



LHAASO探测器及其实验数据处理

姚志国
高能物理研究所

报告内容

- ◆ LHAASO与LHAASO的主要物理目标
- ◆ LHAASO探测器与建设进展
- ◆ LHAASO实验数据获取
- ◆ LHAASO实验数据分析
- ◆ 总结

LHAASO探测器

LHAASO项目

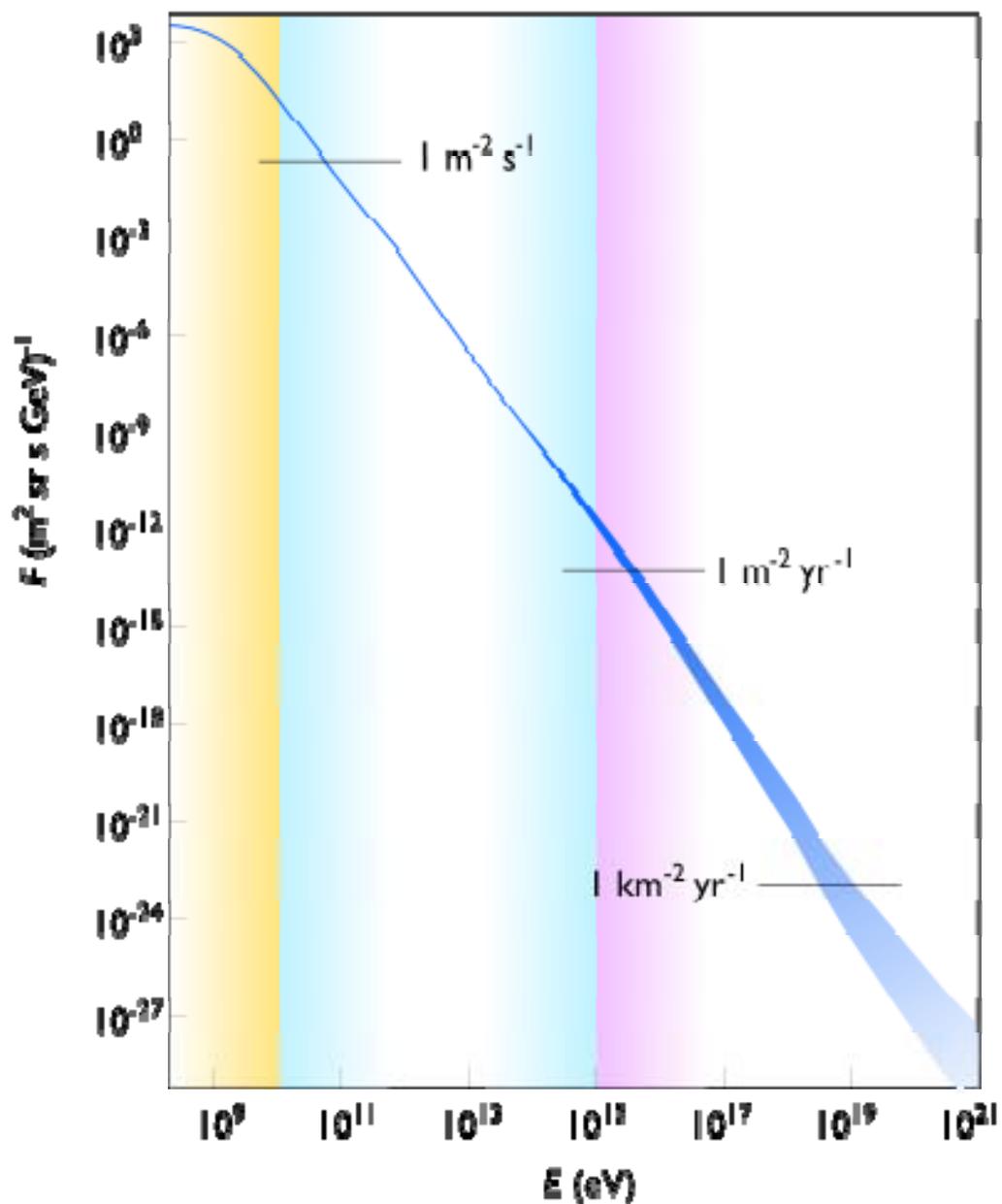
- ◆ “高海拔宇宙线观测站”是十二五期间立项的**国家重大科技基础设施**项目，英文简称“LHAASO”。
- ◆ LHAASO means “Large High Altitude Air Shower Observatory”.
- ◆ 也就是说，LHAASO的主要探测对象是**宇宙线引发的空气簇射**。
- ◆ 2015/12/31立项，总经费约12亿。
- ◆ 建设站址：四川省稻城县海子山（观测基地，4410米）和稻城县城（测控基地，3750米）。

宇宙线的总能谱

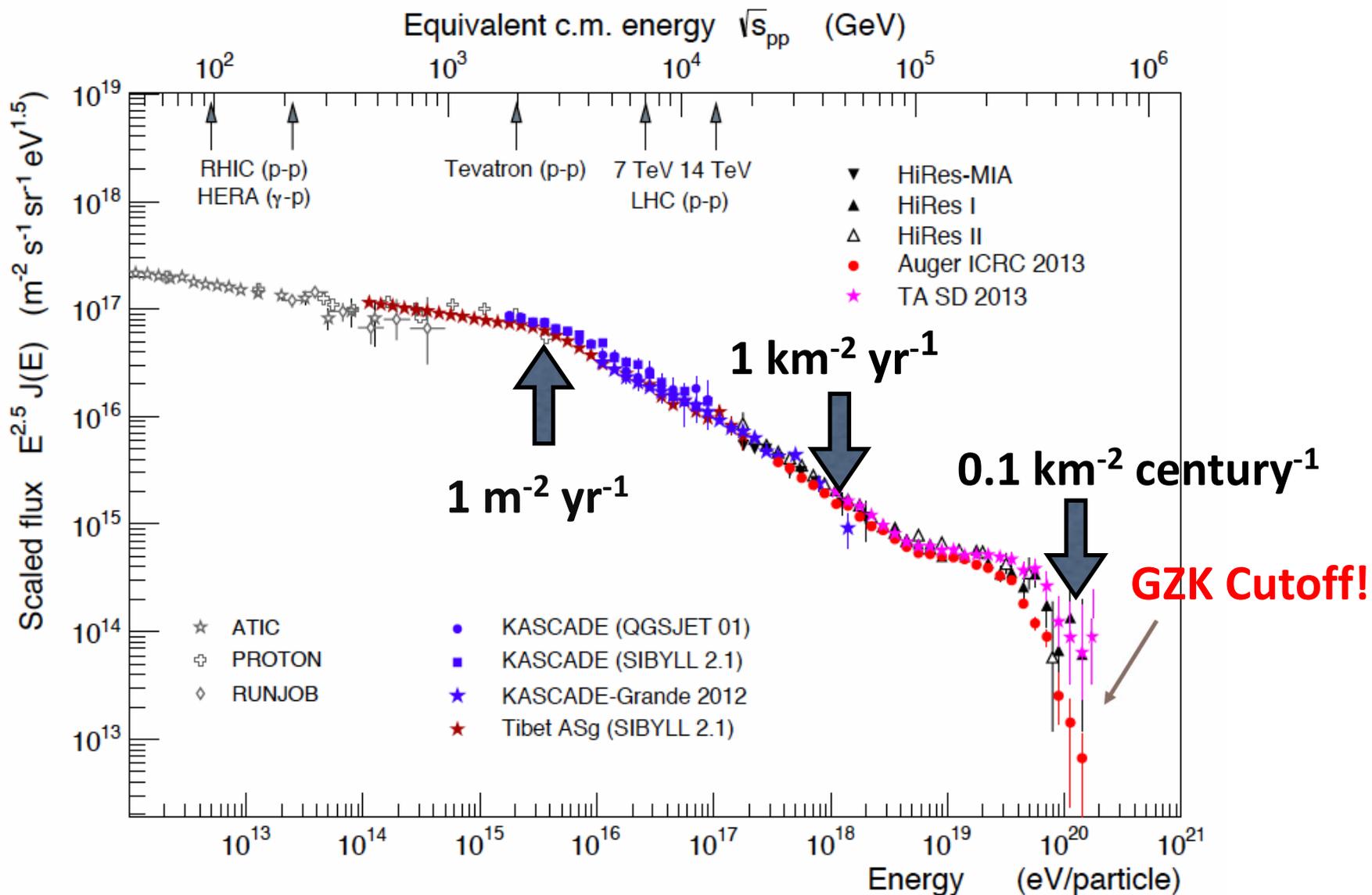
- ◆ 跨越12个量级；
- ◆ 近似幂指数 (power law) 分布；
- ◆ 最高能可达 10^{20} eV！

- ◆ 能量越高，流强越小。

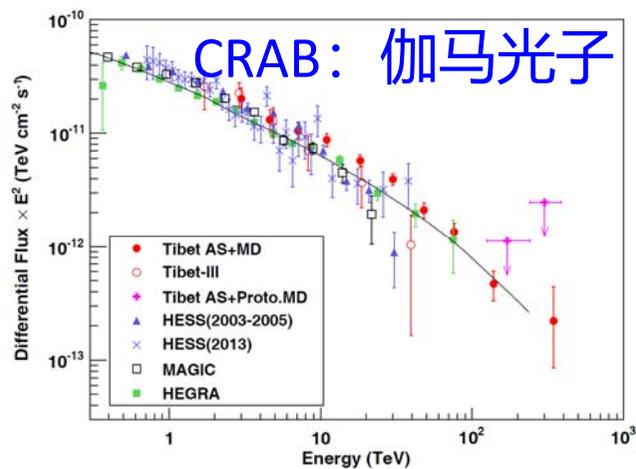
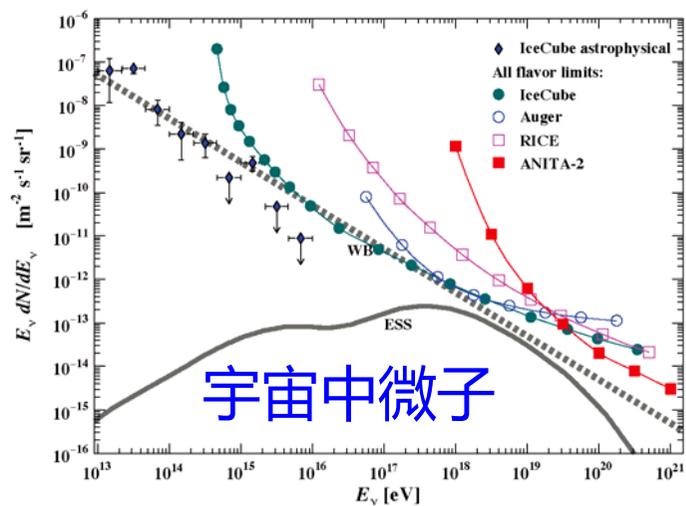
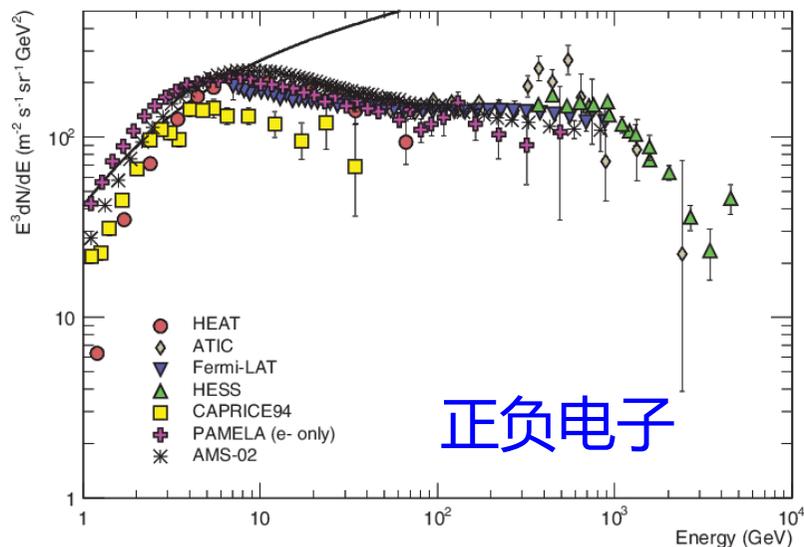
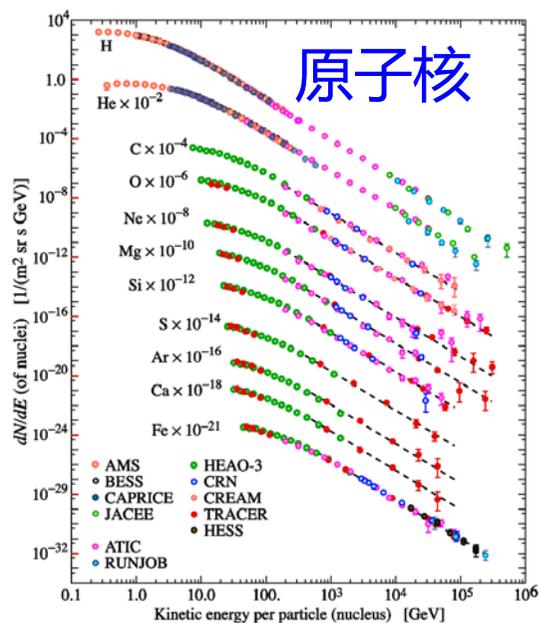
- ◆ 成份：氢核到铁核的所有原子核、伽马光子、电子、中微子等



