W/Z physics at CMS

First Results from the LHC and Their Physical Interpretation

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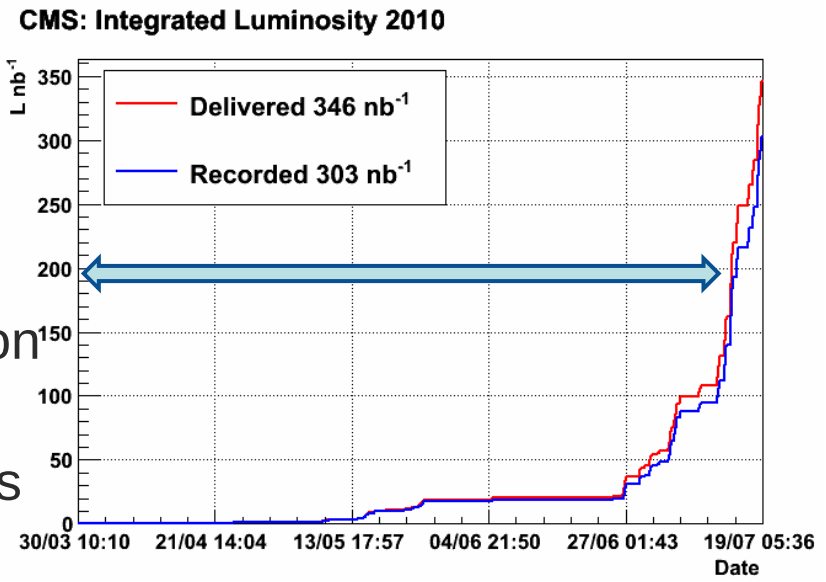
On behalf of the
CMS collaboration

Outline

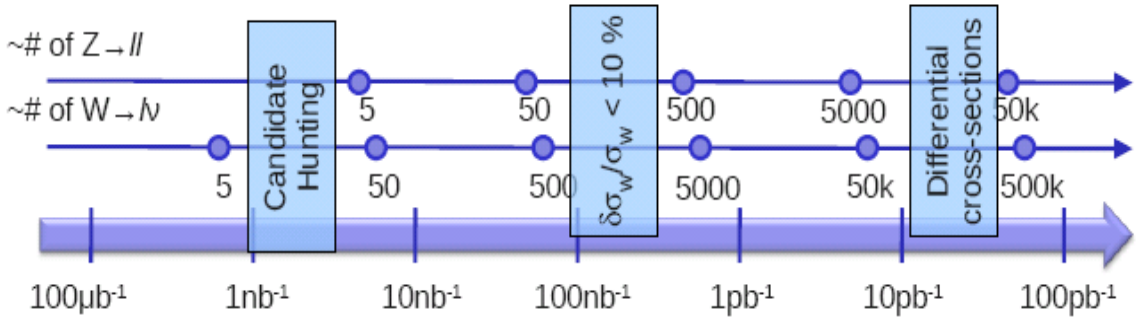
- Introduction
- Muons
  - Muon identification and selection
  - Efficiency
  - W → μ ν
  - Z → μ μ
- Electrons
  - Electron identification and selection
  - Efficiency
  - W → e ν
  - Z → e e
- Systematic uncertainties
- Results

Introduction

- First measurement in pp collisions at 7 TeV of inclusive productions for W and Z
- Importance:
  - Benchmark for lepton reconstruction and ID
  - Test of perturbative QCD and PDFs
  - Possible estimator of luminosity
  - Background of many interesting processes



∫Ldt=198 nb^{-1} analyzed



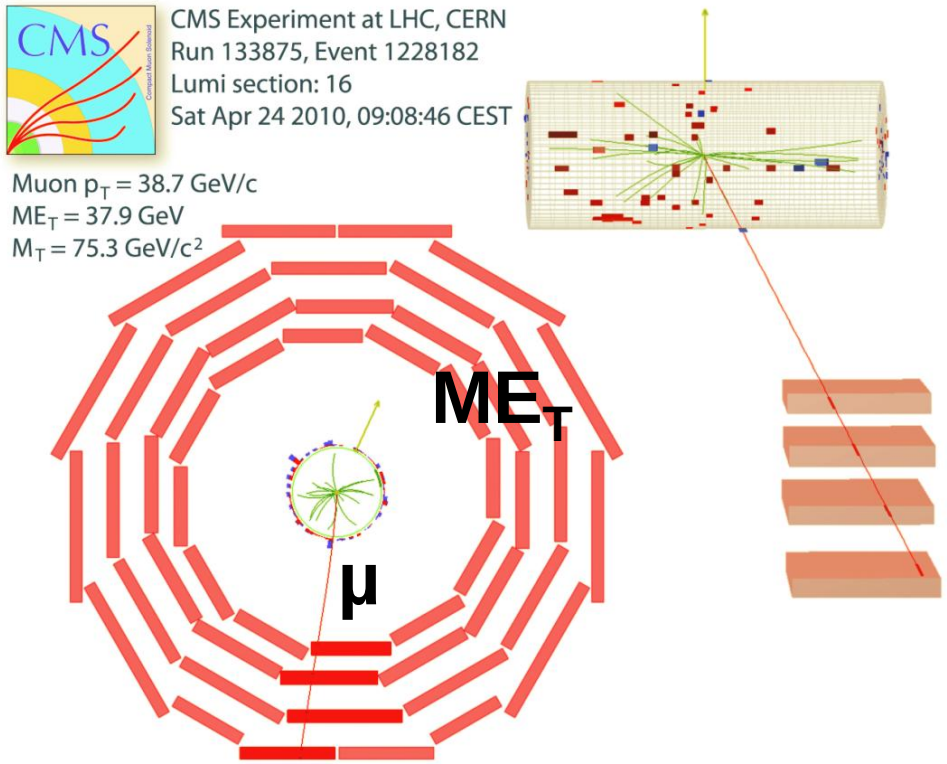
Introduction

- MET
  - Essential piece for W → μ ν analysis
  - Several techniques to compute MET:
    - Pure calorimetrical measurement; with corrections from tracker; using fully reconstructed particles.
  - Result shown to be compatible
    - Used pfMET as baseline for this analysis
- Simulation
  - Large MC sample to evaluate:
    - Acceptance of different non-QCD processes (pt, eta phase space)
    - QCD and signal shape
    - Efficiencies of different selection steps
  - MC generation:
    - POWHEG NLO + CTEQ 6.6 (NLO) (signal), QCD with PYTHIA
    - Full GEANT4 simulation

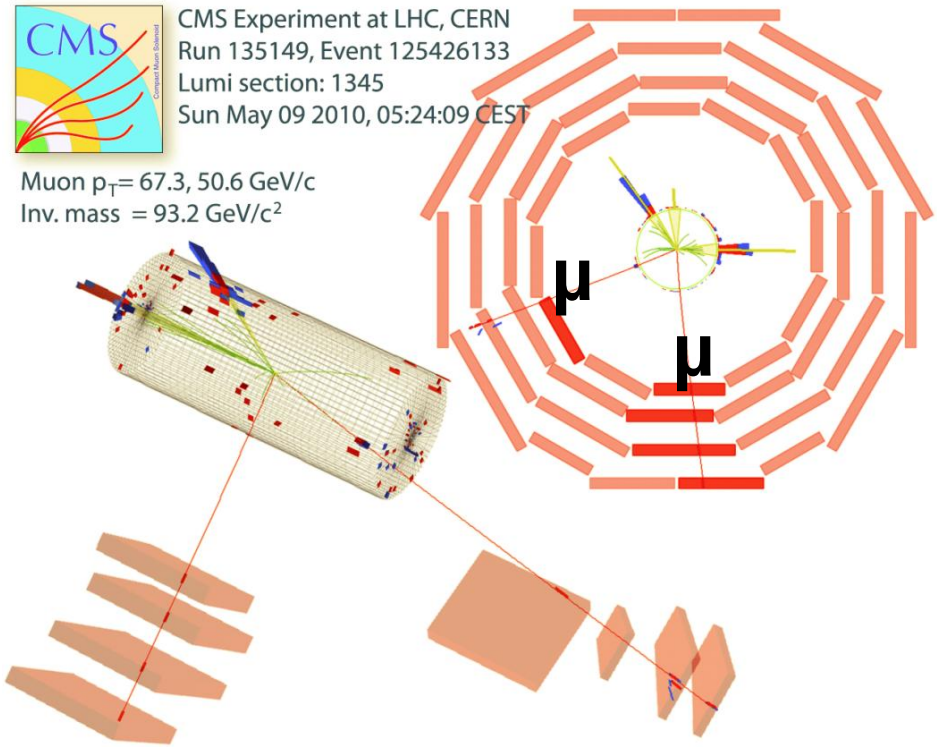
Muon channels

- Muons
  - Muon identification and selection
  - Efficiency
  - $W^{+/-} \rightarrow \mu^{+/-} \nu$
  - $Z \rightarrow \mu^{+} \mu^{-}$

W → μ ν and Z → μ μ



W Candidate



Z Candidate

Muon ID and selection

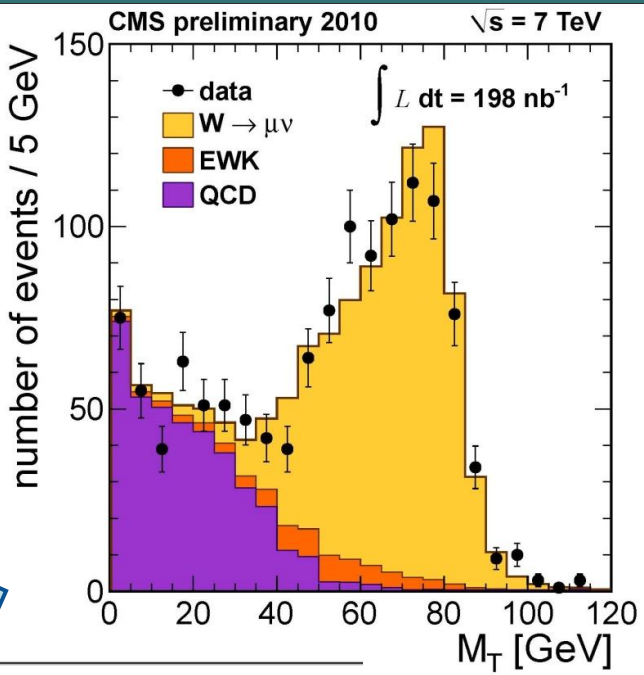
- Event triggered in $|\eta|<2.1$ with pt>9 GeV
- Muon selection:
  - Good qulity muon: Id by two different algorithms, good quality track (χ^2 /ndof < 10).
  - Aviod punch through and good trigger pt measurement: at least segments from two μ chambers
  - Ensure good pt measurement in tracker: # hits in tracker > 10, # hits in pixels > 0
  - Avoid cosmics: impact parameter < 2mm
- W → μ ν channel **Acceptance = 64.1%**
  - Z rejection: Events with 2 μ p_{T1}>20, p_{T2}>10 rejected
  - Isolation: $(\Sigma p_T$ (tk)+ ΣE_T (had+em))/p_T< 15% (ΔR < 0.3)
- Z → μ μ channel **Acceptance = 47.6%**
  - 60 < m$\mu\mu$ < 120 GeV

