Measurement of the lepton charge asymmetry in inclusive pp→W(lν)X at LHC with the CMS detector

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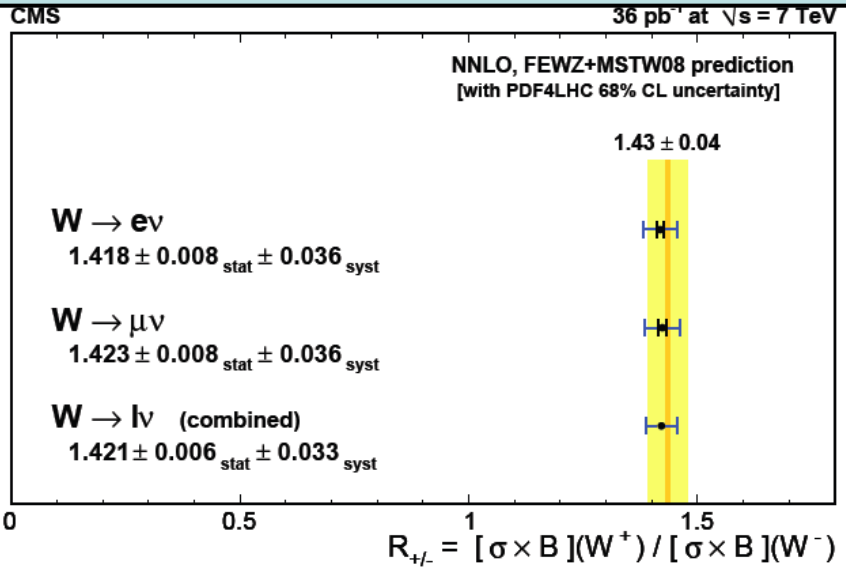
April 12, 2011
DIS2011
Newport News -Virginia-United States

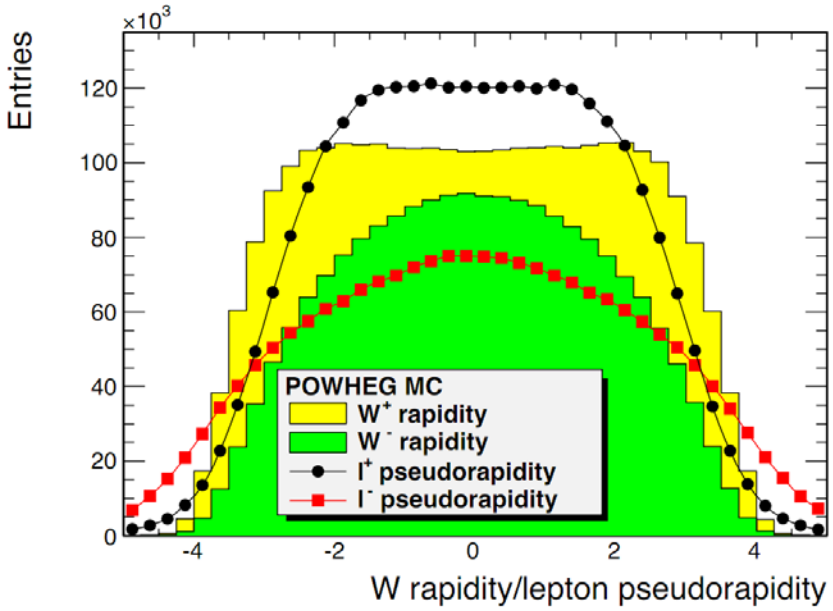
Outline:

- Motivation
- 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.
- The inclusive charge ratio measured by CMS to be 1.42 ± 0.03 in agreement with MSTW PDF predictions



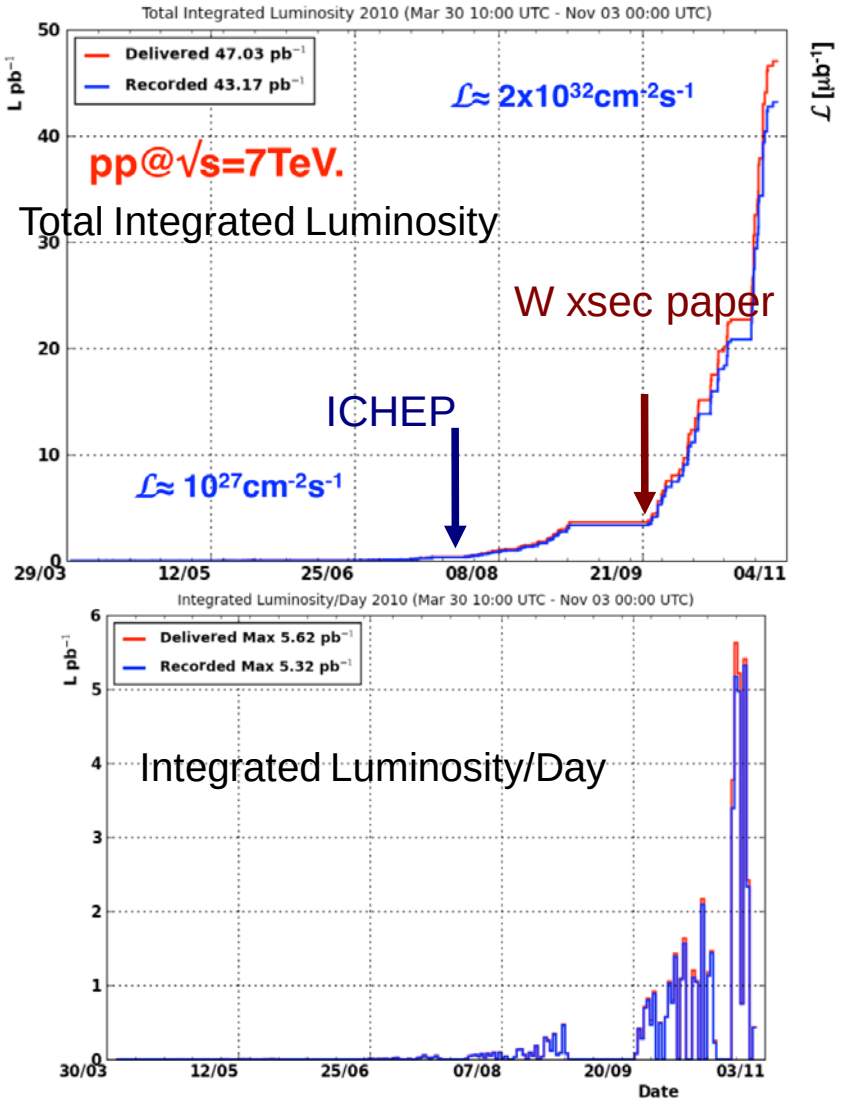


- An asymmetry measurement as a function of boson rapidity can be used to constrain PDFs.
- Direct accessible measurement is the lepton charge asymmetry