宇宙线总能谱 - 观测



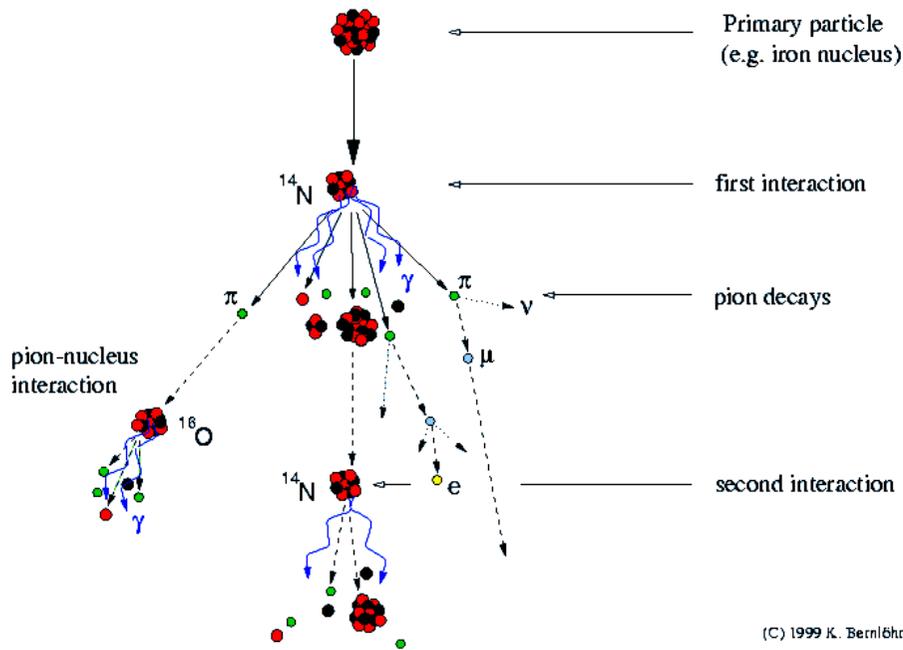
宇宙线成份能谱



空气簇射

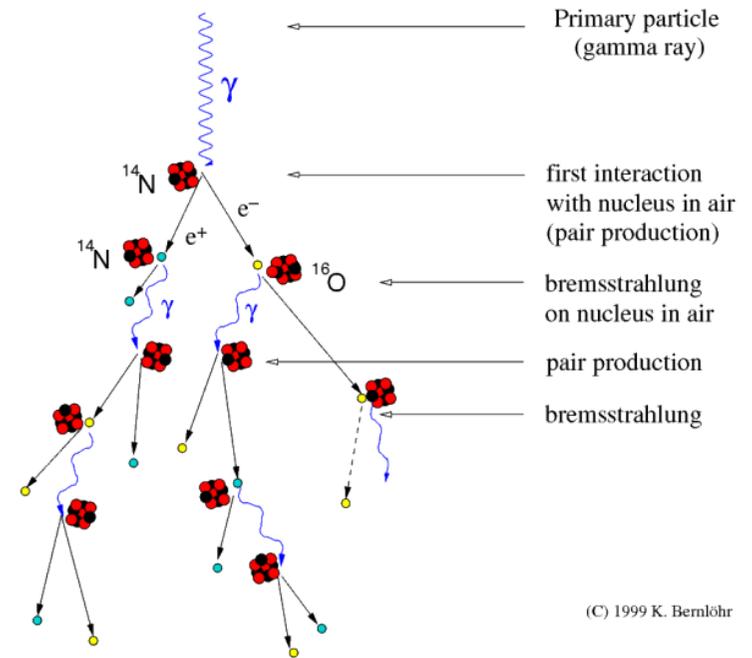
原子核

Development of cosmic-ray air showers



伽马光子

Development of gamma-ray air showers



不同能量空气簇射的纵向与横向发展 (伽马)

100 GeV

1 TeV

10 TeV

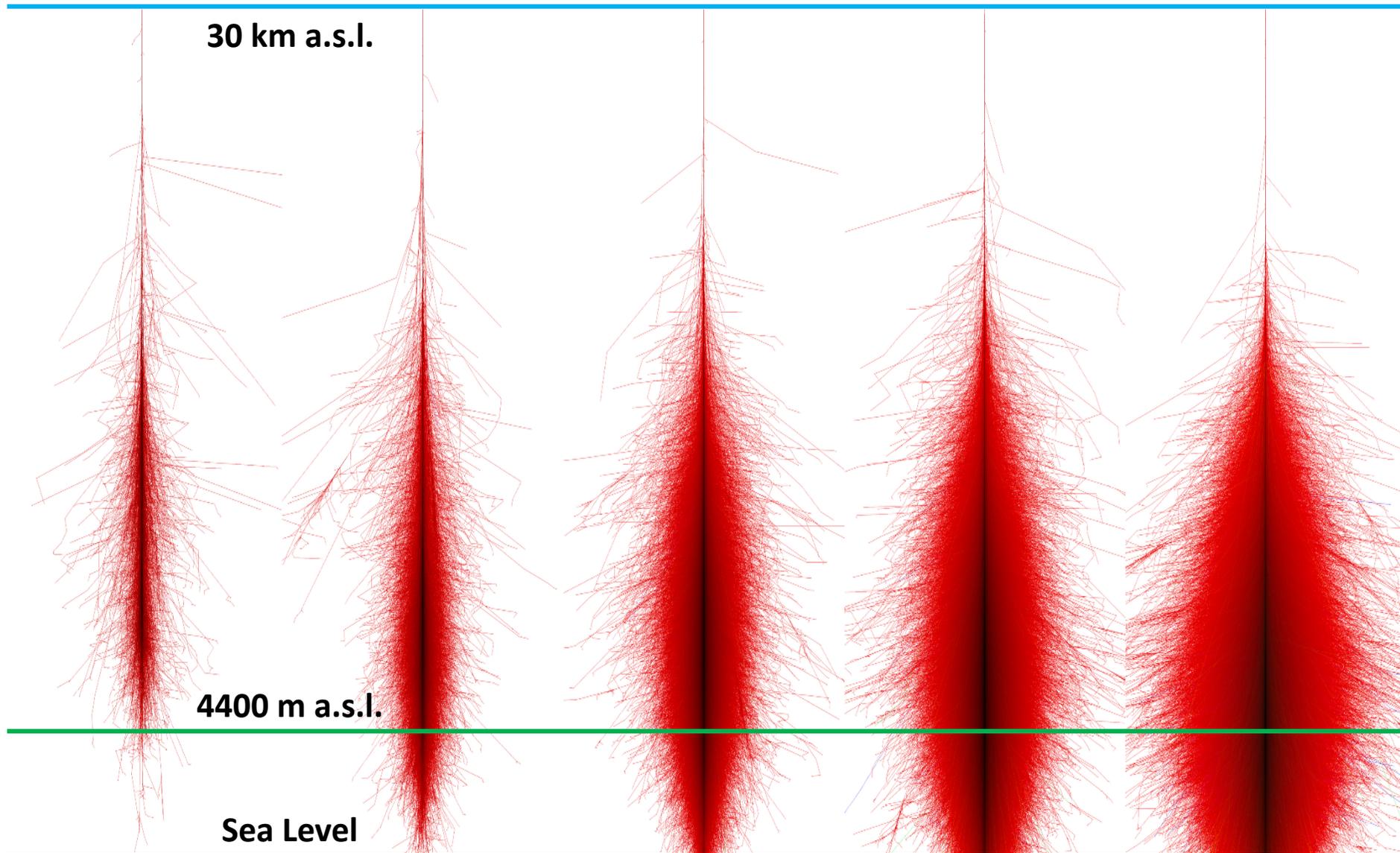
100 TeV

1 PeV

30 km a.s.l.

4400 m a.s.l.

