Measurement of the Lepton Charge Asymmetry in InclusiveW Production in pp Collisions at $\sqrt{s}$ = 7 TeV at the CMS experiment

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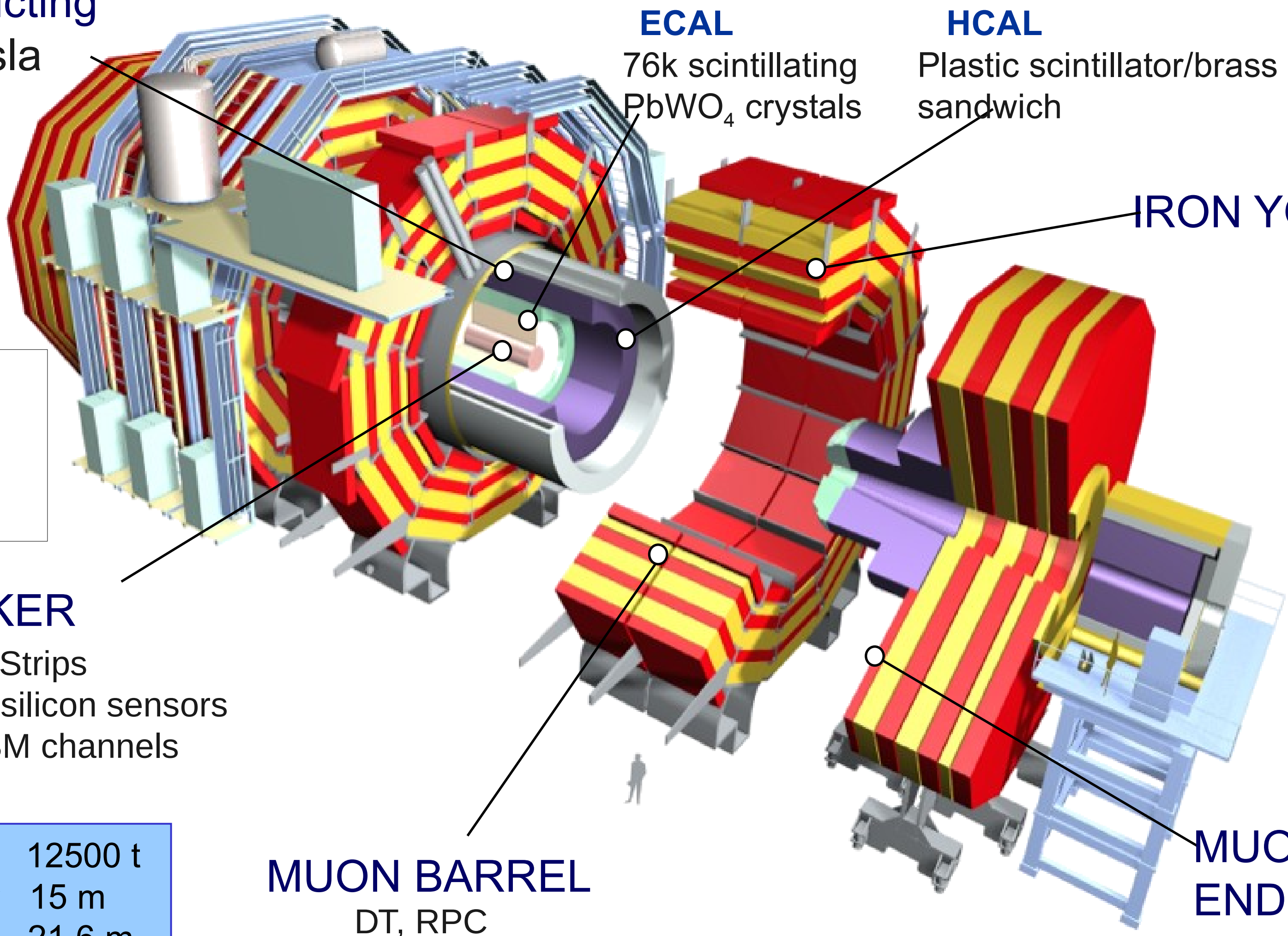
on the behalf of the CMS Collaboration

