Fission fragment mass distribution in the ^{13}C+^{182}W and ^{176}Yb reactions

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Introduction

Fission fragment mass distributions have been measured for many systems and found to be asymmetric in the fission of nuclei with nucleon number A in the range 228-258 and proton number Z in the range 90-100. For lighter systems, it has been observed that fission fragment mass distributions are usually symmetric. At high excitation energies the shell effects are expected to vanish and the nuclei are expected to behave like a charged liquid drop; hence, only symmetric fission is expected for all the nuclei. Even after much experimental and theoretical work in this field, the rate of damping of shell effects with excitation energy is not well known.

It is difficult to measure fission fragment mass distributions at reasonably low excitation energy in such low fissility nuclei (in the mass region of 180-200). Hence, there is not much mass distribution data in this mass region. The recent observation of asymmetric fission of ^{180}Hg following the electron-capture decay of ^{180}Tl [1] has triggered a lot of interest. Calculations [1] showed that the potential energy surface (PES) for this nucleus has a deep symmetric valley at large deformation of the compound nucleus. Still, the nuclei were fissioning with an asymmetric mass split rather than a symmetric one. This measurement [1], which had low compound nucleus excitation energy, showed the importance of dynamical effects in the fission process rather than the simple shell correction to the potential energy surface near scission in this mass region. There were also a few measurements in this mass region by M.G. Itkis *et al.* in the 1990s, which showed either a flat topped mass distribution or even a dip in the centre of the mass distribution. Further analysis of the same data by S.I. Mulgin *et al.* [3] suggested that the fission mass distribution may be affected by two deformed neutron shell closures at N=52 and 68.

Following the measurement by A.N. Andreyev et al. [1], many theoretical calculations aimed at reproducing their observation were performed. These calculations explained the data very well. There were also some preliminary predictions of an asymmetric mass split in the neutron rich W, Re, Os and Ir isotopes by P. Möller and J. Randrup [4] that seem to be influenced by the spherical doubly magic ^{132}Sn nuclei. The enhanced stability around ^{132}Sn is believed to play a role in the fission of actinide nuclei and also in a few of the heavy preactinide nuclei. The ^{201}Tl, ^{195}Au and ^{187}Ir nuclei did not show any such effects due to the ^{132}Sn shell closure [2, 3]. One important question to ask at this point is about the effect of the N/Z ratio: Is a particular combination of deformed/spherical shell structure of the fragments responsible for this effect? Calculations by P. Möller [5] et al. also indicate the importance of N/Z ratio on the fission fragment mass distribution. Their calculation has predicted a more asymmetric fission with increasing excitation energy for the very neutron deficient isotopes of mercury, namely ^{174}Hg and ^{176}Hg which is opposite to expectations, while the other not so neutron deficient isotopes were behaving normally. With this background, it is important to measure the mass distribution of various nuclei in this mass region. This abstract reports our measurements with ^{13}C beams on ^{182}W and ^{176}Yb targets.

Experimental Details and Analysis

The experiment was performed using the Heavy Ion Accelerator Facility at Australian National University, Canberra, Australia. The experiments were performed with pulsed ^{13}C beams of 60, 63 and 66 MeV in energy, with a pulse separation of 106.7 ns. Thin ^{182}W and ^{176}Yb targets were used for the experiment to minimize the fragment energy loss in the target. The ^{182}W target was of thickness 25 μg/cm^2 with a 15 μg/cm^2 natC backing, whereas the ^{176}Yb target was of thicknesses 74 μg/cm^2 with a similar natC backing. We have used the CUBE detector setup which consists of two large-area (284 mm x 357 mm) position sensitive multi-wire proportional counters (MWPCs) mounted at a distance of 180 mm from the target center. The forward detector was at a scattering angle of 45" and backward detector was at 135" with respect to the beam. The fragment velocity vectors are determined using the position and timing

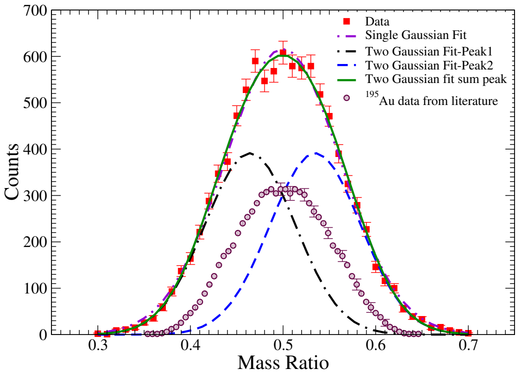

Fig.1 Fission fragment mass ratio distribution data along with single and double Gaussian fits for the ^{13}C+^{182}W $\rightarrow$ ^{195}Hg system at $E^*_{g.s.}$=47.5 MeV. The ^{195}Au data from [2] also shown for comparison.

Fig.1 and 2 shows the mass distribution at E_l=66MeV, for ^{13}C + ^{182}W $\rightarrow$ ^{195}Hg and ^{13}C + ^{176}Yb $\rightarrow$ ^{189}Os system respectively. For both the systems, the mass ratio distributions are reasonably well described by a single Gaussian with centroid at 0.5. The experimental data were fitted with single and double Gaussians to understand the nature of the mass split for all energies.

For ^{13}C+^{182}W system at the two highest excitation energies, the two Gaussian fit better represents the data, and at the lowest excitation energy, there is not a significant difference in the quality of fit between single and double Gaussian fits due to poor statistics. The centroid of the mass distribution peaks at around 91 mass units for the lighter fragment and at around 104 mass units for the heavy fragment. It is interesting to note that the light mass group is

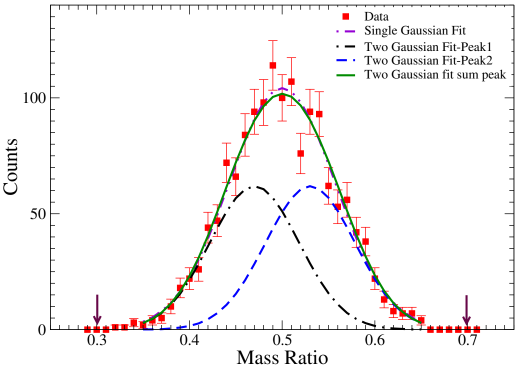

Fig. 5 Fission fragment mass ratiodistribution data along with single and double Gaussian fits for the ^{13}C+^{176}Yb $\rightarrow$ ^{189}Os system at $E^*_{g.s.}$=50.1 MeV.

For the ^{13}C+^{176}Yb system, the single Gaussian has a marginally better χ^2/DF. The ^{13}C+^{176}Yb $\rightarrow$ ^{189}Os fission does not show any asymmetric features, specifically no evidence for an asymmetric fission mode influenced by the doubly magic ^{132}Sn fragment. The further results will be presented in the symposium.

Acknowledgements

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