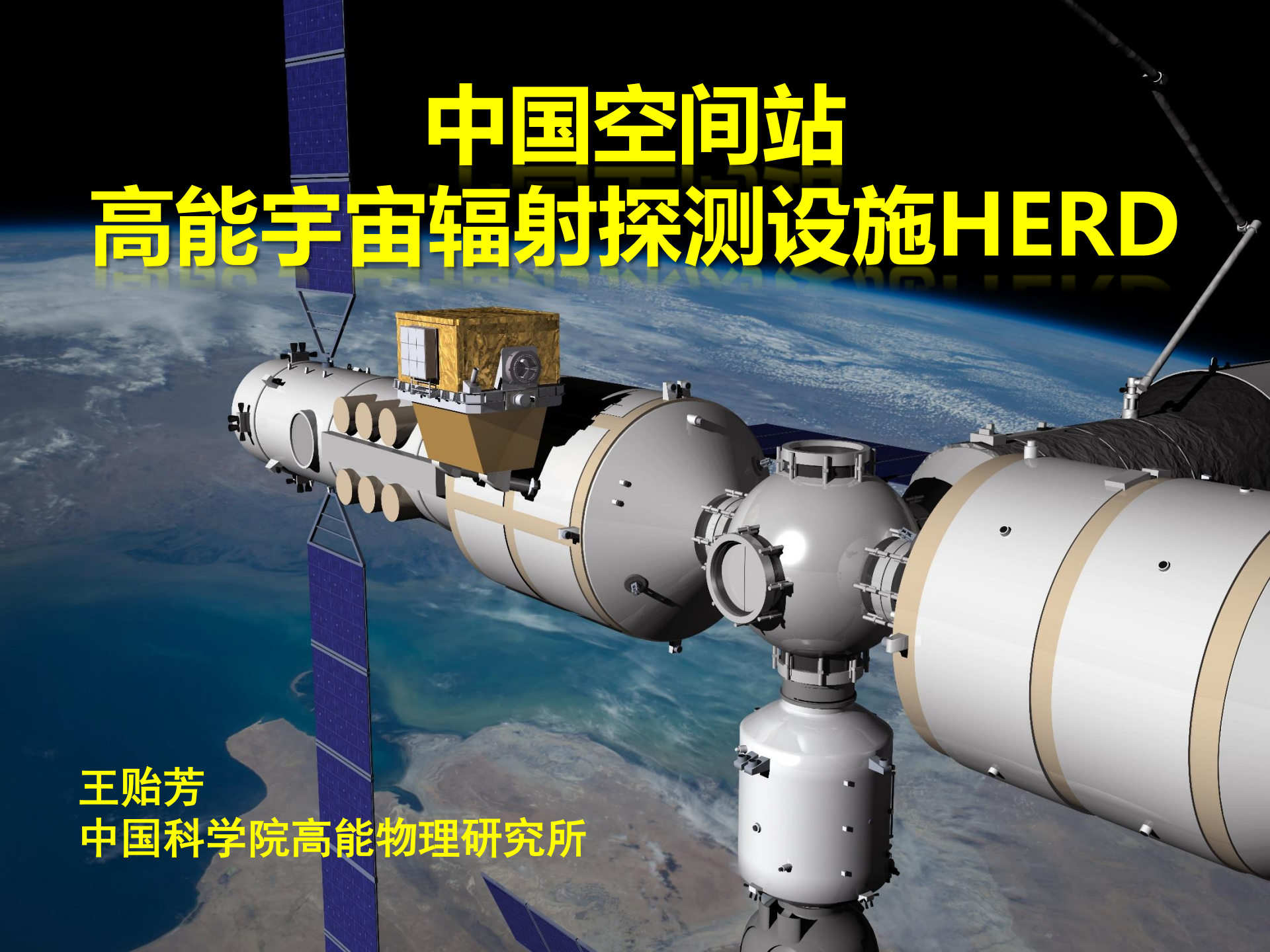


# 中国空间站 高能宇宙辐射探测设施HERD

王贻芳  
中国科学院高能物理研究所



# 中国空间站高能宇宙辐射探测设施HERD

HERD项目是空间天文和粒子天体物理实验，预计在中国空间站上运行10年以上。HERD采用三维位置分辨、五面灵敏的创新设计，核心科学能力将长时间保持大幅度国际领先，将成为中国空间站标志性的旗舰级重大科学实验和具有国际影响的大型国际合作项目。

## ■ 核心科学目标

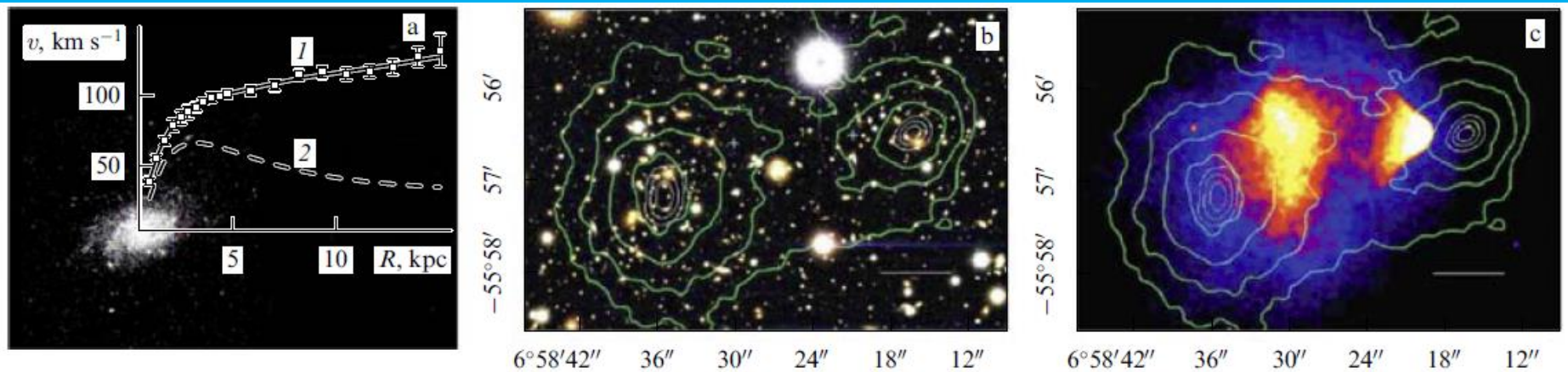
- 以前所未有的灵敏度搜寻暗物质，保证中国占领空间暗物质搜寻的制高点，为解决天文和物理的最重大疑难之一暗物质问题做出关键贡献
- 探究宇宙线起源的世纪之谜，可望在宇宙线物理上取得革命性的突破
  - 首次直接精确测量“膝”区宇宙线能谱和成分

## ■ 天文台科学目标

- 以前所未有的大视场开展高能伽马射线巡天和监视
  - 牵引国际高能天体物理界的重要科学发现，理解宇宙极端条件物理
- 通过多颗脉冲星同时观测探索脉冲星导航的新体制
  - 首次实现同时对全天大部分脉冲星的几乎无间断高信噪比监测

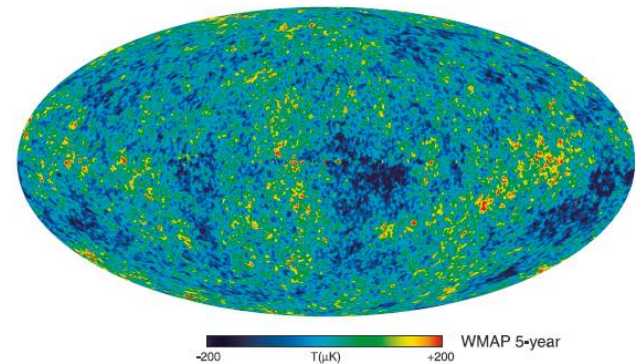
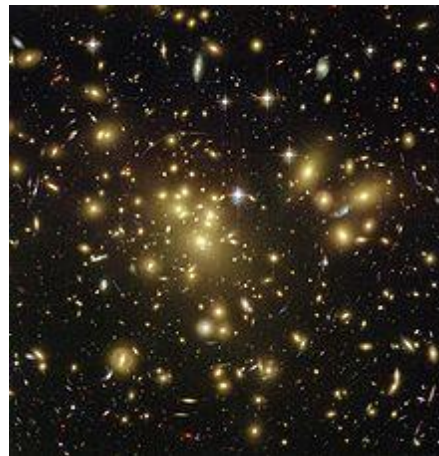


