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Precision measurements of Electron and Positron Fluxes with the Alpha Magnetic Spectrometer on the International Space Station

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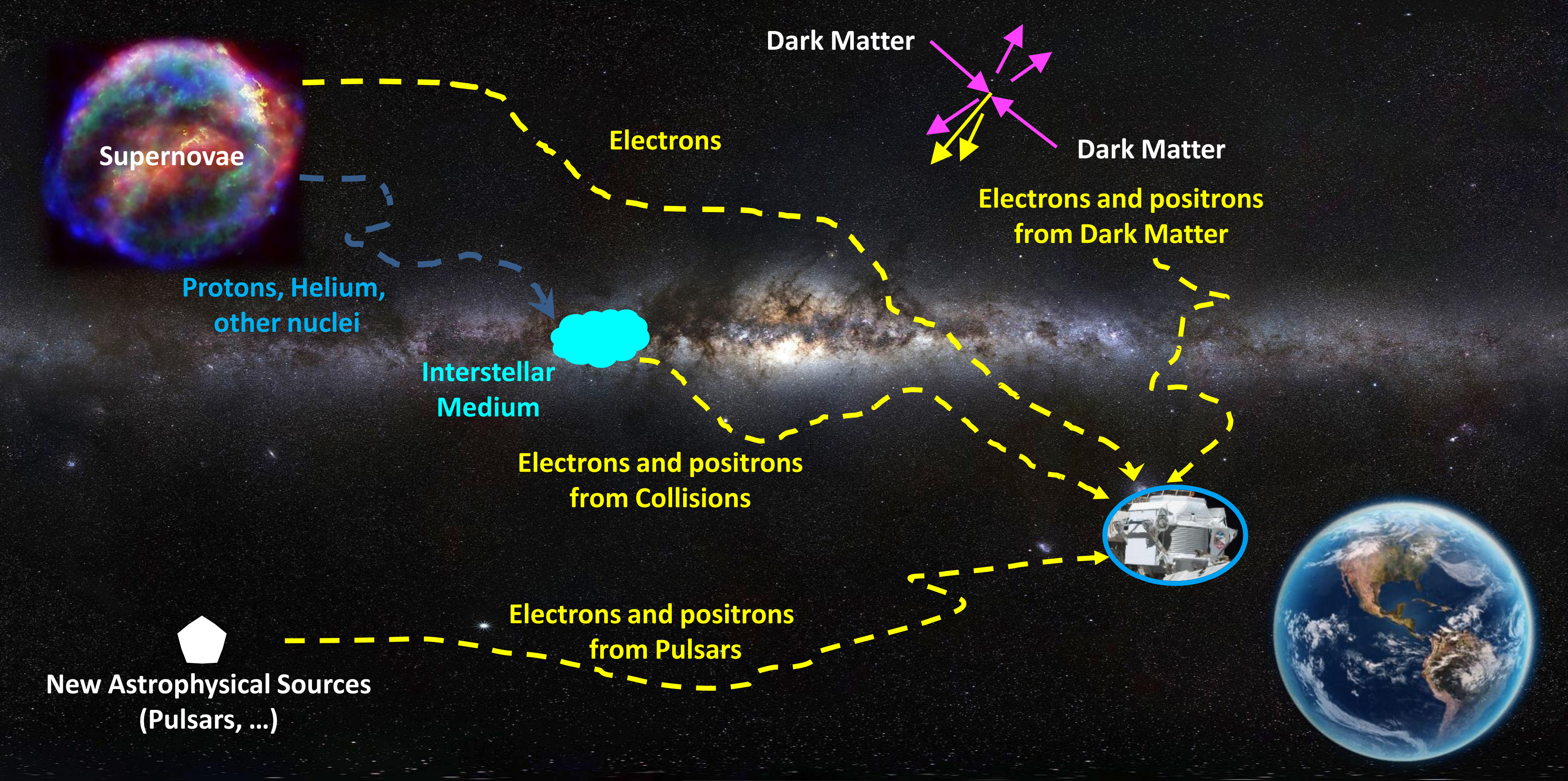
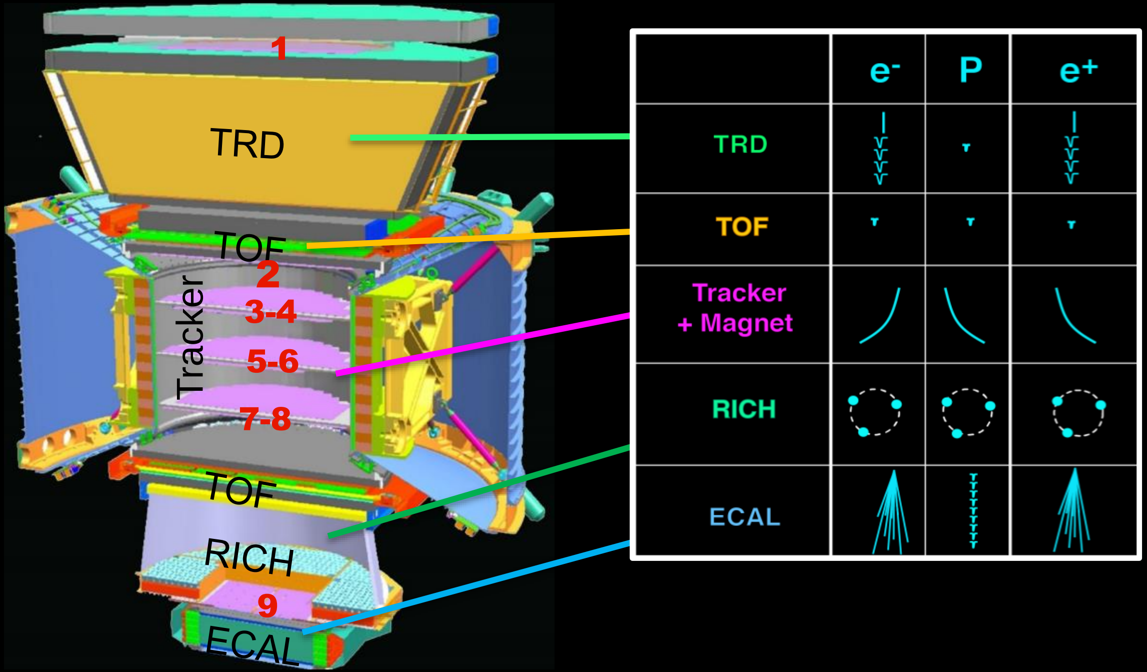
física de partículas

