W and Z Results in CMS

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On behalf of the CMS Collaboration

LHC EW WG meeting

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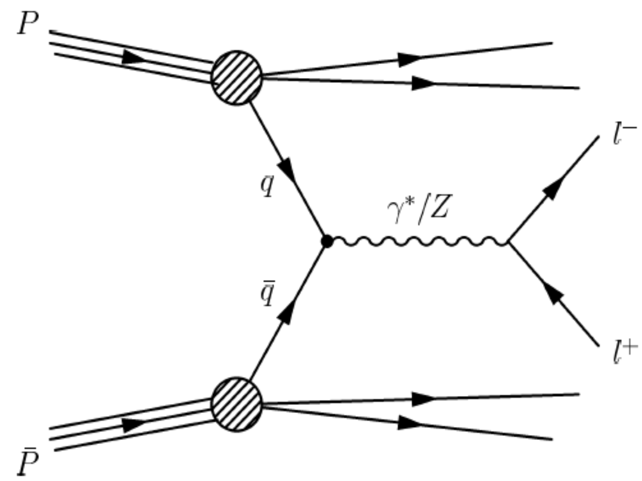
Outline

- Drell-Yan differential cross section at 7 TeV (new in 2013)
- Forward-Backward asymmetry of DY process at 7 TeV
- W charge asymmetry in electron channel at 7 TeV
- Inclusive W and Z cross section at 8 TeV
- Z transverse momentum distribution at 8 TeV (new in 2013)

Drell-Yan Cross Section

- Drell-Yan process
  - Is an important Standard Model benchmark channel
  - Theoretical cross section calculated up to NNLO
    - allowing tests of perturbative QCD
  - Differential cross section dσ/dM depends on PDFs
    - can be used to constrain PDFs
  - Drell-Yan is an important background for searches for physics beyond the Standard Model



- We measure
  - Differential cross section $(1/\sigma_Z)d\sigma/dM$ in dimuon and dielectron channel
  - Double differential cross section $(1/\sigma_Z)d^2\sigma/dMdY$ in dimuon channel

DY Cross Section Measurement

- Full 7 TeV dataset is used; both dimuon and dielectron channel
- Measure the differential cross section $(1/\sigma_Z)d\sigma/dM$
  - normalize differential cross sections to the cross section at the Z peak
  - performed in muon and electron channel
- Measure the double differential cross section $(1/\sigma_Z)d^2\sigma/dMdY$
  - measurement directly usable to constraint PDFs
  - performed in muon channel $|Y| < 2.4$
- Drell-Yan samples are produced with POWHEG MC generator
  - rescaled to NNLO cross section from FEWZ
- Cross section measurement per bin:

Take advantage of the CMS detector's capabilities to measure very low mass DY

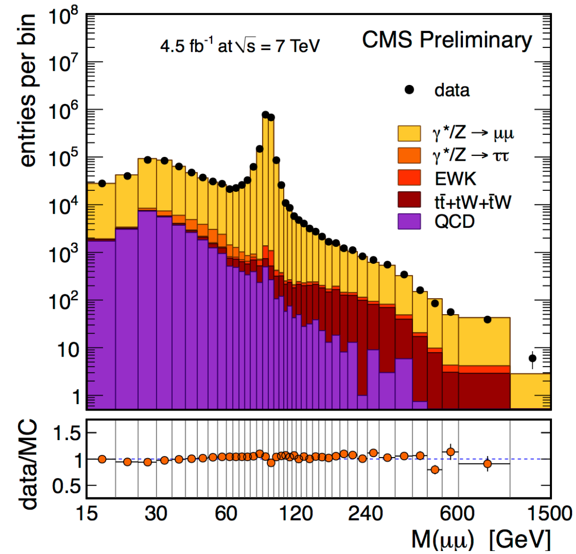
$$\sigma_{i,j} = \frac{N^u_{i,j}}{A_{i,j} \cdot \varepsilon_{i,j} \cdot C_{i,j} \cdot L_{\text{int}}} \qquad R_i = \frac{1}{\sigma_Z}\frac{d\sigma}{dM}$$

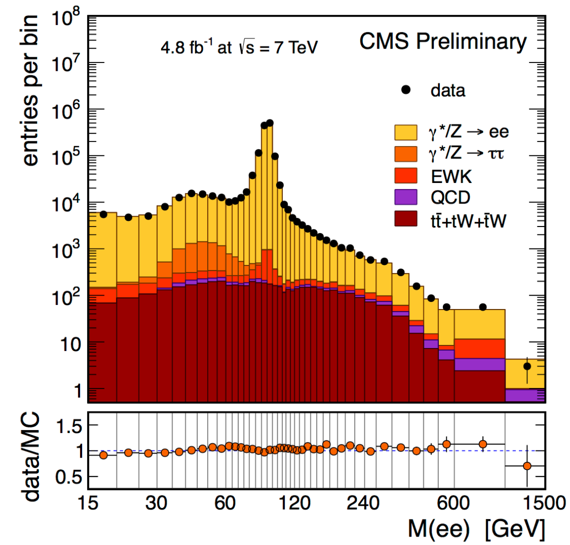
- Note: the acceptance correction is not applied for the 2D measurement

Background Estimation (1)

- Muon channel:
  - Low-mass region: QCD multi-jets
  - Peak region: Drell-Yan $\rightarrow \tau^+\tau^-$, W $\rightarrow l\nu$, dibosons
  - High-mass region: top pair production, dibosons
  - Top quark background is estimated by combining the data-driven e-μ method and MC prediction
    - Applicable for processes decaying to eμ and μμ
    - Reduces systematics in 200-1000 GeV region by 5-10%
  - QCD background determined using the data-driven ABCD method
    - Use muon isolation and charge sign variables to estimate QCD
- Electron channel:
  - Low-mass region: Drell-Yan $\rightarrow \tau^+\tau^-$, top pair production
  - Peak region: top pair production, dibosons
  - High-mass region: top pairs, singe top, dibosons
  - Data-driven technique to estimate backgrounds
    - e-μ method: Drell-Yan $\rightarrow \tau^+\tau^-$, top pairs , WW, single top
    - Fake rate: QCD, W+jets

