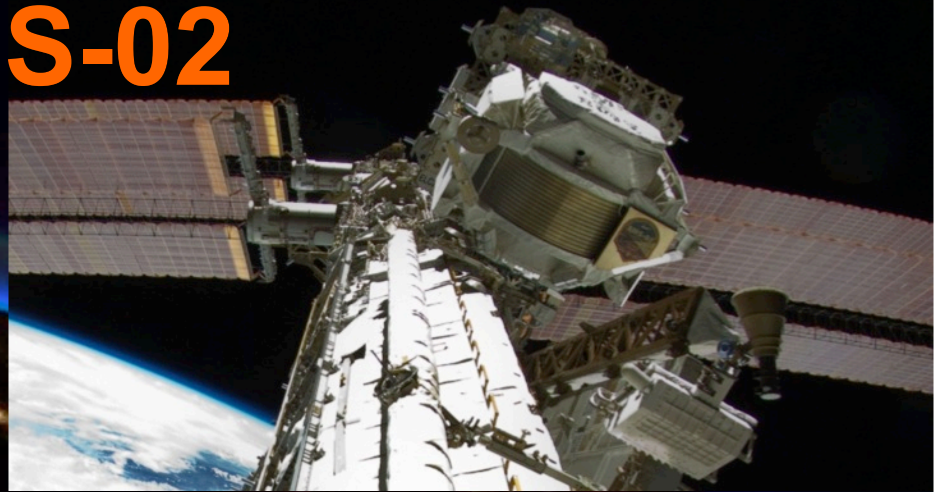
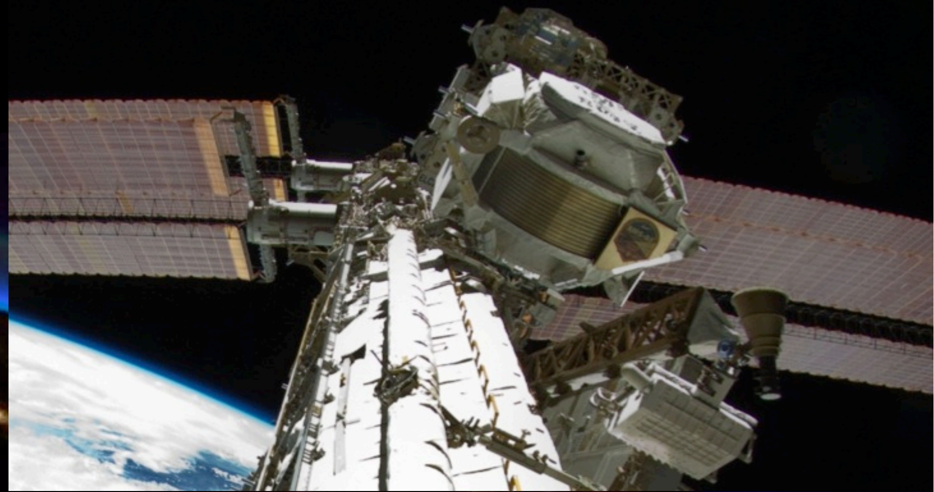
Recent results from AMS-02



Bruna Bertucci
University and INFN Perugia

Gallipoli, Sept. 14-16

CRIS 2015



Outline

① AMS in a nutshell

② Results:

- ✓ Positron and electrons
- ✓ Status of anti-protons
- ✓ Nuclear fluxes

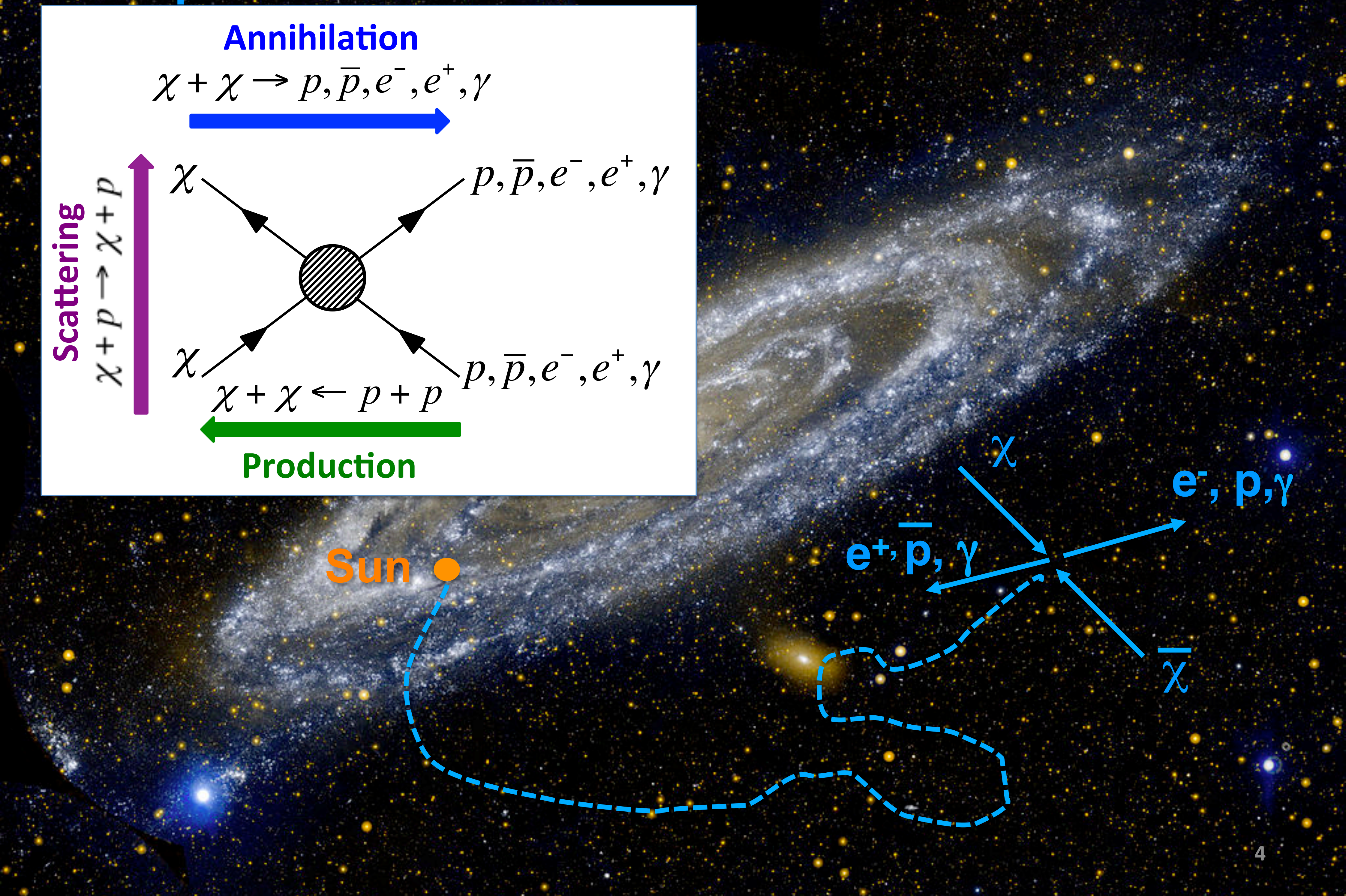
③ Conclusions

AMS is a precision, multipurpose magnetic spectrometer operating on the ISS since 2011 to perform accurate measurements of charged cosmic rays in the GeV-TeV energy range:

Its main objectives:

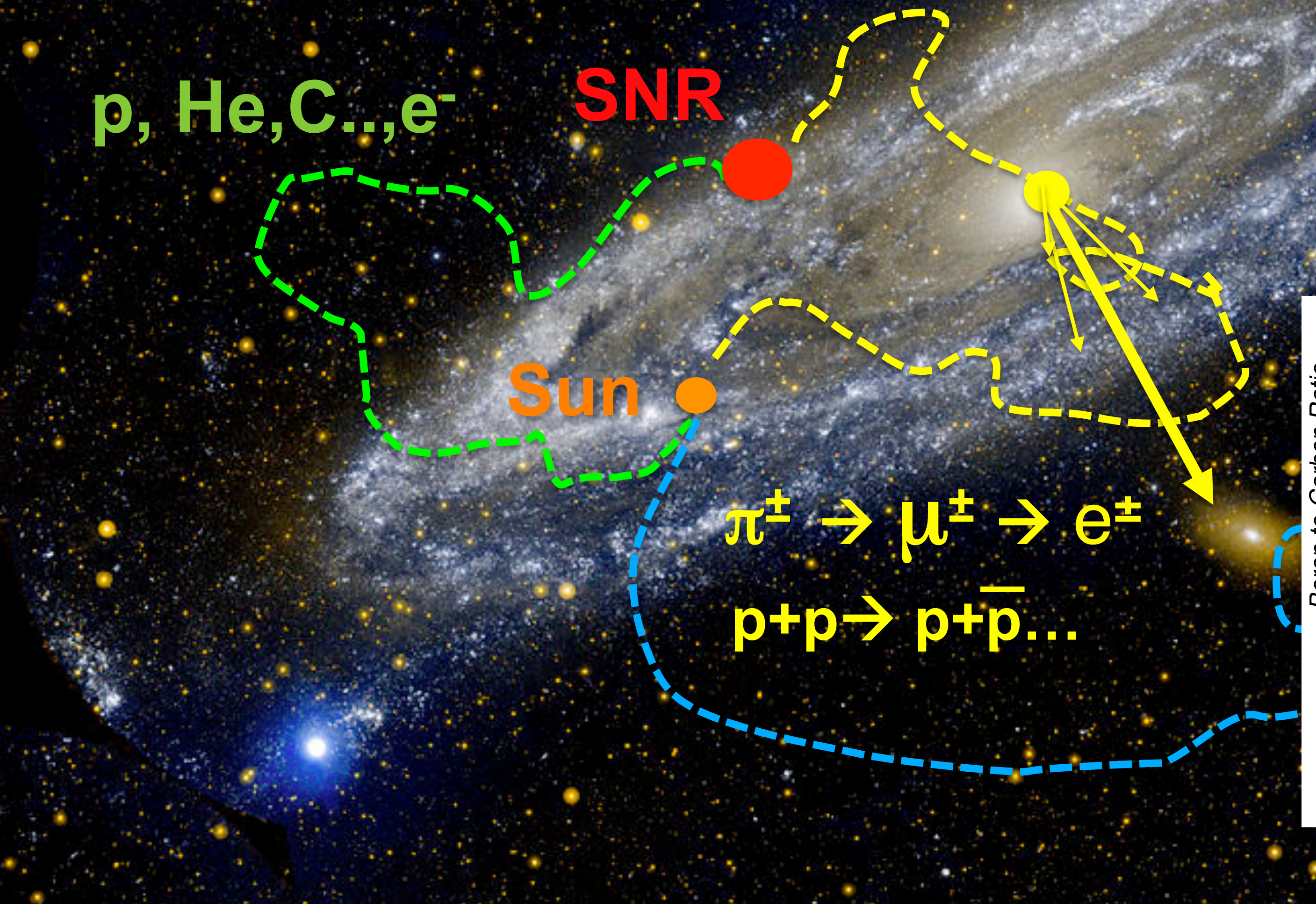
- Searching for the ultimate nature of matter and physics beyond the Standard Model : anti-matter, dark matter, strange matter
- Understanding the origin of cosmic rays and their propagation into the galaxy

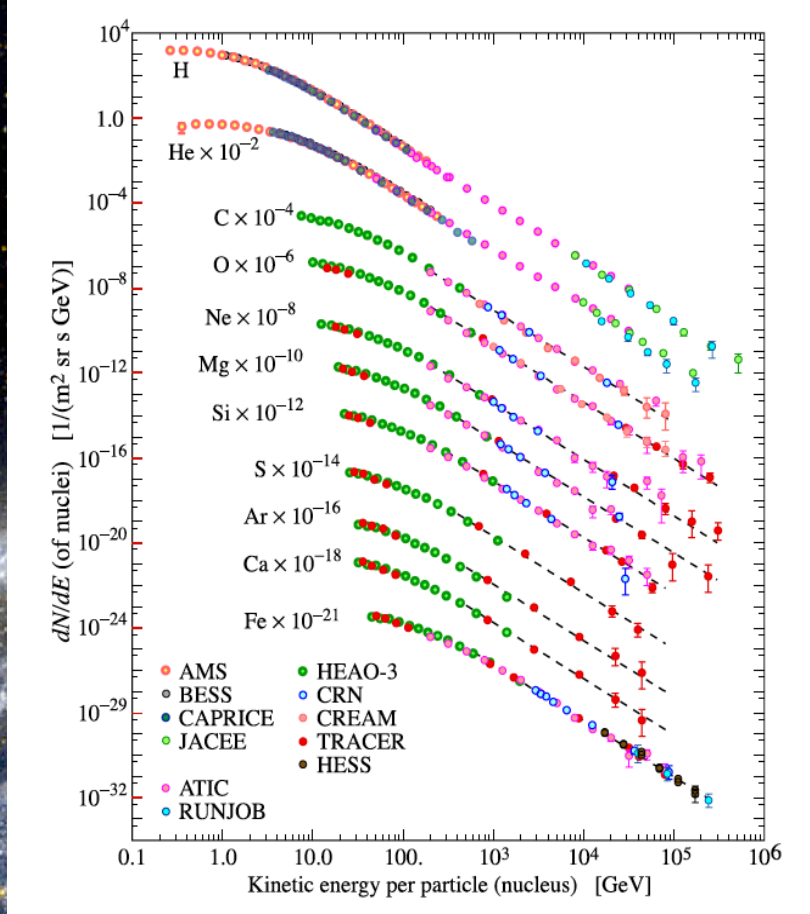
The quest for Dark Matter

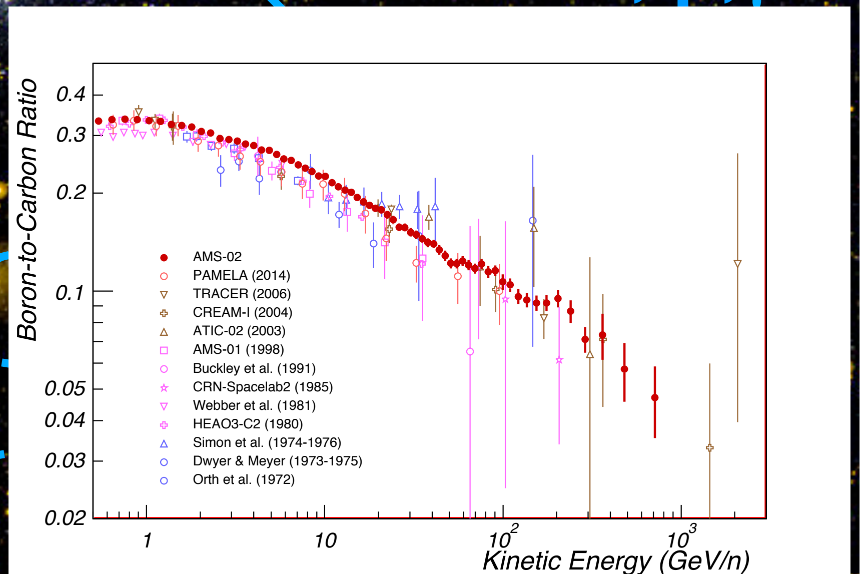


The Cosmic Background:

Origin, propagation and production of CRs and their secondaries

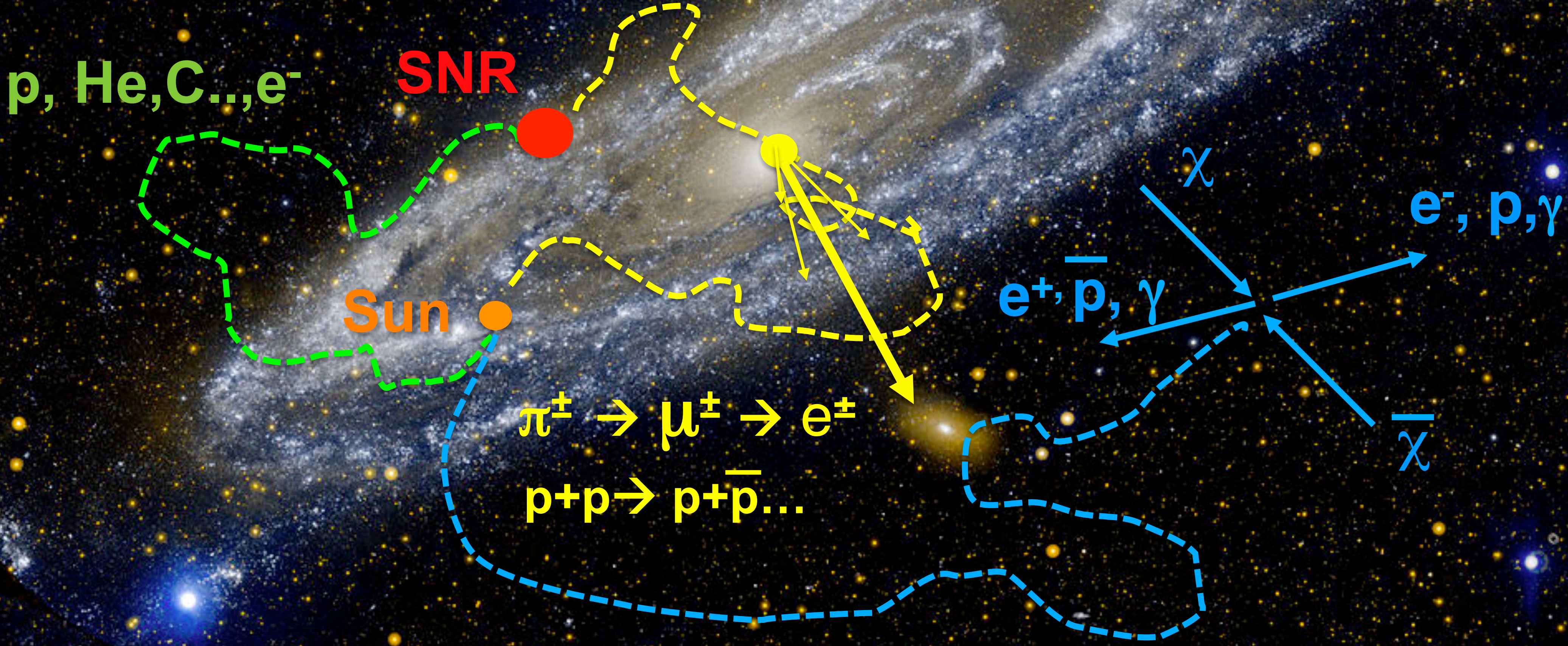


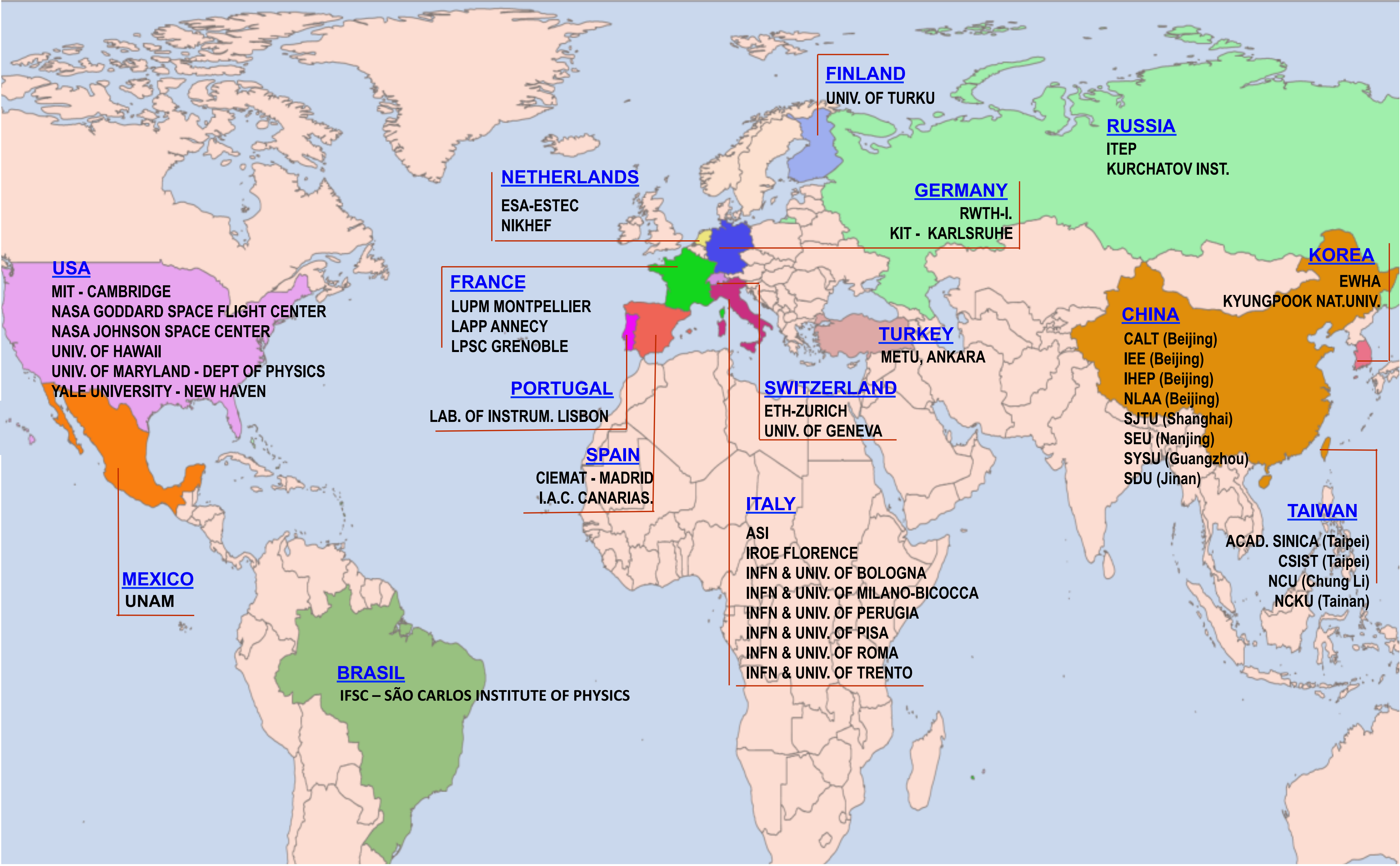




THE EXPERIMENTAL CHALLENGE

- DESIGN : state of the art detectors providing redundant measurements of particle properties
- TEST: test and calibration on ground
- MONITORING on ISS : calibration on flight
- EXPOSURE : Acceptance & Time





