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Comparative Study of Elliptic Elow for Au+Au and Cu+Cu Collisions at 62.4 GeV/A

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***Abstract* - Elliptic flow is one of the most informative observable in search of Quark Gluon Plasma. The elliptic flow coefficient (v_2) variation with centerality for inclusive charged hadrons were studied using events generated by AMPT(Default) for Au+Au & Cu+Cu collisions at center of mass energy of 62.4 GeV per nucleon pair. This study also includes the variation of ratio elliptic flow coefficient for Au+Au to elliptic flow coefficient for Cu+Cu. This study performed for transverse momentum range = 0.2 to 1.0 GeV/c and pseudo rapidity range = -0.35 to 0.35. We compared the simulated data results with RHIC-PHENIX experimental results.**

***Keywords* - Anisotropy, Elliptic flow, Flow, Heavy ion collisions, Quark gluon plasma, RHIC, Simulation.**

I. INTRODUCTION

According to Lattice Quantum Chromodynamics, at temperatures greater than 175 MeV and/or baryon density larger than 5 to 10 times of normal nuclear matter density, the quarks and gluons are no longer confined inside hadrons but are free to roam over distance of the order of nuclear sizes; this new phase of matter is called Quark Gluon Plasma (QGP) [1], [2], [3], [4]. One of the primary goals of the heavy-ion program at accelerators is to search for the possible formation of 'Quark-Gluon Plasma 'phase of nuclear matter. Relativistic Heavy Ion Collider (RHIC) [5] at Brookhaven National Laboratory has been constructed for this purpose and nuclei as heavy as gold (Au) are accelerated to centre of mass energy 62.4 GeV. It is important to study elliptic flow to understand the underlying collision dynamics in heavy ion collisions [6]. Azimuthal distribution of particles can be decomposed into Fourier components and the coefficients can be measured experimentally [7-8].

II. EVENT GENERATION

A popular event generator AMPT (A Multiphase Transport Model) with default setting have been used to generate events for Au+Au and Cu+Cu at centre of mass energy 62.4 GeV per nucleon pair. AMPT is a hybrid transport model, which models an ultra-relativistic nuclear collision using many tools of Monte Carlo simulations [9]. Total 400K events have been generated for pseudorapidity range from -0.35 to 0.35, parameter identical to PHENIX experimental situation.

III. ANALYSIS

The azimuthal distributions are expanded in Fourier series where the coefficients of expansion are the measures of different orders of anisotropy [9]. One can characterizes this anisotropy in terms of a single-particle probability distribution for each collision event. This distribution as a Fourier series with respect to the azimuthal angle of out-going particles φ, can be expressed as:

$$\frac{2\pi}{N}\frac{dN}{d\phi} = 1 + 2\sum_{n=1}^{\infty} v_n \cos n(\phi - \psi_n) \qquad (1)$$

The reaction plane method is applicable when the reaction plane angle is exactly known. The exact reaction plane angle may be known in the simulation.

The reaction plane angle is a parameter of the initial geometry, and it is therefore unknown in experimental data. So an estimated reaction plane, known as event plane, is used for determination of flow coefficients. This method is known as event plane method [8]. In this work we used the more common event plane method for the determination of flow coefficient. Flow coefficients v_n can be defined as:

$$v_{\mathrm{n}} = \left\langle \cos\left[\mathrm{n}(\phi - \psi_{\mathrm{n}})\right]\right\rangle \qquad (2)$$

Where the brackets indicate an average over the single particle probability and the event plane angles Ψn are chosen such that v_n are the (positive) magnitudes of the complex Fourier coefficients.

The first order anisotropy v_1 is called directed flow coefficient; it measures the shift of the centroid of the distribution. The second order anisotropy v_2 is called elliptic flow coefficient; it measures the difference between the major and minor axes of the elliptic shape of the azimuthal distribution.

IV. RESULTS

The data generated from AMPT have been analyzed. The elliptic flow coefficient (v_2) has been determined using event plane method from AMPT (default) events for 0-50% in steps of 10% centrality bins for transverse momentum ranging from 0.2-1.0 GeV/c. The variation of elliptic flow coefficient (v_2) with various centrality percentile for simulated events generated at 62.4 GeV for Au+Au has been studied. The AMPT data results have been compared with results calculated from data sets taken in Run-4 and Run-5 periods by PHENIX at RHIC [10].

The comparative study of the results determined from AMPT result and experimental result for different colliding species at the same energy in the same transverse momentum range are presented here. Fig. 1 shows the elliptic flow coefficient v_2 at different centrality class for Au+Au & Cu+Cu collisions at 62.4 GeV for transverse momentum range 0.2 to 1.0 GeV/c. In these figures blue colour and red colour markers corresponds to results obtained from the experimental result and AMPT result respectively. Filled and Unfilled markers correspond to results for Au+Au and Cu+Cu colliding systems respectively. Fig. 1 shows that the value of elliptic flow is higher for Au+Au collisions in comparison to for Cu+Cu collisions within all centrality classes under study, except for most central collisions (i.e. 0 – 10 % centrality class).

