PROCEEDINGS OF SCIENCE

Electroweak-boson measurements from small to large collision systems with ALICE at the LHC

Shingo Sakai for the ALICE collaboration[a,*]

[a] *University of Tsukuba,*
1-1-1 Tennodai, Tsukuba, Ibaraki 305-8577 Japan

E-mail: sakai.shingo.gw@u.tsukuba.ac.jp

Electroweak bosons, $W^{\pm}$ and Z^{0}, are massive weakly-interacting particles insensitive to the strong interaction. Therefore, they are unique probes in pp and heavy-ion collisions and provide a medium-blind probe of the initial state of the heavy-ion collision. In the ALICE experiment, the productions of $W^{\pm}$ and Z^{0} are studied by exploiting theirleptonic decay channels in a wide rapidity region. In this contribution, the differential cross sections for $W^{\pm}$ and Z^{0} in pp collisions at $\sqrt{s}$ = 13 , p–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 8.16 and Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 are reported. The charged particle multiplicity dependence of W bosons and the associated hadrons production in pp collisions at $\sqrt{s}$ = 13 is also shown.

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[*]Speaker

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1. Introduction

The $W^{\pm}$ and Z^0 bosons have large masses, and they are predominantly generated through the Drell-Yan process in which quarks and antiquarks annihilate [1] in early stage of pp and heavy-ion collisions. Perturbative QCD (pQCD) calculations have successfully described their production cross section in pp collisions. Moreover, the productions of W^+ and W^- are sensitive to the light quark parton distribution function [2]. Recent measurements of the self normalised yield as function of multiplicity in pp collisions at $\sqrt{s}$ =13 showed a faster than linear increase [3]. Models accounting for multiple parton interactions (MPI) and color-reconnection (CR) effects describe the trends observed in data [4]. On the other hand, it is pointed out that the auto-correlation between the measured hadrons and the charged multiplicity plays a role in the enhancement [5]. Since $W^{\pm}$ and Z^0 bosons are colorless, their production is expected to be less sensitive to CR effects than hadron ones. Therefore, their measurements give insight into MPI in high multiplicity events and role of CR for hadron production. In heavy-ion collisions, the nuclear parton distribution functions (nPDFs) is possibly modified due to the presence of a nuclear environment. Since $W^{\pm}$ and Z^0 bosons do not interact with the constituents of the medium, they are expected to carry information about the initial-state nuclear effects, including the modification of the PDFs in a nuclear environment.

2. ALICE apparatus and $W^{\pm}$ and Z^0 boson reconstruction

The analysis were performed using data recorded in pp collisions at $\sqrt{s}$ = 13 , in p–Pb collisions at $\sqrt{s_{\rm NN}}$ = 8.16 , and in Pb–Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 with the ALICE detectors. The details of the detector and its performance are described in Ref. [6].

At midrapidity, the $W^{\pm}$ and Z^0 boson candidates are reconstructed by measuring the electrons from their leptonic decays with the Time Projection Chamber (TPC) and the Electromagnetic Calorimeter (EMCal). Electrons with $p_{\rm T}$ larger than 30 are used. The electrons are identified based on their energy loss (dE/dx) in the TPC, and on the energy-to-momentum ratio ($E/p \sim 1$), where the energy is measured in the EMCal. Since $W^{\pm}$ and Z^0 bosons are isolated from other hadrons, an isolation criterion on the energy information around the electron candidates is applied. Z^0 bosons are reconstructed with an invariant mass of the two identified electrons of opposite sign.

At forward rapidity, the $W^{\pm}$ boson candidates are reconstructed in the single-muon channel with the muon spectrometer. The muons from $W^{\pm}$ boson decay is extracted by fitting the measured single muon transverse momentum spectrum ($p_{\rm T}^{\mu} > 10$) with the templates including background from Z^0 boson and heavy-flavour hadrons decays. The templates were made by the event generator POWHEG [7] for muons from $W^{\pm}$ and Z^0 boson decays and FONLL QCD calculation [8, 9] for heavy-flavour hadrons. In the POWHEG simulations for p–Pb and Pb–Pb collisions, the lead nucleus isospin was taken into account by weighting the proton and neutron contributions.

