J/ψ elliptic flow measurements at forward rapidity in Pb-Pb collisions with ALICE at LHC

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Introduction

Lattice calculations of Quantum Chromo-Dynamics (QCD), predict that at a high temperature and extreme energy density, the nuclear matter undergoes a phase transition to a deconfined state of quarks and gluons, also known as Quark Gluon Plasma (QGP). In the laboratory, the QCD phase diagram and the expected formation of the QGP can be studied using ultra-relativistic heavy-ion collisions. Heavy-quark resonances, produced in high-energy heavy-ion collisions, are important observables for the study of QCD interactions at extreme energy densities. The suppression of charmonium resonances (J/ψ) due to color screening mechanism [1] or its enhancement due to regeneration mechanism [2] have been proposed as a signature of QGP.

ALICE (A Large Ion Collider Experiment [3]) is a general purpose experiment whose detectors identify and measure hadrons, electrons, photons and muons produced in p-p, p-Pb and Pb-Pb collisions at the Large Hadron Collider (LHC) of CERN. In the present analysis two detectors, VZERO and Muon Spectrometer, have been used in addition to the Silicon Pixel Detector (SPD) which provides the interaction vertex information. All of these detectors have full azimuthal coverage.

The VZERO scintillator detector is made of two sets of arrays known as VZERO-A and VZERO-C on each side of the interaction point covering 2.8< η <5.1 and -3.7< η <-1.7, respectively. The amplitude of the VZERO-A signal has been used to estimate the second harmonic event plane (Ψ) of Pb-Pb collisions in present study.

The Muon Spectrometer (-4.0< η <-2.5) is designed to run at the highest muon rate in heavy-ion collisions at LHC. It consists of the following components: a passive front absorber to absorb hadrons and photons from the interaction vertex; high granularity tracking system of 5 stations each with two detection planes; a large warm dipole magnet; a passive muon filter wall, followed by four planes of muon trigger chambers and a inner beam shield surrounding the beam pipe to protect the chambers from high particle flux at large rapidities.

Analysis Method

In the present data analysis, the events triggered by muon unlike (MU) sign trigger are analysed to find out the oppositely signed (OS) dimuon pairs ($m_{\mu\mu}$). The invariant mass spectrum is then fitted to extract the J/ψ candidates. The elliptic flow (v_2) of J/ψ is obtained determining $v_2 = \langle \cos 2(\phi - \Psi) \rangle$ versus invariant mass ($m_{\mu\mu}$) [4], where ϕ is the dimuon azimuthal angle. In this method, v_2 of the OS dimuons is calculated as a function of $m_{\mu\mu}$ and then the resulting $v_2(m_{\mu\mu})$ distribution is fitted using:

$$v_2(m_{\mu\mu}) = v_2^{\rm sig}\alpha(m_{\mu\mu}) + v_2^{\rm bkg}(m_{\mu\mu})[1-\alpha(m_{\mu\mu})],$$

where $v_2^{\rm sig}$ and $v_2^{\rm bkg}$ correspond to the v_2 of the J/ψ signal and of the background, respectively. Here, $\alpha(m_{\mu\mu}) = S/(S+B)$ is the ratio of the signal over the sum of the signal plus background in a given $m_{\mu\mu}$ bin. It is extracted from fits to the OS invariant mass distribution for given $p_{\rm T}$ and centrality

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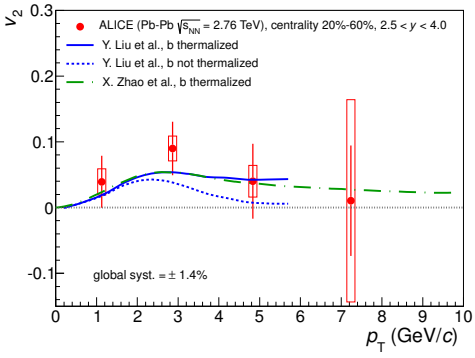

FIG. 1: Inclusive J/ψ $v_2(p_{\rm T})$ for semi-central (20%–60%) Pb-Pb collisions at $\sqrt{s_{\rm NN}}$= 2.76 TeV. Results from [6] for two transport models are also shown.

class. Consistent v_2 values are obtained using an alternative method [5] in which the J/ψ raw yield is extracted, as described before, in bins of $(\phi - \Psi)$ and the v_2 values are evaluated using a fit to the data with the function $\frac{dN}{d(\phi-\Psi)} = A[1 + 2v_2 \cos 2(\phi - \Psi)]$, where A is a normalization constant.

Results

A total of 17.10^6 unlike-sign dimuon recorded in Pb-Pb collisions ($\mathcal{L}_{\rm int} \approx 70\ \mu{\rm b}^{-1}$) at $\sqrt{s_{\rm NN}}$= 2.76 TeV have been used for the present analysis. ALICE has measured a non-zero elliptic flow of inclusive J/ψ for the first time in heavy-ion collision. The largest measured v_2 value is 0.116 ± 0.046(stat.) ± 0.029(syst.) in the transverse momentum range $2 < p_{\rm T} < 4$ GeV/c for semi-central Pb-Pb collisions [6]. The dependence on centrality of the J/ψ v_2 and J/ψ transverse momentum is studied here in the range $0 < p_{\rm T} < 10$ GeV/c (see Figure 1). This elliptic flow measurement is complementary to the previously reported result of inclusive J/ψ nuclear modification factor in [7] and favors the scenario in which a significant fraction of J/ψ are produced from regeneration mechanism. Since a maximum of 11% of J/ψs can be produced from B hadron decays in Pb-Pb collisions at $\sqrt{s_{\rm NN}}$= 2.76 TeV [6], the J/ψ v_2 is also compared with theoretical models [8]-[9] with and without the thermalisation of b quarks as shown in Figure 1.

Conclusions

ALICE reports the first measurement of non-zero elliptic flow of inclusive J/ψ at forward rapidity in Pb-Pb collisions at $\sqrt{s_{\rm NN}}$= 2.76 TeV whereas it is found to be consistent with zero within errors in Au-Au collisions at $\sqrt{s_{\rm NN}}$= 200 GeV [10]. The non-zero v_2 results are in qualitative agreement with the predictions from transport models. This indicates that 50% of the J/ψs are generated from (re)combination mechanism in QGP phase.

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