Impact of LHCb measurements on PDFs

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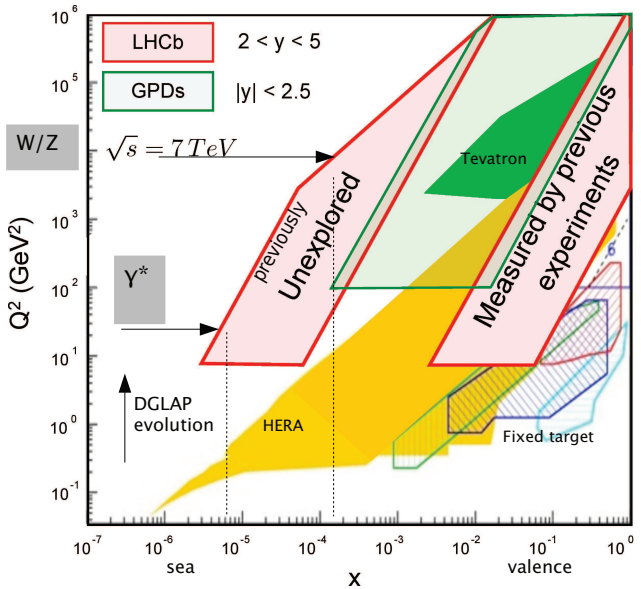
Outline

- Motivation
- The LHCb spectrometer
- W-boson cross section measurement
- Z-boson cross section
- Impact on parton distribution functions
- Conclusions & Outlook

