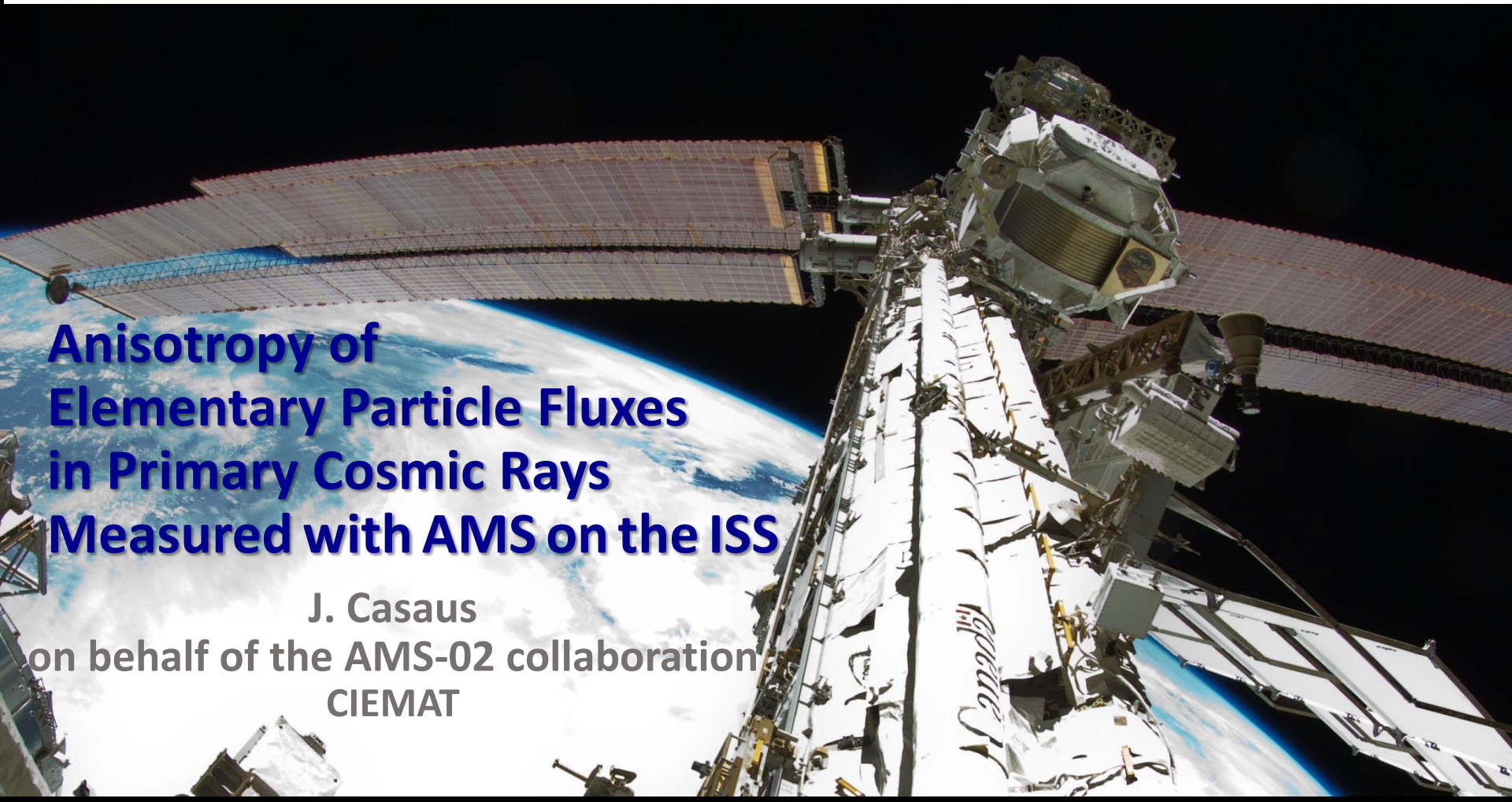
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
EXCELENCIA MARÍA DE MAEZTU
cfp CIEMAT física de partículas



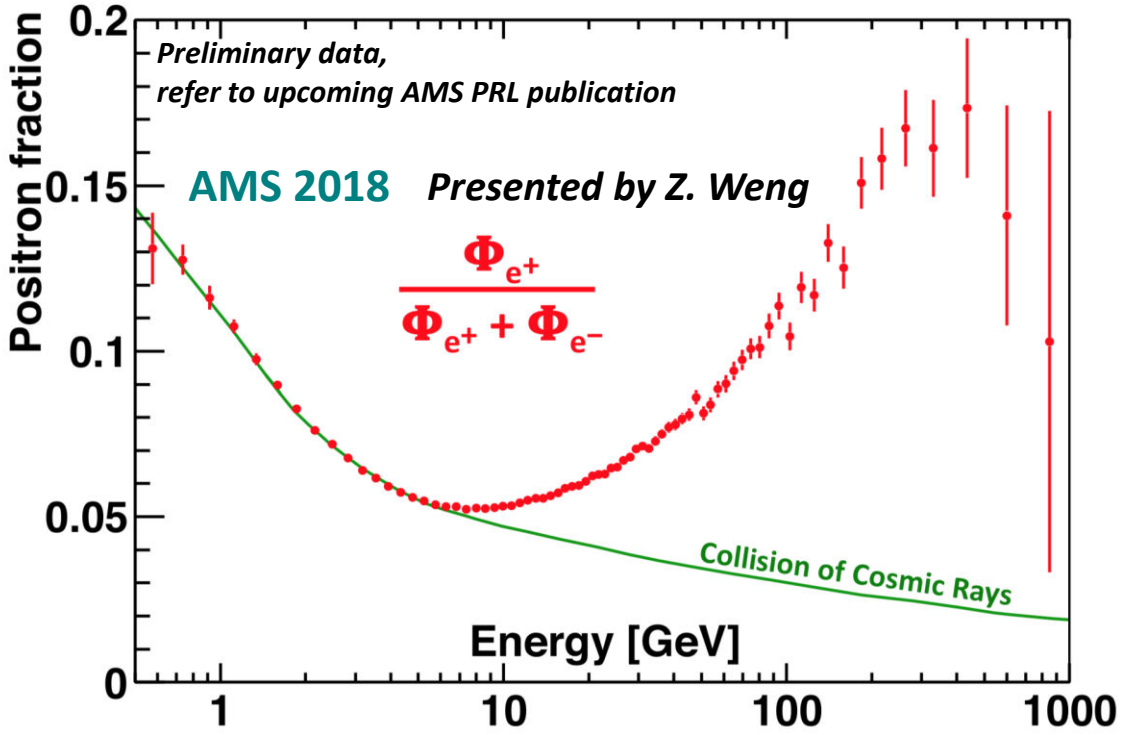
Anisotropy of Elementary Particle Fluxes in Primary Cosmic Rays Measured with AMS on the ISS

J. Casaus
on behalf of the AMS-02 collaboration
CIEMAT

ICHEP2018 SEOUL
XXXIX INTERNATIONAL CONFERENCE ON high Energy PHYSICS
JULY 4 – 11, 2018 COEX, SEOUL

Origin of excess of positrons

Positron fraction shows an excess above 10 GeV that is not consistent with only the secondary production of positrons.

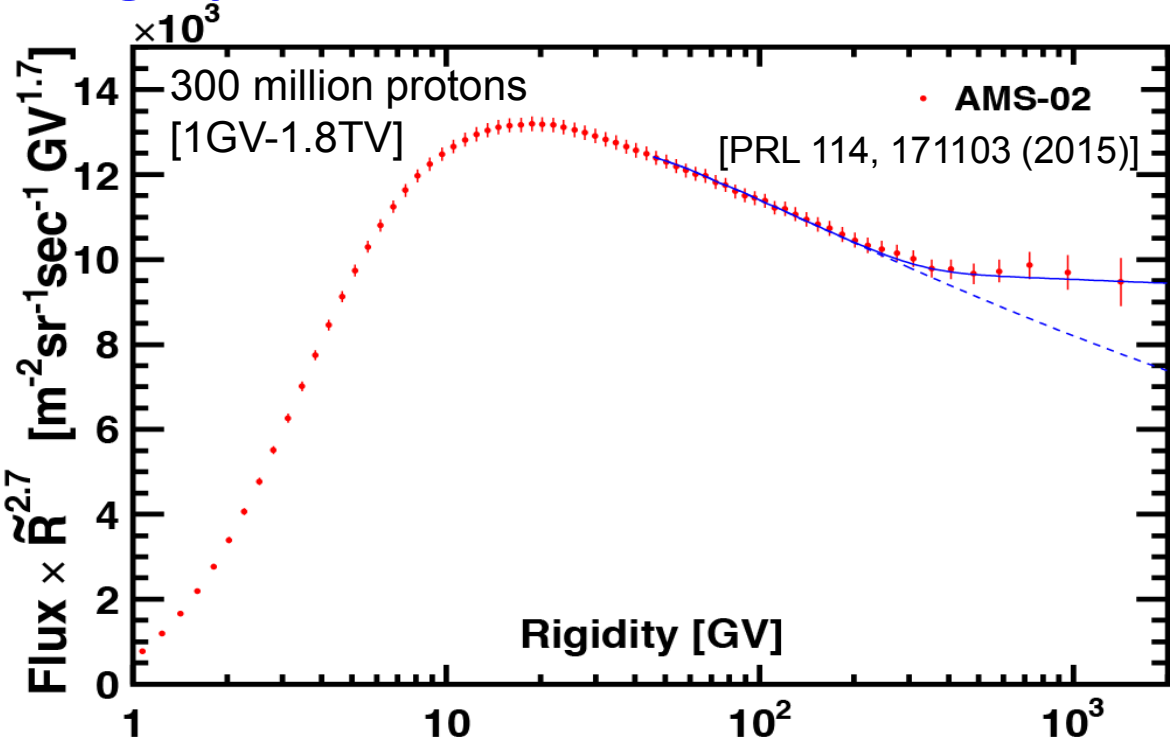


The observation requires the inclusion of primary sources whether from a particle physics or an astrophysical origin.

Astrophysical point sources of cosmic ray positrons and electrons may induce some degree of anisotropy on the measured e^+/e^- ratio.

Origin of structure in proton spectrum

Proton and light nuclei fluxes measured by AMS show a deviation from a single power law above few hundred GeV.

