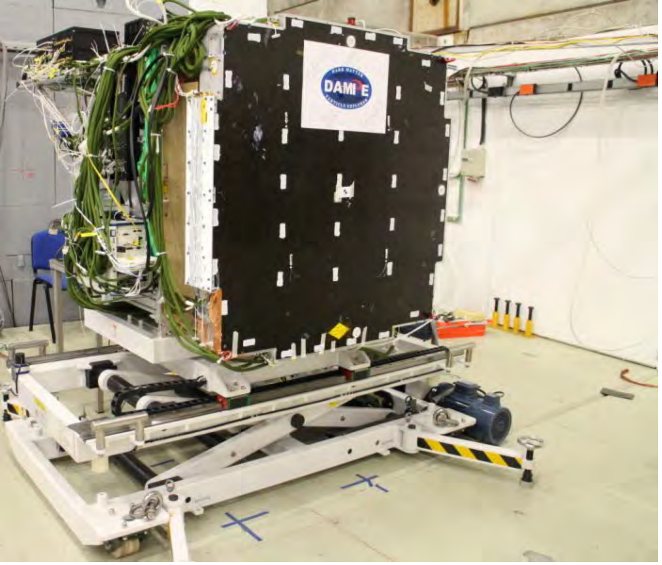


DAMPE (and HERD)

Ivan De Mitri
Università del Salento and INFN, Lecce, Italy

(on behalf of DAMPE and HERD collaborations)

The Future Research on Cosmic Gamma Rays
August 26-29, 2015
La Palma

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
  - INFN and University of Lecce

The DAMPE physics goals

- **High energy particle detection in space**
  - **Study of the cosmic e, γ spectra and Search for DM signatures**
  - **Study of cosmic ray (nuclei) spectrum and composition**
  - **High energy gamma ray astronomy**

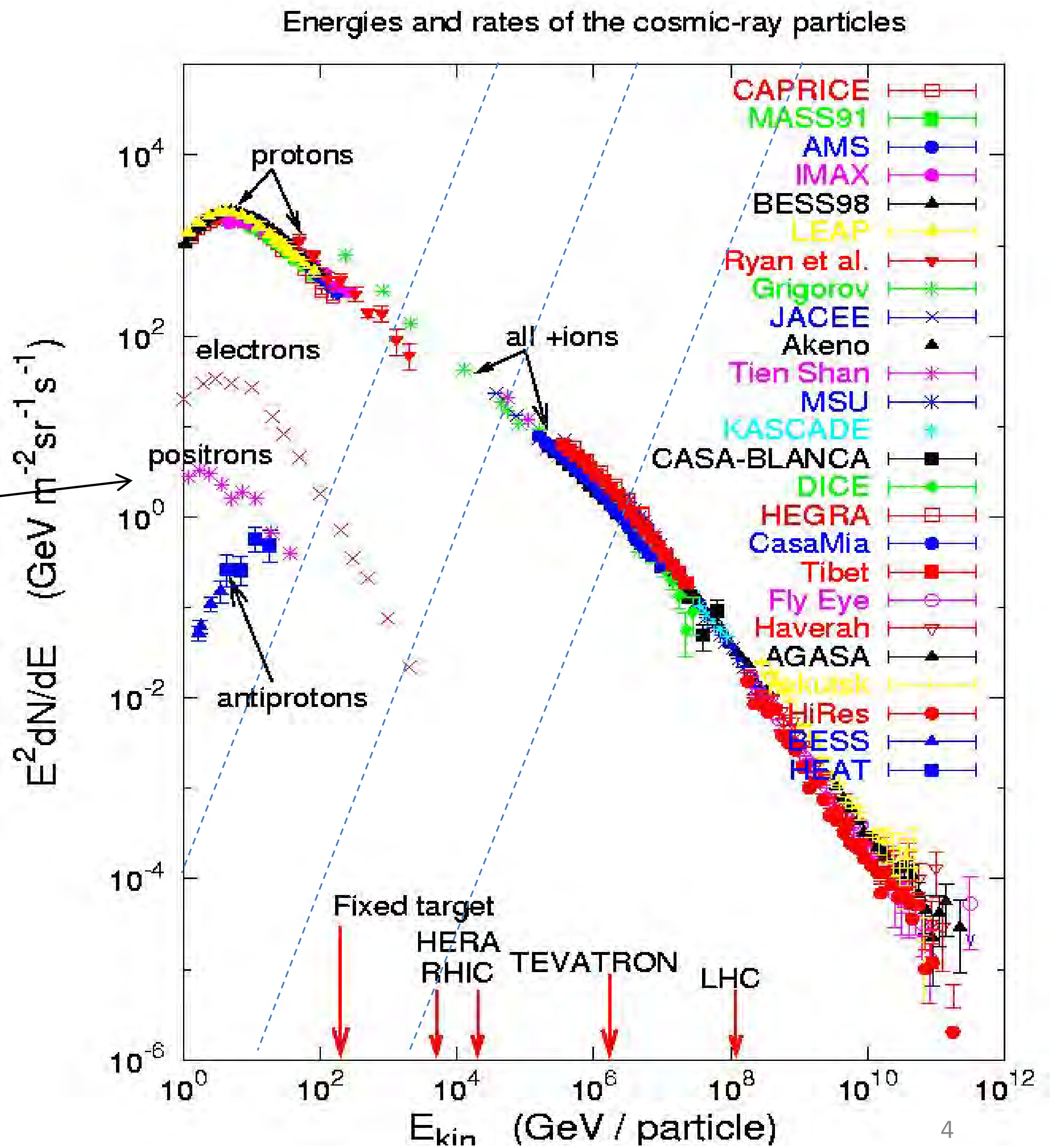
Detection of 10 GeV - 10 TeV e/γ, 100 GeV - 500 TeV CR
Excellent energy resolution and tracking precision
Complementary to Fermi, AMS-02, CALET, ISS-CREAM, …

- **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 beam !

(charged particles)

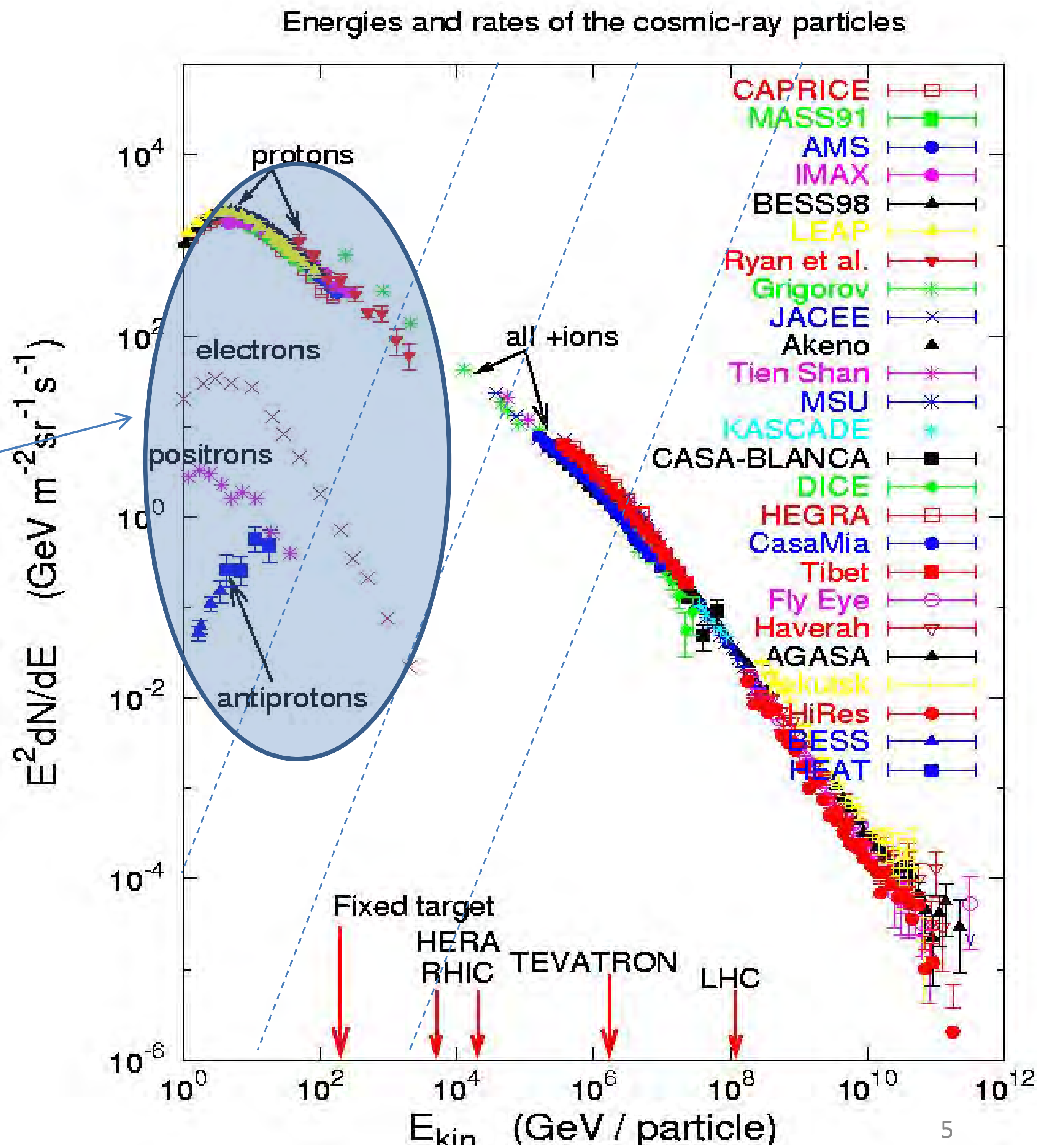
A few years-old scenario



The beam !

(charged particles)

Now measurements by:
PAMELA
CREAM
ATIC
FERMI
AMS-02

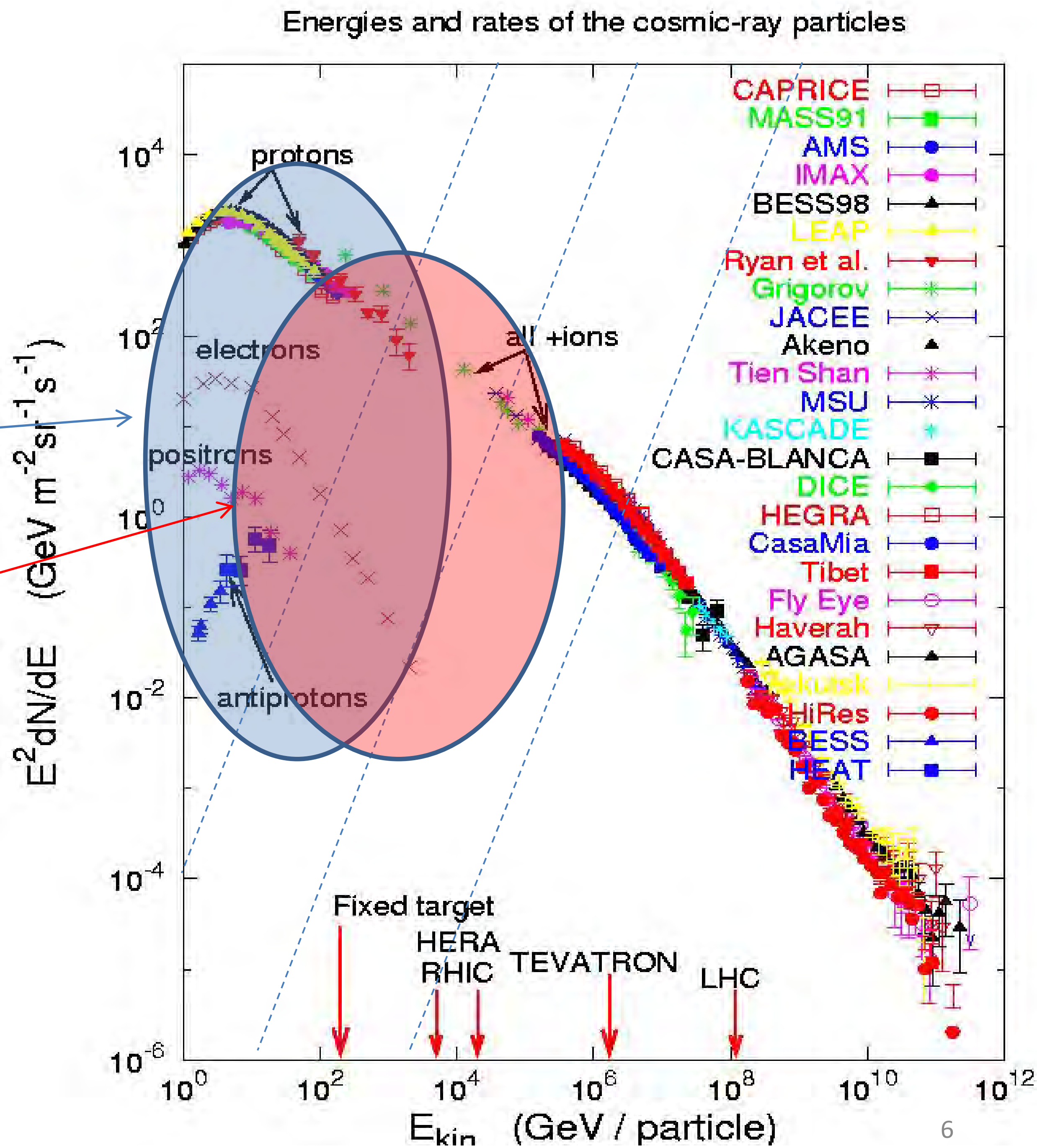


The beam !

(charged particles)

PAMELA
CREAM
ATIC
FERMI
AMS-02

DAMPE



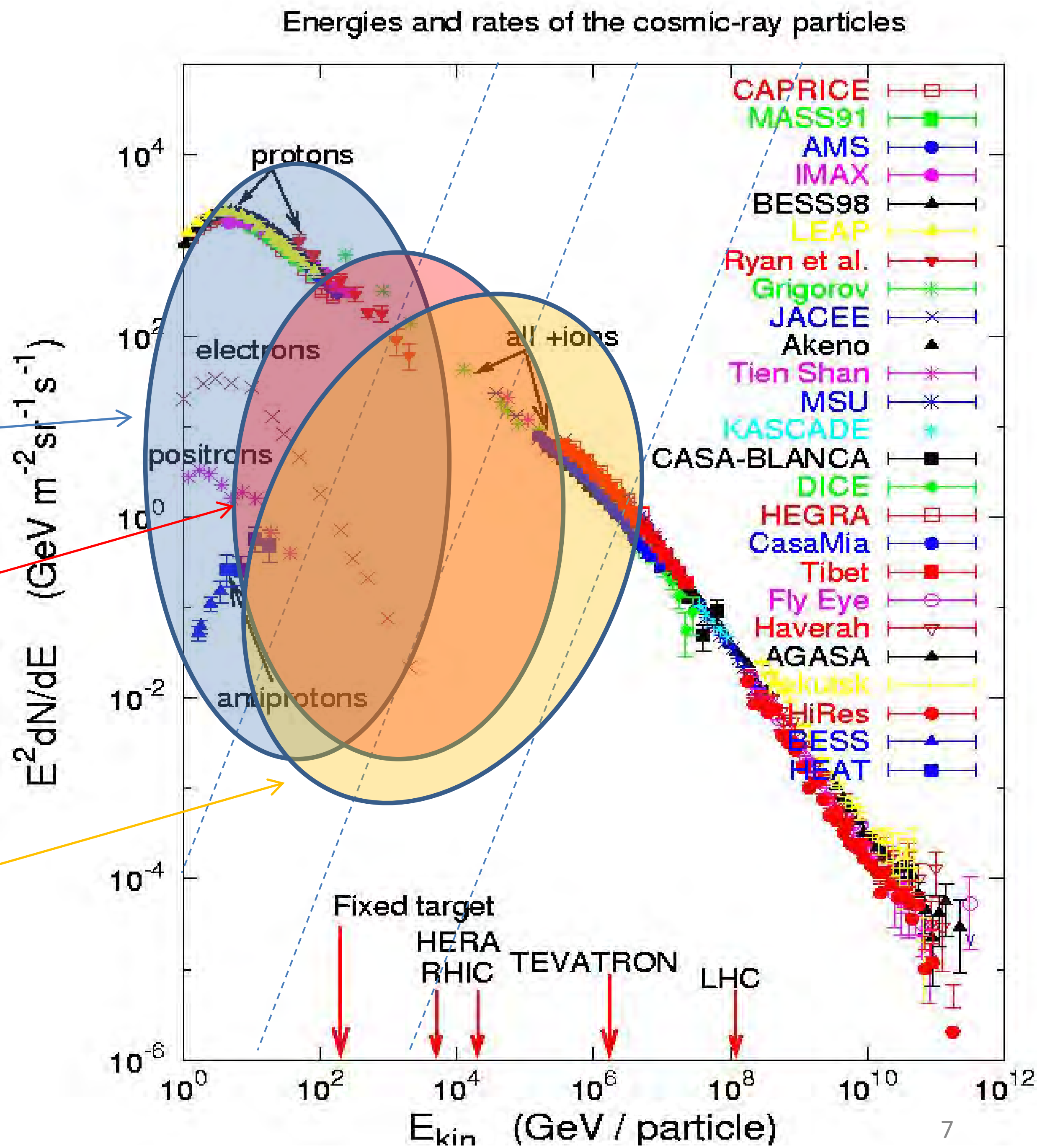
The beam !

