Recent EW measurements

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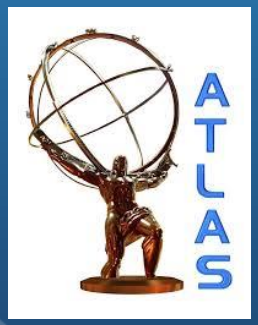


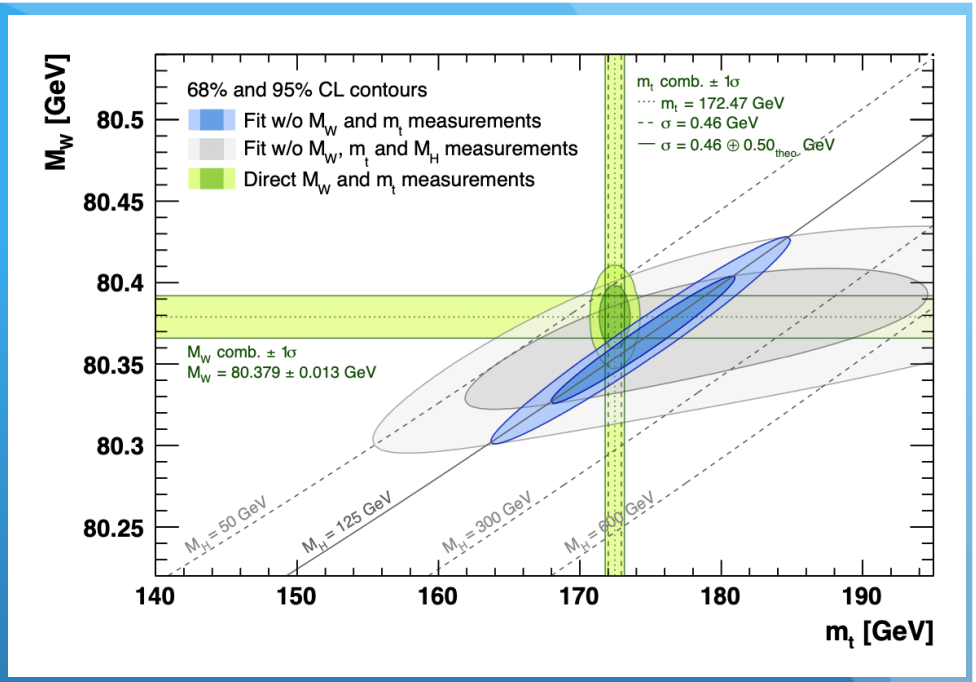
LHCDays2022, Split, Croatia, September 3-8, 2022

Introduction

EW motivation at LHC:

- Cross sections, better understanding of SM predictions
- Backgrounds for searches
- SM parameters

$\alpha_{em}, G_F, m_Z, m_W, m_H, m_{Top}, sin^2\theta_W$



arXiv:1803.01853 Gfitter

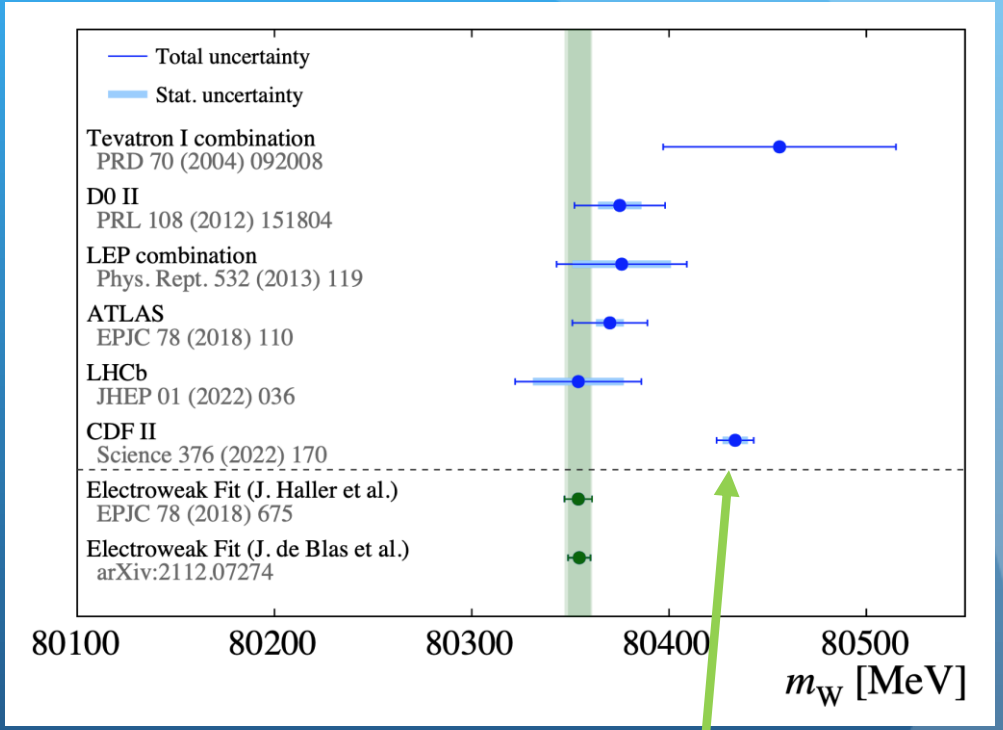
Provides critical tests of SM (NNLO QCD and NLO EW predictions are available)

Requires precise understanding of different sources of uncertainties, both experimental and theoretical

Not in this talk

- W mass
- Top mass
- VBS

These topics will be discussed later in separated talks



Science Vol.376, Issue 6589 (2022) 170

Measurements discussed in this talk

- Forward-Backward asymmetry A_{FB} and angular coefficients
  - CMS: *Eur. Phys. J. C* **78** (2018) 701
    - ATLAS: ATLAS-CONF-2018-037
  - CMS: JHEP 08 (2022) 063
  - LHCb: Phys. Rev. Lett. 129 (2022) 091801
- Z + 2jets EWK
  - ATLAS: Eur. Phys. J C81 (2021) 163
- W branching fraction
  - CMS: Phys. Rev D, vol.105, iss.07 (2022) 2008
- Z invisible width
  - CMS: arXiv: 2206.07110
- Z→ $ll\gamma$ decays
  - ATLAS: ATLAS-CONF-2022-046
- Observation of polarisation states in WZ production
  - ATLAS: ATLAS-CONF-2022-053

Forward-Backward Asymmetry in Z's

CMS: Eur. Phys. J. C 78 (2018) 701
ATLAS: ATLAS-CONF-2018-037

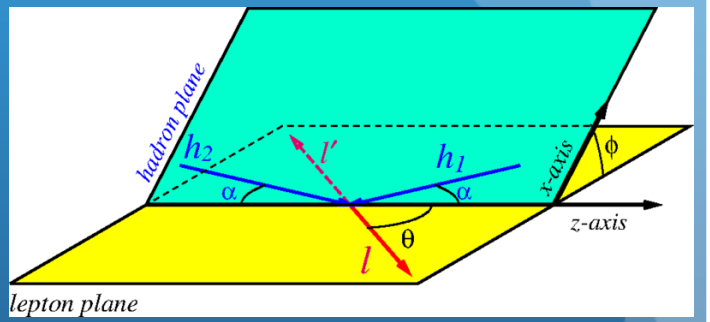
- Vector and axial-vector couplings in NC annihilation

