Ternary fission of ^{236}U with modified scission point model

C. Karthika* and M. Balasubramaniam
Department of Physics, Bharathiar University, Coimbatore - 641046

Introduction

Nuclear fission is an extremely complex reaction. Though decades elapsed since the discovery of fission, there is no concrete theory describing the fission fragment distribution. The problem of nuclear fission was dealt in different methods. Inspired by the scission-point model developed by Wilkins *et al.,* a new model called SPY (scission-point yield) have been proposed by Lemaitre *et al.,*[1]. This model could predict most important binary fission fragment properties, over a huge range of fisioning systems. The model has been slightly modified and applied for the representative case of thermal neutron induced fission of ^{236}U. In addition, for the first time the model is applied for the study of ternary fission of ^{236}U with fixed spherical third fragment.

Model

The ternary system at scission configuration is modelled by three coaxial nuclei separated by a fixed scission distance of 5 fm and their shapes (except third fragment) are described by quadrupole deformation parameter. Two different fragment arrangements are assumed as $A_1A_2A_3$ and $A_1A_3A_2$. The available energy (E_A) of the system at scission configuration is defined as,

$$E_A = \sum_{i=1}^{3} E_i(Z_i, N_i, \beta_i) + \sum_{i,j=1}^{3} E_{ij}^{C}(\beta_i, \beta_j, d_{ij}) + \sum_{i,j=1}^{3} E_{ij}^{N}(\beta_i, \beta_j, d_{ij}) - E_{CN}$$

where the suffix $i, j = 1, 2, 3$ are used to refer heavy, light and third fragment respectively. First term of the above equation is the sum total of three fragment energies each taken as the sum of macroscopic liquid drop and microscopic shell correction determined through Strutinsky prescription using Nilsson levels. $E_{ij}^{C(N)}$ denotes Coulomb (nuclear) energy [2] between fragment pairs i, j such that $i \neq j$ and E_{CN} is the excited compound nucleus energy. A given configuration is energetically reachable only if $E_A < 0$. With absolute E_A, most favourable fragment deformation and fission channel are taken by maximum E_A.

The probability of a particular partition related to the number of states of three-fragment system is,

$$P(A_1, A_2) = \int_0^{E_A} \rho_1(\varepsilon_1) \int_0^{E_A} \int_0^{E_A} \rho_2(\varepsilon_2)\rho_3(\varepsilon_3) \, \delta\left(\varepsilon_2 + \varepsilon_3 - (E_A - \varepsilon_1)\right) d\varepsilon_2 d\varepsilon_3 d\varepsilon_1$$

The above ternary convolution will take care of all possible energy partition between three fragments with $\varepsilon_1 + \varepsilon_2 + \varepsilon_3 = E_A$. The state density of a nucleus with an intrinsic excitation energy ε_i is given by

$$\rho(\varepsilon_i) = \frac{\sqrt{\pi}}{12} \frac{e^{2\sqrt{a_i \varepsilon_i}}}{a_i^{1/4} {\varepsilon_i}^{5/4}}$$

where a_i is an excitation energy dependent level density parameter defined as,

$$a_i = E_i^* / T_\eta^2$$

Here T_η is the temperature for each channel tuned in such a way that it conserves $E_A = E_1^* + E_2^* + E_3^*$ and E_i^* is the excitation energy for each fragment evaluated from Nilsson single particle levels corresponding to that temperature through particle number conservation equations.

The relative yield at the point of scission is calculated as,

$$Y(A_i, Z_i) = \frac{P(A_i, Z_i)}{\sum P(A_i, Z_i)}$$

*Electronic address: `ckarthika.437@gmail.com`

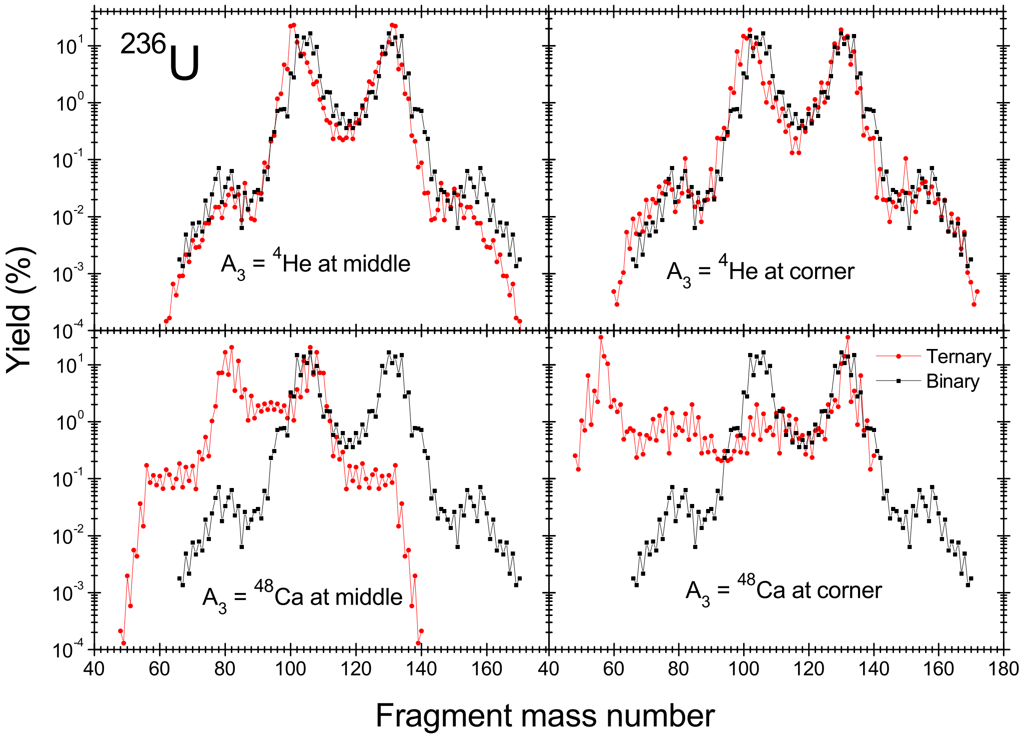

FIG. 1: Yield distribution for thermal neutron induced binary and ternary fission of ^{236}U with ^{4}He and ^{48}Ca as fixed third fragment for the latter case positioned at the middle and corner .

Results

The maximum E_A for all channels in the deformation space for thermal neutron induced binary as well as ternary fission of ^{236}U are calculated. For ternary fission the third fragments considered are ^{4}He and ^{48}Ca. Further, two arrangements were considered wherein the third fragments are positioned at middle of the other two fragments in one case and at the corner in the other case.

In Fig.1, the binary and ternary yields are presented. These two are independent calculations and hence one on one comparison should not be done. The interesting result seen here is, that, if the third fragment is $A_3 = {}^{4}He$ irrespective of its position with respect to the other fragments, the binary and ternay mass distribution are more or less similar except for a small shift in the light fragment group. The heavy fragment group remains same. However, for $A_3 = {}^{48}Ca$ we see different trend. When it is placed at the middle, the distribution shifts and the heavy group of ternary yield matches with light group of binary yield, whereas when it is placed at the corner, the heavy group of ternary yield remains intact with the heavy group of binary yield and only the light group of the ternary yield gets shifted. Moreover, relative magnitude also, considerably changes for heavy third particle.

References

[1] J.-F. Lemaitre *et al.,* Phys. Rev. C **92**, 034617 (2015).

[2] V.Yu. Denisov *et al.,* Phys. Rev. C **95**, 014605 (2017).