Driving potentials for ^{210}Po

A.Sen[1,2*] and T.K. Ghosh[1,2†]
[1]*Physics Group, Variable Energy Cyclotron Centre,*
1/AF Bidhan Nagar, Kolkata 700064, INDIA and
[2]*Homi Bhabha National Institute, Anushakti Nagar, Mumbai 400094, INDIA*

Introduction

Quantum mechanics plays a very important role in understanding the properties of nuclei. From the observation of asymmetric fission fragment mass distribution of actinides to the binding energy of elements, it was apparent that there exists nuclear "shells" which deeply influences the nuclear properties akin to the role electronic levels play in the chemical properties of elements. While electronic levels could be described well theoretically as coulomb interaction is very well understood, the evolution of nuclear shells is still under intense scrutiny. Thus there was the need of shell "models" to mimic the properties of the nucleus influenced by the shell structure in the nucleus. The earliest corrections arising out of such "shell models" were the asymmetry and pairing energy corrections to the liquid drop binding energy systematic.
One of the more famous prescriptions for the implementation of the shell effects is the Strutinsky model [1]. This model has been successfully used to predict the shell corrections in nuclei across the periodic table, and has been widely used for explaining the binding energy variations and the deformations across elements. The prescriptions entails a correction to the uniform distribution from liquid drop potential in the form: $E_{nucl}=E_{LDM} + \delta E$. This correction δE incorporates the difference between an uniform distribution of energy levels and a discretised energy level distribution influenced by quantum mechanics. Such a prescription has been successfully used to describe the deformation in nuclei.

Nuclear fission is a process which has been known to be strongly influenced by this shell structure of the nucleus. An early understanding that the shell closures of the fission fragments influences the fusion fission dynamics was called in question with the discovery of the asymmetric fission of ^{180}Hg [2]. Post this discovery it became a challenge to explain the data with renewed theoretical models. Good quality experimental data were required from across the periodic table to bench mark the predictions of different models. Understanding the influence of shell structure becomes of paramount interest in the present context as the existence of super heavy elements (SHE) depends directly upon it. Thus deciphering the role of the quantal shell effects in the fusion fission dynamics is important for the most optimized choice of target projectile combination for discovery of the Z=119-120 elements. In this paper, the driving potentials have been calculated and applied to experimental data taken at VECC K-130 cyclotron. [3]

Result and discussion

The calculation has been done with respect to the experimental data for ^{210}Po, taken at the VECC K-130 cyclotron where an alpha beam was bombarded on a thin target of ^{206}Pb to populate the nucleus of ^{210}Po over a range of excitation energies from 30MeV and higher. The details of the experiment and its results can be found in [3]. In the aforementioned study it was found that shell effects were found to influence the fission fragment mass distribution at excitation energies at around 30 MeV. The fission fragment mass distribution was found to deviate from being described as a single Gaussian distribution and could rather be described better as a triple Gaussian distribution. Two side peaks with the heavier one centered at around mass $\approx$ 132 u and lighter one at the complementary mass. Peter Moller, *et al*. [4] had already predicted using their 5 dimensional microscopic macroscopic model the presence of such "winged" asymmetric fission fragment mass distribution for ^{210}Po at excitation energies around 30 MeV. Hence the influence of the shell effect could be inferred in the fusion fission dynamics. In the experimental study, the mass distributions were measured over a wide range of excitation energies up to around 48 MeV. The mass distribution at higher excitation energy of around 36

*Electronic address: a.sen@vecc.gov.in
†Electronic address: tilak@vecc.gov.in

Available online at www.sympnp.org/proceedings

MeV was found to be symmetric and well described by a single Gaussian distribution. An earlier study by A. Chaudhuri, *et al.* [5] had established the existence of the shell effects on the fusion fission dynamics at excitation energies of around 40 MeV. However in the present study it was found to have weakened to the point of disappearance in the fusion fission mass distribution probe at the studied excitation energy of around 36 MeV. In order to investigate this phenomena the present calculation has been carried out.

The variation of the strength of the quantal shell effects with the nuclear temperature plays a very important role in the synthesis of super heavy element, specially the currently favoured technique of hot fusion reaction. Since, the shell effects play stabilizing role in the dynamics governing the fusion fission process, populating the compound nucleus at temperatures below the point at which the shell effects are damped out in that nucleus would lead to a better chance of its survival as an evaporation residue. Thus the driving potentials were investigated to look for the degree of weakening of the asymmetric pocket in the potential energy surface governing the fusion fission dynamics. The potential energy for the liquid drop model (LDM) was calculated using the codes of the JINR NRV project [6]. The shell model potentials were estimated on the basis of the adiabatic two center shell model (TCSM) [6]. The temperature dependent potential were calculated, by employing the Strutinsky prescription as described above with a temperature dependence in the functional form of exp($-\gamma$U), where U= E^* - B_f. E^* is the excitation energy, B_f the fission barrier height, and γ the shell damping factor. The resultant driving potentials at the touching configuration has been shown in Fig. 1. The driving potentials may be qualitatively used to explain the experimental observation. The x- axis represents the mass asymmetry of the fragments (α), thus 0 being the symmetric fragments. Thus we see that there lies a pocket at $\alpha \approx 0.24$ which corresponds to mass 130 u.In the experimental data, the location of the heavier mass asymmetric peak was around this predicted region. It was also observed that at the higher excitation energy of around 36 MeV, the pocket in the driving potential almost reduces significantly, thus implying that the contribution of the asymmetric fission weakens. This had also been observed within experimental limits. Since, TCSM had been employed for calculation of this potential, an influence of the closed shell fission fragment of ^{132}Sn may be inferred as influencing the fusion fission dynamics.

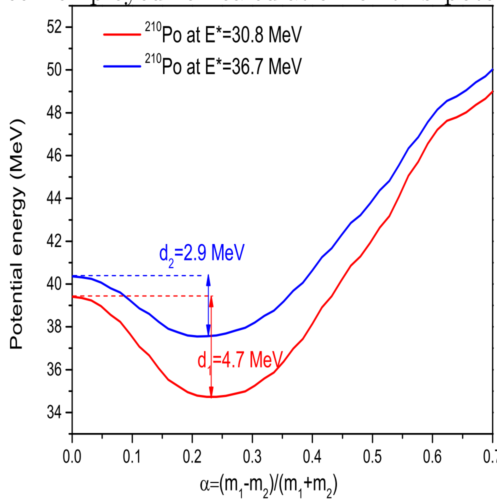

FIG. 1: The driving potentials of ^{210}Po at E^* = 30.8 , 36.7 MeV

While this methodology explains the fission fragment mass distribution qualitatively for ^{210}Po, by employing a very simplistic calculation, it needs to be benchmarked with more experimental data to test its robustness.

References

[1] V.M. Strutinsky, Nucl. Phys. A **95**, 420 (1967).

[2] A. N. Andreev,*et. al.*, Phys. Rev. Lett. **105**, 252502 (2010).

[3] A. Sen,*et.al.*, Phys. Rev. C. **96**, 064609 (2016).

[4] P. Moller,*et. al.*, Phys. Rev. C. **91**, 044316 (2015).

[5] A. Chaudhuri,*et. al.*, Phys. Rev. C. **91**, 044620 (2015).

[6] V.I.Zagrebaev, *et. al.*, http: // nrv.jinr.ru /nrv /