Electroweak physics at LHCb

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on behalf of the LHCb Collaboration

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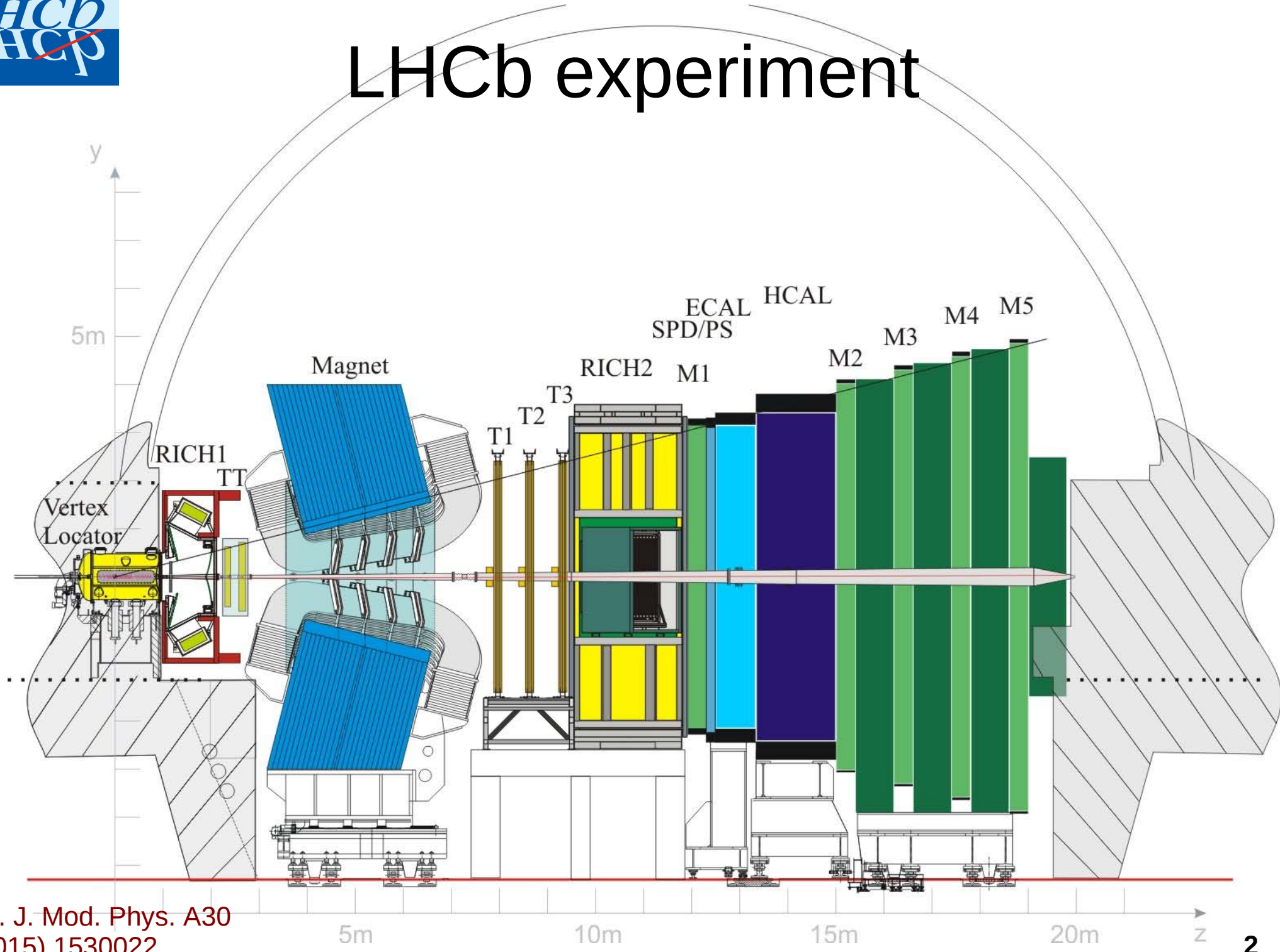
Outline:

- LHCb detector & data taking
- $Z \to \mu^+\mu^-$ and $Z \to e^+e^-$ at 13 TeV
- $W \to e\,\nu$ at 8 TeV
- W/Z + jets at 8 TeV
- $Z \to b\bar{b}$ at 8 TeV
- $Z \to \tau^+\tau^-$ at 8 TeV NEW
- Summary

