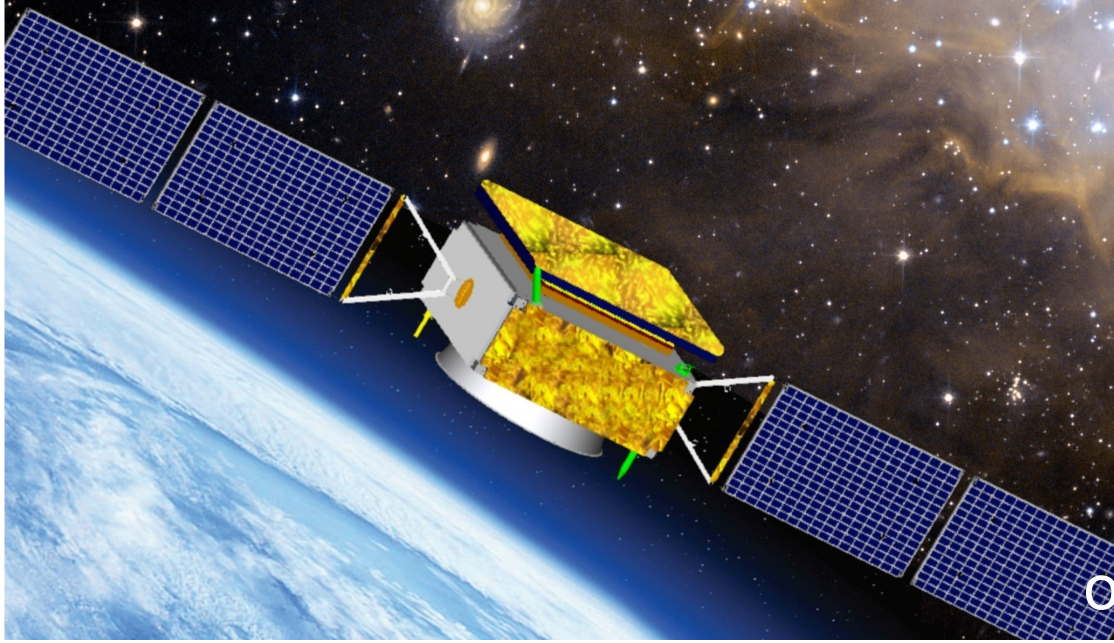
DAMPE: DArk Matter Particle Explorer



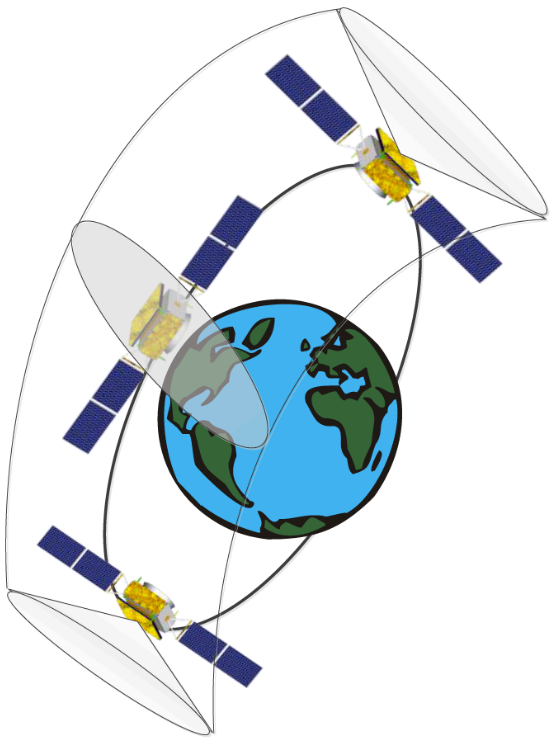
G. Ambrosi
INFN Perugia
on behalf of the DAMPE coll.

DAMPE: One of the Five Approved Satellite Missions of the Chinese Academy of Sciences

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

DAMPE Satellite

- Scheduled launch date late 2015
  - Total weight <1900 kg, power consumption ~850 W
  - Scientific payload ~1400 kg
  - Lifetime > 3 year



- **Altitude: 500 km**
- **Inclination: 97.4065°**
- **Period: 90 minutes**
- **Orbit: sun-synchronous**
- **Launched by CZ 2D rocket**

The DAMPE Collaboration

- The original collaboration
  - Purple Mountain Observatory, CAS, Nanjing
  - 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

DAMPE Observation

- ❑Electron:2GeV-10TeV
- ❑Gamma-rays:2GeV-10TeV
- ❑Proton and Heavy Ions:30GeV-1000TeV

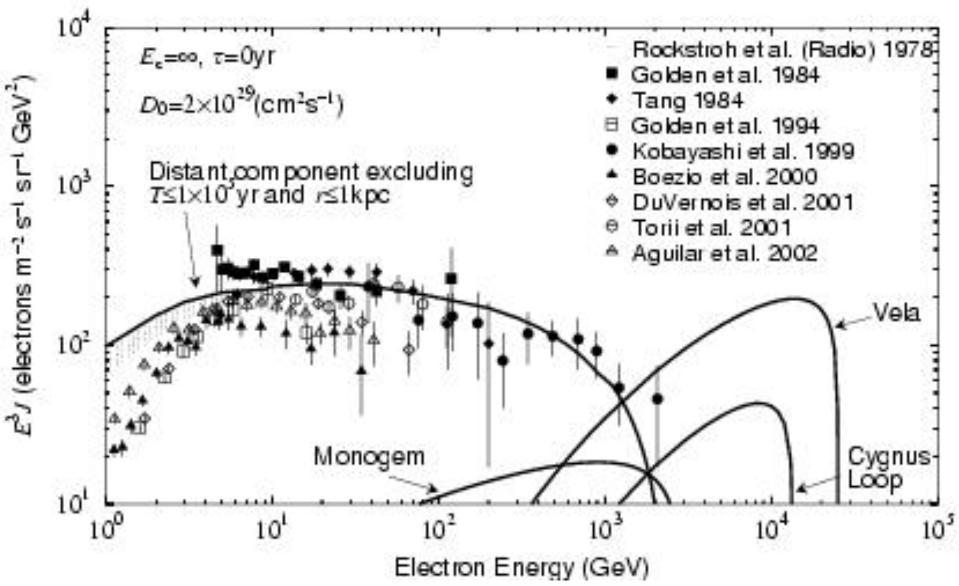
Scientific Objectives

Science Objectives	Observation Targets
Nearby Cosmic-ray Sources	Electron spectrum in trans-TeV region
Dark Matter	Signatures in electron/gamma energy spectra in 10GeV – 10 TeV region
Origin and Acceleration of Cosmic Rays	p-Fe above 30 GeV
Cosmic –ray Propagation in the Galaxy	B/C ratio up to several TeV /n
Gamma-ray Transients	Gamma-ray time profile
Gamma-ray Astronomy	Gamma-ray mapping

Nearby Cosmic-ray Sources

Trans-TeV electron spectrum observation

High energy electron lose energy ∝1/E²
Local TeV electrons:
Age < ~10⁵ years, Distance < 1 kpc
Local TeV electrons → Vela, Monogem, Cygnus Loop



Electron spectrum depending on Vela and Cygnus Loop
Kobayashi, 1210.2813

Cosmic –ray Propagation in the Galaxy

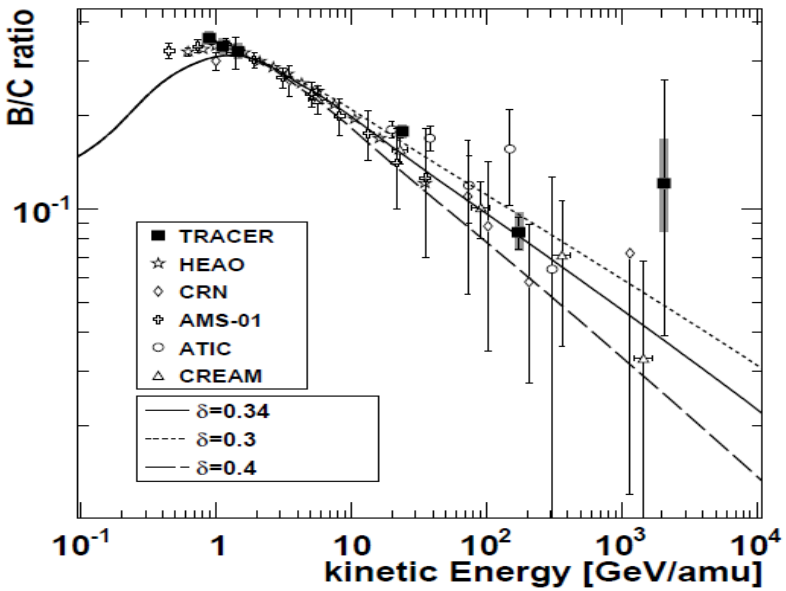
B/C ratio observation

❑ B/C ratio: Secondary/Primay

CNO+ISM→B

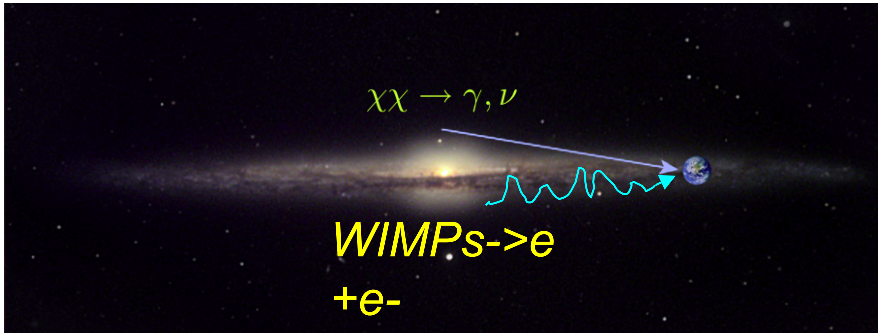
$N_B/N_C \propto \lambda_{esc} * \sigma_{CNO \rightarrow B}$

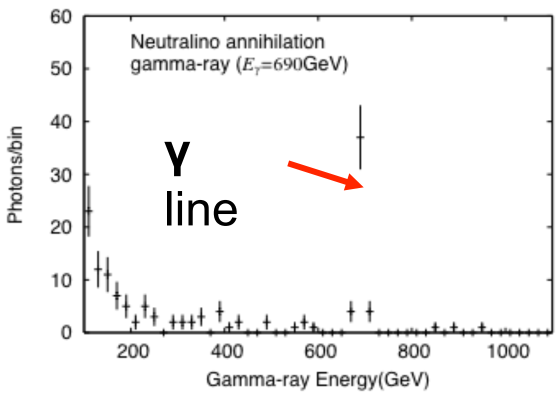
→Propagation in the Galaxy

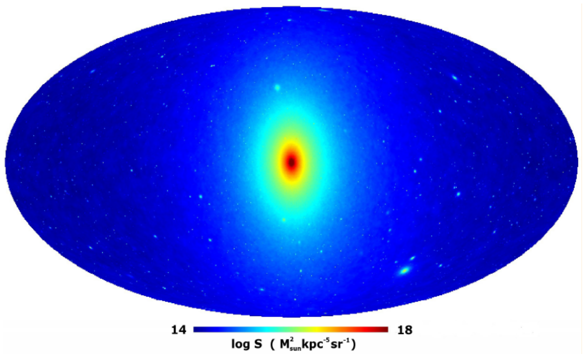


Dark Matter

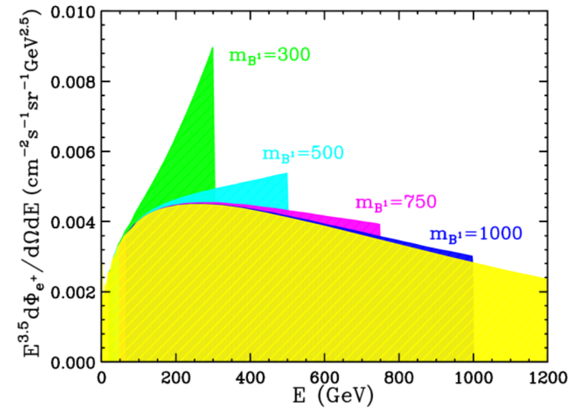
Signals in e&γ spectrum & space distribution







γ –ray Halo



Cut-off in e^+ and e^-

These signals would be smoking gun of dark matter particle

Present status

- Cosmic electrons:

No Space Observation above TeVs

- Cosmic ray Proton and Heavy Ions

from TeV to PeV, no direct element spectral measurement

- Gamma-ray astronomy

There is a gap between space and ground observation (10s GeV -100s GeV)

No High energy resolution observation in space

- Dark matter particle

No proof

We need a new detector

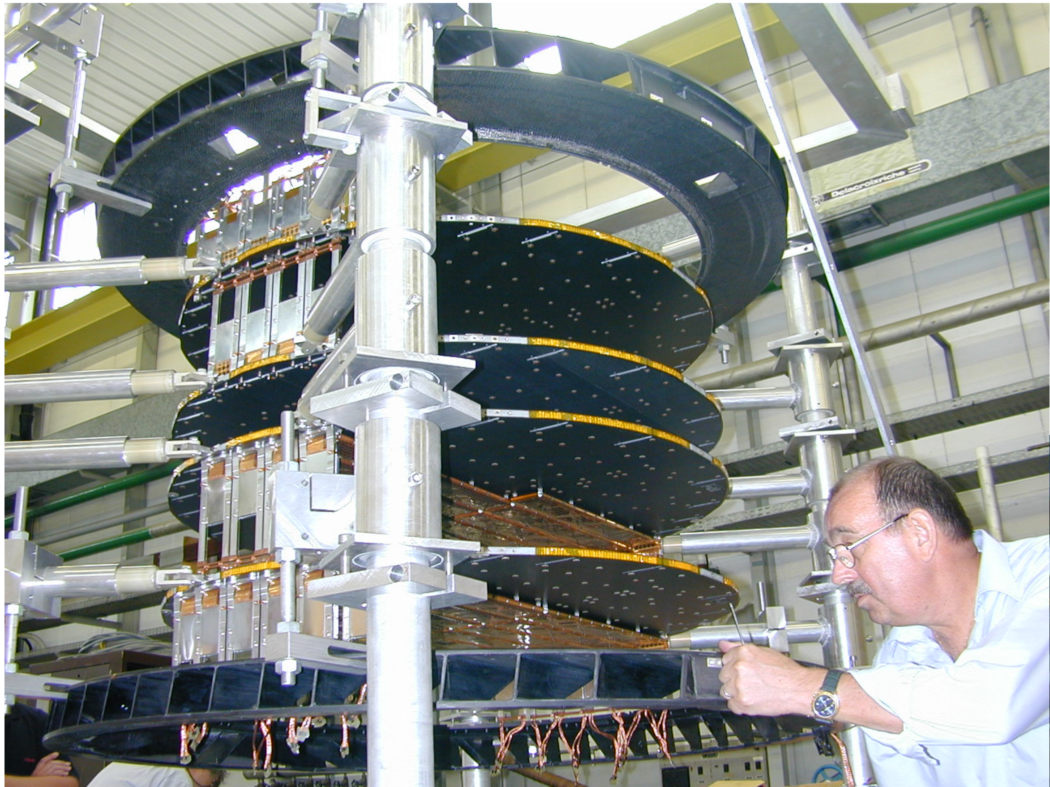
- Energy range >TeV
- Energy resolution better than 1.5%
- Background Rejection above 10^5

