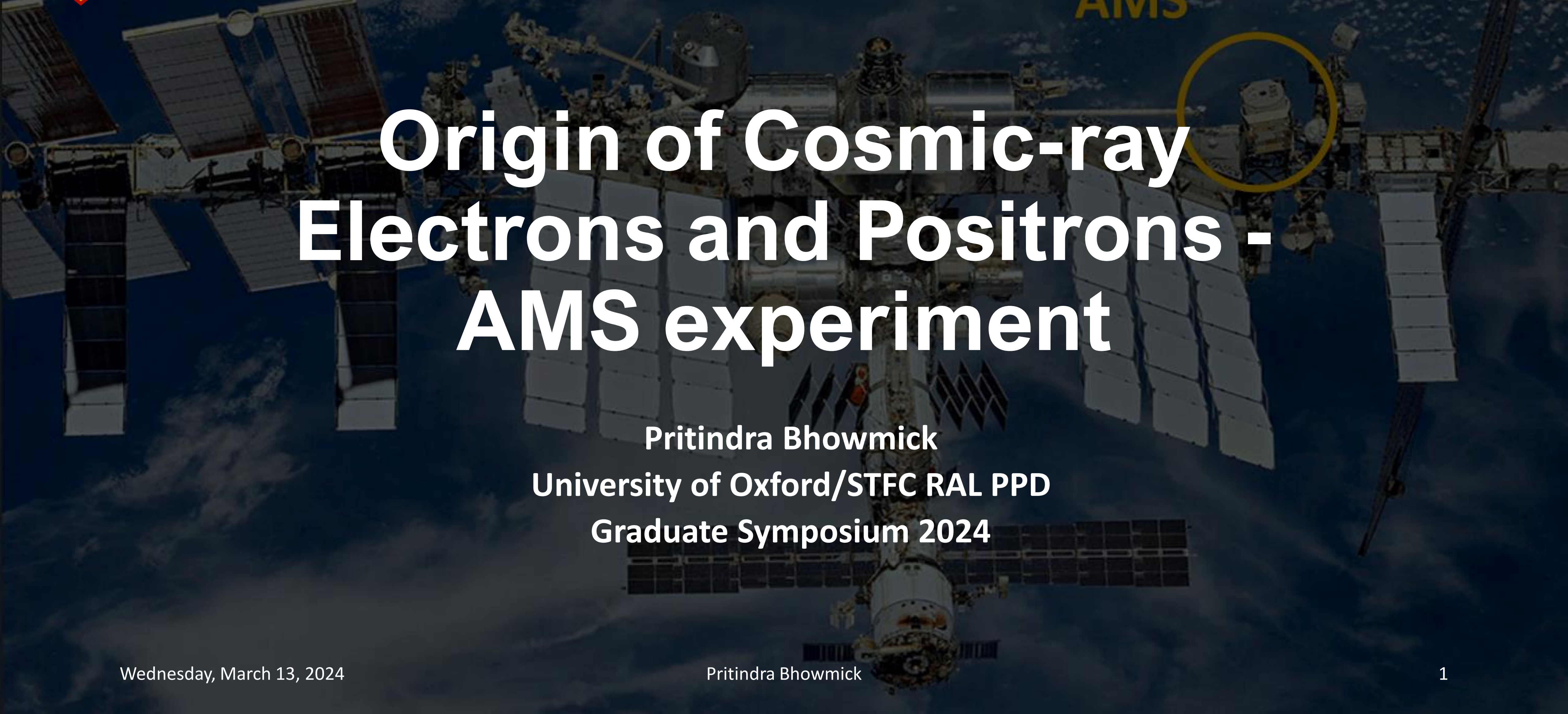
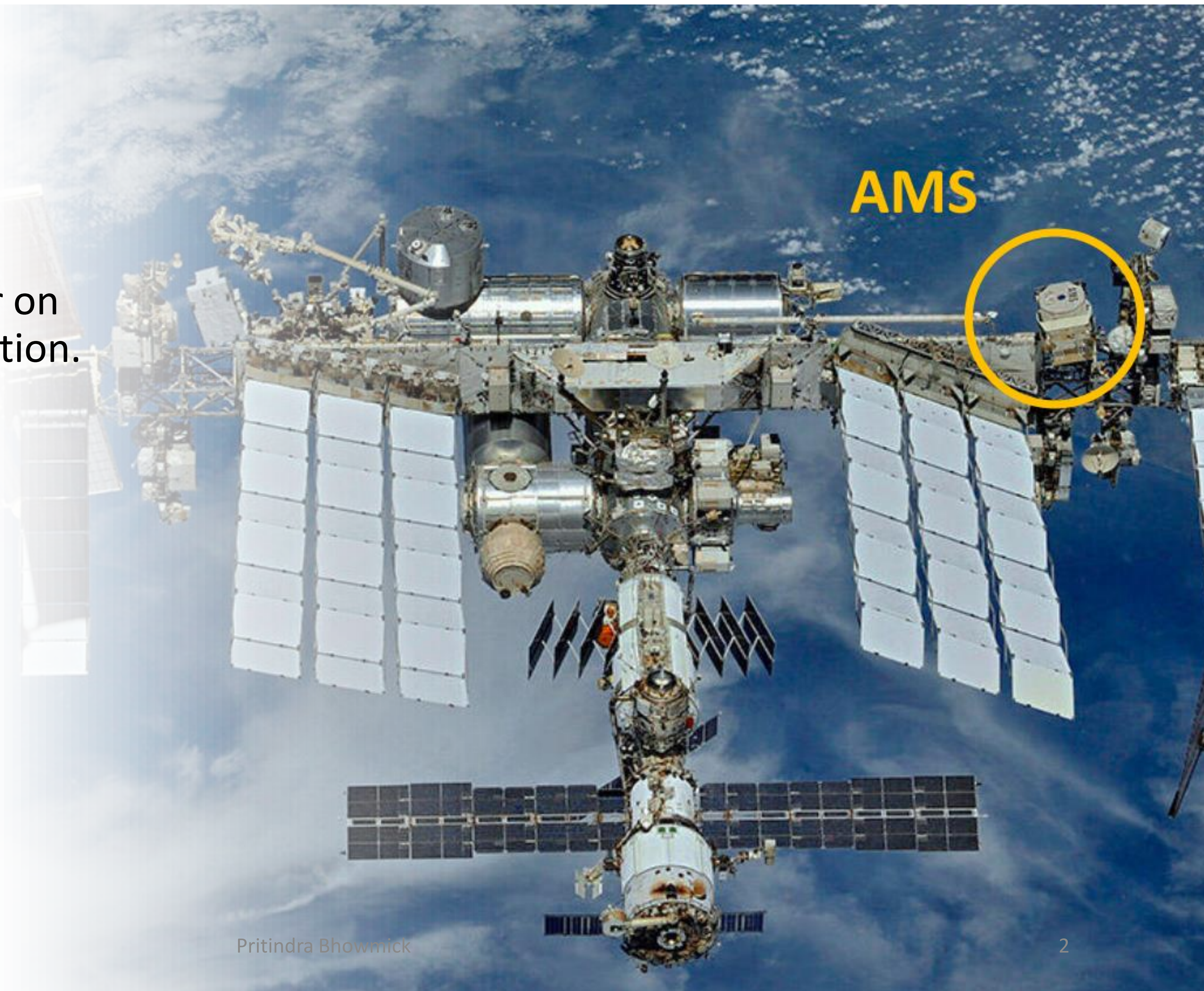


Origin of Cosmic-ray Electrons and Positrons - AMS experiment

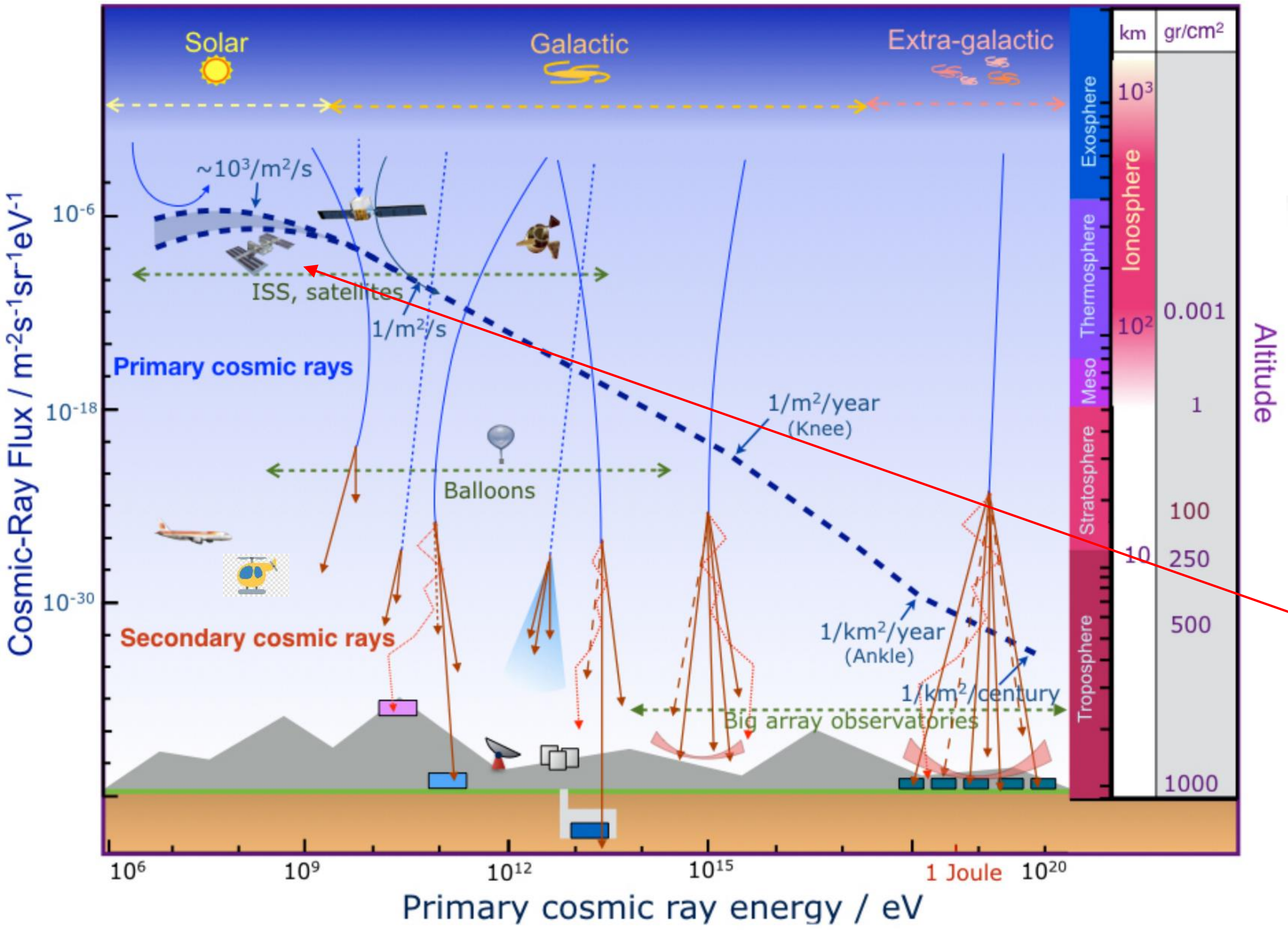
Pritindra Bhowmick
University of Oxford/STFC RAL PPD
Graduate Symposium 2024

The AMS experiment

- A magnetic spectrometer on the International Space Station.
- To measure charge and momentum of Cosmic ray particles.
- Aims to study
  - Dark Matter
  - Antimatter
  - Origin of Cosmos
  - New Phenomenon

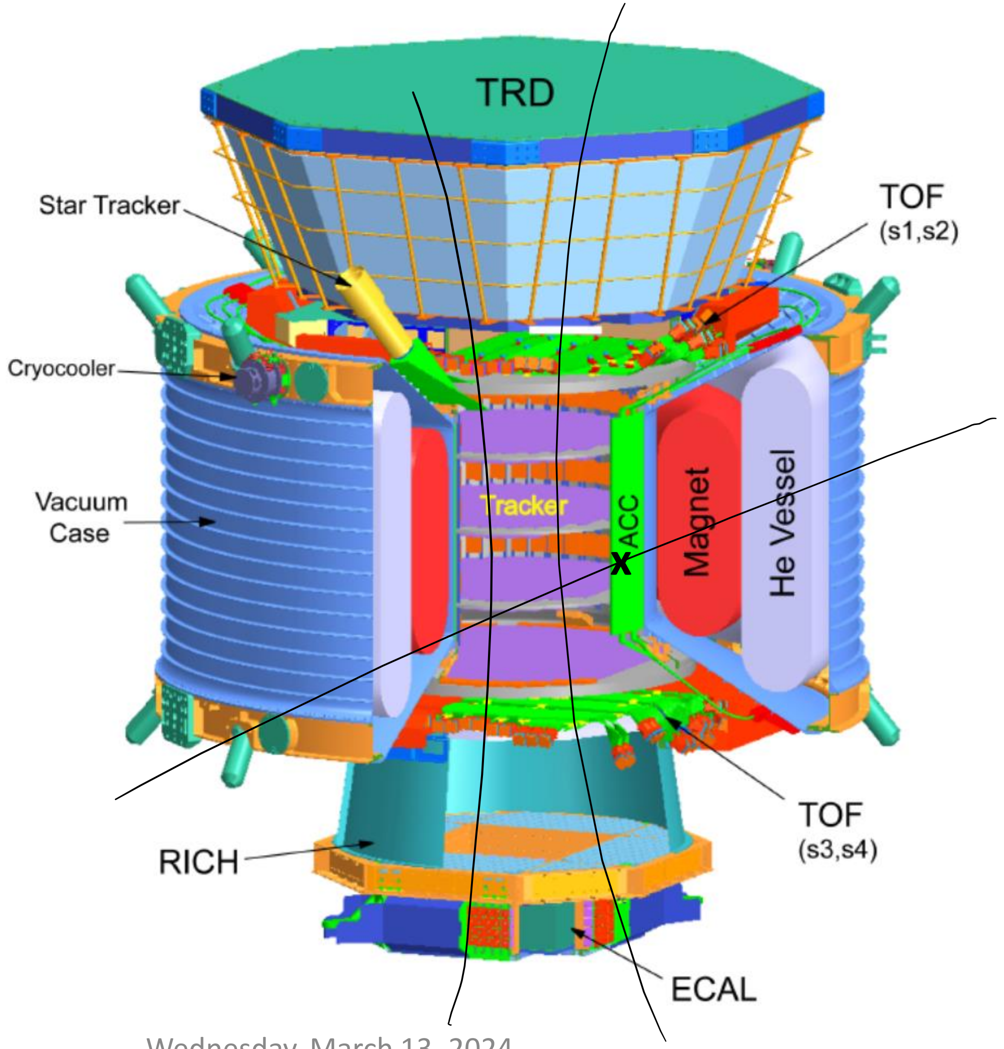


Why Alpha Magnetic Spectrometer in space?



