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Vector boson and quarkonia production in lead-lead collisions with ATLAS detector

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Photons and weak bosons do not interact strongly with the dense and hot medium formed in the nuclear collisions, thus should be sensitive to the nuclear modification of parton distribution functions (nPDFs). The in-medium modification of heavy quarkonium states plays an important role in studying the hot and dense medium formed in the larger collision systems. The ATLAS detector at the LHC, optimized for searching for new physics in proton-proton collisions, is especially well equipped to measure photons, Z, W bosons and quarkonia in the high occupancy environment produced in heavy-ion collisions. We present recent results on Z boson and charmonia yields as a functions of centrality, transverse momentum, and rapidity, from the ATLAS experiment.

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1. Introduction

The environment of collisions of heavy ions at ultrarelativistic energies is not only extrapolation of many collisions of protons but partons interact themselves and can produce the special state of matter called Quark-Gluon Plasma (QGP). This QGP exists only for a short time and particles in it can only interact strongly, so color charged particles like J/ψ can interact with the medium and alter the production of bounded states of quarks [1]. The centrality is used to describe an overlap of colliding nuclei.

The changes in productions yields are quantified by a nuclear modification factor R_{AA}, which can be defined for each centrality bin as:

$$R_{AA} = \frac{N_{AA}}{\langle T_{AA} \rangle \times \sigma^{pp}}, \tag{1.1}$$

where N_{AA} is a number of observed per-event yield, $\langle T_{AA} \rangle$ is a mean of nuclear thickness function, calculated using Glauber model [2], and σ^{pp} is a cross section for measured production in proton-proton (pp) collisions at the same energy of collision. If the R_{AA} is unity, the production is the same as in pp, and if $R_{AA} < 1$, there is a suppresion of production.

These proceedings report the measurements of Z boson and J/ψ productions in $Pb+Pb$ at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV and pp at $\sqrt{s} = 5.02$ TeV collected by the ATLAS detector[3] at the LHC.

2. Z boson

The baseline of the modifications in production rates between pp and $Pb+Pb$ for other measurements are the electroweak bosons yields. The Z boson provides an excellent opportunity for the measurements with its decay channels into a pair of leptons. This analysis uses the dimuon channel in datasets of $Pb+Pb$ (2015) [4], and pp (2015) [5]. The muons are expected to leave signal in both Inner Detector and in Muon Spectrometer, one muon to fire HLT trigger with a reconstructed transverse momentum higher than 8 GeV for $Pb+Pb$ or 14 GeV for pp sample. Events need to have only one interaction (no pile-up) and the Z decay vertex must be closer than 150 mm from the interaction point. In the analysis, muons must have reconstructed transverse momentum (p_T) higher than 20 GeV and pseudorapidity $|\eta|$ below 2.4 for triggered muon or 2.5 for second one, we use only events with the centrality of collision between 0% and 80%. Reconstructed invariant mass of the muon pair must fall into the range of 66 and 116 GeV. The correction factor is formed from the ratio of reconstructed to generated Z bosons in a given bin of p_T^Z and y^Z. This correction acts as a bin-by-bin unfolding and also account for detector performance effects. To improve the accuracy in those corrections, we use "tag-and-probe" method to correct Monte-Carlo (MC) simulation, to calculate scale factor between MC and data.

In Figure 1, the Z boson yields are shown as a function of $|y^Z|$ for bins of centrality in $Pb+Pb$, data from pp together with the next-to-leading-order preturbative Quantum Chromodynamics (NLO QCD) predictions. Both normalised yields and R_{AA} are consistent with the predictions with the exception of bin 40% to 80%, which is after an integration over rapidity aproximately 1.5 standard deviation from unity.

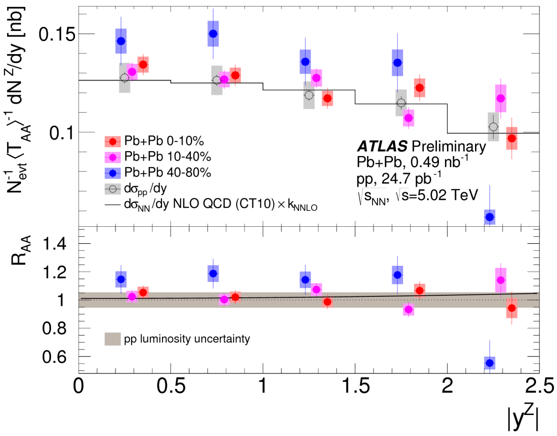

Figure 1: Z boson yield per event in three centrality bins divided by T_{AA} (colored circles) and comparison with theory (solid line) and pp collisions (open circles) as a function $|y^Z|$. In the lower part of the plot is R_{AA} with pp luminosity uncertainty shown as band around unity. Figure is taken from [4].