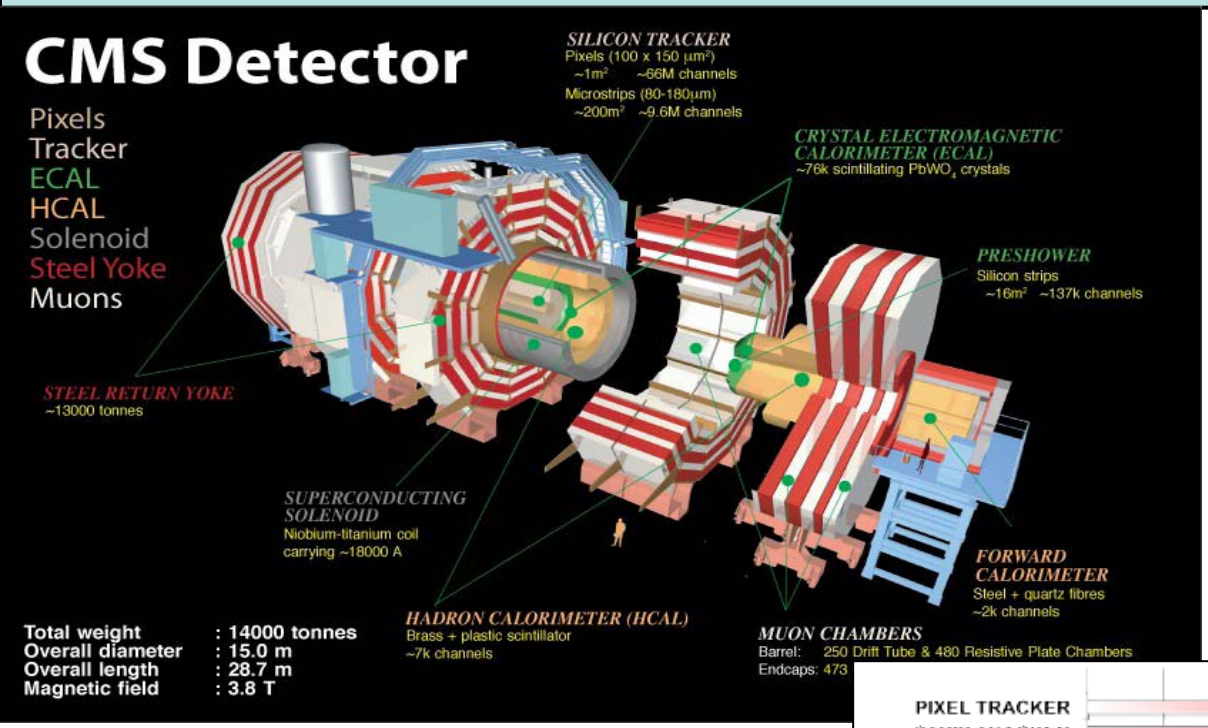
$$\mathcal{A}_{th}(\eta) = \frac{\frac{d\sigma}{d\eta}\left(W^+ \to e^+\nu_e\right) - \frac{d\sigma}{d\eta}\left(W^- \to e^-\bar{\nu}_e\right)}{\frac{d\sigma}{d\eta}\left(W^+ \to e^+\nu_e\right) + \frac{d\sigma}{d\eta}\left(W^- \to e^-\bar{\nu}_e\right)}$$

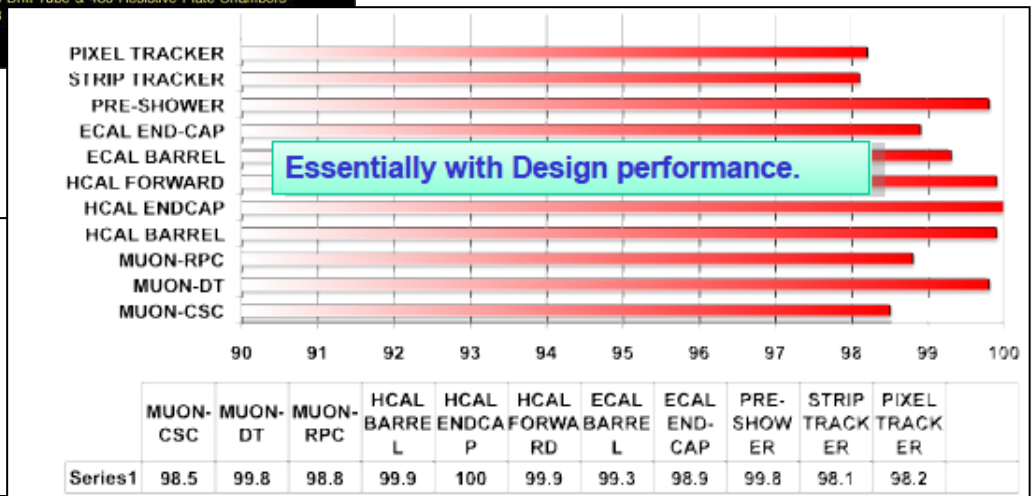
LHC performance in 2010

- 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





	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%

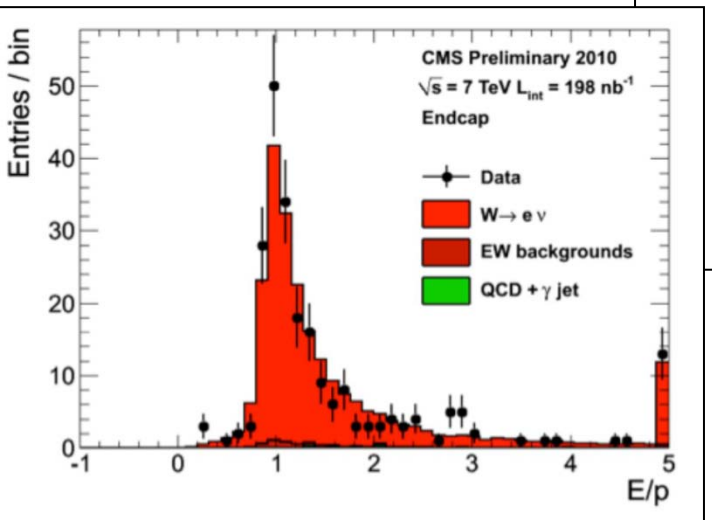
~85% with all subdetectors fully operational

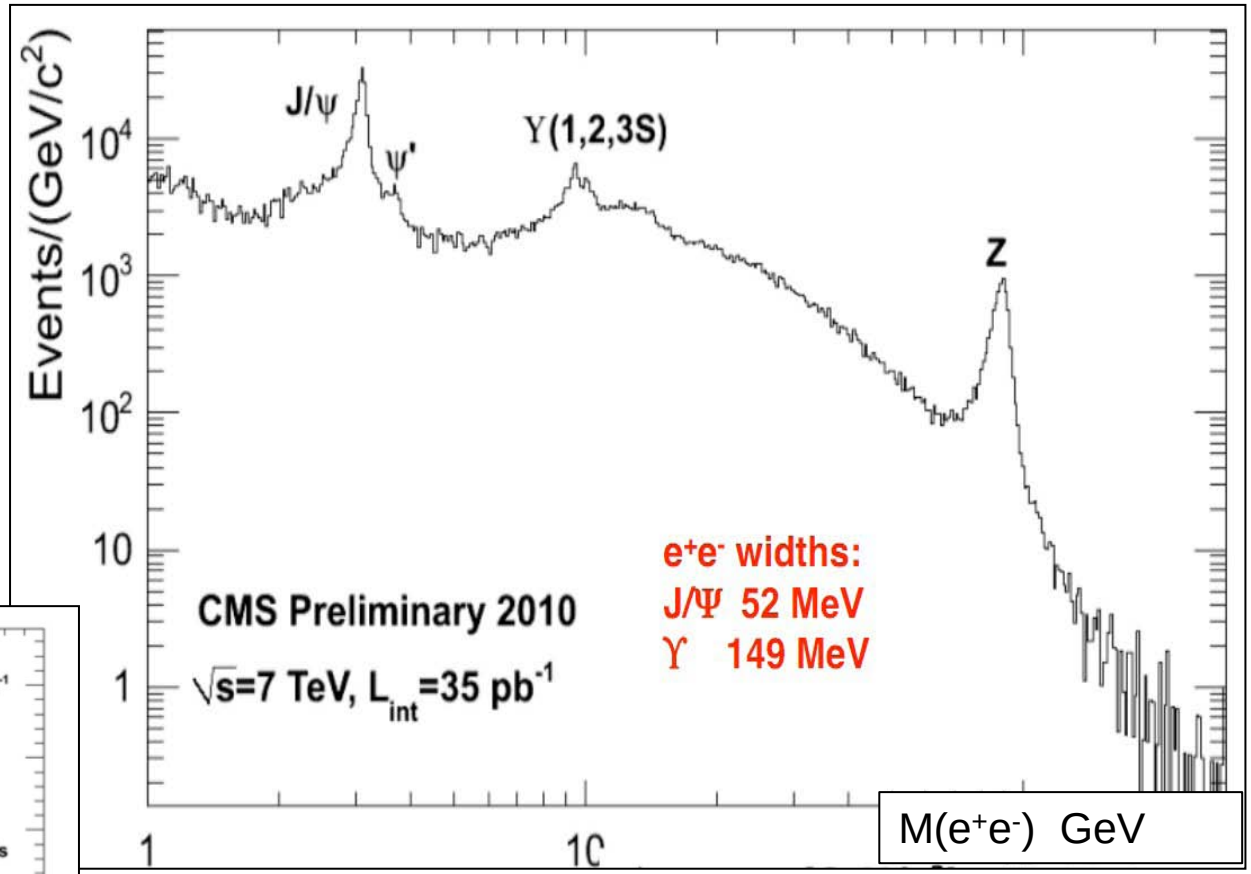
Analysis Overview

- W->lv 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 |η| (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]

