Dark matter particle explorer: science and status

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(On behalf of DAMPE collaboration)

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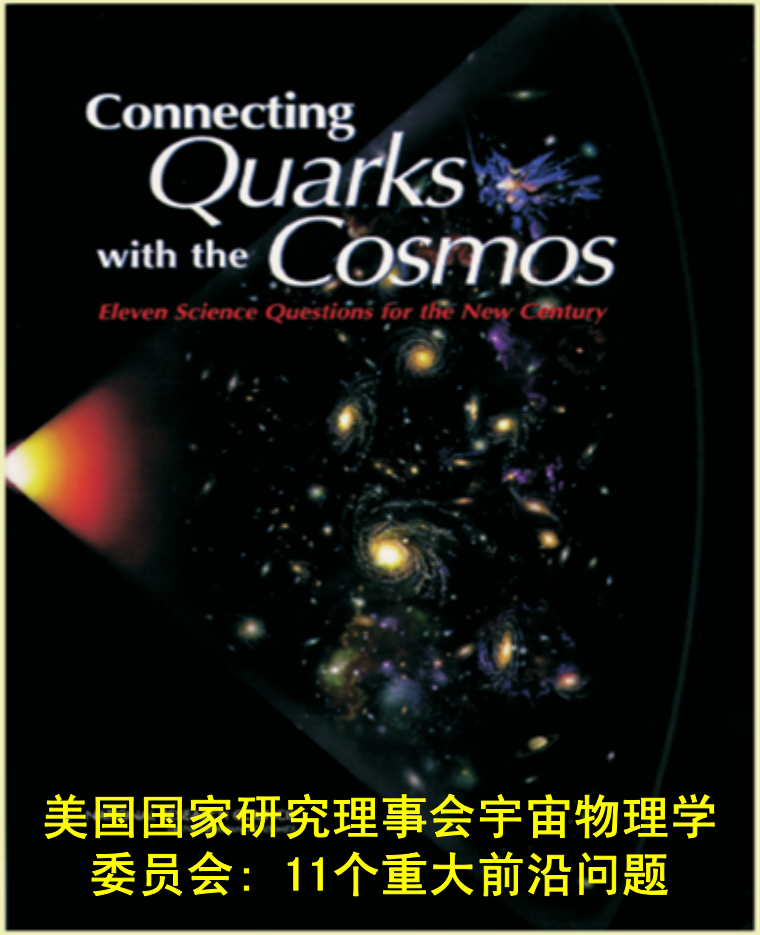
1st LHAASO collaboration meeting, Nankai U., 08/17/2016

DArk Matter Particle Explorer (DAMPE): China's first space science mission launched on 12/17/2015!

Dark matter & cosmic rays: important frontiers

The Eleven Questions Identified by the *Connecting Quarks with the Cosmos* Report



美国国家研究理事会宇宙物理学委员会：11个重大前沿问题

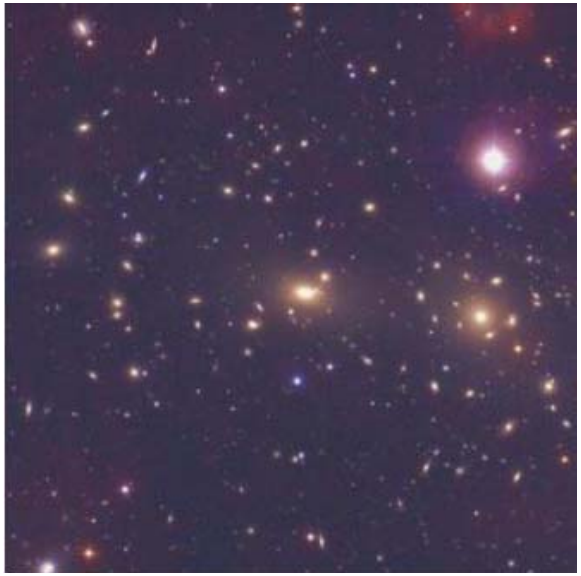
1. What is Dark Matter?
2. What is the Nature of Dark Energy?
3. How Did the Universe Begin?
4. Did Einstein Have the Last Word on Gravity?
5. What are the Masses of the Neutrinos and How Have They Shaped the Evolution of the Universe?
6. How do Cosmic Accelerators Work and What are They Accelerating?
7. Are Protons Unstable?
8. What Are the New States of Matter at Exceedingly High Density and Temperature?
9. Are There Additional Space-Time Dimensions?
10. How Were the Elements from Iron to Uranium Made?
11. Is a New Theory of Light and Matter Needed at the Highest Energies?

Astronomical dark matter

Discovery of dark matter

Fritz Zwicky
1898-1974

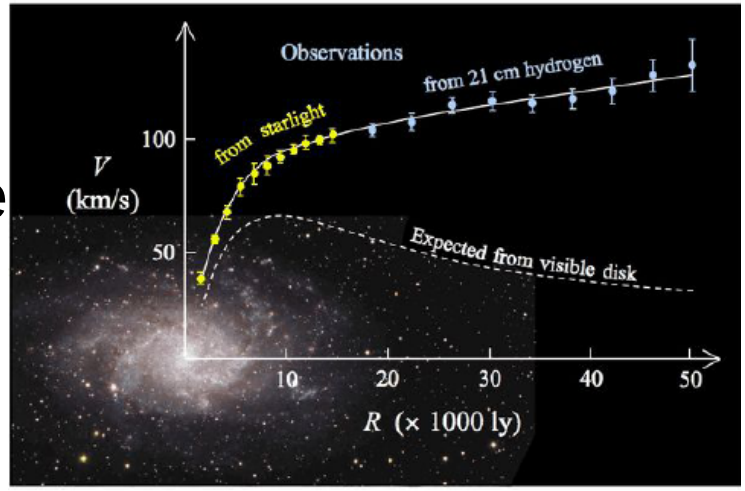
1930s
Cluster dynamics



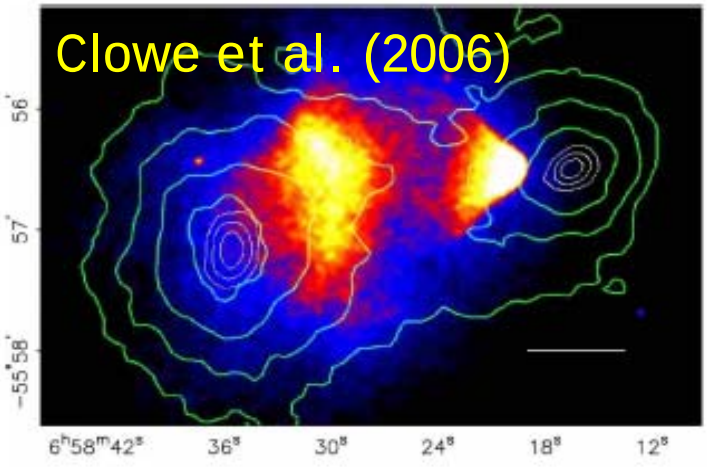
Vera Rubin

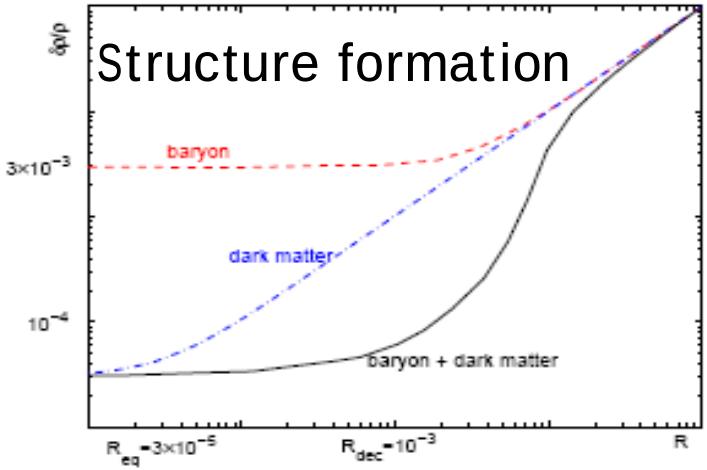
Kent Ford

1960s
Rotation curve

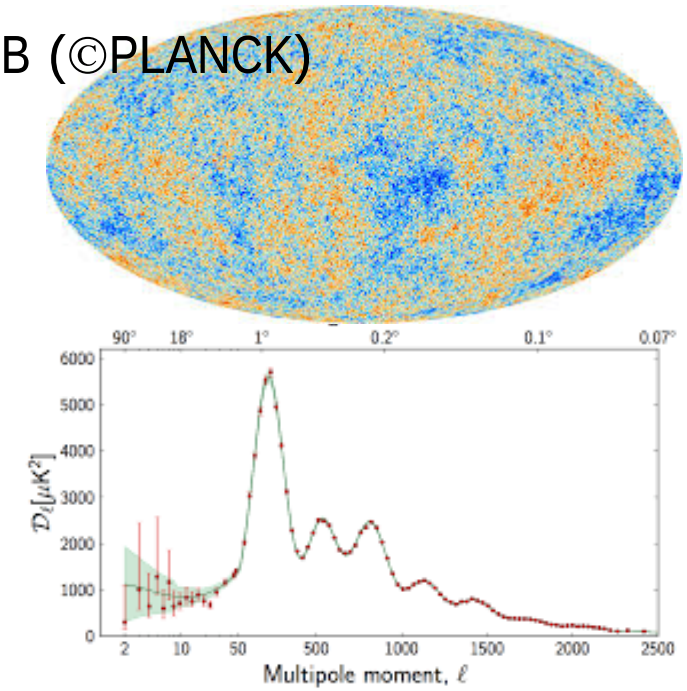


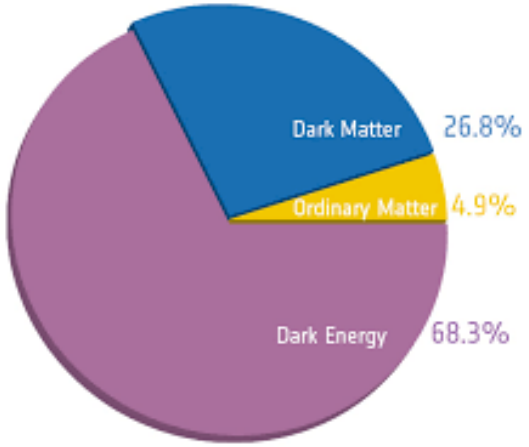
More evidence at various scales





CMB (©PLANCK)

