Collective flow in jetty and isotropic events in Au+Au collision at 30A GeV

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The event shape variable transverse sphericity has succesfully been used to understand a couple of multiparticle emission phenomena like the collective flow and in medium jet modifications in pp collisions at LHC energies [1, 2]. In this investigation we use the transverse spherícty parameter to classify Au+Au collision events at $E_{\rm lab} = 30A$ GeV into a jetty and an isotropic category. The event sample used in this analysis is generated by A Multi-phase Transport Model (AMPT) in its String Melting (SM) version [3]. The objective of this analysis is to understand the dynamics of particle production with varying degree of collectivity at high baryon density and at low to moderate temperature. We start by introducing the transverse momentum matrix of charged particles produced in the mid-rapidity region as,

$$\mathbf{S_{xy}} = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}$$

where

$$a_{11} = \frac{1}{\sum_i p_{T_i}} \sum_i \frac{p^2_{x_i}}{p_{T_i}}$$

$$a_{22} = \frac{1}{\sum_i p_{T_i}} \sum_i \frac{p^2_{y_i}}{p_{T_i}}$$

$$a_{12} = a_{21} = \frac{1}{\sum_i p_{T_i}} \sum_i \frac{p_{x_i} p_{y_i}}{p_{T_i}}$$

Here $p_{T_i} = (p_{x_i}, p_{y_i})$ is the transverse momentum of the i^{th} particle of an event. The sum runs over all charged particles in an event. The diagonalisation of the matrix $\mathbf{S_{xy}}$ will lead to two eigen values λ_1 and λ_2. Let us order them as $\lambda_1 > \lambda_2$ and define transverse sphericity (S_T) as,

$$S_T = \frac{2\lambda_2}{\lambda_1 + \lambda_2}$$

The S_T value lies between 0 and 1 and the extreme limits are classified as,

$$S_T = \begin{cases} 0: & \text{'jetty events'} \\ 1: & \text{'isotropic events'} \end{cases}$$

The jetty events (pencil-like) are generally hard events while the isotropic events are softer. Once the jetty events are identified, it would be possible to study jet medium modification, jet chemistry etc.

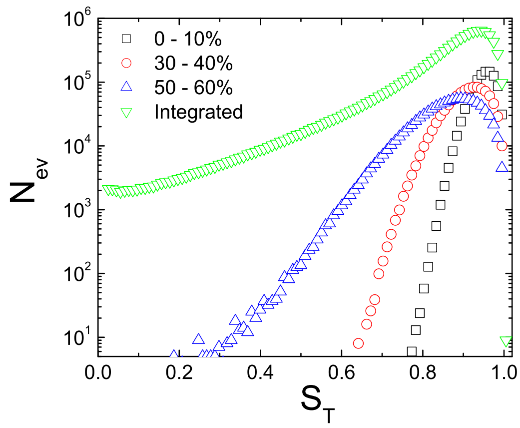

FIG. 1: (Color online) Charged hadron sphericity distribution in Au+Au collisions at $E_{\rm lab}$ = 30A GeV.

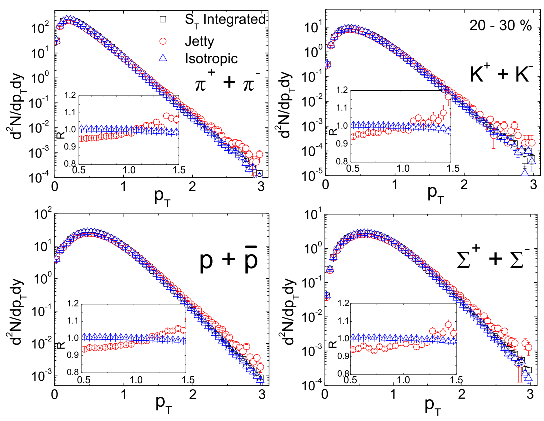

FIG. 2: (Color online) p_T spectra of pions, kaons, protons and sigma at mid-rapidity for isotropic, jetty and S_T integrated events in Au+Au collisions at $E_{\rm lab}$ = 30A GeV.
Inset: Ratio of p_T spectra for isotropic and jetty events to S_T integrated events