Cosmic rays: electrons and positrons



Positron & Electron Identification in AMS

AMS subdetectors provide independent information on cosmic rays (Z, P, E, β) with redundant measurements



Particle Identification

Positron & Electron Identification in AMS

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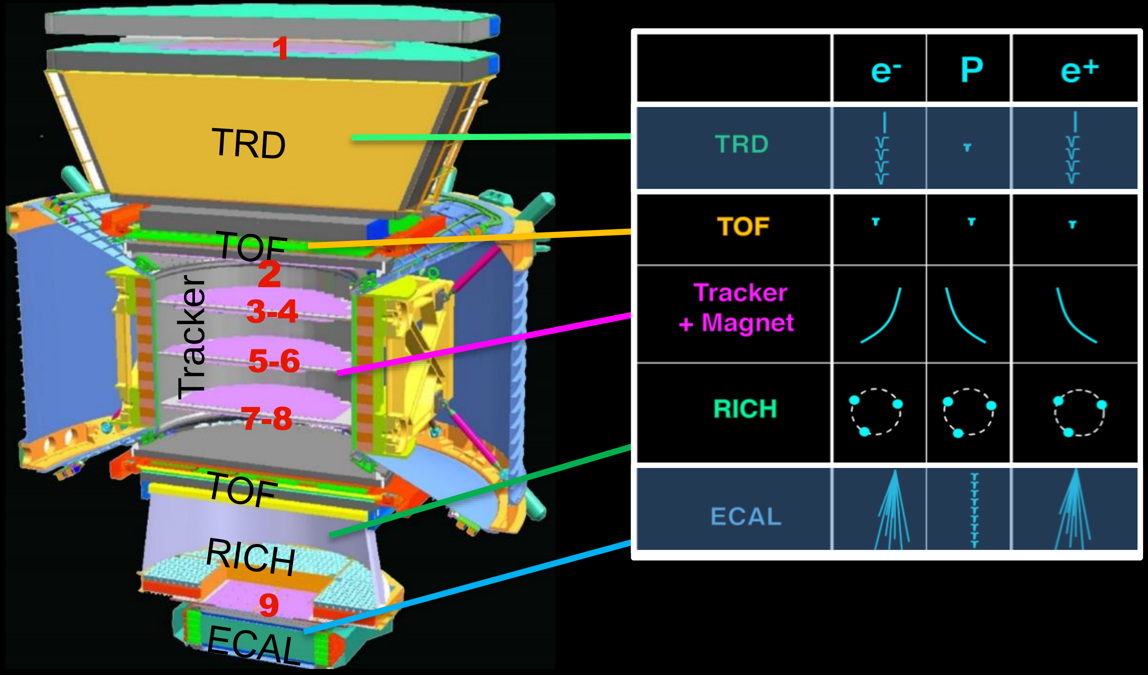
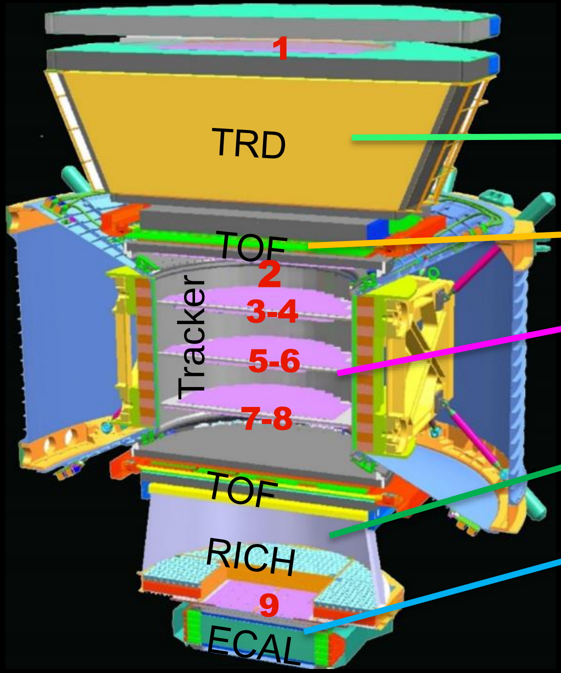


