35th International Conference on High Energy Physics

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

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

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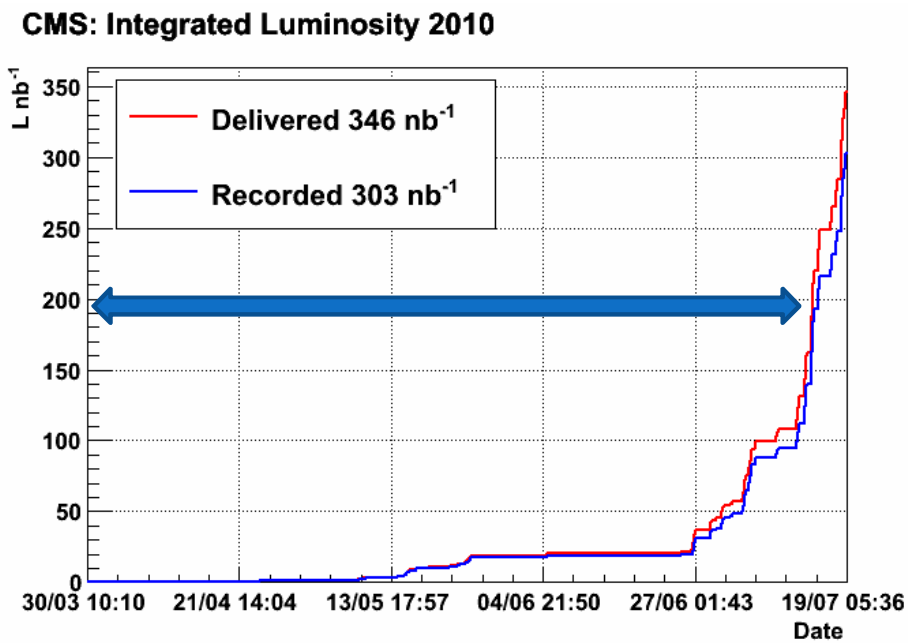
María Cepeda (CIEMAT, Madrid)
on behalf of the CMS Collaboration

CMS

ElectroWeak Physics at the LHC

- Studies of **W and Z bosons** in the early phase of the LHC will allow to
  - Measure the first ElectroWeak observables at the LHC
  - Understand the building blocks for future analysis (leptons, met, jets)
  - Test perturbative QCD predictions and PDFs in pp Collisions at the TeV scale
  - Improve our measurements of Luminosity



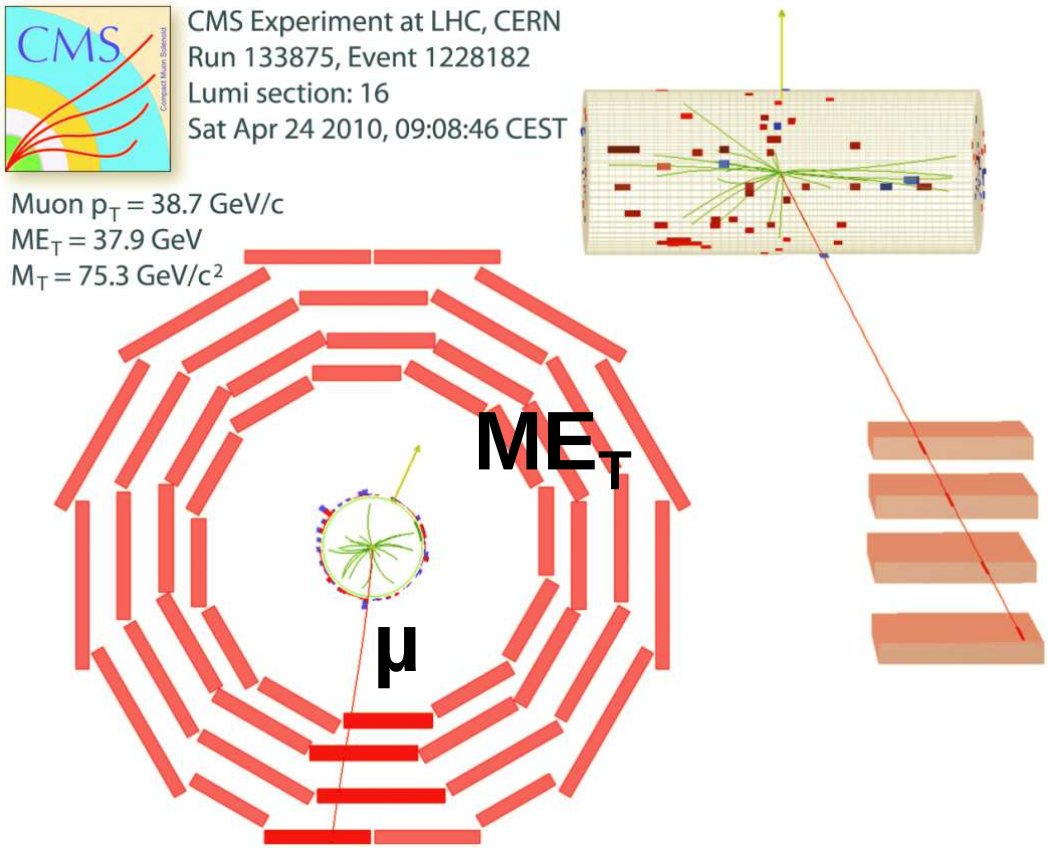
- W and Z are characterized by their **high production rates** and **clean and simple experimental signatures in their leptonic decay channels** :
  - **W: High pt, isolated lepton + high Missing Transverse Energy (ME_T)**
  - **Z: 2 high pt isolated leptons**

- **$\int Ldt = 198\ nb^{-1}$** analyzed
- Data quality ensured both through online monitoring of the detector status and validation of reconstructed quantities

Outline

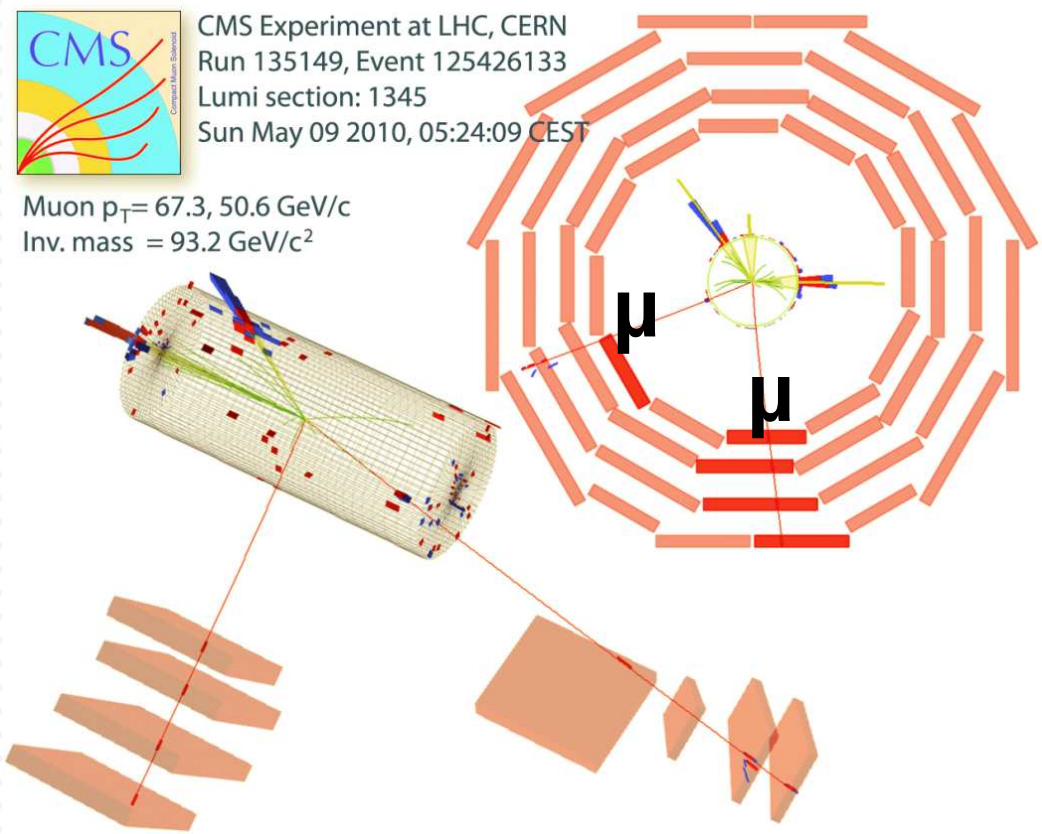
- **Muons**
  - $W \rightarrow \mu\nu$ event selection and cross-section determination
  - $Z \rightarrow \mu\mu$ event selection and cross-section determination
  - Systematic effects
- **Electrons**
  - $W \rightarrow e\nu$ event selection and cross-section determination
  - $Z \rightarrow ee$ event selection and cross-section determination
  - Systematic Effects
- **Measurements**
  - Combined results for cross-section and Ratios
  - W Charge Asymmetry
  - Associated V+Jets production
- **Conclusions**

W→μν and Z→μ⁺μ⁻



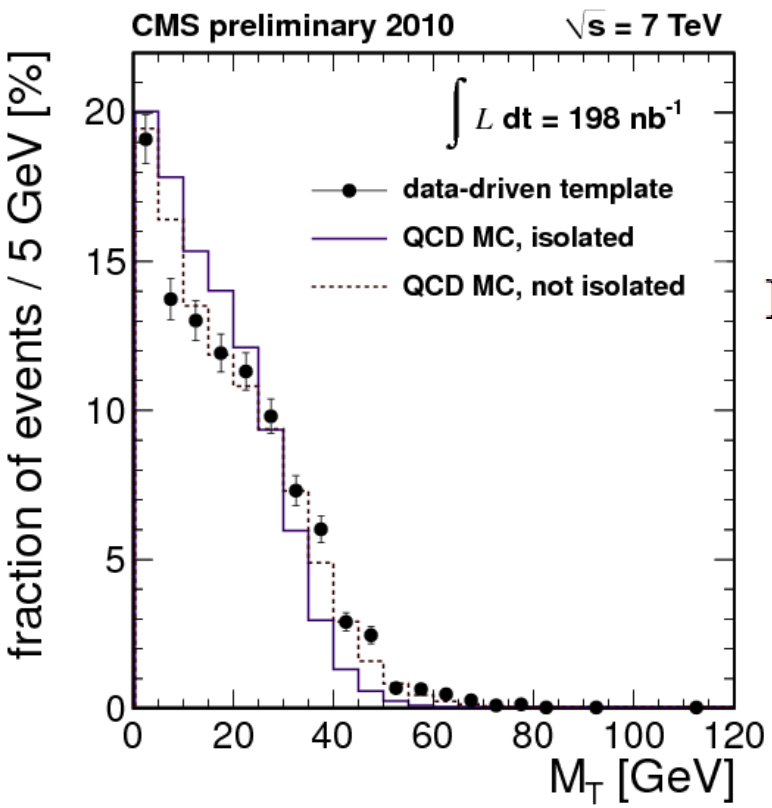
W Candidate

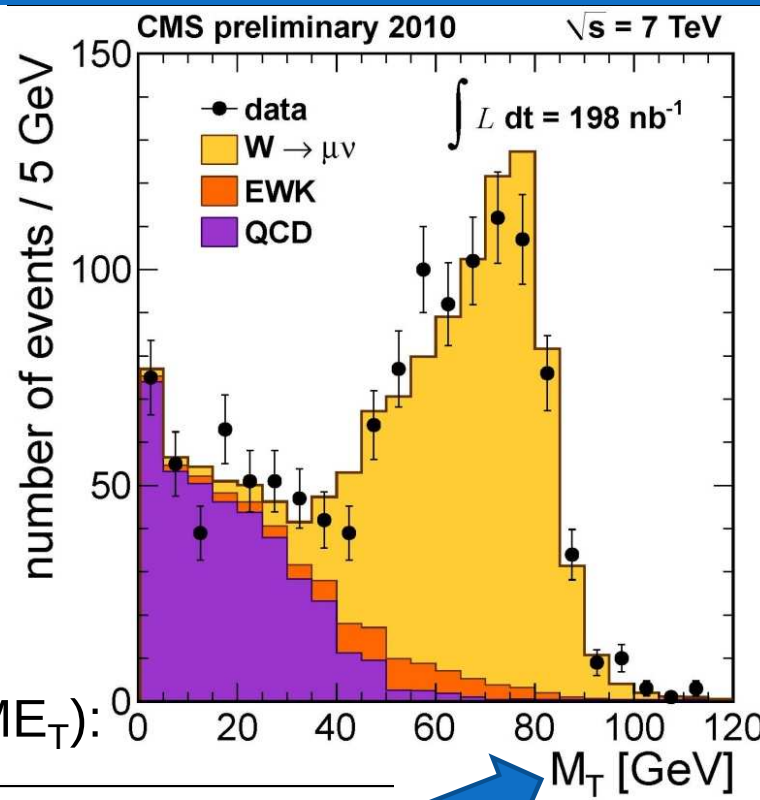
Z Candidate



W→μν Selection

- Event triggered by Level1+HLT , $p_T > 9$ GeV
- **Selection Criteria** :
  - Muon $p_t > 20$ GeV, $|\eta| < 2.1$
  - Isolation $(\Sigma p_T(\text{tk}) + \Sigma E_T(\text{had+em}))/p_T < 15\%$
  - ME_T reconstructed using Pflow techniques
  - Drell Yan rejection (veto on events with a second muon of $p_T > 10$ GeV)



