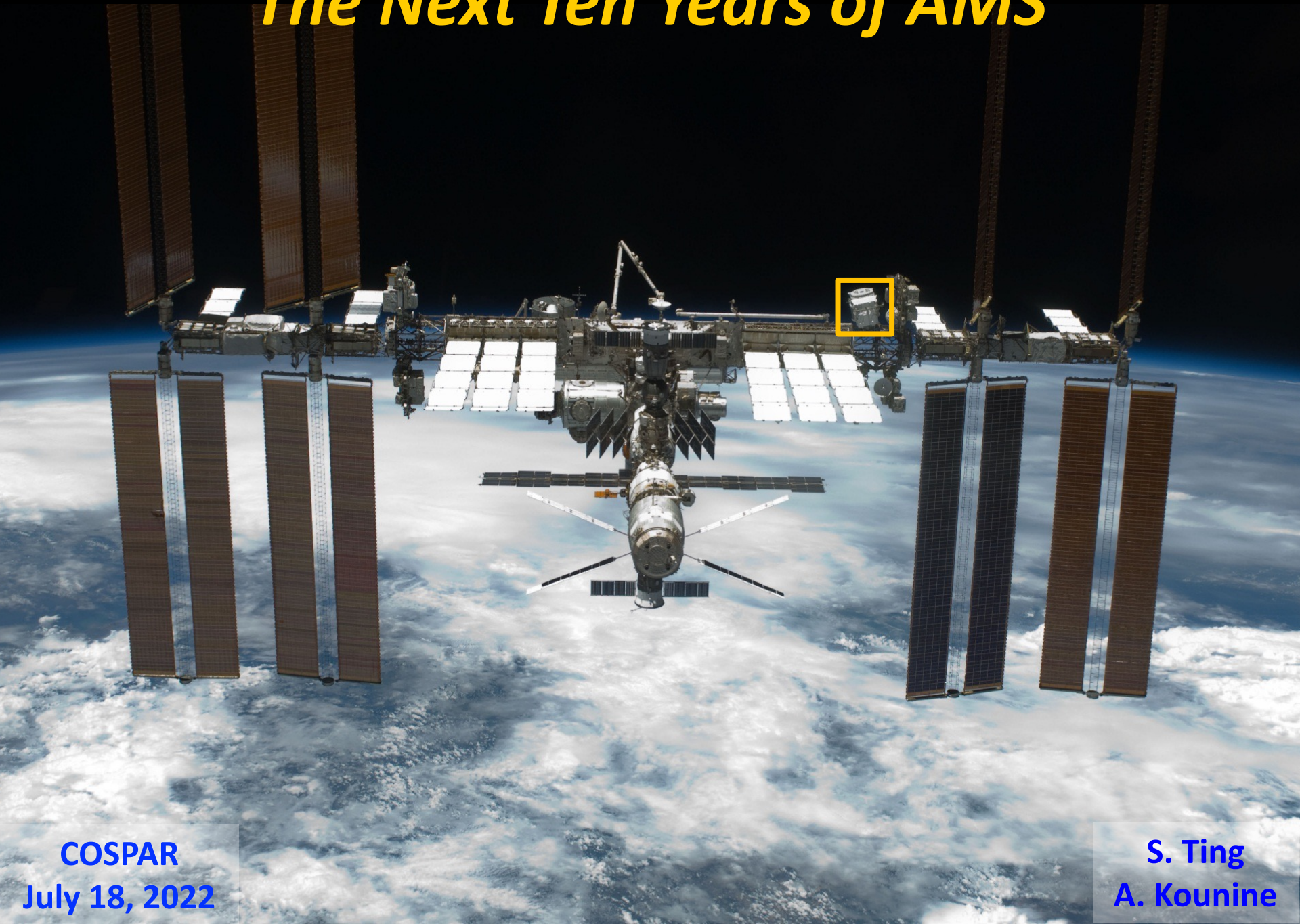


The Next Ten Years of AMS



COSPAR
July 18, 2022

S. Ting
A. Kounine

AMS Publications in the first ten years

- 1) Phys. Rev. Lett. [110](#), 141102 (2013). Editors' Suggestion. Viewpoint in *Physics*.
Highlight of 2013. Ten-Year retrospective.
- 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).

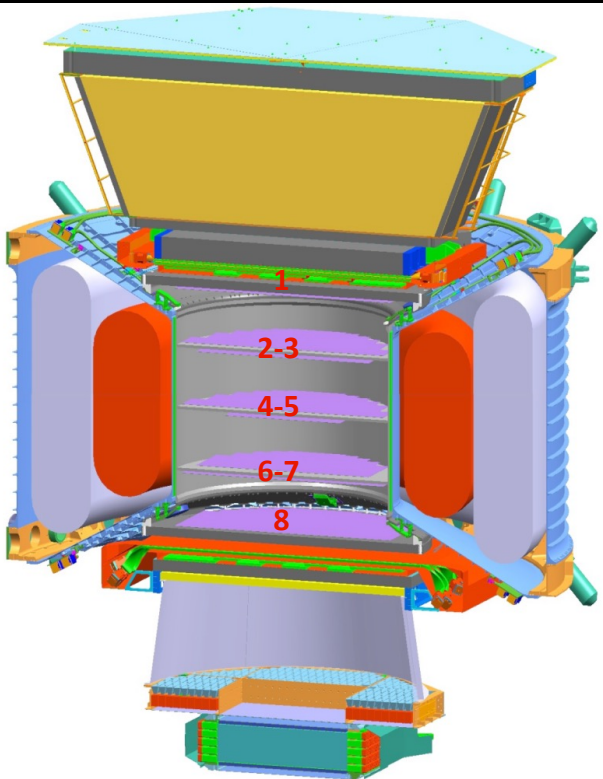
In ten years on the ISS, AMS has recorded more than 200 billion cosmic rays. The accuracy and characteristics of the data simultaneously from many different types of cosmic rays require the development of a new comprehensive model of the universe.

ISS is scheduled to operate through 2030.

