Measurements of heavy flavour production directly or in association with W and Z bosons with ATLAS
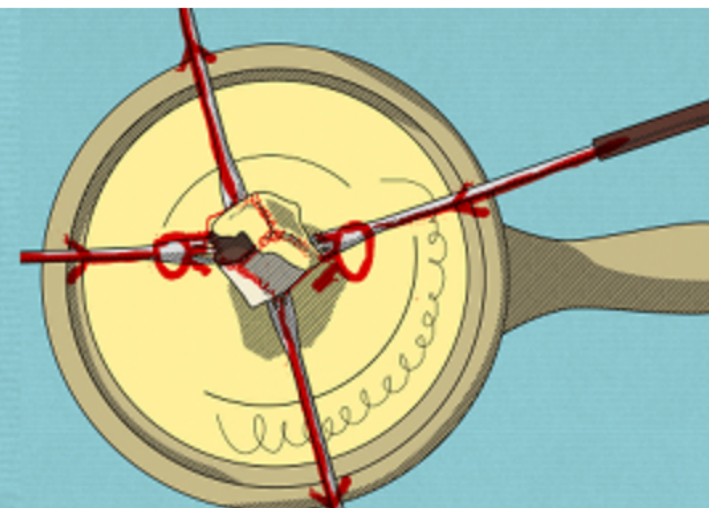
Gabriele Chiodini - INFN Lecce
on behalf of ATLAS collaboration

QCD@LHC

22ND–26TH AUGUST 2016

INTERNATIONAL CONFERENCE ZURICH

Outline and motivations

Direct open HF production:

Charm   **Beauty**

- D at 7 TeV (Roger Jones talk)
- B^+ at 13 and 7 TeV
- b-bar dijet at TeV (Jona Bossio talk)

A. Precise tests of pQCD

B. Tuning and validation of MC generators for LHC

C. Measure quark fragmentation

V boson in association with open HF:

Charm   **Beauty**

- W+c/D
- Z+b and Z+2b

A. Crucial test of state-of-the-art NLO QCD theory and MC modeling

B. s-quark see PDF sensitivity

C. BG for H→bb and BSM processes

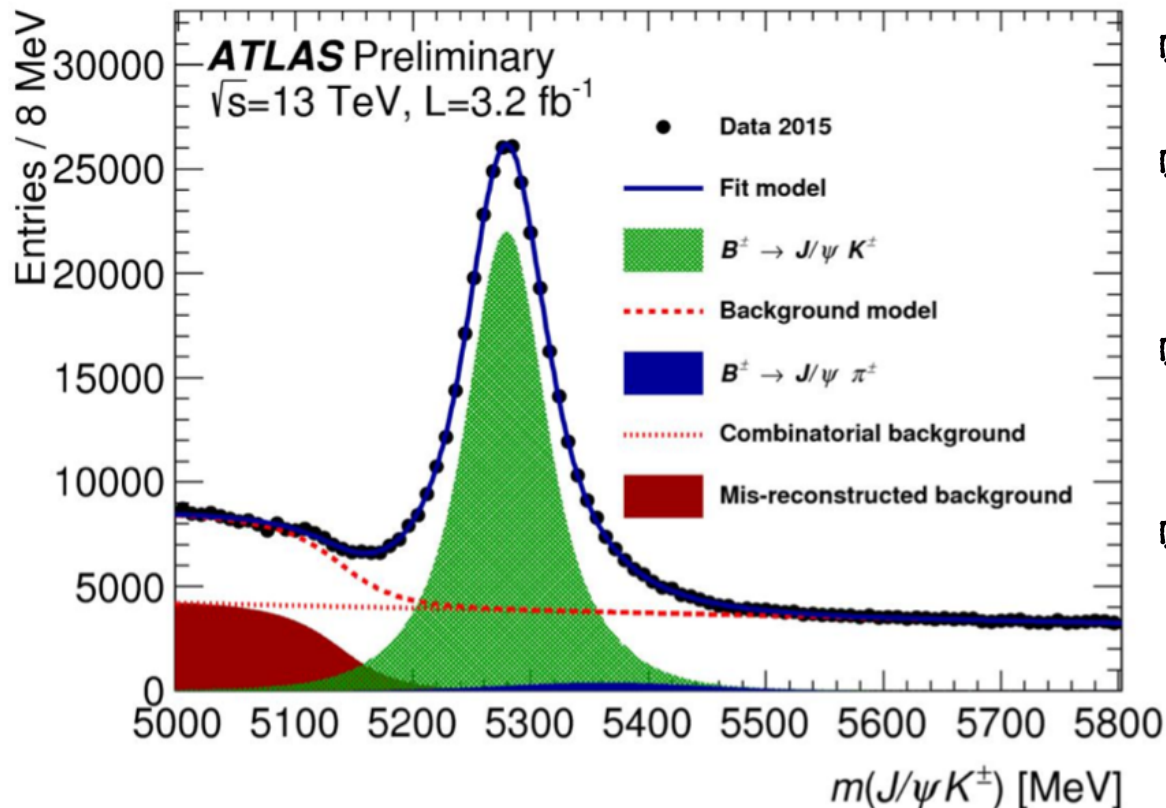Direct and in association with V boson production of hidden flavor: David Bertsche, Roger Jones

Open beauty production

B⁺→J/ψK⁺ exclusive decay at 13 TeV

Initial performance study using full (3.2 fb^{-1}) 2015 pp dataset at 13 TeV. Preparation for further detailed b-hadron measurements!

