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MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat
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Anisotropy of Positron and Electron Fluxes Measured with the Alpha Magnetic Spectrometer on the ISS

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on behalf of the AMS-02 collaboration
CIEMAT

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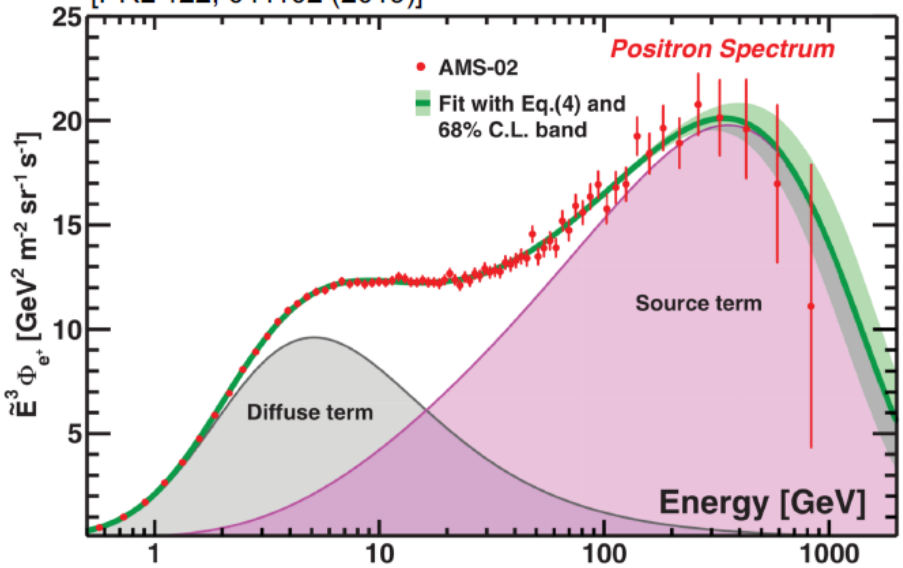
Motivation: e^+

- The **positron** flux shows an excess above 25 GeV that is not consistent with purely secondary production
- The excess is consistent with the existence of a **source term** of high-energy **positrons** with a characteristic cutoff energy (~800 GeV) with a significance of more than 4 sigmas

[PRL 122, 041102 (2019)]



See also: #1024 Towards understanding the origin of cosmic-ray positrons by Zhili Weng

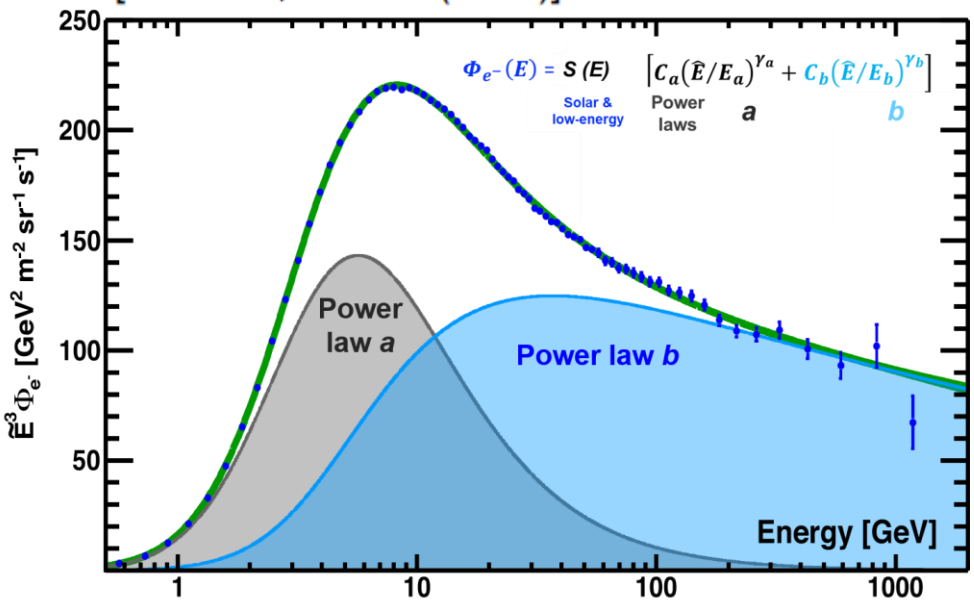
Typically, the **source term** is classified in two scenarios: **astrophysical sources** and **dark matter**

A local source of CR **positrons** may induce some degree of **anisotropy**

Motivation: e^-

- The **electron** flux shows an excess above 42 GeV that is not consistent with low energy trends
- The flux does not have an energy cutoff below 1.9 TeV

[PRL 122, 101101 (2019)]



