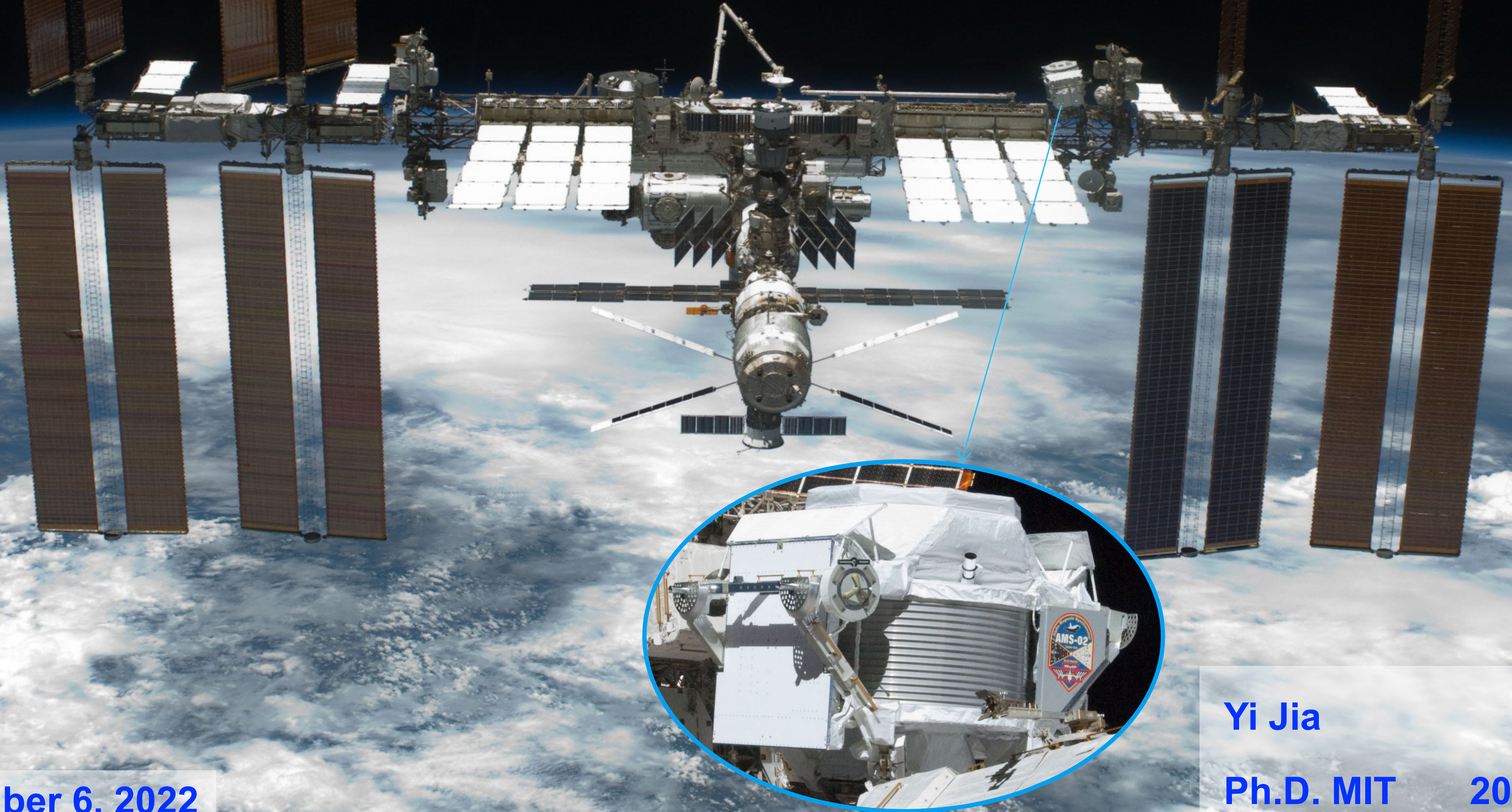
Physics with the Alpha Magnetic Spectrometer (AMS)

Welcome to join AMS



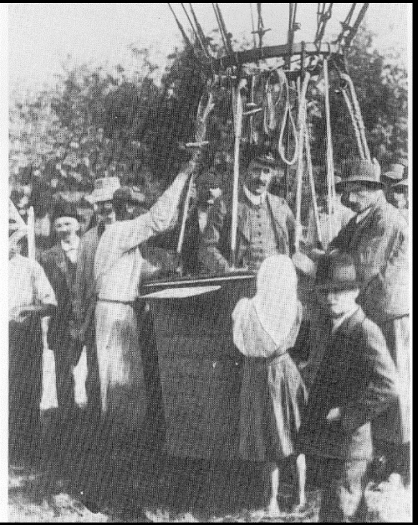
Yi Jia

Ph.D. MIT 2016-2018

September 6, 2022

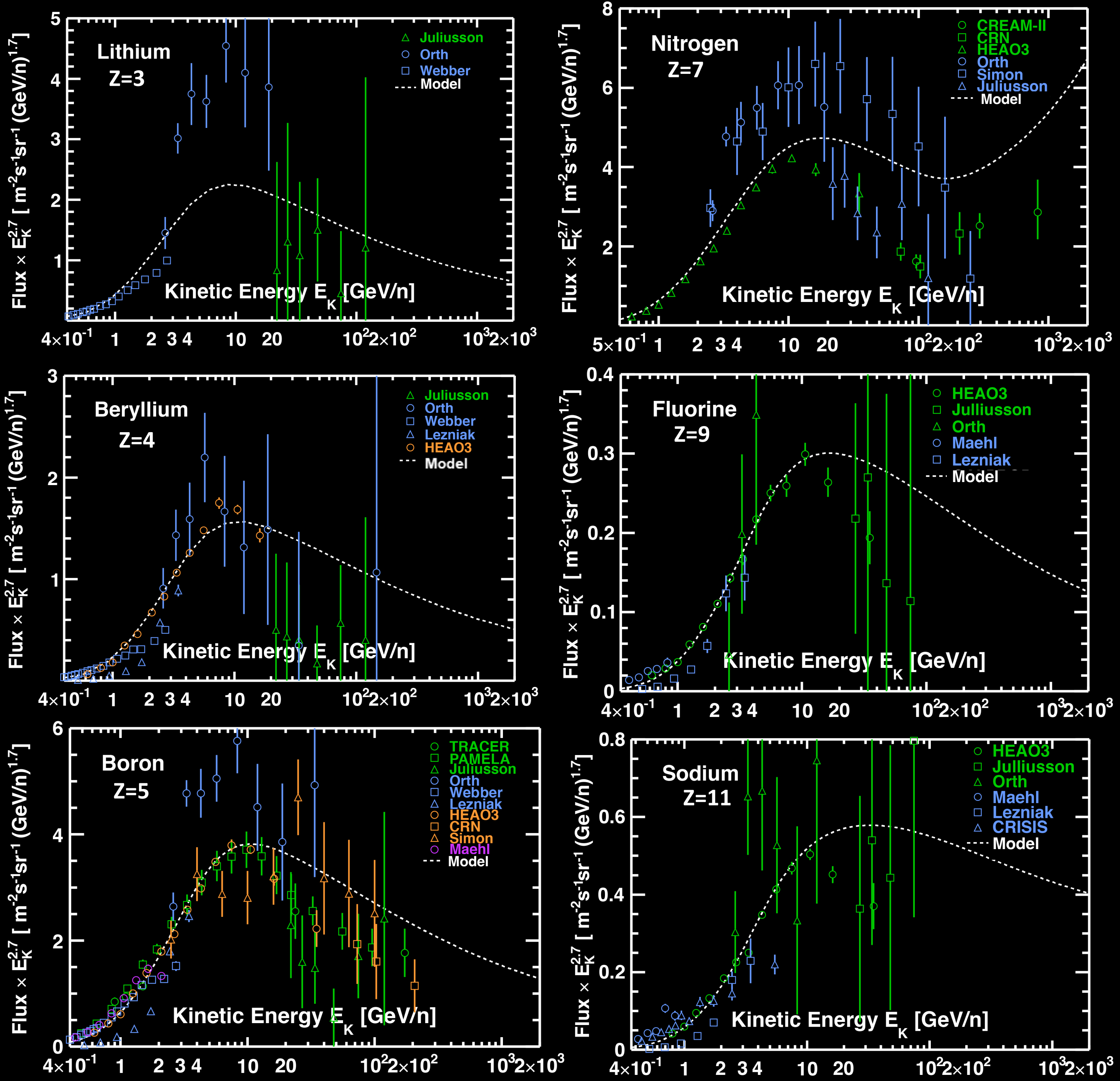
Charged Cosmic Rays in the last 100 years