$$q\bar{q} \rightarrow Z/\gamma^* \rightarrow \ell^+\ell^-$$

$$\bar{f}(g_V^f + g_A^f\gamma_5)f$$

- Differential cross section

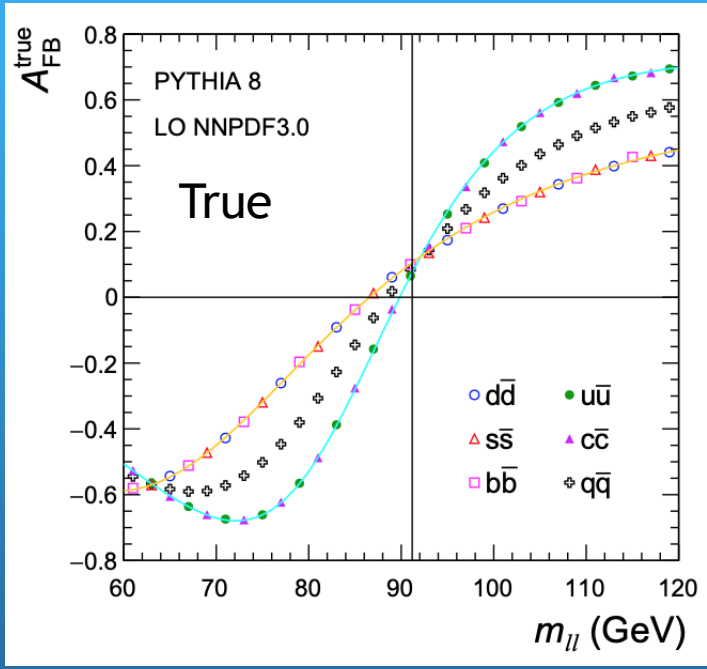
$$\frac{d\sigma}{d(\cos\theta)} = \frac{4\pi\alpha^2}{3\hat{s}}\left[\frac{3}{8}A(1+\cos^2\theta) + B\cos\theta\right]$$



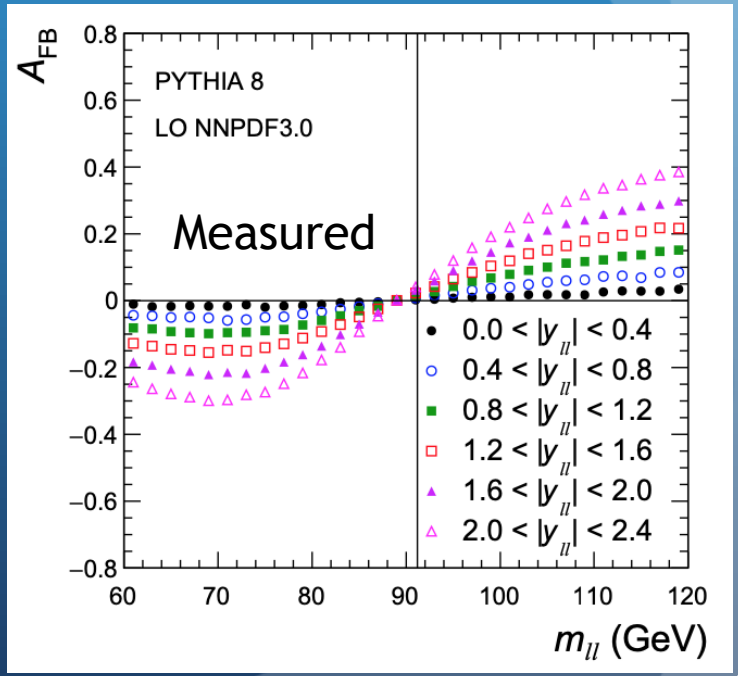
- Collins-Soper frame, the events are classified to forward and backward in CS to calculate the A_{FB}

$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$$

Dilution of A_{FB}

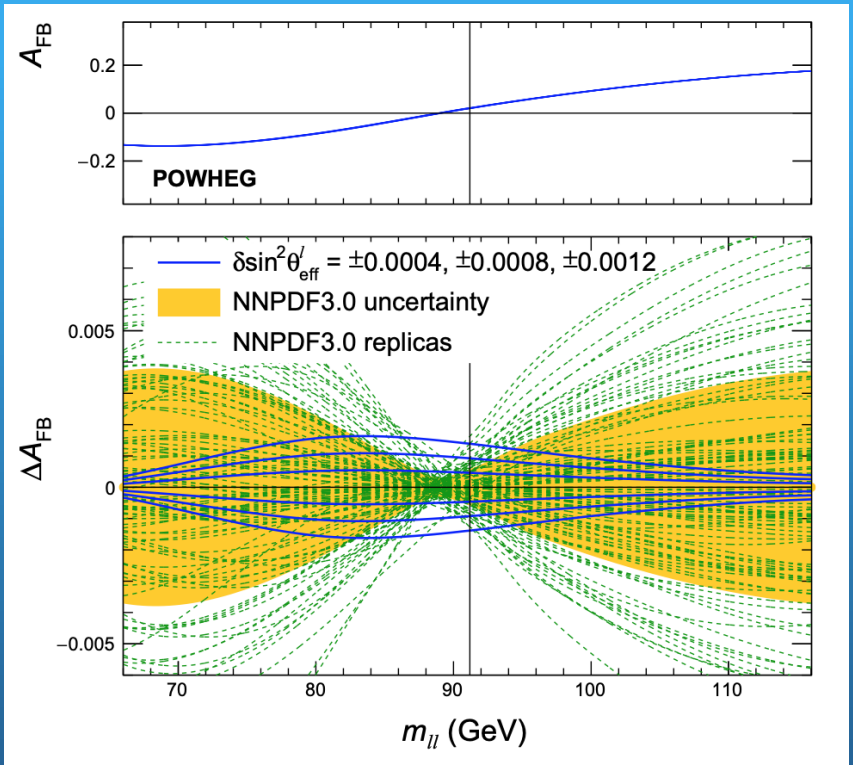


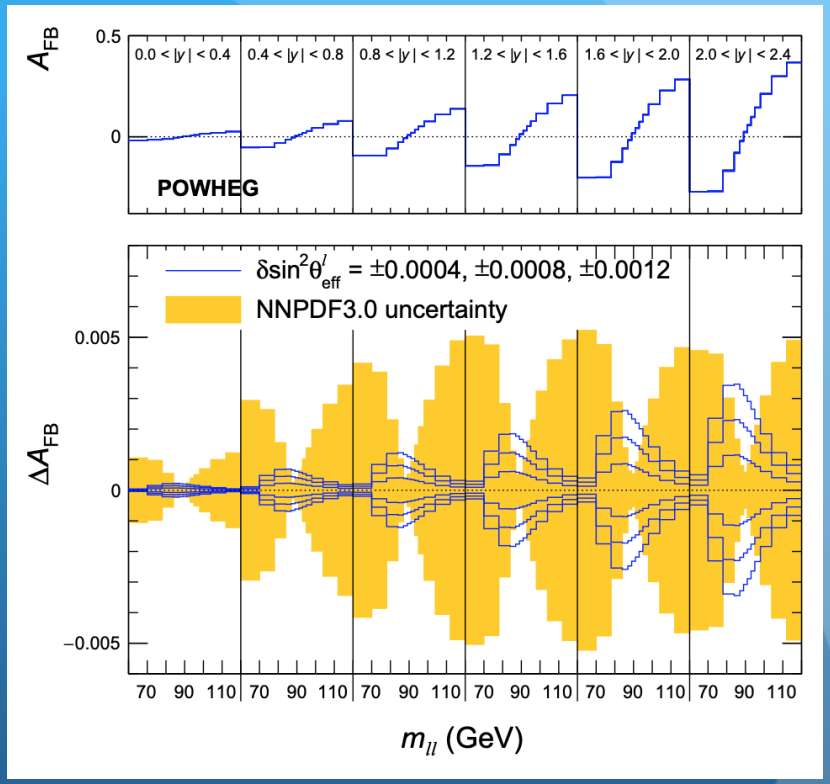
A_{FB} PDF dependence; near Z peak is sensitive to leptonic $\sin^2\theta_{eff}$



