Inclusive Charged Hadron $v_2$ in Au+Au Collisions at $\sqrt{s_{NN}}=7.7 - 39$ GeV in STAR

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Introduction

One of the main goals of the STAR experiment at Relativistic Heavy Ion Collider (RHIC) is to study the properties of the QCD matter at extremely high energy and parton densities, created in the heavy-ion collisions [1]. Recently RHIC has undertaken a Beam Energy Scan (BES) program to look for changes in observation of various measurements as a function of beam energy to study the QCD phase structures.

In the non-central nucleus nucleus collisions, the overlapping area is not spherical. This initial spatial anisotropy is then transformed into momentum anisotropy because of the pressure gradients developed by the subsequent interactions among the constituents [2]. The elliptic flow ($v_2$) is a measure of anisotropy in momentum space. The elliptic flow parameter is defined as the second Fourier coefficient of the particles distribution in emission azimuthal angle ($\phi$) with respect to the reaction plane angle ($\Psi$). For a given rapidity window the second coefficient is

$$v_2 = \langle \cos(2(\phi - \Psi)) \rangle.$$  \hspace{1cm} (1)

The BES program at RHIC allows to study elliptic flow at different baryonic chemical potential ($\mu_B$) from 20 to about 400 MeV [3]. Lattice QCD calculations suggest that the quark-hadron transition is cross-over at small $\mu_B$ or high $\sqrt{s_{NN}}$ and other model calculation suggest that at higher $\mu_B$ or lower $\sqrt{s_{NN}}$ the transition is expected to be first order [4]. According to the reference [5], a non-monotonic behavior of $v_2$ could be observed around the “softest point of the EOS”. Measurement of $v_2$ as function of $\sqrt{s_{NN}}$ and collision centrality could be used to search for the softest point of the EOS in the heavy ion collisions. In addition the $v_2$ measurement using several methods would be helpful to understand non-flow contributions and flow fluctuations.

Data sets and Analysis methods

In this presentation we will report the inclusive charged hadron $v_2$ at midrapidity ($|\eta| < 1.0$) in Au+Au collisions at $\sqrt{s_{NN}} = 7.7$, 11.5, 19.6, 27, and 39 GeV, data was collected in the years 2010 and 2011 by the STAR experiment. The upper panels of Figure 1 show the $p_T$ dependence of $v_2$ from various methods for the 20-30% collision centrality [6]. The $v_2\{\text{FTPC}/\text{BBC}\}$ means $v_2$ measured using event plane reconstructed from the tracks recorded by FTPC (2.5 $< |\eta| < 4.0$)/BBC(3.8 $< |\eta| < 5.2$) detectors and $v_2\{\text{EtaSubs}\}$ implies $v_2$ using $\eta$ sub-event method where the event plane are taken from opposite hemisphere in pseudorapidity. Details of $v_2\{\text{EtaSubs}\}$, $v_2\{2\}$, and $v_2\{4\}$ can be found in [6]. The lower panels of figure 1 show ratio of $v_2$ of all other methods to that of the 2-particle cumulant method. It can be seen that the difference of $v_2\{2\}$ compared to $v_2\{\text{FTPC}/\text{BBC}\}$, $v_2\{4\}$ and $v_2\{\text{EtaSubs}\}$ depends on $p_T$ range. A relatively larger difference is observed in the low $p_T$ region ($p_T < 1$ GeV/$c$) while the difference between $v_2\{\text{FTPC}/\text{BBC}\}$ and $v_2\{4\}$ is relatively small and less dependent on the $p_T$. It suggests the non-flow contribution to the event plane and 2-particle correlation methods depends on $p_T$.

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FIG. 1: The transverse momentum dependence of charged hadron $v_2$ for 20-30% central Au+Au collision at midrapidity for $\sqrt{s_{NN}} = 7.7, 11.5, 19.6, 27$ and 39 GeV [6].

FIG. 2: Charged hadron $v_2$ vs. $p_T$ for various centrality at midrapidity for $\sqrt{s_{NN}} = 7.7$ GeV - 2.76 TeV [6]. The results for $\sqrt{s_{NN}} = 7.7$ to 200 GeV are for Au+Au collisions and those for 2.76 TeV are for Pb + Pb collisions [7].

Results

Upper panels of figure 2 show the energy dependence of charged hadron $v_2$ vs. $p_T$ for different centrality from top LHC energy (2.76 TeV) [7] to lowest RHIC energy (7.7 GeV) [6]. For comparison, the $v_2$ from other energies are divided by a fit to the $v_2$ at 200 GeV. For $p_T < 2$ GeV/c, the $v_2$ values rise with increasing collision energy while beyond $p_T = 2$ GeV/c the $v_2$ results show comparable values within statistical error.

We will present centrality and $\eta$ dependence of the inclusive charged hadron $v_2$. To understand the physical mechanism behind the measurement, we will also compare $v_2$ results from the different collision energies to transport model calculation like a multiphase transport model (AMPT) and the ultrarelativistic quantum molecular dynamics (UrQMD) model.

References