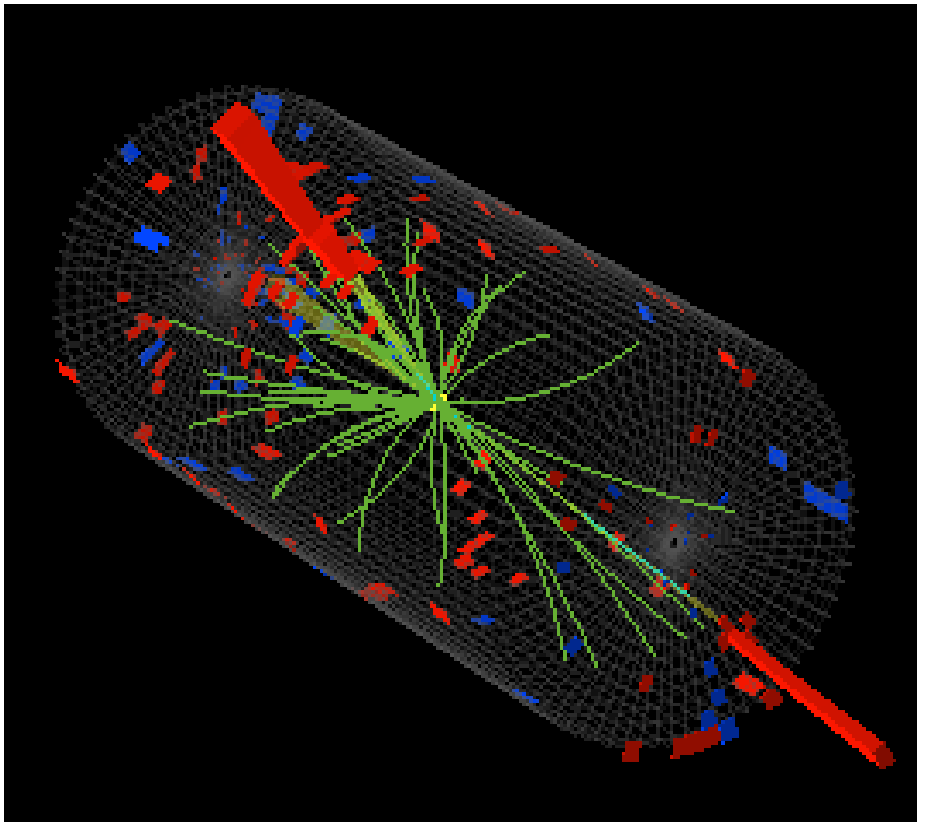
CMS W/Z Cross-Section Measurements @√s = 7 TeV

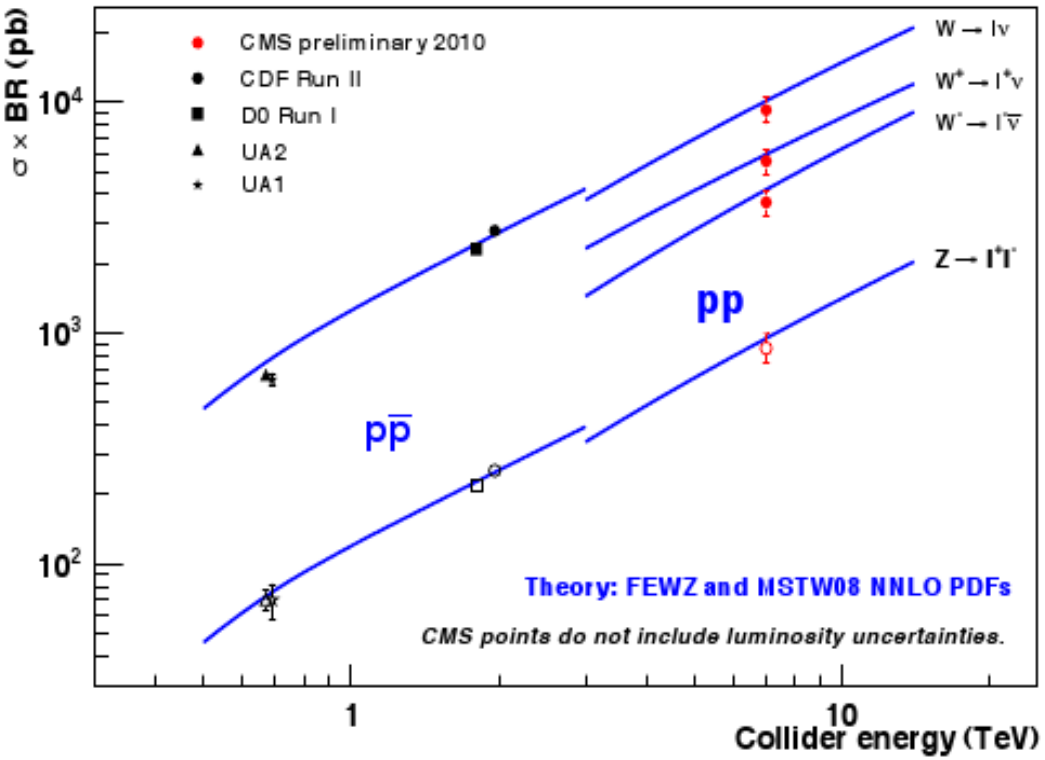


Jeremy Werner
(Princeton University)
on Behalf of the CMS Collaboration

Berkeley/MIT Implications of First LHC Data Workshop @ MIT
Aug 12, 2010

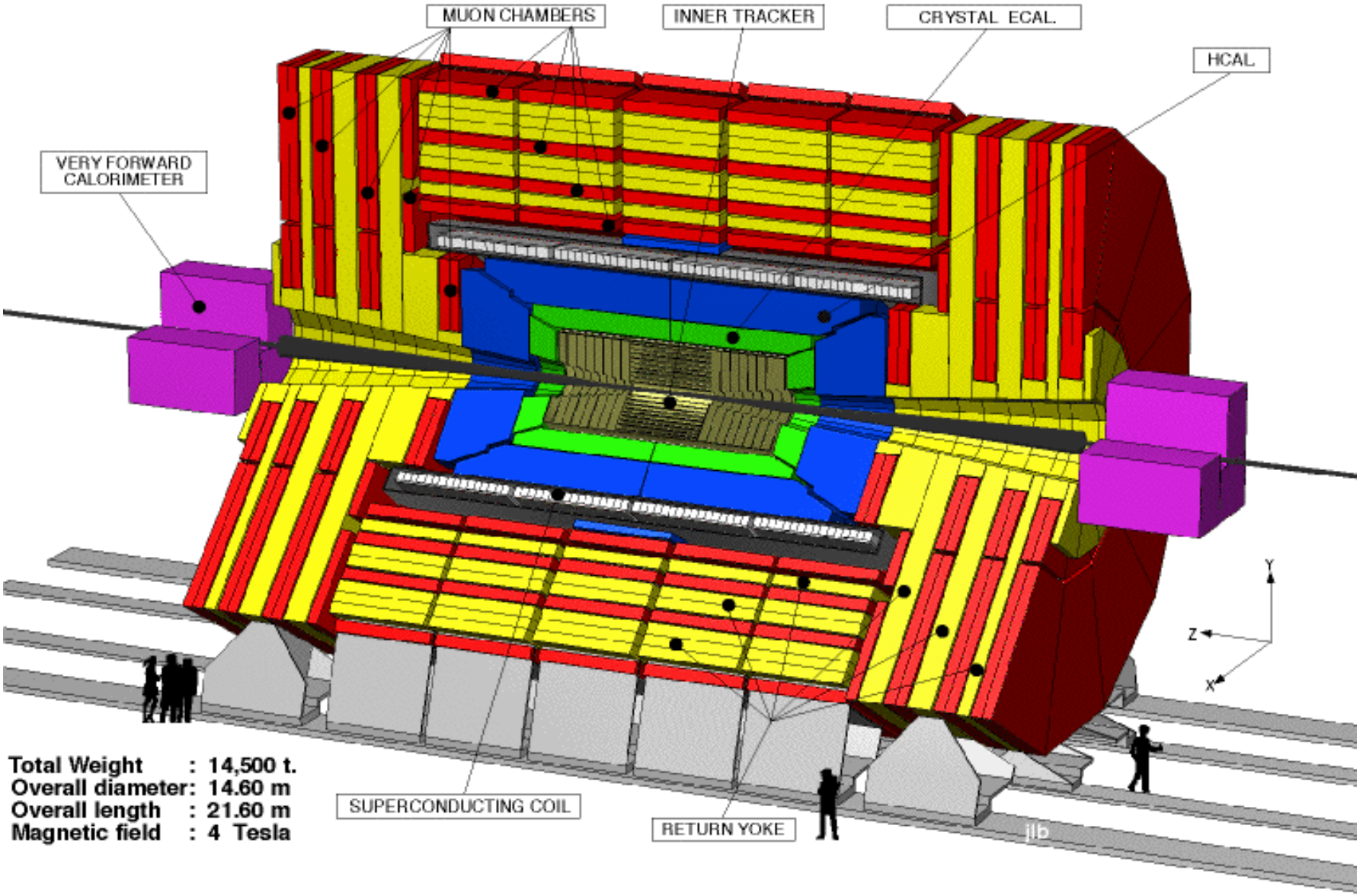
Objectives of W/Z Physics @ CMS

- First observable (measurable) EWK processes @ the LHC
- Well understood → Benchmark for detector performance
  - lepton reconstruction and identification
  - calibration point for detector/analysis techniques
- Precision tests of perturbative QCD and PDFs
- W and Z as a luminometer



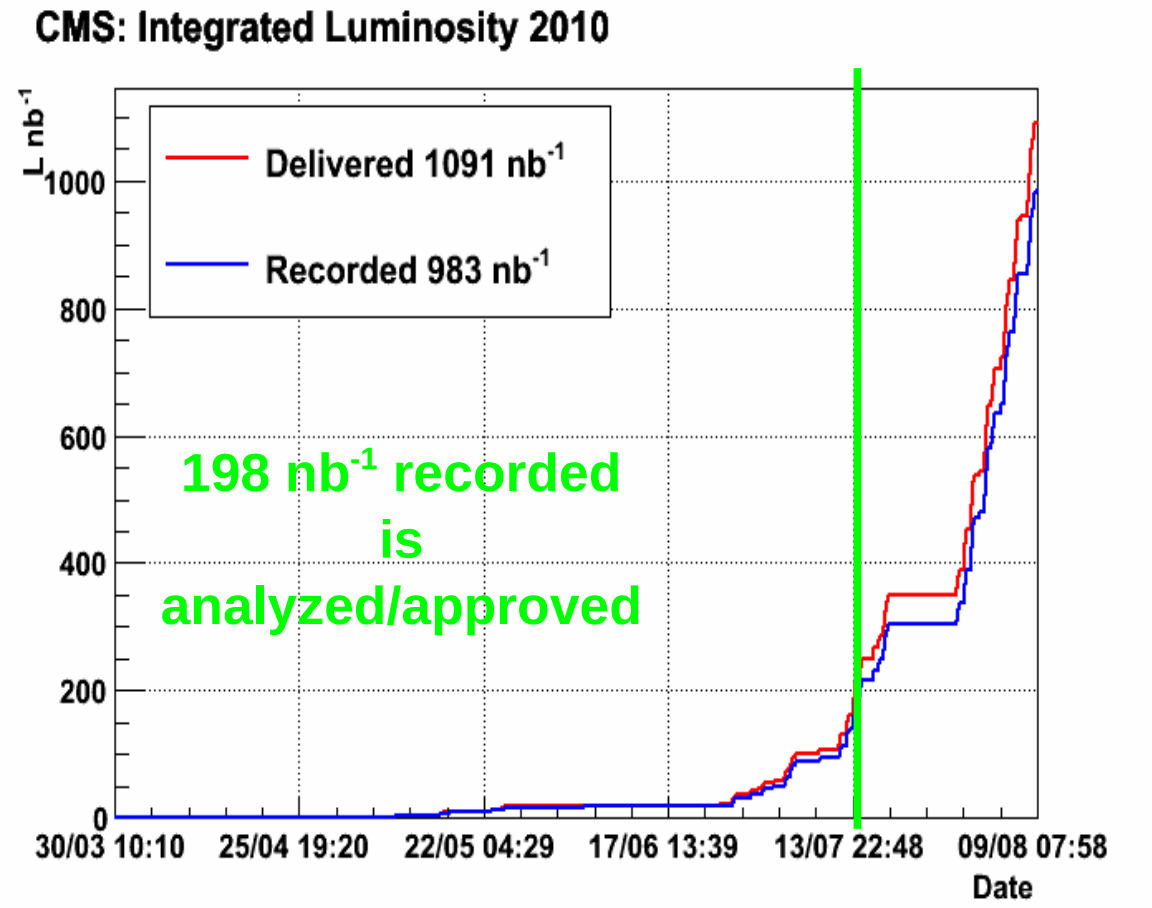
W and Z production are standard candle processes

