b and *c* quark cross-section measurements at LHCb

VII B Physics Workshop Orsay

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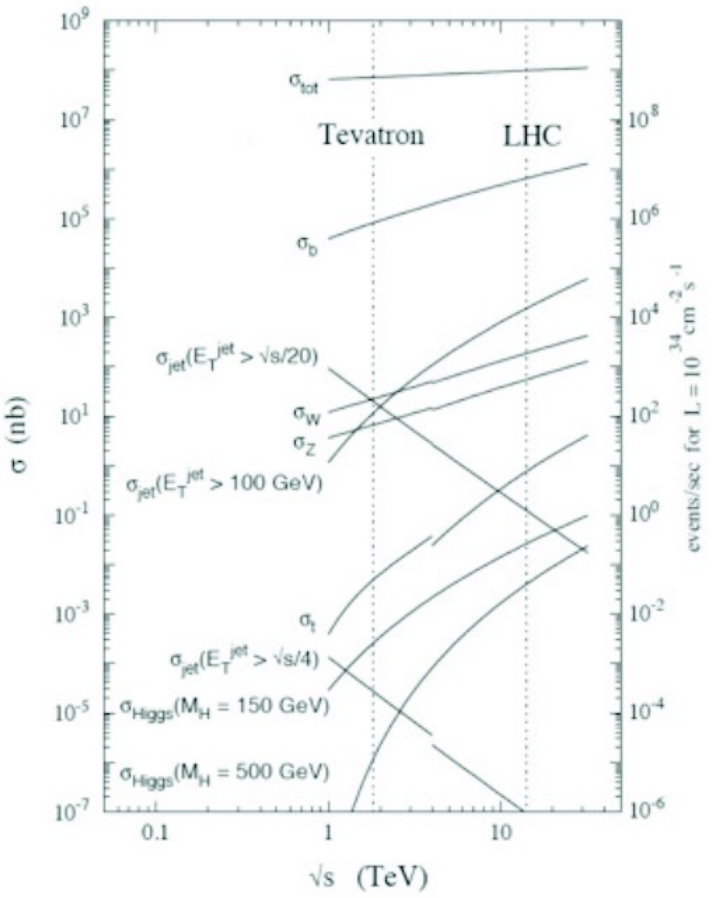
For the LHCb Collaboration

Introduction



At 7 TeV pp collisions, a very large data sample of D hadrons is reconstructed with very early data.

These D hadrons are produced by 2 sources:

- Prompt D: produced at pp interaction → measurement of **c** production cross-section.

- D from B decays → measurement of **b** production cross-section.

Cross-section measurements allow comparison with QCD predictions, and also help to assess expected performances of the experiment whose physics program is based on the study of rare B and D decays.

LHCb detector and definitions

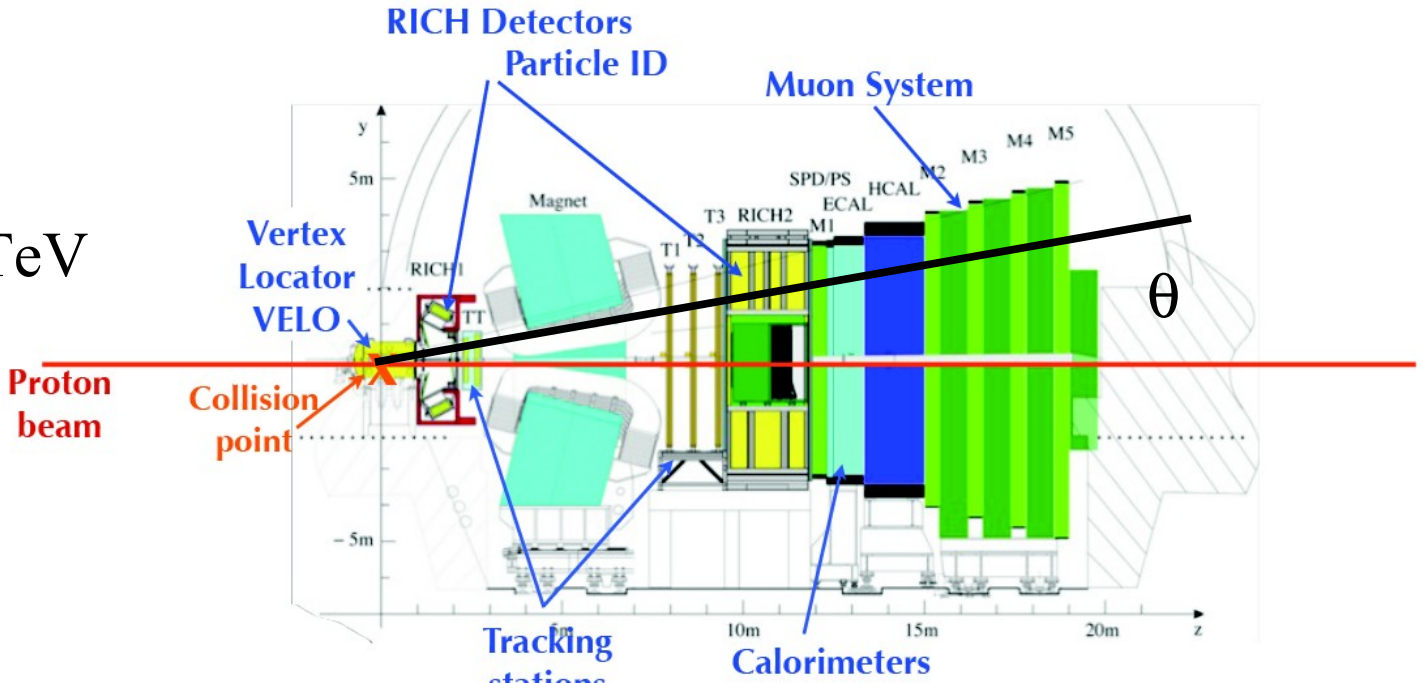
p_T: momentum in plane transverse to beam,

η: pseudo-rapidity, $-\ln(\tan(\theta/2))$

y: rapidity, $\frac{1}{2} \log[(E+p_z)/(E-p_z)]$

<u>LHCb acceptance</u>: $2<\eta<6$, down to $p_T=0$.

