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Measurement of CR anisotropies with the AMS detector on the ISS

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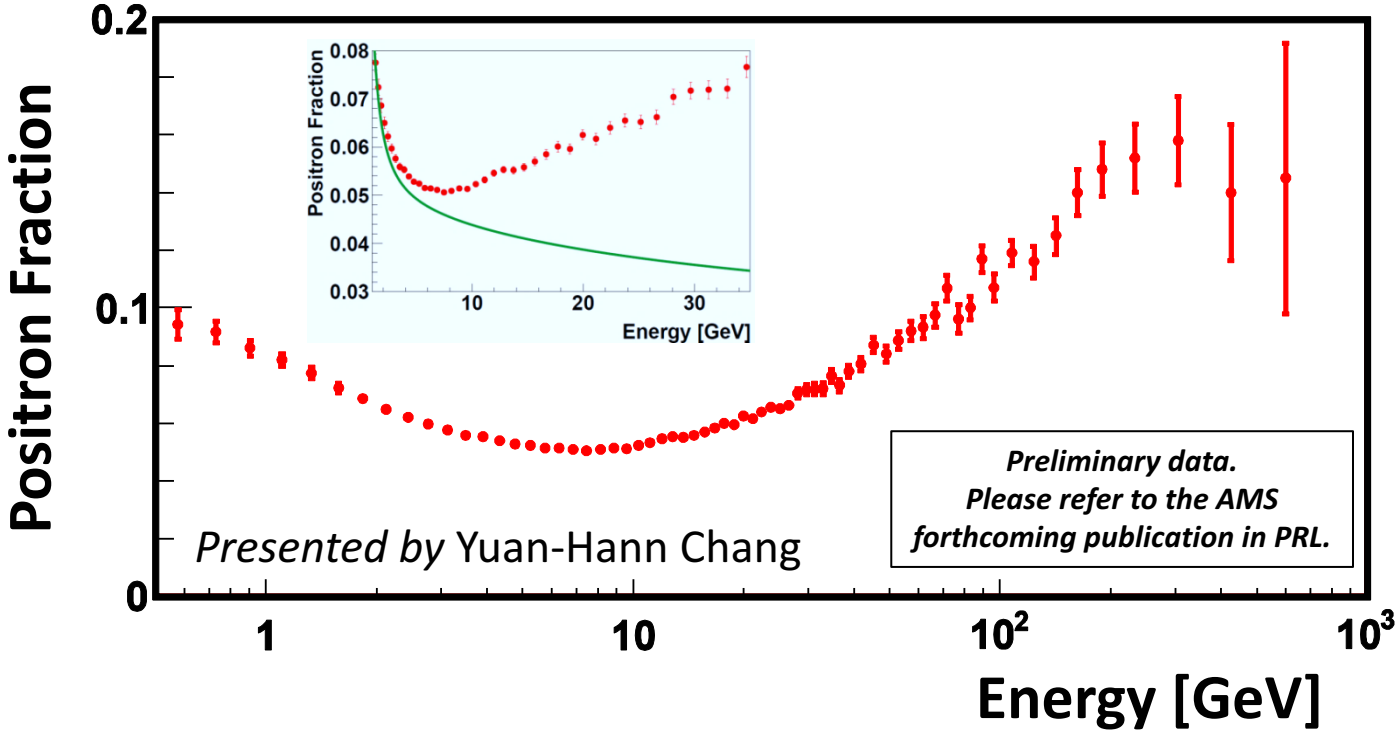
Origin of excess of positrons

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

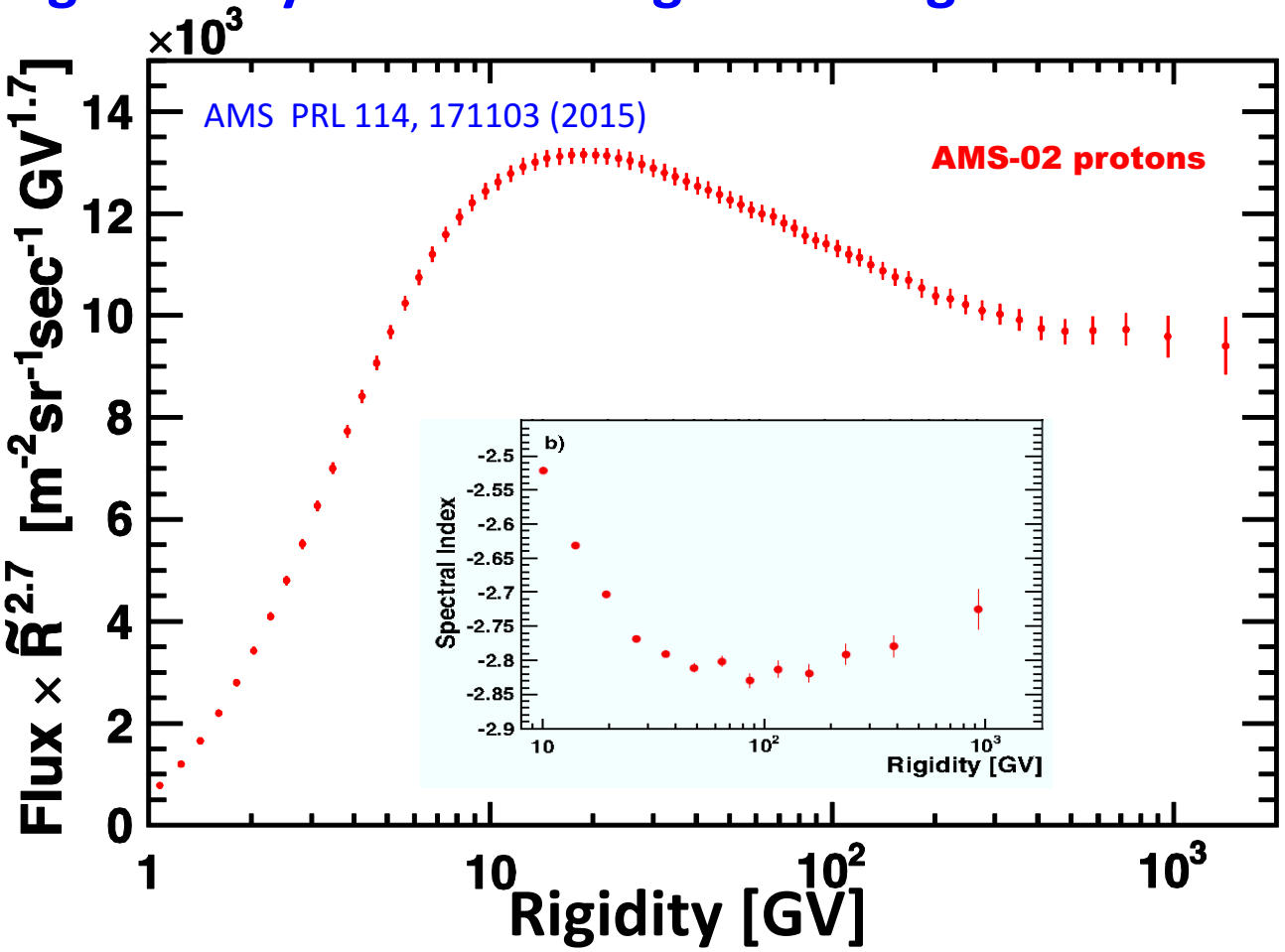


The observation requires the inclusion of primary sources whether from a particle physics or an astrophysical origin.

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

Characterization of cosmic ray spectra

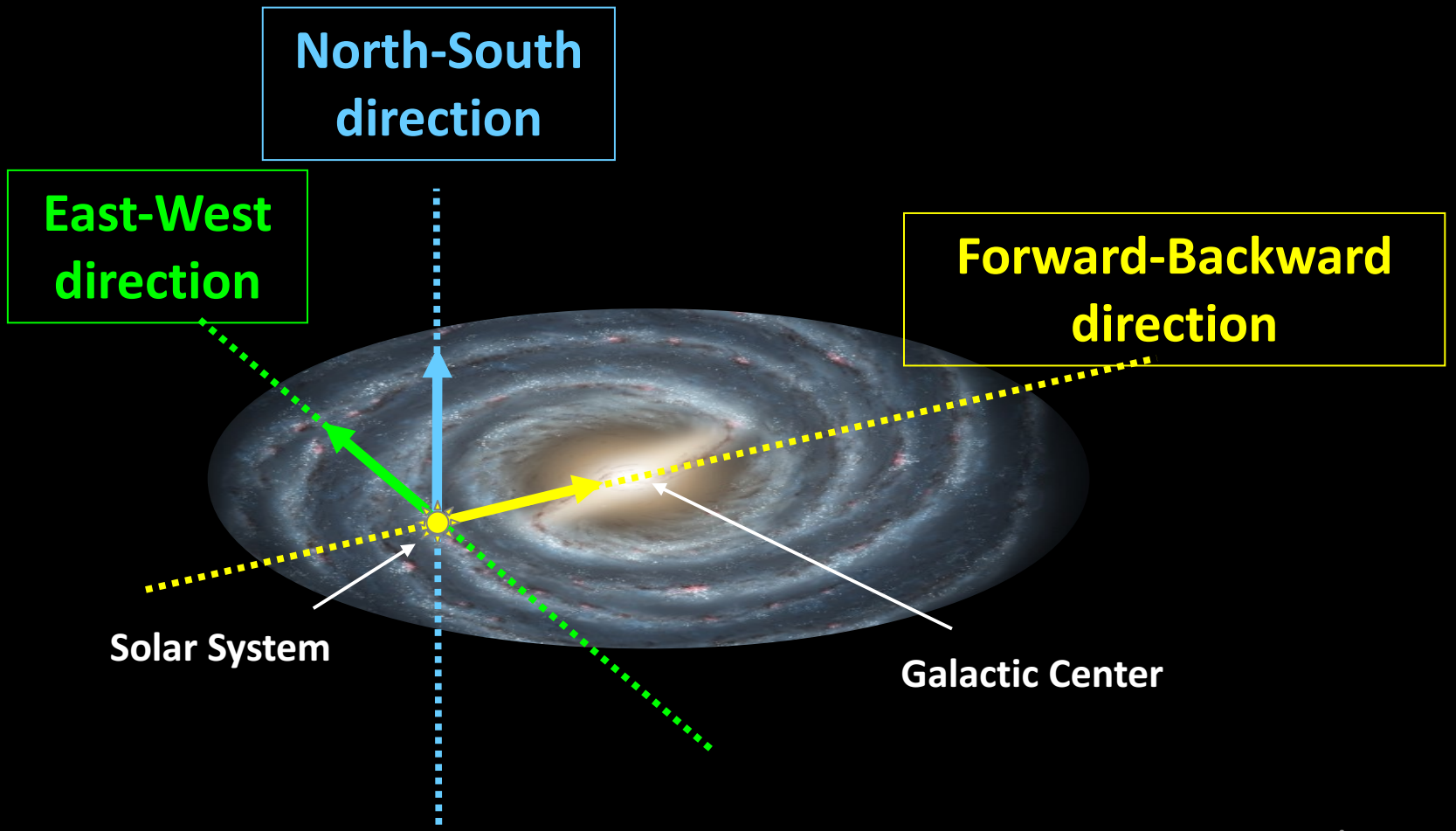
AMS measurements of the proton and helium cosmic ray spectra show that the flux deviates from a single power law and the spectral index progressively hardens at rigidities larger than 100 GV



