# Fusion of $^{7}$Li with $^{124}$Sn at around Coulomb barrier energies

Sushil K. Sharma[1]*, R. Palit[1†], V. V. Parkar[1,2], T. Trivedi[1], J. Sethi[1], S. Saha[1], B.S. Naidu[1], P.K. Rath[3], S. Santra[4], K. Mahata[4] and K. Ramachandran[4]
*[1]DNAP, Tata Institute of Fundamental Research, Mumbai - 400005, INDIA*
*[2]Departamento de Fisica Aplicada, Universidad de Huelva, E-21071 Huelva, SPAIN*
*[3]Department of Physics, M. S. University of Baroda, Vadodara – 390002, INDIA*
*[4]Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai – 400085, INDIA*
** email: pnp.sushil@tifr.res.in, † palit@tifr.res.in*

## Introduction

$^{9}$Be and $^{6,7}$Li are weakly bound nuclei, having break-up threshold energy from 1.48 to 2.45 MeV, predominately breaks up into charged fragments ($^{7}$Li – α + t , $^{6}$Li – α + d and $^{9}$Be – α + $^{5}$He or - 2α + n) in proximity of the target. This allows a noticeable separation for channels of complete fusion (CF) cross-sections from those of incomplete fusion (ICF) cross-sections (A part of projectile is captured by target). In addition, the direct reactions involving transfer of proton or neutron from projectile to target or vice versa can produce different nuclei at excited states. Recently, Li, Be and B induced reaction were used to populate yrast and non-yrast states of stable and neutron rich nuclei near A ≈130 region [1]. The studies of these lighter nuclei have provided many insights into reaction dynamics. The present work is a part of our systematic study of production of variety of nuclei in mass 130 region with weakly bound nuclei through fusion, incomplete fusion and transfer reactions. The main motivation of the present work is to report the measured fusion cross-sections for $^{7}$Li+$^{124}$Sn system.

## Experimental details:

The experiment was carried out using $^{7}$Li beam from the 14UD BARC-TIFR Pelletron accelerator, Mumbai. The beams were incident on $^{124}$Sn target of thickness ≈ 2.5mg/cm$^{2}$ at energies ranging from $B_{beam}$ = 17 – 38 MeV. The thickness of the target was measured using the Rutherford backscattering method. The energies were corrected for the loss at half the target thickness and used in the further analysis. Two Compton suppressed clover detectors were used, one at 125$^{0}$, for absolute cross-section measurement of various reaction channels and other at 90$^{0}$, for identification of unshifted gamma lines. Two charged particle detector telescopes and one monitor detector were also placed at 65$^{0}$, 160$^{0}$ and 30$^{0}$, respectively. The particular angle for monitor is chosen in such a way that even at highest bombarding energy, the elastic scattering remains in the Rutherford scattering regime. A high precision integrator was used for recording the integrated beam current at the beam dump after the target. The data have been acquired in the particle-gamma OR condition. The coincidence between 125$^{0}$ clover detector and particle telescopes (TAC1, TAC2) was also recorded in ADC.

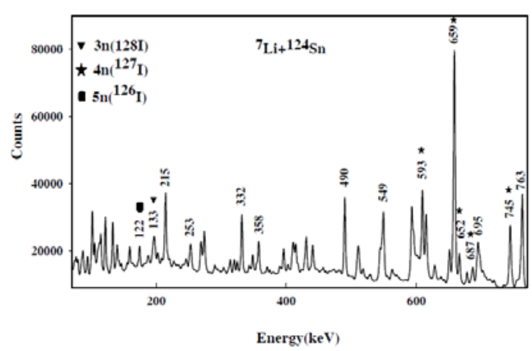


FIG. 1: Gamma ray addback spectrum from the clover at 125$^{0}$ at $E_{lab}$ = 35 MeV.

## Results and Discussion:

Fig. 1 shows the typical gamma ray addback spectrum from the clover at 125$^{0}$ at $E_{lab}$ = 35 MeV for $^{7}$Li+$^{124}$Sn reaction. The gamma lines from the evaporation residues (ERs) have been identified and labeled.

