Towards Understanding the

Origin of Cosmic-Ray Positrons

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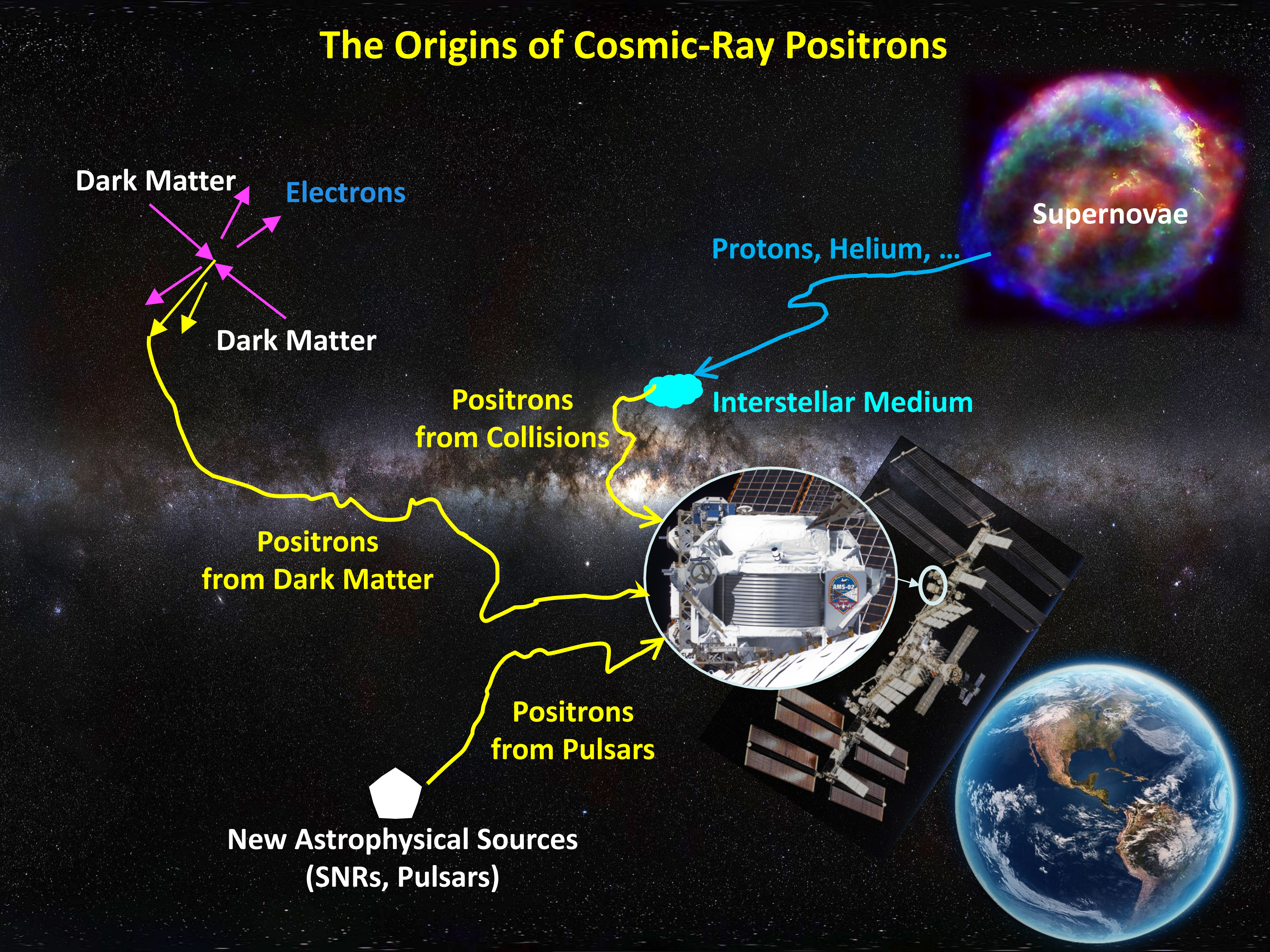
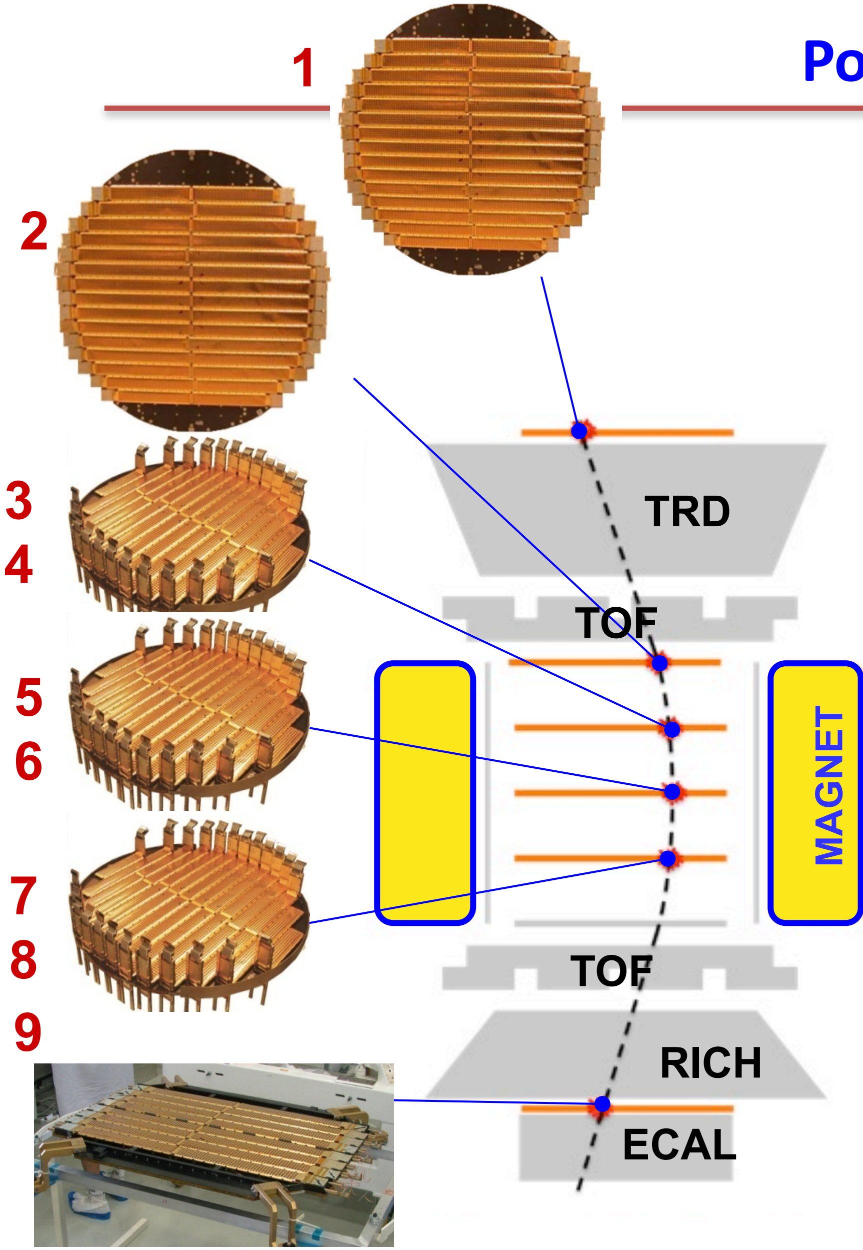
on behalf of the AMS Collaboration

36th ICRC, Madison

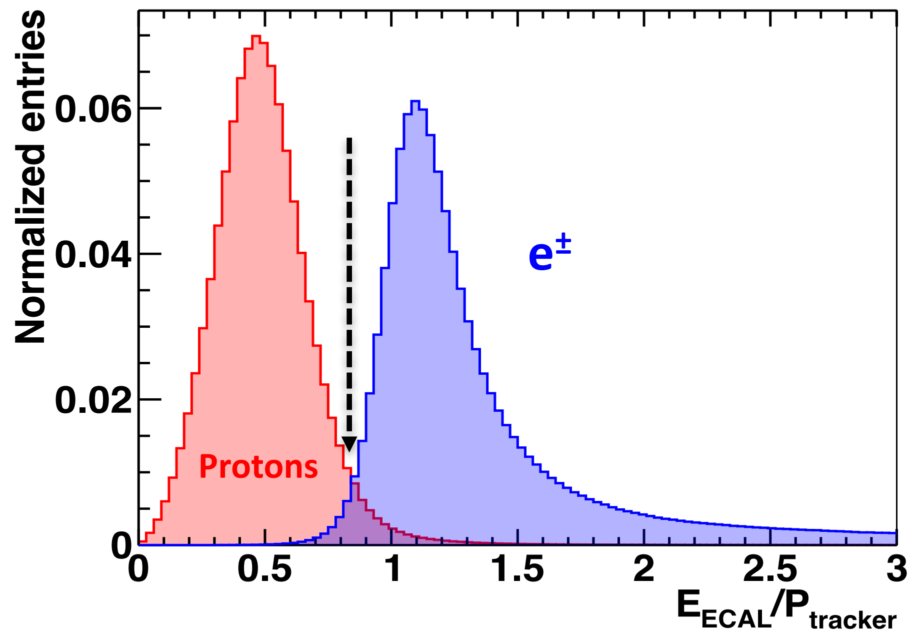

The Origins of Cosmic-Ray Positrons
Dark Matter
Electrons
Dark Matter
Supernovae
Protons, Helium, …
Interstellar Medium
Positrons
from Collisions
Positrons
from Dark Matter
AMS-02
Positrons
from Pulsars
New Astrophysical Sources
(SNRs, Pulsars)

Positrons Measurement in AMS



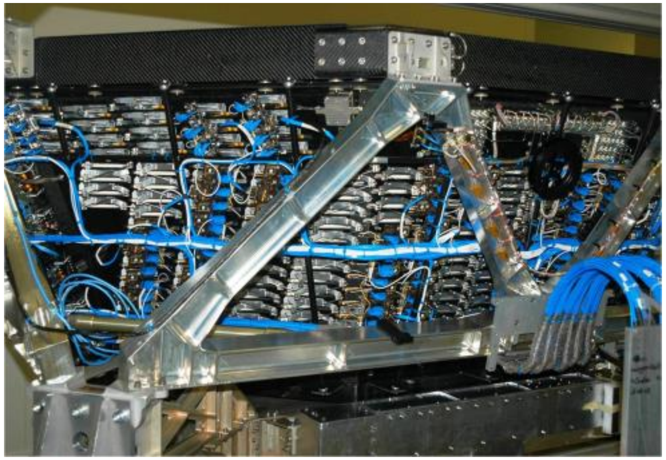
L1 to L9: 3m level arm;
single point resolution 10 μm;