Since ambiguity in the quark direction is more significant at low |y|, the dilution of A_{FB} is also larger there and the measurement is done in bins of |y|

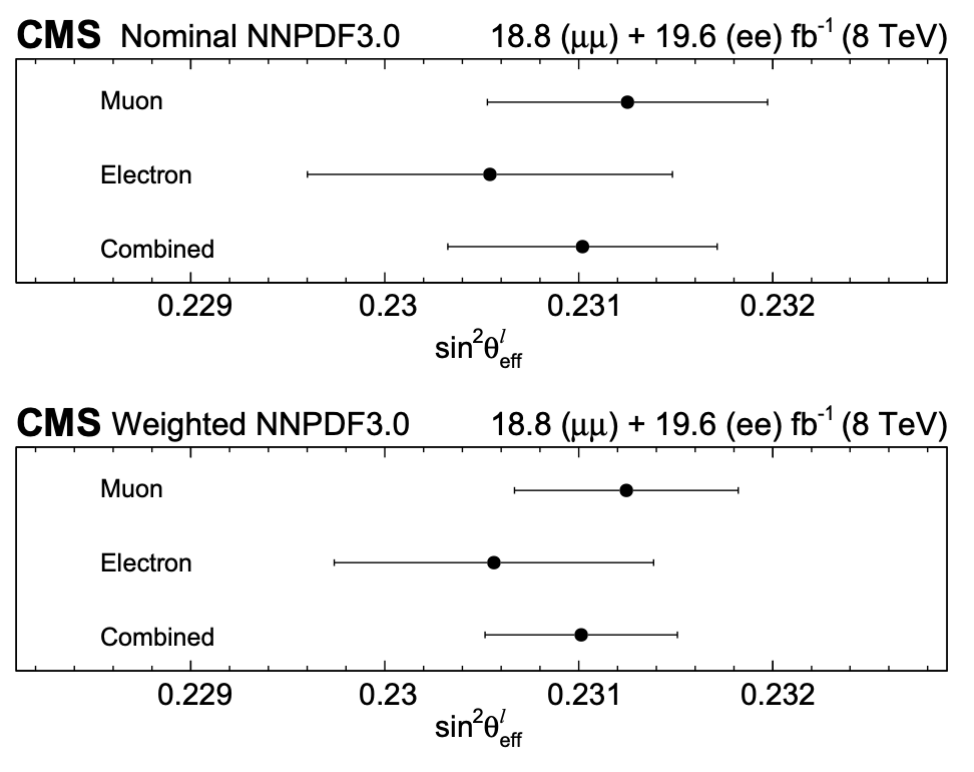
PDF uncertainty





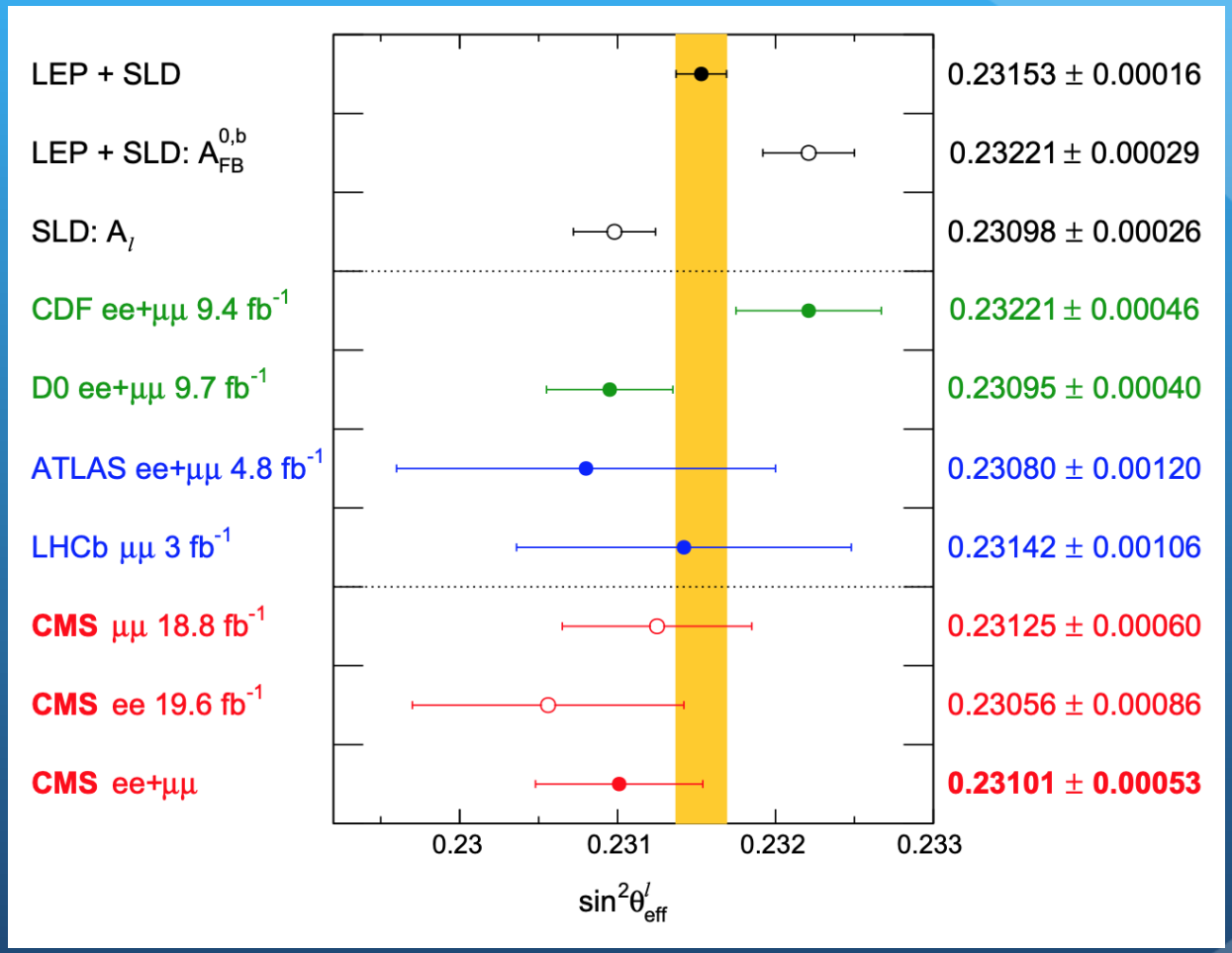
Reducing PDF uncertainty by reweighting.

