Recent Electroweak Results from CMS

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on behalf of the CMS Collaboration

Outline

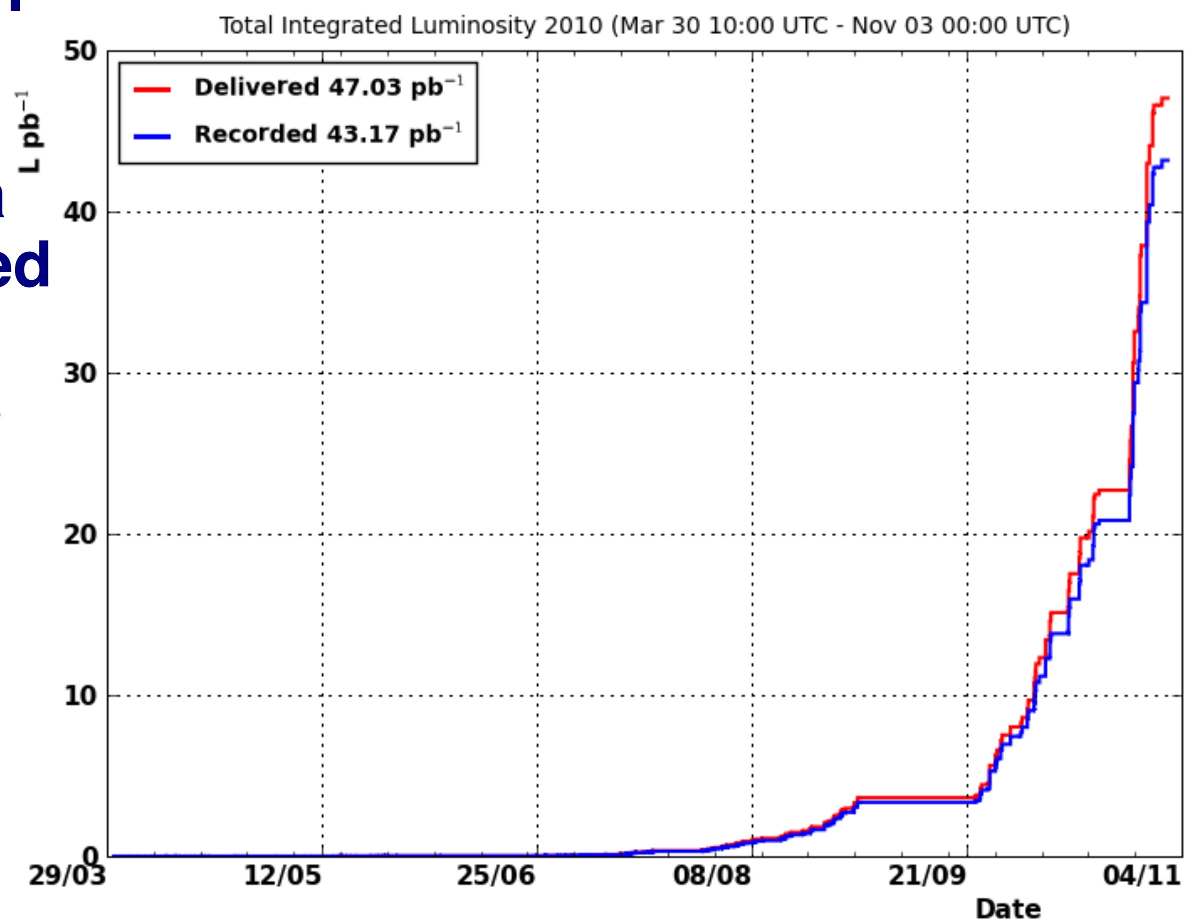
- Introduction
- W/Z Cross Section
- W Charge Asymmetry
- W Polarization
- Vector Boson + Gamma
- WW Cross Section
- Z Differential Cross Section
- Drell-Yan Cross Section
- Z Forward Asymmetry
- Z to Tau tau Cross Section

CMS 2010 Run

2010

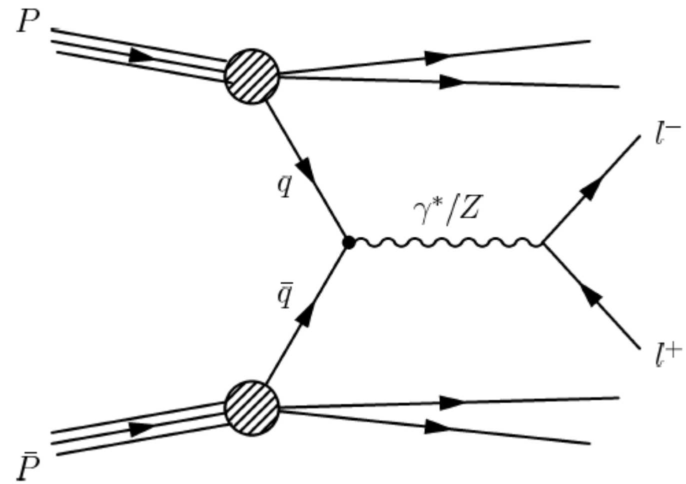
- **All analysis in this talk use 2010 pp collision data with integrated luminosity of ~36 pb^{-1} at $\sqrt{s}$ = 7 TeV**