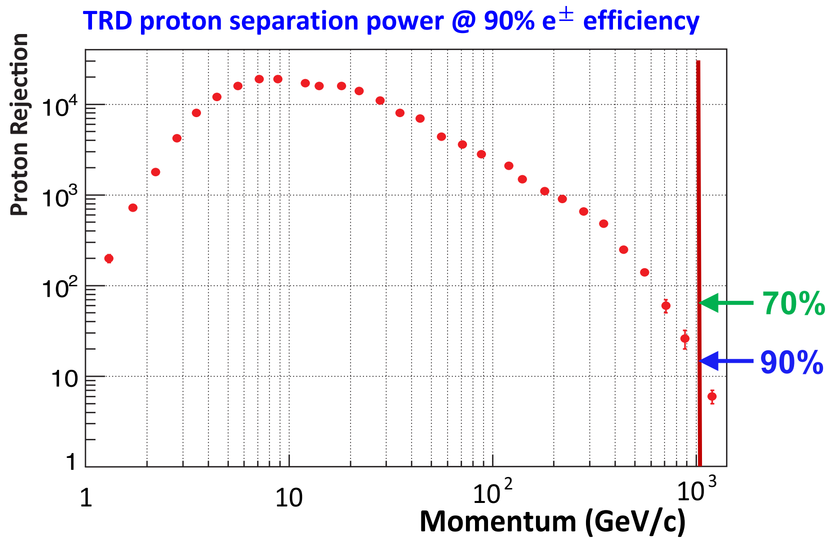
- Tracker and Magnet Measures the sign and magnitude of the positron and electron to few TeV.
- Unique particle identification capability of AMS: Independent Momentum and Energy measurement



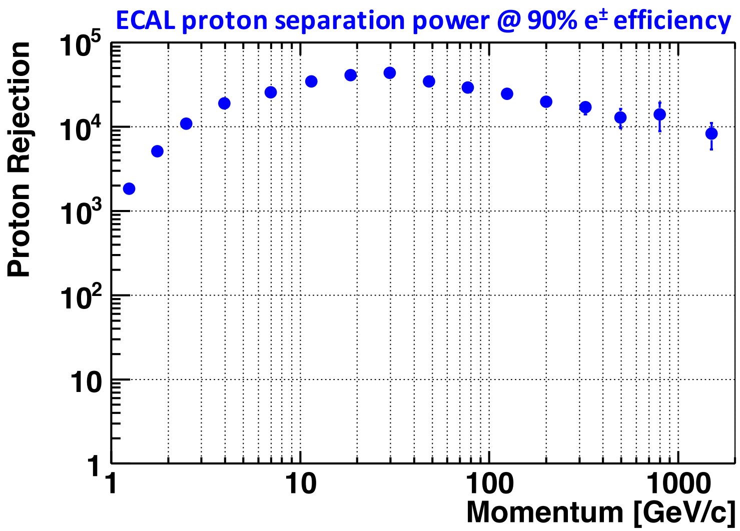
- Identify electron charge confusion:
  - Large angle scattering,
  - Interaction with detector materials.
  - Identified and measured from data using Charge confusion estimator Λ_{CC}

Positrons Measurement in AMS





- **TRD: Identify e± from protons using transition radiation. Combine 20 layers proportional tubes signal: Λ_{TRD} .**



- **ECAL : 17 X_0 , TeV Precision 3D measurement of the energy and shower development of electrons and positrons.**

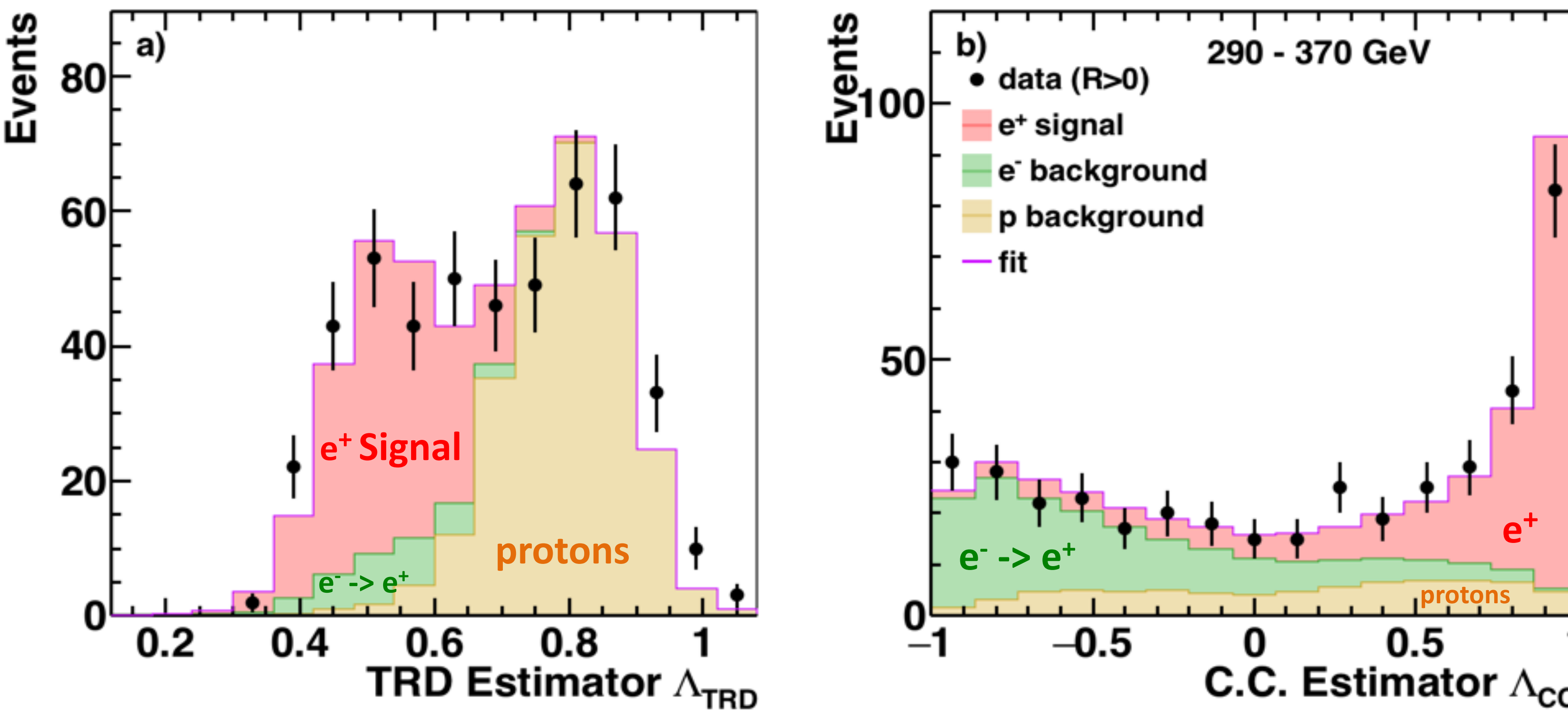
TRD and ECAL are separated by the Magnet

They have independent particle identification: combined rejection > 1 in 10^6

Positrons Measurement in AMS

- For each bin, number of e^+ are obtained from a fit to data sample in $(\Lambda_{TRD} - \Lambda_{CC})$ plane
- Precision determination of Signal and Background from Data
  - Positron Signal are clearly identified in the signal region of Λ_{TRD} and Λ_{CC}
  - Proton : identified by TRD estimator Λ_{TRD}
  - Electron charge confusion measured from data using Charge confusion estimator Λ_{CC}

Fit to Data, Positive Rigidity, 290 – 370 GeV

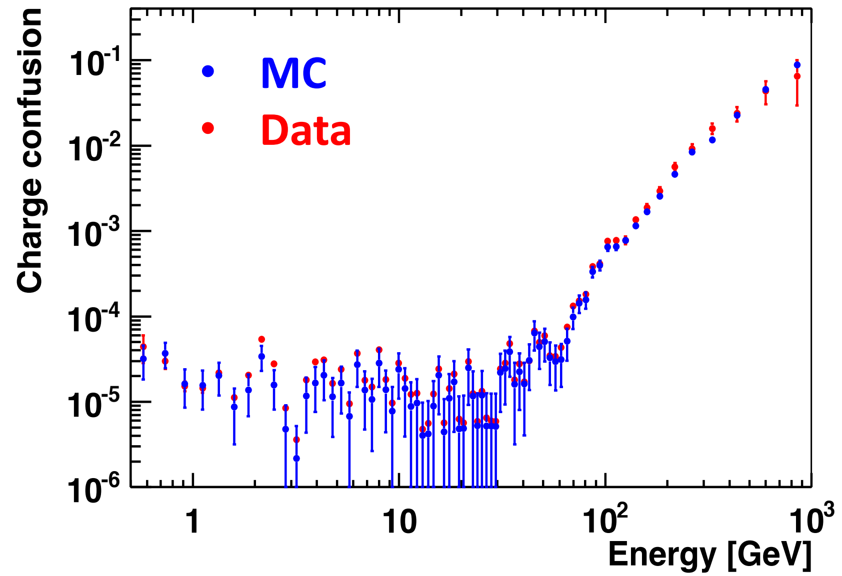


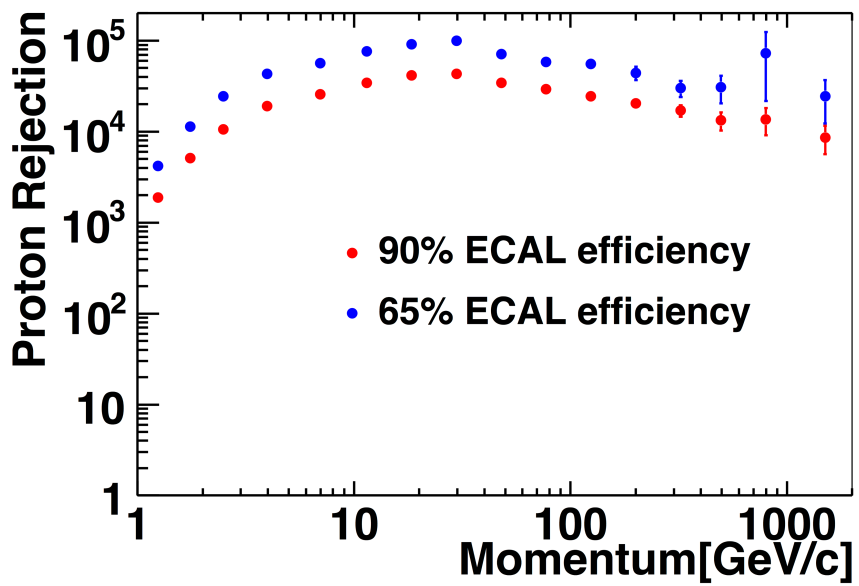
In 6.5 Years: 1.9 million positrons from 0.5 GeV – 1 TeV

Positron Flux Measurement

- Detailed systematic error analysis and exhaustive cross-check with different methods.