Effective mixing angle results



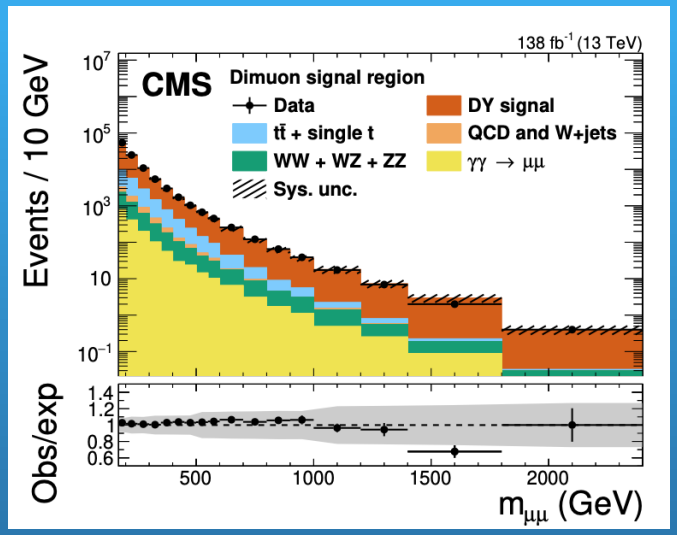
Statistical uncertainty still dominate, followed by PDF, that was reduced by reweighting by 50% .
Experimental uncertainties are relatively small , theoretical are dominated by QCD/scales

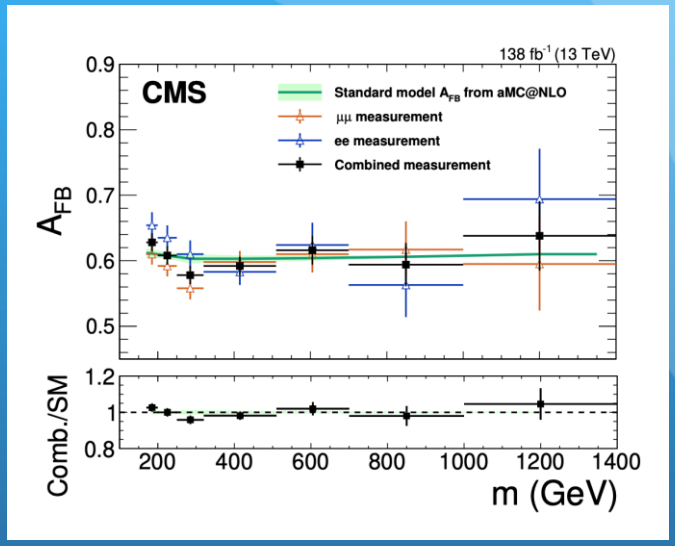
Effective mixing angle: experimental summary

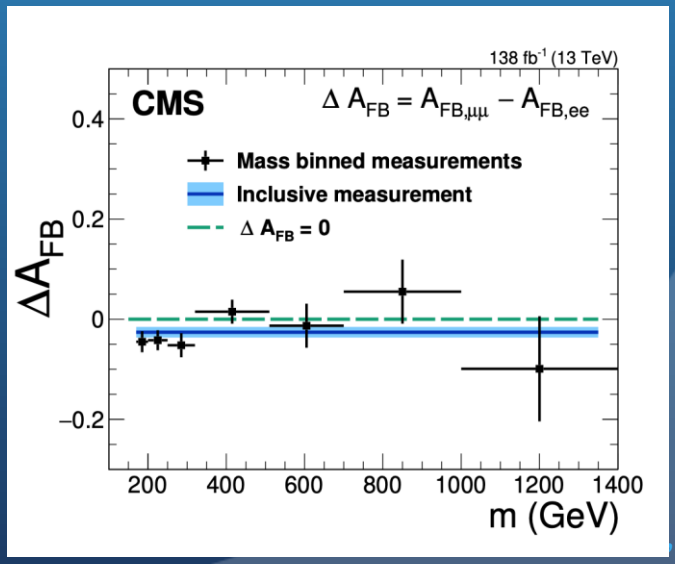


A_{FB} at high dilepton masses

CMS: JHEP 08 (2022) 063







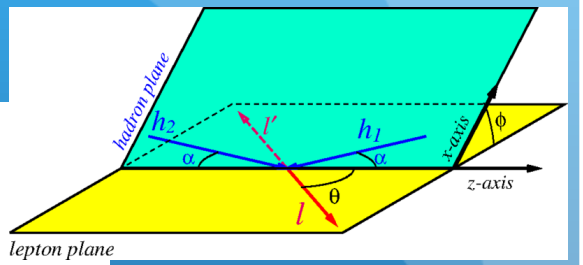
At high masses >170 GeV the SM predictions describe the data well.

No signature of violating of the lepton universality.

Angular coefficients in Z events

LHCb: Phys. Rev. Lett. 129 (2022) 091801

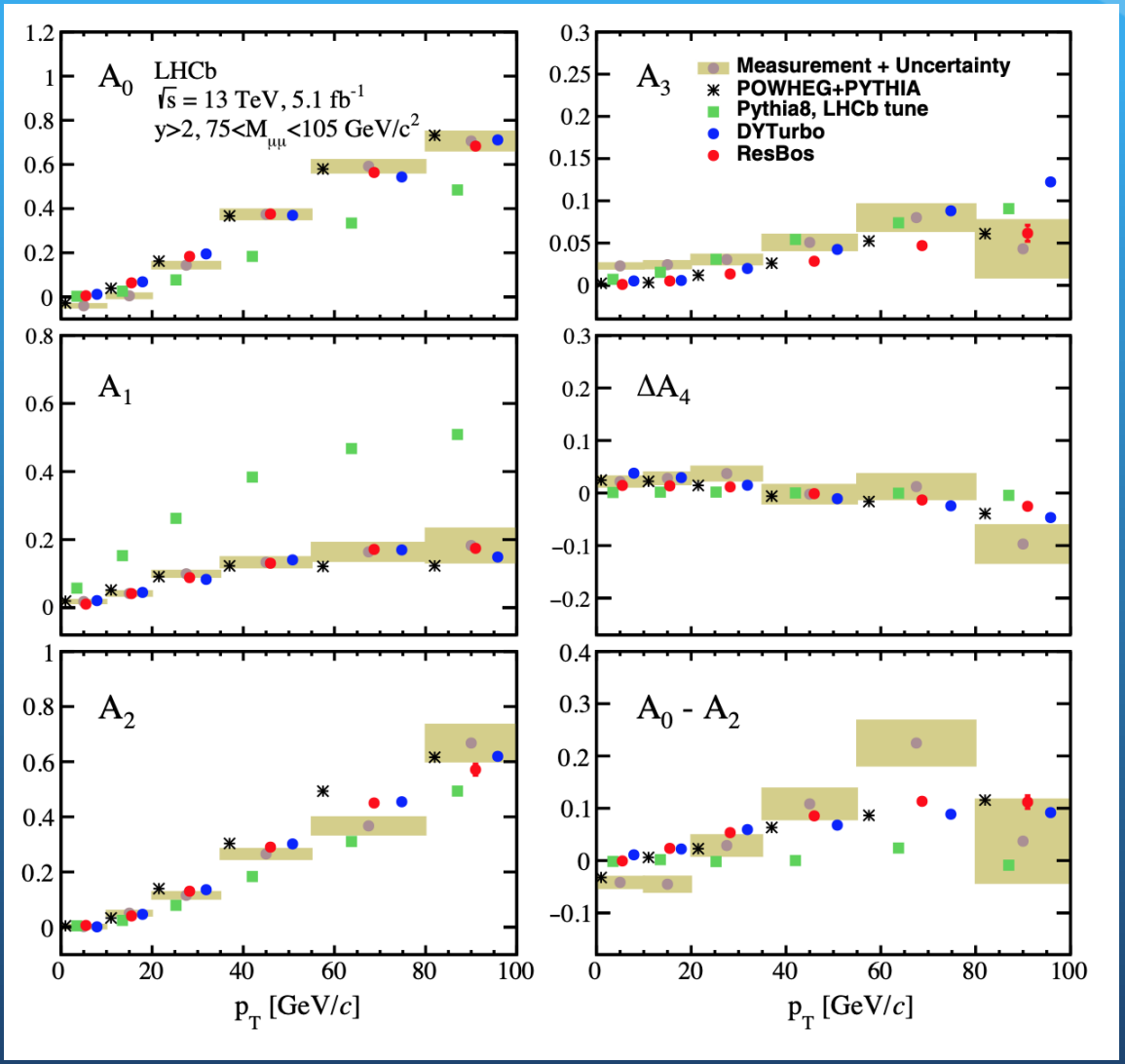
The angles are defined in Collins-Soper frame. Differential cross section can be written as:



$$\frac{d\sigma}{dp_T^Z\, dy^Z\, dm^Z\, d\cos\theta\, d\phi} = \frac{3}{16\pi}\frac{d\sigma^{U+L}}{dp_T^Z\, dy^Z\, dm^Z}$$
$$\Big\{(1+\cos^2\theta) + \frac{1}{2}A_0(1-3\cos^2\theta) + A_1\ \sin 2\theta\ \cos\phi$$
$$+\frac{1}{2}A_2\ \sin^2\theta\ \cos 2\phi + A_3\ \sin\theta\ \cos\phi + A_4\ \cos\theta$$
$$+A_5\ \sin^2\theta\ \sin 2\phi + A_6\ \sin 2\theta\ \sin\phi + A_7\ \sin\theta\ \sin\phi\Big\}.$$

