Measurement of $\sigma(pp \to b\bar{b}X)$ at 7 and 13 TeV

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on behalf of the LHCb collaboration

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Motivation

- Measurements of charm and beauty cross-sections are some of the most interesting QCD studies that come from LHC data
  - Test the accuracy of pQCD predictions
  - Particularly the ratio of 13 TeV to 7 TeV as large scale uncertainties cancel
    - FONLL Cacciari-Mangano-Nason arXiv: 1507.06197
- Also important to have precise measurements for
  - Tests of beyond the standard model physics which rely on production rates to estimate backgrounds
  - Calculating the sensitivity of experiments to SM tests (CP-violation and rare decays)

Analysis strategy

- Using semileptonic decays of b-flavored hadrons decaying into a ground-state charmed hadron in association with a μ:

Accounting for other b-flavored baryons $\delta = 0.25 \pm 0.10$

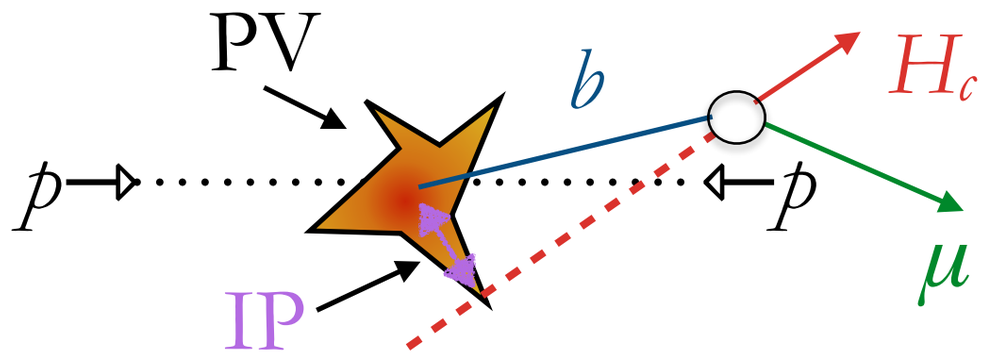
$$\sigma(pp \to H_b X) = \frac{1}{2\mathcal{L}} \left\{ \left[\frac{n(D^0\mu)}{\epsilon_{D^0} \times \mathcal{B}_{D^0}} + \frac{n(D^+\mu)}{\epsilon_{D^+} \times \mathcal{B}_{D^+}} \right] \frac{1}{\mathcal{B}(B \to DX\mu\nu)} + \left[\frac{n(D_s^+\mu)}{\epsilon_{D_s^+} \times \mathcal{B}_{D_s^+}} \right] \frac{1}{\mathcal{B}(B_s \to D_s X\mu\nu)} + \left[\frac{n(\Lambda_c^+\mu)}{\epsilon_{\Lambda_c^+} \times \mathcal{B}_{\Lambda_c^+}} \right] \frac{1+\delta}{\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ X\mu\nu)} \right\}$$

B^+_c, and $b \to u l \nu$ contributions small

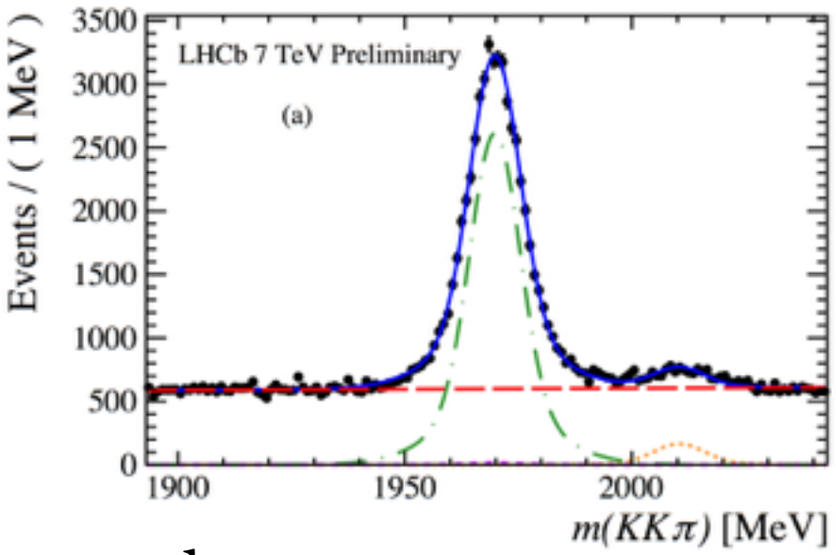
- Assume equality of semileptonic widths of all b hadrons to derive B_s^0 and Λ_b^0 semileptonic branching fractions with measured lifetimes and known semileptonic BFs for $B^{0/+}$
  - Small correction for baryons
- Luminosity = 284.1 ± 4.86 pb^{-1} at 7 TeV and 4.60 ± 0.18 pb^{-1} at 13 TeV