AMS: a large International collaboration
60 institutes / 600 people / 20 years

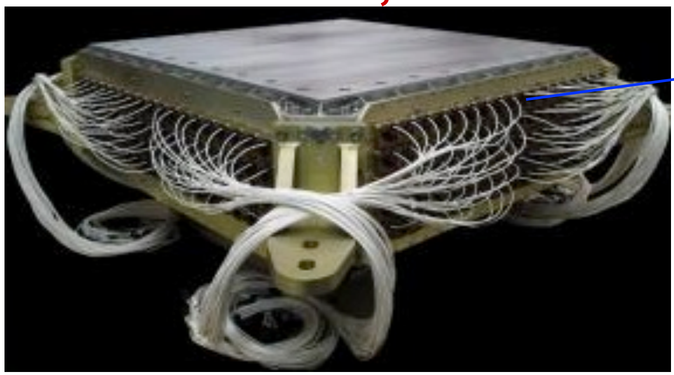
(part of) the Collaboration after the 1st event on orbit

AMS: A TeV precision, multipurpose spectrometer

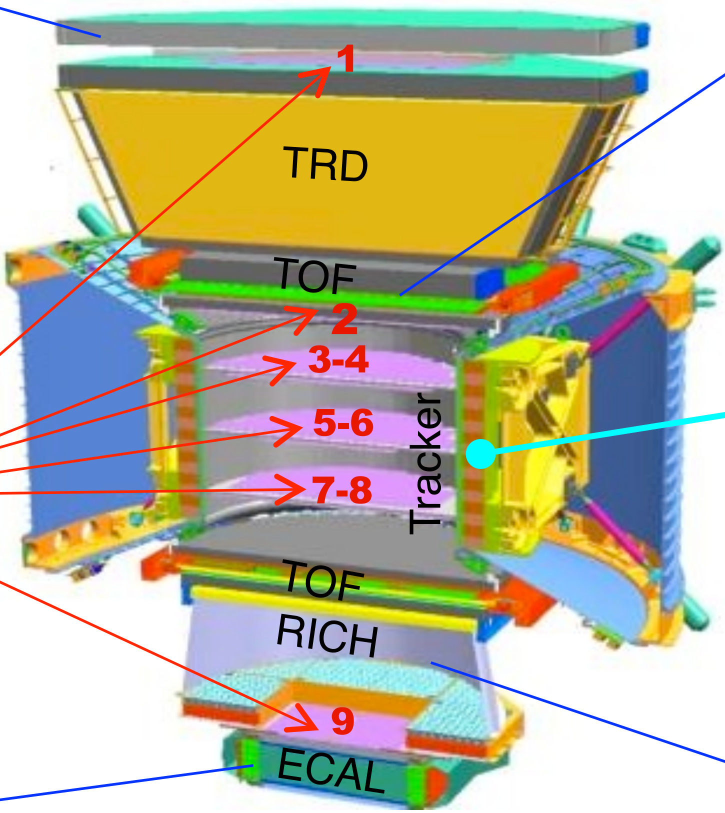
TRD
Identify e^+, e^-

Silicon Tracker
Z, P

ECAL
E of e^+, e^-



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



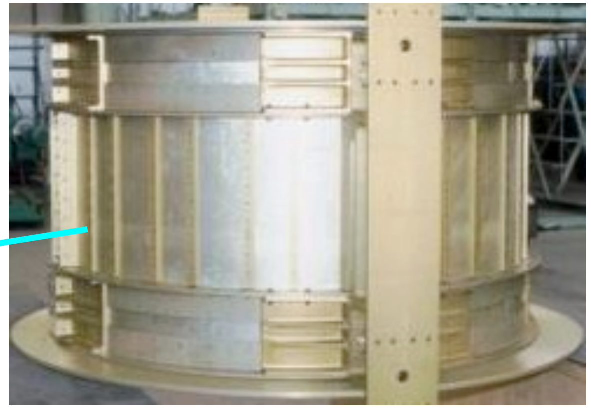
Z and P ~ E

are measured independently by the

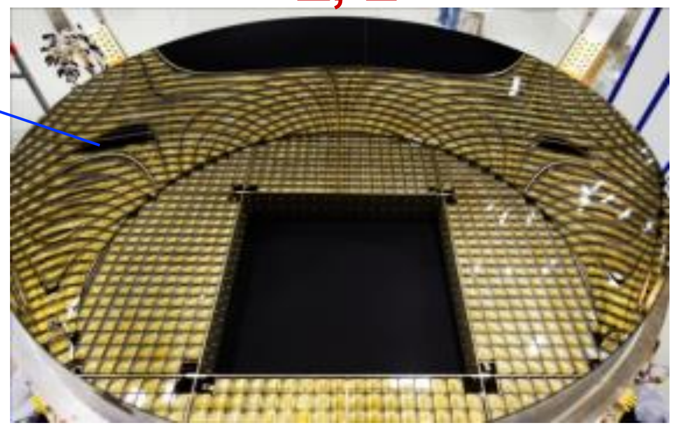
Tracker, RICH, TOF and ECAL

TOF
Z, E

Magnet
±Z



RICH
Z, E

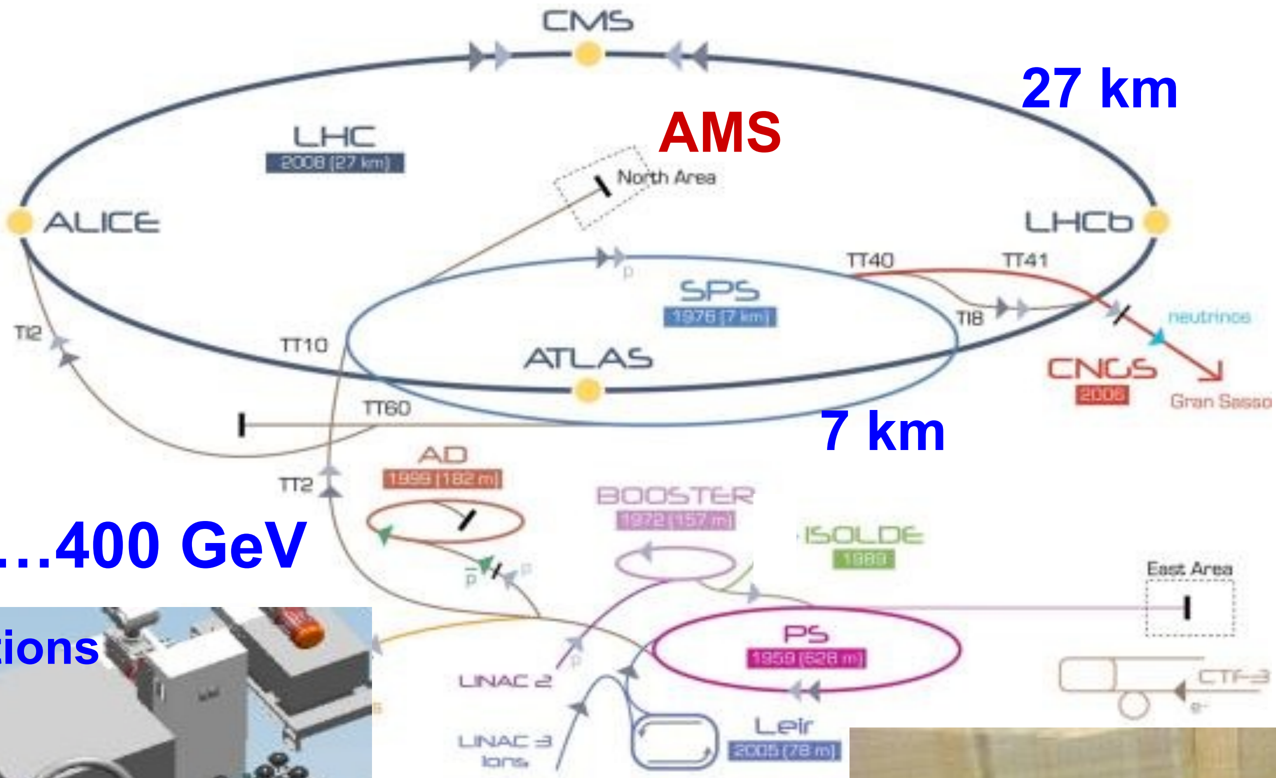


5m x 4m x 3m

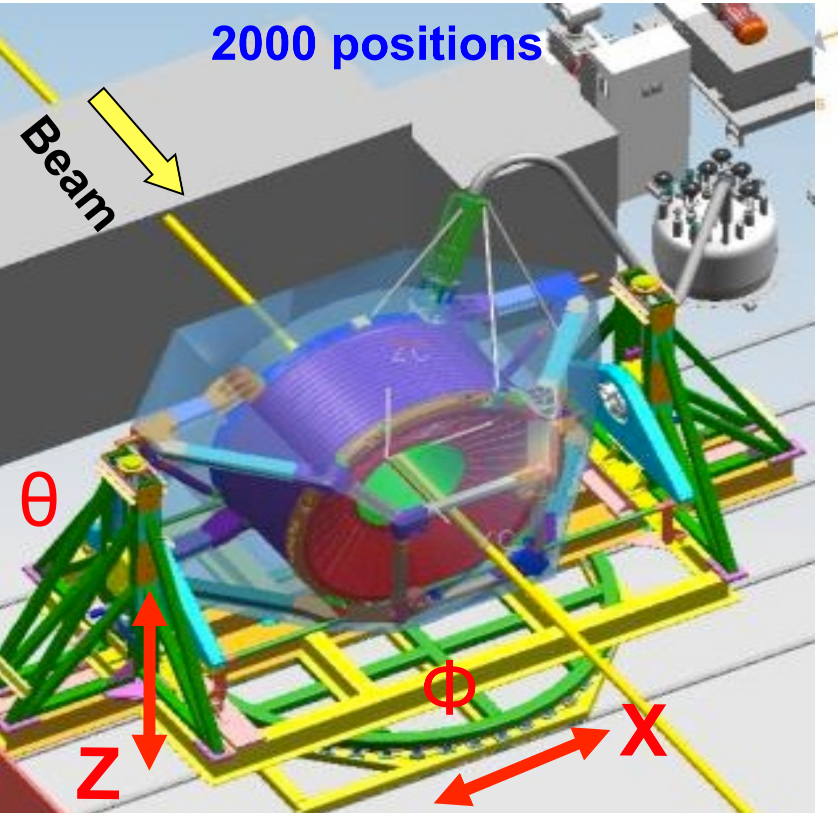
7.5 tons

Acceptance & Exposure time → Statistics !

Extensive tests and calibration at CERN



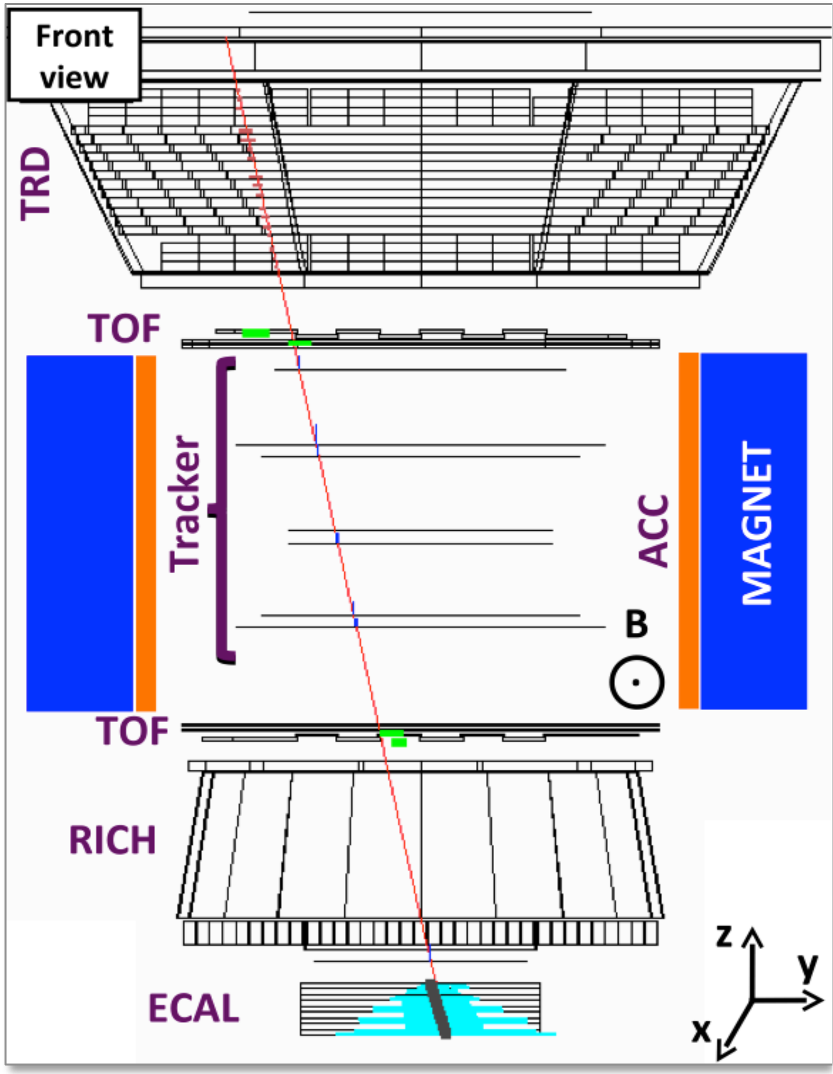
p, e^+, e^-, π 20…400 GeV



Full coverage of anti-matter & CR physics

	e^-	P	He,Li, Be,..Fe	γ	e^+	$\bar{P}$	$\bar{He},\bar{C}$
TRD							
TOF							
Tracker +Magnet							
RICH							
ECAL							
Physics example	Cosmic Ray Physics				Dark matter		Anti matter

600 GeV electron



In 4 years on ISS,

AMS has collected >68 billion cosmic rays.

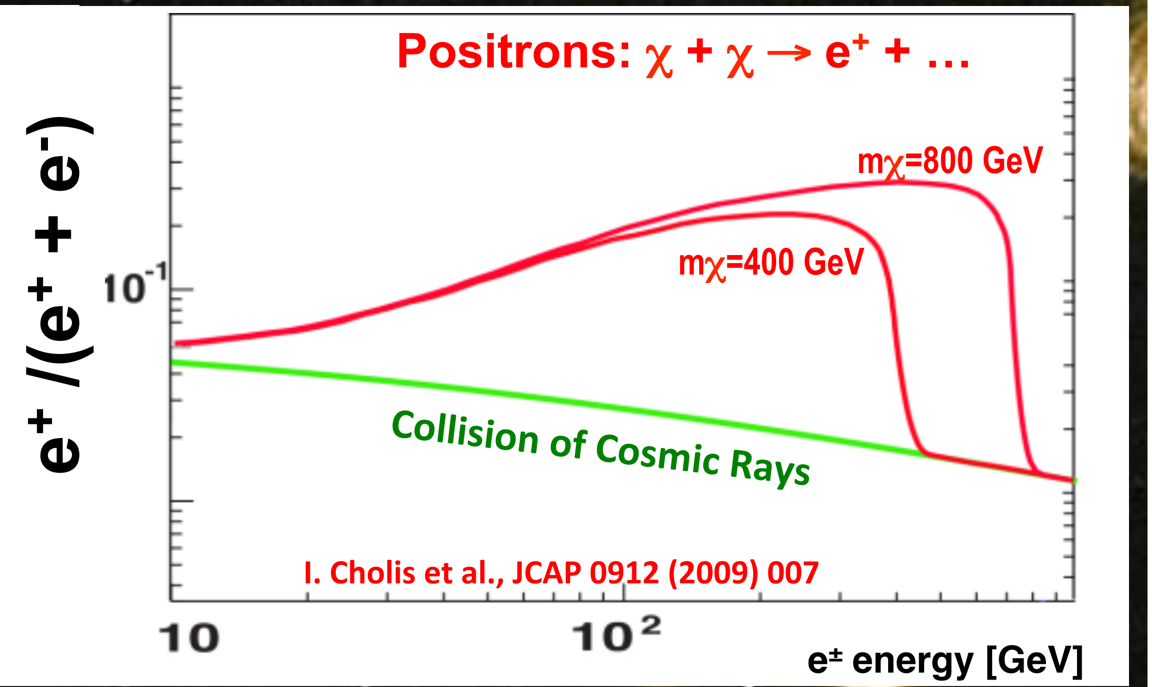
To match the statistics,

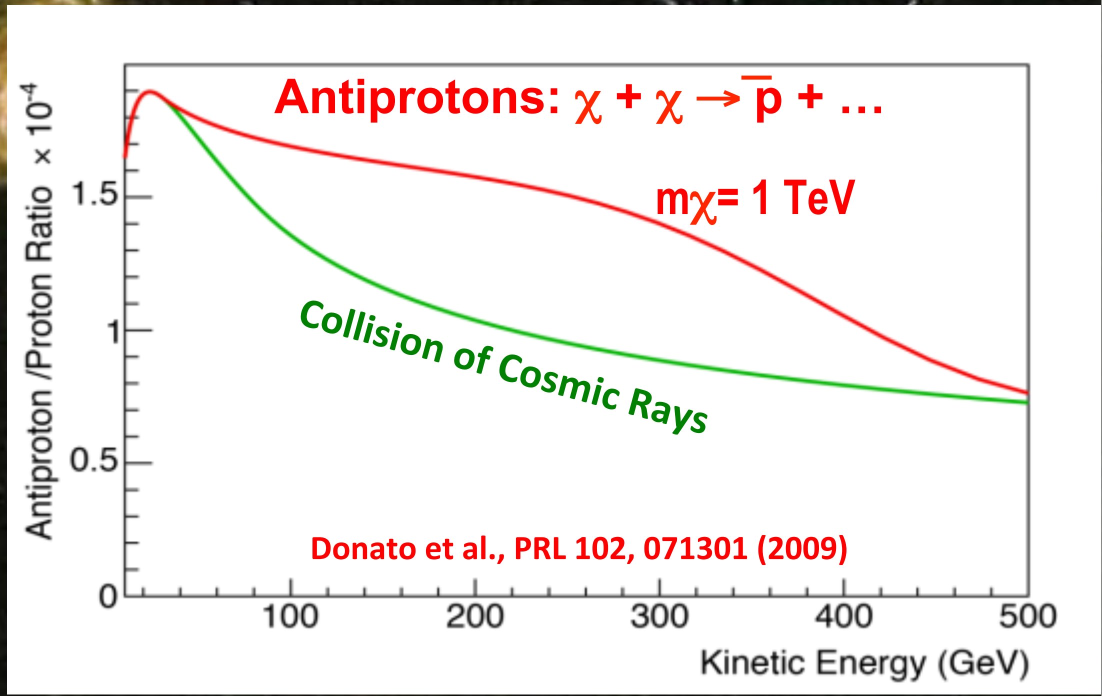
systematic error studies have become important.

