Lepton Charge Asymmetry in Inclusive W Production in CMS at E_{cm} = 7TeV

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on behalf of the CMS Collaboration

PDF4LHC Meeting

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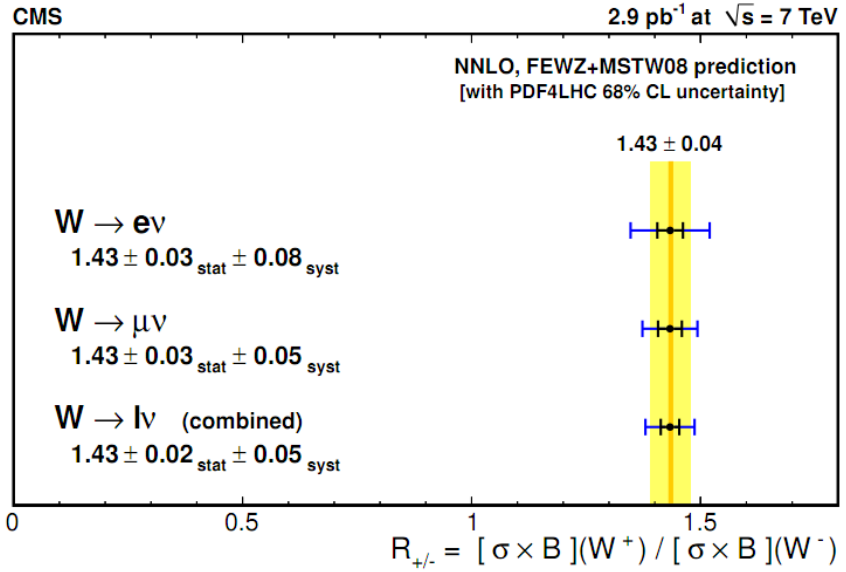
Imperial College London

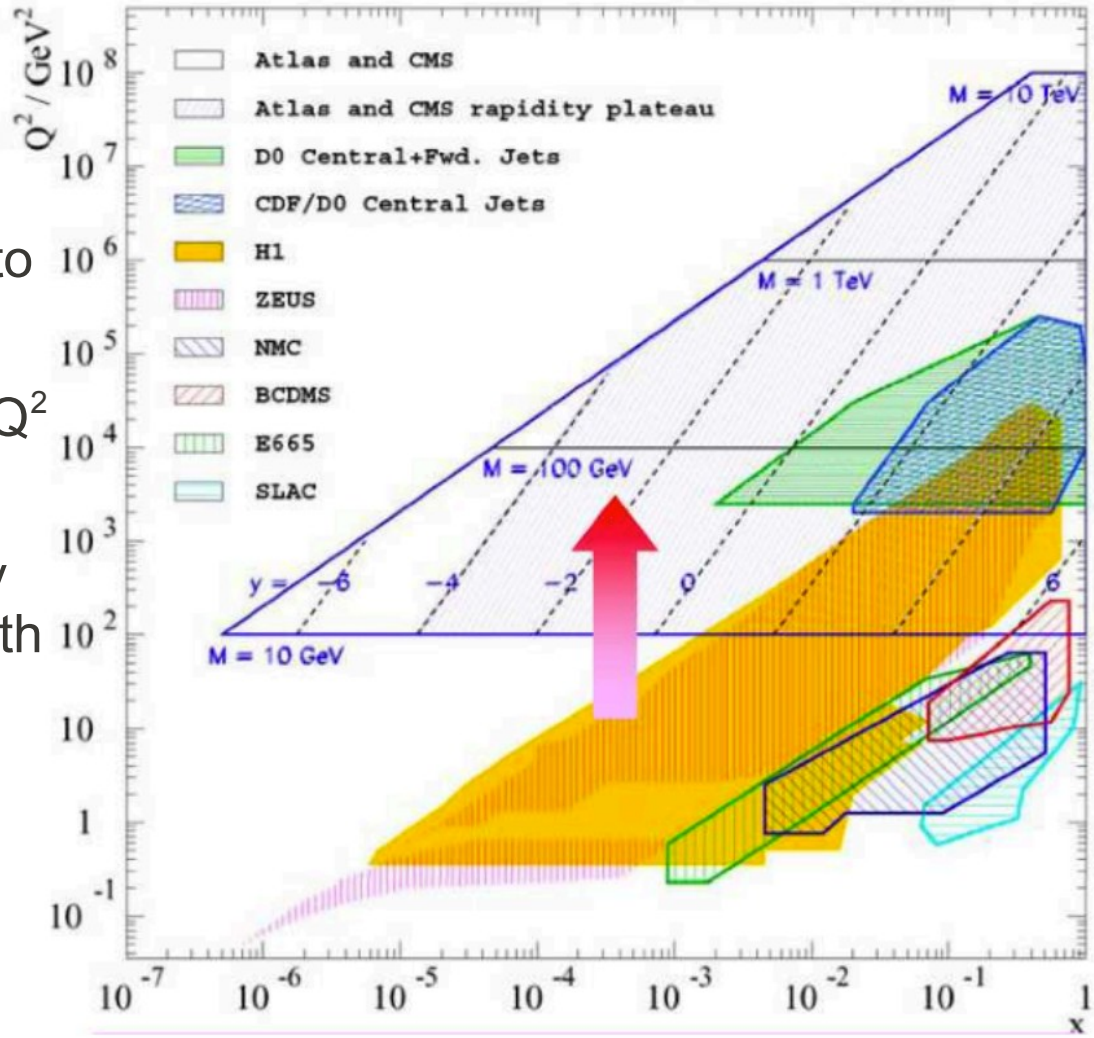
Outline

- Motivation
- LHC and CMS overview
- Electron Channel
- Muon Channel
- Systematics
- Results

Motivation

- In pp collisions, more W+ are expected than W- due to the excess of u valence quarks wrt d quarks.
- An asymmetry measurement as a function of boson rapidity can be used to constrain PDFs.
- LHC is exploring a new region in the x,Q^2 plane
- The inclusive charge ratio measured by CMS to be 1.43 ± 0.04 in agreement with MSTW PDF predictions



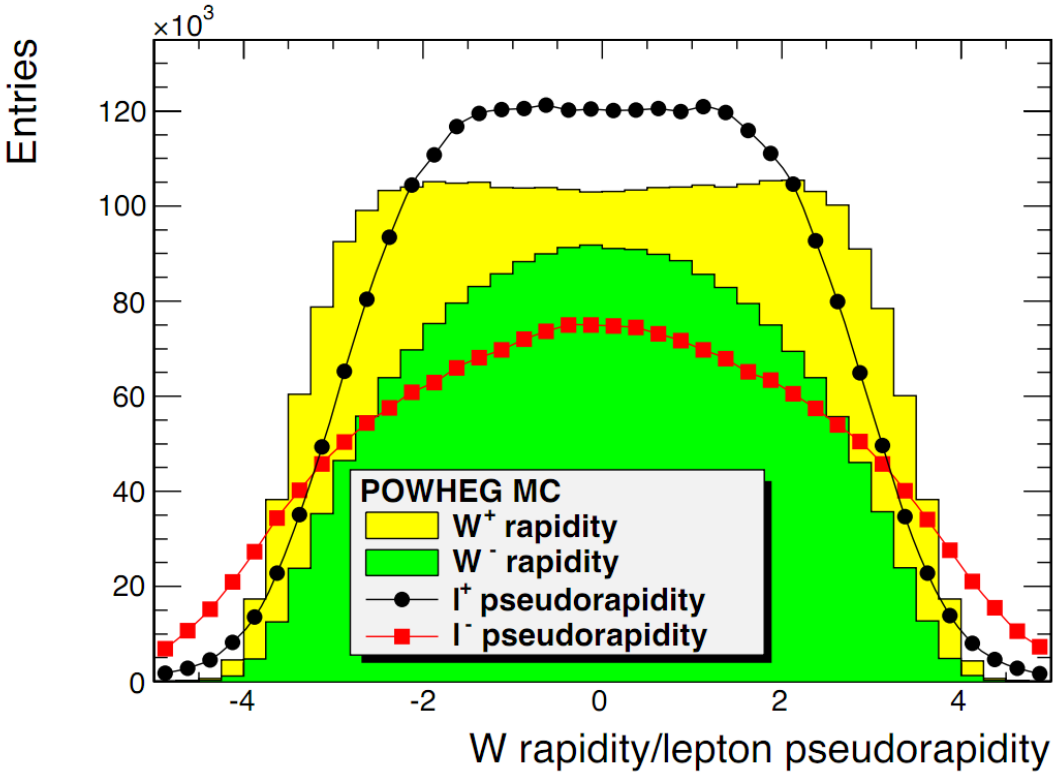


Motivation

- Boson rapidity is not directly accessible
- Direct accessible measurement is the lepton charge asymmetry

$$\mathcal{A}_{th}(\eta) = \frac{\frac{d\sigma}{d\eta}\left(W^+ \to e^+\nu_e\right) - \frac{d\sigma}{d\eta}\left(W^- \to e^-\bar{\nu}_e\right)}{\frac{d\sigma}{d\eta}\left(W^+ \to e^+\nu_e\right) + \frac{d\sigma}{d\eta}\left(W^- \to e^-\bar{\nu}_e\right)}$$

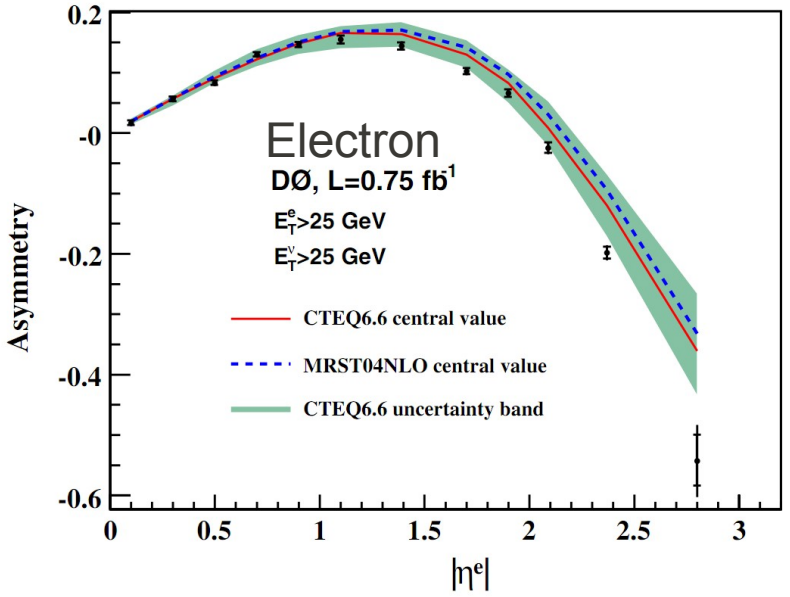
- This asymmetry is given by the combination of the W production asymmetry and the well understood parity violation asymmetry in the W decay.



