Towards Understanding
the Origins of Cosmic Ray Positrons and Electrons

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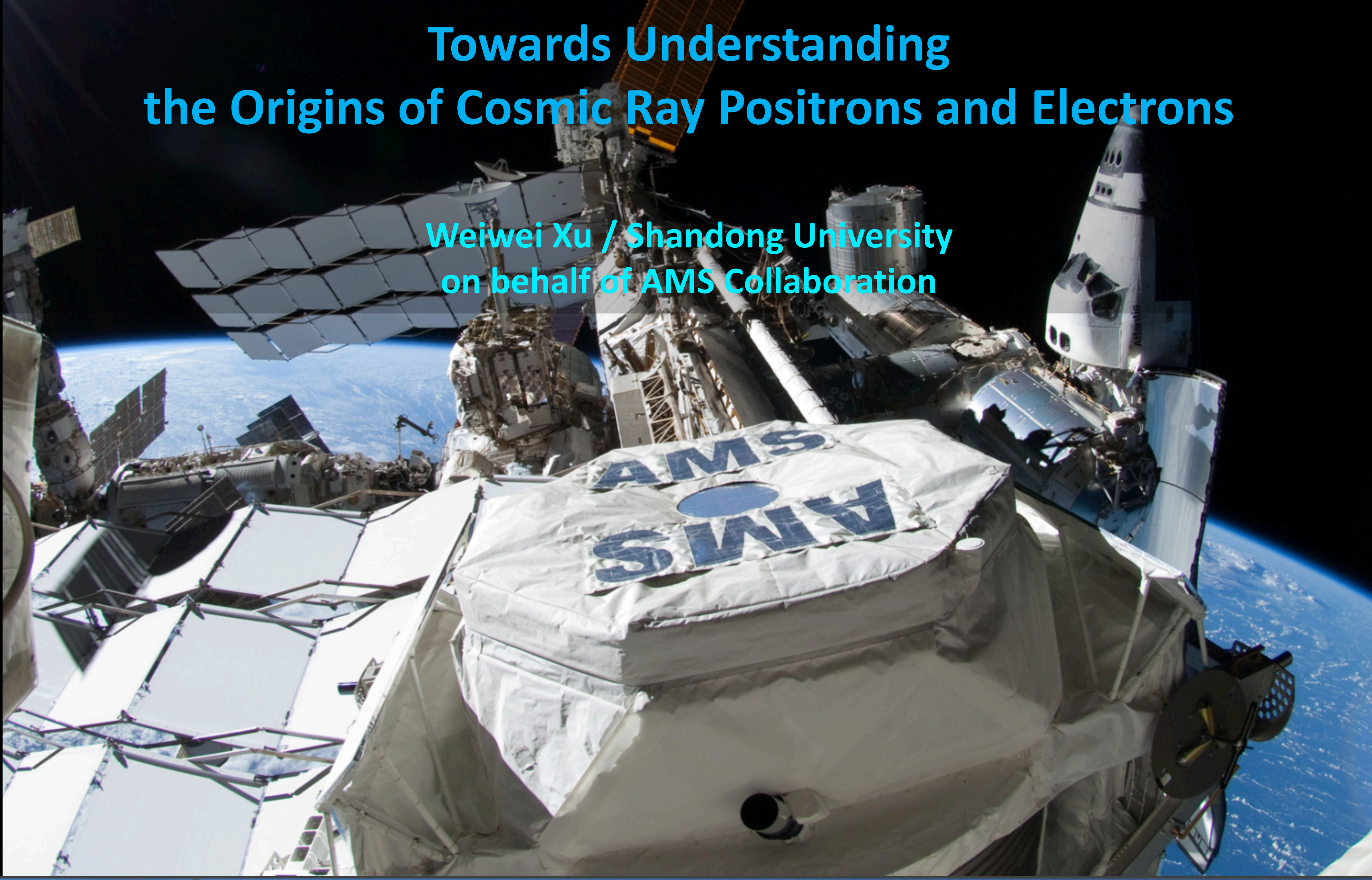
on behalf of AMS Collaboration

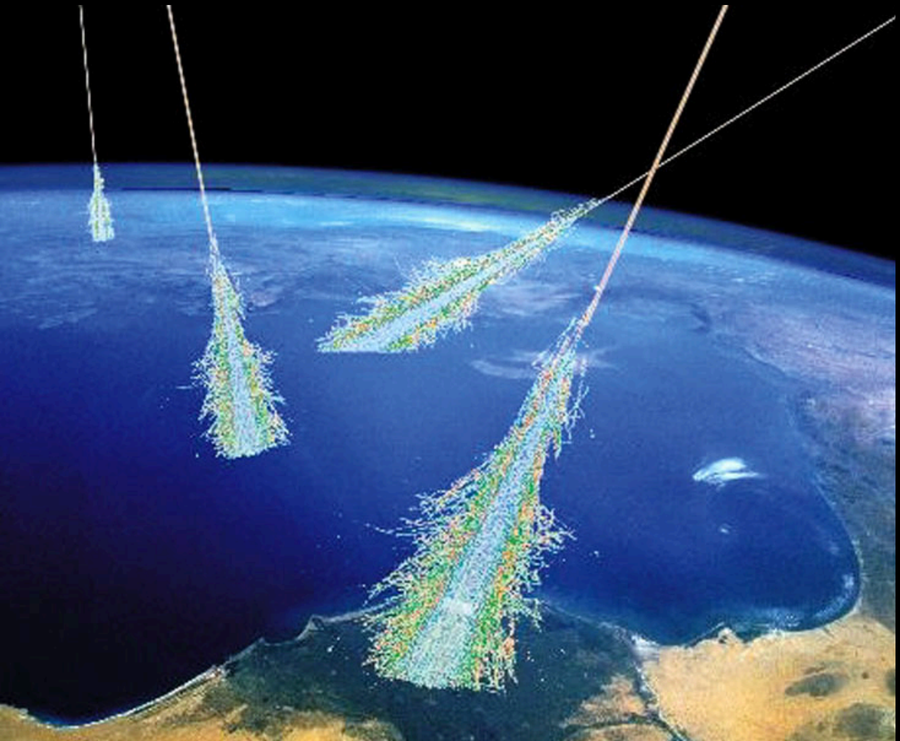


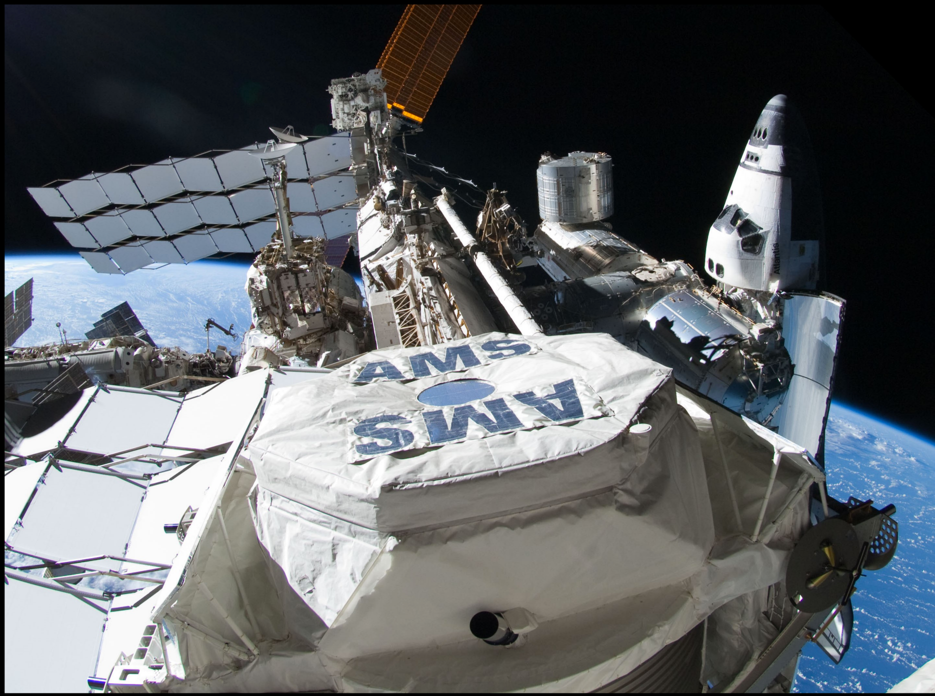
LP2019

29th International Symposium on Lepton Photon
Interactions at High Energies

The physics of AMS on the Space Station: Study of Charged Cosmic Rays

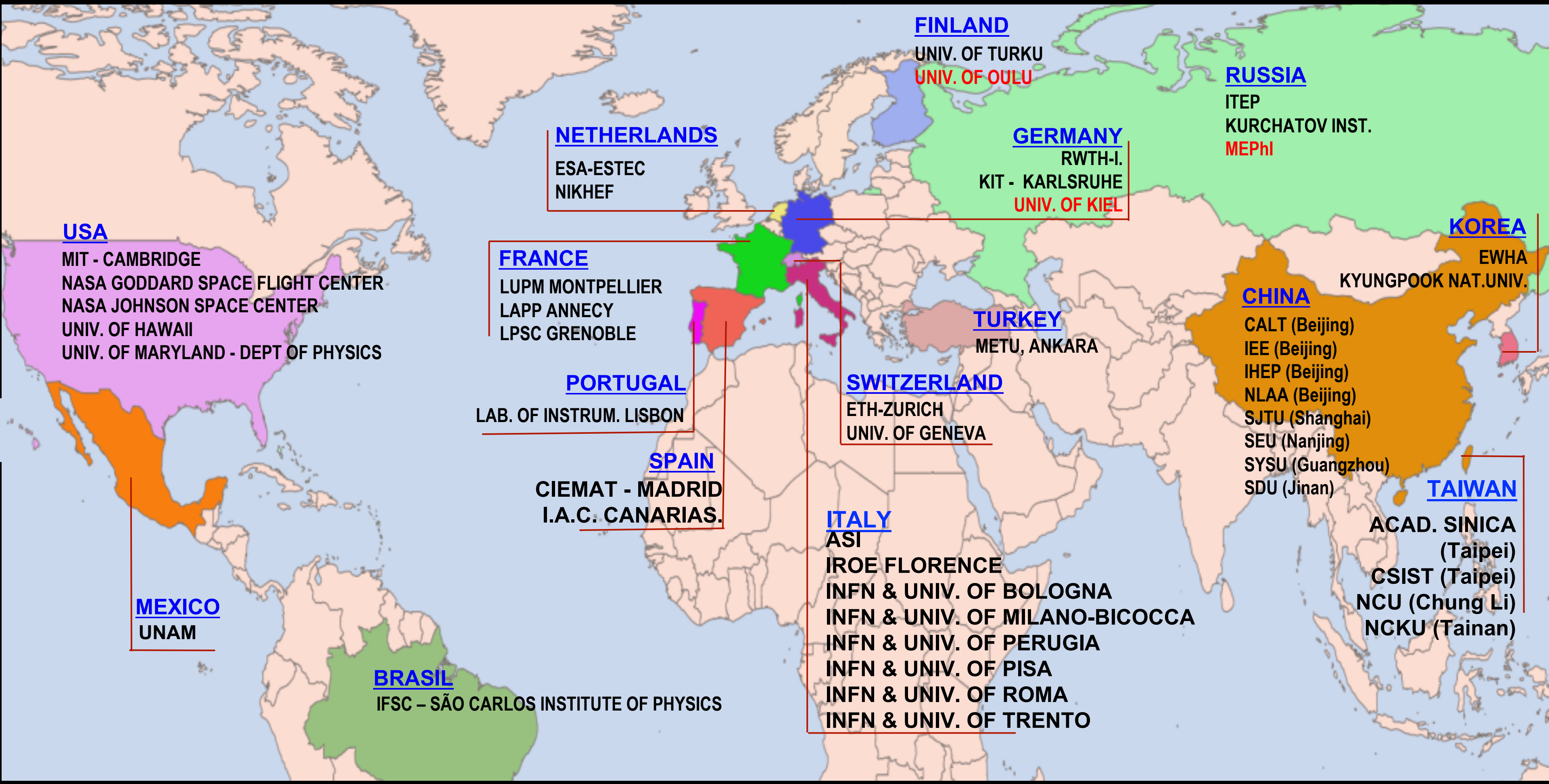
Charged cosmic rays
have mass.
They are absorbed by the
100 km of Earth's atmosphere
(10m of water).





To measure their
charge and momentum
requires
a magnetic spectrometer
in space.

