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Measurement of the Lepton Charge Asymmetry in Inclusive pp $\rightarrow$ W + X $\rightarrow$ (e/ν) + X Production at $\sqrt{s}$ = 7 TeV

Michele Pioppi for the CMS Collaboration

Abstract

A measurement of the lepton charge asymmetry in inclusive pp $\rightarrow$ WX production at $sqrts$ = 7 TeV is presented based on data recorded by the CMS detector at the LHC and corresponding to an integrated luminosity of 36 pb^{-1}

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Measurement of the Lepton Charge Asymmetry in Inclusive W Production in pp Collisions at $\sqrt{s} = 7\,\mathrm{TeV}$ with the CMS detector

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Abstract. A measurement of the lepton charge asymmetry in inclusive $\mathrm{pp} \rightarrow \mathrm{W}X$ production at $\sqrt{s} = 7\,\mathrm{TeV}$ is presented based on data recorded by the CMS detector at the LHC and corresponding to an integrated luminosity of 36 pb^{-1}.

Keywords: CMS, Charge Asymmetry, PDF
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INTRODUCTION

In pp collisions, W bosons are produced primarily via the processes $\mathrm{u\bar{d}} \rightarrow \mathrm{W}^+$ and $\mathrm{d\bar{u}} \rightarrow \mathrm{W}^-$. Due to the presence of two valence u quarks in the proton, there is an overall excess of W^+ over W^- bosons. A high precision measurement of this production asymmetry as a function of boson rapidity at the LHC can contribute to the improvement of the knowledge of the parton distribution functions PDFs [1, 2]. However, due to the presence of neutrinos in leptonic W decays the boson rapidity is not directly accessible. The experimentally accessible quantity is the lepton charge asymmetry, defined to be $\mathscr{A}(\eta) = \frac{\mathrm{d}\sigma/\mathrm{d}\eta(\mathrm{W}^+\rightarrow\ell^+\nu)-\mathrm{d}\sigma/\mathrm{d}\eta(\mathrm{W}^-\rightarrow\ell^-\bar{\nu})}{\mathrm{d}\sigma/\mathrm{d}\eta(\mathrm{W}^+\rightarrow\ell^+\nu)+\mathrm{d}\sigma/\mathrm{d}\eta(\mathrm{W}^-\rightarrow\ell^-\bar{\nu})}$, where ℓ is the daughter charged lepton, η is the charged lepton pseudorapidity in the CMS [3] lab frame.

The lepton charge asymmetry has been studied in $\mathrm{p\bar{p}}$ collisions by both the CDF and D0 experiments at the Fermilab Tevatron Collider [4, 5]. The measurement of the muon charge asymmetry at the LHC was reported recently by the ATLAS experiment [6]. A detailed description of the charge asymmetry measurement in $\mathrm{W} \rightarrow \mathrm{e}\nu$ and $\mathrm{W} \rightarrow \mu\nu$ final states performed by the CMS collaboration is available in this article [7].

ELECTRON RECONSTRUCTION AND $\mathrm{W} \rightarrow \mathrm{e}\nu$ SIGNAL EXTRACTION

Electrons are identified as clusters of energy deposited in the ECAL fiducial volume matched to tracks from the inner silicon tracker. The tracks are reconstructed using a Gaussian-Sum-Filter (GSF) algorithm [8]. Particles misidentified as electrons are suppressed by requiring that the shower shape of the ECAL cluster be consistent with an electron candidate, and that the η and ϕ coordinates of the track trajectory extrapolated to the ECAL match the η and ϕ coordinates of the ECAL cluster. Furthermore, electrons from W decay are isolated from other activity in the event. Candidates are therefore required to have little transverse energy in the ECAL, HCAL, and silicon tracking system within a cone around the electron direction. The $W \rightarrow e\nu$ candidates are selected by further requiring electrons to have $p_T > 25$ GeV, $|\eta| < 2.4$. The Drell–Yan and $t\bar{t}$ backgrounds are suppressed by rejecting events that contain a second isolated electron or muon with $p_T > 15$ GeV and $|\eta| < 2.4$. The events passing the above selection criteria are divided into six bins of electron pseudorapidity ($|\eta^e|$): [0.0, 0.4], [0.4, 0.8], [0.8, 1.2], [1.2, 1.4], [1.6, 2.0], and [2.0, 2.4], for the measurement of the electron charge asymmetry. A binned extended maximum likelihood fit is performed over the $\not{E}_T$ distribution to estimate the $W \rightarrow e\nu$ signal yield for electrons and positrons in each pseudorapidity bin.