# 暗物质之谜



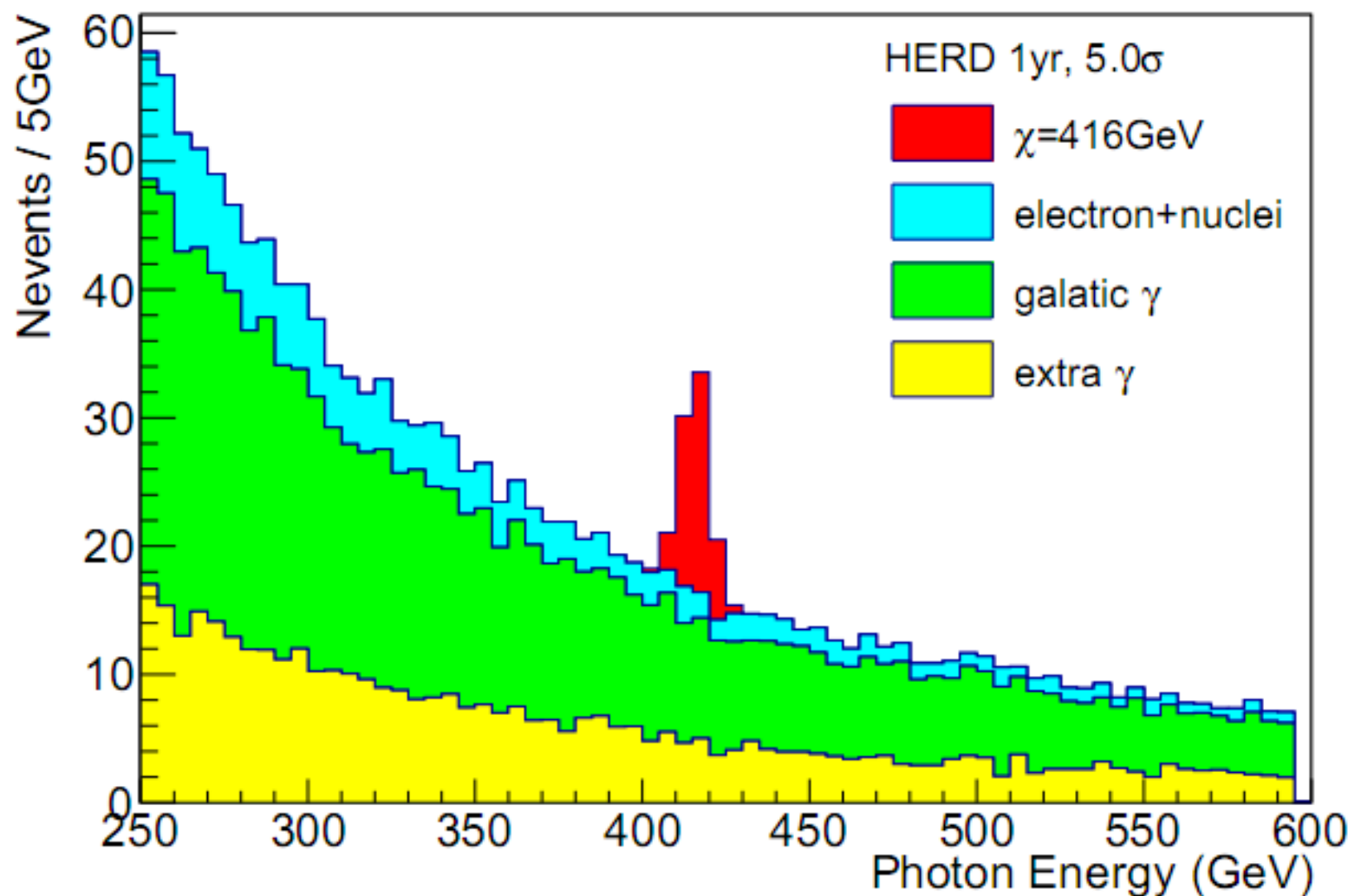
**Figure 2.** (a) Rotation curves for the M33 galaxy [4]: 1, the observed curve, 2, theoretical curve of the glowing galactic disk. (b) Optical and (c) X-ray images of cluster 1E0657-558 obtained with the Hubble and Chandra telescopes, respectively. The curves show mass density contours reconstructed by gravitational lensing [5]. Horizontal axes are the inclination angles, vertical axes are the ascension angles.

- 暗物质确实存在
- 宇宙暗物质和普通物质的比例是大约6:1，但是还没有发现暗物质粒子。



**Figure 12.** The foreground-reduced Internal Linear Combination (ILC) map based on the five year WMAP data.

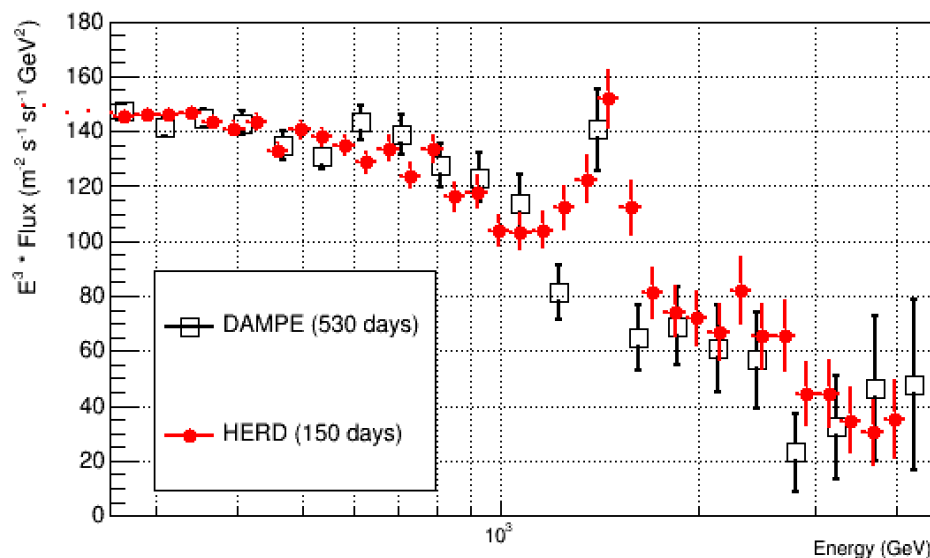
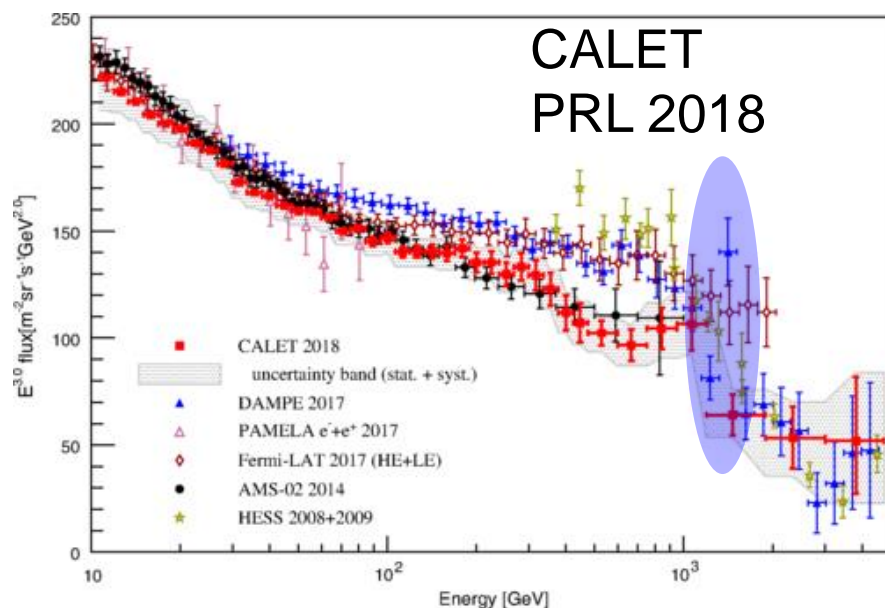
# 模拟的HERD暗物质粒子湮灭线测量结果