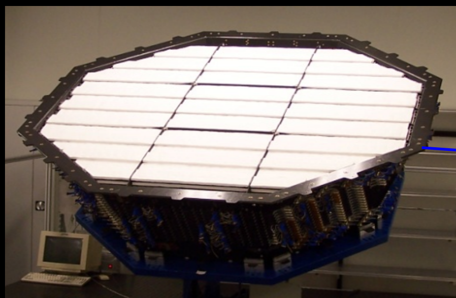
AMS Collaboration



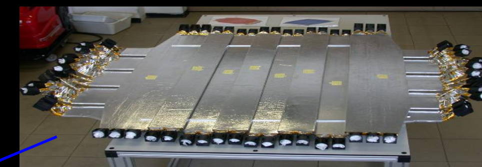
AMS is a space version of a precision detector used in accelerators.

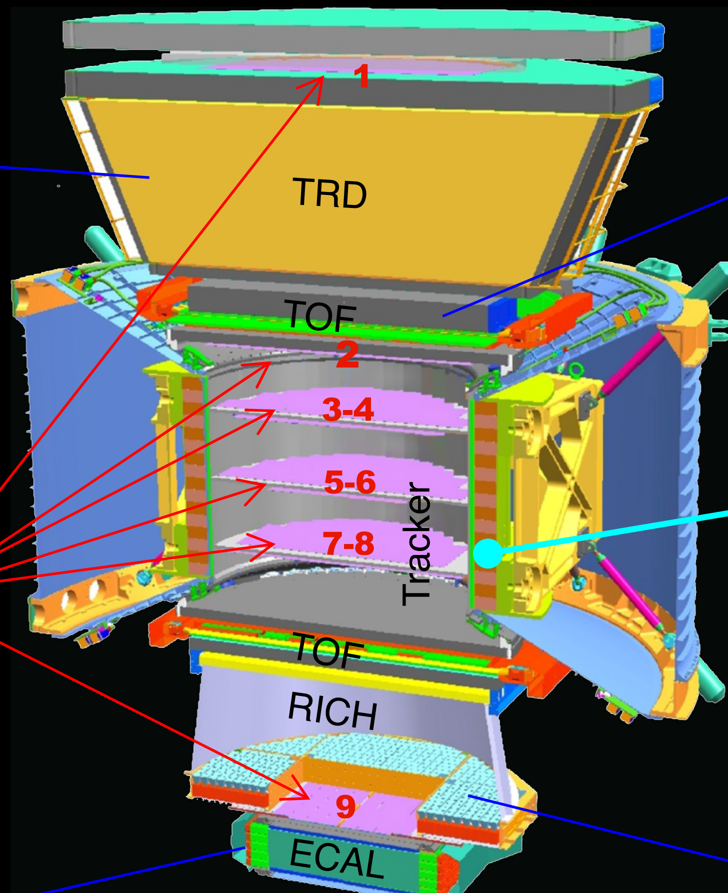
Particles and nuclei are defined
by their charge (Z) and energy (E ~ P)

Transition Radiation Detector (TRD)

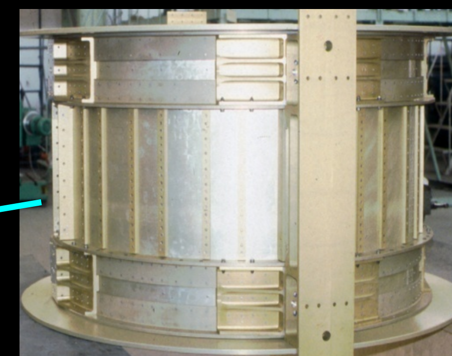


Time of Flight Detector (TOF)

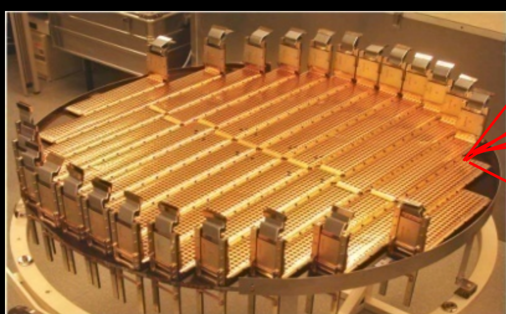




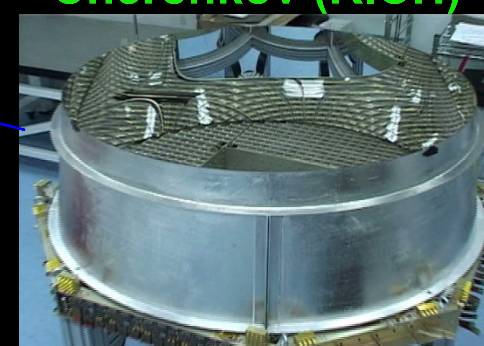
Magnet



Silicon Tracker



Ring Imaging Cherenkov (RICH)

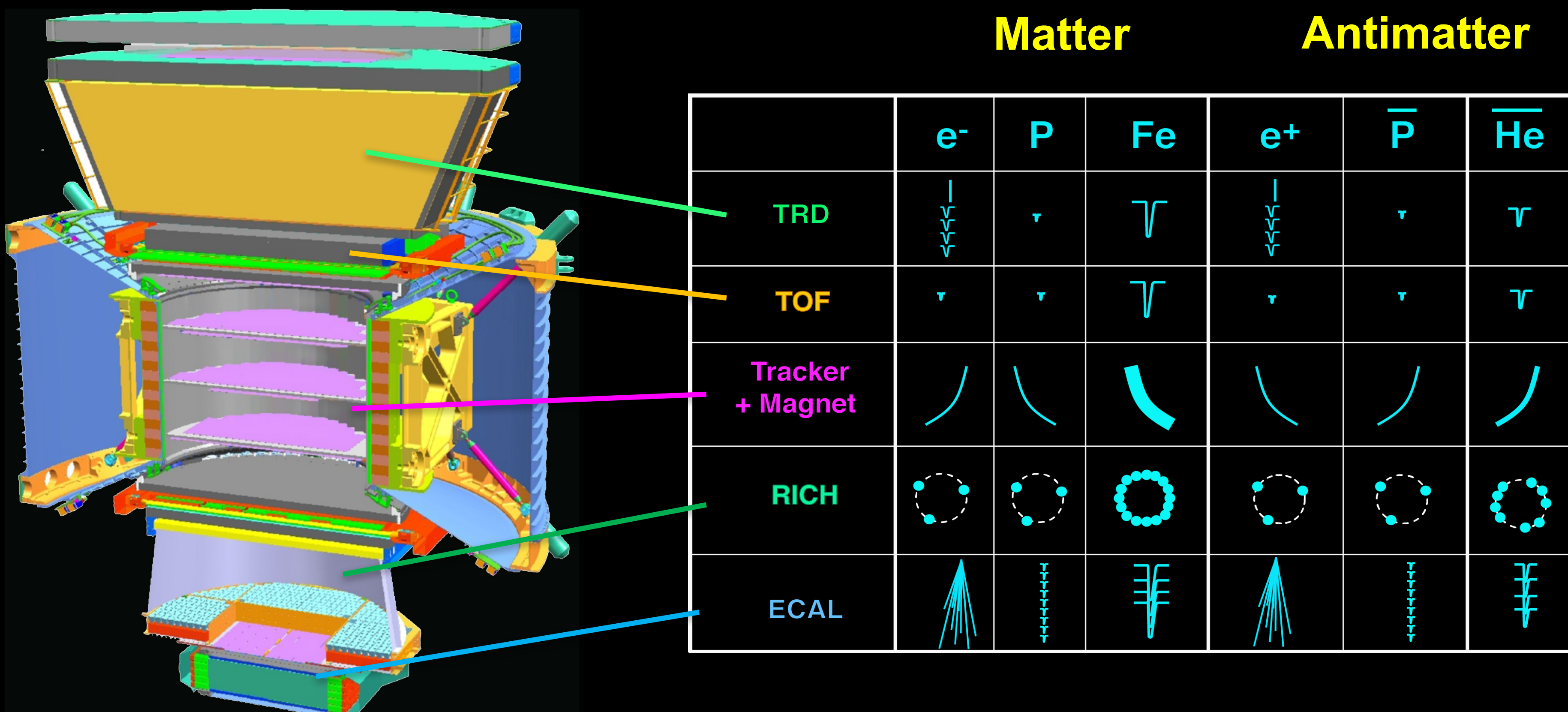


Electromagnetic Calorimeter (ECAL)

Z and P

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

AMS is a unique magnetic spectrometer in space



In 8 years, the detectors have performed flawlessly.

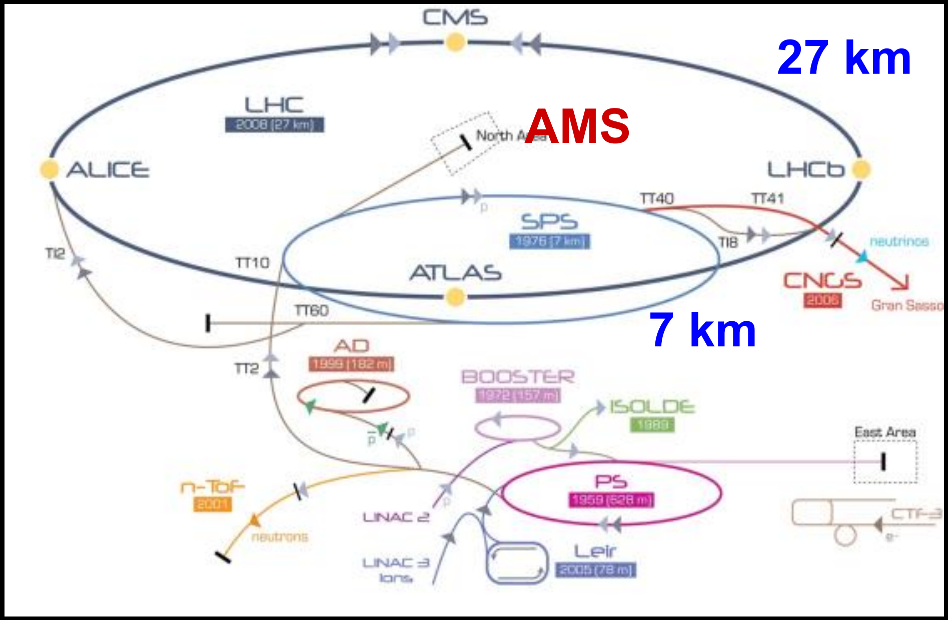
AMS is able to pick out 1 positron from 1,000,000 protons;

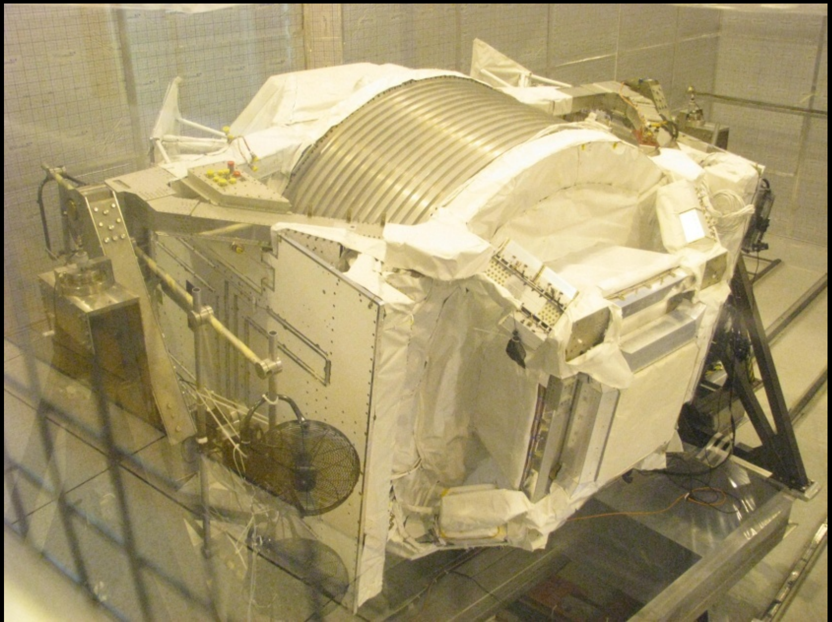
unambiguously separate positrons from electrons up to a trillion eV;

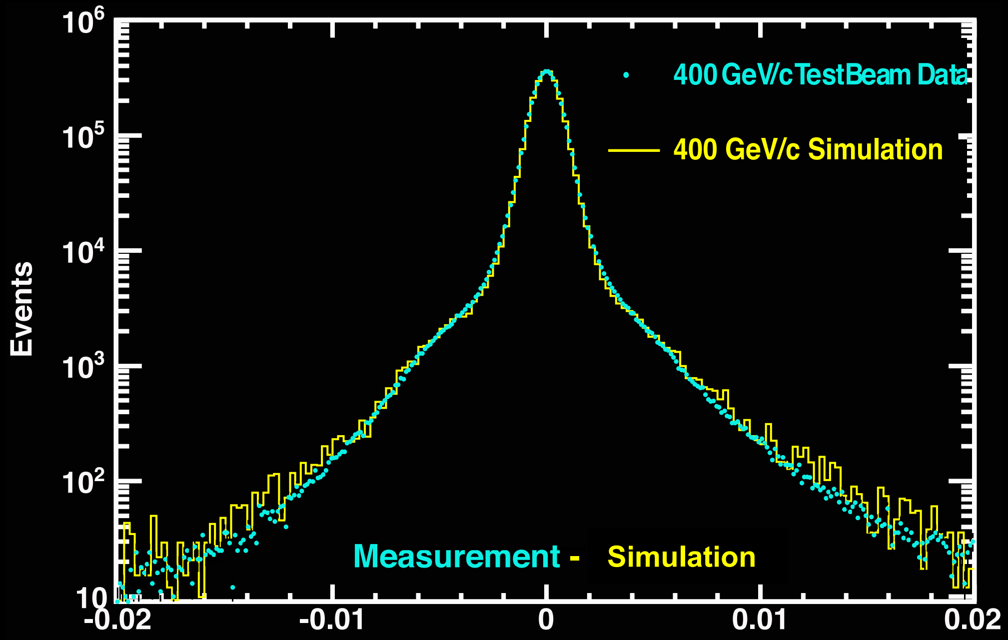
and accurately measure all cosmic rays to trillions of eV.