Particle Identification

- **p are separated from $e^{\pm}$ samples using TRD and ECAL.**

Positron & Electron Identification in AMS

AMS subdetectors provide independent information on cosmic rays (Z, P, E, β) with redundant measurements



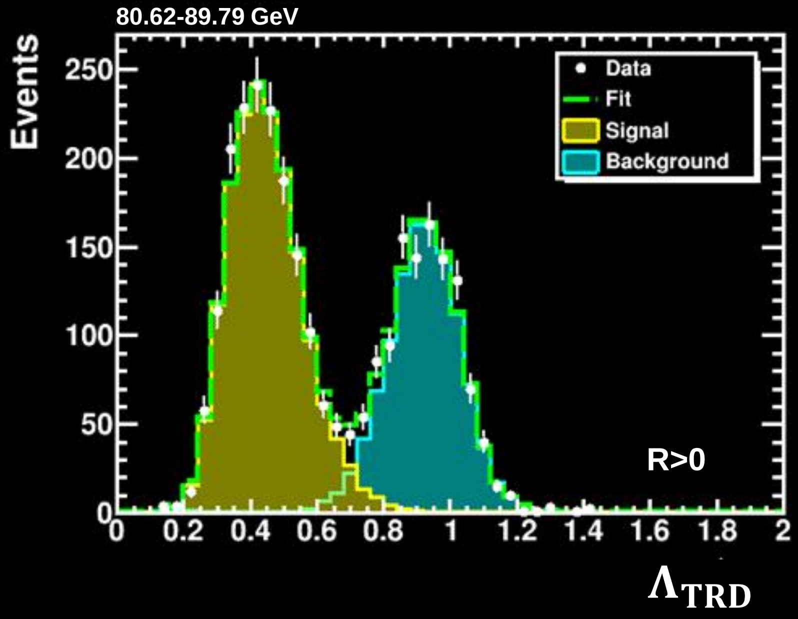
	e^-	P	e^+
TRD			
TOF			
Tracker + Magnet			
RICH			
ECAL			

Particle Identification

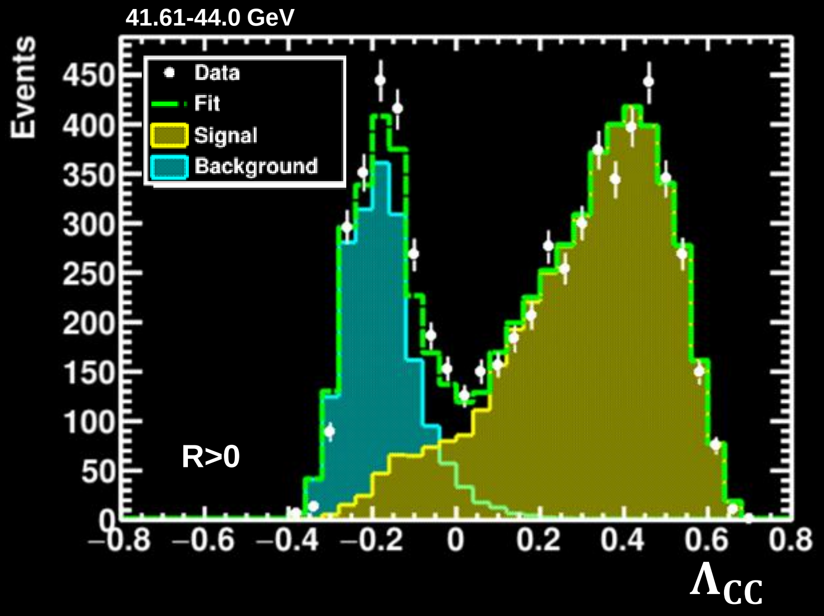
- p are separated from $e^{\pm}$ samples using TRD and ECAL.
- e^- and e^+ are identified with the sign of the track curvature inside the magnetic field.