The Compact Muon Solenoid

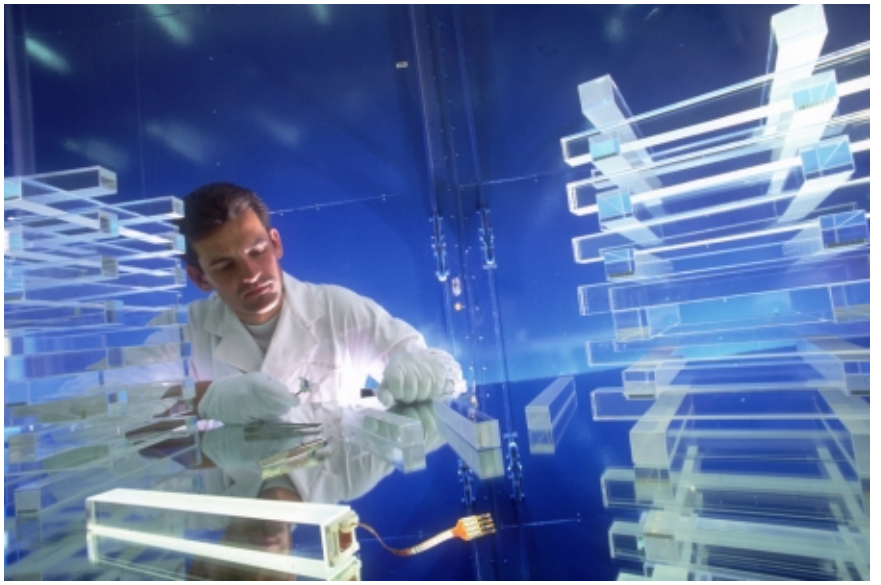


Samples – Data and Monte-Carlo

- √s = 7 TeV pp collision DATA: 198 nb^{-1} recorded, collected 3/30/10 – 7/15/10
- Monte-Carlo:
  - EWK processes – POWHEG (NLO)
  - QCD and ttbar – PYTHIA (LO)



Electron ID and Selection



Dedicated Trigger (P_T > 15 GeV)

+

$PbWO_4$ ECAL clusters of energy deposition

P_T > 20 GeV

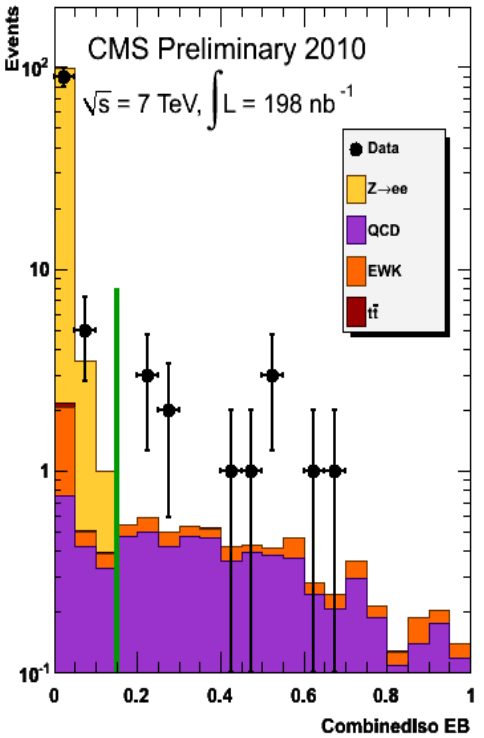
$|\eta|$ < 1.4442 (barrel) OR $|\eta|$ > 1.566 (endcap)

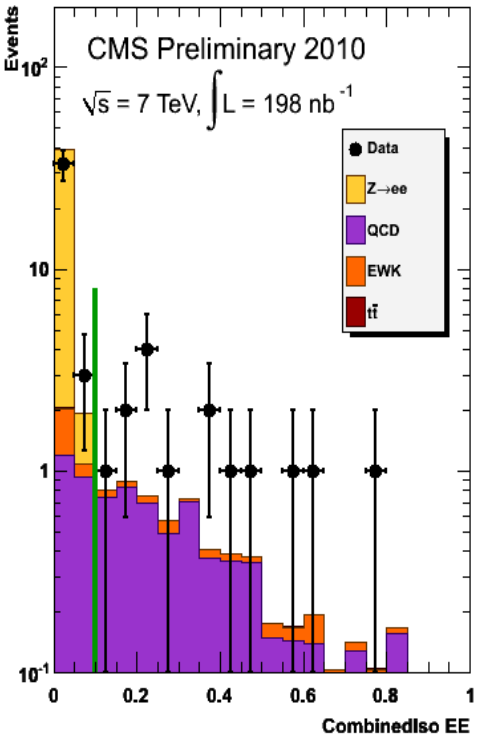
+

Track Matching
(deal w/ bremm and reduce backgrounds)

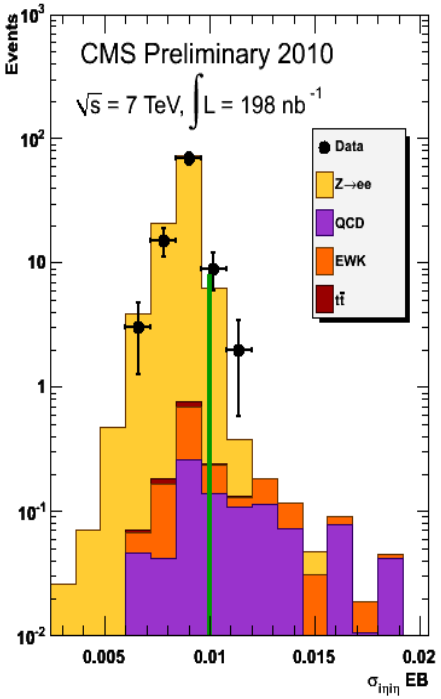
+

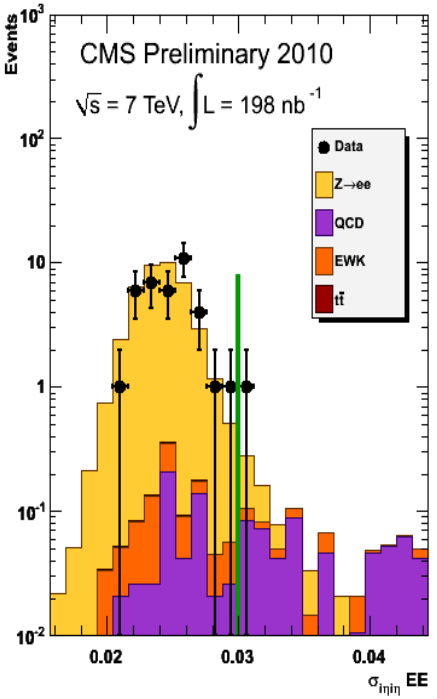
Shower profile cuts
(H/E, $\sigma_{i\eta i\eta}$, $\Delta\eta$)
AND Isolation cuts
(Track+Ecal+Hcal)

