Latest Results from Alpha Magnetic Spectrometer on the International Space Station

TeV Particle Astrophysics
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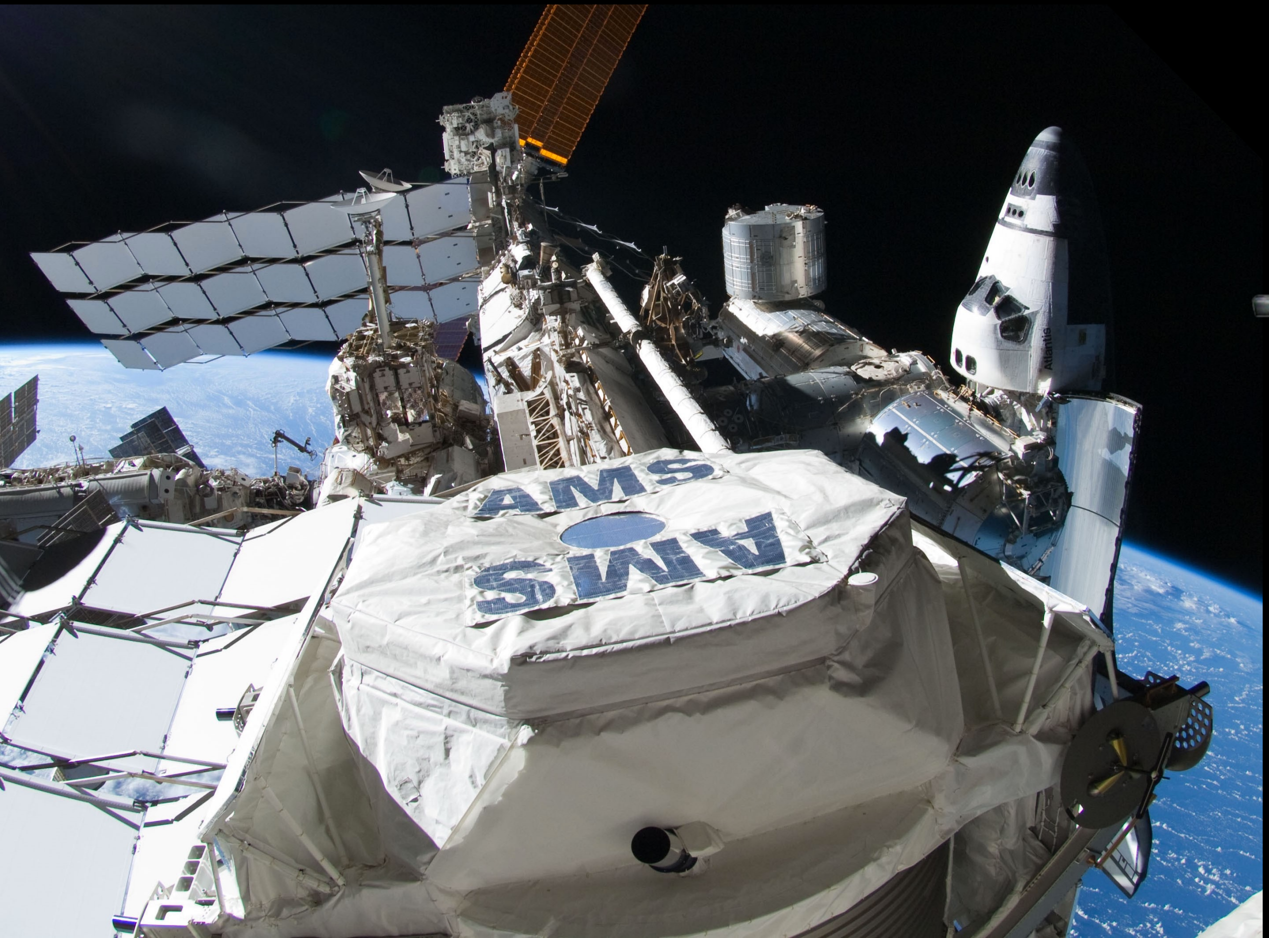
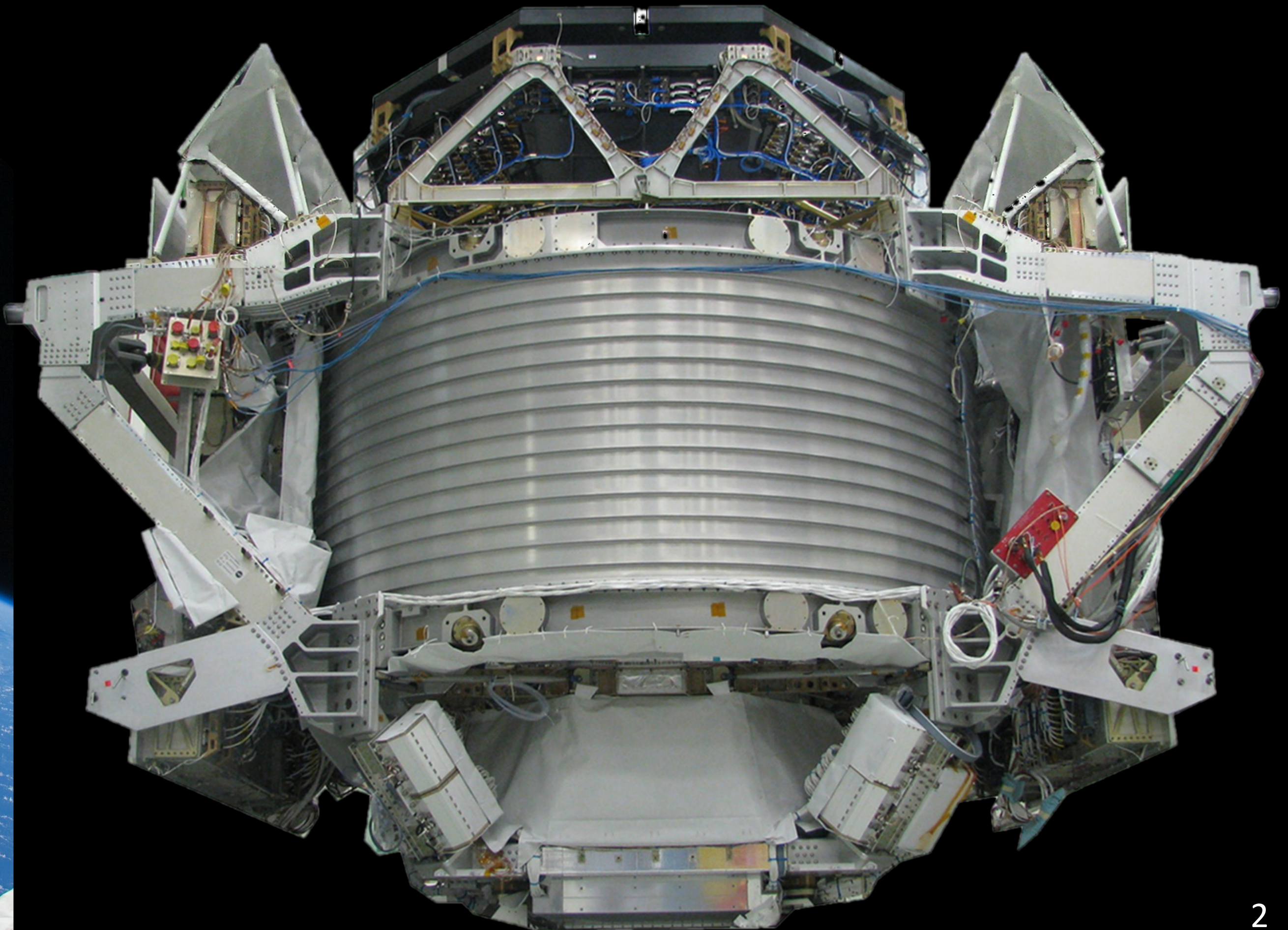
Zhili Weng / MIT
on behalf of the AMS Collaboration

AMS on the Space Station

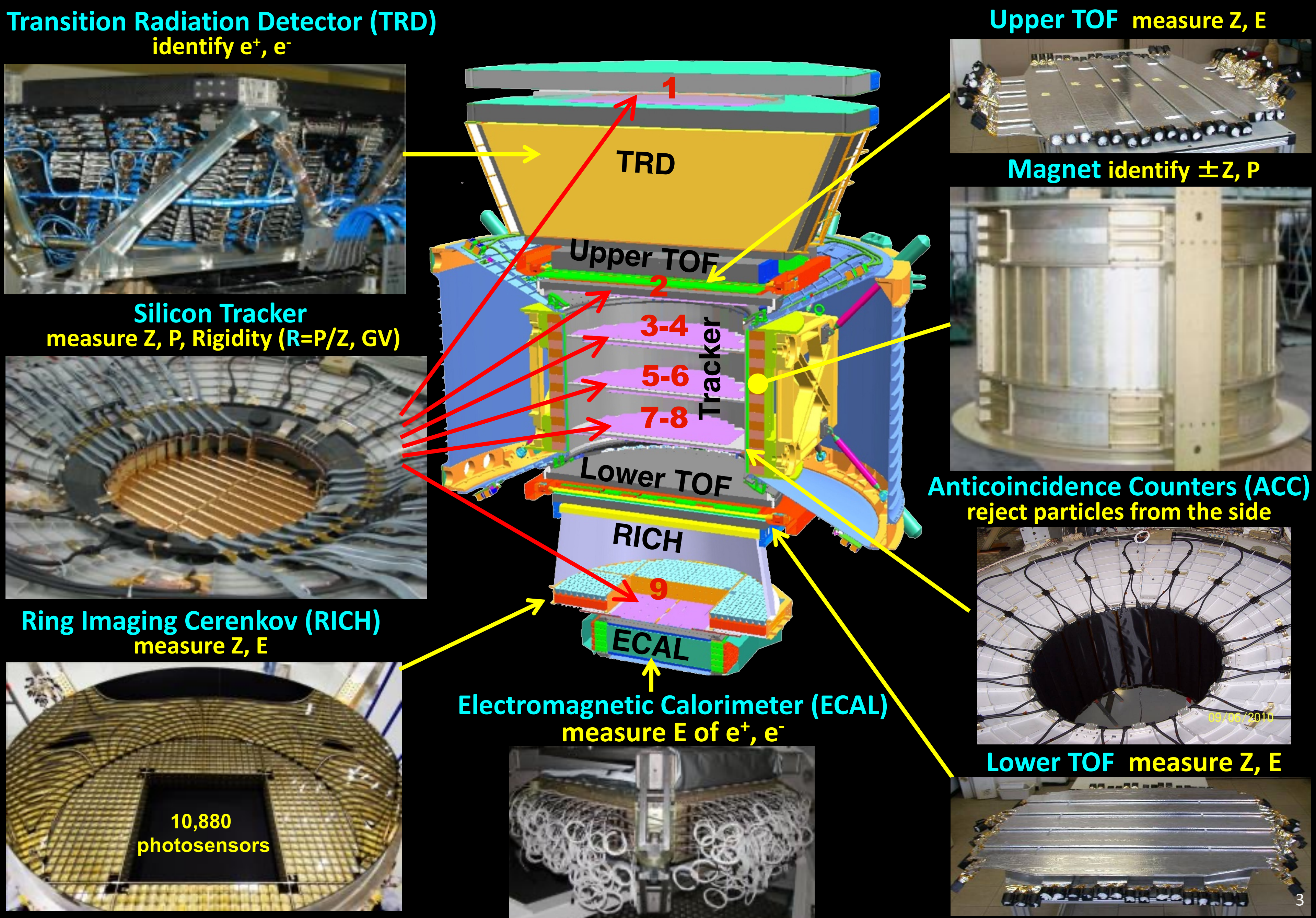
Provides precision, long-duration measurements of charged cosmic rays to study the Origin of the Cosmos, the physics of Dark Matter and Antimatter

A space version of a precision detector used at accelerators.
5m x 4m x 3m, 7.5 tons

