ANISOTROPY

OF COSMIC ELEMENTARY PARTICLES

MEASURED WITH THE ALPHA MAGNETIC SPECTROMETER ON THE ISS

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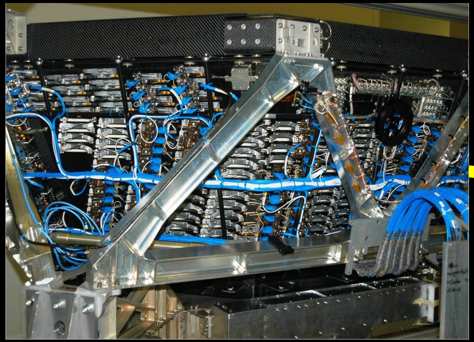
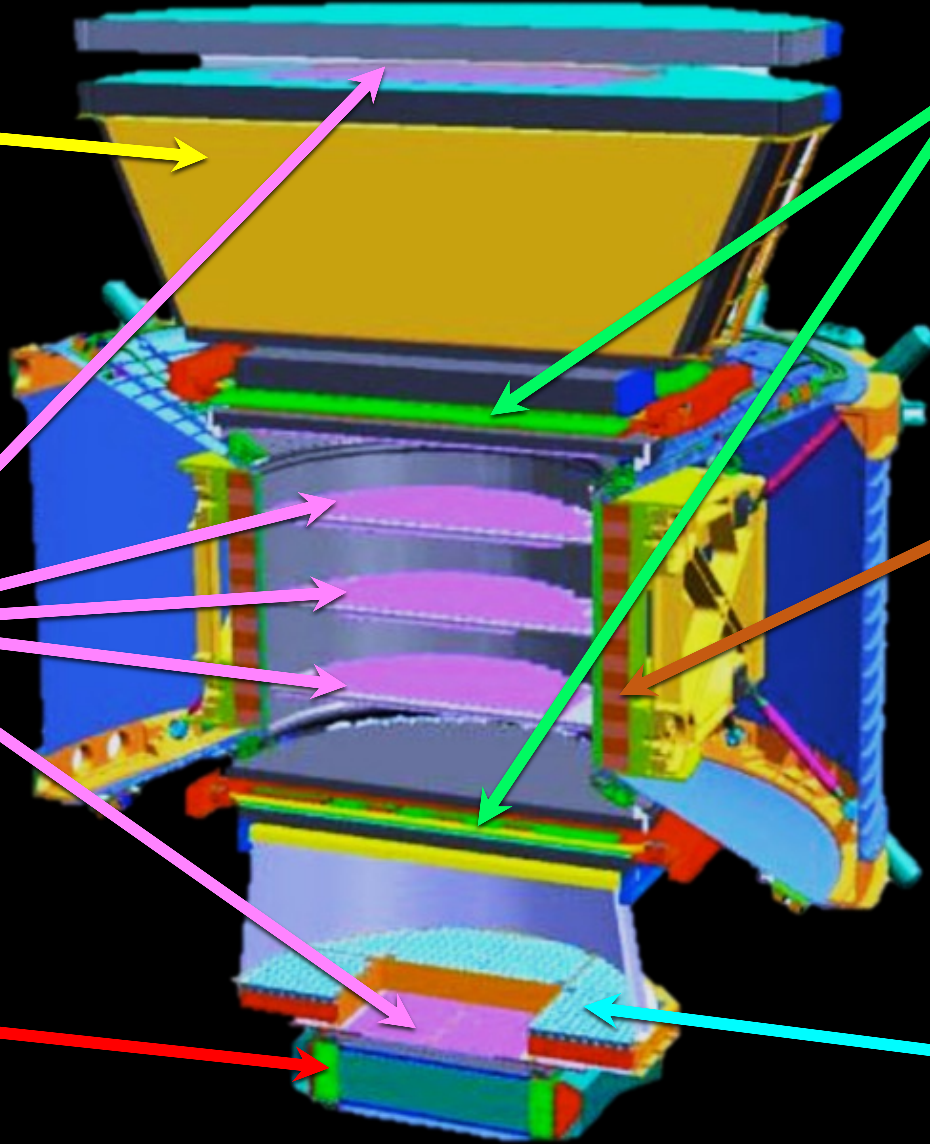
TeV Particle Astrophysics
TeVPA 2026
Tendo Japan
August 30 - September 4, 2026

AMS-02

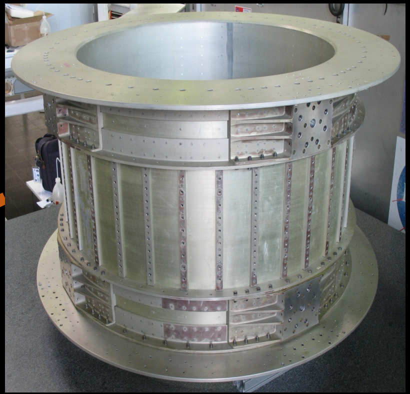
Transition Radiation Detector
Identifies e^+, e^-



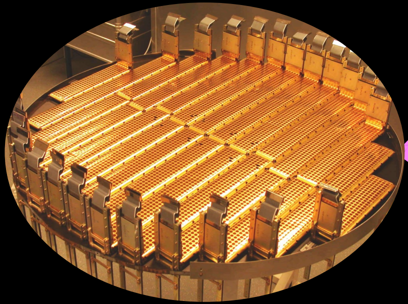
Time Of Flight
Z, β



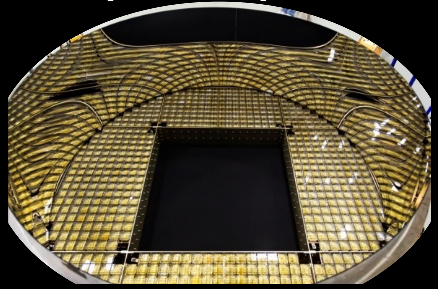
Magnet



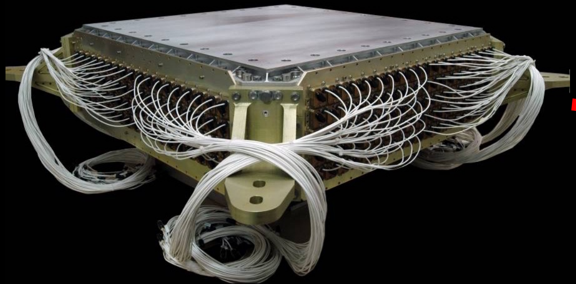
Silicon Tracker
Z, Rigidity



Ring Imaging Cherenkov
Z, β
Isotopic composition



Electromagnetic Calorimeter
Energy of e+, e-

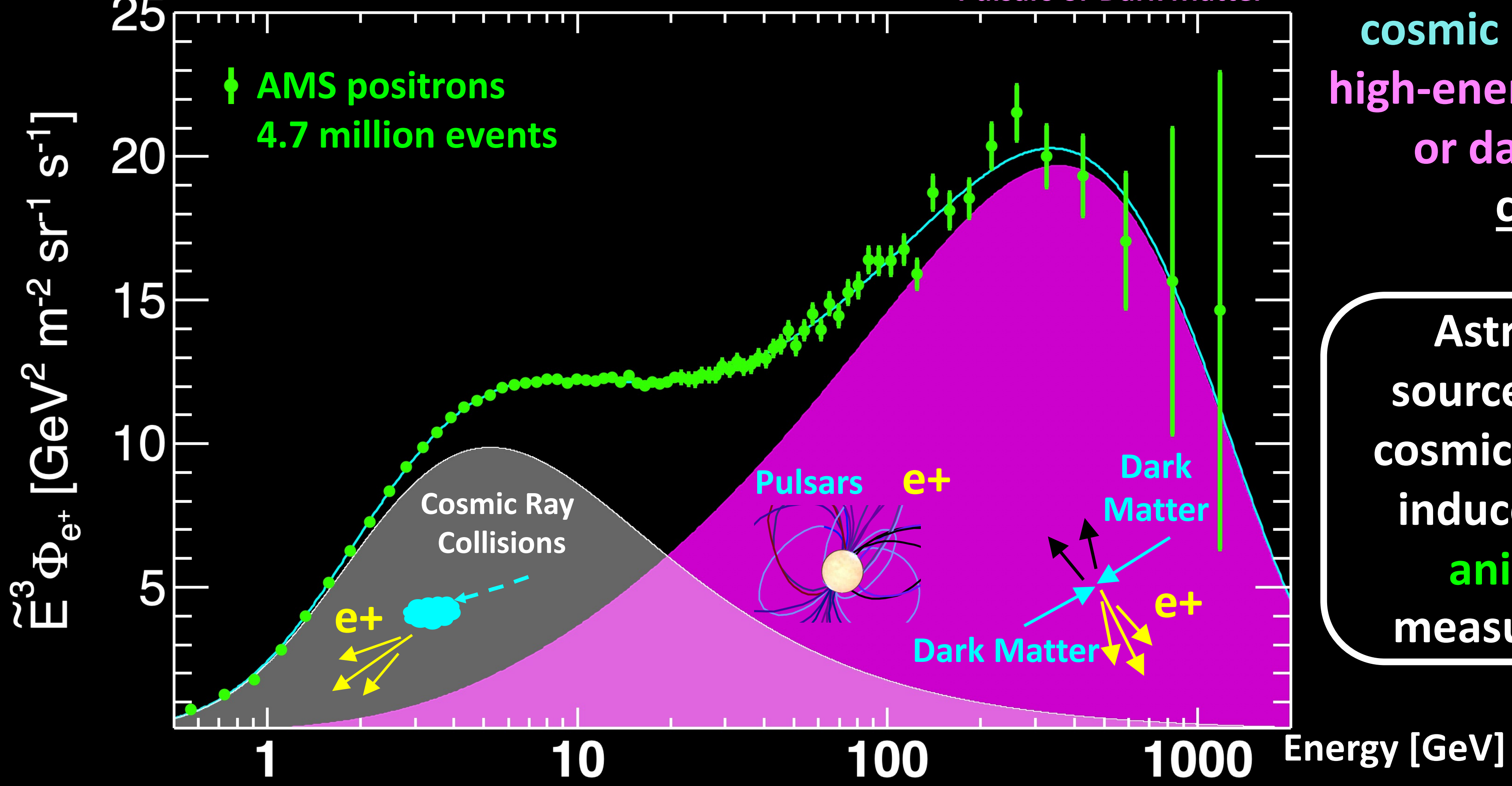


Origin of Cosmic Ray Positrons

Talk by D. Krasnopevtsev
3 Sept

Empirical model: $\Phi_{e^+}(E) = \underbrace{\frac{E^2}{\hat{E}^2}}_{\text{Solar}}\left[\underbrace{C_d(\hat{E}/E_1)^{\gamma_d}}_{\text{Collisions}} + \underbrace{C_s(\hat{E}/E_2)^{\gamma_s}\exp(-\hat{E}/E_s)}_{\text{Pulsars or Dark Matter}}\right]$