Drell-Yan processes at LHCb: Motivation

- Measurements sensitive to parton distribution functions

$$x_{1,2} = \frac{Q}{\sqrt{s}} e^{\pm y}$$

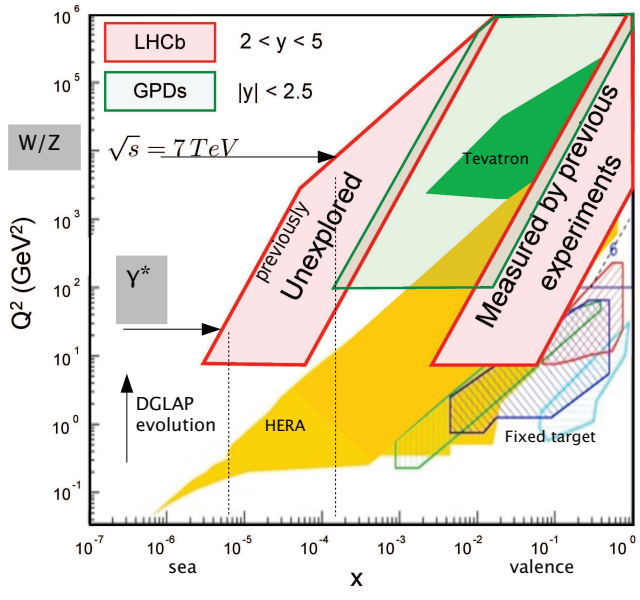


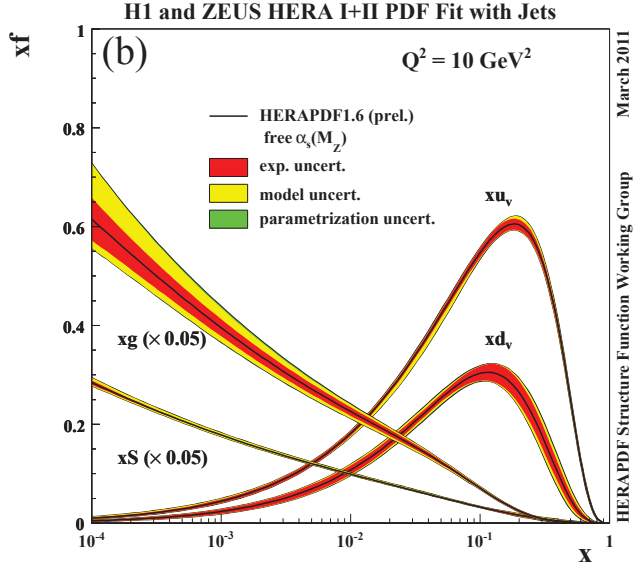
Drell-Yan processes at LHCb: Motivation

- Measurements sensitive to parton distribution functions

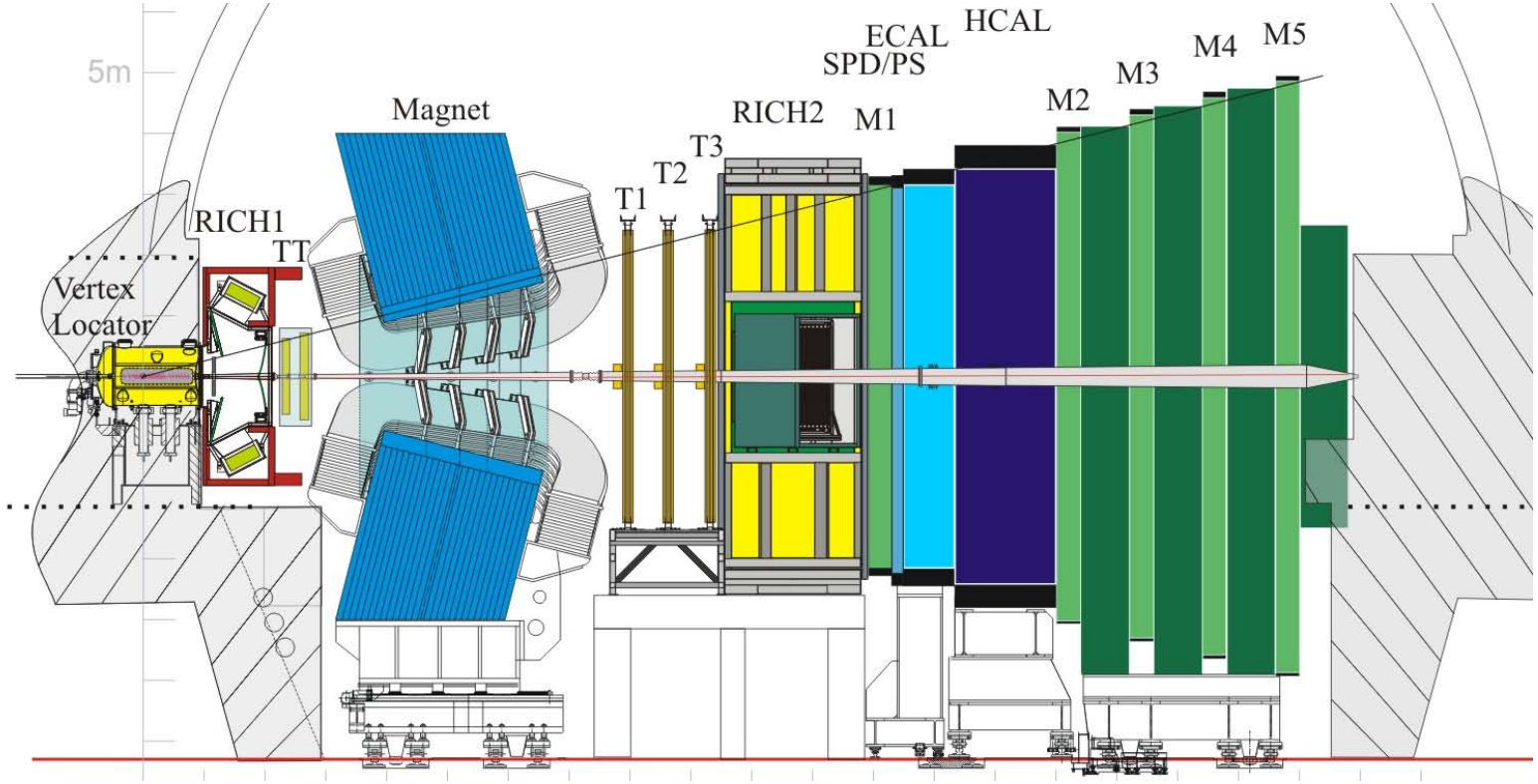
$$x_{1,2} = \frac{Q}{\sqrt{s}} e^{\pm y}$$

- Z boson probes low-x at $x \sim 1.4 \cdot 10^{-4}$ and high-x at $x \sim 1$
- Low-mass Drell-Yan (*e.g.* J/Ψ): $x \sim 8 \times 10^{-6}$ and $x \sim 0.1$
- Boson cross section ratios provide tests of standard model ($\frac{\sigma(W^+)}{\sigma(W^-)} \sim u_v/d_v$)
- Asymmetries probe difference between valence quark distributions in proton
- Unique kinematic range of LHCb complements those of central detectors



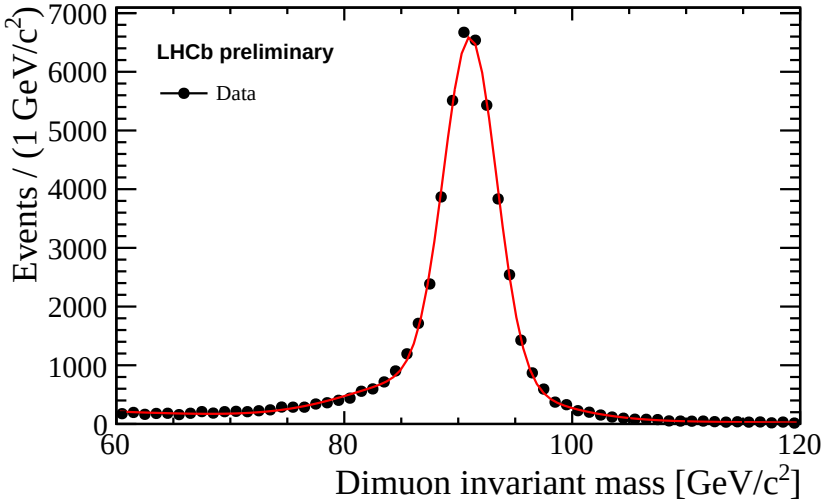


LHCb Spectrometer

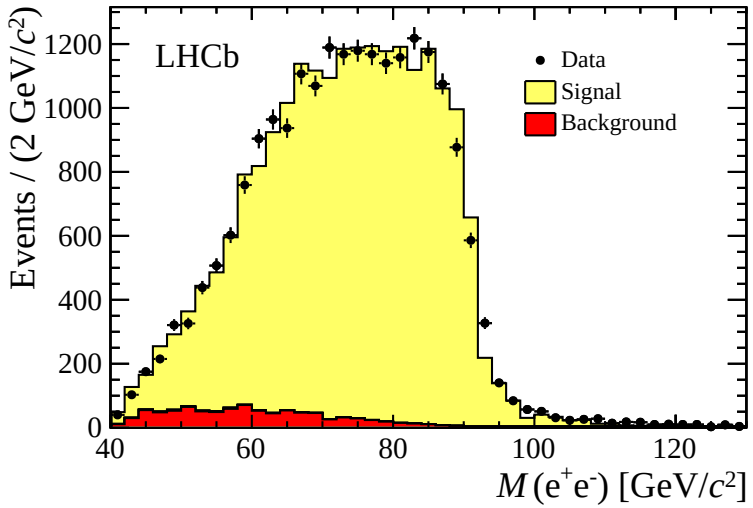


- Acceptance from $2 < \eta < 5$
- Probes down to $x \approx 5 \times 10^{-6}$
- Good IP measurement: $\langle \delta \mathrm{IP} \rangle = 20 \mu\mathrm{m}$ for $p_\mathrm{T} > 2$ GeV:
- μ ID efficiency: ~ 97 % for < 3 % $\pi \rightarrow \mu$ mis-id probability from $p = 2 - 100$ GeV

