Elliptic flow of light nuclei in Au+Au collisions at $\sqrt{s_{NN}}$ = 39, 27, 19.6, 11.5, 7.7 GeV in STAR

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I. INTRODUCTION

A strongly interacting medium of deconfined quarks and gluons, namely Quark Gluon Plasma (QGP), is expected to be formed in high energy heavy ion collisions at RHIC. Many observables are being used to investigate the properties of the QGP. Elliptic flow (v_2), the second order Fourier coefficient of azimuthal distribution of the produced particles with respect to reaction plane [1], is one of them.

In a non-zero impact parameter collision between two identical nuclei, the collision zone is asymmetric. Multiple interaction between the participants transform the initial spatial asymmetry into an anisotropy in momentum space in the final state. One of the way to quantify and study the momentum anisotropy is by decomposing the azimuthal distribution of produced particles in a Fourier series,

$$\frac{dN}{d\phi} = \frac{N}{2\pi}\left[1 + 2\sum_{n} v_n \cos(n\phi - n\Psi_{\mathrm{RP}})\right], n = 1, 2, 3... \quad (1)$$

where, ϕ is the azimuthal angle of the detected particle and Ψ_{RP} is the plane of the symmetry of initial collision zone defined by the impact parameter vector and the beam direction. v_n are called flow coefficient and can be expressed as $v_n = < cos(n\phi - n\Psi_{\mathrm{RP}}) >$, where angular bracket indicate average over all particles over all events. To measure v_2 in experiment, we calculate event plane angle Ψ_2 using the azimuthal anisotropy of the produced particles [1]. We divide an event into two sub-events separated in pseudorapidity window and then calculate Ψ_2 in each sub-events to remove the effect of self correlation and non-flow. The observed number of constituent quark (NCQ) scaling of elliptic flow (v_2) is believed to be the outcome of partonic collectivity at the early stage of heavy-ion collision [2]. It also provides a remarkable evidence that quark coalescence is the dominant mechanism of hadronization at intermediate transverse momentum ($2 < p_T < 6$ GeV/c) [3]. Light nuclei (d, t, ^{3}He) are believed to be formed by coalescence of nucleons. The elliptic flow of these nuclei then can be studied and compared to the elliptic flow of their constituent nucleons since both of them are directly observable by the detectors. By studying and comparing the elliptic flow of light nuclei and their constituent nucleons, we can better understand the particle production mechanism in heavy ion collisions.

II. ANALYSIS

Here we report the centrality and p_T dependence of v_2 of light nuclei at mid-rapidity ($|\eta| < 1$) for Au+Au collisions at $\sqrt{s_{NN}} = 39, 27, 19.6, 11.5, 7.7$ GeV from the STAR experiment.

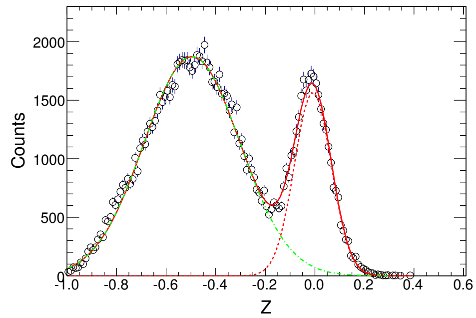

FIG. 1: Z-distribution of anti-deuteron for $1.3 < p_T < 1.9$ (GeV/c) and $0 < \phi - \Psi_2 < \pi/10$(rad) for Au+Au collision at $\sqrt{s_{NN}}$ = 39 GeV with TOF cut $2.8 < m^2 < 4.2$ (GeV^2/c^4). Here red (dashed) curve is Gaussian fit to the signal (anti-deuteron) and green (dot-dashed) line is Gaussian fit to background.

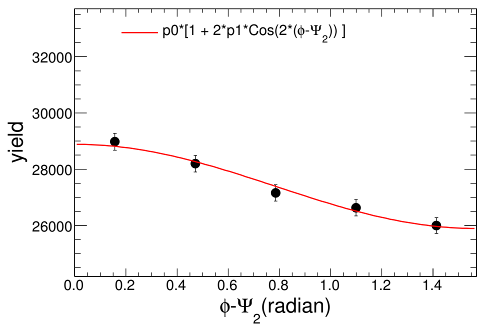

FIG. 2: $\phi-\Psi_2$ distribution of anti-deuteron for $1.3 < p_T < 1.9$ (GeV/c) for Au+Au collision at $\sqrt{s_{NN}}$ = 39 GeV. Red line corresponds to the fit to the data points. Legend shows the fit fucntion used, where p0 and p1 are free parameters.

