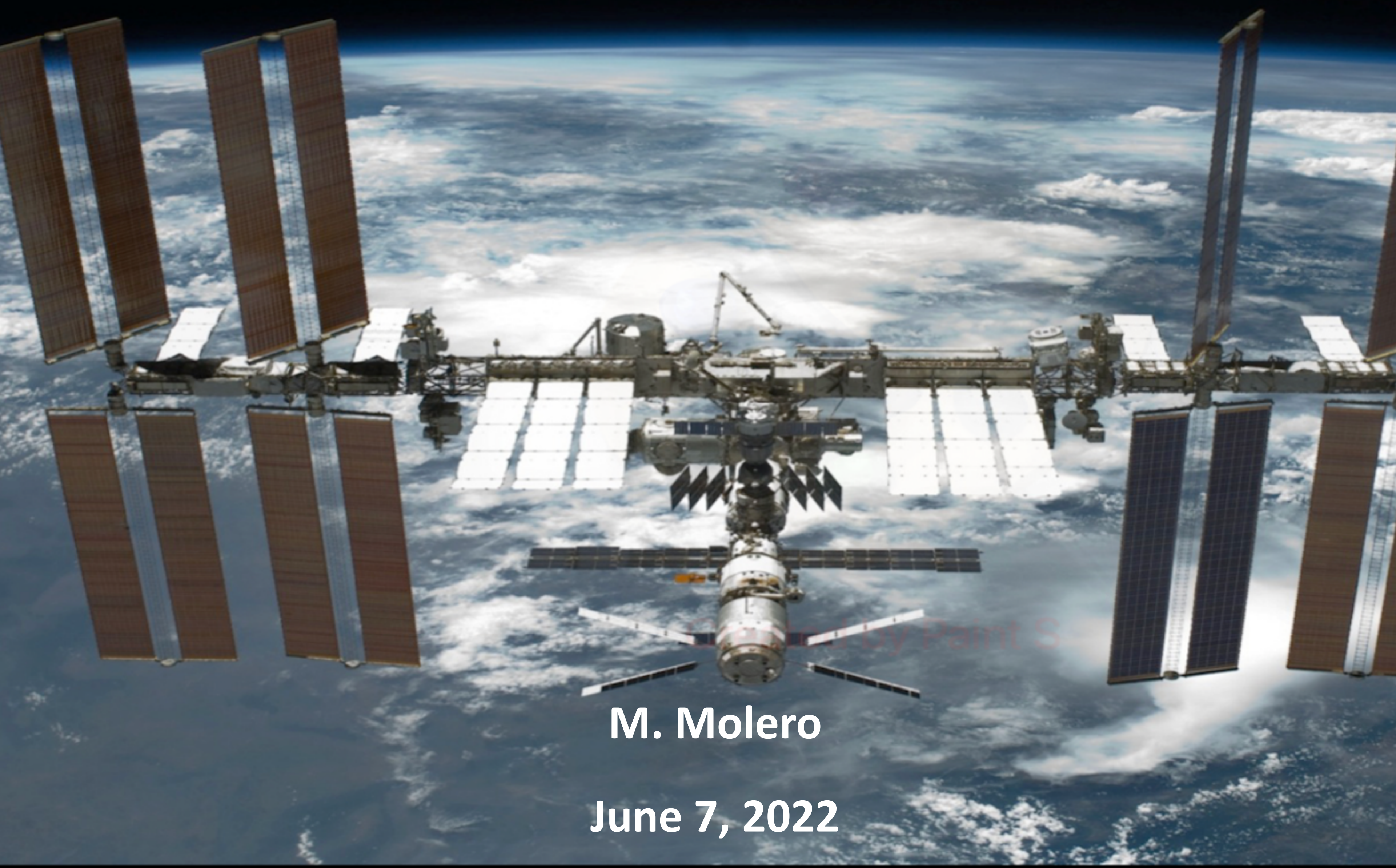
10 years of AMS on the International Space Station

