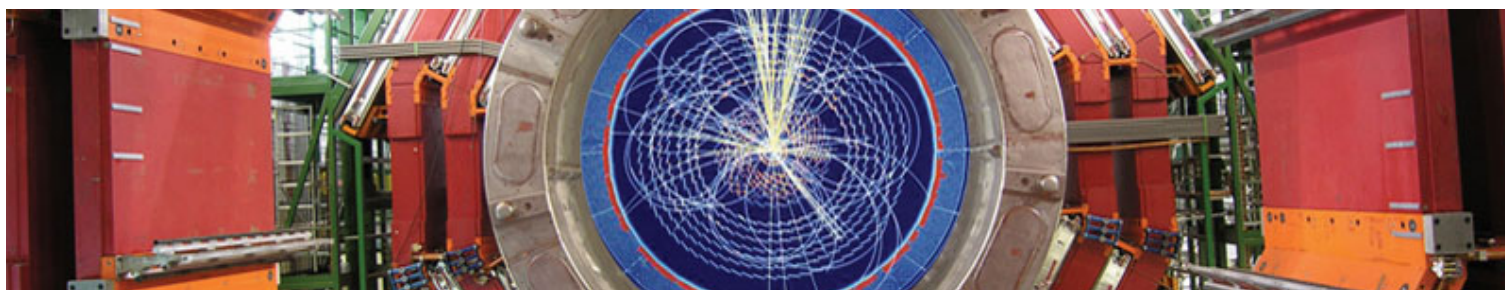


W and Z Studies at CMS



Hwidong Yoo
Purdue University

On behalf of the CMS Collaboration

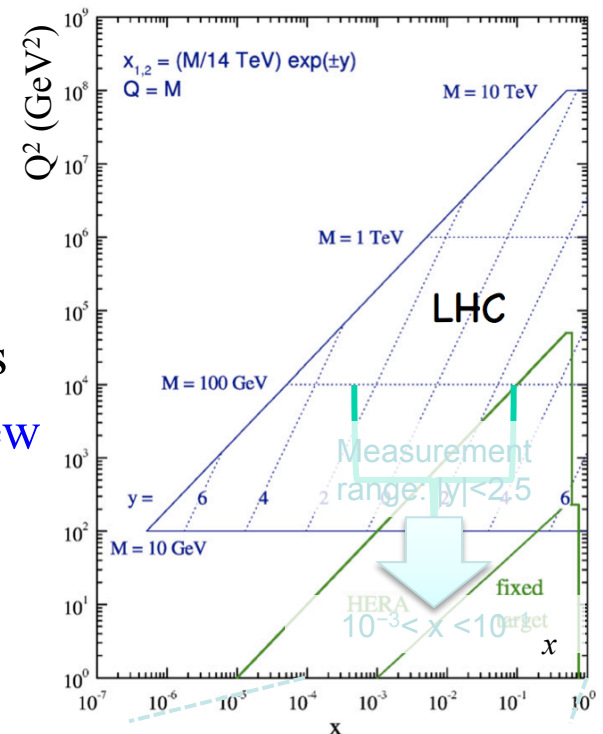
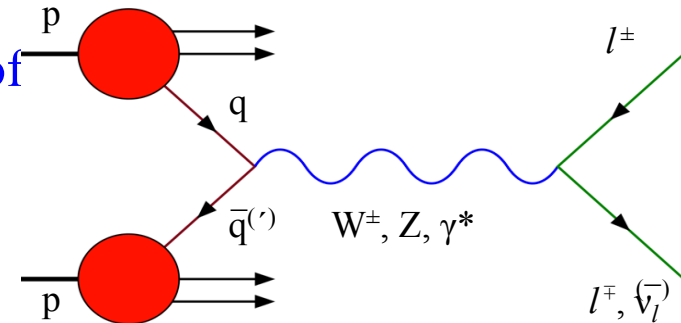
LHCP 2014, New York, USA

Outline

- Present latest public results from CMS with 7 and 8 TeV data
- Inclusive W and Z boson cross sections at 8 TeV
 - Phys. Rev. Lett. 112, 191802 (2014)
- Muon charge asymmetry at 7 TeV
 - Submitted to Phys. Rev. D (arxiv:1312.6283)
- Drell-Yan differential cross section at 7 TeV
 - J. High Energy Phys. 12 (2013) 30
- Measurement of Z production as a function of pT and Y at 8 TeV
 - CMS-PAS-13-013 → **New result!**
 - <http://cds.cern.ch/record/1700115?ln=en>
- All other public results are available at
 - <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP>

W and Z Production at LHC

- Physics motivation: precision physics and tests of the Standard Model
 - W and Z productions are theoretically well understood
 - Constrain PDFs
- W and Z events are used to understand and calibrate our detector response
 - High rates at the LHC
 - Clean signal with leptonic decays
 - Trigger, identification, resolution, efficiencies
- They are important background in searches for new particles



Cross Section and Charge Asymmetry

Cross Section

$$\sigma = \frac{N^{\text{observed}} - N^{\text{background}}}{\text{Acceptance} \cdot \text{Efficiency} \cdot \text{Correction} \cdot \text{Luminosity}}$$

