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Measurement of the Z/γ^* forward-backward asymmetry in muon pairs with the ATLAS experiment at the LHC

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Summary. — A study on muon pairs produced through an intermediate Z/γ^*, in *pp* collisions at the LHC, at a center-of-mass energy of 7 TeV, is presented. After a selection aimed at enhancing the contribution from Z boson decay, the topology of the events is analyzed, and the forward-backward asymmetry is measured. The result is then used to test a method to measure the effective weak mixing angle $\sin^2\theta_W^{eff}$. This note summarizes the results obtained with 2011 data collected by the ATLAS experiment at the LHC, corresponding to an integrated luminosity of $4.8\,\text{fb}^{-1}$.

PACS 13.75.Cs – Nucleon-nucleon interactions (including antinucleons, deuterons etc.).
PACS 14.70.Hp – Z bosons.
PACS 13.35.Bv – Decays of muons.

The differential cross section for fermion pair production in a Drell-Yan process $q\bar{q} \to Z/\gamma^* \to \mu^+\mu^-$, around the Z pole, can be written as

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

where A and B are functions that take into account the weak isospin and charge of the incoming quarks and the transferred momentum Q^2 of the interaction and θ is defined as the angle between the muon and the incoming quark. Events with $\cos\theta > 0$ are called forward events, and events with $\cos\theta < 0$ are called backward events. The forward-backward charge asymmetry A_{fb} is defined as

$$A_{fb} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} = \frac{\int_0^1 \frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta}\mathrm{d}\cos\theta - \int_{-1}^0 \frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta}\mathrm{d}\cos\theta}{\int_0^1 \frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta}\mathrm{d}\cos\theta + \int_{-1}^0 \frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta}\mathrm{d}\cos\theta} = \frac{N_F - N_B}{N_F + N_B} = \frac{3B}{8A}, \tag{2}$$

where N_F and N_B are numbers of forward and backward events.

The Collins-Soper formalism is adopted to minimize the lack of knowledge of the transverse momentum of the incoming quarks. Let $Q(Q_T)$ be the four-momentum (transverse momentum) of the dimuon pair, P_1 and P_2 be the four-momentum of the muon and antimuon respectively, all measured in the lab frame. Then a new variable $\cos\theta^*$ is used instead of the $\cos\theta$ variable and defined as

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

The data sample used in this analysis was collected using the ATLAS detector and corresponds to an integrated luminosity of $4.8\,\mathrm{fb}^{-1}$. After the application of some selection requirements we found $1.3\,\mathrm{M}$ Z/γ^* candidates in data sample. To measure A_{fb} we divide an invariant-mass range, from 60 to 1000 GeV, in 21 bins. In each bin we calculate A_{fb} using eq. (2) and obtain a distribution of *raw* A_{fb} *vs.* $m_{\mu\mu}$. The measured spectrum of the asymmetry needs to be corrected for three main effects: radiative corrections, detector resolution and dilution. The measurement of A_{fb} is corrected for these effects by means of a response-matrix based unfolding. Matrices are calculated using the available Monte Carlo $Z/\gamma^* \to \mu\mu$ samples and then applied to the raw A_{fb} spectrum. The result is an unfolded A_{fb} spectrum.

In order to extract a measurement of $\sin^2\theta^f_{eff}$ from the unfolded A_{fb} spectrum we use an expansion of A_{fb} in terms of the center-of-mass energy, around the Z pole

$$A_{fb}(s) \simeq A_{fb}\left(m_Z^2\right) + \frac{\left(s-m_Z^2\right)}{s}\frac{3\pi\alpha(s)}{\sqrt{2}G_F m_Z^2}\frac{2Q_qQ_f g_{Aq}g_{A\mu}}{\left(g_{Vq}^2+g_{Aq}^2\right)\left(g_{V\mu}^2+g_{A\mu}^2\right)}. \quad (4)$$

This expansion can be used to determine the value of $\sin^2\theta_W^{eff}$ by fitting the A_{fb} *vs.* $m_{\mu\mu}$ distribution in the vicinity of the Z pole. In order to test the validity of the fitting procedure, a closure test on the *true* Monte Carlo sample has been performed. The Monte Carlo default value of the weak mixing angle is $\sin^2\theta_W^{eff} = 0.232$. The result of the fitting procedure applied to the *true* A_{fb} distribution should be in agreement with this default value of the weak mixing angle. The value of $\sin^2\theta_W^{eff}$ extracted from the *true* A_{fb} distribution around the Z pole is

$$\sin^2\theta_W^{eff} = 0.23202 \pm 0.00043. \quad (5)$$