Study of side-feeding time for light mass nuclei

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Introduction

Precise determination of level lifetime is of utmost importance in nuclear γ-spectroscopy. Doppler Shift Attenuation (DSA) method suitable for measuring sub-pico second lifetimes, involves inclusion of proper correction for side-feeding which is synonymous to *unknownfeeding* of the level under consideration [1]. It is possible to avoid a side-feeding contribution by gating on Doppler shifted gamma lines above (GTA) the level being studied in the cascade.

In most of the light mass nuclei (A≤40), low-lying excitation spectra exhibit characteristics of shell model states and long-lived levels ($\tau \geq 10$ ps) are frequently found in the excitation spectra. Side-feeding therefore has often to be considered because the line shapes of the gamma transitions in these cases are usually analysed by gating on lower transitions of a cascade (GTB). Moreover, it is well known that, for a given feeding pattern and in the case of strong side-feeding intensity, the lineshape of the decay gamma-ray is mainly sensitive to the sum of level lifetime (τ) and side-feeding time (τ_{sf}), but less to their individual values [1]. This feature poses ambiguity in determining level lifetimes.

Several attempts [1, 2] to calculate the side-feeding time distribution on the basis of the statistical theory or empirical methods have been proposed for collective states in relatively heavier nuclei. Empirical approaches work satisfactorily only if τ_{sf} is significantly shorter than both the level lifetime and the recoil stopping time. Study of τ_{sf} for non-collective excitation spectra therefore needs urgent attention. In the present work, an empirical approach has been adopted to find the dependence of side-feeding times in nuclei in A≃ 40 region as function of level energies.

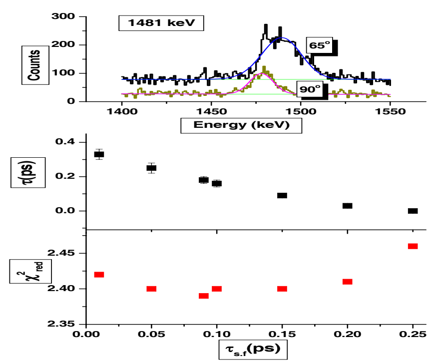

FIG. 1: The τ - τ_{SF} correlation plot with best fitted lineshape for 1481 keV gamma.

Experimental details

The high spin states of ^{31}P, ^{34}S, ^{34}Cl, ^{37}Ar were populated by bombarding 40 MeV ^{12}C beam on ^{27}Al target at 14UD Pelletron accelerator at TIFR, Mumbai. The target consisted of 0.5 mg/cm^2, ^{27}Al with ≃ 10 mg/cm^2 gold backing to stop the recoils.γ-γ coincidence measurement was done with the help of a multiclover array (INGA array), which comprised of 15 Compton suppressed Clover detectors [3]. The detectors were placed at 157°(3), 140°(2), 115°(2), 90°(4), 65°(2),

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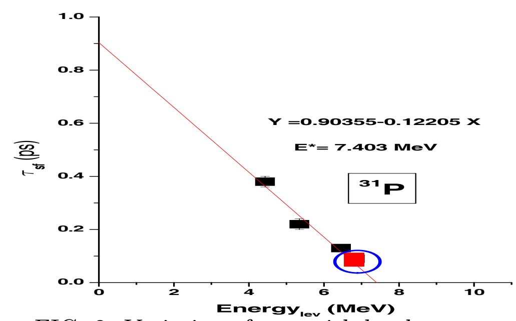

FIG. 2: Variation of τ_{SF} with level energy.

40°(2). Lineshape analysis of the Doppler shifted spectra was done using the code LINESHAPE [4]. The line shapes were projected for different angles, with gates below the transitions of interest (GTB).

Results and Discussion

The necessity for having an empirical relation for side-feeding time even for levels at high excitation energies is shown in Fig.1. The τ - τ_{SF} correlations deduced at 90^o and 65^o for the 1481 keV ($11/2^- \rightarrow 9/2^+$) transition in ^{31}P [5] are illustrated in Fig. 1, which also displays the dependence of the reduced χ^2_{red} on τ_{SF} . The analysis of both lineshapes gives consistent results for τ and τ_{SF}, but with rather large uncertainties due to nearly constant values of χ^2_{red} over a substantial range of τ_{SF}.

Lifetimes of several levels in ^{31}P and ^{34}S have been extensively studied [5] recently. In most of the lineshape fitting the level lifetimes were taken from the previous work to determine the side-feeding time. Due to the presence of a few long lived levels in the low energy spectra of both the nuclei, side-feeding times have been extracted from the higher energy states only. Finally the extracted values of τ_{SF} from various transitions in a particular nucleus, have been plotted as function of excitation energies of the levels. The data for each nucleus are fitted with a straight line. The fitting for ^{31}P for three excited levels at 4.431, 5.343 and 6.454 MeV are shown in Fig.2. According to the empirical relation proposed by Lobach *et al.* [2], $\tau_{SF} = k_{SF}(E^* - E_{lev})$, where E^* is the excitation energy of the entry state of recoils and E_{lev} is the energy of the observed level in MeV. k_{SF} gives the variation of side-feeding time per MeV. From the plots, it has been found that the entry level energies are different for ^{31}P and ^{34}S. Statistical model calculation also supports that entry level energy is less in ^{31}P. Using the linear plot in Fig.2, a consistent value of side-feeding time for the 6.824 MeV level has been determined (marked by a circle) to resolve the ambiguity in the result for the 1481 keV transition in ^{31}P.

This approach to determine the empirical relation of side-feeding time with level energy is thus helpful to determine unambiguously level lifetimes for high spin levels of nuclei in A$\simeq$ 40 region. For low lying levels in these nuclei, the effective side-feeding time will be composed of the side-feeding times estimated from these plots arising out of direct feeding to the level and the times involved in all known branches of the cascade feeding from discrete levels.

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