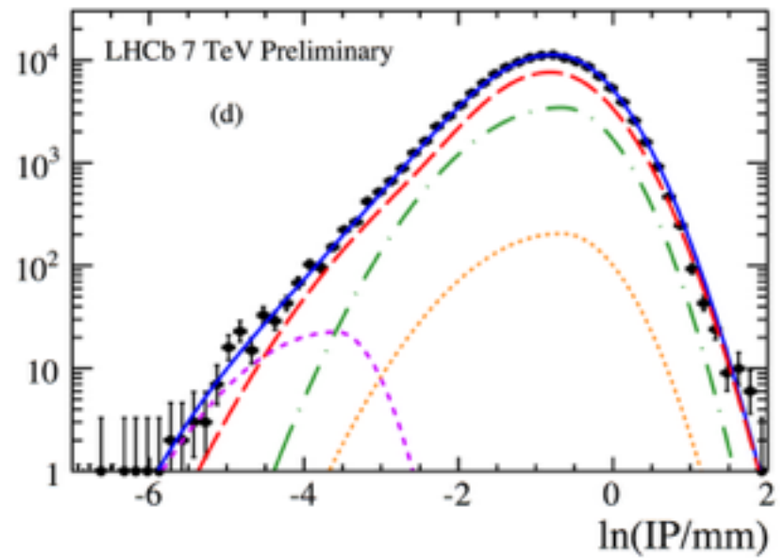
Signal yields

- 2D fits in charm hadron invariant mass and ln(Impact Parameter) to remove peaking prompt background directly
  - In bins of η of the B hadron and p_T(charm+μ)