An upgrade of AMS to reach its original acceptance

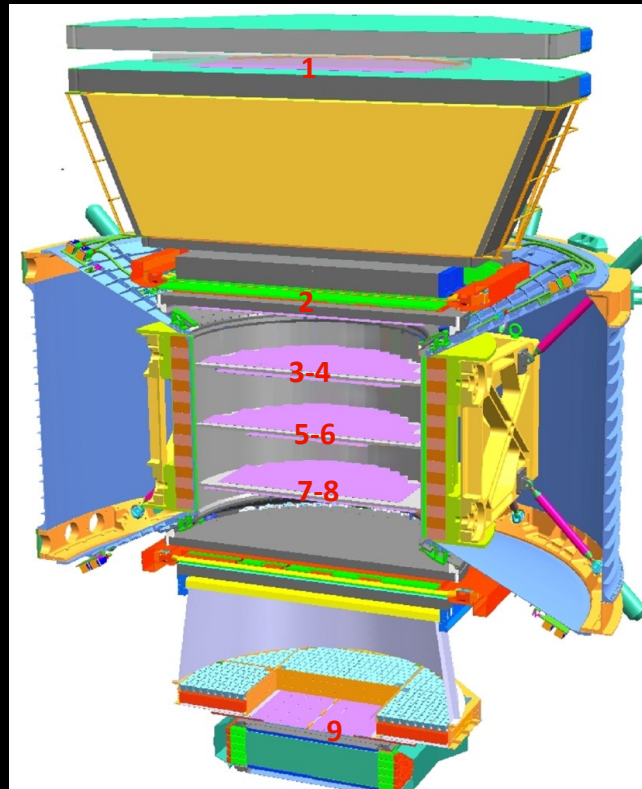
AMS as approved by the DOE
Review Panel in 1995, 1999, and 2006:

*Superconducting Magnet
8 layers of Silicon,
Large Acceptance*



AMS on ISS due to
termination of the Shuttle

*Permanent Magnet,
9 layers of Silicon
(to maintain the resolution),
1/3 of the acceptance*

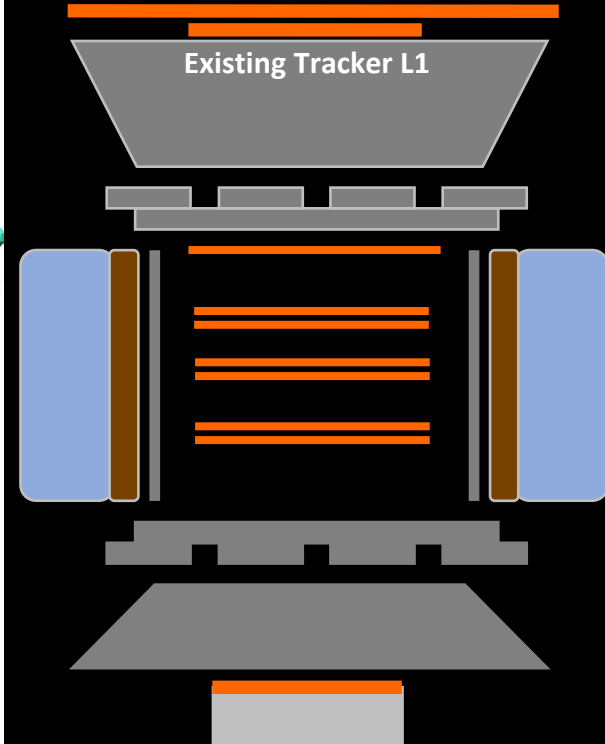


AMS on ISS to 2030

*Permanent Magnet,
10 layers of Silicon
to upgrade to
full acceptance*

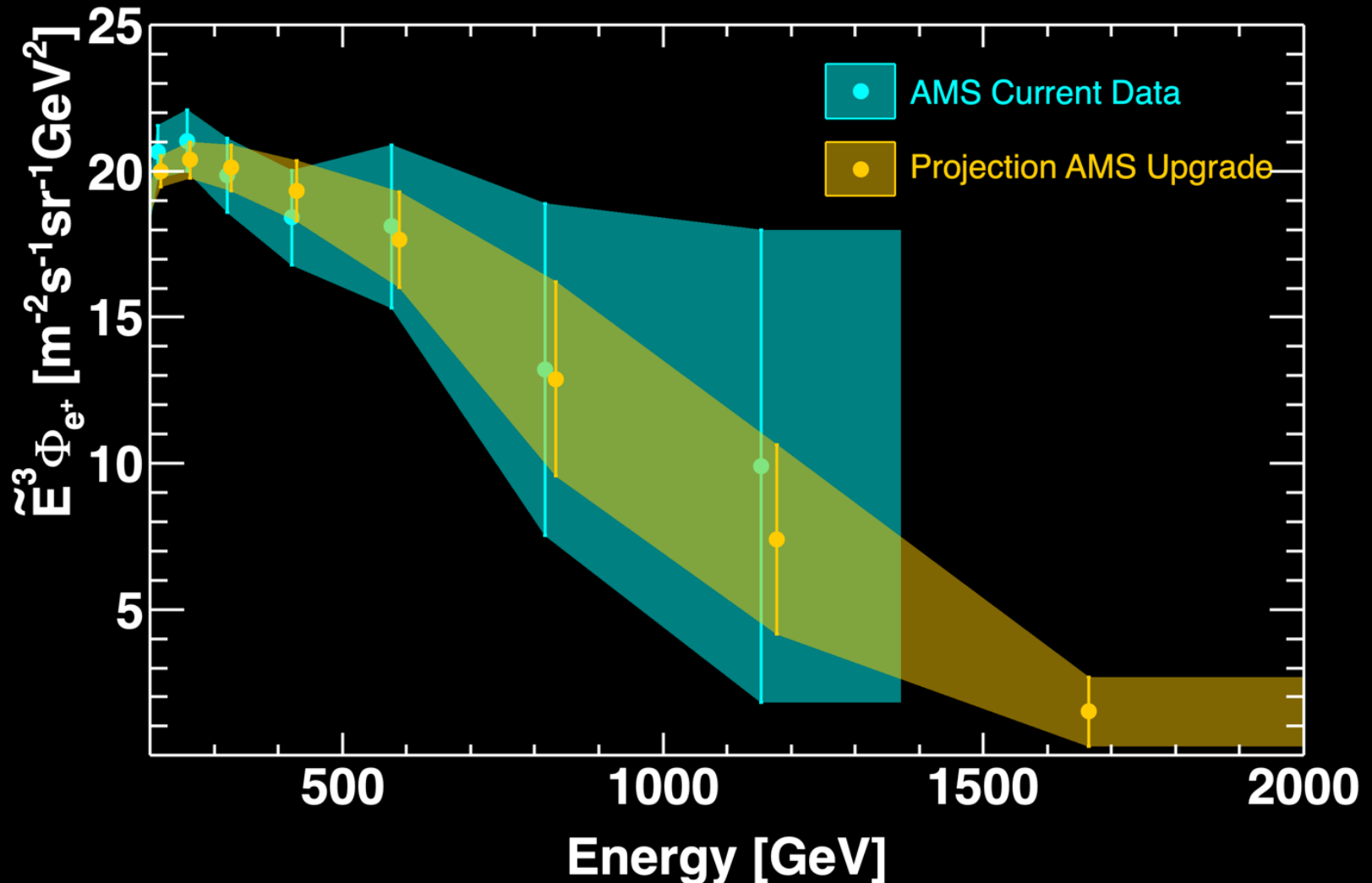
New Silicon Tracker Layer L0

Existing Tracker L1



Physics of the Upgrade - Examples

Extend the energy range of the positron flux measurement **to 2 TeV** from the current 1.4 TeV and **reduce the error by factor of two**

