# High Energy cosmic-Radiation Detection (HERD) Facility onboard China Space Station

# DONG Yong-Wei On behalf of HERD collaboration



## China has started to explore the Extreme Universe



# HERD: High Energy cosmic-Ray Detection facility

- HERD, as a space particle experiment and gamma ray observatory, is a Chinaled large international collaboration with key European contributions led by Italy.
- One of the two flagship scientific experiments onboard China Space Station

Sciences	Extreme topics	Significance	Method
Precise measurement of the cosmic ray electron spectrum and search for high-sensitivity dark matter signals	Extreme origin	Take leading position in the search for space dark matter and make a key contribution to solving one of the most significant astronomical and physical mysteries: the dark matter problem.	Electron features, gamma ray lines
Cosmic ray origin and cosmic ray physics	Extreme energy	Precise & direct cosmic ray spectrum and composition measurements up to the PeV energy, explore the century-old mystery of cosmic ray origin, and combine deep-sea and ground-based multi-messenger observations to make revolutionary breakthroughs in cosmic ray physics.	Composition measurement of nuclei in high energy range
High-sensitivity high-energy gamma-ray sky survey observation and all-sky monitoring	Extreme source	Search and identify gamma-ray corresponding celestial bodies of multi-messenger astronomical signals such as gravitational wave bursts and high-energy neutrinos, understand extreme conditions in the universe, and search for new physical signals such as ultralight particle oscillation effects and Lorentz symmetry breaking effects	Wide FoV, high accuracy gamma ray observation

#### Latest results in electron spectrum



#### Direct measurement of cosmic electron spectrum to highest energy



## Features in electron spectrum from nearby sources?



### Dark matter signals in electron spectrum?



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## High sensitivity in dark matter search



PAMELA: 2006-2016 CALET: 2015-2020; AMS: 2011-2024; DAMPE: 2015-2020; Fermi: 2008-2018; HERD: 2027-

## Origin of cosmic rays



## Expected p and He spectrum (5years, Hoerandel fluxes)



# Direct measurement of CR spectrum to highest energy



### Gamma ray monitoring & survey



#### HERD will be a gamma ray observatory with the largest FoV

#### Acceptance comparison

**Proton Acceptance** 



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## HERD vs. other experiments

Experiment	Energy range(e/γ)	Energy range(p)	Energy res.(e/γ)	Energy res.(p)	e/p sepa.	Acceptan ce(e)m <sup>2</sup> sr	Acceptan ce(p)m <sup>2</sup> sr
FERMI (2008)	1GeV-300GeV	30GeV-10TeV	10%	40%	10 <sup>3</sup>	0.9	<0.28
ISS-AMS02 (2011)	1GeV-1TeV	1GeV-1.8TeV	2%	-	10 <sup>6</sup>	0.12	0.12
ISS-CALET (2015)	1GeV-10TeV	50GeV-10TeV	2%	35%	10 <sup>5</sup>	0.12	
DAMPE(2015)	5GeV-10TeV	40GeV- 100TeV	≤1.5%	25-35%	3*10 <sup>4</sup>	0.3	0.04
HERD(~2027)	10GeV-100TeV 0.5GeV-100TeV(γ)	30GeV-PeV	1%	20%	10 <sup>6</sup>	>3 (10X DAMPE)	>2 (50X DAMPE)

HERD is a next generation experiment, following AMS-02 and DAMPE, with much better performance on direct high energy e, p, gamma-ray detection.