All the corresponding gamma lines cross-sections have been calculated from the relation

$$\sigma_\gamma = \frac{Y_\gamma}{Y_M}\frac{d\Omega_M}{E_\gamma}\sigma_M$$

Where $Y_\gamma$ is the yield of that gamma line, $Y_M$ is the monitor yield, $d\Omega_M$ is the solid angle of the monitor detector, $E_\gamma$ is the absolute efficiency of the gamma lines, and $\sigma_M$ is the Rutherford cross-section at the relative beam energy. The ERs populated in the $^{7}$Li+$^{124}$Sn reaction are odd Z nuclei. Hence to get the total cross-section for the particular ER, we have added all the gamma-ray cross-sections feeding the ground state of that ER. These extracted ER cross-sections have been compared with the calculations from the statistical model code PACE [3]. The details of PACE are as follows.

In PACE, the calculations were carried out by feeding the $\ell$ distribution obtained from the coupled channel code CCFUS [2]. The default potential parameters of PACE have been retained. According to the PACE predictions, the combined contribution of 3n, 4n and 5n channels were found to be $\geq$ 80 -90% in the energy range of our measurement. To take into account the remaining 10-20% contribution from unobserved channels towards CF, the experimental ER data (3n+4n+5n) have been normalized as per the procedure adopted in [4]. In Fig. 2(A), the measured ER cross-sections have been shown along with the PACE predictions. The obtained complete fusion cross-sections are shown as filled circles in Fig. 2(B).

Coupled channels calculations are performed using the code CCFULL [5] to see the effect of couplings on the measured fusion cross-sections. The couplings included are the projectile ground state ($3/2^-$) and the unbound first excited state ($1/2^-$, 0.4776 MeV) with $\beta_{00}$ ($\beta_2$ for the ground state reorientation) = 1.189, $\beta_{01}$ ($\beta_2$ for the transition between the ground and the first excited states ) = $\beta_{11}$ ($\beta_2$ for the reorientation of the 1st excited state ) =1.24 in addition to the vibrational excited state of $^{124}$Sn ($3^-$, $\beta_2$=0.153, $E_x$=2.614 MeV). The 1D BPM (uncoupled) results are shown with dotted line in Fig.2 [B], while the dashed line corresponds to the coupled results. The solid line corresponds to the CC results multiplied by a factor of 0.75. This indicates the suppression of fusion cross section $\approx$ 25% at above barrier energies. However at below barrier energies one cannot have a definite conclusion.

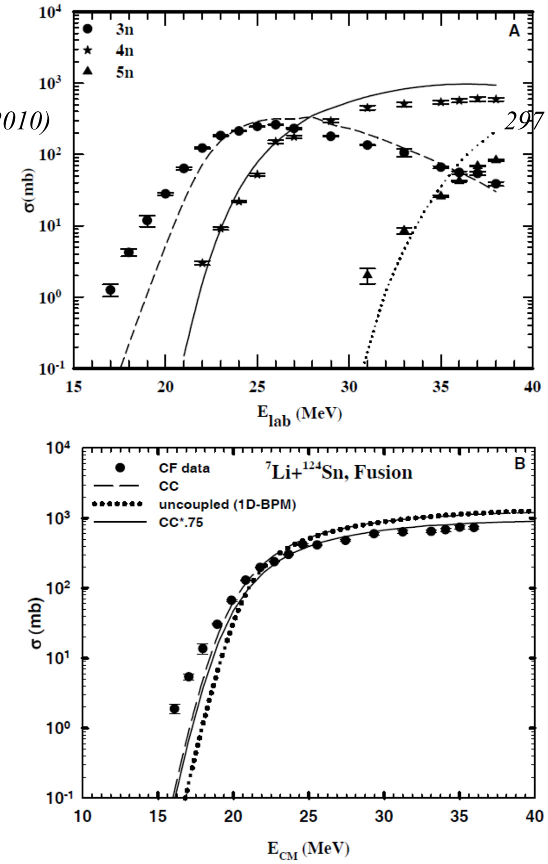


FIG. 2:. (**A**) Measured excitation functions for $^{7}$Li+$^{124}$Sn evaporation channels. The lines are the statistical model predictions. (**B**) The measured complete-fusion cross sections (solid circles) along with the uncoupled (dotted line) and the coupled (dashed line). The solid line shows the later calculations scaled by factor indicated.

**References:**

[1] S.Sihotra *et al.*, Phy. Rev. C 78, 034313 (2008)
[2] C.H. Dasso and S. Landowne, Comp. Phys. Commun. 46, 187 (1987).
[3] A. Gavron, Phys. Rev. C **21**, 230 (1980).
[4] P.K.Rath *et al.*, Phys. Rev. C **79**, 051601(R) (2009).
[5] K. Hagino *et al.*, Comput. Phys. Commun. **123**, 143 (1999).