The Search for the Origin of Dark Matter

Collisions of Dark Matter (neutralinos, χ) will produce a signal of e+, $\bar{p}$, …

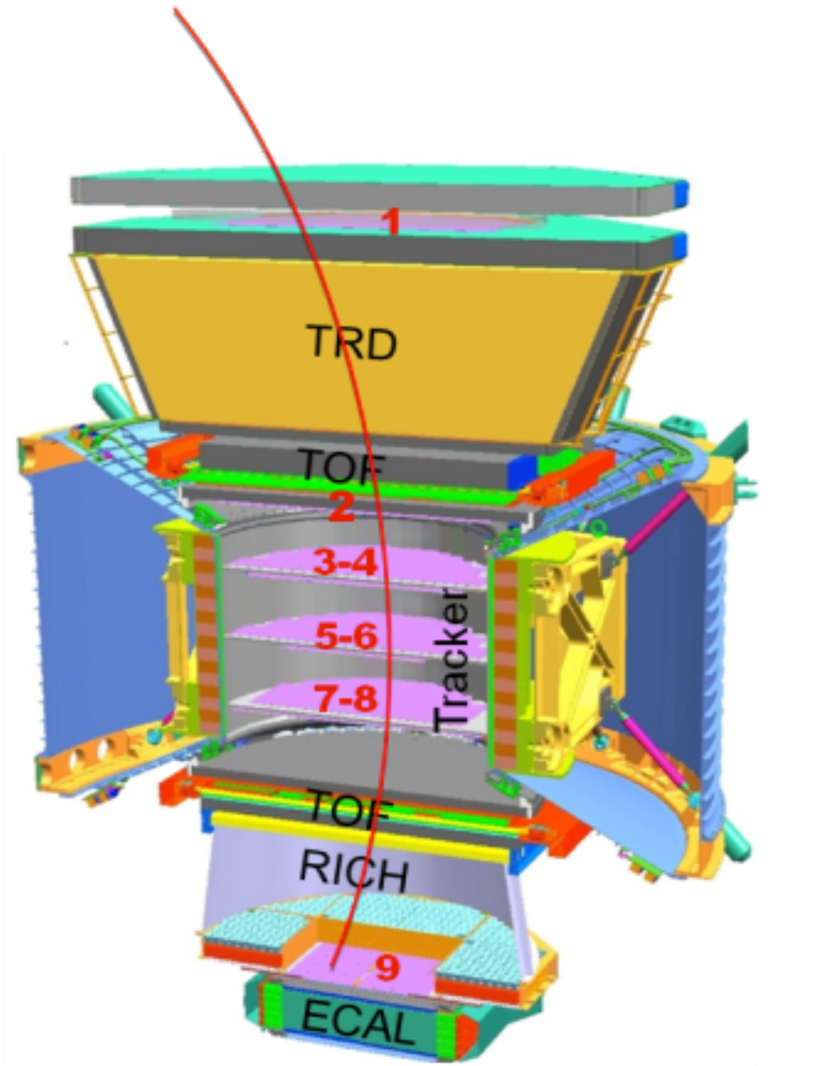
above the background from the collisions of “ordinary” cosmic rays



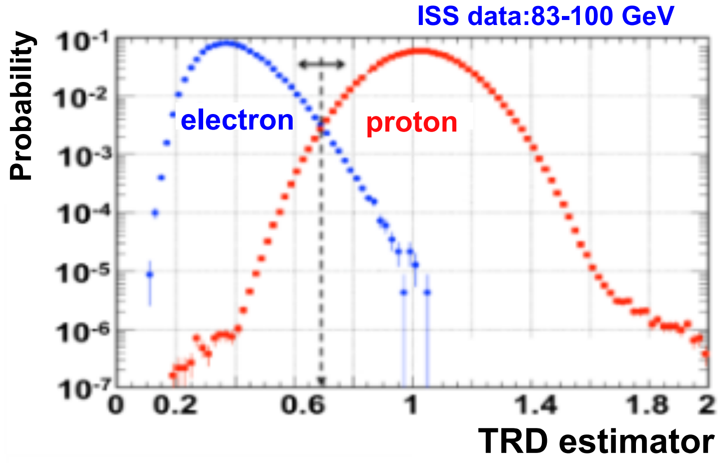


Physics of 11 million e^+, e^- events

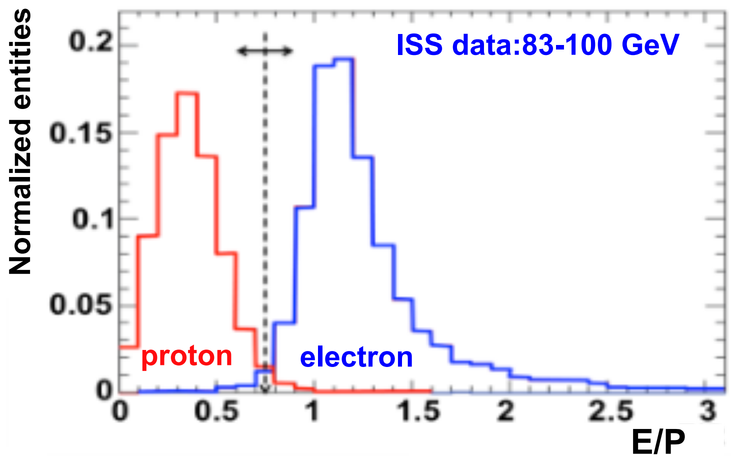
Measuring electrons and positrons



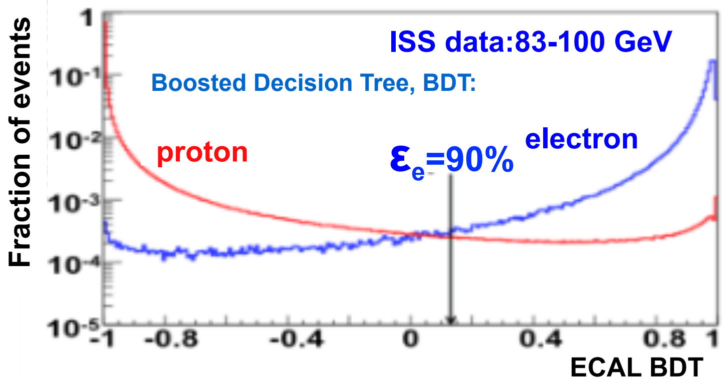
TRD
identify $e^\pm$



TRACKER
measures P
ECAL measures E
$e^\pm$: E=P
proton: E<P



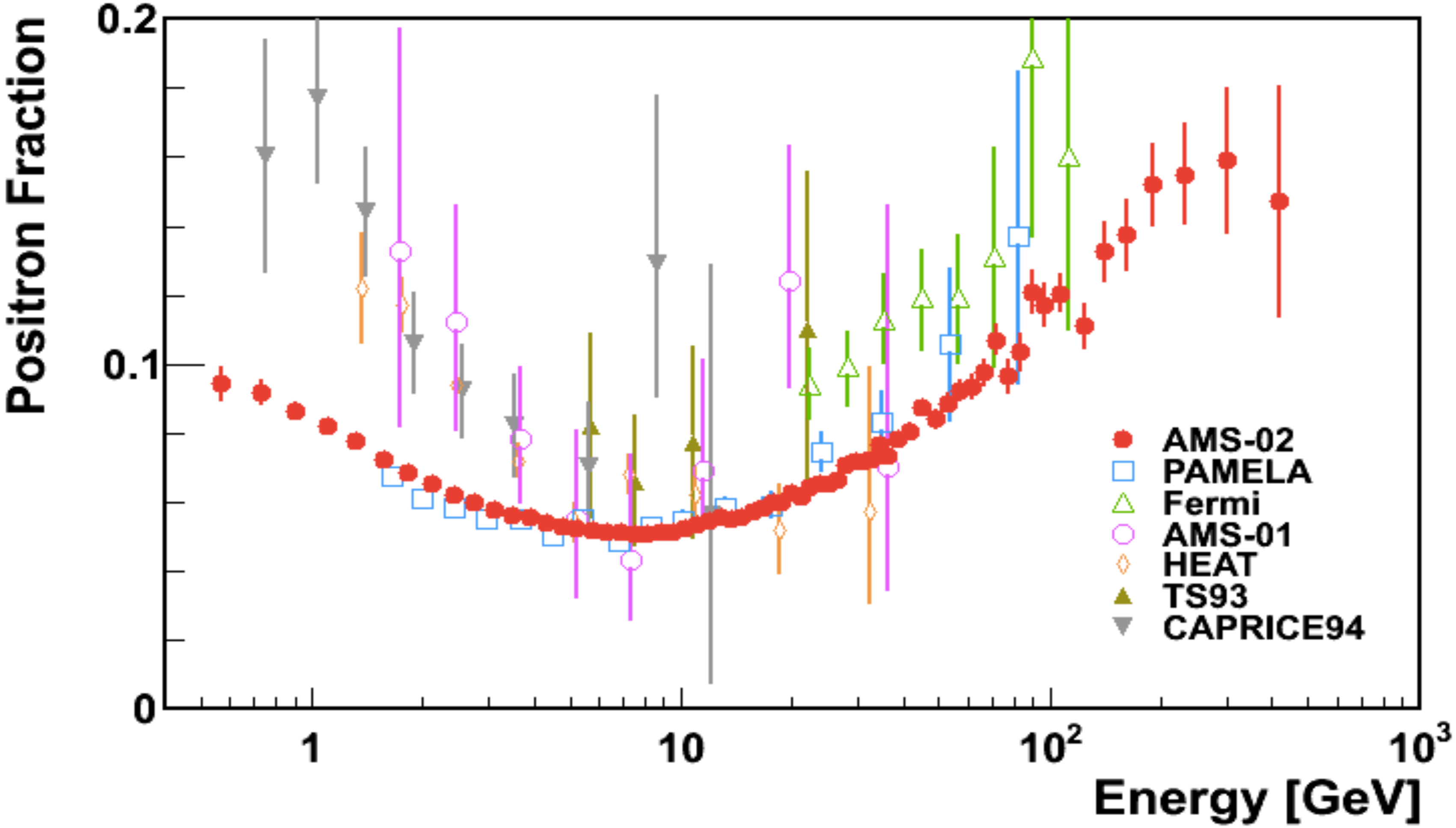
ECAL
measures E and shower shape to separate $e^\pm$ from protons



PRL 113, 121101 (2014) PHYSICAL REVIEW LETTERS week ending 19 SEPTEMBER 2014

High Statistics Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5–500 GeV with the Alpha Magnetic Spectrometer on the International Space Station

10.9 million e+ and e- events



Unprecedented accuracy and energy range allowed a detailed study of the positron fraction behaviour with energy

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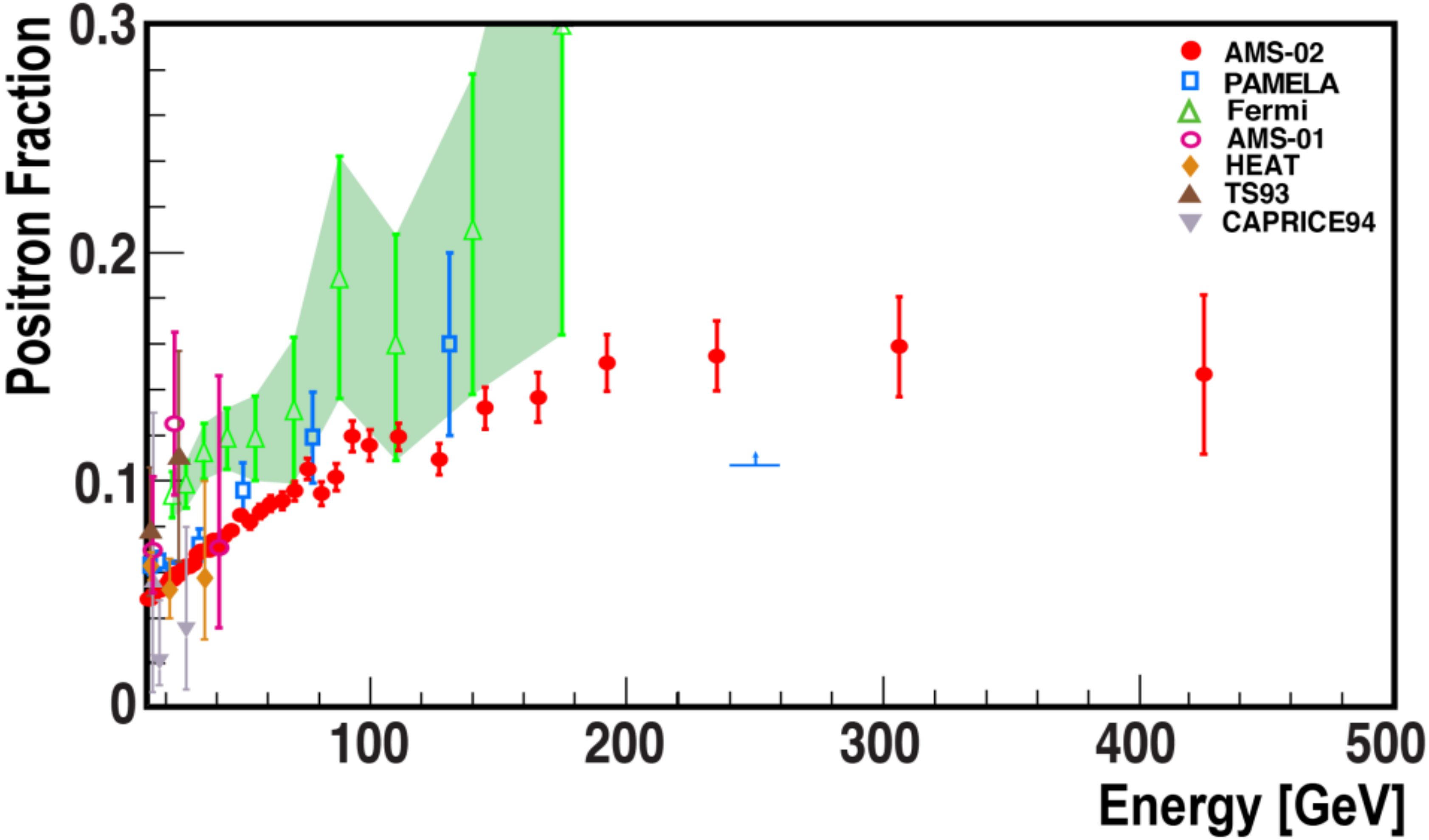
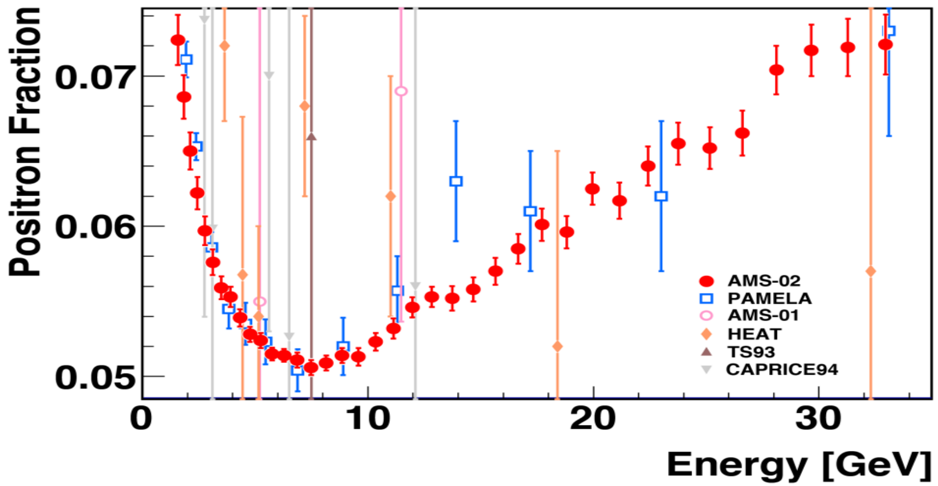
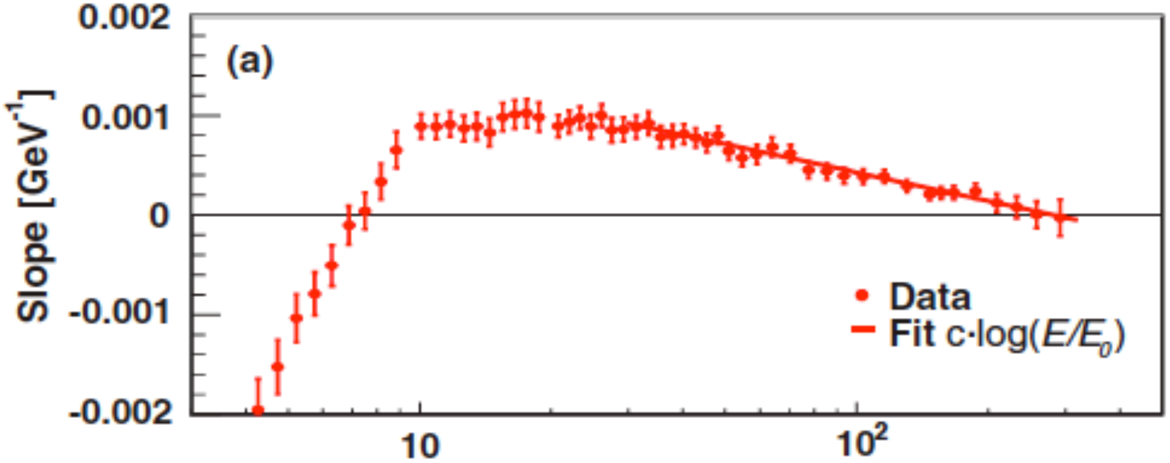


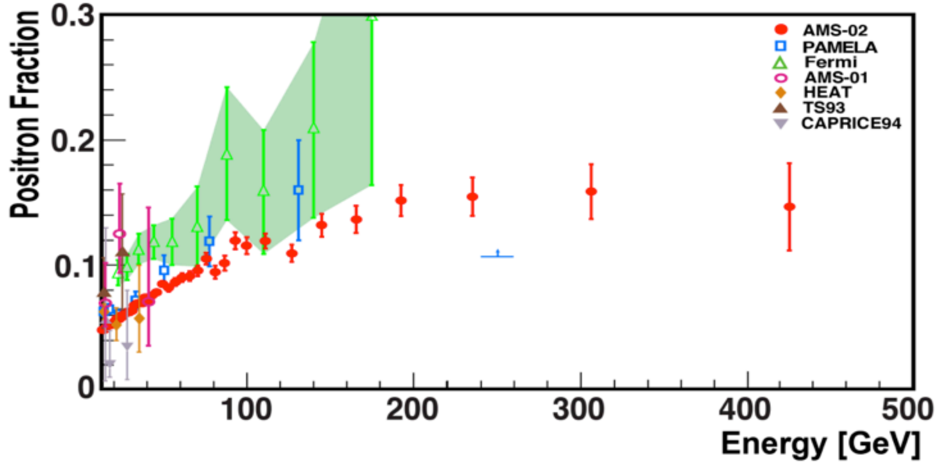
Unprecedented accuracy and energy range allowed a detailed study of the positron fraction behaviour with energy