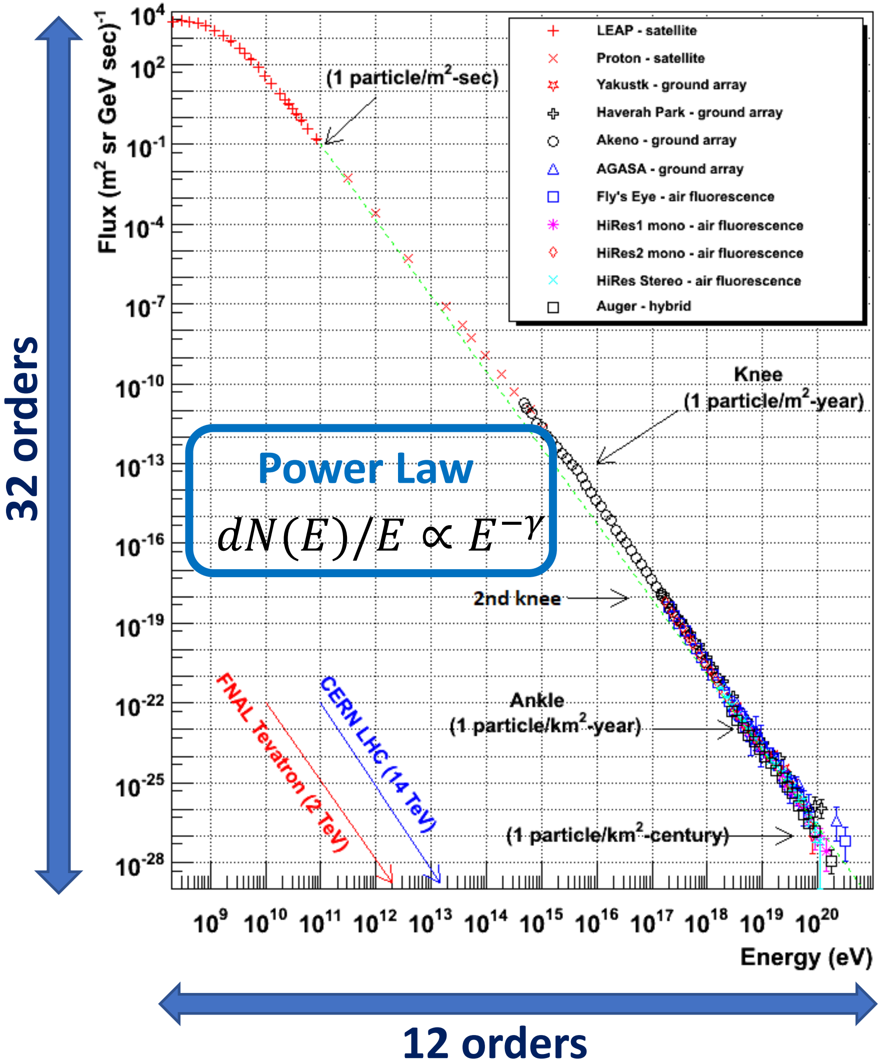


M. Molero

June 7, 2022

Cosmic Rays Spectra

https://www.physics.utah.edu/~whanlon/spectrum.html



Chemical Composition

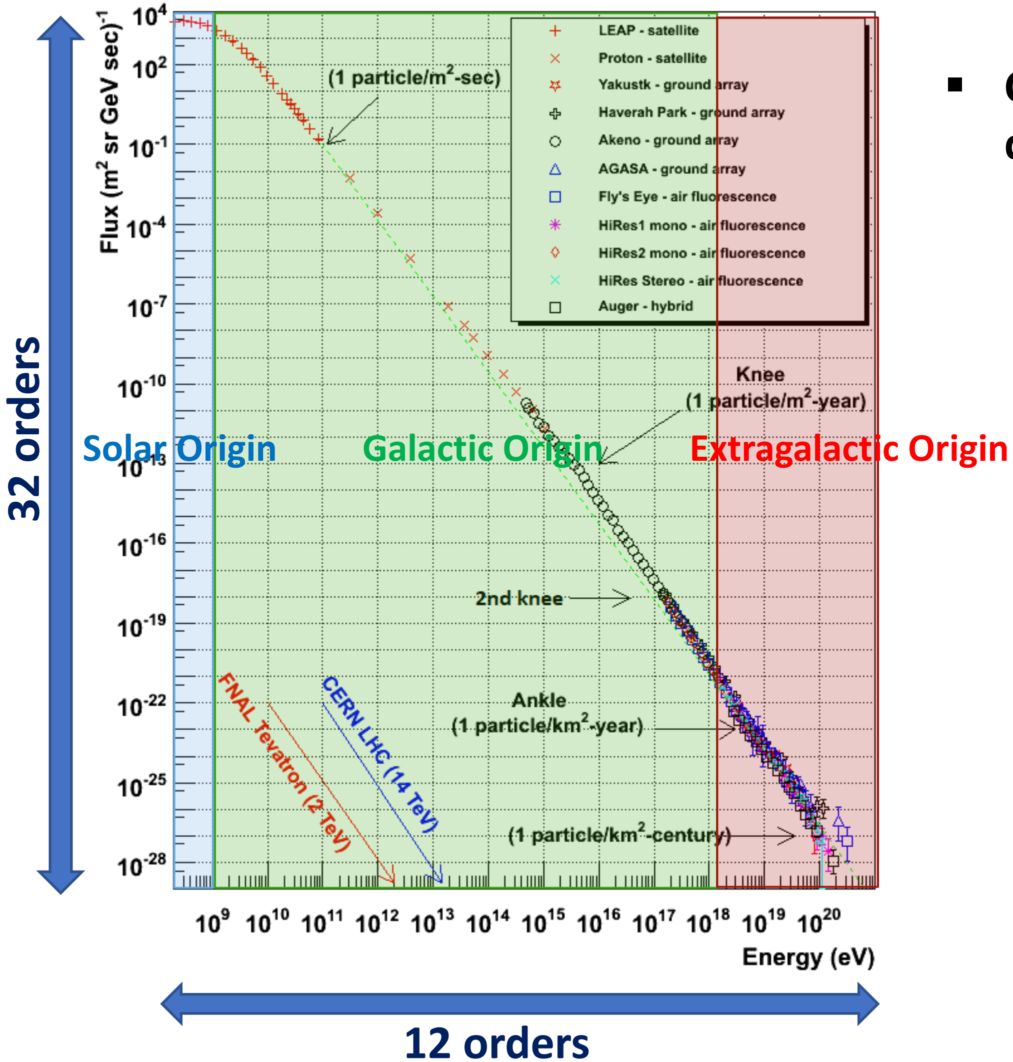
- **Charged cosmic rays (CRs) are mainly formed by:**
  - Protons(86%)
  - Helium (11%)
  - Heavy Nuclei (1%)
  - Electrons (2%)
  - Small fraction of antimatter

Energy Spectra

- **The energy spectra show different changes in the spectral index γ:**
  - Knee
  - 2^{nd} Knee
  - Ankle
  - Suppression

Cosmic Rays Spectra

https://www.physics.utah.edu/~whanlon /spectrum.html



- **Charged cosmic rays can be classified depending on their origin:**

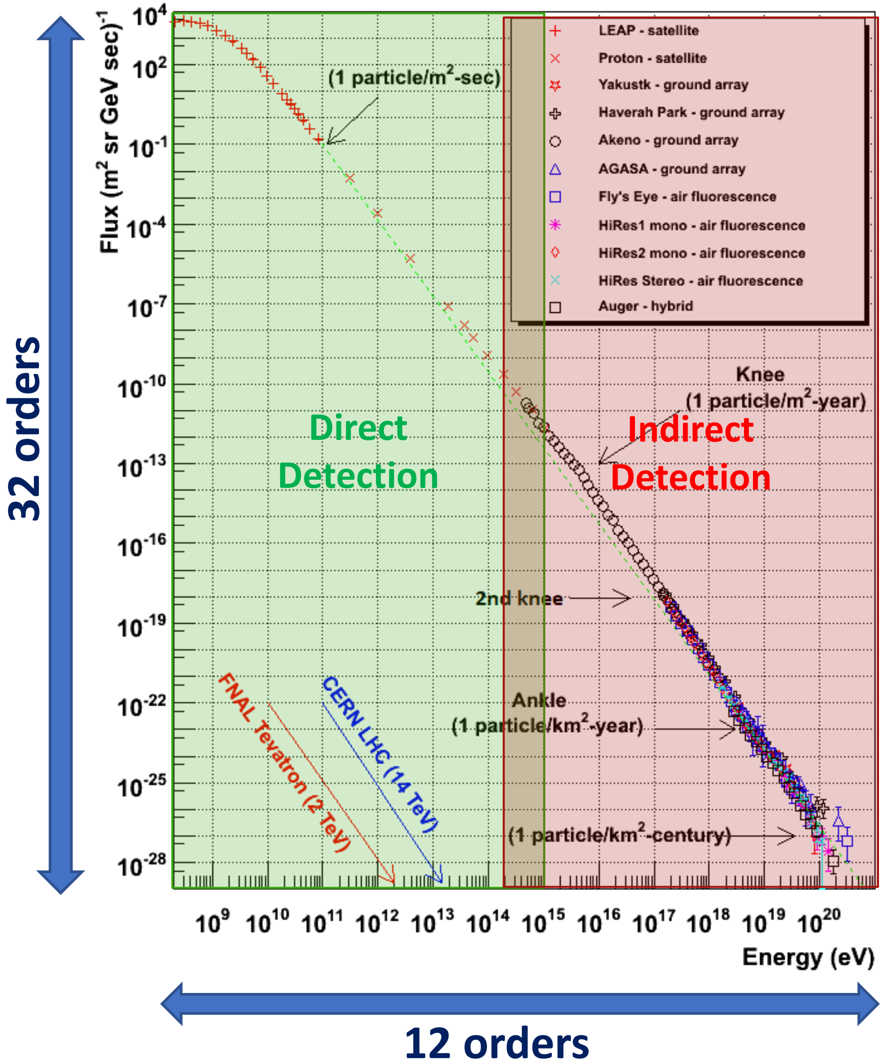
  -**Solar Origin:** Charged particles that constitute the solar wind

  -**Galactic Origin:** Produced in astrophysical sources within the Galaxy (SNRs)

  -**Extragalactic Origin:** Produced in astrophysical sources out of our Galaxy (AGN, GRBs)

Cosmic Rays Spectra

https://www.physics.utah.edu/~whanlon
/spectrum.html



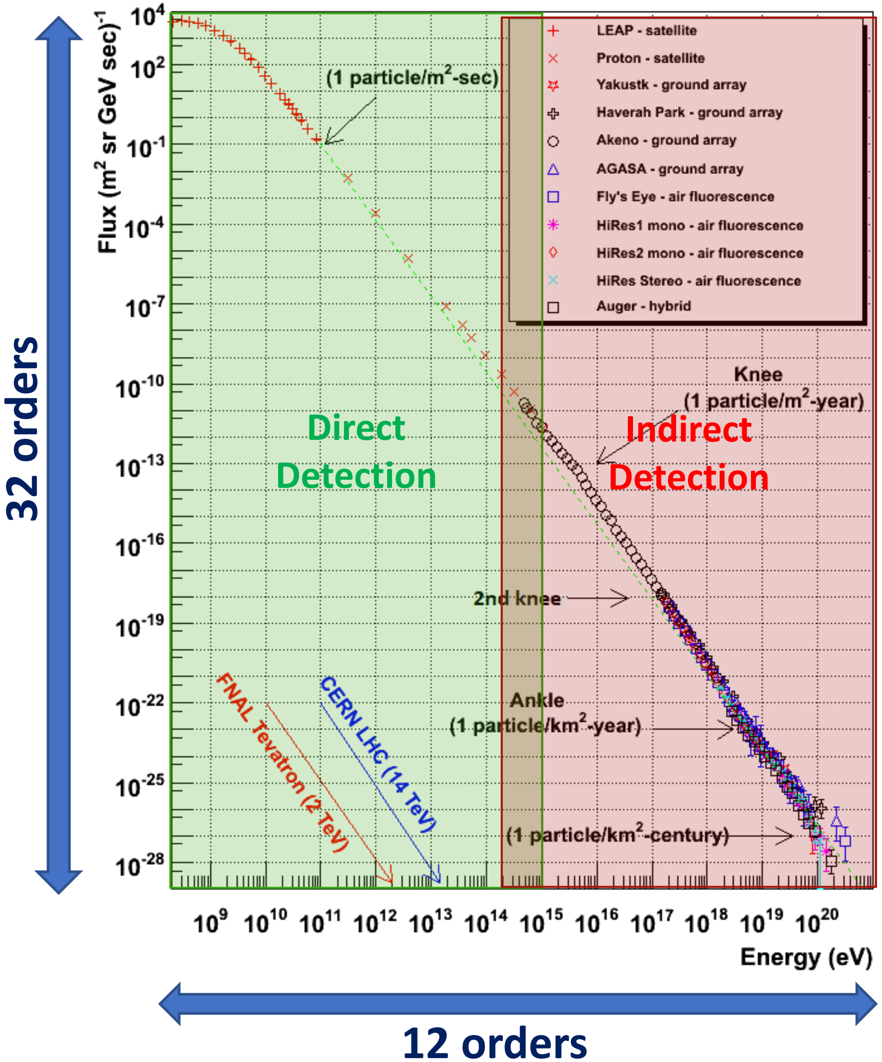
- **Different techniques have been used to measure the cosmic rays spectra:**