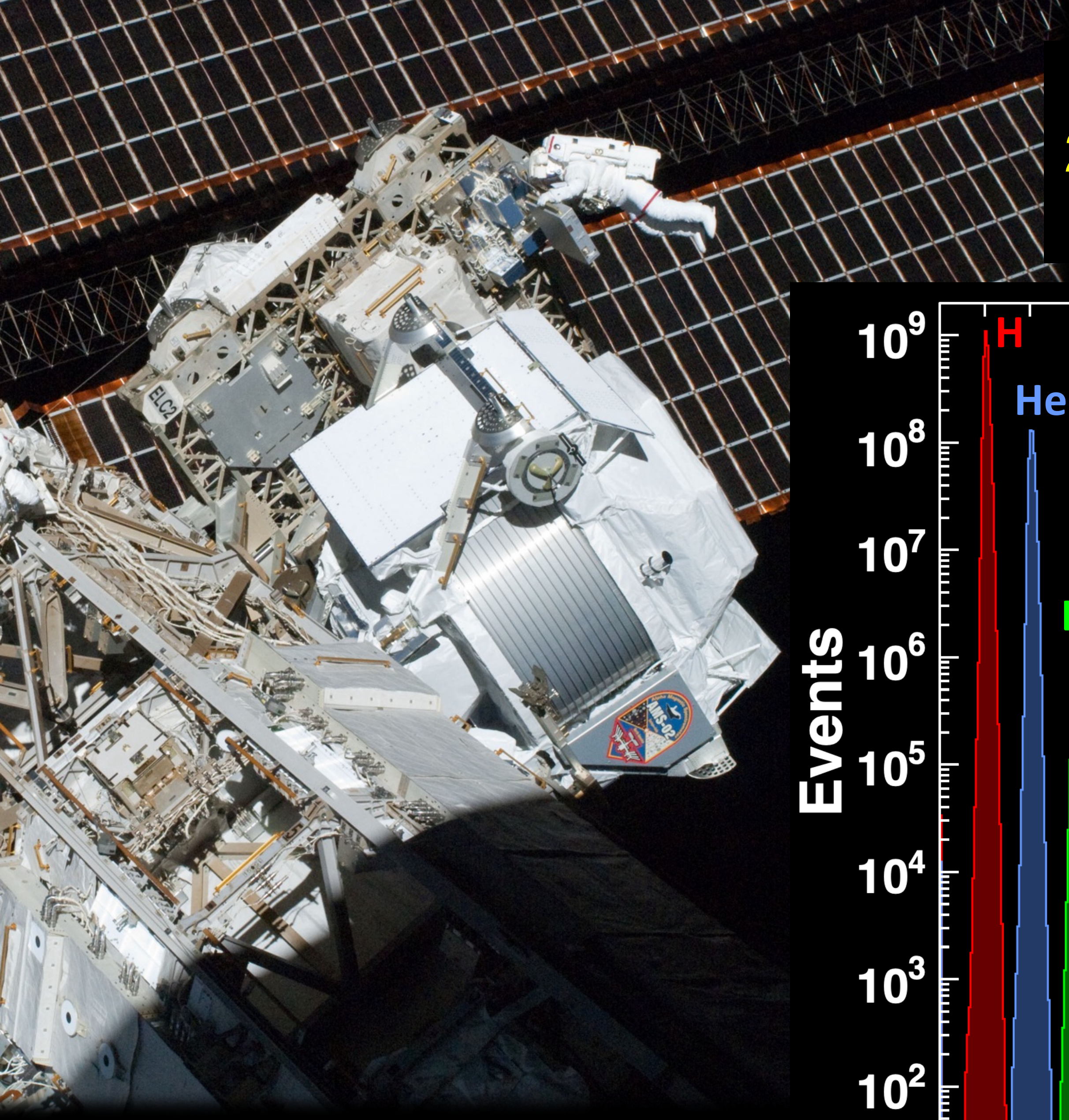


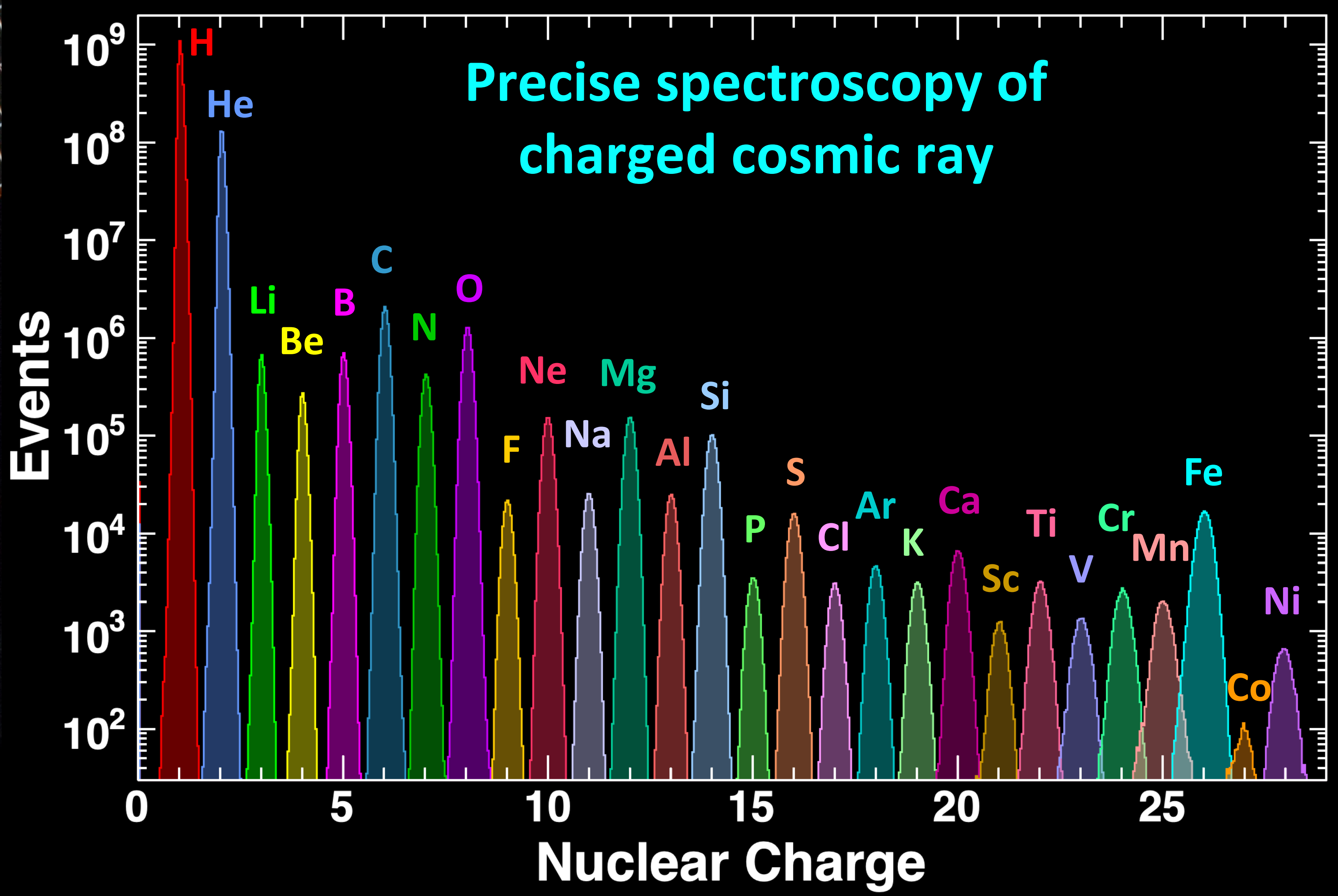


The detectors provide independent information of cosmic rays



In 14 years, AMS have collected over 256×10^9 events of elementary particles and nuclei up to multiple TeV.

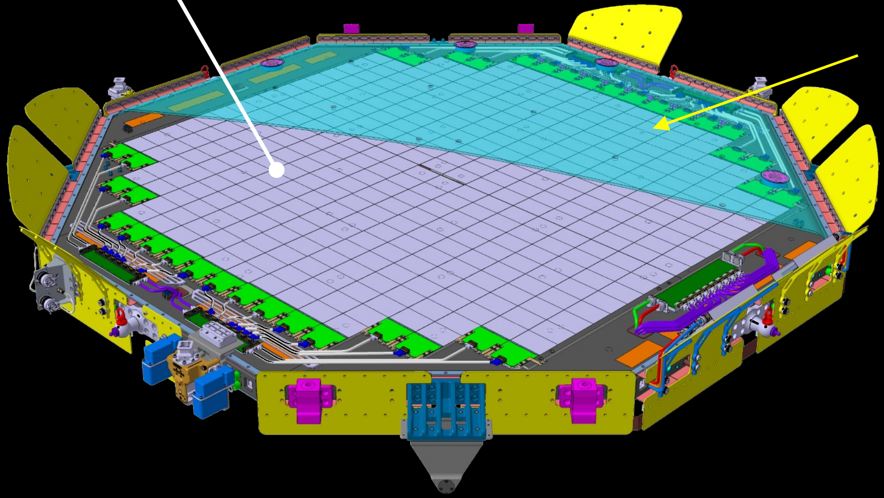




AMS Upgrade: New 4+4m^2 Silicon Tracker Planes

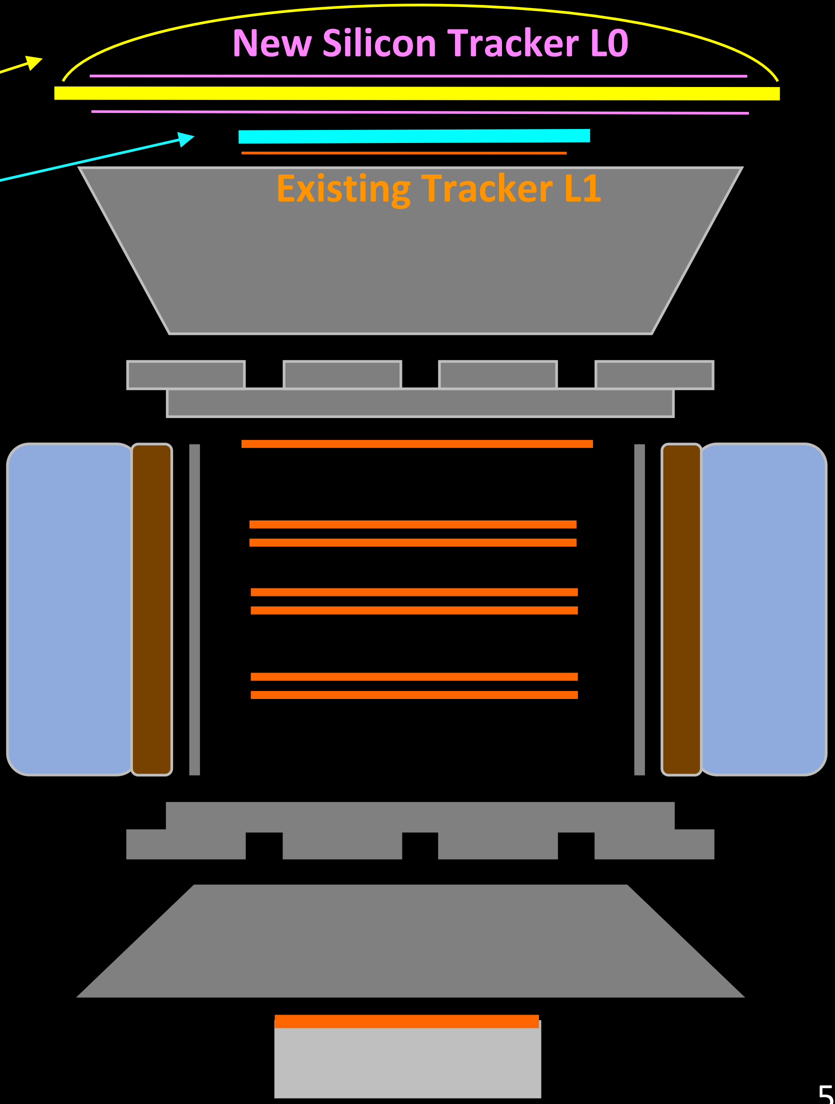
Acceptance increased to 300%,
Reduce background for high-Z nuclei measurement

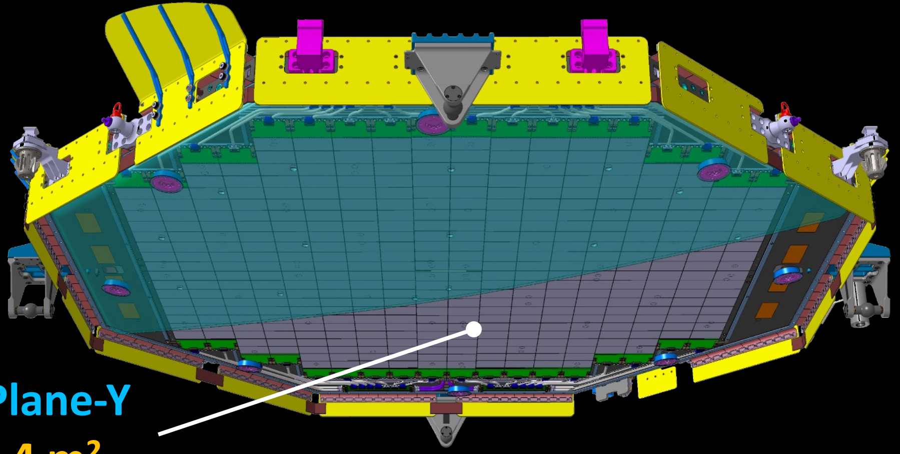
Plane-U
4 m^2



Materials above new L0: 0.5%X_0

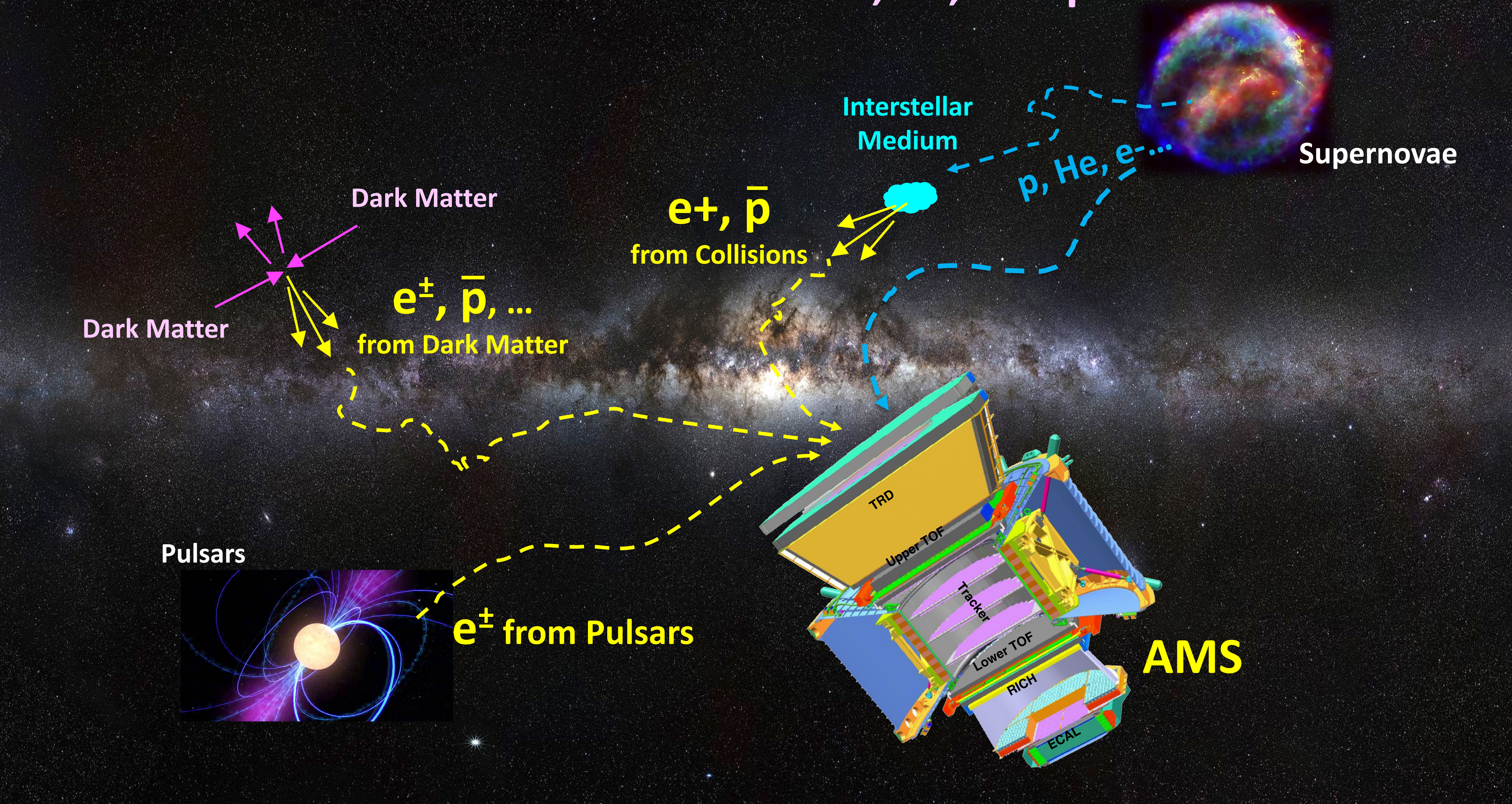
Materials above L1: 5.5% X_0





Plane-Y
4 m^2

Latest Results on e+, e−, and $\bar{p}$



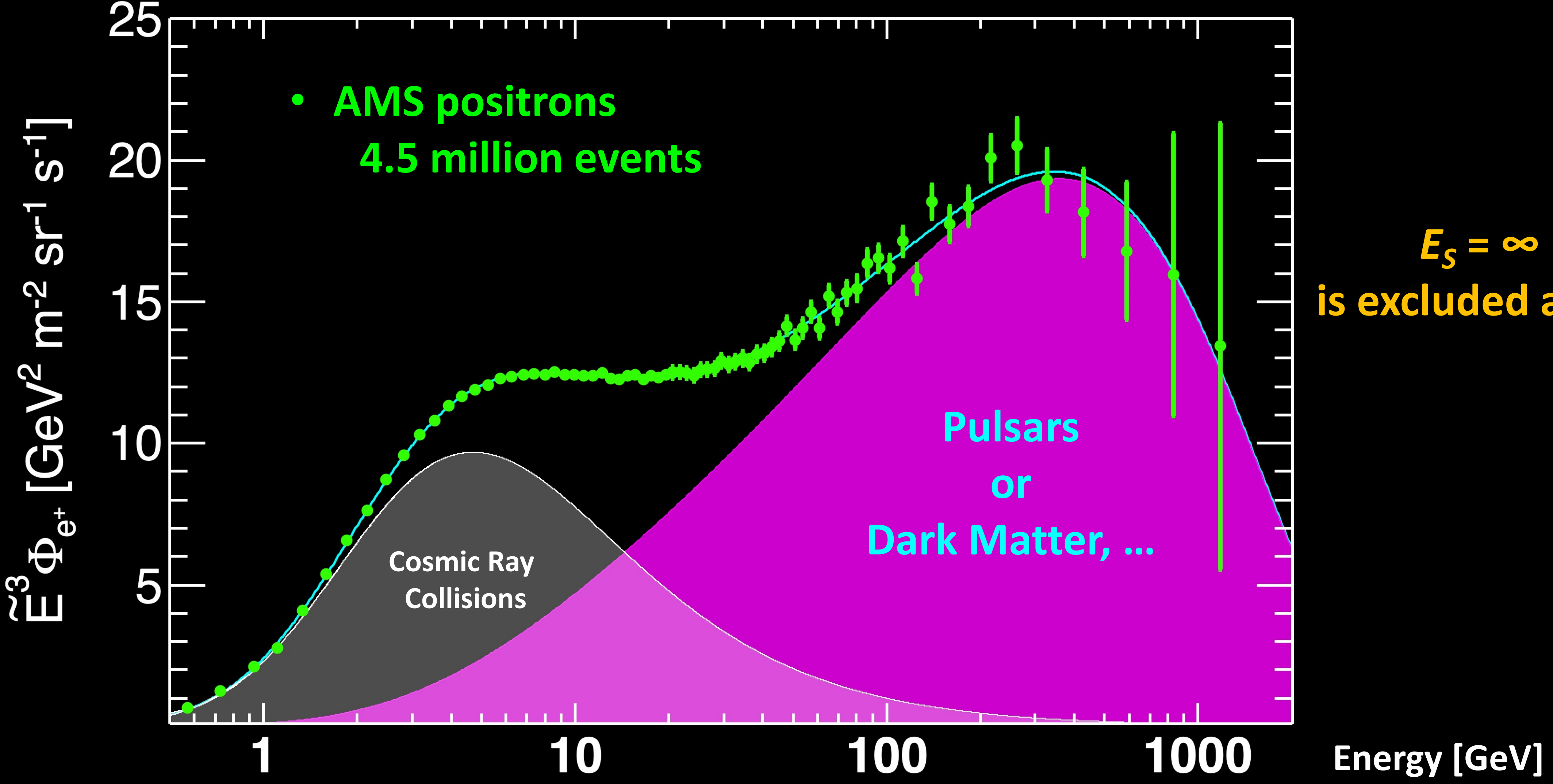
The positron flux is the sum of low-energy part from cosmic ray collisions plus a high-energy part from pulsars or dark matter with a cutoff energy

