W, Z and top production measurements at LHCb

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On behalf of the LHCb collaboration

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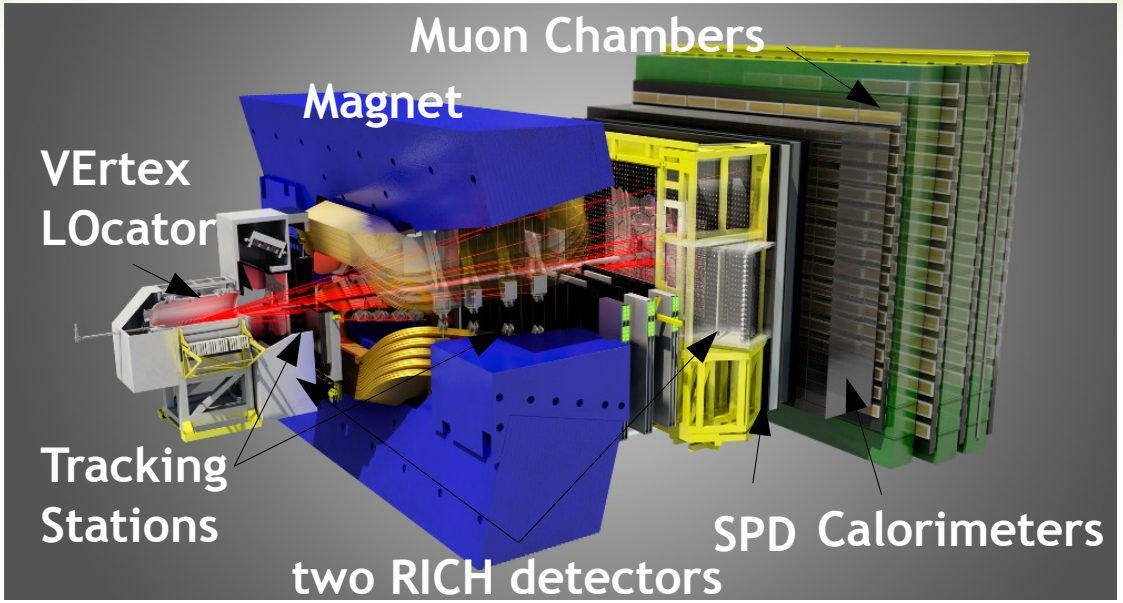
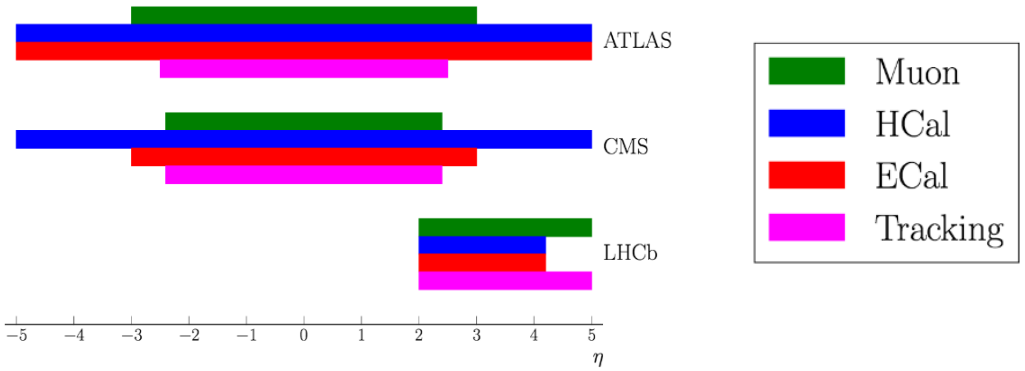
LHCb detector

Int. J. Mod. Phys. A 30, 1530022 (2015)





• **LHCb** is a forward spectrometer initially designed for B physics, now it can be considered a **General Forward Detector**.

• It covers a **unique acceptance** within the LHC experiments ($2 < \eta < 5$).

• **Momentum resolution**: 0.4% at 5 GeV and 0.6% at 100 GeV.

• **Impact parameter resolution** of 13-20 μm at high P_T

• **Muon ID efficiency**: 97% with 1-3% $\mu \rightarrow \pi$ mis-identification.

Introduction

• LHCb offers a **complementary phase space region respect to ATLAS and CMS** for Electroweak and jets measurements.

• Cross-sections measurements of **W and Z production in the forward acceptance** are important tests of the Standard Model.

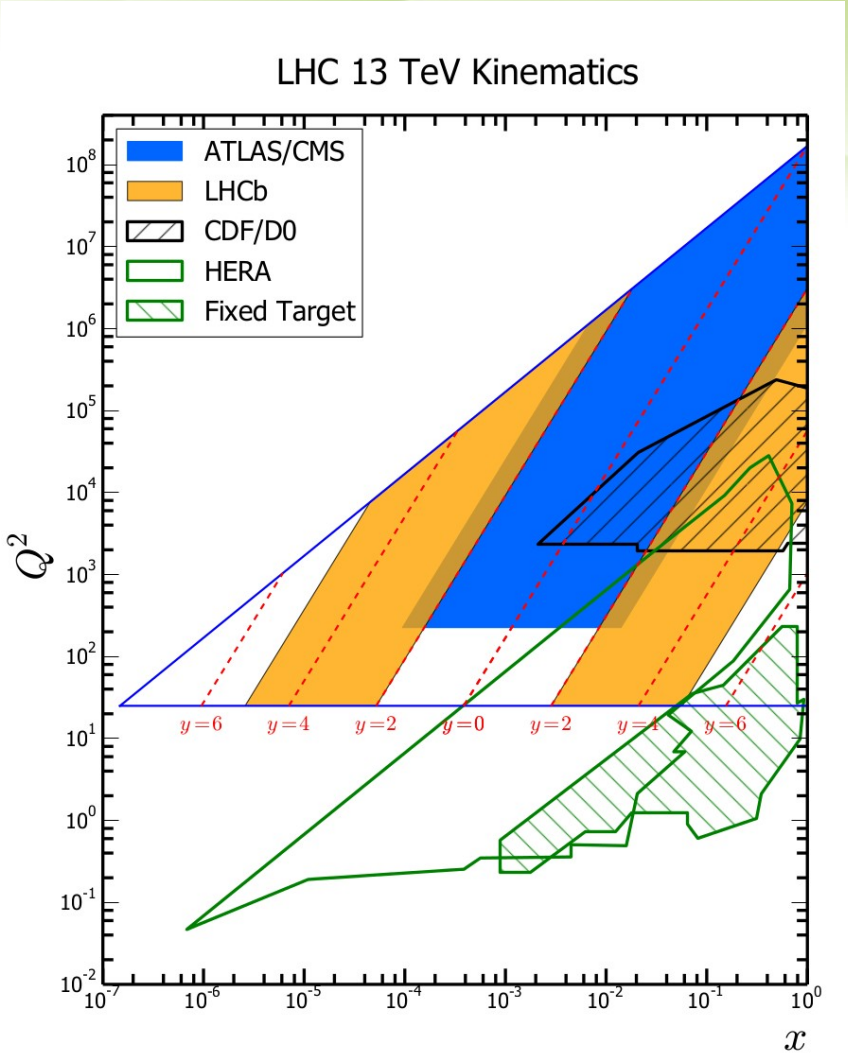
• **Top measurements are also possible!**

