Measurement of anisotropies in cosmic ray arrival directions with the AMS detector on the Space Station

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on behalf of the AMS-02 collaboration

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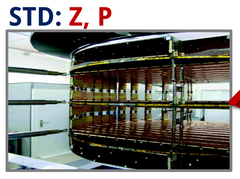
AMS-02 Experiment

A TeV precision, multipurpose spectrometer in space

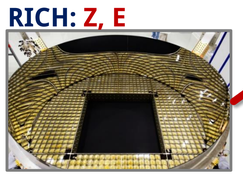
Particles and nuclei are defined by their charge (Z) and energy (E~P)

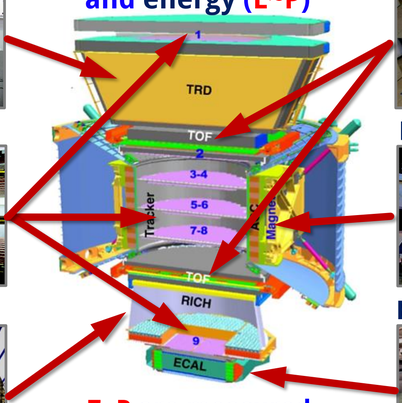
TRD: Identify e^+, e^-

STD: Z, P

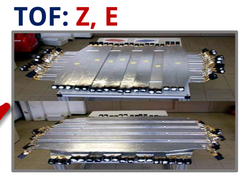


RICH: Z, E

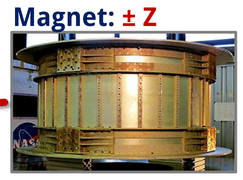




TOF: Z, E



Magnet: ± Z



ECAL: E of e^+, e^-, γ

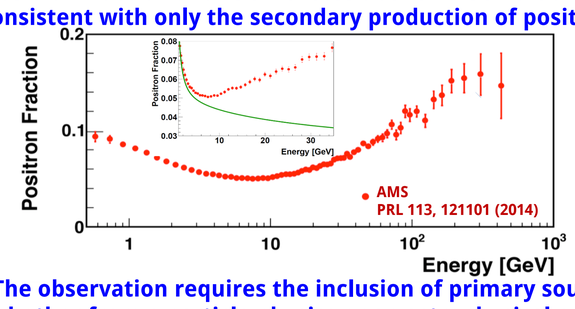
Z, P are measured independently by the Tracker, RICH, TOF and ECAL

Motivation for CR anisotropy searches with AMS-02

AMS-02 observes **structures in the spectra of e+, e-, p, He that cannot be fully explained within the current physical knowledge**. These features may be connected to new **phenomena which could induce some degree of anisotropy in the fluxes**: **local environment** (GMF, solar activity at low rigidity…) or **local sources** (pulsars, SNRs)

Positron fraction

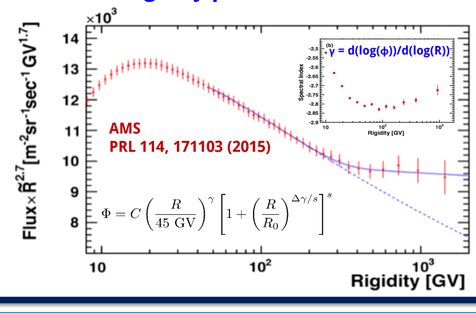
Positron fraction shows an excess above 10 GeV that is not consistent with only the secondary production of positrons.



The observation requires the inclusion of primary sources whether from a particle physics or an astrophysical origin, which may induce some degree of anisotropy on the measured e^+/e^- ratio

Proton flux

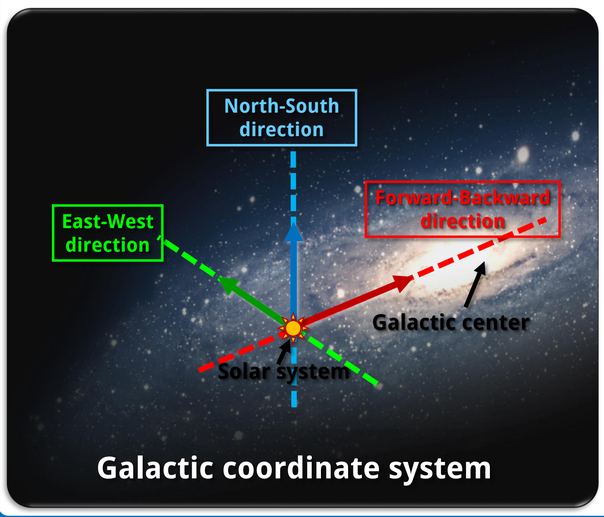
Proton cosmic ray spectra shows that the flux deviates from a single power law. The spectral index progressively hardens at R > 100 GV. A possible directionality in the high rigidity protons is studied