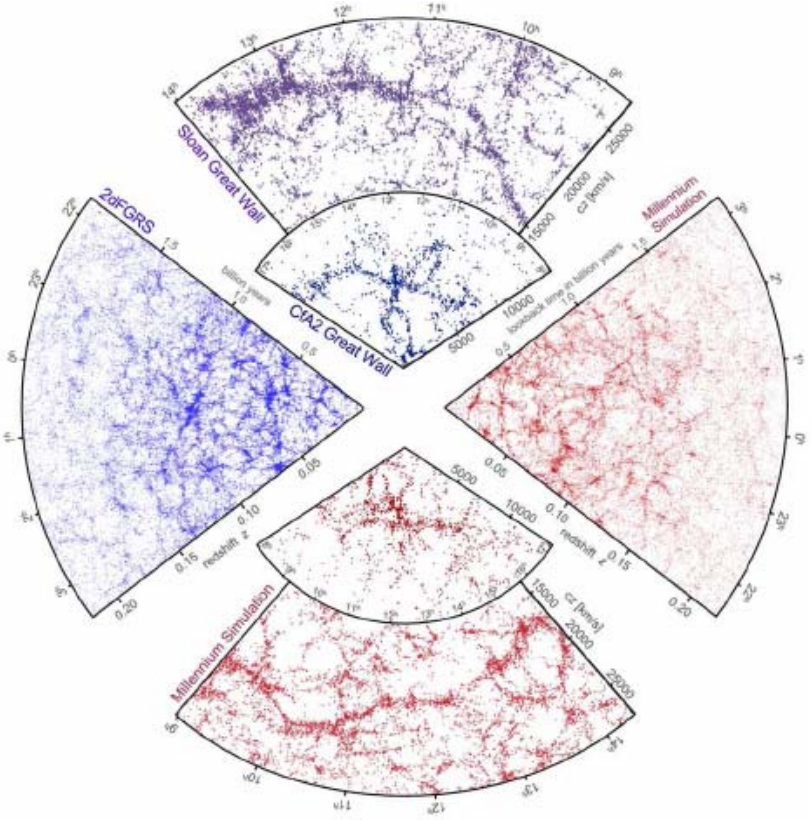




~1/4 dark matter
What are they?

Structure evolution: cold dark matter

Bottom-up structure formation pattern instead of top-down pattern (fragmentation): cold dark matter

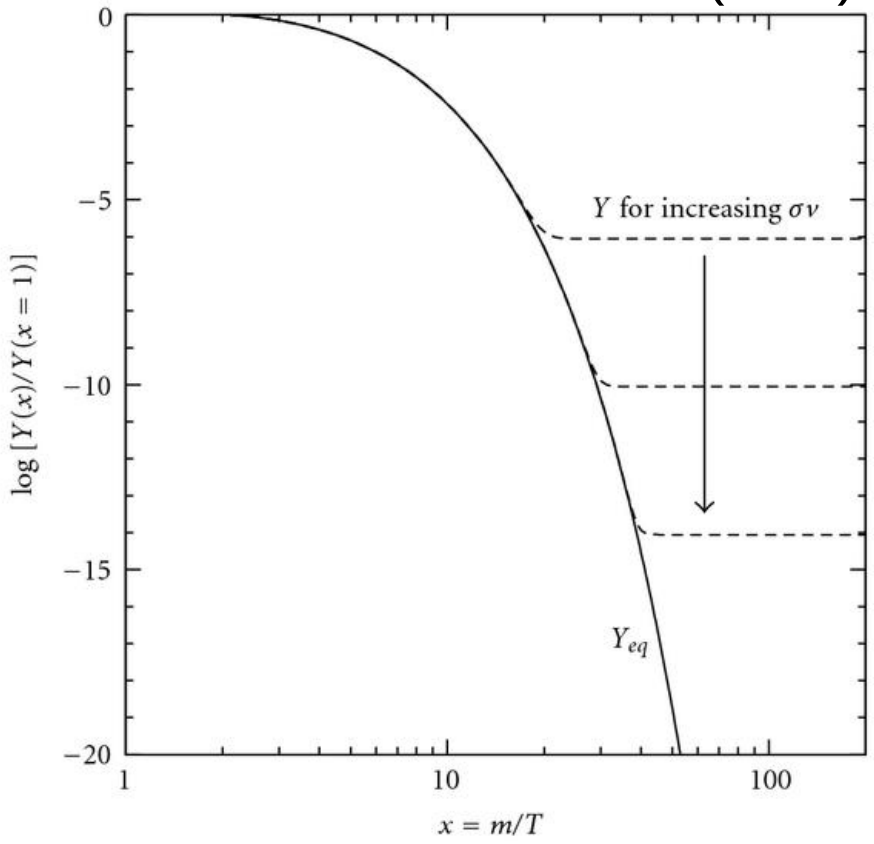


Springel et al. (2006) Nature

CDM simulation vs. galaxy survey

Thermal evolution of dark matter density

Garrett & Duta (2011)

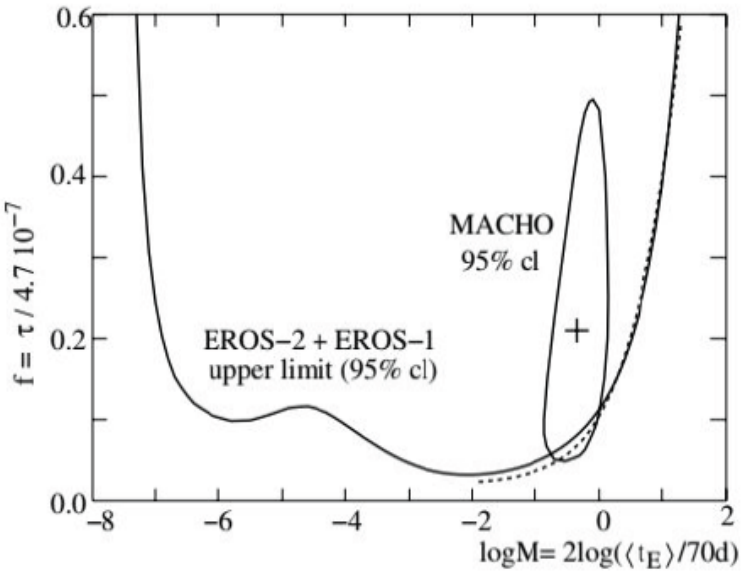


$$\langle \sigma v \rangle \simeq \left(\frac{3 \times 10^{-27} \mathrm{cm}^3 \mathrm{s}^{-1}}{\Omega_\chi h^2} \right)$$

$\sigma \sim 10^{-33}$ cm^2
(TeV neutrino-nucleon cross section ~ 10^{-35} cm^2)

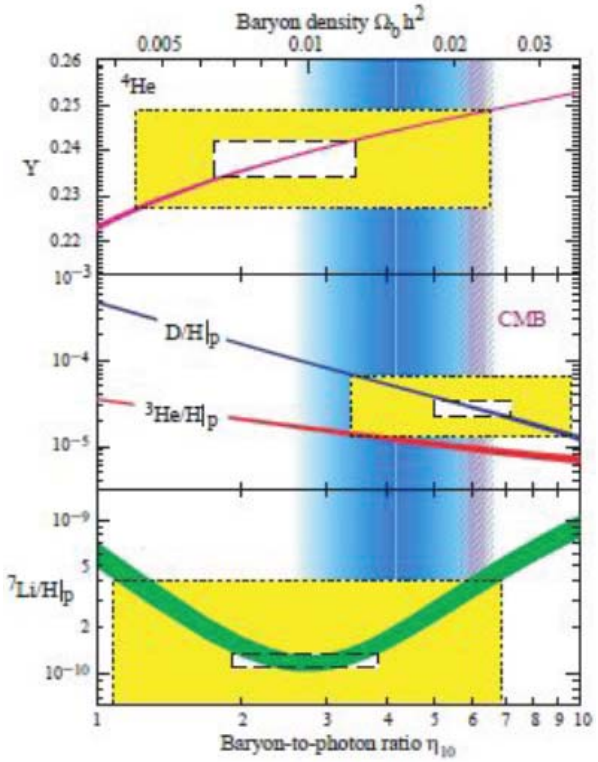
Weak scale interaction!

