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The high resolution array (HiRA) for rare isotope beam experiments ☆

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Abstract

The High Resolution Array (HiRA) is a large solid-angle array of silicon strip-detectors that has been developed for use in a variety of nuclear structure, nuclear astrophysics and nuclear reaction experiments with short lived beta-unstable beams. It consists of 20 identical telescopes each composed of a thin (65 μm) single-sided silicon strip-detector, a thick (1.5 mm) double-sided silicon strip-detector, and four CsI(Tl) crystals read out by photodiodes. The array can be easily configured to meet the detection requirements of specific experiments. To process the signals from the 1920 strips in the array, an Application Specific Integrated Circuit (ASIC) was developed. The design and performance characteristics of HiRA are described.

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1. Introduction

The development of unstable rare isotope beams at laboratories such as the NSCL [1], RIKEN [2], GANIL [3] and GSI [4] now permits the study of nuclei far from the valley of beta stability. Experiments with rare isotope beams elucidate the structure of both very neutron-rich and neutron-deficient nuclei and clarify which reactions contribute meaningfully to the nucleo-synthetic r-process or rp-processes within hot or explosive astrophysical environments. Experiments in such facilities will provide meaningful constraints on the isospin dependent interactions within neutron-rich nuclei and neutron stars.

Many of these experiments require reactions to be induced by the most neutron-rich or neutron-deficient isotopes available. Even at the most advanced rare isotope facilities, the available beam intensities for these exotic nuclei are low. To investigate reactions with such beams, it is critical to use a detection system that efficiently covers most, if not all of the interesting kinematically allowable space. The location, in the lab frame, where particles are emitted depends strongly on the reaction mechanism. A variety of silicon strip arrays have been developed to address such needs [5–8]. At low incident energies, where particles may stop in a relatively thin silicon strip-detector, devices such as TIARA [5], which consists of a single layer

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of silicon have been used for such purposes. With the fast beams produced by projectile fragmentation, however, devices such as LASSA [6], MUST [7] and MUST2 [8] with several layers of detection media have been developed to stop and identify the produced particles. The High Resolution Array (HiRA) belongs to the latter class of strip-detector arrays. It is a highly configurable, highly granular, large solid-angle charged-particle detector with wide dynamic range appropriate for the detection of penetrating reaction products produced at a fast beam facility such as the NSCL [1].

2. Design and performance of the array and its components

HiRA is a modular and expandable array, which currently consists of 20 identical telescopes. Each telescope with an active area of $6.25\,\mathrm{cm} \times 6.25\,\mathrm{cm}$, consists of a 65-μm single-sided silicon strip-detector with 32 strips, a 1.5 mm double-sided (32×32) strip-detector, and four 4 cm long CsI(Tl) crystals. It shares many common features with its predecessor, the Large Area Silicon Strip Array (LASSA) [6], and with other devices such as MUST [7] and MUST2 [8]. Fig. 1 shows a photograph of 16 HiRA telescopes as they were configured in an experiment designed to measure the proton decays of ^{69}Br fragments produced in the H(^{70}Br,d)^{69}Br reactions at $E/A = 65\,\mathrm{MeV}$. This arrangement covers laboratory angles out to approximately 30° with a detection efficiency of 60–70%. Three other angular arrangements have been employed in the first series of experiments; each arrangement was designed to optimize coverage for the decay channels studied in the corresponding experiment.

2.1. Mechanical design of a telescope

In each telescope, all detector elements are encapsulated in an aluminum case, which also serves as a Faraday cage. Fig. 2 depicts the mounting structure of a single HiRA telescope with the aluminum side panels removed from the top and front sides, revealing a color-coded drawing of the internal structure of the array. The front of the telescope can be viewed as a stack of frames. The first frame (not shown), is a window-frame for mounting the aluminized mylar (or other absorber) foils that are part of the Faraday cage. The next is a collimator frame (red), to prevent low energy particles from stopping in the guard ring structure that surrounds the 6.25 cm × 6.25 cm active area of the first silicon detector. The next frame (green) holds the 65 μm thick single-sided silicon detector. A small frame (light green) follows the single-sided silicon detector, which is slotted to allow insertion of an alpha calibration source. Following the source frame, there is a 1.5 mm double-sided silicon strip detector (blue). Dowel pins align this stack of detectors and frames to each other and to the (orange) frame that follows. Aluminum plates surround this stack, providing additional strength and electronic shielding. The (orange) frame, below the double-sided detector, also supports four CsI(Tl) crystals (green) which are mounted in quadrants behind the silicon detectors. These crystals are 4 cm thick and are trapezoidal with front and back surface areas. Glued to the back of each CsI(Tl) crystal is a 1.3 cm thick light guide (purple) followed by a photodiode (not visible) with active areas of 1.8 cm × 1.8 cm. Directly behind the photodiodes are the CsI(Tl) photodiode preamplifiers. The back panel of the detector has four slots through which the silicon and CsI(Tl) signal cables pass through.

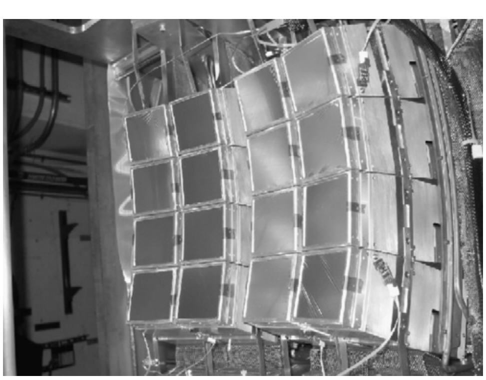

Fig. 1. An Image of 16 HiRA telescopes configured for transfer reaction experiments.

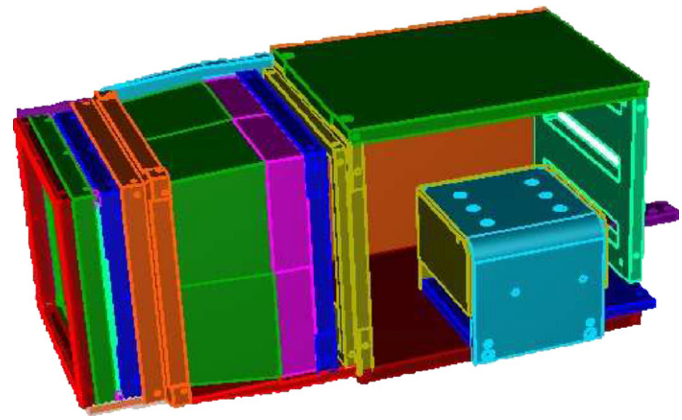

Fig. 2. A technical drawing of a single HiRA telescope.

The telescopes were designed such that they can be mounted together using keys which connect the sides of two telescopes. The keys fit along the ridge near the back of the telescopes. As visible on the right side of the photograph in Fig. 1, the keys, made of Aluminum, are secured by two screws and are aligned by two dowel pins. The photograph shows how four telescopes were keyed together to form one tower.

Each telescope has one single-sided and one double-sided silicon strip-detector giving a total of 96 (32×3) strips. The readout electronics for all these strips is housed in separate boxes which can be mounted inside or outside the vacuum chamber. Mounting the electronics inside vacuum dramatically reduces the number of cables that must be routed through the wall of the chamber. The materials used