Tevatron to LHC

D0 Collaboration:

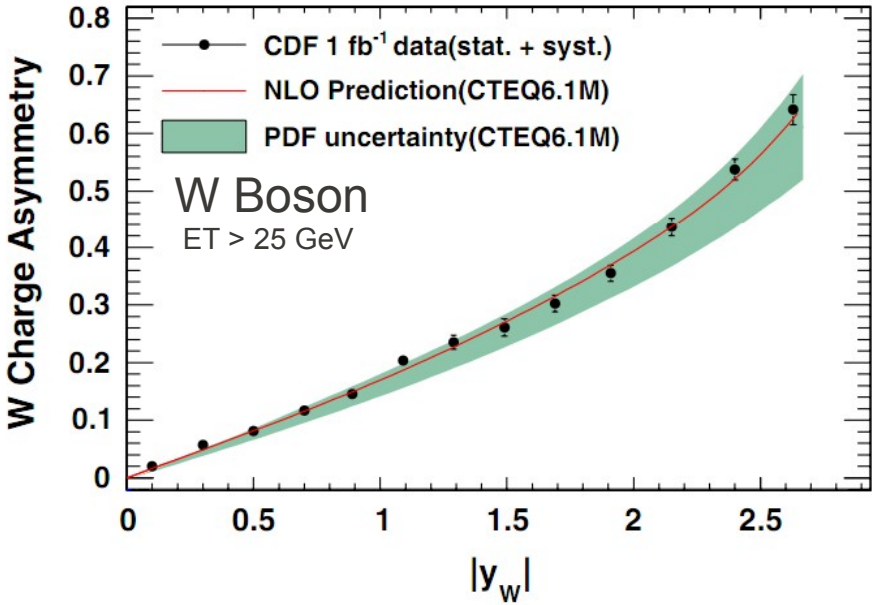
Phys. Rev. Lett. 101, 211801 (2008)

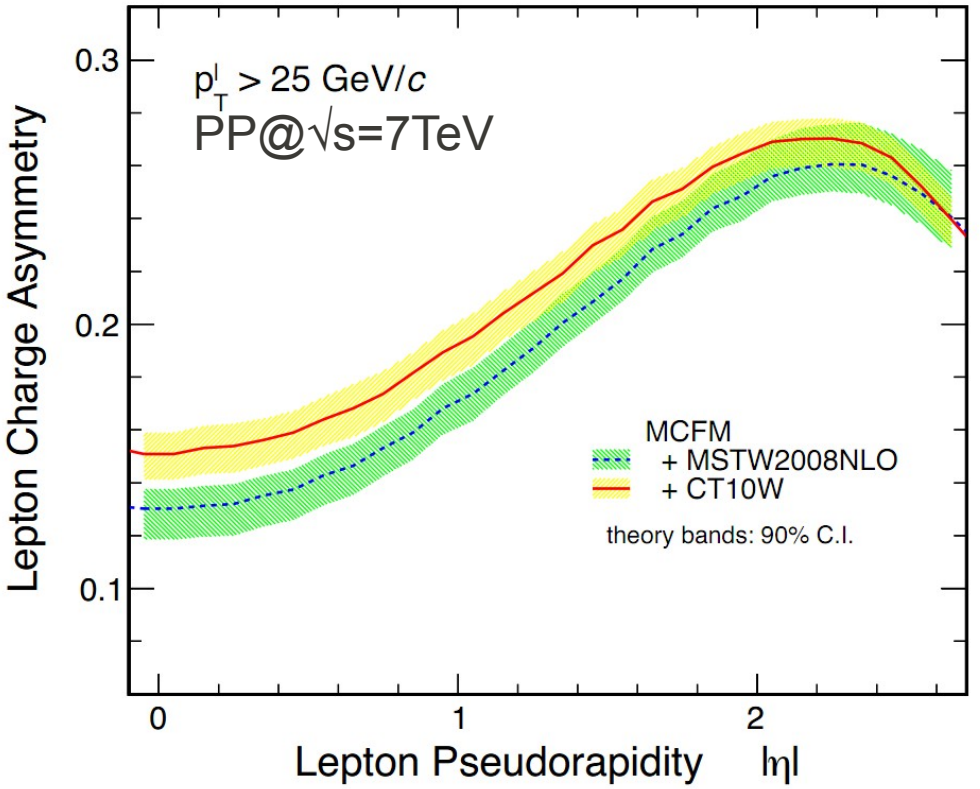


- Lepton charge asymmetry and W charge asymmetry have been studied at Tevatron
- Several authors have reported tension between the lepton charge asymmetry and PDF global fits
- Current predictions for the asymmetry at the LHC do not agree

CDF Collaboration:

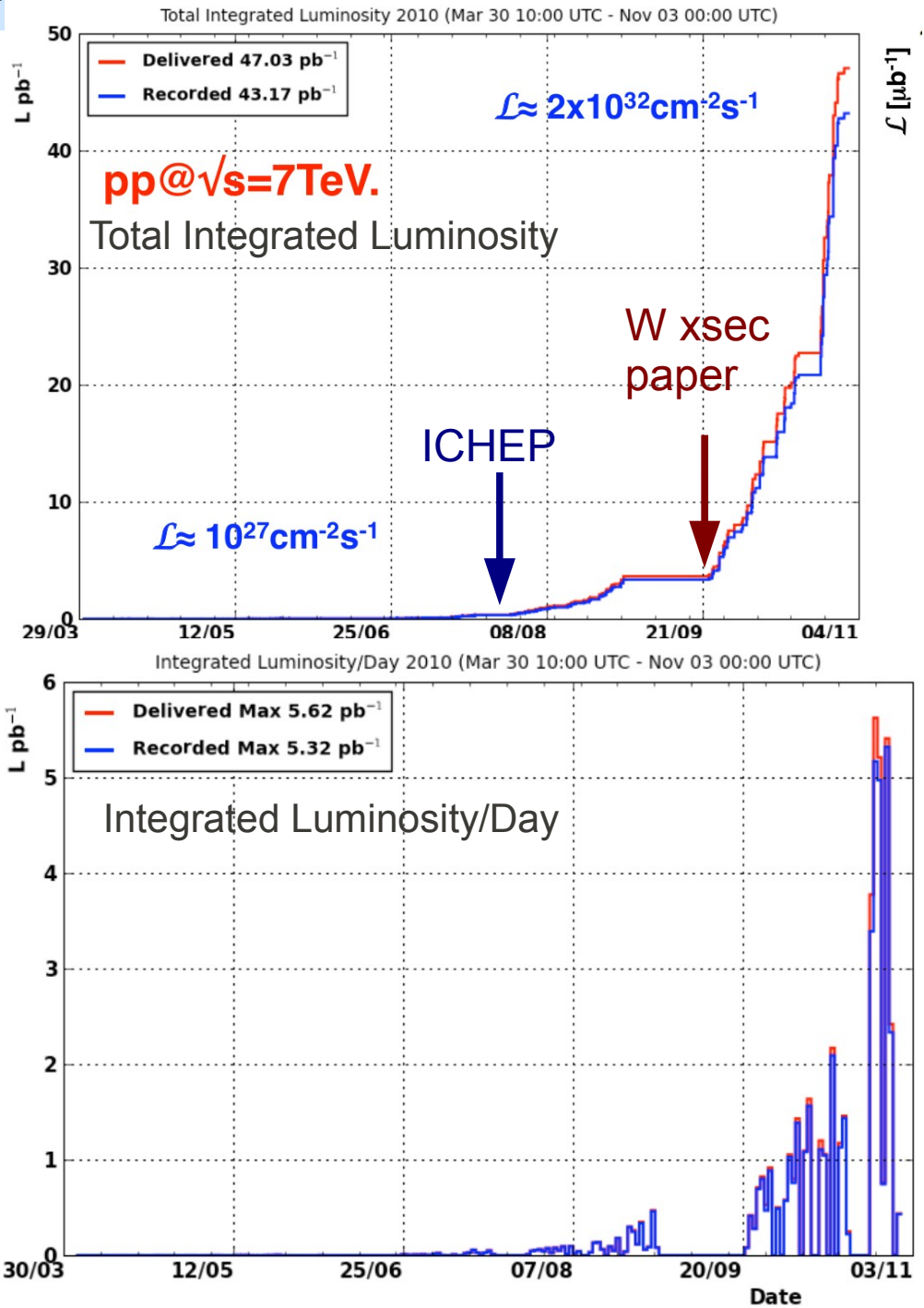
Phys. Rev. Lett. 102, 181801 (2008).



