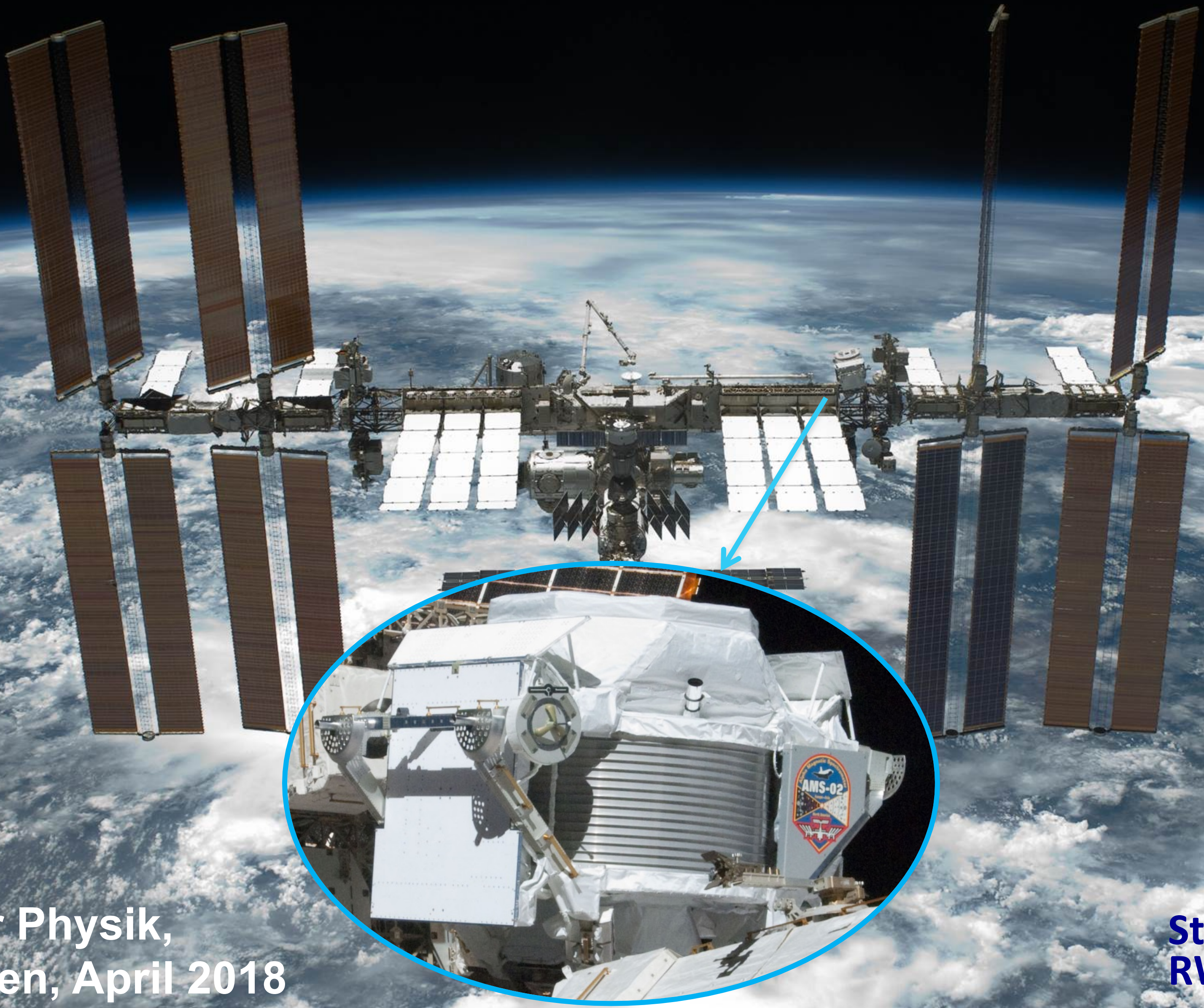
First six years of AMS on the ISS and future perspectives