3. Charmonia

The measurement of J/ψ production in $Pb+Pb$ uses dimuons. Both muons must fall into the kinematic range of $|\eta| < 2.4$ and $p_T^\mu > 4$ GeV, they must pass the "tight" working point selection, have opposite charges, invariant mass in the range $2.6 < m_{\mu\mu} < 4.2$ GeV and reconstructed J/ψ candidates must have transverse momentum p_T higher than 9 GeV. Acceptance and efficiency corrections do not vary significantly in this fiducial region with relation to the systematics uncertainties. The pseudo-proper time (τ) is used to distinguish between prompt and non-prompt production of J/ψ, defined as $\tau = L_{xy} \frac{m_{\mu\mu}}{p_T^{\mu\mu}}$ where L_{xy} is the signed transverse distance between the primary vertex and J/ψ vertex.

In Figure 2, the non-prompt fraction is presented for the pp and the $Pb+Pb$ datasets as functions of p_T. The slope does not depent on the centrality but it is slightly different due to the change in the suppression of fractions in p_T and the fraction of non-prompt is also independent on rapidity.

The nuclear modification factor R_{AA} is shown as a function of the pair p_T and centrality respectively in Figures 3 and 4. They show a strong transverse momentum dependence of J/ψ prompt fraction and independence of non-prompt fraction which explains the difference between pp and $Pb+Pb$ non-prompt fraction in the Figure 2. The R_{AA} as a function of centrality, Figure 4, is comparable for both fractions with the smallest values around 0.2 for the most central bins. The prompt J/ψ mesons are little bit more suppressed in mid-central region but the shapes of function are similar.

4. Summary

The new Z boson and J/ψ results are presented for $Pb+Pb$ collisions at 5.02 TeV measured with the ATLAS detector at the LHC using dimuon decay.

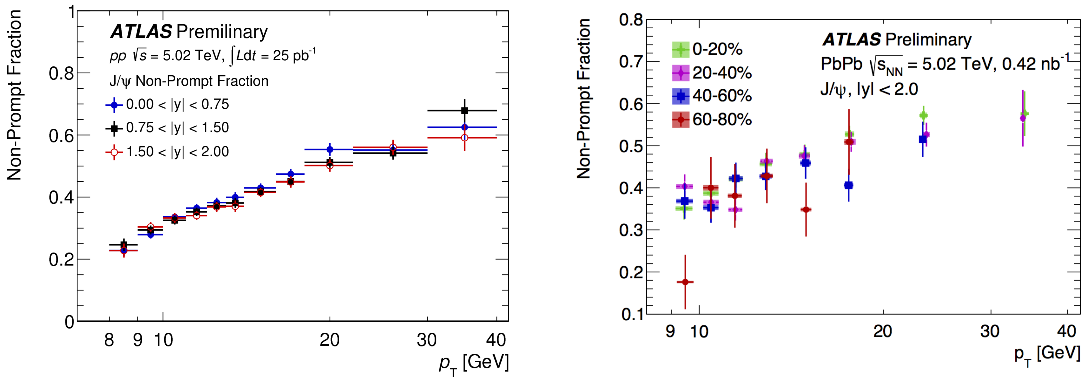

Figure 2: Non-prompt fraction of J/ψ production in 5.02 TeV for pp (left) and $Pb+Pb$ (right) collisions as a function of p_T. The Non-Prompt Fraction is a number of non-prompt J/ψ to the number of inclusively produced J/ψ. Figures are taken from [6].