Number of events observed from data

Number of estimated background events

Determine from simulation

Scale factor between data and MC simulation

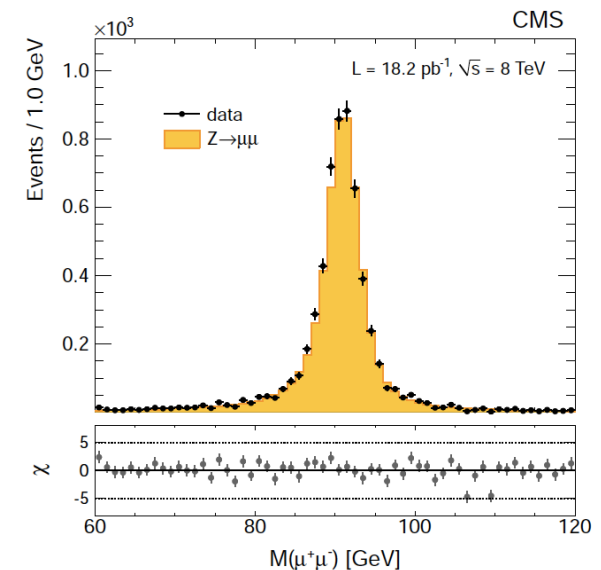
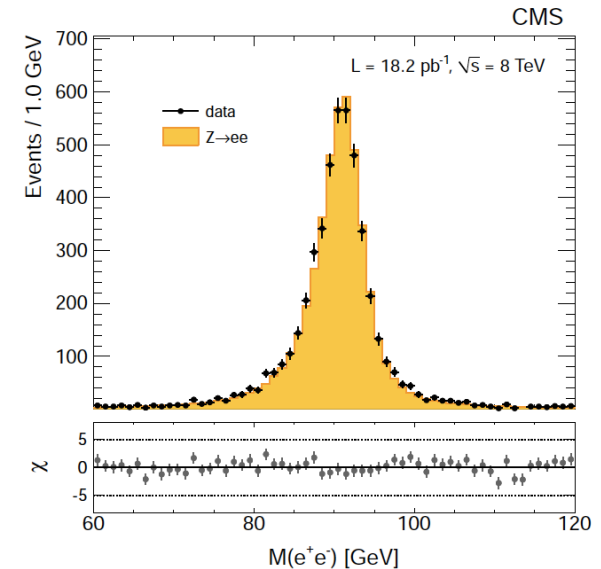
2011(7TeV): ~5/fb
2012(8TeV): ~20/fb
~2.6% uncertainty

Charge Asymmetry

$$A(\eta) = \frac{\frac{d\sigma}{d\eta}(W^+ \rightarrow l^+\nu) - \frac{d\sigma}{d\eta}(W^- \rightarrow l^-\nu)}{\frac{d\sigma}{d\eta}(W^+ \rightarrow l^+\nu) + \frac{d\sigma}{d\eta}(W^- \rightarrow l^-\nu)}$$

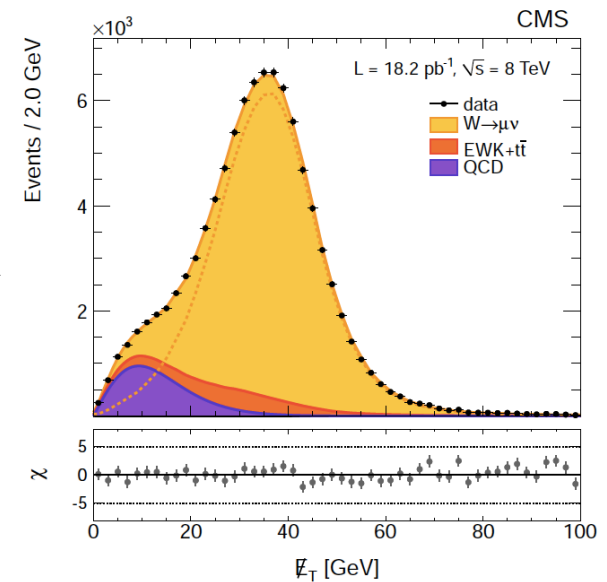
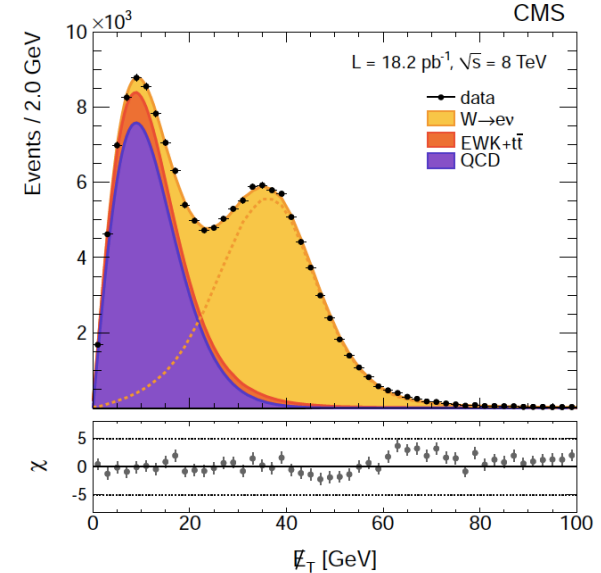
Inclusive W & Z Cross Section at 8 TeV

- Use 18.2/pb of 2012 data collected with low pile-up
 - ~ 5 interactions per bunch crossing
 - CMS requested special LHC conditions during luminosity ramp up
 - Single lepton trigger with lower p_T threshold
- $Z \rightarrow ee, \mu\mu$
 - 2 isolated high p_T leptons ($p_T > 25$ GeV)
 - $|\eta(\mu)| < 2.1, |\eta(e)| < 2.5$ due to acceptance of the trigger
 - Mass range: $60 < M(l\bar{l}) < 120$ GeV
 - Minimal background contamination: ($Z \rightarrow \tau\tau$, diboson, $t\bar{t}$, QCD)