(charged particles)

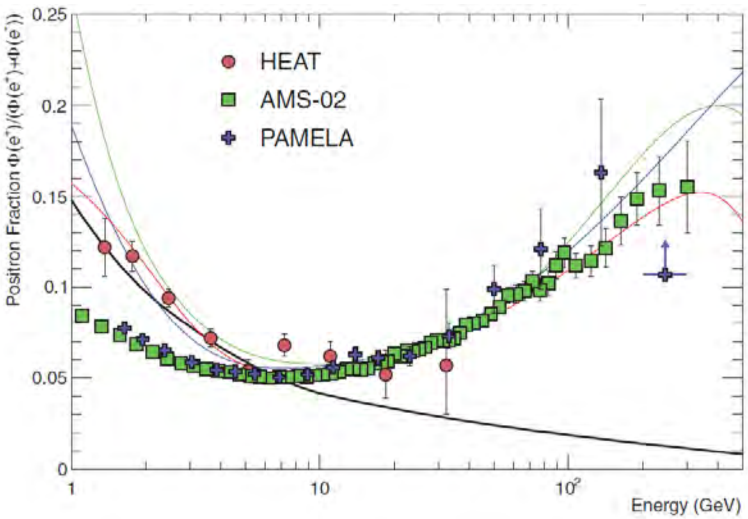
PAMELA
CREAM
ATIC
FERMI
AMS-02

DAMPE

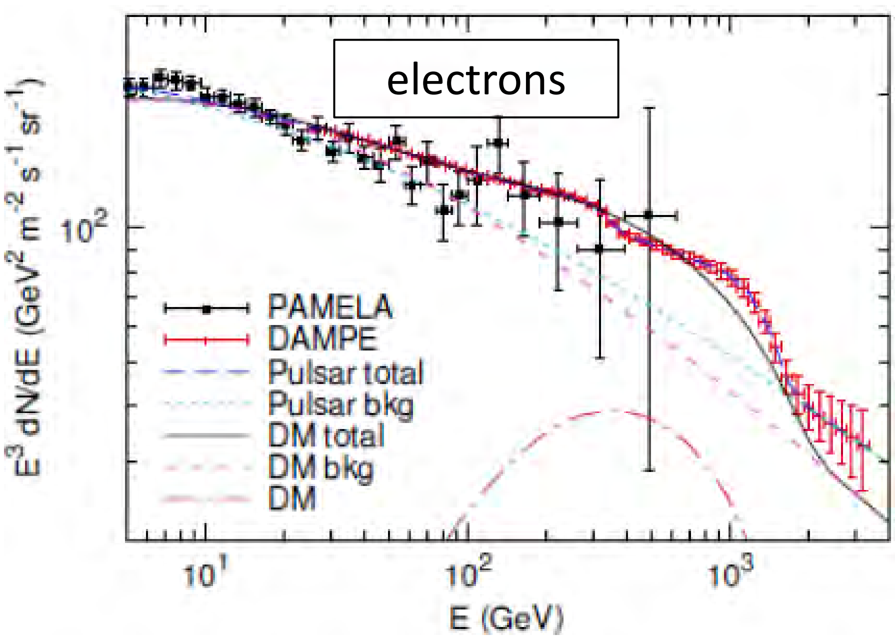
HERD

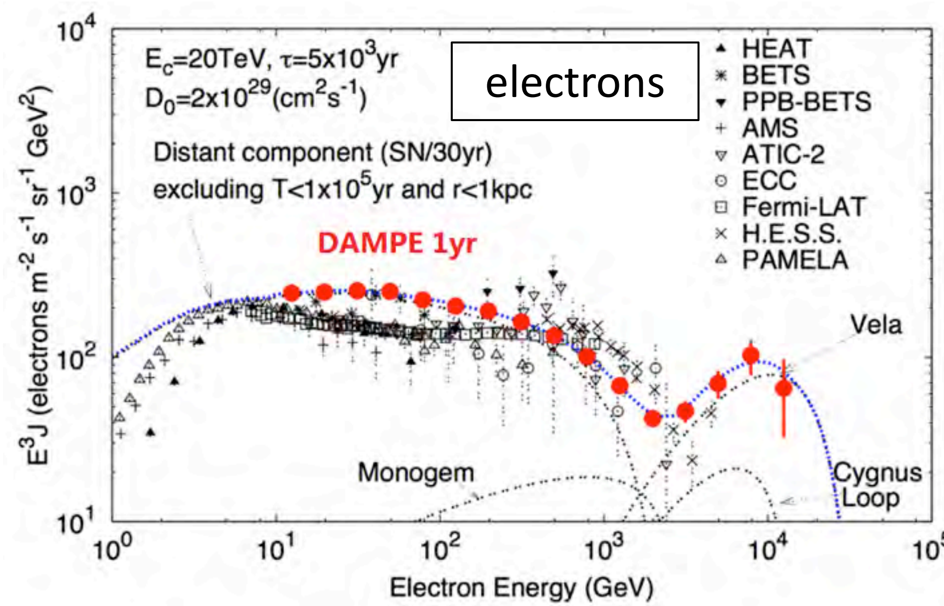


Electrons: Dark Matter vs Nearby Sources

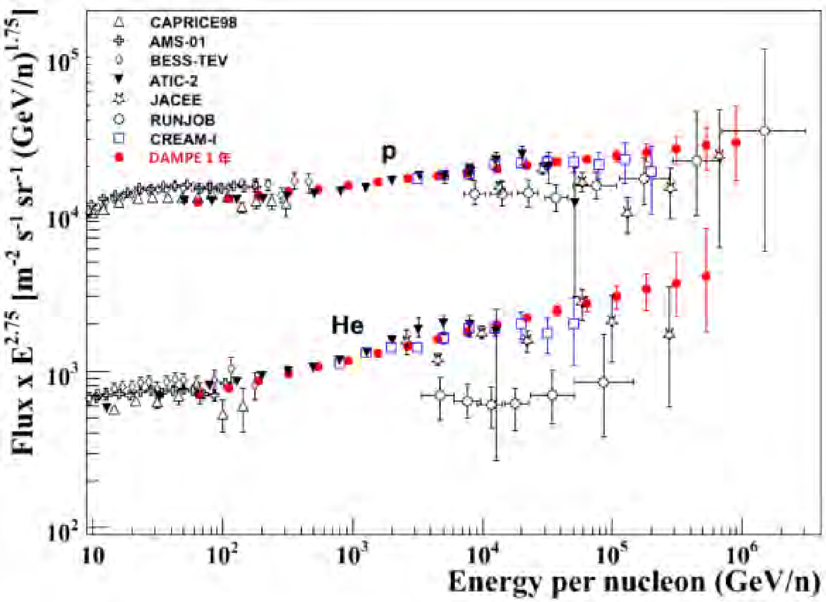


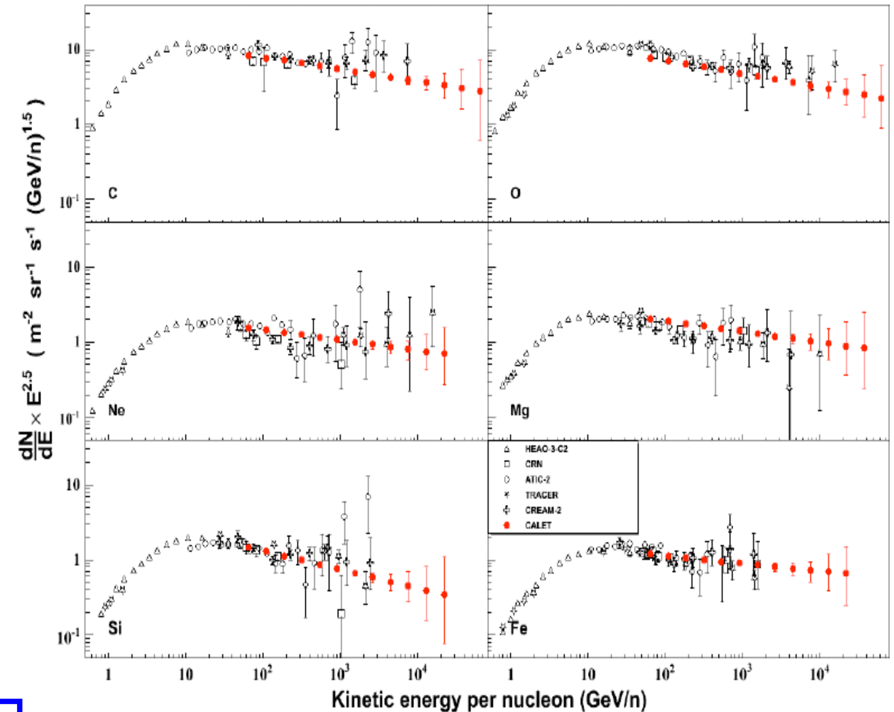
Need a detector in space that can detect electrons well above 1 TeV with very good energy resolution





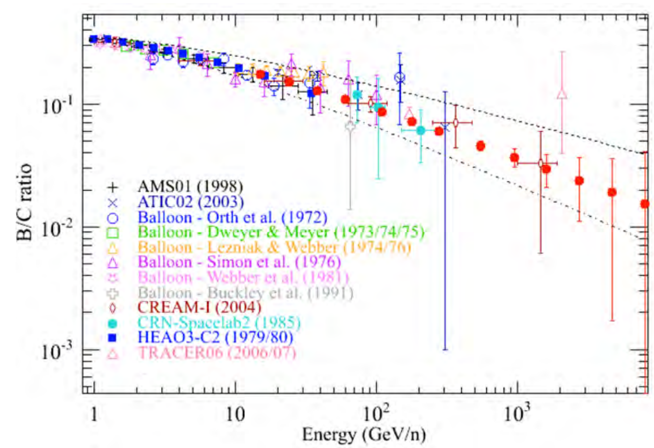
Nuclei: CR Spectra & Composition toward the knee(s)



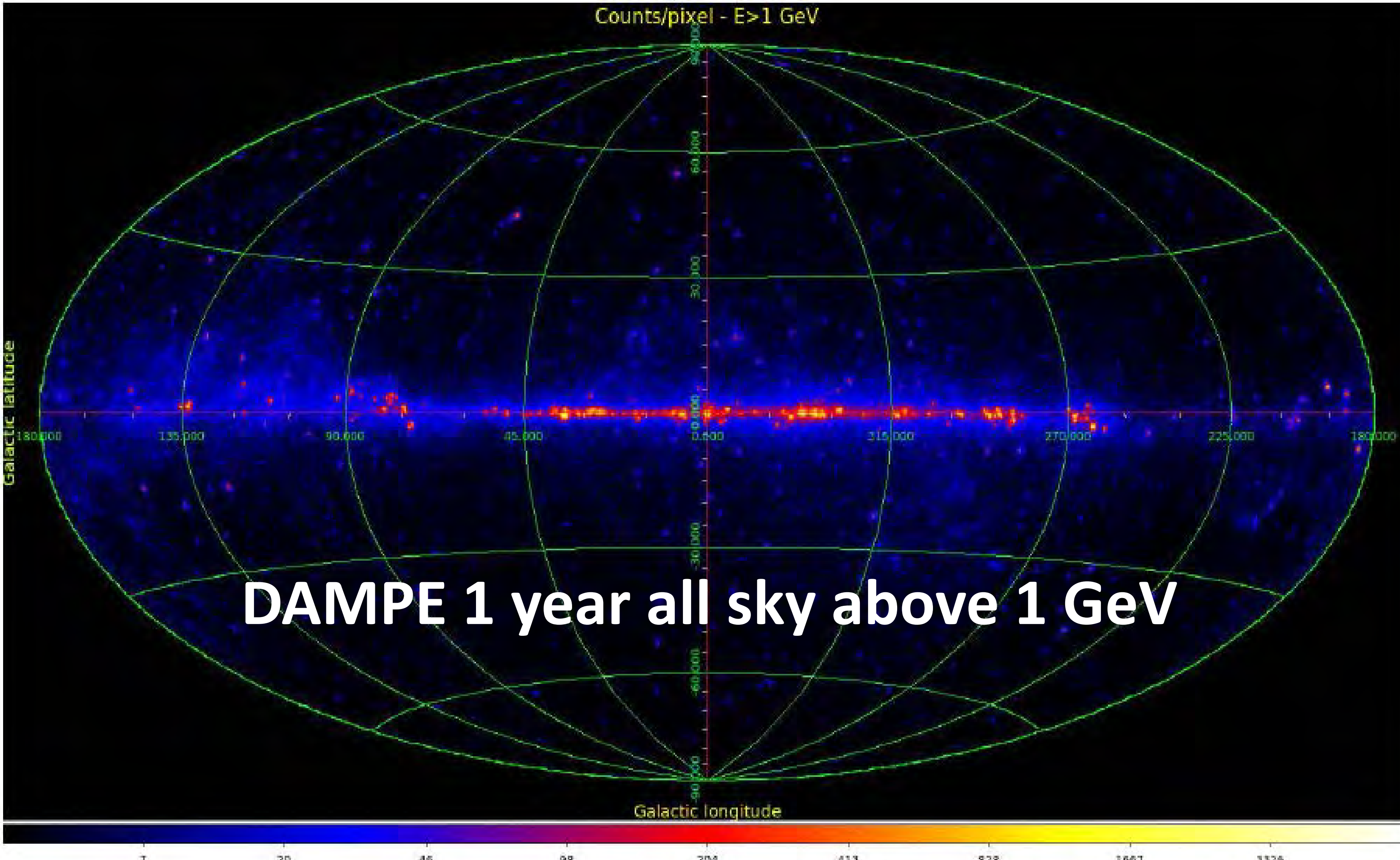


Proton spectrum to	**≈ 900 TeV**
He spectrum to	**≈ 400 TeV/n**
Spectra of C, O, Ne, Mg, Si to	**≈ 20 TeV/n**
B/C ratio to	**≈ 4-6 TeV/n**
Fe spectrum to	**≈ 10 TeV/n**

(Depending on the assumed single primary spectra)

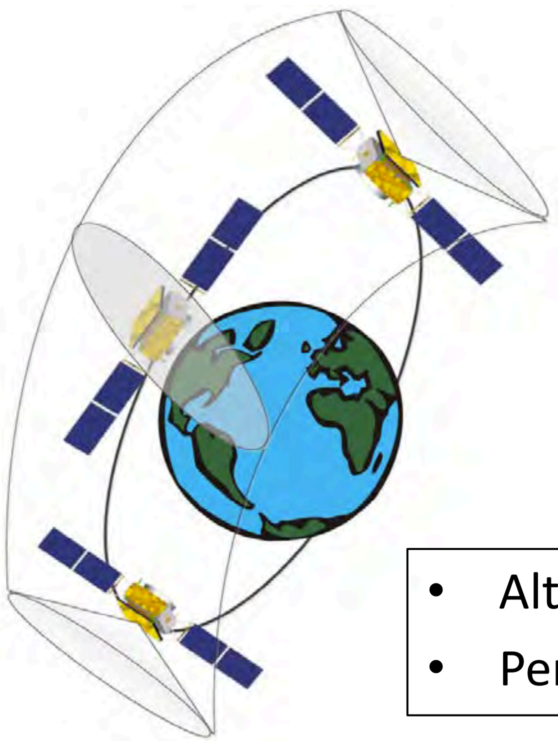


Photons: spectral features (DM) and astronomy



DAMPE in space

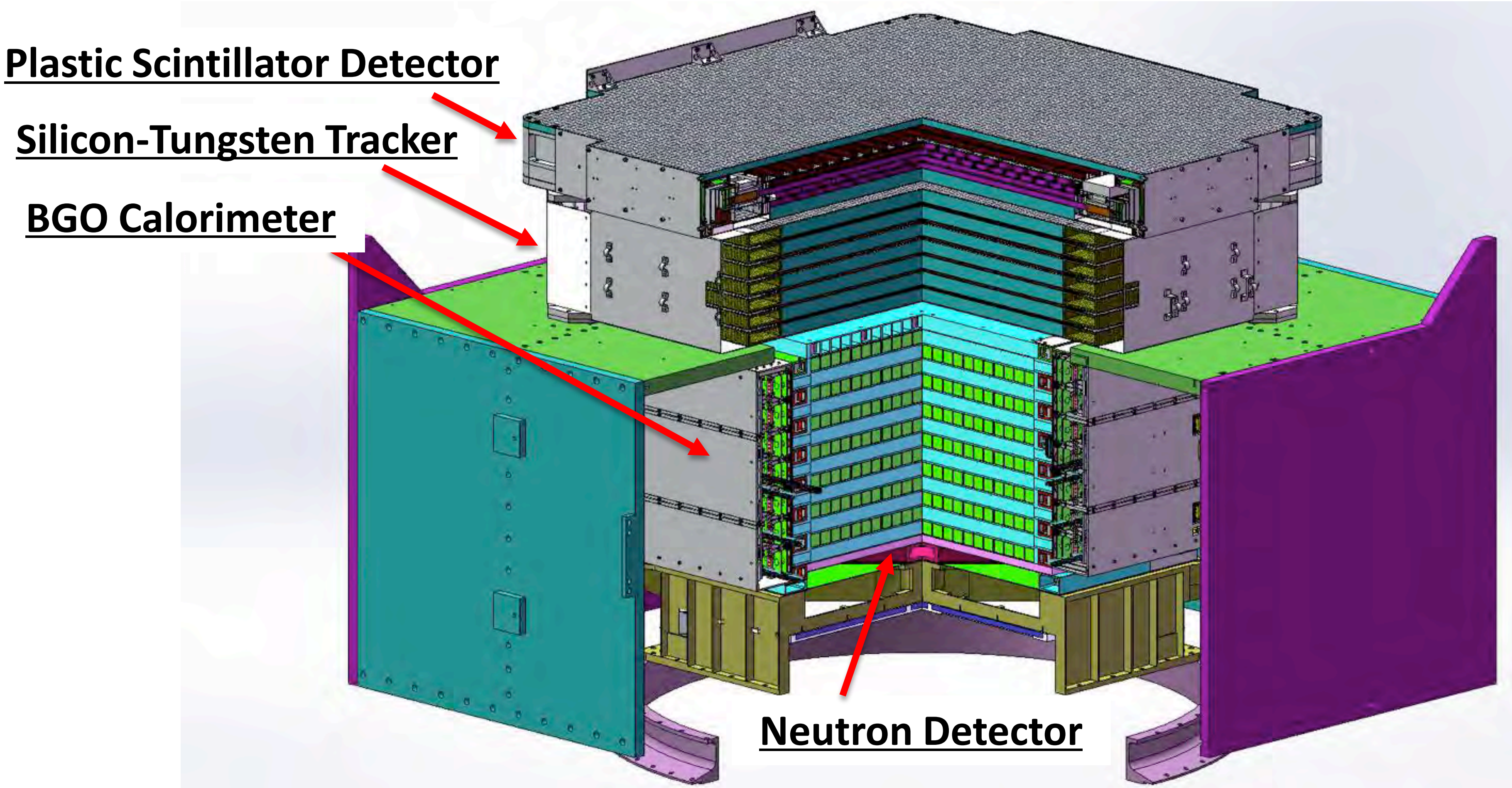
- One of the 5 satellite missions of the Strategic Priority Research Program in Space Science of CAS
  - Approved for construction (phase C/D) in Dec. 2011
  - Scheduled launch date **December 18, 2015**



- Satellite < 1900 kg, payload ~1340kg
- Power consumption 640W (400 W)
- Lifetime > 3 years
- Launched by CZ-2D rockets

