Elliptic flow measurement of inclusive photons at forward rapidities in heavy-ion collision models

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Introduction

In non-central collisions, the overlapping reaction zone of two colliding nuclei is not spherical. Rescatterings among the systems constituents convert the initial coordinate-space anisotropy into a momentum-space anisotropy since the pressure gradient is not azimuthally symmetric. The spatial anisotropy is largest early in the evolution of the collision. As the system expands it becomes more spherical, thus this driving force quenches itself. Therefore the momentum anisotropy is particularly sensitive to the early stages of the system evolution.

The elliptic flow (v_2) measurements are believed to provide information on the dynamics of the system formed in the heavy-ion collisions [1]. Within the framework of a hydrodynamical approach, v_2 is found to be sensitive to the equation of state of the system formed in the collisions [2]. Measurements of elliptic flow at the forward rapidity have revealed an interesting observation of longitudinal scaling of v_2 when plotted as a function of pseudorapidity (η) shifted by the beam rapidity (y_{beam}) [3]. With the upcoming new measurements in the beam energy scan (BES) program at Relativistic Heavy Ion Collider (RHIC) and higher energies at Large Hadron Collider (LHC), this scaling can be put to a further test. For studying such scaling at RHIC and LHC we have mostly multiplicity detectors in forward rapidities at both the colliders. For example, in STAR and ALICE experiments there exists a photon multiplicity detector (PMD) in the range $2.3 < \eta < 3.9$ [4]. In the present work we have studied using heavy-ion collision models the inclusive photons v_2 which can be measured by such a detector.

The v_2 is the 2nd Fourier coefficient of the particle azimuthal angle (ϕ) distribution with respect to the reaction plane angle (Ψ). Where Ψ is the angle subtended by the plane containing the impact parameter vector and the beam direction. Mathematically we can write,

$$\frac{dN}{d\phi} \propto 1 + 2v_2 cos(2(\phi - \Psi)) \quad (1)$$

For a given kinematic window the second coefficient or the elliptic flow parameter is

$$v_2 = < cos(2(\phi - \Psi)) > \quad (2)$$

Here, we present a study of the v_2 for inclusive photons using above approach of measurement from transport models in heavy-ion collisions like Ultra relativistic Quantum Molecular Dynamics (UrQMD) [5] and A Multi Phase Transport (AMPT) model [6]. AMPT model has two versions, one with default settings (here referred as the AMPT default) and the other that includes partonic interactions (referred as AMPT-SM).

Photon vs. neutral pion v_2

Since more than 90% of the inclusive photons come from the decay of π^0 mesons from SPS to LHC energies. We have studied how the decay effect reflects in the measured v_2 for photons relative to those of the parent π^0. Fig.1 shows the v_2 as a function of η. The p_T integrated v_2 of photon is smaller than that for π^0 in minimum bias Pb+Pb collisions. The magnitude of v_2 from AMPT-SM is higher than that from AMPT-default. The lower value of p_T integrated v_2 of photon compared to those for π^0 are comparable is due to photon p_T spectra having a smaller mean transverse momentum compared to corresponding value for π^0. Figure 2 shows the difference in v_2 of π^0 compared to those from the photons divided by the v_2 of phtons as a function of beam energy from AMPT-SM model using minimum bias collisions within $2.3 < \eta < 3.9$. This relative fraction is observed to be almost constant as a function of $\sqrt{s_{NN}}$ and has a value of around 0.44.

