Progettazione, sviluppo e realizzazione del calorimetro dell'esperimento HERD

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a nome della ***Collaborazione HERD***

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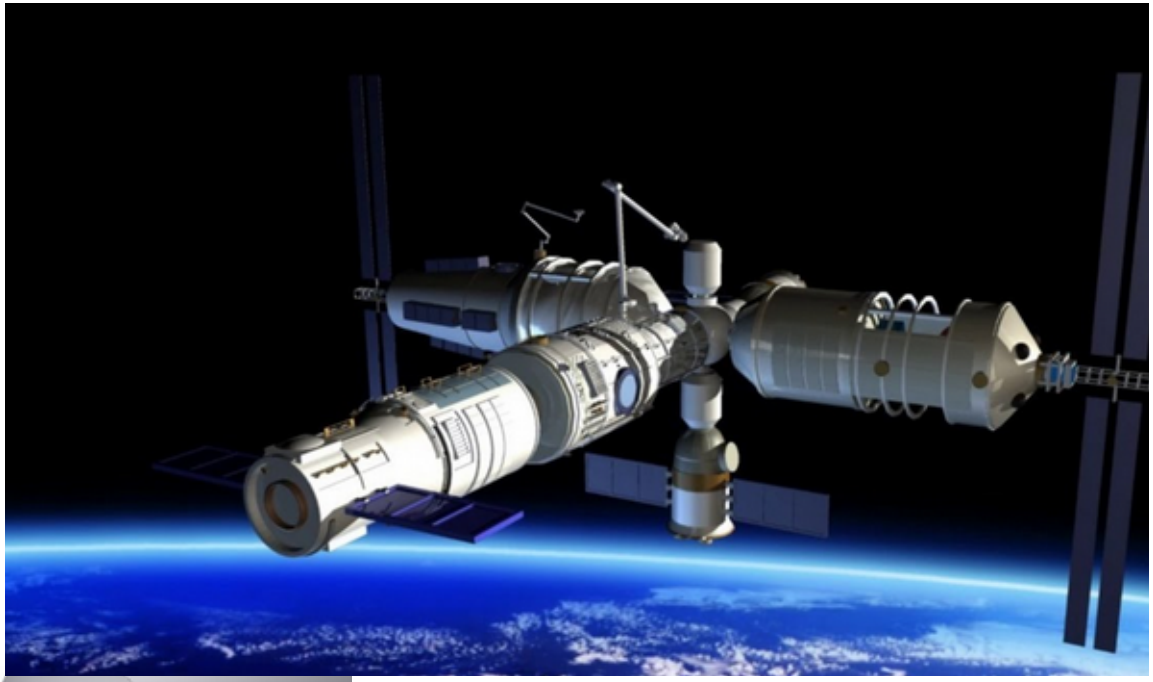
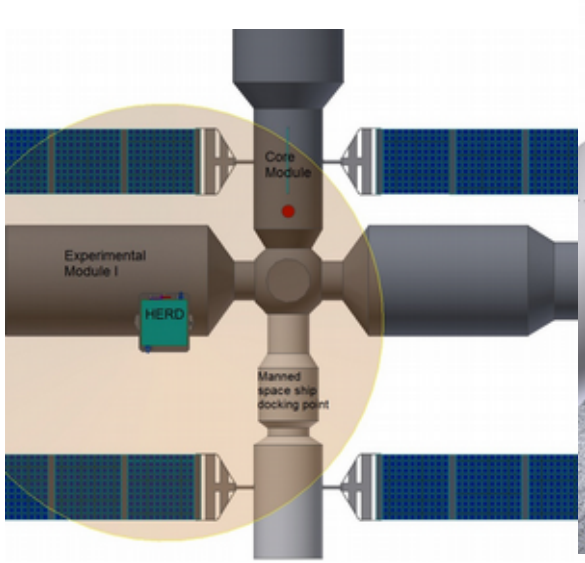
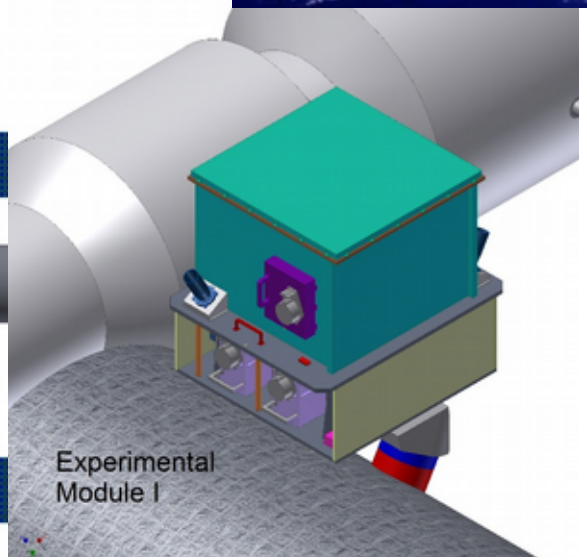
Overview