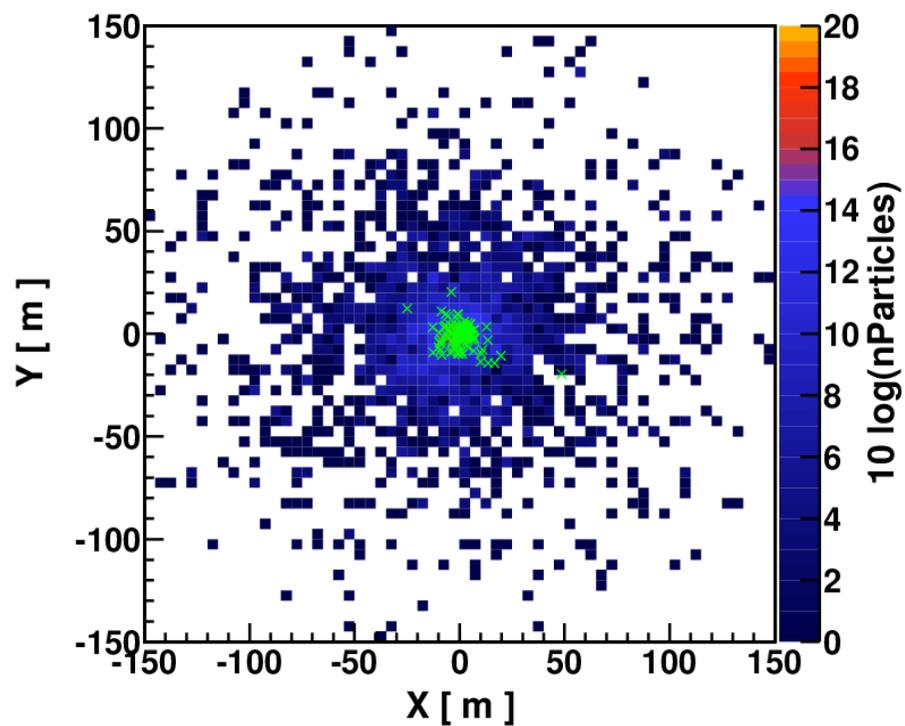
Sea Level



横向分布

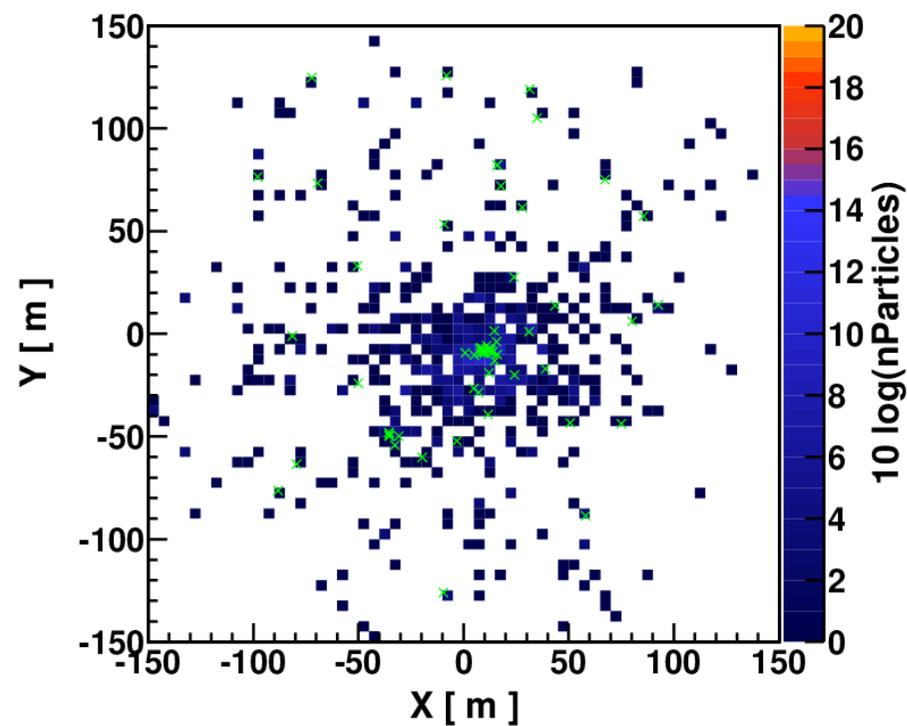
伽马, 5 TeV

Corsika | Gamma , 5 TeV | Secondary: $e^\pm + \mu^\pm \{>2.5 \text{ MeV}\}$

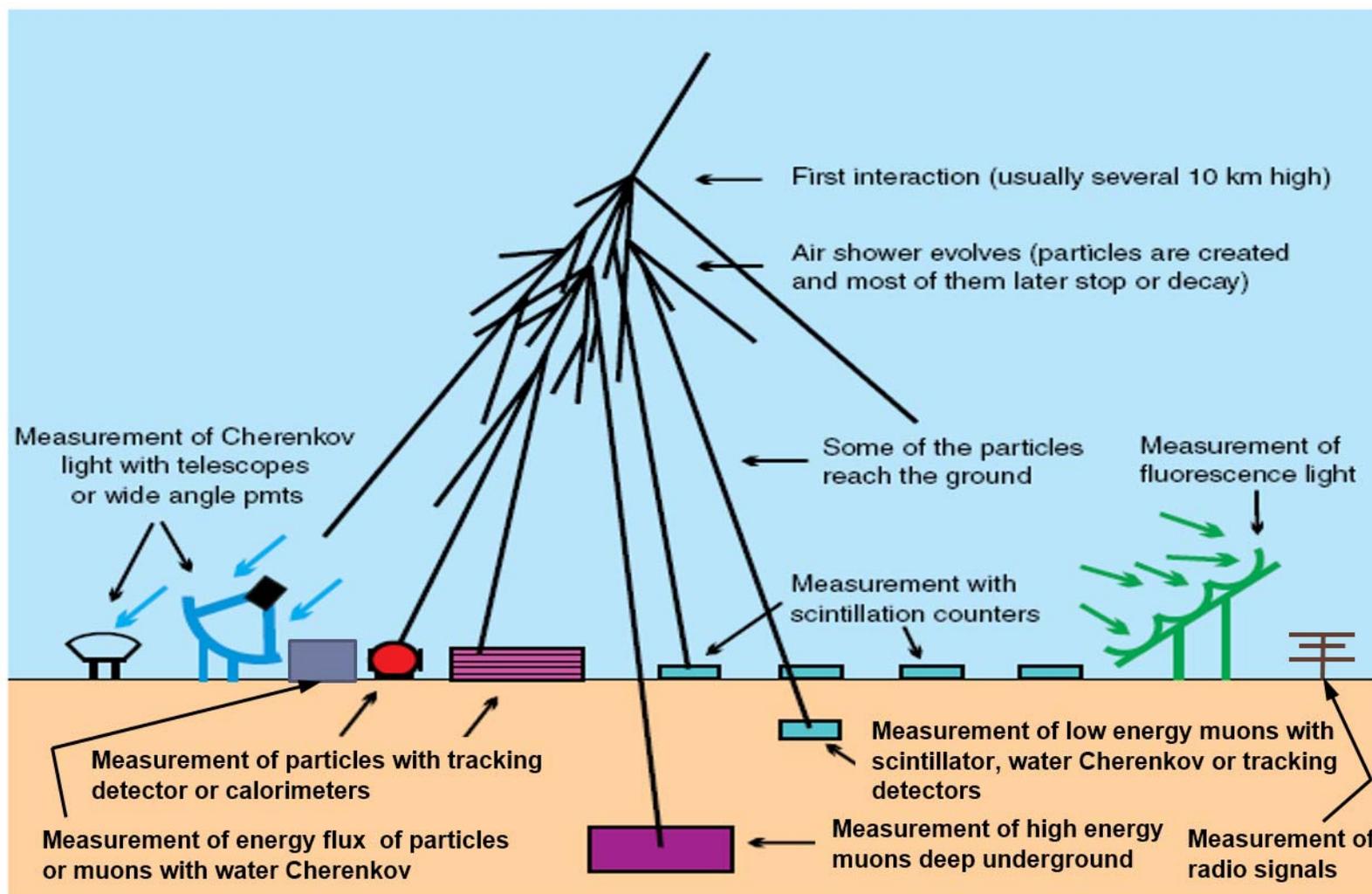


质子, 5 TeV

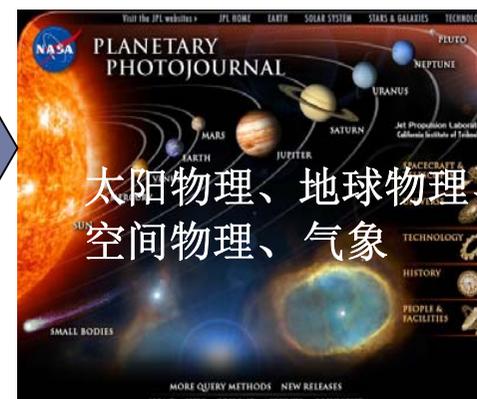
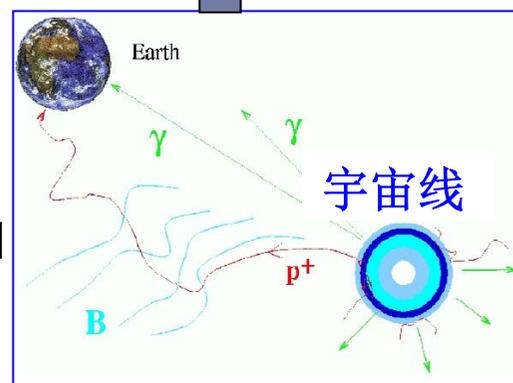
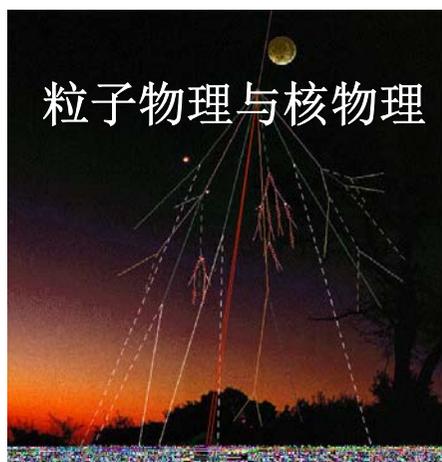
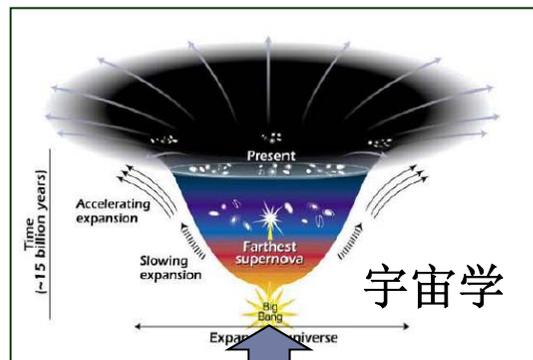
Corsika | Proton , 5 TeV | Secondary: $e^\pm + \mu^\pm \{>2.5 \text{ MeV}\}$