CMS-PAS-SMP-13-003



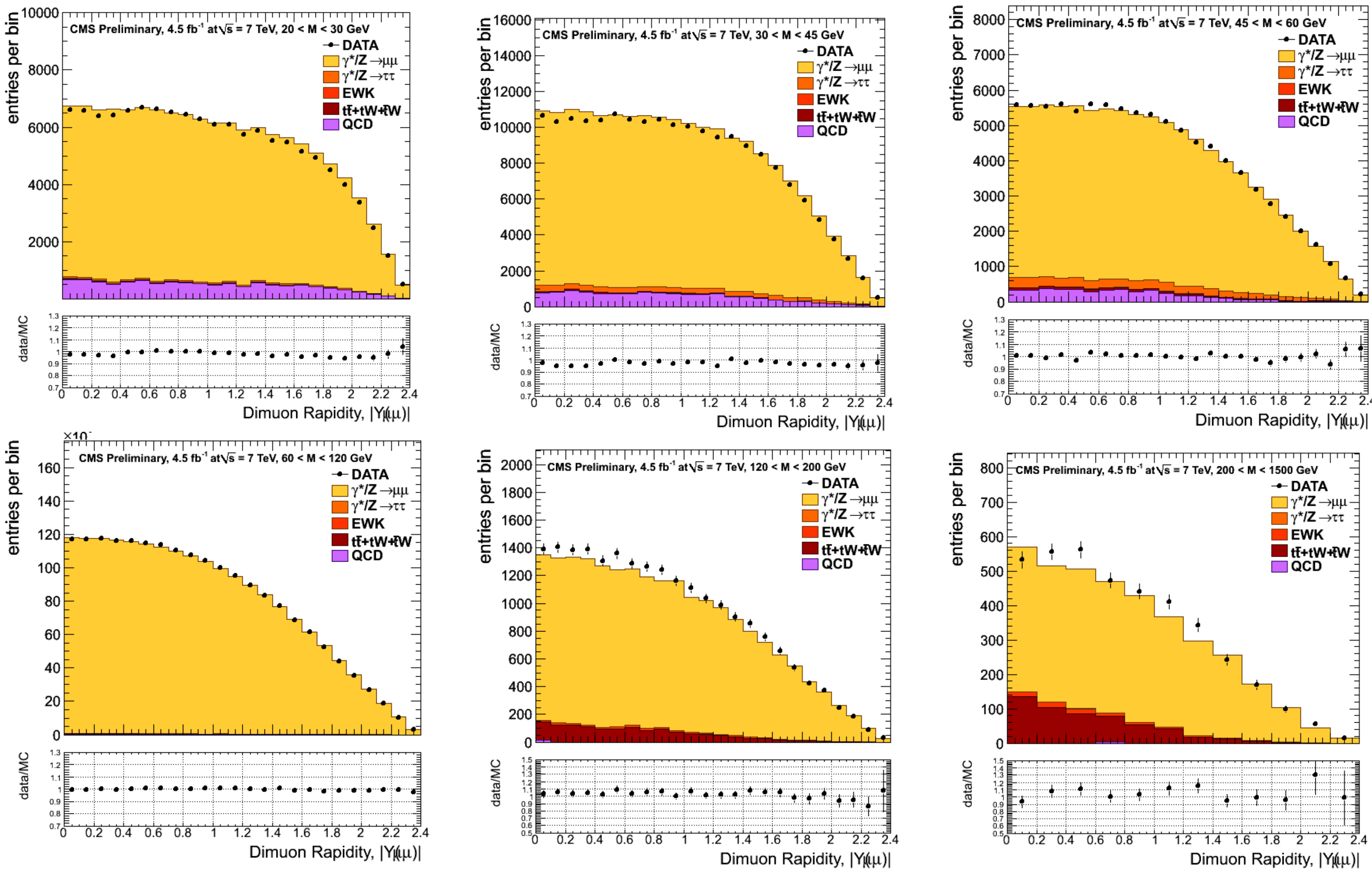


Mass spectrum in the detector acceptance for data and MC events.
The signal is normalized to the NNLO cross section.

Background Estimation (2)

- Dimuon rapidity distributions in 6 mass bins

CMS-PAS-SMP-13-003



Acceptanc and Efficiency

- Acceptance*efficiency is derived from MC according to:

$$A \cdot \varepsilon = \frac{N^{Acc}}{N^{GEN}} \cdot \frac{N^{RECO}}{N^{Acc}} = \frac{N^{RECO}}{N^{GEN}}$$

N_X – number of generated events, with X:
GEN – initial
ACC – in the acceptance
SEL – (RECO) selected

- The acceptance accounts for the lepton p_T and η cuts, the efficiency reflects the full selection
- Efficiencies for leptons are measured using data driven techniques
  - MC efficiencies are corrected to match data
- FEWZ NNLO reweighting procedure is applied to correct for model dependence
- The lepton kinematic distributions are very sensitive to the exact description (especially for very low invariant mass)
  - Thus for proper description of the low invariant mass region NNLO is mandatory

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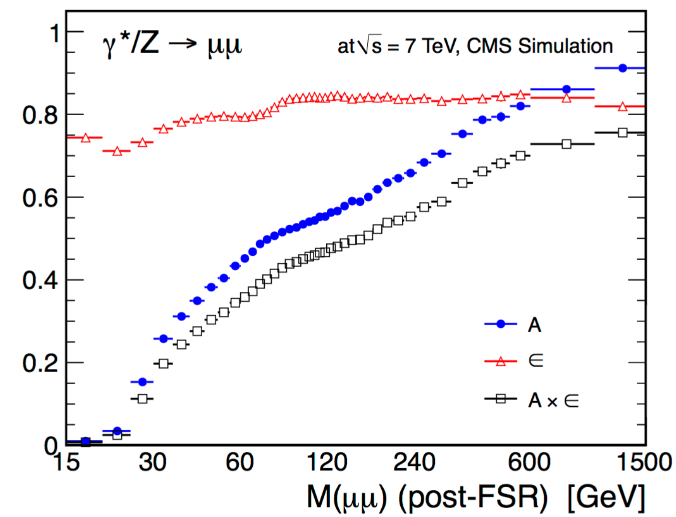

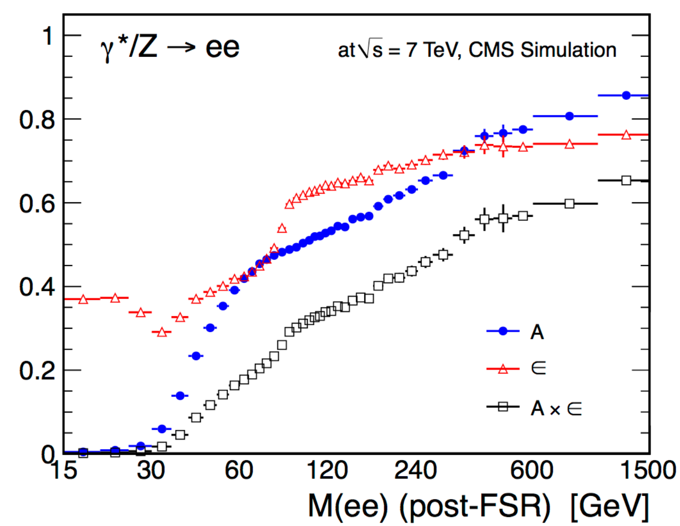

Result of $(1/\sigma_Z)d\sigma/dM$

- $d\sigma/dM$ is measured in 40 mass bins covering the range from 15 to 1500 GeV
- Normalized to Z peak: 60 < M < 120 GeV
- Pre-FSR full acceptance normalizated cross section in dimuon and dielectron
- The uncertainty in the dimuon channel is dominated by efficiency corrections (1%), and FSR systematics (0.3%)
- The uncertainty in the dielectron channel is dominated by the energy scale corrections (0.7%)
- Very good agreement with NNLO theoretical prediction