Data recording efficiency > 90%



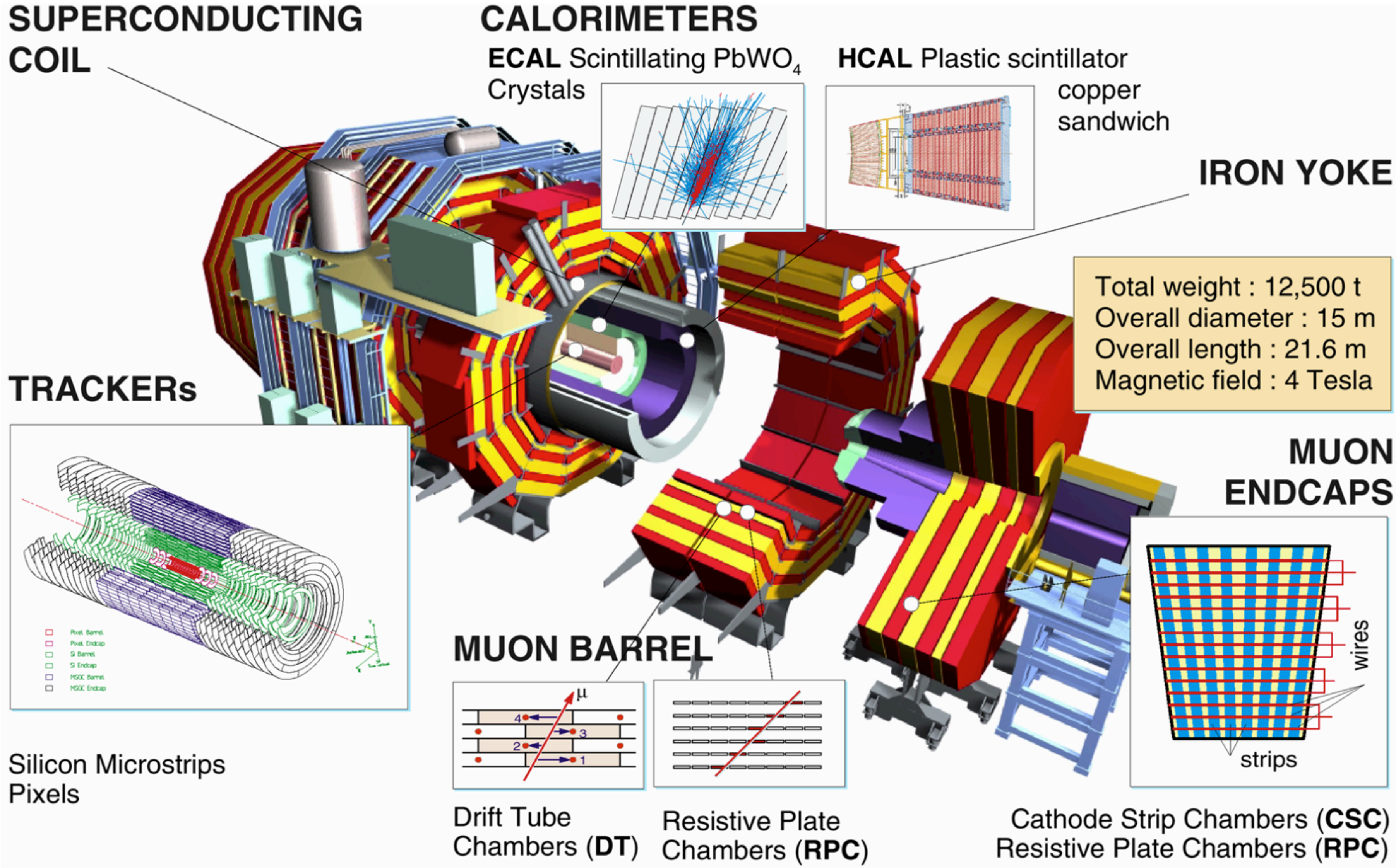
Electroweak at the LHC

- **Electroweak studies are necessary baseline for new physics searches and discoveries beyond the standard model**
  - Dominant signal/background in many searches for new particles
- **By studying precision measurements of electroweak processes, we can make precision measurements of standard model parameters**
  - Deviations may indicate new physics



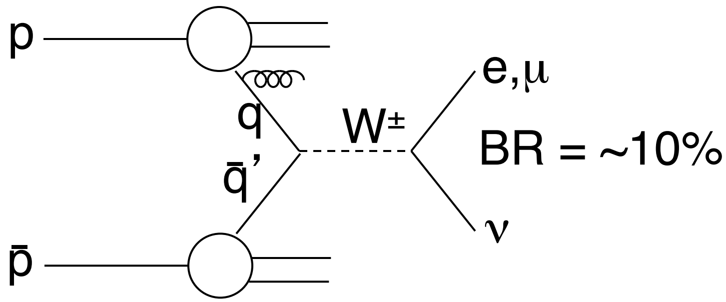
- **Electroweak final states can be used to understand our detector response**