1912: Discovery of Charge Cosmic Rays

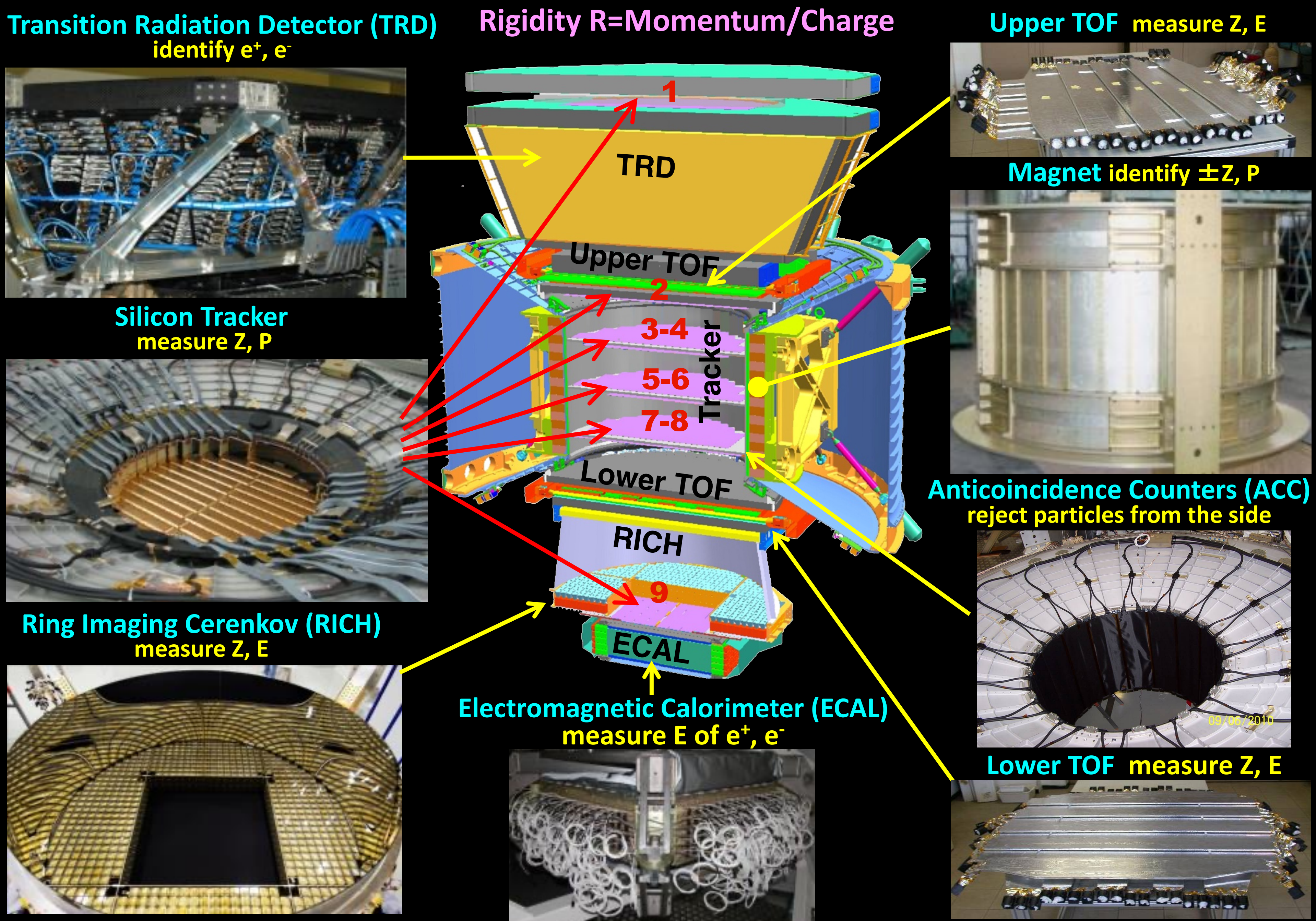


Victor Hess Nobel Prize (1936)

Before AMS: Theoretical models agree with experimental data (large errors).



AMS is a space version of a precision detector used in accelerators



Fundamental Science on the ISS

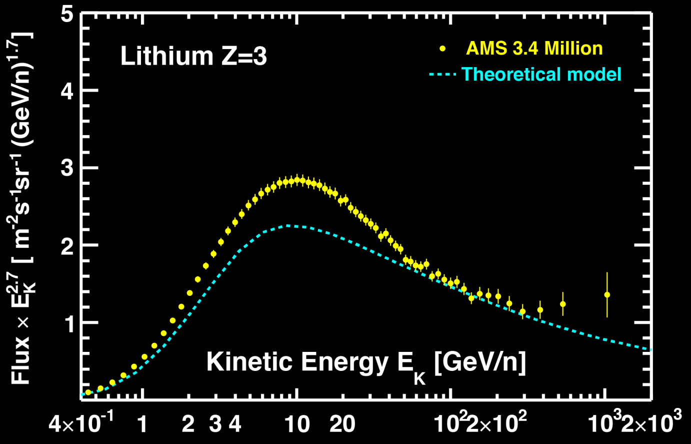
Space is the ultimate laboratory. It provides the highest energy particles.

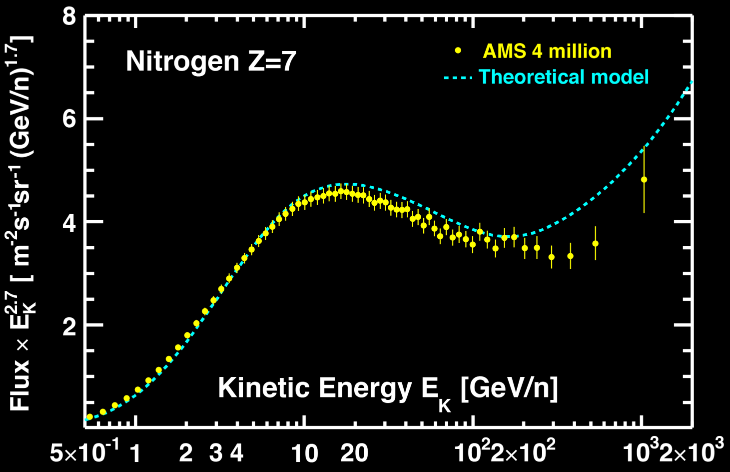
The ISS is a unique platform to support the weight and to provide the power for a precision, long duration experiment, AMS.

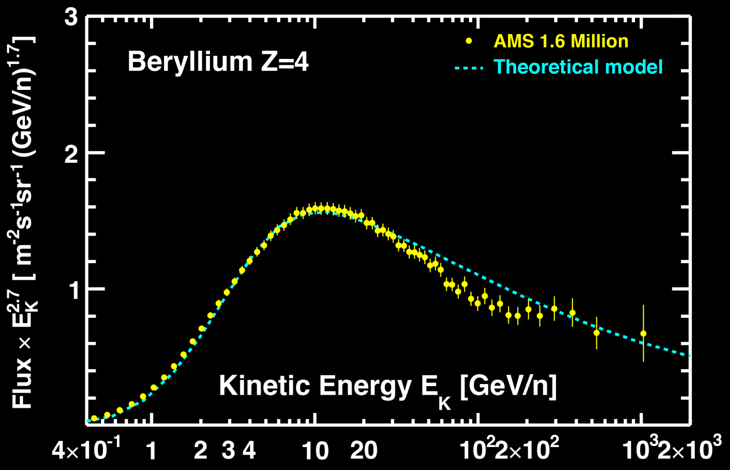
In the past hundred years, measurements of charged cosmic rays by balloons and satellites have typically had 30% to 50% accuracy.

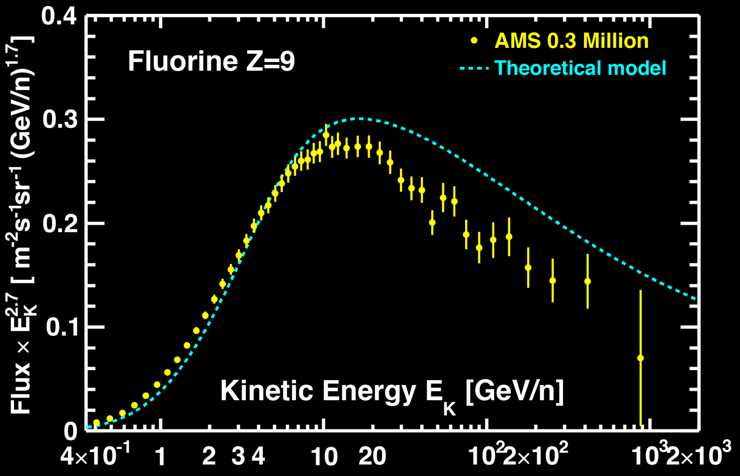
Led by LNS-MIT, AMS is providing cosmic ray information with ~1% accuracy.
The improvement in accuracy is providing new insights about the cosmos.

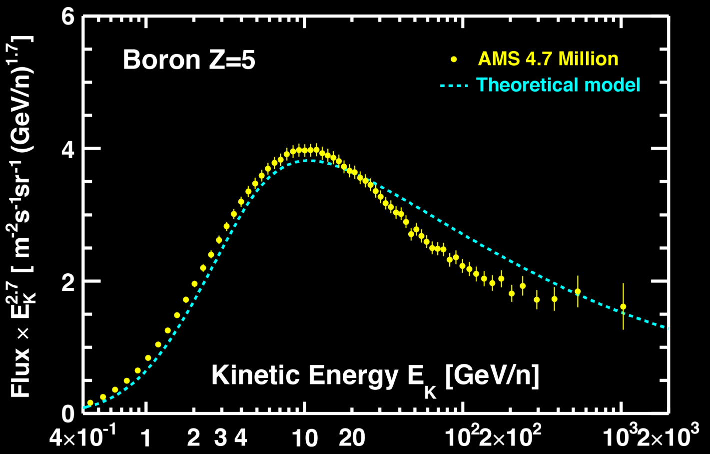
AMS results do not agree with any model

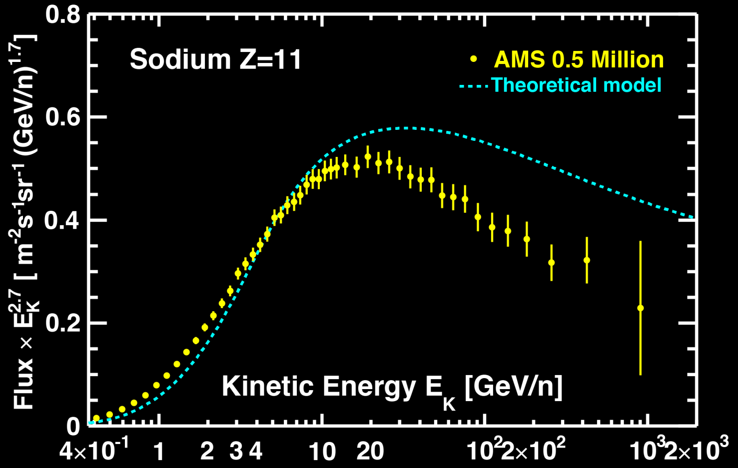












AMS Research topics are selected mostly by the MIT group

Year	Total/year
2022	16
2021	51
2020	53
2019	46
2018	52
2017	58
2016	35
2015	44
2014	34
2013	26
2012	2
2011	4
Totals	421

Publications in *Physical Review Letters*

1) Phys. Rev. Lett. 110, 141102 (2013). Editors' Suggestion. Viewpoint in *Physics*.
2) Phys. Rev. Lett. 113, 121101 (2014). Editors' Suggestion
3) Phys. Rev. Lett. 113, 121102 (2014). Editors' Suggestion. Featured in *Physics*.
4) Phys. Rev. Lett. 113, 221102 (2014).
5) Phys. Rev. Lett. 114, 171103 (2015). Editors' Suggestion
6) Phys. Rev. Lett. 115, 211101 (2015). Editors' Suggestion
7) Phys. Rev. Lett. 117, 091103 (2016).
8) Phys. Rev. Lett. 117, 231102 (2016). Editors' Suggestion
9) Phys. Rev. Lett. 119, 251101 (2017).
10) Phys. Rev. Lett. 120, 021101 (2018). Editors' Suggestion. Featured in *Physics*.
11) Phys. Rev. Lett. 121, 051101 (2018).
12) Phys. Rev. Lett. 121, 051102 (2018). Editors' Suggestion
13) Phys. Rev. Lett. 121, 051103 (2018).
14) Phys. Rev. Lett. 122, 041102 (2019). Editor's Suggestion
15) Phys. Rev. Lett, 122, 101101 (2019).
16) Phys. Rev. Lett. 123, 181102 (2019). Editors' Suggestion
17) Phys. Rev. Lett. 124, 211102 (2020). Editors' Suggestion. Featured in *Physics*.
18) Physics Reports 894, 1 (2021),
19) Phys. Rev. Lett. 126, 041104 (2021). Featured in *Physics*.
20) Phys. Rev. Lett. 126, 081102 (2021). Editors' Suggestion
21) Phys. Rev. Lett. 127, 021101 (2021).
22) Phys. Rev. Lett. 127, 271102 (2021).
23) Phys. Rev. Lett. 128, 231102 (2022).
24) "Cosmic Electrons", *to be submitted*, Phys. Rev. Lett. (2022).
25) "Properties of Beryllium Isotopes", *to be submitted*, Phys. Rev. Lett. (2022).

