Investigating the symmetry and surface energy co-efficient from fragment isotope and charge yield distribution using statistical multifragmentation model

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It has been shown [1] recently from the Statistical Multifragmentation Model (SMM) calculation that the symmetry energy term and the surface energy term in the free energy of the fragments, formed in multifragmentation reaction, are sensitive to the isotopic yield distribution and the charge distribution. The symmetry energy is shown to be sensitive to the fragment isotope yield distribution, and the surface energy to the fragment charge distribution.

a) **Influence of the symmetry energy in SMM**: The symmetry energy of the hot fragments with mass A and charge Z in SMM is parameterized as $E^{sym}(A,Z) = \gamma(A - 2Z)^2/A$. The parameter γ, known as the symmetry energy co-efficient, has a value of 25 MeV for the cold nuclei. For hot fragments, this value is unknown and is sensitive to the fragment isotopic yield distribution. It can be extracted from the experimental data via isoscaling phenomena in multifragmentation reaction.

b) **Influence of the surface energy in SMM**: The surface energy of the hot fragments in SMM is parameterized as $E^{sur}(A,Z) = B(T)A^{2/3}$, where $B(T) = B_o[(T_c^2 - T^2)/(T_c^2 + T^2)]^{5/4}$. The parameter $B_o = 18$ MeV is the standard surface energy co-efficient for cold nuclei. The production of new fragments leads to an increase in the surface contribution to the total energy of the system. A small variation of the surface energy can lead to big changes in fragment charge distribution.

In this work, we aim to constrain the values of the symmetry energy and the surface energy using them as free parameters in the SMM calculation. In the first stage of the calculation we will constrain the value of the symmetry energy using the fragment isotopic yield distribution and comparing them to the experimental yield distribution using the isoscaling technique. The value of the symmetry energy thus obtained can then be used to constrain the surface energy from the fragment charge distribution. Fig. 1 shows the calculated isotope yield distribution for Z = 4, 6, and 8 elements in $^{58}Fe + ^{58}Ni$ and $^{58}Ni + ^{58}Ni$, and $^{58}Fe + ^{58}Fe$ and $^{58}Ni + ^{58}Ni$ reactions for two different values of the symmetry energy γ = 25 and 14 MeV. These yield distribution were used to determine the isoscaling parameter α for the primary and the secondary fragments. Fig. 2 shows the calculated primary (yellow curve) and secondary fragment (blue curve) isoscaling parameters as a function of system excitation energy. The solid red points show the experimentally determined isoscaling parameter. The figure shows the comparison between the experiment and the calculation for the $^{58}Fe + ^{58}Ni$ and $^{58}Ni + ^{58}Ni$ (left column), and the $^{58}Fe + ^{58}Fe$ and $^{58}Ni + ^{58}Ni$ (right column) pair of reactions. The calculations are shown for three different values of the symmetry energy, γ = 25, 20 and 16 MeV. The surface energy co-efficient is kept constant at a standard value of B_o = 18 MeV. It is observed that the experimental isoscaling parameter for both the pairs of reactions could be explained using a symmetry energy value of about 16 MeV.

Having constrained the symmetry energy co-efficient γ from the fragment yield distribution, the surface energy co-efficient B_o was constrained using the charge yield distribution. Fig. 2 shows the comparison between the experimental (solid points) charge yield distribution and the SMM calculated

(curves) charge yield distribution, using different values of the surface energy co-efficient B_o, for $^{58}Fe + ^{58}Ni$ (top) and $^{58}Fe + ^{58}Fe$ (bottom) systems. The calculations were carried out for a constant value of $\gamma = 16$ MeV, as obtained from the constraint on the yield distribution discussed above, and different values of the surface energy co-efficient B_o. Fig. 3 shows the preliminary results from this calculation for the $^{58}Fe + ^{58}Ni$ (top) and $^{58}Fe + ^{58}Fe$ (bottom) systems. Further investigation to understand the charge distribution is underway.

