Isoscaling parameter in nuclear multifragmentation

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Isoscaling is an important property for studying the symmetry energy in intermediate energy nuclear reactions . It is observed both theoretically and experimentally that the ratio of yields $R_{21} = Y_2(N,Z)/Y_1(N,Z)$ from two reactions 1 and 2 having different isospin asymmetry (2 is more neutron rich than 1) exhibit an exponential relationship as a function of neutron(N) and proton(Z) number i.e.

$$R_{21} = Y_2(N,Z)/Y_1(N,Z) = C\exp(\alpha N+\beta Z).$$

where α and β are isoscaling parameters and C is a normalization constant.
We study the dependence of α on system source size, isospin asymmetry, input symmetry energy and temperature for primary fragments i.e. after multifragmentation stage (denoted by dashed lines) as well as secondary fragments i.e. after evaporation stage (denoted by solid lines). In each case α is calculated for fragments having $Z = 6$ to $Z = 13$ and then average value is plotted. The multifragmentation stage is studied by the Canonical Thermodynamical Model [1] which is based on equilibrium statistical mechanics and involves the calculation of partition functions. The decay of excited fragments produced after multifragmentation stage is calculated by evaporation model [2] based on Weisskopf's formalism.
To study the temperature and symmetry energy dependence of α, we take the dissociating systems as $A_1 = 168$, $Z_1 = 75$ and $A_2 = 186$, $Z_2 = 75$. These will represent $^{112}Sn+^{112}Sn$ and $^{124}Sn+^{124}Sn$ central collisions after preequilibrium particles are emitted. The variation of α with temperature (at input $C_{sym} =$ 23.5 MeV) is shown in Fig. 1. Normally due to evaporation the decrease of α is observed at higher temperatures but for lower temperatures (approximately below 4 MeV for these dissociating systems) it increases after evaporation.The change in α(decrease or increase) depends of course on the input value of the symmetry energy coefficient C_{sym}. We show this separately in Fig. 2. In this figure the α is plotted as a function of the input C_{sym} for two different temperatures 5 MeV & 7 MeV both for the primary and the secondary fragments. We can infer from this figure that α vs input C_{sym} is almost linear for the primary fragments. Also it is seen that for very low input C_{sym}, α becomes nearly independent of the temperature. The most important inference, however is that α becomes less sensitive to the input C_{sym} after secondary decay and it is more so for the higher temperatures.

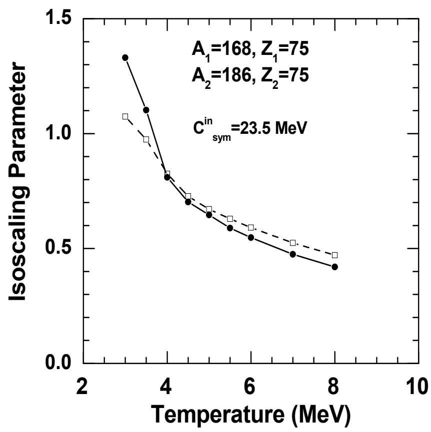

FIG. 1: Variation of isoscaling parameter (α) with temperature.

The primary isoscaling parameter and its change due to evaporation also depends on the difference in assymetry of the two sources (Δ); primary value of α and its change due to

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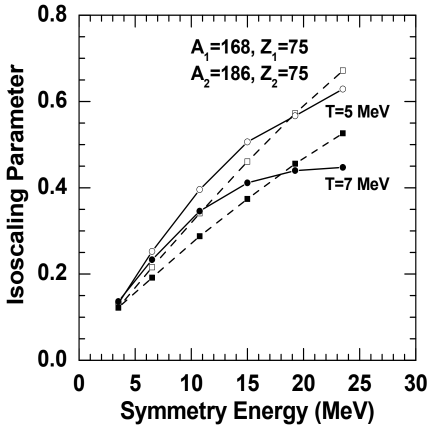

FIG. 2: Variation of isoscaling parameter (α) with input symmetry energy.

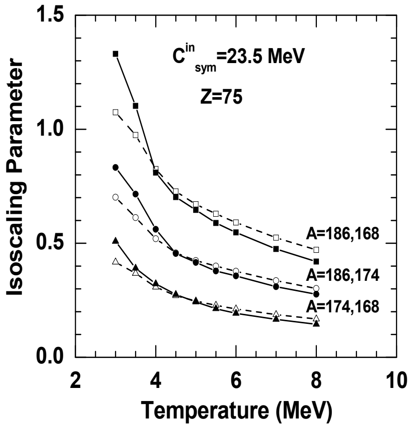

FIG. 3: Effect of isospin asymmetry on isoscaling parameter (α).

evaporation being more for greater Δ where $\Delta = \left(\frac{Z_1}{A_1}\right)^2 - \left(\frac{Z_2}{A_2}\right)^2$. This is shown in Fig.3 for three systems $A_1 = 168$, $A_2 = 174$ and $A_3 = 186$; $Z = 75$ for all the three systems. We have considered these systems pairwise in order to calculate α. For higher T values, α decreases after evaporation but as one decreases T at some point there is a changeover and after that α increases after evaporation. This value of temperature T where this changeover takes place depends on Δ; more the Δ, lower is the value of T where the crossing of the two lines due to primary and secondary fragments occur.

In Figure 4, we show the effect of source size on α. For this purpose, we have kept the N/Z ratio same and have just taken the source sizes to be one-half and one-third of the sources already considered in Fig 1. Δ remains same for all the pair of sources. From Figure 4, we clearly observe that for $T = 3$ & 5 MeV, the value of α remains almost same as we increase the source size both for primary and secondary fragments. For $T = 8$ MeV, one can notice a decrease of α with increase in source size. Also, the change(decrease) in the α due to evaporation is more at the lowest value of T , whereas the change decreases and is very less for the higher values of T.

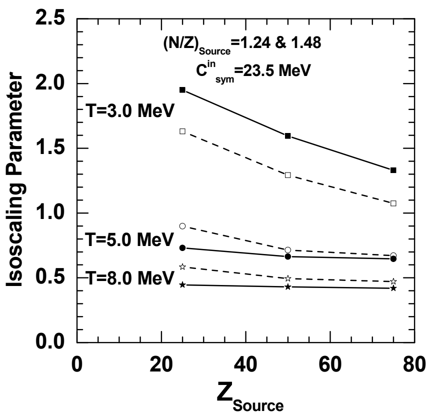

FIG. 4: Dependence of isoscaling parameter (α) on source size.

Therefore we can conclude that the isoscaling parameter for primary and secondary fragments depends on temperature, symmetry energy, isospin asymmetry difference and source size.

References

[1] C. B. Das et al., Phys. Rep **406**, 1, (2005).
[2] G. Chaudhuri, S. Mallik, Nucl. Phys. **A 849**, 190 (2011).