Full fit
Signal
Combinatorial
$D^{*+}\to KK\pi$
Prompt charm



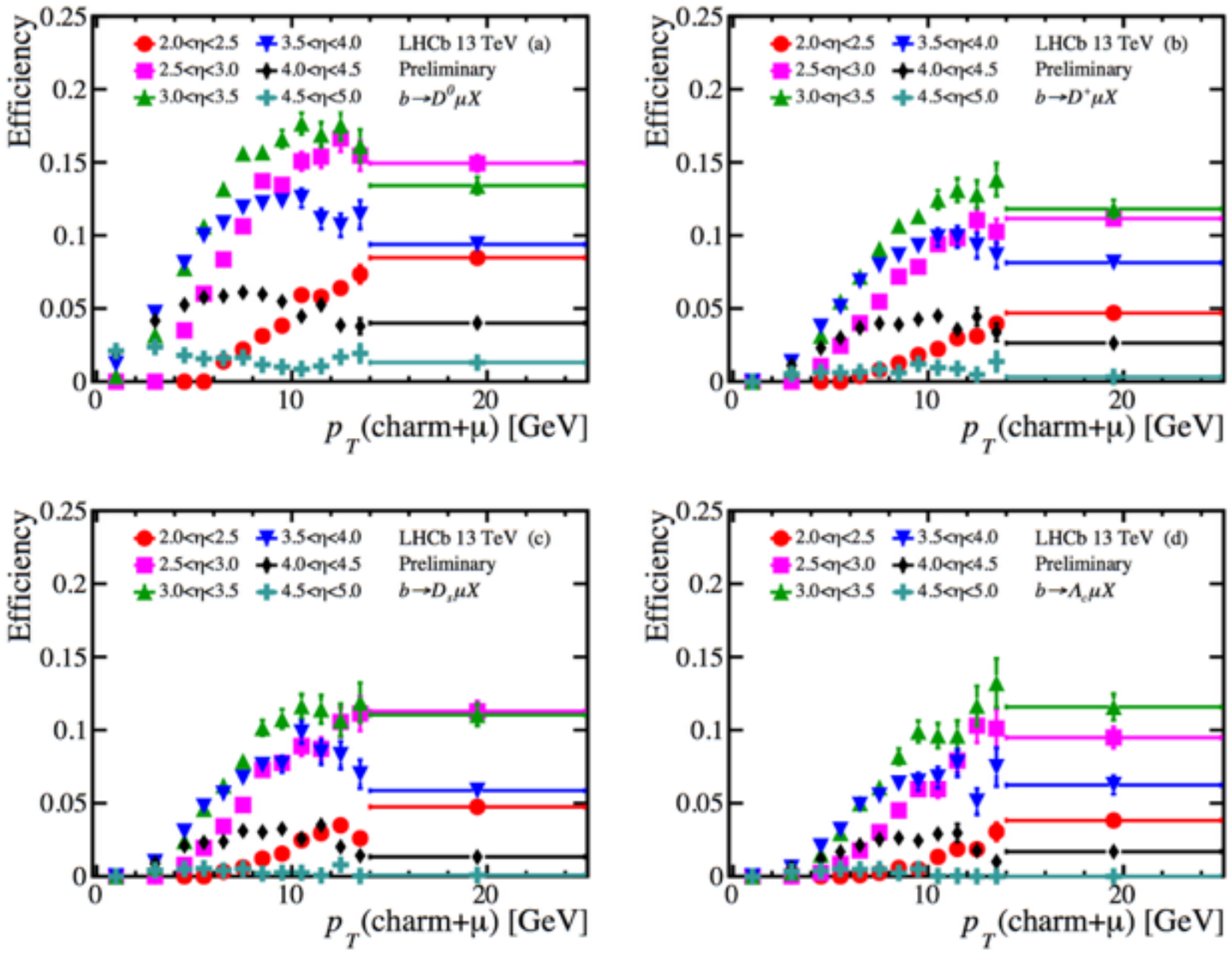


- Other peaking backgrounds estimated with MC (b⟶DDX) and wrong-sign (WS) charm-μ charge combinations (randomly combined charm with a μ)

Source	7 TeV DD	7 TeV WS	13 TeV DD	13 TeV WS
D^0	0.6	0.9	0.7	2.3
D^+	0.5	0.6	0.4	2.1
D_s^+	14.8	0.8	15.1	3.0
Λ_c^+	0.6	0.1	1.0	0.6
$b\bar{b}$	1.9	0.7	1.8	2.0