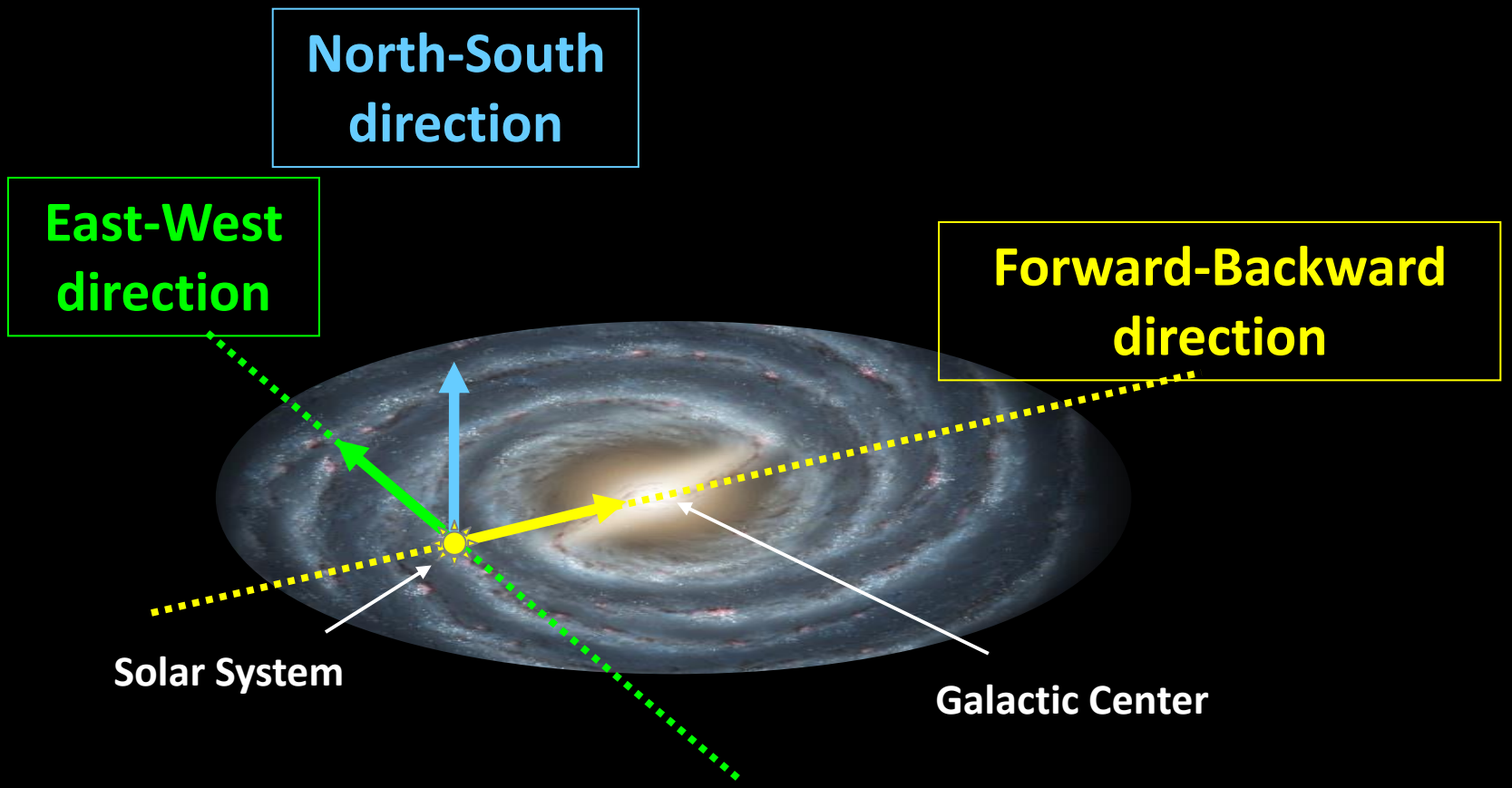
See also: #805 Towards understanding the origin of cosmic-ray electrons by Dimitrii Krasnopevtsev

The origin of the **electron** excess comes from a different source than **positrons**

A local source of CR **electrons** may induce some degree of **anisotropy**

Coordinate System of Analysis

Galactic Coordinates



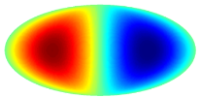
Expansion of the CRs Flux

$$\Phi(\theta,\varphi) = \Phi_0 \left(1 + \sum_{\ell=1} \sum_{m=-\ell}^{m=+\ell} a_{\ell m} Y_{\ell m}(\theta,\varphi)\right)$$

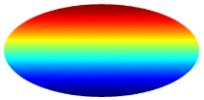
Multipolar Components

Real basis of spherical harmonics

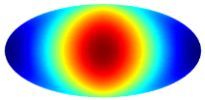
Dipole Components



East-West



North-South



Forward-Backward

$$\rho_{\mathrm{EW}} = \sqrt{\frac{3}{4\pi}} a_{1-1}$$

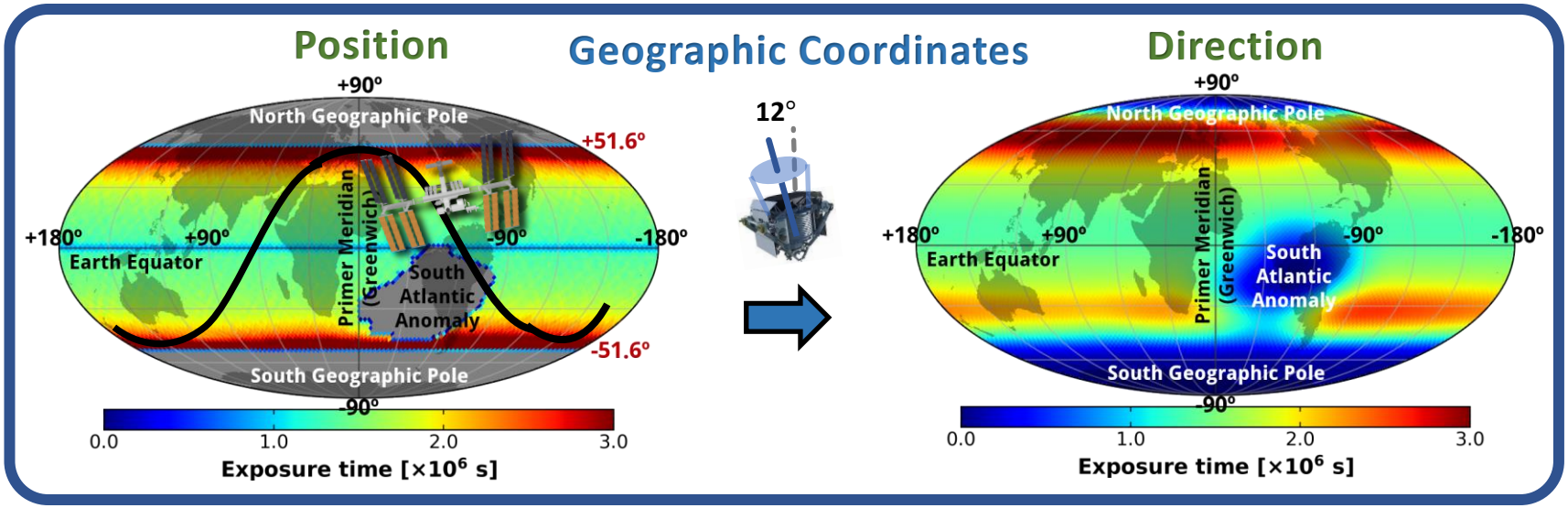
$$\rho_{\mathrm{NS}} = \sqrt{\frac{3}{4\pi}} a_{1+0}$$

