

Measurement of the W boson mass at LHCb

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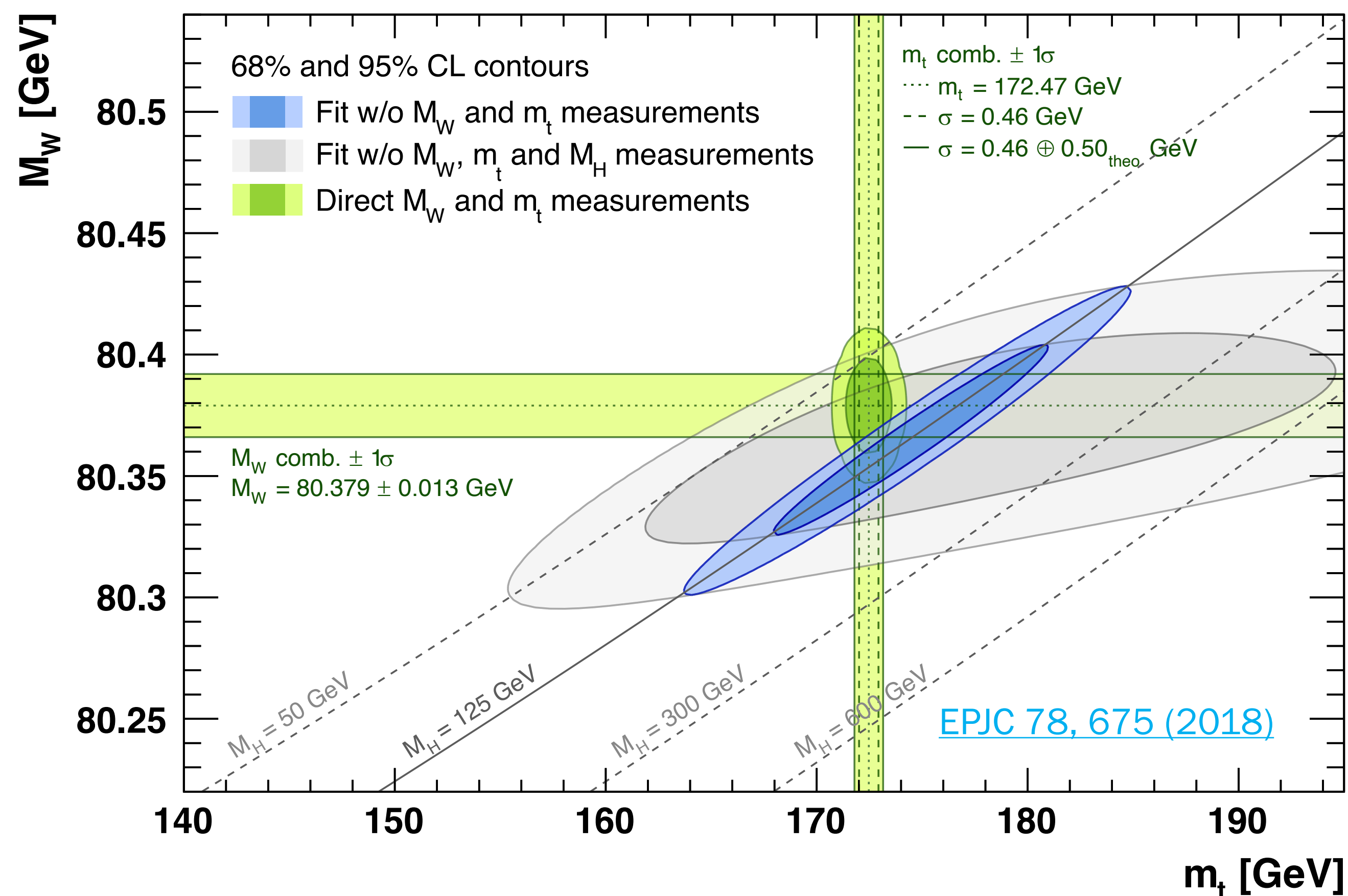