Non-baryonic dark matter



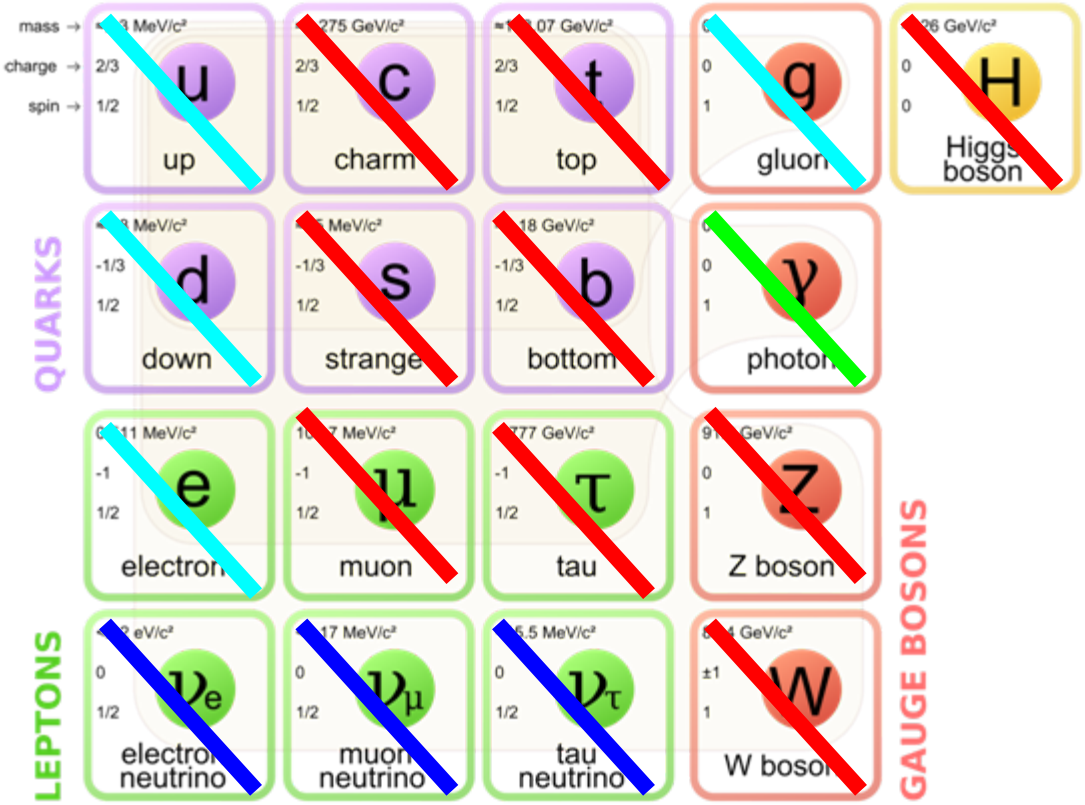
Search for Massive Compact Halo Objects (MACHOs) implies a <10% contribution to the total mass (Tisserand et al. 2007)

BBN theory and observations gives Ω_b~0.05
(Fields and Sarkar 2004)

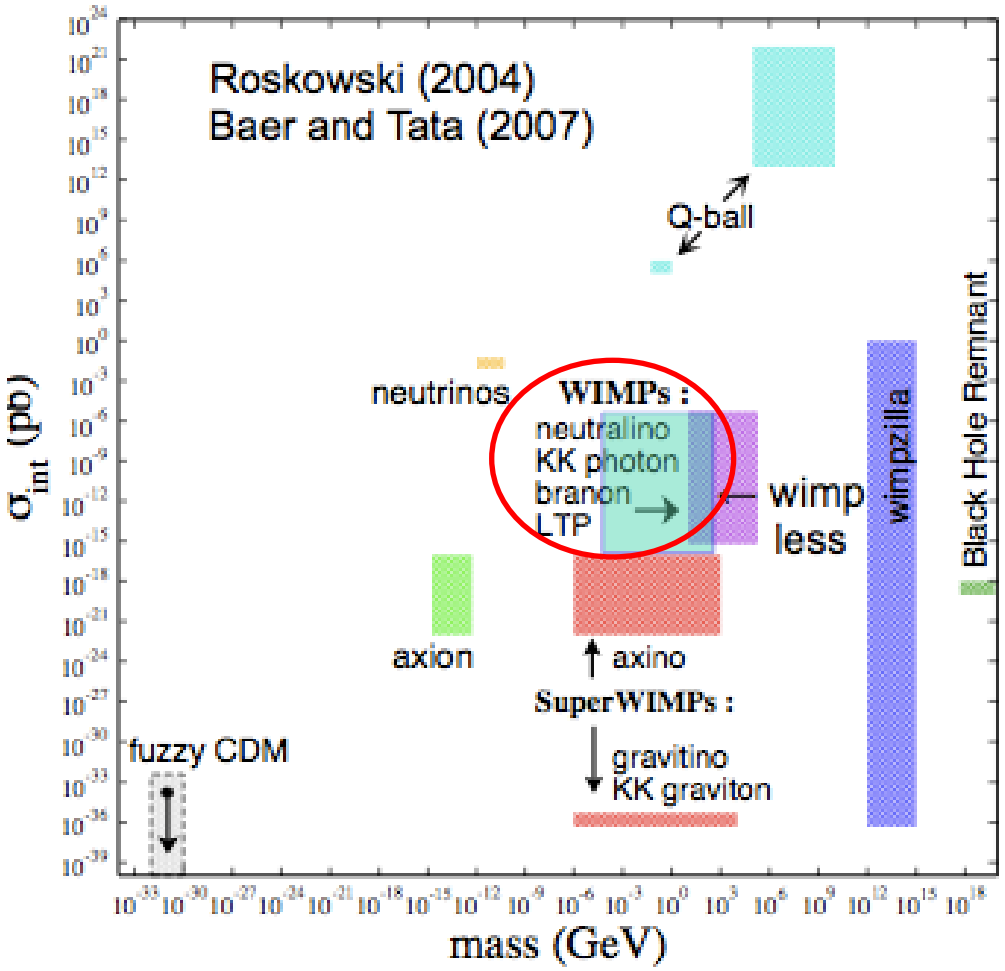


Particle dark matter

From astronomical observations we know dark matter is:
Stable; Massive; Non-baryonic; Weak interacting