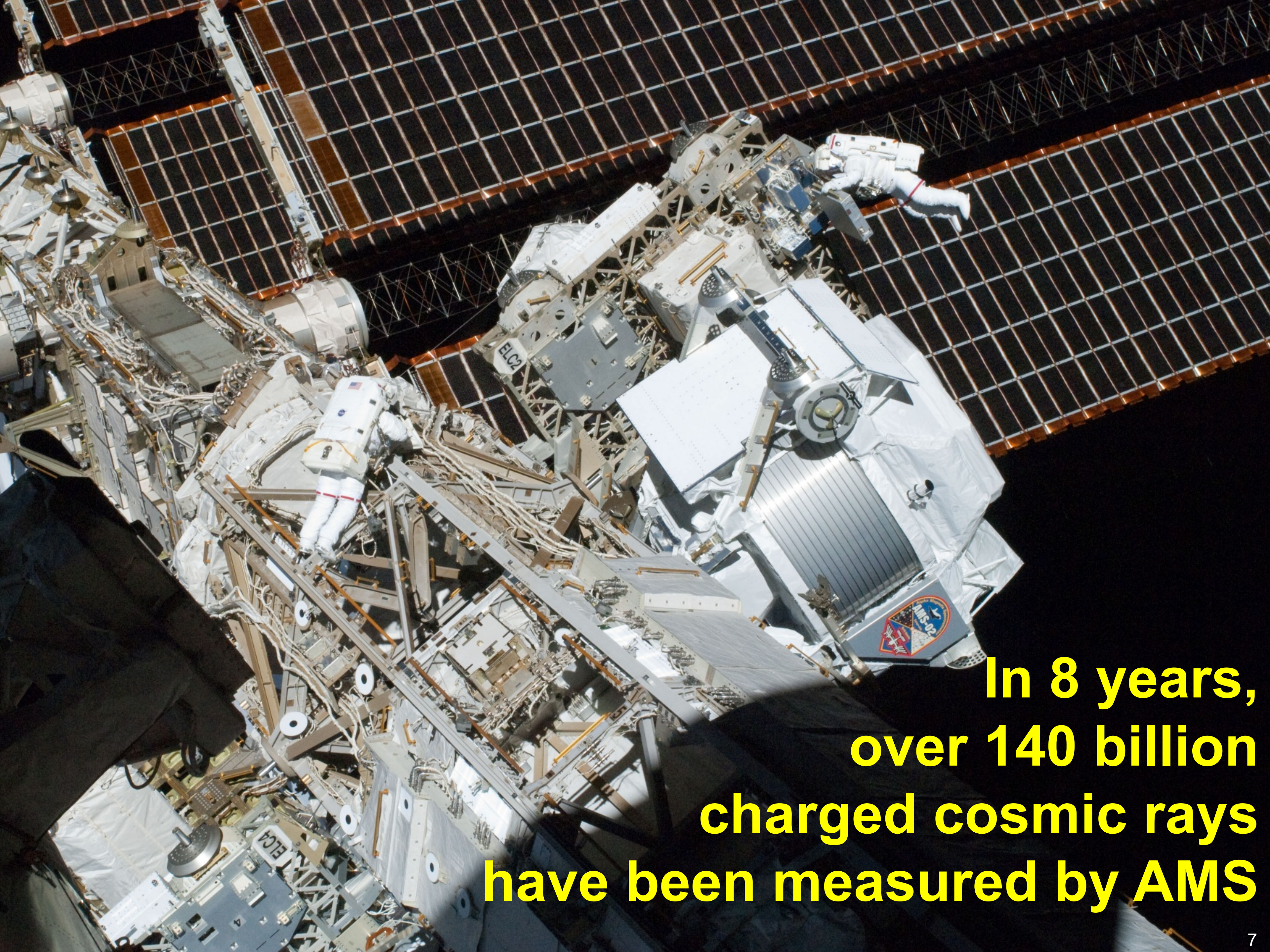
Calibration at CERN

with different particles at different energies



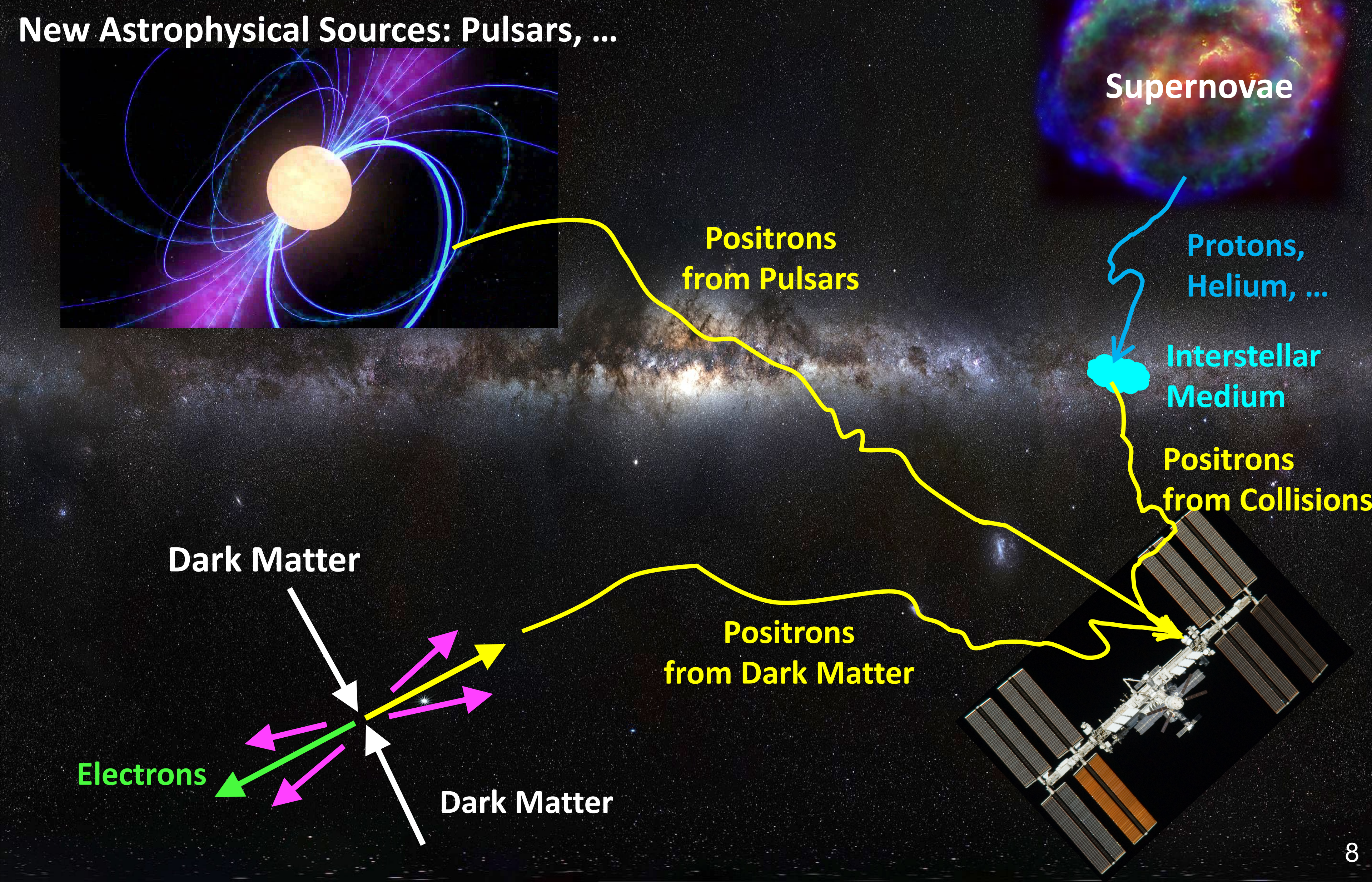




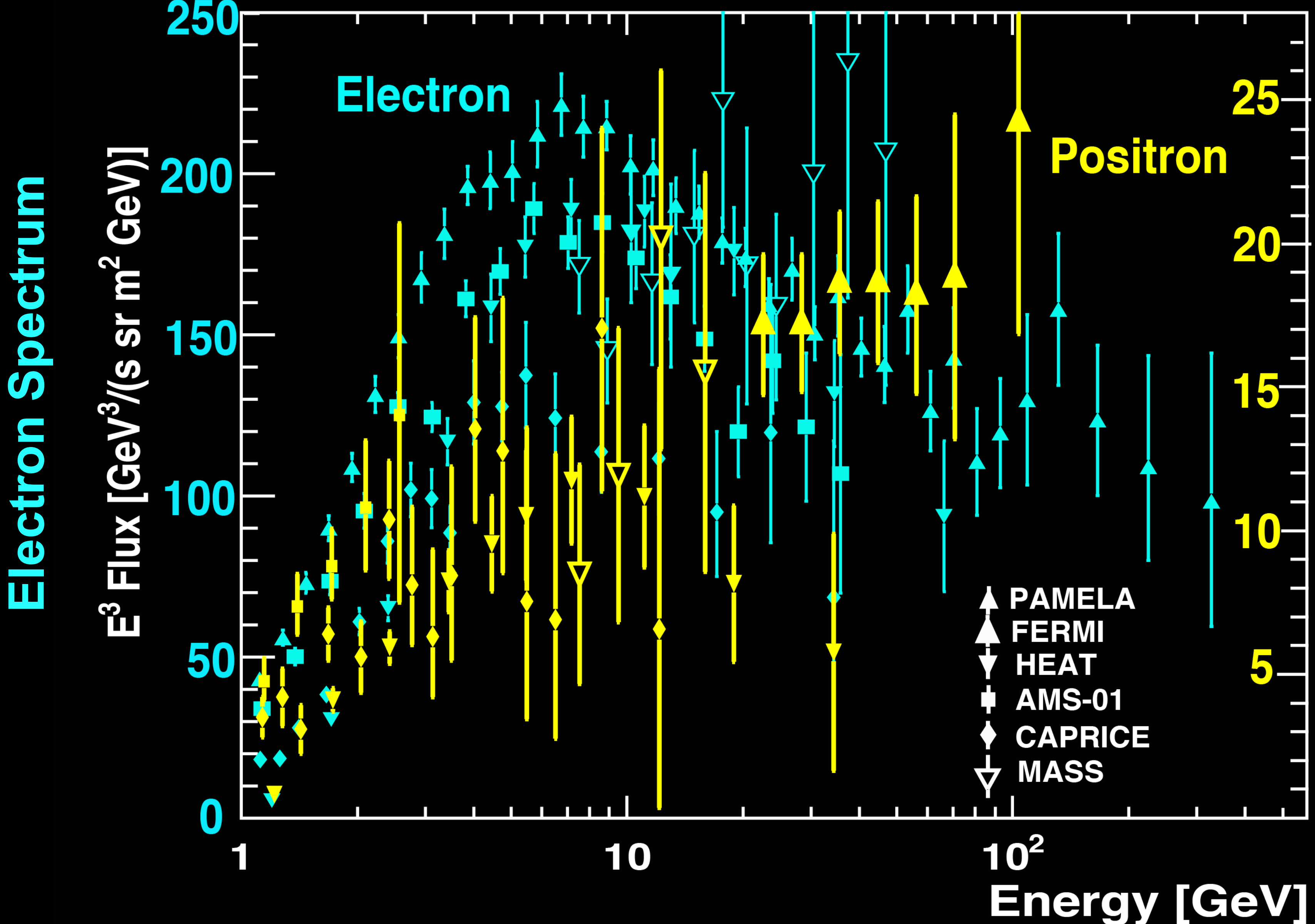


In 8 years,
over 140 billion
charged cosmic rays
have been measured by AMS

AMS Physics Results: on the Origins of Cosmic Positrons

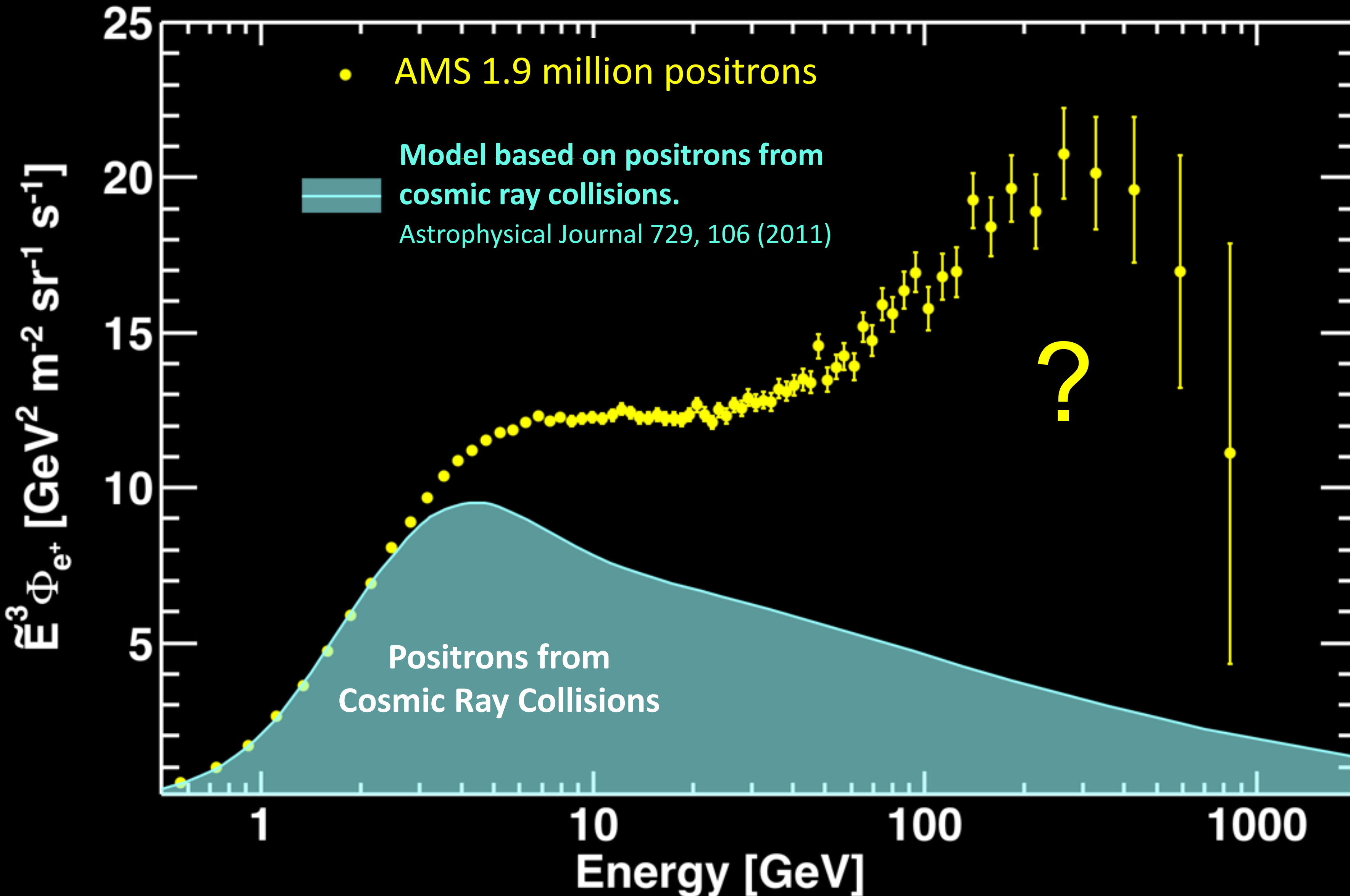


Electron and Positron spectra before AMS

