

HERD: The High Energy cosmic – Radiation Detector

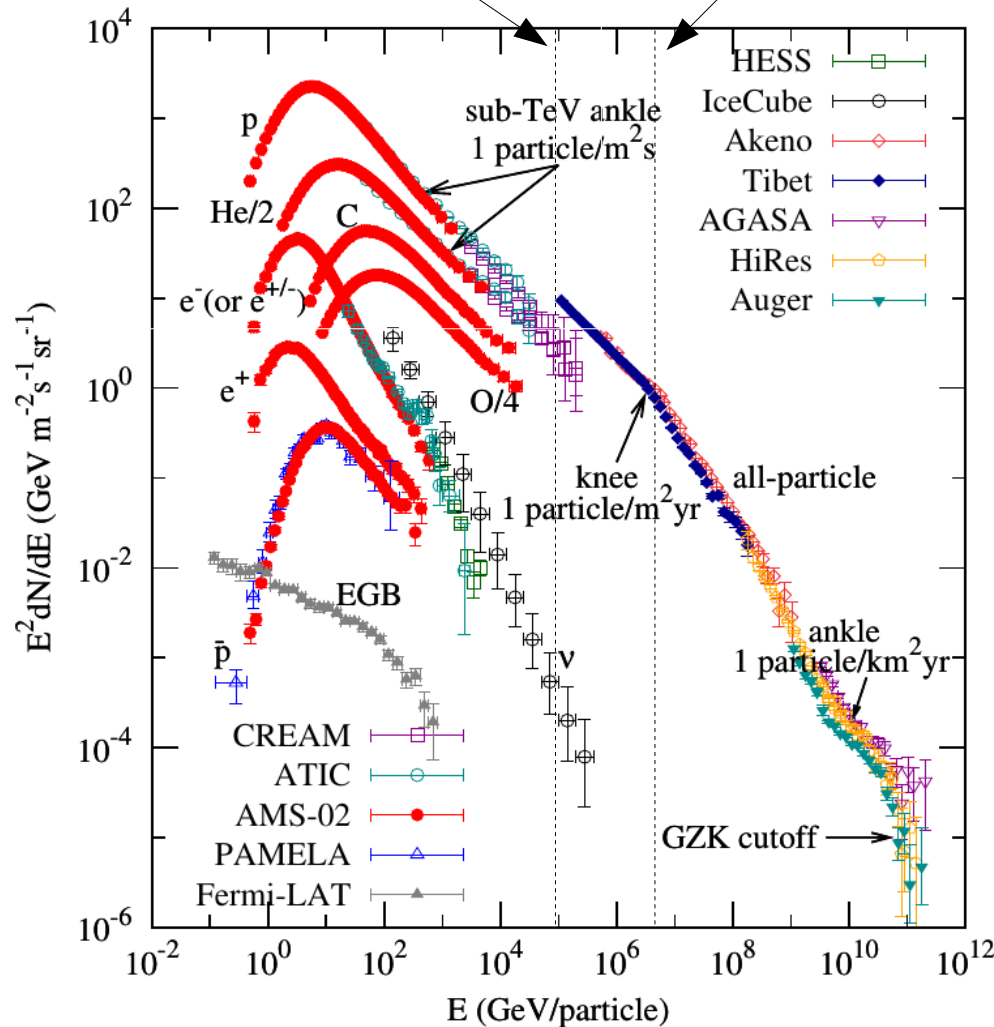
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Gran Sasso Science Institute (GSSI) & INFN – LNGS

Space – based experiments

CR: Direct detection (current)
energy reach

Upper limit for
direct detection



Due to rapidly falling intensity of CR fluxes with energy, experiments with large acceptances, operating over several years needed to explore the CR spectrum at PeV energies.

Direct CR experiments

- Precise measurement of particle charge and energy
- Small G.F. or exposure to provide statistically meaningful measurements above few tens of TeV.

Indirect CR experiments

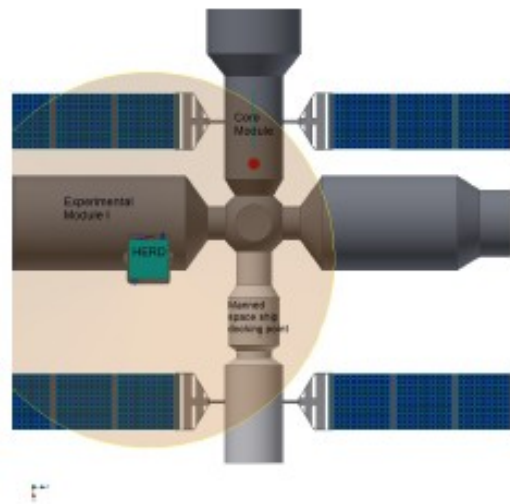
- Huge achievable energies
- Difficulty in making composition studies with small systematics.