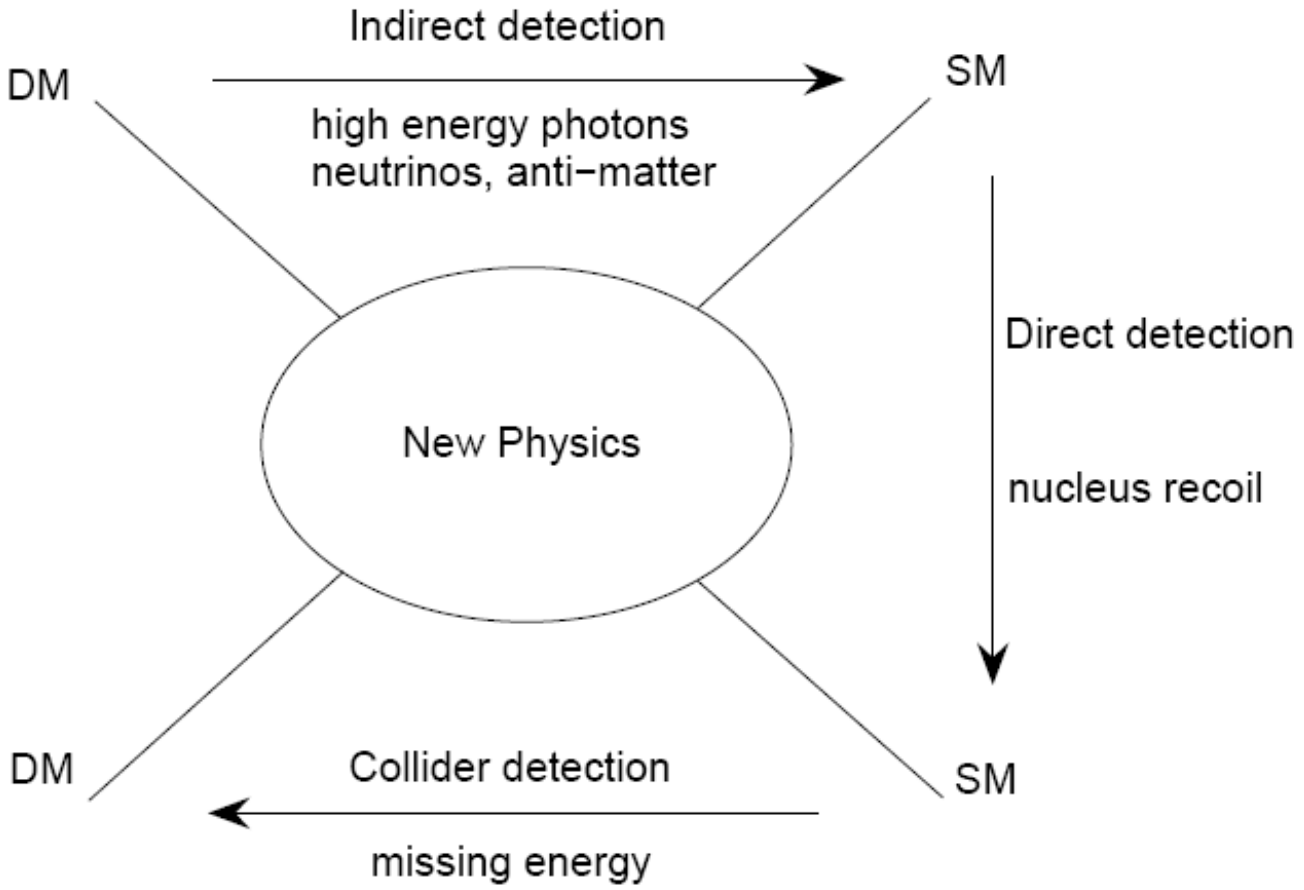


Candidates beyond the standard model

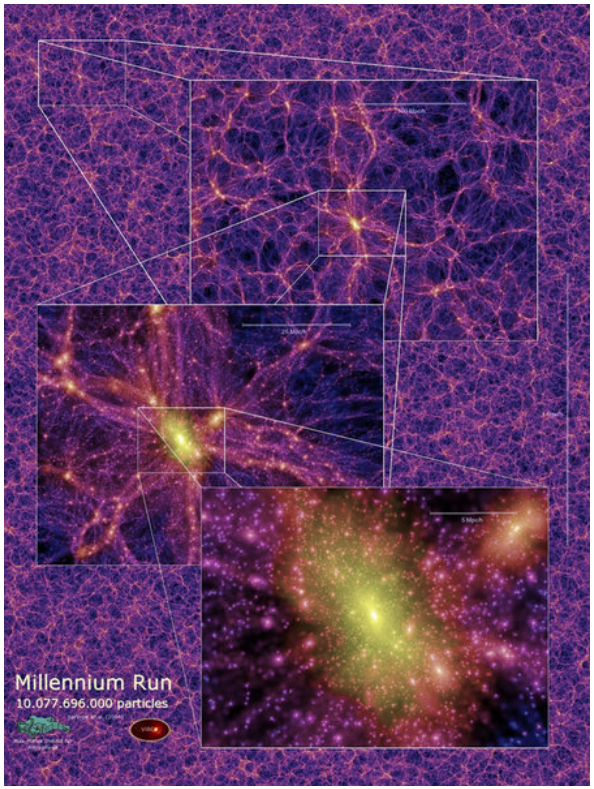


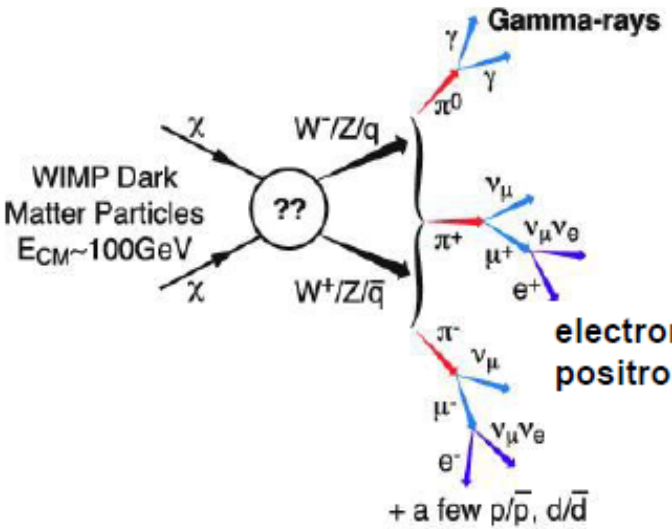
A class of weakly interacting massive particles (WIMPs) is the most probable candidate

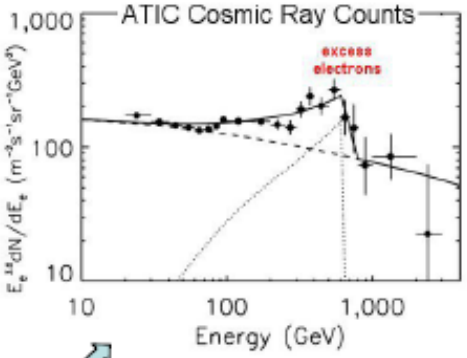
Detection of particle dark matter



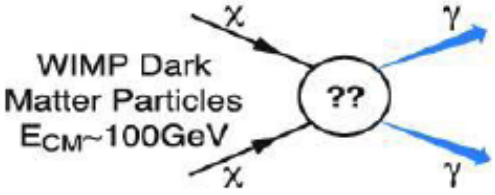
Indirect detection of dark matter

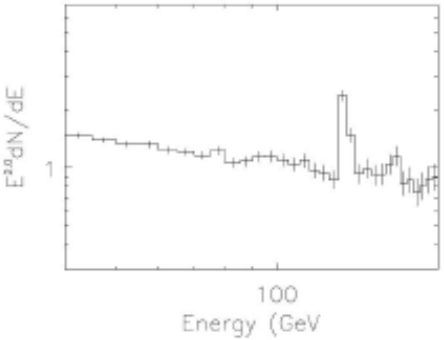






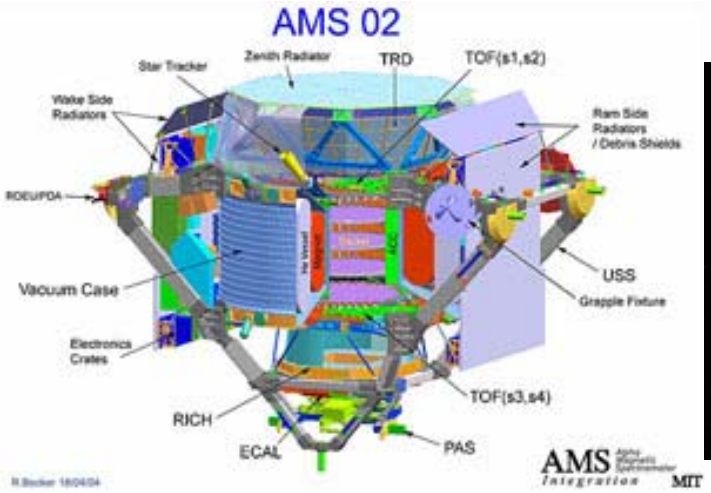
electrons
positrons



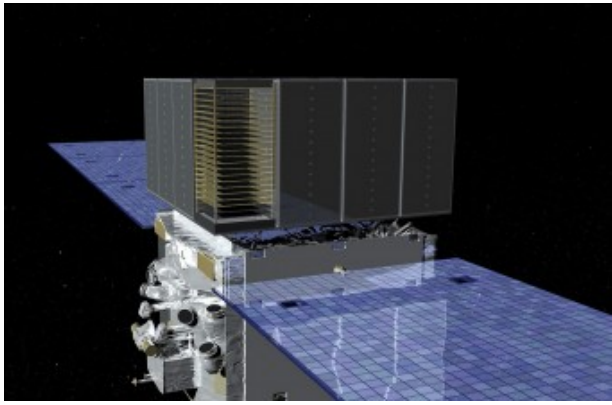


Current cosmic-ray/gamma-ray experiments

CALET



Fermi

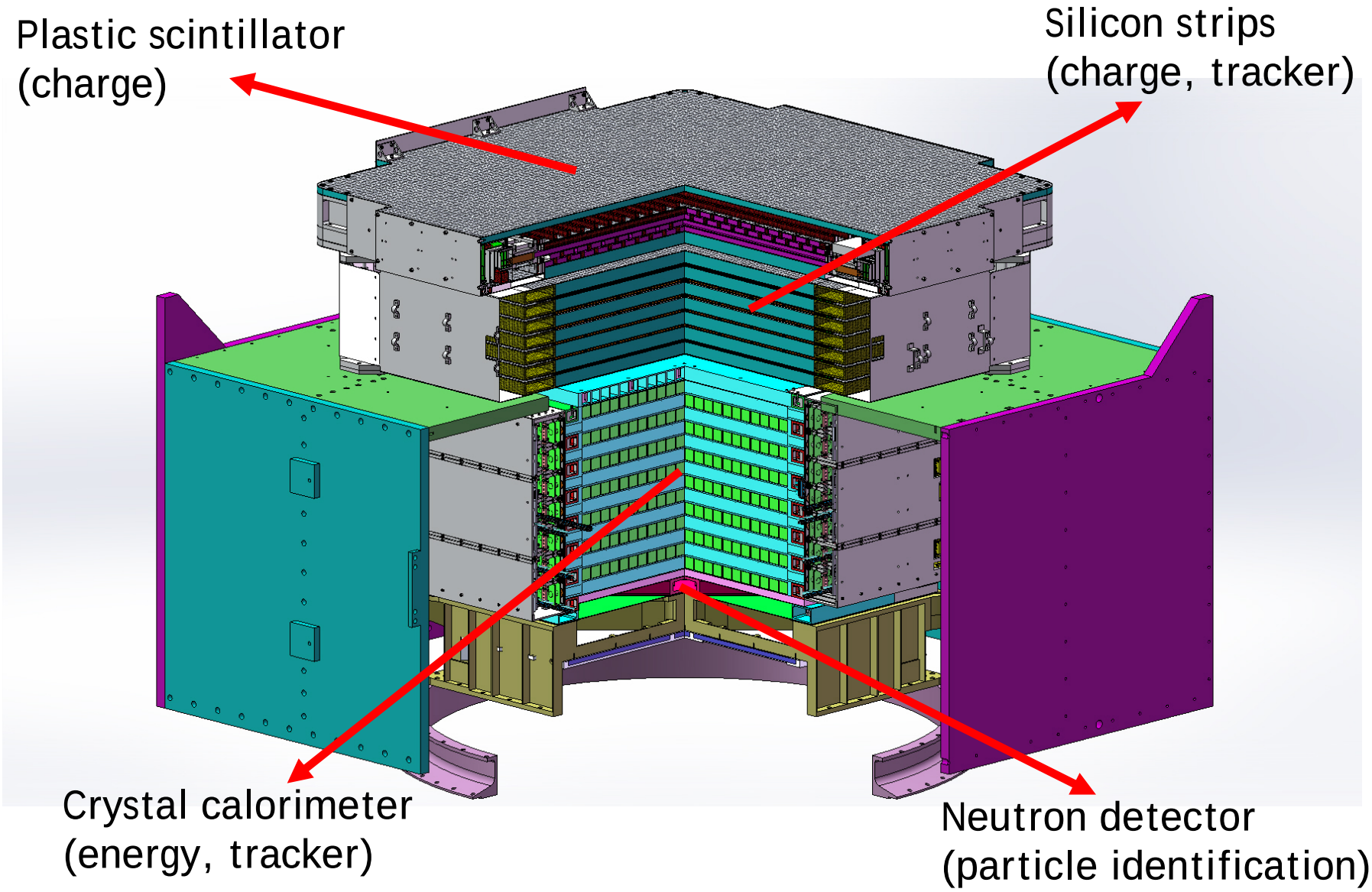


Yangbajing

HESS/MAGIC/VERITAS

Launched successfully at 8:12, Dec. 17, 2015!

