Galactic Cosmic Rays with the DAMPE Space mission

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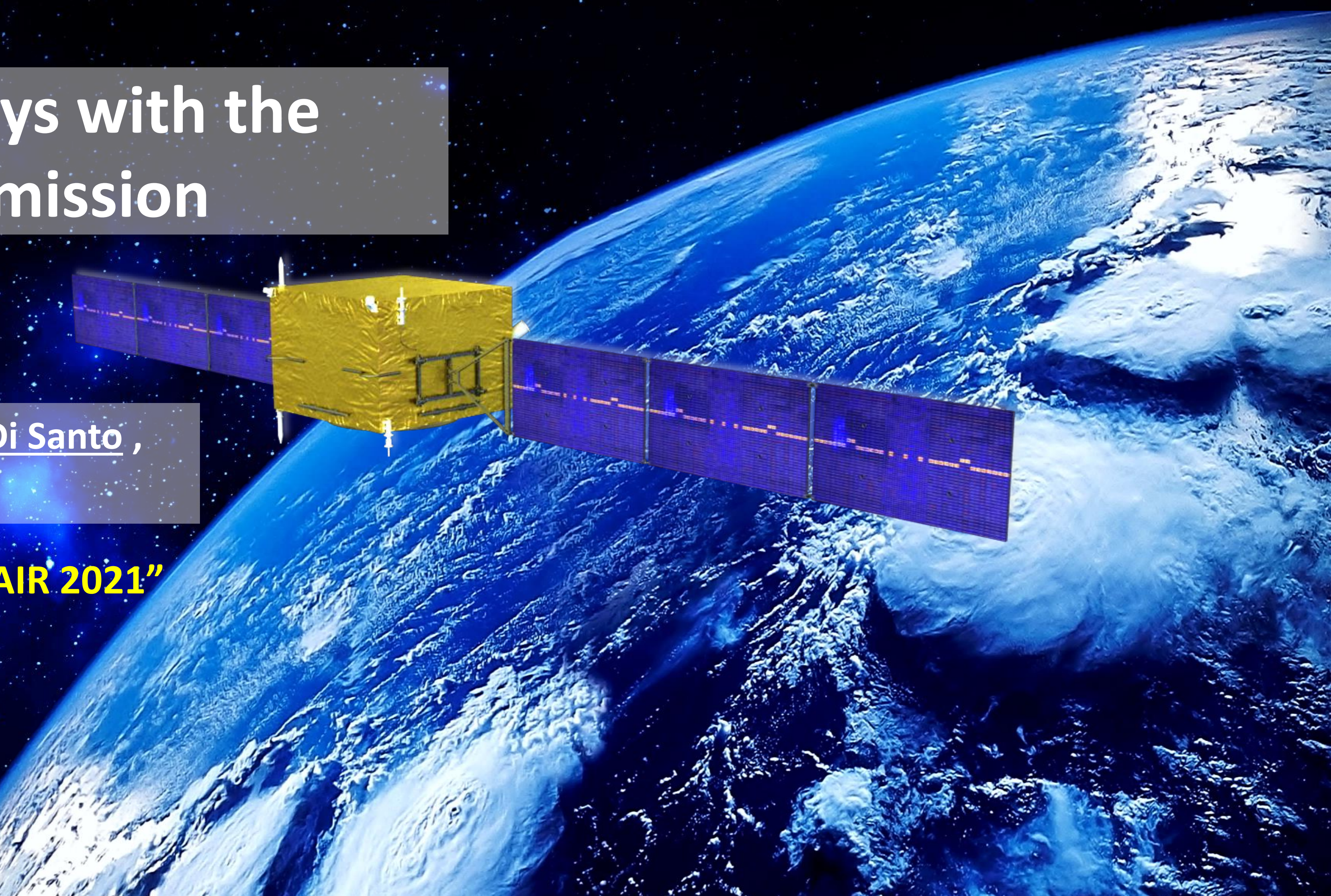
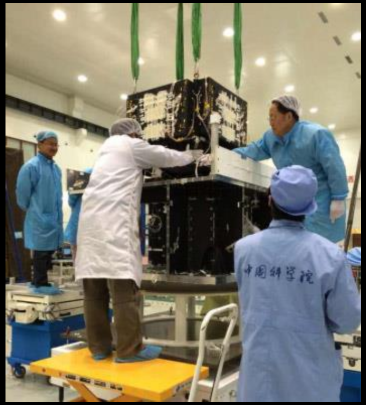


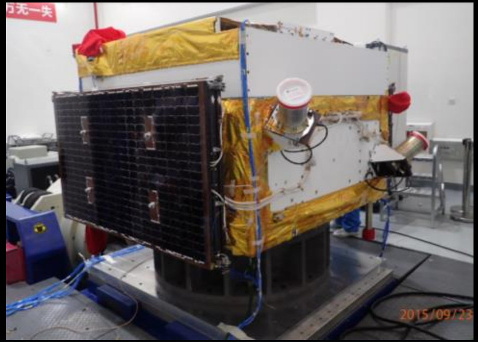
“Astroparticle Physics SCIENCE FAIR 2021”
March 2nd, 2021