Analysis: Event Selection

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



Charge Confused (CC) electrons in the positron sample are reduced with a cut on a CC estimator that combines variables from TRD, TOF and Tracker.



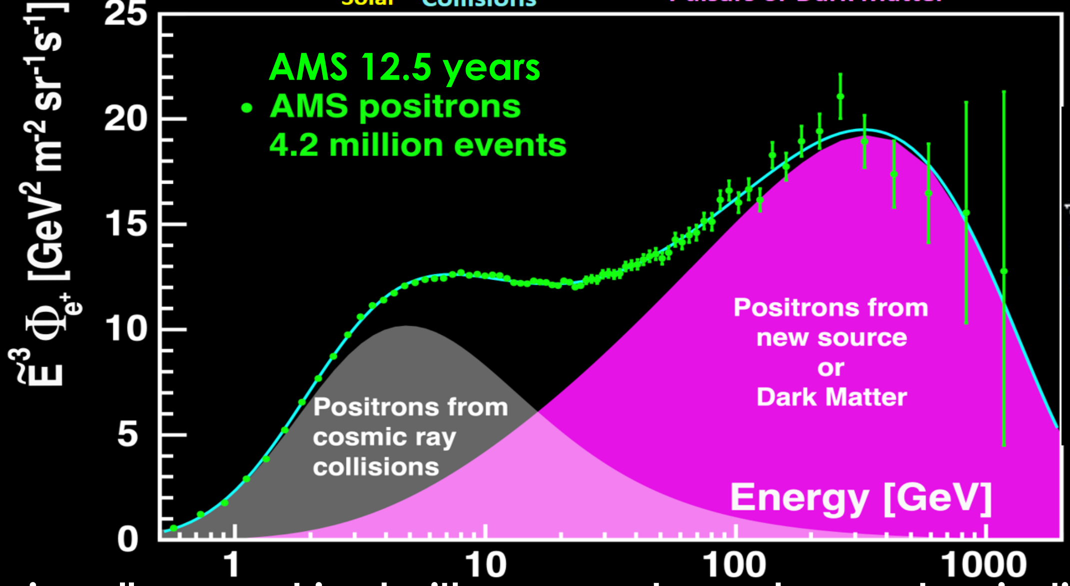
This selection ensures a positron purity above 95% and negligible contamination in the electron sample

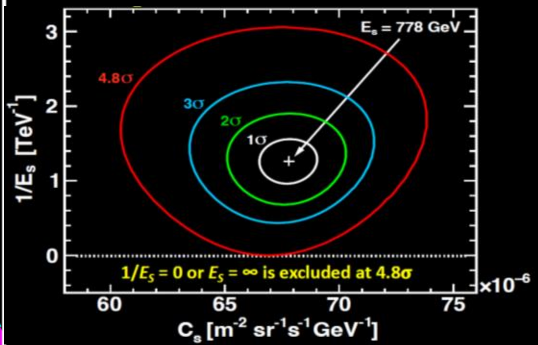
Measurement of the positron flux

The positron flux shows a significant deviation which is not in agreement with only the expected production through collisions with the ISM.

$$\Phi_{e^+}(E) = \frac{E^2}{\hat{E}^2}\left[C_d(\hat{E}/E_1)^{\gamma_d} + C_s(\hat{E}/E_2)^{\gamma_s}\exp(-\hat{E}/E_s)\right]$$