5915 Citations

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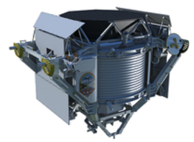
Physical Review Letters • Physical Review • Reviews of Modern Physics • Physics

Dear Sir or Madam,

We are pleased to inform you that the Letter



Properties of heavy secondary fluorine cosmic rays: Results from the Alpha Magnetic Spectrometer

M. Aguilar *et al.*
Phys. Rev. Lett. **126**, 081102 (2021)

Published 25 February 2021

has been highlighted by the editors as an Editors' Suggestion. Publication of a Letter is already a considerable achievement, as *Physical Review Letters* accepts fewer than 1/4 of submissions, and is ranked first among physics and mathematics journals by the Google Scholar five-year h-index. A highlighted Letter has additional significance, because only about one Letter in seven is highlighted as a Suggestion due to its particular importance, innovation, and broad appeal. Suggestions are downloaded more than twice as often as the average Letter, and receive substantially more press coverage. Suggestions are cited at roughly twice the rate of nonhighlighted Letters. More information about our journal and its history can be found on our webpage prl.aps.org.

Yours sincerely,

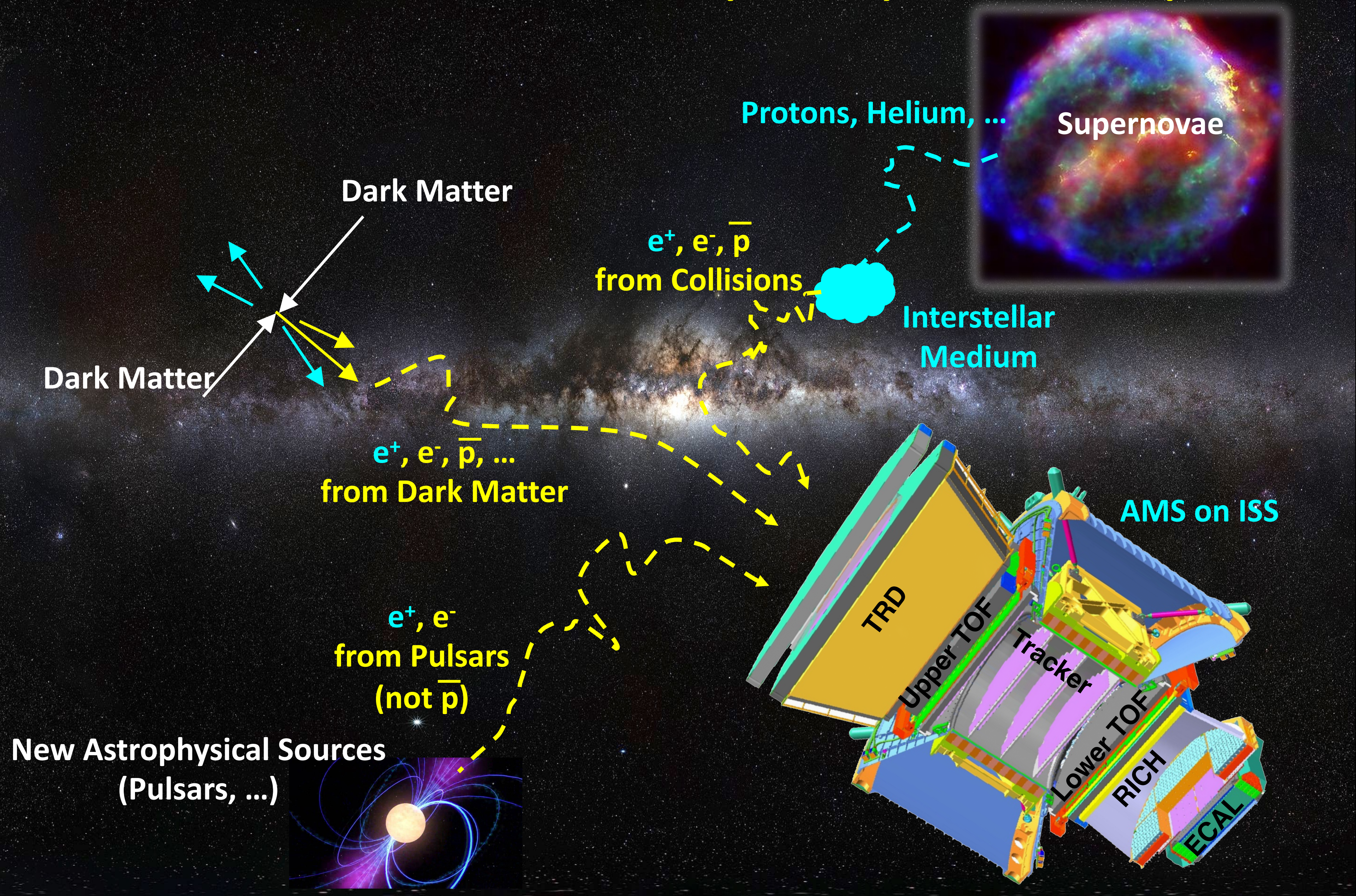
Hugues Chaté
Editor
Physical Review Letters

Michael Thoennessen
Editor in Chief
American Physical Society

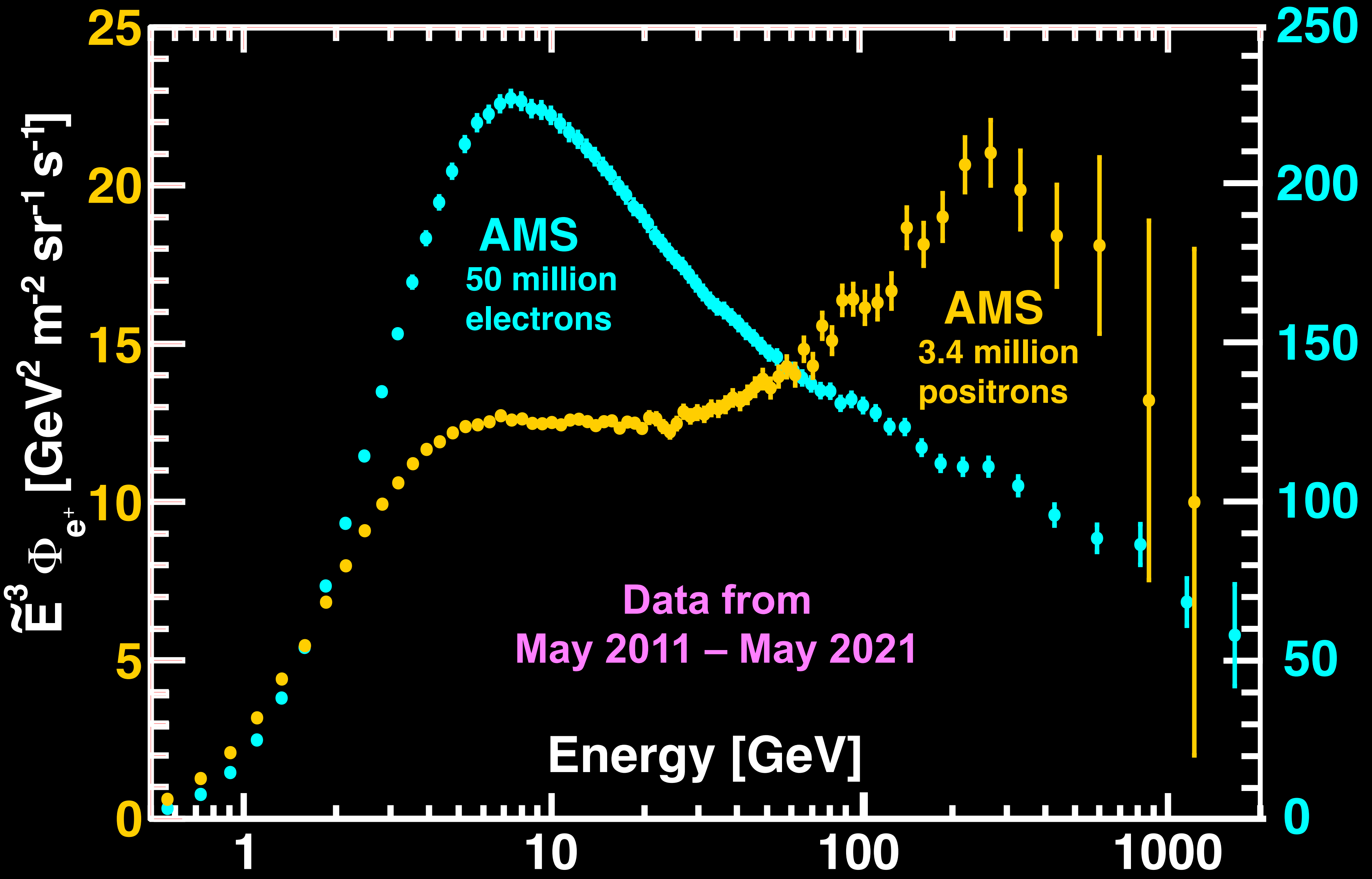
421 Publications (PRL, PRD, NIM-A, APJ…) based on AMS-02
Three peer-reviewed papers per month
Conference proceedings by research physicists and graduate students are not included