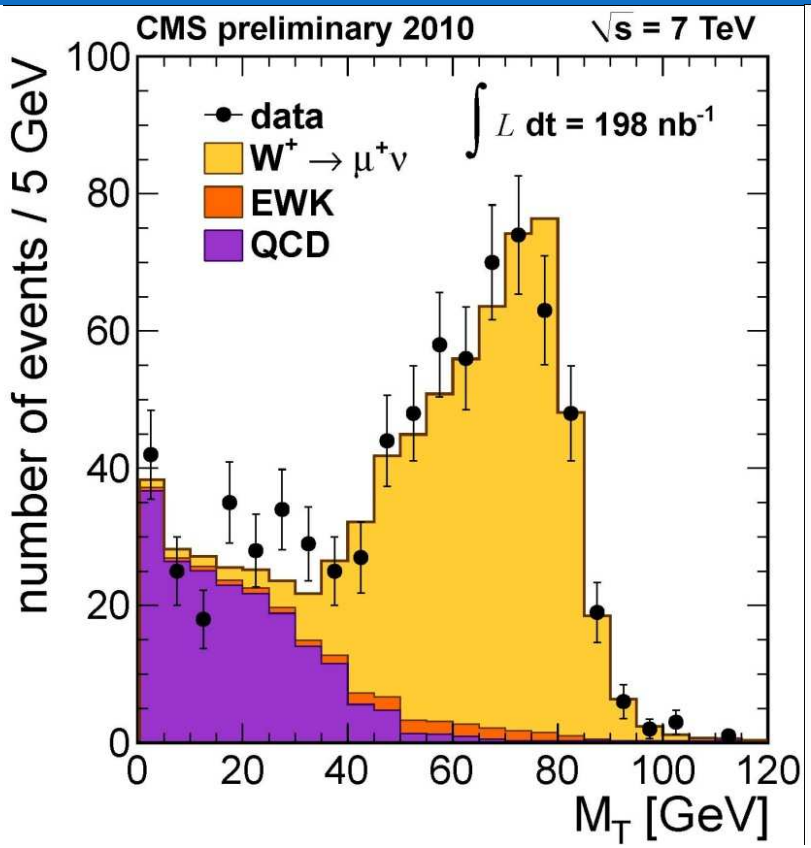


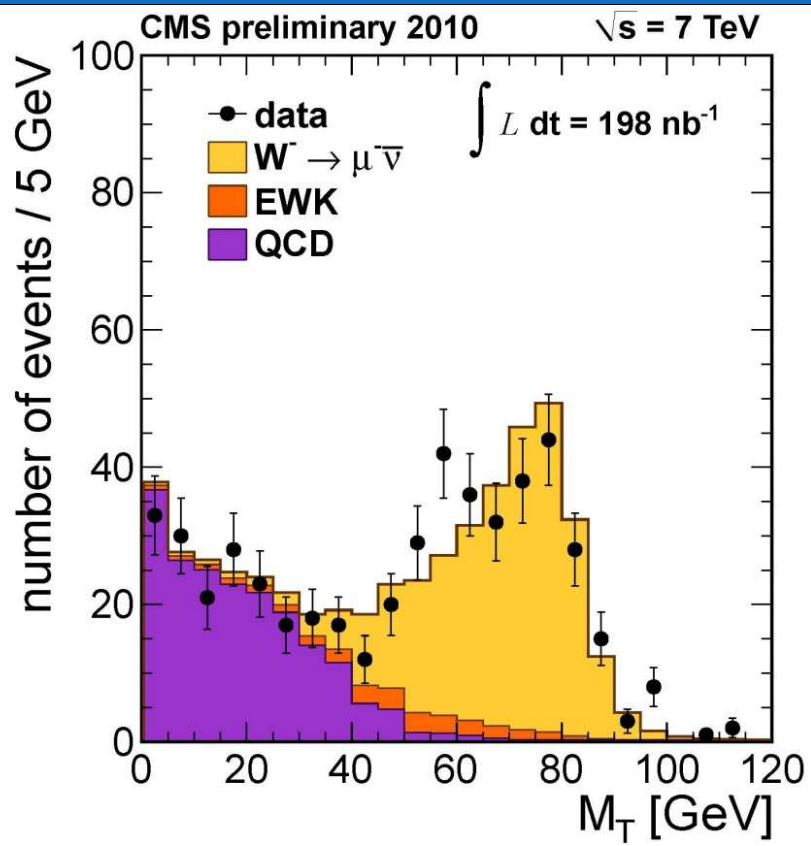
Transverse mass (μ, ME_T):

$$M_T = \sqrt{2 p_T(\mu) \not{E}_T * (1 - \cos(\Delta\phi_{\mu,\not{E}_T}))}$$

- Main source of BG: QCD (b hadron decays)
- W Signal yield extracted through a Binned Likelihood fit to the MT distribution (Signal + QCD & EWK BGs)
- W Signal and EWK MT shapes modeled from MC
- QCD MT Shape extracted from data (isolation inversion)

$W^{\pm} \rightarrow \mu^{\pm}\nu$ Selection





529 ± 24 W^+ Yield

289 ± 13 W^- Yield

(statistical error only)

$\sigma(pp \rightarrow W+X \rightarrow \mu\nu+X) = 9.14 \pm 0.33$ nb

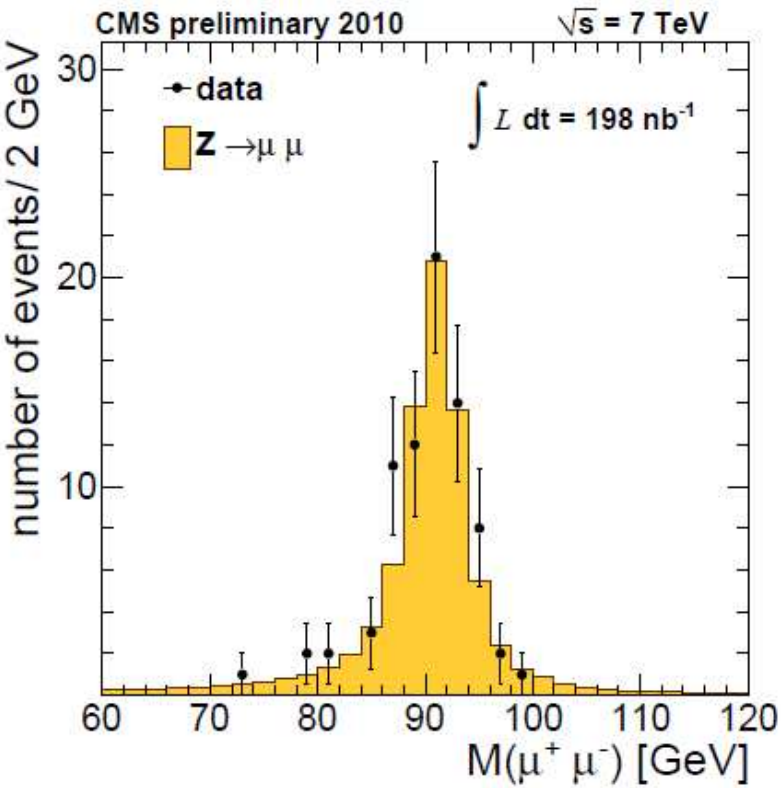
$R = 1.69 \pm 0.12$

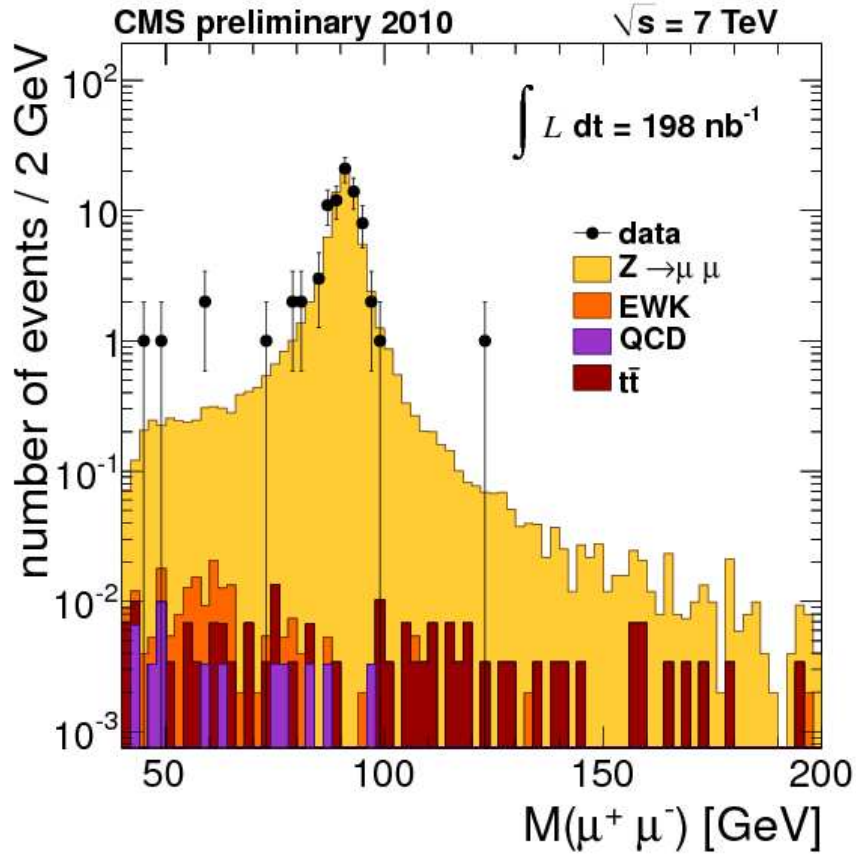
$\sigma(W^+ \rightarrow \mu^+\nu) = 5.75 \pm 0.26$ nb

$\sigma(W^- \rightarrow \mu^-\nu) = 3.39 \pm 0.15$ nb

$Z \rightarrow \mu^+\mu^-$ Selection

- Event triggered by Level1 (Muon)+HLT (Muon+Tracker), $p_T > 9$ GeV
- **Selection Criteria**
  - 2 muons $p_t > 20$ GeV
  - Opposite charge muons
  - At least one in $|\eta| < 2.1$
  - Track-Based isolation ($\Sigma p_T < 3$ GeV)





- Background negligible (~0.3%)
- 77 Events selected the invariant mass range $m_{\mu\mu}$ (60,120) GeV