- Electron Charge confusion:
  - Charge confusion fraction is less than 8% for energy bin [700 – 1000] GeV
  - Measured directly from data. Good agreement between data and Monte Carlo.
- Proton background:
  - The measurement is stable over wide ranges of the selections.
- Accurate Energy Measurement:
  - Uncertainty in the absolute energy scale: ~2% at [10, 300] GeV, ~2.5% at 1TeV





Measurement accuracy are limited by statistical uncertainty

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Editors' Suggestion

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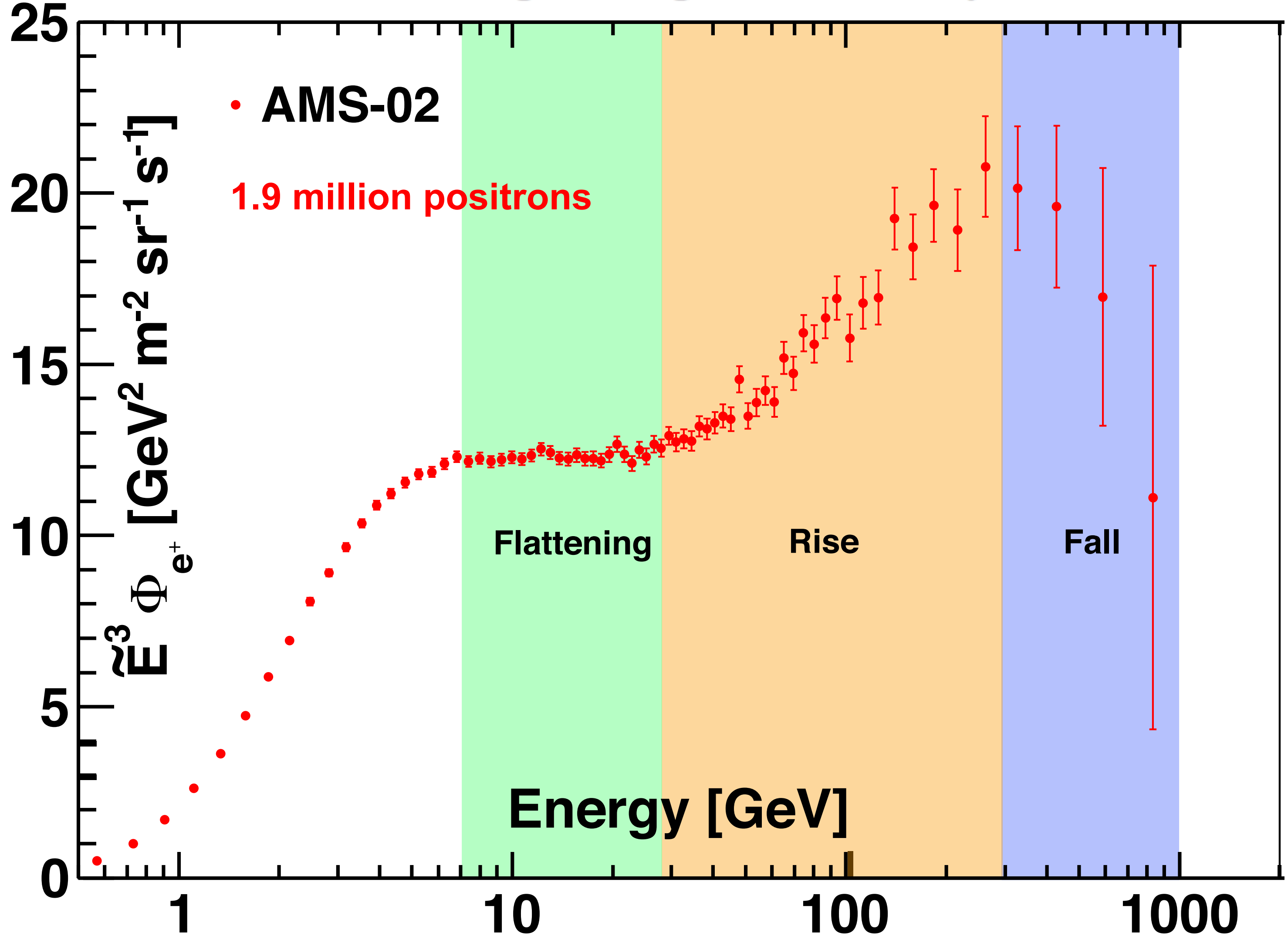
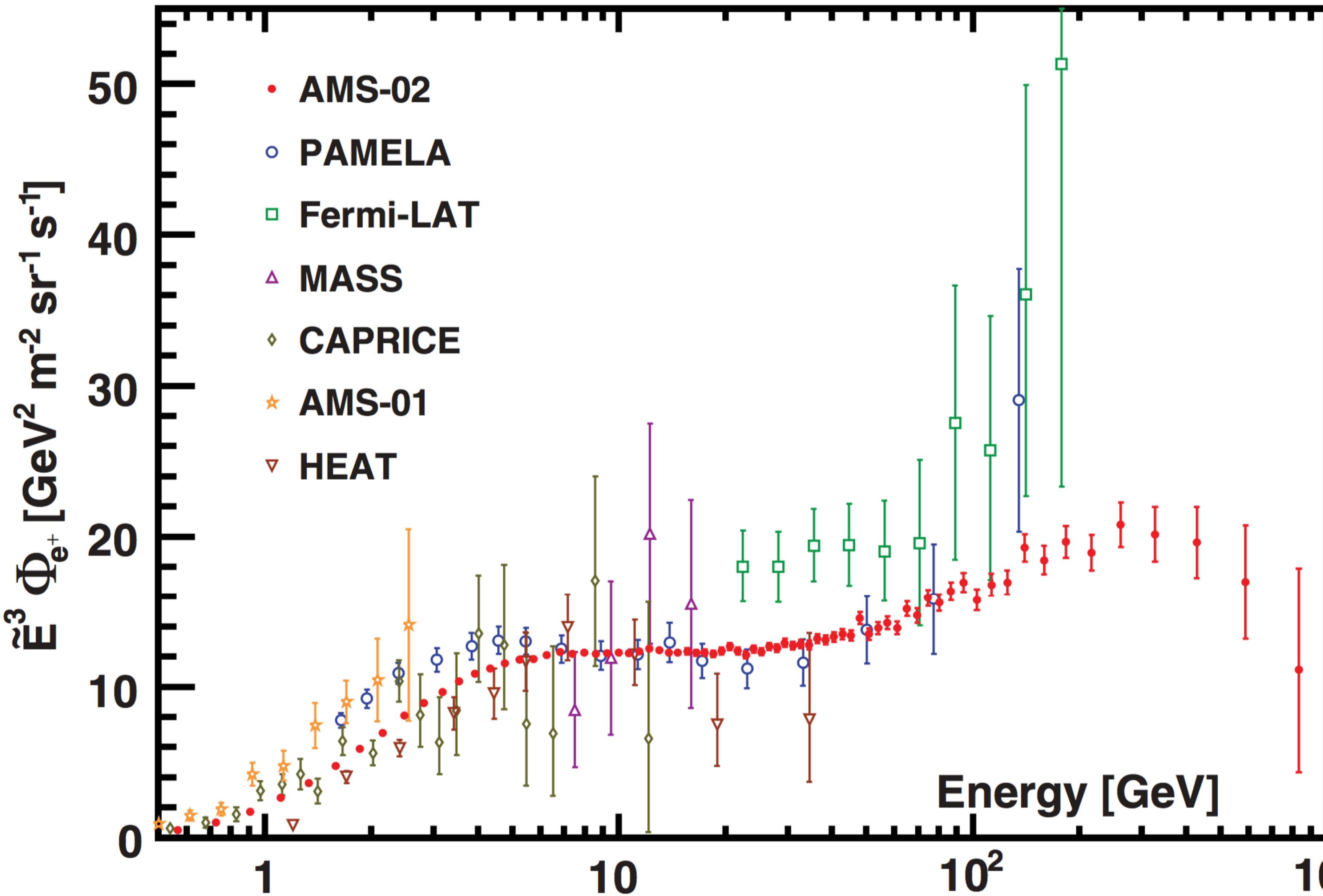


