Recent W/Z results from CMS

Rajdeep M Chatterjee
Tata Institute of Fundamental Research, Mumbai, India
(for the CMS collaboration)

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Outline

- Inclusive Z boson double differential cross-section at 8 TeV :-
  arXiv:1504.03511(submitted to Phys. Lett. B)
- Angular coefficients of Z decay at 8 TeV :-
  arXiv:1504.03512(submitted to Phys. Lett. B)
- Final state radiation in decays of Z boson at 7 TeV :-
  Phys. Rev. D 91 (2015) 092012
- Drell-Yan forward-backward asymmetry at 8 TeV :-
  CMS-PAS-SMP-14-004
- Muon charge asymmetry in W decays at 8 TeV:-
  CMS-PAS-SMP-14-022

Introduction

- Measurements of W/Z cross-sections allow precison tests of the Standard Model.
- Theoretical predictions are available at upto Next-to-Next-to-Leading-Order(NNLO), and deviations with measurements may imply presence of new physics.
- Further these precision measurements enable constraining of the Parton Density Functions(PDF).
- Measurement of angular quantities related to leptons enable a study of the polarization properties of the Z boson and its coupling structure with fermions.
- These processes are an important background to new physics searches.

$d^2\sigma/dp_T(Z)d|Y(Z)|$

Event selection criteria:

- Two identified and isolated muons.
- Leading muon: $p_T > 25$ GeV and $|\eta| < 2.1$
- Second muon : $p_T > 20$ GeV and $|\eta| < 2.4$
- 81 GeV < M(μμ) < 101 GeV

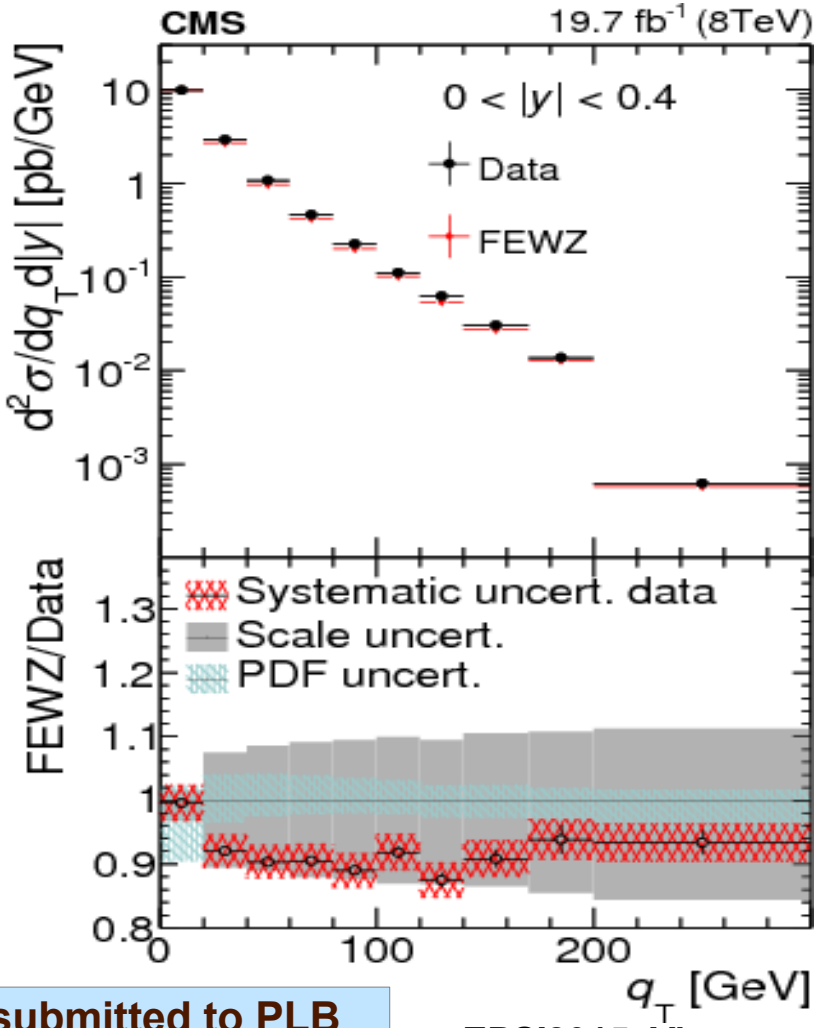
Measurement in fiducial region:
10 bins of $p_T(Z)$ 0-2000 GeV and 4 bins of |Y(Z)| 0-2 .