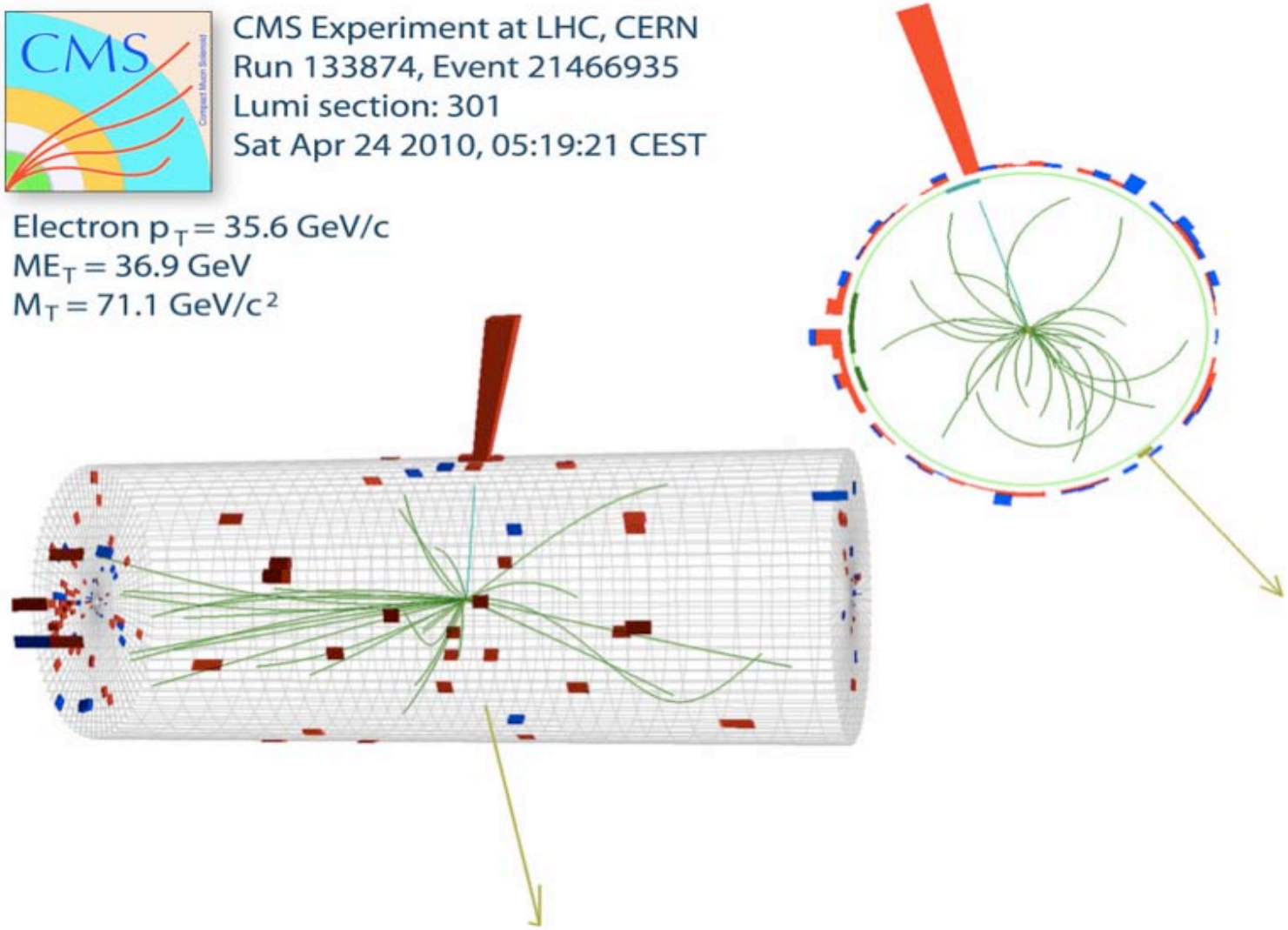
Electron recostruction

Electron reconstruction based on ECAL and silicon tracker sub-detectors



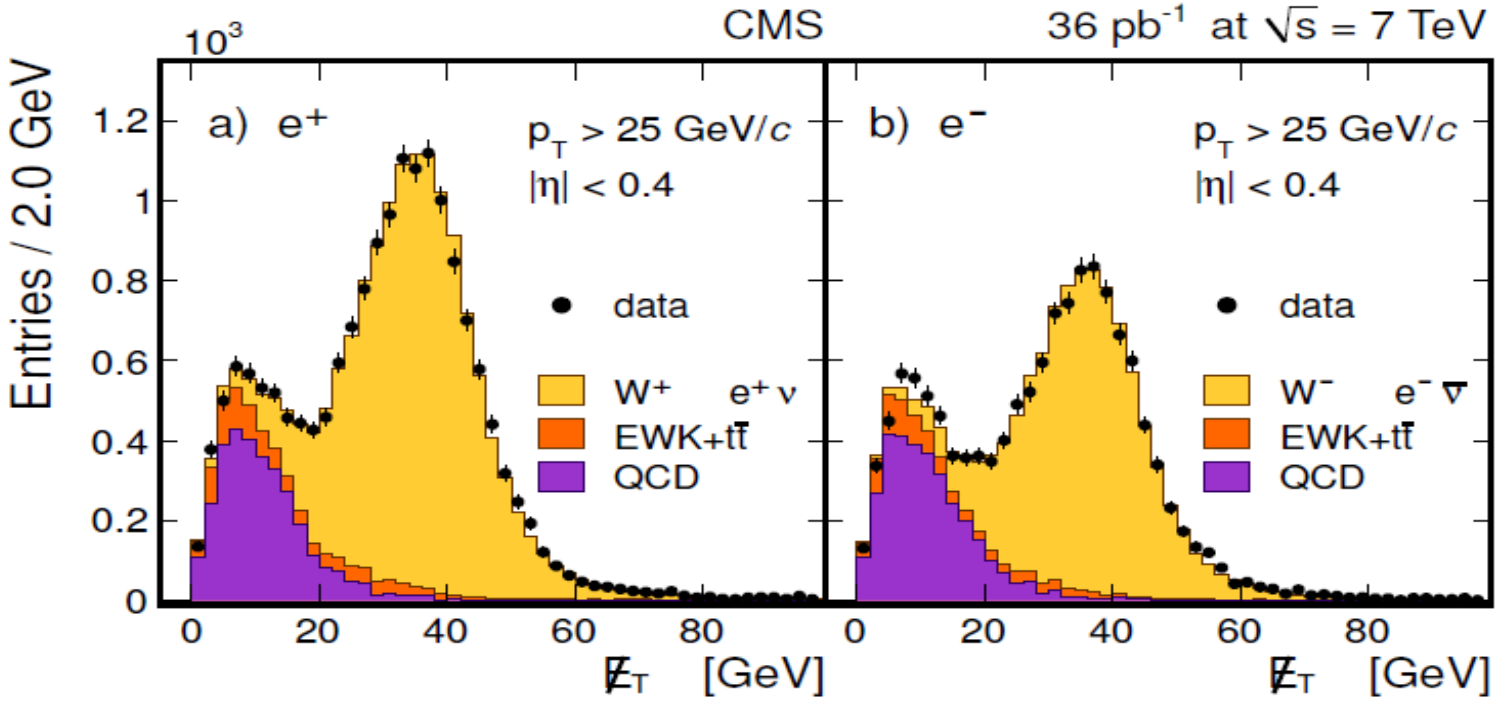


W→eν candidate

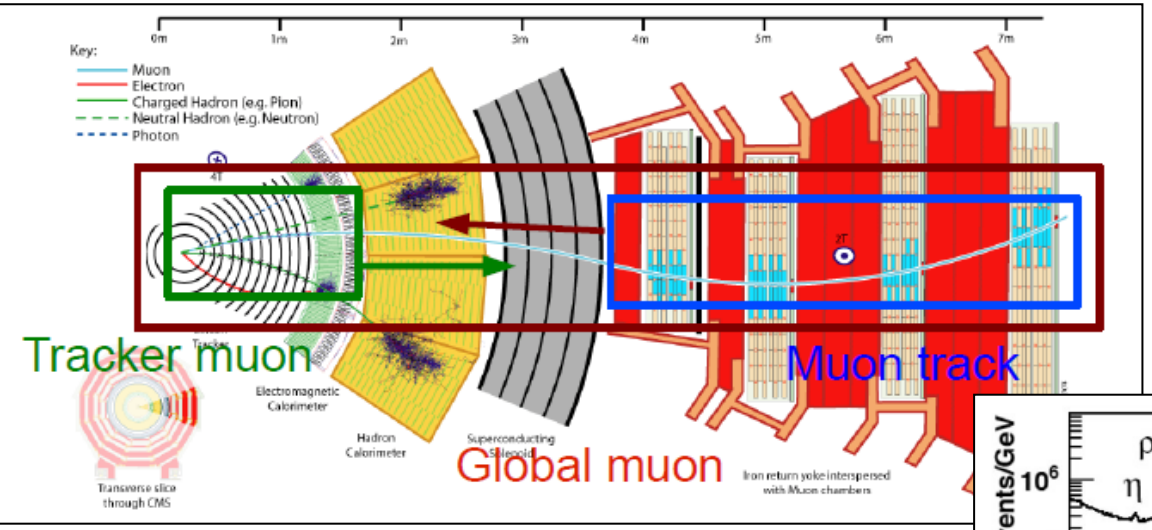


Electron Signal extraction

- **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**

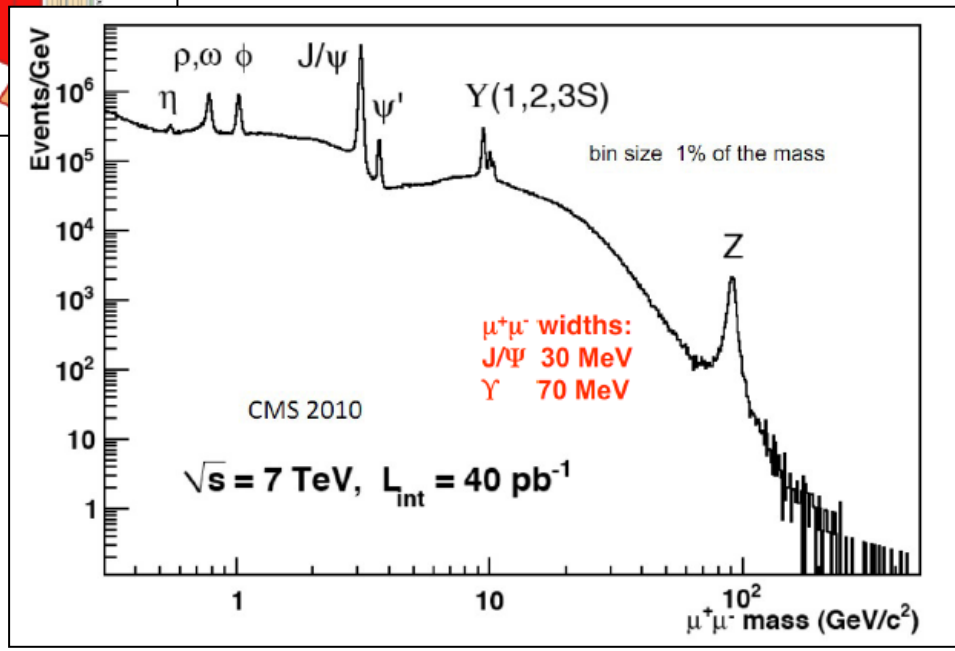


Muons

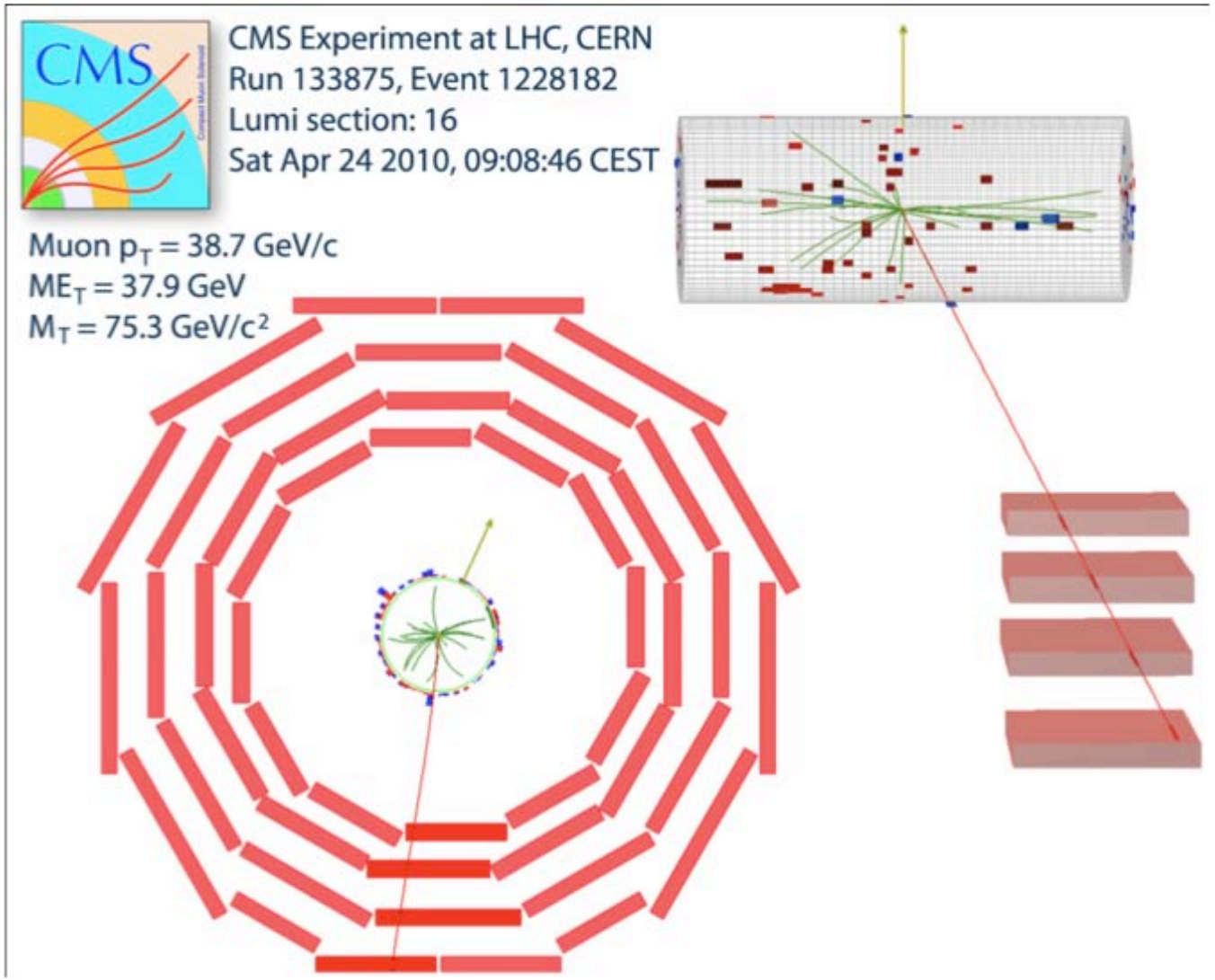


The “M” in CMS is Muon