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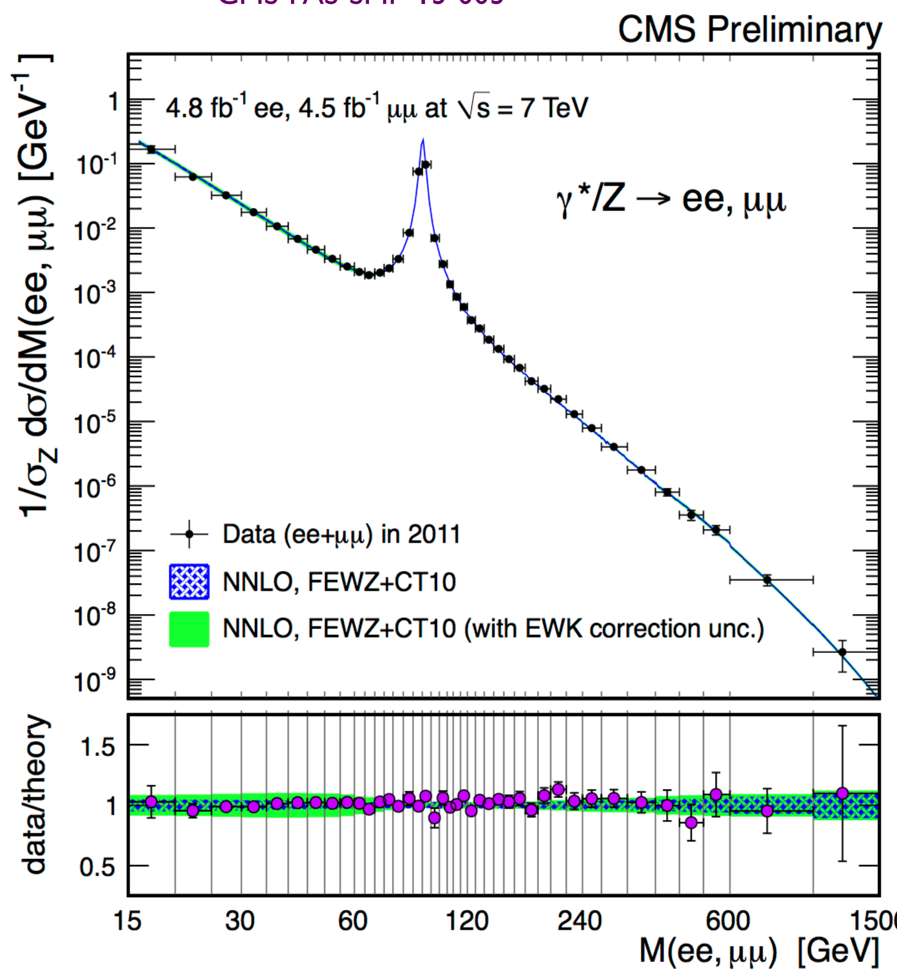

The blue error band for the theory calculation includes the statistical error from the FEWZ calculation and 68% confidence limit (CL) PDF uncertainty combined in quadrature. The uncertainty of EWK correction including γγ initiated processes effect is added in the green error band.

Results of $(1/\sigma_Z)d^2\sigma/dMdY$ (1)