A0-A3 become not 0 at NLO ;
A0-A2=0 Lam-Tung relation (valid at $O(\alpha_S)$) ;
A4 is only coefficient !=0 at LO ;
A5-A7 appear at NNLO .

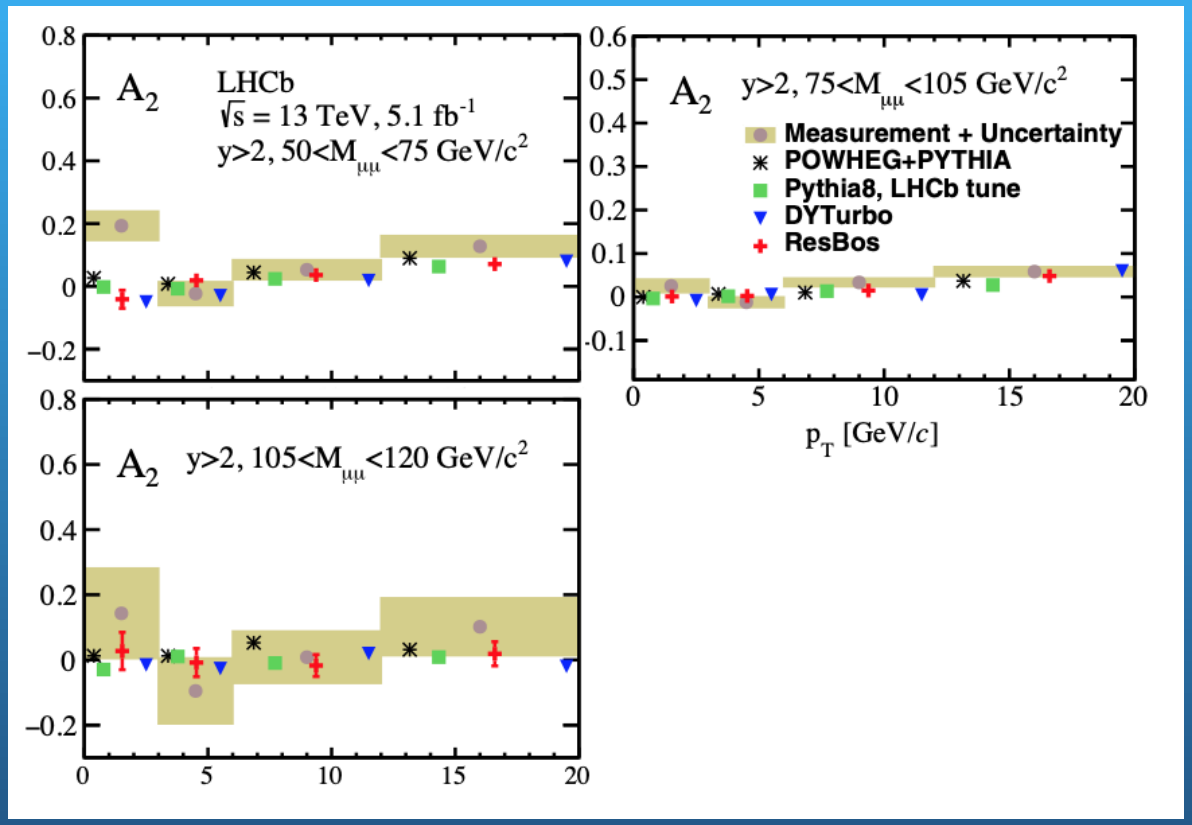
Angular coefficients in Z events



Pythia does not describe the data well.

All MCs describe A3 and Δ A4

Angular coefficients in Z events



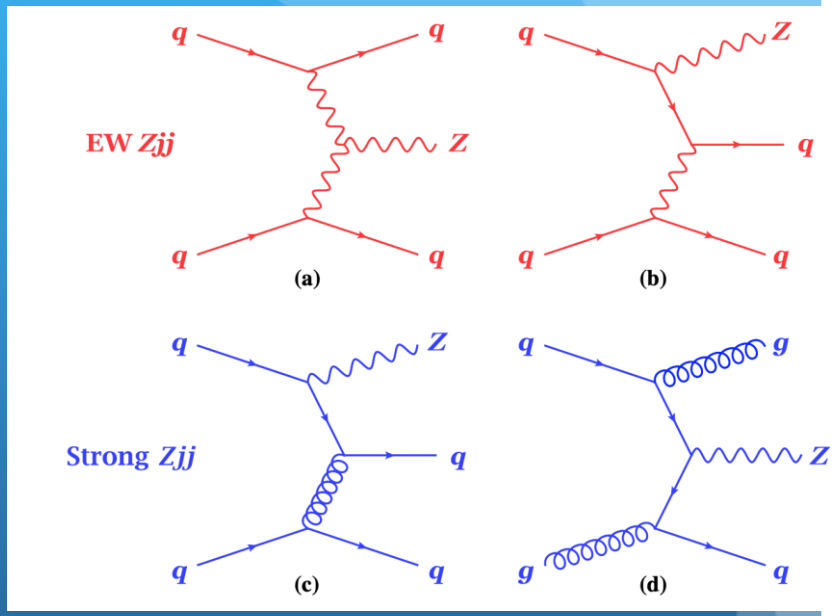
MCs are not describing well the low mass and low P_T region.