Solar Collisions Pulsars or Dark Matter



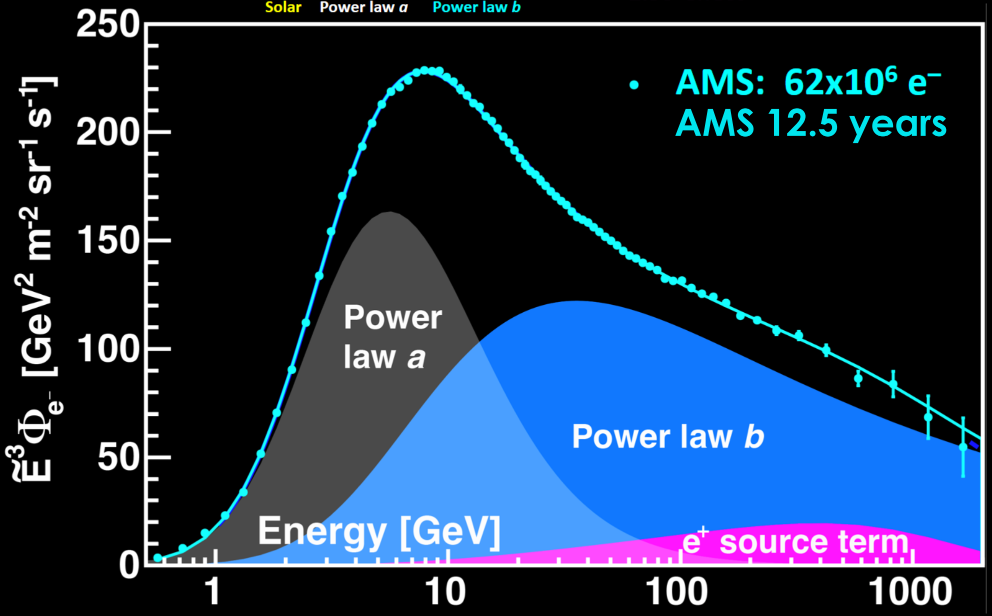


The excess is well parametrized with a source term whose nature is still unclear and its possible explanations are divided in two kinds, Dark Matter or astrophysical point sources like pulsars.

Measurement of the electron flux

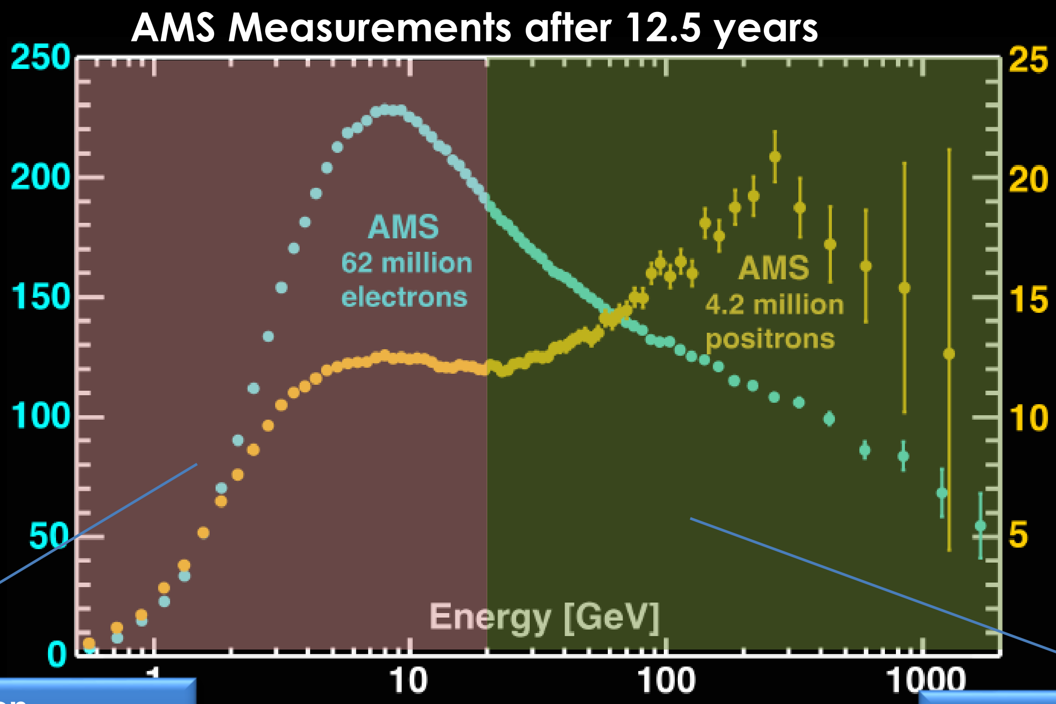
Electron spectrum is described with two power laws (a, b) and the same source term for positrons.

$$\Phi_{e^-}(E) = \underbrace{\frac{E^2}{\widehat{E}^2}}_{\text{Solar}}\left(\underbrace{C_a \widehat{E}^{\gamma_a}}_{\text{Power law } a} + \underbrace{C_b \widehat{E}^{\gamma_b}}_{\text{Power law } b} + \underbrace{\text{Positron Source Term}}_{2.5\sigma \text{ effect}}\right)$$



The significance of the existence of the charge symmetric source term in the electron flux is at 2.5σ