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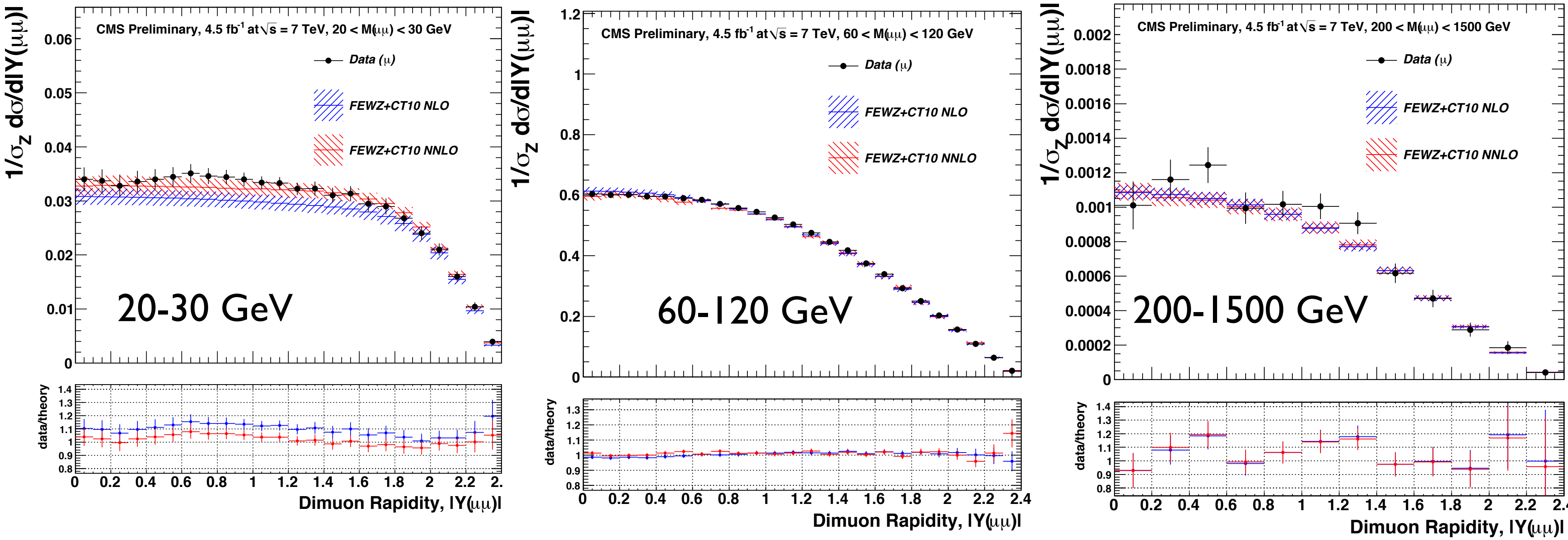
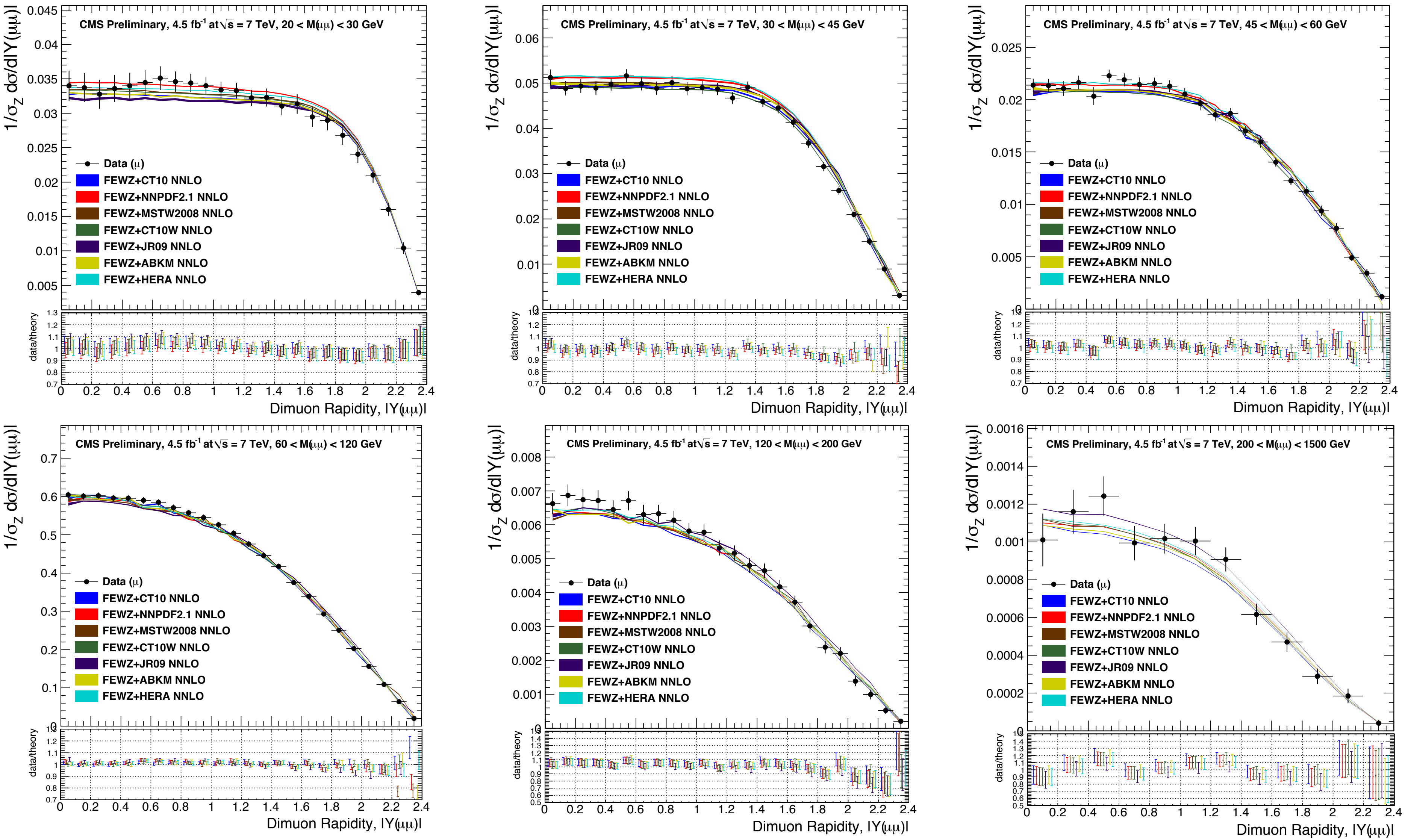


- Measurement within the detector acceptance, to reduce the model dependence
- Performed in 24 rapidity bins between 0 and 2.4 (12 Y-bins for the highest mass bin) and 6 mass ranges: (20-30), (30,45), (45,60), **(60,120)**, (120, 200), (200,1500) GeV
- Low mass very sensitive to PDF uncertainties
- Comparing to FEWZ + CT10 NLO and FEWZ + CT10 NNLO

Results of $(1/\sigma_Z)d^2\sigma/dMdY$ (2)



- Comparison with various NNLO PDF sets: ABKM, CT10, CT10W, HERA, JR09, MSTW2008, NNPDF

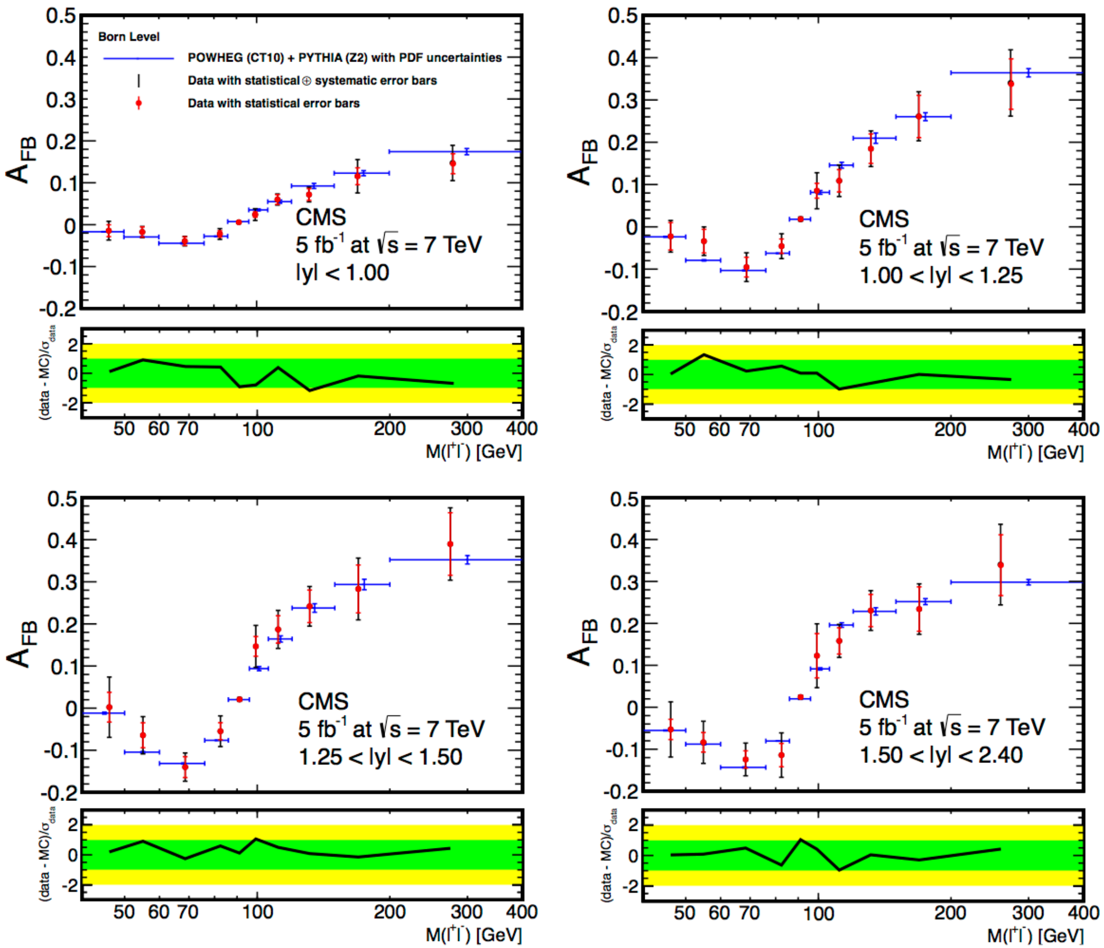
CMS-PAS-SMP-13-003

Forward-Backward Asymmetry

$$\frac{d\sigma}{d\cos\theta^*} = C\left[\frac{3}{8}(1+\cos^2\theta^*) + A_{FB}\cos\theta^*\right] \qquad A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$$