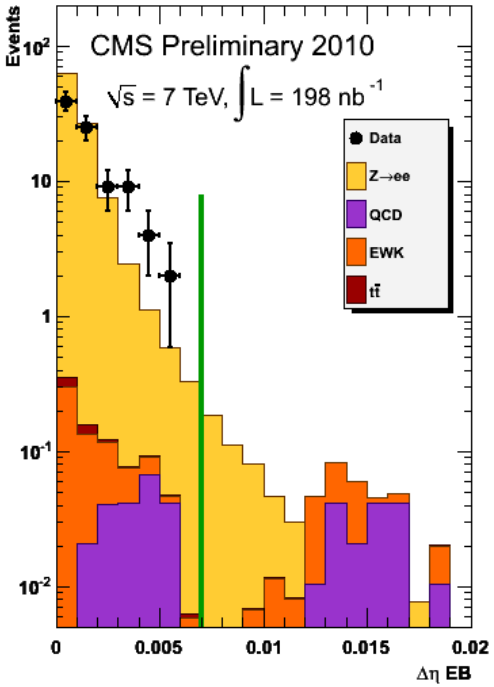


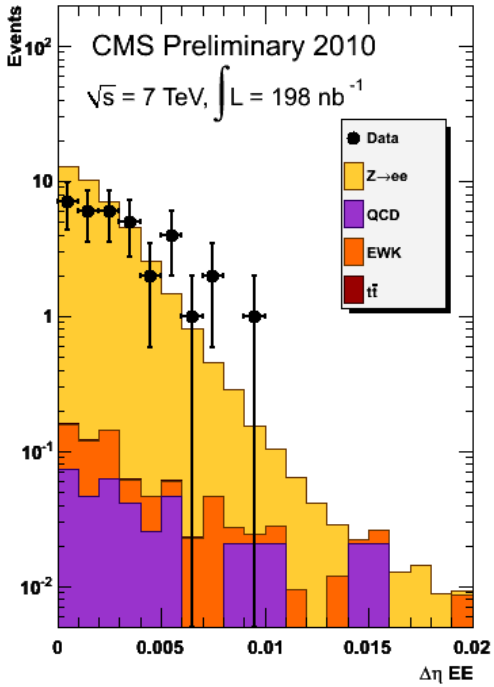


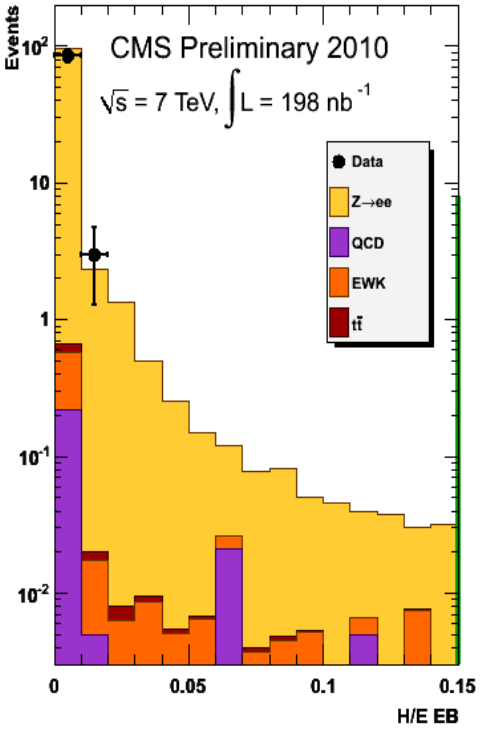
Electron ID and Selection

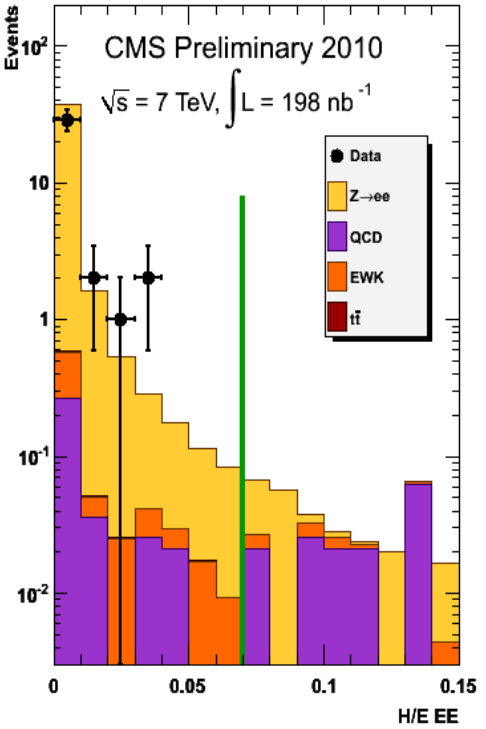




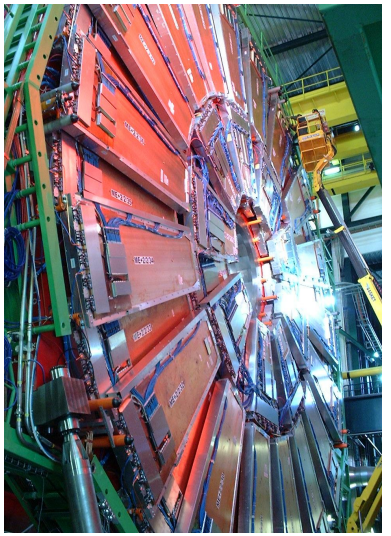








Muon ID and Selection



Dedicated Trigger (P_T > 9 GeV)

+

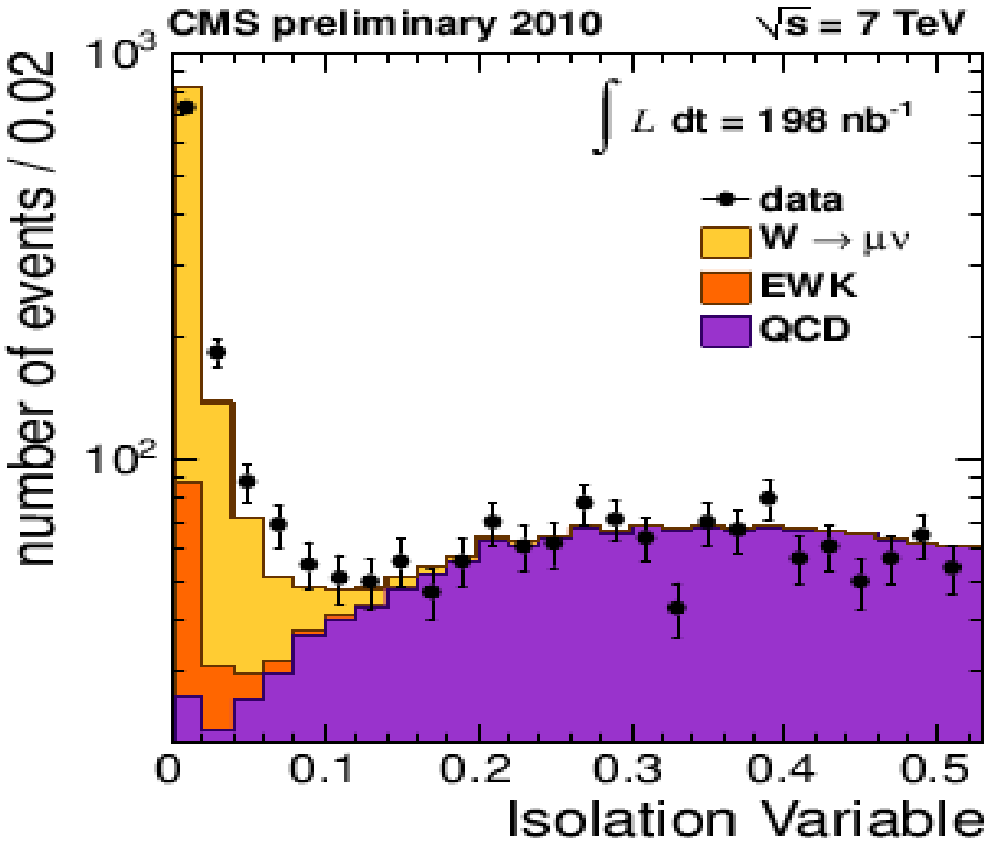
Muon Chamber AND Track based
P_T > 20 GeV
$|\eta|$ < 2.1 (2.4 for one leg of the Z)

+

N_{HITS} , $N_{CHAMBERS}$, χ^2/DOF< 10

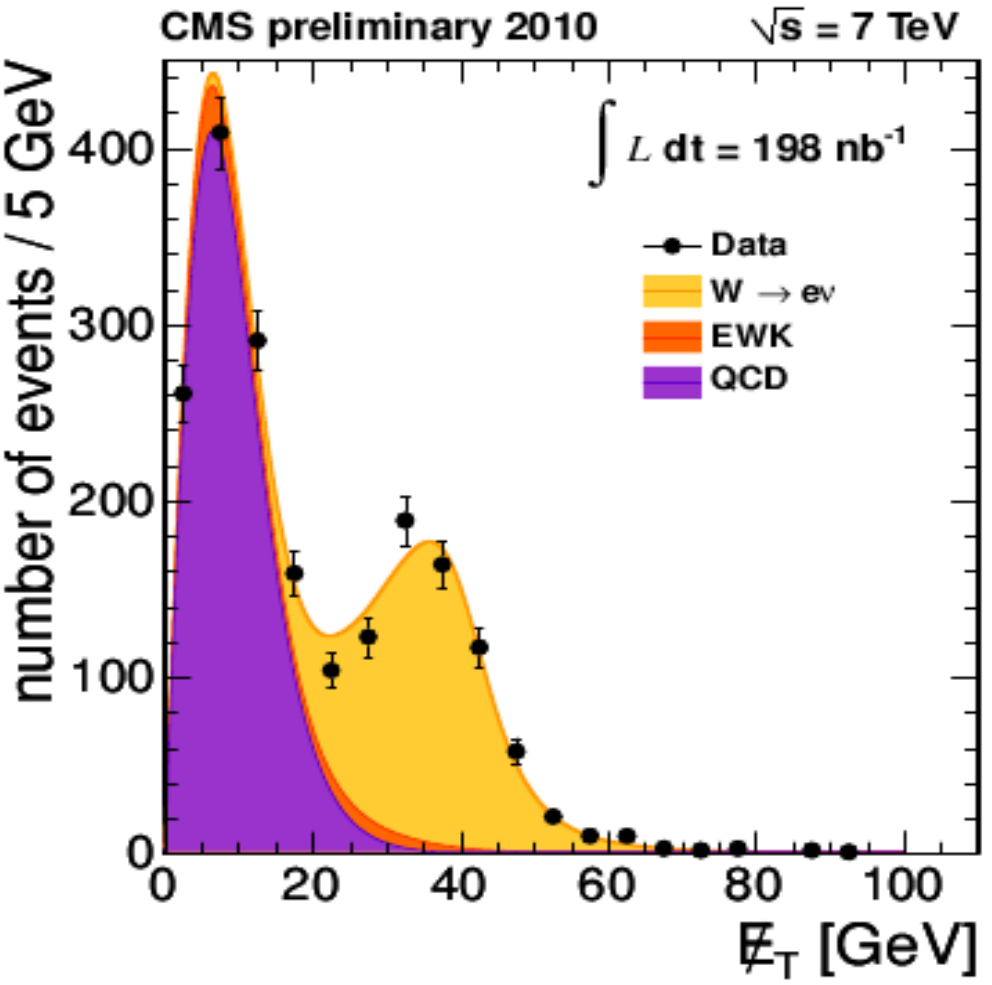
+

Isolation cut
(Track+Ecal+Hcal)



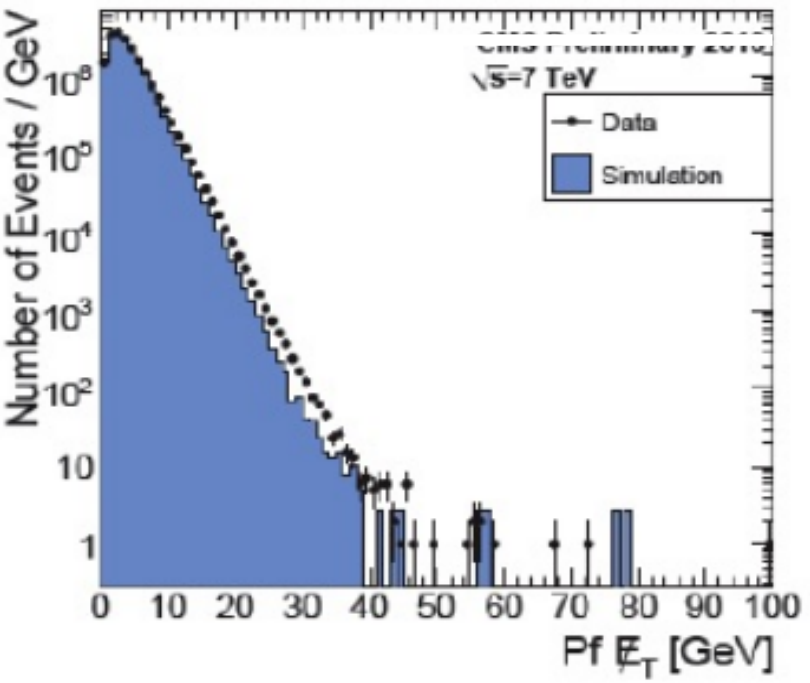
MET

MET is reconstructed using a particle flow algorithm combining calo energy and tracks to get maximal resolution