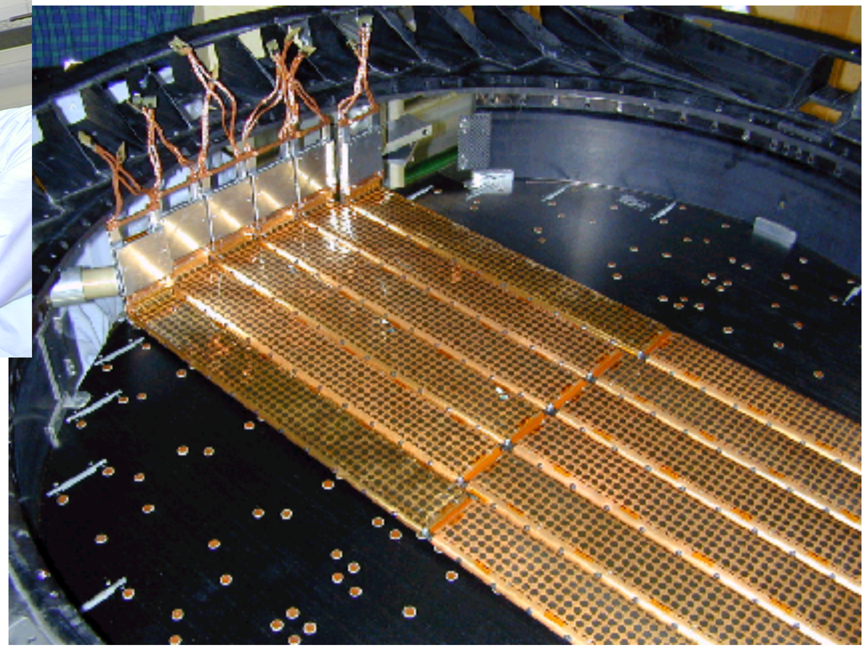
The DAMPE Collaboration

- A growing international collaboration
  - Purple Mountain Observatory, CAS, Nanjing
  - 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
  - University of Geneva, Switzerland
  - INFN Perugia, Italy
  - INFN Bari, Italy

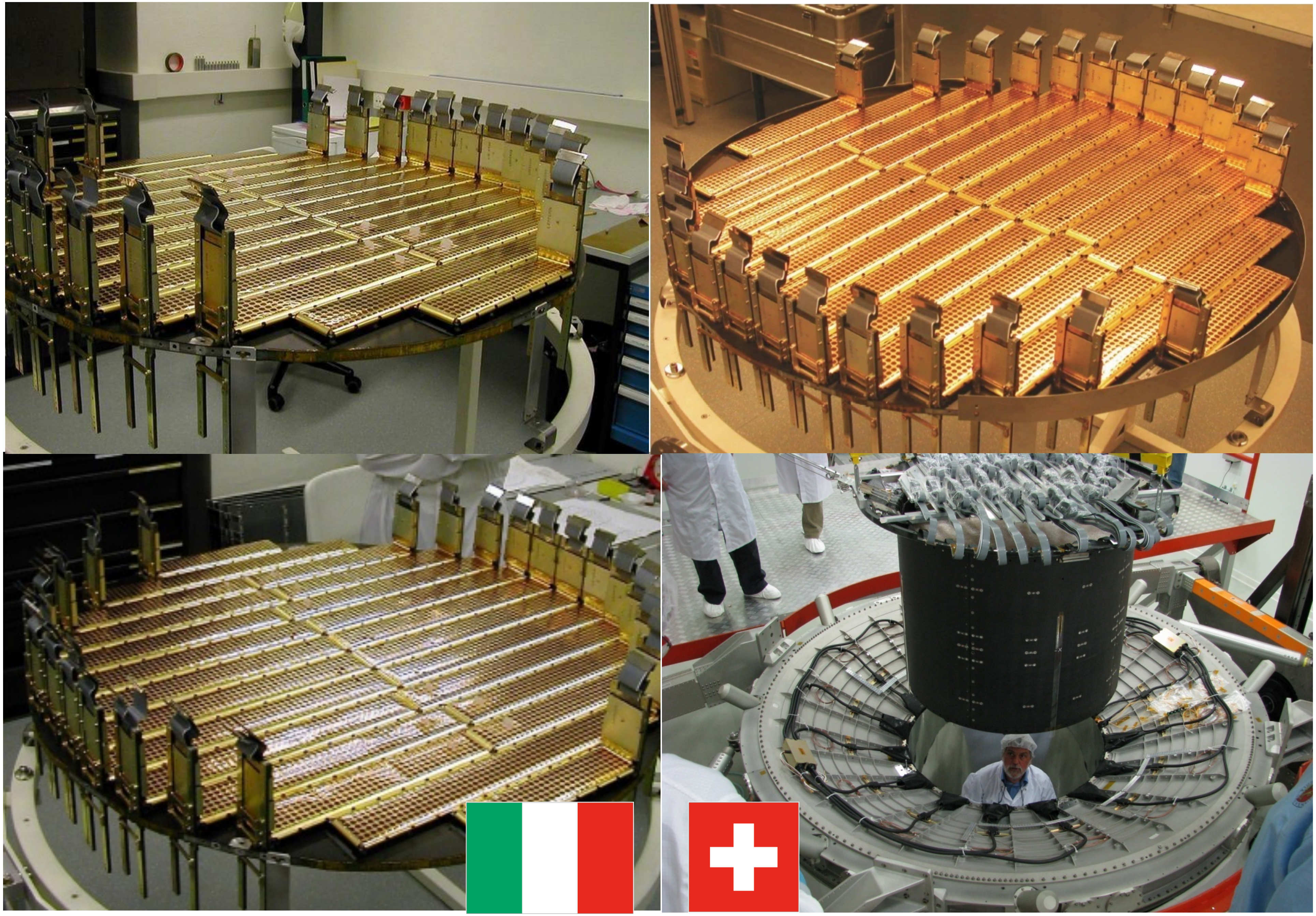
DARK MATTER DAMPE PARTICLE EXPLORER

AMS-01 Silicon Tracker (1998)

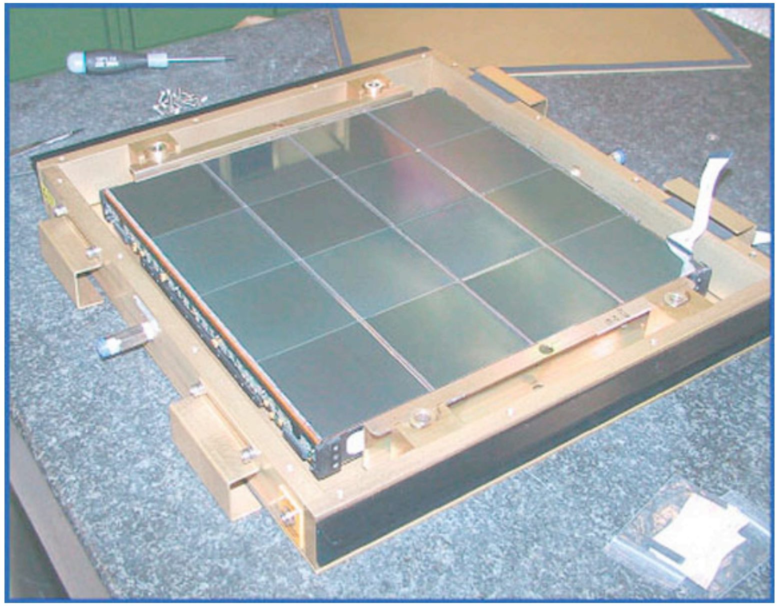


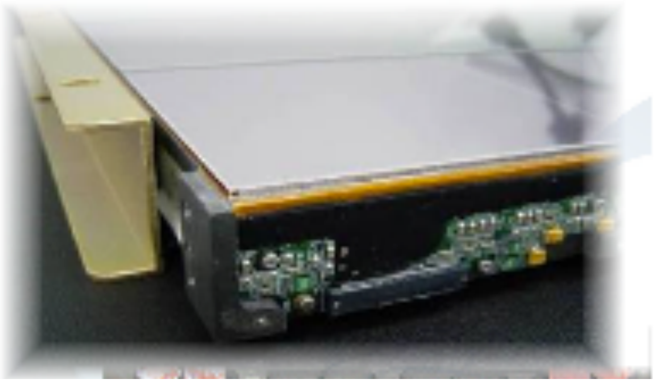


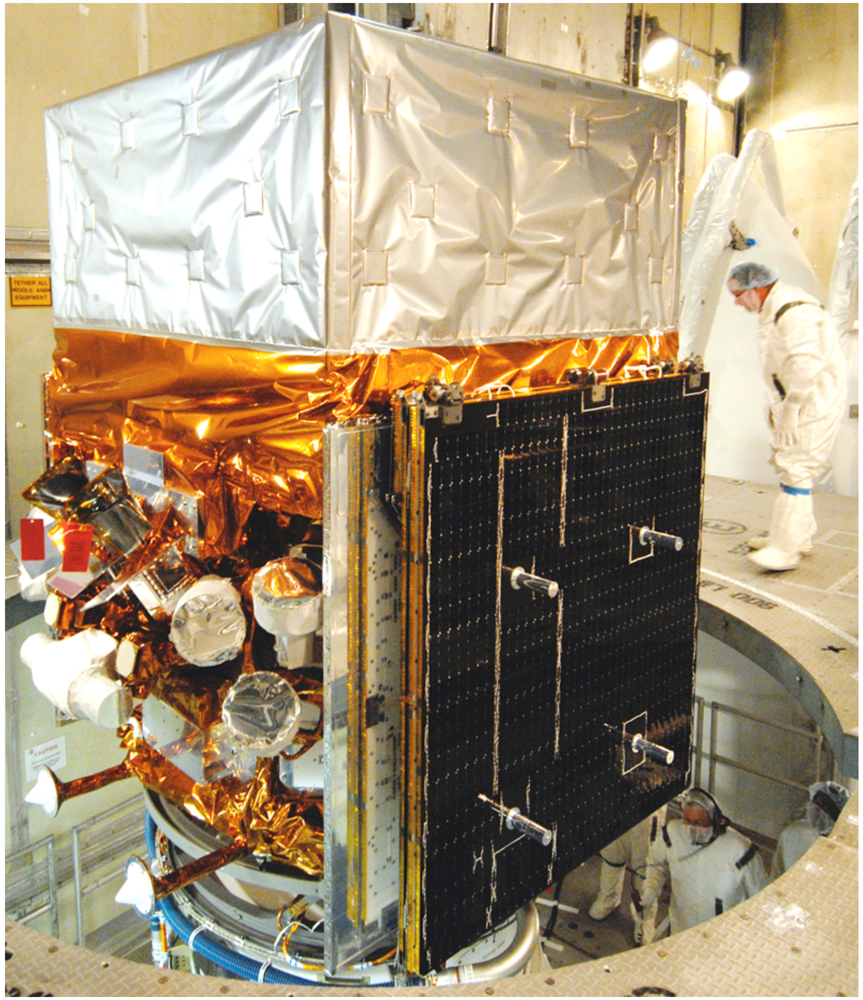
AMS-02: 9 planes with 200,000 channels aligned to 10 microns