HERD: Cosmic Ray experiment onboard the Chinese Space Station (CSS)

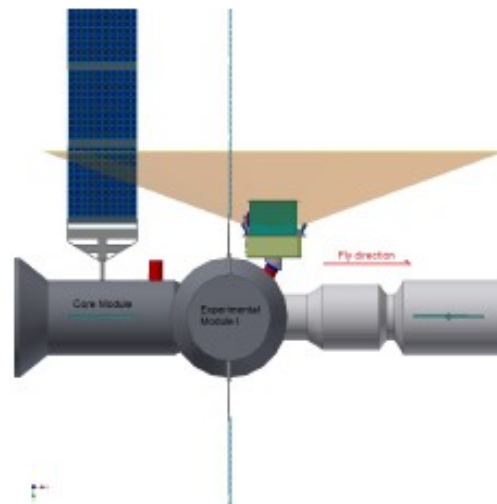
Operation planned around 2025 – 2026
with extended lifetime (~ 5–10 yrs)

Scientific Goals:

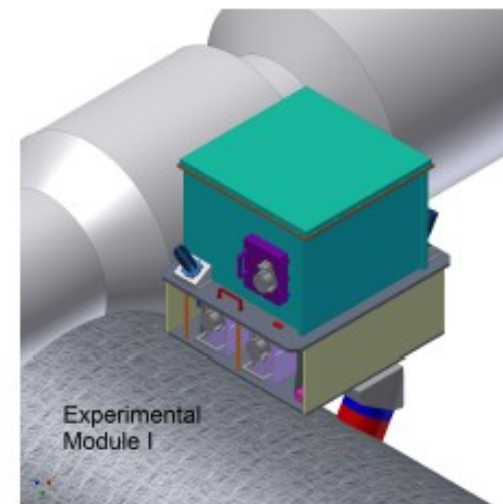
- Cosmic Rays: Precise CR spectra and mass composition up to the PeV range
- Gamma – ray astronomy and transient studies (e.m. counterpart of GW)
- Electron spectra (and anisotropy) up to tens of TeV (nearby sources, ...)
- Indirect Dark Matter searches with high sensitivity



(a) Top view



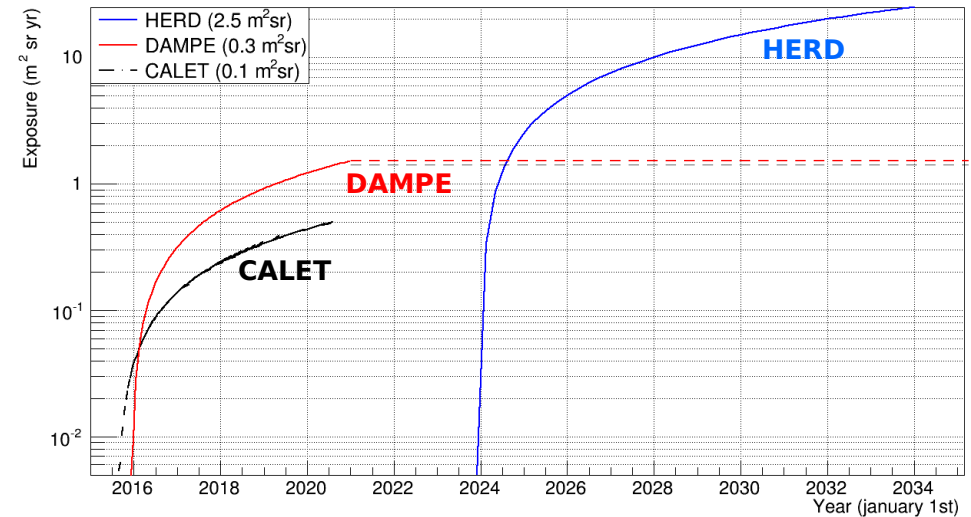
(b) Side view



(c) Oblique view

Large acceptance, deep, 3D calorimeter, with silicon tracker (STK) and plastic scintillators (PSD) for identification of incident primaries.