The **High Energy cosmic-Radiation Detection** (HERD) facility is a space mission that will start operations aboard the **China Space Station** (CSS) around 2026.

It is an *China-led international space mission* developed by the IHEP of CAS together with other institutions across the world, especially from Italy (**INFN**, **ASI**).

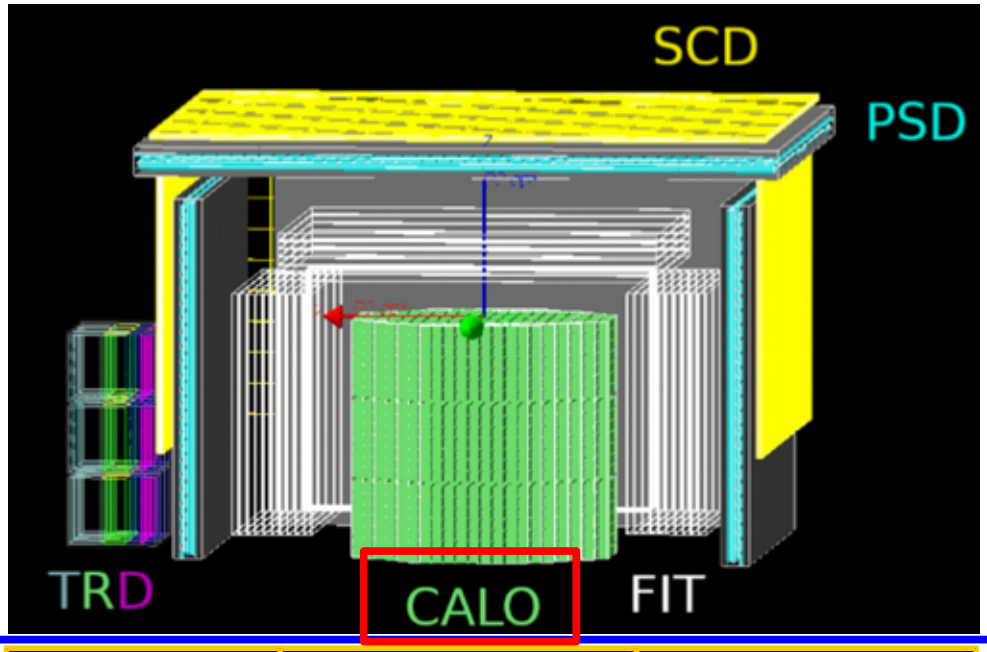






Main goals
Direct measurement on cosmic rays up to the knee region
Gamma-ray monitoring and full sky survey
Indirect dark matter search (e^++e^-, γ,...)

HERD detector and requirements



	e	p, nuclei
Energy Range	10 GeV - 100 TeV	30 GeV - 3 PeV
σ_E/E	1% @ 200 GeV	20% @ 1 PeV
Effective GF	> 3 m^2sr @ 200 GeV	> 2 m^2sr @ 100 TeV

The core of the HERD detector is a 3D, homogeneous, isotropic and finely-segmented calorimeter

