Measurement of the W boson mass at LHCb

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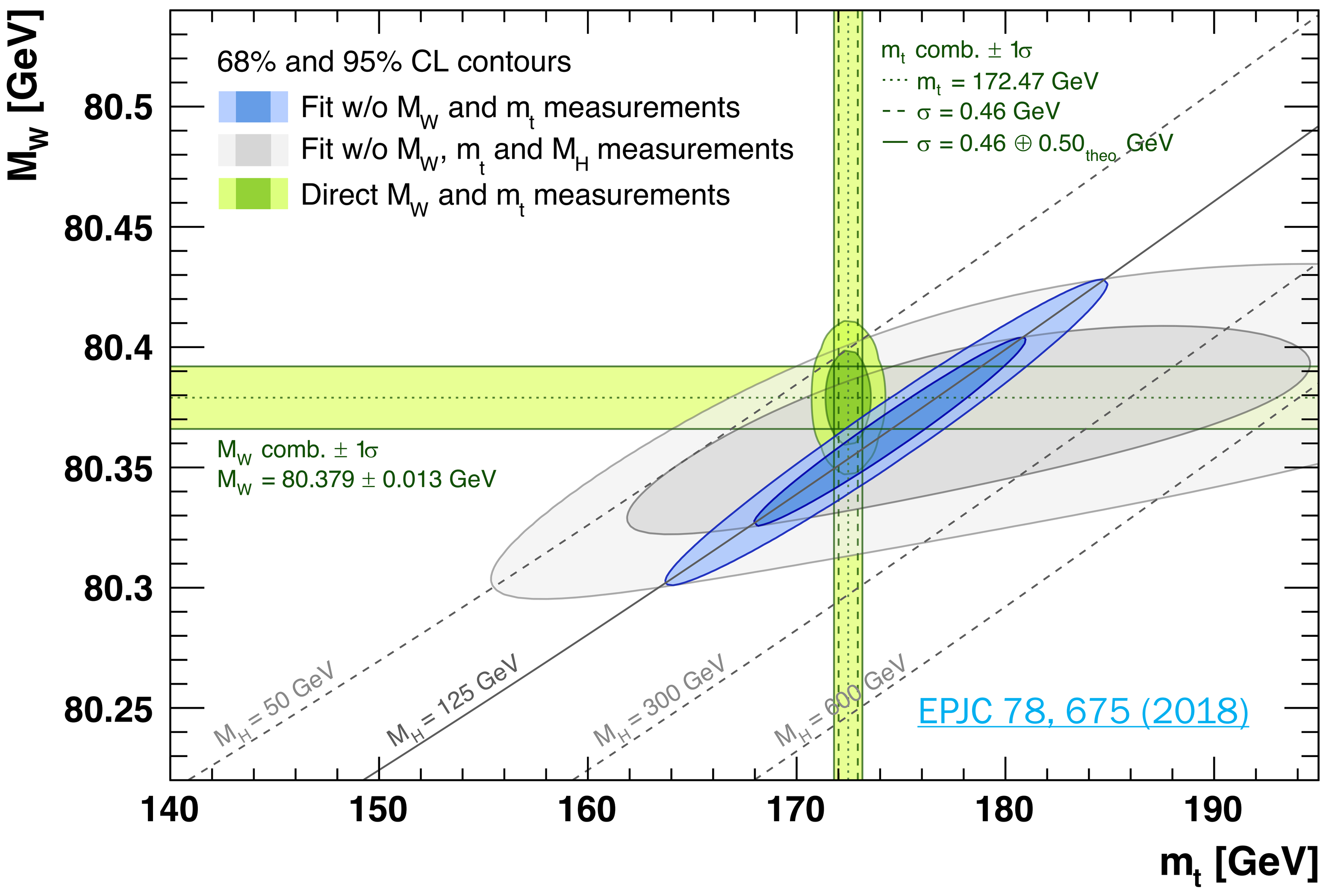
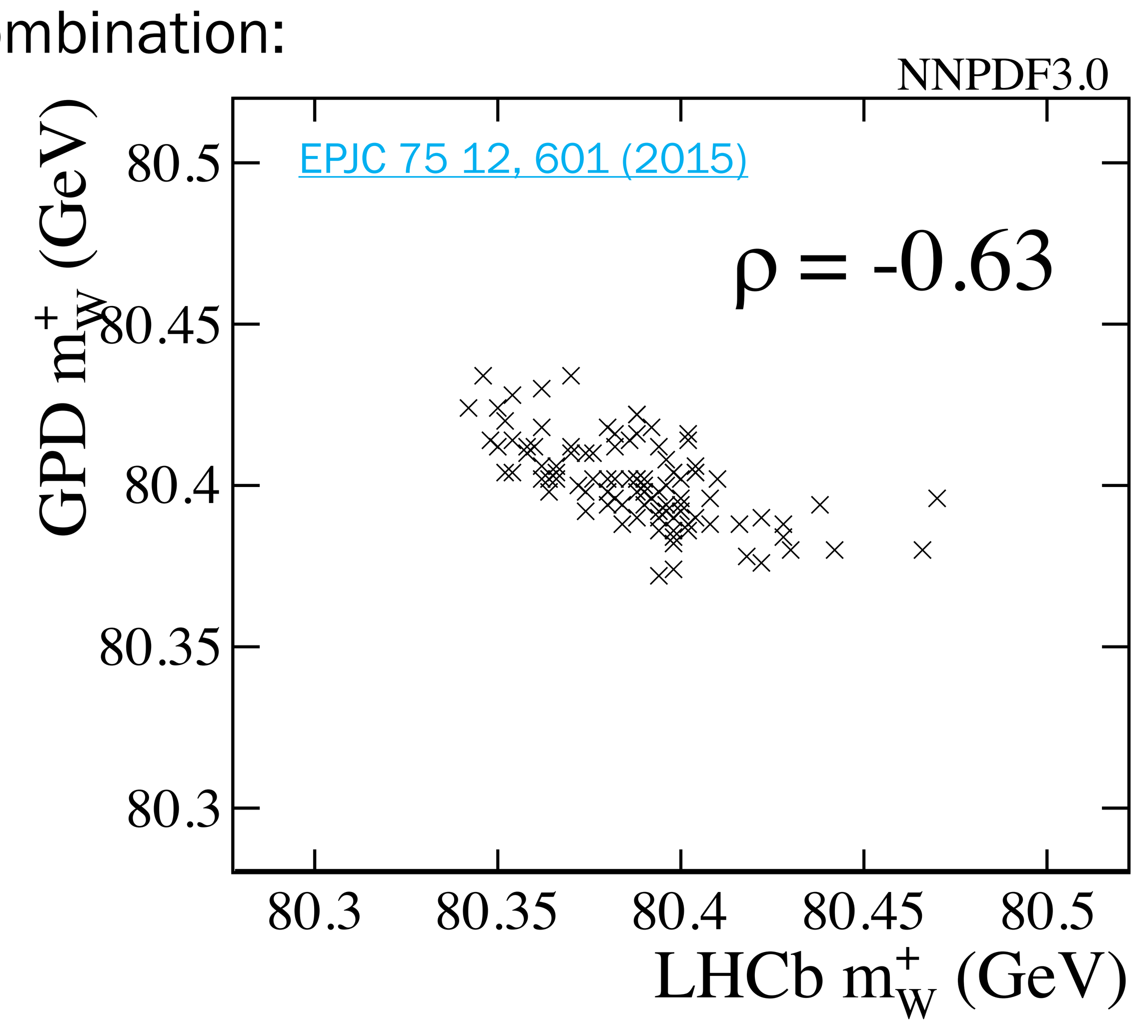
Why should LHCb measure m_W?