DAMPE detector



DAMPE capability

Name	Energy range	Geo. Fac.（m^2.sr)	E. Res	Bg Rej.
PAMELA	~300 GeV	0.002	5-10%	10^4
FERMI	~300 GeV	1.0	5-15%	10^3
AMS-02	~1000 GeV	0.1	3%	10^5
CALET	~3000 GeV	0.12	2%	10^5
ISS-CREAM	~3000 GeV	0.2	15%	10^3
DAMPE	~10,000 GeV	0.3	1.5%	10^5

Scientific goals

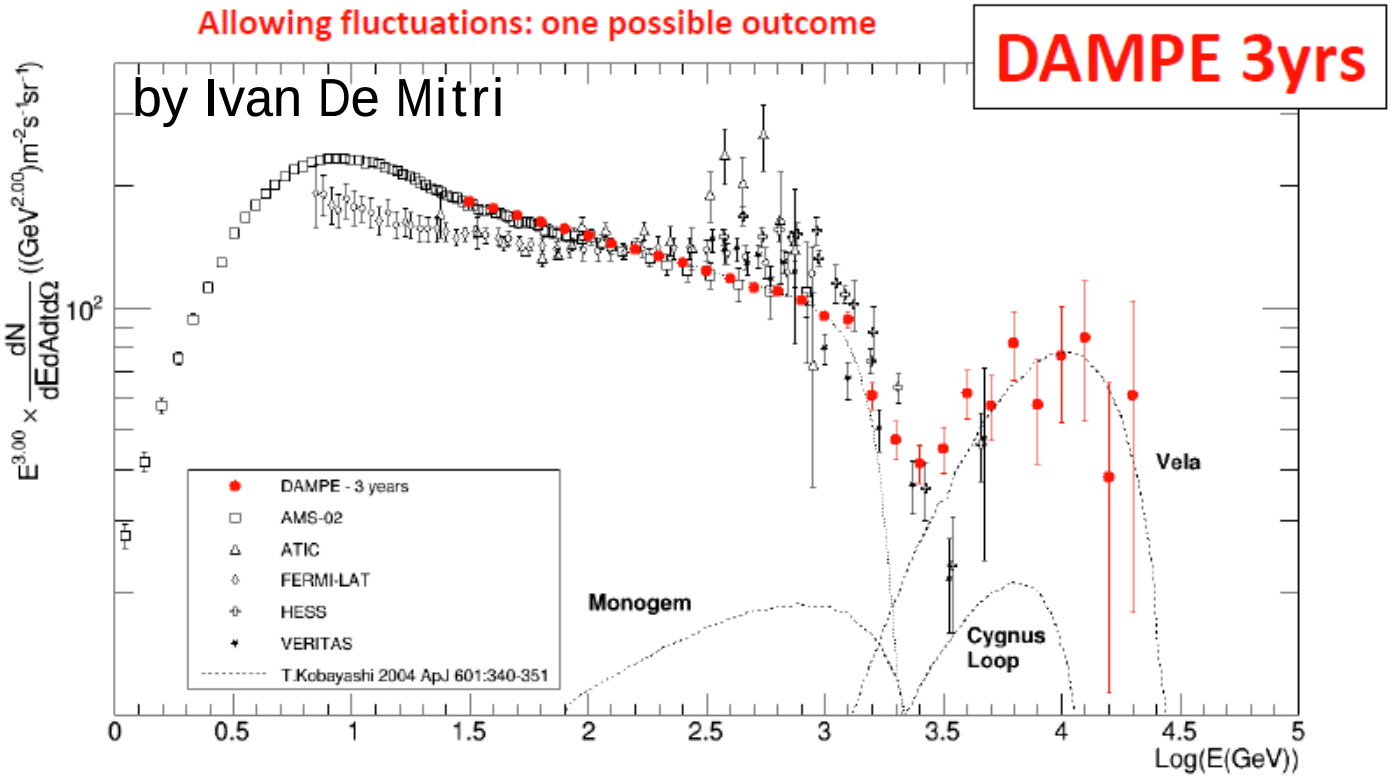
Cosmic ray origin & propagation

Gamma-ray astronomy

Particle dark matter

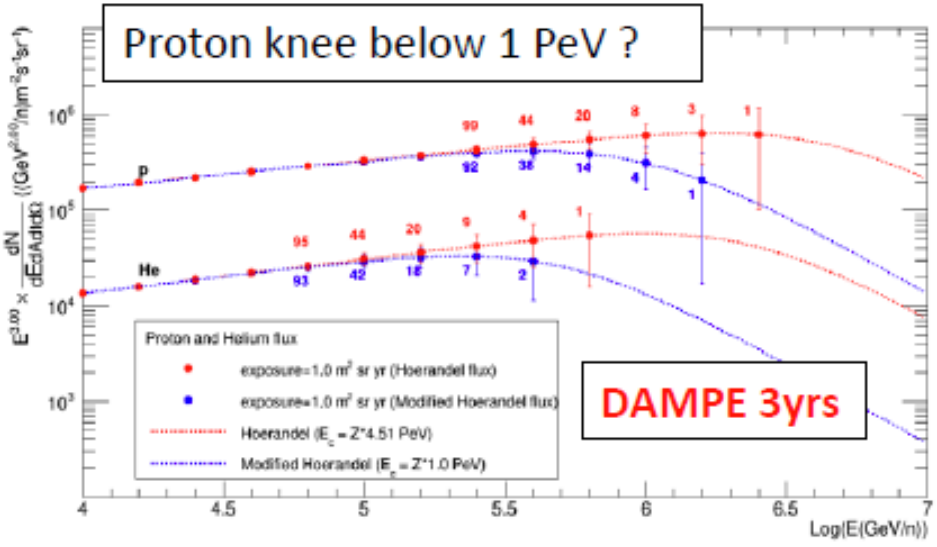
Science with DAMPE

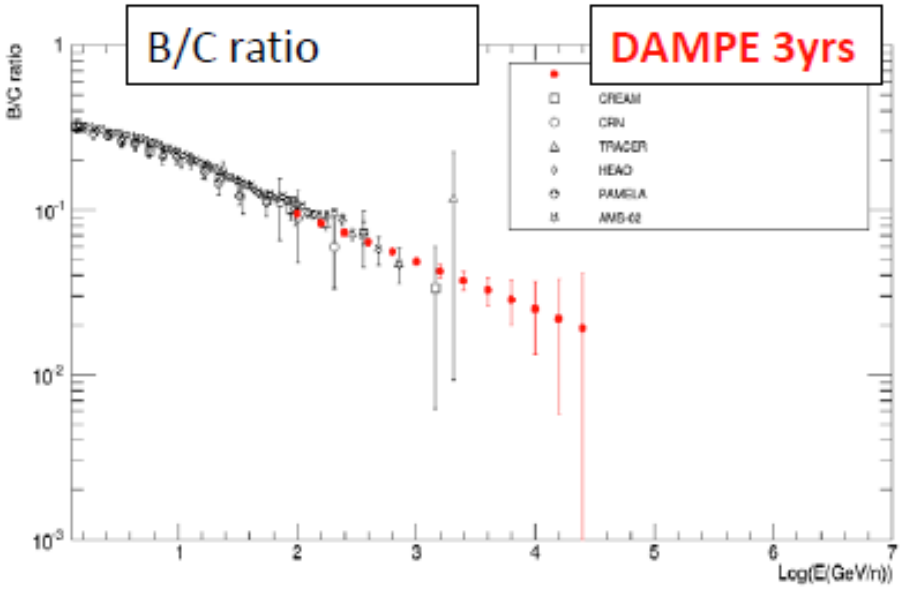
- Measure the electron spectrum up to 10 TeV (probe nearby electron sources and/or dark matter)



Science with DAMPE

- Measure the nuclei spectra (p, He, C…) to beyond 100 TeV (cosmic ray origin, propagation etc.)
- Measure the nuclei secondary-to-primary ratio up to 10 TeV/n (cosmic ray propagation)

