

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 9, September 2017

## Parameterization of Elliptic Flow Coefficient for Au+Au Collisions at Two Beam Energies

Somani Ajit Kumar <sup>1</sup>, Keswani Bright <sup>2</sup>, Bhardwaj Sudhir <sup>3</sup>, Agnihotri Ashish <sup>4</sup>

Research Scholar, Dept. of Physics, Suresh Gyan Vihar University, Jaipur, Rajasthan, India<sup>1</sup>

(Presently working as Lecturer, CMRB Govt. Polytechnic College, Sriganganagar, Rajasthan, India)

Prof. & Head, Dept. of Computer Application, Suresh Gyan Vihar University, Jaipur, Rajasthan, India<sup>2</sup>

Assistant Professor, Dept. of Physics, Govt. College of Engineering & Technology, Bikaner, Rajasthan, India<sup>3</sup>

Prof. & Head, Dept. of Physics, Sri Balaji College of Engineering & Technology, Jaipur, Rajasthan, India<sup>4</sup>

**ABSTRACT:** It is important to study elliptic flow coefficient ( $v_2$ ) to search for the possible formation of Quark-Gluon Plasma. The variation of elliptic flow coefficient with centrality were studied using events generated by AMPT (Default) for Au+Au collisions at center of mass energies of 62.4 and 200 GeV. This work also includes the study of variation of the ratio of  $v_2$  for 200 GeV to  $v_2$  for 62.4 GeV, with centrality. We compared the simulated data results with PHENIX experimental results and found close agreement between them. The whole study was performed for inclusive charged hadrons for most central and mid-peripheral Au+Au collisions in the transverse momentum range from 0.2 to 1.0 GeV/c and pseudo rapidity range from (-) 0.35 to (+) 0.35 (parameter similar to the PHENIX experimental setup). The study of the variation of the ratio of  $v_2$  for 200 GeV to  $v_2$  for 62.4 GeV was parameterized by fitting. We proposed a new formula to know the expected value of  $v_2$  for 200 GeV at particular centrality, provided  $v_2$  for 62.4 GeV is known and vice versa. Similarly, we can know the value of the ratio  $v_2$  for 200 GeV to  $v_2$  for 62.4 GeV at particular centrality.

**KEYWORDS:** Elliptic flow; Heavy ion collisions; Quark gluon plasma.

### 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 distances of the order of nuclear sizes; this new phase of matter is called Quark Gluon Plasma (QGP) [1,2,3,4]. On Earth, ultra-relativistic heavy ion collisions are considered to be the only way to create opportunities for creating and researching QGP. It is important to study elliptic flow to understand the underlying collision dynamics in heavy ion collisions [5]. So it has been extensively studied by theoreticians and experimentalists in recent years.

### II. RELATED WORK

In 1996, Voloshin and Zhang presented the Fourier decomposition [6]. In this approach the different Fourier coefficients give different harmonics in flow, so it was useful to identify the different types of anisotropy in flow. They also give the information about the relative magnitude of each harmonic. The first harmonic coefficient,  $v_1$ , is known as the directed flow (also called sideward flow) and reflects an overall shift in one direction. The second harmonic coefficient,  $v_2$ , is known as the elliptic flow, since the second order particle distribution represents an ellipse [7]. The elliptic flow coefficient has been calculated by various researchers using simulated or experimental datasets. In order to reliably extract information about the elliptic flow, it is important to know the value of the elliptic flow

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 9, September 2017

coefficient corresponding to particular parameters from the available datasets without rigorous analysis. This is precisely what we are going to address in this work.

### III. EVENT GENERATION AND ANALYSIS

A popular event generator AMPT (A Multi-Phase Transport model) with default setting have been used to generate events for Au+Au collisions at center of mass energies of 62.4 and 200 GeV per nucleon pair. AMPT is a hybrid transport model, which models an ultra-relativistic nuclear collision using many tools of Monte Carlo simulations [8]. Events have been generated in the pseudorapidity range from -0.35 to 0.35, parameter similar to the PHENIX experimental setup.

The azimuthal distribution of produced particles is expanded in Fourier series where the coefficients of expansion are the measures of different orders of anisotropy [6,7]. One can characterize 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 can be expressed as:

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

The event plane angle  $\psi_n$  is defined as:

$$\psi_n = \frac{1}{n} \tan^{-1} \left( \frac{\sum_i \sin(n\phi_i)}{\sum_i \cos(n\phi_i)} \right) \quad \dots (2)$$

and the flow coefficient  $v_n$  is defined as:

$$v_n = \langle \cos[n(\phi_i - \psi_n)] \rangle \quad \dots (3)$$

where the brackets  $\langle \rangle$  denote averaging over all particles in all events. As we discussed earlier that the second order coefficient  $v_2$  is called elliptic flow coefficient.

