Determination of pre-scission neutron multiplicities for ^{7}Li + ^{203}Tl system at E* ∼ 43.8 MeV

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Introduction

Pre-scission neutron multiplicity (ν_{pre}), i.e., average number of neutrons emitted before fission is used as a probe to study nuclear dissipation. Earlier it was observed that heavy-ion induced fission excitation functions ($E^{*} > 40$ MeV) are not sensitive to the correlated variation of the fission barrier and the level density parameter at the saddle point. However, the pre-scission neutron multiplicity is sensitive to it. This leads to ambiguities in the interpretation of the fission observable [1]. In case of ^{210}Po, it was also observed that the statistical model, which is constrained using the p and α induced fission excitation functions available at lower energies, under predicts the experimental ν_{pre} values obtained from neutron spectra for ^{12}C induced reaction [2], requiring large dynamical delay at these low energies. The ν_{pre} values from neutron spectra were also found to be larger than those obtained from the fission chance distribution, indicating significant post-saddle contribution [3]. To address these discrepancies, measurement of ν_{pre} of ^{210}Po at lower excitation energy E* = 43.8 MeV have been performed in the present study.

Experimental Details

The reaction ^{7}Li + ^{203}Tl was carried out to populate ^{210}Po at E^{*} = 43.8 MeV. The experiment was carried out at the BARC-TIFR Pelletron-LINAC facility, Mumbai. Bunched ^{7}Li beam of 40 MeV was bombarded on a 0.9 mg/cm^{2} thick ^{203}Tl target with carbon backing. Two silicon strip detectors kept at the distances 8 and 7 cm respectively from the target at backward angles were used to detect fission fragments. Neutrons in coincidence with fission fragments were detected using an array of 15 EJ301 liquid scintillators. The data was collected in list-mode with trigger generated from the fission detectors. The details regarding neutron array and semiconductor detectors are discussed in Ref.[4].

Data Analysis

Walk corrections were applied to the neutron time-of-flight (TOF) spectra to improve the time resolution. The calibration of the TOF spectra were carried out using the γ-peaks corresponding to two consecutive bunches. Good discrimination between neutron and γ-rays could be obtained using the PSD vs TOF spectra. The neutron energy spectra, in coincidence with fission fragments, are obtained from the calibrated TOF spectra. The efficiency correction was applied to the neutron energy spectra. The experimental neutron multiplicity spectra (i.e. number of neutrons per fission per unit solid angle(dΩ) per unit neutron energy (dE$_{\rm n}$ in MeV) are shown in Fig. 1. The pre- and post-scission components of neutron multiplicities and respective temperatures (T$_{\rm pre}$ and T$_{\rm post}$) are obtained by employing a simultaneous moving source least-square fitting procedure to all the measured neutron energy spectra. Considering three moving sources, namely the compound nucleus and two fully accelerated fission fragments, the multiplicity spectra is expressed as

$$\frac{d^2M}{dE_n d\Omega_n} = \sum_{i=1}^{3} \frac{\nu_i\sqrt{E_i}}{2(\pi T_i)^{(}3/2)} \exp[-\frac{E_n - 2\sqrt{E_n E_i/A_i}cos\theta_i + E_i/A_i}{T_i}] \quad (1)$$

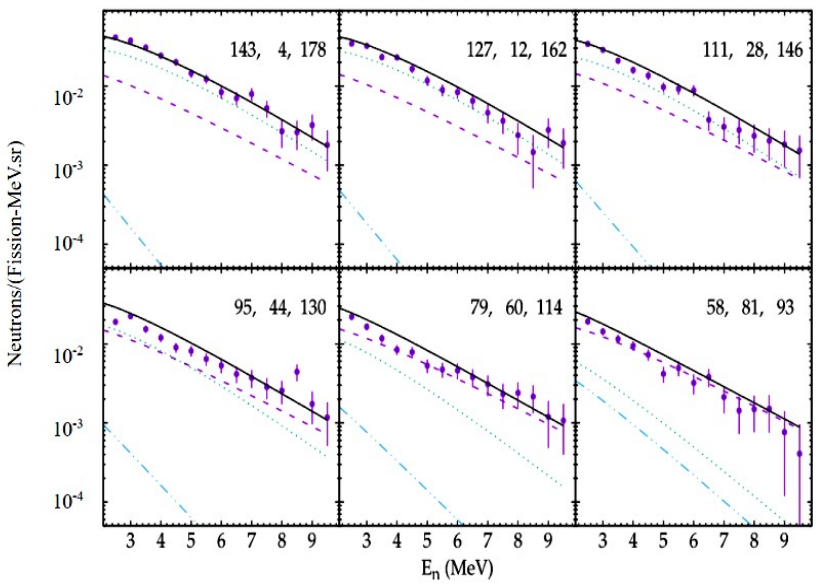

FIG. 1: The measured neutron multiplicity spectra for ^{7}Li+^{203}Tl system at E* = 43.8 MeV are compared with the results of the moving source fit (solid lines). The contributions of the compound nucleus (pre-scission), detected fragment and complementary fragment are shown as dashed, dotted and dot dot dashed lines, respectively. The numbers inside the plots corresponds to absolute values of neutron emission angles with respect to the beam, detected fragment and the complementary fragment velocities.

Results

The pre-scission neutron multiplicity values obtained from moving source fit is 0.93±0.04. The values of ν_{tot} and ν_{pre} obtained from current measurement agree well with the trend obtained from the measurements at higher energies [2]. The ν_{pre} values obtained from the measured neutron spectra are found to be much larger than the statistical model prediction, which reproduces the fission excitation function and the neutron multiplicities extracted from the fission chance distributions [3].

Summary

The pre-scission and post-scission neutron multiplicities are measured for the compound nucleus ^{210}Po at $E^* = 43.8$ MeV. The neutron multiplicities agree well with the data for the same compound nucleus at higher excitation energy. The statistical model predictions are found to be smaller, indicating significant non-statistical contributions. Measured ν_{pre} data at low energy will provide a benchmark for the theoretical calculations and help in more accurate determination of fission properties in this mass region.

Acknowledgments

We thank Pelletron-LINAC staff for smooth operation of the machine during beam time. S.D. would like to thank DST for their funding towards this research work under the scheme DST-INSPIRE fellowship.

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