Methodology

Search of anisotropies in galactic coordinates

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



A **likelihood fit procedure** has been set up to compare the species under study to the reference sky map. It takes into account the differences in the exposure for different rigidities. A **spherical harmonics expansion** of the of the flux (or ratio of fluxes) is obtained:

$$\phi(\theta,\phi) = \phi_0 \left(1 + \sum_{\ell>1} \sum_{m=-\ell}^{m=\ell} a_{\ell m} Y_{\ell m}(\theta,\phi)\right)$$

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

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

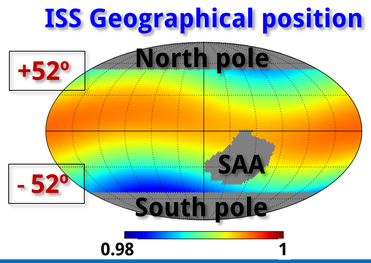
Reference maps for absolute anisotropies

Computation of isotropic skymaps for absolute anisotropies requires a precise understanding of detector's behavior

A **systematic procedure**, valid for all cosmic ray species, has been developed:

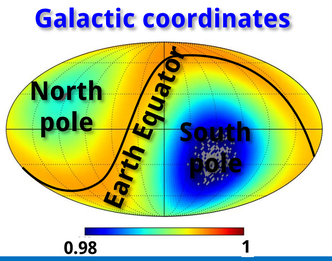
- **Acceptance** is divided in bins, each of one represents a direction in detector's local coordinates. Isotropic skymaps and event distribution maps in galactic coordinates are built for each pixel. **Analysis in individual bins is performed**.
- **Geographical dependence of efficiencies** may induce a spurious signal in cosmic ray arrival directions in galactic coordinates. A **parametrization of efficiencies in terms of spherical harmonics** has been used to take into account these effects.

ISS Geographical position



Parametrization of electron TRD efficiency

Galactic coordinates

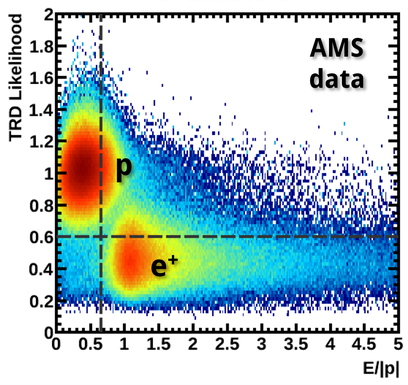


Results

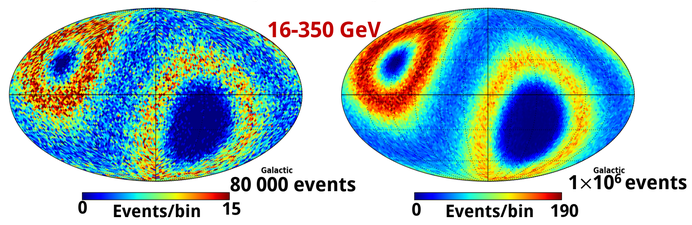
Positron to electron anisotropy

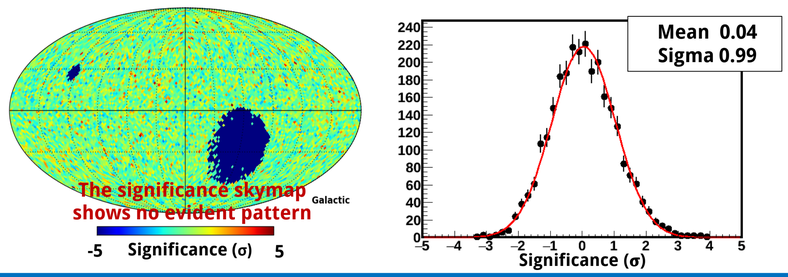
Sample selection

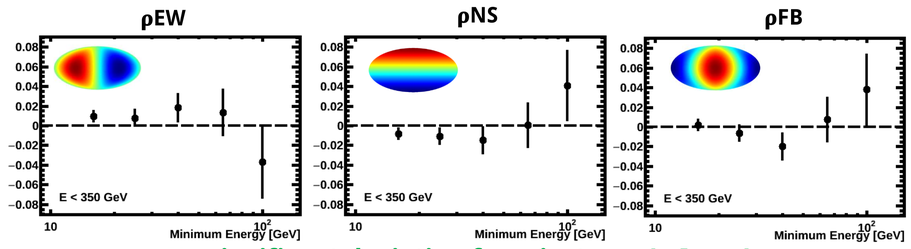
Proton background is reduced to below the percent level with a **selection based on cuts on E/p and the TRD and ECAL estimators**