We used the standard event plane method [7] and for removing autocorrelation, the whole event set is divided into two sub-events sets. The sub-events are created by splitting the pseudorapidity ranges into two subsets for each event in such a manner that each sub-event has same multiplicity [9, 10]. The elliptic flow coefficients  $v_2^P$  and  $v_2^Q$  are calculated for two sub-events P and Q, as follows

$$v_2^P = \langle \cos\{2(\phi_1^P - \psi_2^P)\} \rangle \quad \dots (4)$$

$$v_2^Q = \langle \cos\{2(\phi_1^Q - \psi_2^Q)\} \rangle \quad \dots (5)$$

Where  $\phi_i^P$  and  $\phi_i^Q$  represents the azimuthal angles of particles in sub-event P and Q respectively.  $\psi_2^P$  and  $\psi_2^Q$  represents the event plane angles determined using particles in sub-event P and Q respectively. The averages are calculated over all particles over all events in the particular subevent.

The finite multiplicity limits the exact estimation of the event plane angle. This is corrected by using event plane resolution. So the final expression of flow coefficient after the resolution correction is given by:

$$v_2 = \frac{\sqrt{v_2^P v_2^Q}}{\sqrt{\langle \cos[2(\psi_2^P - \psi_2^Q)] \rangle}} \quad \dots (6)$$

### IV. EXPERIMENTAL 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 in the transverse momentum range from 0.2-1.0 GeV/c. The variation of the elliptic flow coefficient ( $v_2$ ) with various centrality percentile for simulated events generated at 62.4 GeV and 200 GeV for Au+Au collisions has been studied. The AMPT data results have been

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 9, September 2017

compared with results reported by M. Shimomura using datasets taken in Run-4 and Run-5 periods by PHENIX at RHIC [11].

### Variation of elliptic flow coefficient with centrality

The result determined from AMPT dataset and experimental result at different beam energies for the same colliding species in the same transverse momentum range is presented here. Fig. 1 shows the elliptic flow coefficient  $v_2$  at different centrality class for Au+Au collisions at 62.4 & 200 GeV in the transverse momentum range 0.2 to 1.0 GeV/c. In this figure 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 200 GeV and 62.4 GeV colliding energies respectively.

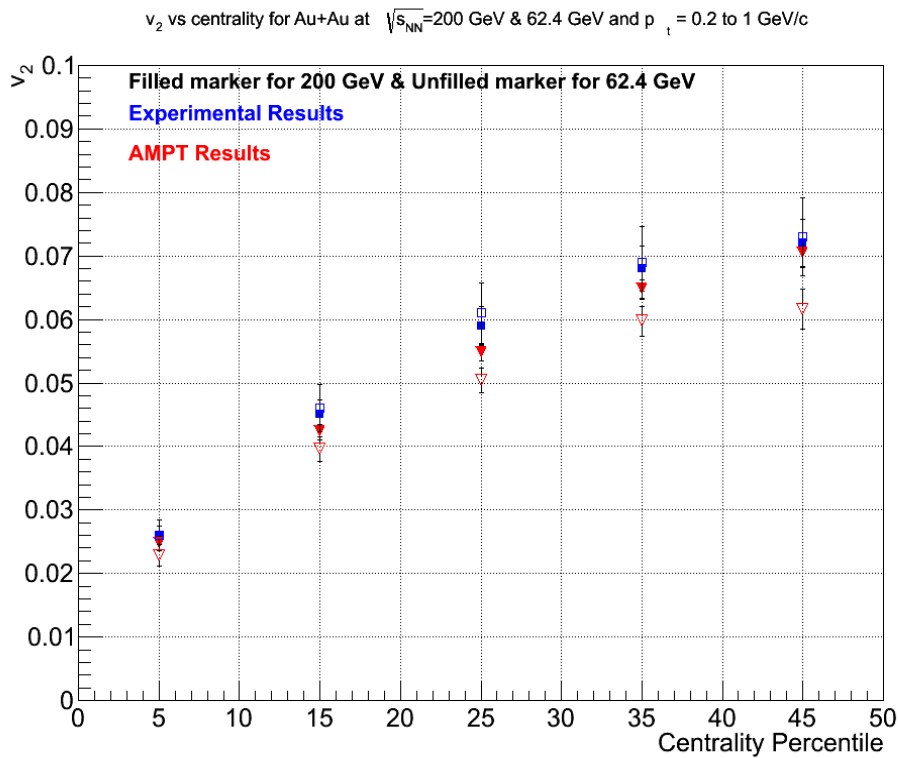


Fig. 1: Variation of elliptic flow coefficient ( $v_2$ ) with centrality for Au+Au collisions at 62.4 & 200 GeV for  $p_t = 0.2$  to 1.0 GeV/c.