B⁺→J/ψK⁺

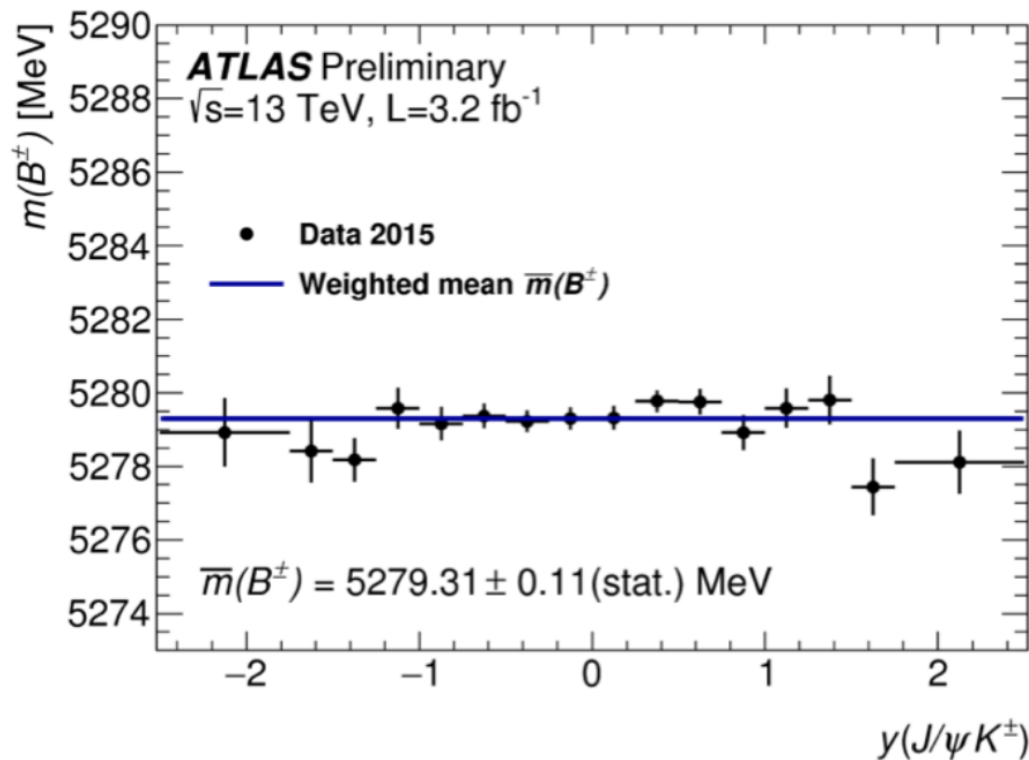- ☑ $p_T(\mu) > 4$ GeV and $p_T(K) > 3$ GeV

- ☑ Three-track vertex $\mu^+\mu^-K^\pm$ ($\chi^2/$ d.o.f < 3)

- ☑ Unbinned fits to $m(J/\psi K^\pm)$ distribution

- ☑ Systematic uncertainty (0.25 MeV) dominated by fit model:

  - Signal: sum of two Gaussians with common mean
  - BG: hyperbolic tangent function + linear function

B$^+$→J/ΨK$^+$ mass at 13 TeV

2015 dataset at 13 TeV used to reconstruct mass in 16 rapidity intervals.

Testing the momentum calibration of Inner Detector tracking,

prerequisite for Run-2 analyses

ATLAS Preliminary
√s=13 TeV, L=3.2 fb^{-1}

● Data 2015

— Weighted mean $\overline{m}(B^\pm)$

$\overline{m}(B^\pm) = 5279.31 \pm 0.11 \text{(stat.) MeV}$

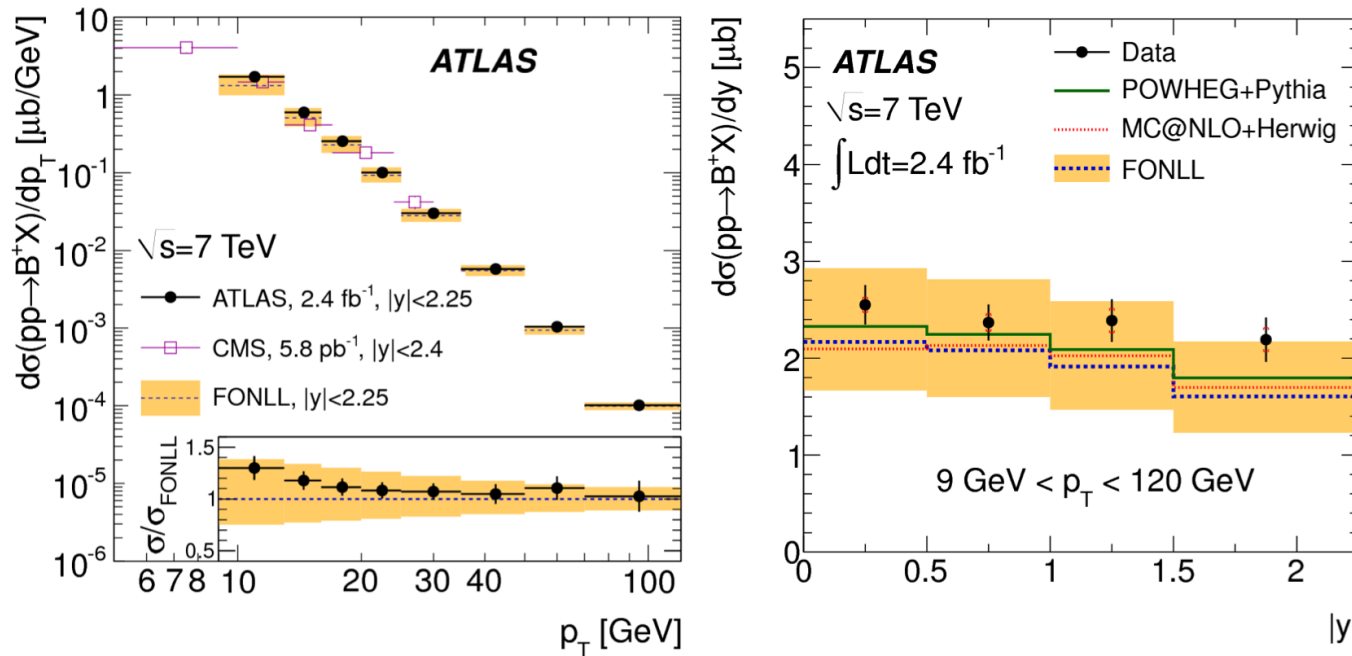Values in different rapidity bins show uniformity of reconstruction over the entire detector

Main systematics from signal model and background parametrization

Measured mass in good agreement with world average and LHCb results

Fit	$B^\pm$ mass [MeV]	Fit error [MeV]
Default Fit	5279.31	0.11 (stat.)
$L_{xy} > 0.2$ mm	5279.34	0.09 (stat.)
World Average fit	5279.29	0.15
LHCb	5279.38	0.11 (stat.) ± 0.33 (syst.)

