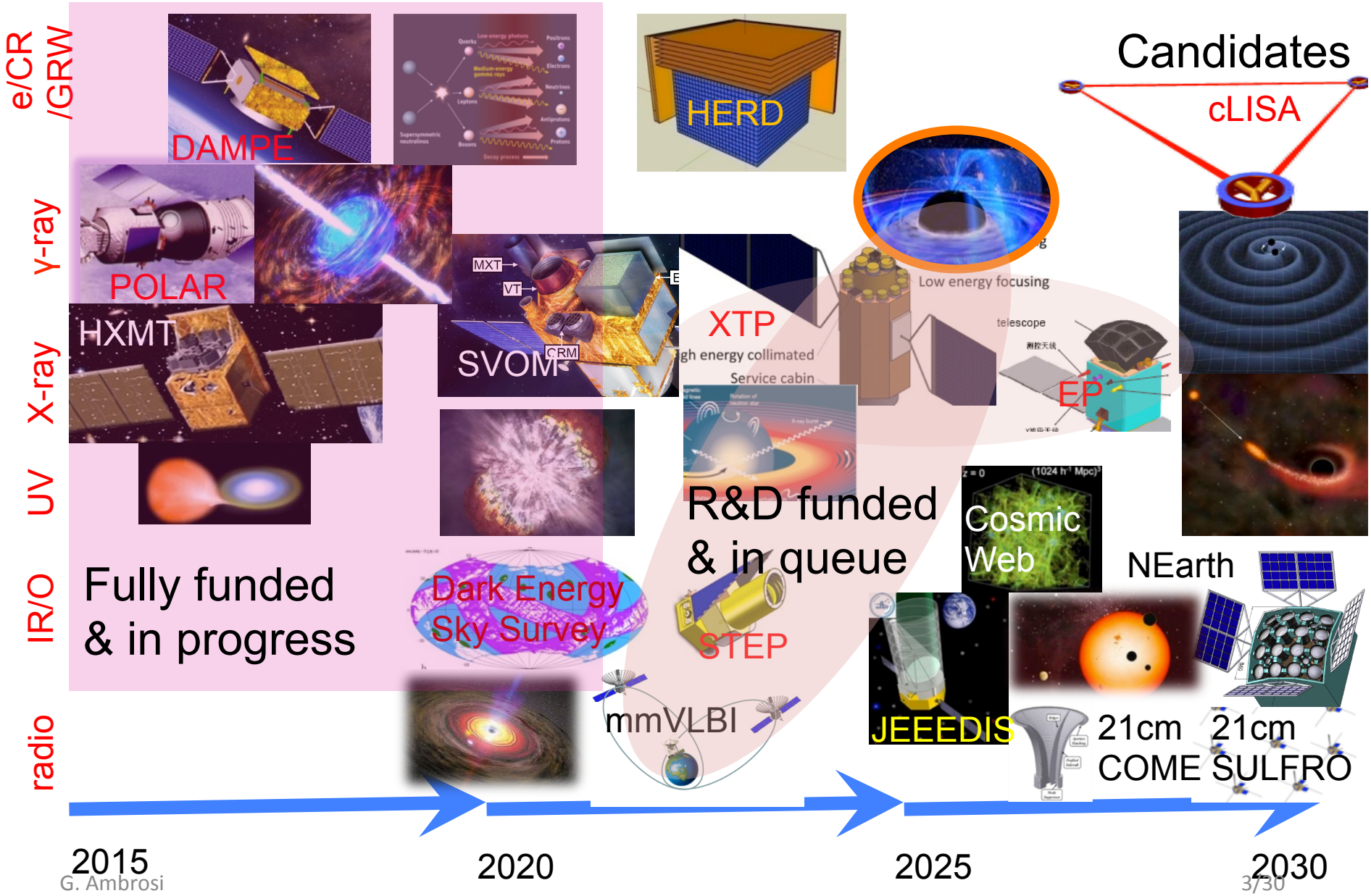
DAMPE (and HERD)

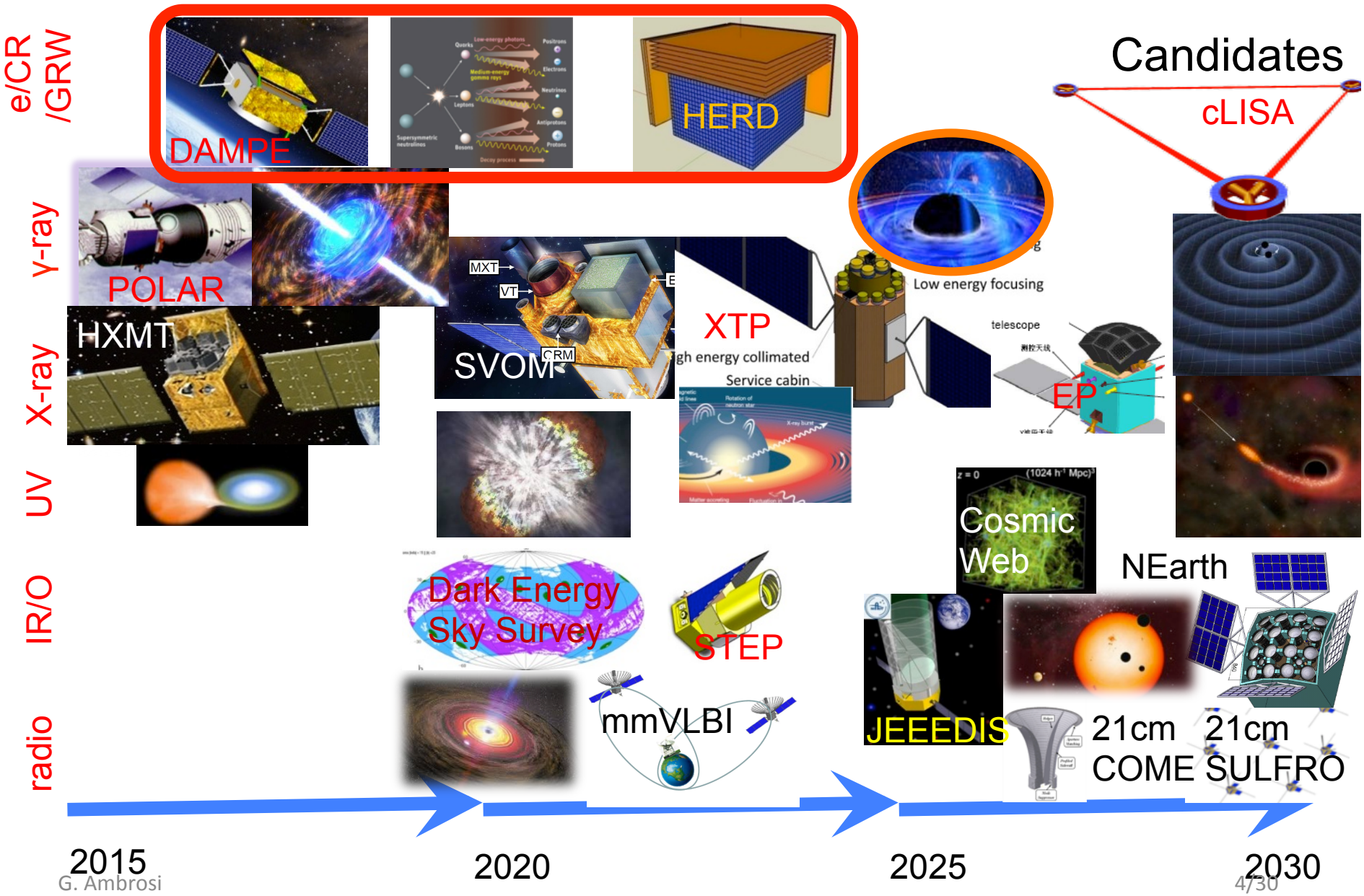
G. Ambrosi
INFN Perugia

China's Future Space Astronomy Missions

China's Future Space Astronomy Missions



China's Future Space Astronomy Missions



DAMPE: Dark Matter Particle Explorer
HERD: High Energy cosmic Radiation Detector

G. Ambrosi
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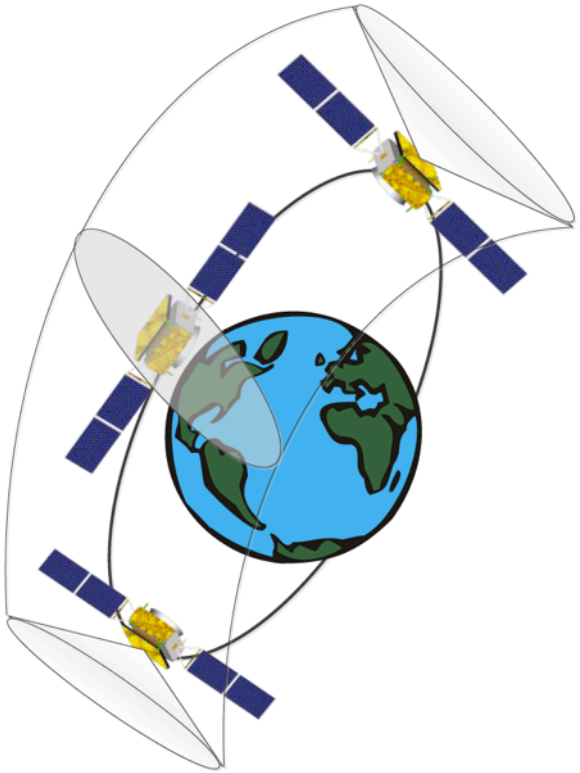
DAMPE: One of the Five Approved Satellite Missions of the Chinese Academy of Sciences (CAS)

- **Hard X-ray Modulation Telescope (HXMT)**
- **Quantum Science Experimental Satellite**
- **DArk Mater Particle Explorer (DAMPE)**
- **Retrievable Scientific Experimental Satellite**
- **Kuafu Space Weather Project (3 satellite)**

DAMPE Satellite

- **Planned launch late 2015**
  - **Total weight ~1900 kg, power consumption ~640 W**
    - **Scientific payload ~1300 kg, ~400 W**
  - **Lifetime > 3 year**

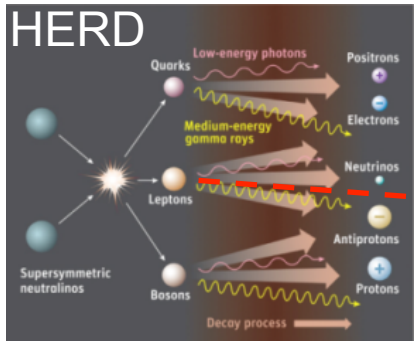
- **Altitude: 500 km**
- **Inclination: 97.4065°**
- **Period: 95 minutes**
- **Orbit: sun-synchronous**

