Fission and quasi-fission dynamics for the super heavy element Flerovium

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The synthesis of super heavy elements (SHE), in pursuit of the island of stability on the chart of the nuclei (around Z=114, N=184), is one of the major goals of today's nuclear physics research. In order to synthesize SHE, fusion of two heavy nuclei is required. After the two fusing nuclei come into the contact configuration, the di-nuclear system may evolve in shape to either form a compact equilibrated heavy nucleus, called compound nucleus (CN), or decay into fission like event before forming a CN, known as quasi-fission. The competition between these two processes exhibits complex behaviour. The production of SHE in higher quantity or those which are yet to be discovered in the laboratory, requires understanding of the mechanism of dynamical evolution that the system undergoes after contact.

The cross section for (super) heavy element formation via fusion evaporation is given by

$\sigma_{ER}(E_{cm})=\sigma_{capture}(E_{cm})\times P_{CN}(E_{cm}) \times P_{survival}(E_{cm})$

where $\sigma_{capture}$ is the capture cross-section for the formation of the di-nucleus system in competition with other peripheral reactions. $P_{survival}$ is the survival probability of the ER which is determined by the competition between fission and neutron evaporation of the excited compound nucleus. P_{CN} is the probability of complete fusion after the capture stage in the di-nuclear system and is an important quantity that determines the fraction of quasi-fission which is believed to be the main culprit for the hindrance of SHE formation.

The heaviest element that have been discovered till date is Z=118. Elements beyond Z=113 have been discovered only in hot fusion reaction with ^{48}Ca beam with actinides target. However, the production of elements beyond Z=118 requires beam heavier than Ca, as targets heavier than Cf are not available for the long duration synthesis experiments of SHE. Here we report the preliminary results of the experimental determination of $\sigma_{capture}$ *and* P_{CN} for the SHE Flerovium (Z=114), produced in reactions with ^{52}Cr beam which is one of the probable candidates for the production of SHE beyond Z=118.

The experiment was carried out at the U400 cyclotron at Flerov Laboratory of Nuclear Reactions, Russia. The target was ^{232}Th of thickness 280 μg/cm^2 on ^{12}C backing (35 μg/cm^2). Beam energies were chosen near the Coulomb barrier. The fragments were detected in coincidence by the double-arm time-of-flight spectrometer CORSET [1]. Each arm of the spectrometer consists of a compact start detector and a position-sensitive stop detector, based on microchannel plates. The data were analysed using standard two-body kinematics [1]. From the measured velocities and angles, the masses and kinetic energies of the reaction products, corrected for energy losses, were calculated.

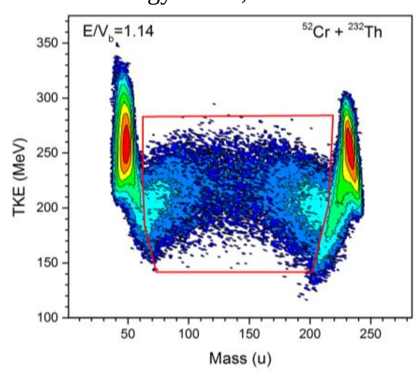

FIG 1: The mass and TKE distributions of binary fragments in ^{52}Cr + ^{232}Th reaction.

Figure 1 shows the typical mass - total kinetic energy (TKE) distributions of the detected binary fragments produced in the reaction ^{52}Cr+^{232}Th. Reaction products between the elastics peaks are fission like fragments (capture), marked by solid lines in the figure. For heavier systems, demarcation of fission like events from elastics, quasi/deep elastics are difficult and may not be unambiguous. Systematics studies reveal that [2] the mass distributions of compound nuclear fission fragments in this mass region have symmetric Gaussian shapes with standard deviation of about 20*u*. Thus, to evaluate the compound nuclear (CN) fission cross section, the contributions of fragments with masses $A_{CN}/2\pm20$ u are considered.

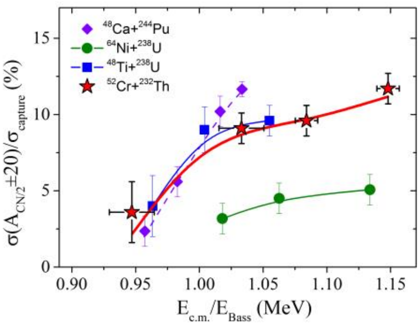

FIG 2: Variation of the contributions of symmetric fragments to the capture cross section.

In Figure 2, we show the relative contributions of mass symmetric fragments ($A_{CN}/2\pm20$) into the capture cross sections. The results of our measurements for reactions ^{52}Cr + ^{232}Th are also compared with those of the previously measured reactions [2] producing SHE. It is interesting to note that, near the Coulomb barrier energy, the contributions of CN fission for Cr induced reaction is very similar to Ti induced reaction producing the same compound nucleus Flerovium.

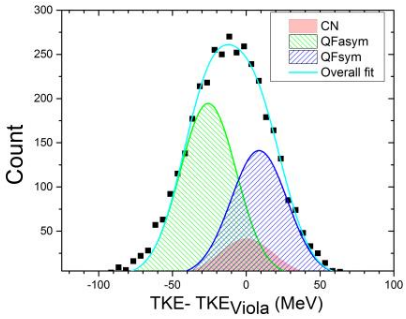

FIG 3: TKE distributions of detected fragments

Figure 3 shows the TKE distributions of the mass symmetric fragments which are formed in three processes. We extract the (i) compound nuclear fission (filled region in fig, peaked at Viola energy), (ii) symmetric and (iii) asymmetric (low energy component) quasi-fission components by decomposing the TKE distribution as a sum of three Gaussians.

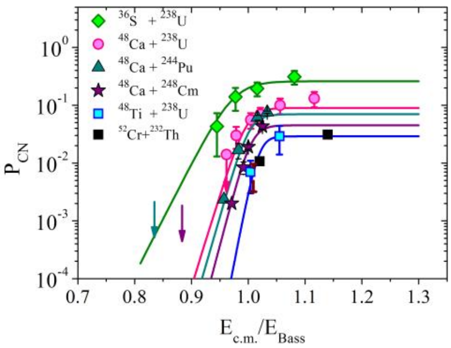

FIG 4: Variation of the contributions of symmetric fragments to the capture cross section.

The fusion probability P_{CN} is deduced as the ratio of the CN fission events (extracted from TKE distributions) and all fission like fragments (capture). In Figure 4, we show the variation of fusion probabilities for the ^{52}Cr+^{232}Th, along with the data of the several systems available in literature [2]. The fusion probability was found to be lower compared to Ca induced reaction producing the SHE Flerovium. The deduced value of P_{CN} could be fitted (shown by solid lines) by simple formula [3], that was proposed to calculate fusion probability in cold fusion reaction, by Zagrebaev and Greiner.

In summary, we present the preliminary results of the experimental value of capture cross section and probability of fusion cross section for SHE Flerovium, produced in ^{52}Cr induced reaction.

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