B⁺→J/ψK⁺ diff. x-sec. at 7 TeV

- $B^+ \rightarrow J/\psi\, K_+$ and $J/\psi \rightarrow \mu^+\mu^-$ branching ratio= $6.03 \pm 0.21 \times 10^{-5}$

- The predictions are normalized to $f(b \rightarrow B^+) = 40.1 \pm 1.3\%$ [PDG]
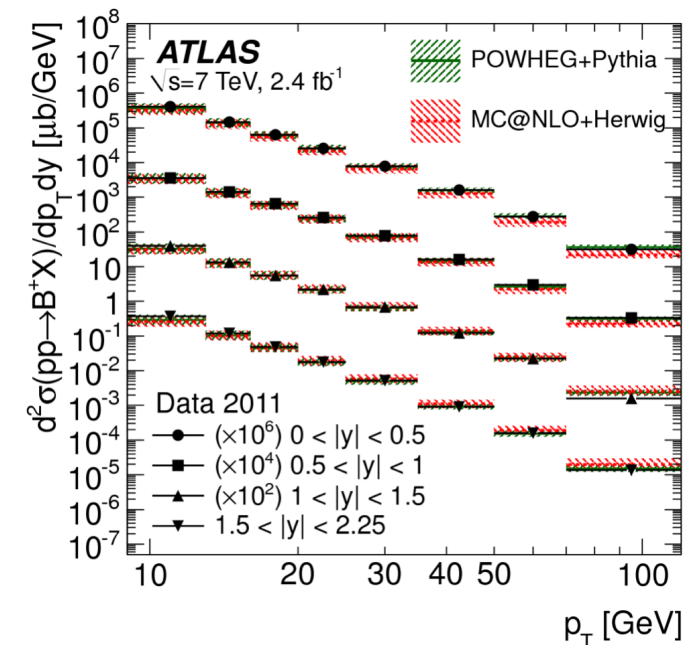
FONLL provides reasonable description although with large theoretical uncertainties

Central predictions are somewhat harder

b fragmentation fraction f_s/f_d at 7 TeV from B^0_s/B^0_d

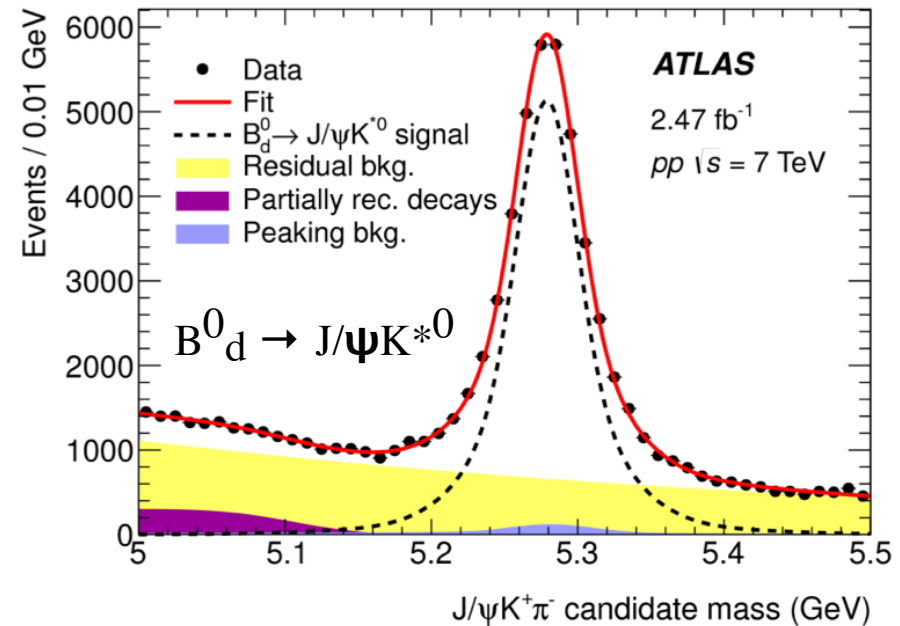Production rate of Bs^0 (Bd^0) hadrons depends on the fragmentation fraction f_S (f_d).

Important for many studies such as $B^0_{d(s)} \to \mu\mu$.

[Phys. Rev. Lett. 115, 262001 (2015)]

$B^0_S \to J/\psi\varphi(K^+K^-)$ and $B^0_d \to J/\psi K*^0$ used to determine f_S/f_d

$N_{B^0_s} = 6640 \pm 100$ $B^0_s \to J/\psi\phi$
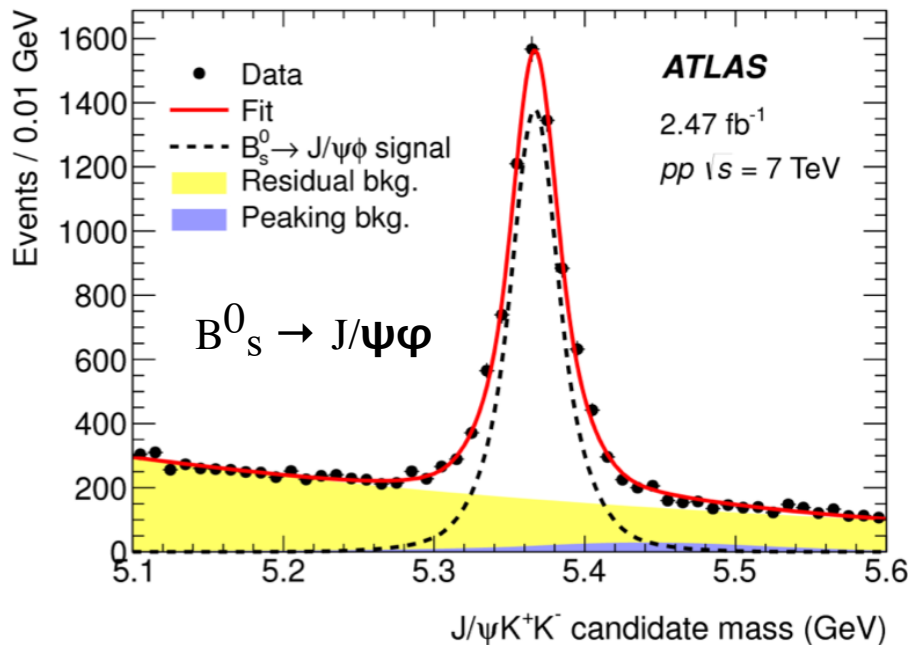
$N_{B^0_d} = 36290 \pm 320$ $B^0_d \to J/\psi K^{*0}$