LHCb experiment

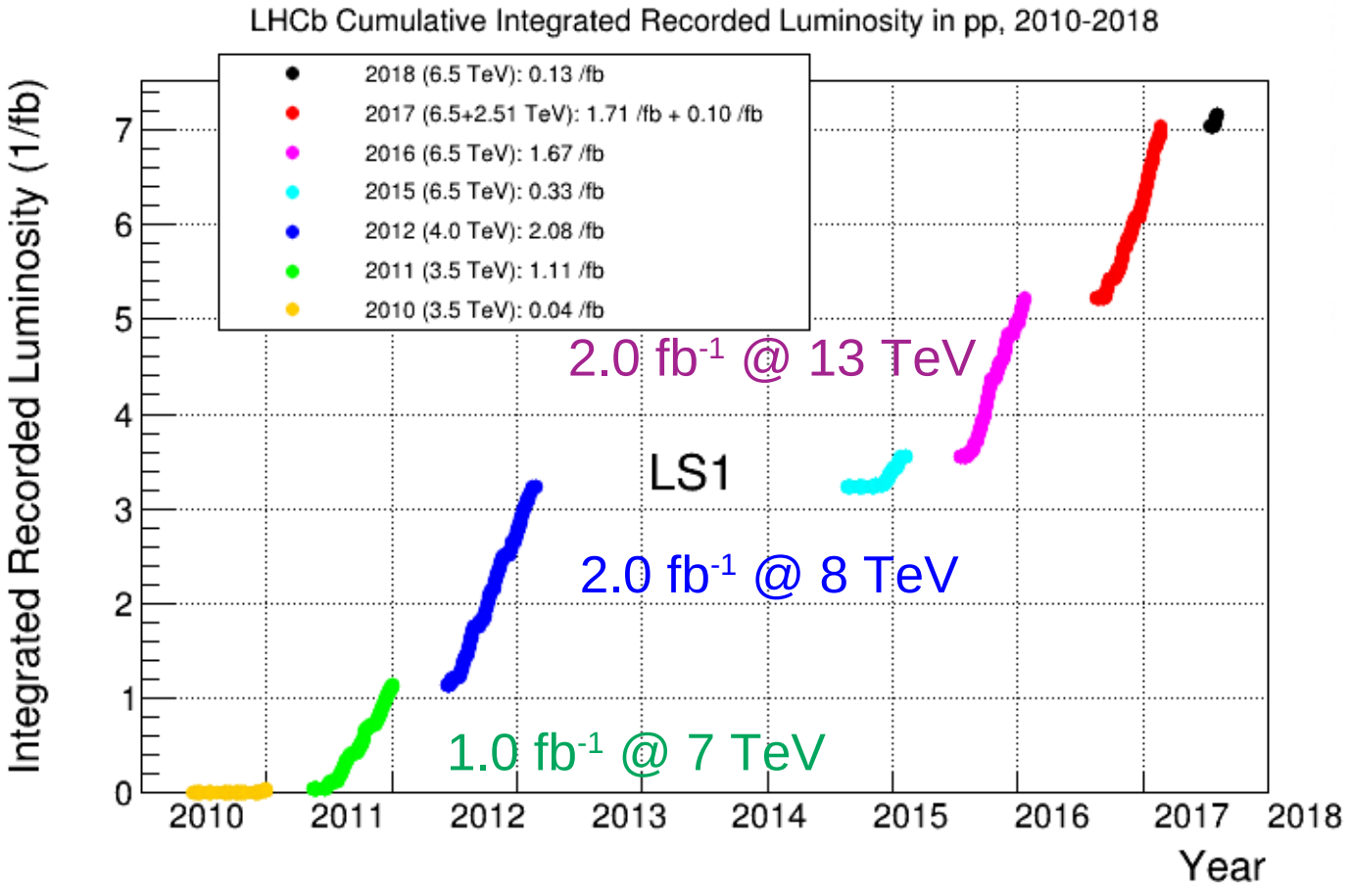


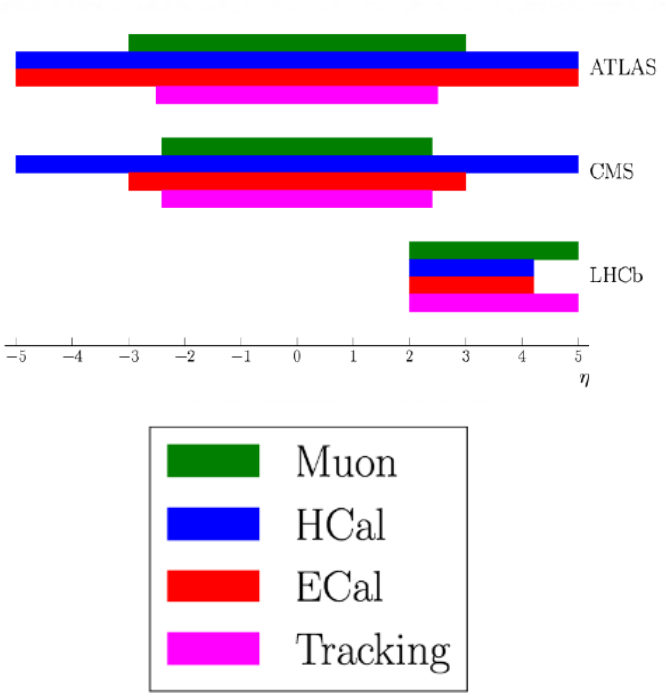
Int. J. Mod. Phys. A30 (2015) 1530022

LHCb performance

- Momentum resolution: 0.4 – 0.6% at 5 – 100 GeV
- 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
- Excellent vertex reconstruction: tagging of b and c jets

Acceptance: $2 < \eta < 5$





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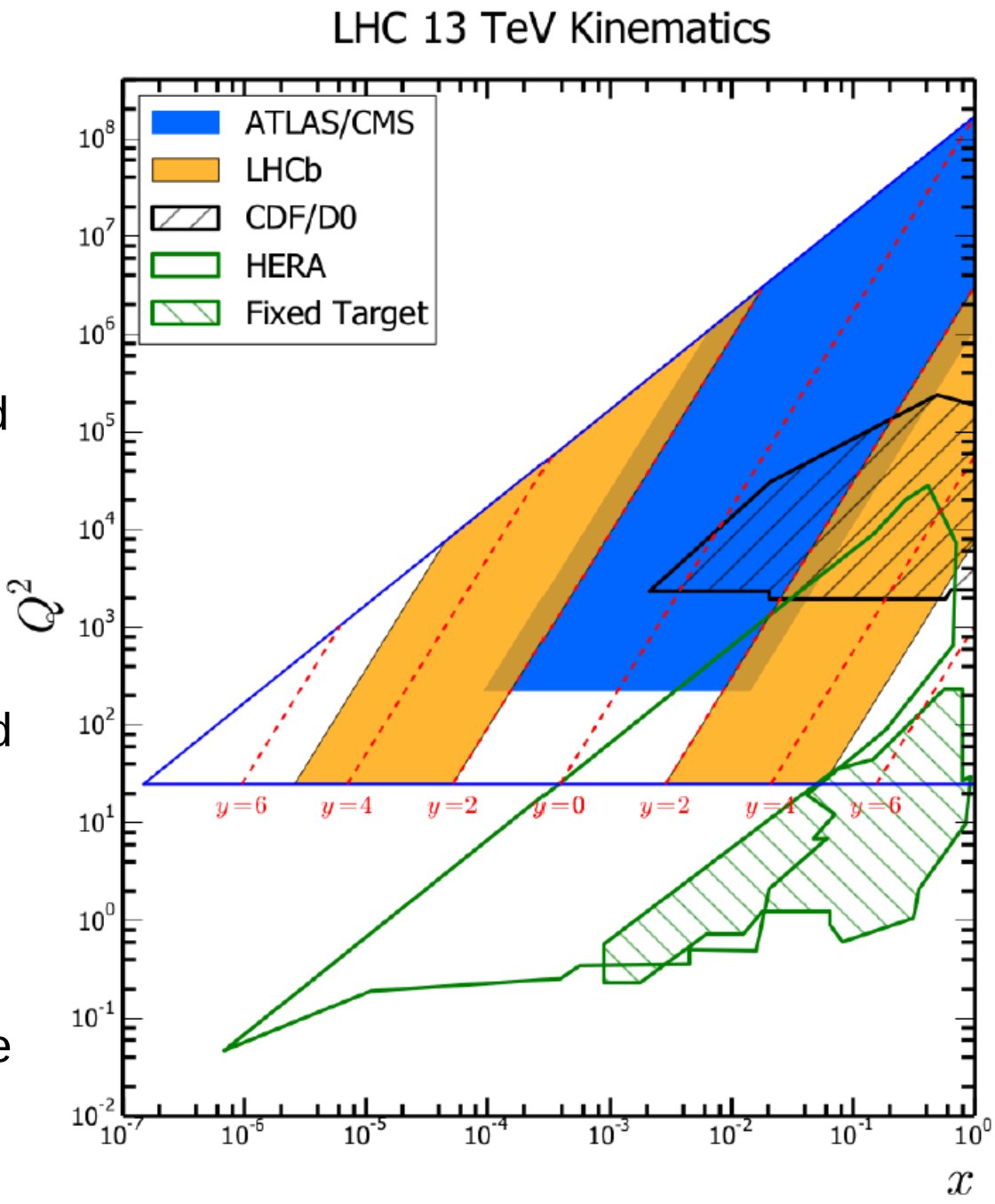
LHCb sensitivity to parton density functions

- LHCb offers a complementary phase space region with respect to ATLAS and CMS for Standard Model tests in electroweak sector:
  - Cross-section measurements of W and Z production in the forward acceptance.
  - Access to Parton Distribution Functions (PDFs) in regions of known high-*x* and unexplored low-*x* partons. PDFs parametrized as

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

- We aim at precise measurement of fundamental parameters of the SM: the electroweak mixing angle, the W mass etc.



