Single W/Z boson production cross sections with the CMS detector

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on behalf of the CMS Collaboration

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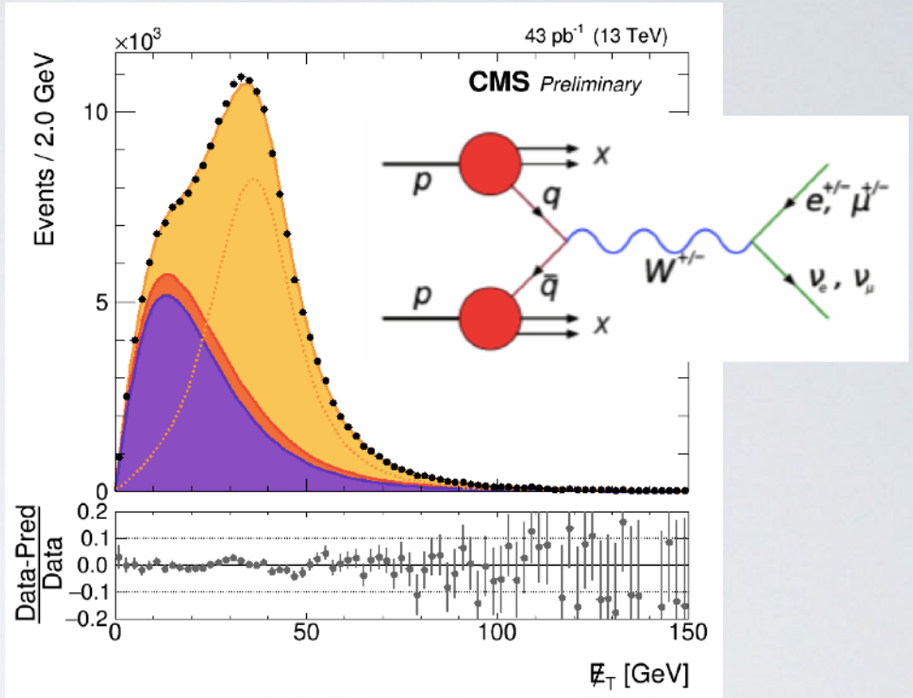
APS Division of Particles and Fields

Introduction: W/Z physics

- **Precision tests of Standard Model**
  - Clean leptonic final states
  - High production cross sections
- Measurements constrain PDF fits



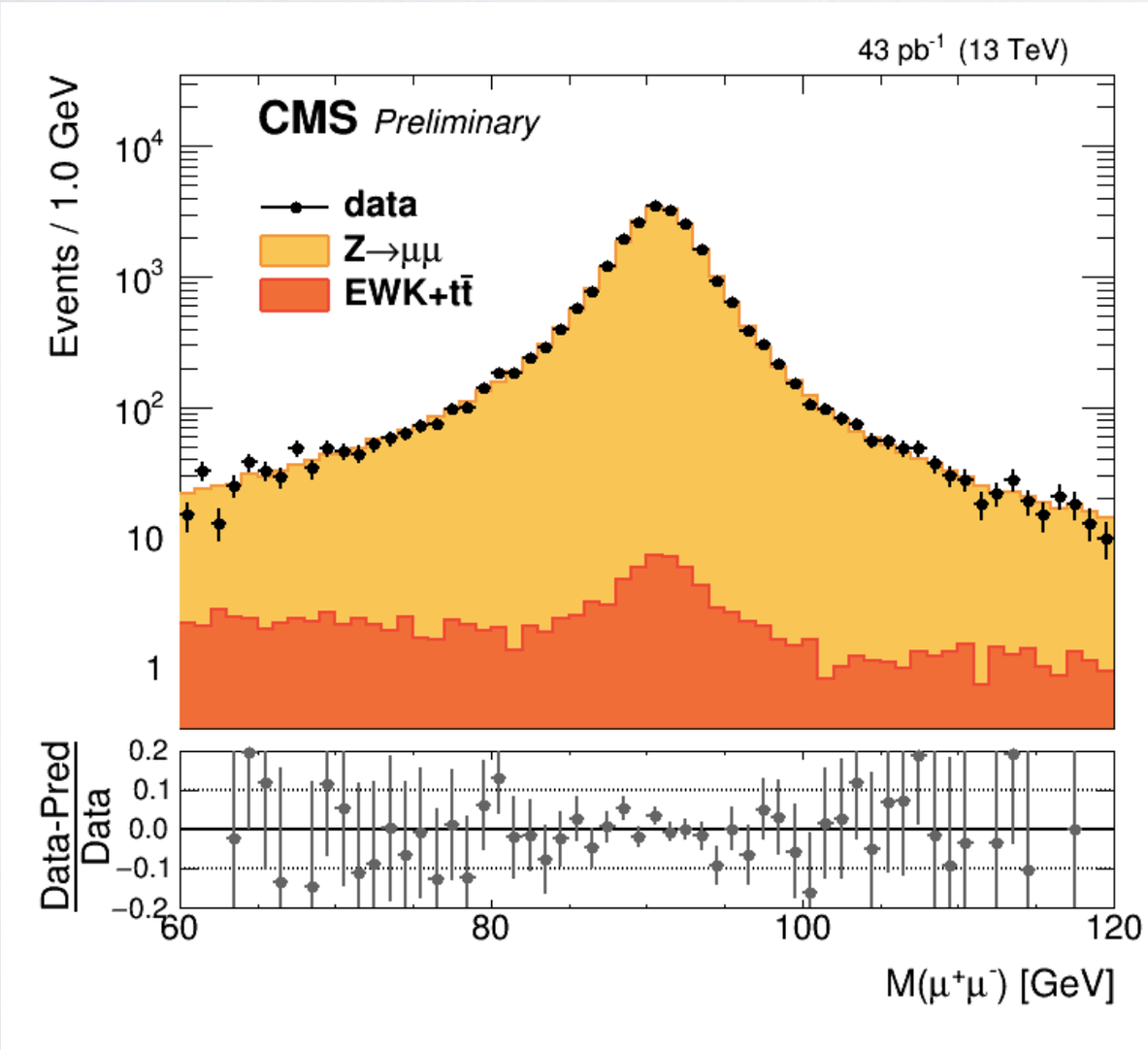
- Today
  - Inclusive W and Z production cross sections at 13 TeV — *CMS-PAS-SMP-15-004*
  - Differential Z cross sections at 13 TeV — *CMS-PAS-SMP-15-011*
  - W and Z transverse momentum spectra at 8 TeV — *JHEP 02 (2017) 096*
  - Differential Drell-Yan cross section at 13 TeV — *CMS-PAS-SMP-16-009*
  - DY forward-backwards asymmetry at 8 TeV — *Eur. Phys. J. C 76 (2016) 325*
  - Charge asymmetry in $W^{\pm}$ events at 8 TeV — *Eur. Phys. J. C 76 (2016) 469*

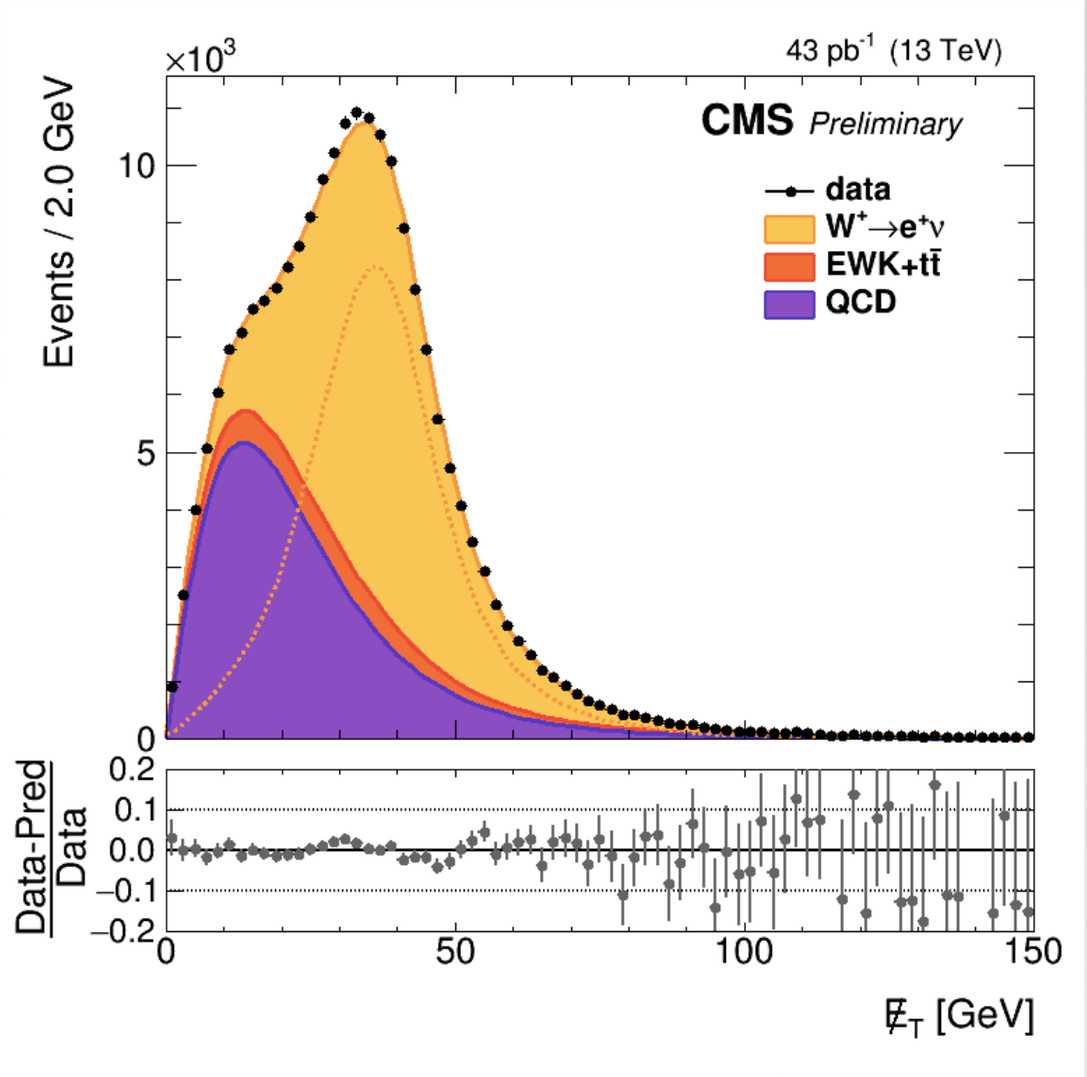
Inclusive W/Z at 13 TeV

CMS-PAS-SMP-15-004

43 pb^{-1} of early 2015 data

- $Z \rightarrow ll$: two energetic, isolated leptons
  - require $60 < m_{ll} < 120$ GeV
  - cut and count (background < 1%)