- 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:

Δm_W (EW fit) = 7 MeV, Δm_W (ATLAS '18 [1]) = 19 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

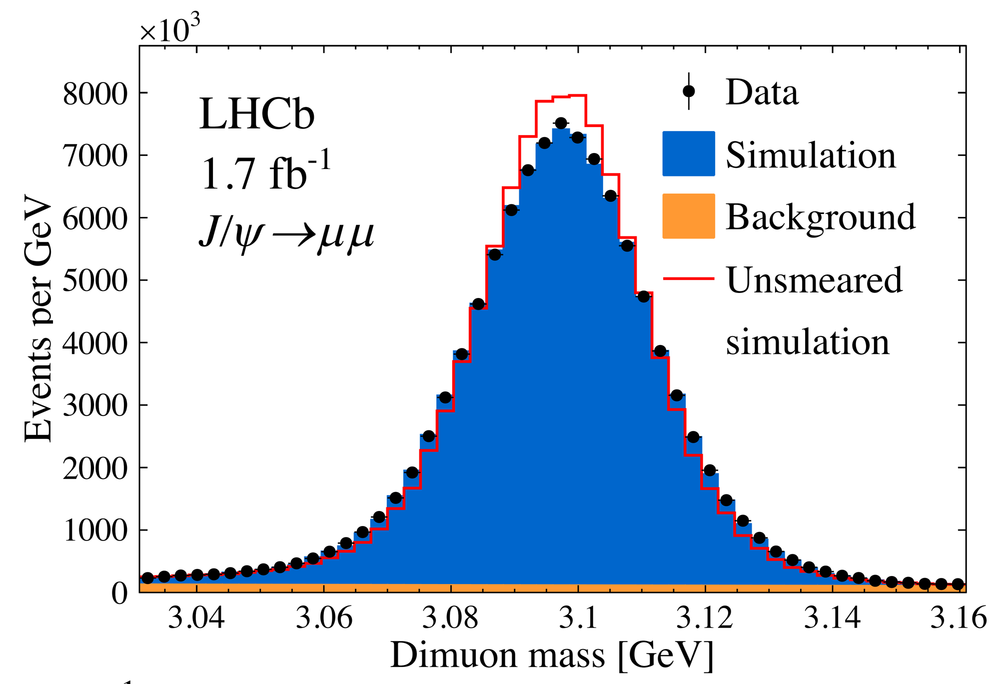
- m_W is extracted in a template fit to the muon q/p_T distribution from $W \to \mu\nu$ -- which peaks at $\sim \pm 2/m_W$ -- and the ϕ^* distribution from $Z \to \mu\mu$.
- W boson production is simulated using POWHEG+Pythia [2, 3] (NLO) and DYTurbo [4] (O(α_S^2)):

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

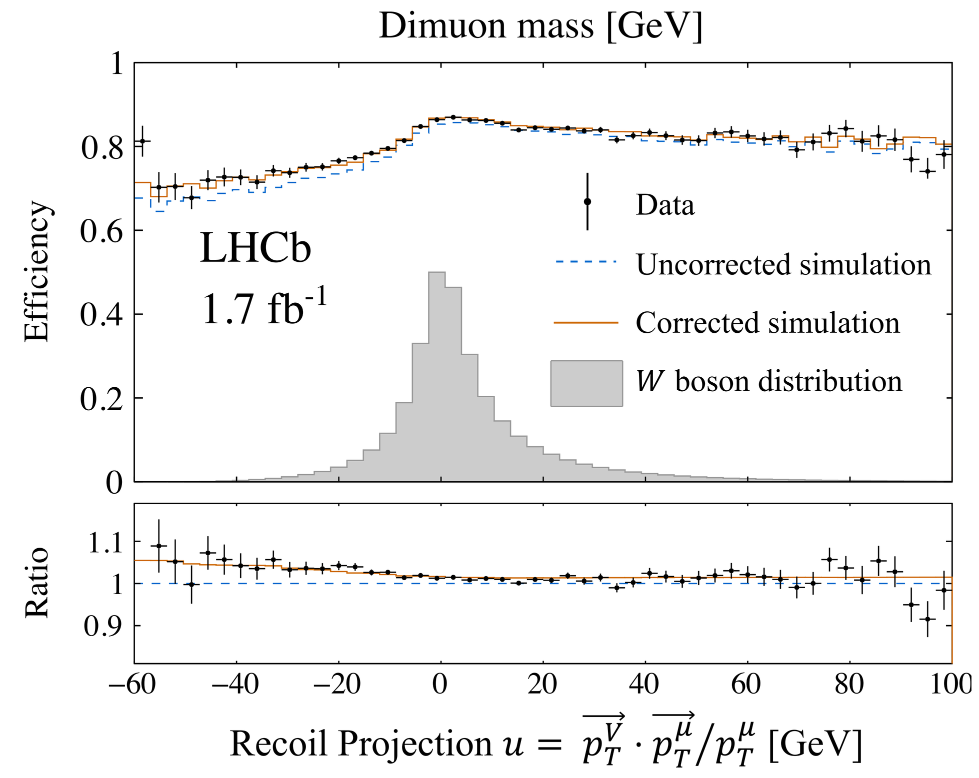
- Nuisance parameters α_S, k_T^{intr} and an A_3 scale factor are also floated to absorb uncertainties in the boson production model.
- Fit model is validated by fitting *pseudodata* generated with other combinations of event generators.