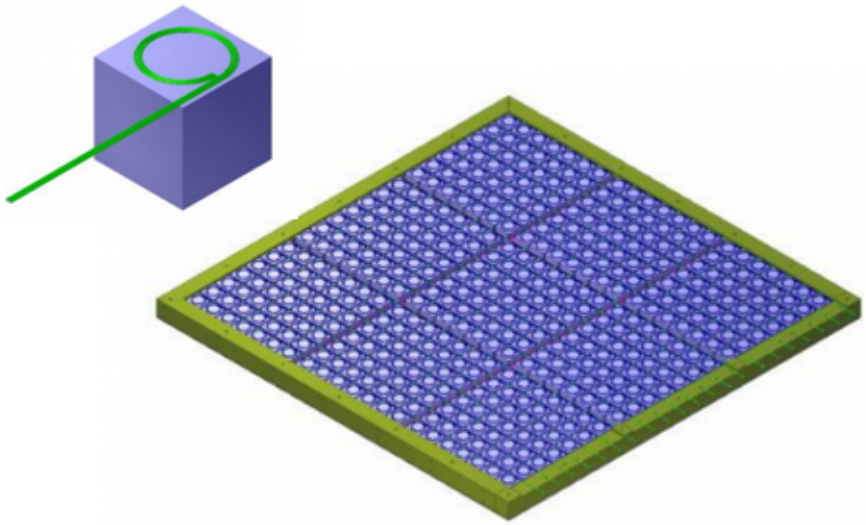
CALO	Energy Reconstruction e/p Discrimination (10^6)
FIT	Trajectory Reconstruction Charge Identification
SCD	Charge Identification
PSD	Charge Reconstruction γ Identification
TRD	Calibration of CALO response for TeV proton

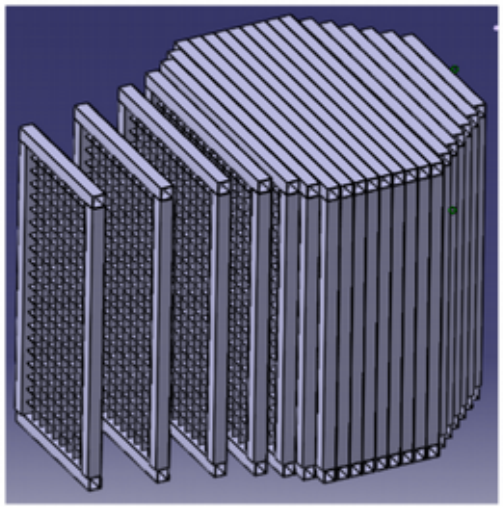
HERD CALOrimeter

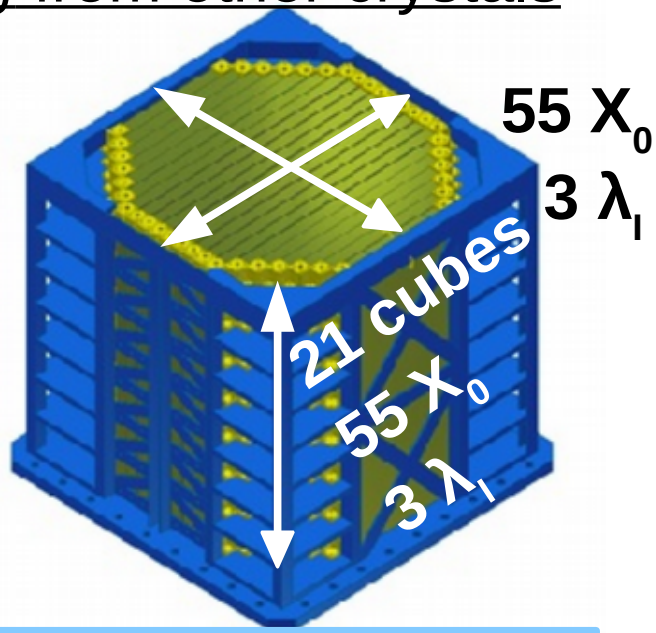
CALO

Innovative design based on INFN CaloCube R&D

Octagonal Prism made of about **7500 LYSO cubic crystals**:
each crystal has *3 cm side* and *4-8 mm spacing* from other crystals