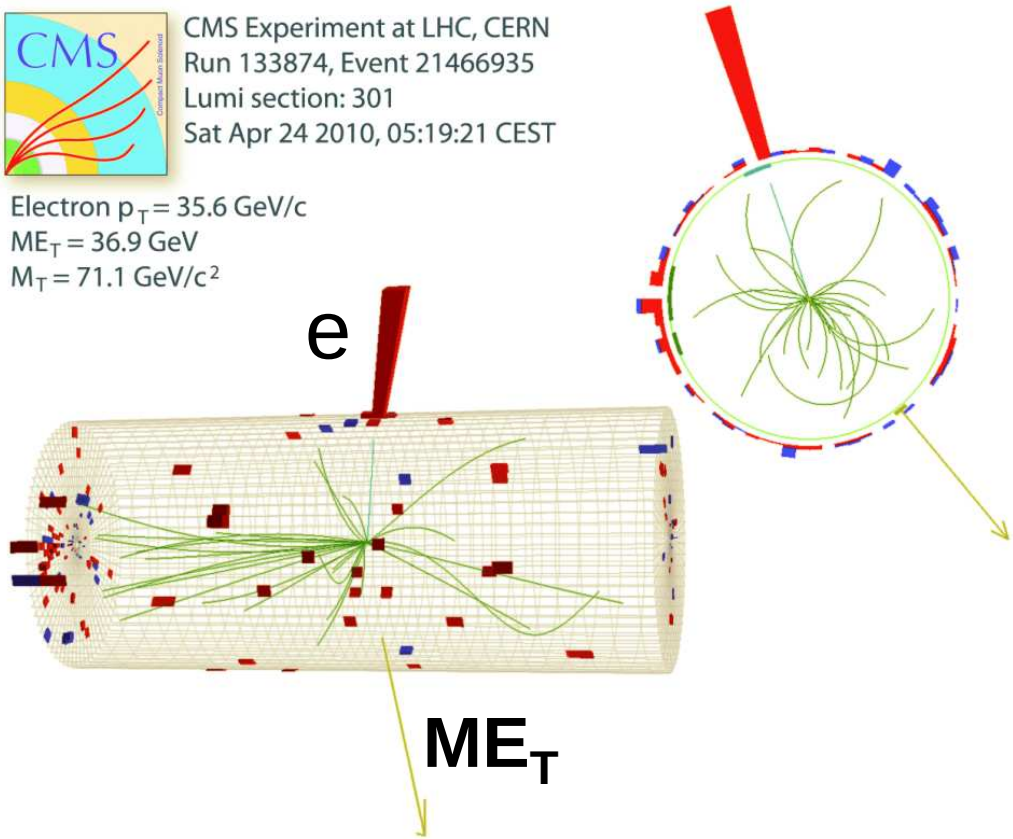
$\sigma(pp \rightarrow Z+X \rightarrow \mu\mu+X) = 0.88 \pm 0.10$ nb

Systematic Uncertainties

- Reconstruction and Lepton ID from data–driven studies
- Momentum Scale and Resolution from J/Psis, cosmic studies, Z Mass spectrum
- E_T scale/resolution from W recoil studies
- QCD Background uncertainty from the difference between isolated MC distribution and non-isolated data template
- PDF uncertainties evaluated via CTEQ66, MSTW08NLO, NNPDF2.0 sets

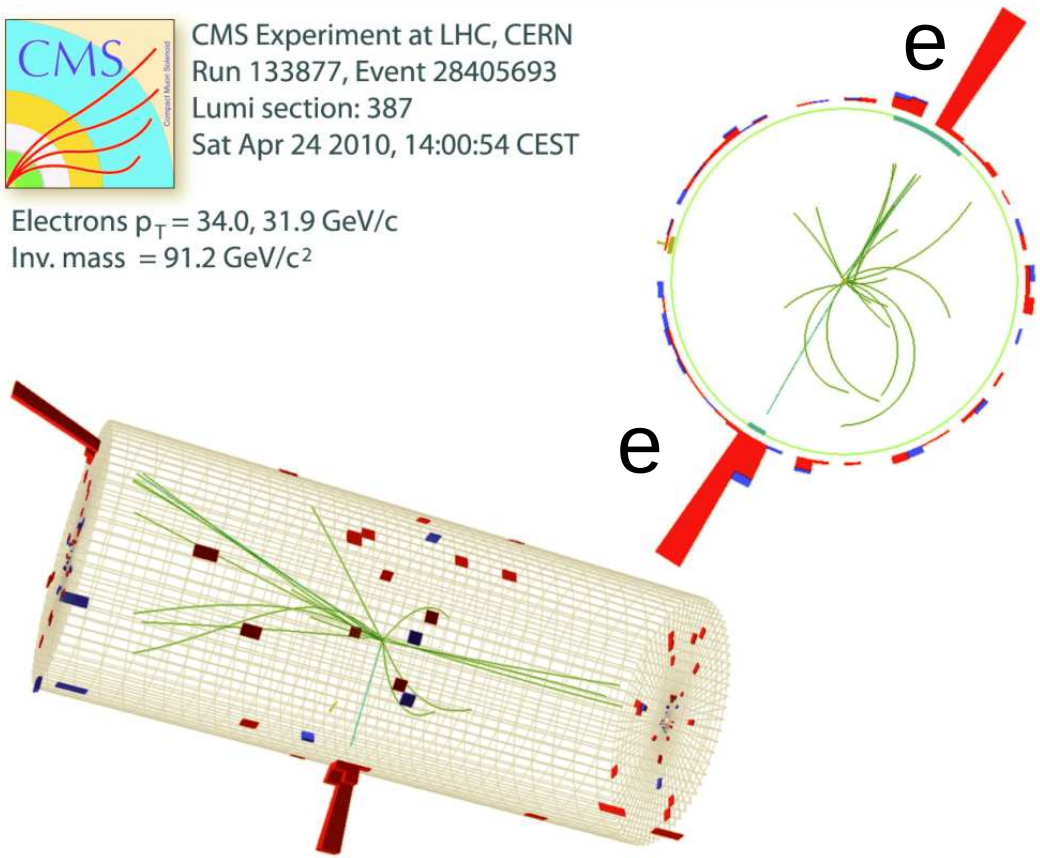
Source	W channel (%)	Z channel (%)
Muon reconstruction/identification	3.0	2.5
Trigger efficiency	3.2	0.7
Isolation efficiency	0.5	1.0
Muon momentum scale/resolution	1.0	0.5
$\not\!\!E_T$ scale/resolution	1.0	-
Background subtraction	3.5	-
PDF uncertainty in acceptance	2.0	2.0
Other theoretical uncertainties	1.4	1.6
TOTAL (without luminosity uncertainty)	6.3	3.8
Luminosity	11.0	11.0

W→eν and Z→ee



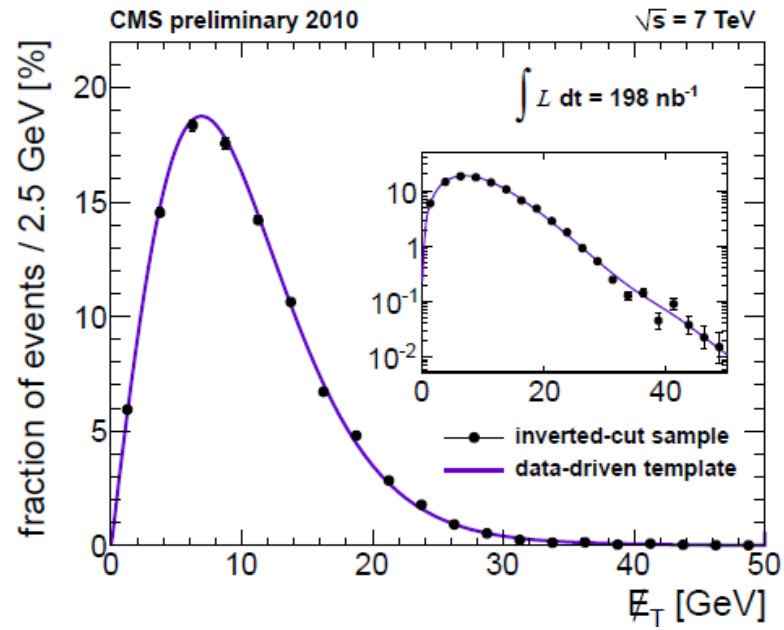
W Candidate

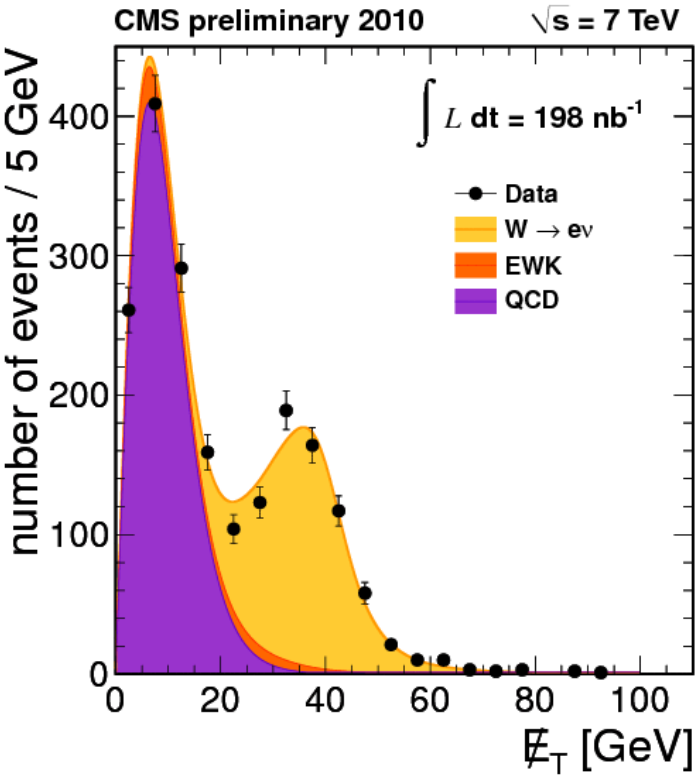
Z Candidate



W→eν Selection

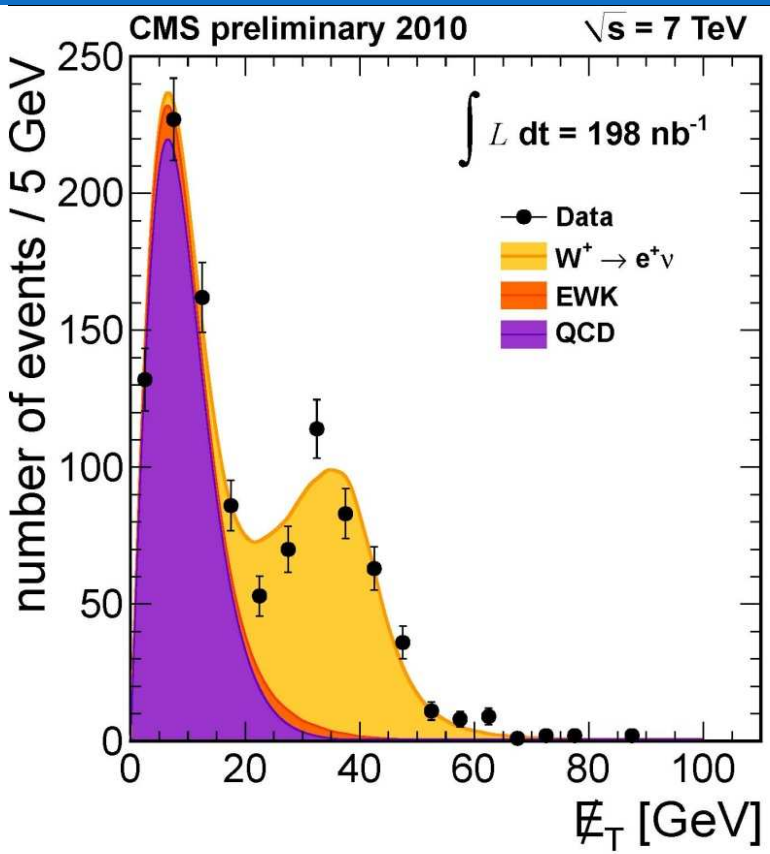
- Events triggered by Level1 (ECAL) + HLT (E_T>15 GeV)
- **Selection Criteria**:
  - Electron E_T> 20 GeV
  - $|\eta|$ < 1.4442 (Barrel), 1.566<$|\eta|$< 2.500 (Endcap)
  - Isolation (independent cuts on track, em, had)
  - Drell Yan rejection (veto on events with a second electron of E_T>20 GeV)

