Mass distribution in ^{35}Cl+^{144}Sm reaction

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Introduction

Heavy ion induced fission has been one of the most widely investigated area in the past few decades. The main emphasis in these studies has been to understand the role of entrance channel and saddle to scission dynamics. The potential energy surface (PES) of the fissioning system is a key element in governing the fusion-fission process. The potential energy surface is determined by liquid drop and single particle energies. In the actinide region the asymmetric mass distribution could be explained by incorporating shell corrections to liquid drop model (LDM) potential energy. Recently, a new type of asymmetric fission was observed in the beta delayed fission of ^{180}Hg with mass ratio 80/100. This was an unexpected observation, as conventional shell effects would result in symmetric fission into two ^{90}Zr fragments (N=50). Observation of asymmetric fission has prompted theoretical calculations on mass distribution in this region. In the calculations in ref [2], a potential energy surface favoring asymmetric fission, at least, at lower excitation energies was obtained. Such a PES is a result of incorporation of single particle effects to LDM. This PES is different from a pure LDM surface, which would have steeply increasing potential energy with increasing asymmetry of mass division. In the beta delayed fission, the excitation energy is low and is limited by the Q value. It would be important to carry out a systematic study, starting from the lowest possible excitation energies to higher energies to investigate the evolution of mass distribution. In the calculations of ref [2], asymmetric mass distribution has been predicted up to excitation energy of 40 MeV.

In view of this, measurement of fission fragment mass distribution has been carried out in ^{35}Cl+^{144}Sm reaction in the beam energy range of 152.5 to 207.7 MeV. Due to the closed shell configuration of ^{144}Sm (N=82), the reaction Q value is highly negative (-85 MeV to check).

Experimental details

Experiments were carried out at BARC-TIFR Pelletron-LINAC facility, TIFR, Mumbai. Electrodeposited target of ^{144}Sm (~120 μg/cm^2) on Al backing (750 μg/cm2) was bombarded with ^{35}Cl beam with energy in the range of 159.4 to 213.8 MeV, so that the beam energy in the target was in the range of 152.5 to 207.7 MeV after energy degradation in the Al backing. Fission fragment mass distributions were measured using two gas-filled detectors placed at the folding angle in the forward hemisphere. The position and timing signals of the gas detector were fed to a TDC. TDC signals were recorded taking RF as a reference. In addition, the cathode signals of the two detectors were fed to start and stop of a TAC. Two monitor detectors were kept at ±25^0 to detect the elastically scattered beam particles.

Results and discussion

Mass distributions were obtained by the velocity ratio method. The chlorine (elastic) peak in the cathode spectrum was used to determine the delay of the detection system with respect to the RF. This delay was slightly adjusted (<1nsec) to make $V_{||}/V_{CN}$ equal to unity. The mutual delay between the two detectors was further adjusted (< 1nsec) to keep the centroid of the mass ratio ($A_{fragment}/A_{CN}$) at 0.5. A plot of the centre of mass angle vs mass number at E_{lab}=156 MeV is shown in Fig. 1. The plot includes complementary fragments also. A cut has been applied to select CM angle range from 80 to 100^0. The corresponding mass distribution is shown in Fig. 2. It can be seen from this figure that mass distribution appears symmetric, though, with a flat top. Gaussian fit to the mass distribution is shown as dashed line. The single Gaussian function does not fit well in the symmetric

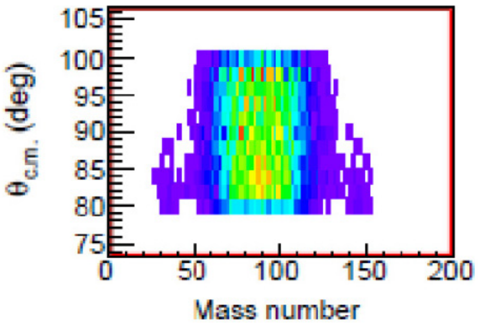

Fig. 1 Plot of centre of mass angle vs mass number at E_{lab}=152.5 MeV

region (χ^2/DF=4.70). This observation suggests that the PES of the fissioning system is different from a pure LDM surface with continuously increasing potential energy with increasing mass asymmetry (ignoring extreme asymmetry values). Incorporation of shell effects would also favour symmetric mass distribution. The observed mass distribution can be correlated to PES obtained in the recent calculations to explain to explain the asymmetric mass distribution in beta delayed fission of ^{180}Hg. The flat top of the mass distribution may be due to a relatively flat PES in the mass asymmetry coordinate arising due to the angular momentum of the fissioning system. Alternatively, this may be a result of overlap of symmetric and asymmetric mass distributions. At the lowest beam energy, the contribution from symmetric fission is expected to be minimum. As an extreme case, the mass distribution was fitted as a sum of two Gaussian functions (shown as solid lines). The fit quality significantly improved (χ^2/DF=2.34) as seen from the symmetric region in Fig. 2. The mass distribution is shown in logarithmic scale in Fig. 3 to compare the fit quality in the asymmetric region. It can be seen from this figure that the two Gaussian fit is better in asymmetric region also compared to the single Gaussian fit. The centroid of the lower wing was obtained as 79.5±0.3. This is close to the value

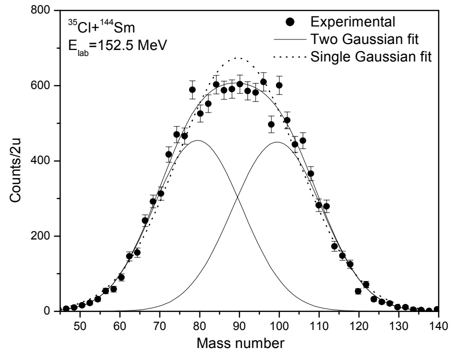

Fig. 2 Mass distribution in ^{35}Cl+^{144}Sm reaction at E_{lab}=152.5 MeV (E*=36.7 MeV)

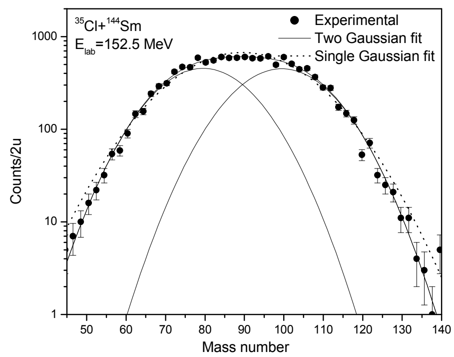

Fig. 3 Same as Fig. 2 (in logarithmic

observed in asymmetric beta delayed fission of ^{180}Hg. Though, the two Gaussian fit describes the data well, this aspect needs more investigation including higher energy data to get a better understanding.

Conclusions

Mass distribution in ^{35}Cl+^{144}Sm reaction has been observed to be symmetric with a flat top which may be correlated to the PES obtained in the recent calculations with the incorporation of single particle effects. Fit to the data at lowest beam energy with a sum of two Gaussian functions is observed to be better than that with single Gaussian.

References

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