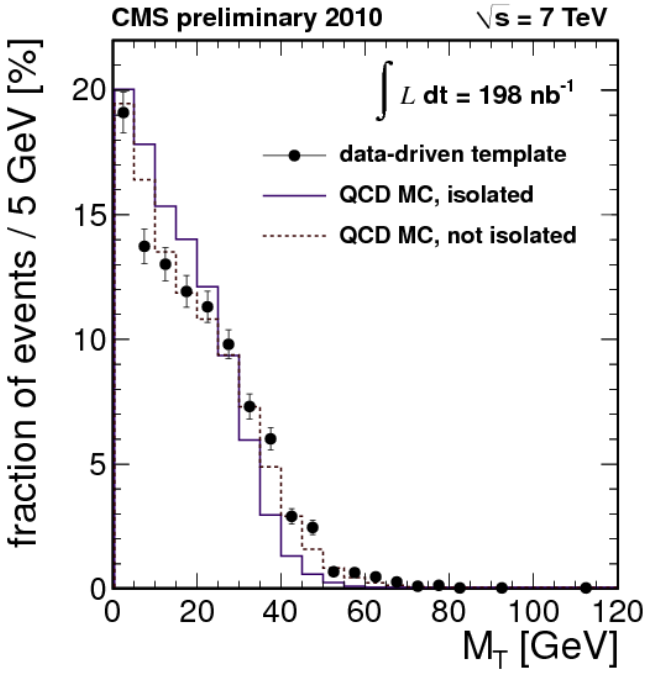
Efficiency

- Efficiency split in several terms (1 single value for whole phase space):
  - $\varepsilon = \varepsilon_{RECO} \times \varepsilon_{TRI} \times \varepsilon_{ISO}$
- ID and selection efficiencies
  - Inclusive muon samples and Tag&Probe methods (switching on/off the different selection cuts)
- Trigger efficiency
  - calculated through Tag&Probe (Zmumu), and cross-checked through Jet, MET and Tau triggered samples
- Isolation efficiency
  - from Random Cone Techniques. Consistent with T&P

W → μ ν

- After selection 1254 W candidates
- Background:
  - QCD: data-driven template
  - EWK processes: Z → μ μ (~3%), W → τ ν (~2%) and Z → τ τ
  - ttbar: negligible (~0.3%)

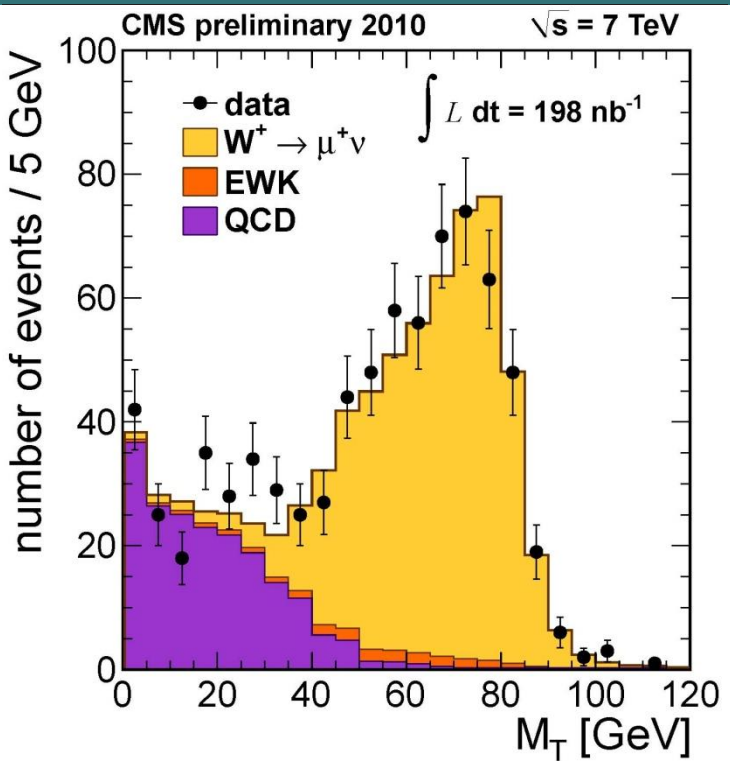


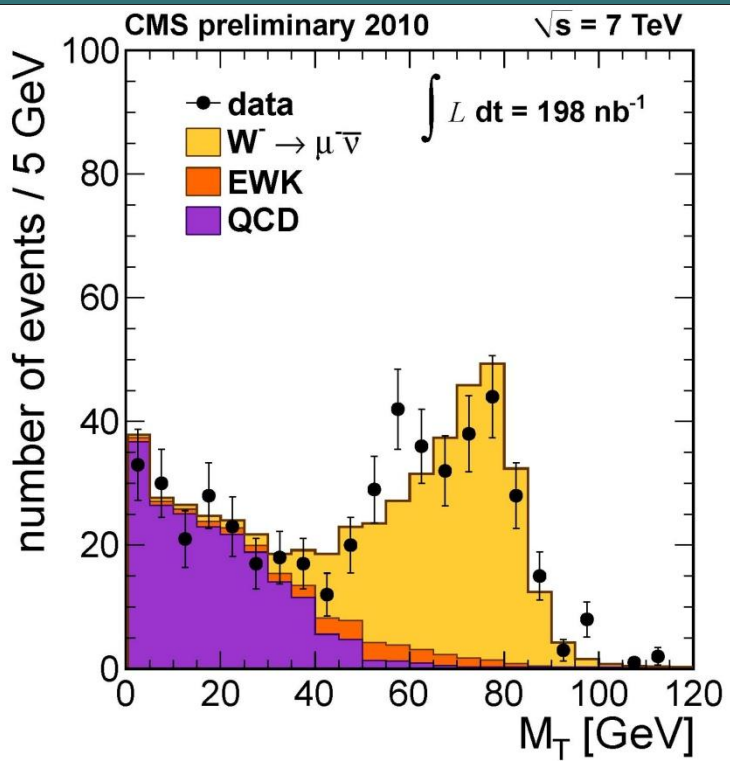


$$M_T = \sqrt{2 p_T(\mu) \not{E}_T * (1 - \cos(\Delta\phi_{\mu,\not{E}_T}))}$$

- **Binned fit** (binned likelihood to M_T)
  - 2 free param. (QCD and W normalization)
  - Signal and EWK bg templates from MC
  - QCD background data-driven method (isolation inversion)

$W \rightarrow \mu \nu$





529 24 W^+ Yield

289 13 W^- Yield

(statistical error only)

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

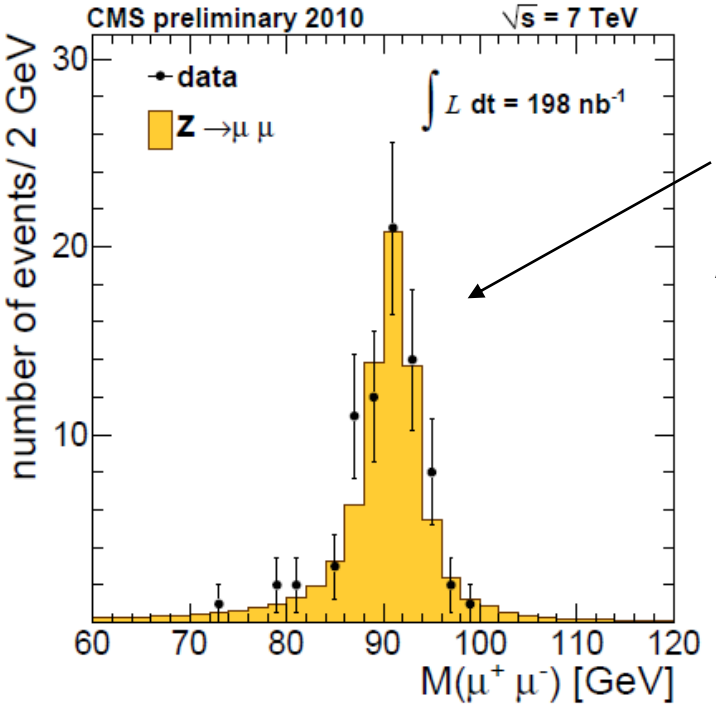
$R = 1.69 \quad 0.12$

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

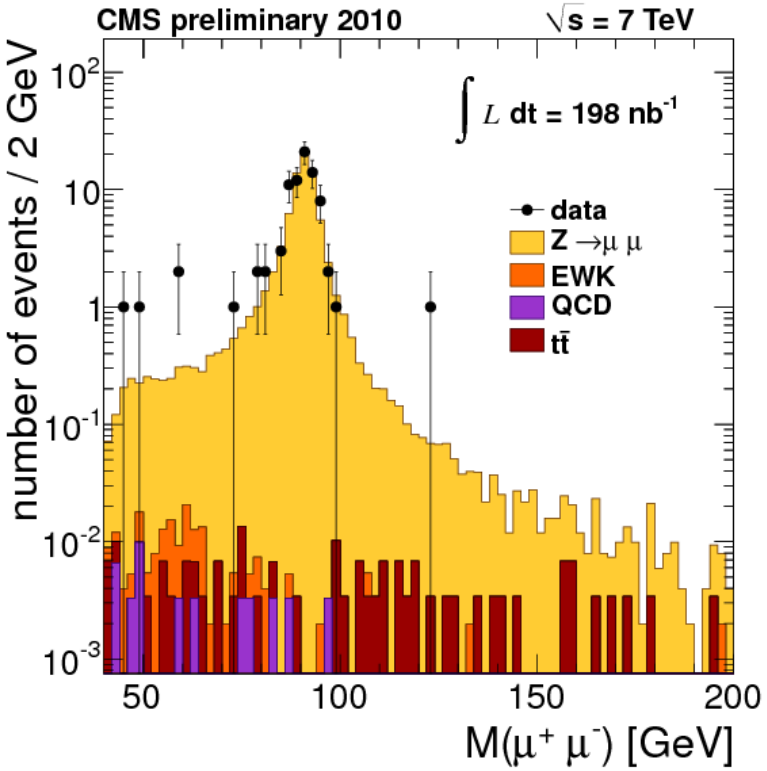
$\sigma(W^- \rightarrow \mu^-\nu) = 3.39 \quad 0.15$ nb

