Two PhD thesis proposals:

- CONSTRUCTION AND CHARACTERIZATION OF THE CALORIMETER OF THE HERD EXPERIMENT

- PERFORMANCE STUDIES OF THE HERD DETECTOR

Field of investigation: direct observation of cosmic rays from space.

Activities: detector construction, test with particle beams, data analysis, Monte Carlo simulations.

Laboratories: INFN Florence, CERN (Geneva, CH), BTF (Frascati, IT), SERMS (Terni, IT)

Information and references: https://www.herd.cloud.infn.it

Supervisors:
- Nicola Mori (mori@fi.infn.it, 0554572660)
- Lorenzo Pacini (pacini@fi.infn.it, 0554572605)

Description of the experiment

The High-Energy Radiation Detection (HERD) facility is a future cosmic-ray detector aimed at performing direct measurements of charged particles at the highest, ever-reached energies (~ PeV scale), and at monitoring the gamma ray sky for transient phenomena. It will be installed on the future Chinese Space Station in 2027. Its physics goals range from astrophysical ones like the investigation of the cosmic-rays acceleration and propagation mechanisms or the monitoring of electromagnetic follow-ups of gravitational waves, to fundamental physics topics as indirect dark matter search. The detector consists of a deep, homogeneous electromagnetic calorimeter made of LYSO cubes with an innovative 3D-mesh isotropic design which allows to observe particles coming not only from directions around the zenith but also from near the horizon, allowing for a full coverage of the whole sky. The calorimeter, whose main role is the measurement of the energy of the detected particles, is complemented by a set of sub-detectors: the FIbrer Tracker (FIT) is a device made of plastic scintillating fibers providing a reconstruction of the track of the particle, the Plastic Scintillator Detector (PSD) works as an anticoincidence shield for identifying gamma rays, the Silicon Charge Detector (SCD) measures the charge of the particle, and the Transition Radiation Detector (TRD) is used to calibrate the response of the calorimeter. Innovative features like a double readout system for the calorimeter or the measurement of the arrival time of the particle on the PSD will allow to improve the control over systematic errors with respect to the current generation of space-based cosmic-ray detectors, making HERD measurements a significant step forward for our understanding of cosmic rays and the physics behind them.

HERD is currently in an advanced design phase: detectors prototypes are being built to test the measurement principle and performance, and optimization studies based on monte Carlo simulations are ongoing.

HERD is an international collaboration led by Chinese institutions like the Institute for High Energy Physics (IHEP, Beijing) with a strong European component led by INFN and Italian universities, with members from Spain, Switzerland and Sweden.

The HERD group in INFN Florence

INFN Florence is responsible of one of the two readout systems of the calorimeter. It consists of a pair of photodiodes of different dimensions attached to each LYSO cube that read the scintillation light

produced in LYSO by the passage of charged particles, and integrates the readout system based on wavelength shifting (WLS) fibers built by IHEP reading the same cube. A total of ~7500 double fotodiodes will be present in the detector. The different sizes allows for extending the energy reach of the instrument in order to reach on the upper end the PeV scale and on the lower end the MIP scale (needed for calibration), for an overall dynamic range above 10^7. The idea of the photodiode readout has been originally conceived by our group and initially developed in the framework of the CaloCube project funded by INFN, whose outcomes are now being applied to the desing and realization of HERD.
The group also features strong skills in data analysis and Monte Carlo simulations, inheriting from the experience in past and current cosmic-ray experiment like PAMELA and CALET, and also coordinates the development of the HERD experiment software for the European partners of the collaboration.

Thesis activities
Two different thesis projects are available:

1. Construction and characterization of the HERD calorimeter readout system
   You will participate to the construction and test of the photodiode readout system for the HERD calorimeter. The activities include:
   - assembly of LYSO cubes with photodiodes for testing the light collection and mechanical properties of the gluing;
   - participation to the vibration and thermal vacuum tests of calorimeter prototype at SERMS facility;
   - laboratory tests of the readout electronics in collaboration with INFN Trieste and CIEMAT Madrid;
   - participation to the beam tests of the readout electronics at the BTF accelerator facility;
   - construction of a medium-sized calorimeter prototype consisting of about 1000 LYSO cubes equipped with PD+WLS double readout system, in collaboration with IHEP Beijing;
   - participation to the beam tests of the prototype at the PS and SPS accelerator facilites at CERN.
2. Performance studies of the HERD detector
   You will study the performance of the HERD detector, especially the calorimeter, by means of Monte Carlo simulations and test beam data, and define the analysis procedures for measuring the fluxes of different particle species. The activities include:
   - reconstruction of the particle energy from calorimeter measurements;
   - electron/proton separation by means of topological analysis of particle showers in the calorimeter;
   - definition and characterization of data analysis procedures for measuring fluxes of different particle species (electrons, protons, atomic nuclei etc.);
   - participation to the data taking sessions at beam tests of the prototype at the PS and SPS accelerator facilites at CERN;
   - management of Monte Carlo data production at the INFN CNAF computing center;
   - development of the simulation and data analysis software framework of the collaboration.

You will become a member of the HERD collaboration and participate to collaboration meetings in Europe and China.
A mixed project between the two proposals above combining hardware and data analysis / software activities can be eventually formulated.