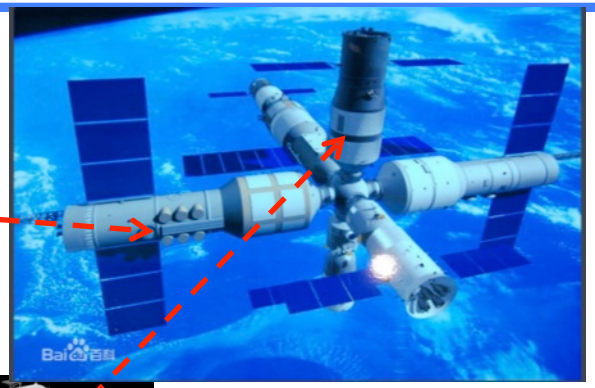


China's Space Station Program

2020

Phase -II

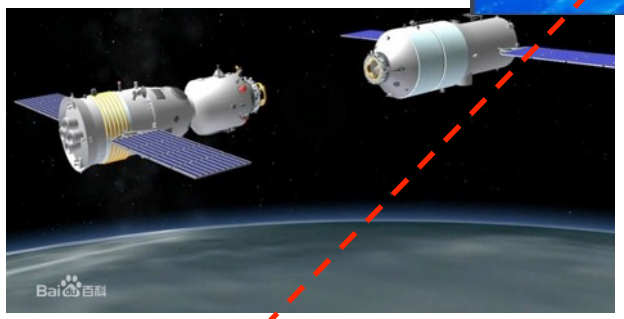




Space Station
3 large modules
~ 60 tons
~10-year lifetime

2016

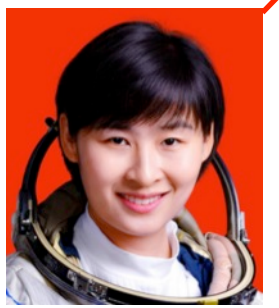
Phase -II



Space lab:
no living cabin

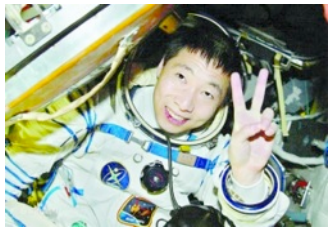
2011

Phase -I



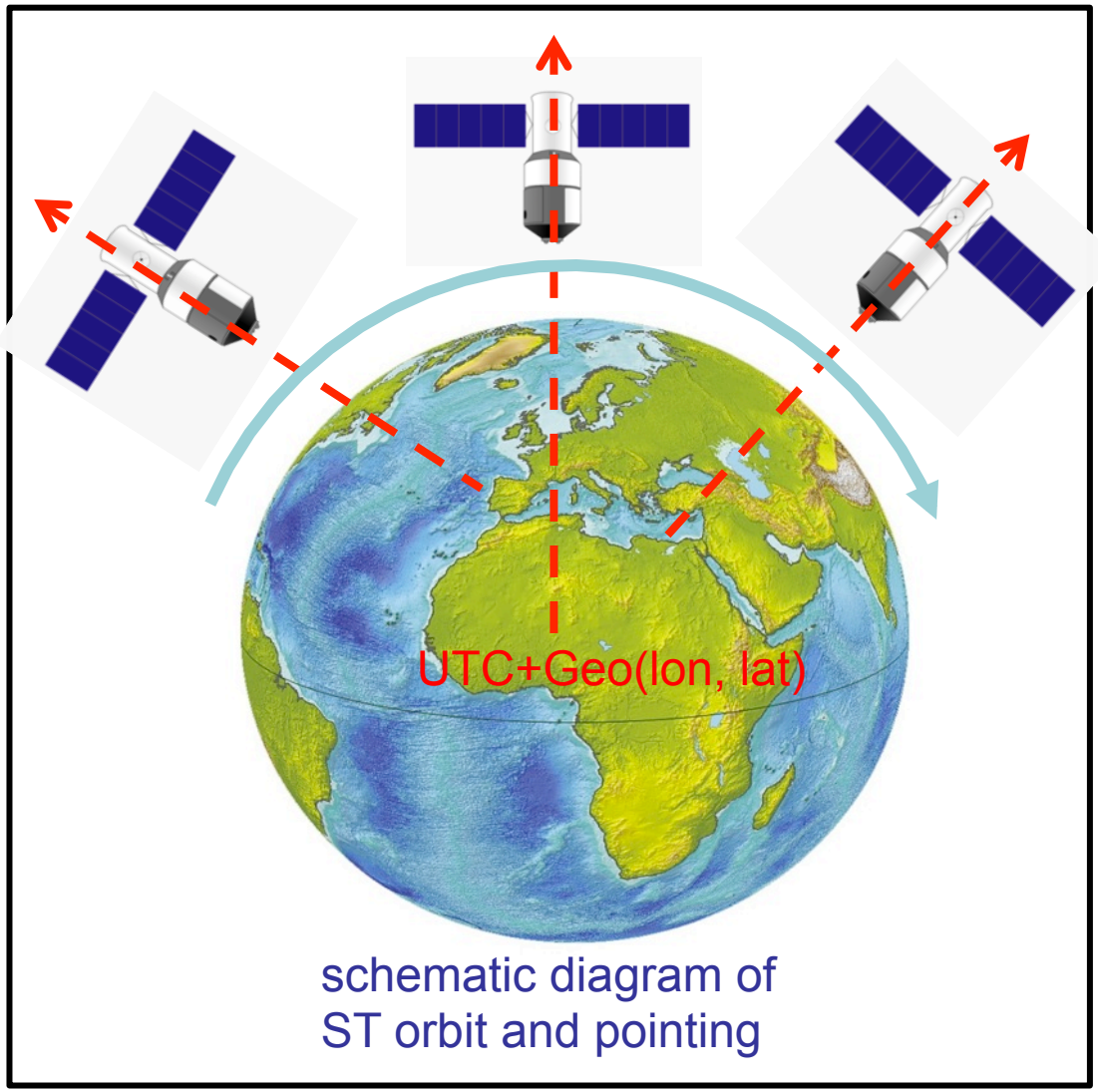
10 astronauts in 5 flights → space walk

2003

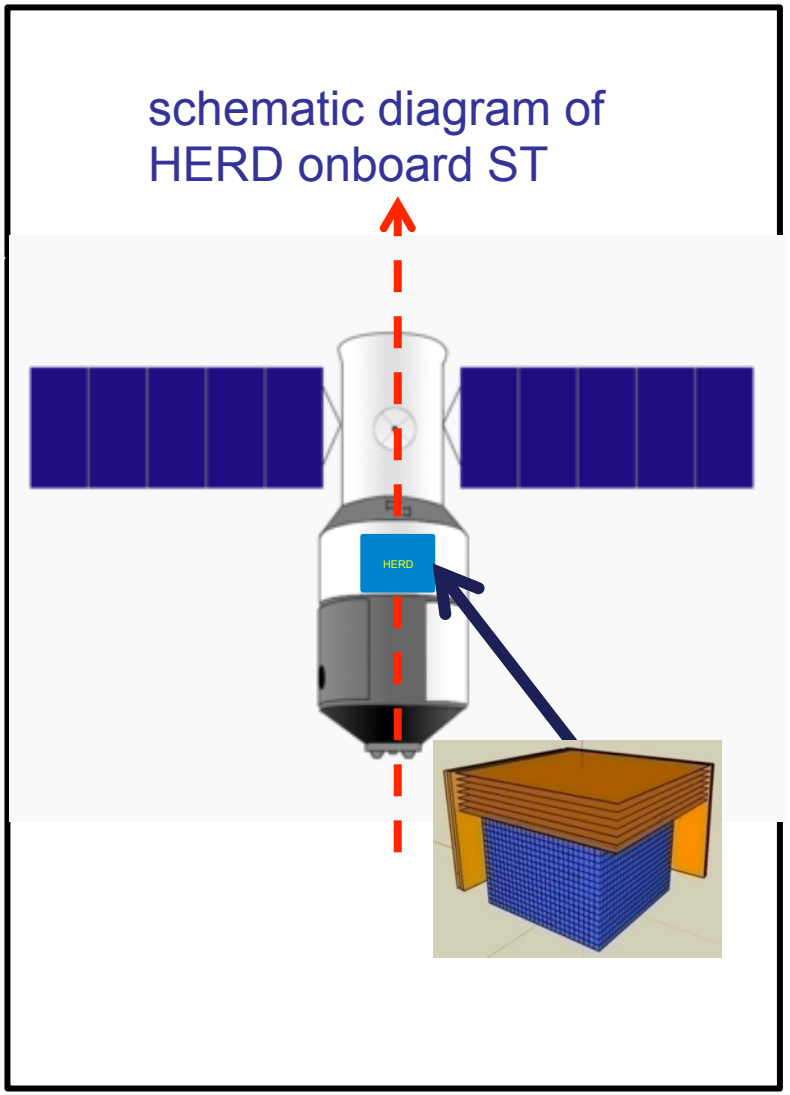



background
Gamma-ray
HERD
electron
proton
He
Dark matter particle

HERD in Space

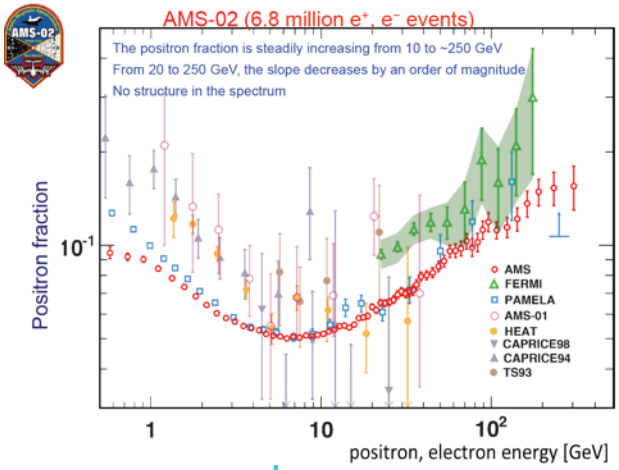


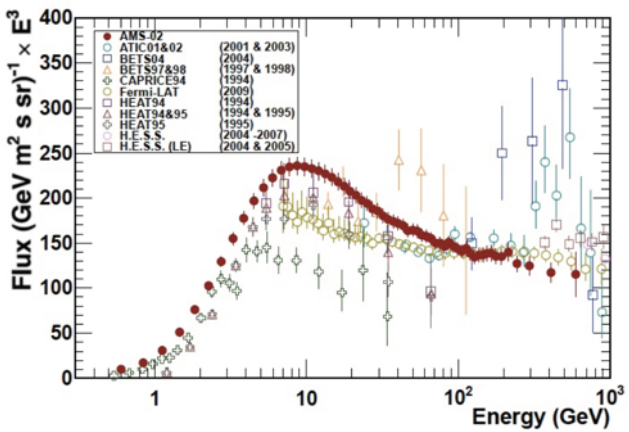
schematic diagram of
ST orbit and pointing

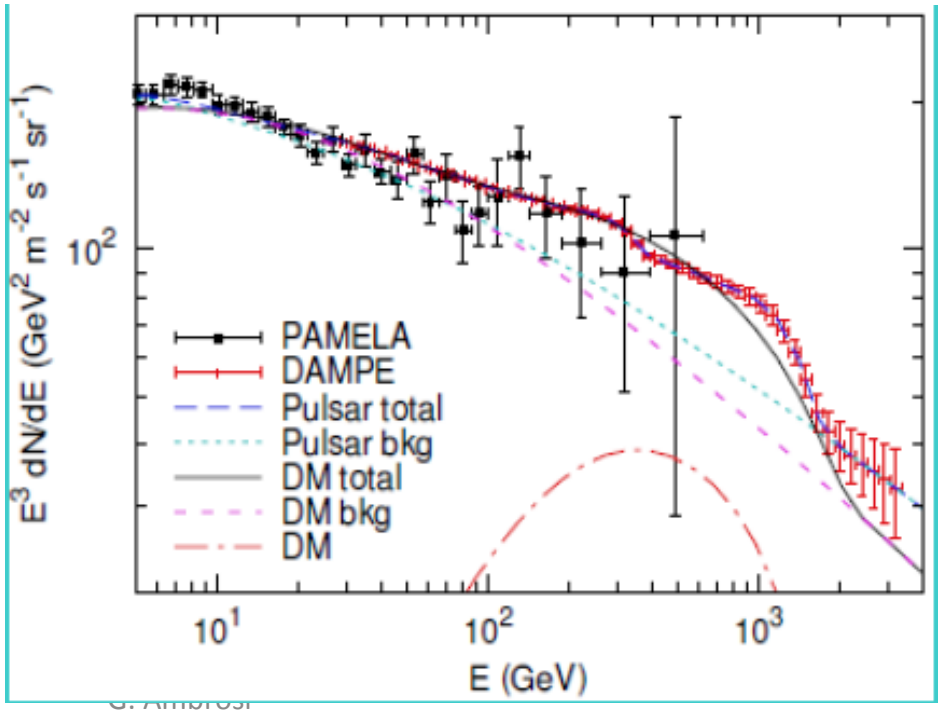


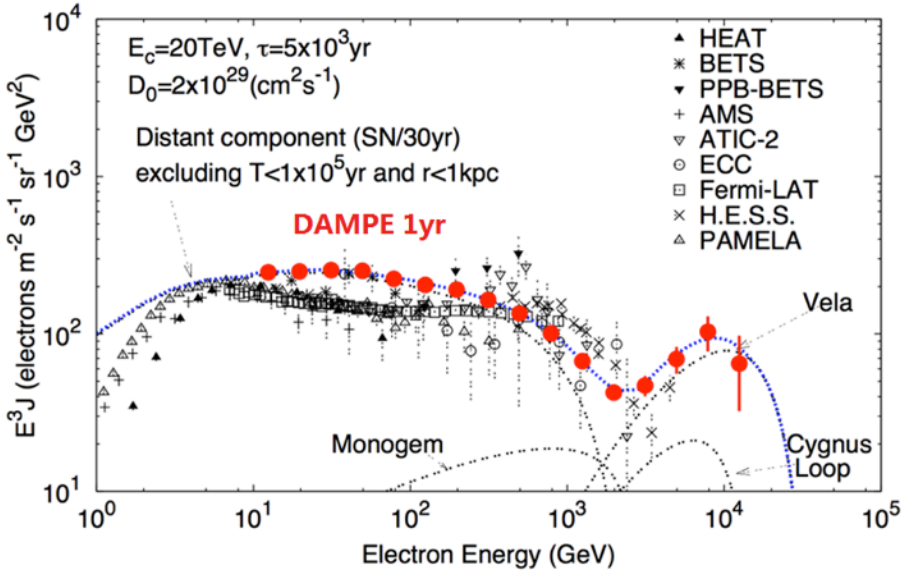
DM or Pulsar?

- **Need a detector in space that can detect electron around 1 TeV with very good energy resolution**









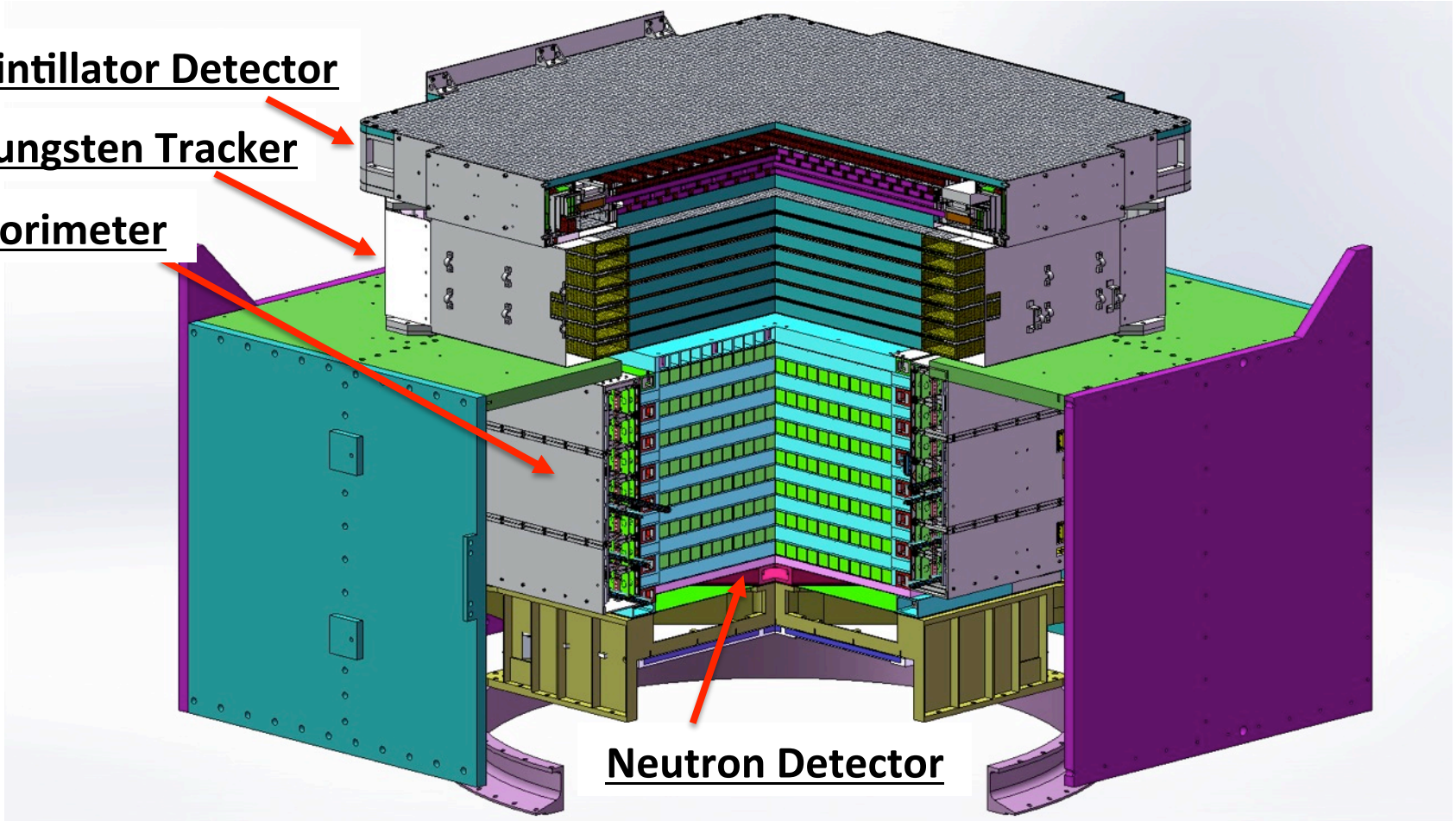
Scientific Objectives of DAMPE

- **High energy particle detection in space**
  - **Search for Dark Matter signatures with e, γ**
  - **Study of cosmic ray spectrum and composition**
  - **High energy gamma ray astronomy**

Detection of 5 GeV - 10 TeV e/γ, 100 GeV - 100 TeV CR
Excellent energy resolution and tracking precision
Complementary to Fermi, AMS-02, CALET, ISS-CREAM, …

- **Follow-up mission to both Fermi/LAT and AMS-02**
  - **Extend the energy reach to the TeV region, providing better resolution**
  - **Overlap with Fermi on gamma ray astronomy**
  - **Run in parallel for some time**

The DAMPE Detector



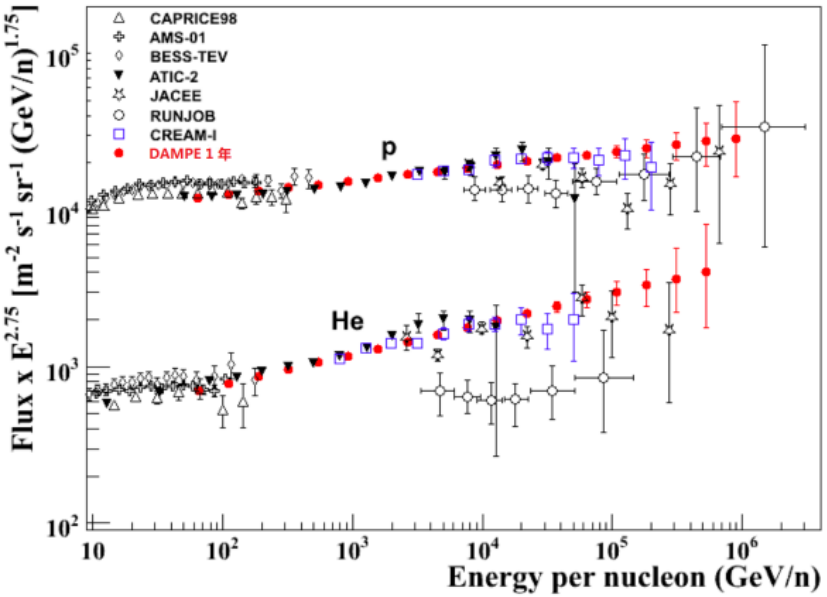
W converter + thick calorimeter (total 33 X_0) + precise tracking + charge measurement ➡ high energy γ-ray, electron and CR telescope

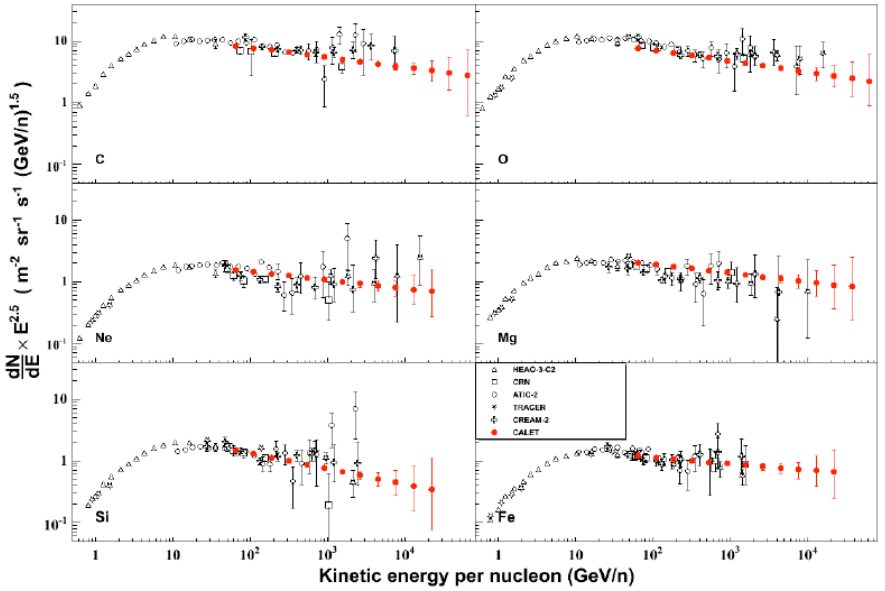
Comparison with AMS-02 and Fermi

	DAMPE	AMS-02	Fermi LAT
e/γ Energy res.@100 GeV (%)	1.5	3	10
e/γ Angular res.@100 GeV (°)	0.1	0.3	0.1
e/p discrimination	10^5	10^5 - 10^6	10^3
Calorimeter thickness (X_0)	31	17	8.6
Geometrical accep. (m^2sr)	0.29	0.09	1