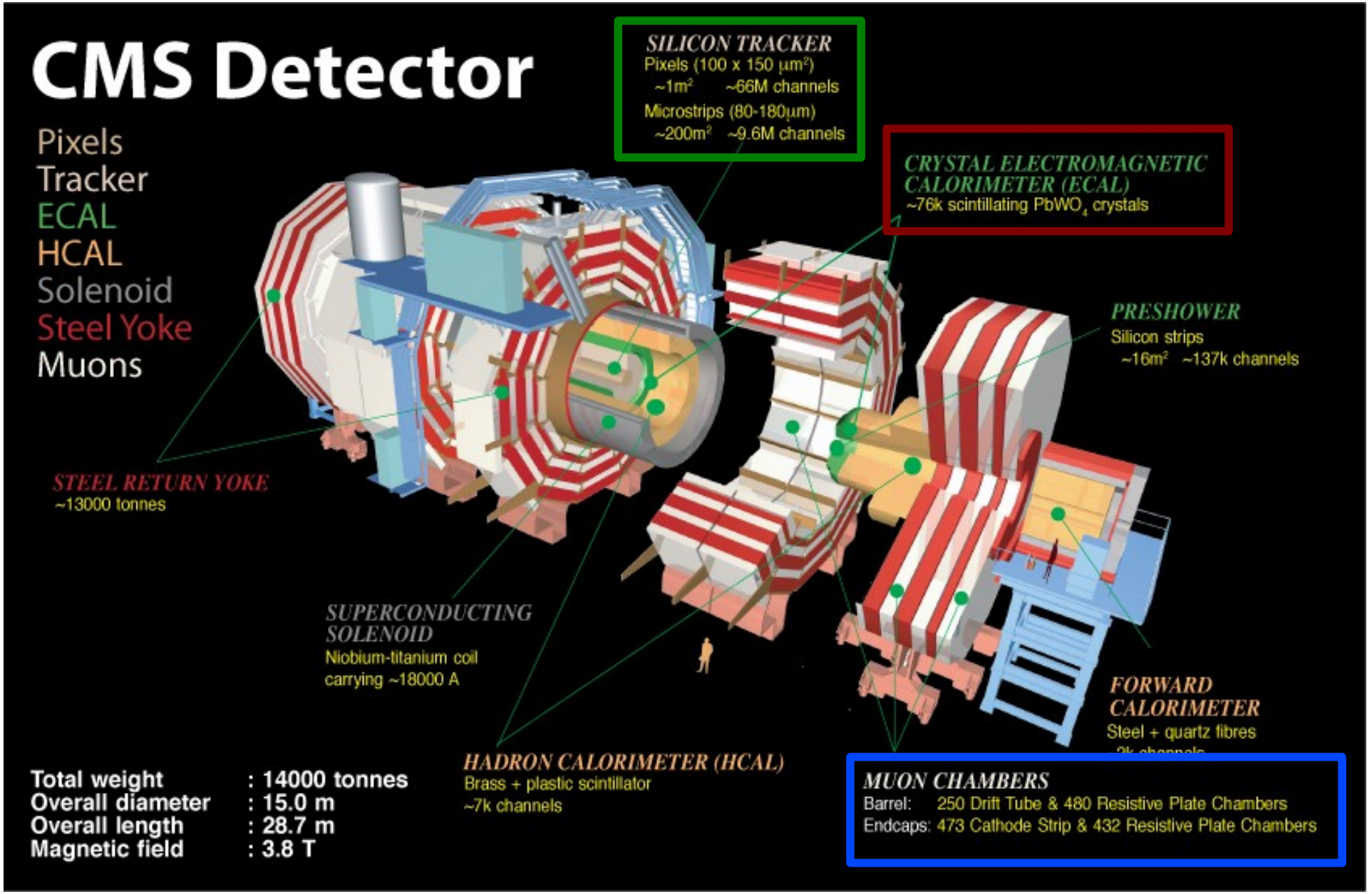


LHC performance in 2010

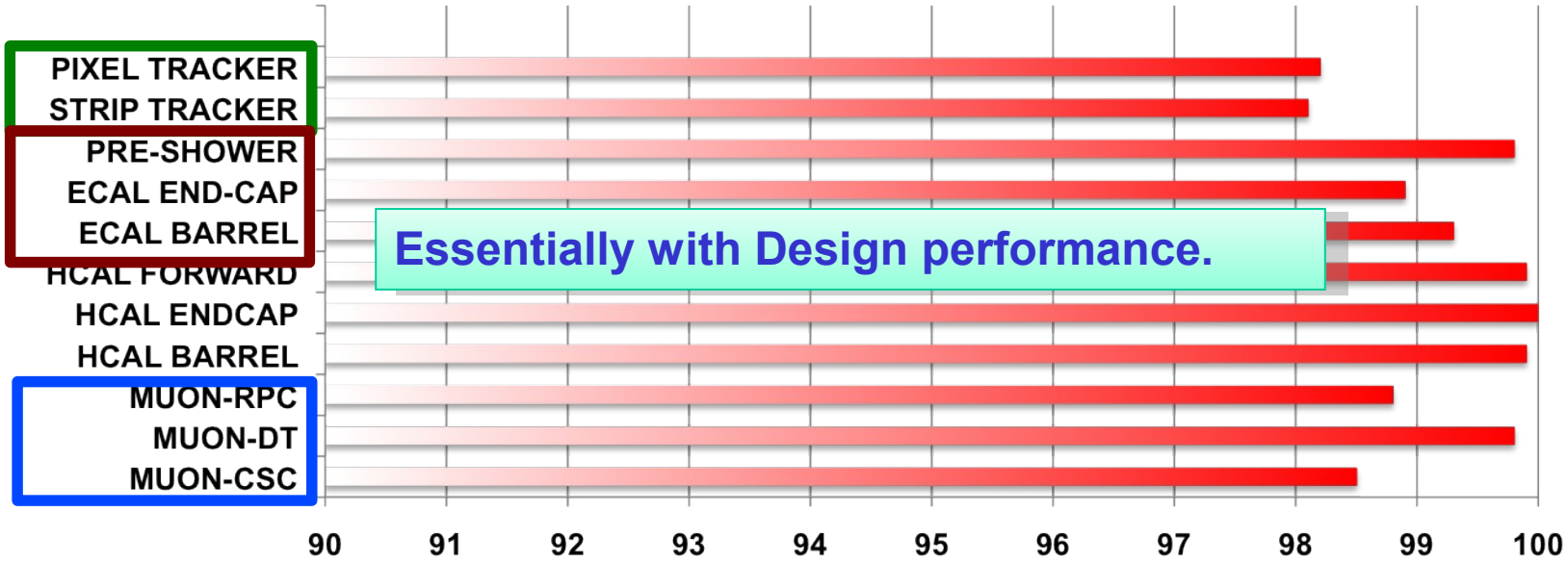
- Mar-Aug: Run2010A
  - ≈ 3pb^{-1}
  - First EWK measurements
- Sep-Nov: Run2010B
  - ≈ 40pb^{-1}
- Steep performance curve
  - By the end of Run2010B more than 5pb^{-1} per day
- In total LHC Delivered 47 pb^{-1},



CMS Detector



CMS detector



	MUON-CSC	MUON-DT	MUON-RPC	HCAL BARREL	HCAL ENDCAP	HCAL FORWARD	ECAL BARREL	ECAL END-CAP	PRE-SHOWER	STRIP TRACKER	PIXEL TRACKER	
Series1	98.5	99.8	98.8	99.9	100	99.9	99.3	98.9	99.8	98.1	98.2	

Proton-proton
LHC Delivered 47 pb^{-1},
CMS recorded 43 pb^{-1}
Overall data taking efficiency 92%
~85% with all subdetectors fully operational

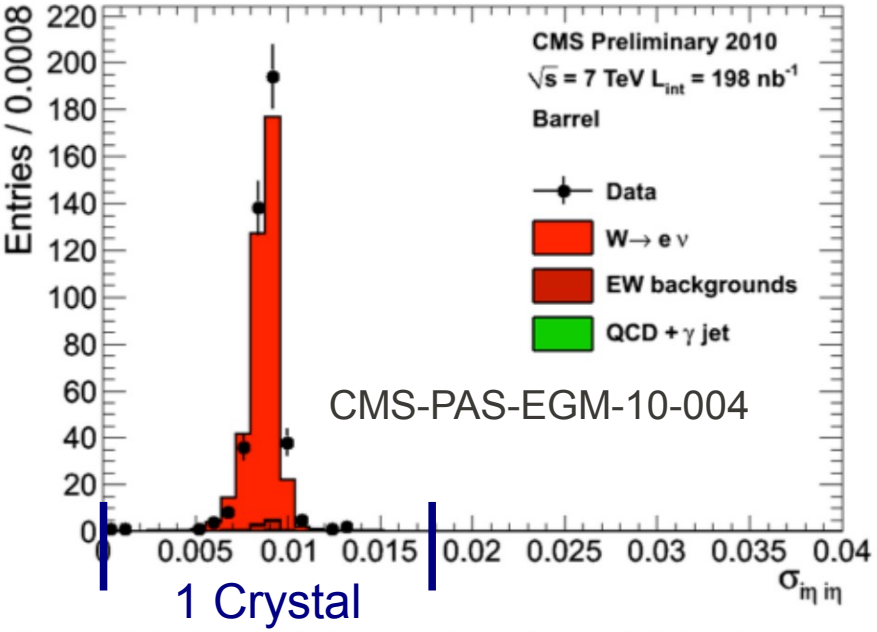
→ Analysis is based on 36 pb^{-1}

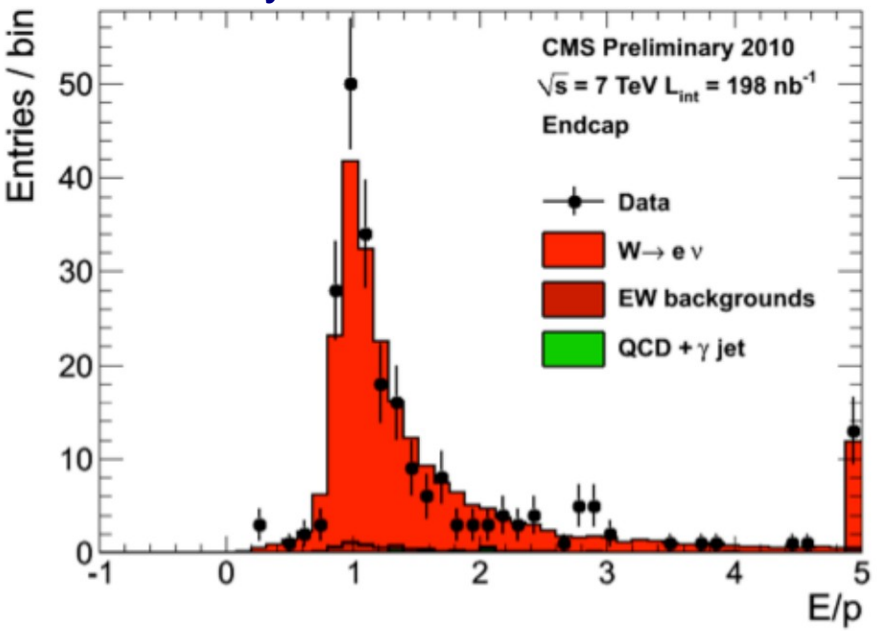
Analysis Overview

- W->lν characterised by
  - High Pt lepton
  - Missing transverse energy due to neutrino
- Background contributions,
  - EWK background ($W \rightarrow \tau \nu$, Drell-Yan)
  - ttbar background
  - QCD background (multi-jet, photon+jet (for electron))
- Both electron and muon analyses are made uniform as much as possible:
  - Inclusive single lepton triggers
  - Common kinematic cuts between electron and muon
  - Consistent treatment of systematic uncertainties
- 6 bins of $|\eta|$ (3 bins in common):
  - Electron: [0.0,0.4], [0.4,0.8], [0.8,1.2], [1.2,1.4], [1.6,2.0], [2.0,2.4]
  - Muon: [0.0,0.4], [0.4,0.8], [0.8,1.2], [1.2,1.5], [1.5,1.8], [1.8,2.1]