$$\rho_{\mathrm{FB}} = \sqrt{\frac{3}{4\pi}} a_{1+1}$$

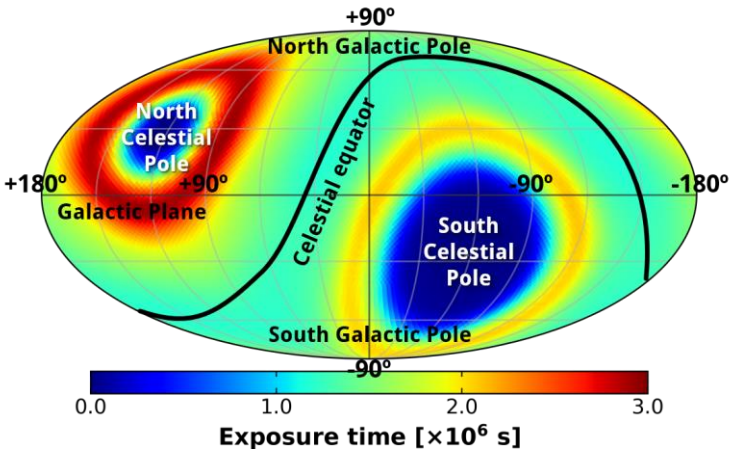
Dipole Amplitude

$$\delta = \frac{\Phi_{\max} - \Phi_{\min}}{\Phi_{\max} + \Phi_{\min}} = \sqrt{\rho_{\mathrm{EW}}^2 + \rho_{\mathrm{NS}}^2 + \rho_{\mathrm{FB}}^2}$$

Exposure of AMS-02



Galactic Coordinates



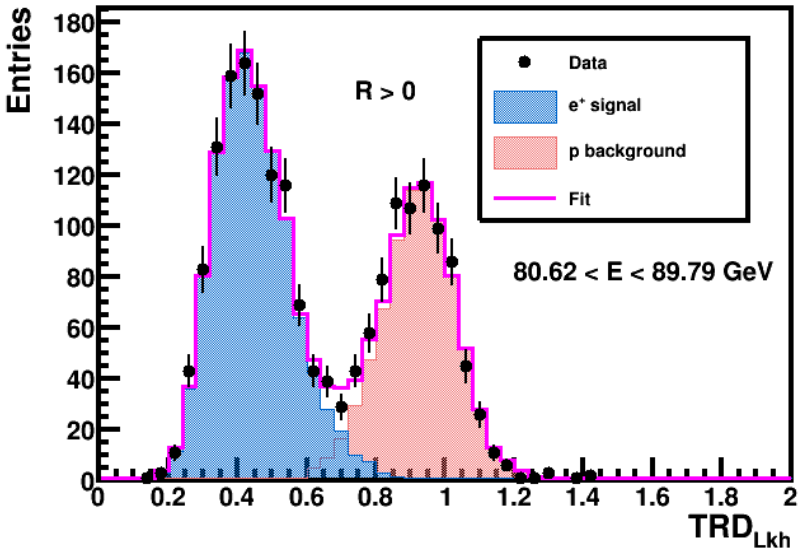
See also:

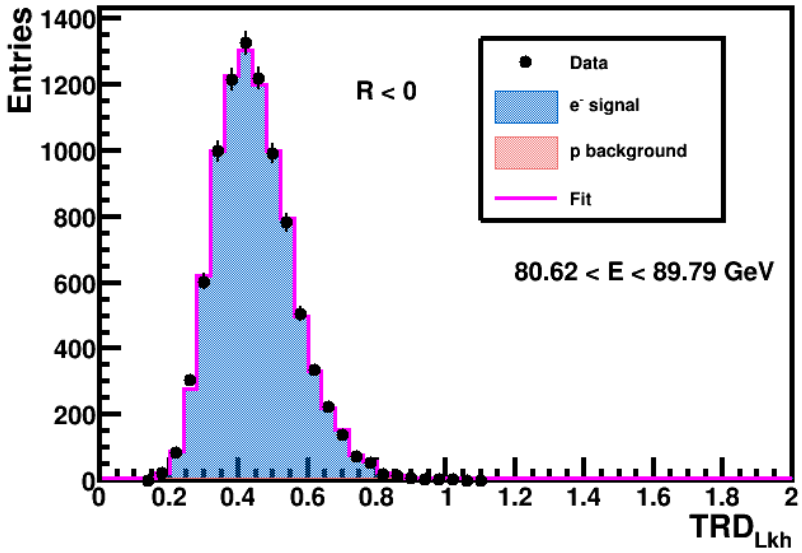
#770 Anisotropy on proton and light primary nuclei with AMS by M.A. Velasco

Positron and Electron Anisotropy

- **Positrons and electrons** are separated from protons with a selection based on a cut on the **ECAL estimator** and a **template fit to the TRD response**
- For the anisotropy analysis, selected events are grouped into **5 cumulative energy ranges**:

  E > 16, 25, 40, 65 and 100 GeV



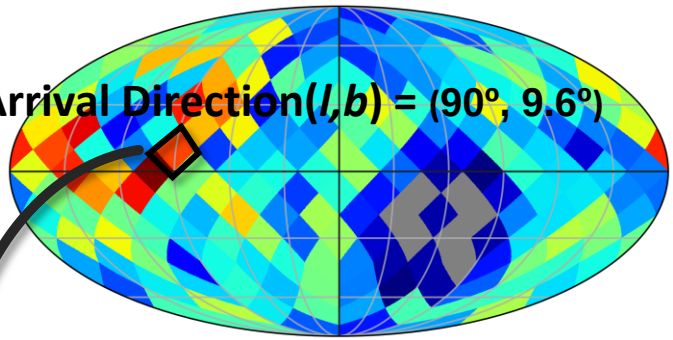


Results are presented for 9 years of data taking with AMS-02

Positron and Electron Anisotropy: Template Fit

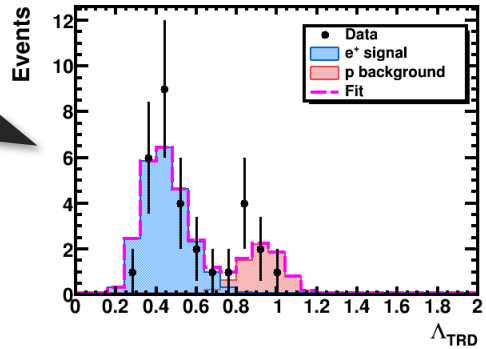
Implementation of the template fit in the anisotropy analysis