Muon track fit including silicon track and muon chamber hits is performed

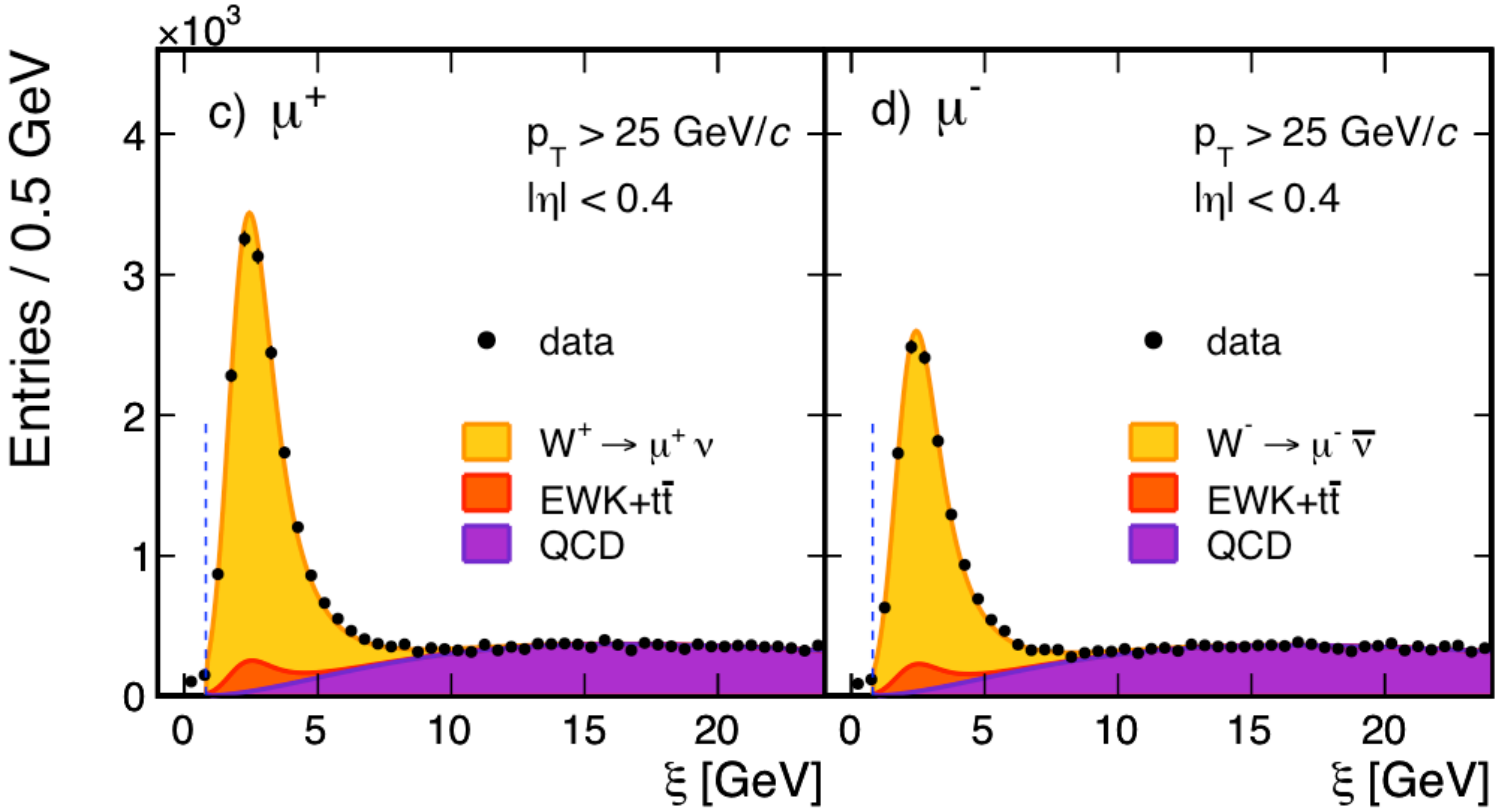


W→μν candidate



Muon Signal extraction

- **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**



Systematic uncertainties

- Relative efficiencies between l+ and l− (R)
  - If R ≠ 1, correction should be applied.
  - R is evaluated using $Z \rightarrow ll$ data
  - We find R compatible with 1