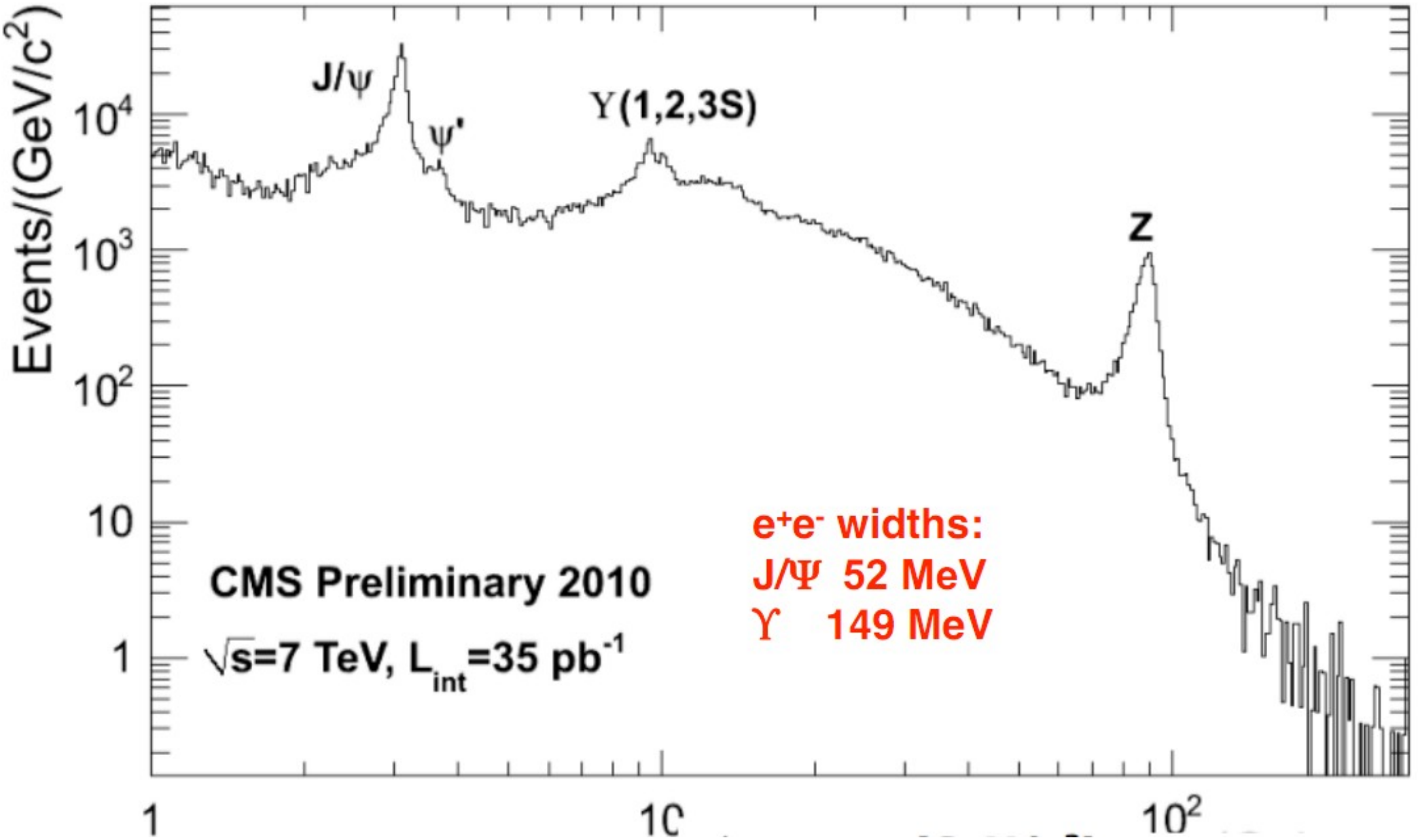
Electron Reconstruction

- Dependant on performance of CMS ECAL and tracking
- The high precision and granularity of EM calorimetry allows
  - Electron energy measurement through collection of bremsstrahlung radiation along a narrow spread in Φ
  - Electron-jet separation through cluster shape in η direction
  - “ECAL driven” seeding from clean ECAL clusters
- High granular pixel and si strips tracking system allows
  - Precise track-ECAL matching
  - Model electron energy loss with “Gaussian Sum Filter”
  - Track seeding