FERMI 2008



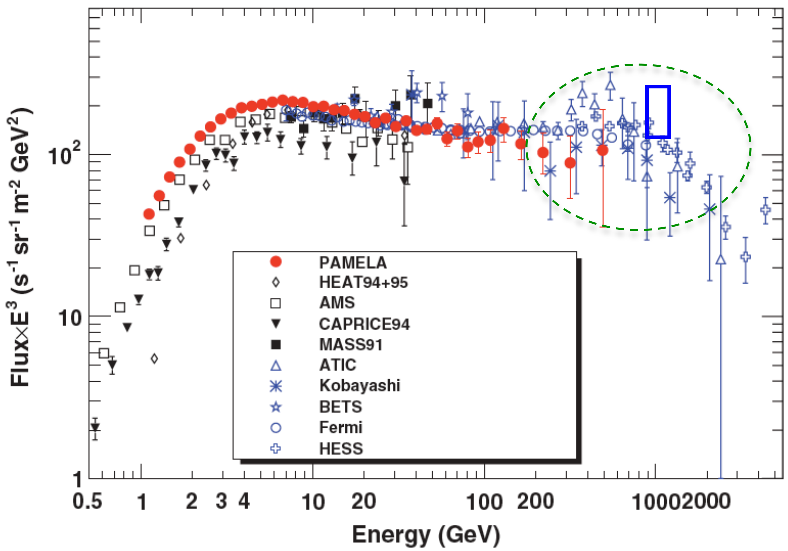




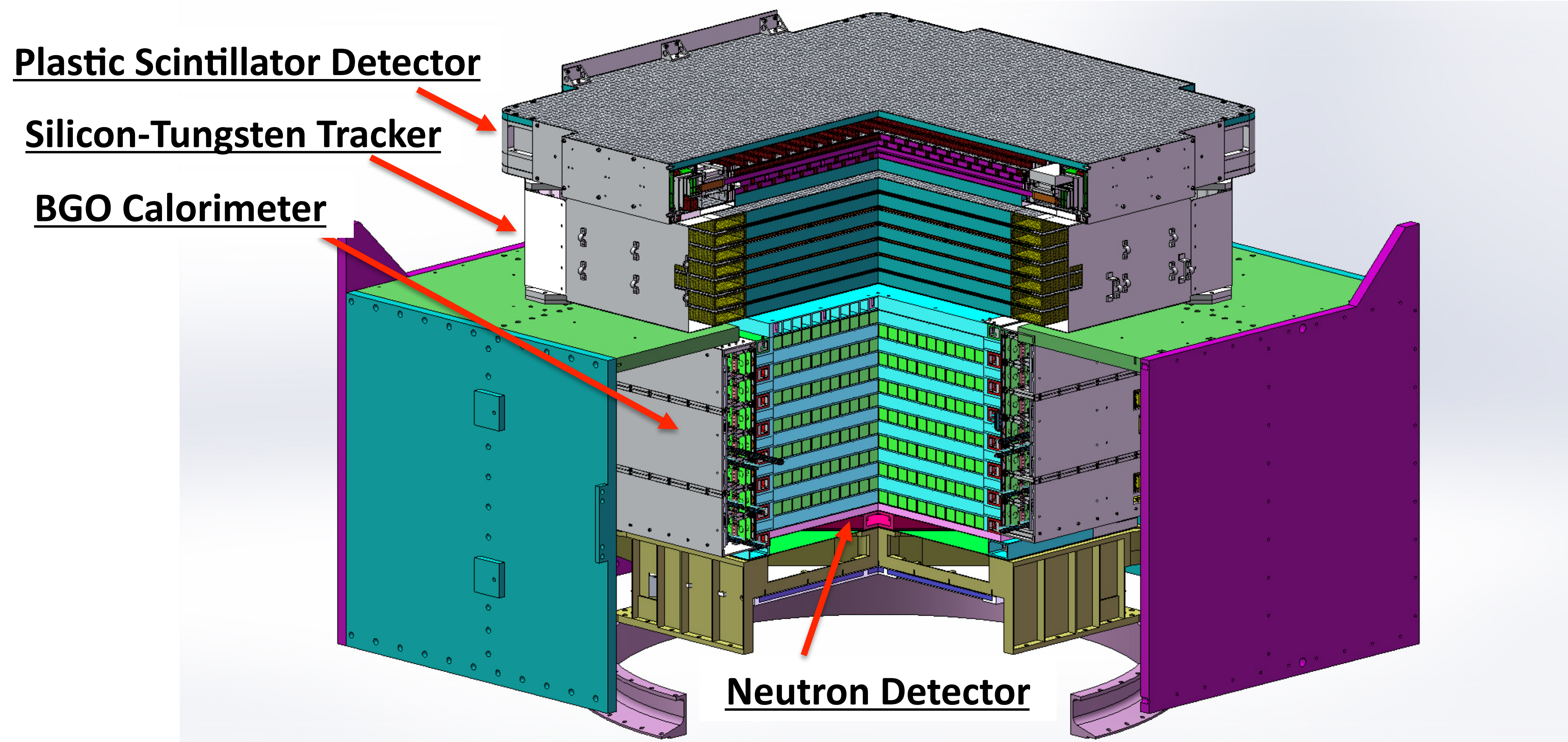
Scientific Objectives of DAMPE

- 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

Covering 2 GeV - 10 TeV e/γ, 30 GeV - 100 TeV CR
Excellent energy resolution and tracking precision
Complementary to Fermi, AMS-02, CALET, ISS-CREAM, …

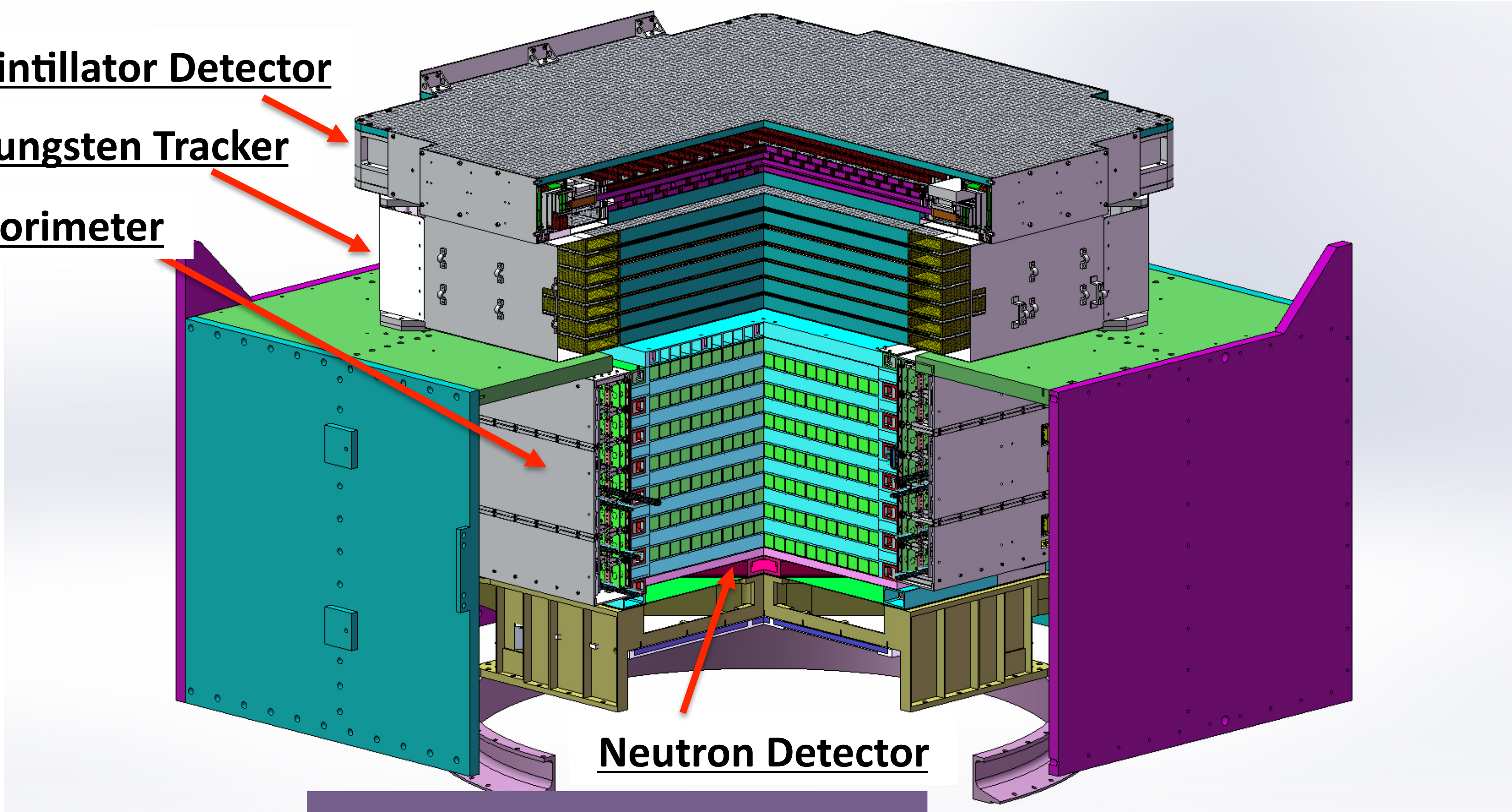


The DAMPE Detector



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

The DAMPE Detector



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

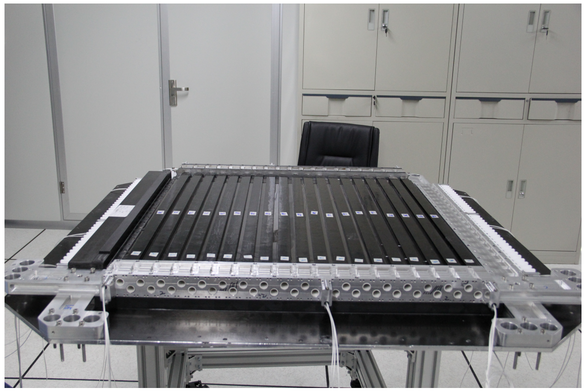
Comparison with AMS-02 and Fermi

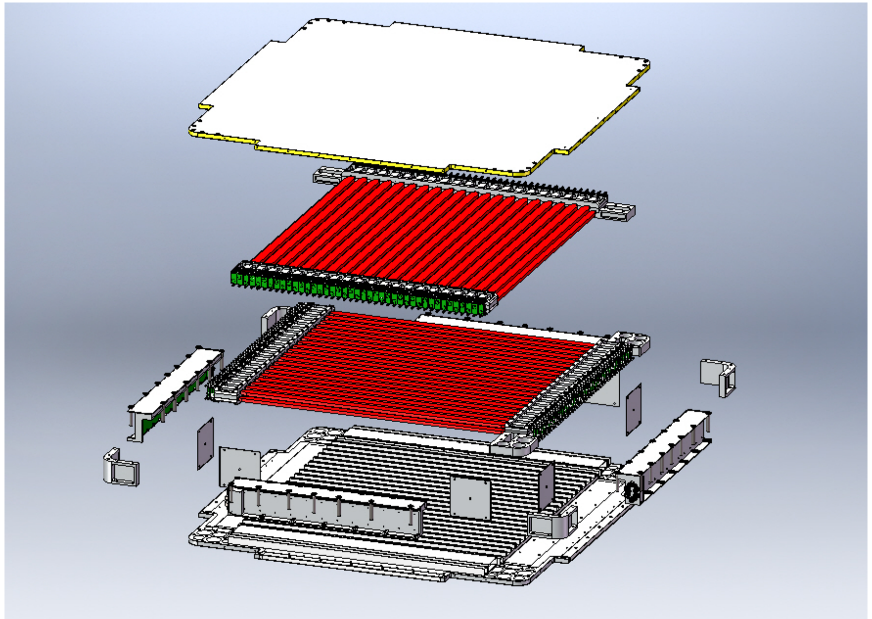
	DAMPE	AMS-02	Fermi LAT
e/γ Energy range (GeV)	5 - 10^4	0.1 - 10^3	0.02 - 300
e/γ Energy res.@100 GeV (%)	1.5	3	10
e/γ Angular res.@100 GeV (°)	0.1	0.3	0.1
e/p discrimination	10^5	10^5 - 10^6	10^3
Calorimeter thickness (X_0)	31	17	8.6
Geometrical accep. (m^2sr)	0.29	0.09 (ECAL)	1

- 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

Plastic Scintillator Detector (PSD)

- Two layers (x and y) of plastic scintillation strips of 1cm thick, 2.8 cm wide and 82 cm long
  - Strip staggered by 0.8 cm, fully covered area: 82cm×82cm
- Readout both ends with PMT, use two dynode signals (factor ~40) to extend the dynamic range
  - FE ASIC VA160 with dynamic range up to 12 pC
- Expected performance
  - Position resolution ~6 mm
  - Charge resolution 0.25 u
  - Dynamic range Z = 1 - 20



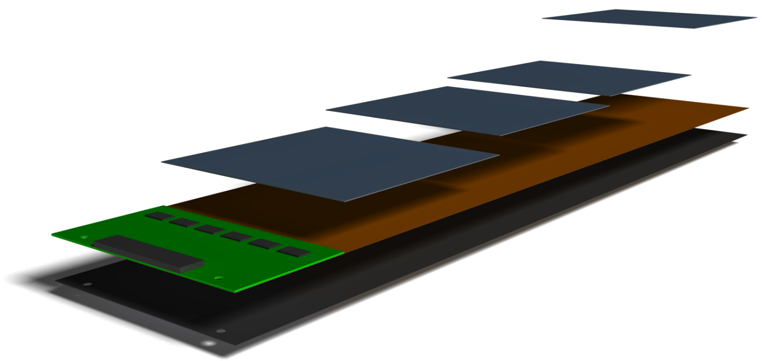


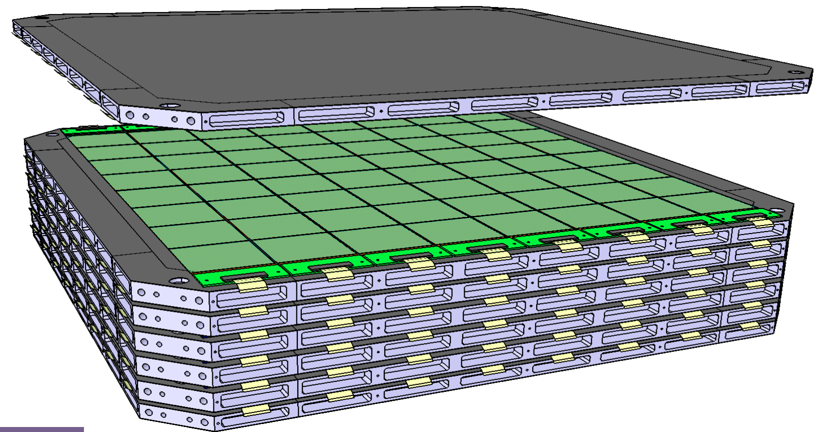
IMP, Lanzhou

Silicon Tungsten Tracker (STK)

- 12 layers of silicon micro-strip detector, 7 support planes
  - Plane: carbon fiber face sheet with Al honeycomb core
  - Sensor 9.5 x 9.5 cm^2, 4 sensors bonded together to form a ladder
  - 16 ladders on each face of the support plane, x-view and y-view
    - Except top and bottom planes: only one face has ladders
- Tungsten plates integrated in trays 2, 3, 4 counting from the top
  - Total 1.43 X_0 for photon conversion

Detection area 76cm x 76cm





UniGE, INFN Perugia & Bari, IHEP Beijing

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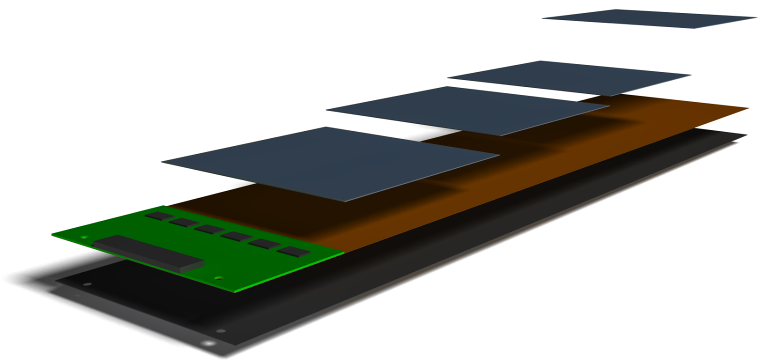