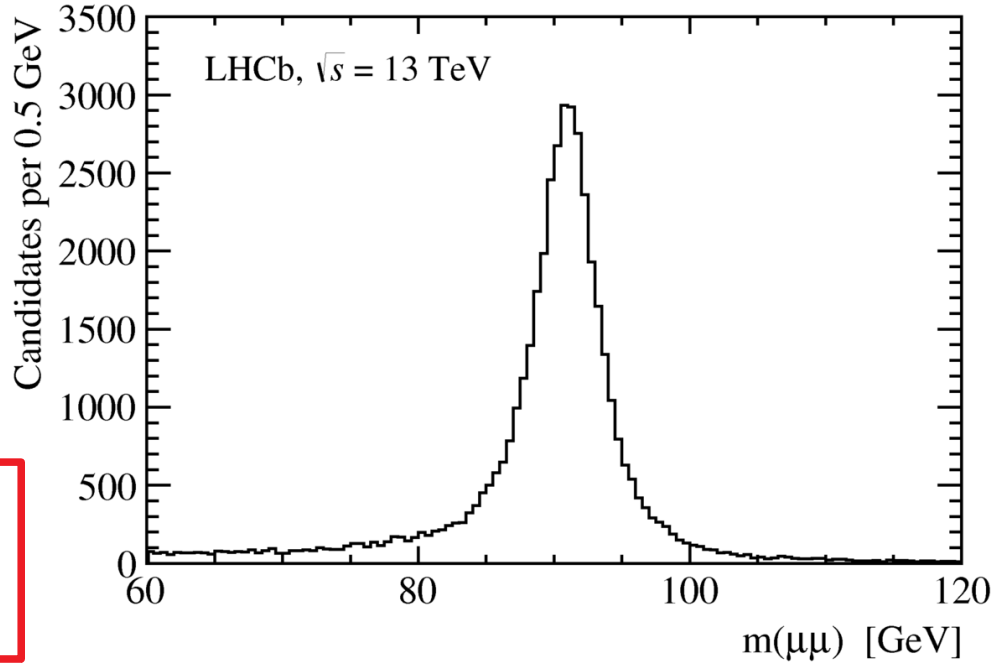
Forward Z production at √s = 13 TeV

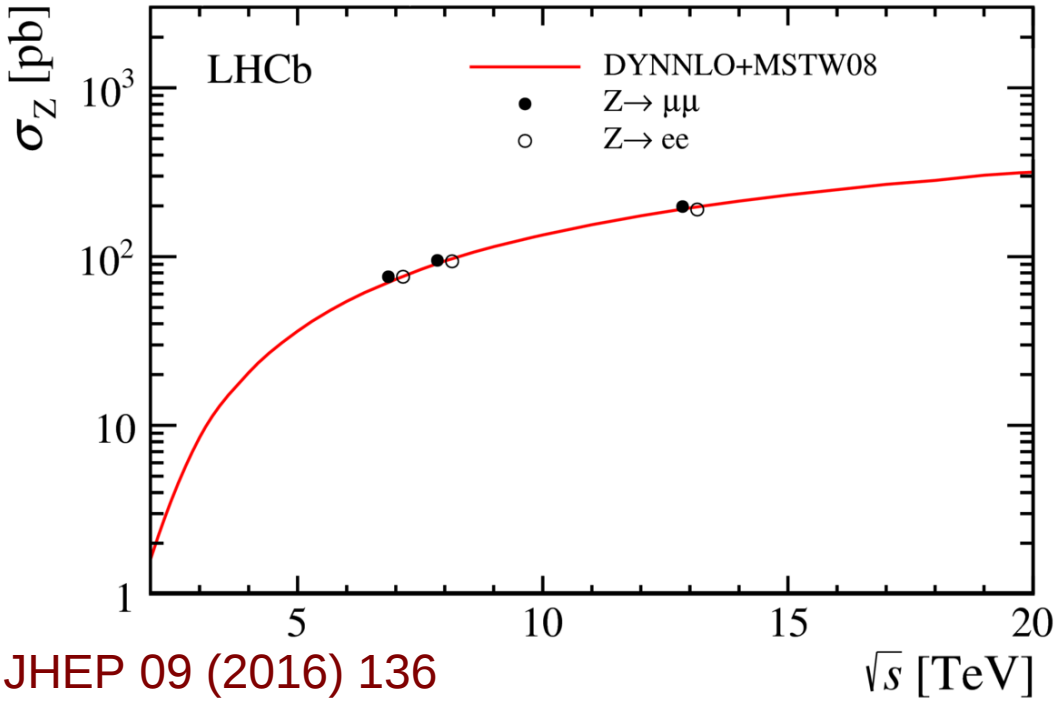
Event selection, $Z \rightarrow \mu^+\mu^-,\ e^+e^-$

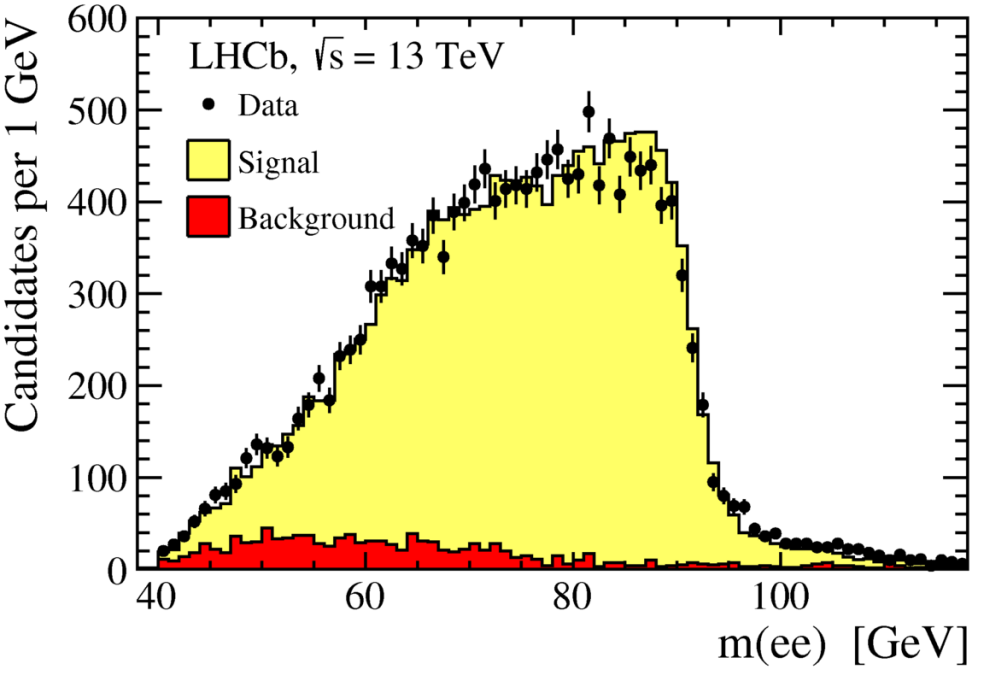
- $2 < \eta_l < 4.5$, $P^l_T > 20$ GeV
- $60 < M(l^+l^-) < 120$ GeV

$\sigma(Z \rightarrow l^+l^-) = 194.3 \pm 0.9 \pm 3.3 \pm 7.6$ pb

Uncertainties: statistics, systematic, luminosity







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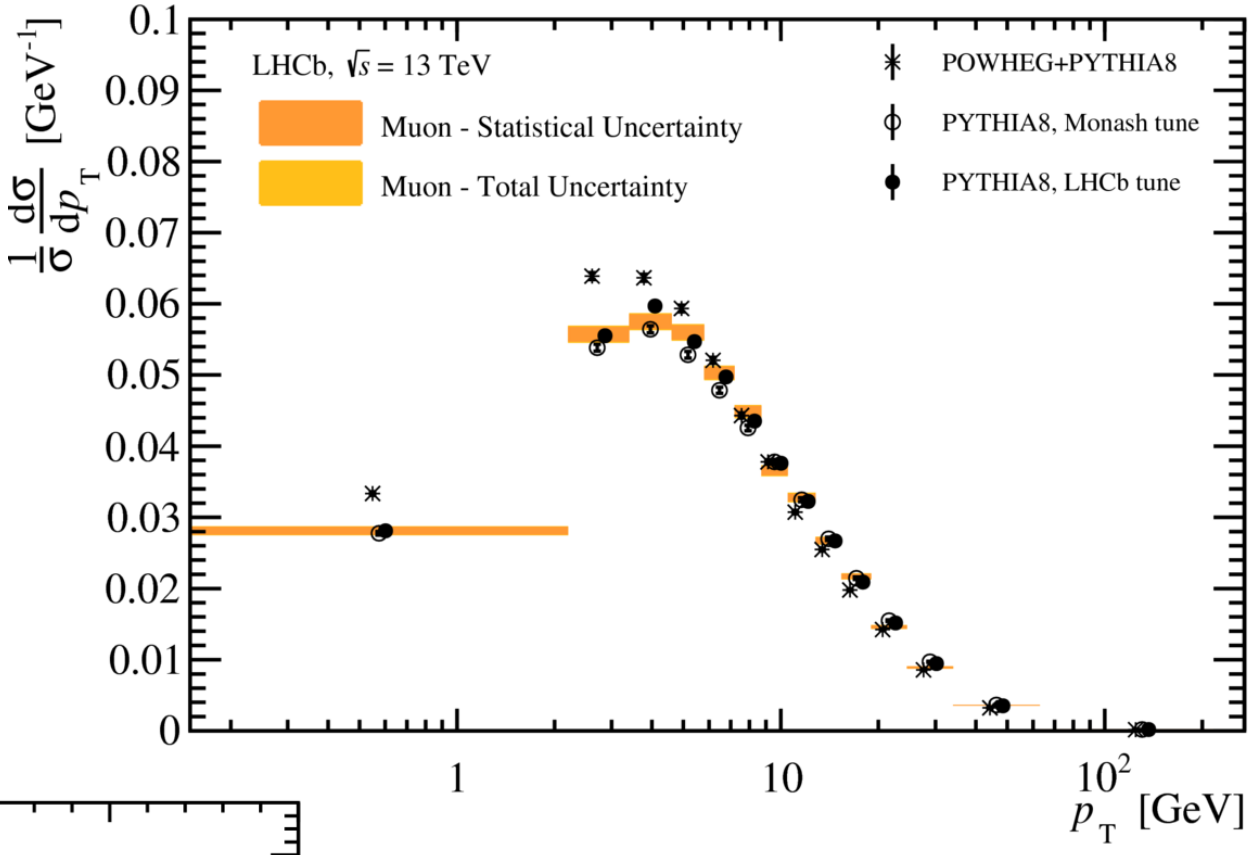
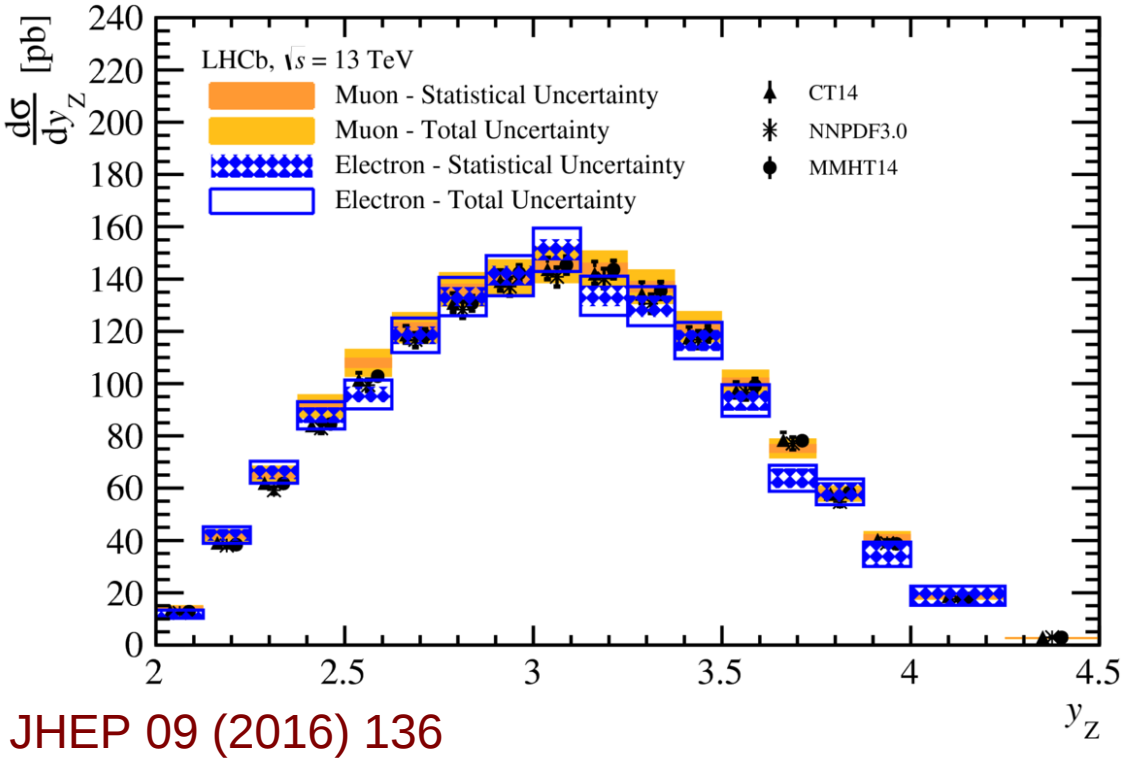
Differential cross-section





