

# Detecting **Dark Matter** in Space

## **Alpha Magnetic Spectrometer**

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# Evidence for Dark Matter

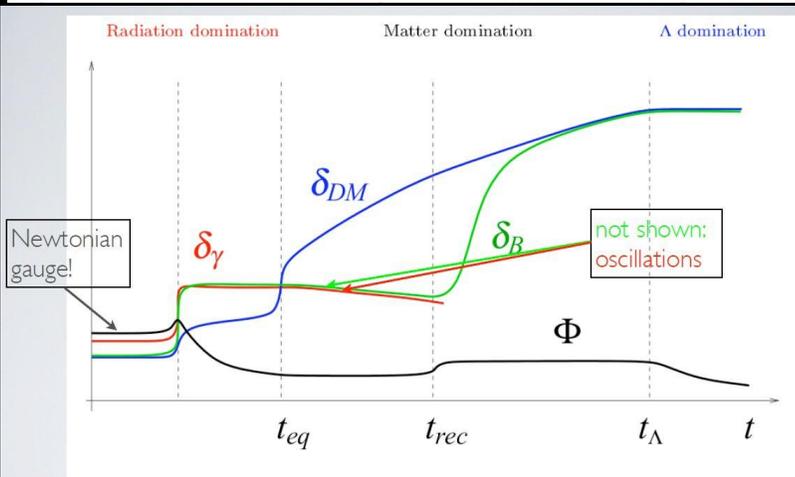
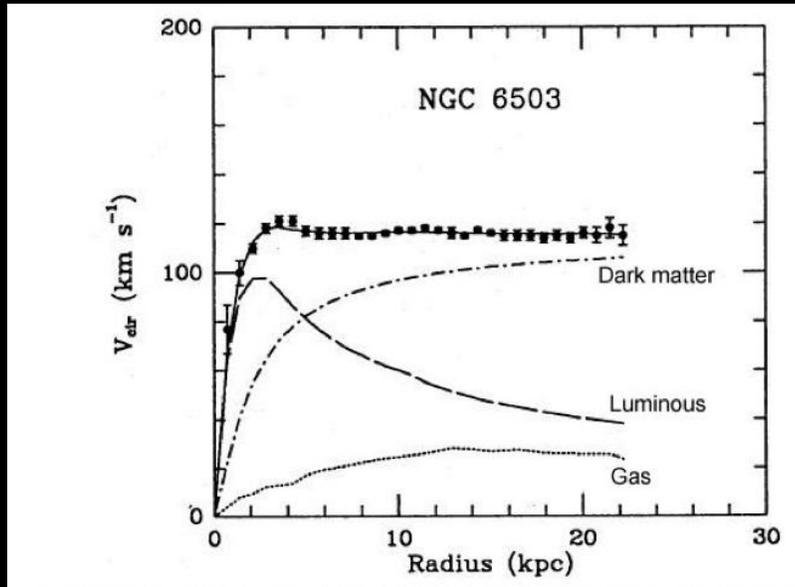
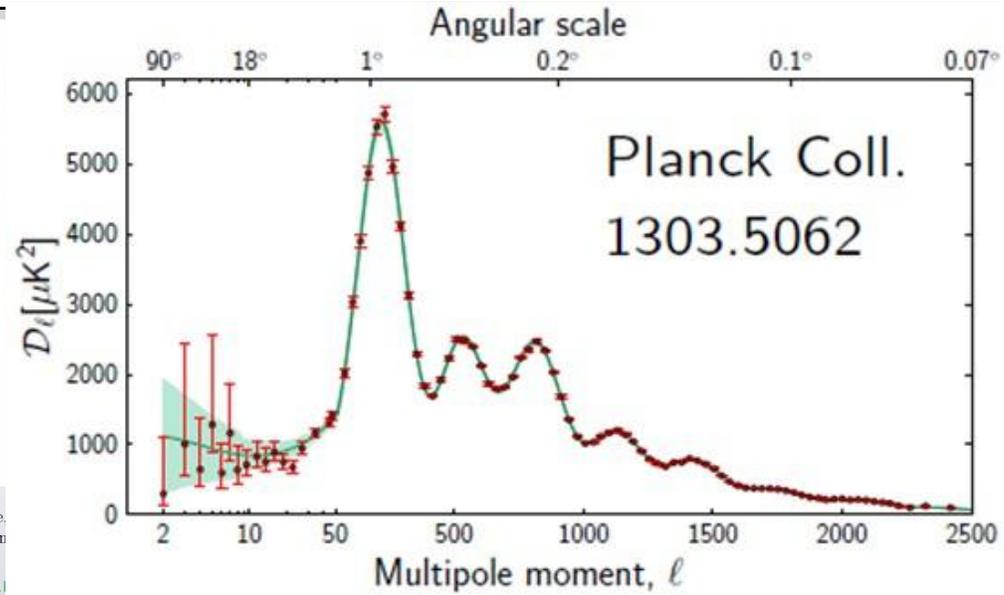
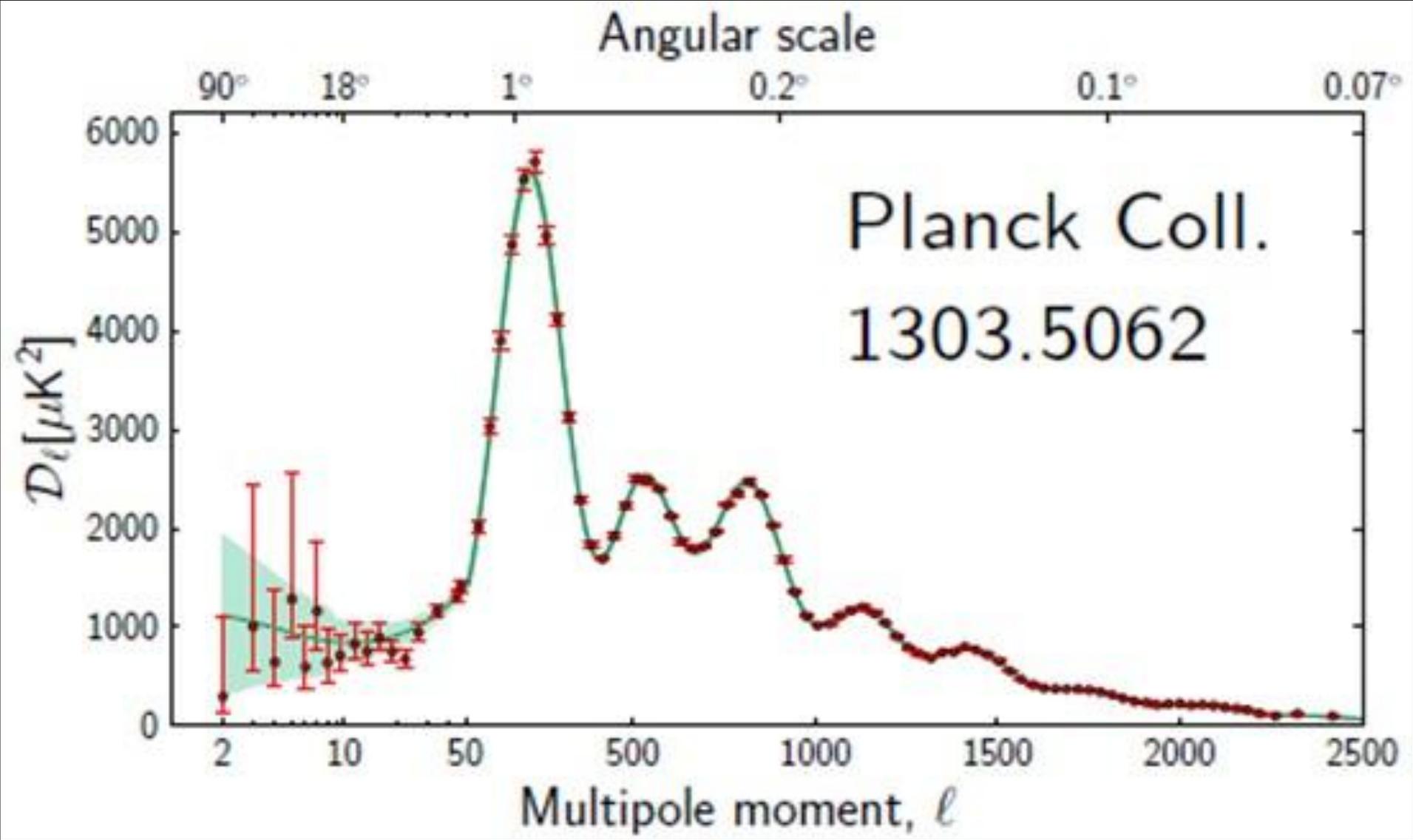


Figure 5: Schematic plot of the evolution of density perturbations in different components. Here,  $\delta = \delta\rho/\rho$ , and  $\Phi$  is the gravitational potential. The left dashed vertical line is the time of horizon crossing of a mode considered.

Rubakov & Vlasov, I008.





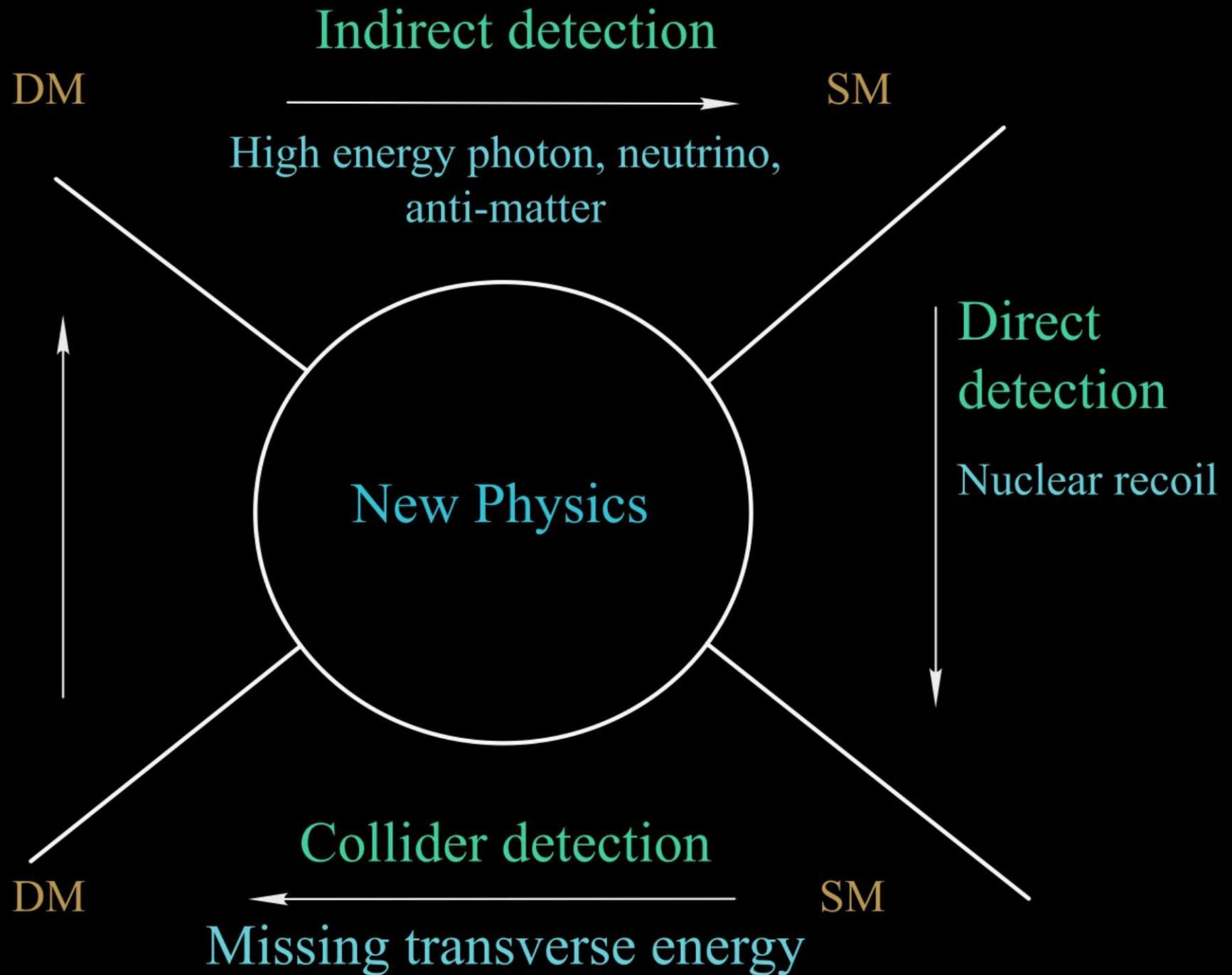
Dark Energy (69.3%)  
 $\Omega_{\Lambda} = 0.692 \pm 0.012$

Baryonic Matter (4.8%)  
 $\Omega_b h^2 = 0.02226 \pm 0.00023$

Cold Dark Matter (25.8%)  
 $\Omega_c h^2 = 0.1186 \pm 0.0020$



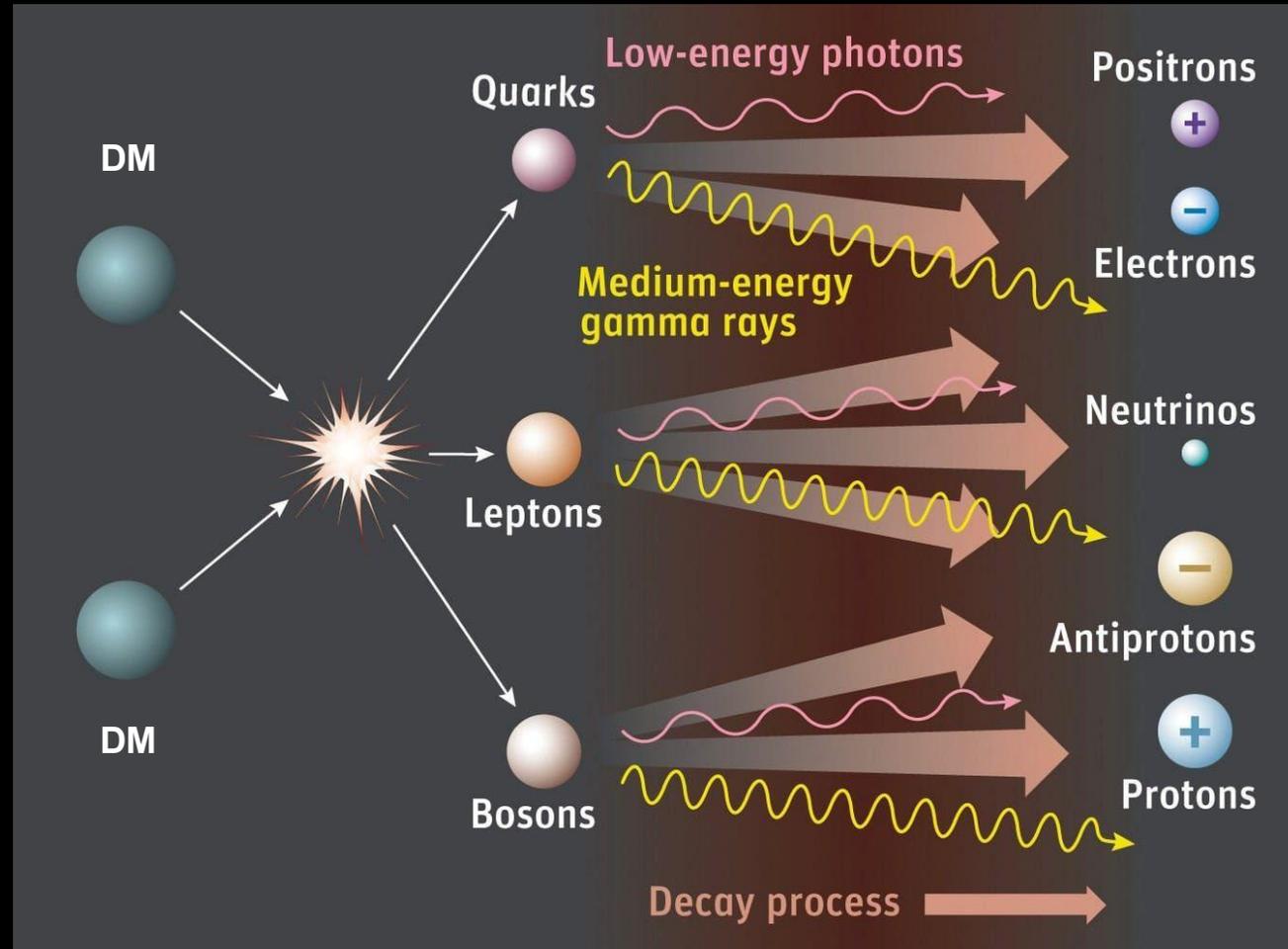
Planck 2015



# Dark Matter Indirect Detection

Dark matter particles (+ dark matter particles) → charged cosmic rays,  $\gamma$  rays, neutrinos  
The annihilation or decay processes of dark matter particles provide additional contributions to these particles

Related experiments: PAMELA, ATIC, Fermi, IceCube, AMS-02, DAMPE, ...