空气簇射的探测



研究宇宙线

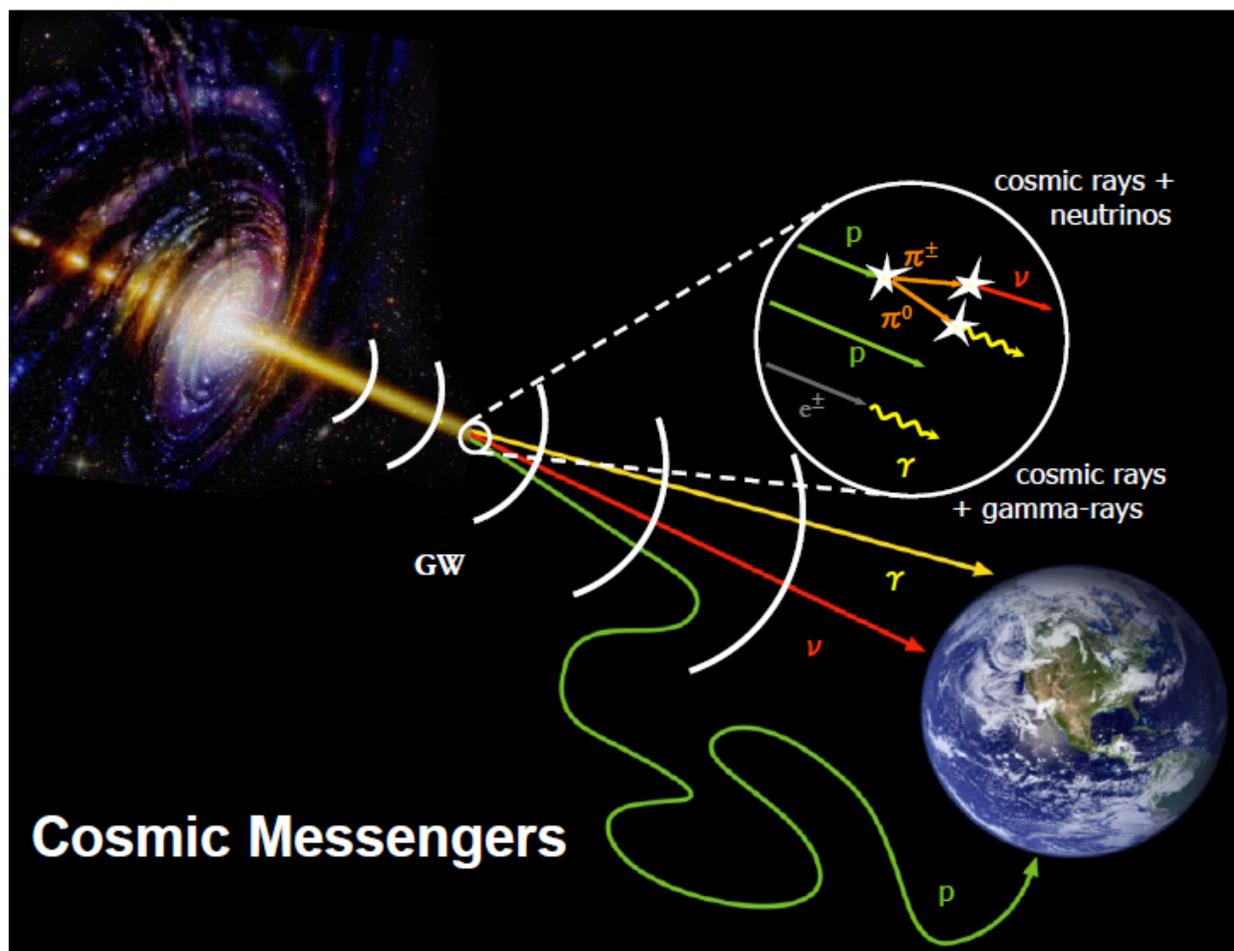


早期：发现了 π 、 μ 、 e^+ ；
现在：强相互作用朝前
区行为

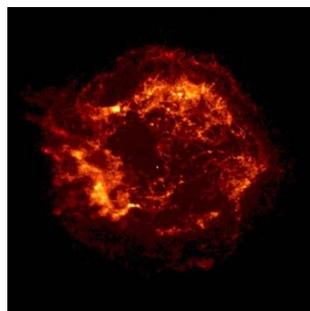


探测宇宙线可以对天体物理现象进行研究

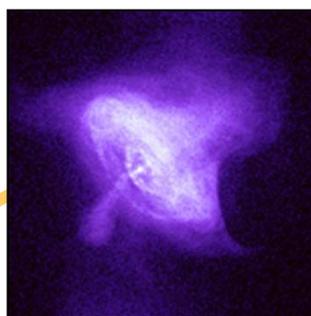
- ◆ 伽马不受磁场偏转，从而可以确定发生源的位置！



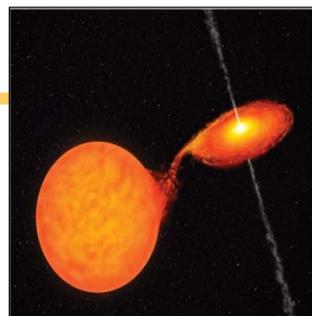
天体物理：甚高能 (>100 GeV) 伽马天文



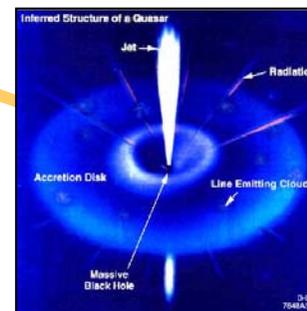
超新星遗迹



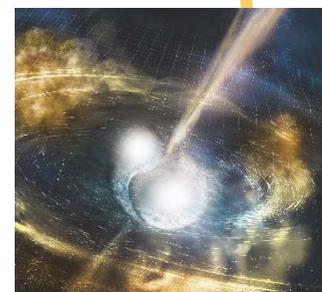
脉冲星



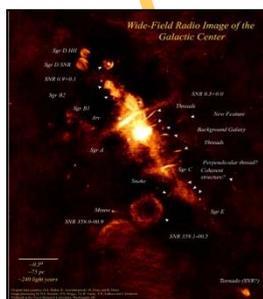
微类星体



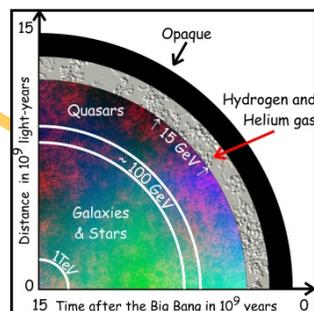
活动星系核



伽玛暴与引力波对应体

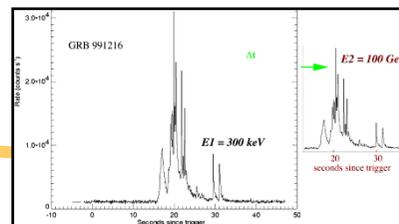


银心和暗物质



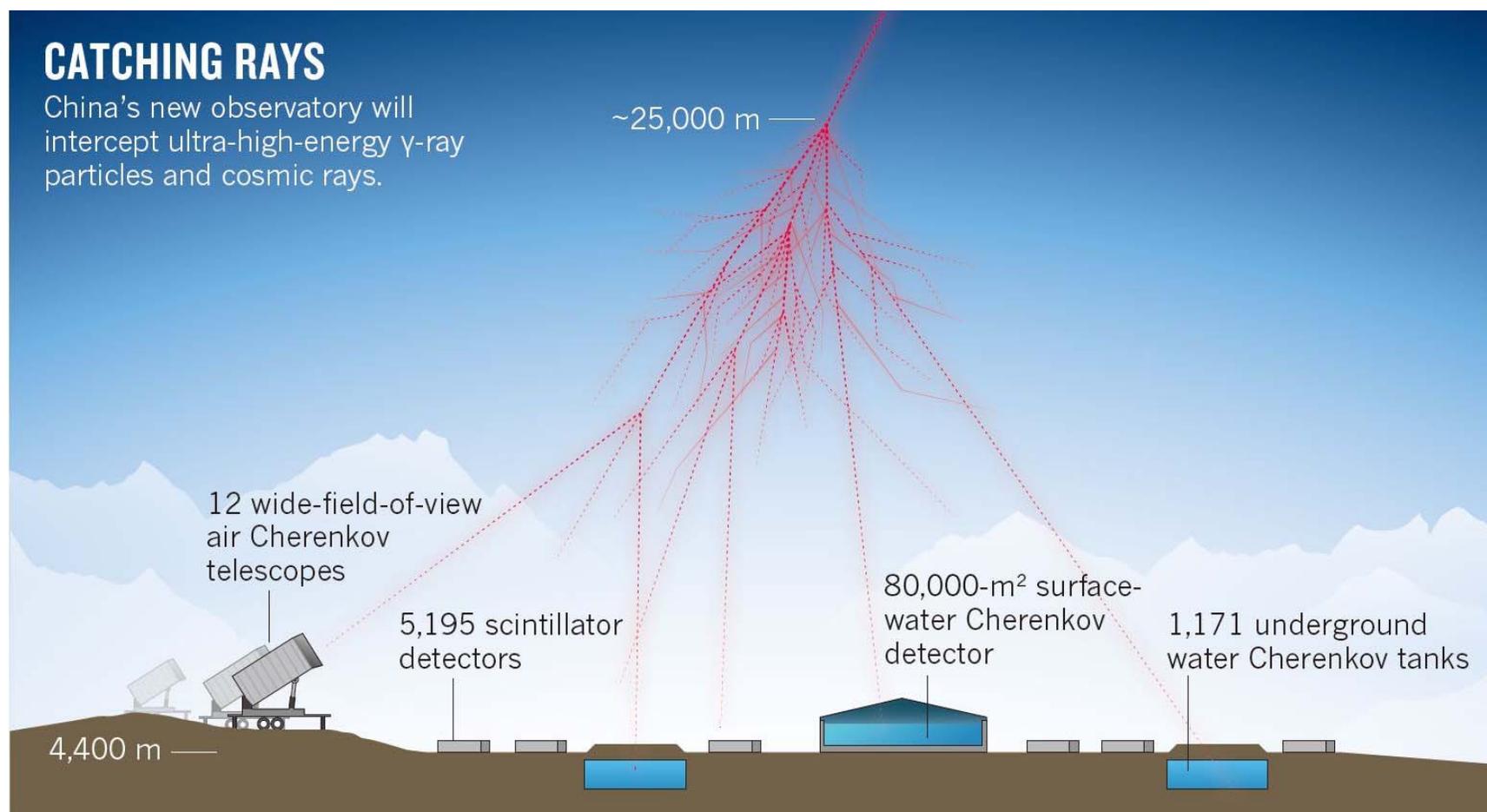
河外背景光和伽马射线视界

百年之谜：
高能宇宙线起源

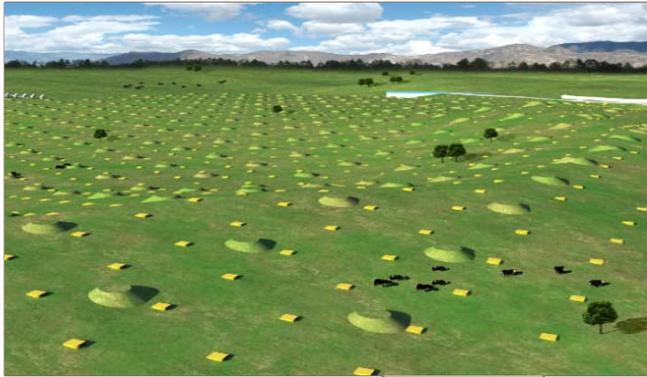


检验光速不变和量子引力理论

LHAASO的对空气簇射的探测



四种类型的探测器，在不同能区对空气簇射进行探测和测量



