Fission time anomaly for highly excited transuranium nuclei

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Introduction

A highly excited (E_X>50 MeV) uranium-like or transuranium complex or nucleus formed by a nuclear reaction might undergo fast quasifission (zero fission barrier) or decay with a broad distribution of fission times. Usually there could be probabilities for both the quasifission and fusion-fission processes. Fission/quasifission times of highly excited (Ex> 50 MeV) uranium-like and transuranium nuclei/complex have been measured by nuclear techniques (prefission neutron clock, rotation time of nuclear complex and GDR clock) and atomic techniques (x-ray clock and crystal blocking). Let us define the meaning of fission time measured by different techniques. Let $f(\tau)$ denote the normalized fission time (τ) distribution and O(τ) a physical quantity that depends on τ. Then the mean value $\langle O\rangle$ is defined as: $\langle O\rangle = \int_0^\infty O(\tau)f(\tau)d\tau$. This measured physical quantity($\langle O\rangle$)is then related to the corresponding fission time using well-known Physics without requiring any model of fission dynamics. So the deduced fission time is a weighted average. However for different experimental techniques, the corresponding weighting factors would be different in different time domains and so the weighted averages would be different. Hence the measured fission times by different techniques would be different and the comparison among them has to be done carefully. It was found from the measurement of fission time by the atomic techniques that in general, a large fraction (>50%) of highly excited fissioning nuclei decayed with long fission times ($>10^{-18}$ sec) giving weighted average from the atomic technique > 10^{-18} sec, whereas the corresponding weighted average from the nuclear techniques (fission angular distribution and prefission neutron multiplicity techniques) were in the range of 10^{-21} sec to 10^{-20} sec. Nuclear clocks are more precise than atomic clocks, but they have a much shorter range. In this talk, we shall discuss whether these weighted averages i.e. measured fission times by different techniques are consistent. The presence of a large percentage (>50%) of long fission time component implies that the nuclear clocks should measure fission time near the upper end of their range, whereas the relevant nuclear experiments find fission times near the lower end of their ranges. We shall specifically discuss the cases of Z=120 superheavy nucleus and many other uranium and transuranium nuclei and complexes. In this context, we shall discuss a recent fission time measurement of highly excited ^{242}Pu produced by ^{4}He+^{238}U reaction at $E_{lab}(^4He)$=60 MeV at VECC, Kolkata, showing narrow K-x-ray peaks and presence of long fission time component for a large percentage of fissioning plutonium nuclei.

Analysis of fission lifetimes

The fission time of highly excited (T≈1.5 MeV) Z=120 nucleus formed by ^{64}Ni+^{238}U reaction were studied by nuclear [1,2] and atomic techniques [3,4]. We shall show that the observed large [4] (>50%) percentage of long fission time component obtained by x-ray technique could not be reconciled with the very short fission time obtained by nuclear techniques using the argument of sensitivity of different techniques in different time domains, because the long fission time component alone would account for all the observed prefission neutron multiplicity leaving no room for the contribution from the fast fission component. Hence, the claim [3,4] of observation of superheavy Z=120 nucleus with a high fission barrier on the basis of measured long fission time by the atomic techniques is in direct conflict with all other available nuclear experimental and theoretical results. Andersen et al. [5] found that all (100%) of the transuranium fissioning complexes formed by ^{58}Ni+W and ^{48}Ti+W reactions had fission times of the order of 10^{-18} sec, whereas R. du Rietz et al.'s observations [6] from the angular distribution of fission fragments for very similar systems contradict Andersen et al.'s observations.

Fission time of excited plutonium

A fission fragment-K-x-ray coincidence experiment was performed at Variable Energy Cyclotron Centre, Kolkata using a 60 MeV ^{4}He beam (beam current = 5 pnA). The target was a 1mg/cm^2 thick electro-deposited natural uranium film on a micron thick aluminum foil. A four-segmented LEPS detector was placed at 90° with respect to the beam axis covering a solid angle of 10 msr to measure x-rays and γ-rays. A large area solar cell detector was placed at 120° with respect to the beam axis covering a solid angle of about 1 sr to detect fission fragments. A random coincidence and background subtracted fission fragment-x-ray coincidence spectrum is shown in Fig. 1. In this figure, we see very broad double-humped gamma rays lines from the fission fragments because of Doppler shift. We see narrow (FWHM = 1.4 keV) plutonium $K_{\alpha 1}$ line. Plutonium $K_{\alpha 2}$ line has merged with uranium $K_{\alpha 1}$ line. We estimate from the yield of plutonium $K_{\alpha 1}$ line and the width of the peak that the average fission delay for all the detected fission events must be greater than 1.65×10^{-18} sec with 95% confidence level. The result indicates that the vast majority of the fissioning events must have very long fission time (~10^{-18} sec).

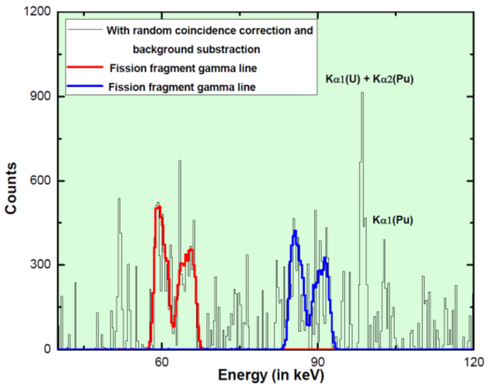

Fig. 1 Coincident x-ray spectrum

This result is in agreement with the observed [7] large percentages of long fission time component in the fission of similarly excited uranium nuclei. However, they are inconsistent with the observation of very short fission time obtained by nuclear techniques at the lower end (~1×10^{-20}sec) of nuclear clock's range for similar (^{243}Am, ^{239}Np) fissioning nuclei [8] at similar excitation energy (T ~1-1.5 MeV).

Conclusion

The fission time measurements obtained by atomic techniques, in general, show the presence of a large percentage (>50%) of long-lived fission time component, whereas the nuclear techniques generally give results for similar fissioning systems at the lower end of nuclear clock's range, indicating that the vast majority of the fission events have very short fission time (~10^{-20} sec). So the fission time obtained from nuclear and atomic techniques are incompatible, in general and cannot be understood by the argument that atomic and nuclear techniques have different weighting factors in different time domains. Efforts are being made to understand the long fission time component by dynamical fission models [5] or introducing the idea of formation of superheavy nuclei [3] with high fission barrier. However these explanations do not address the question of incompatibility between the atomic and nuclear measurements and this incompatibility might indicate new physics beyond the scope of fission physics.

References

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