Single boson production on LHCb including A_{FB}

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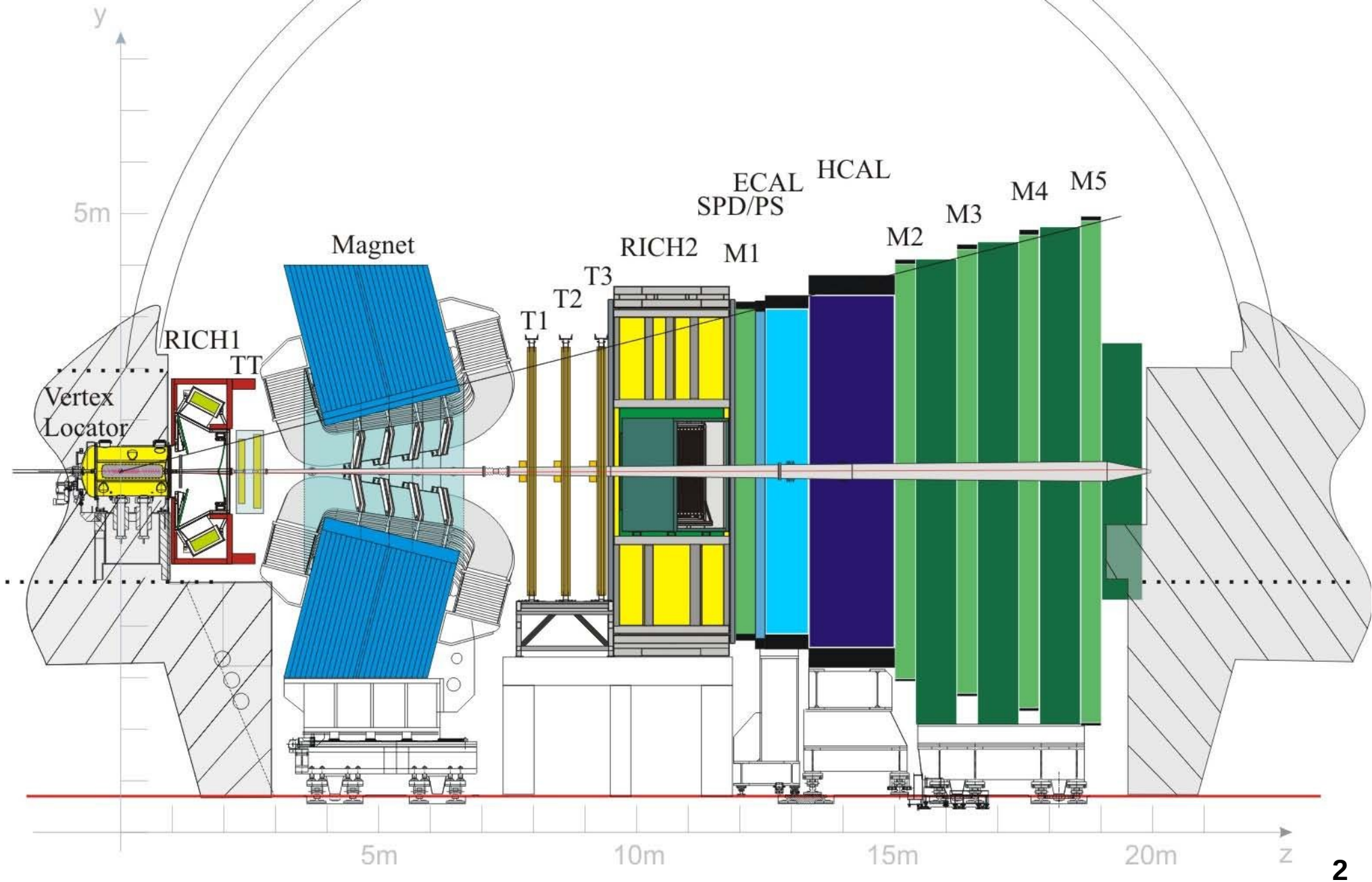
Outline:

- LHCb detector & data taking
- Z & W bosons production at 7 TeV
- Z boson production at 8 TeV
- Forward-backward asymmetry in $Z \to \mu^+\mu^-$
- Summary

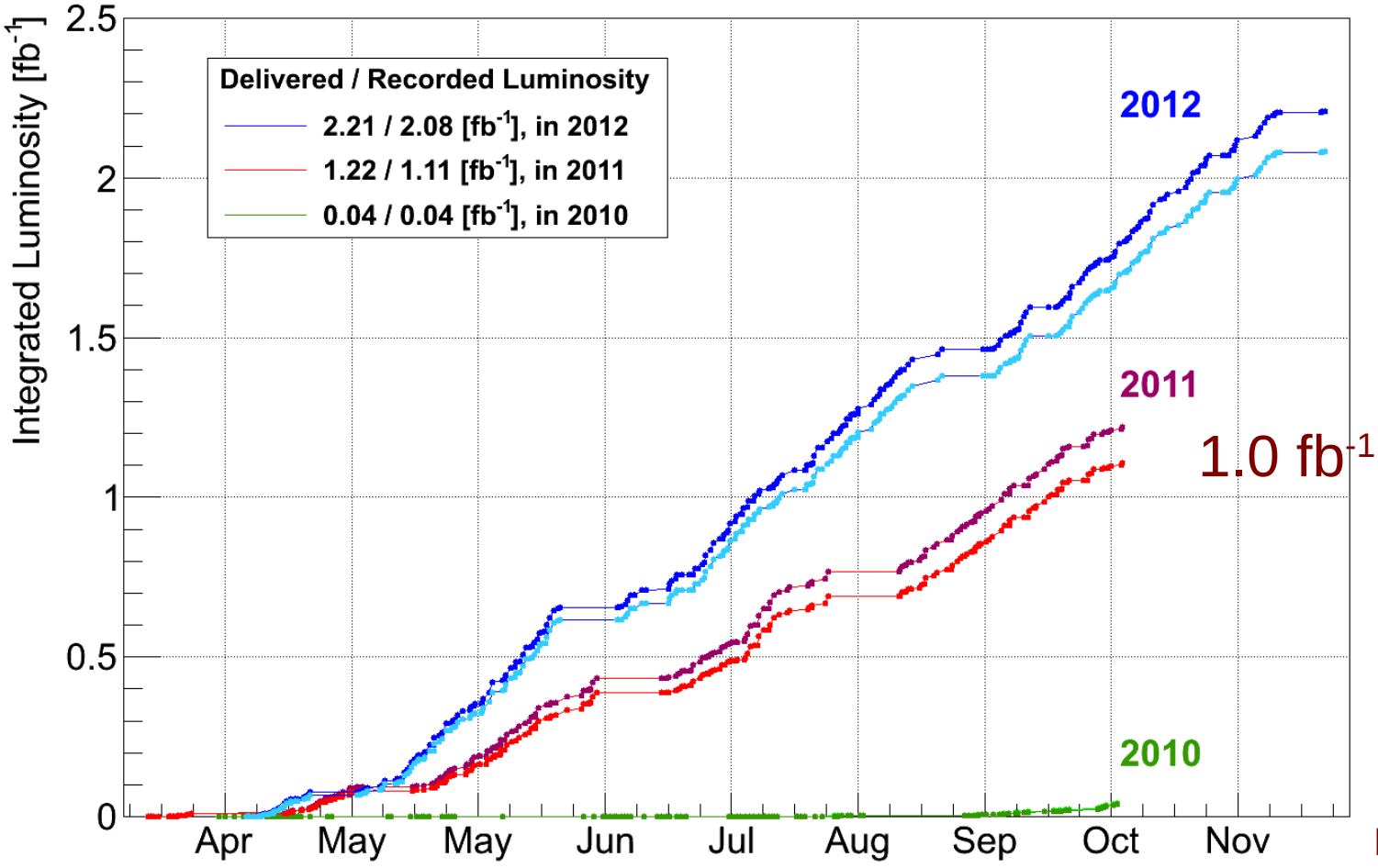
LHCb Experiment



LHCb Performance

- Trigger efficiencies: 90% for dimuon channels
- Muon ID efficiency: 97 % with 1-3 % $\pi \rightarrow \mu$ mis-id probability
- Electron ID efficiency: 90% with 4% $h \rightarrow e$ mis-id probability