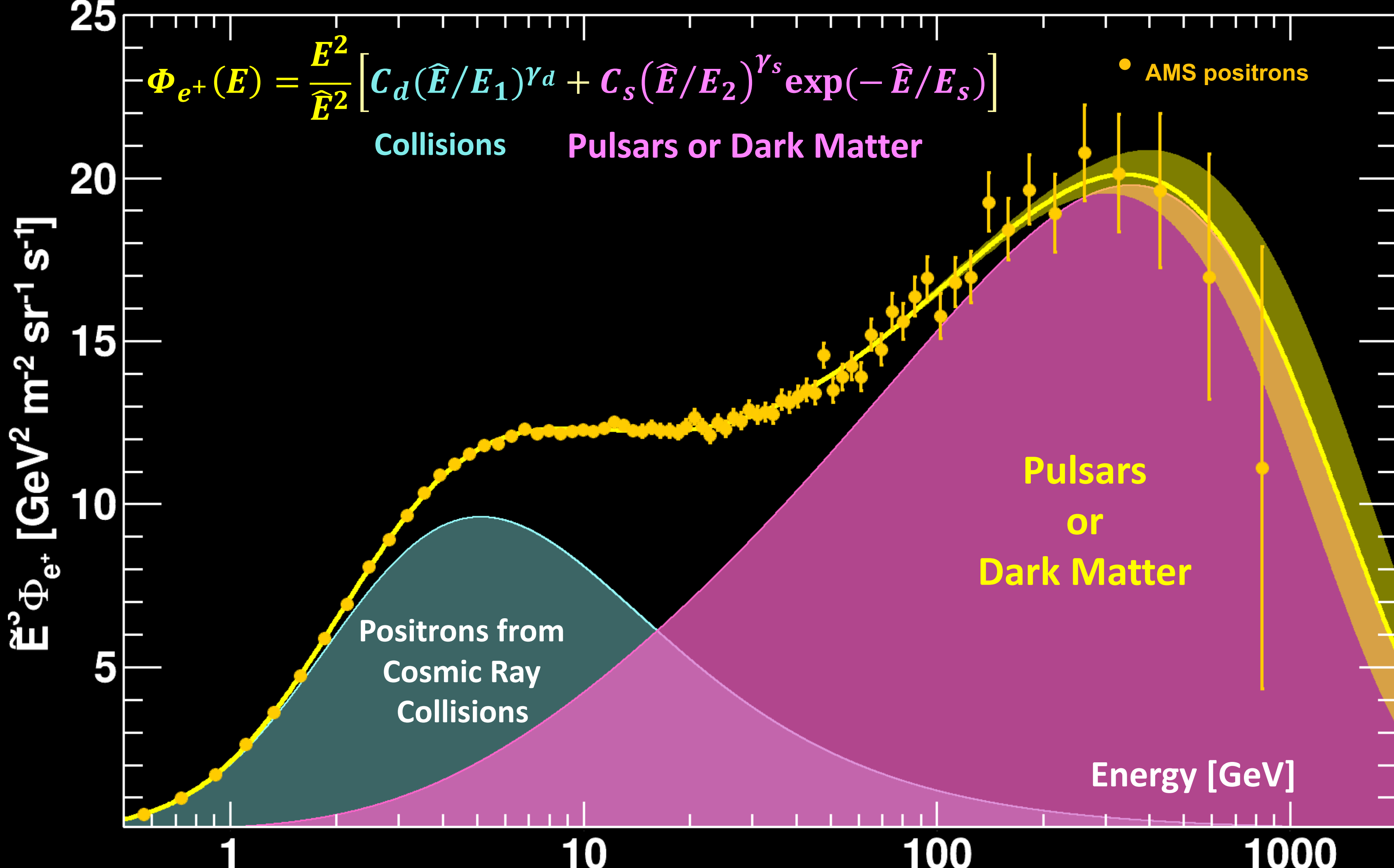


The Origin of Positrons

Low energy positrons mostly come from cosmic ray collisions



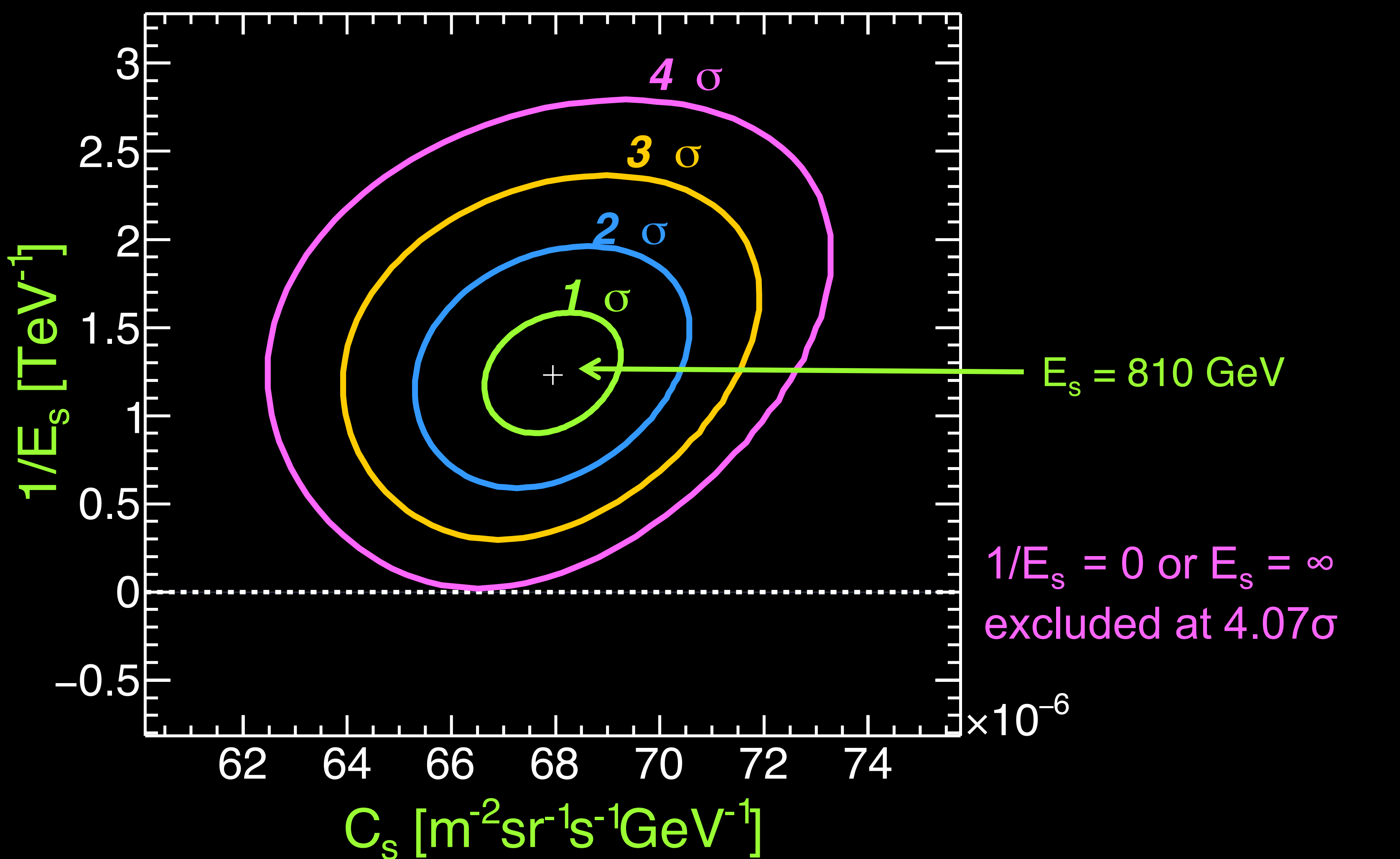
The positron flux is the sum of low-energy part from cosmic ray collisions plus a high-energy part from pulsars or dark matter.



A finite energy cutoff of the source term $E_s = 810^{+310}_{-180}$ GeV, is established with a significance more than 4σ.

