# Evaporation residue spin distribution study for fusion fission reaction in the region A∼200.

G. Mohanto*
*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA*

## Introduction

Synthesis of heavy element has become one of the area of major interest in heavy ion nuclear reaction. The formation cross sections of heavy element is very less and hence it is very important to select the proper reaction. This necessitates more detail study of fusion fission dynamics. Depending on different parameters, fusion may lead to different dynamical path and angular momentum plays a very important role in determining the path. We intended to study the effect of angular momentum on fusion fission dynamics.

In this thesis, fusion fission dynamics was studied using the Evaporation Residue (ER) spin distribution as a probe. ERs are sure signature of compound nucleus (CN) formation. Spin distribution gives us information about the partial waves which survived fission. In this study, we have tried to find the effect of entrance channel mass asymmetry and effect of CN shell closure (Z=82) on ER spin distribution. The mass region 200 was chosen because ER formation and fission both are significant in this mass region. Also, naturally occurring highest shell closure Z=82 and N=126 are present in this mass region.
We have measured ER spin distributions at different energies for two systems $^{30}$Si + $^{170}$Er and $^{31}$P + $^{170}$Er. ER cross sections were measured for $^{31}$P + $^{170}$Er. To study the entrance channel effect, we compared $^{30}$Si + $^{170}$Er with two other earlier reported reactions, $^{16}$O + $^{184}$W and $^{19}$F + $^{181}$Ta [1], forming the same CN $^{200}$Pb. For studying effect of CN shell closure, we have compared $^{30}$Si + $^{170}$Er and $^{31}$P + $^{170}$Er, which form compound nuclei $^{200}$Pb and $^{201}$Bi, respectively.

## Experimental detail

The experiments were performed at IUAC, New Delhi using 15UD pelletron + LINAC accelerator. Pulsed beams of $^{30}$Si (130 - 182 MeV) and $^{31}$P (141 - 188 MeV) were taken with a repetition rate of 2 $\mu$s. Enriched ($>$ 97% enrichment) target of $^{170}$Er was prepared at IUAC by vacuum evaporation technique. The thickness of the target was 130 $\mu$g/cm$^2$, sandwiched between two layers of carbon of thickness 45 and 23 $\mu$g/cm$^2$ [2]. ERs were separated from intense beam background with the help of the gas-filled mass separator HYRA and detected at the focal plane (FP) of HYRA. The detection system at FP was consisted of a large area MWPC, followed by a double sided silicon strip detector, having 16 strips each side. $\gamma$-rays were detected using the TIFR $4\pi$ spin spectrometer, which is a 32 element NaI(Tl) array with 12 pentagonal and 20 Hexagonal detectors. Out of 32, 28(or 29) detectors were used during the experiment which subtends a solid angle of 91% of $4\pi$. The target was placed at the geometrical centre of the spin spectrometer. The flight time of ERs from taget position to FP was $\sim$ 1.5 $\mu$s and hence, pulsed beam of 2 $\mu$s repetition rate was used. A time to amplitude converter (TAC) signal was generated between the MWPC anode and the RF from the beam pulsing system. This TAC signal, along with the energy loss in MWPC, separated ERs from other particles at FP.

## Result and data analysis

The experimental $\gamma$-folds were converted to $\gamma$-multiplicity distributions by using the prescription, given by Van der Werf [3]. If M uncorrelated $\gamma$-rays are emitted and detected with the help of an array of N detectors then,

*Electronic address: gayatrimohanto@gmail.com

the probability of firing p detectors is given by the response function $P^M_{Np}(\Omega_1, \Omega_2....\Omega_N)$, where $\Omega_i$ is efficiency of $i^{th}$ detector. If emitted $\gamma$-rays have a distribution of $P(M)$ then the $\gamma$-fold distribution becomes

$$P(p) = \sum_{M=0}^{\infty} P^M_{Np}(\Omega_1, \Omega_2....\Omega_N)P(M) \quad (1)$$

For the present study, we assumed the P(M) to be a modified Fermi function of the form

$$P(M) = \frac{2M+1}{1+\exp\frac{M-M_0}{\Delta M}} \quad (2)$$

where, $M_0$ and $\Delta M$ are adjustable parameters. These parameters were obtained by fitting the experimental $\gamma$-fold distributions and then the corresponding $\gamma$-multiplicity distributions and spin distributions were obtained. The moments of the distributions were calculated from the standard formula. The ER cross section for $^{31}$P + $^{170}$Er was extracted from the experimental data. CCFULL calculations were performed for both the systems to obtain the partial fusion cross sections. The parameters were adjusted to reproduce the fusion cross sections for $^{30}$Si + $^{170}$Er, which were reported by Hinde *et al.* [4]. Statistical model calculation was performed to calculate the ER cross sections and ER spin distributions. The experimental results were compared with these calculated results. To study the entrance channel effect, we compared experimental results for three systems $^{16}$O + $^{184}$W, $^{19}$F + $^{181}$Ta and $^{30}$Si + $^{170}$Er, forming CN $^{200}$Pb. When the ratio of ER to fusion cross sections ($\sigma_{ER}/\sigma_{fusion}$) was compared for these three systems, it was seen that the ratio was significantly less in case of $^{30}$Si + $^{170}$Er. Moments of $\gamma$-multiplicity distributions for these three systems were compared and the skewness values for $^{30}$Si + $^{170}$Er were found to be minimum whereas, that of $^{16}$O + $^{184}$W were maximum. The mean of the $\gamma$-multiplicity distributions were also less in case of $^{30}$Si + $^{170}$Er. When compared with the statistical model calculations, the experimental spin were found to be less than the predicted values for $^{30}$Si + $^{170}$Er. Lowering of mean $\gamma$-multiplicity for the more symmetric system was attributed to the presence of non-compound fission in $^{30}$Si + $^{170}$Er [5, 6].

ER cross sections and ER gated $\gamma$-multiplicity distributions for these two reactions $^{30}$Si + $^{170}$Er and $^{31}$P + $^{170}$Er were compared to find the stabilizing effect of $Z = 82$ shell closure of CN. Statistical model calculation was performed to obtain ER cross sections and ER spin distributions. It was found that similar CCFULL and statistical model parameters could reproduce the experimental ER cross sections for both the systems and no significant difference was found in the moments of $\gamma$-multiplicity distributions. For $^{31}$P + $^{170}$Er, experimental spin distributions were found to be less than the predicted spin distribution. This was same as that of $^{30}$Si + $^{170}$Er. When two reactions forming compound nuclei $^{200}$Pb and $^{201}$Bi were compared no significant effect on ER survival was observed [7] due to $Z = 82$ shell closure of CN.

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