Source Shape Determination with Directional Correlation Functions

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From the recent results of the 4^{th} INDRA campaign at GSI, it has been found that central collisions of heavy symmetric systems lead to the formation of a heavy, hot and expanding composite nucleus, which exhibits pronounced anisotropies in the fragment yields and kinetic energies, as it has been observed in the Au+Au and Xe+Sn systems studied in the energy range of 40 to 150 A.MeV [1]. Both break-up properties and anisotropies have been successfully reproduced [2] within the extension of the standard version of the Berlin statistical multifragmentation model (MMMC, ref. [3]) to non-spherical sources (D-MMMC, ref. [4]), assuming in all cases a prolate source in the coordinate space, elongated along the beam axis. In order to obtain additional evidence for the geometrical properties of the composite system, directional correlation functions in fragment relative velocity have been used, in comparison with models.

Here, the correlations functions are generated for the longitudinal and the transversal projections – as regard to the beam axis – of the reduced velocity $v_{red} = v_{rel}/\sqrt{Z_1 + Z_2}$, where v_{rel}, Z_1 and Z_2 are the relative velocity and the charges of the two fragments, respectively. In Fig. 1, D-MMMC predictions with three different source elongations are presented: prolate, oblate – i.e. elongated/compressed along the beam with axis ratios 1:0.70 and 1:1.67 – and spherical, with a size Z=79, 6 A.MeV excitation energy and 2.3 A.MeV collective flow. We observe that these functions exhibit a strong sensitivity to the deformation in the magnitude of their depletion at small v_{red}. The correlations between the two biggest fragments of each event that are presented here give the strongest sensitivity within this model. The comparison to the experimental data of Xe+Sn central collisions at 50 A.MeV measured at GSI shows, in both longitudinal and transversal projections, a good agreement with the prolate deformation which had been derived from the study of the fragment anisotropies in yields and kinetic energies [2].

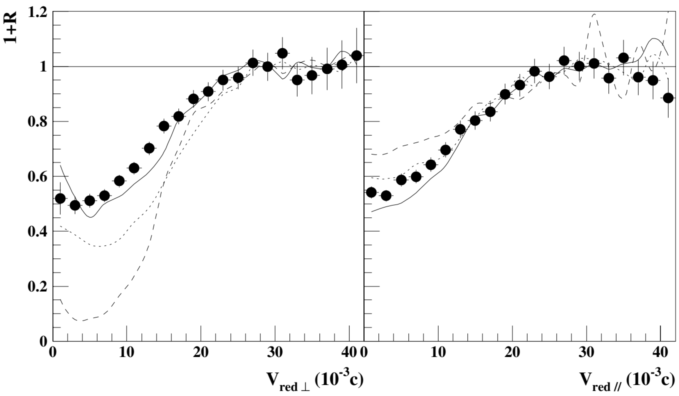

Figure 1: Left: correlation functions in transversal reduced velocity between the two biggest fragments. The symbols represent the data of Xe+Sn at 50 A.MeV central collisions, and the lines are the D-MMMC predictions for the prolate (full), the spherical (dotted) and the oblate (dashed) sources. Right: same representation in longitudinal reduced velocity.

In order to quantify the sensitivity of these directional correlation functions with the geometry of the source, we have simulated various volumes and deformations of ellipsoidal sources, following a simple model. The fragments are sampled according to the experimental distributions in yield and kinetic energy – including the angular dependences –, and placed randomly without overlap into the ellipsoidal "freeze-out" volume. The subsequent time evolution was modeled with N-body Coulomb trajectories. For each simulated source geometry, we have calculated the χ^2 corresponding to the comparison of the projected correlation functions with the experiment. Fig. 2 shows the resulting two-dimensional χ^2 distribution in the plane of the longitudinal and transversal extension of the source, obtained with fragments of $Z = 5{-}7$, compared to the data for central Xe+Sn at 50 A.MeV. We observe a well defined and narrow minimum that indicates a good sensitivity to both the density and the shape in coordinate space. This minimum corresponds to a prolate source having a size ratio $1 : 0.6 \pm 0.1$ which is remarkably close to the D-MMMC deduction.

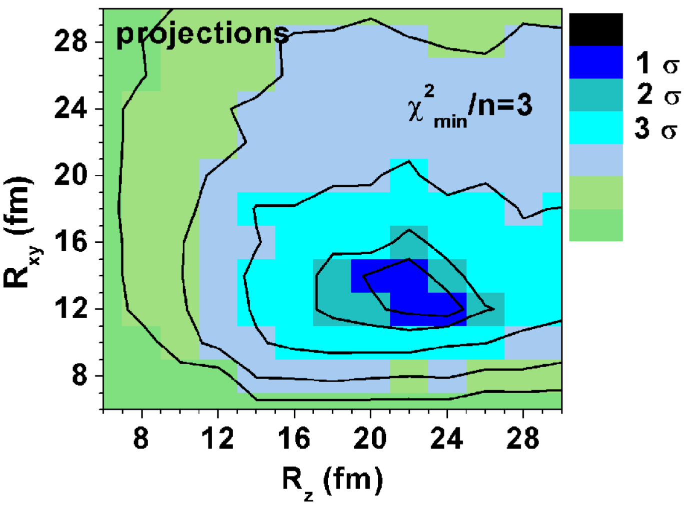

Figure 2: Contour plot (in units of the standard deviation σ) of the two-dimensional χ^2 distribution in the plane of the longitudinal (z) and transversal (xy) extension of the source, as obtained for the comparison of the correlation functions, in projected reduced velocities of fragments with $Z = 5 - 7$, from the experiment and from the N-body Coulomb trajectory calculations.

References

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