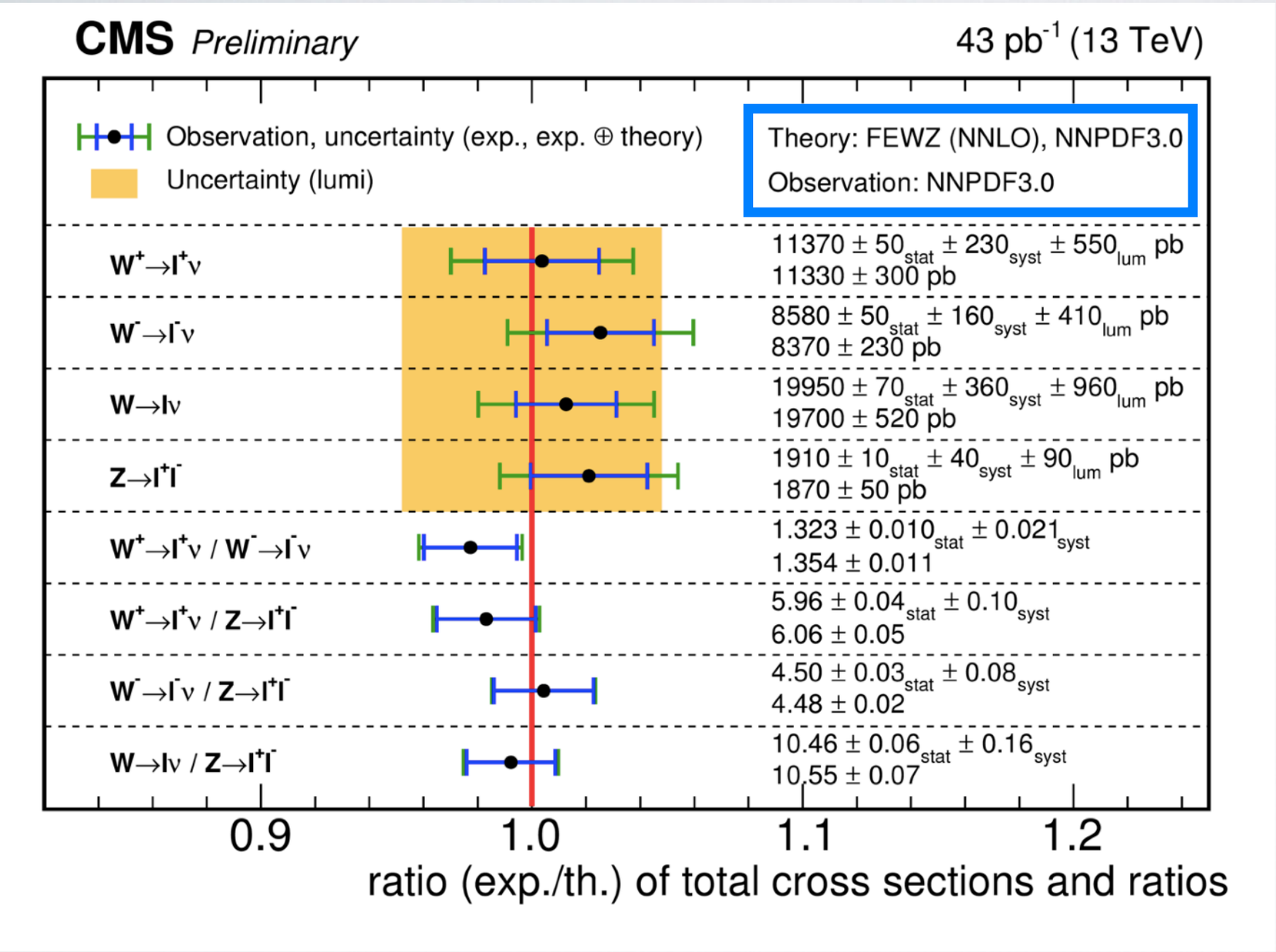




- $W \rightarrow l\nu$: one energetic, isolated lepton
  - fit $\not{E}_T$ distribution with recoil-corrected signal template, QCD, and EWK+$t\bar{t}$ backgrounds

Inclusive W/Z at 13 TeV

CMS-PAS-SMP-15-004



- Compare total (left) and fiducial cross sections with NNLO prediction
- Luminosity and other correlated uncertainties cancel in ratios of cross sections

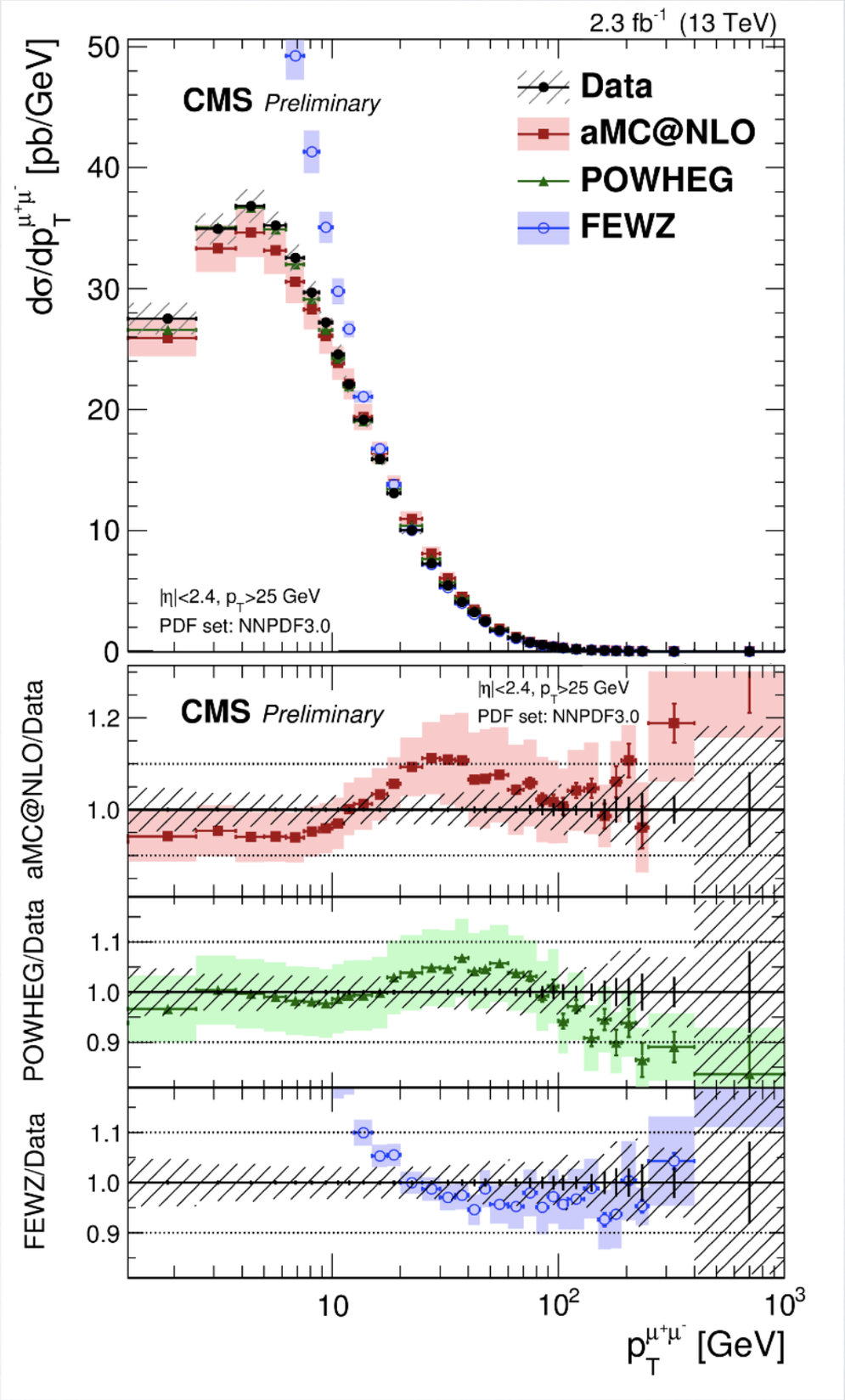
Good agreement between theory and observation

Differential Z at 13 TeV

CMS-PAS-SMP-15-011

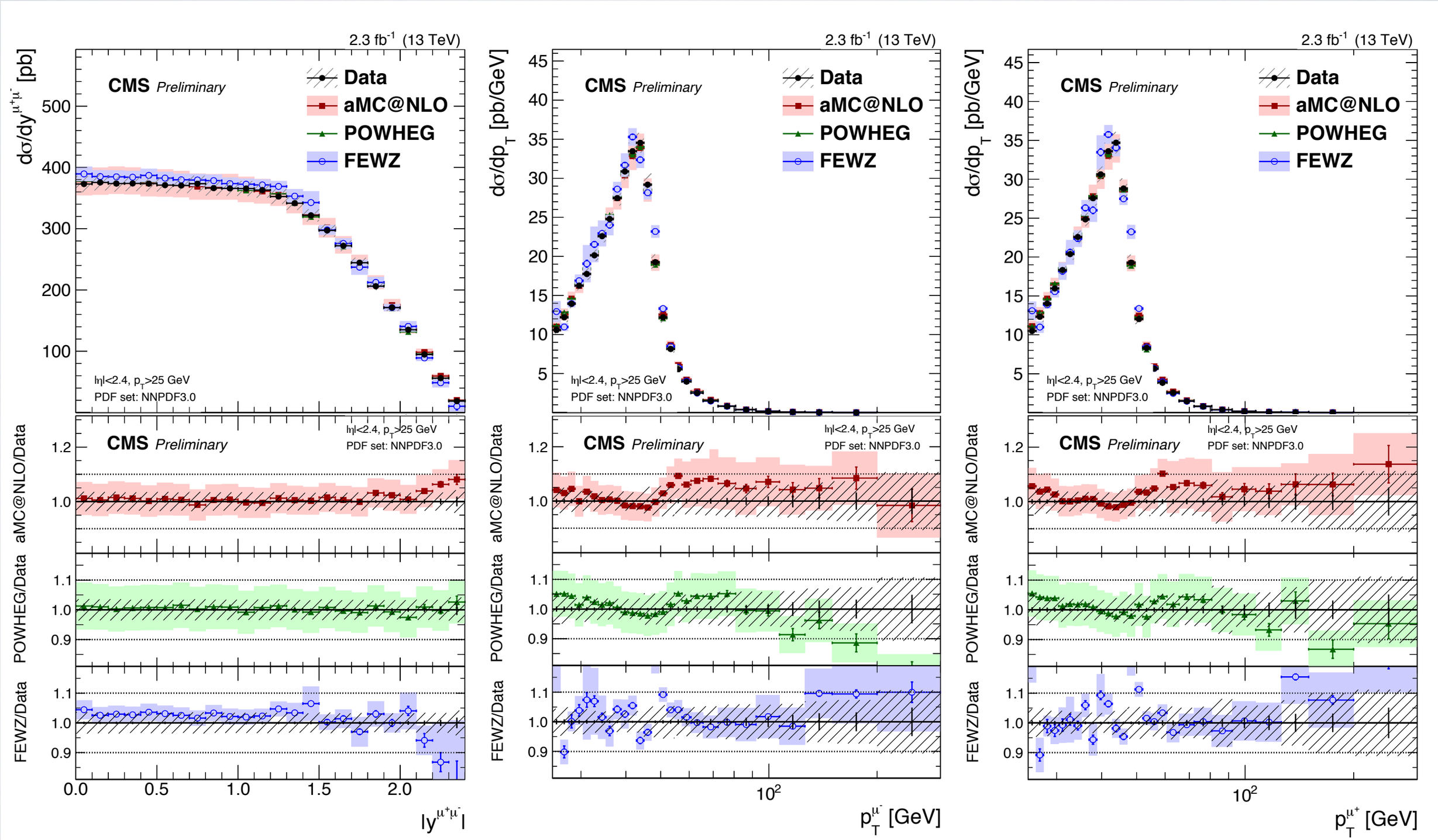
2.3 fb^{-1} of 2015 data

- Muon channel only
- Differential cross sections with boson p_T, $|y|$, ϕ^*, and lepton p_T
- Compare data to
  - **aMC@NLO**
  - **POWHEG**
  - **FEWZ**
- **Generally good agreement**
  - *Resummation effects not included in FEWZ, causes discrepancy at low p_T*



