Isotope asymmetry scaling

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Isotope yields can be given by the following expression along Modified Fisher Model [1],

$$Y(N_f, Z_f) = y_0 A_f^{-\tau} \exp\{[w(N_f, Z_f) + \mu_n N_f + \mu_p Z_f]/T\}, \quad (1)$$

Where y_0 is a normalization constant, τ is the exponent of the mass distribution, $W(N_f,Z_f)$ is Gibbs free energy. Then

$$w(N_f, Z_f)/T = \ln[Y(N_f, Z_f) A_f^{\tau} / y_0] - (\mu_n N_f + \mu_p Z_f)/T, \quad (2)$$

In Gibbs free energy the sum of the volume, surface and coulomb terms is about 8A MeV in the classical mass formula, and therefore one can write $w(N_f,Z_f)$ as

$$w(N_f, Z_f)/A \sim 8MeV - a_a I^2 - \delta, \quad (3)$$

in which $I=(N_f-Z_f)/A_f$ is isotopic asymmetry and δ is the pairing energy. Then from Eq. (2)

$$-\ln[Y(N_f, Z_f) A_f^{\tau} / y_0]/A \sim [-8MeV + a_a I^2 + \delta - (\mu_n N_f + \mu_p Z_f)/A]/T,$$

$$= [-8MeV + a_a I^2 + \delta - \mu_n I - (\mu_p + \mu_n) Z/A]/T, \quad (4)$$

Since Z/A ~ ½ in the last term, this indicates that the isotope yields can be scaled by I. When the isotope yield is normalized by the yield of the ^{12}C as given below,

$$R = Y(N_f, Z_f) A_f^{\tau} / [Y(^{12}C) 12^{\tau}], \quad (5)$$

then

$$-\ln(R)/A = (-8MeV + a_a I^2 + \delta - \mu_n I)/T - (\mu_p + \mu_n) Z/A/T + \ln[Y(^{12}C) 12^{\tau}]/12 \quad (6)$$

This also shows an isotopic asymmetry scaling similar to Eq. (4).

Following the above discussion, the experimental multiplicity of isotopes for $^{64}Zn+^{58}Ni$, $^{64}Zn+^{92}Mo$, $^{64}Zn+^{197}Au$, at 26, 35, and 47 A MeV are examined with AMD-V calculations with Gogny interaction [2,3]. When τ = 0 is used, the experimental isotope yields are well scaled by Eq. (4), but not by Eq. (6) as seen in Fig. 1, where the isotope multiplicity is plotted as a function of the isotopic asymmetry, I.

