IL NUOVO CIMENTO Vol. 34 C, N. 6 Novembre-Dicembre 2011
DOI 10.1393/ncc/i2011-11093-6

Colloquia: IFAE 2011

Measurement of the lepton charge asymmetry in inclusive W production in pp collisions at $\sqrt{s} = 7\,\text{TeV}$ at the CMS experiment

S. Taroni on behalf of the CMS Collaboration
Università di Perugia and INFN, Sezione di Perugia - Perugia, Italy

(ricevuto il 29 Luglio 2011; pubblicato online il 21 Dicembre 2011)

Summary. — Lepton charge asymmetry in inclusive $pp \to WX$ production at $\sqrt{s} = 7\,\text{TeV}$ has been measured by the CMS detector at the LHC, using $36\,\text{pb}^{-1}$ of data. These measurements, performed in both $W \to e\nu$ and $W \to \mu\nu$ channels, provide new insights into proton structure functions.

PACS `14.70.Fm` – W bosons.

1. – Introduction

In pp collisions, W bosons are produced primarily via the processes $\text{u}\bar{\text{d}} \to W^+$ and $\text{d}\bar{\text{u}} \to W^-$. Due to the presence of two valence u quarks in the proton, there is an overall excess of W^+ over W^- bosons. Measurement of this production asymmetry between W^+ and W^- bosons as a function of boson rapidity can provide new insights on the u/d ratio and the sea antiquark densities in the ranges of the Björken parameter x [1] probed in pp collisions at $\sqrt{s} = 7\,\text{TeV}$. 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:

$$A(\eta) = \frac{\text{d}\sigma/\text{d}\eta(W^+ \to l^+\nu) - \text{d}\sigma/\text{d}\eta(W^- \to l^-\nu)}{\text{d}\sigma/\text{d}\eta(W^+ \to l^+\nu) + \text{d}\sigma/\text{d}\eta(W^- \to l^-\nu)}, \tag{1a}$$

where l is the daughter charged lepton, η is the charged lepton pseudorapidity in the CMS lab frame ($\eta = -\ln[\tan(\theta/2)]$ where θ is the polar angle with the beam), and $\text{d}\sigma/\text{d}\eta$ is the differential cross section for charged leptons from W boson decays. The lepton charge asymmetry can be used to test SM predictions with high precision. Due to the V − A structure of the W boson couplings to fermions, theoretical predictions of the charge asymmetry depend on the transverse momentum (p_T) threshold applied on the daughter leptons. For this reason, we measure $A(\eta)$ for two different charged lepton p_T (p_T^l) thresholds, $25\,\text{GeV}/c$ and $30\,\text{GeV}/c$. The measurement is performed in

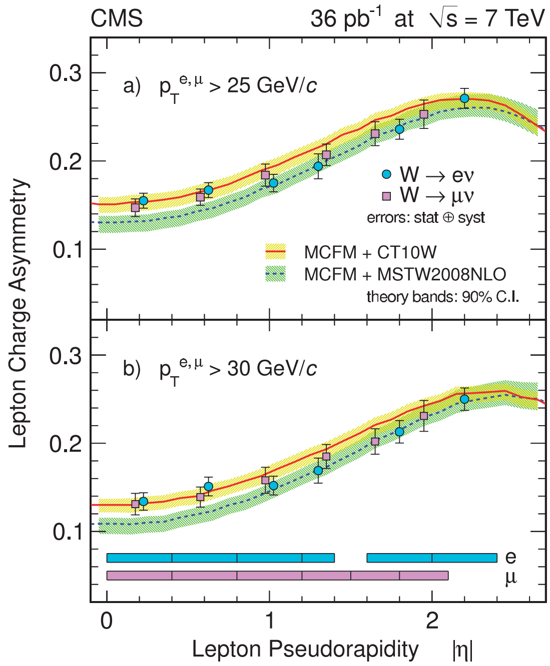

Fig. 1. – Comparison of the measured lepton charge asymmetry to different PDF models for a) lepton $p_T^l > 30\,\mathrm{GeV}/c$ and b) lepton $p_T^l > 30\,\mathrm{GeV}/c$. The error bars include both statistical and systematic uncertainties. The PDF uncertainty band is corresponding to the 90% confidence interval (CI). The bin width for each data point is shown by the filled bars in figure b). The data points are placed at the centers of pseudorapidity bins, except that for display purposes the first three data points are shifted +0.025 (−0.025) for electron (muon).

both $W \to e\nu$ and $W \to \mu\nu$ final states using a dataset corresponding to an integrated luminosity of $36\,\mathrm{pb}^{-1}$ collected by the CMS detector in March-November 2010 [2].