Acceptance: $2 < \eta < 5$



2.0 fb^{-1} @ 8 TeV

1.0 fb^{-1} @ 7 TeV

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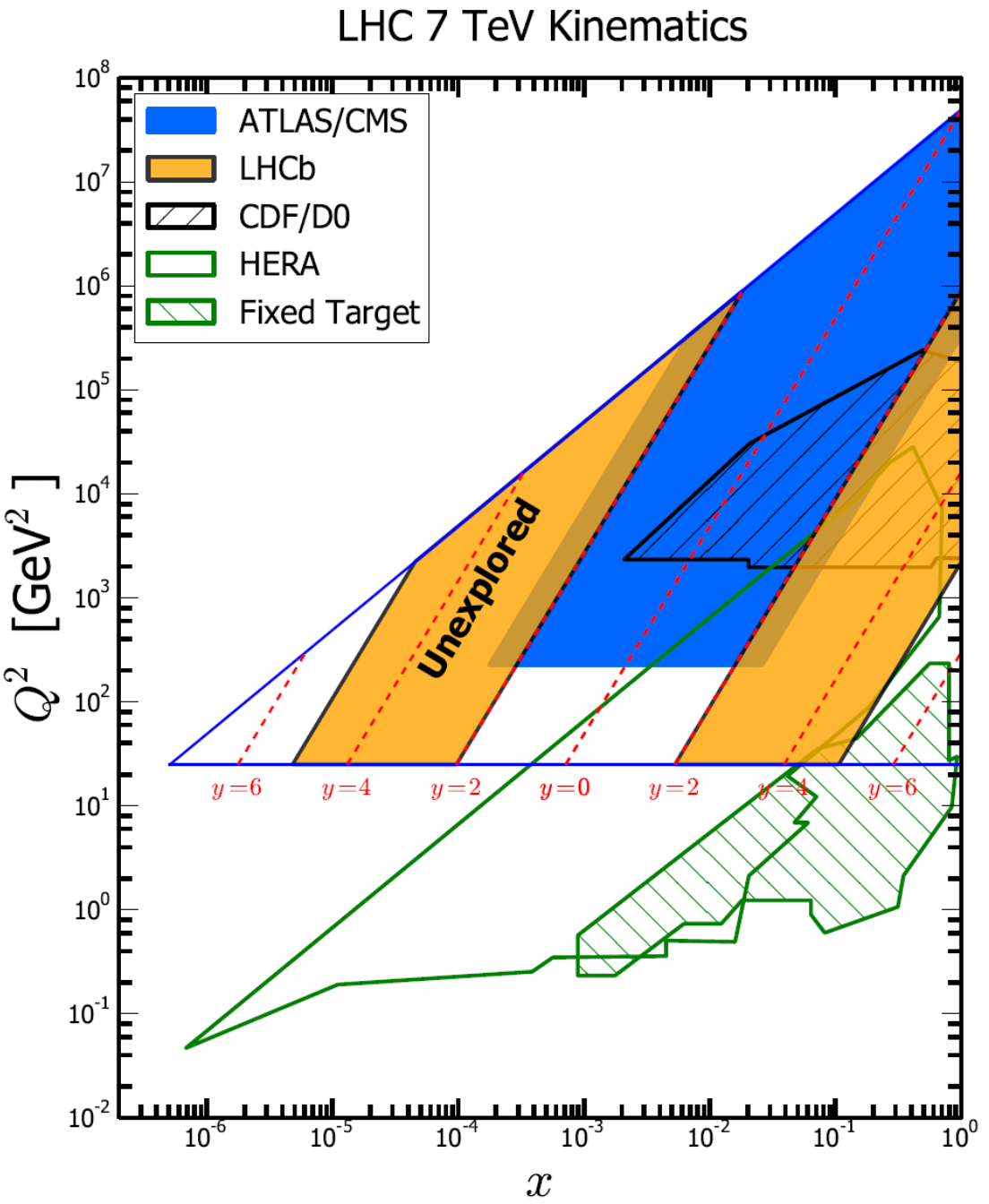
LHCb sensitivity to parton density functions

- LHCb forward acceptance provides unique possibilities to study the Parton Density Fuctions (PDFs)
- PDFs parametrized as (x, Q^2)

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

- Combination of known high-x with unexlored low-x partons

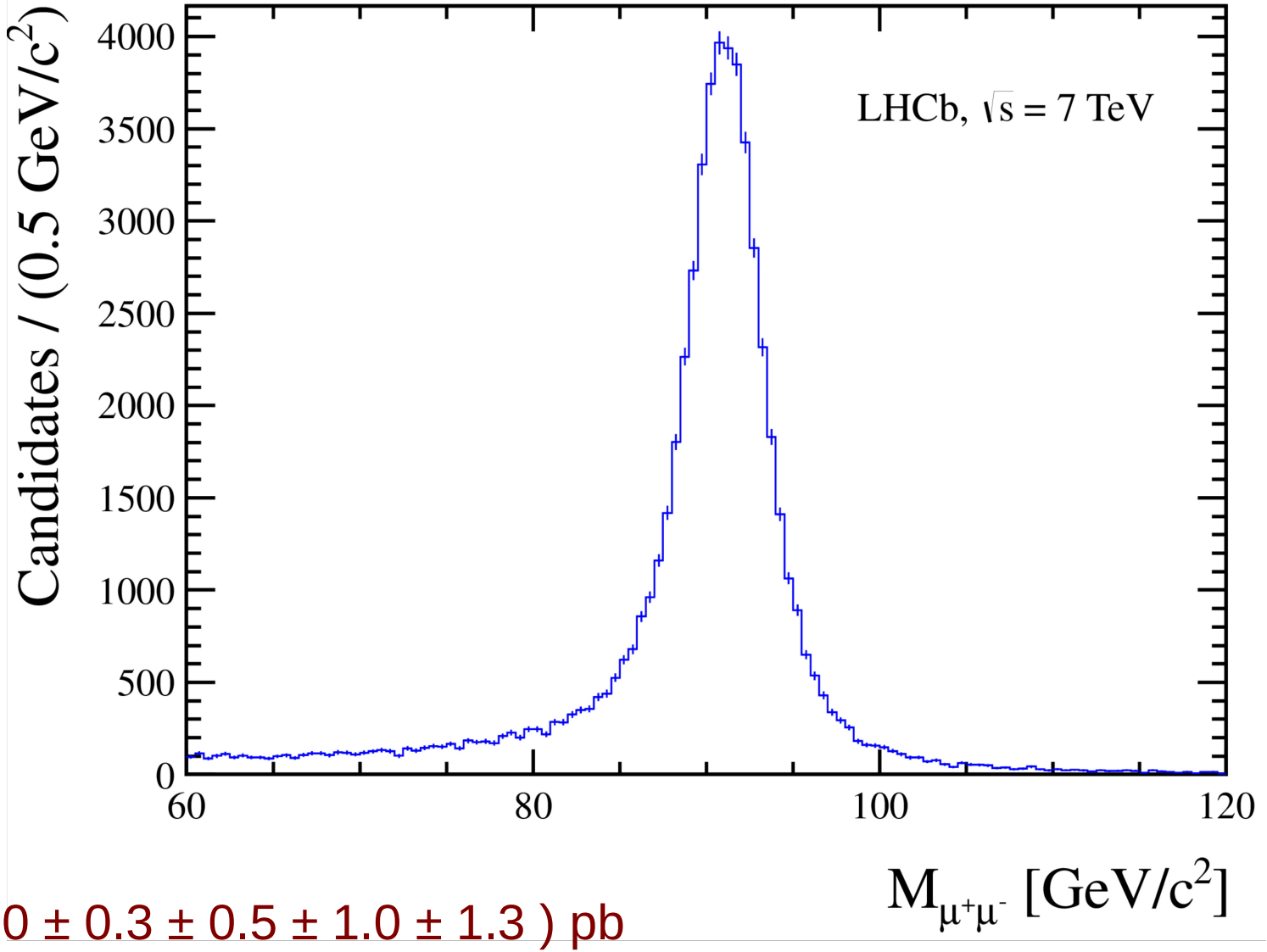


Forward Z[$\mu^+\mu^-$] production at $\sqrt{s}$ = 7 TeV

Events selection

- $Z \rightarrow \mu^+\mu^-$
- $2 < \eta_\mu < 4.5$
- $P^\mu_T > 20$ GeV
- $60 < M\mu\mu < 120$ GeV

