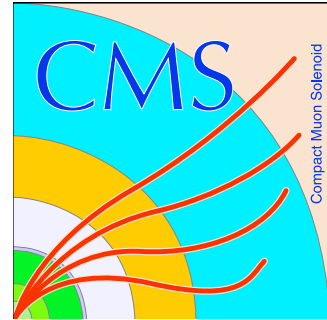


W AND Z PRODUCTION AT CMS



Aleko Khukhunaishvili

Cornell University

On behalf of the CMS Collaboration

DIS 2013

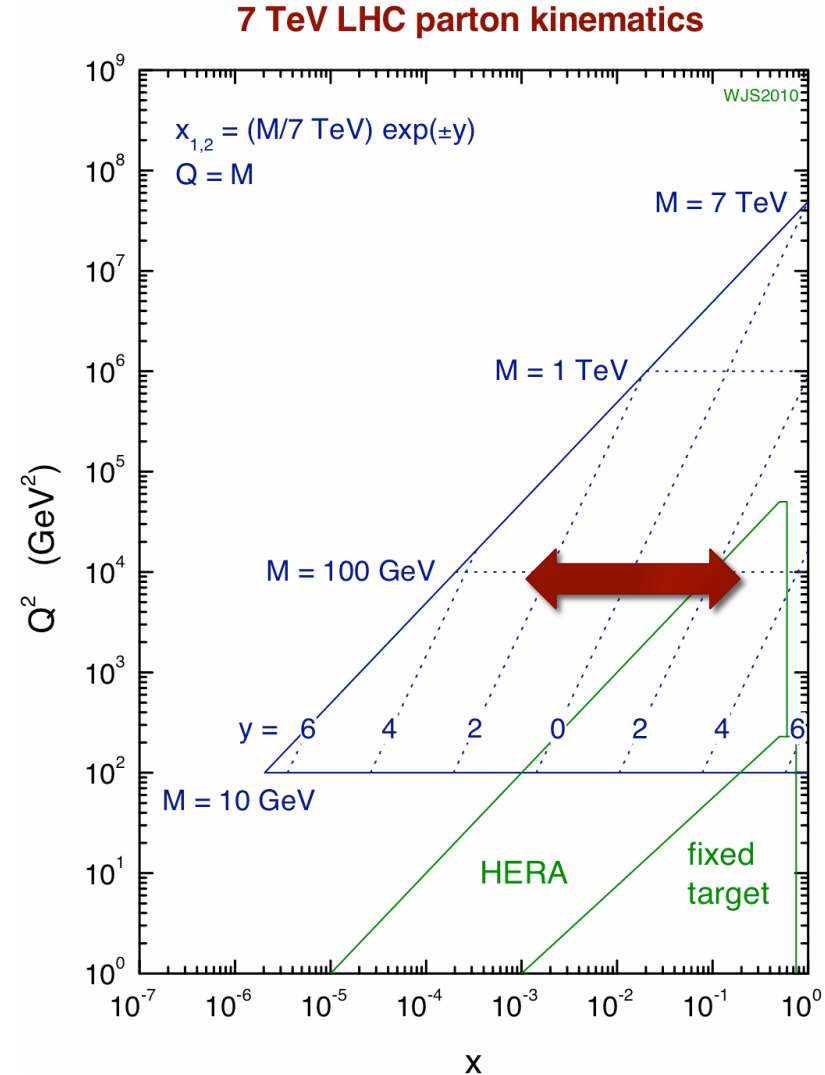
Marseille, April 24



- **W and Z inclusive cross sections at 8 TeV**
- **Z p_T differential cross section at 8 TeV**
- **W electron charge asymmetry at 7 TeV**
- **Drell-Yan differential cross sections at 7 TeV**

Introduction

- W and Z leptonic decays - clean final states
- Test for SM predictions at TeV scale
- Precise measurements sensitive to NNLO theoretical calculations
- Can probe and constrain PDF's in a new kinematic regime at $10^{-3} < x < 10^{-1}$
- Background for Higgs and BSM searches
- Good samples for detector calibration



- Important benchmark for precision measurements at 8 TeV
- Inclusive W and Z cross-sections at 7 TeV were measured with 2010 36pb⁻¹ of data, with ~1% experimental precision
- 8 TeV cross section measurements are performed with the first 19 pb⁻¹ of 2012 data, collected with special conditions, similar to 2010 data:
 - Low pile-up (~5 interactions / bunch crossing)
 - Special trigger menu: single lepton triggers with loose quality criteria and low p_T thresholds
 - 22 GeV for electrons
 - 15 GeV for muons

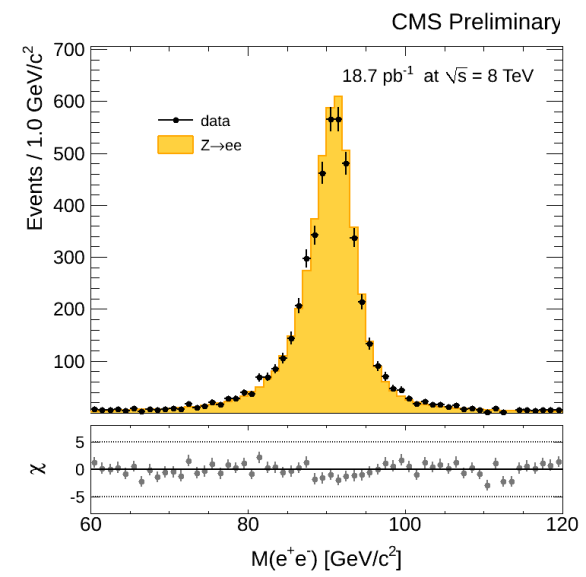
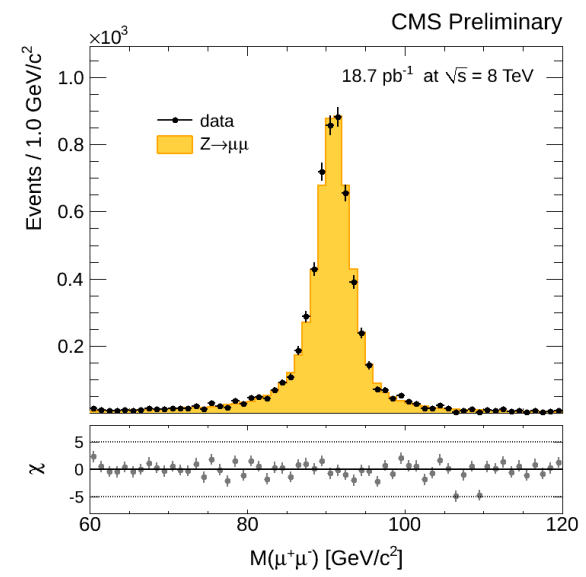
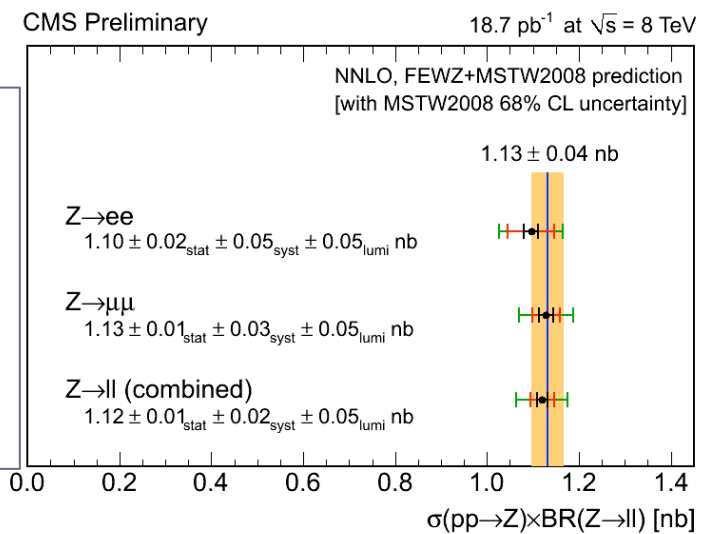
Dimuon and dielectron channels