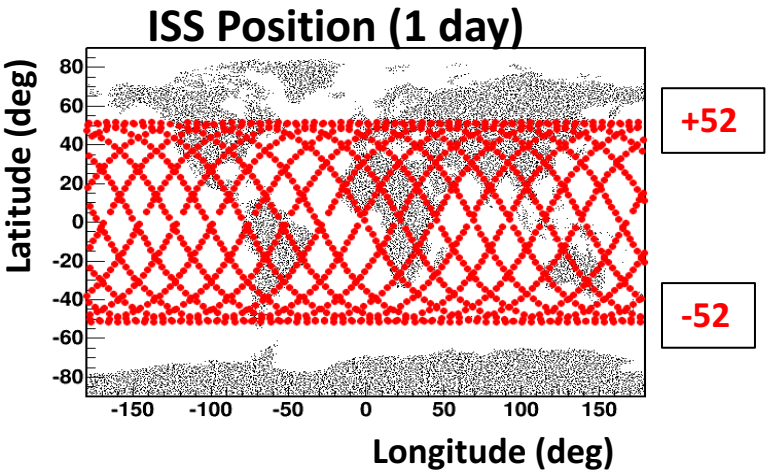
Analysis of anisotropy for high rigidity cosmic rays may help in understanding the origin of these unexpected phenomena

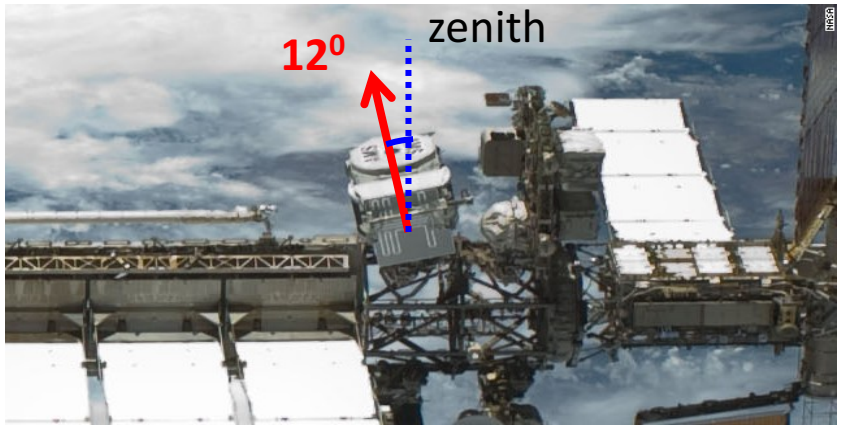
Analysis of anisotropy

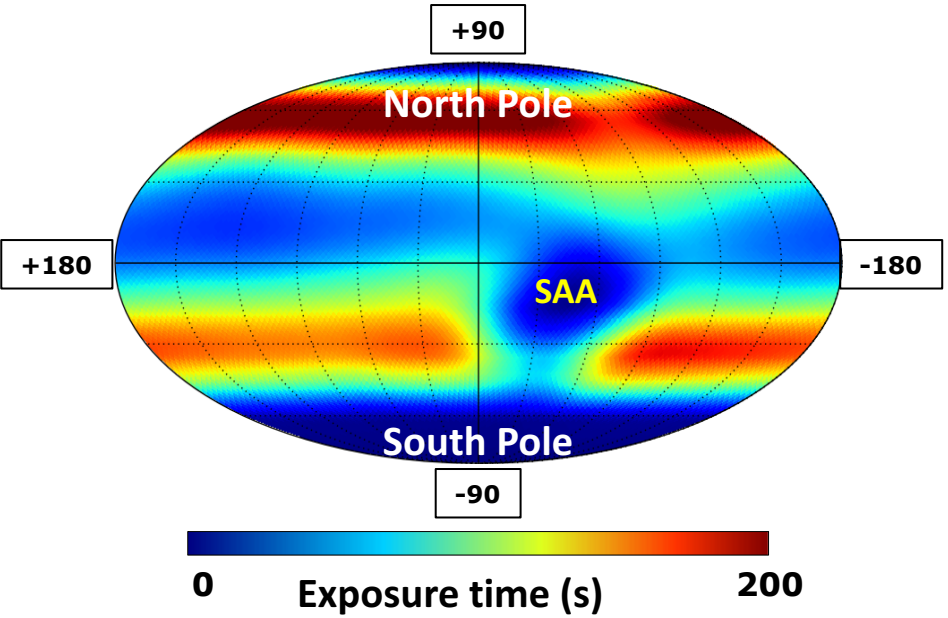
Measurement of the cosmic ray fluxes as function of the arrival direction in Galactic Coordinates