LHAASO



KM2A:
5195 EDs
1171 MDs



WCDA:
3120 cells
78,000 m²

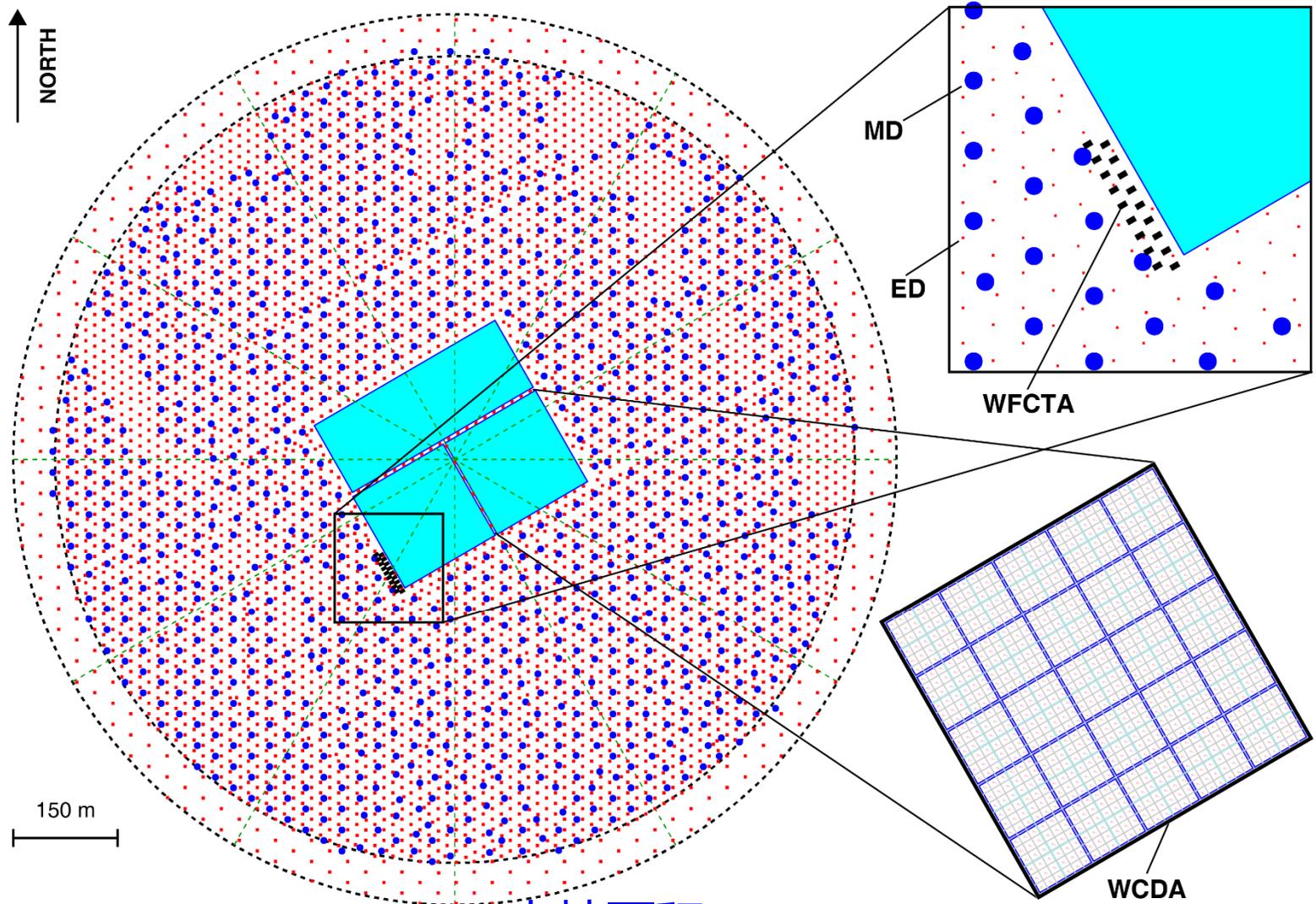
WFCTA:
18 telescopes
1024 pixels each

**Future
Enhancements:
e.g., LHAASO-
ENDA ...**



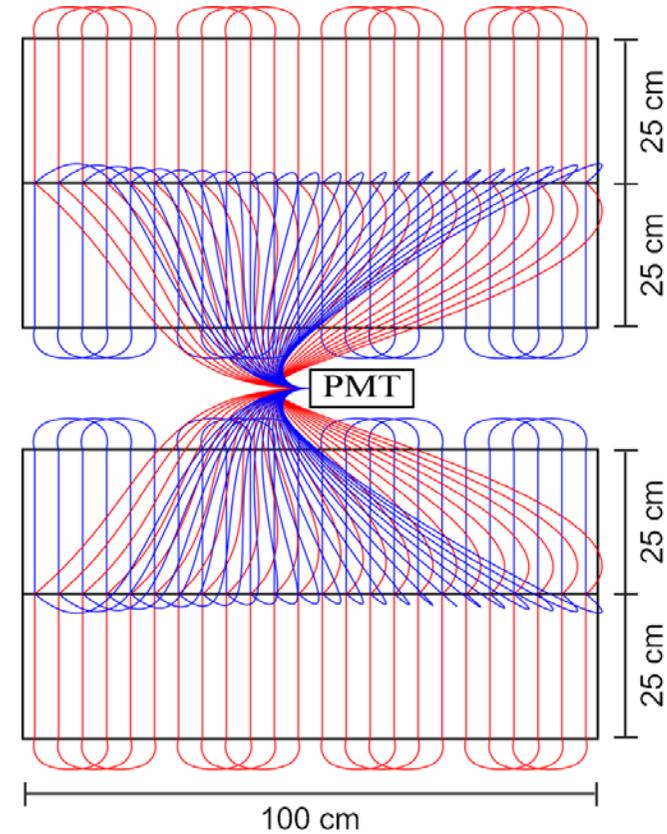
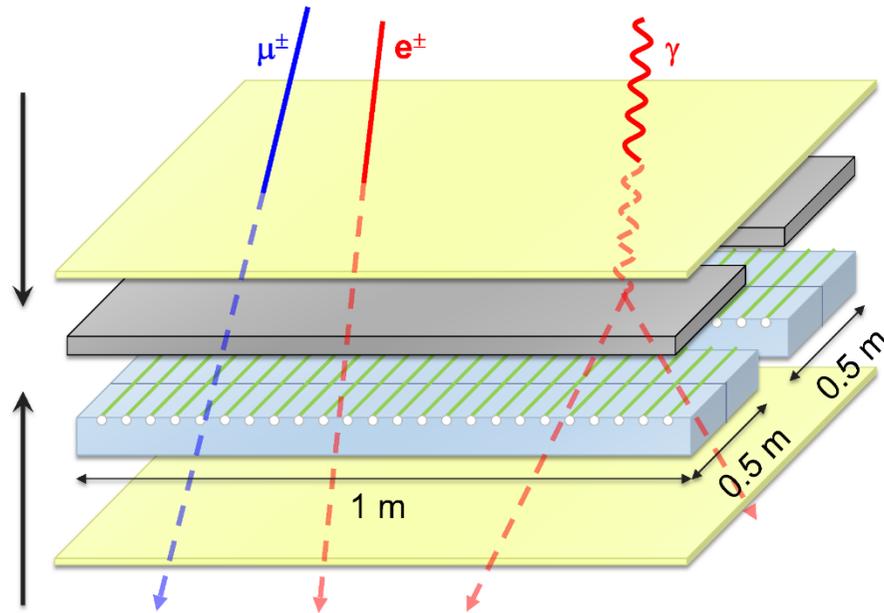
TBD ...

LHAASO探测器阵列布局



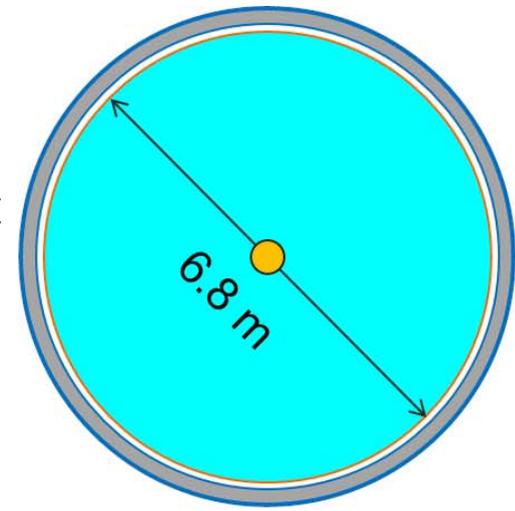
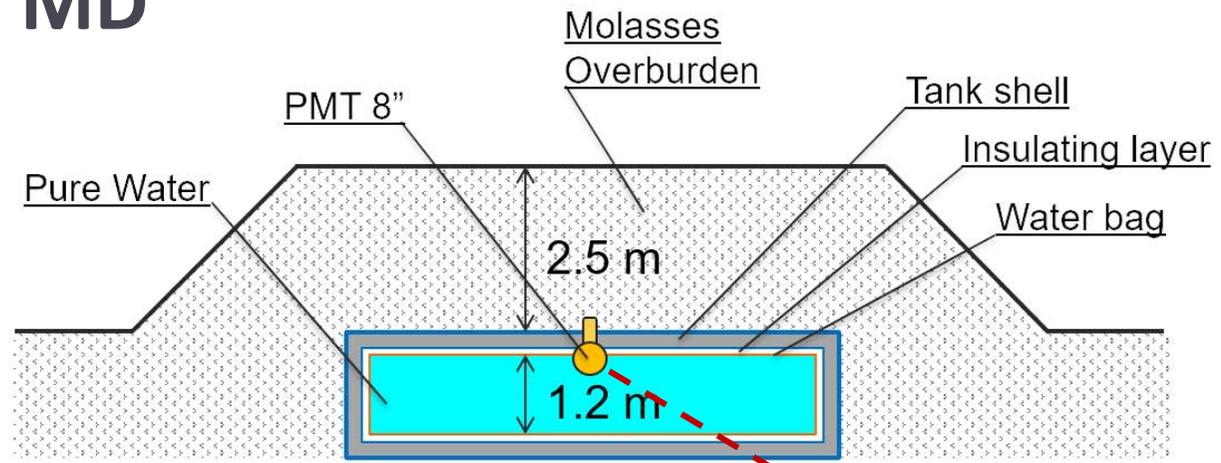
占地面积: 1.3 km²

ED



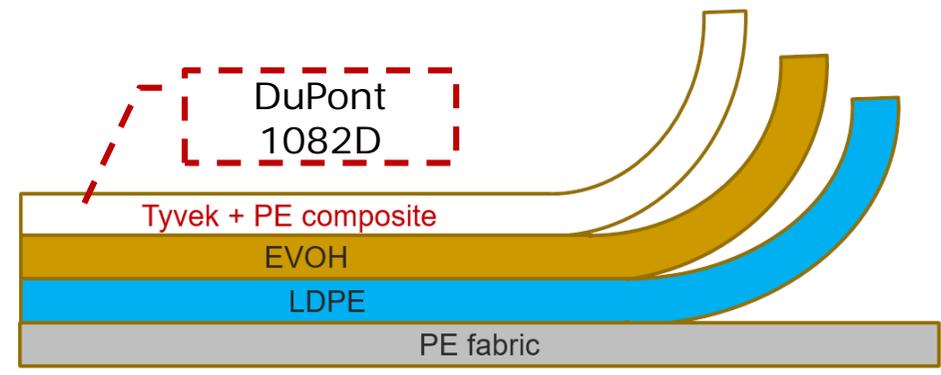
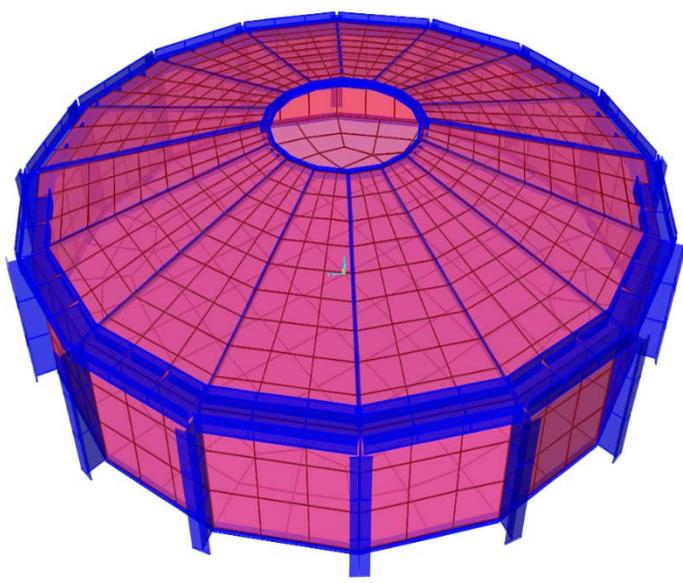
- ◆ Scintillator (SGC BC408): 1 cm thickness, 4 tiles (1 m \times 0.25 m)
- ◆ 24 fibers (SGC BCF92) for each tile
- ◆ One 1.5-in PMT (HZC XP3960)
- ◆ Lead: 0.5 cm
- ◆ Iron case: 0.1 cm
- ◆ Electronics (IHEP) & power supply (Tianjin Centre): in the case

