CMS CR -2010/202

The Compact Muon Solenoid Experiment

Conference Report

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29 October 2010

Measurement of the Forward-backward in $Z/\gamma^* \to \ell^+\ell^-$ Events in CMS at $\sqrt{s} = 7$ TeV

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Presented at *SPIN 2010: 19 th International Spin Physics Symposium (SPIN 2010)*

Measurement of the Forward-Backward Asymmetry in Z/γ^* $\rightarrow \mu\mu$ Events in CMS at 7 TeV

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Abstract. We present the initial steps in the measurement of the forward-backward asymmetry (A_{FB}) for $\mu^+\mu^-$ pairs produced via an intermediate Z/γ^* at $\sqrt{s} = 7$ TeV in the CMS experiment. Our results are based on an integrated luminosity of 198 nb^{-1}. The uncorrected forward-backward asymmetry is measured to be -0.50±0.40 in the mass range 40-70 GeV, and 0.14±0.11 in 70-110 GeV. The measured values are consistent with POWHEG + PYTHIA + full CMS simulation predictions of -0.03 and 0.01 in these two mass bins.

1. Introduction

In the process $q\bar{q} \rightarrow Z/\gamma^* \rightarrow \ell^+\ell^-$ both vector and axial-vector couplings of electroweak bosons to fermions are present. This results in a forward-backward asymmetry in the number of Drell-Yan lepton pairs. This asymmetry depends on the di-lepton invariant mass. Deviations from the Standard Model prediction may indicate the existence of a new neutral gauge boson [1, 2, 3]. Moreover the measurement of forward-backward asymmetry can also improve QCD measurements with higher order corrections and constrain Parton Distribution Functions. In order to do this measurement, we need efficient muon and Z reconstruction, to have a very good understanding of the detectors, and differential distributions of Z bosons, and have the correct lepton energy scale. In this paper, we report the initial steps towards the measurement of forward-backward asymmetry in $Z \rightarrow \mu\mu$ events with the Compact Muon Solenoid (CMS) detector. In section 2, we give a brief description of the CMS detector, in section 3, we present the muon reconstruction and identification. Section 4 summarizes the differential Z boson distributions and the forward-backward asymmetry measurement.

2. The Detector

The central feature of the CMS detector is a 3.8 T superconducting solenoid, of 6 m internal diameter. Within the field volume are the silicon pixel and strip tracker, the crystal electromagnetic calorimeter (ECAL) and the brass/scintillator hadron calorimeter (HCAL). Muons are primarily measured by gas-ionization detectors, installed outside the solenoid, embedded in the steel return yoke as well as by the inner tracker. In addition to the barrel and endcap detectors, CMS has extensive forward calorimetry. A detailed description of the CMS detector can be found elsewhere [4].

3. Muon Reconstruction and Identification

In CMS, muons are measured in the pseudorapidity window $|\eta| < 2.4$, with the all-silicon tracker and the muon system with detection planes made of three technologies: Drift Tubes (DT), Cathode Strip Chambers (CSC), and Resistive Plate Chambers (RPC) [5]. DTs are used in the barrel ($|\eta| < 1.2$), and and CSCs in the endcaps ($0.9 < |\eta| < 2.4$), complemented by a system of RPCs covering both regions up to $|\eta| < 1.6$. Measurements in the calorimeters including the outer hadronic calorimeter (HO) complement the muon identification.

Muon tracks are reconstructed separately in the tracker and in the muon system at first. Using these tracks, muons are reconstructed mainly by two different algorithms, *global muon* and *tracker muon*. Global muon reconstruction starts from the muon tracks reconstructed in the muon system and extrapolates back to the tracks reconstructed by the tracker and a global-muon track is fitted combining the hits in these independent track reconstructions. In the tracker muon algorithm, tracks with $p_T > 0.5$ GeV and $p > 2.5$ GeV are extrapolated to the muon system taking into account the energy loss and multiple scattering effects.

There are several different muon identification methods, however, we have used *tight muon selection* which includes similar requirements that has been used for CMS electroweak measurements. In this selection, the muon must be identified both as global and tracker muon with a global fit with normalized χ^2/dof <10, with at least one muon hit in the track fit, matching muon segments at least in two muon stations, and the tracker track should have at least 11 hits out of which at least one of them should be from the pixel detector. Moreover, transverse impact parameter should be less than 2 mm.

More details on muon reconstruction, identification and kinematic distributions can be found in [6].

4. Forward-Backward Asymmetry in $Z/\gamma^* \to \mu\mu$ Events

The differential cross-section for the process $q\bar{q} \to Z/\gamma^* \to \ell^+\ell^-$ at the parton level is

$$\frac{d\sigma}{d(\cos\theta)} = A(1+\cos^2\theta) + B\cos\theta \tag{1}$$

where θ is the emission angle of the negative muon relative to the quark momentum in the center-of-mass frame, and A and B depend on the weak isospin and charge of the incoming fermions. The asymmetry parameter A_{FB}, and its statistical error, ΔA_{FB} are given by

$$A_{\mathrm{FB}} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} = \frac{N_F - N_B}{N_F + N_B} = \frac{3B}{8A}, \qquad \Delta A_{\mathrm{FB}} = \sqrt{\frac{1 - A_{FB}^2}{N}} \tag{2}$$

where N is the total number of events in the corresponding bin.