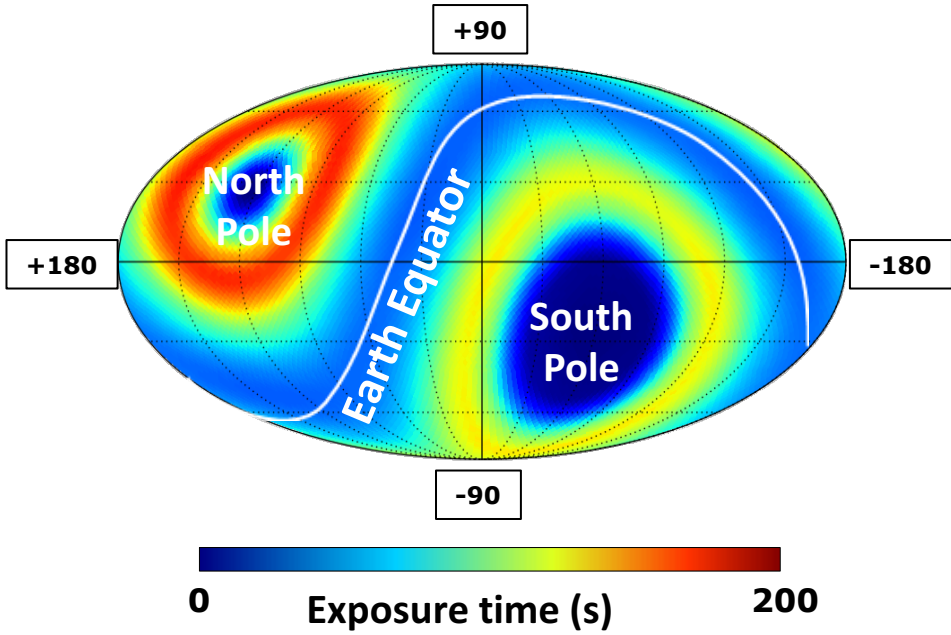


AMS sky coverage







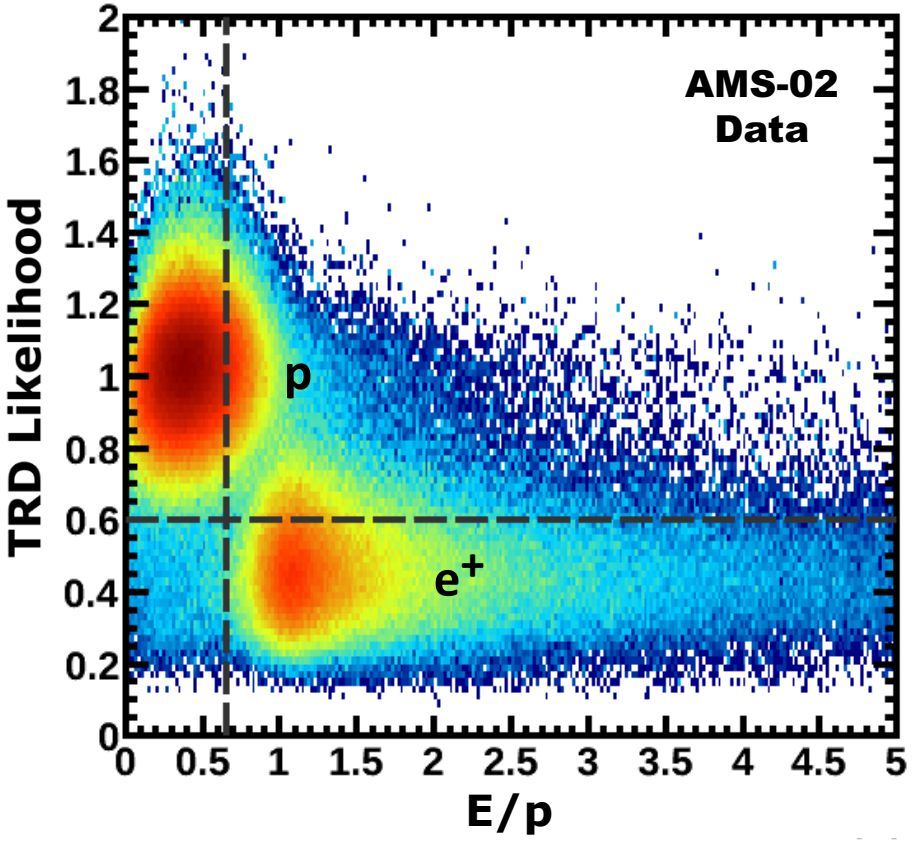


AMS 5 years : Total Exposure time: 1.23×10^8 s

Positron to electron ratio anisotropy

Sample selection

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



Event Sample: AMS 5 years

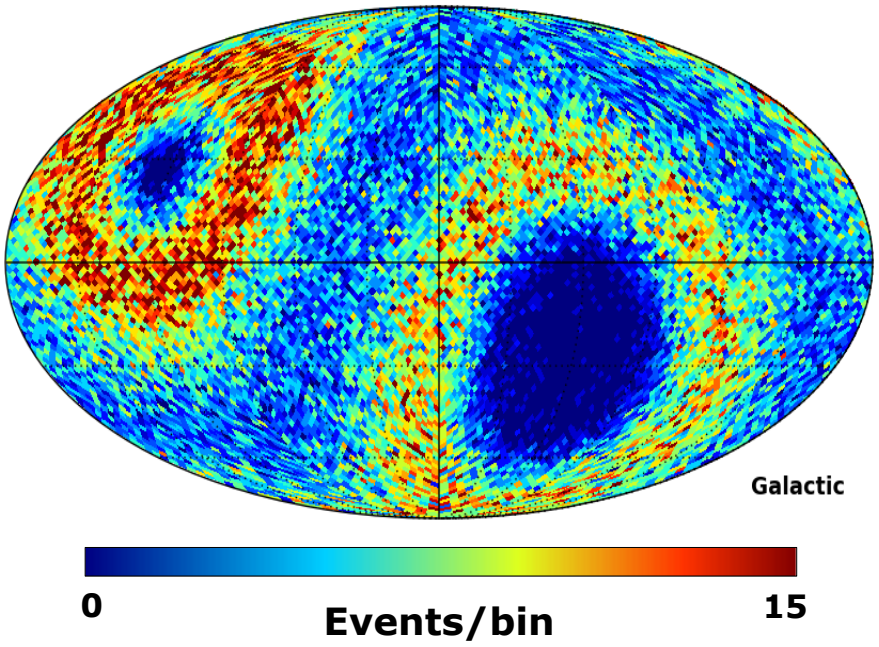
8×10^4 e^+ and 10^6 e^- ($16 < E < 350$ GeV)

Positron to electron ratio anisotropy

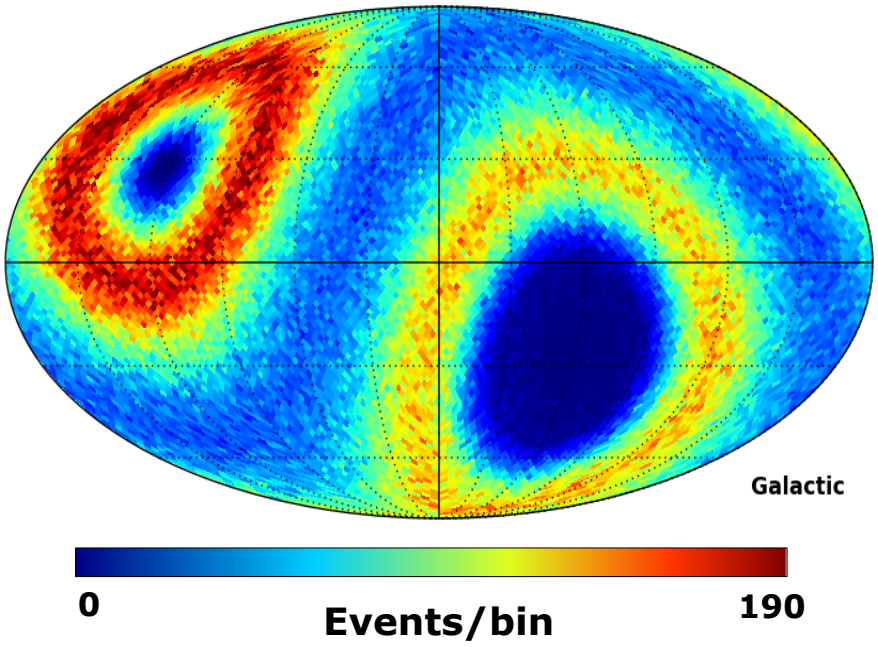
Build the sky map of the positrons and electrons arrival directions in galactic coordinates (b,l)

16 < E < 350 GeV

$8x10^4$ Positrons



10^6 electrons

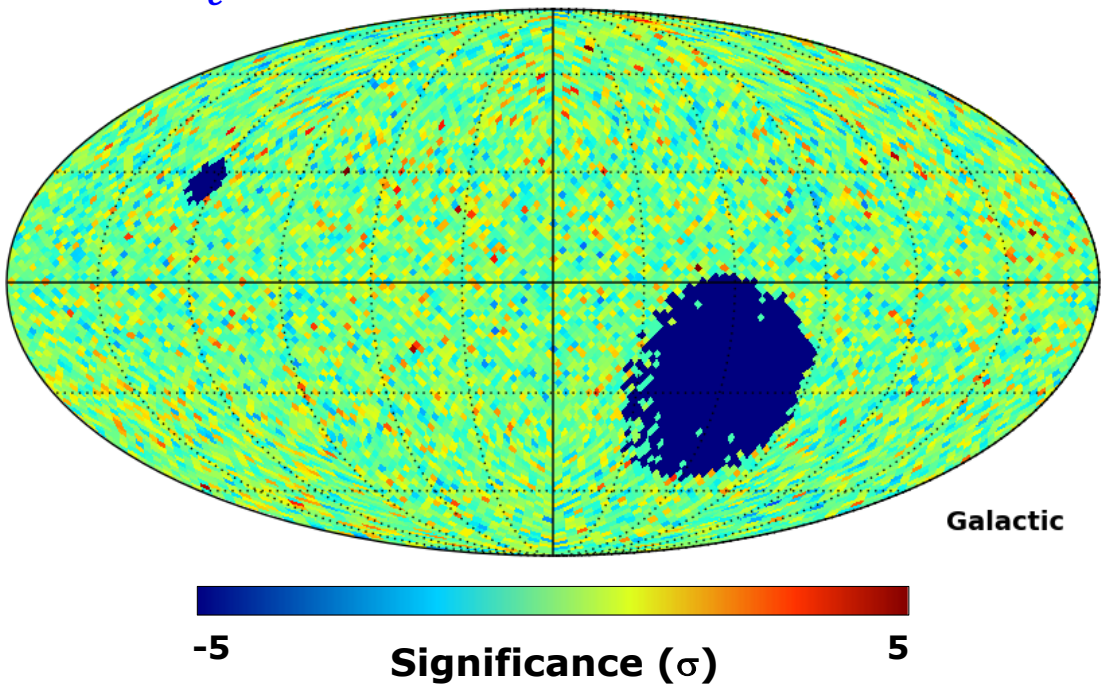


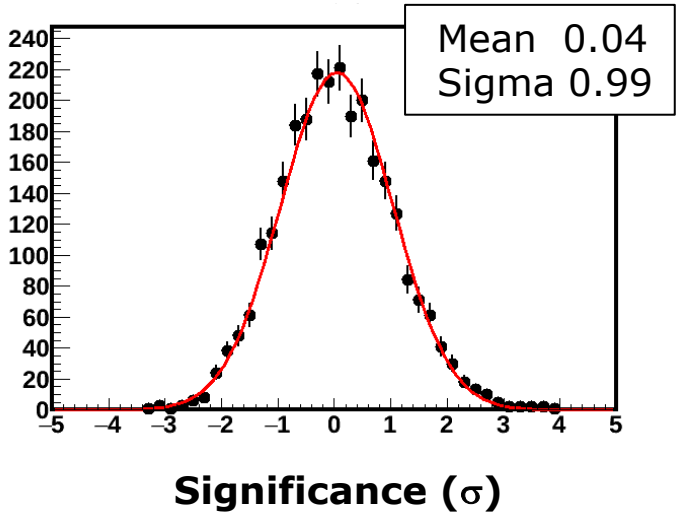
Positron to electron ratio anisotropy

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

$$\frac{r_e(b,l) - \langle r_e \rangle}{\langle r_e \rangle}$$

16 < E < 350 GeV





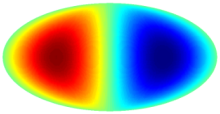
The observed sky map shows no evident pattern

Positron to electron ratio anisotropy

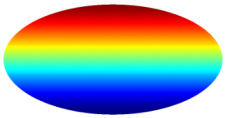
The relative fluctuations of the positron to electron ratio are described by means of a spherical harmonics expansion

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

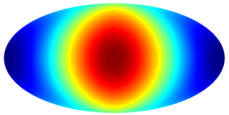
Dipole components



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



North-South $\rho_{NS} = \sqrt{\frac{3}{4\pi}} a_{10}$



Forward-Backward $\rho_{NS} = \sqrt{\frac{3}{4\pi}} a_{1+1}$

Dipole amplitude

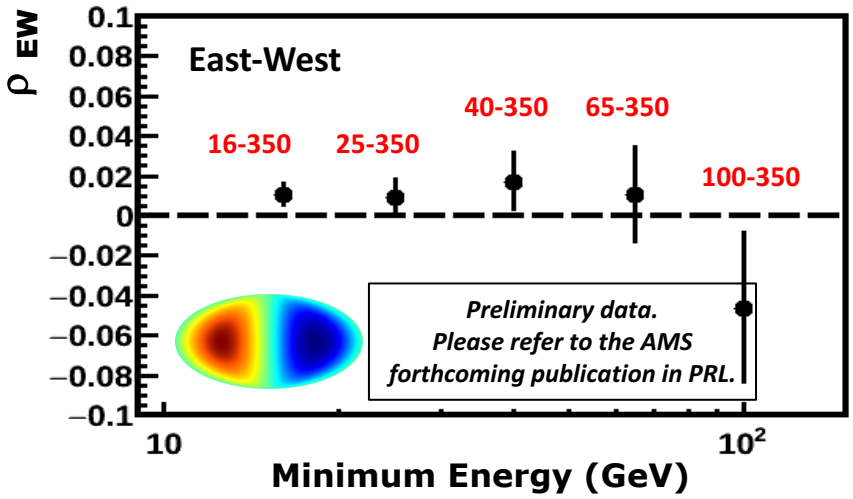
$$\delta = \sqrt{\rho_{EW}^2 + \rho_{NS}^2 + \rho_{FB}^2}$$