Purity: 99.3 ± 0.2%



$\sigma(Z \rightarrow \mu^+\mu^-)$ = (76.0 ± 0.3 ± 0.5 ± 1.0 ± 1.3) pb

Uncertanties: statistics, systematic, beam energy and luminosity

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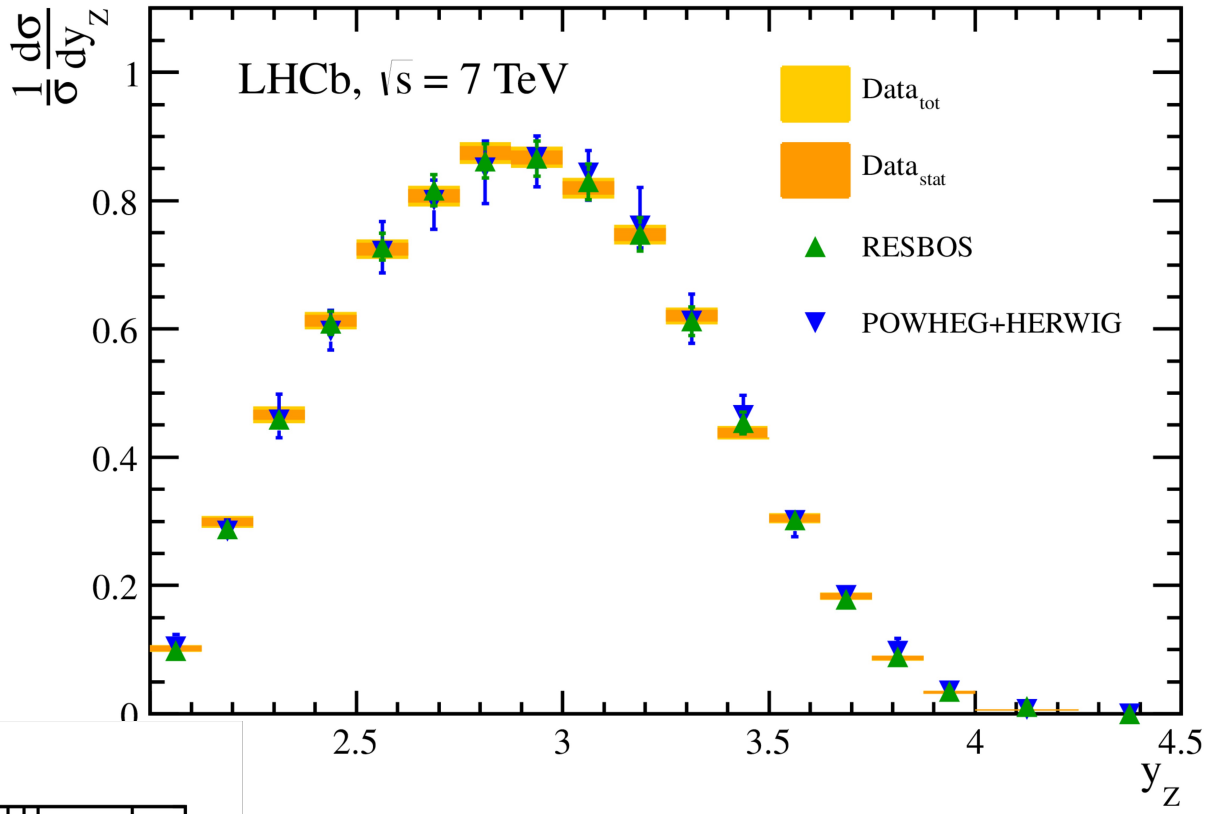
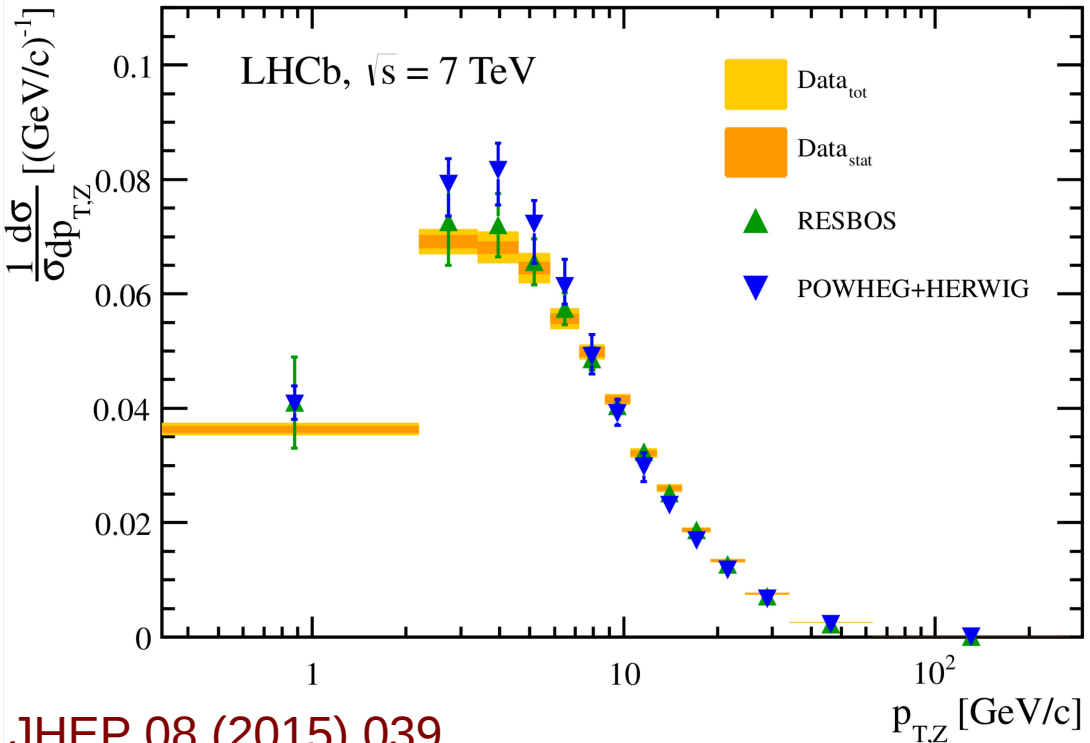
Differential cross-section





