Investigating the role of shell closure in ^{32}S + ^{238}U reaction

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Introduction

The nuclear fission involving cataclysmic rearrangement of nuclear matter is a complex process. The fission fragment mass distribution (FFMD) is very important fission observable to study the fission mechanism. Conventionally, the FFMDs are derived based on 'kinematic coincidence method' in which both fission fragments are detected in coincidence to determine their masses and kinetic energies from the mass and momentum conservation laws. These measurements are limited to a resolution of 4-5 mass unit. The fission yields with A and Z identification, had been obtained via the prompt γ-ray spectroscopy and fine structure in FFMD due to nuclear shells were observed in our earlier work [1]. The facilities at FRS(GSI) and VAMOS(GANIL) measures the yield of fission fragments, completely identified in Z and A, by means of reactions in inverse kinematics [2]. These kind of high quality FFMD data give a more comprehensive view on the influence of shell effects and pairing correlations on fission.

Nuclear fission has been studied via various reaction mechanisms to populate various nuclei across the nuclear chart [2]. The heavy-ion fusion-fission (HIFF) reaction is the only method till date to study the fission property of the nuclei in the vicinity of the super-heavy region. For the HIFF reaction characterized by entrance channel with $Z_p \times Z_t \geq 1600$, the non equilibrium process quasi-fission competes with true fusion-fission. The Fragment mass distribution (FMD) in HIFF reactions have been studied with conventional methods.

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In the present work we report our investigations to explore the nuclear structure effects in the ^{32}S + ^{238}U fusion-fission reaction, for which $Z_P Z_T$ is 1472, and the prompt γ-ray spectroscopy was employed to obtain mass distributions at two incident energies around the Coulomb barrier.

Experimental details

The experiments were carried out using the ^{32}S beam with energies, E_{lab} = 220 and 185 MeV, at the BARC-TIFR pelletron-linac facility, Mumbai. Thick self-supporting ^{238}U targets, 20mg/cm^2 for E_{lab} = 220 MeV and 10mg/cm^2 for E_{lab} = 185 MeV were used. The γ-rays were detected in the Indian National Gamma Array and the data acquisition was carried out using XIA-LLC digital data acquisition system.

Data analysis and results

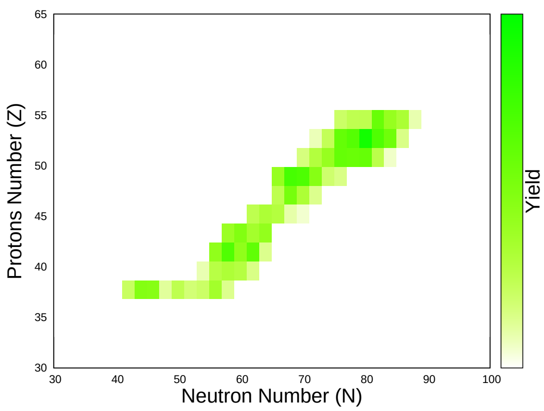

FIG. 1: Relative fragment yield for the isotopes of Sr to Ba produced in the ^{32}S + ^{238}U at E_{lab} = 220 MeV.

The Fig. 1 shows the relative fragment yield for the isotopes of Sr (Z = 38) to Ba (Z = 56), obtained in ^{32}S + ^{238}U reaction at E_{lab} = 220 MeV. The independent fragment yield has been estimated from the analysis of the γ-coincidence data, following the procedure described in Ref [3]. It is to be noted that we have extracted only the yields of the isotopes of Sr to Ba as shown in Fig. 1, so the fragment mass distributions could only be determined for A = 100 to A = 140 mass range. The data is being analysed to estimate the yield of other fragments.

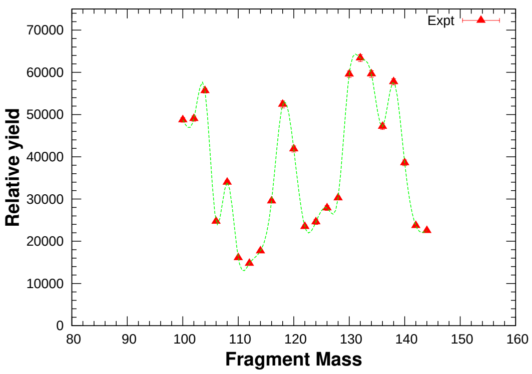

FIG. 2: Fragment mass distribution for A = 100 to A = 140 mass range obtained in ^{32}S + ^{238}U reaction at 220 MeV.

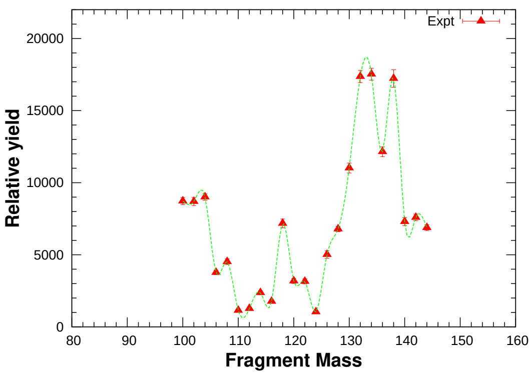

FIG. 3: Fragment mass distribution for A = 100 to A = 140 mass range obtained in ^{32}S + ^{238}U reaction at at 185 MeV.

The FMDs for A = 100 to A = 140 mass range obtained in ^{32}S + ^{238}U reaction at energies, E_{lab} = 220 and 185 MeV are shown in Fig. 2 and Fig. 3 respectively. The FMDs in both cases show structures at mass numbers 118 and 132. From Fig. 1 and Fig. 2 it can be seen that the structure at mass 118 is due to nuclei in the Z = 50 shell region, and the fragments around N = 82 shell closure contribute to the mass at A = 132. It should be pointed out that the mass of doubly magic Sn is 132, and in many FFMD studies the structures around A = 132 were found to be related to this nuclei. However in the present case it is clear that the structure around A = 132 is not related to the doubly magic Sn, but due to nuclei close to Z = 54 and N = 80 which correspond to the symmetric yield from the compound nucleus $^{270}_{104}$**Hs** after considering prompt neutron evaporation. Also the comparison of the FMDs at energies, E_{lab} = 220 and 185 MeV from Fig. 2 and Fig. 3 shows that the relative weight of the structure at A = 118 is decreased for lower energy. Complete mass distribution for the ^{32}S + ^{238}U reaction is being obtained to investigate the role of quasi-fission.

The data analysis is in progress and the results in details will be presented in symposium.

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