Outline

- CMS Detector
- Motivations
- Previous measurements
- Asymmetry measurement
  - Electron reconstruction and signal extraction
  - Muon reconstruction and signal extraction
- Results and conclusions

The CMS Detector



38 Nations,
182 Institutions,
2900 scientists

Total weight	12500 t
Overall diameter	15 m
Overall length	21.6 m

Motivation

- Exploring the proton structure via the asymmetric production of W bosons
- The lepton charge asymmetry is defined as:

$$A(\eta)=\frac{d\sigma/d\eta(W^{+}\rightarrow l^{+}\nu)-d\sigma/d\eta(W^{-}\rightarrow l^{-}\bar{\nu})}{d\sigma/d\eta(W^{+}\rightarrow l^{+}\nu)+d\sigma/d\eta(W^{-}\rightarrow l^{-}\bar{\nu})}$$

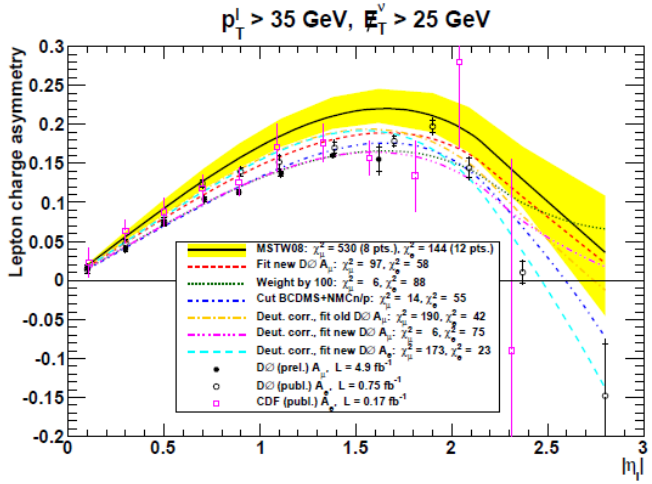
  - The direct observable is the lepton asymmetry which is the combination of the W asymmetry and the well understood parity violation in W decay

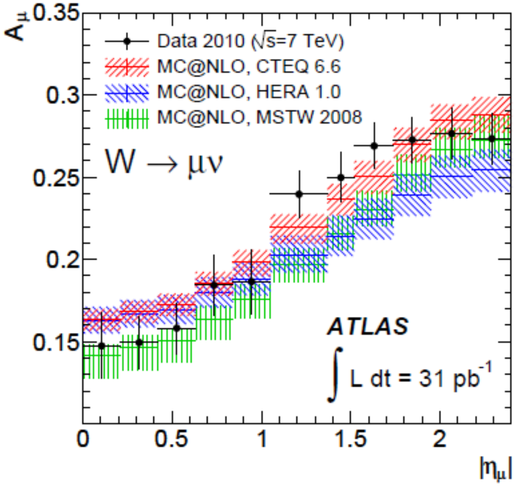
$$A(\eta)=\frac{l^{+}{}_{\eta}-l^{-}{}_{\eta}}{l^{+}{}_{\eta}+l^{-}{}_{\eta}}$$

- Precise prediction from the SM:
  - About 4-5% relative error. Prediction from different PDF models don't agree each other within the PDF error

Previous Measurements

- Charge asymmetry results at Tevatron:
  - D0 (Phys. Rev. Lett. 101, 211801)
  - CDF (Phys. Rev. Lett. 102, 181801)
- Inconsistency between Tevatron results and PDF global fits
  - Lai et al. (Phys. Rev. D82, 074024)
  - Martin et al. (arXiv:hep-ph/1006.2753v2)
- Charge asymmetry measured by ATLAS:
  - arXiv:hep-ex/1010.2130v1
  - arXiv:hep-ex/1103.2929