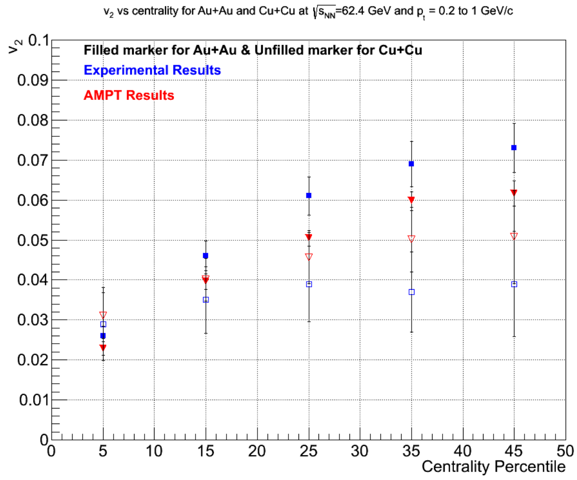

Fig. 1 Variation of elliptic flow coefficient (v_2) with centrality for Au+Au & Cu+Cu collisions at 62.4 GeV for p_t = 0.2 to 1.0 GeV/c.

The study of dependence on colliding species is also performed by studying the ratio of elliptic flow v_2 for Au+Au collisions to v_2 for Cu+Cu collisions at 62.4 GeV determined from AMPT and experimental data. Fig. 2 shows the ratio of elliptic flow v_2 at different centrality class for Au+Au & Cu+Cu collisions at 62.4 GeV for transverse momentum range 0.2 to 1.0 GeV/c. In these graphs blue colour square and red colour circle correspond to results obtained from experimental and AMPT dataset respectively. Fig. 2 represents that the value of the ratio of v_2 is varying in the same manner with centrality for both AMPT and experimental results. The value of the ratio is more than 1 within all centrality classes under study, except for most central collisions (i.e. 0 – 10 % centrality class). This may be due to different eccentricity and initial geometrical anisotropy for most central collisions.

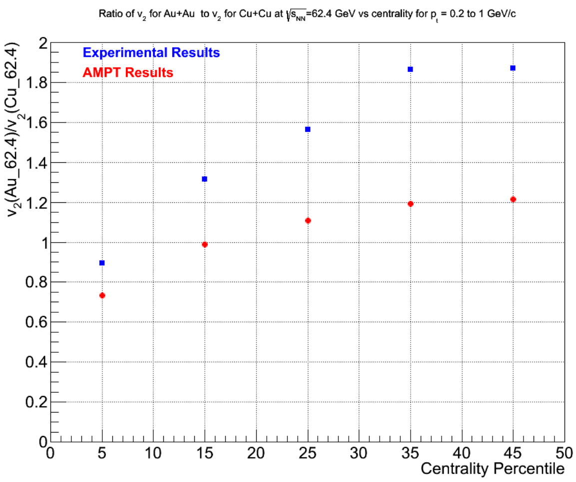

Fig. 2 Variation of ratio of elliptic flow coefficient (v_2) with centrality for Au+Au & Cu+Cu collisions at 62.4 GeV for transverse momentum range 0.2 to 1.0 GeV/c.

To parameterize the study of the ratio of v_2 for Au to v_2 for Cu, fitting of data have performed with a second order polynomial. The fitting equation is

$$\frac{v_2(\mathrm{Au})}{v_2(\mathrm{Cu})} = a + bx + cx^2 \quad (3)$$

Where, x is the mean centrality of centrality class of interval 10%.

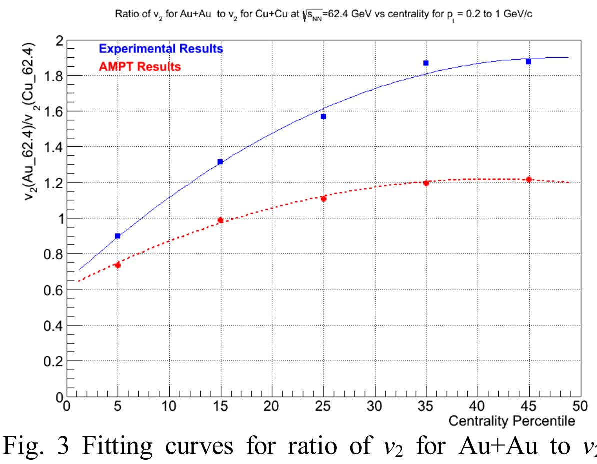

Fig. 3 Fitting curves for ratio of v_2 for Au+Au to v_2 for Cu+Cu collisions at 62.4 GeV for transverse momentum range 0.2 to 1.0 GeV/c.

The values of coefficients of polynomial i.e. fitting parameters a, b and c, as obtained from fit are summarized in Table I. The fitting curve for experimental data and AMPT data in Fig. 3 shows the same trend of variation of the ratio of v_2 for Au to v_2 for Cu with centrality.

TABLE I
Value of fitting parameters

	a	**b**	**c**
Experimental	0.646130	0.052480	-0.000549
AMPT	0.609942	0.029353	-0.000354

V. CONCLUSIONS

The colliding nuclei dependence is studied by comparing elliptic flow coefficient v_2 for Au+Au and Cu+Cu collision at fixed beam energy. This study shows that the value of elliptic flow is higher for Au+Au collisions in comparison to for Cu+Cu collisions for 10 – 50 % centrality. The ratio of v_2, value for Au+Au to v_2, value for Cu+Cu at fixed beam energy is also studied with centrality. The value of the ratio is more than 1 for 10 – 50 % centrality. There is different result for 0 -10 % centrality class, which may be due to different eccentricity and initial geometrical anisotropy for most central collisions. The trend of variation is almost same for experimental and simulated results. This study can predict the expected value ratio of v_2 for Au+Au and Cu+Cu using fitting equation (3) and fitting parameters given in Table 1 for any centrality within the scope of this study.

The study can be improved by using GEANT, to remove detector effect. This study can be extended to much higher Large Hadron Collider (LHC) energies. By studying more about v_2 for another collision system and energies, additional experimental and theoretical insights will be gained that will provide a deeper understanding of the created medium's properties.

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