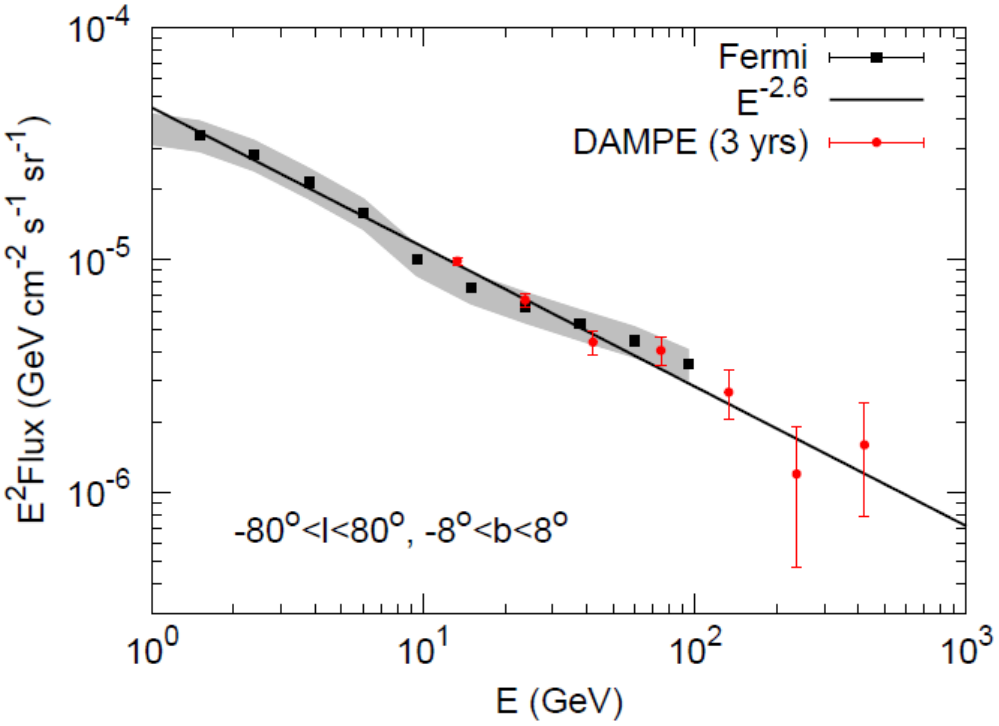


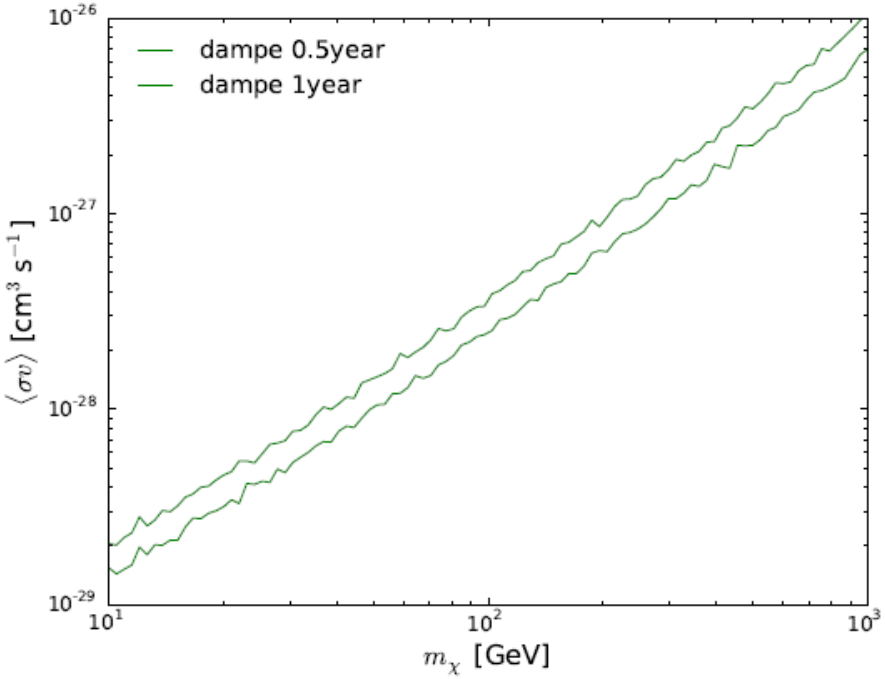


by Ivan De Mitri

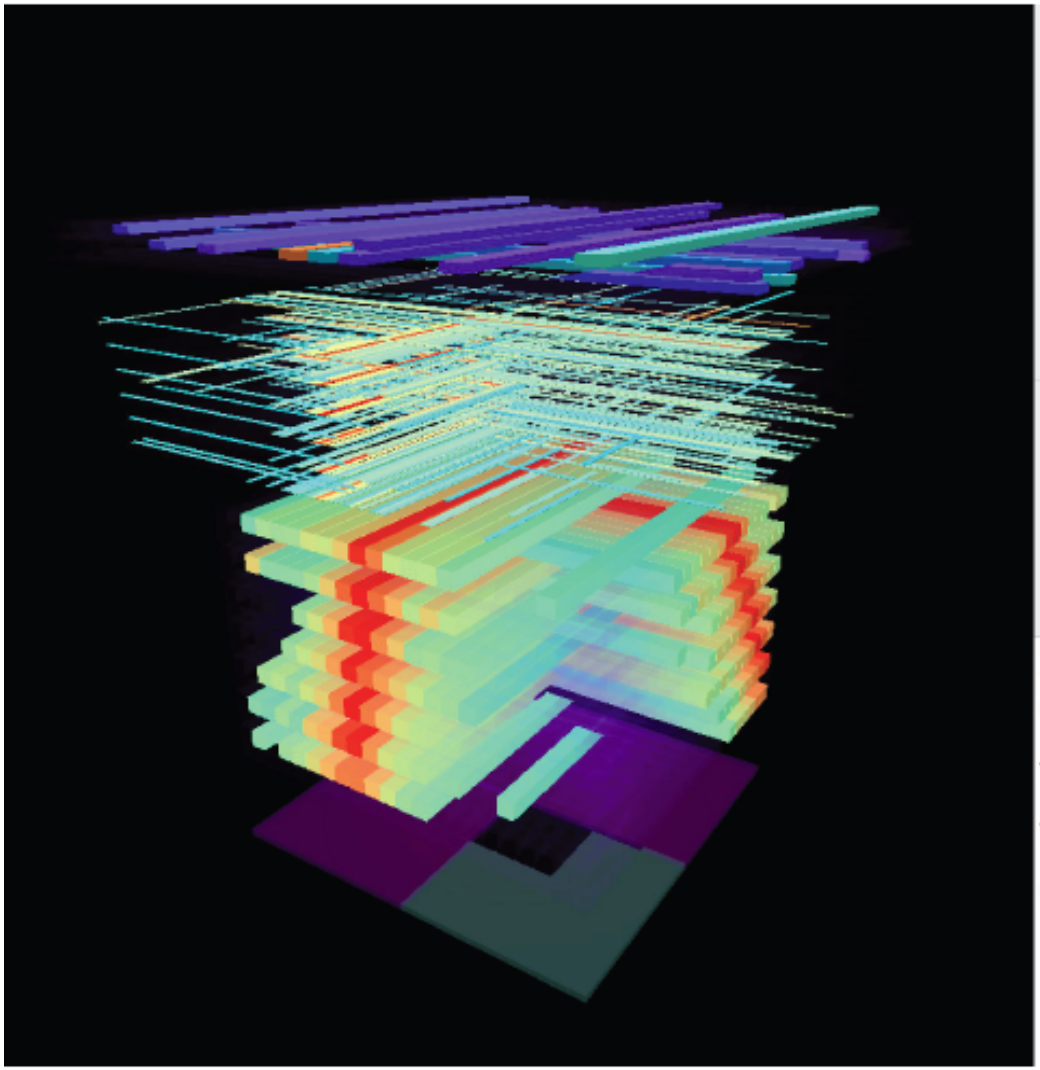
Science with DAMPE

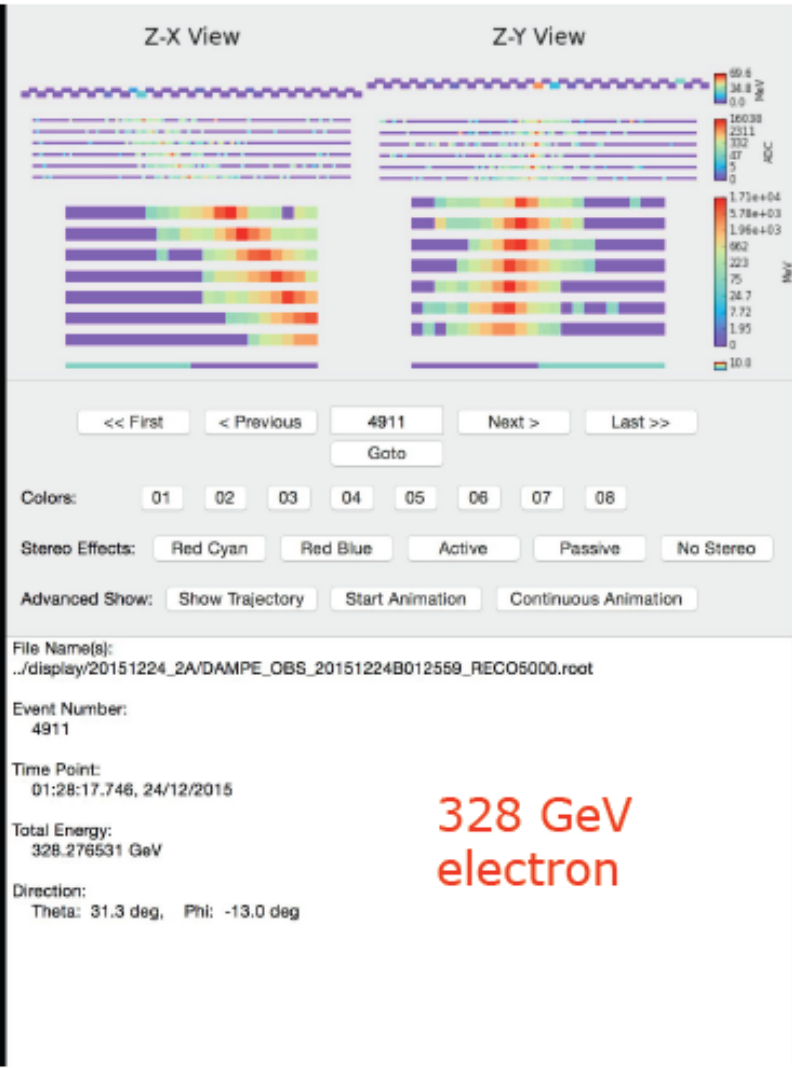
- Measure the diffuse gamma-rays up to 1 TeV (cosmic ray propagation and interaction)
- High sensitivity search for gamma-ray lines in 10-1000 GeV range (dark matter)





