Expansion Dynamics and EoS in Semi-Central Heavy Ion Collisions

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One of the main motivations to study heavy ion collisions at high energies is to obtain information on the equation of state (EoS) of nuclear matter in extreme conditions of pressure and temperature. To reach these conditions, one is confronted with the dynamical aspects, both of the initial phase of the collision and of the evolution stage of the fireball, as well as with the question on the possibility to reach thermal equilibrium in small size systems, and therefore detailed experimental information on the expansion dynamics is needed.

The present work is based on Au+Au, Xe+CsI and Ni+Ni data from FOPI - Phase II experiment at SIS–GSI-Darmstadt. Details on this configuration of the FOPI detector can be found elsewhere [1]. Windows in the CDC (charged particles) multiplicity (CM2, CM3) and $Erat = \sum_i E_{\perp,i} / \sum_i E_{\parallel,i}$ (ER4, ER5) have been used to select impact parameters in the range of 6-8, 4-6, 2-4 and 0-2, respectively, based on a geometrical "sharp cut-off" approximation. Transverse momentum method has been used for reaction plane determination. The analysis has been done in a reference frame rotated by the flow angle [4] and used the polar angular range $80° < \theta_{cm} < 100°$ to select the midrapidity source.

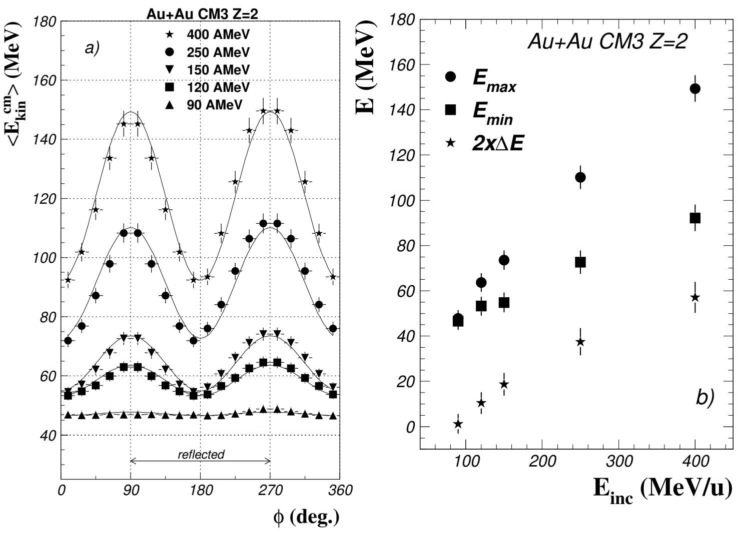

Figure 1: Au+Au, CM3, Z=2 particles: a) $\langle E_{kin}^{cm} \rangle$ vs. Φ; b) excitation function for E_{max}, E_{min} and ΔE.

Fig. 1a shows the azimuthal dependence of $\langle E_{kin}^{cm} \rangle$ for Z=2 particles, Au+Au, CM3 centrality and different incident energies. The lines are the result of a fit with the expression $\langle E_{kin}^{cm} \rangle = E_0$ - 2·ΔE·cos2Φ. From the parameters E_0 and ΔE the quantities E_{min}=E_0-ΔE and E_{max}=E_0+ΔE, corresponding to the mean kinetic energies in- and out-of-plane, are obtained. Their dependence on the mass of the reaction products give access to the amount of ordered motion in the corresponding directions.

The excitation function of E_{max} and E_{min} from 90 A·MeV to 400 A·MeV for Au+Au system, presented in Fig. 1b, shows a continuous increase of both values as a function of incident energy. The lower slope in E_{min} can be due to the fact that the violence of the expansion increases faster as a function of incident energy than the decrease of the passage time. The apparent azimuthal symmetry

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at 90 A·MeV is determined by the balance between squeeze-out and rotational-like phenomena [3].

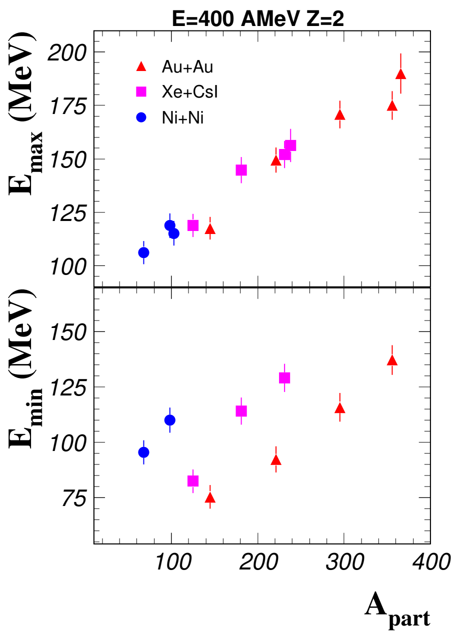

Figure 2: A_{part} dependence of E_{max} and E_{min}, E=400 A·MeV.

Fig. 2 shows the dependence of E_{max} and E_{min} for E=400 A·MeV incident energy (for 150 and 250 A·MeV the dependences are similar) and all three measured systems as a function of A_{part} (the number of the participating nucleons estimated using straight trajectories). E_{max} exhibits almost a linear increase as a function of barionic content of the fireball, with almost no dependence on the colliding system, while E_{min} shows a clear system dependence. A simple geometrical picture shows that for a fixed value of A_{part} the thickness of the spectators has the most dramatic dependence on the system size. Because the shape of the fireball (maybe at the origin of the tiny details in E_{max} vs. A_{part} dependence) and the transit time have little differences from one system to another, the conclusion is that the shadowing effect of the spectators play a major role in the expansion phenomenon.

These observations, correlated with the fact that for the present analysis the "temperatures" extracted using shell expansion fitting of the spectra [4] show in-plane minima as well, lead to a picture of the expansion that looks complementary to the in-plane retardation [5, 4]: in-plane cross-talking with the (supposedly colder) spectator matter can cool down the expanding matter.

Comparison with IQMD microscopic transport model calculations have been done only for Z=1 reaction products. If below 250 A·MeV both HM and SM version are in an acceptable agreement with the experiment (none really reproducing the data), at 250 A·MeV they start to deviate. A comparison of the transverse mean kinetic energy (E_0) favours a higher compressibility (with less sensitivity), while the azimuthal modulation is better reproduced by a lower compressibility, in line with previous comparisons using Plastic Ball [6] and EOS data [4].

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