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The Compact Muon Solenoid Experiment

Conference Report

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16 December 2012 (v3, 14 January 2013)

W and Z bosons measurement in PbPb collisions with CMS

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Abstract

The electroweak bosons W and Z produced in PbPb collisions at LHC at $\sqrt{s} = 2.76$ TeV have been measured and studied through their leptonic decay channel with the CMS detector. In the following we present the measurement of the Z yields as a function of p_T, rapidity and centrality based on 2011 PbPb data with an integrated luminosity of 150 μb^{-1}, and the W yield as a function of centrality as well as the muon charge asymmetry using 2010 PbPb data corresponding to an integrated luminosity of 7.3 μb^{-1}. The dependence of W and Z production as a function of PbPb collision centrality is shown to scale with the number of NN binary collisions.

Presented at *HI-LHC12: Heavy Ion Collisions in the LHC Era*

W and Z bosons measurement in PbPb collisions with CMS

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Abstract. The electroweak bosons W and Z produced in PbPb collisions at LHC at $\sqrt{s}$ = 2.76 TeV have been measured and studied through their leptonic decay channel with the CMS detector. In the following we present the measurement of the Z yields as a function of p_T, rapidity and centrality based on 2011 PbPb data with an integrated luminosity of 150 μb^{-1}, and the W yield as a function of centrality as well as the muon charge asymmetry using 2010 PbPb data corresponding to an integrated luminosity of7.3 μb^{-1}. The dependence of W and Z production as a function of PbPb collision centrality is shown to scale with the number of NN binary collisions.

1. Introduction

For the first time the LHC offers the new opportunity to study W and Z bosons in heavy ion collisions. From 2010 PbPb data at $\sqrt{s} = 2.76$ TeV corresponding to an integrated luminosity of 7.2 μb^{-1}, the CMS experiment [1] reported that the $Z \to \mu\mu$ [2] and $W \to \mu\nu$ [3] do not interact with the hot and dense strongly-interacting medium created in heavy-ion collisions. Indeed, their measurement can allow us to check that their production is unmodified by the medium and thus help us to establish the validity of the Glauber model. Also, they can serve as a reference for other modified probes such as quarkonium production, or the production of an opposite-side jet in Z+jet processes. Finally, their measurement with enough precision can allow to constrain the the initial state of the collision, in particular the nuclear parton distribution functions (PDF).

2. Z bosons

In the Z analysis we require good quality muons with a transverse momentum larger than 20 GeV/c and a pseudo-rapidity $|\eta_\mu| < 2.4$, in order to ensure low background [2]. The dimuon rapidity is limited to $|y| < 2$. Under those conditions, we count 616 Z candidates, i.e. the oppositely charged di-muon pairs which have an invariant mass between 60 to 120 GeV/c^2. The yield of Z bosons (dN_{PbPb}/dy) is then measured as a function of different ranges of Z rapidity (8 bins), p_T (7 bins) and event centrality [1] (6 bins). The centrality classes used here are 50–100%, 40–50%, 30–40%, 20–30%, 10–20% and 0–10% (most central). We calculate the

[1] The centrality of the collisions is determined from the energy deposited in the forward steel/quartz-fibre calorimeters (HF).

yield of $Z \to \mu^+\mu^-$ as a function of p_T ($\frac{d^2N}{dydp_T} = \frac{N(Z\to\mu^+\mu^-)}{\alpha\epsilon N_{MB}\Delta y\Delta p_T}$) and as a function of rapidity ($\frac{dN}{dy} = \frac{N(Z\to\mu^+\mu^-)}{\alpha\epsilon N_{MB}\Delta y}$) where :

- $N(Z \to \mu^+\mu^-)$ (= 616) is the number of counts found in the di-muon invariant mass range of 60–120 GeV/c^2
- α ($\sim$ 70%) and ϵ ($\sim$ 60%) are the acceptance and efficiency corrections
- N_{MB}(= 1.161 billion events) is the number of corresponding minimum bias events corrected for trigger efficiency
- Δy and Δp_T are the bin ranges in consideration

The results are presented in figure 1 (a) and (b) and compared to the pp cross section provided by a next-to-leading-order POWHEG generator, scaled by the proper nuclear overlap function ($d\sigma_{pp}/dy \times T_{\mathrm{AA}}$). To study the Z yield dependence versus centrality we divide N_{MB} by the centrality fraction in consideration. We notice no dependence of the production of Z bosons per binary collision on the number of participants, as shown in 1 (c).

