Deformations at the saddle point from fission fragment angular distribution measurements in A∼200 mass region

K. Mahata,* S.K. Pandit, K. Ramachandran, A. Shrivastava,
C. Palshetkar, A. Chatterjee, S. Santra, A. Parihari, and S. Kailas
Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA

Introduction

According to the Statistical Saddle Point Model (SSPM), the fission fragment angular distribution depends on the angular momentum (J) distribution, effective moment of inertia ($\Im_{\rm eff}$) and temperature (T) at the saddle point of the fissioning nuclei [1]. The effective moment of inertia ($\Im_{\rm eff}$) is related to the shape of the fissioning nuclei at the saddle point. Möller and Sierk [2] have illustrated the importance of the saddle point shape in controlling the dynamics of heavy ion induced fusion-fission reaction. Experimental information about the saddle point shape will have a great ramification for the production of super heavy element.

It has been observed that the measured fission fragment anisotropy values are significantly larger than those predicted by SSPM for ^{12}C+^{198}Pt system, whereas measured anisotropy values for ^{12}C+^{194}Pt system agree well with the SSPM predictions [3]. It was conjectured that the shell effect in the potential energy surface results in reduced $\Im_{\rm eff}$ in comparison to liquid drop value which leads to larger anisotropies. It is of interest to extend the measurement to some more systems to investigate the microscopic variation of $\Im_{\rm eff}$. With this motivation, measurement of fission fragment angular distributions for ^{12,13}C+^{192,194,196}Pt systems has been carried out.

Measurement Details

The fission fragment angular distributions for the above-mentioned systems have been measured using the BARC-TIFR 14 UD Pelletron accelerator at Mumbai. The measurements have been carried out in the laboratory energy range from 60 to 80 MeV, using self-supporting rolled foils of ^{192}Pt (^{192}Pt 57.0%, ^{194}Pt 26.2%, ^{195}Pt 11.2%, ^{196}Pt 4.7%, 1.6 mg/cm^2 thick), ^{194}Pt (97.4% enriched, 0.98 mg/cm^2 thick), ^{196}Pt (96.2% enriched, 1.7 mg/cm^2 thick). Fission fragment angular distributions were measured from 80° to 170° in laboratory using four ΔE-E telescopes consisting of Si surface barrier detectors (thicknesses ΔE 10-22 μm, E 300 μm). Other experimental details are similar as in Ref. [4]. In case of ^{192}Pt target, contributions coming from other isotopes are corrected. Contribution of ^{194}Pt and ^{196}Pt isotopes are estimated using the measured data for those isotopes. Contribution of ^{195}Pt isotope is estimated by interpolating the data for ^{194,196}Pt isotopes. Fission fragment angular anisotropies for ^{12}C+^{192,194,196,198}Pt are compared in Fig. 1.

Results and discussion

Fission fragment angular anisotropy values are calculated according to SSPM using the (E^*, J) distributions of the fissioning nuclei for each chance. The exact expression for angular distribution has been used to calculate fission fragment anisotropy values as discussed in Ref [5]. The (E^*, J) distributions of the fissioning nuclei are obtained using PACE [6] after reproducing fission probabilities ($\sigma_{fis}/\sigma_{fus}$) and prefission neutron multiplicities. Measured fusion cross sections (σ_{fus}) for all the systems are not available and are obtained using the coupled channels code CCFULL after fitting the fusion excitation functions for ^{12}C+^{194,198}Pt systems [7]. Anisotropy values calculated using values of $\Im_{eff}$ from RFRM [8]

---

*Electronic address: `kmahata@barc.gov.in`

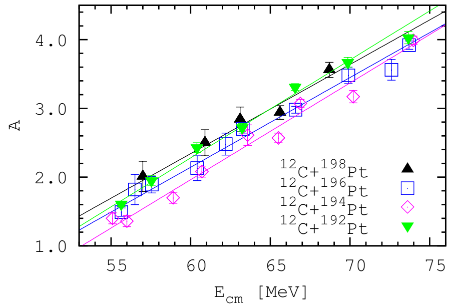

FIG. 1: The fission fragment angular anisotropy (A) values plotted as a function of excitation energy for ^{12}C+^{192,194,196}Pt systems. The lines are to guide the eye.

are found to differ from data. Good agreement could be obtained by normalising the RFRM $\Im_{eff}$ values with energy independent factor.

Fig. 2 (a) and (b) show the weighted average ground state shell corrections (Δ_n^{WA}) and weighted average ground state quadrupole deformation (β_2^{WA}), respectively. Weighted averaging has been done over the distribution of fissioning nuclei at $E_{cm} = 65$ MeV. The values of β_2 have been taken from Ref. [9]. Fig. 2 (c) shows the multiplicative factors (k_I) to RFRM $\Im_{eff}$ values required to fit the experimental anisotropy data. Experimental anisotropy data for ^{12}C+^{194,198}Pt [3] and ^{13}C+^{198}Pt [4] are also included in the analysis. Value of k_I larger (smaller) than unity implies more (less) compact saddle shape as compared to RFRM prediction. While the value of $-\Delta_n^{WA}$ increases monotonously as mass number increases, a correlation between β_2^{WA} and k_I has been observed. As β_2^{WA} goes from +ve (prolate) to −ve (oblate), k_I goes from larger than unity to smaller than unity (more compact to less compact saddle shape as compared to RFRM prediction).

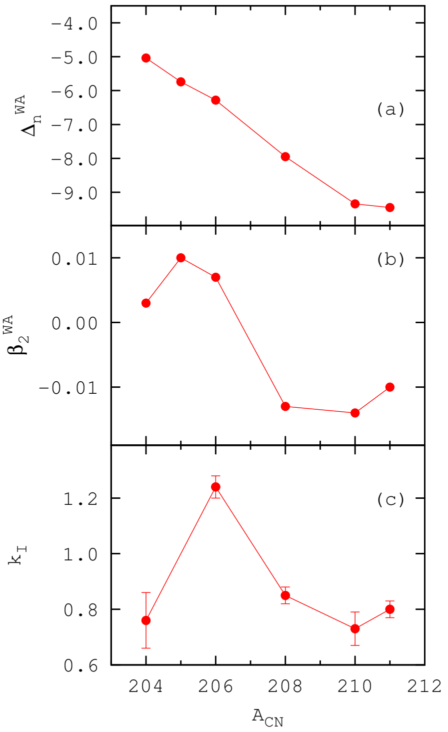

FIG. 2: Weighted average value of ground state (a) shell corrections and (b) quadrupole deformation of the fissioning nuclei. (c) Multiplicative factor to RFRM $\Im_{eff}$ values required to fit the experimental anisotropy data.

References

[1] R. Vandenbosch and J.R. Huizenga, *Nuclear Fission* (Academic press, New York, 1973).

[2] P. Möller and A. J. Sierk, Nature **422**, 485 (2003)

[3] A. Shrivastava *et al.*, Phys. Rev. Lett. **82**, 699 (1999).

[4] K. Mahata *et al.*, Proc. of DAE Symp. on Nucl. Phys. **55**, 260 (2010).

[5] K. Mahata *et al.*, Nucl. Phys. **A720**, 209 (2003)

[6] K. Mahata *et al.*, Phys. Rev. **C 74**, 041301(R) (2006).

[7] A. Shrivastava *et al.*, Phys. Rev. **C 63**, 054602 (2001)

[8] A. J. Sierk, Phys. Rev. **C 33**, 2039 (1986).

[9] P. Möller *et al.*, At. Data Nucl. Data Tables 59, 185 (1995)