W and Z boson production at CMS in pp collisions at $\sqrt{s}$=7 TeV

Jeremiah Mans
University of Minnesota
On behalf of the CMS Collaboration

ICHEP 2010
Paris, France ::: July 22, 2010

Outline

- **Motivations and Physics Reach**
- **CMS Performance**
- **Inclusive measurements**
  - $W \to e\nu$ / $W \to \mu\nu$
  - $Z \to ee$ / $Z \to \mu\mu$
- **Differential Measurements**
  - W charge asymmetry
  - Z rapidity
  - Z/W + jets
- **Outlook**

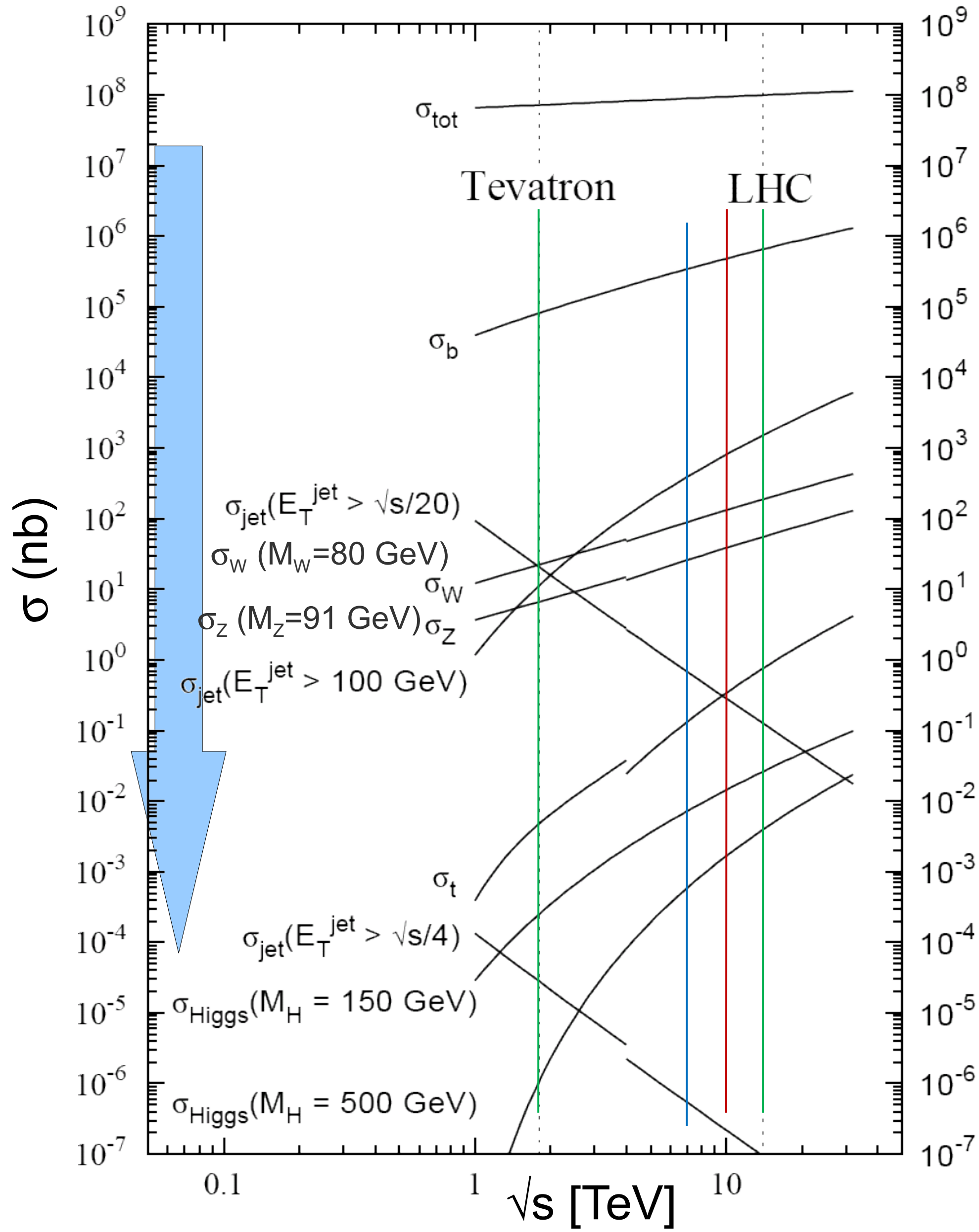
This talk has a broad view of the W/Z, including both new data and near-term prospects. For all the details on the W/Z extraction from first data, see Maria Cepeda's talk tomorrow in Session 1 (11am)

Stepping Stone and Physics Tool

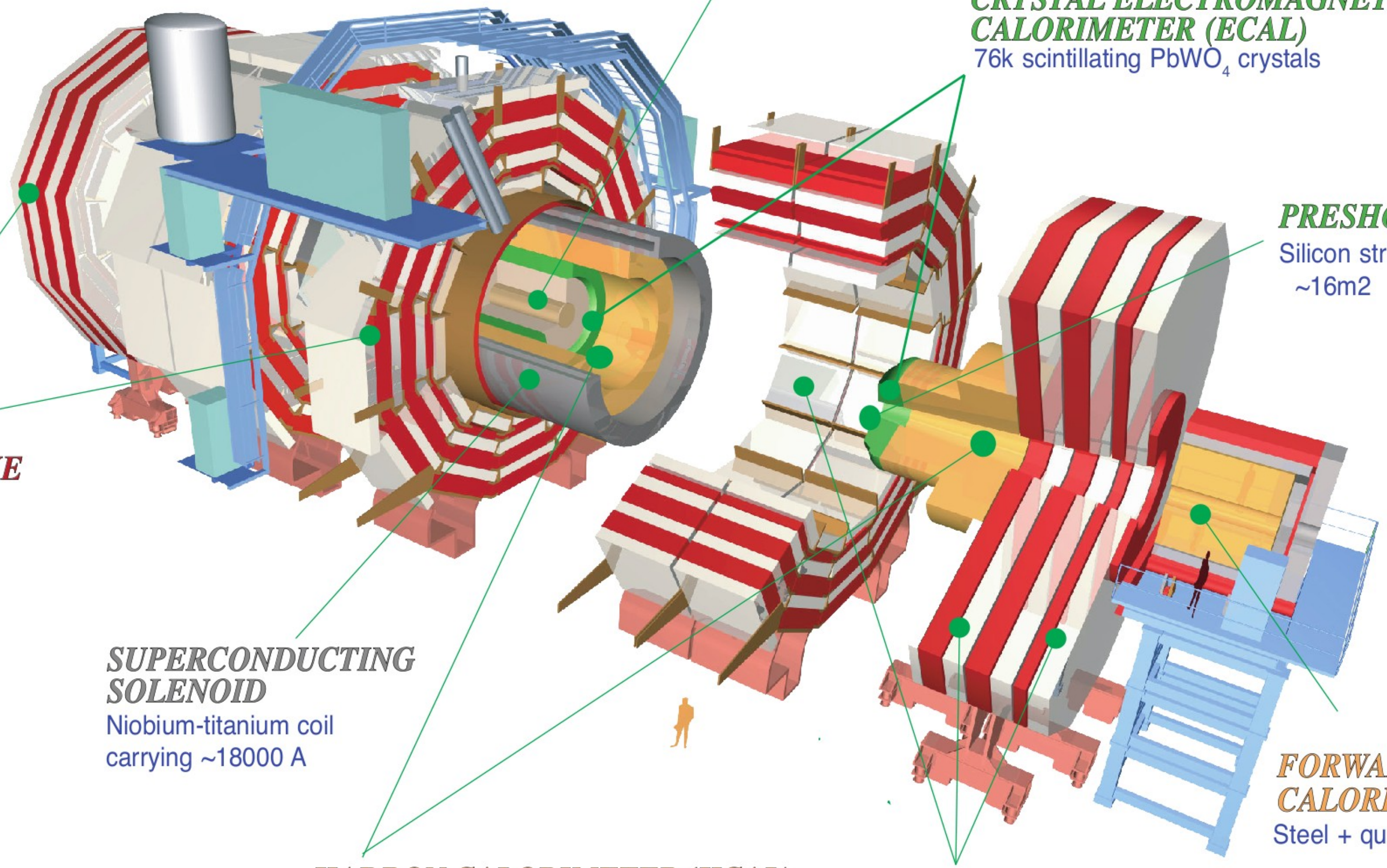
- Properties of W/Z well-established
  - Masses and Widths
  - Decay Products
  - Theoretical understanding of production processes

- Use W/Z as tools to study:
  - Detector effects/performance
  - Luminosity
  - Collision environment (PDFs)
  - Analysis Techniques
- W/Z define a hard scale for many physics measurements

- First Steps
  - Isolation of W/Z signals
  - Understand efficiencies and acceptance
  - Measure cross-sections