Light nuclei are identified using the Time Projection Chamber (TPC) and the Time of Flight (TOF) detectors at STAR. The TPC has full azimuthal coverage

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and identifies the particles from their specific energy loss as a function of momentum in pseudorapidity window -1.8< η <1.8 [4]. We define a variable Z as,

$$Z = \log_e \left[\frac{(dE/dx)_{\rm measured}}{(dE/dx)_{\rm predicted}} \right]. \quad (2)$$

The Z distribution then, will have a peak around zero for the desired particle, as shown in Fig. 1.

Using the TOF detector, we can select the track of interest using proper cut on m^2 where m is the mass of the nuclei. This cut helps to increase the purity of the signal for intermediate p_T region (1< p_T <4 GeV/c). The TOF detector covers $|\eta|$ <0.9 and full azimuth [5]. Two Gaussian fit, one for signal and another for background, is applied to the Z distribution for each ϕ-Ψ_2 bin. Then the background contribution is removed from the signal using the parameters achieved from the fit function. The event plane angle Ψ_2 is defined by

$$\Psi_2 = \frac{1}{2} \left[\tan^{-1} \frac{\Sigma w_i \sin(2\phi_i)}{\Sigma w_i \cos(2\phi_i)} \right]. \quad (3)$$

The sums go over the i particles used in the event plane determination and the w_i are weights. We have removed the effect of self-correlation by excluding the particle whose v_2 is to be calculated from the event plane calculation.

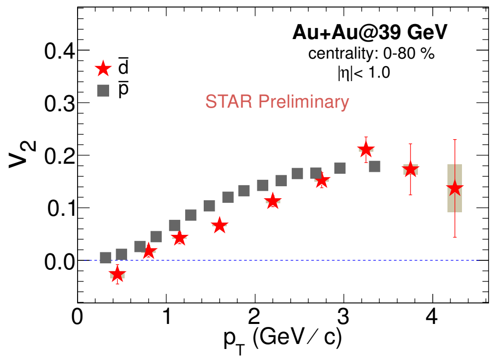

FIG. 3: v_2 of anti-deuteron compared with antiproton for minimum bias Au+Au collisions at $\sqrt{s_{NN}}$ = 39 GeV. The grey bands are sytematic error

After having yield of desired nuclei for all azimuthal range, we get the observed elliptic flow (v_2^{obs}) from the fit to the azimuthal distribution of this particle with respect to the event plane, as shown in Fig. 2. The elliptic flow coefficients with respect to the real reaction plane are then evaluated by dividing observed elliptic flow by the event plane resolution, i.e., $v_2 = v_2^{obs}/R$. Resolution R is determined from two equal multiplicity sub-events planes, Ψ_2^a and Ψ_2^b using equation 11 & 14 of reference [1].

III. RESULTS AND CONCLUSION

In this work we mainly focus on the elliptic flow of nuclei and its scaling. We will present the results from the data collected by STAR in the year 2010 and 2011. As a representative results we show here anti-deuteron results from 119M minimum bias events of Au+Au collision at $\sqrt{s_{NN}}$ = 39 GeV.

Figure 3 shows the v_2 results for anti-deuteron ($\bar{d}$), compared with anti-proton ($\bar{p}$) [6] for minimum bias (0-80%) events of Au+Au collisions at $\sqrt{s_{NN}}$ = 39 GeV. From this result we see that v_2 is lower for anti-deuterons compared to anti-proton for p_T < 2.5 GeV. This is consistent with the mass ordering of v_2 [7].

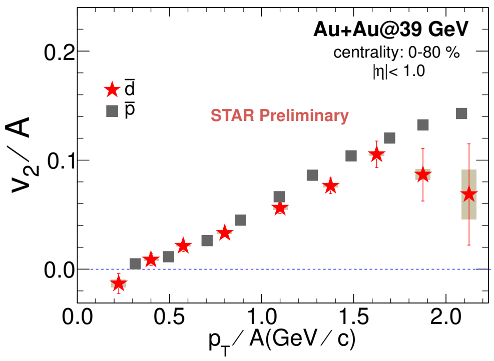

FIG. 4: Mass number scaling of anti-deuteron v_2, compared with anti-proton for Au+Au collision at $\sqrt{s_{NN}}$ = 39 GeV. The error bars are statistical.

In Fig. 4, we show the mass number (A) scaling of anti-deuteron v_2, compared to anti-proton. From this figure, it seems that the scaled v_2 of anti-deuteron tends follow the results of anti-proton for $\sqrt{s_{NN}}$ = 39 GeV. Results for other energies including other nuclei (d, t, ^{3}He) will be shown at the time of presentation.

Acknowledgements

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