# AMS is a unique, precision magnetic spectrometer on the Space Station

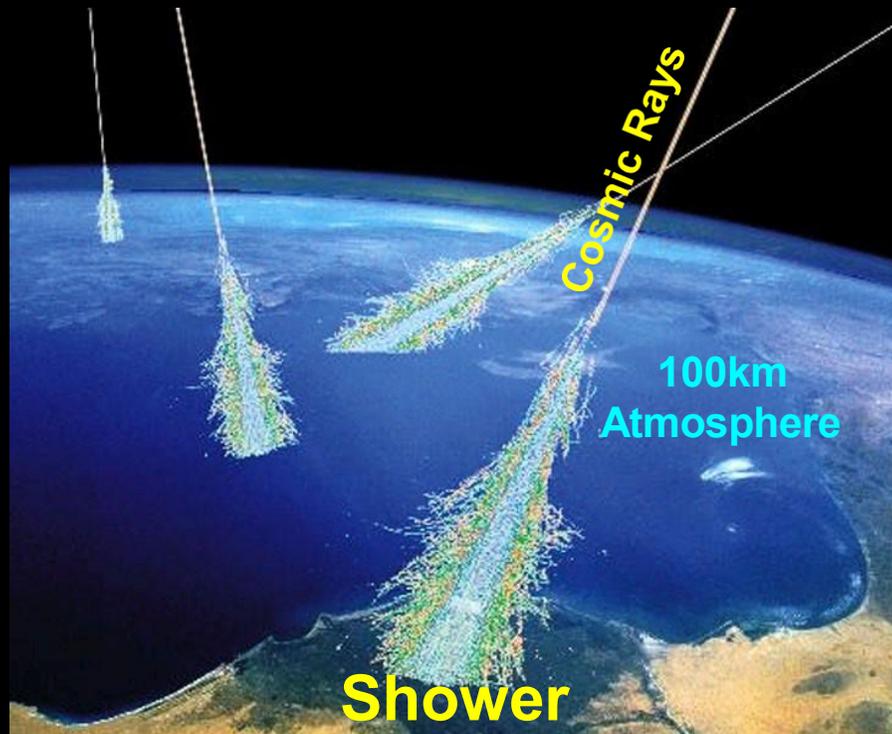
Physics of Dark Matter, Antimatter, the Origin of the Cosmos, and new phenomena through the precision, long-duration measurement of charged cosmic rays

Charged cosmic rays are absorbed by the 100 km of Earth's atmosphere.

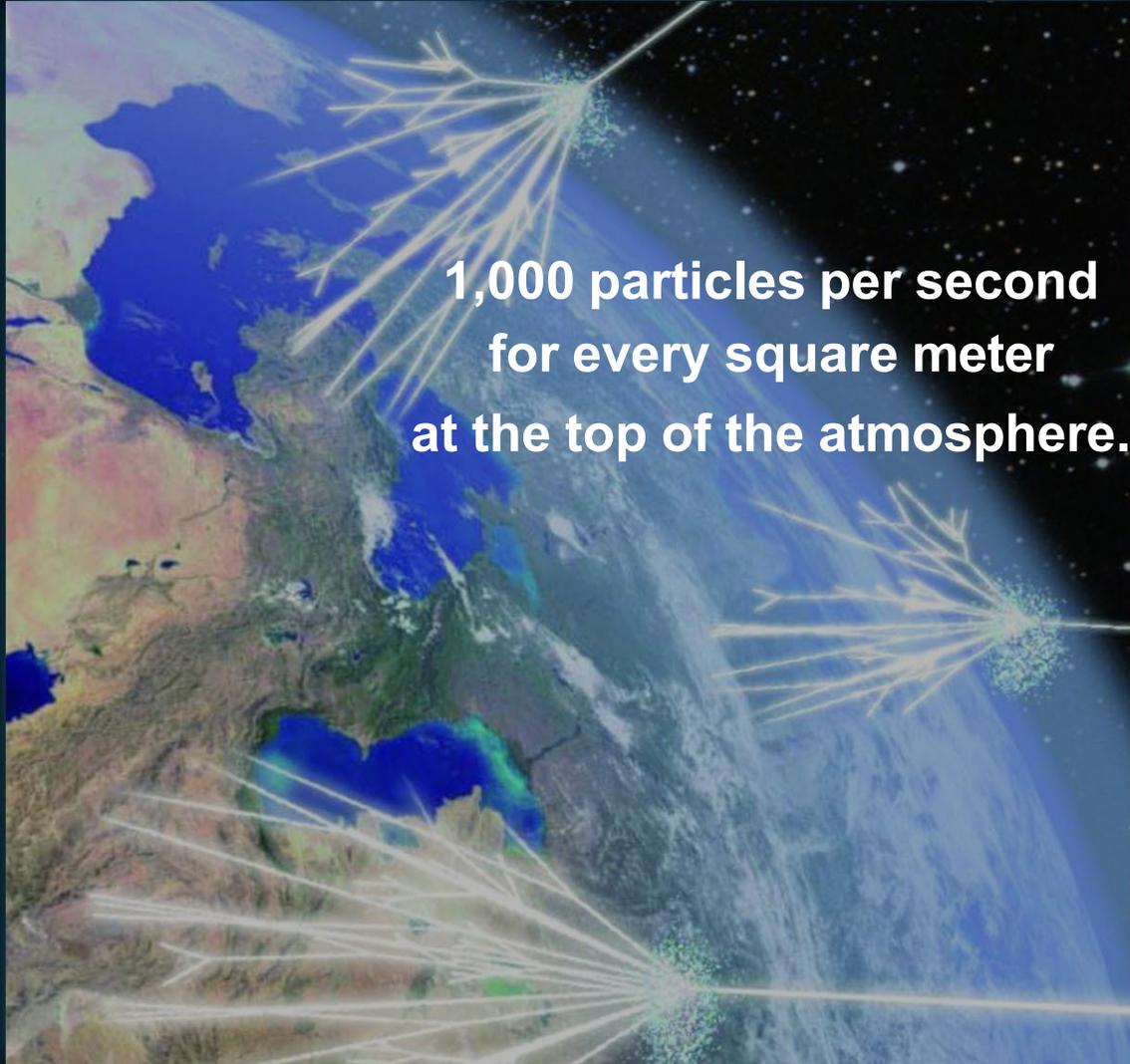
Their properties ( $\pm Z, P$ ) cannot be studied on the ground.

To measure cosmic ray charge and momentum

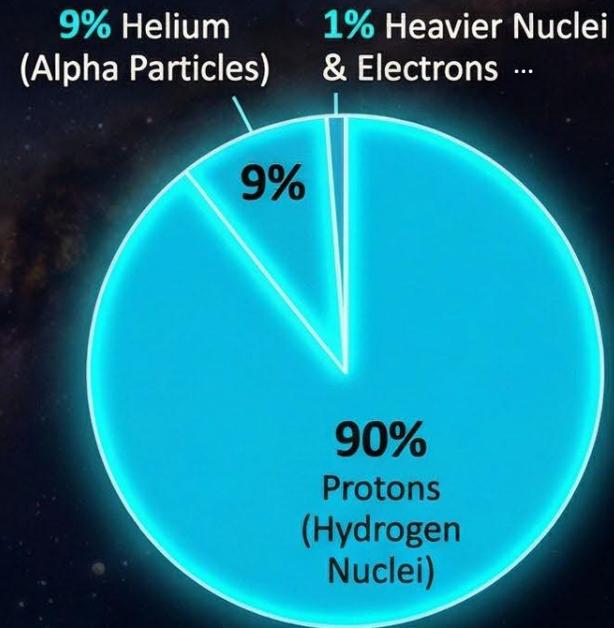
requires a magnetic spectrometer in space.