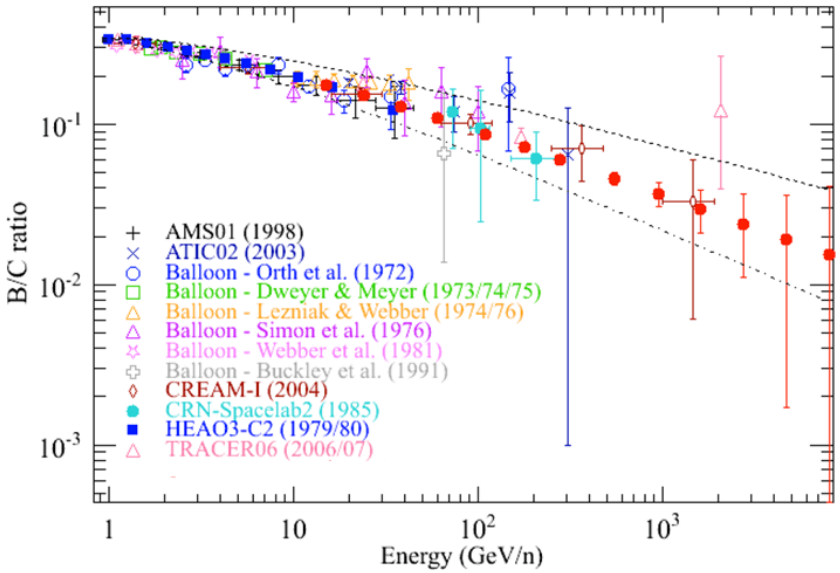
- **Geometrical acceptance with BGO alone: 0.36 m^2sr**
  - **BGO+STK+PSD: 0.29 m^2sr**
  - **First 10 layers of BGO (22 X_0) +STK+PSD: 0.36 m^2sr**

CR Spectrum & Composition with DAMPE





Proton spectrum to	**≈ 900 TeV**
He spectrum to	**≈ 400 TeV/n**
Spectra of C, O, Ne, Mg, Si to	**≈ 20 TeV/n**
B/C ratio to	**≈ 4-6 TeV/n**
Fe spectrum to	**≈ 10 TeV/n**



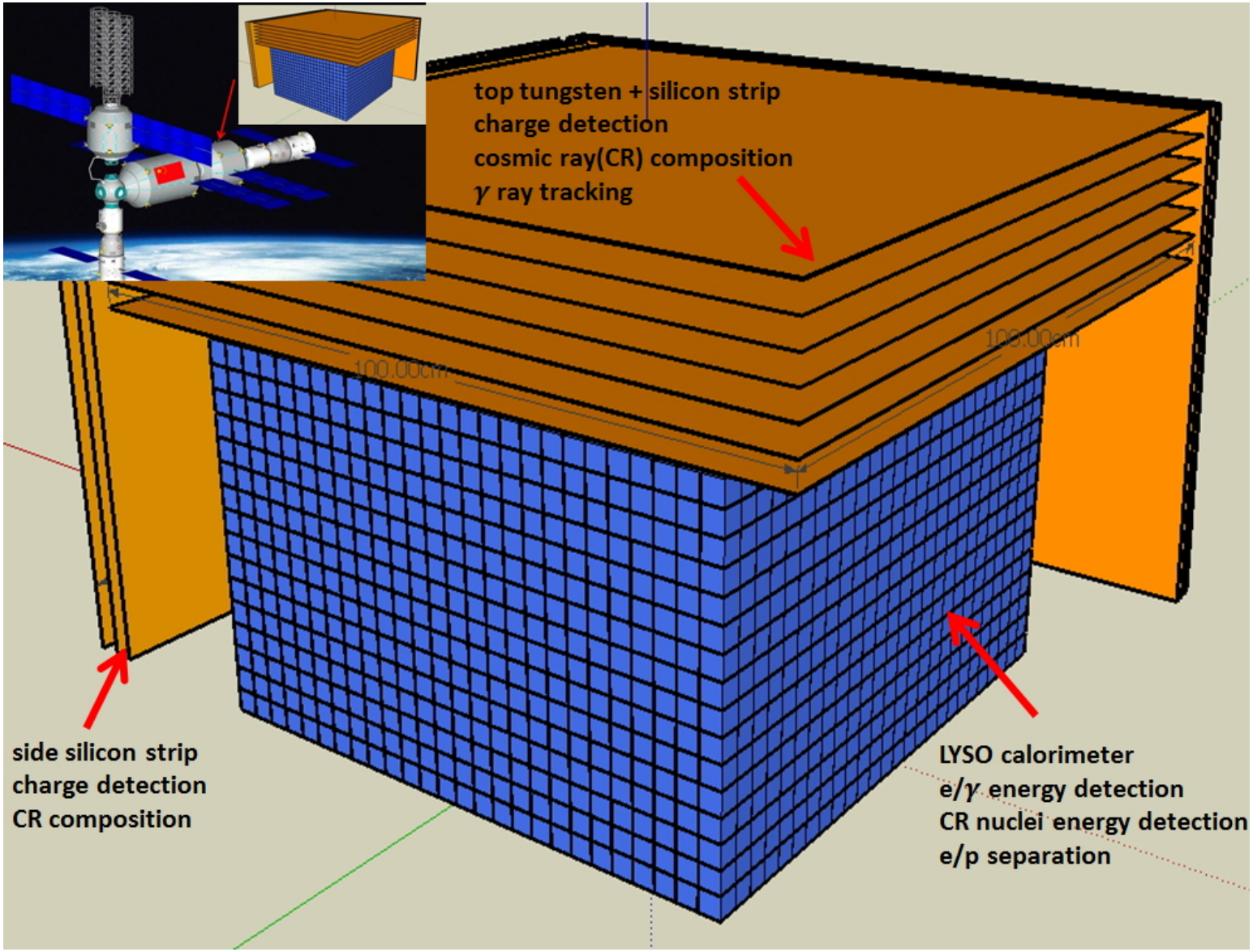
HERD: High Energy cosmic-Radiation Detector

Science goals	Mission requirements
Dark matter search	R1: Better statistical measurements of e/γ between 100 GeV to 10 TeV
Origin of Galactic Cosmic rays	R2: Better spectral and composition measurements of CRs between 300 GeV to PeV* with a large geometrical factor

Secondary science: monitoring of GRBs, microquasars, Blazars and other transients.

*complementary to high mountain cosmic-ray observations

Baseline design of HERD



Expected performance of HERD

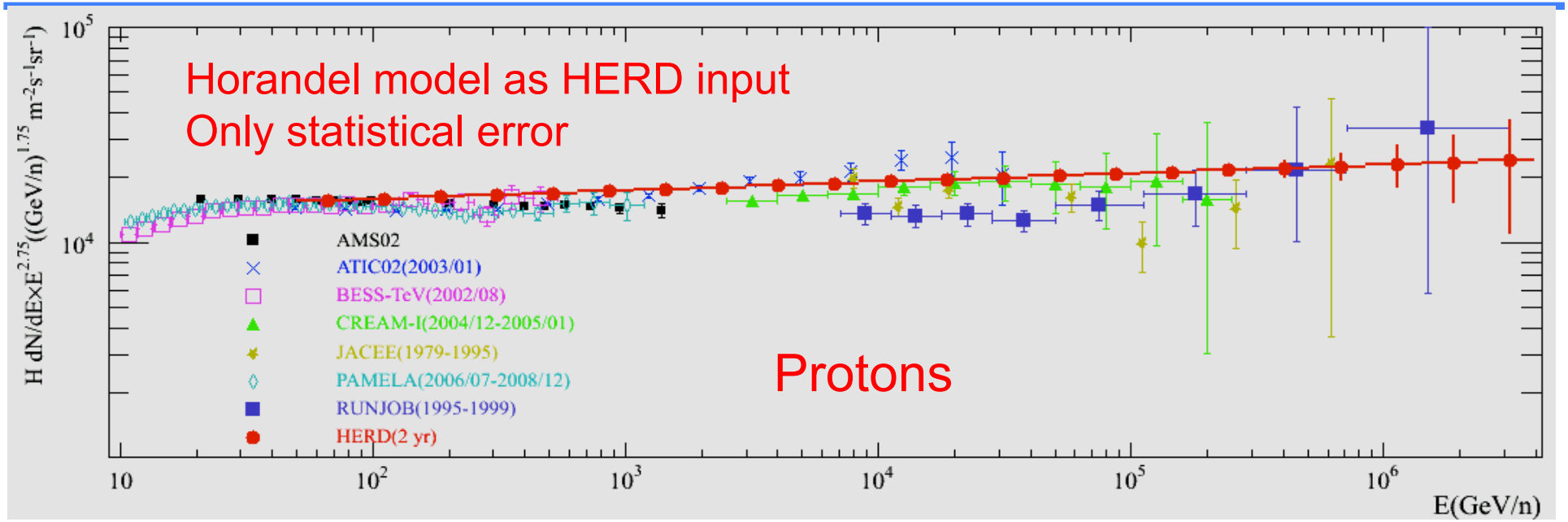
γ/e energy range (CALO)	tens of GeV-10TeV
nucleon energy range (CALO)	up to PeV
γ/e angular resol. (top Si-strips)	0.1°
nucleon charge resol. (all Si-strips)	0.1-0.15 c.u
γ/e energy resolution (CALO)	<1%@200GeV
proton energy resolution (CALO)	20%
e/p separation power (CALO)	$<10^{-5}$
electron eff. geometrical factor (CALO)	3.7 m^2sr@600 GeV
proton eff. geometrical factor (CALO)	2.6 m^2sr@400 TeV

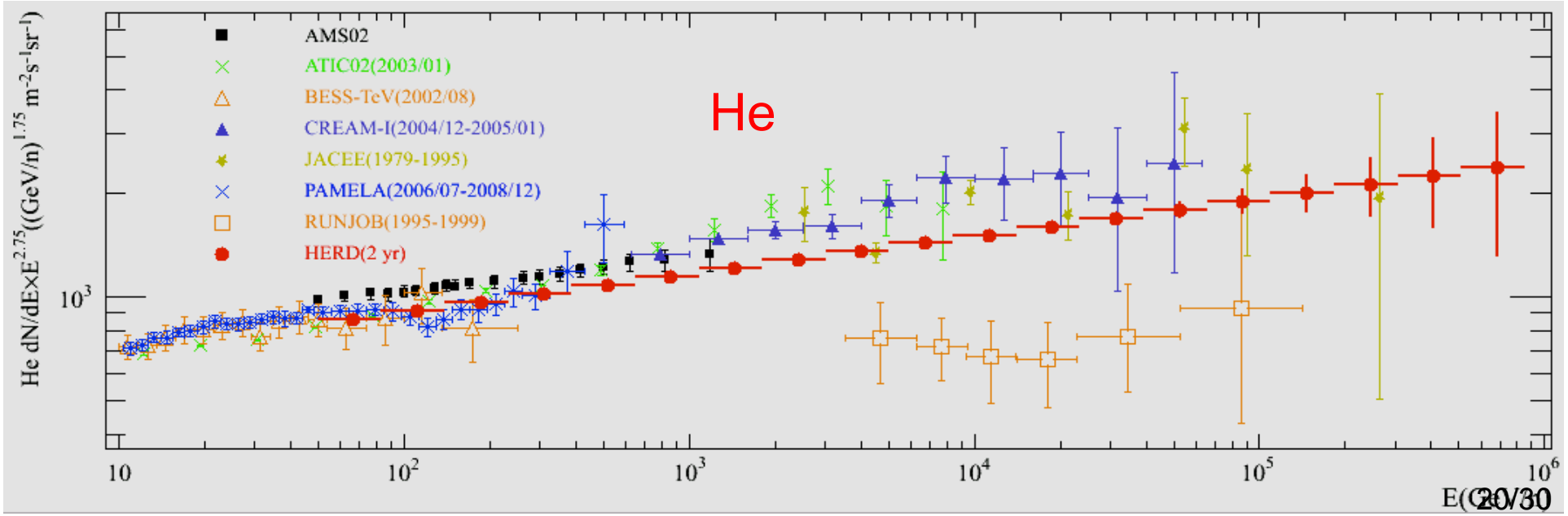
Characteristics of HERD components

	type	size	X0,λ	unit	main functions
tracker (top)	Si strips	70 cm × 70 cm	2 X_0	7 x-y (W foils)	Charge Early shower Tracks
tracker 4 sides	Si strips	65 cm × 50 cm	--	3 x-y	Nucleon Track Charge
CALO	~10K LYSO cubes	63 cm × 63 cm × 63 cm	55 X_0 3 λ	3 cm × 3 cm × 3 cm	e/γ energy nucleon energy e/p separation