Additional characterization of the fluxes



Time variation
Understand the solar modulation

Anisotropies
Identify potential sources

CIEMAT Group leads
both analyses

Anisotropy analysis

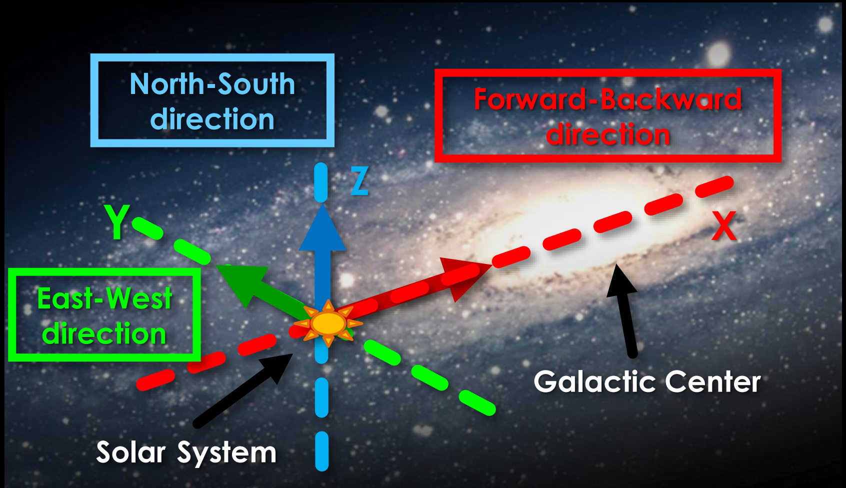
The source of positrons can be explained by:

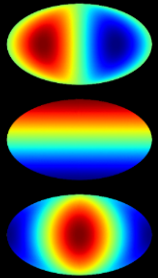
- Dark matter
- Astrophysical point sources as pulsar.

A nearby source of positrons will induce an anisotropy of amplitude at percent level.

The directional dependence of the CR fluxes is described in terms of a spherical harmonic expansion in the galactic coordinate system.

$$\Phi(\theta,\varphi) = \Phi_o(1 + \rho_{EW} \sin\theta \sin\varphi + \rho_{NS} \cos\theta + \rho_{FB} \sin\theta \cos\varphi)$$





ρ_{EW} East-West

ρ_{NS} North-South

ρ_{FB} Forward-Backward

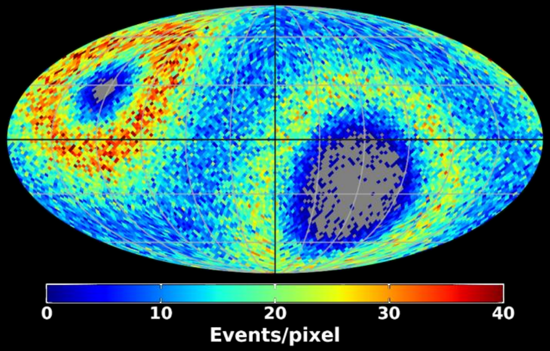
Dipole amplitude

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

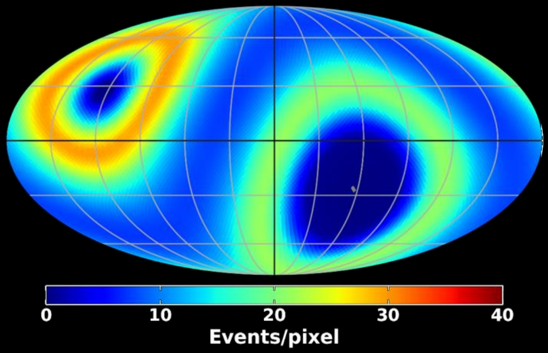
Absolute Anisotropy in the positron flux

The arrival directions of positrons are compared to the expected map for an isotropic flux in galactic coordinates in five cumulative energy bins from 16 to 500 GeV.

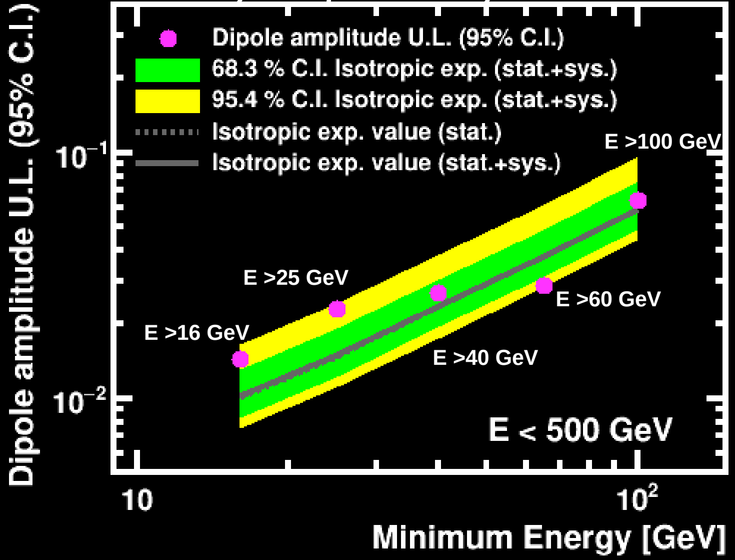
1.5 × 10^5 positrons
AMS 11 years (16<E/GeV<500)



Isotropic map
(with exposure time and efficiencies)