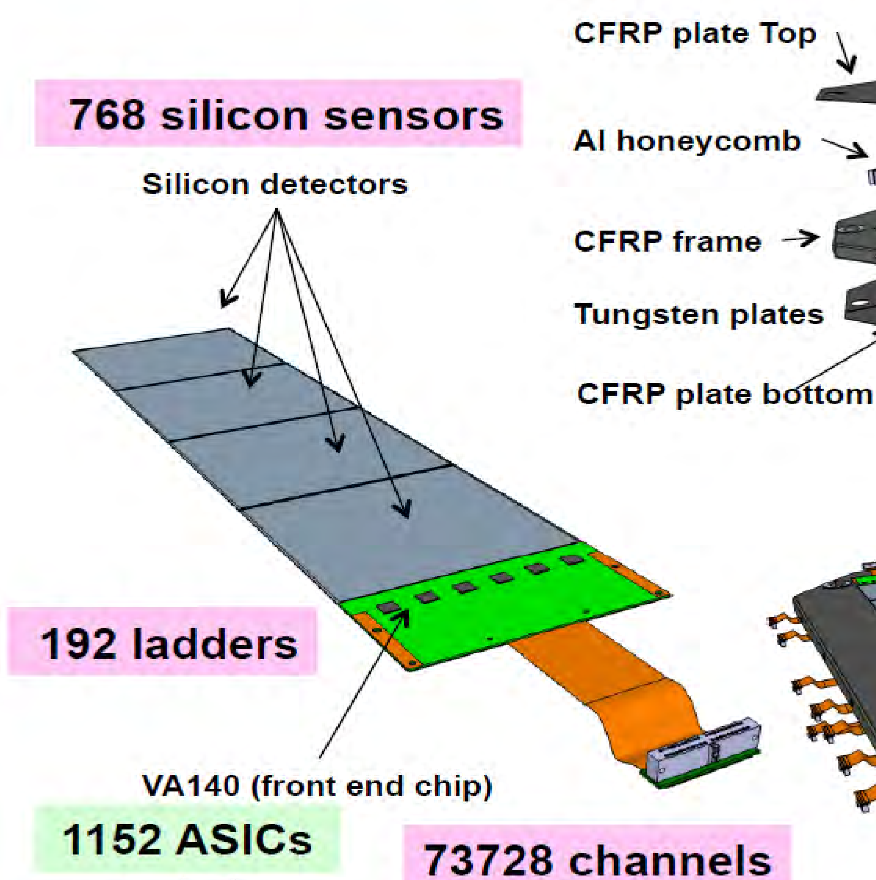
- Altitude 500 km
- Period 90 minutes

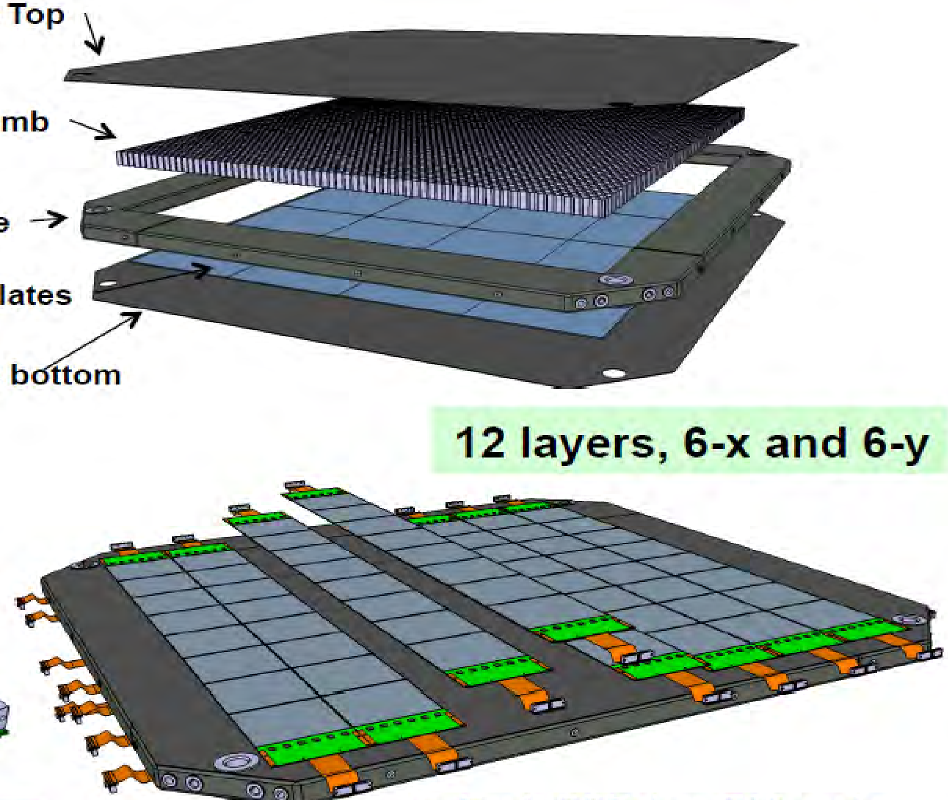
The DAMPE Detector



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

The STK detector



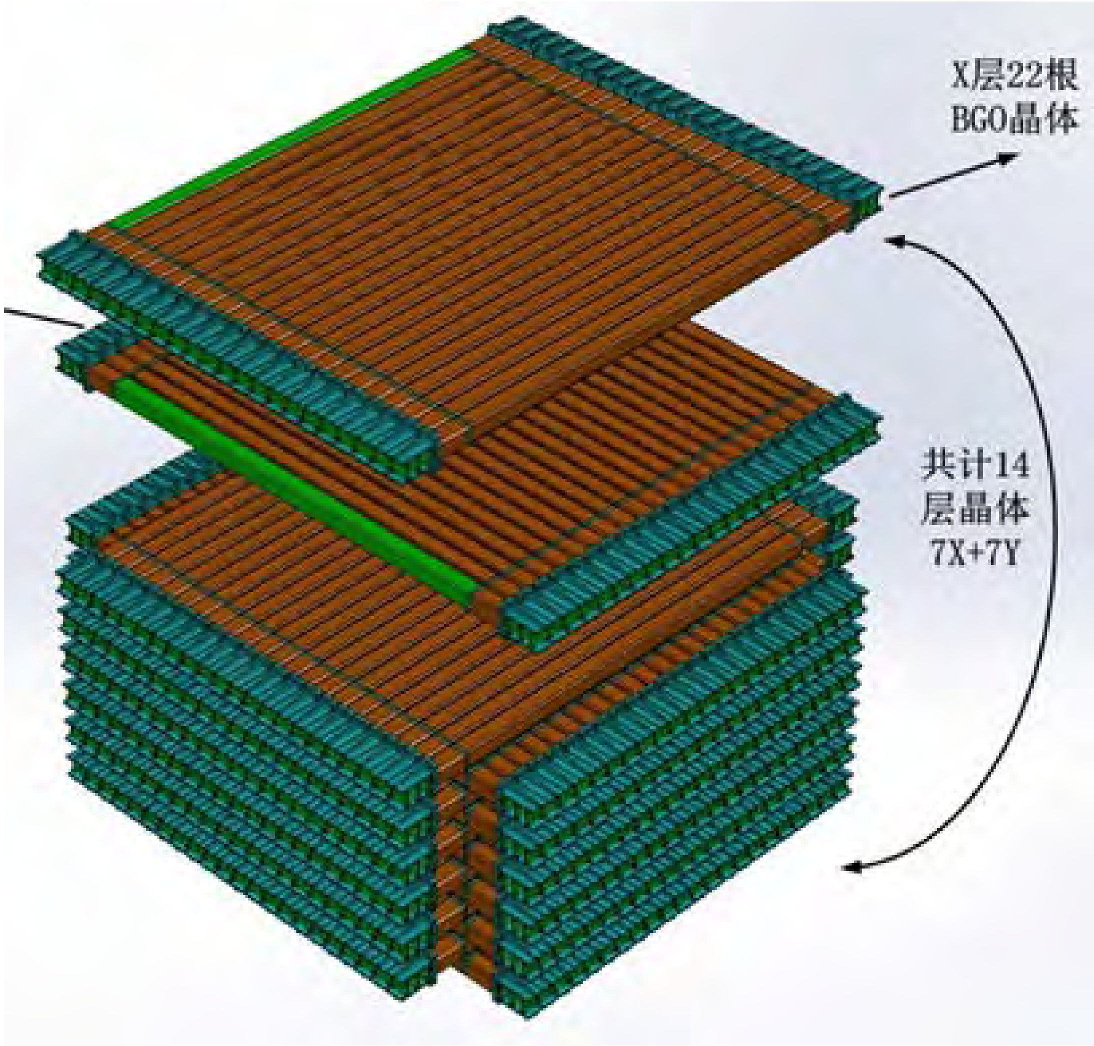


Each ladder is composed by 4 $95 \times 95 \times 0.320$ mm^3 *Silicon Strips Detectors* (SSD).

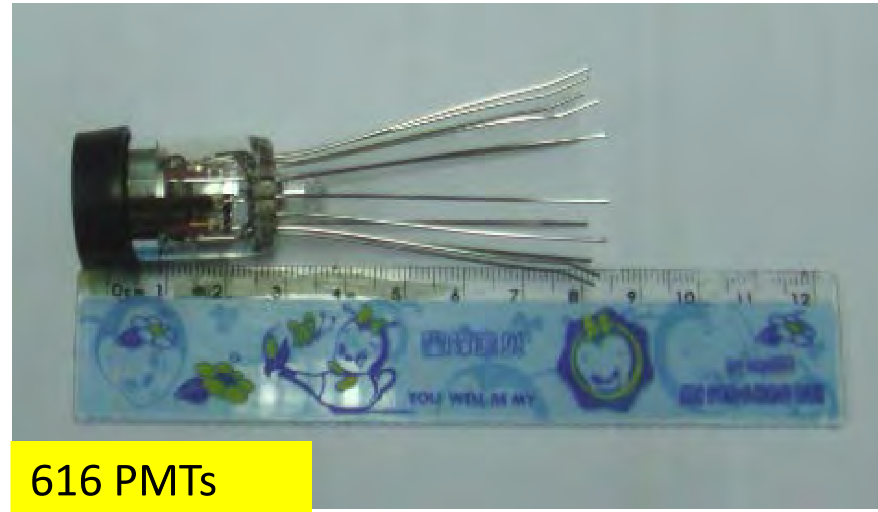
- Each SSD has 768 *strips* (width 48 μm);
- distance between two strips 121 μm;
- 1 over 2 strips is readout (384 channels):a correction on the signal collected must be applied $\Rightarrow$ charge sharing

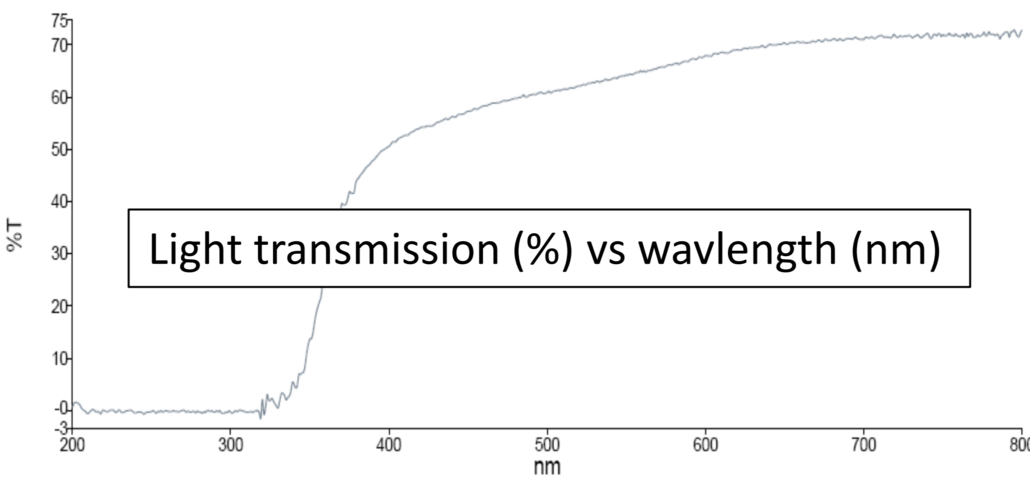
3D Imaging BGO Calorimeter

- 14 layers of 22 BGO crystals
  - Dimension of BGO bar: $2.5 \times 2.5 \times 60\text{cm}^3$
  - Hodoscopic stacking alternating orthogonal layers
  - depth ~$32X_0$
- Two PMTs coupled with each BGO crystal bar in two ends
- Electronics boards attached to each side of module

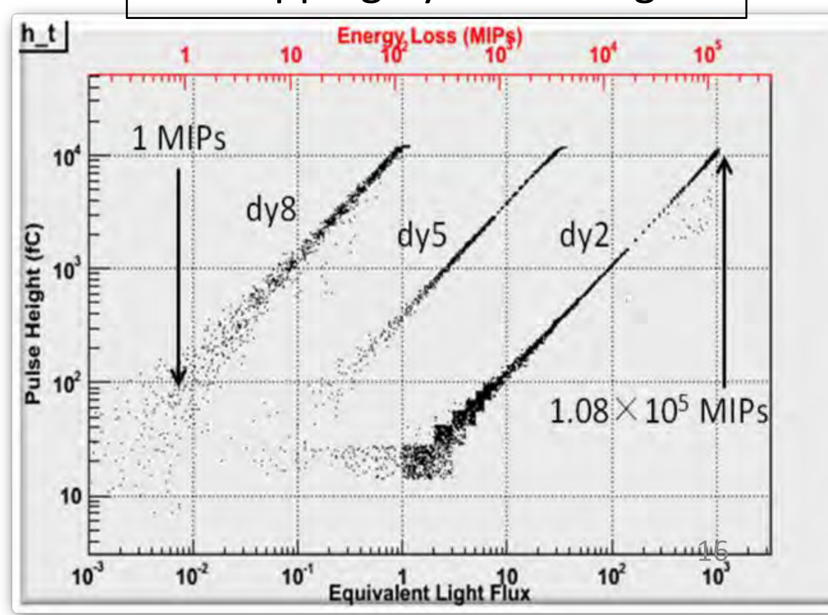


3D Imaging BGO Calorimeter



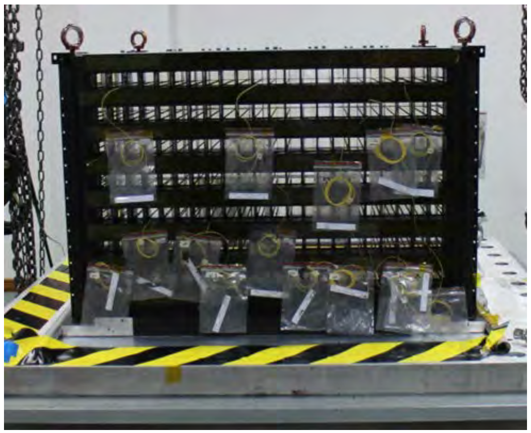


Overlapping dynamic ranges



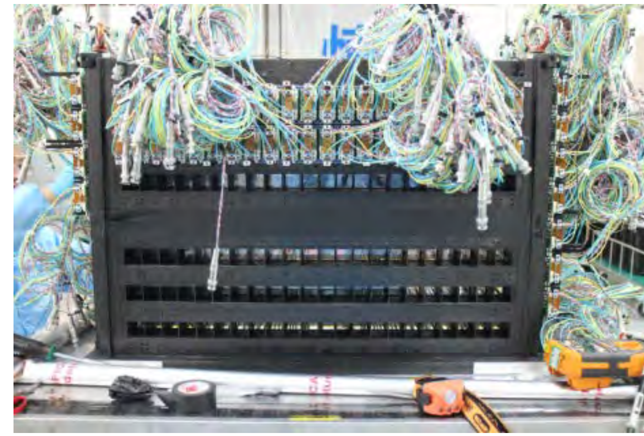
3D Imaging BGO Calorimeter

Assembly

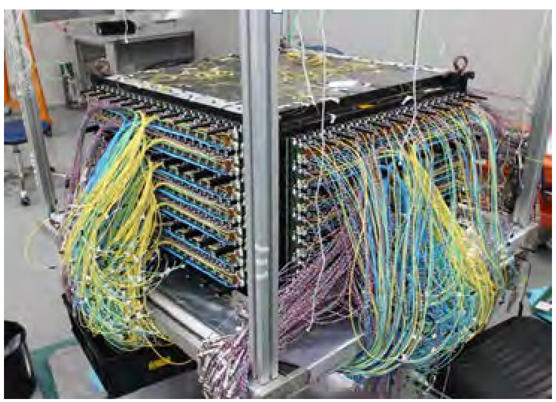


Carbon Fiber Structure

BGO crystal installation



PMT installation



Cable arranging

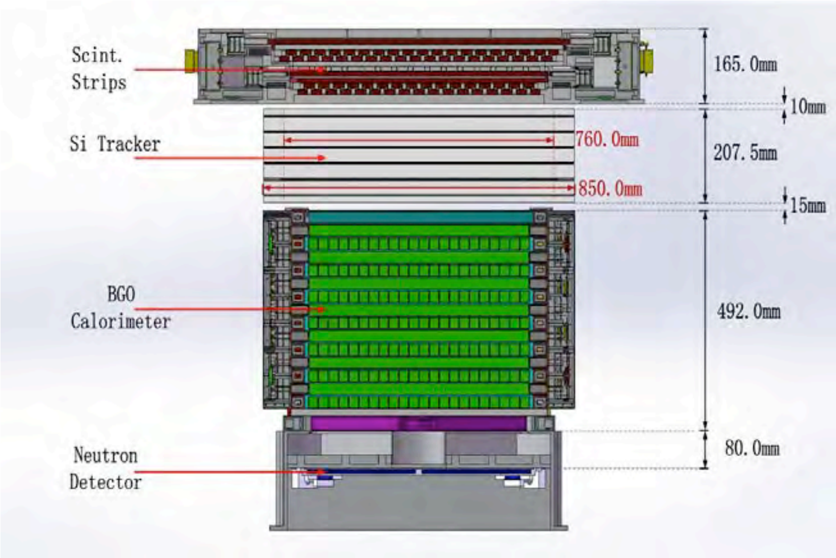
Cable connector

BGO Cal

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**



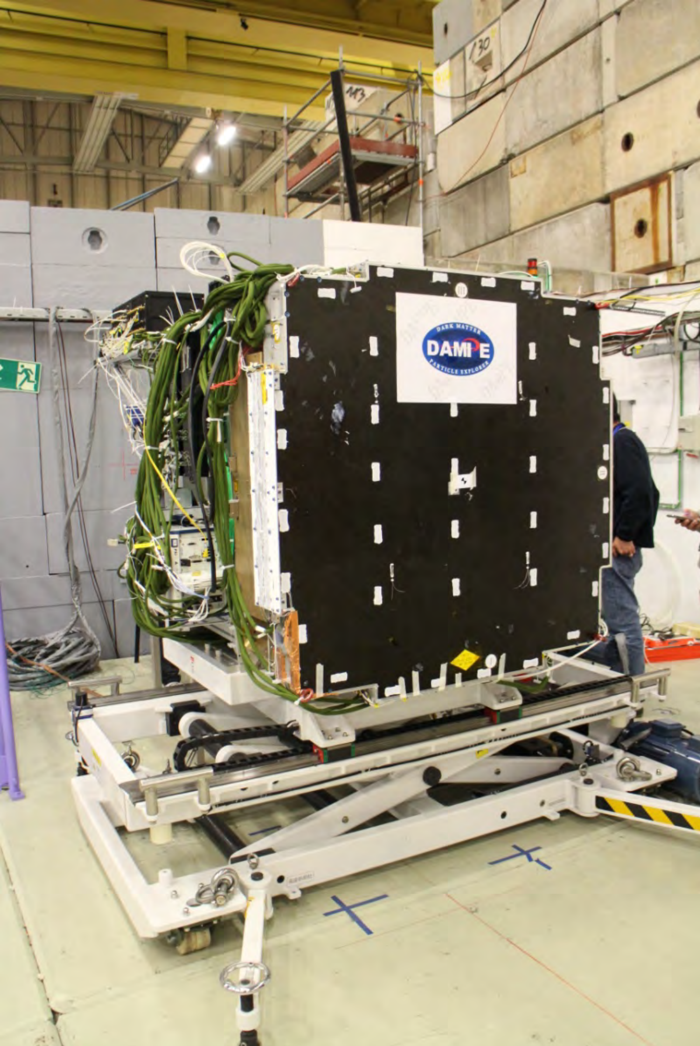
Test beam activity at CERN (nov '14 - nov'15)