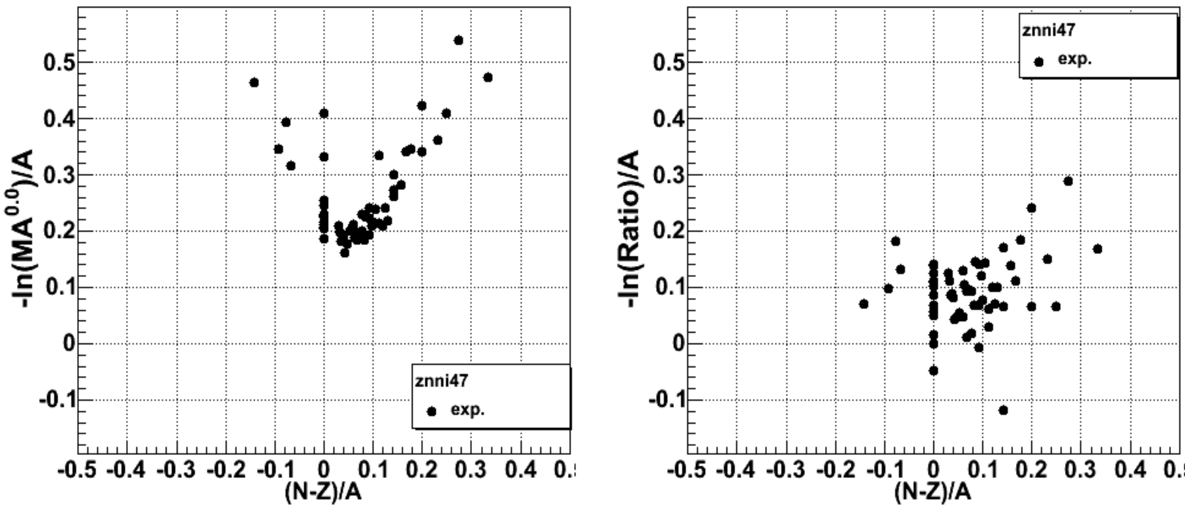

FIG. 1. Isotopic multiplicities are plotted using Eq. (4) (left panel) and Eq. (6) (right panel) with τ = 0 for the violent collision of the case $^{64}Zn+^{58}Ni$ at 47 A MeV.

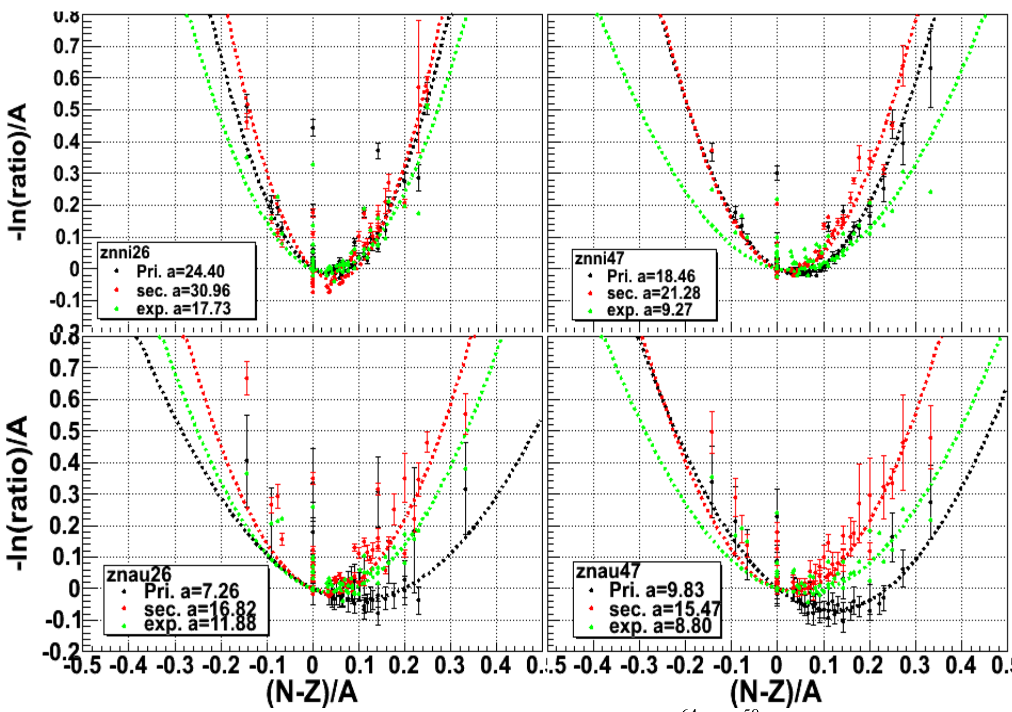

FIG. 2. Isotopic ratios are plotted for violent collisions of $^{64}Zn+^{58}Ni$ at 26A MeV and 47A MeV(upper panel), and $^{64}Zn+^{197}Au$ at 26A MeV and 47A MeV (lower panel) . The green circles represent experimental data, and the black symbols are for AMD-V primary and the red symbols for AMD-V+Gemini, respectively. The dashed lines correspond to the fits with Eq. (6).

On the other hand, if $\tau = 2.3$ is used, the isotopes are well scaled by Eq. (6), as seen in Fig. 2, in which the results of AMD-V simulations are also given. For AMD-V results, the primary and secondary isotope multiplicities are shown in each figure. The secondary yields are obtained by cooling the excited fragments of AMD-V at 300fm/c putting into Gemini[4]. As seen in the figures, the widths and the minima of the quadratic distributions depend significantly on the N/Z ratio of the reaction system and AMD-V simulations reproduce well these trends. On the other hand, the widths of the secondary products, which should be compared to the experimental results, show much narrower distributions. Further detailed studies are now underway.

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