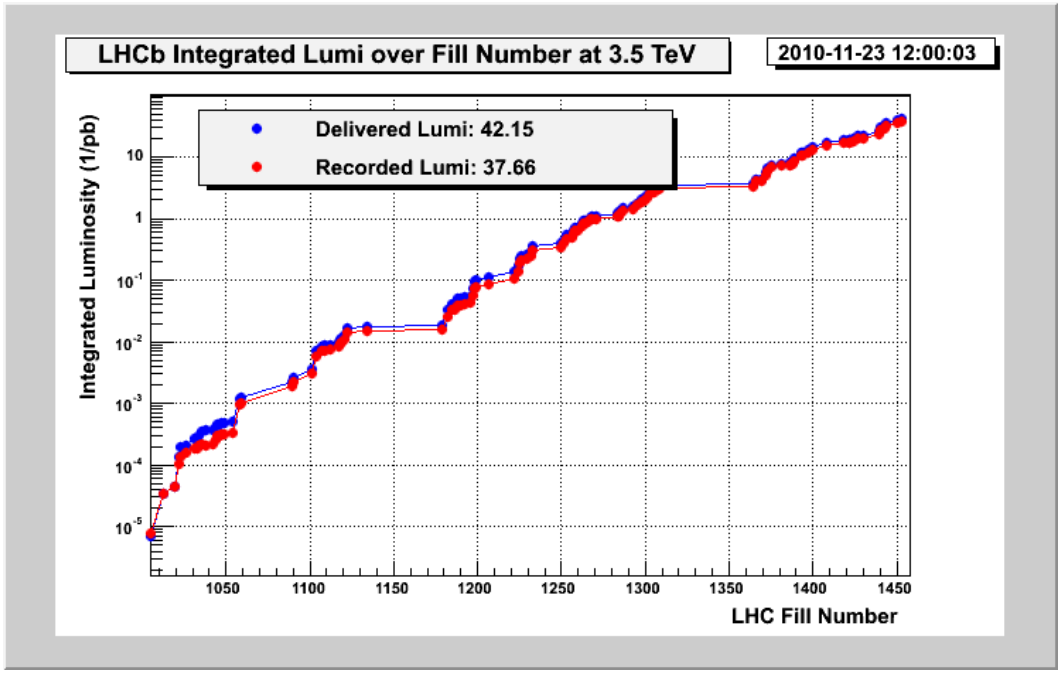
LHCb and charm physics

- unique kinematic range: $2 < \eta < 6$, down to $p_T \lesssim 1$ GeV
- about 10 % of events contain charm
- Vertex Locator: < 10 μm position resolution
- RICH: 2 detectors, 3 radiators excellent π–K separation over large momentum range (2-100 GeV)
- this will allow us to probe charm mixing and CPV – see talk by Joerg Marks



LHCb data

- this year:
  - 38 pb^{-1} integrated luminosity recorded
  - up to $1.7 \cdot 10^{32}$ $cm^{-2}s^{-1}$ instantaneous luminosity
- expect $\sim$ 2 fb^{-1} for next year
- nominal annual luminosity:
  - 2 fb^{-1}
  - at $2 \cdot 10^{32}$ $cm^{-2}s^{-1}$
- this analysis:
  1.8 nb^{-1}