MUON RECONSTRUCTION AND $W \rightarrow \mu\nu$ SIGNAL EXTRACTION

Muon candidates are reconstructed using two different algorithms: one starts from inner silicon tracks and requires a minimum number of matching hits in the muon chambers, and the other finds tracks in the muon system and matches them to silicon tracks. A global track fit including both the silicon track hits and muon chamber hits is performed to improve the quality of the reconstructed muon candidates. A selection on the silicon track distance of closest approach to the beam spot, $|d_{xy}| < 0.2$ cm, is applied to reduce the cosmic ray background. The $W \rightarrow \mu\nu$ candidates are selected by further requiring the muon p_T to be greater than 25 GeV, $|\eta| < 2.1$, and that the candidate matches one of the muon trigger candidates. The Drell–Yan background is suppressed by rejecting events which contain a second isolated muon with $p_T > 15$ GeV, $|\eta| < 2.4$, and passing the above muon quality selections. The events which passed the above selection criteria are divided into six bins of muon pseudorapidity ($|\eta^{\mu}|$): [0.0, 0.4], [0.4, 0.8], [0.8, 1.2], [1.2, 1.5], [1.5, 1.8], and [1.8, 2.1]. The $W \rightarrow \mu\nu$ signal estimation is done by fitting the distribution of an isolation variable $\xi = \Sigma(E_T)$ defined as the scalar sum of the transverse momenta of silicon tracks (excluding the muon candidate) and energy deposits in both ECAL and HCAL in a cone around the muon direction. An unbinned extended maximum likelihood fit to the ξ distribution is performed simultaneously on the $W^+ \rightarrow \mu^+\nu$ and $W^- \rightarrow \mu^-\bar{\nu}$ candidates to determine the total $W \rightarrow \mu\nu$ signal yield and the charge asymmetry in each pseudorapidity bin.

SYSTEMATIC UNCERTAINTIES

The systematic uncertainties considered for both the electron and muon channels are mainly due to the lepton charge misidentification rate, possible efficiency differences between the ℓ^+ and ℓ^-, lepton momentum (energy) scale and resolution, and signal estimation.

The electron charge misidentification rate is measured in data using the $Z/\gamma^* \rightarrow e^+e^-$ data sample to be within 0.1–0.4%, increasing with electron pseudorapidity. The measured electron charge asymmetry is corrected for the charge misidentification rate

TABLE 1. Summary of charge asymmetry ($\mathscr{A}$) results. The theoretical predictions are obtained using MCFM ($\mathscr{A}^{\mathrm{M}}$)

$\lvert\eta^{\mathrm{e}}\rvert$	$\mathscr{A}$(e) ($\pm$stat $\pm$ sys)	$\mathscr{A}(\mathrm{e})^{\mathrm{M}}$	$\lvert\eta^{\mu}\rvert$	$\mathscr{A}(\mu)$ ($\pm$stat $\pm$ sys)	$\mathscr{A}(\mu)^{\mathrm{M}}$
[0.0, 0.4]	$15.5 \pm 0.6 \pm 0.7$	$15.3^{+0.8}_{-1.0}$	[0.0, 0.4]	$14.7 \pm 0.6 \pm 0.8$	$15.3^{+0.8}_{-1.0}$
[0.4, 0.8]	$16.7 \pm 0.6 \pm 0.7$	$16.7^{+0.9}_{-1.0}$	[0.4, 0.8]	$15.9 \pm 0.6 \pm 0.7$	$16.7^{+0.9}_{-1.0}$
[0.8, 1.2]	$17.5 \pm 0.7 \pm 0.8$	$19.2^{+0.8}_{-1.1}$	[0.8, 1.2]	$18.4 \pm 0.6 \pm 1.1$	$19.2^{+0.8}_{-1.1}$
[1.2, 1.4]	$19.4 \pm 1.0 \pm 0.9$	$21.7^{+0.8}_{-1.1}$	[1.2, 1.5]	$20.7 \pm 0.7 \pm 1.0$	$22.0^{+0.8}_{-1.1}$
[1.6, 2.0]	$23.6 \pm 0.8 \pm 0.9$	$25.4^{+0.8}_{-1.1}$	[1.5, 1.8]	$23.1 \pm 0.8 \pm 1.1$	$24.5^{+0.8}_{-1.1}$
[2.0, 2.4]	$27.1 \pm 0.8 \pm 0.9$	$26.9^{+0.8}_{-1.1}$	[1.8, 2.1]	$25.3 \pm 0.8 \pm 1.4$	$26.3^{+0.8}_{-1.0}$

and the statistical error on the electron charge misidentification rate is taken as the systematic uncertainty. The muon charge misidentification rate is at 10^{-5} level showing a negligible effect on the measured muon charge asymmetry.