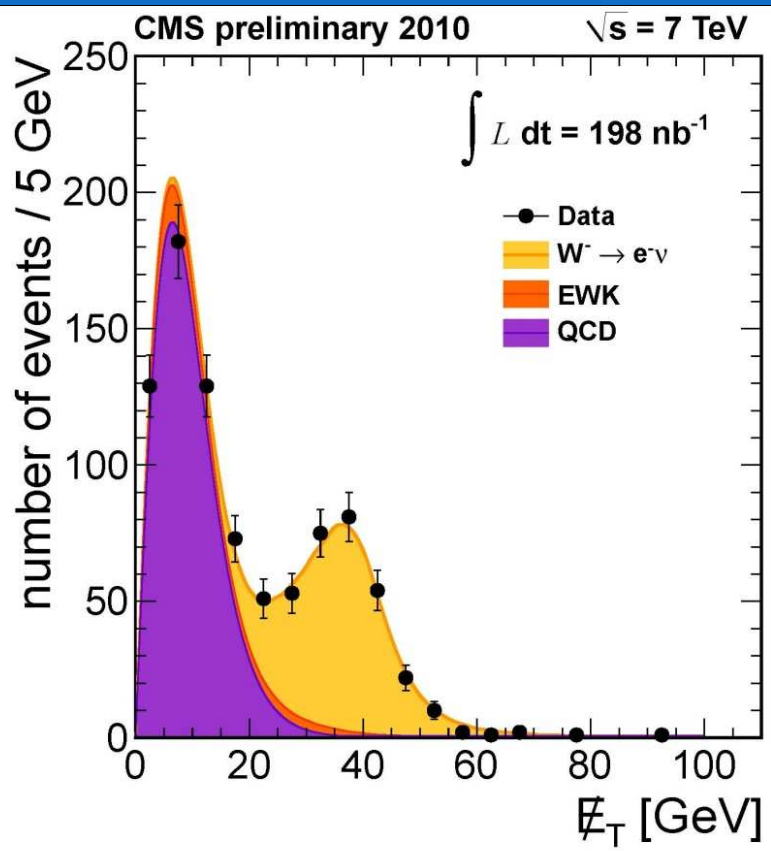




- QCD BG dominated by fake electrons
- Unbinned Likelihood fit to the ME_T distribution
- W Signal and ElectroWeak ME_T shape well modeled from Monte Carlo
- QCD background is parameterized through a modified Rayleigh distribution with E_T dependent resolution

$W^{\pm} \rightarrow e^{\pm}\nu$ Selection





458±23 W^+ Yield

339±20 W^- Yield

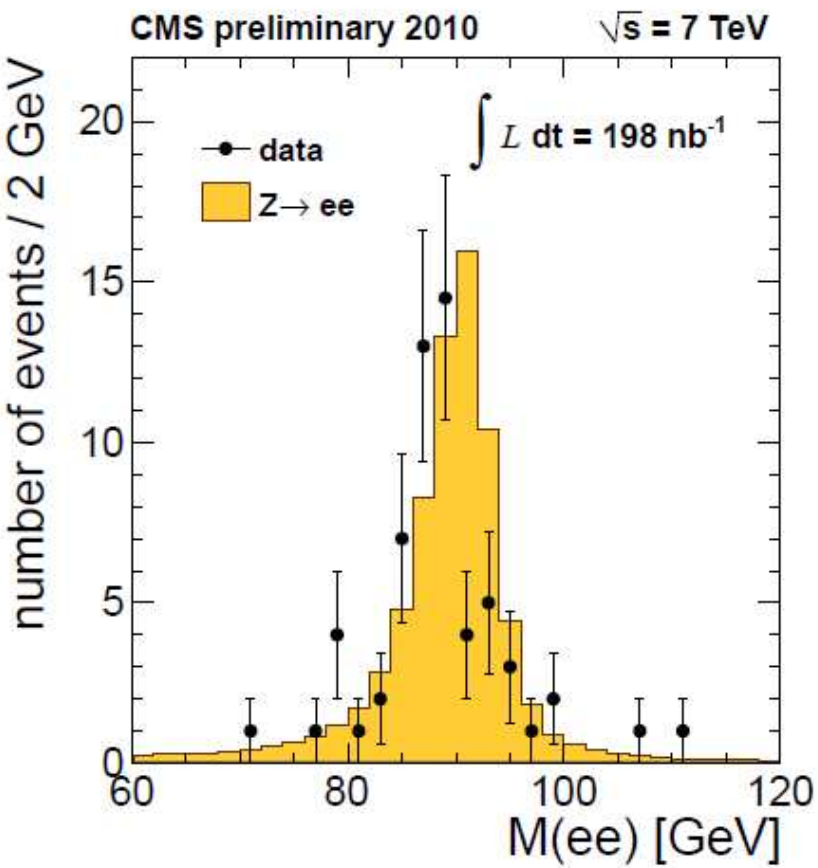
(statistical error only)

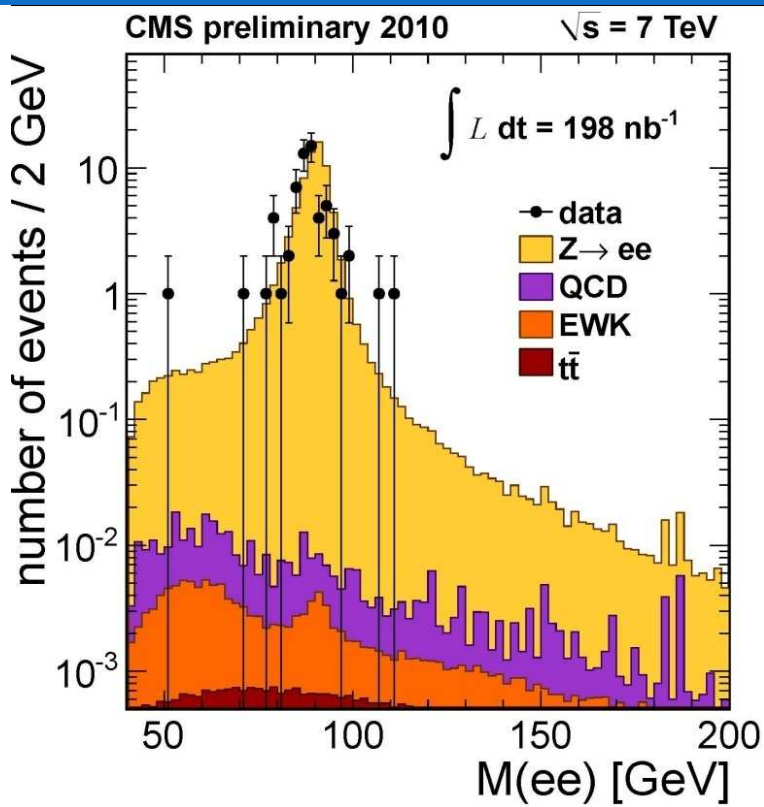
σ(pp→W+X→eν+X) = 9.34 ± 0.36 nb
R = 1.26 ± 0.10

σ(W^+→e+ν) = 5.18 ± 0.26 nb
σ(W-→e-ν) = 4.13 ± 0.24 nb

$Z \rightarrow e^+e^-$ selection

- Events trigger by Level1 (ECAL) + HLT (E_T>15 GeV)
- **Selection Criteria**
  - 2 electrons with E_T>20 GeV
  - Isolated (independently on tracker and calorimeters)





- Background negligible
- 61 events selected in the Invariant mass range m_{ee} (60,120)

$\sigma(pp \rightarrow Z+X \rightarrow ee+X) = 0.88 \pm 0.11$ nb

Systematic Uncertainties

- Electron energy scale and resolution from Z Mass shape
- E_T scale/resolution from W recoil studies
- QCD subtraction uncertainty from comparison with control samples (cut inversion)
- PDF uncertainties evaluated with CTEQ66, MSTW08NLO, NNPDF2.0

Source	W channel (%)	Z channel (%)
Electron reconstruction/identification	6.1	7.2
Trigger efficiency	0.6	-
Isolation efficiency	1.1	1.2
Electron momentum scale/resolution	2.7	-
$\not\!\!E_T$ scale/resolution	1.4	-
Background subtraction	2.2	-
PDF uncertainty in acceptance	2.0	2.0
Other theoretical uncertainties	1.3	1.3
TOTAL (without luminosity uncertainty)	7.7	7.7
Luminosity	11.0	11.0