Origins of Cosmic Particles

Positrons e^+, Electrons e^-, Antiprotons $\bar{p}$, and Protons p

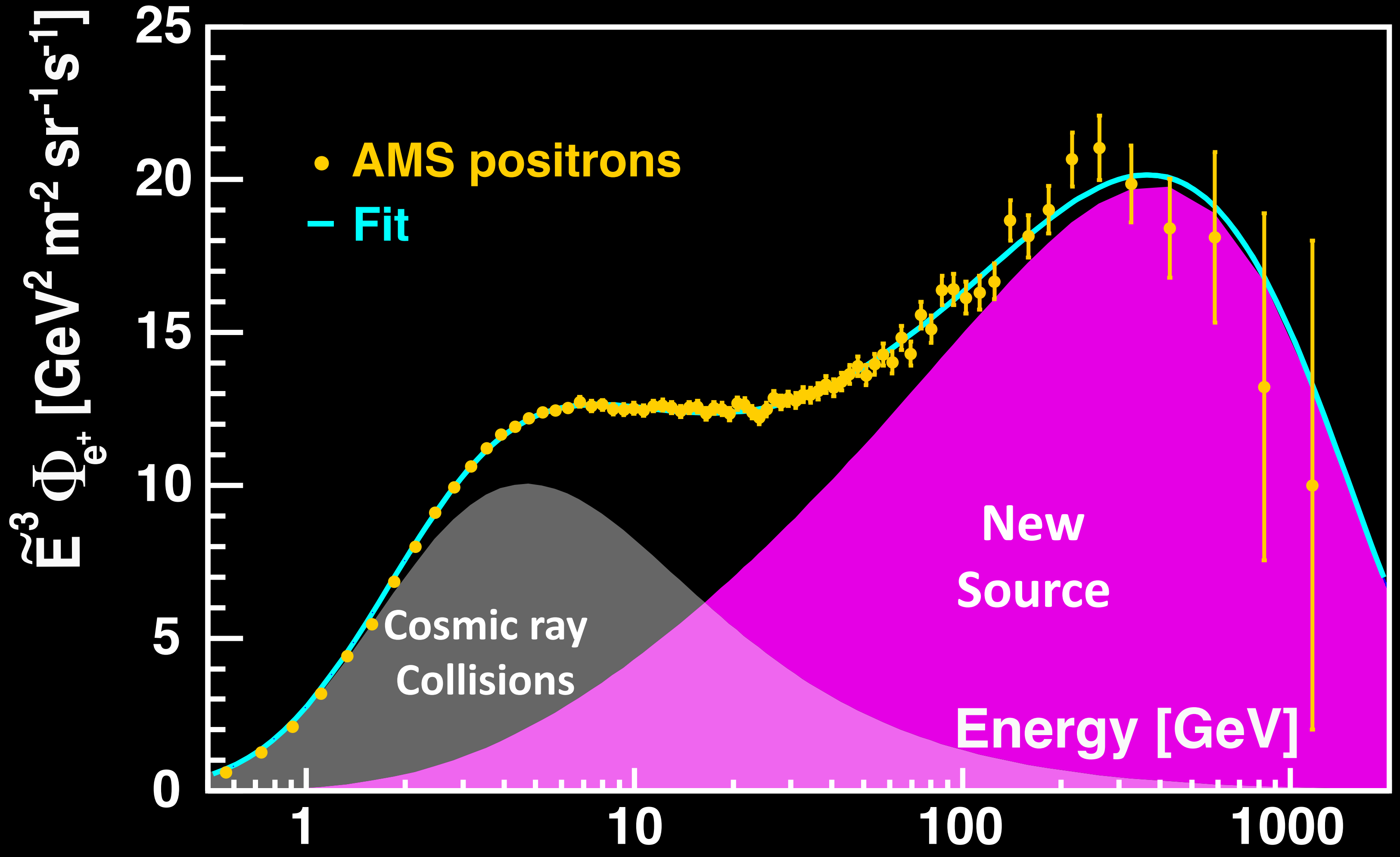


Origin of Cosmic Positron and Electron

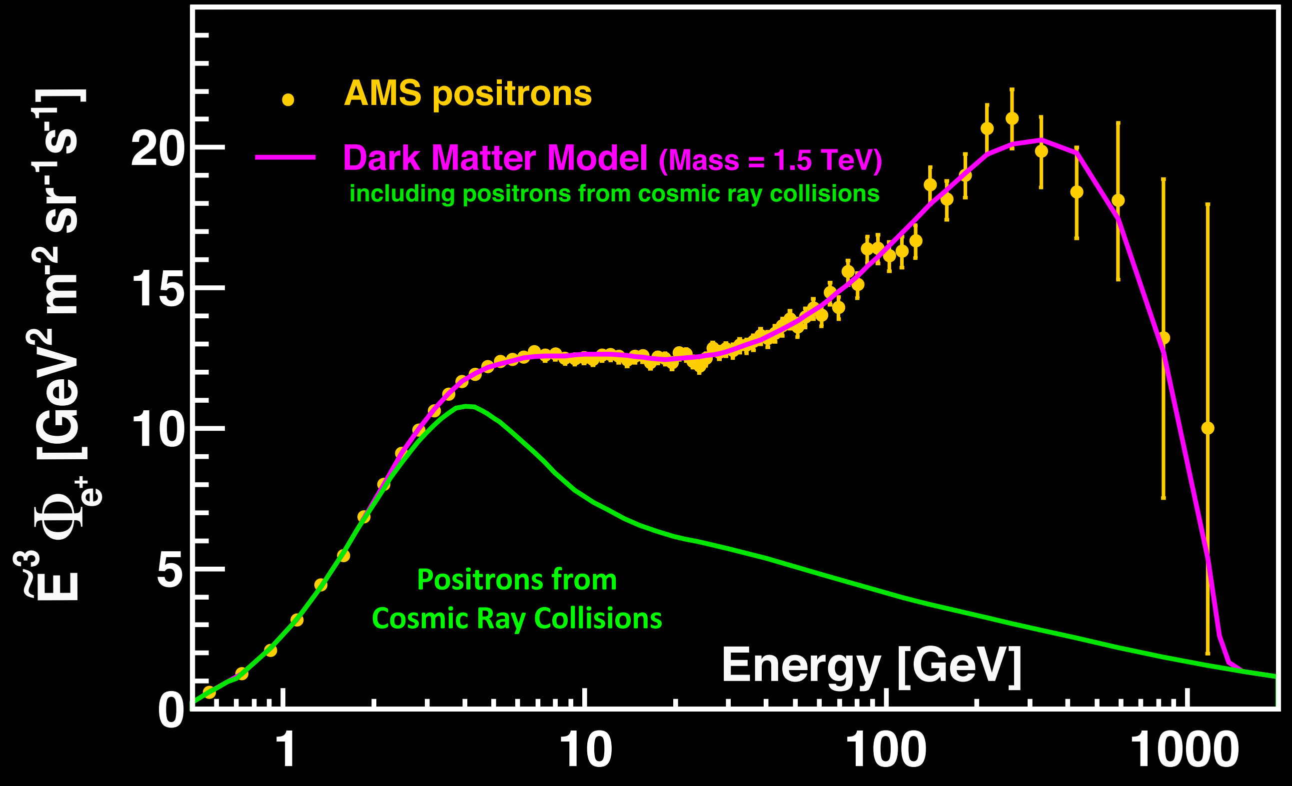


The cosmic positron flux is the sum of a low-energy part from cosmic ray collisions and a high-energy part from a new source.

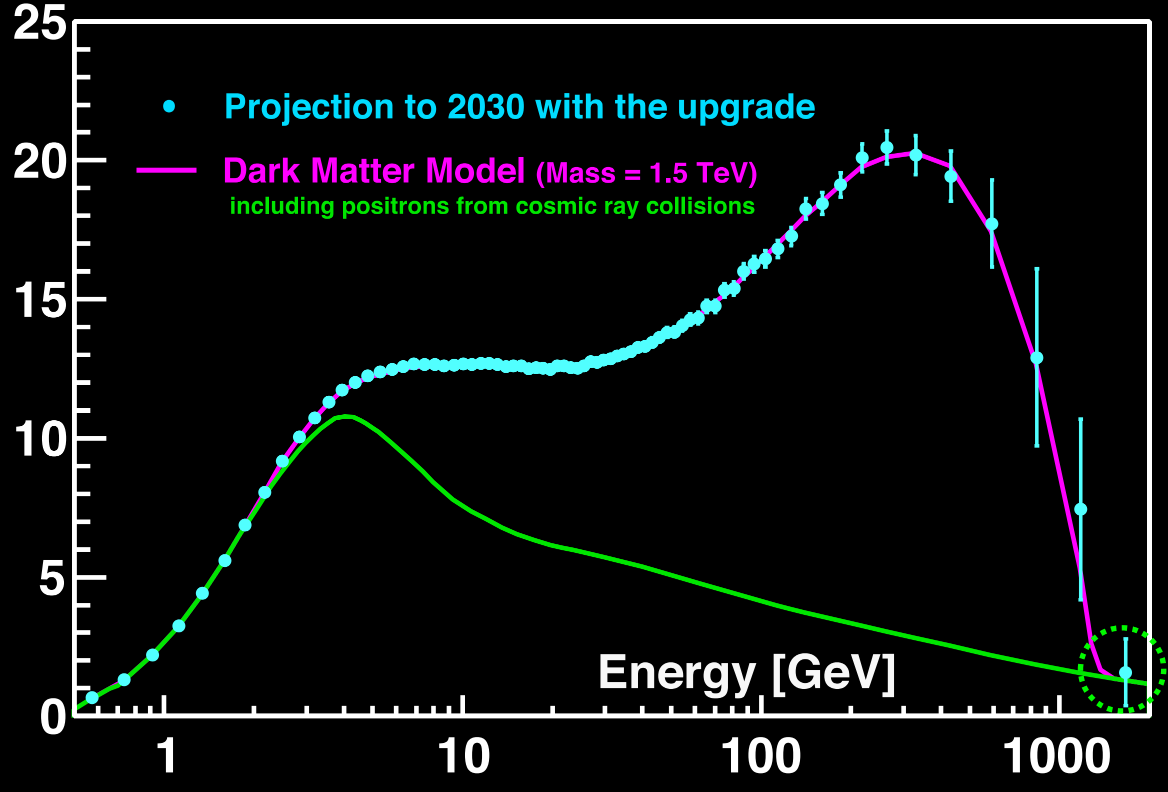
Unexpectedly, the cosmic positron flux has a cutoff at 1 TeV