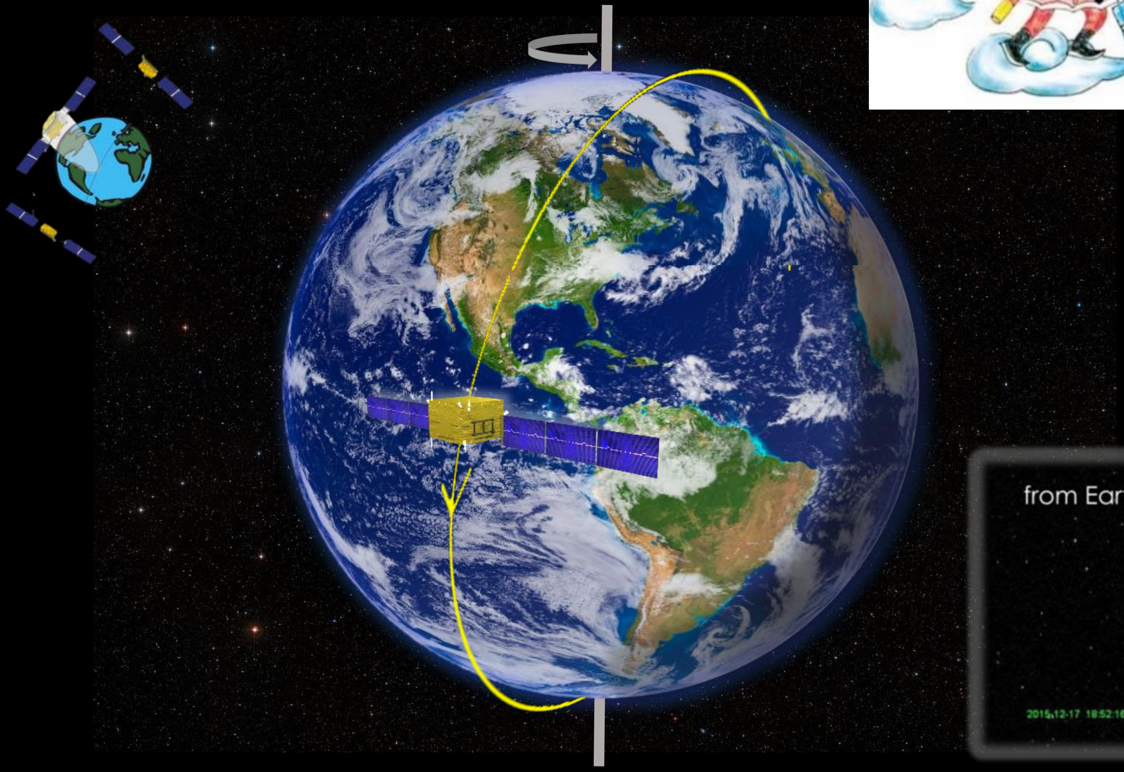
The DArk Matter Particle Explorer Space mission

Satellite-borne particle detector prosed in the framework of the Strategic Pioneer Program on Space Science, promoted by the Chinese Academy of Sciences (CAS).

NAME: DAMPE (CODENAMED «WUKONG», THE MONKEY KING)
LAUNCH: 17th Dec. 2015, CZ-2D rocket
ALTITUDE: 500 km
PERIOD: 95 minutes
ORBIT: Sun-synchronous
LIFETIME > 3 years







The DAMPE Collaboration

- Purple Mountain Observatory
- University of Science and Technology
- Institute of High Energy Physics
- Institute of Modern Physics
- National Space Science Center

- INFN Lecce and University of Salento
- INFN Bari and University of Bari
- INFN Perugia and University of Perugia
- INFN LNGS and Gran Sasso Science Institute

- Geneva University

8th DAMPE Workshop

10-12 December 2018, Gran Sasso Science Institute (GSSI), L'Aquila, Italy

The DAMPE Scientific goals

- Study of Galactic Cosmic Ray composition, origin and propagation
- Search for Dark Matter signatures in lepton and photon spectra
- High Energy Gamma-Ray Astronomy

The DAMPE detector

J. Chang et al., Astrop. Phys. 95 (2017) 6-24

PSD
Plastic Scintillator Detector

- 2 planes with double layer configuration (2D)
- 82 plastic scintillator bars EJ-200 (Eljen Technology Corporation)
- ❑ CHARGE MEASUREMENT ($Z<28$, $Z \propto \sqrt{E}$)
- ❑ γ-RAY VETO

STK
Silicon Tungsten tracKer converter

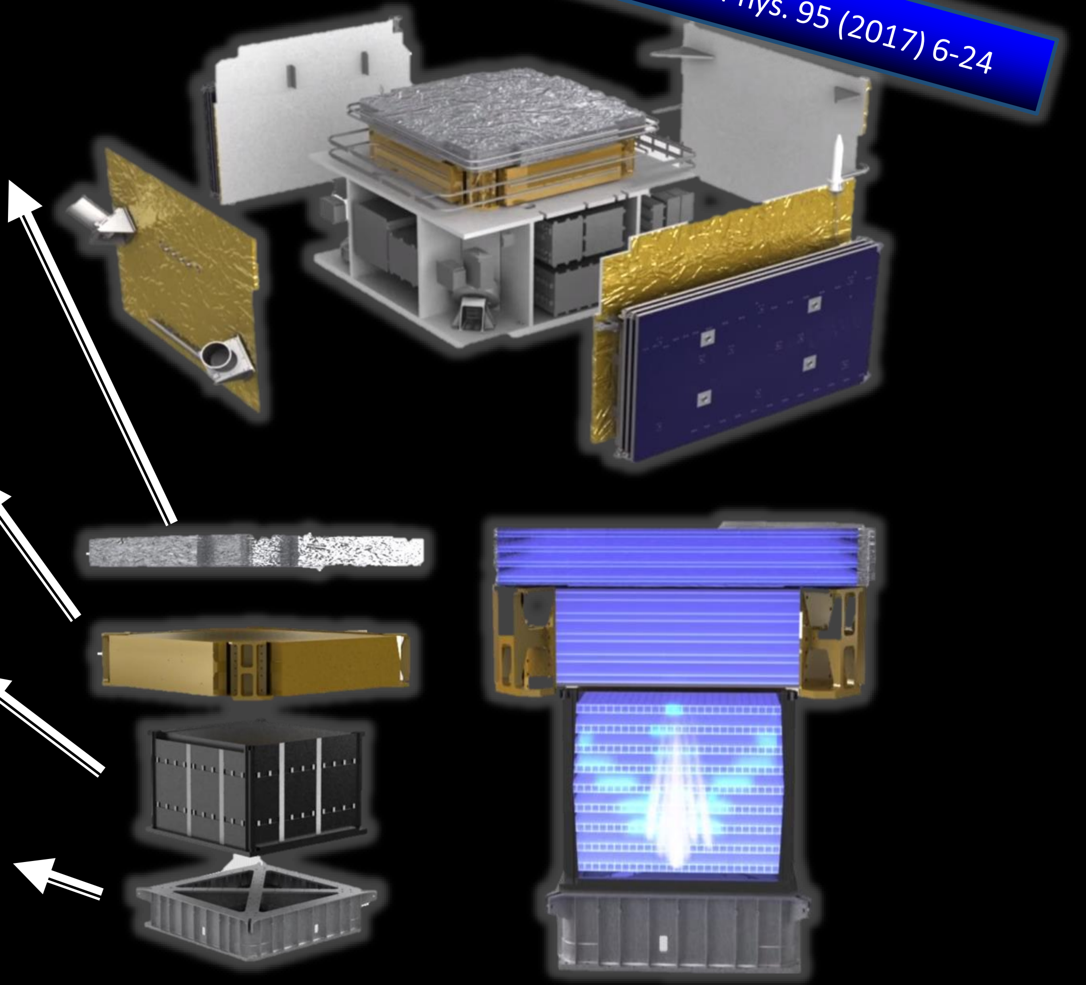
- 6 planes with 2 single-sided silicon layers
- 3 thin tungsten layers (for γ conversion in e^+/e^-)
- ❑ TRACK RECONSTRUCTION
  - ❑ spatial resolution <70 μm for CR ($\theta_{inc} < 60°$)
  - ❑ angular resolution ~0.2° for γ at 10 GeV
- ❑ CHARGE MEASUREMENT ($Z \propto \sqrt{ADC}$)