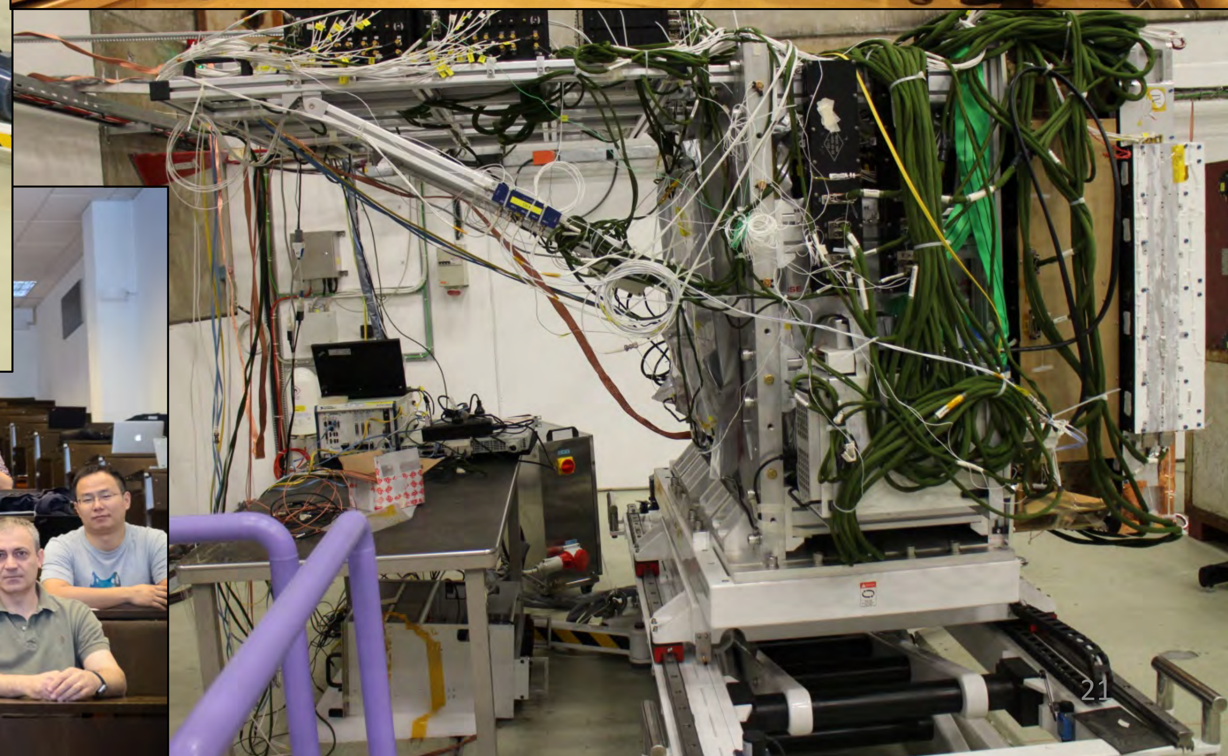
- **14days@PS，29/10-11/11 2014**
  - e @ 0.5GeV/c, 1GeV/c, 2GeV/c, 3GeV/c, 4GeV/c, 5GeV/c
  - p @ 3.5GeV/c, 4GeV/c, 5GeV/c, 6GeV/c, 8GeV/c, 10GeV/c
  - π-@ 3GeV/c, 10GeV/c
  - γ @ 0.5-3GeV/c
- **8days@SPS，12/11-19/11 2014**
  - e @ 5GeV/c, 10GeV/c, 20GeV/c, 50GeV/c, 100GeV/c, 150GeV/c, 200GeV/c, 250GeV/c
  - p @ 400GeV/c (SPS primary beam)
  - γ @ 3-20GeV/c
  - μ @ 150GeV/c,
- **17days@SPS，16/3-1/4 2015**
  - Fragments：66.67-88.89-166.67GeV/c
  - Argon：30A- 40A- 75AGeV/c
  - Proton：30GeV/c，40GeV/c
- **21days@SPS，10/6-1/7 2015**
  - Primary Proton: 400GeV/c
  - Electrons @ 20, 100, 150 GeV/c
  - γ @ 50, 75 , 150 GeV/c
  - μ @ 150 GeV /c
  - π+ @10, 20, 50, 100 GeV/c
- **10days@SPS, 11/11-20/11 2015**
  -- Pb 30AGeV/c (and fragments) (HERD)
- **6days@SPS, 20/11-25/11 2015**
  -- Pb 030 AGeV/c (and fragments)

CERN recognized experiment

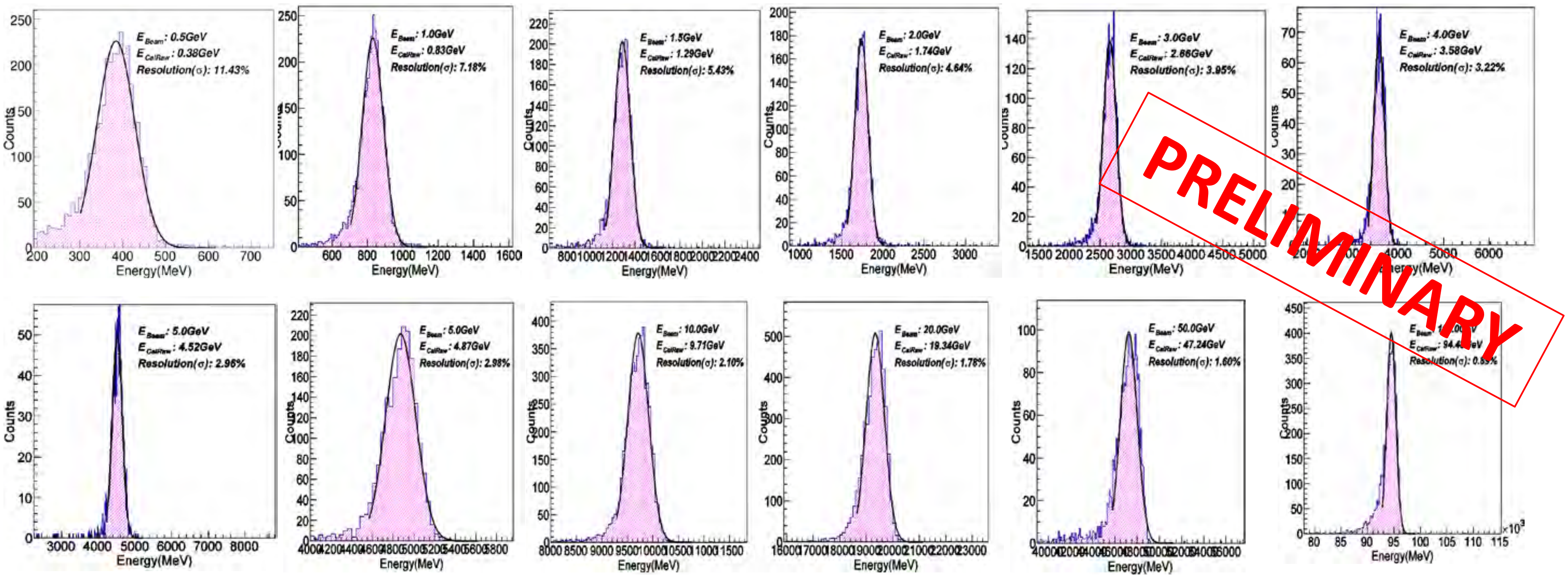
RE29 : DAMPE

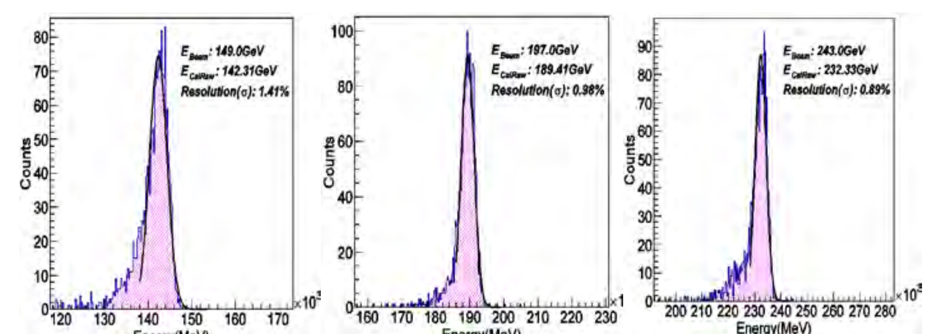
9 Institutions,   55 Participants

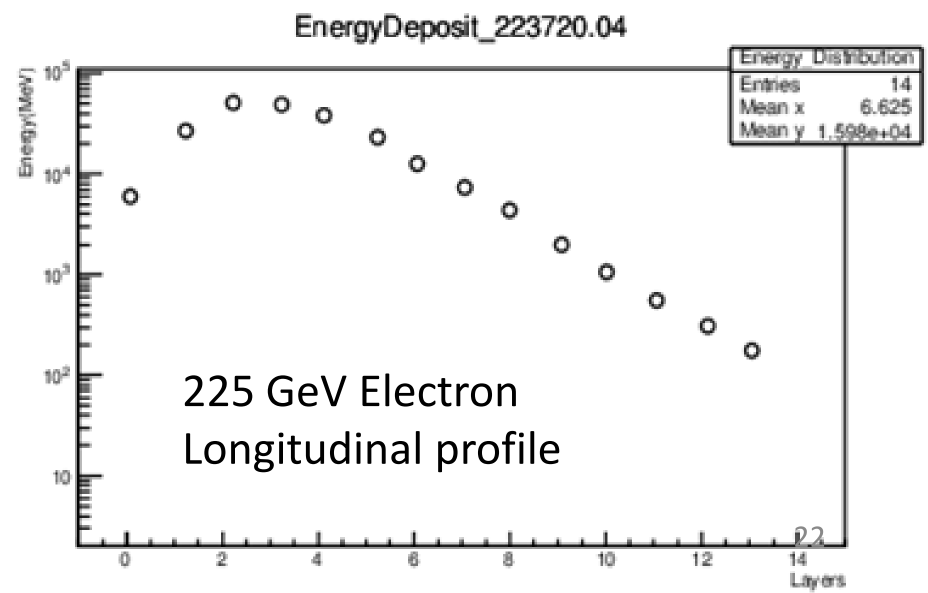




Electron Energy Reconstruction







0.5, 1, 1.5, 2, 3, 4, 5 GeV @ PS

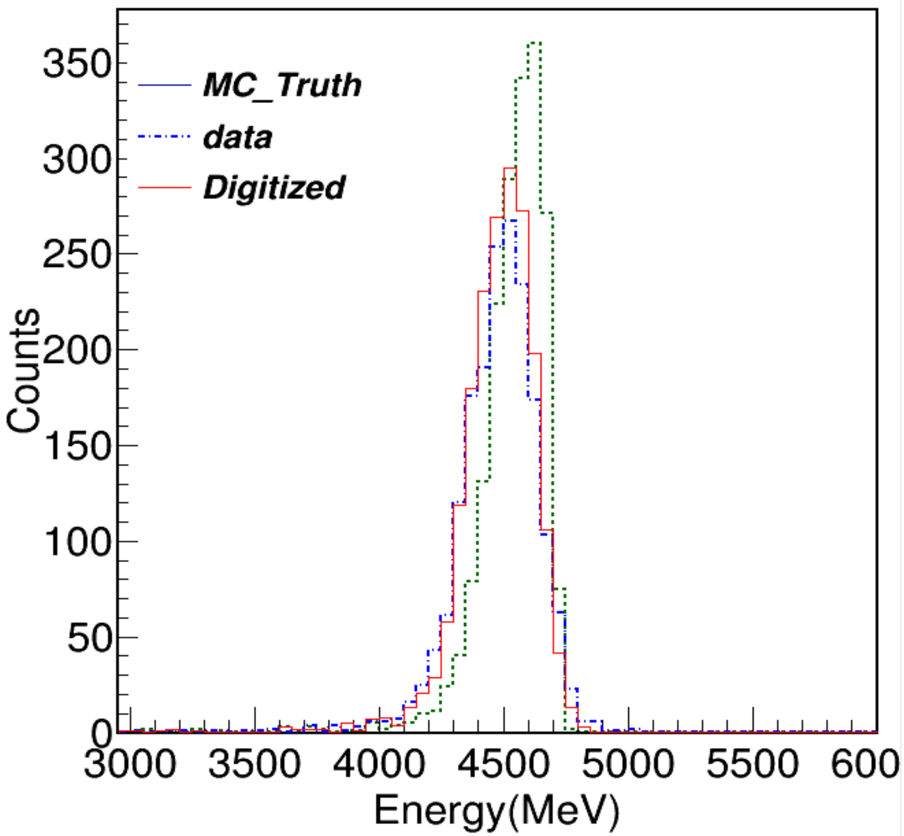
5, 10, 20, 50, 100, 149, 197, 243 GeV @ SPS