  - The statistical uncertainty is propagated to the asymmetry as a systematic uncertainty

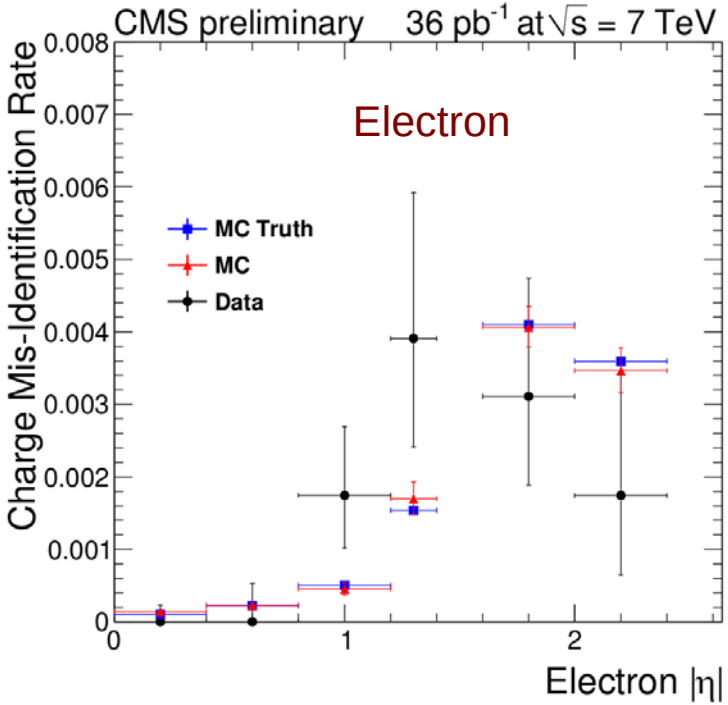
- Signal estimation method
  - Systematic uncertainties evaluated by varying the shapes used in the fits
  - Measured the effect of changing EWK and top backgrounds

- Lepton momentum (energy) scale and resolution
  - 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

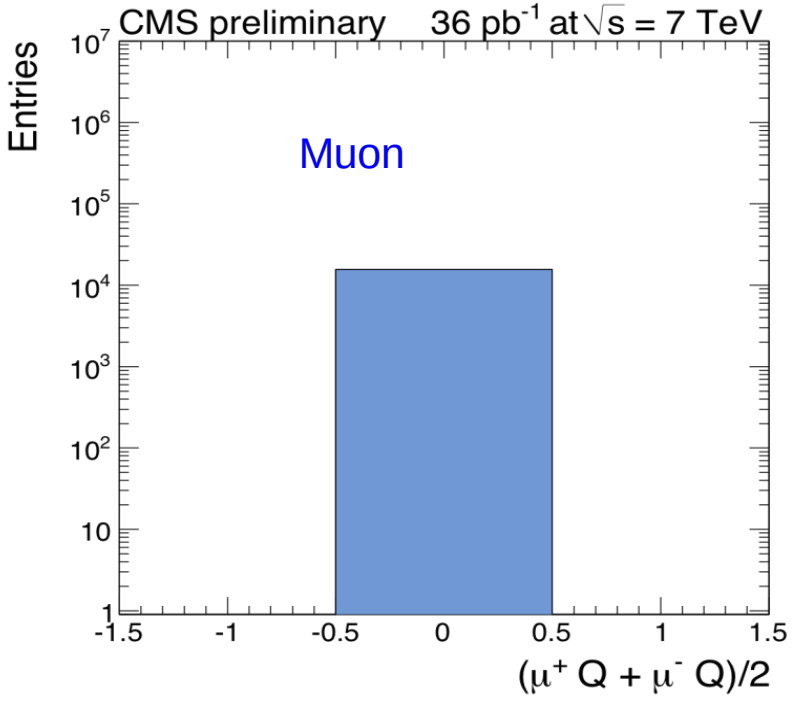
- Rate of lepton charge misassignment (See next slide)