Agrees well with predictions

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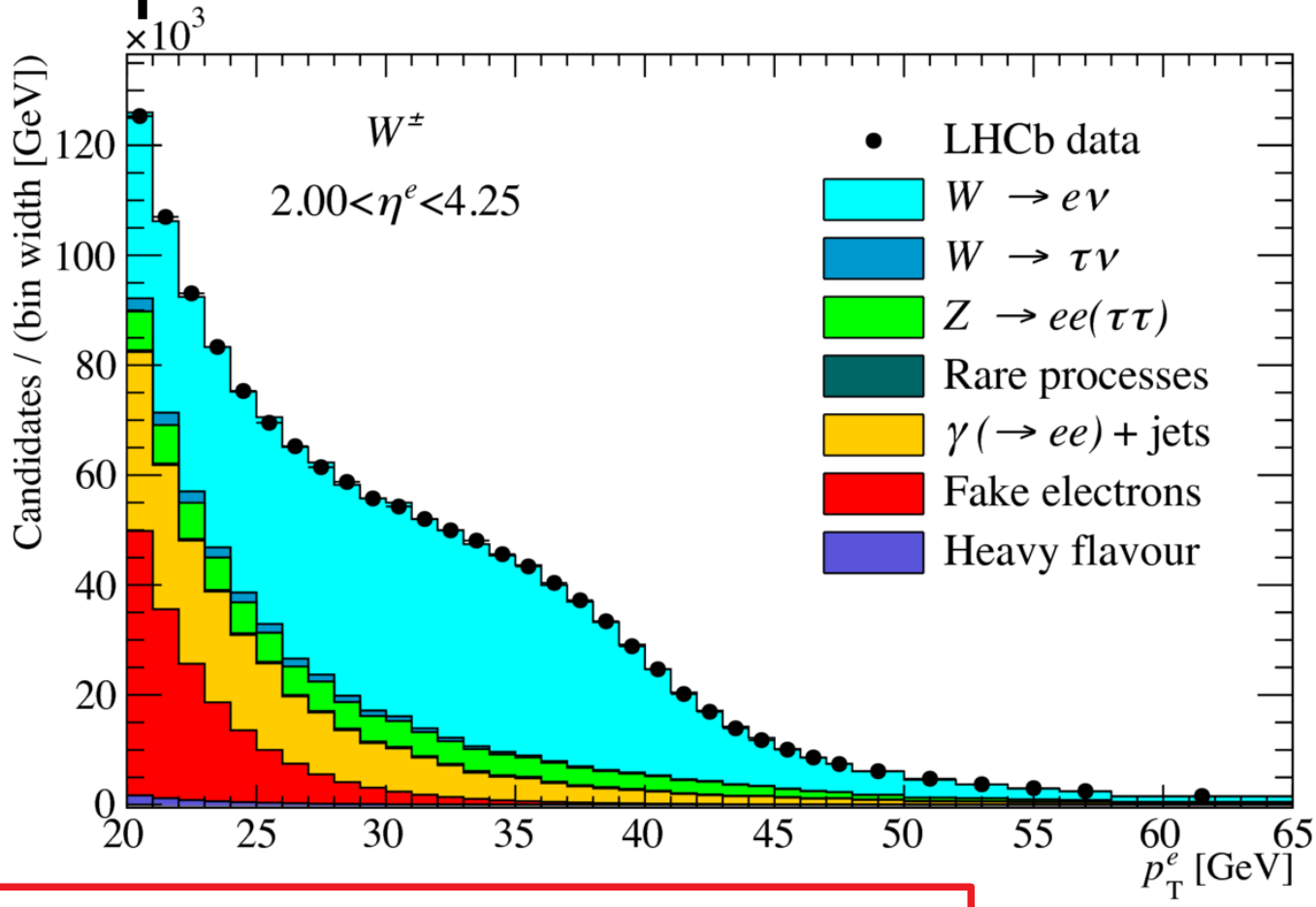
Forward W production at √s = 8 TeV

Selection criteria

- $p_T^e > 20$ GeV
- $2.0 < \eta^e < 4.25$

W yield extracted from the fit to electron p_T distribution



$\sigma(W^+ \rightarrow e^+\nu) = (1124.4 \pm 2.1 \pm 21.5 \pm 11.2 \pm 13.0)$ pb