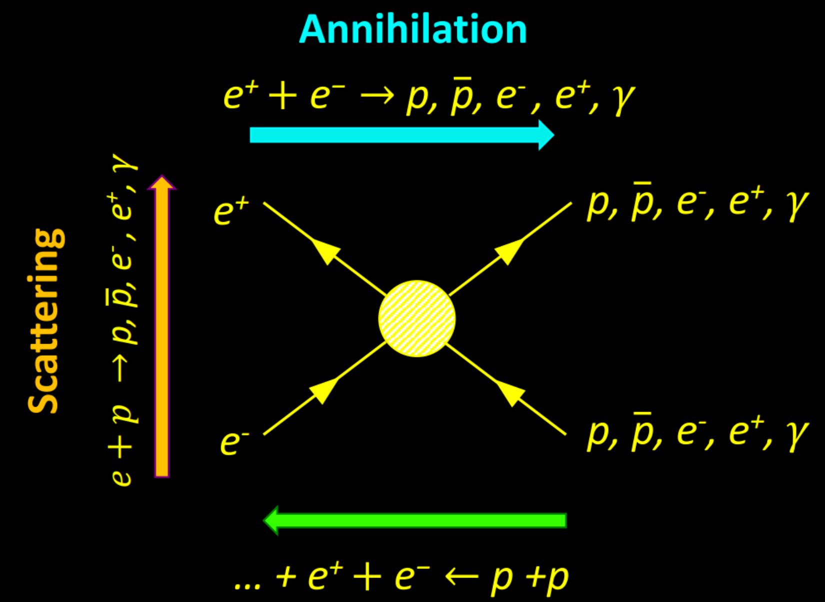
- Observe Primary cosmic rays.
- Magnetic spectrometer for p, Z.
- A magnetic spectrometer in the International Space station

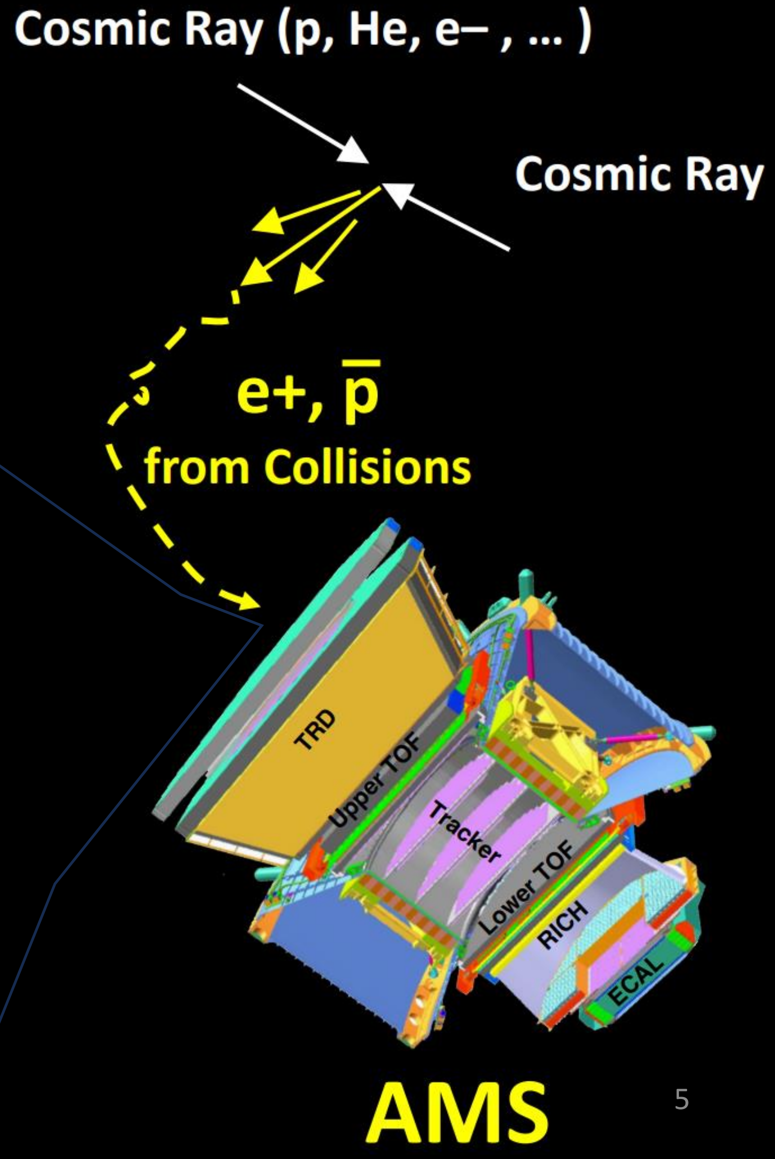
A Precision Particle Detector in Space



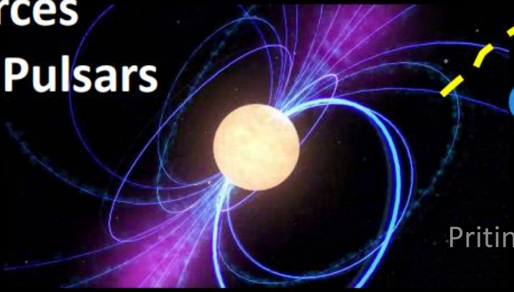
- A transition radiation detector for velocities of the highest-energy particles.
- A ring-imaging Cerenkov detector makes velocity measurement for fast particles.
- Two time-of-flight counters for lower-energy particles' speeds.
- Silicon tracker follows a particle's path.
- A superconducting magnet makes the particle's path curve.
- Two star tracker cameras to measure AMS's orientation.
- Electromagnetic calorimeter, for particle energy.
- An anti-coincidence veto counter notices stray particles sneaking through AMS sideways.

Taken from cyclotron.mit.edu/ams/frames.det.html

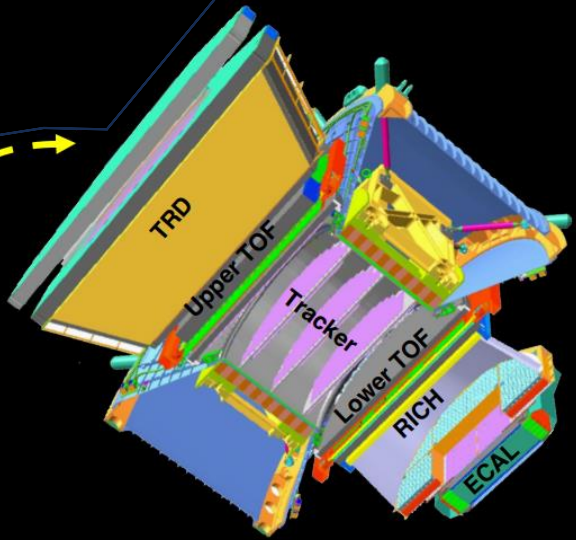

Annihilation
e⁺ + e⁻ → p, p̄, e⁻, e⁺, γ
Scattering
e + p → p, p̄, e⁻, e⁺, γ
e⁺
e⁻
p, p̄, e⁻, e⁺, γ
p, p̄, e⁻, e⁺, γ
… + e⁺ + e⁻ ← p +p


Cosmic Ray (p, He, e− , …)
Cosmic Ray
e+, p̄
from Collisions
TRD
Upper TOF
Tracker
Lower TOF
RICH
ECAL
AMS

