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Electron Charge Asymmetry in $pp \rightarrow W + X \rightarrow l\nu + X$ production @ $E_{cm} = 7\text{TeV}$

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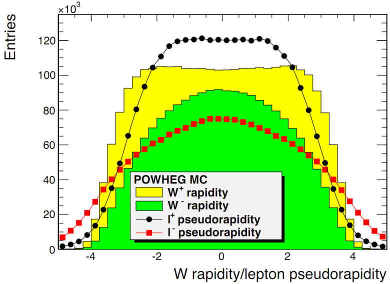
Outline

- Introduction
- History
- Analysis
- 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.
- Boson rapidity is not directly accessible
- Direct accessible measurement is the lepton charge asymmetry

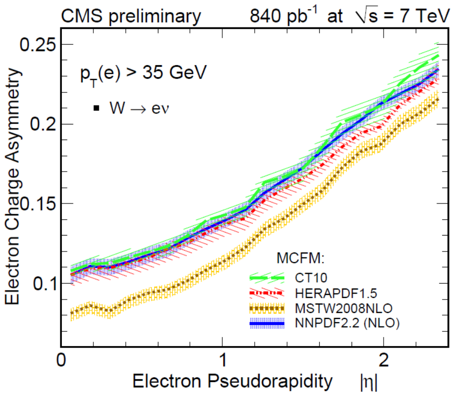


$$A_{th}(\eta) = \frac{\frac{d\sigma}{d\eta}(W^+ \to e^+\nu_e) - \frac{d\sigma}{d\eta}(W^- \to e^-\nu_e)}{\frac{d\sigma}{d\eta}(W^+ \to e^+\nu_e) + \frac{d\sigma}{d\eta}(W^- \to e^-\nu_e)} \quad (1)$$

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

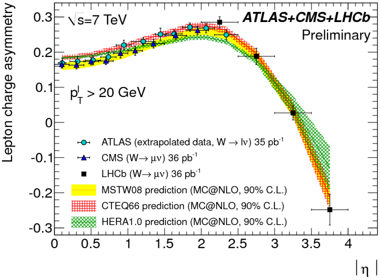
Motivation

- Theoretical prediction precision 4 – 5%
- Current predictions for the asymmetry at the LHC do not agree



History

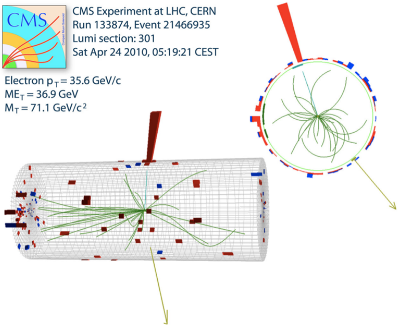
- Previous CMS measurement with the full 2010 dataset of $36pb^{-1}$ in both electron and muon channel
- Lepton charge asymmetry and W charge asymmetry also been studied at ATLAS and LHCb
- Muon channel measurement using $234pb^{-1}$ of 2011 dataset



- This new measurement has been performed with $840pb^{-1}$ of data from the 2011 dataset.

Analysis Overview

- $W \rightarrow e\nu$ characterised by
  - High Pt lepton
  - Missing transverse energy (MET) due to neutrino
- Background contributions,
  - EWK background ($W \rightarrow \tau\nu$, Drell-Yan)
  - $t\bar{t}$ background
  - QCD background (multi-jet, photon+jet)
- The number of the electron / positron is extracted from a extended binned likelihood fit of the MET distribution
- 11 bins in $|\eta|$
  - $0.0 < |\eta| < 2.4$ in bin widths of 0.2
  - $[1.4 - 1.6]$ bin excluded because of the transition region between Ecal Barrel and Ecal Endcap



Event Selection

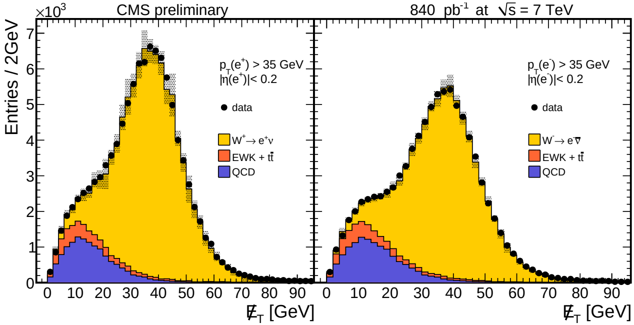
- Electron Selection:
  - $P_T > 35 GeV$
  - Constrained by trigger
- Electron Identification
  - Track cluster matching
  - Shower shape and H/E
  - Track, ECAL and HCAL isolation
  - Conversion rejection
- Z veto
  - 2nd lepton with $P_T > 15$ GeV
- Require that all three methods of charge assignment agree to reduce misassignment (Gaussian Sum Filter, Kalman Filter, Relative phi position of cluster center and first tracker hit)

	$P_T > 35$ GeV
$W \rightarrow e\nu$	76.2%
QCD Background	16.0%
EWK Total Background	7.8%
EWK DYtautau	0.2%
EWK DYee	6.4%
EWK Wtaunu	0.8%
EWK ttbar	0.4%

Table: Composition of selected events.

