Statistical Multifragmentation of Non-Spherical Sources in Au+Au

A. Le Fèvre for the INDRA-ALADIN Collaboration

From the results of previous INDRA campaigns at GANIL, it is known that central collisions of heavy symmetric systems lead to the formation of a heavy, hot and expanding composite nucleus. The break-up properties have been successfully reproduced within standard statistical approaches [1-3], except for pronounced anisotropies in the fragment yields and kinetic energies. This has motivated the extension of the standard version of the Berlin statistical multifragmentation model (MMMC, ref. [4]) to non-spherical sources [5]. Similar anisotropies have been observed in the Au+Au systems studied in the energy range of 40 to 150A.MeV [6, 7], during the 4^{th} INDRA Campaign at GSI. The reaction products have been measured using the 4π multidetector INDRA [8]. For this contribution, we will focus on the central collisions of Au+Au at 80A.MeV, selected using the transverse energy as in [9].

Fragment mean kinetic energies as a function of Z and, for the heaviest fragment, as a function of angle are shown in Fig. 1. Fragments emitted at forward angles are much more energetic than those emitted sidewards. For the heaviest fragment, this decrease of the kinetic energies with the angle is continuous and fairly strong. This cannot result from a detector efficiency effect, since the isotropy of a MMMC-simulated spherical source is fairly well conserved through the INDRA filter. The MMMC simulation of a prolate source, elongated along the beam axis (with a size ratio 1:0.7), is able to reproduce the data, both qualitatively and quantitatively. In the simulations, the size (Z=110), the excitation energy (7A.MeV), and the collective radial flow (5A.MeV) have been adjusted such as to reproduce the experimental partitions and the total kinetic energy of fragments.

The partitions exhibit an anisotropy too, as shown in the left panel of Fig. 2. The multiplicities of heavier fragments are twice as high in the direction of the beam as in sideward direction. The angular distribution of the heaviest fragment exhibits a strong forward-backward focusing. The average size of the fragments emitted sidewards are smaller and, the heavier the fragment, the higher the probability to be emitted forward or backward. These effects are well reproduced by the MMMC simulation with a prolate source, but not with a spherical source, as illustrated in both panels. The MMMC approach explains the anisotropies of partitions and kinetic observables as due to the minimization of the Coulomb energy of the system at freeze-out, which strongly correlates the charge of the fragments with their location inside the deformed volume.

The fact that the present statistical approach explains successfully the partitions and kinetic observables along with their anisotropies demonstrates that the presence of anisotropies does not necessarily imply the absence of equilibrium in the system. It seems that, though some part of the energy has not been relaxed (in deformation and collective flow) and does not participate in the equilibrium, a sufficient degree of equilibration and opening of the phase space has been achieved in the system to validate a statistical description.

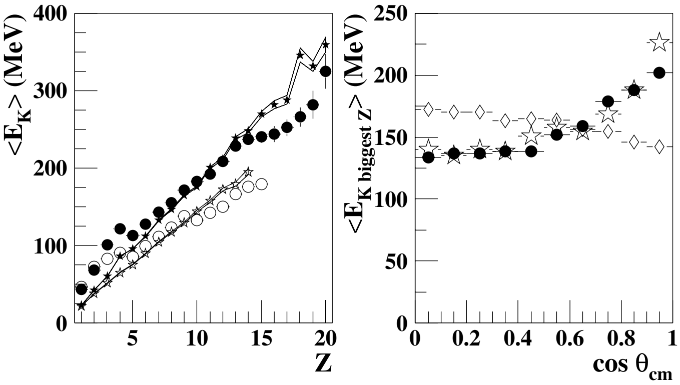

Figure 1: Left: mean kinetic energy of fragments as a function of Z in the center of mass. Circles are experimental data, stars are the MMMC-prolate source prediction. Full symbols account for forward angles (below 60^o around the beam), open symbols for sideward angles (60^o-90^o). Right: mean kinetic energy of the biggest Z as a function of the angle. The circles are the experimental data. MMMC predictions are denoted by stars (prolate) and diamonds (sphere).

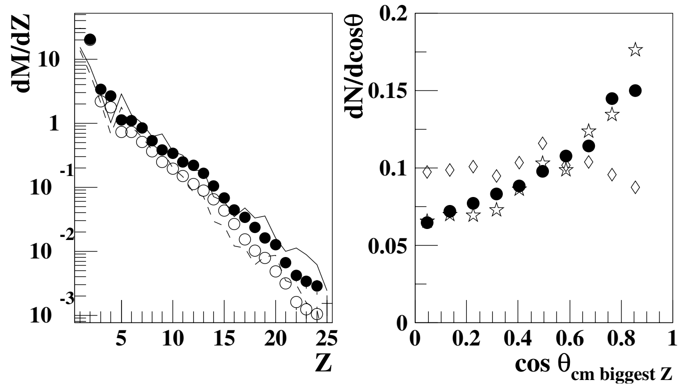

Figure 2: Left: multiplicities of charges normalized to the total solid angle. The circles represent the experimental data, and the lines are the MMMC predictions with the prolate source; like in Fig. 1, forward (full circles and line) and sideward angles (open circles and dashed line) have been separately considered. Right: angular distributions of the biggest fragment; the symbols were chosen as in Fig. 1, right panel.

References

[1] R. Bougault *et al.* (INDRA Collaboration), Proceedings of the Bormio Conference 1997.

[2] N. Marie *et al.*, Phys. Lett. **B391**, 15 (1997).

[3] A. Le Fèvre, Ph.D. thesis GANIL T9703.

[4] D.H.E. Gross, Rep. Prog. Phys. **53**, 605 (1990).

[5] A. Le Fèvre *et al.*, Phys. Rev. C **60**, 051602 (1999).

[6] J. Łukasik *et al.*, GSI Sci. Rep. (2000).

[7] F. Lavaud, PHD Thesis, IPNO-T.01-06 (2001).

[8] J. Pouthas *et al.*, Nucl. Instr. Meth. in Phys. Res. **A357**, 418 (1995).

[9] J. Łukasik *et al.*, Phys. Rev. C **55**, 1906 (1997).