$\chi^2/\mathrm{dof} = 36/66$

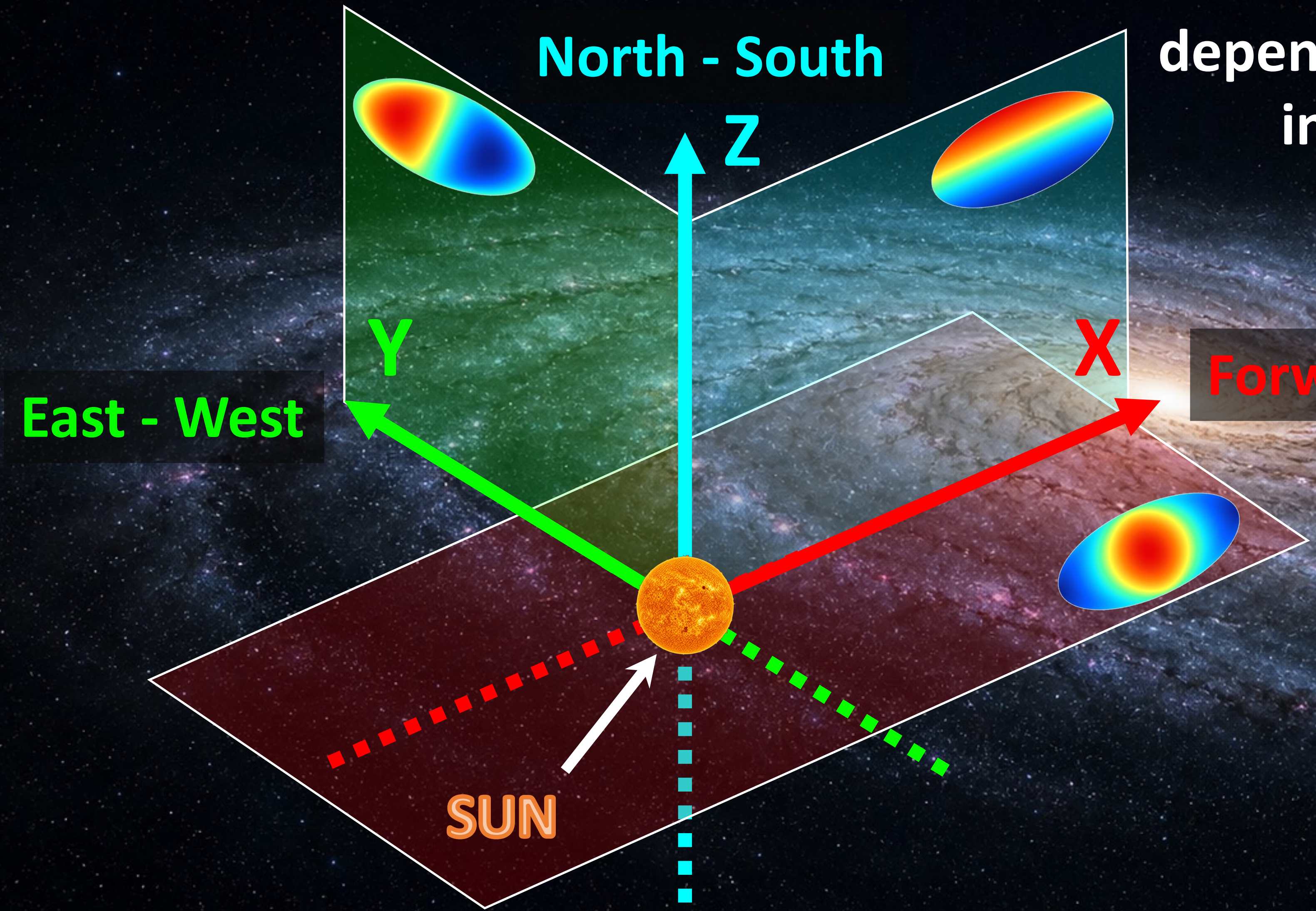


The positron flux is the sum of low-energy part from cosmic ray collisions plus a high-energy part from pulsars or dark matter with a <u>cutoff energy</u>

Astrophysical point sources (like pulsars) of cosmic ray positrons may induce some degree of anisotropy on the measured positron flux

Anisotropy Analysis

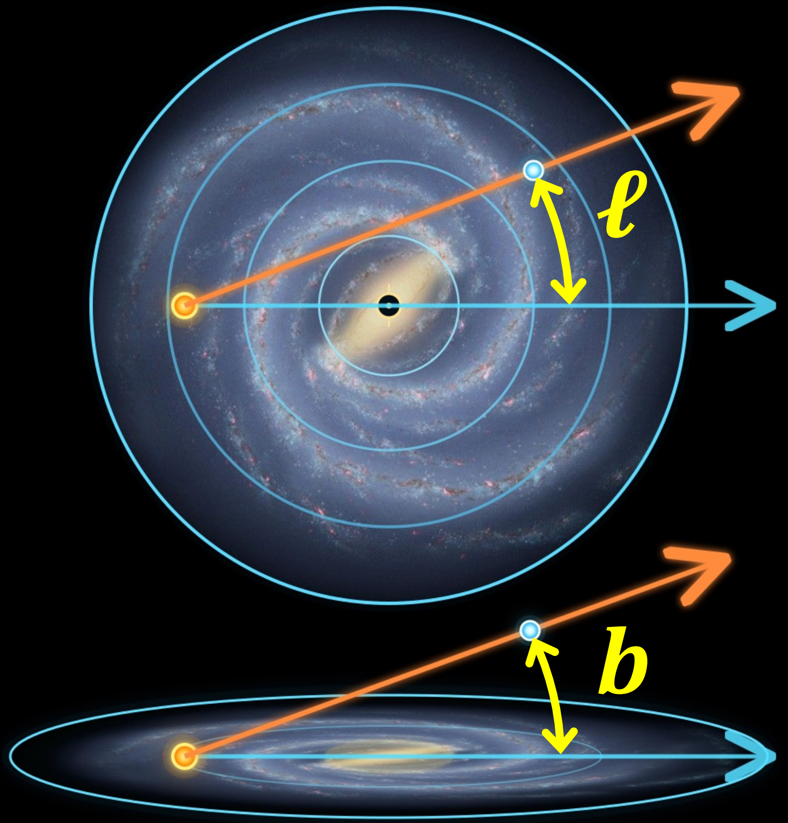
Measurement of the directional dependence of cosmic-ray fluxes in *Galactic Coordinates*



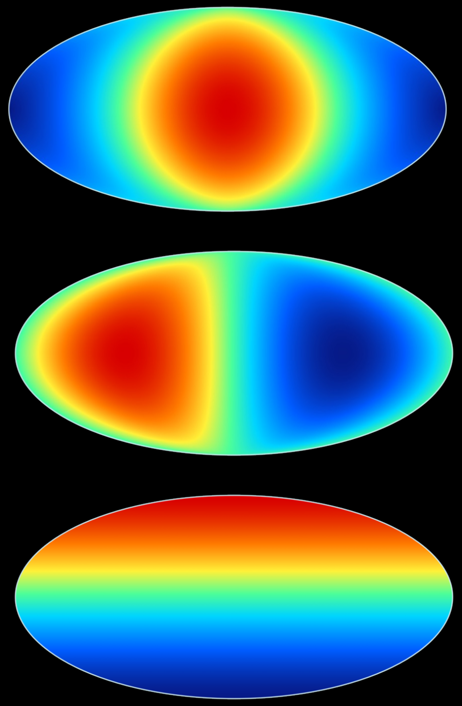
Spherical Harmonic Expansion

Dipole anisotropy (1st harmonic)

$$\Phi(\ell, b) = \Phi_0(1 + \boldsymbol{\rho}_{\mathbf{FB}} \cos b \cos \ell + \boldsymbol{\rho}_{\mathbf{EW}} \cos b \sin \ell + \boldsymbol{\rho}_{\mathbf{NS}} \sin b)$$