MD



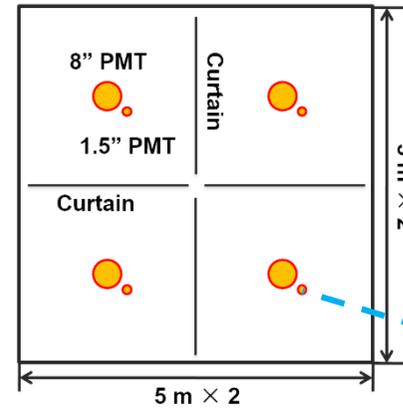
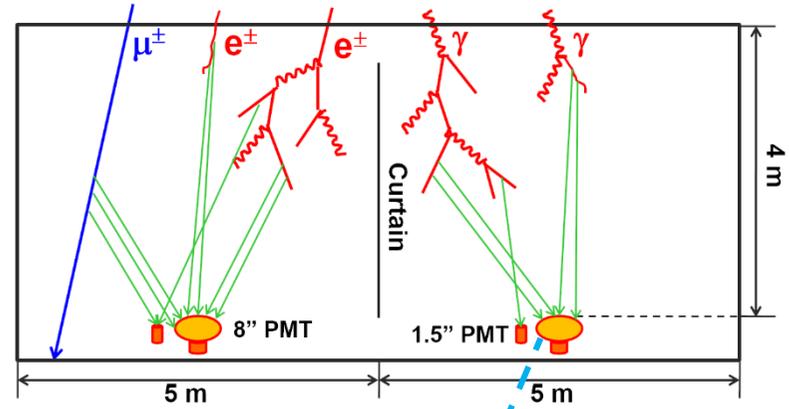
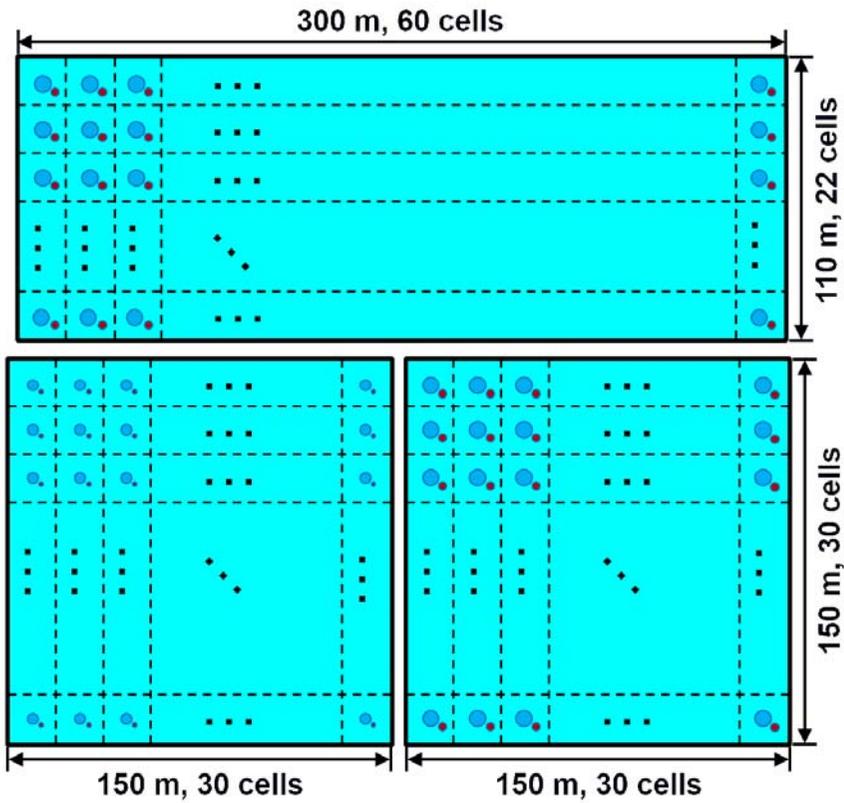
Top view

BHP CR365
(HP R5912)



Electronics: IHEP

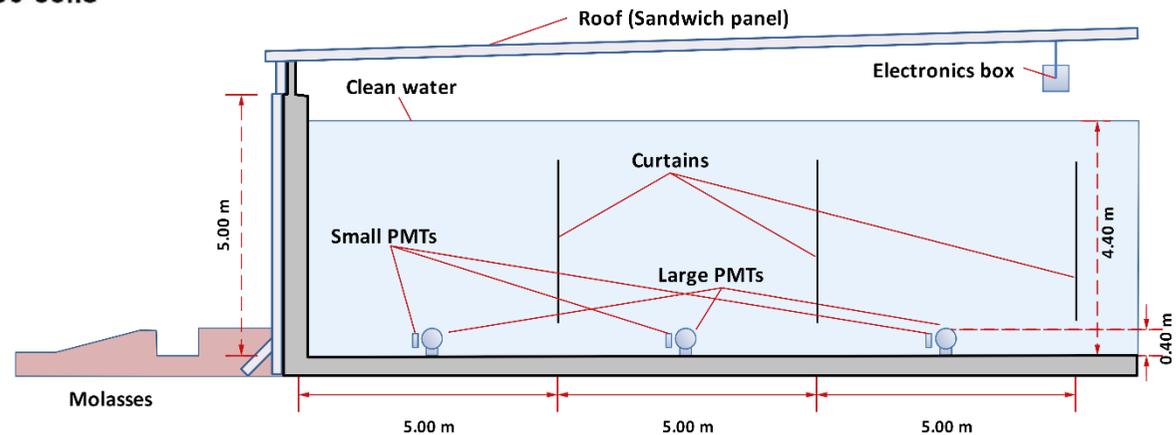
WCDA



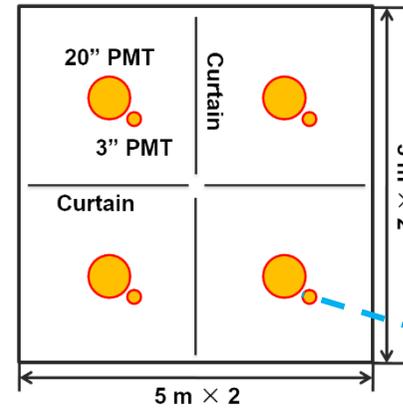
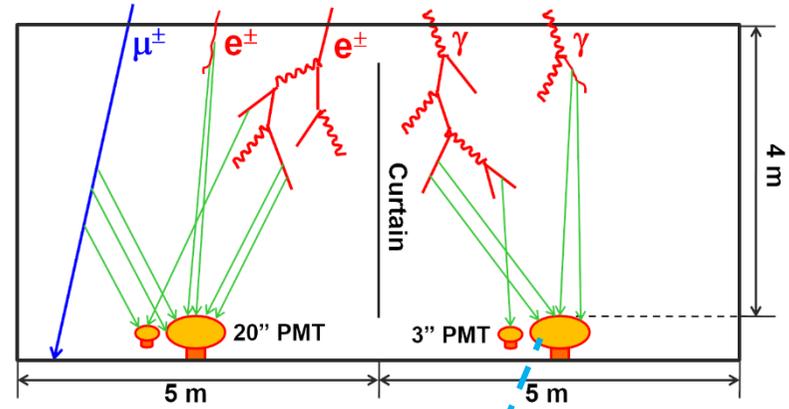
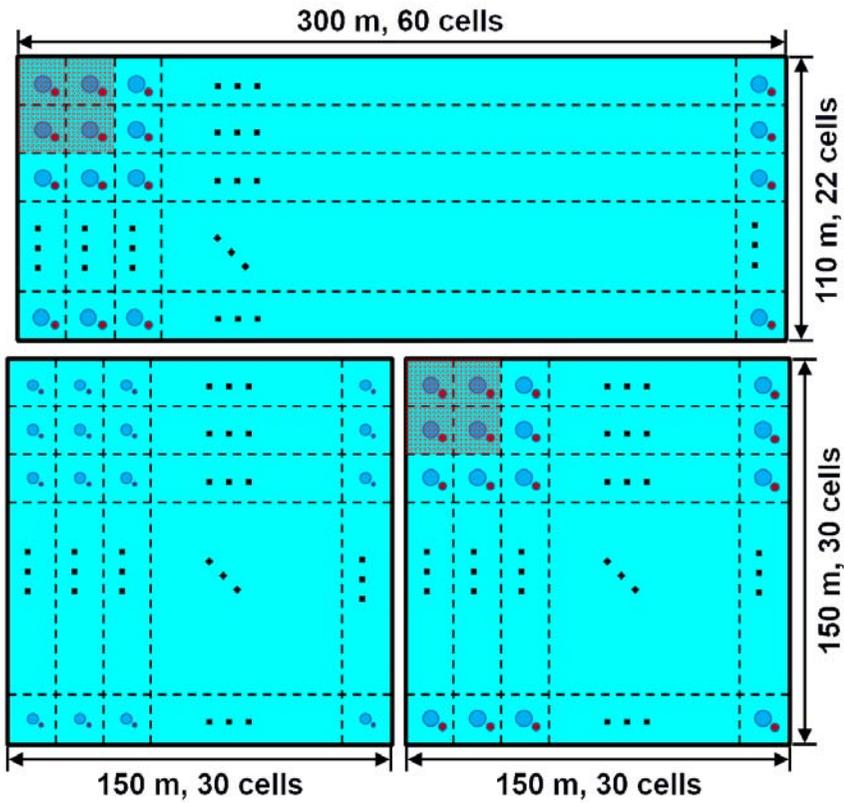
BHP CR365
(HP R5912)