Measurement Strategy

- Searching for a high pT lepton + missing transverse energy
  - Backgrounds: multijet and photon + jets (QCD), Drell-Yan, $t\bar{t}$, and $W \rightarrow \tau\nu$ (EWK) production, cosmic muons
- Measurement performed in both electron and muon channels
  - The two measurements are independent and cross check each other
- Analysis is based on the data recorded by CMS detector in the 2010, corresponding to an integrated luminosity of 36 pb^{-1}

Electron Selections

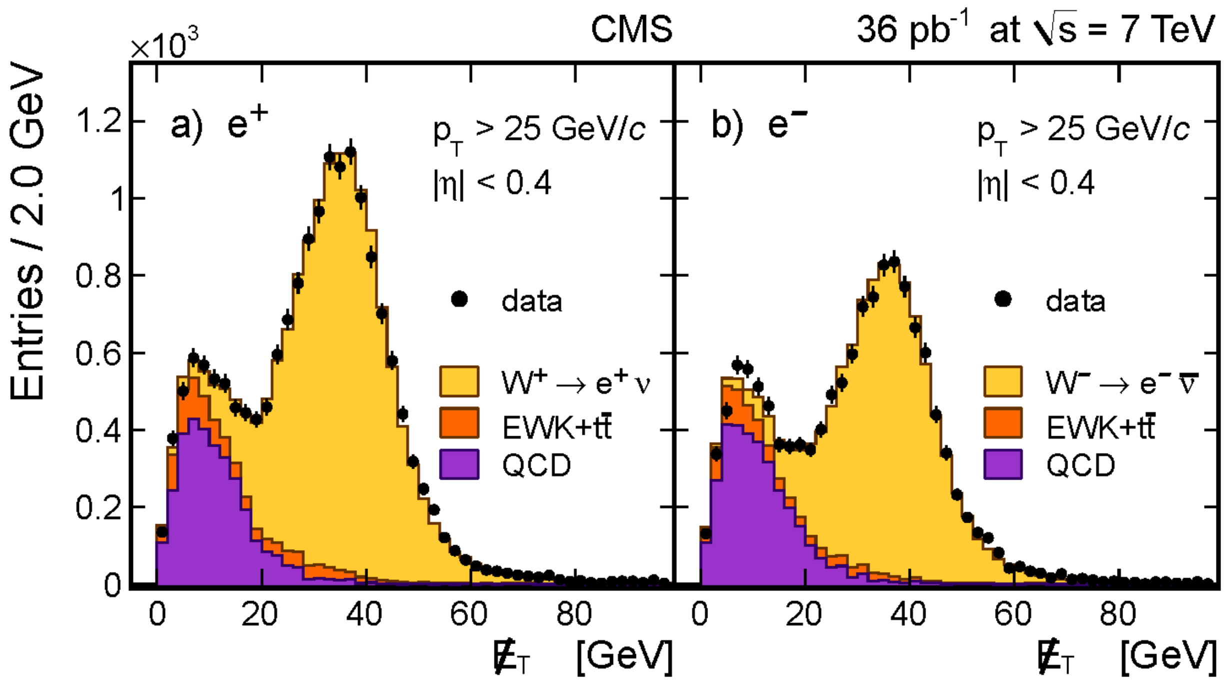
- Electron are identified as cluster of energy in ECAL matched with tracks in the inner silicon tracker.

- Signal selections:
  - The charge is measured in three method (2 track algorithms and one method is based on the azimuthal angle between the interaction point (IP) – ECAL cluster vector and IP – first hit of the track vector). The results are required to be equal.
  - 1 isolated e^- (e^+) with pT > 25 GeV/c, $|\eta|< 2.4$
  - One of the electron trigger candidates fired
  - No other isolated electron (positron) in the event having pT > 15 GeV/c and $|\eta|< 2.4$

Electron signal extraction

- The W→eν signal yield for electrons and positron is extracted with a binned extended likelihood fit of the E_t^{miss} distributions
- The charge asymmetry is obtained from:

$$\frac{N^+ - N^-}{N^+ + N^-}$$



Results of the fits to the data for the first η-bin [0., 0.4]