Phys. Lett. B 718 (2013) 752

- Z-γ* interference leads to Forward-Backward asymmetry in the DY process
- AFB sensitve to the effective $\sin^2\theta_W$ parameter in the SM
- Expect zero asymmetry at the Z peak region, negative in low mass region and positive in high mass region
- Unfolded, combined (ee and mumu), and Born level AFB is measured with acceptance cuts
  - pT > 20 GeV, |η| < 2.4, M(ll) > 40 GeV
- Good agreement with SM predictions

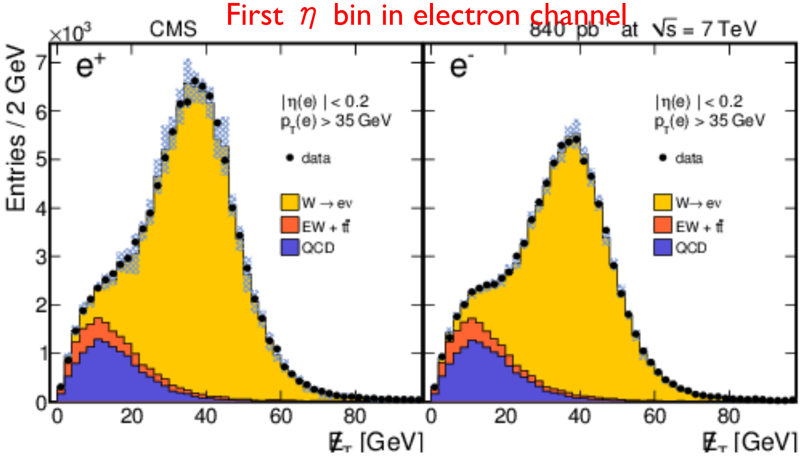


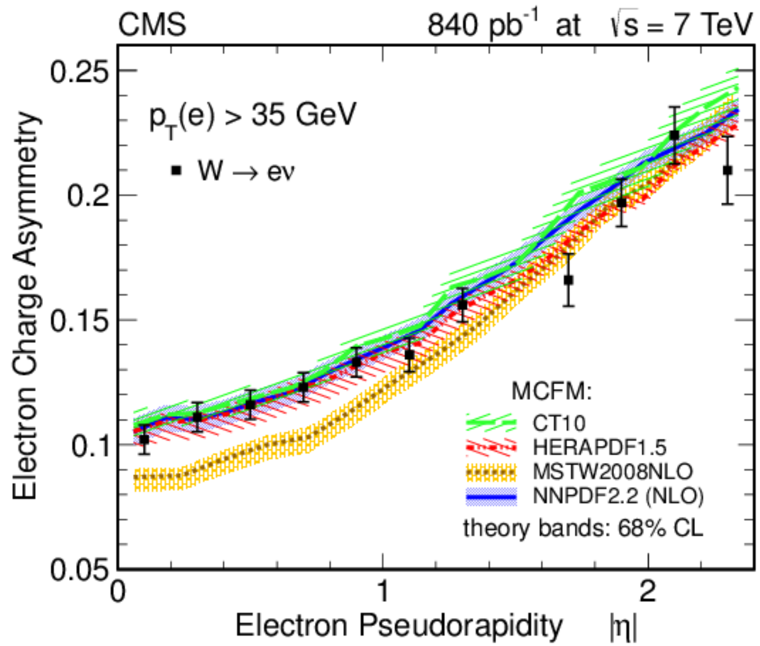
W Charge Asymmetry in Electron Ch.

- Up/down valence quark distribution in pp collisions results in rate difference between positive and negative W bosons
- An asymmetry measurement as a function of the lepton η can be used to constrain PDFs
- Use 840/pb at 7 TeV
- Background contribution increases with η
- The main uncertainties are from signal/ background shape variations and energy scale
- Good agreement with NLO predictions *except* MSTW