Z → μ μ

- After selection 77 Z candidates
- Background (negligible):
  - QCD, Z → τ τ, ttbar (~0.3%)



Good agreement Data/MC without Any corrections



- **Counting of candidates**

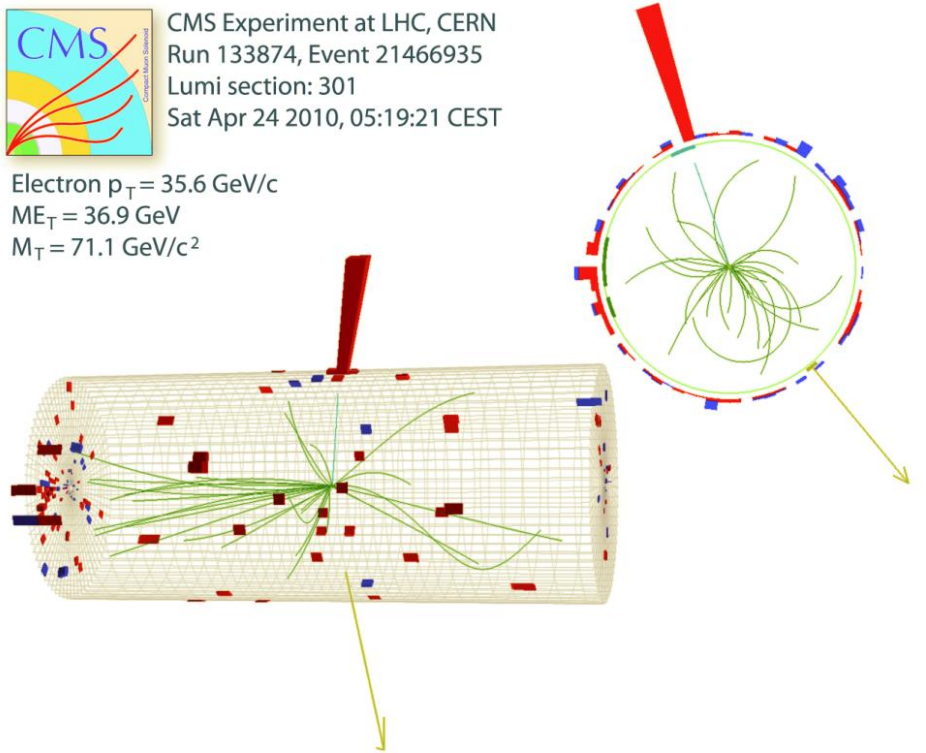
σ(pp→Z+X→μ+X) = 0.88 0.10 nb

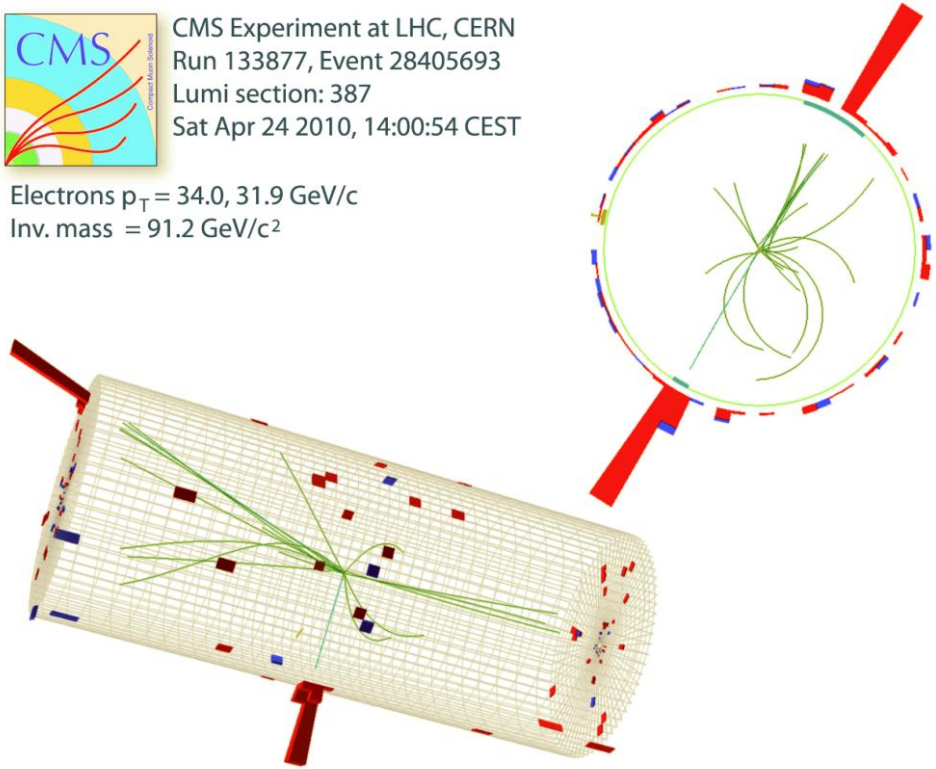
Electron channels

Electrons

- Electron identification and selection
- Efficiency
- $W^{+/-} \rightarrow e^{+/-} \nu$
- $Z \rightarrow e^{-} e^{+}$

W → e ν and Z → e e


CMS Experiment at LHC, CERN
Run 133874, Event 21466935
Lumi section: 301
Sat Apr 24 2010, 05:19:21 CEST
Electron p_T = 35.6 GeV/c
ME_T = 36.9 GeV
M_T = 71.1 GeV/c²
W Candidate


Z Candidate
CMS Experiment at LHC, CERN
Run 133877, Event 28405693
Lumi section: 387
Sat Apr 24 2010, 14:00:54 CEST
Electrons p_T = 34.0, 31.9 GeV/c
Inv. mass = 91.2 GeV/c²

Electron ID and selection

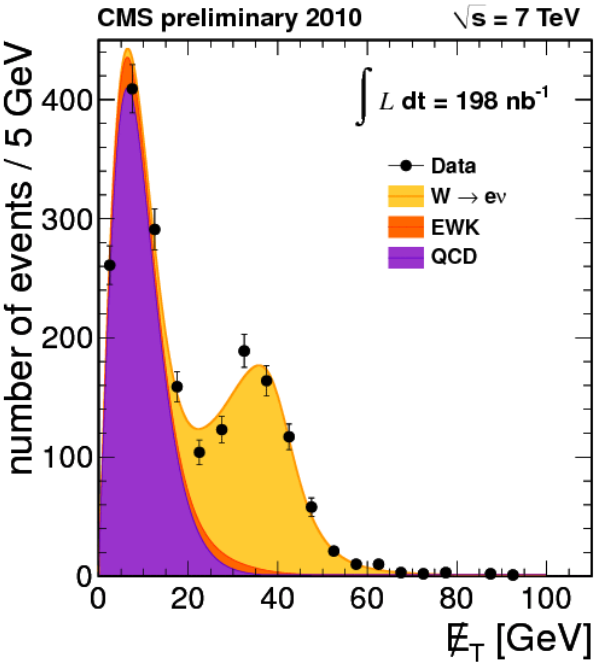
- Event triggered within the region $|\eta|<3$ with a et threshold at 15 GeV
- Electron selection:
  - ET > 20 GeV, $|\eta|<1.144$ (EB) and $1.57<|\eta|<2.5$ (EE)
  - ECAL cluster matched to tracker track; HCAL energy after ECAL cluster limited in a cone; narrow ETA cluster in η.
  - Photon conversion rejection: no missing hit in the electron track before the 1st hit; no partner track near to the electron one.
  - Fake electron rejection: isolation
  - 2 selections applied: tight (ε**=75%,** for Weν), loose (ε**=90%**, for Zee)
- W → e ν channel
  - Events with 2nd electron satisfying loose criteria rejected
- Z → e e channel
  - Two electrons E_T>20 GeV with loose criteria

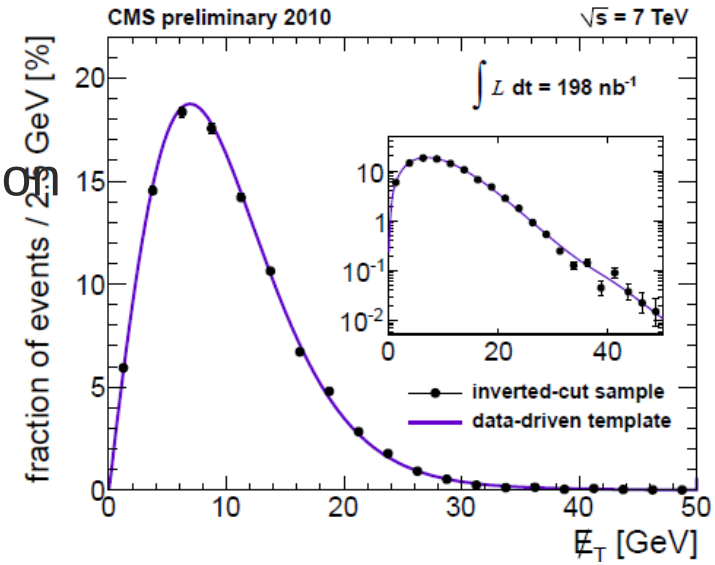
Efficiency

- Split in different terms (1 single value for whole phase space): :
  - $\varepsilon = \varepsilon_{RECO} \times \varepsilon_{TRI} \times \varepsilon_{ISO}$
- Reco and ID efficiencies
  - With Tag&Probe method
- Trigger efficiency
  - From minimum bias collisions
- Isolation
  - Tag&Probe method