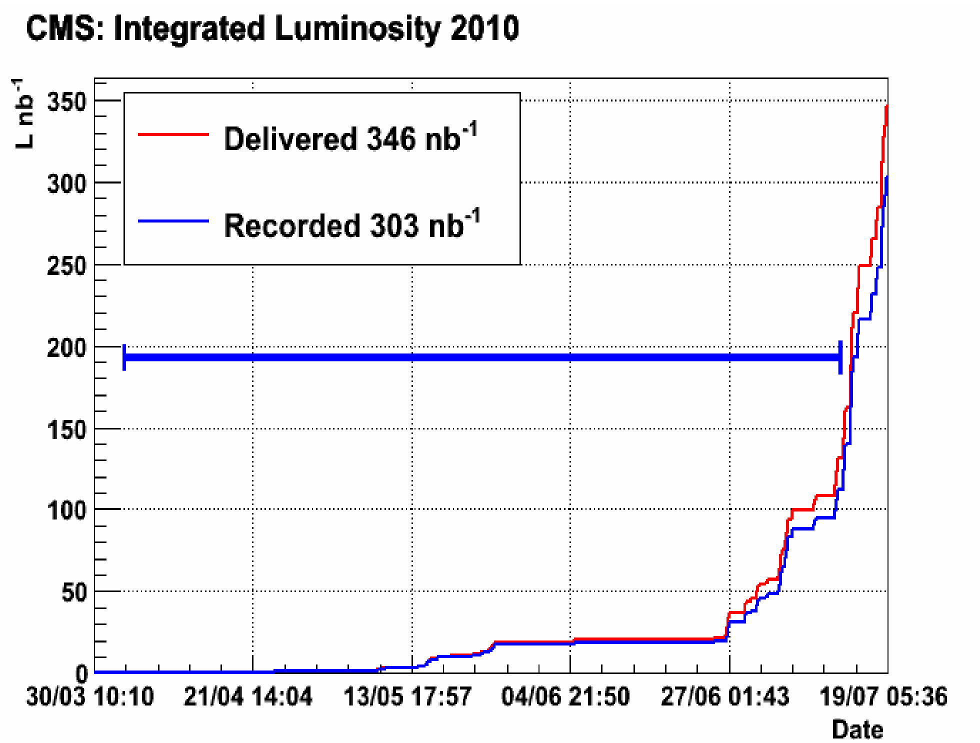
CMS Detector



Total weight : 14000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T

Data and Monte Carlo Samples

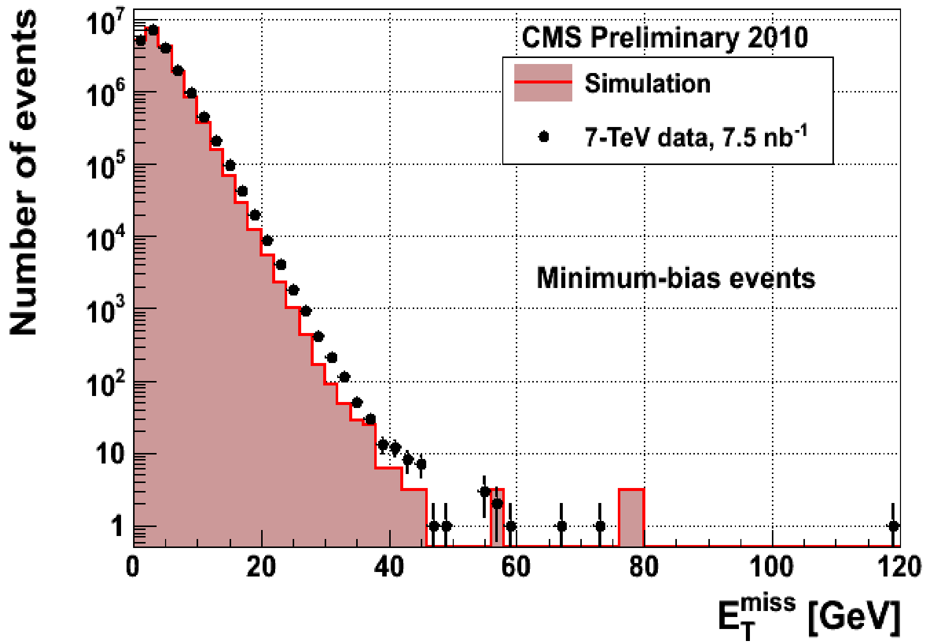
- Data collected at $\sqrt{s}$=7 TeV from March 30 through July 15 2010
  - $\int$ Ldt=198 nb^{-1} analyzed (out of 303 nb^{-1} collected by CMS)

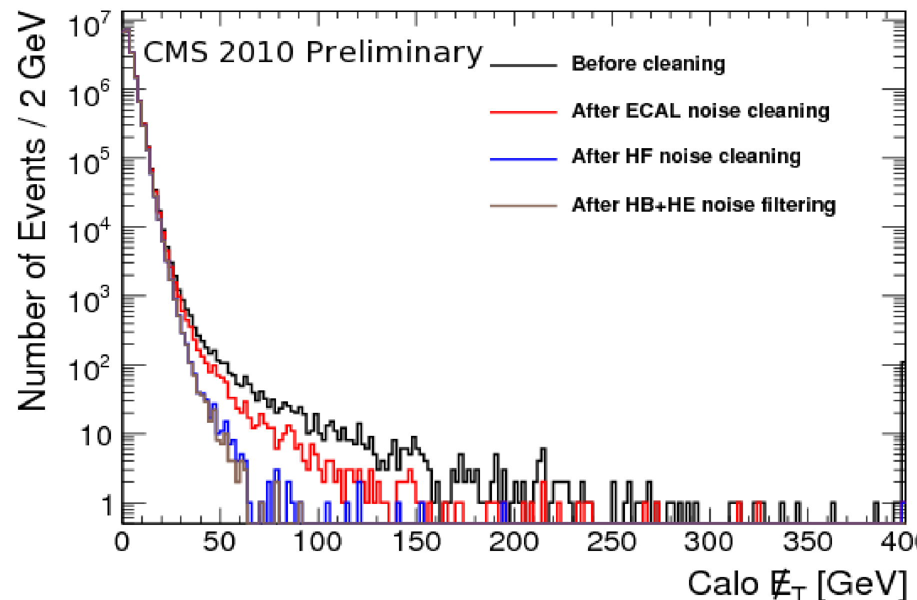


- Large samples of Monte Carlo simulated data used for
  - Validation of analysis techniques
  - Evaluation of signal acceptance and for input to signal and background shapes
- EWK ($W\rightarrow l\nu$, $Z\rightarrow ll$) processes generated with NLO Monte Carlo (POWHEG)
- QCD and some minor backgrounds (ttbar) generated at LO (PYTHIA)

Missing Transverse Energy

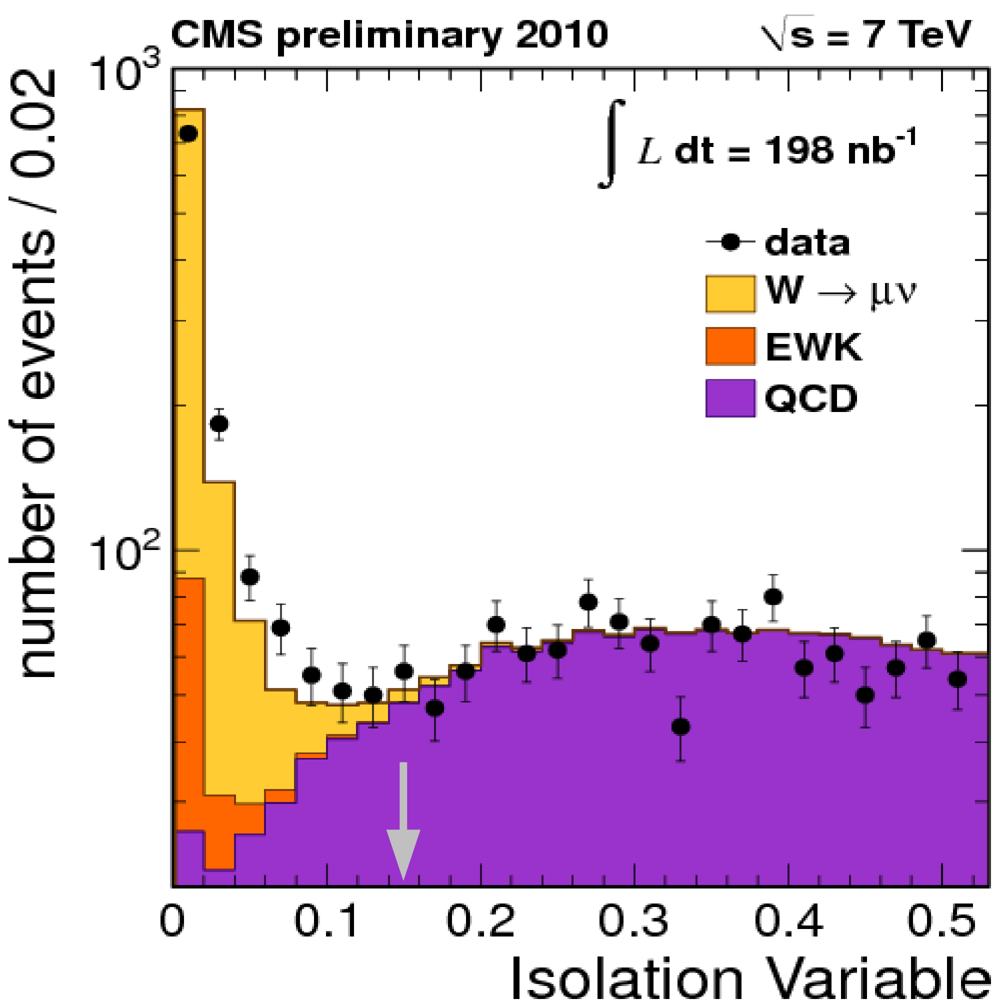
- Missing transverse energy reconstructed using “particle flow” objects which combine calorimeter and track measurements to provide the highest possible resolution
  - Events are also cleaned to remove calorimeter instrumental noise