Differential Z at 13 TeV

CMS-PAS-SMP-15-011



Generally good agreement

Differential Z at 13 TeV

CMS-PAS-SMP-15-011

- Also calculate observable

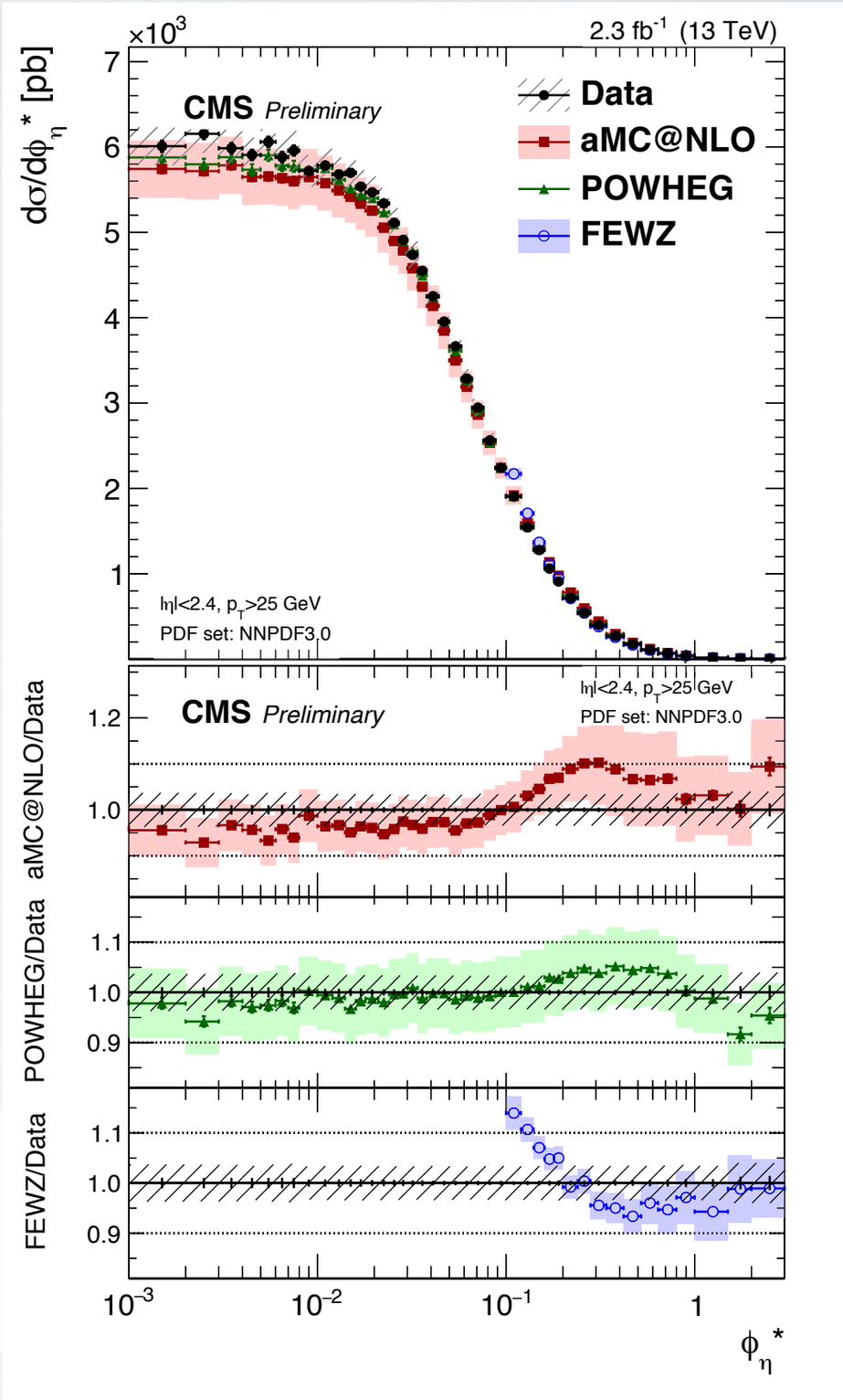
$$\phi^* = \tan\left(\frac{\pi - \Delta\phi}{2}\right)\sin\left(\theta^*_\eta\right)$$

where

$$\cos\left(\theta^*_\eta\right) = \tanh\left(\frac{\eta_- - \eta_+}{2}\right)$$

- Correlated with Z p_T spectrum, but depends only on angular information
  - Smaller uncertainties than p_T measurement

Resummation effects not included in FEWZ

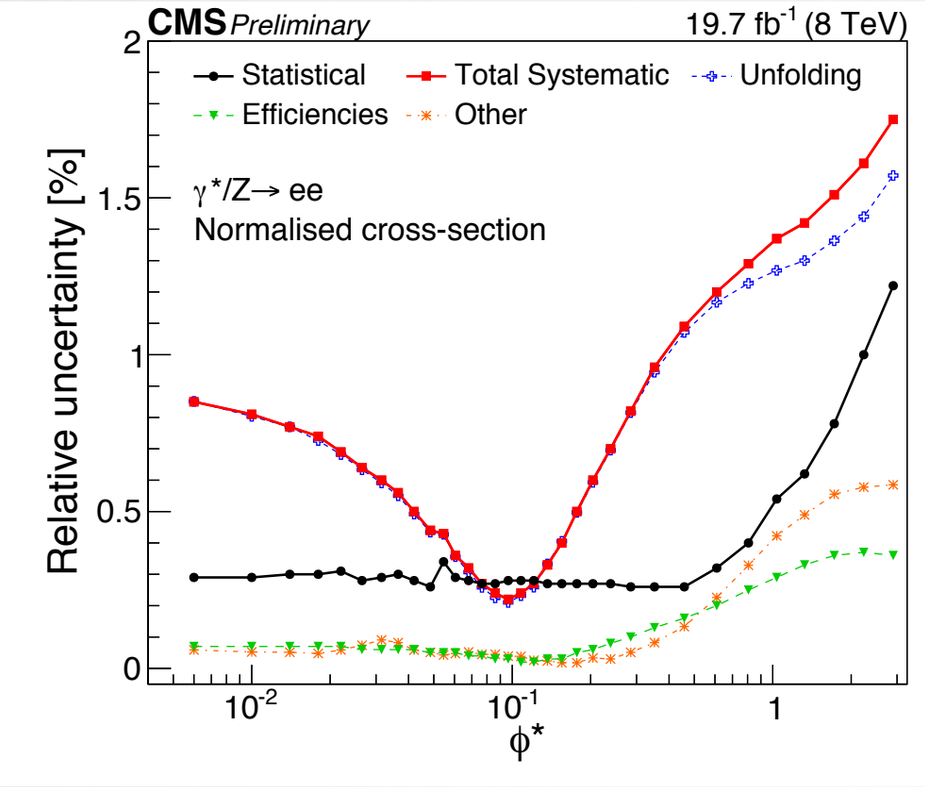


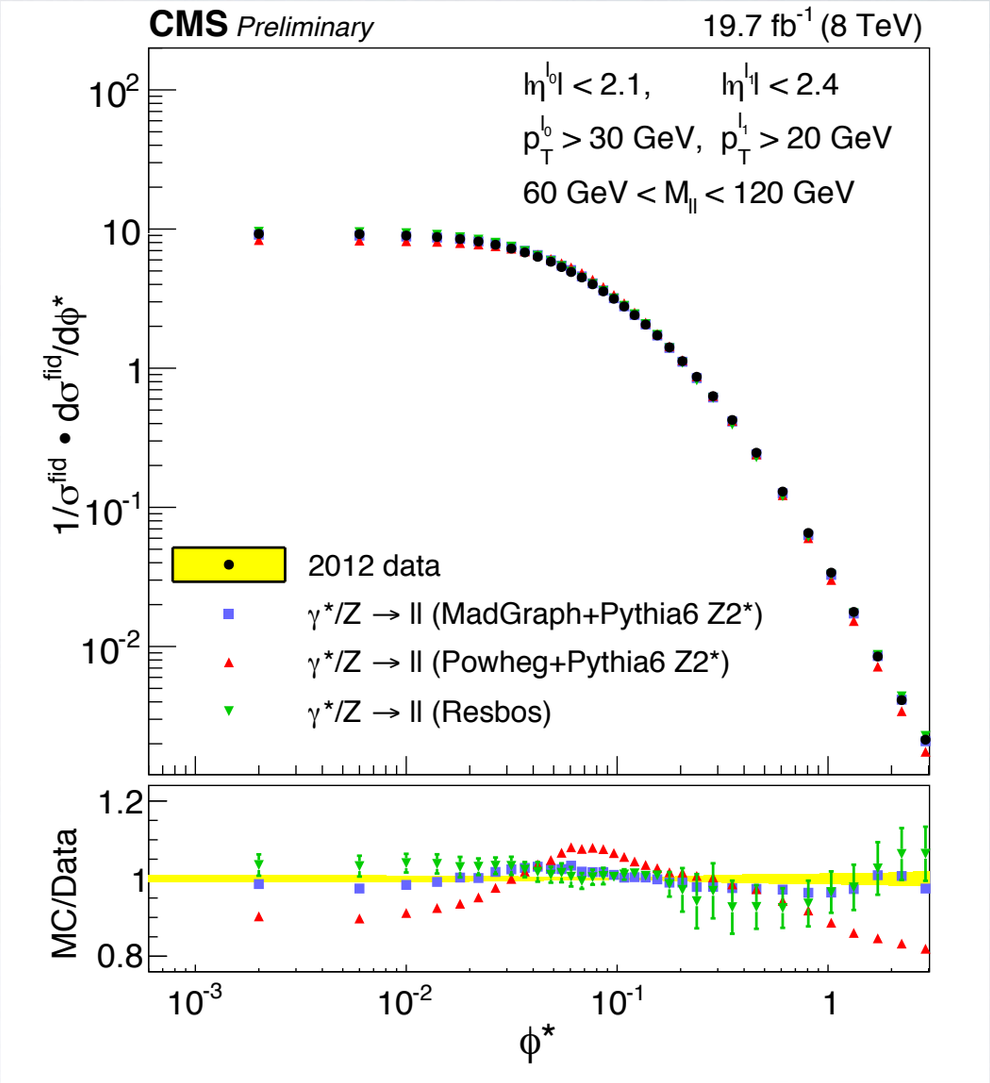
Drell-Yan ϕ^* spectrum

CMS-PAS-SMP-15-002

19.7 fb^{-1} of 8 TeV data

- Measure ϕ^* spectrum normalized to total fiducial cross section
  - **Very low uncertainties, limited by unfolding systematic**





- Compare to MadGraph, POWHEG, and ResBos

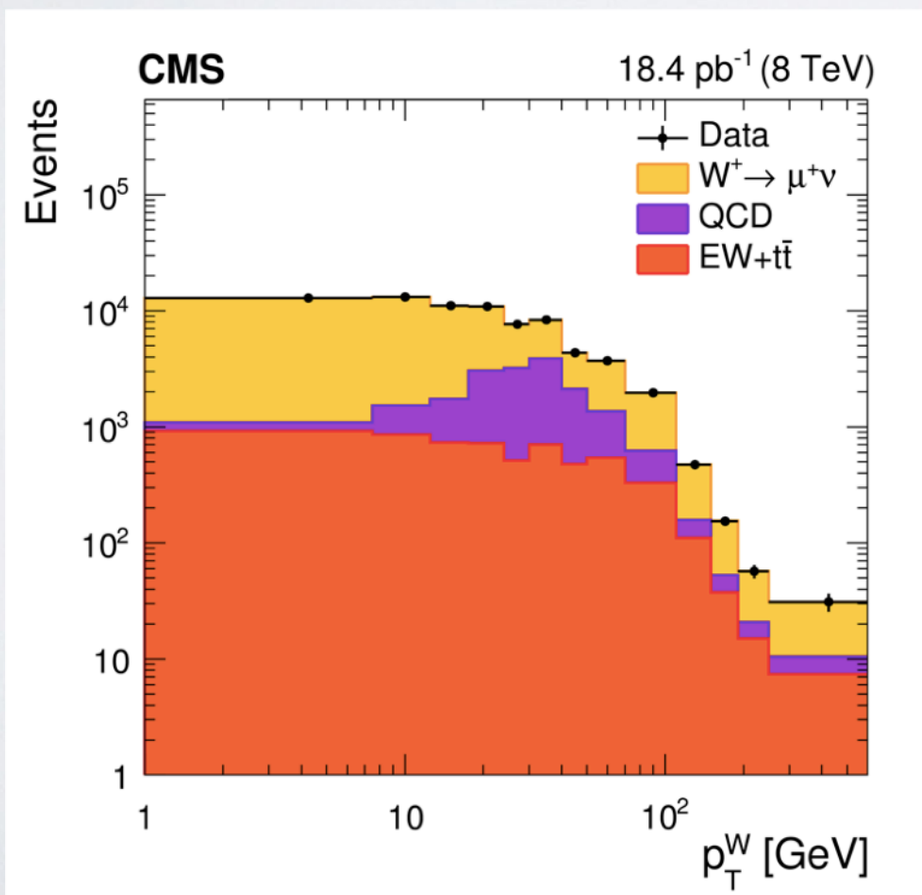
No single tool describes entire spectrum well