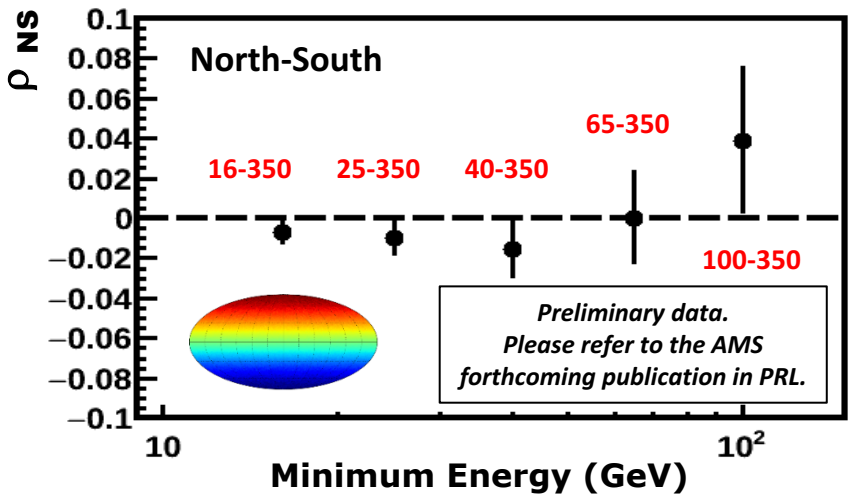
Positron to electron ratio anisotropy

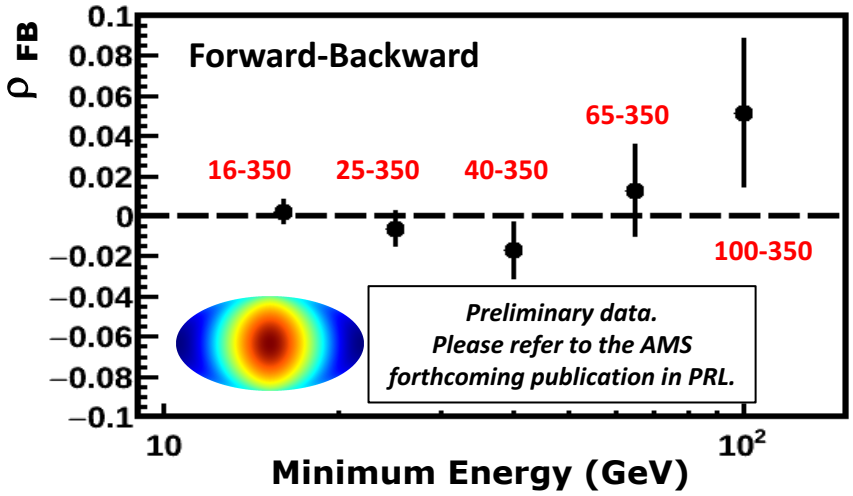
The fluctuations of the positron ratio are described by a spherical harmonic expansion

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

Dipole components – Galactic Coordinates







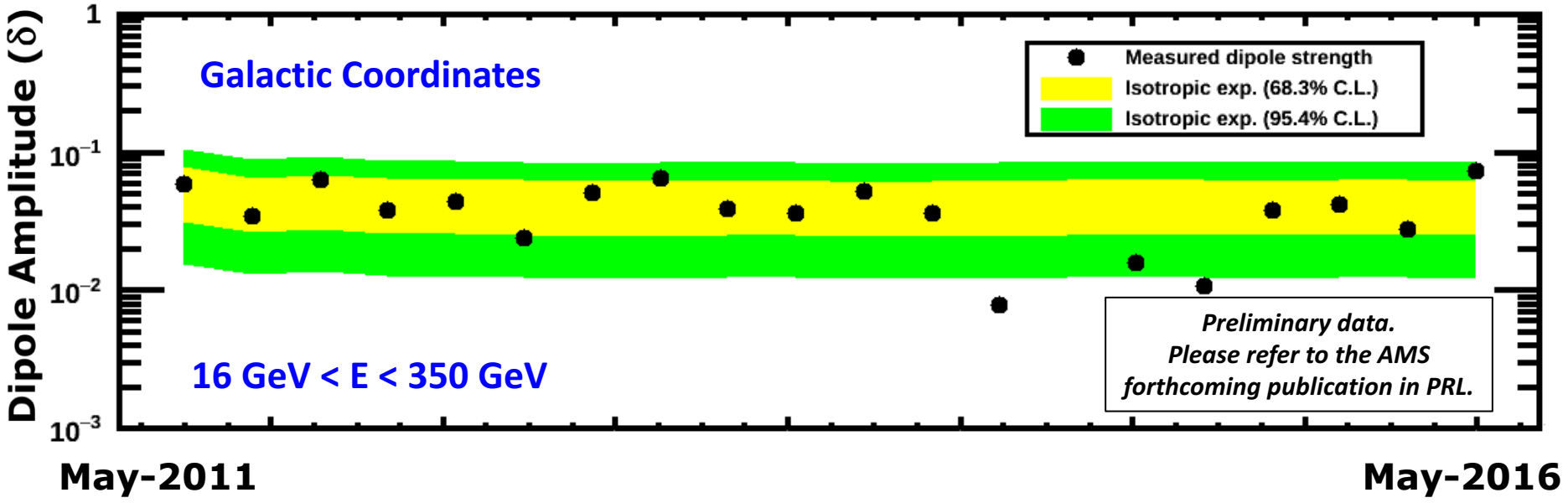
Amplitude of the dipole anisotropy

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

δ < 0.02 at the 95% C.L.

Positron to electron ratio anisotropy

The anisotropy analysis of the e+/e- ratio is repeated for every season in the 5-year sample



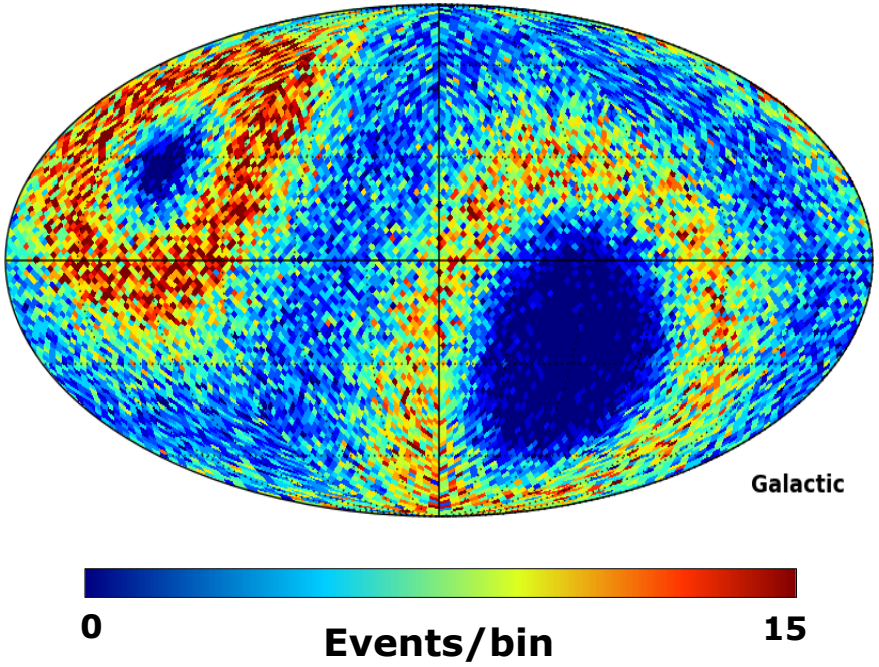
The measured dipole amplitudes are consistent with the expectations from isotropy

Positron absolute anisotropy

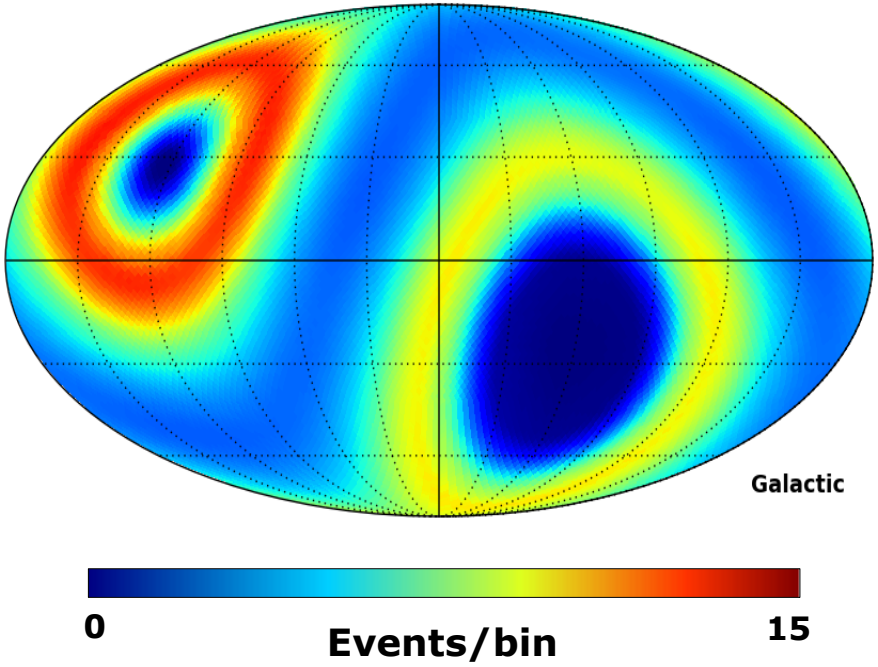
The arrival directions of positron events are compared with the expected map for isotropic flux