One order of magnitude upgrade in exposure wrt current generation CR experiments: 15 – 20 m² sr yr



PSD, 5 sides

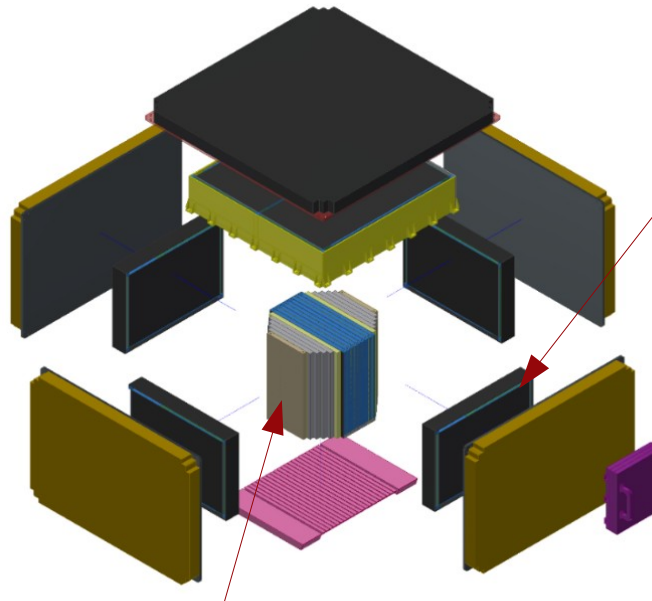
γ -ray/charged particles' ID
Charge measurement

STK (SSD+W), 5 sides

Charge measurement
CR trajectory
Gamma conv. & tracking

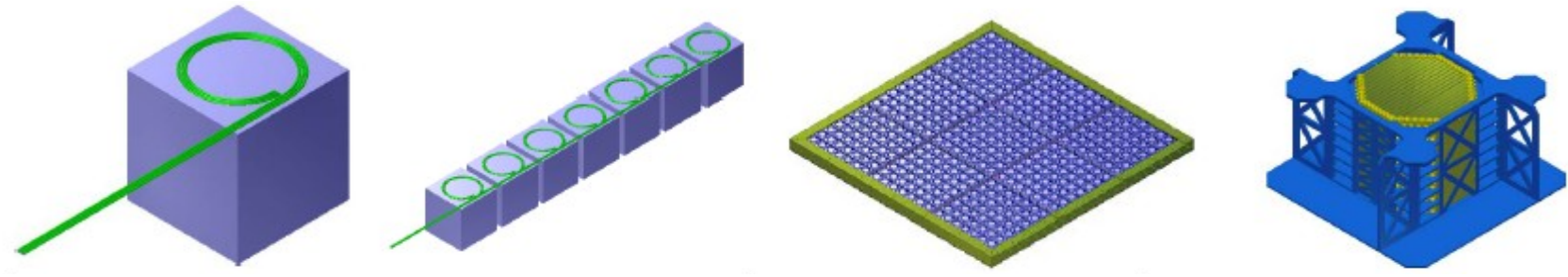
CALO: 3-D
e/ γ /CR Energy
e/p separation

TRD
TeV CR
calibration

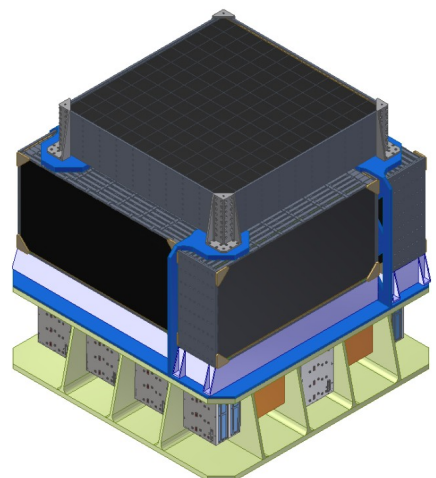
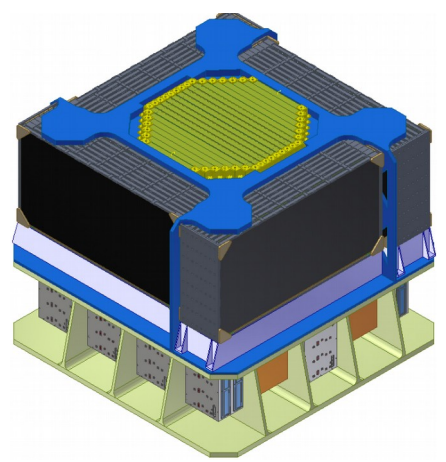
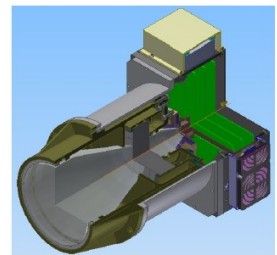
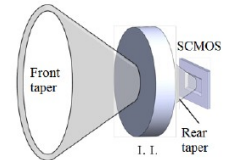
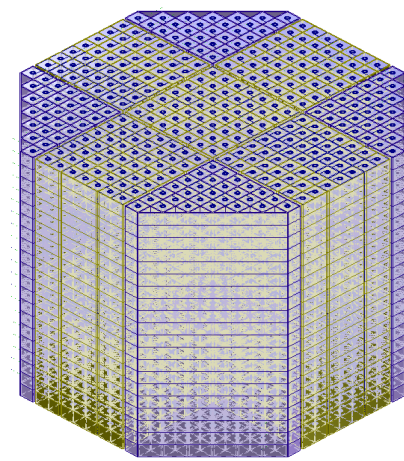