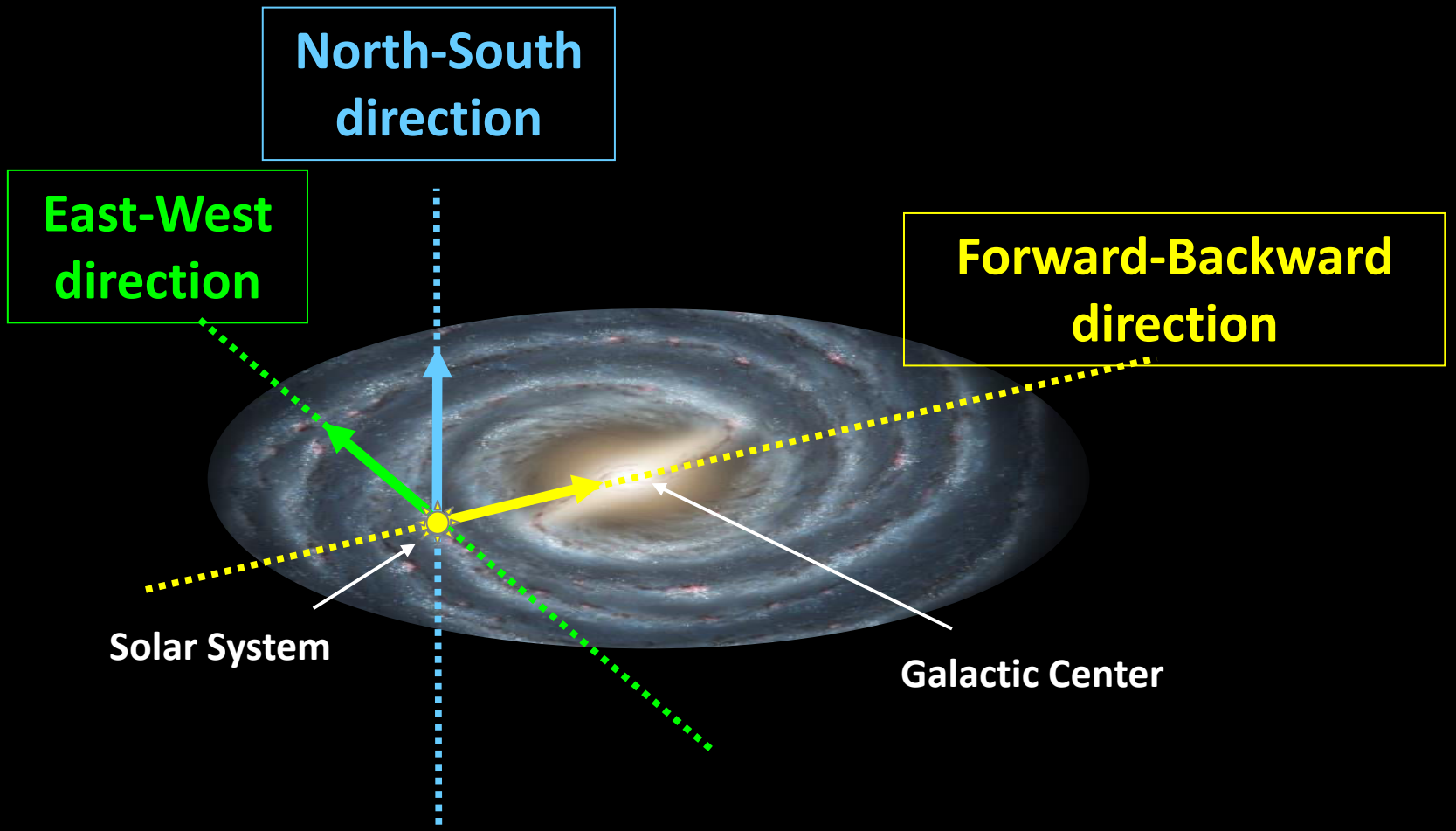


This observation may require modification of cosmic ray transport models or the inclusion of local sources.

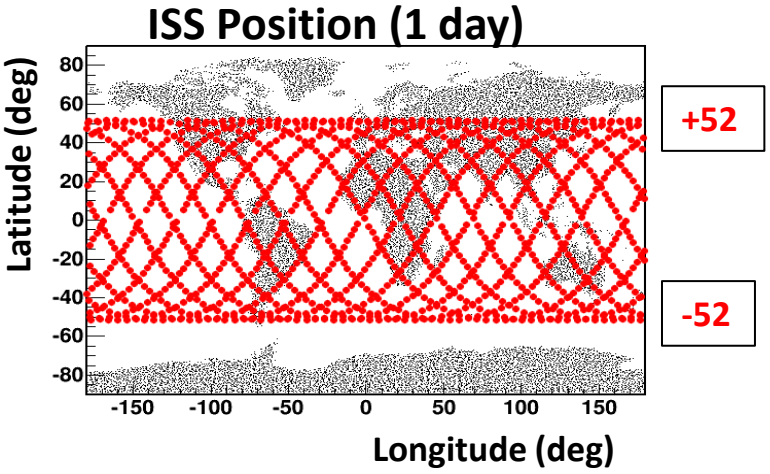
Astrophysical nearby sources of cosmic ray protons and light nuclei may induce some degree of anisotropy on the measured fluxes.

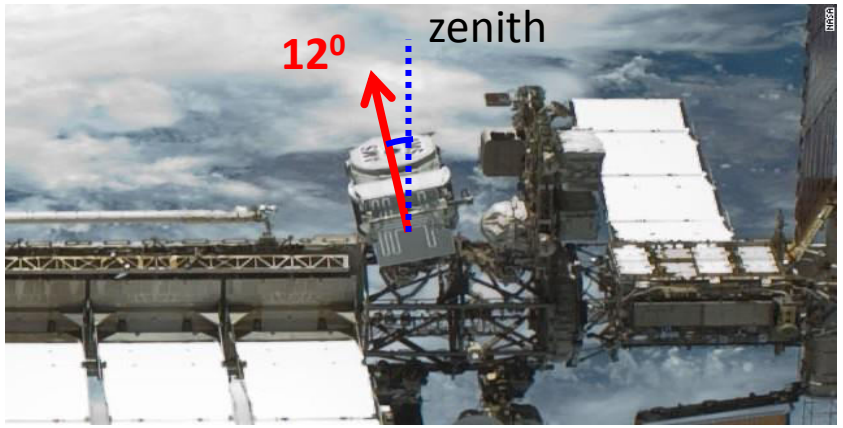
Analysis of anisotropy

Measurement of the cosmic ray fluxes as function of the arrival direction in Galactic Coordinates

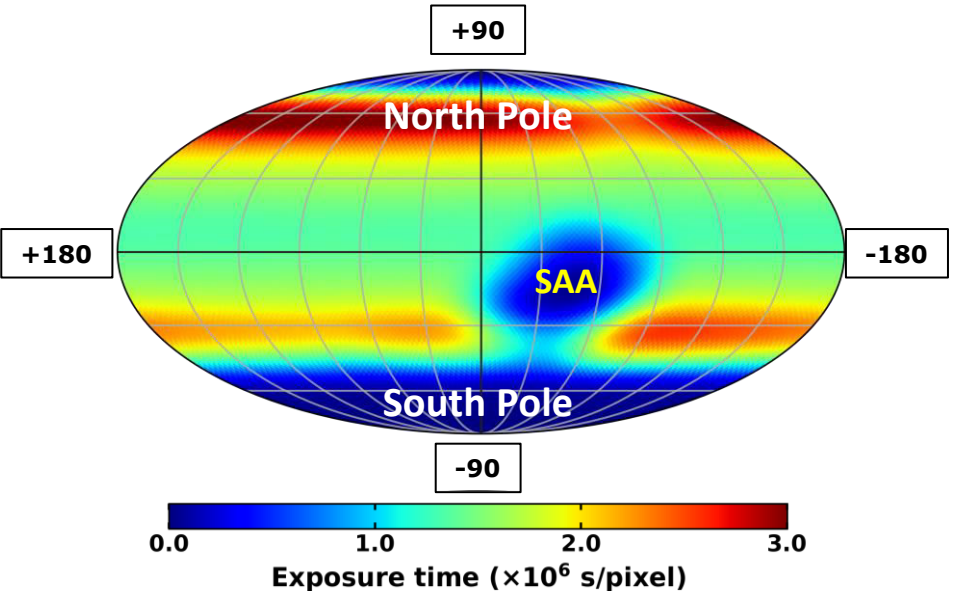


AMS sky coverage

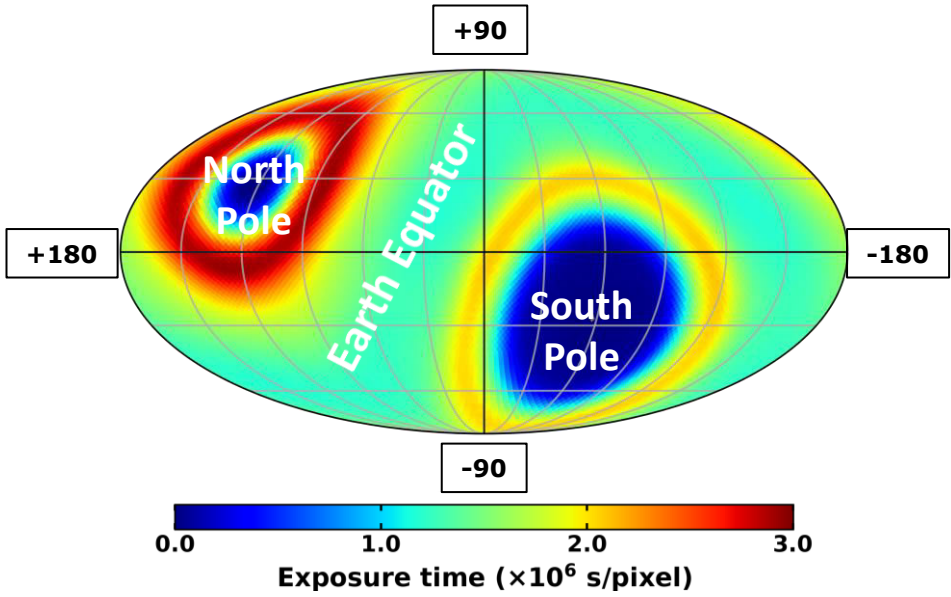




Geographical Coordinates



Galactic Coordinates

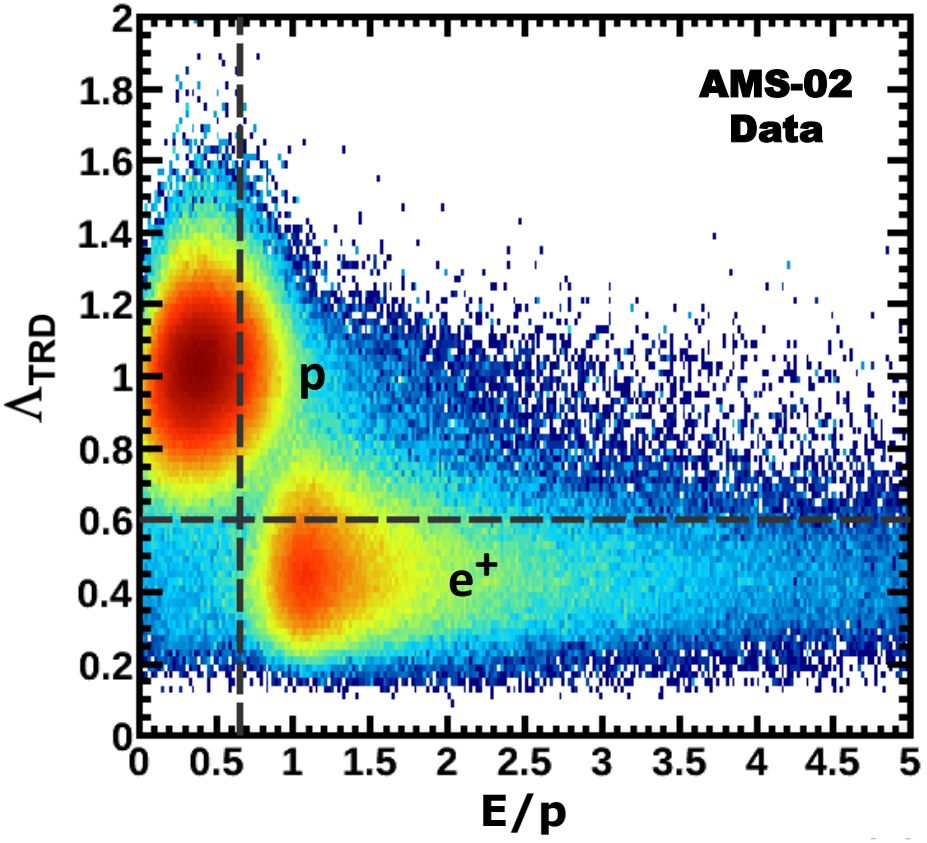


AMS 6 years : Total Exposure time 1.36 x 10^8 s

Positron to electron ratio anisotropy

Sample selection

Proton background is reduced below the percent level with a selection based on cuts on E/p and the TRD and ECAL estimators