New Astrophysical Sources such as Pulsars

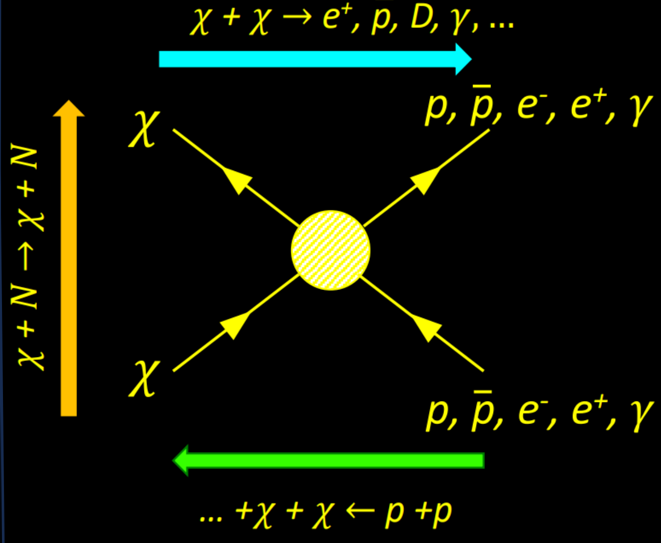


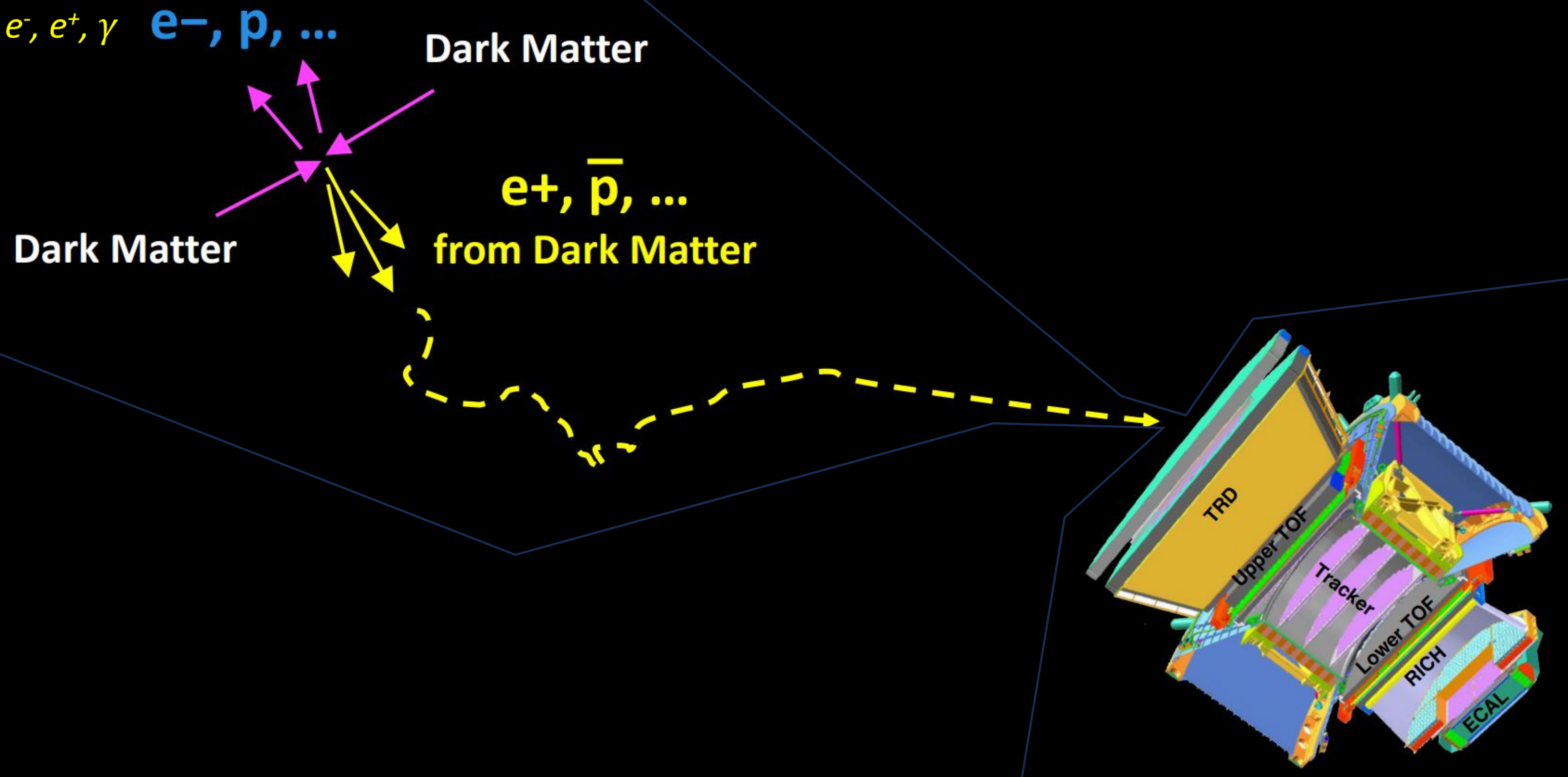
e−, e+ from Pulsars



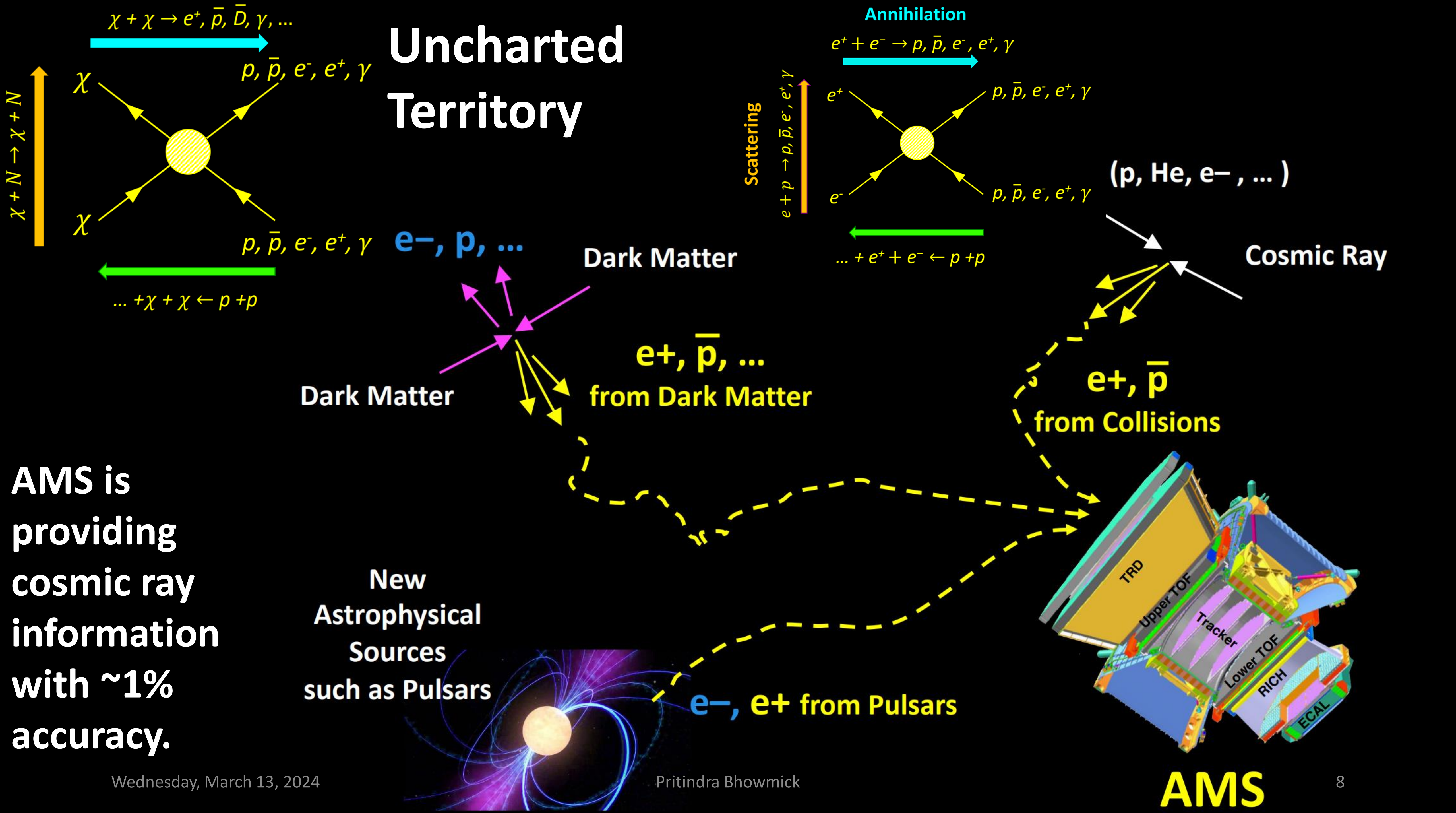
AMS

Uncharted Territory



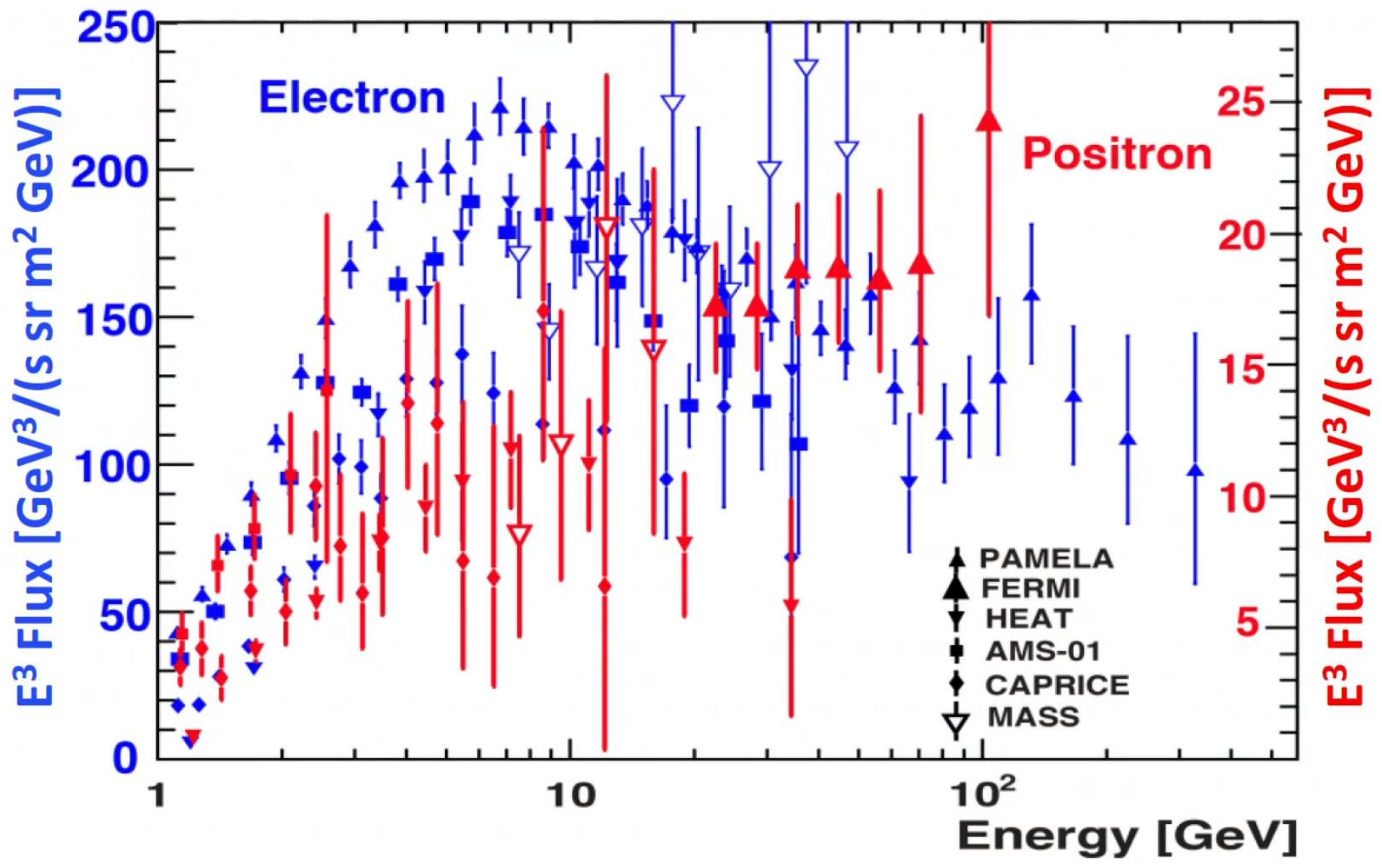


AMS



Uncharted Territory
$\chi + \chi \rightarrow e^+, \bar{p}, \bar{D}, \gamma, \ldots$
$\chi + N \rightarrow \chi + N$
χ
χ
$p, \bar{p}, e^-, e^+, \gamma$
$p, \bar{p}, e^-, e^+, \gamma$
$\ldots + \chi + \chi \leftarrow p + p$
Annihilation
$e^+ + e^- \rightarrow p, \bar{p}, e^-, e^+, \gamma$
Scattering
$e + p \rightarrow p, \bar{p}, e^-, e^+, \gamma$
e^+
e^-
$p, \bar{p}, e^-, e^+, \gamma$
$p, \bar{p}, e^-, e^+, \gamma$
$\ldots + e^+ + e^- \leftarrow p + p$
(p, He, e−, ...)
Cosmic Ray
e−, p, ...
Dark Matter
Dark Matter
e+, $\bar{p}$, ...
from Dark Matter
e+, $\bar{p}$
from Collisions
AMS is providing cosmic ray information with ~1% accuracy.
New Astrophysical Sources such as Pulsars
e−, e+ from Pulsars
TRD
Upper TOF
Tracker
Lower TOF
RICH
ECAL
AMS

Electron and Positron flux before AMS

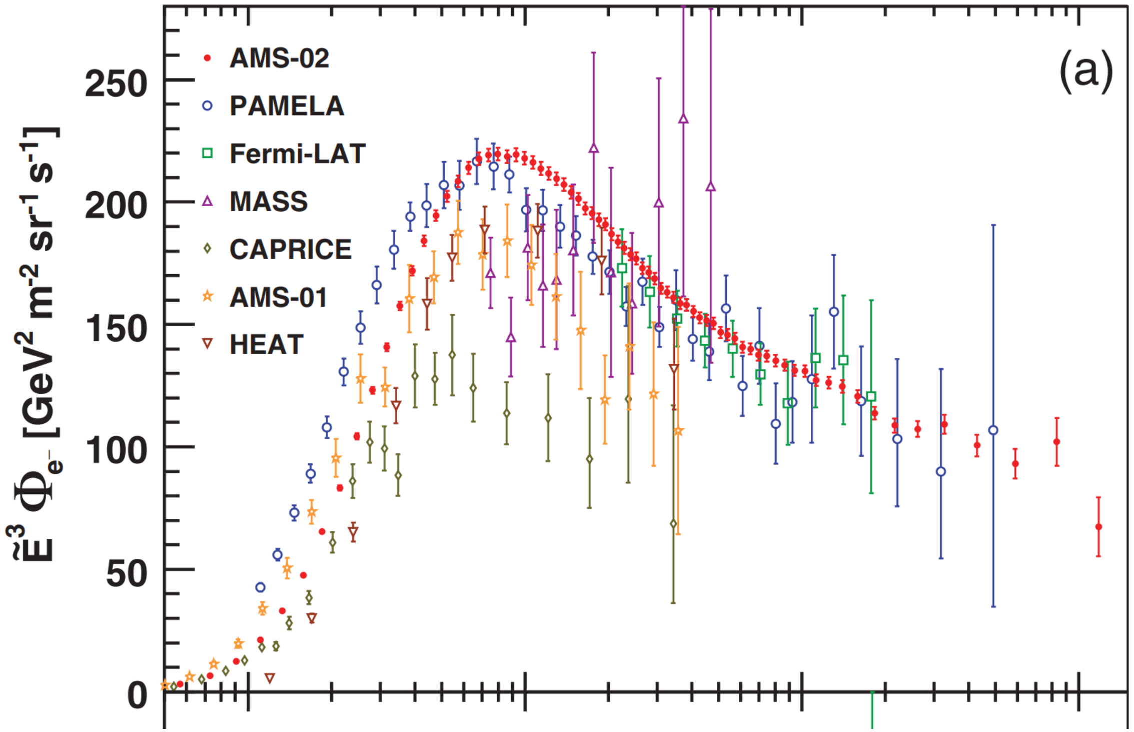


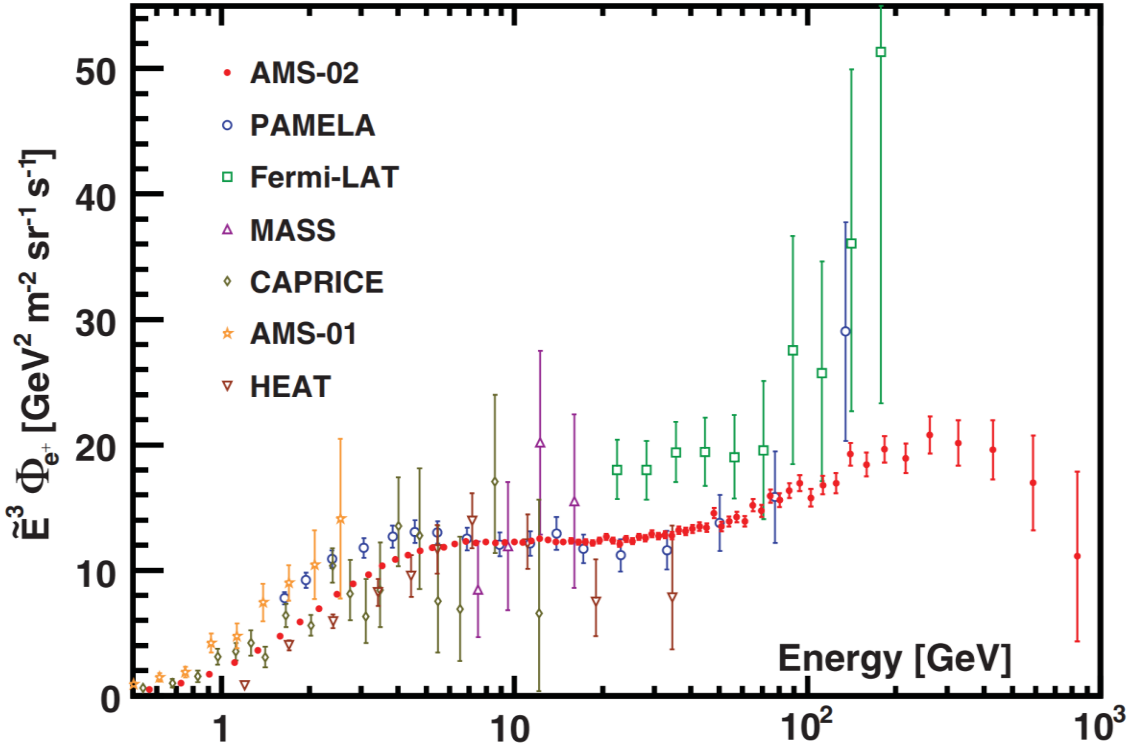
- Very difficult experiments.
- Very high error.
- Low agreement between many experiments.