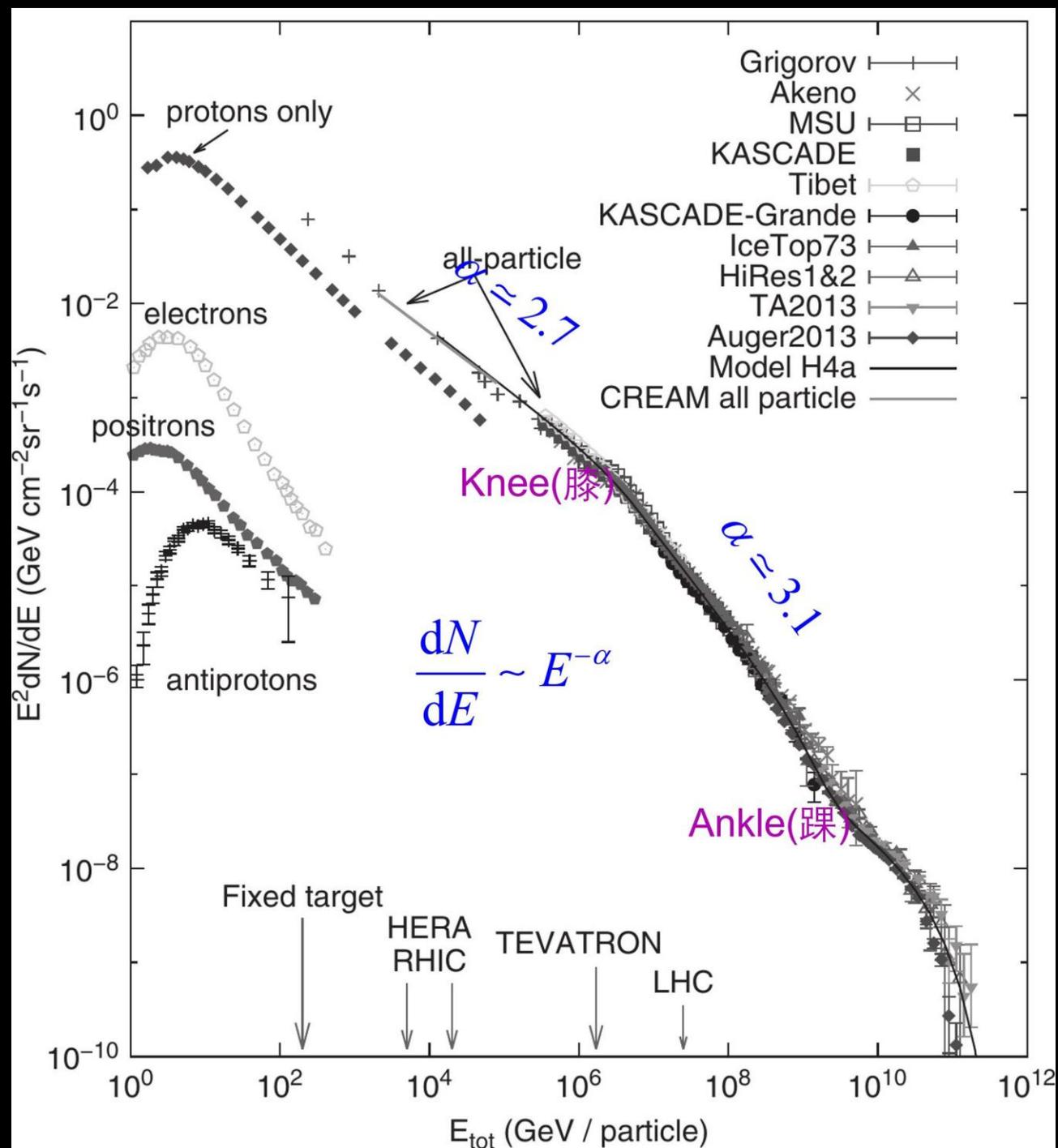
# A brief recap of cosmic rays

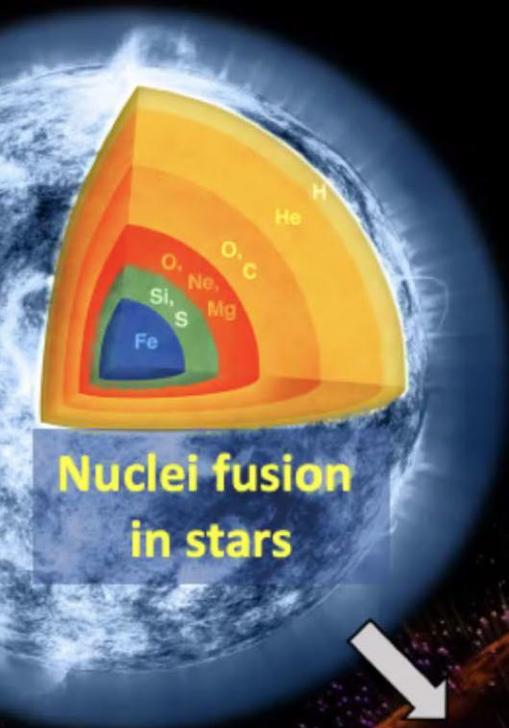


## Cosmic Ray Composition



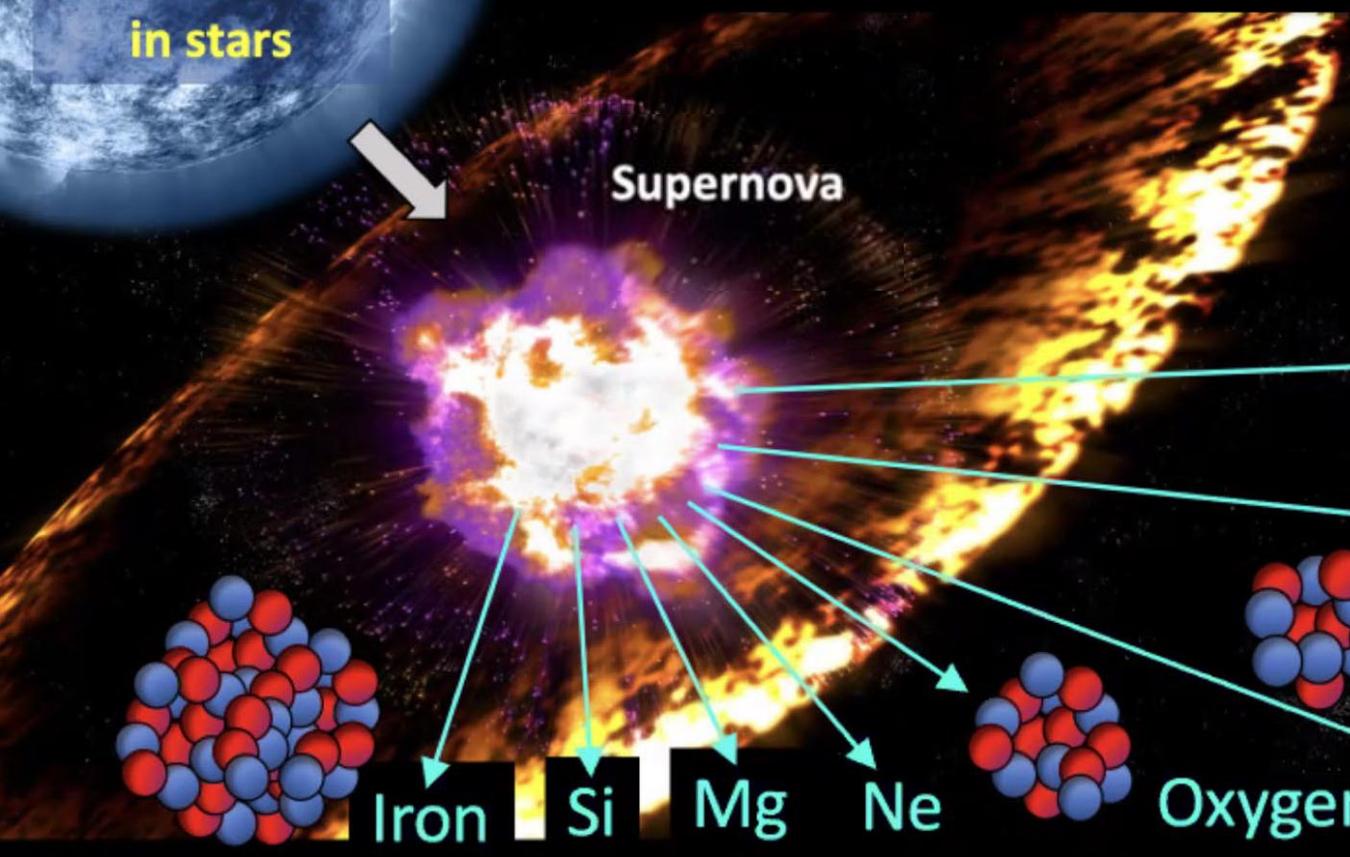
- **90%** Protons (Hydrogen Nuclei)
- **9%** Helium (Alpha Particles)
- **1%** Heavier Nuclei & Electrons





Primary cosmic ray particles are mainly produced during the lifetime of stars and accelerated by supernova shockwaves in the Milky Way.

Primary cosmic ray particles include: electrons, protons (p), helium (He), carbon (C), oxygen (O), neon (Ne), magnesium (Mg), silicon (Si), ..., iron (Fe), and other atomic nuclei.



The energy spectrum of primary cosmic rays, as measured, contains information about their source, acceleration process, and propagation.

● Proton

● Helium

● Carbon

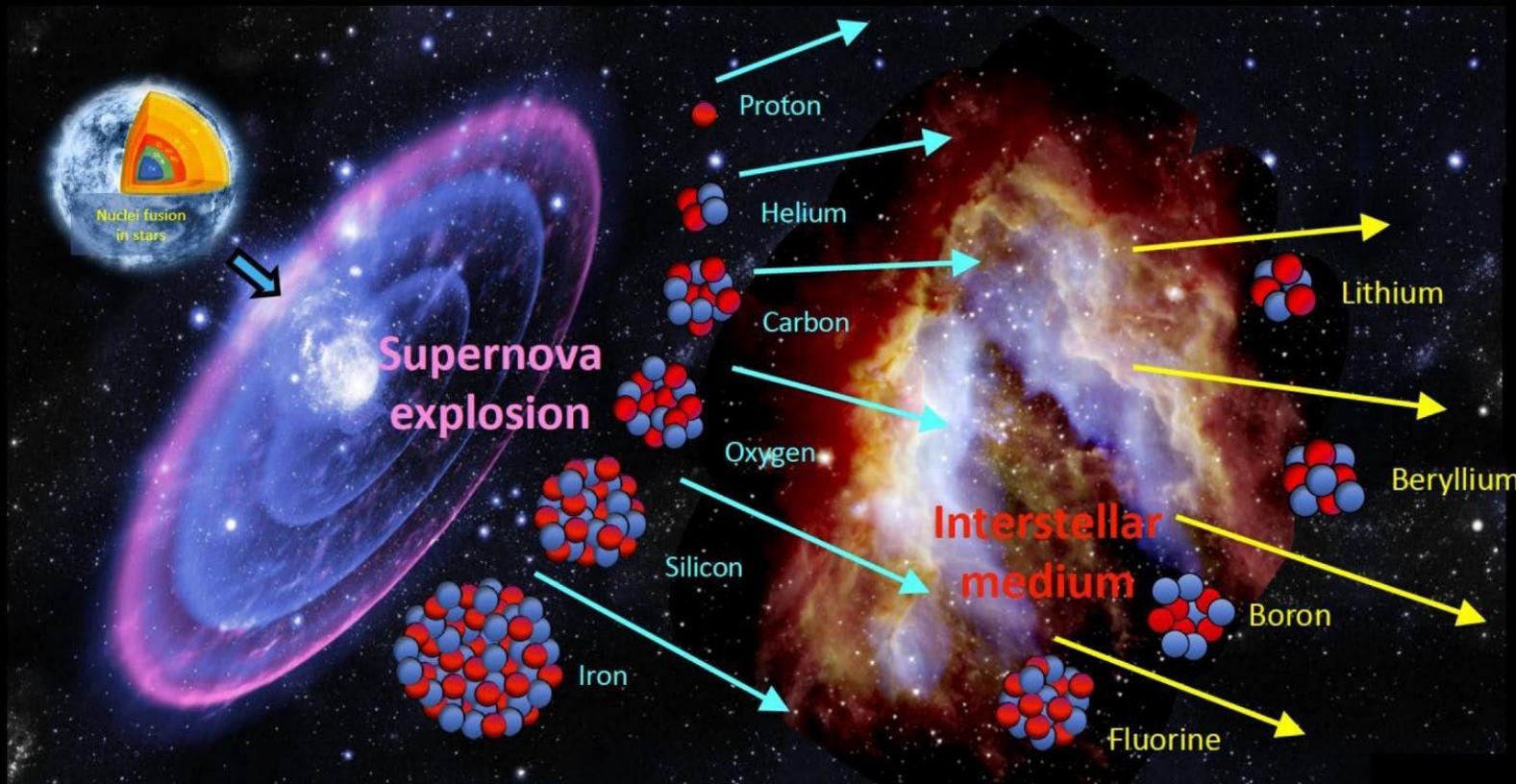
Iron

Si

Mg

Ne

Oxygen



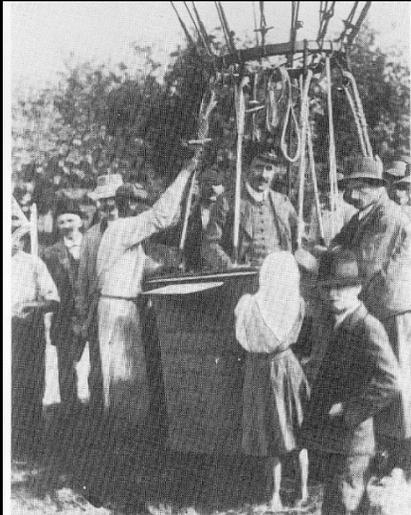
**Secondary cosmic ray** particles are produced by the collisions between primary cosmic ray particles and the **interstellar medium (ISM)**.

Secondary cosmic ray particles include: positrons, antiprotons, and nuclei such as **Lithium (Li)**, **Beryllium (Be)**, **Boron (B)**, and **Fluorine (F)**.

Secondary cosmic ray particles flux, as well as the "secondary-to-primary flux ratio" (e.g., B/C), is crucial for understanding the galactic **propagation, reacceleration** ... of cosmic rays.

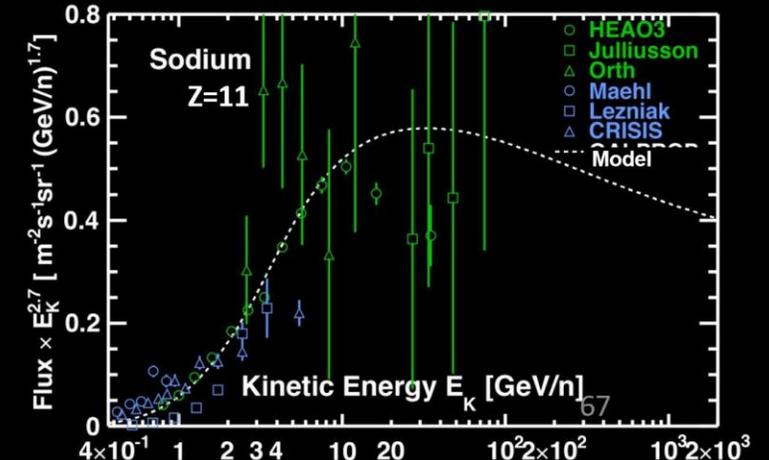
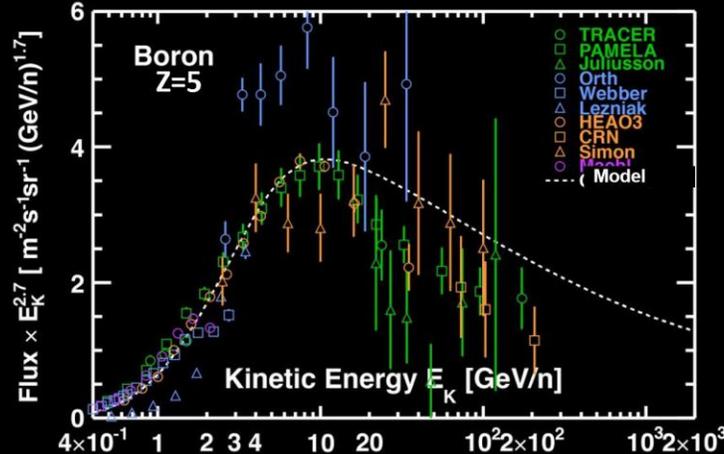
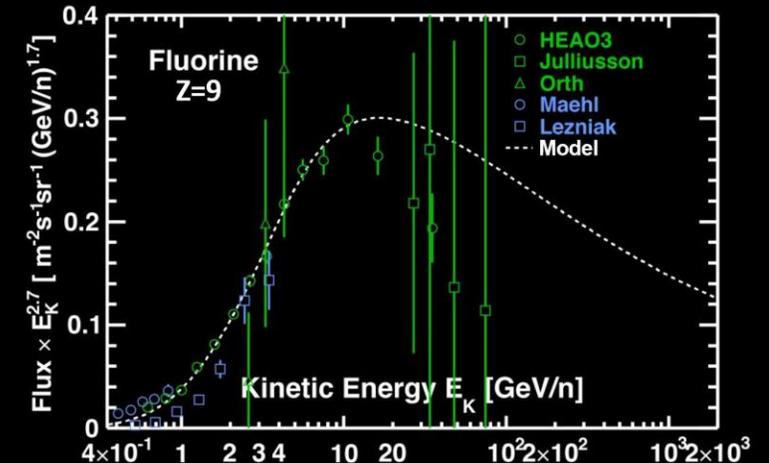
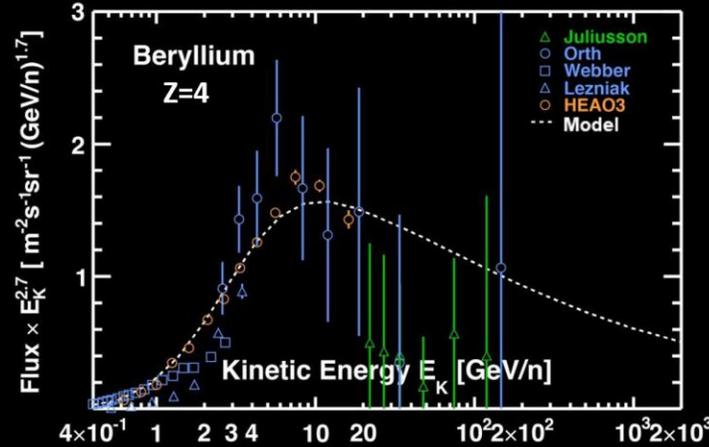
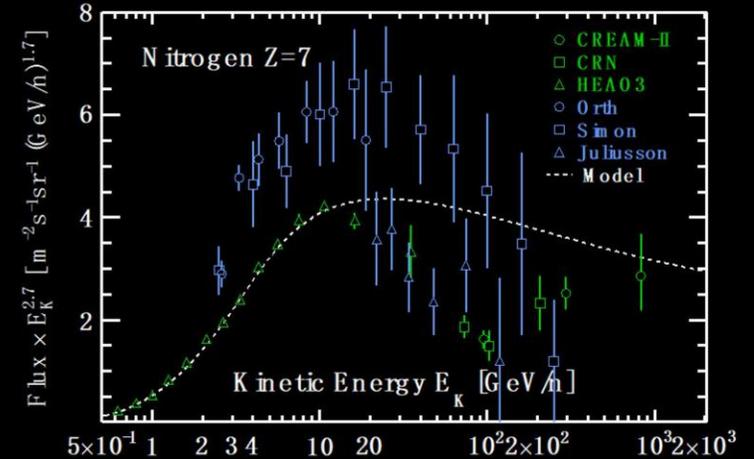
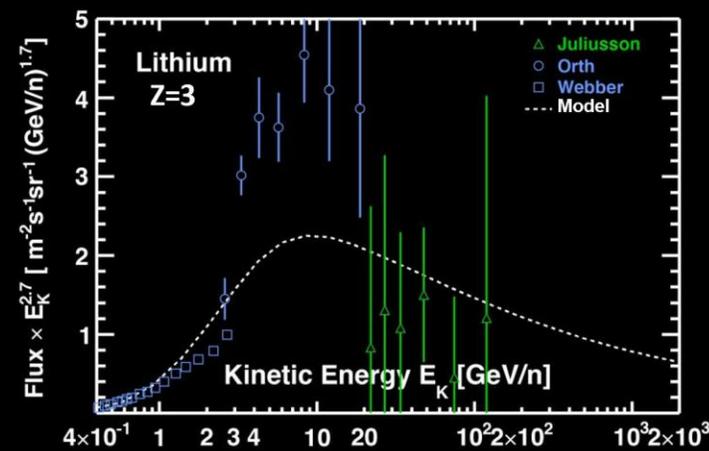
# Cosmic Rays in the last 100 years