Muon selections

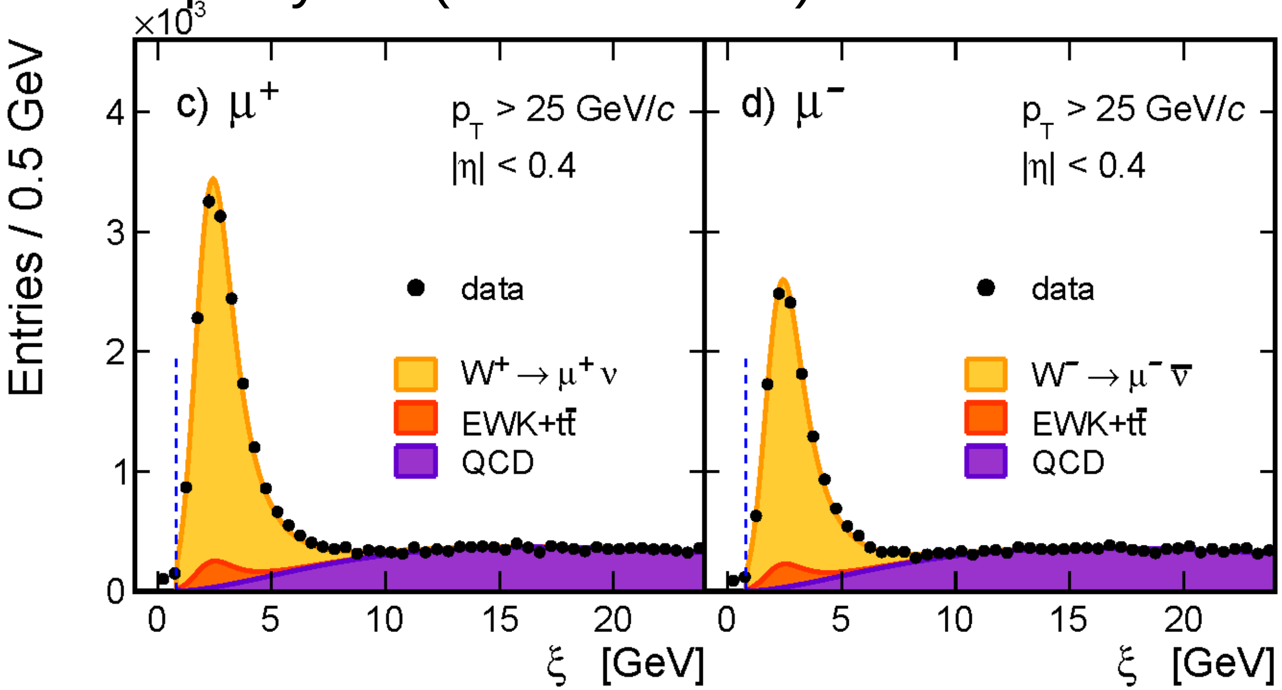
- Muons are reconstructed using muon and tracker detectors.
- Charge value identified from the curvature of the associated silicon track.

- No isolation requirements
- Cut on the distance of closest approach to the beam spot $|d_{xy}|<0.2$
  - Residual cosmic ray contamination is neglected:~10^{-5} of the expected signal yield
- Pt (μ) > 25 GeV/c, $|\eta|< 2.1$
- Veto on a second muon with pt > 15 GeV/c, $|\eta|< 2.4$ and passing the first three requirements (DY suppression)