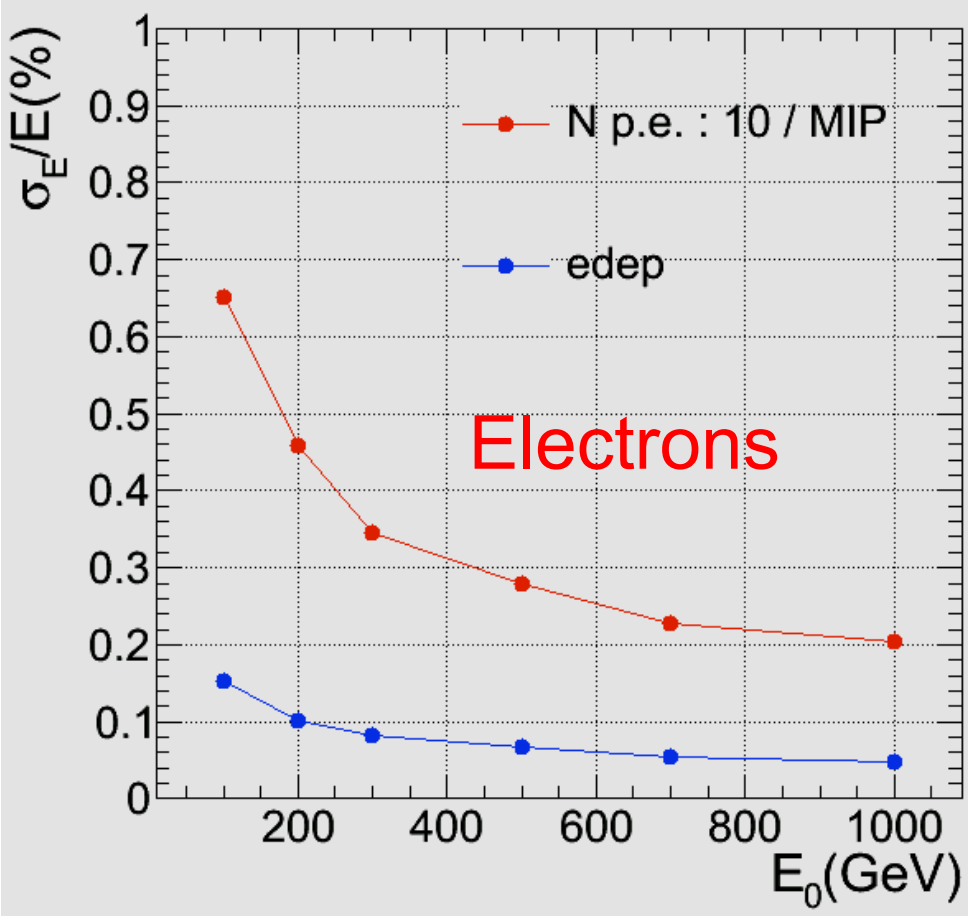
Total detector weight: ~2000 kg

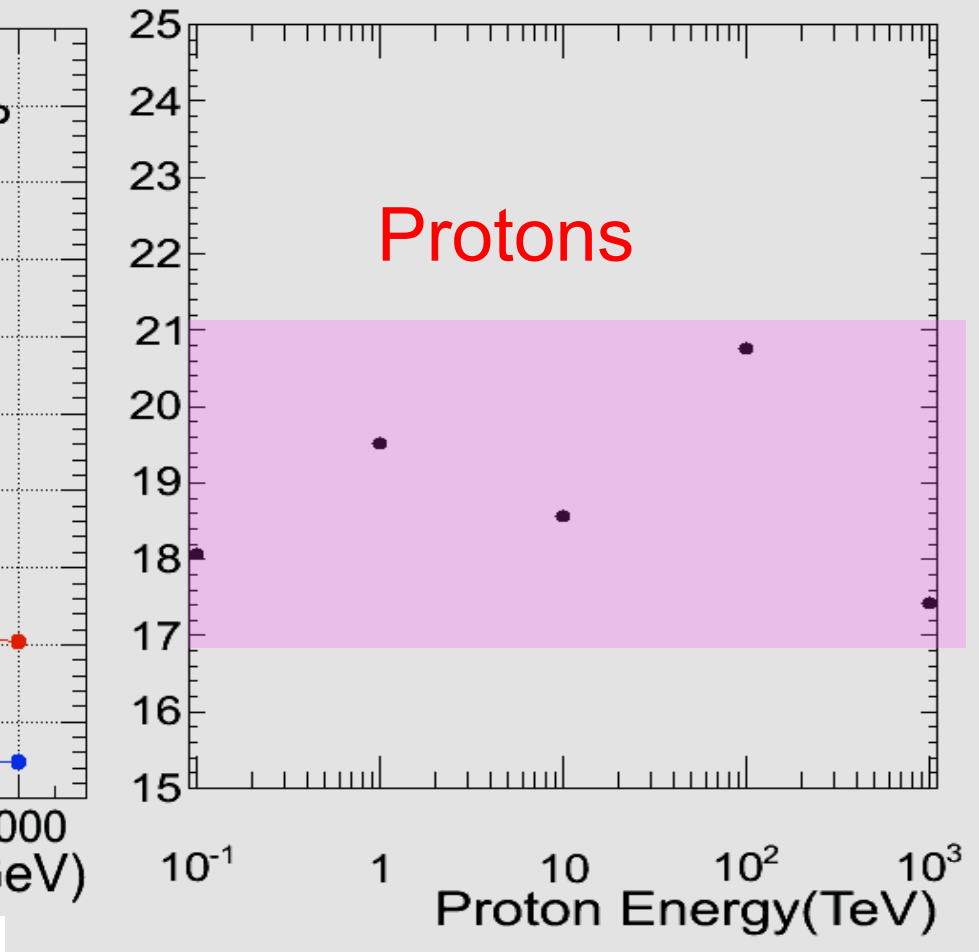
Expected HERD Proton and He Spectra





HERD simulation : energy resolutions

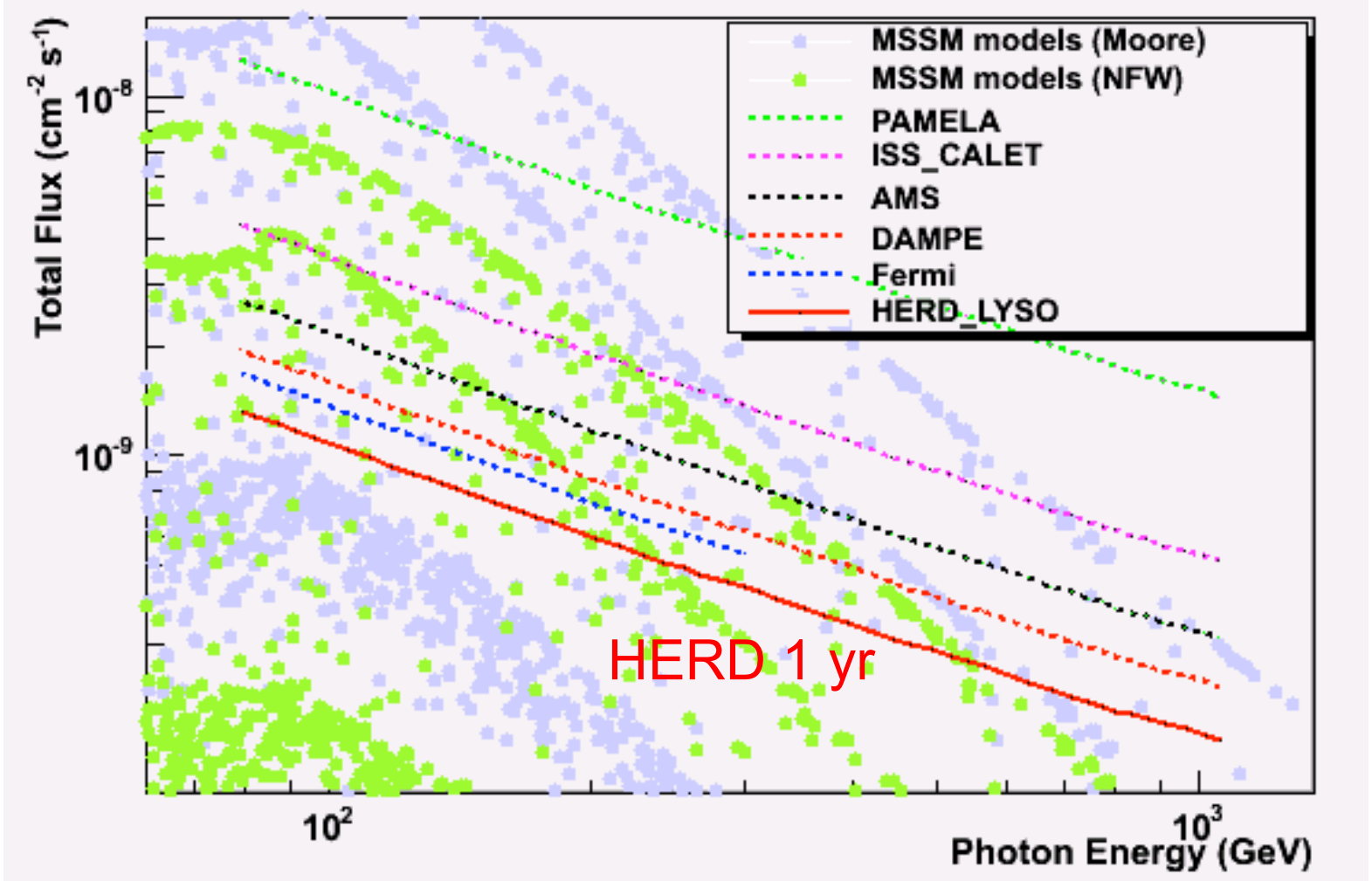




Electron < 1%; Proton: ~20%

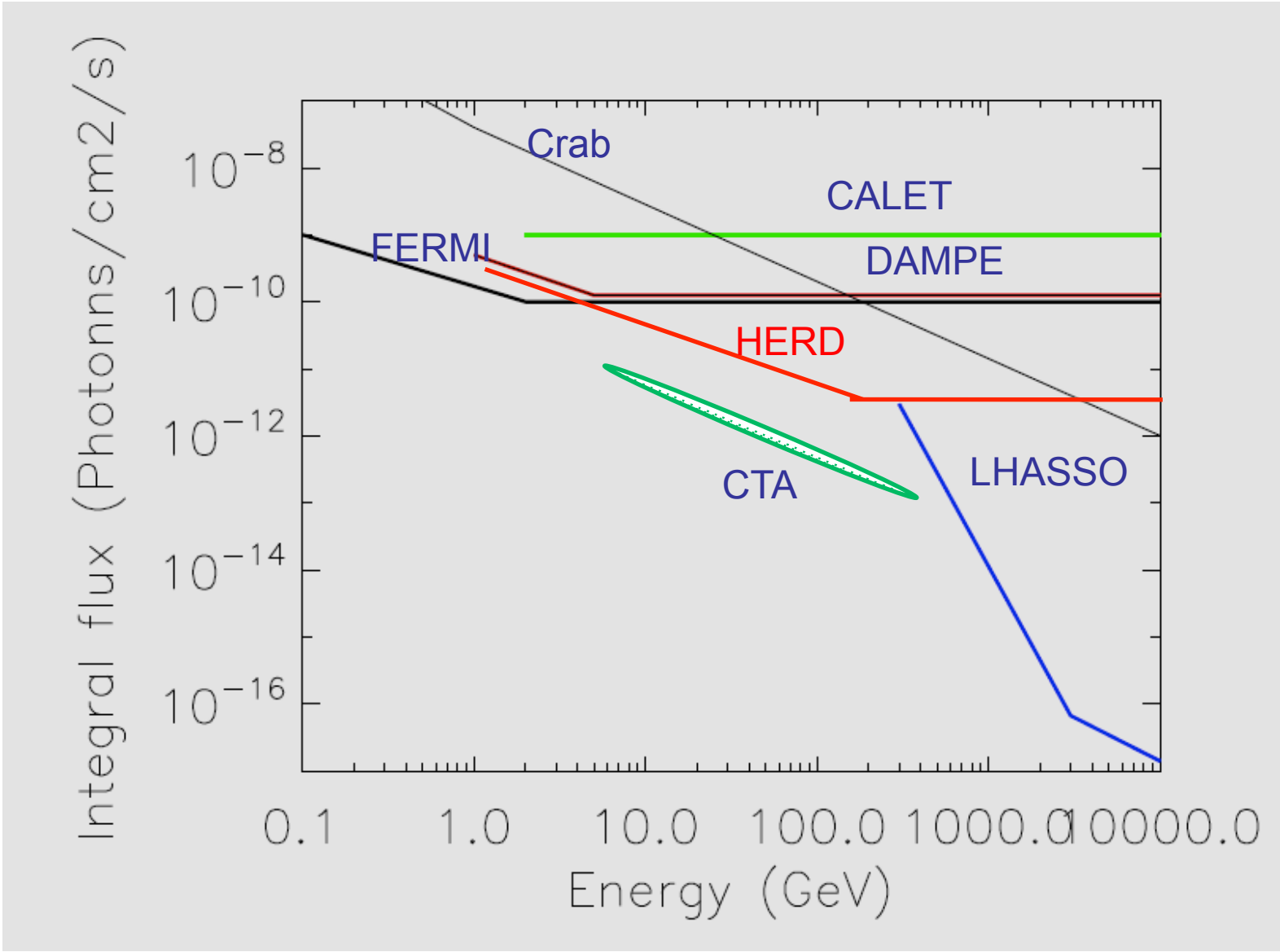
Essential for spectral features!

sensitivity to gamma-ray line

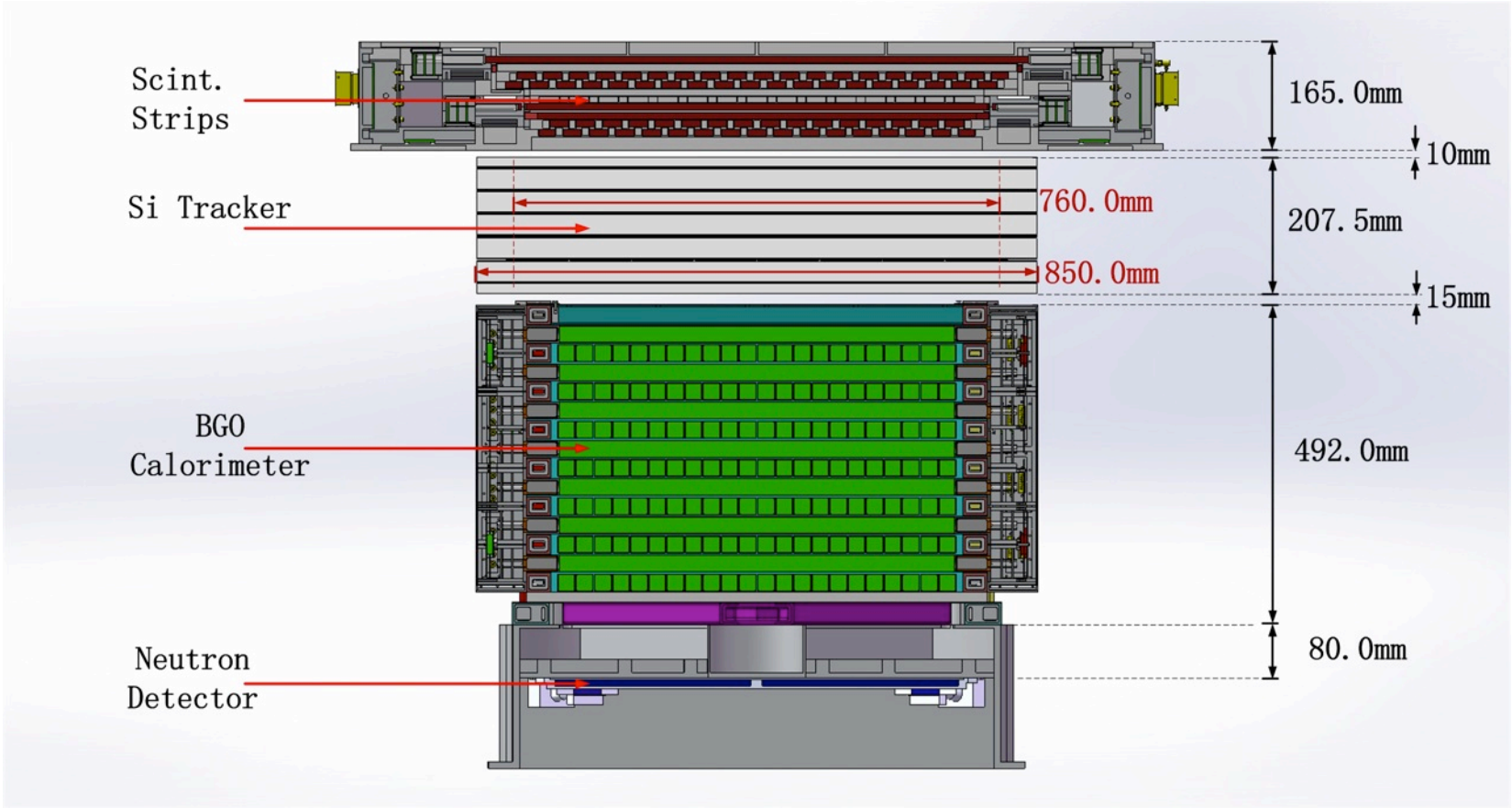


PAMELA: 2006-2016 CALET: 2015-2020; AMS: 2011-2021;
DAMPE: 2015-2020; Fermi: 2008-2018; HERD: 2020-2021

Gamma-ray Sky Survey Sensitivity



The DAMPE Detector



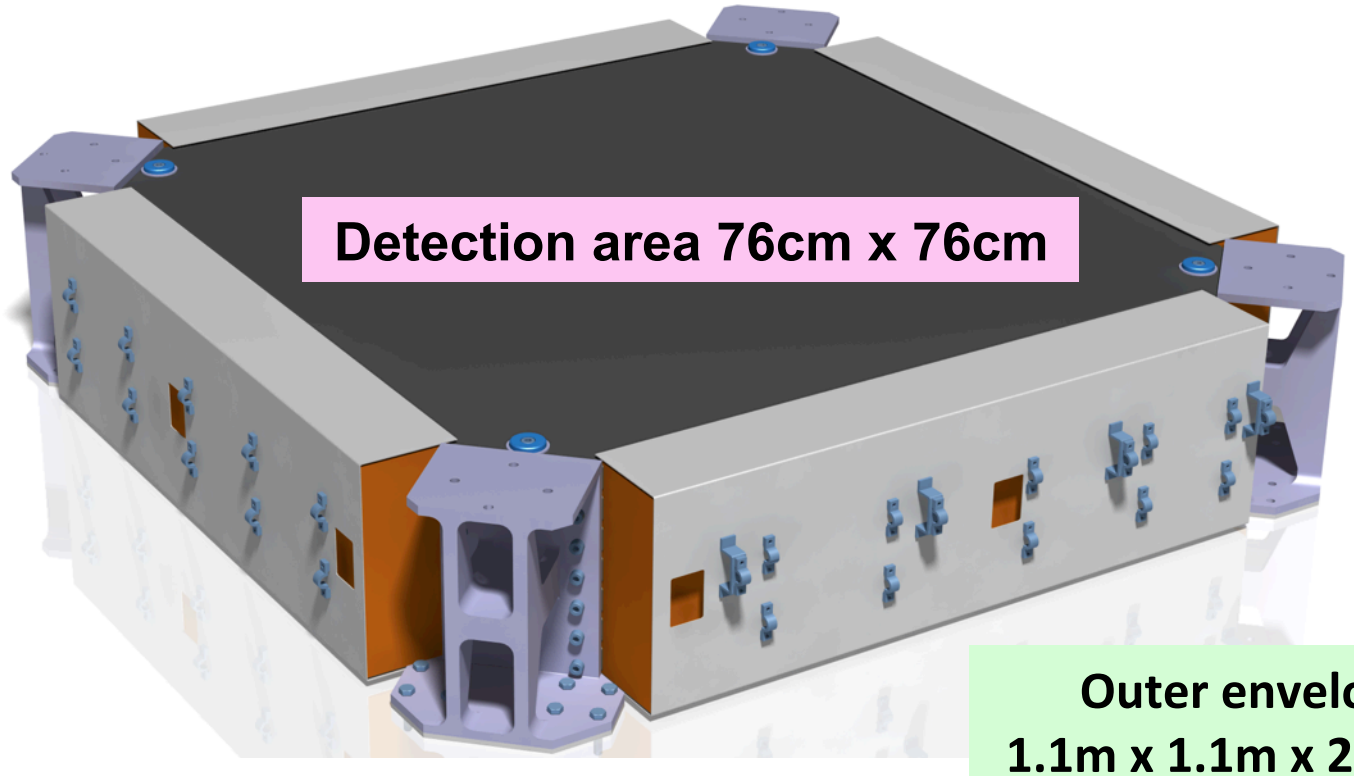
Mass: 1480 Kg
Power: 500 W
Data: 14 Gbyte/day
Liftime: 5 years