Clean signature: 2 isolated high p_T leptons

Selected in mass window: $60\text{GeV} < M < 120\text{GeV}$

Small background contamination

$Z \rightarrow \mu\mu$	$Z \rightarrow ee$
<ul style="list-style-type: none"> $p_T > 25 \text{ GeV}$, $\eta < 2.1$ $\sim 6\text{K}$ candidates 	<ul style="list-style-type: none"> $p_T > 25 \text{ GeV}$, $\eta < 2.5$ $\sim 5\text{K}$ candidates
<ul style="list-style-type: none"> Stat. error = 1.3% Exp syst. = 1.2% <ul style="list-style-type: none"> Dom. by efficiency Theory acc. = 1.9% 	<ul style="list-style-type: none"> Stat. error = 1.4% Exp syst. = 2.8% <ul style="list-style-type: none"> Dom. by efficiency Theory acc. = 2.6%



- Good agreement with Theoretical prediction from NNLO FEWZ+MSTW2008
- Total uncertainty dominated by luminosity (4.4%)

Muon and electron decay channels

Clean signature: isolated high p_T lepton and large Missing Transverse Energy (MET)

Signal extracted with binned maximum likelihood fit to MET

- **Signal shape:** from MC with data driven recoil correction
- **QCD shape floating**
 - In muon channel constrained from control region

$W \rightarrow \mu\nu$

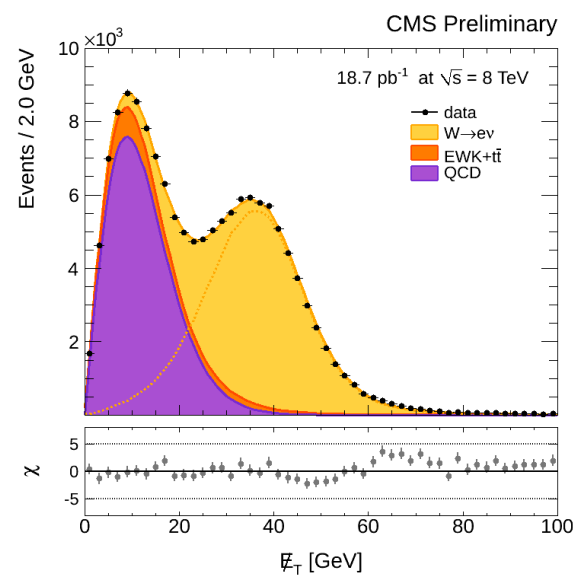
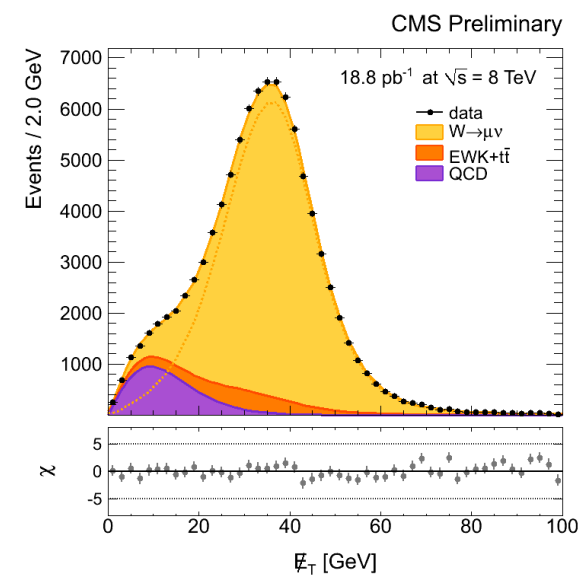
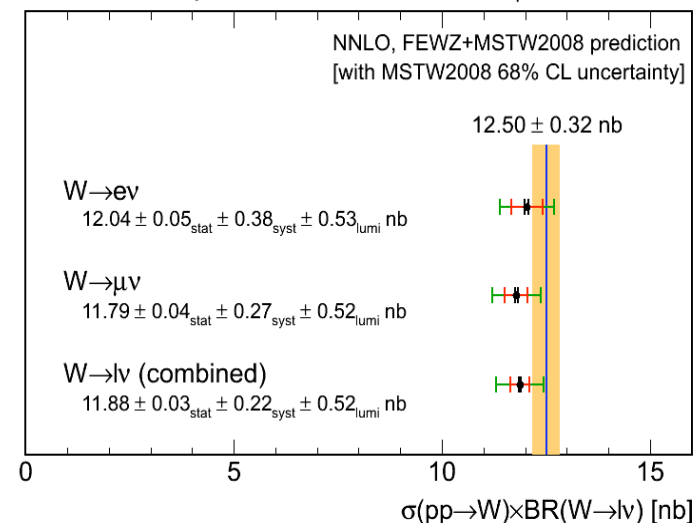
- muon $p_T > 25$ GeV, $|\eta| < 2.1$
- ~81K W events
- Exp. systematics dom. by efficiency (2.5%)

$W \rightarrow e\nu$

- elec $p_T > 25$ GeV, $|\eta| < 2.5$
- ~75K W events
- Exp. systematics dom. by efficiency (1.0%)

CMS Preliminary

18.7 pb^{-1} at $\sqrt{s} = 8$ TeV

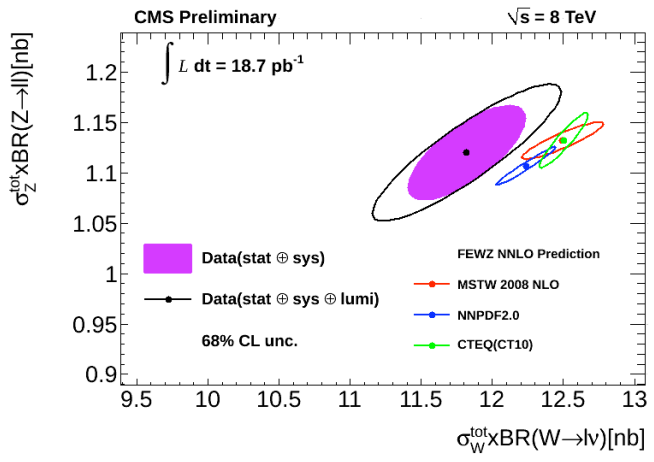
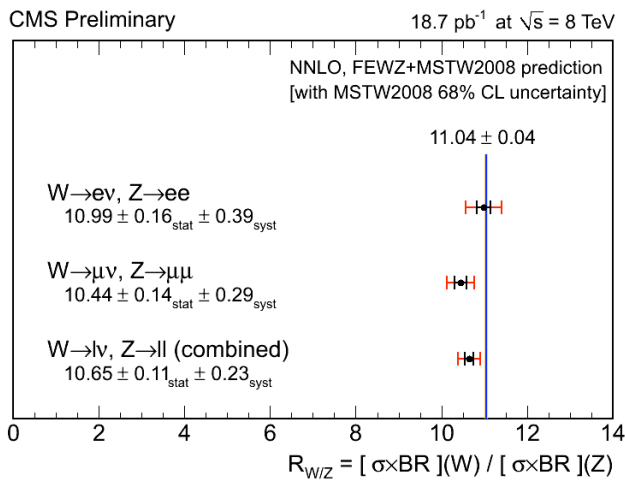