Muons

- Kinematics
  - For W, p_T > 9 GeV, |η| < 2.1
  - For Z, p_T > 20 GeV, one |η| < 2.4
- Good quality muon track
  - Hits in pixels, strip tracker, muon system)
  - χ^2/dof < 10
- Z measurement requires only track isolation of 3 GeV in a cone
- For W measurement, use a relative isolation in a cone of ΔR < 0.3:



$$I^{\mathrm{rel}}_{\mathrm{comb}} = \left\{ \sum (p_T(tracks) + E_T(em) + E_T(had)) \right\} / p_T(\mu)$$

Electrons

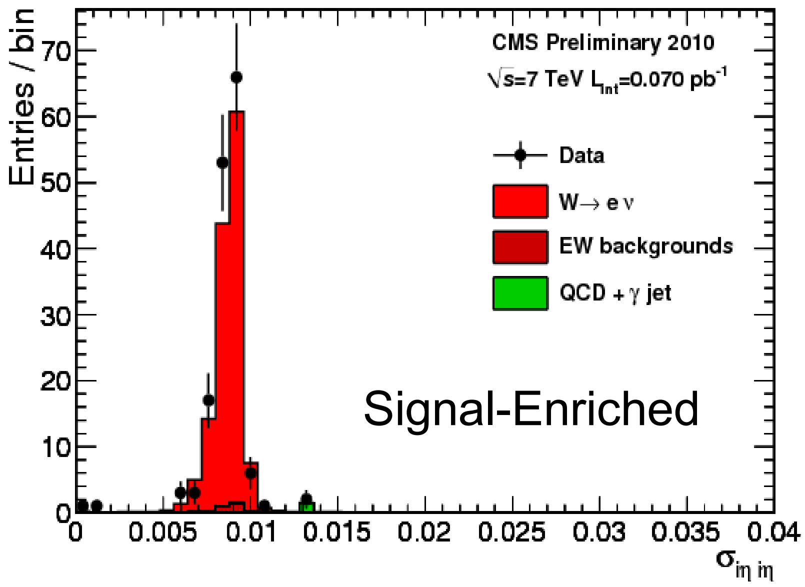
- Kinematics

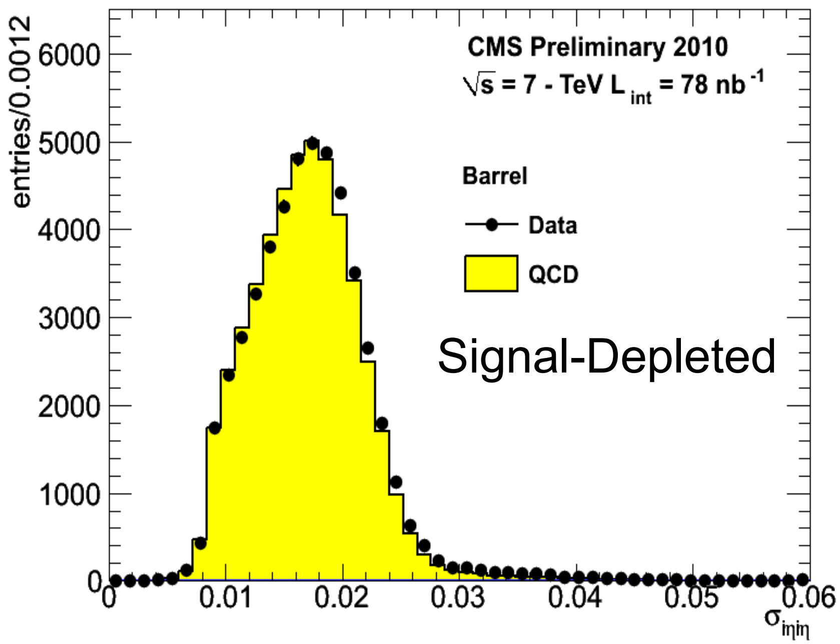
  p_T > 20 GeV

  0.0 < |η| < 1.442

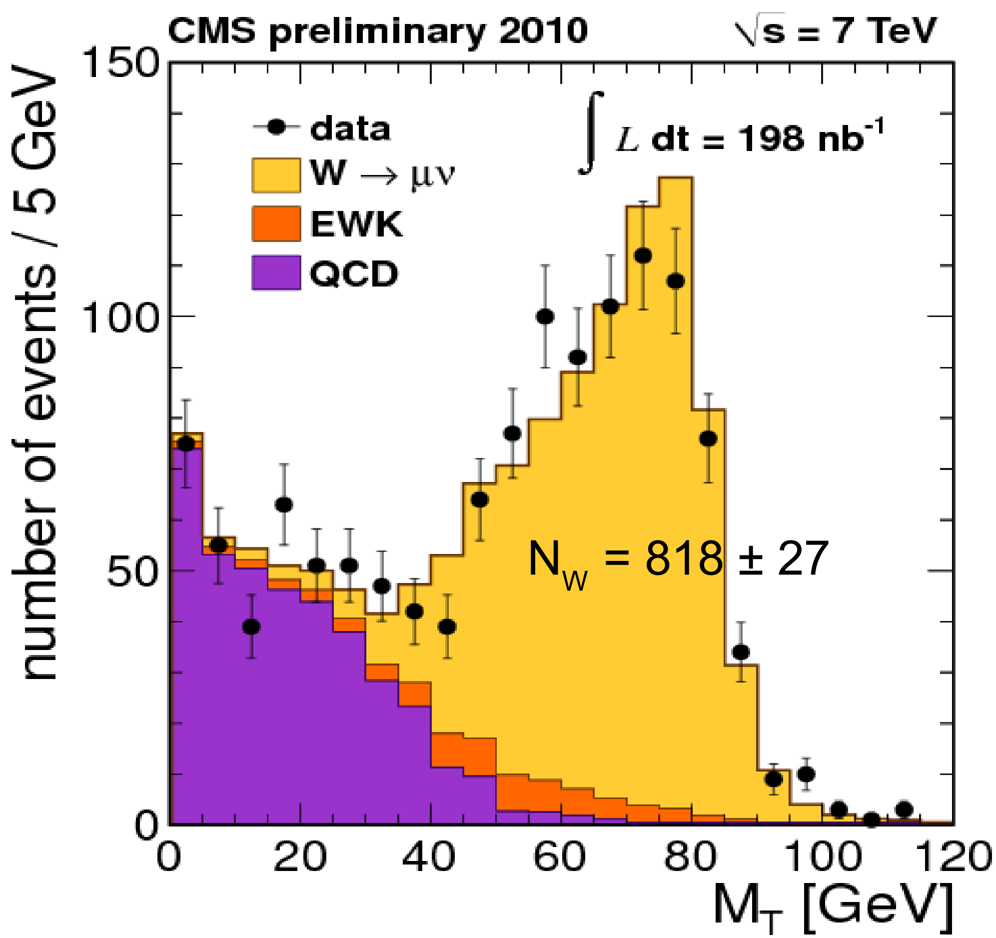
  1.566< |η| < 2.5

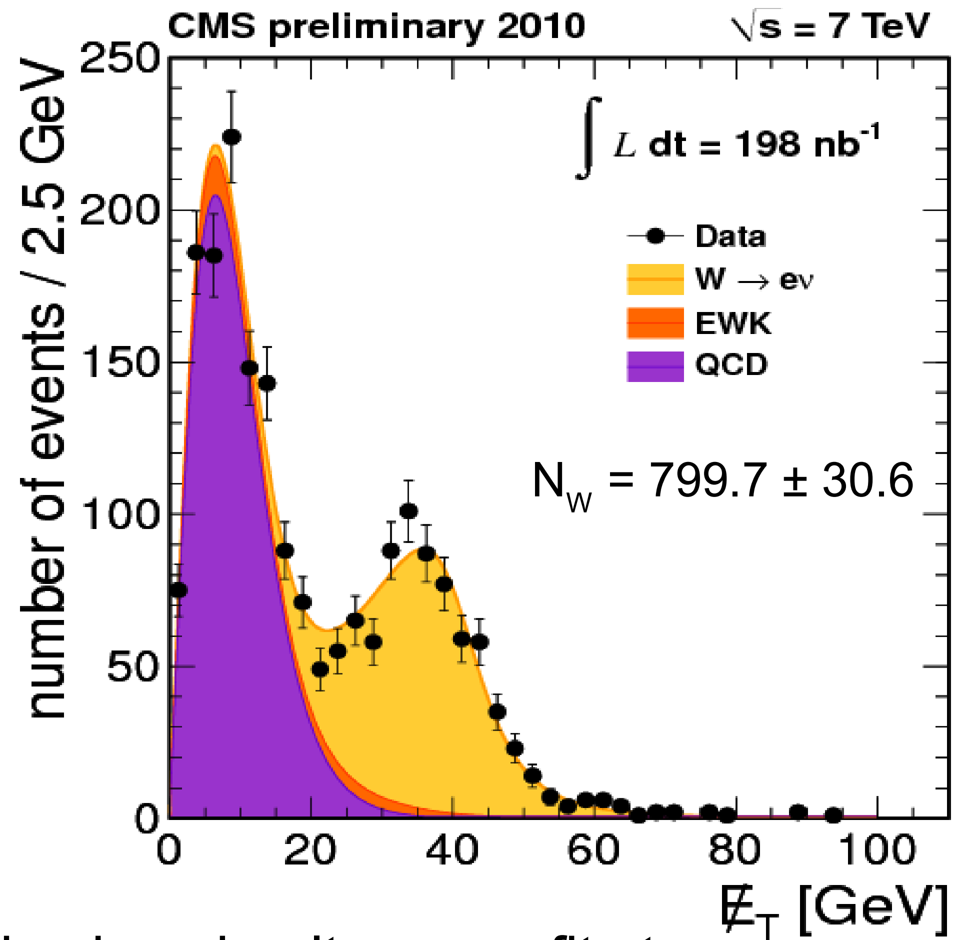
- Specialized track reconstruction to deal with potential large bremsstrahlung
- Electron identification requirements on shower shape variables
- Isolation requirements in tracker ECAL, HCAL





W Signal Extraction





