The influence of shell effects and target deformation in the quasi-fission process


1 Flerov Laboratory of Nuclear Reactions, JINR, Dubna, Russia, 2 INFN and Universita di Padova, 3 INFN, Laboratori Nazionali di Legnaro, 4 Department of Physics, University of Jyväskylä, Finland, 5 Dipartimento di Fisica and INFN, Napoli

I. INTRODUCTION

In order to understand letter the formation of a compact superheavy compound system, future experiments should clearly separate the fusion-fission from the quasi-fission component. The competition between compound nucleus fission and quasi-fission is probably determined by the properties of di-nuclear configuration at contact, where entrance-channel effects are expected to play the major role in the reaction dynamics [1]. In recent years great efforts were concentrated on the investigation of influence of entrance channel properties on heavy-ion reaction dynamics. The experiments show that the complete-fusion cross section of two very massive nuclei is strongly reduced at incident energies around the expected fusion barrier [2], due to the quasi-fission effect. This is clearly manifested in the comparison of evaporation residue cross sections for reaction leading to the same compound nucleus, but having a different mass-asymmetry in the sections for reaction leading to the same compound manifested in the comparison of evaporation residue cross sections with the 19F and 30Si projectiles [2].

II. EXPERIMENTAL SET-UP

Mass-energy distributions of fission fragments (FF), fission and evaporation residues cross sections have been measured in the 40Ca + 154Sm and 48Ca + 144,154Sm reactions from well below to well above the Coulomb barrier. For the 40Ca + 154Sm reaction (with the well-deformed target nucleus: \( \beta_2 = 0.27, \beta_4 = 0.113 \)) we observed an asymmetric component in the fission-fragment mass distributions. A contribution of this component into the total mass distribution increases with respect to symmetric CN fission as the projectile energy decreases. At the Coulomb barrier energy, such mass-asymmetric contribution corresponds to about 30%. In the case of the 48Ca + 144Sm \( \rightarrow \) 192Pb* reaction (with a spherical target nucleus) no asymmetric “shoulders” are observed. In this case we deal with the much more neutron-deficient CN, than in the case of 48Ca + 154Sm \( \rightarrow \) 202Pb*, where the asymmetric component is unambiguously observed. There are at least two reasons for such a difference: the first one is 144Sm is a spherical nucleus, whereas 154Sm is a deformed one. The second reason is that in the case of 154Sm, the magic shells in both heavy and light "shoulders" (Z=28, N=50 in the light fragment and Z=50, N=82 in the heavy one) come into play. Since the 192Pb* CN has 10 neutrons less than the one produced in the reaction with the 154Sm target, only shells in the light fragments influence the mass-energy distribution. Fig. 1 and fig. 2 present the mass-energy distributions of fission fragments for these systems at the excitation energy of about 49 MeV and at the energy corresponding to the angular momentum of about 30 h for each compound nucleus formed in the reactions.
Recently, we obtained preliminary results for the $^{40}\text{Ca} + ^{154}\text{Sm} \rightarrow ^{194}\text{Pb}^*$ reaction leading to approximately the same CN as in the case of $^{48}\text{Ca} + ^{144}\text{Sm}$, but in the former case we deal with a well-deformed target nucleus.

For the $^{40}\text{Ca} + ^{154}\text{Sm}$ system we find the quasi-fission “shoulder” in mass-energy distributions of fission fragments at energies near and below the Coulomb barrier as observed in $^{48}\text{Ca} + ^{154}\text{Sm}$ (see fig.3). Fusion suppression and the presence of quasi-fission at energy near and below the Coulomb barrier was observed for the deformed target $^{154}\text{Sm}$. In the case of the spherical $^{144}\text{Sm}$ target no quasi-fission manifestation was found at the same excitation energy and angular momentum as in the reactions with $^{154}\text{Sm}$. To make this assertion more reliable, additional investigations are needed. One can conclude from the obtained results that the target deformation has a dominant role on the evolution of the composite system, whereas shell effects in exit channel determine the main characteristics of reaction fragments just as in the case of superheavy di-nuclear systems [8].

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