Dipole components



$\boldsymbol{\rho}_{\mathbf{FB}}$

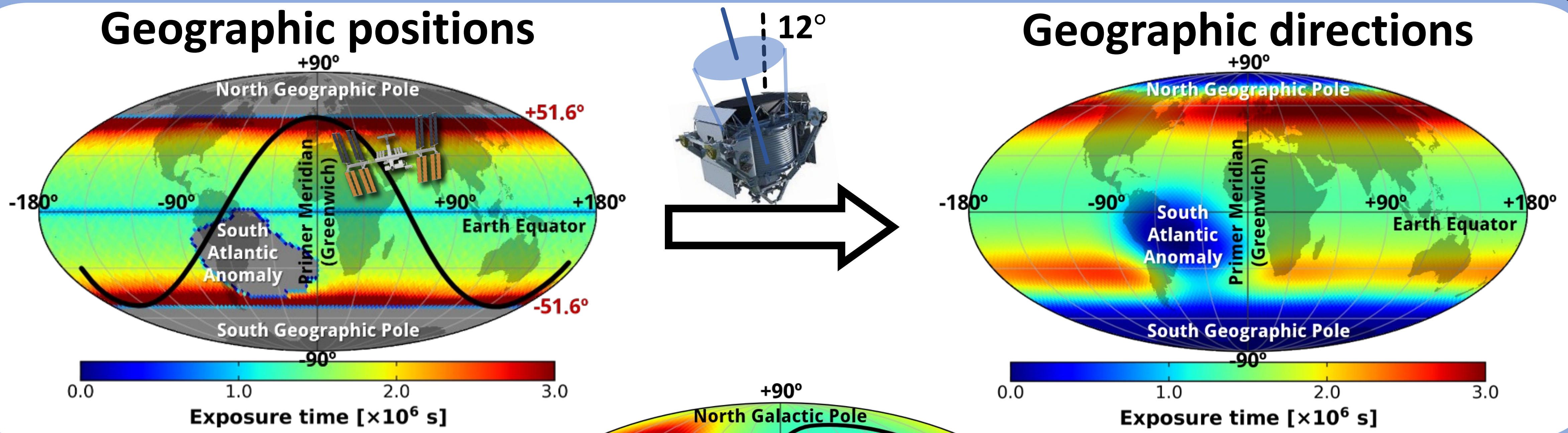
$\boldsymbol{\rho}_{\mathbf{EW}}$

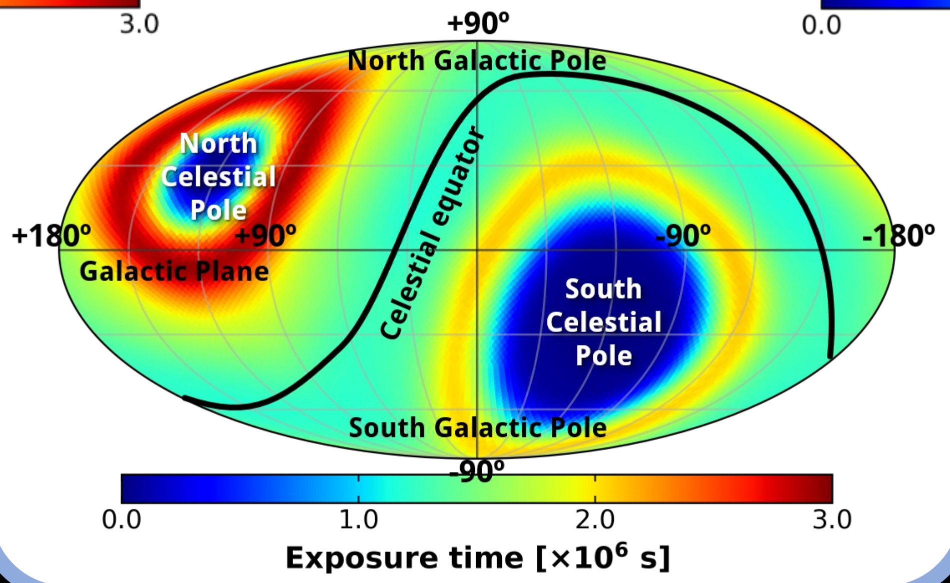
$\boldsymbol{\rho}_{\mathbf{NS}}$

Dipole amplitude

$$\boldsymbol{\delta} = \sqrt{\boldsymbol{\rho}_{\mathbf{FB}}^2 + \boldsymbol{\rho}_{\mathbf{EW}}^2 + \boldsymbol{\rho}_{\mathbf{NS}}^2}$$

AMS Sky Coverage



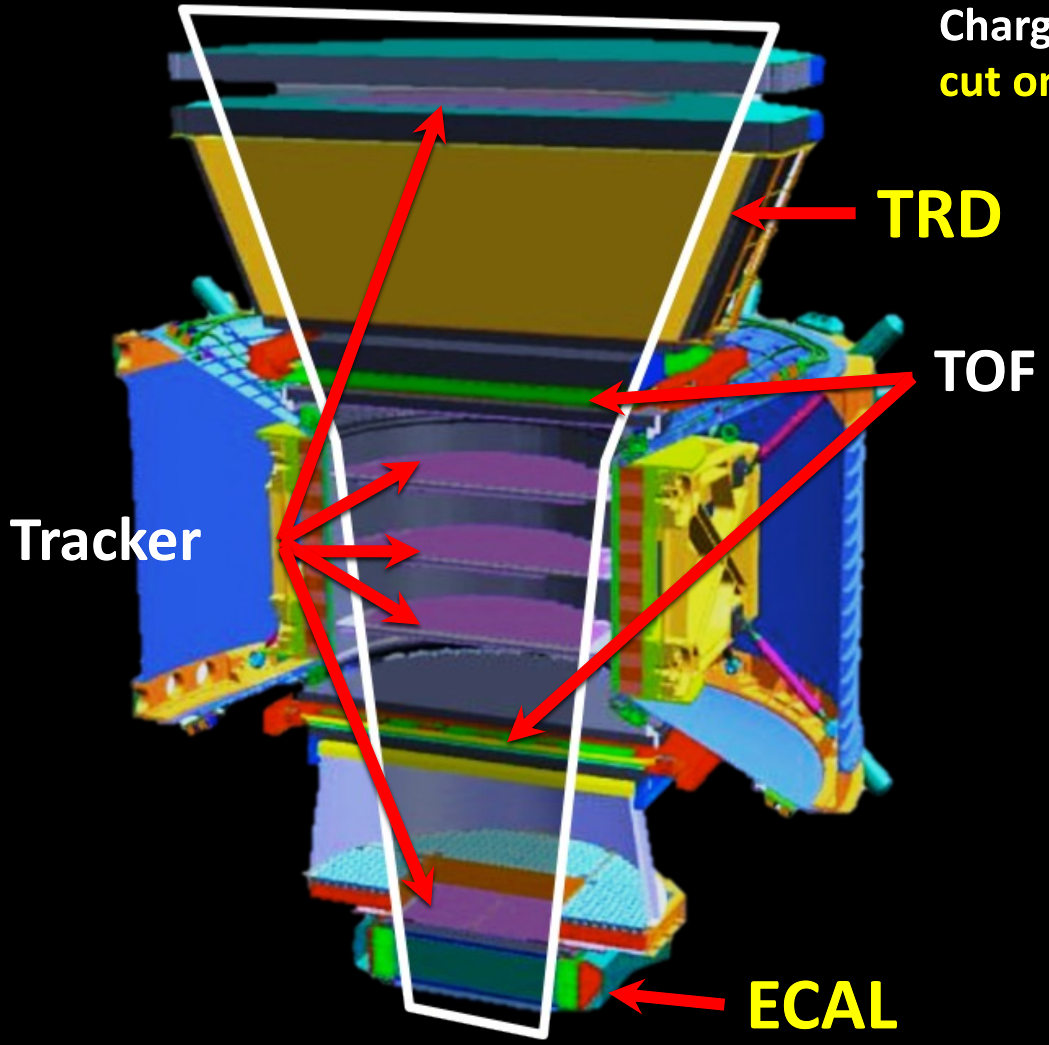


AMS installed on the ISS
Near Earth Orbit:
- Altitude 400 km
- Inclination 52°
- Launch May 2011

Total exposure time
3.15×10^{8} s

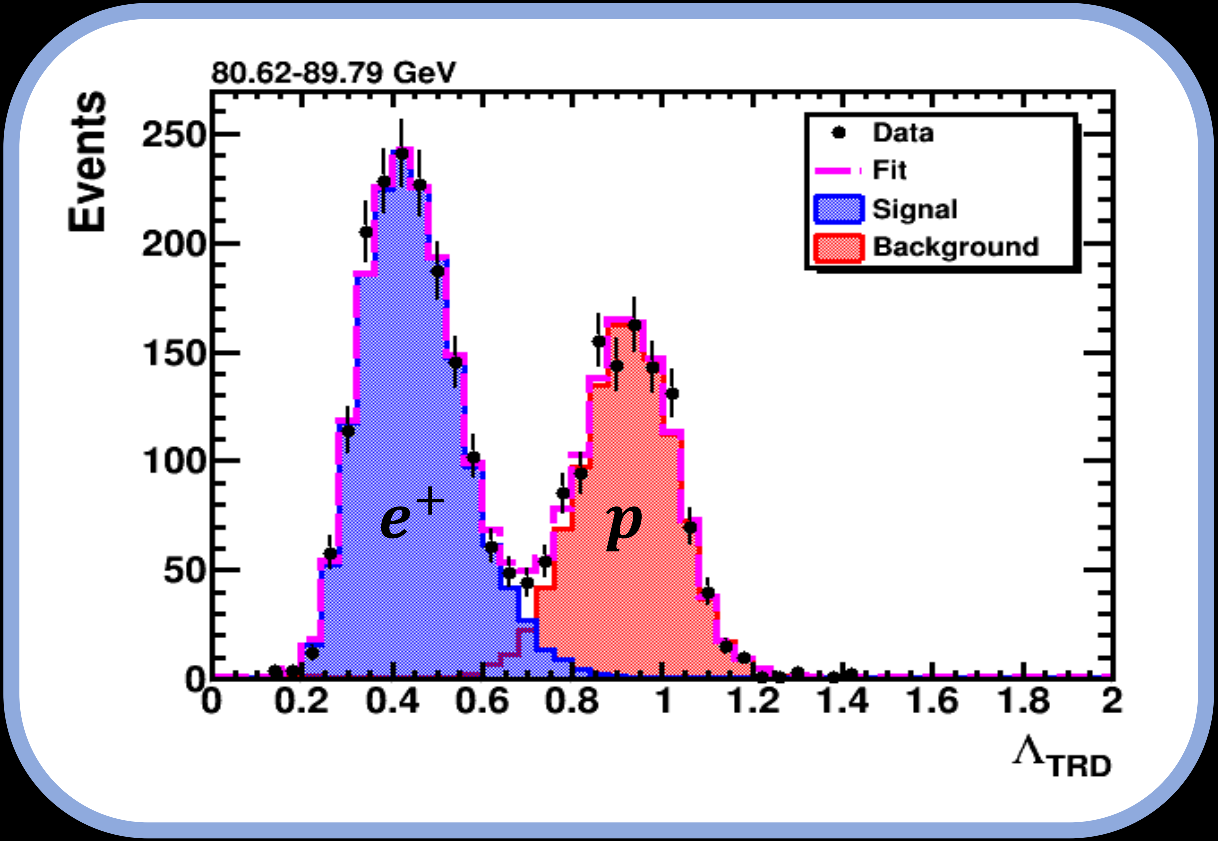
Positron Anisotropy Analysis

Current Analysis
Fiducial Volume TRD - ECAL



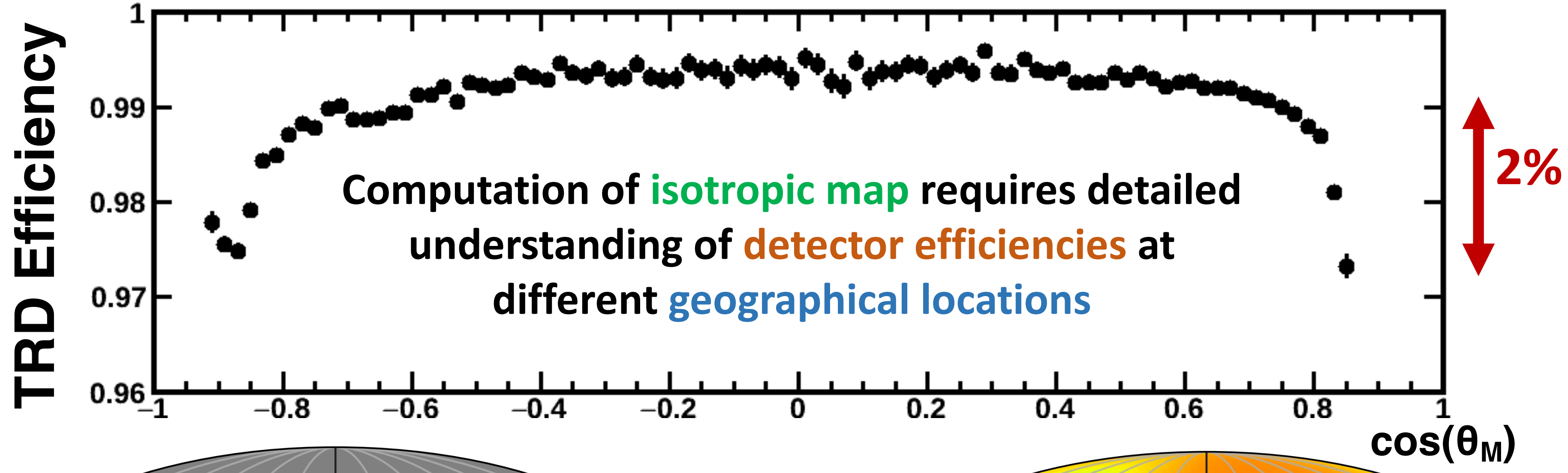
Positrons are separated from protons with a selection based on a cut on the ECAL estimator and the TRD response