Event Sample: AMS 6 years

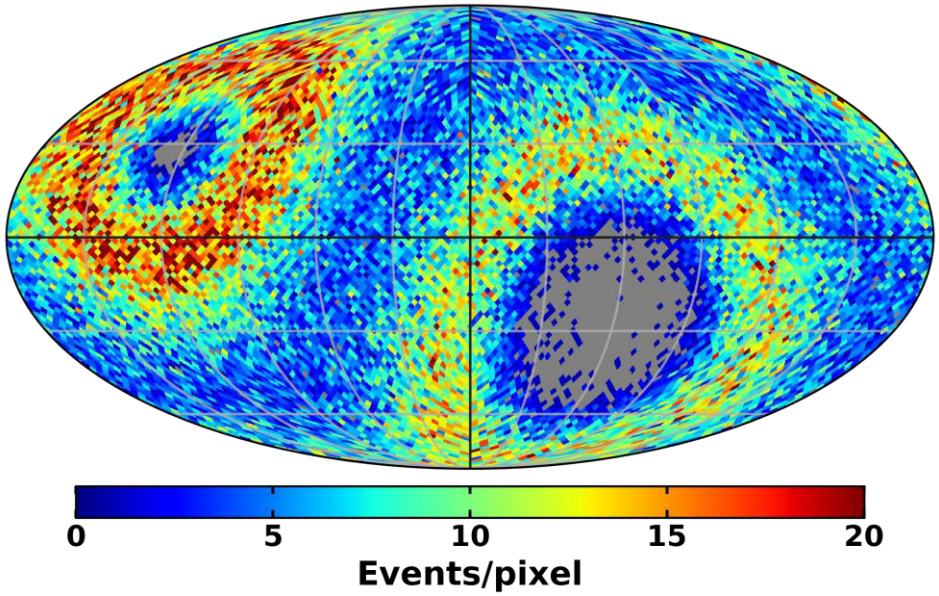
9.2×10^4 e^+ and 1.2×10^6 e^- (16 < E < 350 GeV)

Positron to electron ratio anisotropy

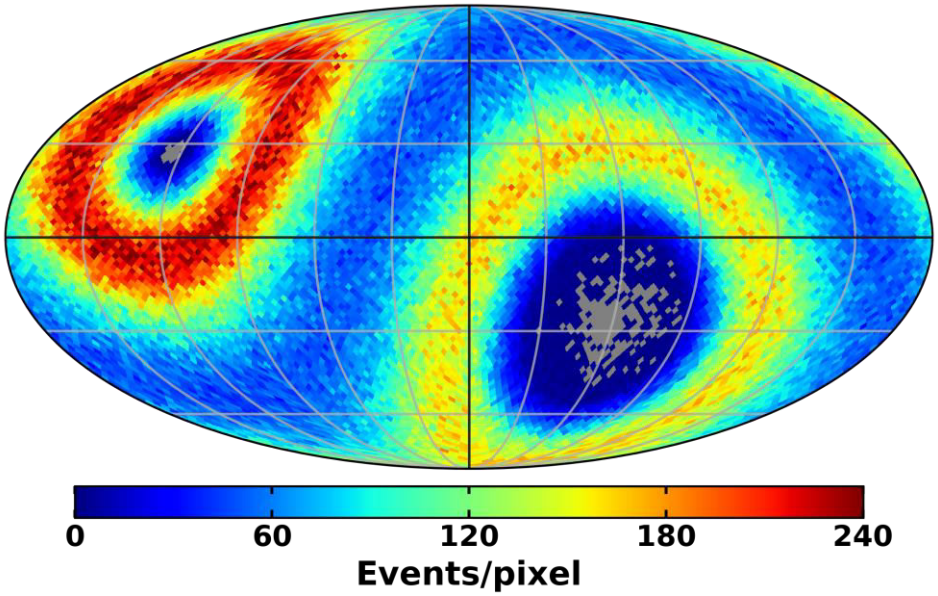
Build the sky map of the positrons and electrons arrival directions in galactic coordinates (b,l)

16 < E < 350 GeV

9.2×10^4 positrons



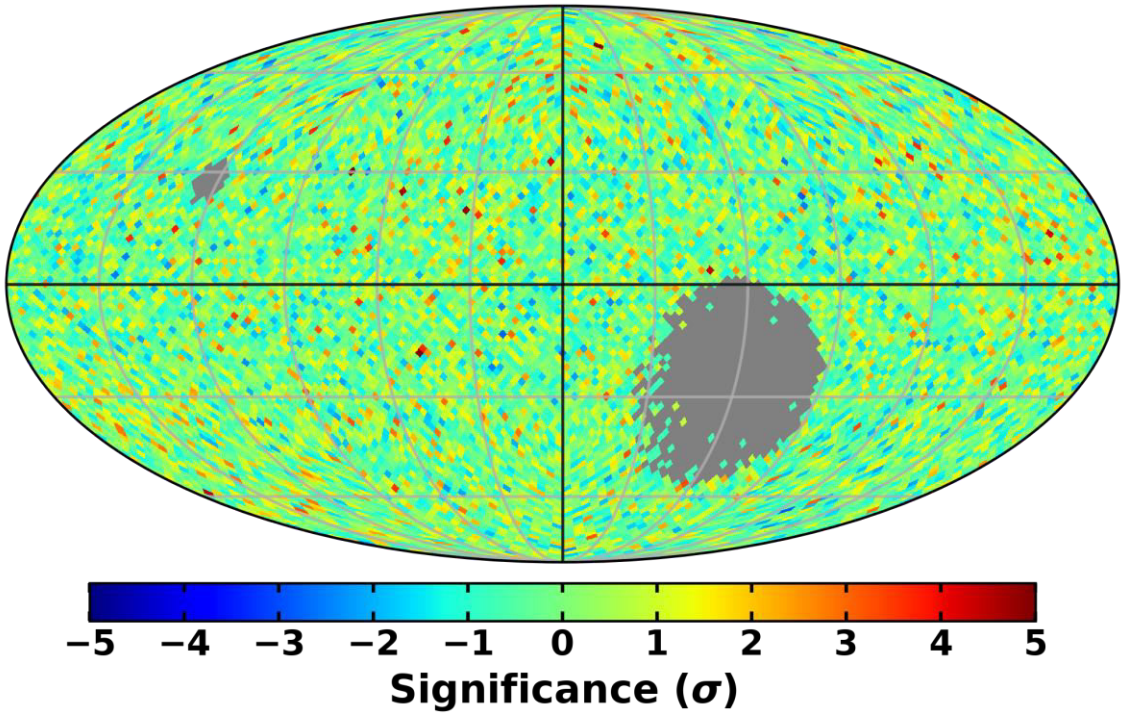
1.2×10^6 electrons

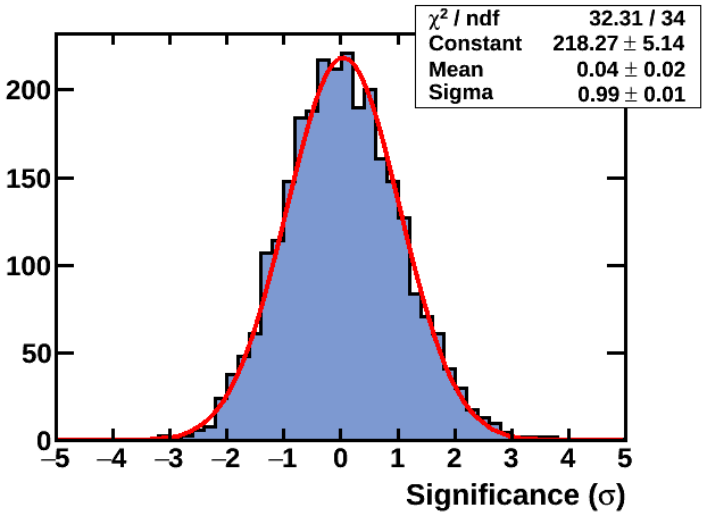


Positron to electron ratio anisotropy

Sky map of the relative fluctuation of the positron to electron ratio, $r_e = e^+/e^-$, in galactic coordinates (b,l)

16 < E < 350 GeV





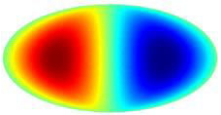
The observed sky map shows no evident pattern

Positron to electron ratio anisotropy

The relative fluctuations of the positron to electron ratio are described by means of a spherical harmonics expansion

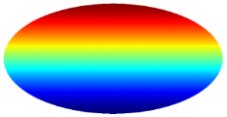
$$r_e(\theta,\phi)/ < r_e > = 1 + \sum_{\ell>1} \sum_{m=-\ell}^{m=\ell} a_{\ell m} Y_{\ell m}(\theta,\phi)$$

Dipole components



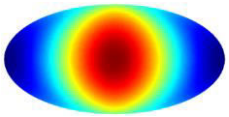
East-West

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



North-South

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



Forward-Backward

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

Dipole amplitude

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

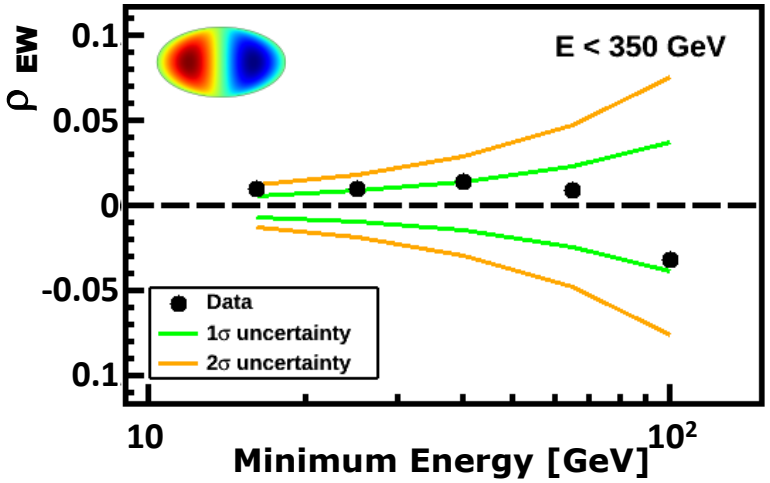
Positron to electron ratio anisotropy

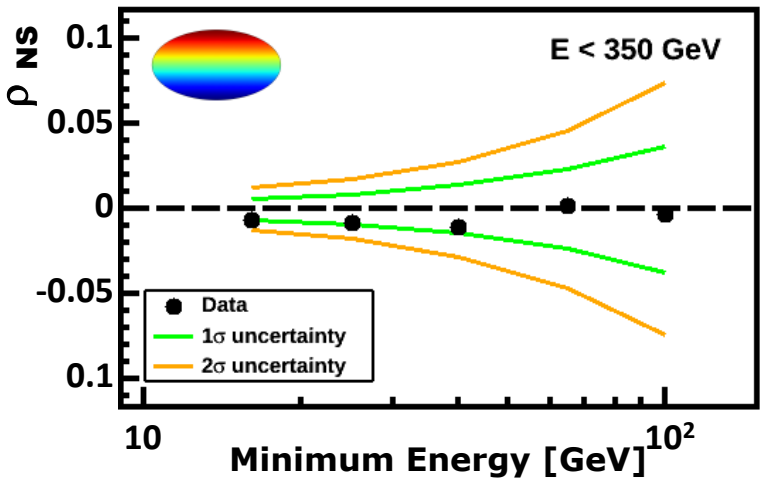
The fluctuations of the positron ratio are described by a spherical harmonic expansion

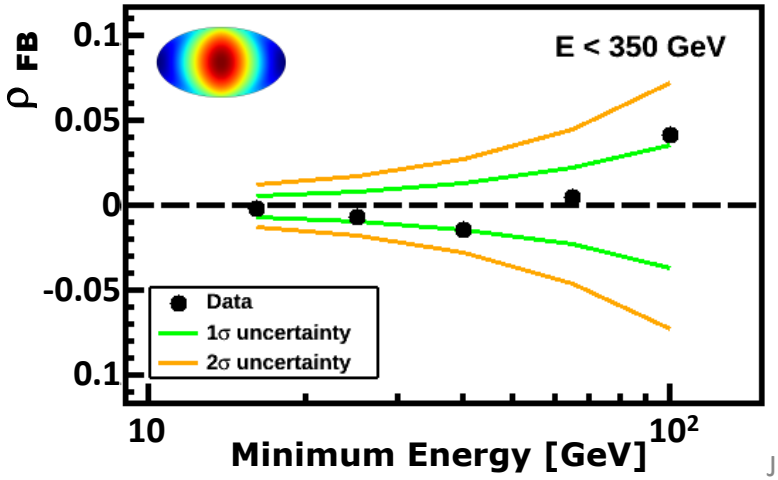
Selected events are grouped into 5 cumulative energy ranges

16-350, 25-350, 40-350, 65-350 and 100-350 GeV.