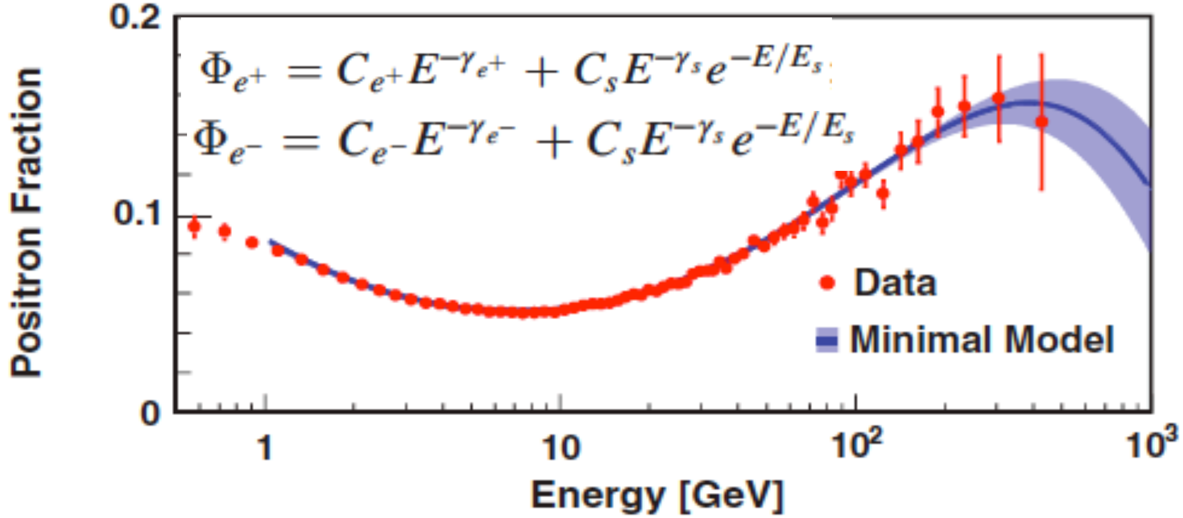
Positron fraction :

- ✓ No sharp structures
- ✓ Steady increase of the positron content up to ≈ 275 GeV
- ✓ Well described by an empirical model with a common source term for e^+/e^-



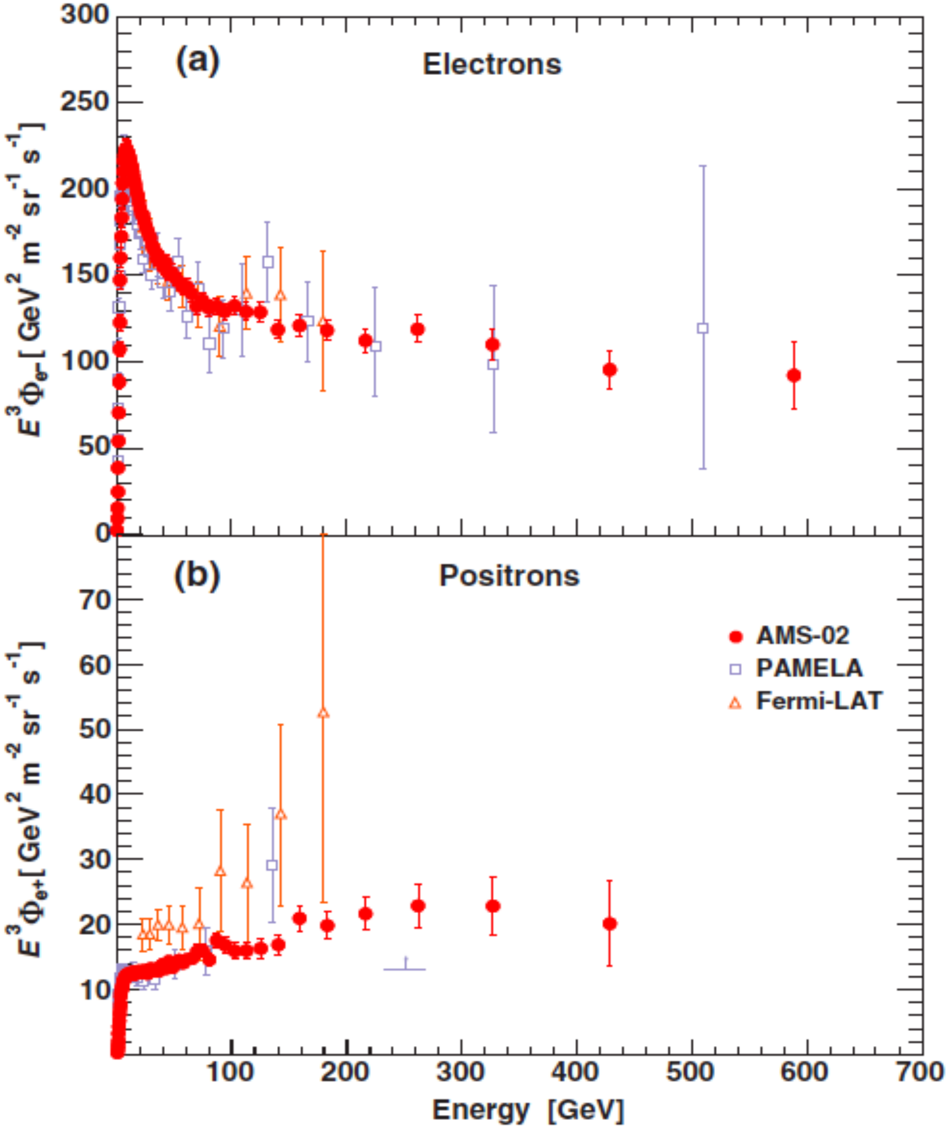


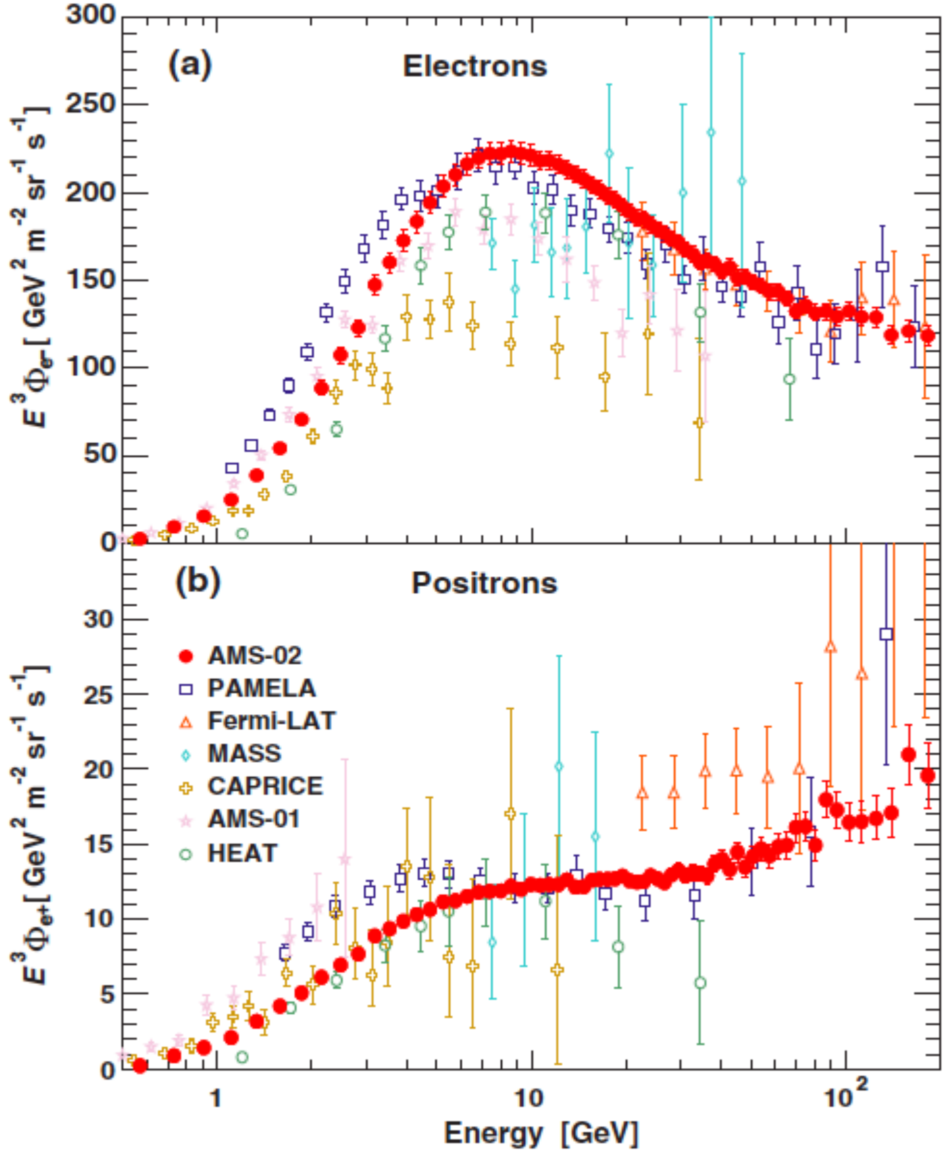




Electron/Positron fluxes:

No sharp structures

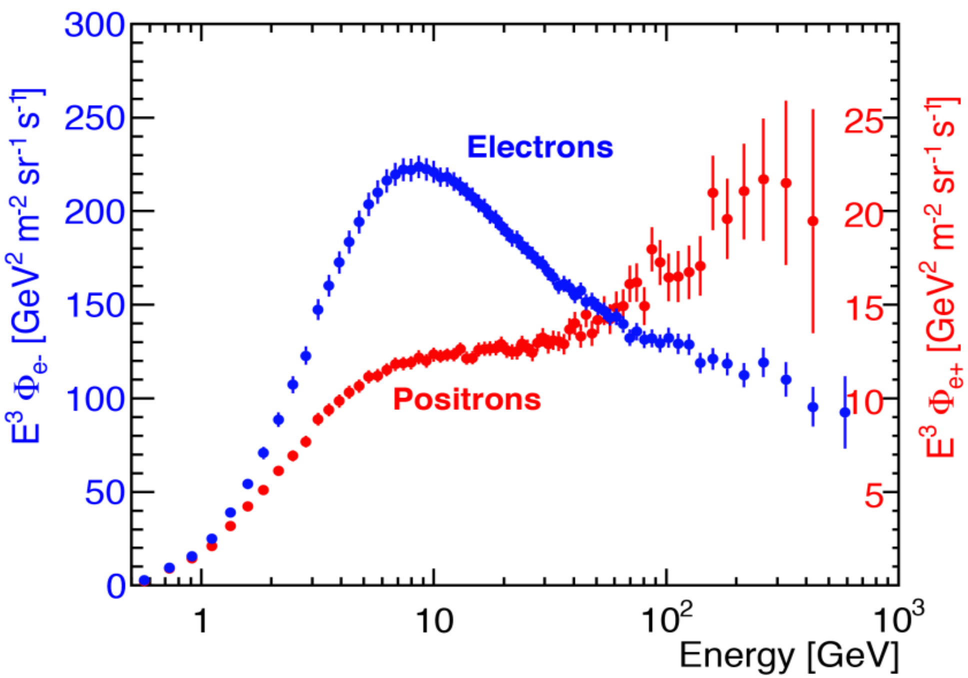


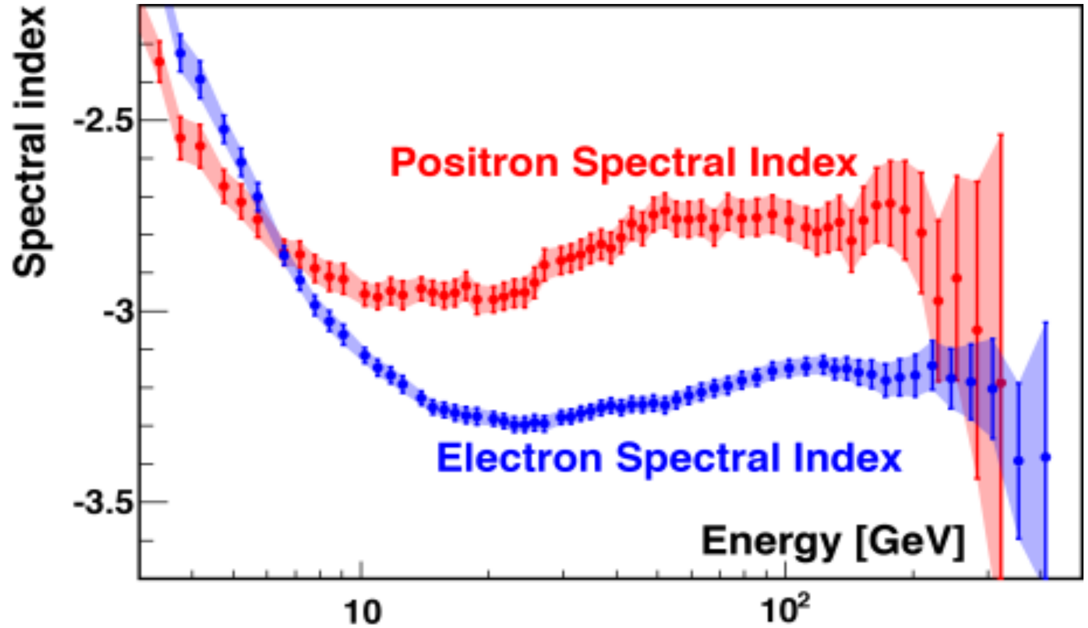


Electron/Positron fluxes:

For the first time a detailed study of the spectral index variation with energy :

$$\gamma_{e^\pm} = d[\log(\Phi_{e^\pm})]/d[\log(E)]$$

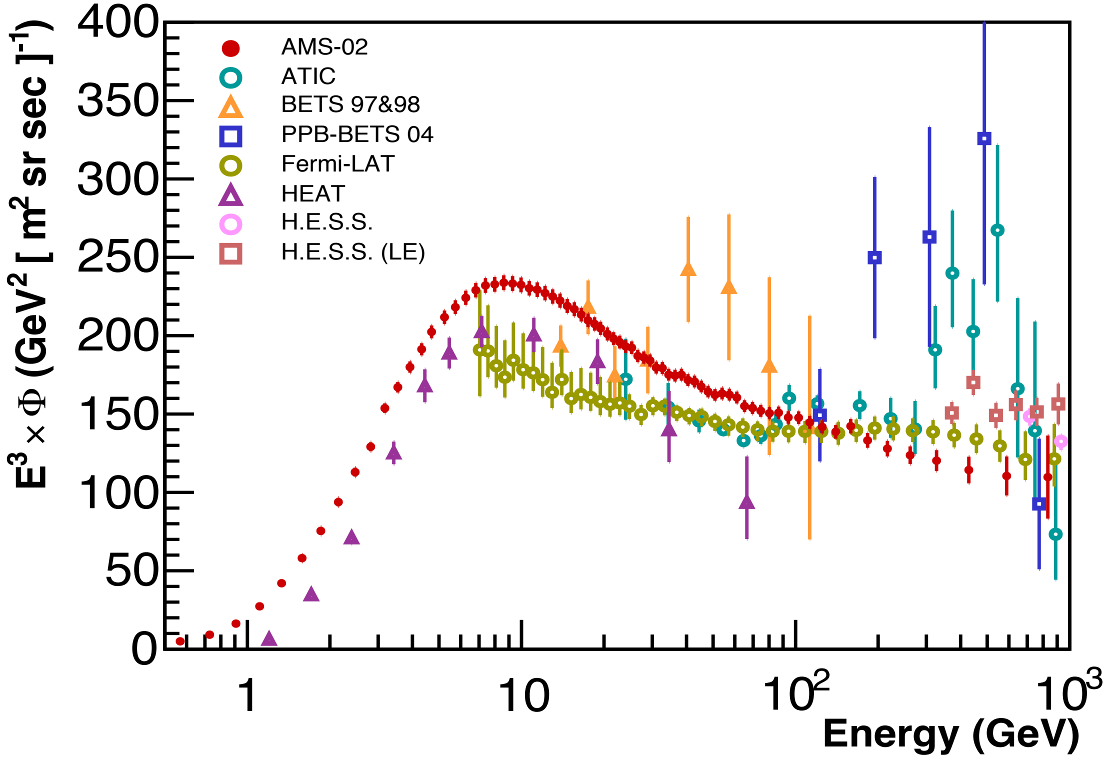


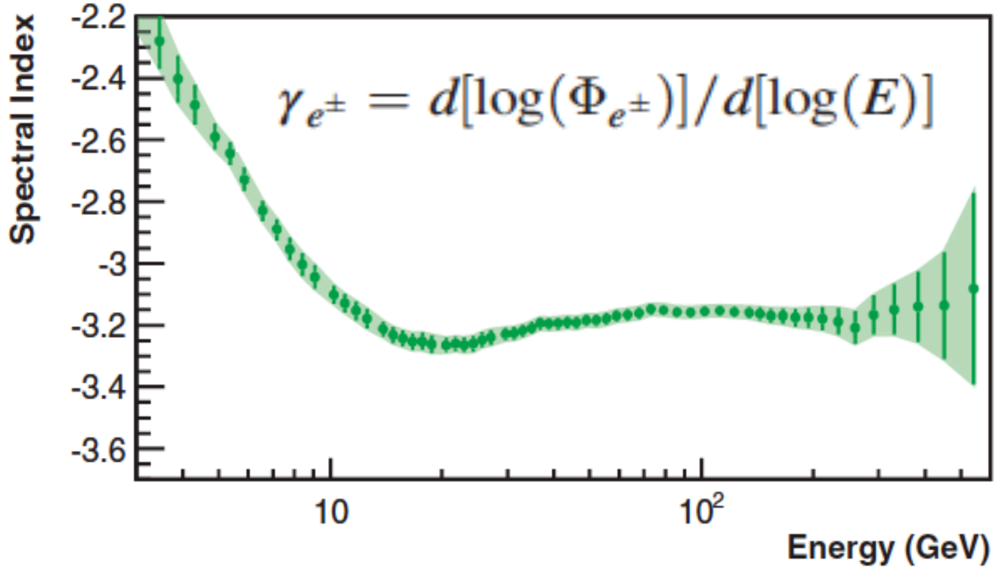


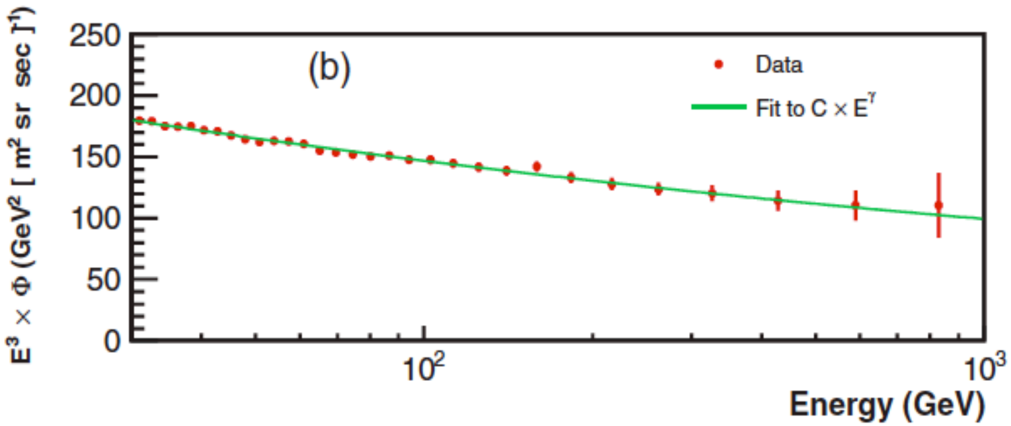
Hardening of the positron spectrum is at the origin of the positron fraction increase…

Electron + Positron flux:

Charge insensitive measurement → higher energy, directly comparable with previous experiments
No sharp structures
A single power low describes the spectrum after 30 GeV







What is AMS observing?