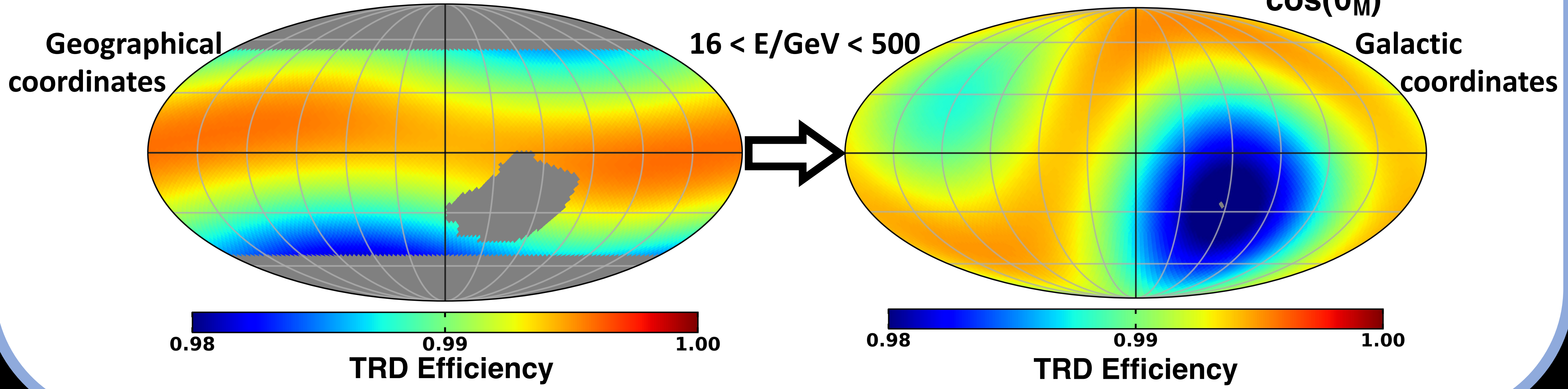
Charge confusion (CC) electrons are reduced to percent level by means of a cut on a CC estimator that combines information from TRD, TOF and Tracker



Positron signal extraction using the TRD response

Detector Efficiencies





Positron Anisotropy: maps

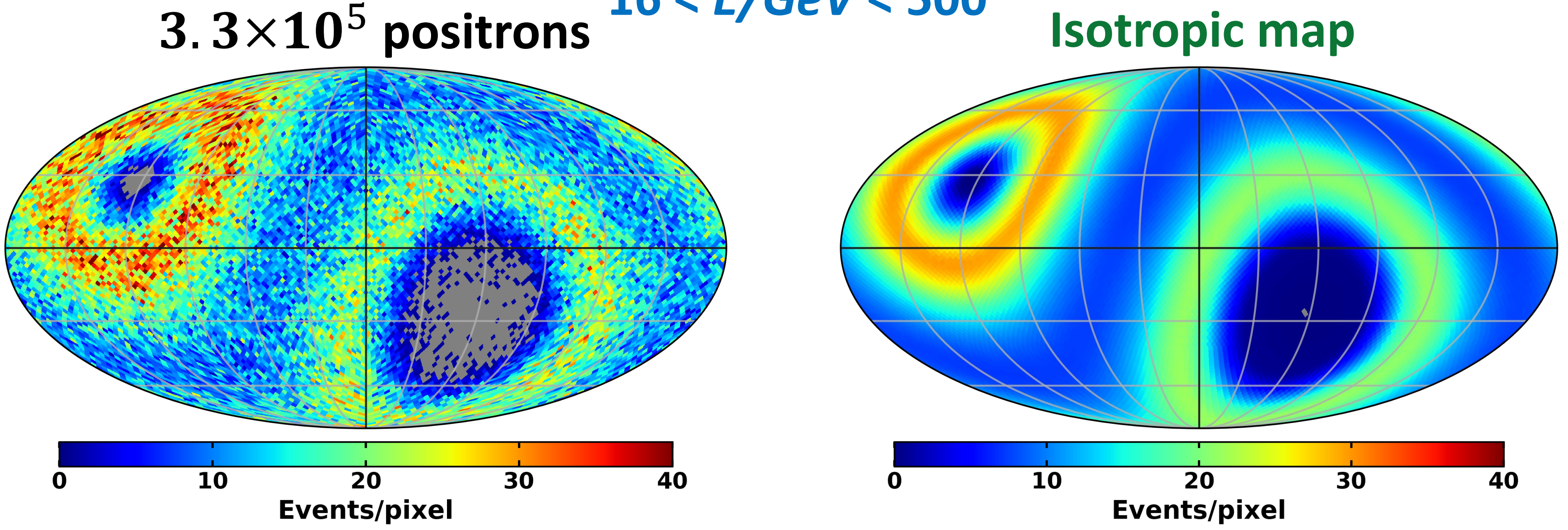
Selected events are grouped into 5 cumulative energy ranges:

16, 25, 40, 65, 100 < *E/GeV* < 500

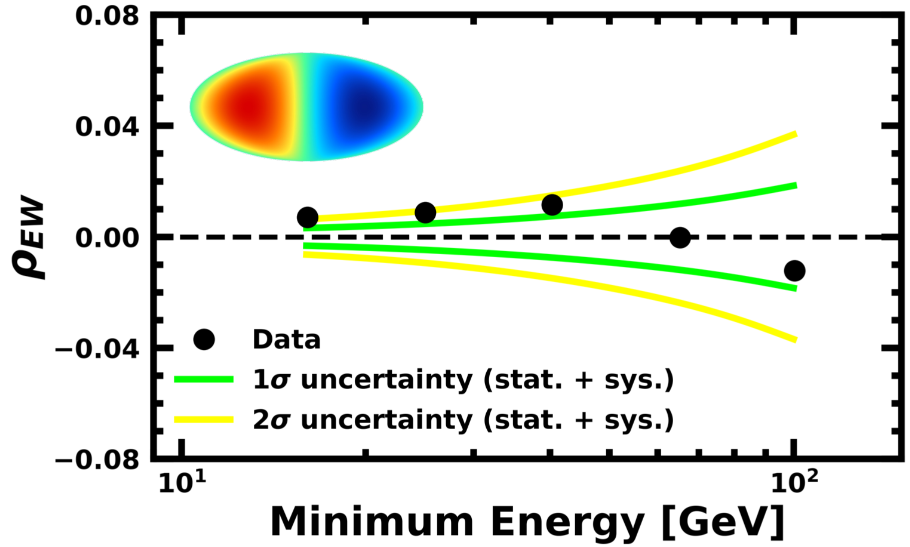
The arrival directions of positron events are compared to the expected map for an isotropic flux in galactic coordinates