- Good agreement with Theoretical prediction from NNLO FEWZ+MSTW2008
- Total uncertainty dominated by luminosity (4.4%)
- Acceptance uncertainty 2.2% for muon and 2.7% for electron

Ratios

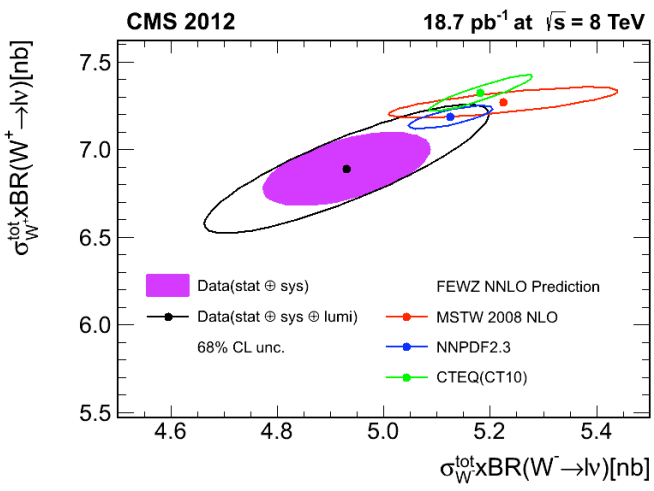
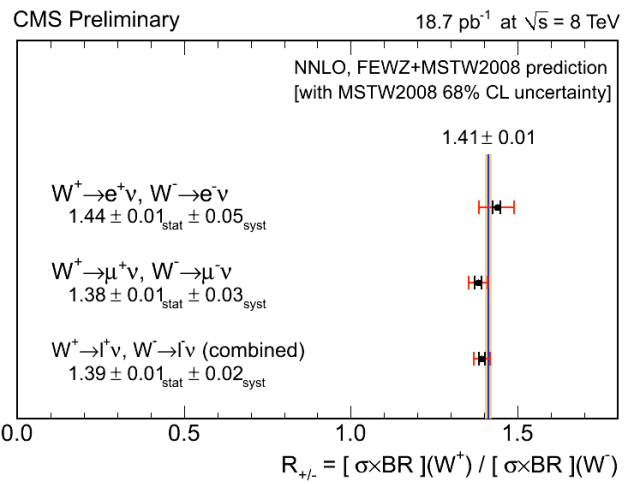
W / Z

- Acceptance error:
 - 2.5% for muons
 - 2.0% for electrons
- Total exp. uncertainty
 - 1.7% for muons
 - 3.9% for electrons



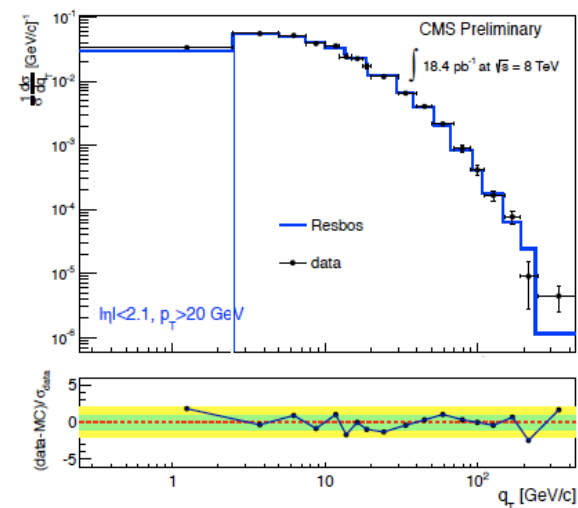
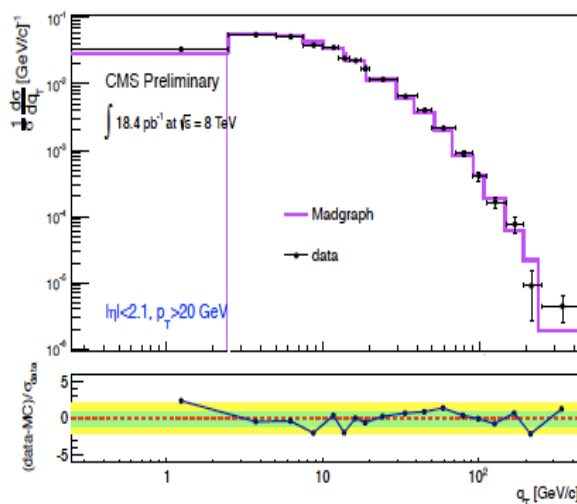
W⁺ / W⁻

- Acceptance error:
 - 1.4% for muons
 - 1.5% for electrons
- Total exp. uncertainty
 - 1.2% for muons
 - 3.8% for electrons



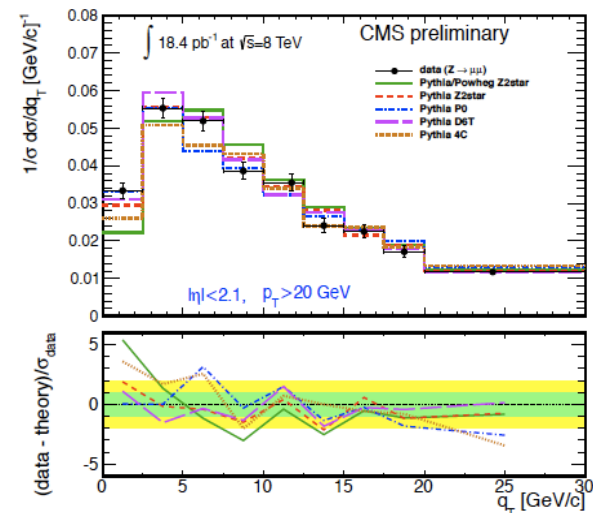
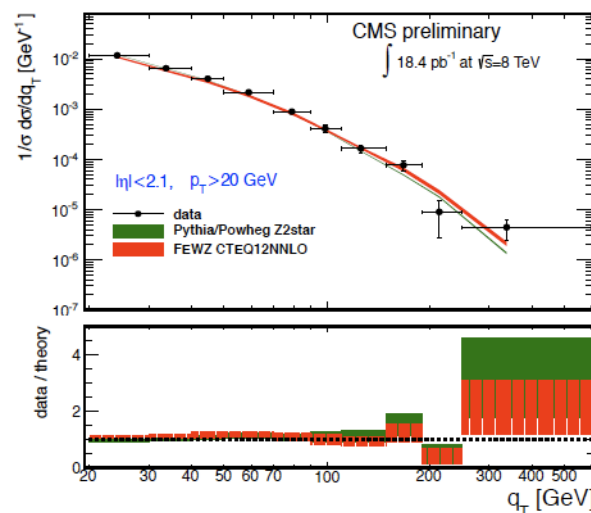
- Part of the experimental and theoretical uncertainties cancel
- Good agreement with theory predictions
- More sensitivity to PDF's in differential cross-sections and asymmetries → next slides