AMS 11 years preliminary data



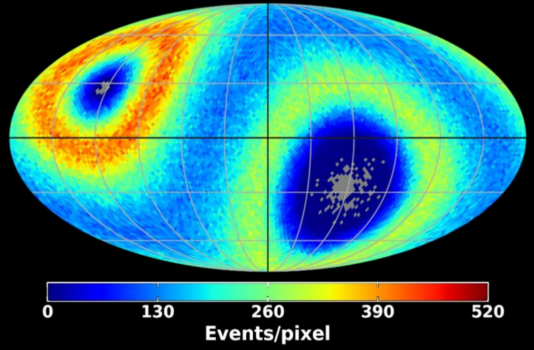
Results are consistent with isotropy

δ < 1.44% at the 95% C.I.
for 16 < E/GeV < 500

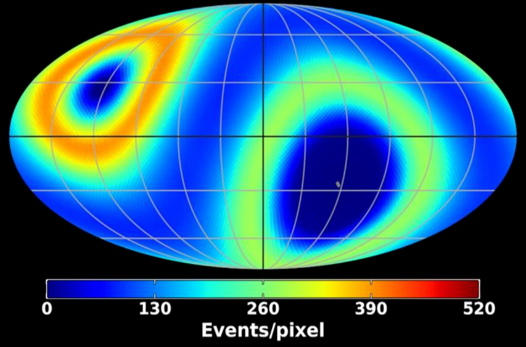
Absolute Anisotropy in the electron flux

The arrival directions of electrons are compared to the expected map for an isotropic flux in galactic coordinates in five cumulative energy bins from 16 to 500 GeV.

3.4×10^6 electrons
AMS 11 years (16<E/GeV<500)



Isotropic map
(with exposure time and efficiencies)



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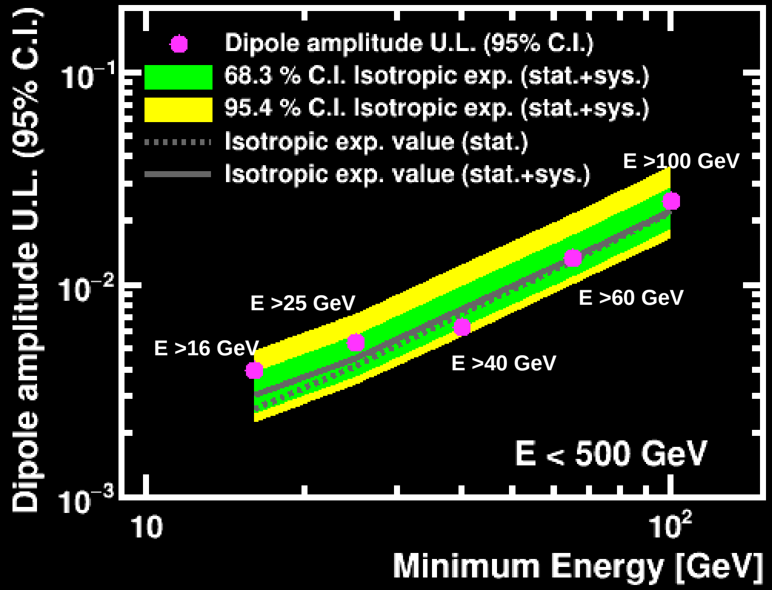
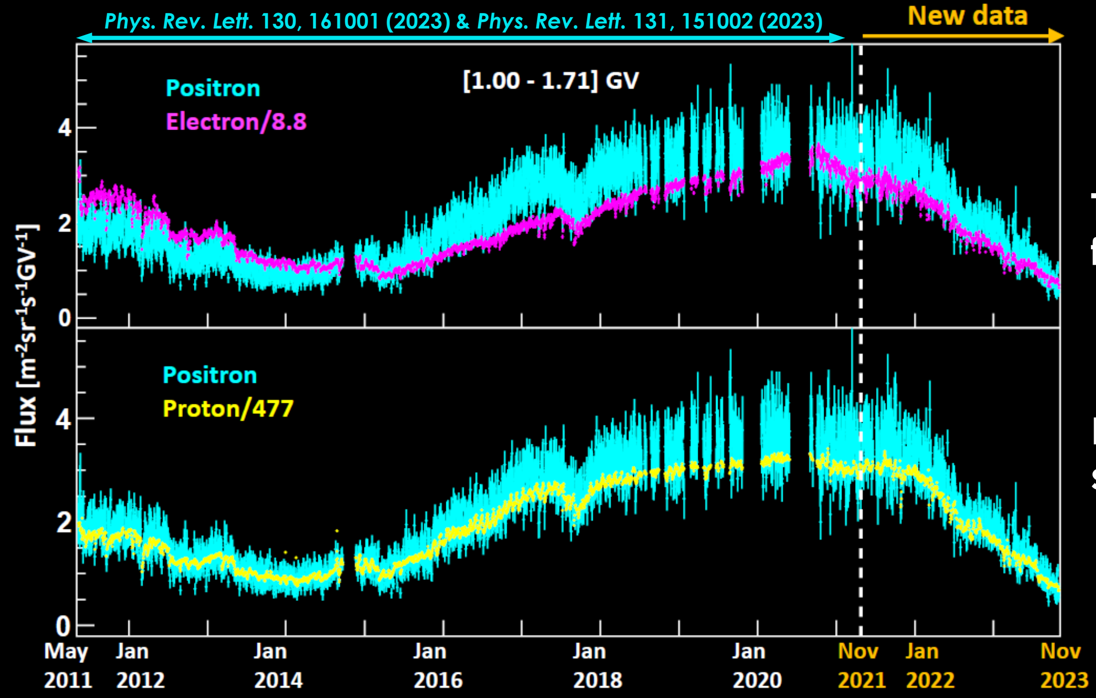