The efficiency difference between ℓ^+ and ℓ^- can result in a bias on the measured charge asymmetry. The efficiency ratio, measured using $\mathrm{Z}/\gamma^* \to \ell^+\ell^-$ data, is consistent with unity within the statistical uncertainty. The statistical errors on the efficiency ratios are treated as systematic uncertainties. This is the dominant systematic uncertainty for both the electron and muon channels.

The measured charge asymmetry in the electron (muon) channel is corrected for lepton energy (momentum) bias and resolution effects determined directly from the $\mathrm{Z}/\gamma^* \to \ell^+\ell^-$ data. The uncertainties on the energy (momentum) scale and resolutions are taken as sources for systematic uncertainties. The charge asymmetry is corrected for the FSR effect and the full correction is taken as additional systematic uncertainty.

Uncertainties on the signal extraction come from signal and QCD parameterization and from the Drell–Yan and $\mathrm{W} \to \tau\nu$ background estimation.

RESULTS AND CONCLUSIONS

The measured charge asymmetry results are summarized in Table 1 with both statistical and systematic uncertainties shown. The measurements have been repeated with a lepton $p_{\mathrm{T}}^{\ell} > 30$ GeV. This requirement selects a subset of events with lepton pseudorapidity closer to the W boson rapidity and enables us to test PDF predictions in a more constrained region of phase space. The electron and muon measurements are in agreement with each other. The experimental results are compared to theoretical predictions obtained using MCFM [9] generators interfaced with CT10W PDF model.

Figure 1 shows a comparison of these asymmetries to predictions from the MSTW2008NLO PDF model and the CT10W PDF model. The central values of both predictions are obtained using the MCFM MC and the PDF error bands are estimated using the PDF reweighting technique [10]. The data suggest a flatter pseudorapidity dependence of the asymmetry than the PDF models studied.

In each pseudorapidity bin the precision of the most inclusive measurements is less than 1.6% for both channels. This high precision measurement of the W lepton charge asymmetry at the LHC provides new inputs to the PDF global fits.

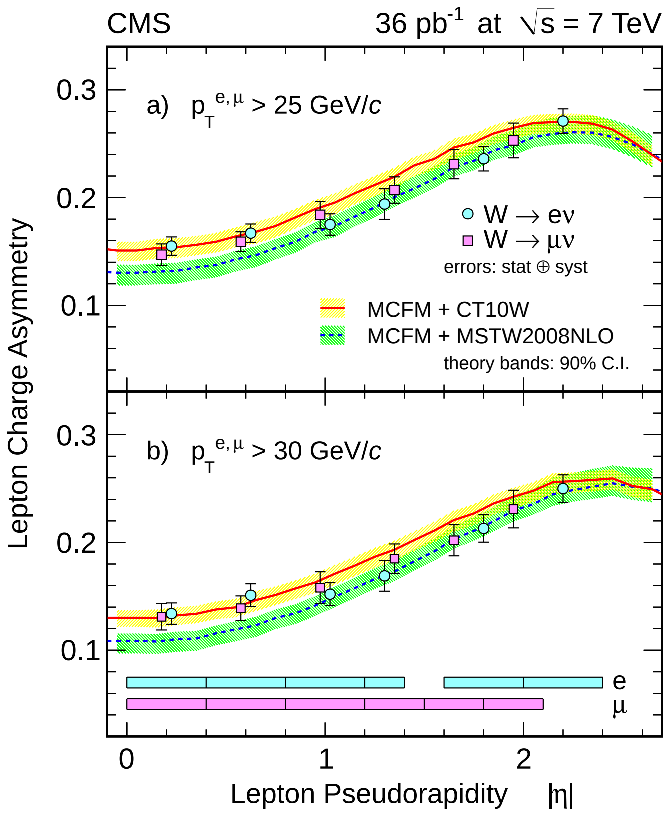

FIGURE 1. Comparison of the measured lepton charge asymmetry to different PDF models for a) lepton $p_{\mathrm{T}}^{\ell} > 25$ GeV and b) lepton $p_{T}^{\ell} > 30$ GeV.

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