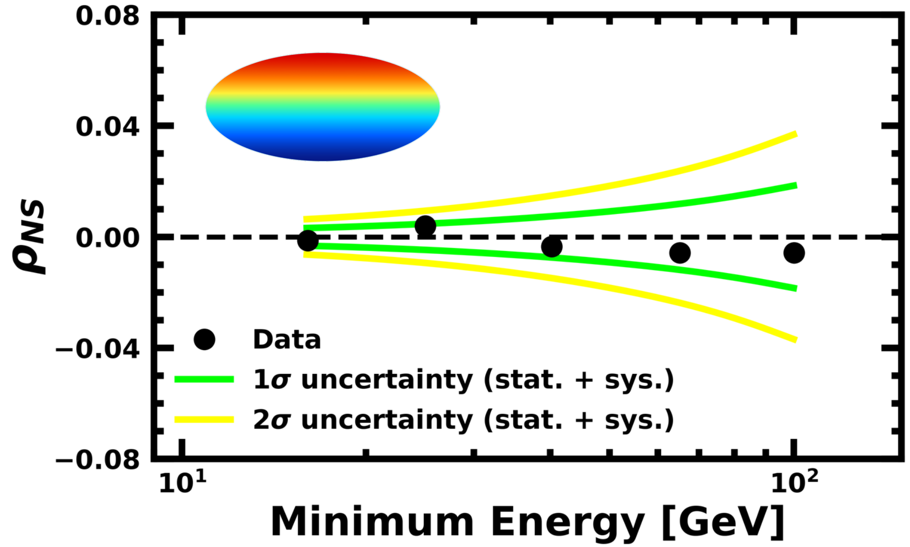
Galactic coordinates

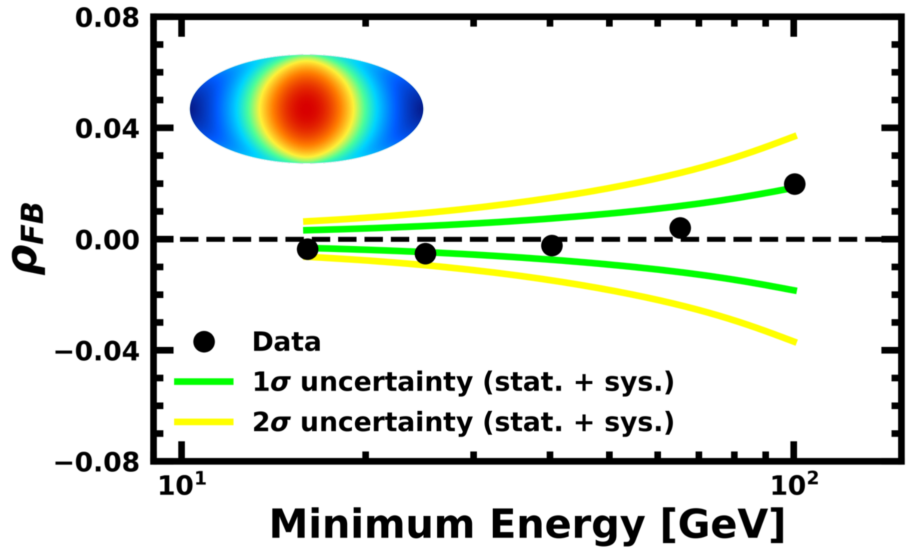
16 < *E/GeV* < 500



Positron Anisotropy: Dipole components

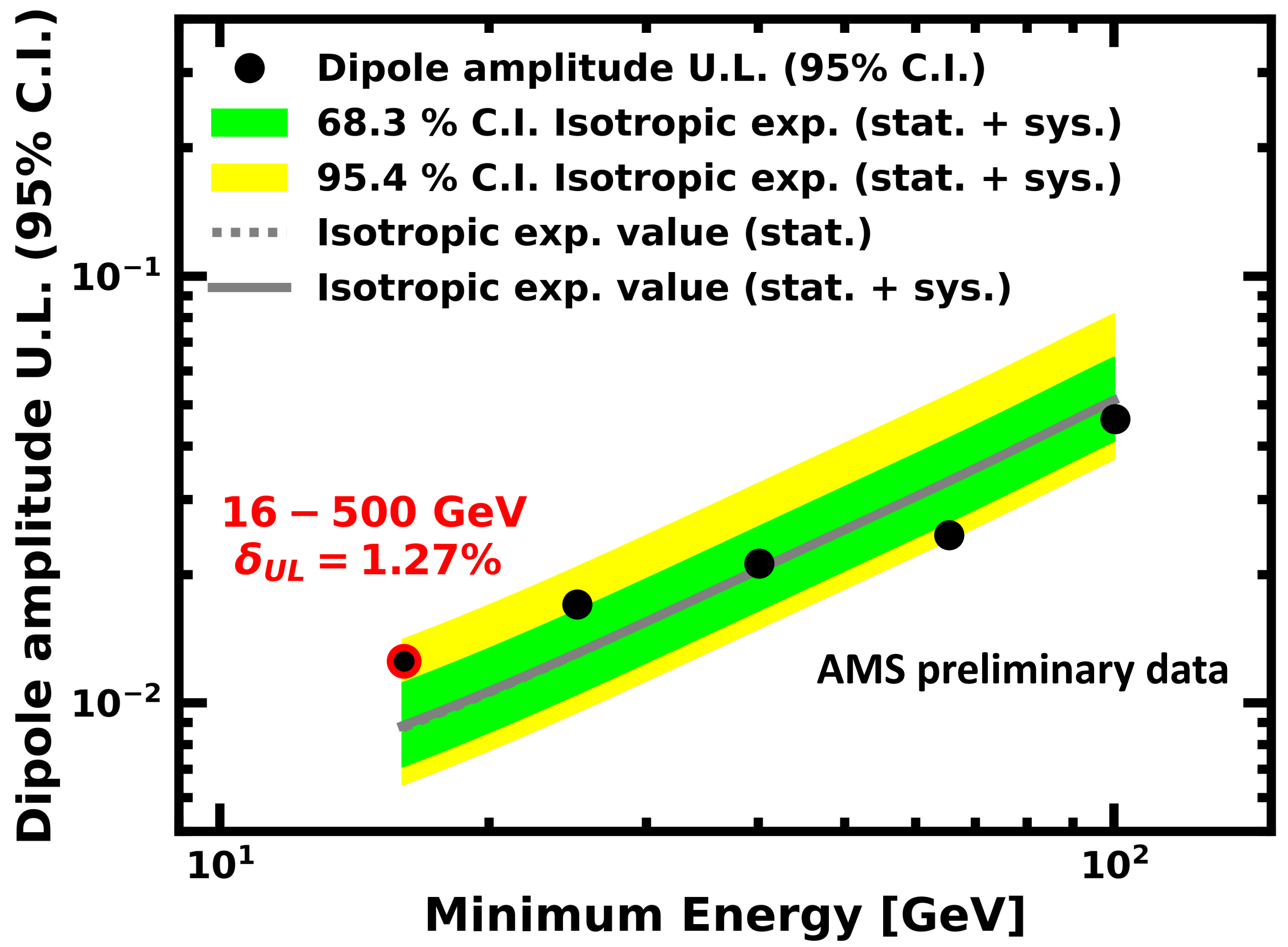






Positron dipole components in galactic coordinates are consistent with isotropy

Positron Anisotropy: Dipole U.L.



Time

2011/05 – 2025/10

3.3×10^5 positron events

16 < *E*/GeV < 500

$\delta_{UL} = 1.27\%$ at the 95% C.I.

for 16 < *E/GeV* < 500

0.89% Iso. Exp. (stat.+sys.)

Electron Anisotropy: maps

Selected events are grouped into **5 cumulative energy ranges**:

16, 25, 40, 65, 100 < *E/GeV* < 500

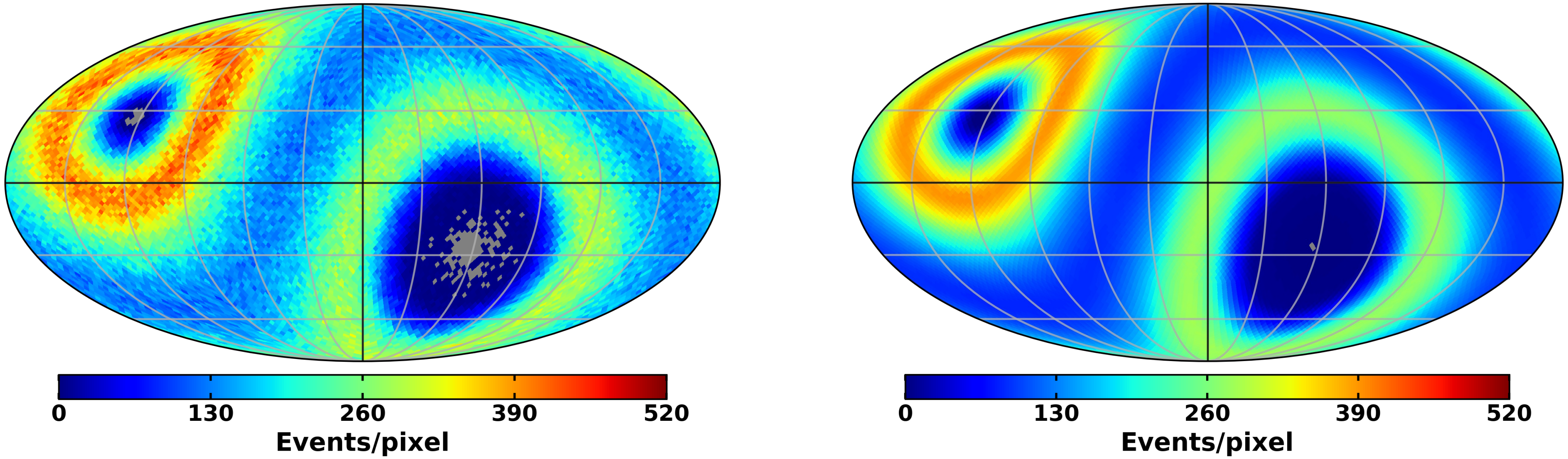
The arrival directions of **electron** events are compared to the expected map for an **isotropic flux** in galactic coordinates