Selected Events

- Apply electron selection, then extended binned maximum likelihood fit to the MET distribution for electrons and positrons separately
- Two template shapes:
  - Signal + EWK backgrounds : MC + correction from $Z \to ee$ recoil in data
  - QCD shape is determined using a signal-free control sample obtained by inverting a subset of the electron ID criteria



Systematics and Corrections

- To compare with the theoretical value, the measured lepton asymmetry has to be corrected for experimental effects:
  - Charge mis-id (ω):
    - Introduces a dilution factor to the real asymmetry
    - Evaluated from the ratio same-sign / opposite-sign Z yield
    - Statistical error propogated to asymmetry as systematic error
  - Relative detection efficiency ($R = \epsilon^{+}/\epsilon^{-}$) between electrons and positrons:
    - The detection efficiency is different for electrons and positrons and produces a bias in the measured asymmetry
    - Measured with tag and probe.
    - Systematic error (energy scale and signal shape) cancel out in the ratio R, only the statistical error is propagated to R

$$\mathcal{A}_R = \frac{1}{1-2\omega}\frac{\mathcal{A}_M(R+1)-(R-1)}{(R+1)-\mathcal{A}_M(R-1)} \simeq \frac{1}{1-2\omega}\left(\mathcal{A}_M - \frac{(R-1)\left(1-\mathcal{A}_M^2\right)}{2}\right) \quad (2)$$

Systematics and Corrections

- Signal extraction method
  - Systematic uncertainties evaluated by varying the shapes used in the fits
- Energy Scale and Resolution
  - The electron energy resolution and scale can introduce a bias on the asymmetry, due to the effect of resolution for leptons with a transverse momentum close to P_T cut.
  - The correction factor has been evaluated by comparing the asymmetry at gen level and the asymmetry after simulating the particle-matter interaction
  - An additional data/mc correction is applied to account for differences between data and simulation

$$P_T^{sim} = P_T^{gen} \otimes Res^{MC} \otimes Res^{Data/MC} \tag{3}$$

  - where:
    - P_T^{gen} is from resbos with CT10
    - Res^{MC} is from a $(W \rightarrow e\nu)$ MC sample
    - $Res^{Data/MC}$ is from a residual data/MC correction

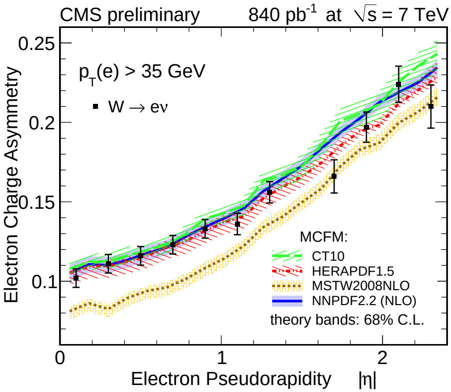
Summary of Systematic Uncertainties

	Stat Error	Signal Yield	Energy Scale and Res.	Charge MisId.	Efficiency Ratio
$0.0 < \|\eta\| < 0.2$	3	1.8	0.6	0.0	4.5
$0.2 < \|\eta\| < 0.4$	3	2.5	0.6	0.0	4.4
$0.4 < \|\eta\| < 0.6$	3	2.7	0.3	0.0	4.4
$0.6 < \|\eta\| < 0.8$	3	2.5	0.3	0.0	4.4
$0.8 < \|\eta\| < 1.0$	3	1.9	0.6	0.1	4.4
$1.0 < \|\eta\| < 1.2$	3	2.4	1.0	0.1	4.9
$1.2 < \|\eta\| < 1.4$	3	2.6	0.8	0.1	5.4
$1.6 < \|\eta\| < 1.8$	3	3.1	0.8	0.1	9.2
$1.8 < \|\eta\| < 2.0$	3	2.0	1.6	0.2	8.7
$2.0 < \|\eta\| < 2.2$	3	2.0	2.6	0.3	10.0
$2.2 < \|\eta\| < 2.4$	4	2.9	2.4	0.3	12.5

Table: Summary of systematic errors, $(\times 10^{-3})$.

- The efficiency ratio is the dominant source of systematic error on our measurement
- This is limited by statistics of the Z data sample
- We also give a full error correlation matrix with the measurement (backup)

Results


CMS preliminary
840 pb-1 at √s = 7 TeV
pT(e) > 35 GeV
W → eν
MCFM:
CT10
HERAPDF1.5
MSTW2008NLO
NNPDF2.2 (NLO)
theory bands: 68% C.L.
Electron Charge Asymmetry
Electron Pseudorapidity |η|
0.25
0.2
0.15
0.1
0
1
2

Conclusion

- Lepton charge asymmetry has been measured in $W \to e\nu$ for $P_T > 35$ GeV in 11 $|\eta|$ bins with 840 pb^{-1}
- $\sigma(Ae) = (6 - 14)x10^{-3}$
- This measurement data with full error correlation matrix will be used by theorists to improve the knowledge of PDFs

Backup

Selection

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	

Table: Electron selection.