Detector modelling & backgrounds

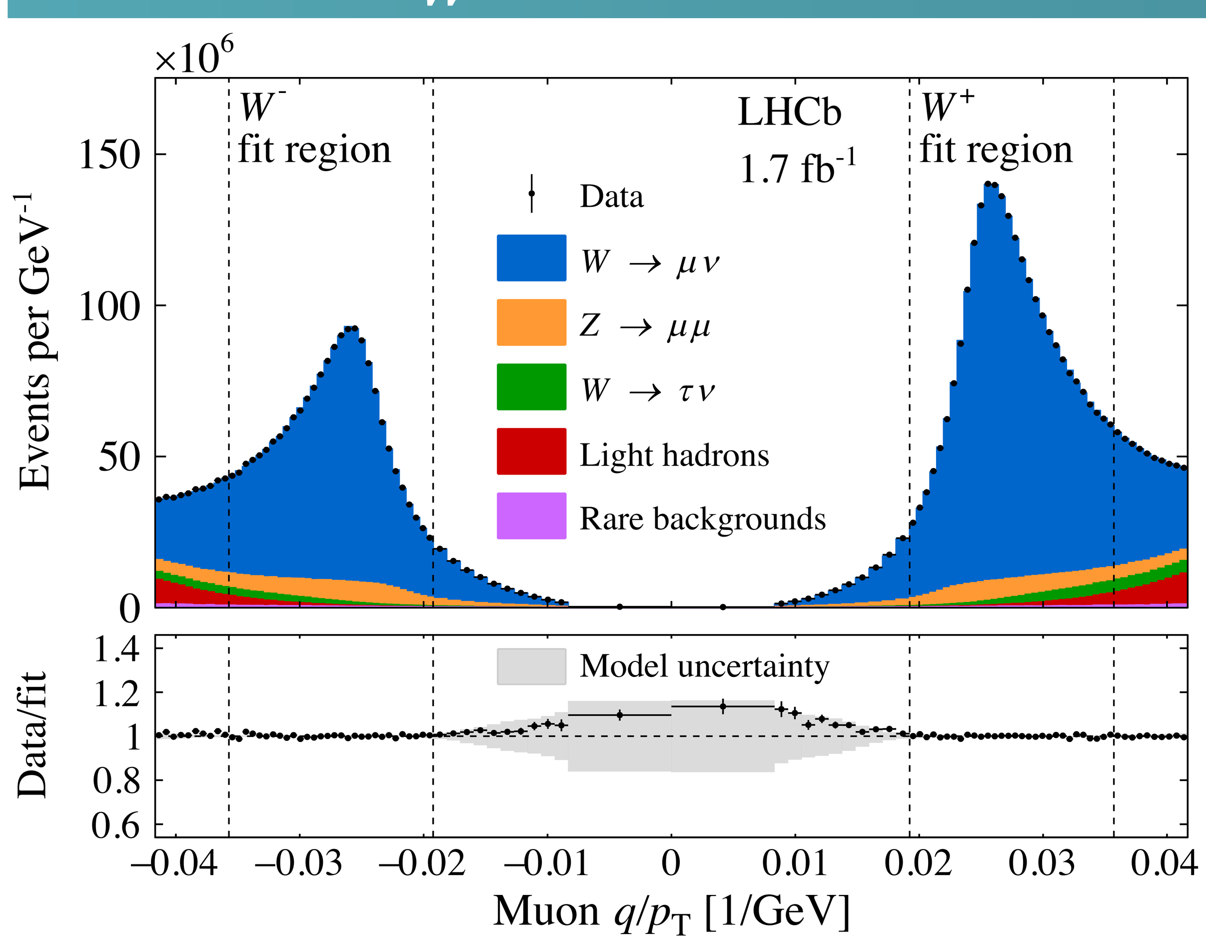
- Custom offline alignment using the pseudomass method [5] is applied, then simulation is smeared based on fits to the J/ψ, $\Upsilon(1S)$ and Z peaks.