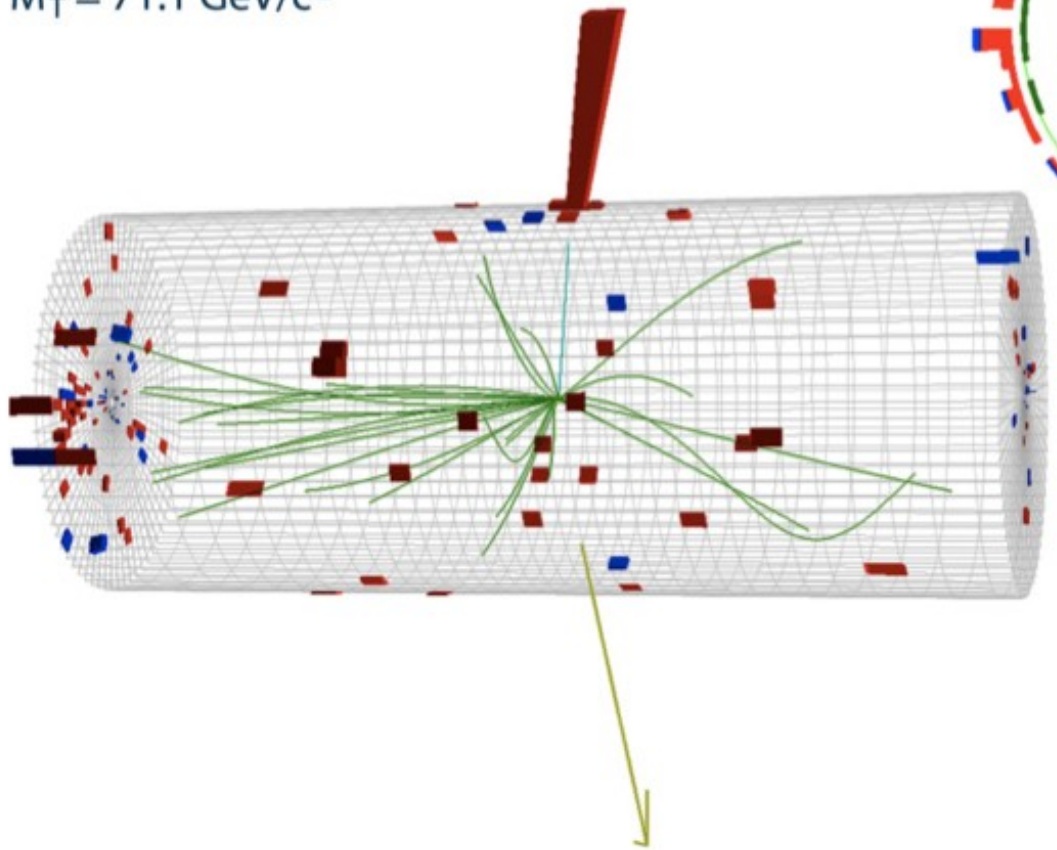
Electron Reconstruction

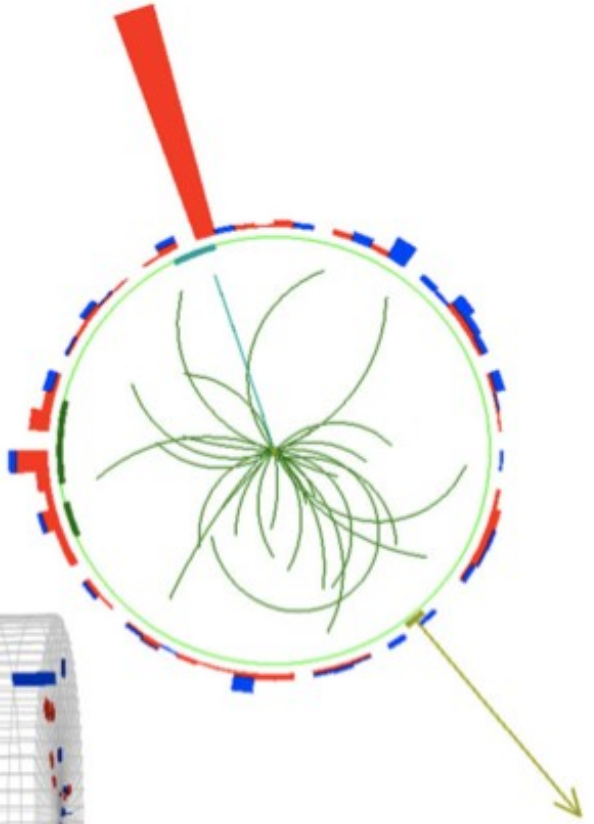


Electron Channel

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





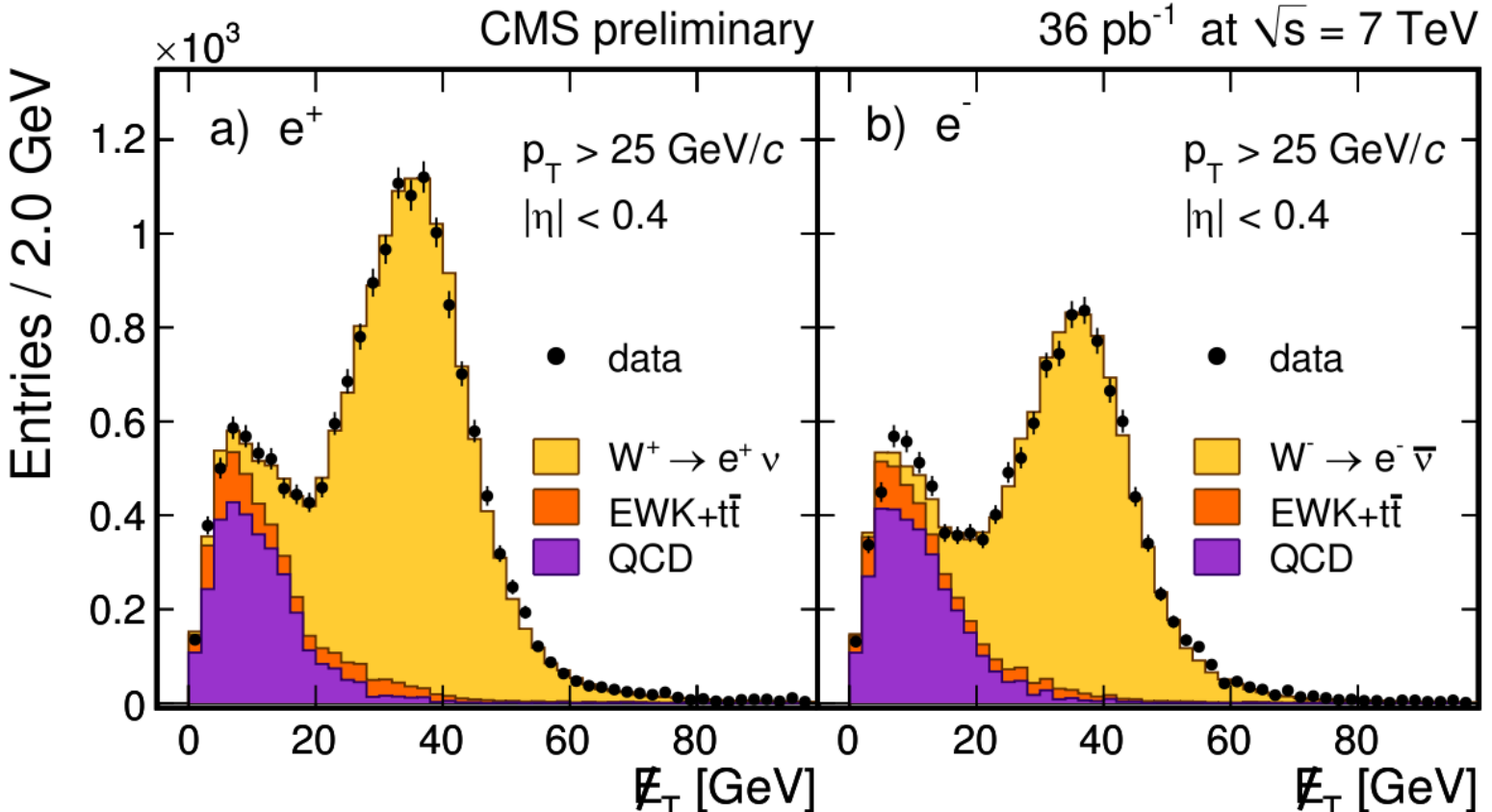
Electron Selection

- Electron Selection:
  - PT > 25 GeV
- Electron Identification
  - Track cluster matching
  - Shower shape and H/E
  - ECAL and HCAL isolation
  - Conversion rejection
- Z veto
  - 2nd lepton with Pt > 15 GeV
- Require that all three methods of charge assignment agree to reduce misassignment
  - Gaussian Sum Filter,
  - Kalman Filter,
  - Relative phi position of cluster center and first tracker hit

- With electron pT > 25 GeV/c:
  - QCD background 28.0%,
  - EWK background 6.4%,
  - ttbar background 0.3%

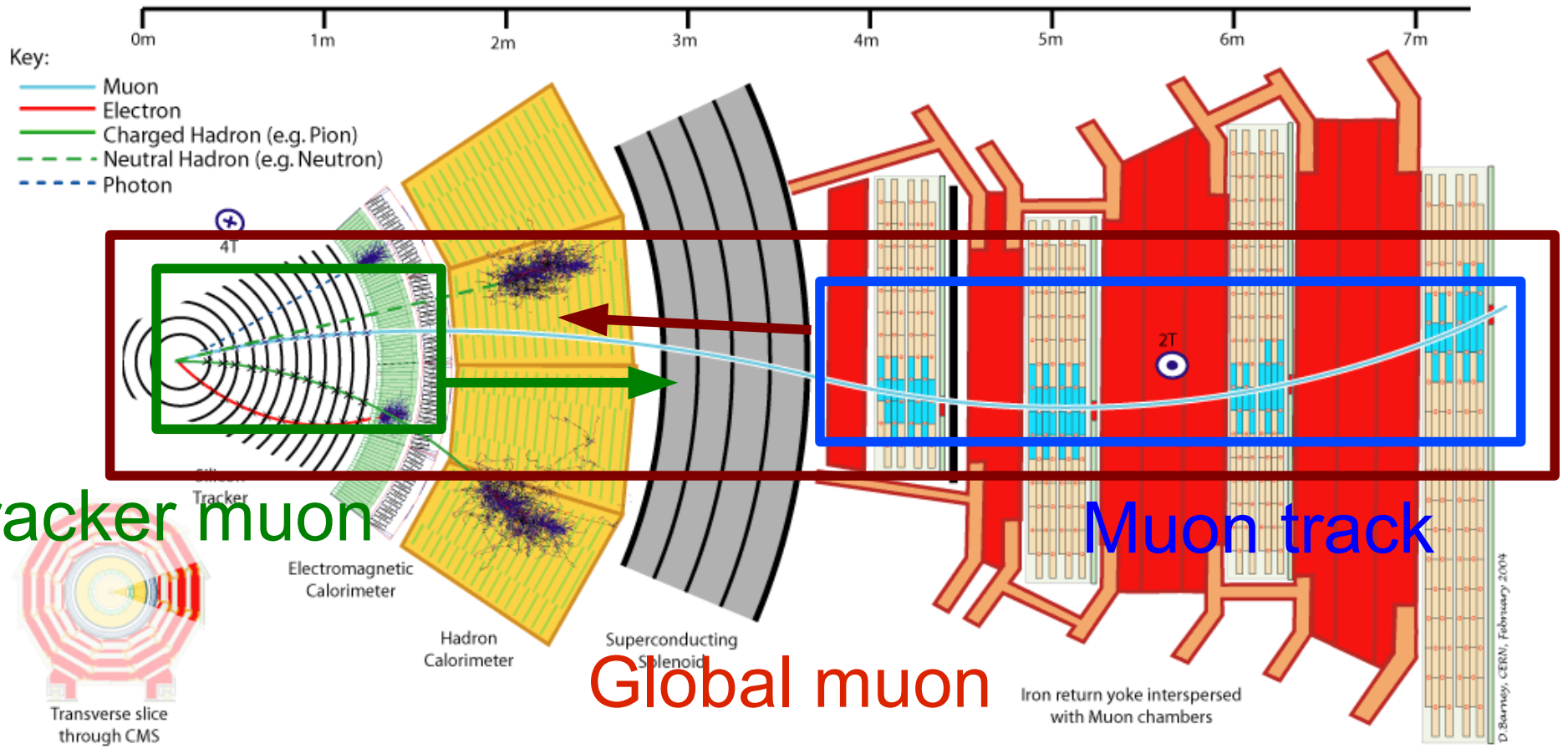
Electron Results

- Apply electron selection, then fit to MET distribution
  - Extended binned maximum likelihood fit to the MET distribution for electrons and positrons separatly
  - Static template shapes
    - Signal + EWK backgrounds : MC + correction from Z to ll recoil in data
    - QCD shape is determined using a signal-free control sample obtained by inverting a subset of the electron id criteria
  - N(QCD) and N(Sig+EWK) free parameters of the fit