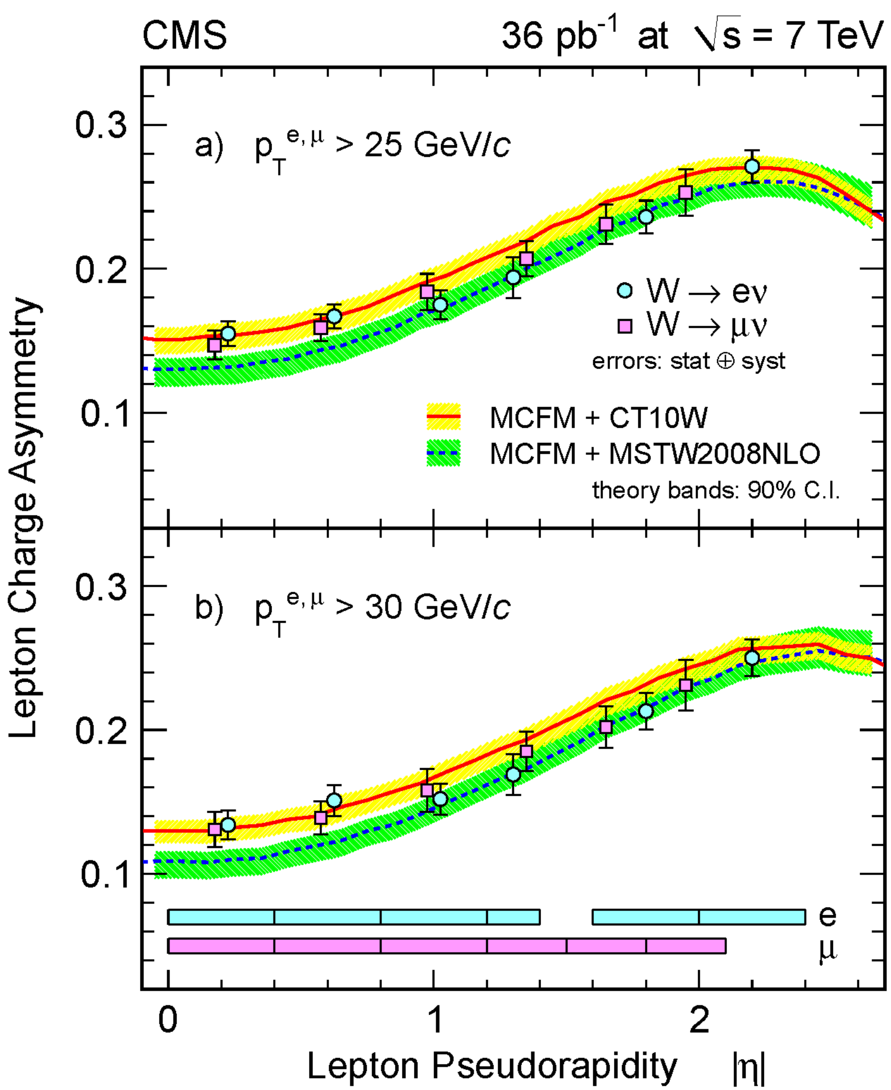
Muon signal extraction

- The total signal yield, and charge asymmetry, is extracted using an unbinned extended maximum likelihood fit to the distribution of $\xi = \Sigma\,(E_T)$
  - ξ: scalar sum of the transverse momenta of the silicon tracks (excluding the muon candidate) and the energy deposit in both ECAL and HCAL in a cone $\Delta R < 0.3$ around the muon direction

  for each pseudorapidity bin (6 bins in total)