16 < E < 350 GeV

$8x10^4$ Positrons

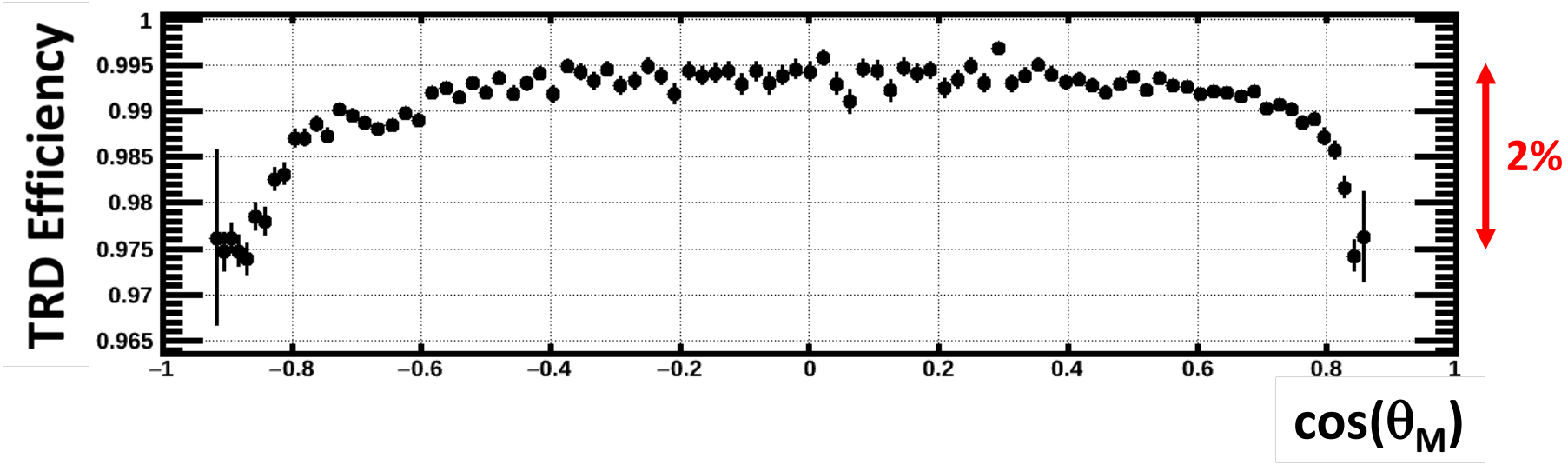


Isotropic map

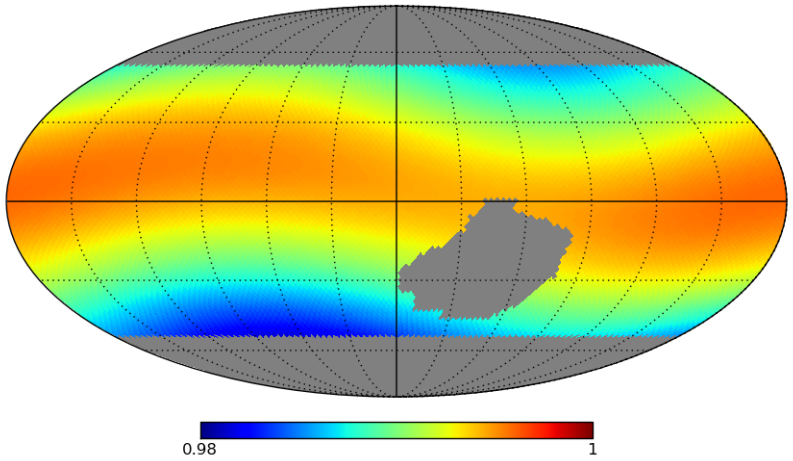


Positron absolute anisotropy

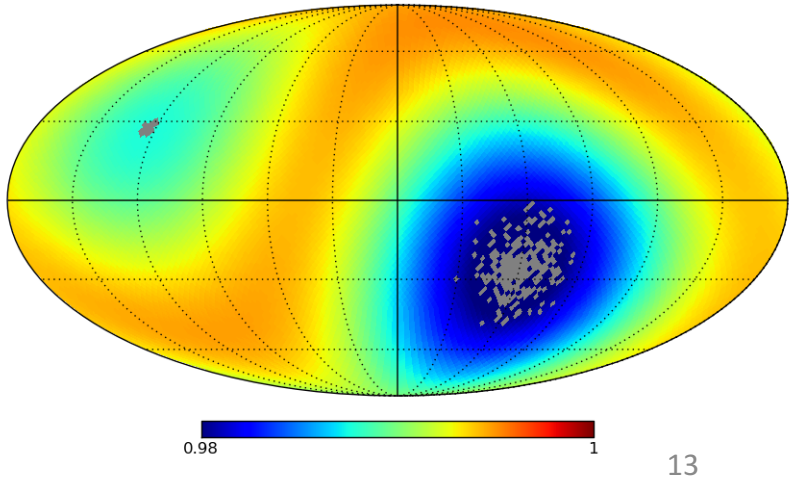
Computation of isotropic map requires detailed understanding of detector efficiencies at different geographical locations