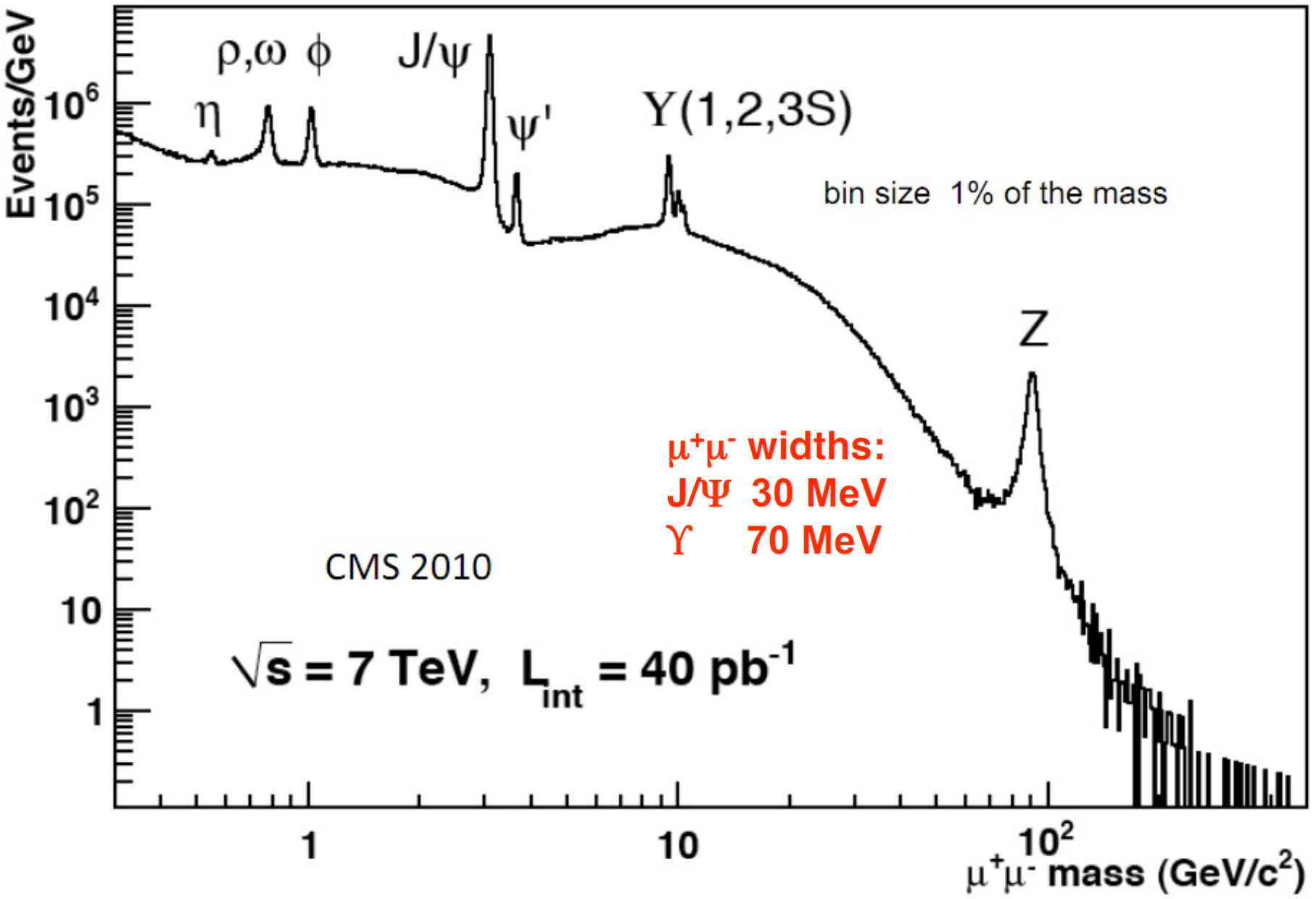
Muon Reconstruction

- The “M” in CMS
- Two methods to reconstruct muons in CMS, global muon (outside to in) and tracker muon (inside to out)

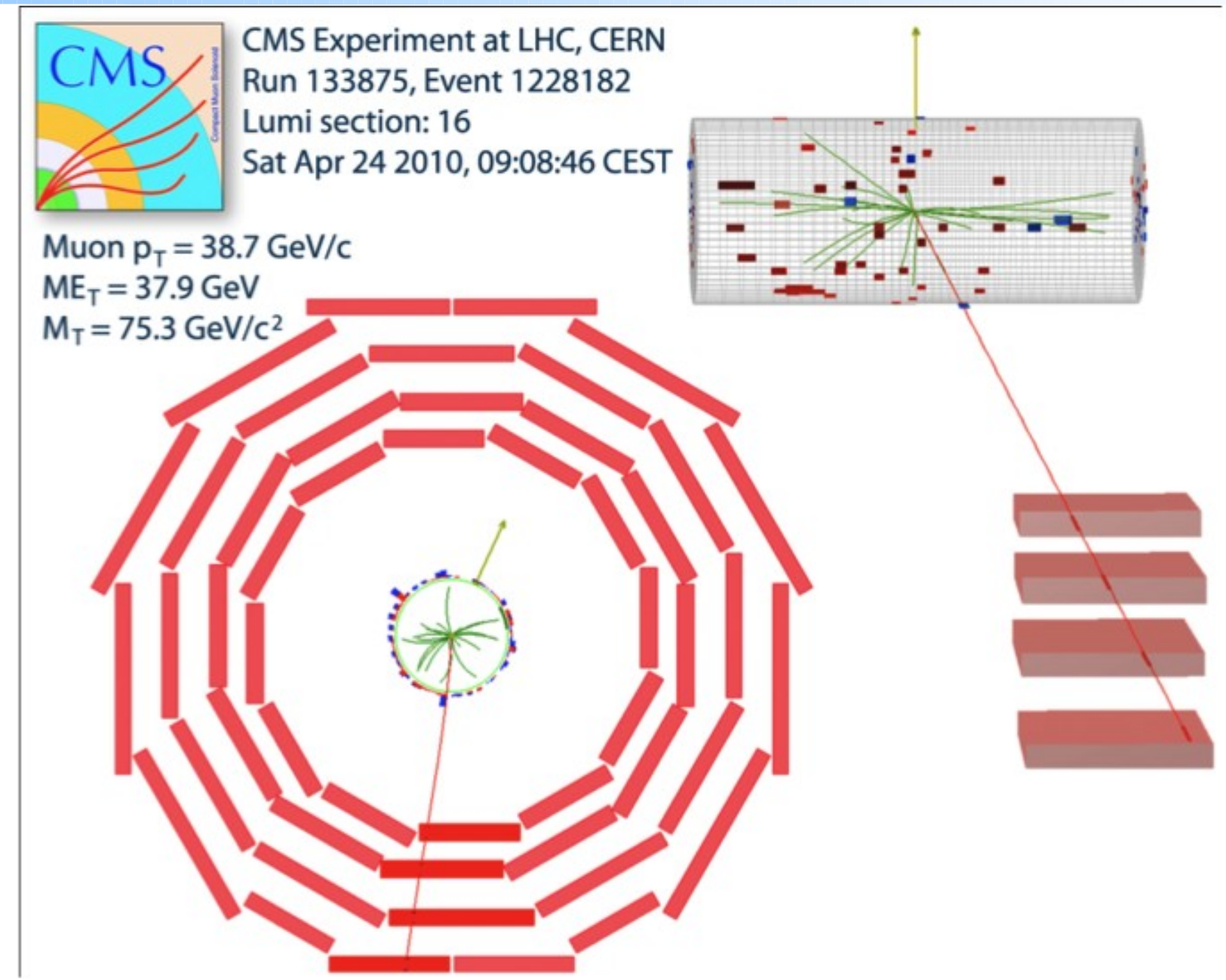


- Track fit including silicon track and muon chamber hits is then performed
- Muon charge is identified using the curvature of the silicon track

Muon Reconstruction



Muon Channel



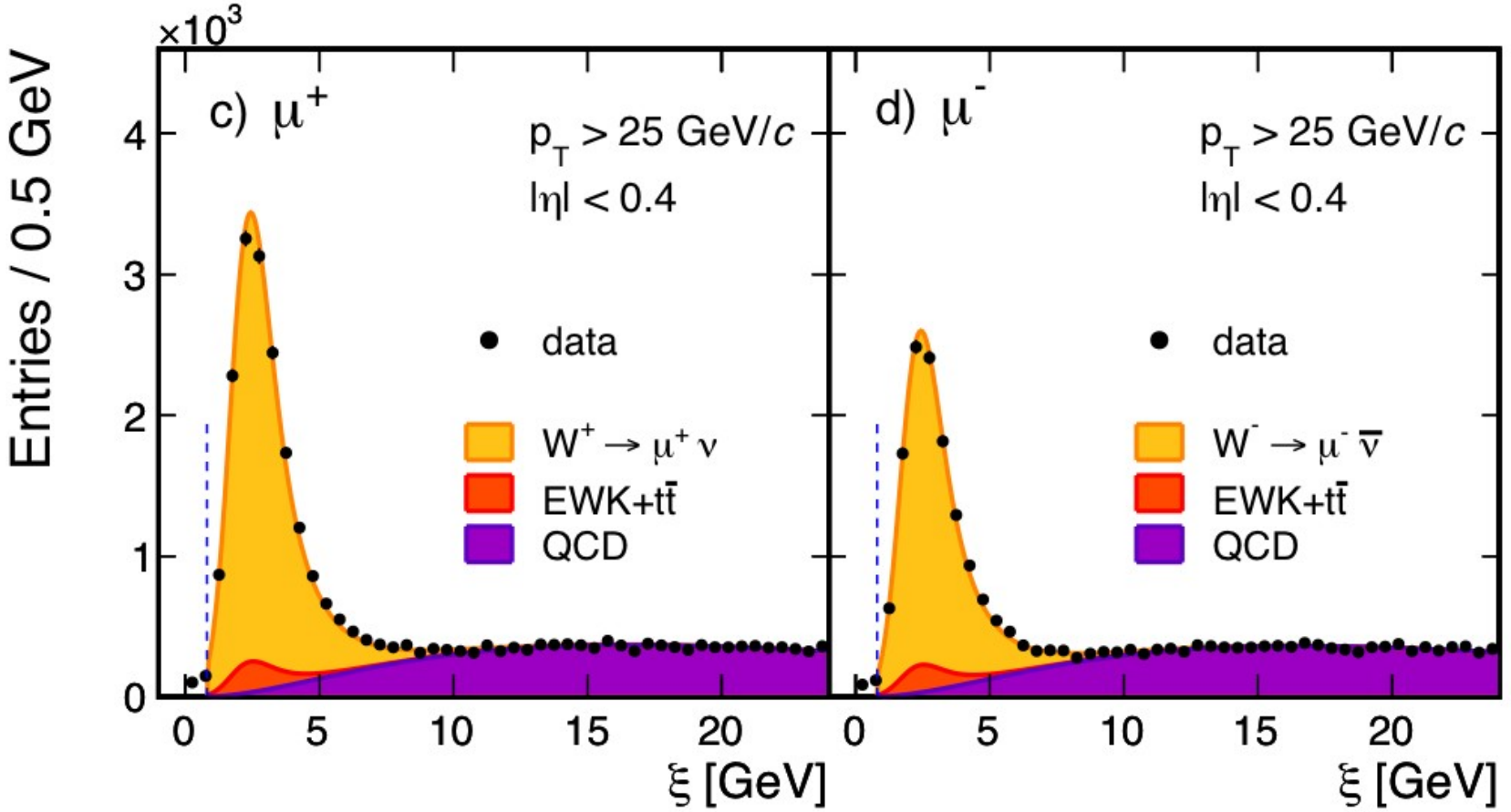
Muon Selection

- Muon Selection:
  - PT > 25 GeV
- Use both global and tracker muons
  - Requirements on the quality of tracker and muon tracks
  - Cosmic muon veto via transverse impact parameter
- Veto Z events
  - 2nd lepton with Pt > 15 GeV

Muon Results

- Apply Muon selection, then fit to Fit to modified isolation variable (The scalar sum of PT of tracks and deposits in ECAL and HCAL within cone $\Delta R < 0.3$)
- Static template shapes
  - Signal + EWK backgrounds : A Modified Landau distribution
  - QCD shape: An empirical function: $\xi^{\alpha} \cdot e^{\beta\sqrt{\xi}}$
- Unbinned extended maximum likelihood fit simultaneously to μ+ and μ− candidates
- Total yield, N(W → μν), and asymmetry, A(W → μν), are obtained in the fit

