Effect of symmetry energy evolution during sequential de-excitation on isoscaling parameter of the fragments produced in multifragmentation reaction

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It has been argued [1] that the effect of sequential decay of the hot primary fragments produced in multifragmentation reactions on the isoscaling parameter α depends not only on the excitation energy of the primary fragments but also on the evolution of the mass/symmetry energy of the primary fragments during the decay. The fragments produced in the primary stage of the multifragmentation reaction are usually hot and their properties (*i.e.* binding energy and mass) differ from those of cold nuclei. If hot fragments in the freeze-out configuration have smaller symmetry energy, their mass at the beginning of the sequential de-excitation will be different, and the isoscaling parameter of the experimentally determined cold fragments will be significantly different from those of the primary fragments. If such is the case, then the comparison between the theoretically calculated and the experimentally measured isoscaling parameter α must be treated with caution.

In order to study the effect of symmetry energy evolution on the isoscaling parameter during the sequential de-excitation of the hot primary fragments, the Statistical Multifragmentation Model (SMM) calculation with a phenomenological approach of Buyuckcizmeci *et al* [2], was carried out. In this approach, one assumes liquid drop masses, $m_{A,Z} = m_{ld}(\gamma)$, for the light particles ($n, p, d, t, {}^3He, \alpha$) if the internal excitation energy of the fragment is large ($\xi = \beta E^*/A > 1$). For lower excitation energies ($\xi < 1$), one assumes a smooth transition to standard experimental masses with shell effects (m_{exp}), and having the following dependence,

$$m_{A,Z} = m_{ld}(\gamma)\xi + m_{exp}(1 - \xi)$$

The excitation energy is determined from the energy balance taking into account the mass $m_{A,Z}$ at the given excitation.

Fig. 1(a) shows the primary and the secondary isoscaling parameter α as a function of symmetry energy γ calculated from the statistical multifragmentation model with the symmetry energy of the hot primary fragments kept fixed. The calculation is for the ^{40}Ar + ^{58}Ni and ^{40}Ca + ^{58}Ni, and ^{40}Ar + ^{58}Fe and ^{40}Ca + ^{58}Ni pair of reactions. The various panels (from top to bottom) correspond to different excitation energies of the multifragmenting system. The dashed lines in each panel correspond to the isoscaling parameter for the primary fragments, and the solid lines to the secondary fragments (*i.e.* after sequential decay). It is observed that there is no significant difference between the primary and the secondary α. Fig. 1(b) shows the result of the calculations when the symmetry energy is varied during the sequential de-excitation of the hot fragments. It is again observed that there is no significant change in the isoscaling parameter α between the primary and the secondary fragments. The main difference, however, in the two figure (Fig 1(a) and 1(b)) is the rate at which isoscaling parameter decreases with decreasing symmetry