Electron Energy Reconstruction

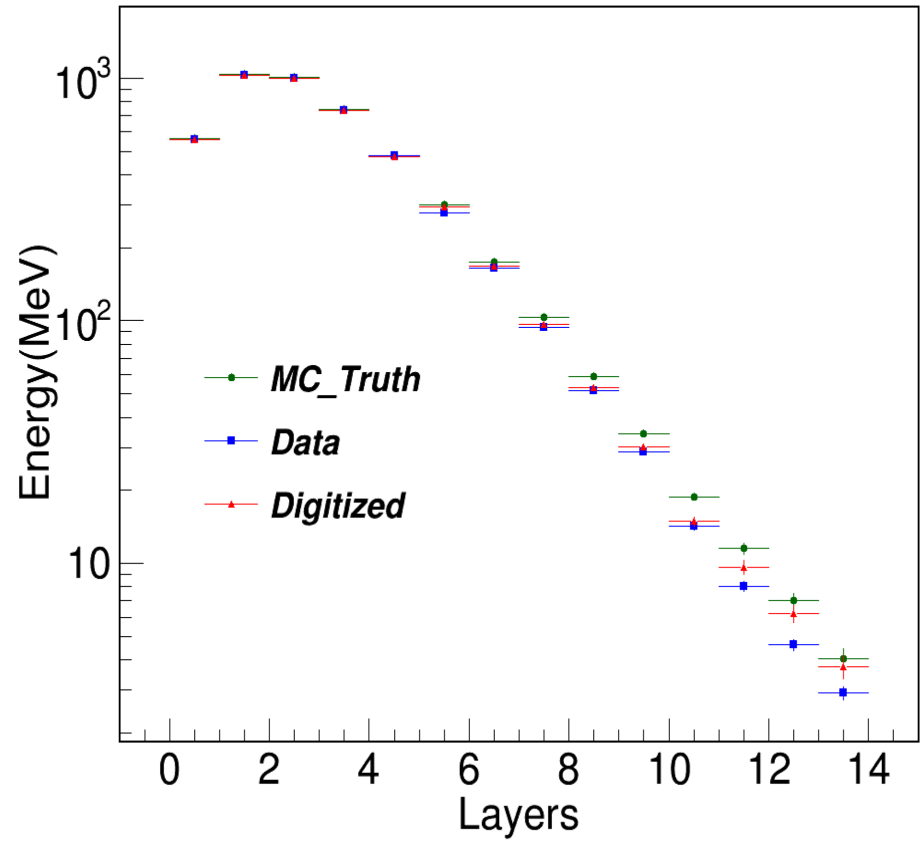
PRELIMINARY

5 GeV electron (simulation & test beam data)

Energy spectra（5GeV）

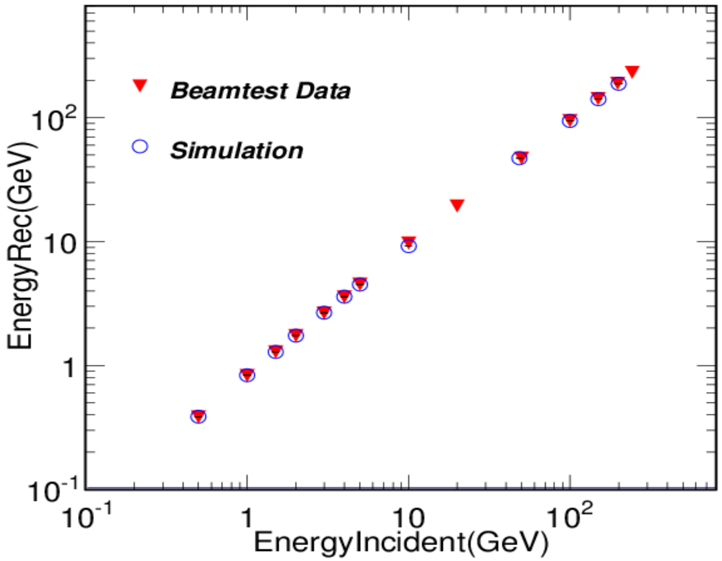


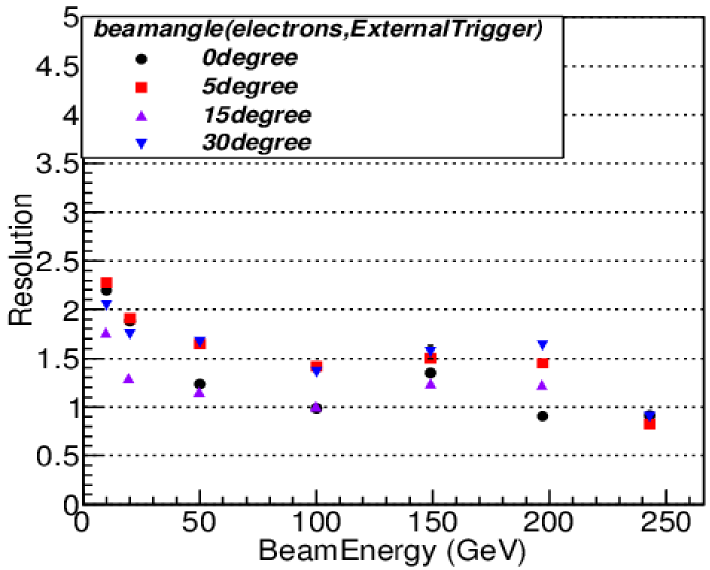
Energy longitudinal distribution

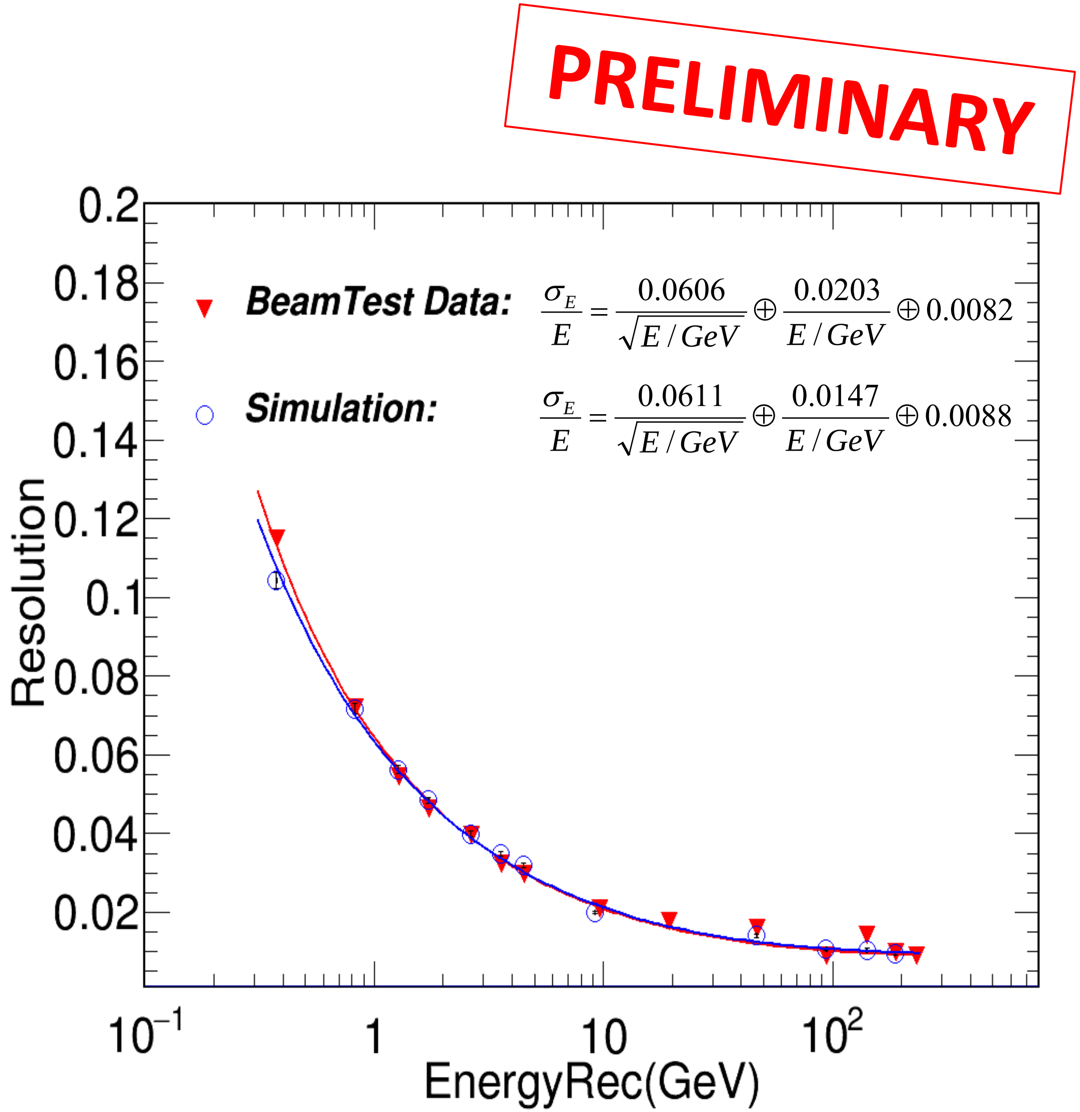


Electron Energy and Angle Reconstruction

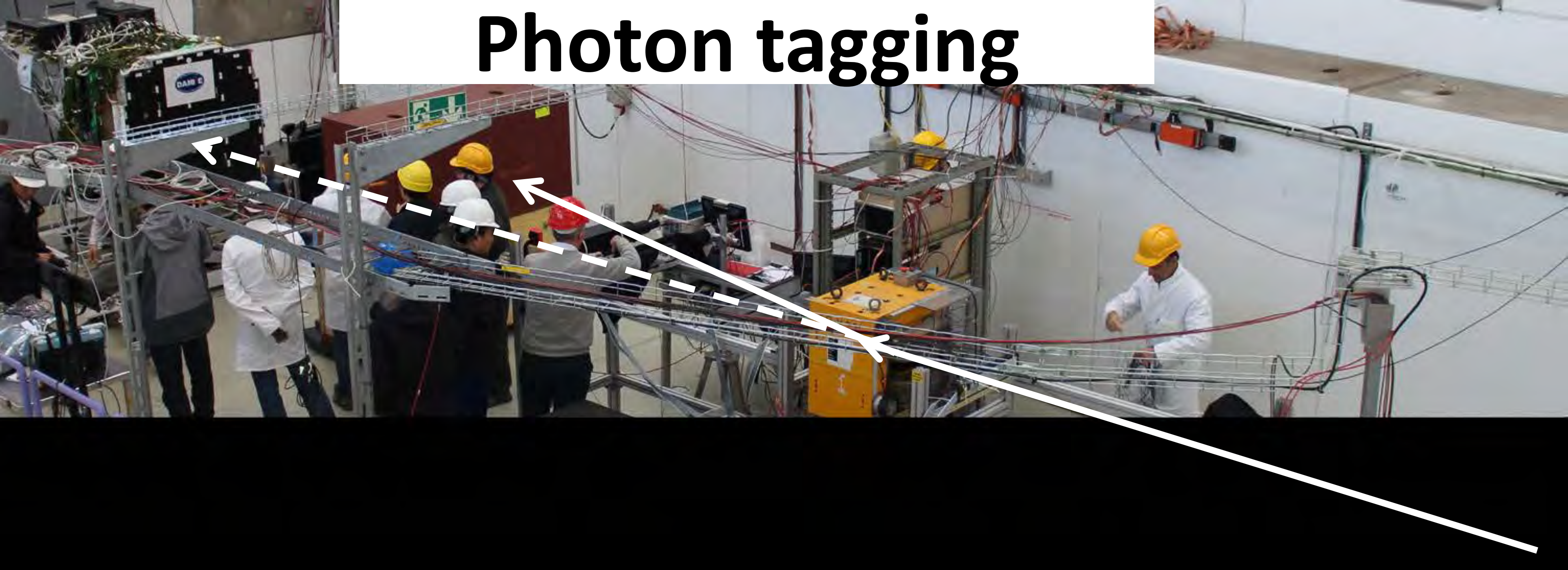
(linearity and resolutions)



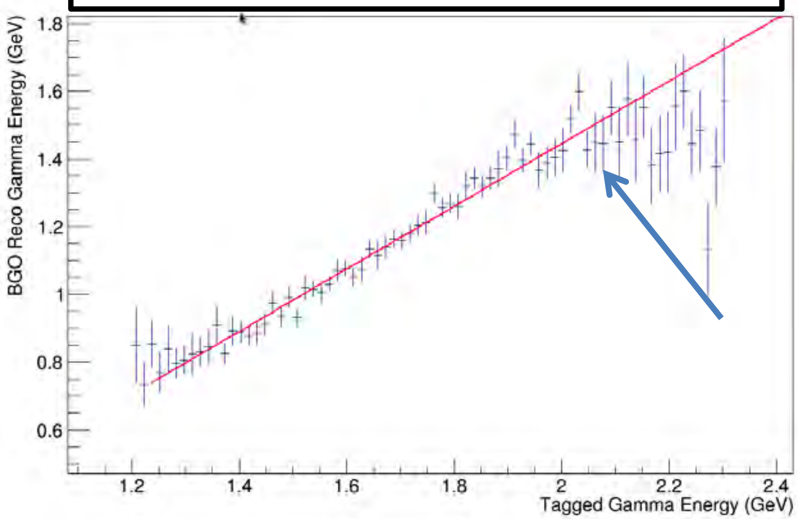




Photon tagging

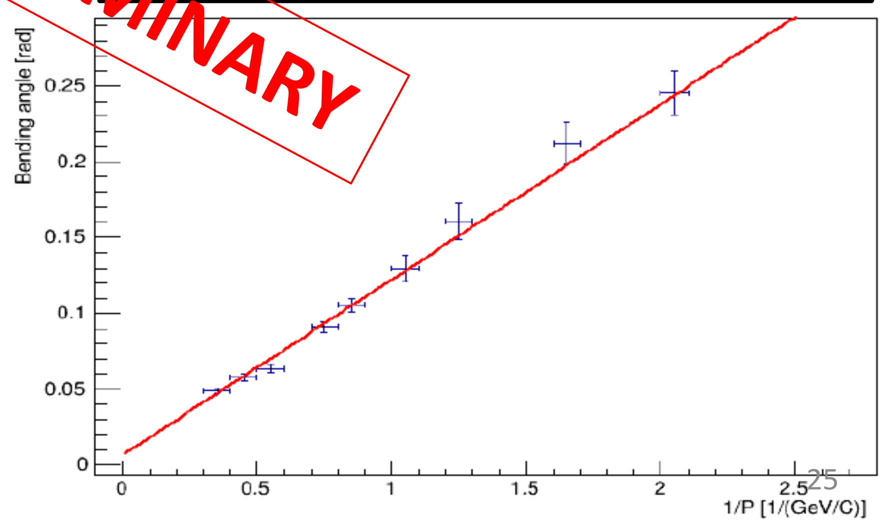


Photon energy measured by BGO
vs
Beam moment –Tagged electron



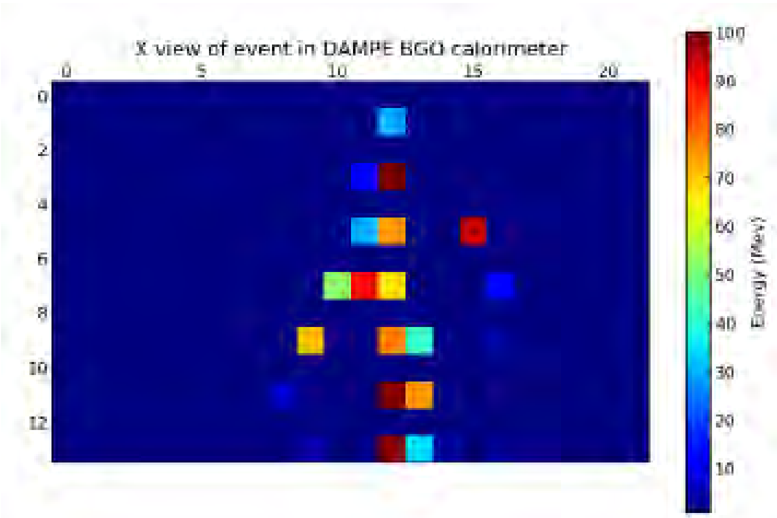
PRELIMINARY

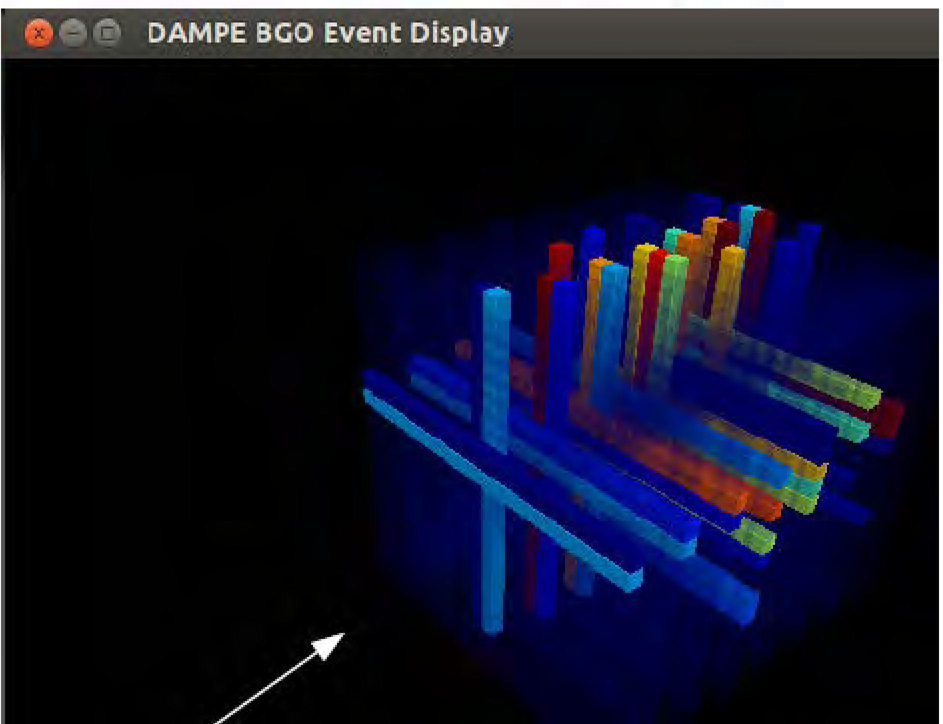
Electron bending angle
vs
1 / Electron Moment