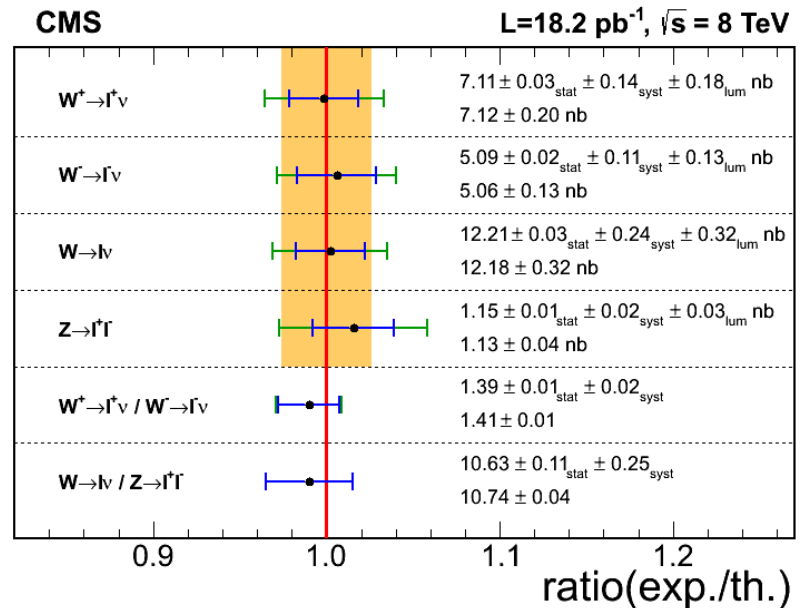
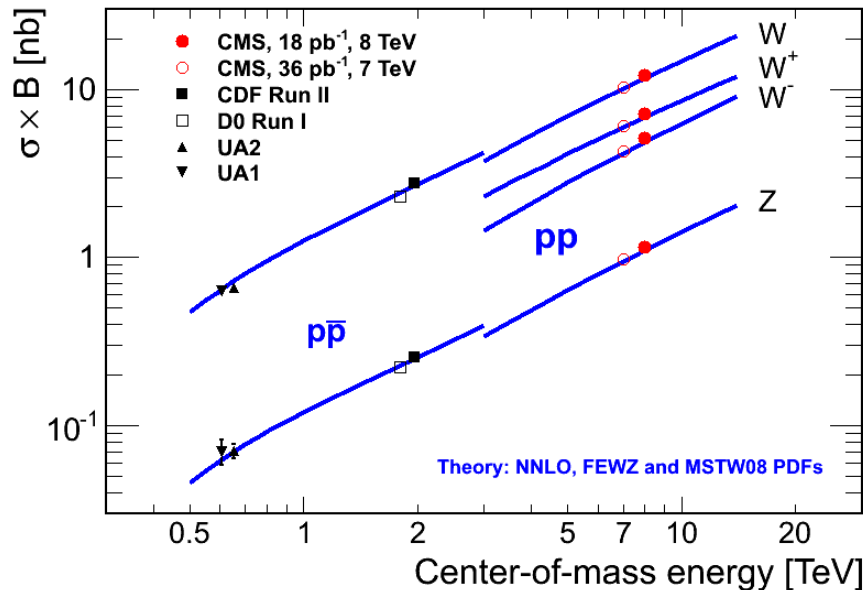
Inclusive W & Z Cross Section at 8 TeV

- $W \rightarrow l\nu$
 - One isolated high p_T lepton and missing transverse energy due to ν
 - Background contributions
 - EWK: $W \rightarrow \tau\nu$, Drell-Yan, diboson
 - $t\bar{t}$, QCD
 - Signal/background extraction
 - Signal shape: MC + recoil tuning from $Z \rightarrow ll$ data
 - QCD: from data with lepton id criteria reversed
 - Extract signal using the maximum likelihood fit to MET distributions



Inclusive W & Z Cross Section at 8 TeV

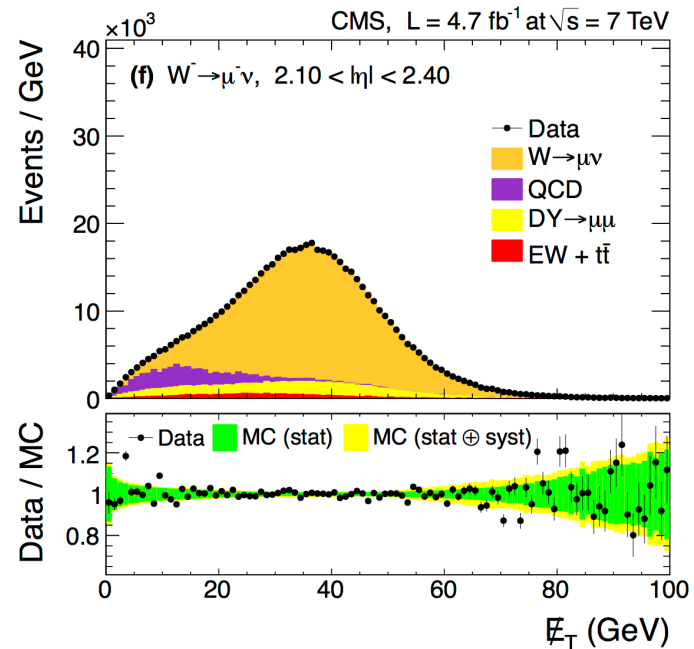
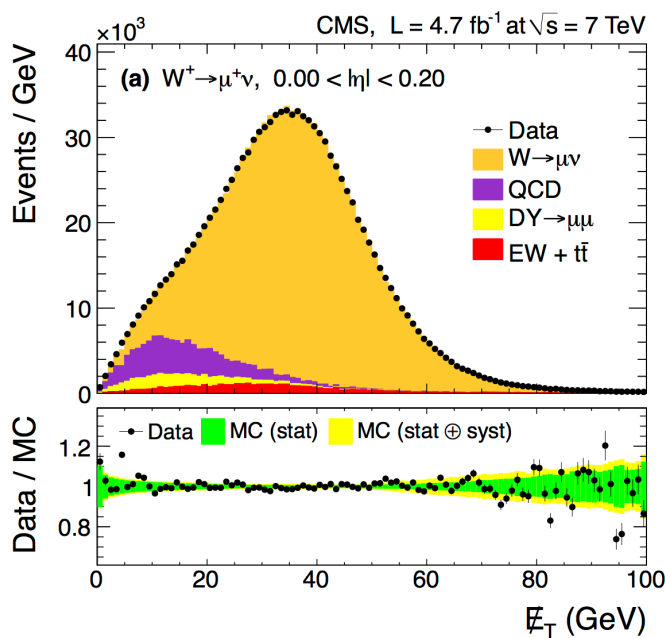
- Total inclusive cross sections times branching fractions for W^+ , W^- , W and Z and their ratios
 - Compare with theoretical expectation (NNLO FEWZ + MSTW08 PDF)
 - Yellow band: luminosity uncertainty (2.6%)