- **Dimuon channel**
- $p_T^{1,2} > 20$ GeV, $|\eta| < 2.1$
- $60 \text{ GeV} < M < 120$ GeV
- $\sim 7\text{K}$ dimuon events



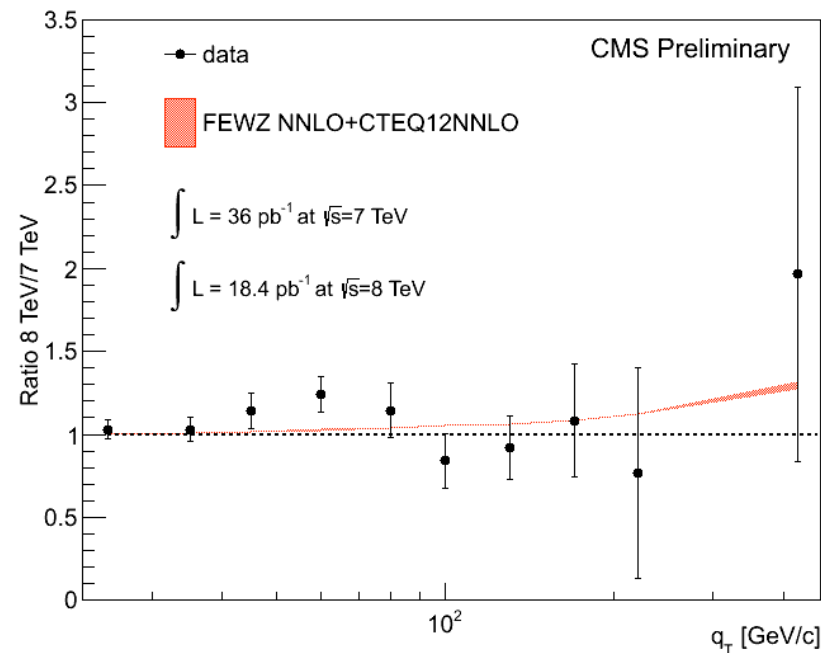
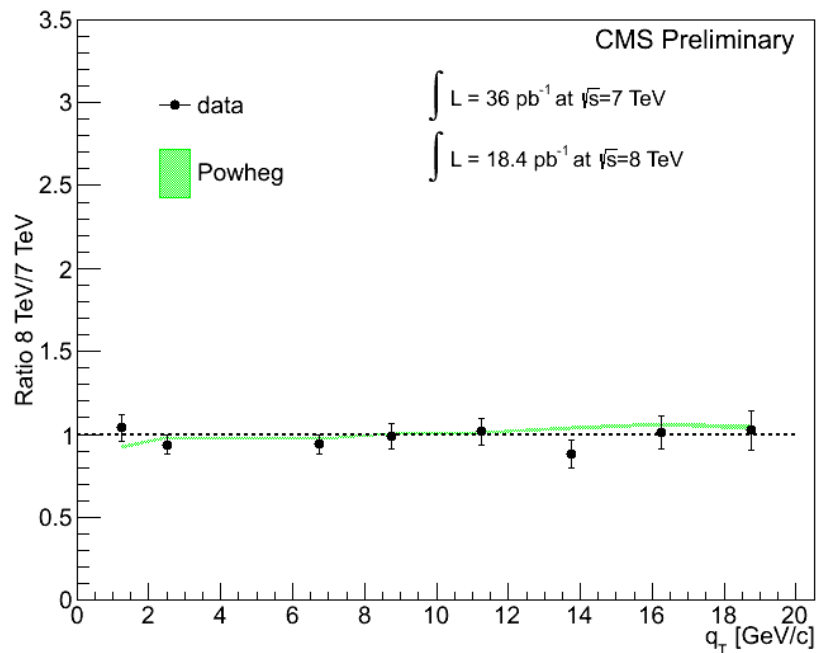
- Good agreement with Madgraph + Pythia Z2*

- Improved description with RESBOS at low q_T



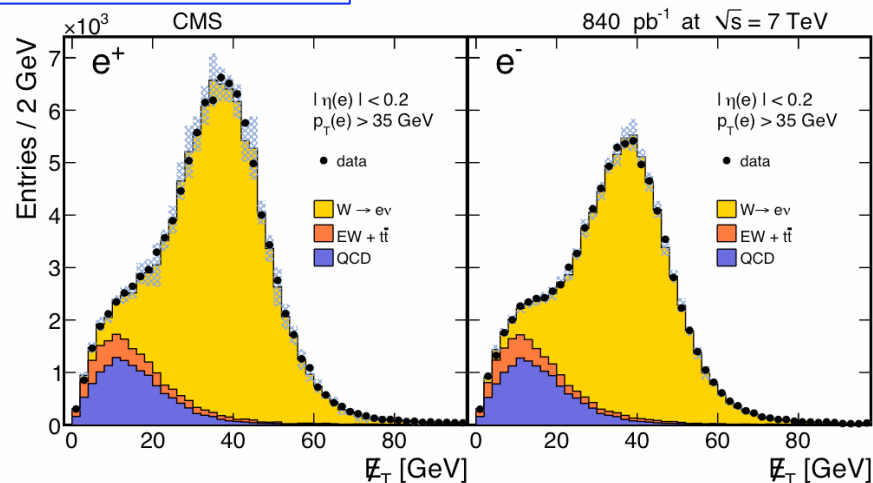
- Good agreement with NNLO FEWZ calculation at high q_T

- Different Pythia UE tunes compared, Z2star gives the best description

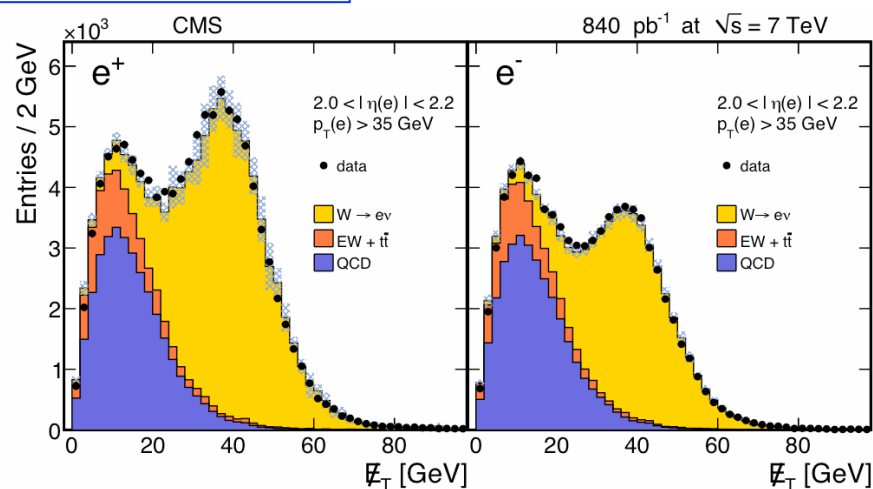


- Result compared with Z p_T measurement at 7 TeV with 2010 data
- Uncertainties are statistics-dominated
- Good agreement with theory predictions at both low and high p_T regions