Geographical Coordinates



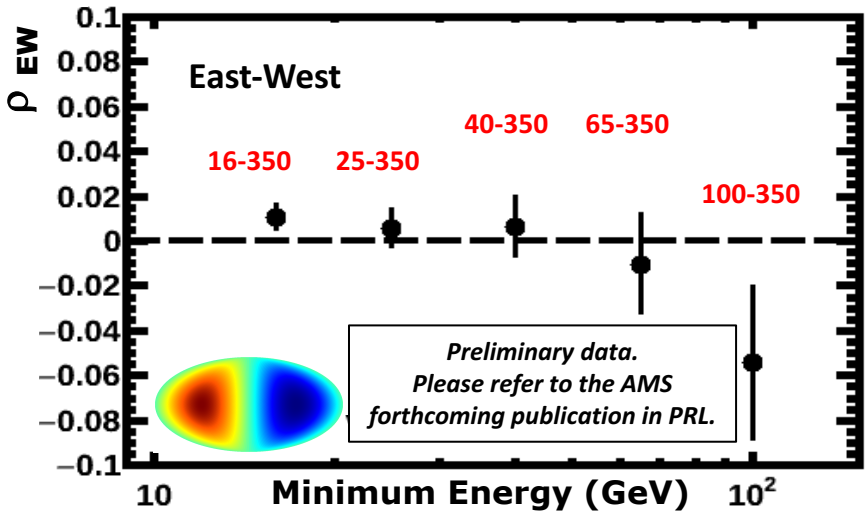
Galactic Coordinates

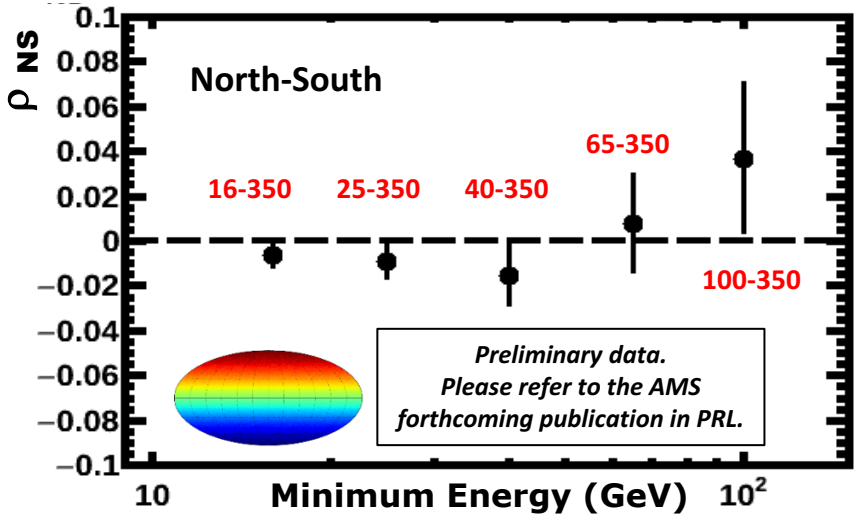


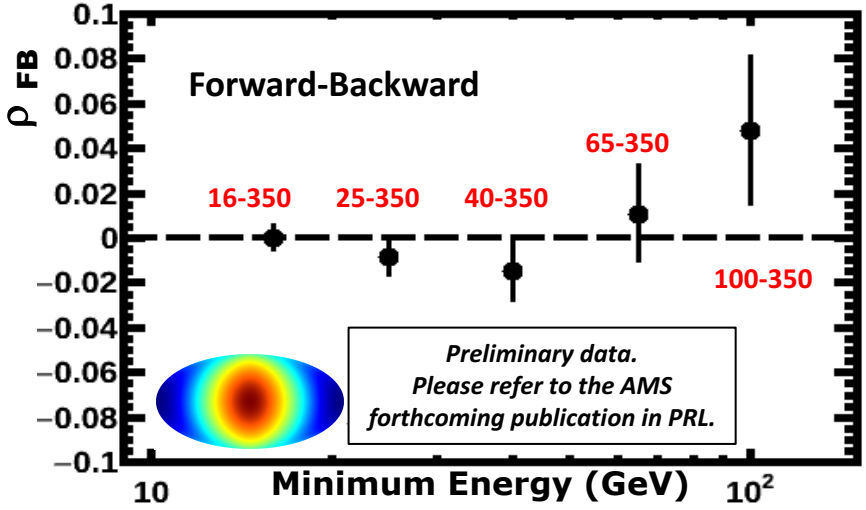
Positron absolute anisotropy

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

Dipole components – Galactic Coordinates







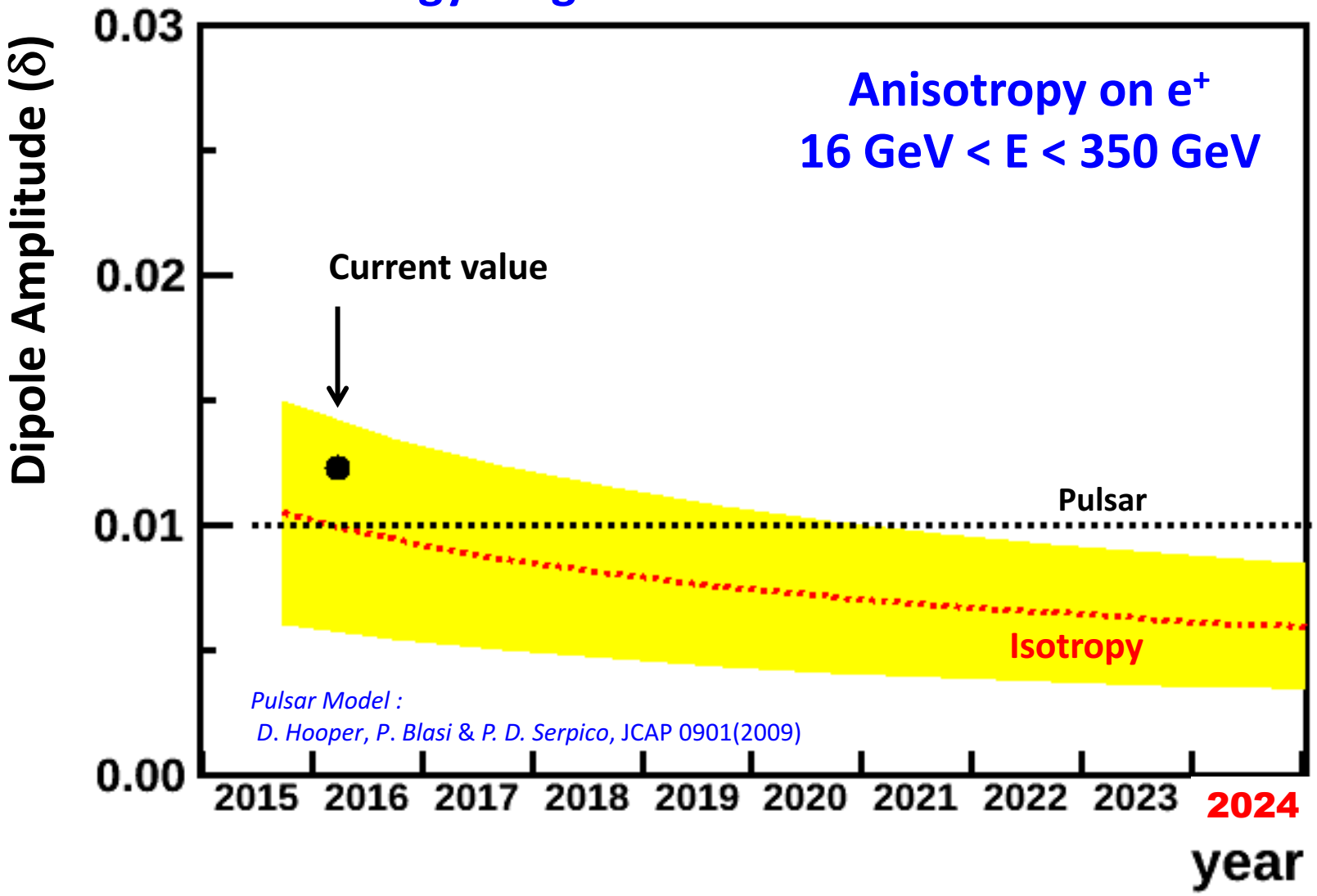
Amplitude of the dipole anisotropy

on the positrons for 16 < E < 350 GeV

δ < 0.02 at the 95% C.L.

Anisotropy on e^+ : Projected dipole amplitude

In 2024, AMS will collect above 200,000 positron events in the energy range 16 GeV < E < 350 GeV

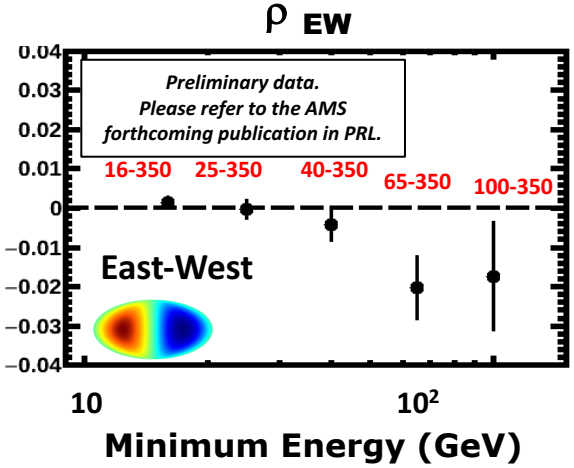


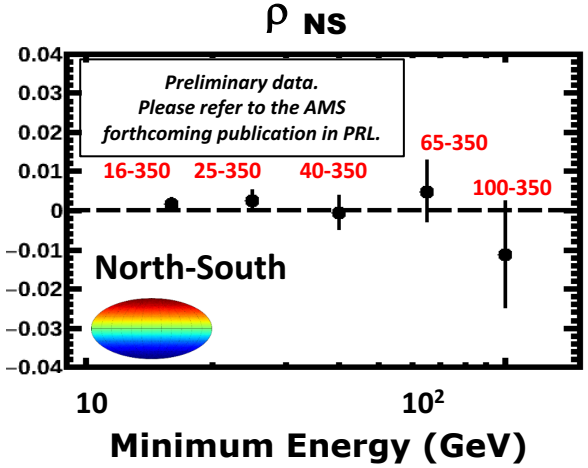
Test of systematics for an anisotropy measurement on a sample of 200,000 positrons

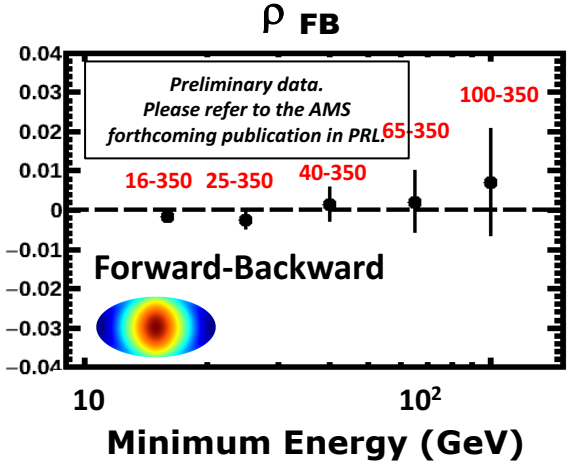
Electron absolute anisotropy (AMS 5 years: 10^6 events)

Selected events are grouped into 5 cumulative energy bins
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)

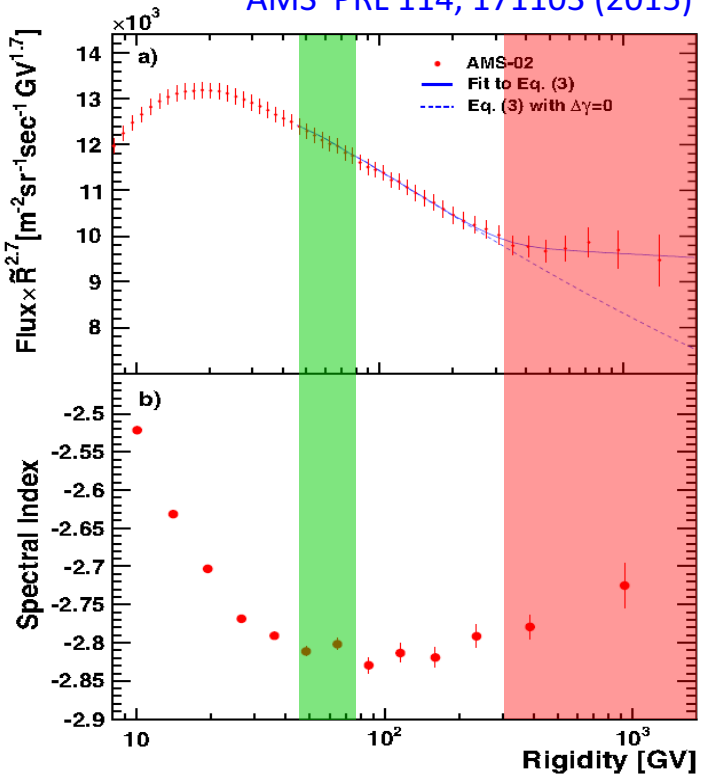
$\delta < 0.005$ at the 95% C.L.