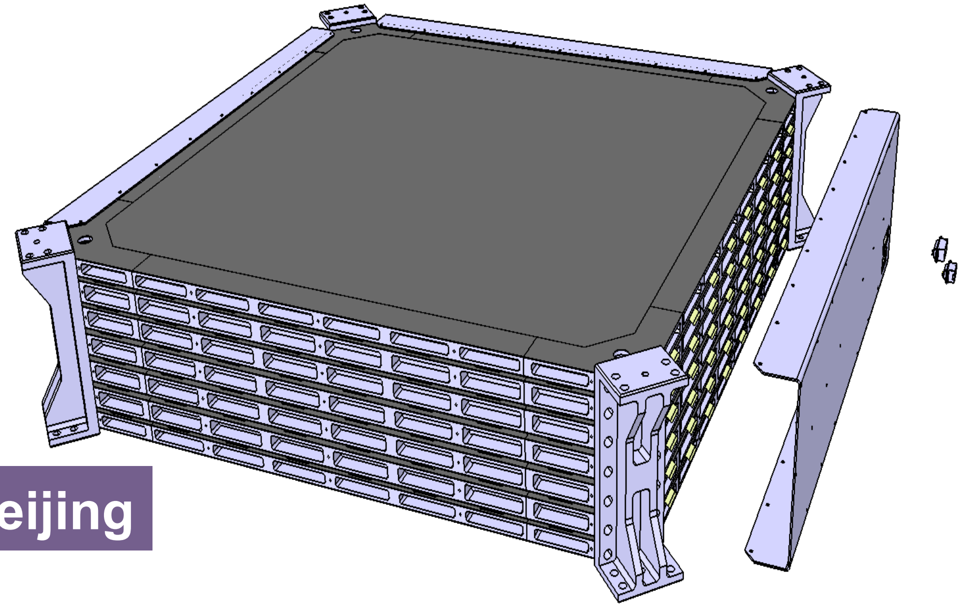

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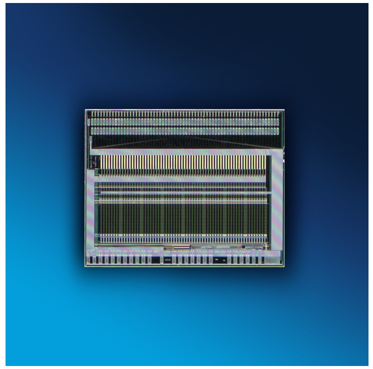
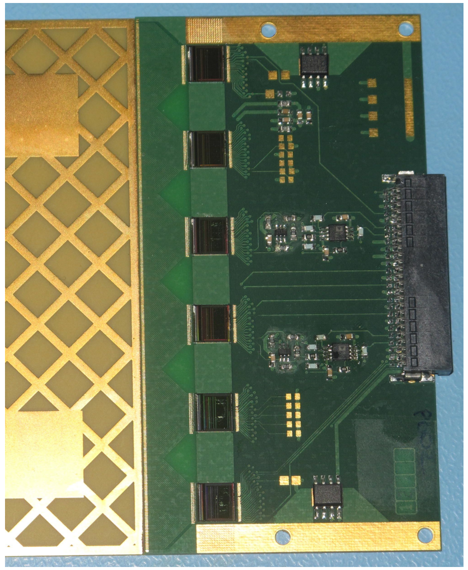
STK Readout Electronics

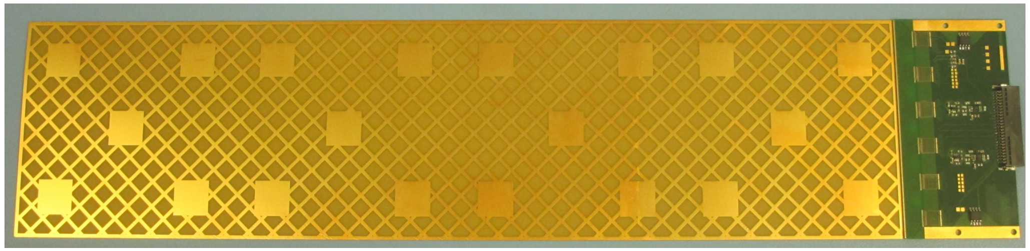
- Readout every other channel, readout pitch 242μm
  - ASIC VA140 from IDEAS, updated version of VA64hdr of AMS
  - Analog readout, resolution better than 70μm



Parameter	VA64HDR9A	VA140
Noise, Cd=50pF (eRMS)	520	430
DNR	+100fC,-200fC	±200fC
Power cons. (mW/channel)	0.8	0.29
Peaking time (μs)	5	6.5
SEL thrshd (MeV·cm^2/mg)	22	21-22

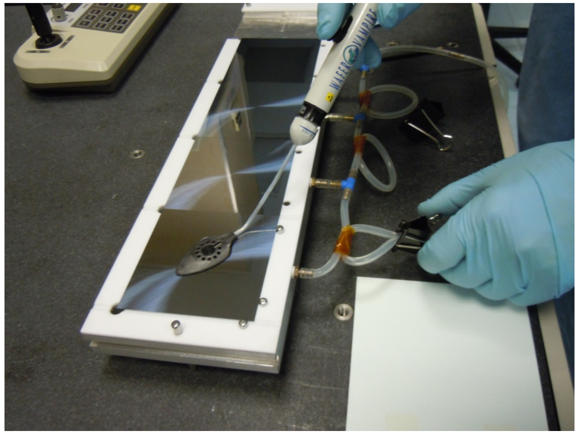


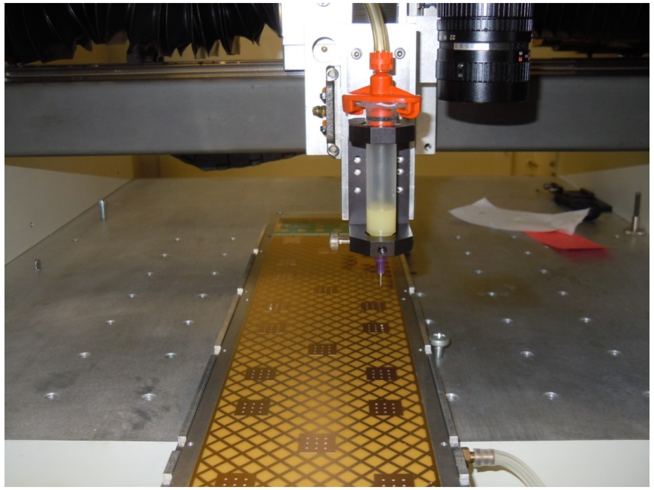
- Tracker Front-end Hybrid (TFH)
  - Kapton flexible bias circuit (250μm FR4) integrated with a PCB housing 6 VAs

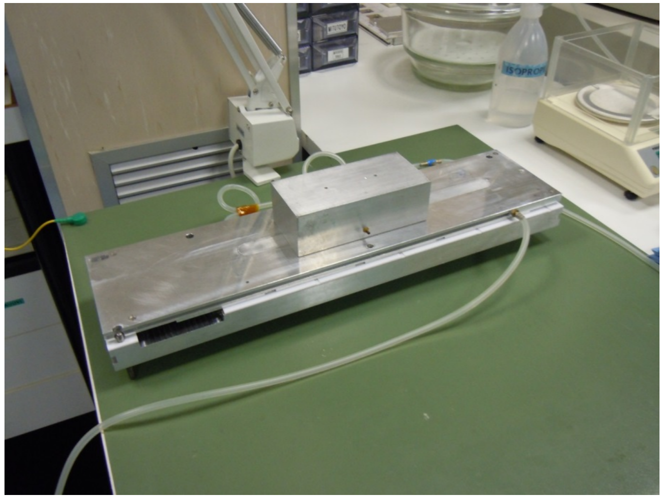


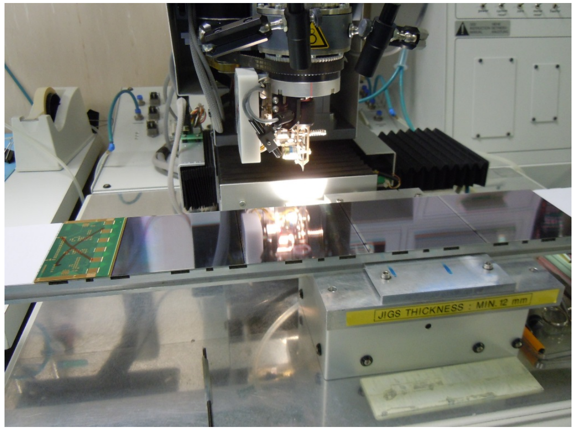
STK: Ladder Assembly

- Special jigs designed to assemble (align, glue and bond) 4 sensors on a TFH to produce a ladder
  - Specification: align 4 sensors to 40 μm, planarity to 50 μm





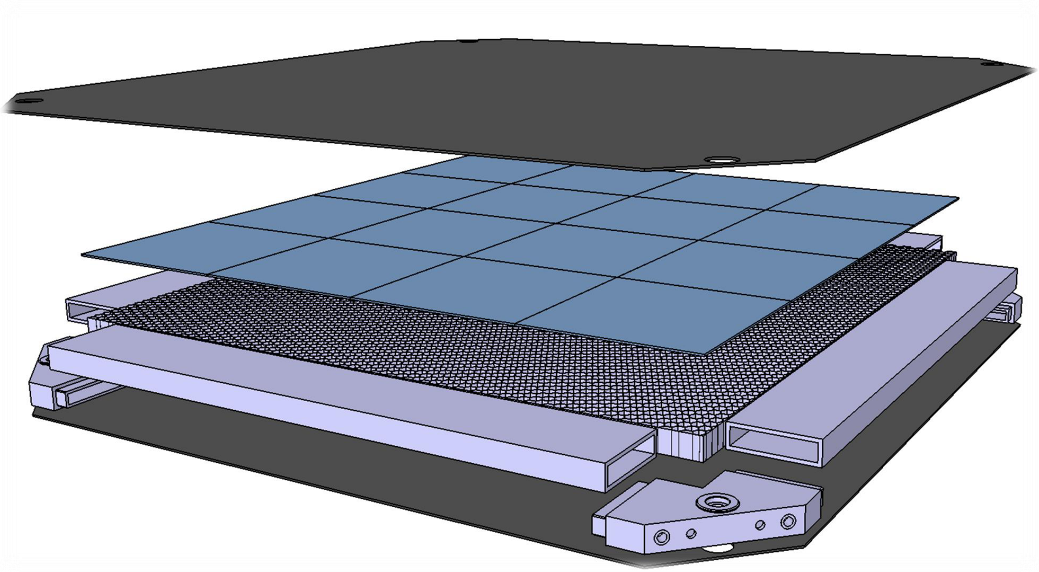


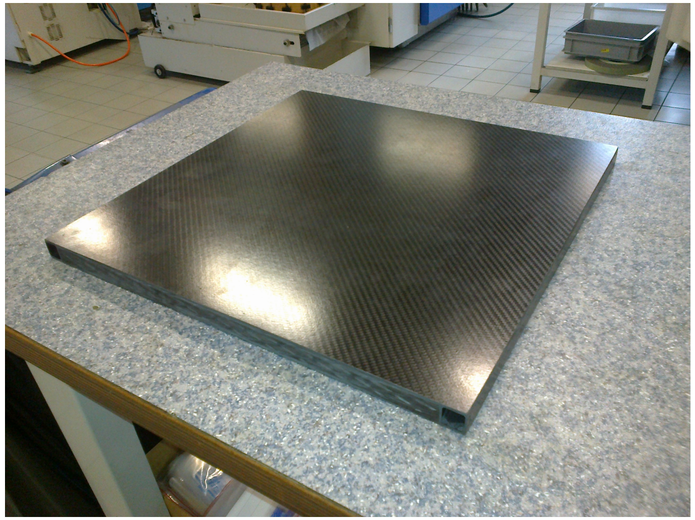


Gig design and prototyping in progress

STK: Support Plane

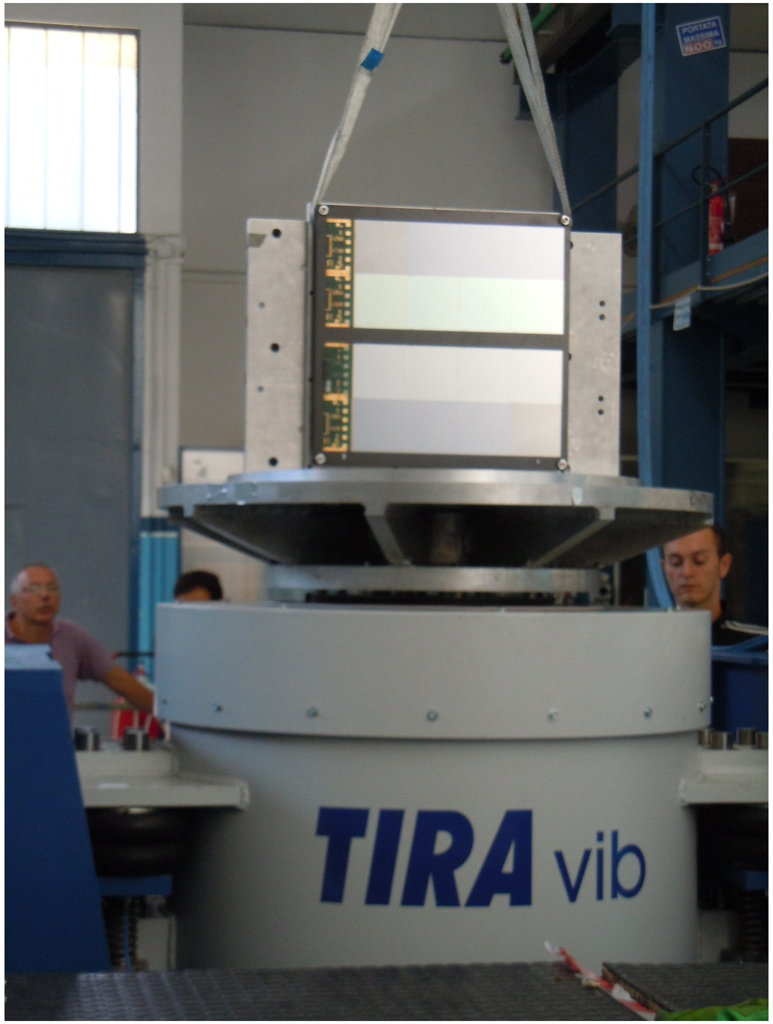
- 7 planes, 3 with tungsten plates
  - 22 kg of tungsten for planes with 2mm plates
  - CFRP side beams and corners to reduce total weight (~140 kg)





- A quarter size plane with 2mm tungsten plates have been produced by Composite Design (a Swiss company)

STK: quarter plane test



SERMS laboratory in Terni

- 3 mechanical and one electrical ladder prototypes mounted on the plane
- vibration and shock test
- thermal cycling

