# Determination of nuclear life time from time stamped decay data

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## INTRODUCTION

The time stamped data recorded, with a fast digital data acquisition system, during the decay of an excited nucleus, produced in an in beam experiment can be used to evaluate the nuclear life time of some of the states in the daughter nucleus. The methods basically depends on the relation between the number of nuclei decays out in time t from an excited state to the lower lying states with average life time $\tau$. The relation between them is given by $N_d(t) = N_0 (1 - e^{-t/\tau})$ where $N_0$ is the number of parent nucleus present at time t=0 and $N_d(t)$ is the integral number of daughter nucleus produced in time t. For a time large enough compared to the mean life time of the state, the number of daughter nuclei produced will reached a saturation value from which we can determine the value of $N_0$. Having information about $N_d(t)$ from the time evolution of the decay data, life time of the excited state can be find out from the inverse slope of $\ln[N_0/\{N_0 - N_d(t)\}]$ vs. t graph.

The digital data acquisition system helps us to store the events with a time stamp by which we can extract the time evolution of the decay spectra.

The motivation of the current investigation is apply this method to measure the previously known half-life of excited state of $^{142}$Sm nucleus populated via the fusion evaporation reaction $^{116}$Cd ($^{31}$p, p4n).

## EXPERIMENTAL DETAILS

The high spin states of $^{142}$Sm were populated by the reaction $^{116}$Cd ($^{31}$P, p4n) at beam energy of 148 MeV provided by the Pelletron Linac at TIFR, Mumbai. The target used in the experiment was 2.4 mg/cm$^2$ $^{116}$Cd on 14.5 mg/cm$^2$ Pb backing. Indian National Gamma Array (INGA) consisting of nineteen Compton suppressed Clover detectors were used to detect de-exciting gamma rays. The decay data was recorded in a fast digital data acquisition system based on Pixie-16 modules of XIA LLC [1]. The data sorting routine MARCOS, developed at TIFR, sorts the time stamped data with different time windows generate the time evolved decay spectra.

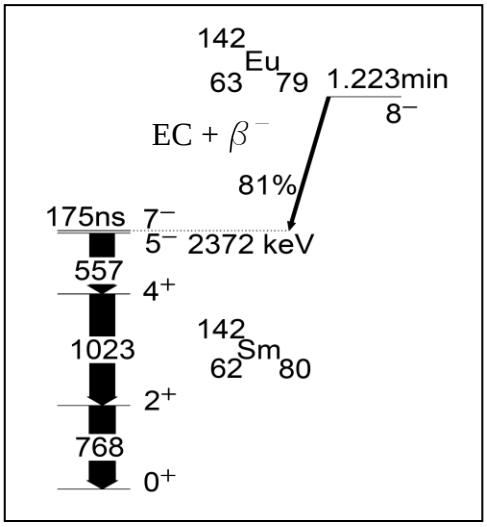


Fig.1. Population of 175ns 7$^-$ isomeric state of $^{142}$Sm from the EC and $\beta^-$ decay of 1.223 min 8$^-$ isomeric state of $^{142}$Eu.

## DATA ANALYSIS AND RESULTS

The 8$^-$ isomeric state of $^{142}$Eu, which has a half-life of 1.223 min, decays to the 175 ns isomeric

state at 2372 keV of $^{142}$Sm nucleus (Fig.1) through the EC and $\beta^-$ decay. This state decays to its ground state via 557, 1023 and 768 keV transitions.

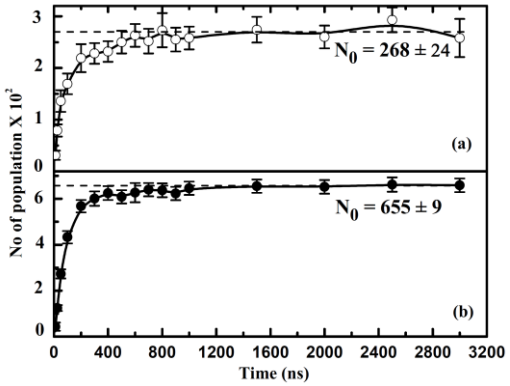


Fig.2. Population of daughter nuclei observed at different time (a) from 768 keV transition, (b) from 1023 keV transition.

To evaluate $N_0$, we determine the area of the respective gamma transitions in the decay spectrum with different time window ranging from 10 to 3000 ns and find out the number of de-exciting nuclei during this time range. The variation of these numbers with time is shown in

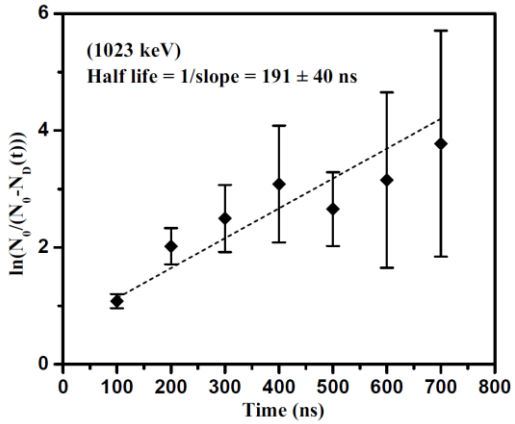


Fig.3. Time variation of $\ln[N_0/\{N_0 - N_d(t)\}]$ as observed from the 1023 keV transition.

Fig.2. For the time range large compared to the life time of the state involved, the saturated portion of the curves are fitted with a straight line in order to determine the value of $N_0$ in the case of two decay out transitions from the isomeric level at 2372 keV viz. 768 and 1023 keV transition. We are not able to determine the population of daughter nucleus via 557 keV transition due to the presence of strong 553 keV contaminated gamma lines in the decay spectrum.

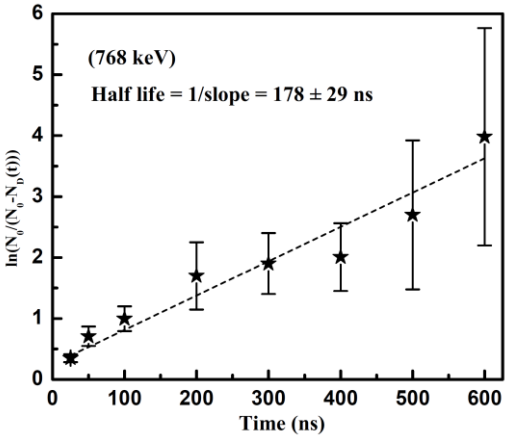


Fig.4. Time variation of $\ln[N_0/\{N_0 - N_d(t)\}]$ as observed from the 768 keV transition.

The life time of the $7^-$ isomeric state at 2372 keV in $^{142}$Sm were obtained from the inverse slope of $\ln[N_0/\{N_0 - N_d(t)\}]$ vs. t graph (Fig.3 & 4). The evaluated values are 191± 40 ns and 178± 29 ns respectively. These values are closed to the previously measured value of 175 ns. We have also tried to determine the life time of a 590 ns isomeric state ($11^-$) in $^{141}$Pm nucleus but the experimental data does not shows any saturation due to the fact that measurement could not possible for a time range long enough compared to the life time of the observed state.

## ACKNOWLEDGMENTS

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## REFERENCES

[1] R. Palit et al. Nucl. Instrum. Methods A 680, 90 (2012).