Determination of temperature profile in projectile fragmentation: A microscopic static model approach

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Projectile like fragments (PLF) produced in intermediate energy heavy ion reactions have an excitation energy which is often characterized by a temperature. Earlier in our projectile fragmentation model [1],the temperature of the PLF was not calculated, rather it was parameterized using the experimental data. In this work we try to determine the temperature profile from a microscopic static calculation and compared it with the earlier parametrization.

In the microscopic calculation, at first Thomas-Fermi (TF) solution of the projectile ground state is calculated using iterative techniques [2]. The kinetic energy is given by

$$T = \frac{3h^2}{10m}[\frac{3}{16\pi}]^{2/3}\int \rho(r)^{5/3}d^3r \qquad (1)$$

For potential energy we take

$$V = A\int d^3r\frac{\rho^2(r)}{2} + \frac{1}{\sigma+1}B\int \rho^{\sigma+1}(r)d^3r + \frac{1}{2}\int d^3rd^3r'v(\vec{r},\vec{r'})\rho(\vec{r})\rho(\vec{r'}) \qquad (2)$$

The first two terms on the right hand side of the above equation correspond to zero range Skyrme interactions where the constants A, B, σ are chosen to fit the values of nuclear matter equilibrium density, binding energy per nucleon and compressibility. Here we use A=-1533.6 MeV fm^3, B=2805.3 MeV fm$^{7/2}$ and $\sigma = 7/6$.

The third term which is a finite range Yukawa term is given by,

$$v(\vec{r},\vec{r'}) = V_0\frac{e^{-|\vec{r}-\vec{r'}|/a}}{|\vec{r}-\vec{r'}|/a} \qquad (3)$$

with V_0=-668.65 MeV and a=0.45979 fm. The TF phase space distribution will then be modeled accordingly by choosing test particles with appropriate positions and momenta using Monte Carlo technique [2]. Throughout this work we consider 100 test particles ($N_{test} = 100$) for each nucleon.

A PLF can be constructed by removing a set of test particles from the given projectile depending upon the impact parameter and radius of the target nucleus. Here we consider, the beam should be sufficiently energetic so that straight line trajectories are a valid approximation. The mass number of the PLF is the sum of the number of test particles remaining divided by N_{test}. Similarly the total kinetic energy of the PLF is the sum of kinetic energies of the test particles divided by N_{test}. For determining the

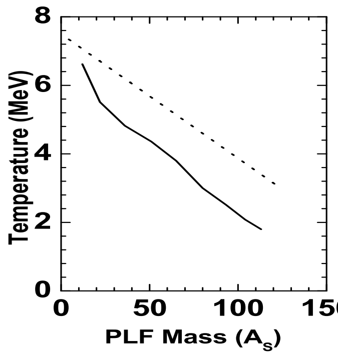

FIG. 1: Variation of excitation energy per nucleon with PLF size ^{124}Sn on ^{119}Sn reaction.

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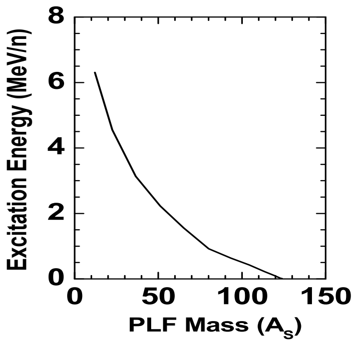

FIG. 2: Plot of temperature against mass number of the PLF for ^{124}Sn on ^{119}Sn reaction. The solid curve is the present model, the dotted line is parameterized as a function of the wound of the PLF defined as 1.0-A_s/A_0 [1].

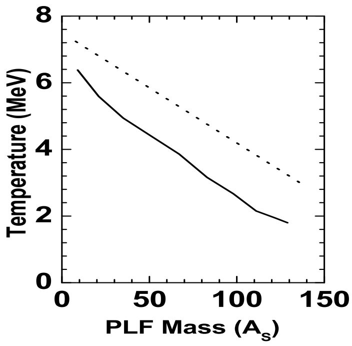

FIG. 3: Curve similar to that of fig.2 but for ^{136}Xe on ^{208}Pb. The dotted curve is from our previous work. [1].

Skyrme, Yukawa and Coulomb potential energy, the required smooth density profile is obtained from the positions of test particles by using Lenk-Pandharipande prescription [3]. In this way, we can determine the total energy of the PLF. But, our actual aim is to determine the excitation energy of the system which motivates us to find the ground state energy of the PLF. Hence, we again use the TF method for a spherical (ground state) nucleus having mass equal to the PLF mass and repeat the entire procedure. This is a static calculation and there is no time evolution.

However we are not finished yet. This gives us the excitation energy but we need to know the temperature corresponding to this excitation. The canonical thermodynamic model (CTM) [4] which is a very successful model of nuclear multifragmentation can be used to calculate the average excitation per nucleon for a given temperature, mass and charge. This model is thereby used to deduce the temperature for the PLF from its excitation energy.

Fig. 1 shows the variation of excitation energy per nucleon (which is directly calculated in this model) with PLF mass for ^{124}Sn on ^{119}Sn reaction. Then the deduced temperature from excitation energy (using CTM) for this reaction is plotted in Fig. 2. Here, this temperature profile is compared with the earlier parameterized temperature profile used in our projectile fragmentation model [1]. Let, at impact parameter (b), the mass of the PLF is $A_s(b)$ whereas the mass of the original projectile is A_0. Then the parameterized temperature is given by

$$T(b) = 7.5 - 4.5[(A_s(b)/A_0)] \tag{4}$$

This formula was seen to give very reasonable fits for many sets of experiments at different beam energies [5]. Fig. 3 shows the comparison between the temperature profile obtained from microscopic static calculation and parameterized temperature given in equation (4) for ^{136}Xe on ^{208}Pb reaction.

Hence we can conclude that, we successfully determine the temperature profile of different projectile fragmentation reactions from basic microscopic approach without any adjustable parameters.

References

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