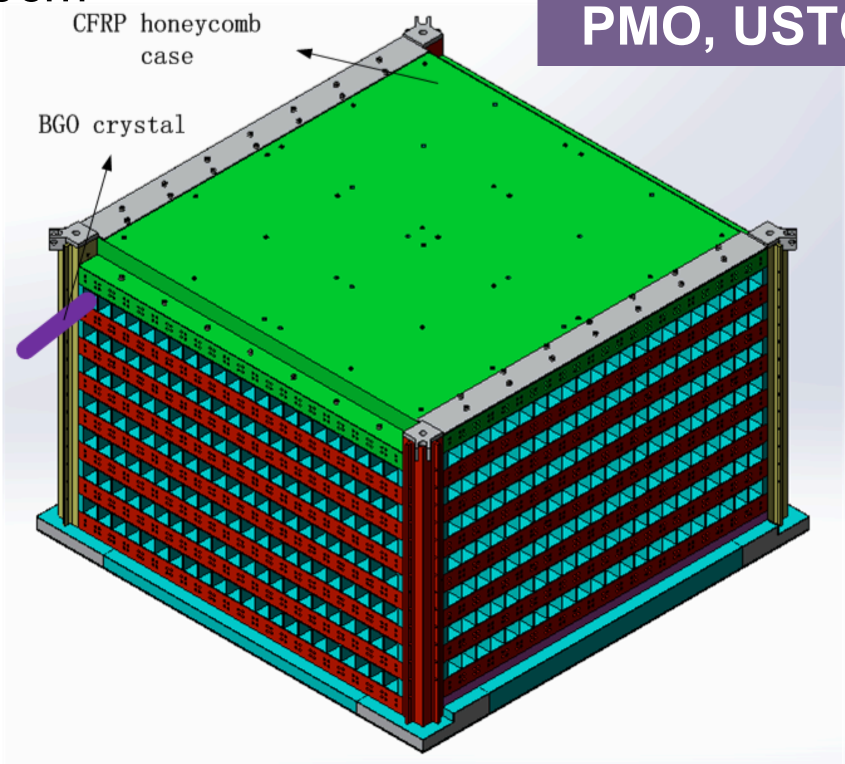
- Preliminary results:
  - electrical behaviour is unaffected by stress
  - Silicon detector ‘move’ by few microns

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

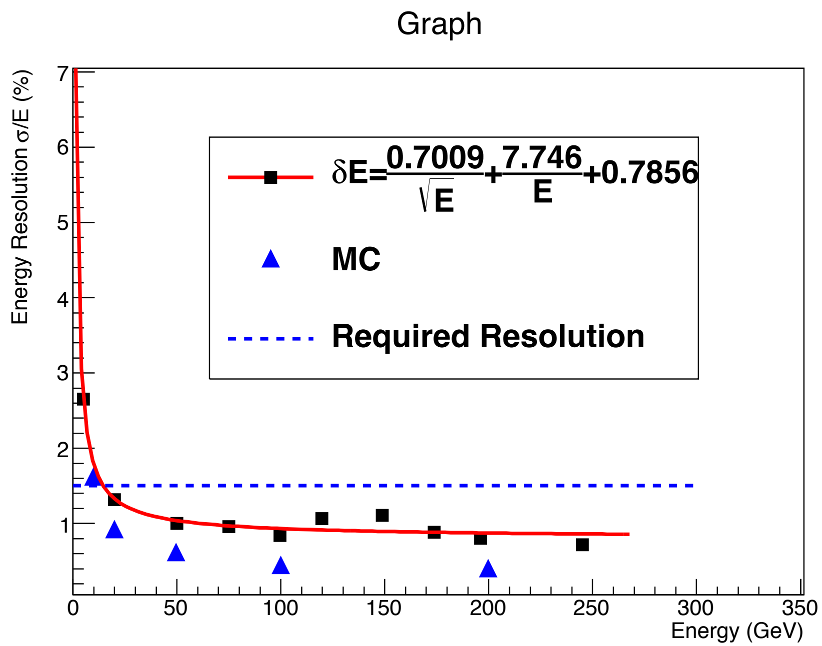
Total thickness 31X_0

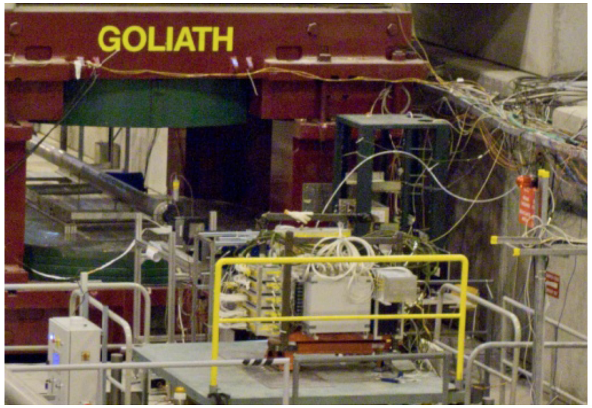


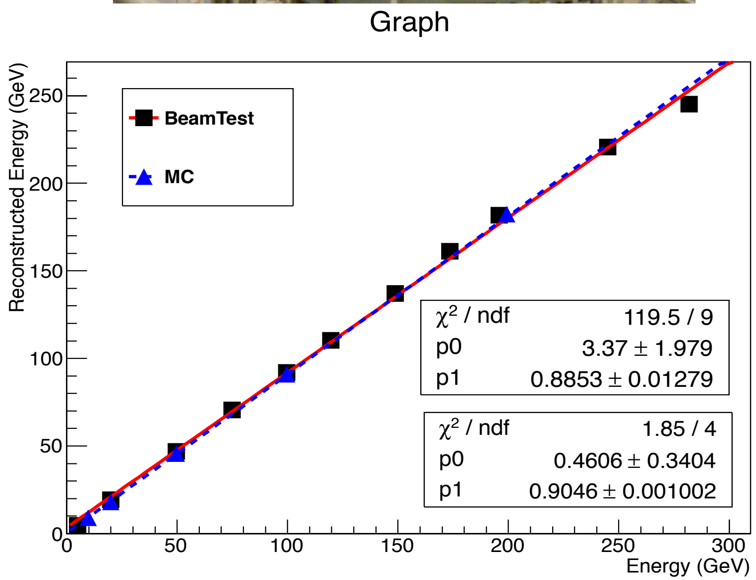
Measure electron/photon energy with great precision between 5 GeV - 10 TeV

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)



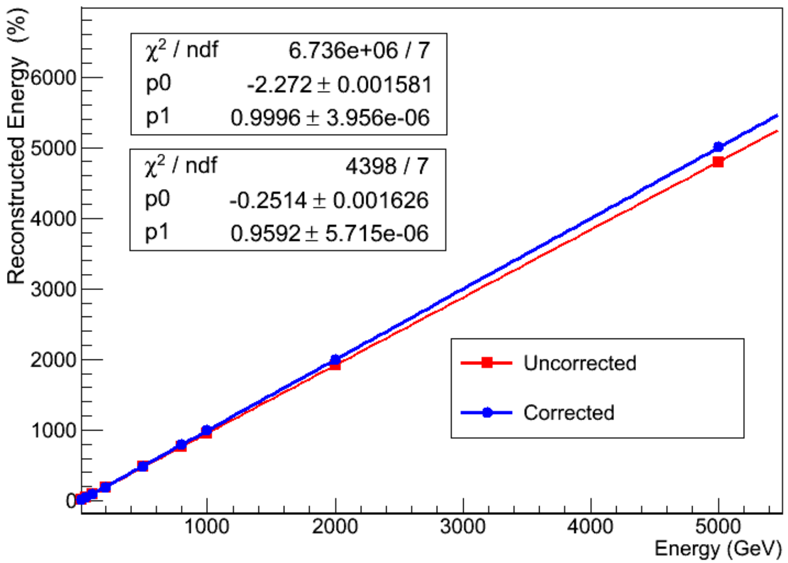


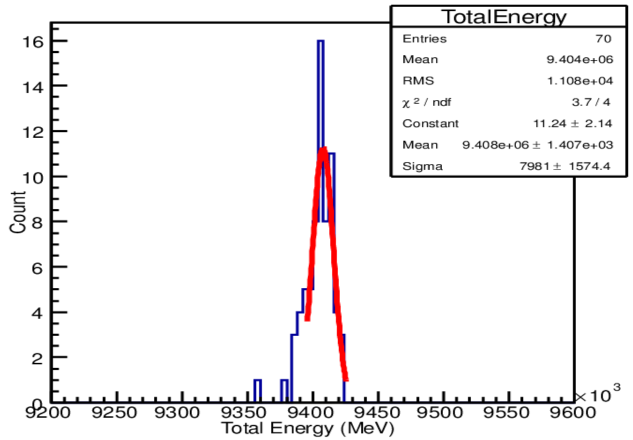


Goal 1% at 800 GeV

good linearity

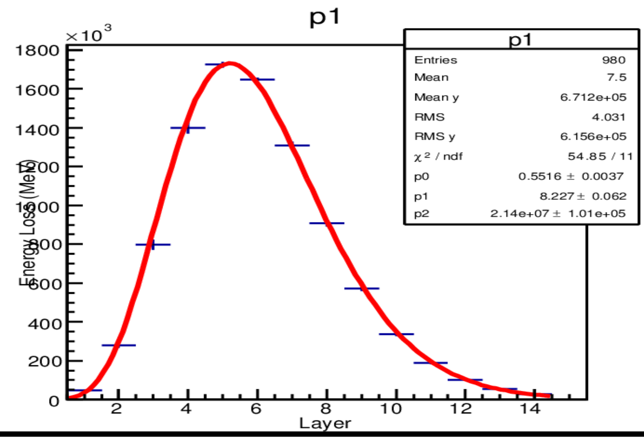
BGO Performance (MC)





10TeV e, Energy deposit=9.4TeV

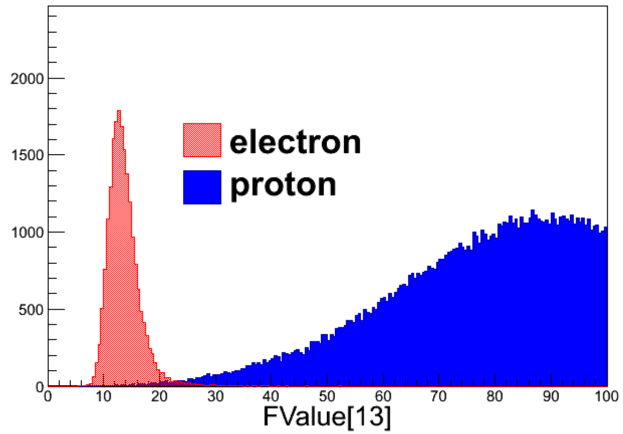
Leakage Correction can also give a better linearity. The gradient from 0.9592 to 0.9996. We wish it perfectly equal to 1.

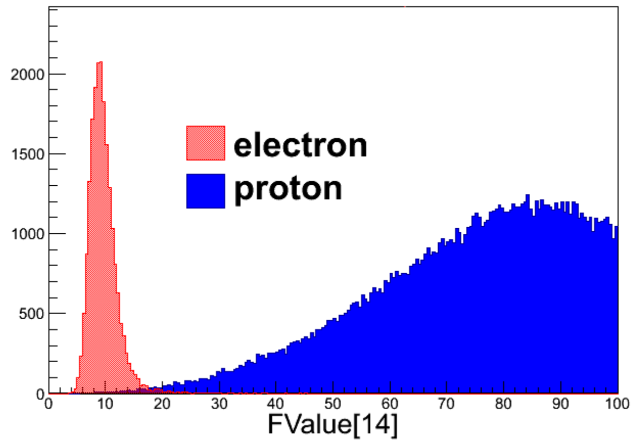


10TeV e shower profile, Only 0.3% energy leakage from bottom

BGO Performance (MC)

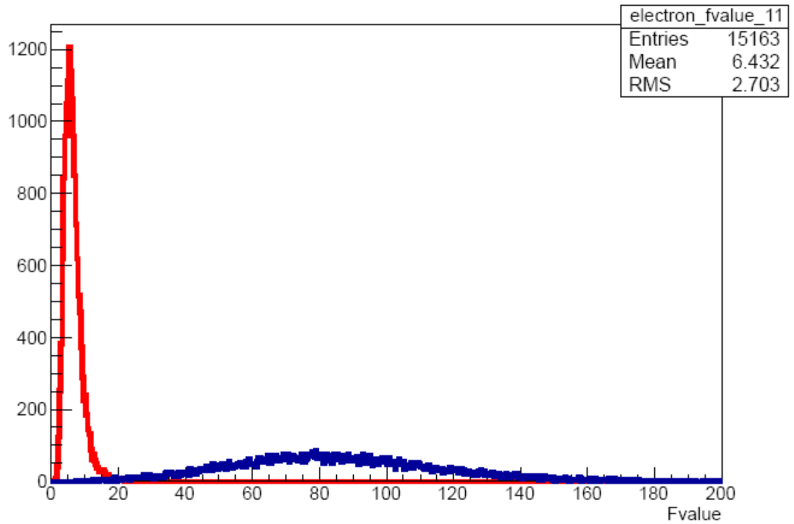
Fvalue = E_{frac} RMS^2, calculated layer by layer



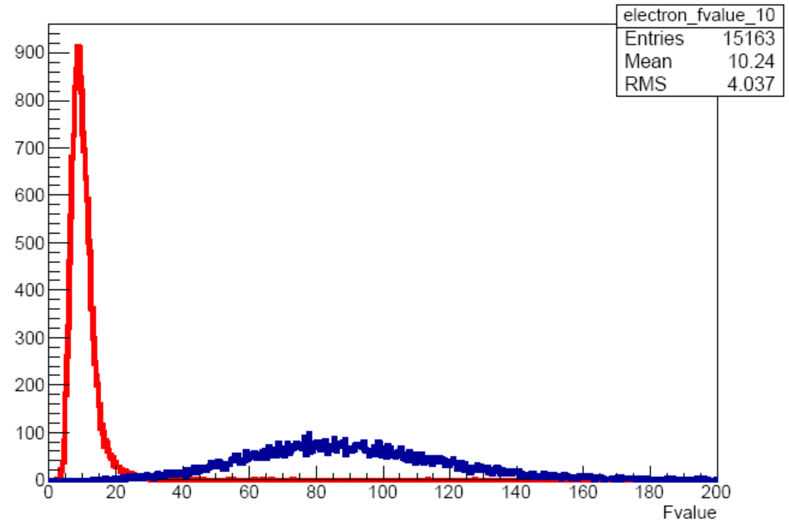


	Electron	**proton**
Energy Range [900,1000] GeV	19963	165617
F13<20&&F14<15	19060	108
Efficiency or False Rejection Rate	**95.48%**	**0.0652%(1.5e +03)**

BGO Performance (Test Beam)