3. W bosons

With 2010 PbPb data at $\sqrt{s} = 2.76$ TeV, the W boson production has been measured through its leptonic muon decay channel ($W^\pm \to \mu^\pm\nu$). The first hint of W observation is the bump present in the muon spectrum, as shown in figure 2 (left). The muon spectrum (solid red dots) is produced by plotting the p_T distribution of all the events selected online with a low (2-3 GeV/c) p_T^μ threshold and $|\eta^\mu| < 2.1$ with strict quality cuts [2] and vetoing on the Z candidate. In this analysis, the energy of the neutrino in the event is estimated by computing a missing transverse momentum $\not{p}_T$ by taking the opposite sign of the vectorial sum of the transverse momenta of all charged particles in the event, with $p_T > 3$ GeV/c. When selecting events with a high p_T muon, the average value of the missing transverse momentum $< \not{p}_T >$ has a very small dependence on centrality and its value is around 40 GeV/c. This value agrees with what is expected for the typical $\not{p}_T$ produced by an undetected neutrino originating from W decay. Therefore, we compute the transverse mass of the W as $m_T = \sqrt{2p_T^\mu \not{p}_T(1-\cos(\phi))}$ where we require $p_T^\mu >$ 25 GeV/c and a $\not{p}_T > 20$ GeV/c and where ϕ is the opening angle between the direction of the high-p_T muon momentum and $\not{p}_T$ vectors. The result is shown in figure 2 (right) where the transverse mass distribution for PbPb data is superimposed on the transverse mass obtained when analyzing pp data with the same procedure (open blue squares). This shows that pp and PbPb results are in a good agreement with a W Pythia signal simulation embedded in PbPb events generated with Hydjet (PYTHIA + HYDJET) (green-hatched histogram) and are almost background free. Residual contamination from other electroweak processes ($Z \to \mu^+\mu^-$ and $W^\pm \to \mu^\pm\nu$) (2%) is subtracted, and the QCD background is estimated to be 1% and included as a systematic uncertainty. We count 275 W^+ and 264 W^- in PbPb and 301 W^+ and 165 W^- in pp by placing a cut of 40 GeV/c^2 on the transverse mass. W, W^+ and W^- yields (dN/dy) in PbPb collisions are scaled by the nuclear overlap function T_{AA} and presented as a function of number of participants (N_{part}) in figure 3 (left). We notice first, that the W production in PbPb collisions does not depend on the centrality of the collision. Second, that the individual W^+ and W^- charge states in PbPb and in pp collisions reflect the different u and d quark content in Pb nuclei and in the proton, what is called the "isospin effect". As a consequence, the nuclear modification factors R_{AA} of W, W^+, W^- are different $R_{AA}(W) = 1.04 \pm 0.07 \pm 0.12$, $R_{AA}(W^+) = 0.82 \pm 0.07 \pm 0.09$, $R_{AA}(W^-) = 1.46 \pm 0.14 \pm 0.16$. The muon charge asymmetry defined as $A = (N_W^+ - N_W^-)/(N_W^+ + N_W^-)$ is studied as a function of the muon pseudo-rapidity for

[2] The quality cut used include the minimum number of hits used in offline reconstruction, the distance in the transverse plane between the muon impact parameter and the primary vertex to be less than 300 μm