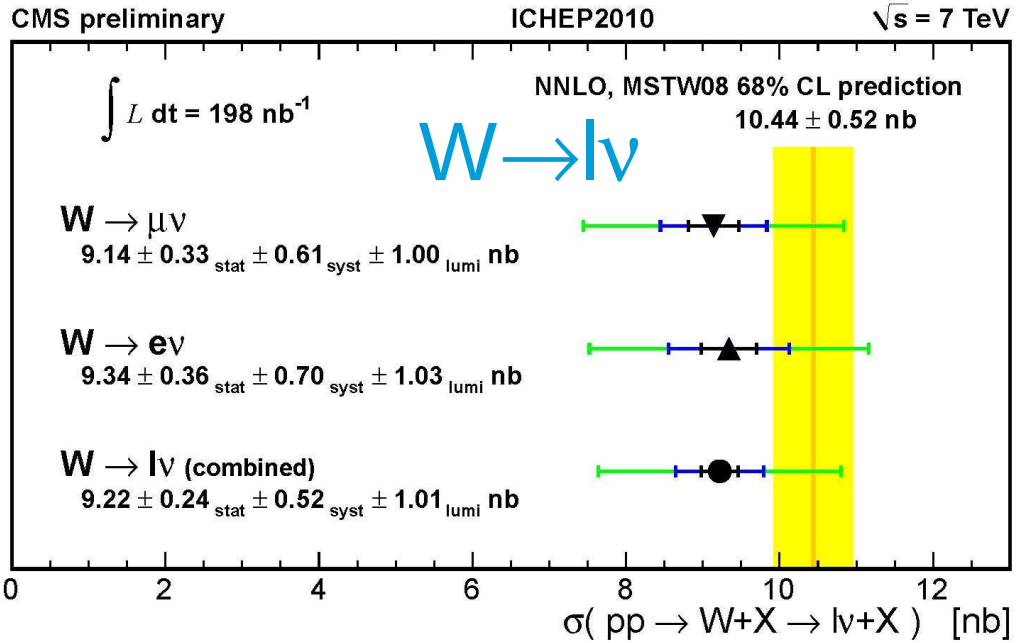
Measurements

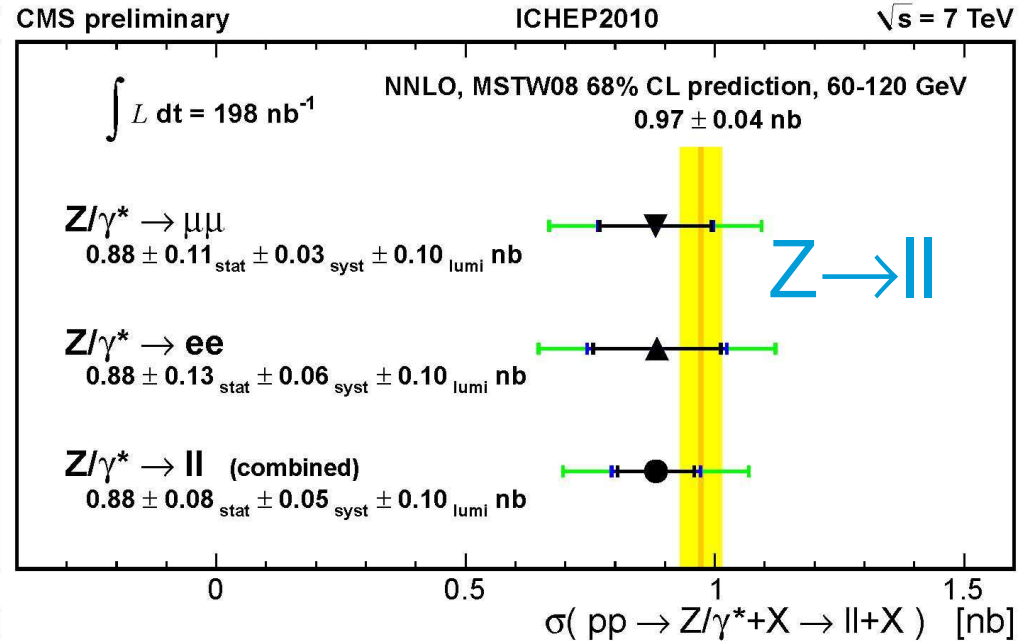
Cross-Sections, Ratios

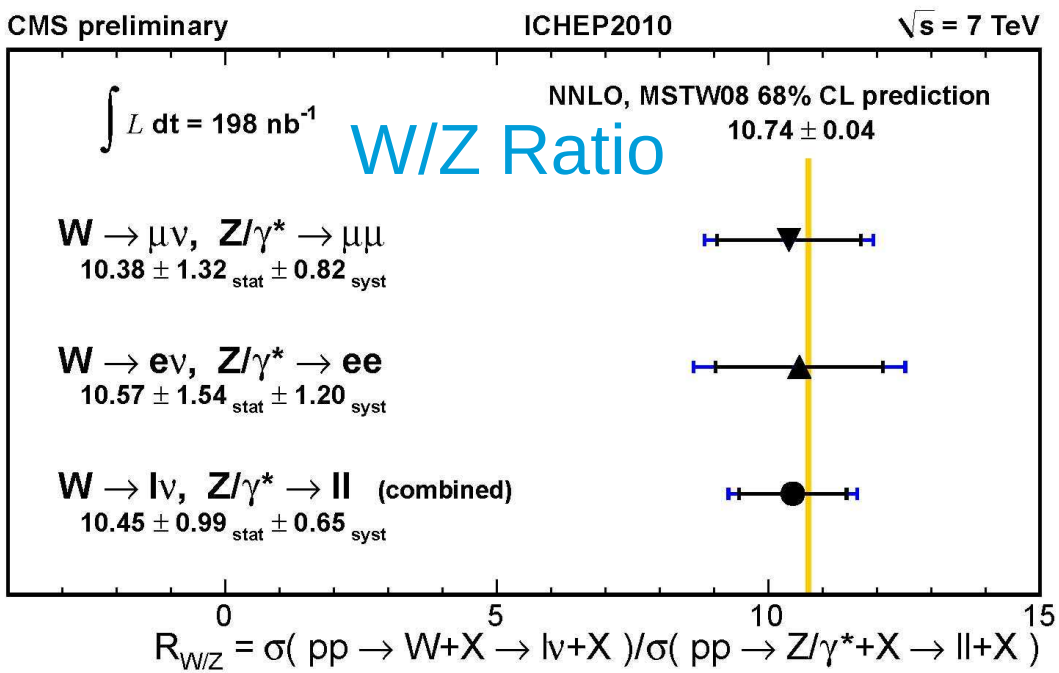
Charge asymmetry

W+Jets associated production

W,Z production cross-sections…

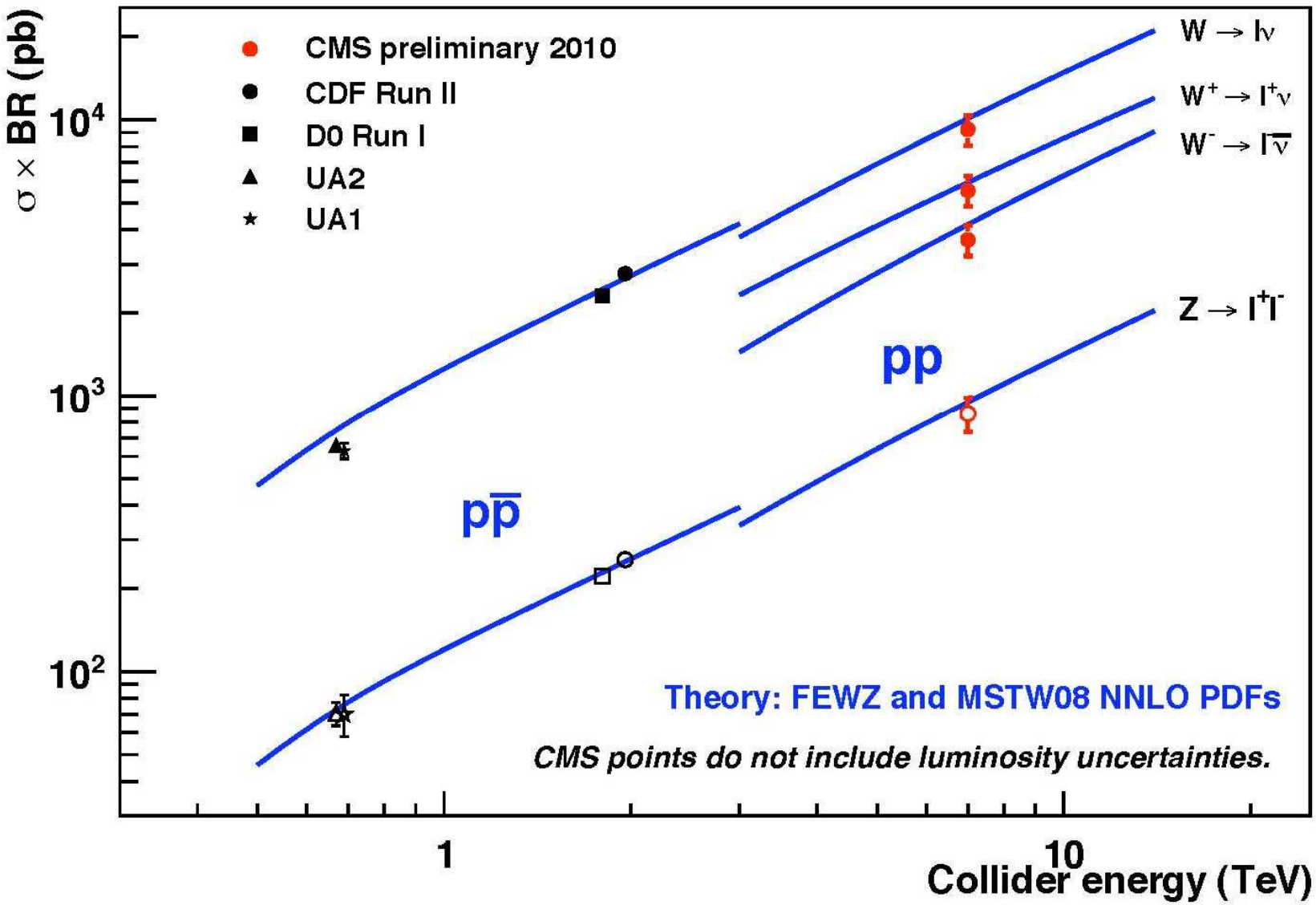




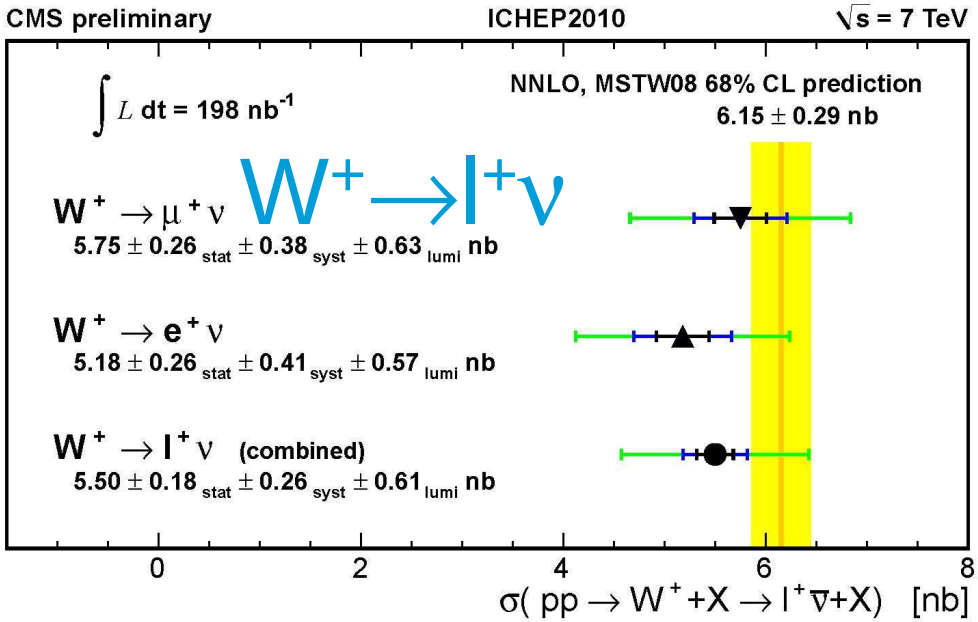


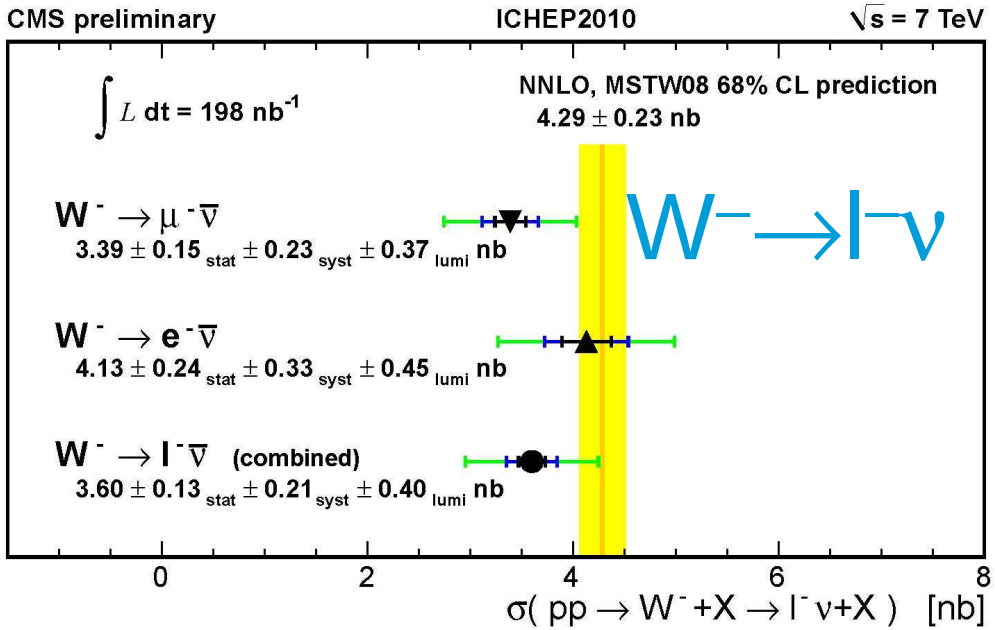
Measurements in agreement with SM predictions