Fvalue 11



Fvalue 12

	e	p
Total events	24556	540145
energy [100,120] GeV	15163	12668
F11<14&F10<19	14462	5
Eff.	**95.38%**	**0.0395%**

STK Performance Studies

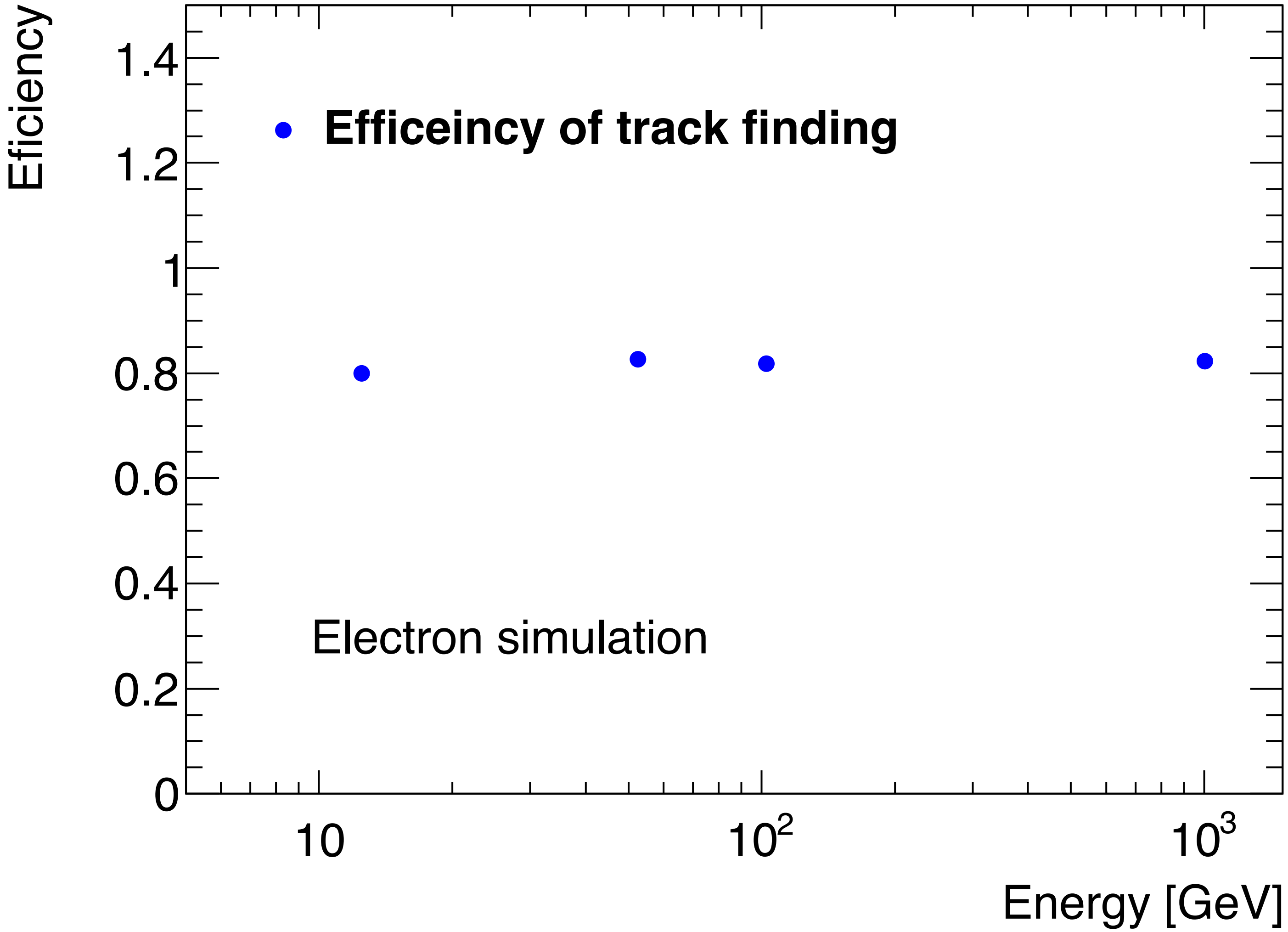
- The STK bring several crucial improvements to the performance of DAMPE
  - Photon identification with conversions
  - Angular resolution for e/γ/CR
  - e/γ separation with precise tracking and hits in the STK
  - e/p separation with precise tracking and hits in the STK
  - CR charge measurement

Simulation results are very preliminary, based on approximate detector description (eg. support structure, electronics response, noise not included, …)

STK Reconstruction

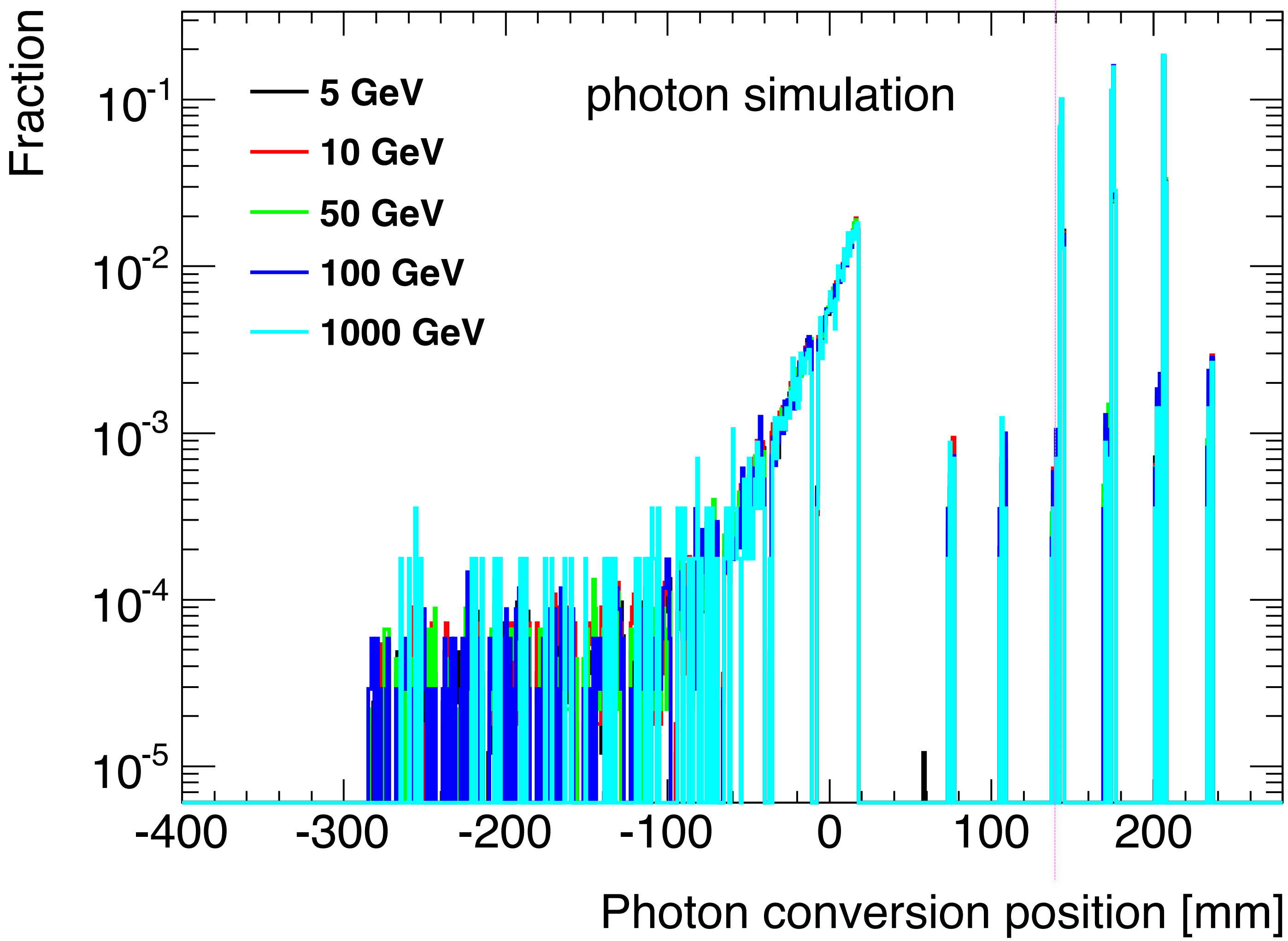
- Cluster finding
  - Special care needed for breaking up long clusters
- Track reconstruction: very challenging because of the thick W plates
  - Necessary to take material into account $\Longrightarrow$ use Kalman filter
- Key is pattern recognition, in particular at very high energy ($\gtrsim$ 1TeV)
  - How to find the right hits of the primary track out of hundreds of hits from pre-shower and backsplash?
- Need to use different track seeding algorithms for different types of particles
  - Simple algorithms are implemented at the moment $\Longrightarrow$ results are indicative only

Electron Tracking Efficiency



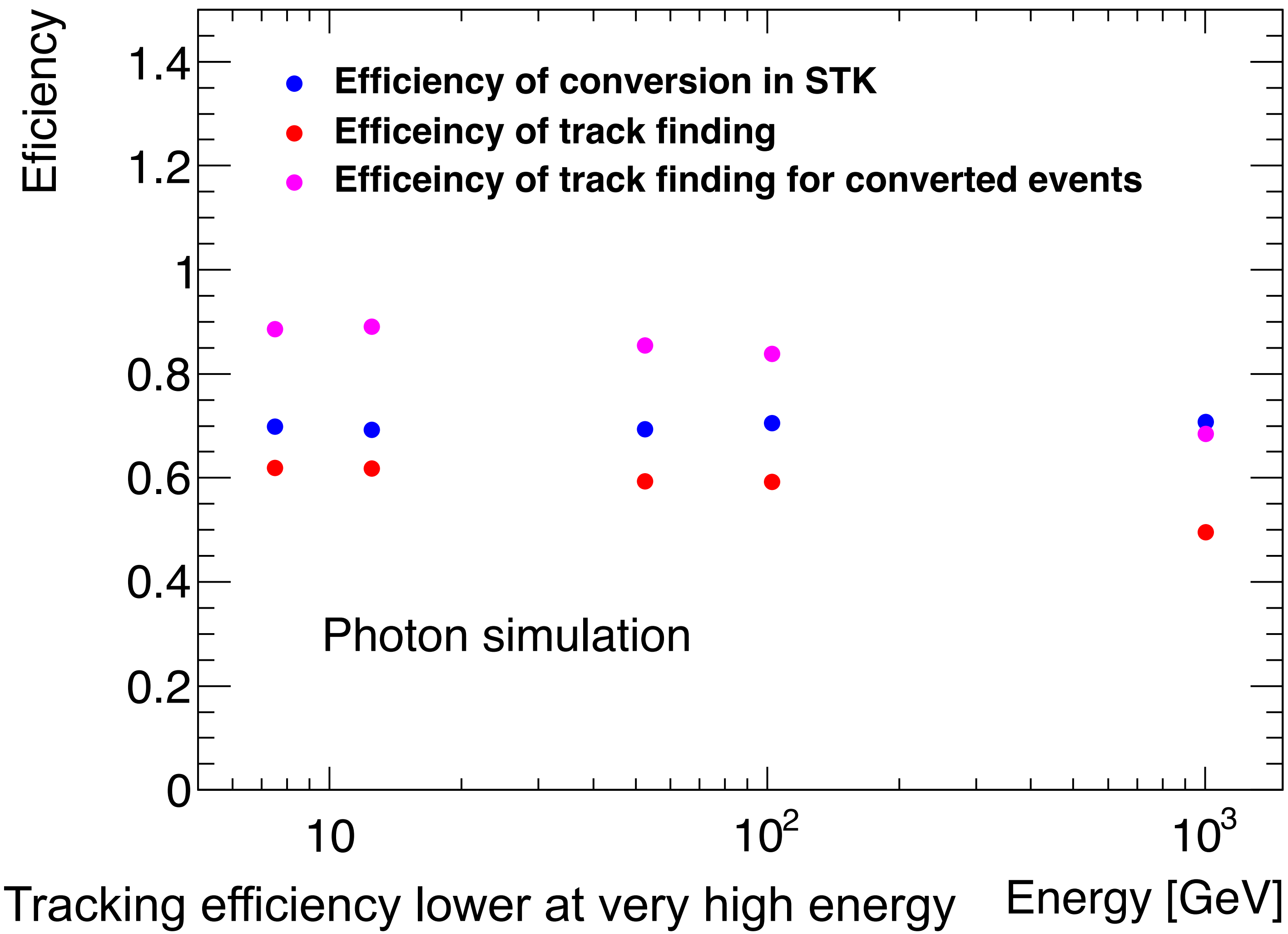
- Include dead areas and cluster finding efficiency of the tracker
  - Require always a space point in the top tracking plane (93%)