High rigidity proton anisotropy

Search for anisotropies in the high rigidity proton sample using the low rigidity proton events (45-80 GV) as reference

$$r_p = p_{high}/p_{low}$$

AMS PRL 114, 171103 (2015)



Sample selection: 5 years

high rigidity protons:
p (300-1800 GV): 0.6 x 10^6 events

low rigidity protons:
p (45-80 GV): 11 x 10^6 events

proton anisotropy

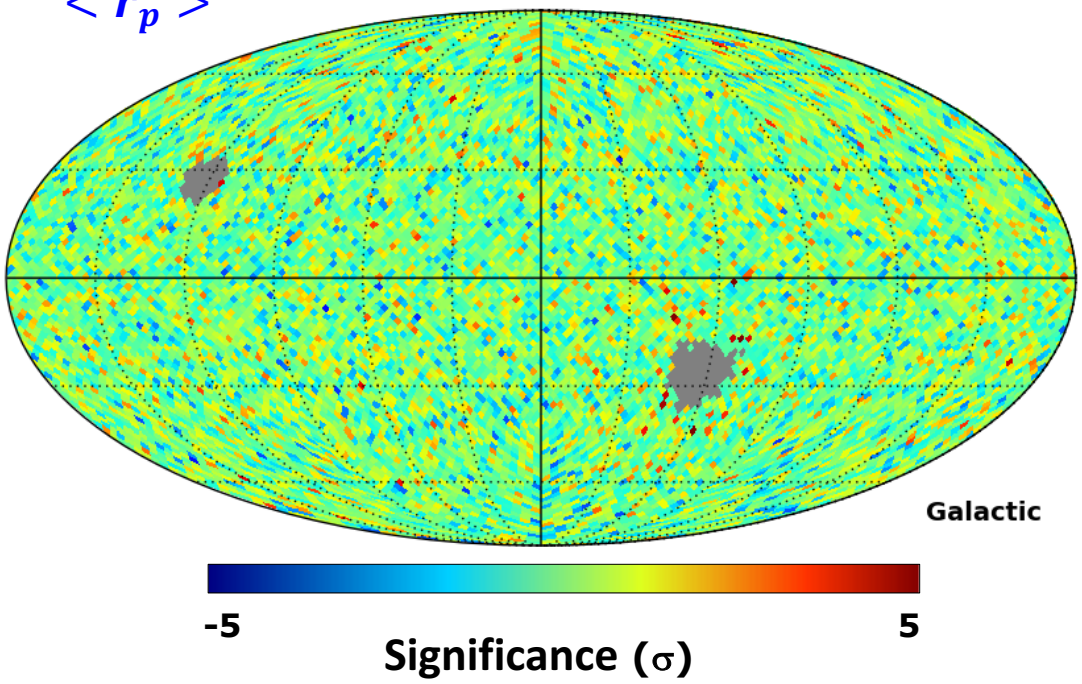
Relative fluctuation of the high rigidity to low rigidity ratio,

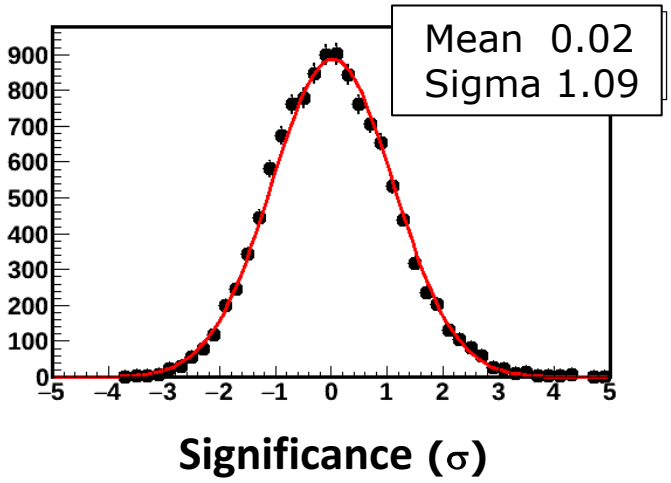
$$r_p = p_{high}/p_{low}$$

in galactic coordinates (b,l)

$$\frac{r_p(b,l) - < r_p >}{< r_p >}$$

Rigidity: 300-1800 GV (0.6 x 10^6 events)





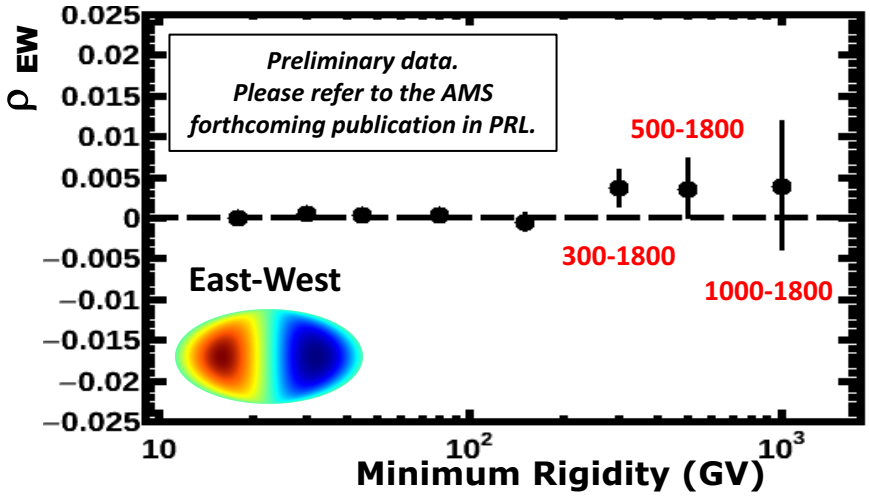
The observed sky map shows no evident pattern

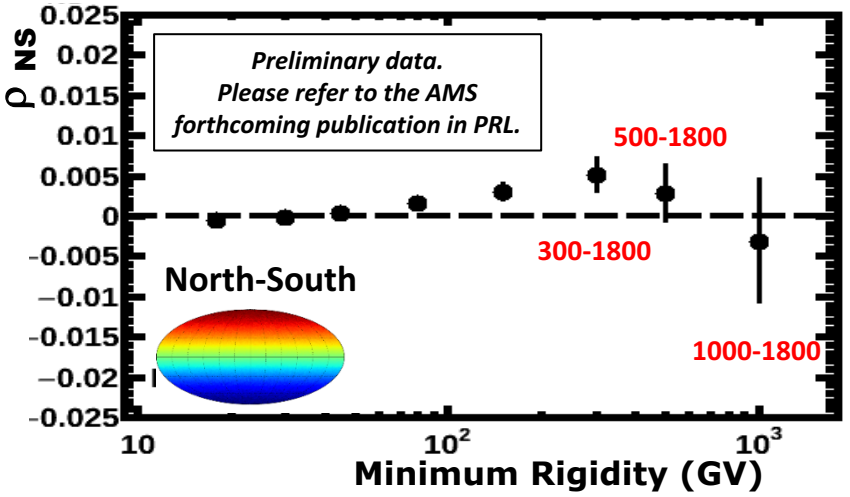
Proton absolute anisotropy

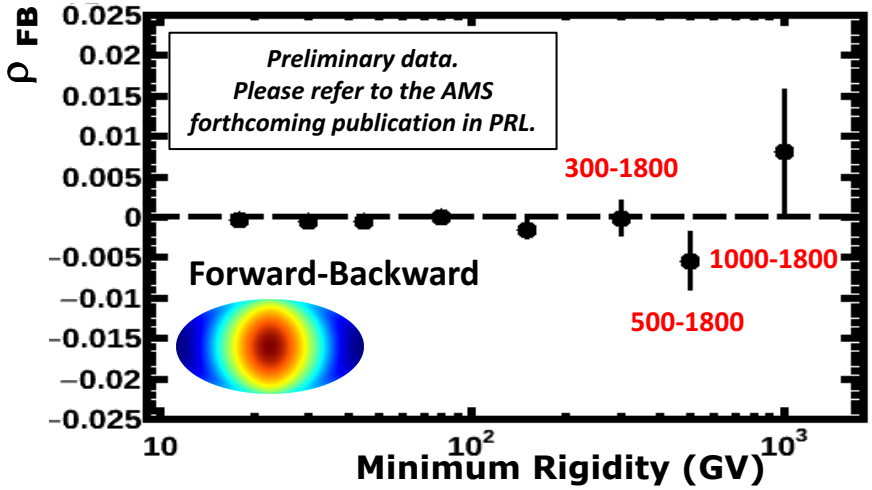
Fluctuations of the proton arrival directions are described by a spherical harmonic expansion

The selected events are grouped into 8 cumulative rigidity bins
18-1800, 25-1800, 45-1800, 80-1800, 150-1800,
300-1800, 500-1800 and 1000-1800 GV

Dipole components – Galactic Coordinates







Amplitude of the dipole anisotropy on protons (Rig: 300-1800 GV)

$\delta < 0.01$ at the 95% C.L.

Summary

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

AMS has measured the e^+ anisotropy in the energy range from 16 GeV to 350 GeV as being consistent with isotropy. An extended data taking, up to 2024, will allow to explore anisotropies of 1% on the positron cosmic ray sample.

No significant deviation from isotropy has been found in the analysis of the arrival directions of the high energy protons.

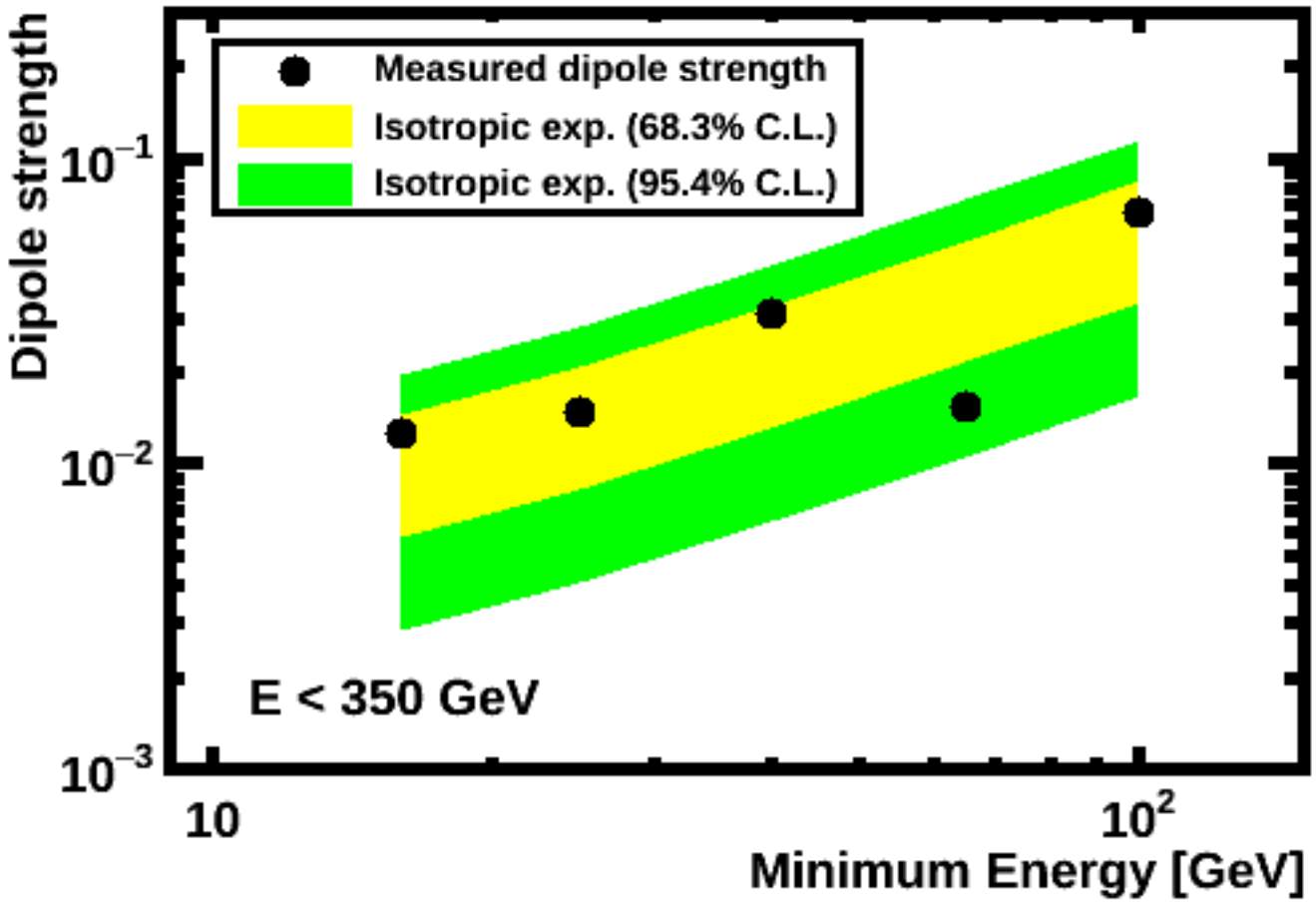
A limit on the amplitude of the dipole anisotropy for protons in the rigidity range between 300 and 1800 GV of $\delta < 0.01$ at the 95% C.L. has been obtained.