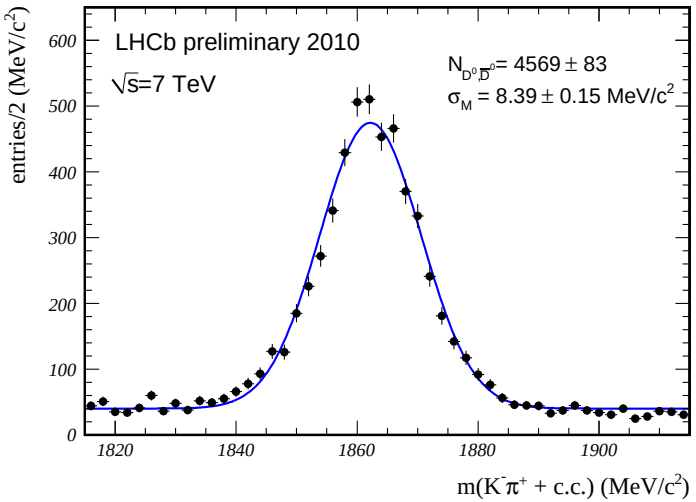


Decay modes and trigger

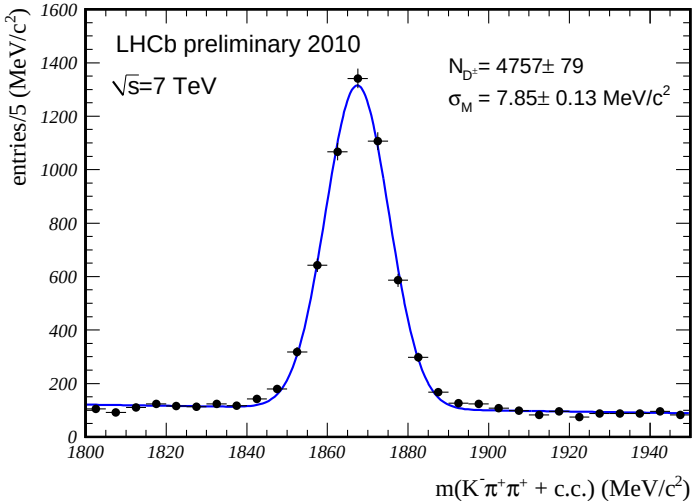
- Use following modes, including charge conjugate:
  - $D^0 \to K^-\pi^+$
  - $D^+ \to K^-\pi^+\pi^+$
  - $D^{*+} \to \pi^+ D^0 (K^-\pi^+)$
  - $D_s^+ \to \phi(K^-K^+)\pi^+$
- do intensive crosschecks
  - independent $D^0 \to K^-\pi^+$ analysis *not* using RICH
  - $D^{*+} \leftrightarrow D^0$
  - $D^+ \leftrightarrow D_s^+$
- the analyses are all cuts based[2]
- trigger:
  - so-called “micro bias” trigger
  - pre-trigger on bunch structure (100 % on filled–filled)
  - trigger on (2d-)track segment in VELO or main tracker

[2] The alternative D^0 analysis uses cuts on combinations of variables

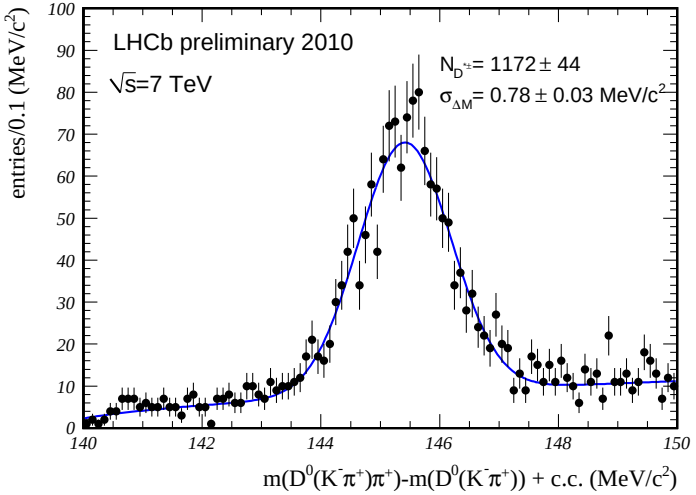
Raw yields



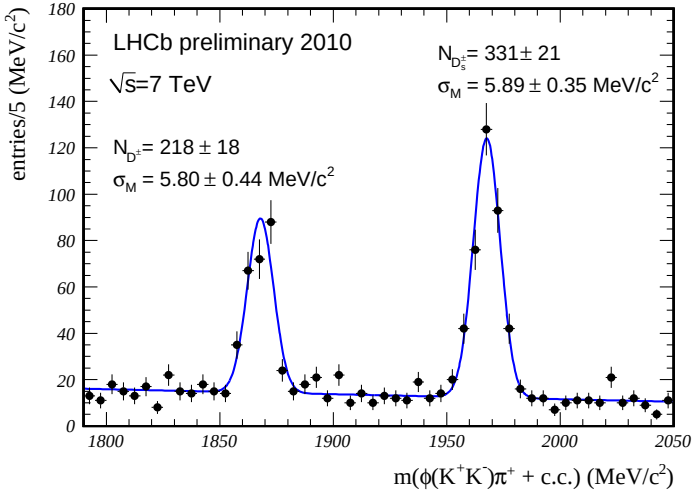
$D^0 \to K^-\pi^+$



$D^+ \to K^-\pi^+\pi^+$



$D^{*+} \to \pi^+ D^0 (K^-\pi^+)$



$D_s^+ \to K^-K^+\pi^+$

Data and cross section determination

- use 1.8 nb^{-1}, early data
- $\rightarrow$ number of collisions per non-empty events ≈ 1