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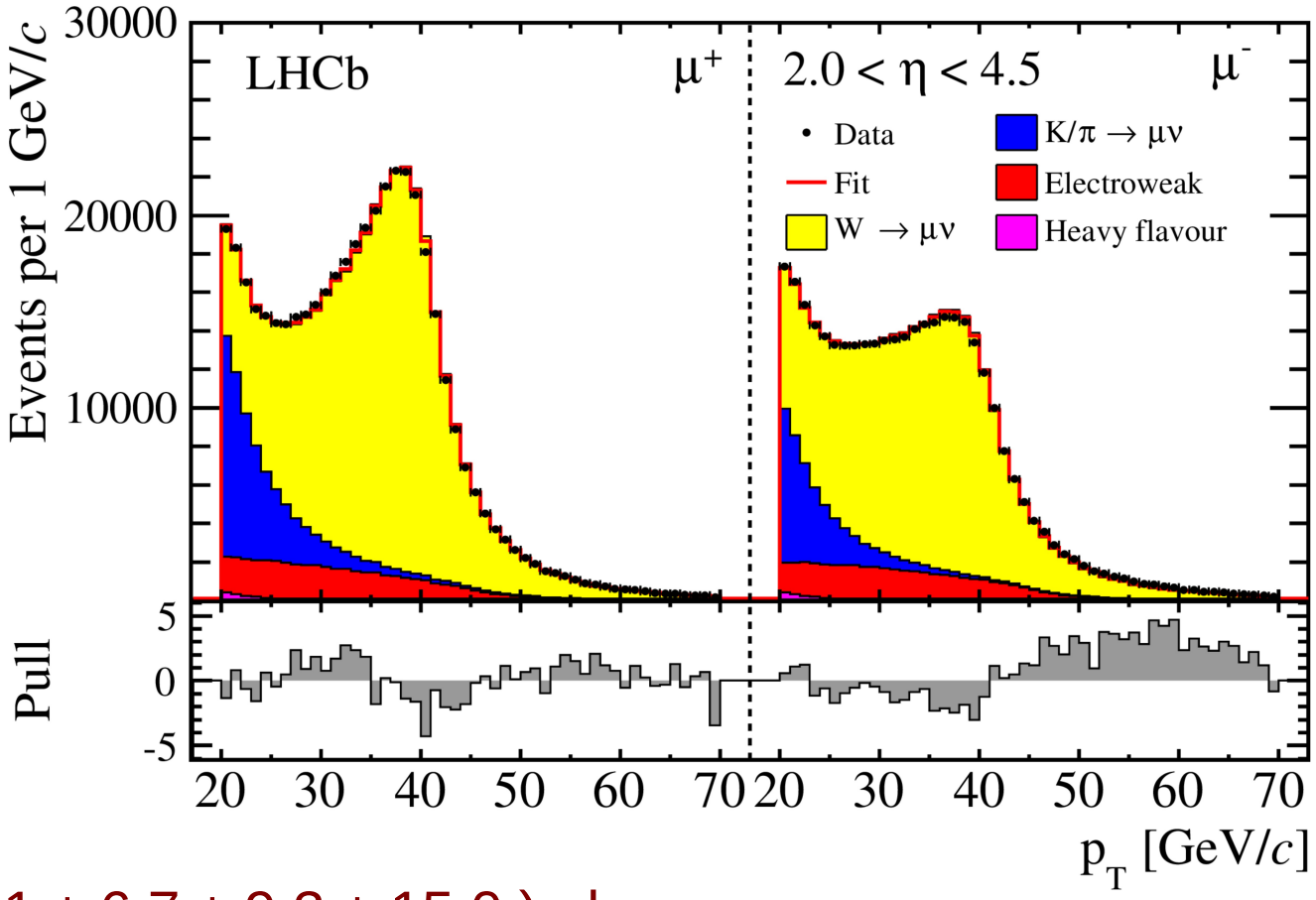
Agrees well with predictions from RESBOS (NLO+NNLL) and POWHEG+Herwig (NLO & Parton Shower)

Forward W production at √s = 7 TeV

Selection criteria

- Isolated single muon
- $20 < P^{\mu}_{T} < 70$ GeV
- Ecal energy deposition: MIP

Signal purity is 77%



$\sigma(W^+ \to \mu^+\nu) = (878.0 \pm 2.1 \pm 6.7 \pm 9.3 \pm 15.0)$ pb

$\sigma(W^- \to \mu^-\nu) = (689.5 \pm 2.0 \pm 5.3 \pm 6.3 \pm 11.8)$ pb

stat syst energy lumi

$R_W = 1.274 \pm 0.005 \pm 0.009 \pm 0.002$

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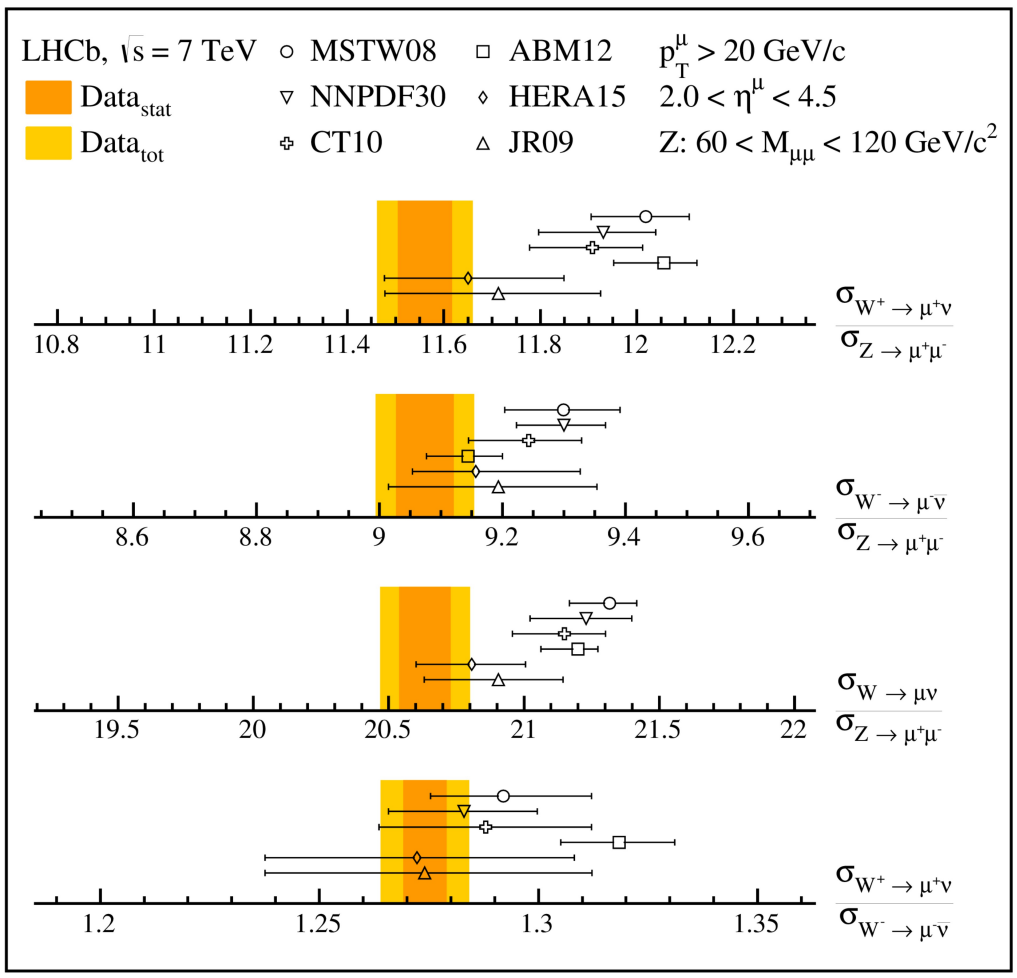
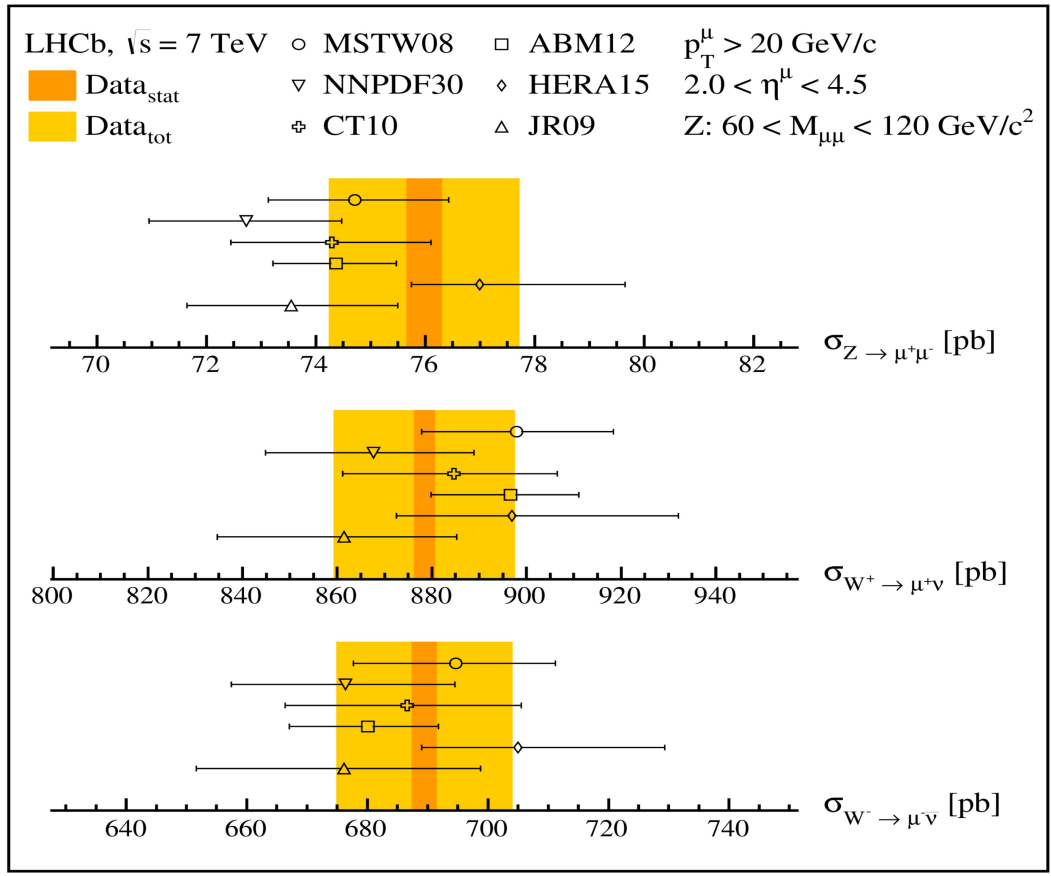
W cross sections at √s = 7 TeV