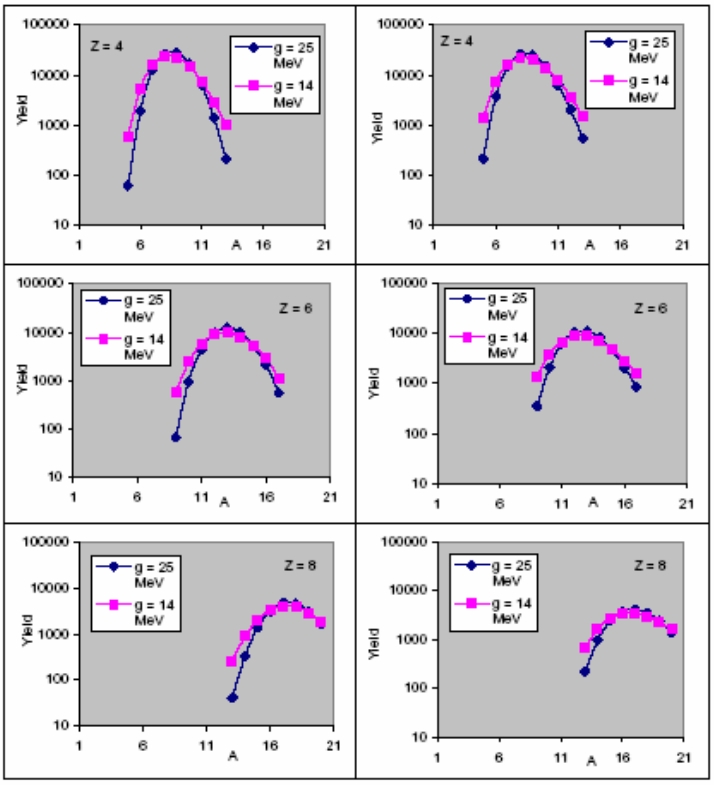

Figure 1. SMM calculated isotope yield distributions for Fe + Ni and Ni + Ni (left), and Fe + Fe and Ni + Ni (right) pair of reactions. The calculations are for two different values of symmetry energy $\gamma = 25$ and 14 MeV.

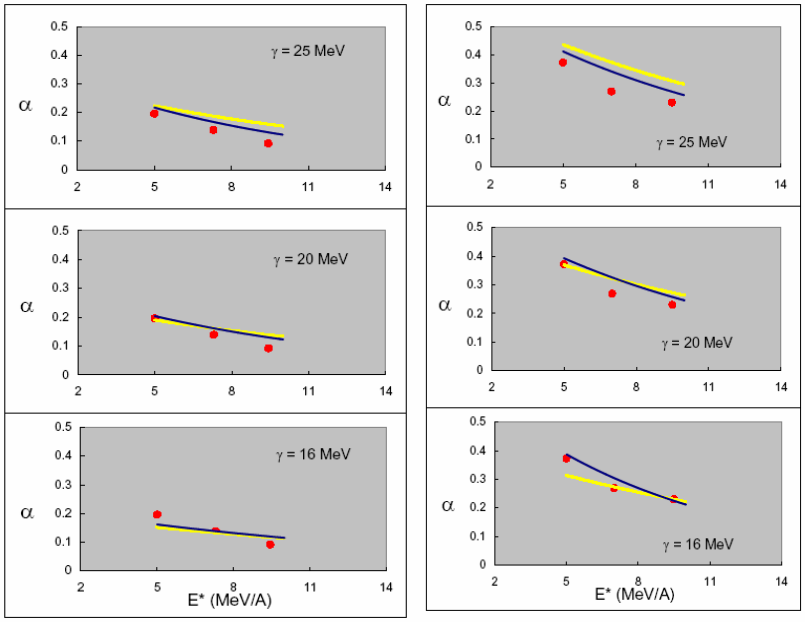

Figure 2. Isoscaling parameter as a function of excitation energy for the Fe + Ni and Ni + Ni, and Fe + Fe and Ni + Ni pair of reactions. The calculations (curves) are for different values of symmetry energy γ.