### Variation of the ratio of elliptic flow coefficients with centrality

The ratio of elliptic flow  $v_2$  at 200 GeV to  $v_2$  at 62.4 GeV for Au+Au collisions determined from AMPT and experimental data. Fig. 2 shows the ratio of elliptic flow  $v_2$  at 200 GeV to  $v_2$  at 62.4 GeV for Au+Au collisions at different centrality class in the transverse momentum range 0.2 to 1.0 GeV/c. In this graph 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.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 9, September 2017

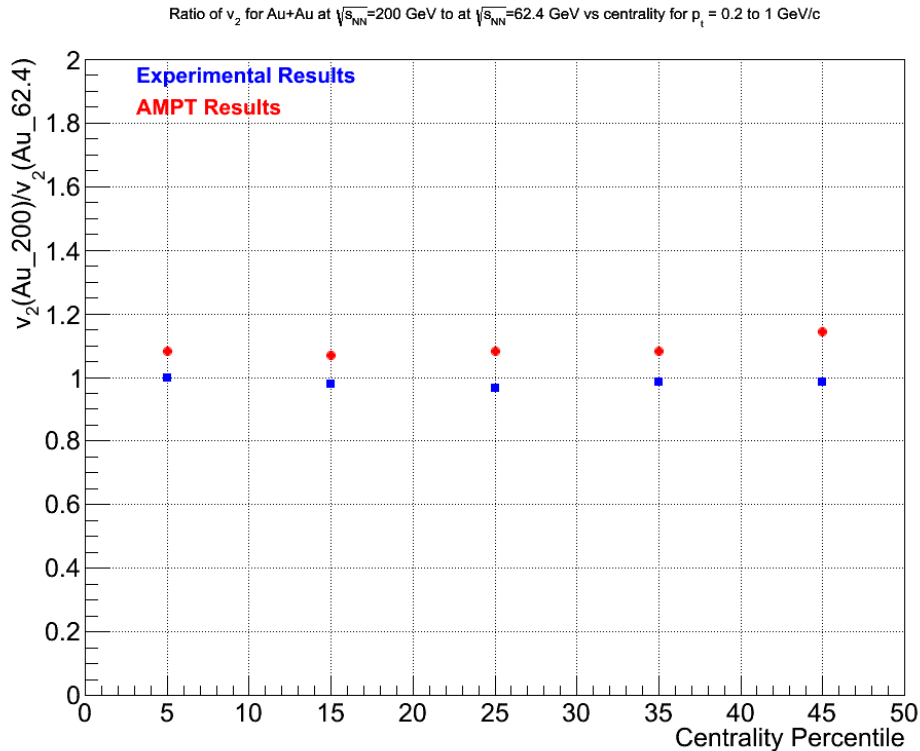


Fig. 2: Variation of the ratio of  $v_2$  at 200 GeV to  $v_2$  at 62.4 GeV for Au+Au collisions with centrality for  $p_t = 0.2$  to 1.0 GeV/c.

### Fitting and parameterization

To parameterize the study of the ratio of  $v_2$  at 200 GeV to  $v_2$  at 62.4 GeV for Au+Au collisions, fitting of data have performed with a variety of functions but second order polynomial provided best result. The fitting equation is

$$\frac{v_2(200)}{v_2(62.4)} = a + bx + cx^2 \quad \dots(7)$$

where x is the mean centrality of centrality class of interval 10%.

The values of coefficients of polynomial i.e. fitting parameters a, b, and c as obtained from fit are summarized in Table 1. The fitting curves for the experimental result and AMPT result are shown in Fig. 3. These curves show the same trend of variation of the ratio of  $v_2$  at 200 GeV to  $v_2$  at 62.4 GeV for Au+Au collisions, with centrality.

Table 1 : Value of fitting parameters

Fitting parameters	For Experimental result	For AMPT result
a	1.013560	1.105910
b	-0.002986	-0.003890
c	0.000057	0.000103