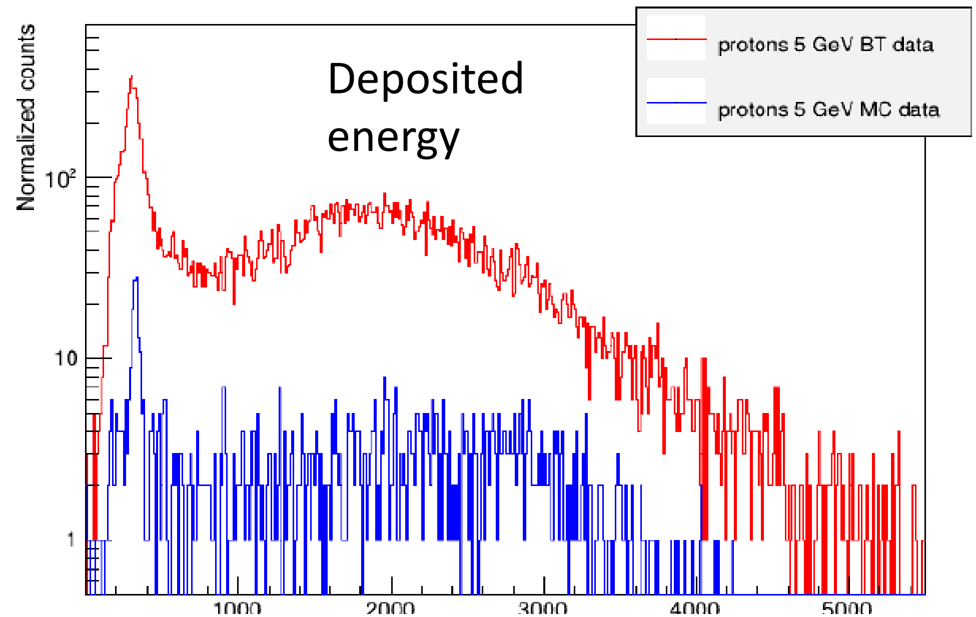


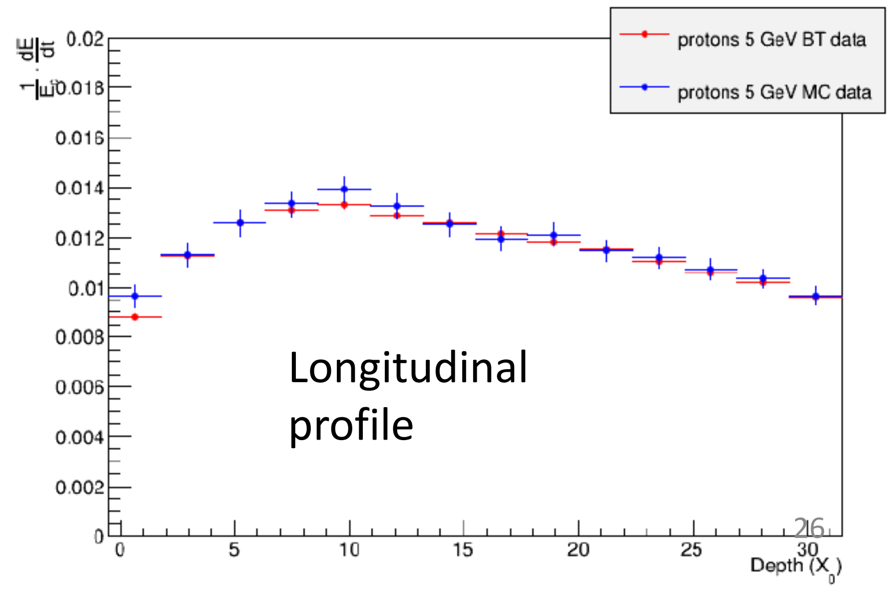
Protons @5 GeV

PRELIMINARY

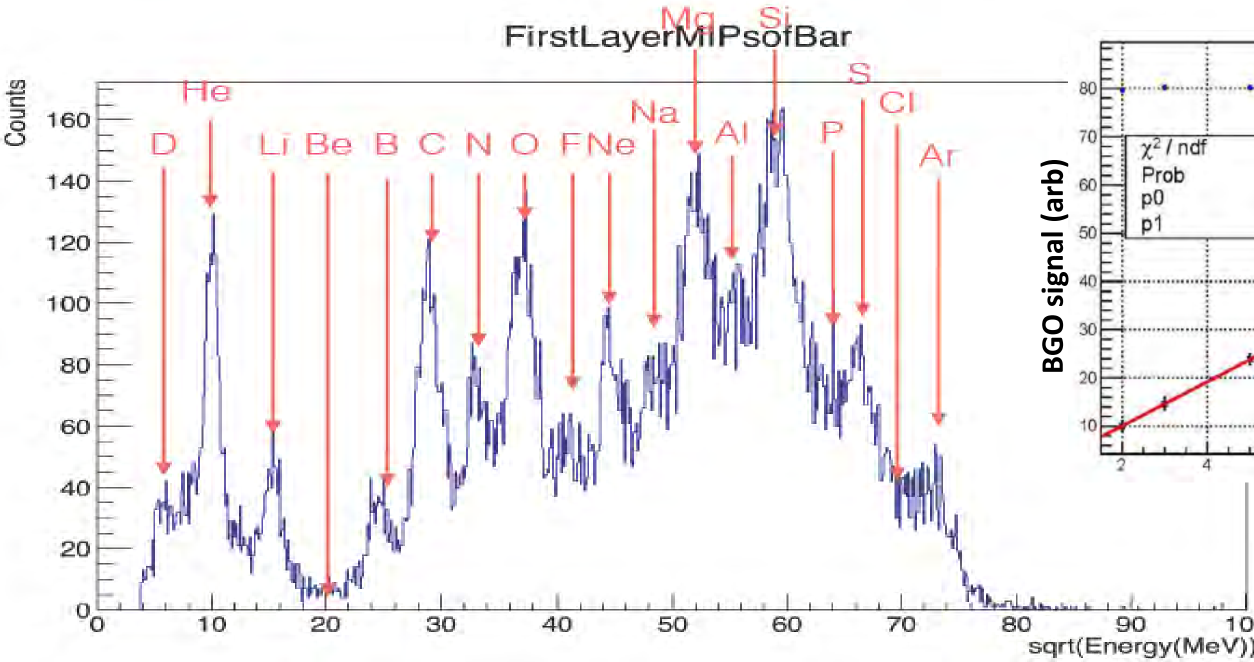


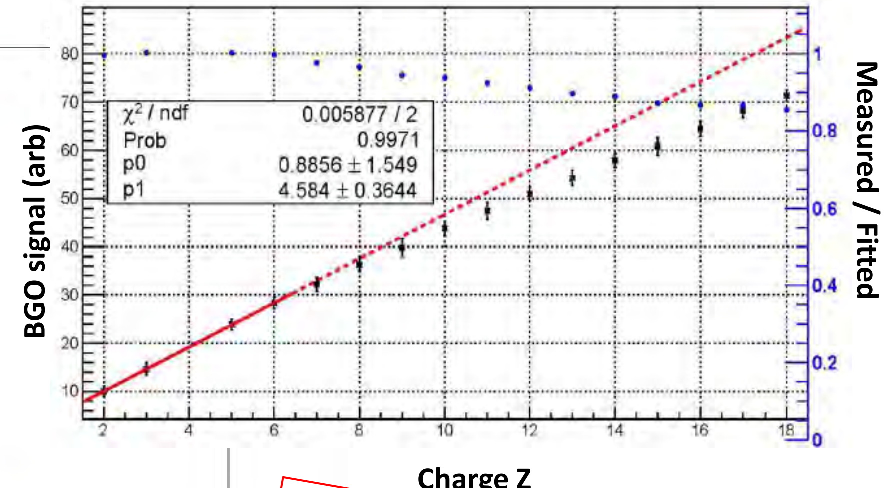




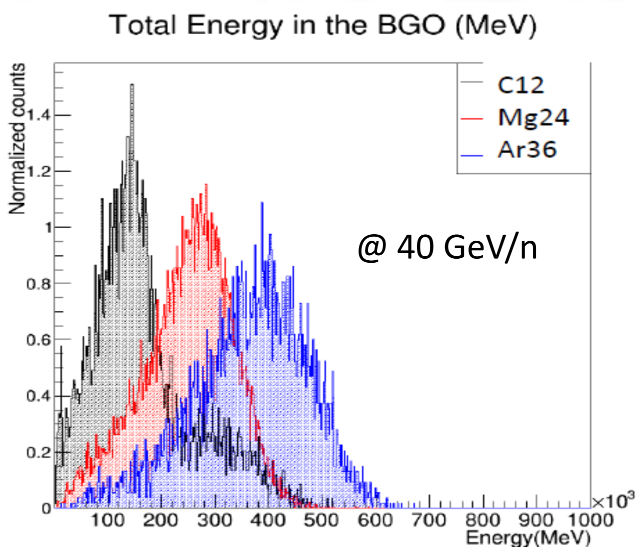


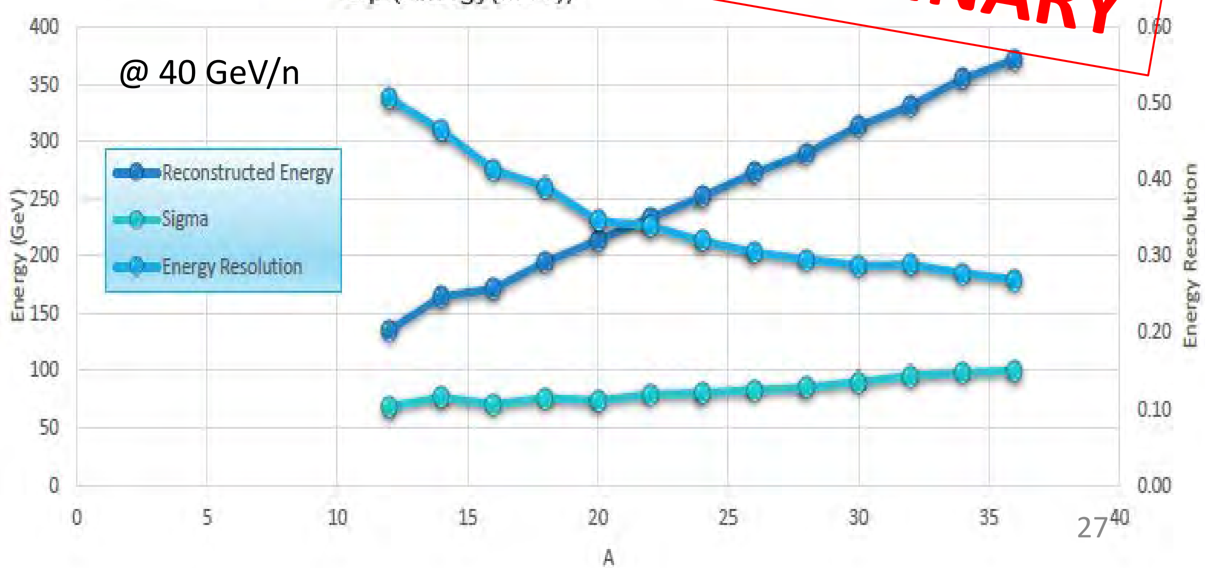
Ions in the BGO calorimeter





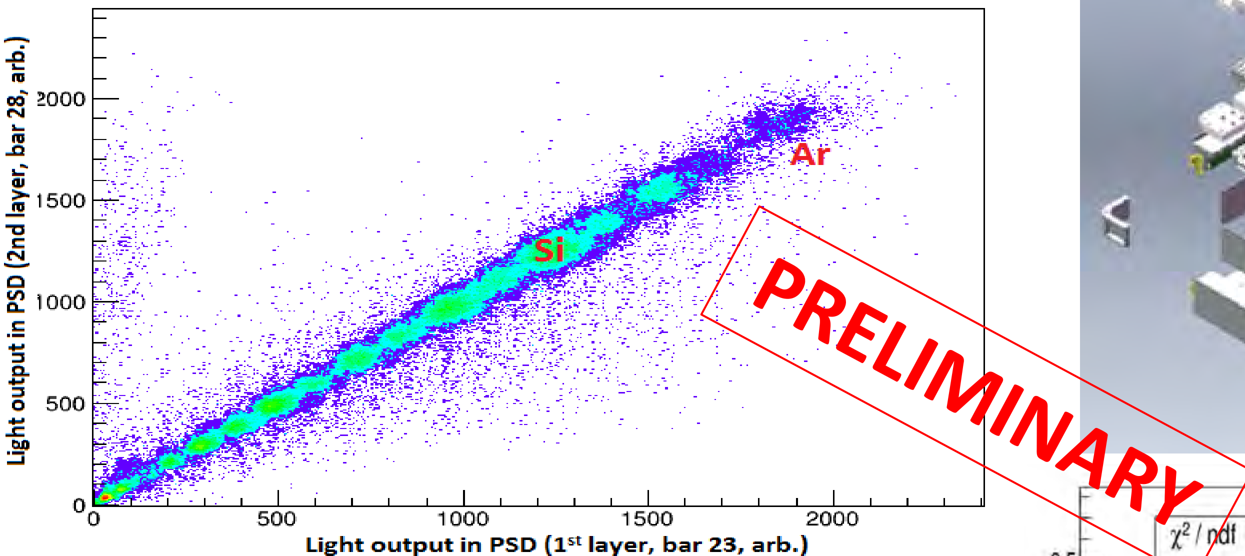
PRELIMINARY

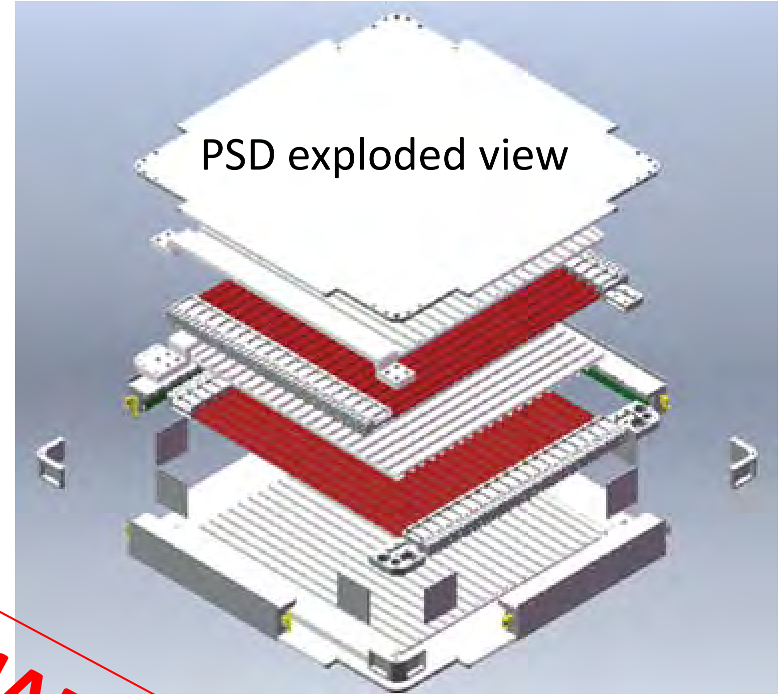


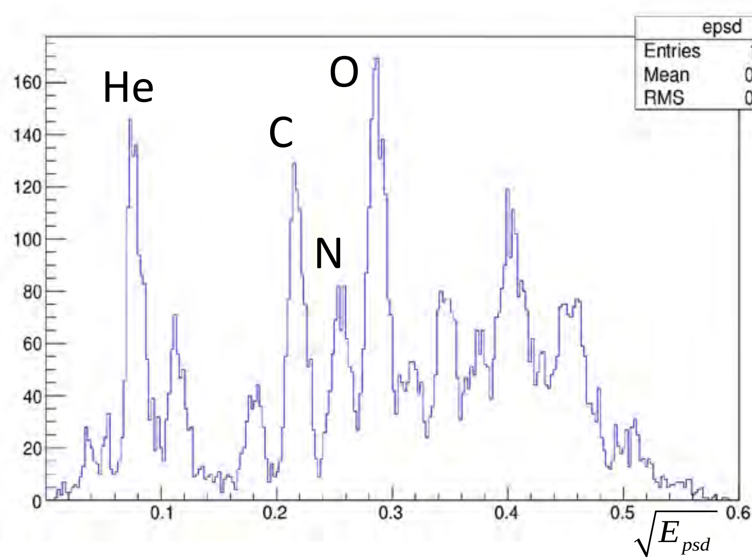


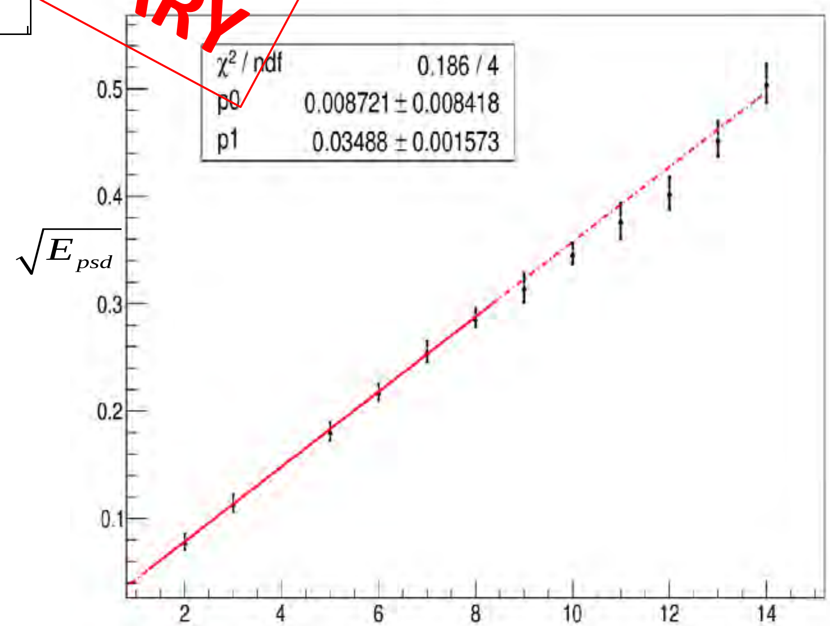
PSD

(Plastic Scintillator Detector)