Signal yields from unbinned maximum likelihood fit to invariant-mass spectra

Strangeness suppression in b fragmentation

The ratio is extracted from the measured signal yields, converted into B meson yields:

$$\frac{f_s}{f_d} = \frac{N_{B_s^0}}{N_{B_d^0}} \frac{\mathcal{B}(B_d^0 \to J/\psi K^{*0})}{\mathcal{B}(B_s^0 \to J/\psi \phi)} \frac{\mathcal{B}(K^{*0} \to K^+ \pi^-)}{\mathcal{B}(\phi \to K^+ K^-)} \mathcal{R}_{eff}$$

Correction for acceptance and selection efficiency ratios in the two modes

$$\frac{f_s}{f_d} \frac{\mathcal{B}(B_s^0 \to J/\psi \phi)}{\mathcal{B}(B_d^0 \to J/\psi K^{*0})} = 0.199 \pm 0.004(\text{stat}) \pm 0.008(\text{sys})$$

$$\frac{\mathcal{B}(B_s^0 \to J/\psi \phi)}{\mathcal{B}(B_d^0 \to J/\psi K^{*0})} = 0.83^{+0.03}_{-0.02}(\omega_B)^{+0.01}_{-0.00}(f_M)^{+0.01}_{-0.02}(a_i)^{+0.01}_{-0.02}(m_c)$$

Final measurement uses perturbative QCD calculation of branching fractions ratio: Phys. Rev. D 89 (2014) 094010, arXiv:1309.0313

Final measurement: $f_S/f_d = 0.240 \pm 0.004(\text{stat}) \pm 0.010(\text{sys}) \pm 0.017(\text{th})$

$\Big[$ Extracted strangeness suppression factor in charm fragmentation

$0.26 \pm 0.05(stat) \pm 0.02(syst) \pm 0.02(br) \pm 0.01(extr)$ **Nucl.Phys. B907 (2016) 717** $\Big]$