$0.0 < |\eta_e| < 0.2$



$2.0 < |\eta_e| < 2.2$



MET distributions in two electron $|\eta|$ bins

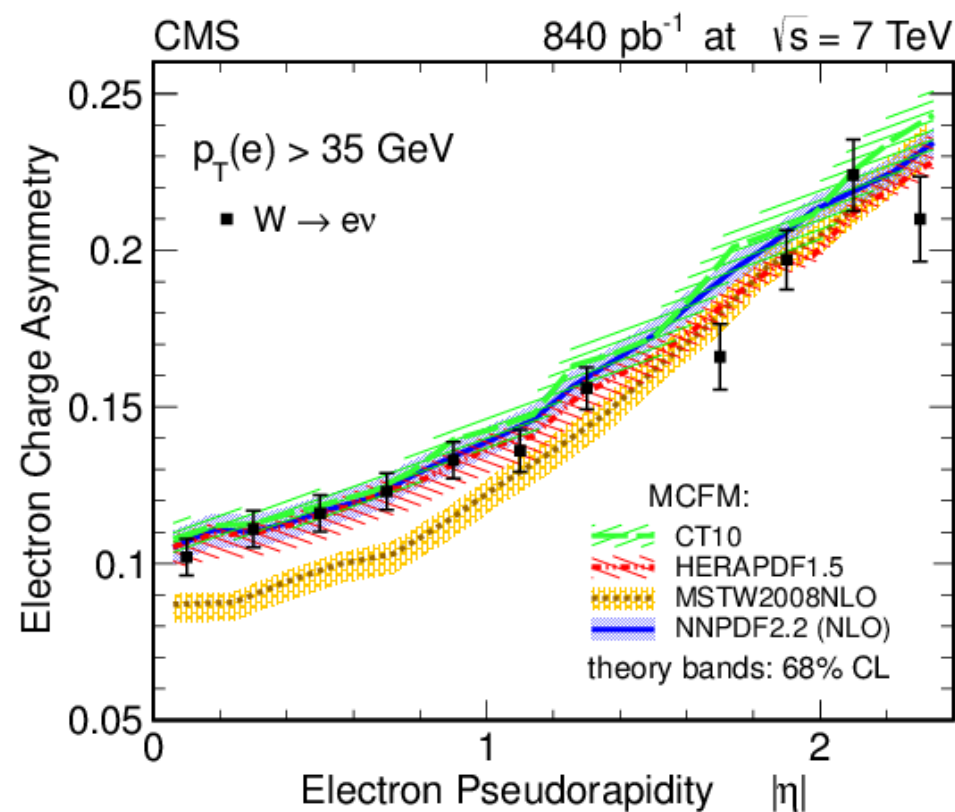
- W charge asymmetry** measured in bins of decay electron η :

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

is sensitive to valence and sea quark contributions at $10^{-3} < x < 10^{-1}$

- Clean measurement**, many systematics cancel out
- Measured with first 840 pb⁻¹ of 2011 data at 7 TeV
- Electron $p_T > 35$ GeV**
- In $\Delta|\eta| = 0.2$ bins, from 0-2.4
- BML fit to extract the signal
- Signal templates from MC with corrected recoil
- QCD templates from control region with inverted electron ID criteria

- Observed asymmetry in each pseudorapidity bin is corrected for
 - Efficiency difference between e^+ and e^-
 - Charge misidentification
 - Momentum scale and resolution
- Full covariance matrix provided
- Dominant uncertainty from $\varepsilon^+/\varepsilon^-$:
 - $\sim 0.5\%$ at low and $\sim 1\%$ at high $|\eta|$
 - limited by Z statistics
- Good agreement with **CT10, HERA & NNPDF**, worse with **MSTW08** (improved in new versions)
- Significant constraining power
- Muon charge asymmetry results at 7 TeV with full 2011 data coming soon...



- Measured with full 2011 7 TeV dataset
- **Differential cross-section: $(1/\sigma_Z) d\sigma/dM$:**
 - In di-muon and di-electron channels
 - Normalized to Z mass peak
 - Full phase-space
 - 40 mass bins, from 15GeV to 1500GeV
- **Double differential cross-section: $(1/\sigma_Z) d^2\sigma/dMdY$:**
 - In di-muon channel
 - Normalized to Z mass peak
 - Within muon kinematic acceptance:
 - $p_T^{1,2} > 14,9$ GeV, $|\eta| < 2.4$
 - 6 mass x 24(12) rapidity bins

Signal model: POWHEG MC reweighted to NNLO FEWZ

Dominant backgrounds:

- **Muon:**

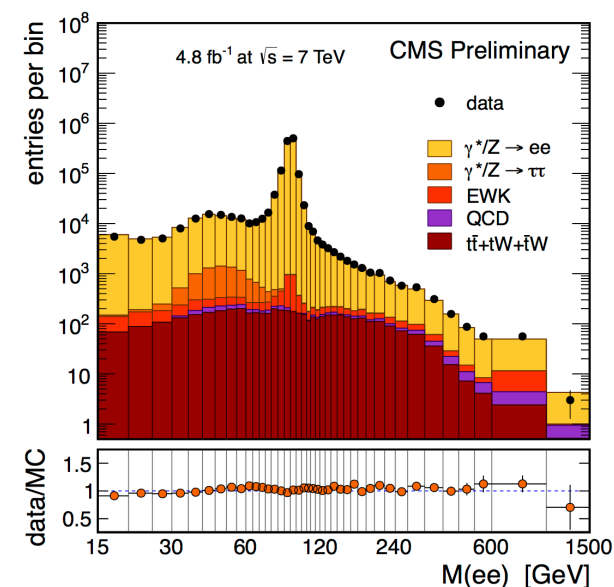
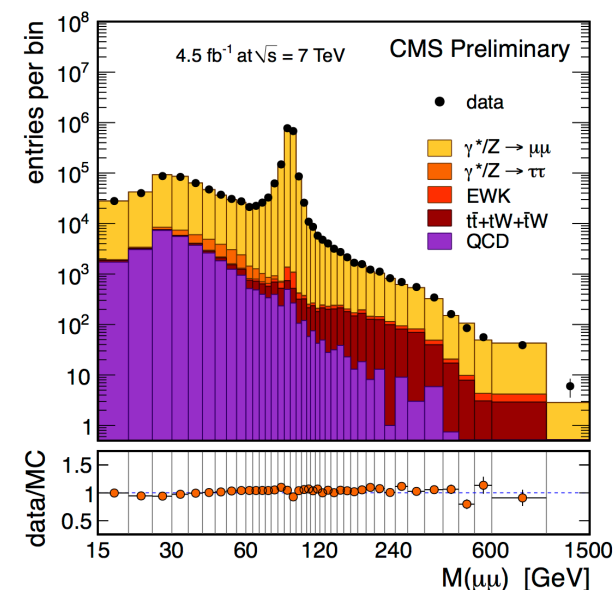
- Low mass: QCD multi-jet
- Peak: $DY \rightarrow \tau\tau$
- High mass, top pair, di-boson