BGO
calorimeter

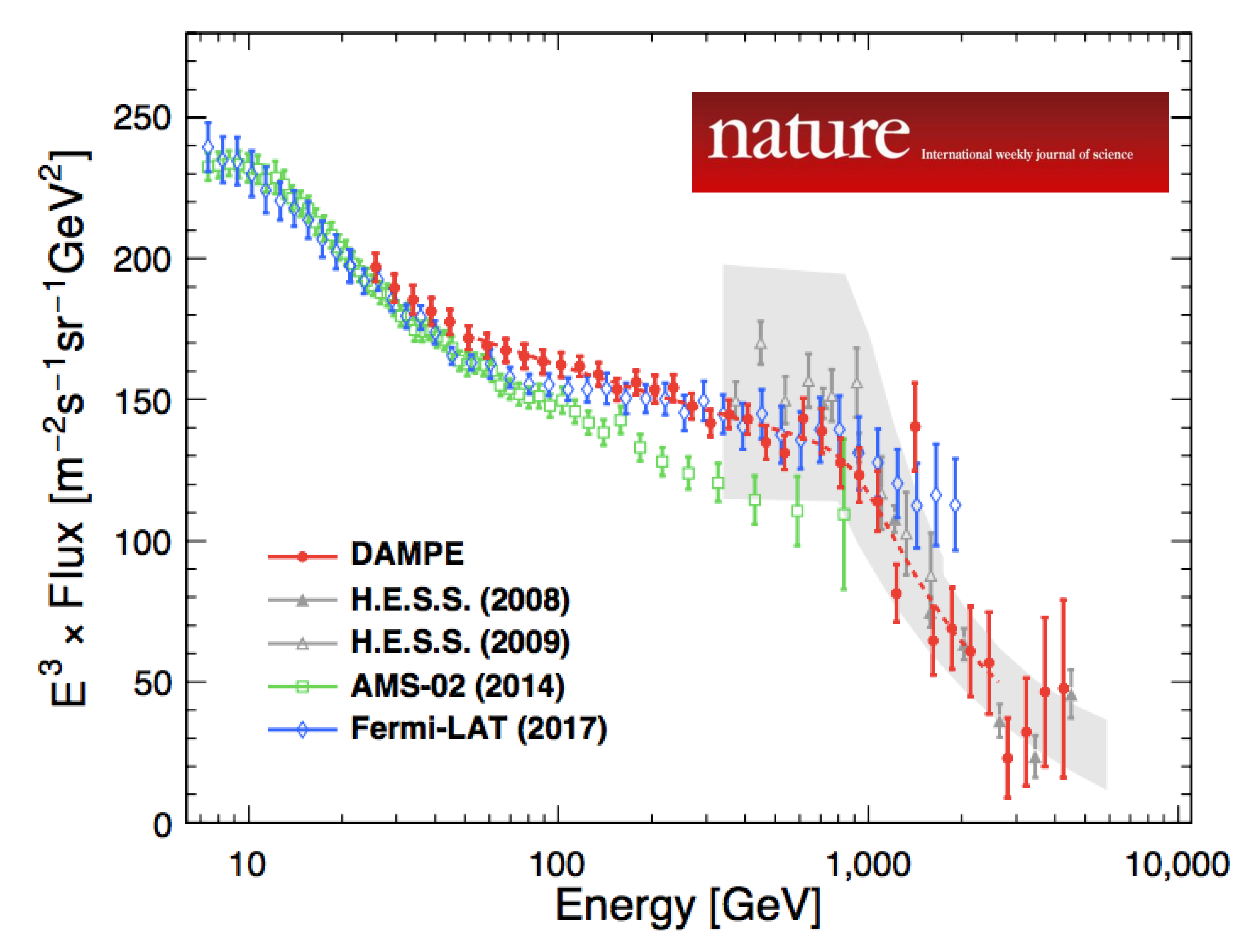
- 14 layers, each one with 22 bars of $Bi_3Ge_4O_{12}$, ~32 X_0
- ❑ ENERGY MEASUREMENT
  - ❑ 1 GeV - 10 TeV for electrons and γ
  - ❑ 50 GeV - 100 TeV for nuclei

NUD
NeUtron Detector

- 1 layer, 4 boron-doped plastic scintillators
- ❑ DETECTION OF NEUTRONS generated in the BGO for hadron/e.m. showers discrimination



Total $e^+ + e^-$ energy spectrum



G. Ambrosi et al., *Direct detection of a break in the teraelectronvolt cosmic-ray spectrum of electrons and positrons*, Nature, 552, 63 (2017).