Dipole components – Galactic Coordinates







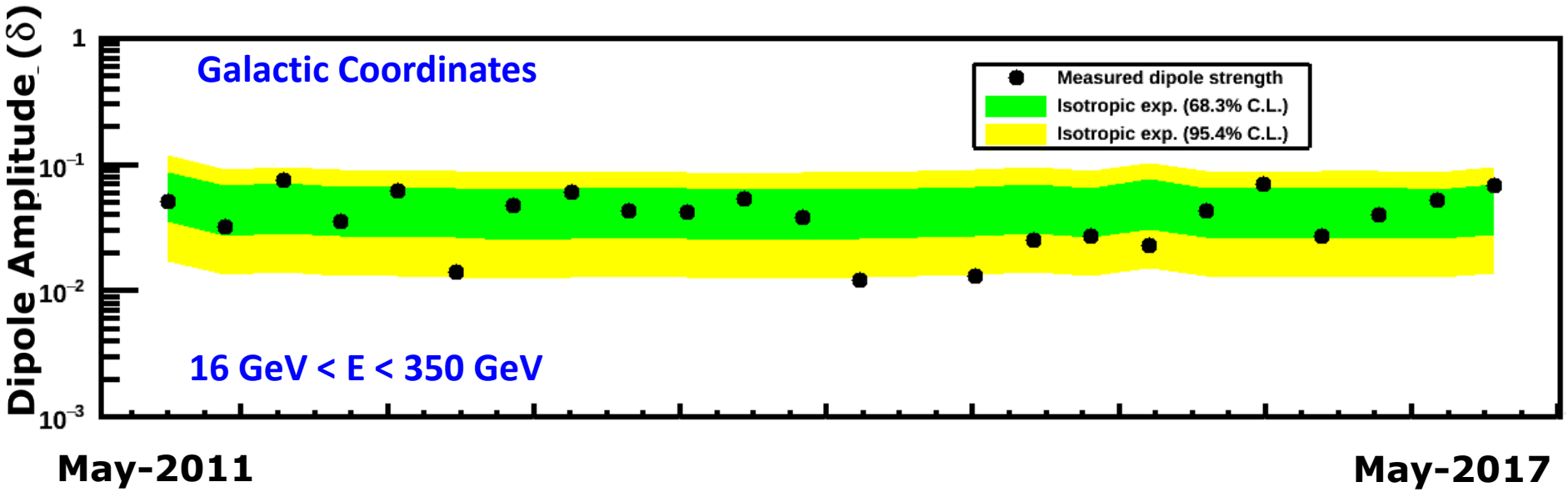
Amplitude of the dipole anisotropy

on the e^+/e^- for 16 < E < 350 GeV

$\delta < 0.020$ (95% C.I.)

Positron to electron ratio anisotropy

The anisotropy analysis of the e+/e- ratio is repeated for every season in the 6-year sample



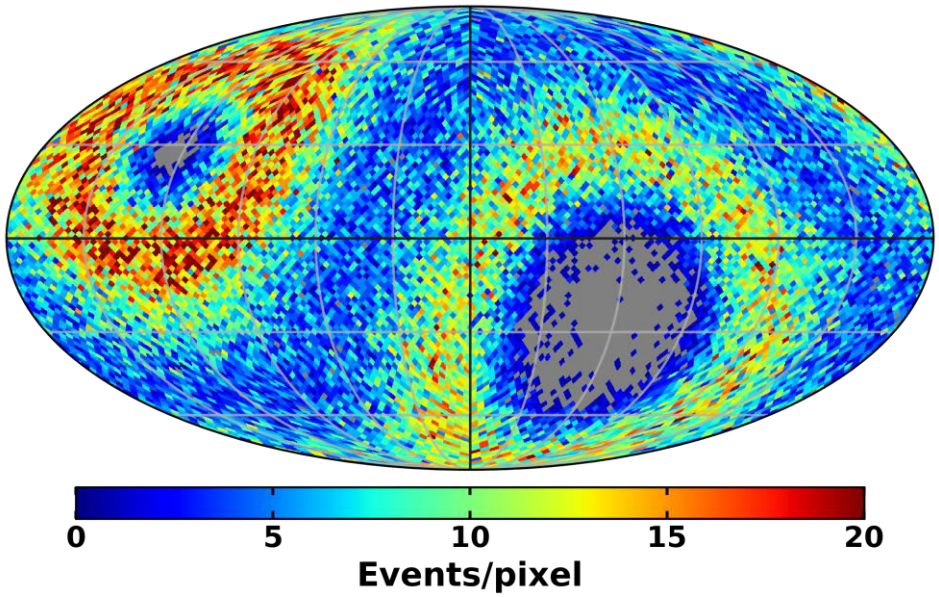
The measured dipole amplitudes are consistent with the expectations from isotropy

Positron absolute anisotropy

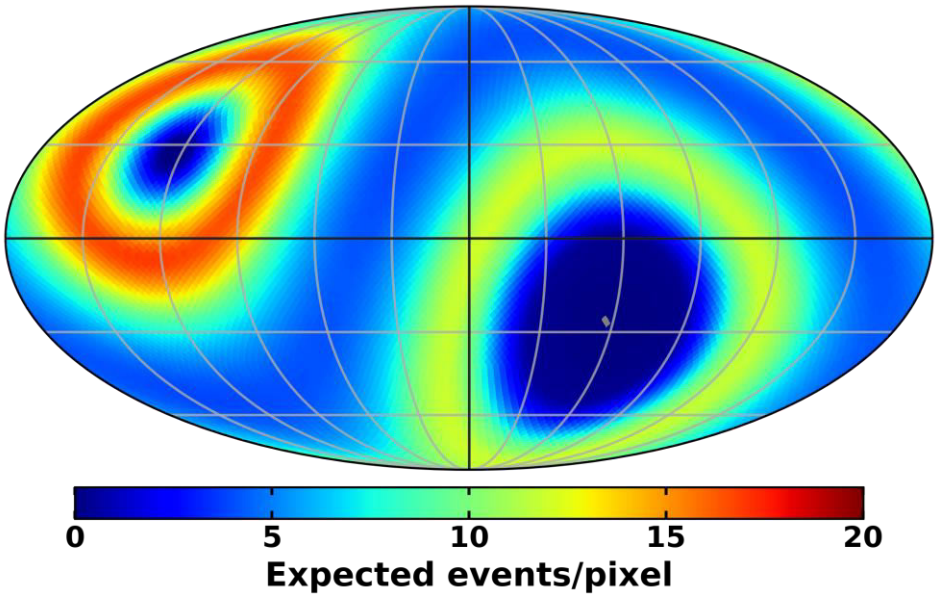
The arrival directions of positron events are compared to the expected map for an isotropic flux

16 < E < 350 GeV

9.2×10^4 positrons

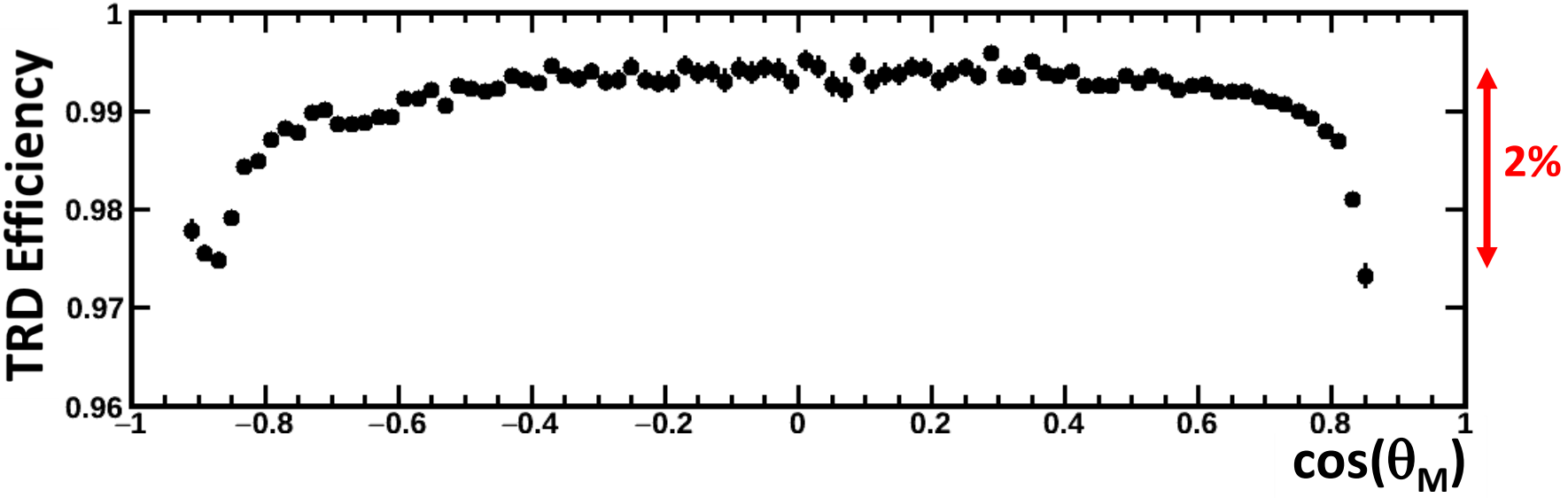


Isotropic map

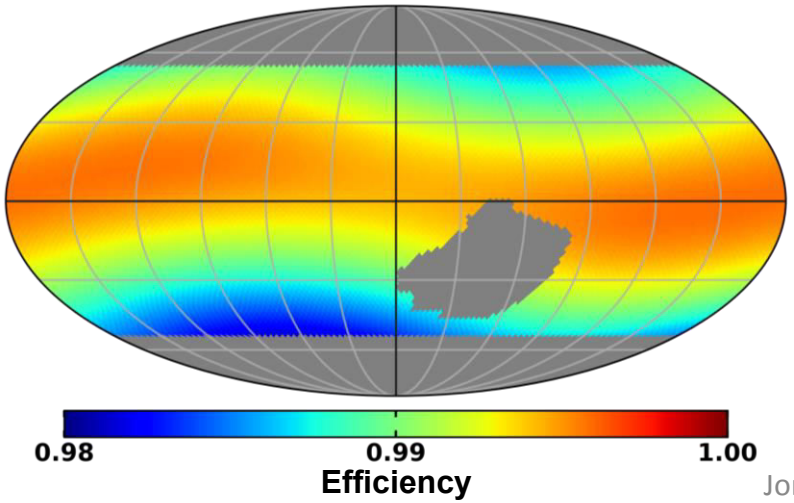


Positron absolute anisotropy

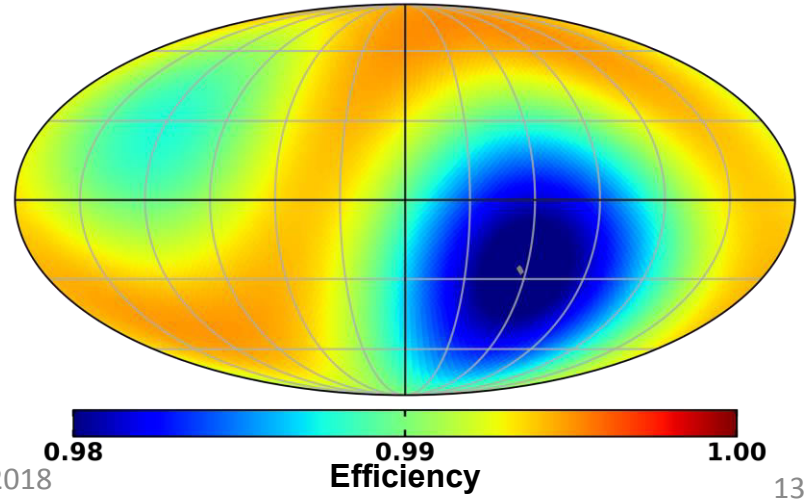
Computation of isotropic map requires detailed understanding of detector efficiencies at different geographical locations



