The High Energy cosmic-Radiation Detection (HERD) Facility onboard China’s Space Station

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on behalf of the HERD Collaboration
High Energy cosmic-Ray Detection facility

• HERD, a China-led mission with a key European contribution led by Italy, is proposed by IHEP as an astronomy and particle astrophysics experiment onboard the China’s Space Station, which is planned for operation starting around 2025 for about 10 years.

• Main Sciences
  – **Dark matter**: Dark matter search with unprecedented sensitivity
  – **Cosmic-ray**: Precise cosmic ray spectrum and composition measurements up to the knee energy
  – **Gamma-ray**: Gamma-ray monitoring and full sky survey
Total e+/− spectrum & DM search

- To confirm ~TeV features in the e+/− spectrum
- To distinguish different origins of excess & features in the e+/− spectrum

(1) 1.4TeV

Four direct meas. with two results!

(2) Spectrum in 10s TeV

(3) Anisotropy
Sensitivity for $\gamma$-line of different experiments

Cosmic-ray Physics

- Space Meas.
  - P
  - He/2
  - C
  - e⁻(or e⁺/⁻)
  - e⁺
  - O/4
  - EGB
- Ground Meas.
  - HESS
  - IceCube
  - Akeno
  - Tibet
  - AGASA
  - HiRes
  - Auger

Limit of Accelerator:

No component measurement yet.

GZK cutoff

E²dN/dE (GeV m⁻² s⁻¹ sr⁻¹)

E (GeV/particle)
Expected HERD Proton and He Spectra

- Well extended to PeV energies
- Critically test any structures between TeV and PeV
- Clearly reveal the knee of light components (Z- or A-dependence)
B/C ratio, ion & super-iron elements

To determine CR propagation parameters and origin of break

To set very stringent limit on super-iron elements
Gamma-ray monitoring & survey

FERMI and ICECUBE discovered a neutrino’s origin as supermassive BLACK HOLE on July 12, 2018

Only one event (<5 sigma) detected. Further neutrino & gamma-ray survey is needed
Gamma-ray sky survey

Expected HERD gamma-ray sky survey sensitivity (5σ)

HERD: 1 year
FERMI/LAT: 1 year
LHAASO: 1 year
CTA: 50 hours (N. FoV)
# HERD specifications

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy range (e/γ)</td>
<td>10 GeV - 100 TeV (e); 0.5 GeV-100 TeV (γ)</td>
</tr>
<tr>
<td>Energy range (CR)</td>
<td>30 GeV - 3 PeV</td>
</tr>
<tr>
<td>Angle resolution</td>
<td>0.1 deg.@10 GeV</td>
</tr>
<tr>
<td>Charge resolution</td>
<td>0.1-0.15 c.u</td>
</tr>
<tr>
<td>Energy resolution (e)</td>
<td>1%@200 GeV</td>
</tr>
<tr>
<td>Energy resolution (p)</td>
<td>20%@100 GeV - PeV</td>
</tr>
<tr>
<td>e/p separation</td>
<td>~10⁻⁶</td>
</tr>
<tr>
<td>G.F. (e)</td>
<td>&gt;3 m²sr@200 GeV</td>
</tr>
<tr>
<td>G.F. (p)</td>
<td>&gt;2 m²sr@100 TeV</td>
</tr>
<tr>
<td>Field of View</td>
<td>+/-70 deg (targeting +/-90 deg)</td>
</tr>
<tr>
<td>Envelope (L<em>W</em>H)</td>
<td>~ 2300<em>2300</em>2000 mm³</td>
</tr>
<tr>
<td>Weight</td>
<td>~ 4000 kg</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>~ 1400 W</td>
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</tbody>
</table>
The novel design of 3-d imaging calorimeter could significantly increase GF, improve particle discrimination and reduce systemic error.
HERD payload

PSD, 6 sides
γ identification
Charge

Tracker, 5 sides
Charge
CR trajectory
γ conv. & tracking

TRD
TeV CR cali.

CALO: 3-D
Energy
e/p separation

~7500 LYSO crystals
(55 R.L, 3 N.I.L.)

Trigger sub-system
Dual readout
with IsCMOS & PD

See also: CRDPOS1-8, 24, 26
Beam test of HERD prototypes

- All key specifications of HERD instruments were tested & verified in the CERN SPS beam tests, with major help from Italy & Switzerland.

CALO prototype (500 LYSO)

1.3%@200GeV e-  

Silicon strips + new ASIC

21.0%@400GeV proton  

HERD prototypes at CERN

TR signals clearly seen

After shower selection

50 GeV e- with radiator
HERD mission concept

- Mission concept
  - Launched with the China-Italy Module and installed on the Module.
  - Periodic calibration is performed every 3-6 months.
  - Several devices are replaced or upgraded every 3-4 years.
  - Telemetry is achieved with the help of relay satellites.
- The HERD proposal was reviewed positively in May 2018 at ASI.
- HERD is written into the joint declaration between China & Italy during the visit of President XI Jinping in March 2019.
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. 7 HERD international workshops have been organized in China and Europe since 2012. 3 CERN beam tests on HERD prototypes have been successfully implemented by Chinese and European colleagues.
Summary

• HERD: Important and frontier scientific objectives in DM search, CR observation and gamma-ray astronomy
  – Confirm & distinguish possible DM and astrophysical origins of excess and features in high-E electron spectrum, and extend the energy range up to >10 TeV
  – Direct measurements of CR composition up to PeV
  – Large acceptance & sensitive high-E γ-ray sky monitoring

HERD will be a flagship and landmark scientific experiment on board the China’s Space Station!

From 2016.09.15 To 2019.07.19

TG-2 spacelab: POLAR

CSS: POLAR-2, CSST, HERD

Thanks!