Collisions   New Source or Dark Matter

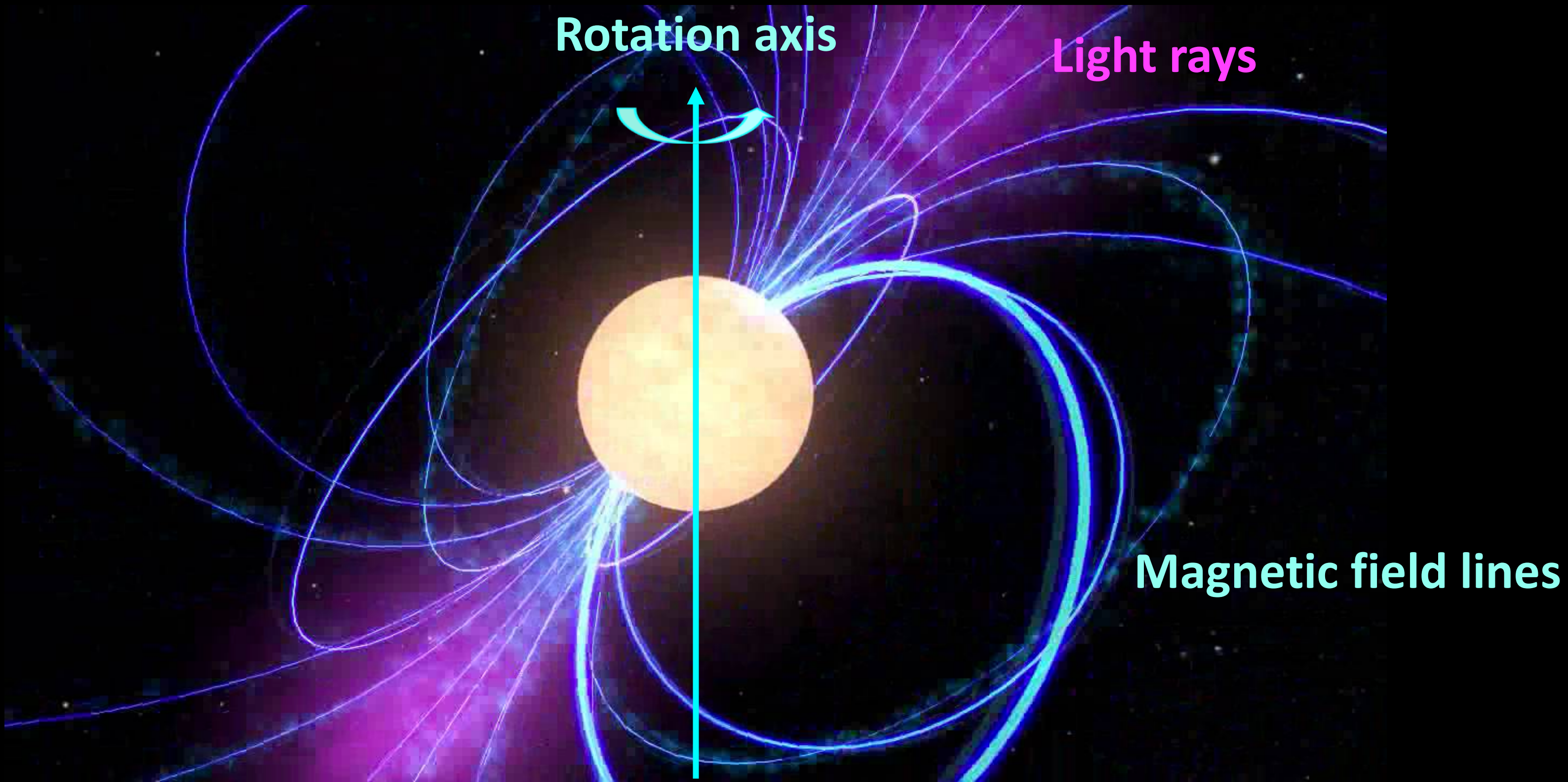
$$\Phi_{e^+}(E) = \frac{E^2}{\hat{E}^2}\left[C_d(\hat{E}/E_1)^{\gamma_d} + C_s(\hat{E}/E_2)^{\gamma_s}\exp(-\hat{E}/E_s)\right]$$



Positrons from Pulsars

1. Pulsars produce and accelerate positrons to high energies.

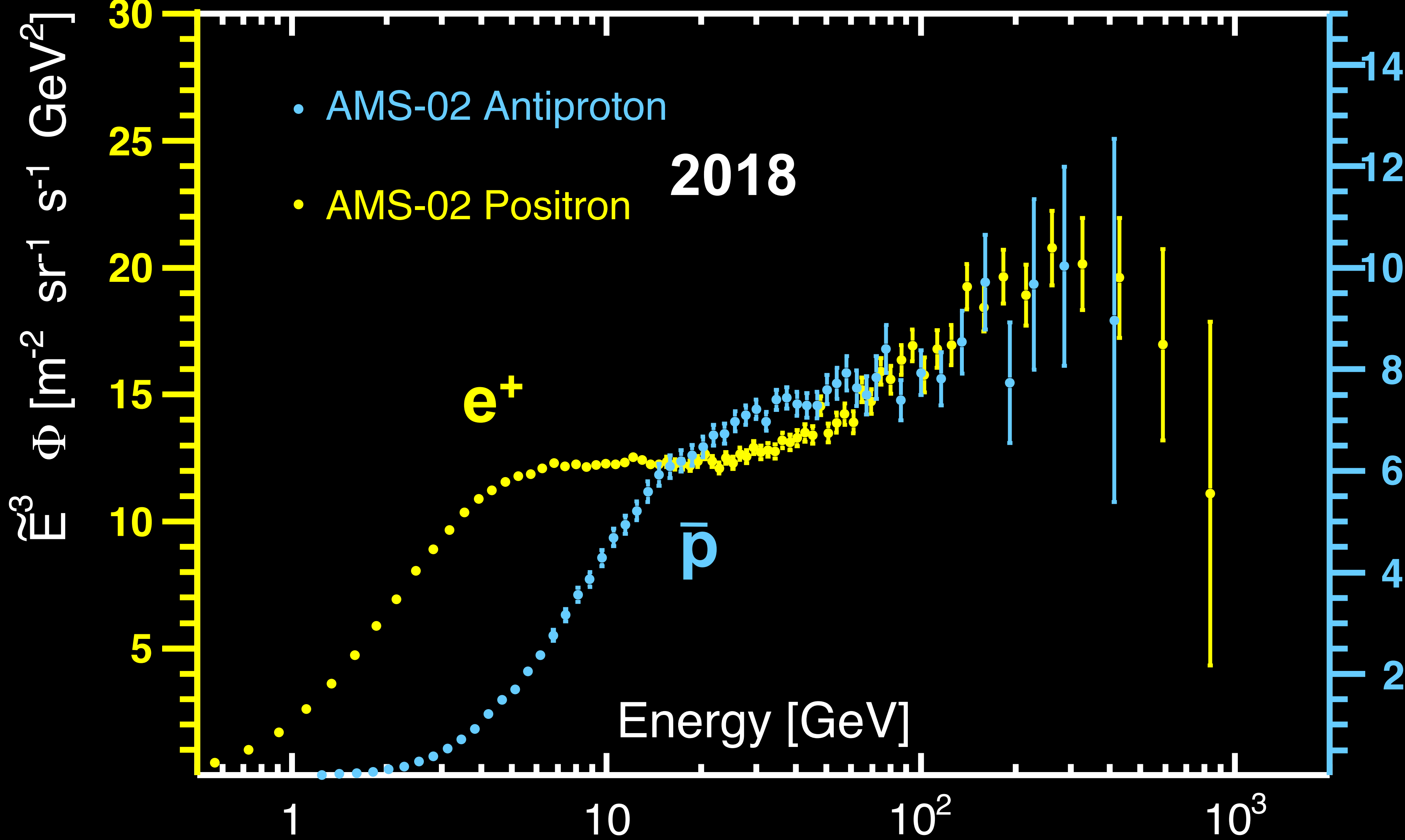
2. Pulsars do not produce antiprotons.



AMS Physics Results:

Antiproton data show a similar trend as positrons.

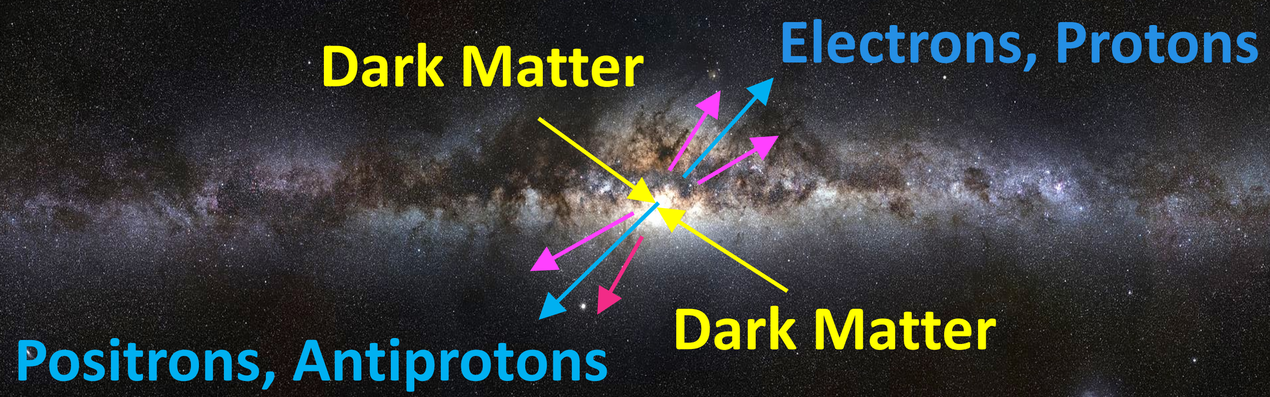
Antiprotons cannot come from pulsars.



Dark Matter

Dark Matter particle have mass *M* and they move slowly.
Before collision the total energy ≈ 2*M*.

Collision of Dark Matter produces positrons and antiprotons.

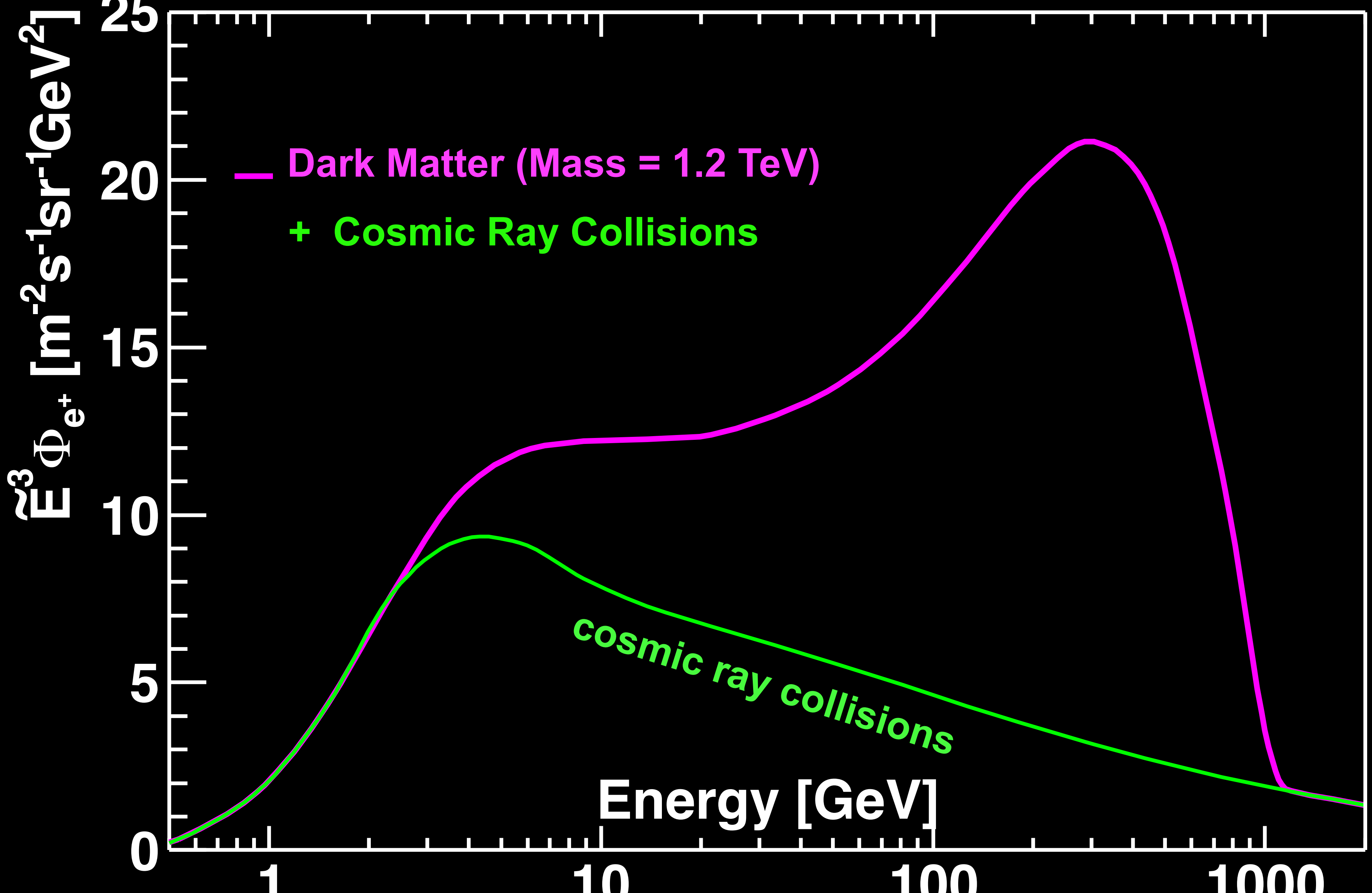


The conservation of energy and momentum requires that the positron or antiproton energy must be smaller than *M*.