• These measurements provide access to **Parton Distribution Functions** in two different regions:

➔ at high Bjorken-x values.

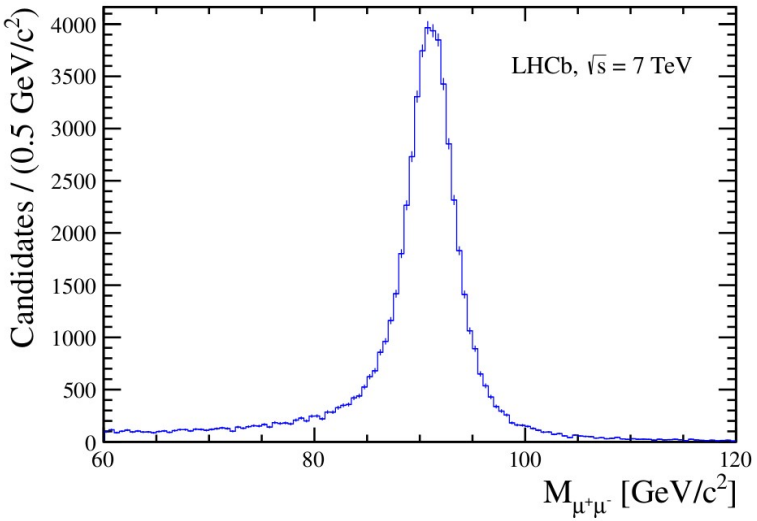
➔ At low x values, **unexplored by other experiments.**

• I'm going to present recent measurements at **7 TeV (1 fb^{-1})**, **8 TeV (2 fb^{-1})** and the first electroweak measurement at **13 TeV (294 fb^{-1})**.



Z inclusive production at 7 and 8 TeV

- Motivation: **test Standard Model and probe PDFs.**

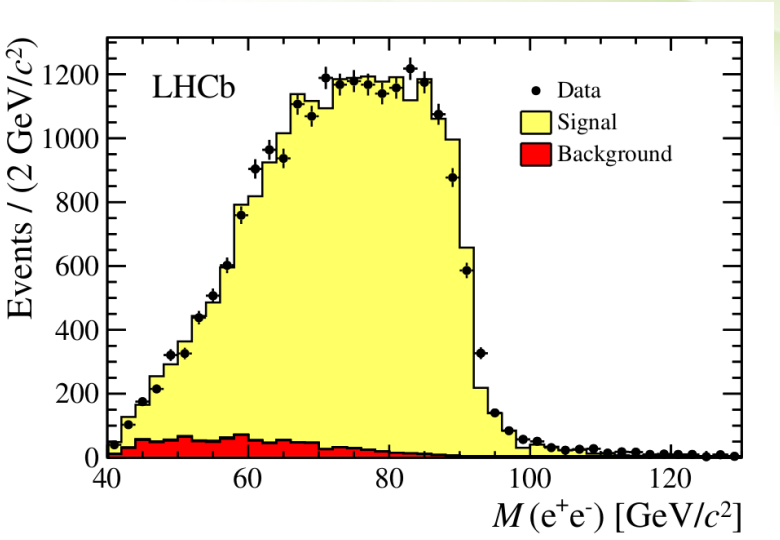


[JHEP 08 (2015) p.039] [JHEP 01 (2016) p.155]

- **Z → μ μ**

- Selection: two muons with P_T > 20 GeV and 2< η < 4.5. $M_{\mu\mu}$ in the range [60,120] GeV.

- Purity = N(Z→ μμ)/N_{sel}>99%



[JHEP 08 (2013) p.106] [JHEP 05 (2015) p.109]

- **Z → e e**

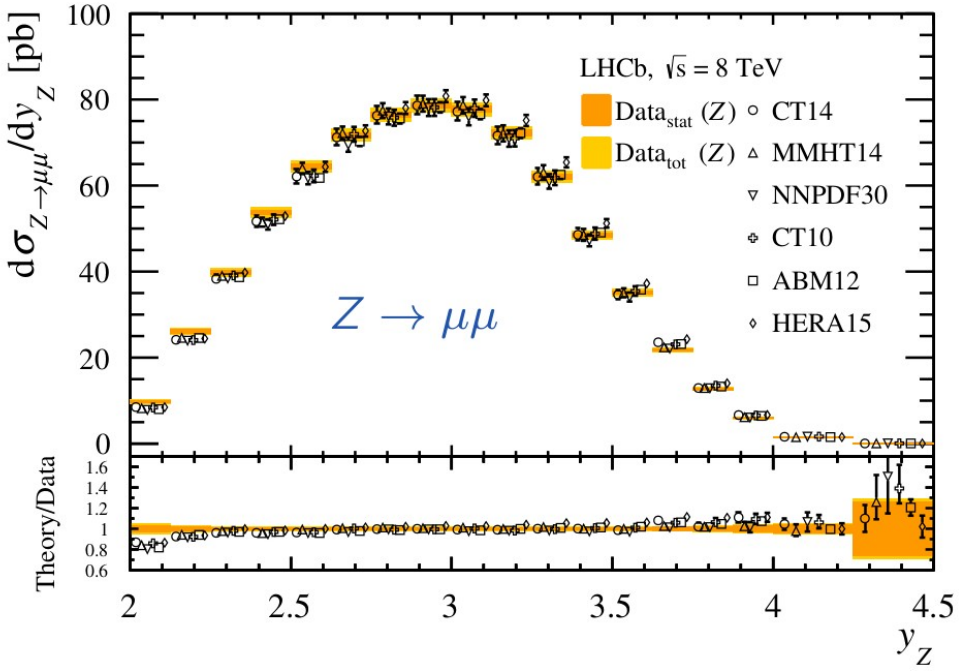
- Selection: two electrons with P_T > 20 GeV and 2< η < 4.5. M_{ee} > 40 GeV.