- Results are consistent between electron and muon channels
- Good agreement with theoretical prediction

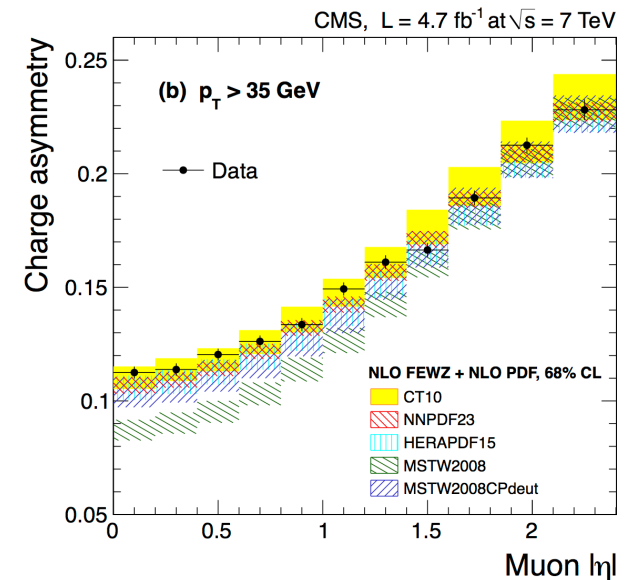
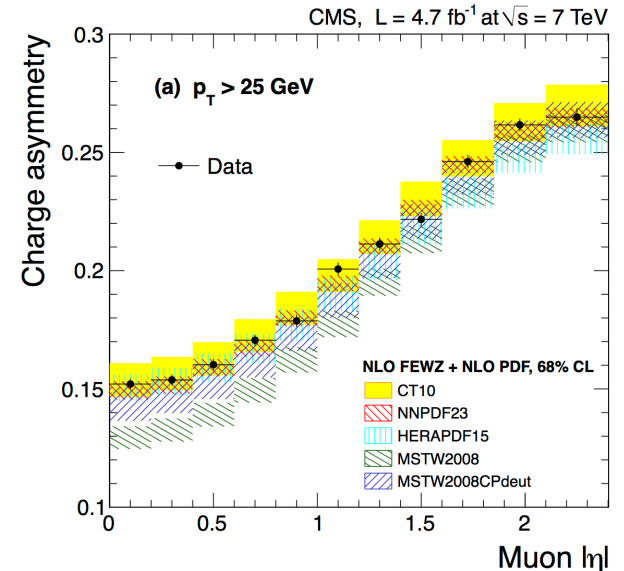
Muon Charge Asymmetry at 7 TeV

- 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 boson rapidity can be used to constrain PDFs
- Measure the asymmetry in 11 bins of $|\eta(\mu)|$ up to 2.4
- Similar event selection and signal/background extraction as inclusive W cross section measurement



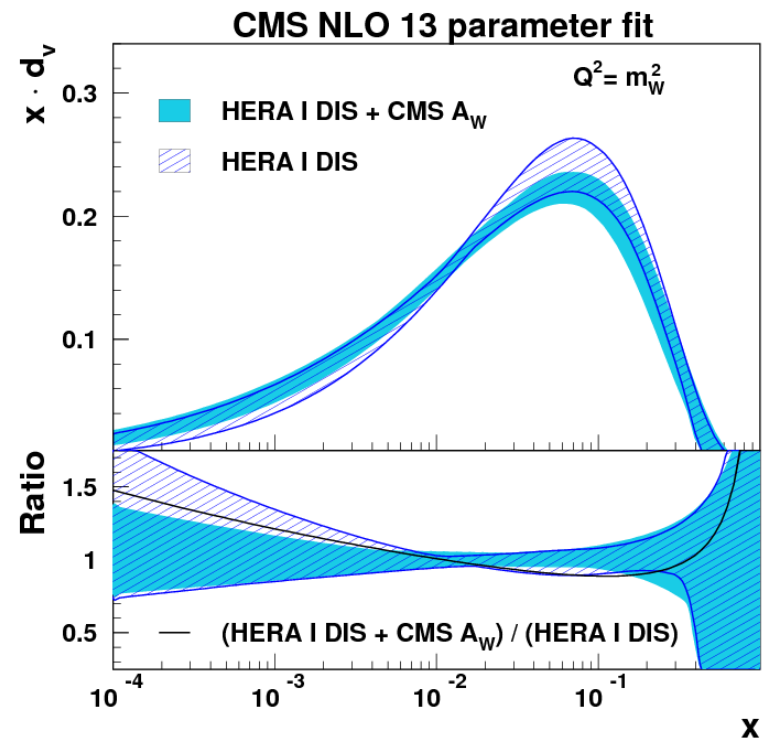
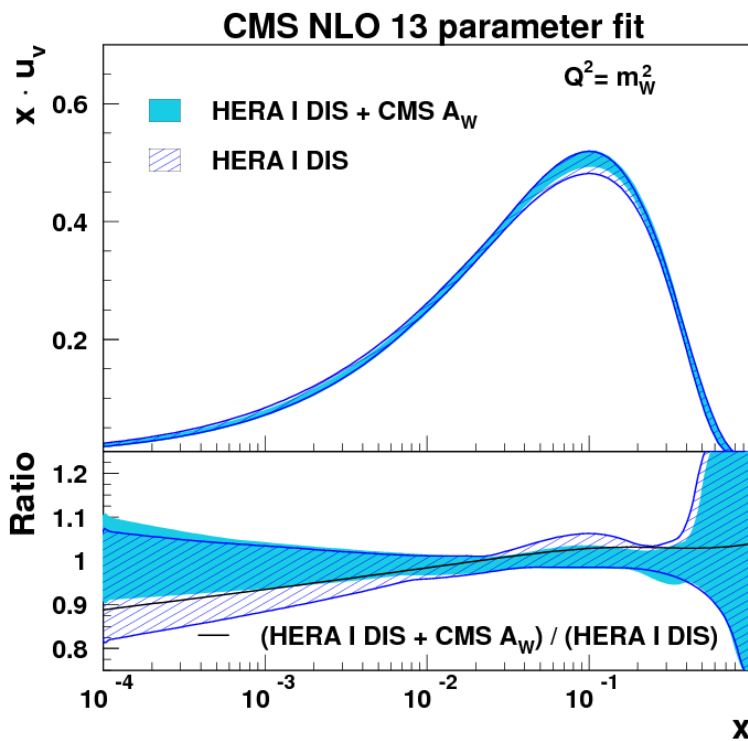
Muon Charge Asymmetry at 7 TeV