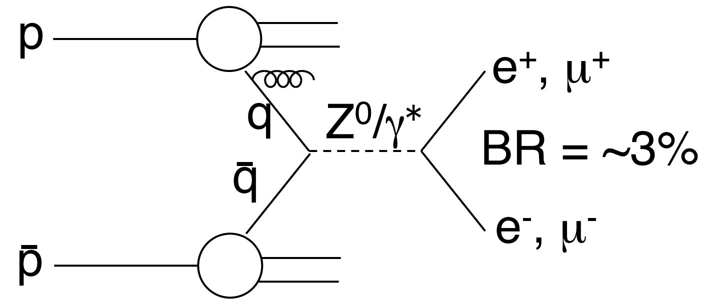
CMS Detector

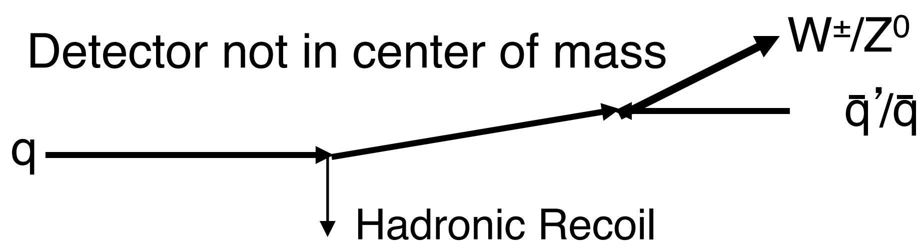


W/Z CROSS SECTION

W/Z Event Signatures

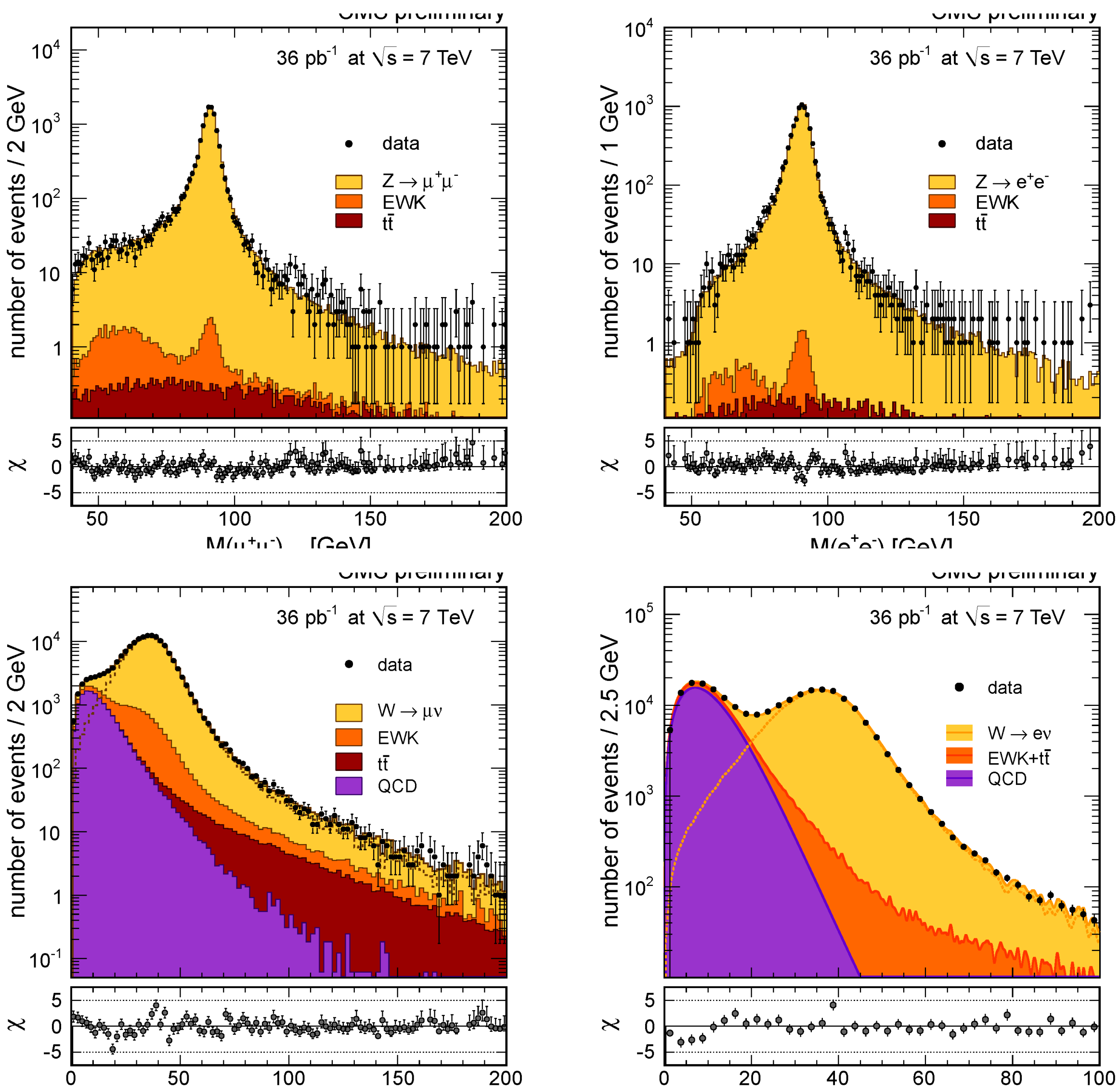






- **Well understood event signatures**
  - Increased understanding of detector by studying W/Z production
- **Electroweak processes are ideal for precise measurements and tests of PDFs**

Cross Section Fit



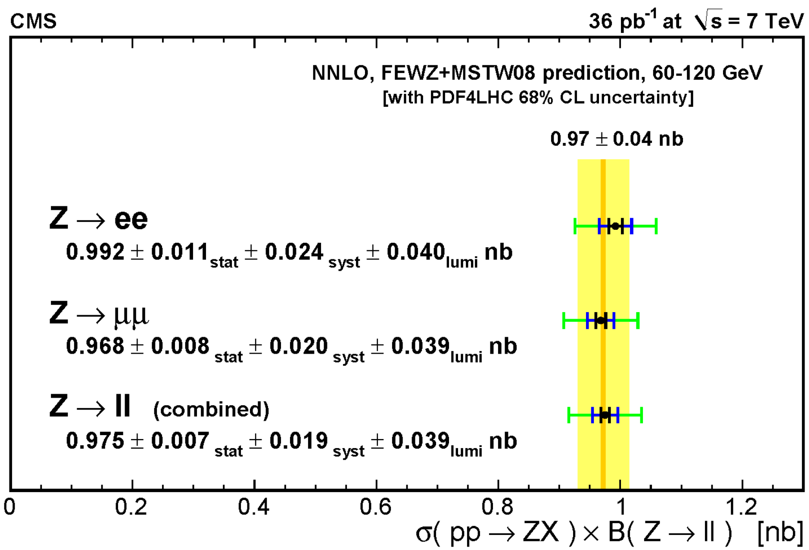
Z Cross Section

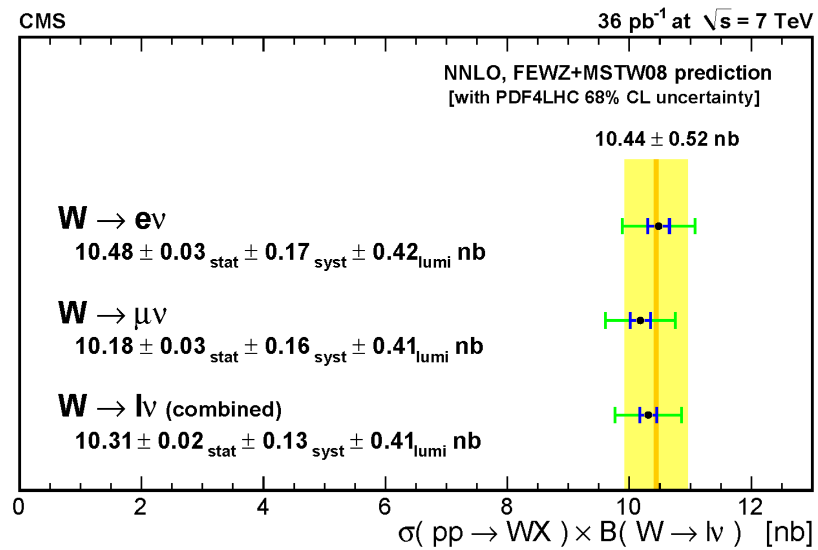
- Fit to mass
- Very little background

W Cross Section

- Fit missing E_T
- Extracted separately or from W total and W^+/W^- ratio

W/Z Result





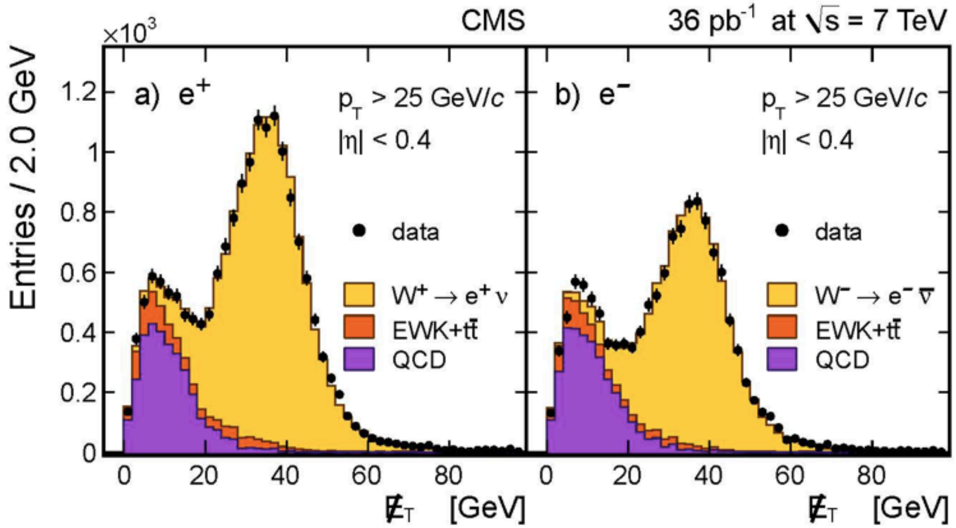
- **Theoretical Models**
  - **We now have accurate NLO theoretical models and NNLO predictions**
  - **Data and NNLO agree**
  - **Experimental uncertainties are significantly reduced thanks to the extensive use of data-driven methods to control efficiencies, backgrounds and signal shapes**