Empirical model:

χ^2/dof = 40/66

$$\Phi_{e^+}(E) = \frac{E^2}{\hat{E}^2}\left[C_d(\hat{E}/E_1)^{\gamma_d} + C_s(\hat{E}/E_2)^{\gamma_s}\exp(-\hat{E}/E_s)\right]$$

Solar Collisions Pulsars or Dark Matter



$E_S = \infty$ is excluded at 5σ

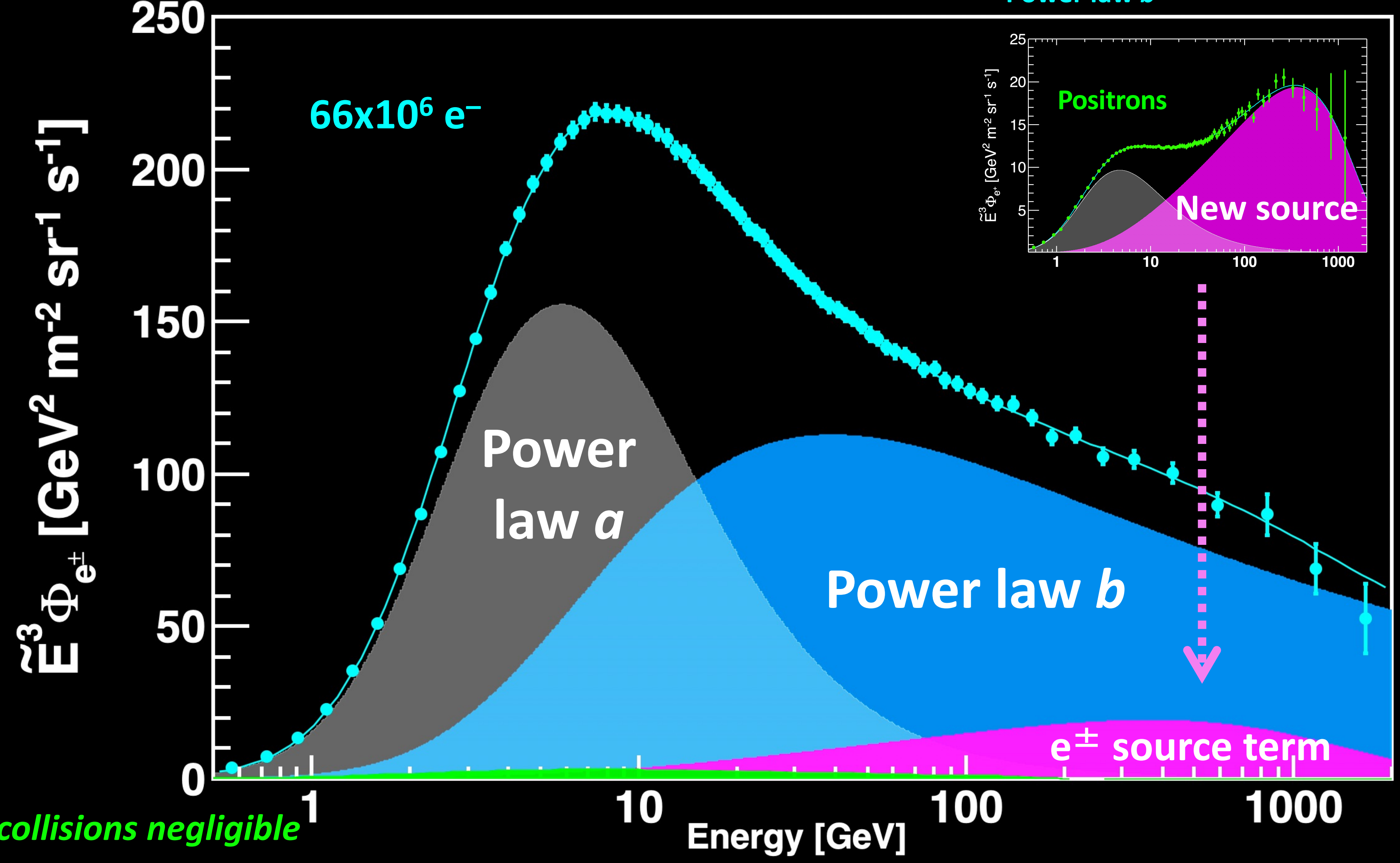
The electron spectrum fits well with two power laws (*a*, *b*) and the measured positron source term

Empirical model:

χ^2/dof = 25/67

$$\Phi_{e^-}(E) = \frac{E^2}{\widehat{E}^2}\left(C_a \widehat{E}^{\gamma_a} + C_b \widehat{E}^{\gamma_b} + \text{Positron Source Term}\right)$$

Solar   Power law *a*   Power law *b*

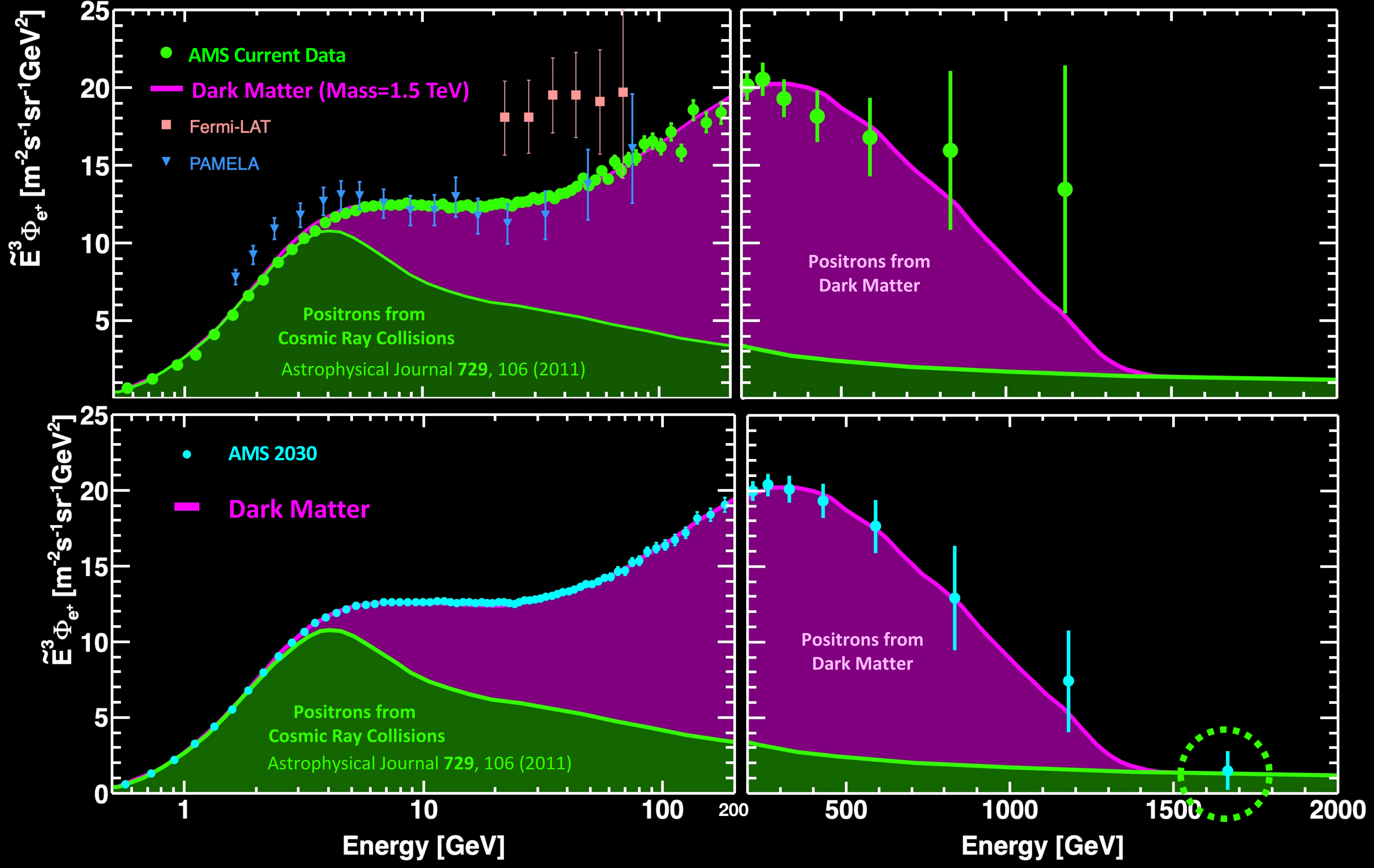


e⁻ from collisions negligible

New sources, like Dark Matter or Pulsars, produce equal amounts of e+ and e–

99.1% CL

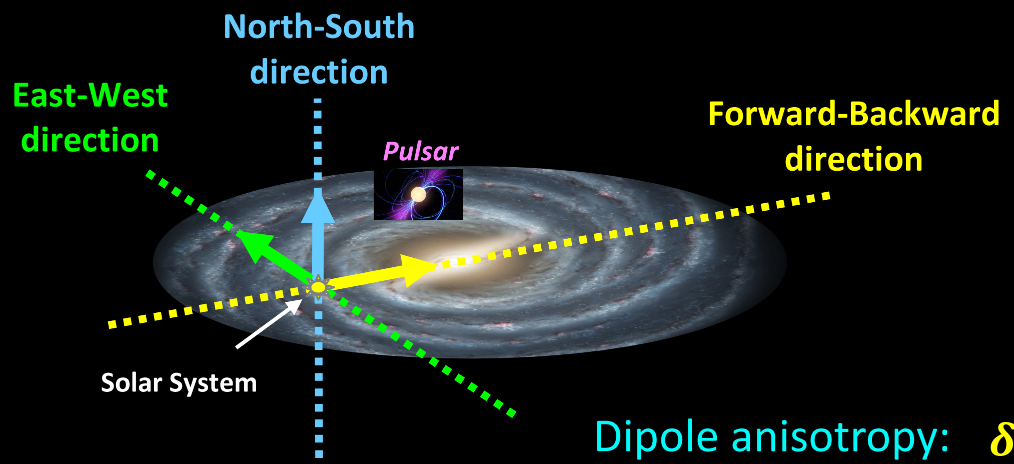
AMS Positron Spectrum and Dark Matter



By 2030, AMS will ensure that the high energy positron spectrum drops off quickly in the 0.2-2 TeV region and the highest energy positrons only come from cosmic ray collisions as predicted in dark matter model

Positron Anisotropy

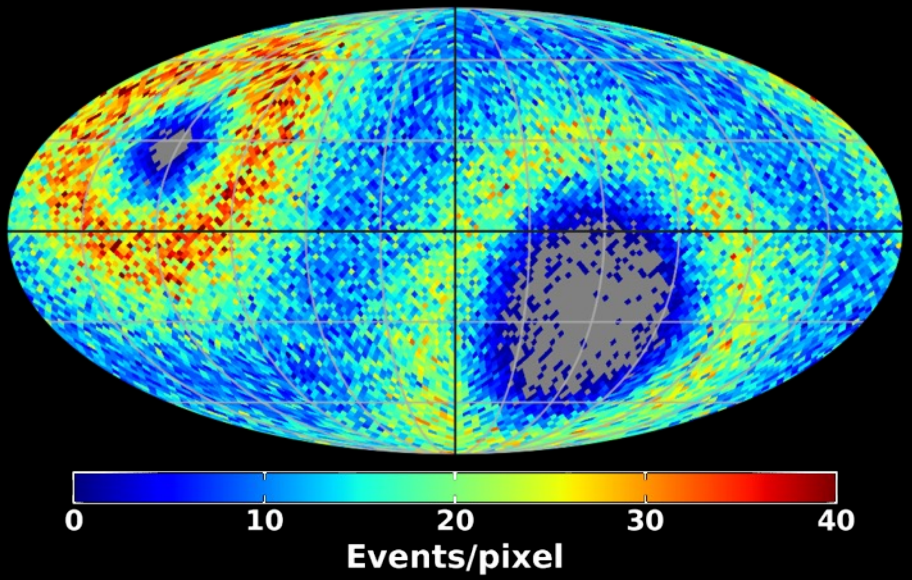
To be presented by Iñaki Garcia



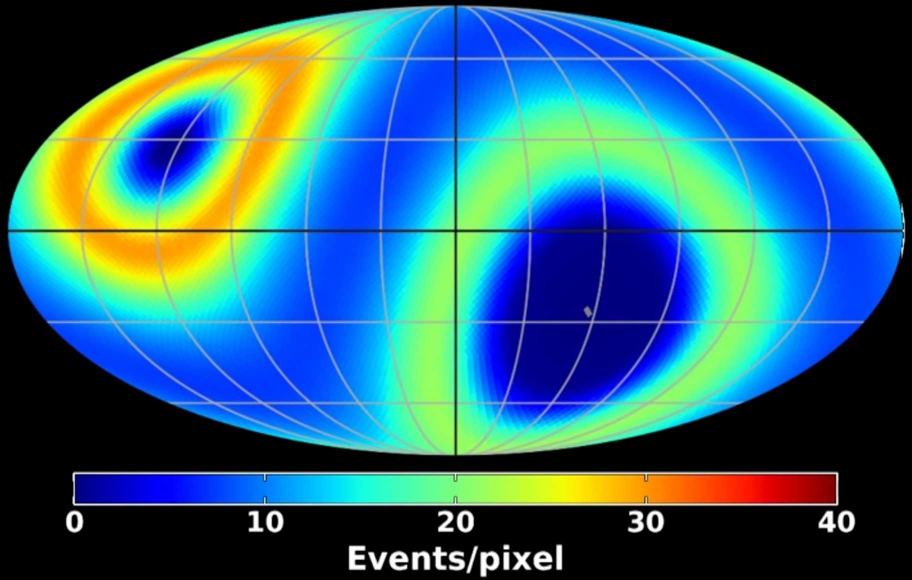
Astrophysical point sources will imprint a higher anisotropy on the arrival directions of energetic positrons than a smooth dark matter halo.