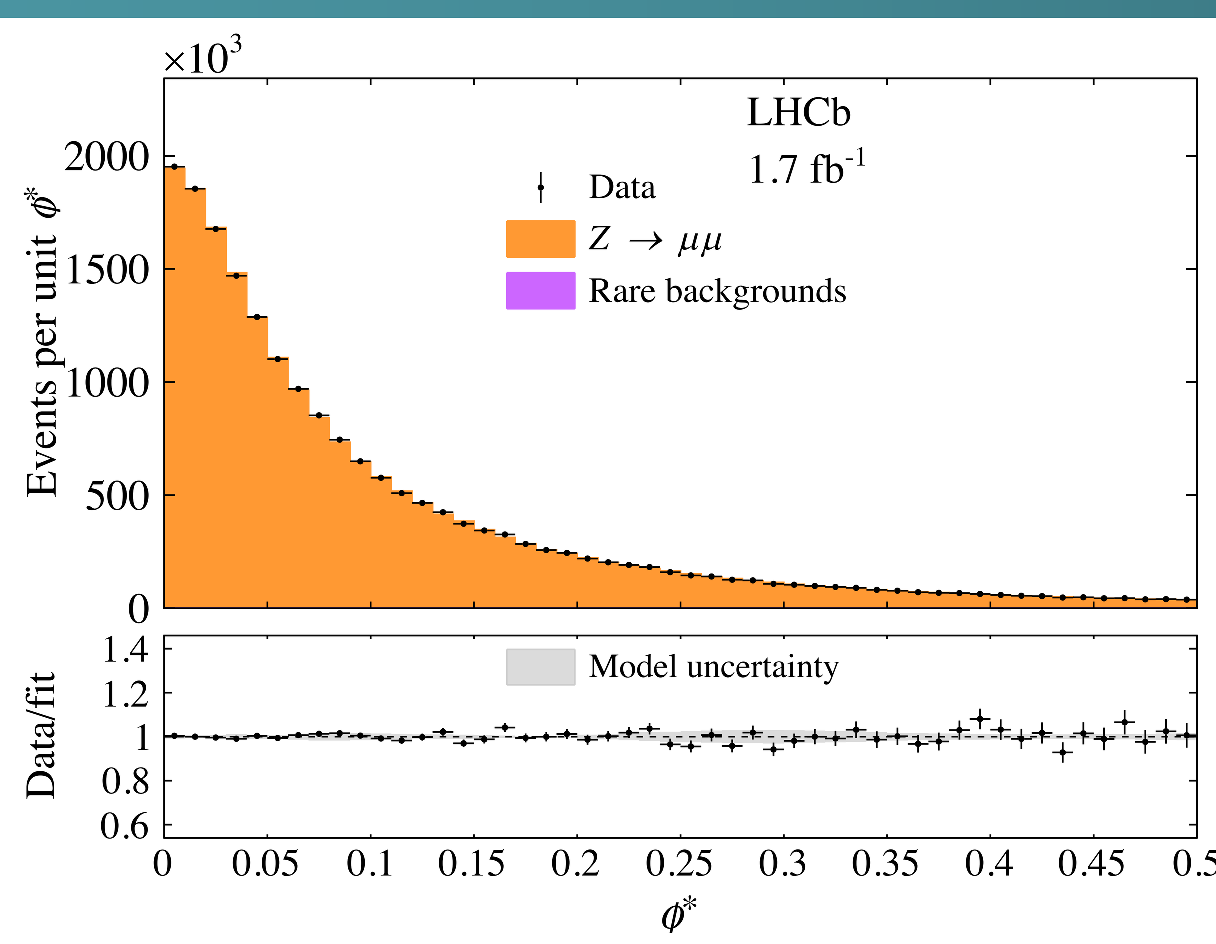


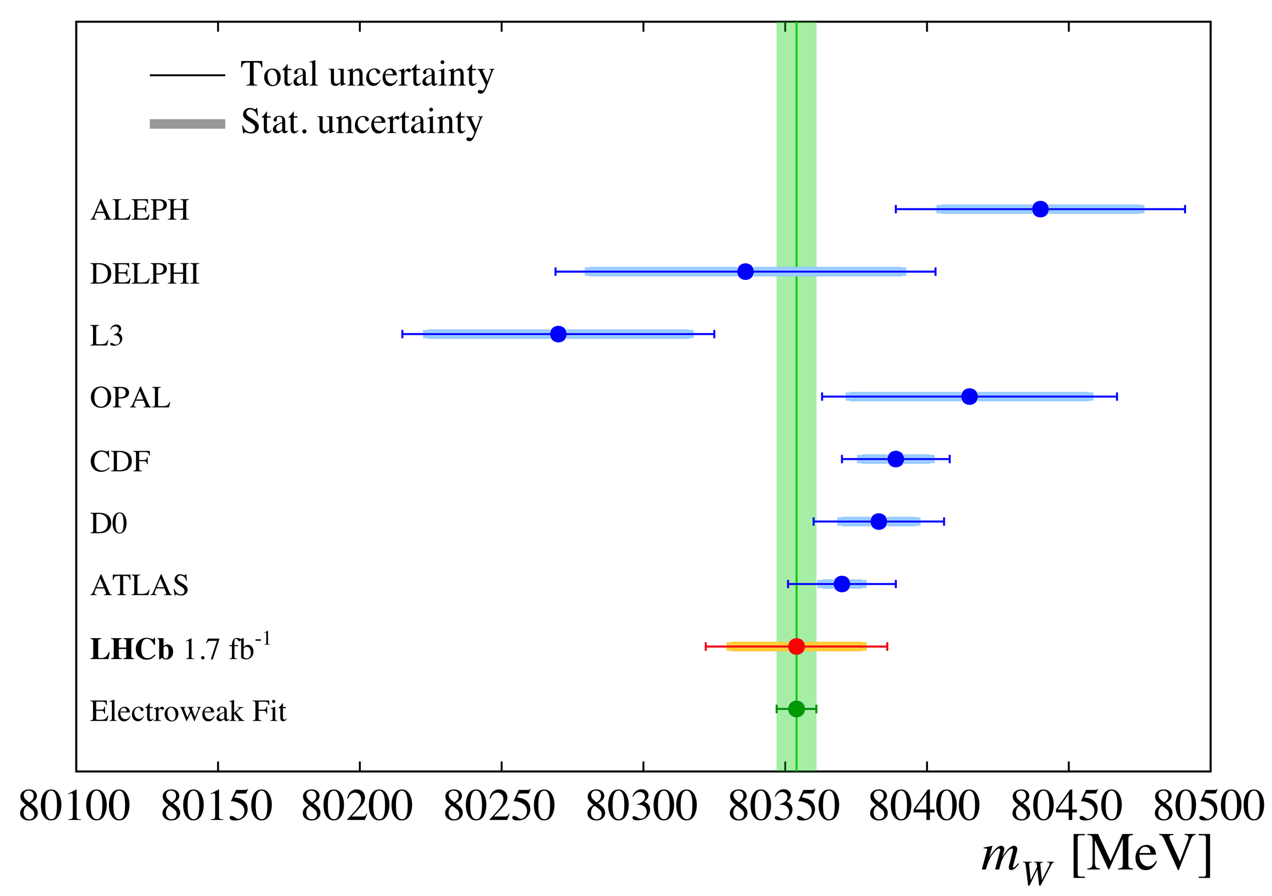
- Muon reconstruction and isolation efficiencies are corrected with tag-and-probe methods.
- EW backgrounds are fully simulated & constrained. Residual QCD background is modelled with a parametric shape, trained on a hadron-enriched data sample.



The fitted m_W result







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

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

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!

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References

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[4]: S. Camarda *et al.*, EPJC 80, 251 (2020)
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[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)

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