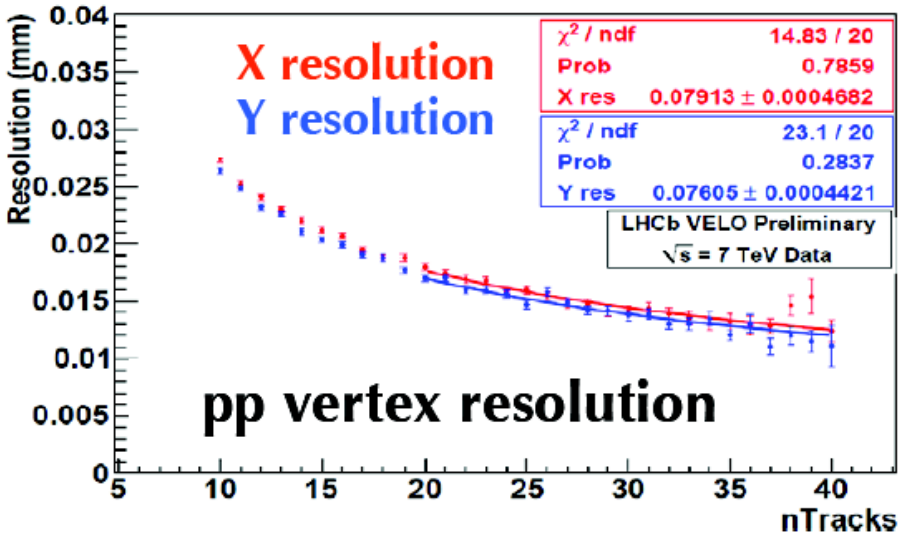
$s^{1/2}=7$ TeV

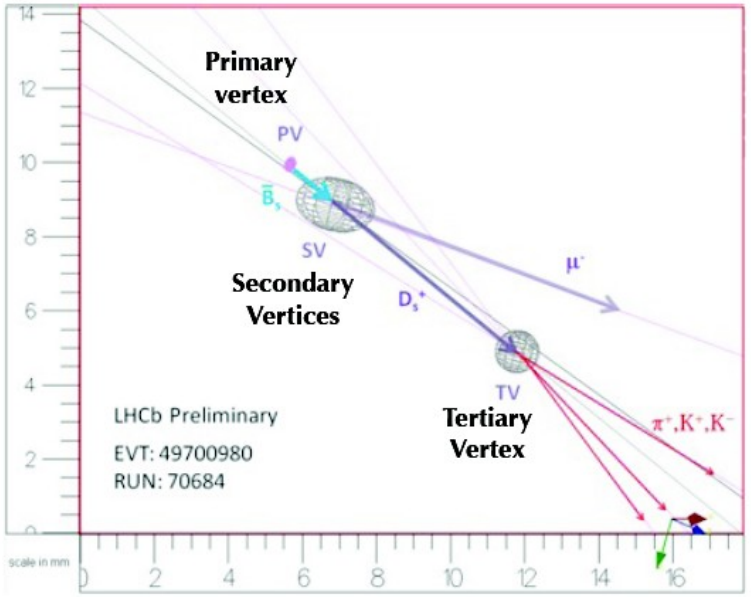


Prompt / B Separation

Vertex reconstruction is fundamental to separate primary (prompt), secondary (B) or tertiary (decay products) vertices:

- Suppression of large combinatorial background (also at trigger level),
- Measurement of lifetimes,
- Time dependent CP violation analysis.



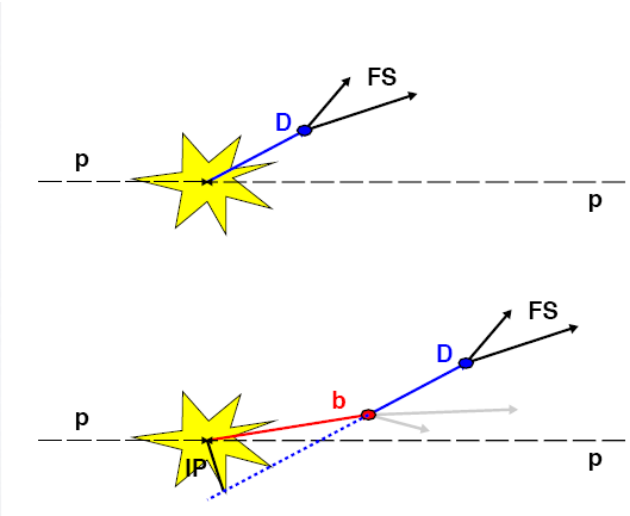


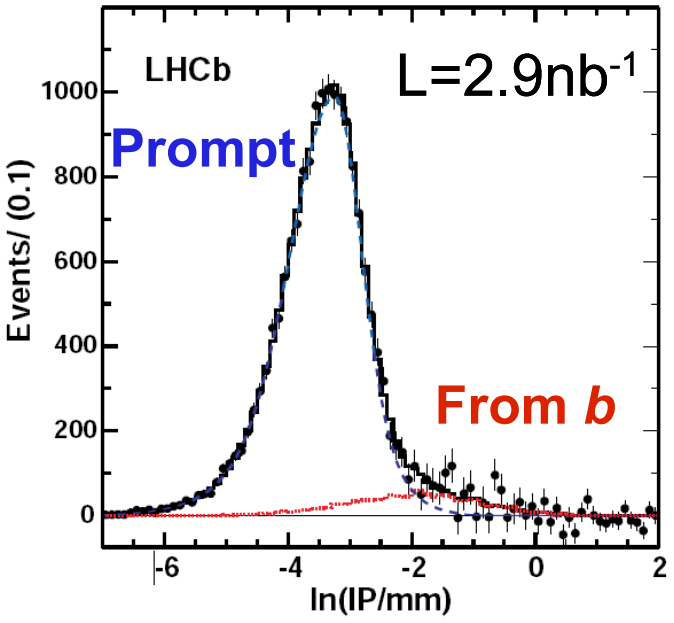
Prompt / B Separation

Prompt D and D from B decays are separated using the Impact Parameter (IP), distance between:

• the D line of flight, computed from the D decay vertex and the reconstructed D momentum,

• the Primary Vertex, formed from the many fragmentation tracks from the pp interaction.





Inclusive $D^0 \rightarrow K\pi$

$c\bar{c}$ cross-section measurement

Use 1.8nb^{-1} of data taken with **interaction trigger** (micro-bias trigger, based on presence of tracks reconstructed in VELO), 100% efficient on charm event.

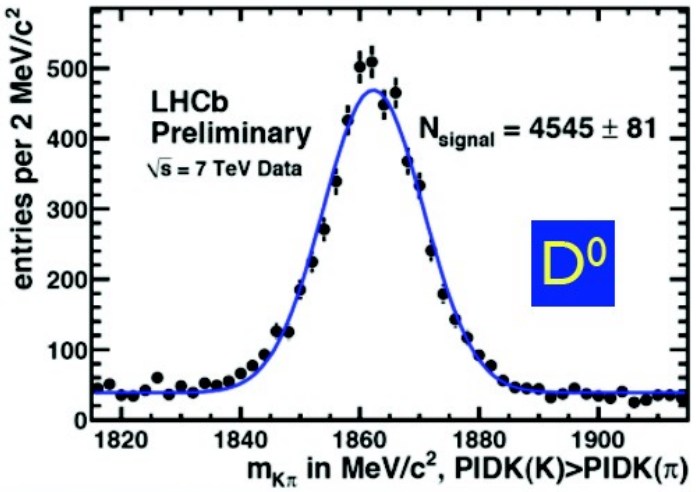
Measure production cross-section of D^0, D^{*+}, D^+, D^+_s in bins of p_T ($0<p_T<8$ GeV) and rapidity y ($2<y<5$).

Contribution of D from B decays is measured on data (Impact Parameter) and subtracted to the final result.

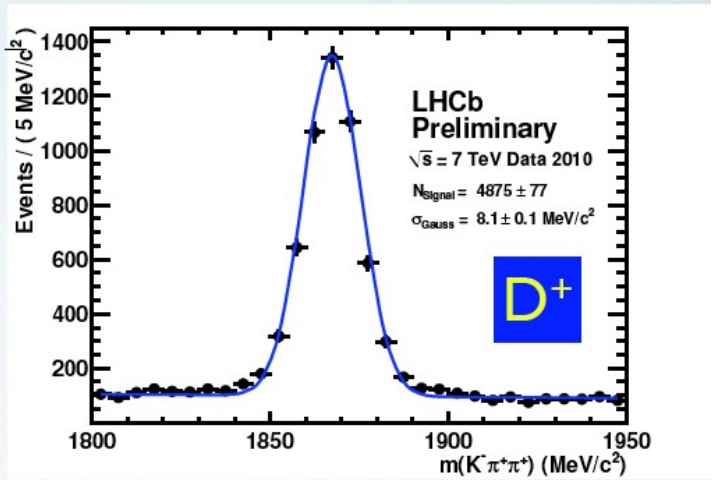
Efficiencies are extracted from Monte Carlo, but are intensively cross-checked on data (in particular PID efficiencies are measured on data using clean calibration samples).

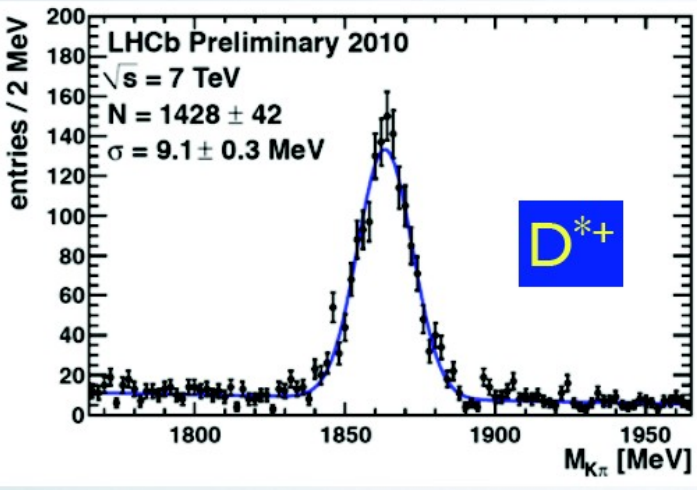
Charm signals ($1.8nb^{-1}$)

