INDRA@GSI : Collective Flow in Au+Au Collisions

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Abstract

Directed and elliptic flow in symmetric heavy ion collisions has been studied using the ^{197}Au + ^{197}Au reactions at incident energies between 40 and 150 AMeV. The reactions have been measured with the 4π multi-detector INDRA at the GSI facility. In particular, the bombarding energy at which the elliptic flow switches from in-plane to out-of-plane enhancement has been determined to be clearly above 100 AMeV in good agreement with the result obtained by the FOPI Collaboration. The new data allows also to extend the experimental excitation function of v_2 to lower energies.

Collective motion of decompressing excited nuclear matter formed in heavy ion collisions has a long history of more than two decades of research (see e.g. [1] for a review) and is still drawing attention of nuclear physicists. The main reason of this continuous interest is the presumed link of the collective phenomena to the nuclear matter equation of state, including possible insight into momentum dependence of nuclear interactions, as well as into the in-medium nucleon-nucleon cross section (see e.g. [2] for a review).

The main aim of this short contribution is to present the first results of the flow analysis applied to the data on Au+Au collisions at energies from 40 to 150 AMeV obtained using the INDRA detector [3] and the beams from the SIS synchrotron at the GSI, and also to relate them to the existing data.

The most convenient way of characterizing the collective flow seems to be the parametrization of the azimuthal distributions of the reaction products, measured with respect to the azimuth of the reconstructed reaction plane, in terms of Fourier coefficients extracted for different rapidity windows. (see e.g. [4] or [5] and refs. therein). In this representation the variation of the first Fourier coefficient, v_1, as a function of rapidity characterizes the directed flow, while the second one, v_2, quantifies the elliptic flow.

Fig. 1 presents the rapidity dependence of the parameter v_1 for Z=2 particles extracted from the INDRA data (filled symbols), for an impact parameter range of about 3-4.5 fm, superposed on the corresponding distributions measured by the FOPI collaboration [6] (open symbols) for 2-5.3 fm impact parameter range. Both data sets represent the values uncorrected for the reaction plane resolution.

As can be seen both measurements fit together. This can be verified especially by looking at the data for 150 AMeV incident energy (squares) which has been measured in both experiments. In the case of the INDRA data, the reaction plane has been reconstructed using the standard flow-vector method [7], excluding the particle of interest and correcting for the momentum conservation effects [8].

An intriguing feature of directed flow that can be observed in Fig. 1 is its negative value at 40 AMeV. A similar observation has been reported in [9], and given possible physical and (or) method related origins. In the present case, the negative flow value is most likely related to the fact that close to the balance energy, E$_{bal}$, where the flow is very weak, the imperfect isolation of the correlations due to momentum conservation may lead to enhanced anticorrelation resulting in a flip of the orientation of the reaction plane. Thus, extraction of directed flow in the vicinity of E$_{bal}$ needs a special care, and possibly new methods of subtracting the non-flow correlations, such as e.g. the one suggested in [5] for high energy collisions.

In particular, one should be careful when applying the above mentioned "standard" method of reaction plane reconstruction, in order to extract E$_{bal}$ by extrapolating to 0 the flow values measured exclusively above or below E$_{bal}$. Such an extrapolation would most likely yield the "0-crossing" energy rather than the energy corresponding to the actual minimum of flow. This minimum can in principle be negative, as shown in [9].

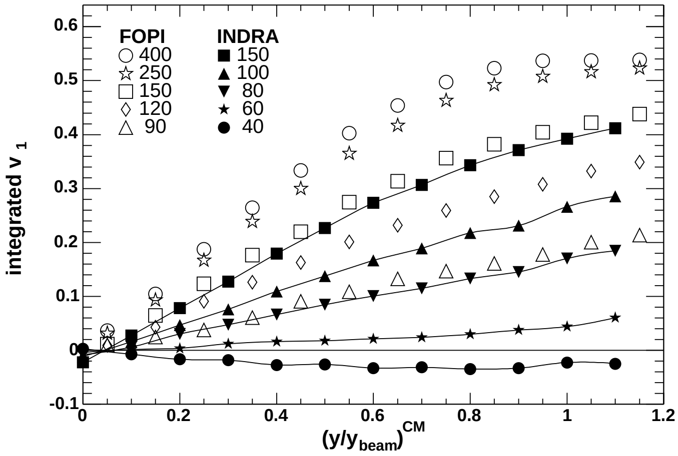

Figure 1: v$_1$ for Z=2 particles integrated over transverse momentum as a function of scaled rapidity. The open and filled symbols represent the FOPI [6] and the INDRA data, respectively. The numbers in the legend indicate the beam energies per nucleon, in MeV.

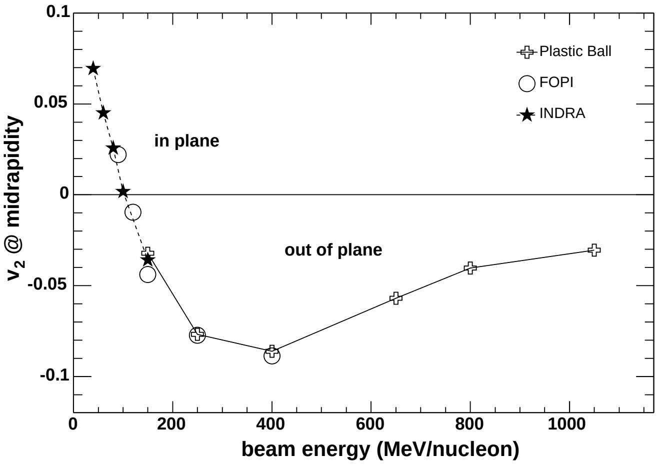

Figure 2: v$_2$ measured at midrapidity for Z≤2 particles in the reference frame rotated by a flow angle. The crosses, circles and stars represent the Plastic Ball [10], the FOPI [11] and the INDRA data, respectively.

Fig. 2 shows a compilation of 3 data sets measured by the Plastic Ball [10] (crosses), FOPI [11] (circles) and INDRA (stars), representing the excitation function of the elliptic flow at midrapidity for Z≤2 particles, in the rotated reference frame and for mid-central collisions (4-6 fm for FOPI and about 4.5-6.5 fm in case of INDRA). All the presented data points represent values uncorrected for the reaction plane resolution. The INDRA data has been analyzed in this case in the same way as the Plastic Ball data by using the kinetic flow tensor method and excluding the particle of interest from the reaction plane reconstruction. The impact parameter has been estimated, as in the case of Fig. 1, using the total transverse kinetic energies of particles with Z≤ 2.

As one can see, all 3 data sets constitute a coherent systematics of v$_2$. Moreover, the INDRA data confirms the FOPI value of the transition energy to be above 100 AMeV for the case in question, and as a result, these experiments set a reliable constraint for transport models which aim at fixing the basic parameters of nuclear interactions from flow observables.

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