The DAMPE Collaboration

- China
  - Purple Mountain Observatory, CAS, Nanjing
    - Chief Scientist: Prof. Jin Chang
  - Institute of High Energy Physics, CAS, Beijing
  - National Space Science Center, CAS, Beijing
  - University of Science and Technology of China, Hefei
  - Institute of Modern Physics, CAS, Lanzhou
- Switzerland
  - University of Geneva
- Italy
  - INFN and University of Perugia
  - INFN and University of Bari

Silicon-Tungsten Tracker (STK)

Project Leader: X. Wu
Technical Coordinator: G. Ambrosi

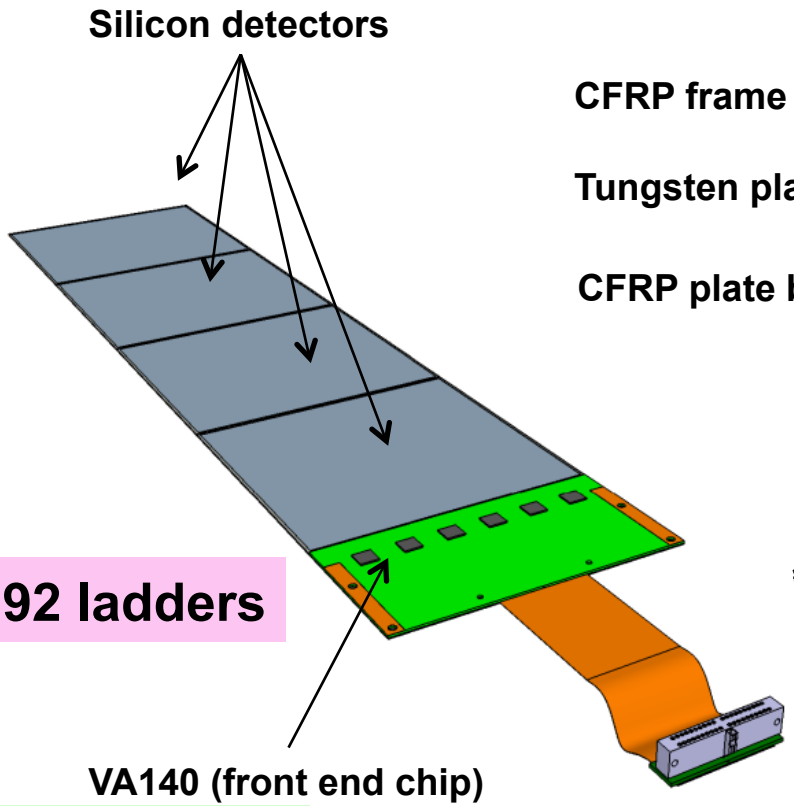


Outer envelope
1.1m x 1.1m x 23.5 cm

- **Weight: ~ 150 Kg**
- **Total power consumption: ~85W**

Si Layer and Ladders

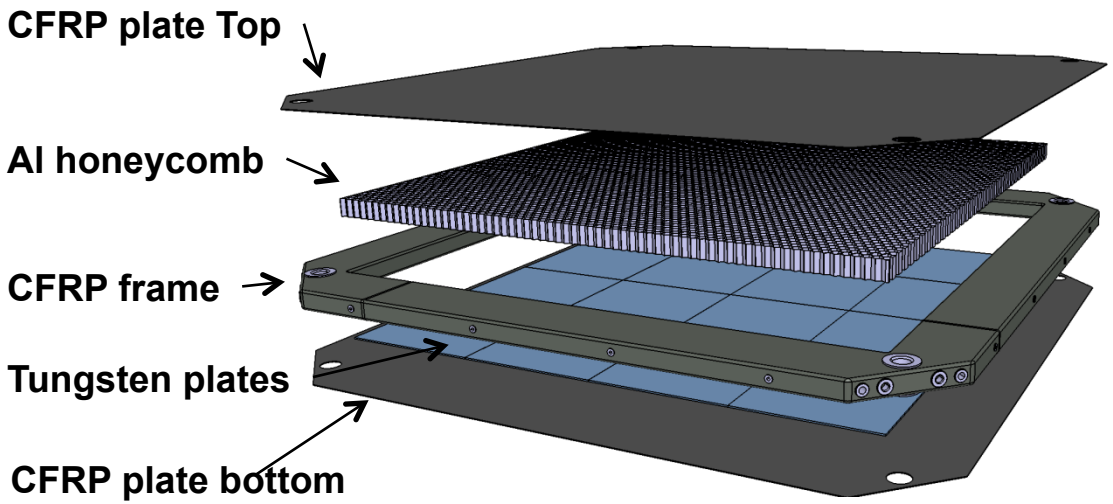
768 silicon sensors



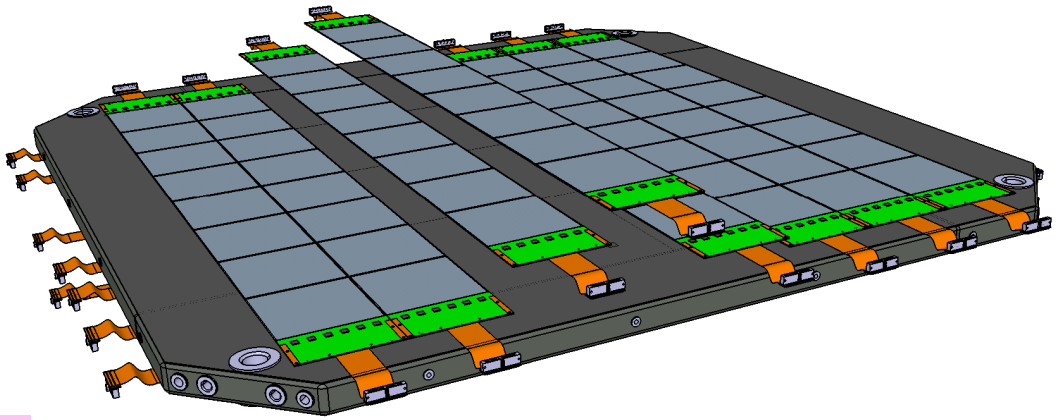
192 ladders

1152 ASICs

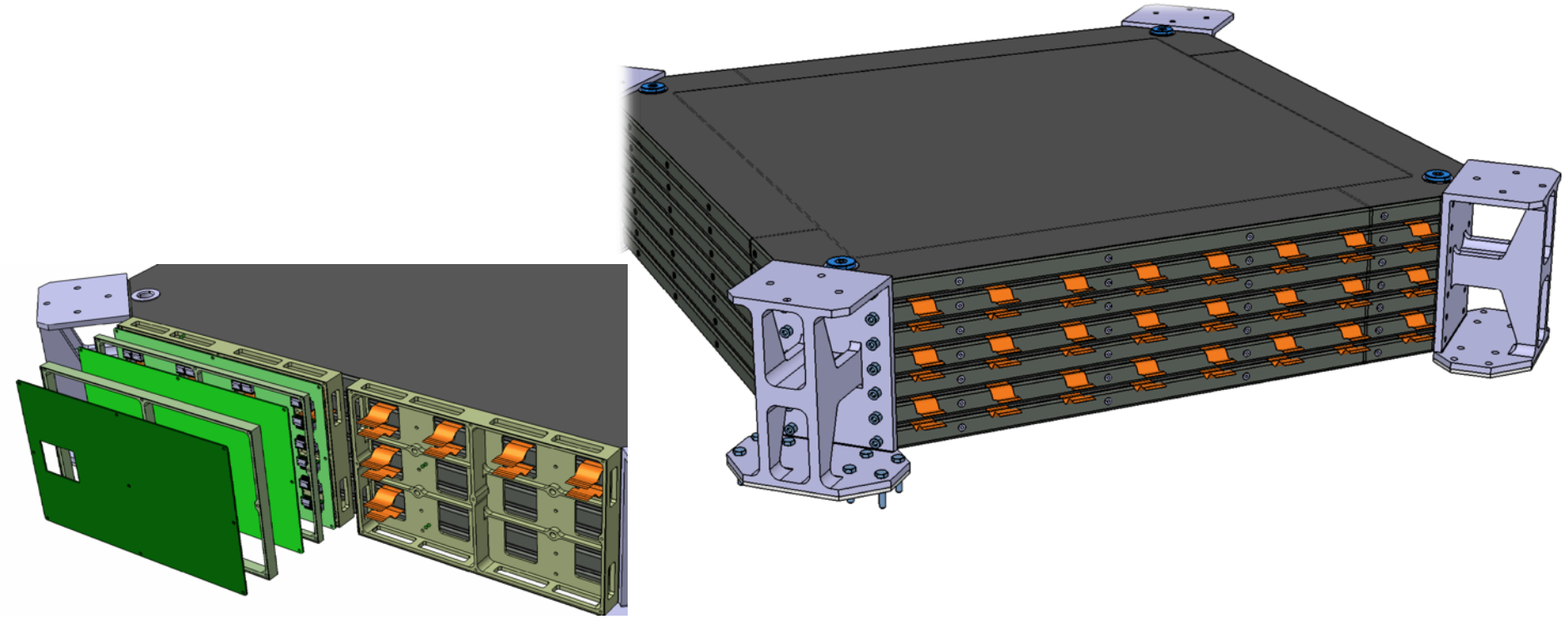
73728 channels



12 layers, 6-x and 6-y



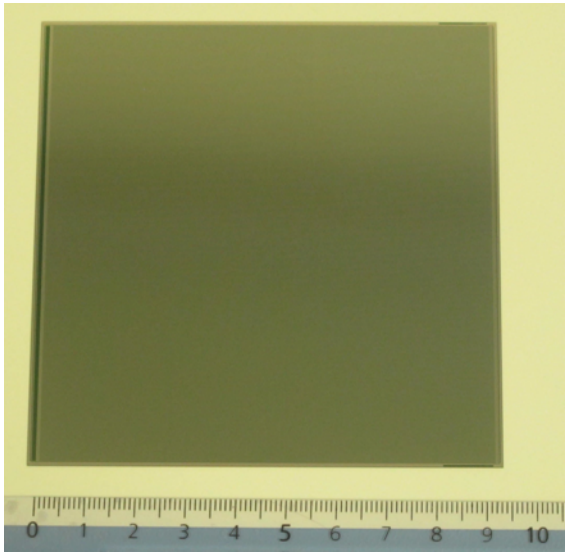
STK Structure



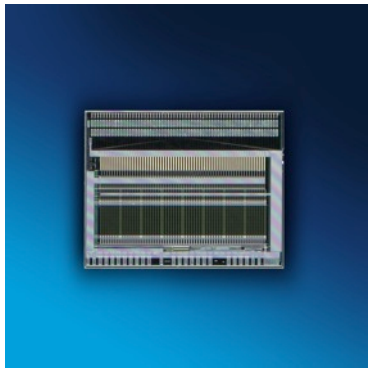
- 12 layers of silicon micro-strip detector mounted on 7 support trays
  - Tray: carbon fiber face sheet with Al honeycomb core
- Tungsten plates integrated in trays 2, 3, 4 (from the top)
  - Total ~1 X_0 for photon conversion
- 8 readout boards on 4 sides

Silicon Sensor and Front End Electronics

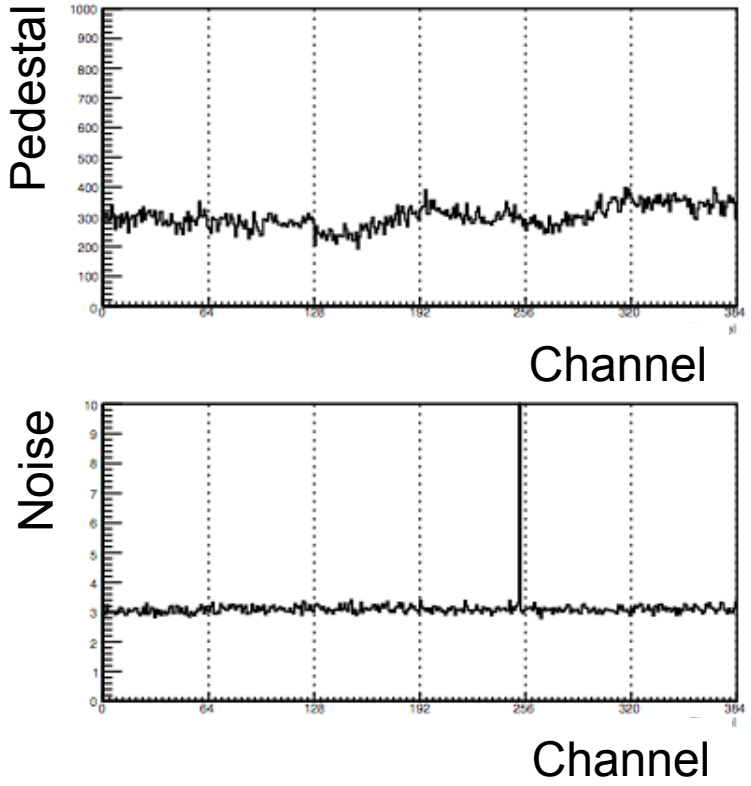
- Single sided silicon strip detectors produced by Hamamatsu Photonics
  - 9.5 x 9.5 cm^2
  - 320±15 µm thick
  - 768 strips with 121 µm pitch
  - Resistivity 5-8 kΩ, V_{fd} 10-80 V
  - $<I_{leak}>$ ~ 150 nA, max 280 nA
- VA140 chip (AMS like) produced by IDEas
  - 64 channel per chip
  - Readout pitch 242 µm
  - Expected position resolution better than 70 µm

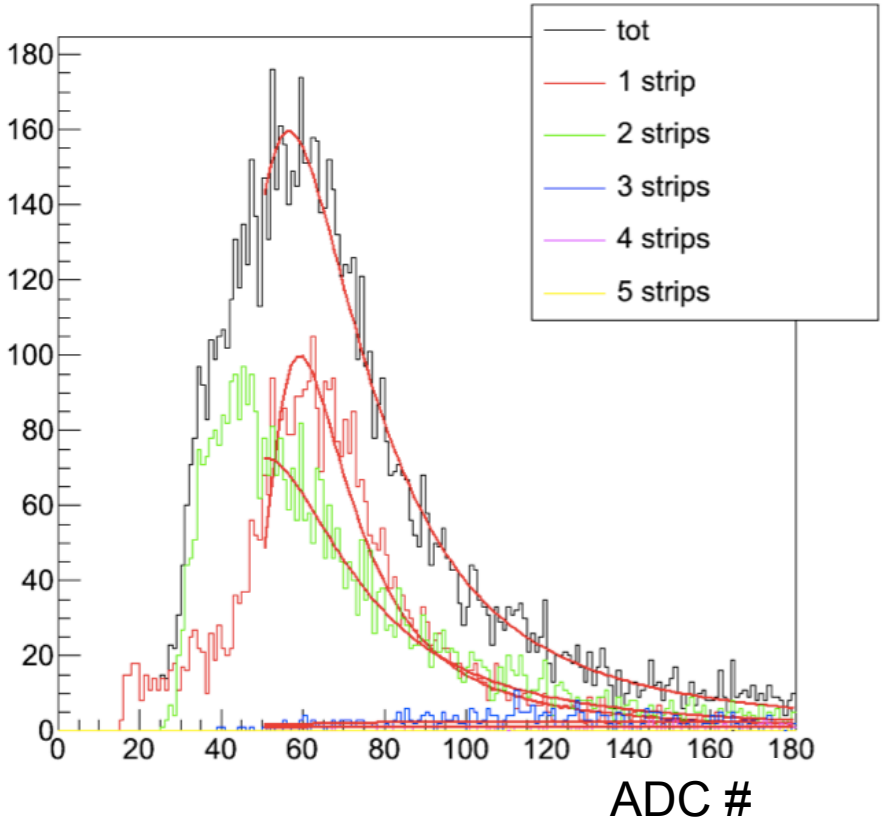


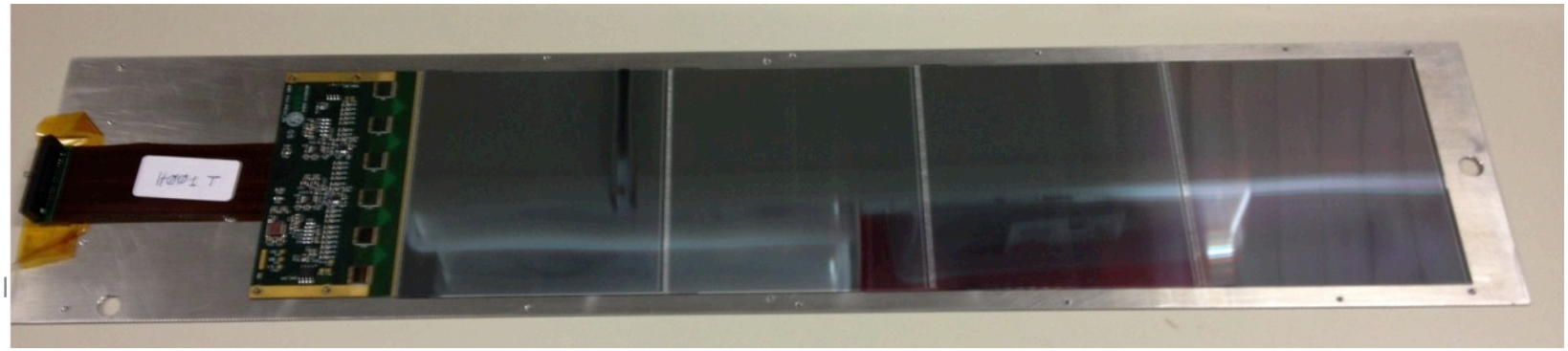
Parameter	VA64HDR9A	VA140
Noise, Cd=50pF (eRMS)	520	430
DNR	+100fC,-200fC	±200fC
Power cons. (mW/channel)	0.8	0.29
SEL thrshd (MeV·cm^2/mg)	22	21-22