Cosmic Positron and Dark Matter



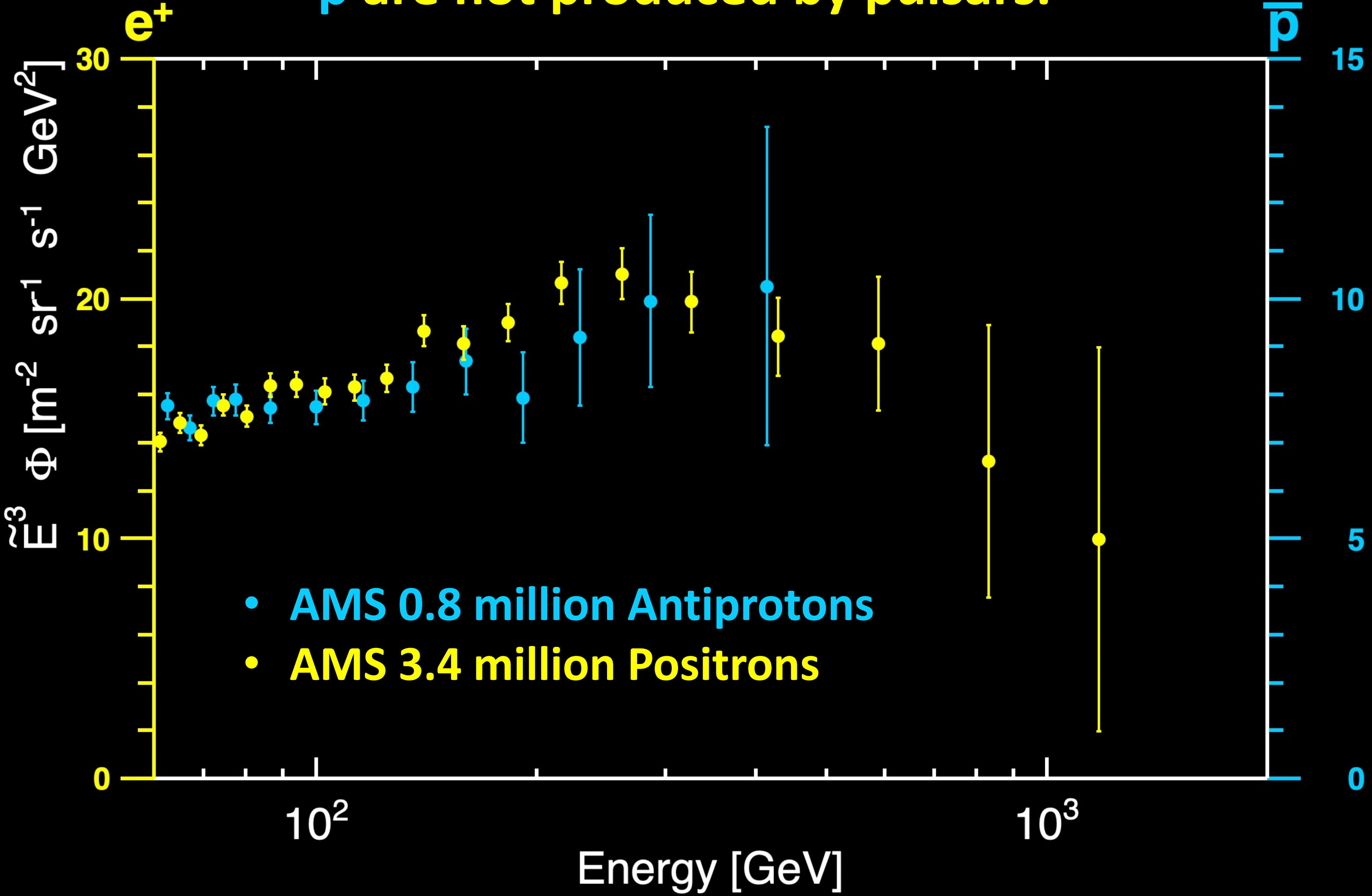
Positron to 2030 with the on-going Upgrade



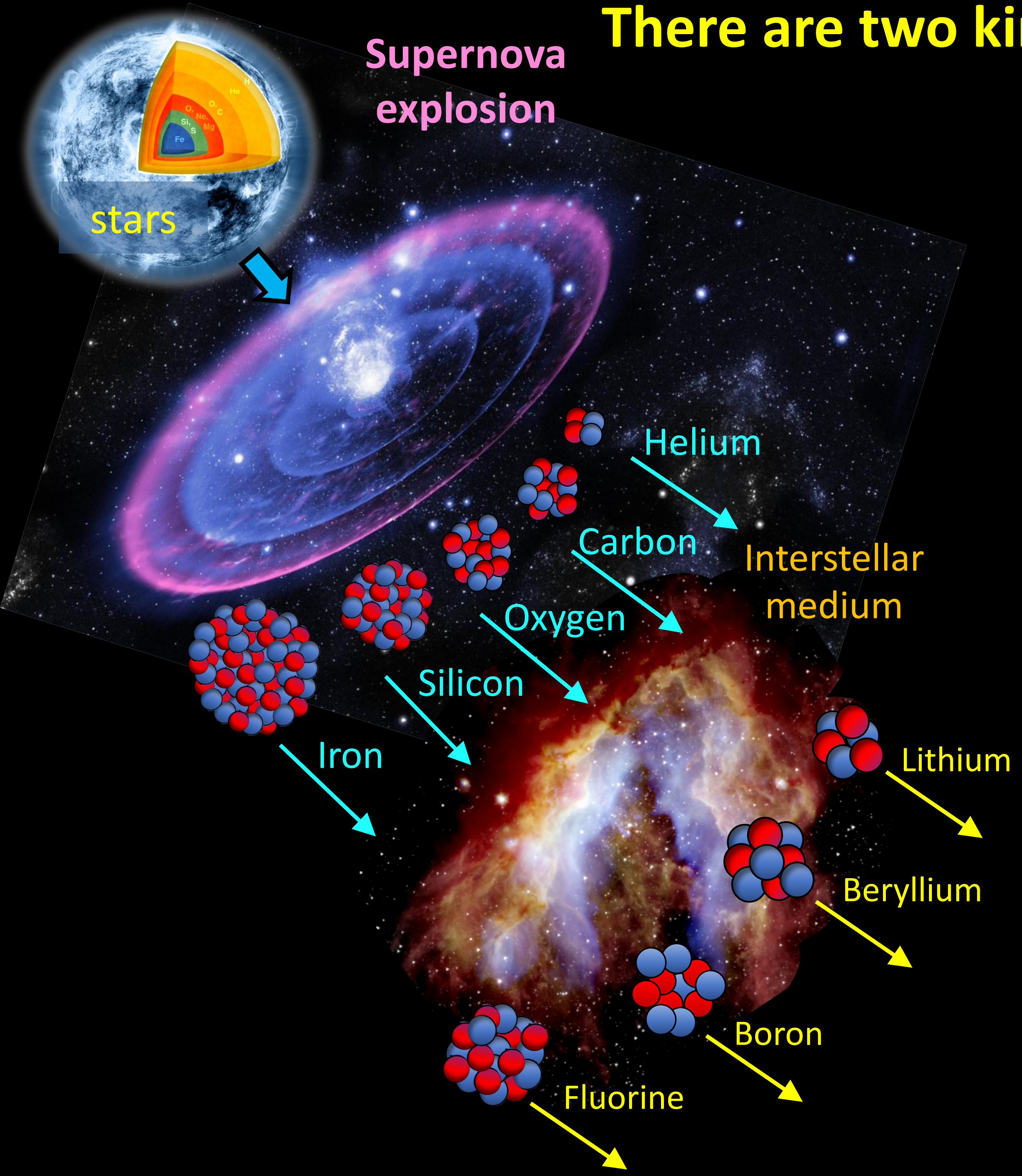
Properties of Cosmic Antiprotons

The $\overline{p}$ and e^+ fluxes have identical energy dependence.

$\overline{p}$ are not produced by pulsars.



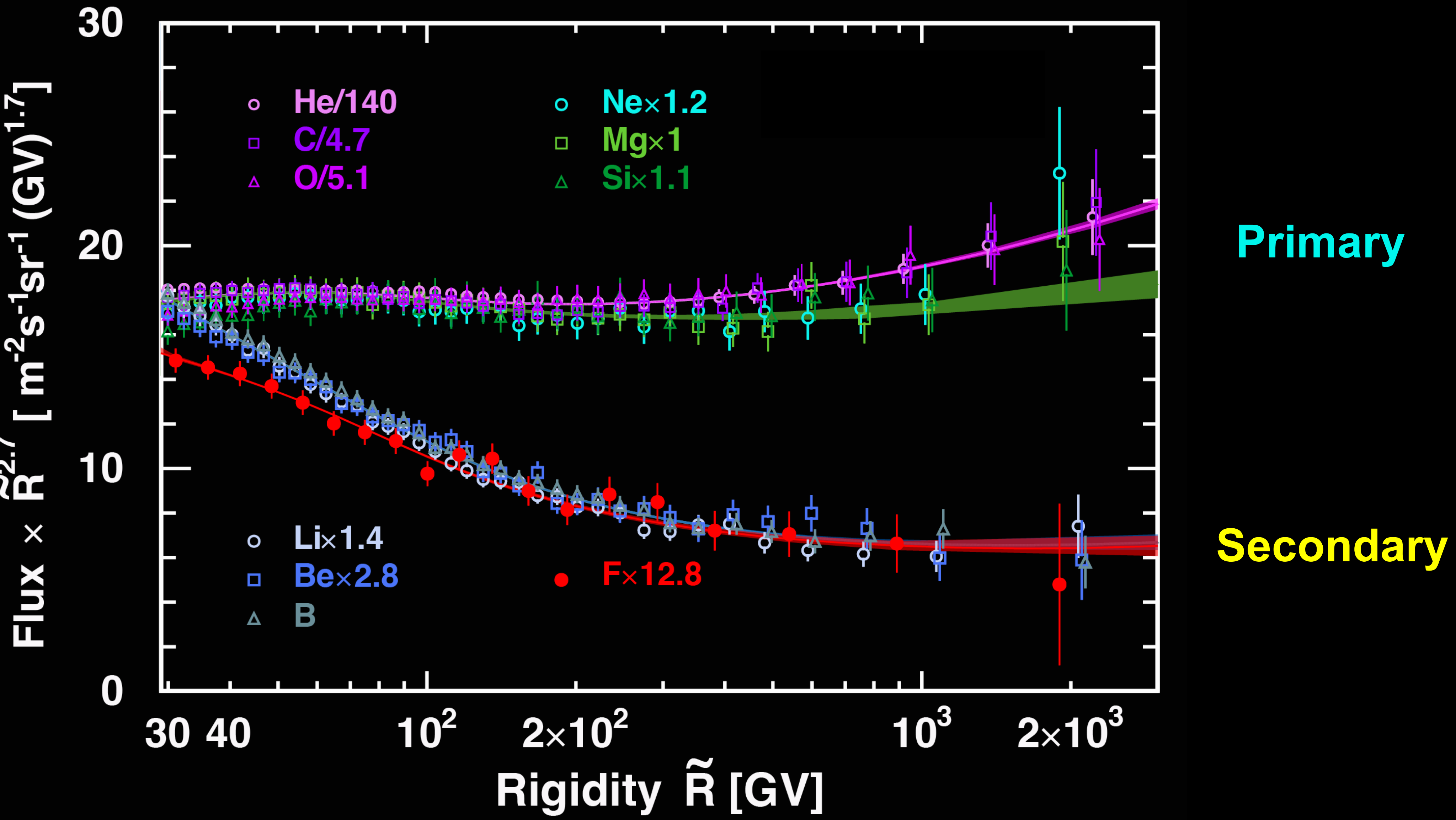
There are two kinds of Cosmic Rays: Primary and Secondary



Primary cosmic rays p, He, C, O … Si … Fe are produced during the lifetime of stars and accelerated by supernovae.