MPI für Physik,
München, April 2018

Stefan Schael,
RWTH Aachen

AMS DAYS at LA PALMA, SPAIN

Monday, 9 April 2018

08:15-10:20 Chair: S. Ting
08:15-08:45 **Ramón J. García López**
Universidad de La Laguna (IAC, ULL)
Welcome & Status of MAGIC and CTA
08:45-09:30 **S. Ting, CERN, MIT**
The AMS Experiment
09:30-10:20 **S. Schael**
AMS Positron Results and Electron Results I
10:20-10:40 Break
10:40-12:10 Chair: M. Salamon
10:40-11:30 **A. Kounine**
AMS Positron Results and Electron Results II
11:30-12:10 **H. Gast, Z. Li**
AMS Low Energy:
Electrons, Positron, Antiprotons
12:10- 13:30 Lunch
13:30-15:45 Chair: J. Ellis
13:30-14:30 **I. Moskalenko**
Cosmic Rays in the Milky Way and Other Galaxies
14:30-15:45 *Discussion on cosmic ray positrons with:* **I. Moskalenko, M. Malkov…**
15:45-16:00 Break
16:00-18:00 Chair: M. Aguilar
16:00-17:00 **M. Unger**
Latest Results from Pierre Auger
17:00-18:00 **I. Cholis**
Tracking down the source of high energy positrons with AMS-02 measurements
18:00-19:00 Chair: Ramón J. García López
18:00-19:00 **W. Gerstenmaier**
NASA Vision for Exploration

Tuesday, 10 April 2018

08:30-10:45 Chair: I. Moskalenko
08:30-09:15 **V. Formato**
AMS Fluxes of Primary Nuclei
09:15-10:00 **A. Oliva**
AMS Fluxes of Secondary Nuclei
10:00-10:45 **L. Derome**
AMS Secondary to Primary Flux ratios
10:45-11:00 Break
11:00-12:00 Chair: M. de Naurois
11:00-11:30 **Q. Yan**
AMS Nitrogen Flux
11:30-12:00 **V. Choutko**
AMS Heavy Antimatter
12:00-13:30 Lunch
13:30-15:30 Chair: E. Resconi
13:30-14:30 **M. de Naurois**
Results from HESS
14:30-15:30 **Y. Tsunesada**
Latest Results from TA
15:30-16:00 Break
16:00-18:30 Chair: H. He
16:00-17:00 **E. Resconi**
Latest Results from IceCube
17:00-17:30 **H. Zhou**
Latest Results from HAWC
17:30-18:30 **V. Bindi, S. Della Torre, C. Consolandi**
AMS Low energy: Proton, Helium
18:30-19:30 Chair: S. Ting
18:30-19:30 **K. Turner**
DOE Vision for the Cosmic Frontier

Wednesday, 11 April 2018

08:30-10:30 Chair: J. Chang
08:30-09:00 **S. Haino**
Proton Flux
09:00-09:30 **Z. Weng**
AMS Properties of Elementary Particles
09:30-10:30 **J. Berdugo**
AMS Antiproton Flux and Anti-Deuteron Studies
10:30-11:00 Break
11:00-12:45 Chair: B. Bertucci
11:00-12:00 **J. Ellis**
Super Symmetric Dark Matter
12:00-12:45 **J. Casaus, I. Gebauer**
AMS Anisotropy in Cosmic Rays
12:45-13:45 Lunch
13:45-16:15 Chair: A. Olinto
13:45-14:15 **B. Bertucci**
AMS & Exploration
14:15-15:15 **J. Chang**
Results from DAMPE
15:15-16:15 **S. Torii**
Latest Results from CALET
16:15-16:30 Break
16:30-17:15 Chair: S. Torii
16:30-17:00 **W. Xu**
AMS Combined (Electron+Positron) Flux
17:00-17:15 **S. Schael**
Comments on the (e+ + e-) results
17:15-19:15 Chair: H.S. Chen
17:15-18:15 **H. He**
The LHAASO Experiment
18:15-19:15 **A. de Rujula**
News on primary cosmic rays and their knees