Dipole anisotropy: $\delta = 3\sqrt{C_1/4\pi}$ C_1 is the dipole moment

Positrons



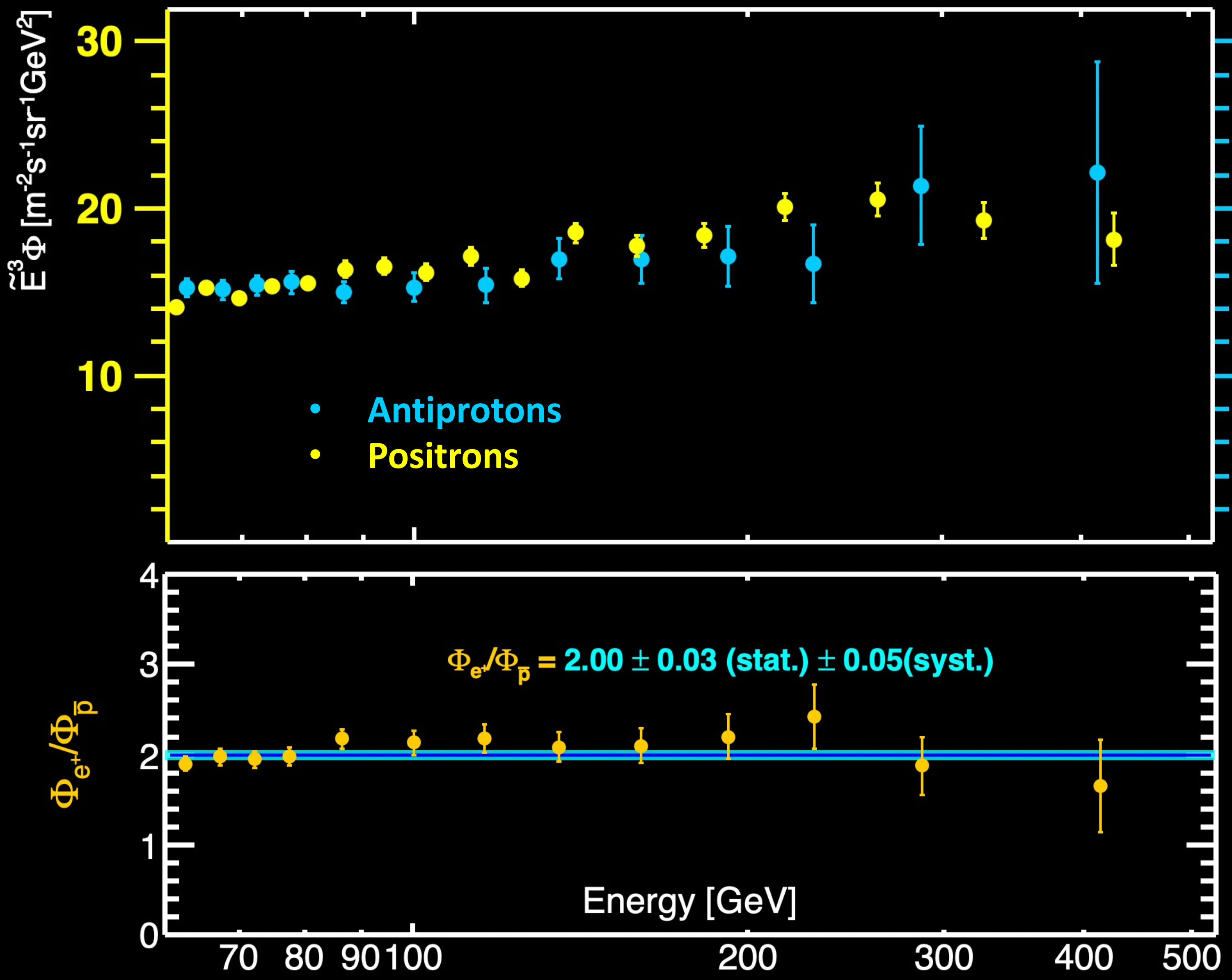
Isotropic map



AMS **Currently at 95% C.I.:** for 16 < E < 500 GeV **δ_{e+} < 0.0144**

Cosmic Antiprotons and Positrons

Above 60 GeV, the $\bar{p}$ and e^+ fluxes have identical rigidity dependence

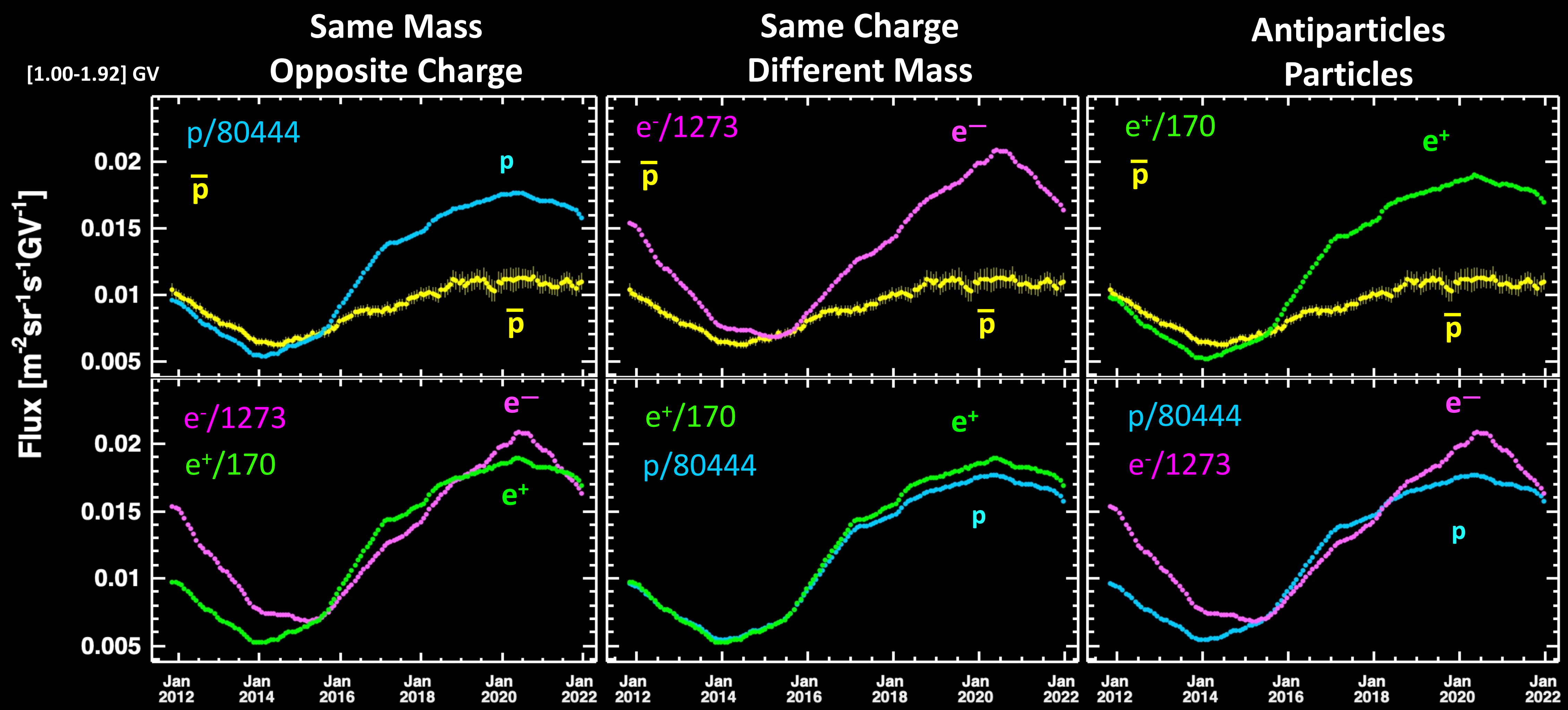


The identical behavior of positrons and antiprotons

excludes the pulsar origin of positrons

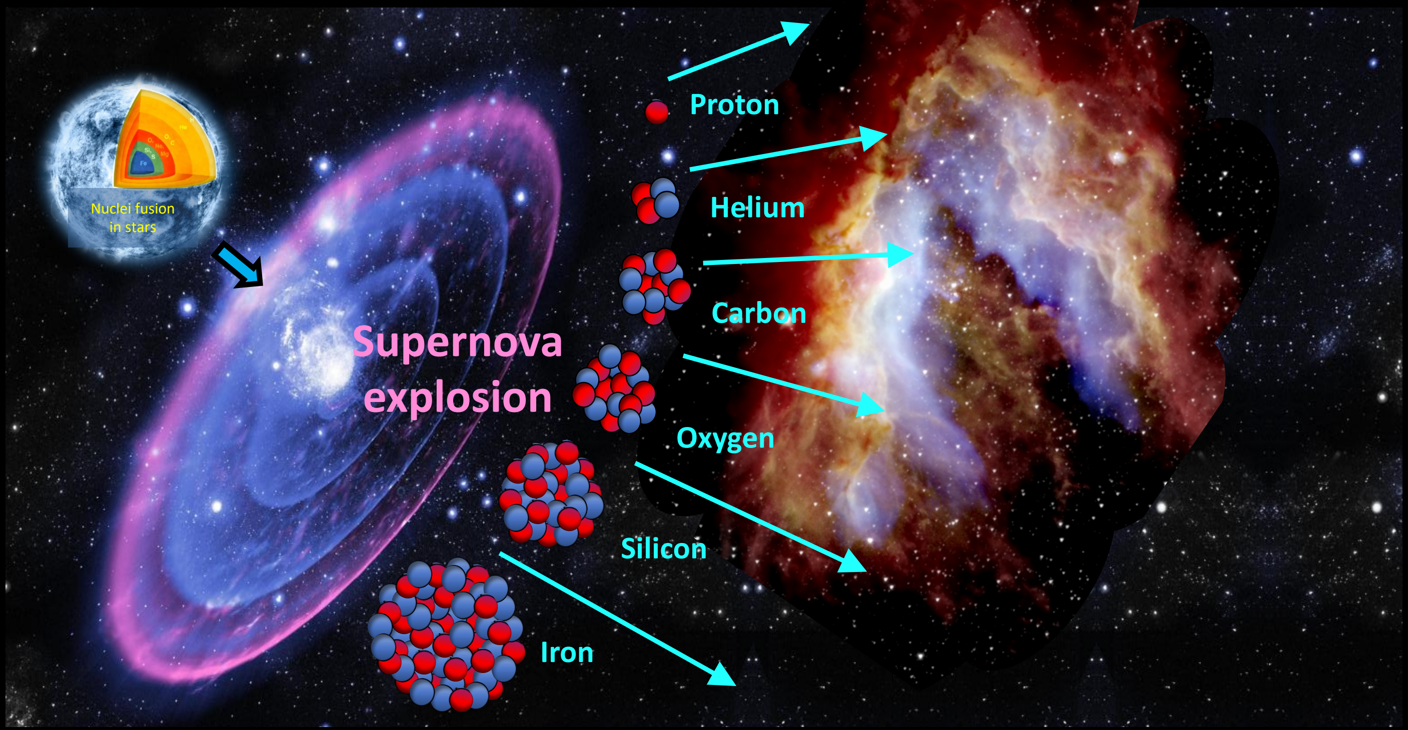
New Results on Elementary Particles (e+, e-, p, $\bar{p}$) in the Heliosphere over an 11-year Solar Cycle (2011-2022)

To be presented by H.Y. Chou

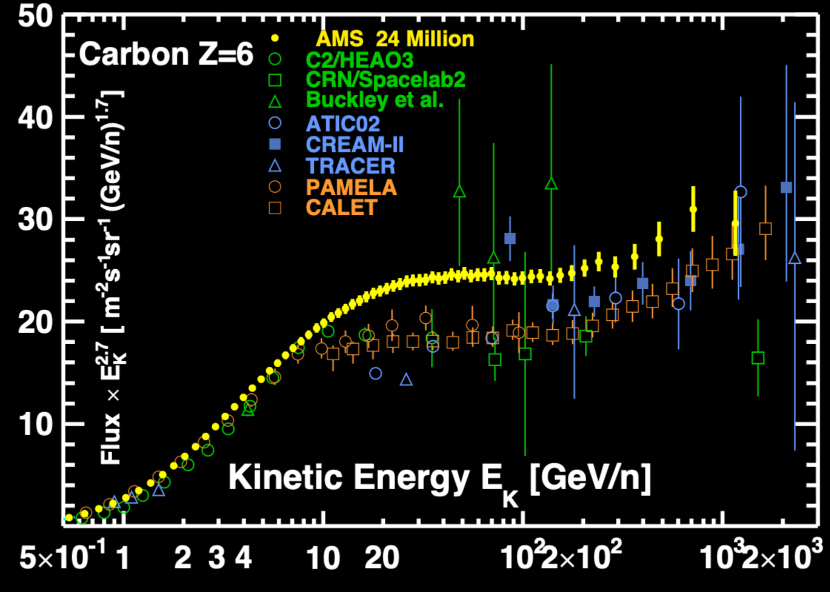


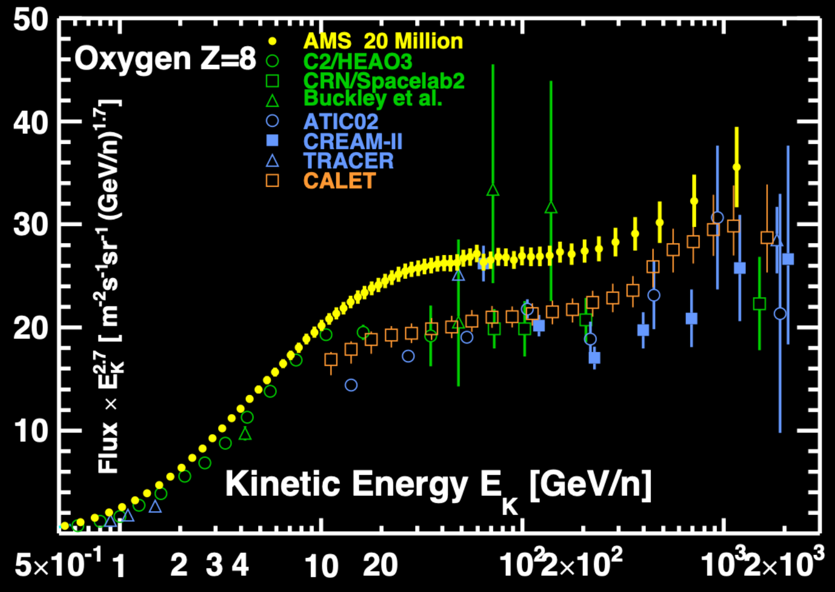
Unique information for understanding solar modulation as a function of mass, charge, and spectral shape

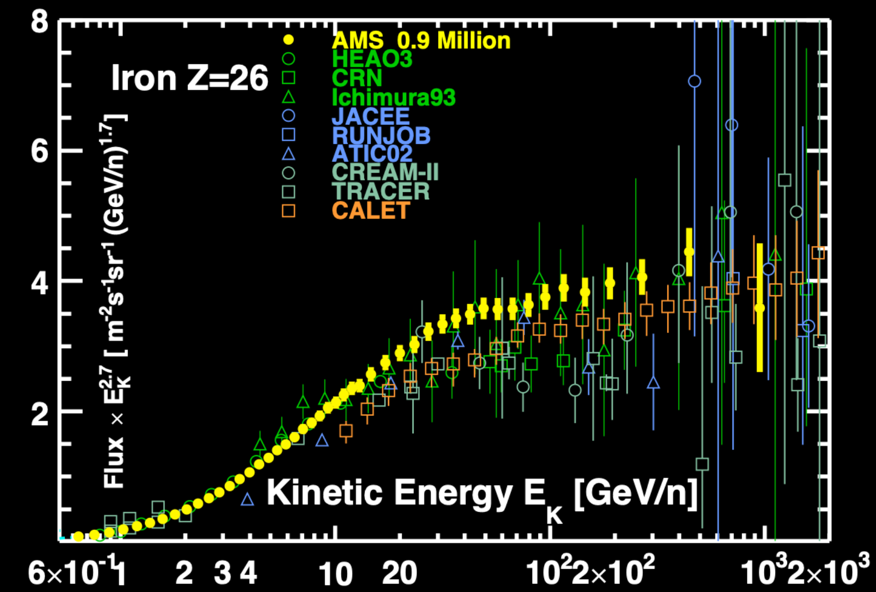
Precision measurements of Cosmic Ray Nuclei in the GeV-TeV energy range