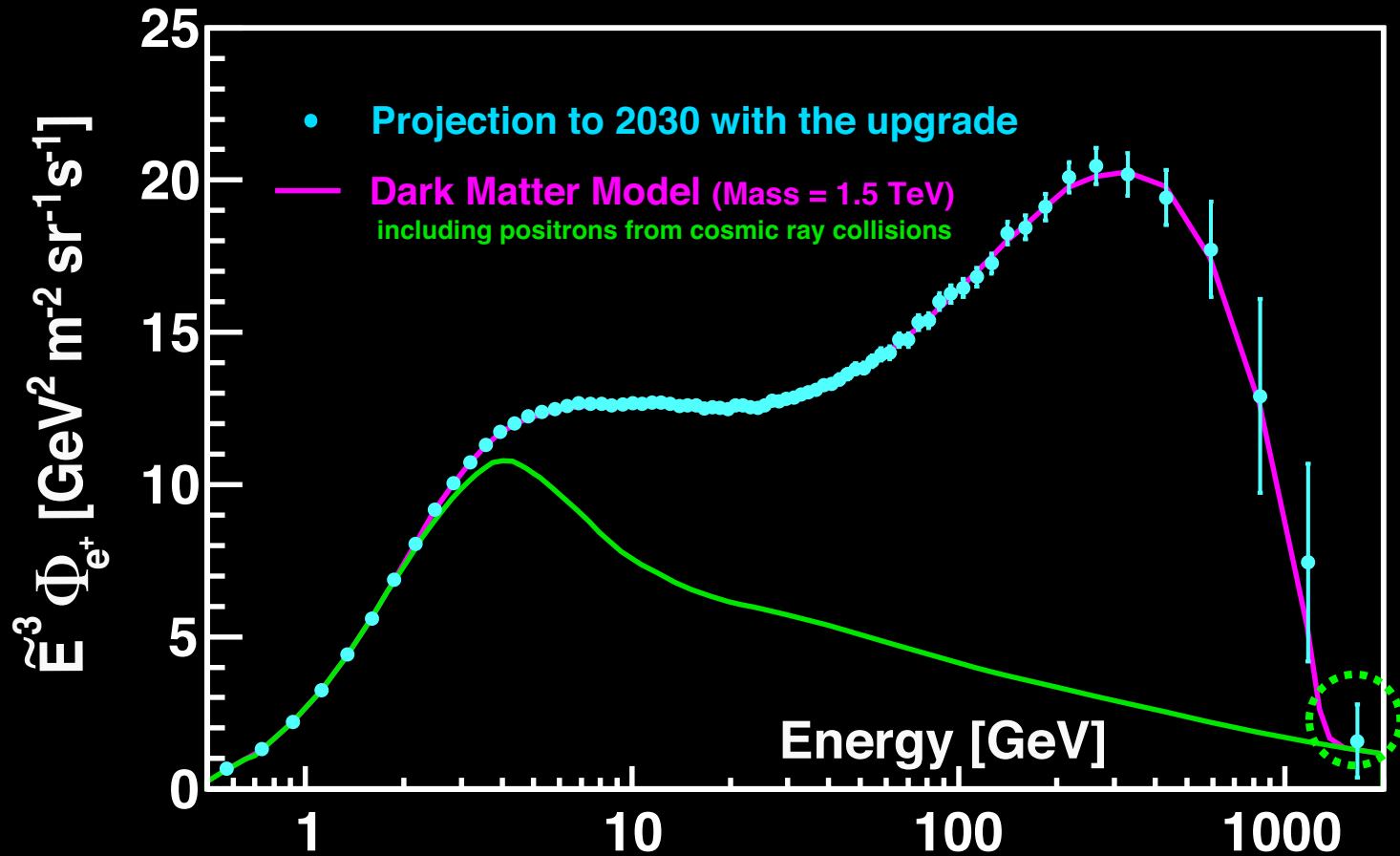


Physics of the Upgrade

This is particularly important at high energies as it will ensure that

the measured high energy positron spectrum indeed

drops off quickly and, in the 1-2 TeV region, the positrons only come from cosmic ray collisions as predicted by dark matter models

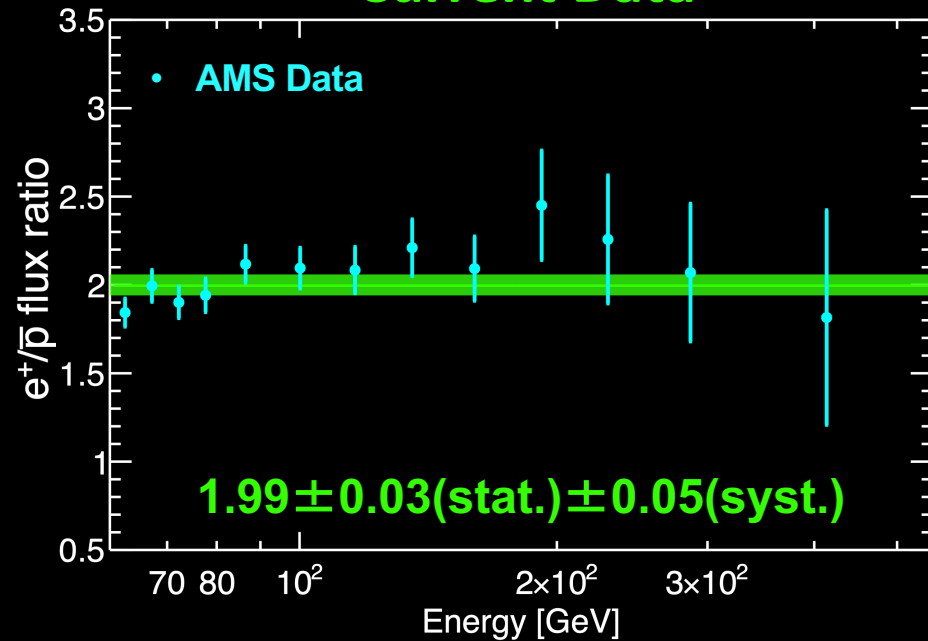


Note that the highest energy point is from collisions only.