Positron spectrum exhibits complex energy dependence

AMS Positron Measurements to uncharted Energy Range



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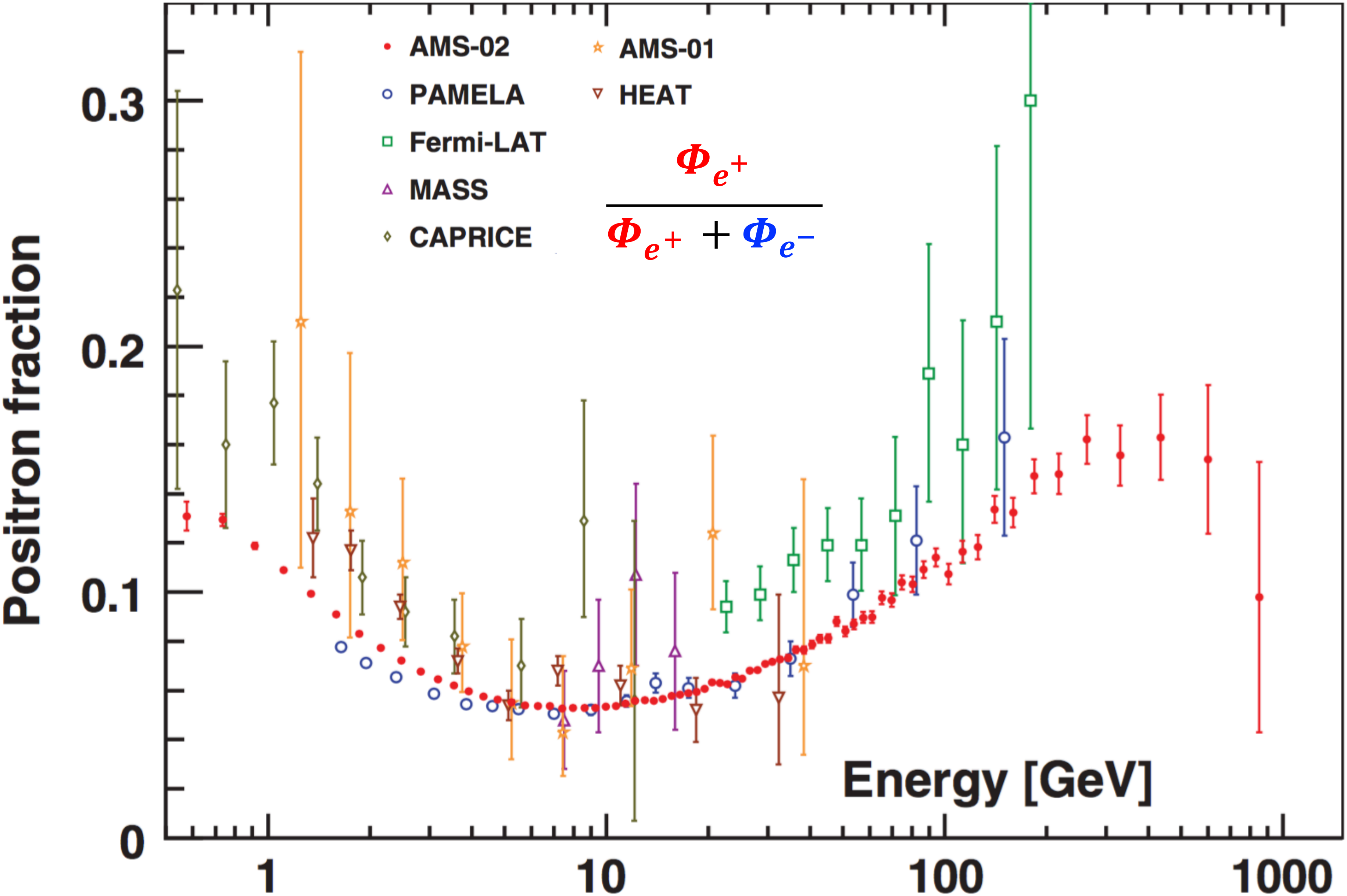
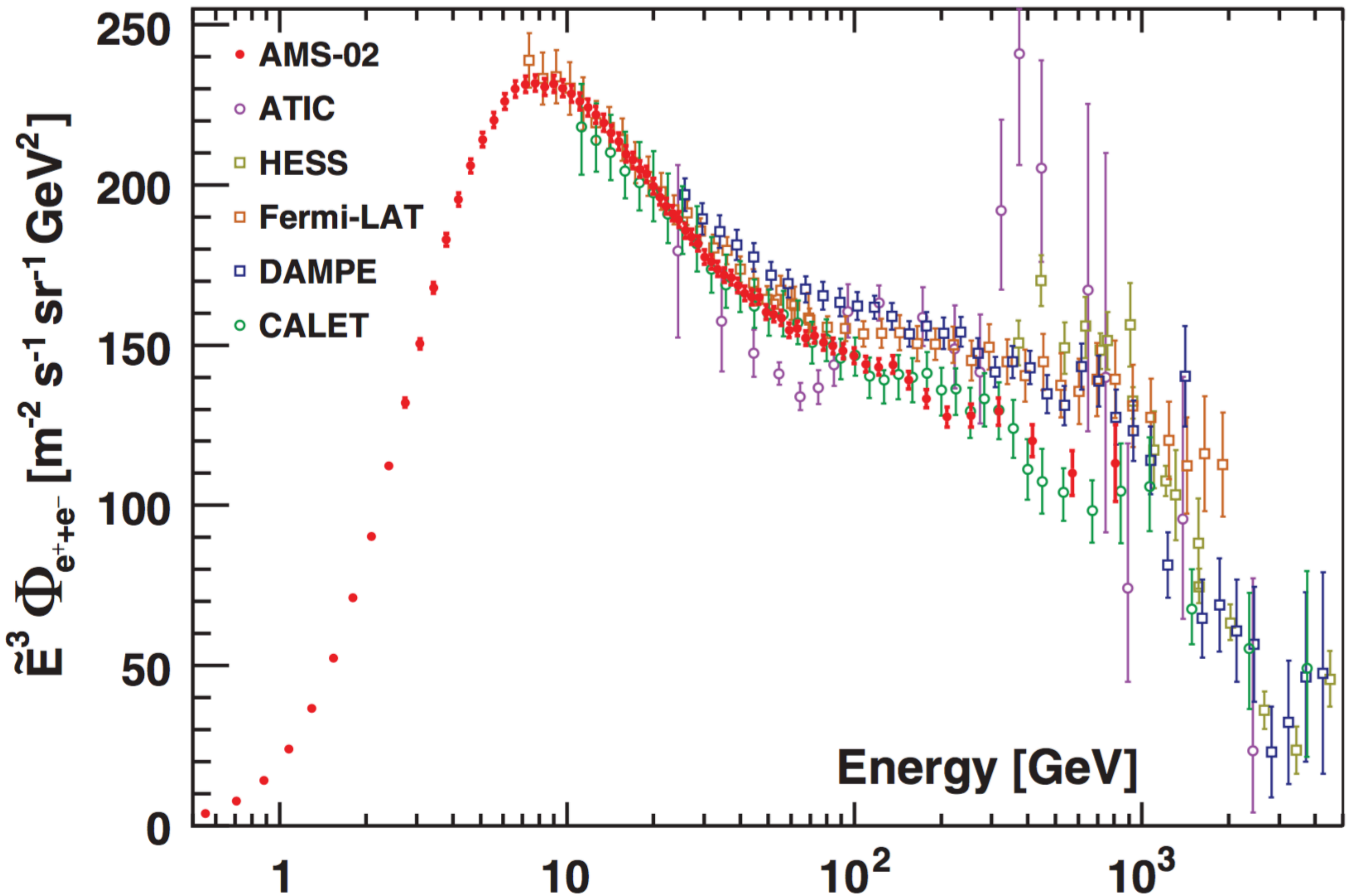
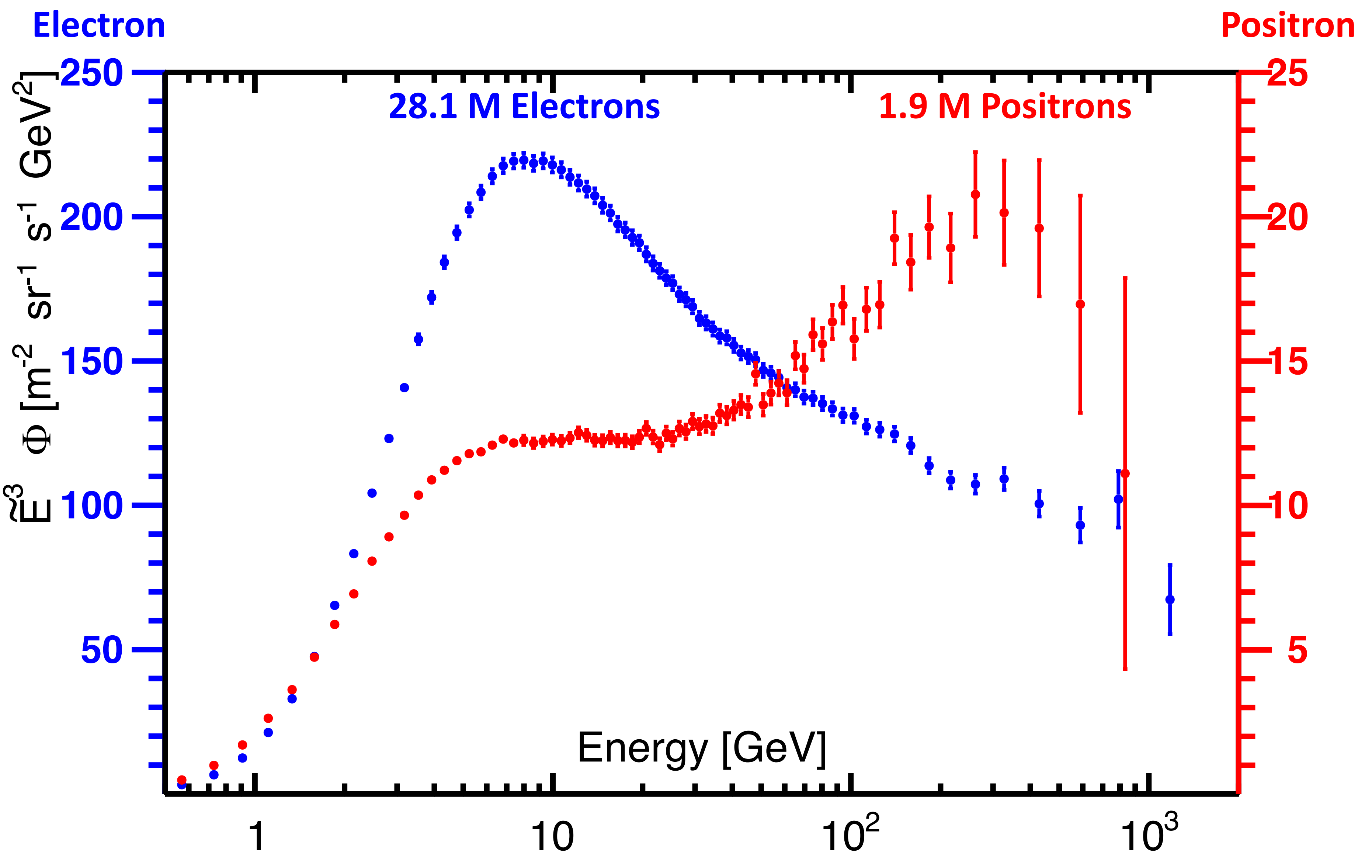