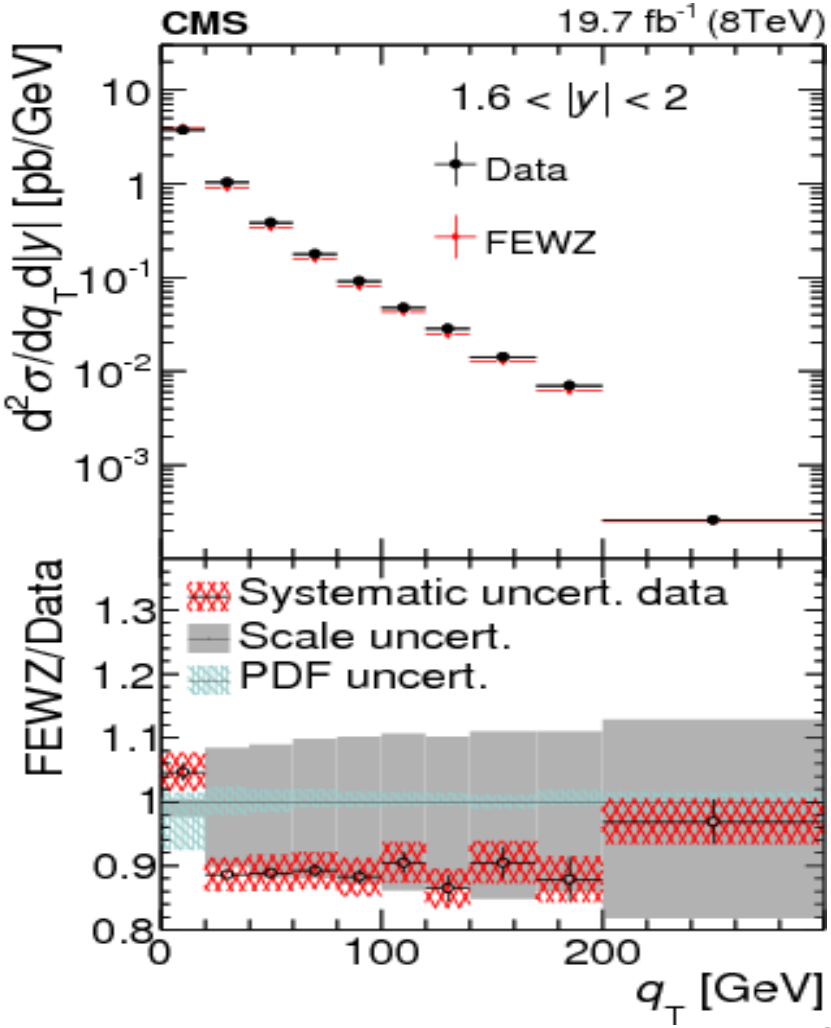
Systematics

- Dominant source luminosity 2.6%

Theory

- FEWZ(NNLO) with NNPDF 2.3





Arxiv: 1504.03511 submitted to PLB

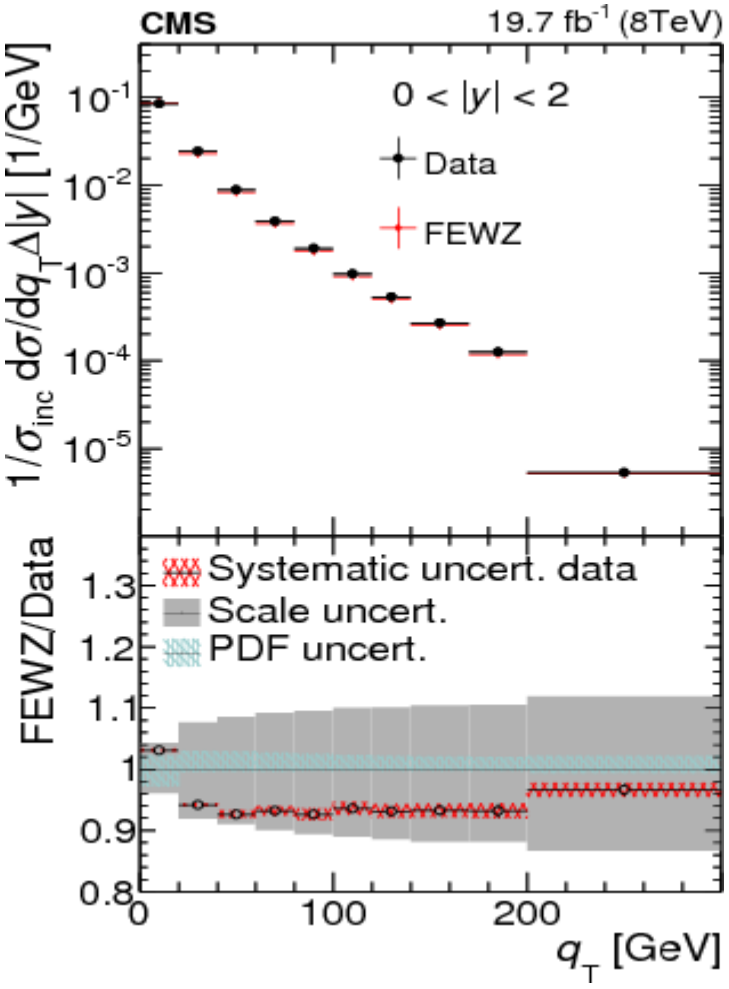
$(1/\sigma_{inc}).d^2\sigma/dp_T(Z)d|Y(Z)|$

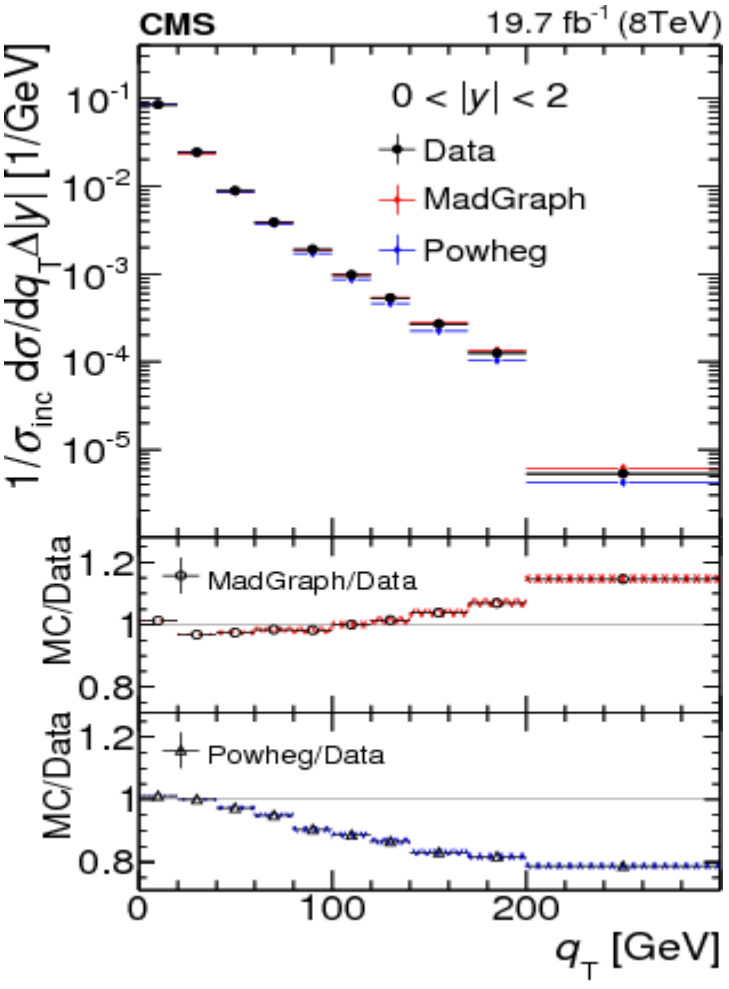
Systematics(normalized)

- Dominant source efficiency corrections ~ 0.2% - 1%

Theory

- FEWZ(NNLO) with NNPDF 2.3
- Madgraph(LO) with CTEQ6L1
- Powheg(NLO) with CT10





The normalized cross-section agrees with FEWZ within theoretical errors(~10%).

Significant deviations seen for both Madgraph and Powheg.

Arxiv: 1504.03511 submitted to PLB

Angular coefficients of the Z boson decay

A_0 , A_1 and A_2 : related to the polarization of the Z boson.

$$\frac{d^2\sigma}{d\cos\theta^* d\phi^*} \propto \left[(1+\cos^2\theta^*) + A_0\frac{1}{2}(1-3\cos^2\theta^*) + A_1\sin(2\theta^*)\cos\phi^* + A_2\frac{1}{2}\sin^2\theta^*\cos(2\phi^*)\right.$$
$$\left. + A_3\sin\theta^*\cos\phi^* + A_4\cos\theta^* + A_5\sin^2\theta^*\sin(2\phi^*) + A_6\sin(2\theta^*)\sin\phi^* + A_7\sin\theta^*\sin\phi^*\right].$$

A_3 and A_4: sensitive to the V-A structure of the muon couplings.