HERD具有发现暗物质湮灭信号的可靠途径

# HERD将能够解决悟空的“尖峰”争议

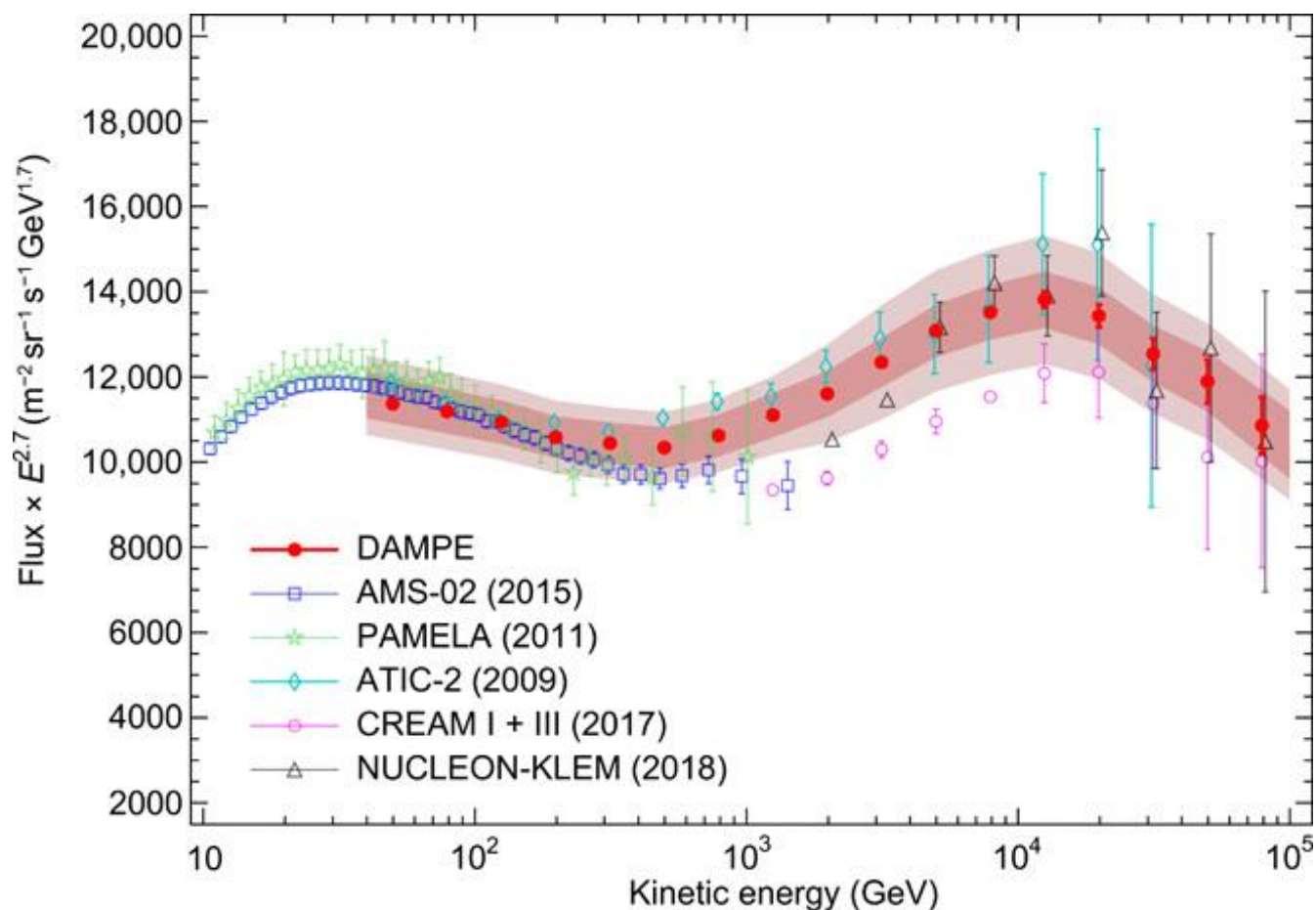
- 日美CALET观测结果与中国悟空卫星 1.4 TeV疑似“暗物质”尖峰显著矛盾，HERD可以给出正确判断。



虽然其精度还不如悟空，但是国际空间站日美CALET实验声称以4倍标准偏差“排除”了悟空的“尖峰”？**需要第三方独立实验高精度测量！**

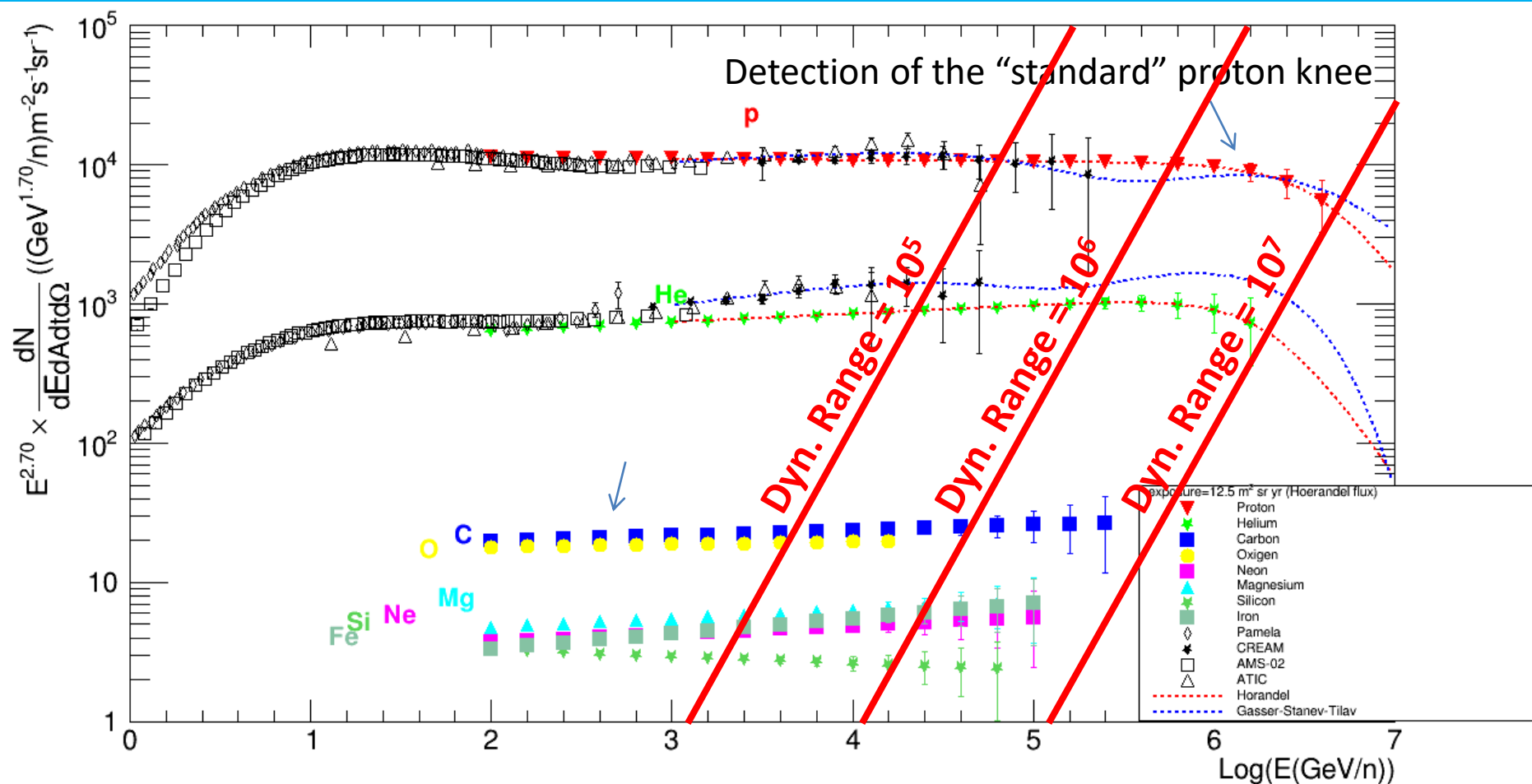
HERD上天半年以内就可以看到  $5\sigma$  的信号，如果悟空的电子谱高能“尖峰”是暗物质信号

# 悟空等空间高能粒子实验最新结果



悟空卫星发表了最高精度的宇宙线质子能谱，然而不同实验在500GeV以上的观测结果存在明显差异。需要高精度判决！

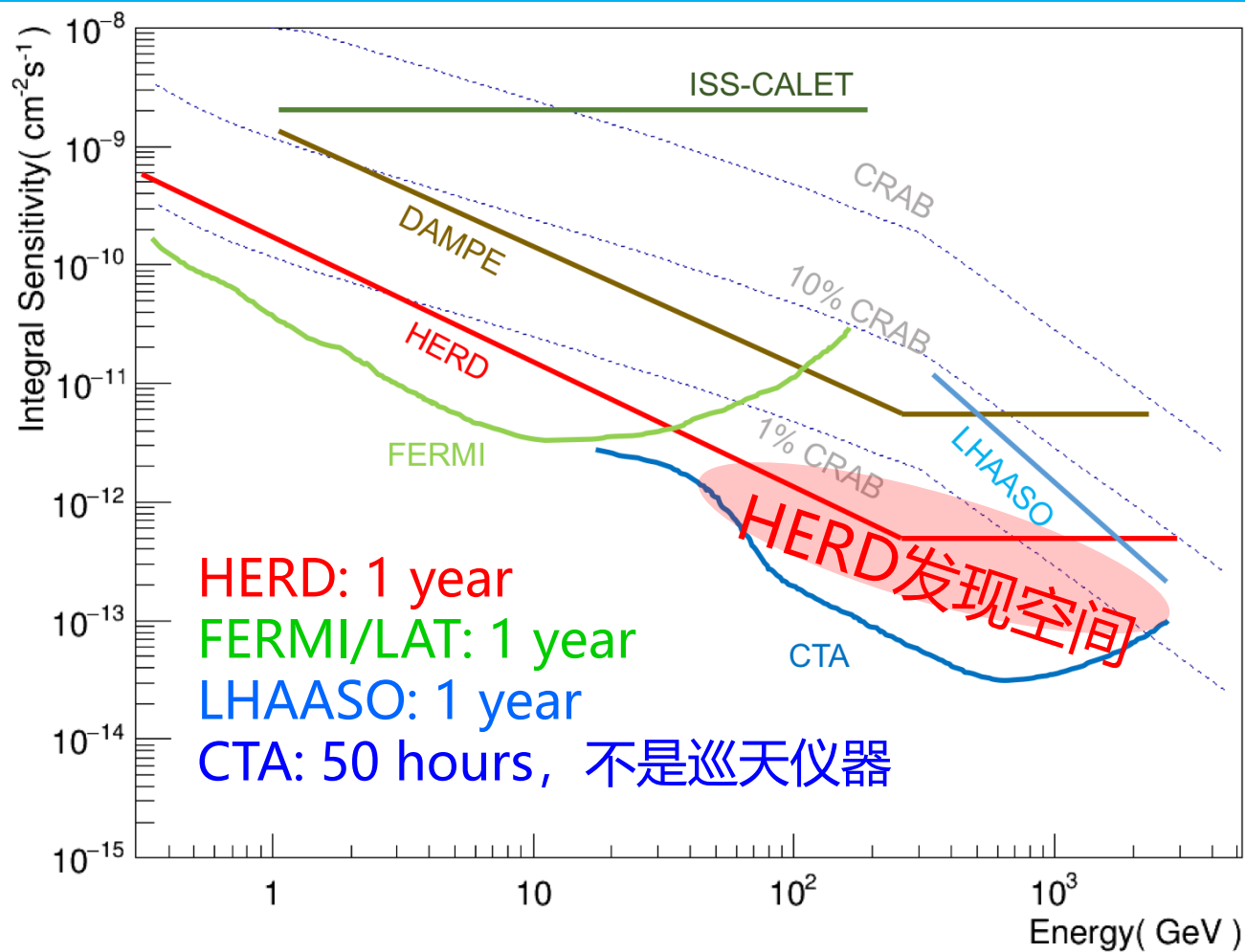
# 大范围高能量宇宙线成分直接测量 (五年预期)