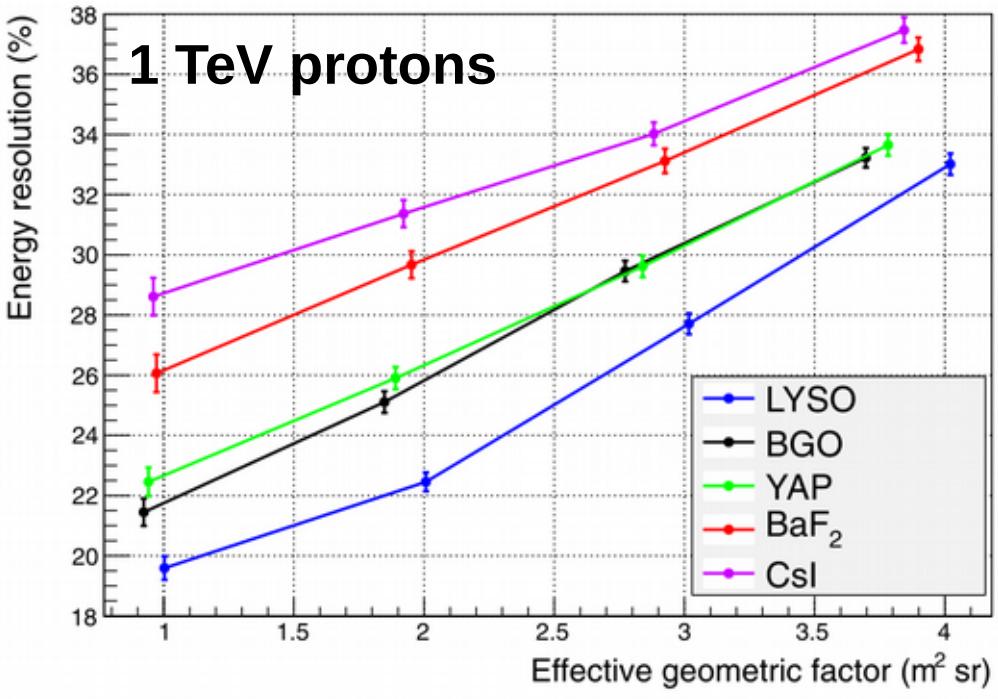






Deep homogeneous calorimeter	→	Good energy resolution
Isotropic 3D geometry	→	Large geometric factor (top + lateral faces)
Shower imaging with 3D segmentation	→	Good e/p discrimination, identification of shower axis and determination of starting point

LYSO crystal



From simulation studies carried out for the Calocube R&D, the **LYSO** crystal resulted to offer *the best compromise between large geometric acceptance and good shower containment*

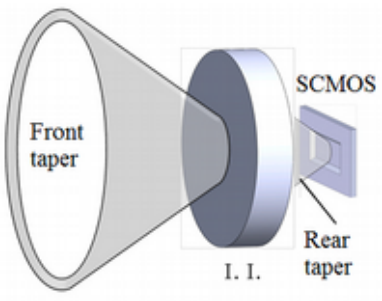
The energy deposit in a 3 cm side cubic LYSO crystal is:

- about 10 MeV for a *proton MIP* (needed for gain calibration)
- about 100 TeV for the maximum of a PeV *proton shower*

A **dynamic range of 10^7** is needed!

Dual readout

Based on the experience from previous space missions, CALO is equipped with **two independent readout system** in order to decrease calibration uncertainty and improve system redundancy.



IsCMOS developed by CAS XIOPM

Three WLS fibers per cube, grouped respectively to a high gain IsCMOS, a low gain IsCMOS and a trigger system.

It is a compact system but it suffers of crosstalk among channels on IsCMOS and radiation damage on Image Intensifier