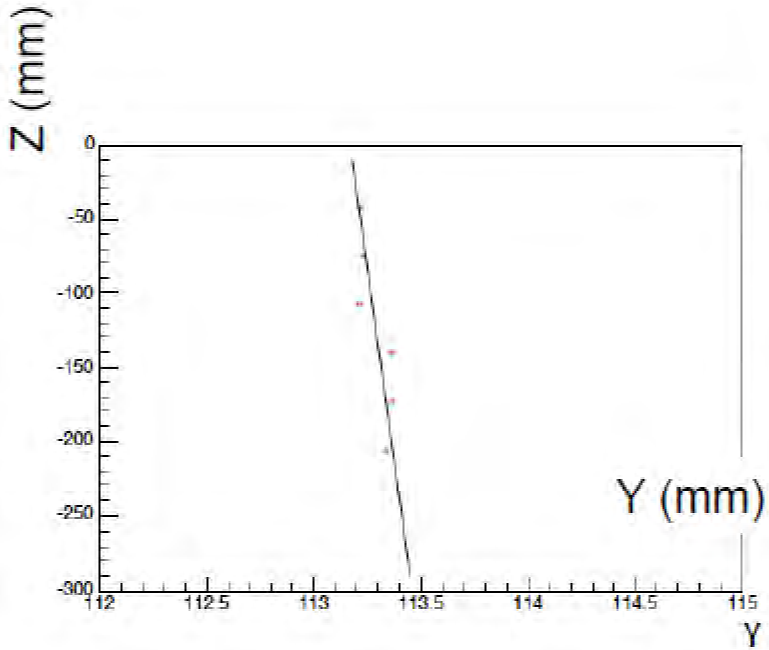


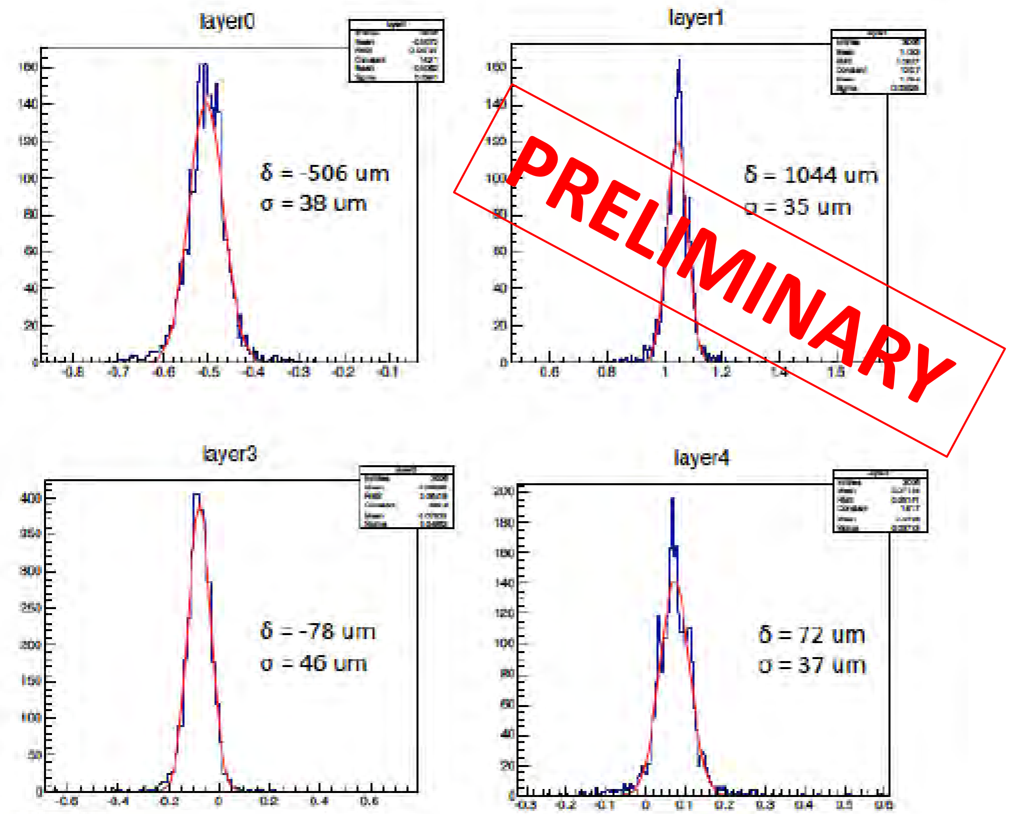


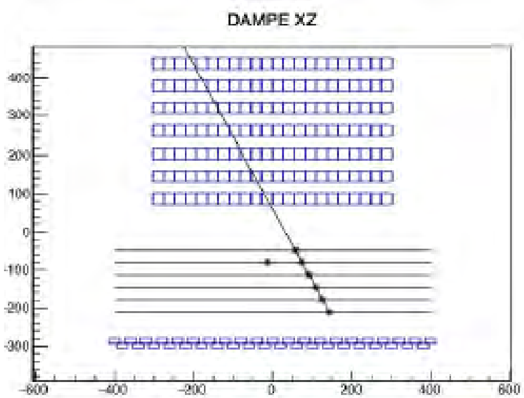


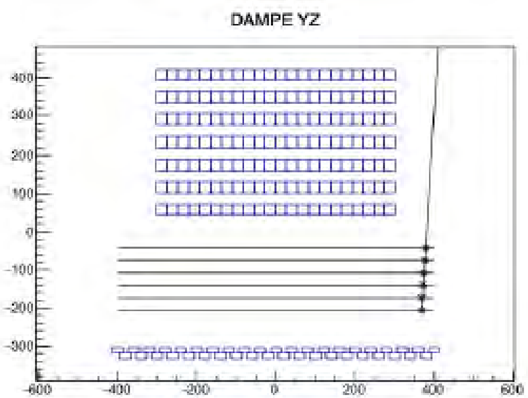


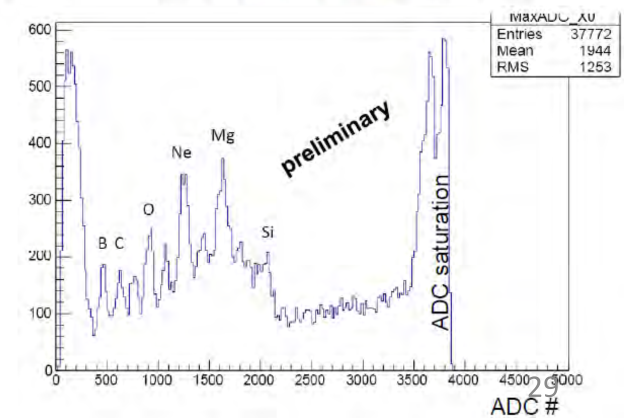
STK preliminary performance evaluation





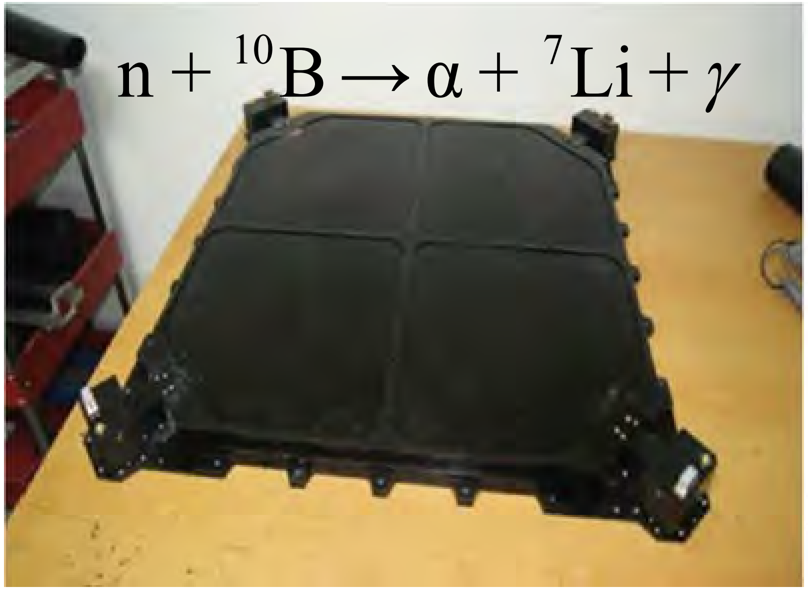


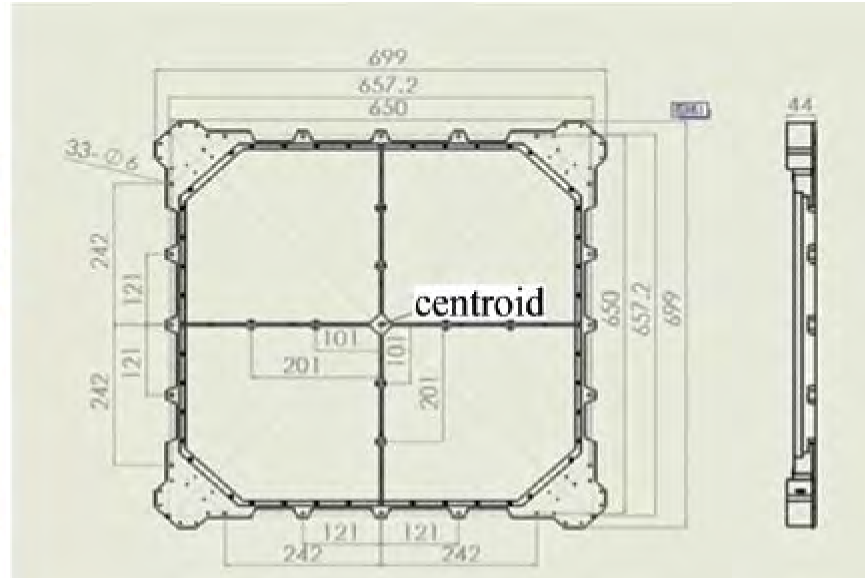


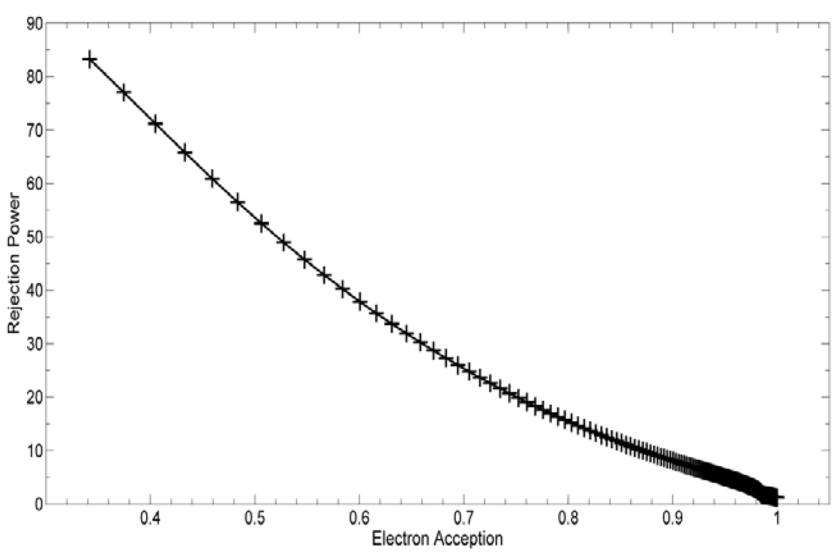


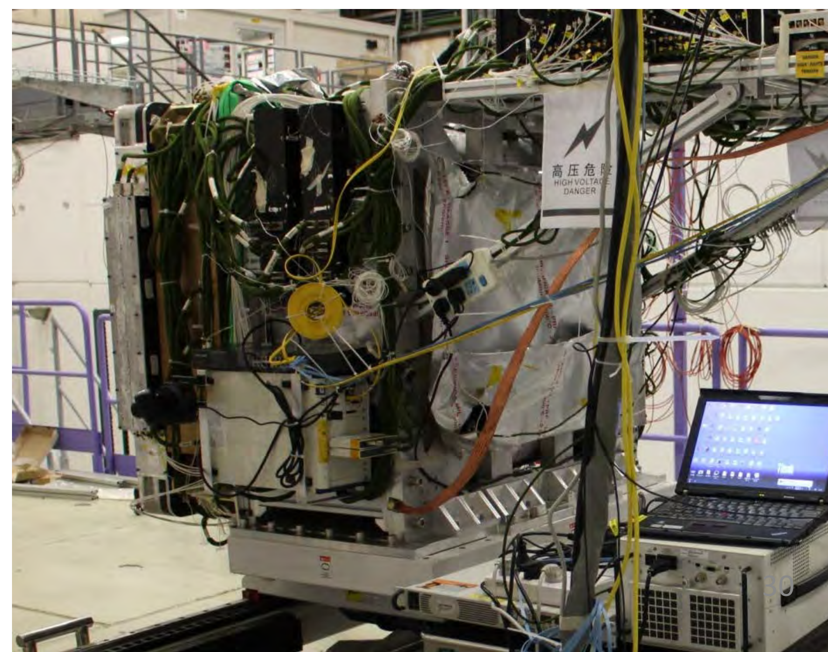
NUD: NeUtron Detector

(Boron doped scintillators)









China’s Space Station Program

2020

Phase -II

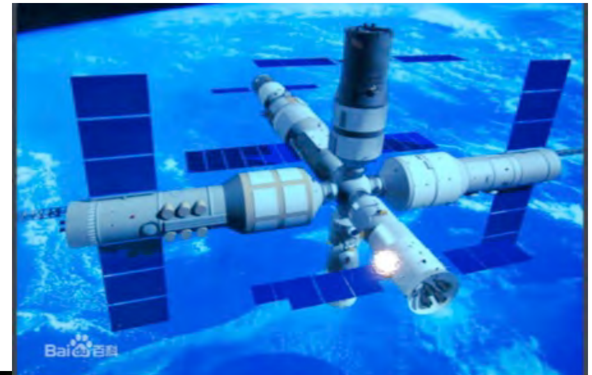
2016

Phase -II

2011

Phase -I

2003



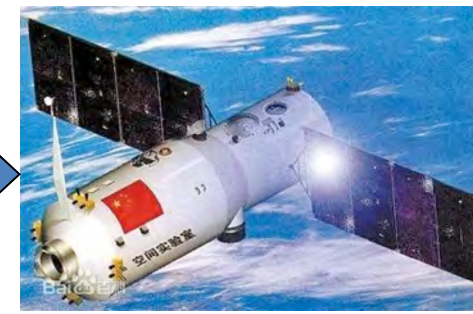
Space Station

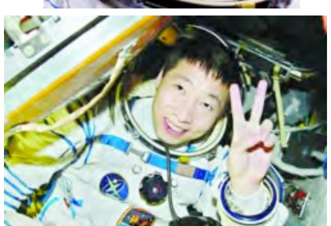
3 large modules

~ 60 tons

~10-year lifetime

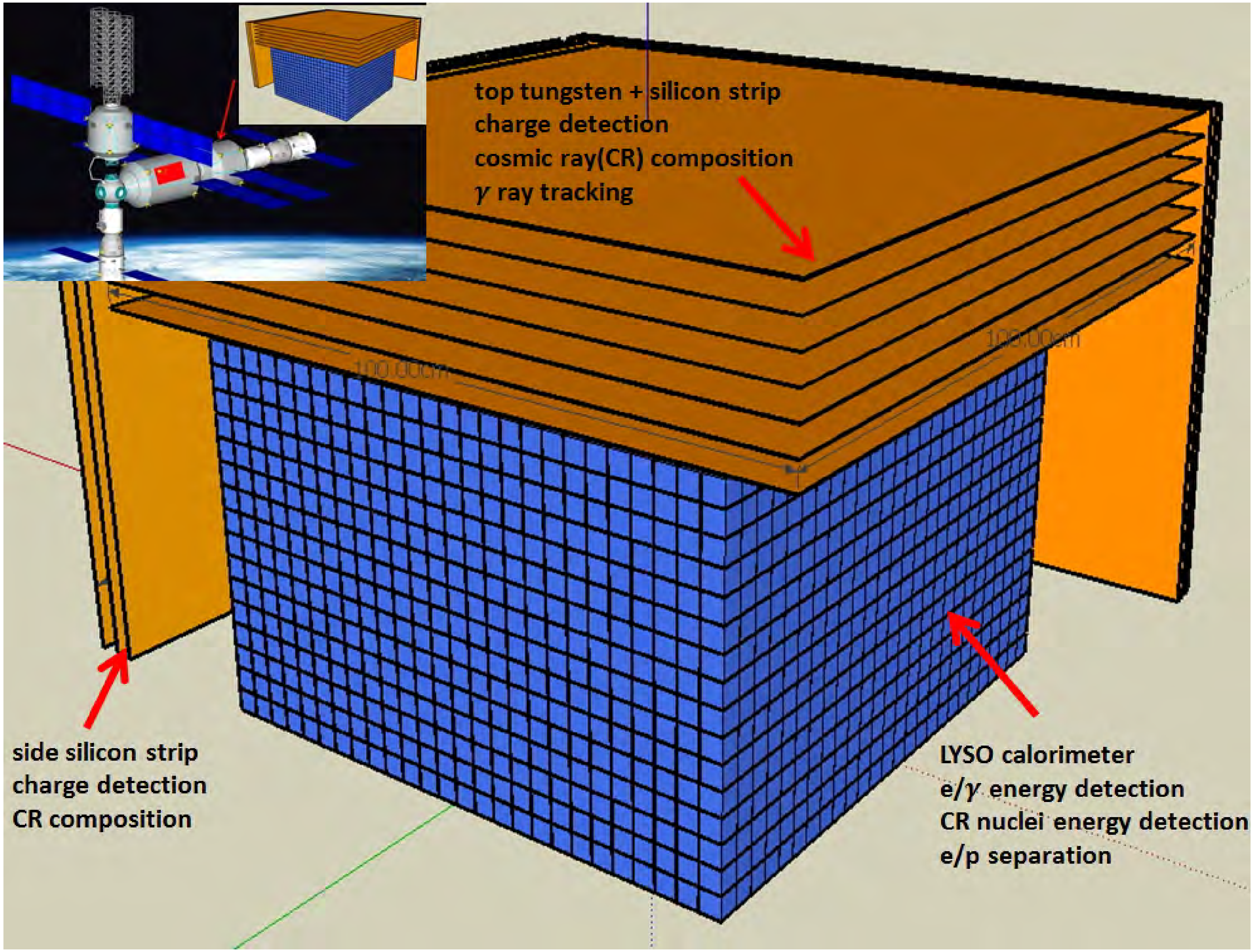
Space lab: no living cabin





10 astronauts in 5 flights → space walk

High Energy Radiation Detector



The HERD Proto-Collaboration Team

- Chinese institutions (more welcome!)

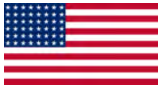
  - Institute of High Energy Physics, Purple Mountain Observatory, Xi’an Institute of Optical and Precision Mechanics, University of Science and Technology of China, Nanjing University, Peking University, Yunnan University, China University of Geosciences, Ningbo University, Guangxi University

- International institutions (more welcome!)
  - Switzerland: University of Geneva

  - Italy: Università di Pisa/INFN, IAPS/INAF, University of Florence/INFN, University of Perugia/INFN, University of Trento/INFN, University of Bari/INFN, University of Salento/INFN-Lecce

  - Sweden: KTH

  - USA: MIT/Harvard



HERD: High Energy cosmic-Radiation Detector

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

Other science goals:
- Monitoring of GRBs,
- Microquasars
- Blazars and other transients.

Characteristics of HERD components

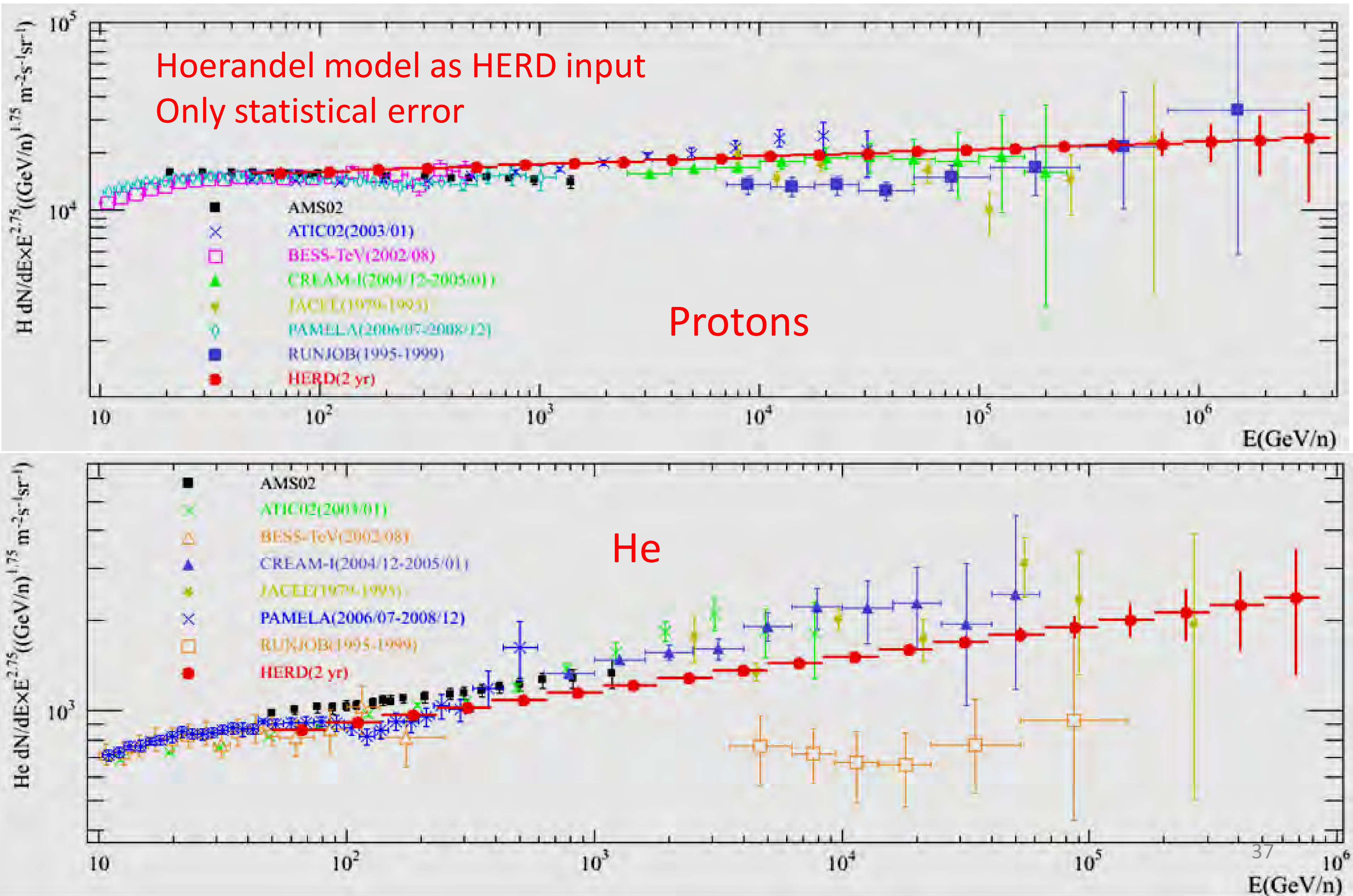
	type	size	X_0, λ	unit	main functions
tracker (top)	Si strips	70 cm × 70 cm	2 X_0	7 x-y (W foils)	Charge Early shower Tracks
tracker 4 sides	Si strips	65 cm × 50 cm	2 X_0	7 x-y (W foils)	Charge Early shower Tracks
CALO	~10K LYSO cubes	63 cm × 63 cm × 63 cm	55 X_0 3 λ	3 cm × 3 cm × 3 cm	e/γ energy nucleon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