Results

Table: Summary of the measured charge asymmetry results. All values are in units $\times 10^{-3}$.

	Measured Asymmetry ($\mathcal{A}$)	Theory Prediction CT10	HERAPDF	MSTW	NNPDF
$0.0 < \lvert\eta\rvert < 0.2$	$102 \pm 3 \pm 5$	109^{+5}_{-5}	106^{+4}_{-8}	83^{+3}_{-5}	107 ± 5
$0.2 < \lvert\eta\rvert < 0.4$	$111 \pm 3 \pm 5$	114^{+5}_{-5}	110^{+4}_{-8}	85^{+3}_{-5}	110 ± 5
$0.4 < \lvert\eta\rvert < 0.6$	$116 \pm 3 \pm 5$	119^{+5}_{-5}	115^{+4}_{-8}	92^{+3}_{-5}	116 ± 5
$0.6 < \lvert\eta\rvert < 0.8$	$123 \pm 3 \pm 5$	126^{+5}_{-5}	122^{+4}_{-8}	98^{+3}_{-5}	123 ± 5
$0.8 < \lvert\eta\rvert < 1.0$	$133 \pm 3 \pm 5$	138^{+5}_{-6}	132^{+4}_{-8}	108^{+4}_{-5}	134 ± 5
$1.0 < \lvert\eta\rvert < 1.2$	$136 \pm 3 \pm 6$	146^{+6}_{-6}	140^{+5}_{-8}	120^{+4}_{-5}	145 ± 5
$1.2 < \lvert\eta\rvert < 1.4$	$156 \pm 3 \pm 6$	164^{+6}_{-7}	153^{+5}_{-7}	136^{+5}_{-5}	158 ± 5
$1.6 < \lvert\eta\rvert < 1.8$	$166 \pm 3 \pm 10$	195^{+8}_{-9}	181^{+5}_{-5}	168^{+5}_{-5}	190 ± 4
$1.8 < \lvert\eta\rvert < 2.0$	$197 \pm 3 \pm 9$	207^{+8}_{-10}	196^{+4}_{-3}	184^{+6}_{-5}	206 ± 4
$2.0 < \lvert\eta\rvert < 2.2$	$224 \pm 3 \pm 11$	224^{+8}_{-11}	211^{+5}_{-3}	198^{+6}_{-5}	219 ± 4
$2.2 < \lvert\eta\rvert < 2.4$	$210 \pm 4 \pm 13$	241^{+8}_{-12}	225^{+9}_{-4}	214^{+6}_{-5}	231 ± 5

Covariance Matrix

	[0.0, 0.2]	[0.2, 0.4]	[0.4, 0.6]	[0.6, 0.8]	[0.8, 1.0]	[1.0, 1.2]	[1.2, 1.4]	[1.6, 1.8]	[1.8, 2.0]	[2.0, 2.2]	[2.2, 2.4]
[0.0, 0.2]	23.7	2.6	2.2	2.5	2.7	2.9	2.9	2.9	2.8	3.1	4.2
[0.2, 0.4]	2.6	26.2	2.6	2.9	3.1	3.3	3.4	3.2	3.0	3.9	4.7
[0.4, 0.6]	2.2	2.6	26.6	2.6	2.8	2.9	3.2	2.9	2.5	3.3	4.1
[0.6, 0.8]	2.5	2.9	2.6	25.6	3.3	3.4	3.7	3.3	2.8	3.7	4.7
[0.8, 1.0]	2.7	3.1	2.8	3.3	23.3	3.9	4.2	3.7	3.4	4.6	5.6
[1.0, 1.2]	2.9	3.3	2.9	3.4	3.9	30.8	4.5	4.1	4.0	5.7	6.8
[1.2, 1.4]	2.9	3.4	3.2	3.7	4.2	4.5	36.5	4.3	3.7	5.8	6.7
[1.6, 1.8]	2.9	3.2	2.9	3.3	3.7	4.1	4.3	94.9	3.8	5.1	6.2
[1.8, 2.0]	2.8	3.0	2.5	2.8	3.4	4.0	3.7	3.8	82.4	6.2	7.0
[2.0, 2.2]	3.1	3.9	3.3	3.7	4.6	5.7	5.8	5.1	6.2	110.7	10.3
[2.2, 2.4]	4.2	4.7	4.1	4.7	5.6	6.8	6.7	6.2	7.0	10.3	171.0

Table: Covariance matrix, $(\times 10^{-6})$.