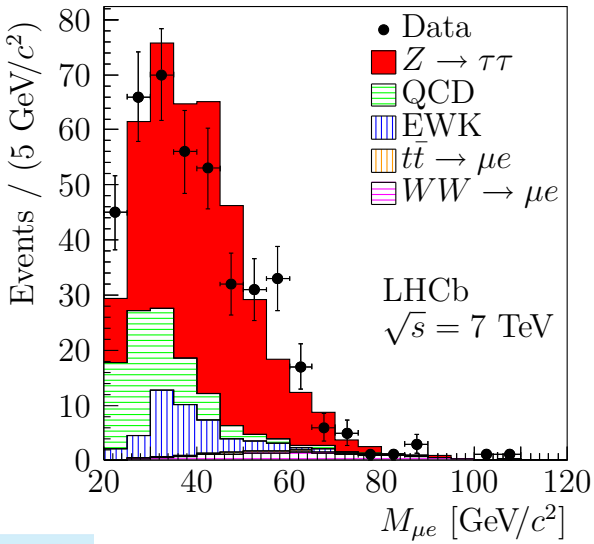
Inclusive Z production at LHCb



Di-muon Invariant mass



Invariant mass of $Z \to e^+e^-$



$Z \to \tau^+\tau^- \to e^\pm\mu^\mp$

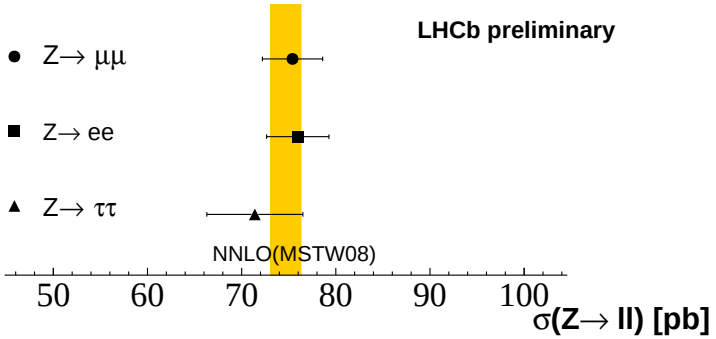
$Z \to l^+l^-$ reconstruction:

- $2 < \eta < 4.5$
- $60 < M_{l^+l^-} < 120$ GeV
- $p_{\mathrm{T}}^{l} > 20$ GeV

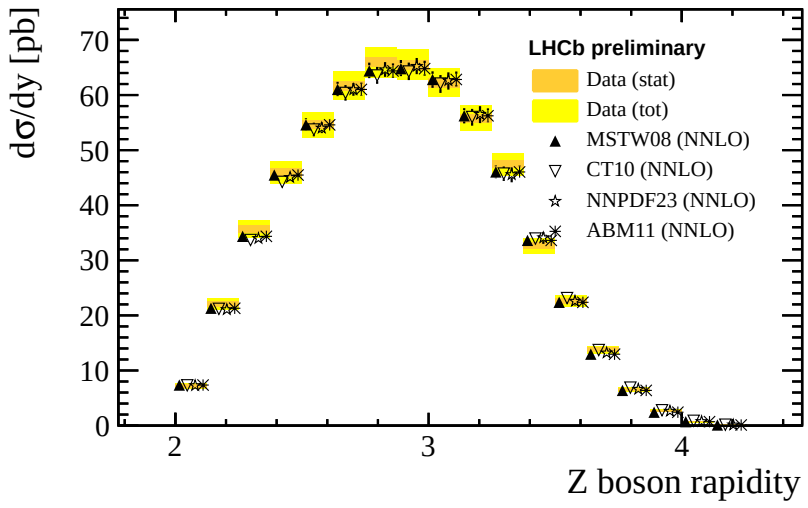
Backgrounds:

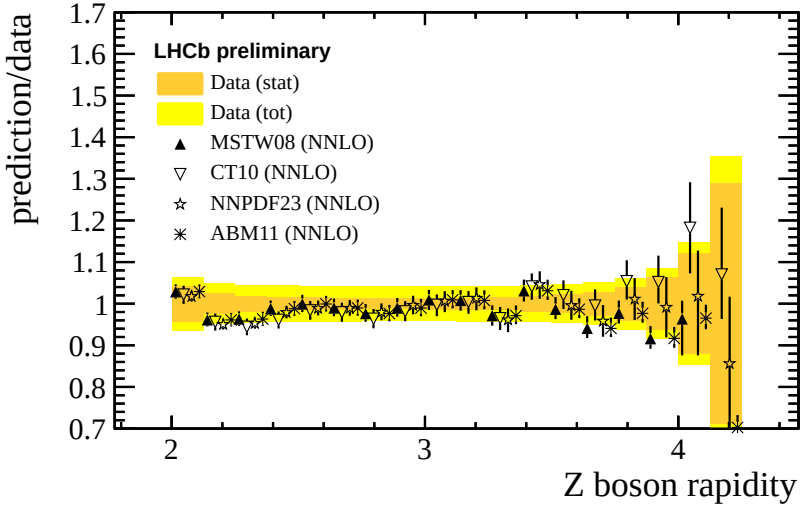
- Muon case: $< 0.3\%$ background
- Electron case: only 4.5% background
- Tau case: $28 - 37\%$ background

Inclusive Z production at LHCb



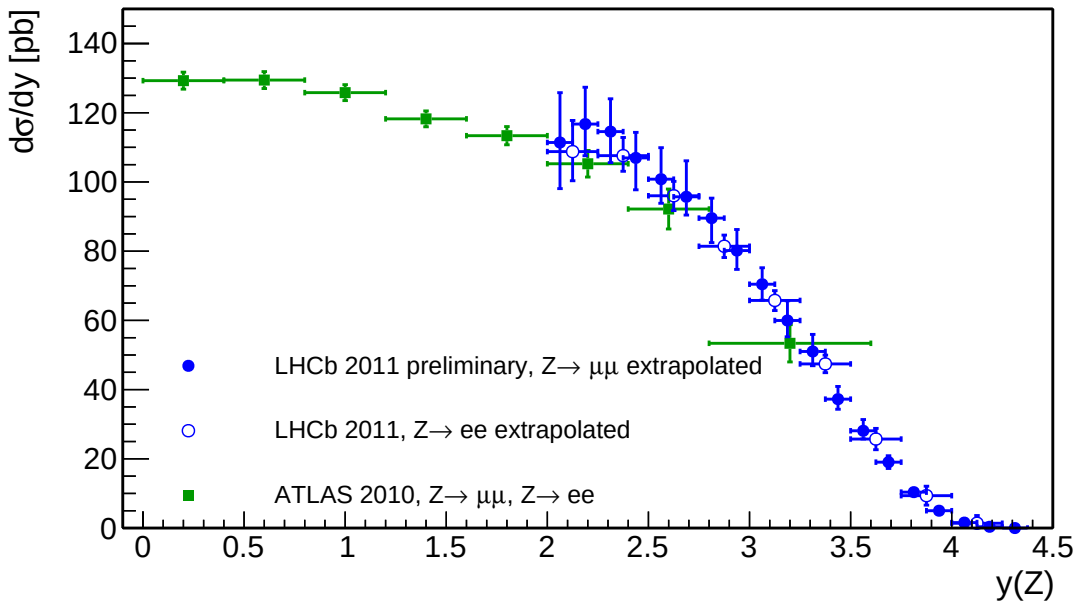
- Good agreement between different channels
- And with NNLO calculations (MSTW08)