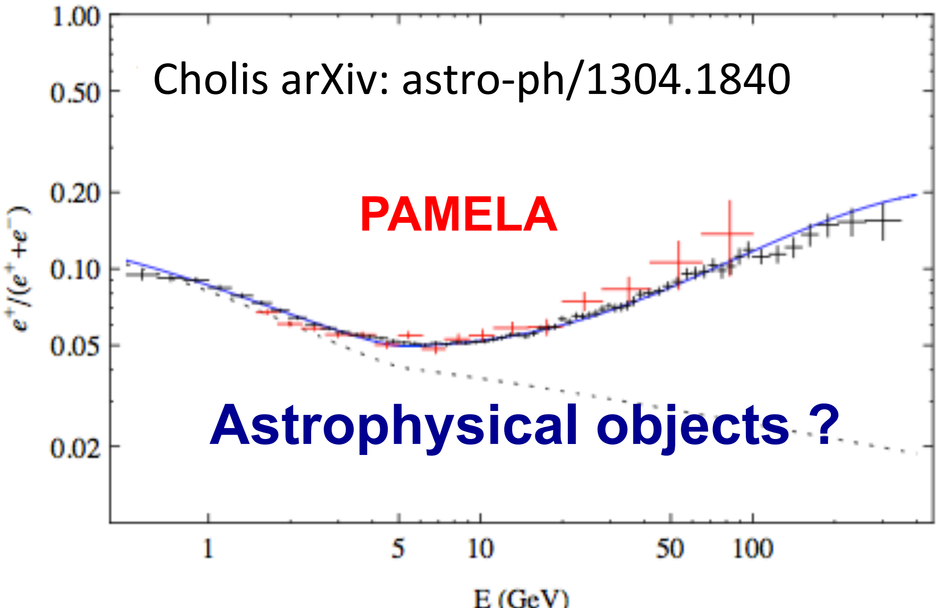
Something "**different**" with respect conventional models of e^+ production by collisions of CR hadrons with the interstellar matter (ISM):

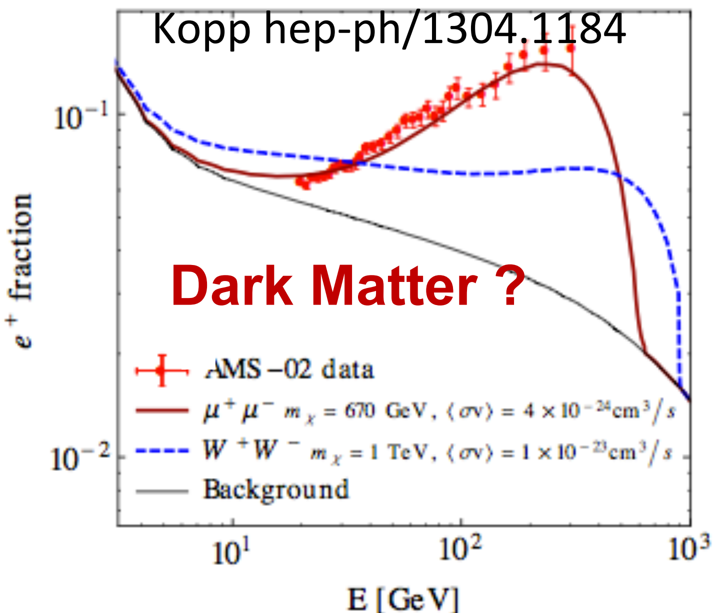
Astrophysical Sources?:

- Local sources as pulsars (slow fall at high energies, anysotropy..)
- Interactions of CR hadrons in old SNR (but this should affect also other secondary species as anti-protons, B/C)

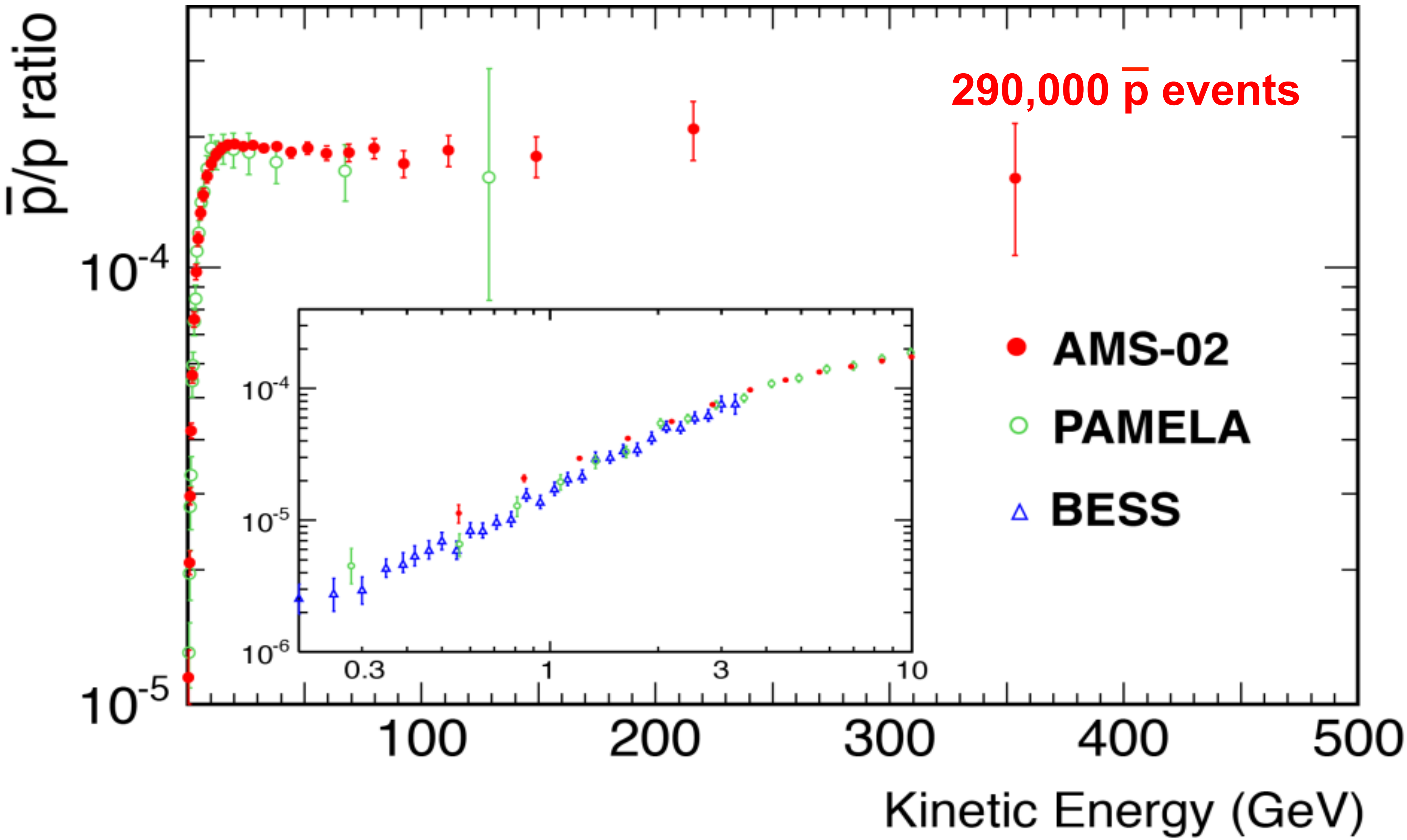
Dark matter?:

- The mass of the DM particle gives a sharp cutoff with energy
- Isotropic distribution
- Effects also on anti-p



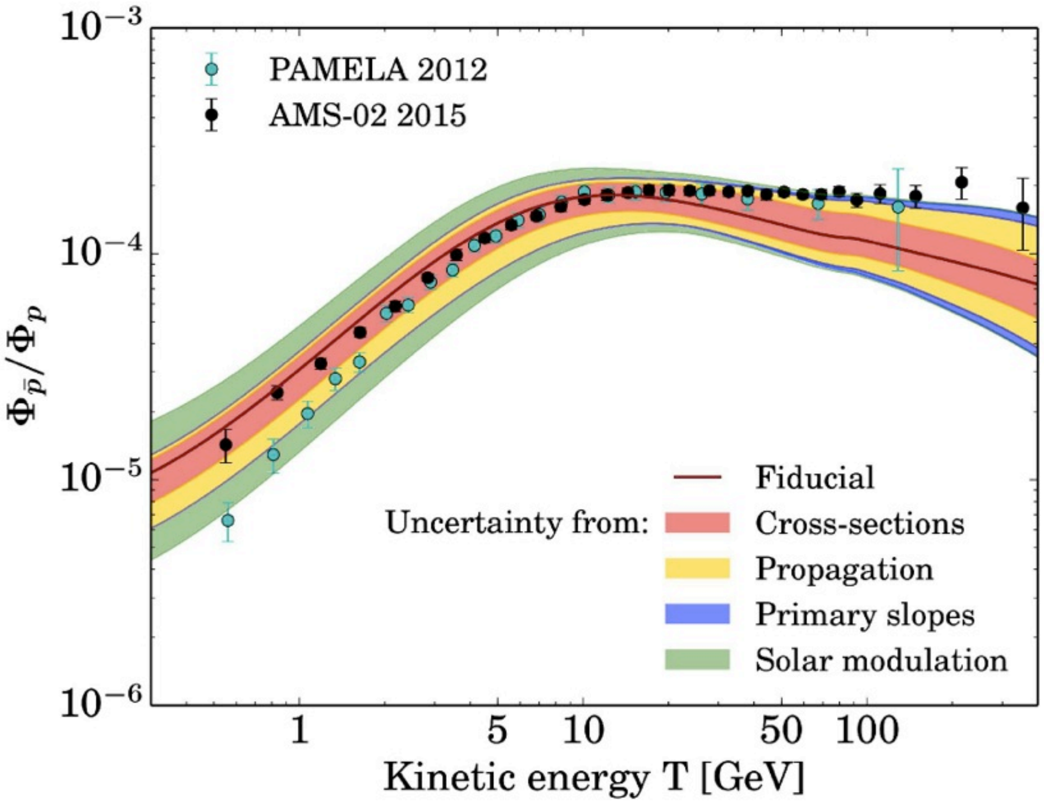


AMS p/$\bar{p}$ status report

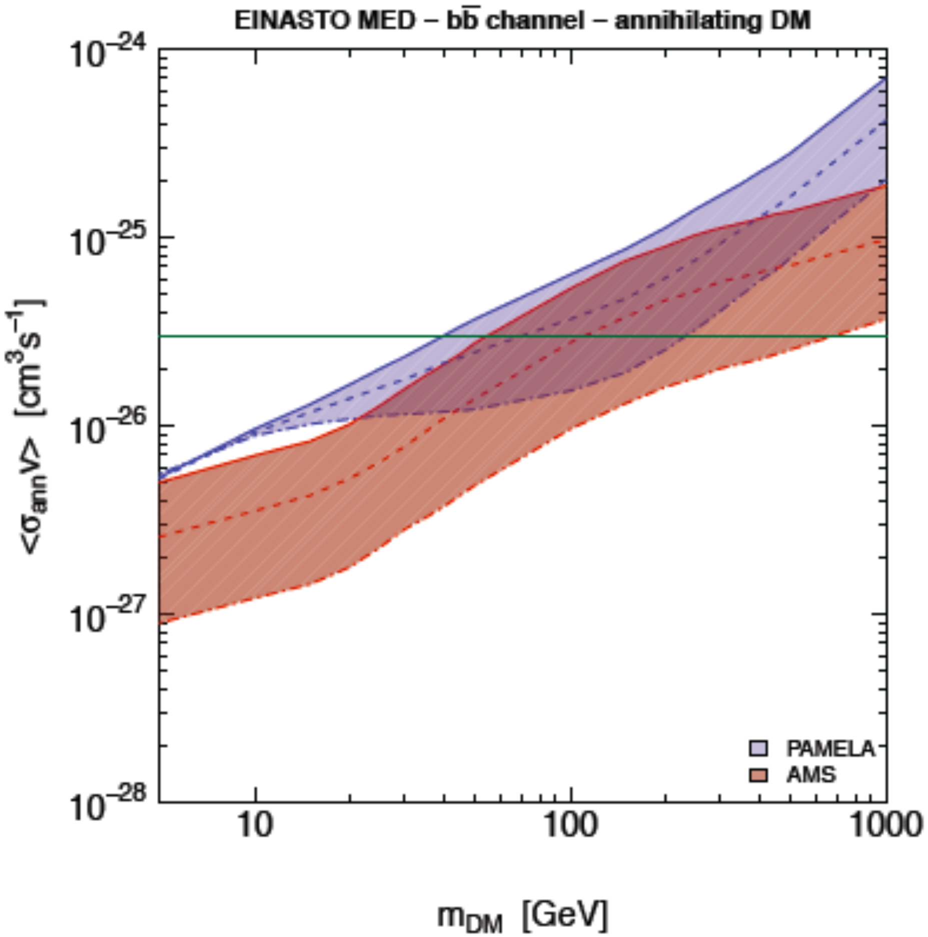


AMS $\bar{p}/p$ status report

The accuracy of the AMS measurement challenges current knowledge of cosmic background !



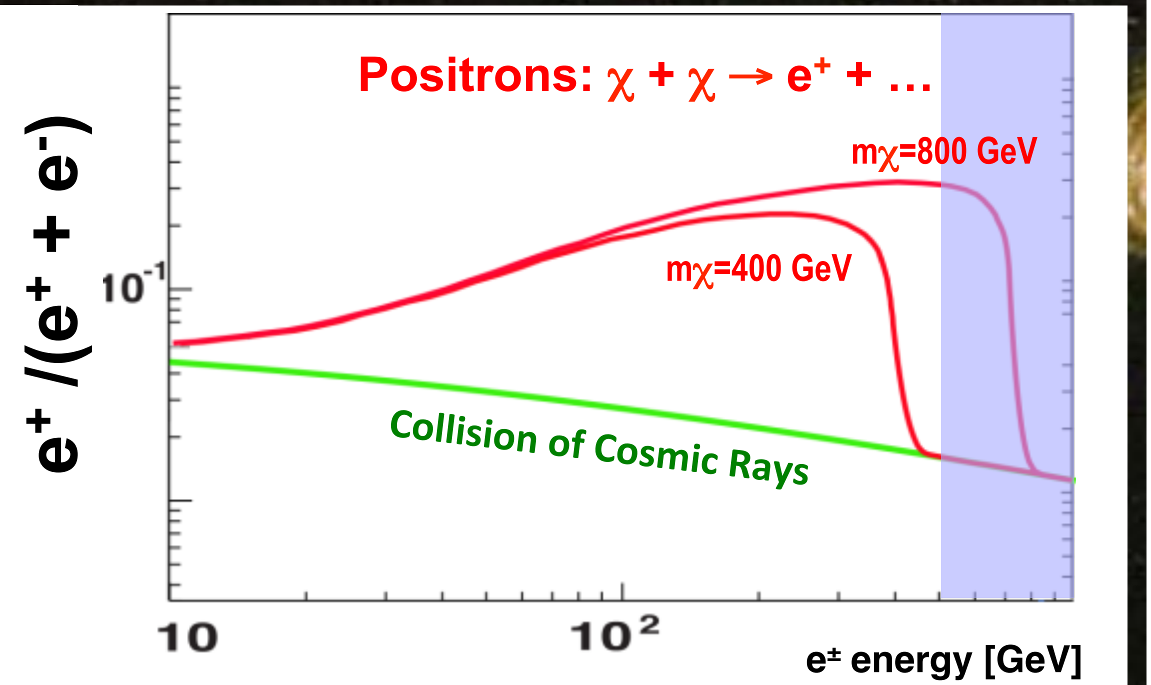
Giesen et al, 2015

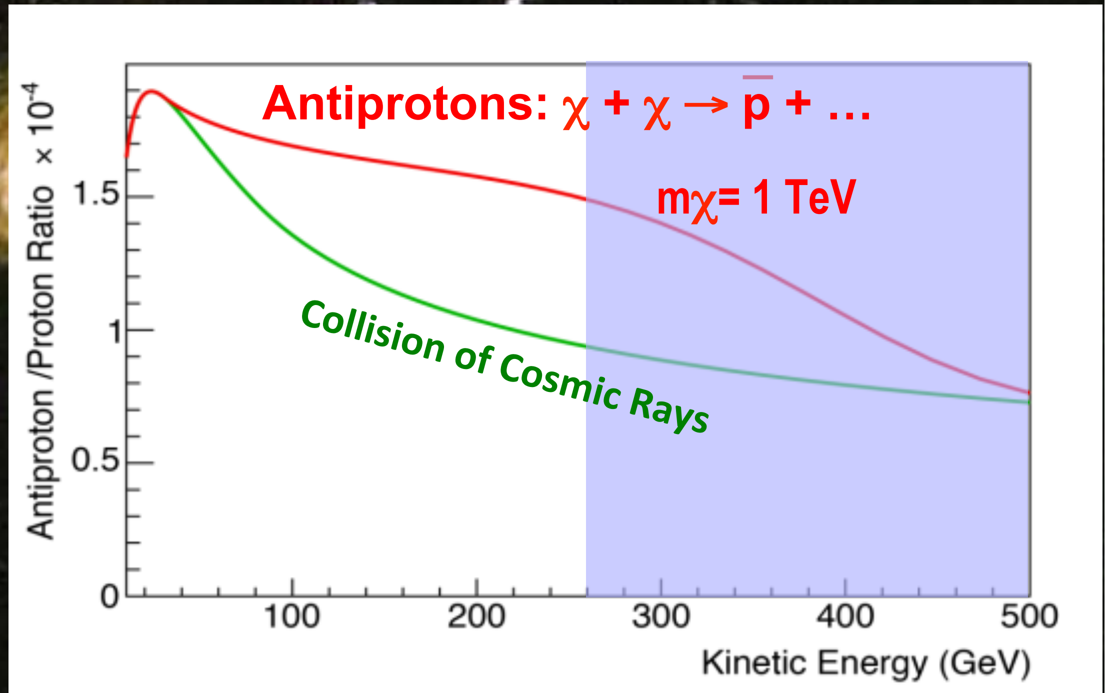


Fornengo, Maccione, Vittino, JCAP 2014

The Search for the Origin of Dark Matter

To identify the Dark Matter signal we will continue to collect e+,e-,$\bar{p}$ ….but

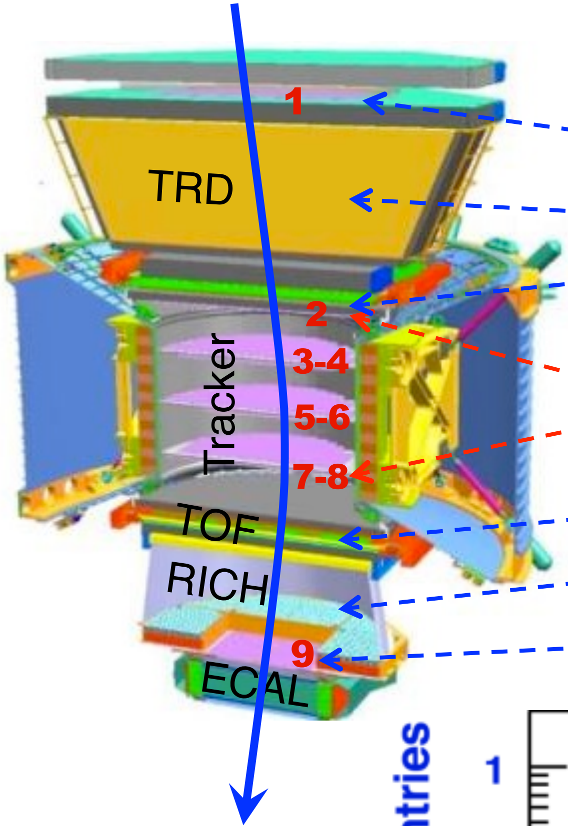




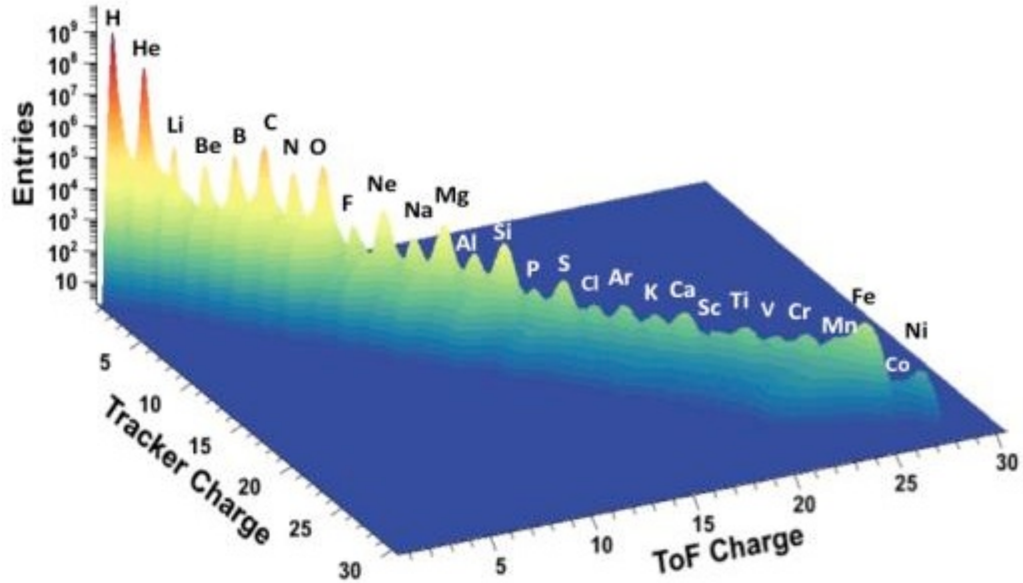
To understand background, we need precise knowledge of:

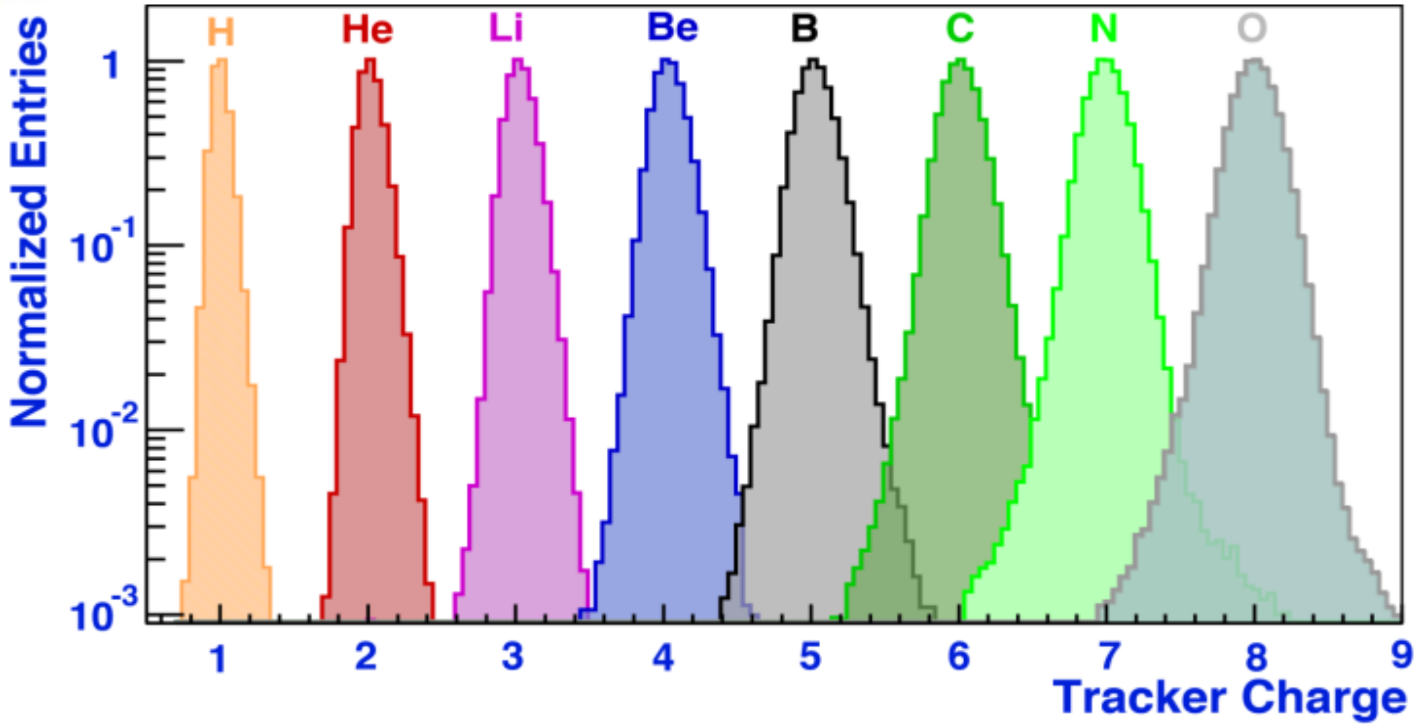
1. The cosmic ray fluxes (p, He, C, …)
2. Propagation and Acceleration (Li, B/C, …)

AMS: Multiple Measurements of Nuclear Charge

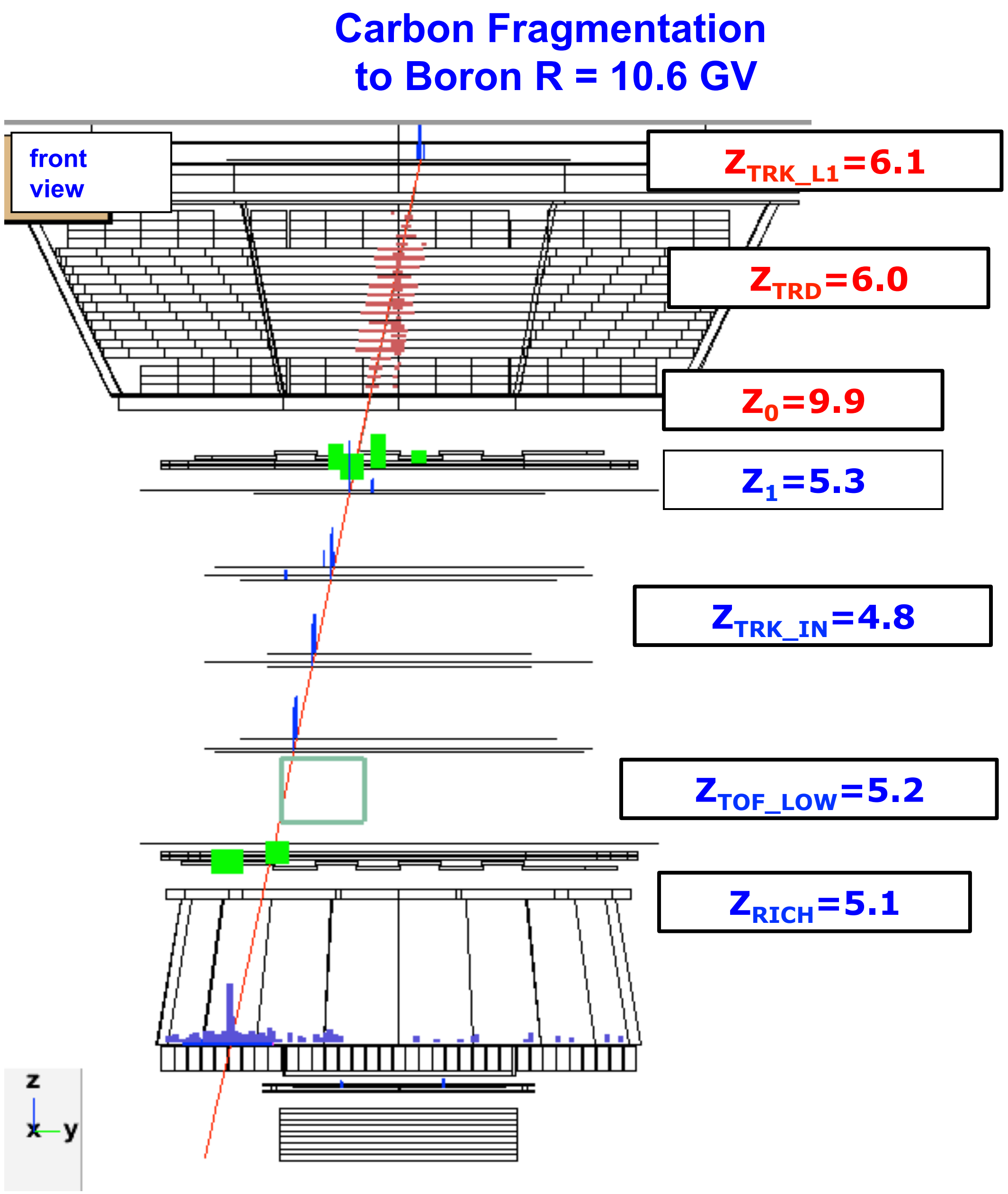


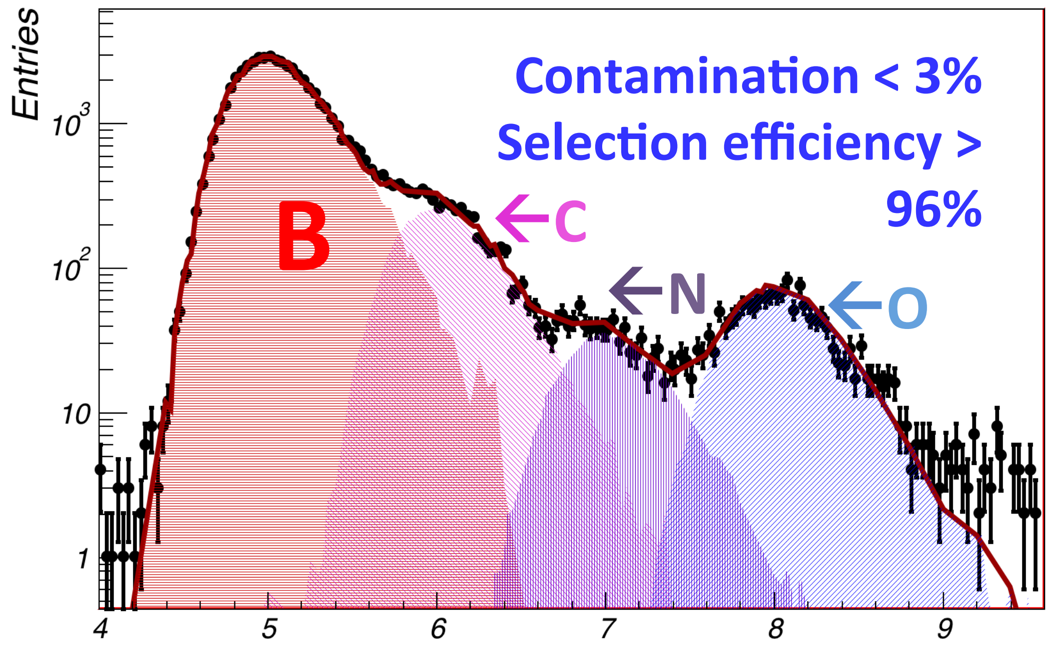
Charge Resolution ($Z=6$)	
Tracker Plane 1	0.30
TRD	0.33
Upper TOF	0.16
Inner Tracker 2-8	0.12
Lower TOF	0.16
RICH	0.32
Tracker Plane 9	0.30





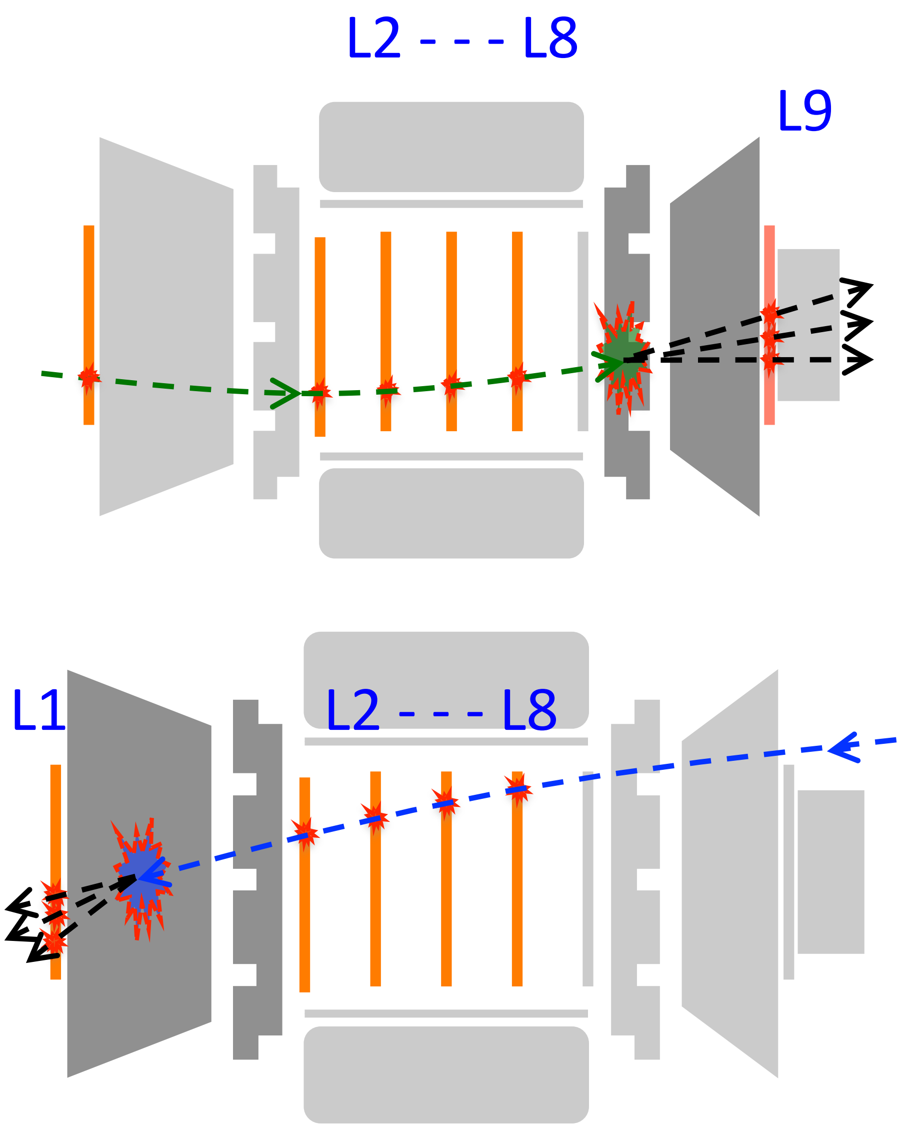
Full Control of fragmentation in the detector





Full control of effects from detector material :

Measurement of nuclear cross sections when AMS is flying in horizontal attitude



First, we use the seven inner tracker layers, L2-L8, to define beams of nuclei: He, Li, Be, B, …

Second, we use left-to-right particles to measure the nuclear interactions in the lower part of the detector.

Third, we use right-to-left particles to measure the nuclear interactions in the upper part of detector.

Precision Measurement of the Proton Flux in Primary Cosmic Rays from Rigidity 1 GV to 1.8 TV with the Alpha Magnetic Spectrometer on the International Space Station

The isotropic proton flux Φ_i for the i^{th} rigidity bin (R_i , $R_i + \Delta R_i$) is:

$$\Phi_i = \frac{N_i}{A_i \varepsilon_i T_i \Delta R_i}$$

To match the statistics of 300 million events, extensive systematic errors studies have been made.

1) $\sigma_{trig.}$:trigger efficiency

2) $\sigma_{acc.}$:
  a. the acceptance and event selection
  b. background contamination
  c. geomagnetic cutoff

3) $\sigma_{unf.}$
  a. unfolding
  b. the rigidity resolution function

4) $\sigma_{scale.}$: the absolute rigidity scale

TABLE I: The proton flux Φ as a function of rigidity

Rigidity [GV]	Φ	$\sigma_{stat.}$	$\sigma_{trig.}$	$\sigma_{acc.}$	$\sigma_{unf.}$	σ_{scale}	$\sigma_{syst.}$
100 – 108	(4.085	0.007	0.006	0.040	0.035	0.022	0.058) $\times 10^{-2}$
108 – 116	(3.294	0.007	0.005	0.033	0.028	0.018	0.047) $\times 10^{-2}$
116 – 125	(2.698	0.006	0.004	0.027	0.023	0.016	0.039) $\times 10^{-2}$
125 – 135	(2.174	0.005	0.004	0.022	0.019	0.013	0.032) $\times 10^{-2}$

PRL 114, 171103 (2015) PHYSICAL REVIEW LETTERS week ending 1 MAY 2015

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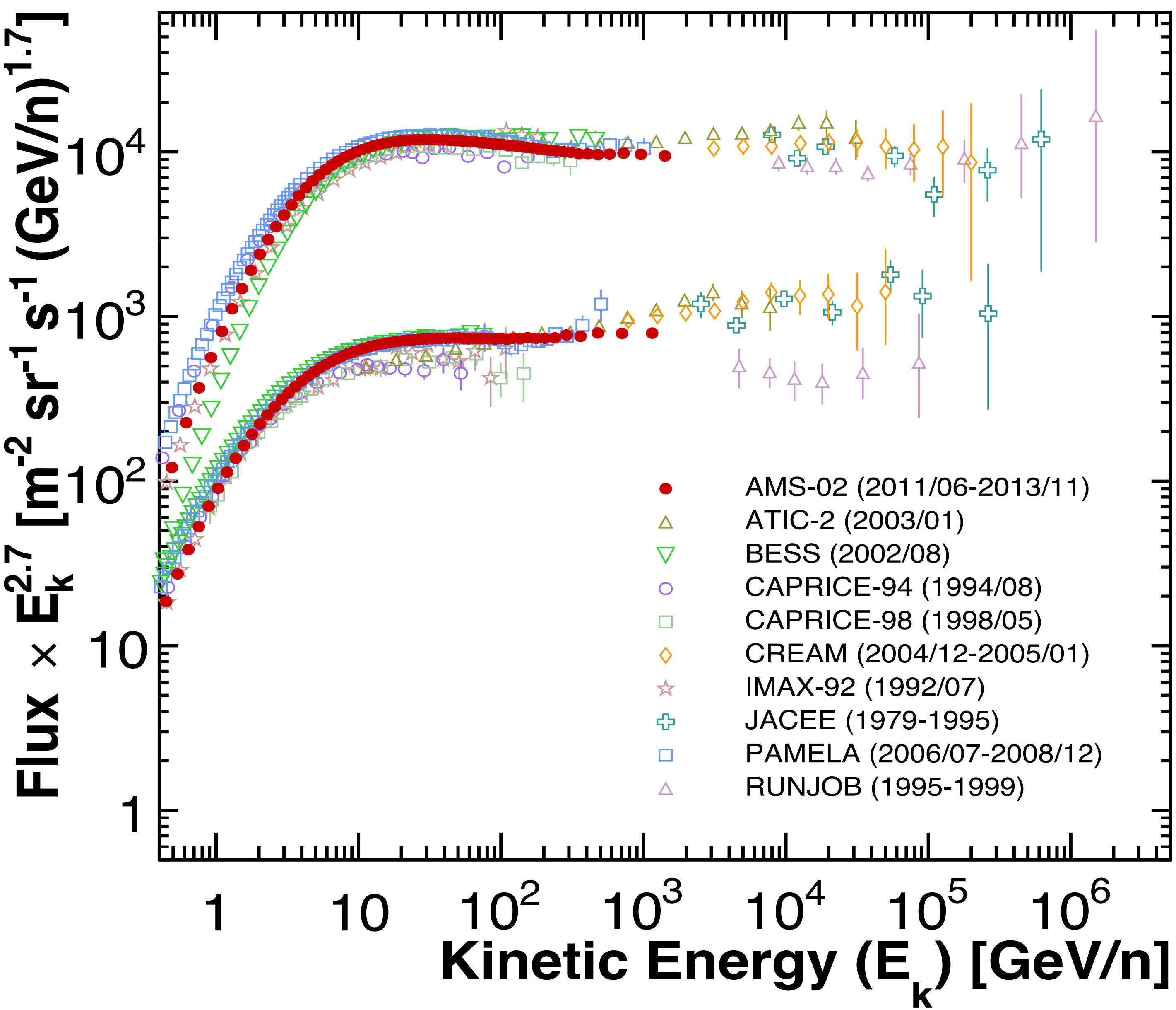
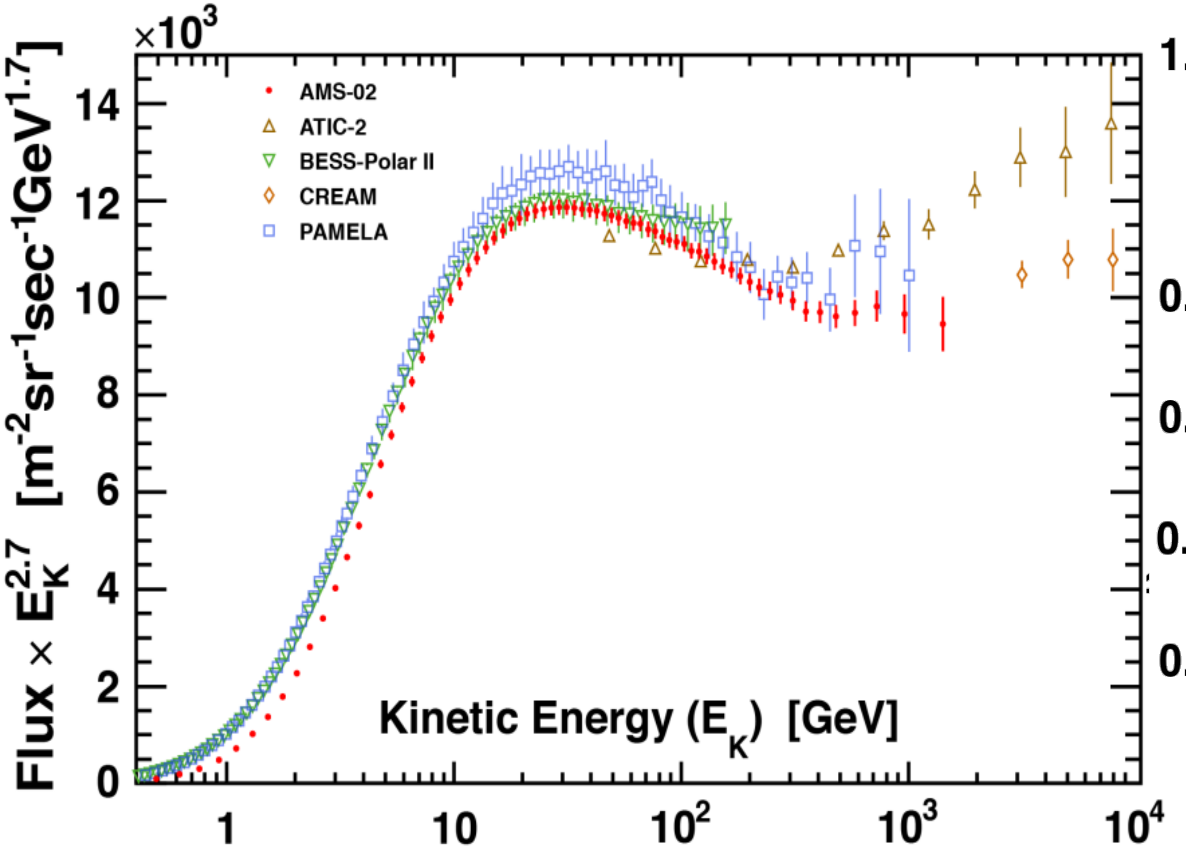
He flux measurement up to 3 TV submitted to PRL