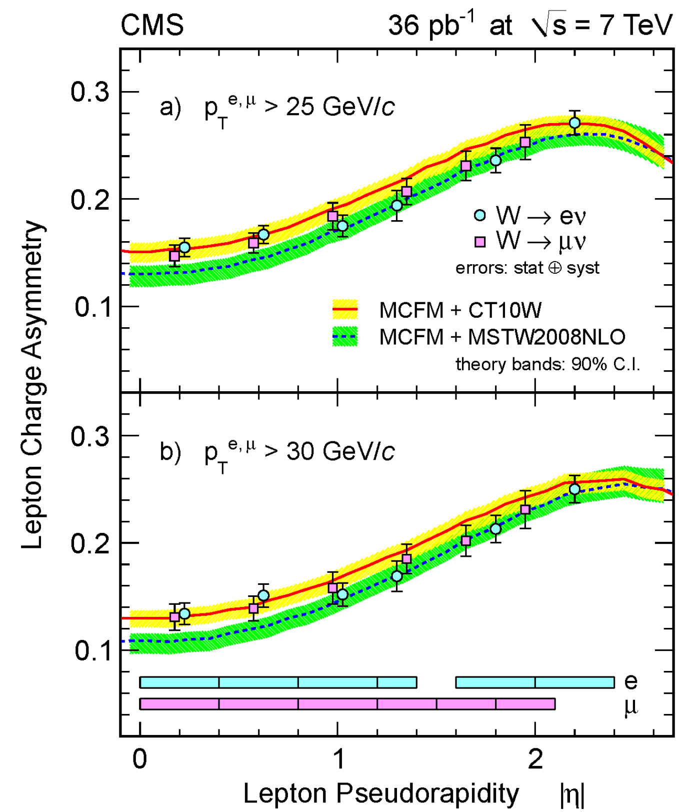
W CHARGE ASYMMETRY

W Charge Asymmetry

- A first natural extension of the W inclusive studies is the study of the W^+/W^- ratio as a function of different kinematic variables
  - W and Z production at LHC proceeds at the hard scattering level and first order via collisions of a valence quark (u,d) and a sea antiquark
  - Due to the different valence quark content of the proton, one expects an asymmetry in the production rates of W+ and W-
  - N(W+)/N(W-) = 2 counting just valence quarks (p≡uud)
  - In practice N(W+)/N(W-) is closer to 1.5 due to the sizeable contribution from sea-sea quark interactions
- Measurement of the W charge asymmetry at the LHC is sensitive to the proton structure
  - We are entering the regime where our measurements can constrain the PDF's
- Most systematic uncertainties cancel in the ratio

W Charge Asymmetry Results





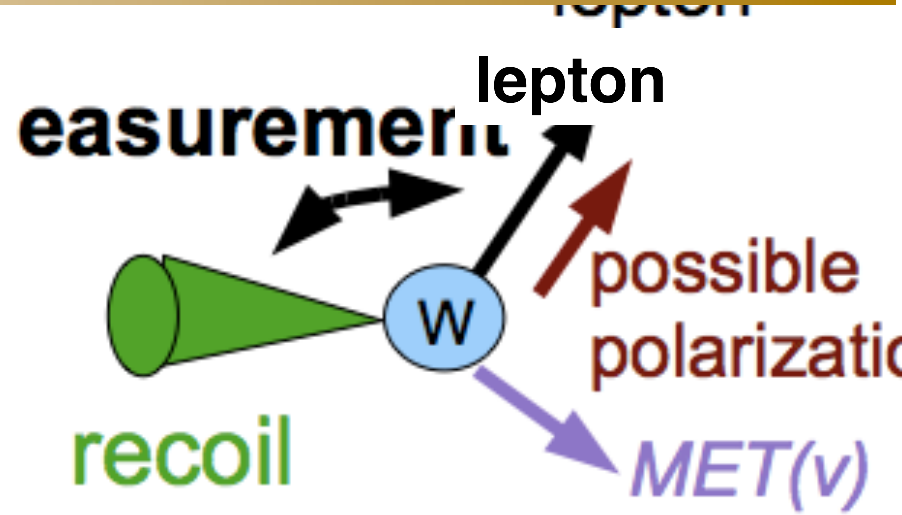
- **Good agreement between electron and muon results**
- **Should provide first constraints on PDF's from LHC**

W POLARIZATION

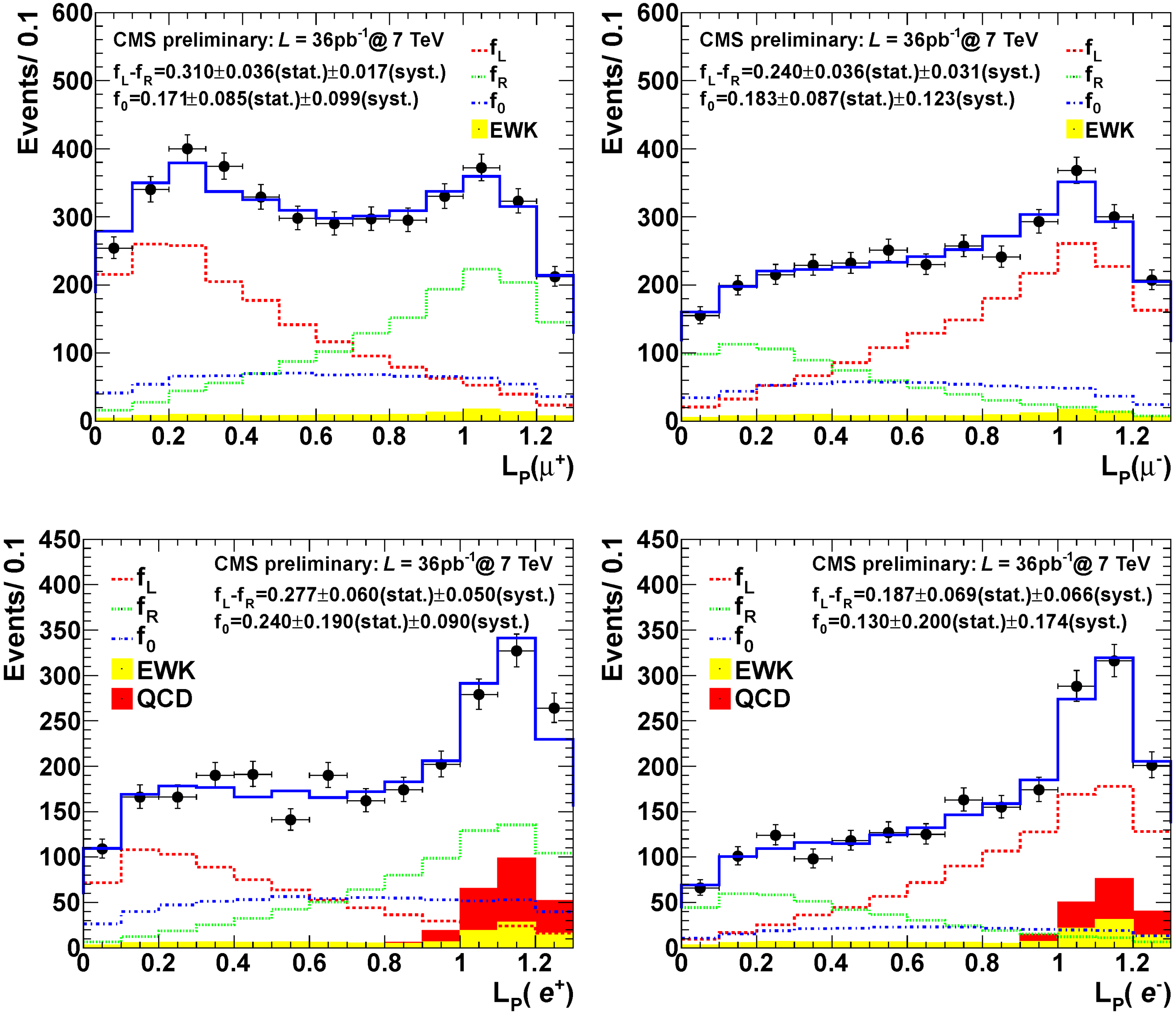
W Polarization

- **W bosons exhibit polarization when produced with hard jets at LHC**

$$LP = \frac{\vec{p}_T(\ell) \cdot \vec{p}_T(W)}{|\vec{p}_T(W)|^2}$$



- **θ: angle of lepton in W rest frame wrt boson flight direction in the lab frame**
  - cos θ: amount of W momentum imparted to the charged decay lepton
  - We measure LP instead of cos θ
  - LP: projection of $p_T(l)$ onto $p_T(W)$
    - **At high $p_T(W)$, LP = cos θ**
- **Polarization indicates proportion of quark-gluon and quark-quark contribution**