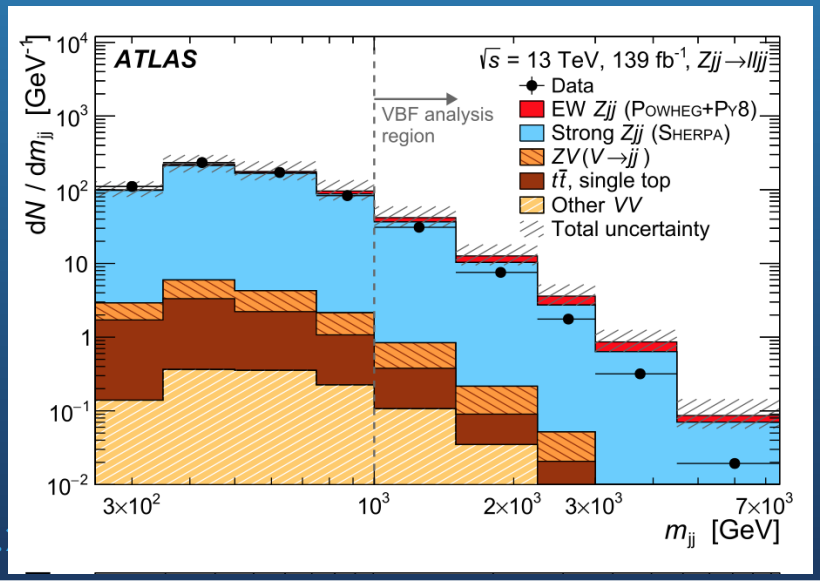
EW production of Z with two jets

ATLAS: Eur. Phys. J C81 (2021) 163

Signal
t-channel $O(\alpha_{EW}^4)$

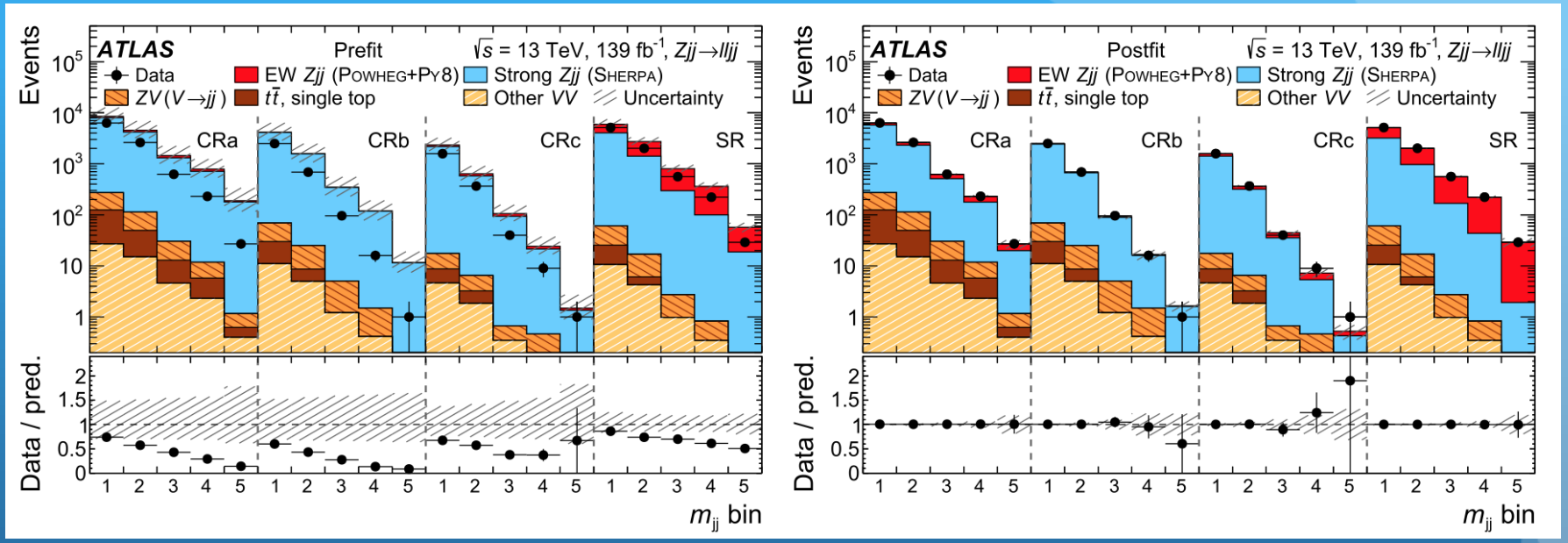
Background
no weak boson exch. in t-channel
$O(\alpha_{EW}^2\ \alpha_S^2)$

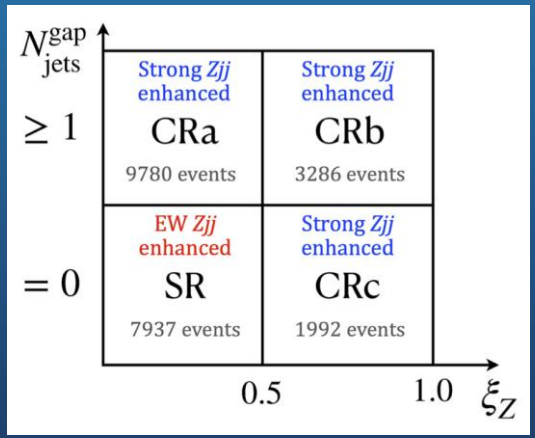




Predictions do not describe data

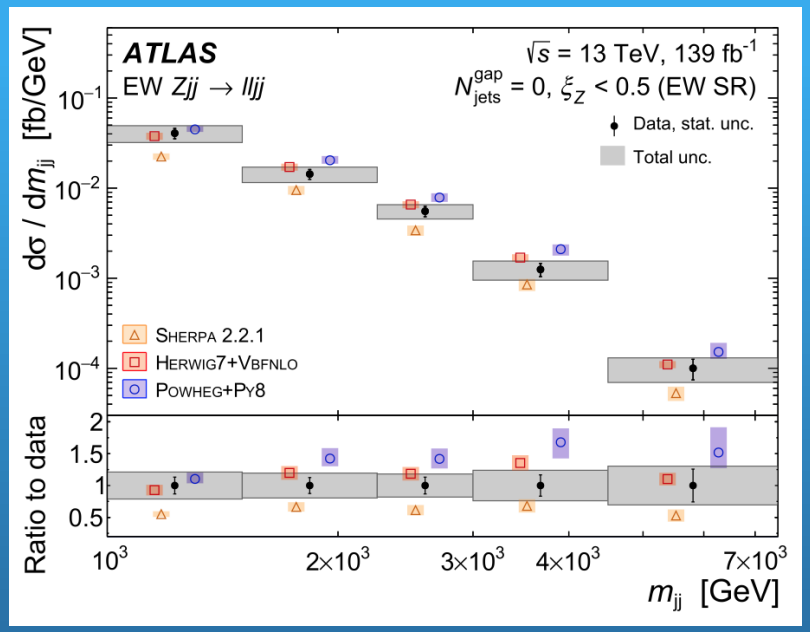
EW production of Z with two jets

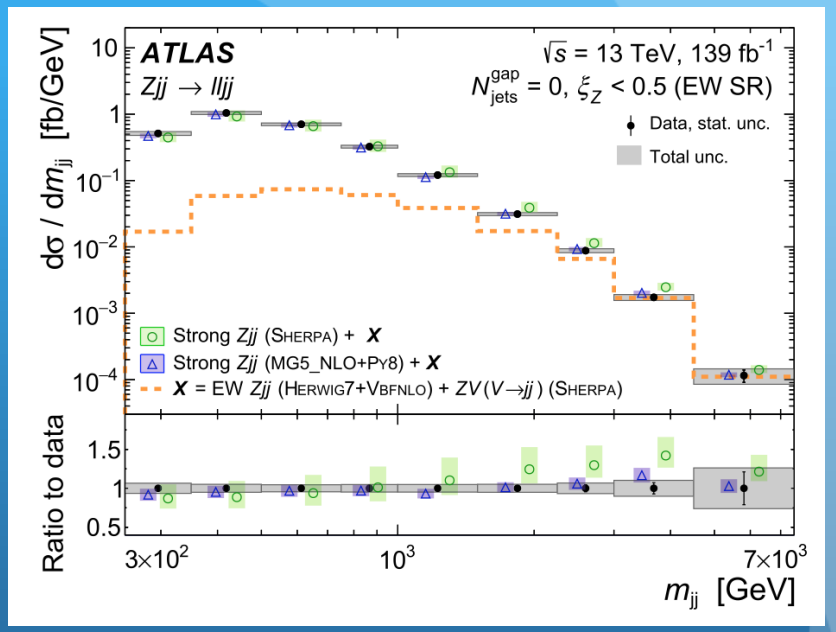




Predictions do not describe data - reweighting is done using control regions – after reweighting good description of the signal region is achieved