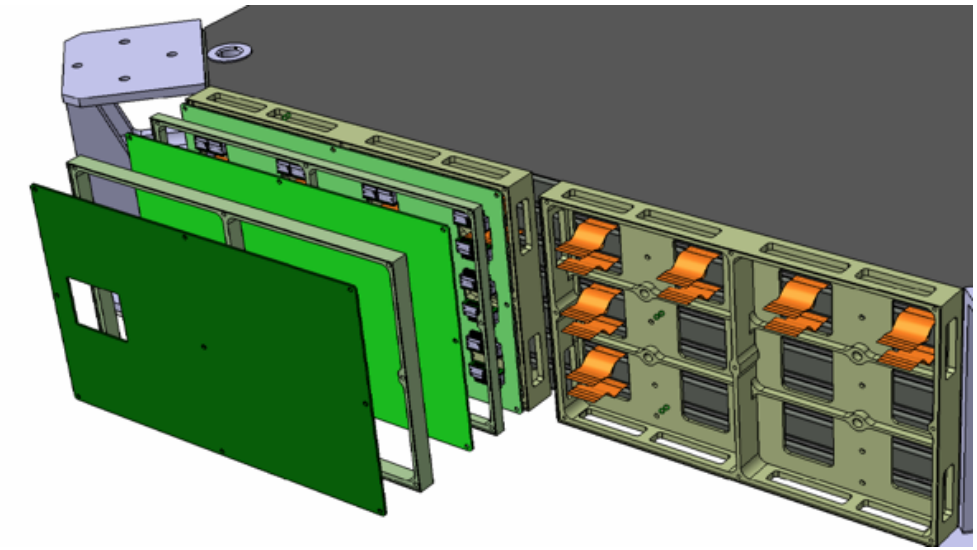
Ladder Test

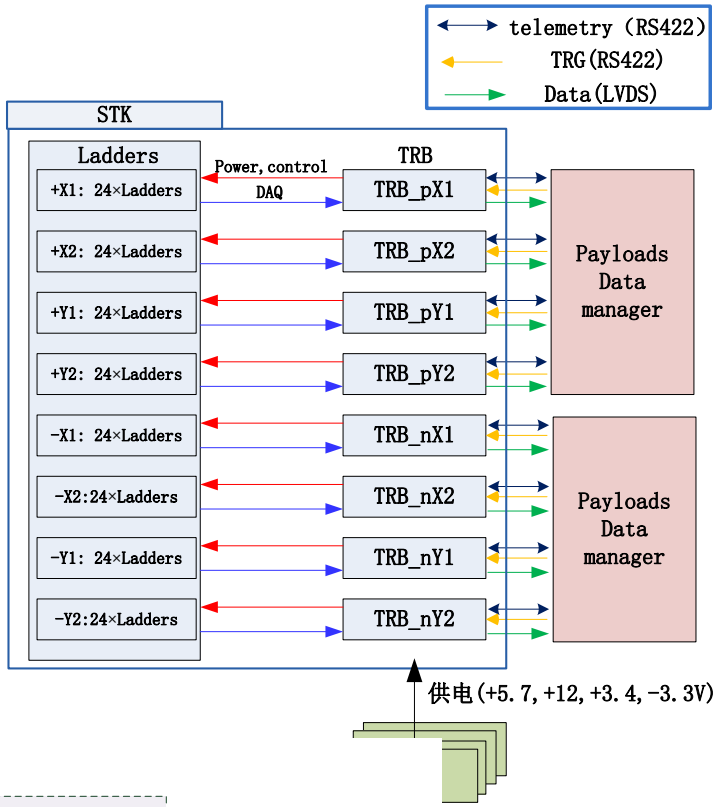

Pedestal
Channel
Noise
Channel

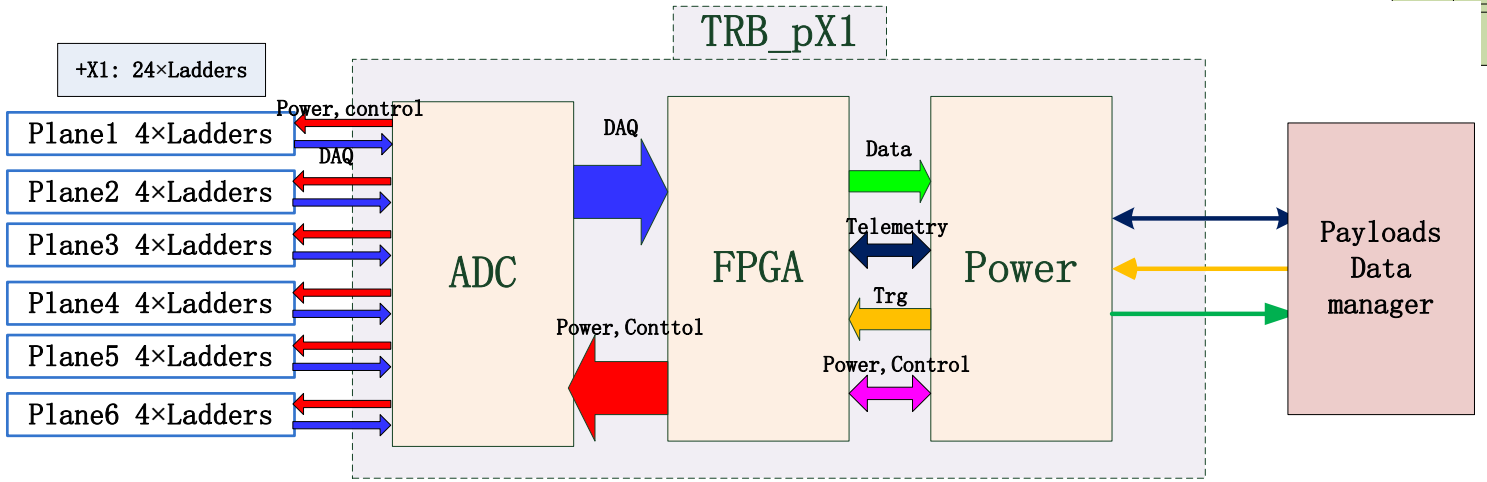

tot
1 strip
2 strips
3 strips
4 strips
5 strips
ADC #



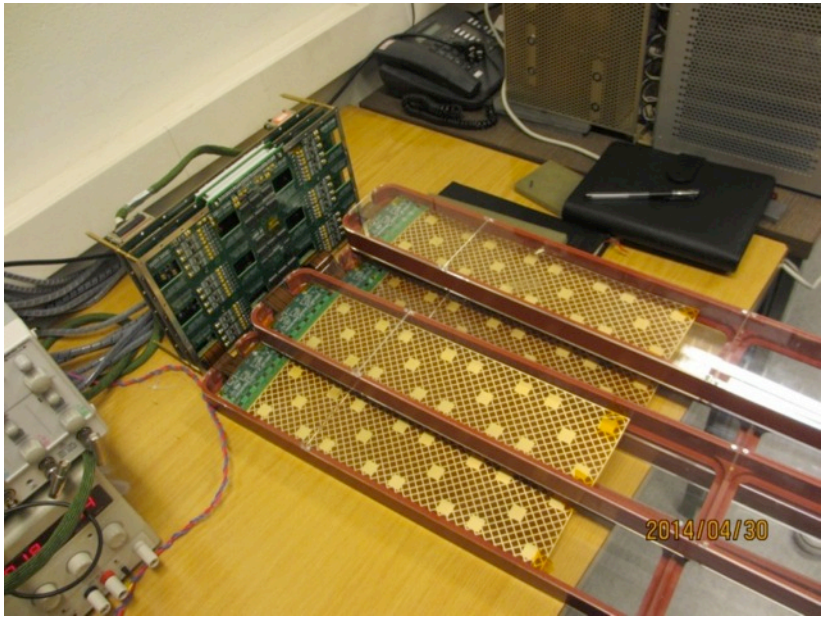
Readout and Power electronics (IHEP)