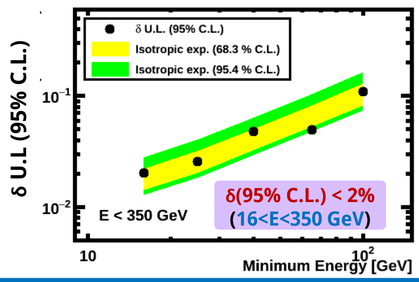
5 years (May 2011 – May 2016)







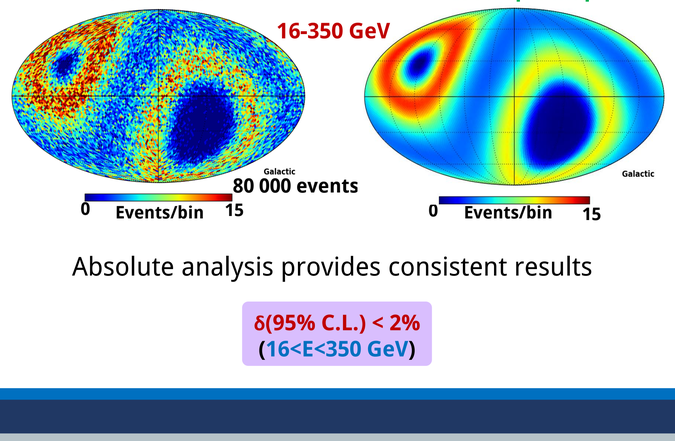
No significant deviation from isotropy is found



Positron absolute anisotropy

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

5 years (May 2011 – May 2016)

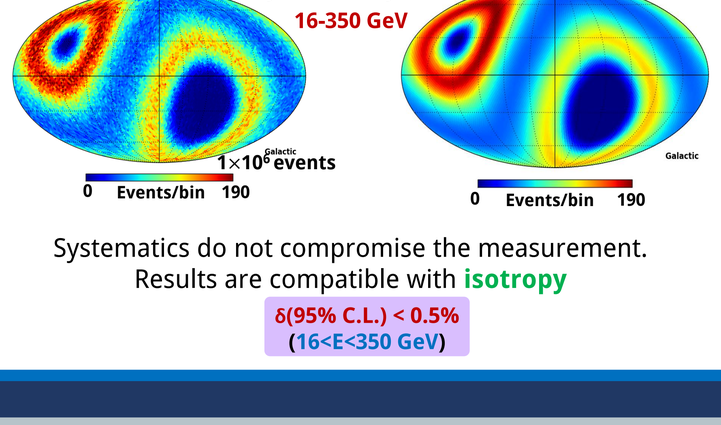


Absolute analysis provides consistent results

δ(95% C.L.) < 2%
(16<E<350 GeV)

Electron absolute anisotropy

By the end of the data taking in 2024, AMS-02 will collect about 200 000 positrons. Electron absolute anisotropy is a test of the systematics of this measurement

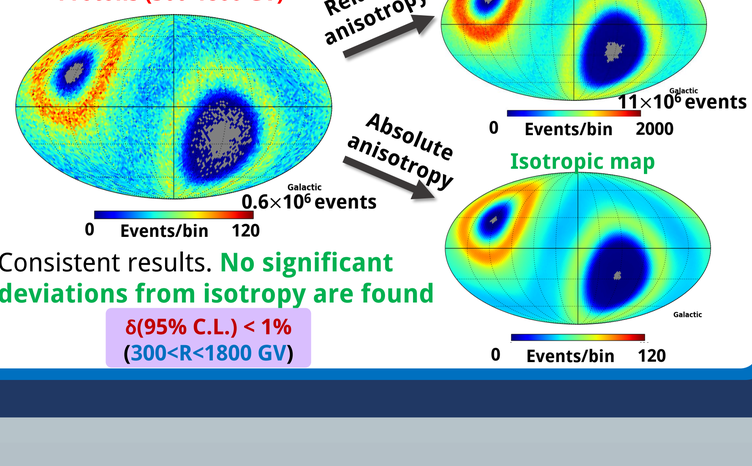


Systematics do not compromise the measurement. Results are compatible with **isotropy**

δ(95% C.L.) < 0.5%
(16<E<350 GeV)

Proton anisotropy

Anisotropy of high rigidity protons is studied considering low rigidity protons (45-80 GV) as reference. Proton absolute anisotropy is also studied



Consistent results. **No significant deviations from isotropy are found**

δ(95% C.L.) < 1%
(300<R<1800 GV)