AMS-02 electron and positron spectra

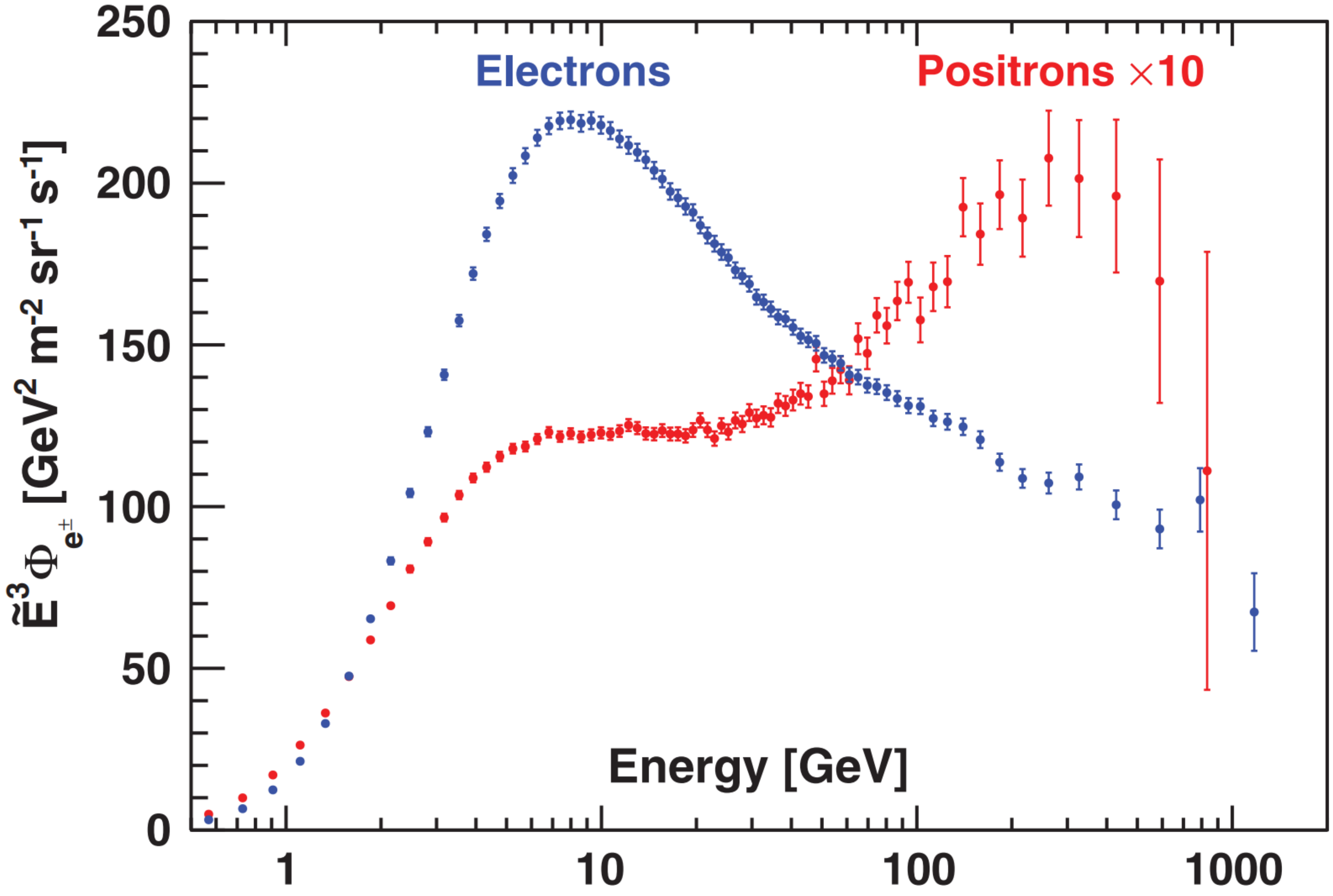
Much lower error.

Better primary cosmic ray spectrum data than any other experiment



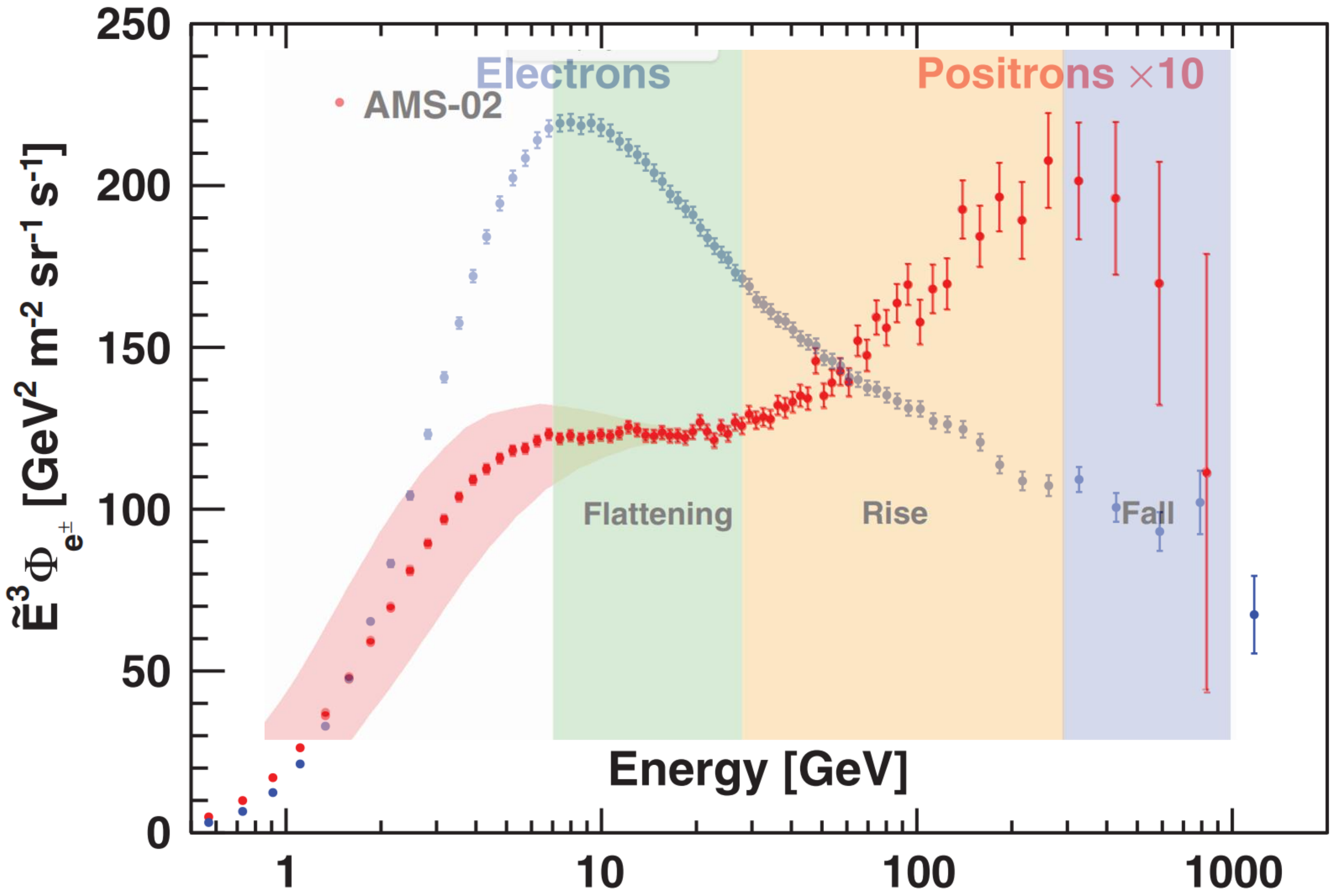


AMS results from 2018



28.1 Million Electrons.
1.9 Million Positrons.

AMS results from 2018

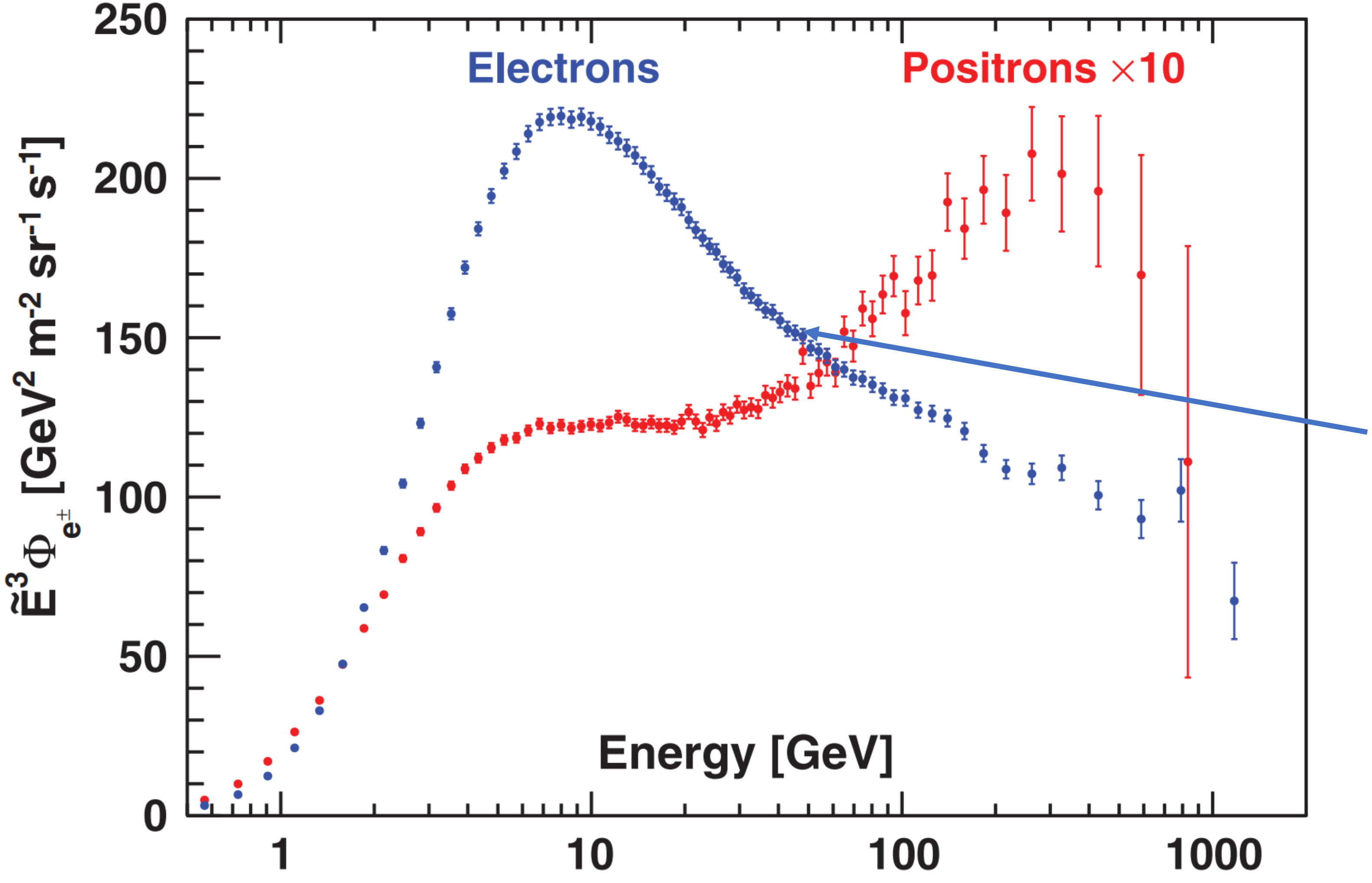


28.1 Million Electrons.
1.9 Million Positrons.

Breaking down the spectrum

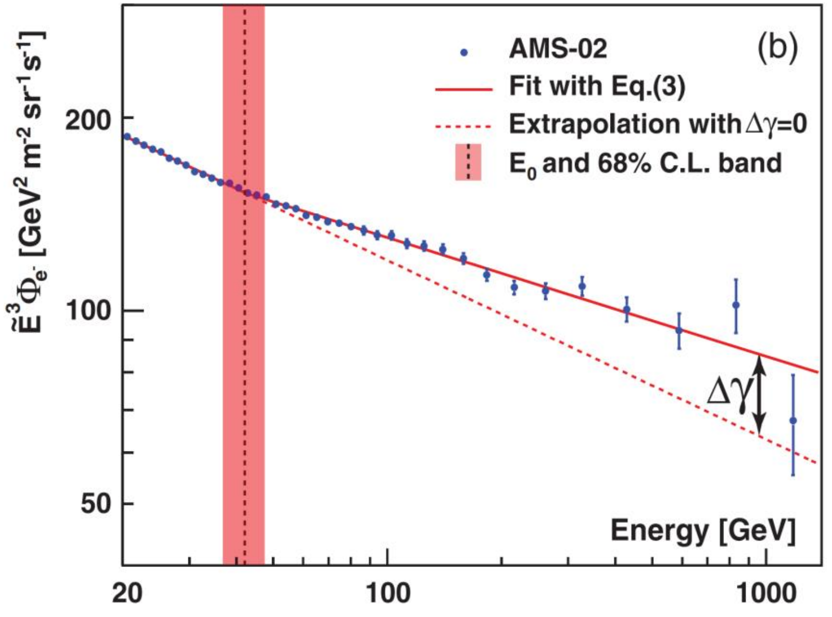
Spectral Index - source dependant

$$\Phi \propto E^{\gamma} = \begin{cases} E^{\gamma_1}; E < E_0 \\ E^{\gamma_2}; E > E_0 \end{cases}$$