Map in galactic coordinates



Energy Bin

80.62 < *E*/GeV < 89.79



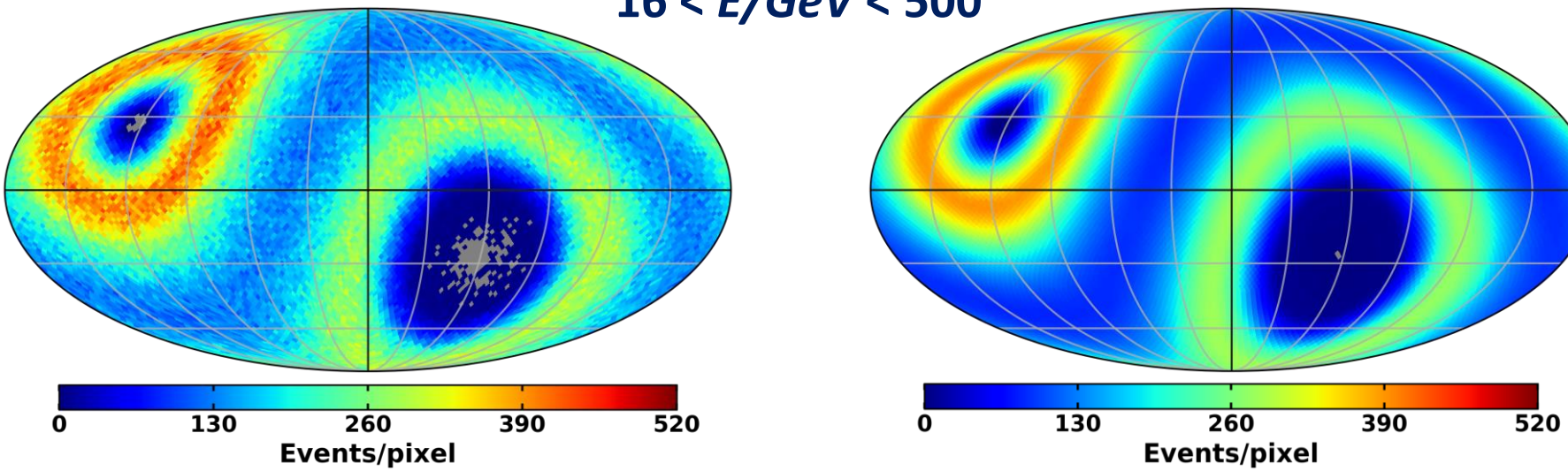
- The **template fit** technique allows to extract the number of **signal** and background events in each **energy bin** and **arrival directions** in galactic coordinates
- Each event is included in the anisotropy analysis with a weight to the anisotropy given by its **purity** (fraction of signal events according to its value of the Λ_{TRD})