HZC XP3960

Electronics:
USTC + SCU



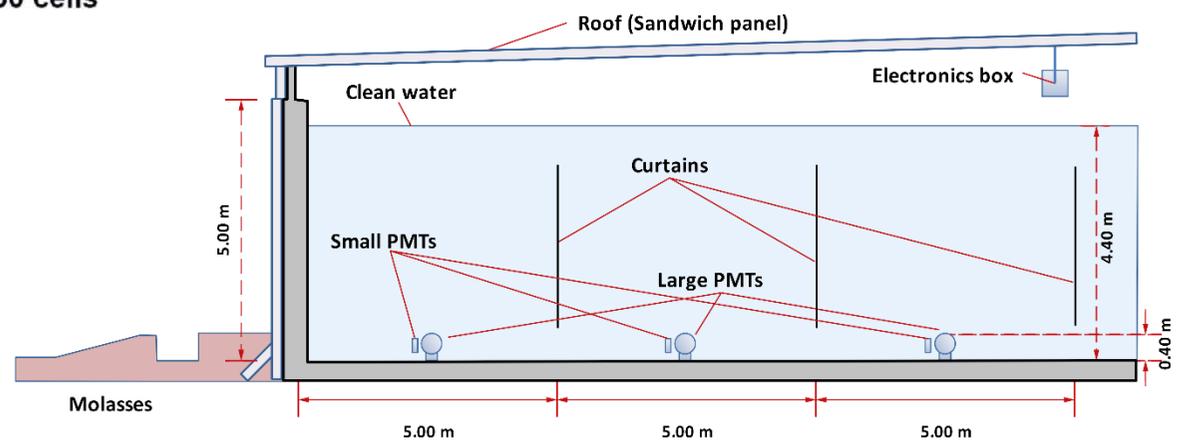
WCDA



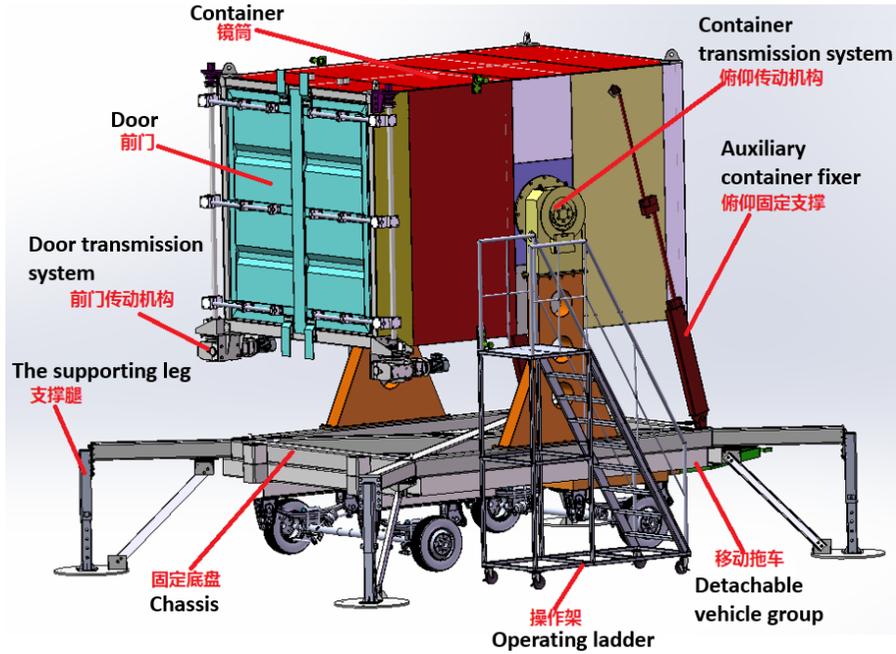
NNVT
GDB6203

HZC XP72B22

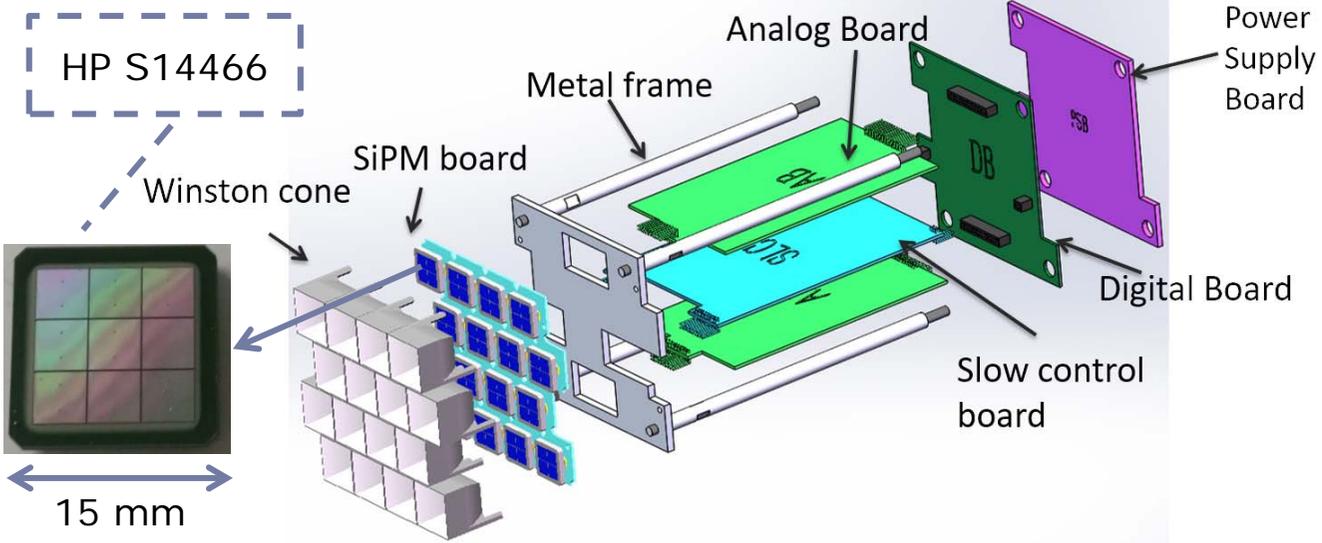
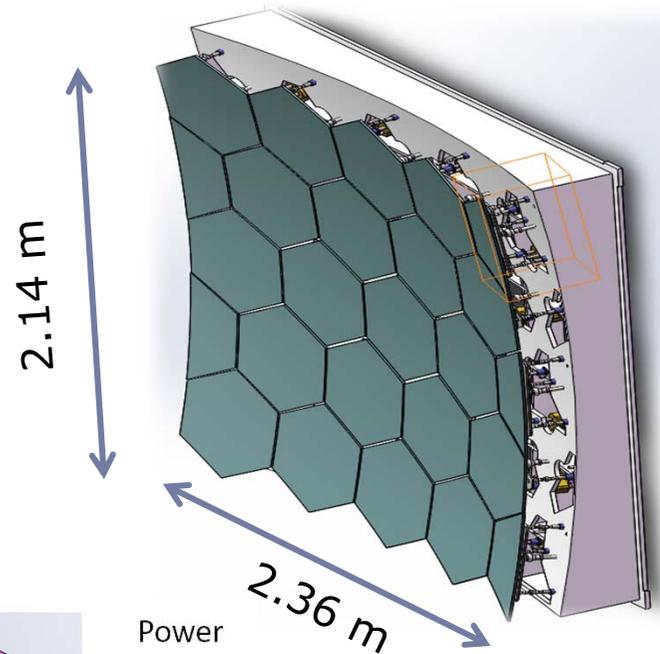
Electronics:
USTC + SCU



WFCT



Hexagonal mirror side length: 219.1 mm
 Curvature radius: 5800 mm
 Focal length: 2780 mm



1/64 (a sub-cluster) of the camera

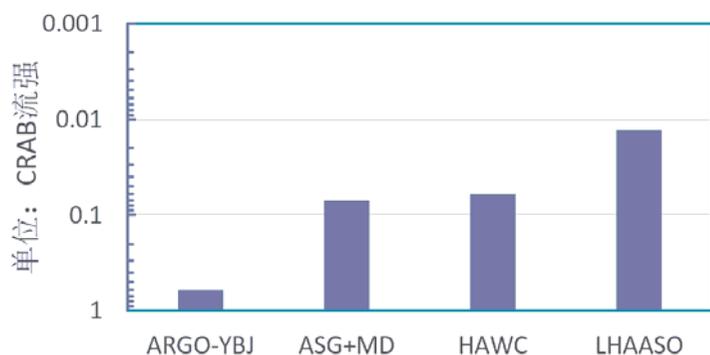
Electronics: SCU

15 mm

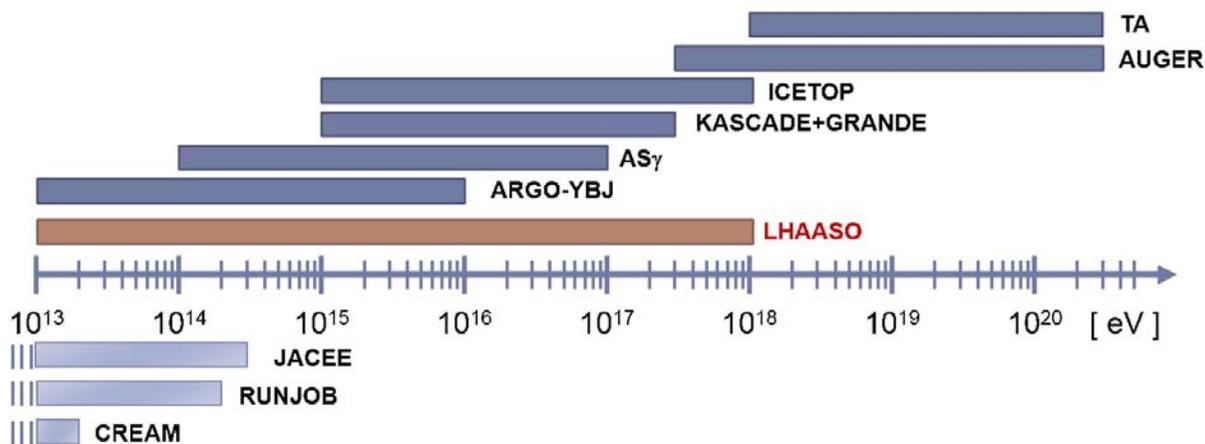
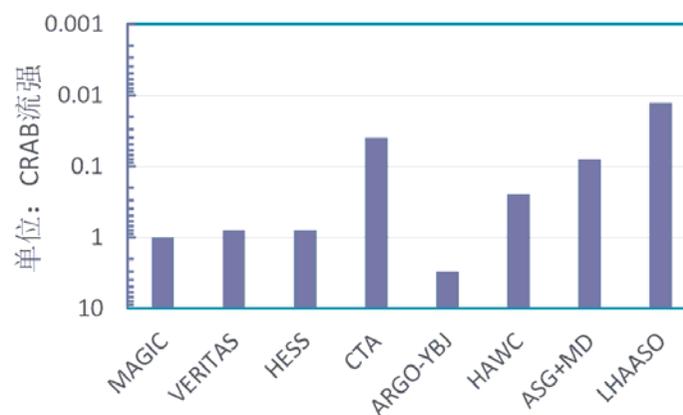
LHAASO的国际地位

- ◆ 中能区 (1 TeV – 30 TeV) 灵敏度最优的伽马巡天探测器;
- ◆ 高能区 (30 TeV – 1 PeV) 灵敏度最好的伽马天文探测器;
- ◆ 能区跨度范围 (10 TeV – 1 EeV) 最大的宇宙线探测器。

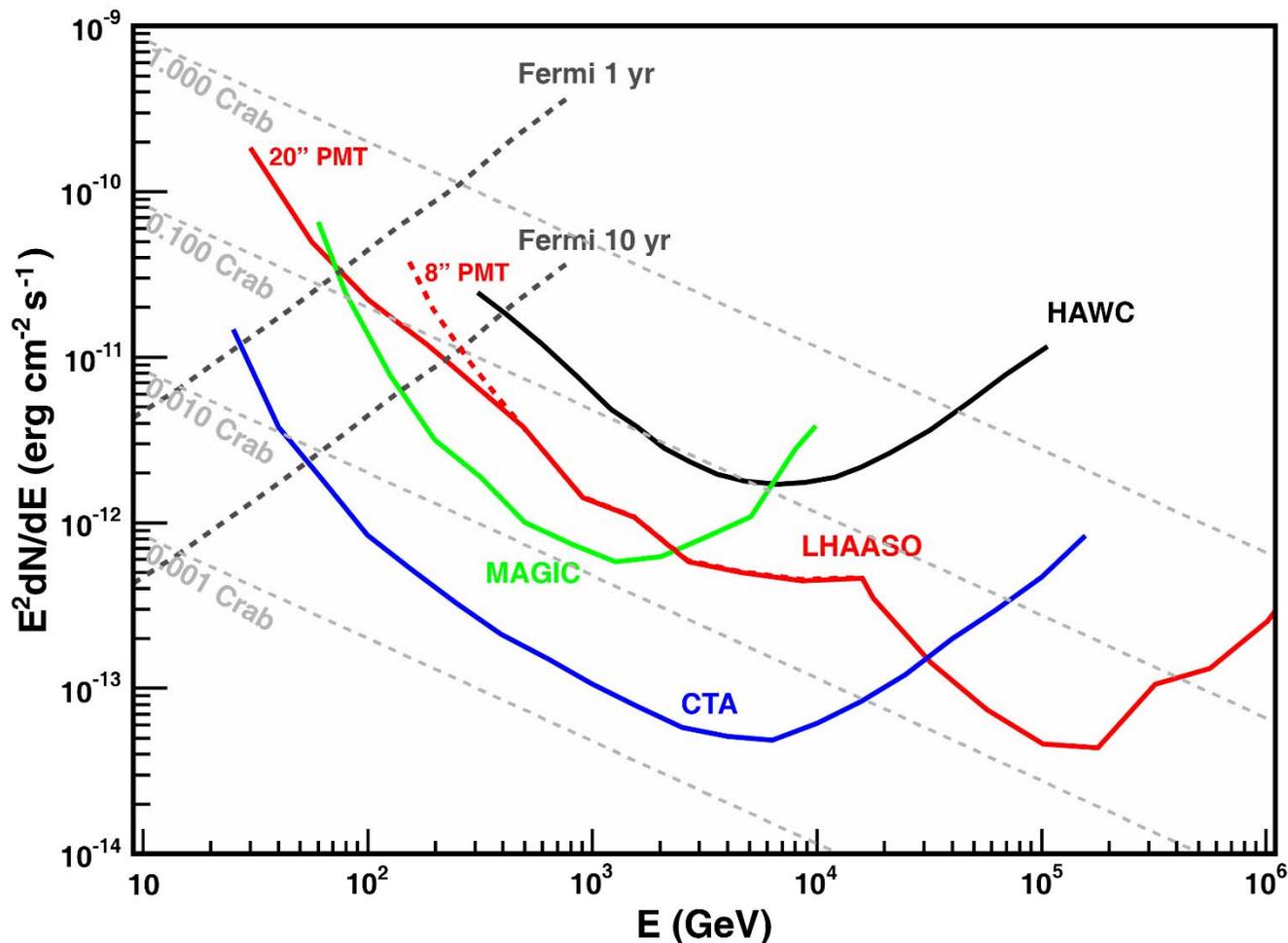
巡天类型望远镜灵敏度对比
中能区 (1 TeV–30 TeV)



所有类型望远镜灵敏度对比
高能区 (30 TeV–1 PeV)