Item	Value
Energy range (e/ γ)	10 GeV-100 TeV(e); 0.5 GeV-100 TeV (γ)
Energy range (CR)	30 GeV – 3 PeV
Angular resolution	0.1 deg. @ 10 GeV
Energy resolution (e)	1-2% @ 200 GeV
Energy resolution (p)	20-30% @ 100 GeV – PeV
e/p separation	$\sim 10^{-6}$
G.F. (e)	> 3 m ² sr @ 200 GeV
G.F. (p)	> 2 m ² sr @ 100 TeV
Pointing	Zenith
Field of View	+/-70 deg
Lifetime	5 – 10 years

HERD Subdetectors: Calorimeter (CALO)



Item	Value
Type of crystal	LYSO
Nuclear interaction length	3 (55 X_0)
Number of crystals	~7500
Crystal dimension	3cm * 3cm * 3cm
Fiber readout	3 WLSF/crystal



Possible partial readout of crystals with PhotoDiodes (Calocube) for calibration and extended dynamic range.

The **Silicon Tracker (STK)** is designed for:

- Precise CR/e trajectory
- Gamma – ray conversion & tracking
- Complementary charge measurement (up to $Z = 26$)

SSD layers:

Top: 6 X/Y
Lateral: 3/6 X/Y

STKs

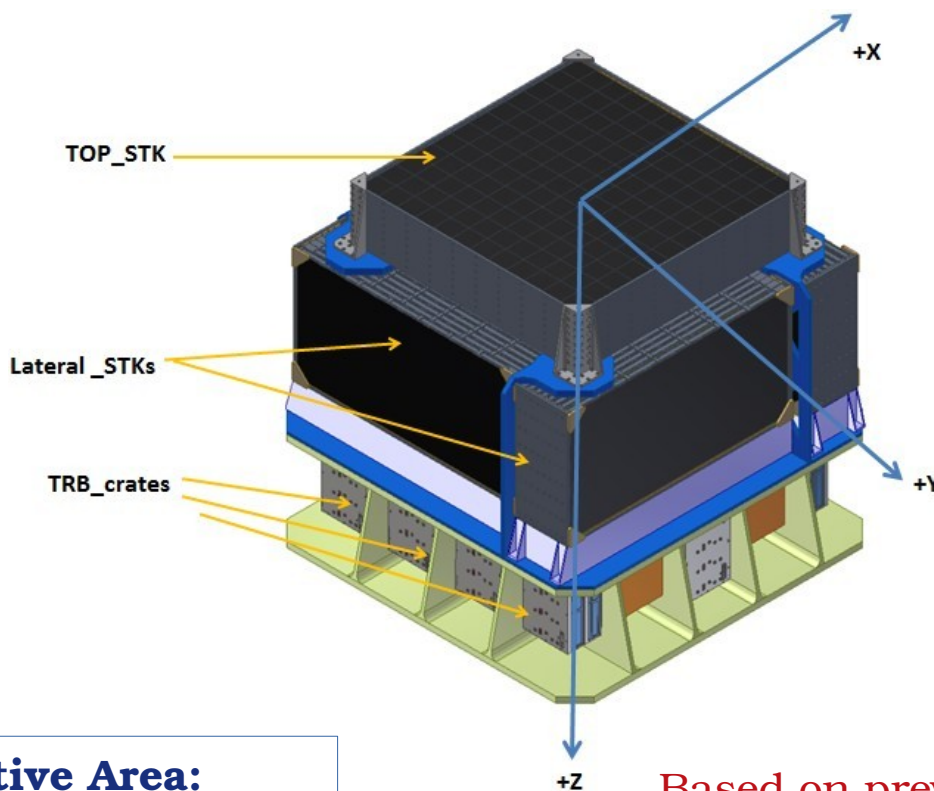
1 Top + 4 Lateral

FoV coverage: >80%

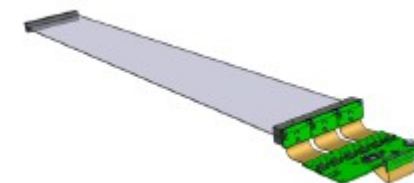
Angular resolution:
0.1 deg. @10 GeV

Effective Area:

Top: ~133 cm * 133 cm
Lateral: ~ 114 cm * 66.5 cm



Optimized configurations are being tested and implemented in HERD (i.e., Fiber Trackers).



