Symmetry Energy and Multifragmentation of ^{40}Ar, ^{40}Ca + ^{58}Fe, ^{58}Ni Reactions at 25, 33, 45 and 53 MeV/nucleon

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Recently, the possibility of extracting information on the symmetry energy and the isospin of the fragments in a multifragmentation reaction has gained tremendous importance. Traditionally, the symmetry energy has been extracted by fitting the binding energy in their ground state with various versions of the liquid drop mass formula. The properties of the nuclear matter are then determined by theoretically extrapolating the nuclear models designed to study the structure of real nuclei. However, real nuclei are cold, nearly symmetric and found at equilibrium density. It is not known how the symmetry energy behaves at temperature and density away from the normal nuclear matter. In a multifragmentation reactions the fragments produced are highly excited and neutron-rich; their yields depend on the available free energy, which in turn depends on the symmetry energy and the extent to which the fragments expand. It has been shown that the isoscaling parameter α is proportional to the symmetry energy part of the fragment binding energy. Therefore, by studying the isoscaling parameters one can extract information about the symmetry energy and the properties of the fragments under non-normal nuclear conditions.

Fig. 1 (left) shows a comparison of the Statistical Multifragmentation Model (SMM) calculated α with the experimentally determined α as a function of excitation energy for different values of the symmetry energy γ. The dotted lines correspond to the primary fragments and the solid lines to the

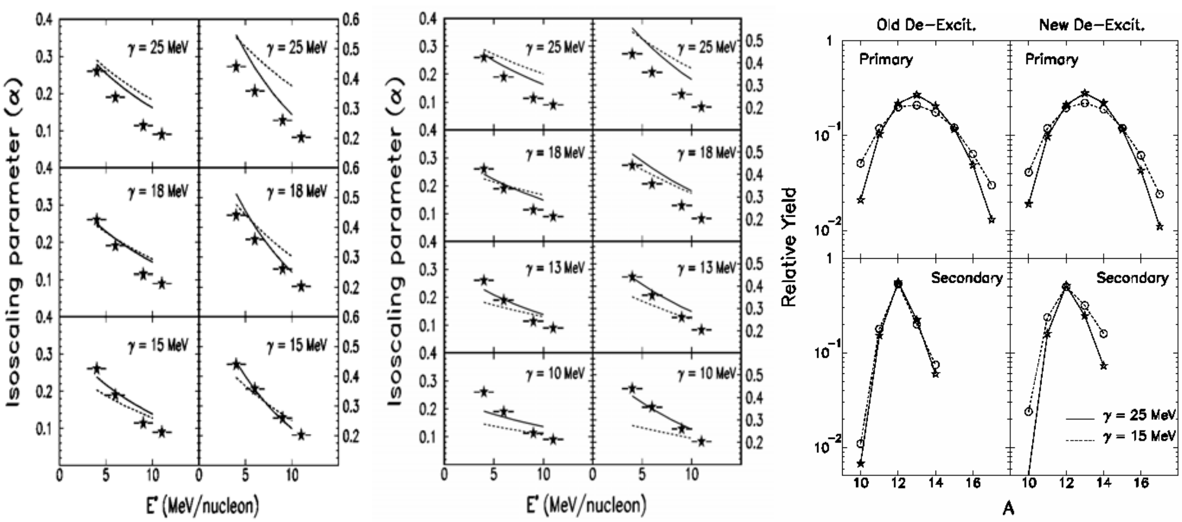

Figure 1. (Left) Comparison of the SMM calculated α with the experimentally determined α. The left panel in the figure corresponds to the Ar + Ni and Ca + Ni pair of reactions, and the right to Ar + Fe and Ca + Ni pair. (Center) same as the left, but with evolving symmetry energy during sequential decay of the hot primary fragments. (Right) Comparison between the calculated fragment isotopic distributions for the C element using two different assumptions.

secondary fragments. It is observed that the experimentally determined α can be reproduced simultaneously at all excitation energies by assuming a single value of the symmetry energy, $\gamma = 15$ MeV. This value of symmetry energy is significantly lower than the value of $\gamma = 25$ MeV used for ground state nuclei near saturation density.

Fig. 1 (center) shows the same calculation, which takes into account the mass evolution of the hot primary fragments due to lower symmetry energy during their sequential de-excitations. It is observed that in this case, the experimental α values can be explained by symmetry energy $\gamma = 10 - 13$ MeV. The difference in the two calculations can be understood by comparing the final fragment yield distributions as shown in fig. 1 (right). It is observed that the calculation with the standard de-excitation leads to a narrow final distribution and the isotopes are concentrated close to the β-stability line. The difference in the final yield distributions for $\gamma = 15$ MeV and $\gamma = 25$ MeV is very small. This difference is much pronounced in the new calculation. The final isotopic distributions in this case are wider and shifted towards neutron-rich side.

The lower value of the symmetry energy ($\gamma = 15$ MeV) required in this analysis was obtained by assuming a constant freeze-out density of 1/3 ρ_0 in the SMM calculation and is consistent with our Fe, Ni + Fe, Ni analysis, where the comparison between the experiment and the calculations was made for each excitation energy with evolving density.

The above results indicate that the properties of nuclei produced at high excitation energy, isospin and reduced density could be significantly different from those of the cold isolated nuclei.

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