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

First η bin in electron channel



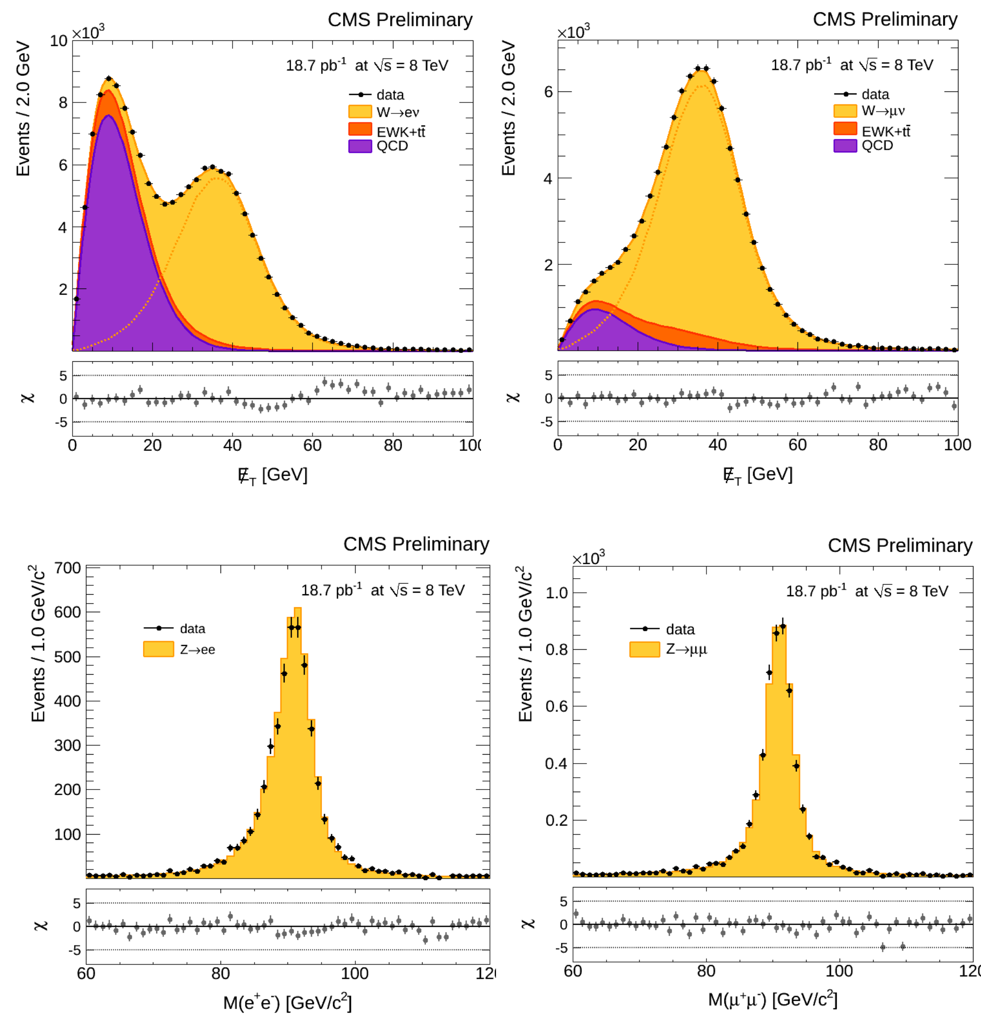


PRL 109 (2012) 111806

Inclusive W and Z Cross Sections

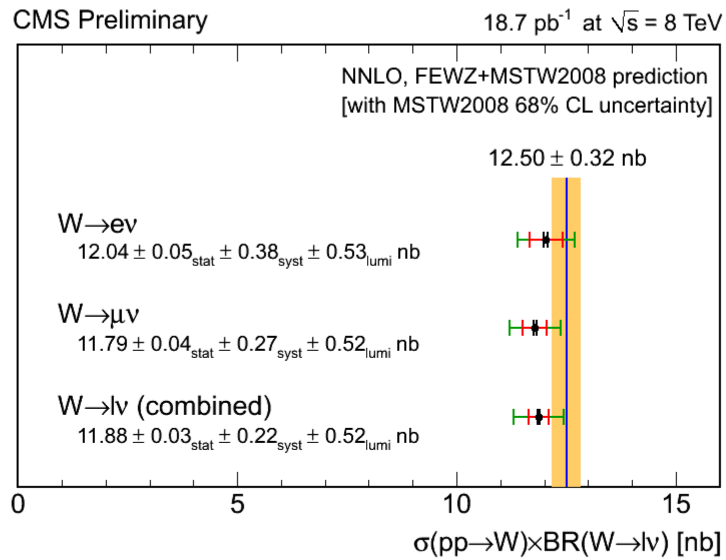
- Measure the inclusive W and Z cross section at 8 TeV with low pileup event (~5 pileup events on average)
  - CMS requested special LHC conditions during luminosity ramp up
  - 18.8 / pb
  - Similar way like the measurement with 2010 data (36/pb)
    - J. High Energy Phys. 10 (2011) 132
    - Measurement with 1% precision
- Signal extraction
  - W: template fit on the MET distribution
  - Z: cut and count
- Efficiencies, resolutions, acceptances are corrected

CMS-PAS-SMP-12-011



Results of W/Z Cross Sections at 8 TeV

- From pQCD prediction we expect an increase of the cross section of 15 - 20 % from 7 to 8 TeV
- Measure the W/Z, W^+/W^- ratios and the 7/8 TeV ratio to test pQCD
- Good overall agreement with theory predictions at NNLO both at 7 and 8 TeV



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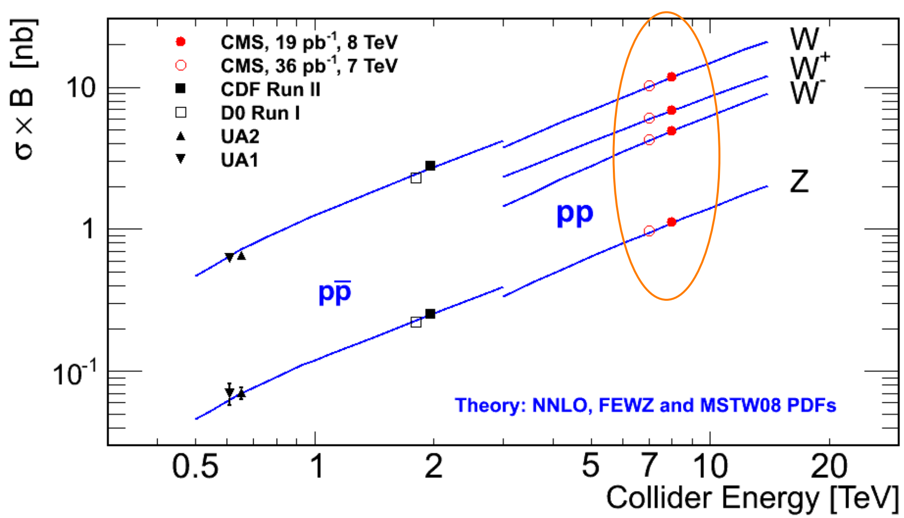
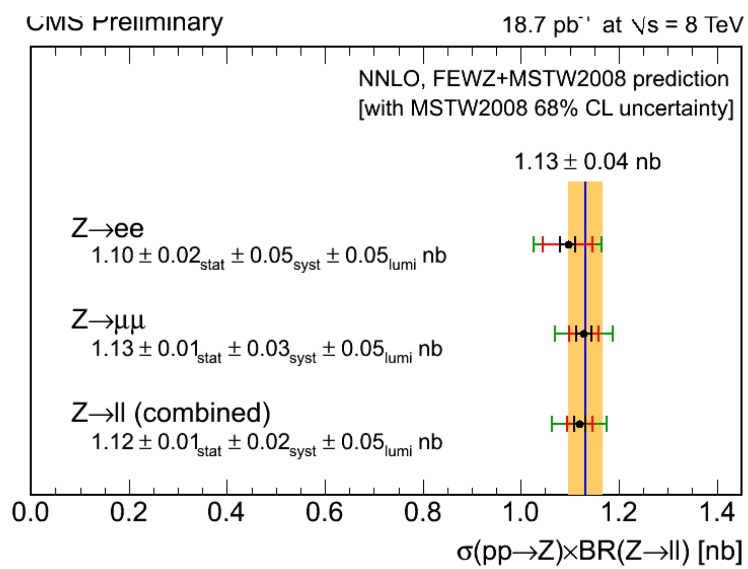
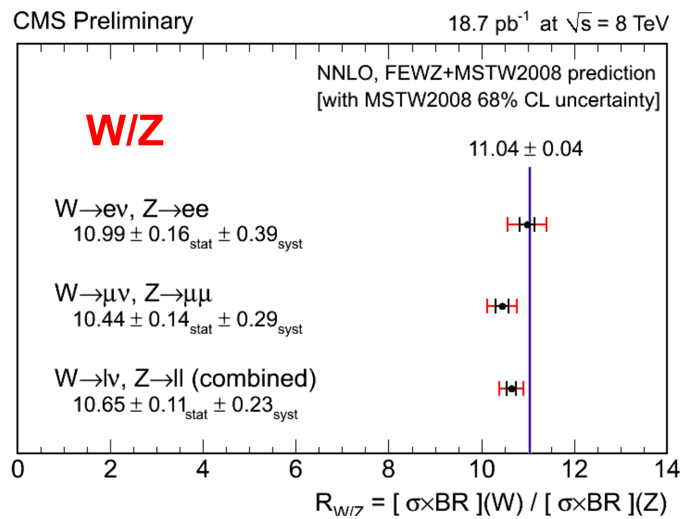