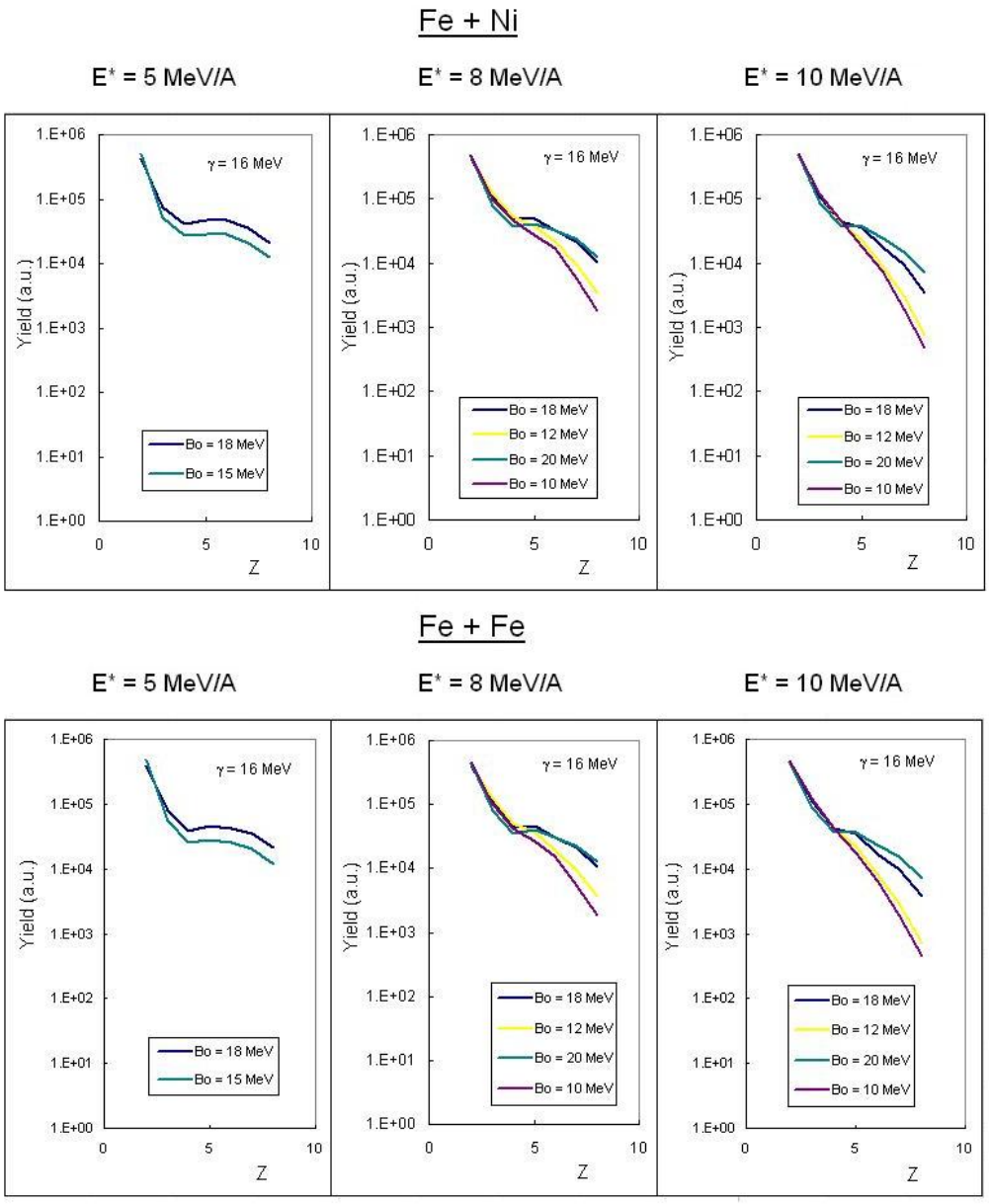

Figure 3. Comparison between the experimentally determined and SMM calculated charge distribution for Fe + Ni and Fe + Fe systems at different excitation energies, and using different values of the surface energy co-efficient.

[1] A. S. Botvina *et al.*, Phys. Rev. C **74**, 044609 (2006).