A_5 , A_6 and A_7: predicted to be small and set to zero.

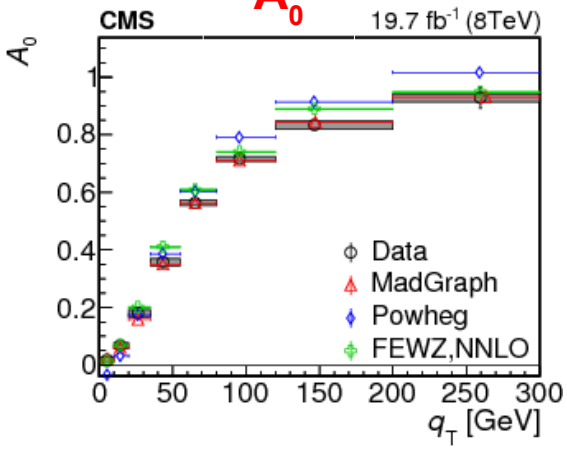
Collins and Soper, PRD 16(1977) 2219

- θ* and Φ* are the polar and azimuthal angles of the neg. charged lepton in the Z boson rest frame.
- A_0 , A_1 , A_2 , A_3 and A_4 are extracted by fitting the cos θ* and Φ* data distributions using simulated signal and background templates.

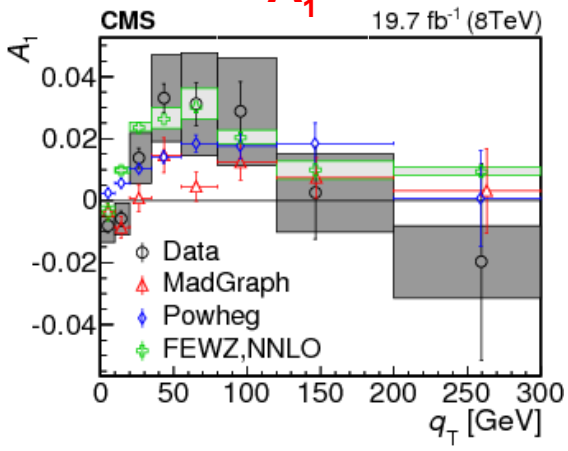
Angular coefficients of the Z boson decay

Arxiv: 1504.03512 submitted to PLB

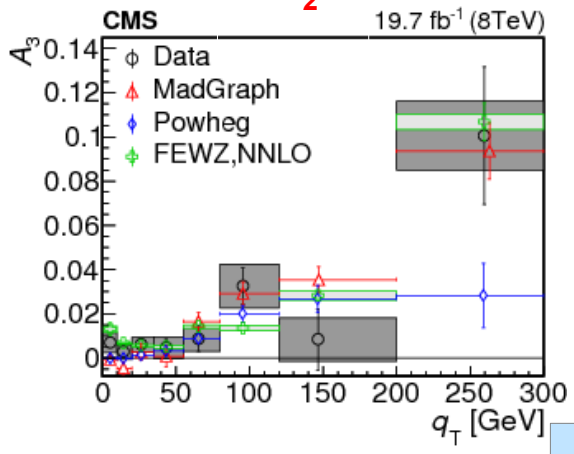
A_0



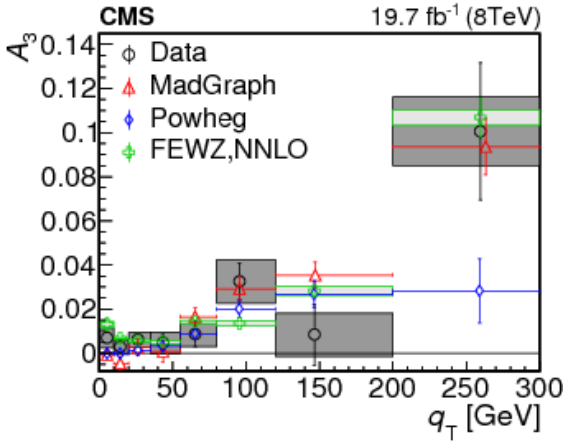
A_1



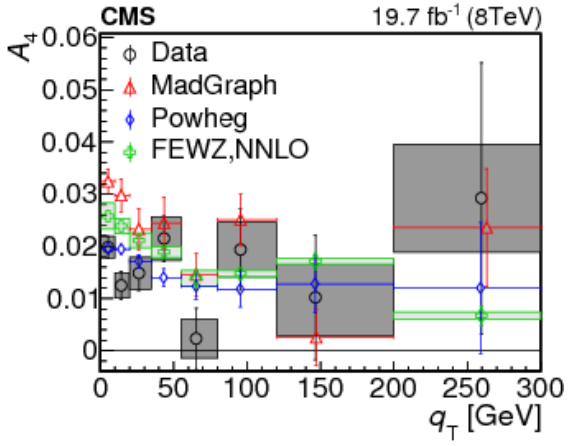
A_2



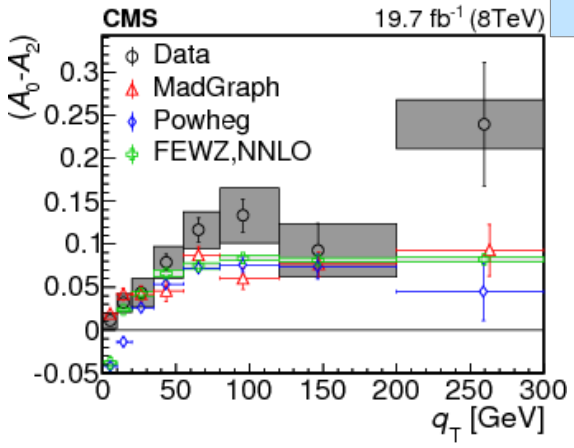
A_3



A_4



$A_0 - A_2$



|Y|<1

Event selection criteria:

- Two identified and isolated muons.
- Leading muon: p_T> 25 GeV and |η| < 2.1
- Second muon : p_T> 20 GeV and |η| < 2.4
- 81 GeV < M(μμ) < 101 GeV