Asymmetry Results

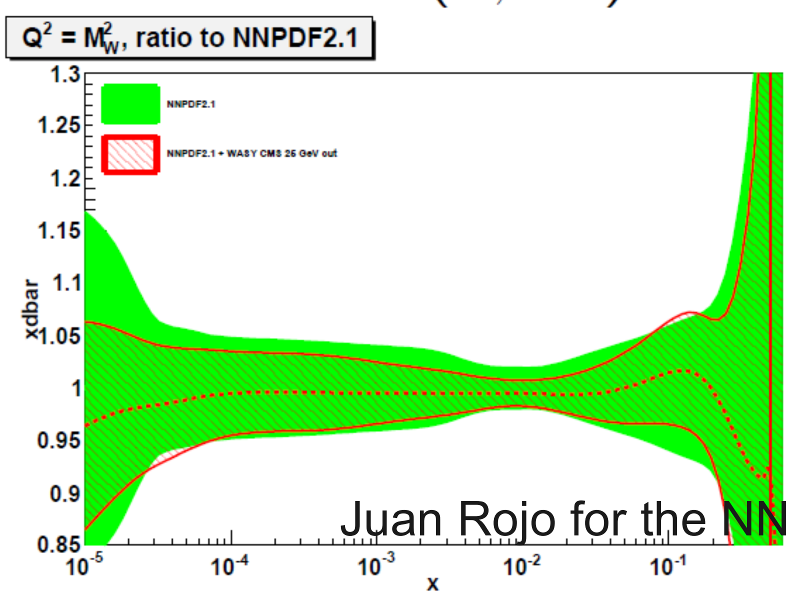


- Lepton charge asymmetry in six bins of absolute lepton pseudorapidity |η|.
  - No threshold on the transverse missing energy is applied.
  - The error bars correspond to the sum in quadrature of statistical and systematic uncertainties.
  - The CMS data are compared to two theory predictions at the NLO in QCD
- CMS data suggest a flatter pseudorapidity dependence of the asymmetry than the PDF models studied

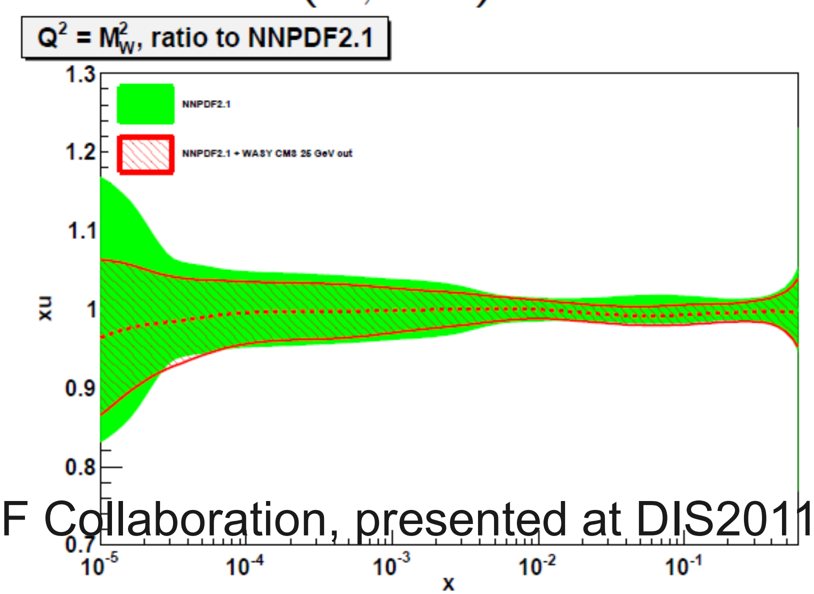
Conclusions

- The CMS experiment has measured the lepton charge asymmetry in both the electron and muon decay channels using 36 pb^{-1} of integrated luminosity
- In each pseudorapidity bin the precision is better than 1.6% for both electron and muon channels
- This high precision measurement provides new inputs to the PDF global fit.

$\bar{d}(x, Q^2)$



$u(x, Q^2)$



References

- CMS Collaboration, *Measurement of the Lepton Charge Asymmetry in InclusiveW Production in pp Collisions at* $\sqrt{s}$ *= 7 TeV*, arXiv:1103.3470
- Juan Rojo for the NNPDF Collaboration, https://wiki.bnl.gov/conferences/images/b/b7/Parallel.SF-PD.RojoJuan-NNPDF-EWK.041211.talk.pdf , DIS2011

Backup slides

Electron signal extraction - II

- The signal E_t^{miss} shape is derived from MC simulation with an event by event correction to account for the energy scale and resolution difference between data and MC based on the hadronic recoil energy distribution in $Z/\gamma^* \rightarrow e^+e^-$
- QCD background from a signal free data sample obtained inverting the selections
- Other background (Drell – Yan, $t\bar{t}$ and $W \rightarrow \tau\nu$) from MC simulations. Fixed normalization relative to the signal yield from NLO cross sections
  - According to our MC simulations, the background composition is:
    - 28% QCD
    - 6.5% EWK
    - 0.2% $t\bar{t}$
- Yields of QCD and signal are free parameters in the fit

