Temperature dependence of the nuclear caloric curve

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The relation between temperature and excitation energy for nuclei has been studied in much detail to extract information on the properties of nuclear matter. Recently, a mass-dependence of the nuclear caloric curve has been demonstrated [1]. Dependence on the orthogonal degree of freedom, the neutron-proton asymmetry, is not constrained. Theoretical models differ on the magnitude and even the sign of the asymmetry dependence [2-6]. Observation of such dependence may provide insights into the mechanism of nuclear disassembly, allow for a refined interpretation of fragment yield information (e.g. in isoscaling), provide support for the interaction between a nuclear "gas" and a nuclear "liquid", and provide a new way to access information on the nuclear asymmetry energy.

Quasi-Projectile (QP) sources produced in symmetric collisions of ^{70}Zn, ^{64}Zn and ^{64}Ni at E/A = 35MeV were reconstructed event by event using the fragments and free neutrons measured in the NIMROD-ISiS detector array [7] to obtain the charge, mass and excitation energy. The uncertainty in the free neutron measurement has been investigated and does not significantly affect the results shown here. The excitation is determined from the charged particle kinetic energy, the free neutron multiplicity, and the Q-value of the QP breakup. Temperatures are calculated using the quadrupole momentum fluctuation thermometer [8] and the Albergo thermometer [9].

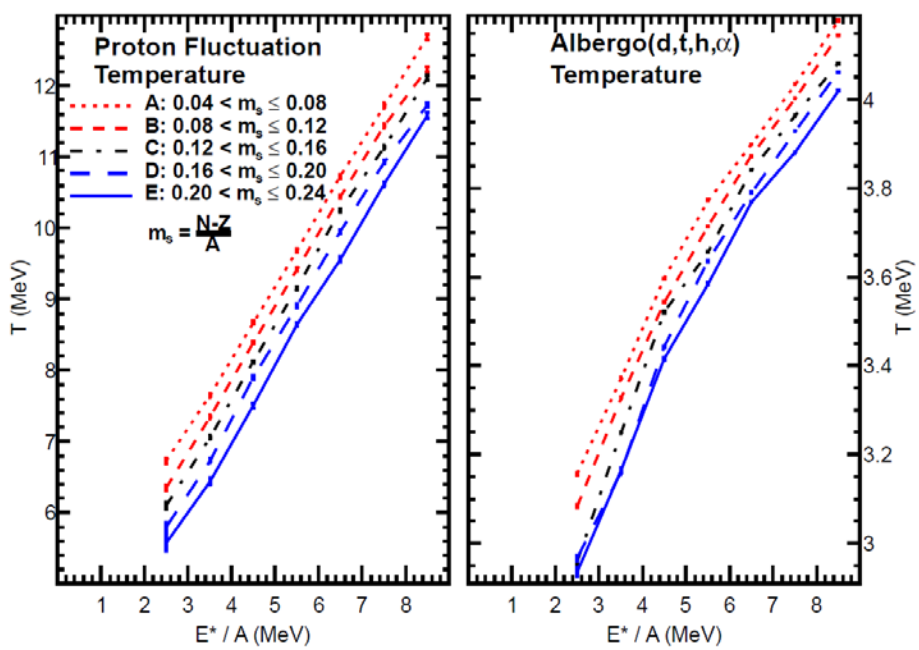

FIG. 1. Caloric curves for isotopically reconstructed sources with mass 48≤A≤52. Each curve corresponds to a narrow range in source asymmetry, m_s=(N-Z)/A. Left Panel: Temperatures are extracted using the momentum quadrupole fluctuation method. Right Panel: Temperatures are extracted using the Albergo yield ratio method.

The left panel of Fig. 1 shows the caloric curves extracted with the quadrupole fluctuation thermometer using protons as the probe particle for QPs with mass 48≤A≤52. Each series of points corresponds to a narrow selection in composition, m_s = (N-Z)/A. Increasing the neutron content of the QP shifts the caloric curve to lower temperatures. In fact, the caloric curves for different m_s bins are nearly equally spaced. The right panel of Fig. 1 shows the caloric curves obtained with the Albergo(d,t,h,α) thermometer with the same selections on m_s. Here too, increasing the neutron content lowers the temperature. For both of these thermometers, the change in temperature with changing m_s does not exhibit a dependence on excitation energy. The selection on the asymmetry of the QP rather than the asymmetry of the initial system is important since the initial systems each have broad and largely overlapping distributions of QP asymmetry.

The dependence of the change in temperature, ΔT, between two sources as a function of Δm_s, the difference in their compositions, is shown in Fig. 2. The change in temperature has been averaged over excitation. Both thermometers exhibit a negative correlation of ΔT with Δm_s, and both are well described by a linear fit over the broad range in source asymmetry, with slope -7.3 MeV for the momentum quadrupole fluctuation temperature and -1.2 MeV for the Albergo temperature. Other charged particle probes of the quadrupole momentum fluctuation temperature also show linear trends of ΔT with Δm_s with slopes of the same order of magnitude. This result may be compared to the recent result from the ALADIN collaboration [10]. How the asymmetry dependence changes as the reaction mechanism evolves from evaporation to multifragmentation will be the focus of future studies.

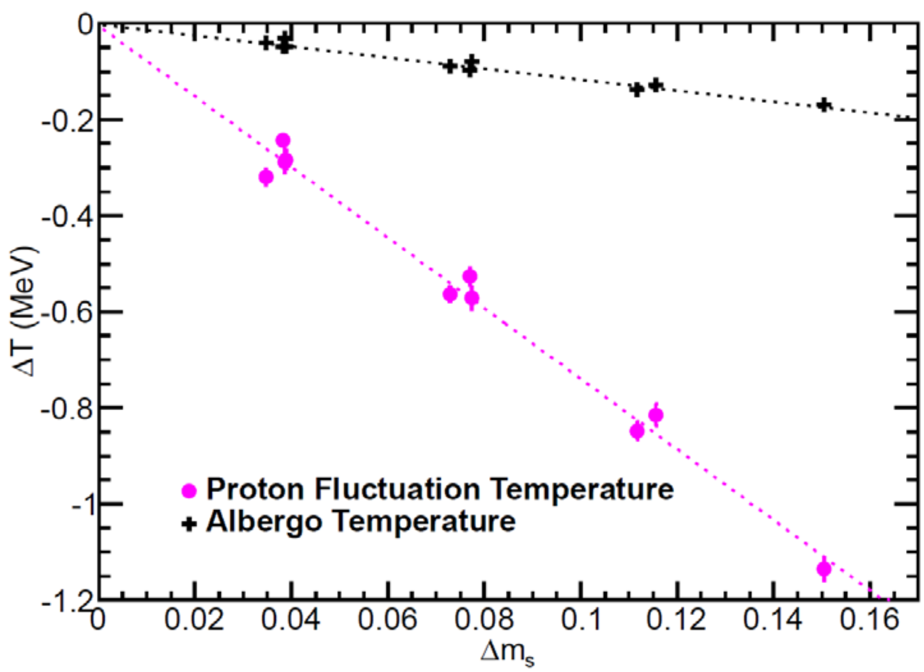

FIG. 2. Change in temperature as a function of the change in source asymmetry m_s = (N-Z)/A. The dashed lines are linear fits to the experimental data.

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