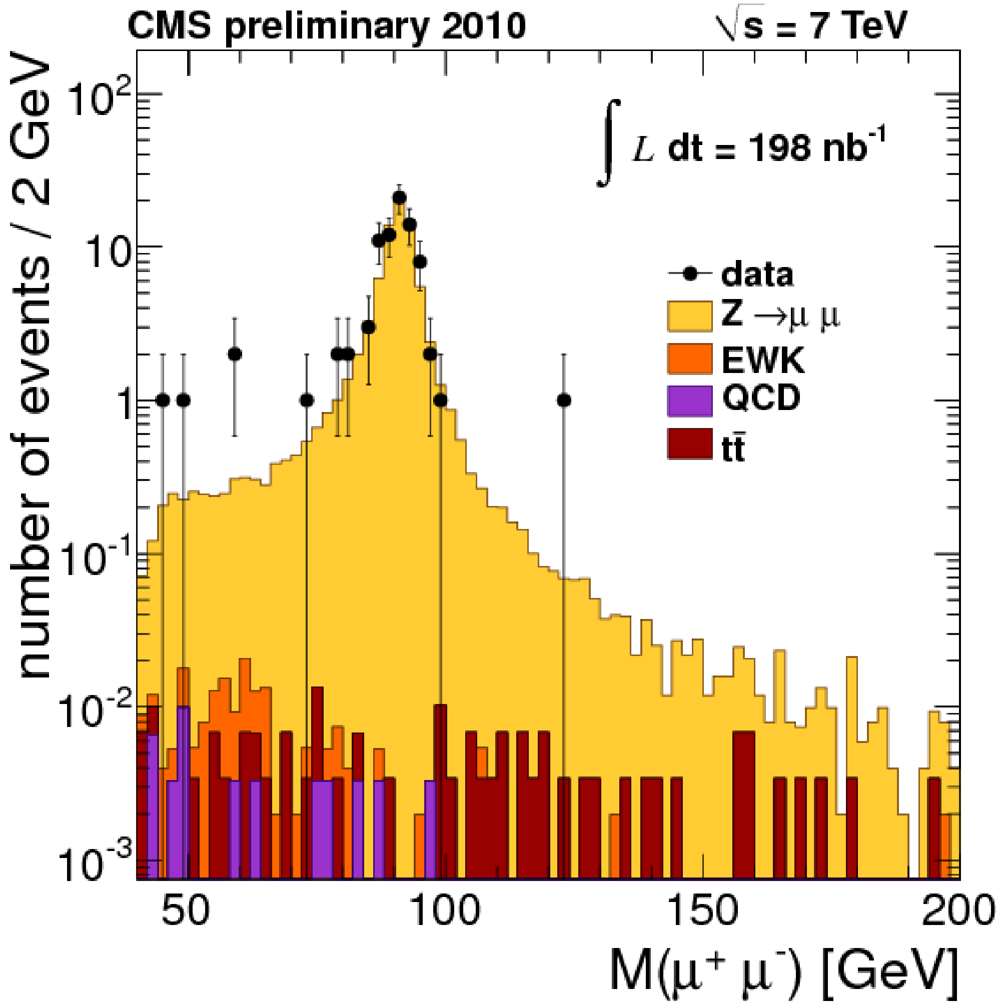
- Yield of W bosons determined using simultaneous fits to background and signal contributions.
- QCD background shapes obtained using data, electroweak background and signal shapes from Monte Carlo simulation

Systematic Errors for W

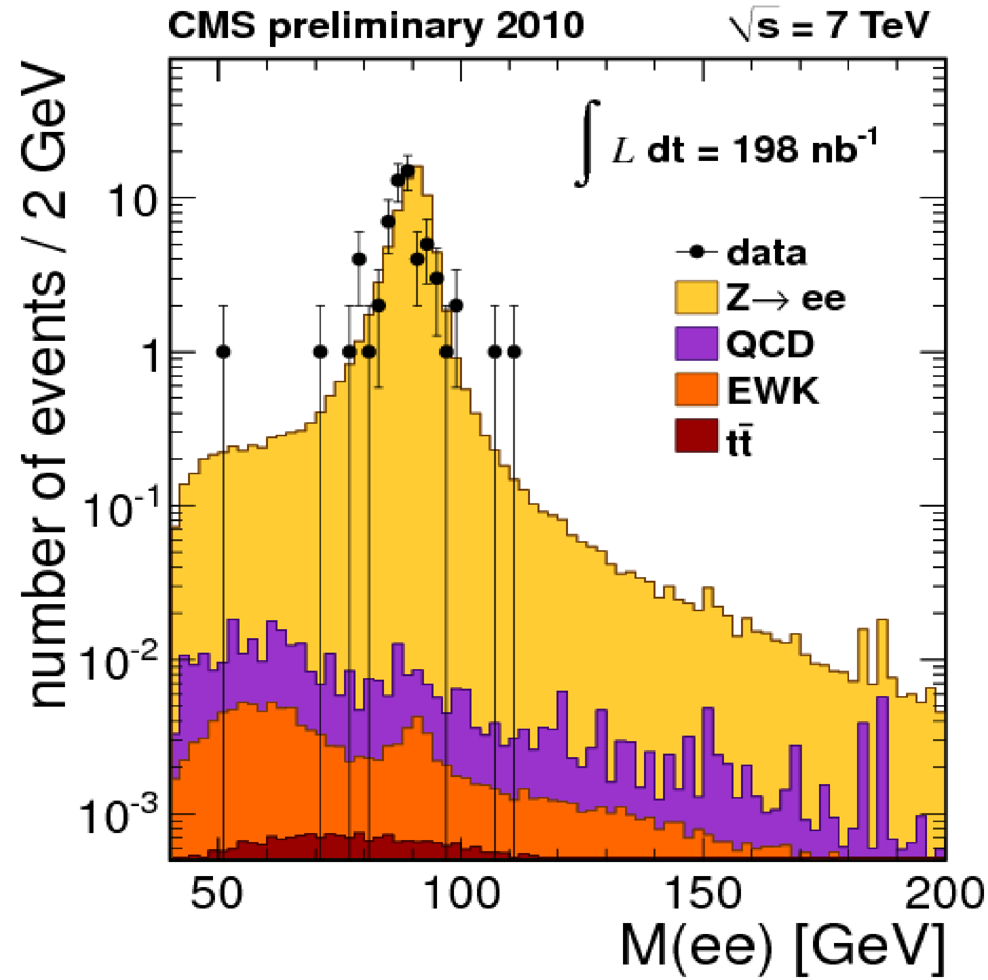
- Efficiencies and scales studied in Z events and recoil studies
- Background uncertainties from cut inversion studies and control samples
- PDF uncertainties evaluated via CTEQ66, MSTW08NLO, NNPDF2.0 sets

Source	$W \to \mu\nu$ (%)	$W \to e\nu$ (%)
Lepton reconstruction	3.0	6.1
Trigger Efficiency	3.2	0.6
Isolation Efficiency	0.5	1.1
Momentum/energy scale	1.0	2.7
MET scale and resolution	1.0	1.4
Background subtraction	3.5	2.2
PDF uncertainty in acceptance	2.0	2.0
Other theoretical uncertainties	1.4	1.3
Total systematic error	6.3	7.7
Luminosity uncertainty	11.0	11.0