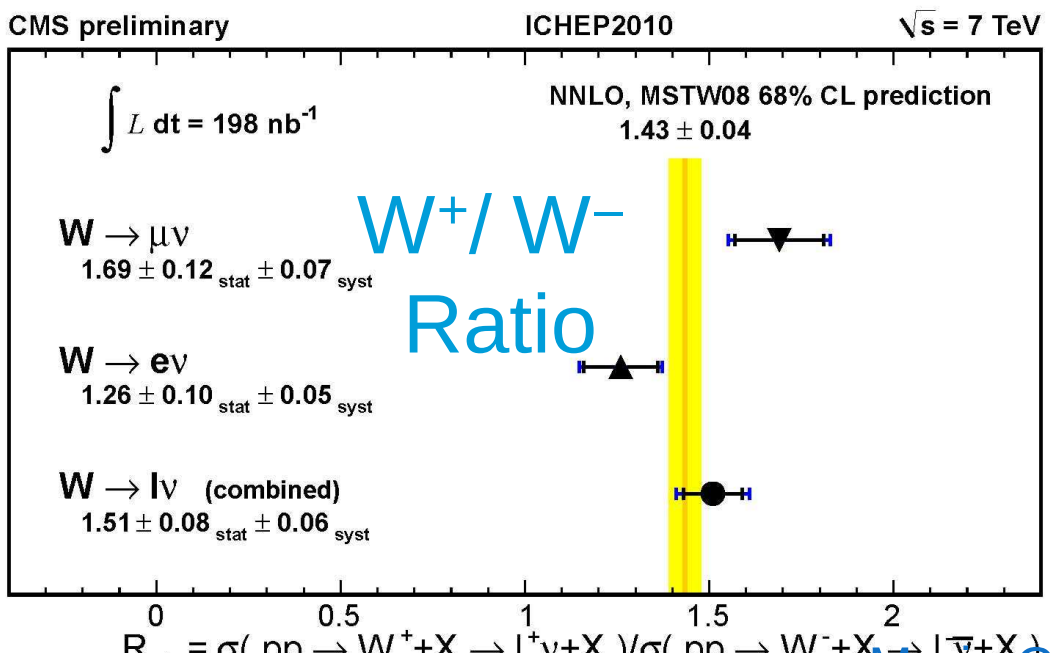
… added to the picture



W^+, W^- Cross-Sections



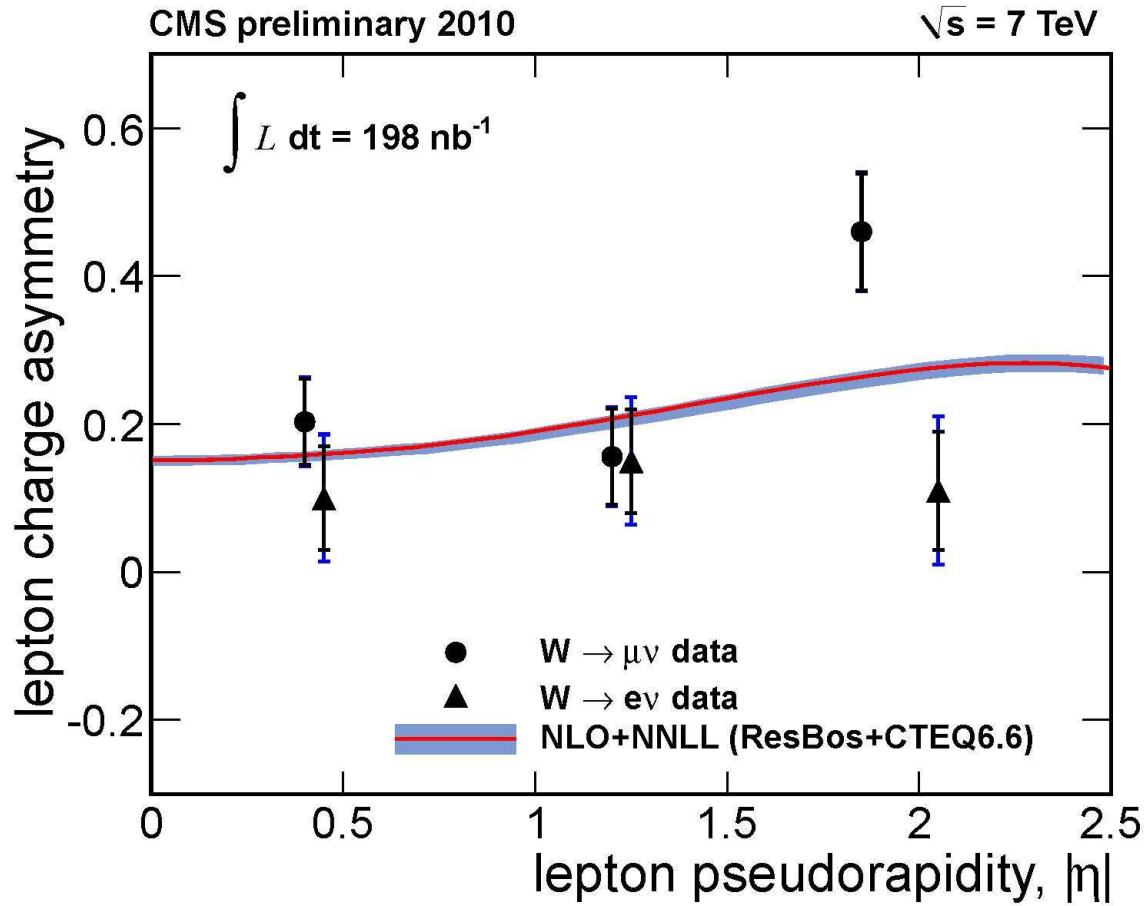




W Charge Asymmetries

- W charge asymmetry as a function of lepton pseudorapidity will improve our knowledge of Parton Density Functions (PDFs)

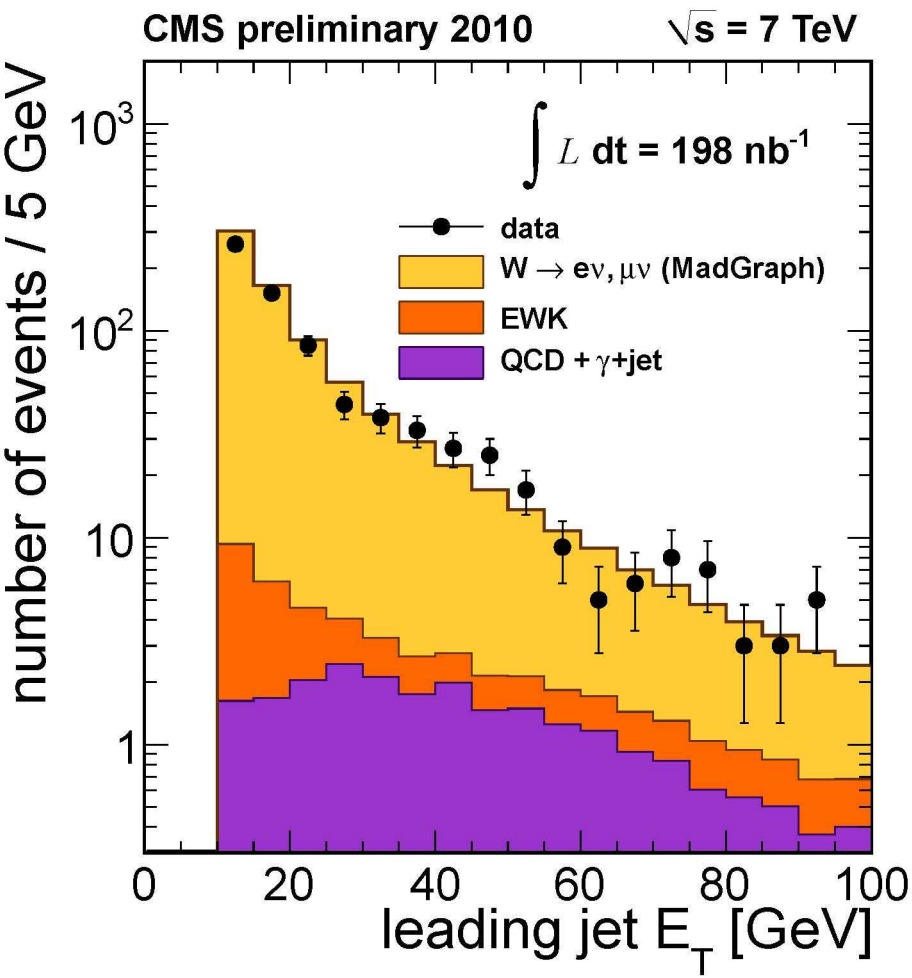
$$A(\eta) = \frac{d\sigma^{(+)}/d\eta_\ell - d\sigma^{(-)}/d\eta_\ell}{d\sigma^{(+)}/d\eta_\ell + d\sigma^{(-)}/d\eta_\ell}$$

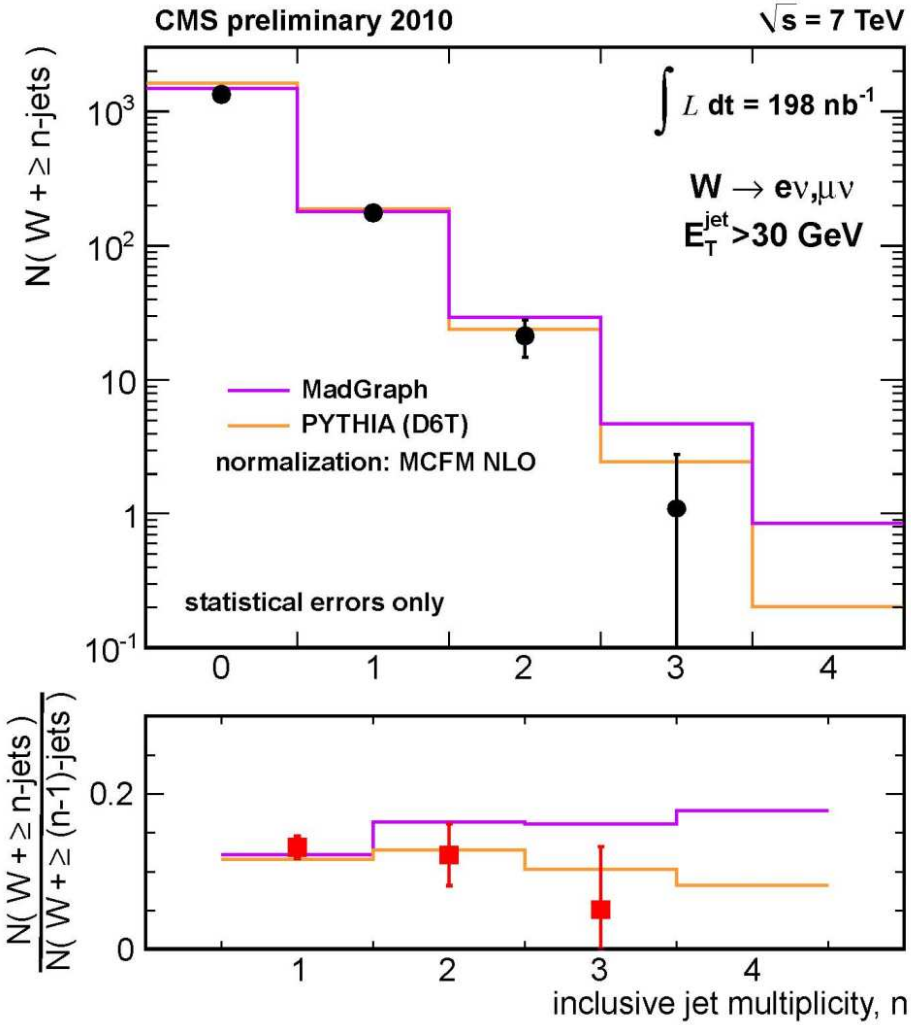


- With the current limited statistics, we perform a first measurement in 3 pseudorapidty bins

W+Jets Associated Production

- **Jet Reconstruction:**
  - Anti-Kt algorithm (infra-red safe)
  - Particle Flow





- Statistical error only

  (Jet energy scale (10-20%))

Conclusions

- We have presented the **first measurements of ElectroWeak physics** in CMS
  - **Inclusive Cross-Sections of W and Z in their leptonic decays (e, mu)**
  - **Ratios of W/Z and W^+/W^- cross sections**
  - **W Charge asymmetry as a function of the lepton pseudo-rapidity**
  - **W +jets Production**
- Efficiencies and Backgrounds studied and evaluated from data control samples
- Leptons and ME_T performance is in very good agreement with Monte Carlo simulations of the CMS detector

All results are in agreement with the Standard Model predictions,

References

- **CMS PAS EWK-10-002**: "Measurements of Inclusive W and Z Cross Sections in pp Collisions at $\sqrt{s}$ = 7 TeV"

  http://cdsweb.cern.ch/record/1279615

- Other EWK results at ICHEP2010

  - J. Mans, "W and Z boson production in pp collisions at CMS at $\sqrt{s}$ = 7 TeV" (Session 2)

  - L. Lusito, "Evidence for Z -> tau+ tau- Production in 7 TeV proton-proton Collisions" (poster)

  - E. Yazgan, "Forward-backward Charge Asymmetry for Muon Pairs via Z/gamma* at 7 TeV in CMS" (poster)

