LCHP Poster Session – Belgrad, May 2023

Improved W boson Mass Measurement using 7 TeV Proton-Proton Collisions with the ATLAS Detector

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Motivation to measure the m_W

- W boson charged mediator of the weak force
- Discovery in 1983 by SppS at CERN
- Many measurements of the W boson properties since then
- Value of m_W can be used to test the consistency of the Standard Model
- Completely determined by other SM parameters

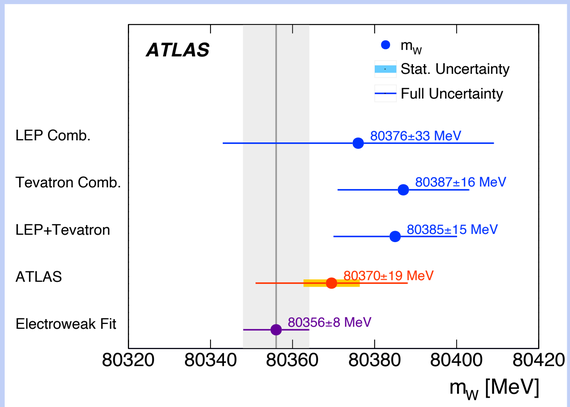
fine-structure constant

Δr radiative corrections

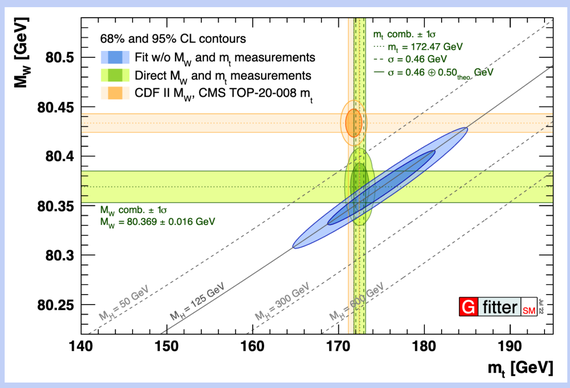
$$m_W = \left(\frac{\pi\alpha_{\text{em}}}{\sqrt{2}G_{\text{F}}}\right)^{\frac{1}{2}} \frac{\sqrt{1+\Delta r}}{\sin\theta_{\text{W}}}$$