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

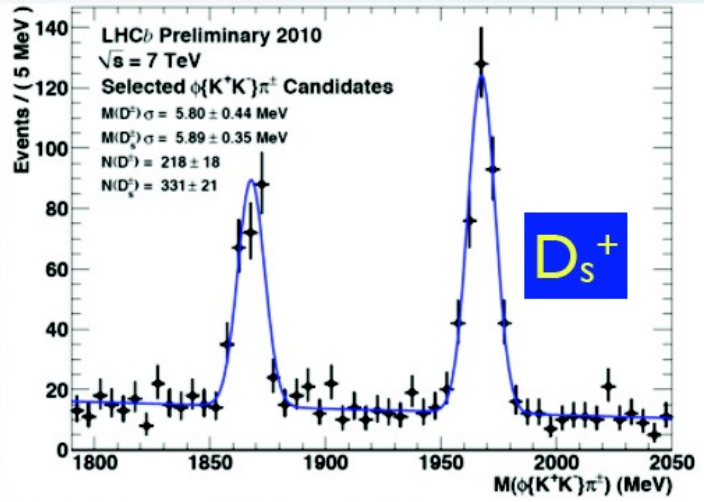


$D^+ \rightarrow K^- \pi^+ \pi^+$



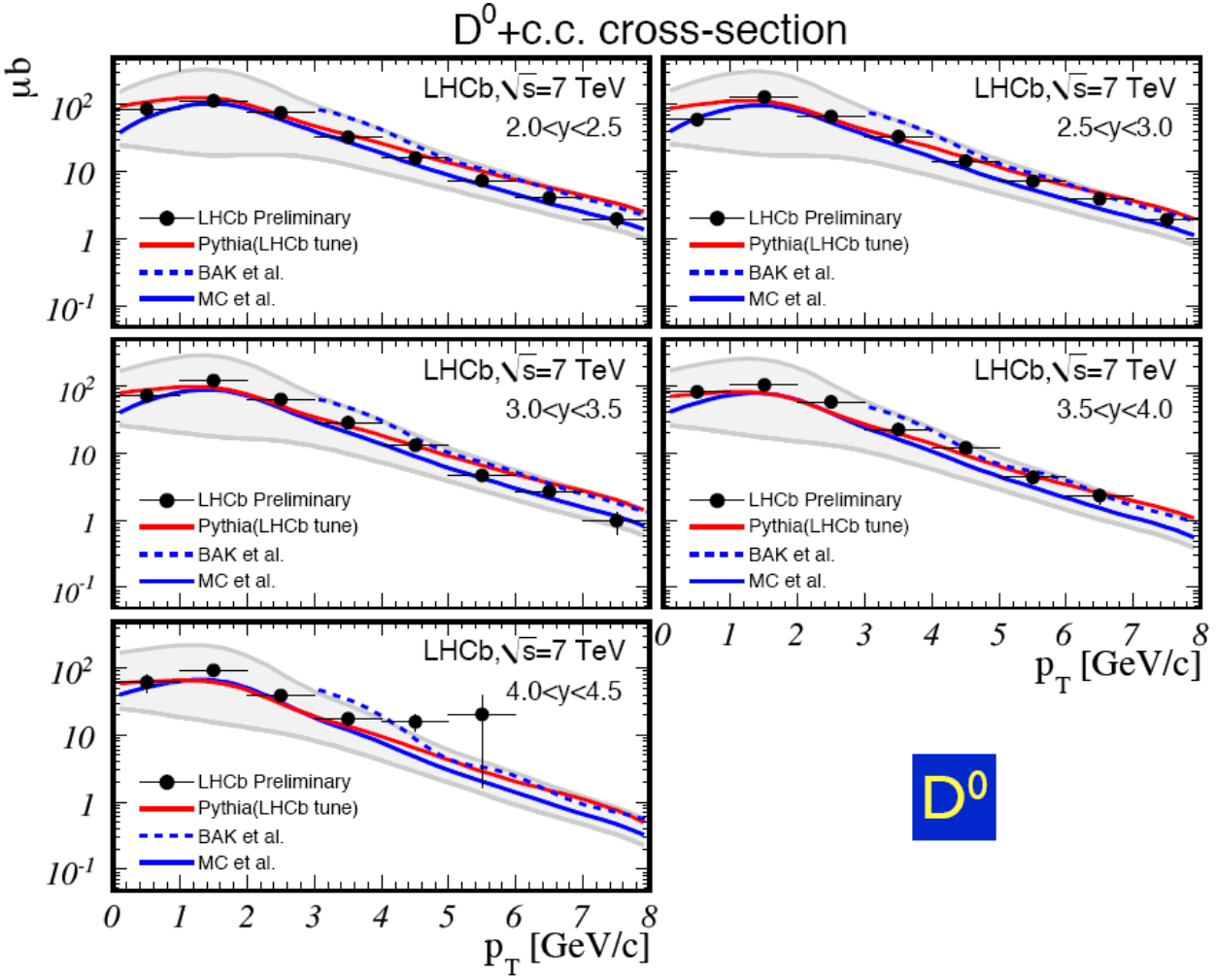


$D^{*+} \rightarrow D^0 (K^- \pi^+) \pi^+$



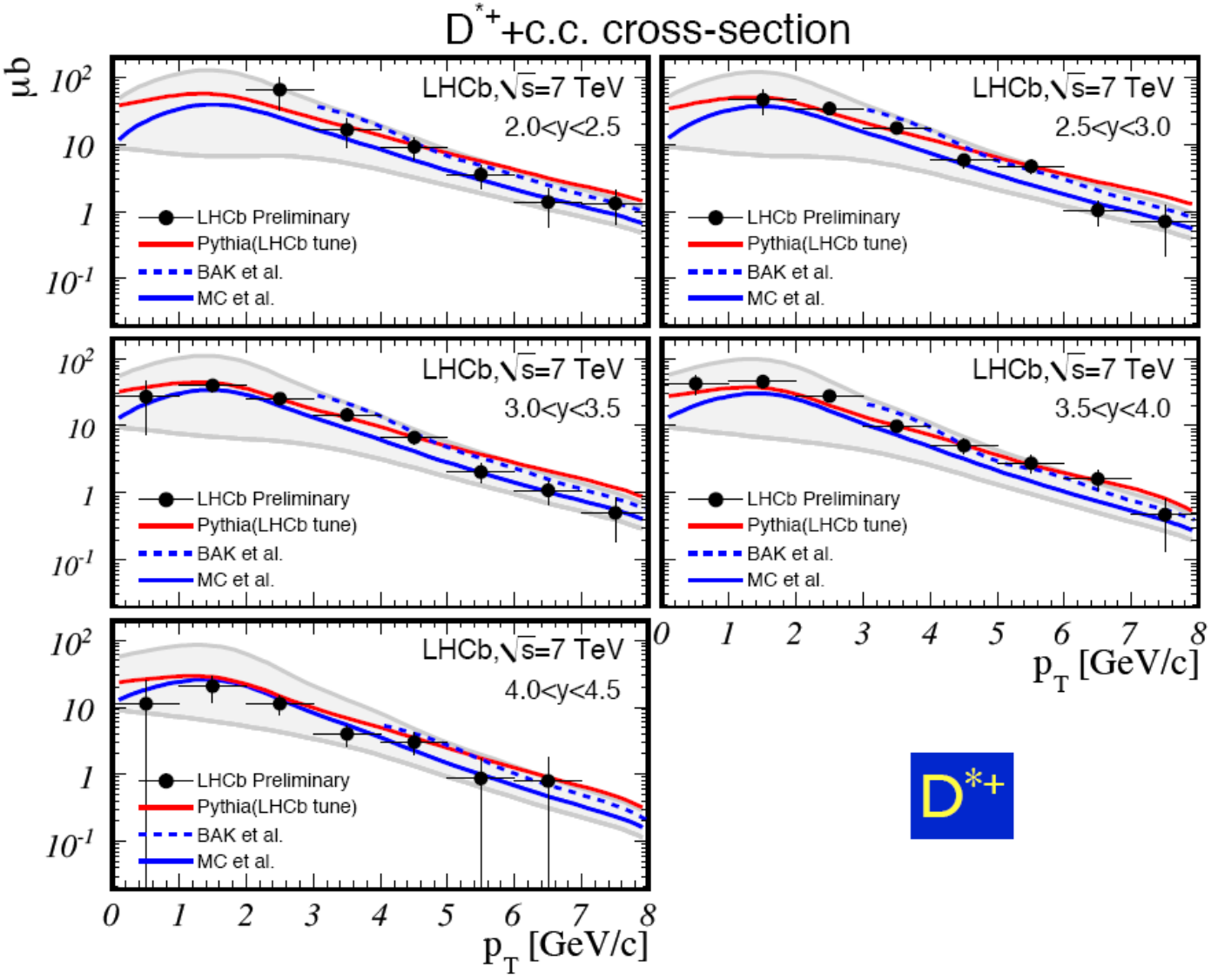
$D_s^+ \rightarrow \phi (K^- K^+) \pi^+$

