The Plastic Scintillator Detector of the HERD space mission

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Introduction

CR detection remains in the forefront of intense research and is represented by a **plethora of sophisticated experiments** aiming to clarify their **origin, acceleration and propagation mechanisms in the Universe**.

Forthcoming space–based experiments should incorporate requirements related to: **increased geometric factor, extended mission duration, & high discrimination power in separating different cosmic radiation components.**

The High Energy cosmic-Radiation Detector (HERD) was proposed to address these requirements, as one of the primary instruments to be installed on–board China's Space Station. **Primary scientific goals reside in the fields of CR physics, gamma–rays and (indirect) dark matter searches, up to the highest achievable energies in space.**

The HERD Space Mission

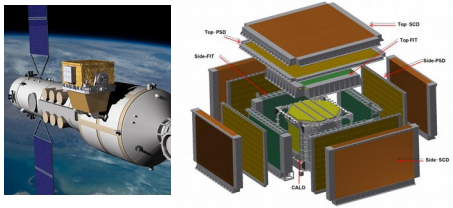


Fig. 1: Graphical representation of HERD, (left) installed on the Chinese Space Station (CSS) along with (right) an exploded detector view illustrating its various sub-detectors.

HERD is instrumented (from its core toward outer layers):

- **A deep (~55 X_0, 3 λ_I) 3D cubic calorimeter (CALO)**
- **Fiber Tracker (FiT) mats,**
- **Plastic Scintillator Detector (PSD),**
- **Silicon Charge Detector (SCD),**
- **Transition Radiation Detector (TRD)**

This design ensures detection of incident particles from both its top and 4 lateral sides, along with a factor 10 increase in acceptance.

PSD: Bar option

The proposed bar layout is composed of **long scintillators regarding the top surface, while shorter bars will be instrumented on the lateral sides**. Alternating scintillator bars along the X and Y axes will be interleaved, in order to assist in track identification and charge measurement. **Main advantages of this layout concern the optimal number of readout channels and ease of instrumentation.**

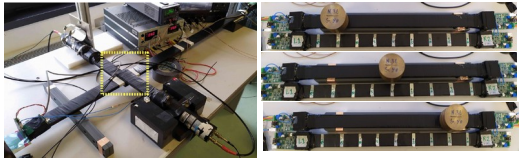


Fig. 2 (Left) 1.5m bar configuration readout by 2 SiPMs/side with a trigger imposed by 2 scint. bars + PMTs in "sandwich" configuration, aimed towards CR muon measurements in various positions. (Right) ^{90}Sr source measurements along a 50cm bar with 1 SiPM/side.

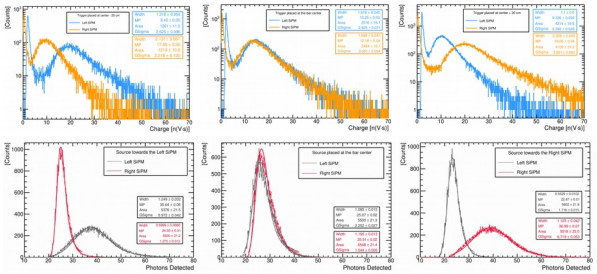


Fig. 3: SiPM spectra of photons detected in different trigger positions along a 50cm bar, concerning measurements with CR muons (top) and a radioactive ^{90}Sr source (bottom). Blue/yellow & black/red colored distributions correspond to left/right SiPMs respectively. Each contribution is fitted with a Landau convoluted with a Gaussian function.

PSD: Tile option

In the tile configuration, rectangular scintillators are being tested in order to **cover both top and lateral faces** of the instrument, **adopting similar instrumentation technique to Fermi–LAT that provided satisfactory results in reducing back–splash effects.**

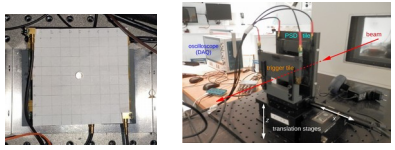


Fig. 4: (a) Tile configuration readout by 6 SiPMs (15 μm cell size) with a ^{90}Sr radioactive source placed on various trigger positions and (b) Tile configuration readout by 6 SiPMs (50 μm cell size), with tests being carried out with proton/carbon beams of variable energies at CNAO.