AMS (Positron + Electron) Flux Compared to Other Experiments

$\Phi_{e^+} + \Phi_{e^-}$

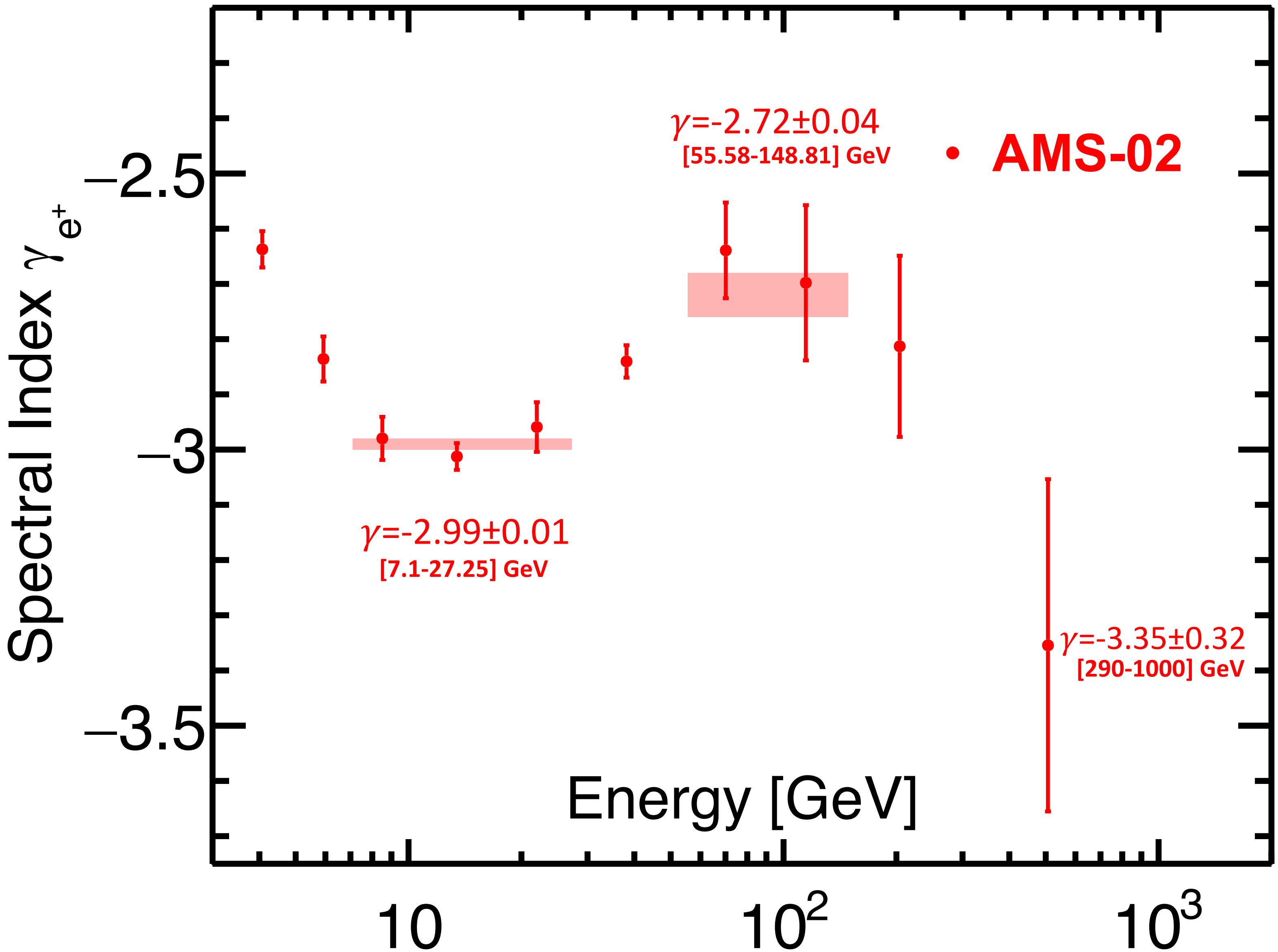


Distinct Behavior of Positrons and Electrons



Distinctive properties of Positron Spectrum

Positron flux spectral index $\gamma = d[\log(\Phi_{e^+})]/d[\log(E)]$ exhibits complex energy dependence



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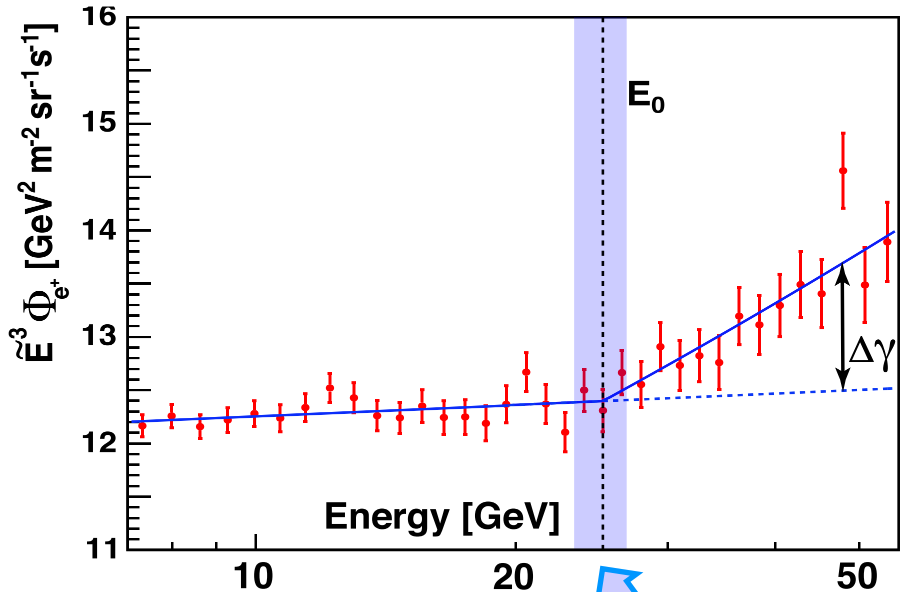


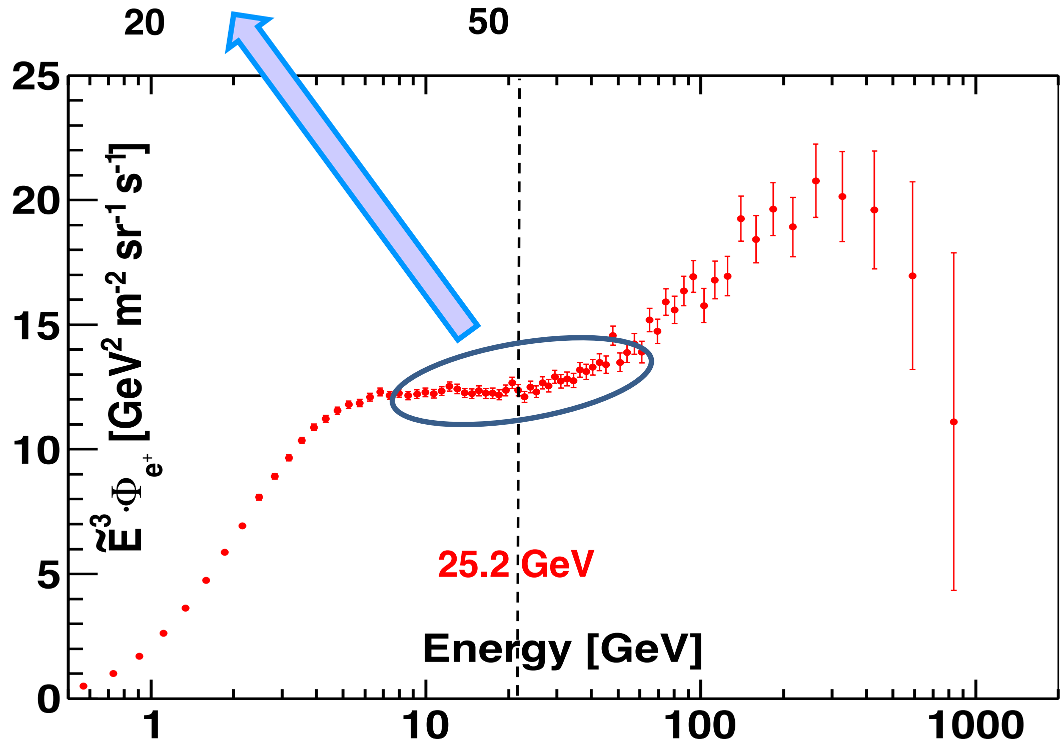
Fits of the data to

$$\Phi_{e^+}(E) = \begin{cases} CE^{\gamma}, & E \le E_0; \\ CE^{\gamma}(E/E_0)^{\Delta\gamma}, & E > E_0. \end{cases}$$