$\sigma(W^- \rightarrow e^-\nu) = (809.0 \pm 1.9 \pm 18.1 \pm 7.0 \pm 9.4)$ pb

Uncertainties: statistics, systematic, energy, luminosity

$B(W \rightarrow e\nu) / B(W \rightarrow \mu\nu) = 1.020 \pm 0.002 \pm 0.019$

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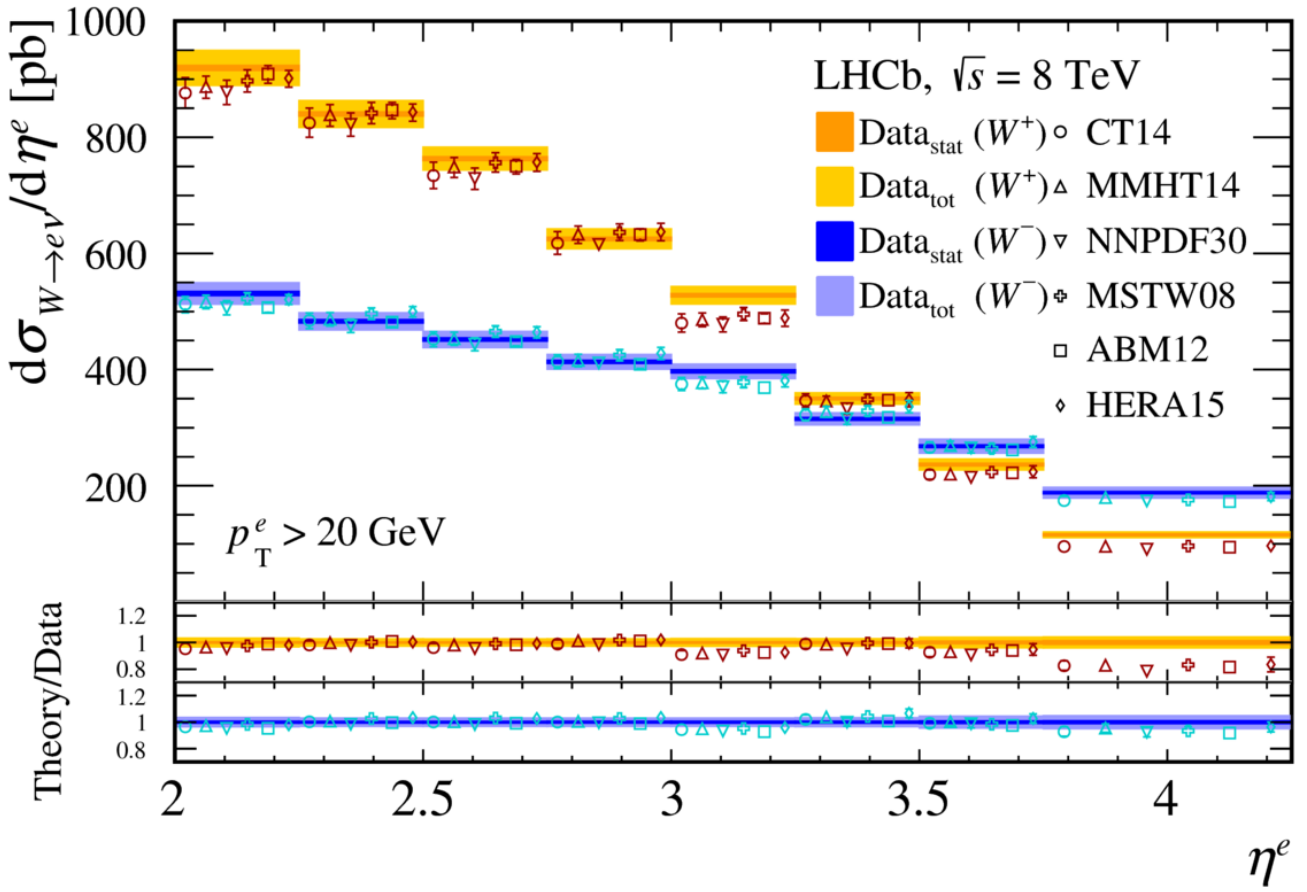
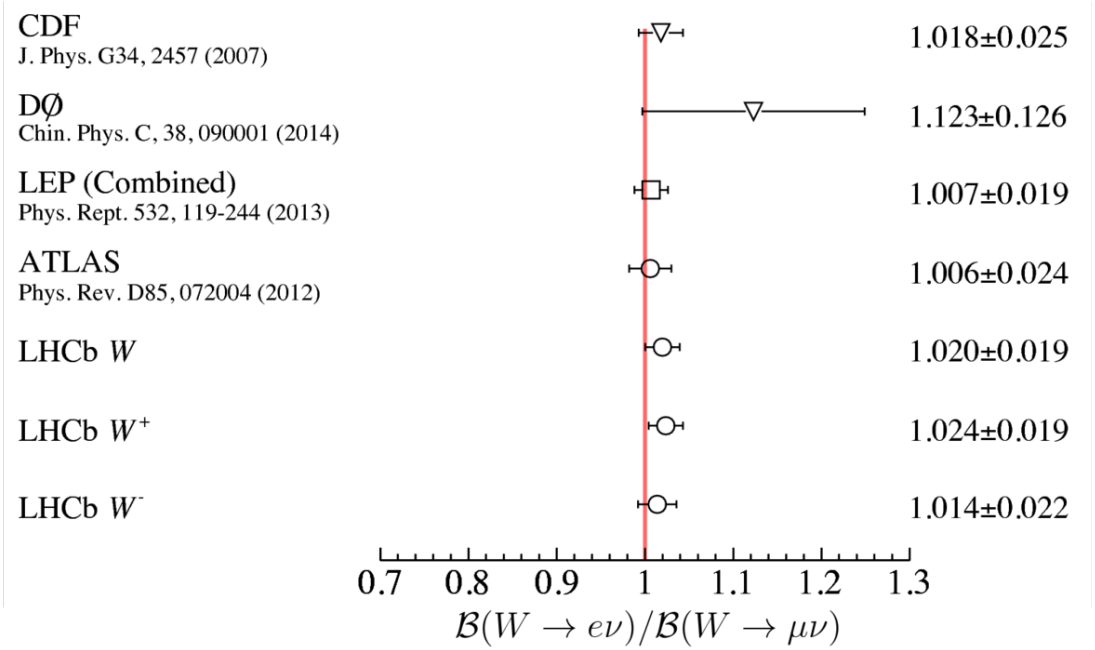
Forward W production at √s = 8 TeV





Differential cross section as a function of η^e is compatible with the prediction.

B(W→eν) / B(W→μν) ratio is consistent with unity.

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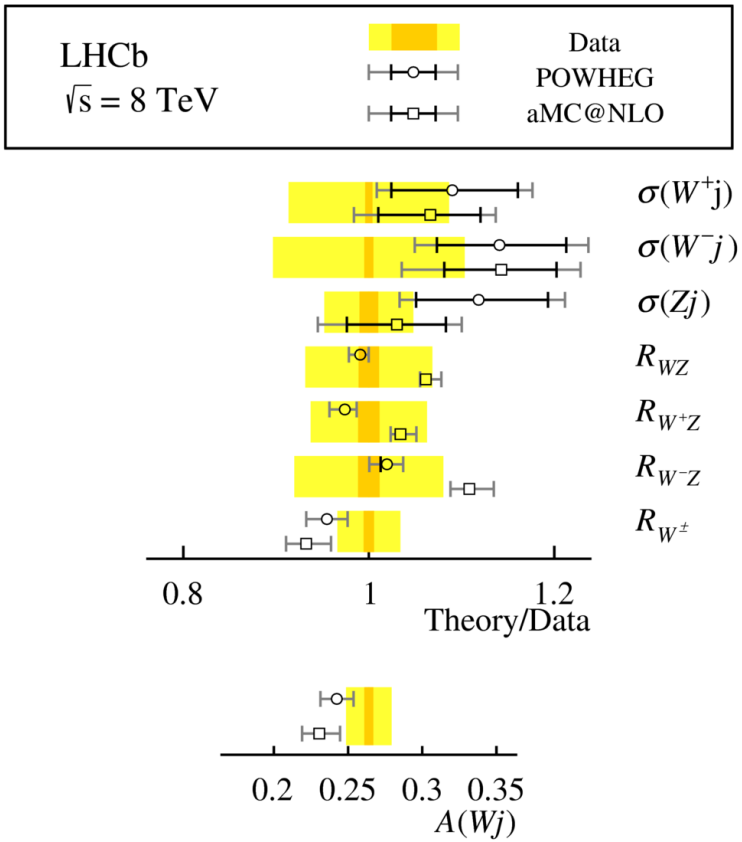
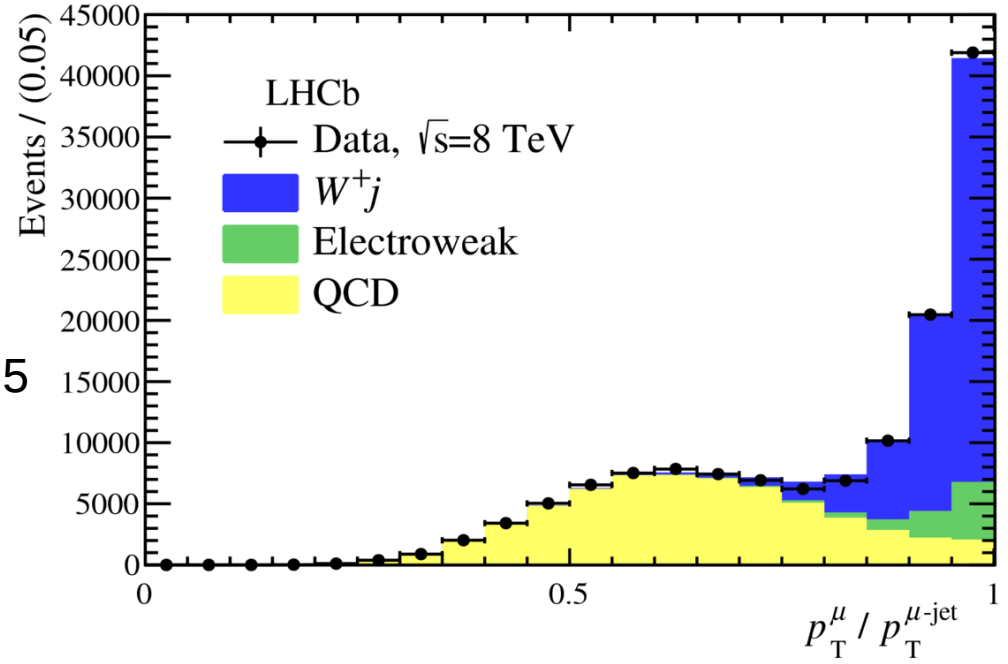
W/Z + jets production at √s = 8 TeV