HERD的大接收度和高能区对理解宇宙线起源至关重要！



# HERD将成为最大视场的伽马射线天文台



天体物理成为诺奖热点领域（近20年七次获奖，近4年三次）



# 重要科学成果规划

- **一年“快”成果：**解决能量高达 $10^{10}$  keV电子和 $10^{11}$  keV质子的能谱特征的争议，对“暗物质”做出严格约束
- **三年“大”成果：**最高精度的高能电子和宇宙线成分测量
- **五年“巡天”成果：**最高统计量的高能电子各向异性、高能伽马弥散辐射、高能伽马谱线（暗物质湮灭）
- **十年“无人区”成果：**能量高达 $10^{12}$  keV高能质子“膝”的直接测量，各种宇宙线成分的最高能量直接测量
- **从头至尾“即时”成果：**与空间站POLAR-2配合，将伽马射线暴的能区从 $1-10^3$  keV扩展到 $10^6$  keV以上；前所未有的大视场伽马变源监视，高能中微子和引力波爆发协同研究；多脉冲星同时观测，探索脉冲星导航新体制。（美国费米伽马射线天文台2008年发射，重要成果至今仍然不断涌现）

# HERD总体任务方案

去年11月开始在9办领导下与五院等优化迭代：

- HERD及其转接机构通过货运飞船上行。
- 货船与空间站对接后，机械臂将载荷取出转运至舱I舱外挂点完成有效连接，开展连续在轨观测。

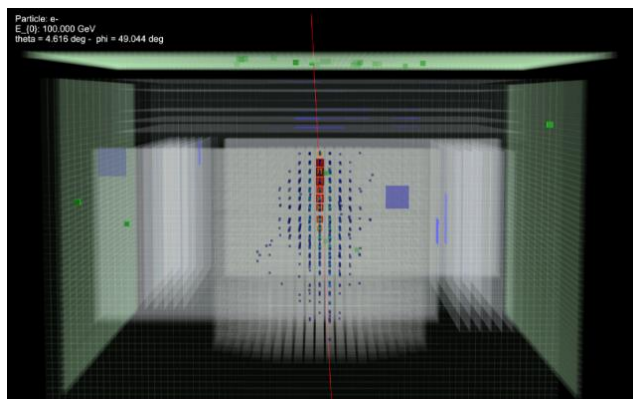


HERD转运安装示意

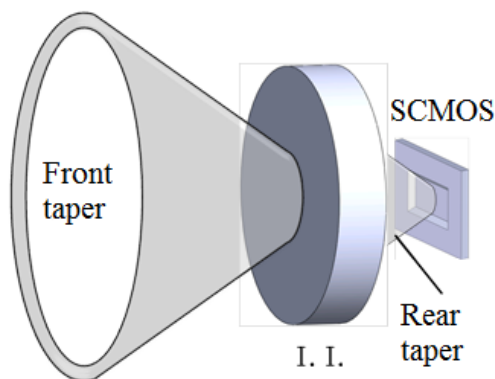
载荷总重：3吨以内  
载荷包络： $\sim 2.6 \times 2.2 \times 3.0 \text{ m}^3$   
载荷视场： $\pm 90^\circ$   
载荷功耗： $\geq 1000 \text{ W}$   
测控数传：100 Mbps(平均)  
工作寿命：10年以上  
航天员需求：协助安装、更换  
舱外液冷回路需求：有  
舱外应用信息系统需求：有

# 中国提出的创新方案

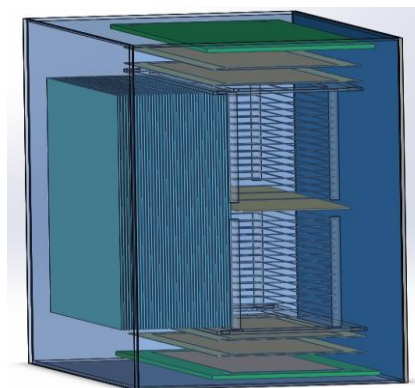
- 中国提出、得到验证并且被国际同行接受的创新方案
  - 三维成像、五面灵敏量能器概念
    - 以较少的资源实现世界领先的接收度；显著提升几何因子，改善粒子鉴别能力，系统误差更小，实测结果更可靠
  - 光纤+增强相机读出：系统简单，便于晶体热控
  - 穿越辐射探测器：TeV以上粒子在轨标定，保证数据可靠



高能粒子簇射



增强相机



共腔穿越辐射探测器

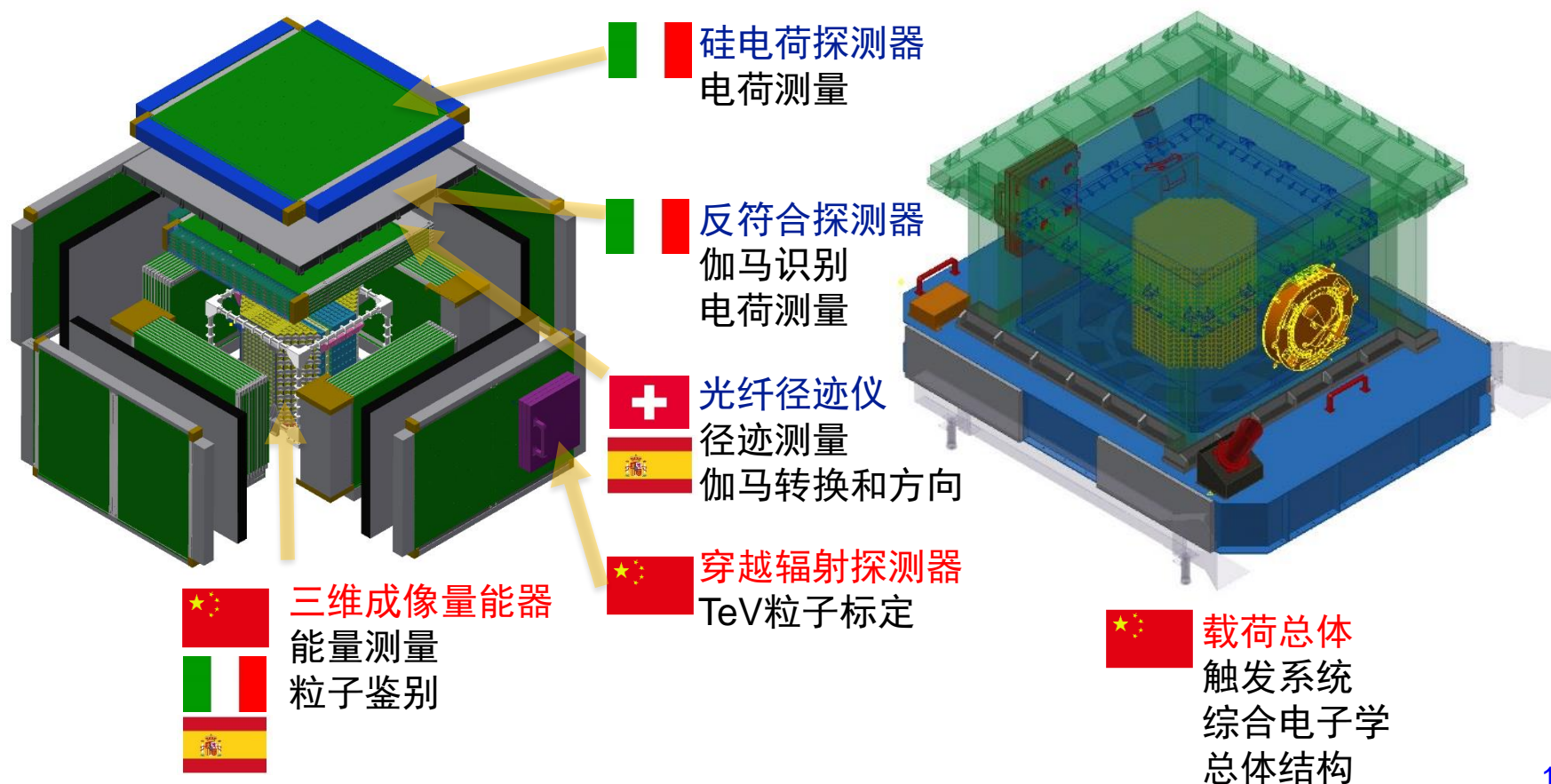
# 各空间实验主要性能参数对比

实验 (运行时间)	探测能区(e/ $\gamma$ )	探测能区(p)	能量分辨 (e/ $\gamma$ )	能量分辨 (p)	e/p鉴别	电子接收 度m <sup>2</sup> sr	质子接收 度m <sup>2</sup> sr
美国卫星 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	--
中国悟空卫星 DAMPE(2015)	5GeV-10TeV	40GeV- 100TeV	$\leq 1.5\%$	25-35%	3*10 <sup>4</sup>	0.3	0.04
中国空间站 HERD(~2025)	10GeV-100TeV 0.5GeV-100TeV ( $\gamma$ )	30GeV- PeV	1%	20%	10 <sup>6</sup>	>3	>2