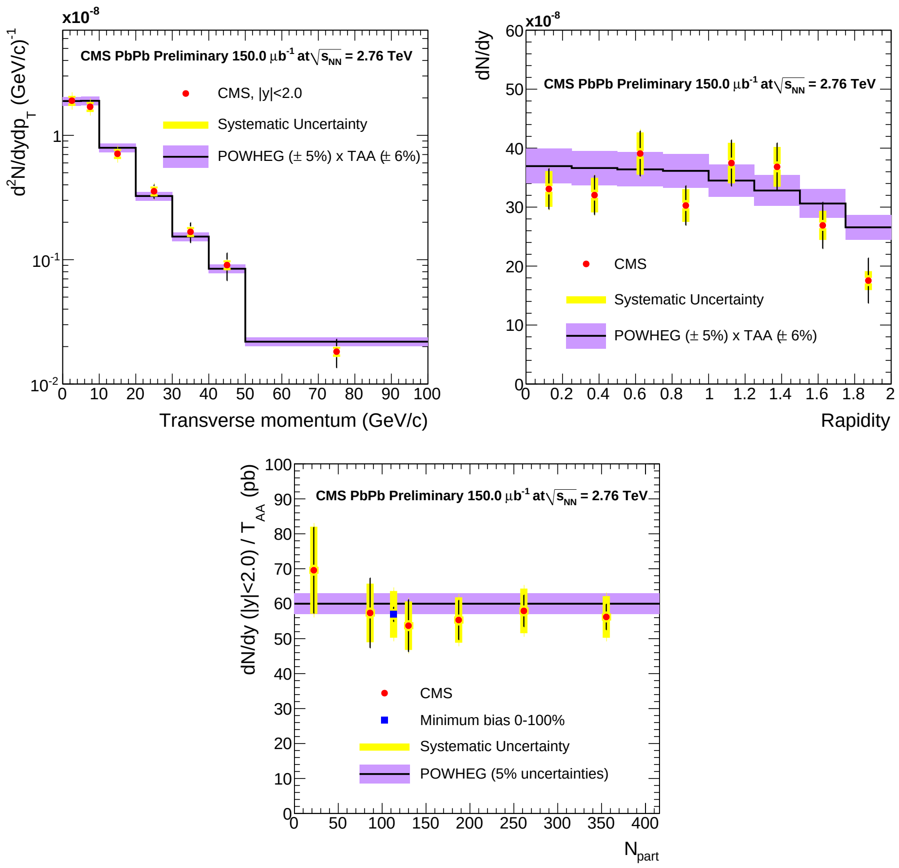

Figure 1. (a) $\mathrm{Z} \to \mu^+ \mu^-$ yields versus the Z boson transverse momentum. (b) $\mathrm{Z} \to \mu^+ \mu^-$ yields versus the Z boson rapidity. (c) Event centrality dependence of the $\mathrm{Z} \to \mu^+ \mu^-$ yield per event divided by the expected average nuclear overlap function T_{AA}. The vertical scale equivalently corresponds to Z yields per binary collision (N_{coll}) times the nucleon-nucleon cross section, and is thus directly comparable to the pp cross section from the POWHEG generator displayed as a black line. On the horizontal axis, event centrality is depicted as the average number of participating nucleons N_{part}. Vertical lines (bands) correspond to statistical (systematic) uncertainties.

both pp and PbPb collisions and shown to agree – within the uncertainties – with the predictions from MCFM generator using MSTW08 PDF for pp and for PbPb data when adding the EPS09 PDF [3] as presented in figure 3 (right).

4. Conclusions

W and Z electroweak boson production is consistent with the binary-collision scaling hypothesis ($R_{AA} = 1$) and can thus serve as reference to modified probes. More statistics could reveal PDF modification. The W from the second run, as well as the electronic decay channels of W and Z are still to be analysed. On the longer term, after the first long LHC shutdown, a significant Z+jet event sample will be available. Even with the isospin effect driving the W^+, W^- to have non-unity values of R_{AA}, the fact that they are flat with centrality demonstrates that the underlying hard scattering processes that lead to W and Z production are well understood thereby adding significance to other CMS observations such as jet suppression.