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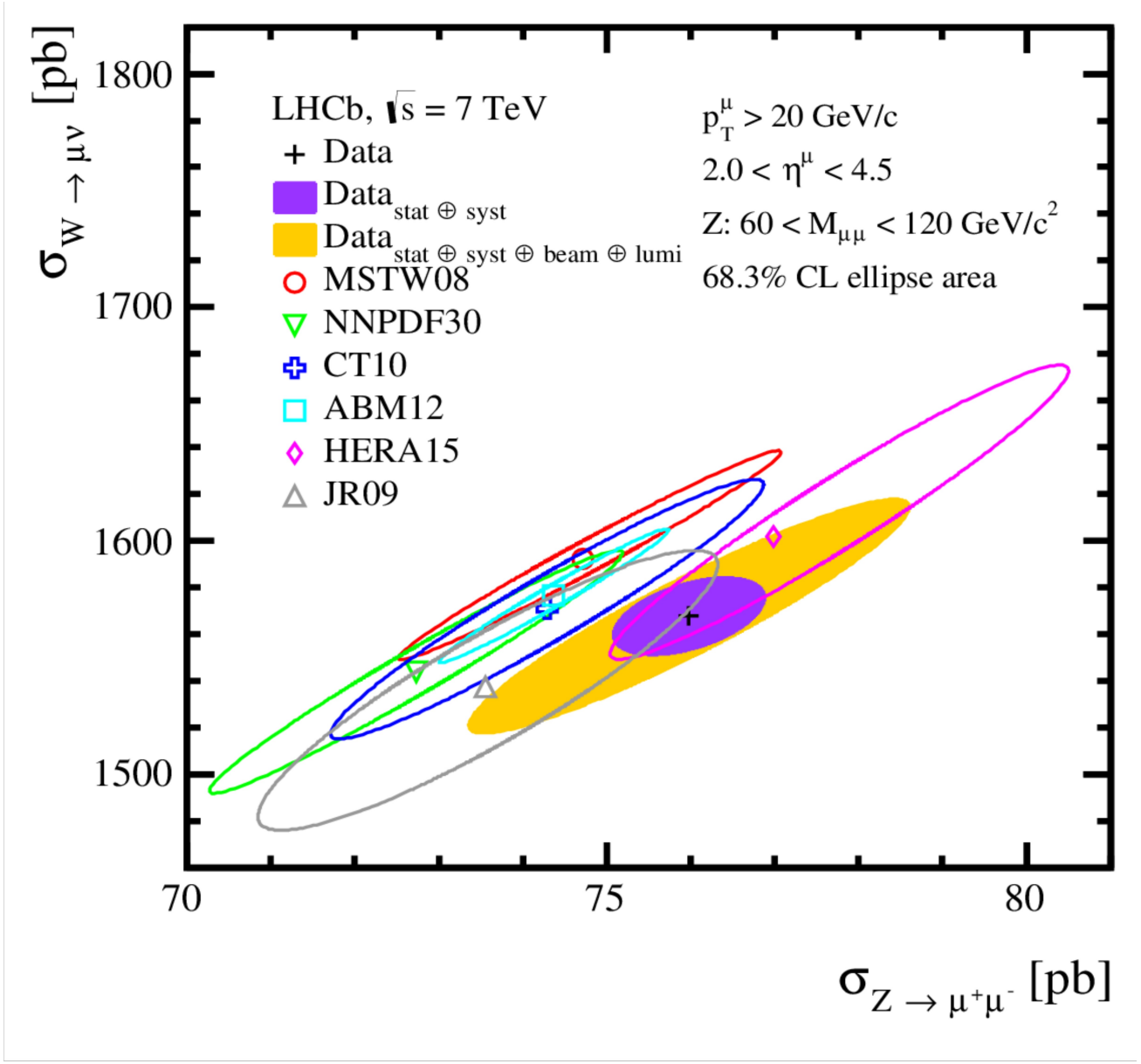
Measured cross-sections in comparison with NNLO predictions



$R_{WZ} = 20.63 \pm 0.09 \pm 0.012 \pm 0.05$

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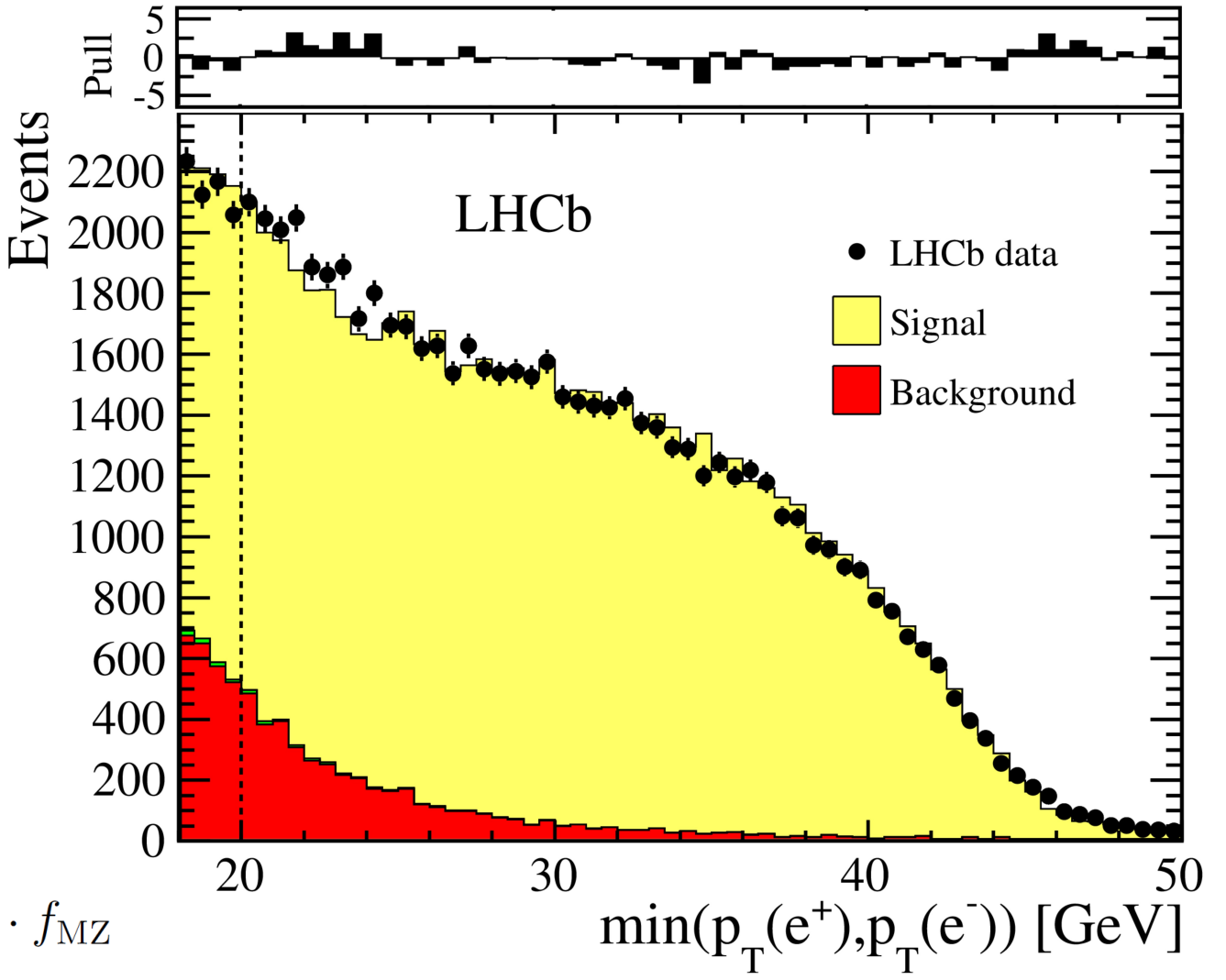
Forward Z[e⁺e⁻] production at √s = 8 TeV