- Dominant systematic uncertainty
 - Efficiency correction
 - QCD background
 - Muon momentum scale correction
- Measure muon charge asymmetry with two different p_T cuts: 25 and 35 GeV
- Compare with NLO FEWZ predictions with 5 PDFs
 - Good agreement with CT10, NNPDF and HERA
 - Observe deviation with MSTW2008
 - Improve significantly by flexible parameterization in MSTW2008CPdeut



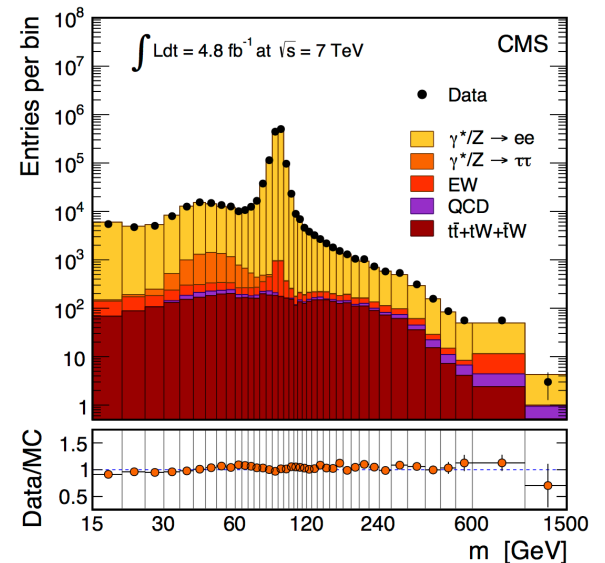
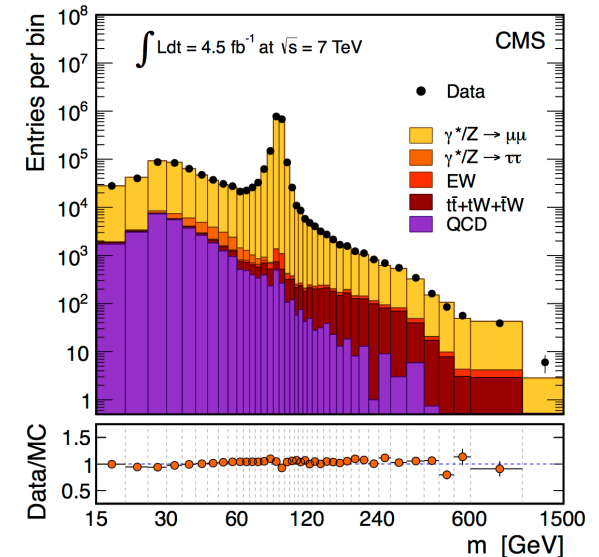
Muon Charge Asymmetry at 7 TeV

- Look into the impact of including this result in HERA PDF fit
 - 13 parameter fixed-s fit to the HERA I DIS data and CMS muon charge asymmetry result
 - Significant impact on the d-valence quark