Photon Conversion Position



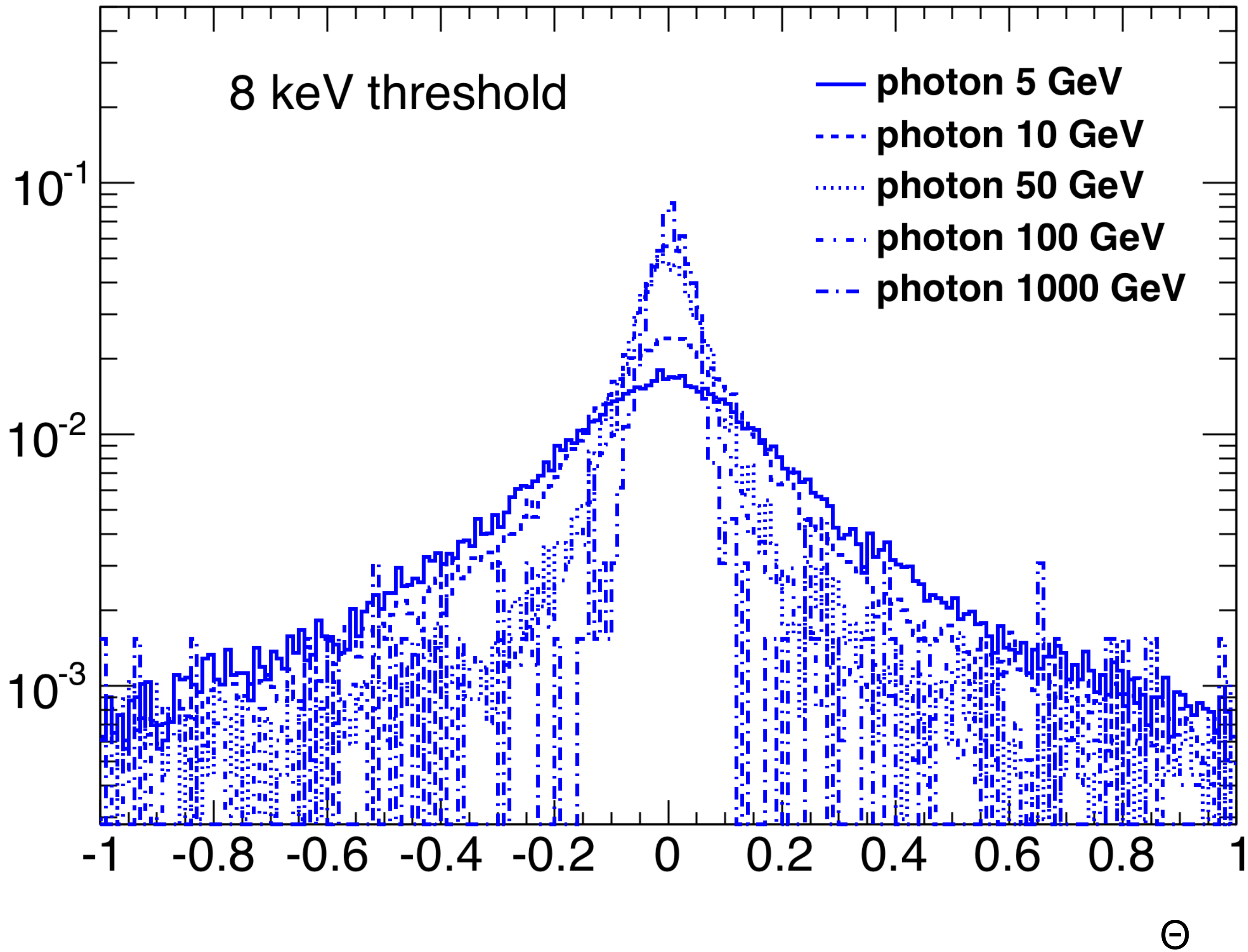
Conversion probability in converter (~70%) independent of energy

Eff. of Conversion and Track Finding

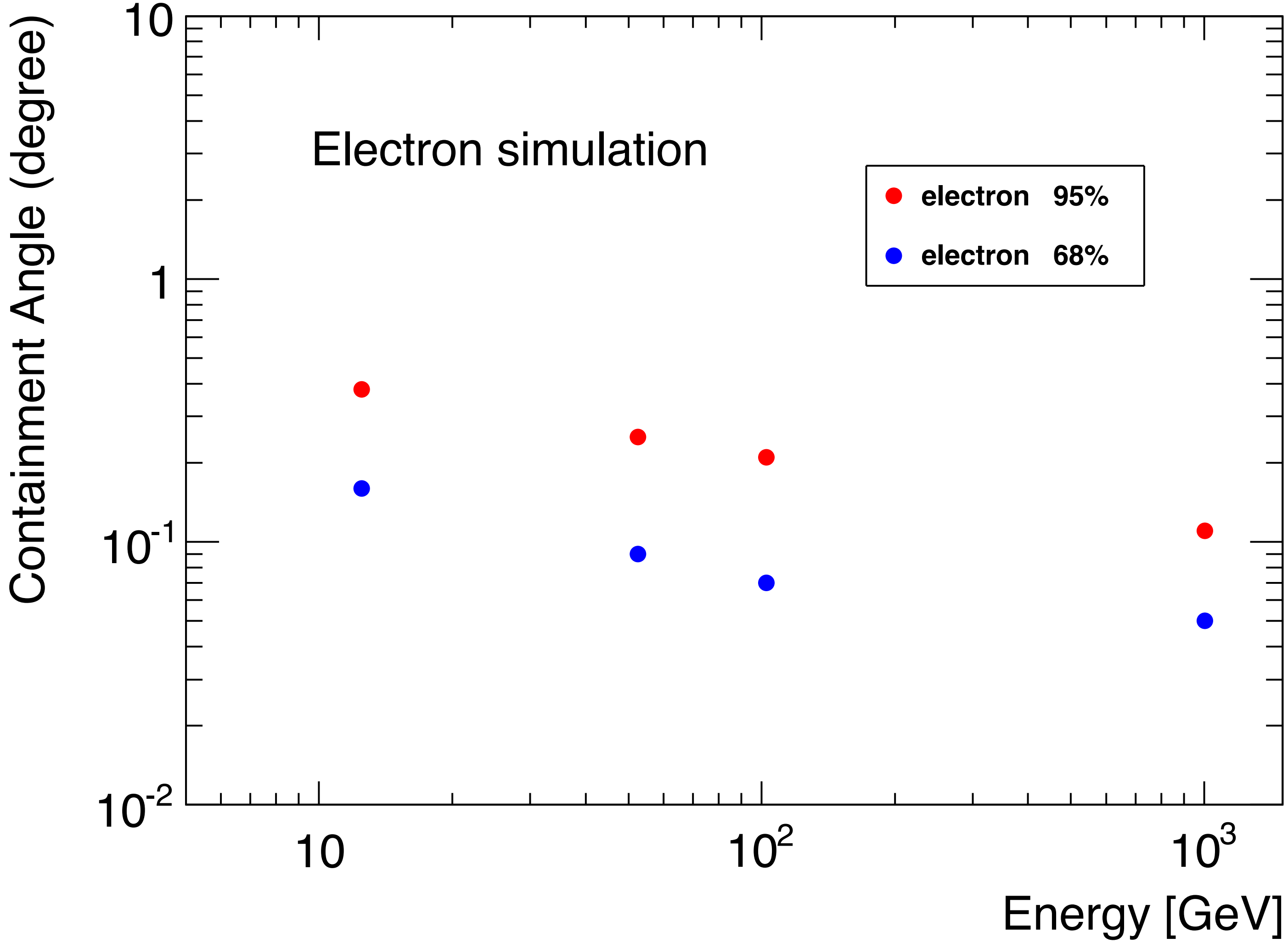


- Tracking efficiency lower at very high energy
  - Need more sophisticated track seeding
  - Use non-converting photons at high energy