Muon signal extraction - II

- The calorimeter energy deposit is corrected to ensure a uniform transverse energy response as a function of polar angle
- After the correction, the energy deposit is independent from the polar angle
- The correction is obtained from MC and checked with real $Z/\gamma^* \rightarrow \mu\mu$
- The $W \rightarrow \mu\nu$ signal, DY, $t\bar{t}$, and $W \rightarrow \tau\nu$ backgrounds show the same and lepton charge independent shape (MC study plus $Z/\gamma^* \rightarrow \mu\mu$ real data)
- QCD background shape has been determined from a control sample obtained selecting events with large impact parameter and little E_t^{miss}
- The expected QCD multijet, EWK and tt background are about ~13%, 6.9% and 0.3% in the ξ region 0-10 GeV

Systematics - I

- Lepton charge misidentification rate
  - Electrons: studied with $Z/\gamma^* \rightarrow e^+e^-$ real data, misid rate is 0.1-0.4% increasing with lepton pseudorapidity. The measured electron charge asymeetry is corrected with the value and the statistical error of the misID rate is taken as systematics uncertainty
  - Muons: studied with cosmic rays, less than 10^{-4}. Estimated from MC $\sim 10^{-5}$. It has been considered negligible
- Possible efficiency differences between positive and negative leptons
  - The total lepton efficiency is found compatible to one studying the $Z/\gamma^* \rightarrow l^+l^-$ data samples for l^+ and l^- respectively. No correction is applied
  - Electrons: measured inclusive efficiency ratio: 1.007 ± 0.014. The error is used to determine the systematic uncertainty
  - Muons: the statistical uncertainty of the bin by bin efficiency ratio is used

Systematics – II

- Lepton momentum (energy) scale and resolution. These corrections are necessary to compare the results with theoretical predictions
  - Lepton scale and resolution are determined from $Z/\gamma^* \rightarrow l^+l^-$ data and are used to smear MC lepton p_T^l at generator level. The corrections are obtained comparing the asymmetry result in MC before and after the smearing. The correction uncertainties are taken as source of systematics
    - Electrons: the energy scale bias is dominant and within 1%
    - Muons: the momentum scale bias is dominant and within 1%
  - QED final stare radiation (FSR) is also considered, it reduced the asymmetry by 0.001 – 0.002. The correction is an additional source of systematics.

Systematics – III

- Signal parametrization: small bias at the level of 0.001-0.002. Studied with pseudo-experiments
  - QCD background in electron channel studied varying the control region
  - DY background in muonic channel dominated by the limited number of the $Z/\gamma^* \to \mu\mu$ and variations of the acceptance ratio for one vs two muons. This ratio is studied using POWHEG and PYTHIA
  - $t\bar{t}$ varied by 18.6% according to the theoretical uncertainty of the cross section
  - The ratio of the $W \to \tau\nu$ background to the $W \to \mu\nu$ signal and ratio of the $Z/\gamma^* \to \tau\tau$ background to the $Z/\gamma^* \to \mu\mu$ background are estimated using both POWHEG and PYTHIA MC simulations.

Summary of Systematics

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

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

All values are in percent

Asymmetry results

	$p_T^\ell > 25\,\mathrm{GeV}/c$				$p_T^\ell > 30\,\mathrm{GeV}/c$			
$\|\eta^e\|$	$\mathcal{A}$(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	$+0.8/-1.1$
$\|\eta^\mu\|$	$\mathcal{A}(\mu)$($\pm$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	$+0.8/-1.1$

- The theoretical predictions are obtained using RESBOS (A^R) and MCFM (A^M) interfaced with CT10W PDF model. The PDF uncertainties (Δ(+/-)) are estimated using the PDF reweighting technique. The charge asymmetries and PDF errors are given in percent.