EW production of Z with two jets



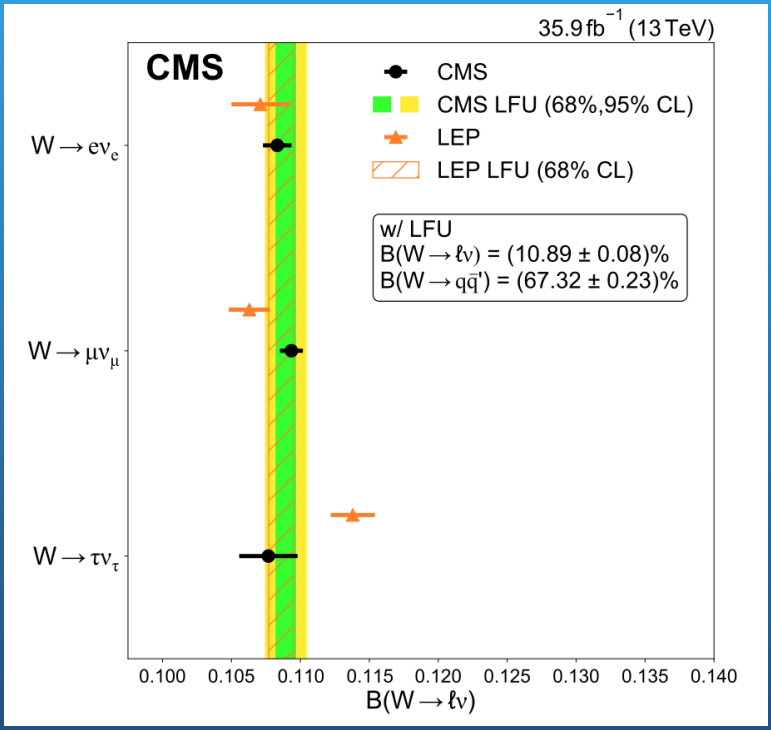


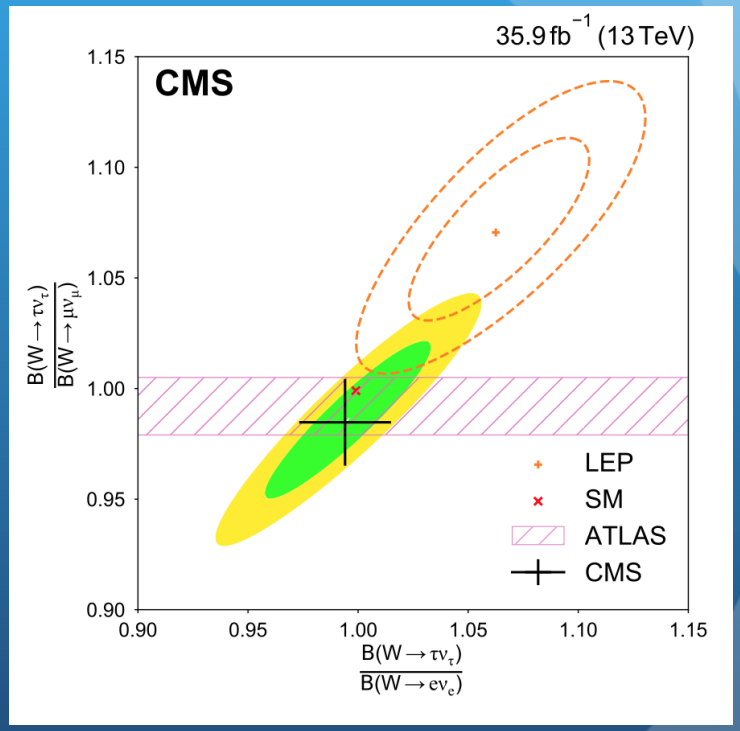
Herwig+Vbfnlo describes data,
other MCs provide satisfactory description

Measurement of the W branching fraction

CMS: Phys. Rev D.105.072008

LEP: $R_{\tau/(e+\mu)} = 1.066 \pm 0.025$!!! 2.6σ



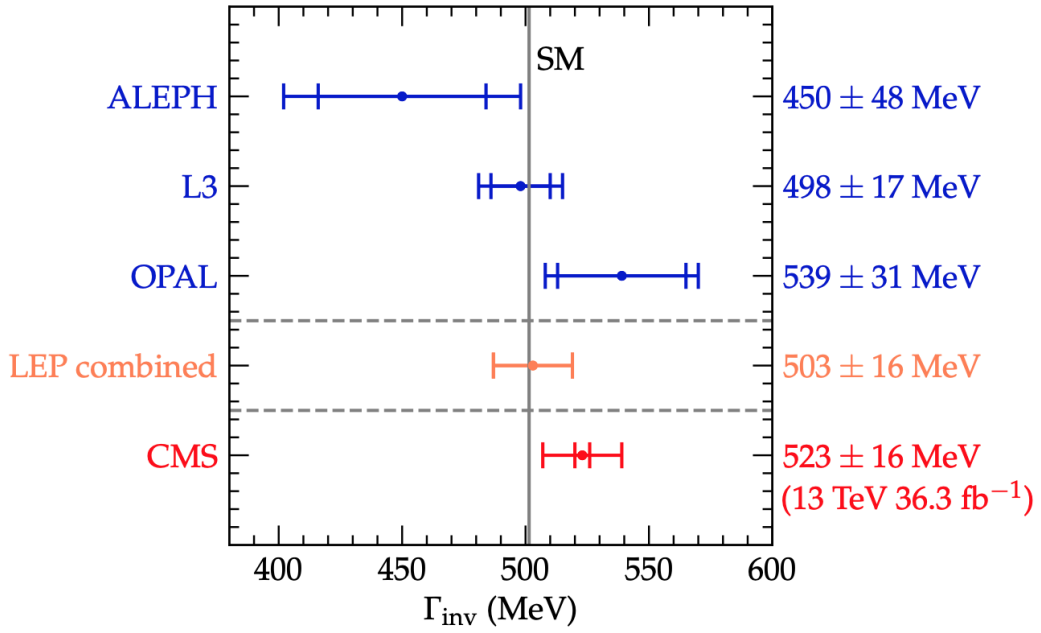


Results are consistent with SM and are more precise than LEP

Z boson invisible width

CMS: arXiv: 2206.07110

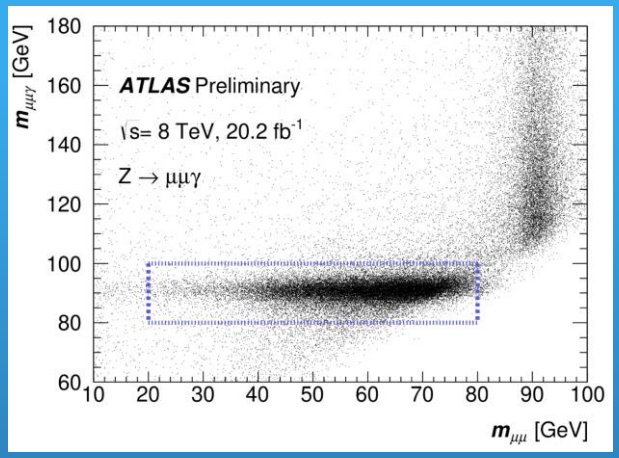
$$\Gamma(Z \to \nu\bar{\nu}) = \frac{\sigma(Z+\text{jets})\mathcal{B}(Z \to \nu\bar{\nu})}{\sigma(Z+\text{jets})\mathcal{B}(Z \to \ell\ell)}\Gamma(Z \to \ell\ell)$$