Systematics

- Dominant source efficiency corrections

Theory

- FEWZ(NNLO) with CT10, Madgraph(LO) with CTEQ6L1 and Powheg(NLO) with CT10

Angular coefficients of the Z boson decay

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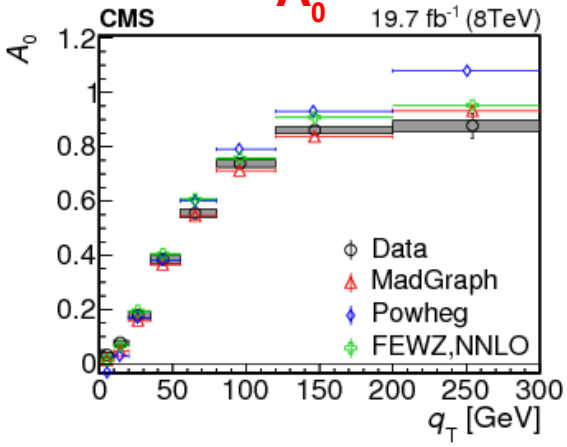
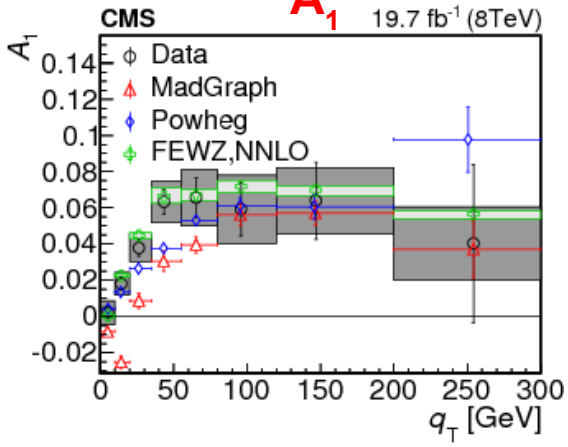
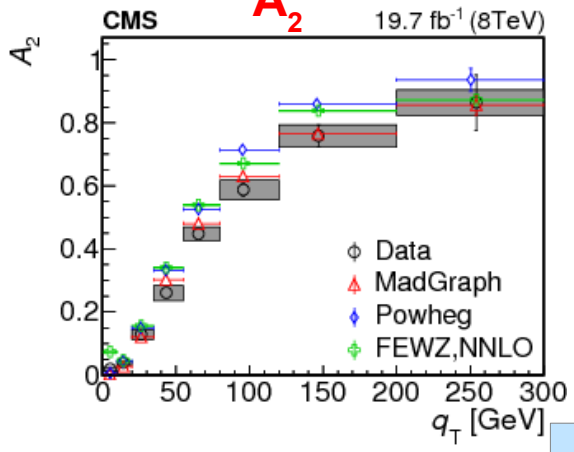
A_0



A_1

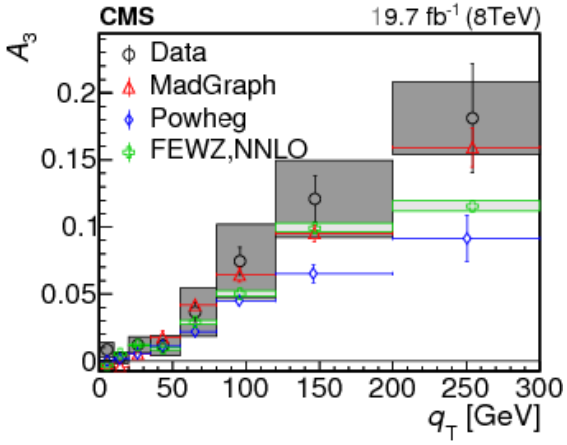


A_2

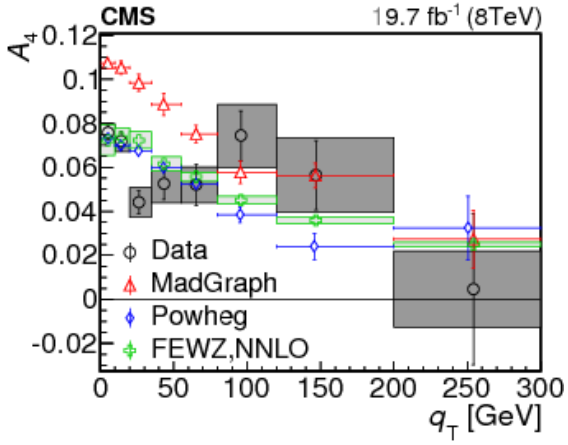


1<|Y|<2.1

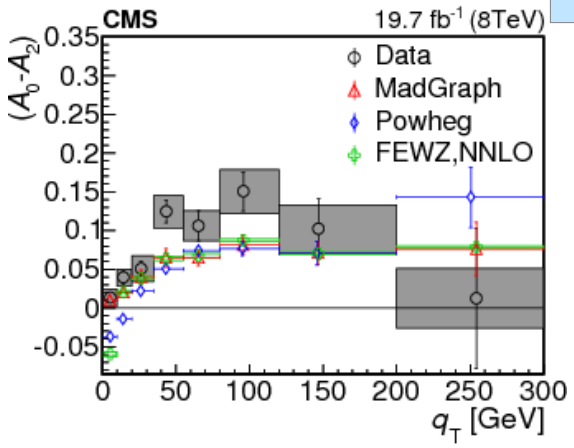
A_3



A_4



$A_0 - A_2$



Measurement in fiducial region:
8 bins of $p_T(Z)$ 0-300 GeV
2 bins of |Y(Z)| 0-2.1 .

Data-Theory agreement

- For A_0 and A_2 agreement with Madgraph is better.
- For A_1 , A_4 agreement with FEWZ and Powheg are better.

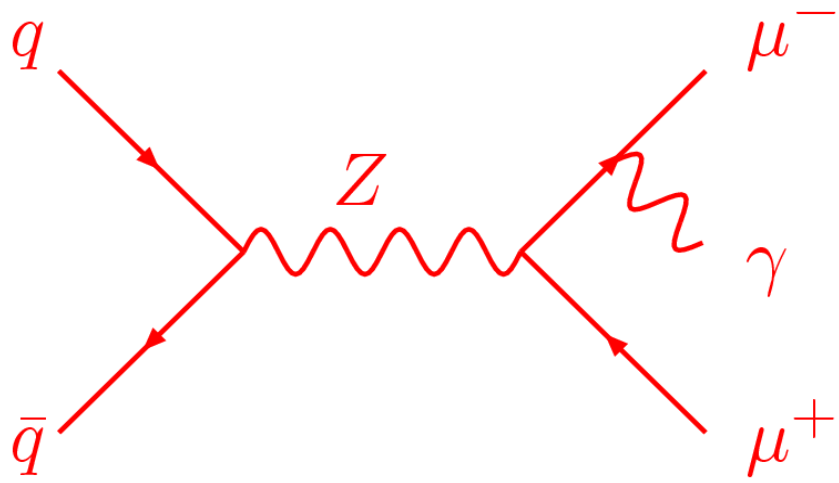
Final state radiation in Z boson decays

The following quantities have been measured:

- $d\sigma/dE_T(\gamma)$
- $d\sigma/d(\Delta R_{\gamma\mu})$

  where $\Delta R_{\gamma\mu} = \sqrt{[\,(\Phi_\gamma - \Phi_\mu)^2 + (\eta_\gamma - \eta_\mu)^2\,]}$

  The muon nearer to the photon(in terms of ΔR) is considered.