Geographical Coordinates



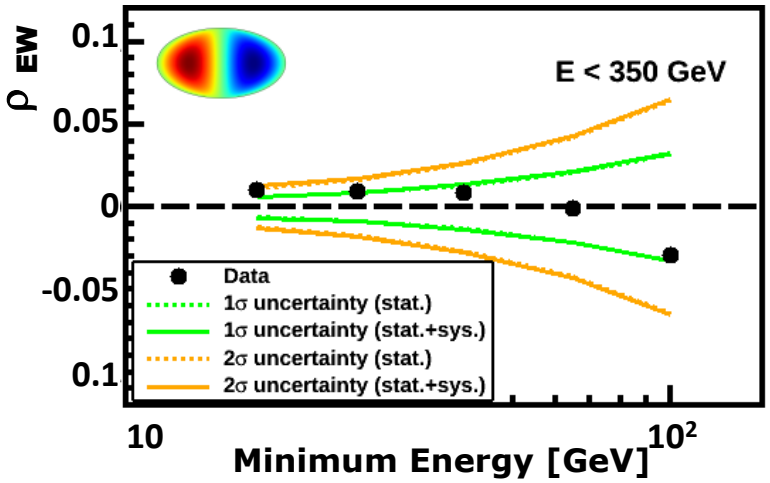
Galactic Coordinates

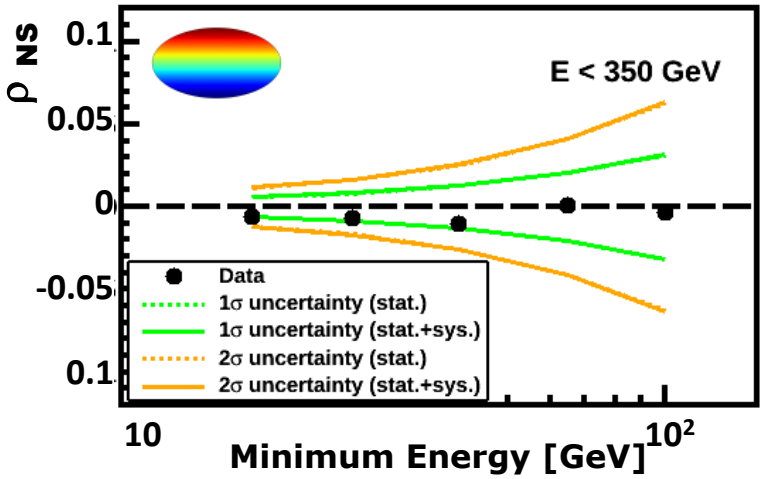


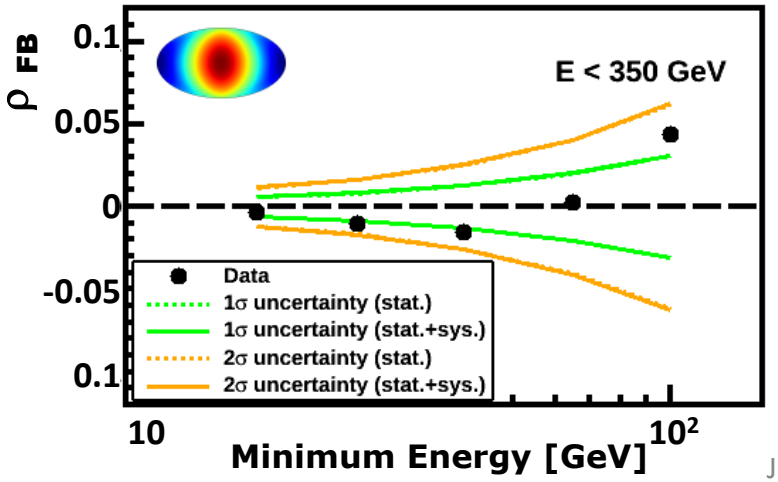
Positron absolute anisotropy

Selected events are grouped into 5 cumulative energy ranges
16-350, 25-350, 40-350, 65-350 and 100-350 GeV.

Dipole components – Galactic Coordinates







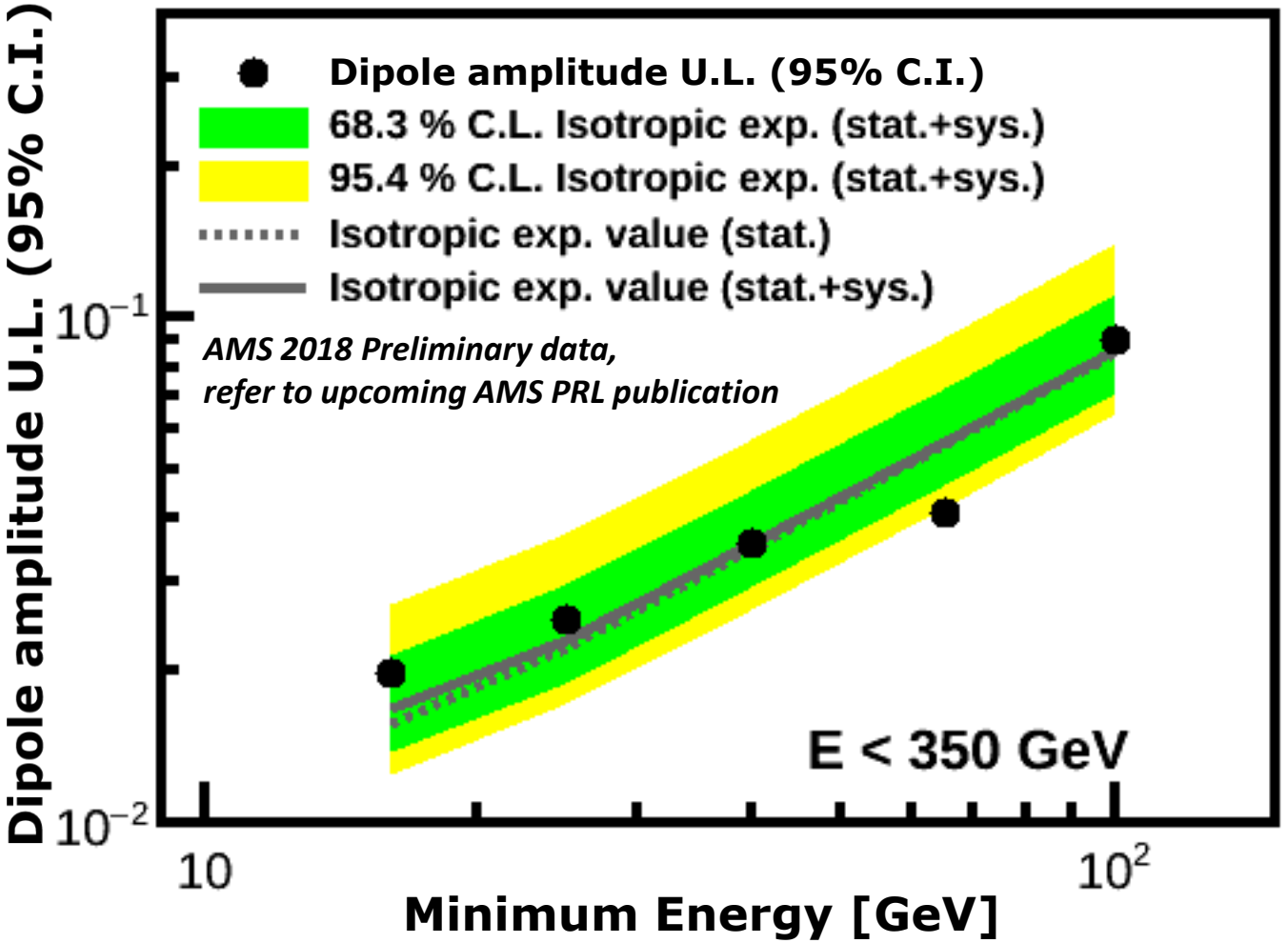
Amplitude of the dipole anisotropy

on positrons for 16 < E < 350 GeV

δ < 0.020 (95% C.I.)

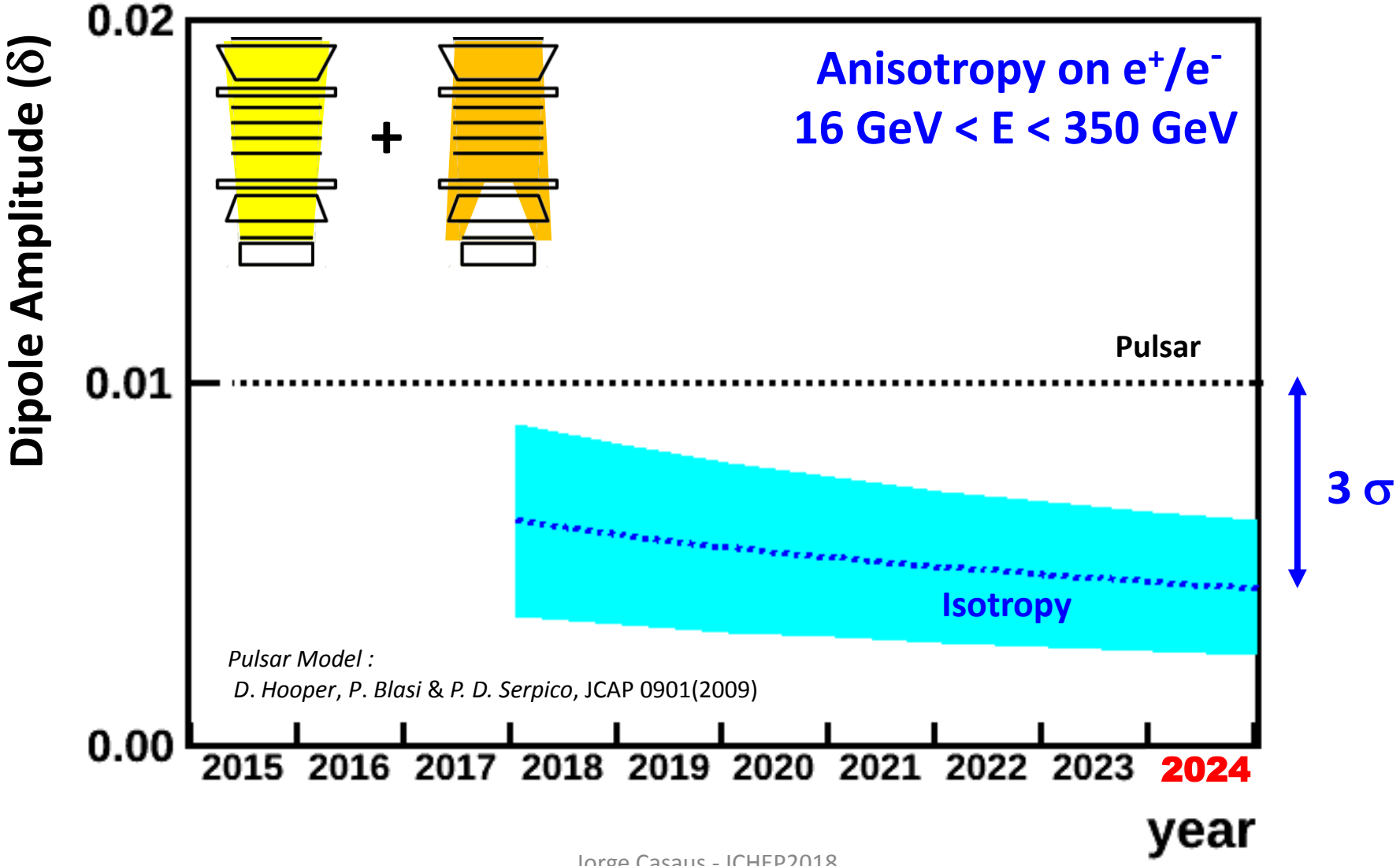
Anisotropy on e^+ : dipole upper limits

Upper limits are set for each energy range



Anisotropy on e^+ : Projected dipole amplitude

By 2024, with an improved analysis AMS will have collected above 400,000 positron events in the energy range 16 GeV < E < 350 GeV

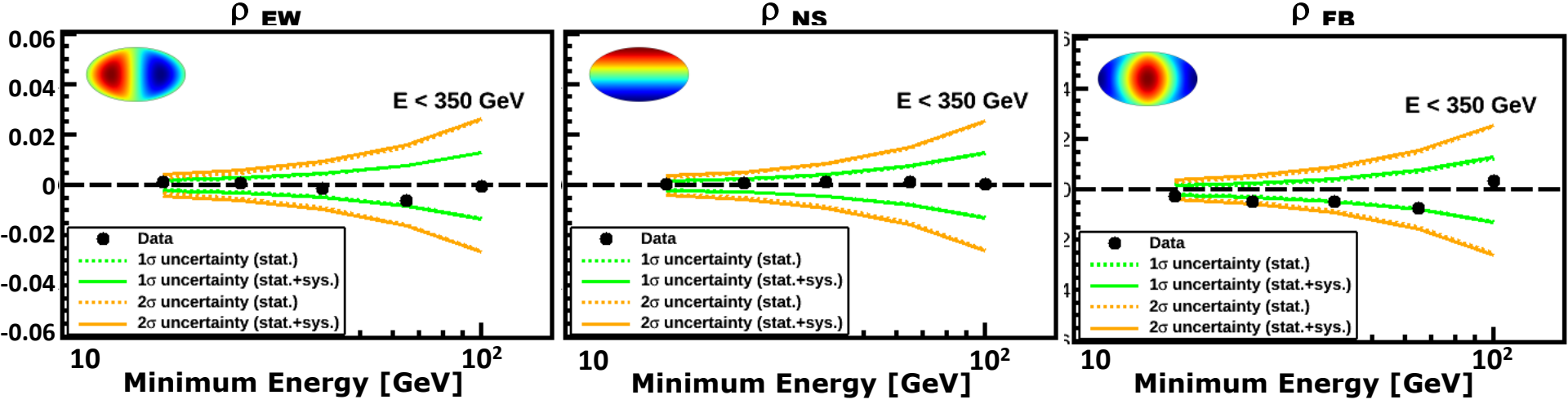


Test of systematics for an anisotropy measurement on a sample of 400,000 positrons

Electron absolute anisotropy (AMS 6 years: 1.2×10^6 events)

Selected events are grouped into 5 cumulative energy ranges
16-350, 25-350, 40-350, 65-350 and 100-350 GeV.