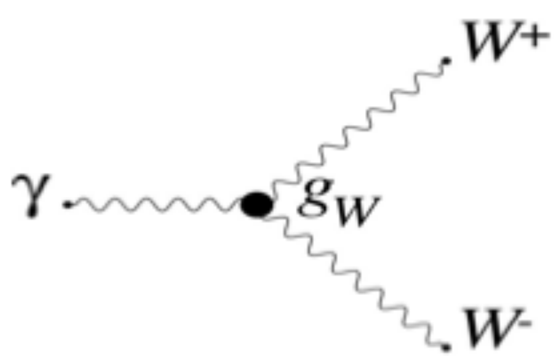
This establishes for the first time that W bosons produced in pp collisions are predominantly left-handed, as predicted by the Standard Model.

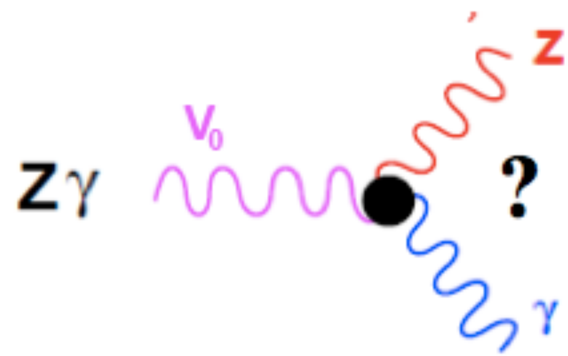
Results have same sensitivity as LEP data.

V + GAMMA

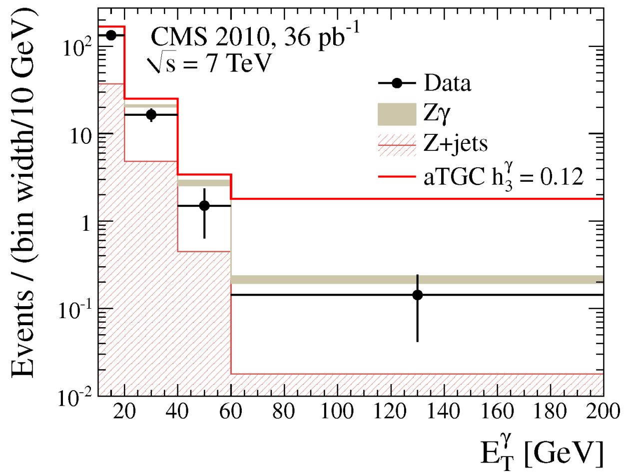
V + Gamma

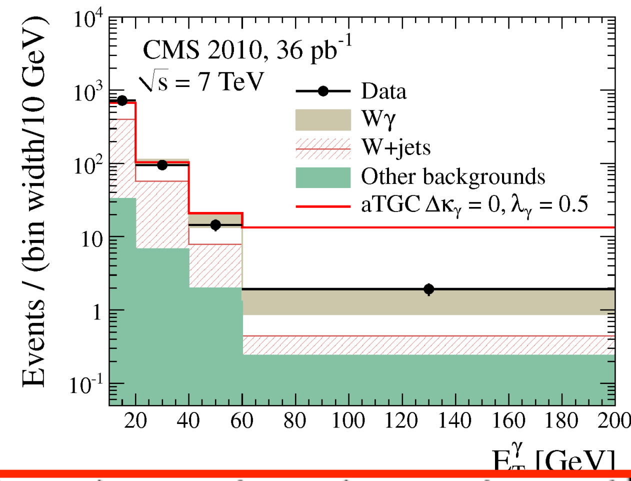
- **Diboson physics**
  - Allows tests of triple-gauge coupling (TGC) in standard model
  - Final states appearing in several new physics models
- **Measure the Wγ and Zγ cross section and compare with standard model prediction**





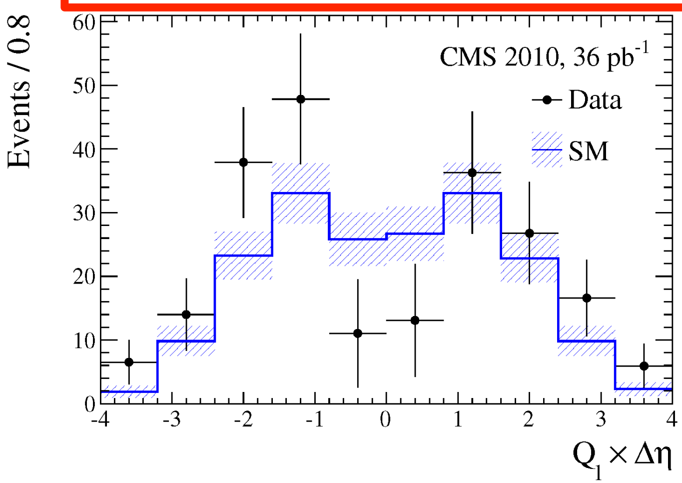
V + Gamma Results





$$\sigma(pp \to W\gamma + X)B(W \to l\nu) = 55.9 \pm 5.0(stat.) \pm 5.0(syst.) \pm 6.1(lumi.)\ pb$$

$$\sigma(pp \to W\gamma + X)B(W \to l\nu) = 9.3 \pm 1.0(stat.) \pm 0.6(syst.) \pm 1.0(lumi.)\ pb$$

