Studies in Nuclear Structure relevant to Astrophysics: experimental efforts

Maitreyee Saha Sarkar*
Nuclear Physics Division, Saha Institute of Nuclear Physics, Kolkata 700064, INDIA

Introduction

Studies of nuclear reactions relevant to astrophysical scenario often require measurement of cross section in pico-barn to nano-barn range. So we need high beam current, extremely pure isotopically enriched targets, which can withstand high beam load over a long time, environment with low gamma and other nuclear radiation background and innovative techniques to suppress unwanted beam - induced events. Even the backing of the target used should contain no or very low concentration of impurities having atomic number Z lower than that of the target.

Presently, the Nuclear Physics group in Saha Institute of Nuclear Physics is working for installation of a high-current, low energy Accelerator as the primary component of the Facility for Research in low Energy Nuclear Astrophysics (FRENA)[1], a national facility, at Kolkata. We hope that installation of the machine will start next year. Parallel to efforts for seeking statutory permissions and procuring essential components for radiation monitoring etc, our group has also started planning and installing related experimental facilties. The target preparation setup is being tested and plans for procuring a new system has started. We have standardized implanted target preparation and characterization methods utilizing different facilities in the institute as well as in other laboratories in the country and abroad. We have prepared problem specific targets for studying reactions for astrophysical interests. A test experiment with one of these targets in another smaller facility has been performed to understand the limitations in these low energy measurements. We are arranging detector combinations and testing techniques to set up low background detection systems using digital data acquisition systems for successful utilization of FRENA facility. We are also working to learn state-of -the-art theoretical techniques for interpreting the experimental data in a better way.

In the presentation I shall briefly highlight different aspects of our experimental endeavors relevant for utilizing the FRENA facility to its best for understanding issues in Nuclear Astrophysics.

Targets

Implantation technique has been found to be one of the most effective methods to produce isotopically pure targets. We have prepared a few isotopically pure targets using this technique [2]. The characterization of these implanted targets need special attention. The techniques utilized will be discussed and limitations in some of them will be presented. Estimation of types of impurities present in these targets is also important which also need special techniques.

Being the slowest process of the CNO cycle, study of the $^{14}N(p, \gamma)^{15}O$ (Q = 7297 keV) capture reaction is of high astrophysical interest [3]. From an experiment utilizing one of the ^{14}N implanted targets, a preliminary estimate of the lifetime of 6792 keV state in ^{15}O has been obtained, using Doppler shift attenuation method (DSAM). The sensitivity of the results with respect to the uncertainties in various input quantities has been tested [4]. The uncertainties have prompted us to plan new studies to understand and reduce them for determination of more accurate lifetimes of similar systems. This endeavor will be helpful to design a better experiment with FRENA.

*Electronic address: maitrayee.sahasarkar@saha.ac.in

Background suppression

In recent years, several facilities have been built all over the world to provide clean environments shielded from both cosmic rays and natural radioactivity. We have been studying the background gamma radiation - their characteristics and possible ways of reducing them since long [5].

Recently, we have rejuvenated a massive NaI(Tl) sum spectrometer [6–8] and utilized it as both passive and active shield to reduce background gamma radiations [9].

However, additional contributions to the background generated from the Compton scattering events and the escape peaks of the gammas of interest also need careful elimination. We have been using various types of gamma and x-ray detectors having single crystal and composite ones [10] to compare their background gamma characteristics originated from Compton effects and some spurious ones [11]. The dependence of these characteristics on the detector type and electronics used will be highlighted.

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