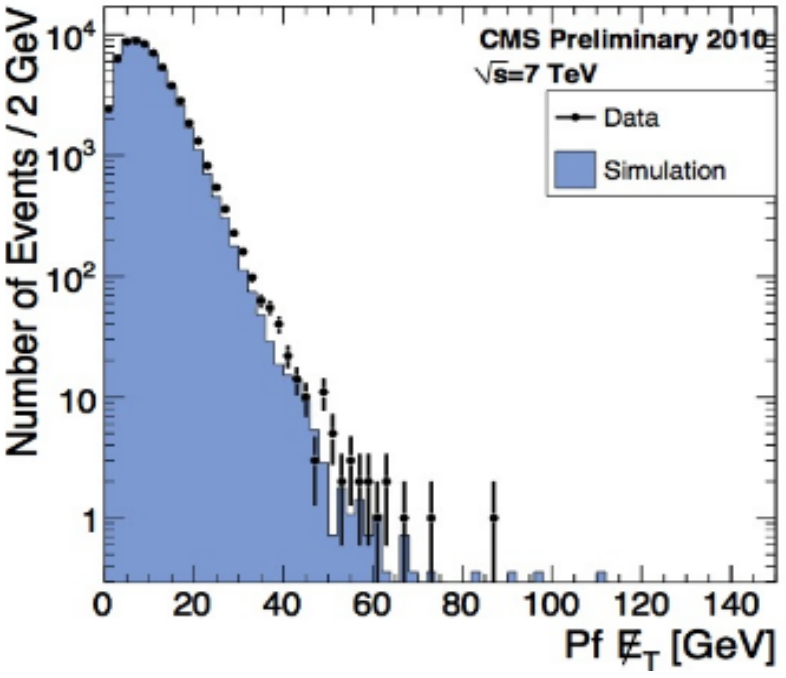


MET

Minimum Bias

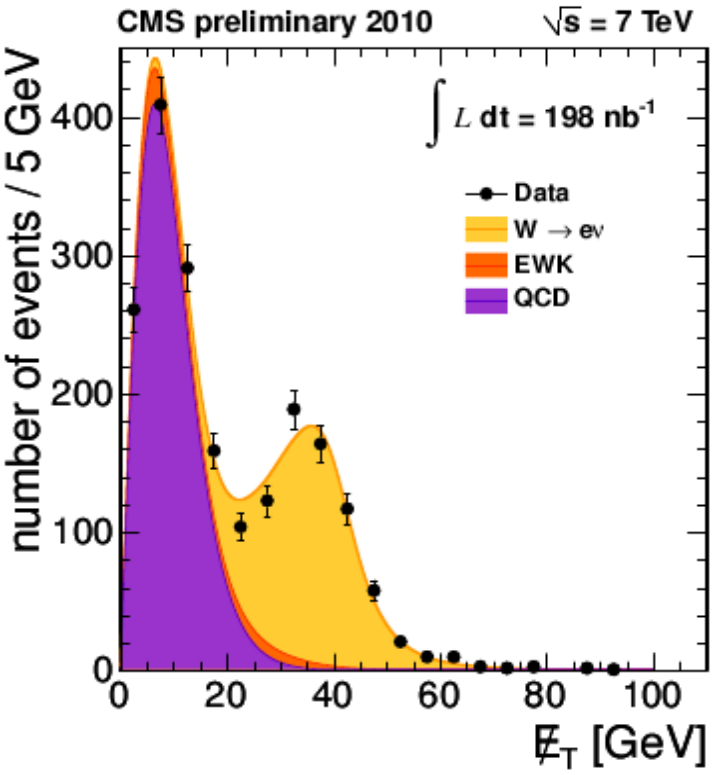


Dijets: P_T > 25 GeV, $|\eta|$ < 3



W Signal Extraction

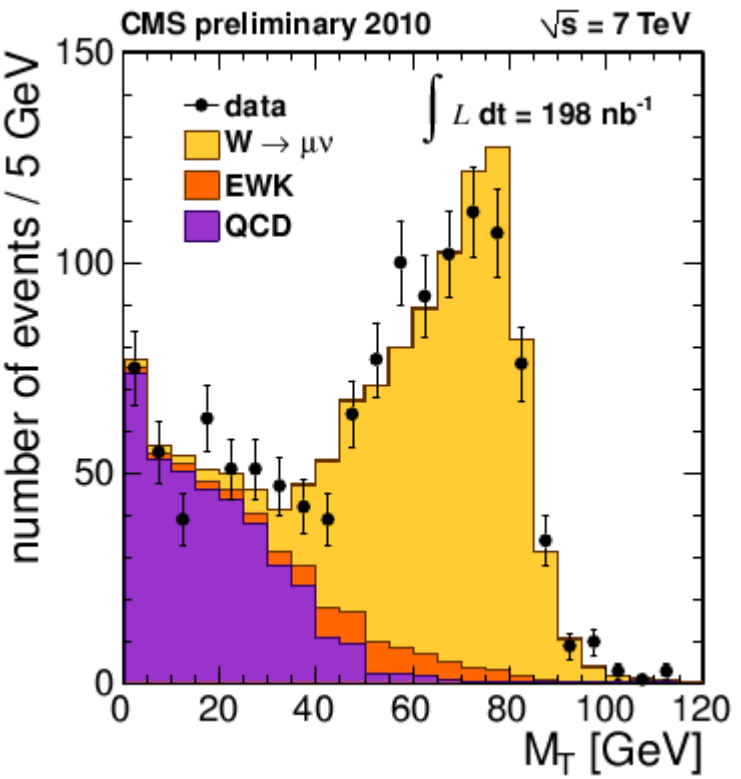
Electron



Yield from simultaneous fit of S+B to data MET distro

N = 818 ± 27

Muon

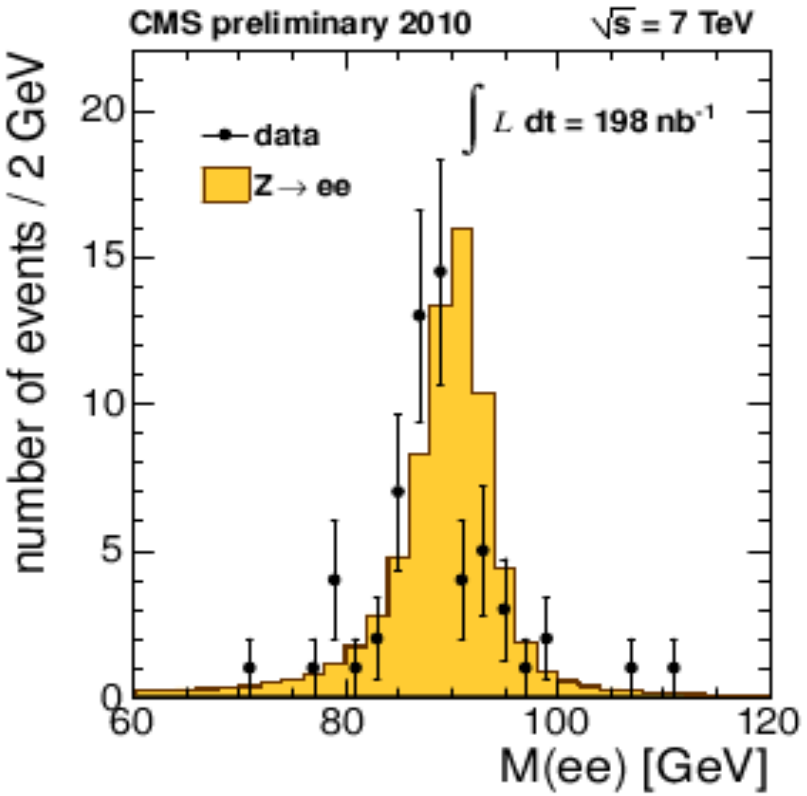


Yield from simultaneous fit of S+B to data M_T distro

N = 800 ± 31

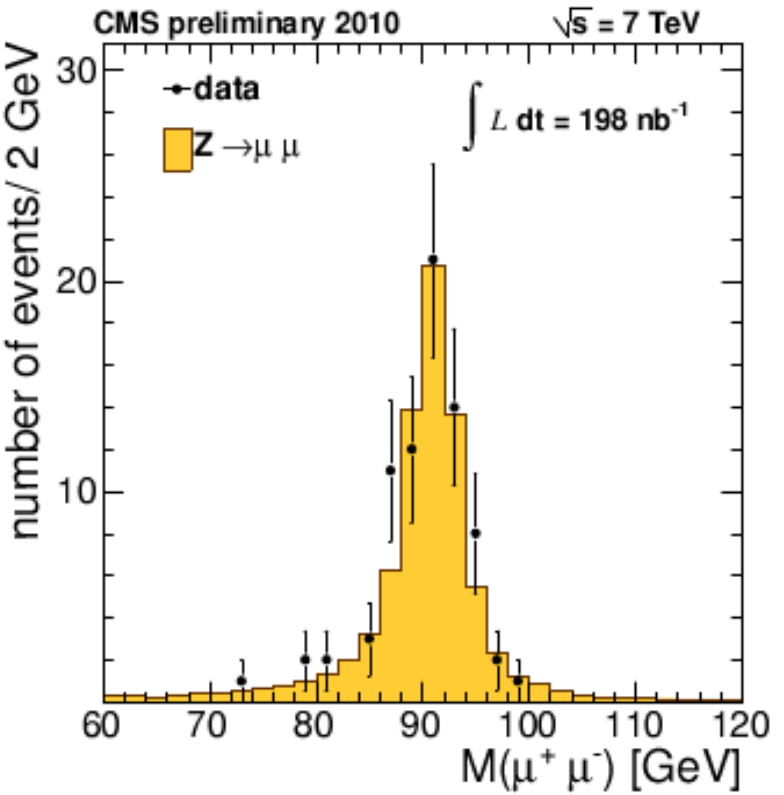
Z Signal Extraction

Electron



Yield from counting
N = 61

Muon



Yield from counting
N = 77

$60 < M_{ee} < 120$ GeV

Electron Channel Systematics

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

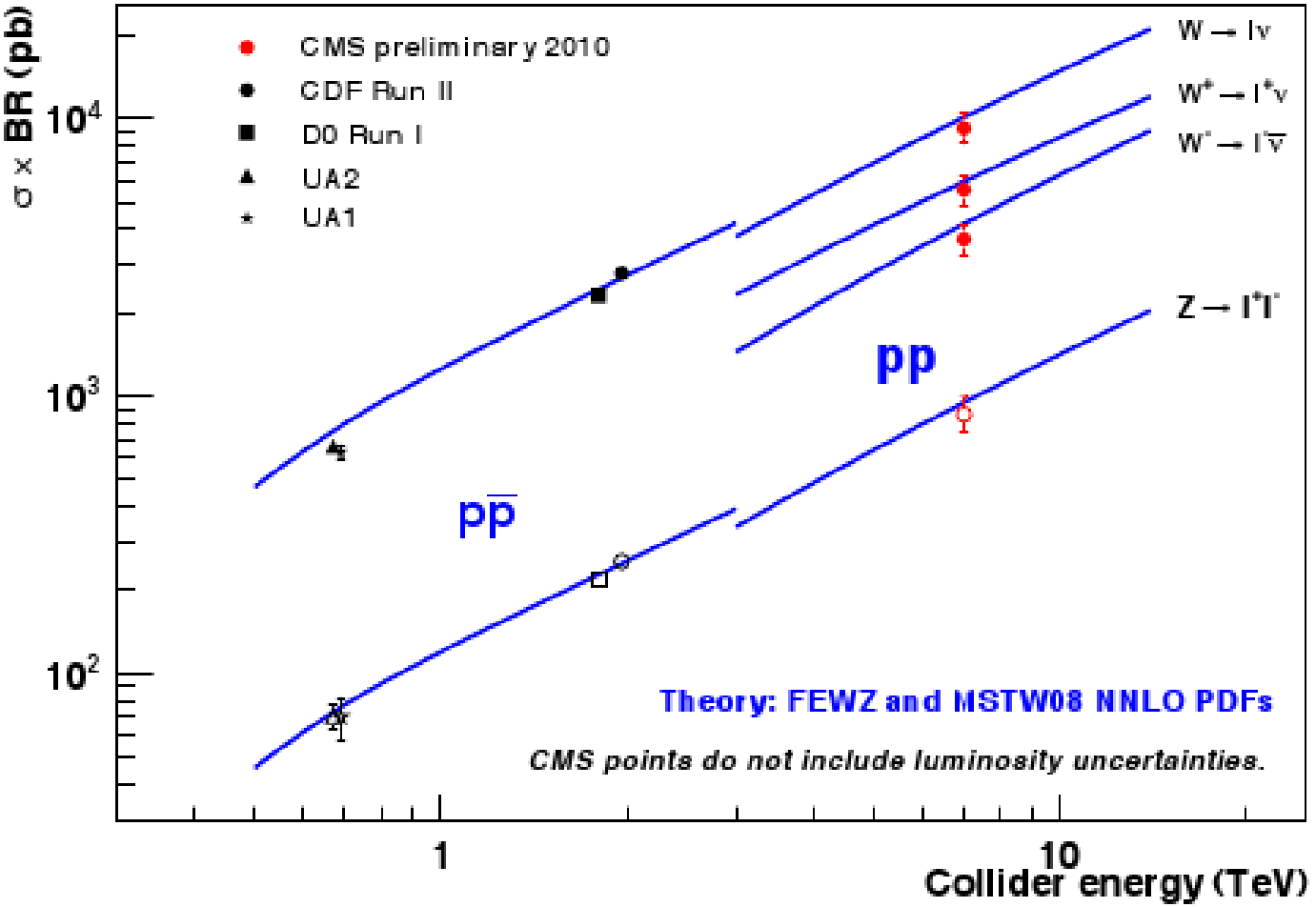
Lumi systematic dominates