Z Signal Extraction



Observed : 77 Z→μμ candidates with 60 GeV < $m_{\mu\mu}$ < 120 GeV

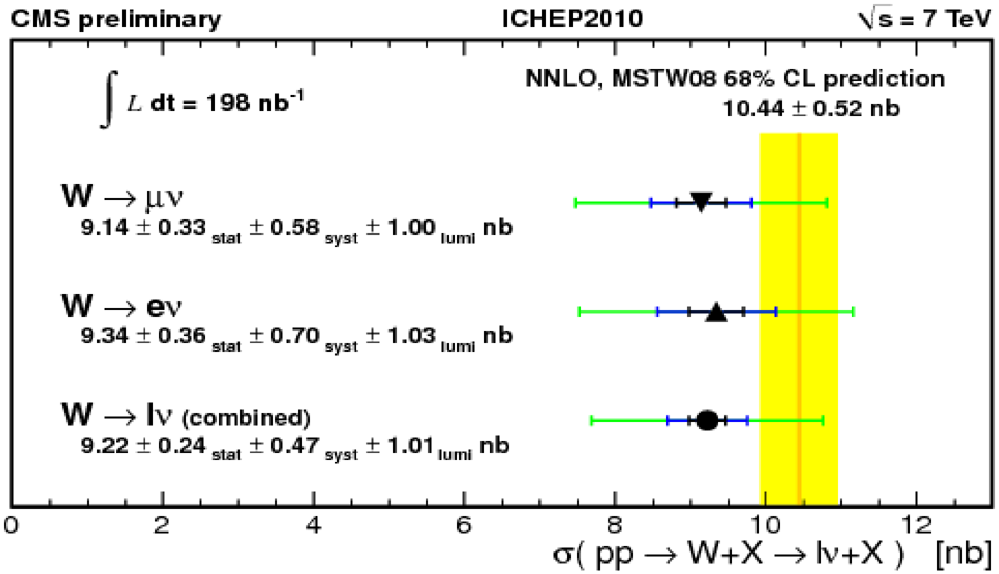


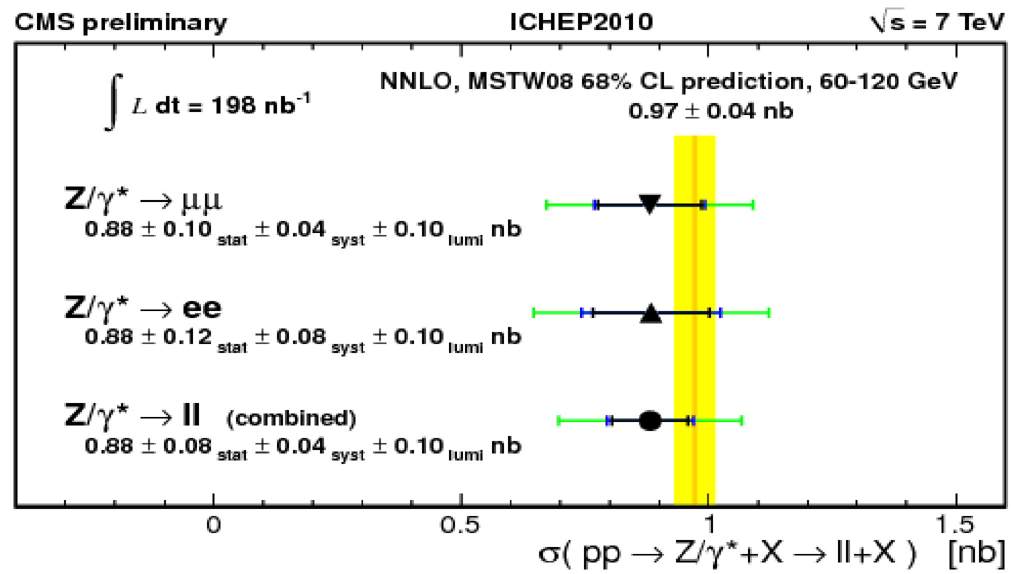
Observed : 61 Z→ee candidates with 60 GeV < m_{ee} < 120 GeV

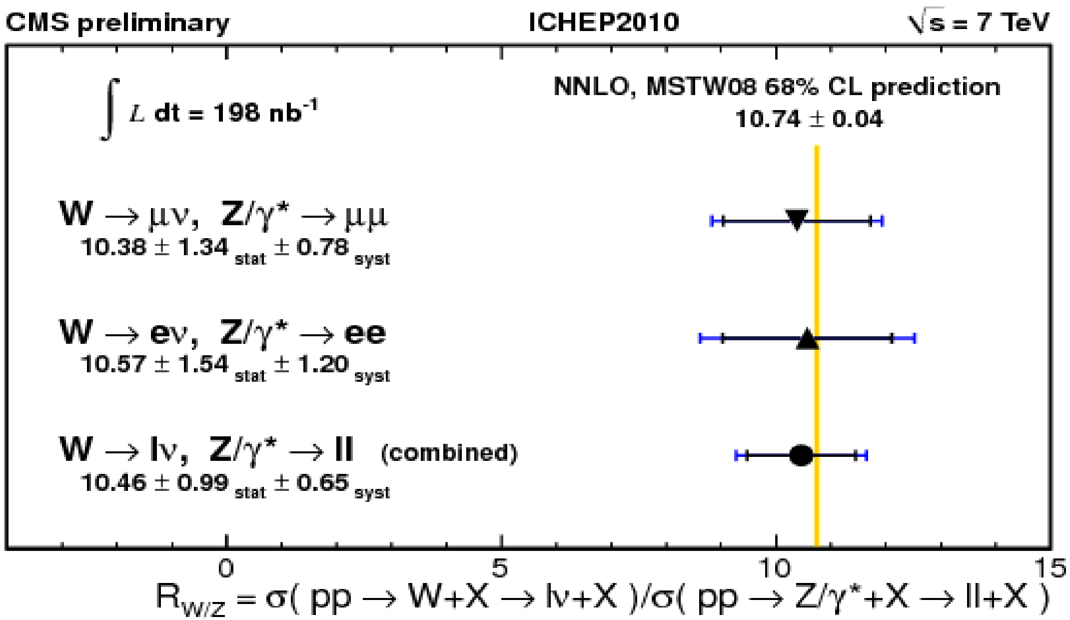
Systematic Errors for Z

Source	$Z \rightarrow \mu\mu$ (%)	$Z \rightarrow ee$ (%)
Lepton reconstruction	2.5	7.2
Trigger Efficiency	0.7	-
Isolation Efficiency	1.0	1.2
Momentum/energy scale	0.5	-
PDF uncertainty in acceptance	2.0	2.0
Other theoretical uncertainties	1.6	1.3
Total systematic error	3.8	7.7
Luminosity uncertainty	11.0	11.0