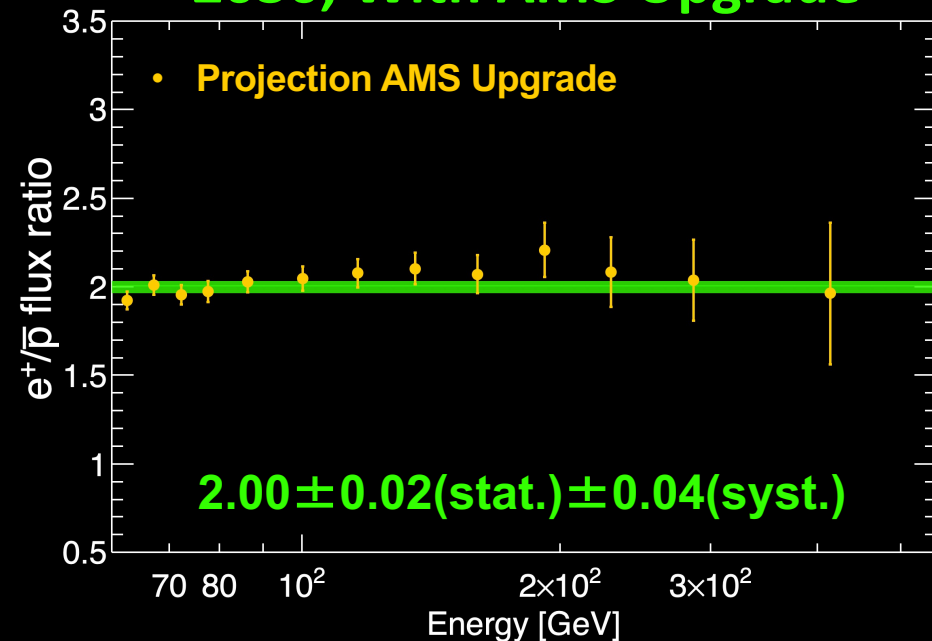
This upgrade will greatly improve the accuracy of the measurement of positrons and antiprotons.

The constant value of the positron/antiproton ratio excludes the pulsar origin of positrons.