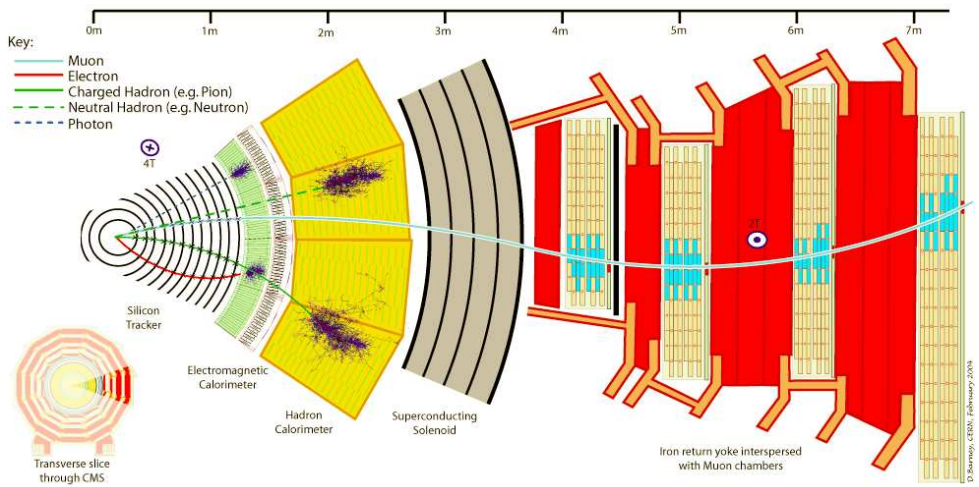
  - J. Damgov , "A Study of the Production of Vector Bosons and Jets at 7 TeV" (poster)

Muon Reconstruction and Identification

- Events recorded online using Level-1 Muon trigger and High Level Trigger (pt> 9 GeV, |η|<2.1)

- **Muon Identification:** Consistency between **tracker detector and muon system measurments:**
  - Muon reconstructed by two algorithms (in-out, out-in)
  - Good quality of Global fit (muon+tracker)
- **Precise measurement of momentum** ensured requiring a minimal amount of tracker hits, and at least one in the innermost detector

- Muon must have minimal activity in tracker and calorimeters
- **Cosmic contamination** reduced through a cut on transverse impact parameter



Reconstruction, ID Efficiencies estimated through Inclusive muon samples and Tag&Probe methods

Trigger efficiencies calculated through Tag&Probe, and cross-checked through Jet, MET and Tau triggered samples

Isolation efficiency from Random Cone Techniques. Consistent with Tag&Probe

More details in G. PETRUCCIANI's talk

Electron Reconstruction and Identification

- Events required to pass Level-1 and High Level Trigger requirements , with a ECAL cluster E_T>15 GeV

Talk by R. SALERNO

- **Electron ID** requirements:
  - Clusters of ECAL deposits matched to tracks in the inner detector , taking into account bremsstrahlung
  - Good matching (track, cluster) in η and φ
  - ElectroMagnetic shower shape characteristics (limited leakage in the hadronic calorimeter, narrow width in η)
- Photon conversion rejection (hits in tracker, opening angle with neighbour tracks)
- **Isolation criteria ,** cutting separately on tracker, Ecal and Hcal activity around electron candidates, (rejection of misidentificated particles + real electrons from jet fragmentation)

Efficiency studies on data:

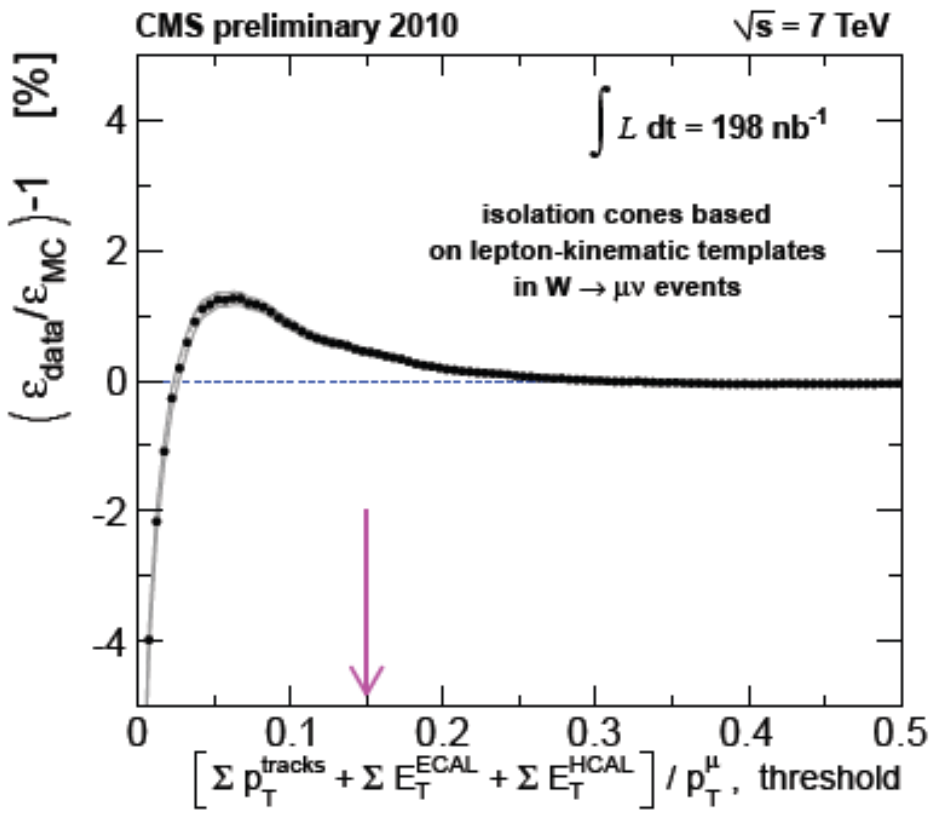
Reconstruction and ID Efficiencies calculated from Tag&Probe

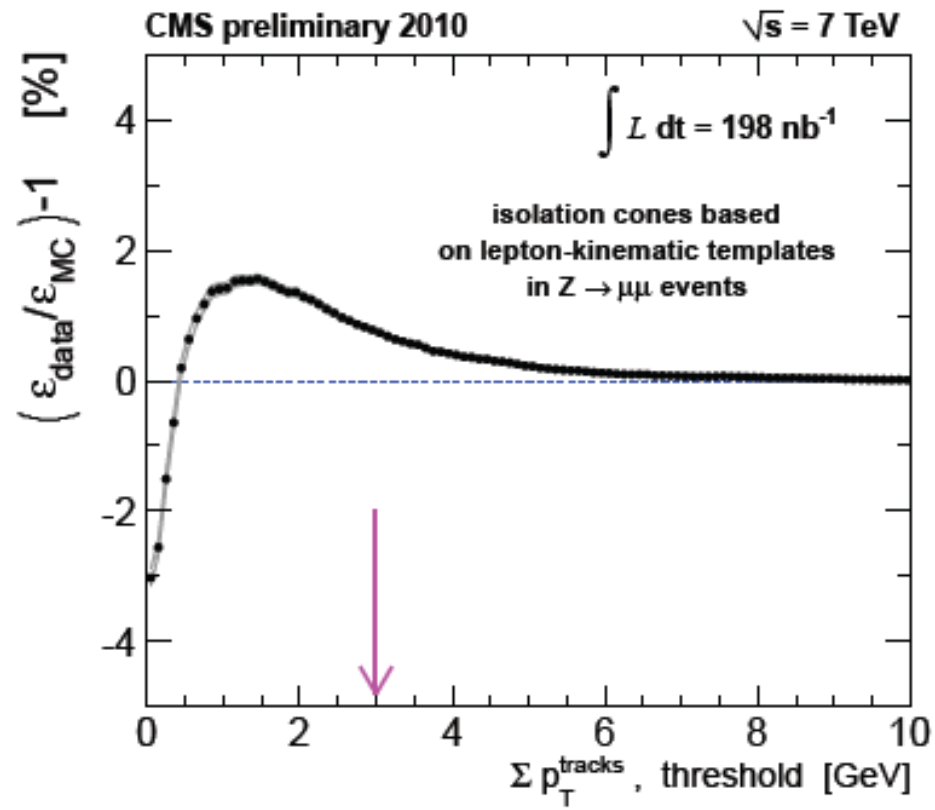
Trigger Efficiency from Minimum Bias collisions

Isolation efficiency from Random ConesE

Isolation Efficiencies

- Random Cone studies for Isolation Efficiency performed both for muons and electrons

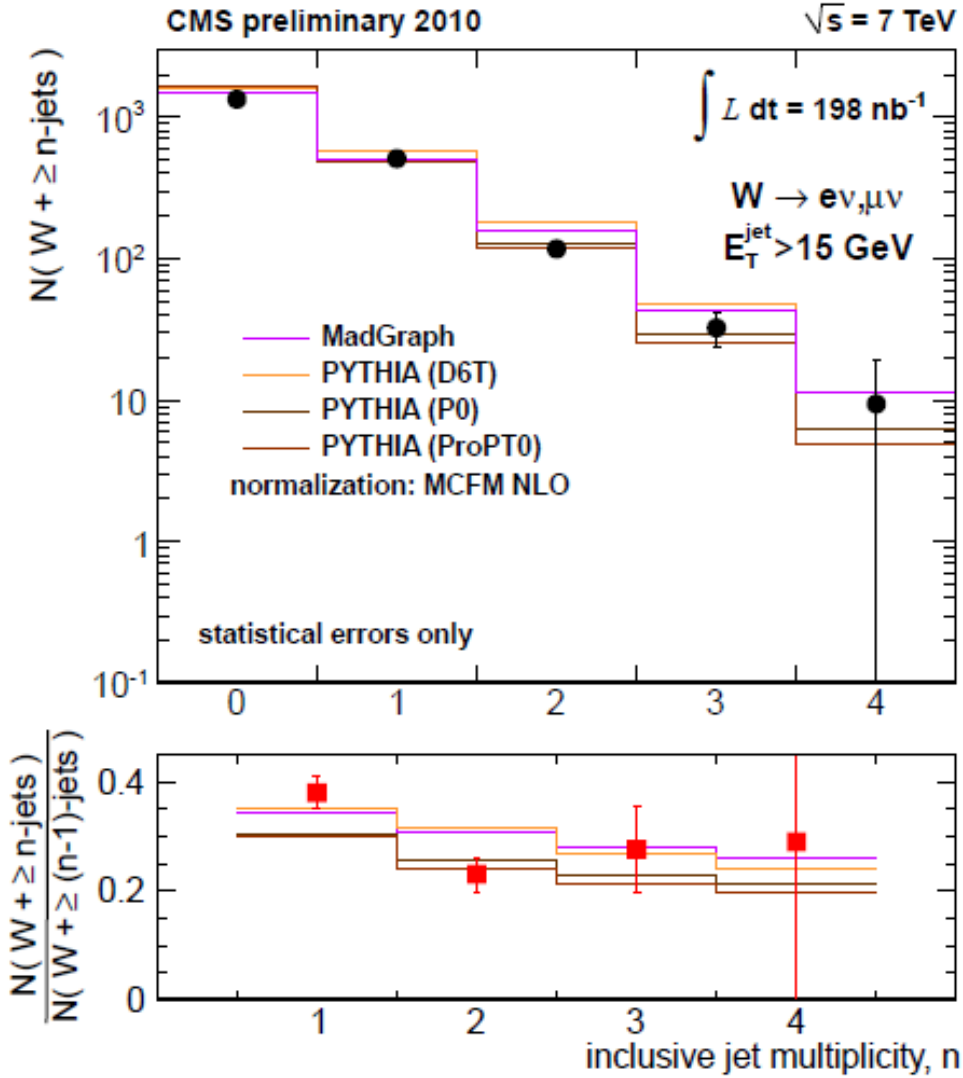




W+Jets Associated Production

- Same lepton selection as the inclusive analysis

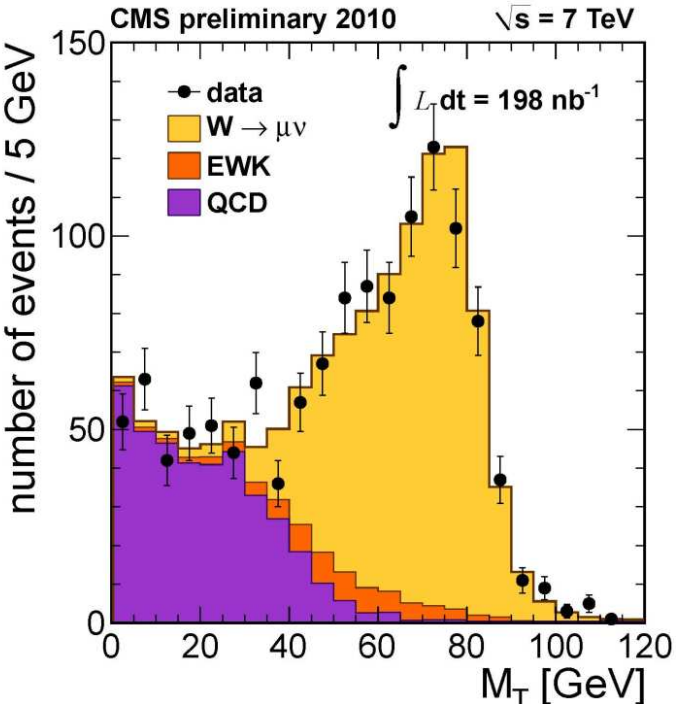
- **Jet Selection:**
  - Infra-red safe Anti-Kt Jet reconstruction
  - Two thresholds E_T>15 GeV and E_T>30 GeV
  - Lepton-Jet separation: ΔR<0.5
  - Particle Flow reconstruction
  - Cone radios of ΔR=0.5,
  - |η|<2.5

