Resilient Reducibility in Nuclear Multifragmentation

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The complexity of nuclear multifragmentation underwent a remarkable simplification when it was *empirically* observed that many aspects of this process were: a) "reducible"; and b) "thermally scalable" [1–4].

"Reducibility" means that a given many-fragment probability can be expressed in terms of a corresponding one-fragment probability, i.e., the fragments are emitted essentially independent of one another.

"Thermal scaling" means that the one-fragment probability so extracted has a thermal-like dependence, i.e., it is essentially a Boltzmann factor.

Both "reducibility" and "thermal scaling" were observed in terms of a global variable, the transverse energy E_t, which was assumed to be proportional to the excitation energy of the decaying source(s) [1].

In particular, it was found that the Z-integrated multiplicity distributions $P(n)$ were binomially distributed, and thus "reducible" to a one-fragment probability p. With higher resolution, it was noticed that for each individual fragment species of a given Z, the n_Z-fragment multiplicities $P(n_Z)$ obeyed a nearly Poisson distribution, and were thus "reducible" to a single-fragment probability proportional to the mean value $\langle n_Z \rangle$ for each Z [2].

Empirically, "reducibility" and "thermal scaling" are pervasive features of nuclear multifragmentation. "Reducibility" proves nearly stochastic emission. "Thermal scaling" gives an indication of thermalization.

Recently, there have been some questions on the significance (not the factuality) of "reducibility" and "thermal scaling" in the *binomial* decomposition of Z-integrated multiplicities [5]. For instance, had the original distribution in the true excitation-energy variable been binomially distributed and thermally scalable, wouldn't the process of transforming from excitation energy E to transverse energy E_t through an (assumedly) broad transformation function $P(E, E_t)$ destroy both features?

Specifically, under a special choice of averaging function (Gaussian), for a special choice of parameters (variance from GEMINI [6]), and for special input p (the excitation energy dependent one-fragment emission probability) and m (the number of "throws" or attempts) to the binomial function, the binomial parameters *extracted* from the averaged binomial distribution are catastrophically altered, and the initial thermal scaling is spoiled [5].

It should be pointed out that while the decomposition of the many-fragment emission probabilities $P(n)$ into p and m may be sensitive to the averaging process, the quantity $\langle mp \rangle$ is not [5]. However, both p and $\langle mp \rangle$ are known to give linear Arrhenius plots with essentially the same slope (see Fig. 1). This by itself demonstrates that no damaging average is occurring.

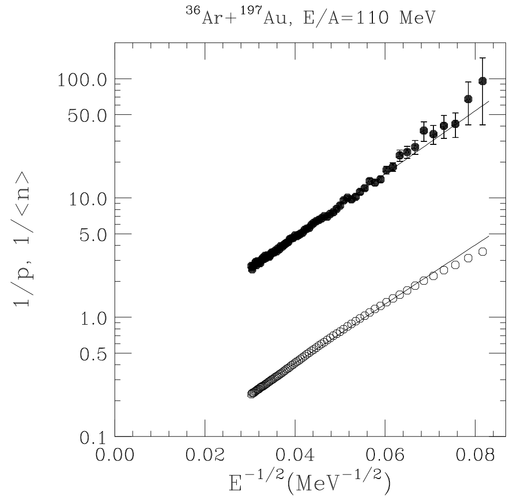

FIG. 1. The inverse of the single fragment emission probability (solid circles) and the inverse of the average fragment multiplicity (open circles) as a function of $1/\sqrt{E_t}$ for the reaction Ar+Au at E/A=110 MeV. The solid lines are linear fits to the data.

Furthermore, we have observed that by restricting the definition of "fragment" to a single Z, the multiplicity distributions become nearly Poissonian and thus are characterized by the average multiplicity $\langle mp \rangle$ which gives well behaved Arrhenius plots [2]. *Thus, the linearity of the Arrhenius plots of both p and* $\langle mp \rangle$ *extracted from all fragments, and the linearity of the Arrhenius plots of* $\langle mp \rangle$ *for each individual Z value eliminate observationally the criticisms described above. In fact, it follows that no visible damage is inflicted by the true physical transformation from E to* E_t. *Therefore, the experimental Poisson "reducibility" of multiplicity distributions for each individual Z and the associated "thermal scaling" of the means eliminates observationally these criticisms.*

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