Thursday, 12 April 2018

08:30-10:30 Chair: F. Donato
08:30-09:30 **P. Blasi**
A Physical Description of the Cosmic Ray Transport in the Galaxy
09:30-10:30 **M. Malkov**
CR Acceleration Mechanisms in SNRs: Stress Test by AMS-02 recent data
10:30-10:45 Break
10:45-12:15 Chair: M. Unger
10:45-11:45 **F. Donato**
Theory
11:45-12:15 **P. Zuccon, C. Delgado**
AMS Isotope Studies
12:15 -13:30 Lunch
13:30-15:10 Chair: B. Wyslouch
13:30-14:10 **Y.-F. Zhou**
Theory
14:10-15:10 **P. Mertsch**
Theory
15:10-15:30 Break
15:30-18:30 Chair: S. Ting
15:30-16:30 *Discussion on cosmic ray nuclei with:*
I. Moskalenko, M. Malkov,
F. Donato, P. Blasi, P. Mertsch…
16:30-17:30 **A. Olinto**
Latest Results from EUSO
17:30-18:00 **S. Schael**
Next Generation AMS
18:00-18:30 **S. Ting**
Conclusions


Roque de los Muchachos Observatory

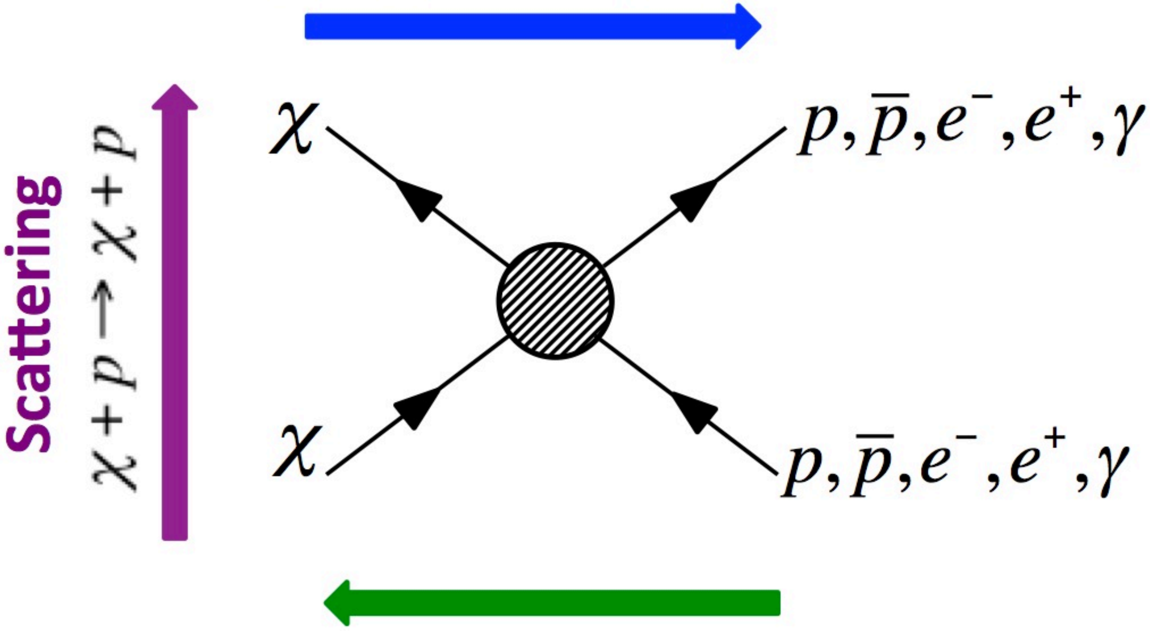
Three independent methods to search for Dark Matter

PANDA
LUX
CRESST
XENON
CDMS
...