Systematics:

- $d\sigma/dE_T(\gamma)$: 5.1% - 8.9 % *
- $d\sigma/d(\Delta R_{\gamma\mu})$: 3% - 8.8 % *

  * excluding the last bin where the uncertainty is ~ 20 % arising out of background estimation.

Event selection criteria:

- Two identified and isolated muons.
- Leading muon: $p_T > 31$ GeV and $|\eta| < 2.4$
- Trailing muon : $p_T > 9$ GeV and $|\eta| < 2.4$
- Acollinearity > 0.005 radians
- $E_T(\gamma) > 5$ GeV and $|\eta(\gamma)| < 2.4$ excluding $1.4 < |\eta(\gamma)| < 1.6$
- $0.05 < \Delta R_{\gamma\mu} < 3$
- Signal region: 30 GeV < $M_{\mu\mu}$ < 87 GeV

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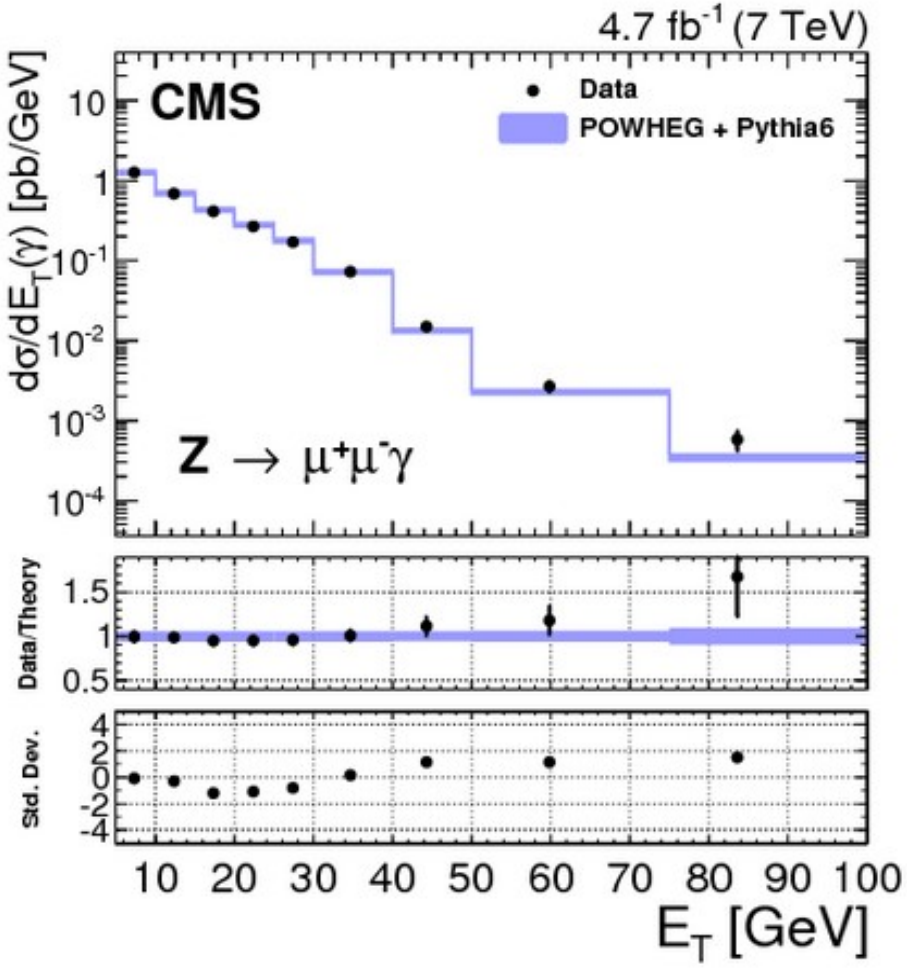
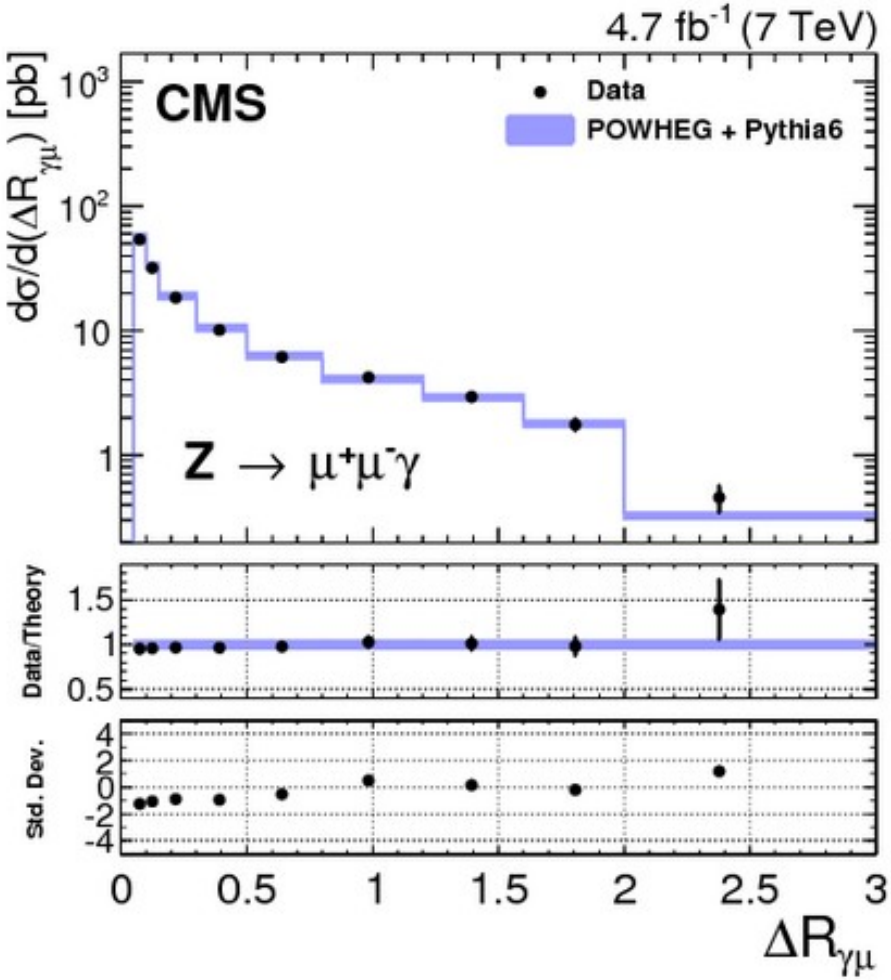
Final state radiation in Z boson decays





Theory

- **Powheg + Pythia 6 with CT10 as PDF**

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Forward-backward asymmetry in DY events

For a given dilepton mass the LO cross-section at parton level can be expressed as:

$$\frac{d\sigma}{d(\cos\theta)} = A(1+\cos^2\theta) + B\cos\theta$$

Here θ is the angle of the neg. Lepton relative to the quark momentum in the di-lepton rest frame.

