Aspects of Reducibility and Thermal Scaling in Multifragmentation

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Recent experimental evidence of binomial reducibility and thermal scaling in multifragmentation, has raised a number of physical and technical issues that need to be addressed. To this end, two simulations of multifragment decay have been implemented, a binomial simulation and a Poisson one [1]. By means of the binomial simulation, the reducibility of the n-fold intermediate-mass-fragment multiplicity and charge distributions to the one-fragment emission values has been investigated. With both simulations, the effects of using the transverse energy as a measure of the system excitation energy have been evaluated. Possible experimental biases in the results have been evaluated as well.

We have implemented binomial and Poisson decay simulations to address a number of issues connected to the experimental multifragmentation studies presented in Refs. [2–7]. For the binomial simulation, we have assumed that the n-fragment emission probabilities P_n are distributed according to the binomial distribution, and that multifragmentation is empirically reducible to a combination of nearly independent fragment emissions. Moreover, we have assumed a thermal dependence of the elementary emission probability p on the nuclear temperature.

By processing simulated events, we have tested the standard procedures utilized in the experimental data analysis. We have verified that the simulation input is recovered without significant loss of information and how the final results reflect different input conditions.

The simulation results strengthen the validity of the reducibility approach used in the experimental work and the physical meaning of quantities such as the elementary probability p. Reducibility is a valid approach also when multiple sources of fragment emission are created in the collision, if one of the sources is dominant. The Arrhenius plot is a powerful tool to explore the thermal features of the elementary probability p, even though the determination of the actual fragment emission barrier B, proportional to the slope of the plot, can be hampered by the presence of source residues and by small size effects.

From both binomial and Poisson simulations it appears that the total transverse kinetic energy E_t is a good observable that can be reliably used for the measurement of the excitation energy in multifragmentation studies at intermediate energies. In our simulations, the transverse energy is linearly correlated with the system excitation energy and weakly correlated with the IMF multiplicity. We have demonstrated that neither event-to-event fluctuations nor E_t auto-correlation effects are large enough to distort a Poisson distribution into a binomial distribution. In particular the mean and variance of the N_{IMF} distribution are reasonably well preserved, even when the measurement of E_t is limited by the detection efficiency.

We have tested the effects of a reduced geometric efficiency as well as the effects of a software replica of the detection device. We have shown that a reduced geometric efficiency preserves binomiality and that efficiency corrections can be applied through the binomial parameters p and m. We have explored the effects of a finite detection acceptance on the Arrhenius plot and have shown that when the geometric acceptance is reduced, it is still possible to recover the binomial input without significant loss of information. The introduction of an energy dependent efficiency, instead, can compromise this possibility, especially when the transverse energy is used as a measure of the system excitation energy.

We have also shown that, in a binomial decay scenario, the n-fold IMF charge distributions are reducible to the 1-fold, consistent with the experimental findings. In the binomial simulation, the n-fold charge distributions are independent of the fold number n as long as a sizeable remnant serves as a reservoir of mass, charge and excitation energy. A dependence on n arises when the entire system is consumed.

The results of the decay simulations have made us more confident that the experimental procedures utilized in the data analysis of Refs. [2–7] are correct, and that the empirical findings of reducibility and thermal scaling in multifragmentation are not an artifact of incomplete detection efficiency nor are they generated by the auto-correlation of the variable used to estimate the excitation energy.

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