Muon Channel Systematics

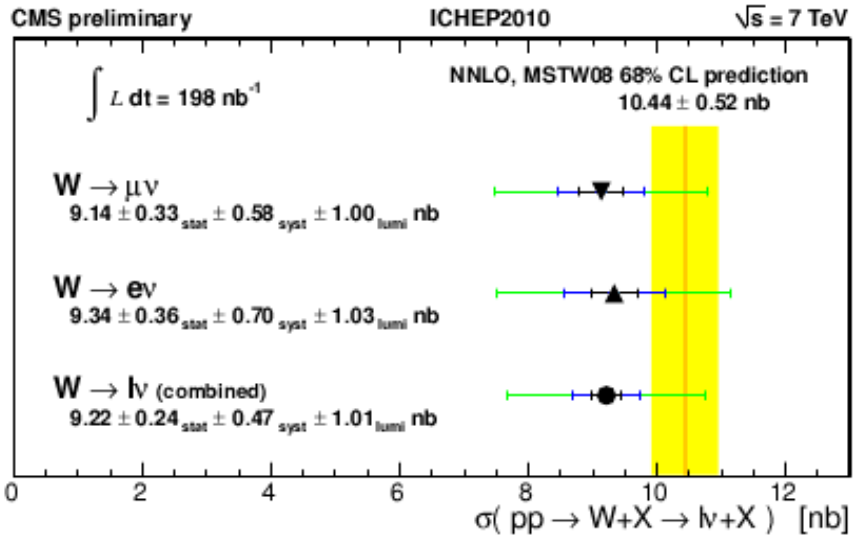
Source	W channel (%)	Z channel (%)
Muon reconstruction/identification	3.0	2.5
Trigger efficiency	3.2	0.7
Isolation efficiency	0.5	1.0
Muon momentum scale/resolution	1.0	0.5
$\not\!\!E_T$ scale/resolution	1.0	-
Background subtraction	3.5	-
PDF uncertainty in acceptance	2.0	2.0
Other theoretical uncertainties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

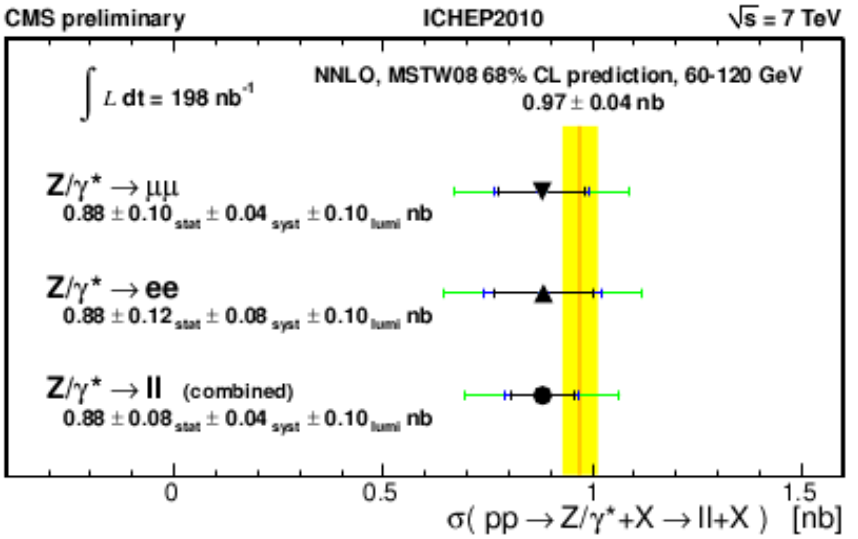
Lumi systematic dominates

Cross-Section Results

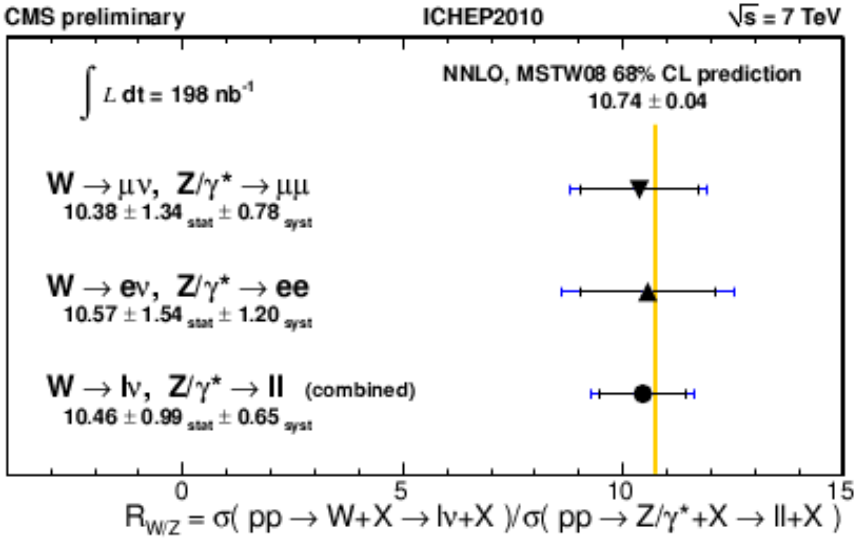


Cross-Section Results



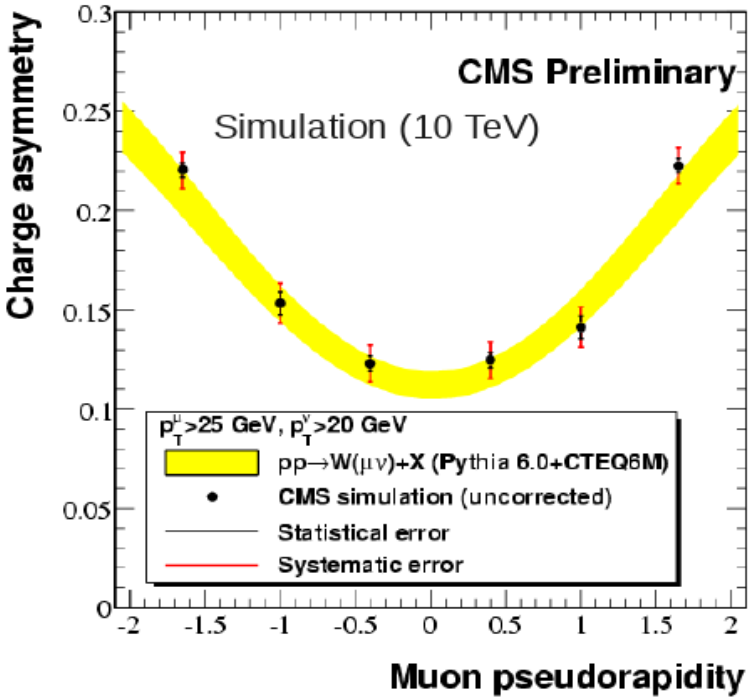


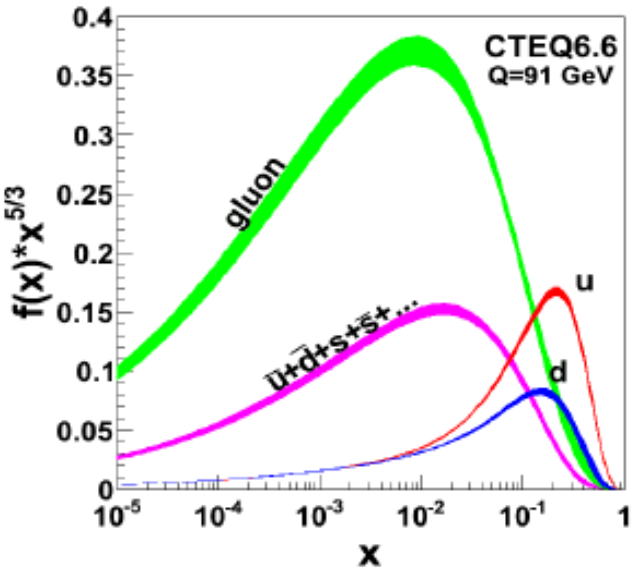
All results agree with the Standard Model predictions