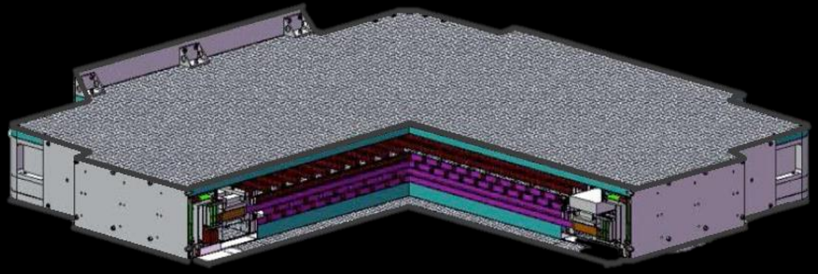
- 530 days of data (Dec. 2015 – Jun. 2017)
- 2.8 billion events of CRs
- 1.5 million events of e^+e^- with energy >25 GeV

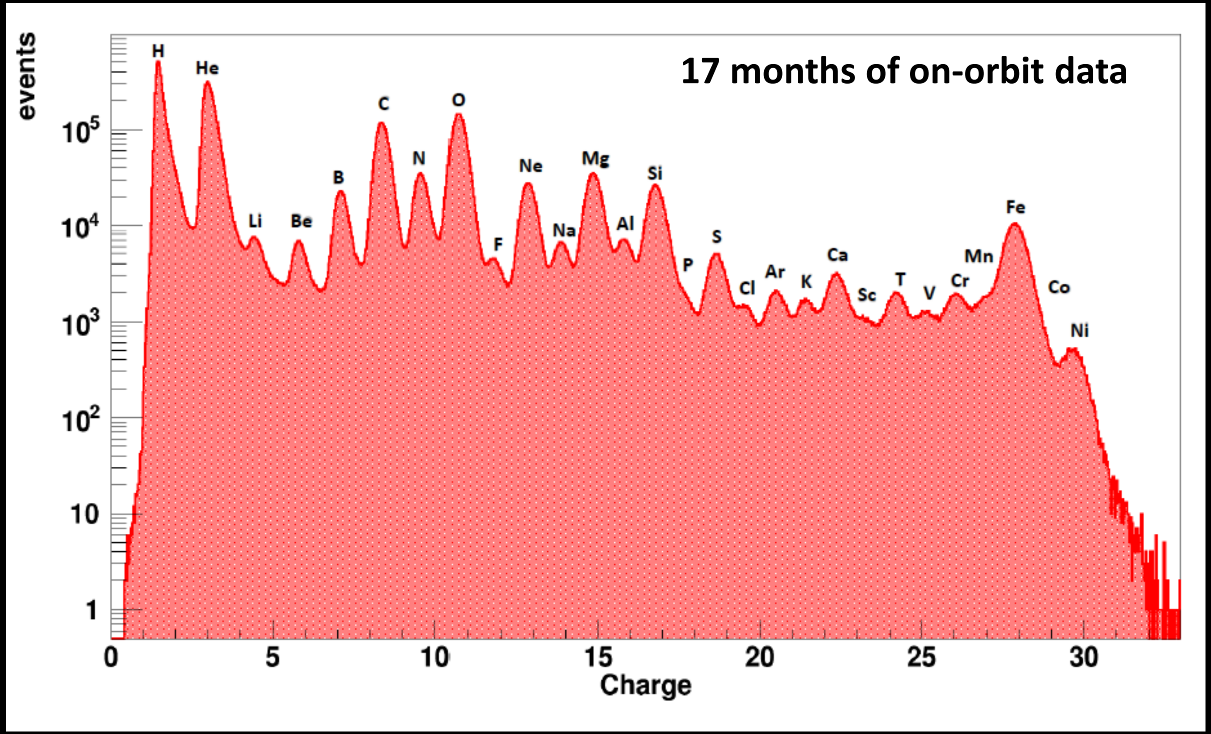
Direct detection of a spectral break at ~ 1 TeV with 6.6 σ confidence level

Analysis with new data is on-going…

Identification of nuclei with the PSD

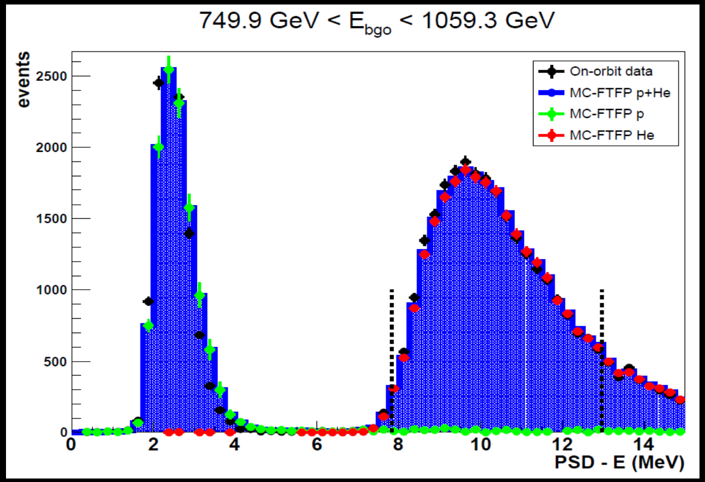
Charge selection performed by using the energy measurements provided by both the PSD layers.