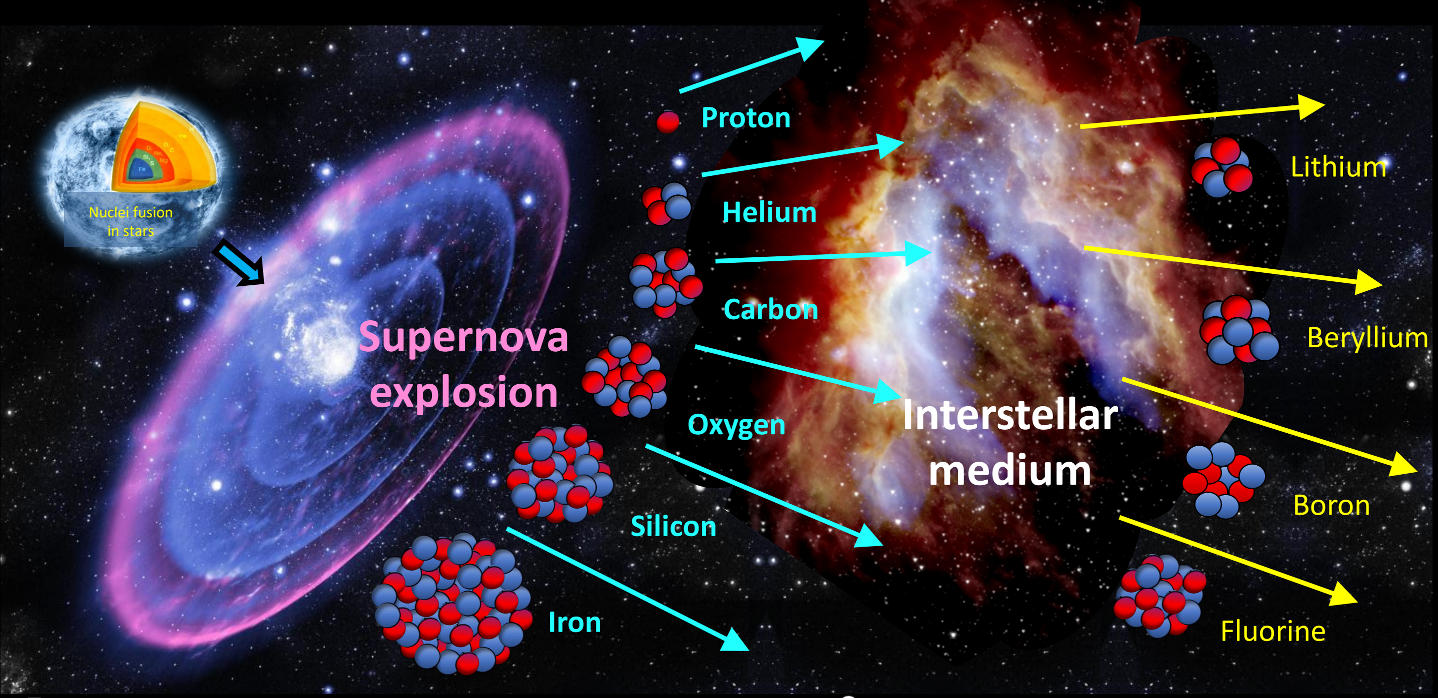


Primaries p, He, C, O, Si, …, Fe are produced in stars and accelerated by supernovae.

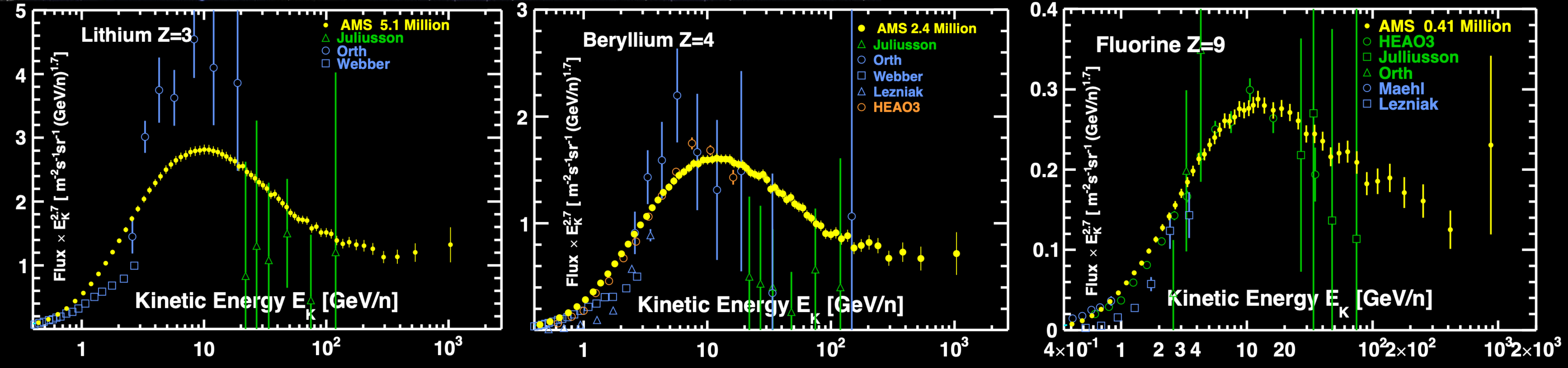








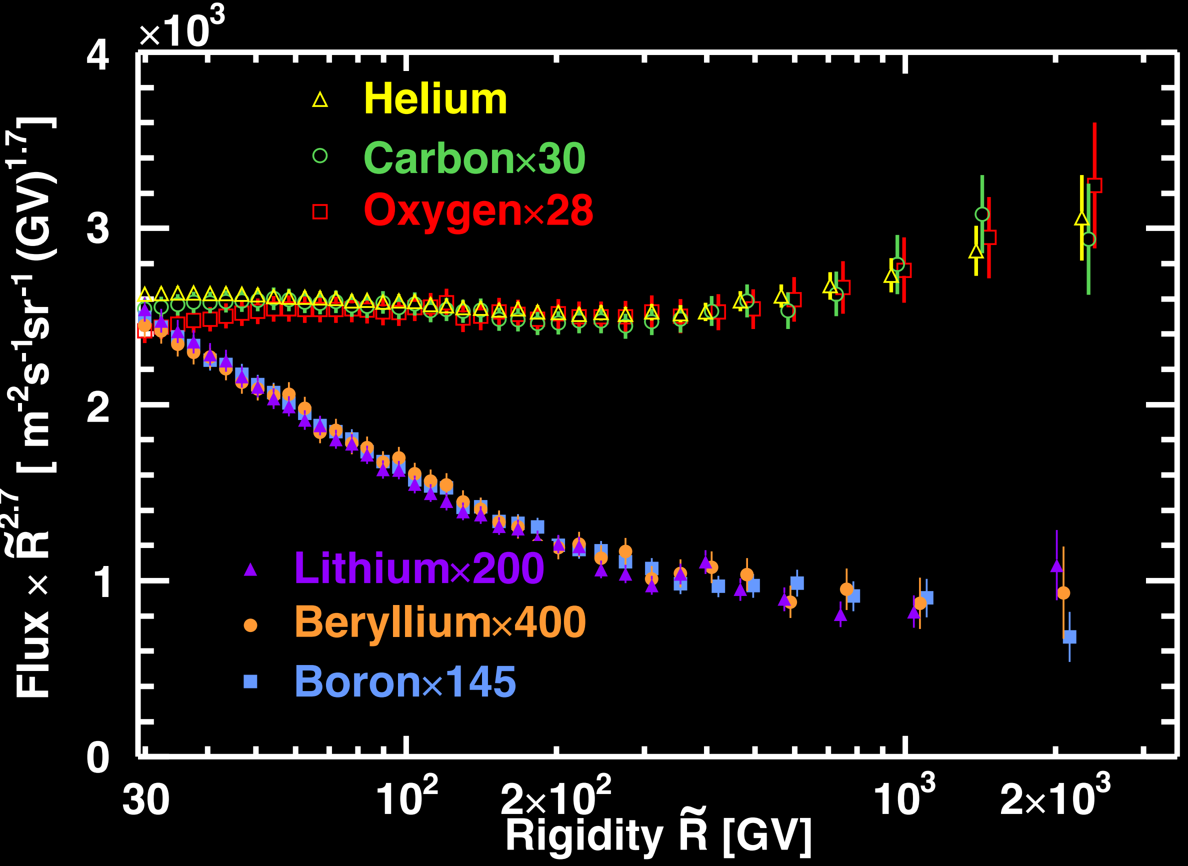
Secondaries Li, Be, B, and F are produced by the collision of Primaries with the interstellar medium



Measurements of the cosmic ray nuclei fluxes are important in understanding their origin, acceleration, and propagation processes in the Galaxy.