1912:  
Discovery of Cosmic  
Rays



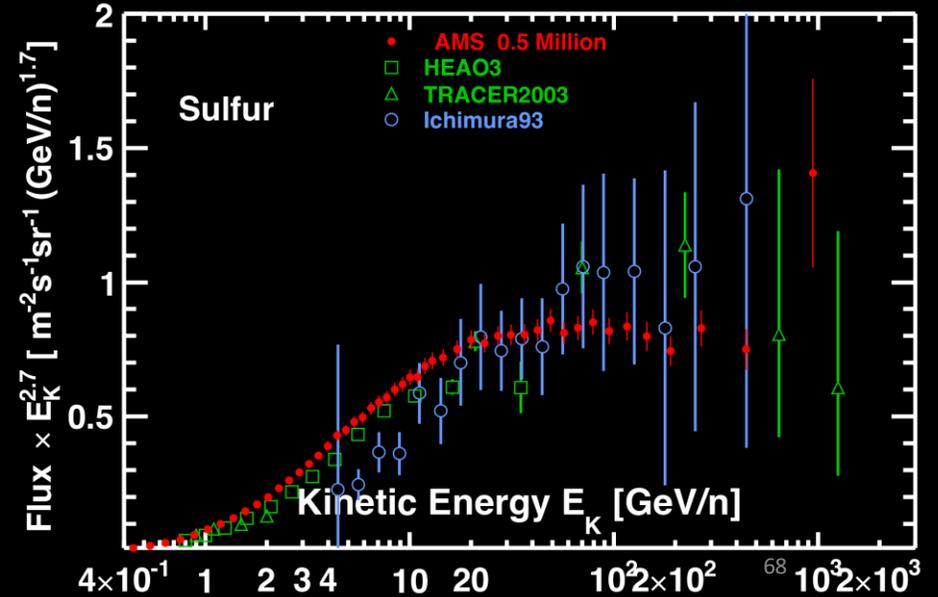
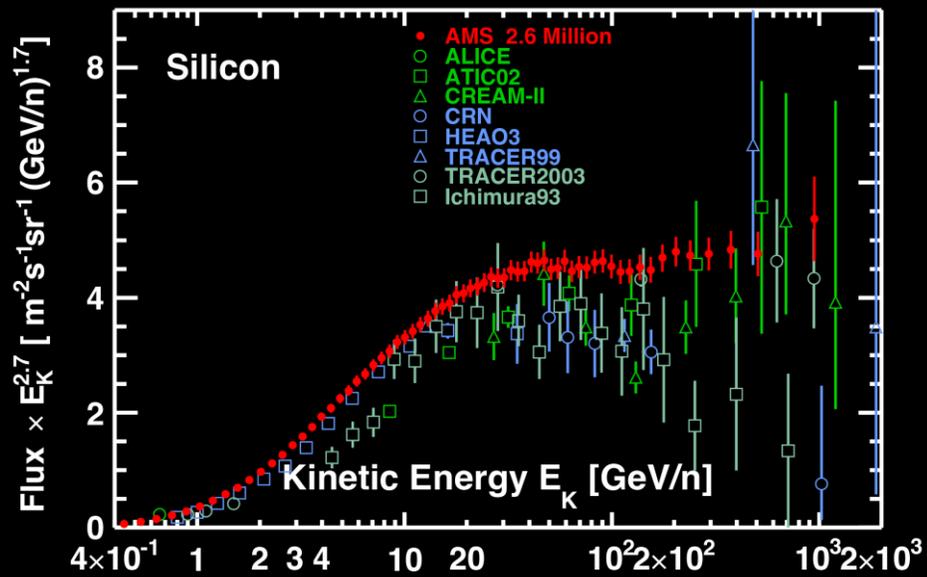
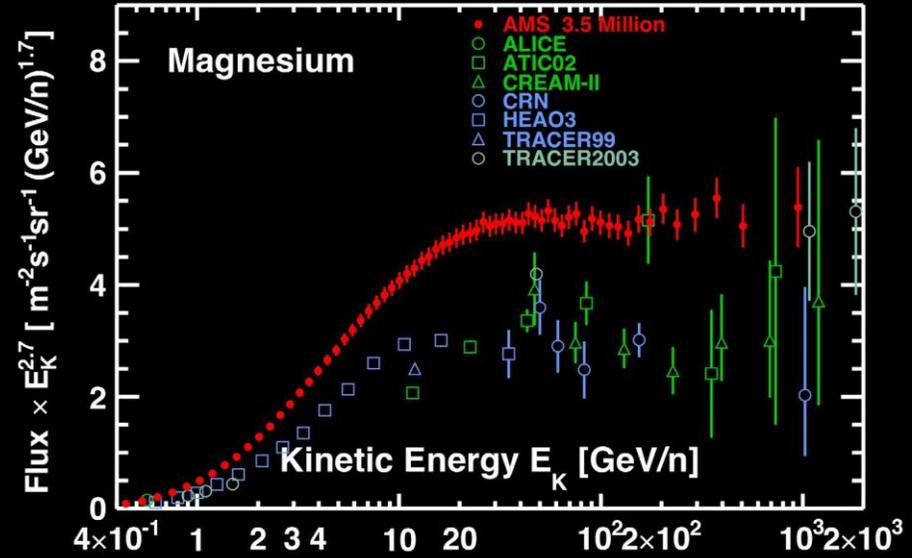
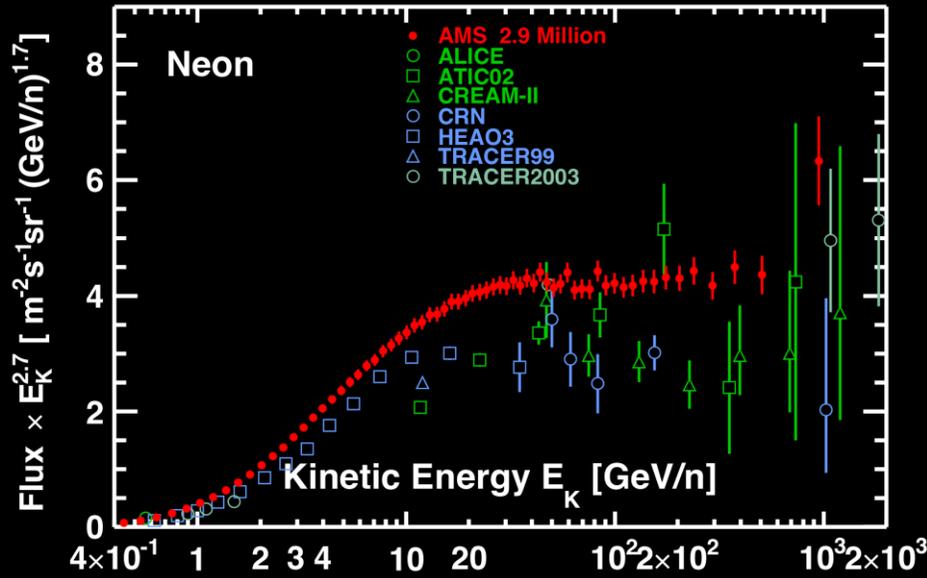
Victor Hess  
Nobel Prize (1936)

Before AMS:  
Many theoretical  
models agree with  
experimental data



# Examples of AMS Results compared with earlier measurements

The precision of all AMS results cannot be explained by current models.



# AMS is a space version of a precision magnetic spectrometer used at accelerators

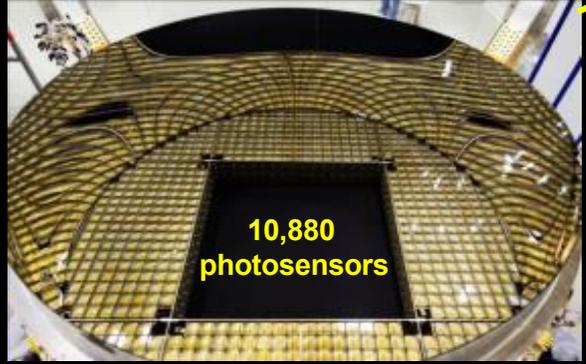
Transition Radiation Detector (TRD)  
identify  $e^+$ ,  $e^-$



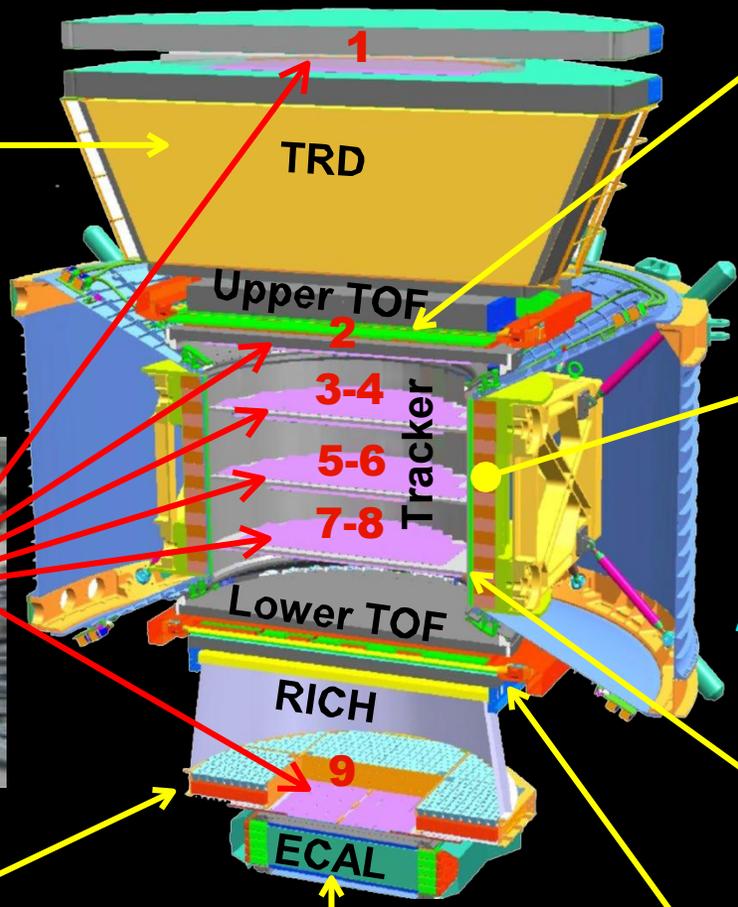
Silicon Tracker  
measure Z, P



Ring Imaging Cherenkov (RICH)  
measure Z, E



10,880  
photosensors



Electromagnetic Calorimeter (ECAL)  
measure E of  $e^+$ ,  $e^-$



Upper TOF measure Z, E



Magnet identify  $\pm Z, P$



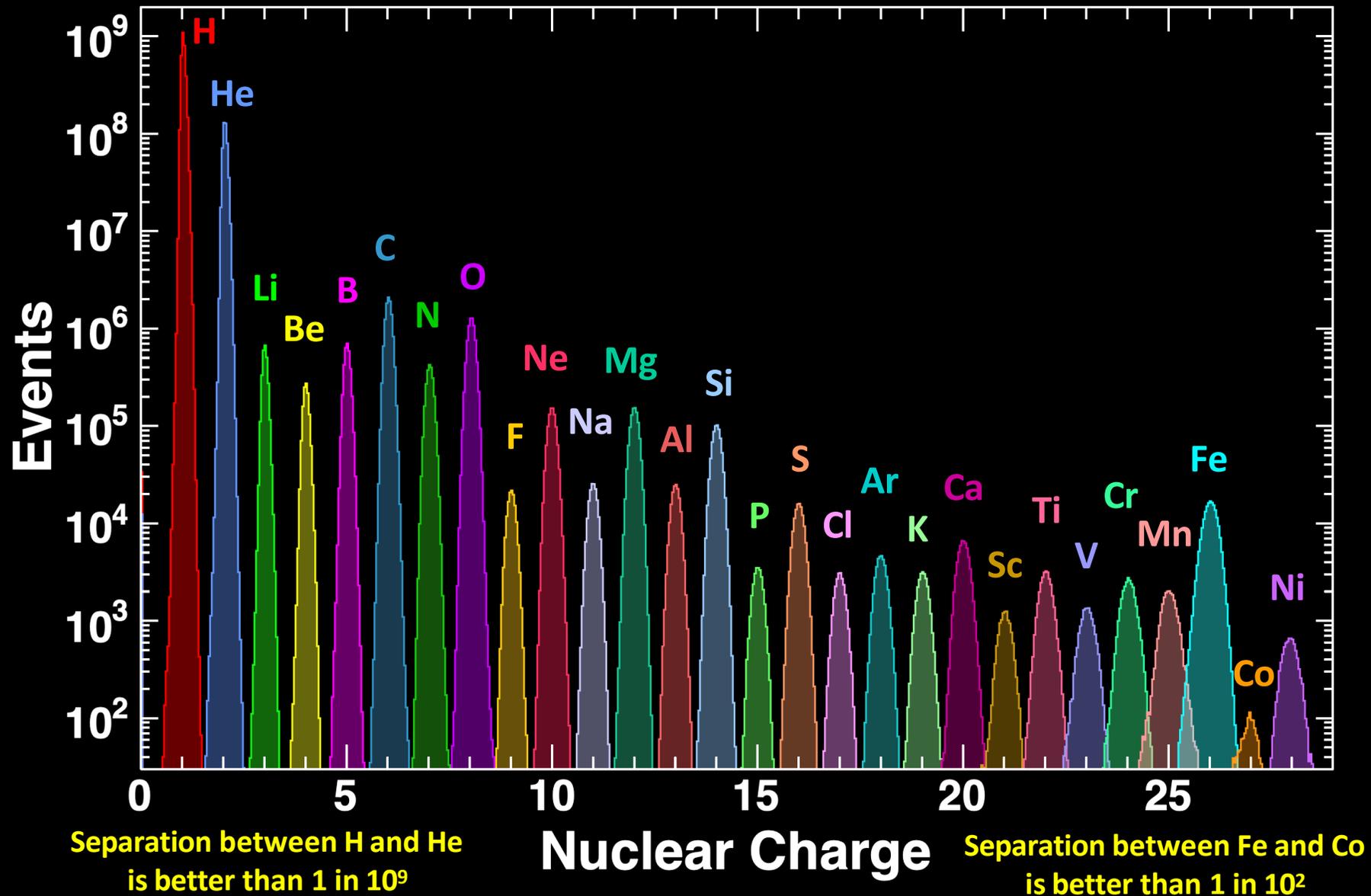
Anticoincidence Counters (ACC)  
reject particles from the side