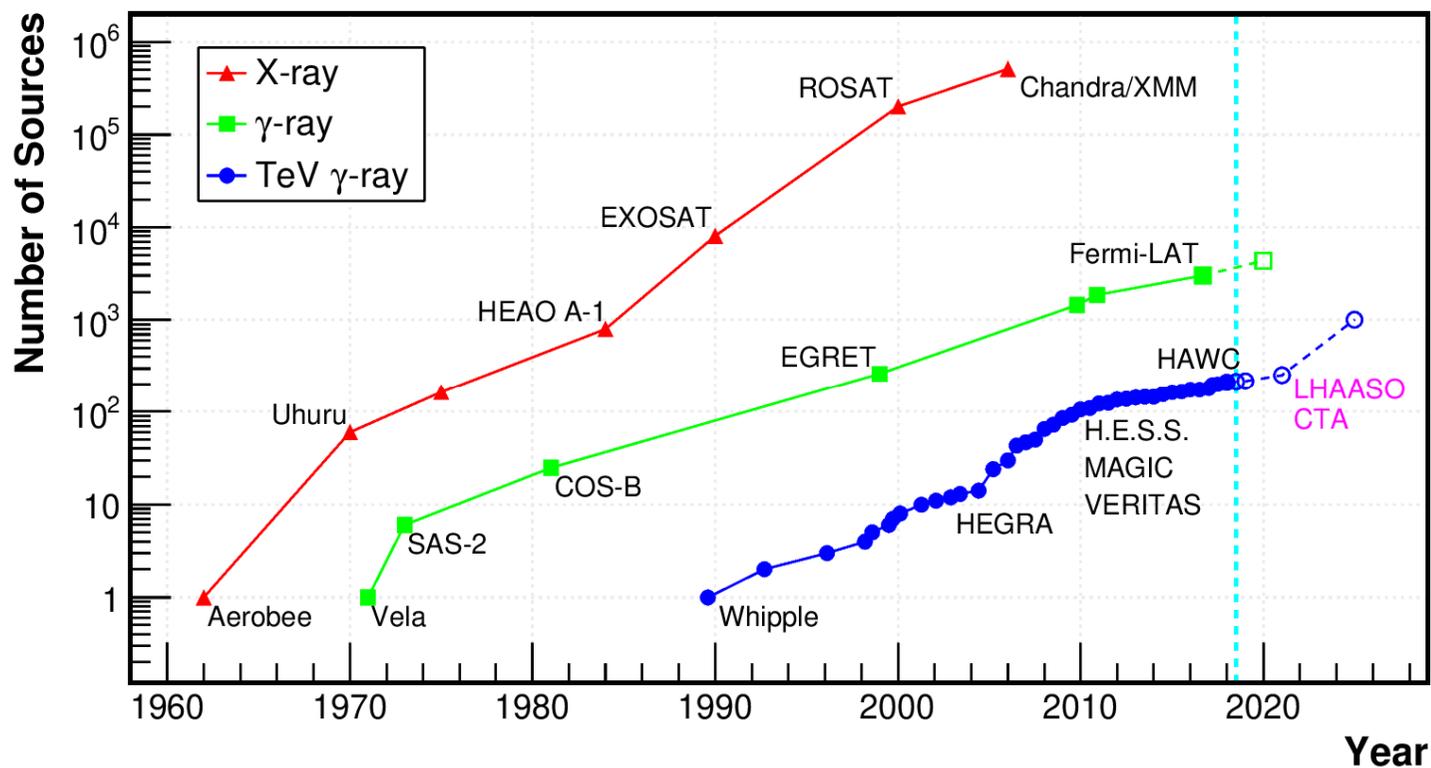


伽马探测微分灵敏度



LHAASO: 全天候大视场探测器。优势: 巡天、瞬变现象、扩展源

发现源数目的预期：Kifune's Plot



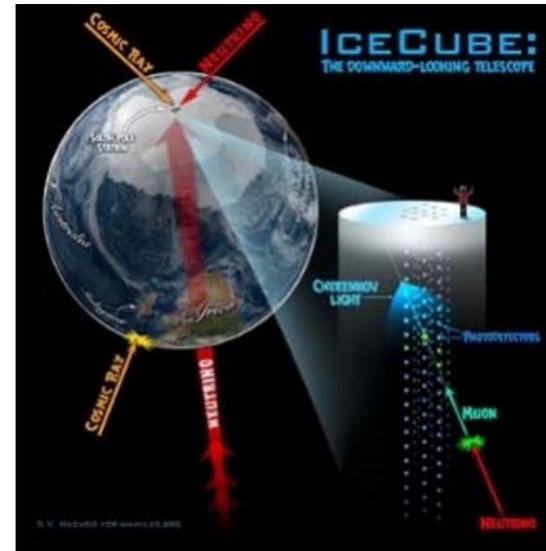
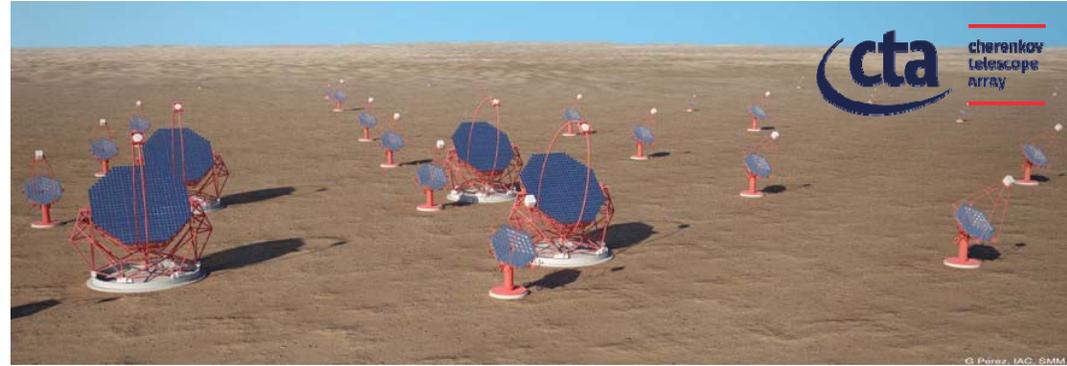
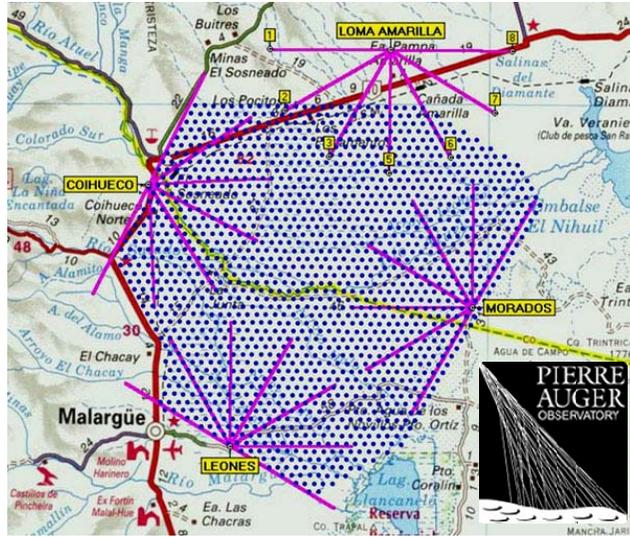
LHAASO + CTA: 200 → 1000 @ 2025年

四足 立



最高能段的天文观测：

- ◆ 粒子天文
- ◆ 伽马天文 (定点)
- ◆ 伽马天文 (巡天)
- ◆ 中微子天文



科学目标

◆ 甚高能伽马巡天与监测 (100 GeV-1 PeV):

- Galactic sources;
- Extragalactic sources & flares;**
- VHE emission from GRBs;
- Diffused Gamma rays.

◆ 伽马射线能谱测量 (100 GeV-1 PeV) :

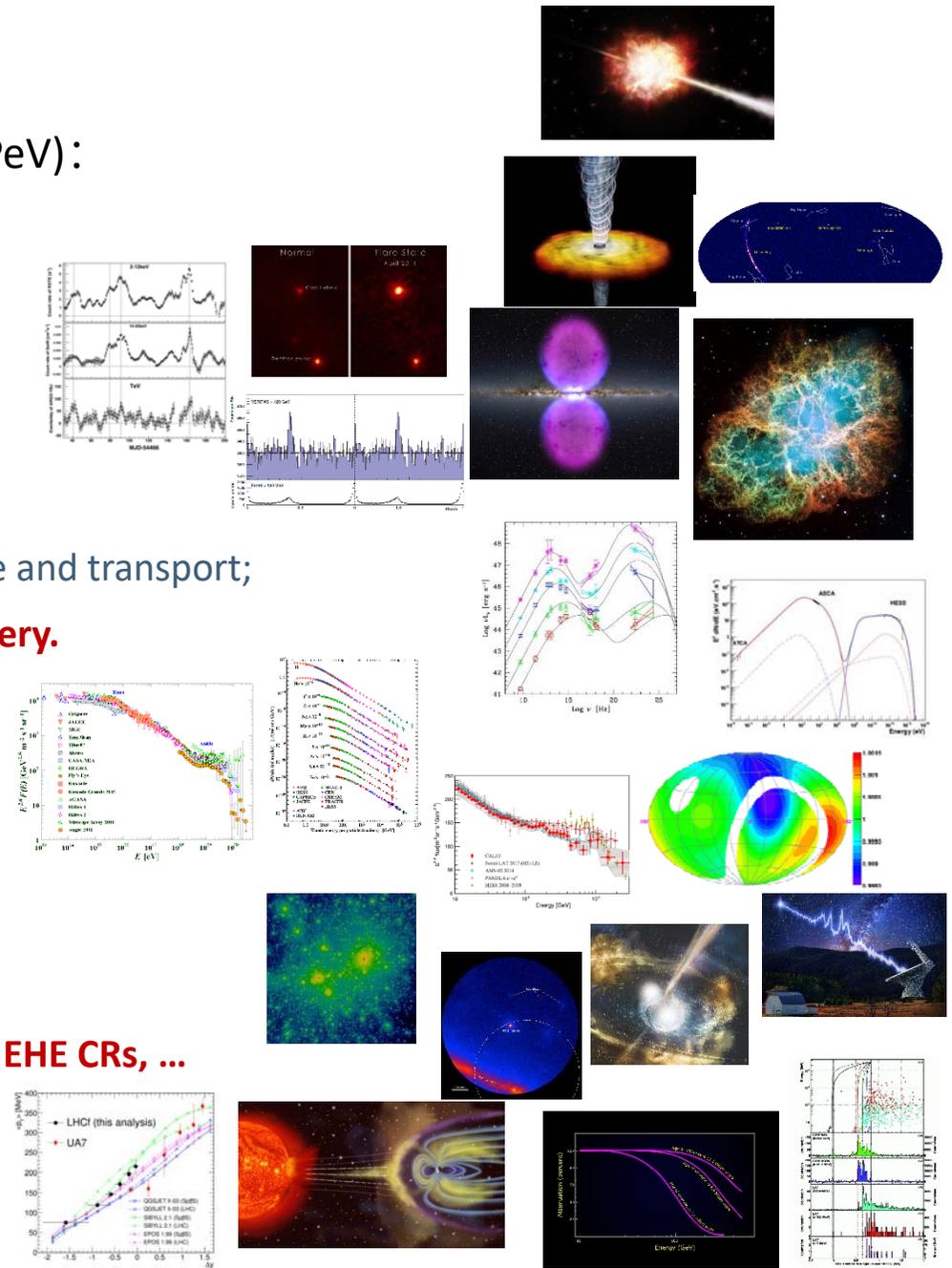
- Mechanisms of the acceleration, escape and transport;
- Origin of cosmic rays – 100 years' mystery.**

◆ 宇宙线测量 (10 TeV-10 PeV):

- Components and spectrums;**
- Anisotropy of VHE cosmic rays.

◆ 其它:

- Dark matter;
- Counterparts of neutrinos, GWs, FRBs, EHE CRs, ...**
- Sun storm & IMF;
- Particle physics;
- ...



LHAASO现状：1/4建成并运行