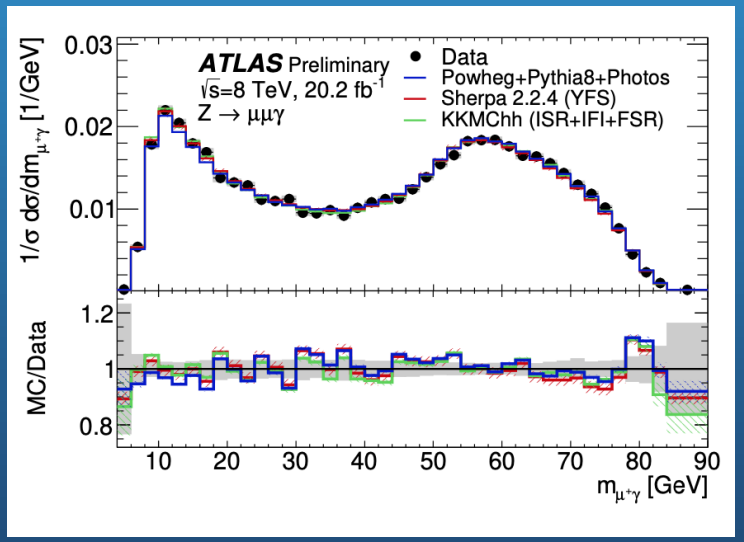
Single most precise measurement, compatible with SM

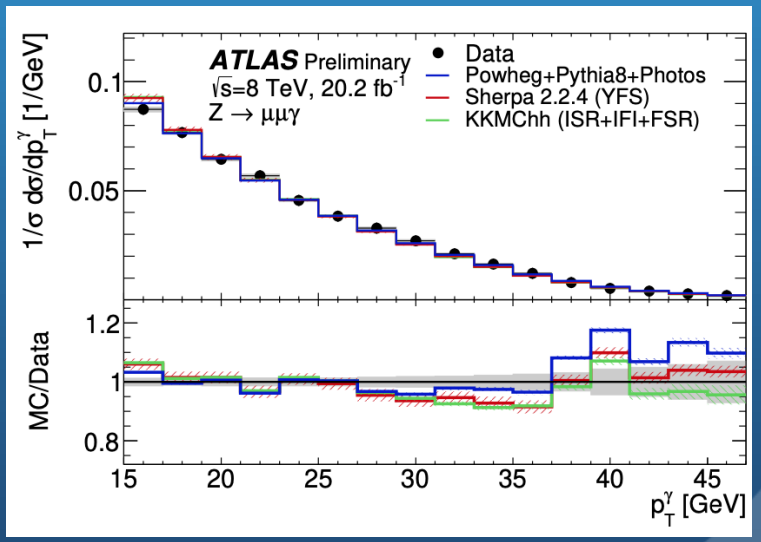
Z→ $ll\gamma$ decays

ATLAS: ATLAS-CONF-2022-046



Study the final-state radiation of photons in Drell-Yan production of *Z* bosons decaying to an electron or muon pair.



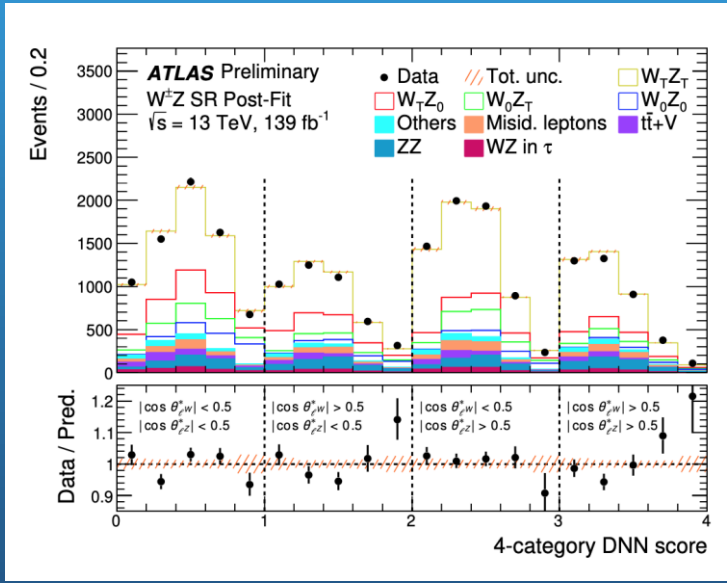


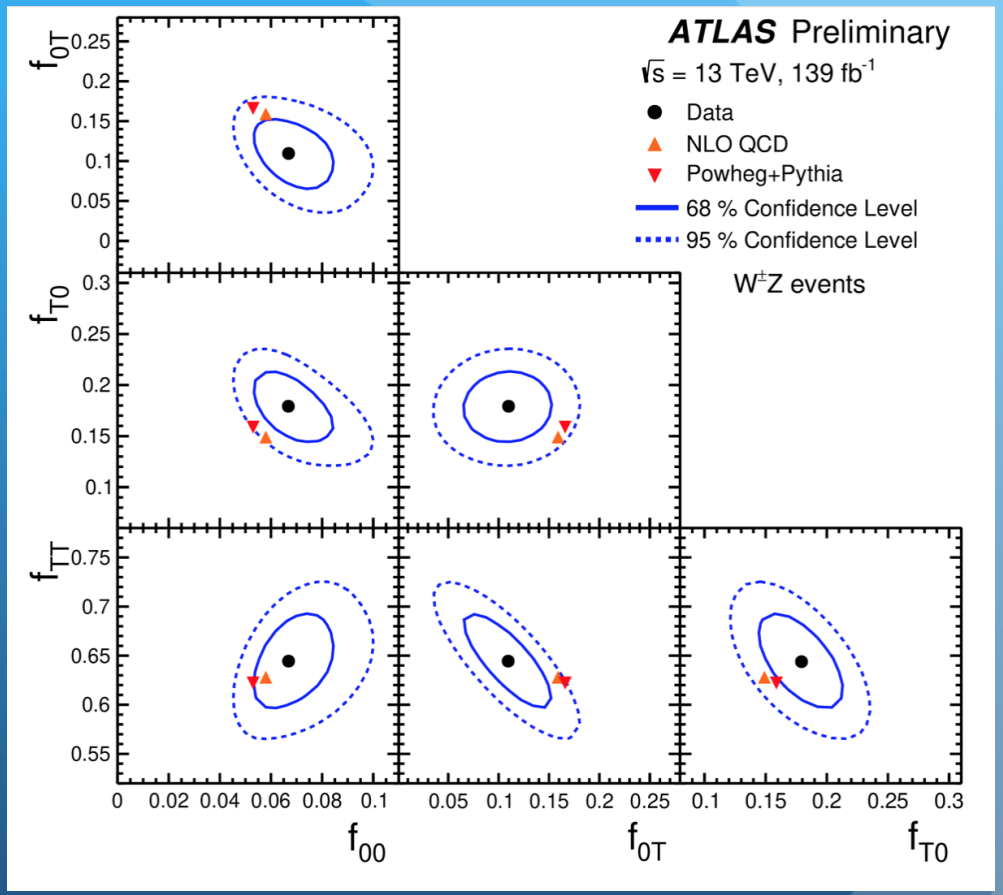
The results are in agreement with predictions of MC generators containing state-of-the-art QED FSR calculations.

Polarisation states in WZ production

ATLAS: ATLAS-CONF-2022-053

Multivariate discriminant is used to separate the four joint helicity states.





The simultaneous pair-production of longitudinally polarised vector bosons is measured for the first time with a significance of 7.1 standard deviations.

Conclusions

- Few recent EW measurements were presented.
- The measurements are at 13 TeV with partial or full Run2 statistics.
  - In many cases we are already restricted by systematics, understanding of uncertainties is extremely important.
- Looking forward to see Run3 results soon !

Backup