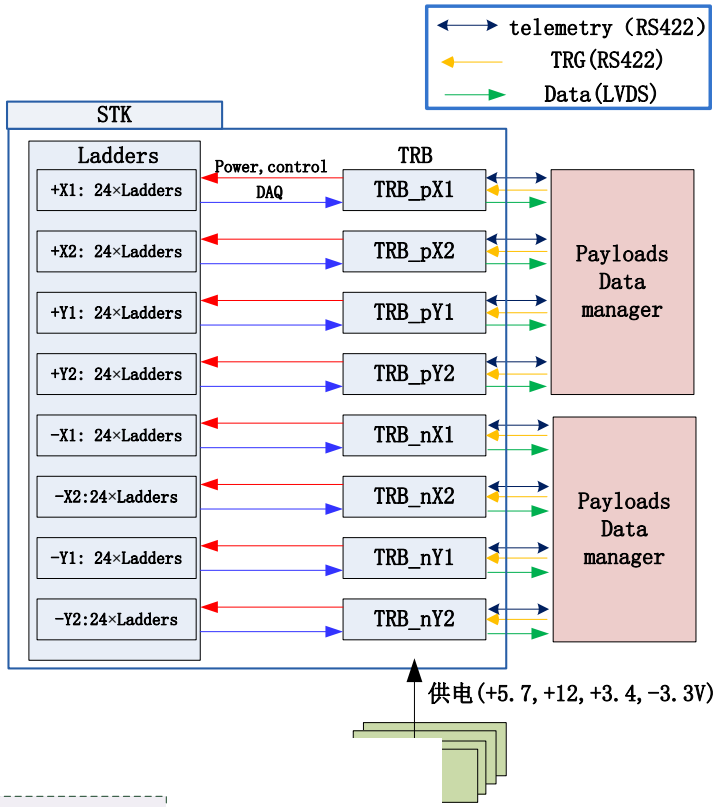


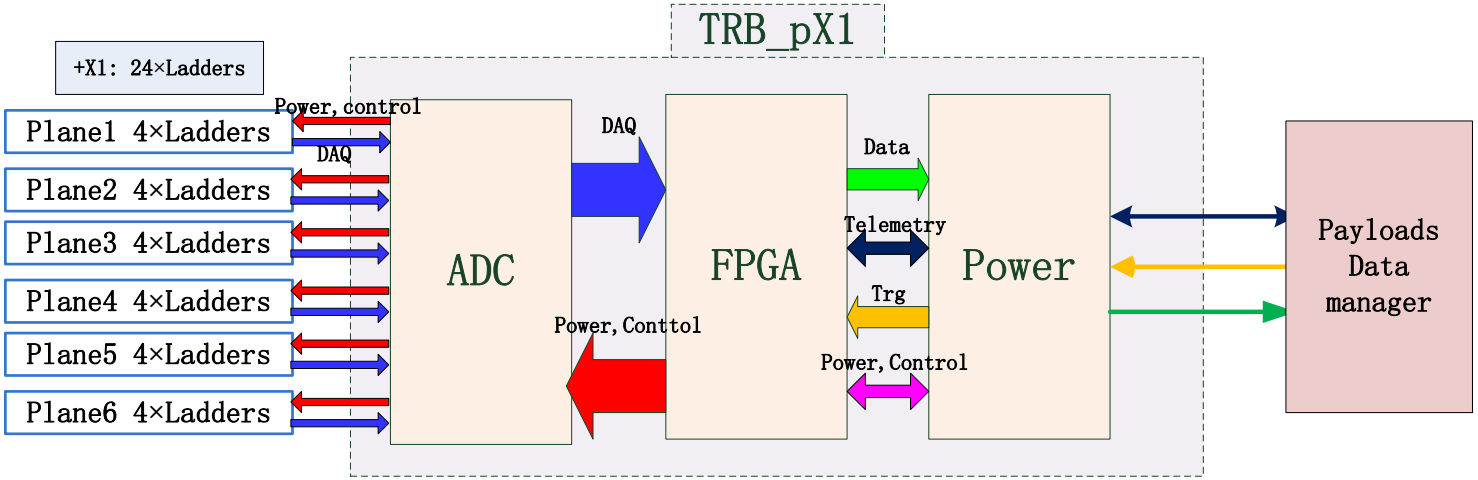




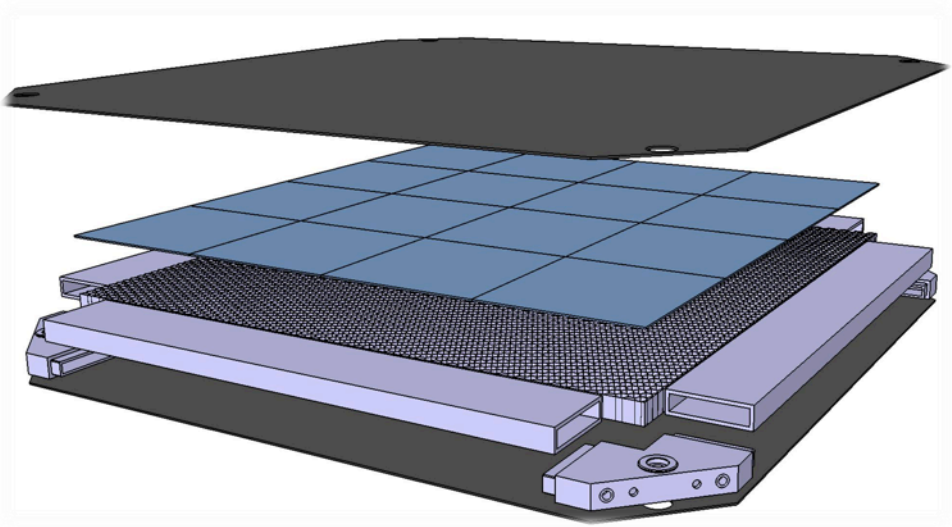
Readout and Power electronics

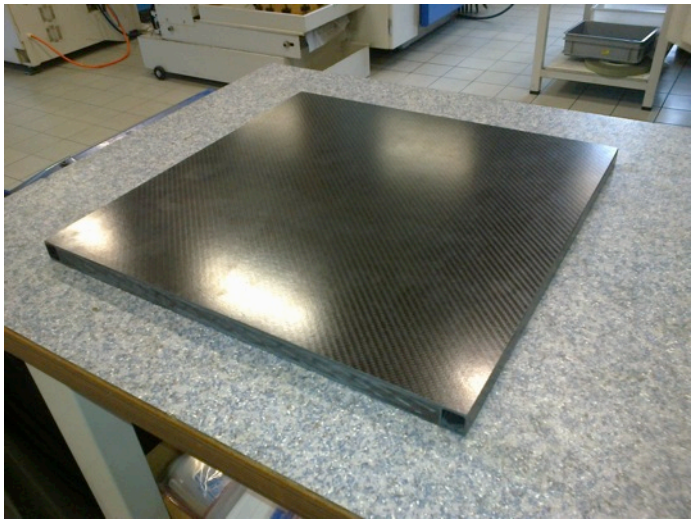


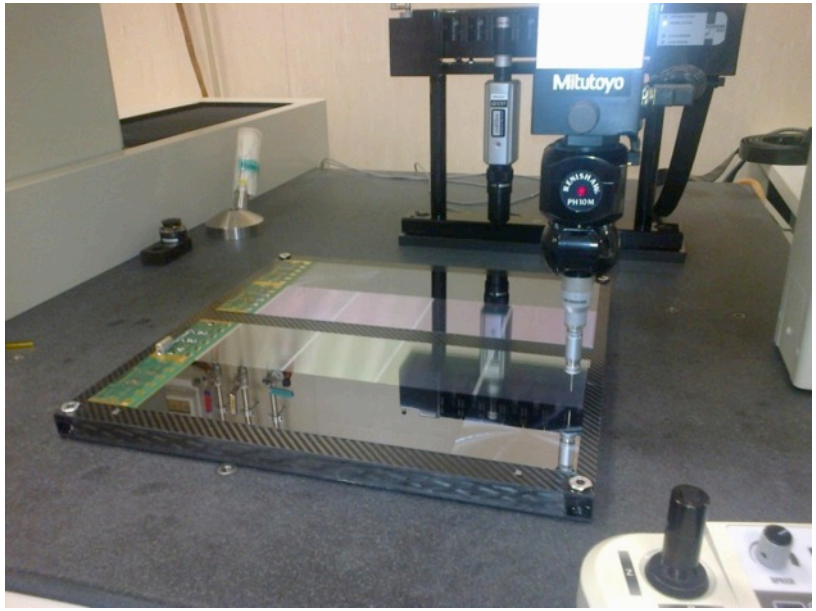




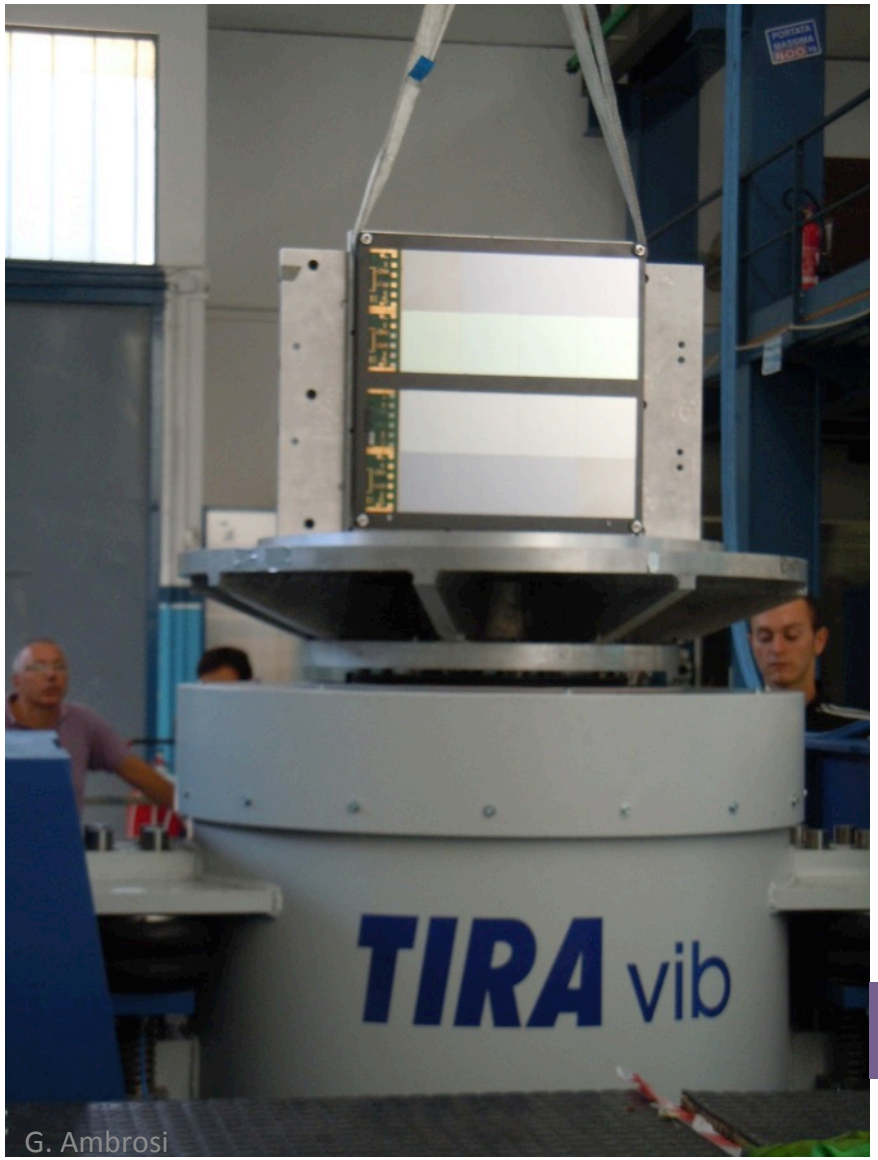
STK Quarter Plane (2013)







STK Quarter Plane Test (2013)

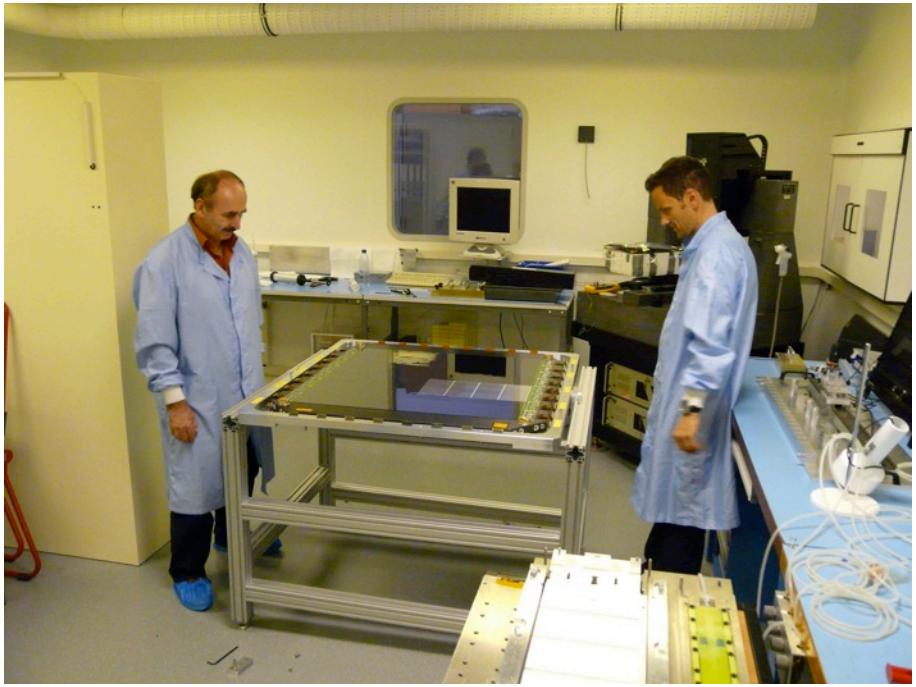


- 3 mechanical and one electrical ladder prototypes mounted on the plane
- Vibration and shock test
- Thermal cycling

- Results:
  - Electrical behaviour is unaffected by stress
  - Silicon detector 'move' by few microns

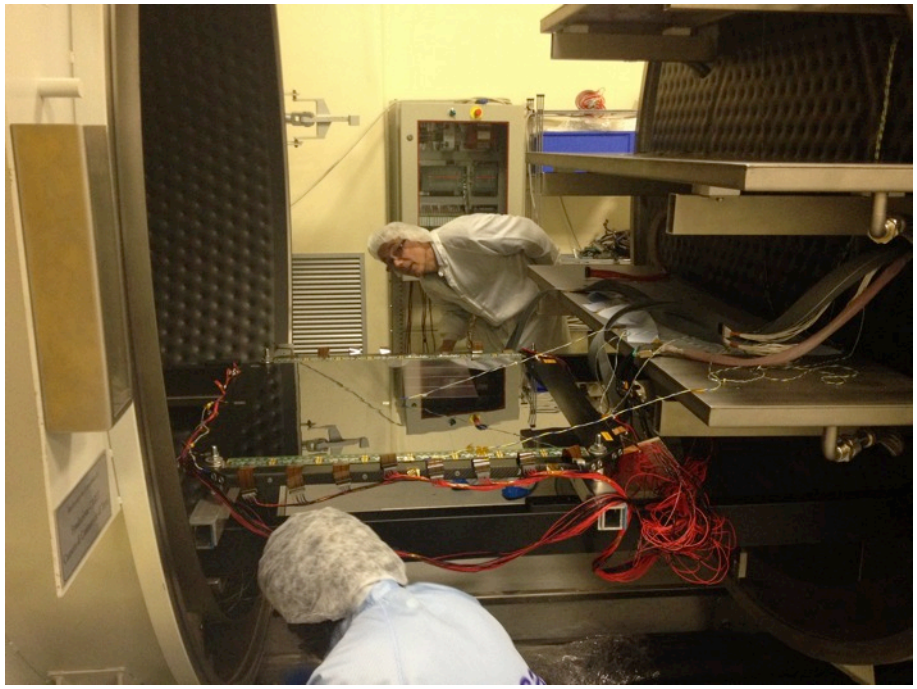
SERMS laboratory in Terni (Italy)

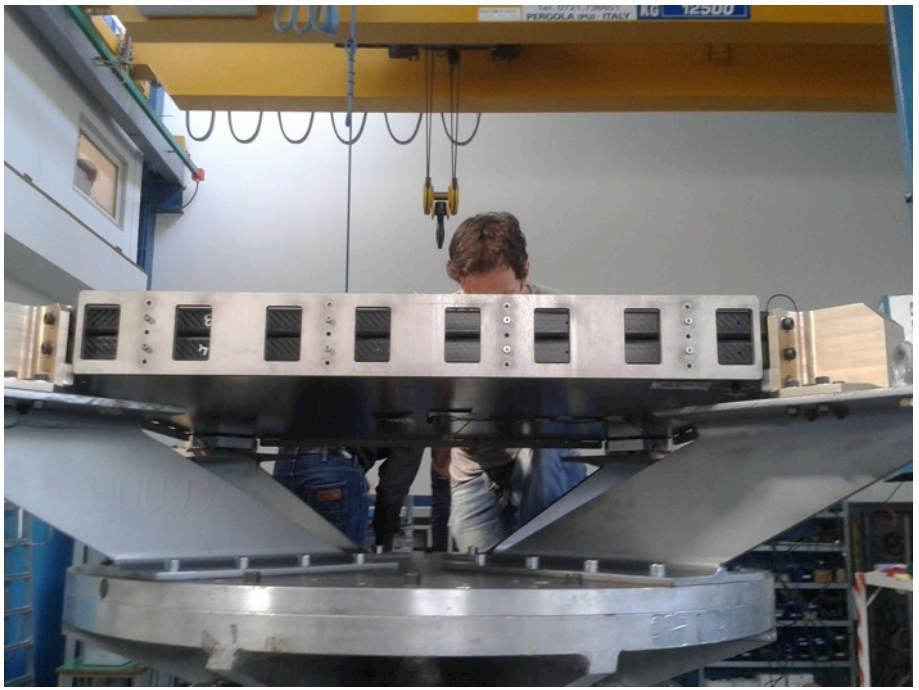
STK Full plane integration (4/2014)



STK Full Plane Test (02-04/2014)

- **Vibration and TV test of EQM planes**





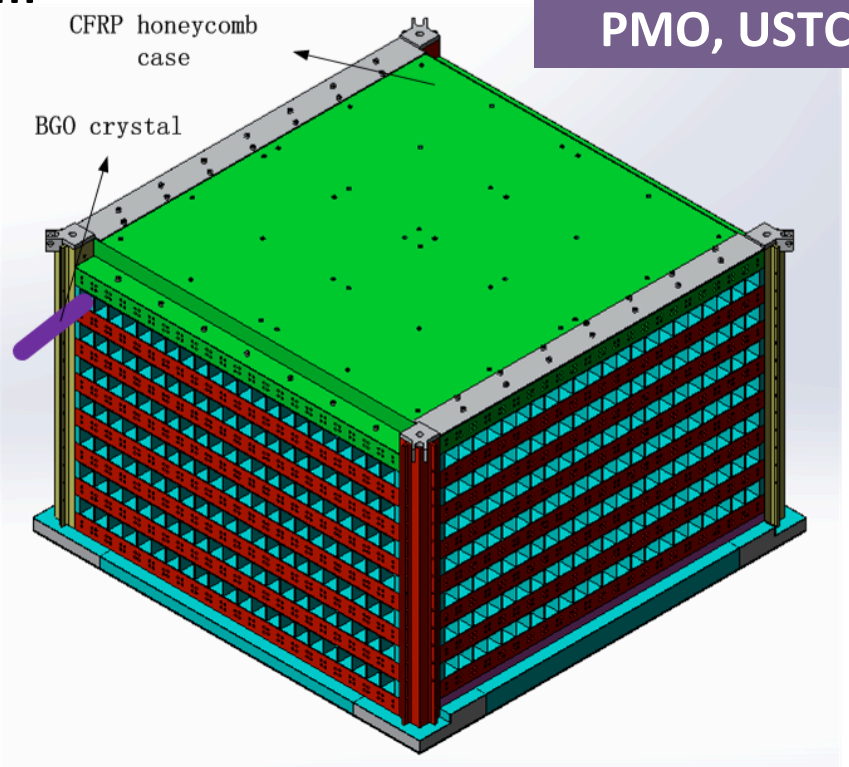
SERMS laboratory in Terni (Italy)

BGO Calorimeter (BGO)

- 14-layer BGO hodoscope, 7 x-layers + 7 y-layers
  - BGO bar 2.5cm×2.5cm, 60cm long, readout both ends with PMT
    - Use 3 dynode (2, 5, 8) signals to extend the dynamic range
  - Charge readout: VA160 with dynamic range up to 12 pC
  - Trigger readout: VATA160 to generate hit signal above threshold
    - Detection area 60cm×60cm

PMO, USTC

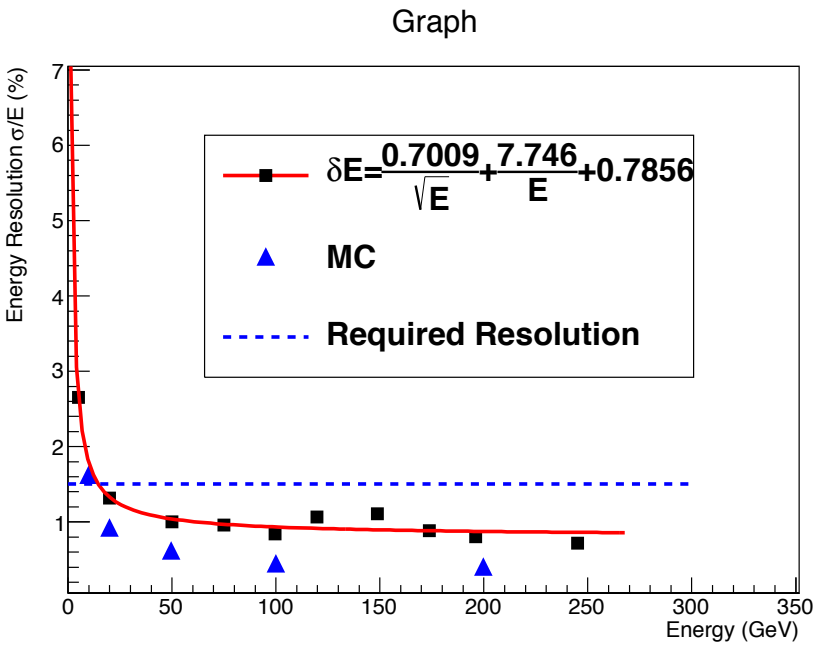
Total thickness $31X_0$

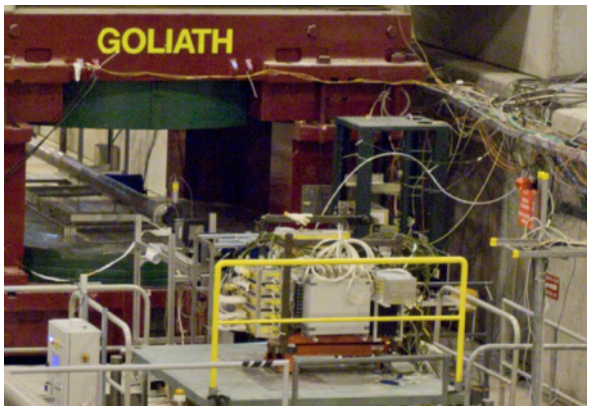


Measure electron/photon energy with great precision between 5 GeV - 10 TeV

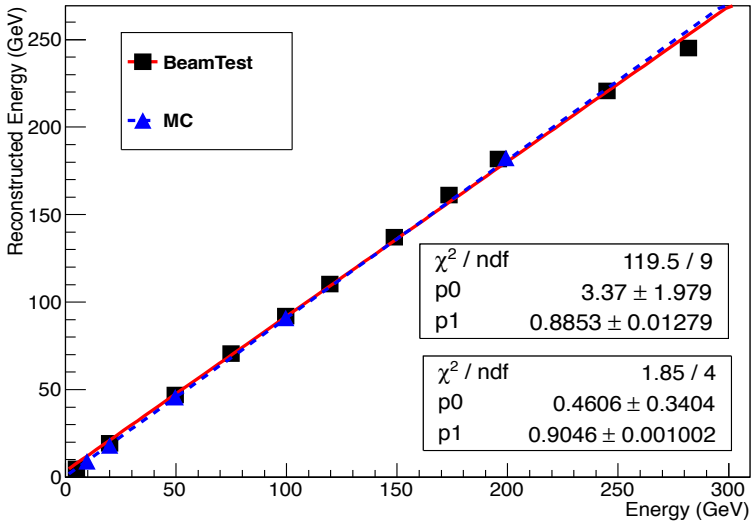
BGO Performance

- **A prototype calorimeter (12 layers, 30cm×30cm) was tested with high energy electrons and protons beams at CERN in October 2012.**
  - **Resolution <1.2% above 20 GeV (requirement 1.5% at 100 GeV)**