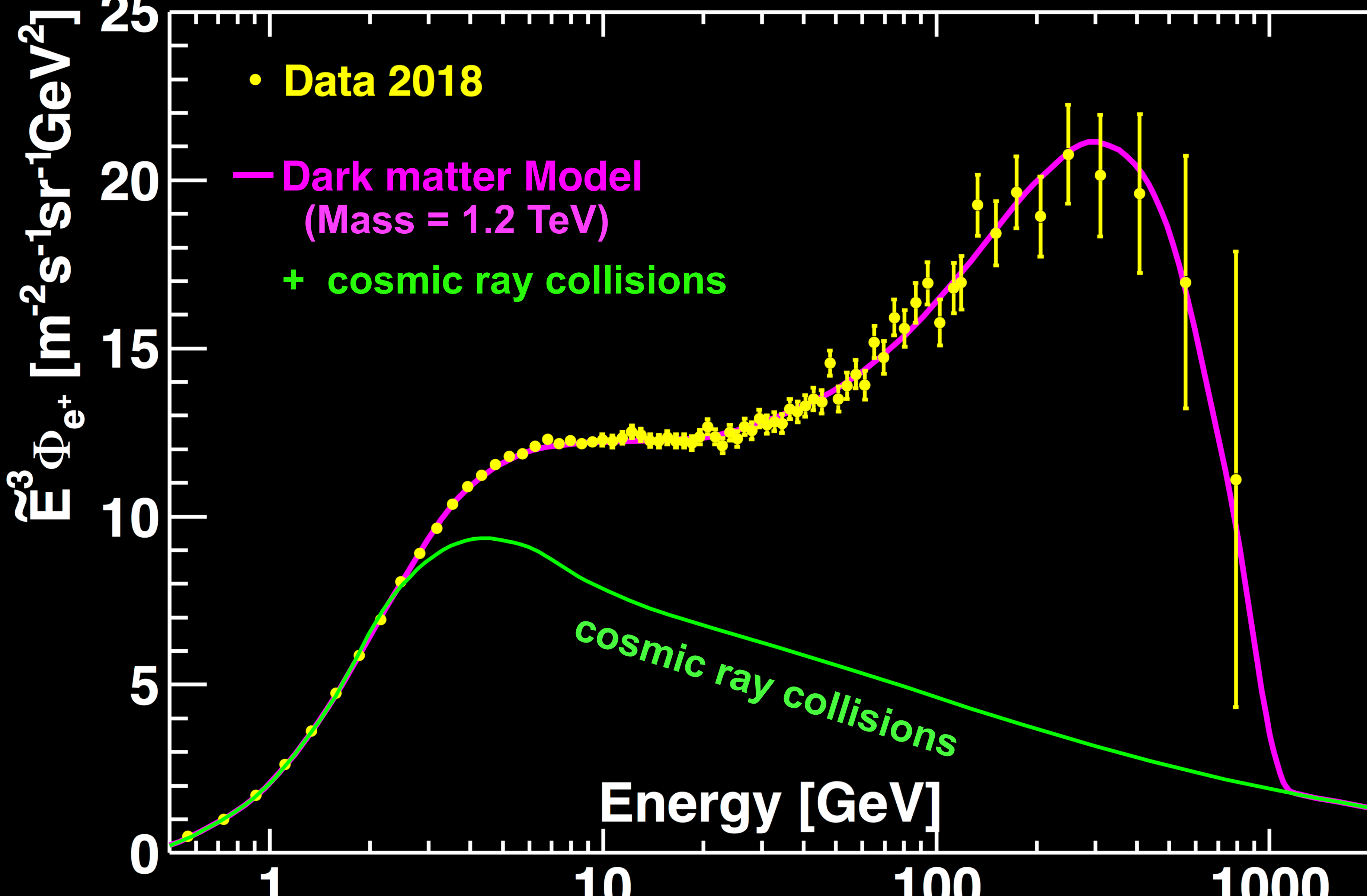
So, there is a sharp cutoff in the spectra at *M*.

Dark Matter Model Prediction of Positron Spectrum

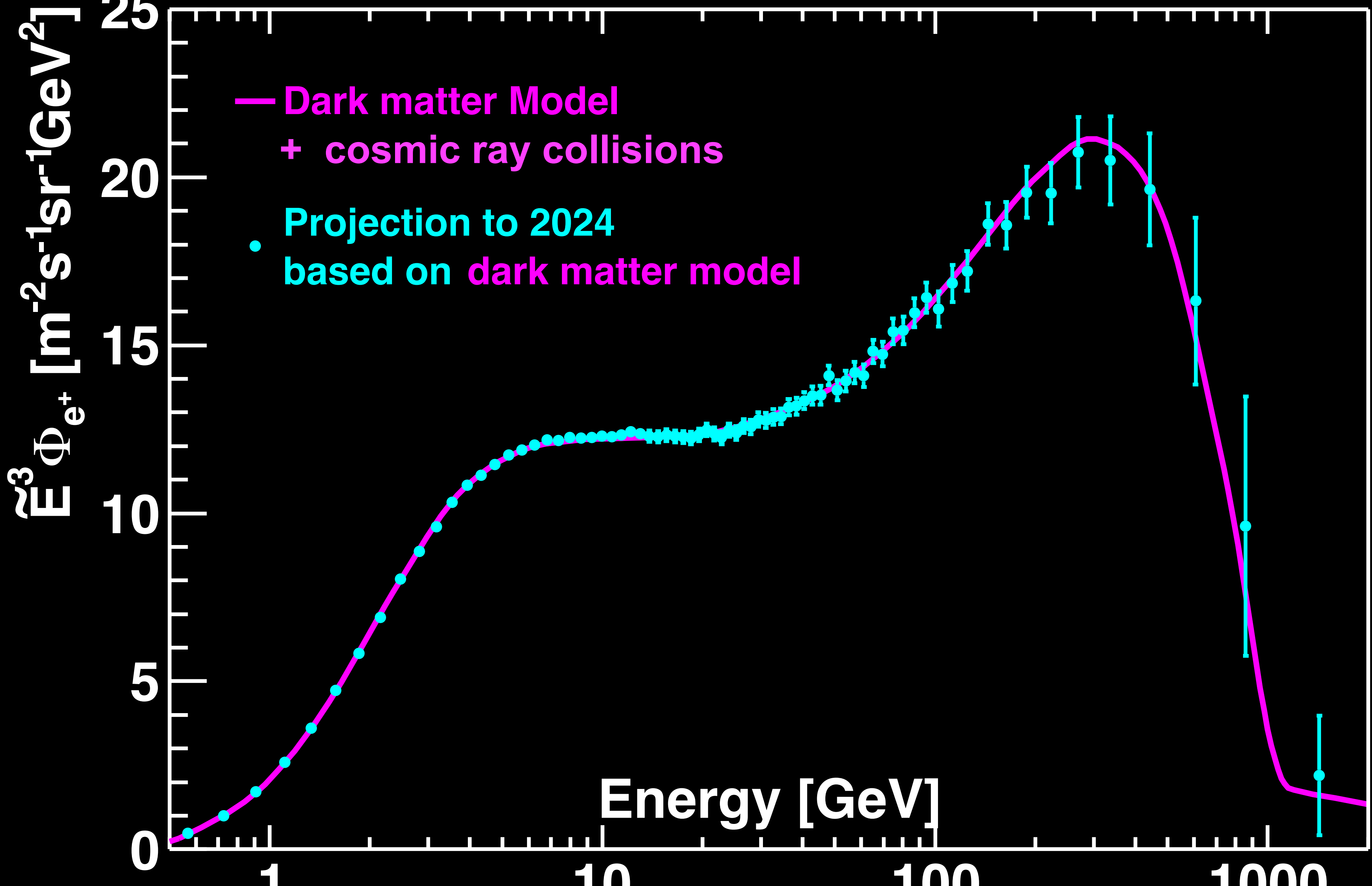
with a characteristic sharp drop-off at high energies



Positrons and Dark Matter Model (2018)



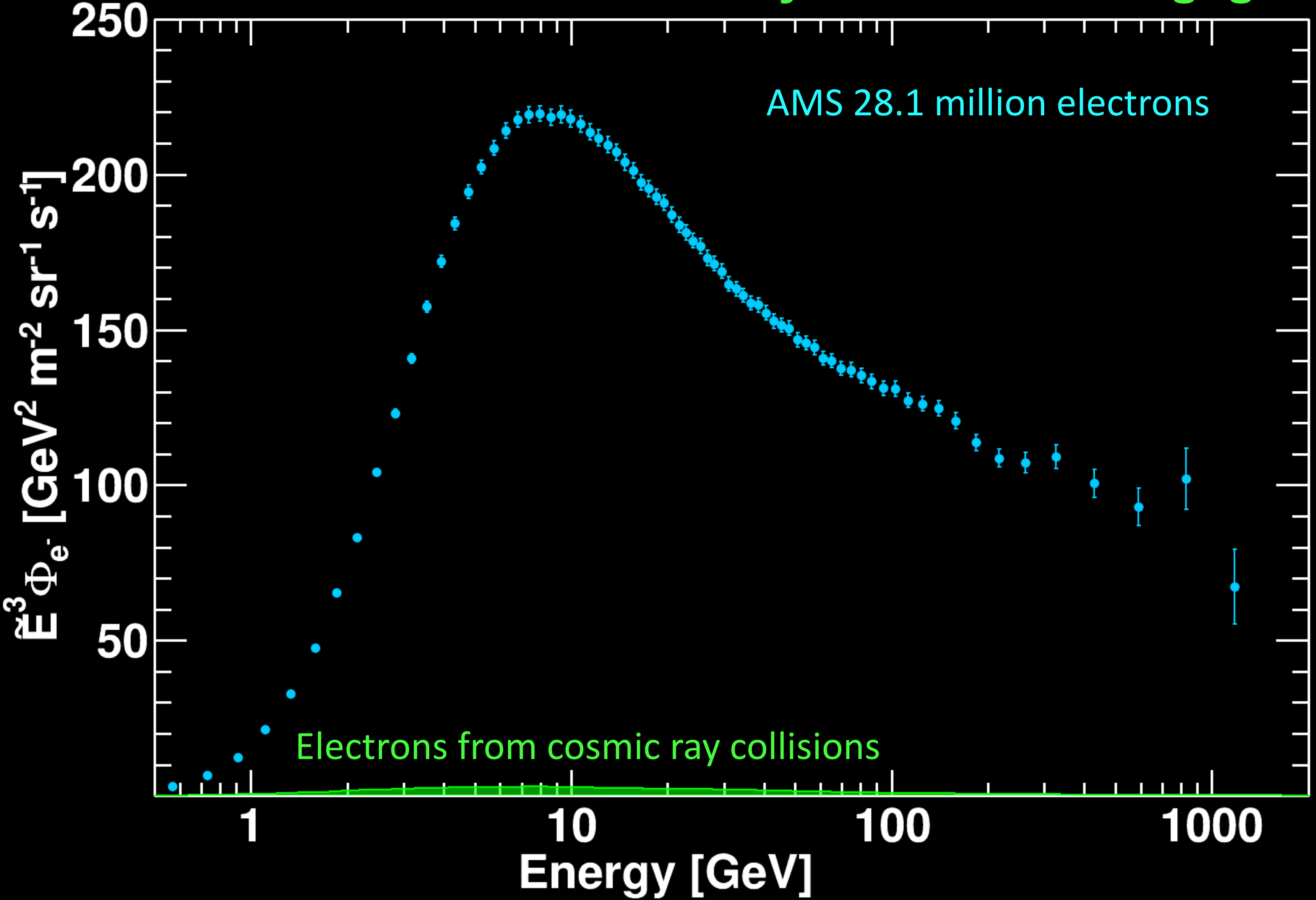
Positrons and Dark Matter Model by 2024



AMS Physics Results:

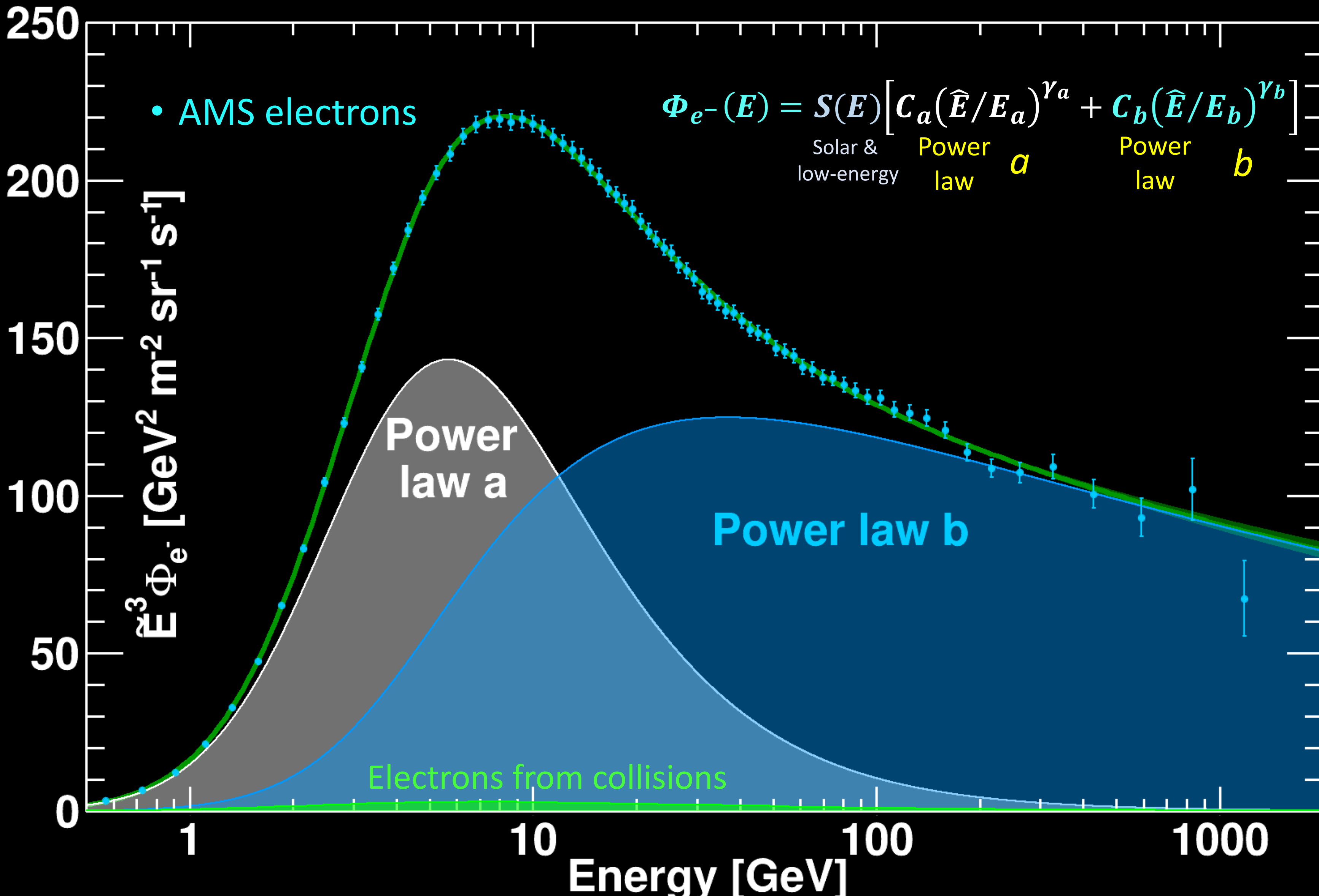
The Origins of Cosmic Electrons

The contribution from cosmic ray collisions is negligible



The electron flux can be described by two power law functions *a* and *b*

What is the origin of power law a and power law b?

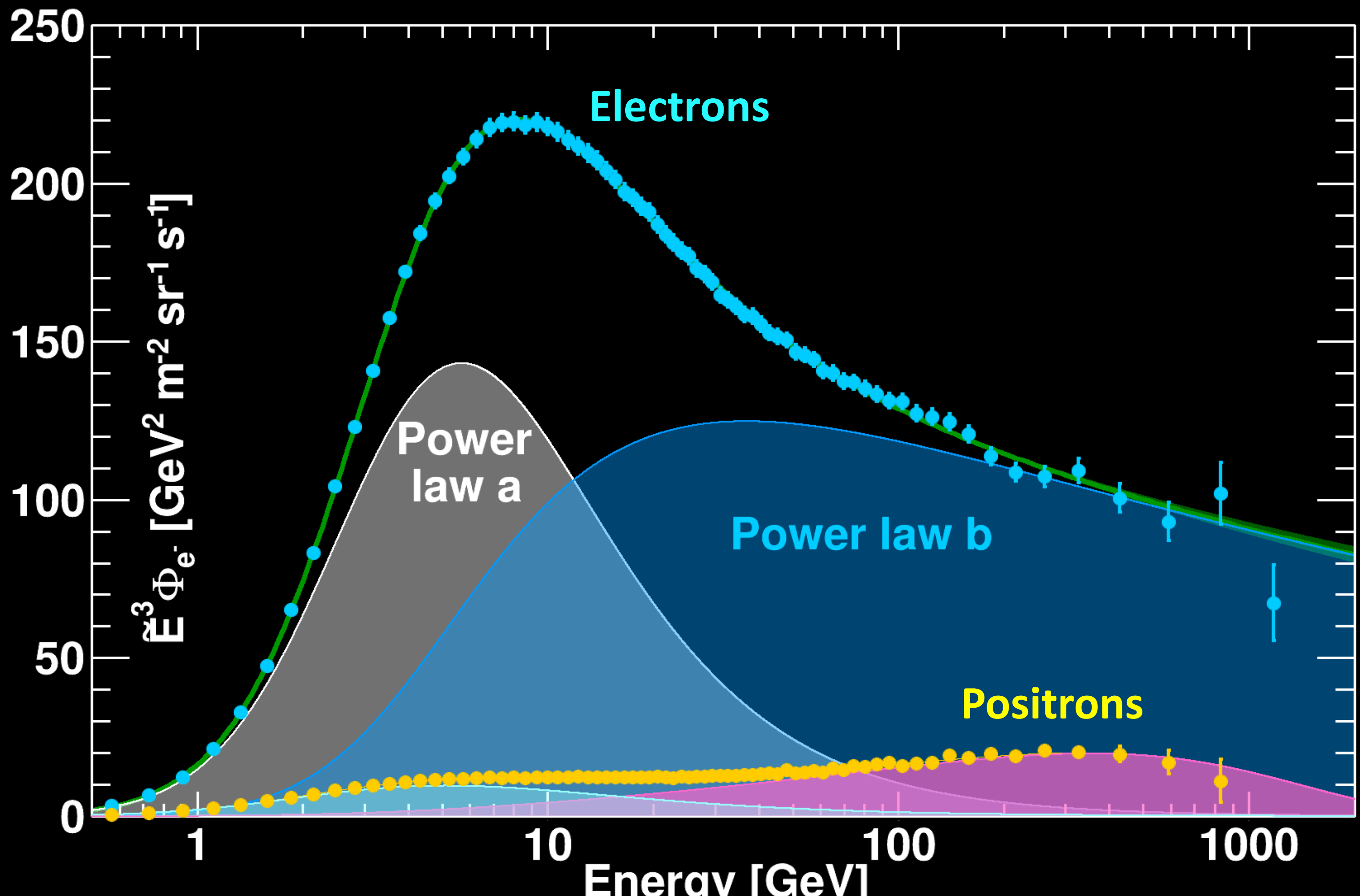


Conclusion

Electrons originate from different sources than positrons; the electron spectrum comes from two power law contributions.

The positron flux is the sum of low-energy part from cosmic ray collisions plus a high energy part from pulsars or dark matter. The positron flux has a cutoff energy E_S.

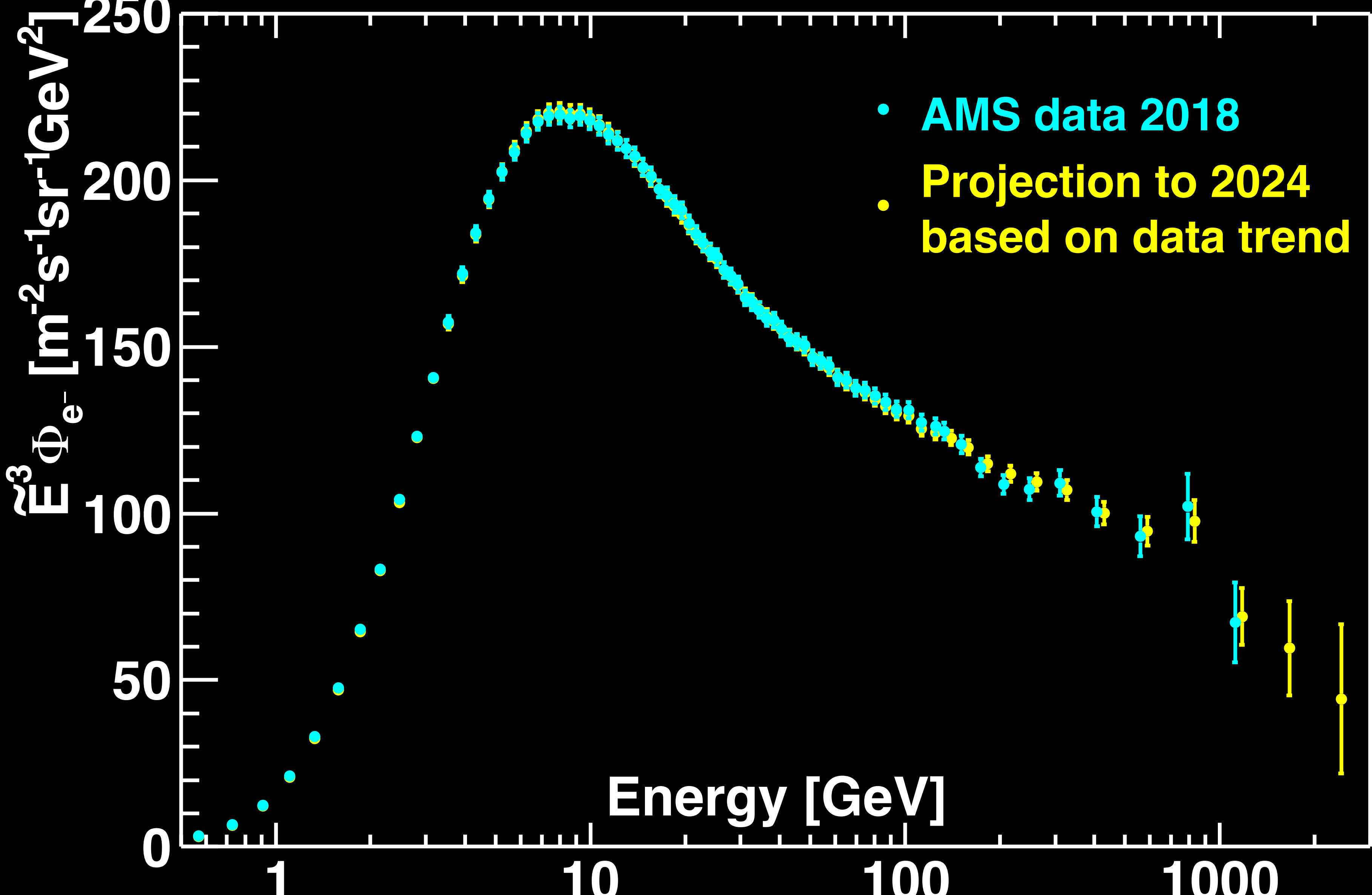
The antiproton spectrum is inconsistent with the pulsar origin of positrons.