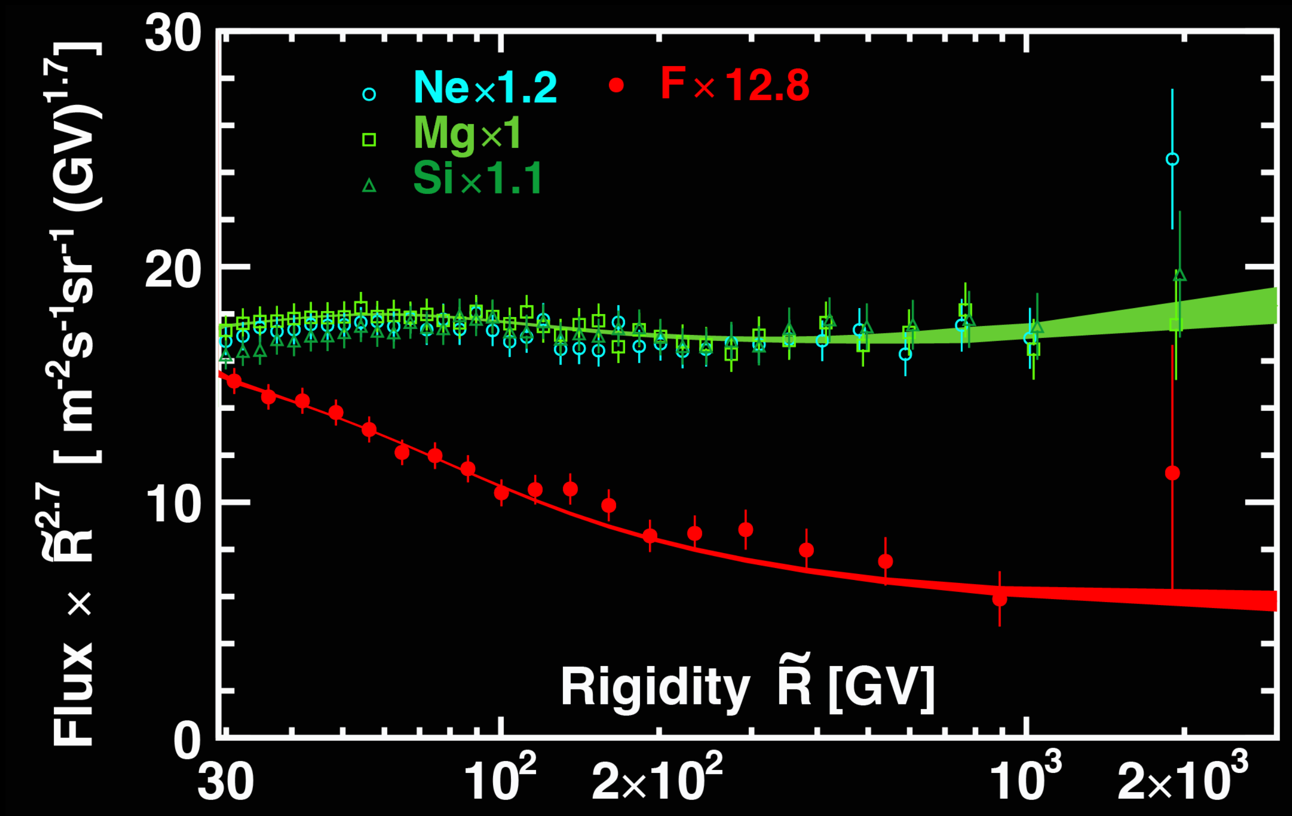
Light Nuclei 2 ≤ Z ≤ 8

He-C-O primaries compared with Li-Be-B secondaries



Heavier Nuclei 9 ≤ Z ≤ 14

Ne-Mg-Si primaries compared with F secondaries

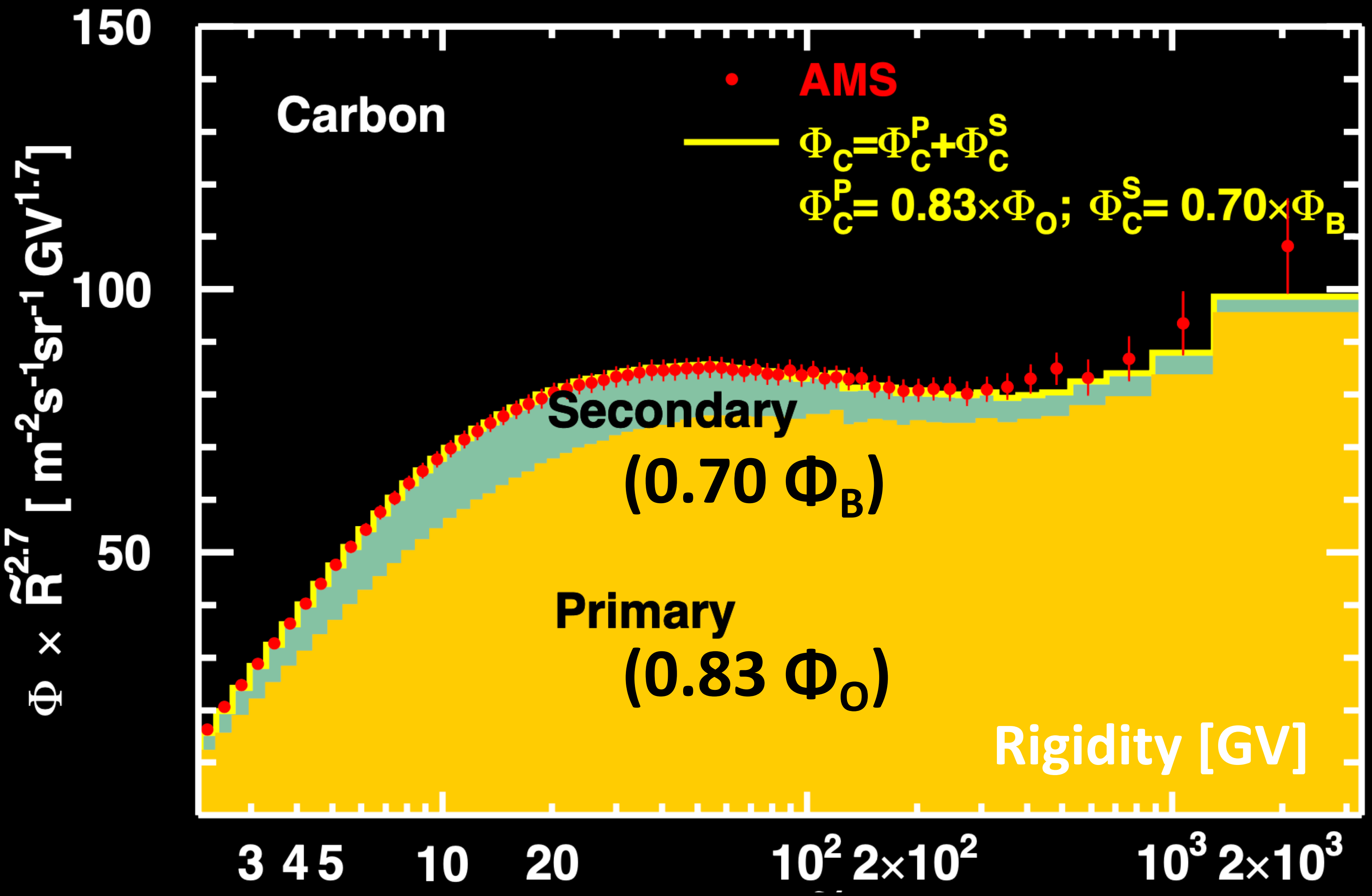


To be presented by Z. Liu, J. Zhang

Light and heavy nuclei each have two distinct classes

Composition of Cosmic Nuclei

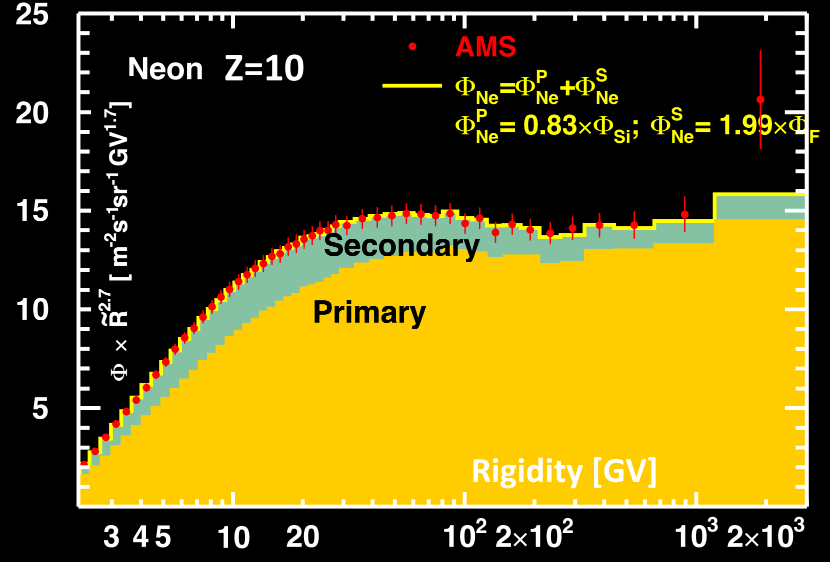
AMS result show that all nuclei fluxes can be presented as a weighted sums of the characteristic primary flux (O, Si) and a characteristic secondary flux (B, F)

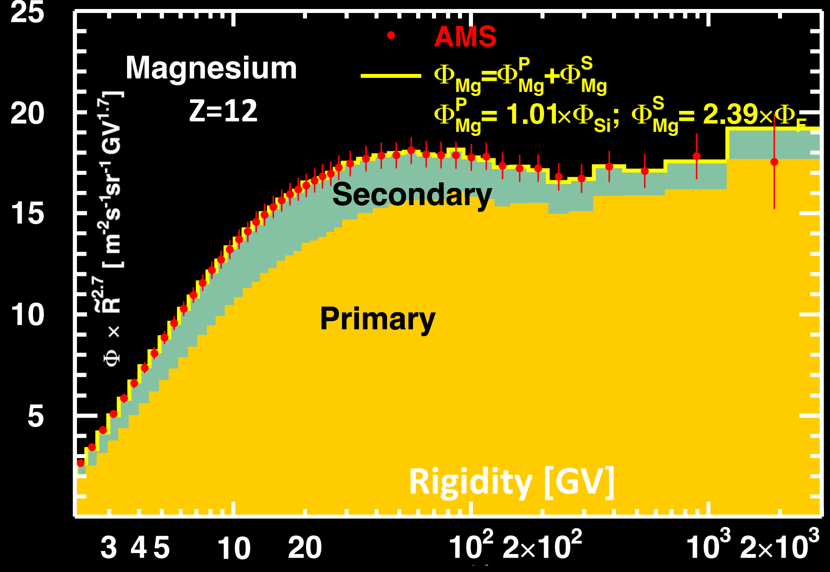


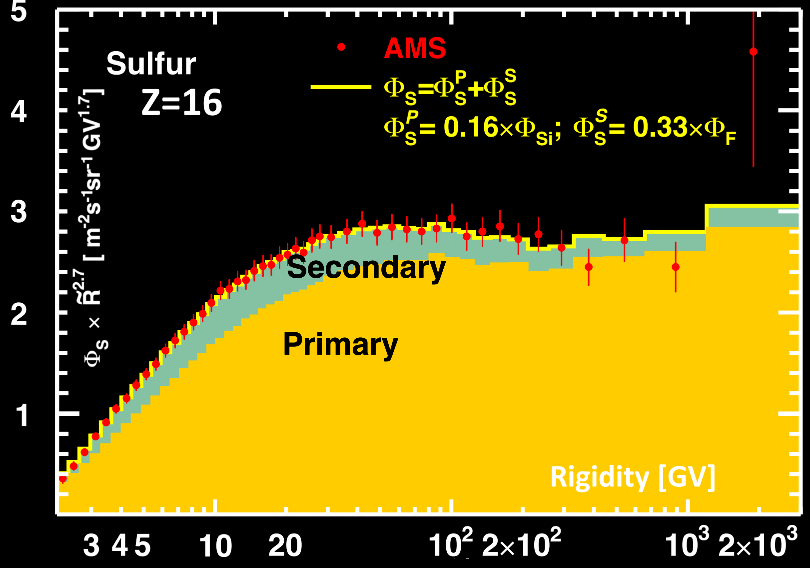
Carbon is NOT pure primary. They have significant secondary component

Model-independent measurements of the relative abundances at the source (before cosmic ray propagation): $\Phi_C / \Phi_O = 0.83 \pm 0.025$

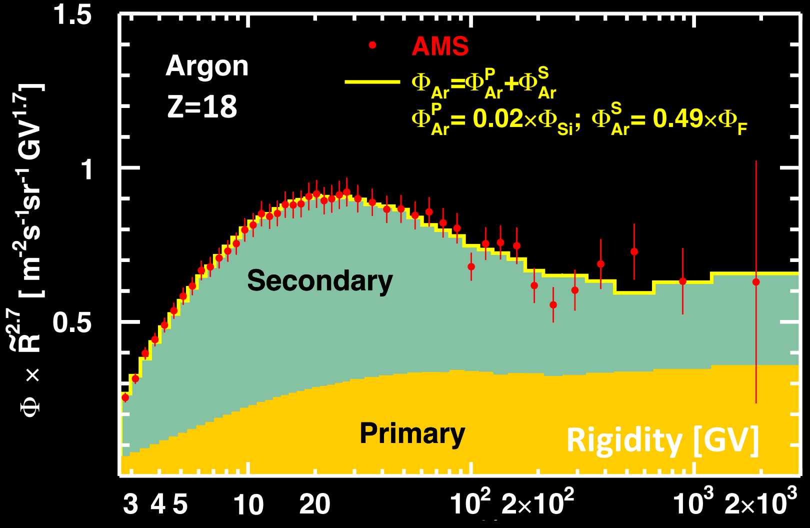
Traditional primary cosmic rays Ne, Mg, and S have a significant secondary component.

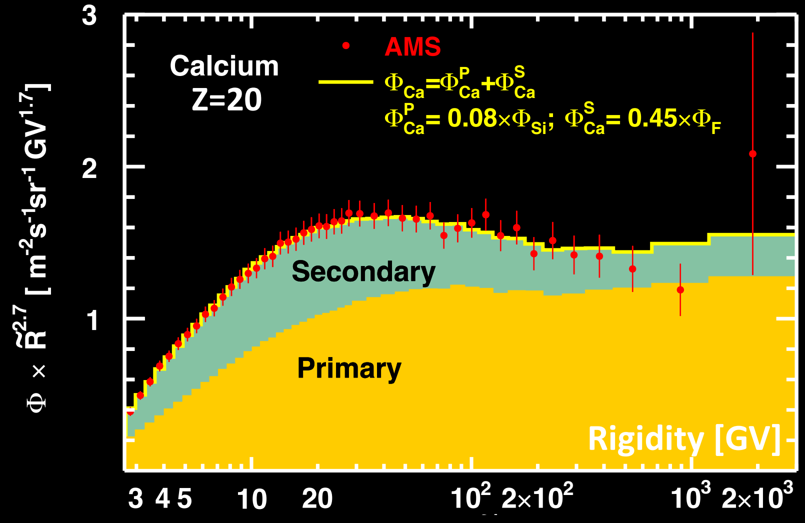






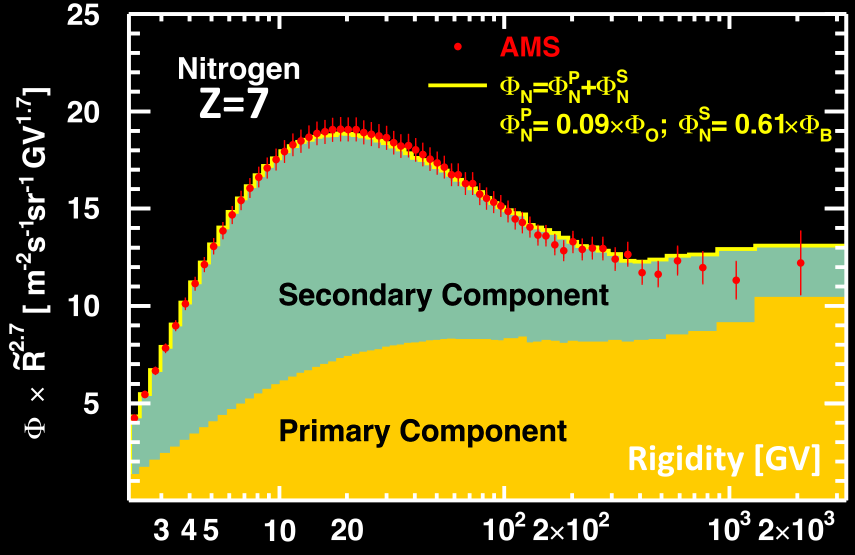
At the source : $\Phi_{Ne}/\Phi_{Si}=0.83\pm0.025$ $\Phi_{Mg}/\Phi_{Si}=1.01\pm0.025$ $\Phi_S/\Phi_{Si}=0.16\pm0.006$

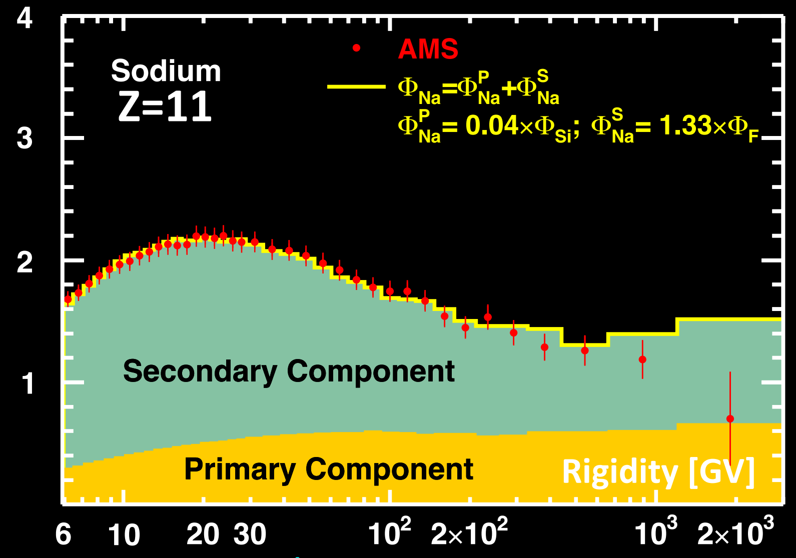


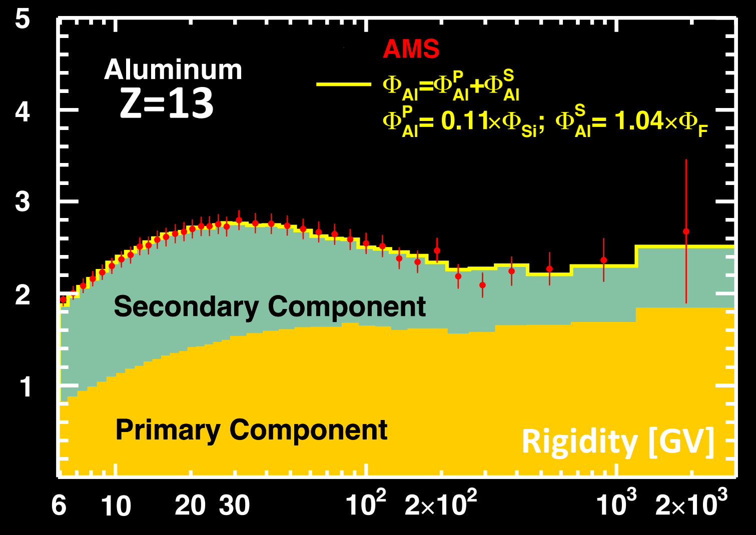


At the source : $\Phi_{Ar}/\Phi_{Si}=0.021\pm0.002$ $\Phi_{Ca}/\Phi_{Si}=0.076\pm0.003$

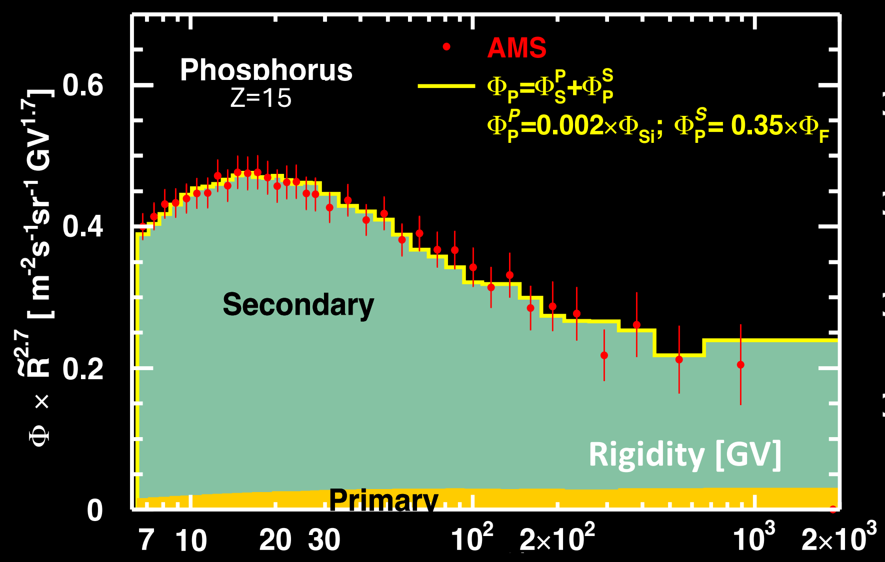
Odd-Z nuclei have more secondaries than even-Z