HERD是国际空间站AMS和悟空卫星的后续项目，科学性能有显著提升，重量不到AMS的一半，只比其它实验略重。

# 载荷实施方案：中欧各贡献~1/2

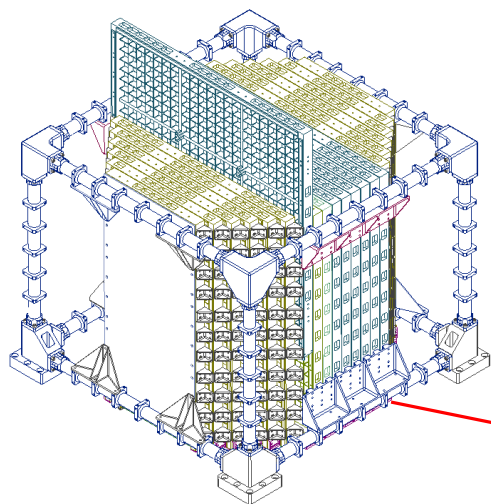
- HERD有效载荷包含五种仪器，从内而外分为三维成像量能器CALO、光纤径迹仪FIT、反符合探测器PSD、硅电荷探测器SCD和穿越辐射探测器TRD。



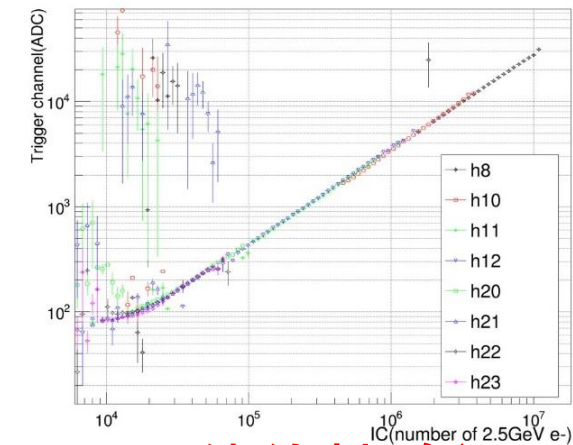
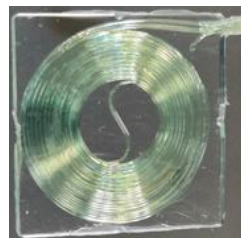
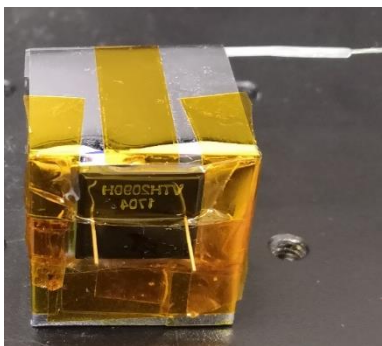


# 三维成像量能器CALO：中方为主

## ■ 能量测量，粒子鉴别



7500块  
LYSO晶体  
3核作用长度  
55辐射长度



晶体线性验证 1:1布局样机



晶体阵列

中科院高能所

触发系统

中科院高能所

高、低量程  
增强相机

中科院西光所

PD读出系统

意大利、西班牙

增强相机每三年需要在轨更换

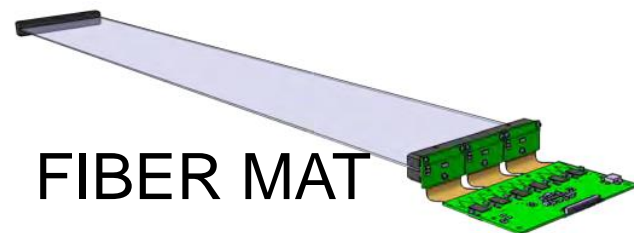
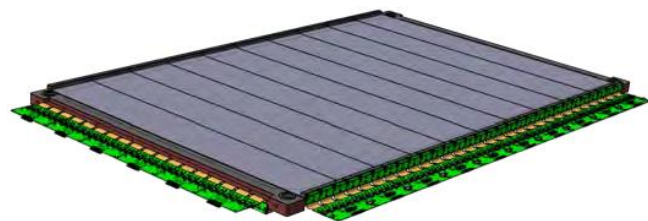
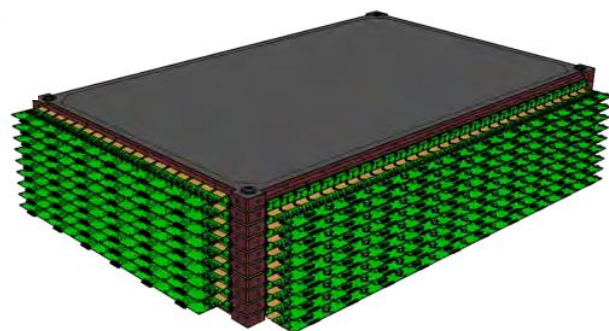
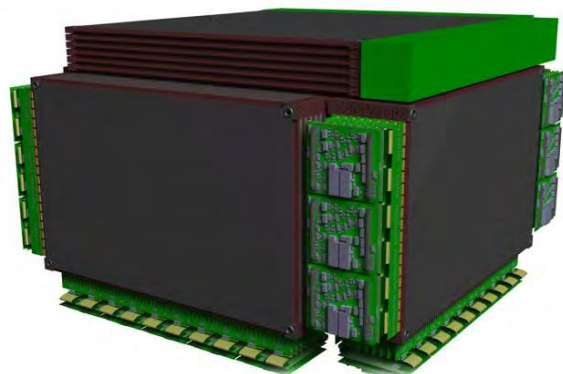
# 光纤径迹仪FIT：瑞士、西班牙

- 伽马径迹测量
- 粒子方向
- 电荷测量

- 光纤径迹仪特点

- 地面LHCb和Mu3e实验成熟技术
- 设计更灵活，便于实现高覆盖率
- 兼具电荷测量能力
- 闪烁光纤直径~250微米
- 每个FIBER MAT由SiPM阵列读出
- 瑞士日内瓦大学牵头，西班牙ICCUB负责ASIC芯片

瑞士、西班牙



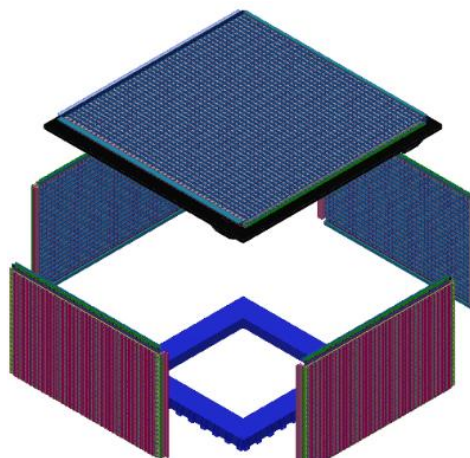
# 塑闪反符合探测器PSD：意大利

- 低能伽马识别
- 电荷粗测

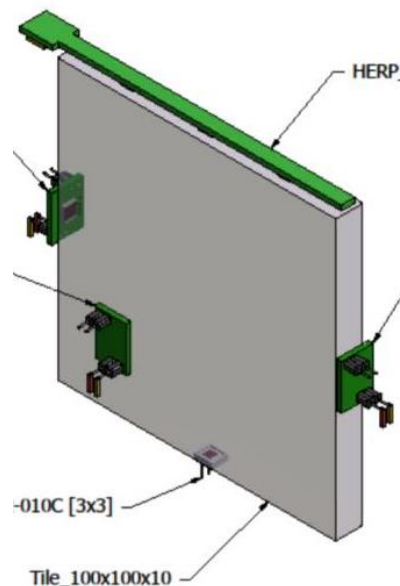
- 反符合探测器特点

- 对量能器全覆盖，识别低能带电粒子
- 快响应，200纳秒内提供触发信号

- 塑闪长条Bar方案 或 塑闪方块tile方案
- 多片SiPM读出，保证电荷测量和备份
- 意大利INFN多家分部联合研制



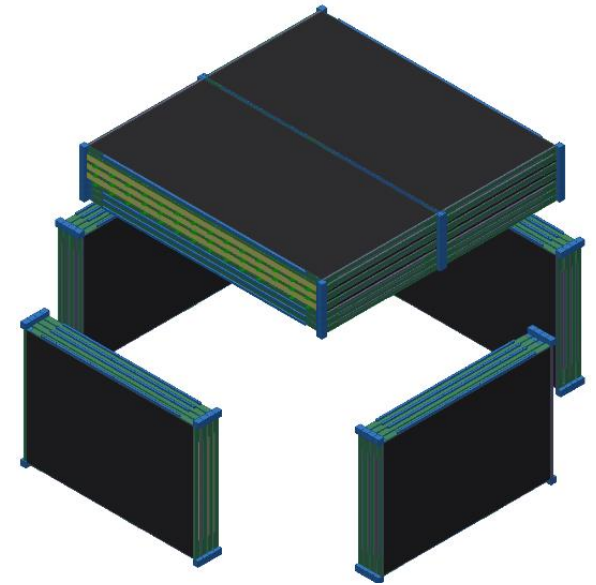
意大利



# 硅电荷探测器SCD：意大利

- 功能：电荷测量
- 硅电荷探测器特点
  - 位于载荷最外层，避免电荷碎裂
  - 覆盖面积大，近2米\*2米
  - 电荷测量能力达铁核以上
- 单面硅微条探测器SSD（每片9.5\*9.5cm）串联，最长串联10片
- SSD定制设计，满足大动态
- 定制ASIC芯片，满足大动态
- 意大利INFN佩鲁贾牵头，INFN都灵负责ASIC芯片