3. Results

3.1 $W^{\pm}$ and Z^0 production in pp collisions at $\sqrt{s}$ = 13

The cross sections for electrons ($30 < p_{\rm T} < 60$) from $W^{\pm}$ decays are shown in Fig. 1. The measured cross sections are compared with POWHEG simulations [7] which are based on

NLO pQCD. The CT10NLO PDFs [12] were used in these calculations, and the bands represent the theoretical uncertainty from the PDFs. The measured cross sections are consistent with the POWHEG calculations within experimental and theoretical uncertainties.

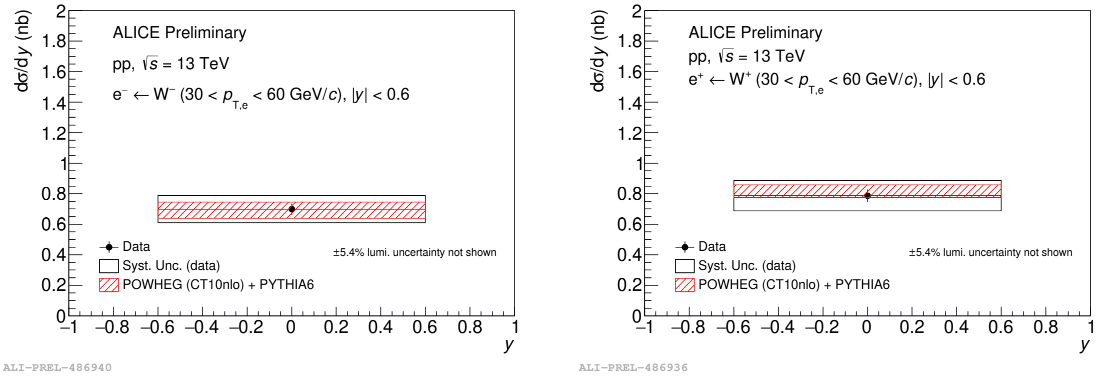

Figure 1: Cross section of electrons (left) and positrons (right) from W^- and W^+decay in pp collisions at $\sqrt{s}$ =13 , respectively, compared with POWHEG calculations with CT10NLO PDFs (red bands).

Figure 2 left shows the electron-positron pair invariant mass of the reconstructed Z bosons at midrapidity. One of the electrons (or positrons) have a transverse momentum greater than 30 and within $|y| < 0.6$. The fiducial cross section of Z bosons is determined for mass range from 60 to 108 GeV/c^2 and is shown on Fig. 2 right. The result is consistent with POWHEG calculations combined with the CT14NLO PDFs within errors.

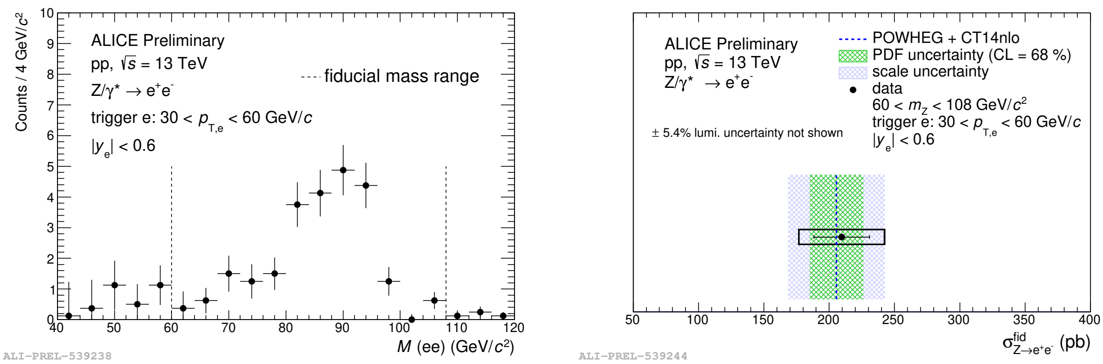

Figure 2: Invariant mass of dielectrons from Z^0 decay (left) and fiducial cross section of the reconstructed Z^0 bosons (right) in pp collisions at $\sqrt{s}$ = 13 .