  -**Direct Detection (space-borne/balloon-borne detectors)**
  - Good particle identification
  - Size/weigh constraints

  -**Indirect Detection (ground-based detectors)**
  - Reaches the highest energies of the spectra
  - Poor particle identification

Cosmic Rays Spectra

https://www.physics.utah.edu/~whanlon
/spectrum.html



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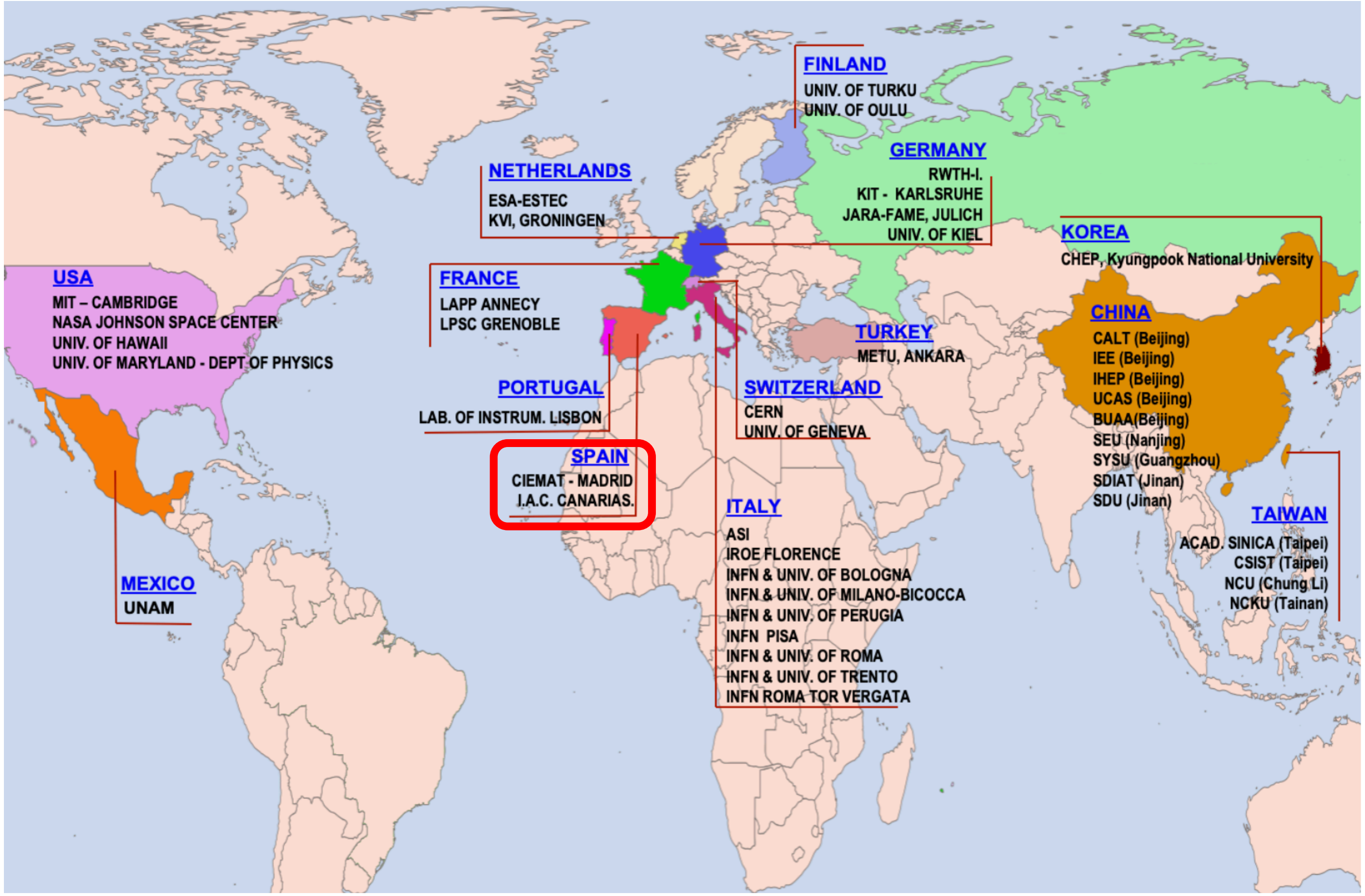
AMS-02

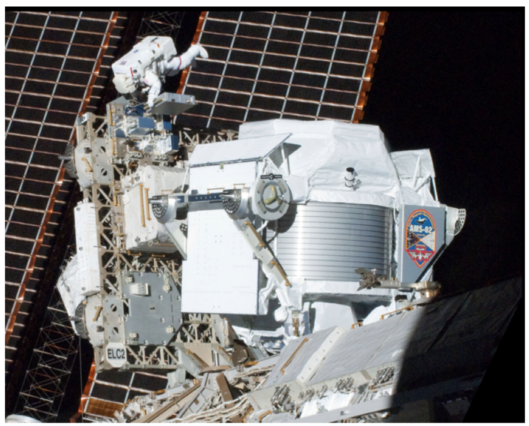
The AMS Collaboration

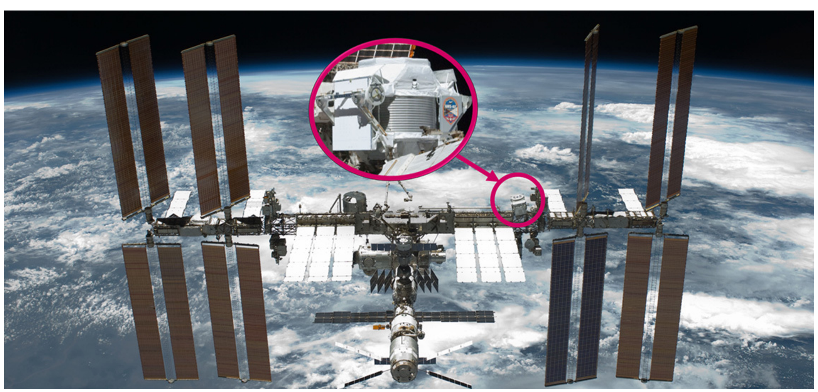
AMS is an international collaboration of 44 institutions from America, Europe and Asia



The AMS-02 Experiment

AMS-02 is a multipurpose particle physics detector that was installed onboard the International Space Station (ISS) in May 2011 to carry out a long-term mission of fundamental physics research in space





The physic objectives of the experiment include:

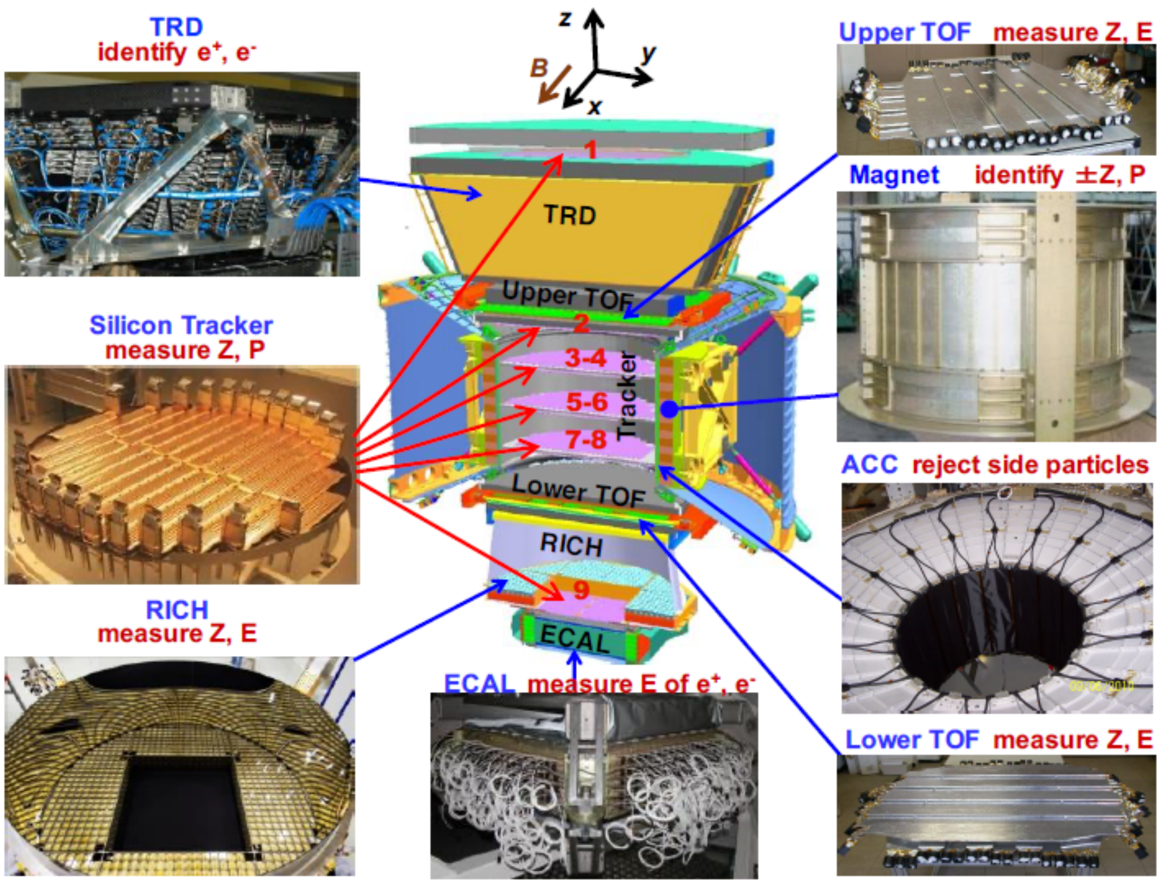
-Indirect searches of Dark Matter

-Searches of Primordial Antimatter

-Origin and propagation of charged cosmic rays

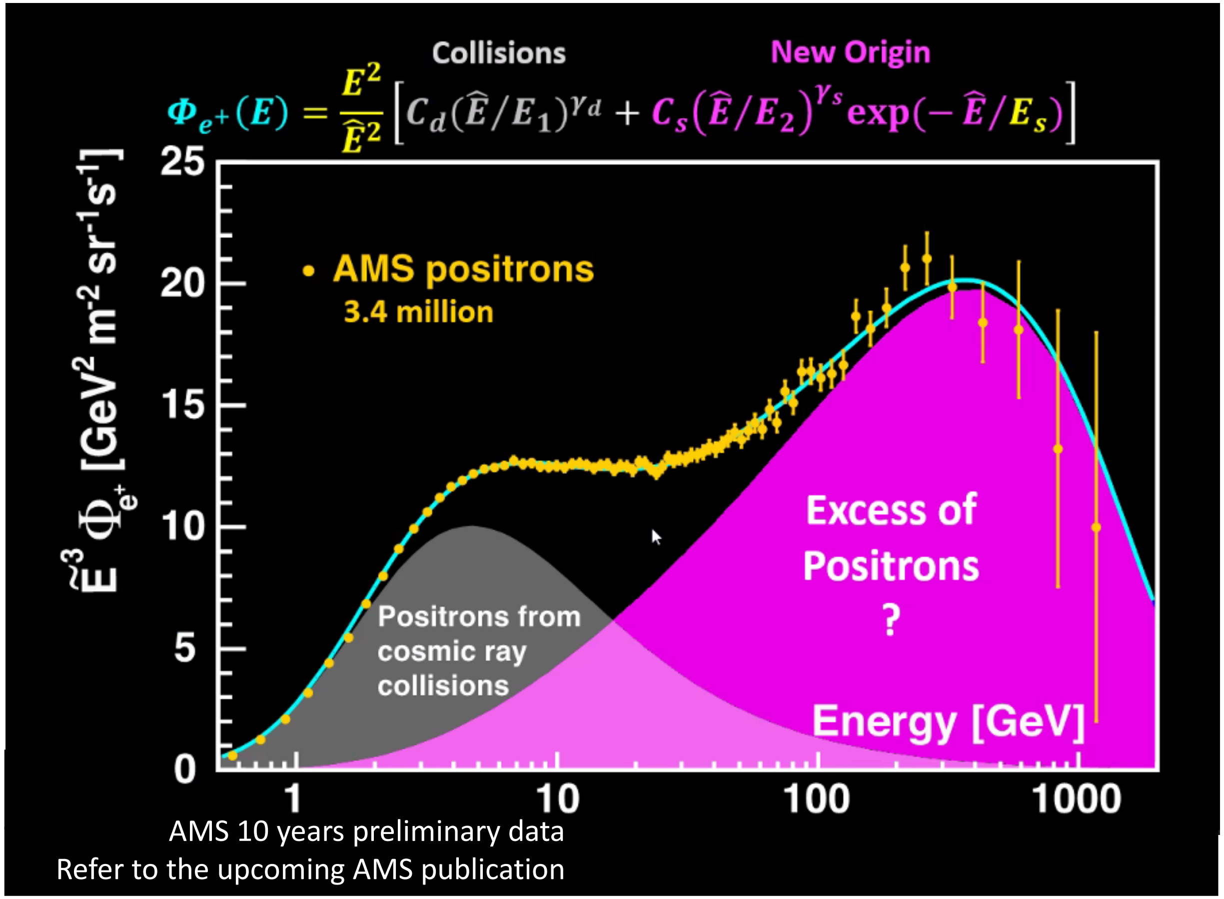
The AMS-02 Detector

AMS-02 is composed of a permanent magnet and 6 subdetectors to provide redundant measurements of the incoming particle properties



Positron Flux

The positron flux measured by AMS-02 shows an excess at high energies that is not consistent with a purely secondary production