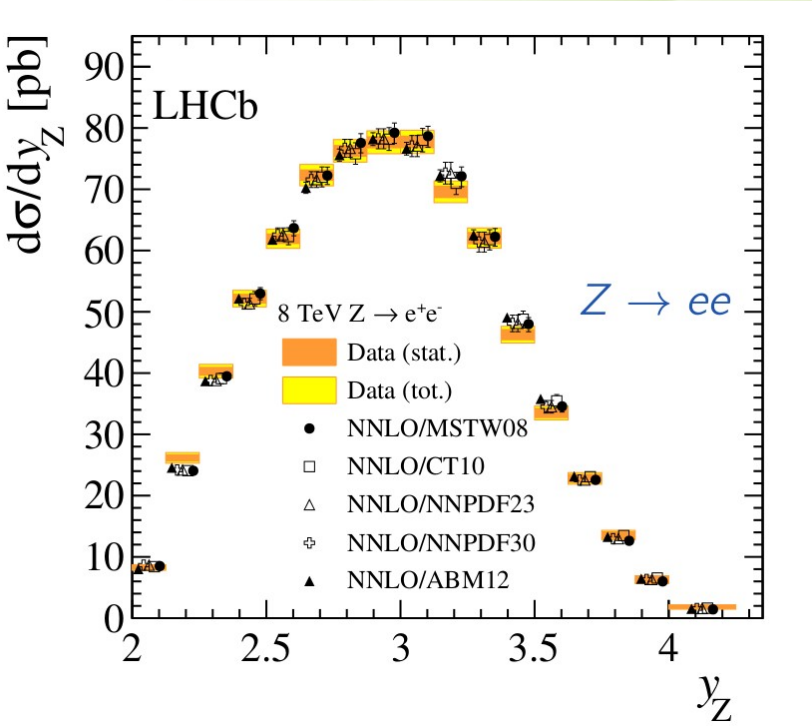
- **Peak smeared by bremstrahlung.**

- Purity = N(Z→ ee)/N_{sel}>95% → background from electron mis-ID

Z inclusive production at 7 and 8 TeV

- The differential cross section in bins of rapidity:





- The experimental error is **dominated by luminosity and beam energy uncertainties**.
- **NNLO predictions obtained using different PDFs sets are compatible with data.**

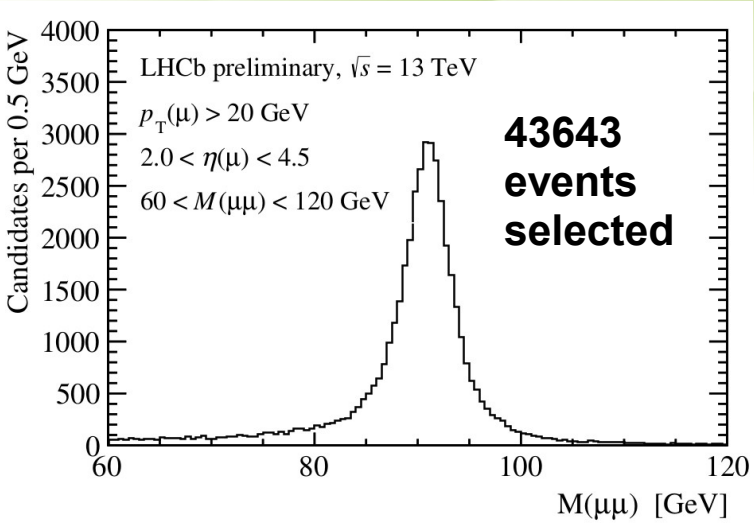
Z inclusive production at 13 TeV

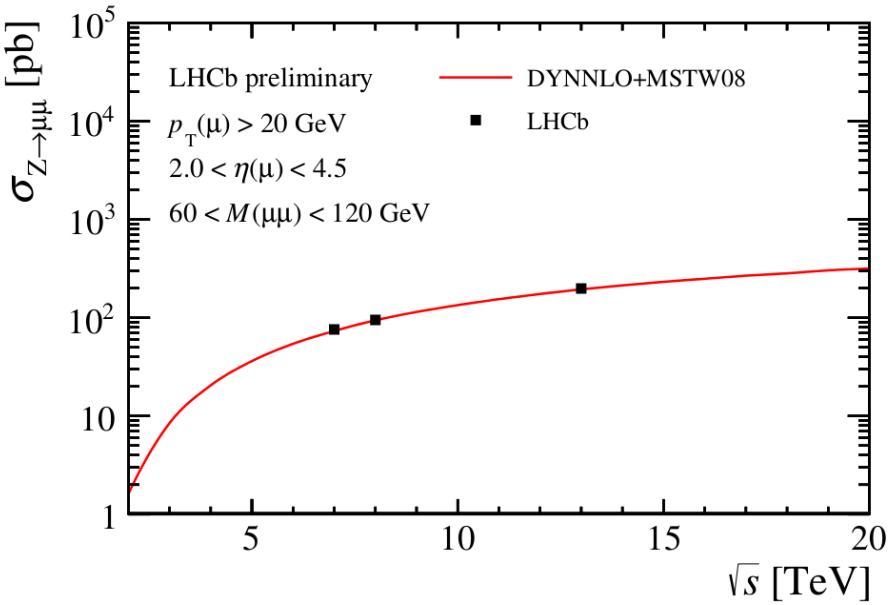
LHCb-CONF-2016-002

- **Measurement of inclusive Z → μ μ cross section at 13 TeV.**

- Probes PDFs at lower x value than Run I

Limited by knowledge of luminosity (luminosity measurement with gas fixed target, SMOG system [JINST 9 (2014) P12005])