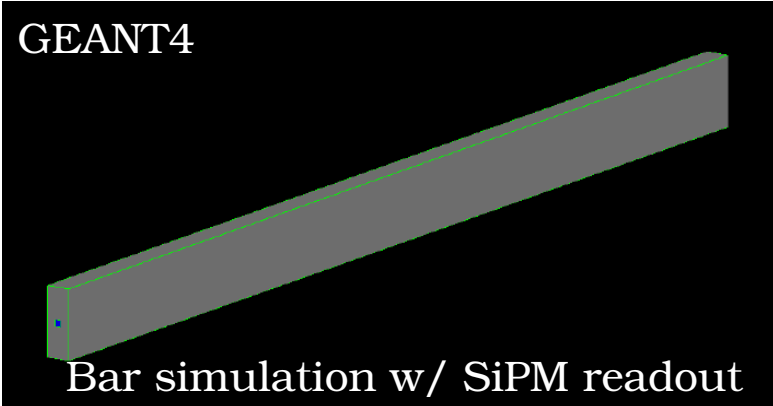
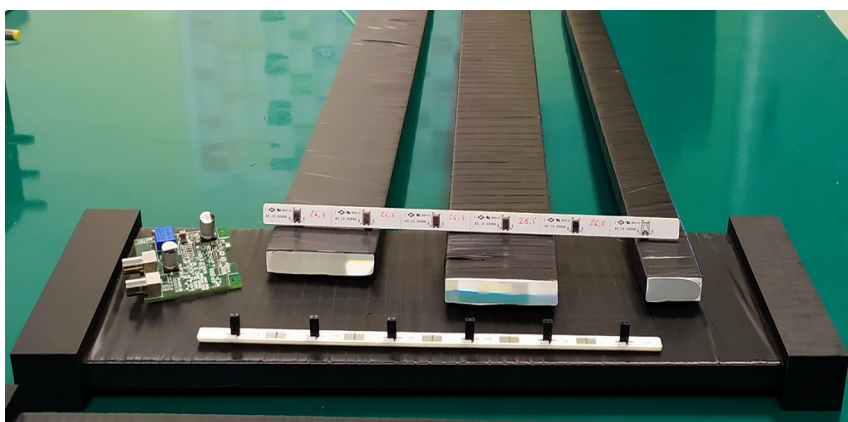
Based on previous experience with AGILE, AMS-02, FERMI and DAMPE missions.

The **Plastic Scintillator Detector (PSD)** is optimized for:

- Gamma rays/charged particles' identification
- CR identification by charge measurement

Various configurations of **Scintillator bars + SiPMs** under test in **GSSI - LNGS**

Fraction of the bar + SiPM selection at GSSI – LNGS

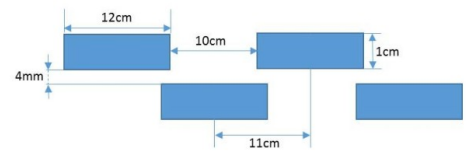
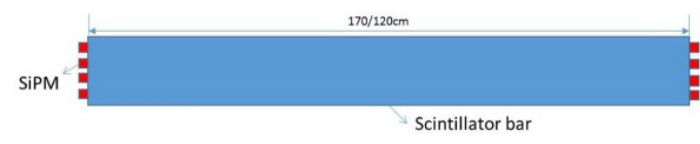


Design

- 1 X/Y layer on top and 4 lateral sides
- 1 X layer in the bottom side
- **SiPM utilization**
 - High & low range (covering $Z = 1 - 26$)

