Design and Development of a small setup for measurement of capture cross section relevant for astrophysical scenario

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Introduction

The study of nuclear reactions, particularly those involving light nuclei like proton, neutron and alpha capture, is crucial for understanding astrophysical scenarios such as stellar nucleosynthesis. These reactions help to explain the processes that generate elements in stars and other astrophysical environments. We are motivated by the need to design a compact setup that can precisely measure capture cross-sections relevant to these astrophysical processes. This setup can be used at in-house facility of Saha Institute of Nuclear Physics(FRENA)[1]; and other accelerator facilities in India.

The procedure for measuring capture cross-sections involves studying the gamma-ray emissions following the capture of protons, neutrons, or alpha particles by a target nucleus. When a particle is captured, the nucleus enters an excited state and subsequently de-excites via gamma transitions. By detecting these gamma rays and applying proper efficiency corrections, we can determine the capture cross-sections with high precision.

To conduct such measurements, a low-energy accelerator like FRENA, coupled with our compact setup, is ideal. This setup allows for detailed investigations of nuclear reactions at stellar energies, which are essential for refining our understanding of the p-process, rp-process, and the CNO cycle in stellar environments.

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These types of measurements are not only fundamental to nuclear astrophysics but also critical for constructing and validating astrophysical models, ultimately enhancing our understanding of element abundances in the universe.

Chamber Design and Vacuum System

Custom-designed vacuum-shielded chamber has been developed to accommodate experimental setups for capture cross-section measurements. The chamber is built from stainless steel with provisions for target insertion, beamline connection, and detector placement. The chamber's vacuum capability has been tested to achieve pressures as low as 10^{-5} mbar, ensuring minimal interference from residual gases during beam-target interactions.

The chamber is equipped with various ports and vacuum gauges, allowing for real-time monitoring of vacuum levels. The system includes turbo pumps and backing pumps to achieve and maintain ultra-high vacuum conditions, ensuring optimal experimental conditions during the bombardment of targets by ion beams.Vacuum-Shielded Chamber and the pump are shown in FIG.1.

Detector Setup

We have integrated a data acquisition system with the setup, where multiple gamma detectors can be placed. We are using $6''$ LaBr detectors (inorganic scintillator) which can measure up to 30 MeV gamma ray, with large efficiency. HPGe detectors have been used for better resolution.

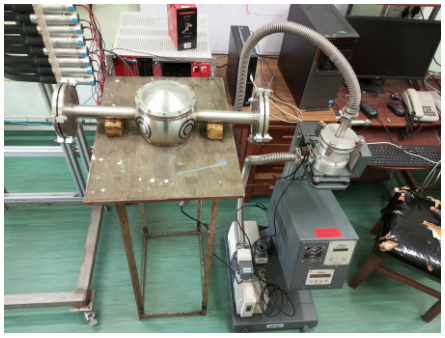

FIG. 1: Vacuum-Shielded Chamber with the pump

FIG. 2: Data Acquisition system

Data Acquisition System

A sophisticated data acquisition system[2] has been used with a CAEN DT5730S digitizer[3], as shown in FIG.2. The system is capable of handling both singles and coincidence data, allowing us to capture a wide range of events. FIG.3 shows data acquisition control interface of CoMPASS,which is a multiparametric DAQ software for physics applications. Analysis using Pulse Shape Discrimination (PSD) technique is also in progress.

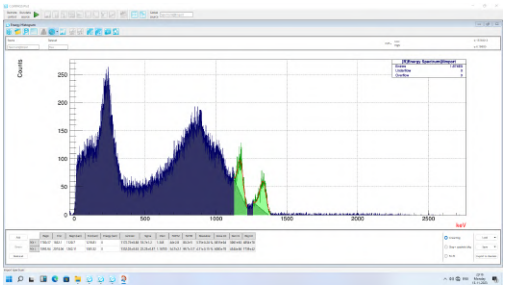

FIG. 3: Data Acquisition Control Interface

References

(1)Facility for Research in Experimental Nuclear Astrophysics (FRENA),`https://www.saha.ac.in/web/frena-about-frena`
(2) CoMPASS Multiparametric DAQ Software for Physics Applications, `https://www.caen.it/products/compass`
(3) CAEN Tools for Discovery, `https://www.caen.it/products/dt5730`