DSAM Analysis with Novel Backing using Modified LINESHAPE Program

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Introduction

Measurement of nuclear level lifetimes is an imperative aspect of nuclear structure research. Different techniques, depending on the magnitude of the lifetimes being addressed are adopted in experiments. The current paper aims in addressing the analysis procedures related to the DSAM technique [1]. The method is based on extracting the level lifetimes from offline analysis of the Doppler broadened lineshapes of the transition (peaks) of interest by appropriately incorporating the stopping process of the recoiling nuclei in the target and the backing, geometry of the γ-ray detectors and feeding of the state of interest by higher lying levels (that impacts the observed lifetime of the state). Uncertainties pertaining to the stopping process and the side feeding of the state of interest by unobserved levels are the principal issues plaguing the determination of lifetimes from DSAM technique. Several standard codes are available for analysis of Doppler broadened lineshapes of which the LINESHAPE [2] package is one that is widely used for the purpose. The package combines several programs of which the DECHIST program simulates the stopping of the recoils in the target and the backing. The present work describes modifications in the dechist program to represent the experimental conditions and thus reducing the uncertainties related to the simulations of the stopping process.

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Programming

The standard version of the dechist program accepts only elemental form of the target and the backing, as inputs. Further, the same target is used for calculating the reaction kinematics as well as the stopping power for the recoils. This is not realistic for experiments carried out with oxide / molecular targets which are sometimes characterized by very different density compared to the element and have different stopping power. In the present context, we refer to the experiments carried out by our group on (i) the spectroscopy of nuclei in the $A \sim 30$ region with ^{18}O target, in the form of Ta_2O_5 of thickness 9.25 mg/cm^2 [3, 4] and (ii) the measurement of lifetimes using thick low density material in the form of aerogel (SiO_2) wherein the incident beam underwent reactions with the Si and O components leading to the population of nuclei in the $A \sim 20$ and $A \sim 40$ regions [5]. Lifetime analysis of the aforesaid data requires that the Ta_2O_5 and SiO_2 targets are appropriately incorporated in the stopping calculations. Firstly, the dechist program has been modified to accept and use different targets for the kinematic calculations and the stopping power calculations. For instance, in case of the Ta_2O_5 data, ^{18}O has been used as the target for the kinematic calculations while Ta_2O_5 has been used for the stopping power determination. However, the elemental representation of the oxide material as the stopping medium, as accepted by the standard dechist program, is still inaccurate. To circumvent this problem, effective Z and effective A of the oxide material, calculated from the prescription in Ref. [6], has been used respectively for the atomic number and the mass number of

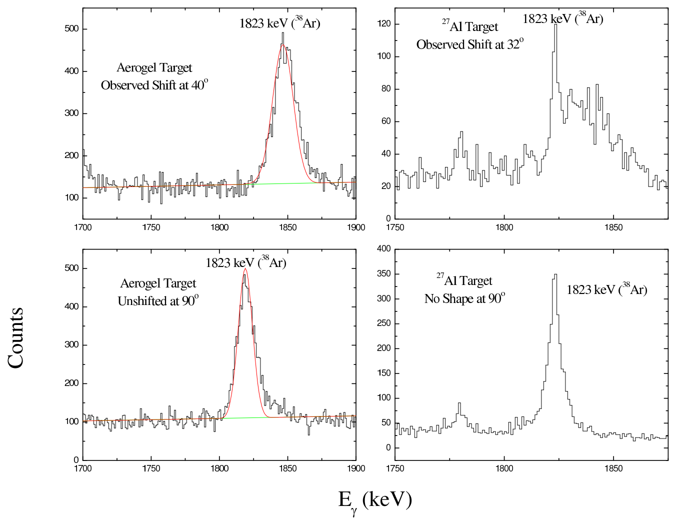

FIG. 1: Complete shift of 1823 keV peak from ^{38}Ar in aerogel medium compared to only the shape observed in Al medium. The comparison illustrates the advantage of using aerogel in magnifying the Doppler effects for transitions representing lifetimes in the range of few ps.

the stopping medium. The resulting stopping powers calculated by dechist agrees with those calculated by the SRIM code by 5-10%, on the average. The standard dechist program simulates the stopping process by generating the recoils uniformly throughout the length of the target. However, in reality the cross section of production of a particular residue varies with the beam energy and should be considered to fit the corresponding lineshape. Modifications of the dechist program have been made to implement the cross section dependence. The same can be applied to fit the lineshapes resulting from the use of a thick target being used for the reaction as well as the stopping medium wherein the reaction of interest has varied cross sections at different depths of the target.

Results

The modified programs have been used to estimate the level lifetimes for nuclei populated in the aforesaid experiments. An example of the resulting fit is illustrated in Fig. 1 for the 1823 keV transition peak of ^{38}Ar from reaction of ^{12}C beam with aerogel. The aerogel has been introduced as a novel stopping medium by our group [5]. Fig. 1 depicts the complete shift observed in the 1823 keV peak, de-exciting the 6.409 MeV (1 ps) level in ^{38}Ar, in the aerogel medium. From the fit of the shifted peak, using the modified programs, a preliminary upper limit of 1.7 ps has been obtained for the 6.409 keV level. Analysis is in progress to validate the modified programs and the results will be presented in the symposium.

References

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