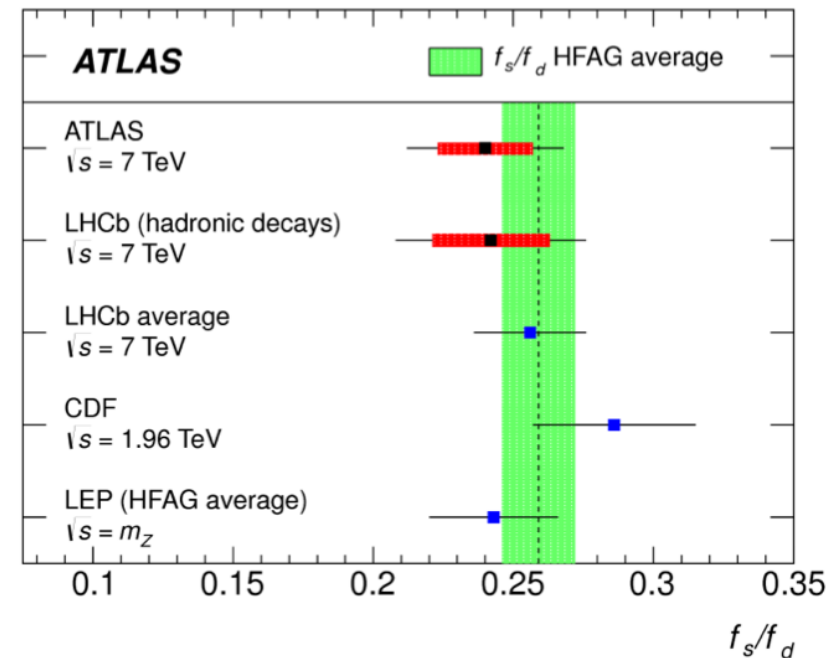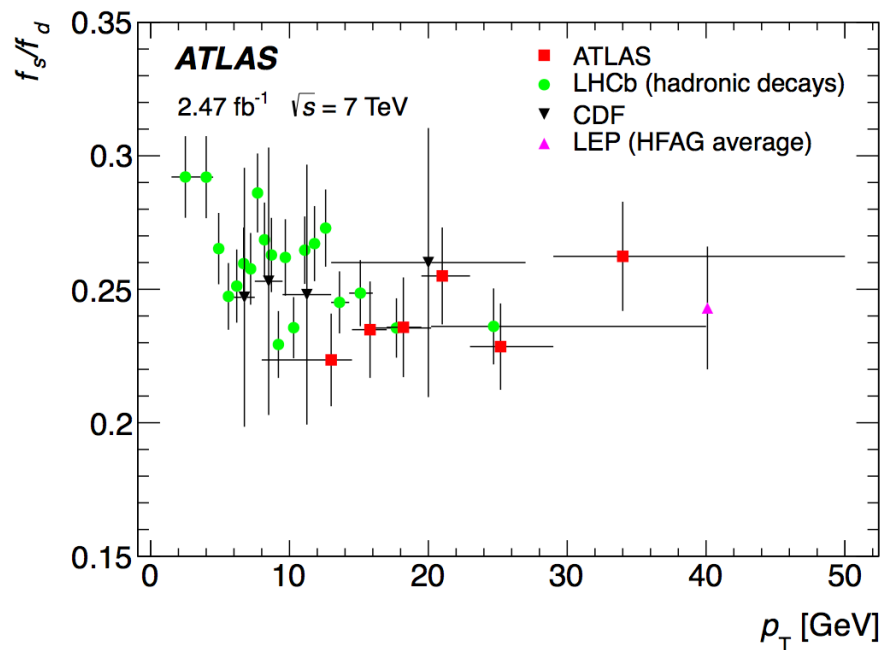# f_s/f_d p_T and η dependence 7 TeV
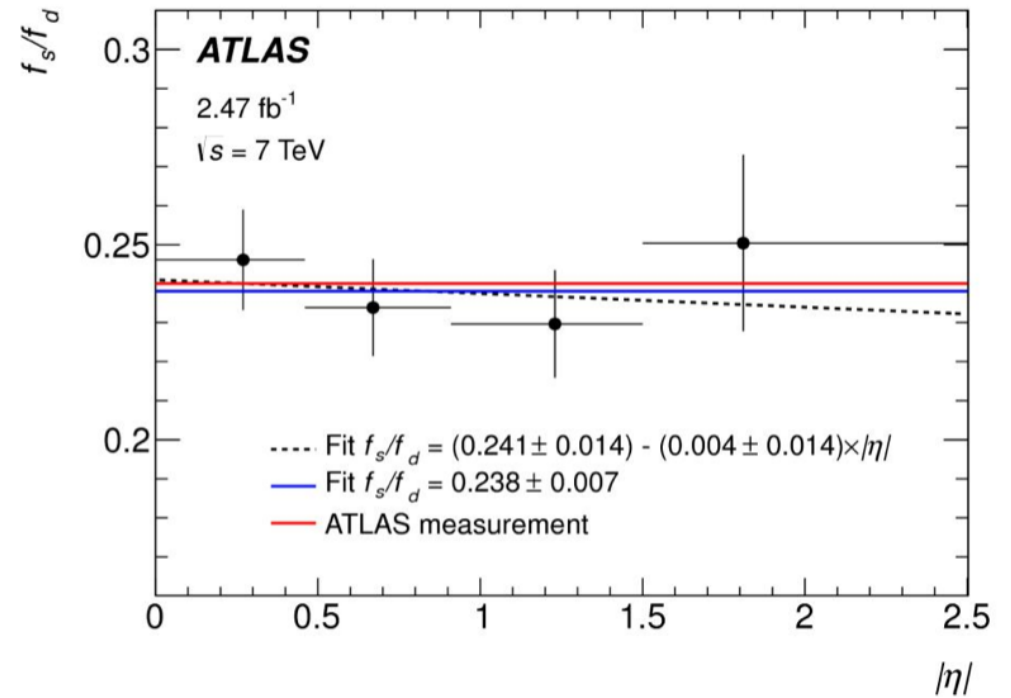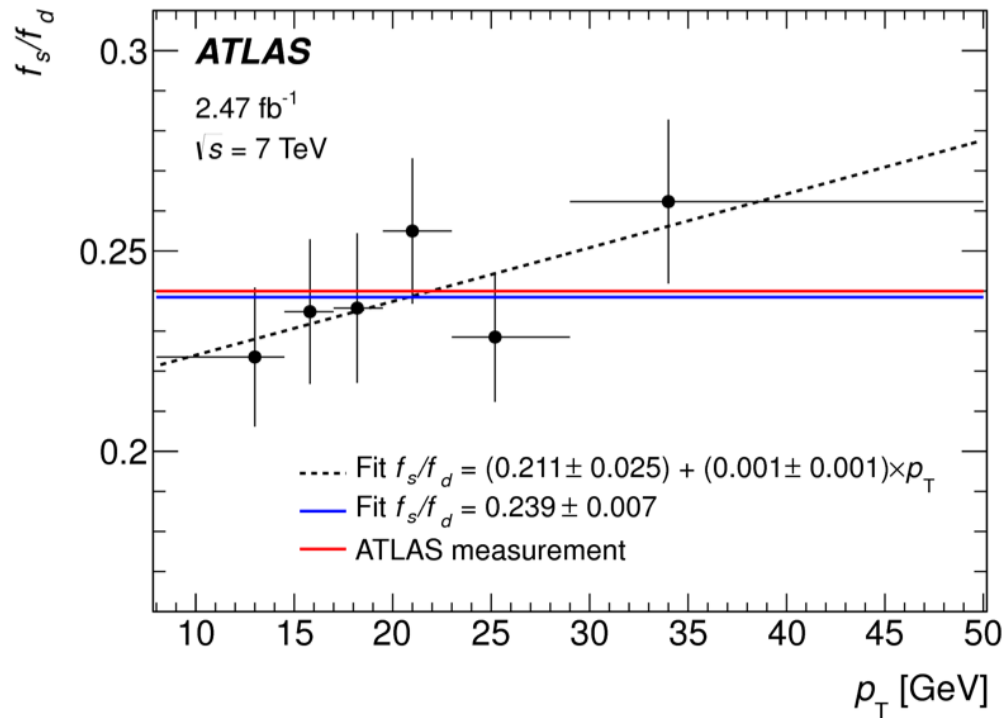
No sizeable p_T and η dependence

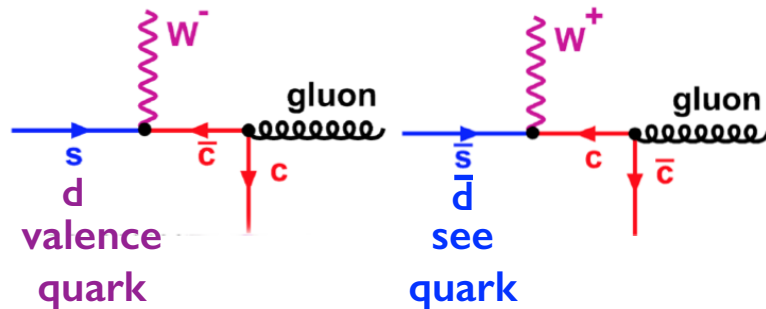# Comparison of f_s/f_d with other experiments