Lower TOF measure Z, E



# Charge measurement using multiple AMS subdetectors in combination





# AMS Payload Operations Control Center at CERN



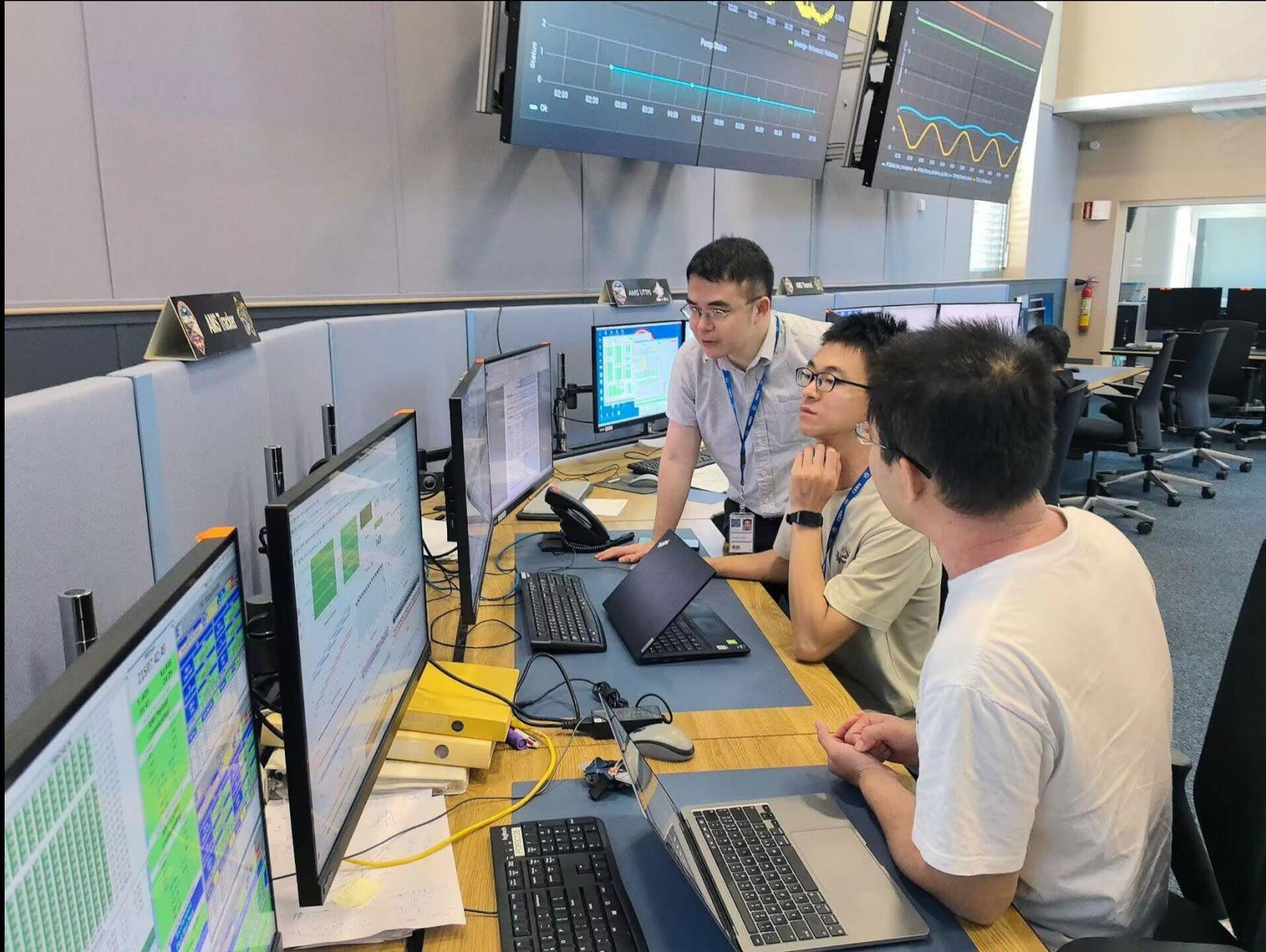
**Flight and Ground Operations**

**Detector Operations**

**Thermal Operations**

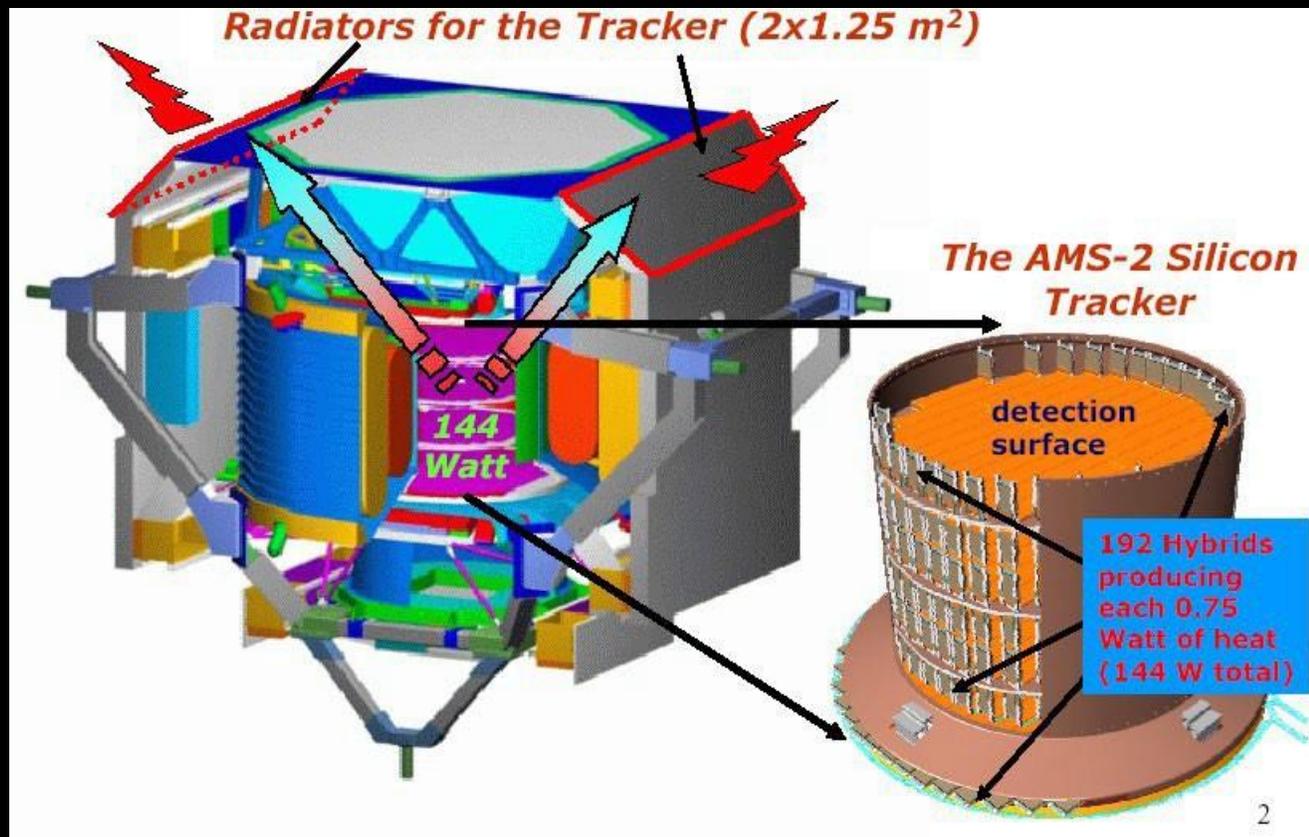
**Fully staffed 24 hours per day, 365 days per year**

# Faculty and students from Sun Yat-sen University participating in AMS shifts



## Tracker Thermal Control System (TTCS) design by SYSU :

- **Small radiator size ( $\varnothing$  2.6 m, 9 m)**
- **High temperature uniformity and stability ( $\ll$  1 K per 10 m over 90 min)**
- **Operating temperature range:  $-15\text{ }^{\circ}\text{C}$  to  $+15\text{ }^{\circ}\text{C}$**



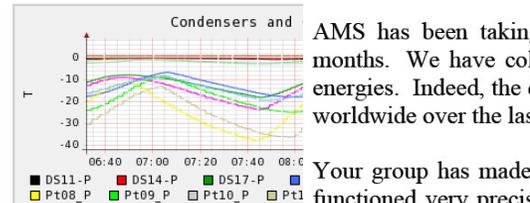
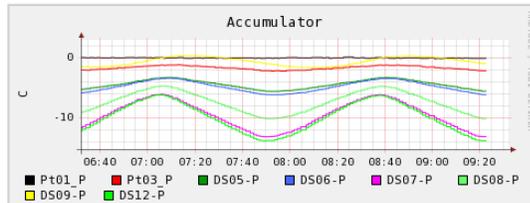
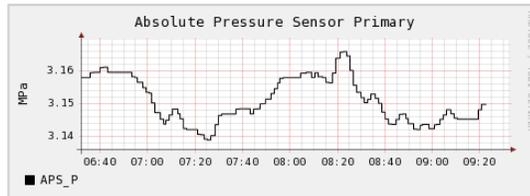
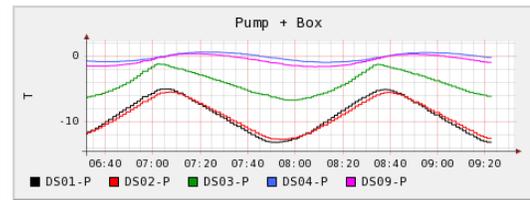
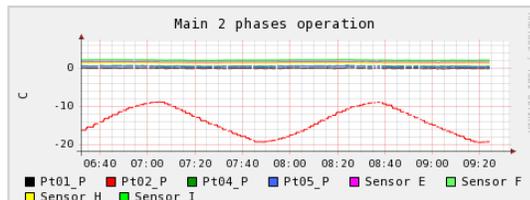
# AMS-TTCS has been operating reliably and stably in orbit for more than three and a half

## TTCS Health Primary

Showing last hour 3\_hours 6\_hours day 3\_days week

Until now or 09:32 27/06/2011

TTCE-A  
TTCE-B



Dear Professor He,

AMS has been taking data successfully on the International Space Station for close to six months. We have collected an enormous amount of data from cosmic rays at extremely high energies. Indeed, the data that we have collected are more than all the cosmic-ray data combined worldwide over the last hundred years.

Your group has made important contributions to the AMS Tracker Cooling system, which has functioned very precisely and reliably. This is the first system of its kind to be used in space. This cooling system will be extremely important for future space exploration, particularly for manned space flights to distant planets. I also believe that the Tracker Cooling system will have many industrial and scientific applications on the ground.

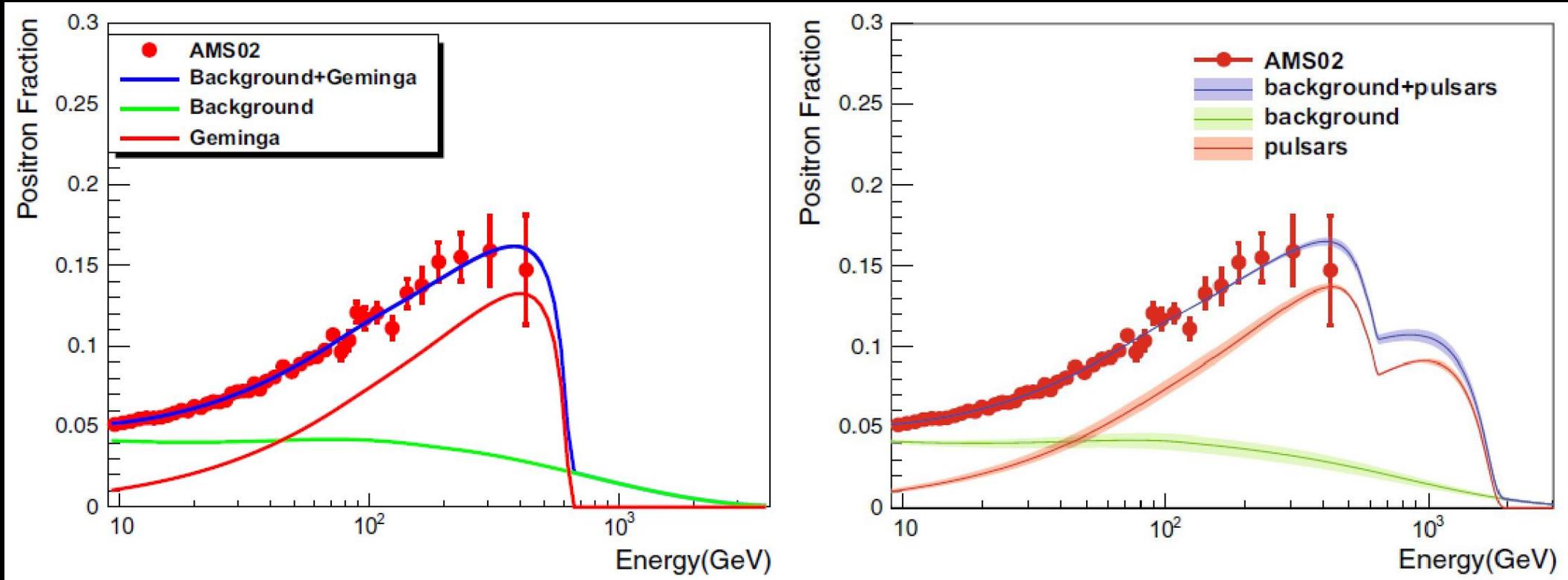
Please accept my congratulations for your successful completion of this important task.

May I advise you to write up the design, the construction, the testing and the operational experience of the AMS Tracker Cooling System together with your colleagues from Holland, Italy, M.I.T. and Taiwan, and have it published in Nuclear Instruments & Methods.