Physics of cosmic electrons to 2024

What is the origin of power law a and power law b?

Is there a cutoff for electrons at higher energies?



The systematic errors on the electron flux

Five sources of systematic errors are identified:

1) **Uncertainty in efficiency correction**

2) **Uncertainty in fit templates definition**

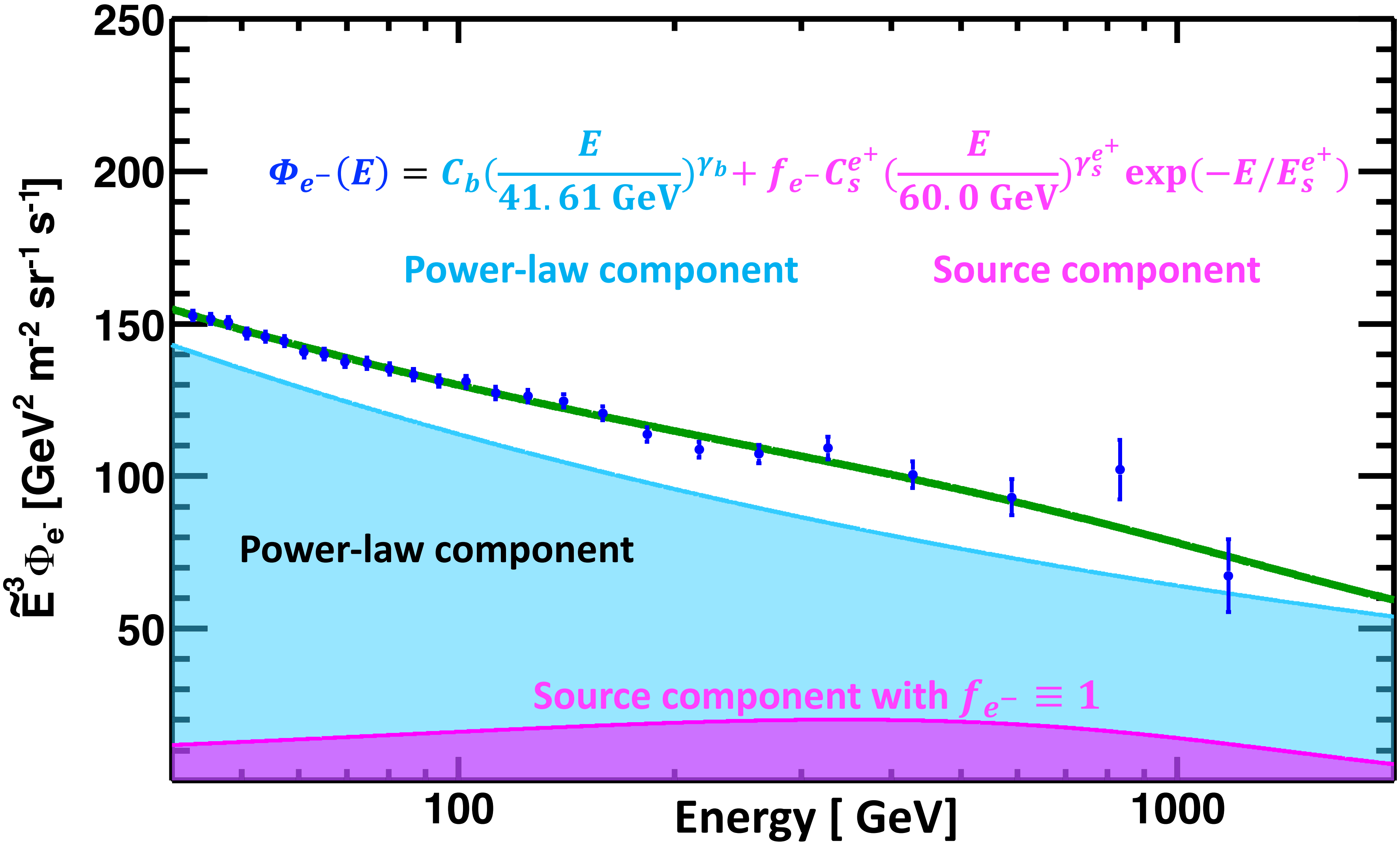
3) **Uncertainty in charge confusion estimation**

4) **Uncertainty in unfolding**

Sources 2), 3), and 4) are negligible for electron flux, as the electron sample is of high purity

5) **Energy scale, treated as the error on the energy bin boundaries.**

The origin of high energy electrons (II)



- AMS Electron flux is consistent with a charge symmetrical source which produce positrons and electrons with equal amount.
- The fit yields $f_{e^-} = 0.5^{+1.2}_{-0.6}$ leaving f_{e^-} as a free parameter, which means the significance to the source term comes mostly from the positron data.

The existence of the charge symmetric source term

$$\Phi_{e^-}(E) = C_{e^-}(E/E_1)^{\gamma_{e^-}} + f_{e^-}\, C_s^{e^+}(E/E_2)^{\gamma_s^{e^+}} \exp(-E/E_s^{e^+})$$

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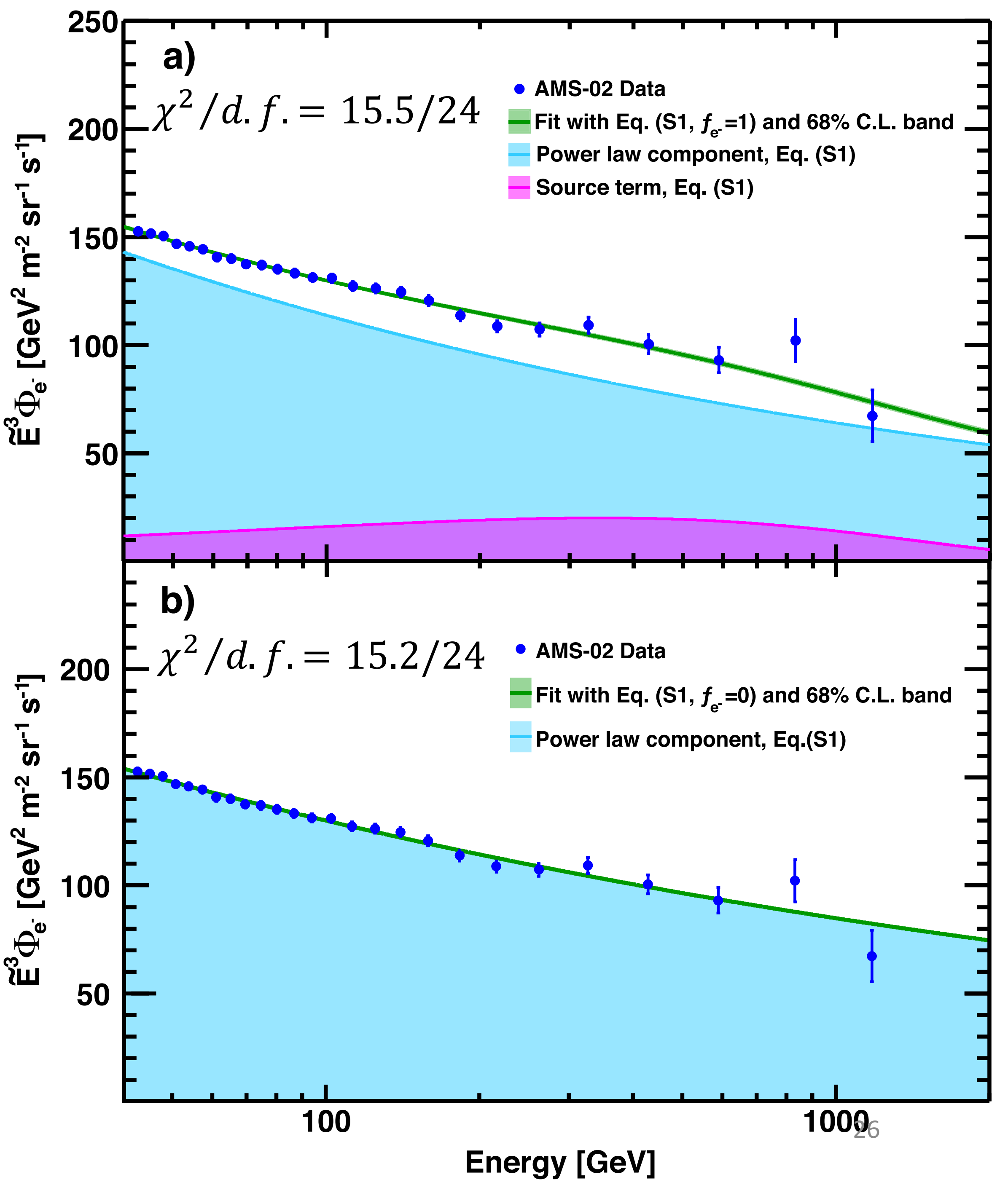
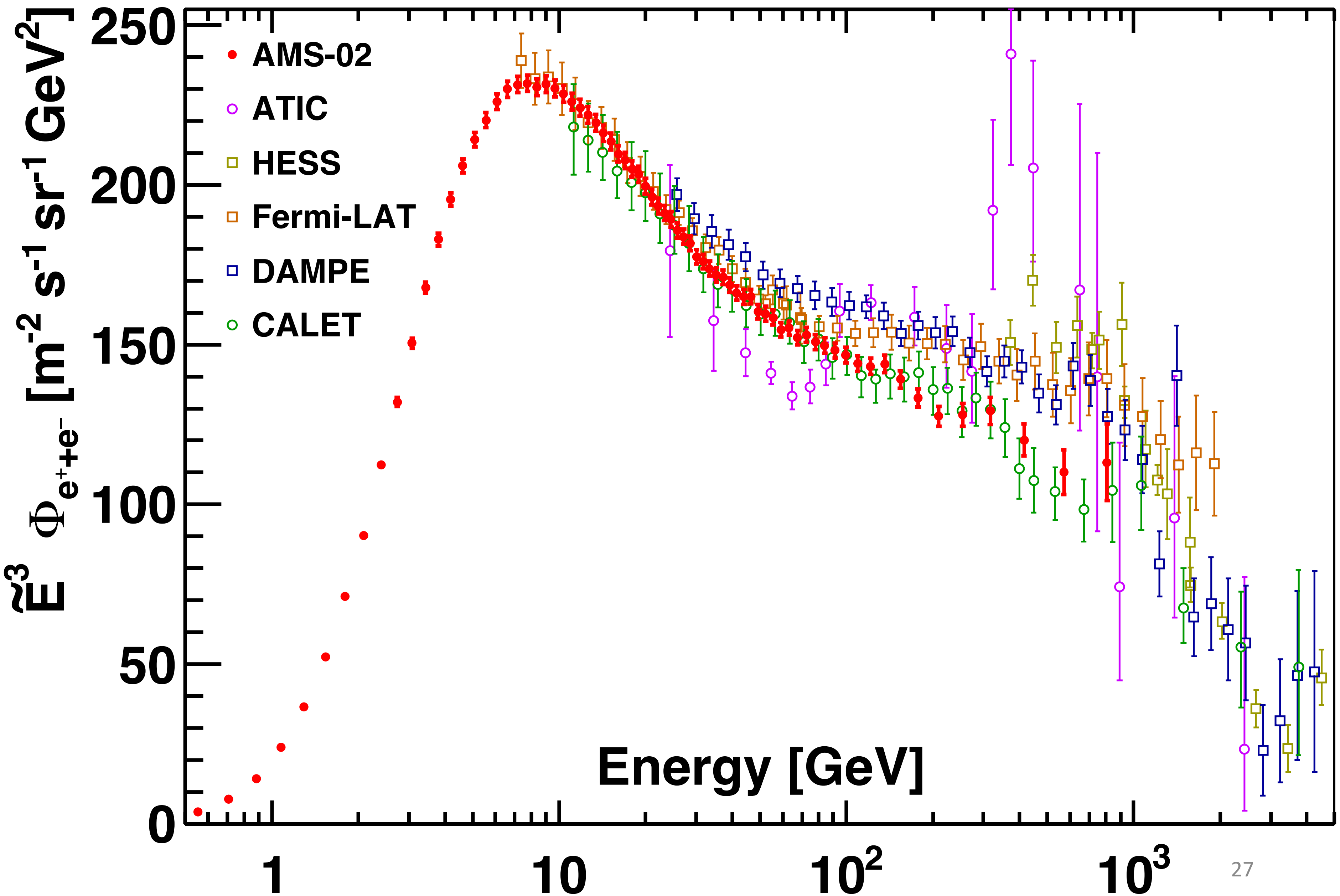


AMS (electron + positron) spectrum with earlier measurements



AMS positron fraction together with earlier measurements