Longitudinal scaling of photon v_2 at RHIC BES and LHC

With the emergence of LHC and RHIC Beam Energy Scan program, the longitudinal scaling of

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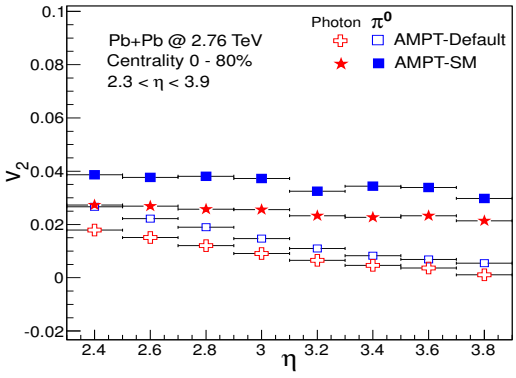

FIG. 1: Elliptic flow (v_2) as a function of η for inclusive photons and π^0 from AMPT-default and AMPT-SM in Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76\ TeV$.

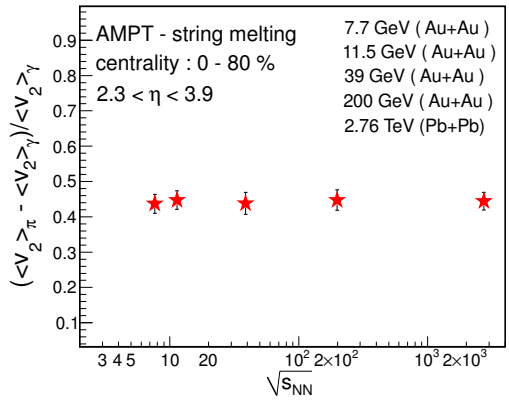

FIG. 2: Ratio of the difference in average elliptic flow (v_2) for π^0 and inclusive photons to the v_2 of photons as a function of beam energy.

v_2 can be put to further test. RHIC has recently completed the BES program by collecting data for $\sqrt{s_{NN}} = 7.7 - 200\ GeV$ and LHC has collected Pb+Pb data at $\sqrt{s_{NN}} = 2.76\ TeV$.

Figure 3 shows the v_2 for inclusive photons as a function of $\eta - y_{beam}$ for $\sqrt{s_{NN}} = 7.7\ GeV$ to 2.76 TeV using AMPT-SM with default settings. The parton cross section is taken as 10 mb. We observe the usual longitudinal scaling of v_2 .

Recently it was shown that although the results with a partonic cross section of 10 mb in AMPT-SM at RHIC is able to explain the measured distributions, for those at LHC energies one requires a smaller cross section of 1.5 mb. In Fig. 3 we also

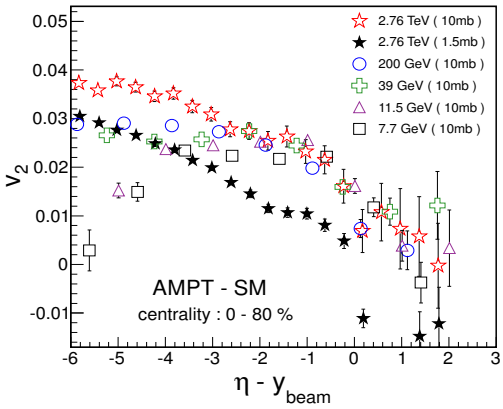

FIG. 3: Inclusive photon v_2 as a function $\eta - y_{beam}$ for Au+Au collisions at $\sqrt{s_{NN}} = 7.7, 11.5, 39, 200\ GeV$ and Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76\ TeV$.

show the v_2 vs. $\eta - y_{beam}$ from AMPT-SM using cross section of 1.5mb at $\sqrt{s_{NN}} = 2.76\ TeV$. We find the longitudinal scaling behavior is violated.

Summary

We have presented inclusive photon v_2 in RHIC BES and LHC using transport models UrQMD and AMPT. We find that there is about 40% decrease in the p_T integrated v_2 of photons relative to those from π^0 for $\sqrt{s_{NN}} = 7.7\ GeV$ to 2.76 TeV. The AMPT-SM model predicts that if parton-parton cross-section is independent of beam energies then one should observe longitudinal scaling in inclusive photons v_2. If the collisions at lower and higher energies require different cross-sections for explaining the measured distributions, we would expect a breakdown of the longitudinal scaling.

References

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