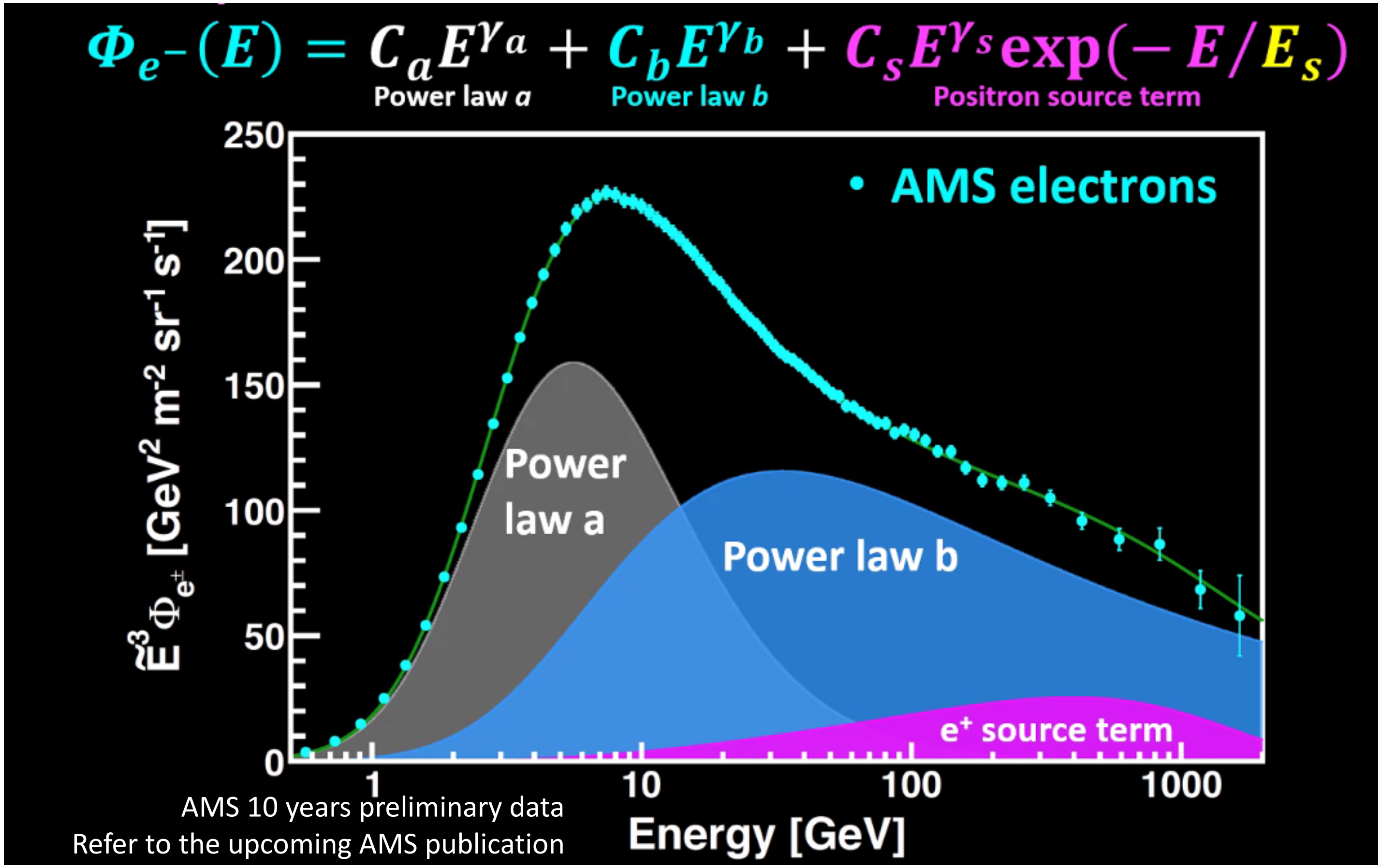


The source term at high energies is typically classified in two scenarios:

- Dark Matter
- Pulsars

Electron Flux

The electron flux measured by AMS-02 shows an excess above 42 GeV that is not consistent with low energy trends

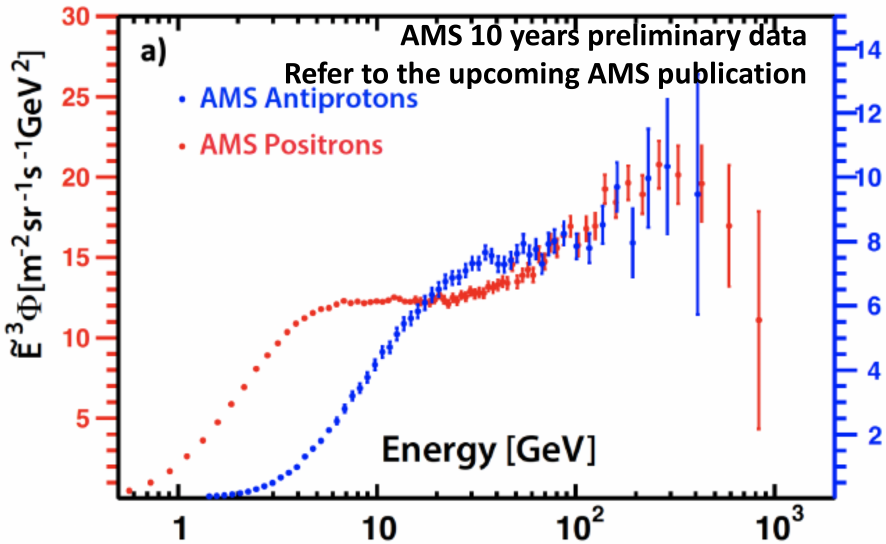


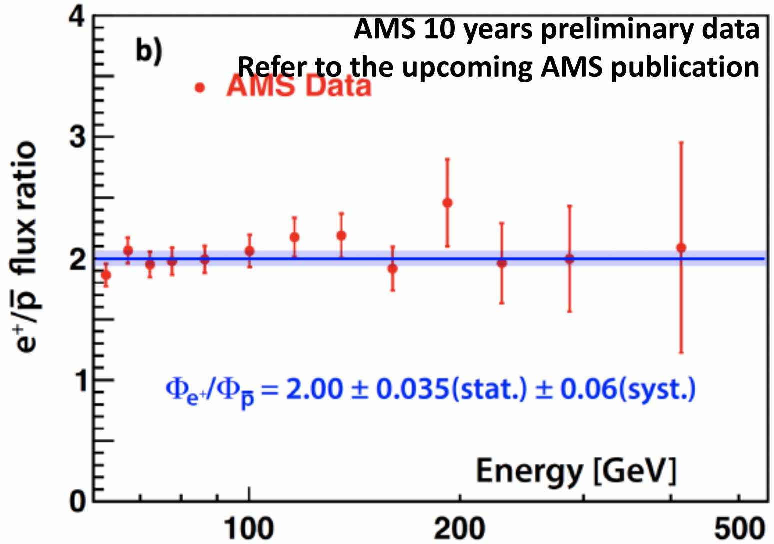
The electron spectrum has a contribution from a positron-like source term

Antriproton vs Positron Flux

The measurement of **the antiproton flux** **could help to understand the** **origin of the positron excess**:

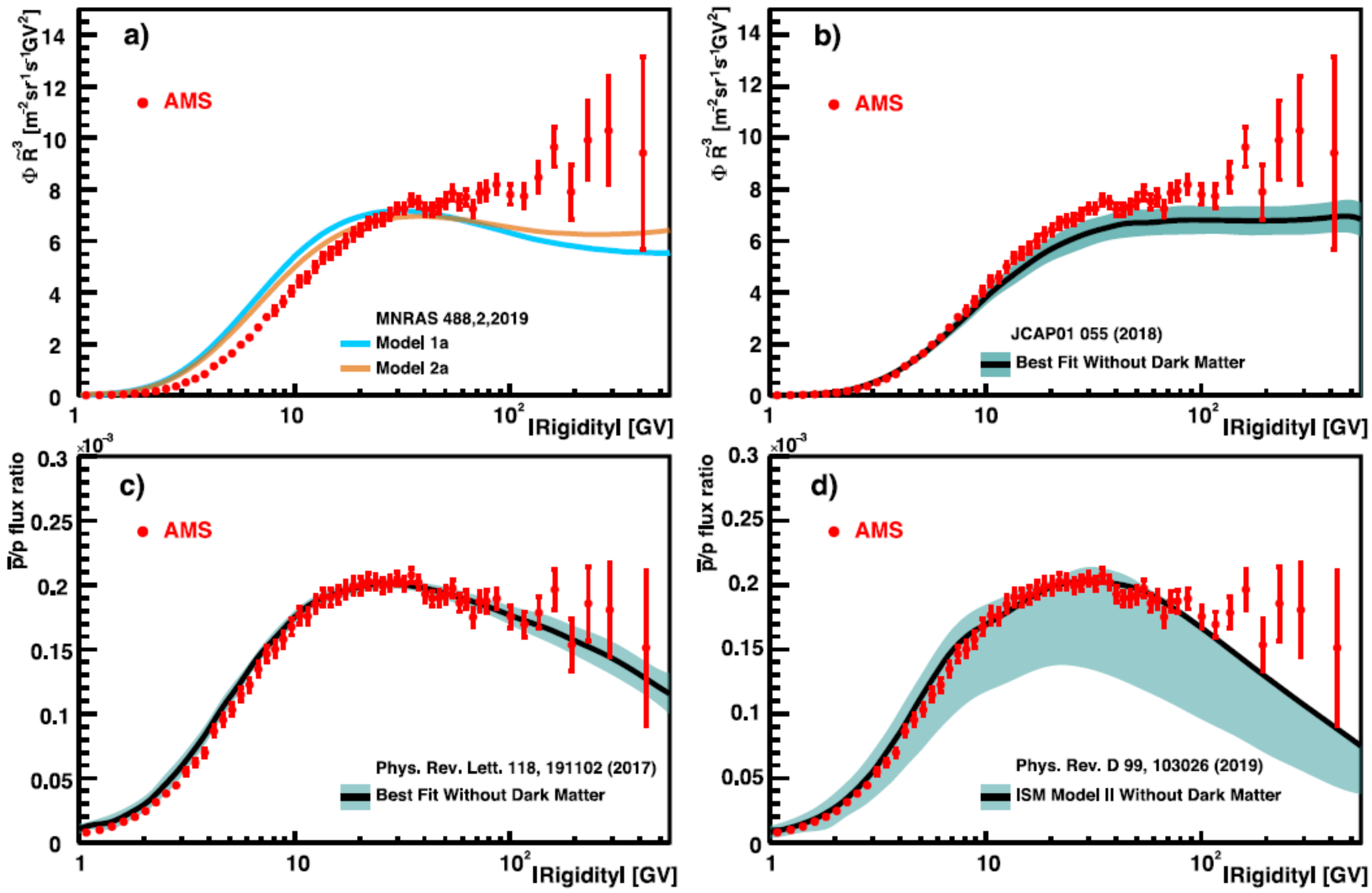
- Antiprotons are not produced in pulsars
- An excess in the antiproton flux could indicate the presence of dark matter





Above 60 GeV **the positron and antiproton fluxes have a** **similar behavior**

Origin of the Antriproton Flux

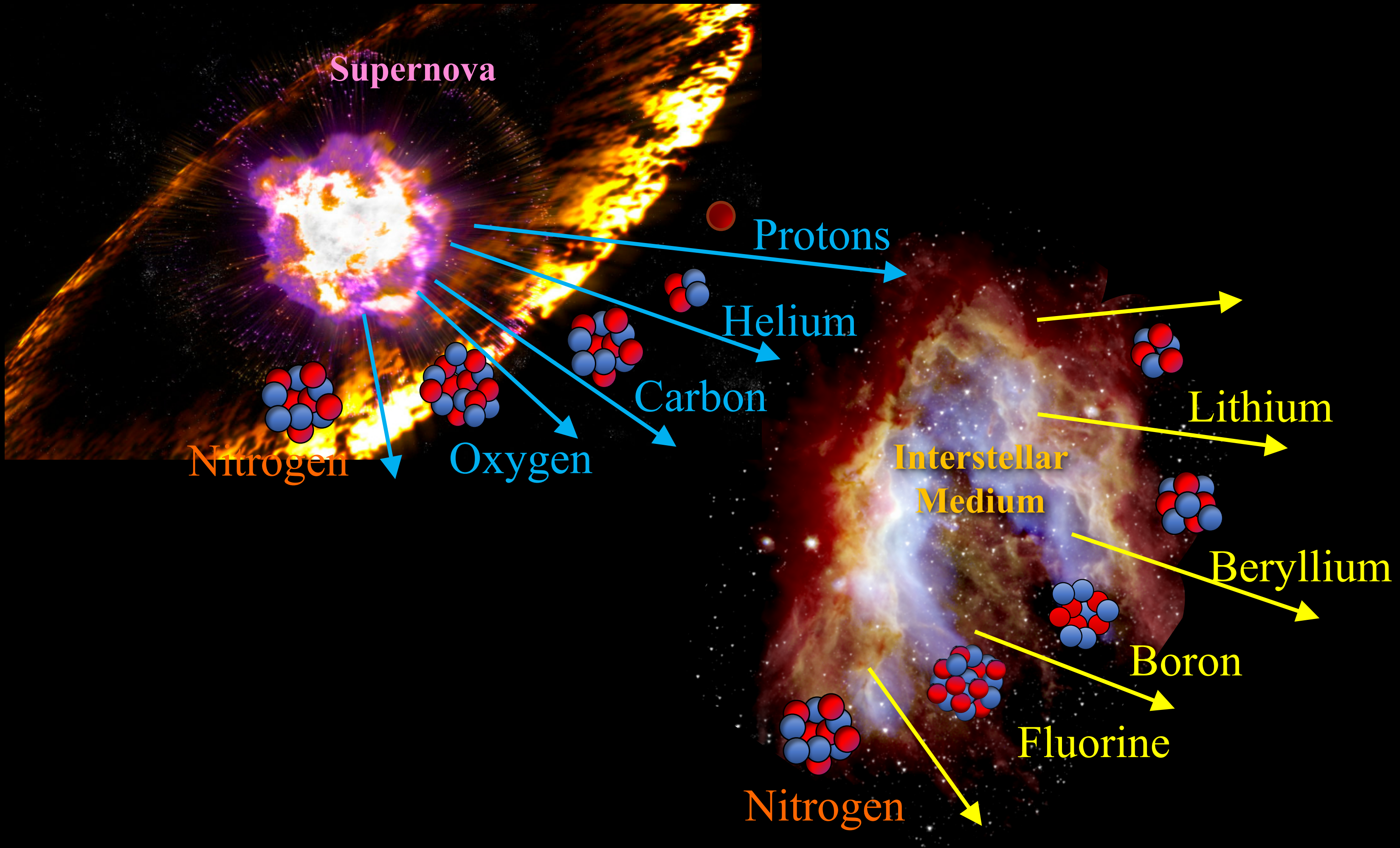


The uncertainties in the propagation models **do not provide a definitive interpretation about the origin of antiprotons**

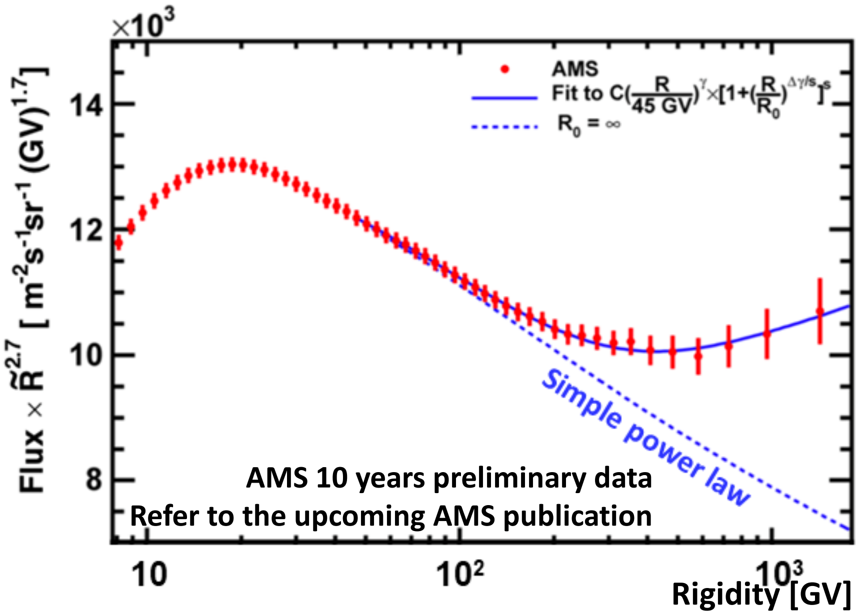
⇒ precise measurement of the primary and secondary cosmic rays