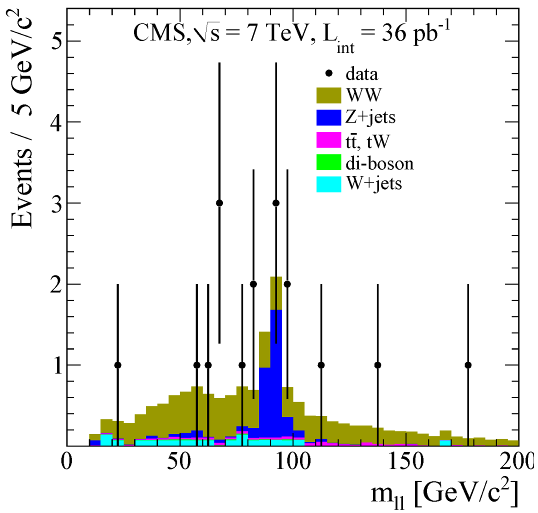


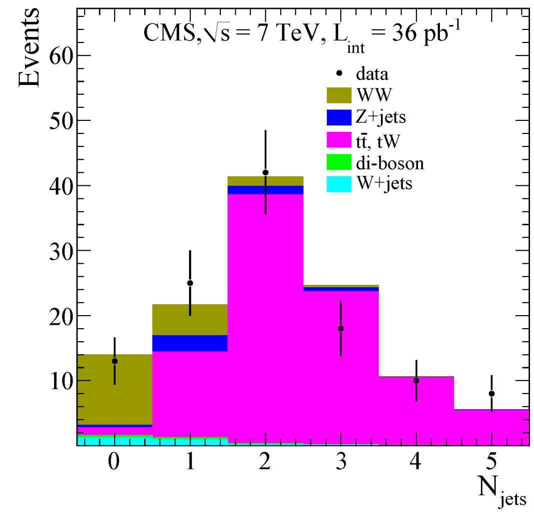
RAZ

- Unique feature of W-boson coupling to massless photon. $\sigma(q_1 q'_2 \to W\gamma)$ vanishes at certain angles of W-boson with the quark. ($\cos\theta^* = \pm 1/3$).
- Data consistent with standard model.

WW DIBOSON MEASUREMENT

WW Results





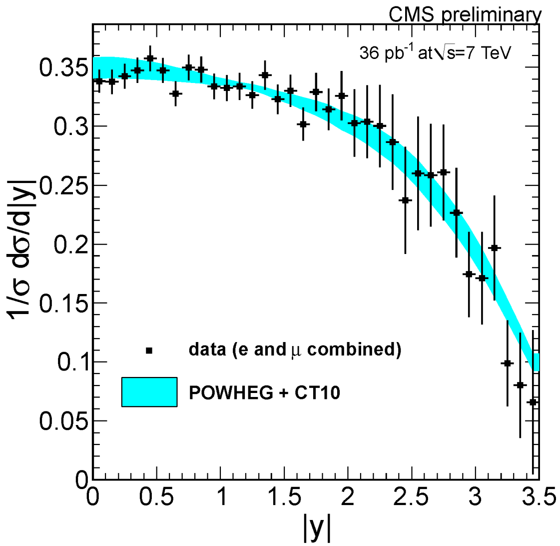
$$\sigma(WW) = 41.1 \pm 15.3(stat) \pm 5.8(syst) \pm 4.5(lumi)\ \ pb$$

- **Important measurement before performing H→WW searches**
- **Look for W to e or mu decays**

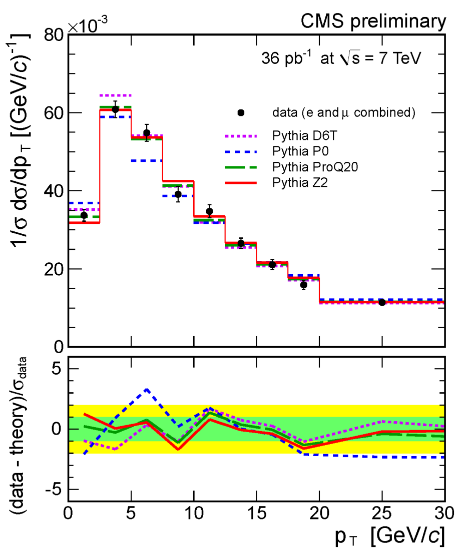
- **Allows exclusion of Higgs particle in a four-generation standard model scheme in range 144-207 GeV**

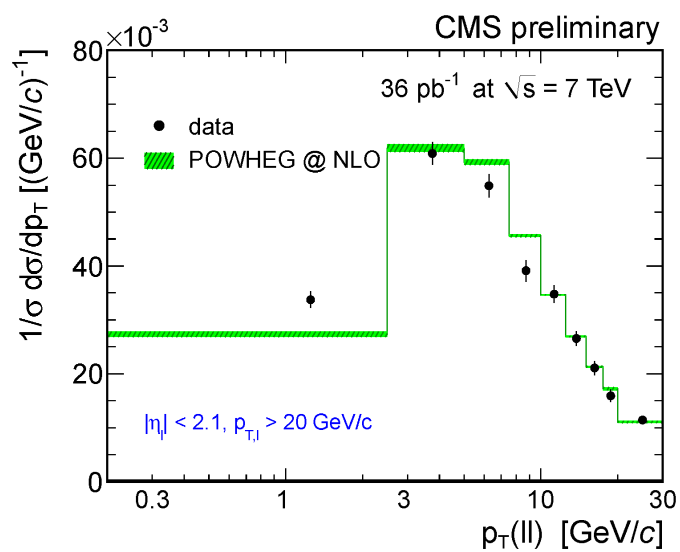
Z DIFFERENTIAL CROSS SECTION

Z Differential Cross Section



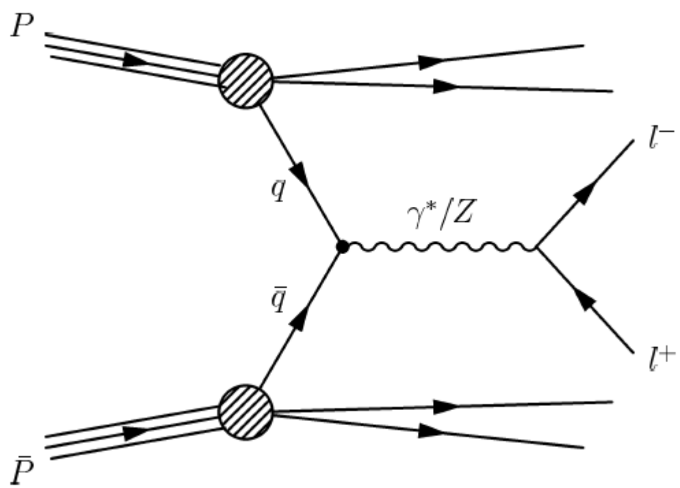
- **Z p_T spectrum agrees with latest PYTHIA and slight disagreement with POWHEG (PYTHIA Z2)**
- **Good eta agreement with NLO prediction**



