Midrapidity emissions, can they be thermal?
First results of the INDRA@GSI Campaign

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High quality experimental data obtained with the 4π multi-detector system INDRA set up on the beam delivered by SIS offer now an unique opportunity to perform a detailed study, including the isospin degree of freedom, of the collisions of both symmetric (Au+Au, Xe+Sn) and asymmetric (C+Au, C+Sn) systems in a broad energy range. It covers the interesting transition region from around the Fermi energy up to relativistic energies, approaching the participant-spectator domain.

Non-central collisions of symmetric heavy systems turn out to be essentially of binary character with pronounced projectile and target like sources. Nevertheless, a sizable amount of detected particles and fragments have parallel velocities intermediate between those of the projectile and of the target [1]-[3] and their importance increases with the increasing centrality of the collision. They are often referred to as midrapidity (-velocity) emissions.

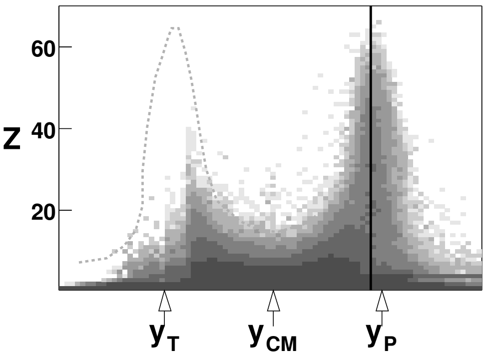

Figure 1: Z vs rapidity distribution of fragments from peripheral collisions Au+Au at 80 MeV/n. The dashed line marks the target-side region which is affected by detection thresholds. The arrows denote the target, CM and projectile rapidities, respectively.

These emissions seem to be strongly influenced by dynamical effects and are thought to proceed on a relatively short time scale. One can imagine various scenarios of formation of those midrapidity fragments following the predictions of various dynamical or hydrodynamical models. These scenarios include fast pre-equilibrium particles, neck emitted particles and fragments, as well as light fission fragments preferentially aligned in between the two main reaction partners. The importance of these midrapidity emissions can be viewed from Fig. 1, which presents the rapidity distribution of fragments emitted from the reaction Au+Au at 80 MeV/n at large impact parameters. The vertical line corresponding to the projectile-like source rapidity is drawn to emphasize a strong forward-backward asymmetry with respect to it.

Numerous analyses assume the existence of a well defined statistically equilibrated source. Can midrapidity emissions be regarded as those originating from such a source? Certainly not all of them, however at least a fraction of these emissions, in the vicinity of the Coulomb ring, can be interpreted in the framework of the statistical multifragmentation model (SMM) [4] provided, the Coulomb influence of the heavy partner on the (multi)fragmenting excited nucleus is taken into account. Inclusion of, preferentially elliptical, flow and angular momentum effects also seems to be important.

Fig. 2 presents the predictions of the SMM (left panels) and of a hybrid, the molecular dynamics model CHIMERA [5] plus the statistical sequential decay model GEMINI [6] used as an afterburner (right panels). These predictions are compared with the experimentally measured (middle panels) invariant cross sections of lithium ions emitted in peripheral Au+Au reaction at 80 MeV/n.

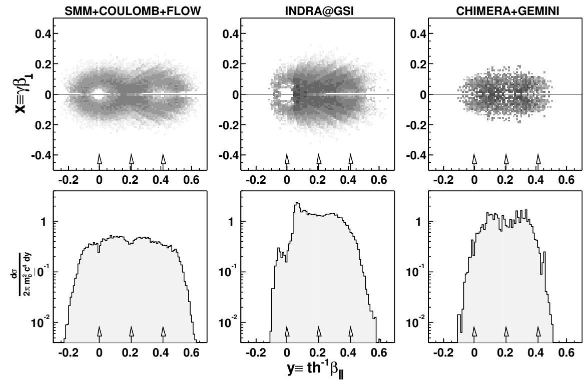

Figure 2: Invariant cross sections of lithium fragments emitted in peripheral reaction of Au+Au @ 80 MeV/n (upper row) and their projections (lower row). The central column gives the experimental results.

The above figure shows that, at least qualitatively, both models: statistical and dynamical, can account for midrapidity emissions. For a clear separation of the equilibrated and the dynamical components further studies are required, including consistent statistical treatment and careful adjustment of flow, and possibly inclusion of angular momentum and deformation effects in SMM, for a range of impact parameters and energies. Dynamical models should be traced more carefully in terms of emission and equilibration times.

References

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