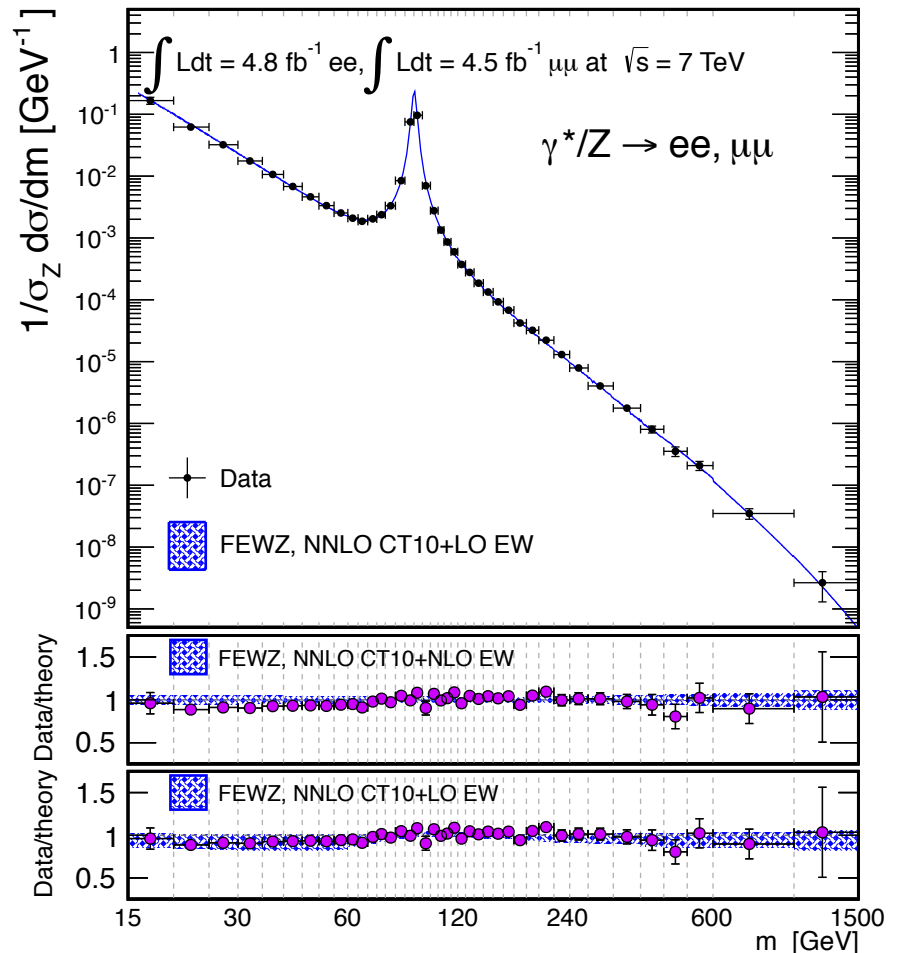
Drell-Yan Diff. Cross Section at 7 TeV

- Drell-Yan process
 - Is an important Standard Model benchmark channel
- We measure
 - Differential cross section $(1/\sigma_Z)d\sigma/dM$ in dimuon and dielectron channel with 40 mass bins
 - $15 < M(ee, \mu\mu) < 1500$ GeV
 - Double differential cross section $(1/\sigma_Z)d^2\sigma/dMdY$ in dimuon channel with 132 mass-rapidity bins
 - $20 < M(\mu\mu) < 1500$ GeV, $|Y(\mu\mu)| < 2.4$
 - Normalized to Z peak
 - $60 < M(\mu\mu) < 120$ GeV
 - Use full 7 TeV data ($\sim 5/\text{fb}$)



Drell-Yan Diff. Cross Section at 7 TeV

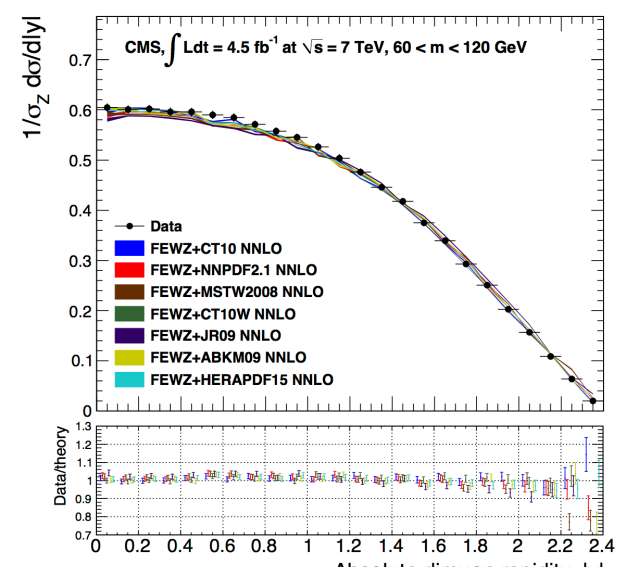
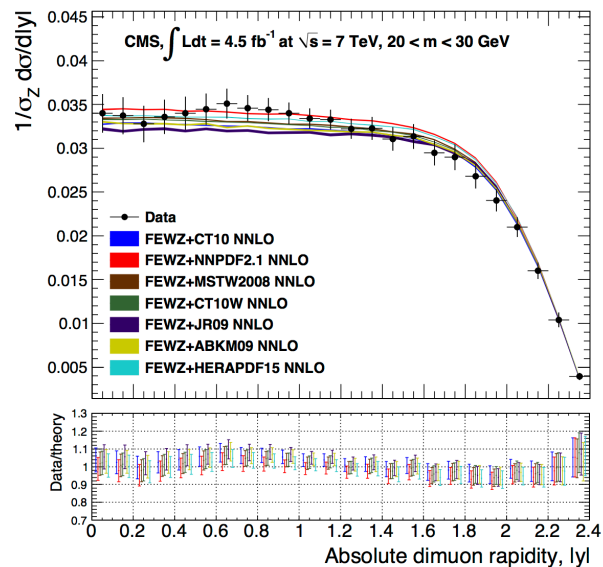
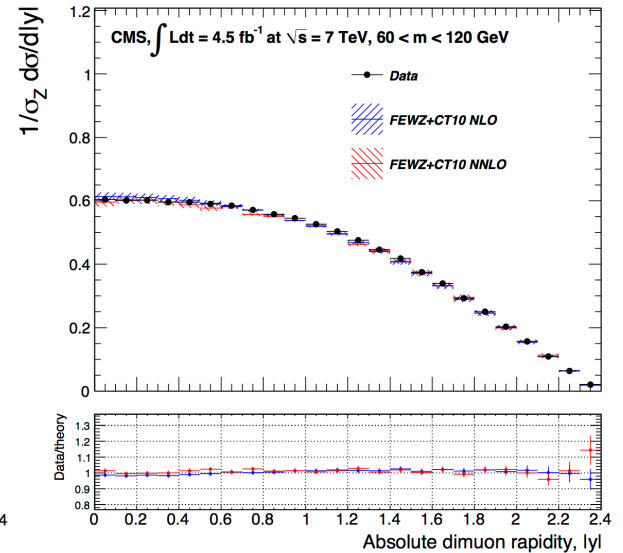
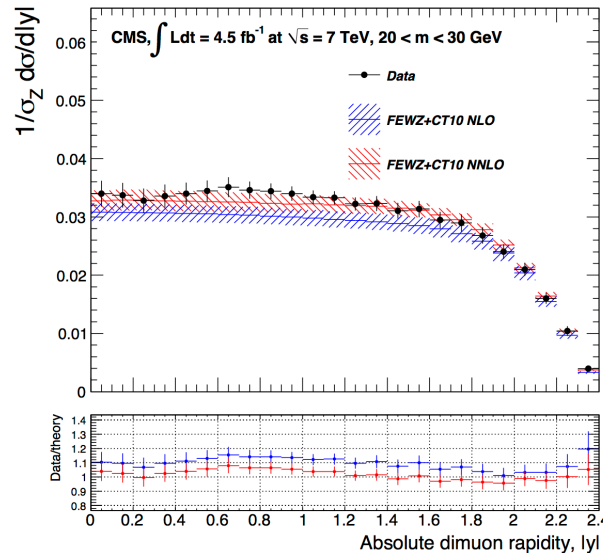
- Result of $(1/\sigma_Z)d\sigma/dm$
 - Pre-FSR full acceptance normalized cross section in dimuon and dielectron
 - Provide results for post-FSR (no FSR correction) and fiducial region
- Dominant systematic uncertainties
 - Efficiency correction
 - Detector resolution
 - Backgrounds in high mass
- Very good agreement with NNLO theoretical prediction



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.