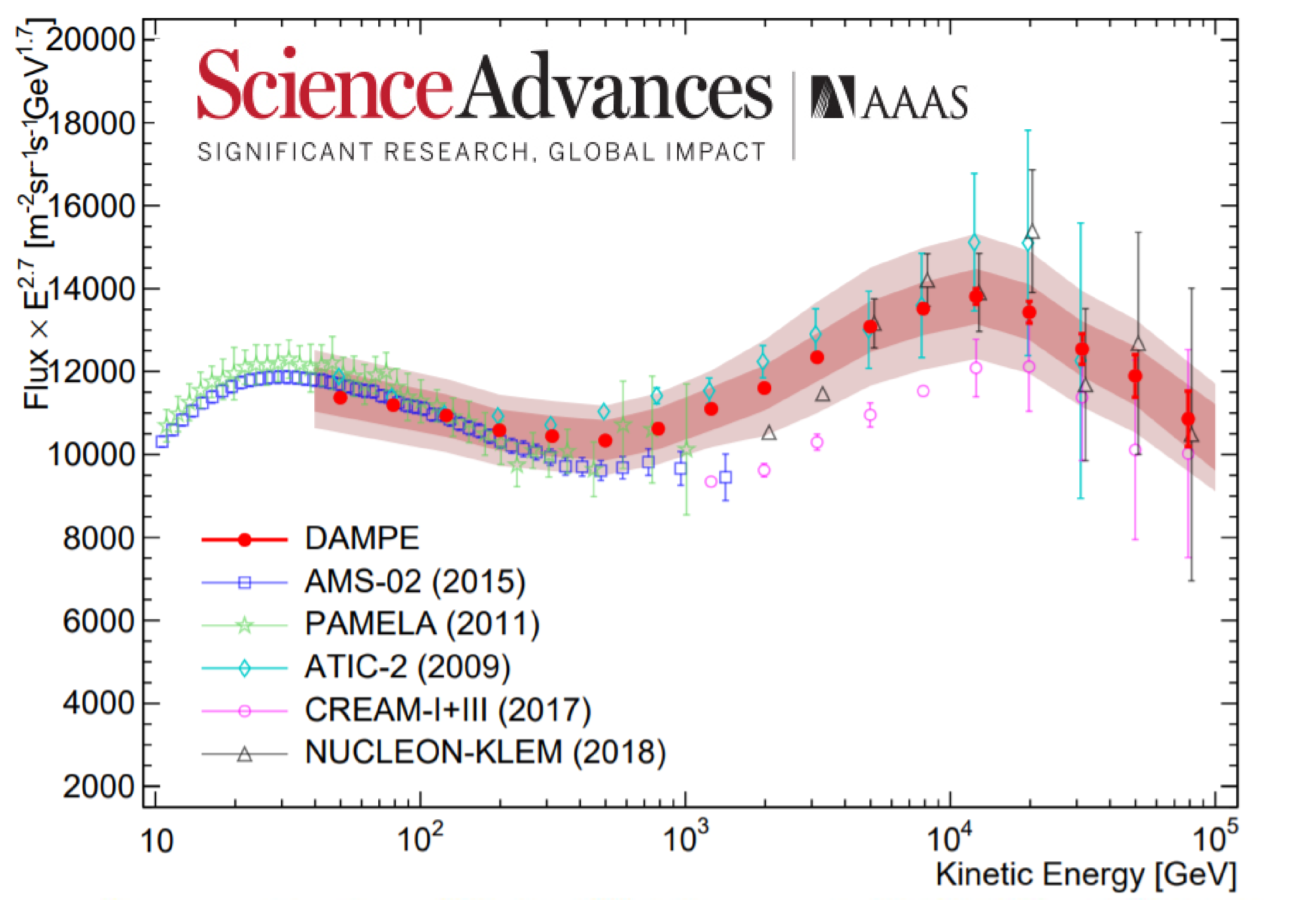


BETHE-BLOCH FORMULA $\frac{dE}{dx} \propto Z^2$

According to the Bethe-Bloch formula, the energy released through ionization inside the PSD by a crossing CR is proportional to the square of its charge.



Proton flux measured by DAMPE



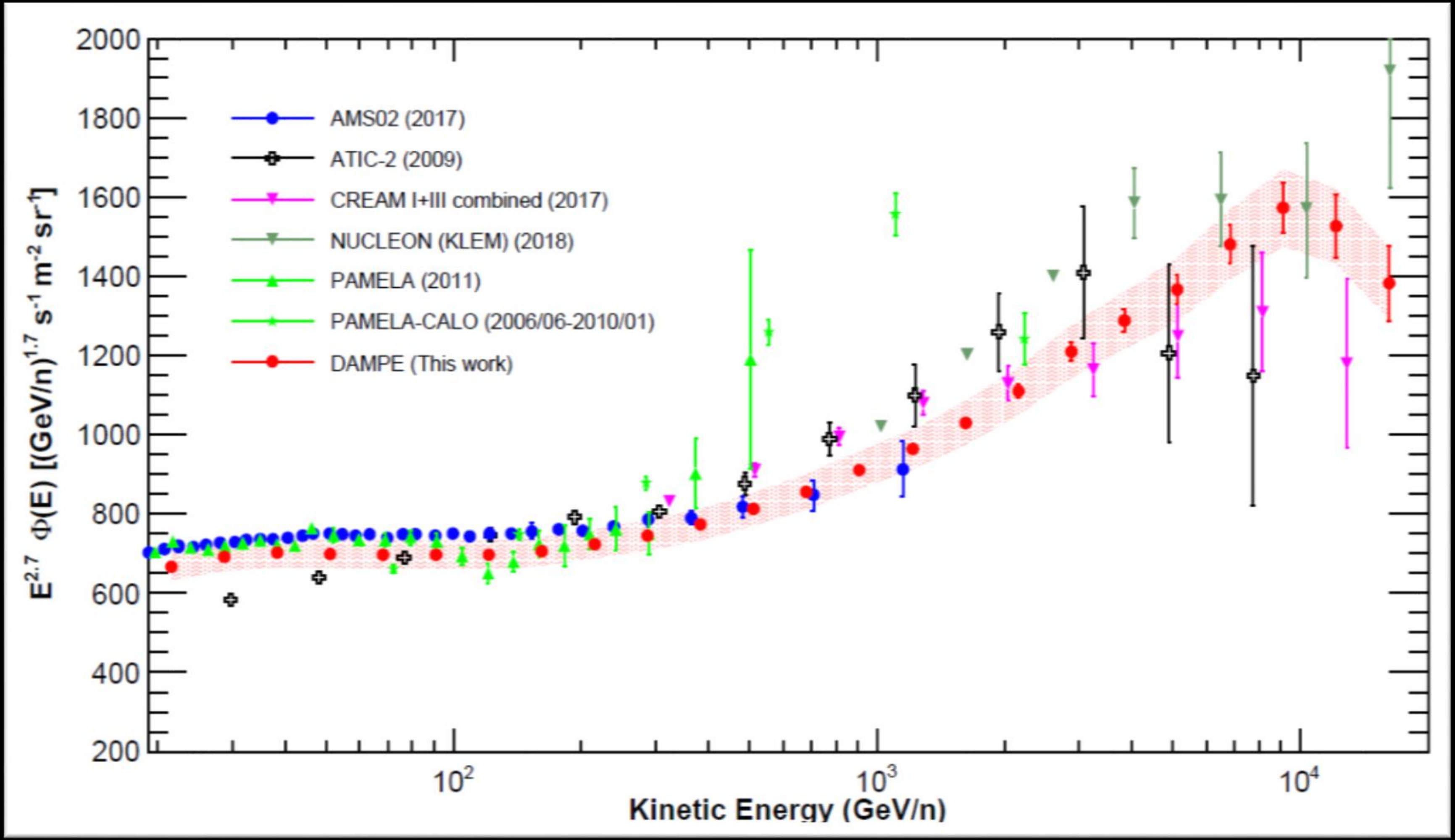
Proton spectrum from 40 GeV to 100 TeV measured with DAMPE (red filled dots).