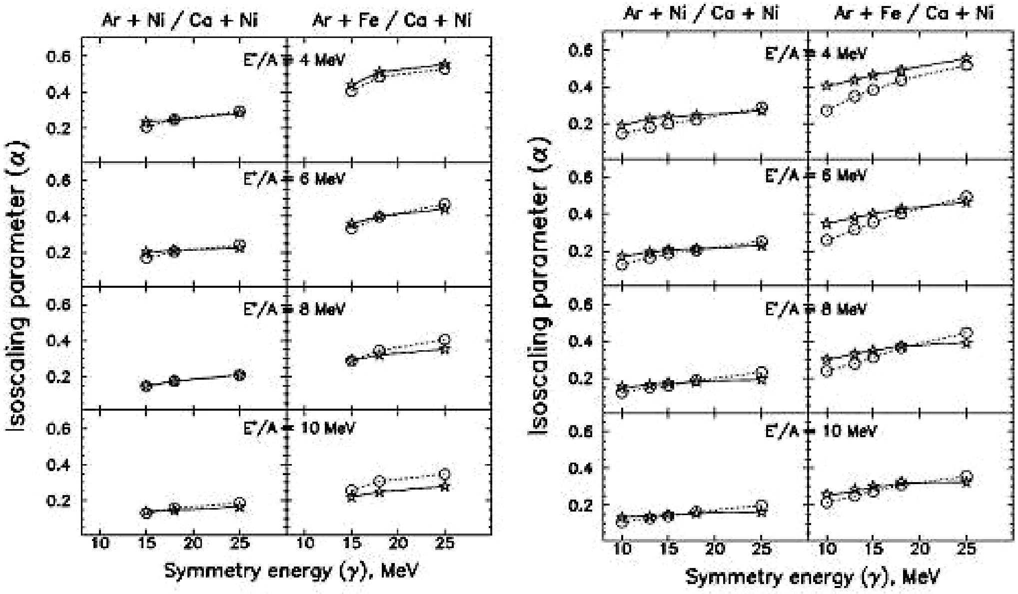

Figure 2. 1(a): Left, Isoscaling parameter α as a function of symmetry energy for various excitation energies. The symmetry energy is kept fixed during the sequential decay of the primary fragments. Figure 1(b): Right, Isoscaling parameter as a function of symmetry energy with symmetry energy evolving during sequential decay of the primary fragments.

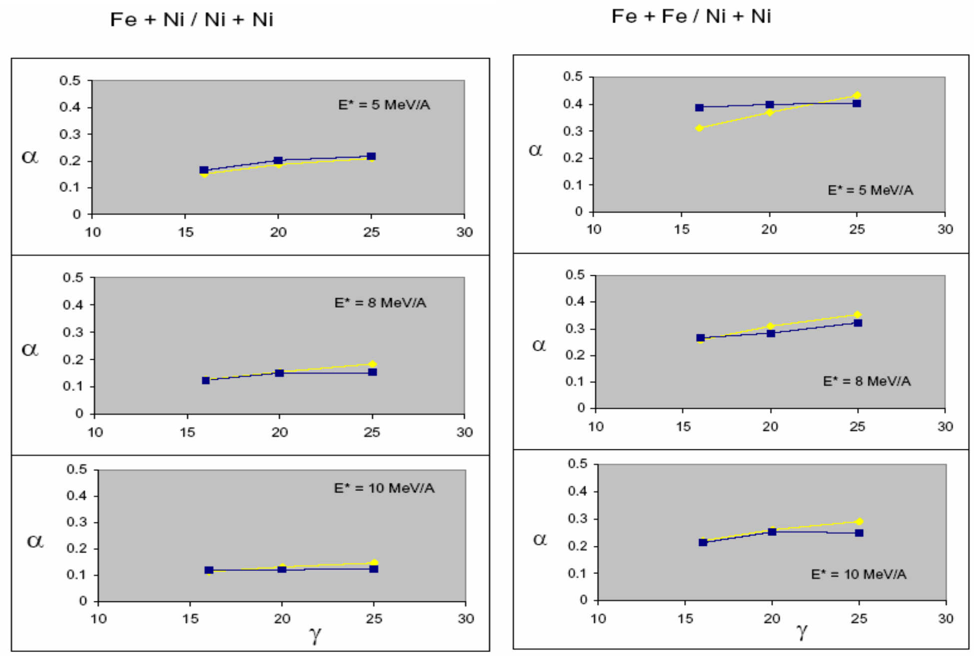

Figure 1. Same as in Fig. 1, but for ^{58}Fe + ^{58}Ni ^{58}Ni +^{58}Ni, and ^{58}Fe + ^{58}Fe ^{58}Ni + ^{58}Ni pair of reactions.

energy. The decrease is much slower in the calculation where the symmetry energy dependence of the mass is taken into account during the secondary de-excitation. The slower decrease in the isoscaling parameter results in the calculation being able to reproduce the experimental isoscaling parameter at a slightly lower value of symmetry energy [3]. A similar feature (shown in Fig. 2) is also observed for the ^{58}Fe + ^{58}Ni ^{58}Ni + ^{58}Ni, and ^{58}Fe + ^{58}Fe ^{58}Ni + ^{58}Ni reactions.

[1] M. Colonna and M. B. Tsang, Eur. Phys. J. A **30**, 165 (2006).
[2] N. Buyukcizmeci, R. Ogul, and A. S. Botvina, Eur. Phys. J. **25**, 57 (2005).
[3] J. Iglio *et al.*, Phys. Rev. C **74**, 024605 (2006).