We use the Collins-Soper frame [7] in order to reduce the effects arising from the non-zero transverse momentum of the incoming quarks. In this frame, θ^*_{CS} is defined as the angle between the negative muon momentum and the z' axis that bisects the angle between the quark and the anti-quark in the dimuon center of mass frame. The angle θ^*_{CS} is given by using quantities measured in the lab frame

$$\cos\theta^*_{CS} = \frac{2(P_1^+ P_2^- - P_1^- P_2^+)}{\sqrt{Q^2(Q^2 + Q_T^2)}} \tag{3}$$

where Q and Q_T are the four-momentum and the transverse momentum of the di-muon system, P_i represent the ith component of the four momentum, and $P_i^{\pm} = 2^{-1/2}(P_i^0 \pm P_i^3)$.

Forward (backward) events are defined by $\cos\theta^*_{CS} > 0$ (< 0). The A_{FB} is evaluated using angular distributions of dimuons at different invariant mass bins. Data corresponding to 198

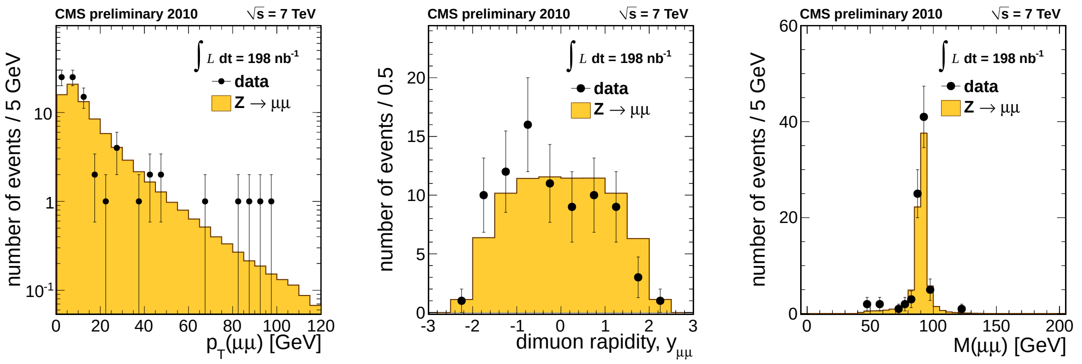

Figure 1. Transverse momentum distribution (left), rapidity distribution of the dimuon events (middle) and mass distribution in MC and data of the dimuon events .

nb^{-1} do not allow precise measurement in many mass bins, therefore, we report uncorrected $A_{\rm FB}$ in two dimuon mass bins of 40< $M_{\mu\mu}$ <70 GeV, and 70< $M_{\mu\mu}$ <110 GeV.

A data set taken by CMS at 7 TeV collisions is used which was selected using an unprescaled high-level single muon trigger that requires the muons to be contained in $|\eta| \leq 2.1$ with $p_T^\mu > 9$ GeV. Monte Carlo Drell-Yan (DY) signal sample is produced by a next-to-leading order generator (POWHEG [8]) with a cut of 20 GeV on the mass of the di-muon system. The PDF set CTEQ66M is used and QED final-state-radiation is incorporated via the parton-shower algorithm PYTHIA [9]. The generated events are reconstructed using the full CMS detector simulation.

We require a pair of opposite charge muons to pass the muon identification and isolation criteria in the offline analysis. Muon isolation is used to distinguish single muons from muons overlapping with jets. For this selection, the scalar sum of p_T of all tracks reconstructed in cones of $R = 0.3$ around the direction of a muon momentum is required to be less than 3 GeV.

In order to measure $A_{\rm FB}$, the quark and antiquark directions need to be known. However, at the LHC these directions can not be known directly. However, since the antiquark is a sea quark, on average, the antiquark should have less momentum than the valence quark. Therefore we can assume that the Z boson is boosted in the quark direction and then correct for this effect by properly accounting for misidentification probabilities. The probability that the above assumption is not correct (mistag probability) does also depend on mass of the dimuon system. The measured $A_{\rm FB}$ values can be related to the *true* $A_{\rm FB}$ values through dilution factors. The dilution can be corrected in an event-by-event basis, extracting the mistag probability from Monte Carlo as a function of the dimuon rapidity and mass [10].

Transverse momentum, rapidity (η), and mass distribution of the selected dimuon events in data and Monte Carlo are displayed in Figure 1. Figure 2 shows the cos θ^*_{CS} distribution and the measured and estimated A$_{\rm FB}$. This asymmetry has not been corrected for resolution or dilution effects. These effects are important in a precision measurement, but are small compared to the current statistical errors. The uncorrected forward-backward asymmetry is measured to be -0.50±0.43 in the mass range 40-70 GeV, and 0.14±0.11 in the mass range 70-110 GeV using 198 nb^{-1} of data. The measured values are consistent with POWHEG + PYTHIA + full CMS simulation predictions of -0.03 and 0.01 in these two mass bins.

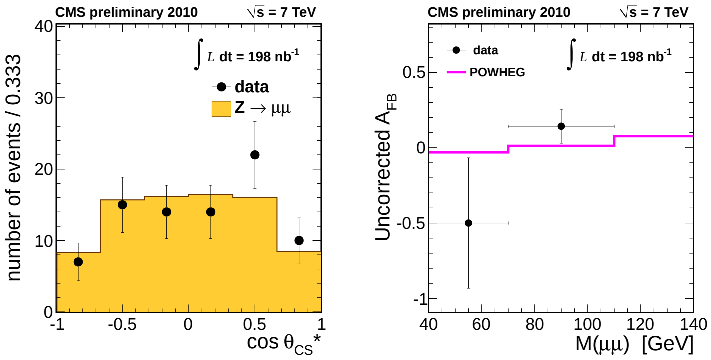

Figure 2. $\cos\theta^*_{CS}$ distribution for the di-muon events (left) and the measured asymmetry in data with estimated asymmetry in Monte Carlo. Only statistical errors are shown.

5. References

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