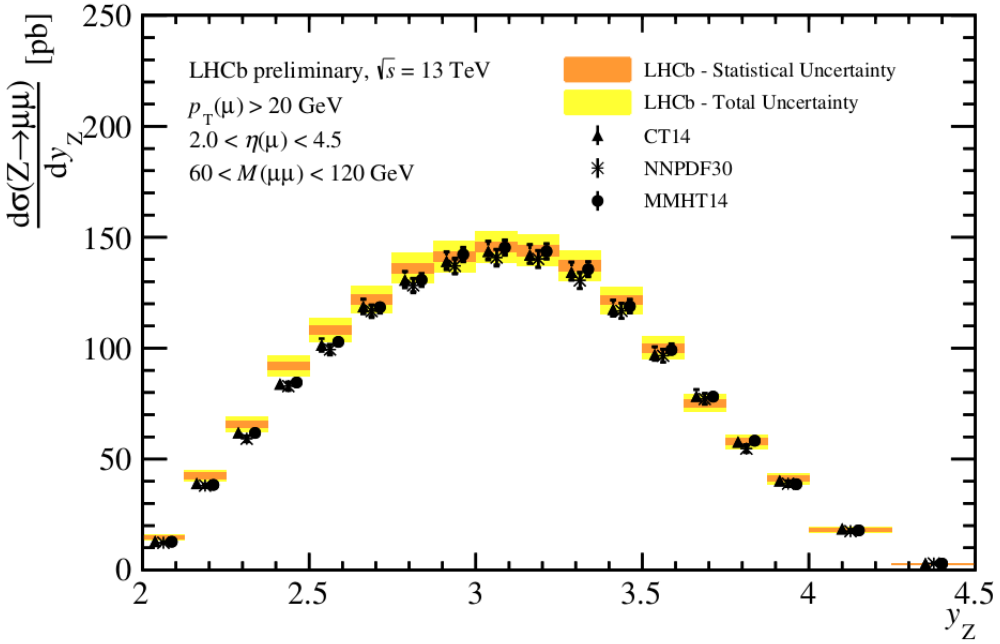


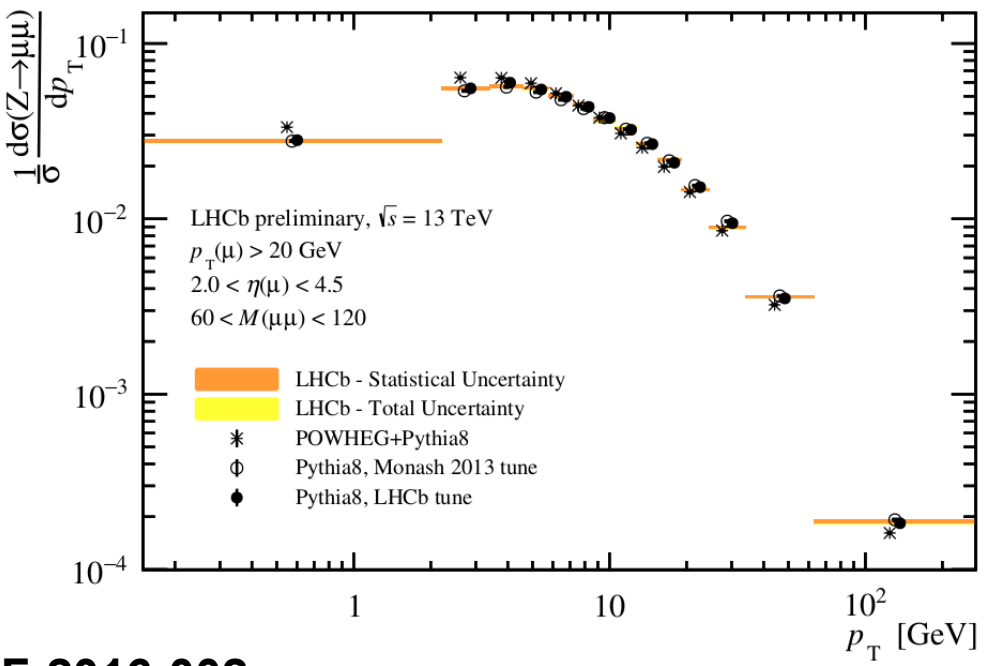
First Electroweak measurement at 13 TeV at LHCb !

σ(pp → Z + X) = 198.4 ± 1.0 (stat.) ± 4.7 (syst.) ± 7.7 (lum.) pb

Z inclusive production at 13 TeV

- The differential cross section in bins of Z rapidity and transverse momentum :



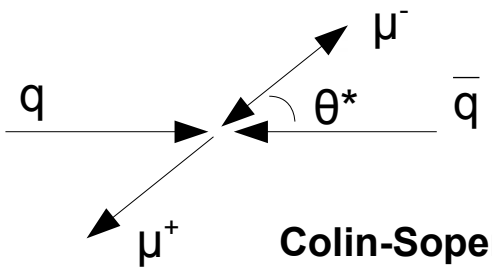


LHCb-CONF-2016-002

- **NNLO predictions obtained using different PDFs sets are compatible with data.**

Forward backward asymmetry in Z->μμ

- **Motivation: measure the electroweak mixing angle.**



Colin-Soper frame (di-muon rest frame)

The forward backward asymmetry is defined as:

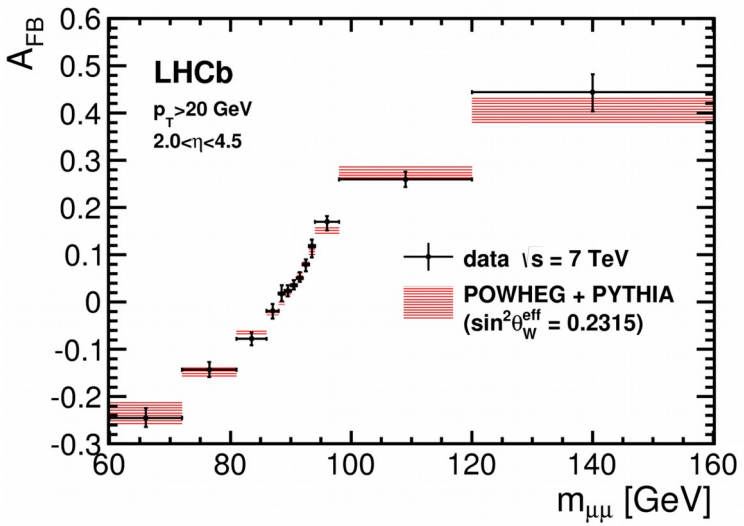
$$A_{FB} = \frac{N_F - N_B}{N_F + N_B}$$

N_F : number of forward decay ($\cos\theta^* > 0$)

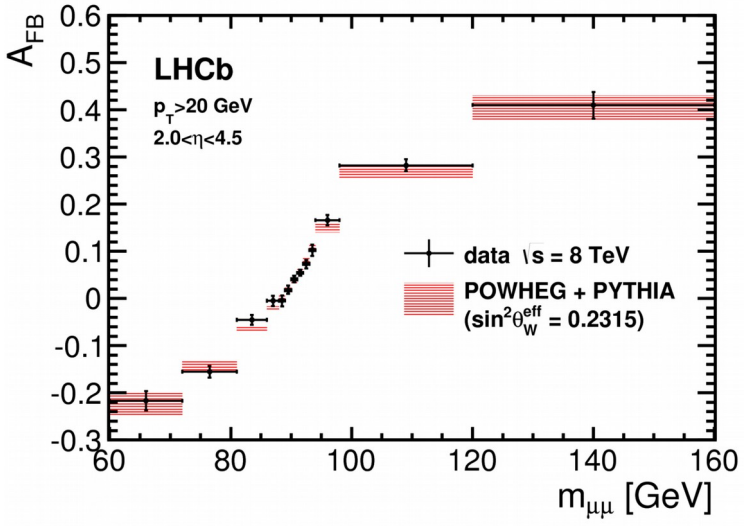
N_B : number of backward decay ($\cos\theta^* < 0$)

- **A_{FB} at 7 and 8 TeV compared to theory [JHEP 11 (2015) 190]:**

7 TeV



8 TeV

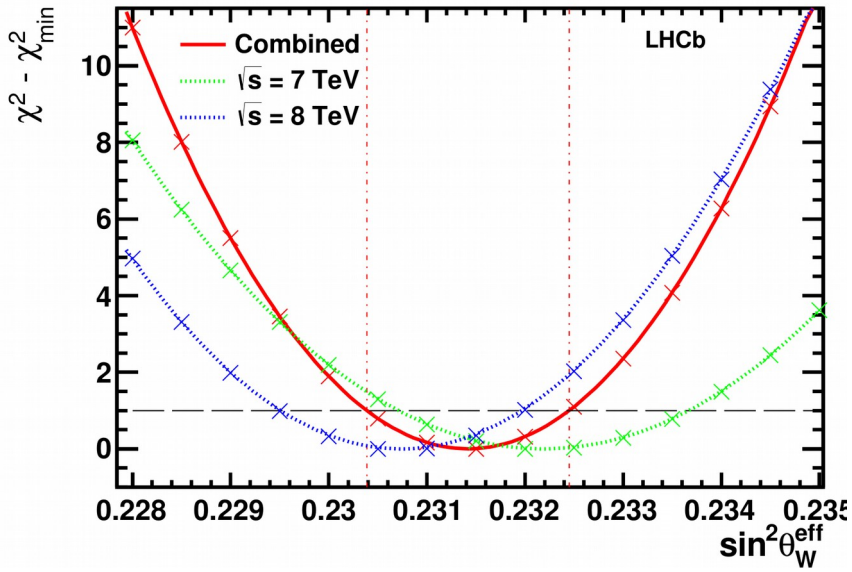


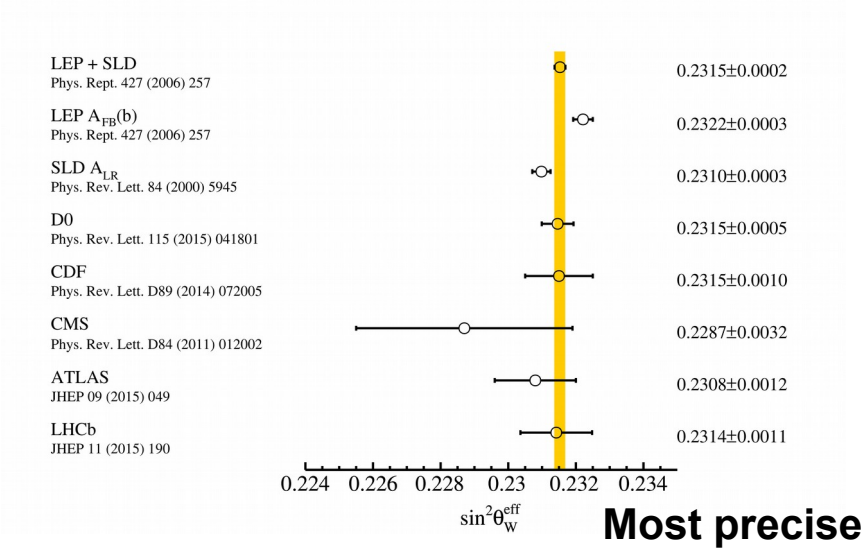
$\sin^2\theta^{eff}_W$

• **At high rapidities A_{FB} is enhanced**, and there is an increased sensitivity to $\sin^2\theta^{eff}_W$ respect to low rapidities: due to PDFs the high-x parton tend to be the quark and not the anti-quark.

• **Simulation samples are generated with different values of $\sin^2\theta^{eff}_W$** . The measured one is chosen by comparing the simulations with the measured A_{FB}, using a X^2.