D^0 cross-section results

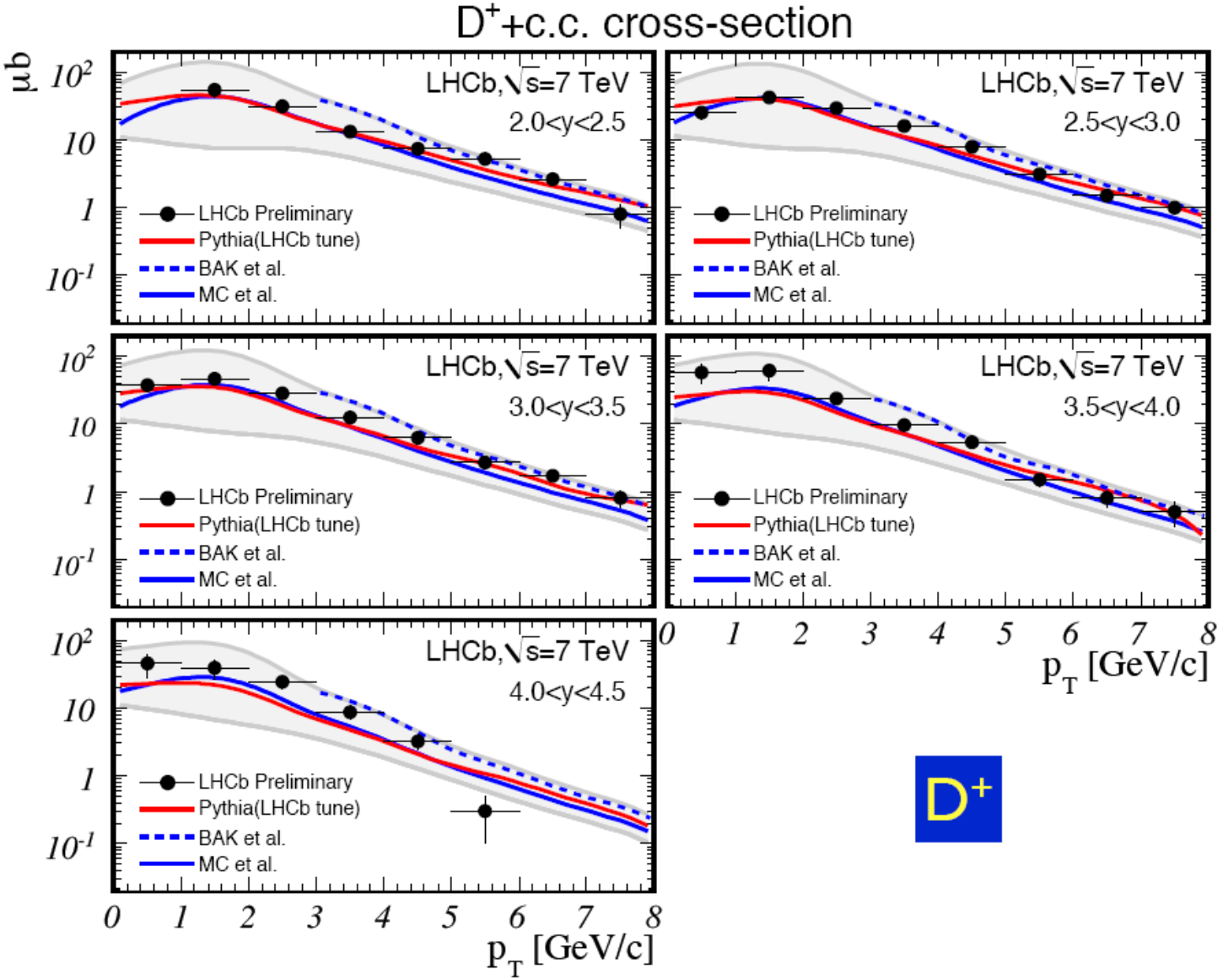


- BAK et al. [Kniehl, Kramer, Schienbein, Spiesberger]
- MC et al. [Cacciari, Frixione, Mangano, Nason, Ridolfi]