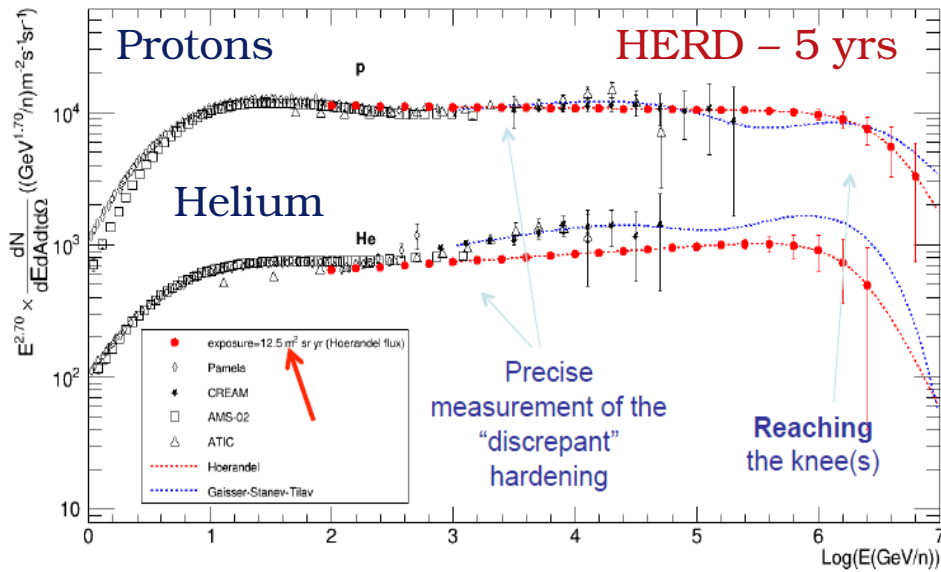
Bars vs Tiles layout

Resulting from the optimization of efficiency, mechanics, no. of channels and backsplash effects



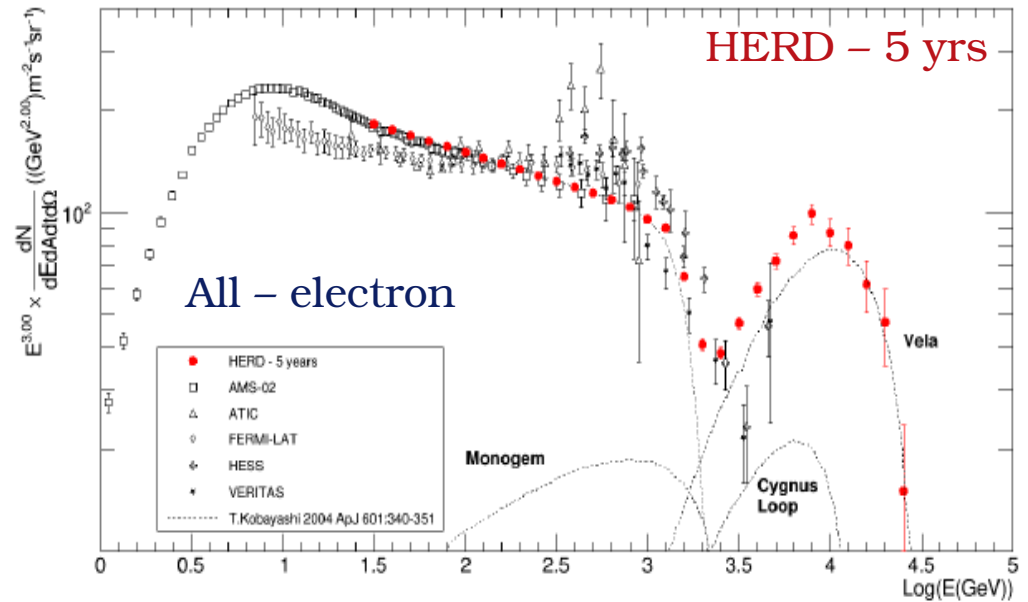
Proton & Helium spectra

Reaching up to a few PeV, signaling the first direct observation of the “knee”