Results compared to previous experimental results (historical tension between LEP/CDF)

Good agreement with recent LHCb results, significantly improving the world average

HF + V production

W$^{-,+}$+c/D*$^{+,-}$
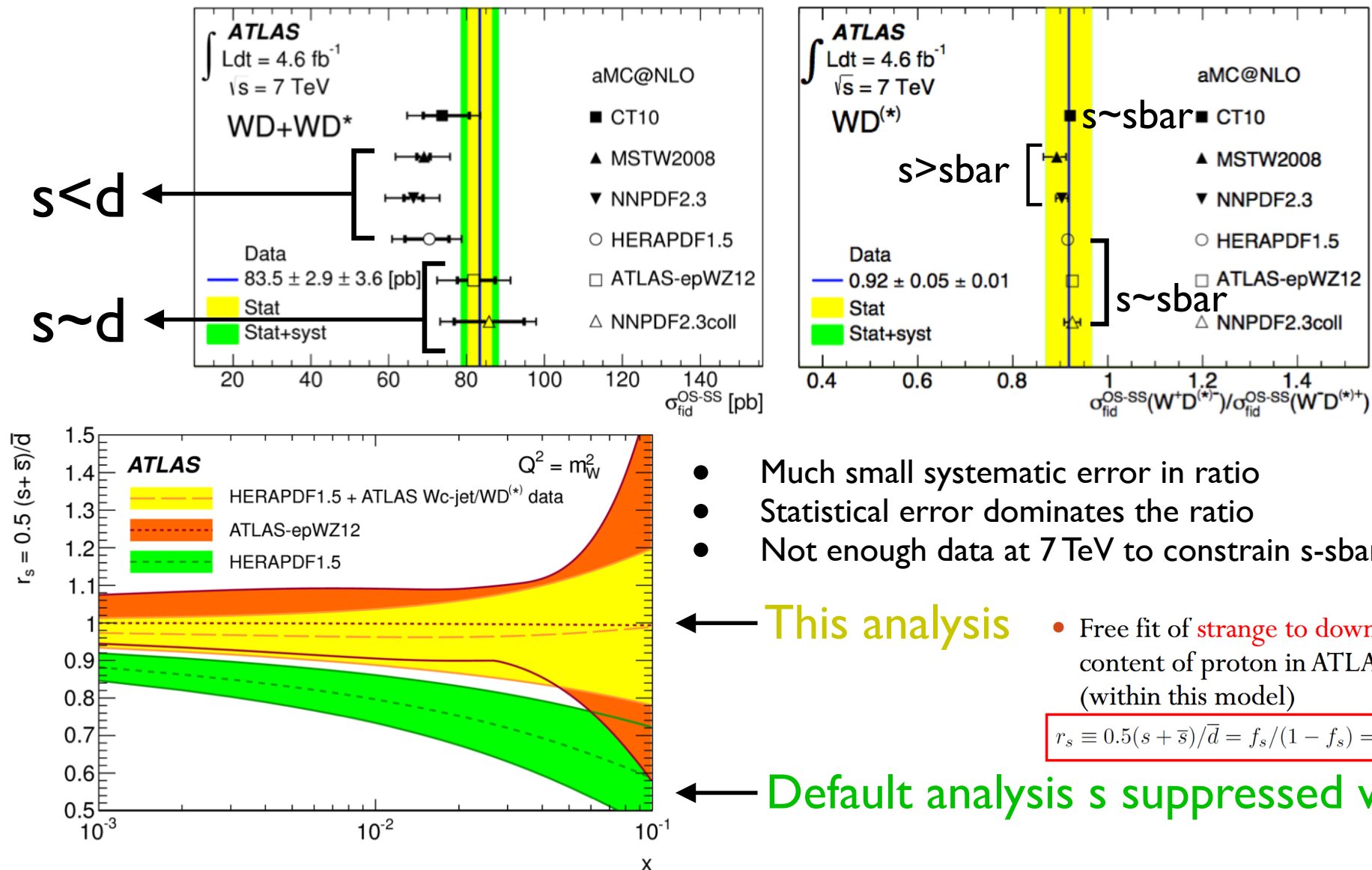

LO in s and
not Cabibbo Suppressed

– LO process: q→Wc; q=d, s, b

- d quark ≈ 10%

- s quark dominates

- Directly sensitive to s-quark PDF at x~0.01

- W charge to tag c-flavor.

– Experimental measurements :

- Some fixed target exp. (eg NuTeV) favour s-quark sea suppression w.r.t. d-quark sea

- ATLAS W/Z measurements favour SU(3) flavour symmetric sea (**JHEP 05 (2014) 068**)
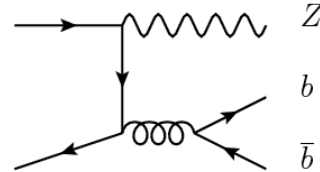
Strange see in protons at 7 TeV

- Much small systematic error in ratio
- Statistical error dominates the ratio
- Not enough data at 7 TeV to constrain s-sbar asymmetry

This analysis

Default analysis s suppressed wrt d

- Free fit of strange to down sea content of proton in ATLAS data (within this model)

$$r_s \equiv 0.5(s+\bar{s})/\bar{d} = f_s/(1-f_s) = 0.96^{+0.26}_{-0.30}$$

Z+b and Z+bb

Background to many channels (eg. VH→Vbb) and sensitive to QCD effects (eg. modelling of Parton shower)
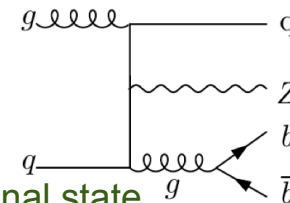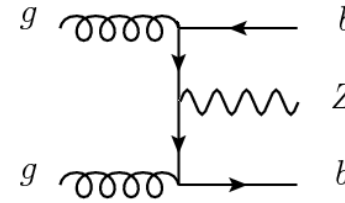
qq scattering ~ 17%
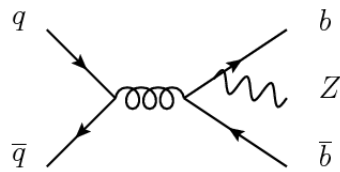
qg scattering ~3%