AMS

Annihilation

$\chi + \chi \rightarrow e^{+}, \bar{p}, \gamma, \ldots$



$\chi + \chi \leftarrow p + p$

Production

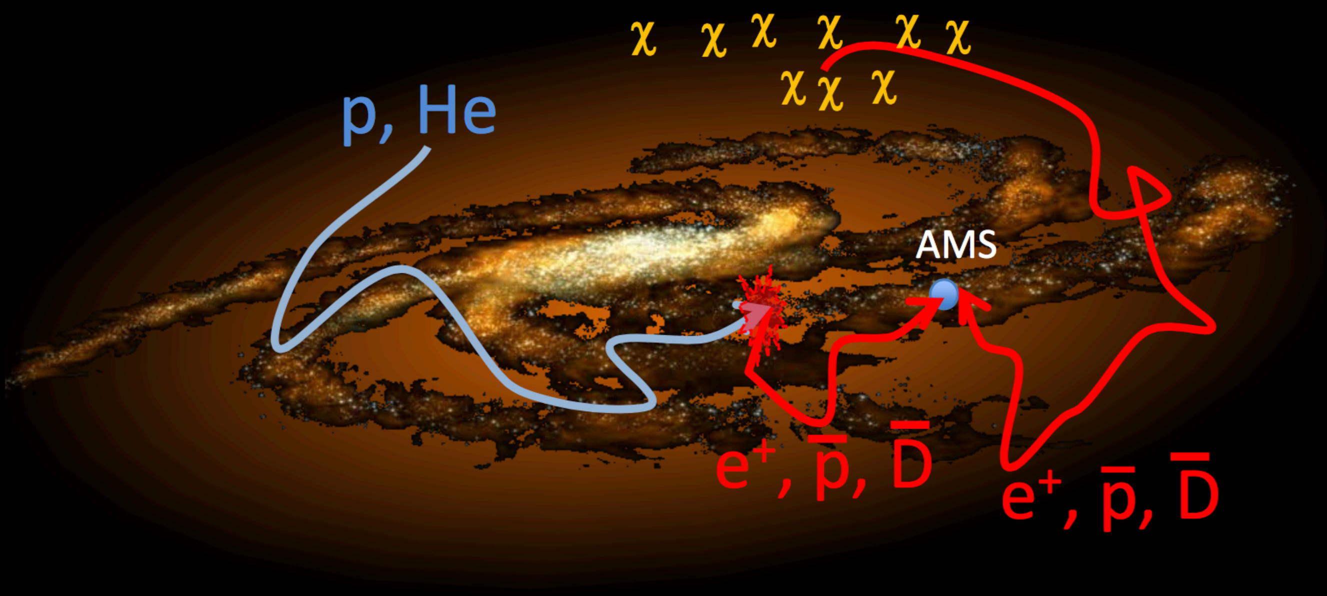
ATLAS, CMS

Dark Matter

Collision of Cosmic Rays with Interstellar Matter produces e^+, $\bar{p}$, $\bar{D}$

Dark Matter annihilation also produces light antimatter: e^+, $\bar{p}$, $\bar{D}$

The excess of e^+, $\bar{p}$, $\bar{D}$ from Dark Matter annihilations can be measured by AMS