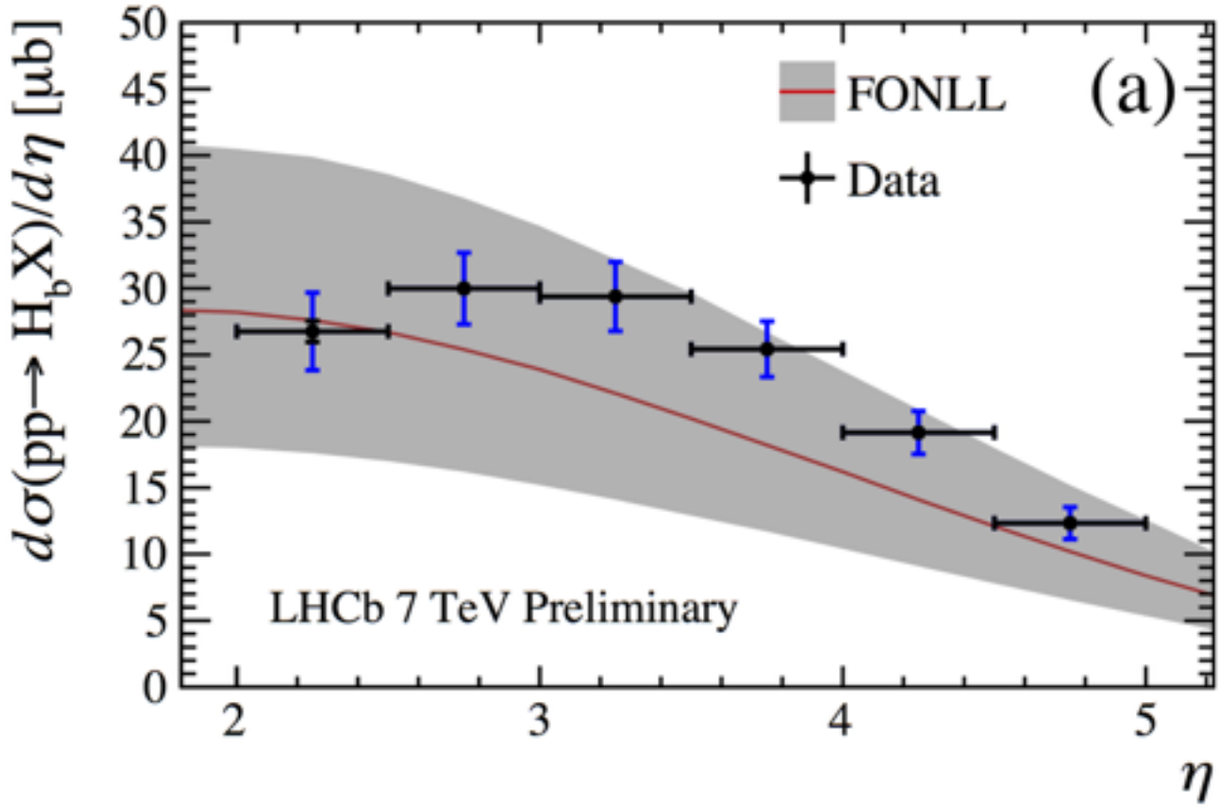
Efficiency corrections

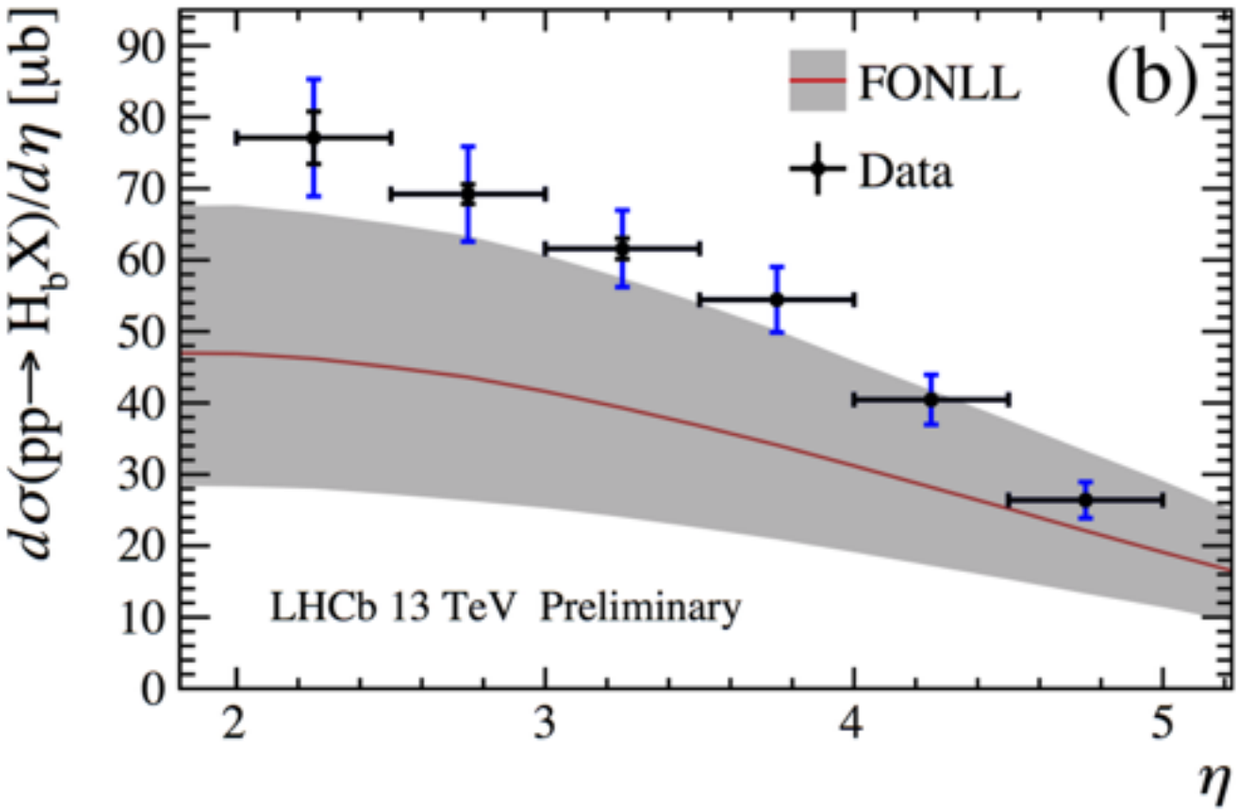
- Tracking, trigger, and particle identification efficiencies determined from data-driven methods
- Other kinematic selection efficiencies from Monte Carlo samples
- Binned in η of the B hadron and p_T(charm+μ)