Galactic coordinates

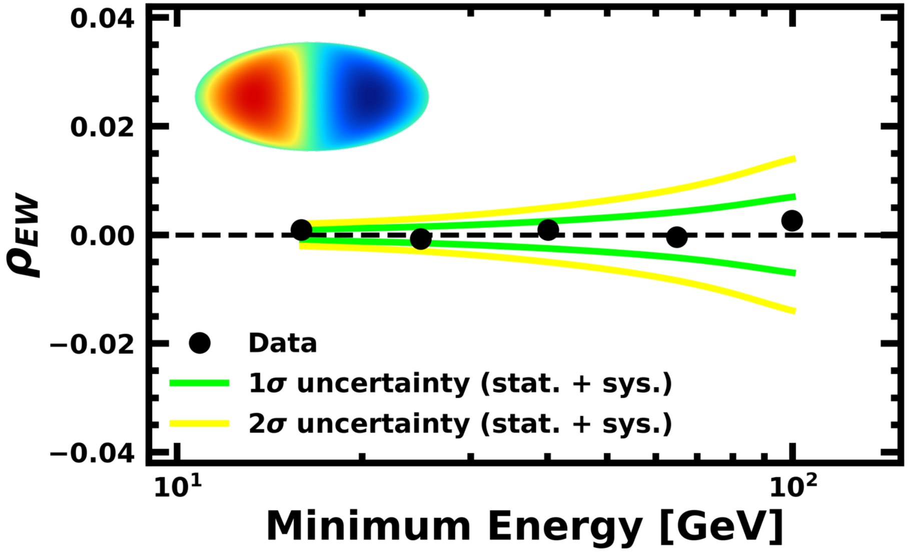
16 < *E/GeV* < 500

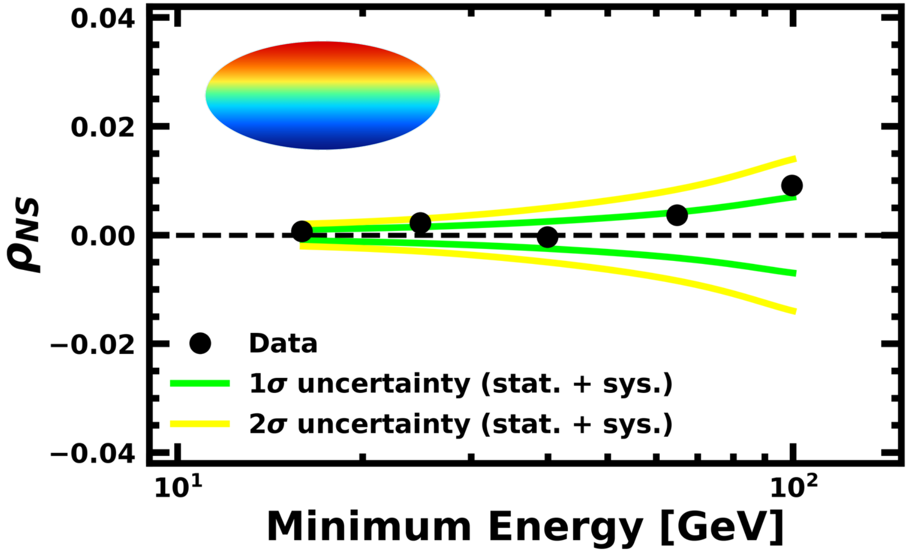
$4.4{\times}10^6$ electrons

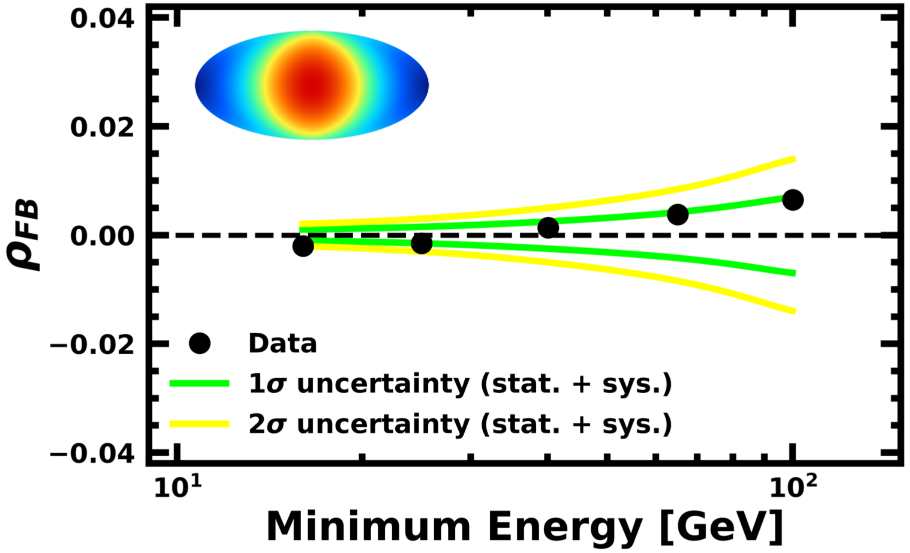
Isotropic map



Electron Anisotropy: Dipole components

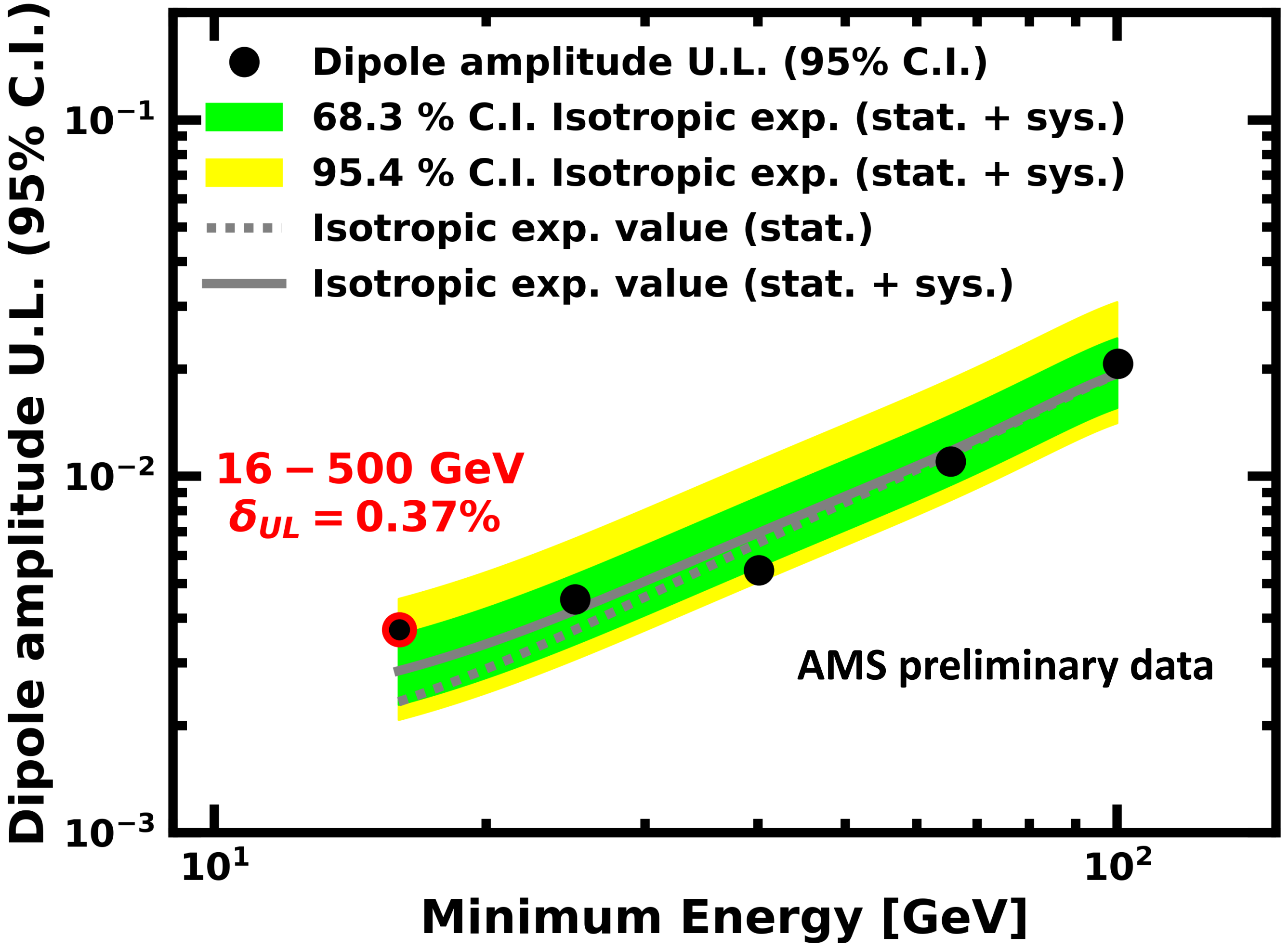






Electron dipole components in galactic coordinates are consistent with isotropy

Electron Anisotropy: Dipole U.L.

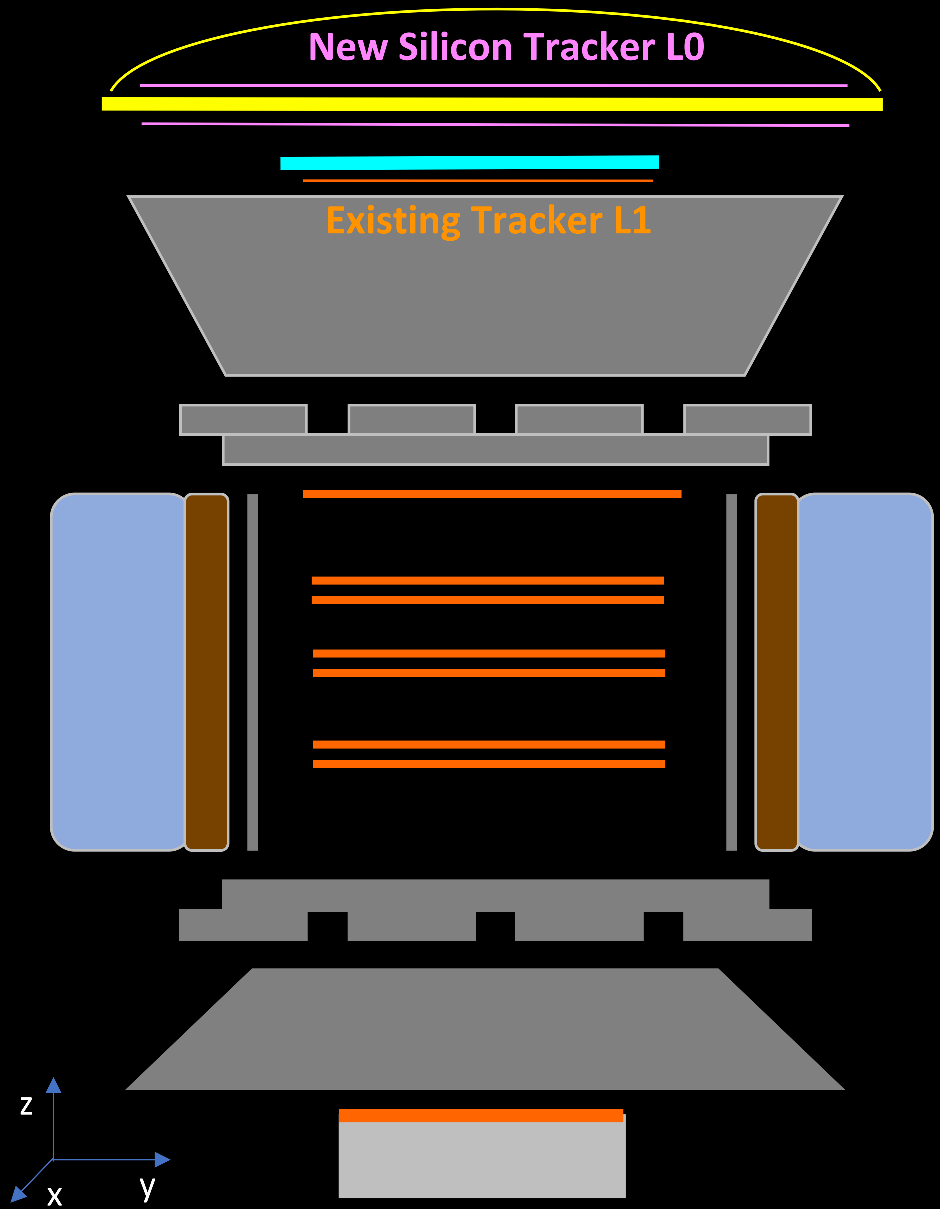


Time
2011/05 – 2025/10

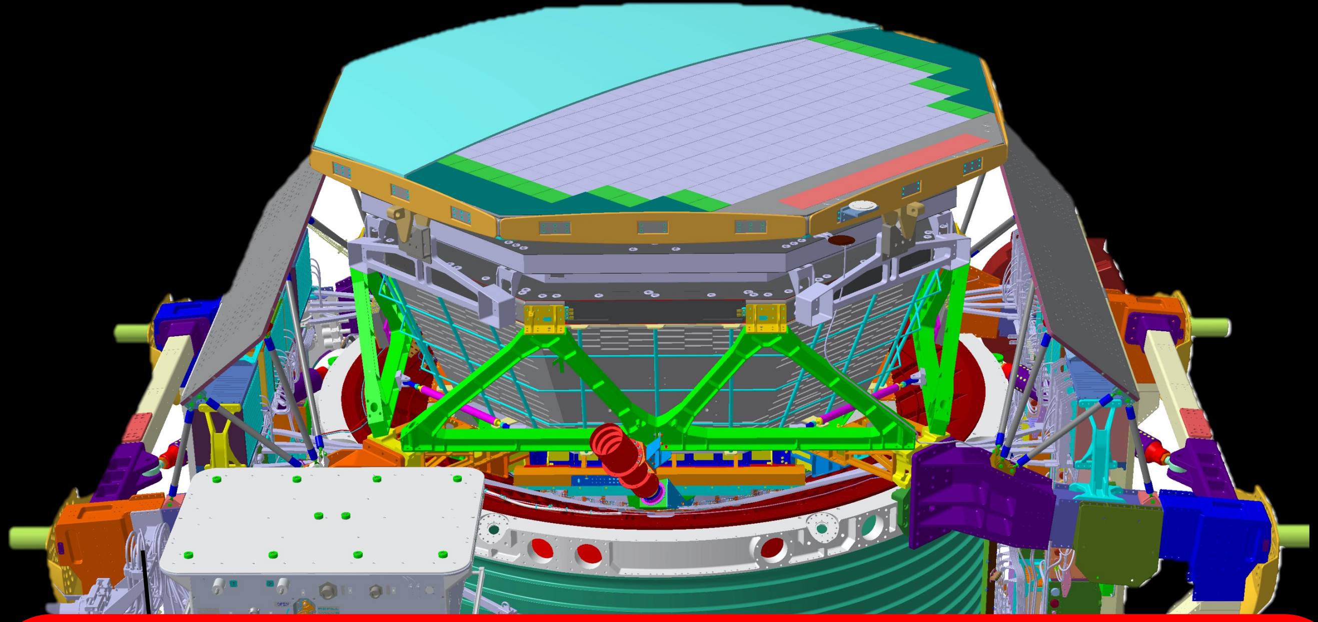
4.4×10^{6} electron events
$16 < E/\mathrm{GeV} < 500$

$\delta_{UL} = 0.37\%$ at the 95% C.I.
for $16 < E/GeV < 500$
0.28% Iso. Exp. (stat.+sys.)