$\sin^2\theta^{eff}_W$ = 0.23142 ± 0.00073 (stat.) ± 0.00052 (syst.) ± 0.00056 (th.) [JHEP 11 (2015) 190]





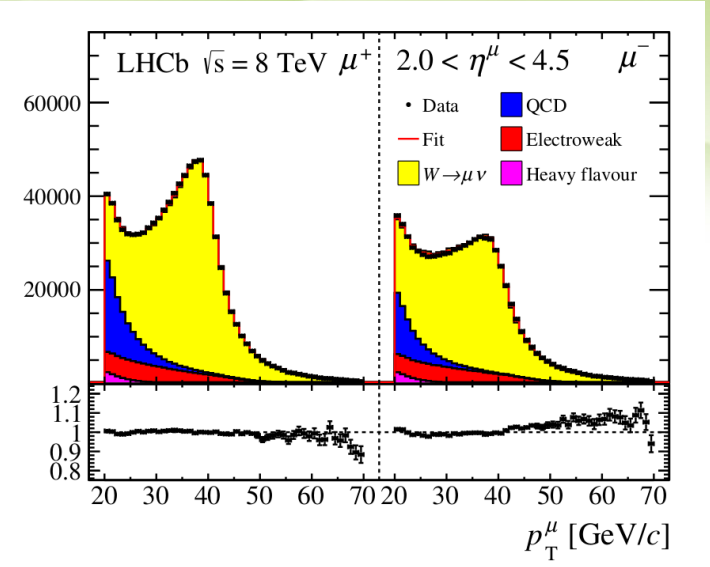
Most precise $\sin^2\theta^{eff}_W$ measurement at LHC!

• Systematic error dominated by curvature/momentum and PDFs incertainties.

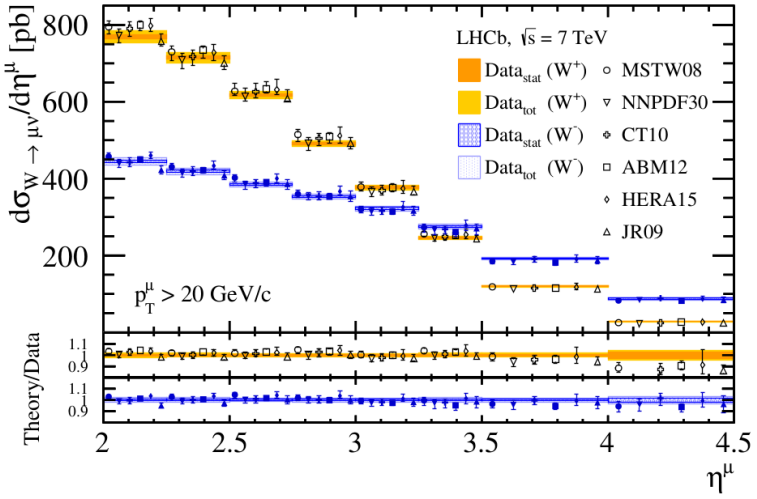
W inclusive production at 7 and 8 TeV

[JHEP 08 (2015) p.039] [JHEP 01 (2016) p.155]

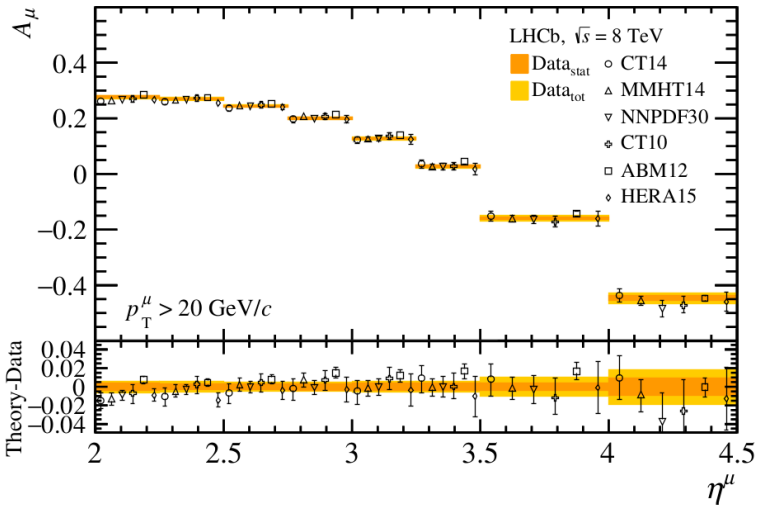
- **Reconstruction of W → μν**
- Selection: one muon with P_T > 20 GeV and 2< η < 4.5
- Purity determined in bins of pseudorapidity, with fits to the muon P_T



Differential cross section



Charge asymmetry



- Experimental error dominated by luminosity and beam energy uncertainties.
- **NNLO predictions obtained using different PDFs sets are compatible with data.**

W(→μν) + jet at 8 TeV

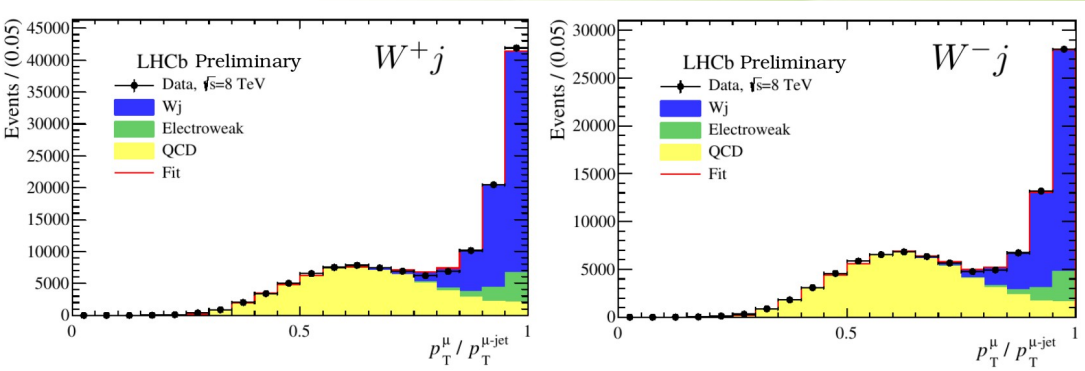
- **Jet reconstructed from Particle Flow inputs and clustered by anti-kt (R=0.5)**