Secondary cosmic rays Li, Be, B, and F are produced by the collision of primary cosmic rays with the interstellar medium.

Unexpected Results of Primary and Secondary Cosmic-Ray



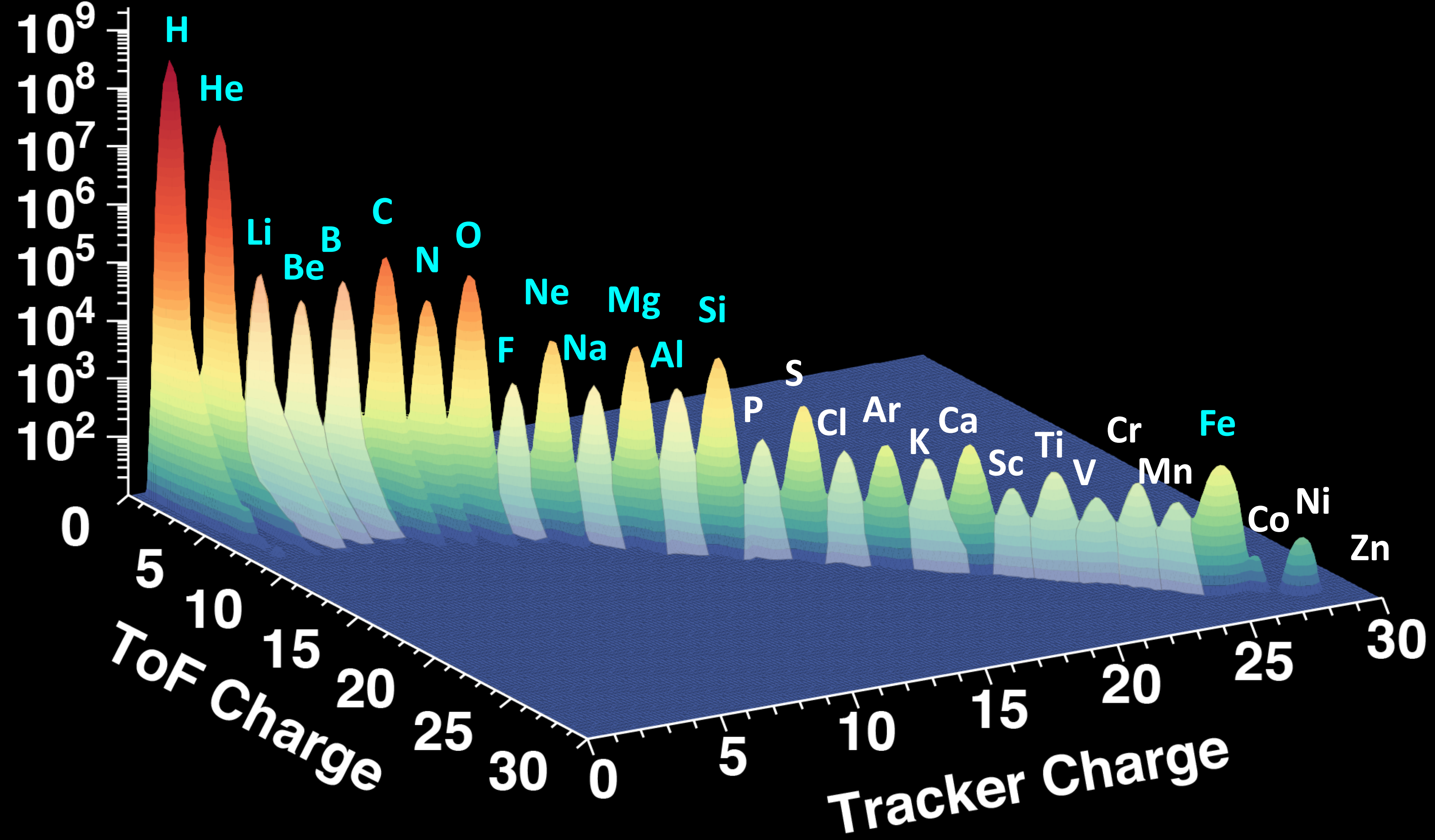
Primary cosmic rays have two distinct classes: He-C-O and Ne-Mg-Si.

Secondary cosmic rays also have two classes: Li-Be-B and F.

11 Years of Precision Measurements of Cosmic Nuclei by AMS

We have studied **15 elements** with high precision. None agrees with model predictions.

We are upgrading the acceptance to study the other **14 elements with high precision**.



Cosmic Antimatter: e^+, $\bar{p}$, $\bar{D}$, $\overline{He}$, $\bar{C}$, $\bar{O}$ …

Matter is defined by its mass *M* and charge *Z*.

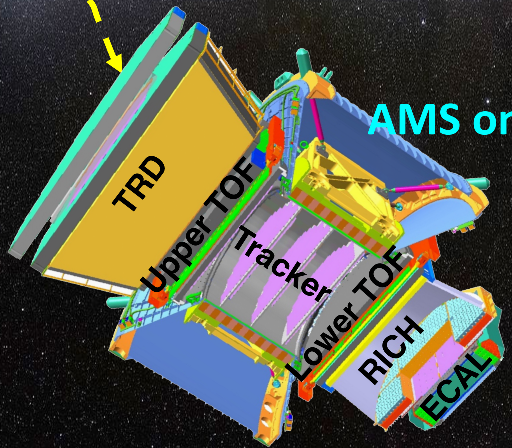
Antimatter has the same mass *M* but opposite charge –*Z*.