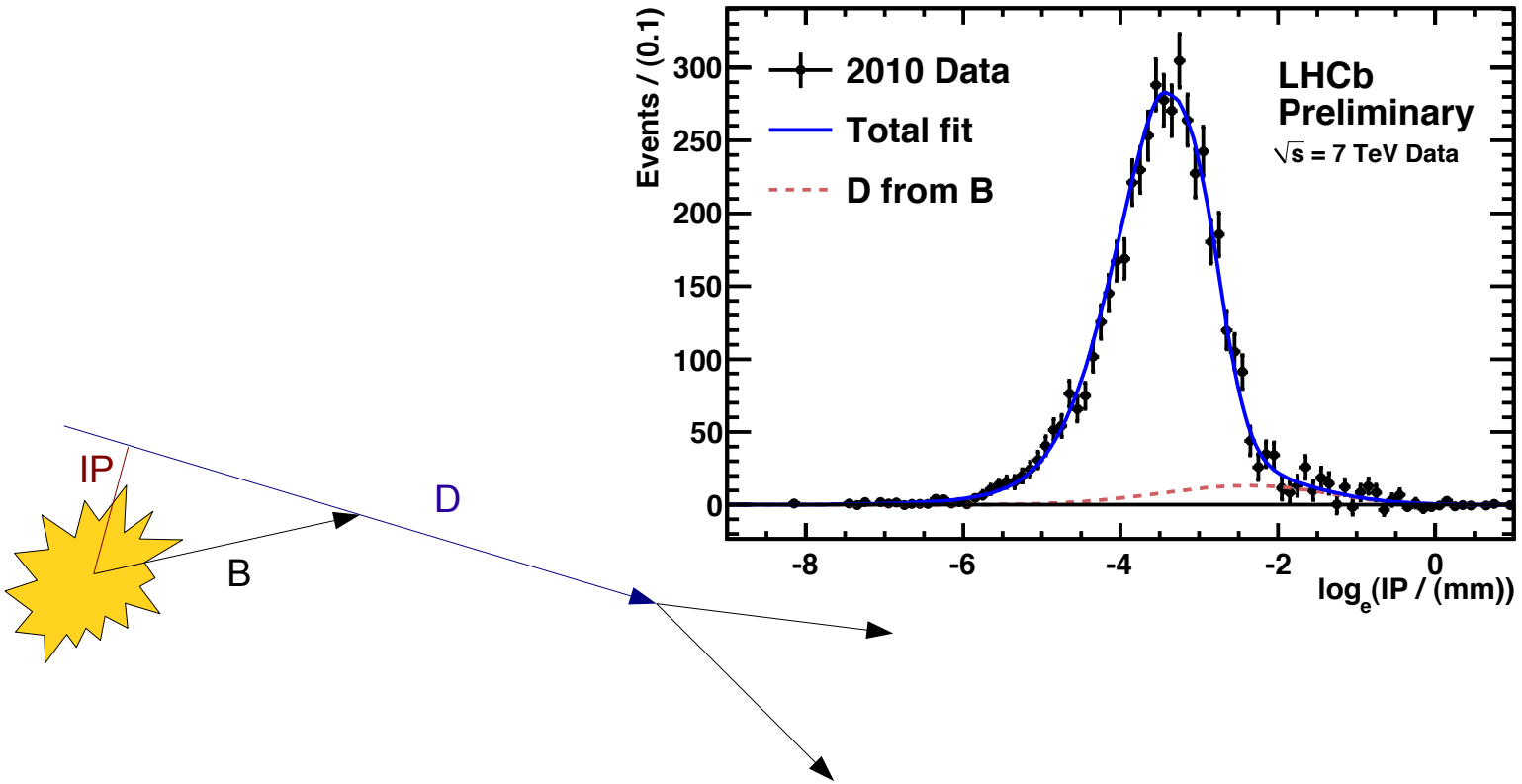
To get cross section:

1. raw yields in bins of rapidity and transverse momentum
2. measure contamination from secondary charm on data
3. determine selection efficiency from MC simulation
4. PID cut efficiency measured on data
5. calculate cross section integrated over bin

$$\sigma = \frac{N_{\text{signal}}}{\varepsilon_{\text{tot}} \cdot \mathcal{B}_{\text{PDG}} \cdot \mathcal{L}_{\text{int}}}$$

Prompt component extraction

- secondary charm: *D* from decay of long-lived particles
- selections favor prompt decays
- secondary fraction from D impact parameter distribution



Systematic errors – varying with analysis

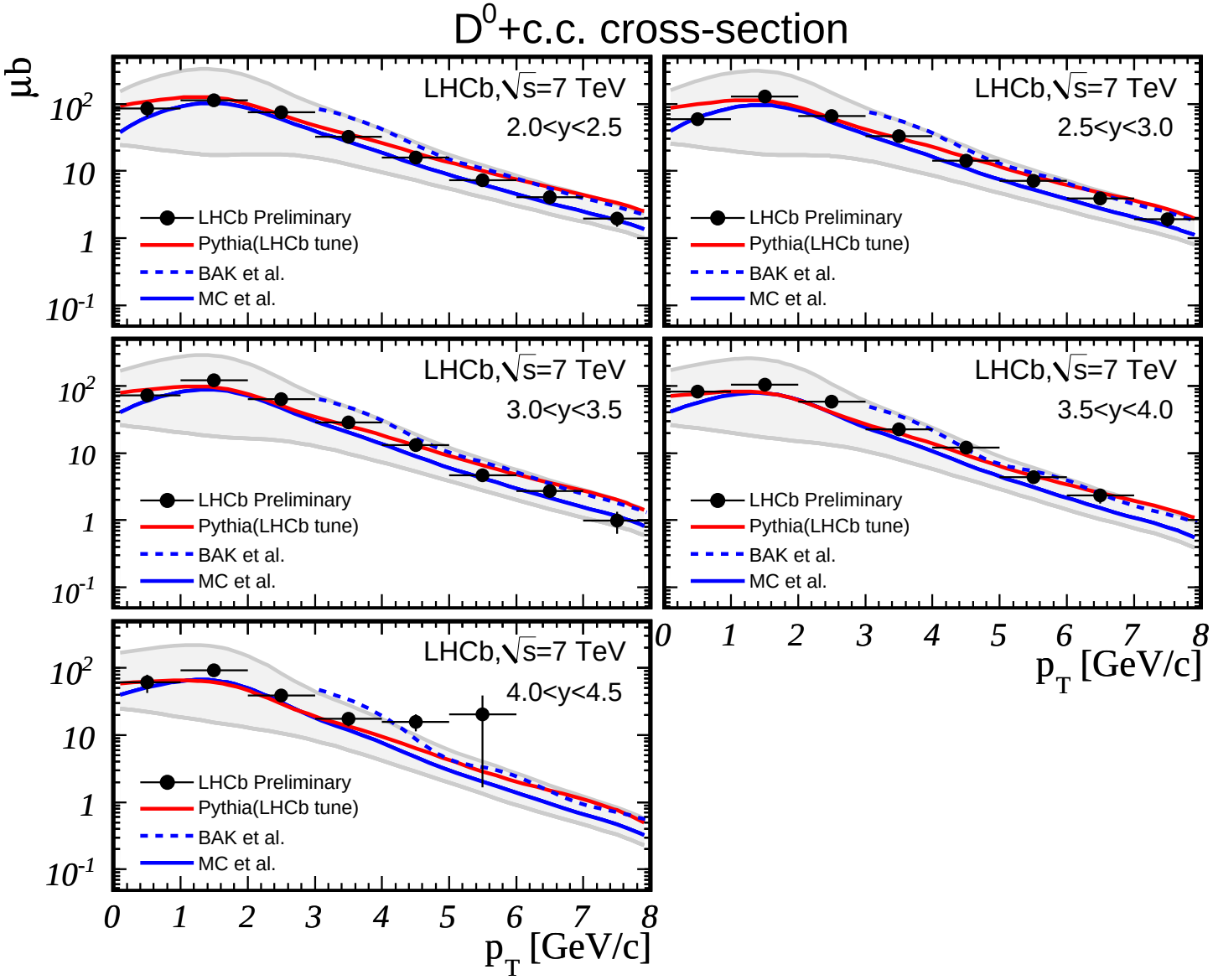
Correlated systematic errors:

- luminosity determination: 10 %
- tracking efficiency: correlated 3 % per track
- branching ratio error: 1.3 to 5.1 %
- peaking background: 0 to 1.6 %

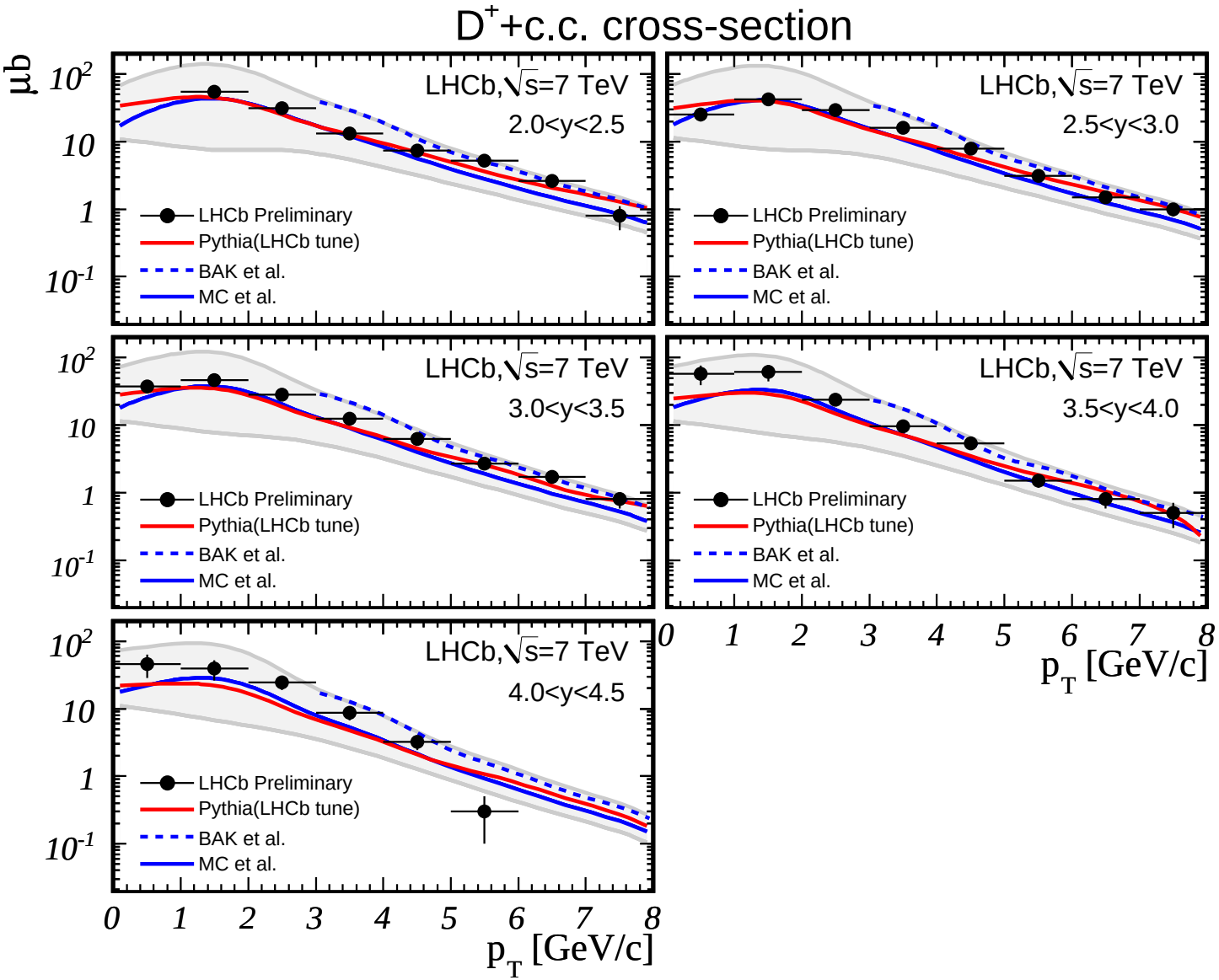
Uncorrelated systematic errors:

- cut efficiency correction: 3.4 to 5.4 %
- MC statistics: 1 to 10% (high value only at edges)
- PID efficiency correction: 1 to 10 %
- prompt secondary subtraction: 2 to 4.1 %
- fit procedure: 1 to 4.5 %