Preliminary Results

7 and 13 TeV results

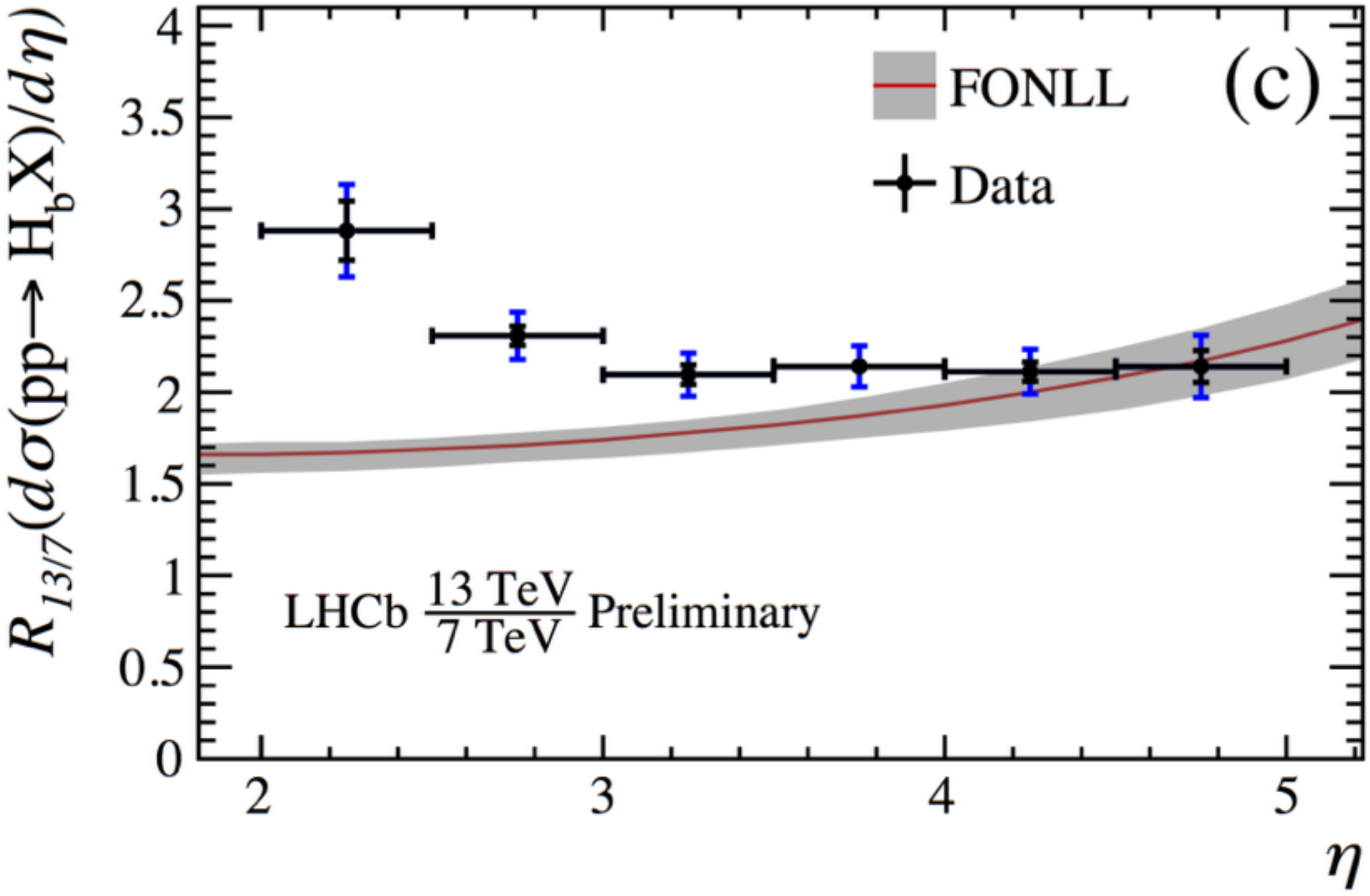




7TeV: 71.7±0.5(stat)±6.5(syst) μb (62^{+28}_{-22} μb Theory)