3.2 Multiplicity dependence of W$^\pm$ and associated hadron production in pp collisions at $\sqrt{s}$ = 13

Figure 3 shows the self-normalised yields of electrons from W$^\pm$ bosons and charged hadrons in association with W bosons as a function of normalised charged-particle multiplicity at midrapidity in pp collisions at $\sqrt{s}$ = 13 . The production of electrons from W$^\pm$ bosons is linear with respect to the multiplicity. On the other hand, this trend of the associated hadron production is faster than linear. The trend has several interpretations, and one possible explanation is the auto-correlation between the measured hadrons and the charged multiplicity [5]. In contrast, W bosons show a linear trend as they are less correlated with multiplicity. The result is compared with PYTHIA8 predictions [10] including MPI and CR, which describe the measurements within uncertainties.

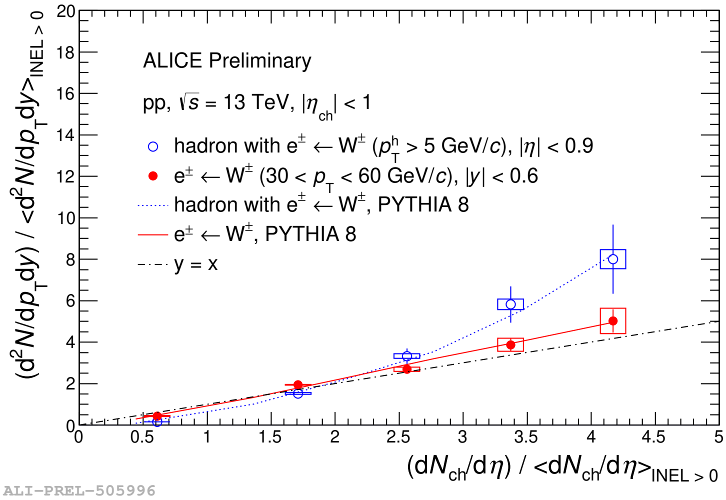

Figure 3: Self-normalised yields of $e^{\pm} \leftarrow$ W$^{\pm}$ and associated hadrons vs. normalised charged-particle pseudorapidity density compared with expectations from PYTHIA8 [10] simulation including CR effects [11].

3.3 W$^{\pm}$ in p–Pb and Pb–Pb collisions

Figure 4 shows the ratio of the measured cross section for muons from W^{+} in ALICE [13] and CMS [14] to pQCD calculations using CT14 PDF [15] (without nuclear modification) or the CT14 with the EPPS16nPDFs [16] in p–Pb collisions at $\sqrt{s_{\rm NN}}$ = 8.16 . The ALICE experiment extends to larger $|y|$ region and results are in agreement with the observed trend at the edges of the CMS acceptance. A suppression is observed at the largest rapidity with respect to the calculation using CT14 PDF without nuclear effect, indicating a nuclear modification of the parton distribution function.

The W$^{\pm}$ boson production yield in Pb–Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 normalised by the nuclear overlap function ($\langle T_{\rm AA}\rangle$), as a function of the centrality, is shown in Fig. 5. The production of hard probes in peripheral collisions is possibly influenced from event selection and geometry biases. These biases introduce a suppression of W$^{\pm}$ in peripheral collisions. The result is compared with HG-PYTHIA [17] calculations that include these biases. While the model calculations show good agreement with the data, the limited statistics do not allow to conclude on the presence or not of those biases.