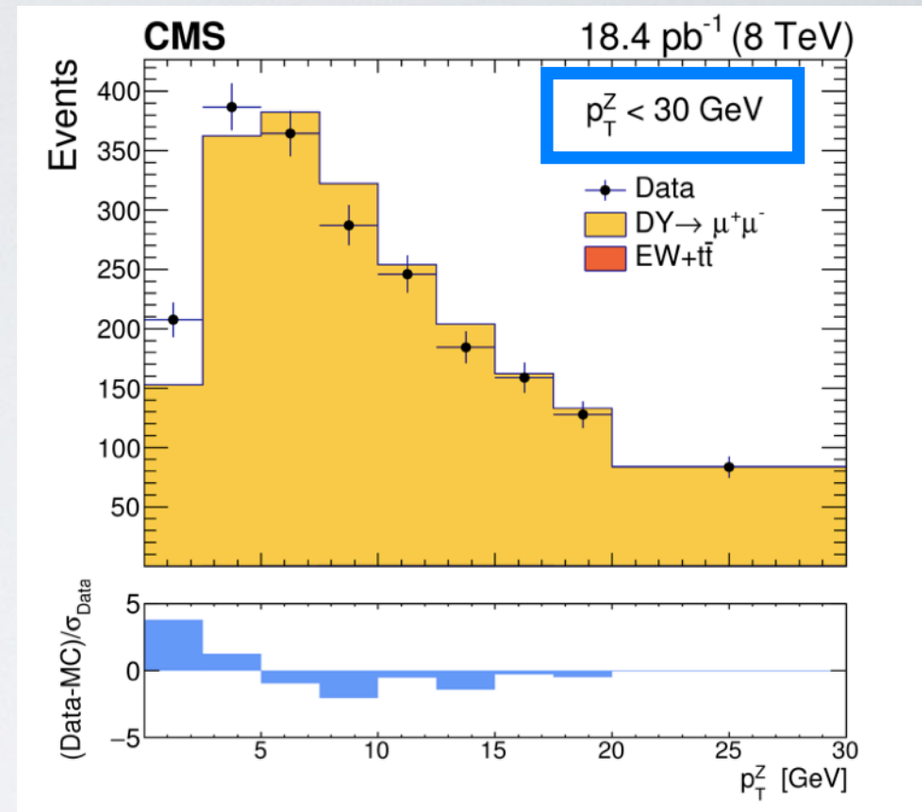
Diff. W/Z p_T at 8 TeV

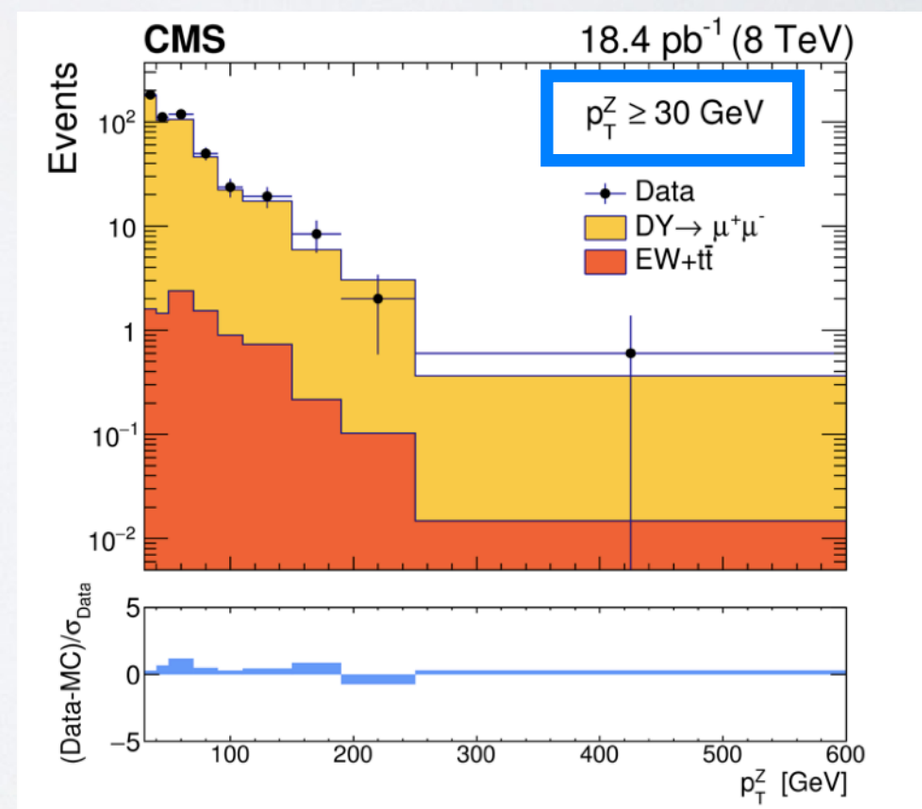
JHEP 02 (2017) 096

18.4 pb^{-1} at 8 TeV

- Low pileup data for optimal $\not{E}_T$ resolution
- Extract signal yield in each p_T bin
  - For W, simultaneous fit to signal and QCD control region







Diff. W/Z p_T at 8 TeV

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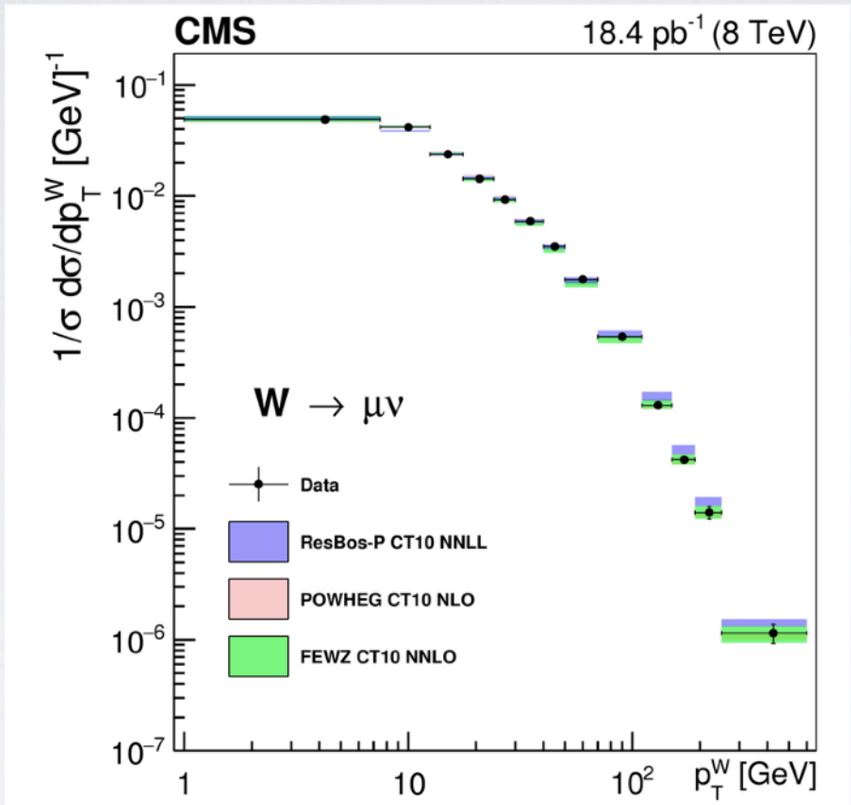
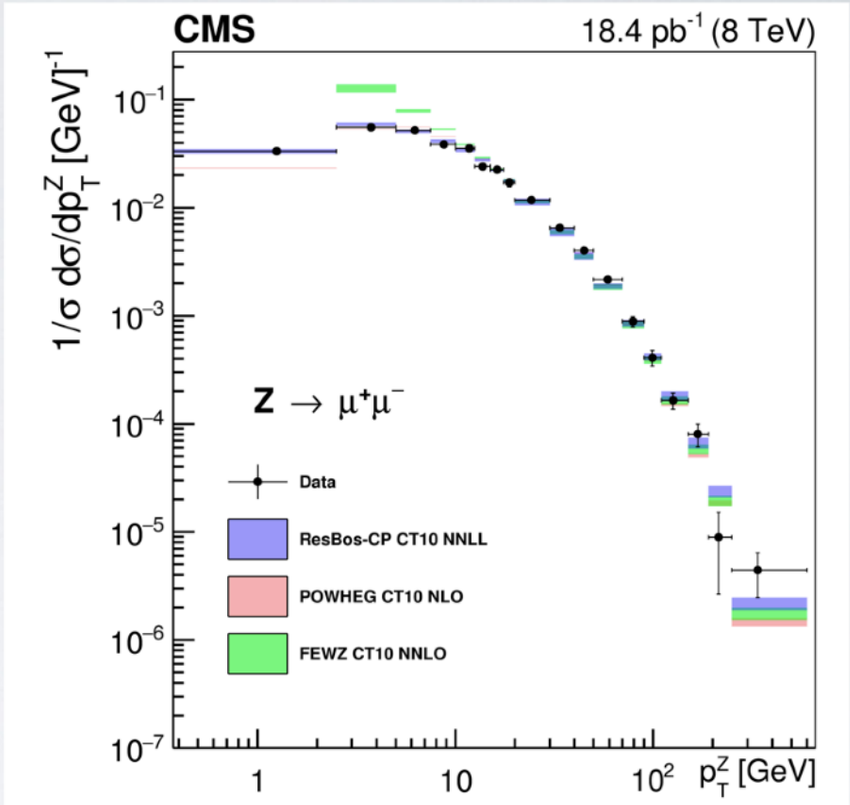
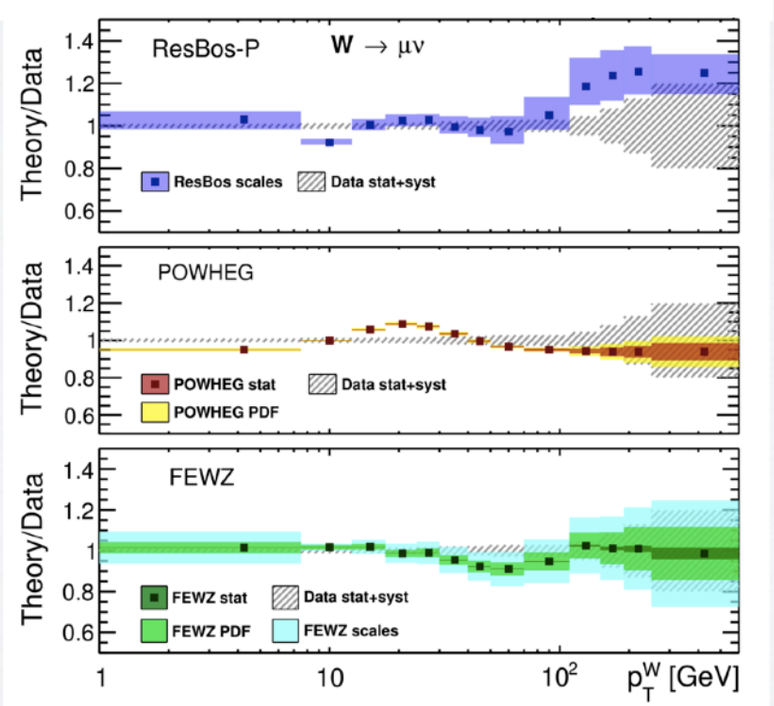
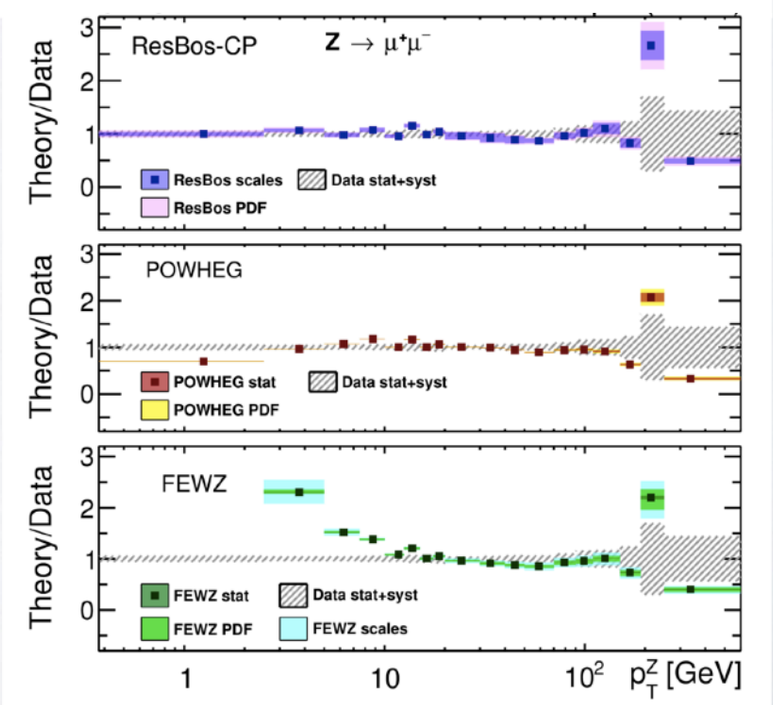
- Compare data with **ResBos**, **POWHEG**, and **FEWZ**