Q. An et al., *Measurement of the cosmic ray proton spectrum from 40 GeV to 100 TeV with the DAMPE satellite*, Science Advances, 5, 9, (2019).

The proton flux measurement provided by DAMPE confirms a spectral hardening at ~300 GeV previously observed by AMS-01, PAMELA, ATIC and CREAM.

The indication of a spectral softening in the proton spectrum measurement provided by CREAM and NUCLEON has been strongly confirmed and measured with the greatest accuracy by DAMPE at ~ 13 TeV with 4.6 σ of confidence level.

Helium flux measured by DAMPE

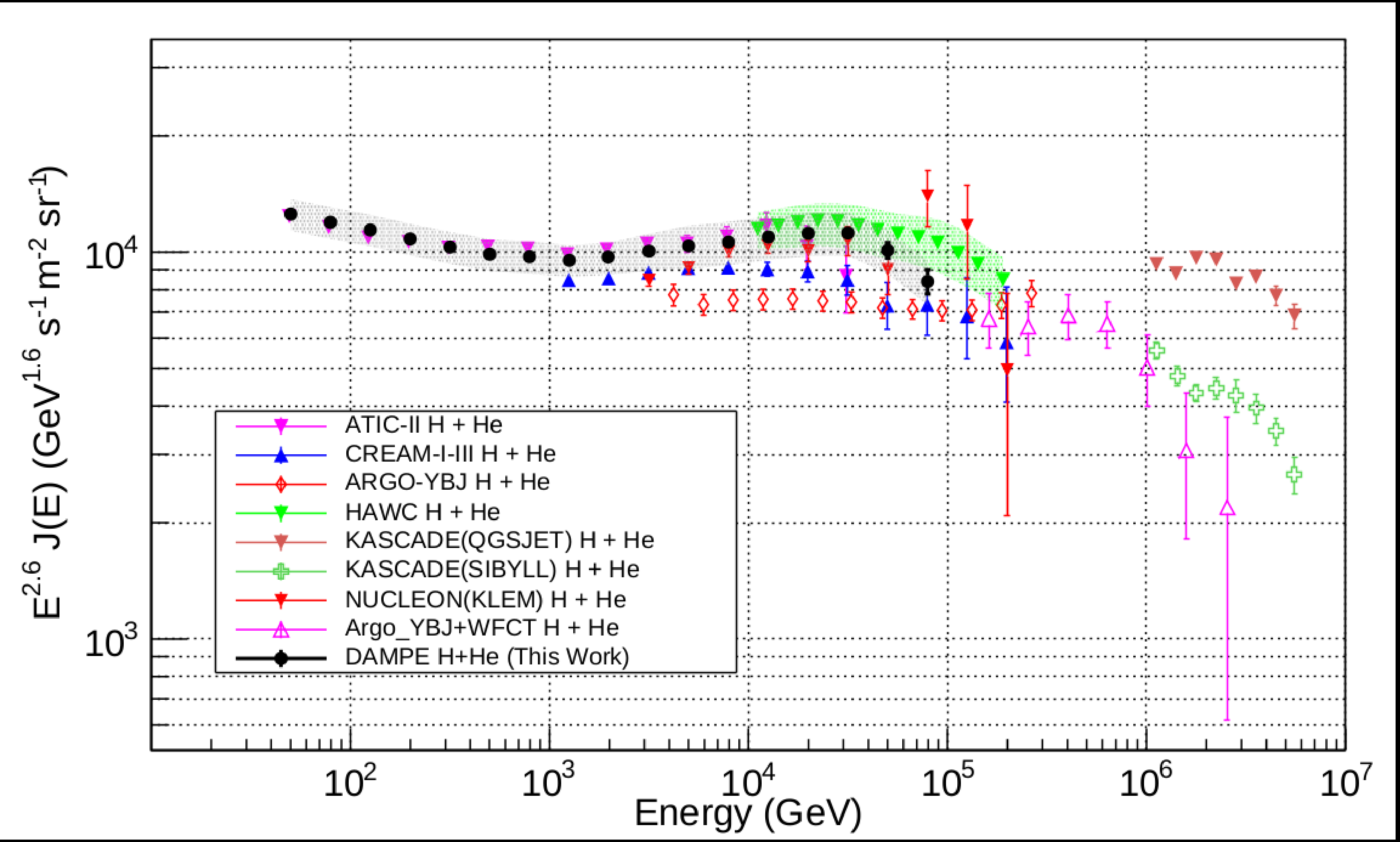


Spectral *hardening* clearly visible at hundreds of GeV/n, confirming the observations highlighted by AMS-02 and PAMELA.

Spectral *softening* revealed at ~10 TeV/n and detected for the first time with a relatively high precision, but confirming the hint provided by CREAM and NUCLEON, even if with lower statistics and larger uncertainties.

The helium paper has been submitted by the DAMPE Collaboration to ***Physical Review Letters (PRL) and it is currently under review***

Proton+Helium flux measured by DAMPE



A measurement of the light component (Proton + Helium) is useful for several reasons:

- Check of consistency with the individual p and He flux measurements (with negligible background);
- DAMPE could work as a bridge between direct and indirect measurements covering a wide energy range.

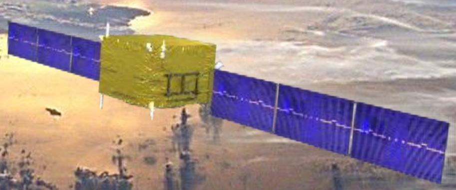
Preliminary results show good agreement with previous experiments. The light component analysis is on-going.