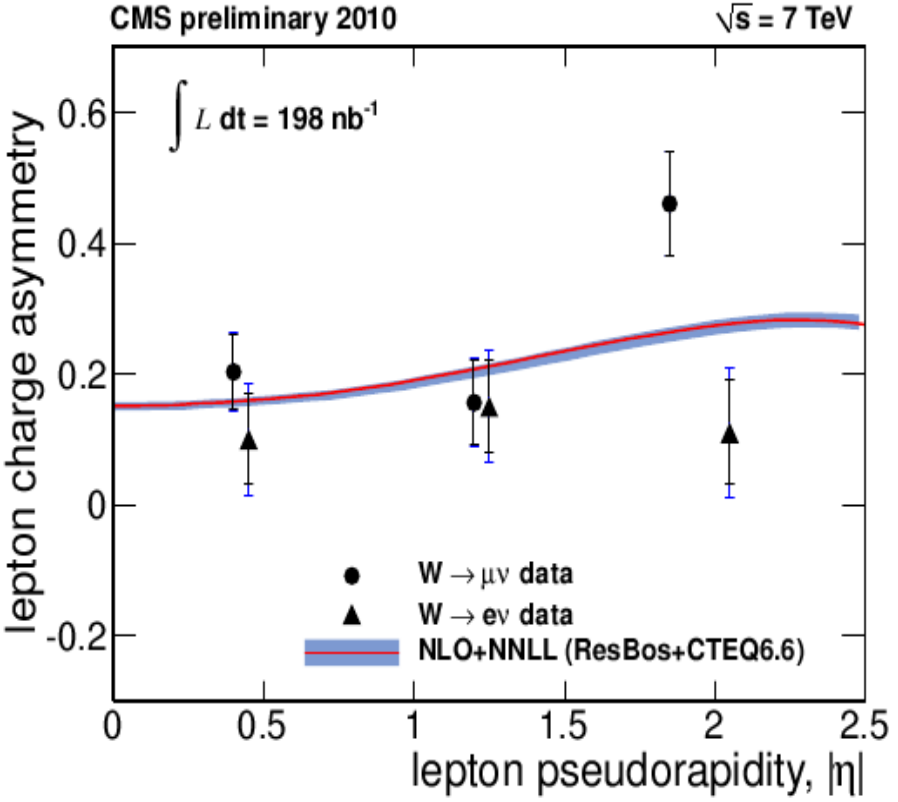


W lepton charge asymmetry, W+jets, and luminosity

W lepton charge asymmetry



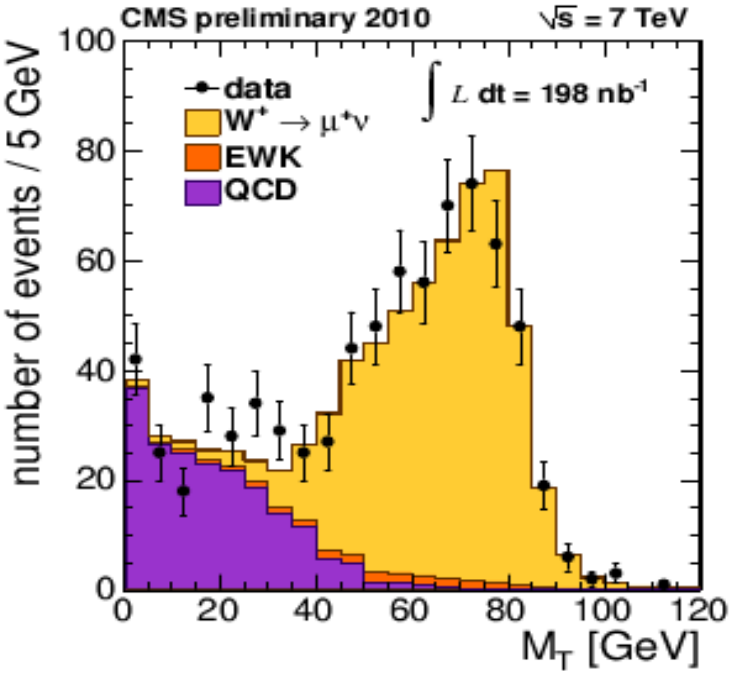




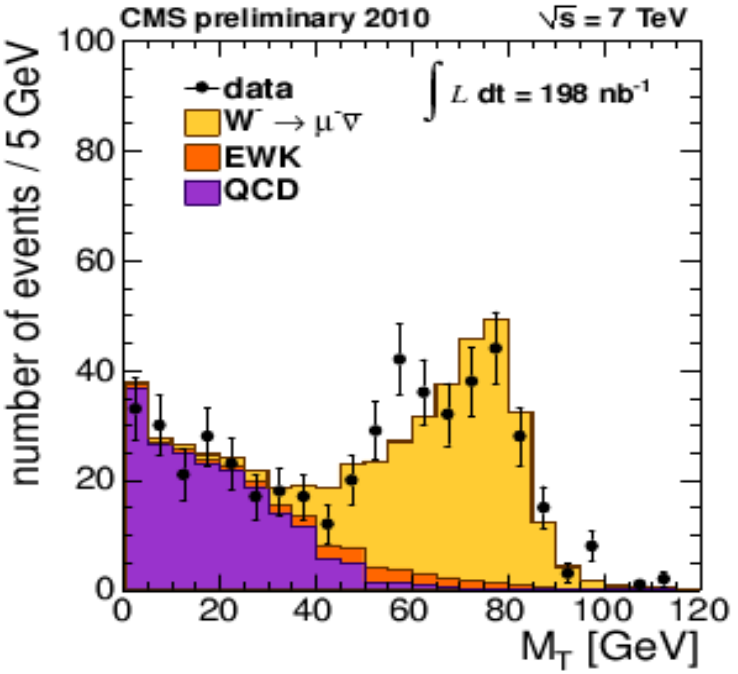
$$A(\eta) = \frac{d\sigma^{(+)}/d\eta_\ell - d\sigma^{(-)}/d\eta_\ell}{d\sigma^{(+)}/d\eta_\ell + d\sigma^{(-)}/d\eta_\ell},$$

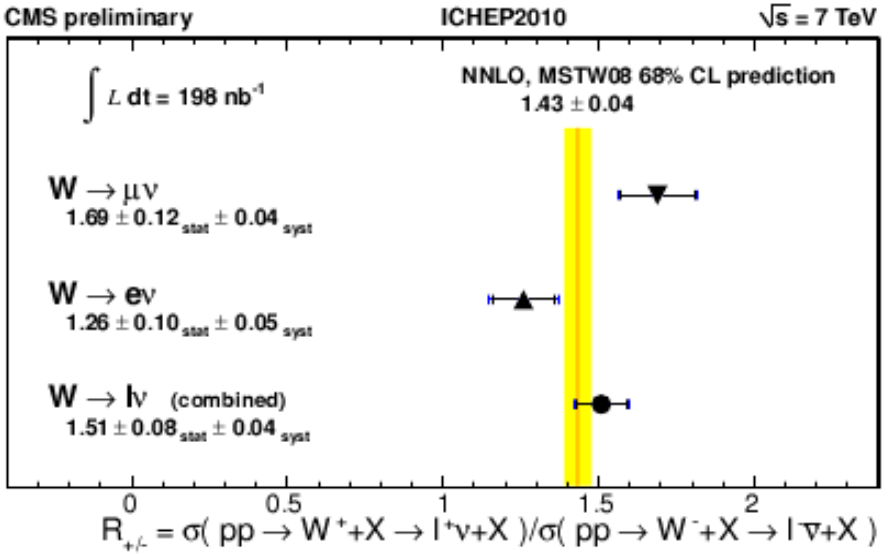
W lepton charge asymmetry

$W^+ \to \mu\nu$



$W^- \to \mu\nu$



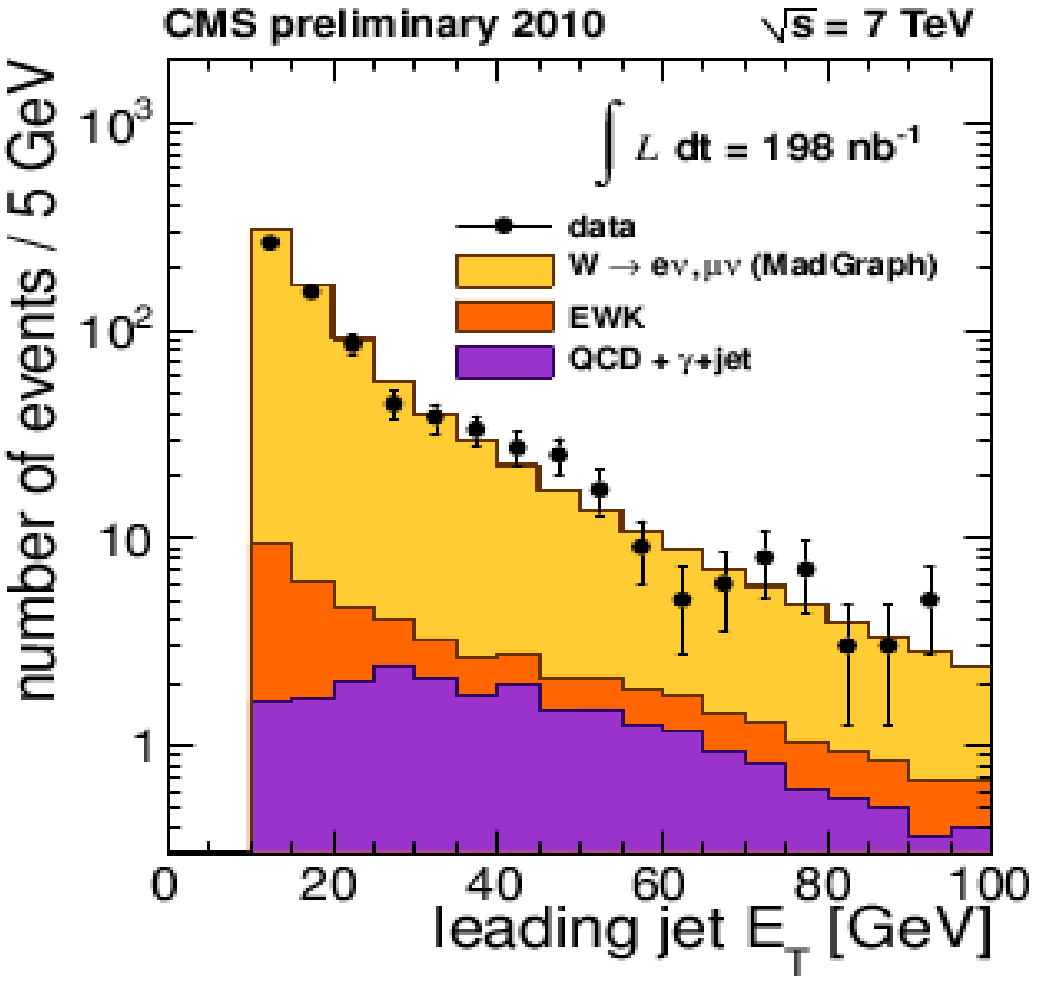


W+jets

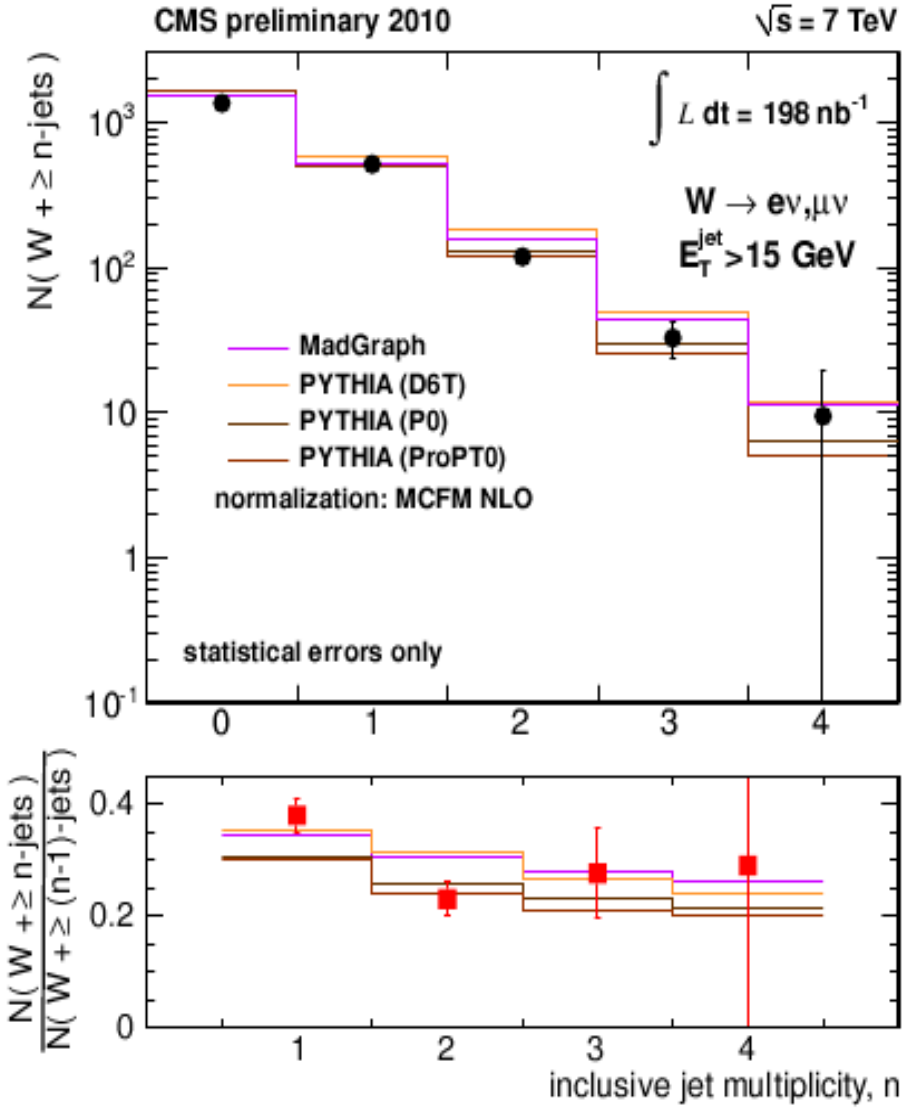
W+jets is a large background for many searches