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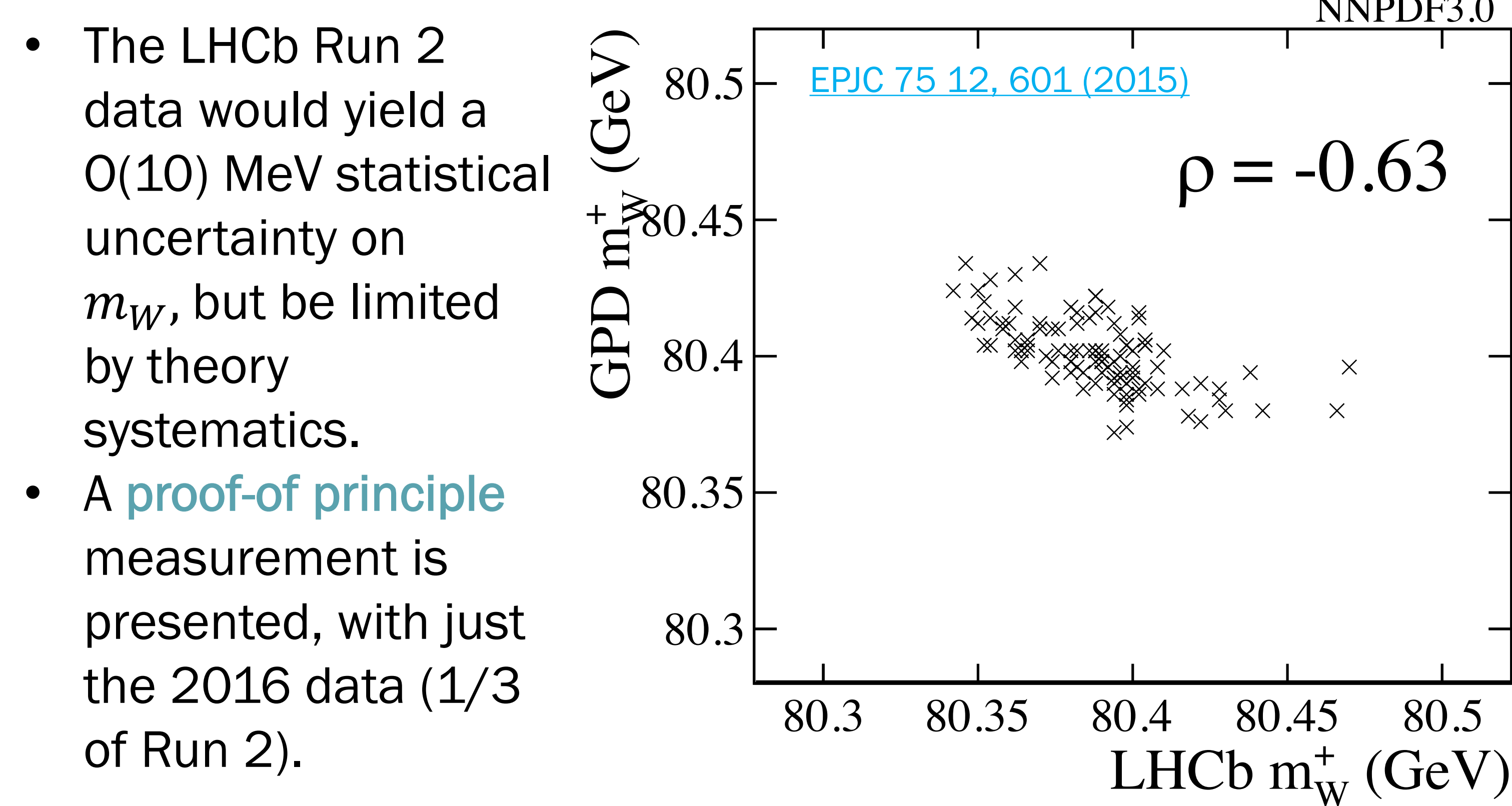
Why should LHCb measure m_W ?