Selection criteria

- $Z \rightarrow e^+e^-$
- $2 < \eta_e < 4.5$
- $P^e_T > 20$ GeV
- High energy deposition
- $M(e^+e^-) > 40$ GeV



$$\sigma = \frac{N(e^+e^-) - N(e^\pm e^\pm) - N_{bg}}{\epsilon \cdot \int \mathcal{L} dt} \cdot f_{MZ}$$

$\sigma(pp \rightarrow Z \rightarrow e^+e^-) = (93.81 \pm 0.41 \pm 1.48 \pm 1.14)$ pb

Uncertanties: statistics, systematic and luminosity

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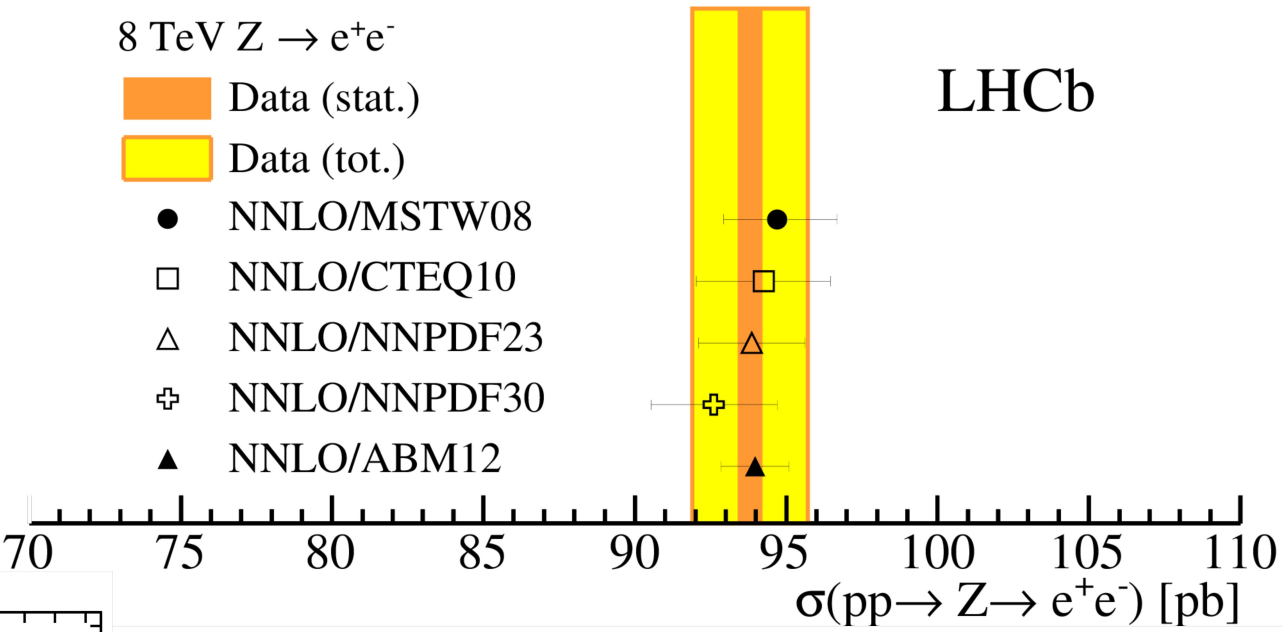
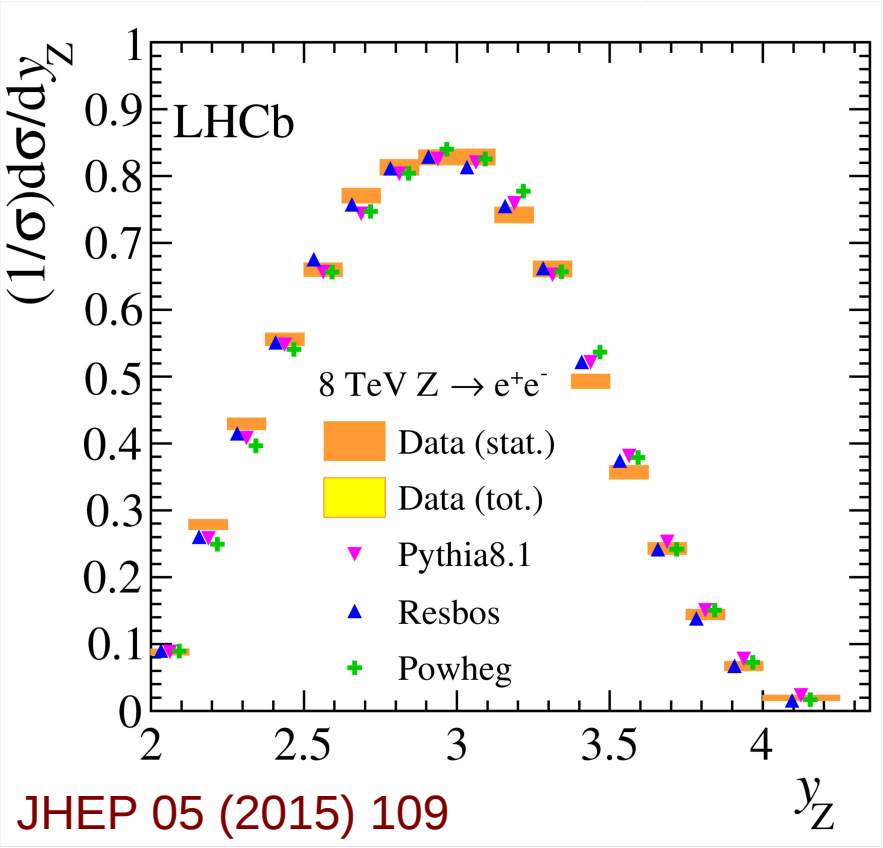
Measured cross-section





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Agrees well with predictions from RESBOS (NLO+NNLL) and POWHEG+Herwig (NLO & Parton Shower)

Forward-backward asymmetry in $Z \to \mu^+\mu^-$

- SM predicts different Z boson couplings for left and right handed fermions.
- This leads to an asymmetry in polar angle for charged leptons.
- θ^* is angle between μ^+ and z-axis direction in Collins-Soper frame.
- Differential cross section can be written as

$$\frac{d\sigma}{d\cos\theta^*} = C\frac{4}{3}\frac{\pi\alpha^2}{s}\left(A\frac{3}{8}(1+\cos^2\theta^*) + B\cos\theta^*\right)$$

where A and B correspond to vector and axial-vector couplings respectively.

- The forward-backward asymmetry is defined as

$$A_{FB} \equiv \frac{N_f - N_b}{N_f + N_b}$$

where N_f and N_b are number of events with positive and negative value of $\cos\theta^*$.