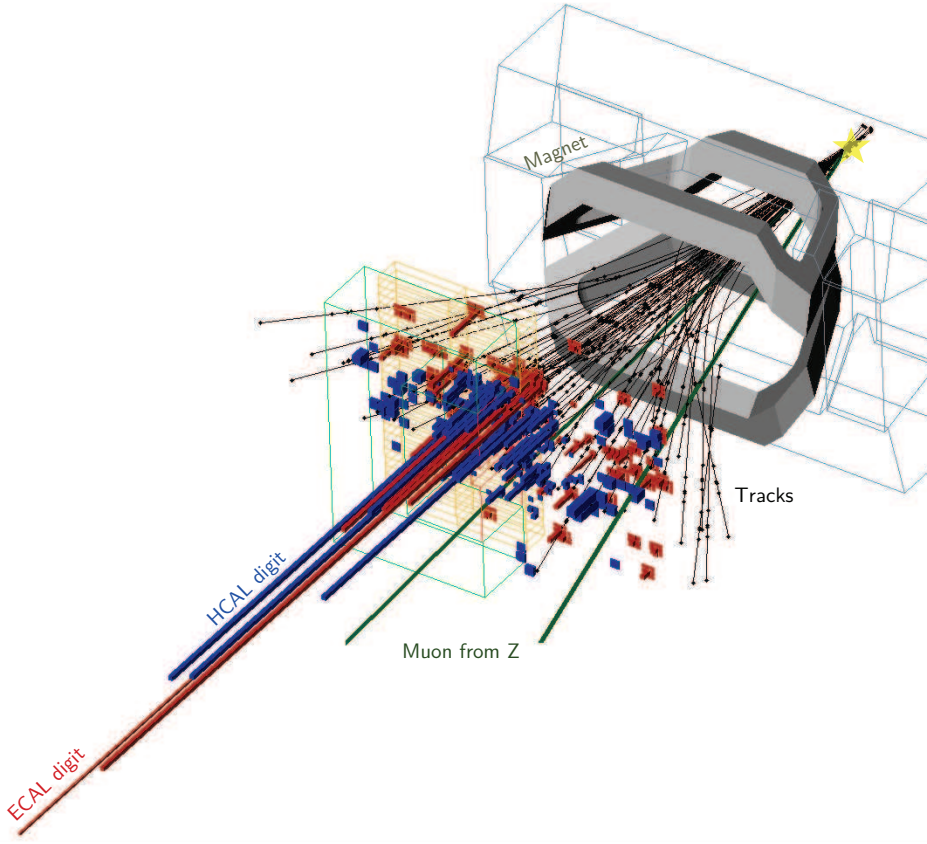
Inclusive Z production at LHCb

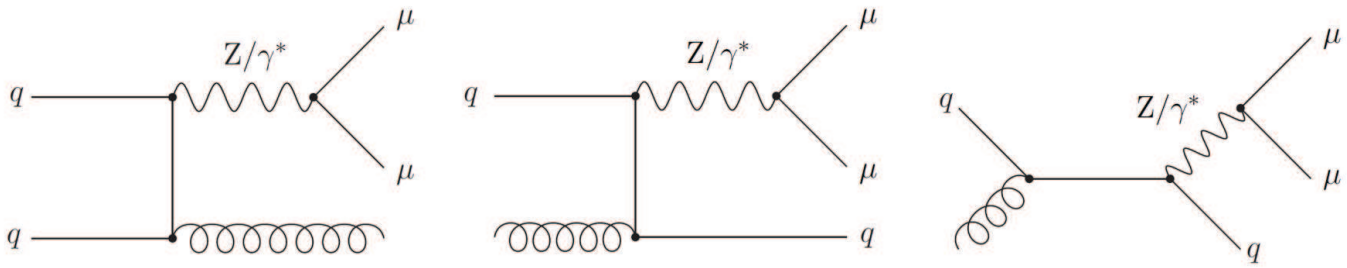
- $\mathcal{L} = 1.0\ \mathrm{fb}^{-1}$ at $7\ \mathrm{TeV}$ analyzed
- LHCb data corrected for additional ATLAS cuts
- Compares well to ATLAS data (JHEP 12 (2010) 060)