- Comparing direct measurements of m_W to indirect predictions is a stringent test of the Standard Model. However, the power to constrain new physics is limited by direct measurements of m_W :

$$\Delta m_W (\text{EW fit}) = 7 \text{ MeV}, \quad \Delta m_W (\text{ATLAS '18 [1]}) = 19 \text{ MeV}.$$



- Because of LHCb's complementary (forward) acceptance to ATLAS and CMS, historically-limiting PDF uncertainties will anticorrelate in an combination:



- The LHCb Run 2 data would yield a $O(10)$ MeV statistical uncertainty on m_W , but be limited by theory systematics.
- A **proof-of-principle** measurement is presented, with just the 2016 data (1/3 of Run 2).

Analysis strategy & physics modelling

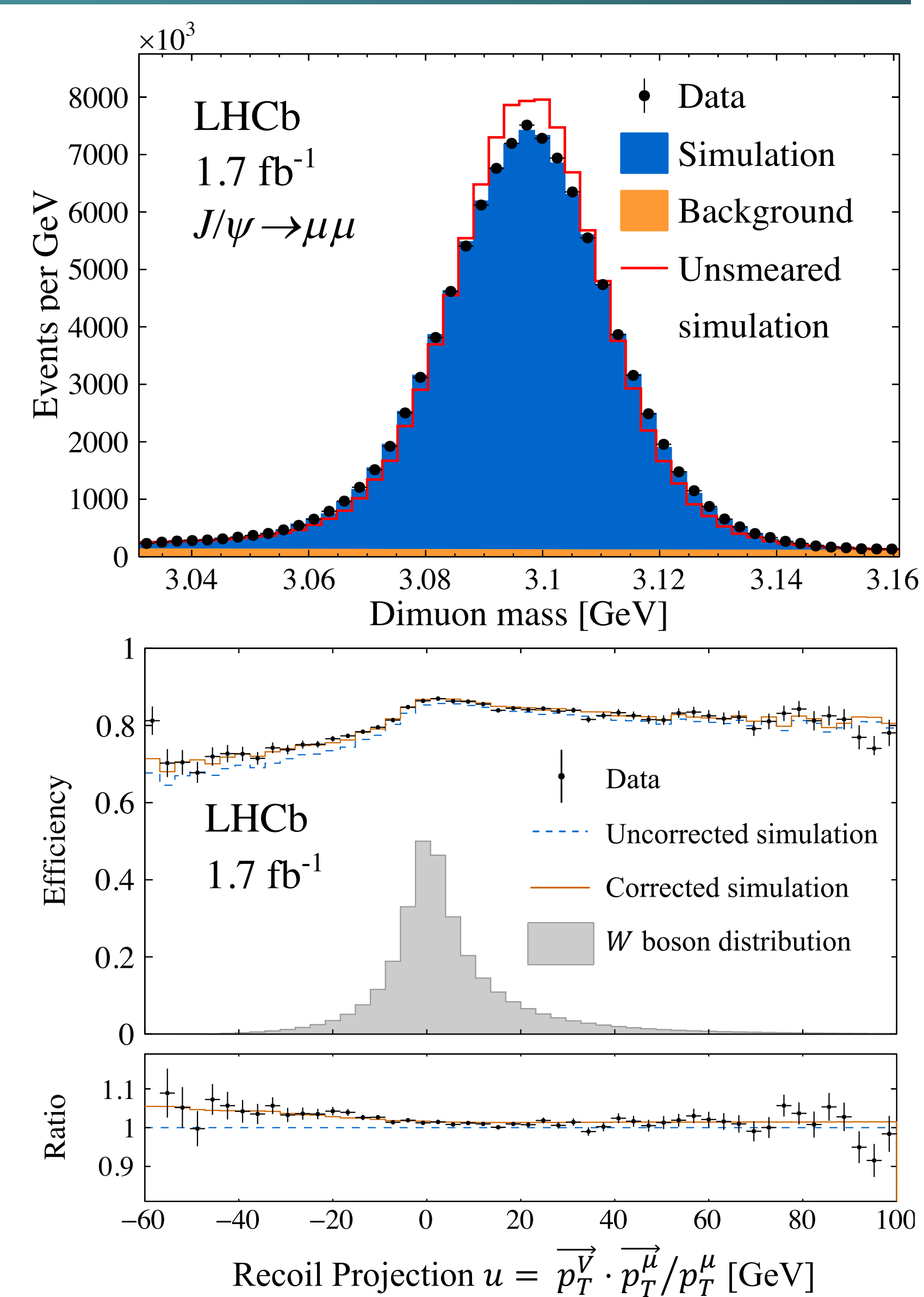
- m_W is extracted in a template fit to the muon q/p_T distribution from $W \rightarrow \mu\nu$ – which peaks at $\sim \pm 2/m_W$ – and the ϕ^* distribution from $Z \rightarrow \mu\mu$.
- W boson production is simulated using POWHEG+Pythia [2, 3] (NLO) and DYTurbo [4] ($O(\alpha_S^2)$):

$$\frac{d\sigma}{dp_T^V dy dM d\cos\theta d\phi} \propto \underbrace{\frac{d\sigma^{\text{unpol}}}{dp_T^V dy dM}}_{\text{Unpolarised cross-section (POWHEG+Pythia)}} \times \underbrace{f(\theta, \phi, A_i)}_{\text{Angular terms (} A_i = \text{angular coefficients, DYTurbo)}}$$

