Application of state-of-the-art Monte Carlo simulations in DSAM analysis

S. Das[1], S. Samanta[1], R. Bhattacharjee[1], S.S. Bhattacharjee[1], R. Raut[1],*
S. S. Ghugre[1], A. K. Sinha[2], U. Garg[3], L. Chaturvedi[4], T. Trivedi[4],
S. Mukhopadhyay[5], R. Chakrabarti[5], A. Dhal[6], M. Kumar Raju[6], N. Madhavan[6], R.P. Singh[6], S. Muralithar[6], S. Saha[7], J. Sethi[7], and R. Palit[7]
[1]*UGC-DAE CSR, Kolkata Centre, Kolkata 700098, INDIA*
[2]*UGC-DAE CSR, Indore 452017, INDIA*
[3]*Department of Physics, University of Notre Dame, Indiana 46556, USA*
[4]*Guru Ghasidas University, Bilaspur 495009, INDIA*
[5]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai 400085, INDIA*
[6]*Inter University Accelerator Centre, New Delhi 110067, INDIA and*
[7]*Tata Institute of Fundamental Research, Mumbai 400005, INDIA*

Introduction

The Doppler Shift Attenuation Method (DSAM) is the technique of choice to measure level lifetimes in the range of few tens of fs to few ps. One of the significant component in implementing the method is the simulation of the slowing down process of the residual nuclei, produced in the nuclear reaction, in the target and the backing medium. The stopping powers used for the purpose are identified as one of the principle sources of uncertainty on the extracted lifetime values. The DSAM is typically practiced with a thin-target-on-thick-backing setup wherein the backing is conventionally chosen to be a high-Z elemental (Au, Ta, Pb) one for which the stopping powers are expected to be known with reasonable ($\sim$ 10-15%) accuracy. However, certain spectroscopic endeavours require use of molecular targets that compounds the aforementioned uncertainties stemming from the associated stopping powers. For instance, the structural investigations of the nuclei in the $A \sim 30$ region ($sdfp$), routinely use the ^{18}O target that come in the form of metallic oxides like Ta_2O_5. Further, depending on the method of fabrication, the molecular target can assume a substantial thickness that operate both as the target as well as the backing thus obscuring the stopping simulations. The latter is owing to the decreasing beam energy along the thickness of the target and the consequent evolution in the yield of the residues that has to be incorporated in the simulation exercise. The widely used programs for DSAM analysis, LINESHAPE [1] for instance, calculates the stopping powers from one of the earlier models that may be replaced with updated and experimentally benchmarked theories as available with the contemporary software like SRIM [2]. It is further desired to use the stopping simulations based on these improved stopping models into lifetime analysis. The current work pertains to the application of the stopping simulations carried out using the state-of-the-art SRIM (TRIM) code for determination of level lifetimes.

Programming developments

The TRIM code is conventionally used in the domain of material studies to simulate the transport of ions in a medium. The proposition of using these simulations for lifetime analysis require that the aspects of a nuclear reaction, with their bearing on the observed Doppler shaped / shifted spectra, be embodied, as is befitting for the purpose of DSAM analysis. These incorporations include, (i) energy-angle distribution of the residues following particle evaporation from

*Electronic address: rraut@alpha.iuc.res.in

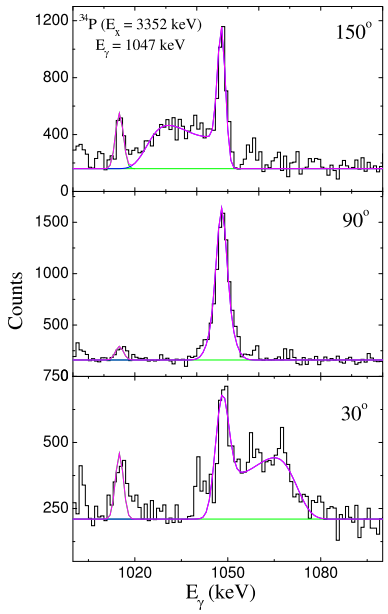

FIG. 1: Lineshape fit of the 1047 keV peak in the ^{34}P nucleus.

the compound nucleus and, (ii) changing yield of the residue with decreasing beam energy along the thickness of the target, that is significant particularly for thick target setups. A set of programs have been developed for the purpose. The energy-angle distribution has been calculated using the PACE4 [3] code and has been used to correct the TRIM simulated trajectories that are characteristically initiated, with a fixed (user defined) energy, aligned to the X-direction. The programming has also included the exercise of distributing the trajectories, that always initiate at the origin of the stopping medium in the TRIM execution, as per the residue yield distribution also calculated using the PACE4 code. Finally, the trajectory information obtained from TRIM, that come as energy and co-ordinate information recorded at certain interval, is converted into time profile of the velocity (β) and direction of the residues, to be used for subsequent analysis. Currently, the simulation output of these programs is compatible with the LINESHAPE package, for the remaining analysis for extraction of the level lifetimes.

Results

The new developments have been applied for lifetime analysis in the *sdpf* nuclei (^{26}Mg, ^{29}Si, ^{33,34}P and ^{33}S) populated in a set of experiments with heavy-ion (^{13}C, ^{16,18}O) beams on ^{18}O target, in the form of Ta_2O_5, at E_{lab} = 30-34 MeV. The detection system has been the Indian National Gamma Array (INGA), stationed at different accelerator centers in the country. The analysis has been carried out both for levels with previously known lifetimes as well as for some of the new states. Fig. 1 represents a typical fit to the observed Doppler shape in the ^{34}P nucleus, obtained following the use of the TRIM simulations, through the new developments, with the LINESHAPE programs. The resulting lifetimes are in satisfactory agreement to the previously reported values and validate the present methodology. The level lifetime provides for a stringent test to the model calculations and the validity of the parameters used therein. Large basis shell model calculations have been carried out as a part of the present endeavours, using the NuShellX [4] code and a comparison has been made for the lifetimes as well as the transition probabilities. A varied degree of agreement has been noted for the range of nuclei studied in the present work and shall be elaborated in the Symposium.

The INGA Project was partially supported by the Department of Science and Technology, Government of India (Grant No. IR/S2/PF-03/2003-III).

References

[1] J. C. Wells and N. R. Johnson, ORNL Report **6689**, 44(1991).
[2] www.srim.org
[3] A. Gavron Phys. Rev. C**21**, 230(1980).
[4] B. A. Brown and W. D. M. Rae, MSU-NSCL Report (2007).