Full Results







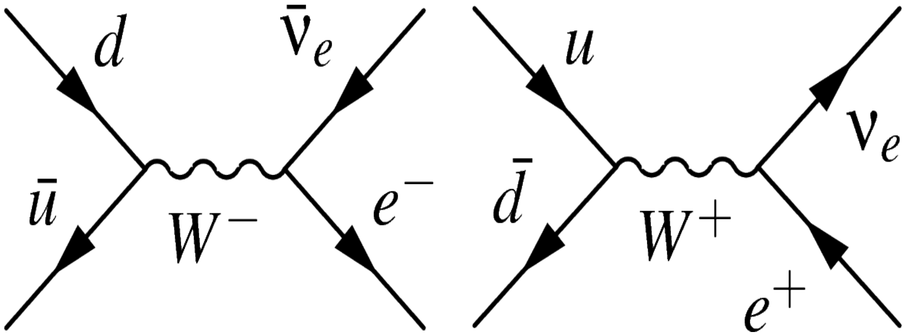
Slicing up the Vector Bosons

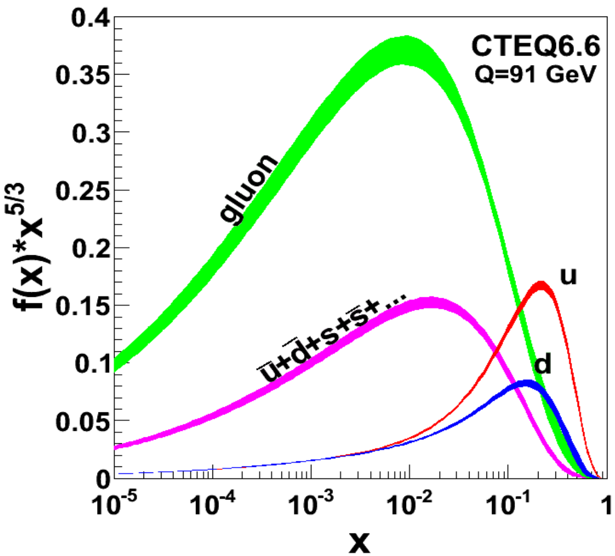
-- or --

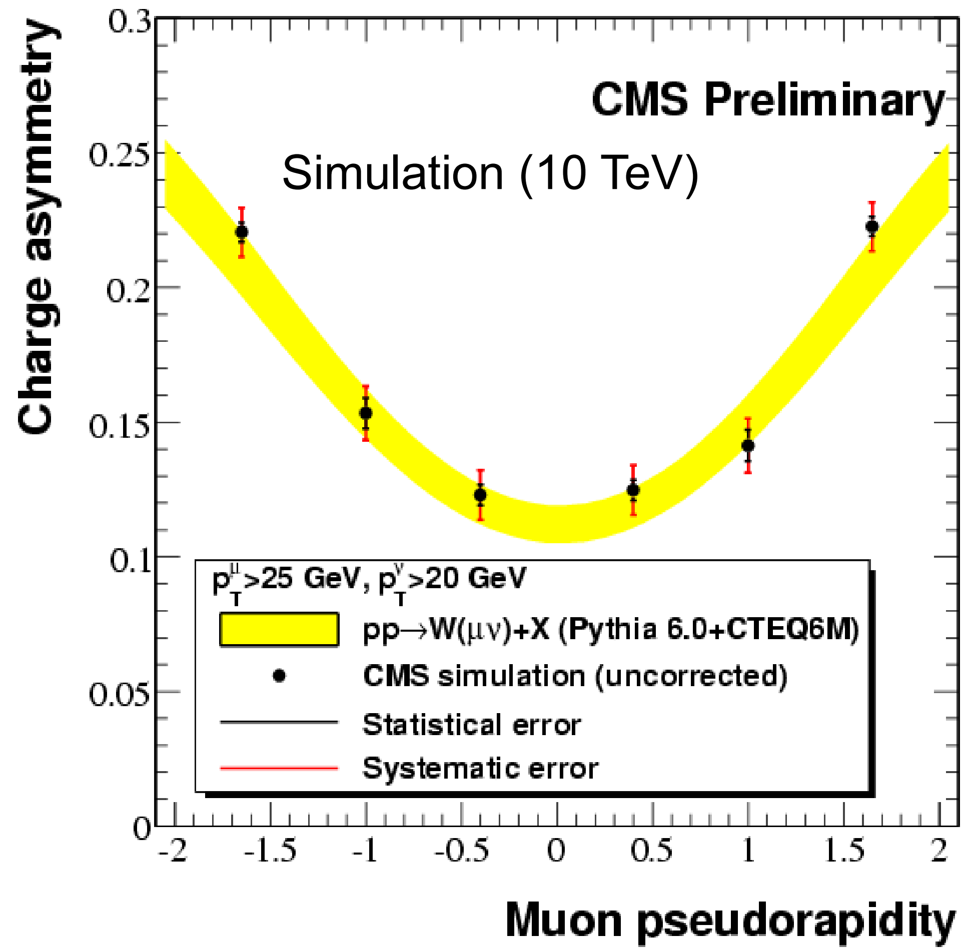
Differential Measurements of the Z and W

W charge Asymmetry

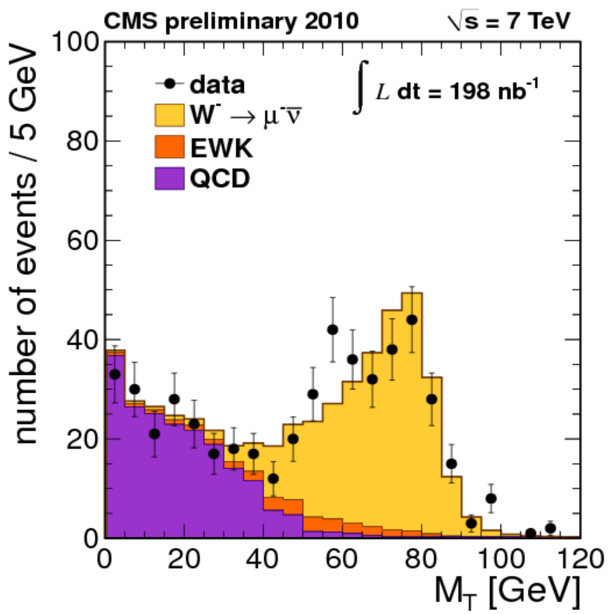
$$A(\eta) = \frac{\frac{d\sigma}{d\eta}(W^+ \to \mu^+\nu) - \frac{d\sigma}{d\eta}(W^- \to \mu^-\nu)}{\frac{d\sigma}{d\eta}(W^+ \to \mu^+\nu) + \frac{d\sigma}{d\eta}(W^- \to \mu^-\nu)}.$$