Fermi constant

Weinberg angle

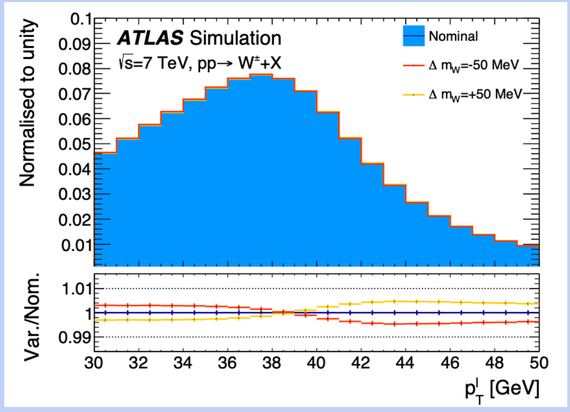


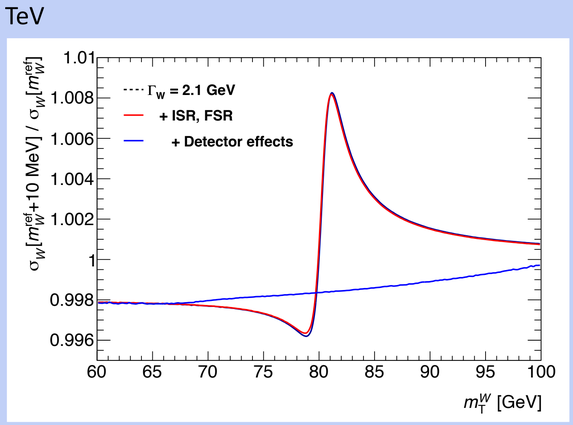
Measurement status from 2017

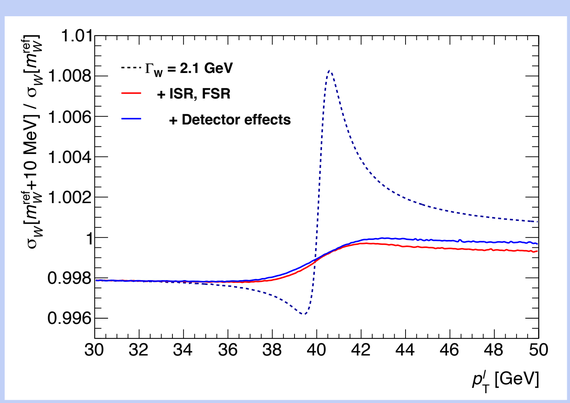


Measurement and analysis overview

- Consider leptonic decays of W boson
- MC templates for varied m_W hypotheses in kinematic observables (p_{T}^{l} and m_{T}^{W})
- 14 different measurement categories per kinematic observable (lepton flavour, pseudorapidity, charge)
- Signal selection and calibrations unchanged w.r.t. 2017 analysis
- New verification: Pythia AZ tune describes hadronic recoil spectrum of W bosons in low pile-up data at 5 TeV

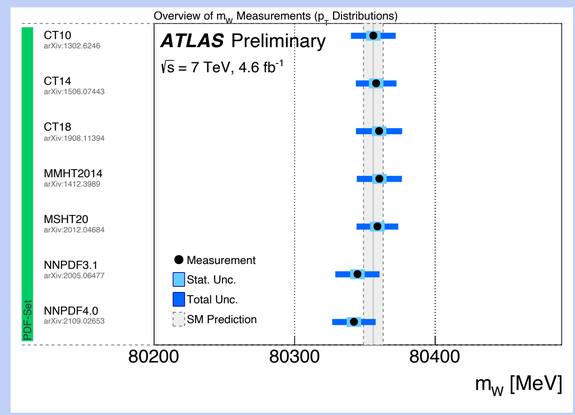






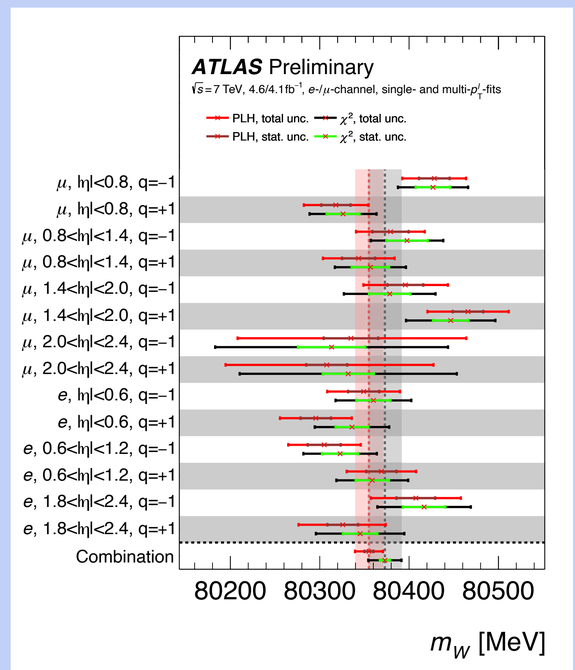
Improvements

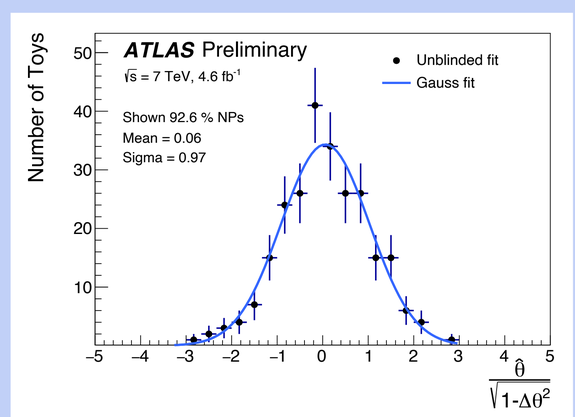
- Multijet Background Estimation
  - Correct luminosity value for determination of MJ bkg contamination in SR
  - New transfer functions to calculate shape from CR to SR
  - Systematic shape variations
  - Reduction of unc. by 2 MeV
- Electroweak unc. evaluated at detector level
  - Increase of unc. by 1-2 MeV
- Recovering data in electron channel
  - Increase statistics by 1.5%
- Improved random generator setup of electron energy calibration
  - Negligible effect on mass
- Overall shift of +2 MeV in p_{T} and + 6 MeV in m_{T}
  - Driven by MJ background improvements
- Added width as NP
- More PDF Sets studied
  - CT10, CT14, CT18, MMHT2014, MSHT20, NNPD3.1, NNPDF4.0
  - CT18 new baseline



