PROCEEDINGS OF SCIENCE

Measurement of the forward-backward asymmetry in the neutral current Drell-Yan process with ATLAS

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A measurement of the forward-backward asymmetry for the neutral current Drell-Yan process by the ATLAS experiment is presented. The asymmetry is measured using dielectron and dimuon final states in pp collisions at the LHC with $\sqrt{s}$=7 TeV data. For the dielectron channel, the measurement includes electrons detected in the forward calorimeter which extends the covered phase space to the region less sensitive to the PDF uncertainties. The result is then used to extract a measurement of the effective leptonic weak mixing angle.

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1. Introduction

Due to the $V-A$ nature of the electroweak interaction, the leptons produced in the annihilation process, $q\bar{q} \rightarrow Z/\gamma^* \rightarrow l^+l^-$, present a forward-backward asymmetry ($A_{\rm FB}$) with respect to the quark direction in the rest frame of the dilepton system. This analysis [1], done with the ATLAS experiment [2] at the Large Hadron Collider (LHC), defines $A_{\rm FB}$ using angles in the Collins-Soper (CS) frame [3], where the cosine of the decay angle $\cos\theta^*_{\rm CS}$ can be written as a function of the lepton momenta in the laboratory frame. The dilepton events having $\cos\theta^*_{\rm CS} > 0$ are classified as forward (F), while those having $\cos\theta^*_{\rm CS} < 0$ are classified as backward (B). The asymmetry $A_{\rm FB}$ is then defined as:

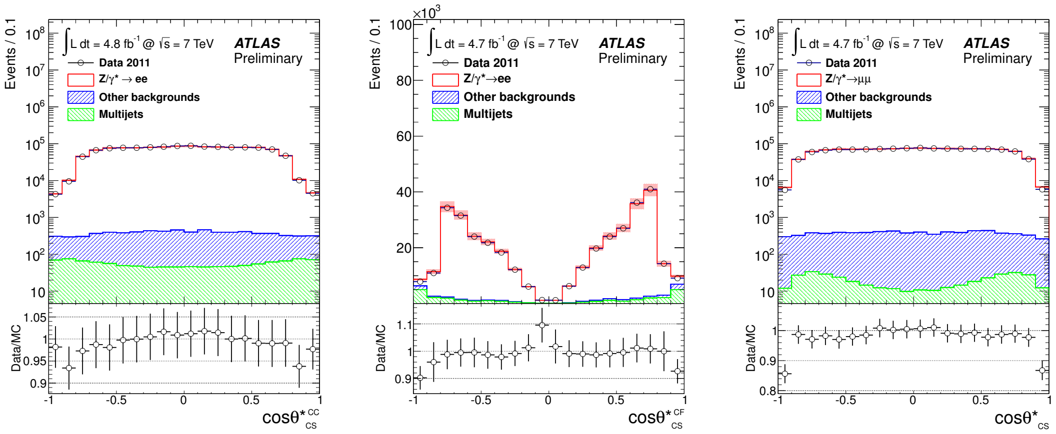
$$A_{\rm FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} \tag{1.1}$$

where σ_F and σ_B are the cross sections for the respective forward and backward configurations. The sign of $\cos\theta^*_{\rm CS}$ is determined by the incoming quark, but there is no way in pp collisions to determine to which beam it belonged. This ambiguity produces a significant dilution, i.e. a reduction, of the measured asymmetry $A_{\rm FB}$. The probability of misidentifying the quark direction decreases with increasing boost of the dilepton system. This also means that dileptons produced at larger rapidities are less affected by this dilution. Several Standard-Model parameters can be extracted from the measured $A_{\rm FB}$ distribution. One of these is the electroweak mixing angle, $\sin^2\theta_{\rm W}$, which is defined at tree level as 1-m_W^2/m_Z^2. When higher-order loop corrections are taken into account, the expression is modified to be the effective weak mixing angle, $\sin^2\theta_{\rm W}^{\rm eff}$.