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



Systematic uncertainties

$p_{\mathrm{T}}^{\ell} > 25\,\mathrm{GeV}/c$

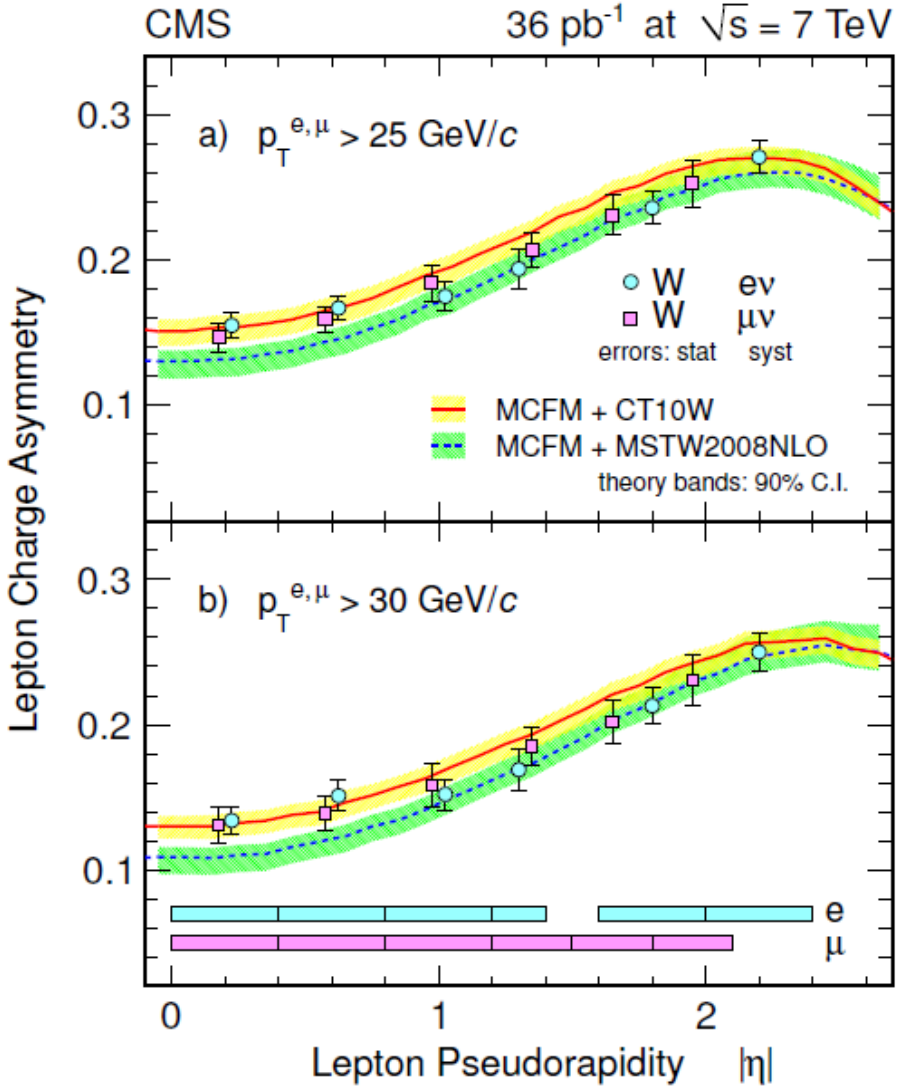
	Electron Channel						Muon Channel					
$\lvert\eta\rvert$ bin	[0.0, 0.4]	[0.4, 0.8]	[0.8, 1.2]	[1.2, 1.4]	[1.6, 2.0]	[2.0, 2.4]	[0.0, 0.4]	[0.4, 0.8]	[0.8, 1.2]	[1.2, 1.5]	[1.5, 1.8]	[1.8, 2.1]
Charge Misident.	0.02	0.03	0.03	0.08	0.09	0.10	0	0	0	0	0	0
Eff. Ratio	0.70	0.70	0.70	0.70	0.70	0.70	0.59	0.39	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. & Bkg. Estim.	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

$p_{\mathrm{T}}^{\ell} > 30\,\mathrm{GeV}/c$

	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 Misident.	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. & Bkg. Estim.	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

- 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

	$p_T^\ell > 25\,\mathrm{GeV}/c$				$p_T^\ell > 30\,\mathrm{GeV}/c$			
$\lvert\eta^e\rvert$	$\mathcal{A}$(e) ($\pm$stat $\pm$ sys)	$\mathcal{A}^R$	$\mathcal{A}^M$	$\Delta(+/-)$	$\mathcal{A}$(e) ($\pm$stat $\pm$ sys)	$\mathcal{A}^R$	$\mathcal{A}^M$	$\Delta(+/-)$
[0.0, 0.4]	$15.5 \pm 0.6 \pm 0.7$	15.7	15.3	$+0.8/-1.0$	$13.4 \pm 0.7 \pm 0.7$	13.4	13.1	$+0.7/-0.9$
[0.4, 0.8]	$16.7 \pm 0.6 \pm 0.7$	16.9	16.7	$+0.9/-1.0$	$15.1 \pm 0.7 \pm 0.8$	14.6	14.5	$+0.8/-0.8$
[0.8, 1.2]	$17.5 \pm 0.7 \pm 0.8$	19.3	19.2	$+0.8/-1.1$	$15.2 \pm 0.7 \pm 0.8$	16.9	16.8	$+0.8/-1.0$
[1.2, 1.4]	$19.4 \pm 1.0 \pm 0.9$	21.6	21.7	$+0.8/-1.1$	$16.9 \pm 1.1 \pm 0.9$	19.1	18.9	$+0.8/-1.0$
[1.6, 2.0]	$23.6 \pm 0.8 \pm 0.9$	25.6	25.4	$+0.8/-1.1$	$21.3 \pm 0.9 \pm 0.9$	23.4	23.7	$+0.8/-1.1$
[2.0, 2.4]	$27.1 \pm 0.8 \pm 0.9$	27.1	26.9	$+0.8/-1.1$	$25.0 \pm 0.9 \pm 0.9$	25.7	25.4	$+0.8/-1.1$
$\lvert\eta^\mu\rvert$	$\mathcal{A}(\mu)$($\pm$stat $\pm$ sys)	$\mathcal{A}^R$	$\mathcal{A}^M$	$\Delta(+/-)$	$\mathcal{A}(\mu)$($\pm$stat $\pm$ sys)	$\mathcal{A}^R$	$\mathcal{A}^M$	$\Delta(+/-)$
[0.0, 0.4]	$14.7 \pm 0.6 \pm 0.8$	15.7	15.3	$+0.8/-1.0$	$13.1 \pm 0.7 \pm 1.0$	13.4	13.1	$+0.7/-0.9$
[0.4, 0.8]	$15.9 \pm 0.6 \pm 0.7$	16.9	16.7	$+0.9/-1.0$	$13.9 \pm 0.7 \pm 0.9$	14.6	14.5	$+0.8/-0.8$
[0.8, 1.2]	$18.4 \pm 0.6 \pm 1.1$	19.3	19.2	$+0.8/-1.1$	$15.8 \pm 0.7 \pm 1.3$	16.9	16.8	$+0.8/-1.0$
[1.2, 1.5]	$20.7 \pm 0.7 \pm 1.0$	22.0	22.0	$+0.8/-1.1$	$18.5 \pm 0.8 \pm 1.1$	19.6	19.4	$+0.8/-1.0$
[1.5, 1.8]	$23.1 \pm 0.8 \pm 1.1$	24.6	24.5	$+0.8/-1.1$	$20.2 \pm 0.8 \pm 1.2$	22.2	21.9	$+0.8/-1.1$
[1.8, 2.1]	$25.3 \pm 0.8 \pm 1.4$	26.5	26.3	$+0.8/-1.0$	$23.1 \pm 0.9 \pm 1.5$	24.5	24.1	$+0.8/-1.1$