- ❑ QCD background estimated using data-driven “ABCD” method using same-sign and non-isolated muon control regions
- ❑ Top-pair is determined with data-driven technique using e, μ data sample

- **Electron:**

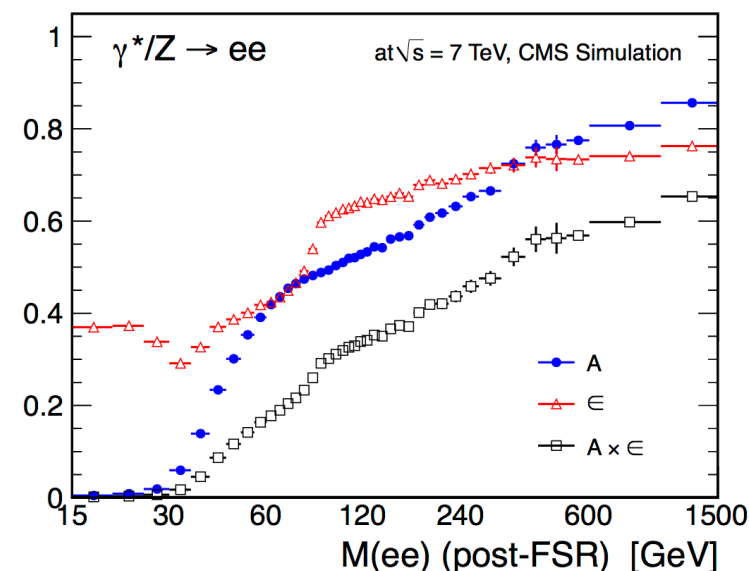
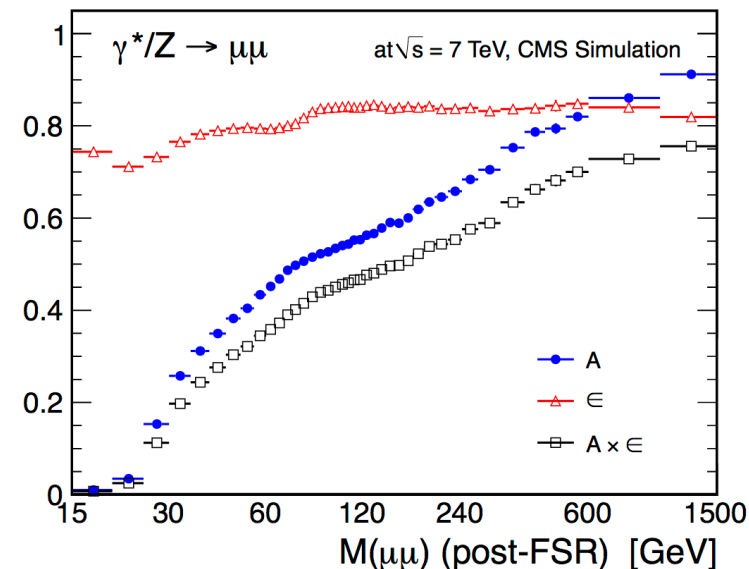
- Low mass and peak: $DY \rightarrow \tau\tau$
- High mass: $t\bar{t}$, di-boson

- ❑ $DY \rightarrow \tau\tau$, top, di-boson backgrounds determined with $e-\mu$ technique
- ❑ QCD and W +jets by applying fake-rate on a sample with one electron failing selection

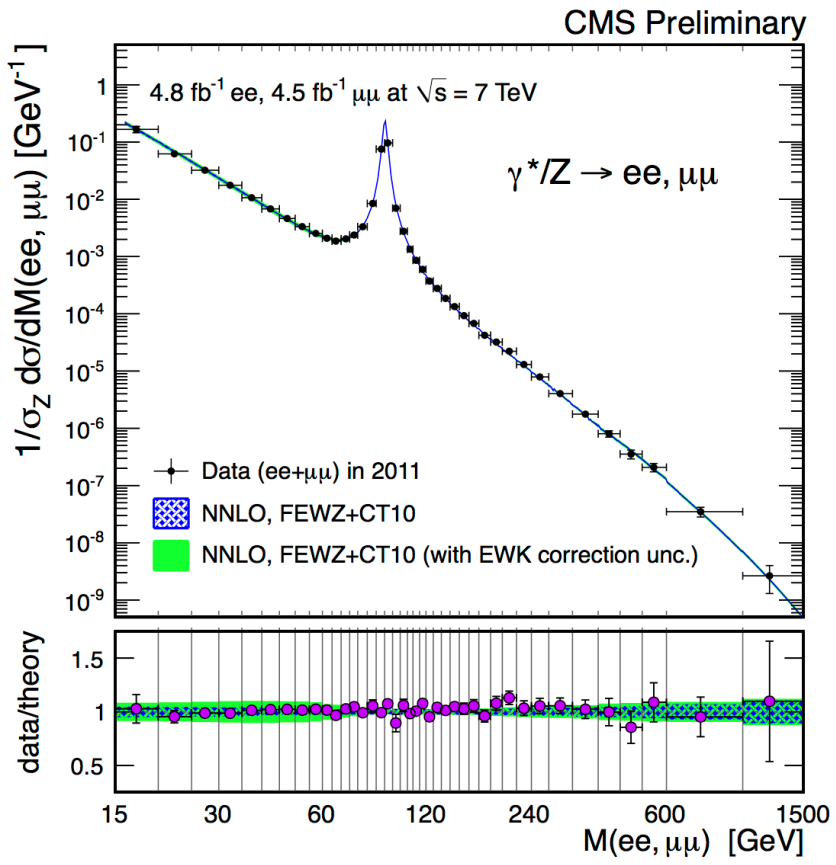


Corrections applied to background-subtracted, observed signal yields

- **Detector resolution effects unfolded:**
 - Take into account bin-to-bin migrations
 - Determined with Monte-Carlo simulation
- **Efficiency** (trigger & offline quality selection)
 - Measured efficiencies in MC corrected to match with data
- **Acceptance** (lepton p_T and η cuts)
 - $p_T^{1,2} > 14, 9$ GeV, $|\eta| < 2.4$ muons
 - $p_T^{1,2} > 20, 10$ GeV, $|\eta| < 2.5$ electrons
 - Determined from MC
 - NNLO FEWZ re-weighted Powheg used
(double differential measurement done within acceptance)
- **Final State Radiation (FSR) effects unfolded**
 - Take into account migration into and out of the acceptance region
 - Migration between measurement bins