Spectral Index – Slope of log vs log curves

γ = d(logΦ)/d(logE)

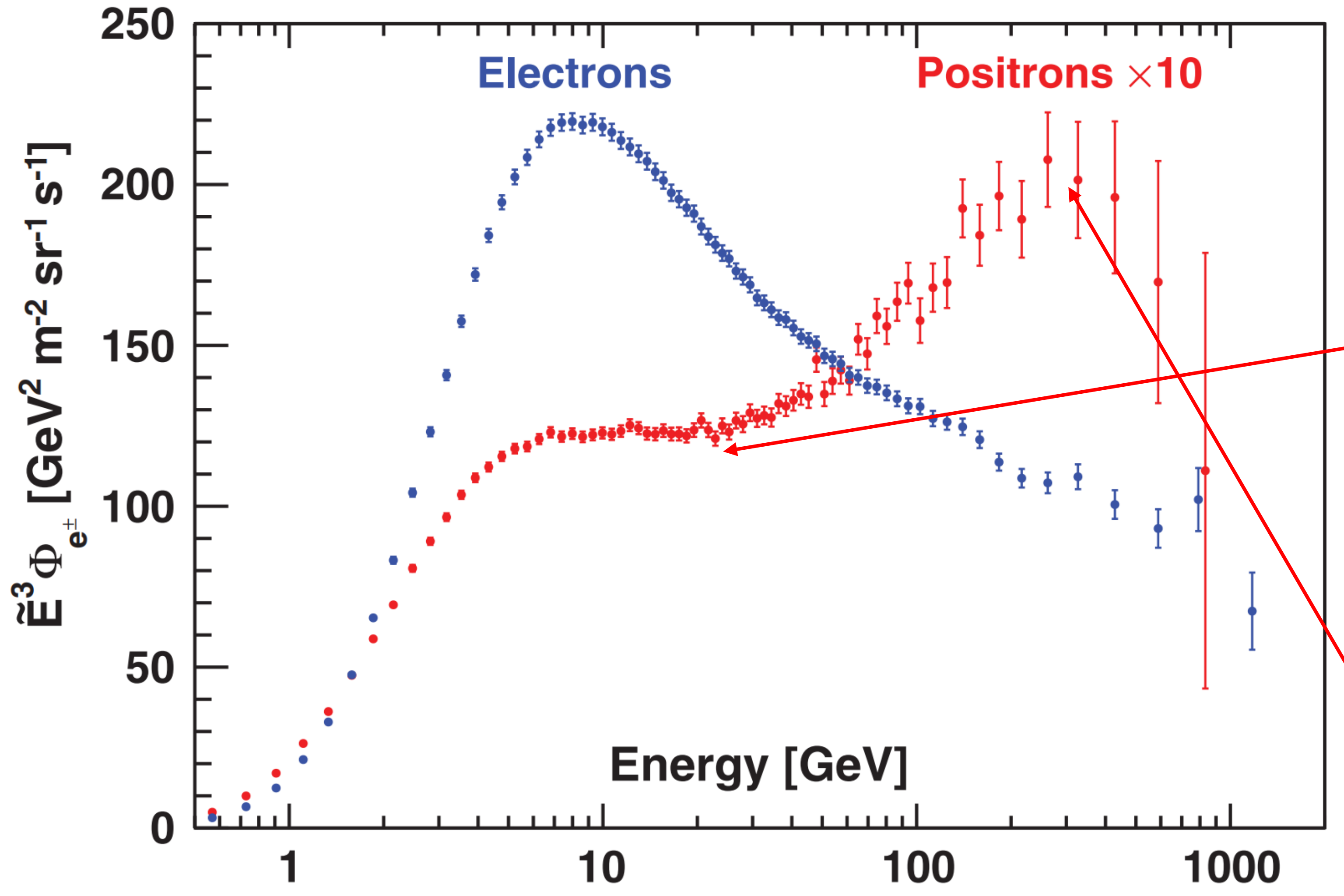


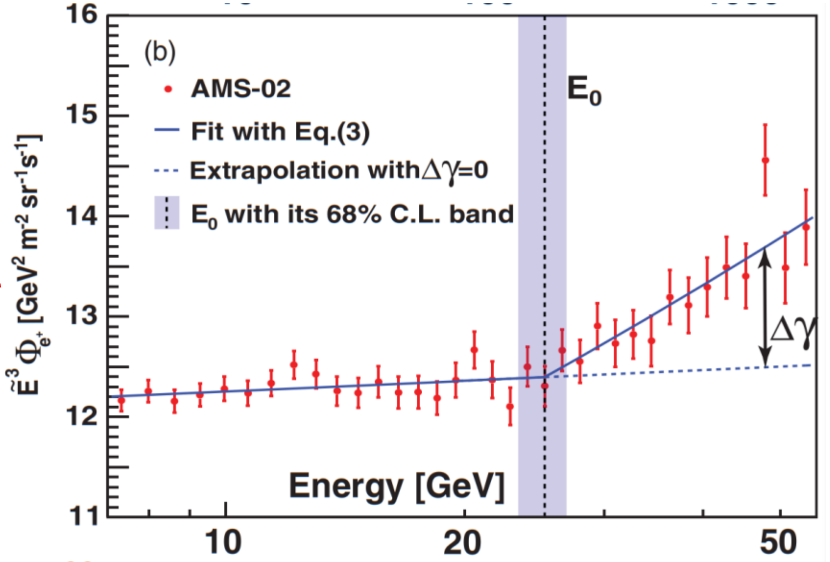
Electron excess from 42.1±5.4 GeV.

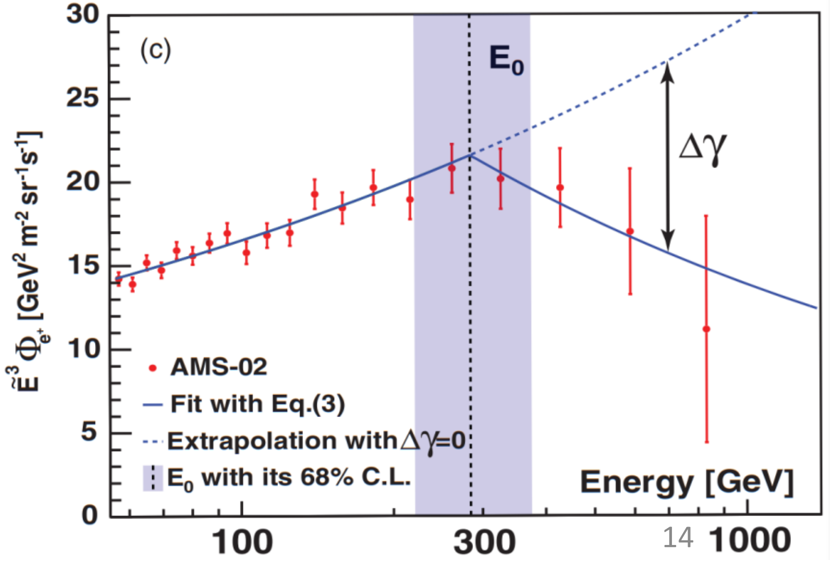
Breaking down the spectrum

Spectral Index - source dependant

$$\Phi \propto E^{\gamma} = \begin{cases} E^{\gamma_1}; E < E_0 \\ E^{\gamma_2}; E > E_0 \end{cases}$$







Positron Excess @ 25.2±1.8 GeV

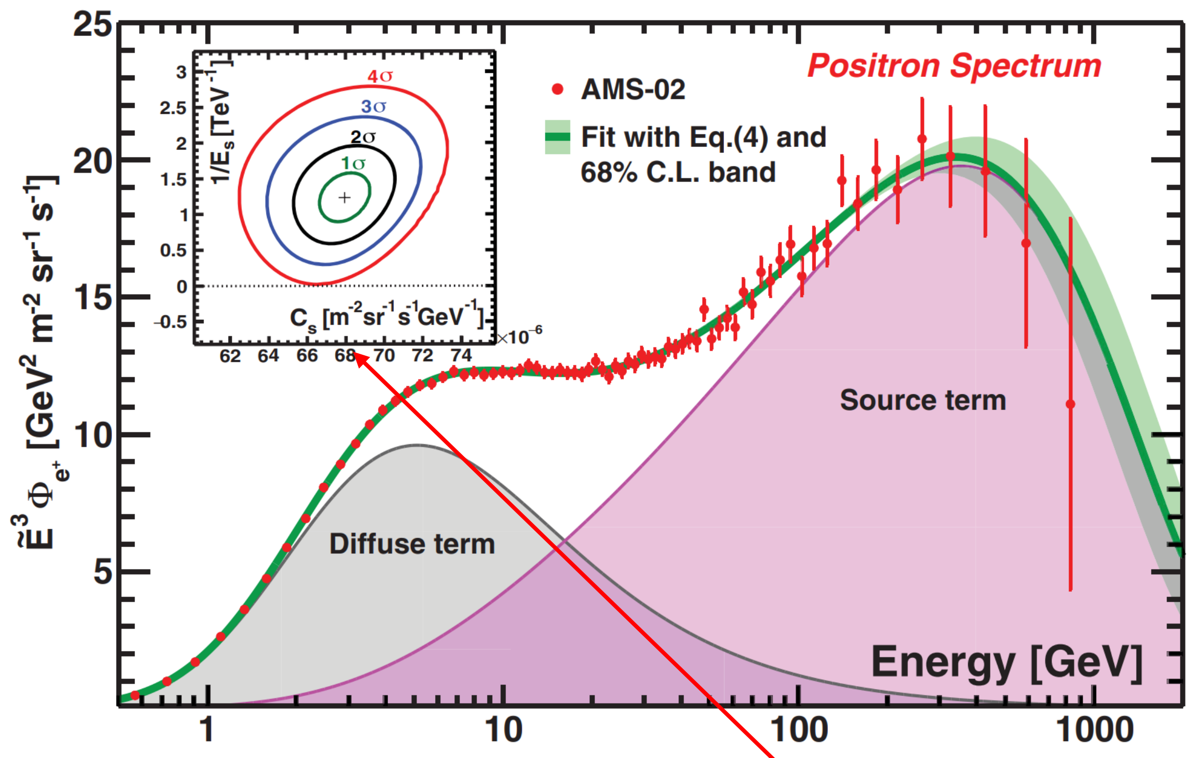
Sharp positron drop @ 284^{+91}_{-64} GeV

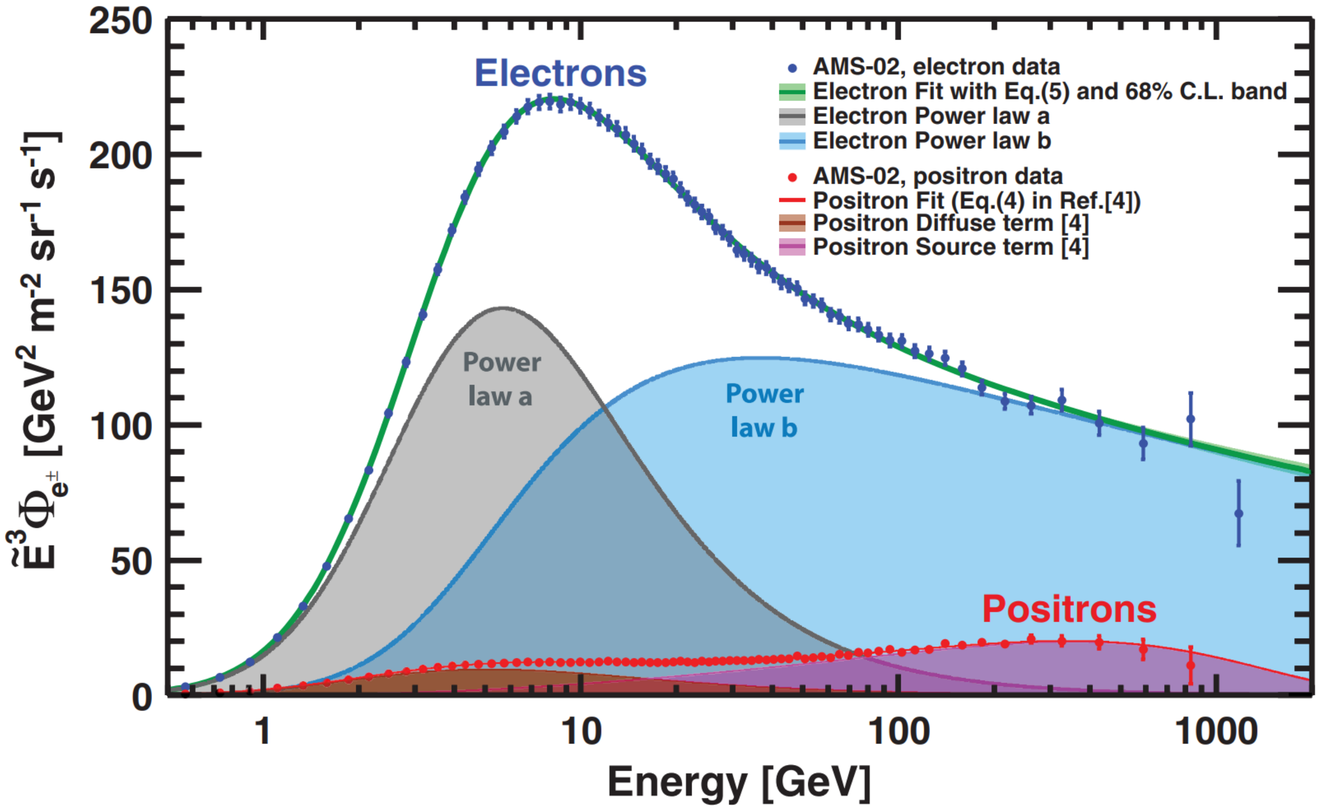
Consistent with the existence of a new source of high-energy positrons with a characteristic cutoff energy.