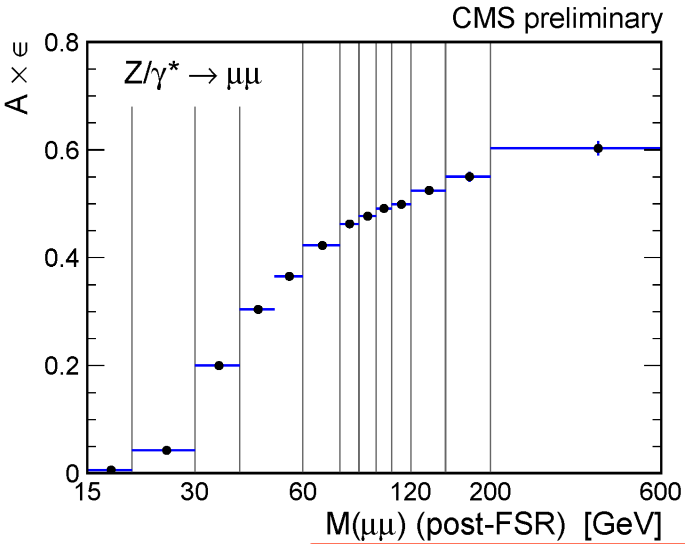


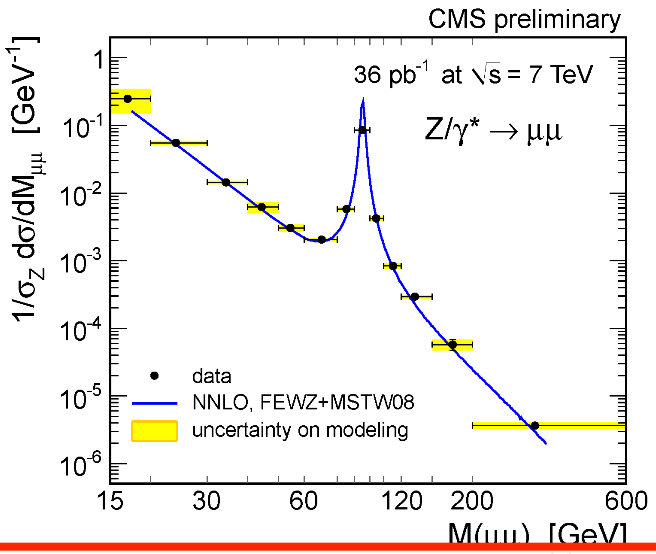
DRELL-YAN

- **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 parton density functions (PDFs)
    - **Cn be used to constrain PDFs**
  - Drell-Yan is an important background for searches beyond the standard model



Drell-Yan Differential Cross Section



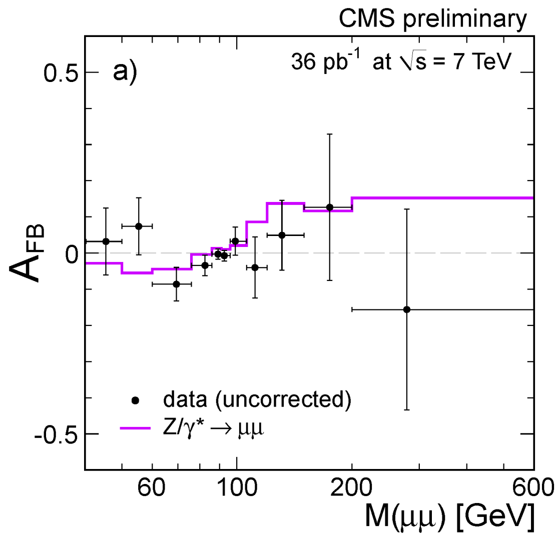


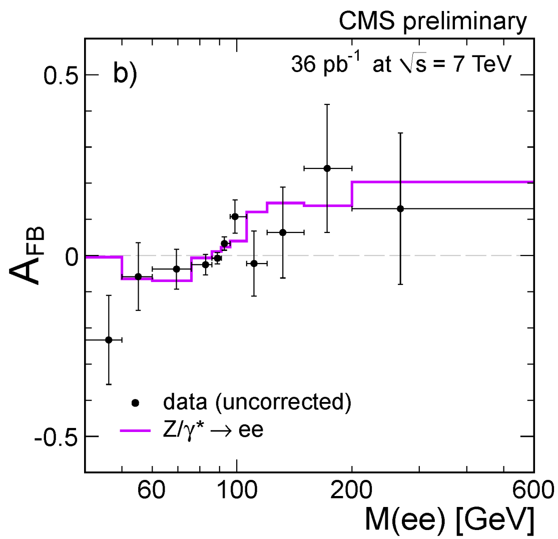
The peak cross section value: $\sigma_{\mu\mu} = 926 \pm 8_{stat} \pm 8_{syst} {}^{+14}_{-23}{}_{PDF} \pm 37_{lum}$

- Drell-Yan differential cross section normalized to the Z peak was measured in the muon channel in 13 mass bins with 36.4 ± 1.5 pb^{-1}
  - our result for the absolute cross section in the Z peak region consistent with the published CMS result
- Comparison with theoretical NNLO prediction: good agreement with data if modeling uncertainty is taken into account
  - PDF dependences and higher order effects studied over wide mass range

Z FORWARD ASYMMETRY

Asymmetry Result





$$\frac{d\sigma}{d\cos\theta} = \frac{3}{8}(1+\cos^2\theta^*) + A_{FB}\cos\theta^*$$

$$A_{FB} = \frac{(N_F - N_B)}{(N_F + N_B)}$$

- Θ^*: quark-lepton angle in CM
  - ~Collins-Soper angle of beam direction and dilepton
- A_{FB}: depends on quark flavor and $\sin^2\theta_W$
  - Asymmetry measurement sensitive to the $\sin^2\theta_W$
- We expect zero asymmetry at the Z pole ($v_l \approx 0$), negative below and positive above (driven by the axial couplings to the Z)

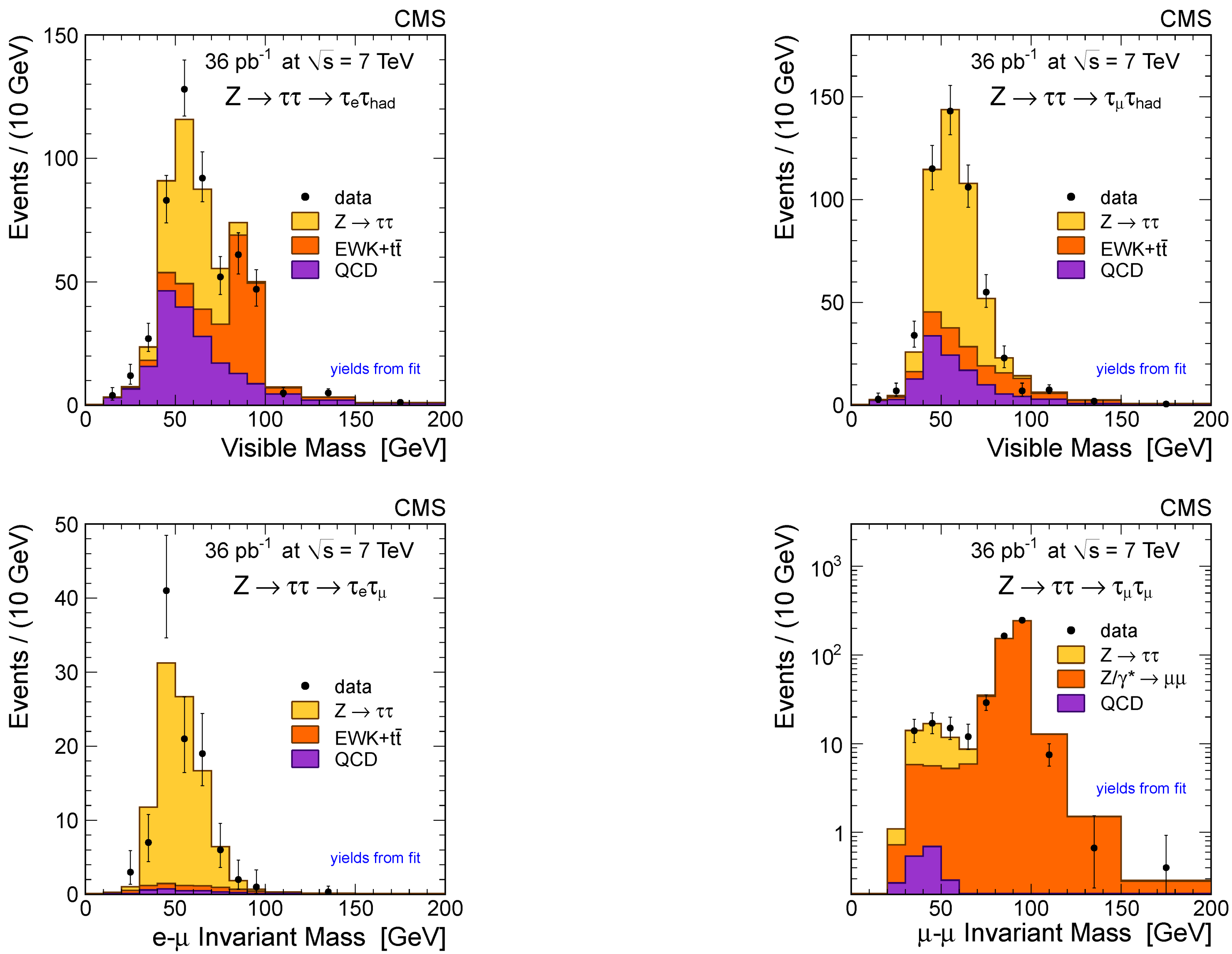
$$\sin^2\theta_{eff} = 0.2287 \pm 0.0077(stat.) \pm 0.0036(sys.)$$