A_{FB} is defined as:

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

σ_F: forward events [cos θ > 0]
σ_B: backward events [cos θ < 0]

The analysis is performed in both di-muon and di-electron final states

Event selection criteria($Z\to\mu^+\mu^-$):

- p_T> 20 GeV and |η| < 2.4 (for both muons)

Event selection criteria($Z\to e^+e^-$):

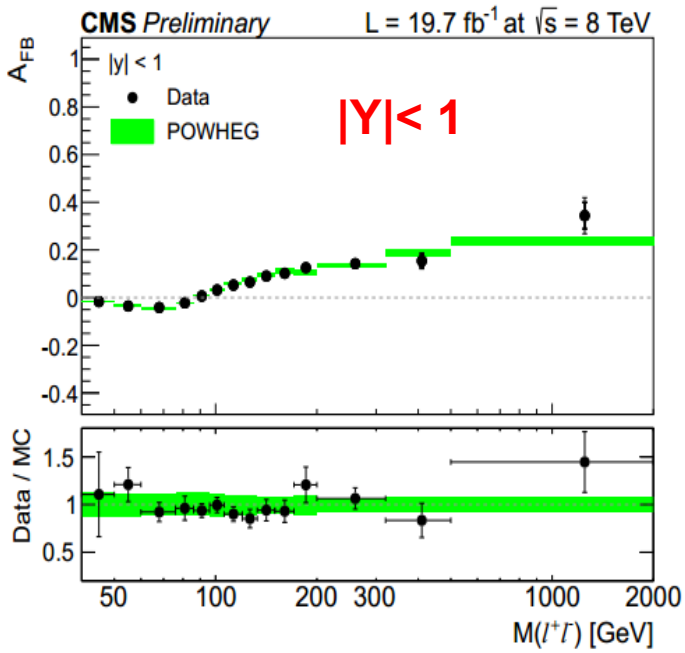
- p_T> 20 GeV and |η| < 2.4 (for both electrons)

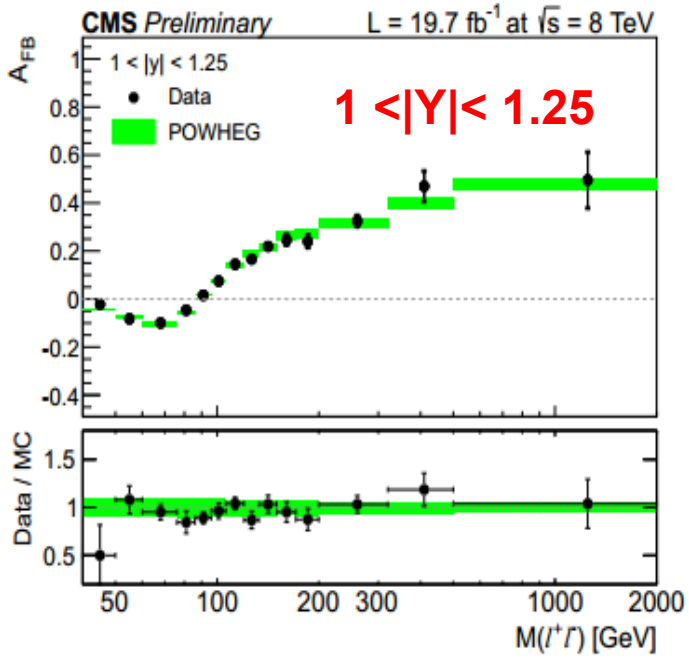
High η event selection:

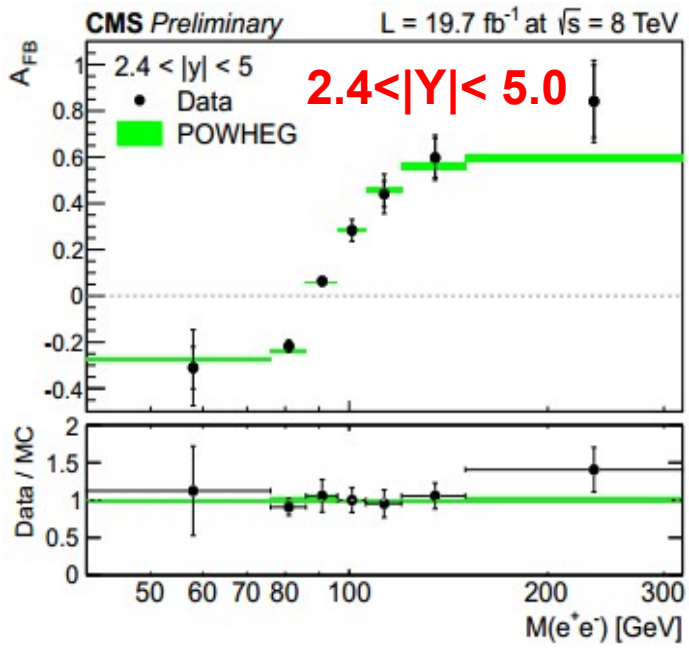
- Leading e : p_T> 30 GeV and |η| < 2.4
- Sub-leading e : p_T> 20 GeV and 3.0 <|η| < 5.0

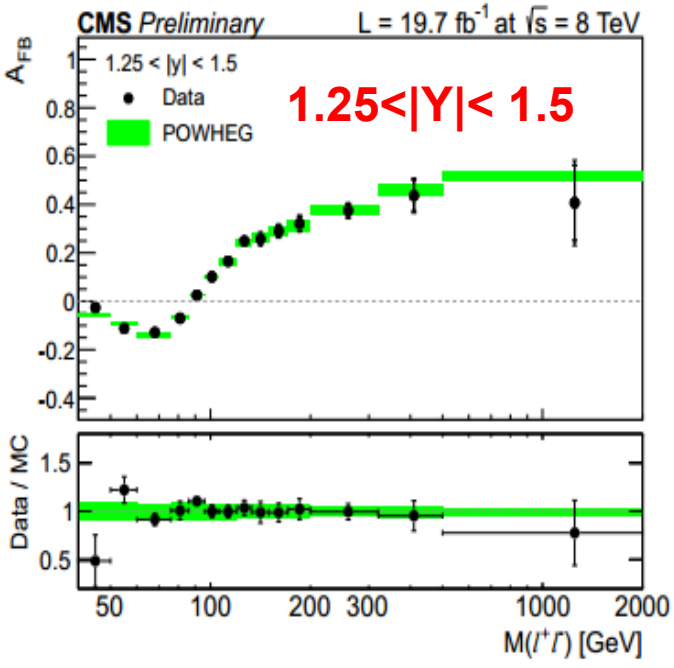
- **Measurement as a function of di-lepton invariant mass in 5 absolute rapidity bins from 0-5 .**
- **Results in the two channels for |Y|< 2.4 are combined assuming the systematics are uncorrelated between the electron and muon channels.**