Conclusions

Since the day of its launch, DAMPE has provided very interesting results about the study of Galactic Cosmic Rays, as the measurements of proton and helium spectra with unprecedented energy resolution.

In order to add another piece to the complicated puzzle of the CR origin and propagation, further measurements are still needed for energy spectra of heavier nuclei and at higher energies.

The DAMPE collaboration is currently focused on these topics, aiming to obtain further important results!

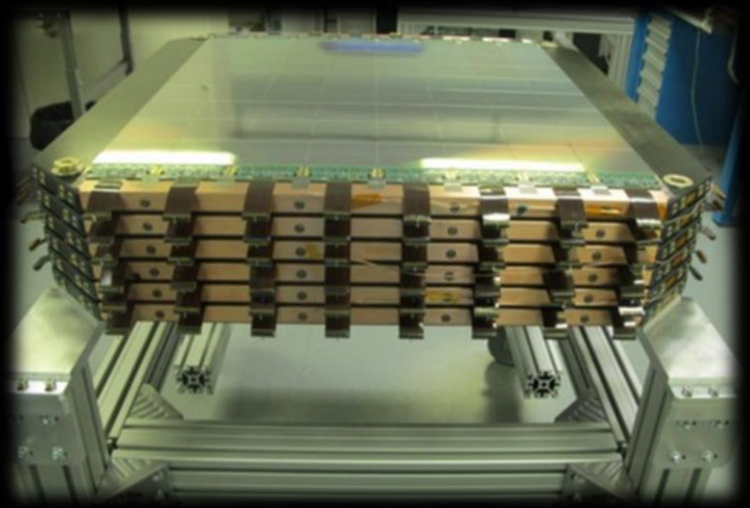



JOIN DAMPE,
THE MONKEY KING WANTS YOU.

THANK YOU

BACKUP

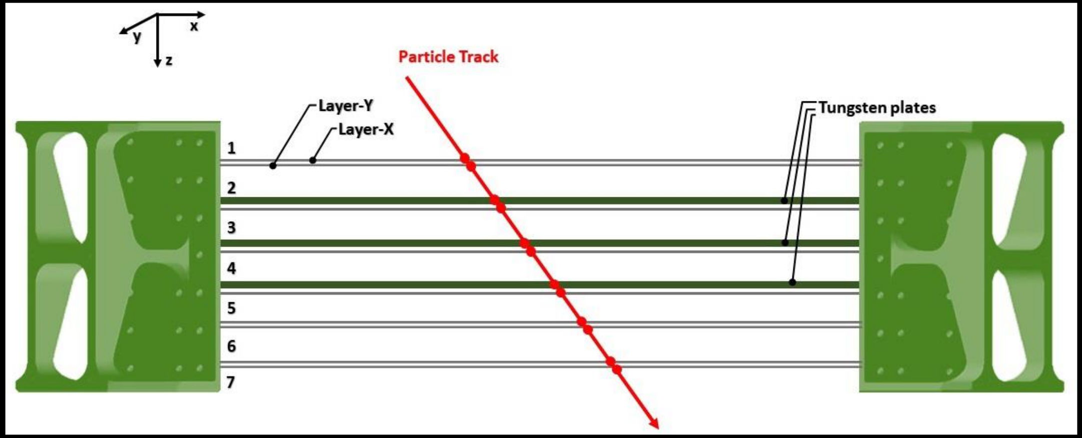
The Silicon-Tungsten tracKer converter

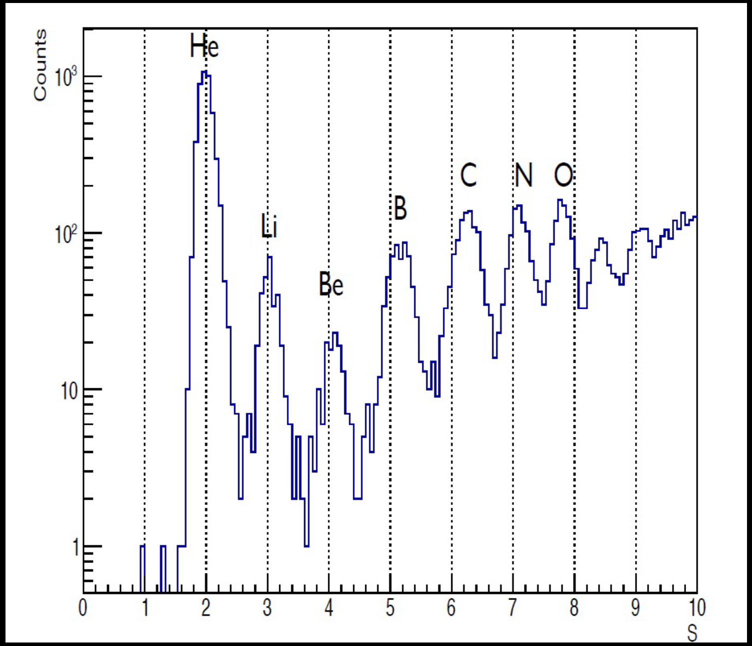


STK

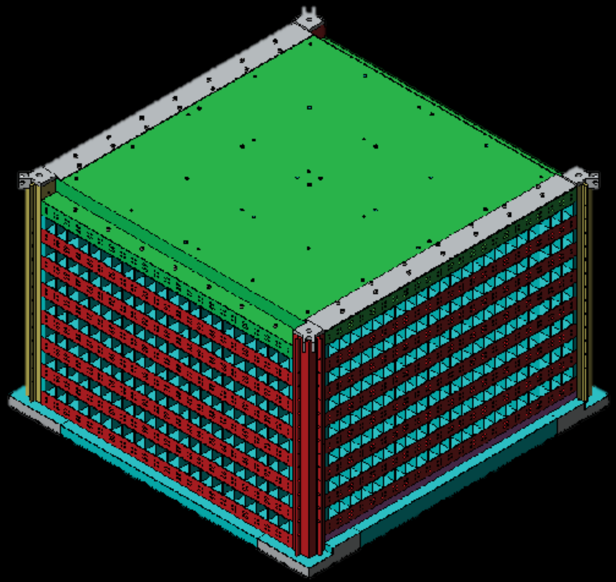
- 6 planes with 2 single-sided silicon layers
- 3 thin tungsten layers (for γ conversion in e^+/e^-)