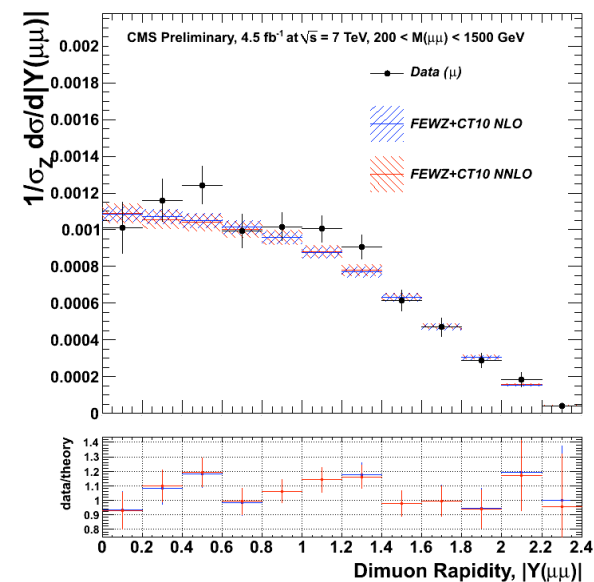
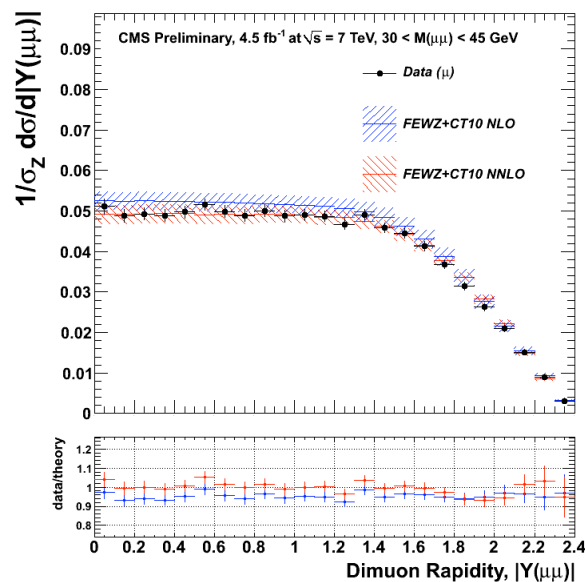
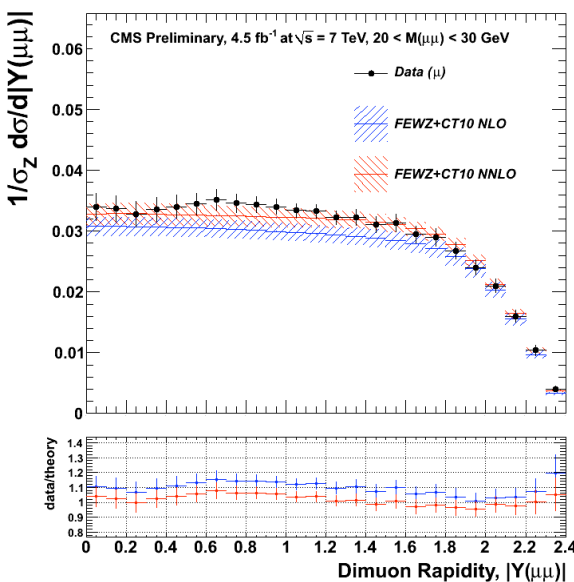


- **Measured in full phase-space**
 - Corrected for efficiency & acceptance
 - Unfolded detector resolution & FSR
- **ee and $\mu\mu$ channels combined**
 - taking into account correlations
- **Dominant exp. systematics:**
 - **Muon:**
 - low mass: efficiency $\sim 2\%$
 - peak: det resolution $\sim 2-3\%$
 - high: background $\sim 5\%$, 15% (last bin)
 - **Electron:**
 - low mass: total $\sim 3-5\%$
 - peak: e-scale & bkgd $\sim 15\%$
 - high: background $4-7\%$, 30% (last bin)
- **Acceptance & modeling**
 - uncertainty at low mass $\sim 10\%$
- **Theory calculation with NNLO FEWZ+CT10**
- **Additional EWK corr. uncertainty from photon induced processes**
- **Good agreement with theory prediction in entire mass range!**

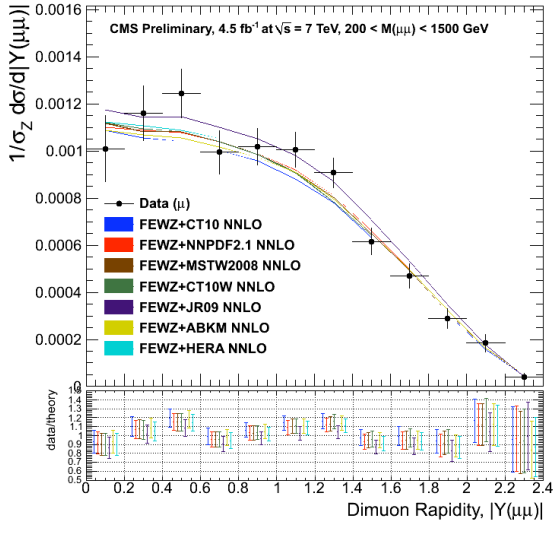
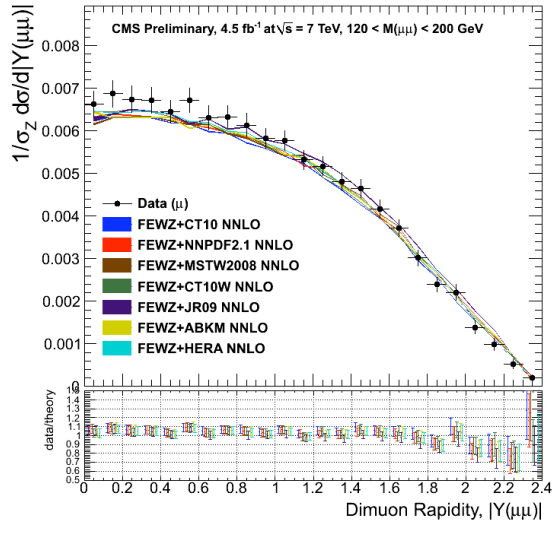
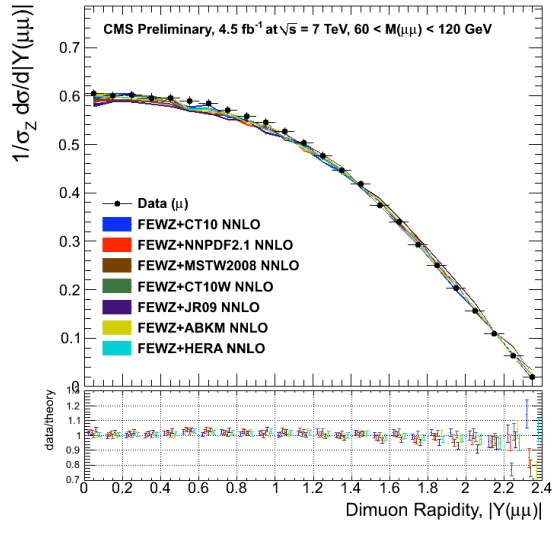
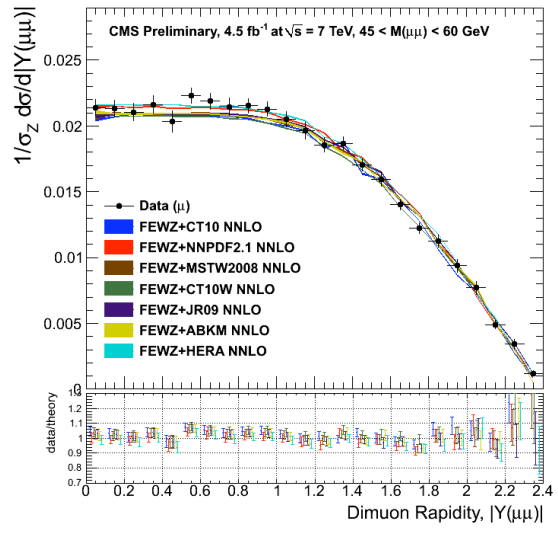
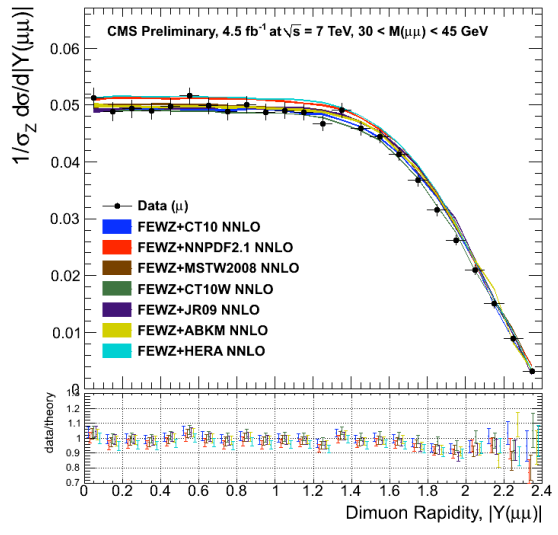
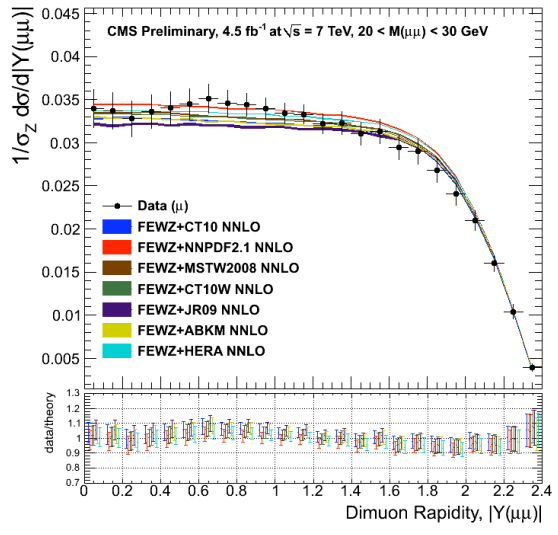