W → e ν

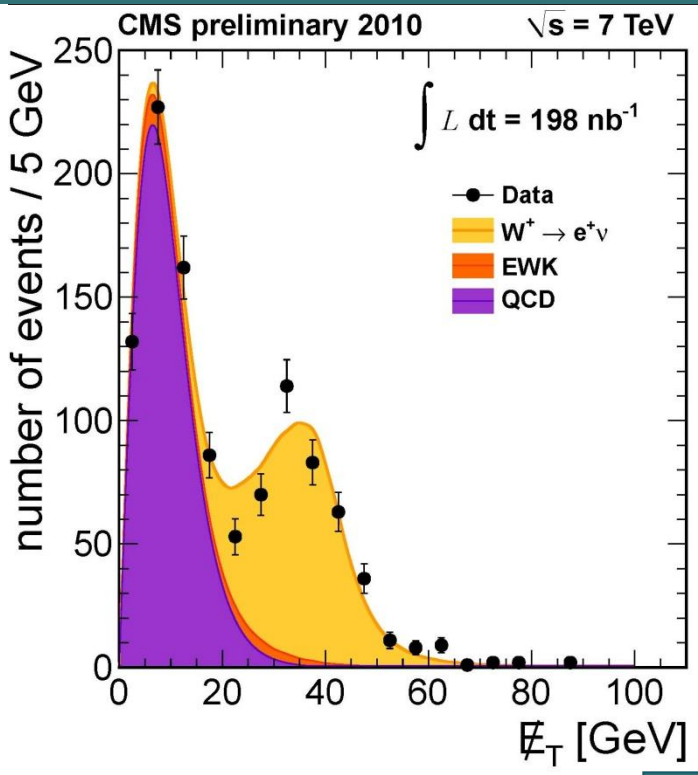
- After selection 1931 W candidates
- Background:
  - QCD: modeled with Rayleigh distribution
  - EWK processes: Z → e e, W → τ ν
  - Prompt photons

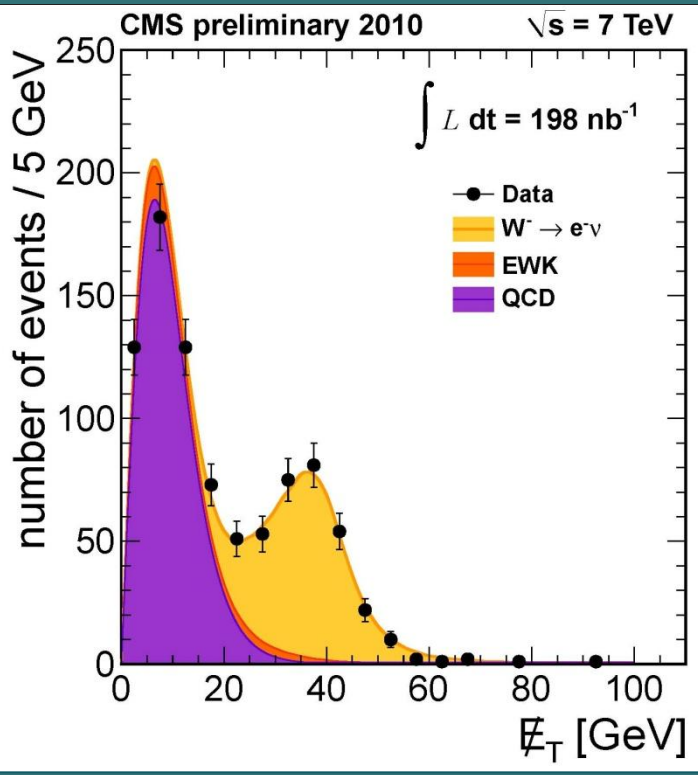




- **Unbinned fit** (likelihood to MET)
  - 4 free param. (QCD and W normalization, Rayleigh parameters)
  - Signal and EWK background modeled from MC

W → e ν





458 23 W^+ Yield

339 20 W^- Yield

(statistical error only)

σ(pp→W+X→eν+X) = 9.34 0.36 nb

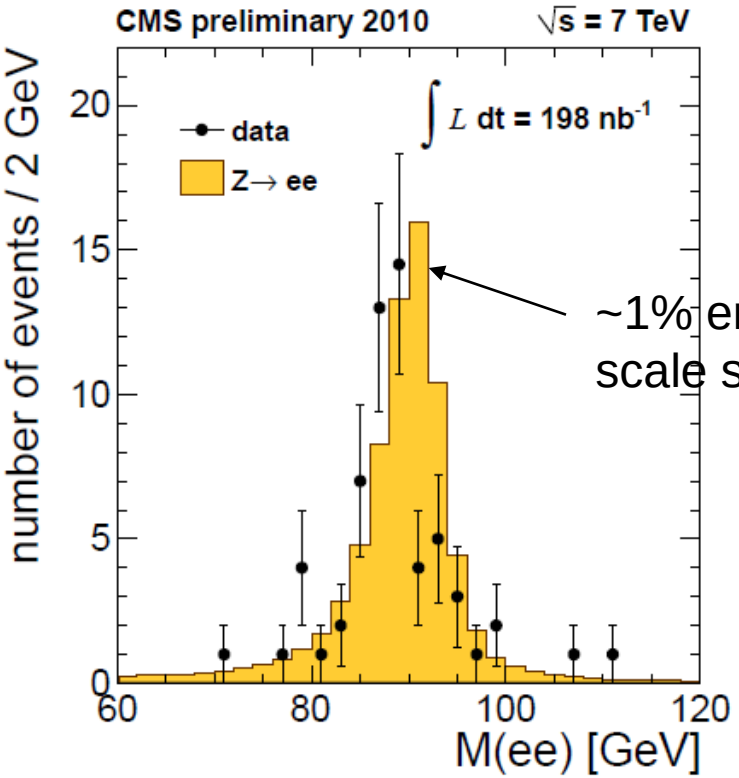
R = 1.26 0.10

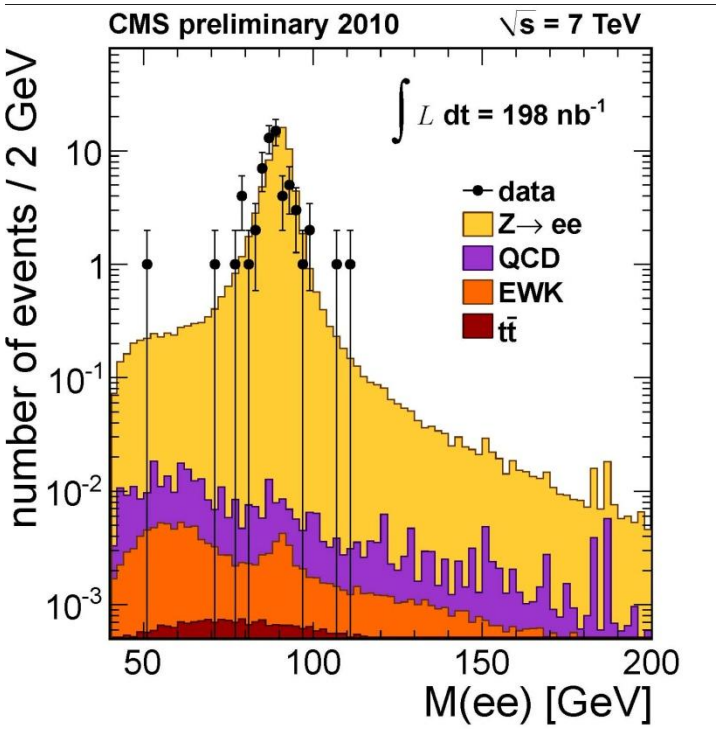
σ(W^+→e+ν) = 5.18 0.26 nb

σ(W-→e-ν) = 4.13 0.24 nb

Z → e e

- After selection 61 Z candidates
- Background (negligible), less than one event expected.
- **Counting candidates**





σ(pp→Z+X→ee+X) =0.88 0.11 nb

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- Electrons
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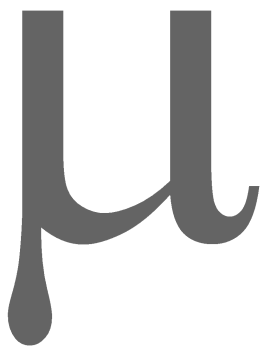
  - W → e ν
  - Z → e e
- Systematic uncertainties
- Results



Systematics

Muons:

- 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

Systematics

Electrons:

- 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 (%)
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
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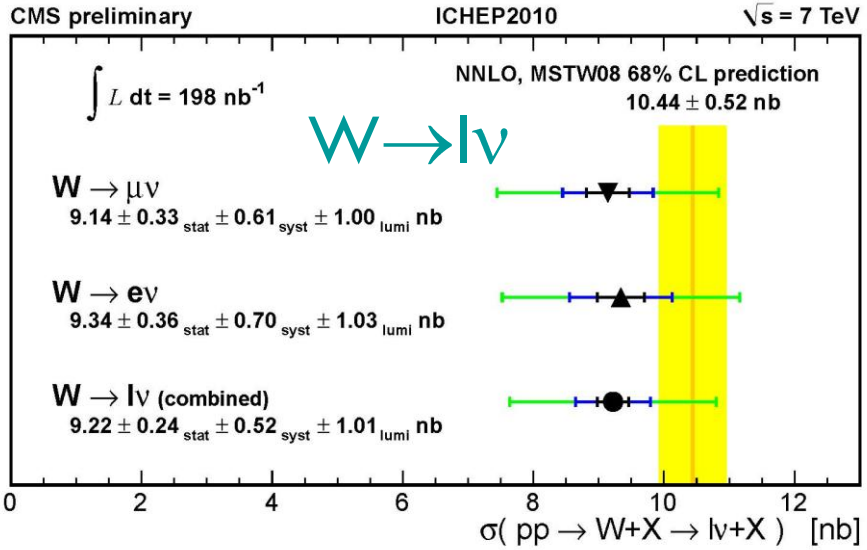
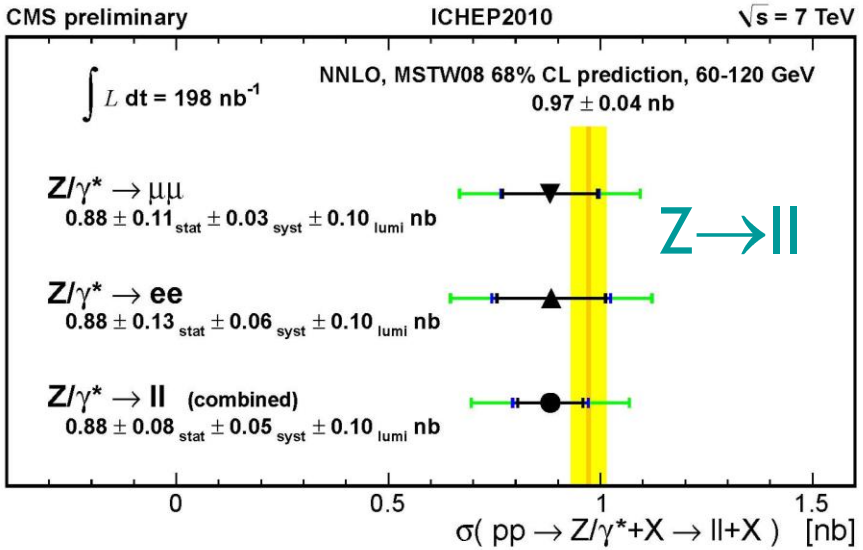
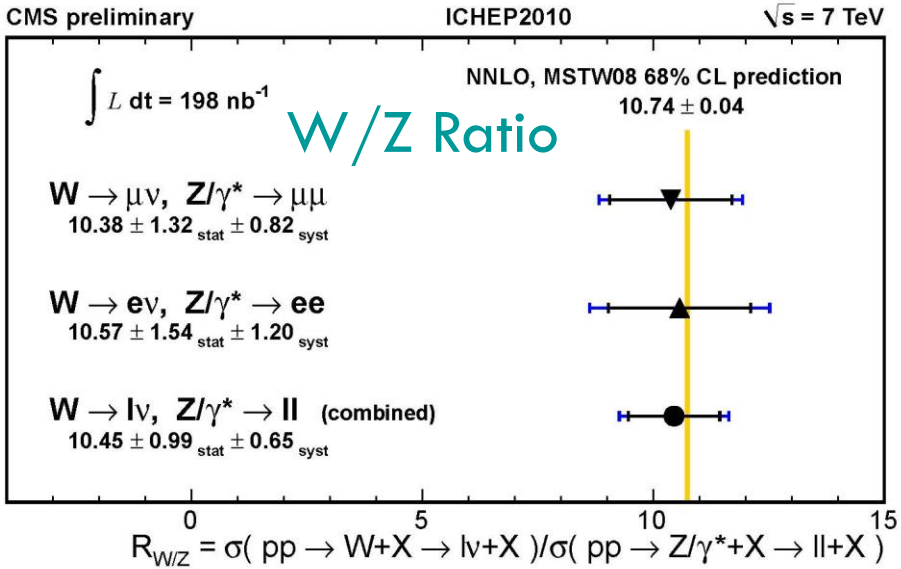
W,Z production cross-sections