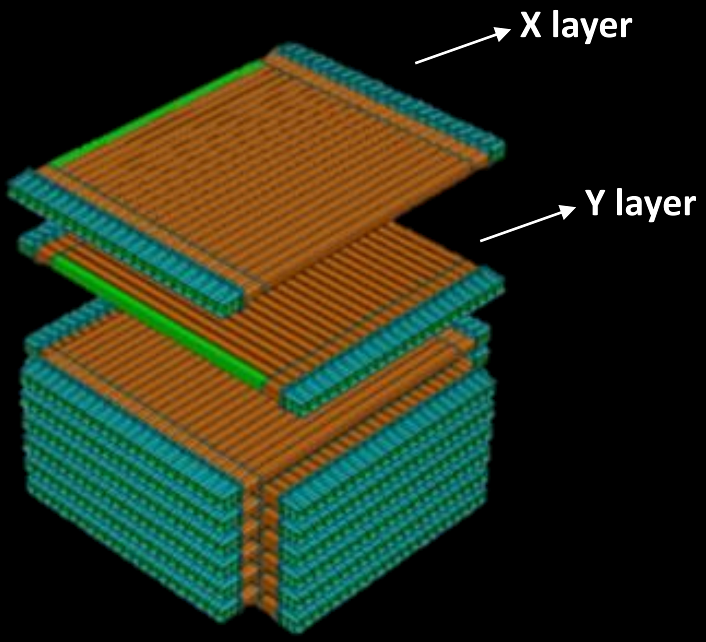
- ❑ TRACK RECONSTRUCTION
  - ❑ spatial resolution <70 μm for CR (θ_{inc}< 60°)
  - ❑ angular resolution ~0.2° for γ at 10 GeV
- ❑ CHARGE MEASUREMENT ($Z \propto \sqrt{ADC}$)





The BGO calorimeter





BGO

- 14 layers, each one with 22 bars of $Bi_3Ge_4O_{12}$, ~32 X_0
- ENERGY MEASUREMENT
  - 1 GeV - 10 TeV for electrons and γ
  - 50 GeV - 100 TeV for nuclei

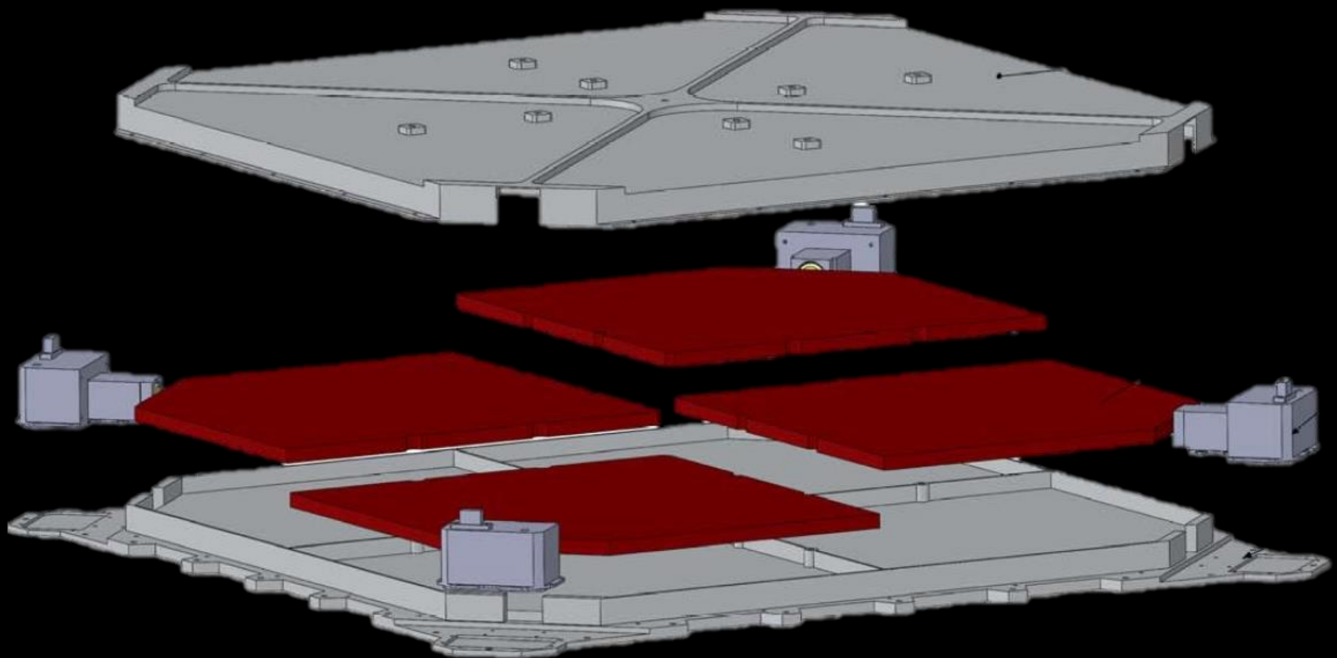
The BGO calorimeter provides 4 triggers:

- **UnBiased Trigger (UBT)**
- **High Energy Trigger (HET)**
- **Low Energy Trigger (LET)**
- **MIP Trigger (MIPT)**

Energy resolution: 1.5%@800GeV (e/γ)
<40%@800GeV (p)

The energy resolution for helium nuclei is about 20% for a 40 GeV/n beam and 25% for a 75 GeV/n beam, in the case of normal incidence. For all the other ions it is always better than 30%.

The NeUtron Detector



The relative abundance of neutrons in hadronic showers is much higher with respect to the electromagnetic case, with a difference of almost one order of magnitude in some cases. These neutrons thermalize after few microseconds and they can be detected by the NUD observing the result of the neutron capture process:

$$^{10}\mathrm{B} + n \rightarrow {}^{7}\mathrm{Li} + \alpha + \gamma$$

NUD

- 1 layer, 4 boron-doped plastic scintillators
- detection of neutrons generated in the BGO for hadron/e.m. showers discrimination