With best regards,



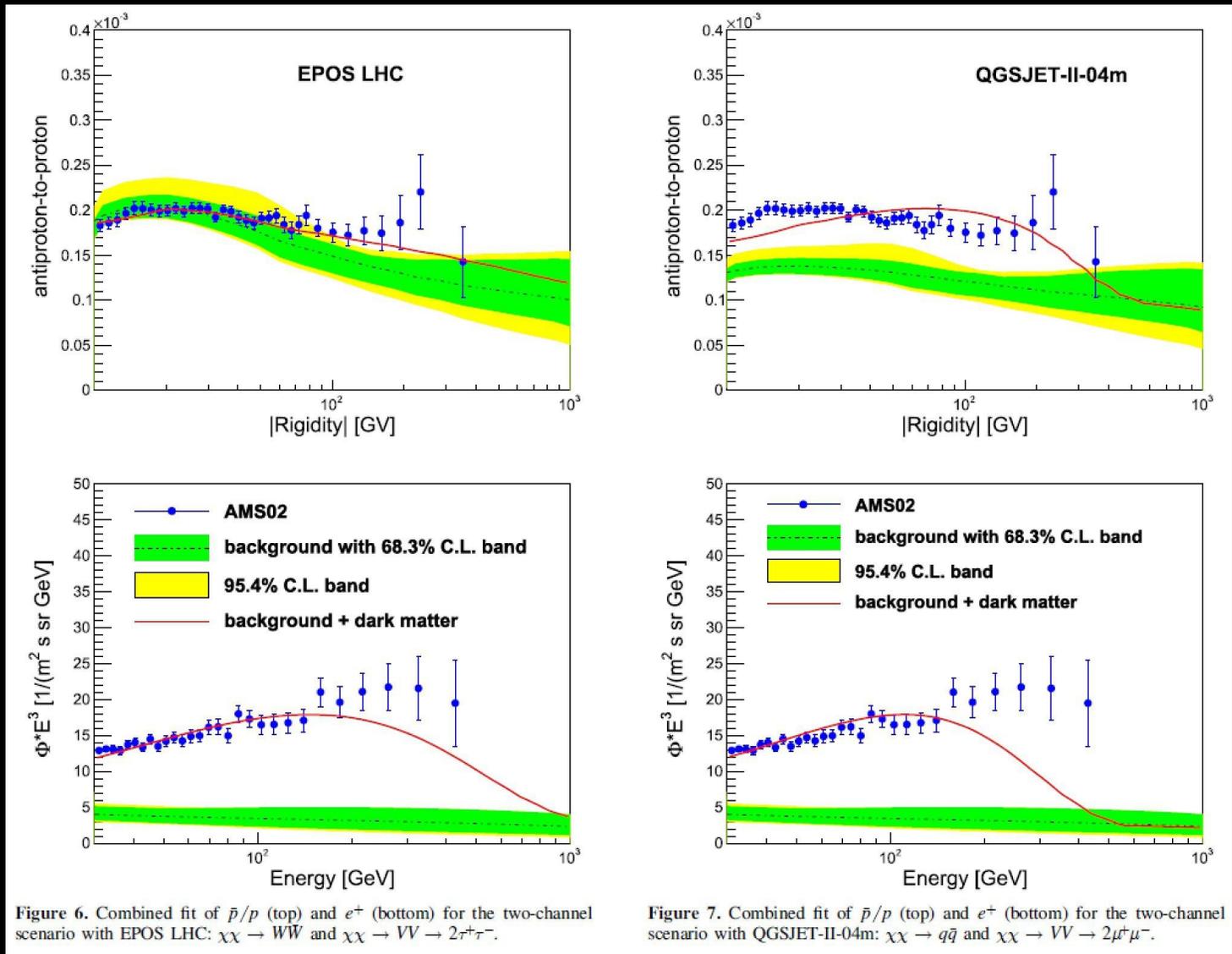
# Interpreting the AMS-02 positron energy spectrum using pulsars



Single pulsar

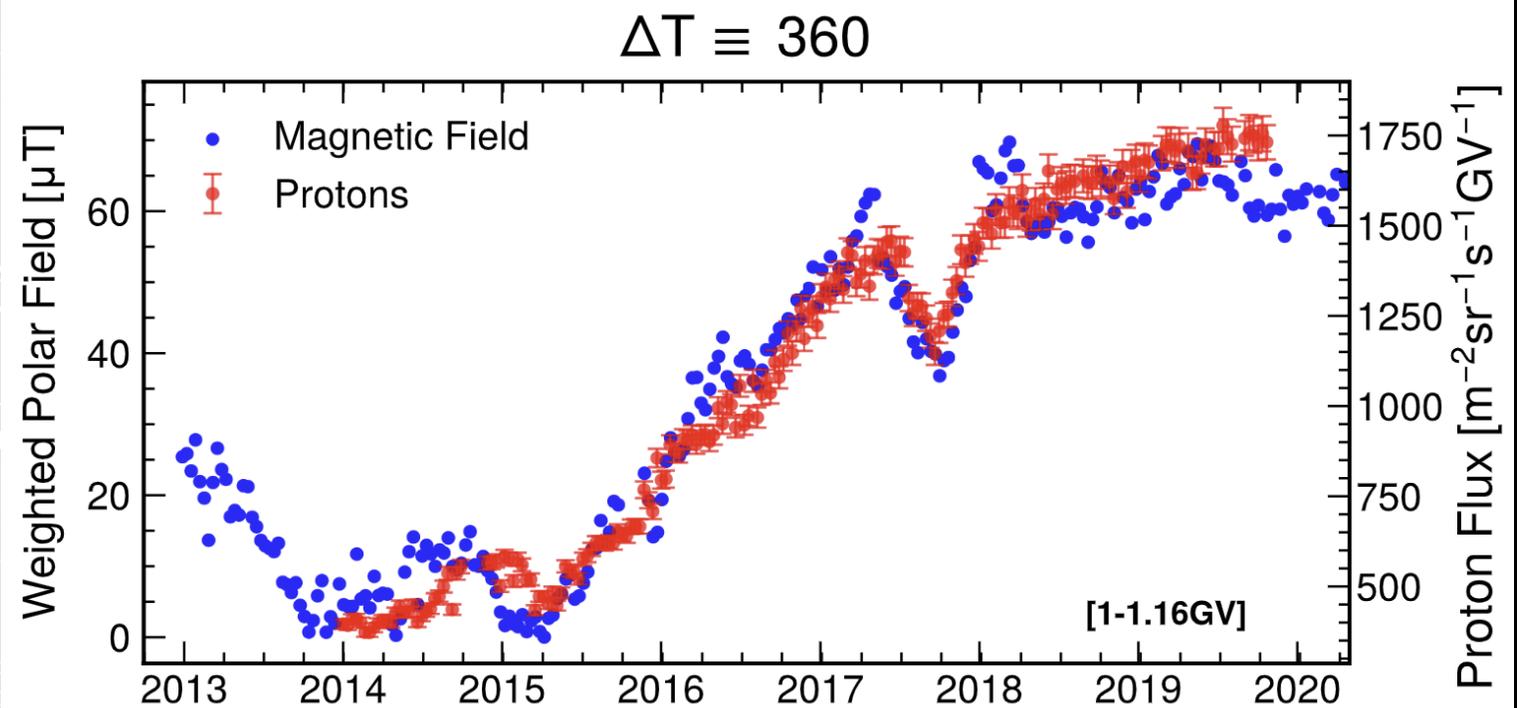
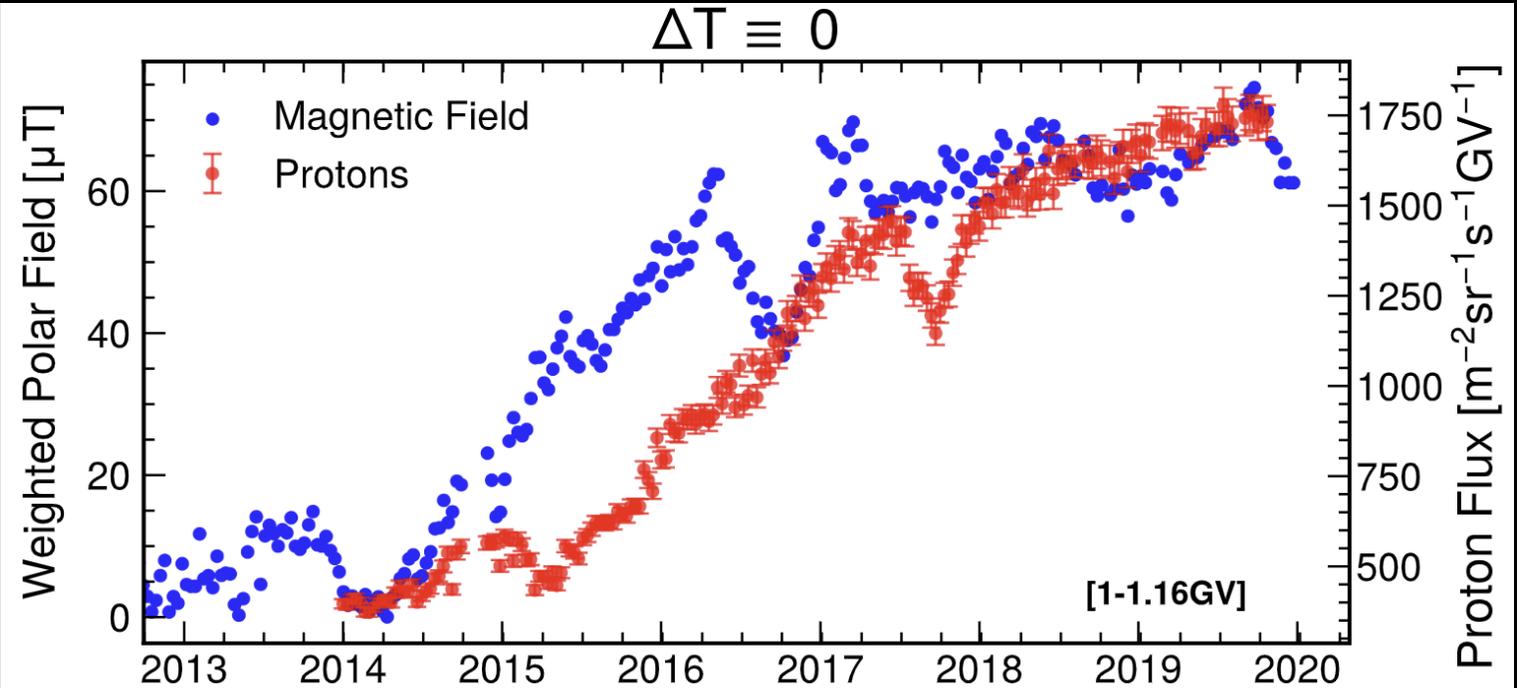
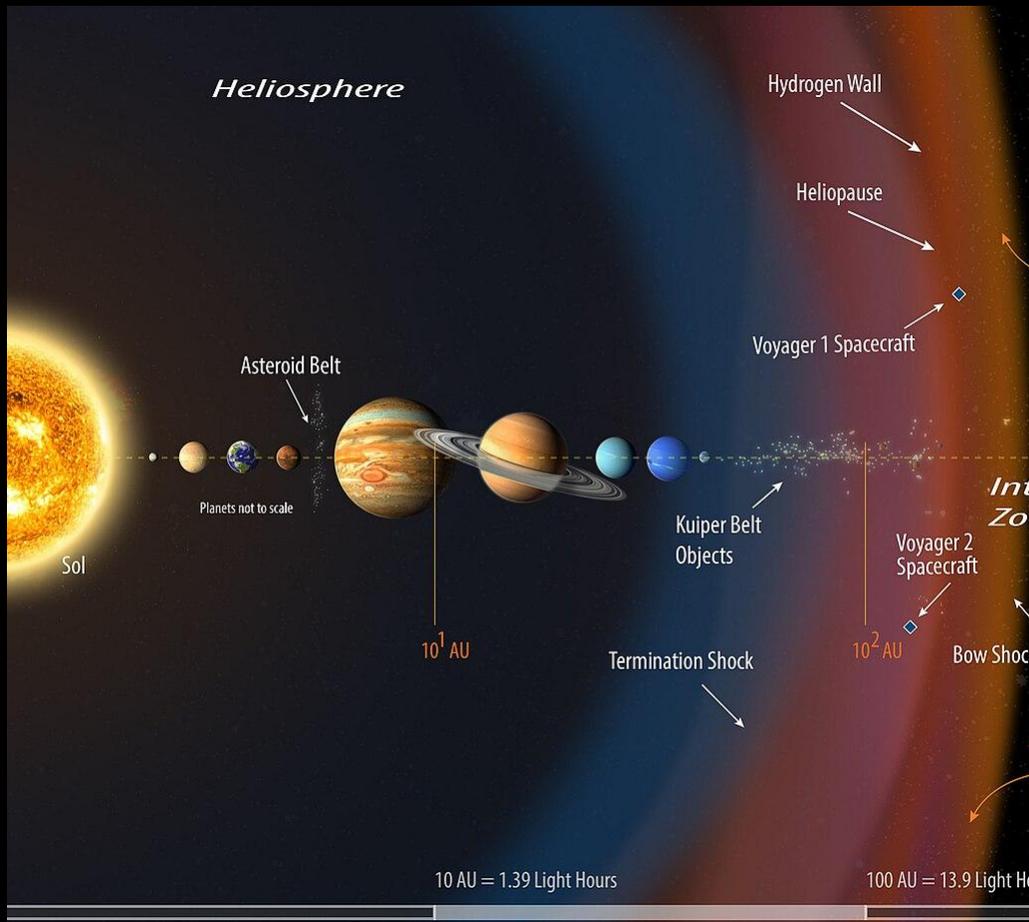
3 pulsars

# Interpreting the AMS-02 positron and antiproton energy spectra using **dark matter**



[PRD 111, 083050 (2025)]

The **polar field** and the **proton fluxes** vary in the same trend if a delay of **360 days** is applied to the magnetic field.