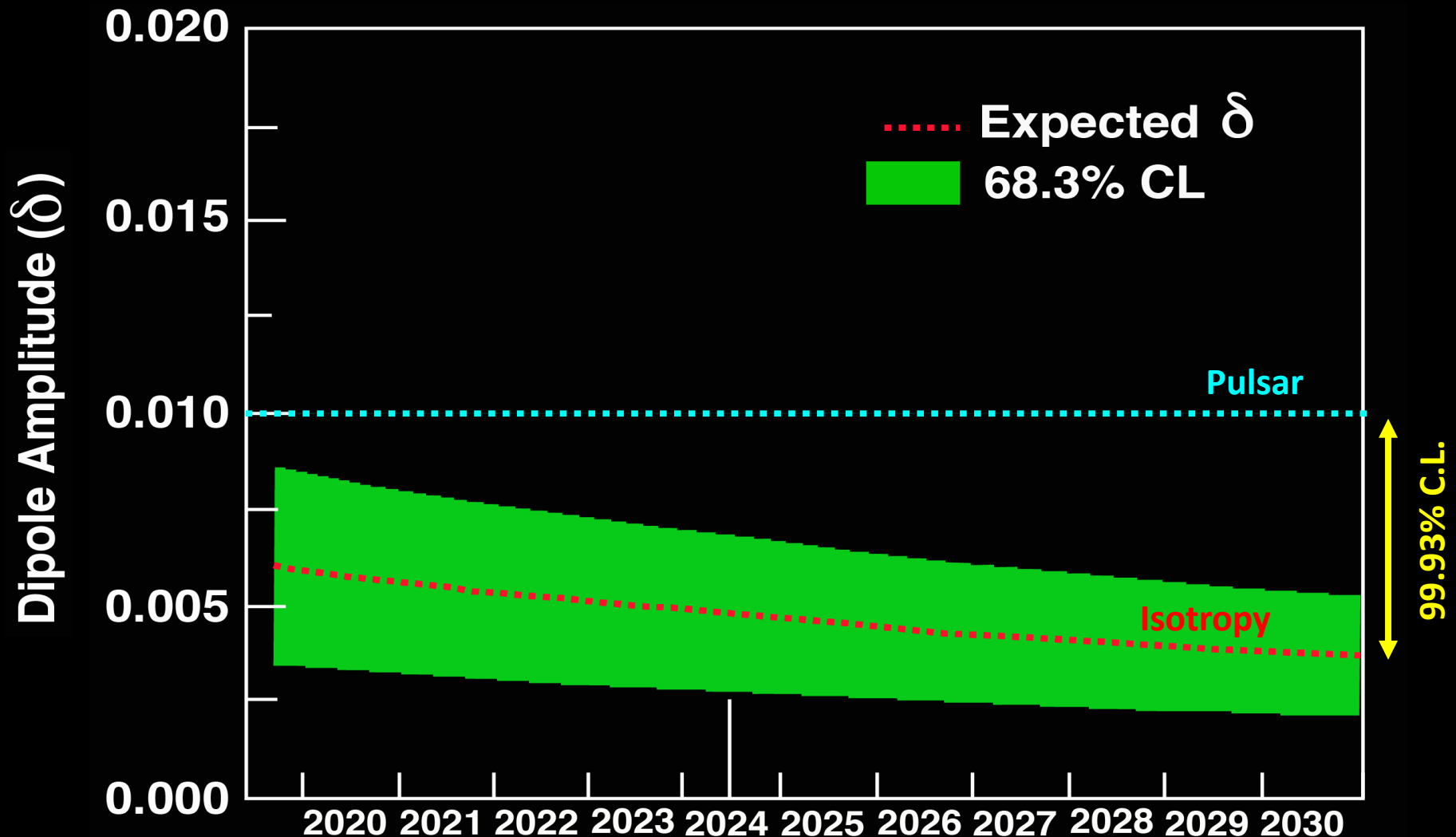
Current Data



2030, With AMS Upgrade

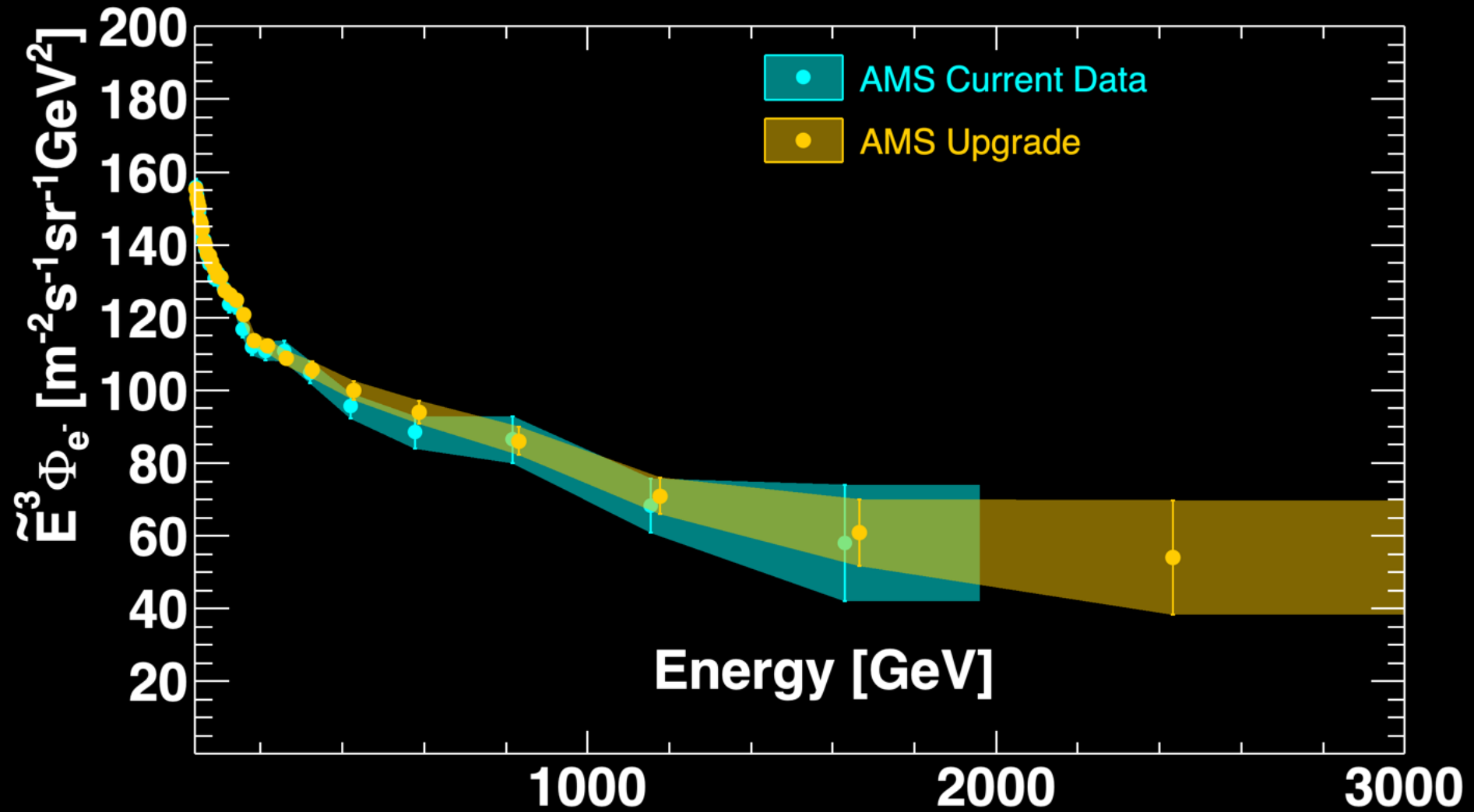


With the upgrade, the positron statistics will allow us to measure the anisotropy accurately to permit **a separation** between **dark matter** and **pulsars** at the **99.93% C.L.**



Positron anisotropy projection up to 2030 with upgrade

The upgrade will extend the energy range of the electron flux measurement from **2 TeV to 3 TeV** and **reduce the error by a factor of two.**



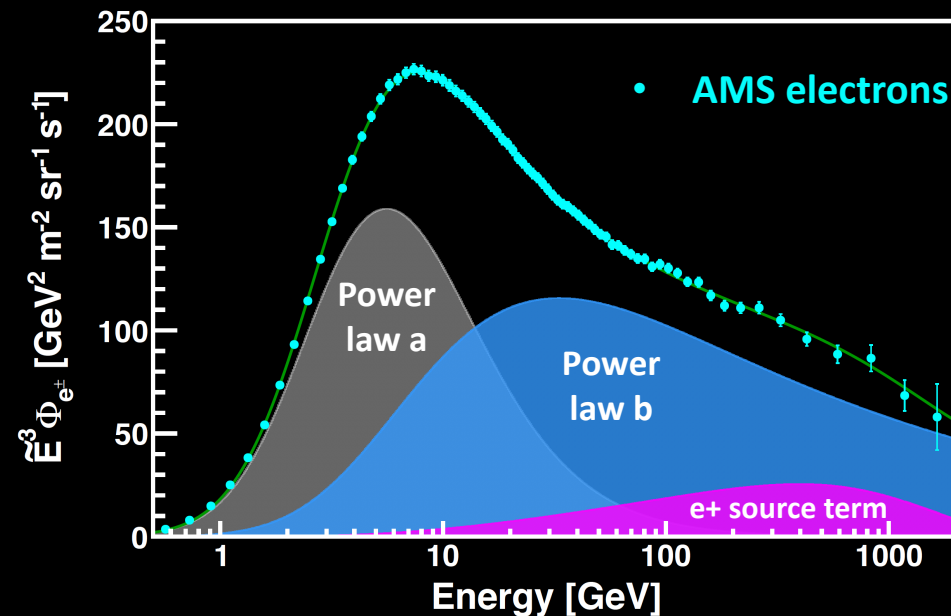
New sources like Dark Matter will produce equal amounts of positrons and electrons

$$\Phi_{e^-}(E) = C_a E^{\gamma_a} + C_b E^{\gamma_b} + C_s E^{\gamma_s} \exp(-E/E_s)$$