意大利



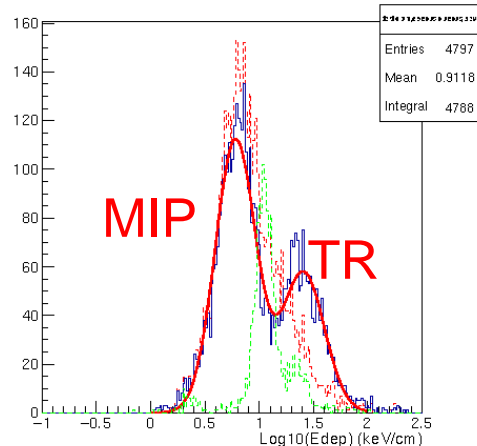
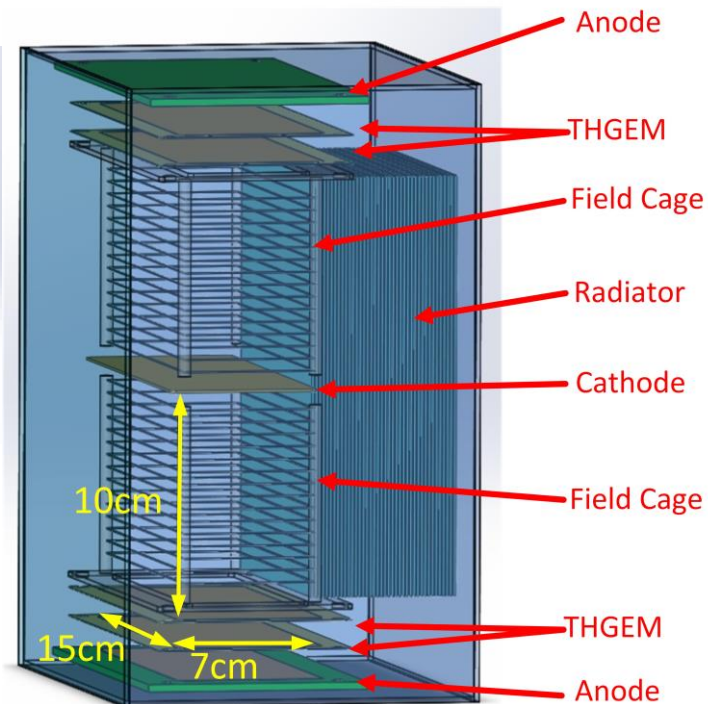
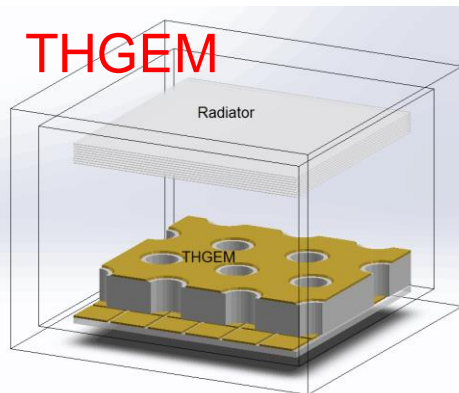
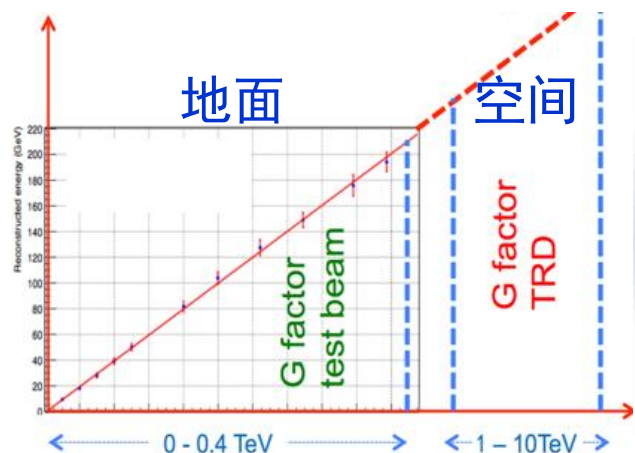
DAMPE STK ladder



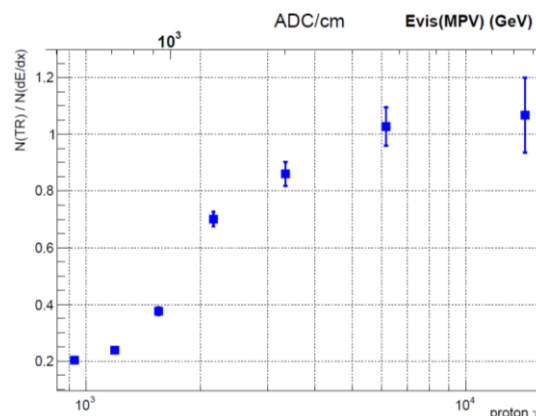
# 穿越辐射探测器TRD：中方

■ 功能：TeV核子绝对能标

广西大学



MWPC energy response to [2.25, 2.5] TeV protons



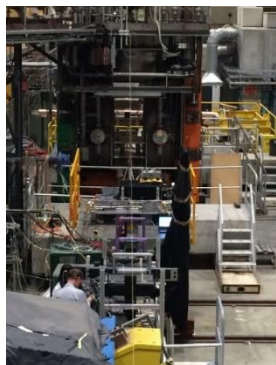
2 months simulated observation,  $\sim 6300\text{ cm}^2$ .

闭气共腔Side-on  
型穿越辐射探测器

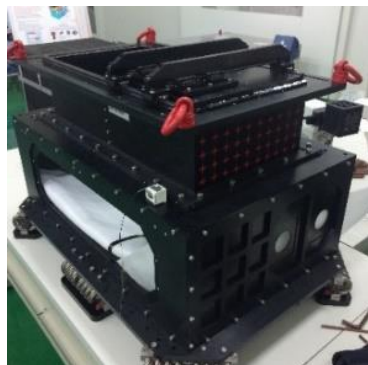


# 国内外发展状况和研制基础

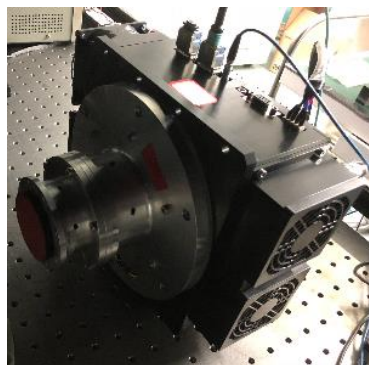
- 合作组全面参加了AMS实验和悟空卫星的研制及科学研究
- 国际合作组于2015-2018年**共三次**在欧洲核子中心进行了束流试验，验证了创新方案和工艺的原理可行性。