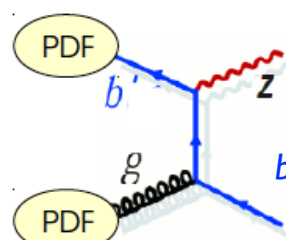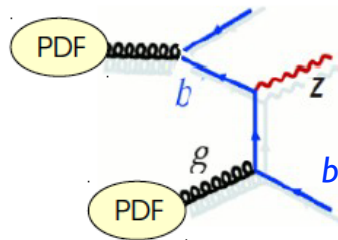gg splitting in initial state ~80%

gg splitting in final state

Not presents in W+bb

LO in b

JHEP 10 (2014) 141

Measured multiple $d\sigma fid/dX$ with X variables sensitive to various QCD effects

Theoretical predictions generally provide a good description of the shape of the data.

4 Flavors Number Schema
- □ HQ only in final state
- □ Sum all power of (m_H^2/Q^2) but only 1st log(Q^2/m_H^2)

5 Flavor Number Schema
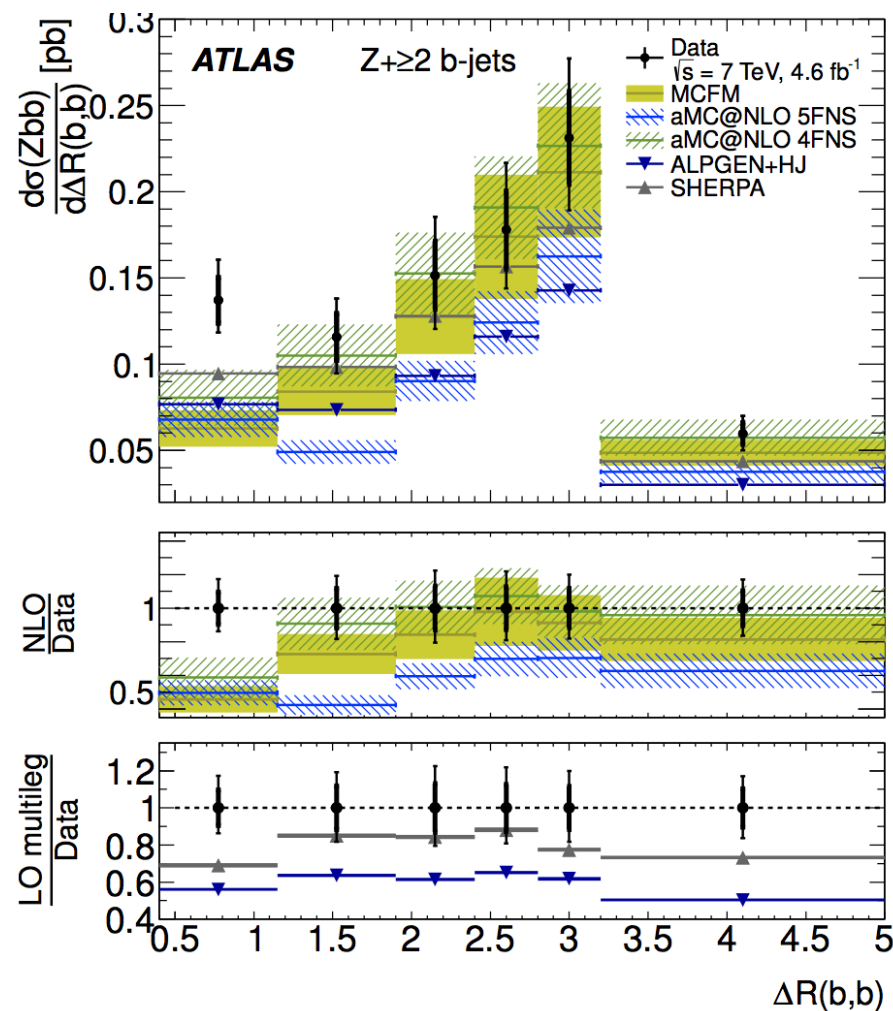- □ HQ are partons
- □ resums log(Q^2/m_H^2) but ignores power of (m_H^2/Q^2)