AMS L0 Upgrade



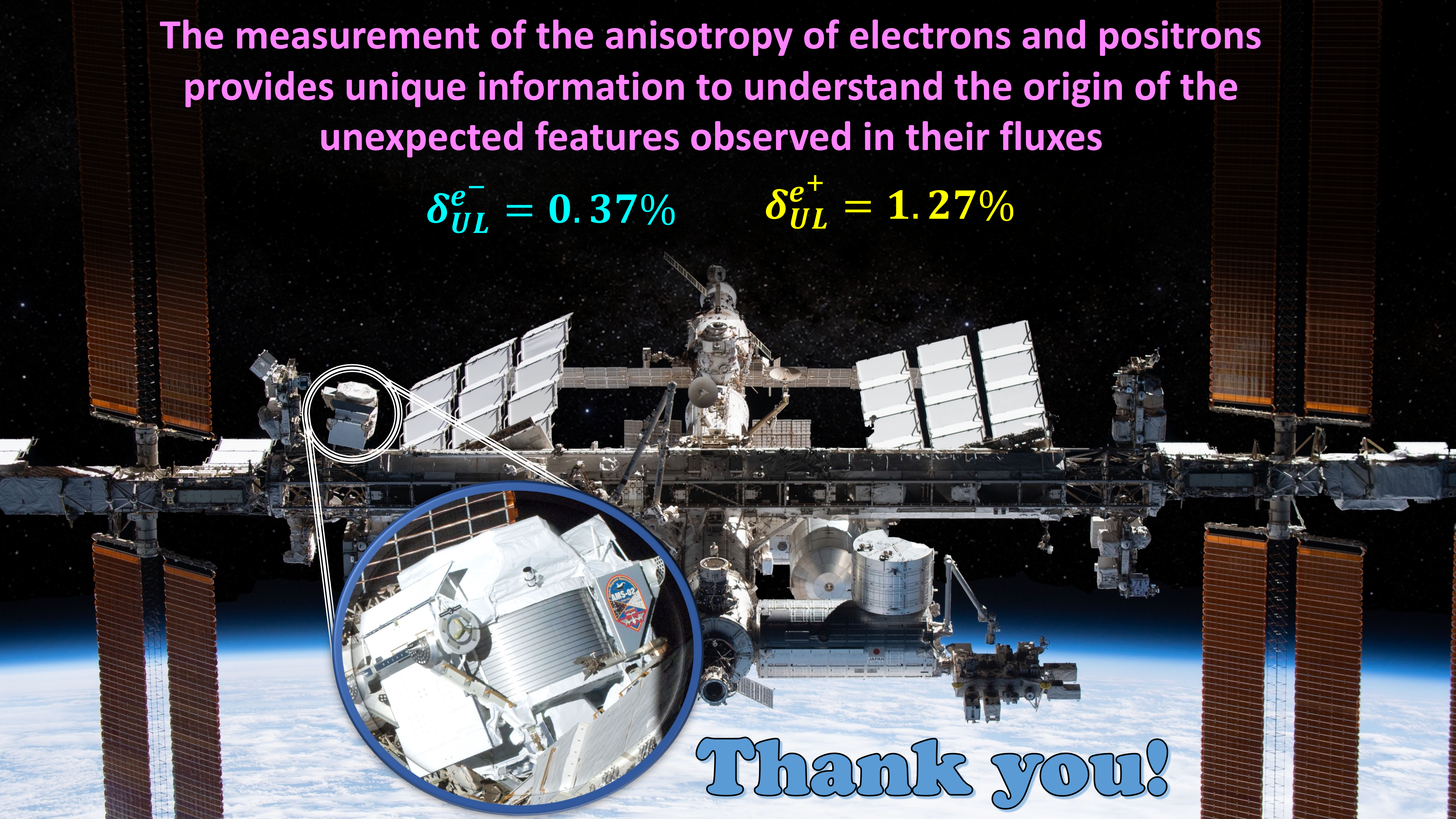
With completion of L0 Upgrade AMS acceptance will increase to up to 300%



With the L0 upgrade, AMS will provide measurements of the spectra of positrons, electrons, antiproton and 14 high-Z elements, from P to Zn, due to large increase of the statistics and large reduction of the backgrounds. This will allow accurate measurements at highest energies, there no data exist

The measurement of the anisotropy of electrons and positrons provides unique information to understand the origin of the unexpected features observed in their fluxes

$\delta_{UL}^{e^-} = 0.37\%$ $\delta_{UL}^{e^+} = 1.27\%$



Thank you!

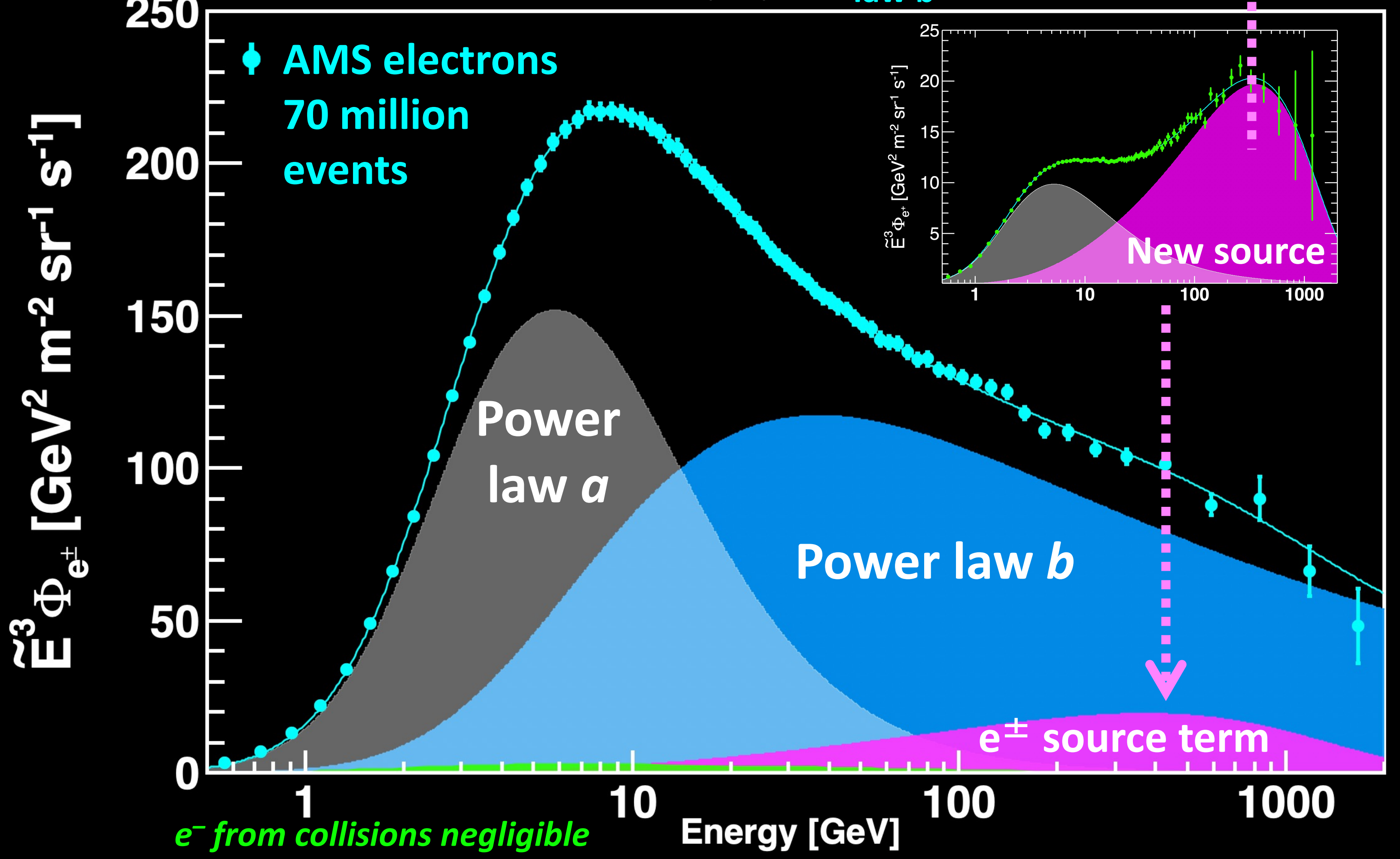
BACK UP

Talk by D. Krasnopevtsev
3 Sept

Origin of Cosmic Ray Electrons

Empirical model: $\Phi_{e^-}(E) = \underbrace{\frac{E^2}{\widehat{E}^2}}_{\text{Solar}} \Big(\underbrace{C_a \widehat{E}^{\gamma_a}}_{\text{Power law a}} + \underbrace{C_b \widehat{E}^{\gamma_b}}_{\text{Power law b}} + \text{Positron Source Term}\Big)$