Dipole components – Galactic Coordinates



Measurements are compatible with isotropy

Amplitude of the dipole anisotropy
on electrons ($16 < E < 350$ GeV)

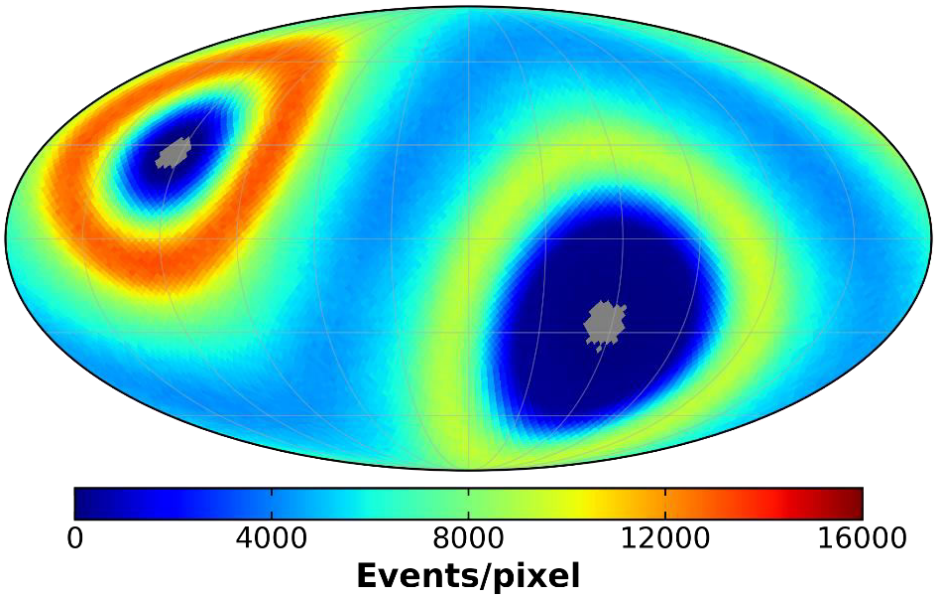
$\delta < 0.005$ (95% C.I.)

Proton absolute anisotropy

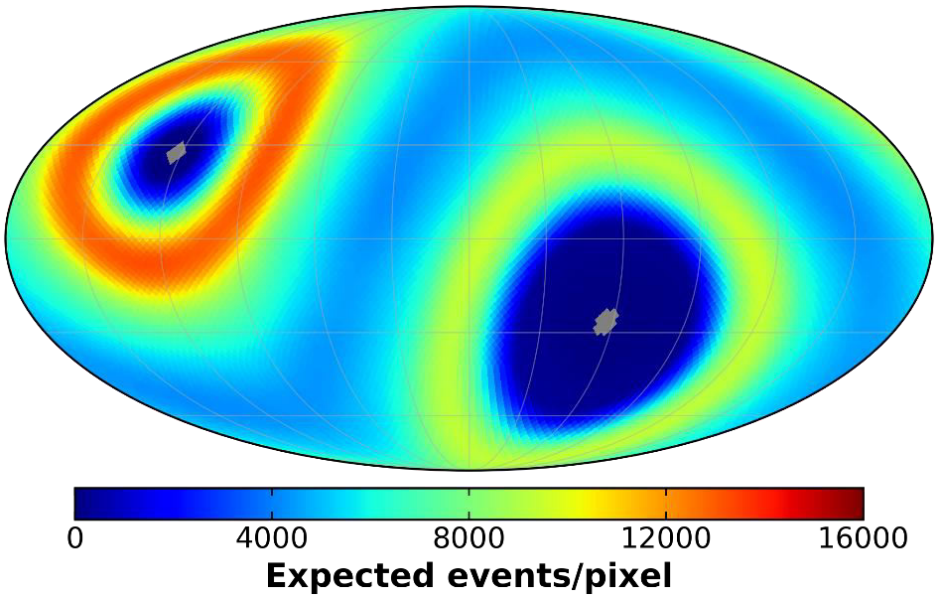
The arrival directions of proton events are compared to the expected map for an isotropic flux

R > 18 GV

9.1×10^7 protons

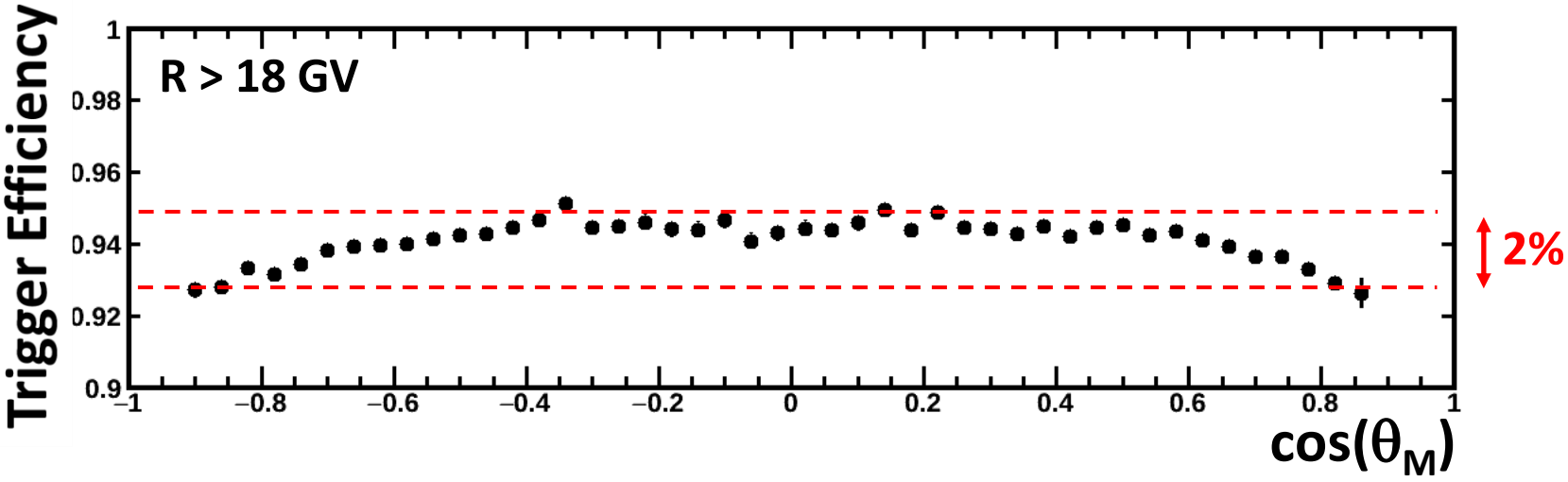


Isotropic map

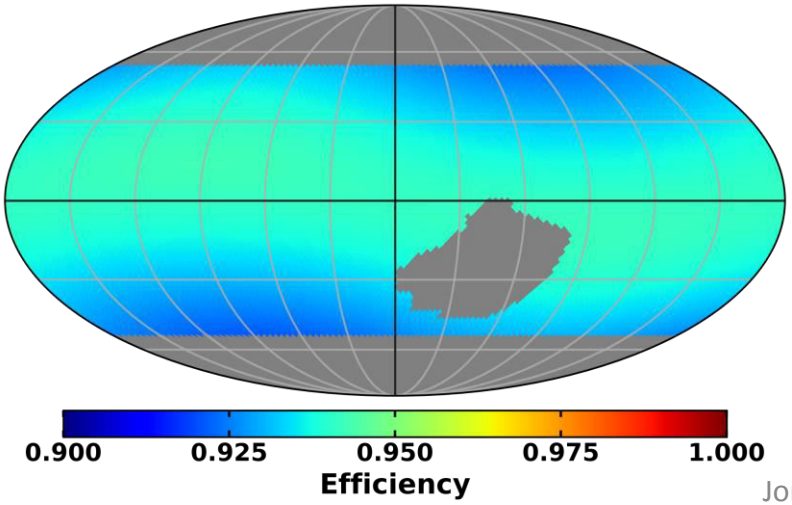


Proton absolute anisotropy

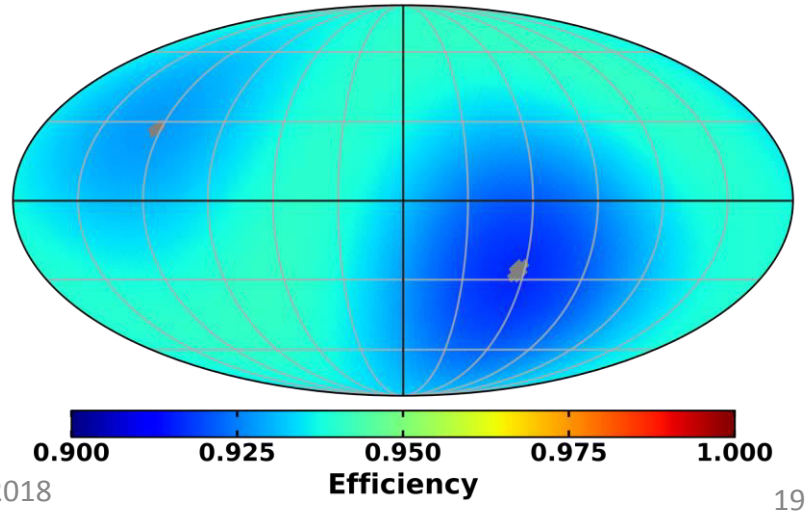
Computation of isotropic map requires detailed understanding of detector efficiencies at different geographical locations