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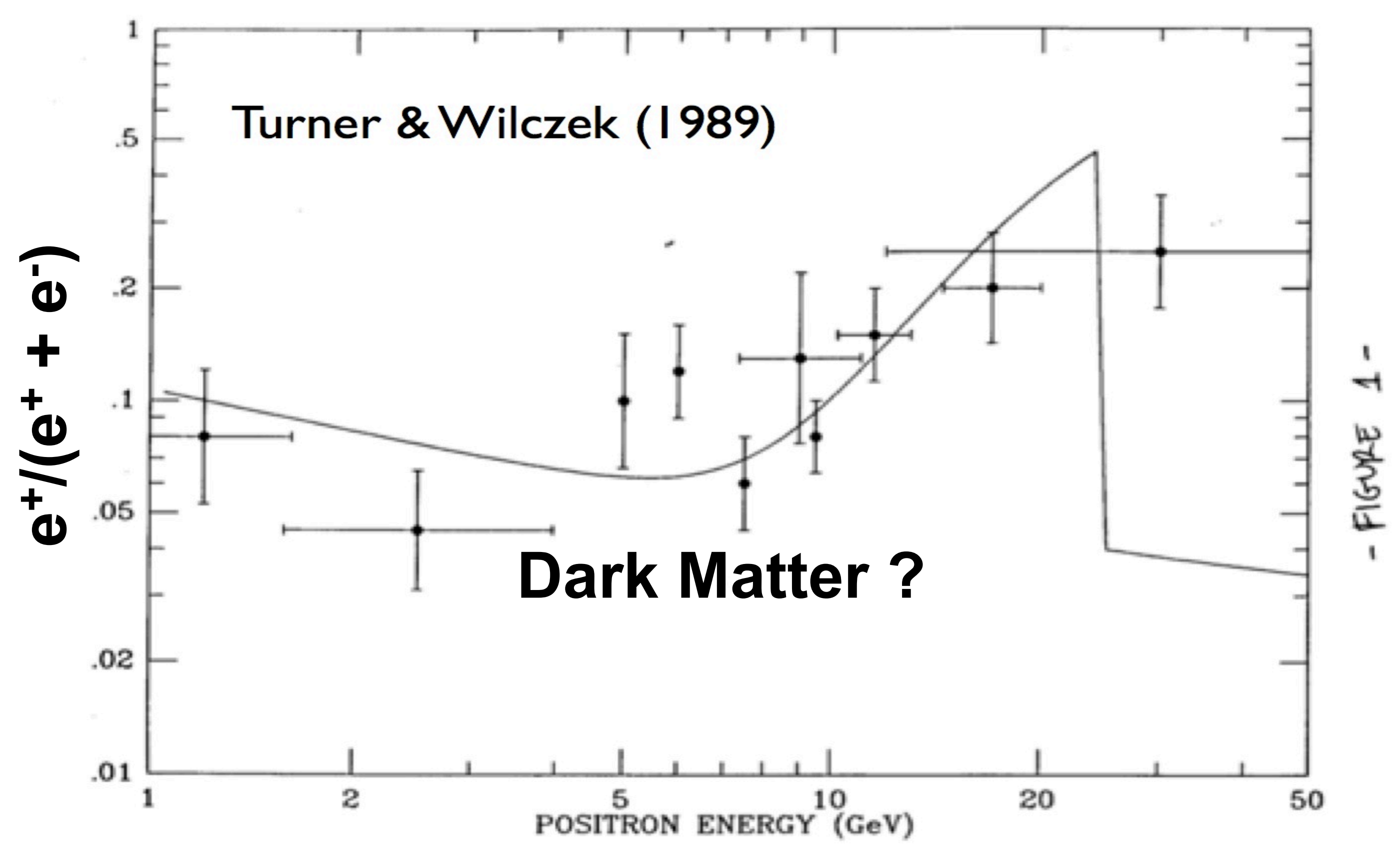
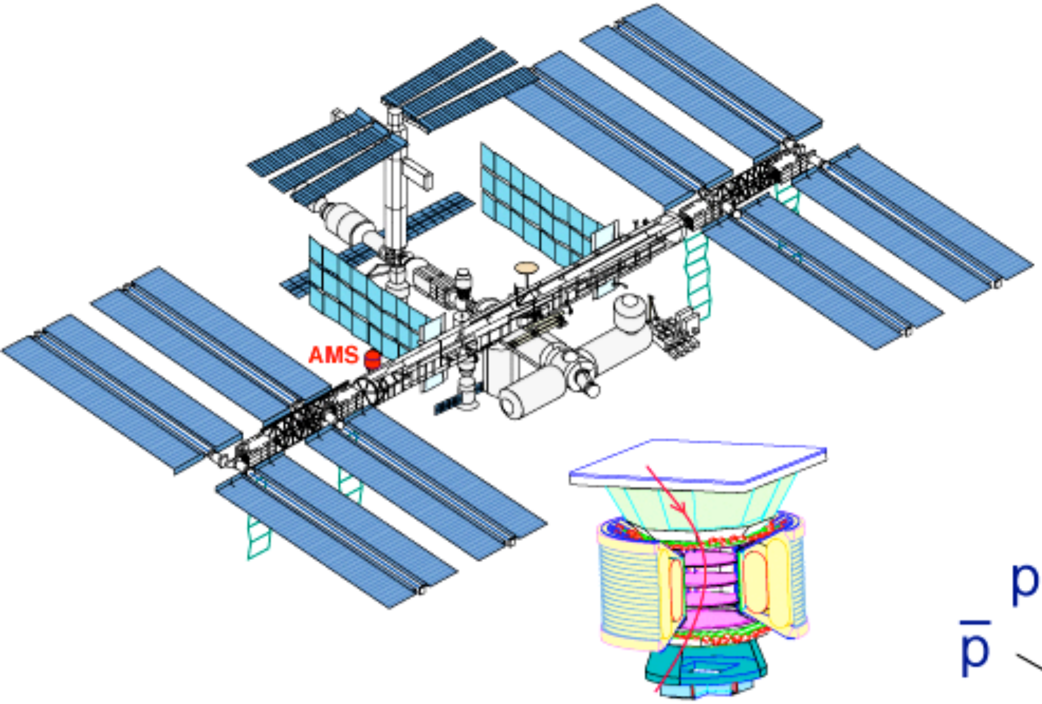