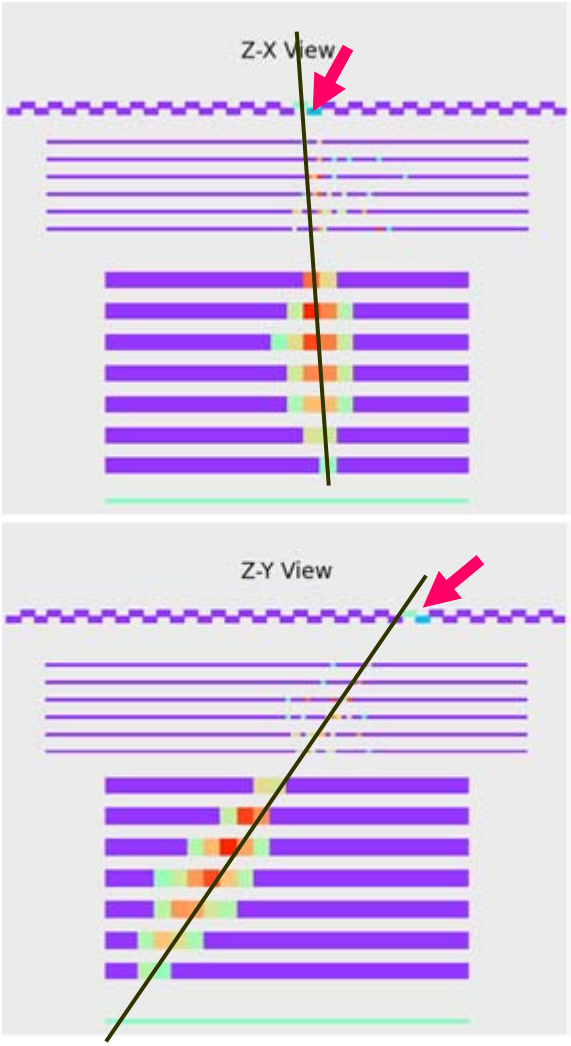
First light on 12/24/2015



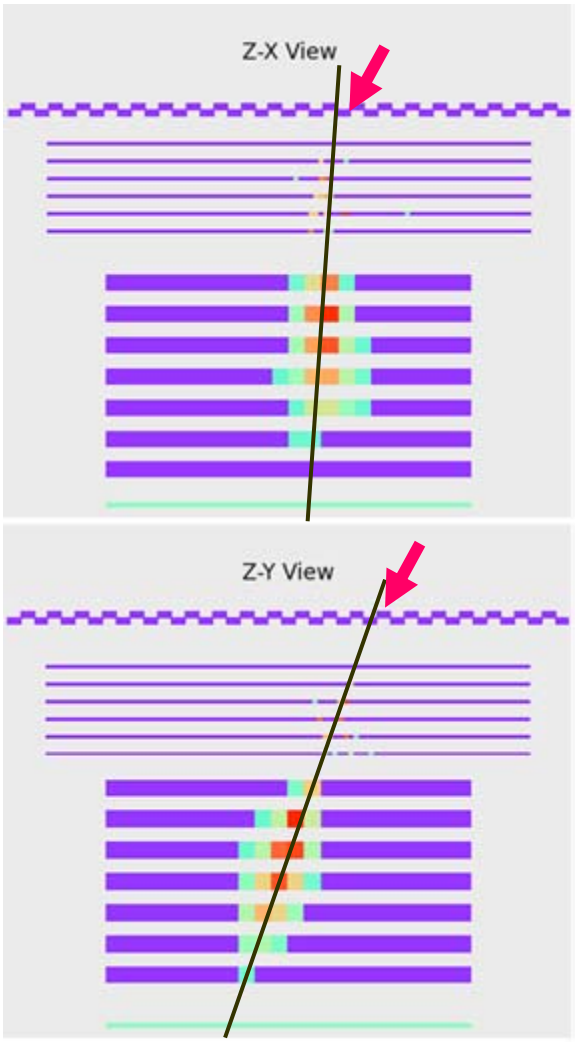


Various events

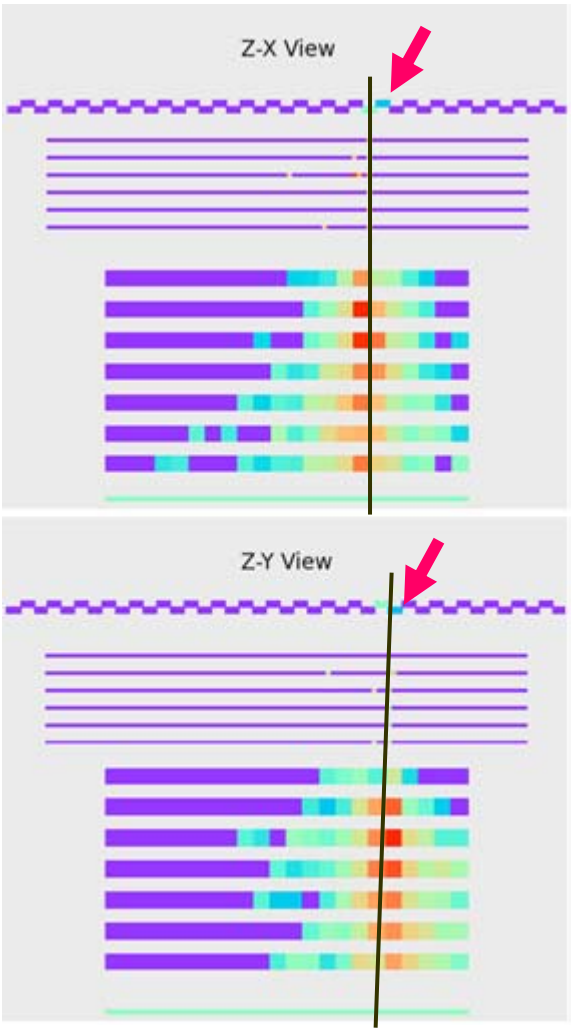
Electron



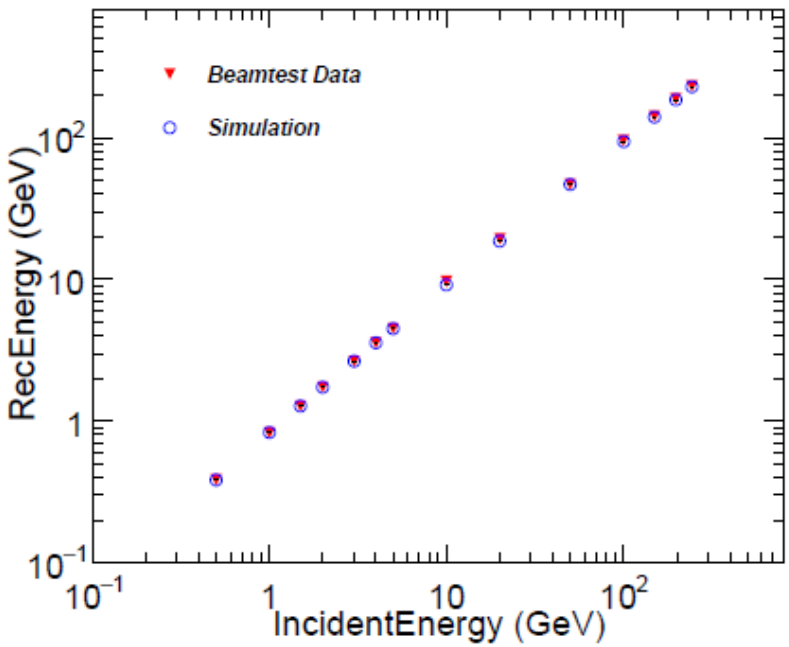
Gamma

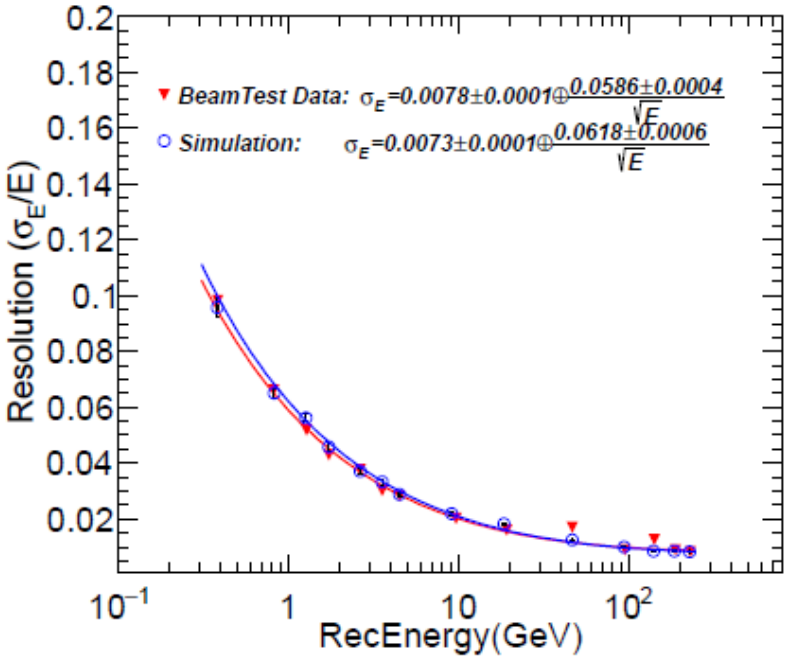


Proton

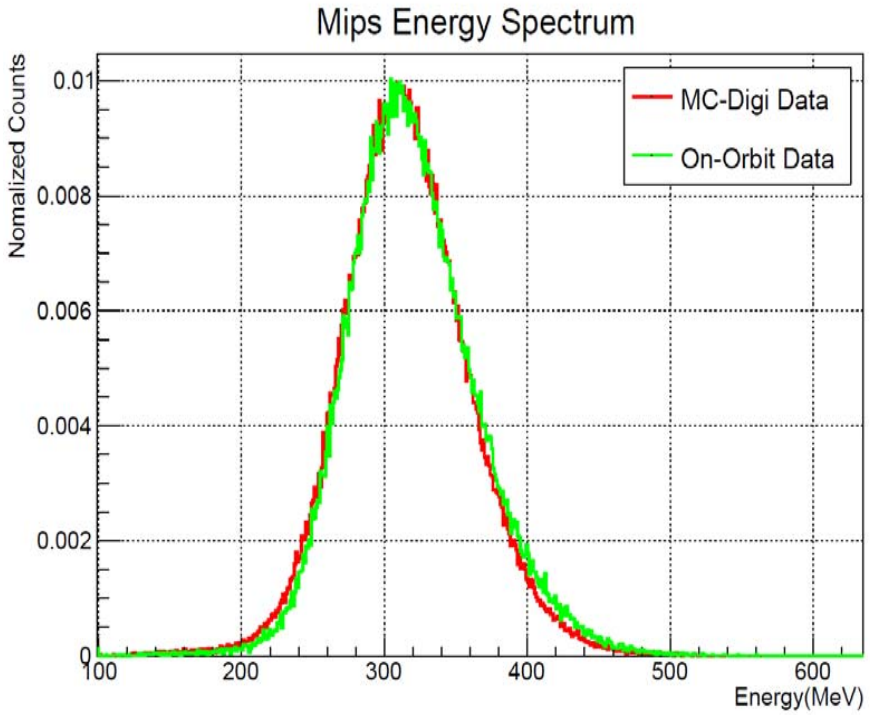


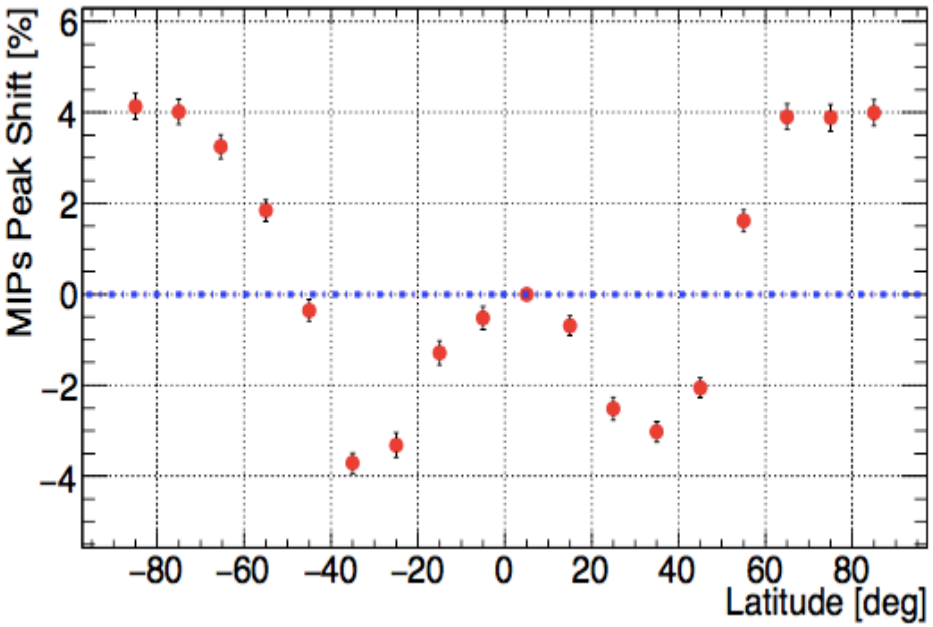
Beam test results (energy reconstruction and resolution)





MIPs calibration

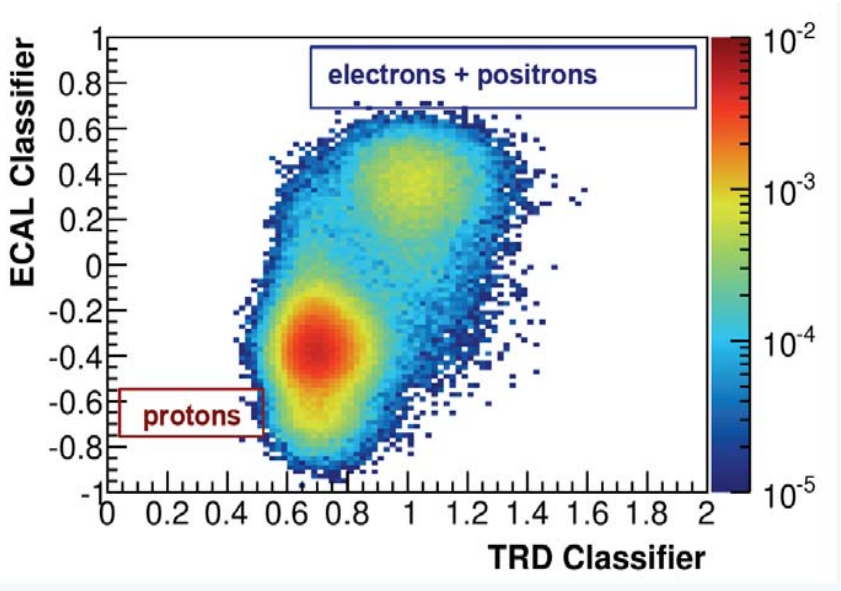




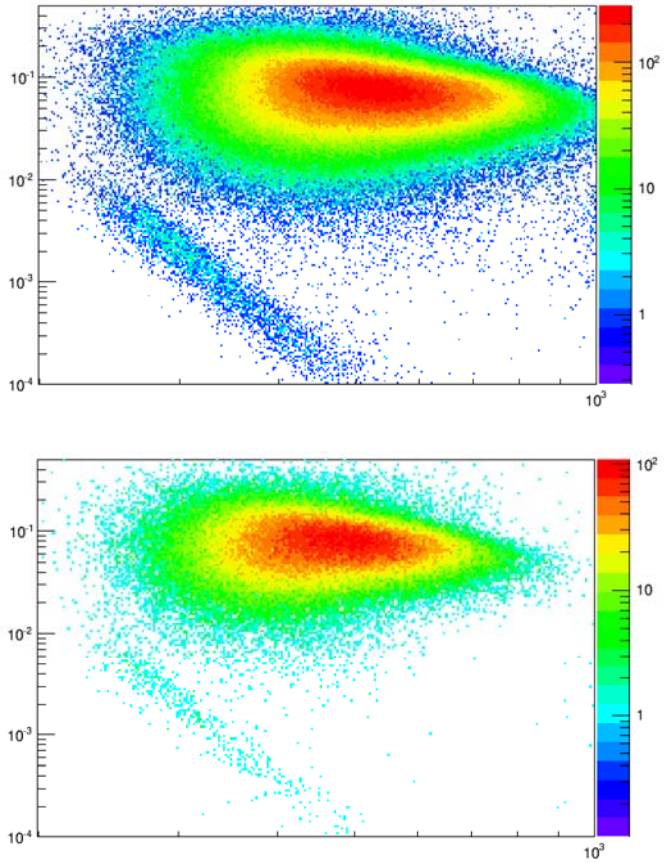