- **Reasonable agreement**





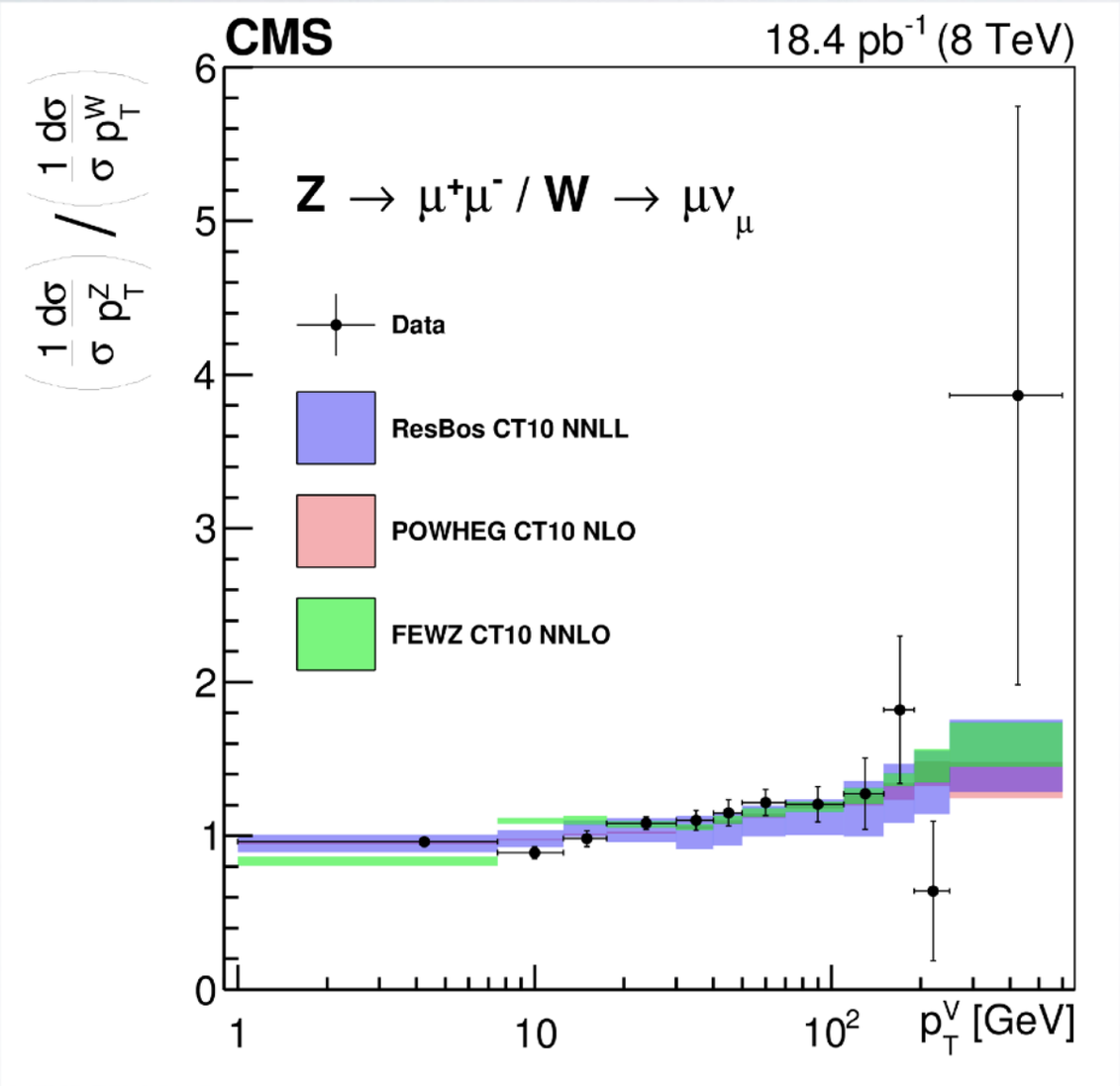


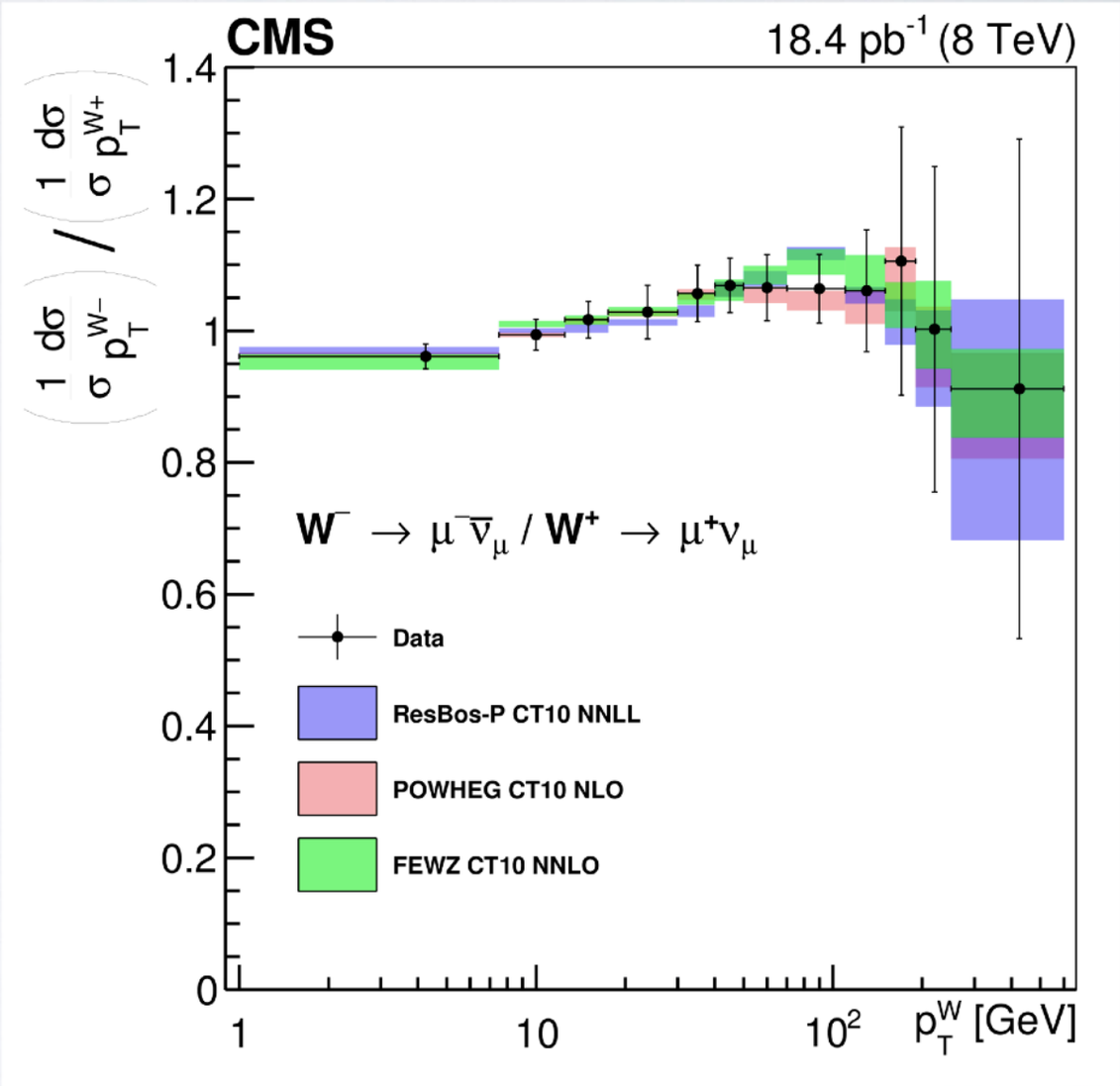


Diff. W/Z p_T at 8 TeV

JHEP 02 (2017) 096

- Also measure ratio of cross sections Z/W and W^-/W^+ for each p_T bin





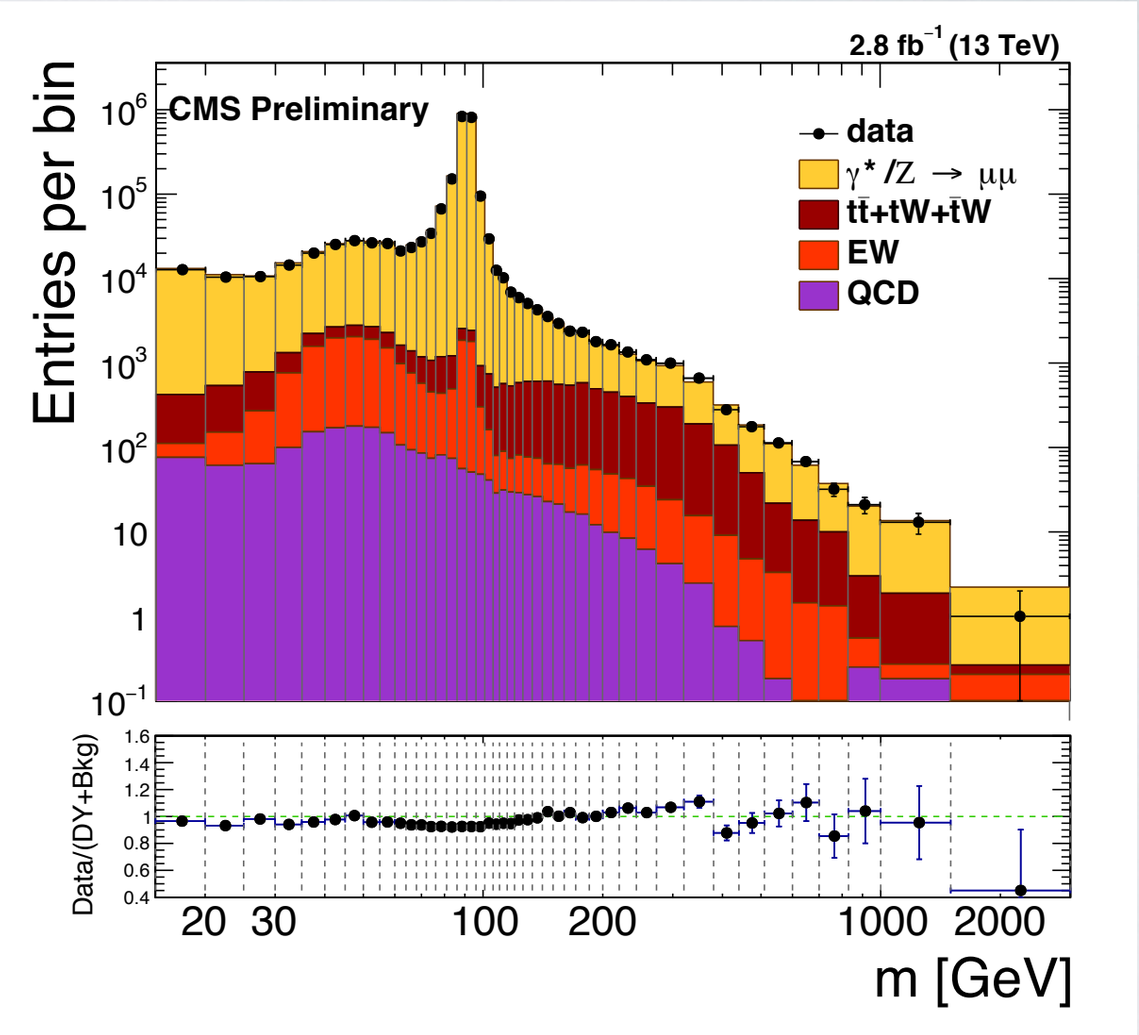
Generally good agreement between data and prediction