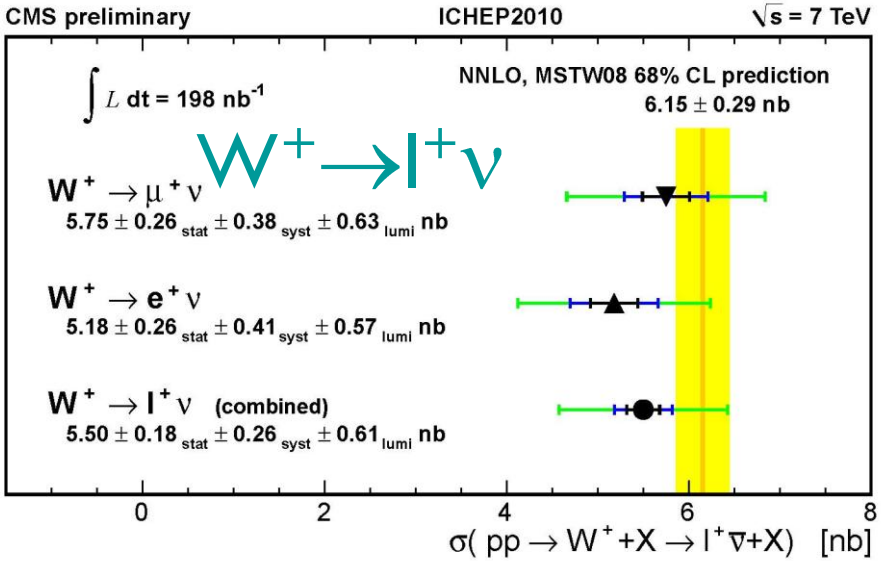


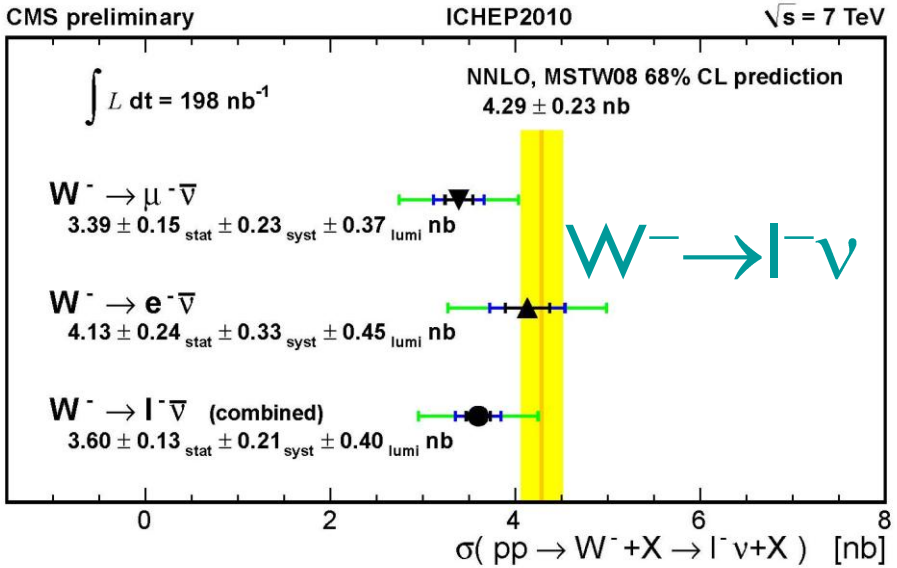


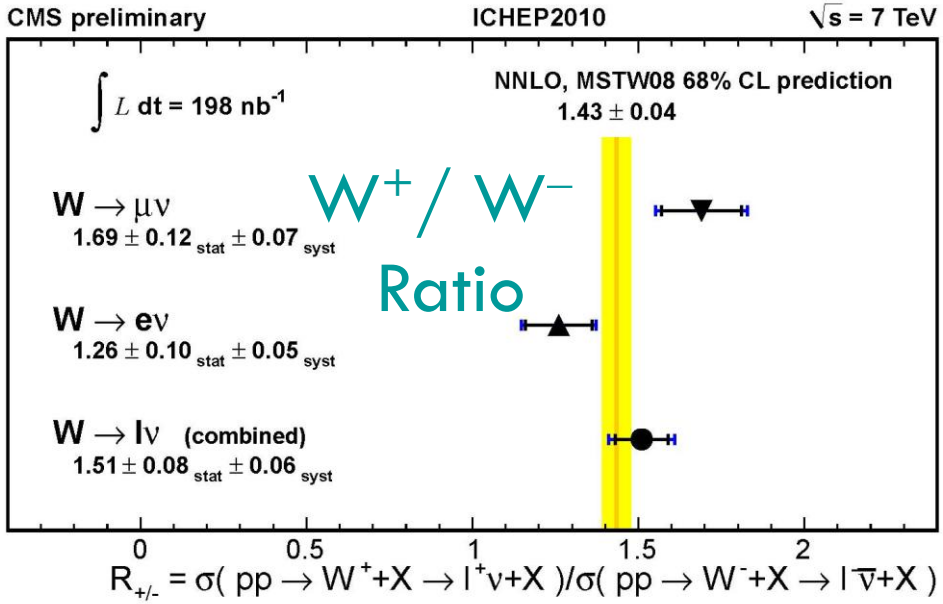


Measurements in agreement with SM predictions

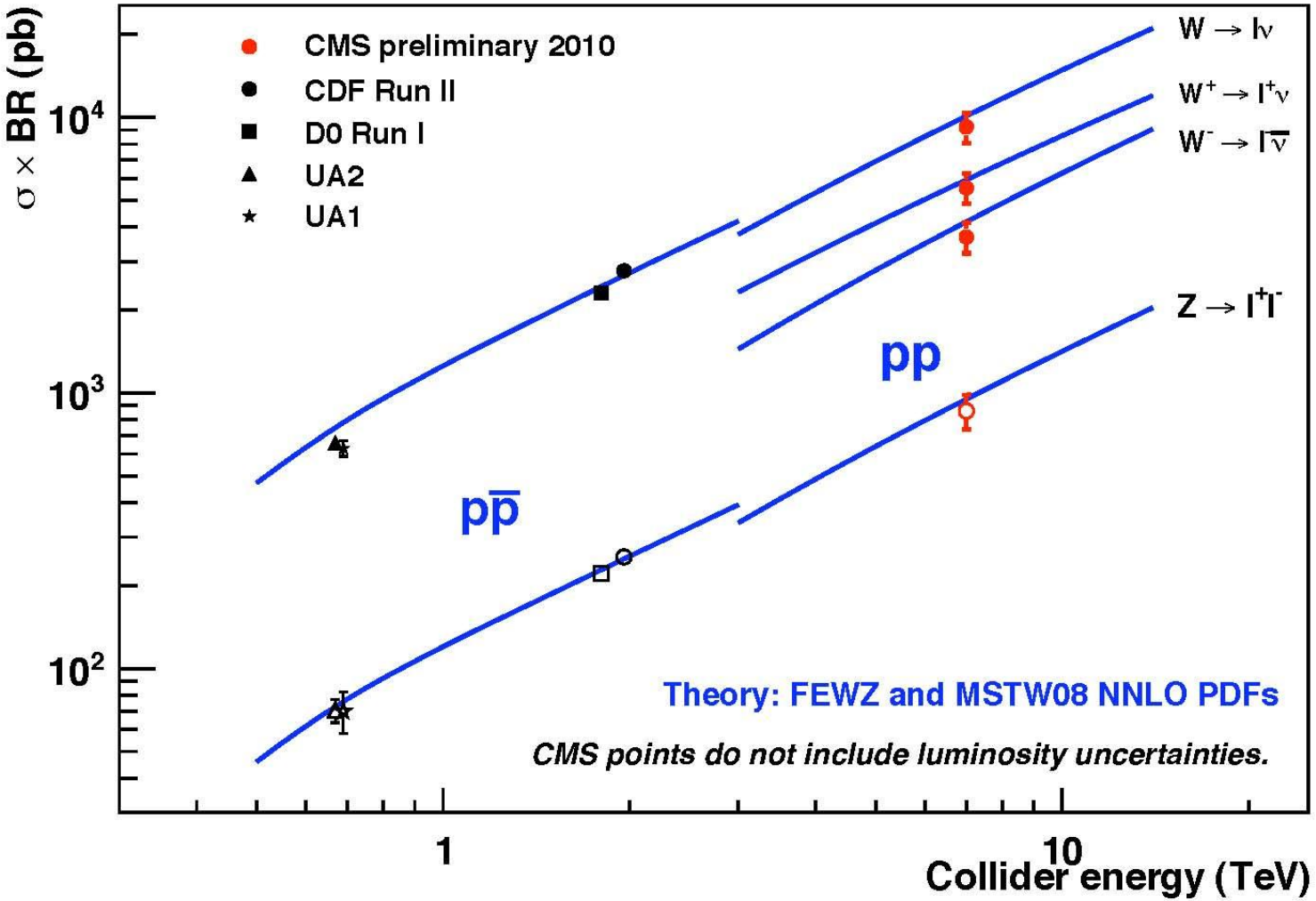
W^+, W^- Cross-Sections





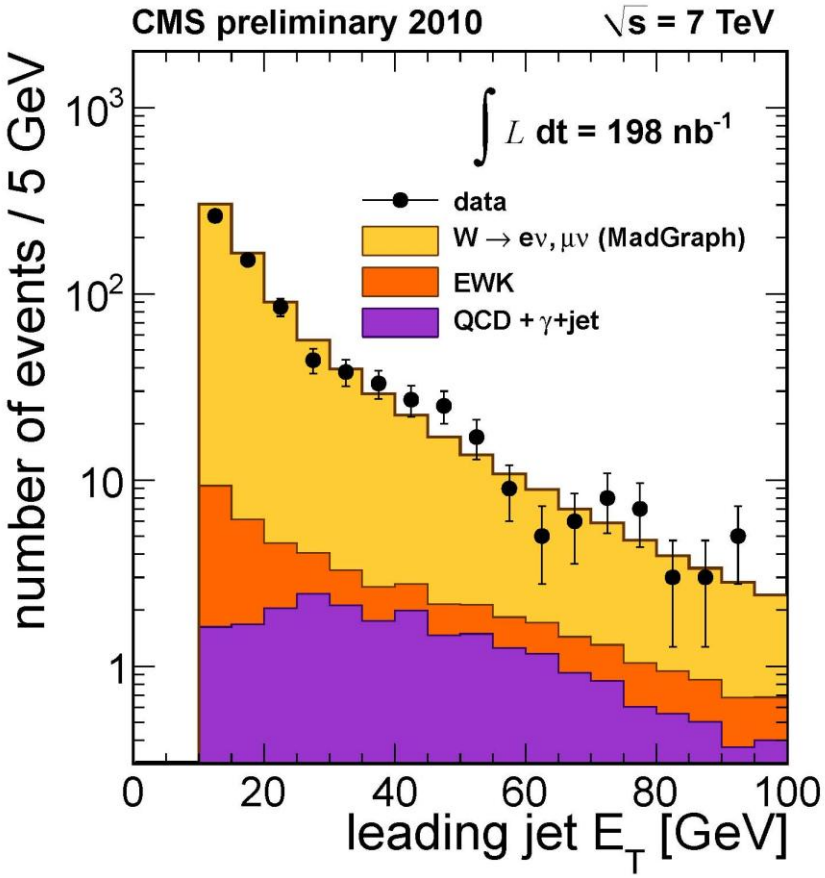


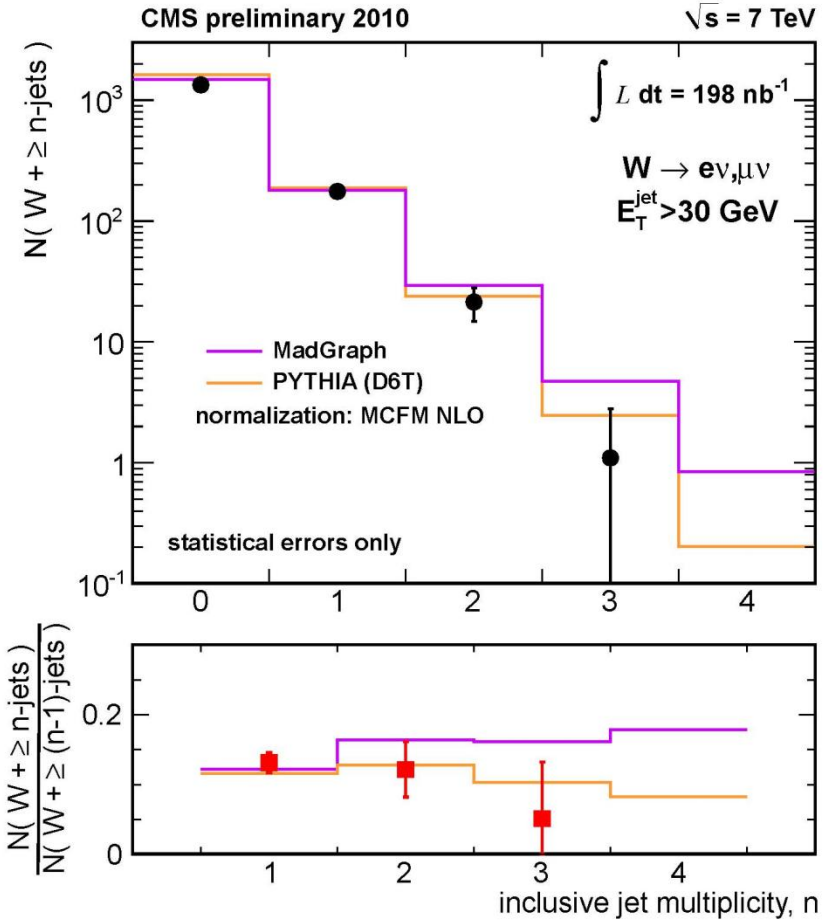
W, Z production cross-sections



W+Jets Associated Production

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





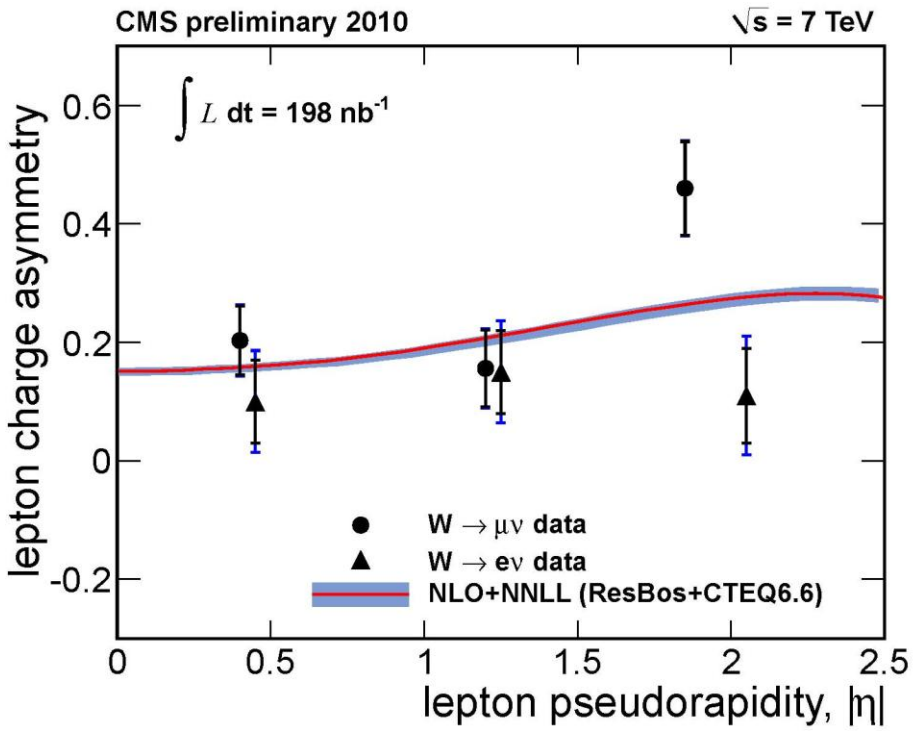
Statistical error only

(Jet energy scale (10-20%))

W Charge Asymmetries

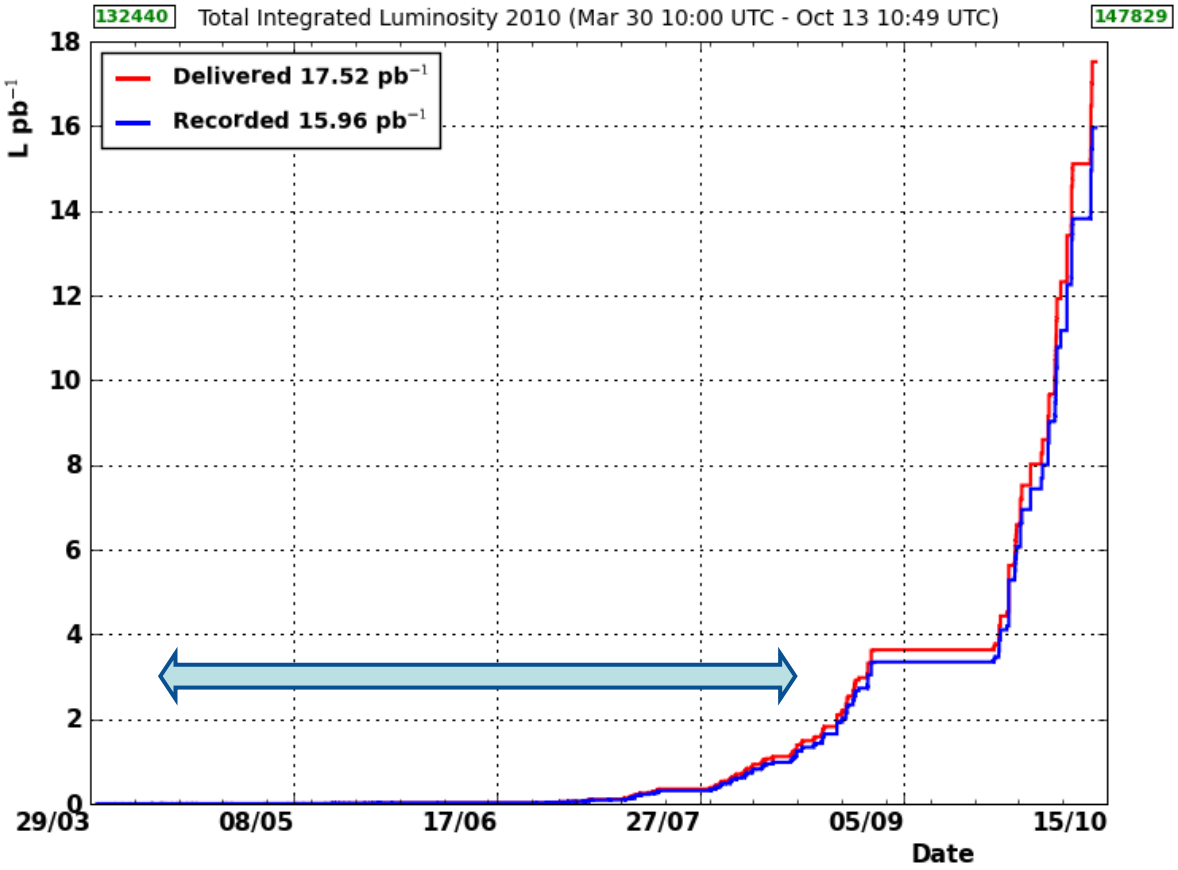
- With the current limited statistics, we perform a first measurement in 3 pseudorapidty bins
- W charge asymmetry as a function of lepton pseudorapidity will improve our knowledge of Parton Density Functions (PDFs)