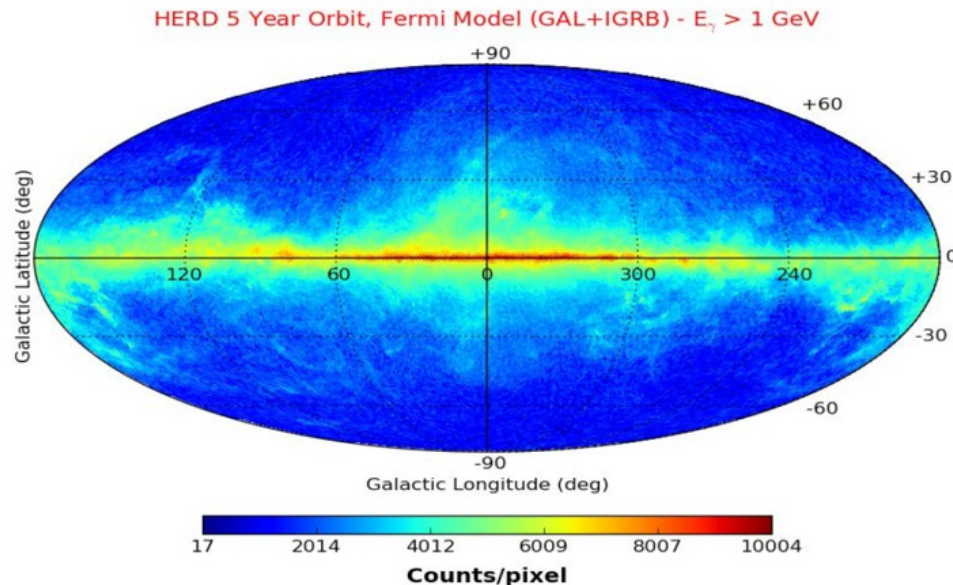
All – electron spectrum

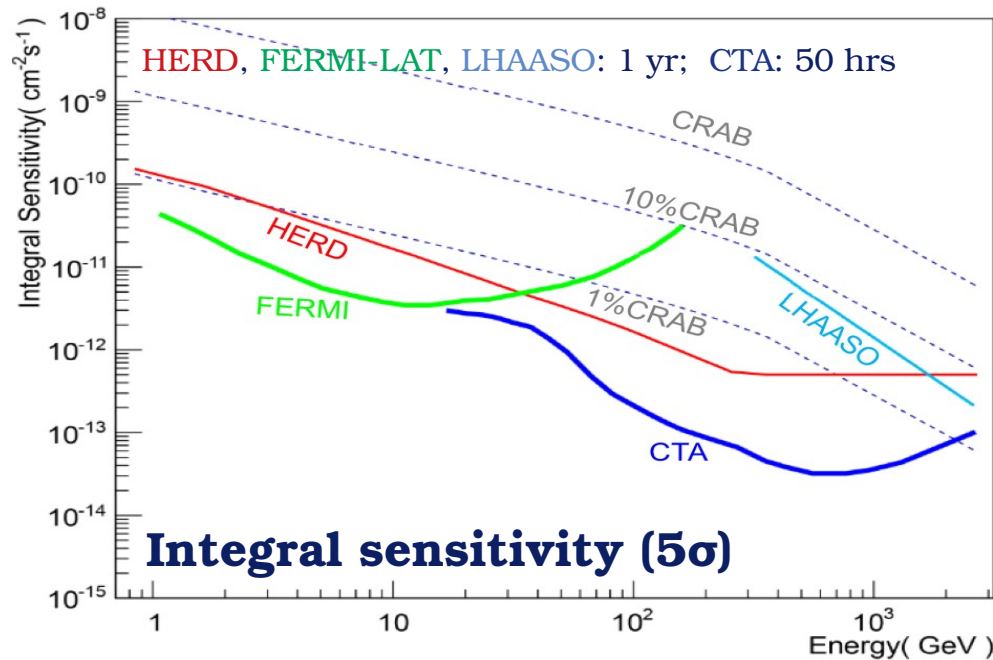
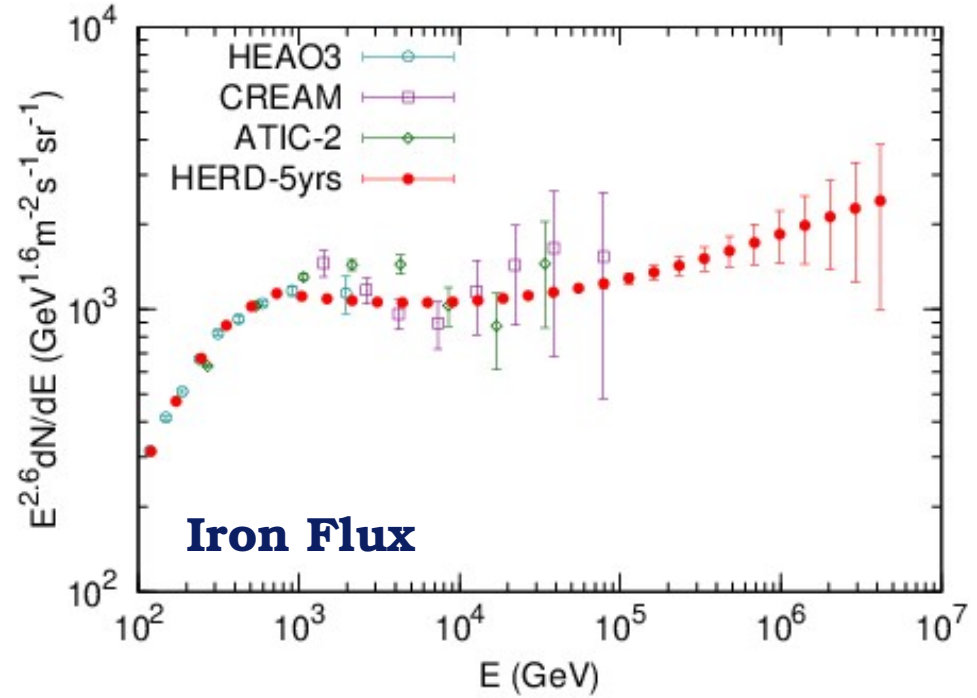
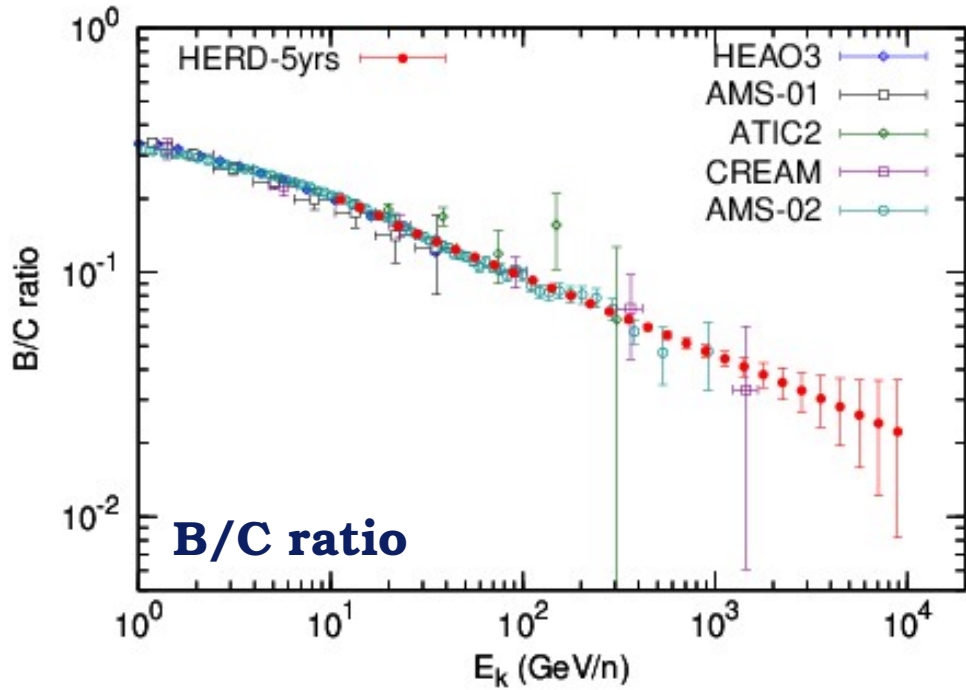
Up to few tens of TeV, with satisfying energy resolution