Forward-backward asymmetry in $Z \to \mu^+\mu^-$

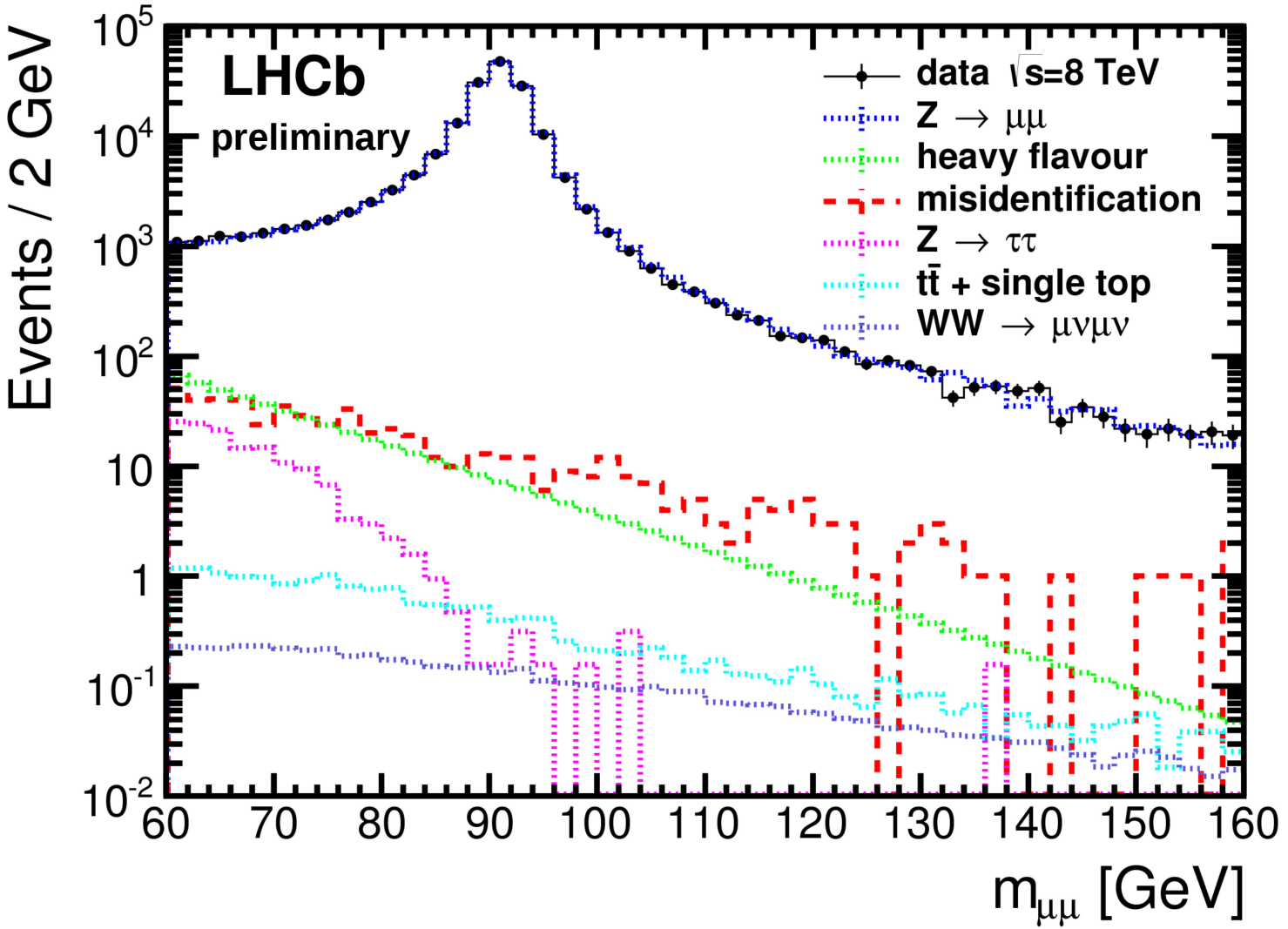
- In SM $\sin^2\theta_w$ is the mixing angle between neutral states associated to U(1) and U(2) gauge groups and relates the strength of photon couplings to that of Z boson.
- $\sin^2\theta_w^{eff}$ is defined as function of the ratio of the vector and axial effective couplings between the Z boson and fermions. It is a function of $\sin^2\theta_w$ and can be extracted from anglurar analysis in θ^*.
- Value of $\sin^2\theta_w^{eff}$ have been determined by LEP, SLD, CDF, D0, ATLAS, CMS.
- Determination of $\sin^2\theta_W^{eff}$ from A_{FB}: There is dilution factor due to unknown which proton contained the quark and which contained the anti-quark. In the forward region the initial state quark tends to be the high-x parton that travels towards LHCb => sensitivity to $\sin^2\theta_W^{eff}$ is less diluted by not knowing which proton contained the quark and which contained the anti-quark.

Forward-backward asymmetry in $Z \to \mu^+\mu^-$

Selection criteria:

- $2 < \eta_\mu < 4.5$
- $P^\mu_T > 20$ GeV
- $60 < M\mu\mu < 160$ GeV

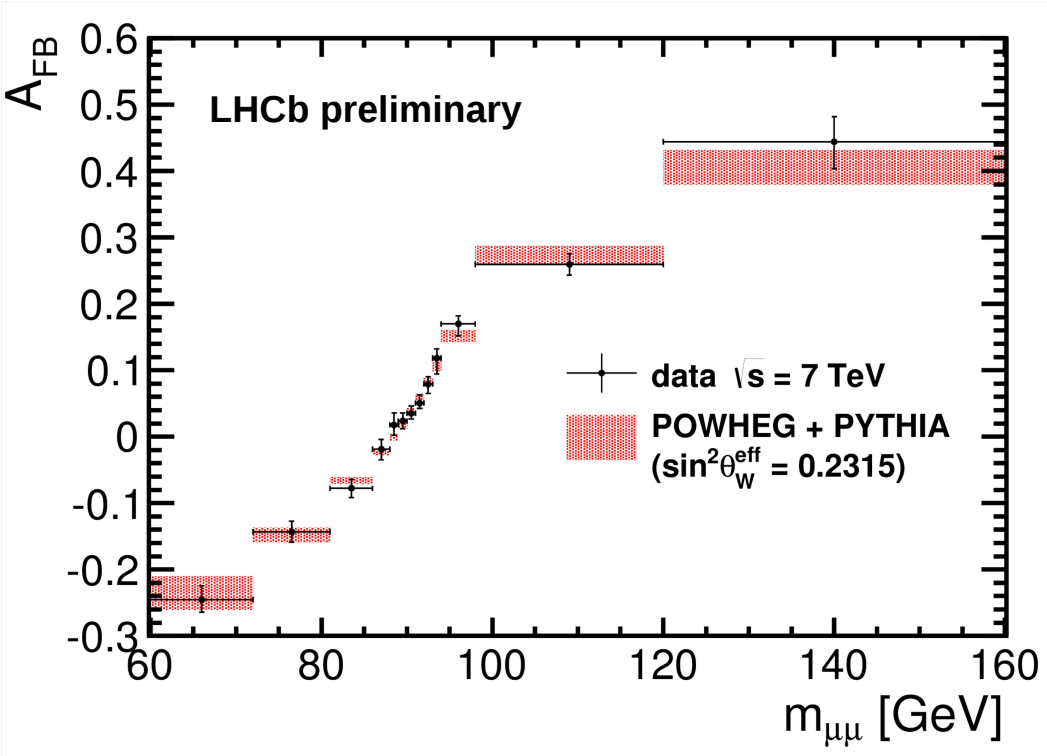
99% purity

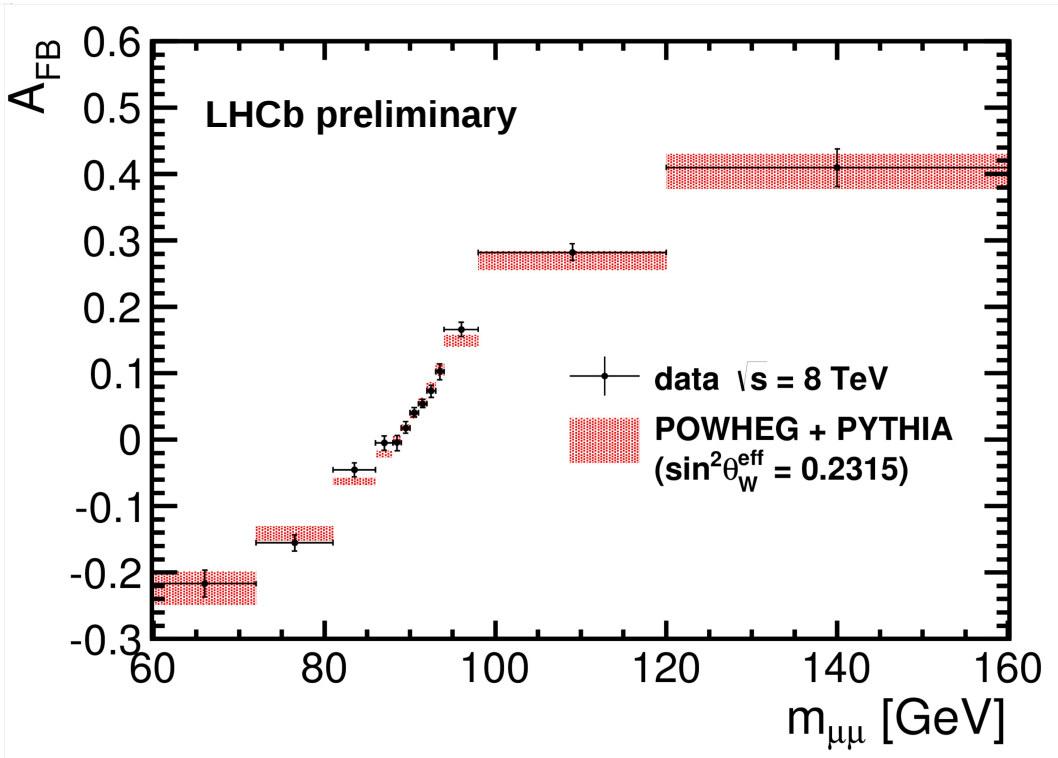


Preliminary: LHCb-paper-2015-039

Forward-backward asymmetry in $Z \to \mu^+\mu^-$

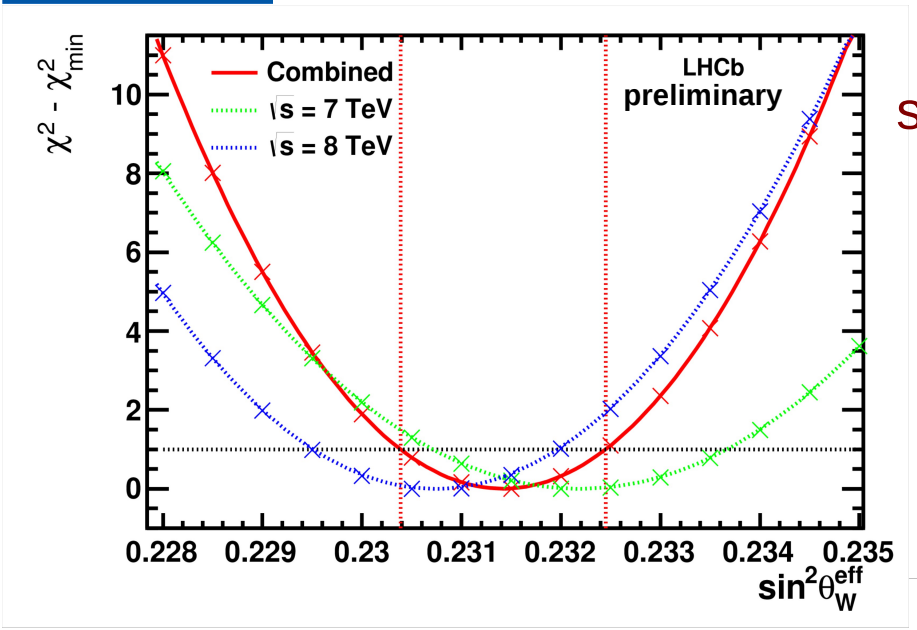
$$A_{FB} \equiv \frac{N_f - N_b}{N_f + N_b}$$





Preliminary: LHCb-paper-2015-039

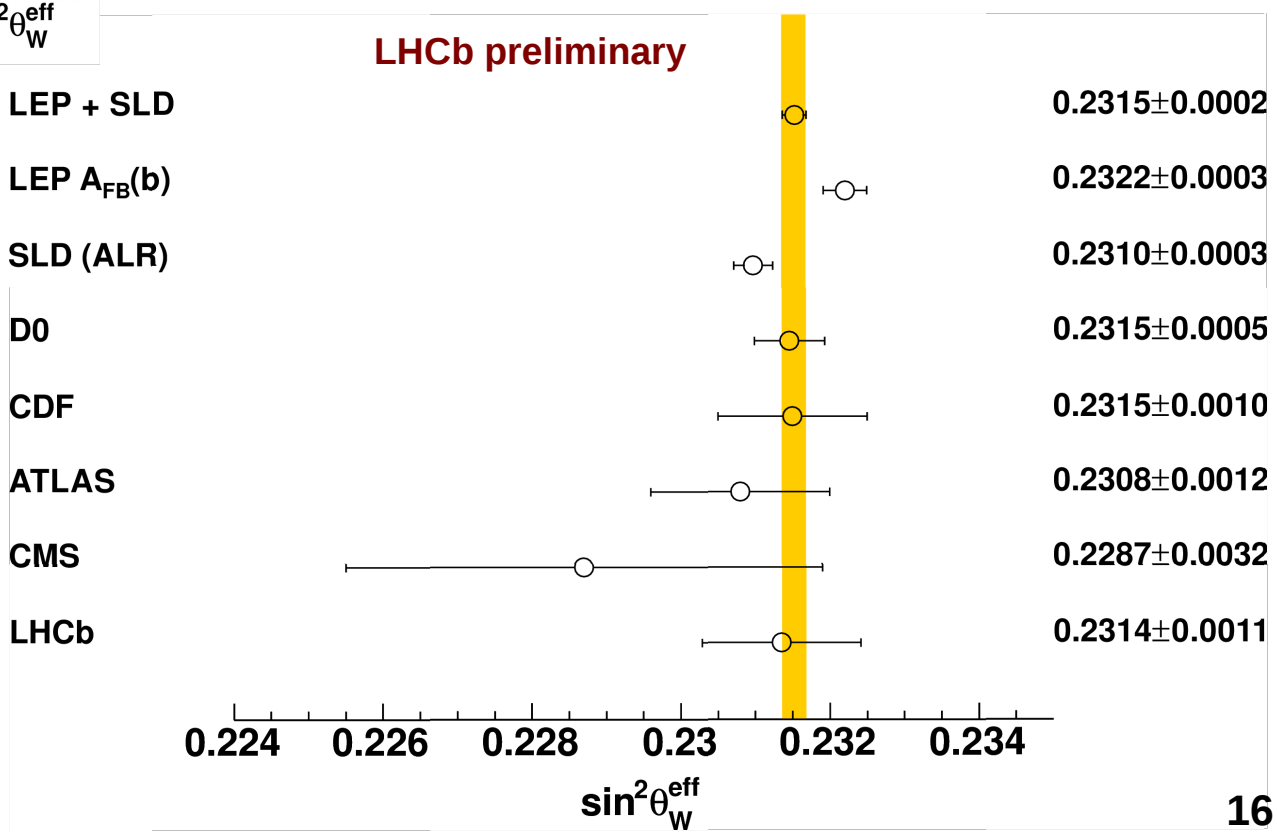
$\sin^2\theta_W^{\text{eff}}$



$\sin^2\theta_W^{\text{eff}} = 0.23142 \pm 0.00073 \pm 0.00052 \pm 0.00056$

(stat) (syst) (theo)

Forward events allow extraction of $\sin^2\theta_W^{\text{eff}}$ with greater precision than events at central rapidities.



Preliminary: LHCb-paper-2015-039

Conclusion

- Forward W and Z bosons production cross sections have been measured at $\sqrt{s}$ = 7 and 8 TeV. Results are consistent with NNLO pQCD calculations.
- Forward-backward asymmetry for $Z \rightarrow \mu^+\mu^-$ has been measured as a function of $\mu^+\mu^-$ invariant mass for 7 and 8 TeV data. The measured value of $\sin^2\theta_W^{eff} = 0.2314 \pm 0.0011$ is consistent with previous results.
- Further results are expected... and even more from Run 2.
- Stay tuned!

Backup

Forward Z production systematic uncertainties

Source	Uncertainty (%)
Statistical	0.39
Trigger efficiency	0.07
Identification efficiency	0.23
Tracking efficiency	0.53
FSR	0.11
Purity	0.22
GEC efficiency	0.26
Systematic	0.68
Beam energy	1.25
Luminosity	1.72
Total	2.27

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Forward W production systematic uncertainties

Source	$\Delta\sigma_{W^+\to\mu^+\nu}$ [%]	$\Delta\sigma_{W^-\to\mu^-\overline{\nu}}$ [%]	ΔR_W [%]
Template shape	0.28	0.39	0.59
Template normalisation	0.10	0.10	0.06
Reconstruction efficiency	1.21	1.20	0.12
Selection efficiency	0.33	0.32	0.18
Acceptance and FSR	0.18	0.12	0.21
Luminosity	1.71	1.71	—

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A_{FB} in $Z \to \mu^+\mu^-$ systematic uncertainties

Uncertainty	Type	Average $\Delta\lvert A_{FB}^{\text{pred.}}\rvert$
PDF	1σ	0.0062
scale	max/min	0.0040
α_s	max/min	0.0030
FSR	max/min	0.0016

preliminary