(non) Flow in pp collisions at LHC

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Introduction

The elliptic flow has been found to be one of the most interesting observables at Relativistic Heavy Ion Collider (RHIC). The elliptic flow is measured via the azimuthal anisotropies in heavy ion collisions and is used to determine the collective properties of the system, e.g. thermalization, EOS, viscosity[1][2][3]. In pp collisions due to smaller number of produced particles one usually does not consider collectivity. However, at Large Hadron Collider (LHC) energies, in high multiplicity pp events the achieved energy density might be comparable to the energy density in Au+Au collisions at RHIC energies. These high multiplicity pp events therefore, might require theoretical treatments based on hydrodynamical expansion with high density initial condition[4].

Measurement of v_2 in simulation at LHC energy

Various methods have been used to measure the v_2 at RHIC. We have performed a detailed study of the applicability of the various methods for determining v_2 in pp collisions at LHC. The event generator HIJING, has been used for the simulation at $\sqrt{s} = 10$ TeV.
Using the conventional event plane method v_2 dependence on the p_t and multiplicity has been studied. In this method the reaction plane angle, ψ_{rp}, is determined from the azimuthal distribution of the outgoing particle

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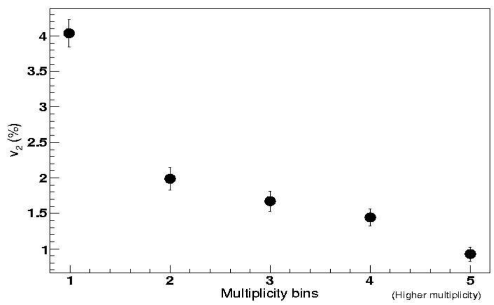

FIG. 1: The p_t integrated v_2 of charged particles at $\sqrt{s}$= 10 TeV. The multiplicity bins 1, 2, 3, 4, and 5 correspond to the charged mupltiplicity in the range (0 to 155), (155,188), (188,266), (266,294) and (294,700) respectively.

as,

$$\psi_{rp} = \frac{1}{2} tan^{-1} \frac{\sum sin(2\phi_i)}{\sum cos(2\phi_i)} \quad (1)$$

where, ϕ_i is the angle of azimuth of the outgoing particle. The v_2 is then calculated using the following equation,

$$v_2 = \langle cos(2(\phi_i - \psi_{rp})) \rangle \quad (2)$$

where, ϕ_i is the angle of azimuth of the outgoing particle and ψ_{rp} is the angle of azimuth of the reaction plane. Different approaches have been applied to remove the non-flow contributions to v_2 obtained by the conventional event plane method. An important factor which is found to reduce the non-flow effects is the η-gap between the particles used for determinig the event plane and the particles of which v_2 is measured.
The azimuthal correlation of the particles with the reaction plane can be expressed as a sum of the flow and the non-flow terms and can be

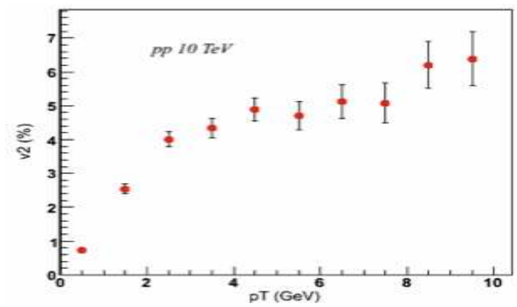

FIG. 2: The p_t dependence of v_2 of charged particles at $\sqrt{s}$= 10 TeV.

given in terms of scalar product as,

$$\langle u_b Q^\star \rangle^{AA} = (V_b V_p + \delta^{AA}) M^{AA} \qquad (3)$$

where, the first and second term of the right side of the equation denotes the flow and non-flow term respectively. M^{AA} is the multplicity, Q is the flow vector given by,

$$Q = \sum cos(2\phi_i) + i \sum sin(2\phi_i) \qquad (4)$$

and u is the unit vector constructed for each particle as,

$$u_i = cos(2\phi_i) + isin(2\phi_i) \qquad (5)$$

For pp collisions (assuming there is no flow) we can write eq. 3 as,

$$\langle u_b Q^\star \rangle^{pp} = \delta^{pp} M^{pp} \qquad (6)$$

If

$$\delta^{AA} \approx \frac{\delta^{pp}}{N_{coll}} \approx \frac{\delta^{pp}}{M^{AA}} M^{pp} \qquad (7)$$

then we can write,

$$\langle u_b Q^\star \rangle^{AA} = V_b V_p M^{AA} + \langle u_b Q^\star \rangle^{pp} \qquad (8)$$

Therefore, knowing the $\langle uQ^\star \rangle^{AA}$ and $\langle uQ^\star \rangle^{pp}$ one can determine the flow in AA collisions.

Results

The multiplicity dependence of the p_t integrated v_2 of charged particles is shown in Fig.1 for pp collisions at $\sqrt{s}$=10 TeV.

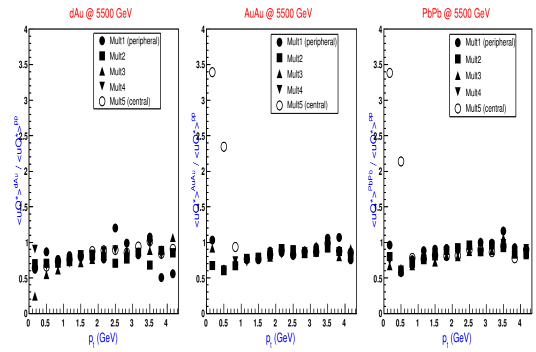

FIG. 3: The ratio, $\langle uQ^\star \rangle^{AA}/\langle uQ^\star \rangle^{pp}$ of charged particles for d+Au (left), Au+Au(middle) and Pb+Pb (right) at 5.5 TeV.

We observe that the v_2 decreases as the charged multiplicity increases. In Fig.2 the p_t dependence of v_2 is depicted. The ratio, $\langle uQ^\star \rangle^{AA}/\langle uQ^\star \rangle^{pp}$ for d+Au, Au+Au and Pb+Pb is shown in Fig.3 for 5.5 TeV. The $\langle uQ^\star \rangle$ is observed to be similar for pp and AA collisions without any added flow at $\sqrt{s}$ = 5500 GeV as well as $\sqrt{s}$ = 900 GeV. However, there is a positive slope in the ratio $\langle uQ^\star \rangle^{AA}/\langle uQ^\star \rangle^{pp}$, with p_t. The details of the analysis methods and the results will be presented.

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