Transverse Velocity Scaling in Au+Au Midrapidity Emissions

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Both, central and peripheral collisions of symmetric heavy ions at intermediate energies, despite having been studied for decades now, are still drawing attention, still provide new pieces of information, and still contain open questions. In order to study these reactions in more detail a series of experiments has been performed during the 4^{th} INDRA Campaign carried out at the GSI. The reaction products formed using the beams delivered by the SIS synchrotron were measured with the 4π multidetector INDRA [1]. In this contribution we will focus on the Au+Au reactions at energies 40-150 A MeV (see also [2]).

In peripheral and mid-central collisions the 2 heaviest residua or their remnants remembering the entrance channel conditions, are usually accompanied by a sizable amount of particles and fragments with parallel velocities intermediate between those of the projectile and of the target [3-6]. They are often referred to as *midrapidity* (*midvelocity*) emissions. The origin of these midrapidity fragments and related reaction scenarios are still debated and their characteristics are still a matter of interest.

Inspection of transverse velocities, or energies, for different rapidity bins leads to some interesting observations.

The upper row of Fig. 1 presents invariant cross sections for Li fragments from Au+Au @ 100 A MeV reaction, as a function of transverse velocity and rapidity with the indicated rapidity cuts for different centrality selections. The middle row presents transverse velocity distributions of Li ions for different bombarding energies, and the bottom one the corresponding mean transverse energies.

At projectile rapidity and for peripheral collisions (left column) a pronounced Coulomb component is seen in the velocity spectra. The position of the peak is remarkably constant for all bombarding energies and indicates emission from the surface of the heavy primary fragment.

The Coulomb component is nearly absent or possibly spread out over a wide velocity range in the emissions at midrapidity where one can observe two different scaling behaviors for the peripheral and central collisions. In the central case (right panel), both, the mean and the width of the spectra *increase* considerably with increasing bombarding energy and with the fragment mass (see also bottom right panel). This reflects the increasing importance of flow for central collisions [7].

For peripheral reactions (middle column), a particularly intriguing behavior is observed. The shapes of the velocity spectra are between Gaussian and exponential and *invariant* with respect to the incident energy and also with respect to the mass in the range of Z indicated in the middle bottom panel. The corresponding mean transverse energies of about 28 MeV for lithium ions seem too large for a purely thermal origin and are larger than the value of 14.6 MeV temperature obtained from the Goldhaber model [8] with $p_{\mathrm{F}} = 265$ MeV/c (the thick horizontal line) but may reflect the additional Coulomb potential that is generated

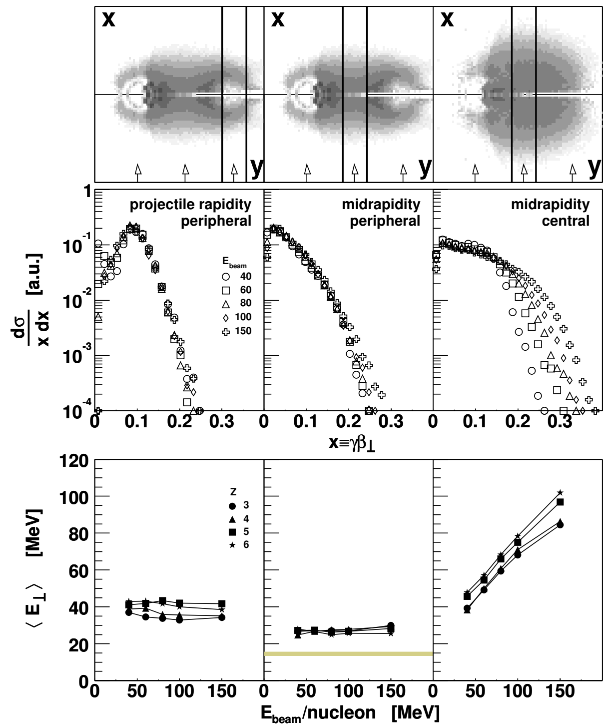

Figure 1: Top row: invariant cross sections for Z=3 fragments as a function of transverse velocity (x) and rapidity (y), for Au+Au @ 100 A MeV reaction with the indicated rapidity cuts. The arrows denote, from the left, the target, CM, and projectile rapidities, respectively. Middle row: invariant transverse velocity distributions for Z=3 at bombarding energies from 40 to 150 A MeV. Bottom row: mean transverse energies of IMFs with $3 \leq Z \leq 6$ as a function of incident energy. The thick solid line represents the Goldhaber model prediction. The 3 columns correspond to three selections in rapidity and centrality: projectile rapidity and peripheral collisions (left column), midrapidity and peripheral collisions (middle column) and midrapidity and central collisions (right column), respectively.

by the two heavy residua in the neck region.

Simulations of nucleon-nucleon collisions imply that the Pauli blocking of the collisions can be partly responsible for this invariance. The mean transverse energies of nucleons scattered into the midrapidity region show a very weak dependence on incident energy provided Pauli blocking is effective. Otherwise, the mean transverse energies increase with the incident energy. Within a coalescence picture one might expect invariance of mean transverse energies at midrapidity also for fragments.

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