4. Summary

The productions of W$^{\pm}$ and Z^{0} bosons were measured with the ALICE experiment in pp collisions at $\sqrt{s}$ = 13 , in p–Pb collisions at $\sqrt{s_{\rm NN}}$ = 8.16 and in Pb–Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02

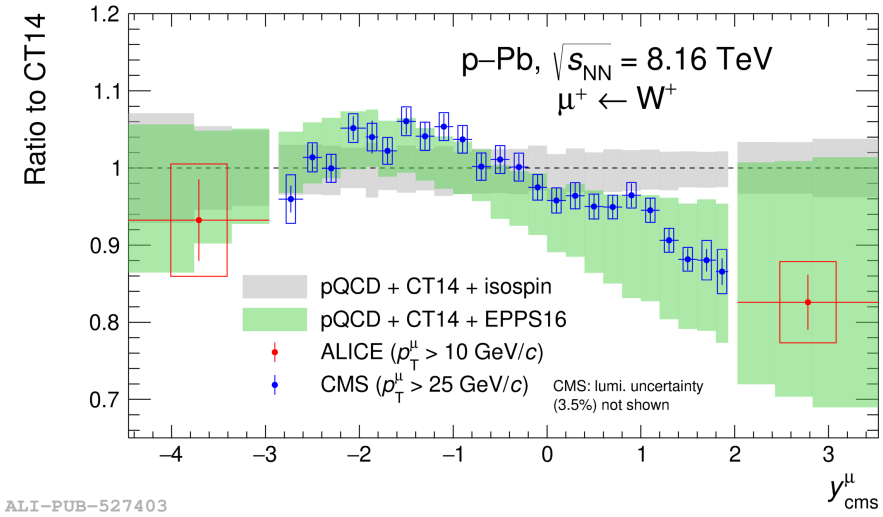

Figure 4: Ratio to CT14 predictions of the production of muons from W^+ decays as a function of rapidity in p–Pb collisions at $\sqrt{s_{NN}} = 8.16$.

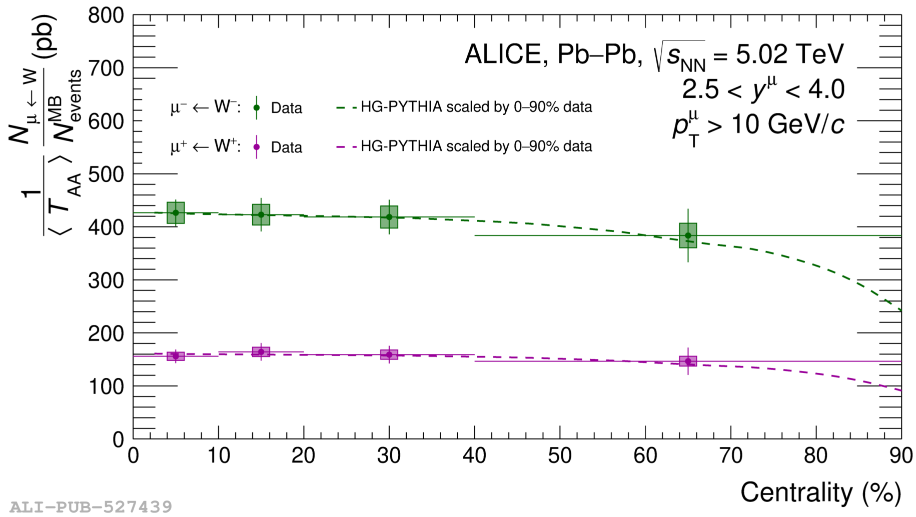

Figure 5: Normalised invariant yield of muons from W^+ and W^- as a function of the centrality in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$. The measured production is compared with HG-PYTHIA calculations [17].

. In pp collisions, the measured cross sections for $e^\pm \leftarrow W^\pm$ and Z^0 bosons are in good agreement with theoretical predictions based on pQCD. The production for $e^\pm \leftarrow W^\pm$ shows an increasing linear trend as a function of the charged-particle multiplicity. In p–Pb collisions, ALICE reaches the largest rapidity for $W^\pm$ productions. The result for W^+ suggests a significant modification of PDFs in a nuclear environment. In Pb–Pb collisions, the normalised invariant yield of muons from W^+ and W^- as a function of the centrality is consistent with HG-PYTHIA [17] calculations.

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