Statistical methods

- Transition from χ^2 fit to profile likelihood fit
  - Allows to profile systematics
  - Include systematics into global optimisation
- Transformed toy systematics into original pattern space with principal component analysis
- Used 12 templates around nominal MC mass (80399 MeV) with linear vertical interpolation
- Reproduce legacy results
  - Use CT10 PDF set
  - Test consistency of PLH fit with χ^2 fit with statistical unc. only
  - Compare two fit methods with systematics
- Consistency tests with CT18 PDF set
  - different fit ranges
  - charge and lepton flavour
- Correlate p_{T} and m_{T} fits
  - Estimate correlation with pseudodata based on toy-variations of all systematics
  - Correlation factor of 0.6
- PLH fit shifts the central value
  - checked with MC toy study
- Pulls of NP behave as expected

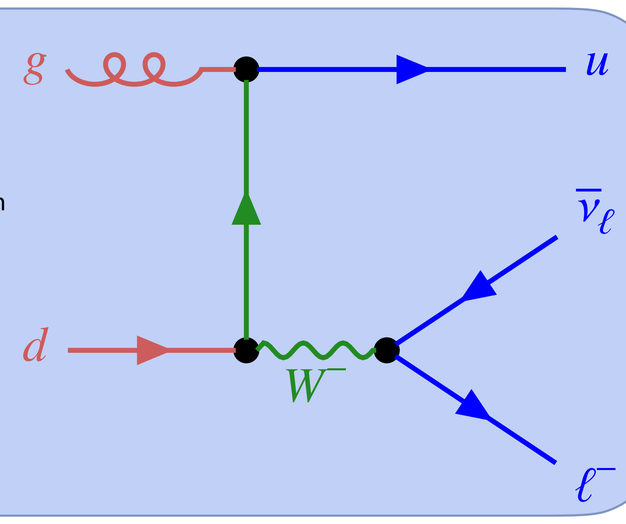




Validation of re-analysis

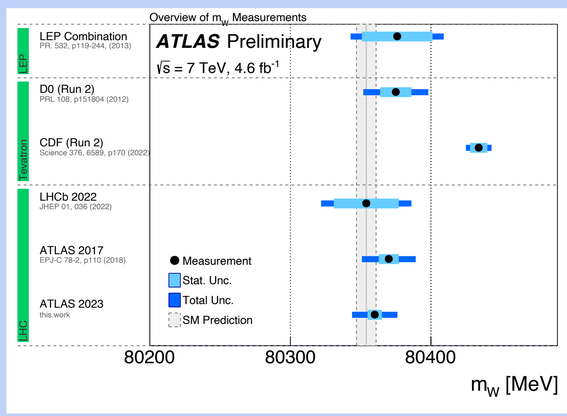
- Perfect/good agreement for cutflows
- Good agreement for shape comparison
- Repeated and updated data-driven MJ background
- Tested correct implementation of calibrations on Z-boson events
- Implemented successfully χ^2 fit
- Re-evaluated all systematic uncertainties
- Updated χ^2 fit combinations

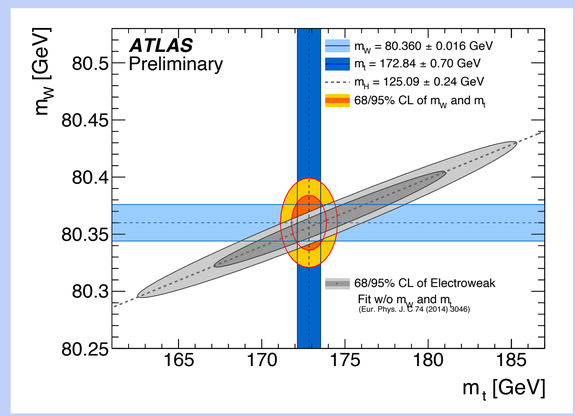
➡Closure for analysis design



Results

- $m_W = 80360 \pm 16$ MeV
- Reduced uncertainty by 15%
- Central value shifted by -10 MeV compared to previous analysis





References

The ATLAS Collaboration, *Improved W boson Mass Measurement using 7 TeV Proton-Proton Collisions with the ATLAS Detector*, ATLAS-CONF-2023-004, http://cds.cern.ch/record/2853290

More information: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/StandardModelPublicResults