Results are consistent with isotropy

δ < 0.39% at the 95% C.I.
for 16 < E/GeV < 500

Time variations and Solar modulation

At low energies the fluxes are modulated by the solar activity
Fluxes exhibit short-term variations on the scale of days to months and long-term variations on the scale of years



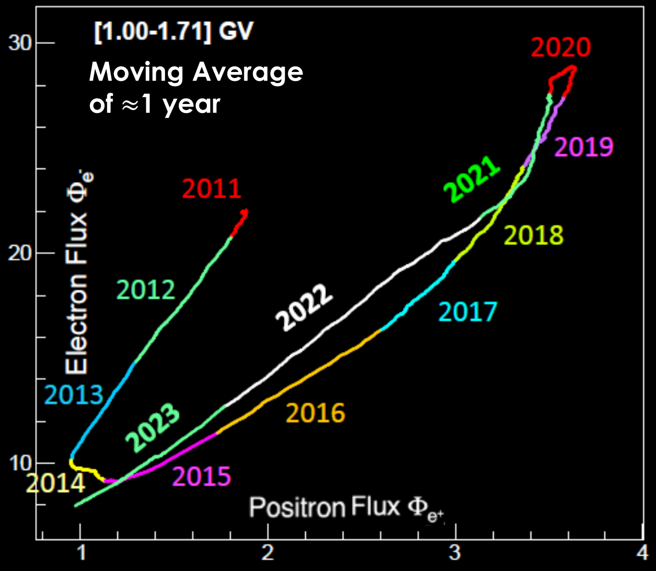
Time variations of positron and electron fluxes are clearly different.

Positron and proton fluxes present a similar behavior over time.

Time variation and Solar modulation

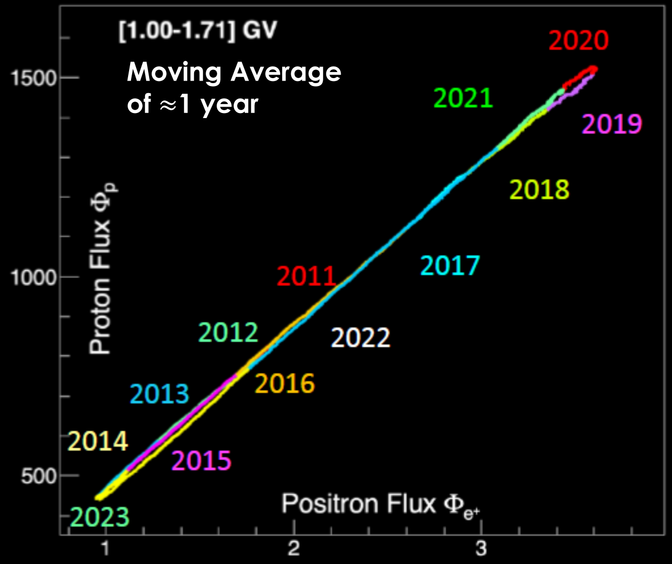
At low energies the fluxes are modulated by the solar activity

Same mass, opposite charge



Complex hysteresis

Different mass, same charge



Linear correlation

Conclusions

- AMS has provided the most precise measurements of the electron and positron fluxes, which show unexpected features:
  - Positron flux can not be explained by only secondary production and needs a source term.
  - Electron flux is consistent with the presence of the same source term as positron flux.
- Analysis of the arrival directions provides useful information which may explain these observed features in their spectra.
  - Both fluxes are compatible with the isotropy.
- Analysis of time variations reveals that the effect of the solar modulation is different for particle with same mass and opposite charge sign.
- AMS-02 will continue taking data with increased sensitivity until the end of the ISS operation to shed light on the origin of the observed features.