Abstract

The HERD experiment is a future experiment for the direct detection of high energy cosmic rays. The instrument is based on a calorimeter optimized not only for a good energy resolution but also for a large acceptance. Each crystal is equipped with two read-out systems: one based on wavelength shifting fibers and the other based on two photodiodes with different active areas assembled in a monolithic package. In this poster we discuss the photodiodes read-out system, focusing on the experimental requirements, the system design and the estimated performances.

The HERD experiment

Future experiment dedicated to the direct detection of cosmic rays. Installation on the Chinese Space Station scheduled in 2027.

Calorimeter characteristics:
- 3D
- homogeneous
- isotropic
- deep (55 X0, 3 λ)
- finely segmented
- composed by about 7500 LYSO scintillating crystals
- large acceptance (2 m^2 sr for electrons, 1 m^2 sr for protons)
- good energy resolution (<2% for electrons, ~30% for protons)

Calorimeter requirements:
- strong control of energy scale independent triggers
- redundancy

Two different read-out systems:
- wavelengths shifting fibers (WLSF) coupled to Intensified scientific CMOS (IsCMOS)
- pairs of photodiodes with different active areas assembled in a monolithic package

Read-out challenges:
- high dynamic range (>10^5)
- low power consumption

Performance of the PD read-out system

Typical noise of the system:
- 27.5 ADC
- 22.5 ADC after common noise correction

In orbit, the calibration of the LPD signal will be done using the signal correlation with the LPD in high energy shower release.

LPD/SPD ratio measured using multiparticle beam at two test beam facilities:
- at the LABEC facility in Florence with 2 MeV protons
- measured ratio LPD/SPD: 19.5 ± 1.5

In the Lab at ELEKTA VERSA HD with photons:
- 22.5 ADC after calibration of the SPD
- 27.5 ADC

Prototype tested at SPS

Channel-by-channel calibration of LPD using muon signal:
- 250 GeV muons MPV = (126 ± 4) ADC

Channel-by-channel calibration of SPD using proton showers:
- (6 ± 2) ADC for SPD
- (110 ± 10) ADC for LPD

Prototype with 63 crystals equipped with WLSF and monolithic packages tested in 2021 at the CERN Super Proton Synchronotron (SPS).

Three types of particles:
- muons
- protons
- electrons

Development of the new sensor

- maximum detectable energy
- Signal to Noise Ratio (SNR) of SPD near the saturation of LPD
- Extension of the active dynamic range:
  - optical fiber with a transmittance of about 1.5% on the surface of the SPD to reach a dynamic range larger than 10^5

Estimation of the dynamic range:
- maximum detectable energy before saturation of a few TeV

Home-made monolithic package

PD read-out system design

The PD read-out system is based on a monolithic package composed by two photodiodes with different active areas.

VTH2110 photodiode:
- maximum detectable energy before saturation of a fewTeV

VTP9412 photodiode:
- maximum detectable energy

Prototype with 63 crystals equipped with WLSF and monolithic packages tested in 2021 at the CERN Super Proton Synchronotron (SPS).

Three types of particles:
- muons
- protons
- electrons

Development of the new monolithic package:
- collaboration with Excelitas
- first new 1000 monolithic packages installation on a prototype that will be tested in 2023 at CERN SPS

Overlapping region in the operative range of both LPD and SPD.