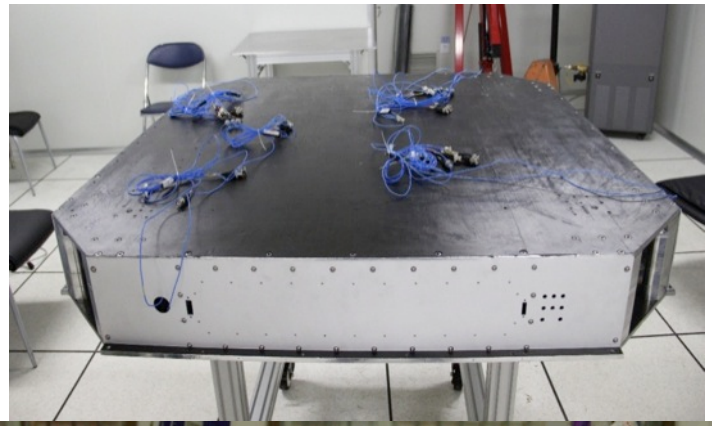
Graph

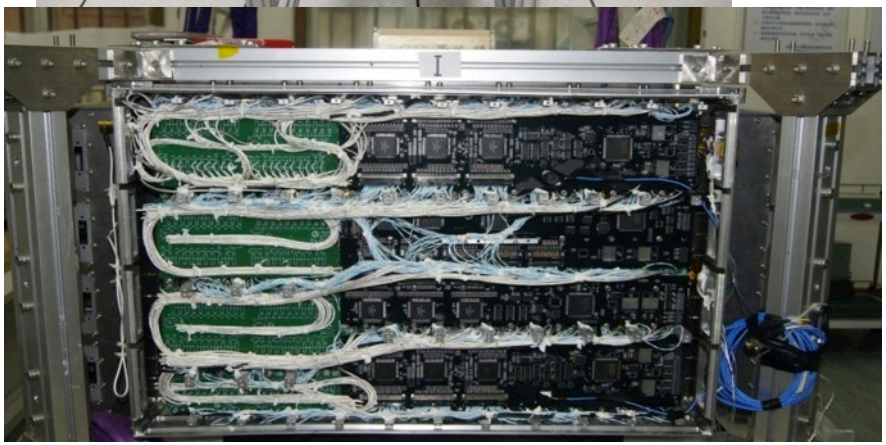


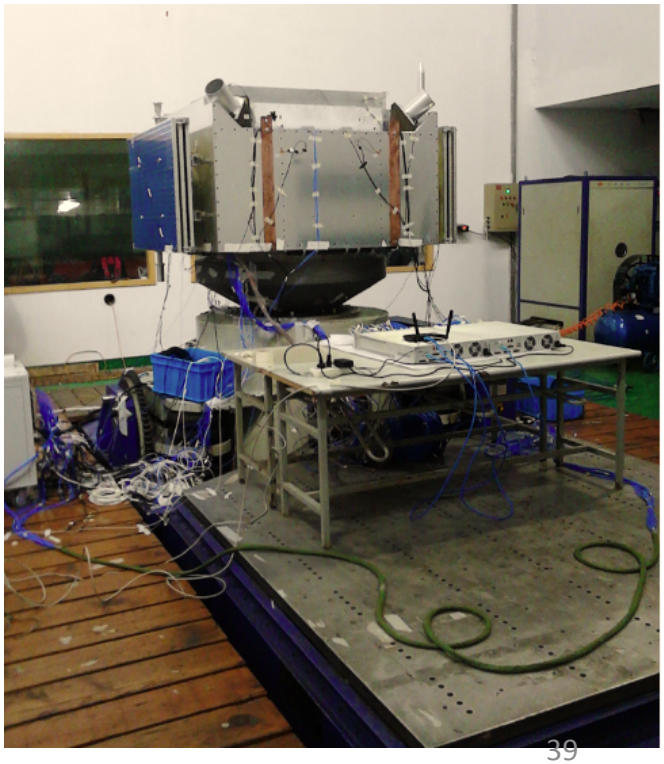
Goal 1% at 800 GeV

Good linearity

Status of DAMPE





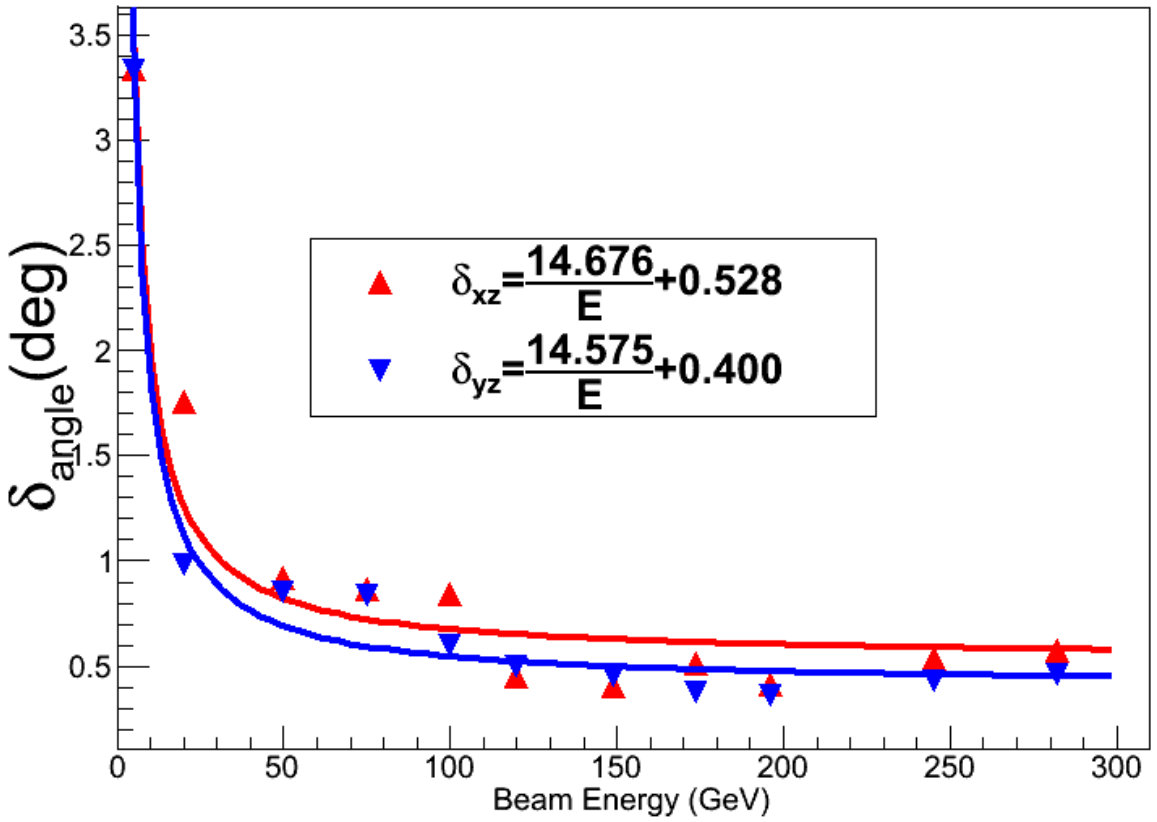


- Engineering modules of PSD, BGO and NUD are being tested

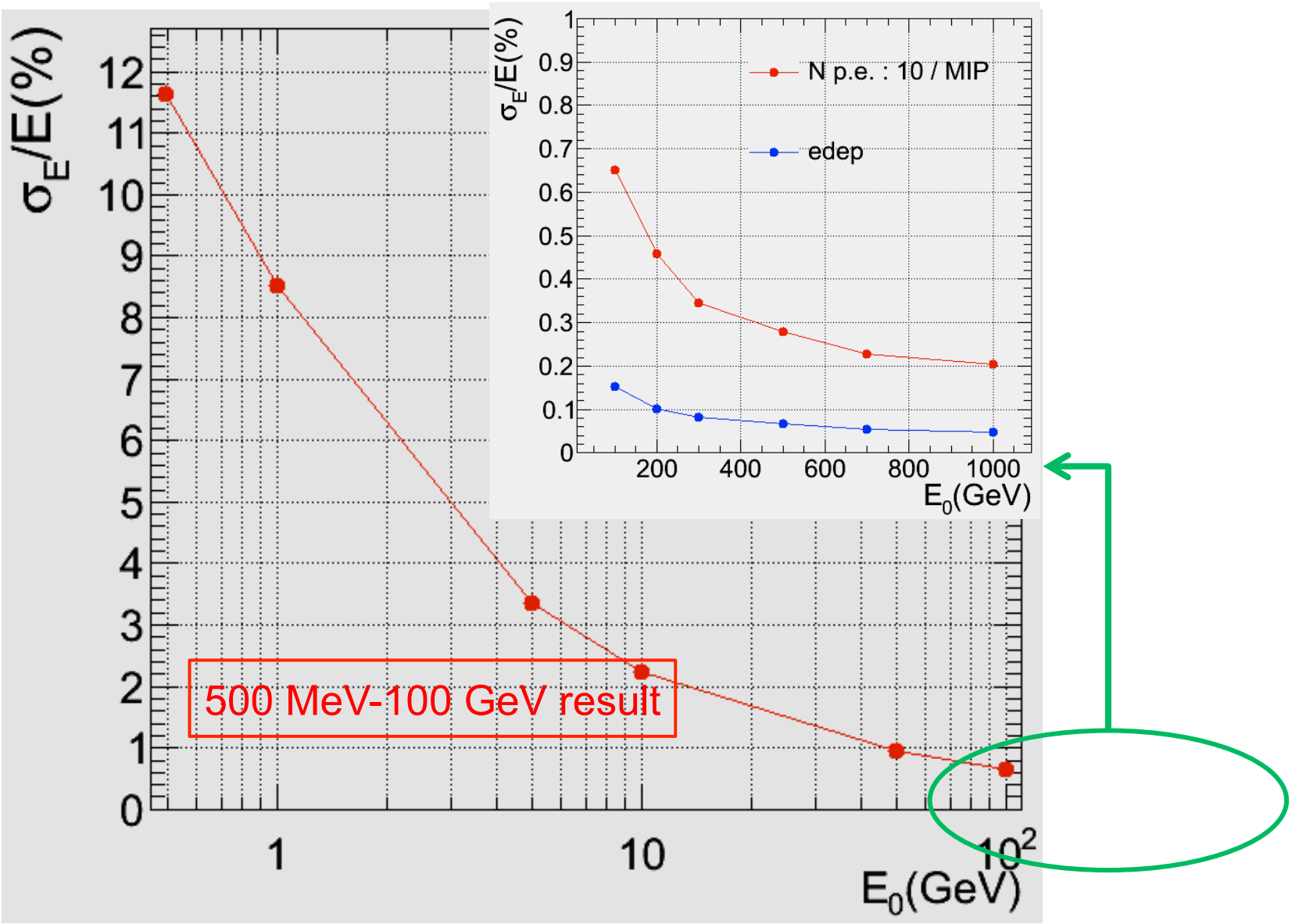
Conclusions

- China has a very dynamic ‘space activity’
- Several interesting projects are active (HXMT, POLAR, DAMPE) with significant international collaboration
- DAMPE will be studying high energy CR and photons in two years from now
- HERD is an opportunity to further increase the energy range and the detection reach in CR measurement

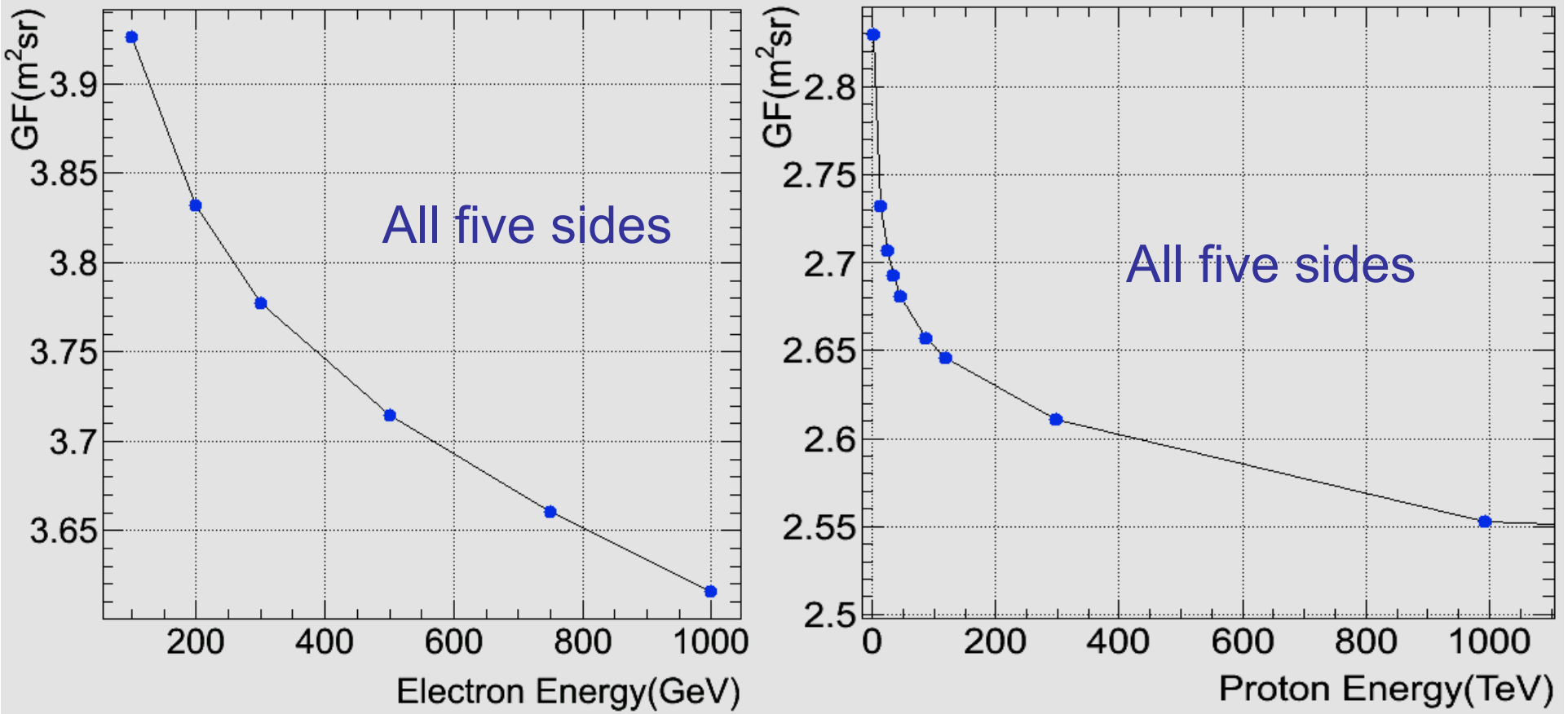
DAMPE angular resolution



Energy Resolution for gamma-rays



HERD Eff. Geometrical Factor: CALO



$$N_{obs} = F \times G_{eff.} \times T_{exp.} \times \eta_{pid} \times \eta_{reco}$$

DM annihilation line of HERD