Where do $e^{\pm}$ come from

Cosmic ray collisions

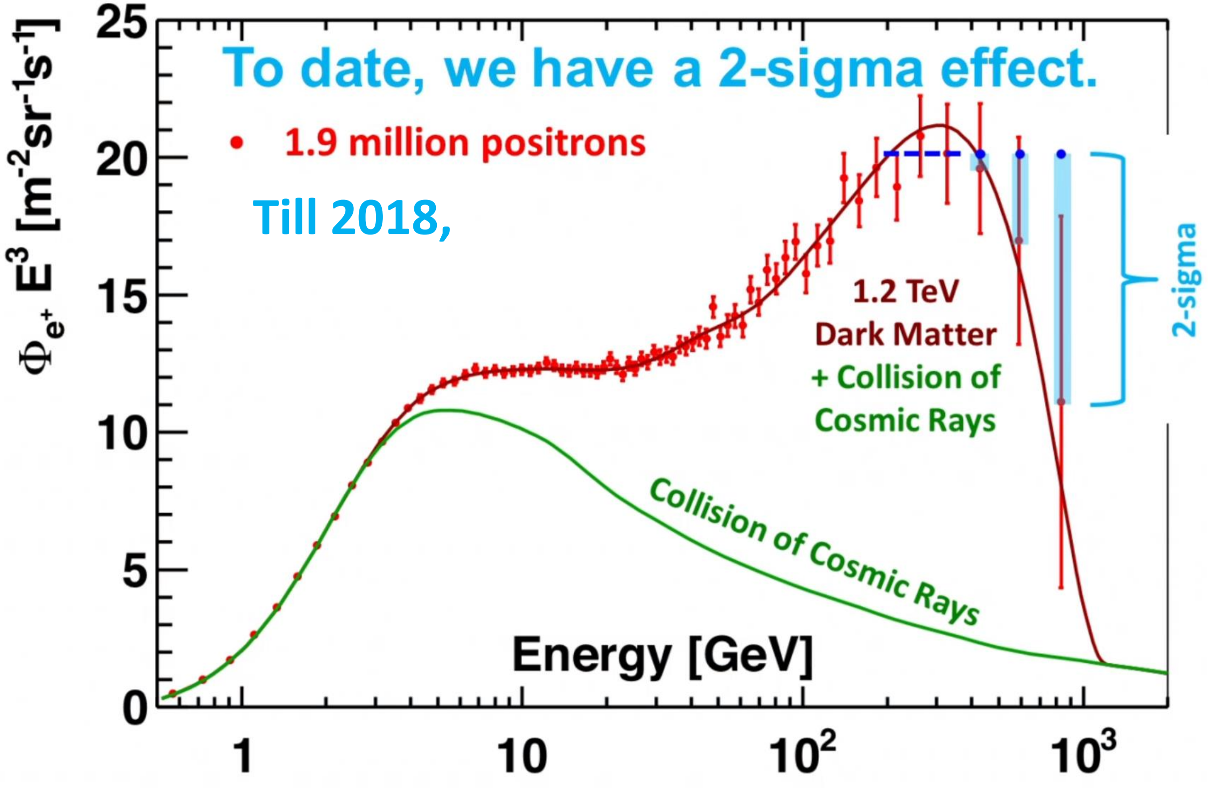
Dark Matter/Pulsars



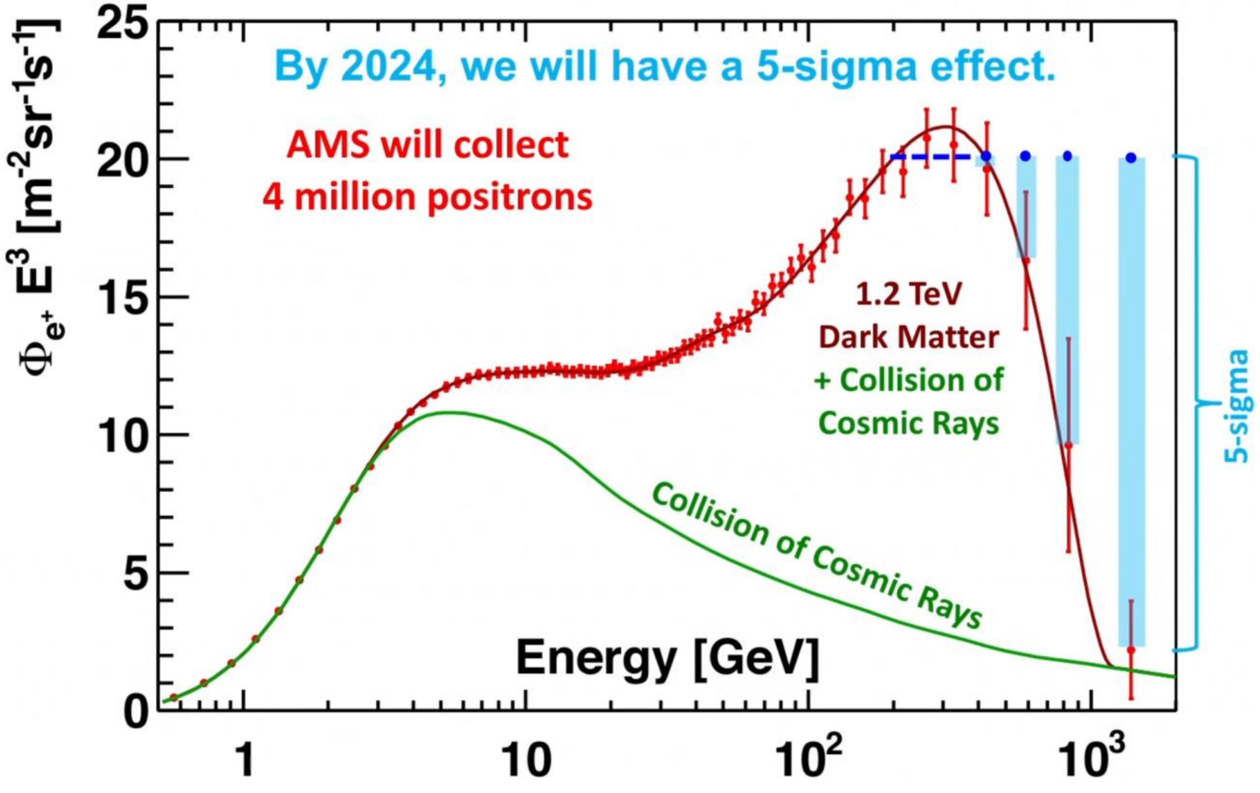


Source Energy for source term.

Big Discovery? Maybe …

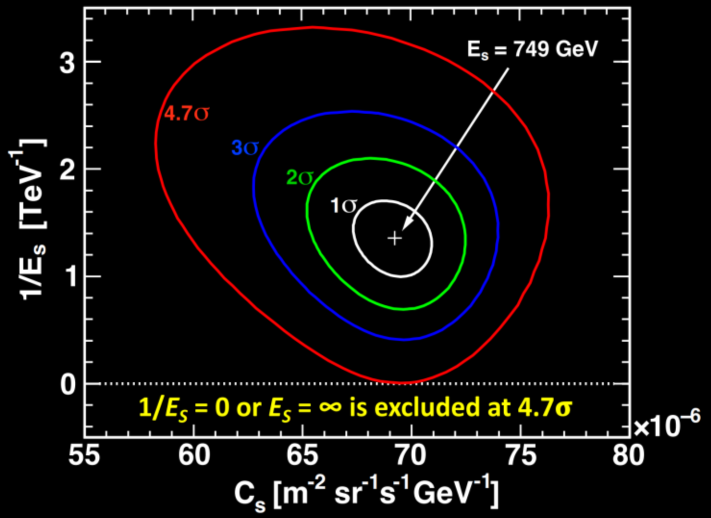


CERN Colloquium, Samuel Ting, 24/05/2018

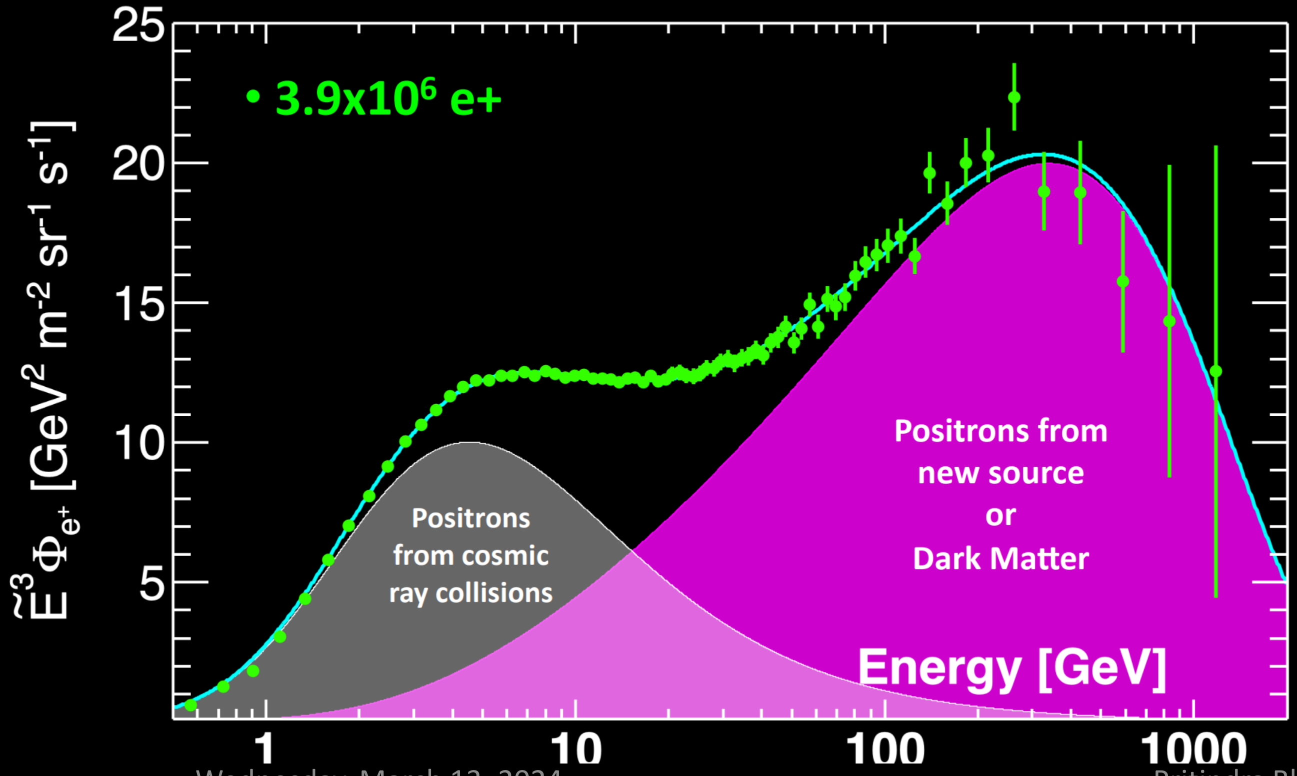


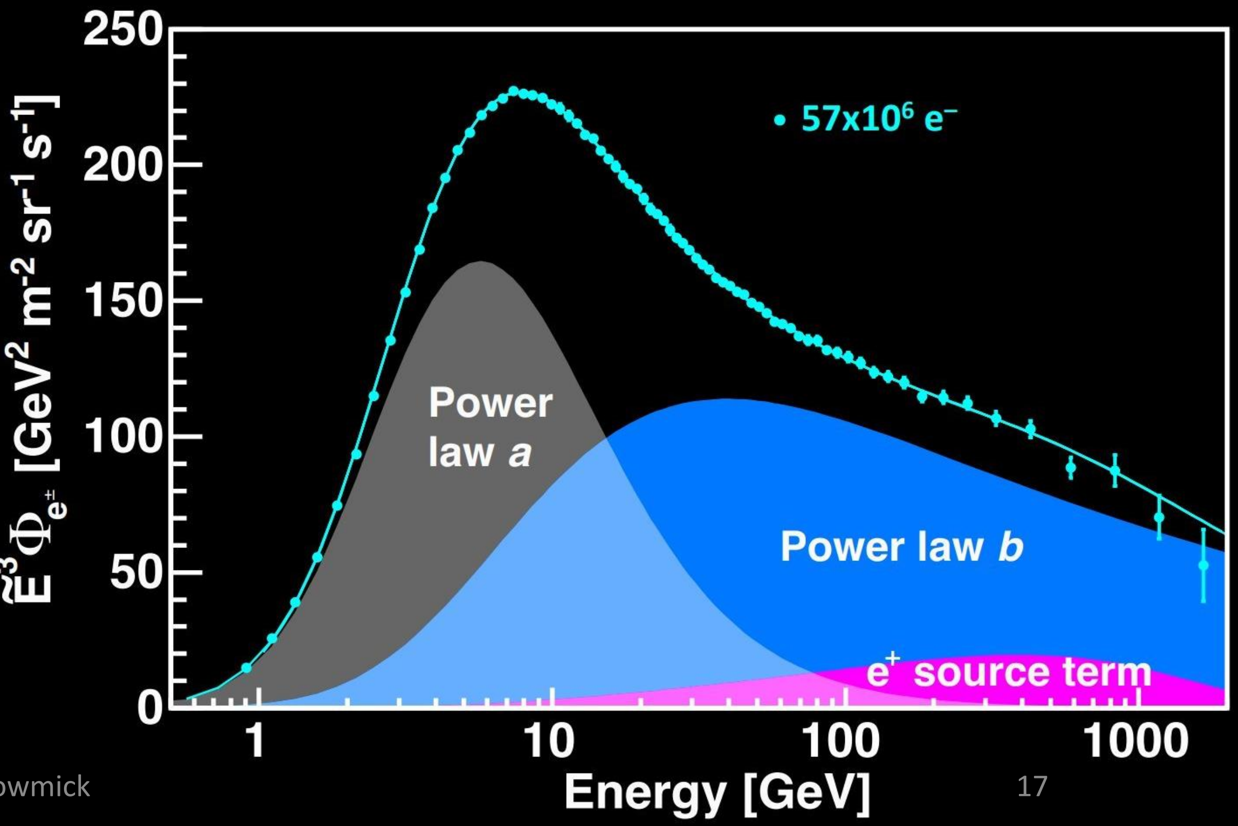
Its 2024 now! Do we have more conclusive results?