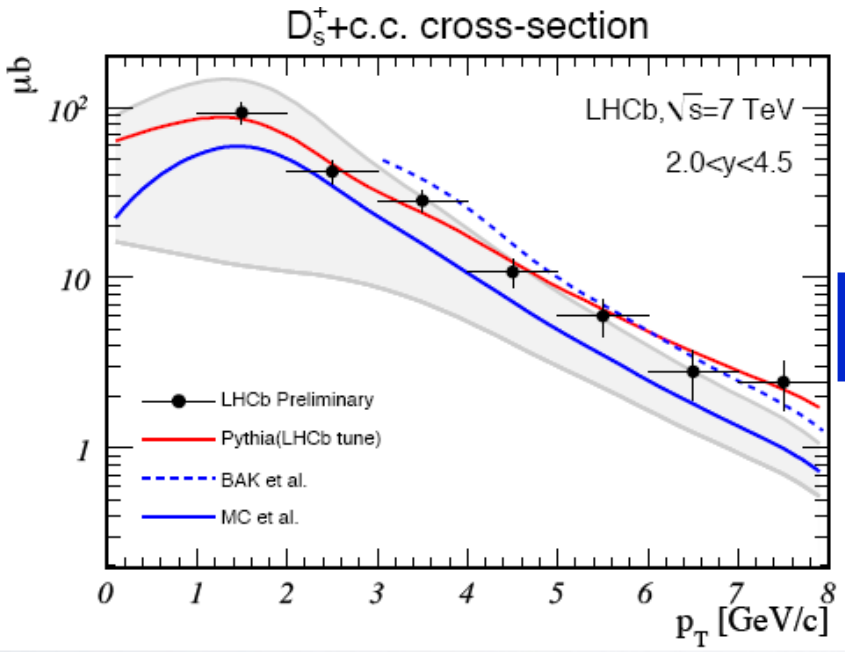
D^{*+} cross-section results



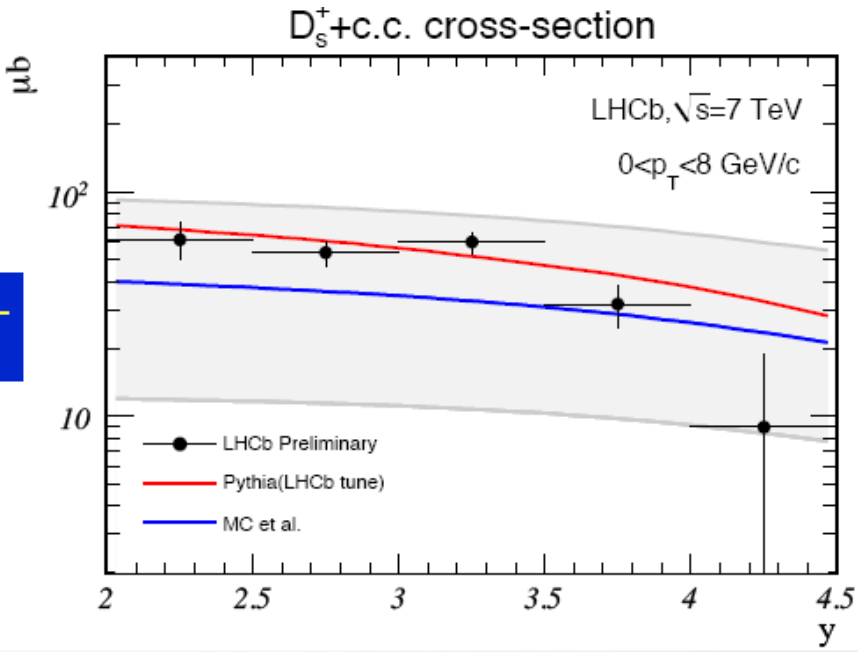
D^+ cross-section results



D_s^+ cross-section results



D_s^+

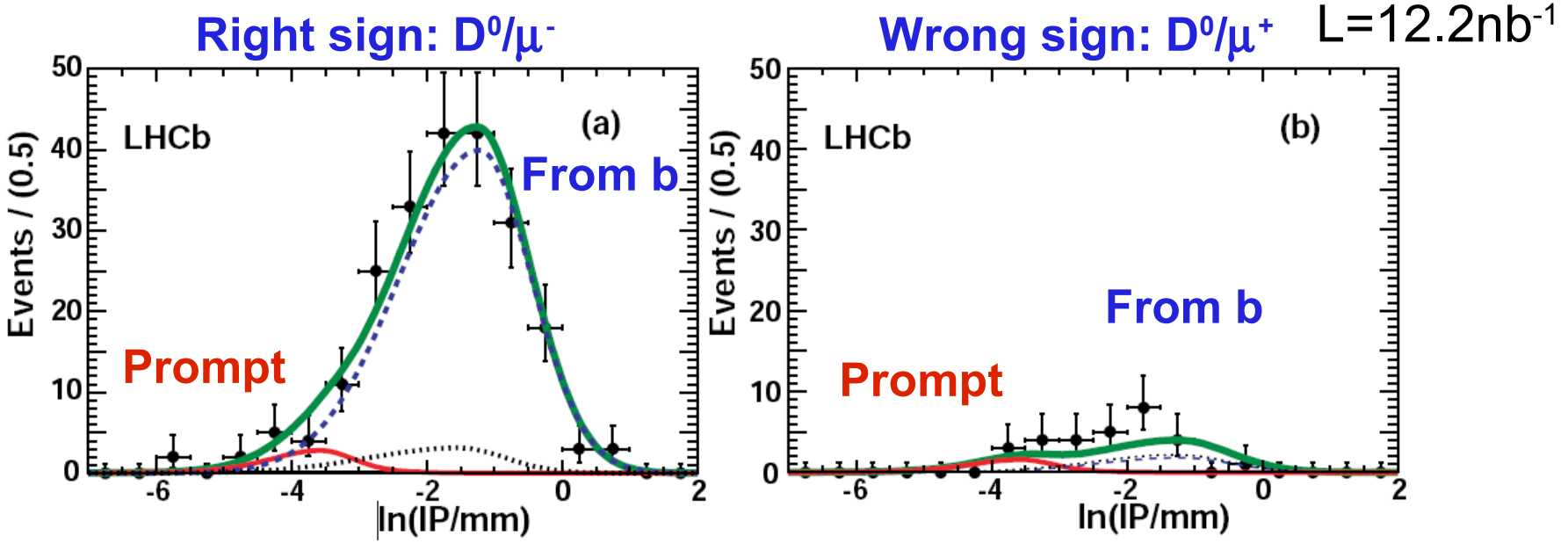


$b\bar{b}$ cross-section measurement

Principle: separate statistically prompt D and D from B using the ln(IP) distribution.

Use $D^0 \to K\pi$, and associate with a μ with charge correlated with D^0 flavour to enrich D^0 sample in "D^0 from B".

Infer b cross-section from LEP measurement of $Br(b \to D^0 X \mu^- \nu) = (6.84 \pm 0.35)$ %



$b\bar{b}$ cross-section measurement

2 data sample with different triggers:

- **2.9 nb^{-1} early data**, with open interaction trigger (micro-bias).
- **12.2 nb^{-1} data triggered with single muon** trigger with p_T>1.3 GeV, 50% efficient.

Signal yield is determined from a unbinned maximum likelihood fit to the Kπ mass distribution and to the ln(IP) distribution. Combinations of D^0 with a misidentified μ are measured from data and subtracted from signal.

The sample is divided in 4 bins of η(B), 2<η<6, where η of the B meson is measured with the Primary Vertex and the $D^0\mu$ vertex.

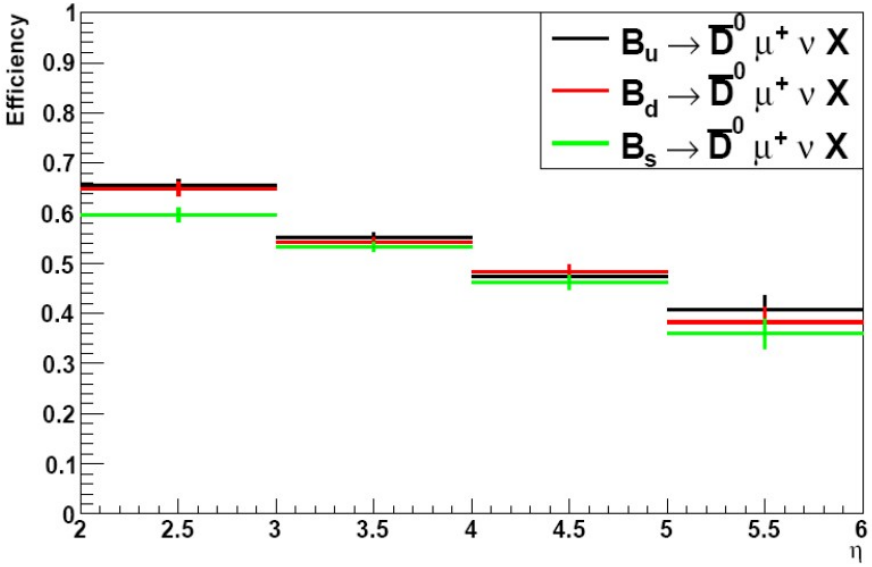
Efficiencies (8% in total) are taken from Monte Carlo, but cross-checked extensively on data.