Electron Anisotropy

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

2.4×10^6 electrons | **Isotropic map**

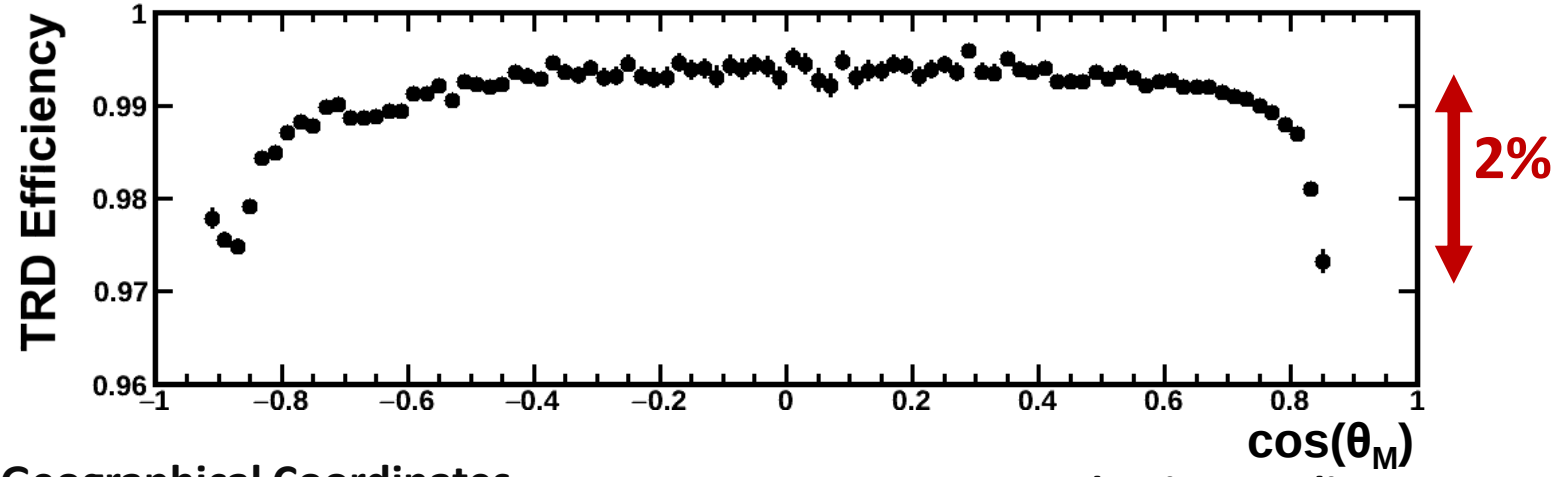
$16 < E/GeV < 500$

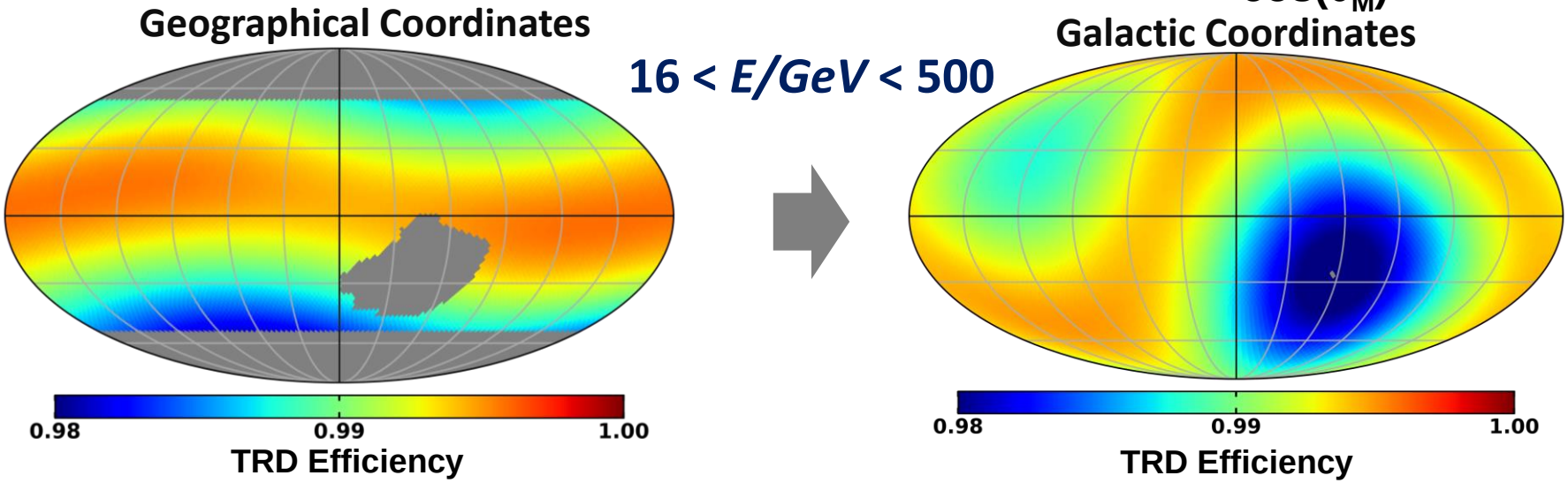


In addition to the sensitivity to **nearby astrophysical sources**, the measurement of **electron anisotropy** provides a test of systematics for the positron analysis

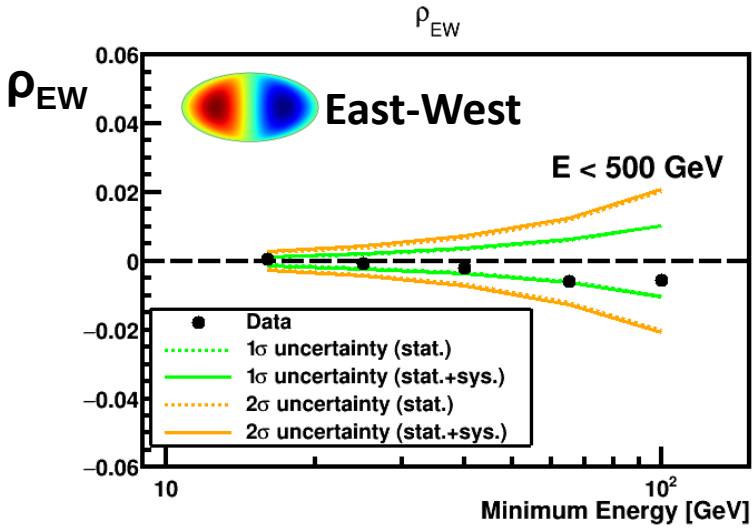
Electron Anisotropy: Detector Efficiencies

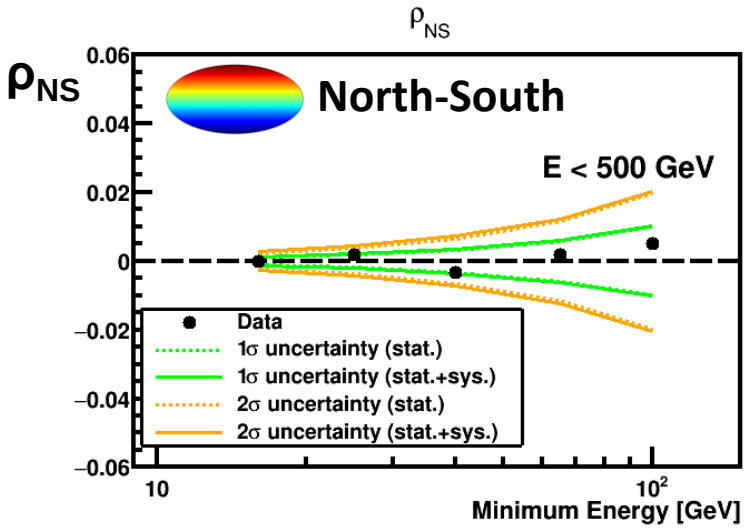
Computation of isotropic map requires detailed understanding of detector efficiencies at different geographical locations