1- Neutral component:

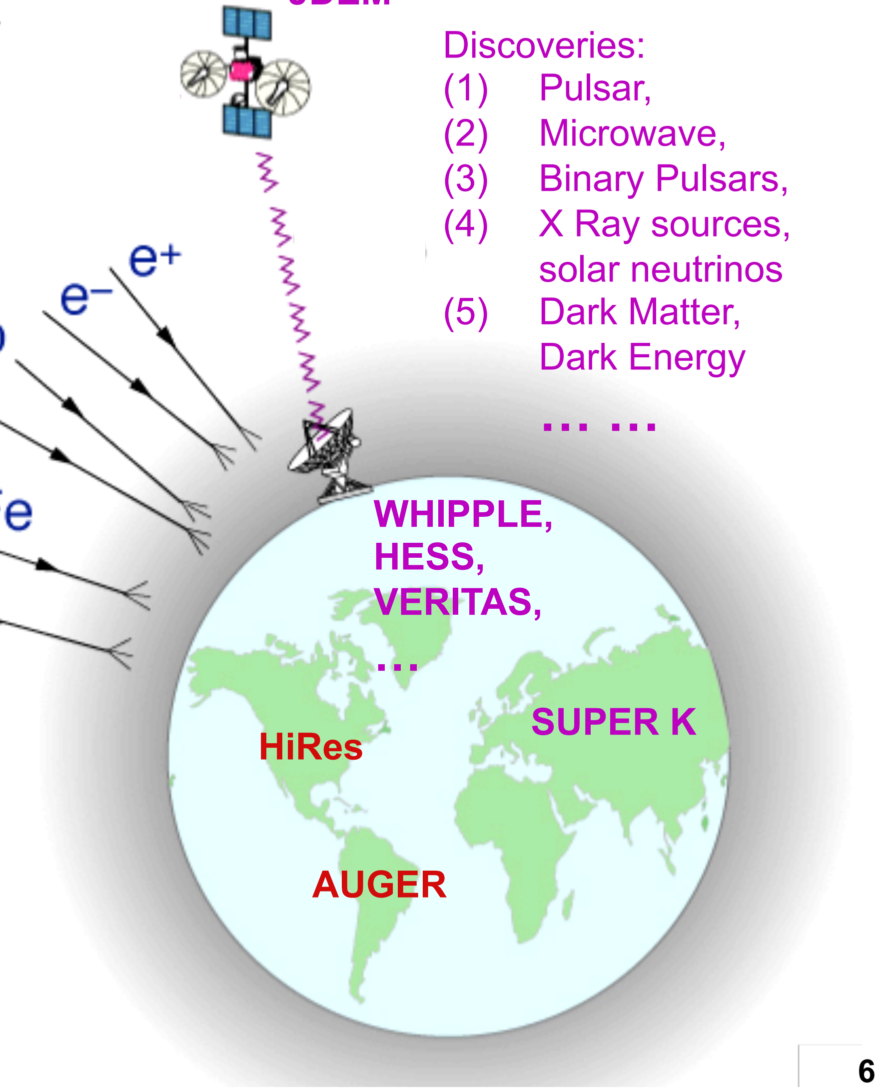
γ, ν

Hubble, Chandra, GLAST, JWST, JDEM

Discoveries:
(1) Pulsar,
(2) Microwave,
(3) Binary Pulsars,
(4) X Ray sources, solar neutrinos
(5) Dark Matter, Dark Energy
…… ……