$Z \to \mu^+\mu^-$ plus jet

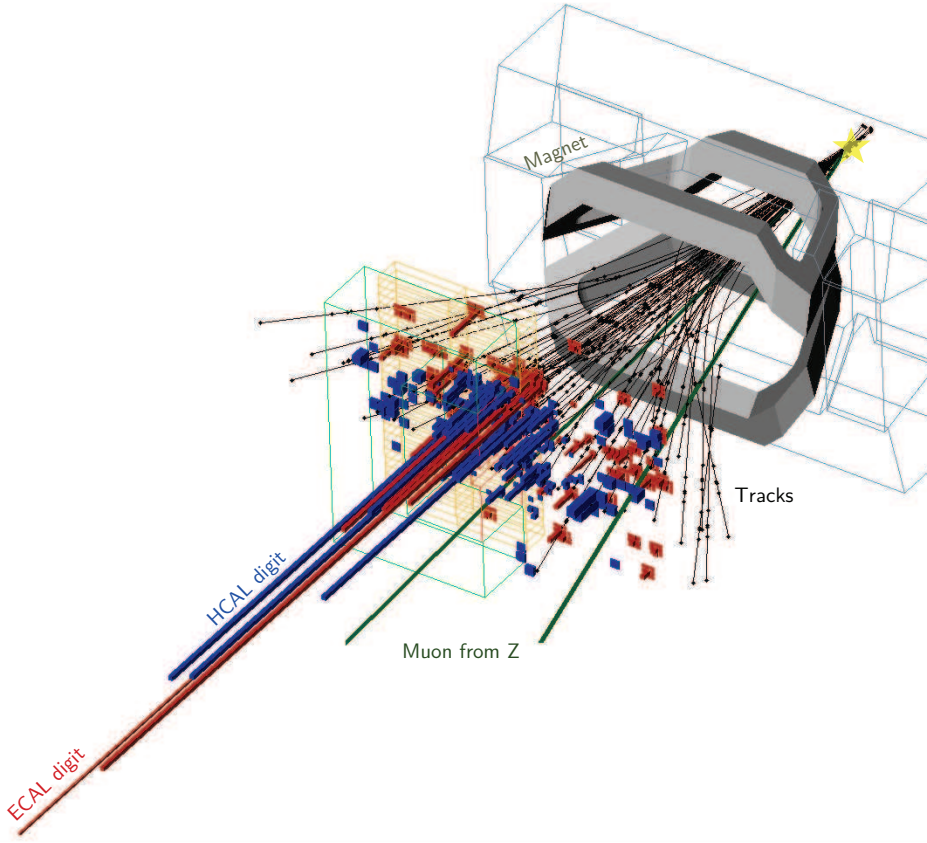
- Sensitive to gluon content of proton,
- to higher-order pQCD corrections, and