Drell-Yan Double-Differential Cross Section

- **DY double differential cross section** measured in dimuon channel
- Normalized to Z mass peak
- **Within kinematic acceptance:** $p_T^{1,2} > 14,9$ GeV $|\eta| < 2.4$
- **6 mass bins:** [20-30], [30-45], [45-60], [60-120], [120-200], [200-1500] GeV
- **24 rapidity bins** (12 in last mass bin), between **0** and **2.4**



- Compared to **NLO** and **NNLO FEWZ+CT10** theoretical predictions
- At low mass **NNLO** corrections are important
- **Sensitive to PDF** uncertainties

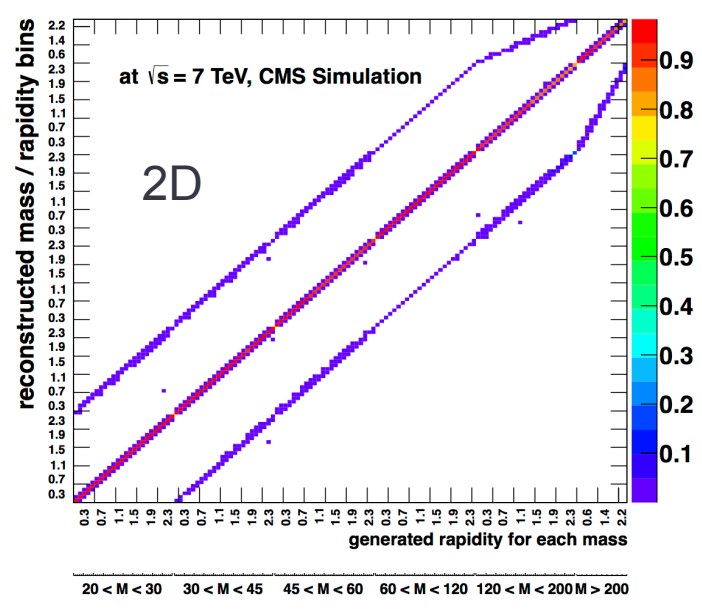
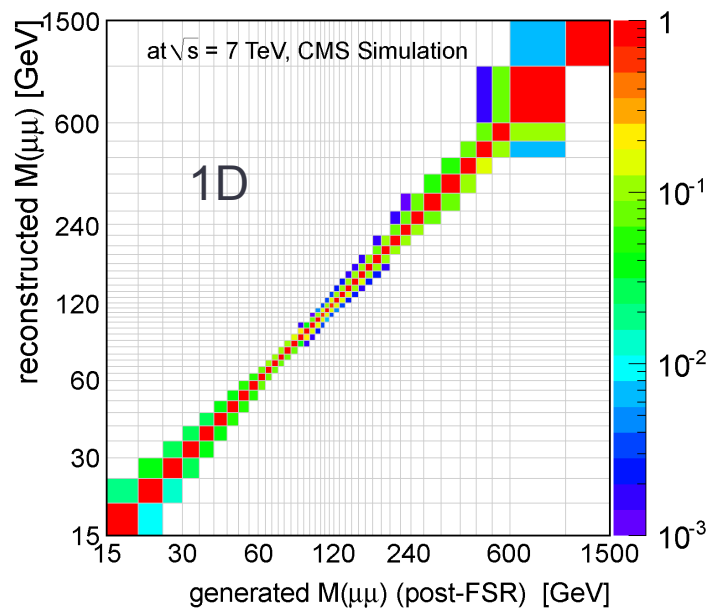


- Comparison with NNLO FEWZ + Different PDF sets (only central members)
- Can be used to constrain PDF's

- **Presented results from following measurements**
 - W and Z inclusive cross sections at 8 TeV (CMS-SMP-12-011)
 - Z p_T differential cross section at 8 TeV (CMS-SMP-12-025)
 - W electron charge asymmetry at 7 TeV (CERN-PH-EP-2012-151)
 - Drell-Yan differential cross sections at 7 TeV (CMS-SMP-13-003)
- **Precise test of the Standard Model at TeV scale**
- **Measurements sensitive to NLO and NNLO calculations**
- **Results in a good agreement with theory predictions**
- **PDF's probed and constrained in a new kinematic regime**
- **More results from 7TeV and 8TeV measurements still to come...**
- **<https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP>**

Backup

Unfolding detector resolution effects →



Unfolding FSR effects →