Geographical Coordinates

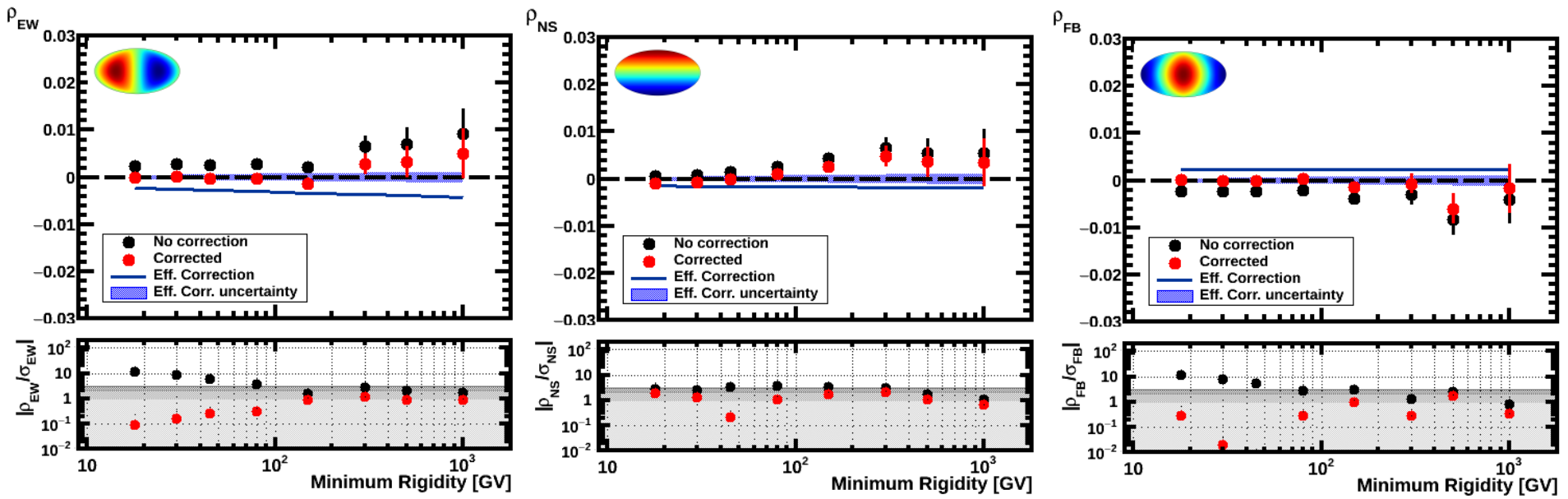


Galactic Coordinates



Proton absolute anisotropy

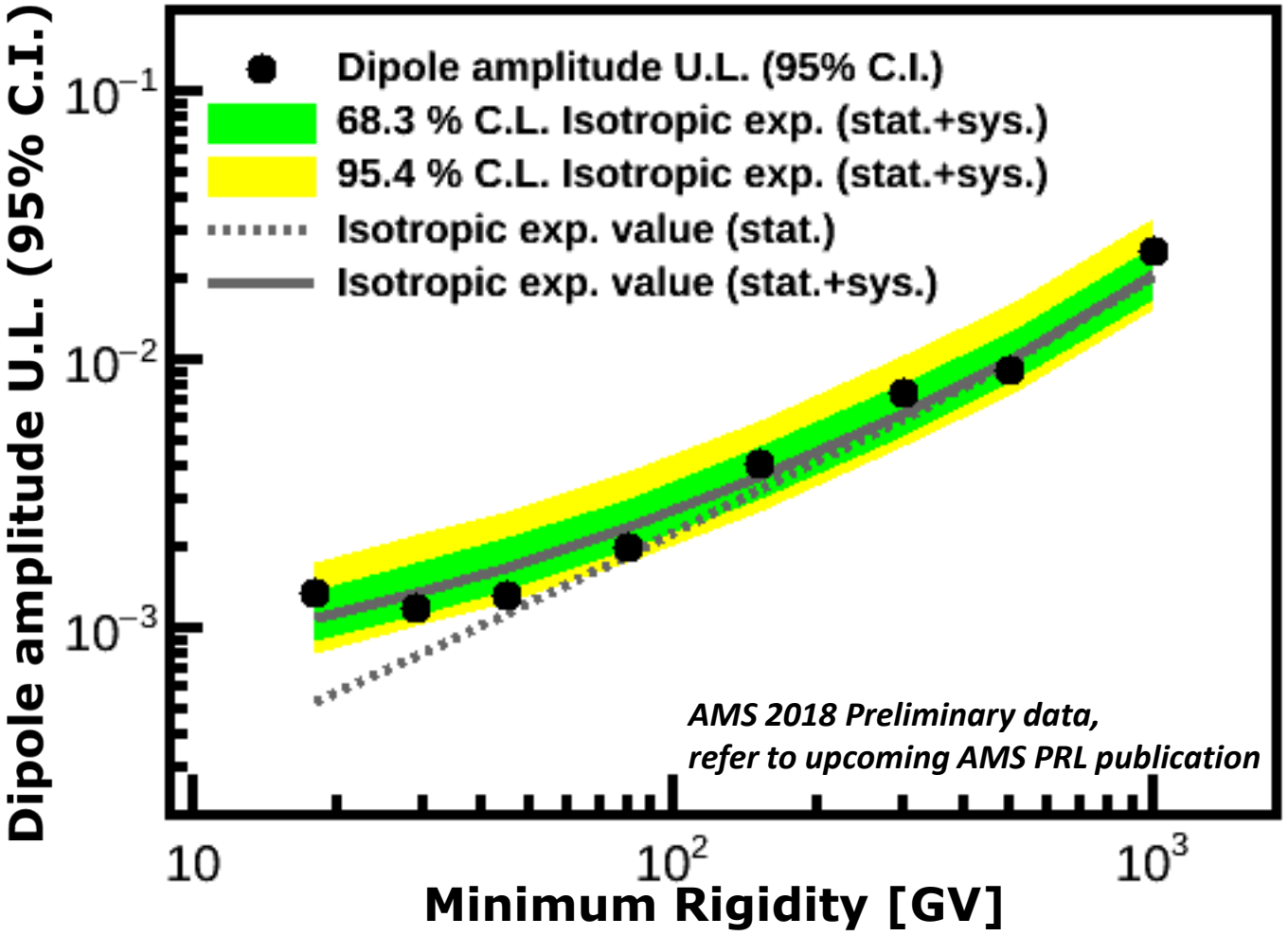
Corrections on individual components are computed for each selection efficiency to produce the corrected isotropic map



- **Before corrections, significant deviations from isotropy are observed, specially at lower rigidities**
- **After corrections, measured dipole components are consistent with isotropy in all rigidity ranges**

Anisotropy on p : dipole upper limit

- ✓ Systematics on efficiency corrections limit the sensitivity at low R to 0.1%
- ✓ Measurement limited by statistics for R > 100 GV
- ✓ Upper limit on dipole amplitude $\delta < 0.8\%$ for R > 300 GV



Summary

The new features measured by AMS on high energy cosmic rays for e^+, e^- and protons point to new phenomena. The study of their anisotropy is a way to understand their origin.

AMS has measured the absolute anisotropy in their arrival directions on the sample collected after 6 years of data taking.

Positrons in the energy range from 16 GeV to 350 GeV are consistent with isotropy and an upper limit to the dipole component $\delta < 2\%$ is obtained.

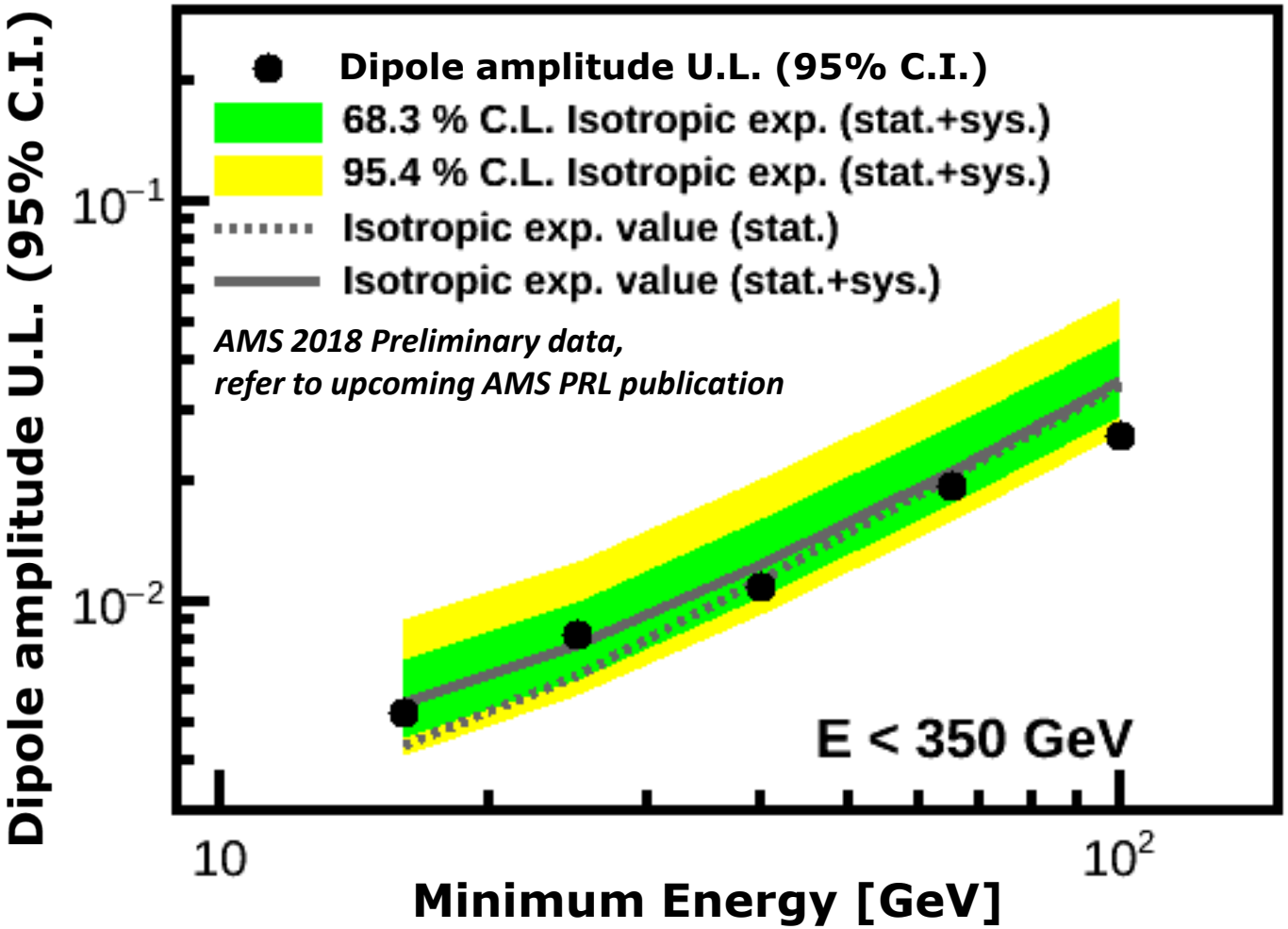
An extended data taking until 2024, will allow to exclude anisotropies of 1% on the positron cosmic ray sample and test models of compact astrophysical sources for the origin of the positron excess.

Protons are found consistent with isotropy and an upper limit to the dipole component $\delta < 0.8\%$ for $R > 300$ GV is obtained.