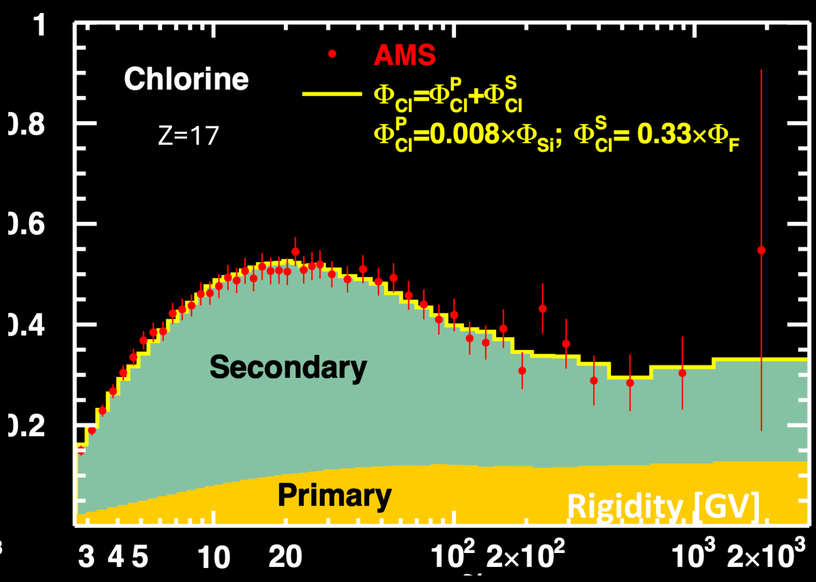


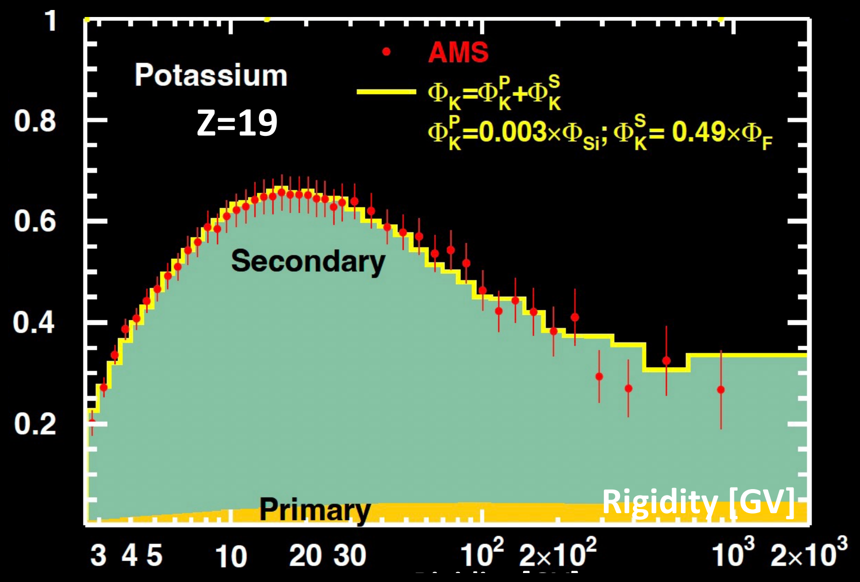




At the source : Φ_N/Φ_O=0.09 ± 0.002 Φ_{Na}/Φ_{si}=0.038 ± 0.003 Φ_{Al}/Φ_{si} = 0.105 ± 0.004

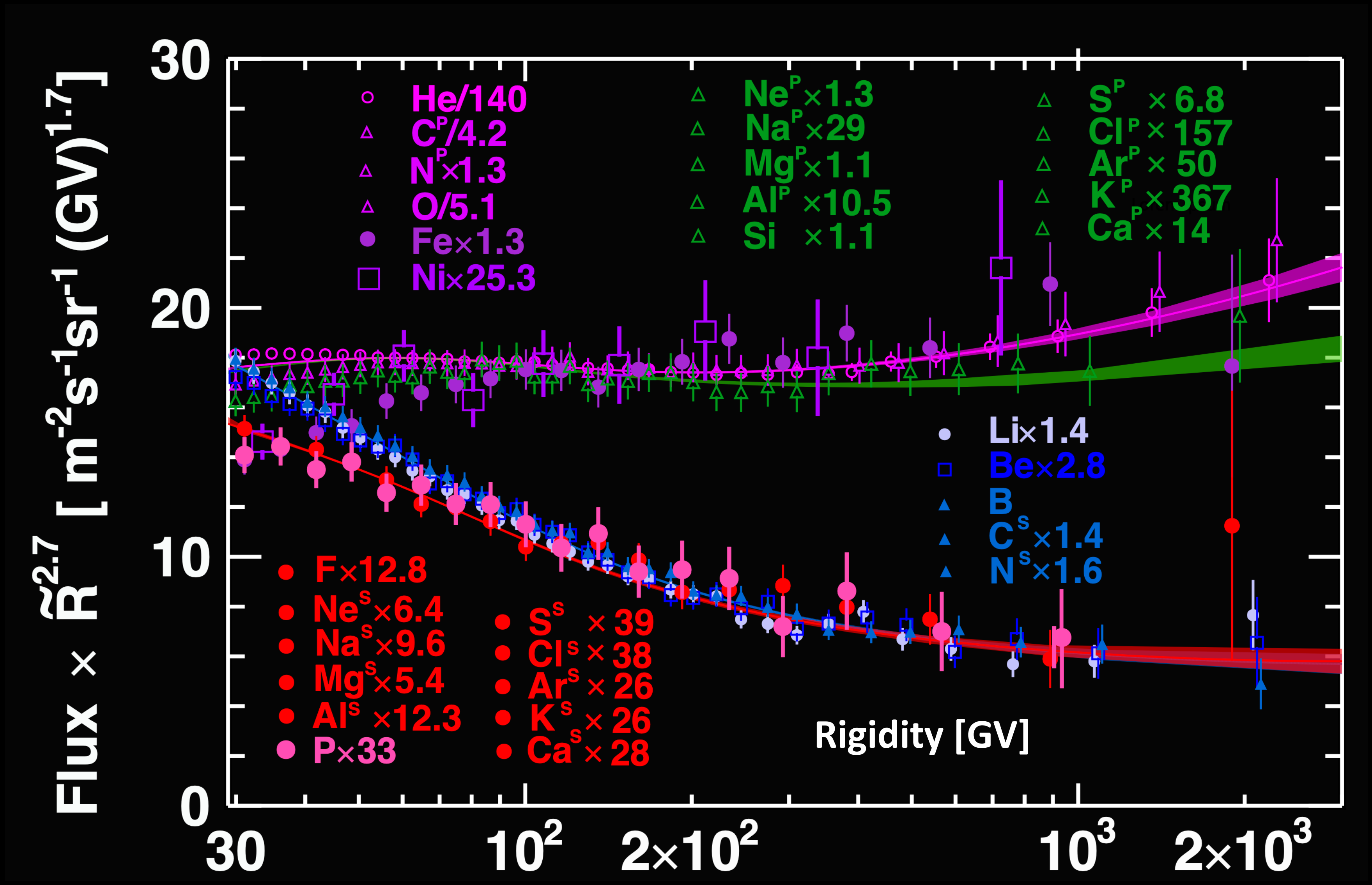


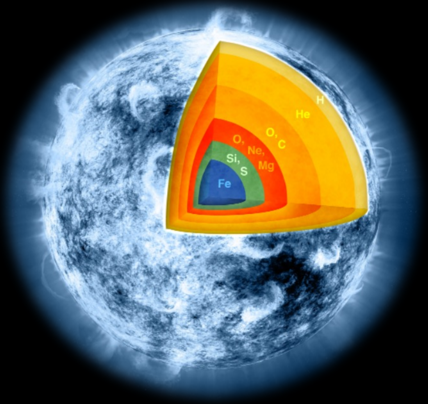




At the source : Φ_P/Φ_{si}=0.002± 0.001 Φ_{Cl}/Φ_{Si}= 0.008 ± 0.001 Φ_K/Φ_{Si}=0.003 ± 0.001

Primary and Secondary Decomposition for All Cosmic Ray Fluxes

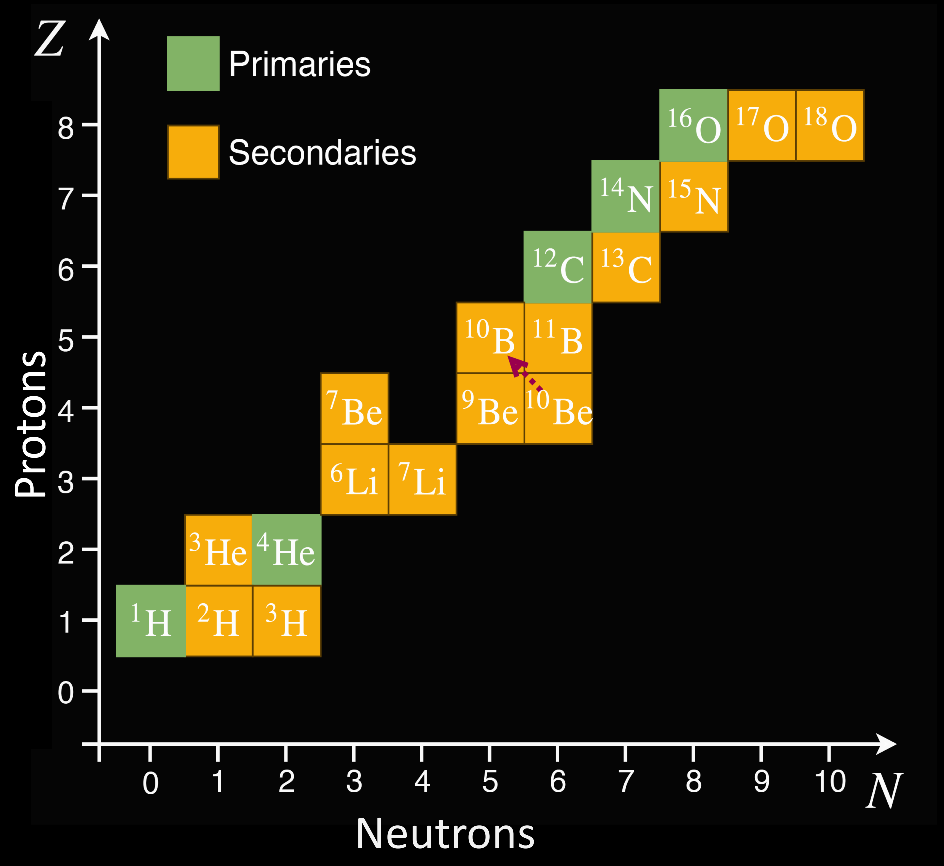




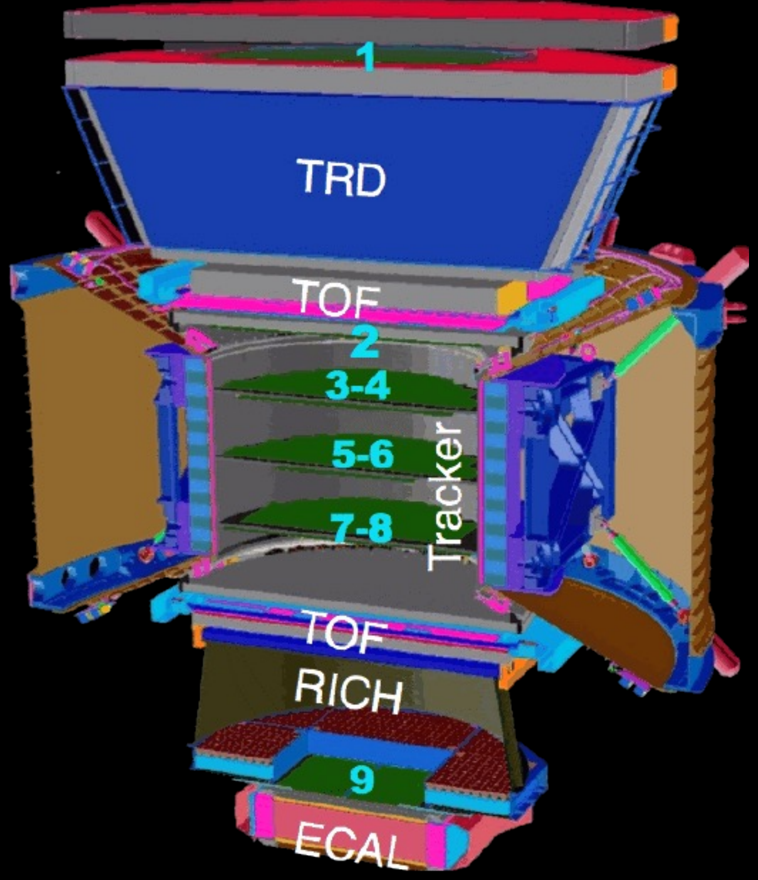
With the L0 upgrade AMS will provide precision measurement of the high-Z elements at the highest energy

Precision measurement of isotopes by AMS

Unique information on origin and propagation of cosmic rays.