2. – Lepton identification and signal extraction

A detailed description of the CMS experiment can be found elsewhere [3]. This measurement is based on the excellent performance of the electromagnetic calorimeter (ECAL), of the muon system, and of the tracking system. Electrons are identified as clusters of energy deposited in the ECAL fiducial volume matched to tracks from the inner silicon tracker (silicon tracks). The $W \to e\nu$ candidates are selected by further requiring electrons to be isolated, to have $p_T > 25\,\mathrm{GeV}/c$, $|\eta| < 2.4$, and to be associated with one of the electron trigger candidates used to select the electron dataset. No selections on missing transverse energy (E_T^{miss}) are applied. According to Monte Carlo (MC) simulations, the data sample of selected electrons consists of about 28% QCD background events, about 6.5% electroweak (EWK) background events, and about 0.2% $\mathrm{t\bar{t}}$ background events. 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. The fourth bin is reduced to a width of 0.2 in order to exclude the transition region between the ECAL barrel and endcaps.

A binned extended maximum likelihood fit is performed over the E_T^{miss} distribution to estimate the $W \rightarrow e\nu$ signal yield for electrons (N^-) and positrons (N^+) in each pseudorapidity bin. The charge asymmetry is obtained from $(N^+ - N^-)/(N^+ + N^-)$.

Muons are obtained using a global track fit including both the silicon track hits and muon chamber hits in order to improve the quality of the reconstructed candidates. The muon charge is identified from the signed curvature of the associated silicon track. To reject the cosmic muons, the tracks have to come from the interaction point ($|d_{xy}| < 0.2\,\text{cm}$). The $W \rightarrow \mu\nu$ candidates are selected by further requiring the muon p_T to be greater than $25\,\text{GeV}/c$, $|\eta| < 2.1$, and that the candidate matches one of the muon trigger candidates. No isolation selection is applied. To reject the background, there is a veto on the presence of other muons having $p_T > 15\,\text{GeV}/c$ and $|\eta| < 2.4$. From MC studies, the expected QCD multijet, EWK, and $t\bar{t}$ backgrounds are about 13.0%, 6.9%, and 0.3%, respectively. 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 hadronic calorimeter (HCAL) in a cone $\Delta R < 0.3$ around the muon direction. An unbinned extended maximum likelihood fit to the ξ distribution is performed simultaneously on the $W^+ \rightarrow \mu^+\nu$ and $W^- \rightarrow \mu^-\nu$ candidates to determine the total $W \rightarrow \mu\nu$ signal yield and the charge asymmetry in each pseudorapidity bin.

3. – Asymmetry result

Figure 1 shows a comparison of these asymmetries to predictions from the CT10W PDF model [4] and the MSTW2008NLO PDF model [5]. The central values of both predictions are obtained using the MCFM MC [6] and the PDF error bands are estimated using the PDF reweighing technique [7].

Our data suggest a flatter pseudorapidity dependence of the asymmetry than the PDF models studied. The error bars of the experimental values include both the statistical and the 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.

In summary, CMS has measured the lepton charge asymmetry in both the $W \rightarrow e\nu$ and $W \rightarrow \mu\nu$ channels using a data sample corresponding to an integrated luminosity of $36\,\text{pb}^{-1}$ collected with the CMS detector at the LHC. 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.

REFERENCES

[1] Björken J. D. and Paschos E. A., *Phys. Rev.*, **185** (1969) 1975.
[2] CMS Collaboration, *JHEP*, **04** (2011) 050 and references therein.
[3] CMS Collaboration, *JINST*, **0803** (2008) S08004.
[4] Lai H. L. *et al.*, *Phys. Rev. D*, **82** (2010) 074024.
[5] Martin A. D. *et al.*, *Eur. Phys. J. C*, **63** (2009) 189.
[6] Campbell J. M. and Ellis R. K., *Phys. Rev. D*, **62** (2000) 114012.
[7] Bourilkov D., Group R. C. and Whalley M. R., hep-ph/0605240v2 (2006).