With muon pT > 25 GeV/c:
- QCD background 13.0%,
- EWK background 6.9%,
- ttbar background 0.3%

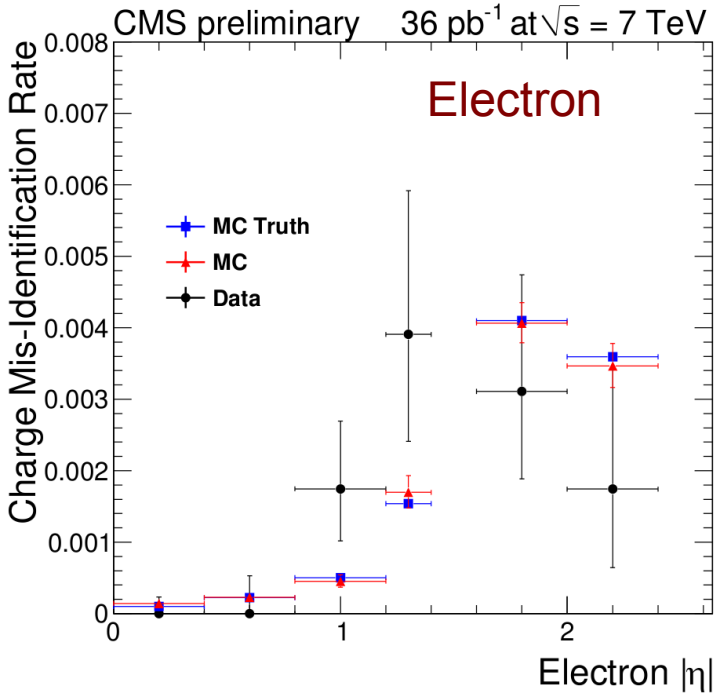


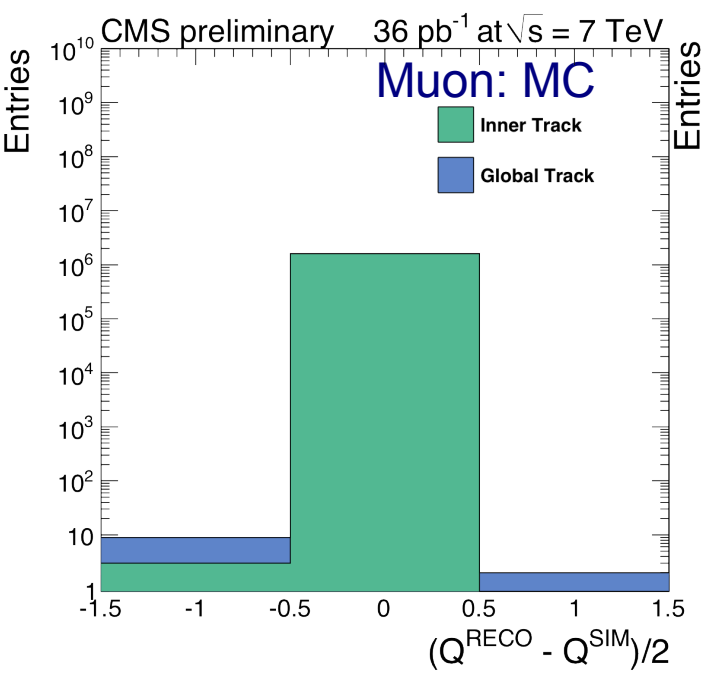
Systematics

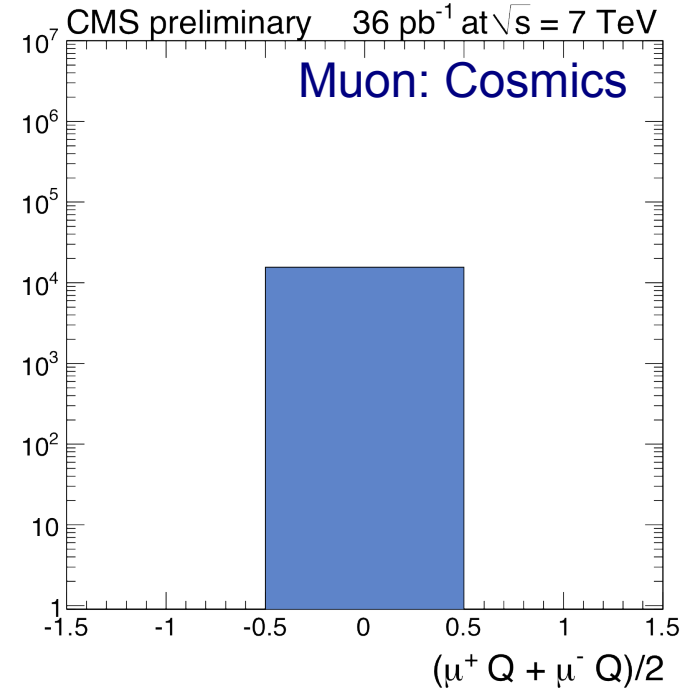
- Four main sources of systematic uncertainty in both channels
  - Rate of lepton charge misassignment
  - Relative efficiencies between l+ and l−
  - Lepton momentum (energy) scale and resolution
  - Signal estimation method

Lepton Charge Misassignment

- Tevatron experiments (CDF up to 5%, D0 up to 9%)
- Electron: Z → ee same sign yields.
  - Barrel 0.1%; Endcap 0.4%
  - Result is corrected for this and the statistical error on the mis-ID rate is taken as the systematic uncertainty
- Muon: determined in W signal MC (10^{-5})
  - Further studied using cosmic data where one muon is reconstructed as 2 muons with opposite charge
  - No such events found in 16422 cosmic muons (< 10^{-4})
  - Charge Misassignment is negligible in muon channel







Other Systematics

- Relative Efficiency (R =ε+/ε−)
  - If R ≠ 1, correction should be applied.
  - R is evaluated using Z → ll data
  - We find R compatible with 1,
  - The statistical uncertainty is propagated to the asymmetry as a systematic uncertainty
- Signal Extraction Method
  - Systematic uncertainties evaluated by varying the shapes used in the fits
  - Measured the effect of changing EWK and top backgrounds
- Momentum (Energy) Resolution and Scale
  - Resolution of leptons smears the PT spectra resulting in a bias of the measured asymmetry which we correct for.
  - Uncertainties on the resolution and scale are evaluated with Z->ll events and are taken as sources of systematic error

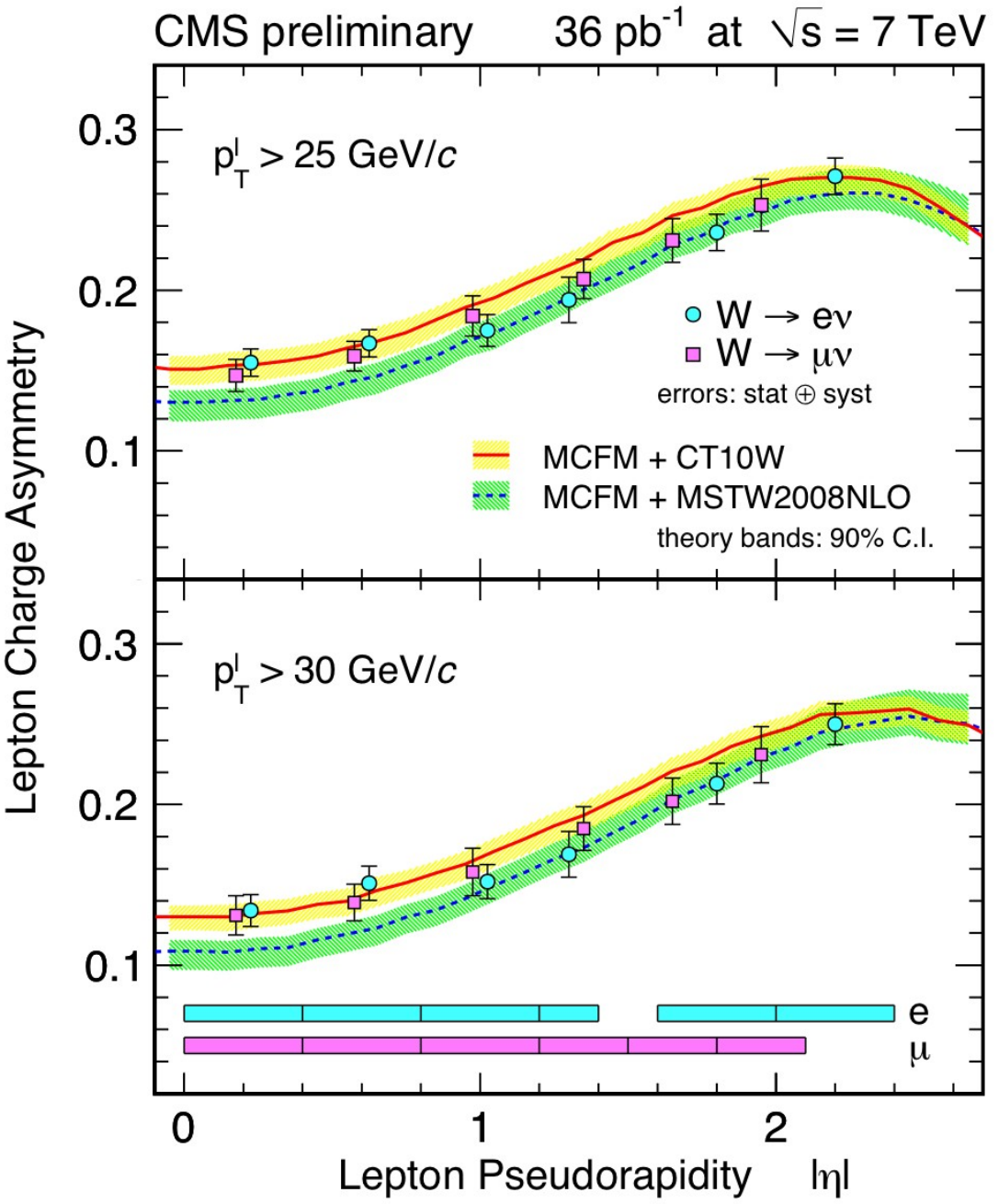
Systematics

$p_T^\ell > 25\,\text{GeV}/c$												
	Electron Channel						Muon Channel					
$\lvert\eta\rvert$ bin	[0.0 - 0.4]	[0.4 - 0.8]	[0.8 - 1.2]	[1.2 - 1.4]	[1.6 - 2.0]	[2.0 - 2.4]	[0.0 - 0.4]	[0.4 - 0.8]	[0.8 - 1.2]	[1.2 - 1.5]	[1.5 - 1.8]	[1.8 - 2.1]
Charge Mis-ID (%)	0.02	0.03	0.03	0.08	0.09	0.10	0	0	0	0	0	0
Eff. Ratio (%)	0.70	0.70	0.70	0.70	0.70	0.70	0.59	0.39	0.92	0.72	0.81	1.17
e/μ Scale (%)	0.11	0.09	0.19	0.47	0.40	0.45	0.50	0.48	0.50	0.48	0.50	0.42
Sig. Estimation (%)	0.16	0.19	0.26	0.33	0.25	0.25	0.23	0.29	0.34	0.40	0.53	0.58
Total (%)	0.73	0.73	0.77	0.90	0.85	0.87	0.80	0.68	1.10	0.95	1.08	1.37