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



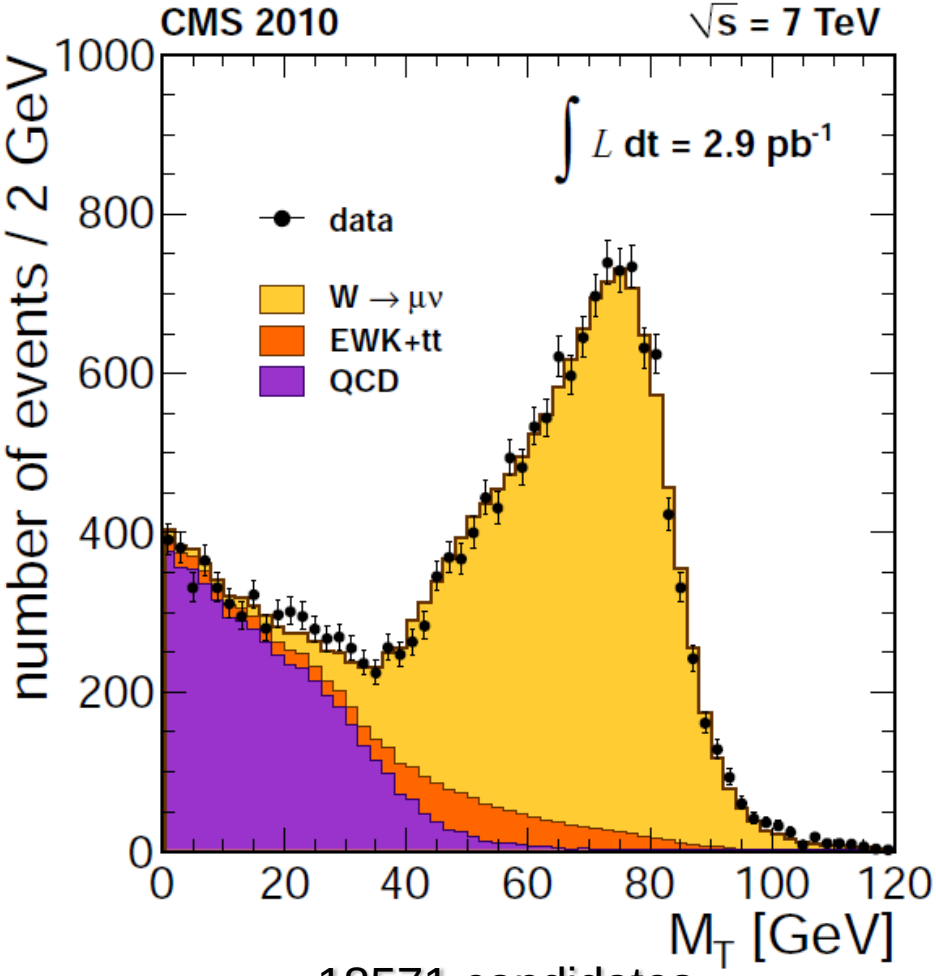
Updated results (~2.9 pb^{-1})

- New public plots for ~2.9 pb^{-1}
- Results systematically limited
- Starting “differential cross section” era



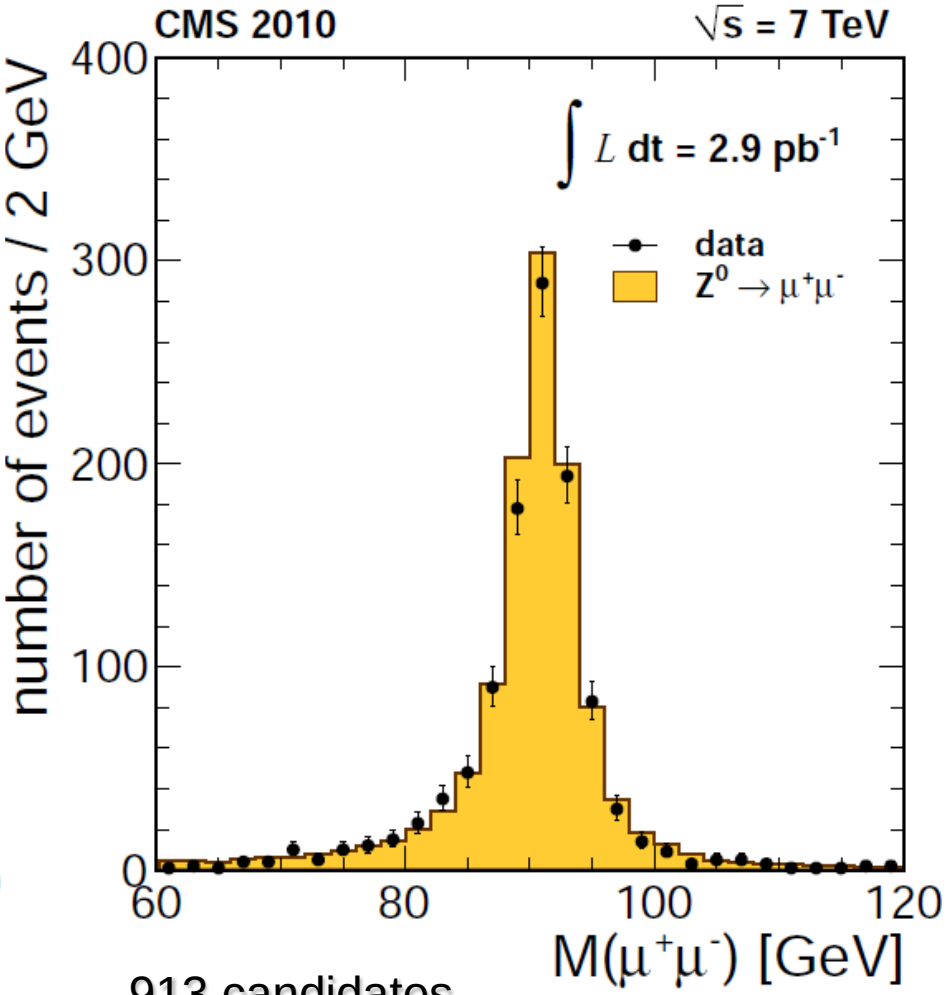
Updated results (2.9 pb^{-1})