2. Event selection, signal and data samples

This analysis [1] uses data collected by the ATLAS detector from pp collisions in the LHC at the centre-of-mass energy $\sqrt{s}$=7 TeV in 2011, corresponding to an integrated luminosity of 4.8 $\rm fb^{-1}$ for the electron channels and 4.7 $\rm fb^{-1}$ for the muon channel. Electron candidates in the central region ($|\eta| < 2.47$) must be matched to a reconstructed track from the inner detector. A transverse energy requirement, $E_{\rm T} > 25$ GeV, was applied to both central and forward ($2.5 < |\eta| < 4.9$) candidates. Muons must have $p_{\rm T} > 20$ GeV and lie within $|\eta| < 2.4$. Selected events must contain at least one pair of electrons or muons. Electron pairs consist of either two candidates in the central region (central-central, referred to as CC) or one central electron candidate and one forward electron candidate (central-forward, referred to as CF). Figure 1 shows the resulting $\cos\theta^*_{\rm CS}$ distributions after event selection for the three channels. The uncertainties contain both the relevant statistical and systematic components and include the effects of: parton distribution functions (PDFs), energy/momentum scale and resolution, imperfect knowledge of the trigger efficiency and charge misidentification [4, 5, 6]. Some discrepancies between data and Monte Carlo (MC) are observed in the first and last bins in $\cos\theta^*_{\rm CS}$. However, their impact on the measurement of the $A_{\rm FB}$ and $\sin^2\theta_{\rm W}^{\rm eff}$ is small, since only the integral of the positive and negative side of these distributions is relevant.

Monte Carlo samples used for signal were generated and simulated in the common ATLAS offline software framework. The Z/γ^* signal samples were generated using PYTHIA6.4 [7] and reweighted to the MSTW2008LO PDFs [8]. Higher-order corrections were taken into account using PHOTOS [9], HORACE [10] and MCFM [11] generators. Contributions from different background sources were estimated using either MC or data-driven techniques. For dibosons, $Z/\gamma^* \to \tau\tau$ and $t\bar{t}$, MC was used. The small contribution from multijet and W+jets backgrounds containing non-isolated leptons from heavy-flavour decay and fake leptons from jets was estimated using data-driven techniques [1].



(a) (b) (c)

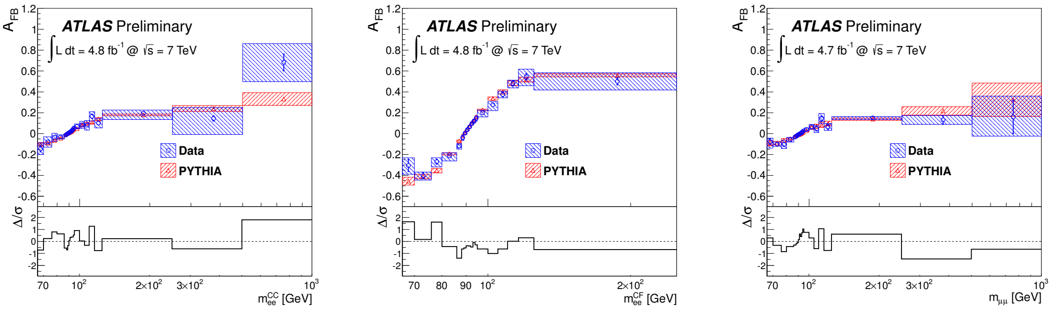
Figure 1: Distributions of $\cos\theta^*_{\rm CS}$ obtained from the event selections described in the text, for the CC electron (a) and muon (c) channels in log scale. The CF electron channel is shown in linear scale (b). Data are shown as open circles and the total expectation is shown as a line with a band representing the total uncertainty (statistical and systematic). The lower panel of the plot shows the data/MC ratio with the total uncertainty [1].

3. Measurement of $A_{\rm FB}$

The raw $A_{\rm FB}$ distributions are obtained in the electron and muon channels, after background subtraction. The measured raw asymmetry can be unfolded from detector-level to parton-level, to allow for more straightforward comparisons with theoretical predictions. The unfolding must correct for effects which include the finite resolution of the detector and the effect of radiative corrections (final-state radiation, FSR). To properly account for these corrections, dileptons are unfolded to the pre-FSR state, referred to as *Born*-level. The RooUnfold toolkit [12] was used to perform the unfolding using an iterative Bayesian method. Figure 2 shows the $A_{\rm FB}$ spectra for all three channels unfolded to *Born*-level. Good agreement is observed between the measured and predicted spectra.