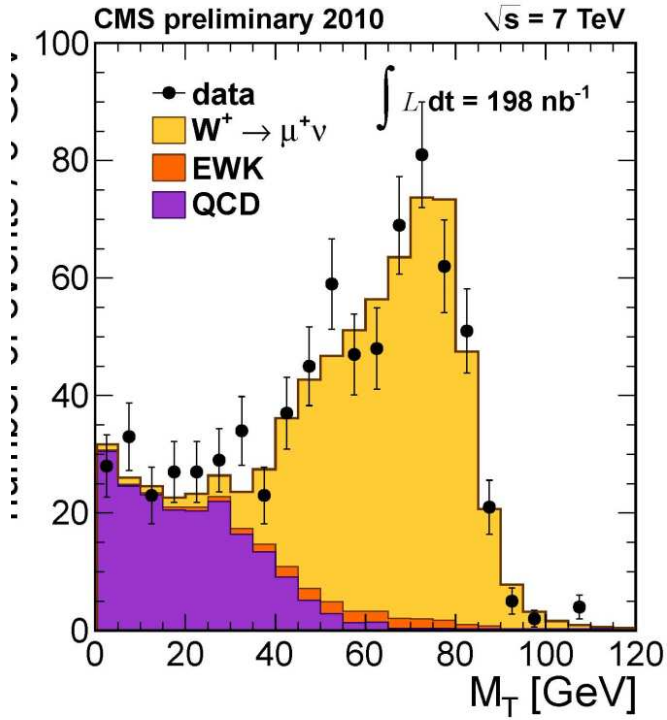


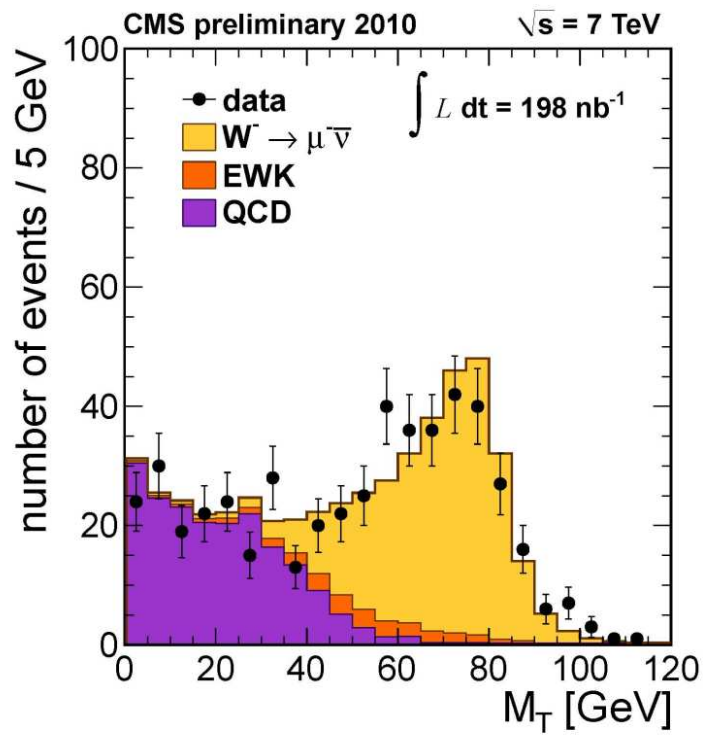
- M_T used as discriminating variable in both channels

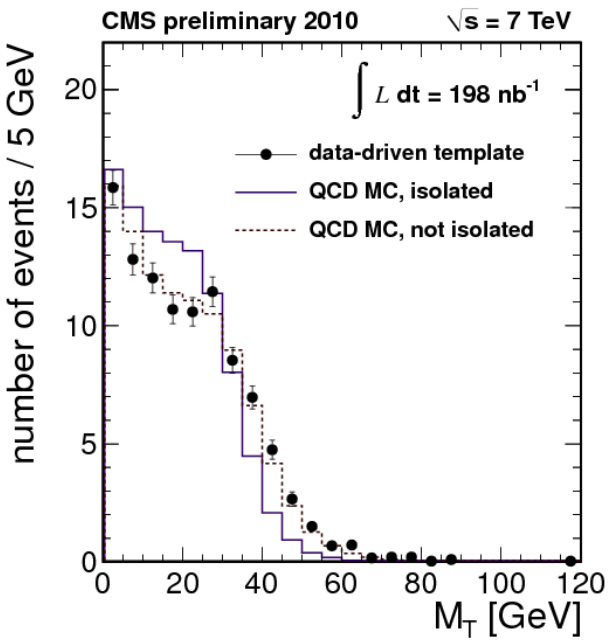
- Main source of systematics error: jet energy scale (10-20%)

$W \rightarrow \mu\nu$, Track-ME_T Algorithm





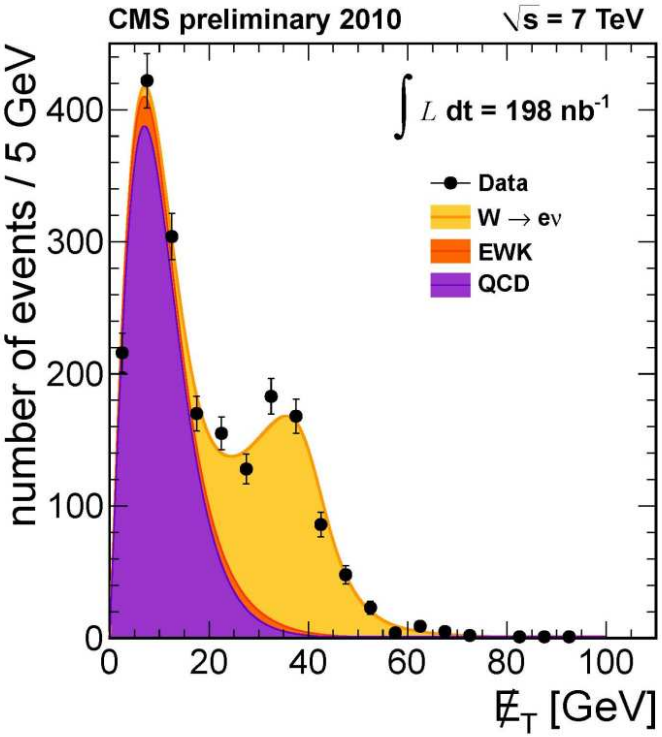


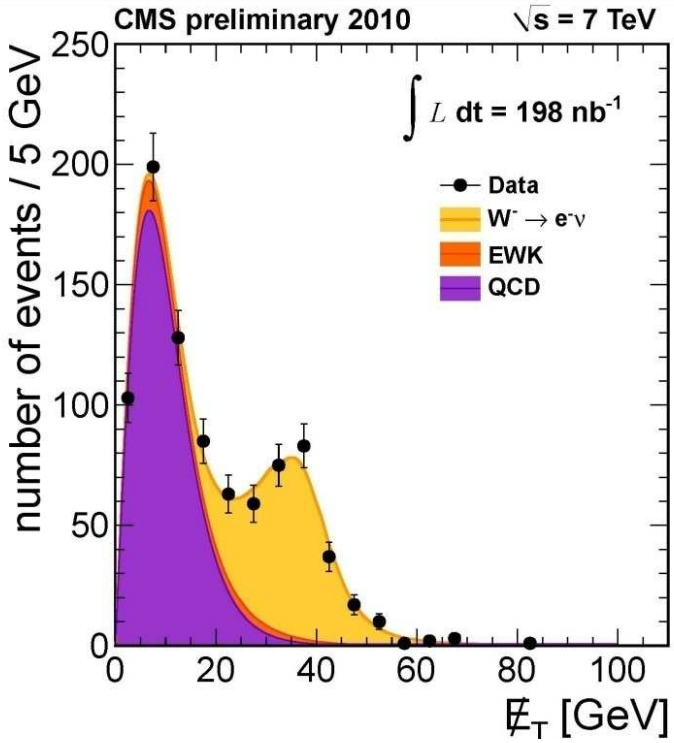


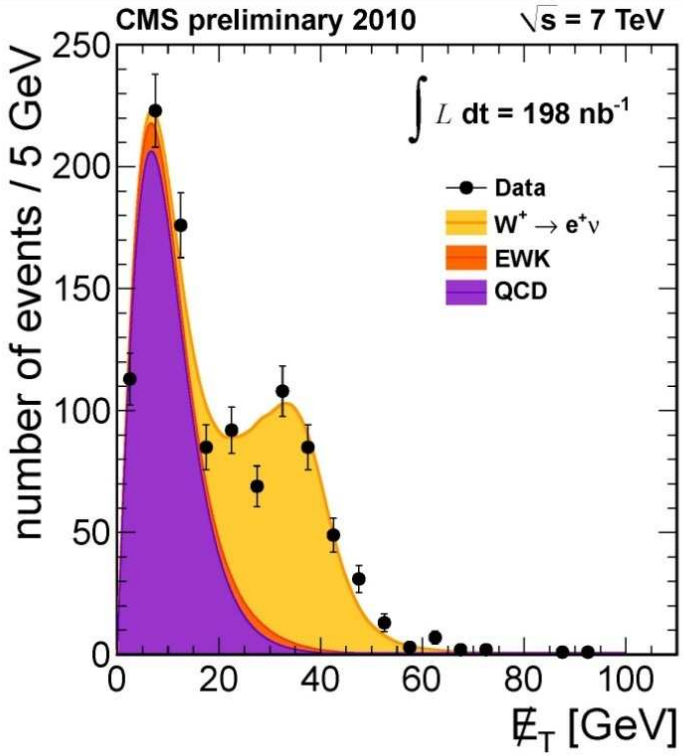
Alternative MET reconstructon algorithm used for cross-check

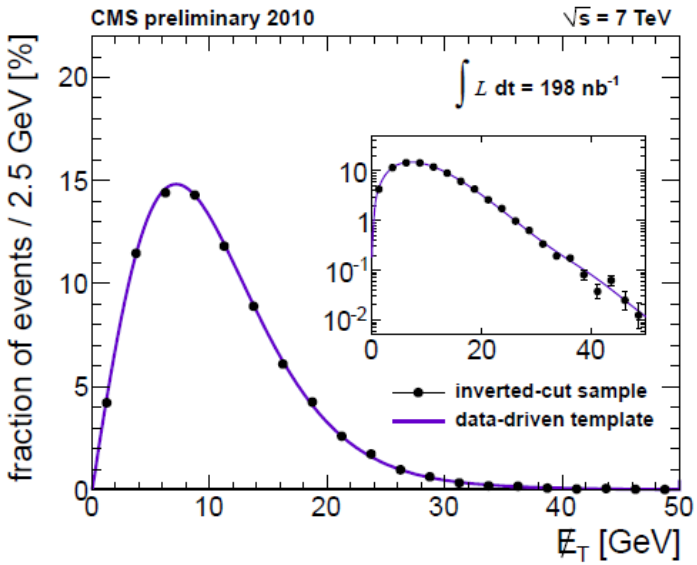
Results in perfect agreement for the baseline particle-flow and track-corrected ME_T analysis

$W \rightarrow e\nu$, Track-ME_T Algorithm









Alternative ME_T reconstructon algorthym used for cross-check

Results in perfect agreement for the particle-flow and track-corrected ME_T