H and He fluxes

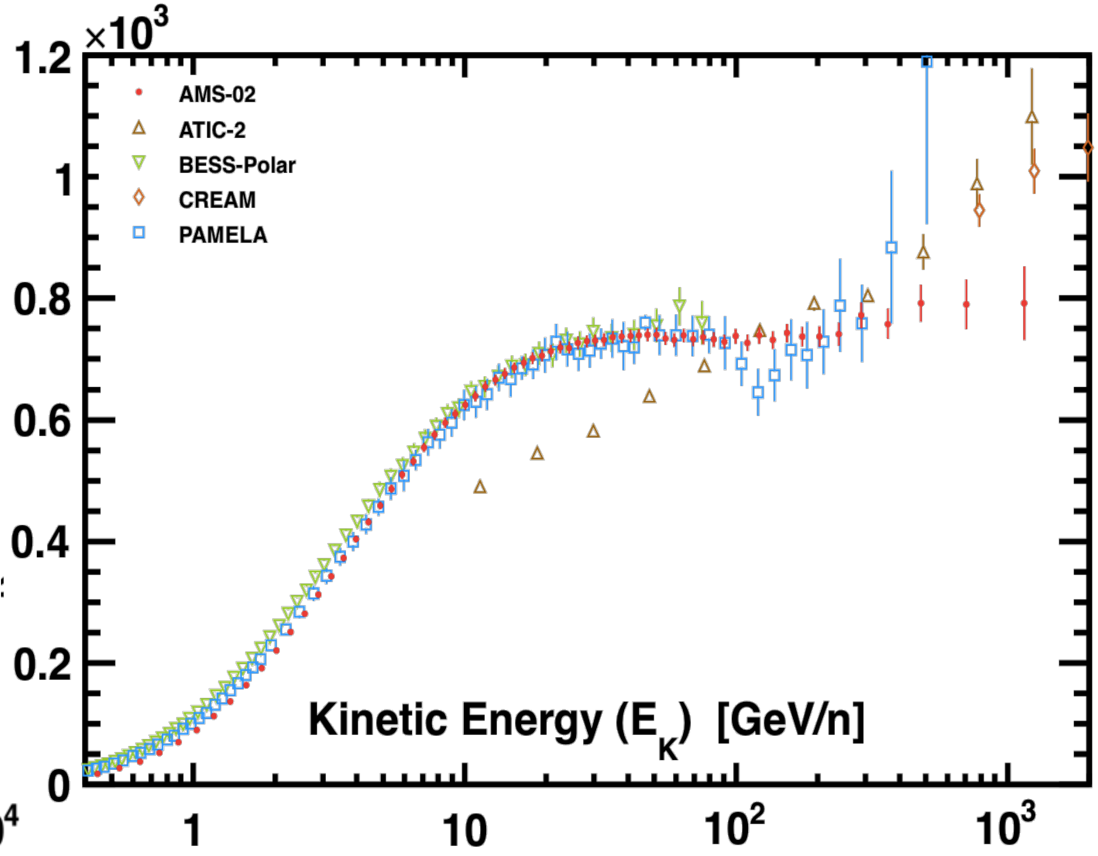


AMS H and He fluxes

AMS-02 H flux measurement: 300 million events



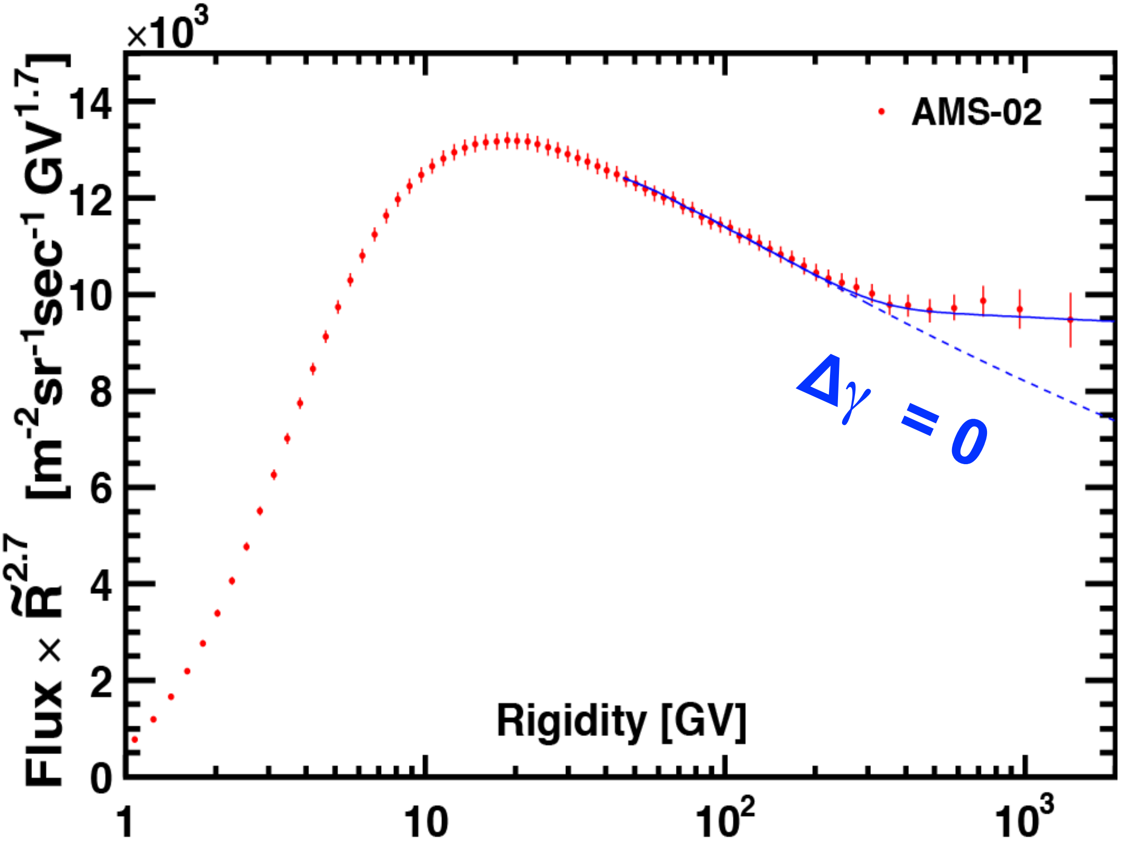
AMS-02 He flux measurement: 50 million events

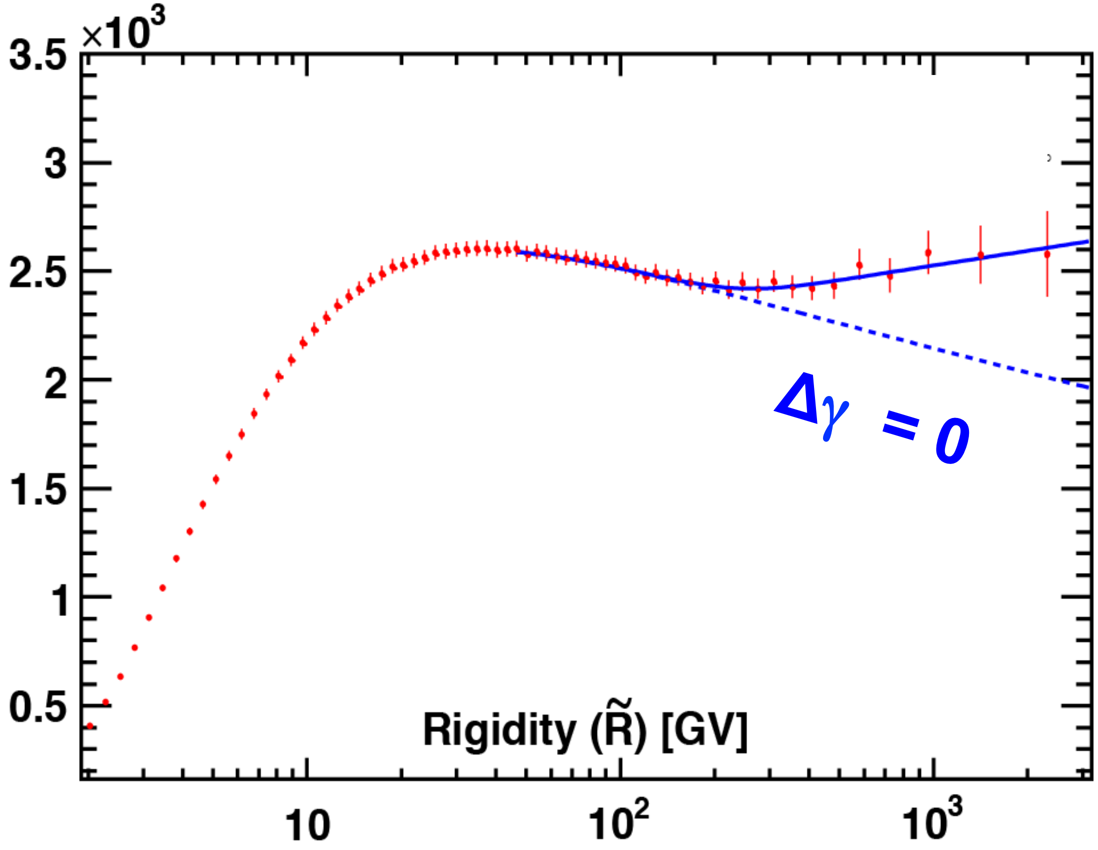


AMS H and He fluxes

Two power laws $R^{\gamma}, R^{\gamma+1}$ with a characteristic transition rigidity R_0 and a smoothness parameter s well describe H, He measured spectra:

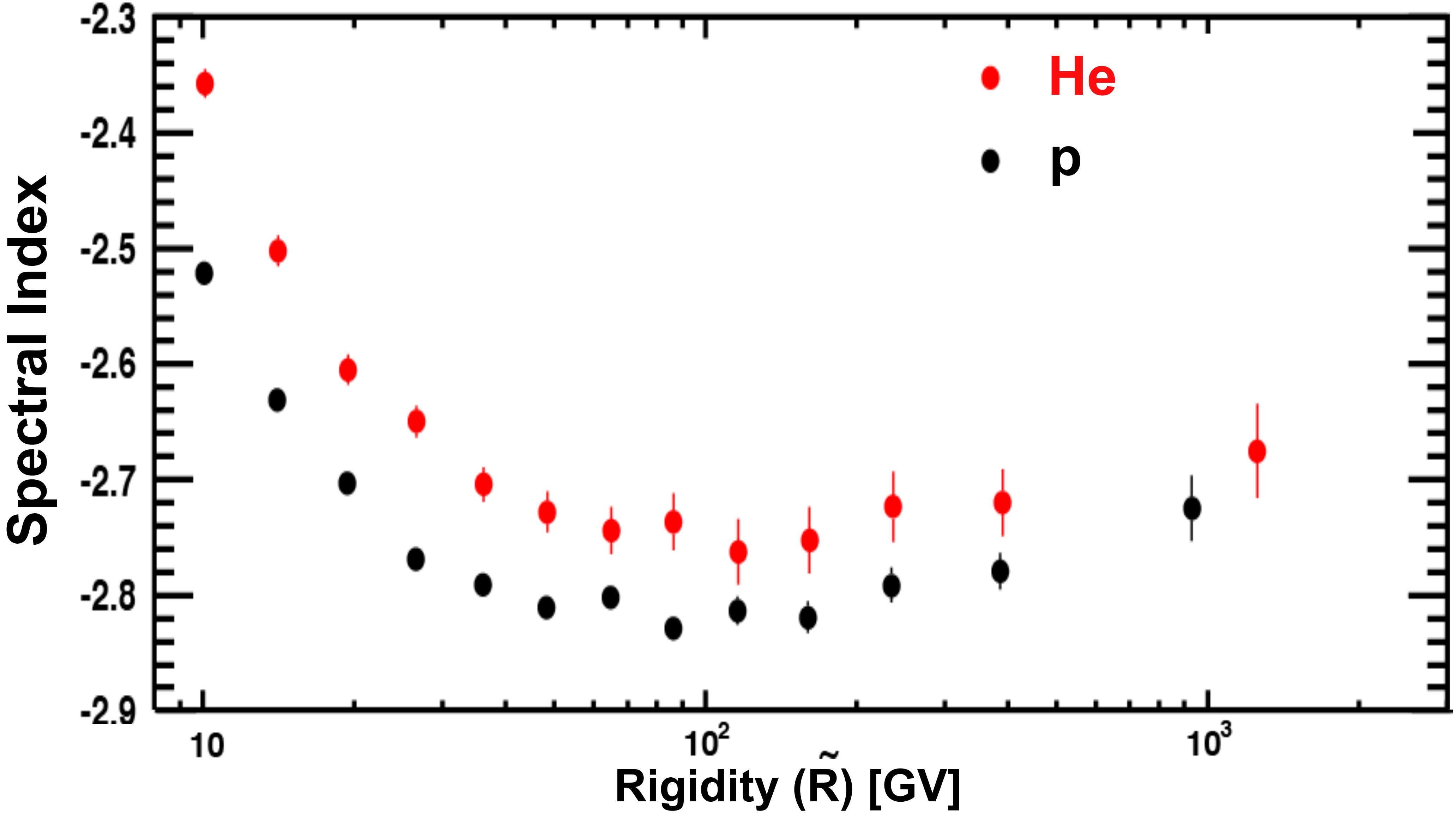
$$\Phi = C\left(\frac{R}{45GV}\right)^{\gamma}\left[1+\left(\frac{R}{R_0}\right)^{\Delta\gamma/s}\right]^{s}$$