Gamma - ray Sky Map

5 years of data taking with $E_{\gamma} > 1$ GeV





The HERD consortium includes 130+ scientists from China, Italy, Switzerland, Spain, Germany, Denmark, Sweden, Russia, etc.

Most of the members have been collaborating on previous high energy experiments in science and hardware development.

8 HERD international workshops have been organized in China and Europe since 2012.



The **H**igh **E**nergy cosmic-**R**adiation **D**etector (HERD) has been proposed as one of the prominent space payloads onboard the future China's Space Station (CSS), planned for operation around 2026 with a lifetime of about 5 – 10 years.

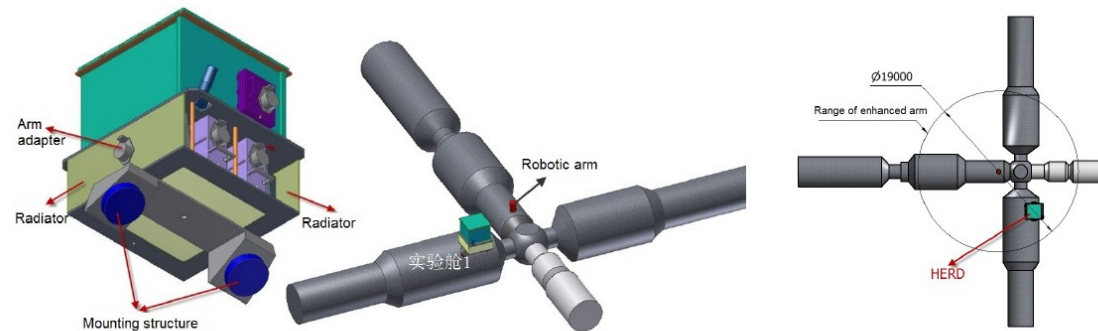
The HERD space mission, presented as a novel approach in high – energy space detectors, will be addressing open problems in fundamental physics and Cosmic Rays.

Its design results in a factor 10 G.F. increase, as opposed to previous missions.

Capable of providing satisfactory particle identification, owing to the 3D calorimeter, structured as an octagonal prism.

In the current configuration, HERD will be able to:

- Provide precise measurements of CR spectra and composition, up to PeV
- Enhance the detection capabilities in HE gamma – ray astronomy
- Search (indirectly) for DM particle signatures



(a) Position of the HERD mounting point

(b) Operation range of the enhanced robotic arm