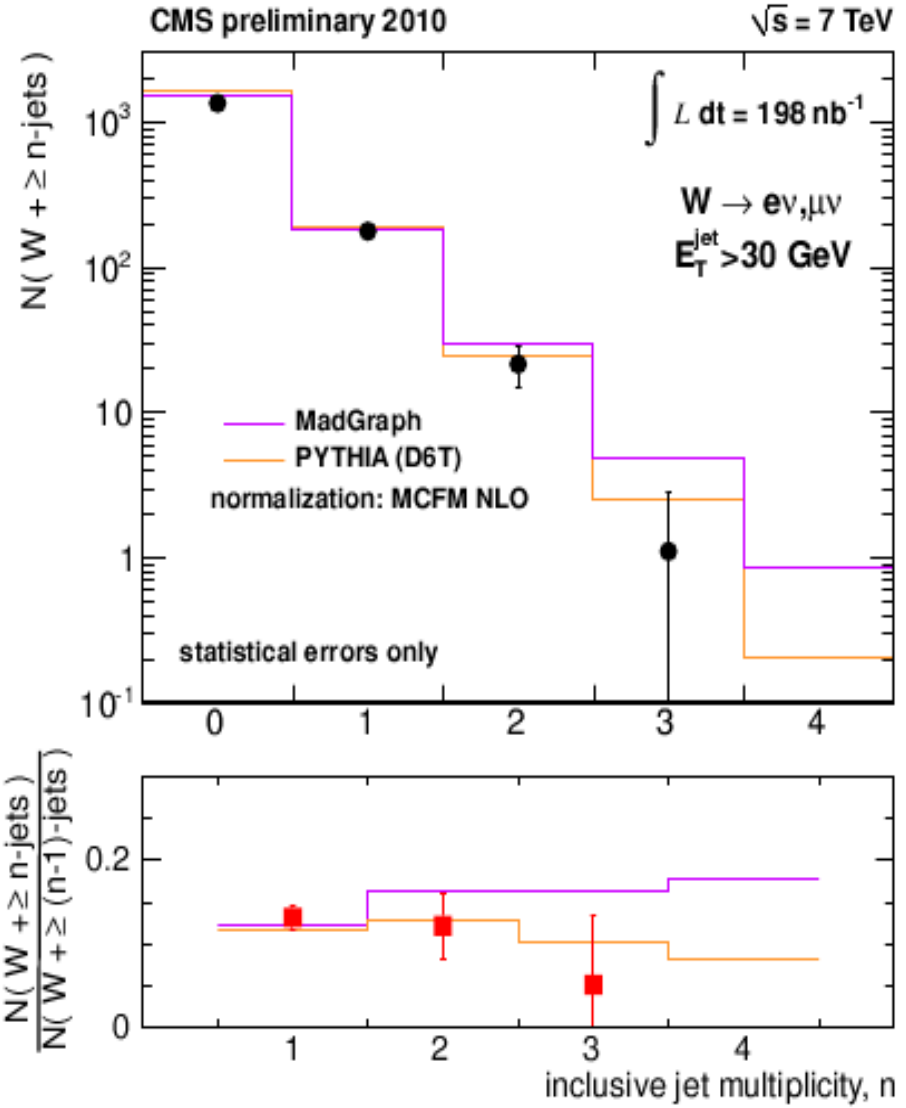
Same W selections as before, but now require $M_T > 50$ GeV and ≥ 1 jet having $P_T > 10$ GeV

Infrared safe Anti-kt Jet clustering with $\Delta R = 0.5$



W+jets


CMS preliminary 2010
√s = 7 TeV
∫ L dt = 198 nb⁻¹
W → eν,μν
E_T^jet >15 GeV
MadGraph
PYTHIA (D6T)
PYTHIA (P0)
PYTHIA (ProPT0)
normalization: MCFM NLO
statistical errors only
N(W + ≥ n-jets)
N(W + ≥ n-jets) / N(W + ≥ (n-1)-jets)
inclusive jet multiplicity, n


CMS preliminary 2010
√s = 7 TeV
∫ L dt = 198 nb⁻¹
W → eν,μν
E_T^jet >30 GeV
MadGraph
PYTHIA (D6T)
normalization: MCFM NLO
statistical errors only
N(W + ≥ n-jets)
N(W + ≥ n-jets) / N(W + ≥ (n-1)-jets)
inclusive jet multiplicity, n

W and Z bosons as a luminometer

$$N^{\mathrm{obs}}_{Z/\gamma^*} = \sigma^{\mathrm{tot}}\,\mathrm{B}R(Z/\gamma^* \to \ell^+\ell^-)A_{Z/\gamma^*}\int \mathcal{L}dt.$$

A – theoretical and experimental acceptance after all selection criteria (~3% (theory) + experimental systematic)

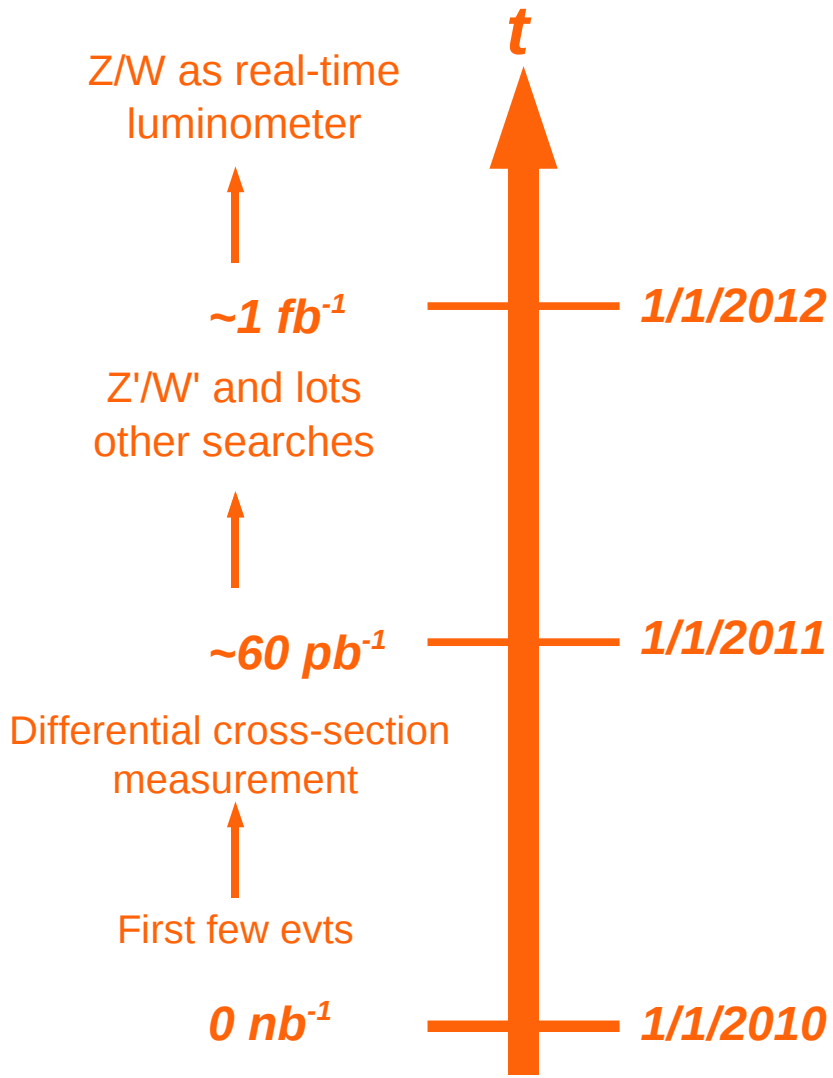
σ×BR – cross-section × branching ratio – known theoretically (~4% systematic)

Absolute Calibrator: **At $\int\mathscr{L}$dt = 1 pb^{-1} expect 400 (4000) Z (W) bosons per lepton channel**

Real-Time Monitor: **At $\mathscr{L}$ = 10^{33} cm^{-2}s^{-1} expect 10 (100) Z (W) bosons per lepton channel every 30 seconds**

Conclusions

- Presented early W and Z cross-section measurements at CMS
  - Consistent with the Standard Model
- These EWK processes are standard candles
  - Agreement between data and Monte-Carlo
  - Testament to CMS being a beautiful detector and the collaboration being prepared to leverage it for physics analysis
- Outlook
  - Ready to make precision EWK measurements
  - EWK processes starting to be used as calibration points
  - W and Z bosons will be a luminometer