Total detector weight: ~2000 kg

Expected performance of HERD

γ/e energy range (CALO)	tens of GeV-10TeV
nuclei energy range (CALO)	up to PeV
γ/e angular resol. (top Si-strips)	0.1^{o}
nuclei 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

One example: HERD Proton and He Spectra



Summary

- DAMPE is among CAS funded projects for space
- Better/extended performance than existing detectors for e/γ/CR towards larger energies
- Systematic activity on assembly, qualification, test beam and simulation on schedule
- Preparation for mission data analysis is ongoing
- Launch foreseen on december 18, 2015

- HERD: an opportunity to further increase the energy range and the detection reach in galactic CR measurements
- Novel calorimetric concept

More Stuff

(SNR) Maximum CR energy (for protons)

$$\varepsilon \approx 230\, n_e^{1/2}\, u_7^2\, R_{\rm pc}\ \mathrm{TeV}$$

Cas A

$$\varepsilon \approx 160\ \mathrm{TeV}$$

shock vel ~ 5,000 km s^{-1}

T. Bell
GSSI workshop
Sep. 2014

Sedov phase

$$\varepsilon \approx 20\, E_{44}^{1/3}\, n_e^{1/6}\, u_6^{4/3}\ \mathrm{TeV}$$

shock vel in 1,000 km s^{-1}

Blast wave energy in 10^{44}J

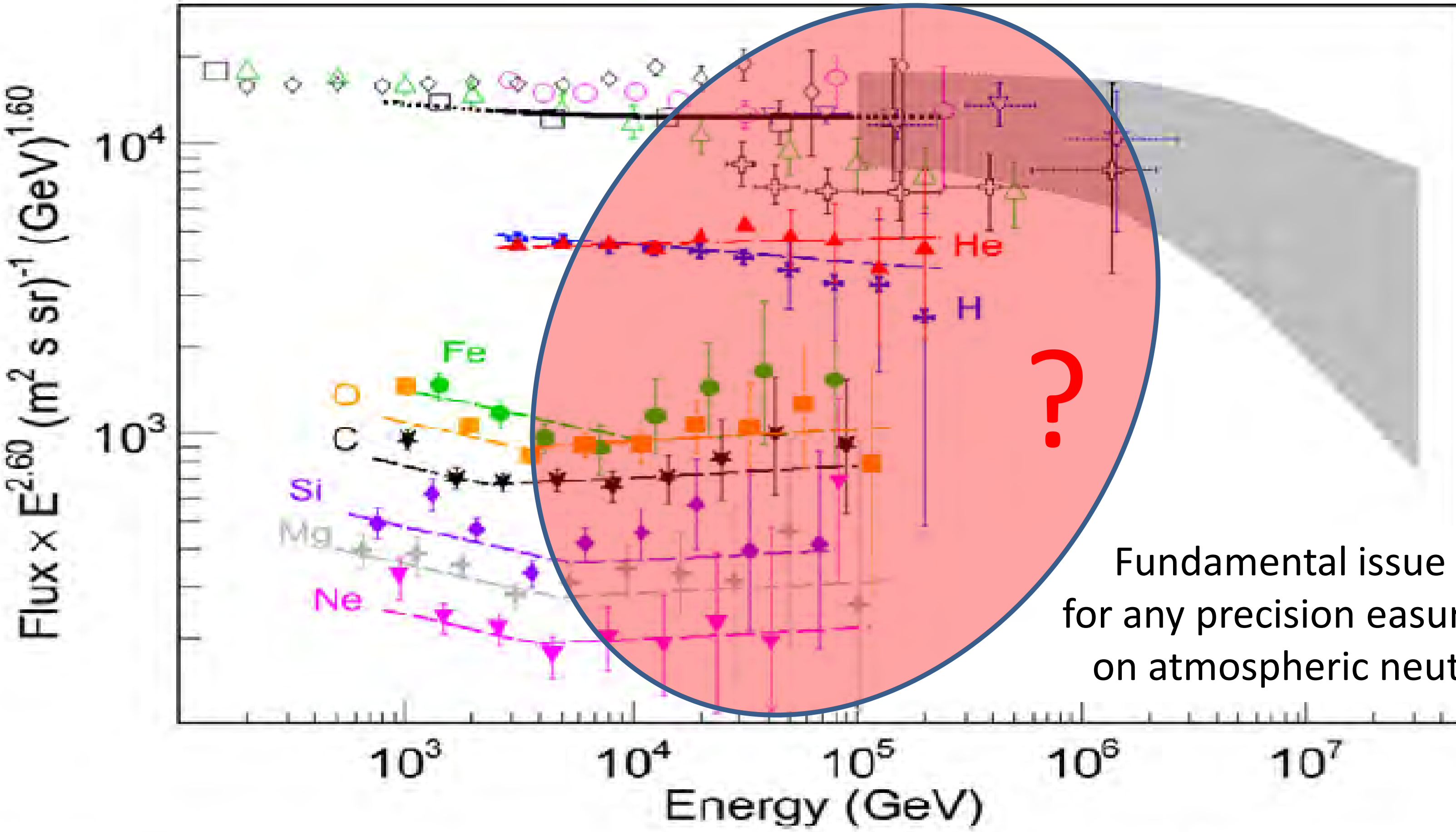
SN expansion into circumstellar wind

wind mass loss in 10^{-5} solar masses yr^{-1}

$$\varepsilon = 800 u_7^2 \sqrt{\frac{\dot{M}_5}{u_4}}\ \mathrm{TeV}$$

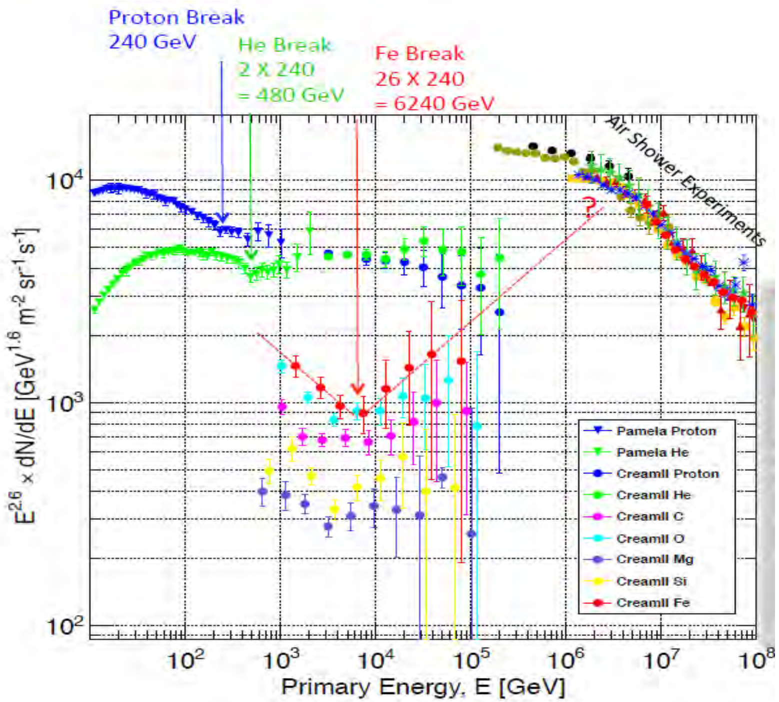
wind vel in 10 km s^{-1}

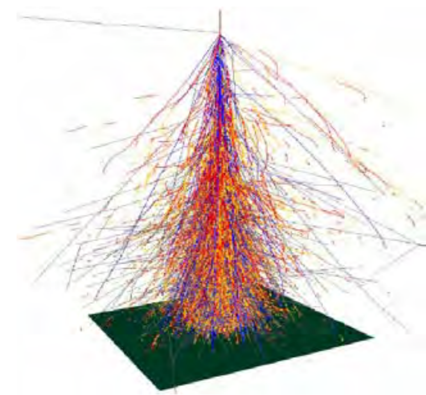
Difficult to get far beyond PeV (Schure & Bell 2013)



Fundamental issue also
for any precision easurement
on atmospheric neutrinos

Fig. 11. The all-particle spectrum (black solid curve) obtained by summing up CREAM elemental spectra from p to Fe (filled symbols) is compared with previous measurements (open symbols): ATIC-1 [35], black squares; JACEE, blue downward triangles; RUNJOB, black crosses; Ichimura et al. [71], green upward triangles; SOKOL [72], pink circles. The gray shaded area indicates ground based indirect measurements. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)





Direct measurements

Requirements:

Calorimetry vs Spectrometry

Large acceptances

<30% resolutions

Output:

Fully explore the sub-PeV region

Limitations:

Surface/weight limited

Hard to reach the all-particle knee

Need high technology

Indirect measurements

Requirements:

Multi-Hybrid approach

Operate at (not too) high altitude

Large surfaces / samplings

Output:

Reach the highest energies

Limitations:

Very poor mass resolution

Intrinsically limited by systematics

Give many hints but few answers

What is needed

- Focus on the 100TeV-10 PeV energy region
- Measure the “knees” of each species

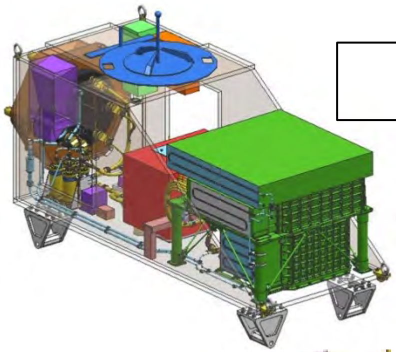
HECR spectroscopy

Together with high energy gamma and neutrinos astronomies

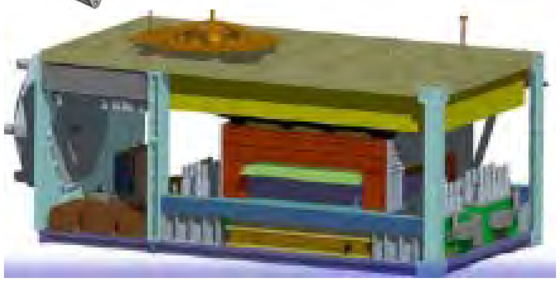
- Indentify galactic sources
- Understand acceleration and diffusion mechanisms
- Better understand the transition to extragalactic

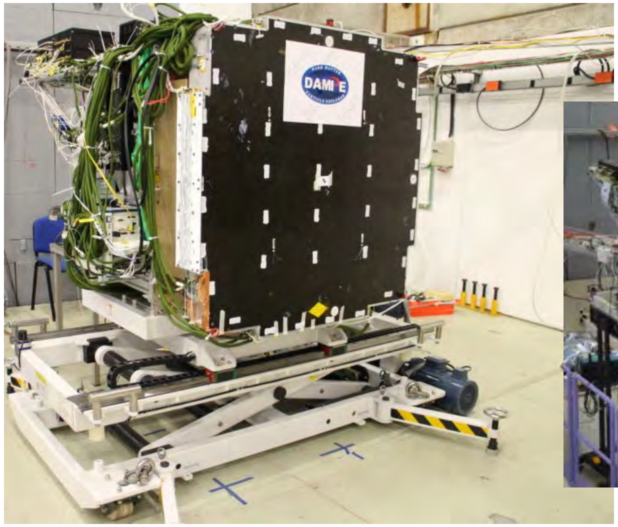
Current and Future projects (space)

CALET



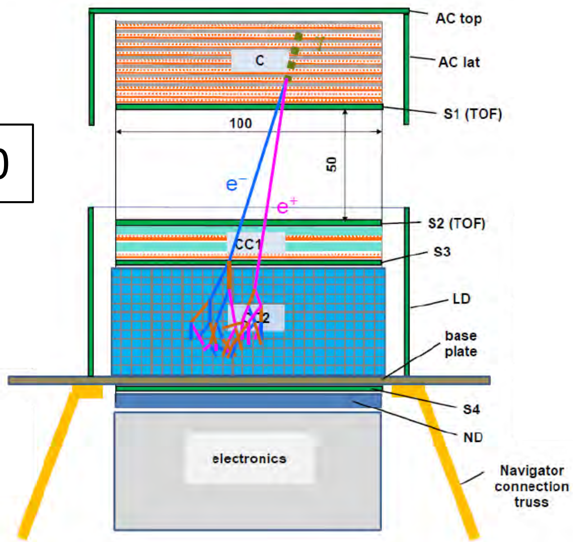
ISS_CREAM



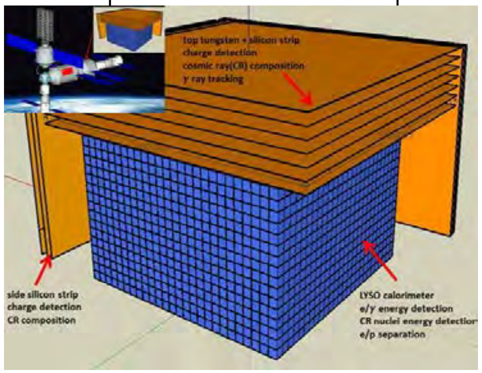


DAMPE

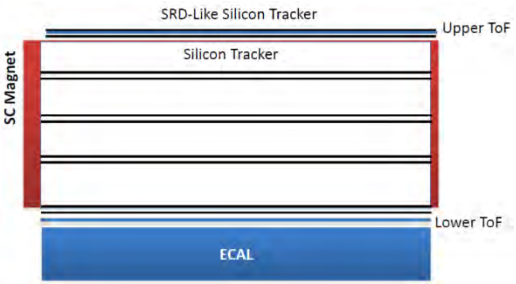
Gamma-400

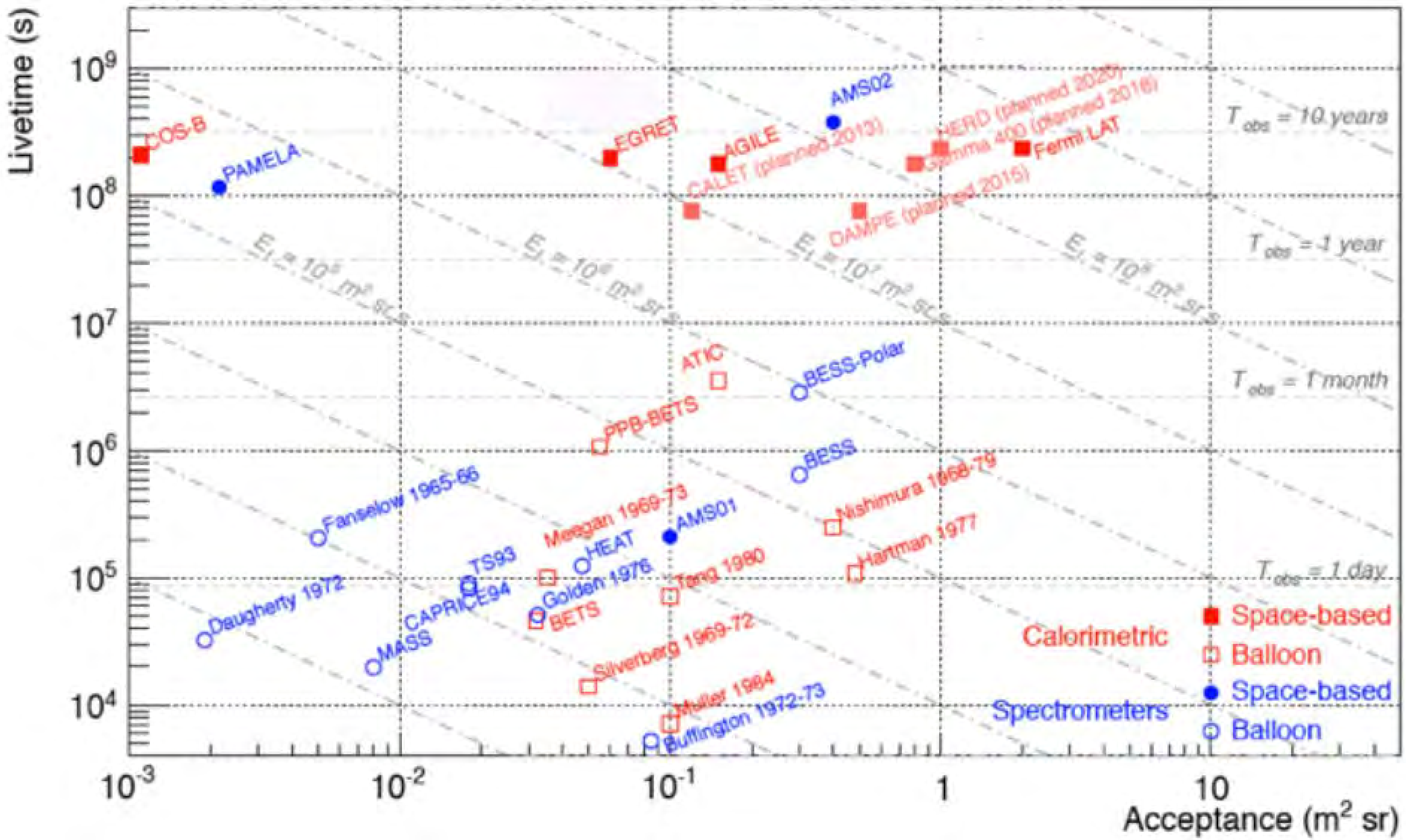


HERD



AMS-03




Livetime (s)
Acceptance (m² sr)
COS-B
PAMELA
EGRET
AGILE
AMS02
CALET (planned 2013)
HERD (planned 2020)
Gamma 400 (planned 2018)
Fermi LAT
DAMPE (planned 2015)
T obs = 10 years
T obs = 1 year
T obs = 1 month
T obs = 1 day
ATIC
BESS-Polar
PPB-BETS
BESS
Nishimura 1968-79
Fanselow 1965-66
Meegan 1969-73
AMS01
Hartman 1977
TS93
HEAT
Golden 1976
Tang 1980
Daugherty 1972
CAPRICE94
BETS
MASS
Silverberg 1969-72
Muller 1984
Buffington 1972-73
Calorimetric
Spectrometers
Space-based
Balloon
Space-based
Balloon