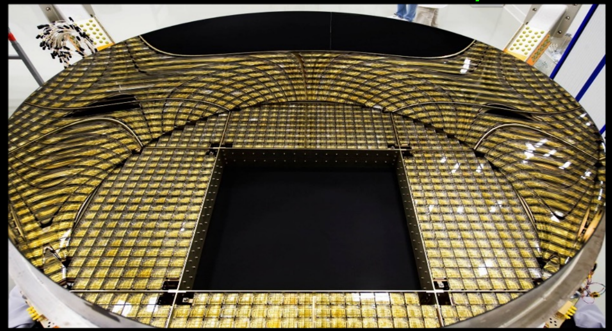
$$M = \frac{P\sqrt{1-\beta^2}}{\beta}$$



Time-of-Flight: β and Z

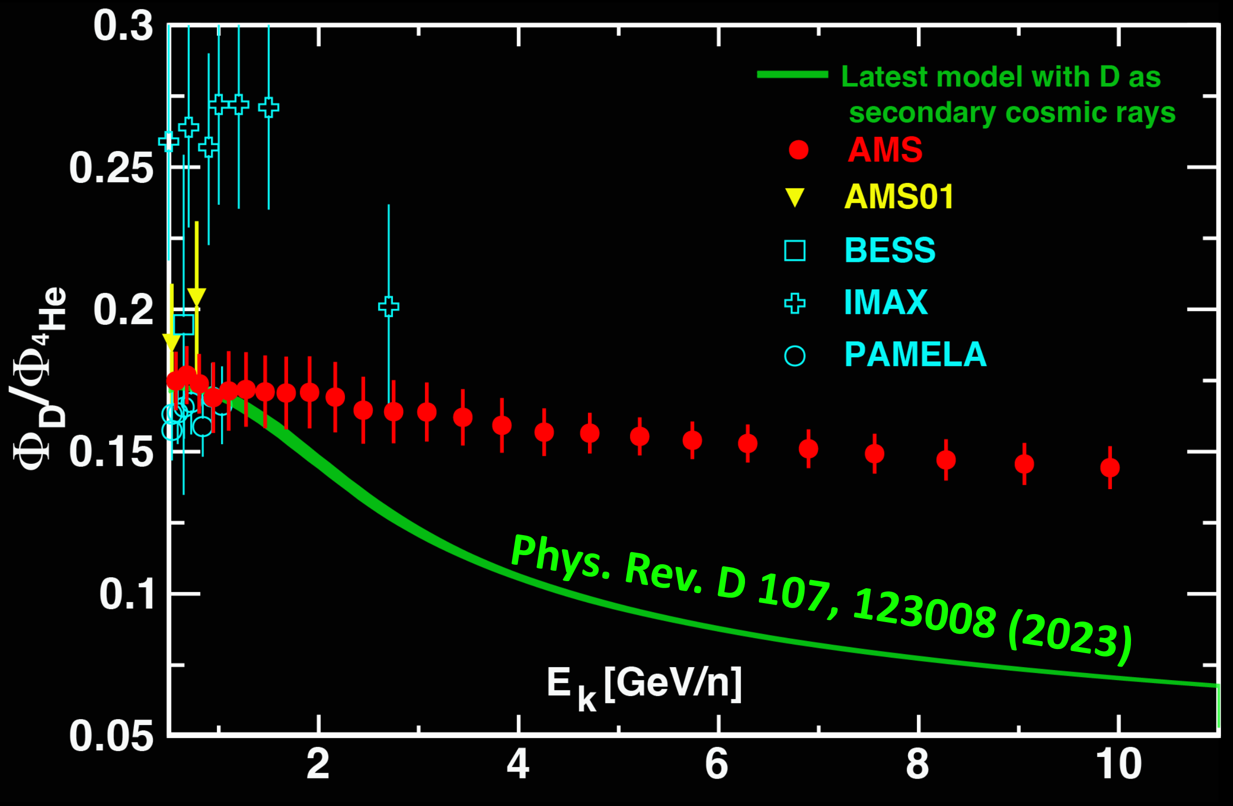
Silicon Tracker + Magnet: P and Z

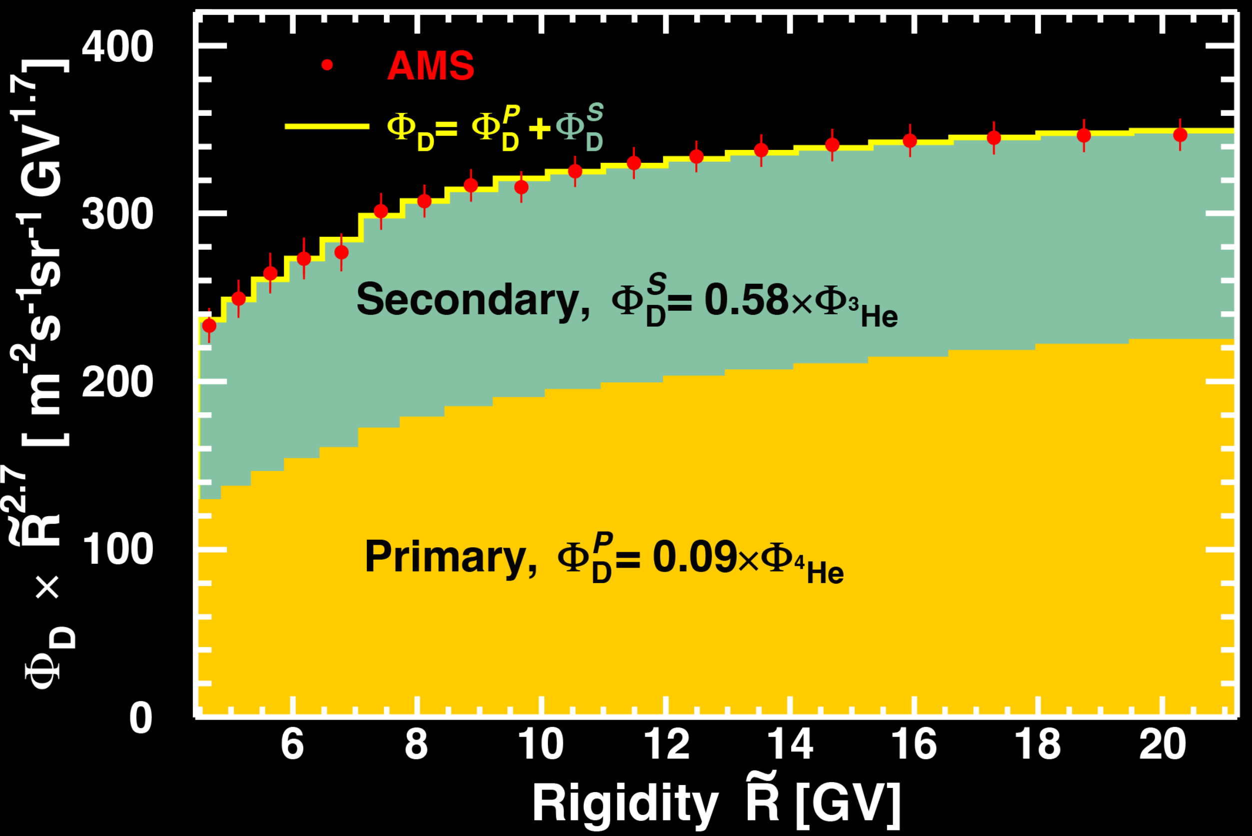
Ring Imaging Cerenkov (RICH): β and Z



Origin of Cosmic Deuterons

To be presented by F. Nicolás

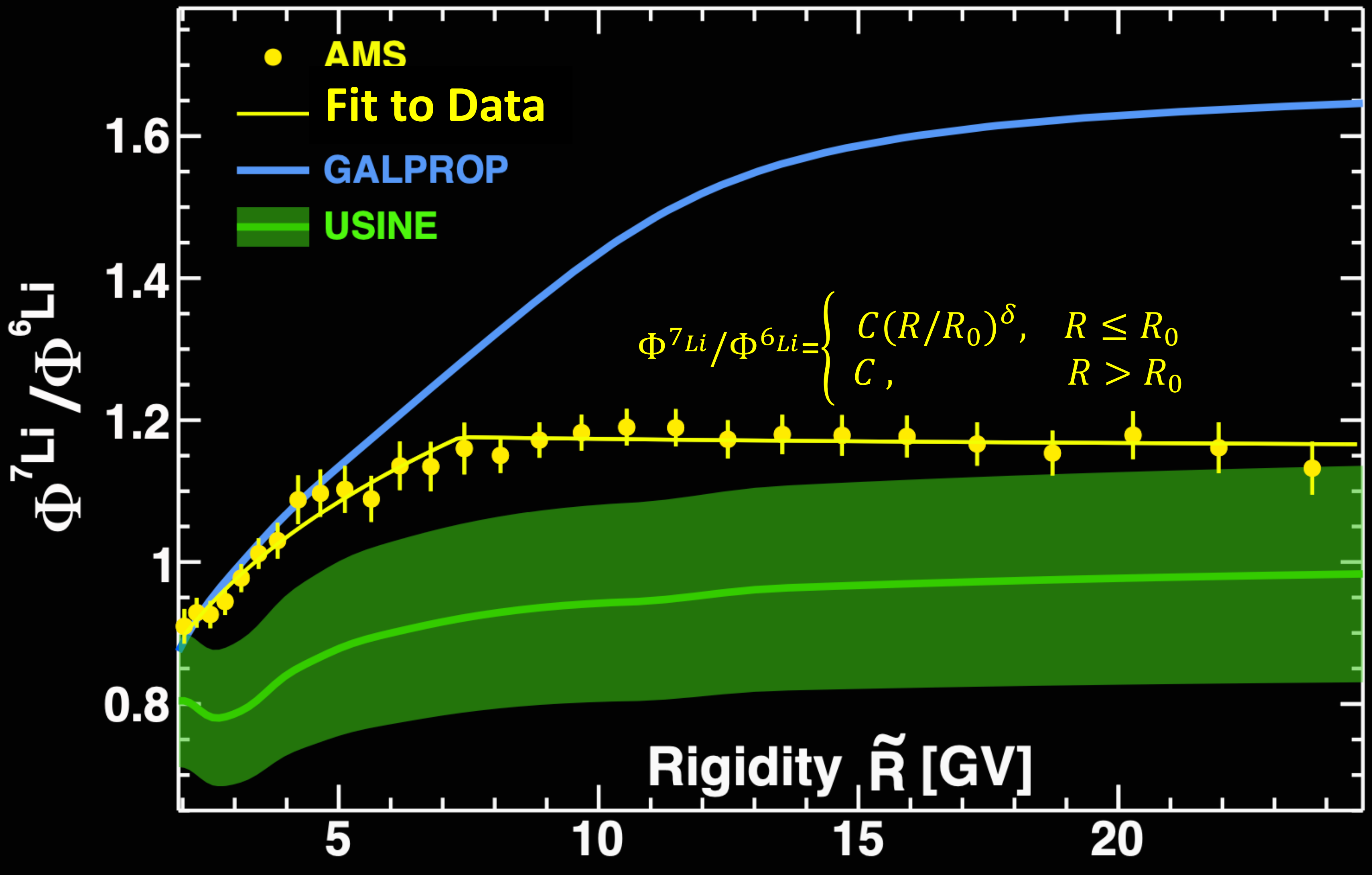




The AMS results disagree with the latest model with D as secondary cosmic rays

Deuterons have a significant primary component

Origin of Cosmic Lithium



Model assuming a primary component in the ^{7}Li flux

Model assuming secondary origin of ^{6}Li and ^{7}Li

Above ~7 GV, the rigidity dependence of ^{6}Li and ^{7}Li fluxes are identical. Excludes the existence of a sizable primary component in the ^{7}Li flux

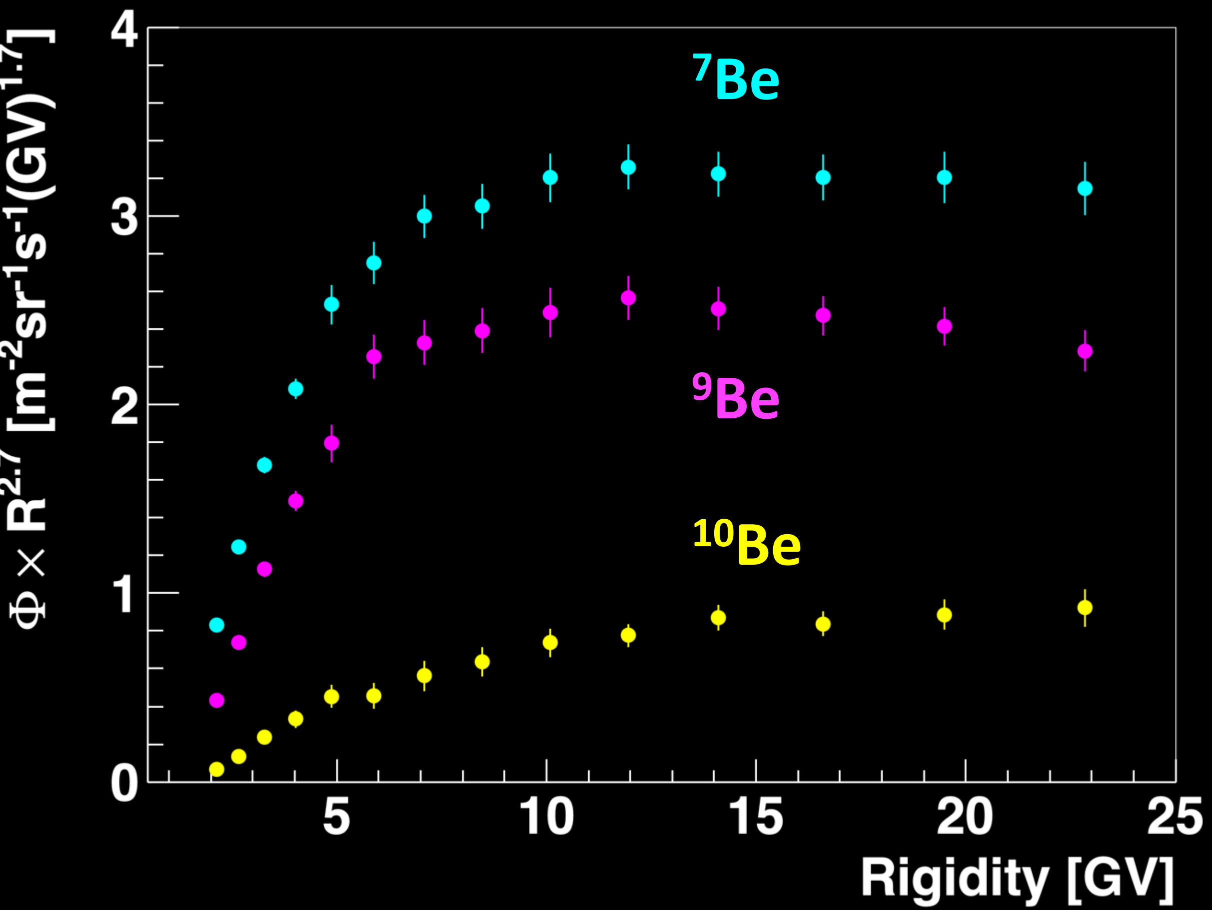
New Results on Beryllium Isotopes

To be presented by D. Krasnopevtsev

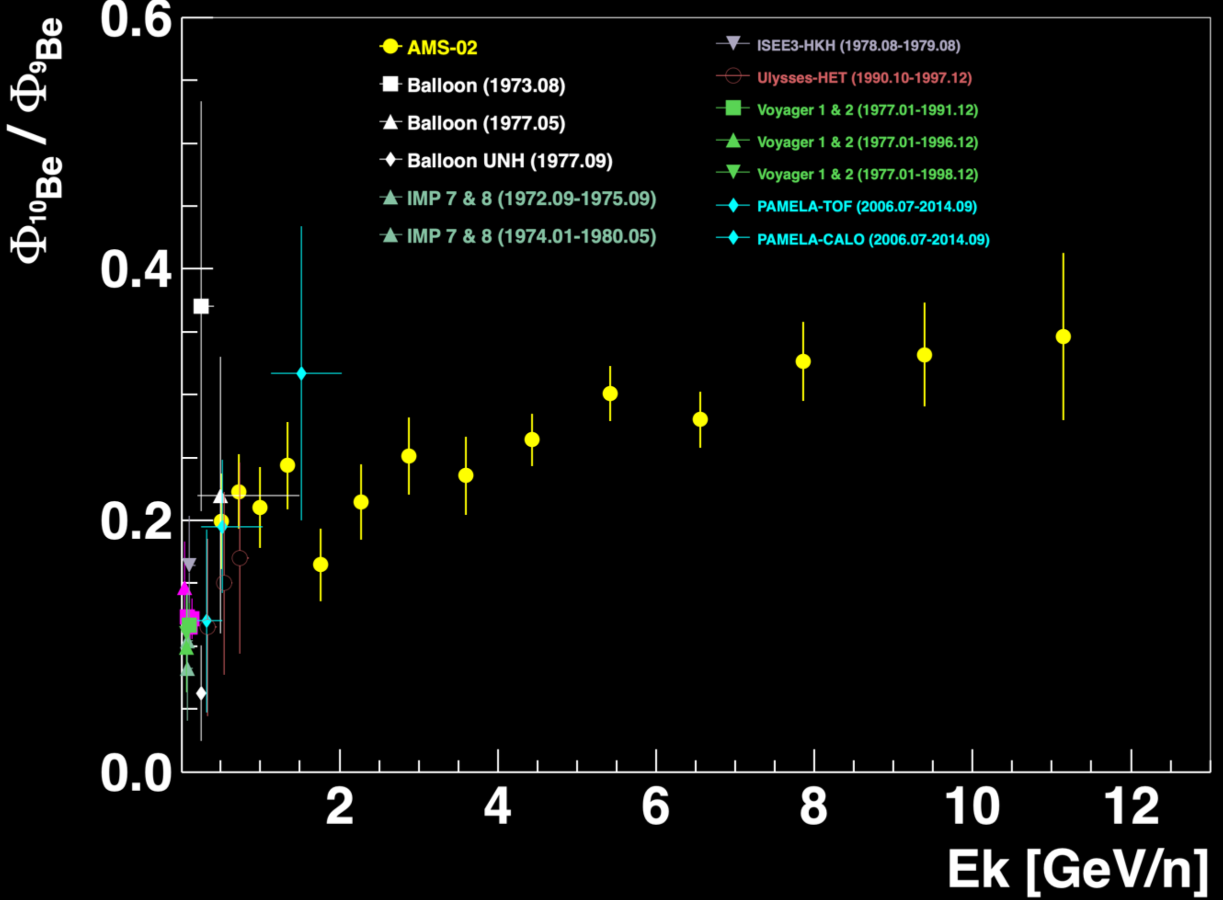
^{9}Be propagate in the entire galactic halo,

^{10}Be decay before reaching the boundary of the Galaxy.

^{10}Be/^{9}Be measures the Galactic halo size ***L***



^{10}Be/^{9}Be Flux Ratio



In 14 years on the ISS,

AMS is providing cosmic ray information with ~1% accuracy with energies up to multi-TeV.

We look forward to more exciting discoveries.