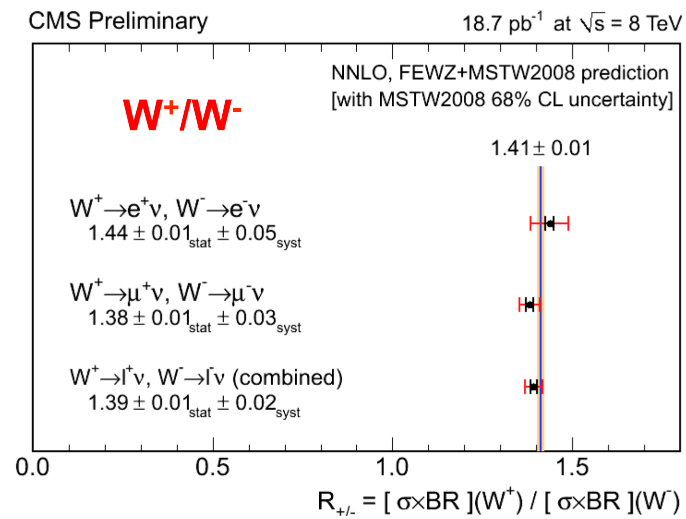


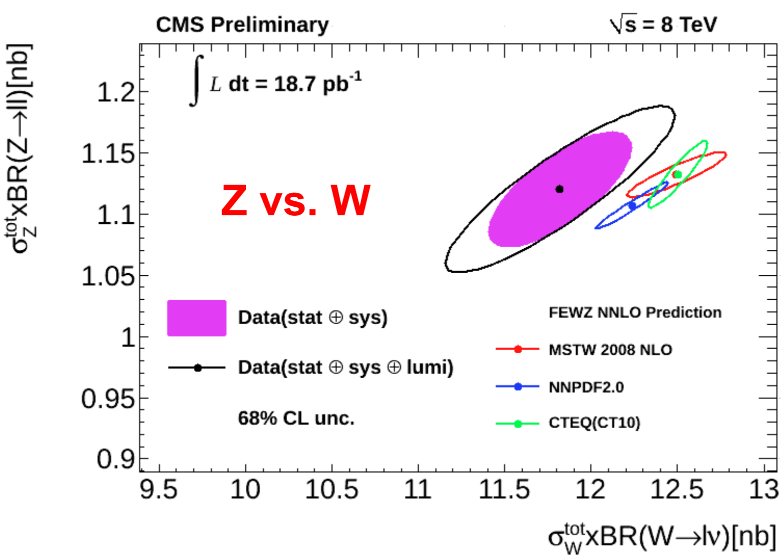
Ratio of Cross Sections at 8 TeV

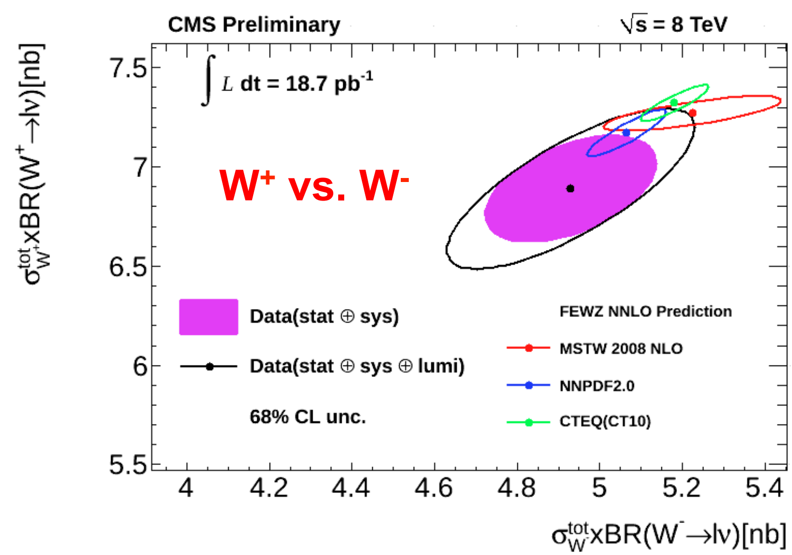
CMS-PAS-SMP-12-011

- Cancelation of both experimental and theoretical systematic errors in ratio
- W/Z ratio at 8 TeV: 1.5 sigma difference with most PDFs