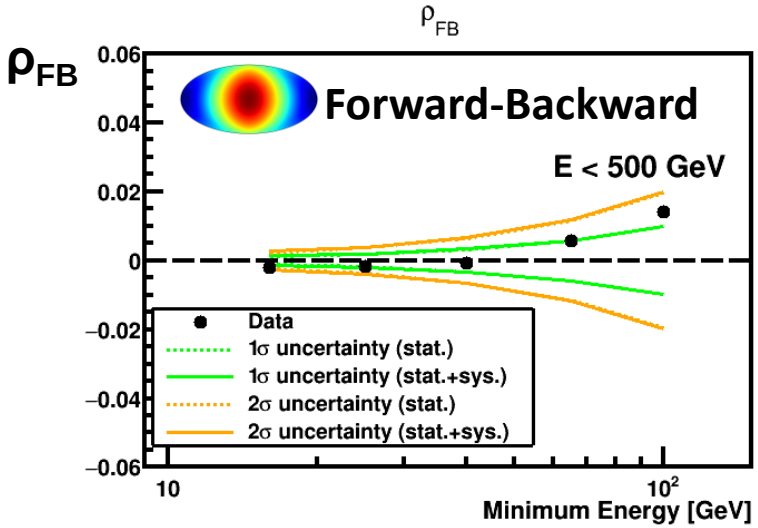




Electron Anisotropy: Dipole Components



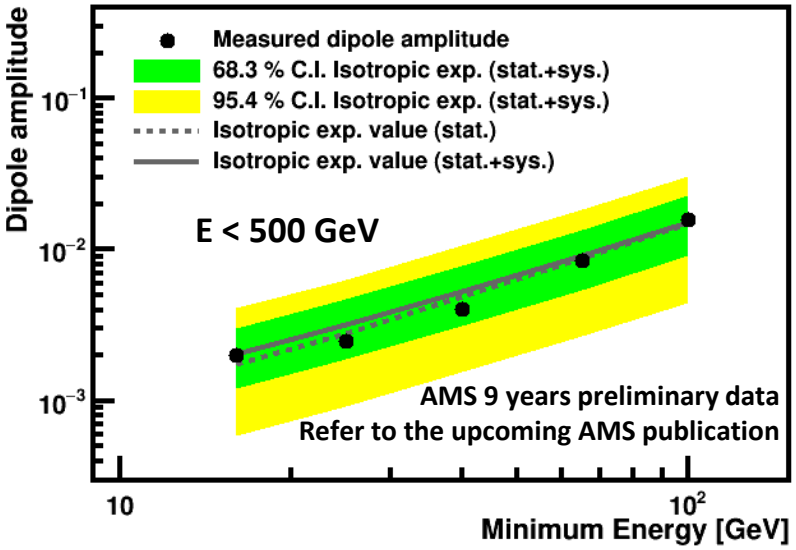


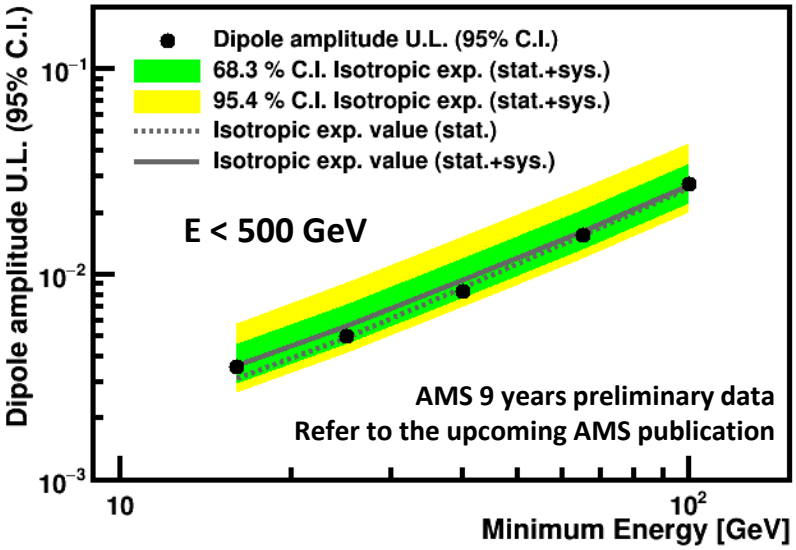


Electron dipole components in galactic coordinates are consistent with **isotropy**

Electron Anisotropy: δ_M and δ_{UL}

Results are **consistent with isotropy** and **upper limits** to the dipole amplitude are established