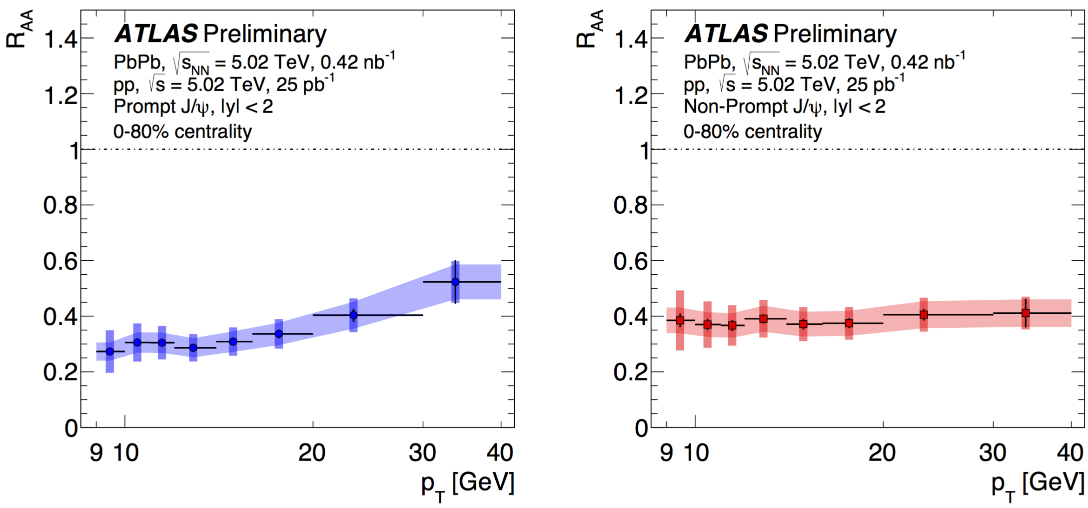

Figure 3: The nuclear modification factor as a function of p_T for prompt fraction (left) and non-prompt fraction (right) of J/ψ. Plots were produced for canditates with $|y| < 2$ and tranverse momentum in range $9 < p_T < 40$ GeV. Figures are taken from [6].

The Z boson yields are found to be well described by pQCD calculation scaled by T_{AA}. Nuclear modification factor R_{AA} is consistent with unity within uncertainties for all bins in rapidity and centrality after scaling by T_{AA}. The Z boson yields provide an alternative for T_{AA} independent of the Glauber model calculations for use in ratio with yields of other particles, for example J/ψ [7].

The J/ψ measurement shows that fractions of prompt and non-prompt J/ψ are strongly p_T-dependent and are independent on rapidity. We observe a similar p_T dependence for pp and for $Pb+Pb$ environment with a small change in the slope of a function, due to the different suppression of J/ψ fractions. The nuclear modification factor R_{AA} shows a p_T dependence for prompt J/ψ, and no significant dependence in p_T for non-prompt fraction due to the different production mechanisms. Both fractions have a strong centrality dependence and have the maximal suppression

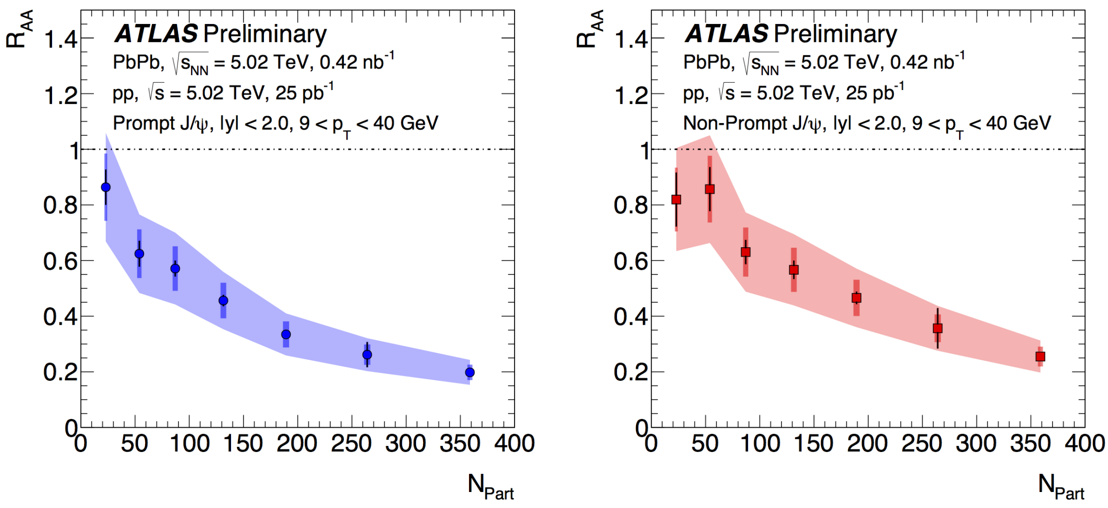

Figure 4: The nuclear modification factor as a function of centrality for prompt fraction (left) and non-prompt fraction (right) of J/ψ. Plots were produced for canditates with $|y| < 2$ and collisions with centrality from 0% to 80%. Figures are from [6].

for the most central collisions. Similarity of the patterns of functions in centrality was unexpected and will need a better understanding of the production mechanisms.

5. Acknoledgements

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