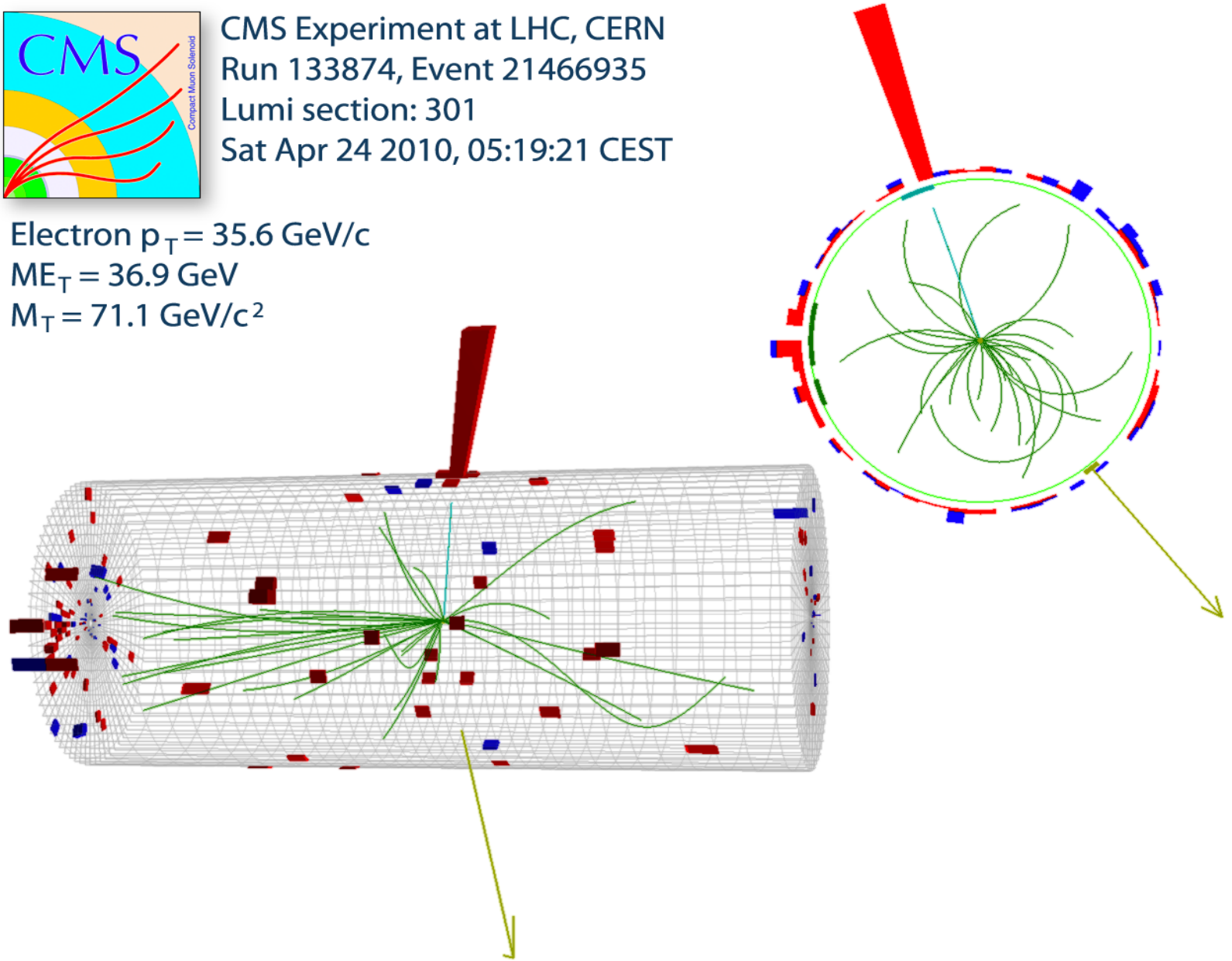


Backup – Event Displays

W→eν

CMS Experiment at LHC, CERN
Run 133874, Event 21466935
Lumi section: 301
Sat Apr 24 2010, 05:19:21 CEST

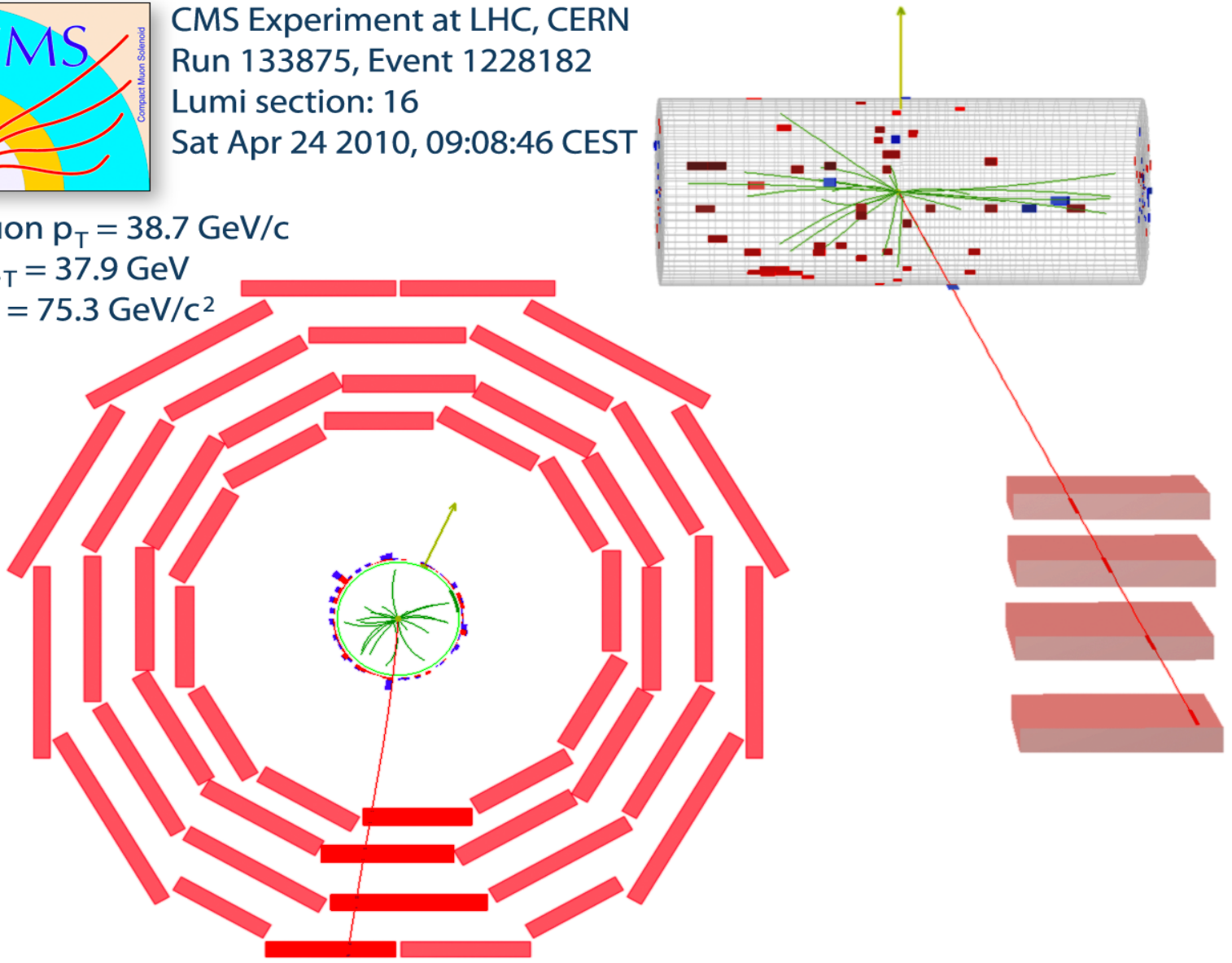
Electron $p_T = 35.6$ GeV/c
$ME_T = 36.9$ GeV
$M_T = 71.1$ GeV/c^2



W→μν

CMS Experiment at LHC, CERN
Run 133875, Event 1228182
Lumi section: 16
Sat Apr 24 2010, 09:08:46 CEST

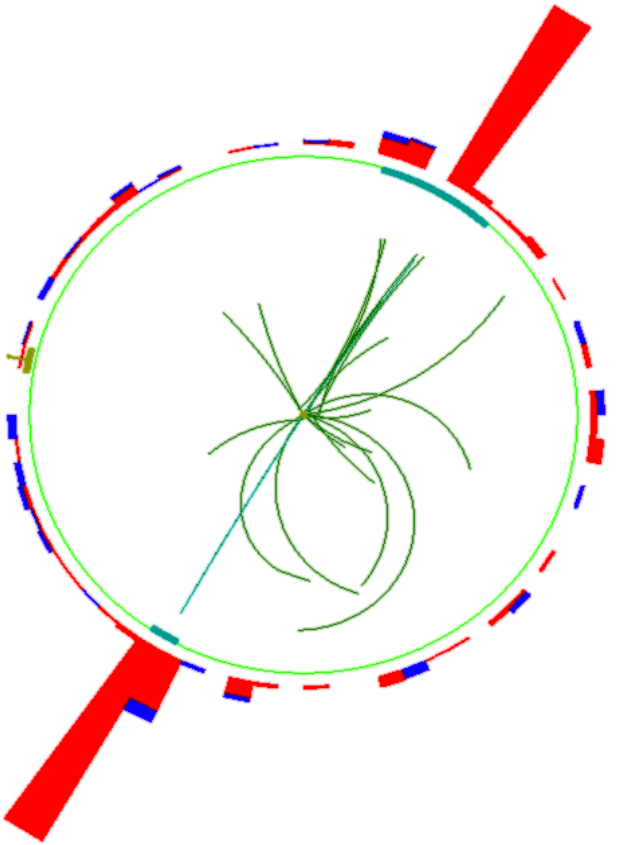
Muon $p_T = 38.7$ GeV/c
$ME_T = 37.9$ GeV
$M_T = 75.3$ GeV/c^2

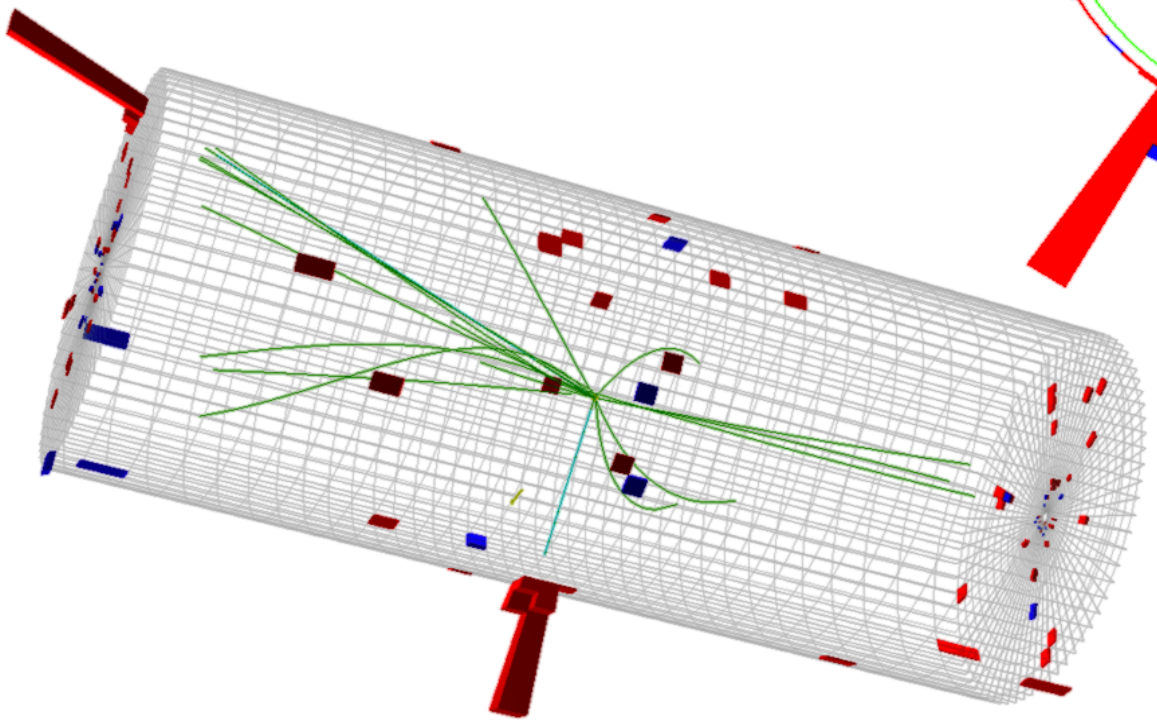


Z→ee

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/c^2





Z→μμ

CMS Experiment at LHC, CERN
Run 135149, Event 125426133
Lumi section: 1345
Sun May 09 2010, 05:24:09 CEST

Muon p_T= 67.3, 50.6 GeV/c
Inv. mass = 93.2 GeV/c^2