Data from 2023

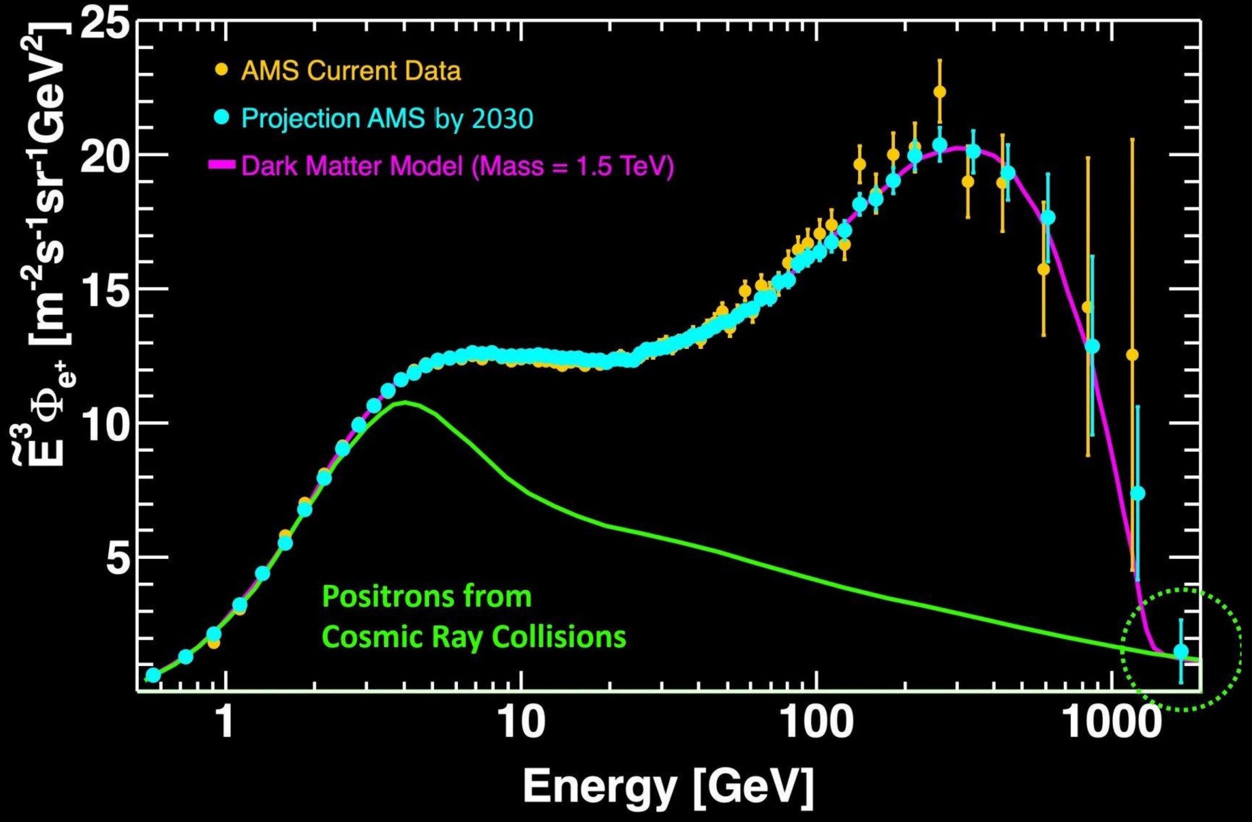


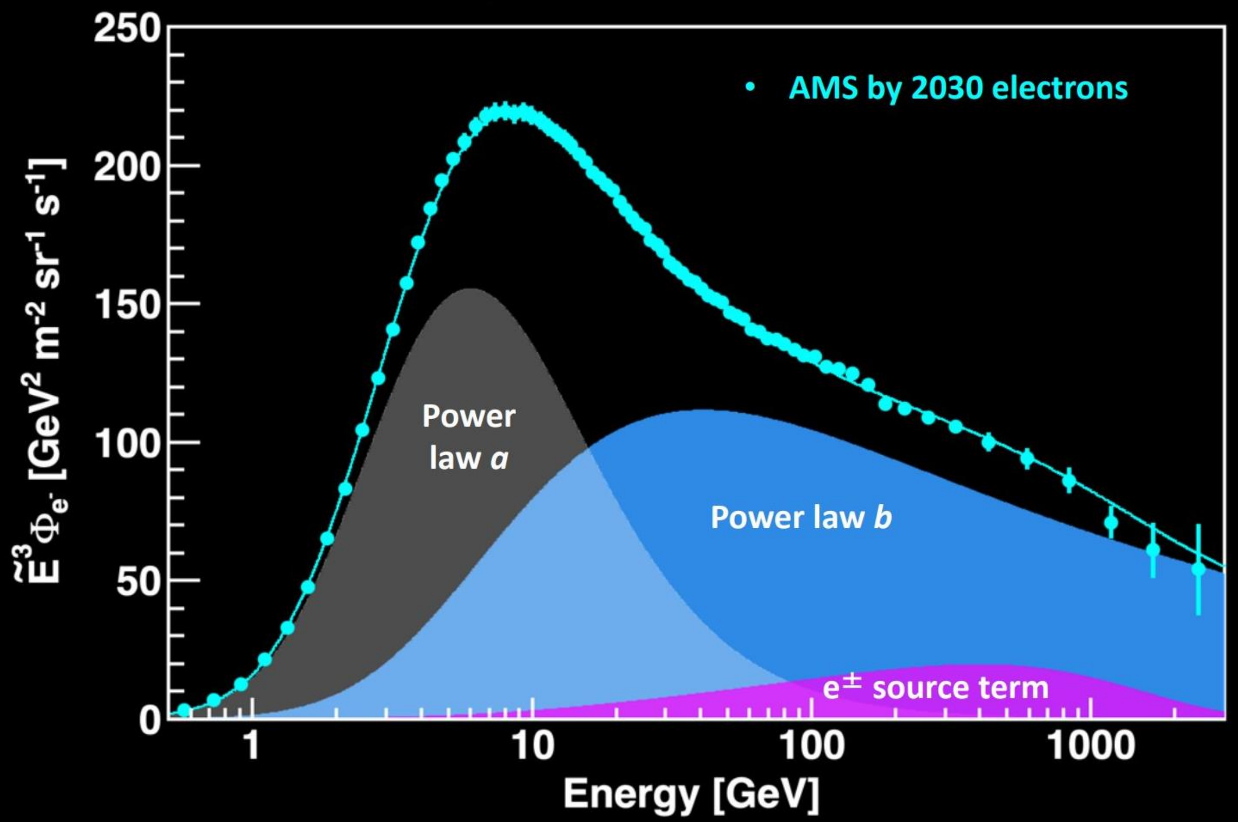
CERN Colloquium, Samuel Ting, 08/06/2023
The error is still quite high in high energies!