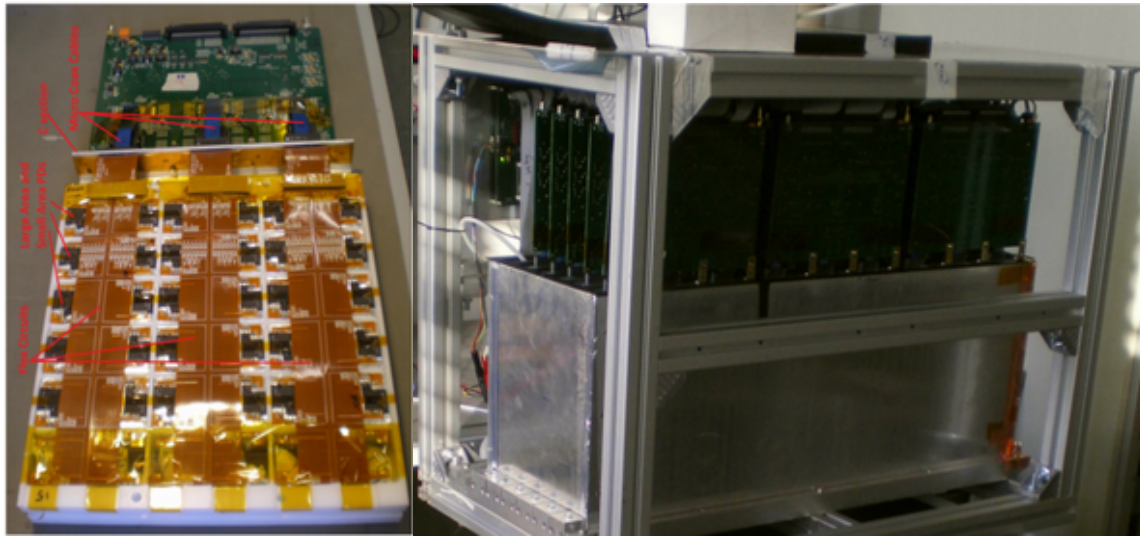
Two photodiodes per cube with a area ratio of 1:100 connected to a high dynamic range electronics (developed by INFN Trieste).

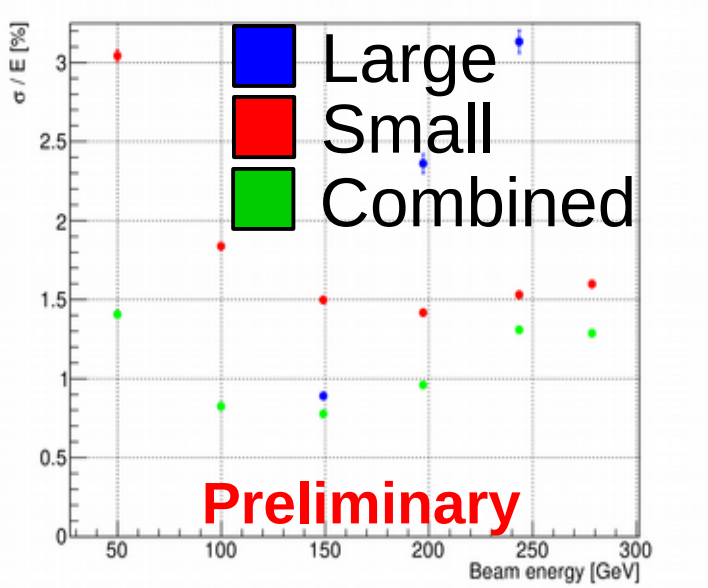
It is a simple and compact system, but it suffers of direct ionization in the sensor