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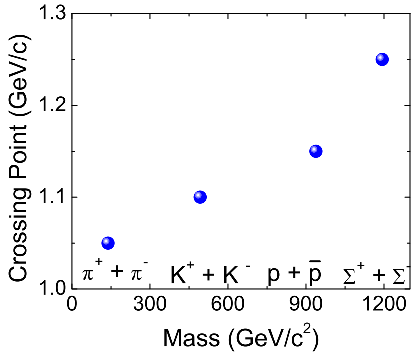

FIG. 3: (Color online) Crossing point of the ratio of the p_T spectra of isotropic and jetty events to S_T intergrated events as a function of particle mass in Au+Au collisions at $E_{\rm lab}$ = 30A GeV.

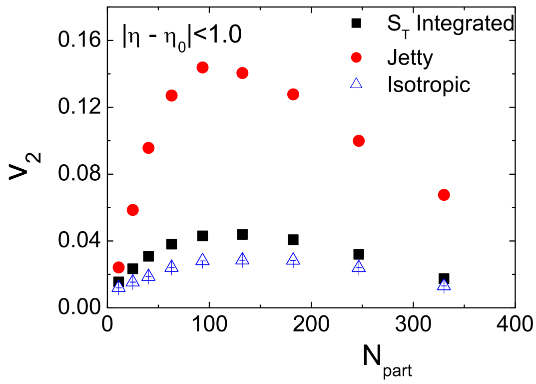

FIG. 4: (Color online) Elliptic flow coefficient (v_2) as a function of $N_{\rm part}$ for the isotropic, jetty and S_T integrated events in Au+Au collisions at $E_{\rm lab}$ = 30A GeV.

We have analysed a sample of 10 million Au + Au collision events at $E_{\rm lab} = 30A$ GeV using the AMPT-SM model. The sphericity distributions of charged hadrons in different centrality classes at midrapidity are shown in Fig. 1. It is observed that the distribution shifts towards $S_T = 1$ as we move from peripheral to central collisions. In order to disentangle the low and high sphericity events we have applied the 20%-cut on either side of the sphericity distribution. Events with the lowest 20% sphericity values are called the jetty events while those having the highest 20% values are called isotropic. In Fig. 2 we present the p_T spectra of pion, kaon, proton and sigma particles in the 20−30% centrality class for the two different sphericty categories as well as for the S_T integrated events. The plots in the insets shows the ratio (R) of the p_T spectra of isotropic and jetty events to that of the sphericity integrated events. It is noticed that the low p_T regions are dominated by the isotropic events, whereas somewhere in the $1.0 \leq p_T \leq 1.5$ GeV/c region the jetty events start to dominate. At higher p_T particle production is mostly due to the jetty events. In Fig. 3 we note that the crossing point in the p_T distribution from isotropic to jetty eevnts shifts towards higher p_T with increasing mass. This may be a possible signature of the onset of collectivity in the system.

The experimental results from AGS to LHC have established that the centrality dependence of elliptic flow (v_2) [4] provides valuable information about the degree of thermalisation achieved in a nucleus-nucleus collision system. The elliptic flow parameter v_2 as a function of collision centrality ($N_{\rm part}$) is plotted in Fig. 4. v_2 peaks at the mid-central collisions which is a consequence of both finite amount of initial state asymmetry and moderate number of final state particles which carry the information. We observe that, over the entire centrality range v_2 for the jetty events are significantly and consistently larger than that of the isotropic events. This observation justifies the nomenclature 'isotropic events'. Near $N_{\rm part} = 100$ the dominantion of jetty events in the centrality dependence of v_2 is found to be maximum, and it is nearly 5 times larger than the v_2 values of the isotropic events. The sphericity integrated v_2 values are however closer to the isotropic values. At 30A GeV the contribution of v_2 from the jetty events has been nearly eclipsed by the isotropic contribution, leading to some kind of isotropization of the elliptic flow. This is a result of different weightage associated with the two types of events over the entire sample. Thus, the sphericity separated results unveil the importance of different event types on the contribution to the elliptic flow. In near future we shall probe the initial state for a better understanding of the sphericity dependent differences in v_2 distribution along with other flow harmonics.

References

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