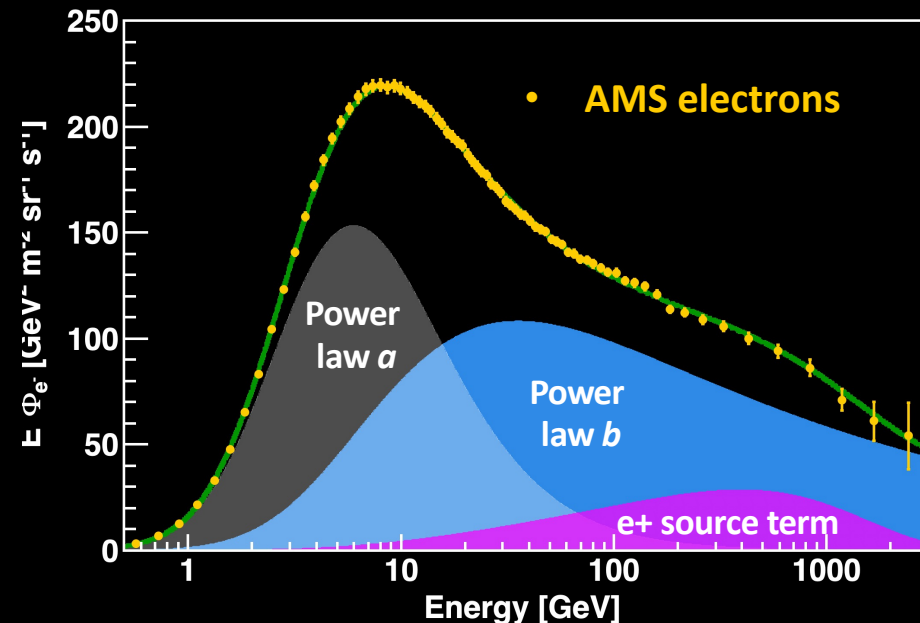
Power law a
Power law b
Positron source term

The upgrade will establish the charge-symmetric nature of the high energy source

Current Data
95% C.L. detection of source term



With Upgrade
99.994% C.L. detection of source term



Three independent methods to search for Dark Matter χ

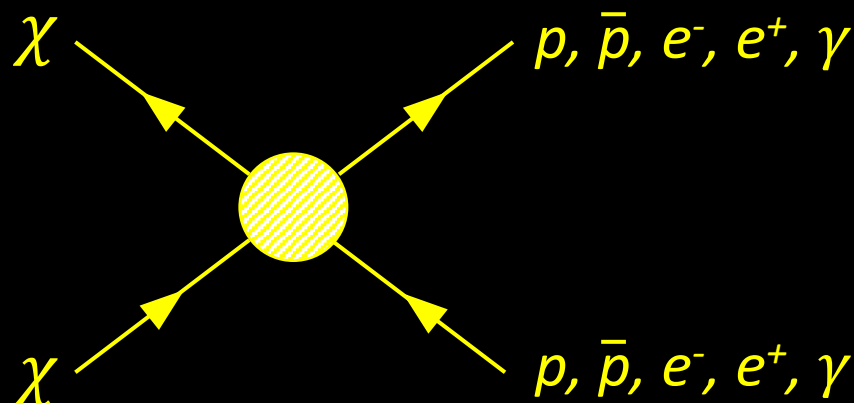
XENON
DARKSIDE
DAMA/LIBRA
LUX
CDMS II
PandaX
...