Drell-Yan Diff. Cross Section at 7 TeV

- Results of $(1/\sigma_Z)d^2\sigma/dM dY$
 - Fiducial region cross section with FSR correction
 - Provide full covariance matrices for PDF fits
- Comparison with various NNLO PDFs

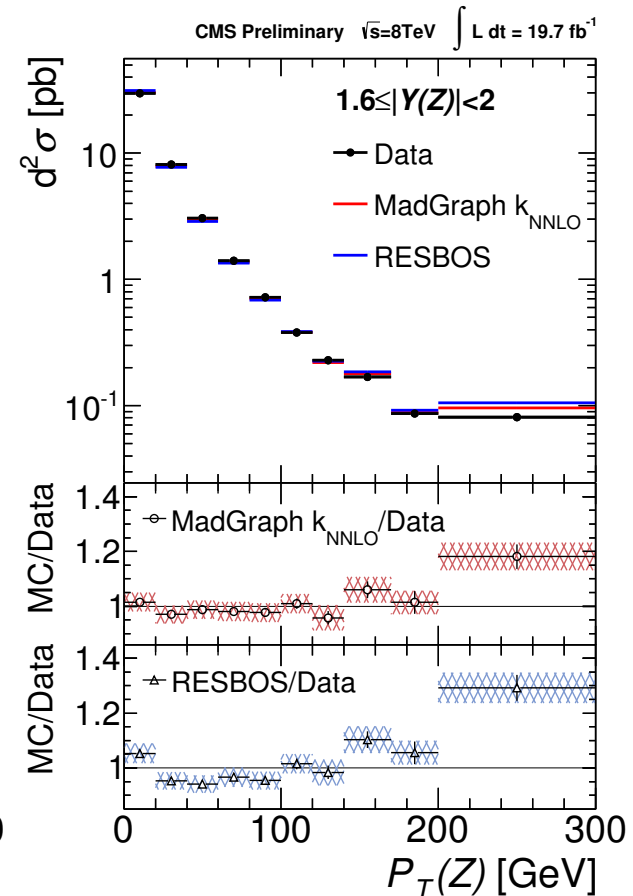
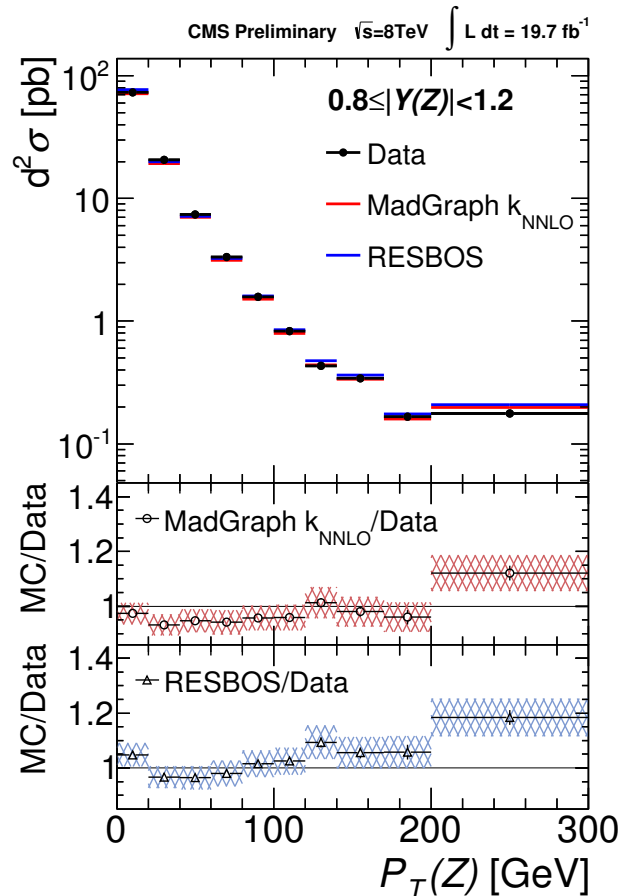
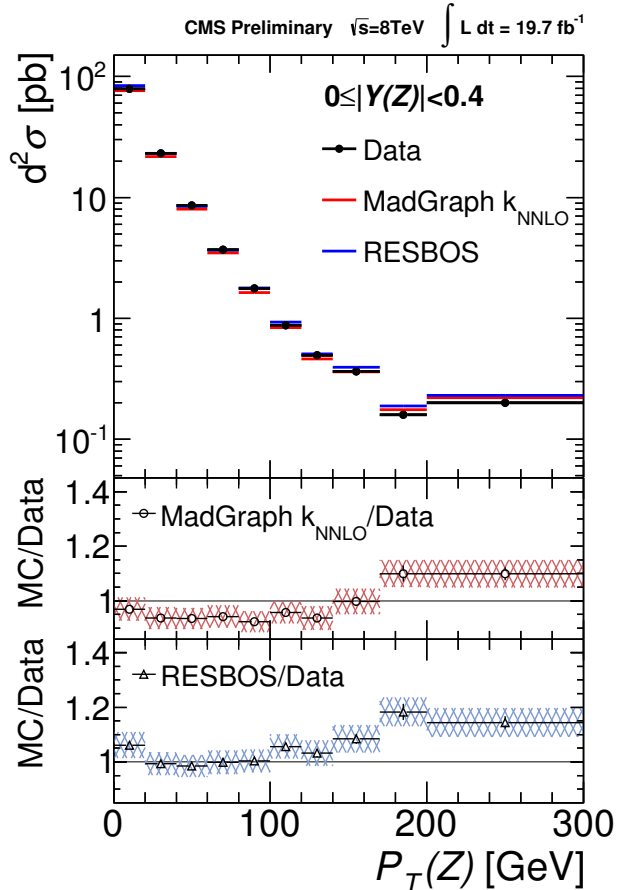