- $W \rightarrow \mu \nu$



18571 candidates

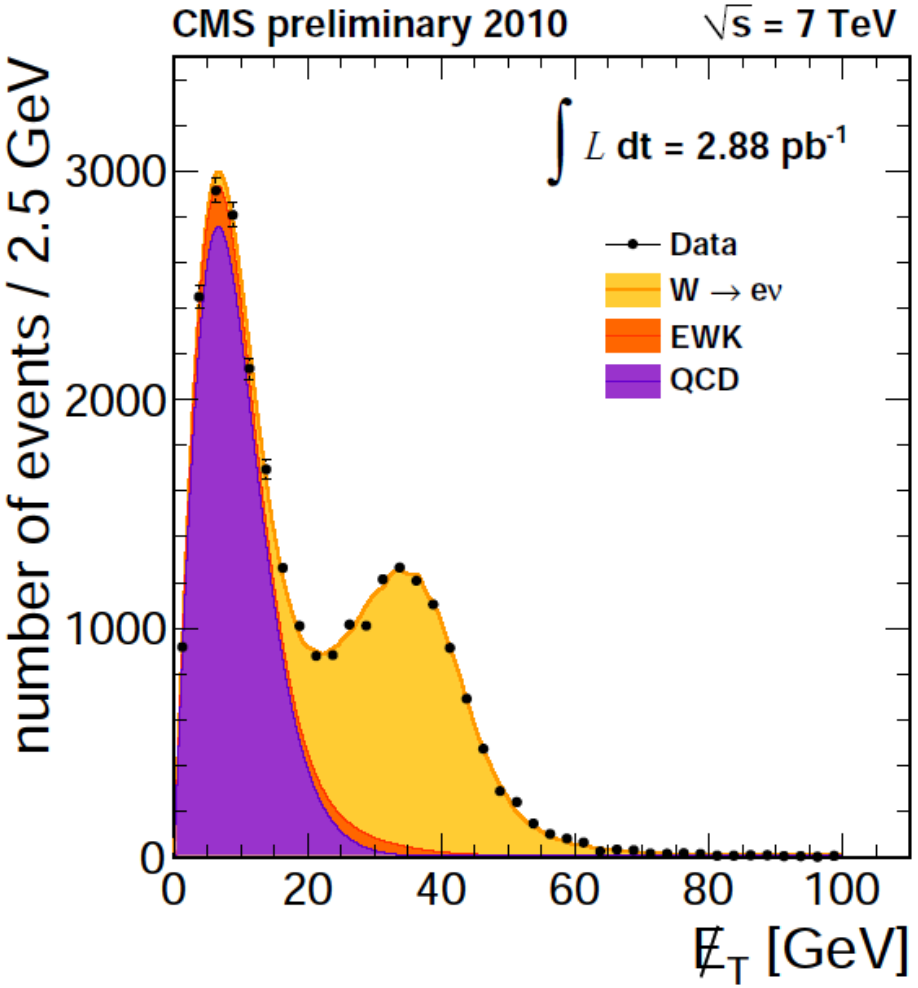
- $Z \rightarrow \mu \mu$



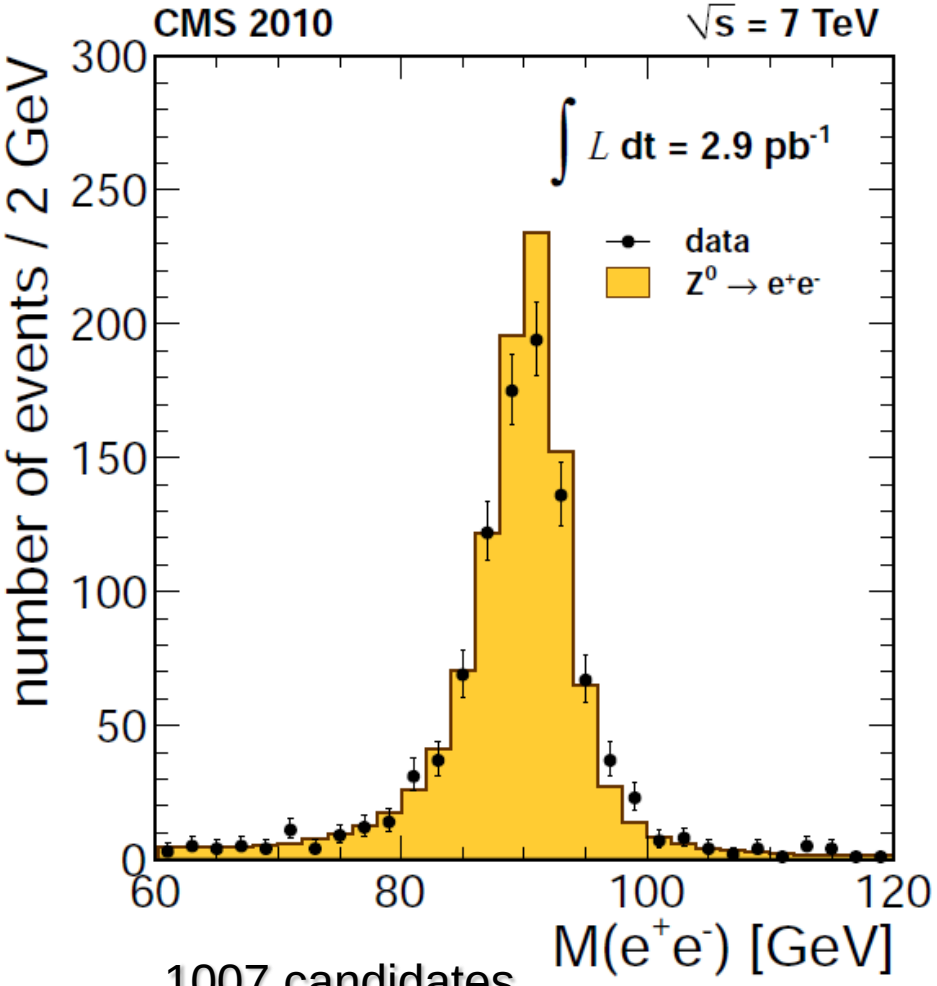
913 candidates

Updated results (2.9 pb^{-1})

- W → e ν
- Z → e e



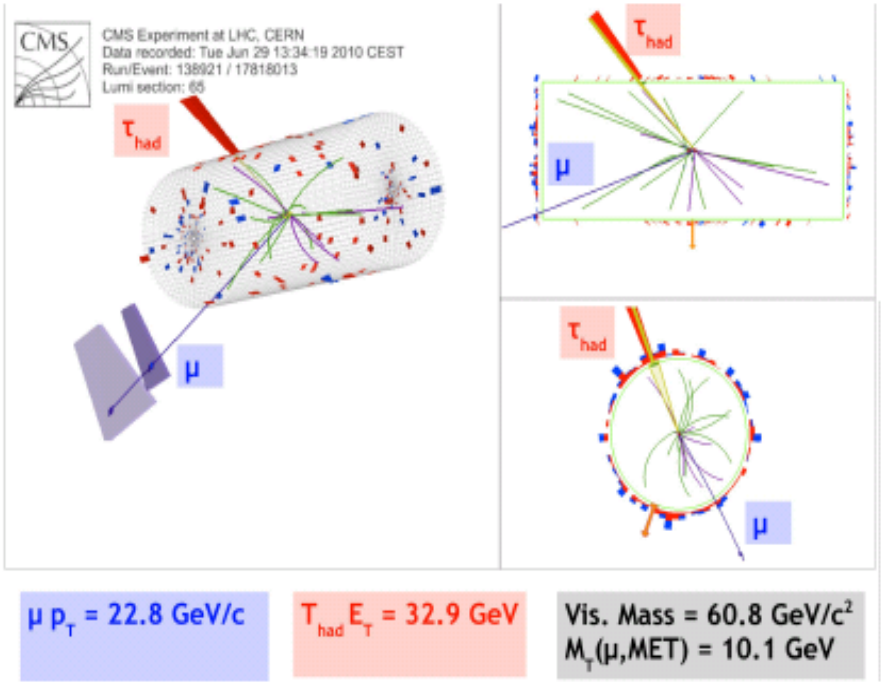
27875 candidates



1007 candidates

Z → τ τ

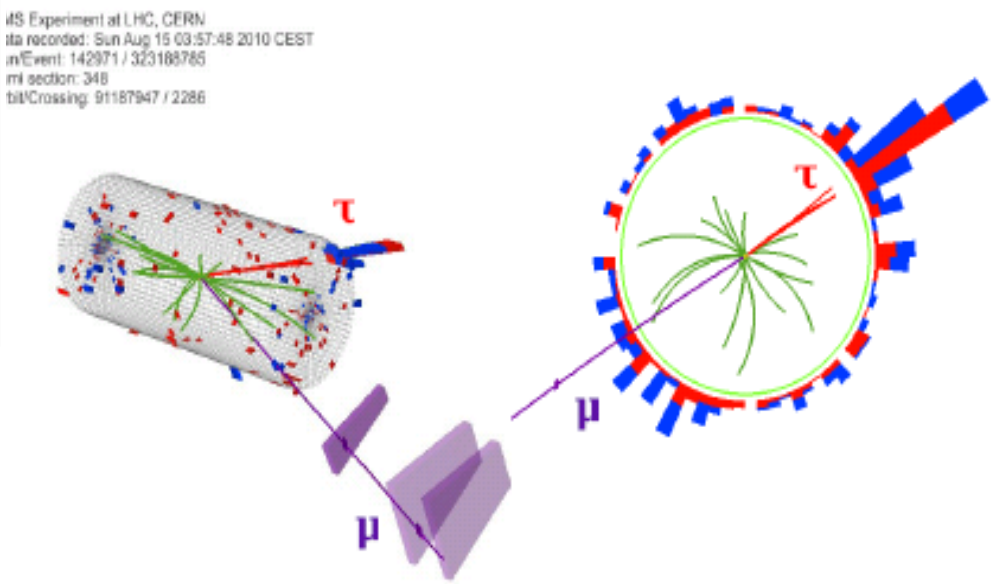
- First convincing signal of Z → τ τ with 1.7 pb^{-1}



μ p_T = 22.8 GeV/c

T_{had} E_T = 32.9 GeV

Vis. Mass = 60.8 GeV/c^2
M_T(μ,MET) = 10.1 GeV



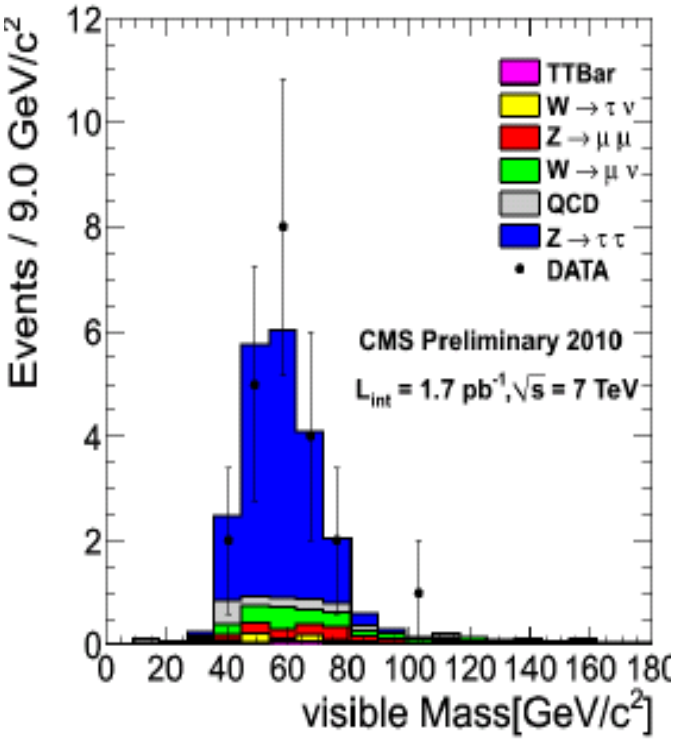
μ Pt = 32.4 GeV/c
η = 1.7

τ Pt = 37.4 GeV/c
η = 1.5
Mass = 1.2GeV/c²

Vis. Mass= 70 GeV/c²
M_T(μ,MET) =4.1 GeV

$Z \rightarrow \tau\,\tau$

- First preliminary results with 1.7 pb^{-1}.
- Tau selection
  - Mu Pt >15 GeV
  - $Iso^{rel}_{comb} < 0.1$
  - Tau Pt > 20 GeV
  - Loose isolation



Conclusions

- The first **measurements of ElectroWeak physics** in CMS are presented
  - Cross section of W and Z in e and μ channels
  - Ratios of W/Z and W+/W- cross sections
  - **First measurement of diferencial cross sections**
  - **W + jets production**
- At the same time:
  - Lepton reconstruction and ID tested
  - Possible indicator of LHC luminosity
- Waiting for new data to enter the “differential cross section” era

In agreement with Standard Model