MIPs energy spectrum is consistent with simulation (and beam test)

MIPs variation with latitude consistent with geomagnetic cutoff

e/p separation

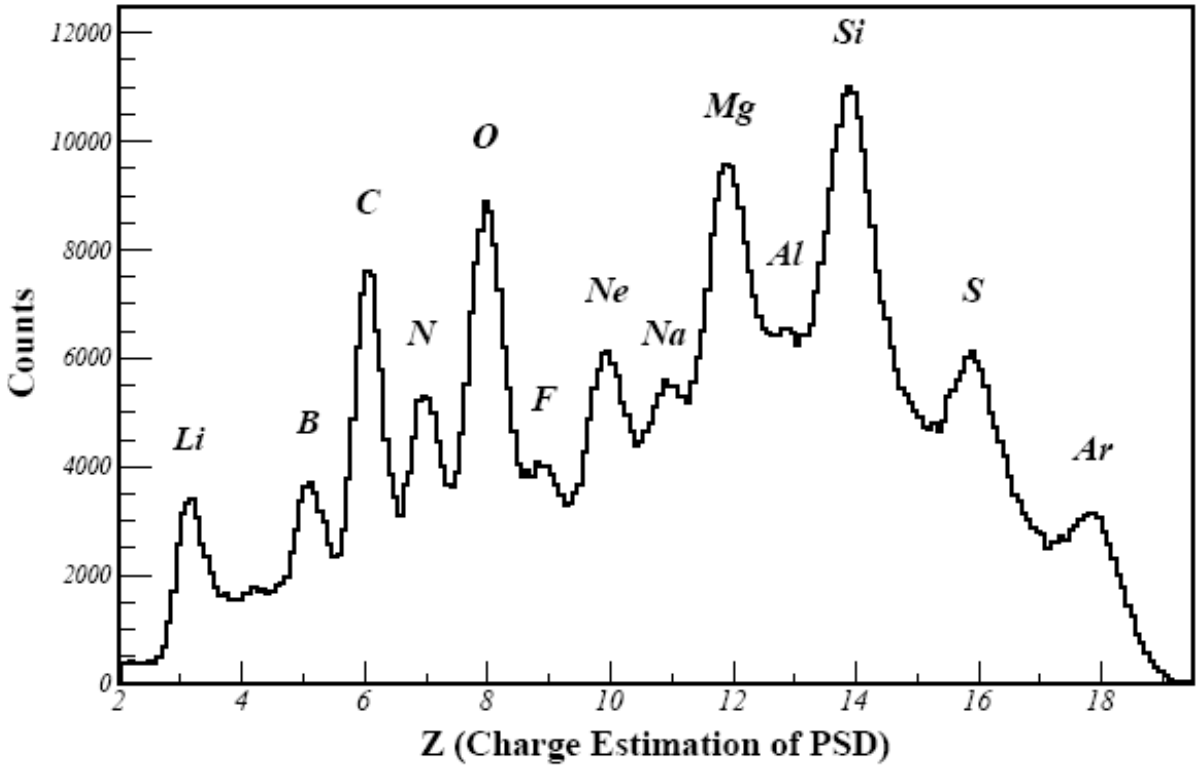


AMS02 @ ~100 GeV



DAMPE up to 1 TeV

Charge reconstruction



Charge resolution 0.19 for O, 0.39 for Fe

卫星整体状态

卫星关键指标：
指向精度和稳定度优于0.3度
温度控制精度优于1度；

探测器工作正常率
PSD：100%
BGO：100%
STK： 99.85% (指标97.5%)
中子：100%

截至2016年6月7日：
- **在轨稳定飞行165天**
- **累计接收数据2634轨**
- **下传数据4.5TB**
- **观测8亿个高能粒子**
- **完成了全天区首次全覆盖**

和LHAASO相关的科学

- 测量分成分宇宙线能谱(研究宇宙线起源，膝等)
- 变源的联合监测(DAMPE设计寿命3年，有可能延长至5年)
- 电子谱的测量？

谢谢大家！