13TeV: 164.9±2.2(stat)±14.6(syst) μb (111^{+51}_{-44} μb Theory)

σ(13 TeV)/σ(7 TeV) results



Ratio: $2.20 \pm 0.24(\text{stat}) \pm 0.12(\text{syst})$ ($1.790^{+0.21}_{-0.19}$ Theory)

Summary

- Cross-section measurements are important as they assess the accuracy of QCD predictions
- The LHCb experiment has performed the b quark cross-section measurement at both 7 and 13 TeV and the ratio of 13 TeV/ 7 TeV, and find tension between data and theoretical predictions at low η

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Thank you for you attention!

Backup slides follow

SL branching fractions

Particle	τ (ps) measured	$\mathcal{B}_{\rm SL}$ (%) measured	$\Gamma_{\rm SL}$ (ps^{-1}) measured	$\mathcal{B}_{\rm SL}$ (%) to be used
$\overline{B}^0$	1.519 ± 0.005	10.31 ± 0.19	0.0678 ± 0.0013	10.31 ± 0.19
B^-	1.638 ± 0.004	11.09 ± 0.20	0.0680 ± 0.0013	11.09 ± 0.20
$\langle \overline{B}^0_s + B^- \rangle$		10.70 ± 0.19		10.70 ± 0.19
$\overline{B}^0_s$	1.533 ± 0.018			10.40 ± 0.30
Λ^0_b	1.467 ± 0.010			10.35 ± 0.28

Charm branching fractions

Decay	$\mathcal{B}$ (%)	Source
$D^0 \to K^-\pi^+$	3.91 ± 0.05	PDG [8]
$D^+ \to K^-\pi^+\pi^+$	9.22 ± 0.17	CLEO III [12]
$D_s^+ \to K^-K^+\pi^+$	5.44 ± 0.18	PDG [8]
$\Lambda_c^+ \to pK^-\pi^+$	$5.84 \pm 0.27 \pm 0.23$	BES III [13]
	$6.84 \pm 0.24^{+0.21}_{-0.27}$	Belle [14]
	6.36 ± 0.35	Average†

† Uncertainty increased due to discrepant central values.

δ correction

- Based on a paper by Voloshin

$$\Gamma(\Xi_b^- \to \Xi^- X \mu^- \overline{\nu}) = \Gamma(\Lambda_b^0 \to \Lambda X \mu^- \overline{\nu}),$$

Tevatron $$\frac{\sigma(\Xi_b^-)}{\sigma(\Lambda_b^0)} = 0.11 \pm 0.03 \pm 0.03,$$

[exp.] [SU(3)]

- Since lifetimes (and hence SL BF) of Ξ_b^- and Λ_b are equal within uncertainty add 11% to the Λ_b rate
  - x2 using isospin invariance for Ξ_b^0
  - Adding in other contributions from Ω_b^-, and any other baryons (~3%)
  - δ=0.25±0.10

Systematic uncertainties

Source	7 TeV	13 TeV	Ratio 13/7
Luminosity	1.7%	3.9%	3.8%
Tracking efficiency	3.8%	3.8%	1.7
b semileptonic BR [1.1]	2.1%	2.1%	0
Charm hadron BR [1.5]	2.6%	2.6%	0
B decay cocktail	1.0%	1.0%	0
Ignoring b cross-feeds [1]	1.0%	1.0%	0
Background	0.2%	0.3%	0
$b \to u$ decays [1]	0.3%	0.3%	0
δ [1]	2.0%	2.0%	0.2%
Total	5.9%	6.9%	4.2%

- Shown are bin-independent uncertainties
- Bin-dependent uncertainties are due to efficiencies and range from 4-9% for the absolute cross-section measurements and 2-5% for the cross-section ratio