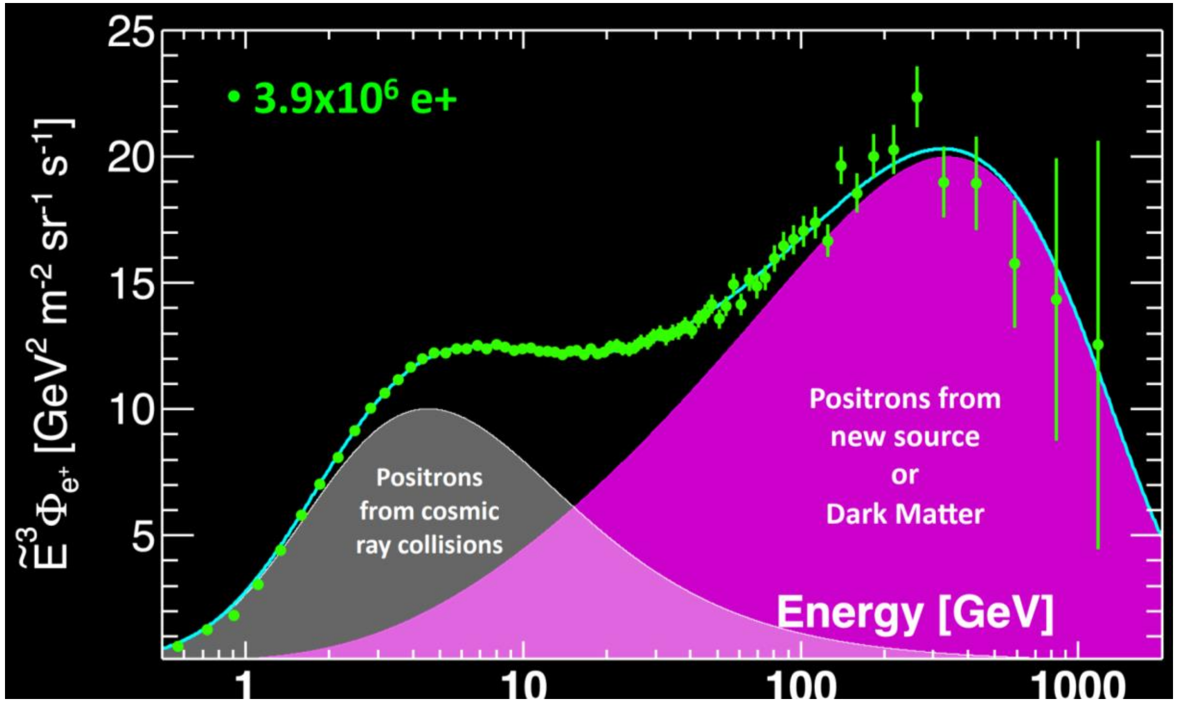
Predictions in 2023

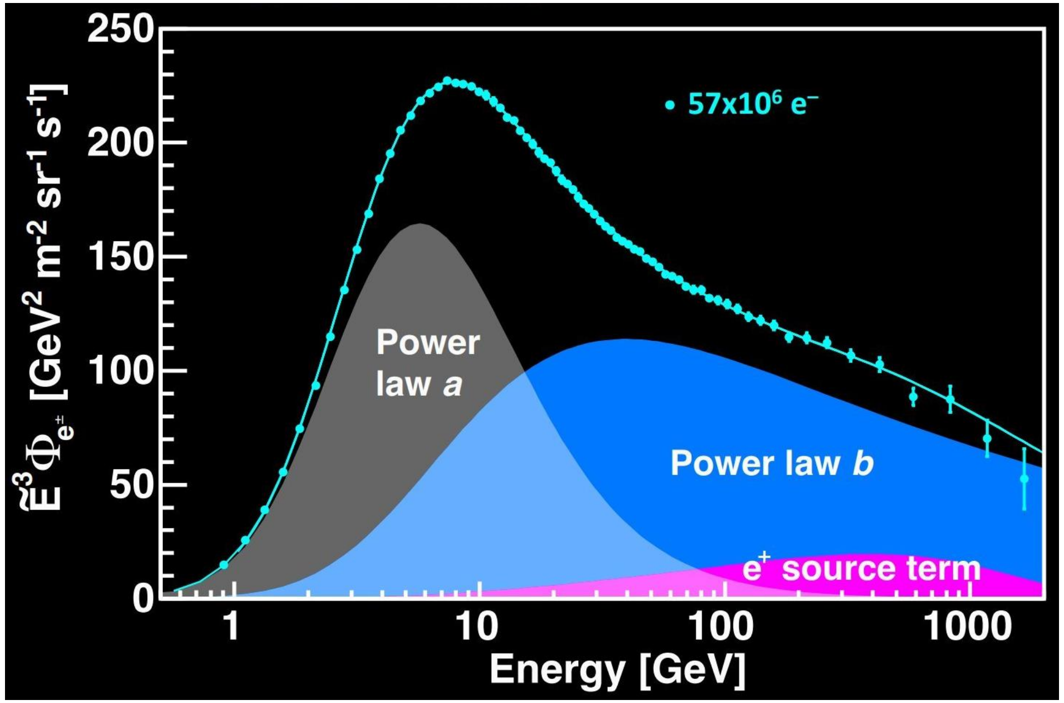




CERN Colloquium, Samuel Ting, 08/06/2023

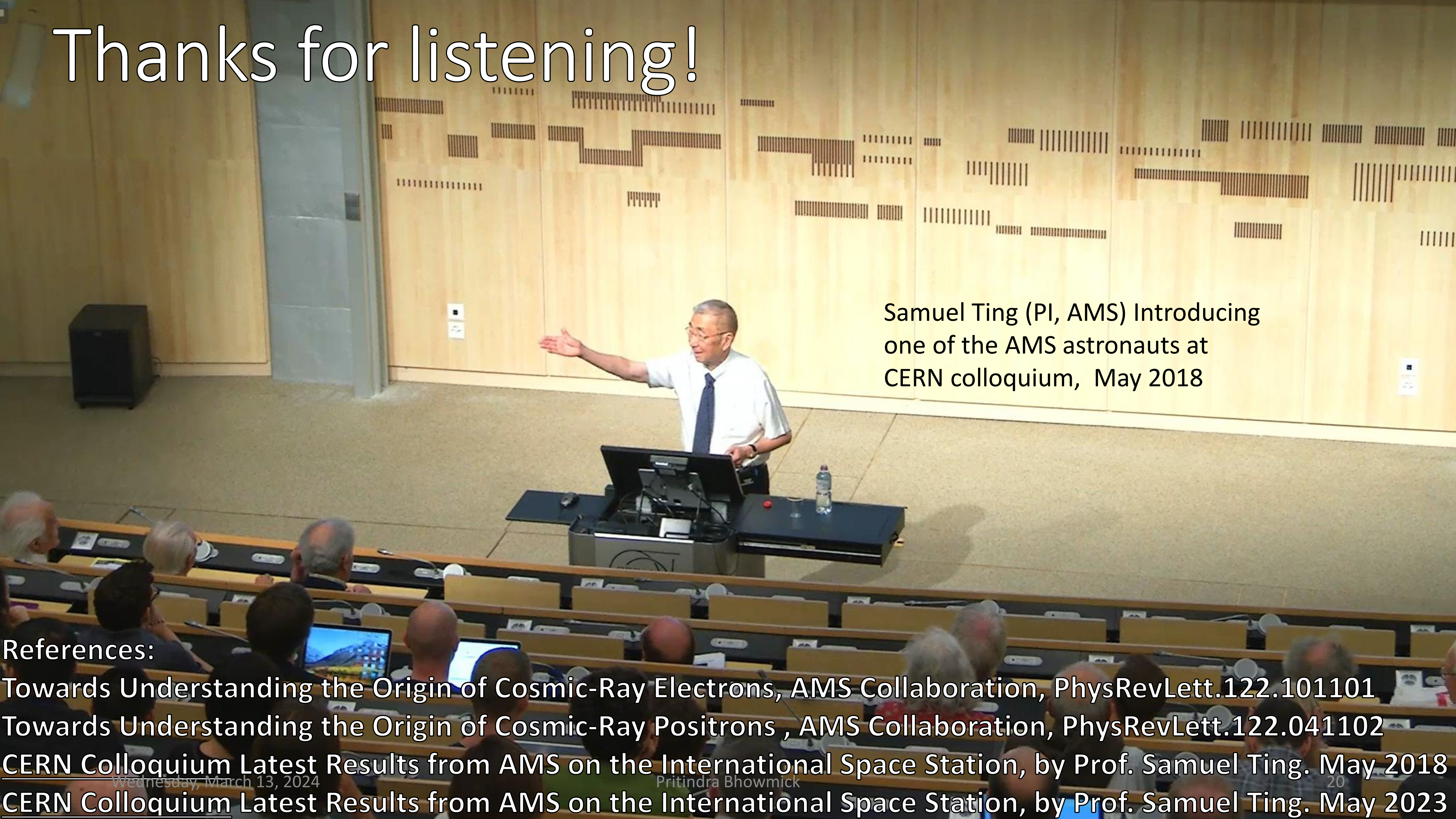
Conclusion





- Positron flux is well described by the sum of
  - Diffuse term - positrons produced in the collision of cosmic rays - dominates at low energies.
  - New source term of positrons - dominates at high energies.
- Electron flux described well by two sources.

Thanks for listening!



Samuel Ting (PI, AMS) Introducing one of the AMS astronauts at CERN colloquium, May 2018

References:

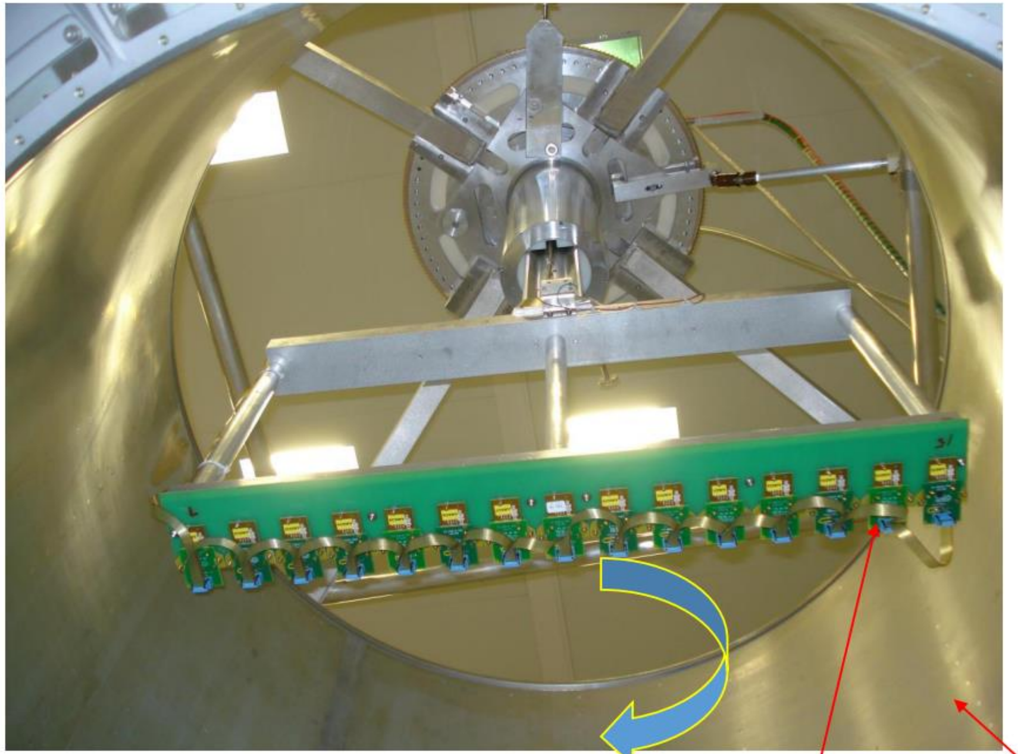
Towards Understanding the Origin of Cosmic-Ray Electrons, AMS Collaboration, PhysRevLett.122.101101

Towards Understanding the Origin of Cosmic-Ray Positrons , AMS Collaboration, PhysRevLett.122.041102

CERN Colloquium Latest Results from AMS on the International Space Station, by Prof. Samuel Ting. May 2018

CERN Colloquium Latest Results from AMS on the International Space Station, by Prof. Samuel Ting. May 2023

AMS . SUPRA MAGNET



Vue bottom. Inside magnet with Hall probes 15x

Bench Quadripodes

ELECTRIC ENGINE

ROTATION AXIS

Up-Down

Ø int. magnet:900mm

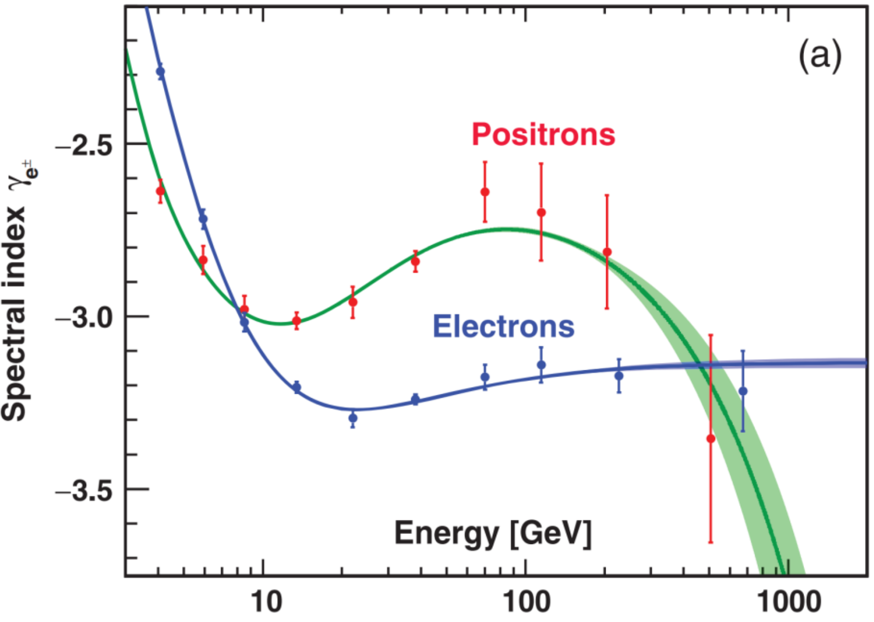
13/05/2020 DT Seminar 29

CERN Magnet Measurement Team in Detector Technologies.

In service for all magnet mapping needs.

- Back in 2010, my old CERN team was involved in the Magnet mapping of the AMS magnet.
- Measuring the magnetic field with an accuracy better than 1%.

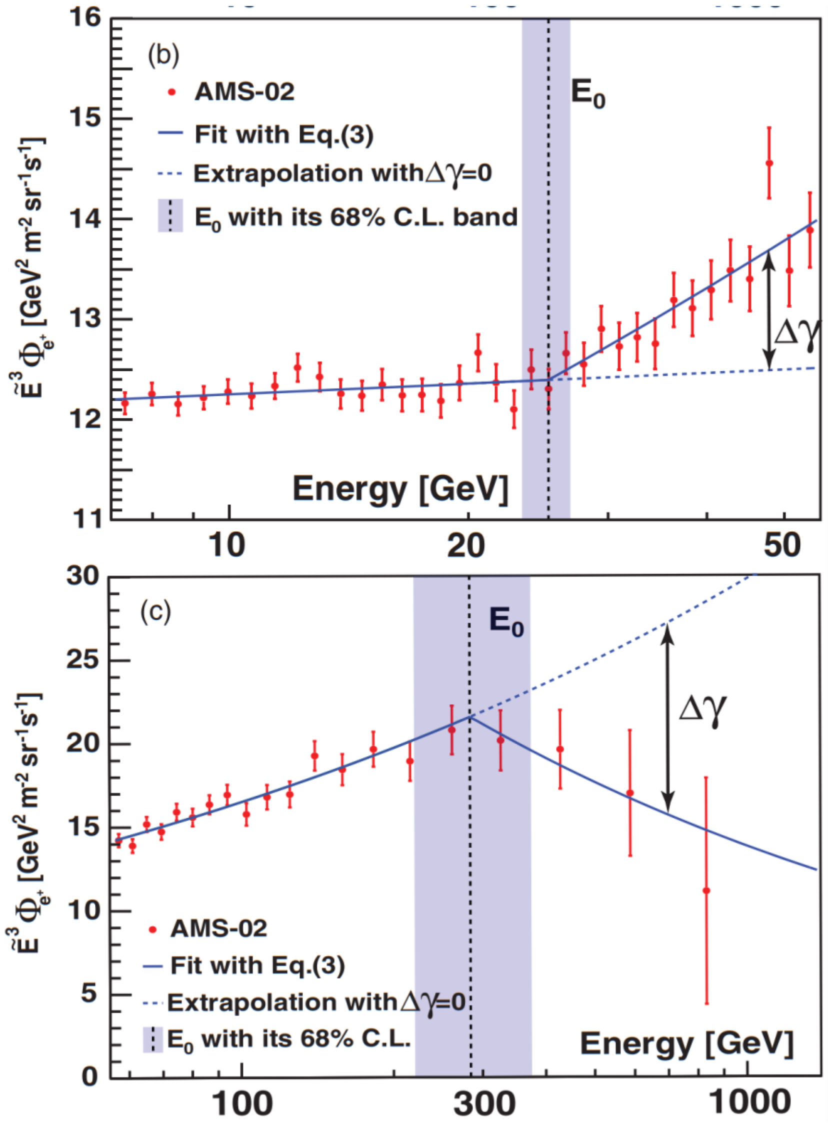
Flux spectral index



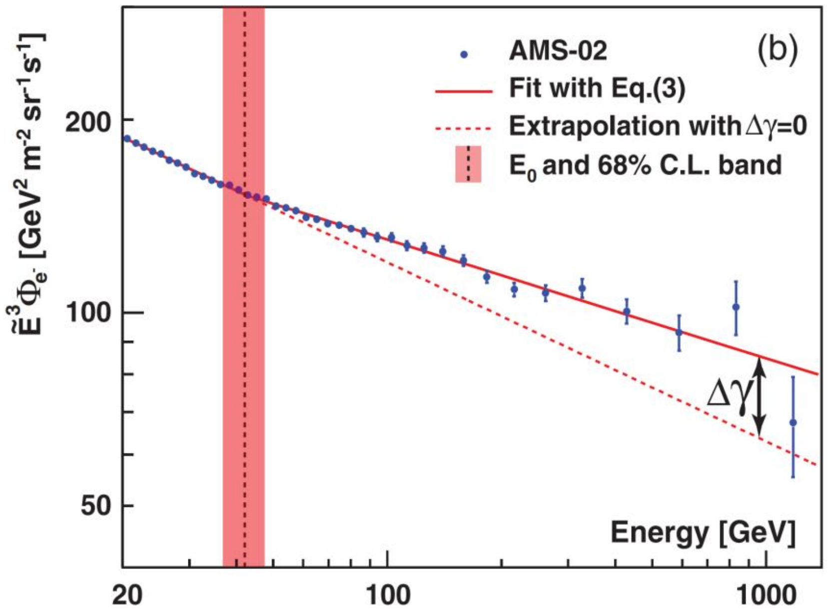
$$\gamma = d(\log\Phi)/d(\log E)$$

$$\Phi_e(E) = \begin{cases} C\ E^{\gamma}, & E \le E_0 \\ C\ E^{\gamma}(E/E_0)^{\Delta\gamma}, & E > E_0 \end{cases}$$

Positron spectrum



Electron spectrum



Positron Excess @ 25.2±1.8 GeV
Sharp positron drop @ 284^{+91}_{-64} GeV
Electron excess from 42.1±5.4 GeV.

This complex behavior of the positron flux is consistent with the existence of a new source of high-energy positrons with a characteristic cutoff energy.