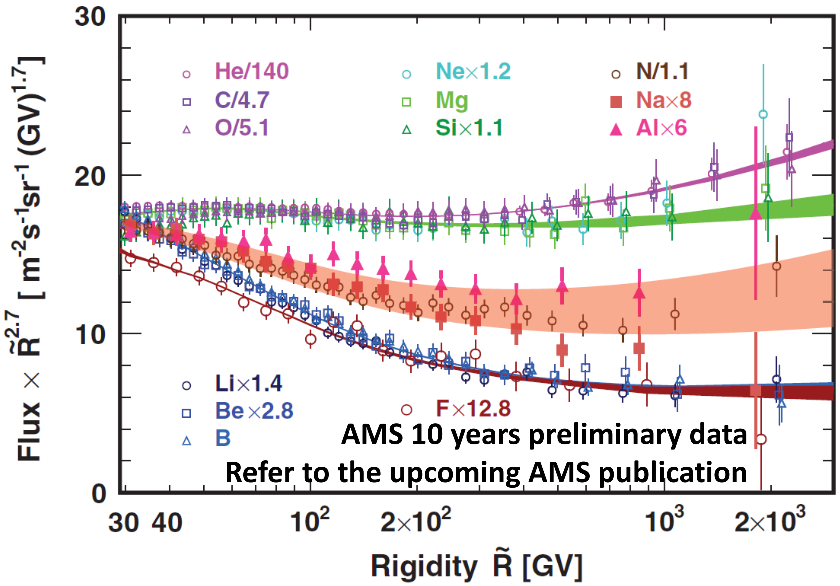
Primary + Secondary Cosmic Rays

The precise measurement of the primary and secondary cosmic rays provide information about the sources, the propagation and the interstellar medium



Primary + Secondary Cosmic Rays

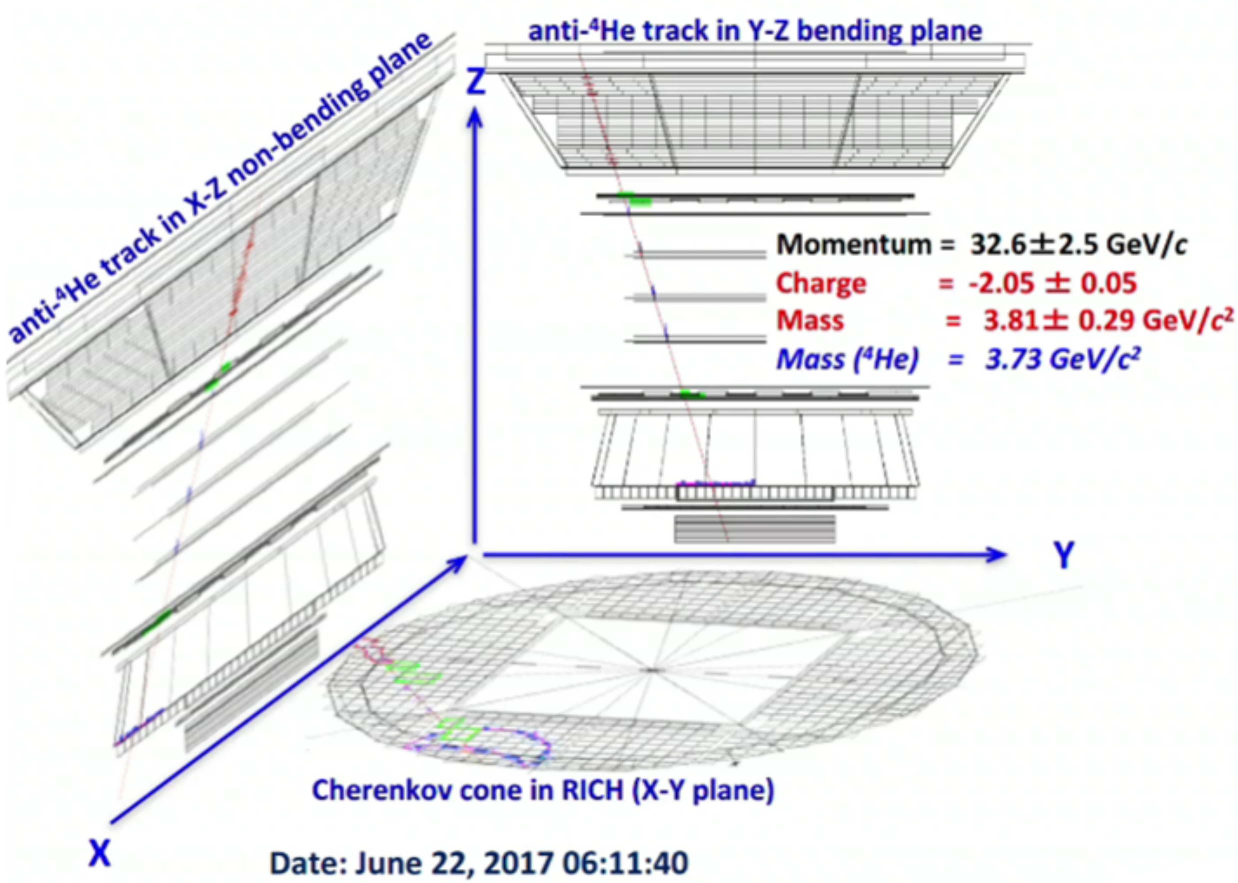




All nuclei progressively deviate from a single power law at high rigidities

Searches of primordial antimatter

AMS-02 has observed a few antihelium candidates with charges and masses consistent with ^{3}He y ^{4}He



The fraction of antihelium events over the background is of ∼1 over 100 million of helium ⟹the response of the detector needs to be understood

Conclusions

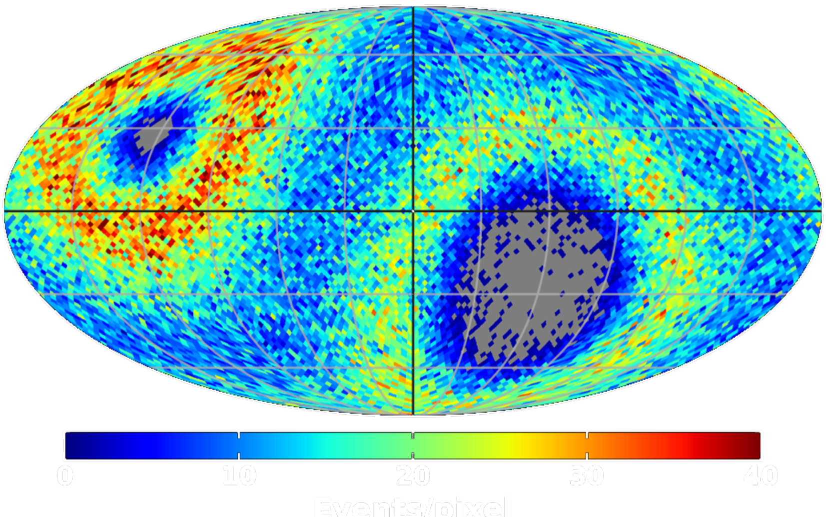
- **AMS-02 is a unique detector in space that has provided unexpected results**
- **The measurement of light antimatter (positrons and antiprotons) with AMS-02 has revealed unexpected features in the fluxes that challenge the traditional models. This allows to perform searches of dark matter**
- **The precise measurement of the primary and secondary cosmic rays helps to understand the acceleration and propagation models**
- **The detection of antinuclei with AMS-02 could indicate the presence of antimatter domains in the Universe**
- **AMS-02 has been continuously measuring cosmic rays for more than 10 years and it will continue until the end of the ISS (2030)**

Origin of the positron excess: Anisotropies

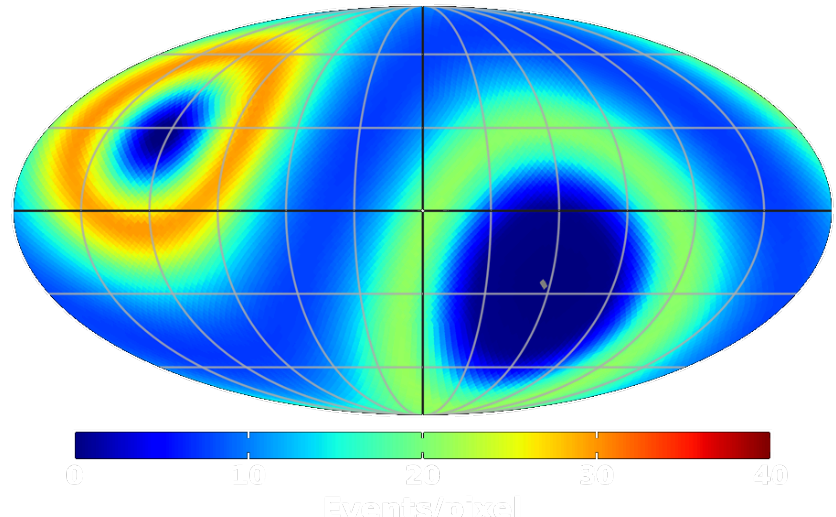
How to distinguish between pulsars and dark matter to explain the positron excess?