$\chi^2/\text{dof} = 42/67$

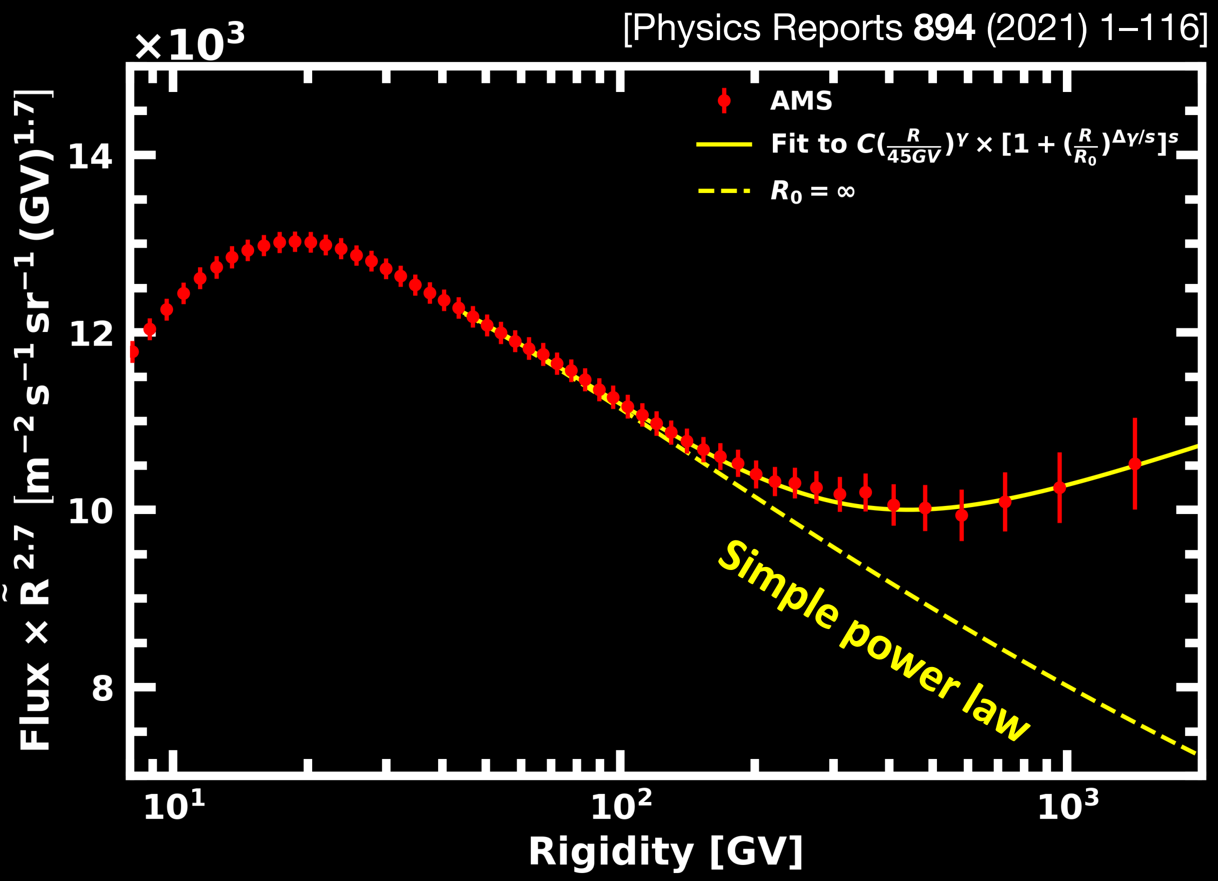


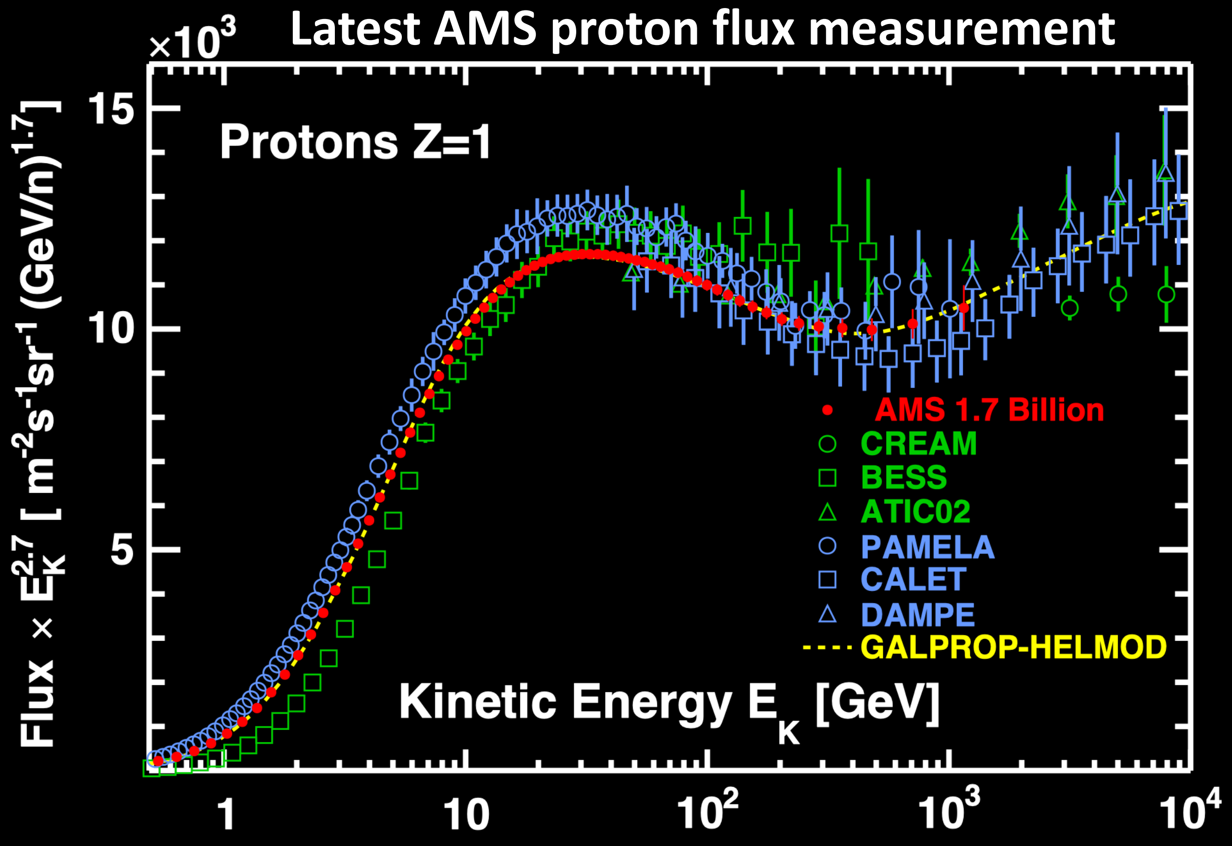
The spectrum fits well with two power laws (*a*, *b*) and the measured positron source term

Nearby astrophysical sources of cosmic ray electrons may induce **some degree of anisotropy** on the measured electron flux

Origin of Cosmic Ray Protons

Proton flux measured by AMS shows a deviation from a single power law above 200 GV



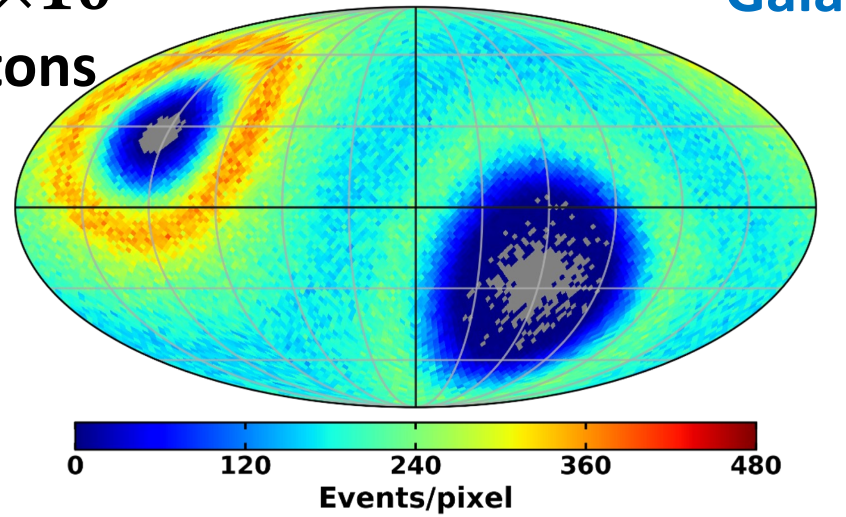


A local source of CR protons may induce some degree of anisotropy in the high rigidity sample

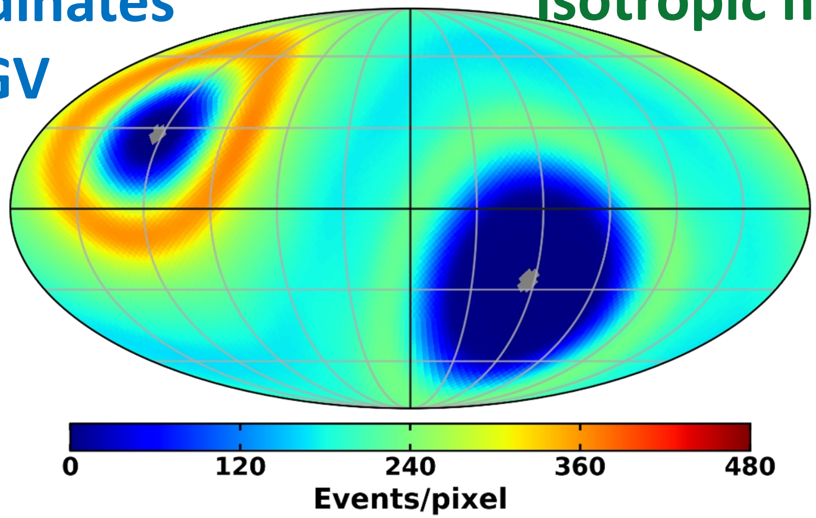
Proton Anisotropy

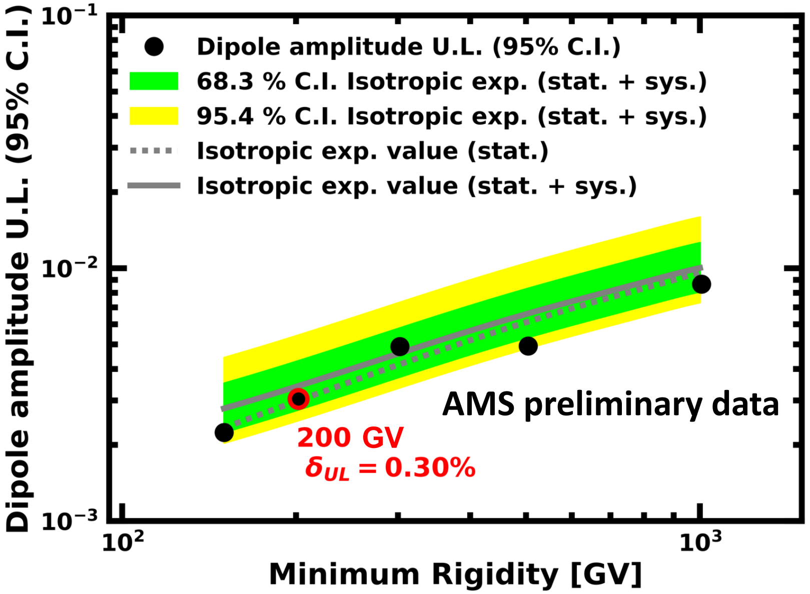
2.6×10^6 protons

Galactic coordinates
R > 200 GV



Isotropic map





Results are consistent with isotropy and upper limit to the dipole amplitude is established

$\delta_{UL} = 0.30\%$ at the 95% C.I. for R > 200 GV
0.34% Iso. Exp. (stat.+sys.)