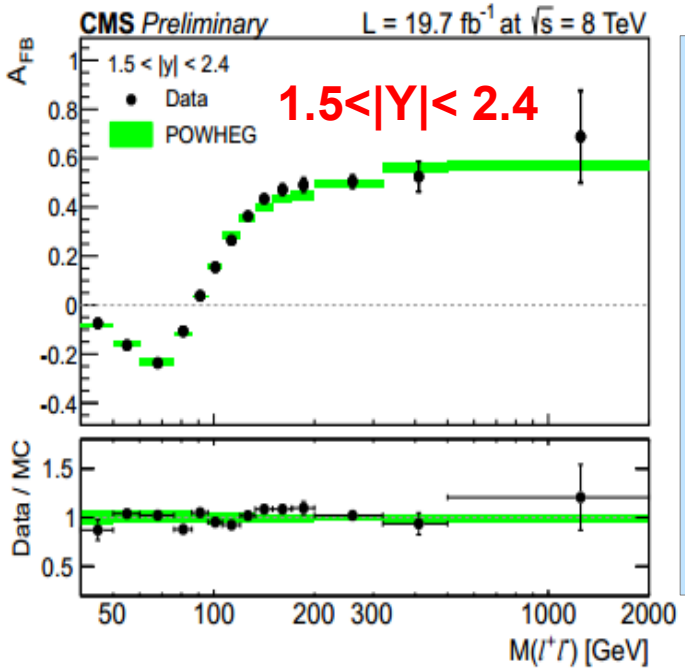
Forward-backward asymmetry in DY events











All but the top rightmost plot are combined between electron and muon channels.

Dominant systematics due to background estimation.

Results in good agreement with Powheg(NLO)+CT10

CMS-PAS-SMP-14-004

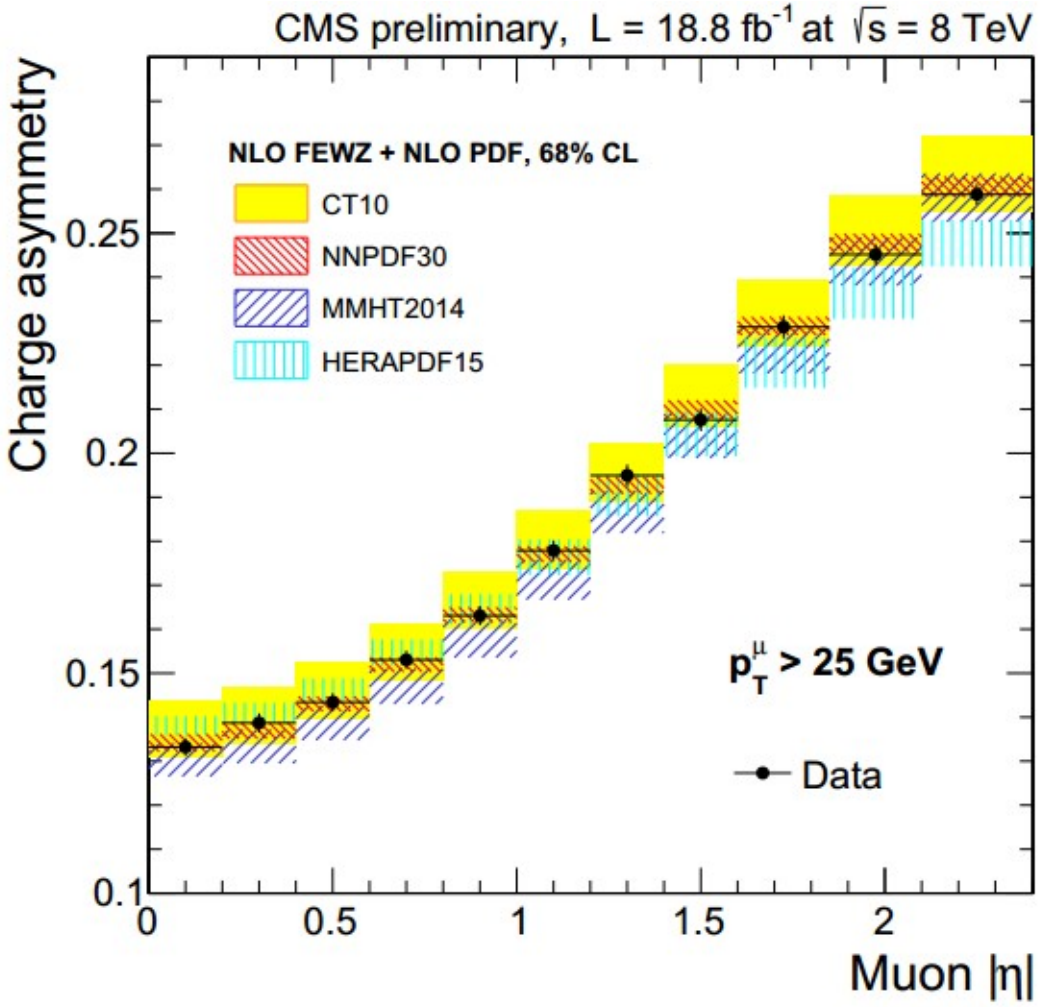
Muon charge asymmetry in W decays

Event selection criteria:

- One identified and isolated muon.
- Muon: p_T> 25 GeV and |η| < 2.4
- Veto event: If sub-leading muon p_T> 15 GeV

- Measurement in 11 bins of |η(muon)| from 0.0 - 2.4
- In each |η| bin MET templates from simulation are fitted to the MET in data.
- Fits are performed simultaneously to extract the number of W^+ and W^- events.
- Effects due to muon efficiency and FSR are corrected.
- Total systematics ~ 0.2 % - 0.26% dominated by QCD background estimation .

