Available online at www.sciencedirect.com

ScienceDirect

Nuclear and Particle Physics Proceedings 279–281 (2016) 161–165

www.elsevier.com/locate/nppp

The High Energy Cosmic Radiation Facility onboard China's Space Station

M. Xu[a], on behalf of the HERD collaboration

[a] *Key Laboratory of Particle Astrophysics, Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China*

Abstract

The High Energy cosmic-Radiation Detection (HERD) facility is one of several space astronomy payloads onboard China's Space Station, which is planned for operation starting around 2020. It is designed as a next generation space facility focused on indirect dark matter search, precise cosmic ray spectrum and composition measurements up to the knee energy, and high energy gamma-ray monitoring and survey. HERD is mainly composed of a high granularity cubic calorimeter (CALO) with deep absorption length surrounded by micro-strip silicon trackers (STKs) from five sides, thus maximizing the geometrical acceptance. An overall description of the design will be described. Moreover, R&D is under way for reading out the LYSO signals with optical fiber coupled to image intensified CCD (ICCD) and the prototype of 1/40 CALO for beam test at CERN.

Keywords: space experiment, calorimter, cosmic ray, beam test

1. Introduction

The steepening power law of the primary cosmic ray (CR) spectrum around several PeV, the so-called knee structure is a classic problem in CR physics as it is related closely to the physics of acceleration and propagation of CRs, but still unresolved[1]. Weakly Interacting Massive Particles (WIMPs) are well motivated candidates of DM particles because they can account for the observed DM density naturally[2]. WIMPs can be detected in CRs through its annihilation into electrons or gamma-rays, resulting in structures to be seen in the otherwise predicted smooth spectra. Some circumstantial evidence or hints of anomalies have been reported[3, 4, 5, 6]; however, astrophysical sources like pulsars and pulsar wind nebulae can also contribute to these results. Experimental data from more precise measurement at higher energies are needed to address the above major problems in fundamental physics and astrophysics.

The High Energy cosmic-Radiation Detection (HERD) facility has been planned as one of several space astronomy payloads of the cosmic lighthouse program onboard China's space station, which is planned for operation starting around 2020 for about 10 years. The main scientific objectives of HERD are: 1) indirect dark matter search through spectra and anisotropy of high energy electrons and gamma-rays from 100 MeV to 10 TeV; 2) precise cosmic ray spectrum and composition measurements up to the knee energy, and high energy gamma-ray monitoring and survey from 100 MeV up to 10 TeV. In this paper, we describe the design of HERD and its basic characteristics determined with Monte-Carlo simulations, as well as ongoing R&D efforts in developing HERD prototype for beam test.

2. HERD design and expected performance

Our design goal for HERD is simply to optimize its geometrical, absorption depth and its granularity, thus maximizing the acceptance after taking into account the detection and event reconstruction efficiency. To do this, we find that the HERD design with a cubic calorimeter (CALO) of 63 cm×63 cm×63 cm so as to detect particles arriving from every direction in space is required , which is made of nearly 10^4 pieces of granulated LYSO crystals of 3 cm×3 cm×3 cm each, as illustrated in Fig. 1. From any incident directions, CALO has a minimum

http://dx.doi.org/10.1016/j.nuclphysbps.2016.10.023

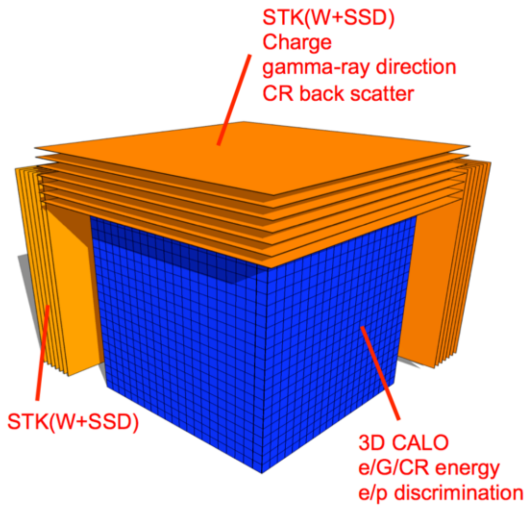

Figure 1: Schematic diagram of the baseline design of HERD. The five sides identical STKs except the bottom for mechanical support, with each side is made of seven layers of silicon micro-strips, sandwiched with tungsten foils, for absolute charge, direction and early shower measurement; the cubic CALO, for energy measurement and provide particle ID information.

stopping power of $55X_0$ and 3λ, where X_0 and λ are radiation and nuclear interaction lengths, respectively. Such a deep and high granularity calorimeter is also essential for excellent electron-proton separation and energy resolutions of all particles. It also has some directional measurement capability with the reconstructed 3-D showers. In order to measure the charges and incident directions of cosmic rays, CALO is surrounded by the same seven-layer silicon trackers (STKs) which is made of silicon micro-strip detectors sandwiched with tungsten foils from all five sides except the bottom for mechanical support, to ensure the maximum field of view (FOV) for electrons and gamma-rays. Plastic scintillators surrounding HERD from all five sides are needed to reject most low energy charged particles, in order to have maximum efficiency for high energy cosmic rays and electrons, as well as gamma-rays of all energies. Please refer to Zhang et al (2014) for more details of the requirements and design[7].

Extensive simulations have been carried out with GEANT4 and FLUKA, in order to evaluate the scientific performance of the HERD baseline design. The simulations show that electrons and photons with a high energy resolution ($\sim$ 1% for electrons and photons and 20% for nuclei) and a large effective geometry factor (>3 m^2sr for electrons and diffuse photons and >2 m^2sr for nuclei) can be achieved under this design.

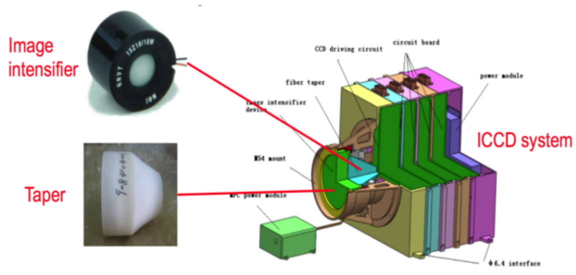

Figure 2: Schematic diagram of the ICCD system. The optical taper transmits precisely the image from its input surface coupled with WLS fibers to its output surface which coupled with the image intensifier. And then the signals will be enhanced by the image intensifier and finally collected by the fast and weak light imaging CCD chip.

Please refer to Xu et al (2014) for further details of the simulations[8].

3. Beam Test Objectives

The HERD calorimeter prototype is placed in the H4 beam line of the Super Proton Synchrotron (SPS) at CERN in November 2015, and data from proton, electron and fragmentation particles of primary Pb ions on a production target is collected at energies several tens of GeV up to 400 GeV.

A key technology of HERD is the signal readout system of the 10^4 pieces of LYSO crystals with sufficient signal to noise ratio and large dynamical range. In order to minimize the power consumption of readout electronics and heat dissipation inside CALO, we choose to channel the scintillation light out of the LYSO crystals with optical coupling onto CCDs, as illustrated in Fig. 2.

The beam test is intended to validate the hardware and software of HERD, and at the same time the beam test have several other major objectives including measurement of the energy resolution, angular resolution, particle identification power and data taking efficiency.

As the test beams from the accelerator can only provide particle energies up to 400 GeV which is about several orders of magnitude short of HERD energy range, the response of the detector at higher energies should be carried out by using the extrapolation of Monte Carlo simulation, which means one can verify the precision of said simulations by comparing simulation to measurement at available energies and assess their likely accuracy at higher energies.