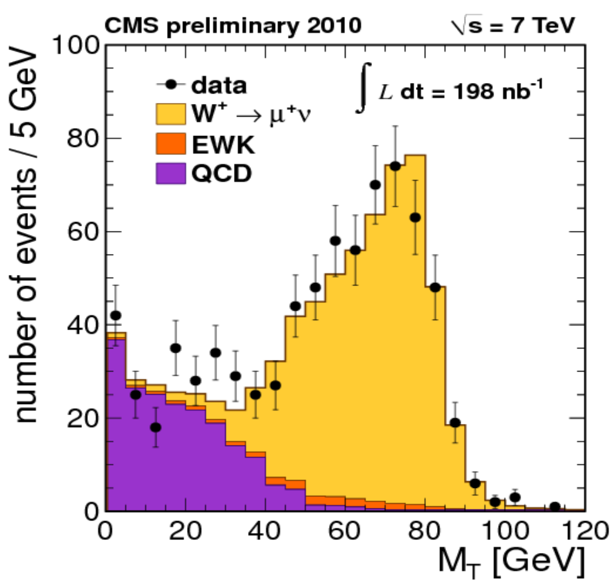




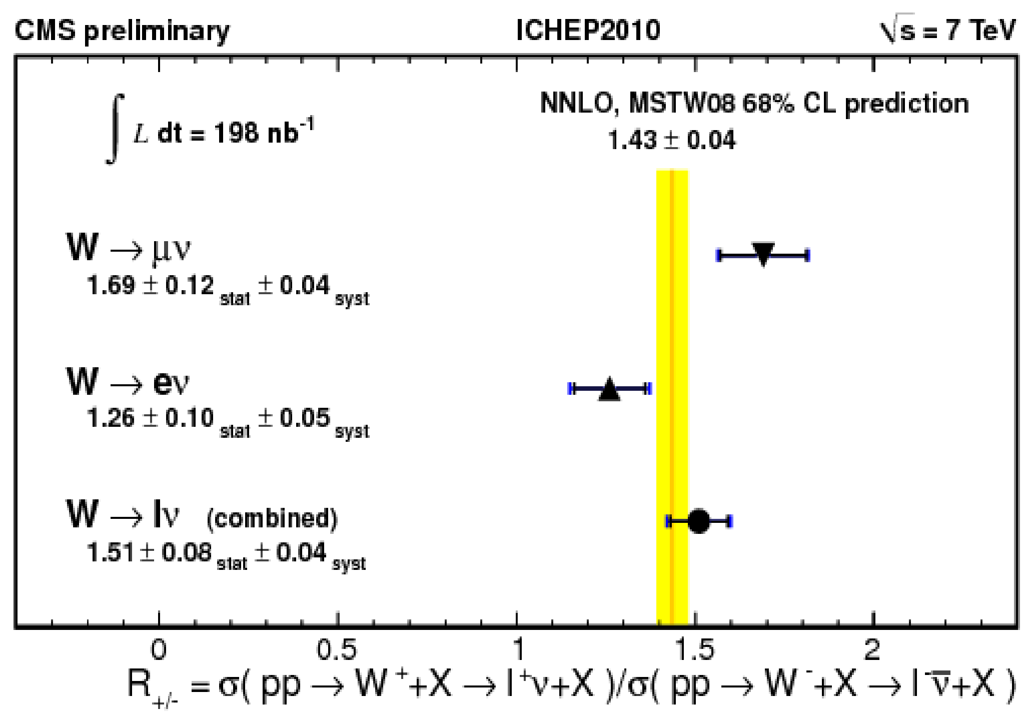


W by charge

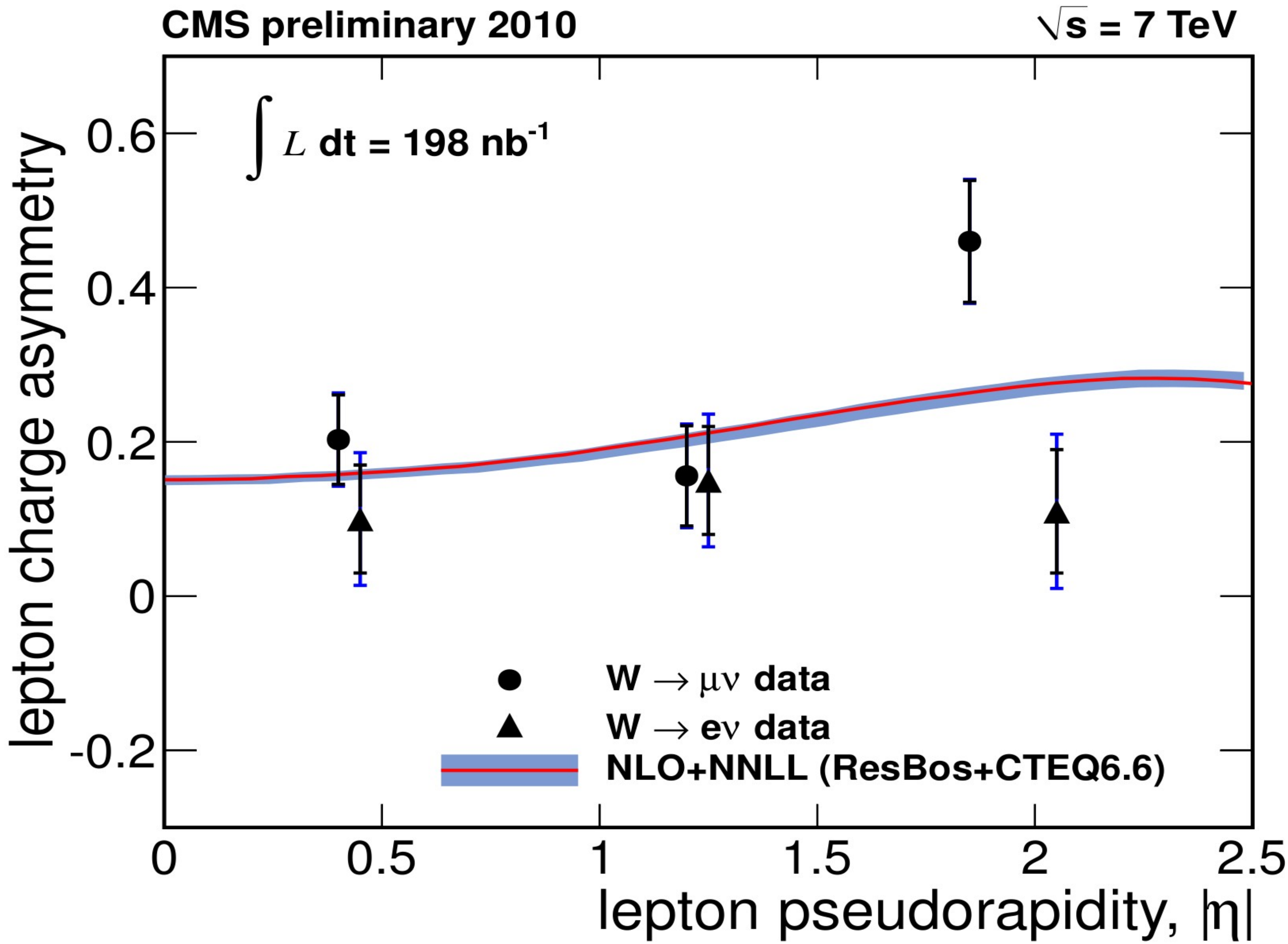




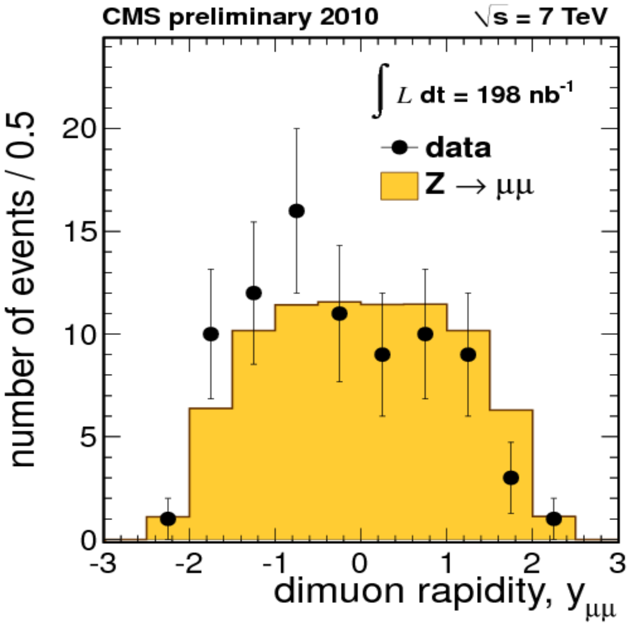
- Both electron and muon channels produce separate fit measurements for W^+ and W^-
  - Some kinematic differences between W^+ and W^- result in slightly different total efficiencies for W^- and W^+

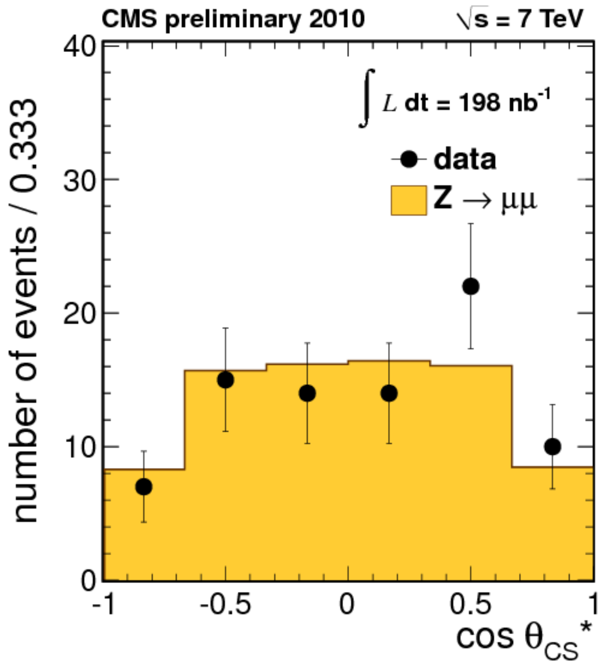


Initial W Asymmetry Results



Z Differential Distributions (Uncorrected)