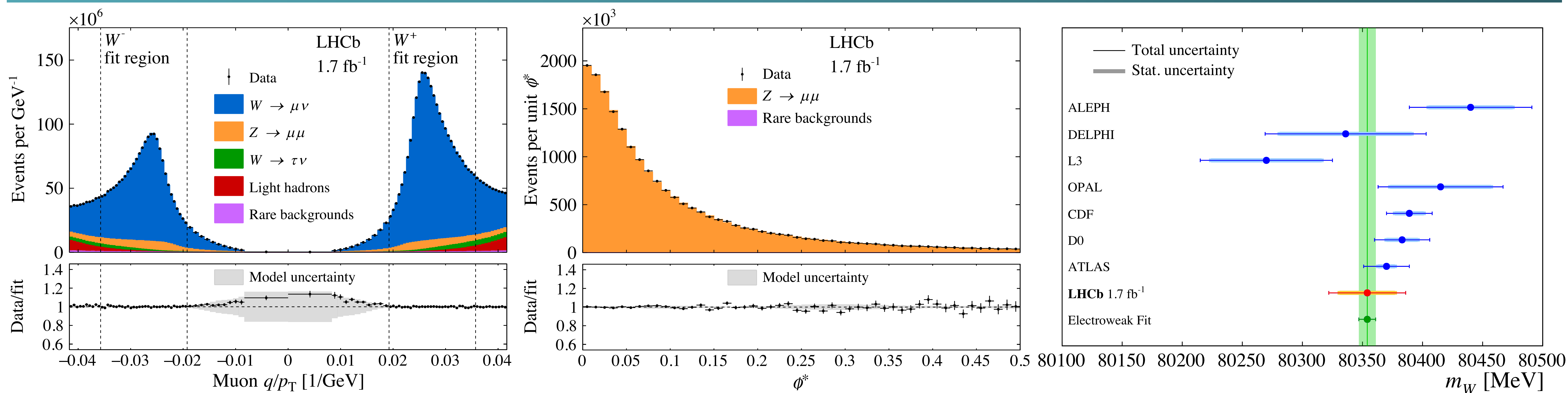
- Nuisance parameters α_S , k_T^{intr} and an A_3 scale factor are also floated to absorb uncertainties in the boson production model.
- Fit model is validated by fitting pseudodata generated with other combinations of event generators.

Detector modelling & backgrounds

- Custom offline alignment using the pseudomass method [5] is applied, then simulation is smeared based on fits to the J/ψ , $\Upsilon(1S)$ and Z peaks.
- Muon reconstruction and isolation efficiencies are corrected with tag-and-probe methods.
- EW backgrounds are fully simulated & constrained. Residual QCD background is modelled with a parametric shape, trained on a hadron-enriched data sample.



The fitted m_W result



- The arithmetic average of results using NNPDF31 [6], CT18 [7] and MSHT20 [8] PDF sets is

$$m_W = 80354 \pm 23_{\text{stat}} \pm 10_{\text{exp}} \pm 17_{\text{theory}} \pm 9_{\text{PDF}} \text{ MeV},$$

with a total uncertainty of 32 MeV.

- The leading systematics are: p_T^W model (11 MeV), A_i (10 MeV), PDFs and momentum scale & resolution (7 MeV).
- Approx. 20 MeV total uncertainty is targeted using the full Run 2 dataset.
- Working on reducing the dominating systematic uncertainties!

References

[1]: ATLAS Collaboration, [EPJC 78, 110 \(2018\)](#)
 [2]: L. Barze et al., [EPJC 73, 2474 \(2013\)](#)
 [3]: T. Sjöstrand et al., [Comp. Phys. Comms 191, 159 \(2015\)](#)
 [4]: S. Camarda et al., [EPJC 80, 251 \(2020\)](#)

[5]: W. Barter, M. Pili and M. Vesterinen, [EPJC 81, 251 \(2021\)](#)
 [6]: NNPDF Collaboration, [EPJC 77, 663 \(2017\)](#)
 [7]: T.-J. Hou et al., [PRD 103, 014013 \(2021\)](#)
 [8]: S. Bailey et al., [EPJC 81, 341 \(2021\)](#)