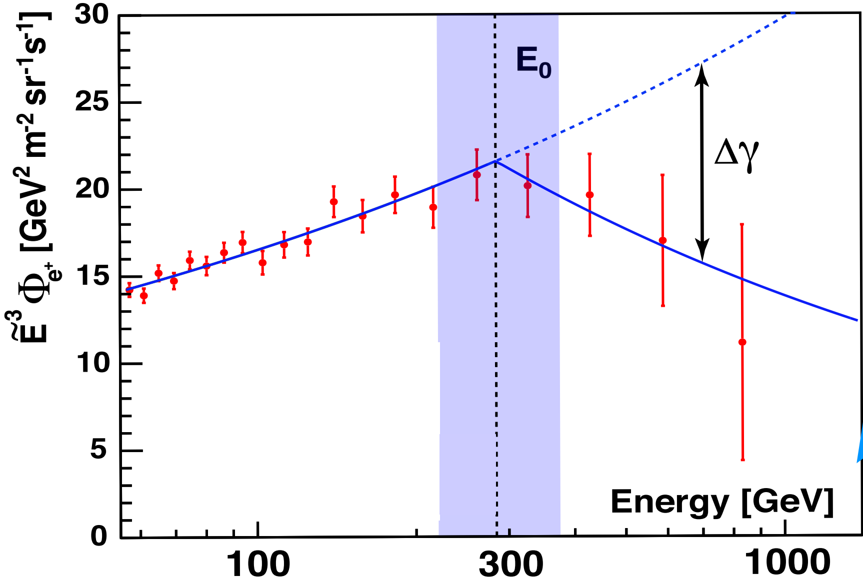
A significant excess above

$E_0 = 25.2 \pm 1.8$ GeV

The significance of this change is established at more than 6σ



Distinctive properties of Positron Spectrum



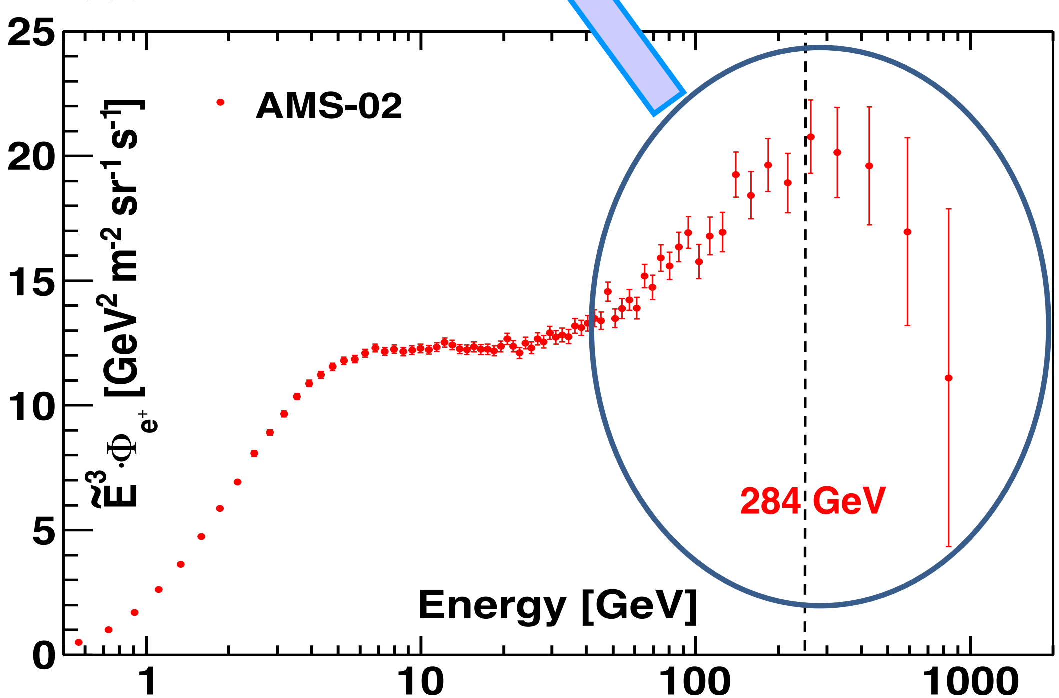
Fits of the data to

$$\Phi_{e^+}(E) = \begin{cases} CE^{\gamma}, & E \le E_0; \\ CE^{\gamma}(E/E_0)^{\Delta\gamma}, & E > E_0. \end{cases}$$

A sharp drop-off at

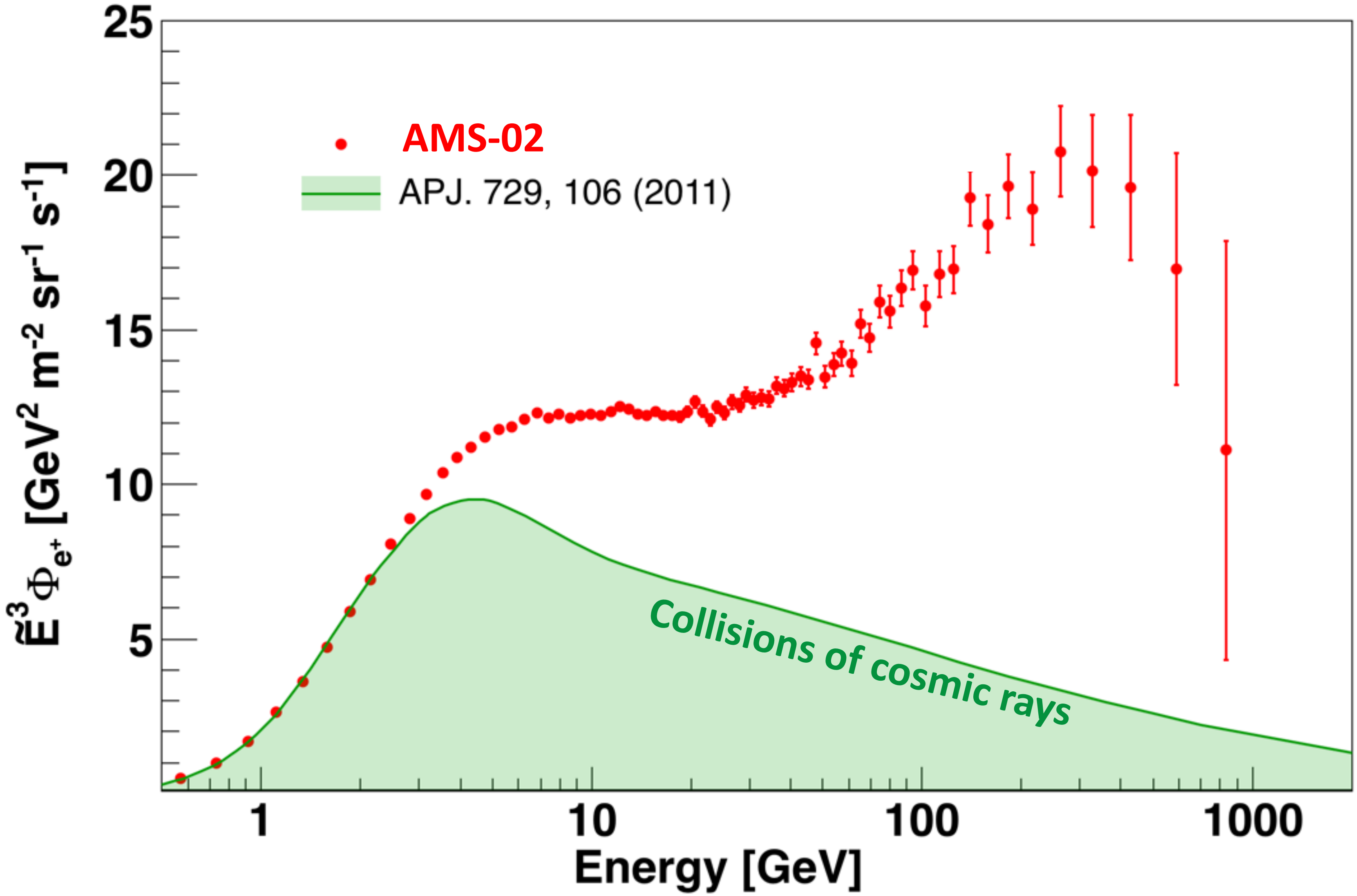
$$E_0 = 284^{+91}_{-64}\ \text{GeV}$$

The significance of this change is established at more than 3σ



The Origin of Cosmic-Ray Positrons

These distinct behavior can not be explained by traditional cosmic ray models.



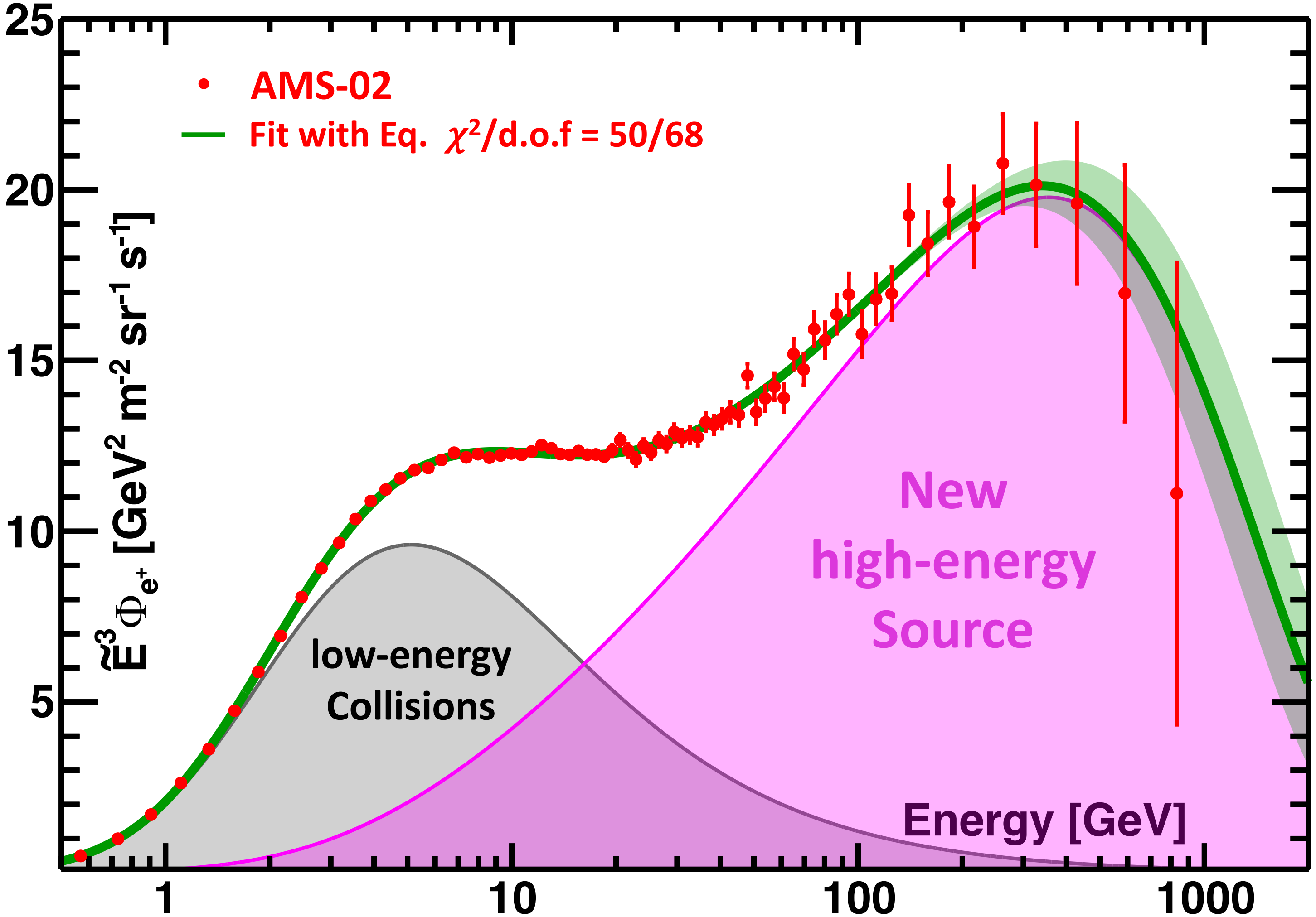
The positron flux by far exceeds the prediction from collision of cosmic rays, requiring a primary source of e^+

The positron flux is the sum of two components:

Low-energy from collisions plus a new source at high-energy

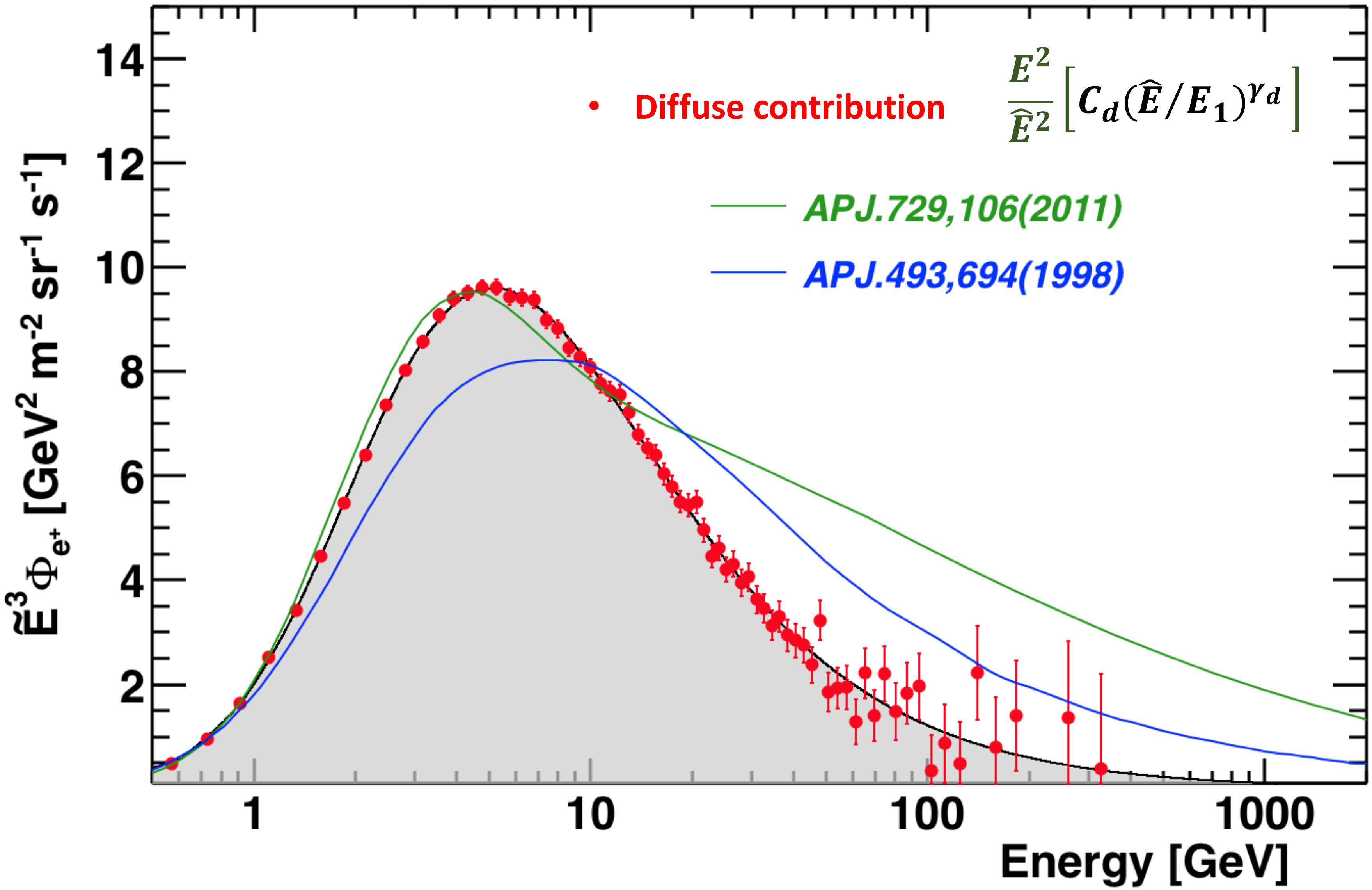
Collisions | Source

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

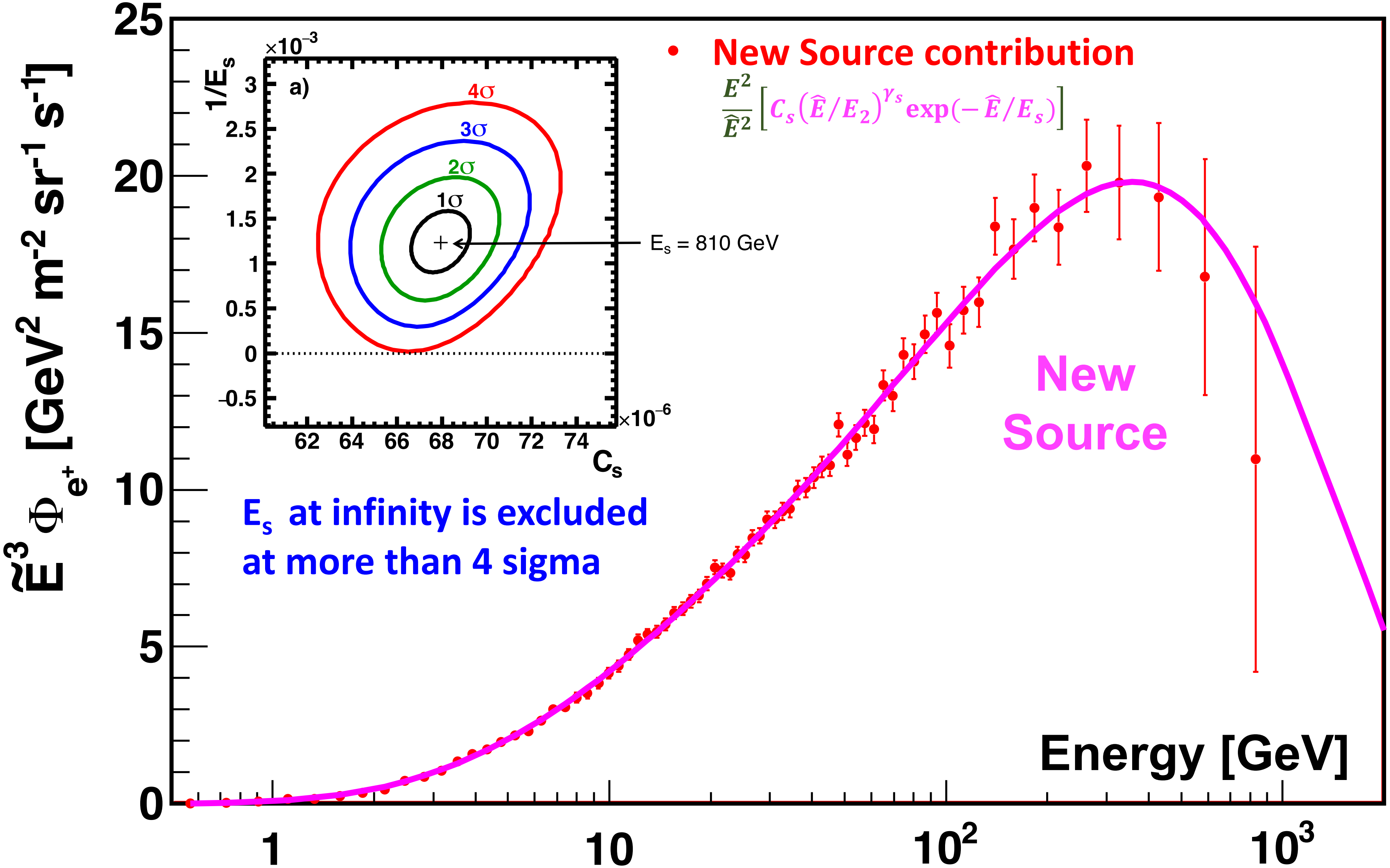


The Origin of Positrons at low energy

At low energy, positron comes from collision of cosmic rays.