$\bar{D}$ can come from antimatter star or dark matter collisions

Heavy antimatter can only be produced from antimatter star

$\bar{D}$, $\overline{He}$, $\bar{C}$, $\bar{O}$ …

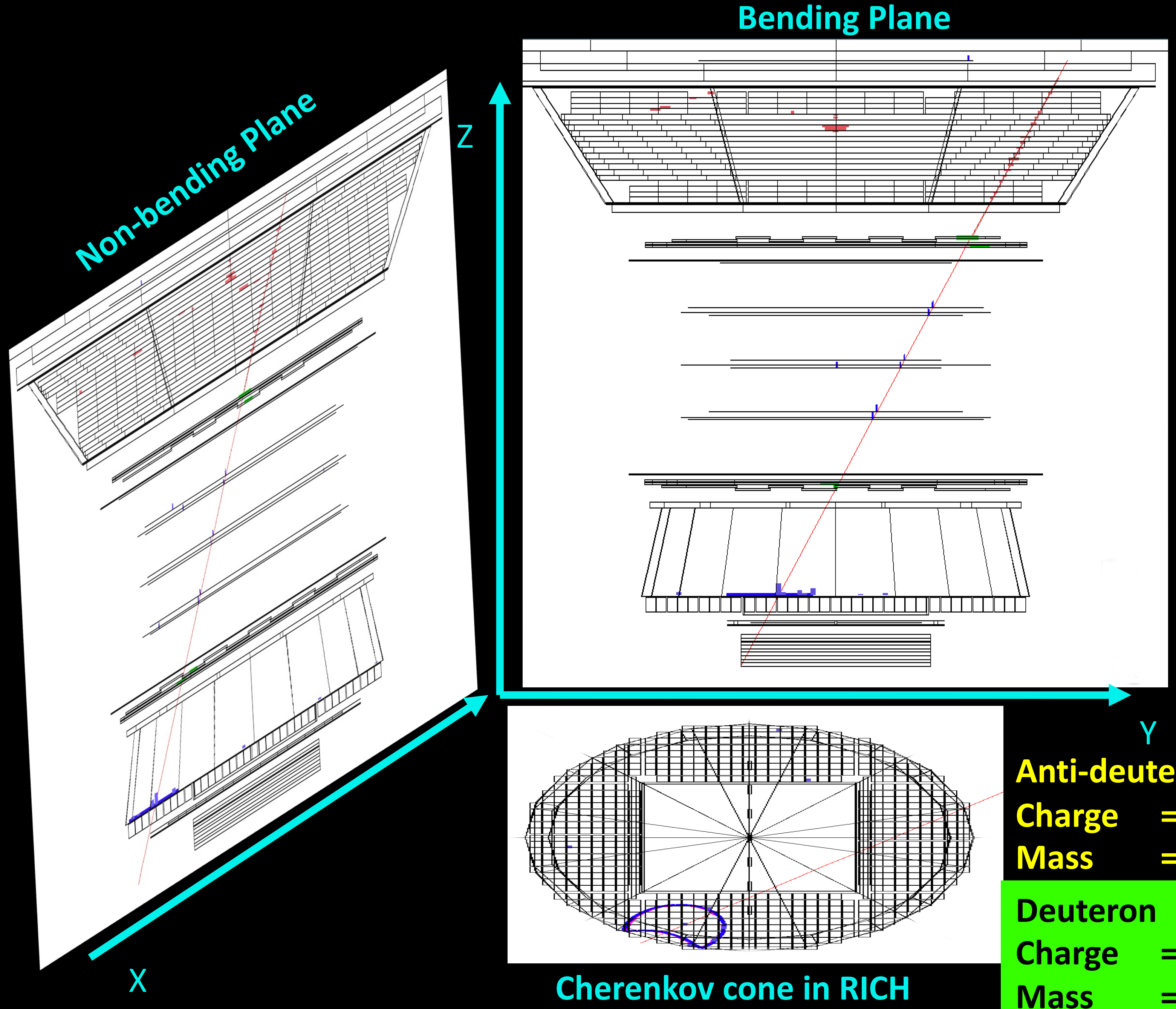
Antimatter Star



AMS on ISS

AMS is a unique antimatter spectrometer in space

An Anti-Deuteron Candidate from ~100 million deuterons and ~10 billion protons



Anti-deuteron Candidate

Charge = -1.02 ± 0.05

Mass = 1.9±0.1 *GeV/c²*

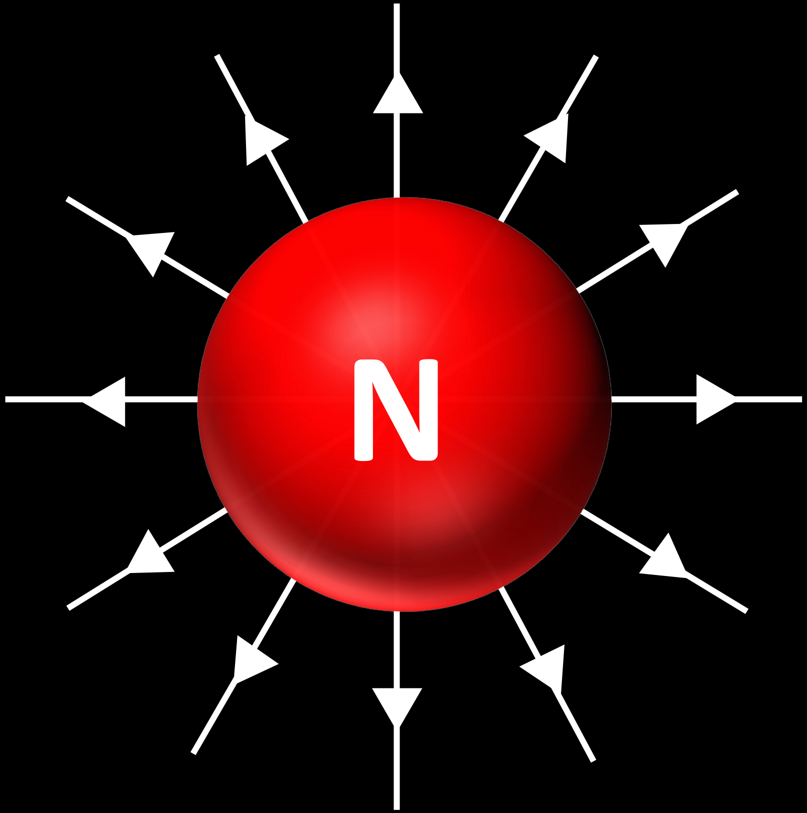
Deuteron

Charge = +1

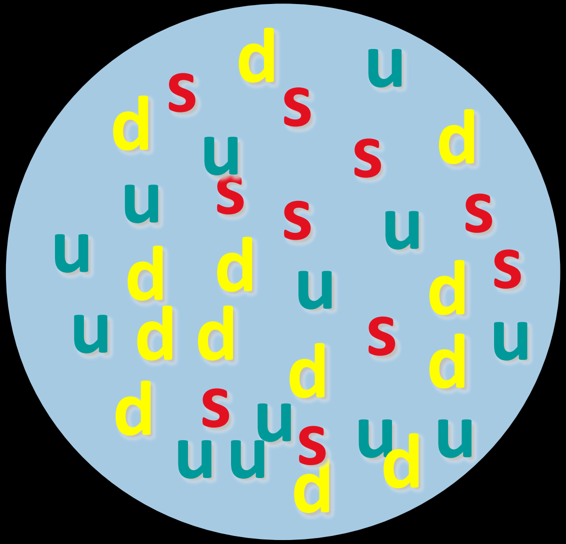
Mass = 1.88 *GeV/c²*

Research Topic: New Particles in Cosmic Rays

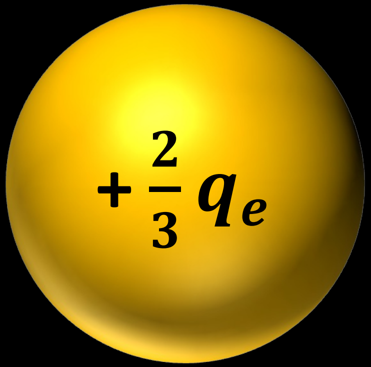
Magnetic monopole



Strangelet

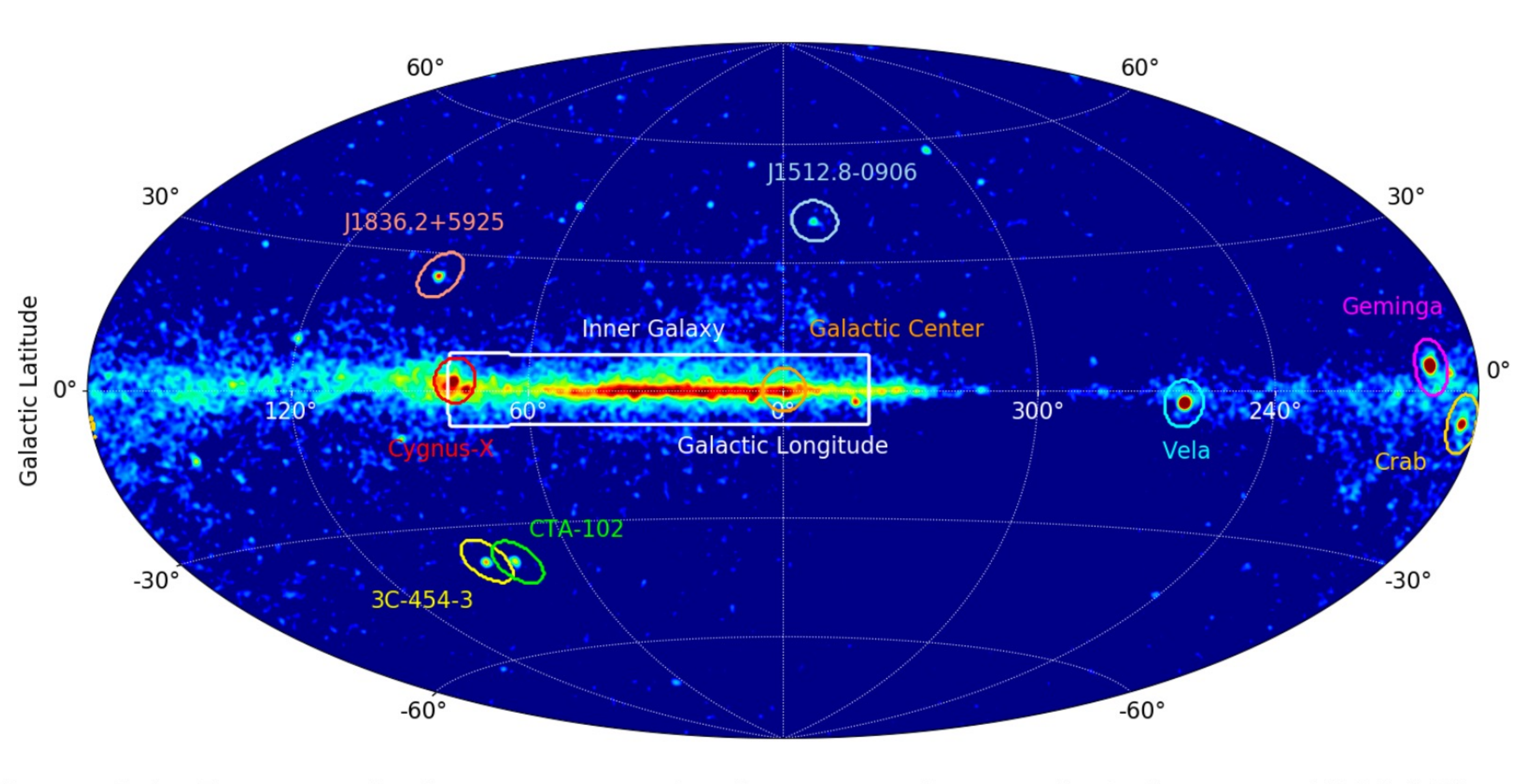


Fractionally charged particles

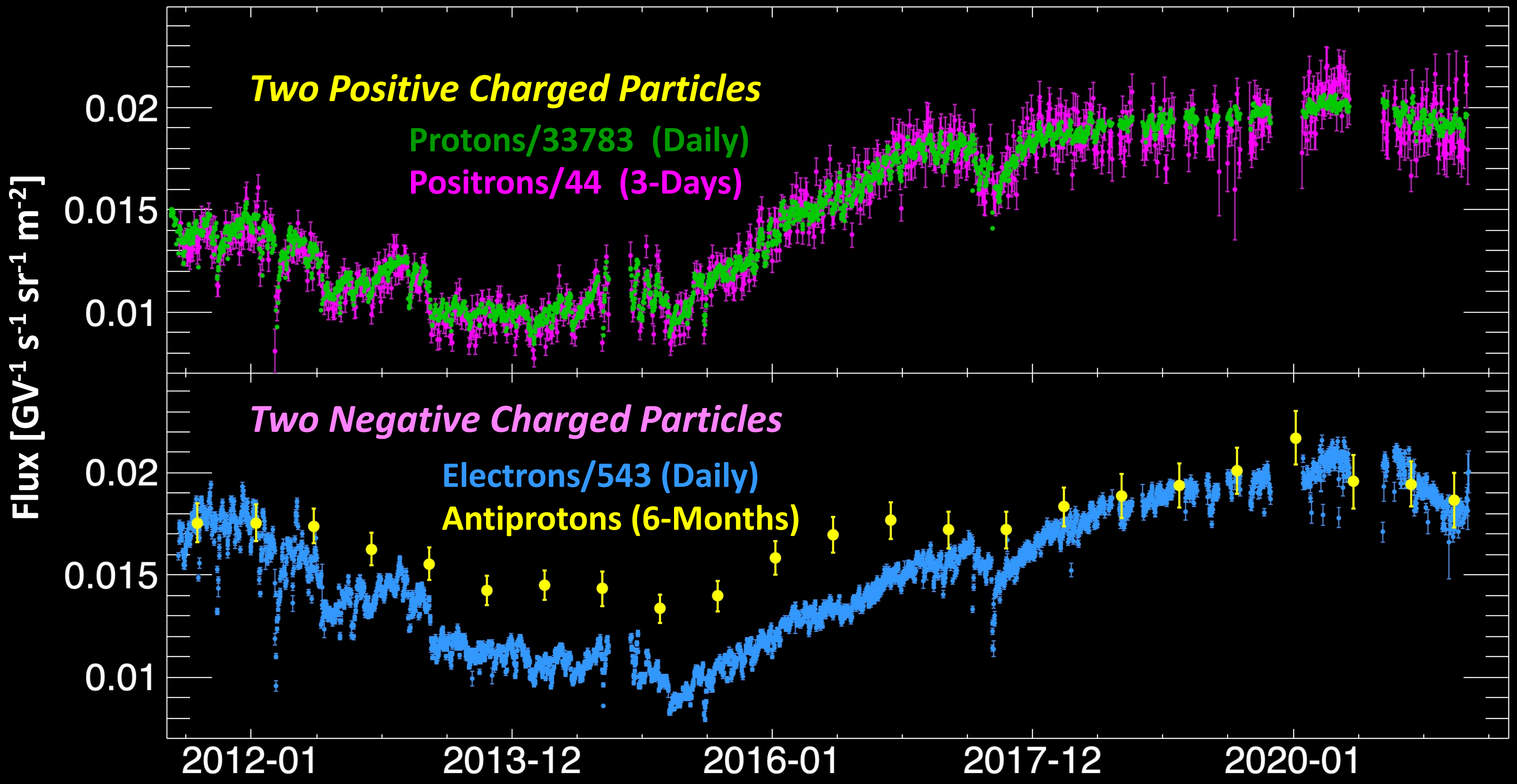


Research Topic: Photon Polarization

AMS photon results from $\gamma \rightarrow e^+ e^-$: 500 MeV to 100 GeV



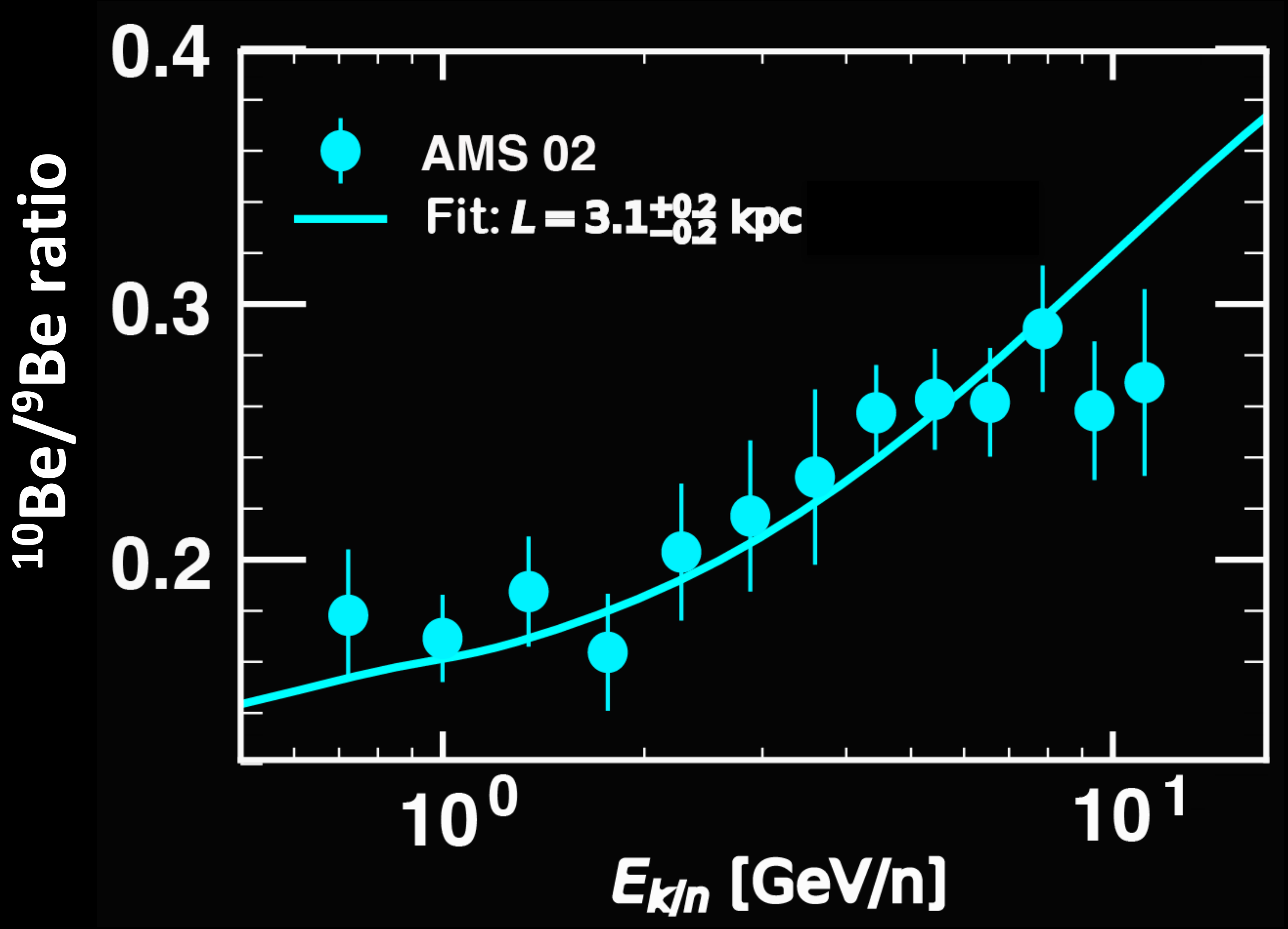
Research Topic: Elementary Particles in the Heliosphere
(Protons, positrons, electrons, and antiprotons)



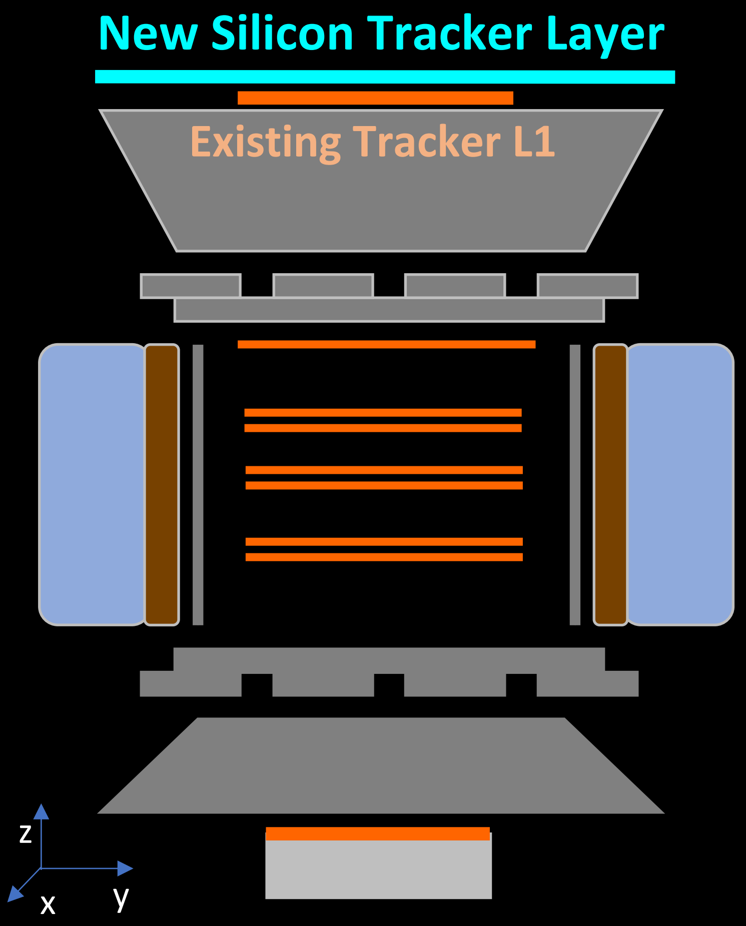
|Rigidity| = 1.92-2.97 GV

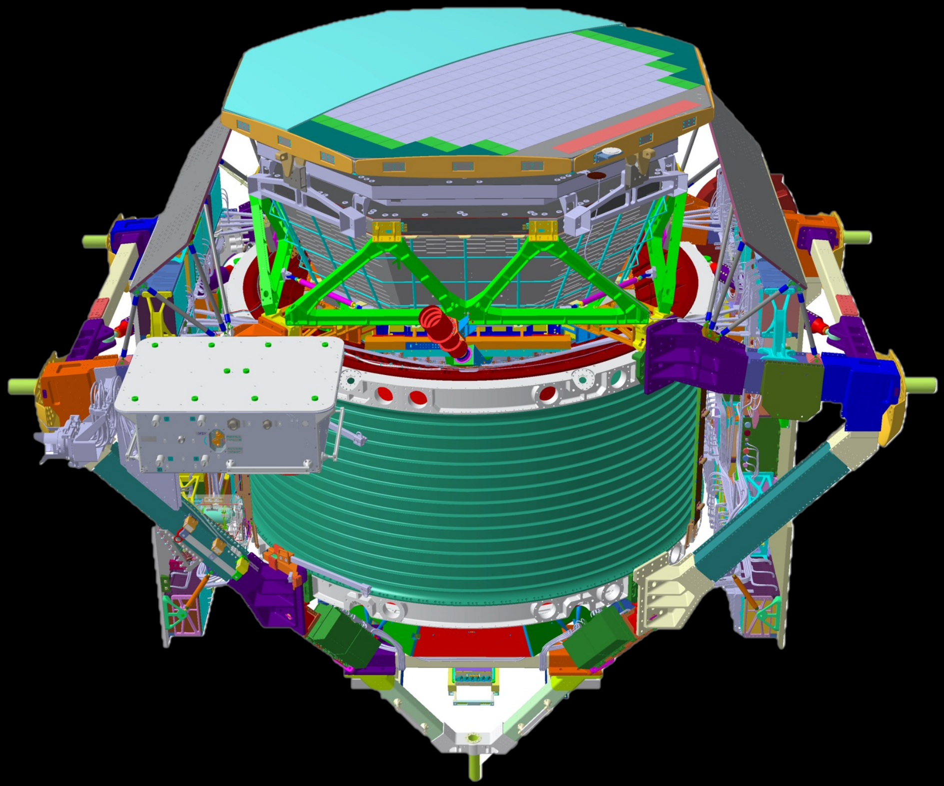
Research Topic: Cosmic Isotopes