# **HERD** payload



Around 800k reading channels in total



	G.F. (e)	>3 m <sup>2</sup> sr@200 GeV
	G.F. (p)	>2 m <sup>2</sup> sr@100 TeV
r	Energy range (e/γ)	10 GeV - 100 TeV (e); 0.5 GeV - 100 TeV (γ)
	Energy range (p)	30 GeV - 5 PeV
	Charge meas.	Z=1-28; <0.15 c.u.@Z=1
	Energy resolution (e)	1%@200 GeV
	Energy resolution (p)	<25%@100 GeV – PeV
	e/p separation	>3*10 <sup>5</sup> (90% eff.@100GeV)
	Angular resolution	0.1 deg.@10 GeV

# CALOrimeter

- CALOrimeter (3 N.I.L. and 55 R.L.)
  ~7500 LYSO crystals
- From octagon to sphere. +8% acceptance



China, Italy, Spain





# Silicon Charge Detector (SCD)

- Charge measurement
- Features of SCD
  - Located at outmost to avoid ion fragmentation
  - Large detection area
  - Z =1 to 28
- Four superlayers (X&Y) SSDs
- 10 SSDs at most bonded in a row
- Customized SSD and ASIC for large DR





#### 17/24

Italy, China

# **Plastic Scintillation Detector (PSD)**

- Gamma-ray ID.
- Charge measurement
- Basic requirements
  - Full coverage of CALO for LEG trigger
  - Fast veto signal within 200ns
- Geometry of detection unit: Bar and/or tile
  - To reduce impact of backsplash effect
- PS readout by multiple SiPMs for redundancy





#### Italy, Spain, China

# Flber Tracker (FIT)

#### Tracking

Charge measurement

#### Heritage of FIT

- Based on LHCb & Mu3e technology
- Robust design for high coverage ratio
- Diameter of scintillator fiber:~250um
- FIBER MAT is readout by SiPMs
- One fiber MAT includes
  - 2130 scintillating fibers
  - 384 SiPMs



## **Transition Radiation Detector (TRD)**

• Energy calibration of TeV nuclei



China

# **In-orbit Trigger**

- Multi-level trigger strategy
- Sub-detectors divided into multiple regions
- Optimization: Ultra Low Energy Gamma (~100MeV), LE & High Z (~GeV)



China, Spain

#### Joint study of key performances of HERD detectors

• 5 rounds of CERN beam tests were carried out (from 2015 to 2022).



# HERD consortium

- The HERD consortium includes ~200 scientists from China and Europe.
  - Most of the members have been collaborating on previous high energy experiments in science and hardware development.
- 8 international workshops (in person) have been organized in China and Europe since 2012.
- 5 CERN beam tests on HERD prototypes have been successfully implemented by Chinese and European colleagues.
- Managing structure: Institution Leaders Board; Technical Executive Board; Publication Board

	Participating institutions
Payload Module	IHEP
CALO	IHEP, XIOPM, NNVT, CMBA; INFN Florence; CIEMAT
SCD	INFN Perugia, INFN Torino, etc.; IHEP, PMO
FIT	Univ. of Geneva, EPFL; ICCUB
PSD	INFN Bari, INFN Pavia, INFN Lecce, GSSI, etc.; ICCUB, IFAE; IHEP
TRD	GXU, CCNU, IMP
Trigger	IHEP, CIEMAT, IFAE, etc.
Ground calibration	IHEP, GXU, INFN sections, Univ. of Geneva, CERN
Science center	IHEP, SDU, ASDC & INFN-CNAF (Italy)
Sciences	IHEP, PMO, USTC, YNO, NAOC, SDU, GXU, TSU, PKU, NJU, YNU, SWJTU, HKU, Academia Sinica, and institutions from Italy, Switzerland, Spain, etc.



# **General progress**

- Successfully reviewed by the the joint review meeting organized by ASI and CSU of CAS in May 2018.
- The HERD experiment is written into the joint declaration between China & Italy in March 2019.
- Reviewed by Ministry of Finance (mandated by CMSA) in 2021
  - 1<sup>st</sup> in scientific merits and technical feasibility, full budget allocated.





# **General progress in China**

- Construction of China Space Station (CSS) has been completed in 2022.
- HERD will be carried to CSS by the Multi-Functional Module (MFM) in 2027.
- General payload-level design jointly performed by CSU and IHEP is completed.
  - Conceptual layout design with ergonomics consideration
  - Preliminary design on mechanical, thermal, electronics, data flow...
  - Payload AIT
- Study of key technologies and specifications is completed.



#### We look forward to HERD in space! Thanks!