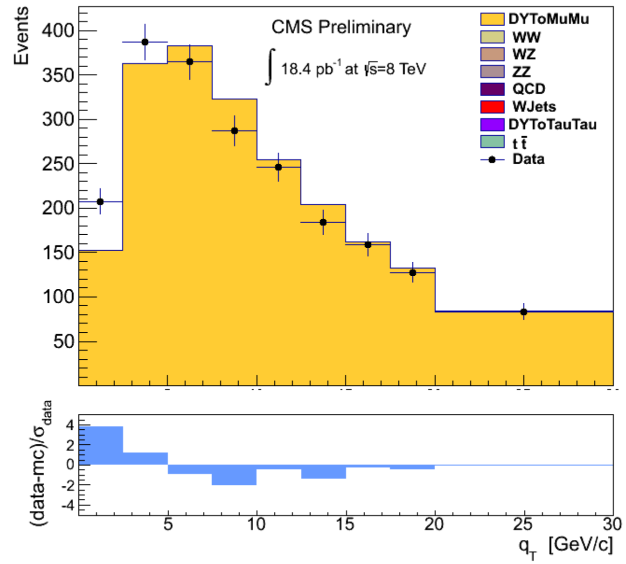


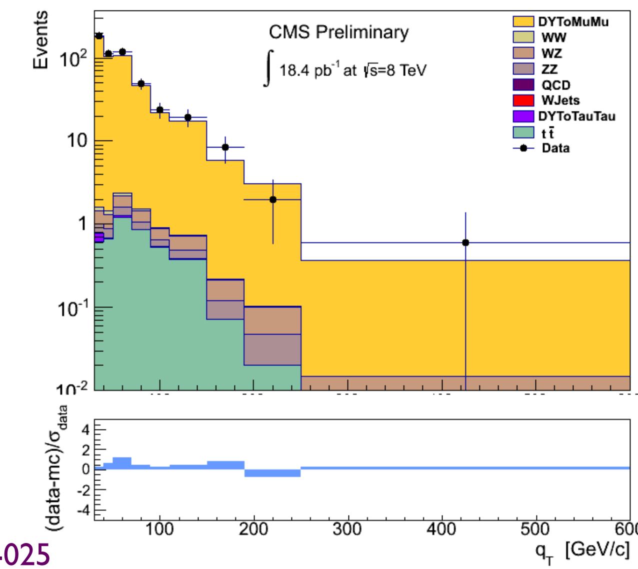




Z Transverse Momentum

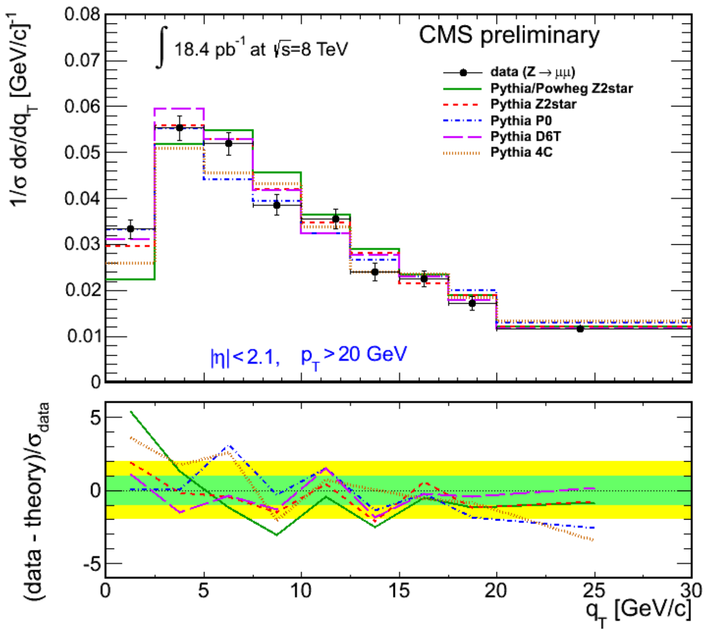
- Z boson is produced with a non-zero qT because of quark/gluon radiation from the initial-state partons
  - Non-perturbative prediction of soft gluon emission in the low qT range
  - Perturbative QCD prediction for hard gluon radiation in the initial state in the high qT range
- Measure the Z qT differential cross section at 8 TeV
  - Use low pileup data (18/pb)
  - Muon channel only
  - Similar way like the measurement with 2010 data (36/pb)
    - Phys. Rev. D 85 (2012) 032002
- Background estimation using data-driven method
- Efficiency, resolution, FSR, acceptance are corrected
- Statistical uncertainty is dominant

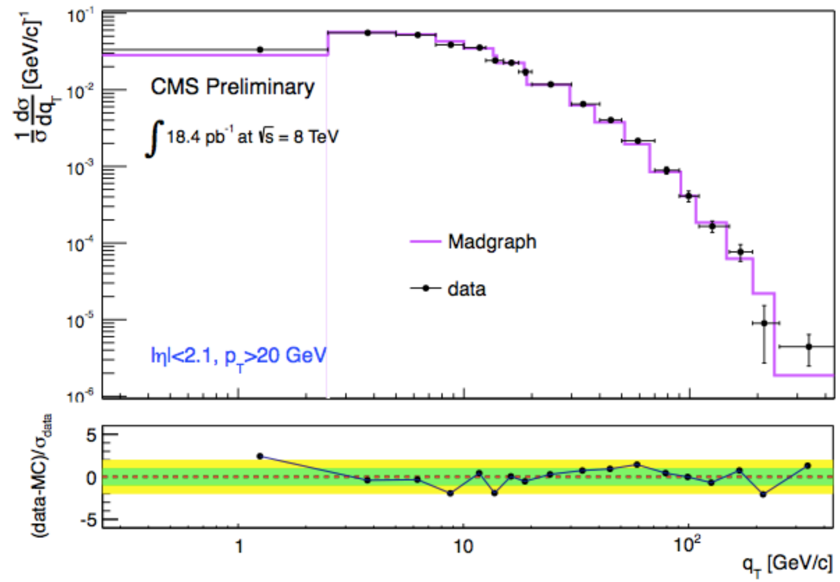




CMS-PAS-SMP-12-025

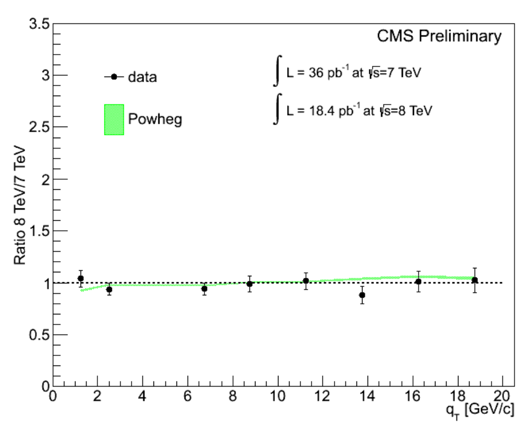
Results of $(1/\sigma_Z)d\sigma/dqT$ at 8 TeV

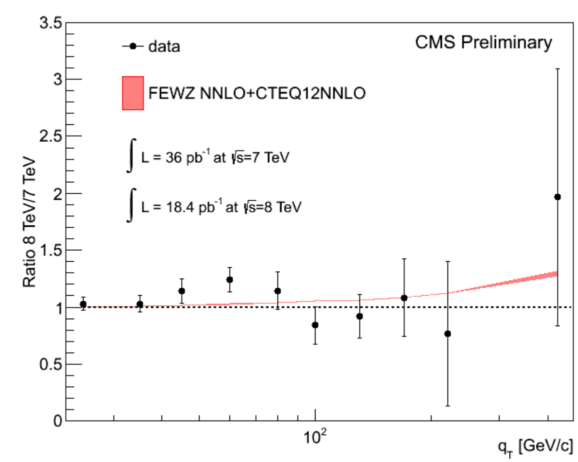




CMS-PAS-SMP-12-025

- Pythia+Z2star has good agreement in low qT regime
- Madgraph has good agreement in high qT regime
- Overall good agreement in the ratio of data and the theory predictions





Summary

- Impressive amount of EWK results from CMS
  - Precise test of the Standard Model at TeV scale
  - Results from ATLAS and CMS are in general in agreement
  - Agreement with theory across orders of magnitude
  - Starting to set serious constraints on electroweak parameters and PDFs
  - Measurements are challenging NLO and NNLO predictions
- You can find all details in the following link:
  - https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP#Vector_Boson_Production
  - Many more public results in the link
- Still most of the LHC data at 8 TeV to be analyzed
  - More results with improved precision expected soon, stay tuned!