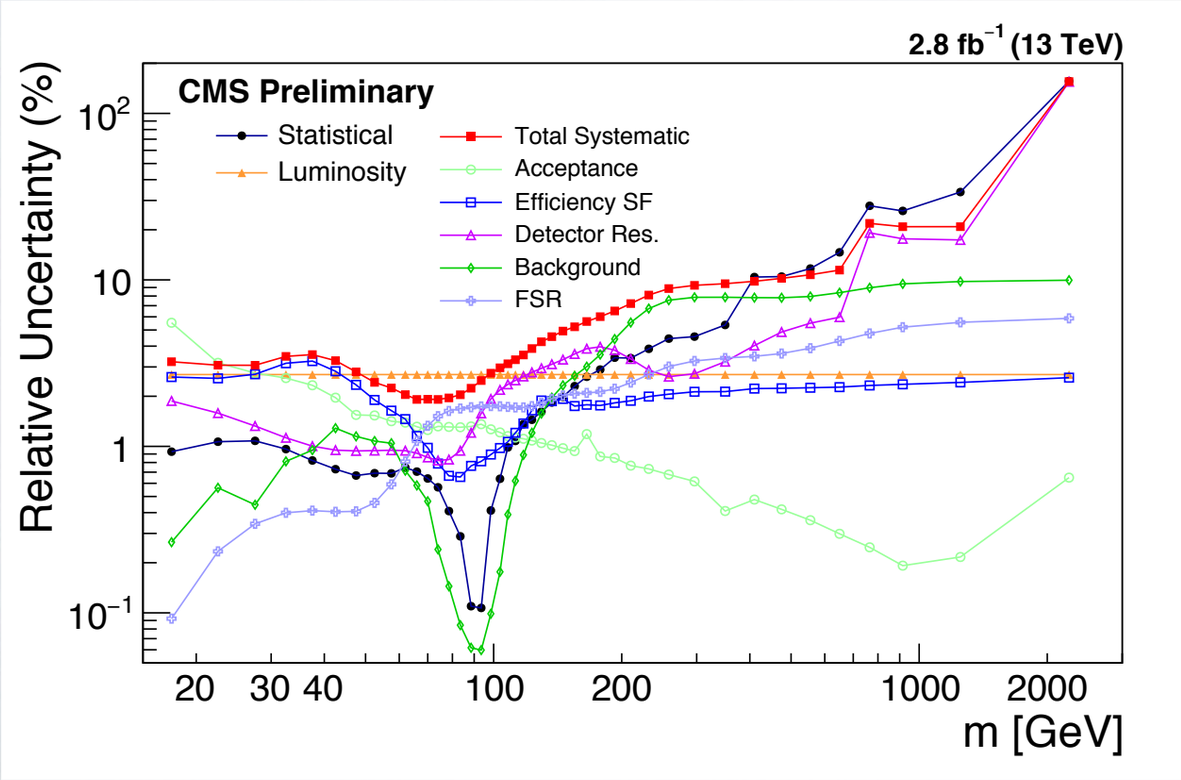
Diff. Drell-Yan at 13 TeV

CMS-PAS-SMP-16-009

2.8 fb^{-1} of 2015 data

- Muon channel only
- Differential measurement of $\gamma^*/Z \rightarrow ll$ as a function of m_{ll}
  - $15 < m_{ll} < 3000$ GeV

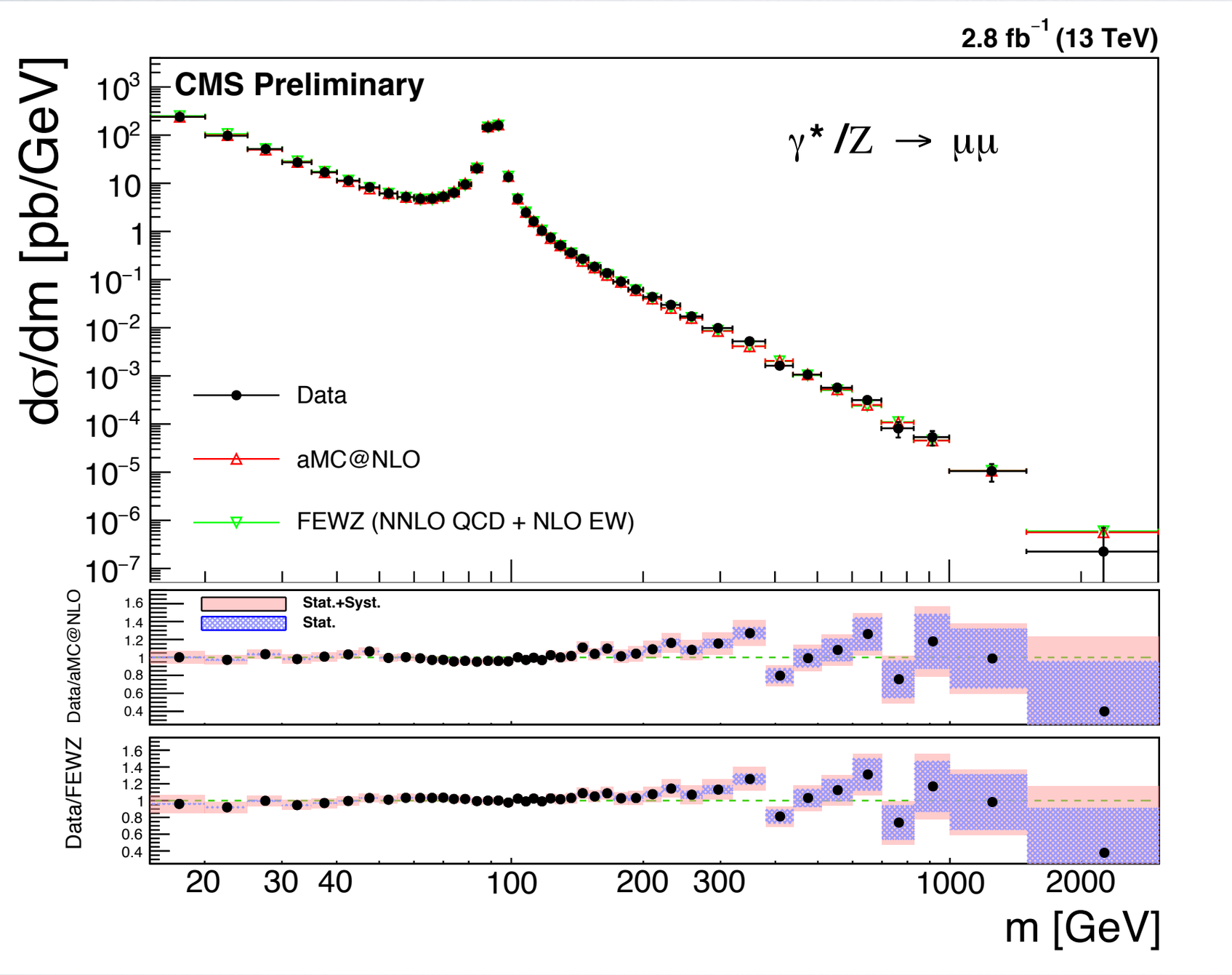




- Efficiency and background uncertainties dominate,
- Statistics-limited at high mass

Diff. Drell-Yan at 13 TeV

CMS-PAS-SMP-16-009



- Good agreement between **data**, **aMC@NLO**, and **FEWZ** predictions

DY Forward-Backward Asymmetry at 8 TeV

Eur. Phys. J. C 76 (2016) 325

19.7 pb^{-1} at 8 TeV

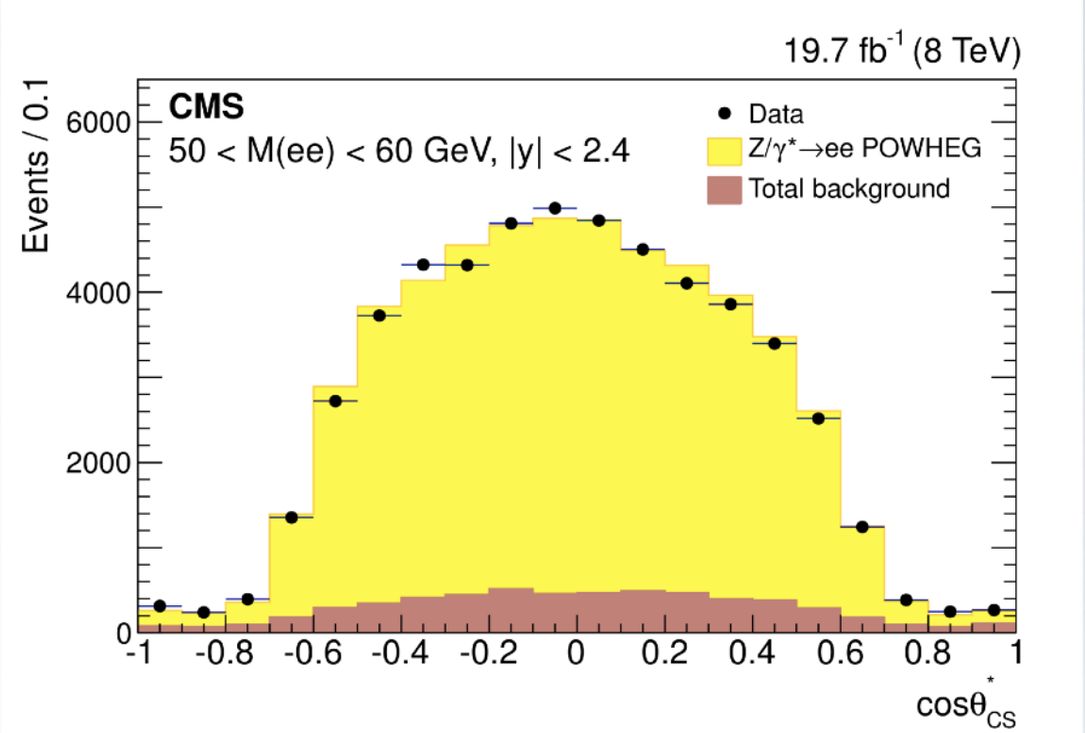
- Uses electrons out to $|\eta|=5$ in hadronic forward calorimeter (no tracker coverage)