**AMS 2011-2026**

**Continuous data-taking**



**Latest Results: 2011-2022**

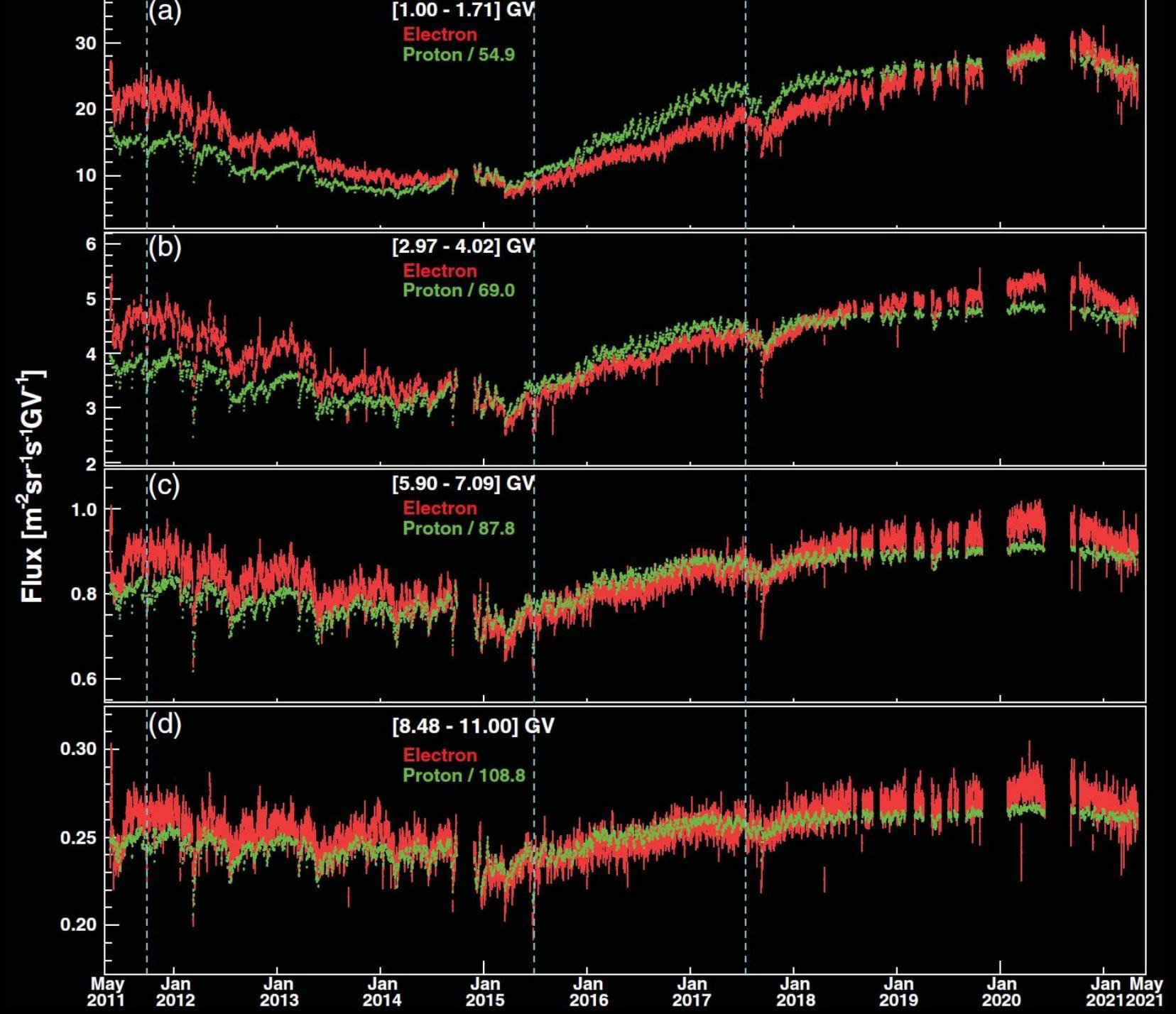
[PRL. 130, 161001 (2023)]

Sign effect of solar modulation

Electron and proton fluxes, covering rigidity 1.00–41.9 GV .

Electrons and protons do not evolve identically in time.

Electron and proton fluxes show both long-term (year-scale) modulation and short-term (days-to-months) structures.

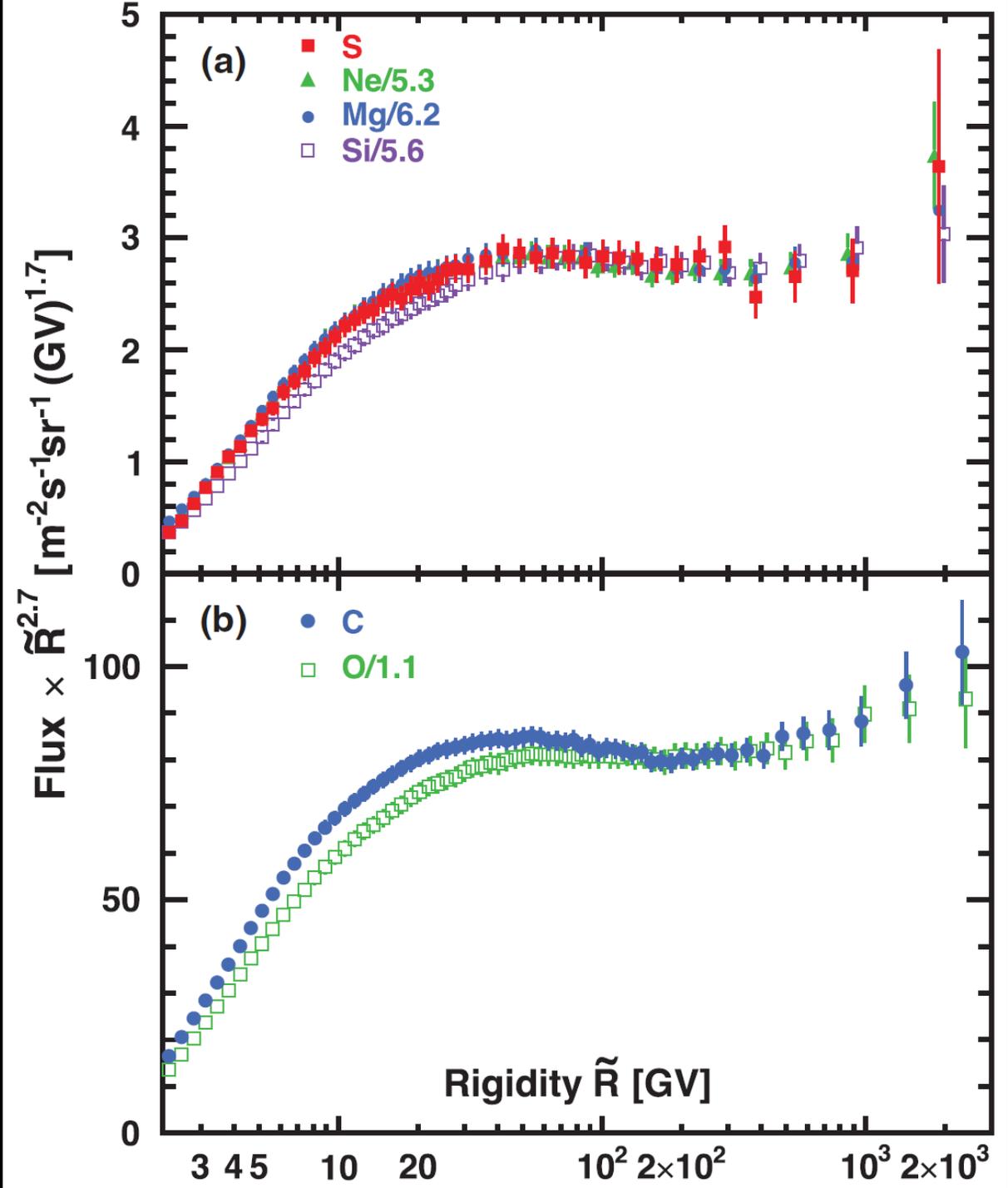


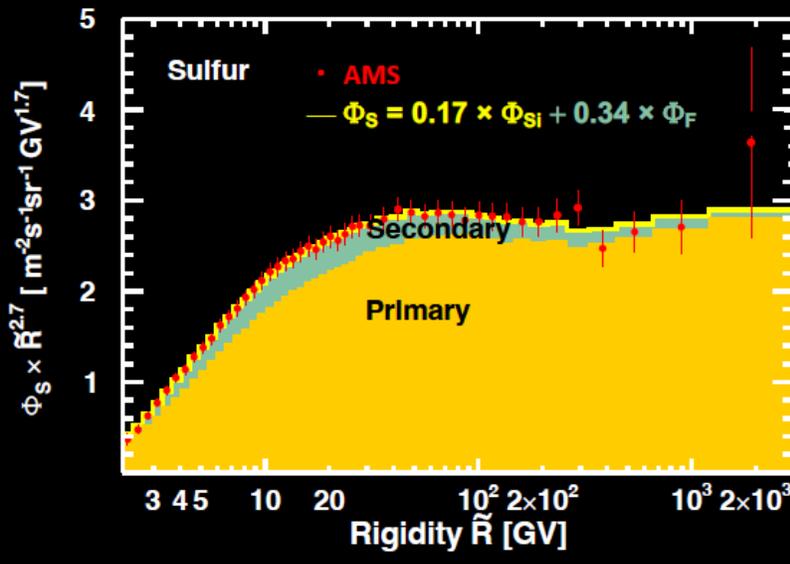
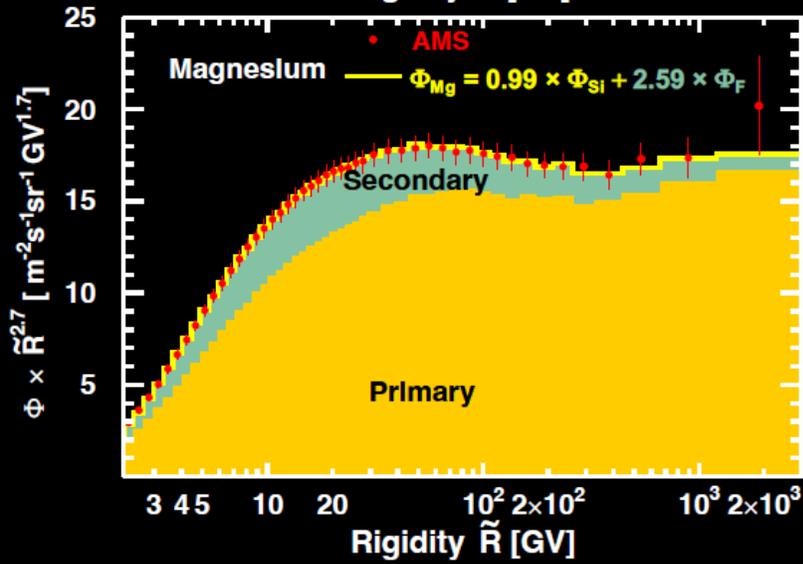
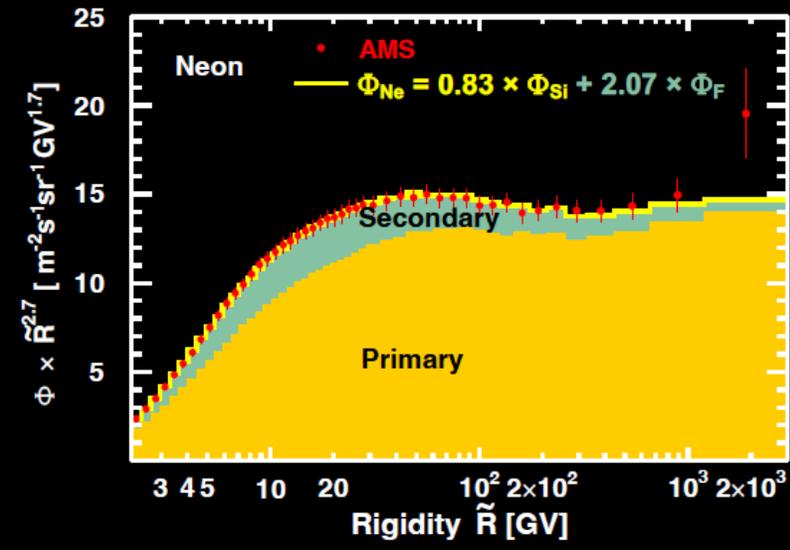
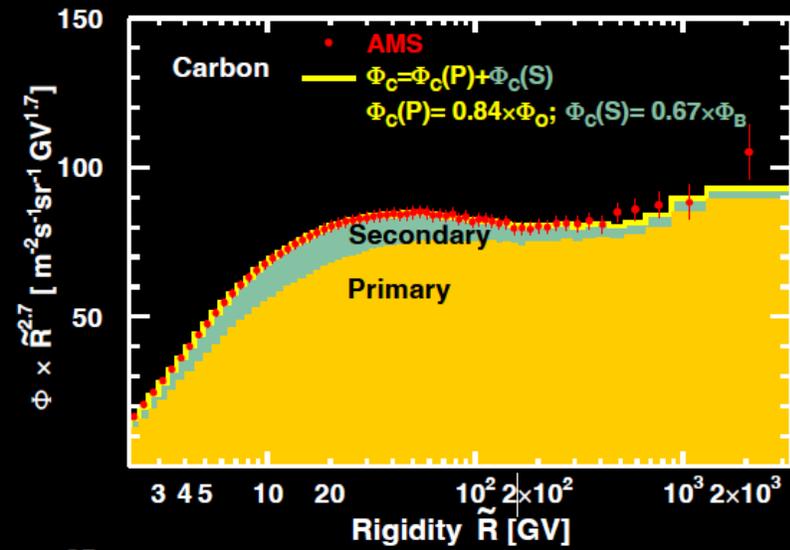
[PRL 130, 211002 (2023)]:

The rigidity dependence of **Sulfur** is identical to the **Ne-Mg-Si** group at high rigidities.

The rigidity dependence of **Carbon** and **Oxygen** is different in low rigidities.