The confinement time measured with ^{10}Be determines the halo size L of the galaxy



AMS for the next ten years:
Upgrade with new Silicon Tracker Layer
Acceptance increased to 300%





AMS Research in Physics and Instrumentation

In 11 years, none of our results agree with any model. The AMS results open a new field in the understanding of the cosmos

- Origin of cosmic positron, electron, and antiproton: Cosmic positrons and antiprotons provide unique signal for the origin of dark matter
- Cosmic Antimatter $\overline{\mathrm{D}}$, $\overline{\mathrm{He}}$, $\overline{\mathrm{C}}$, $\overline{\mathrm{O}}$ … : Dark matter and antimatter star
- Systematic studies of cosmic ray nuclei up to nickel: provide fundamental knowledge of cosmos
- Other topics: new particles, photons, particles in the heliosphere, cosmic isotopes …
- Major detector development for the on-going upgrade to increase the acceptance by 300%

Contact at MIT:
Yi Jia (jiay@mit.edu)
Peter Fisher (fisherp@mit.edu)
Matthew Behlmann (behlmann@mit.edu)

At CERN:
Vitaly Choutko (vitaly.choutko@cern.ch)
Andrei Kounine (Andrei.Kounine@cern.ch)
Mike Capell (Michael.Capell@cern.ch)
Tatiana Medvedeva (Tatiana.Medvedeva@cern.ch)

PI:
S. Ting (samuel.ting@cern.ch)