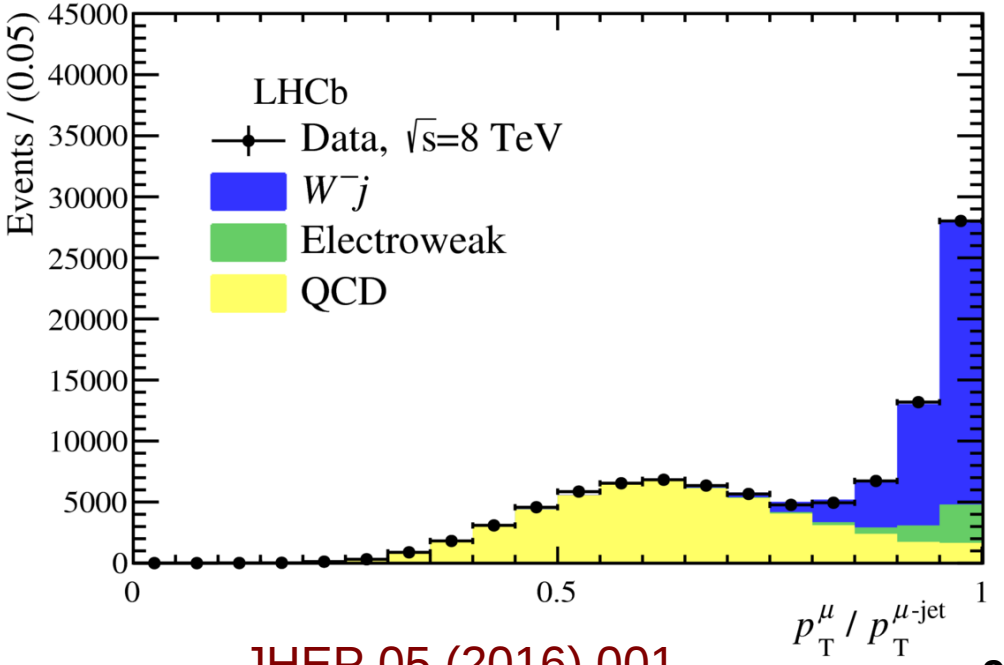
Selection criteria

- LHCb standard jets: anti-kt with R=0.5
- W → μν and Z → μμ decay channels.
- Jet: p_T > 20 GeV, 2.2 < η < 4.2, ΔR(jet, μ) > 0.5

Fit to the muon isolation $p_T(\mu)$ / p_T(μ-jet)







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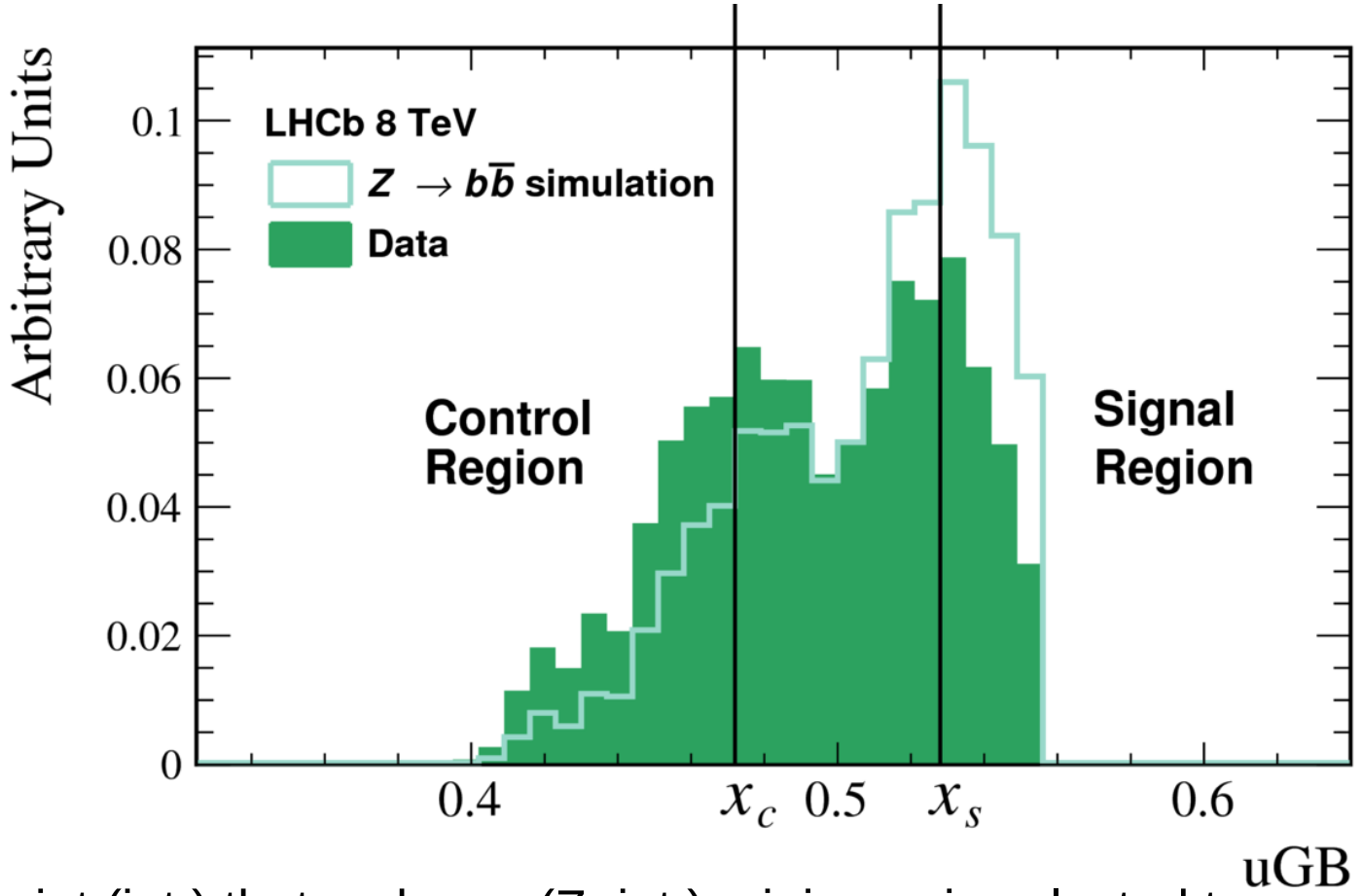
Forward $Z \to b\bar{b}$ production at $\sqrt{s}$ = 8 TeV

Selection criteria

- $P^{jet}_T > 20$ GeV
- $2.2 < \eta_{jet} < 4.2$
- $45 < M_{jj} < 165$ GeV



- An additional balancing jet (jet_3) that makes $p_T(Z+jet_3)$ minimum is selected to separate $Z \to bb$ from QCD.
- $Z \to b\bar{b}$ is separated from QCD using adopted uniform Gradient Boost BDT (eliminated dependence on m_{jj}).
- Simultaneous fit to m_{jj} in signal (enhanced $Z \to b\bar{b}$ yield) and control (low $Z \to b\bar{b}$ yield) regions, to measure the Z yield.