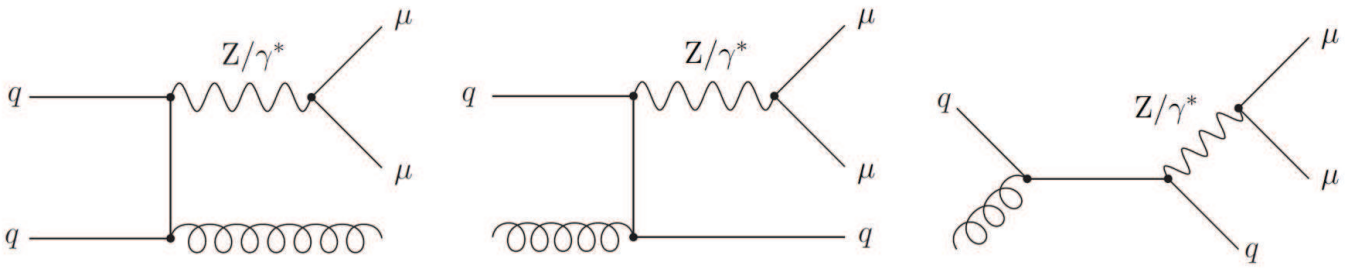




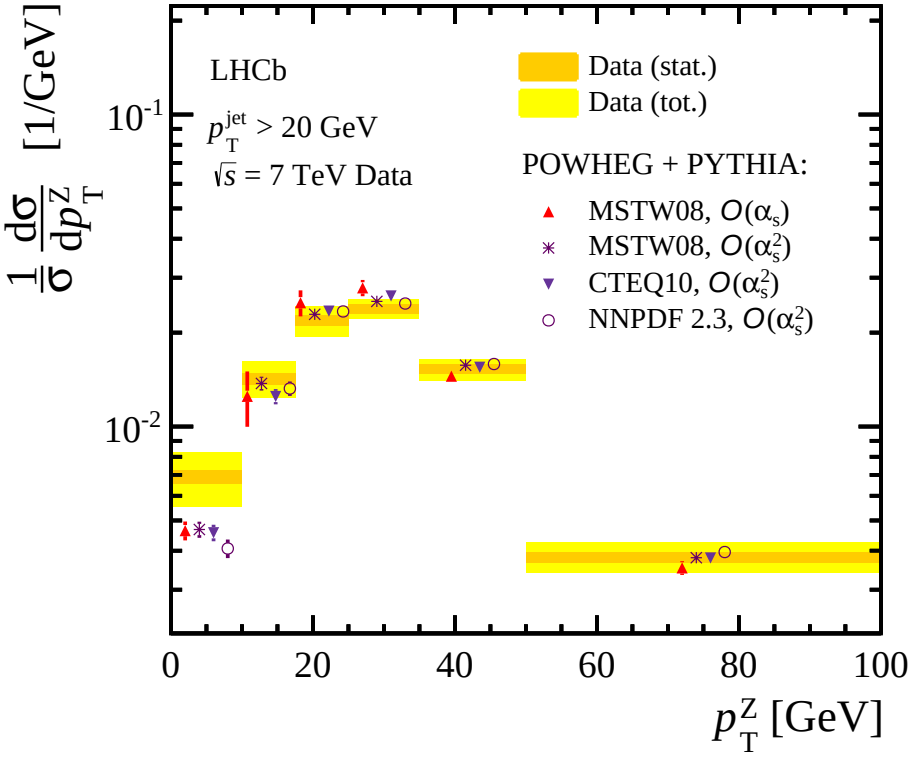
$Z \to \mu^+\mu^-$ plus jet

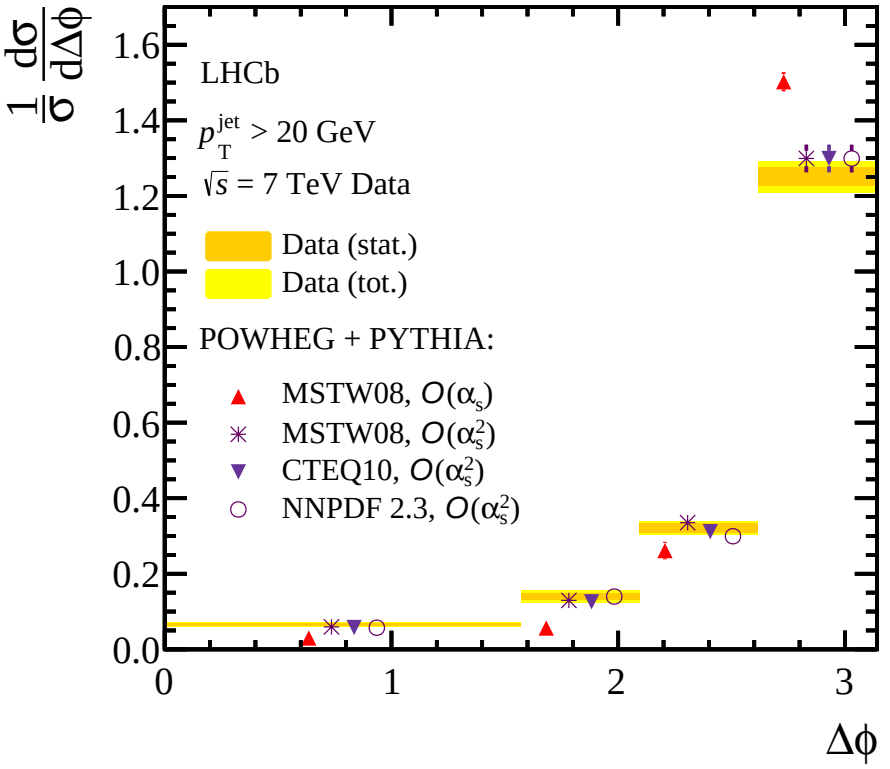
- Sensitive to gluon content of proton,
- to higher-order pQCD corrections, and
- $\mathcal{L}^{\text{int}} = 1.0\ \text{fb}^{-1}$ at $\sqrt{s} = 7\ \text{TeV}$
- Jets: anti-k_{T} algorithm ($R = 0.5$)
- Jet-muon separation: $\Delta r(\text{jet}, \mu) > 0.4$
- $p_{\text{T}}^{\text{jet}} > 20\ \text{GeV}$





$Z \to \mu^+\mu^-$ plus jet



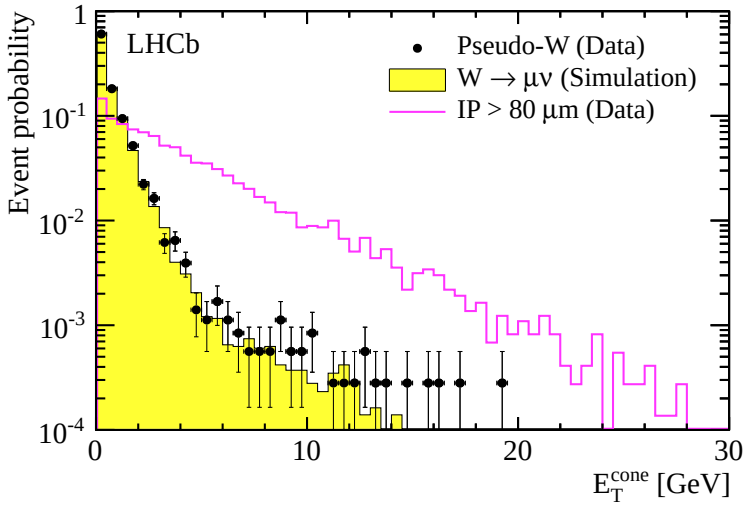


JHEP 01 (2014) 033

W boson cross section at LHCb

$W^{\pm} \to \mu^{\pm}\nu$ reconstruction:

- $2 < \eta_{\mu} < 4.5$
- $20 < p_{\mathrm{T}}^{\mu} < 70$ GeV
- Require μ from W decay to be isolated
- Isolation variables well described by simulation



Scalar sum $p_{\mathrm{T}}^{\mathrm{cone}}$ around μ track

Background:

- From heavy-flavour: IP < 40 μm
- γ^*/Z: no other μ with $p_{\mathrm{T}} > 2$ GeV
- Remaining: decay in flight of K/π

LHCb: Submitted to JHEP (arXiv:1408.4354v1)

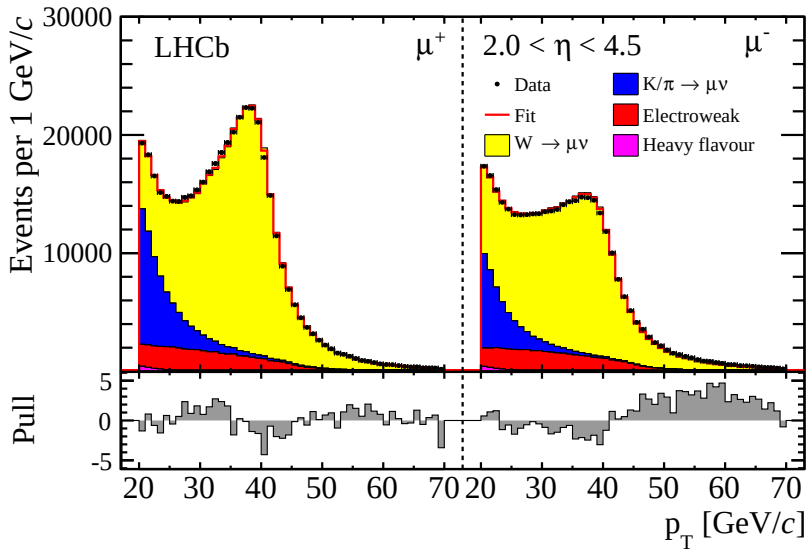
Background:

	Shape	Normalization
$W \to \mu\nu$	simulation	fit
K/π decay in flight	data	fit
$\gamma^*/Z \to \mu\mu$	simulation	fixed
$W \to \tau\nu, Z \to \tau\tau$	simulation	fixed
Heavy flavor	data	fixed
hline		

Resulting purities:

W^+ 77.17 ± 0.19 %

W^- 77.40 ± 0.23 %



μ^+ μ^-

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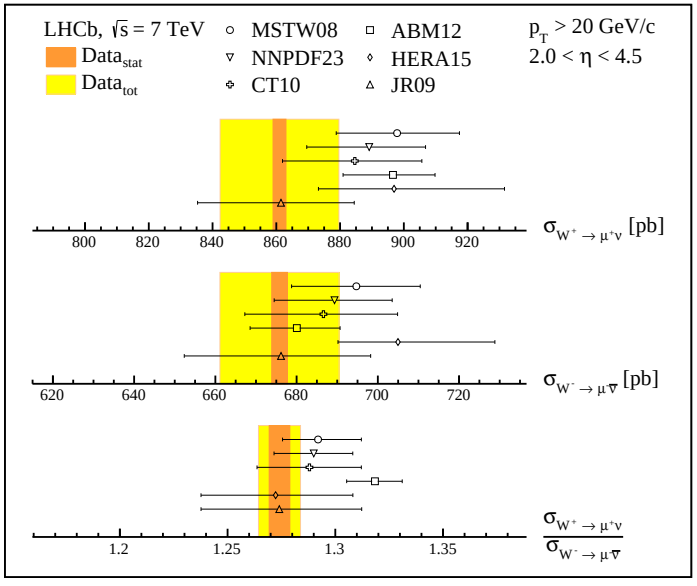
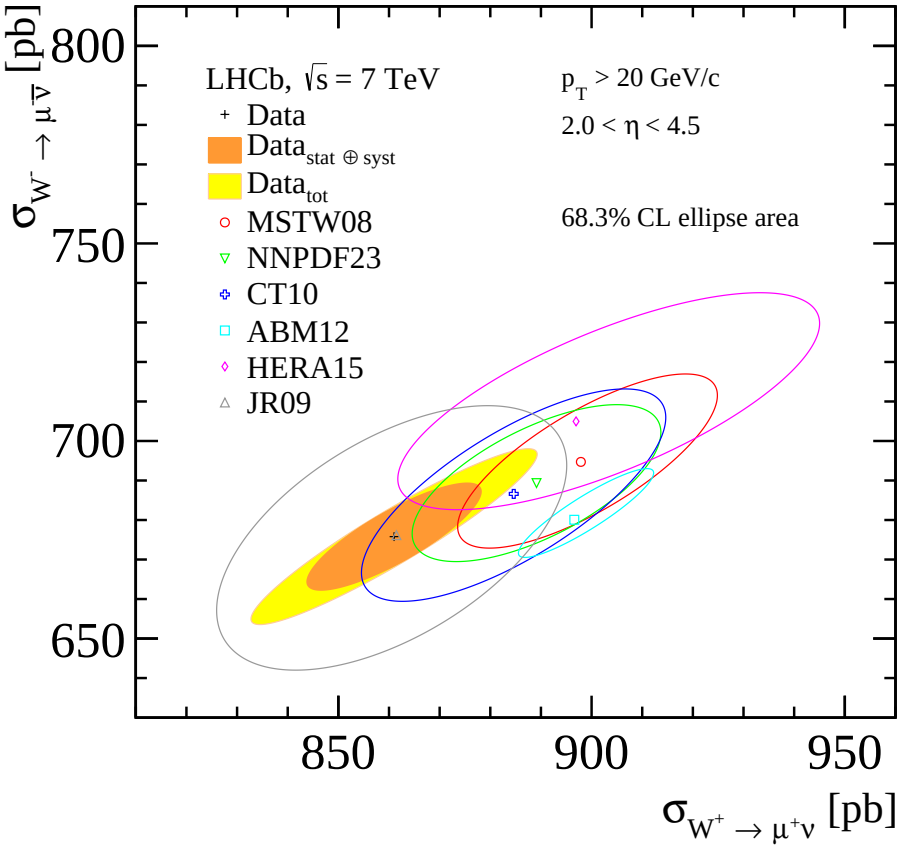
W boson cross section at LHCb



$W^{\pm}$ cross sections and ratios compared to various PDFs

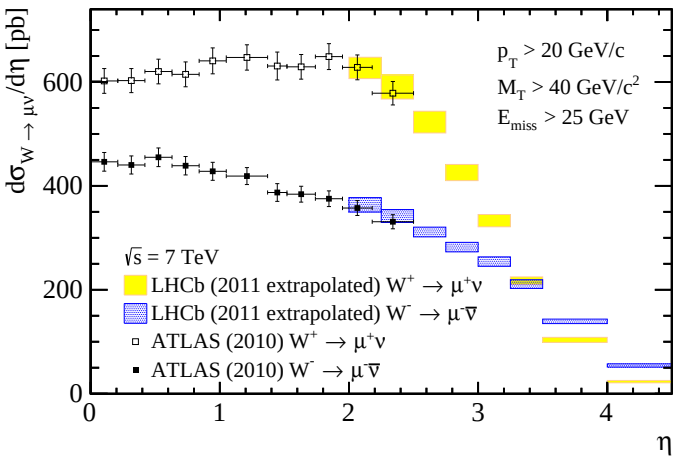
- Statistical error much smaller than systematic
- 1.3% systematic error
- And only 1.7% error from luminosity measurement



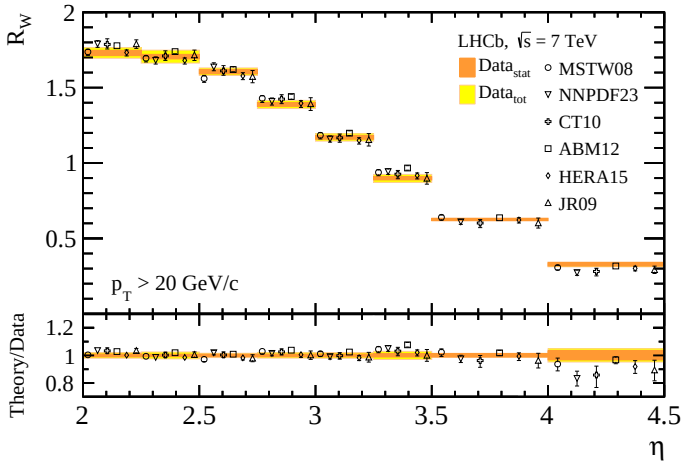
Correlation between $\sigma(W^+)$ *vs.* $\sigma(W^-)$

LHCb: Submitted to JHEP (arXiv:1408.4354v1)