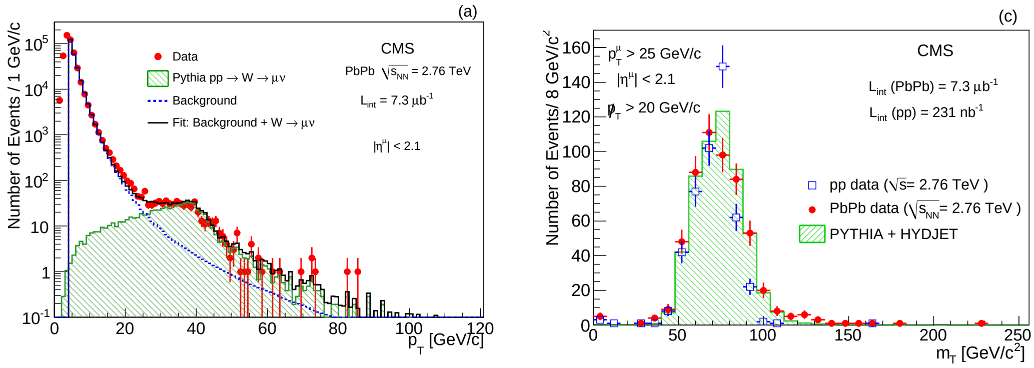

Figure 2. Left: Single-muon transverse-momentum spectrum for $|\mu| < 2.1$ in PbPb data (red points). Signal (green hatched histogram) and background (blue-dashed histogram) contributions are fitted (black-solid line) to the data. Right: Transverse mass distribution for selected events in PbPb (red-filled circles) and pp (blue open squares) data, compared to PYTHIA + HYDJET simulation (hatched histogram). The error bars represent statistical uncertainties .

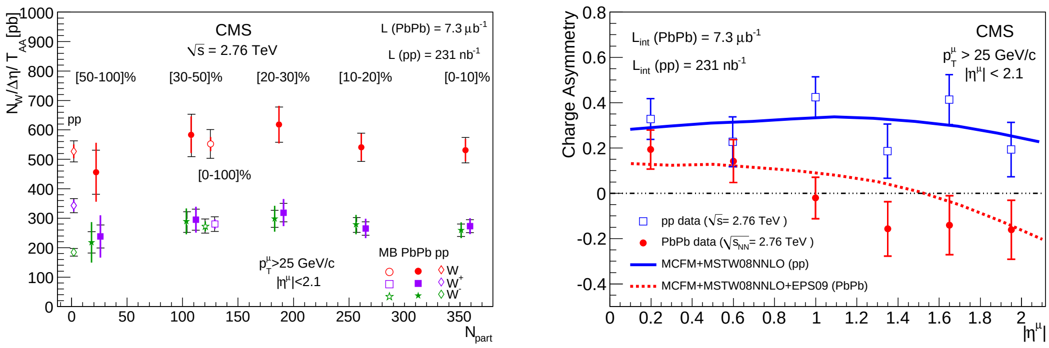

Figure 3. Left: Centrality dependence of normalised W cross sections in PbPb collisions, for all W candidate (red filled points) and separated by charge, W^+ (violet-filled squares) and W^- (green-filled stars). The open symbols at N_{part}= 120 represent the minimum bias events. At N_{part}= 2, the corresponding cross sections are displayed for pp collisions for the same $\sqrt{s}$. The cross sections are given for the phase space region $p_T^{\mu} > 25$ GeV/c and $|\eta| < 2.1$ [3]. Right: Muon charge asymmetry $A = (N_W^+ - N_W^-)/(N_W^+ + N_W^-)$ as a function of the muon pseudorapidity for PbPb (red points) and pp (blue squares) collisions at 2.76 TeV for muons in the same phase space region.

References

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[3] CMS Collaboration, "Study of W boson production in PbPb and pp collisions at $\sqrt{s_{NN}} = 2.76$ TeV", CMS, Phys.Lett.B 715 (2012) 66 doi:10.1016/j.physletb.2012.07.025. arXiv:1205.6334 [nucl-ex]