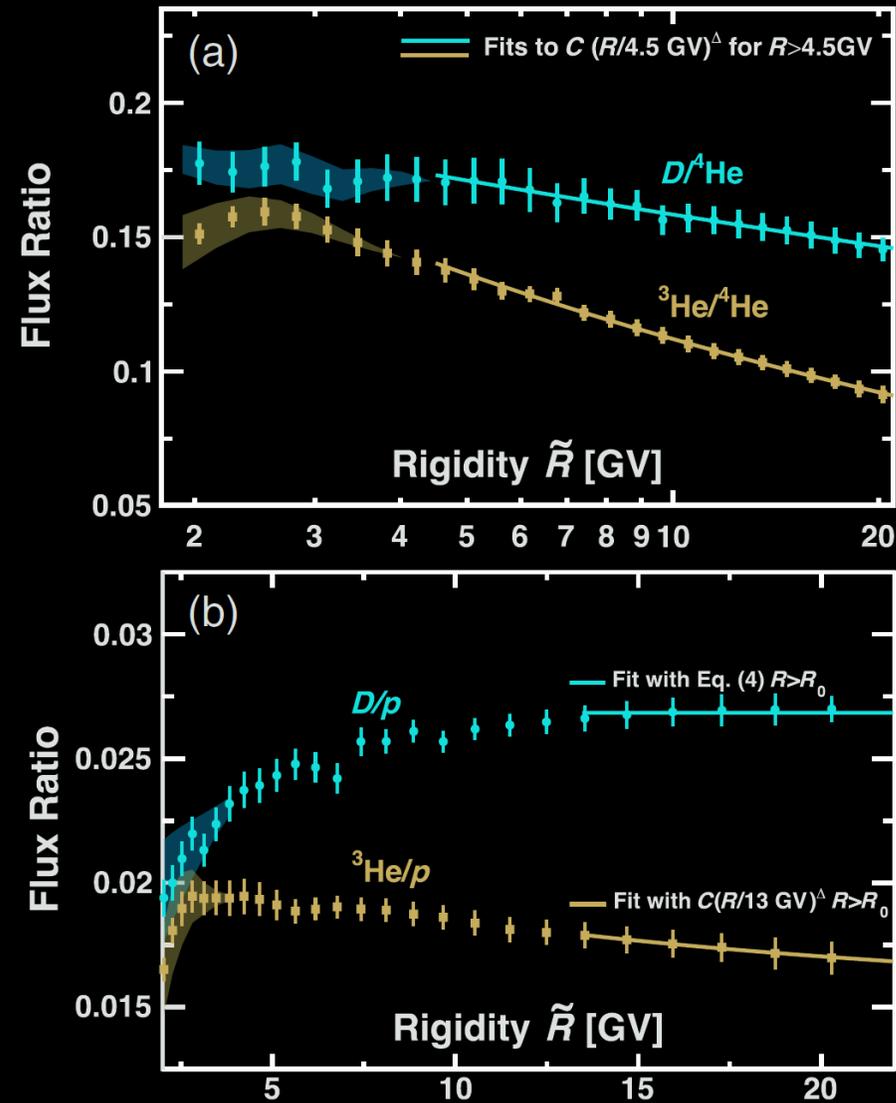
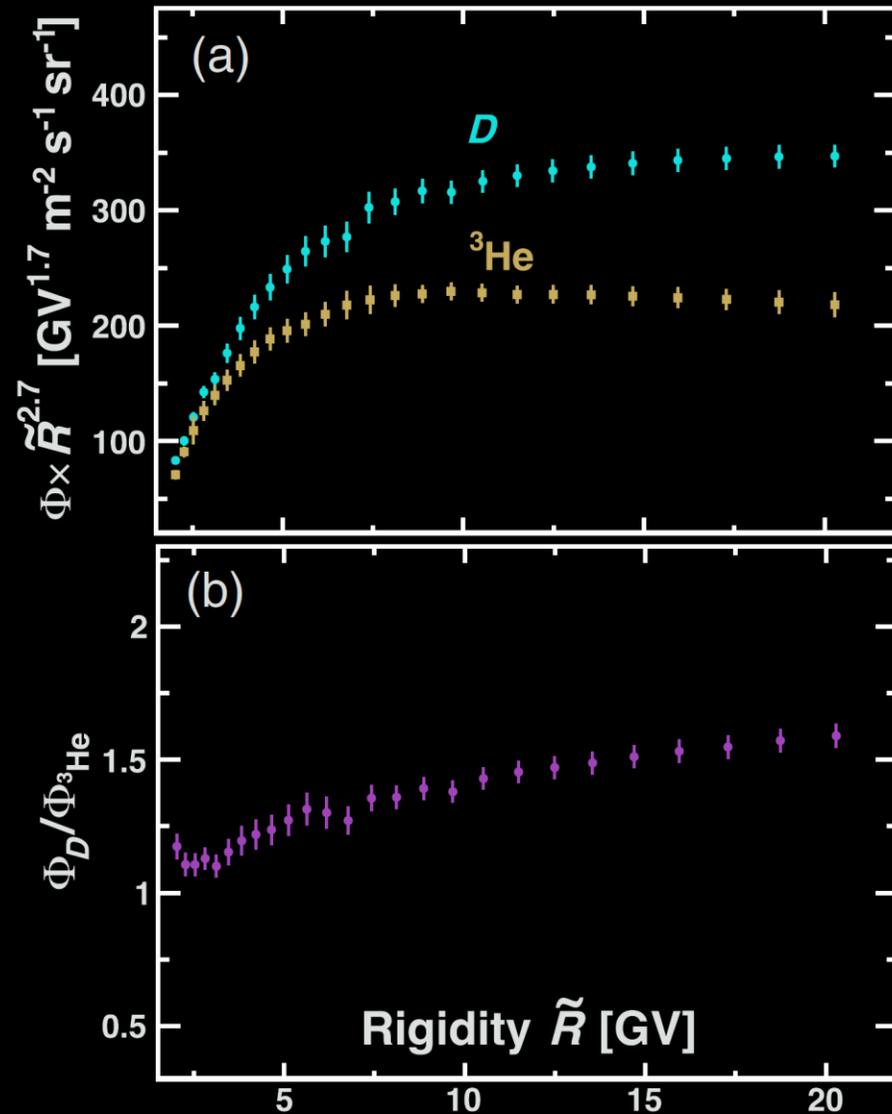
Same **acceleration mechanisms** at high energies, their **propagation or composition** differs at lower energies."

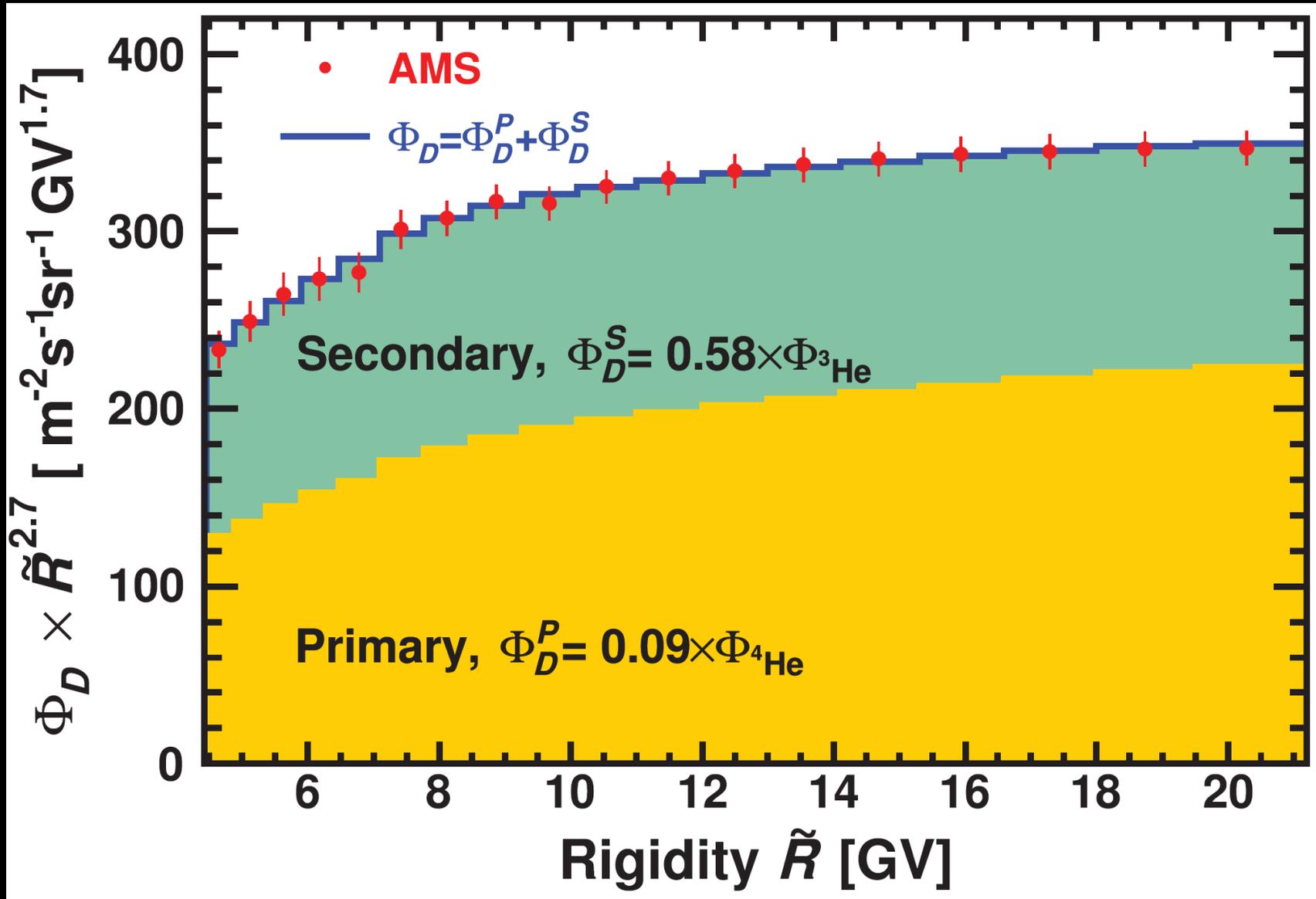




[PRL 130, 211002 (2023)]: Primary cosmic ray nuclei, traditionally considered to be Carbon (C), Neon (Ne), Magnesium (Mg), Sulfur (S), and others, all contain a certain proportion of secondary components.

# AMS Experiment Measurements of Cosmic Deuteron (D)



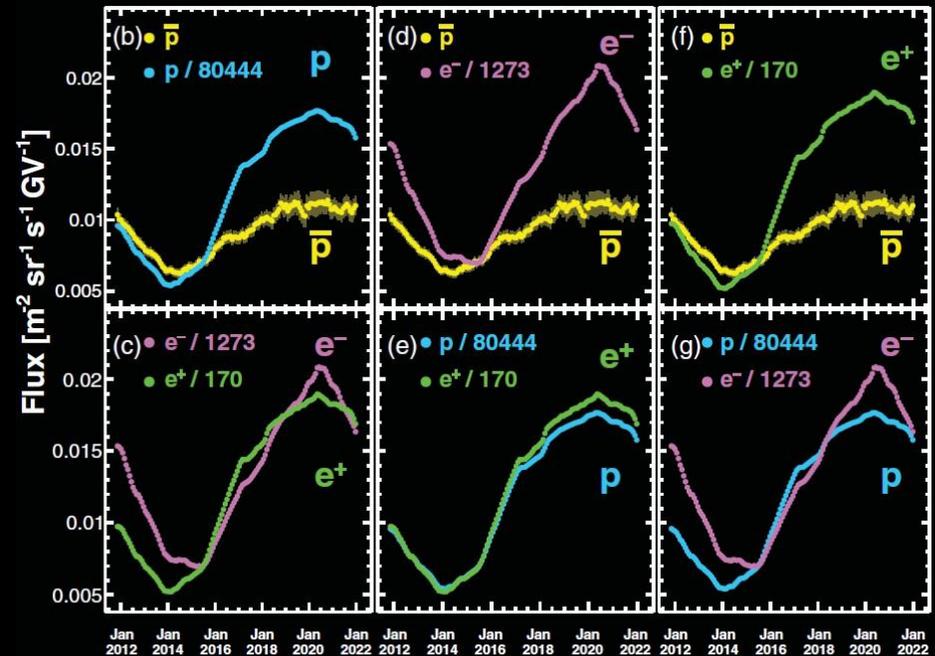
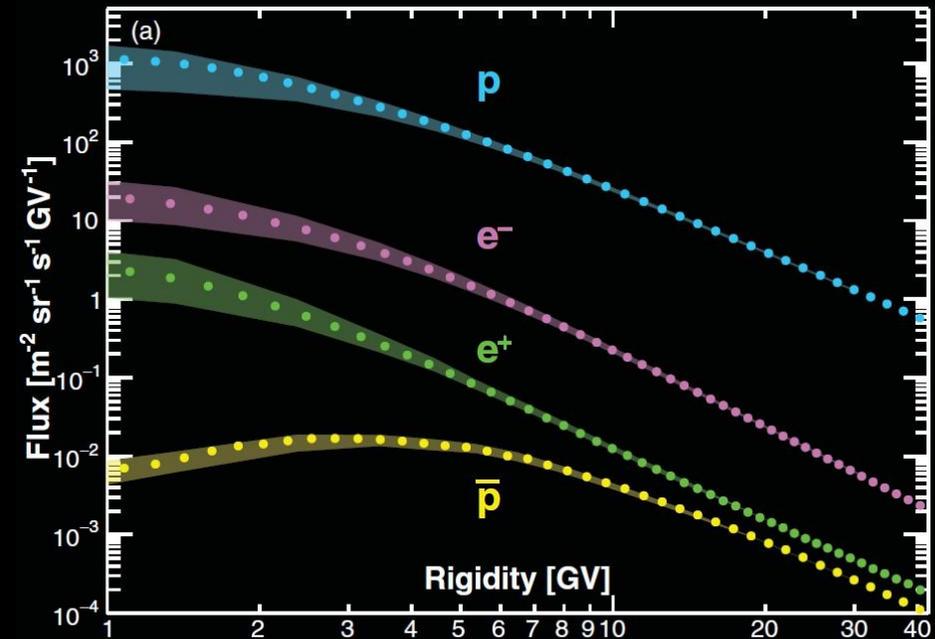


[PRL. 134, 051002 (2025)]:

The spectral shape of **antiprotons** (yellow) is distinct.

**All fluxes** correlate with solar activity.

Particles with the **same charge sign** are **modulated similarly** in time, regardless of their mass



# AMS on ISS

AMS 2011-2026

Continuous data-taking

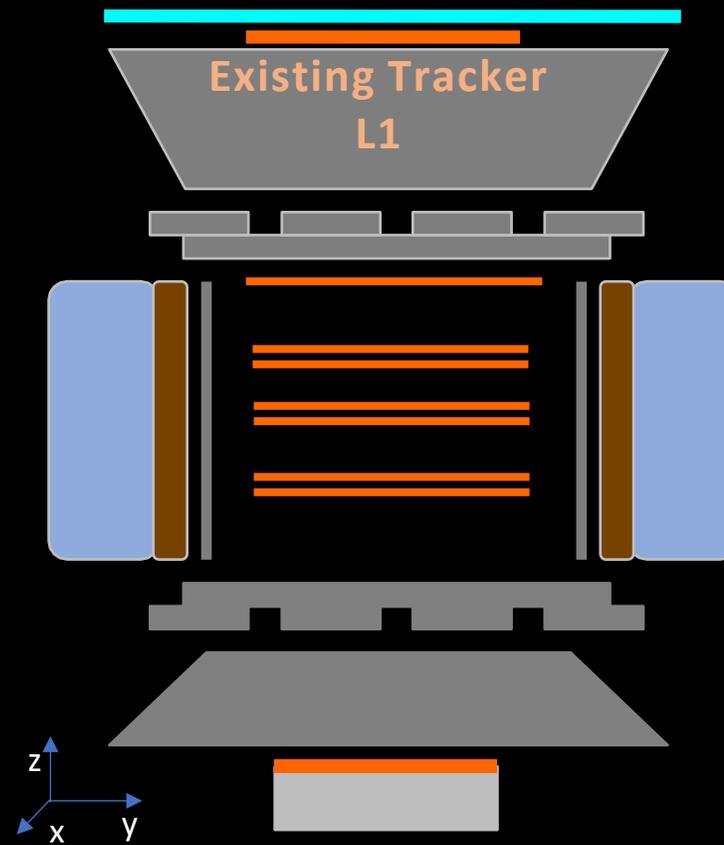


Latest Results: 2011-2022

AMS 2026-2030

New 8m<sup>2</sup> Silicon Tracker Layer

Acceptance increased to 300%



and Projections

# Summary and Outlook

- The detection of **dark matter** is a major frontier topic in modern science and represents an important window into physics beyond the Standard Model.
- Through precise measurements of cosmic rays, particularly positrons and antiprotons, **AMS** can search for signatures of dark matter in space.
- Before 2030, **AMS** plans to upgrade its silicon tracker, which is expected to enable dark matter searches with **higher precision** and over a **wider energy range**.