- Positrons injected by pulsars would have a directionality of (∼ 1%) which would be more intense than for the dark matter

Positron map of the arrival directions in galactic coordinates



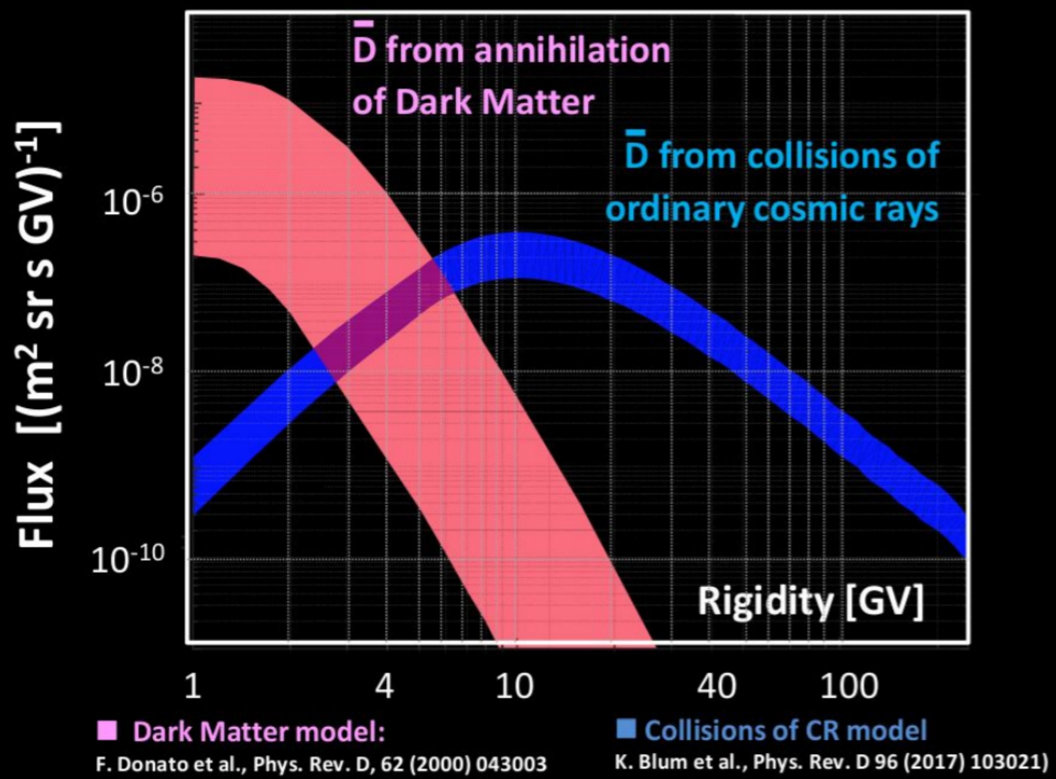
Reference map under the hypothesis that positrons are isotropic



- **No deviations from isotropy have been found**
- **The measurement of the anisotropy until the end of the ISS would allow to explore anisotropies at the 1% level**

Searches of Dark Matter: Antideuteron Flux

The measurement of antideuterons may serve as an almost background-free channel
⇒ provides an additional channel in the searches of dark matter

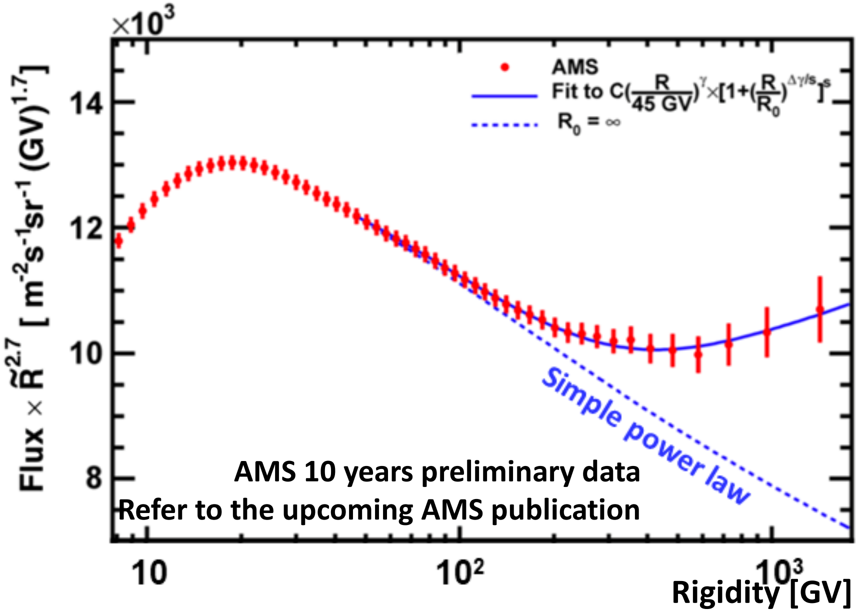


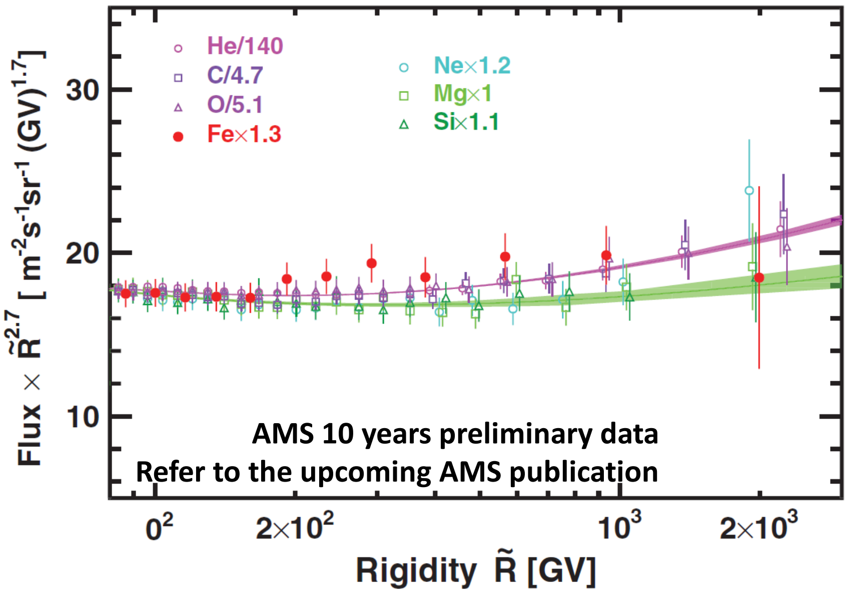
The antideuteron flux is much lower than the antiprotons flux

Primary Cosmic Rays

The fluxes show different features:

- All deviate from a single power law at high rigidities
- Light nuclei (He, C and O) have an identical rigidity dependence
- Heavy nuclei (Ne, Mg and Si) have a different behavior from the light nuclei
- The iron flux has an identical behavior than the light nuclei





Secondary Cosmic Rays

The fluxes show different features:

- All deviate from a single power law at high rigidities
- They have a different behavior than the primary cosmic rays
- Two group of secondaries are observed:
  - Li, Be, B
  - F