Δθ of best track, photon

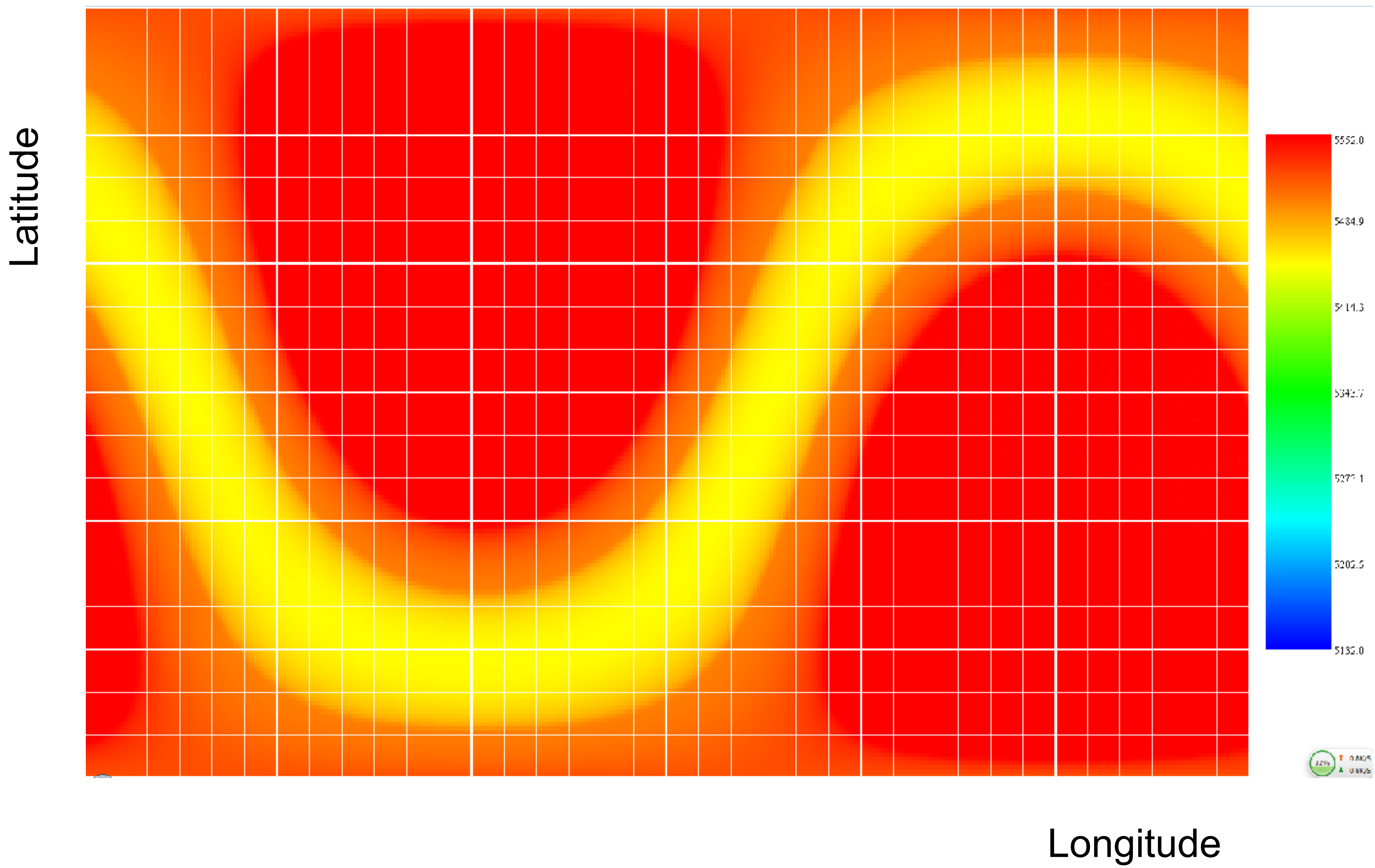


Electron Angular Resolution

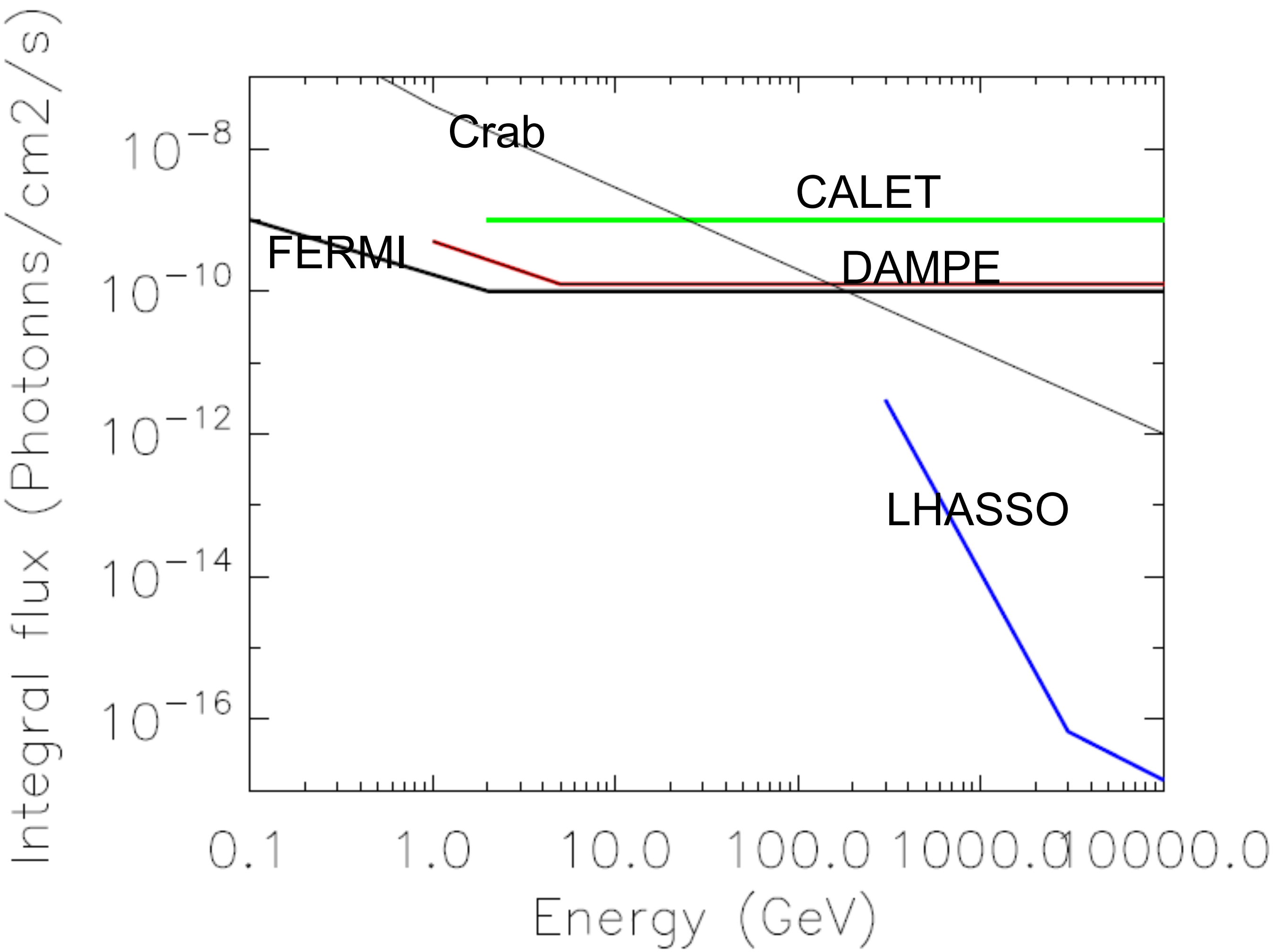


95% containment angle <0.3° for energy 10 GeV – 1 TeV

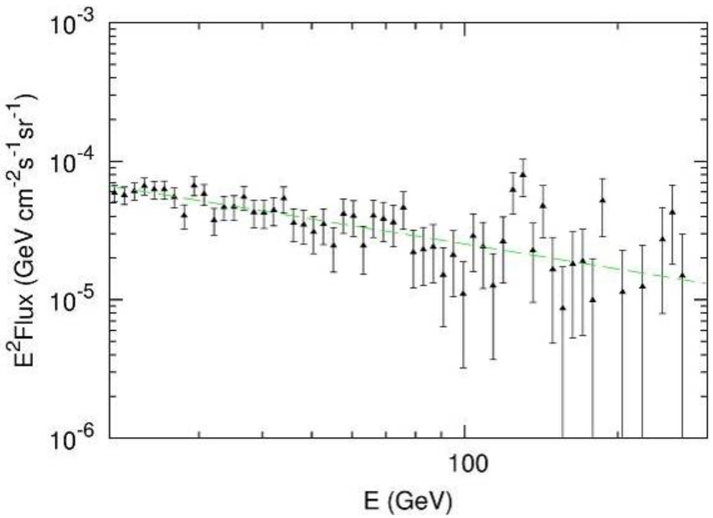
Exposure time, 1 year



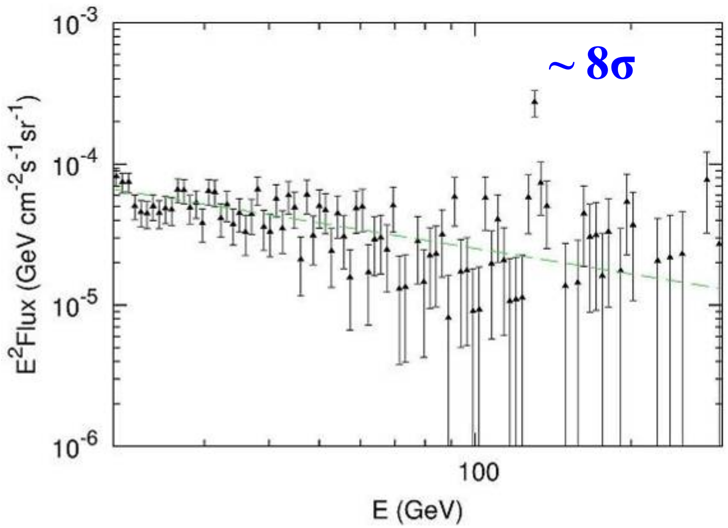
Gamma-ray Sensitivity



DAMPE for 130GeV line by FERMI

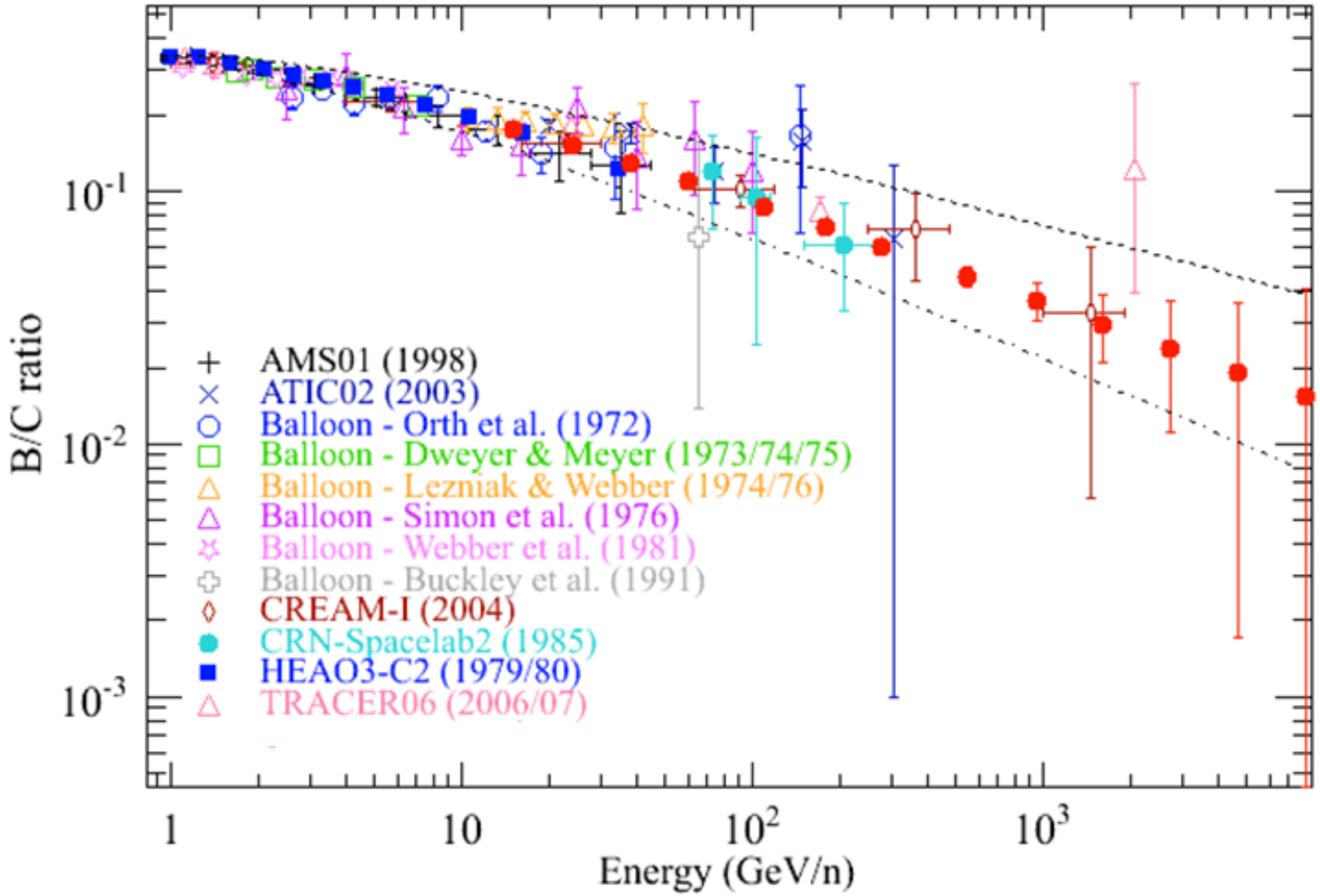


Fermi, 195 Weeks

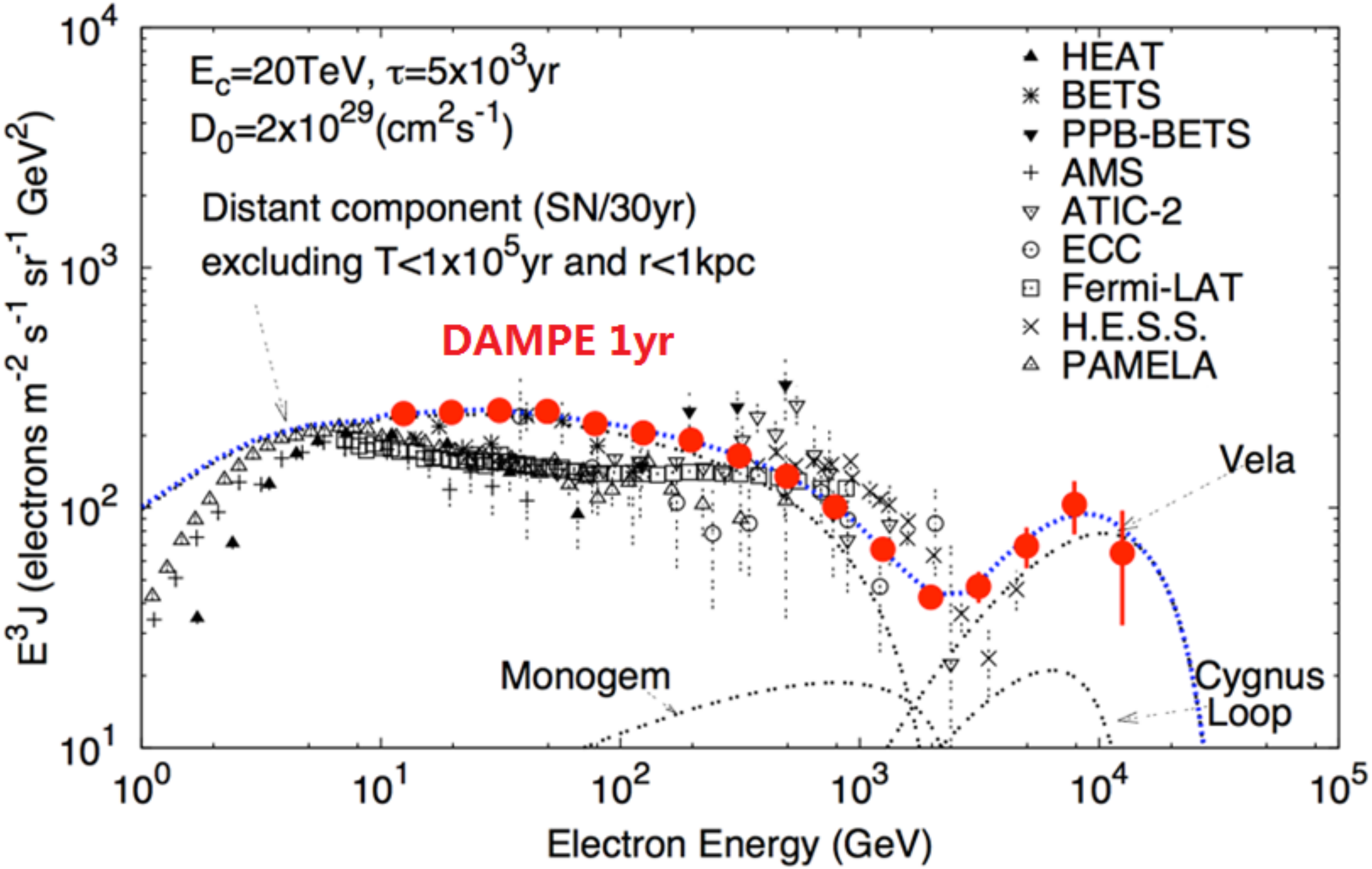


DAMPE 3 years

B/C ratio (1 year)



Expected electron spectrum (1yr) by Vela source



Expected performance for γ and e

γ performance

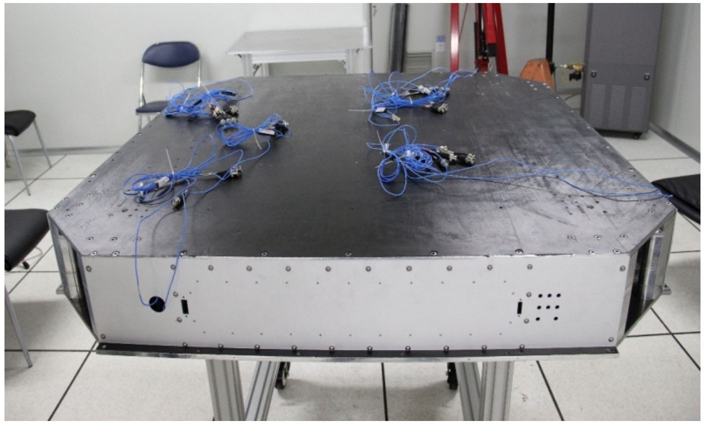
Range	2GeV-10TeV
Effective Area	3000cm2@10GeV
Field of View	2.8 sr
Geometry Factor	$0.81m^2.sr$
Energy resolution	1.5%@100GeV
Angular resolution	0.1^{O}@10GeV%
Point source Sensitivity	$8.5X10^{-11}cm^{-2}s^{-1}$

e performance

Range	2GeV-10TeV
Geometry Factor	$0.3m^2.sr$
Energy resolution	1.5%@100GeV
Angular resolution	0.1^{O}@10GeV%
Proton Rejection	10^5
Gamma seepartion	100

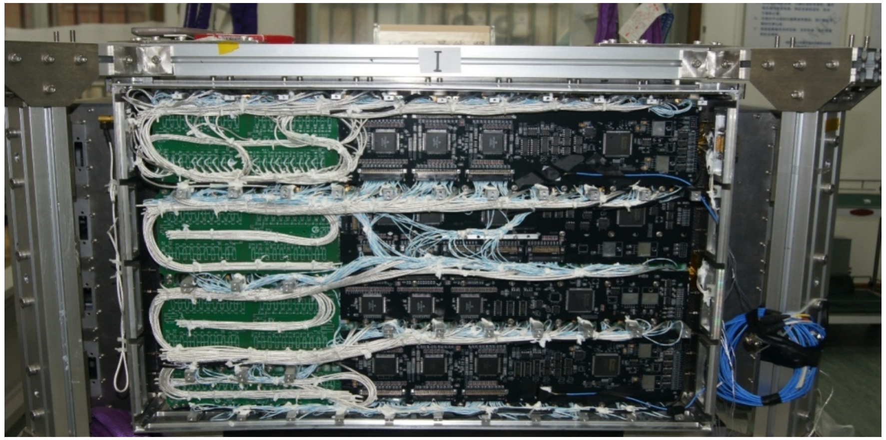
Detectors status

Plastic
Hodoscope

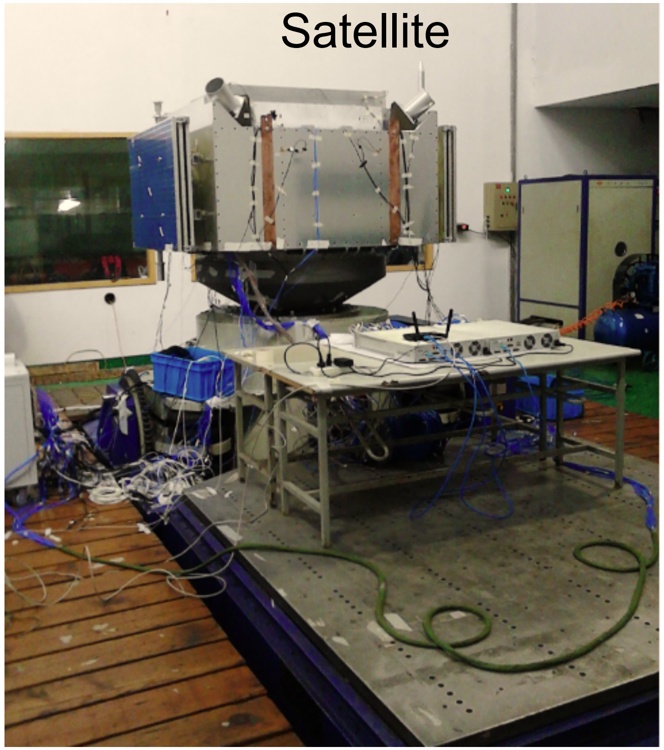


Neutron Detector

BGO Cal.



Satellite



Conclusion

- DAMPE is a powerful space telescope for high energy electron, γ-ray, and cosmic rays
  - The combination of a thick total absorption calorimeter with a Si-W tracker provide excellent energy resolution, angular resolution and particle identification in the 10 GeV to multi-TeV range
  - Above multi-TeV pattern recognition is challenging for the tracker, but the calorimeter provides competitive angular resolution at these high energies
- Hardware construction is in good progress, a full STK EQM test is planned in mid 2014
- DAMPE launch in late 2015

谢谢!