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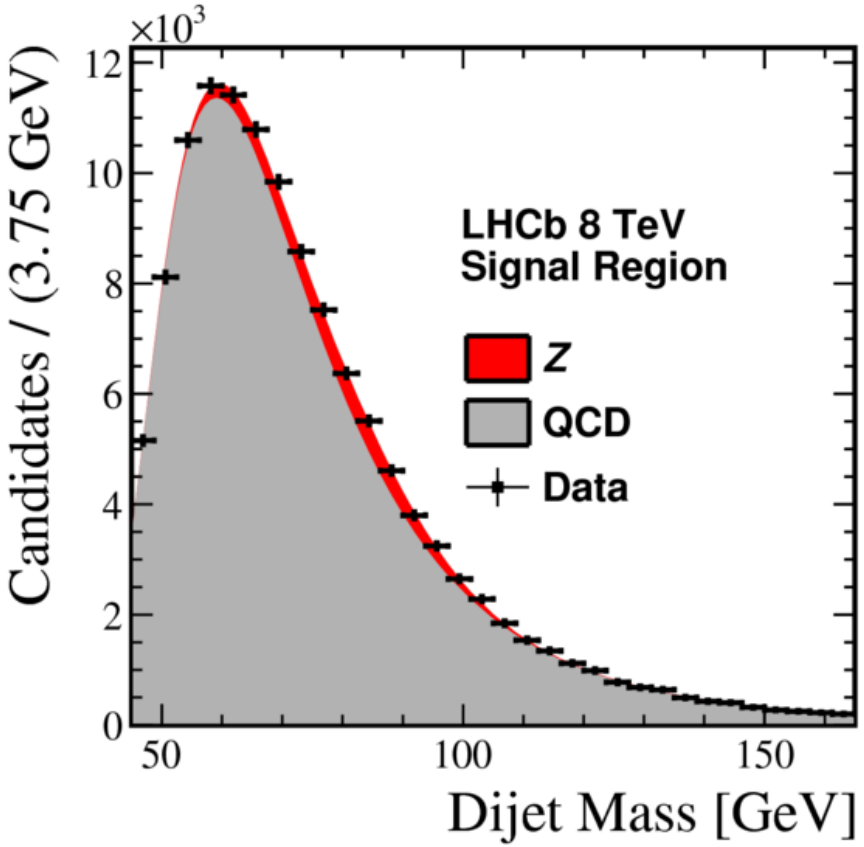
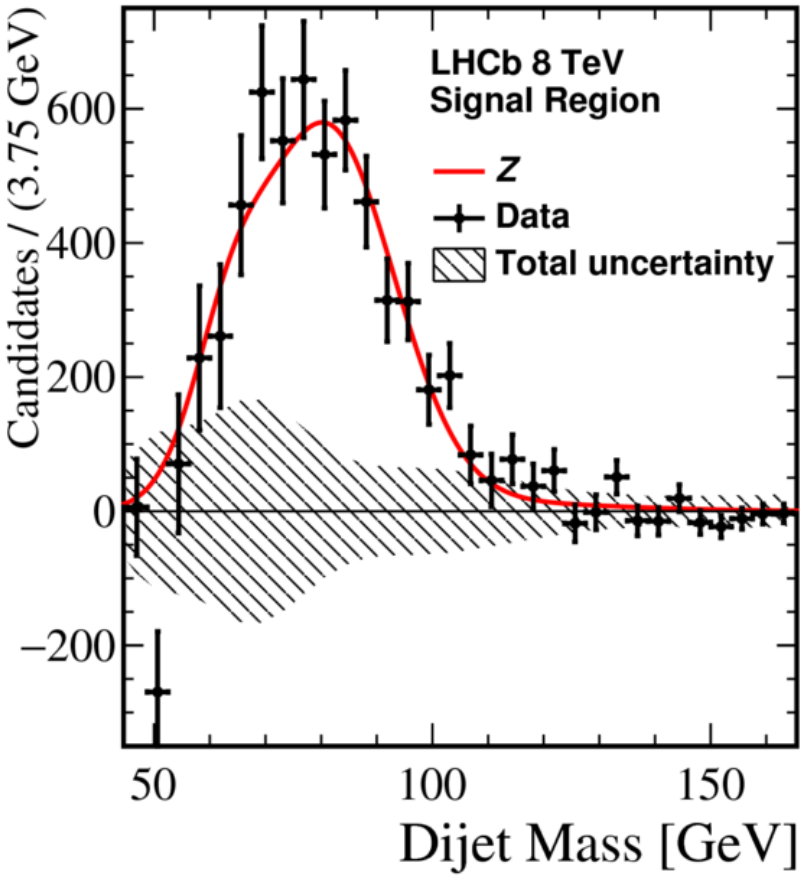
Forward $Z \to b\bar{b}$ production at $\sqrt{s}$ = 8 TeV





$Z \to b\bar{b}$ peaks at ~80 GeV: radiation outside of the jet cone, missing energy, asymmetric jet energy resolution.

$\sigma(pp \to Z \to b\bar{b}) = (332 \pm 46 \pm 59)$ pb

Uncertanties: statistics, systematic (dominated by flavour tagging)

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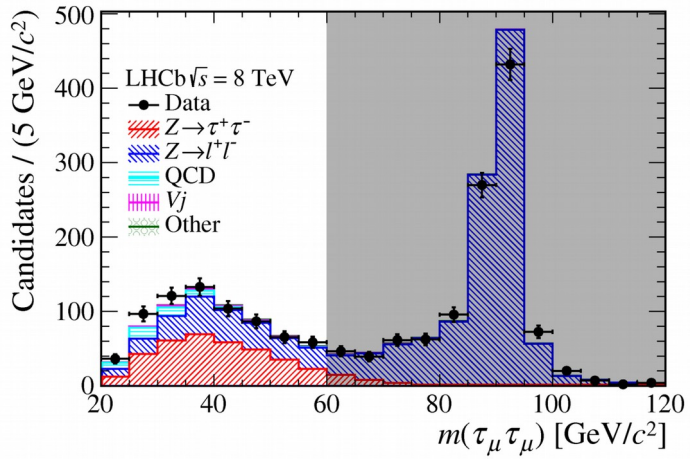
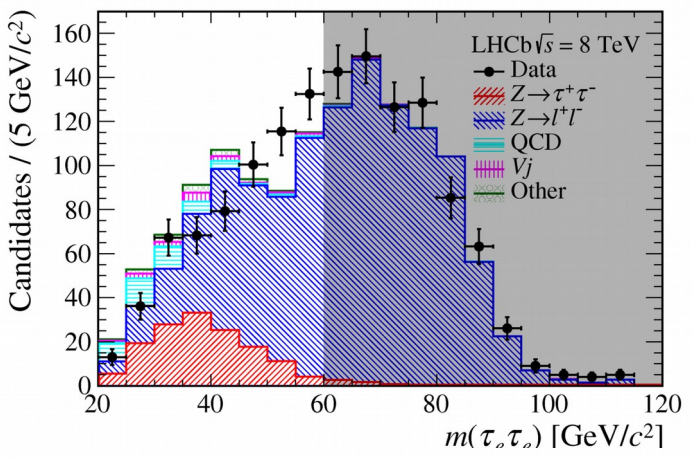
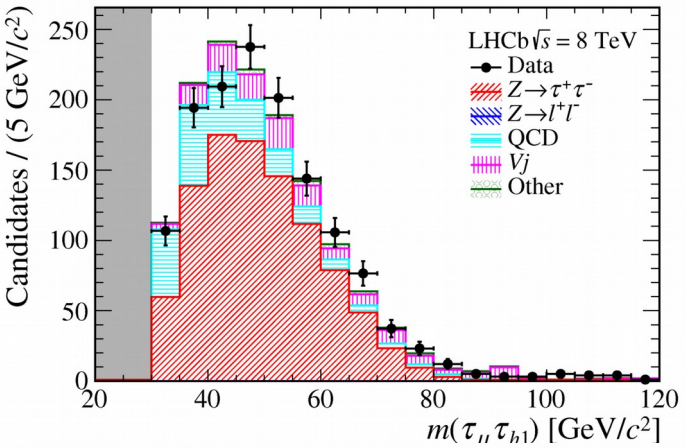
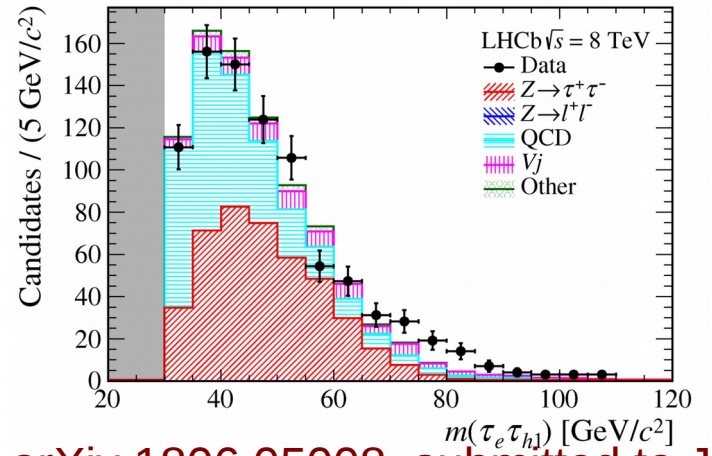
Forward $Z \to \tau^+\tau^-$ production at $\sqrt{s}$ = 8 TeV