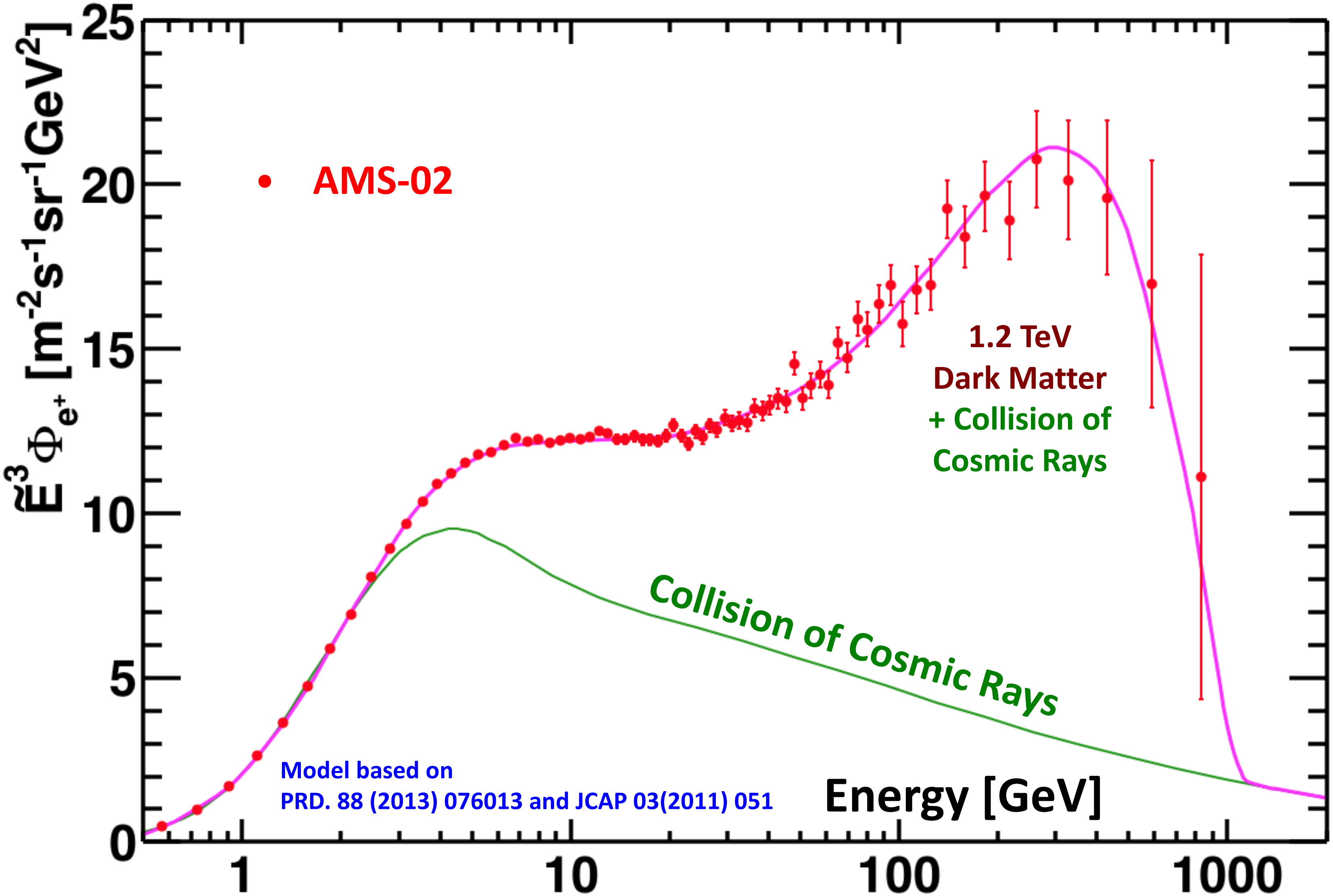
The Origin of Positrons at high energy



Energy cutoff of the source term $E_s = 810^{+310}_{-180}$ GeV

The Origin of Positrons at high energies

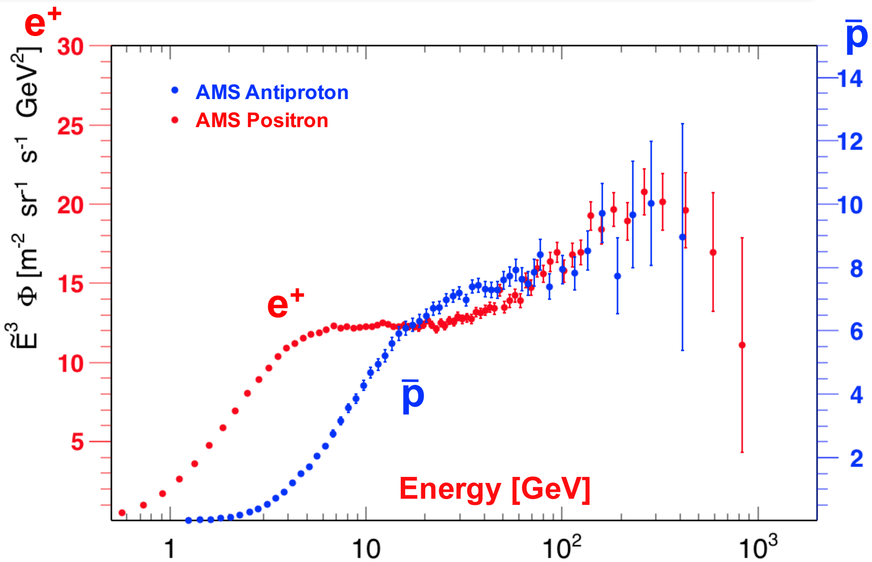
1) Particle origin: Dark Matter



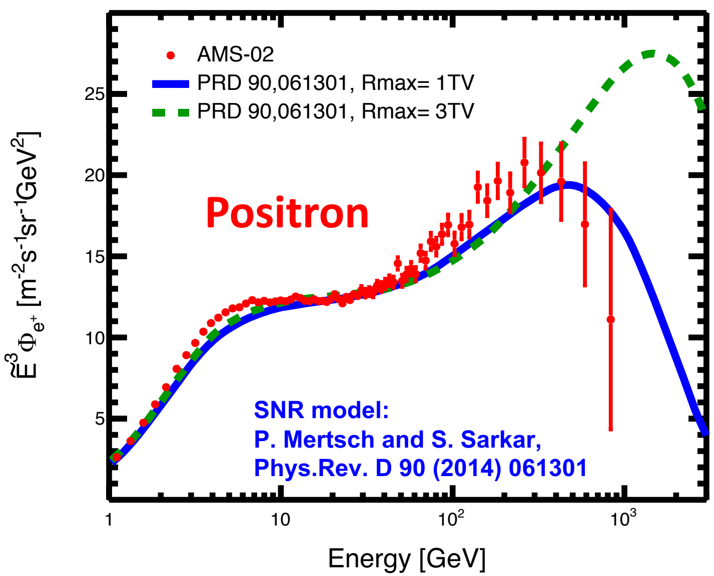
The AMS results appear to be in agreement with a 1.2 TeV Dark Matter Model

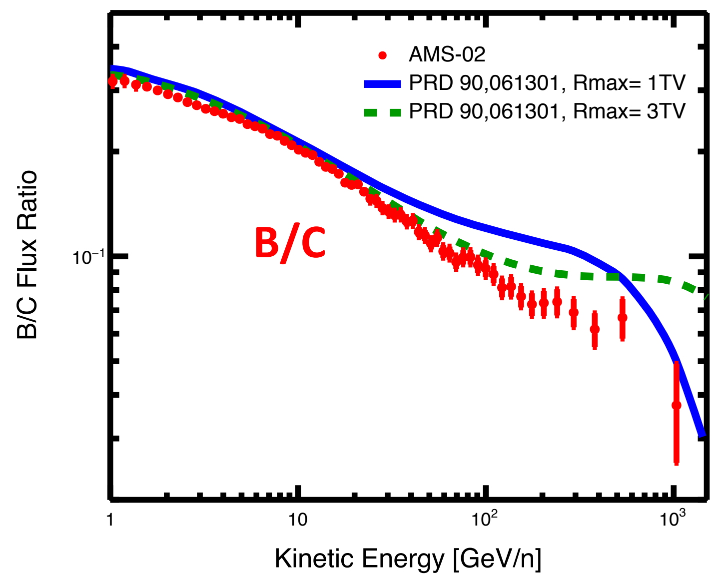
2) Possible Astrophysical Sources of Positron

- Point sources like Pulsars will imprint an observable anisotropy in e^+ direction. Up to now, the positron flux is consistent with isotropy.
- AMS measurement shows that antiproton and positron have similar behavior above 60GeV. Pulsars do not produce antiprotons.



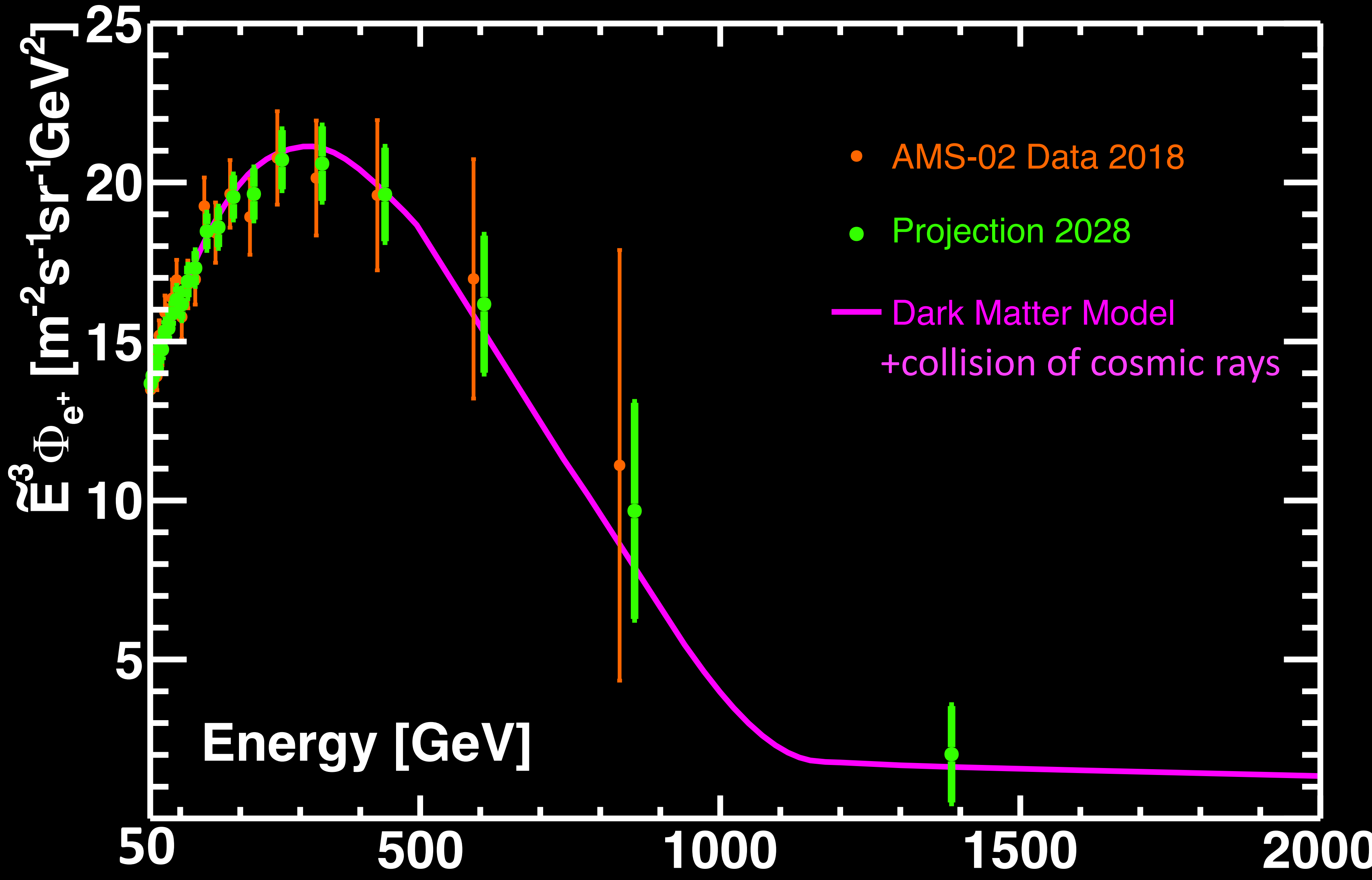
- Models with secondary particle accelerated by Supernova remnants do not agree with precision AMS measurements.





Precision measurements from AMS on Primaries, Secondaries, antiprotons, and positron, electron anisotropy would distinguish different origins of cosmic-ray positrons

AMS will extend the measurements beyond 1 TeV



Conclusion and Outlooks

- Precision measurements by AMS of the positron flux to 1 TeV.

- The positron flux shows distinctive energy dependence:
  (a) a significant excess starting from 25.2±1.8 GeV
  (b) a sharp drop-off above 284 GeV,

- These properties are not explained by ordinary CR models:
  An primary source of high energy positrons.

- The positron flux is well described by the sum of a diffuse term and a new source term with a finite energy cutoff at 810 GeV, with a significance of more than 4σ.

- By continuing the measurement through the live time of the Space Station, we will be able to improve the accuracy and extend to higher energy, and determine the origin of high energy positrons.