Z+bb diff. x-sec at 7 TeV
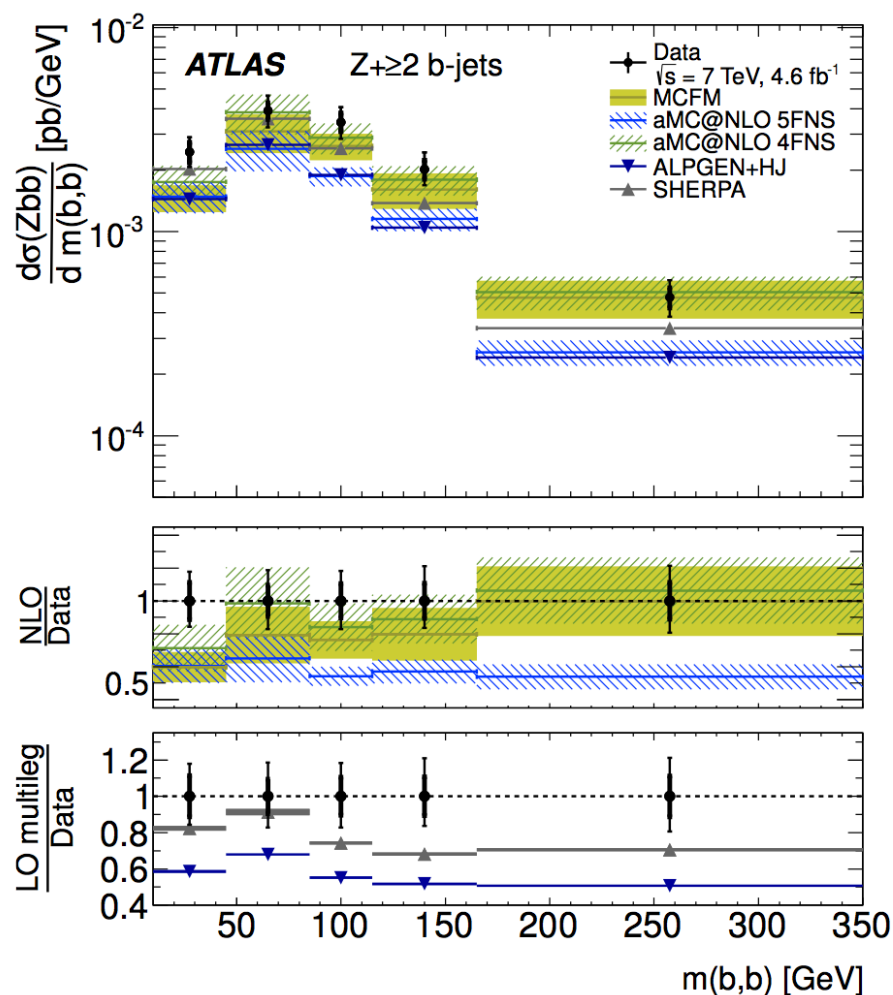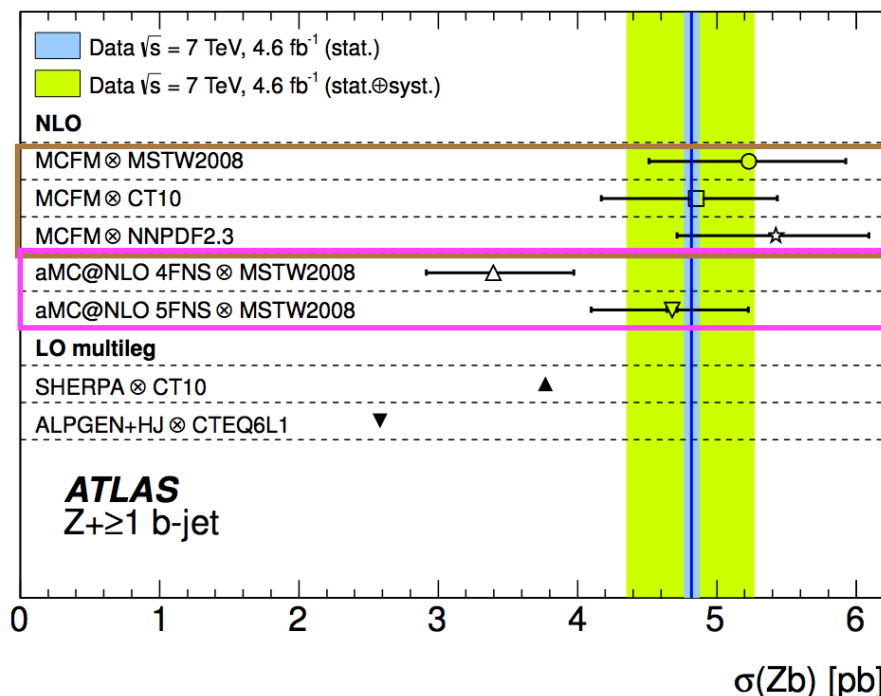

VH(bb) fits binned in both pT(V) and m(b,b)

Collinear bb, which is dominated by parton shower, it is not well described
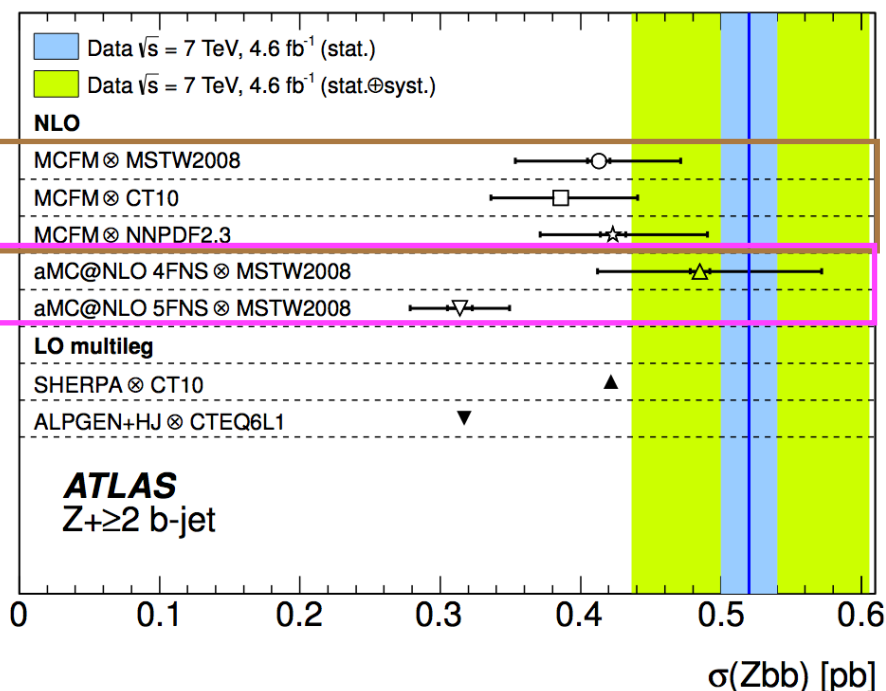
Z+b and Z+bb vs Theory

5FNS aMC@NLO preferred for Zb.

4FNS aMC@NLO underestimates Zb central rapidities.

4FNS aMC@NLO preferred for Zbb but comparison not fare because 5FNS aMC@NLO for Zbb is at LO.

NLO predict correctly x-sec but LO multileg underestimate x-sec

Theory uncertainties dominated by scale prevent strong constraints on b-quark PDFs in this channel.

Data uncertainties dominated by systematics due to b-jet tagging efficiency and b-jet template shape

Conclusions

☑ First studies of open beauty with 2015 pp collision data at √s=13 TeV.

☑ Measurement of the fragmentation fraction offers tests of PDFs and SM QCD

☑ Measurements of V + HF:

- W+c provides important insight on strange quark PDF

- V+b helps understanding and modelling of HQ production in QCD

Many more exciting HF results from both the Run 1 and Run 2 soon!