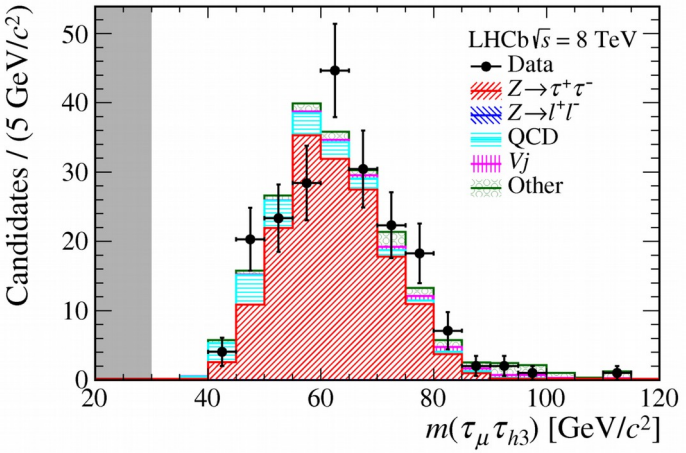
- Test of lepton flavour universality by comparison with $Z \to \mu^+\mu^-$ and $Z \to e^+e^-$
- Tau is reconstructed in leptonic (muon or electron) or hadronic (one or three hadrons) final state. Seven streams: μμ, ee, eμ, μh, eh, μ3h, e3h.
- Selection criteria $2.0 < \eta(\tau) < 4.5$, $p_T(\tau) > 20$ GeV, $60 < m(\tau\tau) < 120$ GeV.

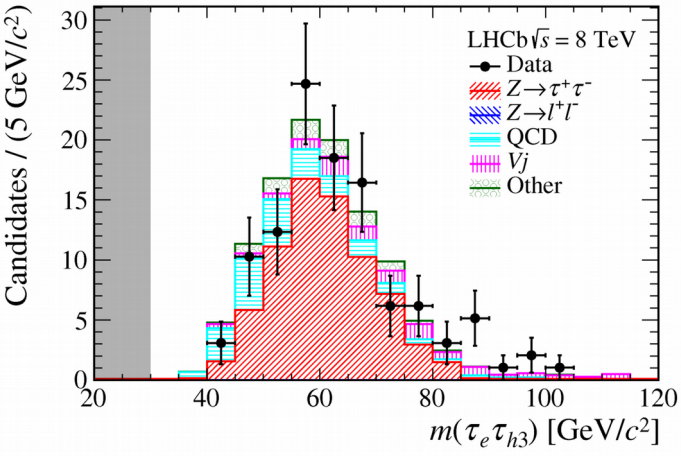






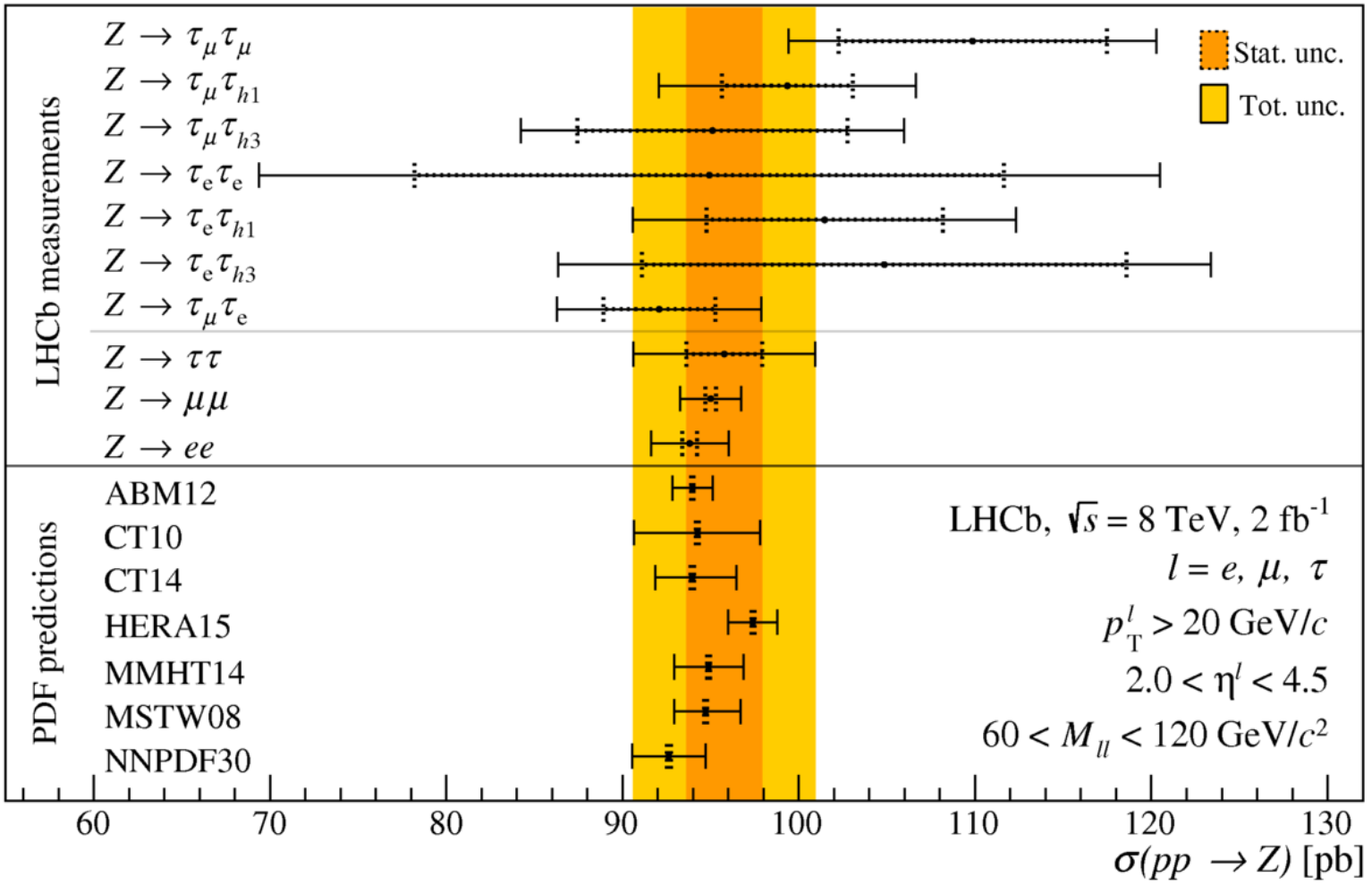






arXiv 1806.05008, submitted to JHEP

Forward $Z \to \tau^+\tau^-$ production at $\sqrt{s}$ = 8 TeV



Test of lepton universality

$$\frac{\sigma^{8\,\mathrm{TeV}}_{pp\to Z\to\tau^+\tau^-}}{\sigma^{8\,\mathrm{TeV}}_{pp\to Z\to e^+e^-}} = 1.021 \pm 0.057$$

$$\frac{\sigma^{8\,\mathrm{TeV}}_{pp\to Z\to\tau^+\tau^-}}{\sigma^{8\,\mathrm{TeV}}_{pp\to Z\to\mu^+\mu^-}} = 1.008 \pm 0.055$$

arXiv 1806.05008, submitted to JHEP

Conclusion

- LHCb performed measurements of W and Z boson production in the forward region of pp collisions, unexplored by other experiments. These measurements provide unique tests of the Standard Model including Lepton Flavour Universality and constraints on the PDFs.
- This talk includes:
  - Forward W and Z boson production cross sections have been measured at $\sqrt{s}$ = 8 and 13 TeV.
  - First measurement of $Z \to b\bar{b}$ production at $\sqrt{s}$ = 8 TeV.
  - New measurement of forward $Z \to \tau^+\tau^-$ production at $\sqrt{s}$ = 8 TeV and test of lepton universality.
- Further results are expected… Stay tuned!

Backup