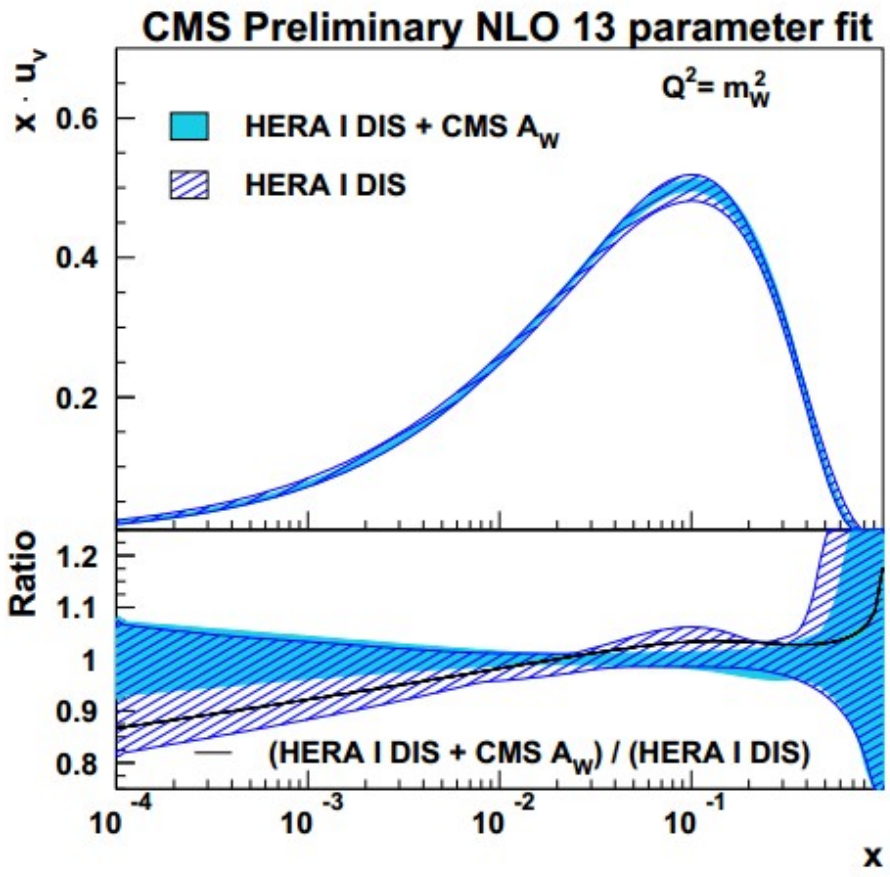
$$\mathcal{A}(\eta) = \frac{\frac{d\sigma}{d\eta}(W^+ \to \mu^+\nu) - \frac{d\sigma}{d\eta}(W^- \to \mu^-\bar{\nu})}{\frac{d\sigma}{d\eta}(W^+ \to \mu^+\nu) + \frac{d\sigma}{d\eta}(W^- \to \mu^-\bar{\nu})}$$



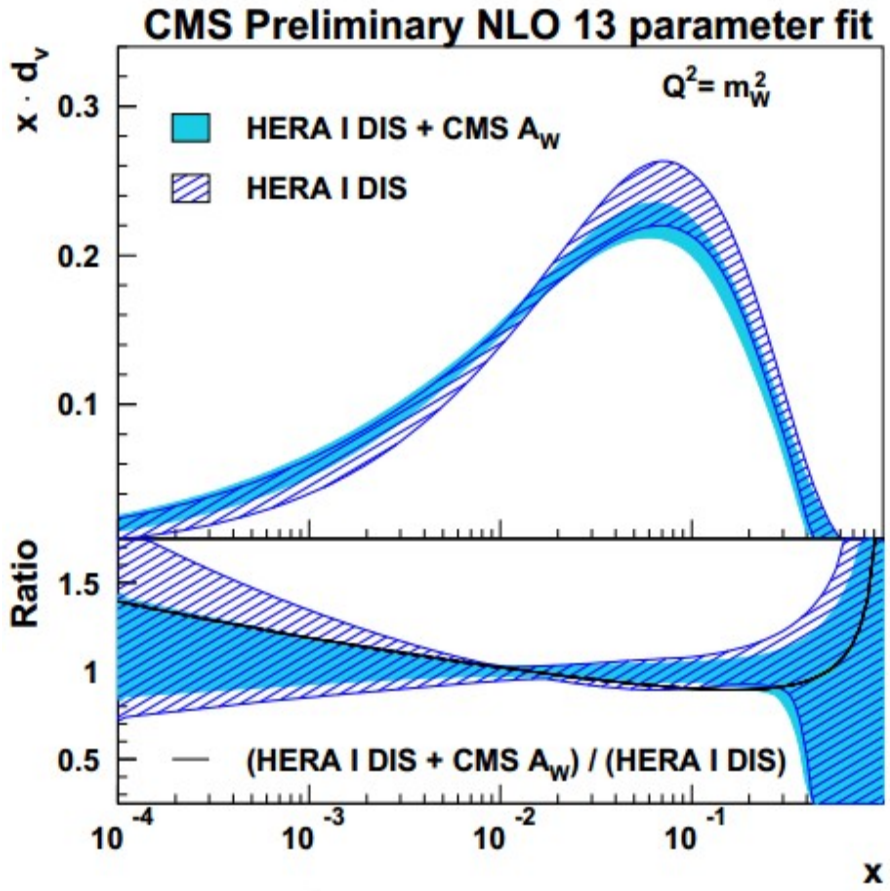
CMS-PAS-SMP-14-022

Muon charge asymmetry in W decays

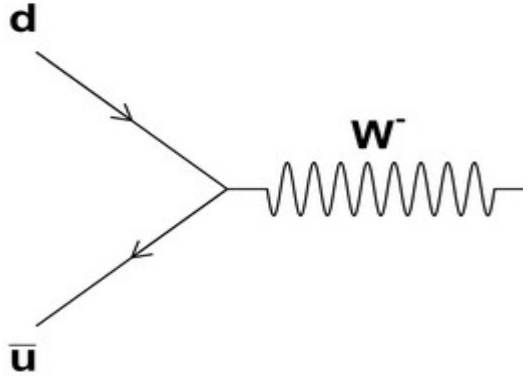
Valence up quark PDF



Valence down quark PDF



- **Fits performed using the current measurement along with HERA I DIS data**
- **The theory for the charge asymmetry is obtained using MCFM(NLO)**
- **Clear improvement in the precision of the valence quarks PDFs over the entire x range is seen**



CMS-PAS-SMP-14-022

Summary

- Measurements with W/Z events using the full 8 TeV dataset at CMS are presented.
- The results compared with the current standard model predictions agree fairly well.
- The uncertainties in these mesurements are well understood and are mostly below that of the corresponding theoretical predictions.
- Hence more precise theoretical calculations are needed for better agreement with data.
- A clear impact of these measurements is seen in better constraining the parton distribution functions.

THANK YOU

BACKUP

Event reconstruction and selection

Electrons(|η| < 2.5)

- Identification based on shower shape variables.
- Isolation criteria removing contribution from pileup.
- Use information from ECAL and tracker.

Electrons(3.0<|η| < 5.2)

- Using information from HF
- Identification based on shower shape variables.
- No charge information.

Muons((|η| < 2.4)

- Using information in the tracker and muon chambers.
- Identification based on track quality criteria.
- Isolation criteria removing contribution from pileup

Missing transverse energy(MET)

- Negative vector sum of all reconstructed objects.