BACKUP SLIDES

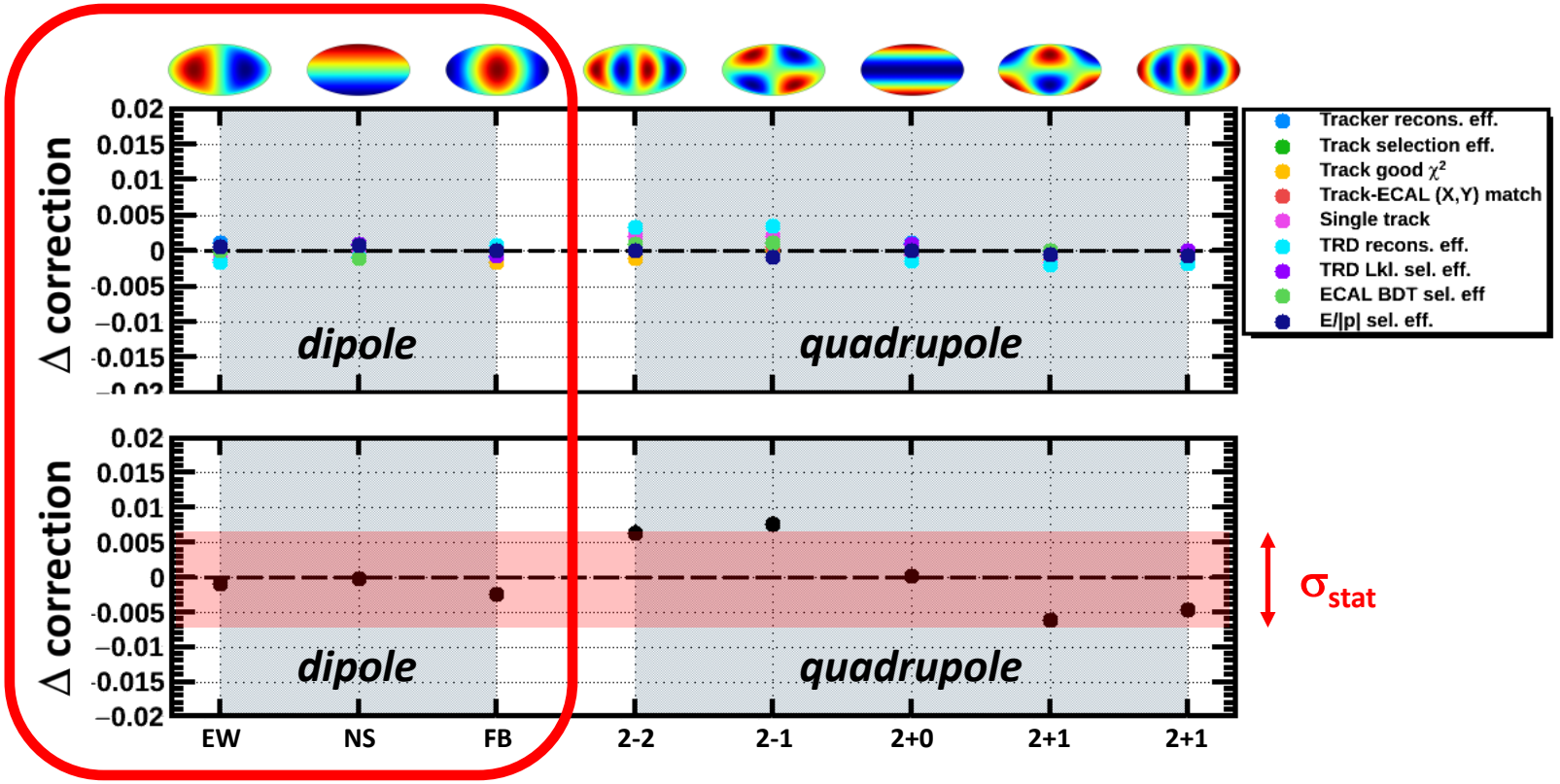
Anisotropy on e^- : dipole upper limit

Upper limits are set for each energy range



Positron absolute anisotropy

Corrections on individual components are computed for each selection efficiency to produce the corrected isotropic map

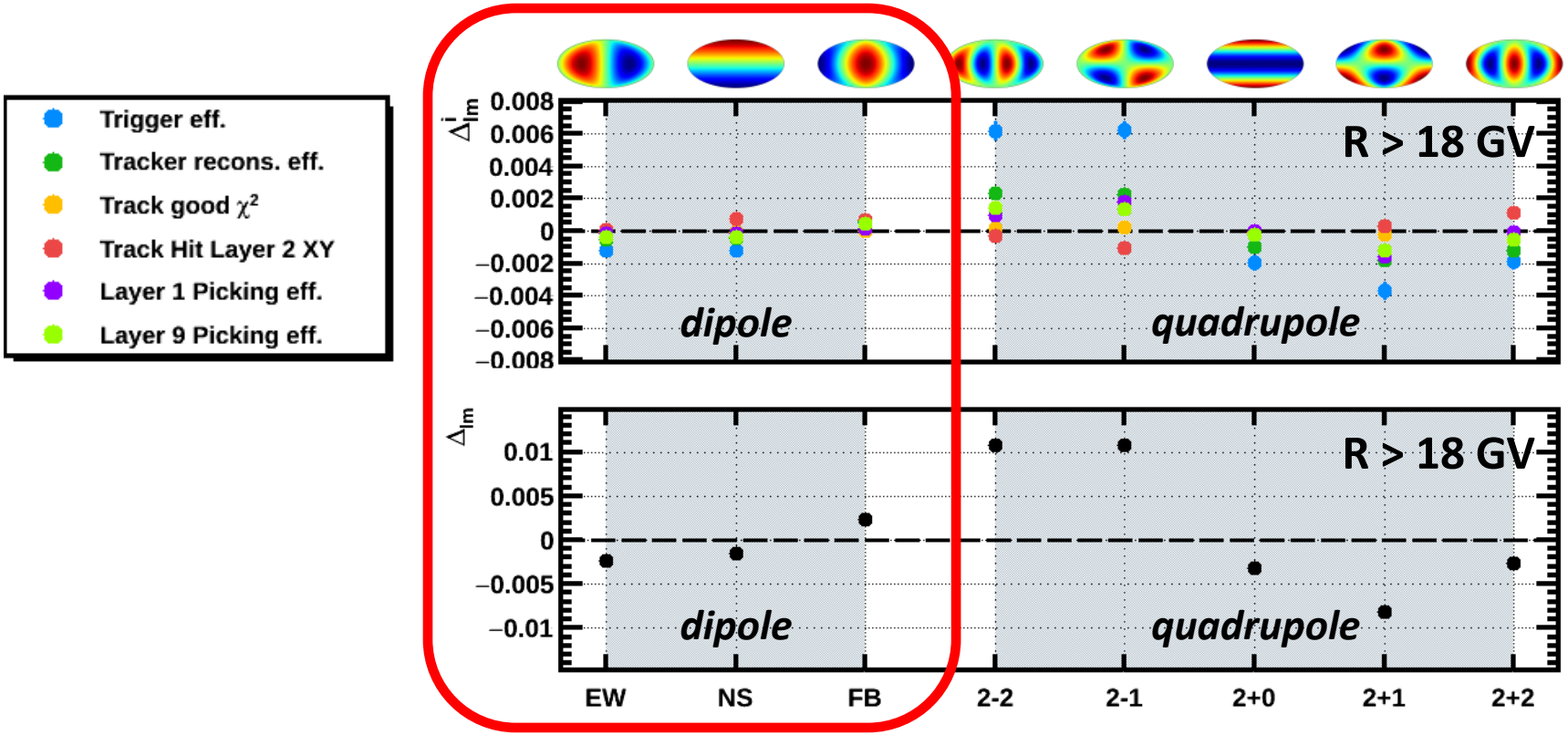


Efficiency corrections to the dipole components are well below the statistical error of the positron sample.

After efficiency corrections, the small remaining dependence on geographical coordinates is included as an additional systematic uncertainty

Proton absolute anisotropy

Corrections on individual components are computed for each selection efficiency to produce the corrected isotropic map

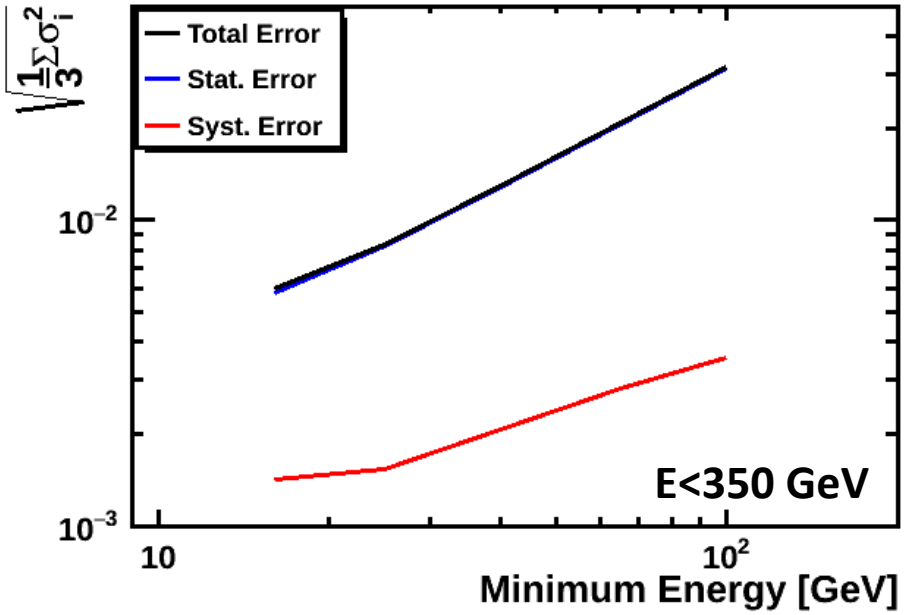


- **Significant efficiency corrections for all dipole components**
- **At low rigidities, the uncertainty on the corrections dominates the total error in the dipole measurement**

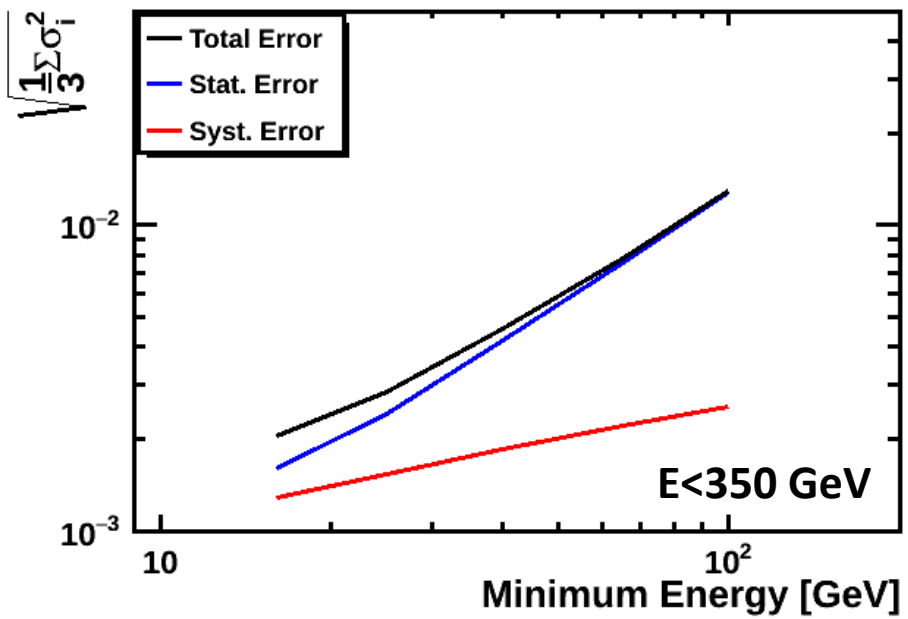
AMS Dipole Error Breakdown

Errors on positron and electron dipole dominated by statistics at all energies

positron – Galactic Coordinates



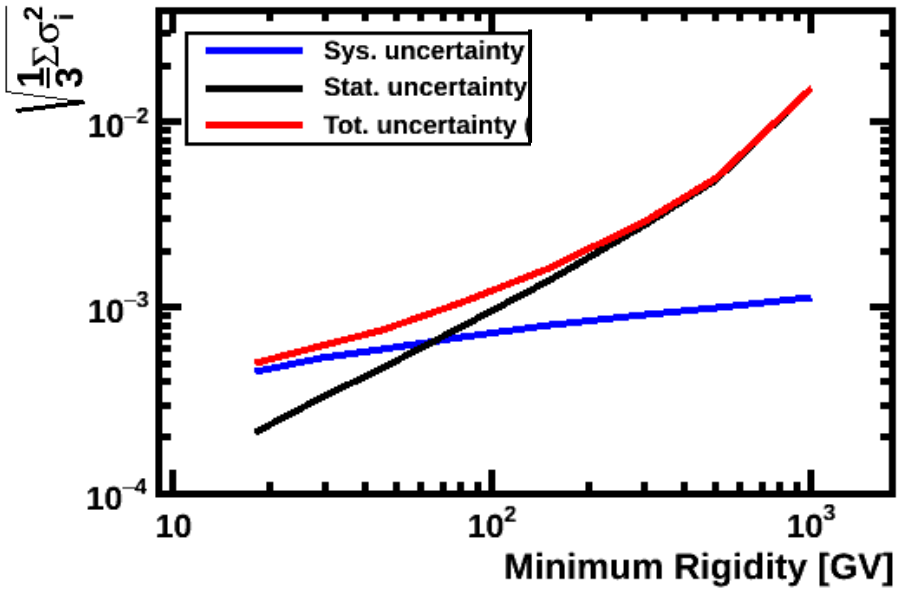
electron – Galactic Coordinates



AMS Dipole Error Breakdown

Errors on proton dipole dominated by statistics above 80 GV

proton – Galactic Coordinates



proton – Galactic Coordinates