束流实验现场



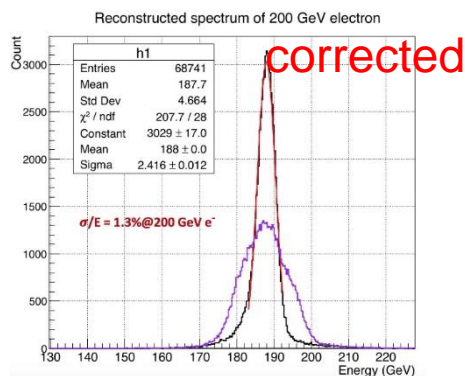
500块晶体阵列



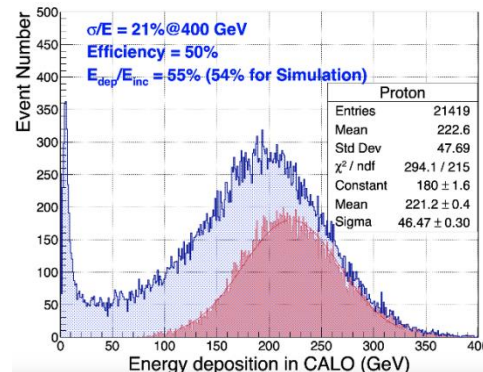
增强相机



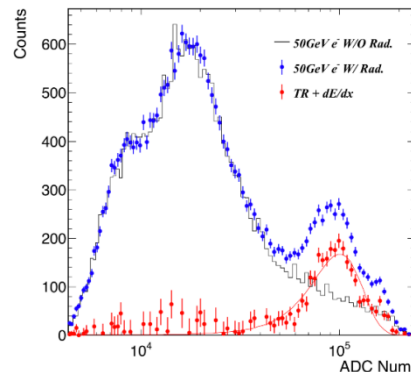
穿越辐射探测器



1.3% @ 200 GeV  $e^-$



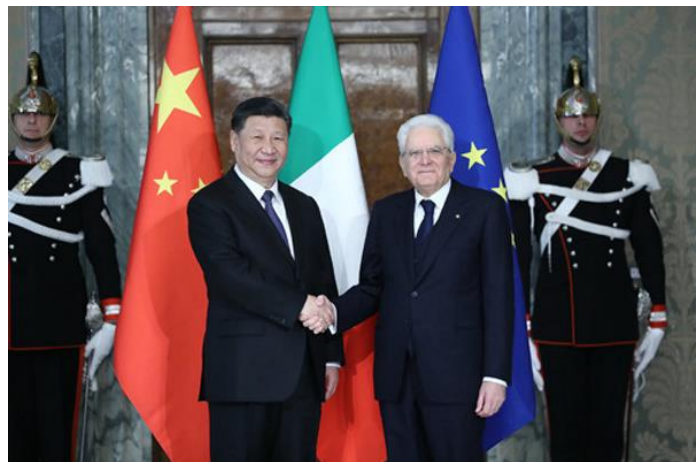
20.7% @ 400 GeV P



穿越辐射探测器信号

# HERD项目得到了中意高层的肯定

- 2018年5月，HERD项目建议书顺利通过由意大利空间局和中国科学院空间应用总体部组织的联合评审。
  - 评审组一致认为HERD致力于解决前沿科学问题，其科学目标独一无二，载荷方案满足需求，国际合作方案切实可靠
- 2019年3月，HERD列入《中华人民共和国和意大利共和国关于加强全面战略伙伴关系的联合公报》。
  - 第十七条：“中国载人航天工程办公室和意大利空间局正在...探讨联合开展高能宇宙辐射探测（HERD）等空间科学实验”。



# 国内、国际研发支持

- 中科院国际大科学计划“培育”项目和基金委重大仪器专项（自由申请）项目执行中、科技部重点研发专项列入指南
- 2018-2019年，由中科院空间应用中心牵头，向科技部申请“探索极端宇宙”国际大科学计划和培育专项。国内40家、国外12家科研院校响应并发函支持。
- 欧洲团队和领导机构来函支持科学家参加HERD项目。
  - 意大利空间局、意大利核物理研究院INFN和多个分部，HERD欧方PI
  - 西班牙能源环境研究中心CIEMAT、西班牙高能物理研究所IFAE、西班牙宇宙科学研究所ICCUB
  - 瑞士空间办公室、瑞士日内瓦大学

# 意大利空间局和意大利INFN支持信函



To: Prof. Ming GAO  
General Director of CSU

Subject: the mission HERD at ASI

Dear Prof. Ming GAO,

with the present letter I have the pleasure to confirm the great scientific interest of the Italian Space Agency in the HERD mission.

The valuable scientific merit of the HERD mission was assessed in May 2018, when the Italian Space Agency hosted the Joint Review Meeting on HERD Proposal, organized in collaboration with CSU and actively participating to the review process with a board of prominent experts appointed by the Agency itself.

The joint ASI-CSU board provided a very positive outcome on this mission, strongly recommending the prompt involvement in the next phases of the mission in view of its adoption.

Since the completion of the review, ASI is continuously updated on the status of the HERD mission and the related advances in the payload design by the Italian scientists participating in the phase A study, and we are pleased to learn that HERD has been recommended as one of the two top priority experiments on the China Space Station in the discipline of Astronomy and Astrophysics.

Given the scientific value of the mission, the great interest in the mission by a large Italian Scientific Community with a long-standing experience on cosmic-rays physics with space detectors, as well as the programmatic progress in the HERD mission, ASI is willing to consider the support to the next phases of the project, subject to final budget allocation as well as scientific and cost reviews.

With my best regards,

Negri Maria  
Barbara

Barbara Negri

Head of the Exploration and Observation of the Universe Division

at the Italian Space Agency



Dr. Oliviero Cremonesi  
Piazza della Scienza, 3  
20126 Milano Italy

Subject: the mission HERD at INFN

Dear Dr. Shuang-Nan Zhang,

with the present letter I have the pleasure to confirm the great scientific interest of INFN and in particular of the National Astroparticle Physics Scientific Committee (2<sup>nd</sup>) on the HERD project.

A large community of physicists and engineers (currently about 70 people from 10 INFN sections) with a long standing experience on cosmic rays physics with space detectors is active on the HERD project.

INFN has financed the HERD project with about 700 k€ in the last two years, and a budget of the same amount to support the activities in 2021 will be discussed in our yearly review meeting in two weeks.

Although no final financial commitment has been defined yet, it is a clear will of the INFN community and the INFN management to give an important contribution to the HERD project.

Milano, Sep. 2<sup>nd</sup>, 2020

Dr. Oliviero Cremonesi  
(Chair of INFN Committee 2 - Astroparticle Physics)



# 西班牙CIEMAT、IFAE和ICCUB支持信函



Prof. Shuang-Nan Zhang  
Division for Particle Astrophysics  
Institute of High Energy Physics  
Chinese Academy of Sciences  
Beijing 100049, China

Madrid, 7<sup>th</sup> September 2020

Dear Prof. Shuang-Nan Zhang,

It has been brought to our attention that the High Energy cosmic-Radiation Detection (HERD) facility has been recently recommended as a top priority experiment for the China's Space Station (CSS). It is our pleasure to confirm the strongest scientific and technological interest of the participating Spanish institutions, and, in particular, of the *Centro de Investigaciones Energéticas Medioambientales y Tecnológicas* (CIEMAT).

CIEMAT is the largest Spanish Public Research Organization in the field of energy and environment. CIEMAT employs about 1,400 people and has become the reference center not only in the energy field, but also in some specific fields of basic research in Spain, one of them being Experimental Particle and Astroparticle Physics.

CIEMAT has collaborated with the Institute for High Energy Physics of the Chinese Academy of Sciences (IHEP) for more than 30 years in forefront scientific experiments of Particle Physics (L3 experiment at LEP accelerator, CERN) and Astroparticle Physics (AMS experiment onboard the International Space Station) to accomplish fundamental research in particle physics and cosmology. Our successful scientific and technological endeavor with IHEP has been further strengthened with the participation in HERD of a team of CIEMAT physicists and engineers since 2017 with the support of the Spanish Space Program.

It is our judgement that HERD is a unique research facility to tackle fundamental physics problems from space such as the nature of dark matter, the Galactic cosmic ray accelerators and the high energy gamma ray sky.

We express our strong interest in continuing CIEMAT participation in HERD and to foster our technological and scientific contribution in the framework of an international collaboration.

  
Prof. Nicanor Colino

Director Department of Basic Research CIEMAT Head Astroparticle Physics Division CIEMAT



  
Prof. Javier Berdugo



Edifici Cn Universitat Autònoma de Barcelona  
E-08193 Bellaterra (Barcelona) Spain  
[www.ifae.es](http://www.ifae.es)

Prof. Shuang-Nan Zhang  
Division for Particle Astrophysics  
Institute of High Energy Physics  
Chinese Academy of Sciences  
Beijing 100049, China

Dear Prof. Shuang-Nan Zhang,

It has been brought to my attention that the High Energy cosmic-Radiation Detection (HERD) facility has been recently recommended as a top priority experiment for the China's Space Station (CSS). It is my pleasure to confirm the strongest scientific and technological interest of the *Institut de Física d'Altes Energies* (IFAE), in Barcelona, Spain.

IFAE ([www.ifae.es](http://www.ifae.es)) conducts experimental and theoretical research at the frontier of fundamental physics, namely in Particle Physics, Astrophysics and Cosmology, since 1992. IFAE also works at the cutting edge of detector technology, applying its knowhow to Medical Imaging and other applied research fields. IFAE has obtained twice (periods 2013-2016 and 2017-2020) the Severo Ochoa award granted by the Spanish government to a few leading national research centers, and it is one of the founding centers of the Barcelona Institute for Science and Technology (BIST, [www.bist.eu](http://www.bist.eu)). IFAE is one of the leading research institutes in the young field of Gamma-ray Astronomy, having constructed and operated several critical hardware components of the MAGIC and CTA telescopes, and leading several of the highest-impact scientific results in the research field.

Since 2018, we have been supported by the Spanish Space Program to conduct prospective studies for the participation of IFAE in a next-generation gamma-ray space mission. Those studies have led IFAE to start a participation in HERD, with the aim of assessing and optimizing the capabilities of the detector for gamma-ray astronomy. We plan to request the Spanish Space Program for further funds to continuing, completing and expanding this activity, as well as to participate in the R&D activities leading to the construction of those hardware components of the detector crucial for gamma-ray detection.