Z TO TAU TAU CROSS SECTION

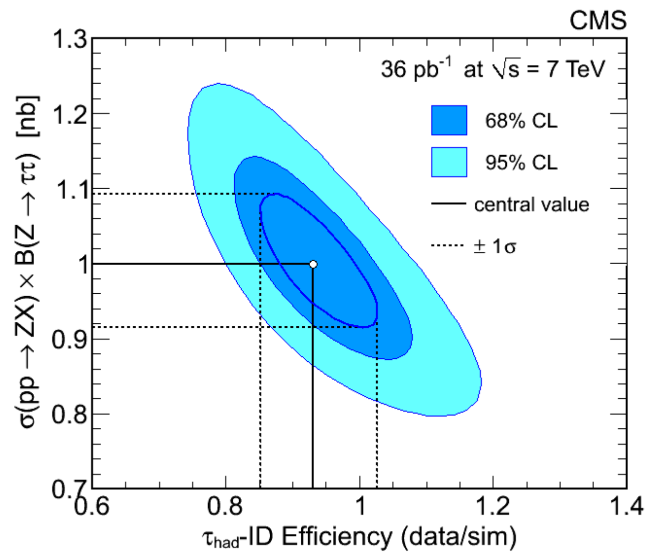
$Z \rightarrow \tau\tau$

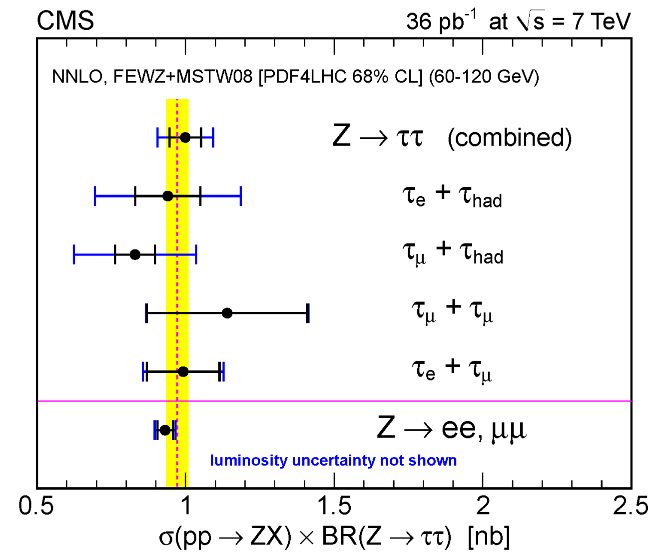
- **$Z \rightarrow \tau\tau$ is important source of high energy τ leptons in standard model**
  - Important background in searches for physics beyond the standard model

Visible Mass Spectra



Z➔ττ Results



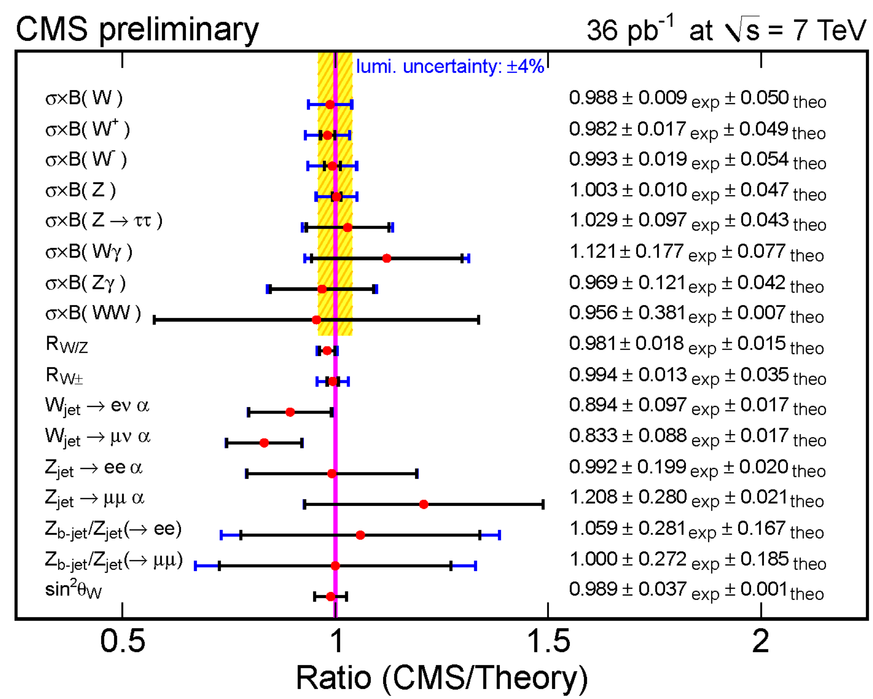


σ*BR(Z/γ*➔τ+τ-) = 1.00 ± 0.05 (stat.) ± 0.08 (sys.) ± 0.04 (lumi.) nb

- **Clear signal in all four channels**
- **Good data and NNLO agreement**

Summary -- 2010

- **With the first 36 pb^{-1} of LHC data, CMS has provided many precision electroweak measurements**
  - Inclusive and differential cross sections of boson decays into leptons
  - Precise measurements of observables
  - Observation of diboson final states
- **Comprehensive view of electroweak measurements at the LHC are in agreement with theoretical expectations**



Summary -- 2011

- **We have already far surpassed 2010 data collection**
- **Entering an exciting realm of (fingers crossed ☺) new physics**
- **Precise electroweak measurements lay the foundation for new physics discovery**
- **Many new studies in 2011 to be baseline for going beyond the standard model**