$b\bar{b}$ cross-section systematic errors

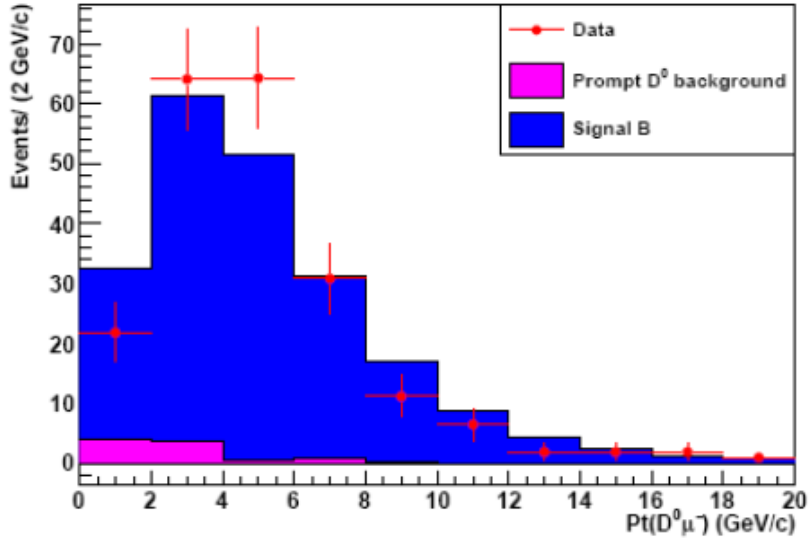
Source	Error (%)	Source	Error (%)
Luminosity	10.0	Prompt & Dfb shapes	1.4
Tracking efficiency	10.0	$\mathcal{B}(D^0 \to K^-\pi^+)$	1.3
$\mathcal{B}(b \to D^0 X \mu^- \overline{\nu})$	5.1	$D^0\mu^-$ vertex χ^2 cut	1.2
Assumed branching fractions	4.4	Kaon identification	1.2
LEP fragmentation fractions	4.2	Muon fakes	1.0
Generated b p_{T} distribution	3.0	D^0 mass cut	1.0
Muon identification	2.5	D^0 vertex χ^2 cut	0.6
χ^2_{IP} cut	2.5	D^0 flight distance cut	0.4
MC statistics	1.5	Pion identification	0.3
Total		17.3%	

Measurement is done integrating over p_{T} spectrum and summing over different *B* species.

$b\bar{b}$ cross-section: checks



Trigger efficiency as a function of η: checked on data using independant triggers

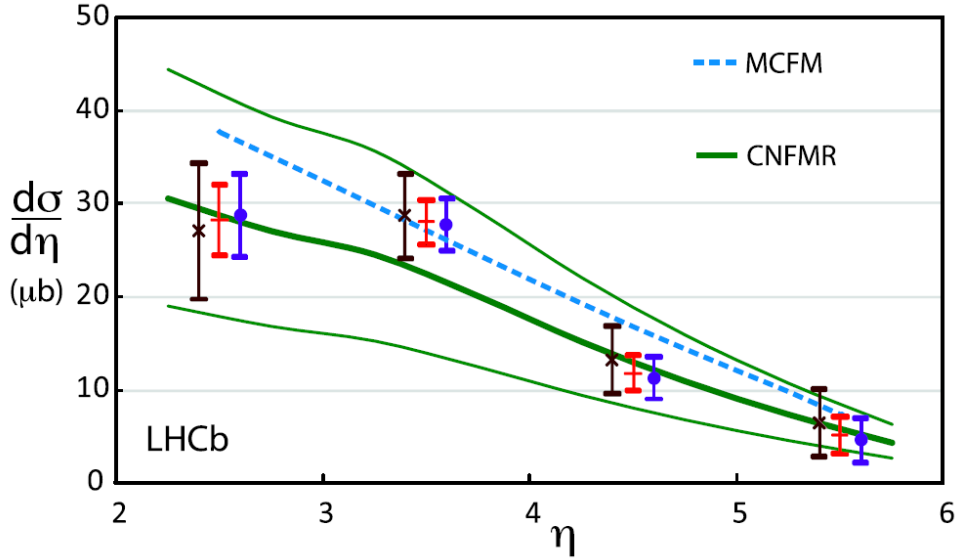


Cross-check of p_T(B) spectrum of our Monte Carlo generator.

$b\bar{b}$ cross-section results

Average cross-section to produce a b or b hadron:

$$\sigma(pp \to H_b X) = \frac{\#\text{ of detected } D^0\mu^- \text{ and } \overline{D}^0\mu^+ \text{ events}}{2\mathcal{L} \times \text{efficiency} \times \mathcal{B}(b \to D^0 X \mu^- \overline{\nu})\mathcal{B}(D^0 \to K^-\pi^+)}$$



Only statistical error for LHCb data: **average**, **microbias** and **muon triggered** data.

Submitted to PLB

Very good agreement in absolute value and η shape with 2 theories:

- MCFM [Monte Carlo for FeMtobarn processes, Nason, Dawson, Ellis, http://mcfm.fnal.gov], NLO with MSTW8NL PDF.
- CNFMR [Cacciari, Frixione, Mangano, Nason, Ridolfi, JHEP 0407 (2004) 33], NNLO with CTEQ6.5 PDF.

$b\bar{b}$ cross-section results

Over the LHCb acceptance, $2<\eta<6$:
$\sigma(pp \to H_b X) = (75.3 \pm 5.4 \pm 13.0)\ \mu b$, very close to the cross-section used for LHCb performance studies.

In good agreement with cross-section from $b \to J/\psi\ X$, see Giulia Manca's talk.

Cross-section quoted using b hadronization fractions measured at LEP. When using fractions measured by CDF,
$\sigma(pp \to H_b X) = (89.6 \pm 6.4 \pm 15.5)\ \mu b$. [Mainly due to f(b-baryon) = $(9.1 \pm 1.5)\% \to (21.4 \pm 6.8)\%$].

Using η spectrum from PYTHIA 6.4, the cross-section is also extrapolated to the full space (multiplying by 3.77):
$\sigma(pp \to b\bar{b}X) = (284 \pm 20 \pm 49)\ \mu b$.

Conclusions

First LHCb measurements of flavour physics: c and b production cross-sections at 7 TeV pp center-of-mass energy.

Measurements in good agreement with predictions: c and b cross-sections are huge $\rightarrow$ validate yield estimates presented since several years by LHCb.

Publication of charm cross-section measurement soon, with extended dataset, and other hadrons (Λ_c^+).

Beauty cross-section measurement published, similar studies with semi-leptonic decays ongoing (b hadronization fractions, ...)