δ_M = 0.20% for 16 < *E/GeV* < 500

δ_{UL} = 0.36% at the 95% C.I. for 16 < *E/GeV* < 500

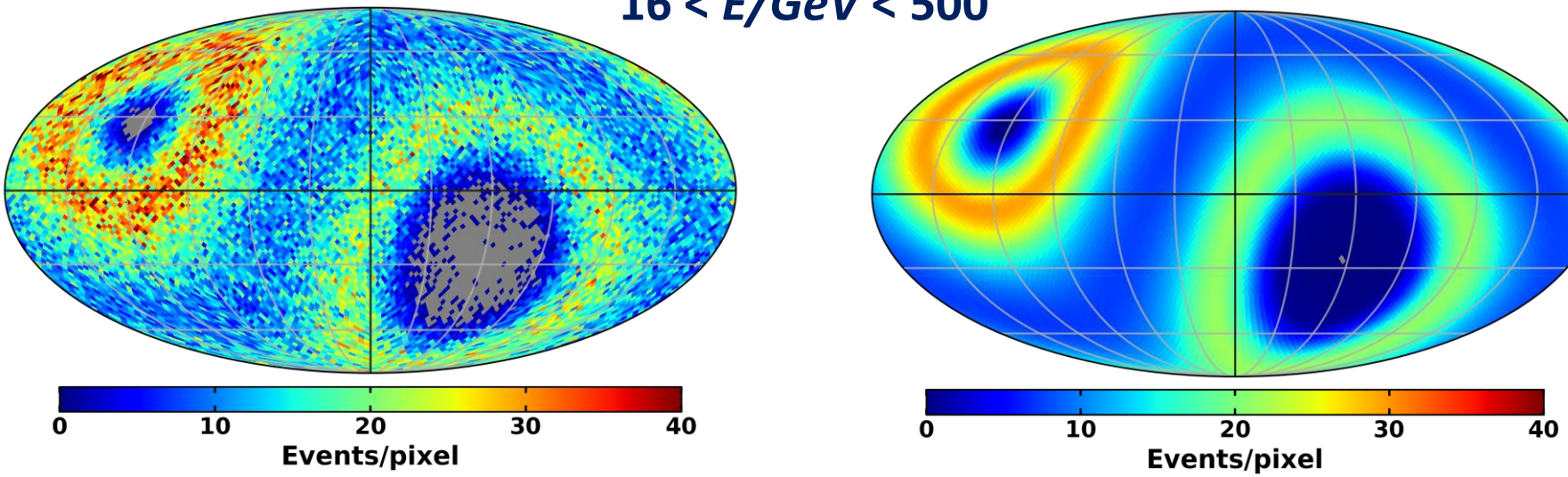
Positron Anisotropy

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

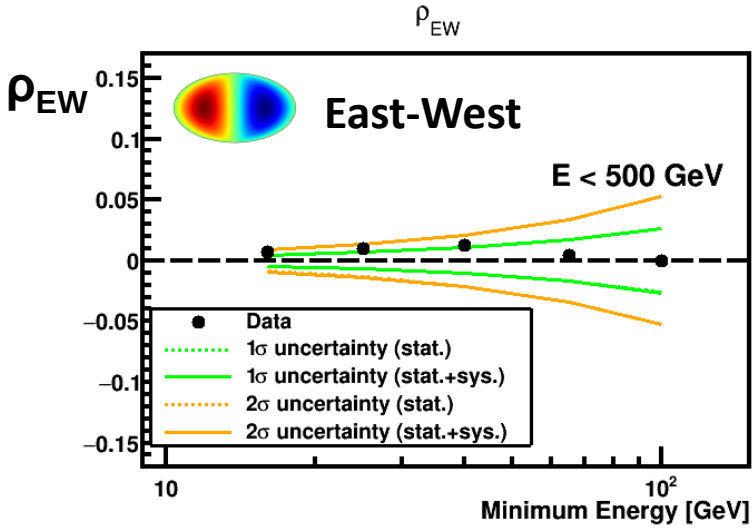
1.8×10^5 positrons

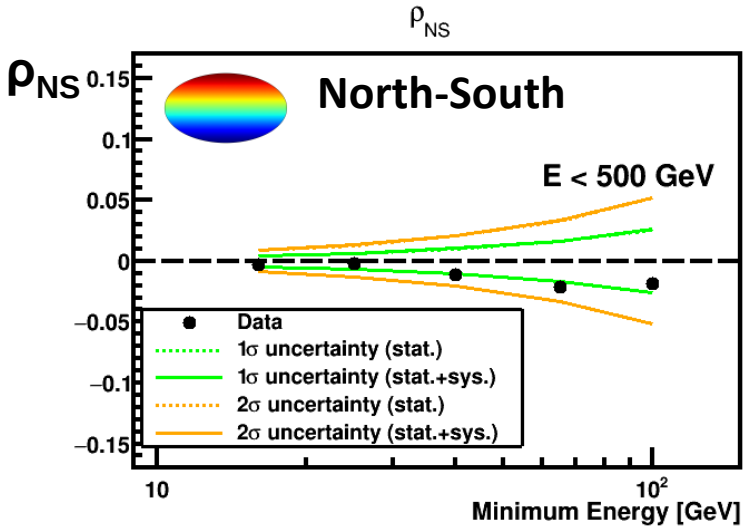
Isotropic map

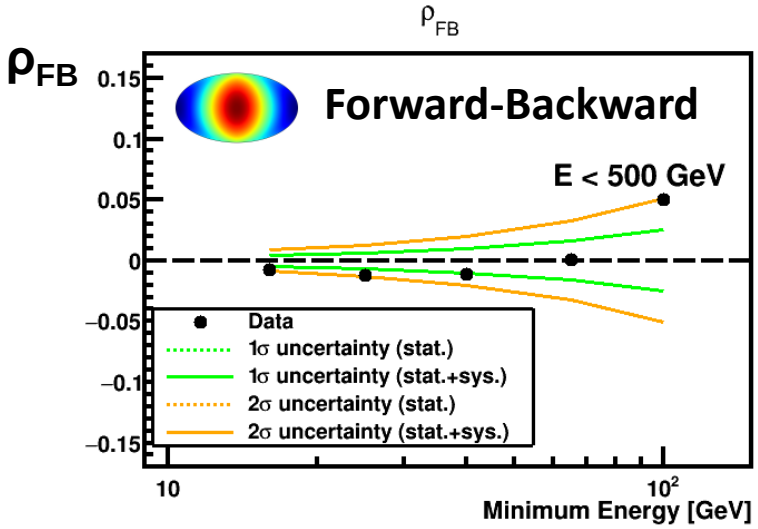
$16 < E/GeV < 500$



Positron Anisotropy: Dipole Components



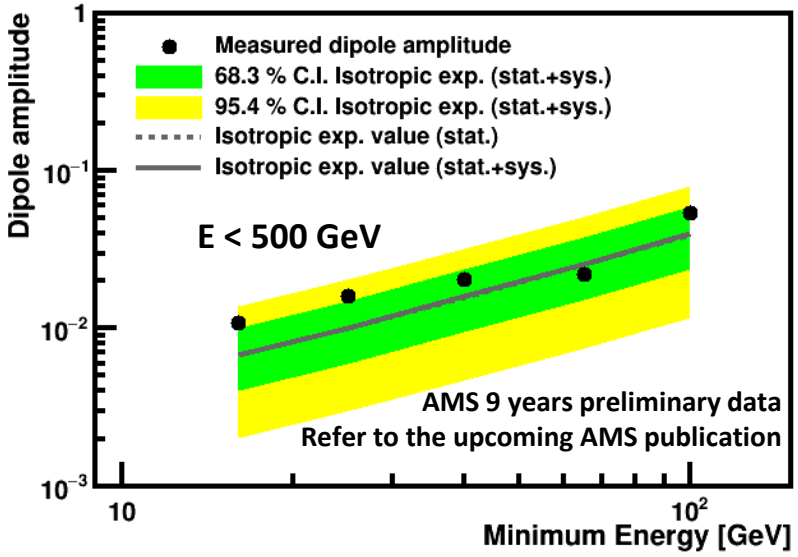


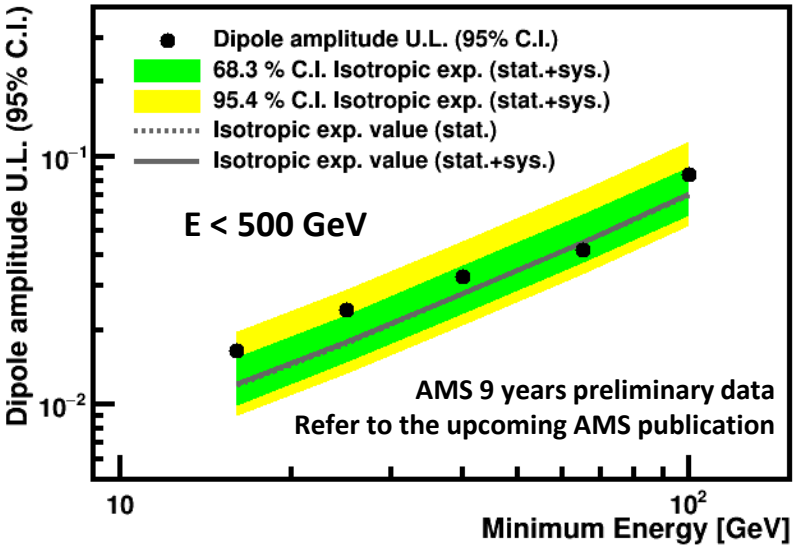


Positron dipole components in galactic coordinates are consistent with **isotropy**

Positron Anisotropy: δ_M and δ_{UL}

Results are **consistent with isotropy** and **upper limits** to the dipole amplitude are established



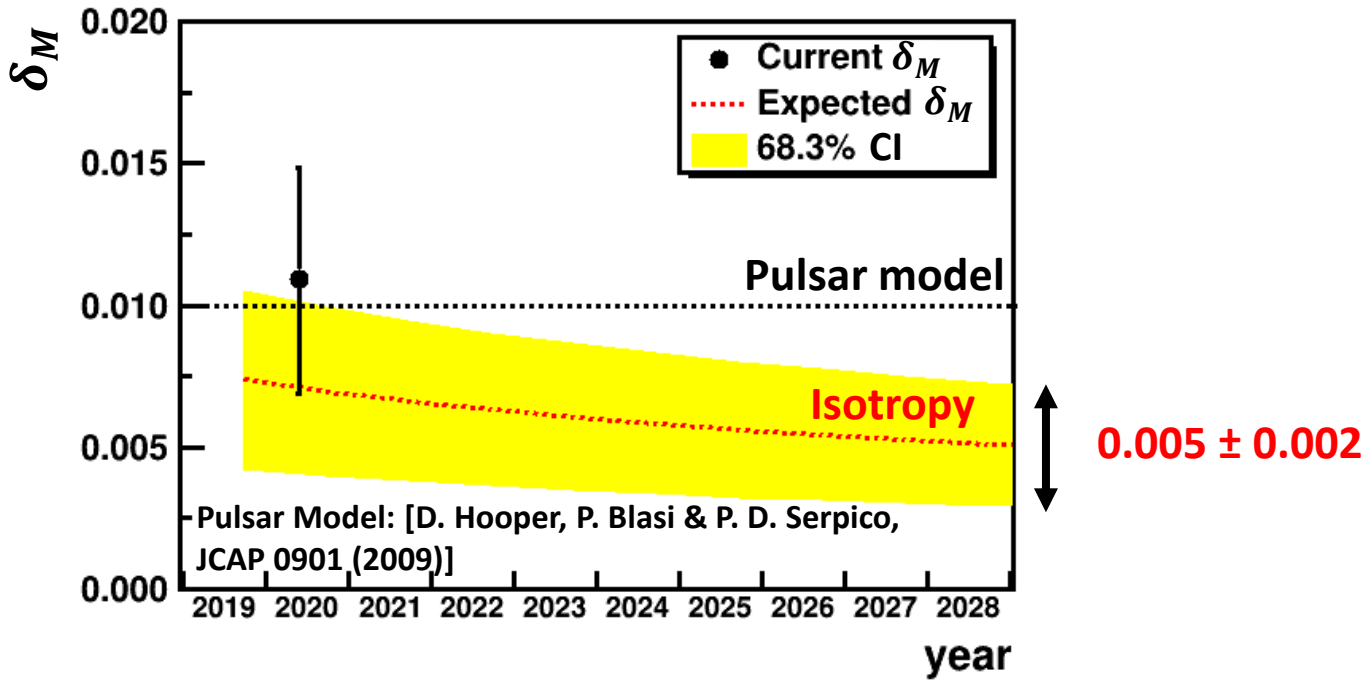


δ_M = 1.09% for 16 < *E/GeV* < 500

δ_{UL} = 1.65% at the 95% C.I. for 16 < *E/GeV* < 500

Positron Anisotropy: Projection to 2028

- By 2028, the increased positron statistics will allow AMS to measure the anisotropy parameter δ_M to an accuracy of 0.2%
- Therefore, AMS will be sensitive to anisotropies at the 1% level, as predicted by the current pulsar models



Conclusions

- AMS measurements have shown new features in the positron and electron fluxes that challenge the traditional models

- The study of the directionality of the cosmic rays provides additional information to the energy dependence of the fluxes and, in particular, it may help to understand the origin of the observations

- A measurement of the anisotropy in the arrival directions of positrons and electrons in galactic coordinates has been performed

- Positrons and electrons in the energy range of 16-500 GeV are consistent with isotropy and upper limits to the dipole amplitude at the 95% C.I. are obtained:
  - Positrons: δ_{UL} = 1.65 %
  - Electrons: δ_{UL} = 0.36 %

- AMS will continue taking data until the end of the ISS operation, currently 2028. By that time AMS measurement will be sensitive to the positron anisotropy level predicted by pulsar models