4. Measurement of $\sin^2\theta_{\rm W}^{\rm eff}$

Measurements of the leptonic effective weak mixing angle, $\sin^2\theta_{\rm W}^{\rm eff}$, have been made using the raw $A_{\rm FB}$ spectra. The value of $\sin^2\theta_{\rm W}^{\rm eff}$ was extracted from each of the measured $A_{\rm FB}$ spectra by comparing the raw asymmetry to Monte Carlo predictions produced with varying initial val-



(a) (b) (c)

Figure 2: A_{FB} unfolded to *Born*-level (see text), for the CC electron (a), CF electron (b) and muon (c) channels. The boxed shaded region on the data shows the total uncertainty with error bars representing the statistical uncertainty, and on the MC represents only the statistical uncertainty. The ratio plots display the distribution of pulls (Δ/σ), where σ is the quadratic sum of the all of the uncertainties [1].

ues of the weak mixing angle in the dilepton invariant mass range 70-250 GeV. All systematic uncertainties on the measured A_{FB} spectra have been propagated to the measurements of $\sin^2\theta_{\mathrm{W}}^{\mathrm{eff}}$.

The combined results from the three measurements, assuming lepton universality is:

$$\sin^2\theta_{\mathrm{W}\ \mathrm{combined}}^{\mathrm{eff}} = 0.2297 \pm 0.0004(\mathrm{stat.}) \pm 0.0009(\mathrm{syst.}) = 0.2297 \pm 0.0010(\mathrm{tot.}).$$

The systematic error on the combined result is dominated by the PDF uncertainty (0.0007). The main contributions to the total systematic uncertainties on the individual and combined results are included in Table 1.

The results from this analysis, as well as the results from the other collider experiments, are shown in Fig. 3. The combined result of this analysis agrees within 1.8 σ with the current best PDG global fit [13].

Uncertainty source	CC electrons (10^{-4})	CF electrons (10^{-4})	Muons (10^{-4})	Combined (10^{-4})
PDF	9	5	9	7
MC statistics	9	5	9	4
Electron energy scale	4	6	–	4
Electron energy smearing	4	5	–	3
Muon energy scale	–	–	5	2
Higher-order corrections	3	1	3	2
Other sources	1	1	2	2

Table 1: Main contributions to the systematic uncertainties on the $\sin^2\theta_{\mathrm{W}}^{\mathrm{eff}}$ values extracted from the three analysis channels and on the combined result. Null entries (denoted by "–") correspond to an uncertainty that does not apply to a specific channel [1].

5. Conclusions

The Z/γ^* forward-backward asymmetry has been measured using the data recorded with the

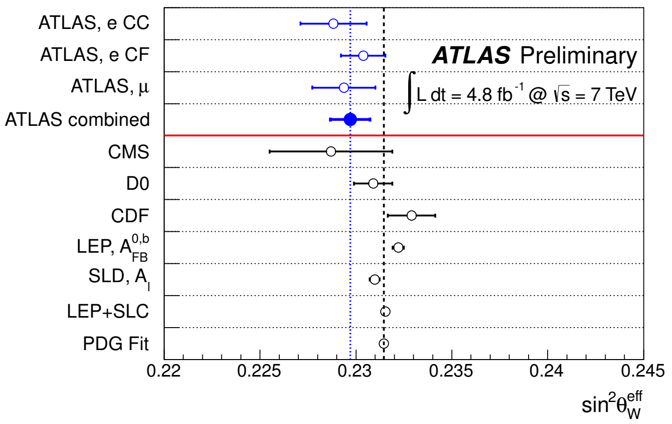


Figure 3: Comparison of the results of this analysis [1] with other published results for $\sin^2\theta_W^{\text{eff}}$. A vertical dotted line illustrates the results from the ATLAS combined measurement reported here and a vertical dashed line shows the results from the current PDG global fit [13].

ATLAS detector from *pp* collisions in the LHC at $\sqrt{s}$=7 TeV in 2011 corresponding to an integrated luminosity of 4.7 - 4.8 fb^{-1}. Raw spectra were measured and subsequently unfolded to correct for detector effects and radiative corrections. A measurement of the leptonic effective weak mixing angle, $\sin^2\theta_W^{\text{eff}}$ was also presented. Results from the electron and muon final states have been combined and are consistent with previous measurements. This result is the first from a hadron collider to combine electron and muon final states in a measurement of $\sin^2\theta_W^{\text{eff}}$ around the Z pole.

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