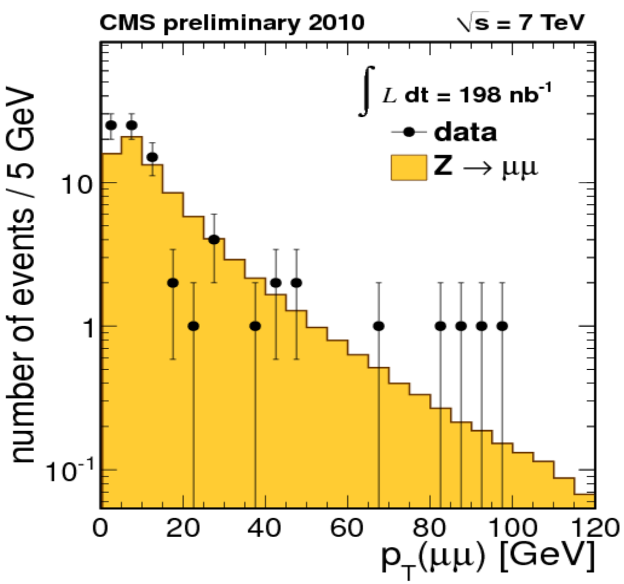


Many powerful differential measurements possible for dileptons

$$\frac{d\sigma(Z \to l^+ l^-)}{d\cos\theta_{CS}}$$

$$\frac{d\sigma(Z \to l^+ l^-)}{d q_T}$$

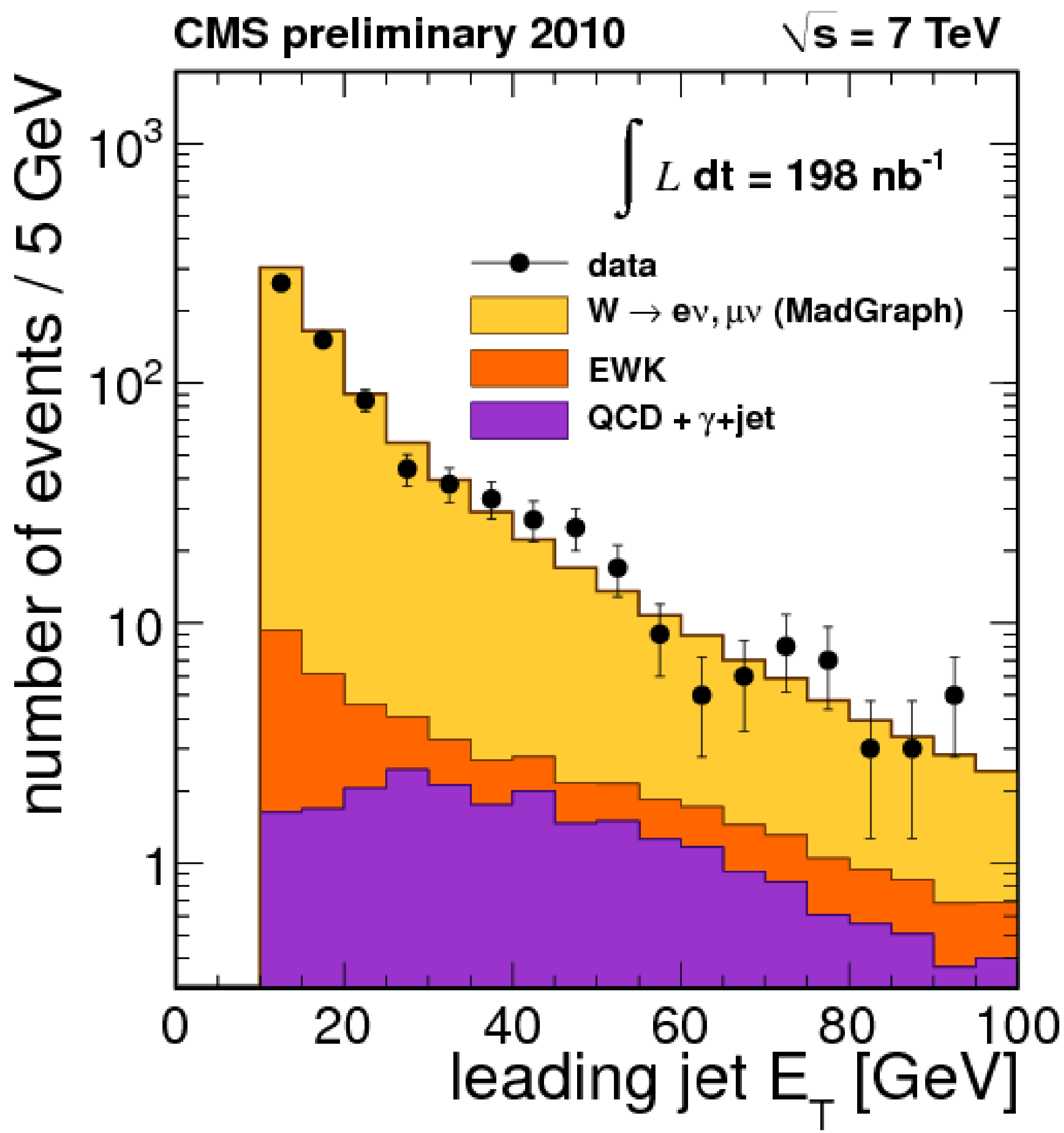
$$\frac{d\sigma(Z \to l^+ l^-)}{d Y}$$



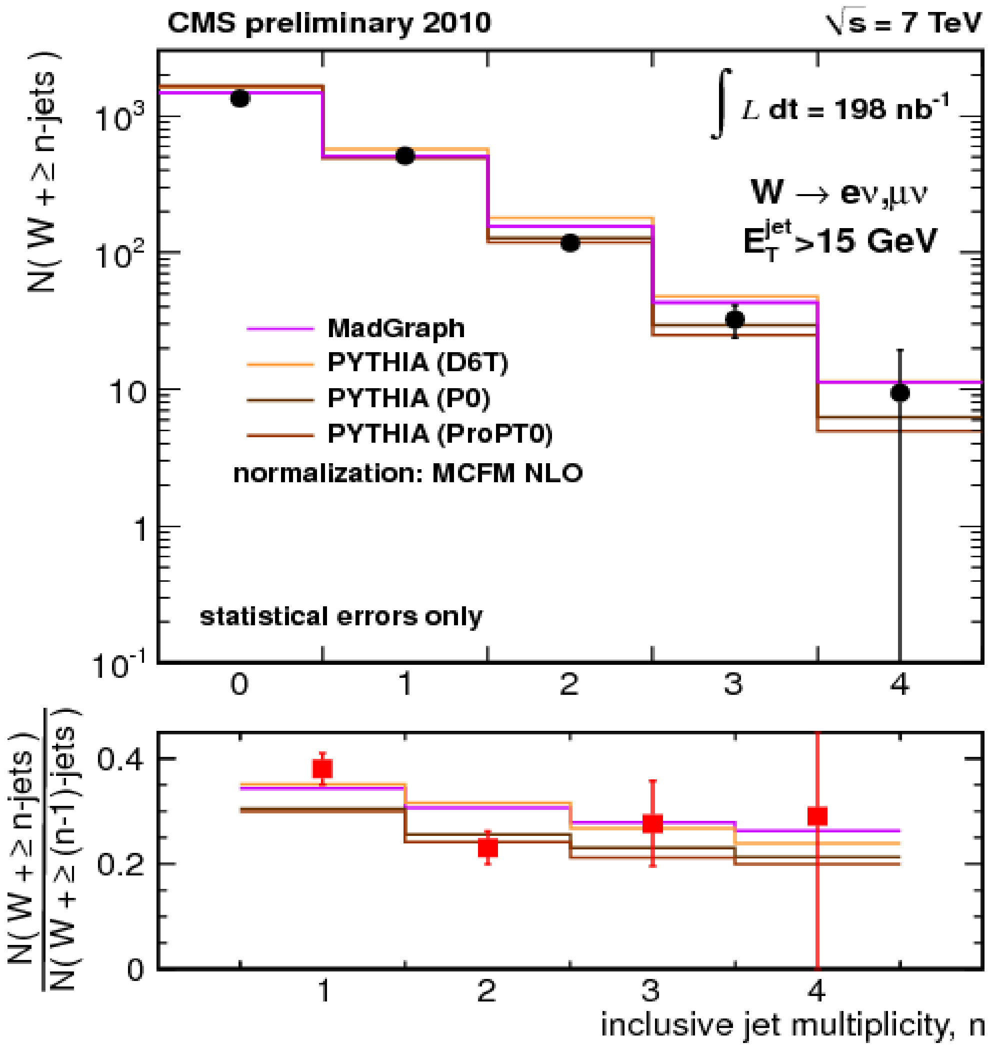
Even more Z results in the poster
"Forward-backward Charge Asymmetry for
Muon Pairs via Z/gamma* at 7 TeV in CMS"

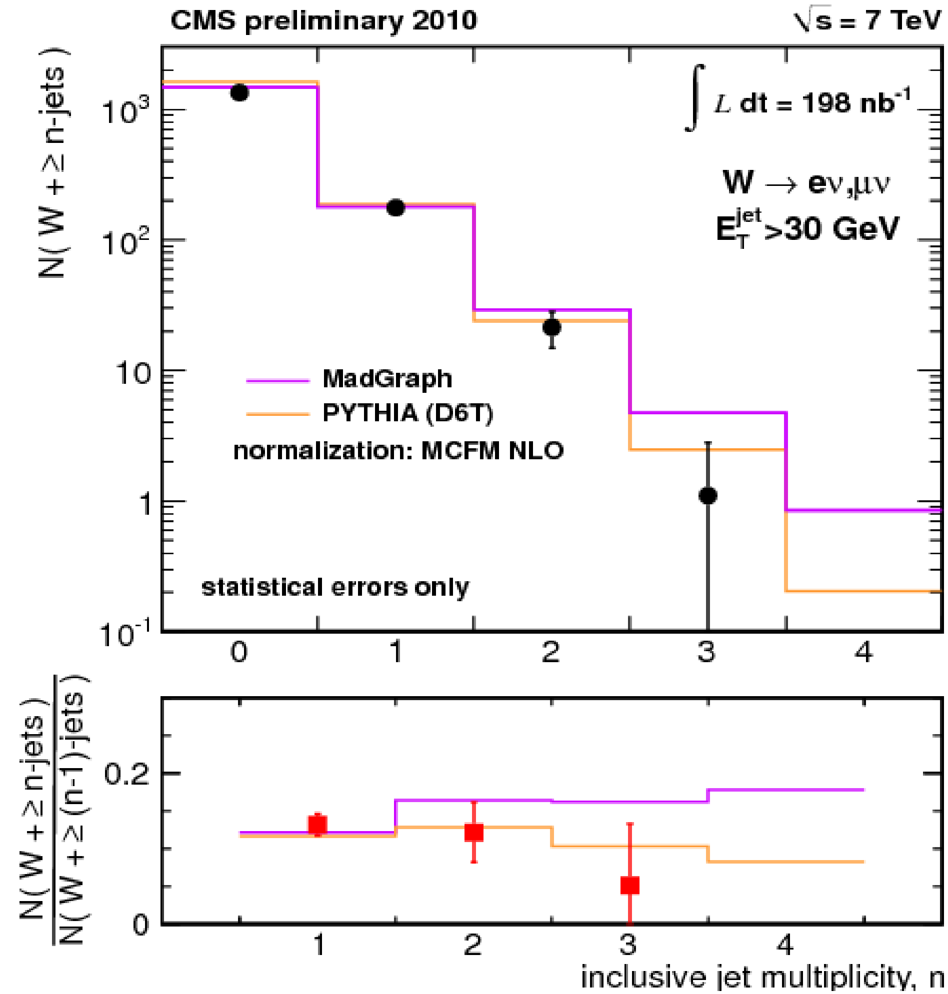
W/Z + Jets

- Crucial background to many new physics searches
  - Also an interesting measurement tool for QCD dynamics
- Measurement follows same selection as for inclusive analysis, but adds a focus on jet production
- Algorithm used: Anti-k_t (ΔR = 0.5) using Particle Flow Objects in $|\eta| < 2.5$



W/Z + Jets





See the poster “A Study of the Production of Vector Bosons and Jets at 7 TeV “ for even more information on the V+jets results from CMS

Outlook

- CMS is now making measurements with significant precision for EWK processes, filling in our understanding of EWK physics
- The next 1-2 months should provide sufficient data for inclusive measurements and the full year dataset will be sufficient for precise differential measurements