Z p_T and Y Cross Section at 8 TeV

- Z boson production at large p_T is dominated by qg process
 - Constrain gluon PDFs
- Use muon channel: $Z \rightarrow \mu\mu$
 - Use full 8 TeV dataset ($\sim 20/\text{fb}$): improve a precision significantly (in particular $p_T > 100 \text{ GeV}$) compared to previous Z p_T CMS results
 - Determine cross section in fiducial region
 - Normalized to inclusive Z cross section (in the fiducial region)
 - Use 10 bins of $p_T(Z)$ and 5 bins of $Y(Z)$
- Following corrections are applied
 - Efficiency: factorization of tracking, trigger, id, and isolation of muon
 - Parameterized by $p_T(\mu) - |\eta(\mu)|$ and $p_T(Z) - \cos\theta^* - |\phi^*|$ to take into account the event kinematics
 - Muon momentum scale and resolution to correct misalignment
 - MC is weighted in $p_T(Z)$ and $Y(Z)$ shape in data to determine the response matrix for unfolding
 - Background subtraction using data-driven technique

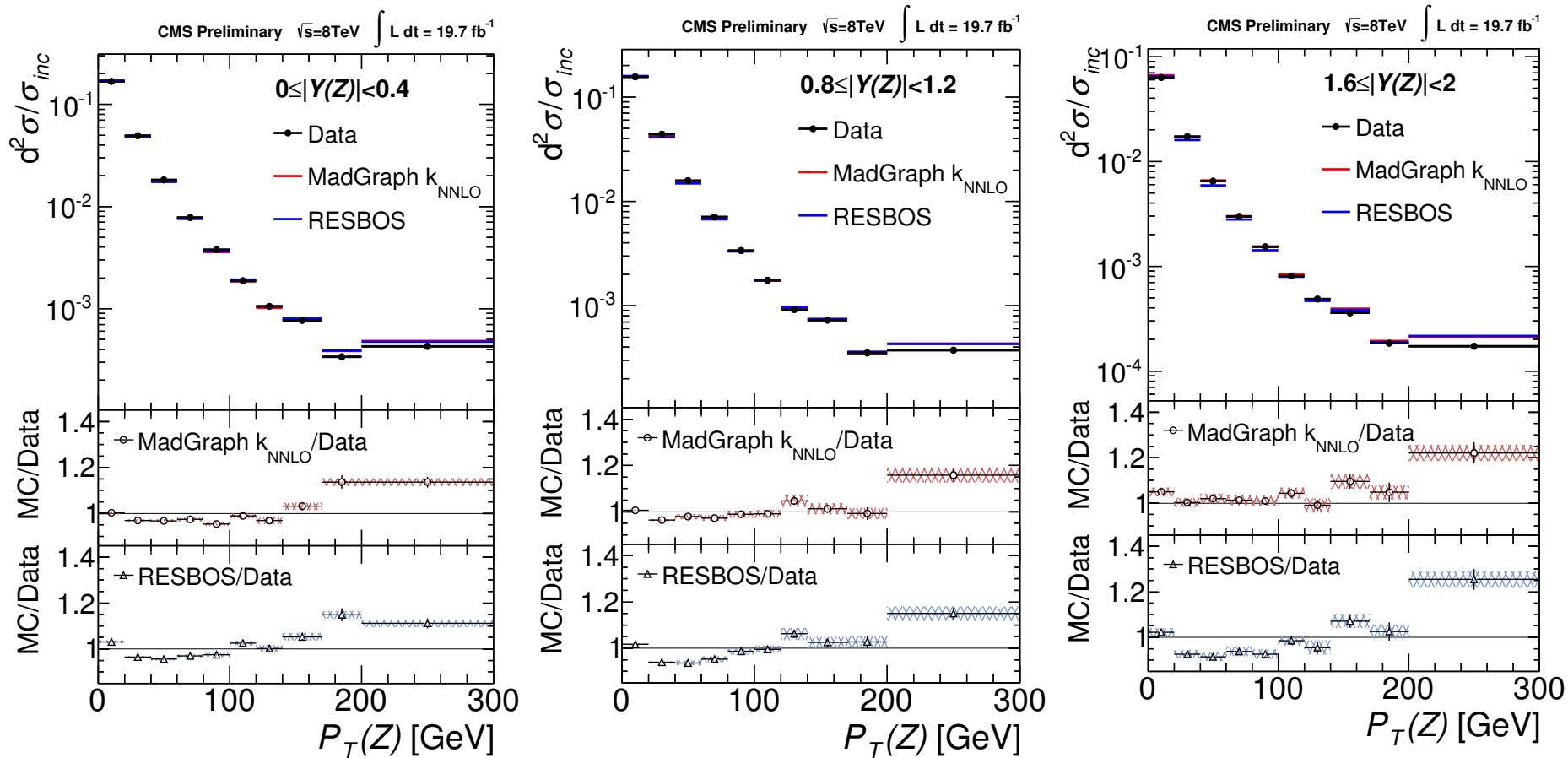
Z p_T and Y Cross Section at 8 TeV

- Absolute fiducial cross section
- Comparison to Madgraph+Pythia6 and RESBOS
 - Shape in $p_T(Z)$ is not well predicted by theory



Z p_T and Y Cross Section at 8 TeV

- Normalized fiducial cross section
- Comparison to Madgraph+Pythia6 and RESBOS
 - Shape in $p_T(Z)$ is not well predicted by theory



Summary

- Impressive amount of EWK results using W and Z boson production from CMS
 - Precise test of the Standard Model at TeV scale
 - Agreement with theory across orders of magnitude
 - Provide powerful 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 are available at the above link
- Many other results with 7 and 8 TeV datasets are in pipeline
 - More results with improved precision expected soon, stay tuned!

Back Up