A^R = Resbos + CT10W predictions

A^M = MCFM + CT10W predictions

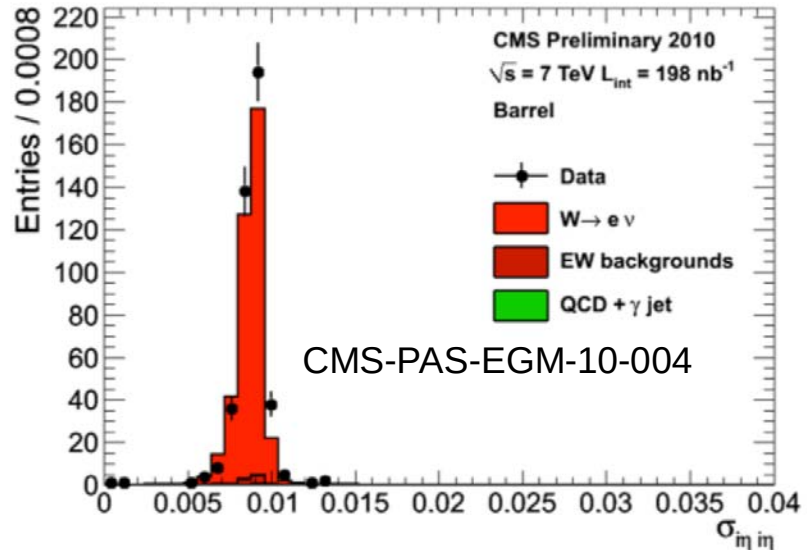
Summary

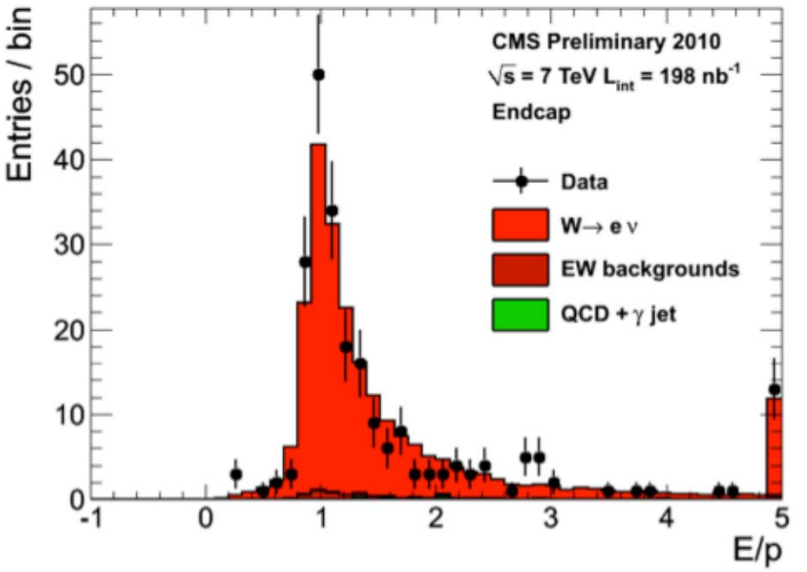
- We have measured the lepton charge asymmetry in both electron and muon channels with 36 pb^{-1} with two different charged lepton pt cut (arxiv:1103.3470)
- The precision is <1.6% in each bin
- Electron and muons results are in good agreement with each other.
- Our data suggests a flatter η dependence of the asymmetry than the PDF models studied
- Precision of the measurements is significant enough to provide new inputs to PDF global fits
- Results will be published soon in JHEP

Back-up

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 Selection

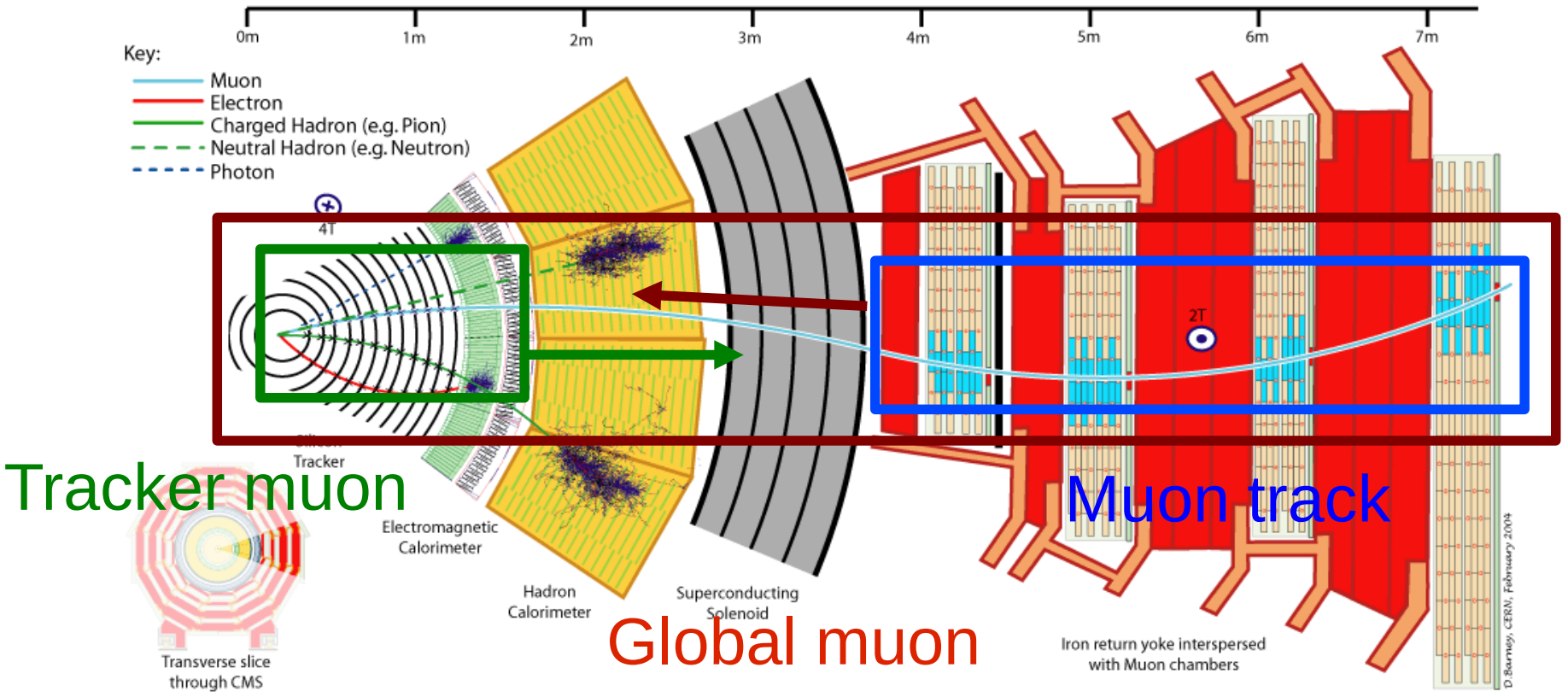
- Electron Selection:
  - PT > 25 GeV
- Electron Identification
  - Track cluster matching
  - Shower shape and H/E
  - Track, ECAL and HCAL isolation
  - Conversion rejection
- Z veto
  - 2nd lepton with Pt > 15 GeV
- Require that all three methods of charge assignment agree to reduce misassignment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

Variable	cut value (barrel)	cut value (endcap)
ID Cuts		
H/E	0.04	0.025
$\Delta\phi$	0.06	0.03
$\Delta\eta$	0.004	0.007
$\sigma_{\eta\eta}$	0.01	0.03
Isolation Cuts		
ISO_{trk}/E_T	0.09	0.04
ISO_{ecal}/E_T	0.07	0.05
ISO_{hcal}/E_T	0.10	0.025
Conversion Rejection Cuts		
Missing Hits	≤ 0	
Dist || Dcot	> 0.02	

- With electron pT > 25 GeV/c:
  185K W→eν candidates
  - QCD background 28.0%,
  - EWK background 6.4%,
  - ttbar background 0.3%

Muon Reconstruction

- 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 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

Variable	Cut value
Global Track Fitting chi-squared	< 10
Silicon Track Hits	$>= 11$
Valid Muon Hit	$>= 1$
Valid Pixel Hit	$>= 1$
Muon Matches	> 1
$\|dxy\|$ (beam spot)	$< 0.2cm$

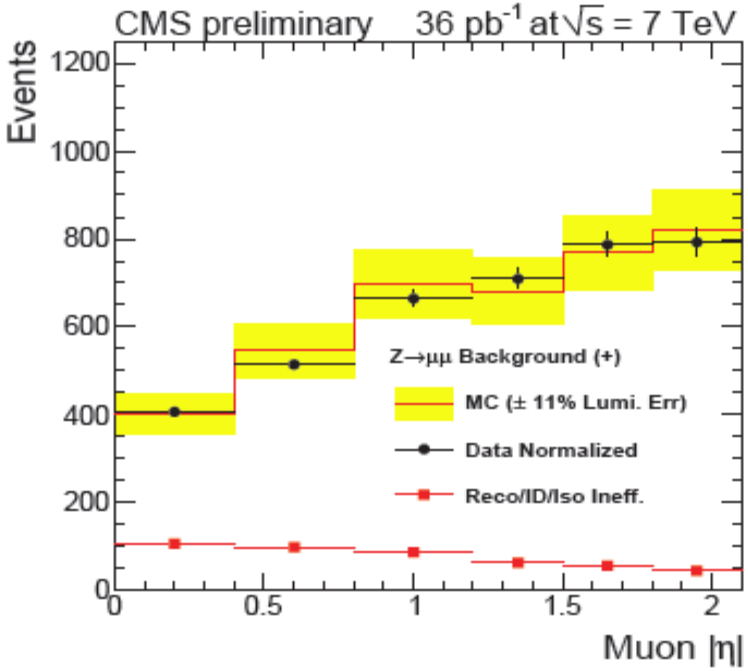
- With muon pT > 25 GeV/c:

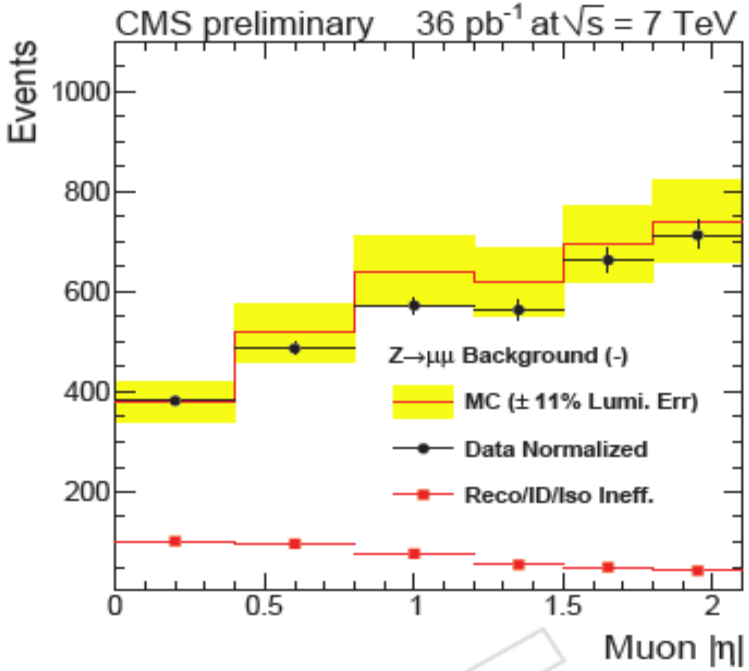
271K $W \rightarrow \mu\nu$ candidates

- QCD background 13.0%,
- EWK background 6.8%,
- ttbar background 0.3%

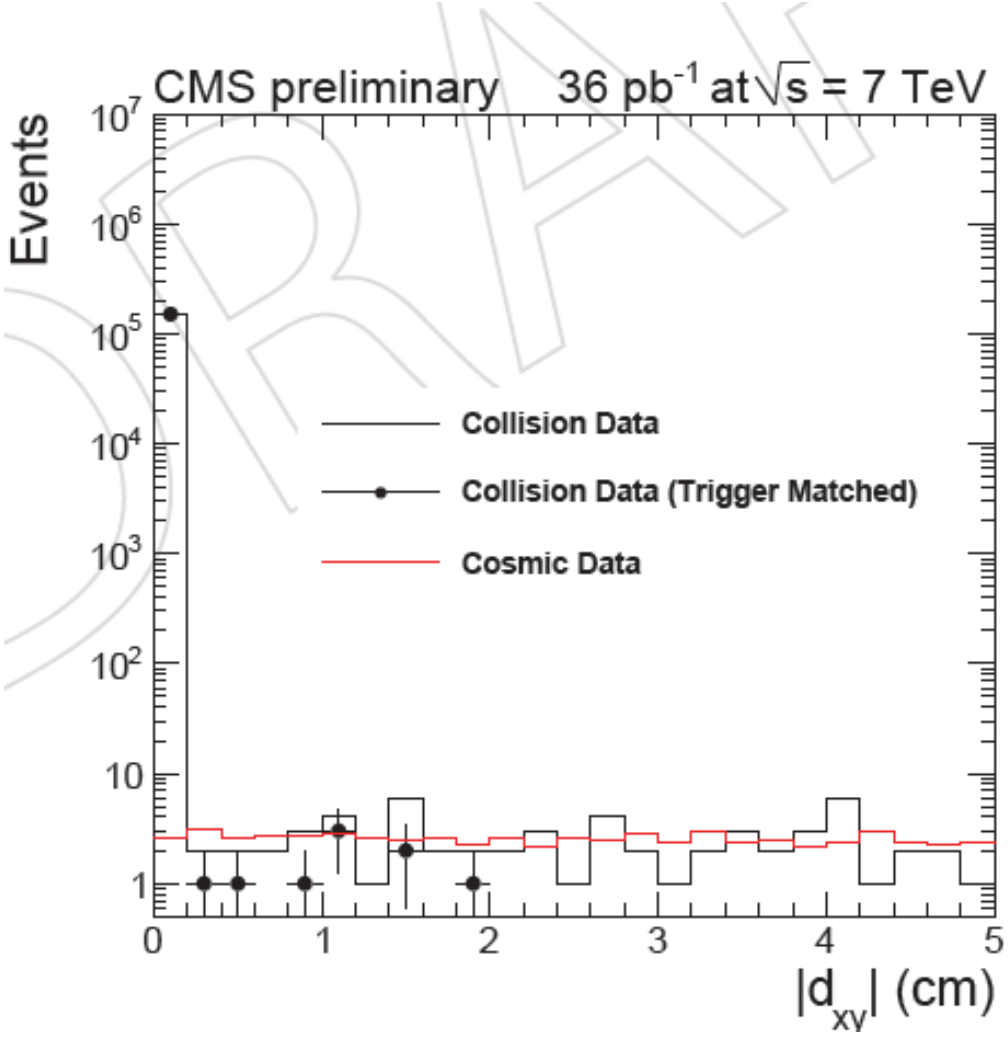
Drell-Yan Background estimation in the muon channel

- 2 sources of background:
  - One lepton out of the detector acceptance (90%)
    - DY reco events (from DATA) * relative acceptance (from MC)
  - Reconstruction/Identification inefficiency (10%)
    - Estimated in data



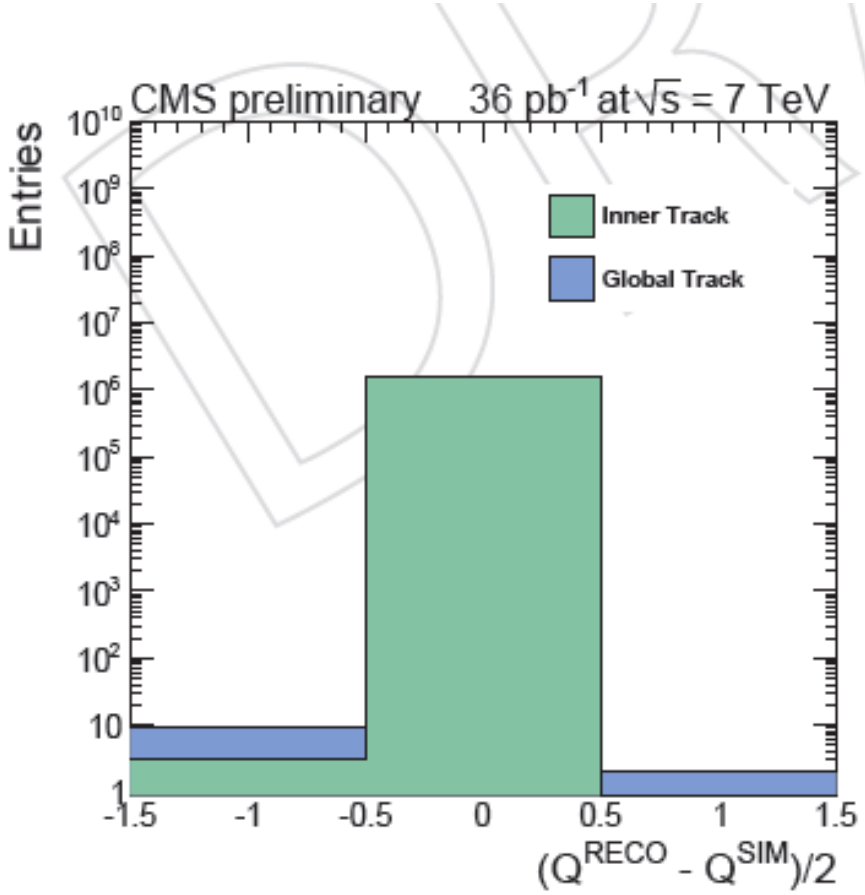


Background from cosmic rays



Estimation perfomed by extrapolating the impact parameter distribution in the signal region

Muon charge misassignment from MC



Electron results for pt>35 GeV