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 9, September 2017

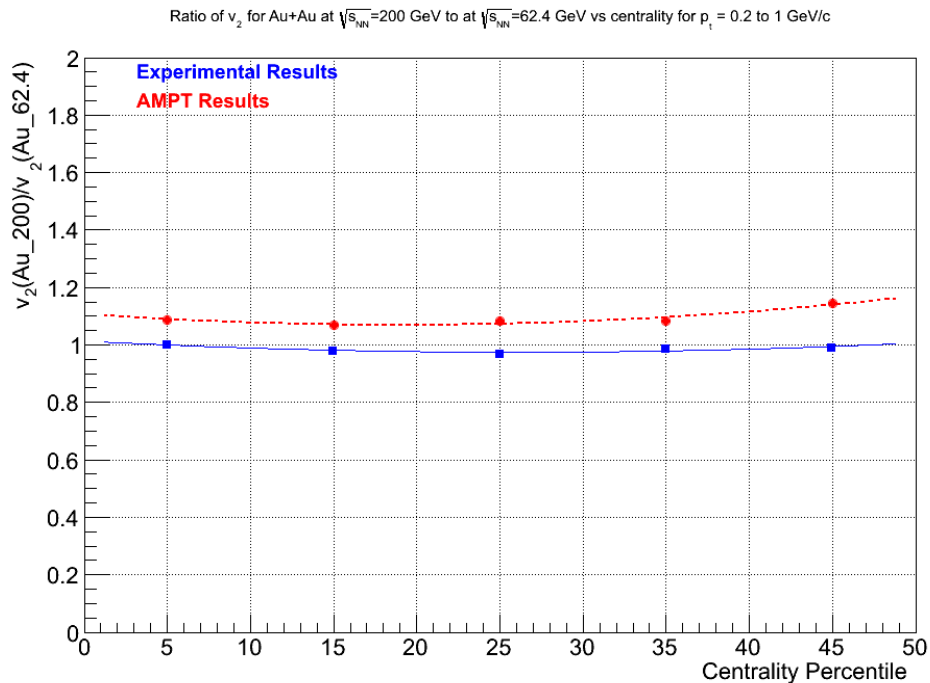


Fig.3: Fitting curves for the ratio of  $v_2$  at 200 GeV to  $v_2$  at 62.4 GeV for Au+Au collisions for  $p_t = 0.2$  to 1.0 GeV/c.

## V. CONCLUSION AND RECOMMENDATION

In summary, We proposed a new formula to know the expected value of  $v_2$  for Au at 200 GeV/A at particular centrality, provided  $v_2$  for Au is known at 62.4 GeV/A. This new formula can also be used to know the expected value of  $v_2$  for Au at 62.4 GeV/A at particular centrality, provided  $v_2$  for Au is known at 200 GeV/A. Similarly, we can know the value of the ratio of  $v_2$  at 200 GeV to  $v_2$  at 62.4 GeV for Au+Au collisions at any centrality between 0 – 50 % by using fitting equation (7) and fitting parameters given in Table 1.

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.

## REFERENCES

- [1] Karsch, F., "Lattice Results On QCD Thermodynamics", Nucl. Phys. A 698, pp. 199–208, 2202.
- [2] McLennan, L. D., Svetitsky, B., "A Monte Carlo Study Of SU(2) Yang-Mills Theory At Finite Temperature", Phys. Lett. B 98, 195, 1981.
- [3] Fodor, Z., Katz, S. D., "Lattice Determination Of The Critical Point Of QCD At Finite T And Mu", JHEP, 0203:014, 2002.
- [4] Allton, C. R., et al, "The QCD thermal phase transition in the presence of a small chemical potential", Phys. Rev. D 66:074507, 2002.
- [5] Ollitrault, J. Y., "Anisotropy As A Signature Of Transverse Collective Flow", Phys. Rev. D 46, pp. 229-245, 1992.
- [6] Voloshin, S., Zhang, Y., "Flow Study In Relativistic Nucl. Collisions by Fourier Expansion Of Azimuthal Particle Distribution", Z. Phys. C 70, pp. 665-672, 1996.
- [7] Poskanzer, A. M., Voloshin, S. A., "Methods For Analyzing Anisotropic Flow In Relativistic Nuclear Collisions", Phys. Rev. C 58, pp. 1671-1698, 1998.
- [8] Lin Z. W., Ko, C. M., Li, B. A., Zhang, B., Pal, S., "A Multi-Phase Transport Model For Relativistic Heavy Ion Collisions", Phys. Rev. C 72, 064901, 2005.
- [9] Somani, Ajit Kumar, Bhardwaj, Sudhir, Agnihotri, Ashish, "Elliptic Flow Due to Charged Hadrons for Au+Au Collisions at RHIC Energy 62.4 GeV", AIP conference proceedings, Vol. 1728, 020262, pp. 1-3, 2016.
- [10] Bhardwaj, S., Somani, A. K., Agnihotri, A., "Contribution of charge pions elliptic flow in relativistic heavy ion collisions", AIP conference proceedings Vol. 1536, pp. 1109-1110, 2013.
- [11] Shimomura, M., "Systematic Study of Azimuthal Anisotropy for Charged Hadron in Relativistic Nucleus-Nucleus Collisions at RHIC-PHENIX", Ph. D. thesis, 2009.