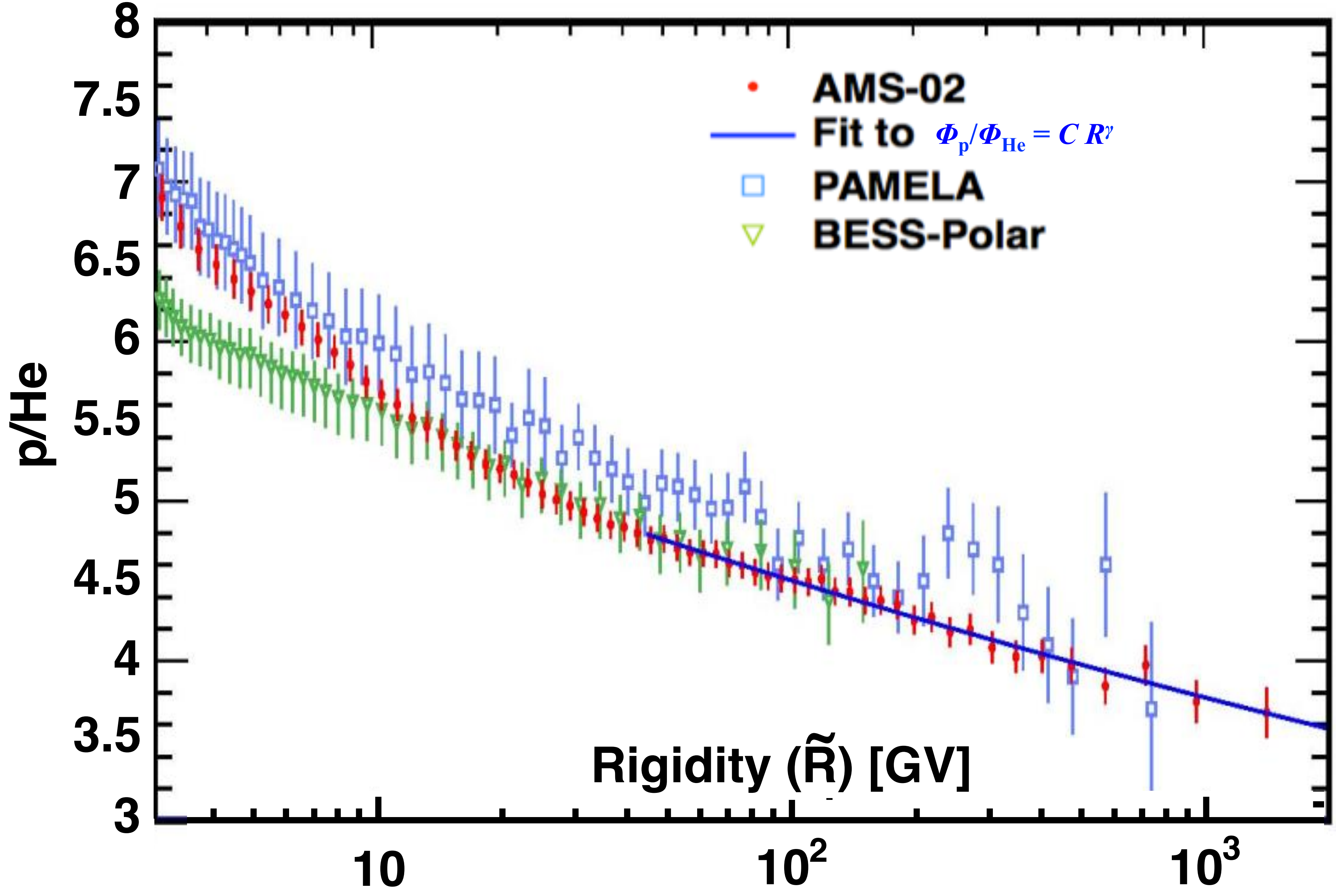


Model Independent Spectral Indices Comparison

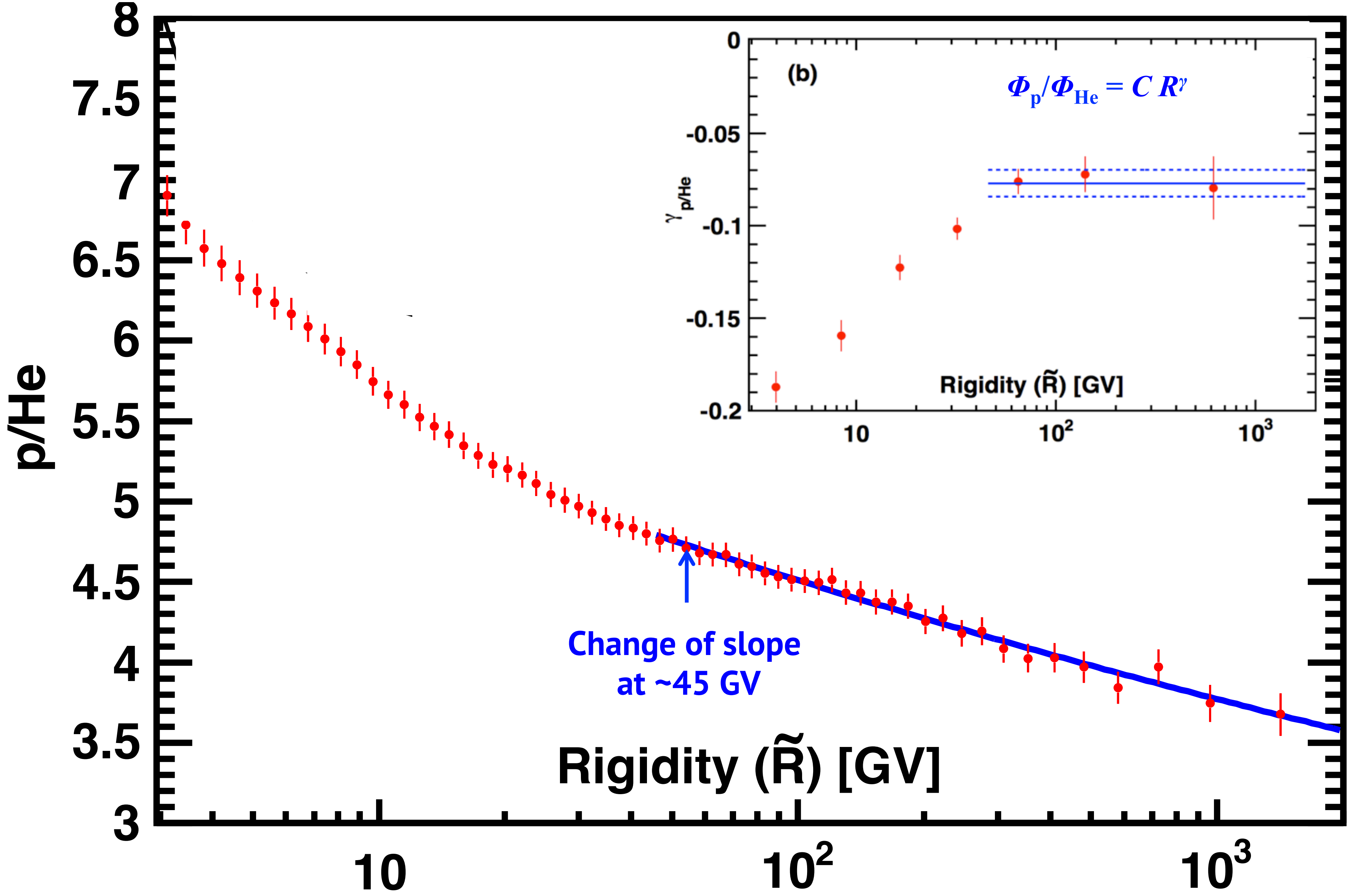
$$\gamma = d\log(\Phi) / d\log(R)$$



AMS p/He flux ratio

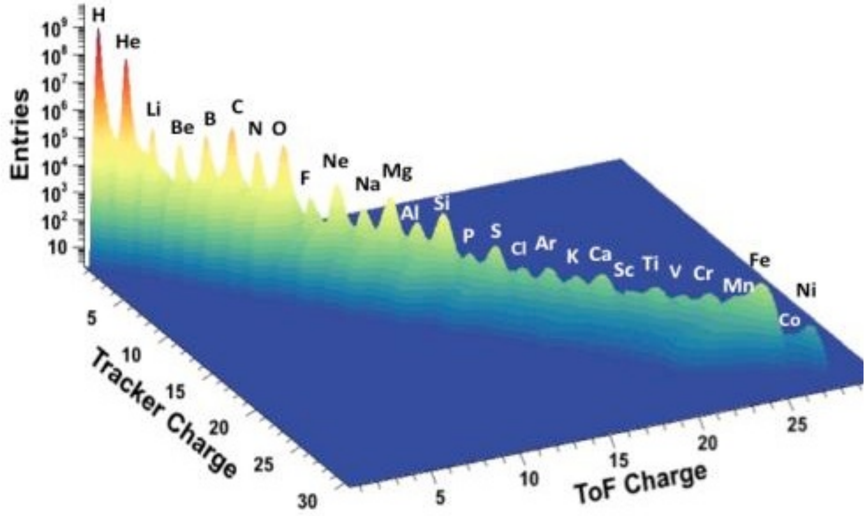


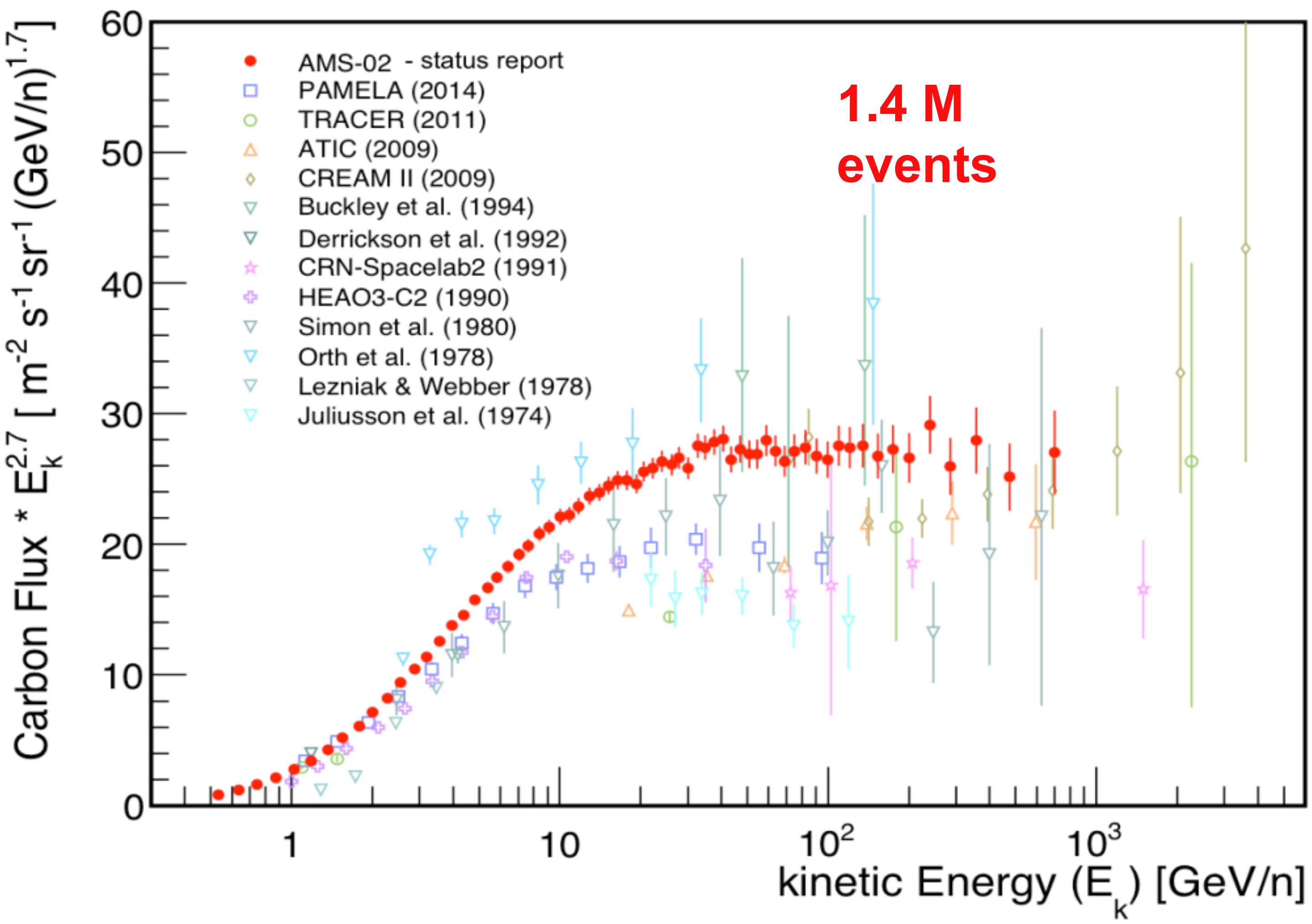
AMS p/He flux ratio



More nuclear fluxes are coming..

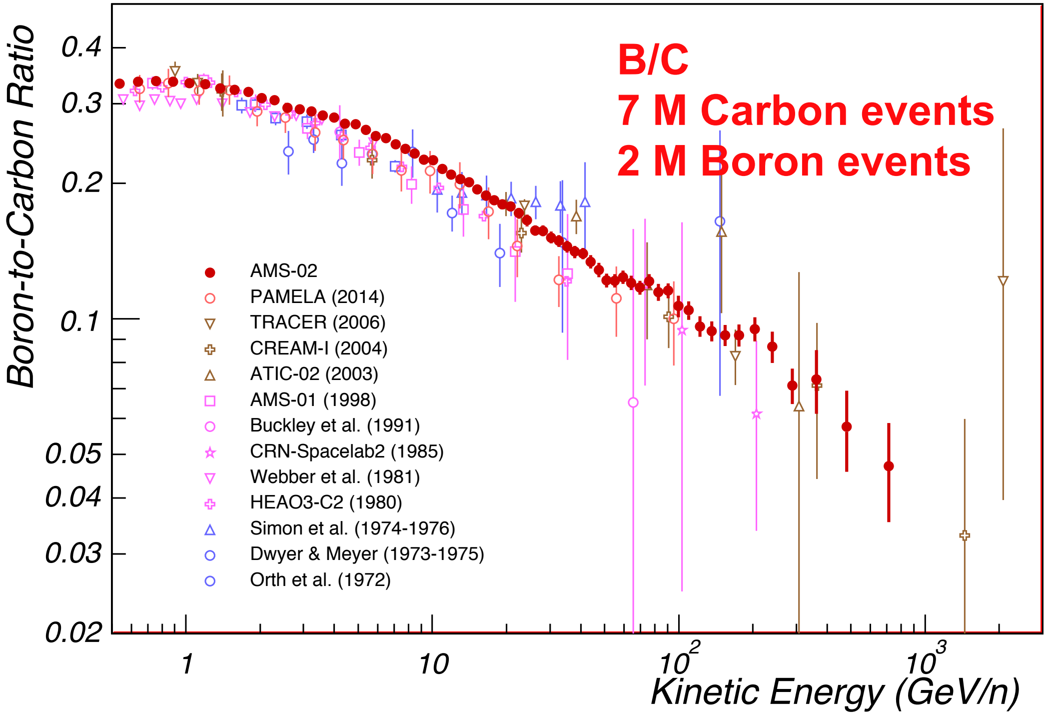
Primaries: e.g. C

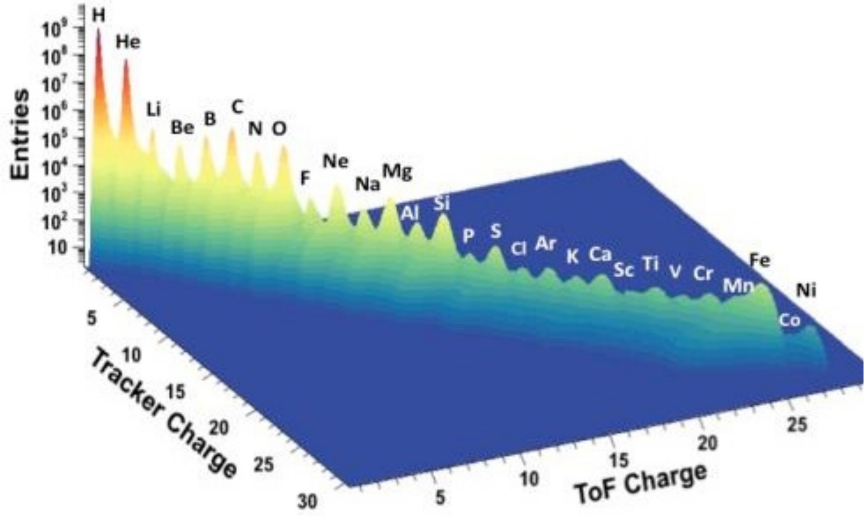


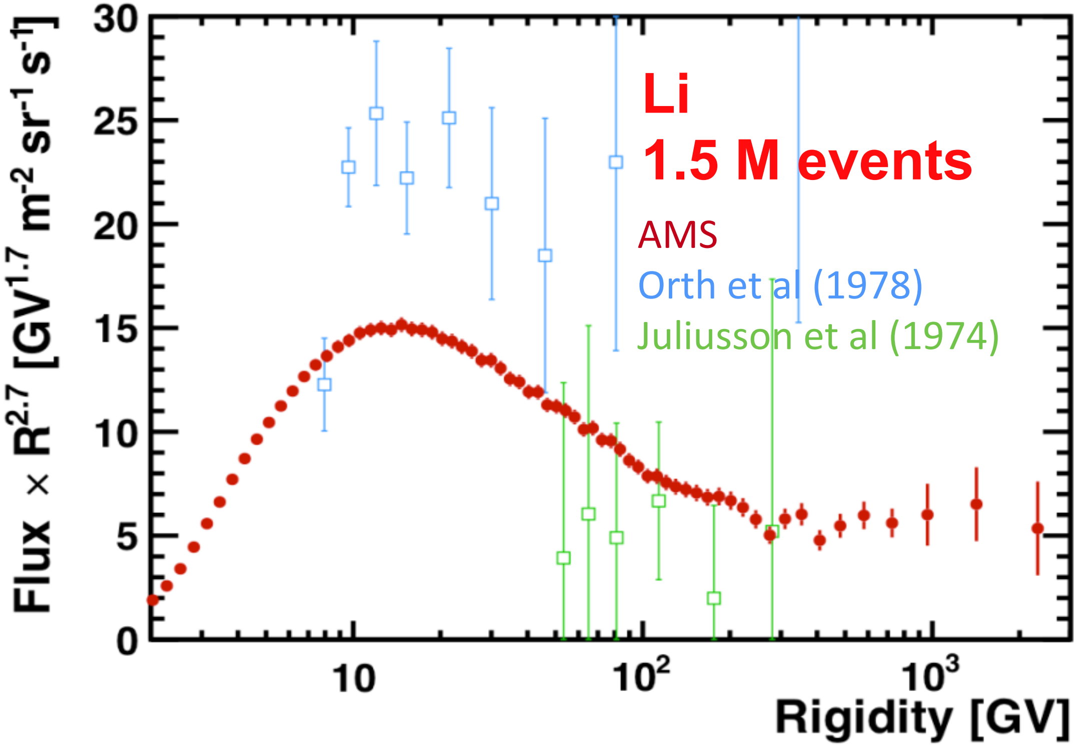


More nuclear fluxes are coming..

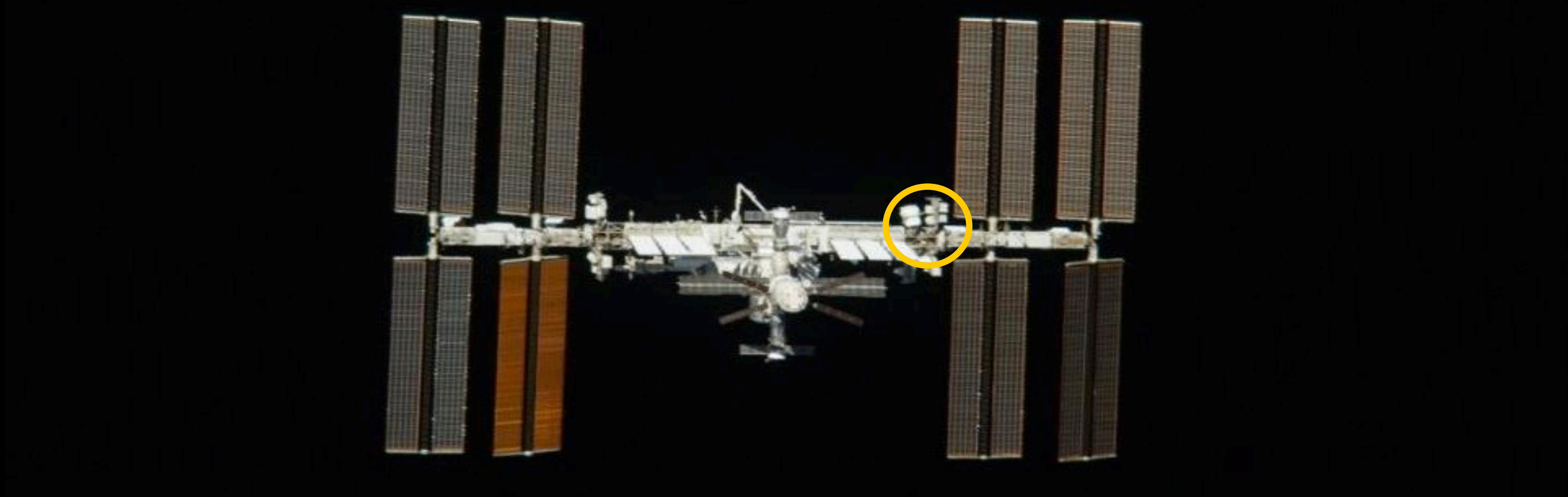
Secondaries:





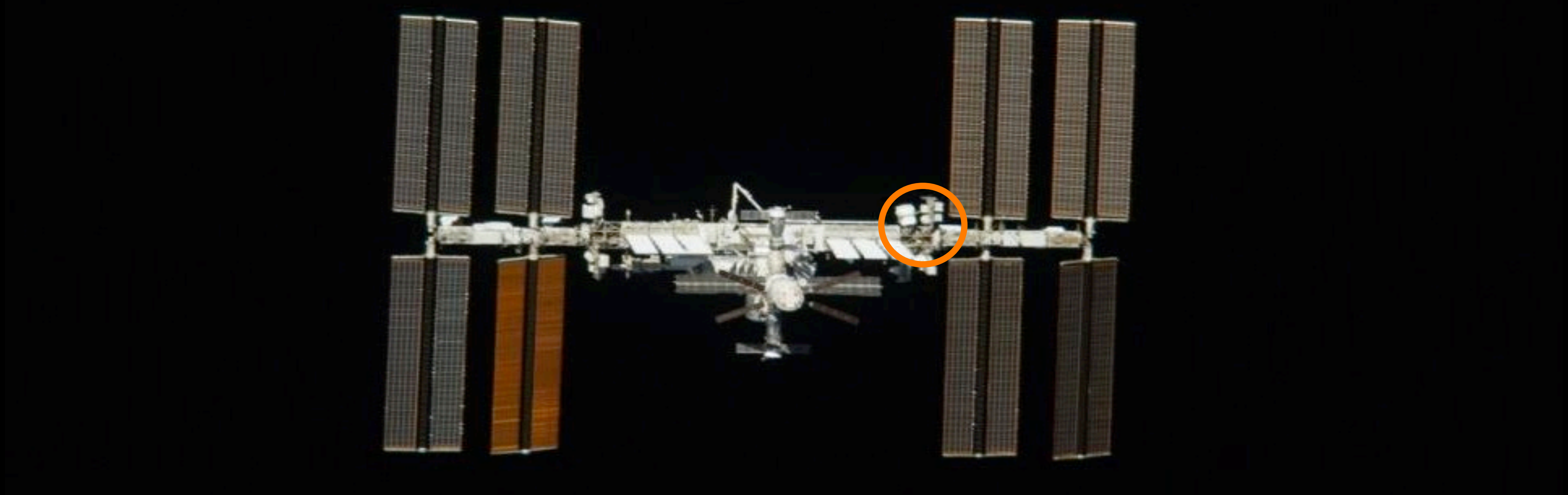


Conclusions



- In AMS is providing simultanenous measurements of different cosmic ray species with O(%) accuracy in an extended energy range
- new phenomena are being highligted by these measurements whose nature will be futher clarified as more data will be collected by the experiment.

Conclusions



AMS will match the lifetime of the Space Station

- ✓ Continue the study of Dark Matter
- ✓ Search for the Existence of Antimatter
- ✓ Search for New Phenomena, …
- ✓ Time dependent effects of low energy CR

THANKS FOR YOUR ATTENTION !