$p_T^\ell > 30\,\text{GeV}/c$												
	Electron Channel						Muon Channel					
$\lvert\eta\rvert$ bin	[0.0 - 0.4]	[0.4 - 0.8]	[0.8 - 1.2]	[1.2 - 1.4]	[1.6 - 2.0]	[2.0 - 2.4]	[0.0 - 0.4]	[0.4 - 0.8]	[0.8 - 1.2]	[1.2 - 1.5]	[1.5 - 1.8]	[1.8 - 2.1]
Charge Mis-ID (%)	0.02	0.02	0.03	0.07	0.08	0.10	0	0	0	0	0	0
Eff. Ratio (%)	0.70	0.70	0.70	0.70	0.70	0.70	0.59	0.39	0.93	0.72	0.82	1.18
e/μ Scale (%)	0.07	0.17	0.26	0.46	0.53	0.55	0.80	0.78	0.83	0.81	0.73	0.77
Sig. Estimation (%)	0.16	0.19	0.26	0.33	0.25	0.25	0.20	0.20	0.27	0.35	0.51	0.56
Total (%)	0.72	0.75	0.79	0.91	0.92	0.93	1.01	0.90	1.27	1.14	1.21	1.52

Asymmetry Results

- We repeat the measurement with a PT cut of 30GeV
- The electron and muon results are in good agreement
- The results are compared to predictions from the MSTW2008NLO PDF model and the CT10W model obtained using the MCFM MC tool, the uncertainties are estimated using PDF reweighting technique
- Our data suggests a flatter η dependence of the asymmetry than the PDF models studied



Asymmetry Results

	$p_T^\ell > 25$ GeV		$p_T^\ell > 30$ GeV	
$\lvert\eta^e\rvert$	$\mathcal{A}(e)$ ($\pm$stat $\pm$ sys)	Prediction	$\mathcal{A}(e)$ ($\pm$stat $\pm$ sys)	Prediction
[0.0 - 0.4]	$0.155 \pm 0.006 \pm 0.007$	$0.157^{+0.010}_{-0.010}$	$0.134 \pm 0.007 \pm 0.007$	$0.134^{+0.009}_{-0.009}$
[0.4 - 0.8]	$0.167 \pm 0.006 \pm 0.007$	$0.169^{+0.010}_{-0.011}$	$0.151 \pm 0.007 \pm 0.008$	$0.146^{+0.009}_{-0.010}$
[0.8 - 1.2]	$0.175 \pm 0.007 \pm 0.008$	$0.193^{+0.009}_{-0.011}$	$0.152 \pm 0.007 \pm 0.008$	$0.169^{+0.009}_{-0.011}$
[1.2 - 1.4]	$0.194 \pm 0.010 \pm 0.009$	$0.216^{+0.010}_{-0.012}$	$0.169 \pm 0.011 \pm 0.009$	$0.191^{+0.010}_{-0.012}$
[1.6 - 2.0]	$0.236 \pm 0.008 \pm 0.009$	$0.256^{+0.010}_{-0.014}$	$0.213 \pm 0.009 \pm 0.009$	$0.234^{+0.011}_{-0.015}$
[2.0 - 2.4]	$0.271 \pm 0.008 \pm 0.009$	$0.271^{+0.012}_{-0.017}$	$0.250 \pm 0.009 \pm 0.009$	$0.257^{+0.013}_{-0.018}$
$\lvert\eta^\mu\rvert$	$\mathcal{A}(\mu)$ ($\pm$stat $\pm$ sys)	Prediction	$\mathcal{A}(\mu)$ ($\pm$stat $\pm$ sys)	Prediction
[0.0 - 0.4]	$0.147 \pm 0.006 \pm 0.008$	$0.157^{+0.010}_{-0.010}$	$0.131 \pm 0.007 \pm 0.010$	$0.134^{+0.009}_{-0.009}$
[0.4 - 0.8]	$0.159 \pm 0.006 \pm 0.007$	$0.169^{+0.010}_{-0.011}$	$0.139 \pm 0.007 \pm 0.009$	$0.146^{+0.009}_{-0.010}$
[0.8 - 1.2]	$0.184 \pm 0.006 \pm 0.011$	$0.193^{+0.009}_{-0.011}$	$0.158 \pm 0.007 \pm 0.013$	$0.169^{+0.009}_{-0.011}$
[1.2 - 1.5]	$0.207 \pm 0.007 \pm 0.010$	$0.220^{+0.009}_{-0.012}$	$0.185 \pm 0.008 \pm 0.011$	$0.196^{+0.010}_{-0.012}$
[1.5 - 1.8]	$0.231 \pm 0.008 \pm 0.011$	$0.246^{+0.010}_{-0.014}$	$0.202 \pm 0.008 \pm 0.012$	$0.222^{+0.011}_{-0.014}$
[1.8 - 2.1]	$0.253 \pm 0.008 \pm 0.014$	$0.265^{+0.010}_{-0.015}$	$0.231 \pm 0.009 \pm 0.015$	$0.245^{+0.011}_{-0.016}$

Predictions made with CT10W PDF model

Conclusion

- We have measured the lepton charge asymmetry in both electron and muon channels with the full 2010 dataset.
- The statistical precision is within $0.006 - 0.008$
- Electron and muons results are in good agreement with each other.
- Our data suggests a flatter η dependence of the asymmetry than the PDF models studied
- We have made a high-precision measurement of the lepton charge asymmetry at the LHC.
- Precision of the measurements is significant enough to provide new inputs to PDF global fits

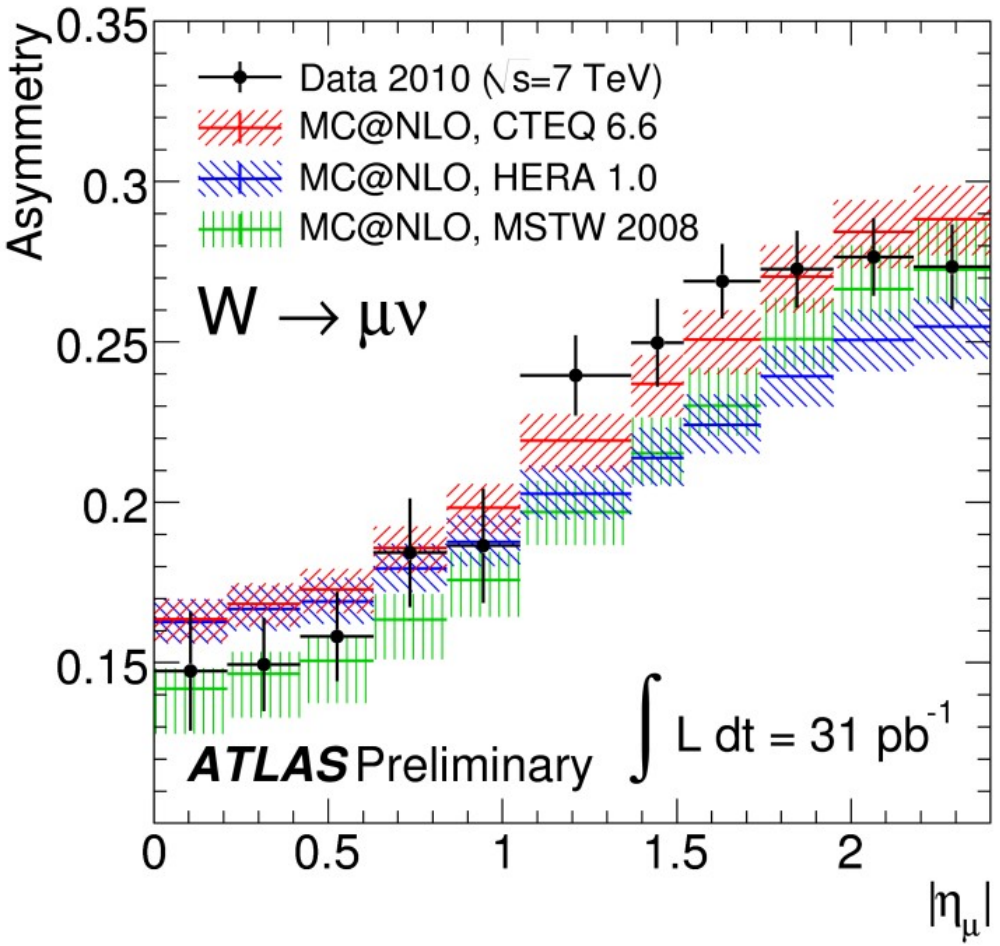
Outlook

- Future relevant CMS measurements in approval process:
  - Drell-Yan Cross Section (dσ/dM) Measurement
  - Differential Cross Section for Z bosons
  - Forward backward asymmetry of Lepton Pairs and the Weak-mixing Angle at CMS
  - W Cross Section Measurement with full 2010 dataset
  - W Polarisation Measurement

Backup Slides

Other LHC measurements

ATLAS Collaboration:
LATHUILE WORKSHOP 2011



LHCb Collaboration
Kruger2010: Workshop