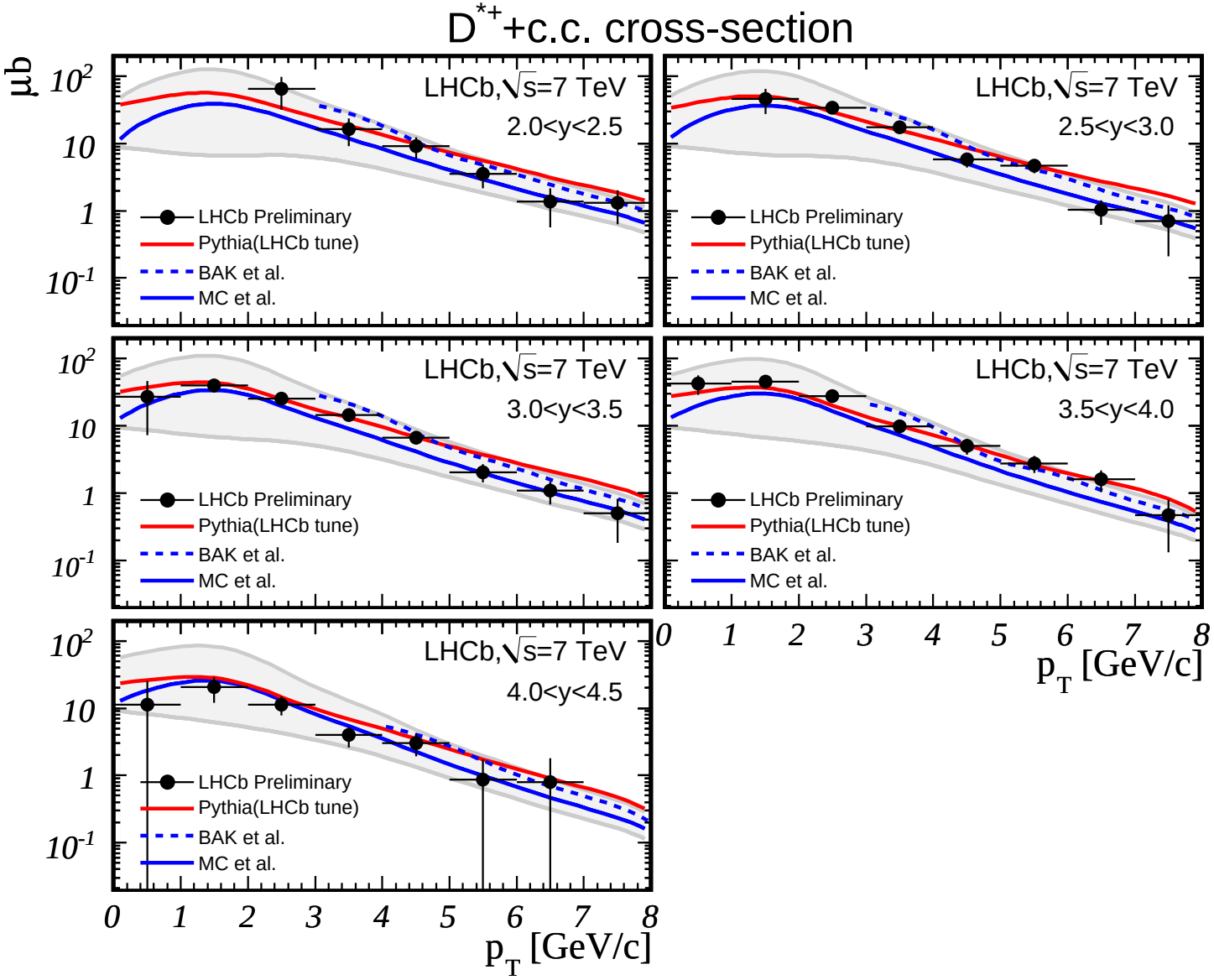
Results for $D^0 + \overline{D^0}$



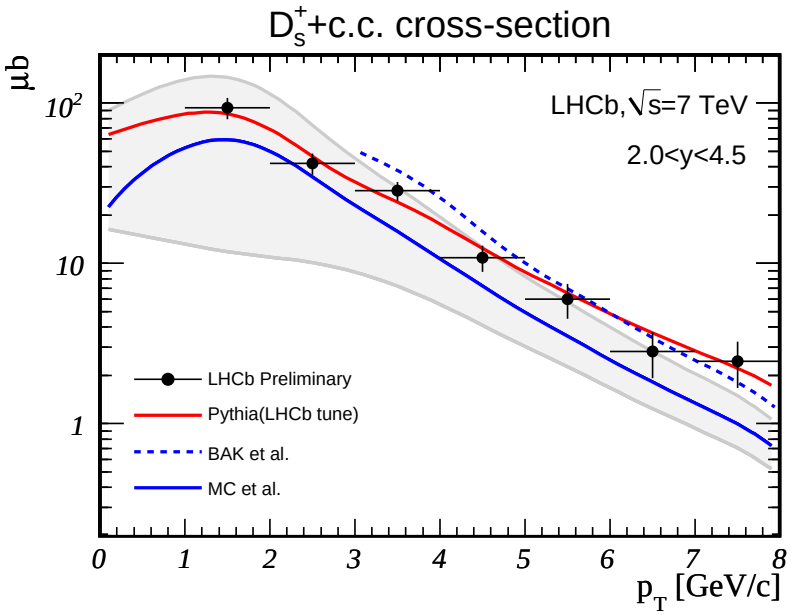
Results for $D^{\pm}$

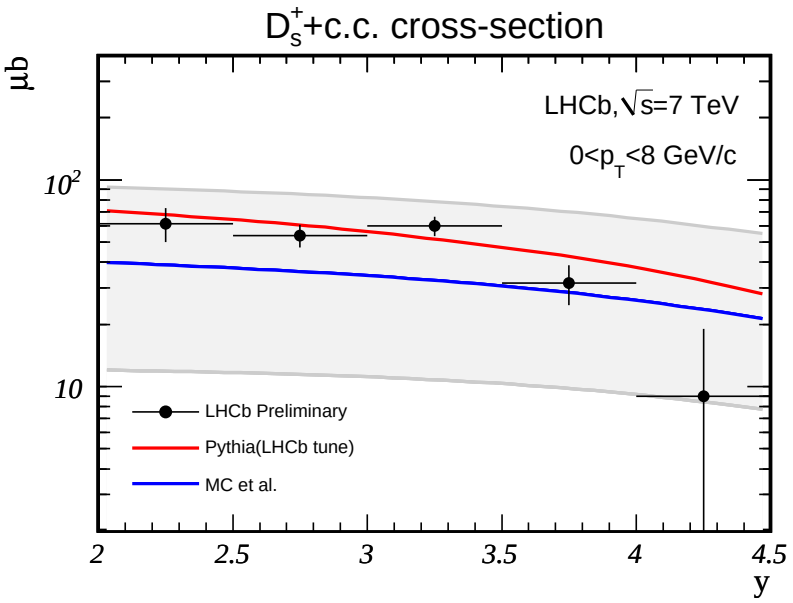


Results for $D^{*\pm}$



Results for $D_s^{\pm}$





Integrated charm cross section

Integrate over acceptance and use transition probability $f(c \to H)$ quark to hadron from literature.
To compare with $\sigma(pp \to b\bar{b}X)$ at LHCb[3] extrapolate to pseudorapidity $2 < \eta < 6$ and 4π.

- integrated for $(0 < p_T < 8)$ GeV, $2 < y < 4.5$: $\sigma(pp \to c\bar{c})_y = 1.23 \pm 0.19$ mb
- $\sigma(pp \to c\bar{c})_\eta = 1.74 \pm 0.27$ mb
- $\sigma(pp \to c\bar{c})_{4\pi} = 6.1 \pm 0.9$ mb
- $\sigma(pp \to b\bar{b})_\eta = 0.075 \pm 0.014$ mb
- $\sigma(pp \to b\bar{b})_{4\pi} = 0.28 \pm 0.05$ mb

$\Rightarrow$ Charm cross section is a good factor 20 larger than the bottom cross section at $\sqrt{s} = 7$ TeV.

[3] Physics Letters B, Volume 694, Issue 3, p. 209-216 (2010)

Summary and outlook

- LHCb detector producing good results
- open charm cross-section results presented
- in broad agreement with theory

Outlook:

- public note on these analyses out this week (LHCb-CONF-2010-013)
- in progress: update using 14 nb^{-1}
- will include also Λ_c cross section