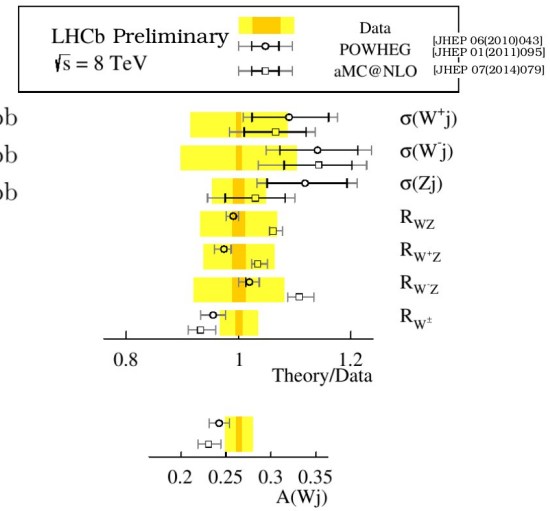
- Jet P_T > 20 GeV and 2.2 < η < 4.2

- P_T(jet + μ-jet) > 20 GeV → μ-jet: reconstructed jet containing the muon.

- Purity estimated from fit to the muon isolation: PT(μ)/PT(μ-jet)

[LHCb-PAPER-2016-11]





		stat.	syst.	lumi.
σ_{W^+j}	=	$56.89 \pm 0.23 \pm 5.08 \pm 0.66$ pb		
σ_{W^-j}	=	$33.10 \pm 0.17 \pm 3.54 \pm 0.38$ pb		
σ_{Zj}	=	$5.71 \pm 0.06 \pm 0.27 \pm 0.07$ pb		
R_{WZ}	=	$15.77 \pm 0.18 \pm 1.11$		
R_{W^+Z}	=	$9.97 \pm 0.12 \pm 0.64$		
R_{W^-Z}	=	$5.80 \pm 0.07 \pm 0.48$		
$R_{W^\pm}$	=	$1.72 \pm 0.01 \pm 0.06$		

$A(Wj) = 0.264 \pm 0.003 \pm 0.015$

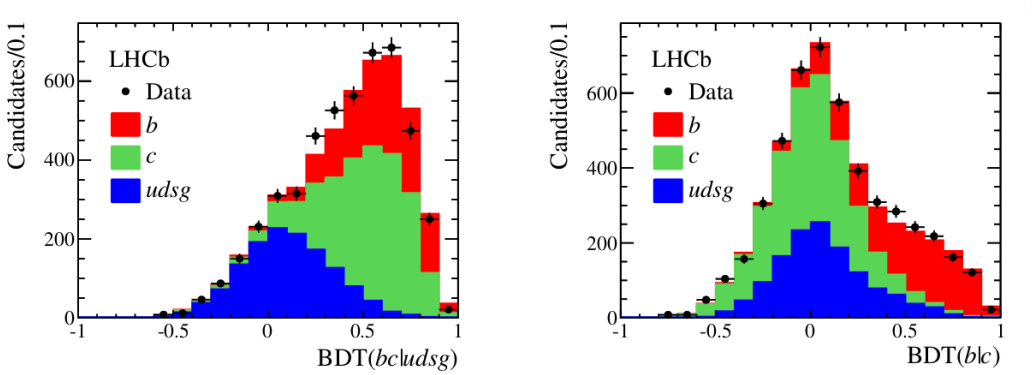
- Background from multi-jets and Electroweak processes.

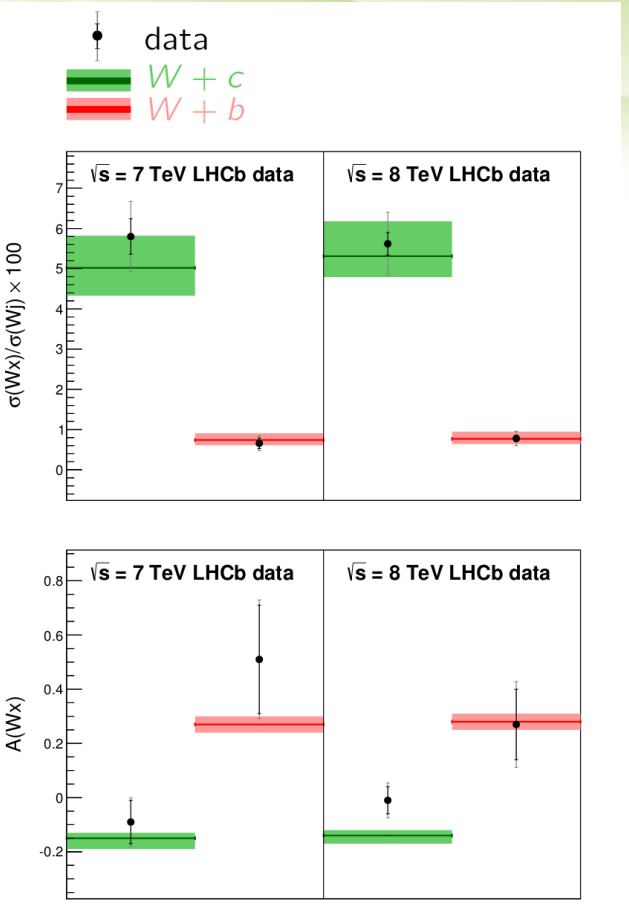
- **Total cross sections in agreement with NLO calculations.**

- Uncertainities dominated by W purity fit and jet energy scale.

W(->μν)+b/c/light jet at 8 TeV

[Phys. Rev. D92 (2015) p. 052001]





- The jet flavour composition of the W + jet sample can be studied.

- **Heavy flavour tagging** performed using Secondary Vertices (SV) reconstructed inside the jet.

- 2 BDT are trained for light/heavy and b/c separation, using SV observables as inputs.

- Jets composition obtained with a fit to the BDT observables distributions.