AMS will provide large sky coverage anisotropy measurements in the GeV-TeV energy range for individual cosmic ray particles.

BACKUP SLIDES

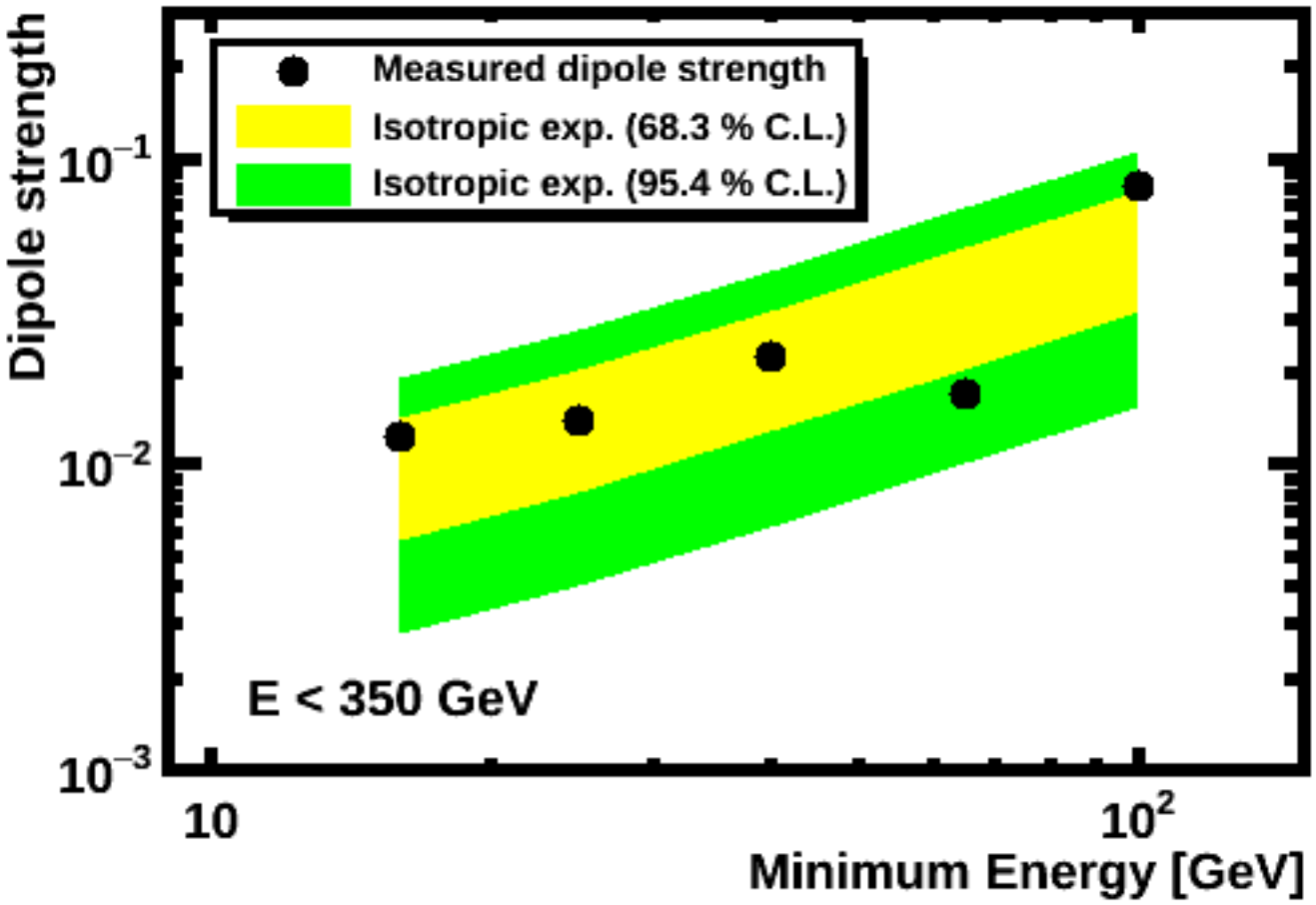
Positron to electron ratio anisotropy

Dipole Strength Vs Energy – Galactic Coordinates



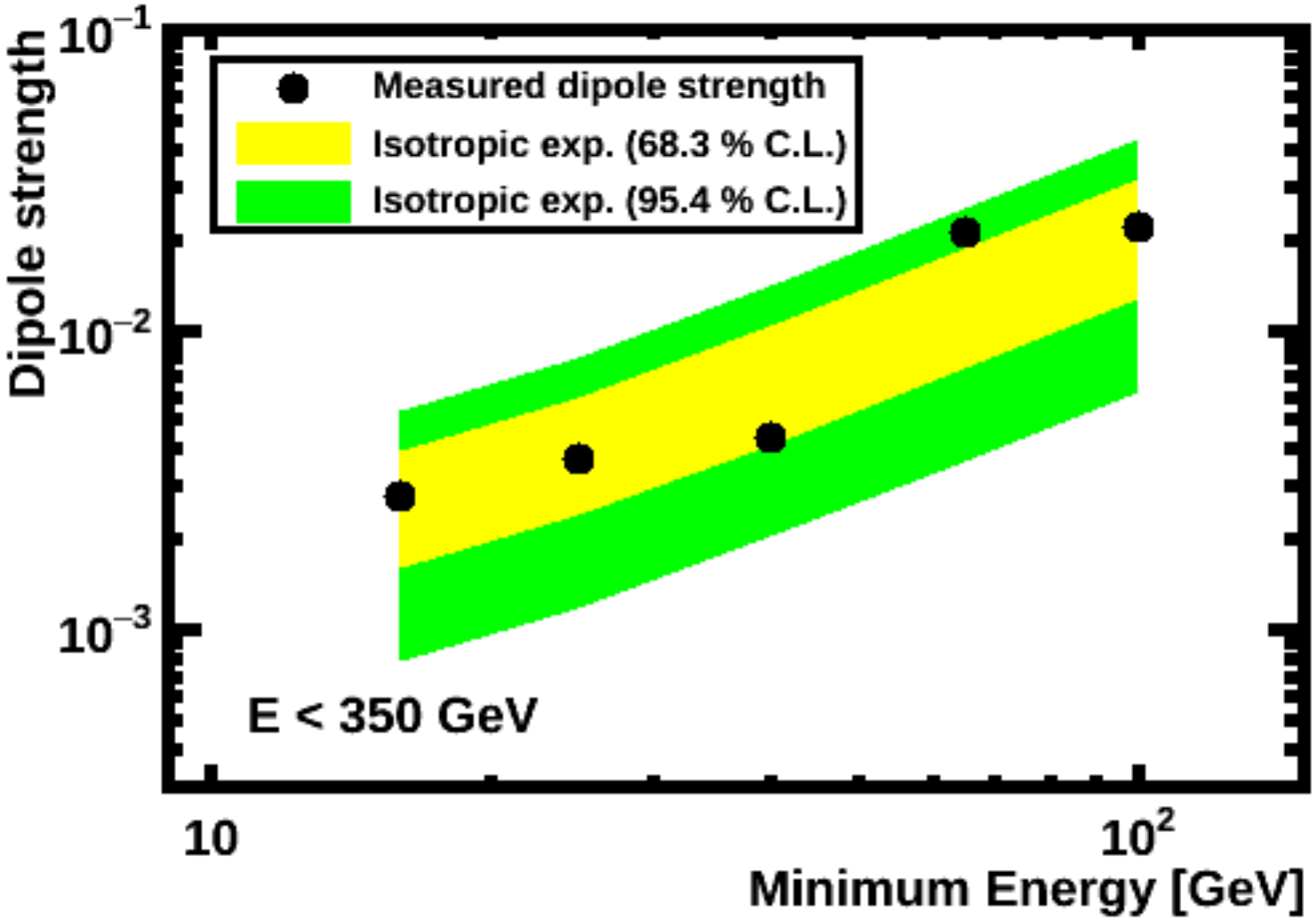
Positron absolute anisotropy

Dipole Strength Vs Energy – Galactic Coordinates



Electron absolute anisotropy

Dipole Strength Vs Energy – Galactic Coordinates



Proton absolute anisotropy

Dipole Strength Vs Energy – Galactic Coordinates