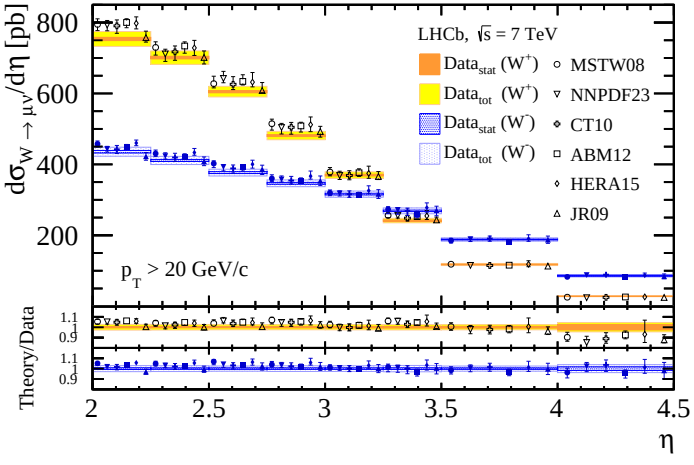
W boson cross section at LHCb



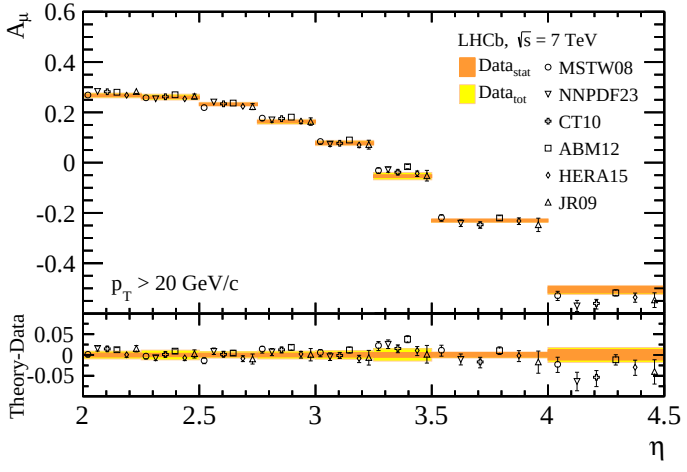
Comparison of $\sigma(W^{\pm})$ to ATLAS data



$W^{\pm}$ cross section ratio *vs.* various predictions



$\sigma(W^{\pm})$ *vs.* η compared to various predictions

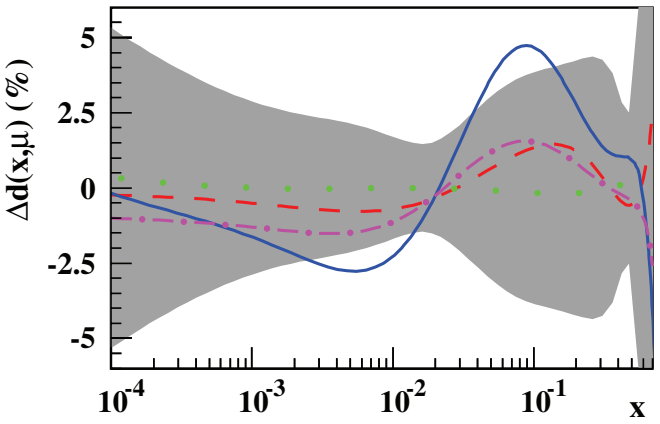


Lepton charge asymmetry *vs.* η

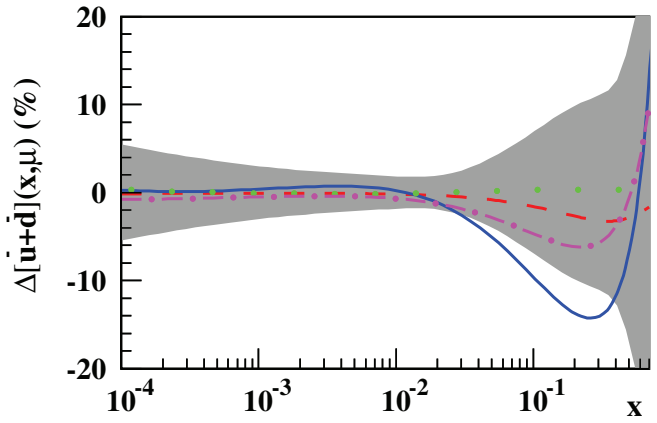
ATLAS: PR D85 (2012) 072004

Impact of LHCb data on parton distribution functions

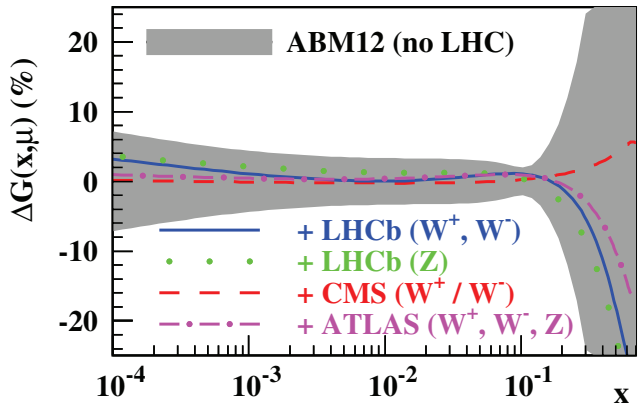
- LHCb data used by Alekhin *et al.* (PR D89, 054028)
- LHCb data used also by NNPDF, Ball *et al.* (NP B867 (2013) 244–289)
- PDFs nicely describe LHCb $W^{\pm}$ and Z decays
- Large impact of LHCb data



Impact of LHCb data on d-quark PDF



Impact on sea quark PDF



Impact on gluon PDF

ABM: PR D89, 054028
LHCb: JHEP06 (2012) 058
LHCb: JHEP02 (2013) 106

Conclusions & Outlook

- Unique kinematic regime accessed by LHCb down to $(x \sim 5 \cdot 10^{-6})$
- Cross sections for $Z \to \mu^+\mu^-, e^+e^-, \tau^+\tau^-$
- Cross sections for inclusive $W^{\pm} \to \mu^{\pm}\nu$
- W results very accurate; updated $Z \to \mu^+\mu^-$ to be released soon
- Data used for PDF fits
- LHCb data consistent with ABM12 & NNPDF2.3 PDFs
  - Large relative impact of LHCb data thanks to forward kinematic regime
  - Only fraction of data used...
  - *e.g.* $Z +$ jet not included in PDF fits
- More LHCb data available: low-mass Drell-Yan data: $J/\Psi, \phi(2S)$ & $\Upsilon(1S)$ cross sections