Prototype performances

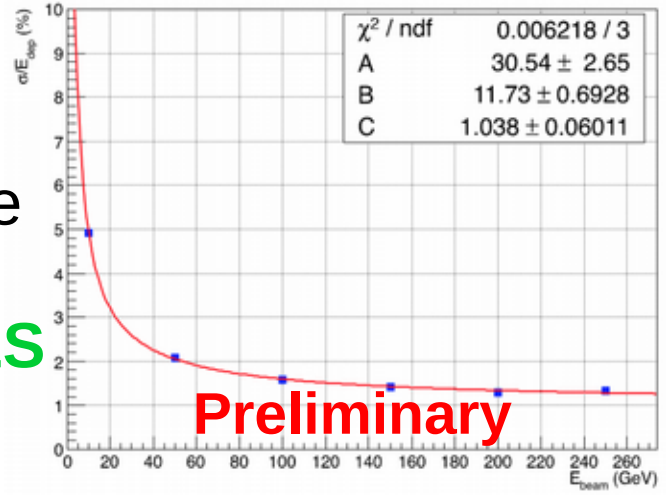
with electron beam

CsI:Tl prototype readout using **PD**





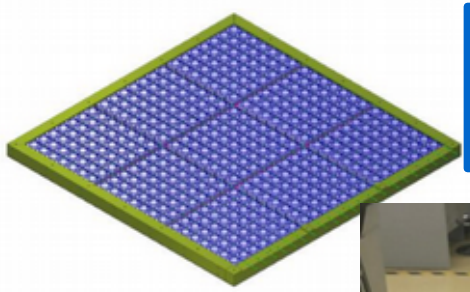
LYSO prototype readout using **WLS**



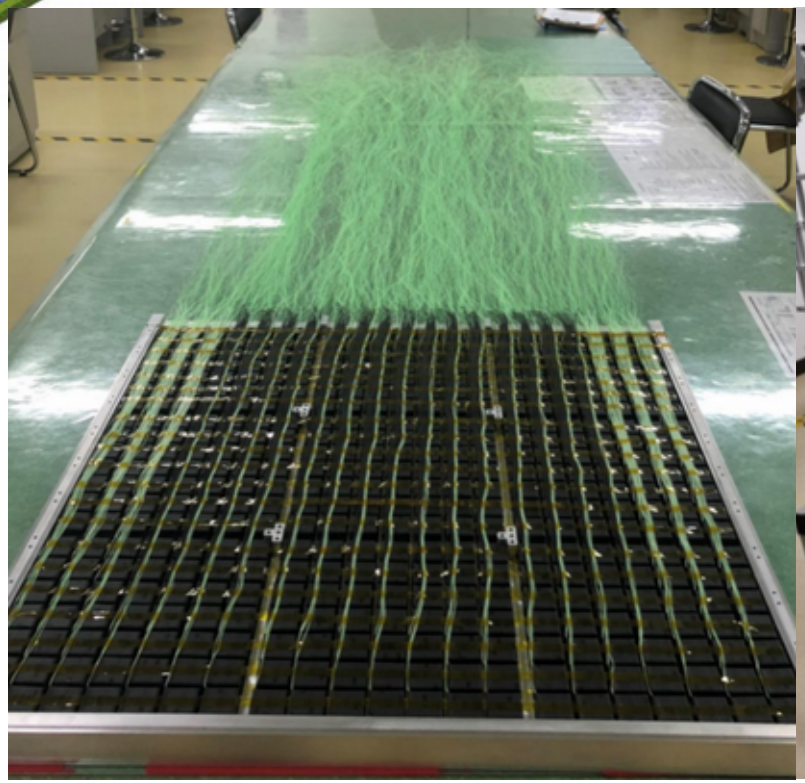
Good and similar performances among the two prototypes with different readout systems.

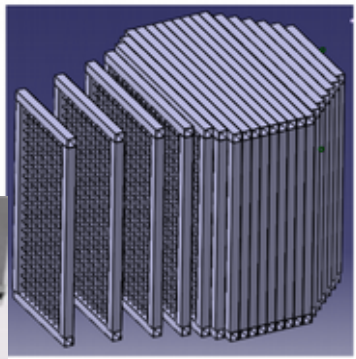
Next year we will build and test a prototype equipped with dual readout (WLS + PD).

Assembly Integration and Test



A dedicated prototype made of 2200 crystals was realized for AIT verification





The feasibility of fiber routing and array assembly was confirmed

Summary

The **High Energy cosmic-Radiation Detection** (HERD) facility is a China-led international space mission that will start its operation around 2026 aboard the future China's Space Station.

HERD will accomplish *important and frontier goals* on **DM search, CR observations and Gamma-Ray astronomy**, extending by at least one order of magnitude in energy the current measurements.

This will be possible thanks to its novel design, based on a **3D, homogeneous, isotropic and finely-segmented calorimeter**, made of about 7500 LYSO cubic crystals of 3 cm side.

This solution leads to **good energy resolution and geometric factor** (1% and >3 m^2sr for EM showers, 20% and >2 m^2sr for hadronic showers), as determined from simulations and prototypes.

In the next year, the collaboration plans to assemble **a prototype very similar to the final configuration**, to investigate the feasibility of the integration and to carefully study the expected performances.