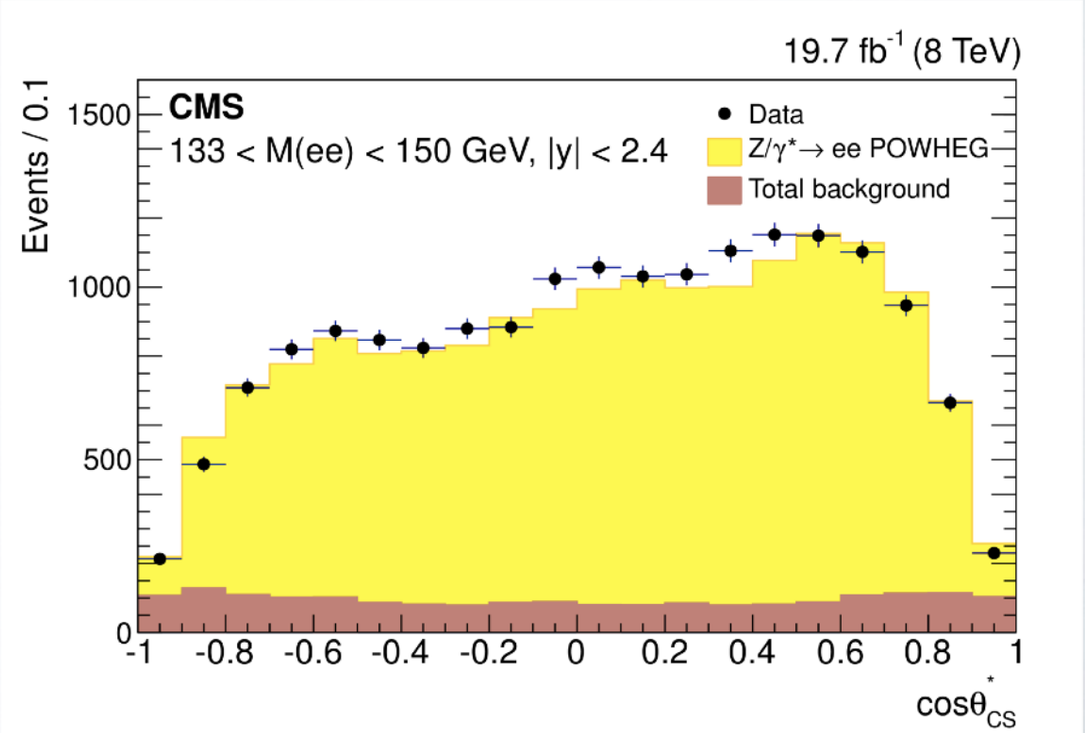
- Measure

$$\cos\theta^*_{\mathrm{CS}} = \frac{2\left(P_1^+ P_2^- - P_1^- P_2^+\right)}{\sqrt{Q^2\left(Q^2 + Q_T^2\right)}}$$

- then define forward-backwards asymmetry

$$A_{\mathrm{FB}} = \frac{\sigma_{\mathrm{F}} - \sigma_{\mathrm{B}}}{\sigma_{\mathrm{F}} + \sigma_{\mathrm{B}}}$$





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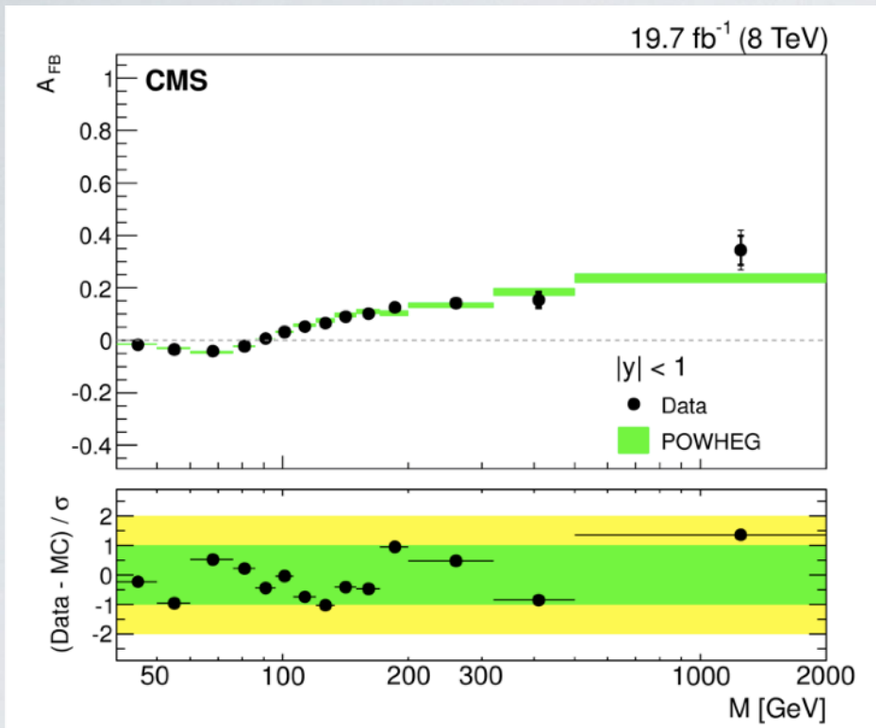
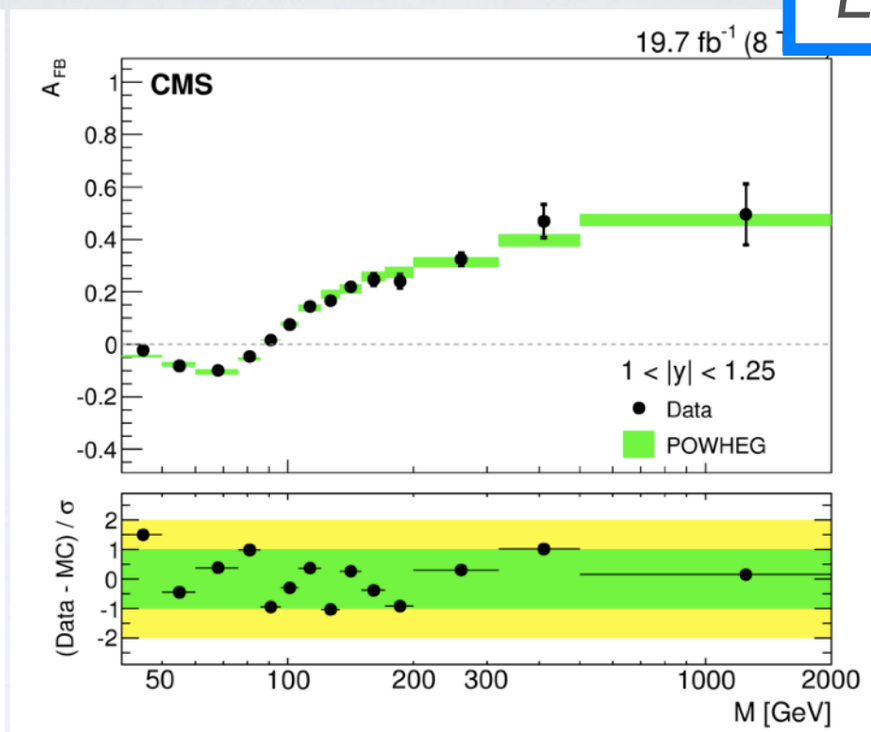
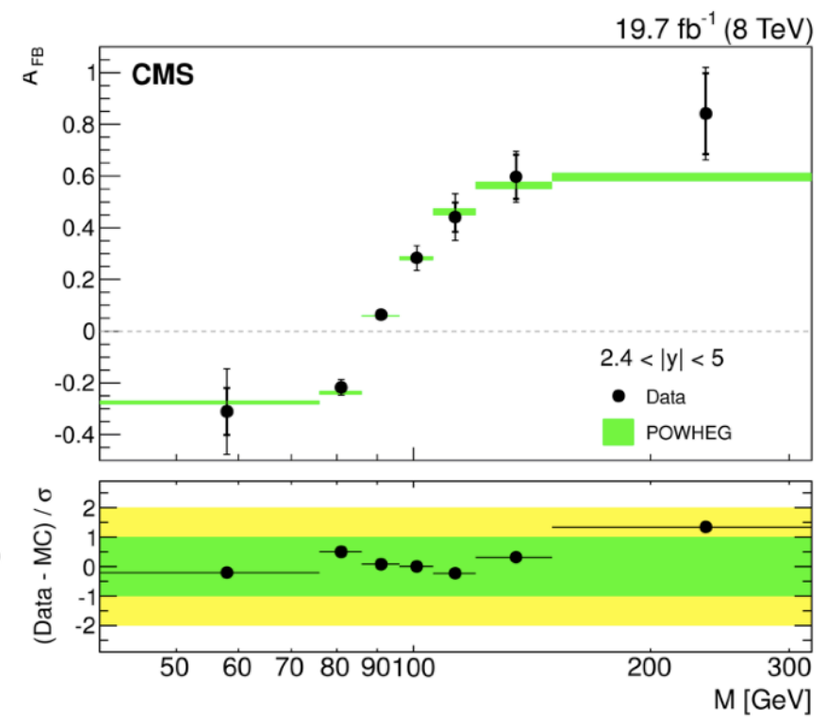
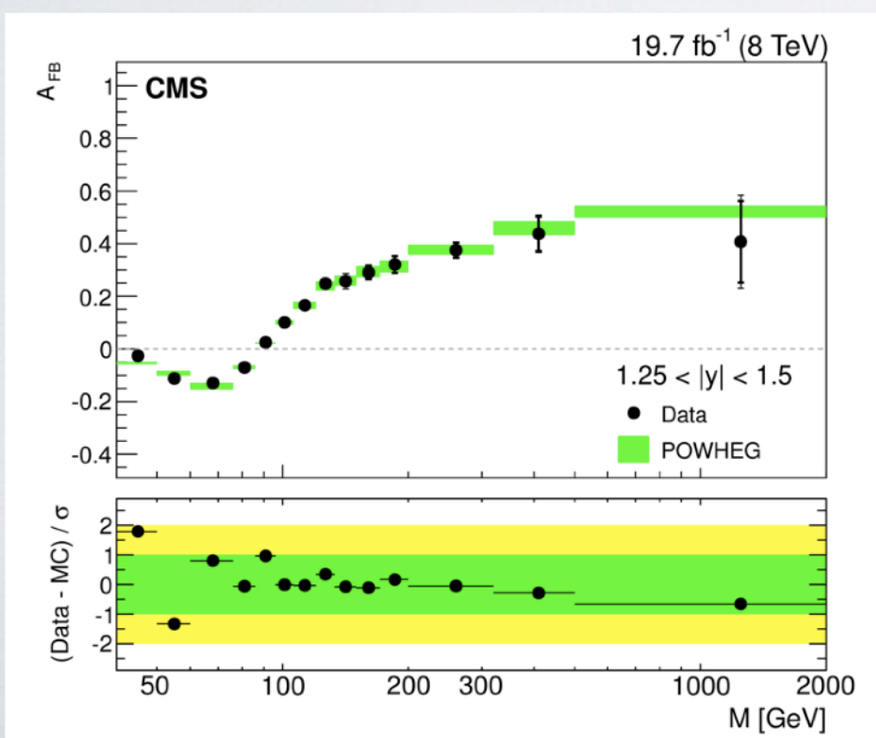
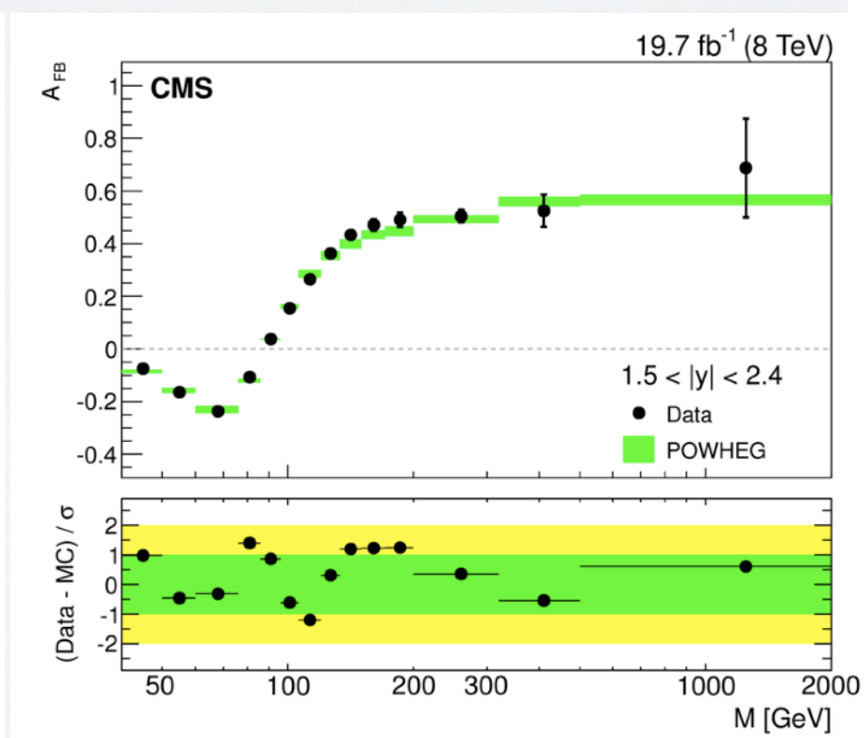