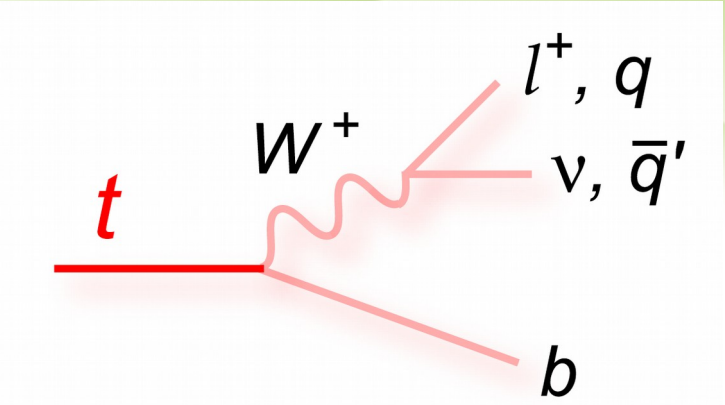
- Measurements: **W ratios (W+x/W+light) and charge asymmetries.**

- Uncertainty dominated by statistical errors, **b and c tagging uncertainties estimated from data.**

- **Measurements are compatible with theory** (2-σ tension on the W+c asymmetry)

Top in the forward region

- **Measurement**: first observation of **top** in the forward region, in the W+b final state**, [Phys. Rev. Lett. 115, 112001 (2015)]**



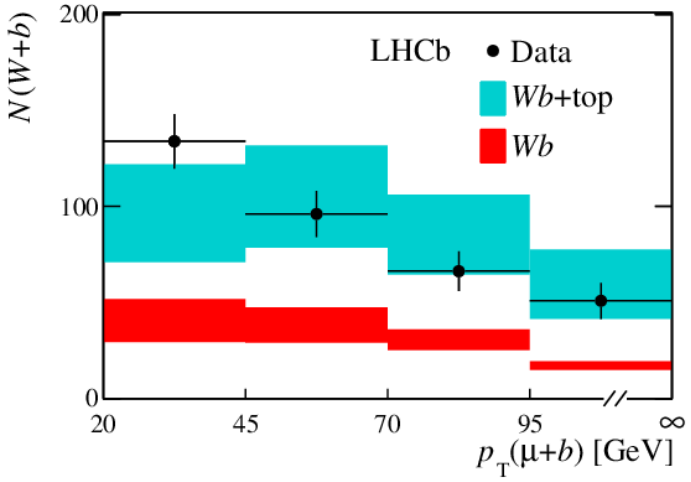
- **Motivations**:
  - The enhancement at forward rapidities of $t\bar{t}$ production via gg and qg scattering, respect to gg fusion, may result in a **large charge asymmetry,** sensitive to physics beyond the Standard Model.
  - Forward $t\bar{t}$ events can be used to **constraint PDFs at large momentum fraction.**

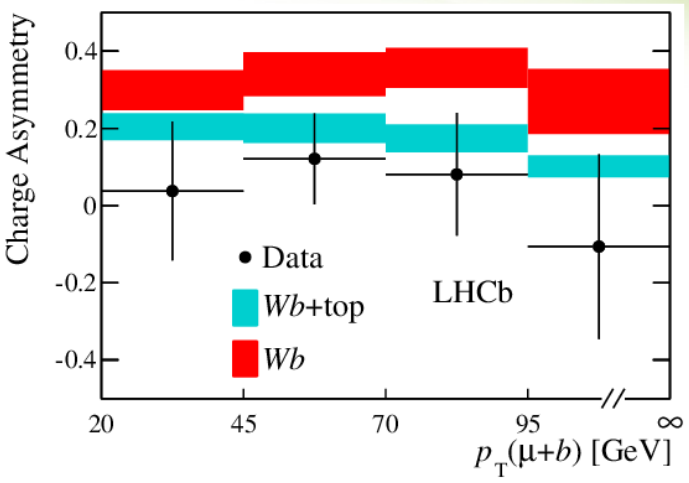
- **Data**: 1 fb^{-1} and 2 fb^{-1} respectively from pp collisions at 7 and 8 TeV
- **Selection**: P_T(muon) > 25 GeV, 50 GeV < P_T(jet) < 100 GeV

Top in the forward region

[Phys. Rev. Lett. 115, 112001 (2015)]

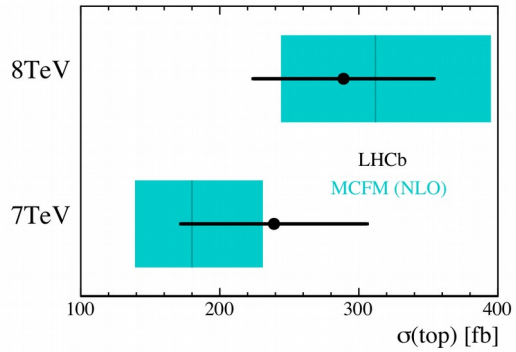
- **Strategy**: Study the W+b fitted yield and W charge asymmetry in function of PT(muon +b) → fit the top cross section





- **Results:**

$$\sigma(\text{top})[7\,\text{TeV}] = 239 \pm 53\,(\text{stat}) \pm 38\,(\text{syst})\,\text{fb}$$
$$\sigma(\text{top})[8\,\text{TeV}] = 289 \pm 43\,(\text{stat}) \pm 46\,(\text{syst})\,\text{fb}$$



- **Standard Model prediction:** $180^{+51}_{-41}(312^{+83}_{-68})$ fb at 7(8) TeV

- **The top cross section in the forward region is expected to increase of a factor 10 at 13 TeV.**

Conclusions

• LHCb offers a **complementary phase space region** respect to ATLAS and CMS for Electroweak and top measurements.

• **W and Z production in the forward region**, inclusive or in association with a jet, has been measured using data collected during Run I.

• **First LHCb measurement at 13 TeV in the Electroweak sector**: inclusive $Z \rightarrow \mu\,\mu$ cross section.

• Most precise measurement at LHC of $\mathbf{\sin^2\theta^{eff}_W}$.

• **First observation of top in the forward region** using the Run I dataset.

• **New measurements with Run I and Run II data in preparation!**


Thanks for your attention!
UXB

Backup slides

W(→μν) + jet at 8 TeV

- Good agreement of differential distributions with NLO predictions: **[LHCb-PAPER-2016-11]**