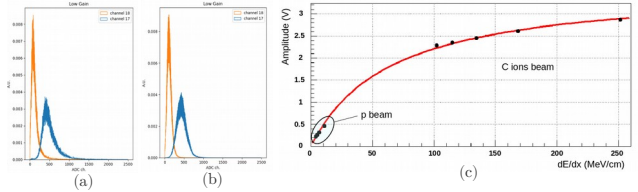
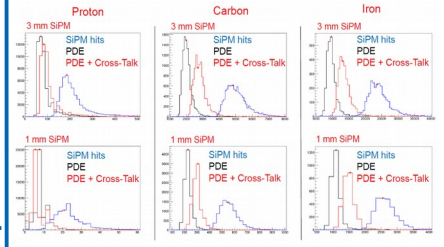


Fig. 5: Low gain test results with (a) cosmic ray muons and (b) a ^{90}Sr radioactive source in various trigger positions along the tile, obtained with a CAEN DT5550W DAQ board. (c) Absolute pulse amplitude as a function of the deposited energy, extracted from proton/carbon beam data. Birk's law can successfully describe the loss of linearity.

PSD: Simulation activities

A dedicated GEANT4 – based simulation software is developed with **customized tile/bar layouts**, in order to **evaluate performances of various configurations and their inherent properties, along with their response to different particles & nuclei.** Such efforts are **significant in complimenting all ongoing PSD laboratory activities.**



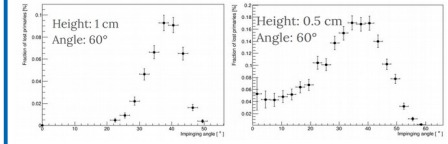
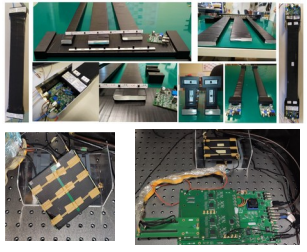


Fig. 6: (Top) Mean number of detected photons by 2 different SiPM sizes and 3 different particle types, applying PDE and cross-talk model corrections, for the tile configuration. (Bottom) Hermeticity studies concerning the feasibility of novel trapezoidal bars as opposed to default rectangular designs, focusing on the fraction of lost primaries with respect to different impinging angles.

The Plastic Scintillator Detector

The PSD of HERD will operate as an anti–coincidence detector (discriminating incident photons from charged particles), while **providing charge measurement of incoming CR nuclei in a range of Z = 1 – 26. Main requirements**: **high detection efficiency, broad dynamic range & good energy resolution. Two design layouts:** one based on **long scintillator bars while the other on square (or rectangular) tiles,** both coupled with Silicon Photomultipliers.



HERD PSD Beam Test @ CERN

Of great importance in evaluating and determining the optimal PSD layout (along with HERD as a whole), will be the **upcoming test beam campaign, taking place at CERN SPS** and scheduled for Oct/Nov 2021. Such an endeavor will lead to **systematic performance tests of PSD bar and tile prototypes,** being a **collective effort of mechanical, software and hardware groups** inside the collaboration.

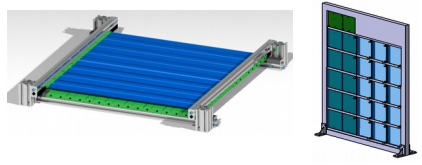


Fig. 7: Preliminary mechanical configurations concerning bar (left) and tile (right) designed prototypes, to be tested at CERN.

Conclusions

The High Energy cosmic–Radiation Detector (HERD) is one of the prominent space – borne instruments to be installed on–board China's Space Station (CSS), with an expected lifetime of 5–10 years. In this work, **the Plastic Scintillator Detector (PSD) was illustrated along with a brief presentation of its ongoing and upcoming activities.**

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