Good agreement within uncertainties

Charge asymmetry and diff. W at 8 TeV

Eur. Phys. J. C 76 (2016) 469

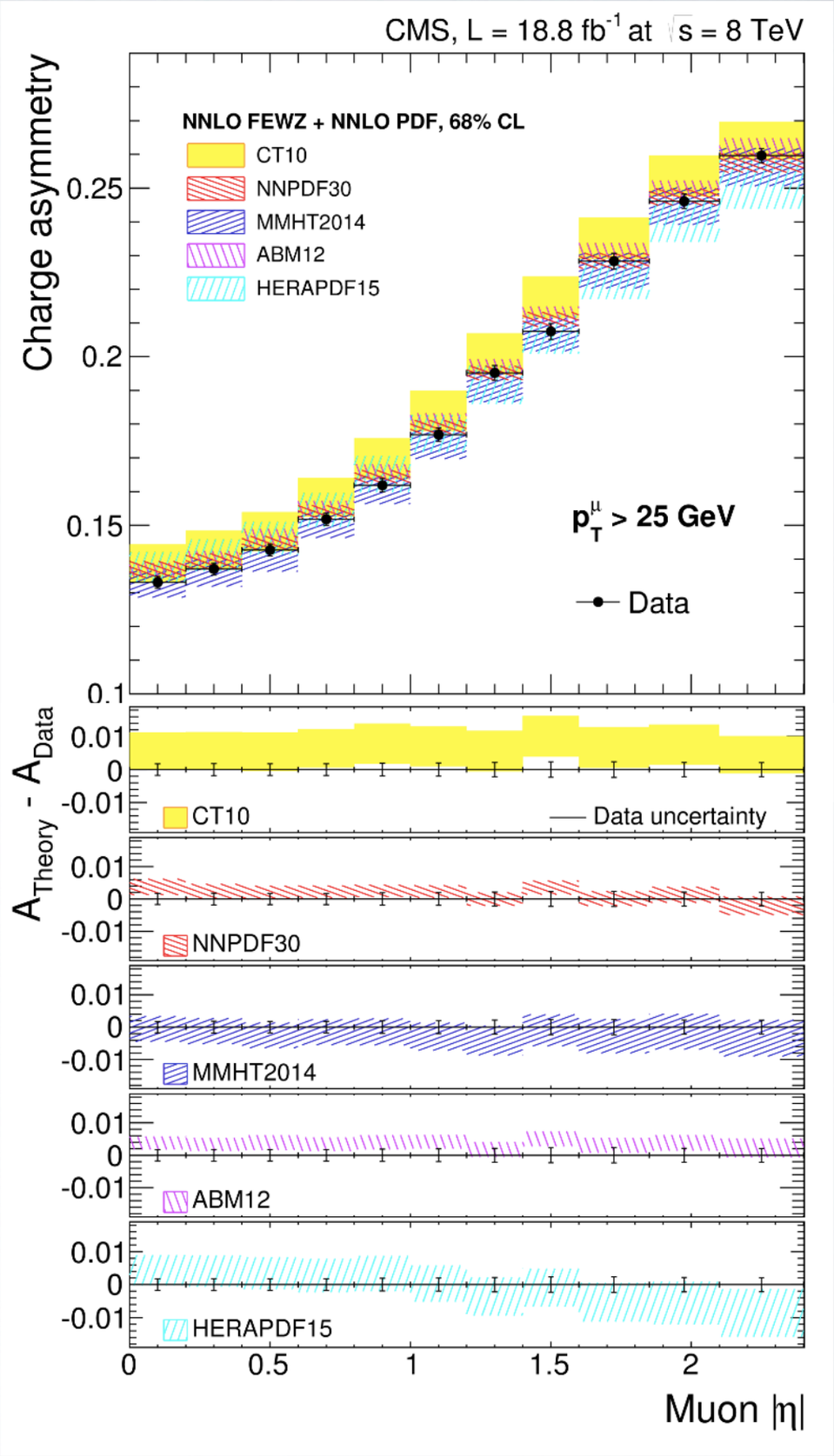
18.8 pb^{-1} at 8 TeV

- Muon channel only
- In each η bin, calculate

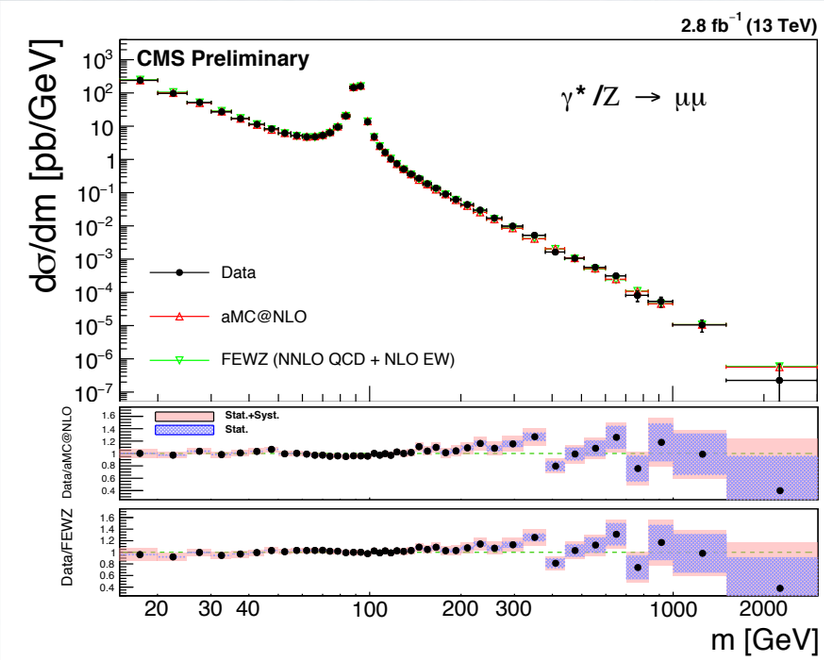
$$A(\eta) = \frac{\sigma_\eta^+ - \sigma_\eta^-}{\sigma_\eta^+ + \sigma_\eta^-}$$

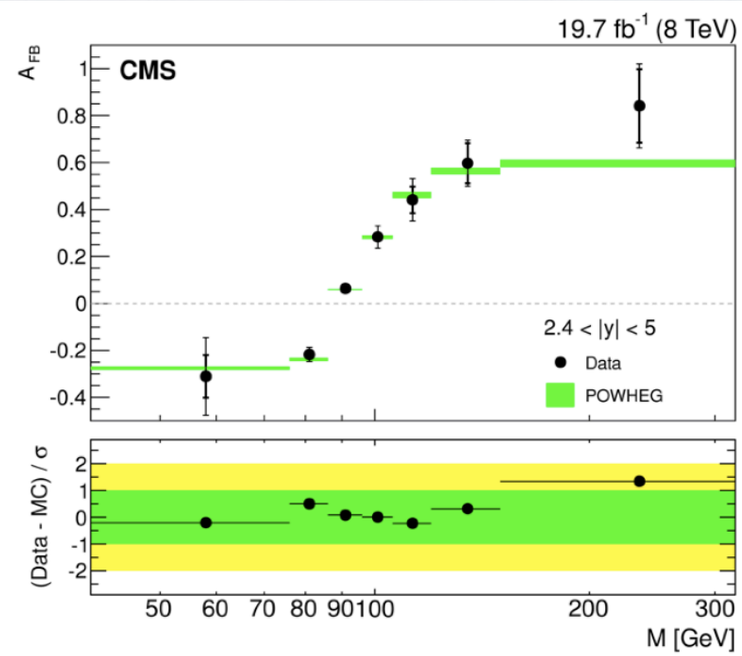
- Compare with various PDF sets

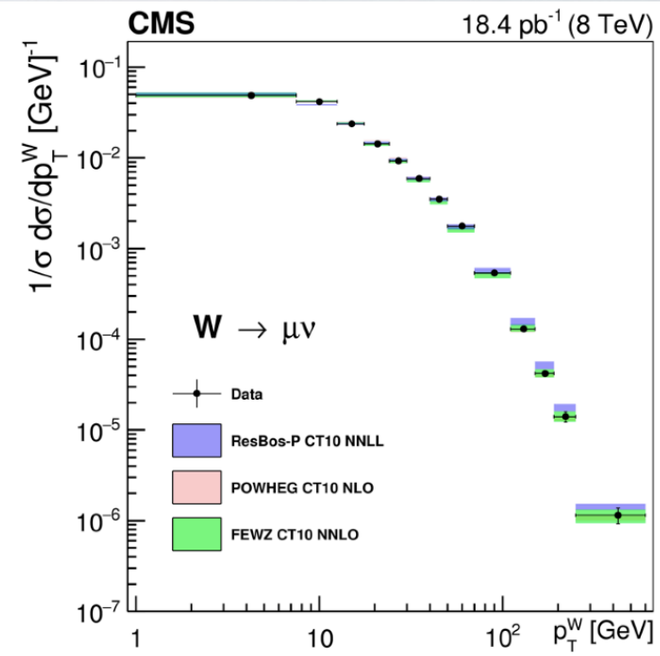
Data uncertainties smaller than those of PDFs — constraint for new PDF fits

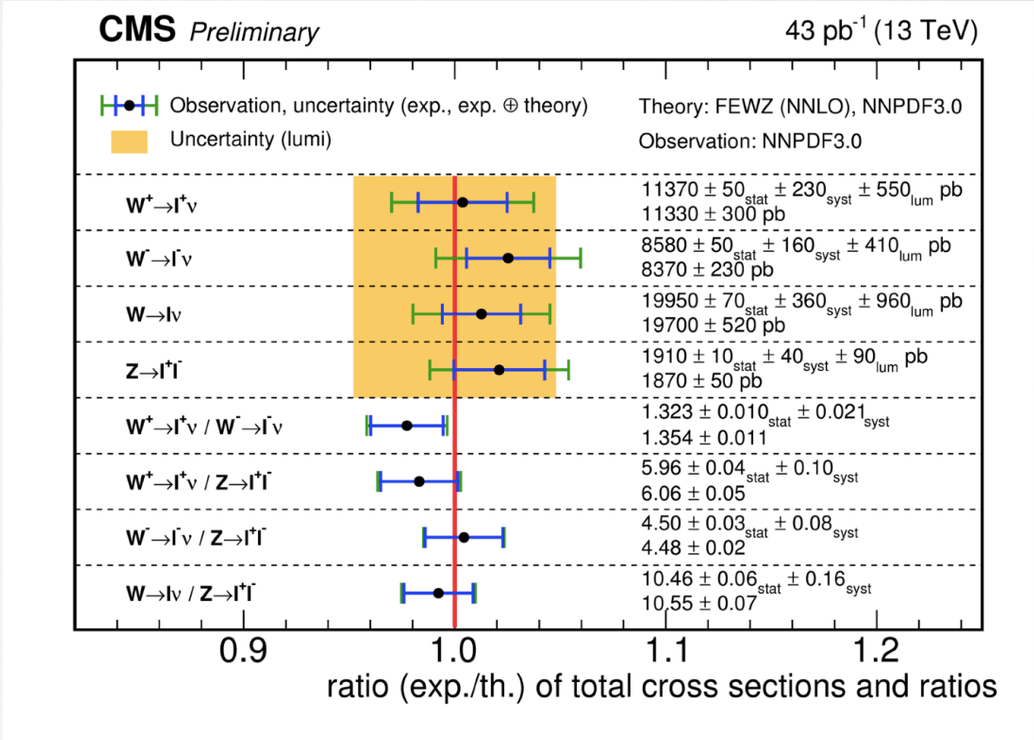


Summary









- Inclusive and differential W and Z boson cross section measurements and ratios with 13 and 8 TeV data
  - Generally good agreement with theory

- Full list of CMS results:

  http://cms-results.web.cern.ch/cms-results/public-results/publications/

- And many analyses in progress!