It is our judgment that HERD is a unique research facility to tackle fundamental physics problems of our interest, such as the nature of dark matter, the Galactic cosmic ray accelerators and the high-energy gamma ray sky.

We express our strong interest in consolidating IFAE's participation in HERD and we seek to make technological and scientific contributions in the framework of an international collaboration.

Barcelona, September 10<sup>th</sup> 2020



Dr. Ramon Miquel  
Director, IFAE



Institut de Ciències del Cosmos  
UNIVERSITAT DE BARCELONA

Institut de Ciències del Cosmos  
Facultat de Física  
C. Martí i Franqués, 1  
08028 Barcelona  
Tel. +34 934 021  
[secretaria@icc.ub.edu](mailto:secretaria@icc.ub.edu)  
<http://icc.ub.edu/>

Prof. Shuang-Nan Zhang  
Division for Particle Astrophysics  
Institute of High Energy Physics  
Chinese Academy of Sciences  
Beijing 100049, China

Dear Prof. Shuang-Nan Zhang,

It has been brought to my attention that the High Energy cosmic-Radiation Detection (HERD) facility has been recently recommended as a top priority experiment for the China's Space Station (CSS). It is my pleasure to confirm the strongest scientific and technological interest of the participating Spanish institutions, and, in particular, of the Institute of Cosmos Sciences of the University of Barcelona (ICCUB, <http://icc.ub.edu/>).

The University of Barcelona (UB) was founded in 1450. Today it boasts of a student body of about 63,000 and a research staff of 5,600 members. Degrees are offered in 73 different areas of teaching with numerous postgraduate and doctorate programs as well as continuing education courses. The UB is the largest of the six universities of Barcelona and of the ten in Catalonia. The UB is ranked the first Spanish university, and the twenty third European institution in scientific quality and productivity. The ICCUB is an interdisciplinary center devoted to fundamental research in the fields of cosmology, astrophysics and particle physics. In addition, the institute has a strong technology program through its participation in international collaborations in observational astronomy and experimental particle physics.

ICCUB is collaborating with the Institute for High Energy Physics of the Chinese Academy of Sciences (IHEP) in forefront scientific experiments as HERD, or LHCb detector at CERN. The ICCUB is also involved in important space missions, as Gaia, Solar Orbiter, Ariel and LISA, and in ground-based gamma-ray instruments as MAGIC and CTA.

A team of ICCUB physicists and engineers is participating in HERD project since 2018 with the support of the Spanish Space Program. It is our judgement that HERD is a unique research facility to tackle fundamental physics problems from space such as the nature of dark matter, the Galactic cosmic ray accelerators and the high energy gamma ray sky. The ICCUB researchers involved in Dark Matter studies will certainly benefit HERD unique data. Also, HERD, as wide FoV gamma ray observatory, will be a crucial instrument for high energy astrophysicists in ICCUB. A replacement for FERMI will soon be needed, particularly when the CTA observatory becomes operative. From the technological point of view, the ICCUB is collaborating with the University of Geneva

UNIVERSITAT DE  
BARCELONA



# 瑞士空间办公室和日内瓦大学支持信函



Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs,  
Education and Research EAER  
State Secretariat for Education,  
Research and Innovation SERI  
Swiss Space Office

CH-3003 Bern, SERI

Prof. Shuang-Nan Zhang  
Institute of High Energy Physics  
Chinese Academy of Sciences  
Beijing 100049  
China

Unser Zeichen: SBFI-D632.12-PRX/11/1  
Referenz/Aktenzeichen: SBFI-D-E13D3401/134  
Sachbearbeiterin: Valerie Koller  
Bern, 29.09.2020

**Letter of Awareness – Swiss contribution to the proposed High Energy Radiation Detection (HERD) facility on board the China Space Station**

Dear Prof. Shuang-Nan Zhang,

The Swiss Space Office (SSO) is pleased to learn that the HERD instrument, proposed by the Institute of High Energy Physics in Beijing, has been recommended as one of the two top priority experiments on the China Space Station in the discipline of Astronomy and Astrophysics.

We understand that the contribution from the Swiss team, under the lead of the Swiss PI Prof. Xin Wu from the University of Geneva, is a Fiber Tracker (FIT), which has recently been chosen as the baseline tracker technology for HERD. The Swiss contribution shall be complemented with a strong scientific involvement in the overall mission.

The successful Phase B development of the FIT has been supported by the SSO through the PRODEX program of the European Space Agency (ESA). Given the programmatic progress in the HERD mission, and subject to final budget allocations as well as scientific, technical and cost reviews conducted by our national authorities, the Swiss Delegation to ESA is willing to consider extending the support to future project phases. The Swiss Delegation would further advocate the required support for the Swiss contribution to HERD at the respective ESA bodies.

I remain available should you have any further questions.

Sincerely,

State Secretariat for Education,  
Research and Innovation SERI

Renato Krpoun  
Head Swiss Space Office

Digitally signed by  
Krpoun Renato  
NGNJQP  
Bern, 2020-09-29 (with  
time stamp)

State Secretariat for Education, Research and Innovation SERI  
Renato Krpoun  
Einsteinstrasse 2, 3003 Bern  
Tel. +41 58 460 58 92, Fax +41 58 464 96 14  
renato.krpoun@sbfi.admin.ch  
www.sbf.admin.ch



UNIVERSITÉ  
DE GENÈVE

FACULTÉ DES SCIENCES  
Département de physique  
nucléaire et corpusculaire

Prof. Xin WU

Direct line: +41 22 379 66 23  
+41 22 379 62 72

Prof. Shuang-Nan Zhang

Institute of High Energy Physics  
Chinese Academy of Sciences

Beijing 100049, China

Geneva, September 29, 2020

Dear Prof. Shuang-Nan Zhang,

I am very excited to be informed that there had been important progress on the adoption of the HERD mission as an experiment on China's Space Station. As the PI of the HERD project in Switzerland, it is my pleasure to reiterate the strong scientific interest of the Swiss astroparticle physics community on this flagship mission that will shape the landscape of space astroparticle physics in the coming decades. The HERD project has been highlighted in the latest versions of roadmaps of both the Swiss space science and the Swiss particle physics.

The University of Geneva is a founding member of the HERD international collaboration and has been playing a leading role the project since 2012. In particular we have proposed and developed the Fiber Tracker (FIT) technology which has been recently adopted as the baseline tracker technology of HERD. Supported by the SSO through the ESA PRODEX program in the last 3 year, the Phase B development of the FIT will be completed by the end of 2020.

The HERD activities have also been strongly supported in terms of scientific and technical personnel as well as research infrastructure by participating Swiss institutes, currently consisting of the Department of Nuclear and Particle Physics and the Department of Astronomy of the University of Geneva, as well as the Department of Physics of the Swiss Federal Institute of Technology in Lausanne (EPFL). The HERD project is in addition supported by the Swiss National Science Foundation (SNSF).

It is therefore our strong belief that the Swiss teams will proceed to the FIT construction phase once the HERD mission will be adopted, thus making a substantial contribution to the future success of the HERD project.

Sincerely

Prof. Xin Wu

HERD Swiss PI  
Head of the Space Astroparticle Physics Group  
Department of Nuclear and Particle Physics  
University of Geneva

# 预计经费

- 预计载荷研制总经费14.53亿元（中方部分，欧方大致相当）
  - 含需在轨更换设备的研制费用（约3年一次）

单位 (万元)	载荷总体	量能器	增强相机 +2次在轨更换	触发系统	穿越辐射 探测器	综合电子 学
概算	22840	23697	58855	9224	8292	22359

- 预计科学研究总经费2.19亿元
- 部署为5个课题和36个子课题方向，全国几十个单位参加研究
  - 高能电子谱精细测量和暗物质搜寻：电子精确能谱结构、临近电子源贡献、电子谱各向异性测量、类轴子暗物质等
  - 宇宙线起源和宇宙线物理研究：质子能谱、氦核能谱、宇宙线硼碳比、寻找原初锂的加速证据、铁核及超铁元素等
  - 高能伽马射线天文：银河系星际伽马辐射、银河系风和费米气泡、活动星系核粒子加速机制、宇宙学和早期宇宙等
  - 多信使天文学
  - 脉冲星导航新体制研究

# HERD：有重大科学意义、技术可行、基础坚实

有创新	中国科学家提出了三维成像量能器及其光纤成像读出方案。
有优势	最大接收度、最高动态范围、最宽视场、空间最高能量。
有科学	在暗物质探测、宇宙线探测和伽马天文等方面科学能力国际领先，从运行到结束每个阶段预期都有重大科学成果。
有平台	空间站平台提供了实现科学目标所必须的资源和维护，在9办领导下通过与五院等沟通迭代，基本满足工程和约束条件。
有基础	超过10年预研和关键技术攻关，国际团队联合在欧洲核子中心完成了三次束流实验，验证了创新方案原理和关键指标。
有团队	欧洲多国实质性参加并贡献设备，项目国际合作组超过180位科学家，国内40个单位、国外12个单位正式发函参加。
有提升	将和空间站POLAR-2形成很好的互补，与地面超高能伽马射线、高能中微子、引力波天文台协调观测，提升科学产出。

请专家批评指导！ 谢谢！