Scattering underground

$$\chi + N \rightarrow \chi + N$$

AMS
Annihilation in space

$$\chi + \chi \rightarrow e^+, \bar{p}, \bar{D}, \gamma, \dots$$

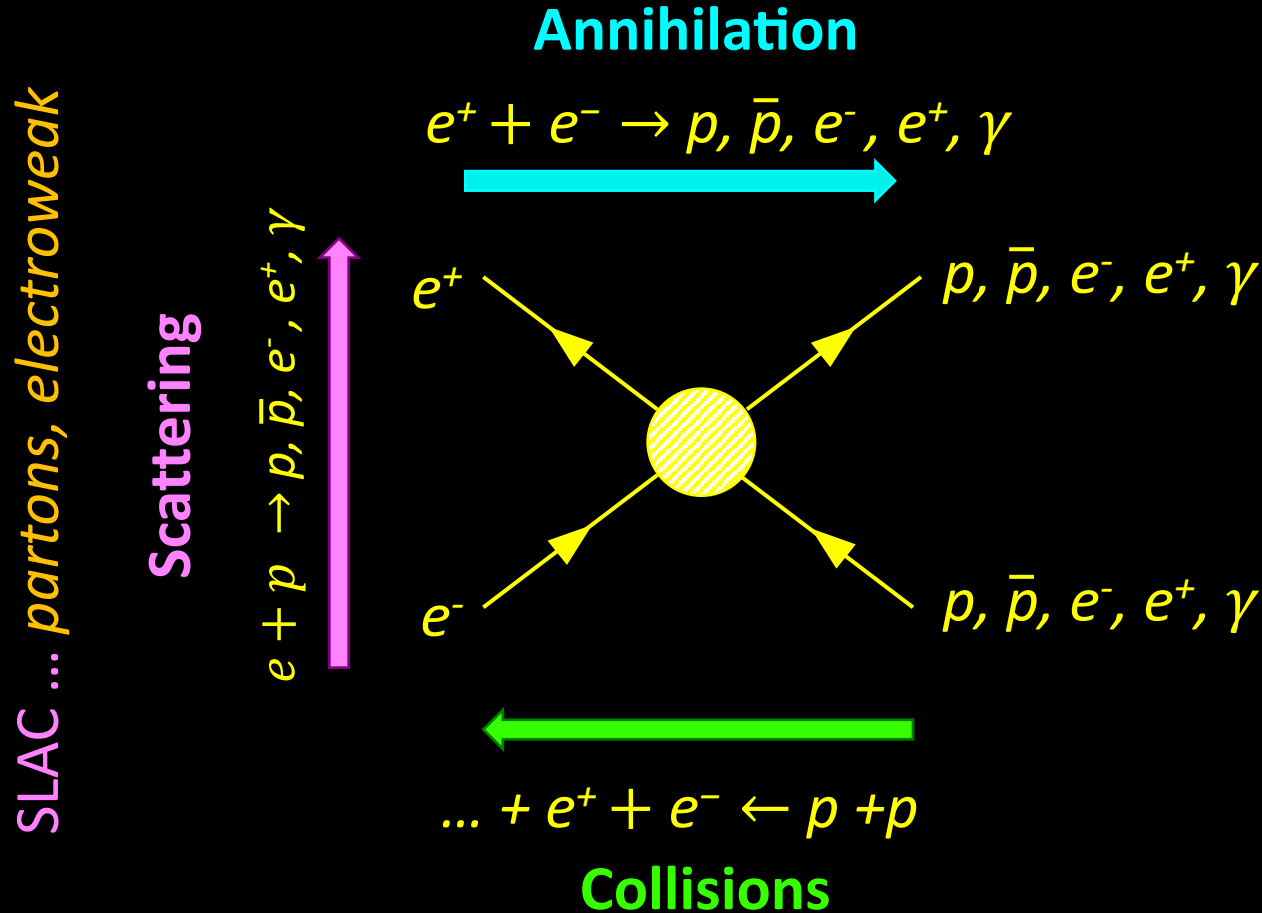


$$\dots + \chi + \chi \leftarrow p + p$$

Production in accelerators
LHC CERN

Physics of electrons and protons

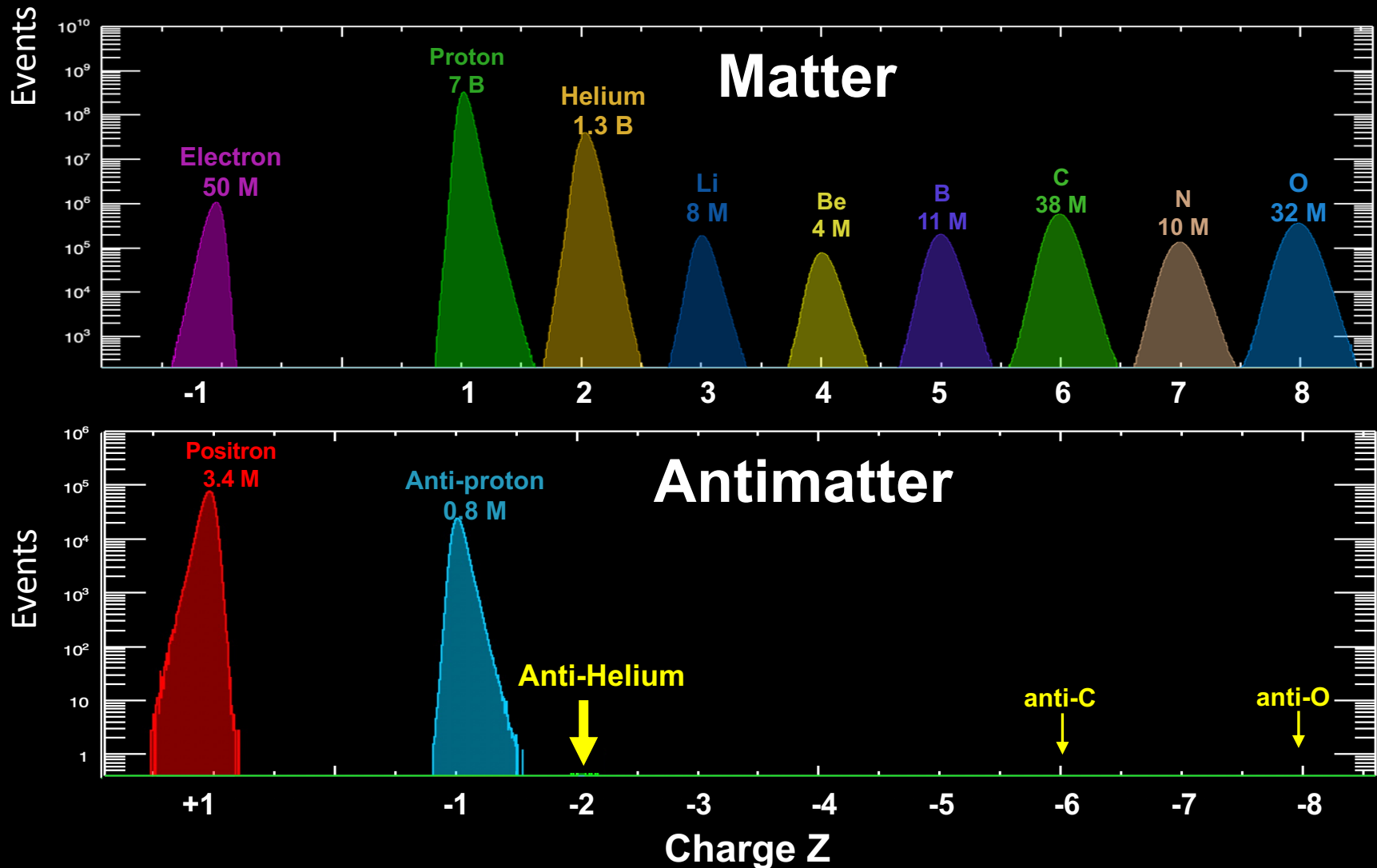
SPEAR, DORIS, PEP, PETRA, LEP, ... ψ, τ



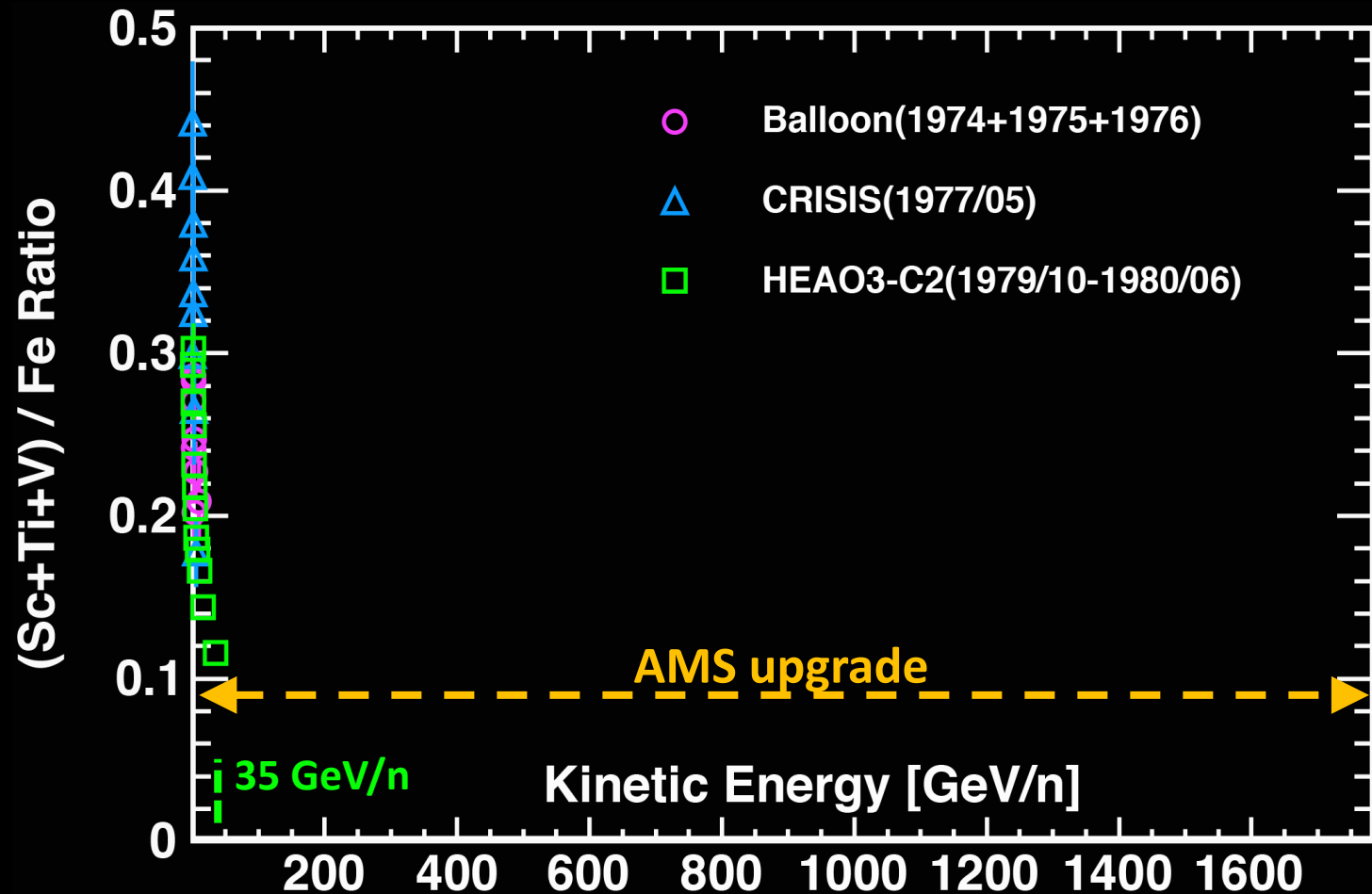
SLAC ... partons, electroweak

BNL, FNAL, LHC ... J, Y, T, Z, W, h^0

The upgrade provides
additional measurement points and continues the study of antimatter
such as anti-deuterons, anti-helium, and anti-carbon

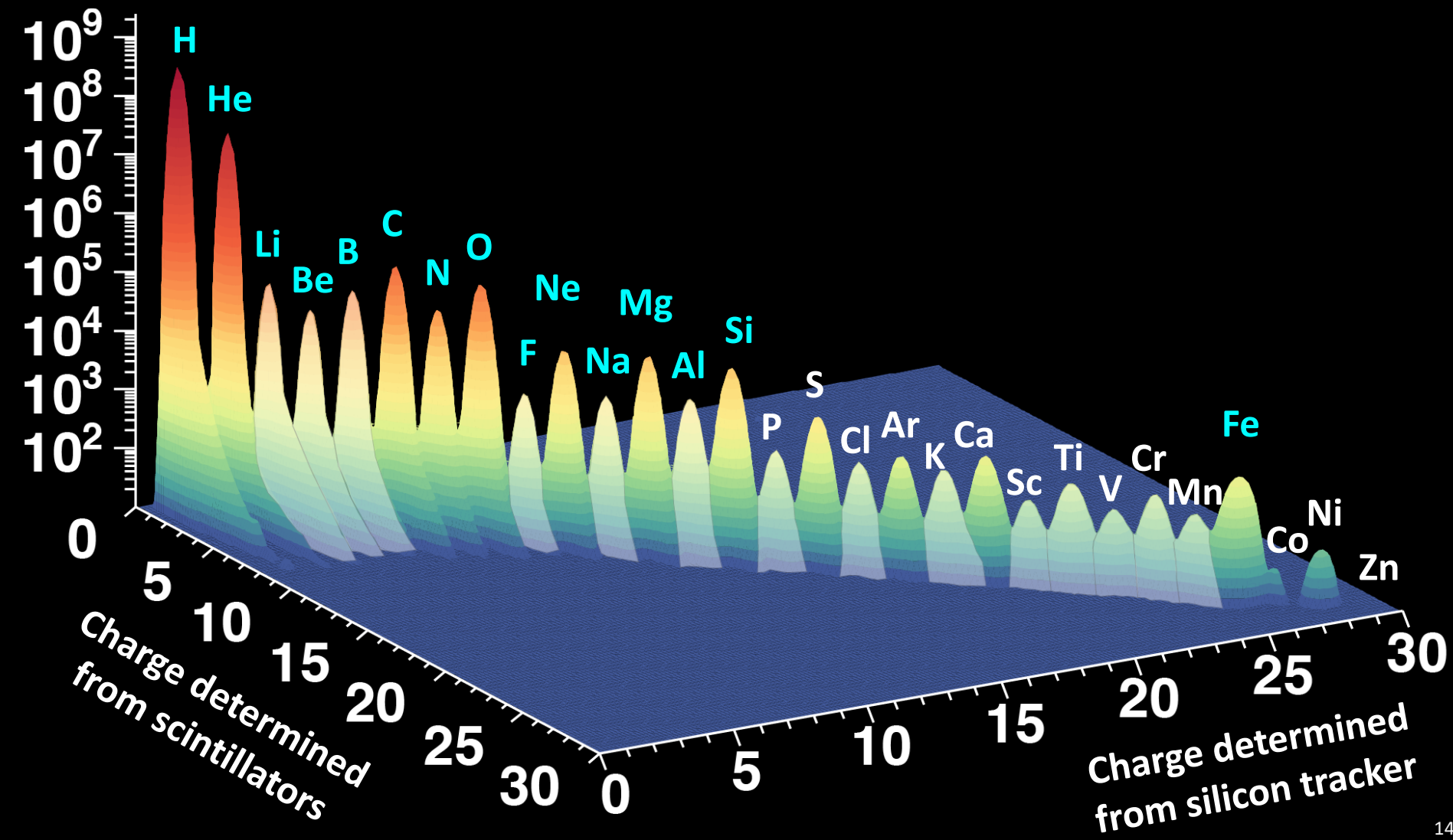


Provide accurate measurements of the **spectra of 14 heavy elements**, from phosphorus to zinc. This is a new region in cosmic ray physics **where no data exists**.



Measurements of Heavy Secondary-to-Primary Ratio (Sub-Fe/Fe)
AMS will measure each individual element.

In the first ten years we studied 15 elements. None fits to any cosmic ray model. The upgrade will enable us to provide a complete and accurate spectrum for all the 29 elements and provide the foundation for a comprehensive theory of cosmic rays.



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.

Based on the last ten years,
we can expect many surprises
in the next ten years