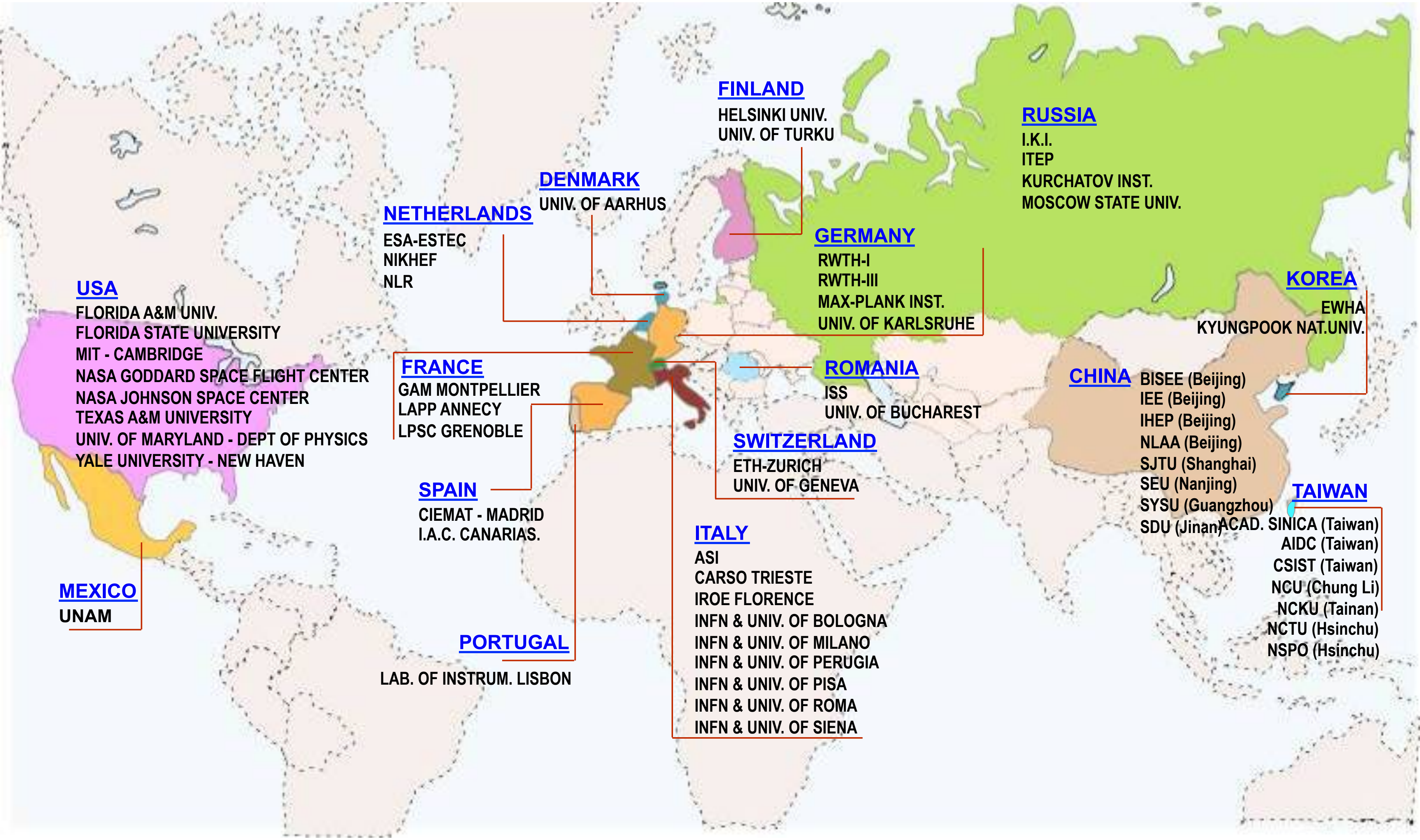
2- Charged component: He, Be, C, Fe



S. Ting, MIT

AMS is an International Collaboration

16 Countries, 60 Institutes and 600 Physicists, 17 years



USA
FLORIDA A&M UNIV.
FLORIDA STATE UNIVERSITY
MIT - CAMBRIDGE
NASA GODDARD SPACE FLIGHT CENTER
NASA JOHNSON SPACE CENTER
TEXAS A&M UNIVERSITY
UNIV. OF MARYLAND - DEPT OF PHYSICS
YALE UNIVERSITY - NEW HAVEN

MEXICO
UNAM

NETHERLANDS
ESA-ESTEC
NIKHEF
NLR

DENMARK
UNIV. OF AARHUS

FINLAND
HELSINKI UNIV.
UNIV. OF TURKU

FRANCE
GAM MONTPELLIER
LAPP ANNECY
LPSC GRENOBLE

SPAIN
CIEMAT - MADRID
I.A.C. CANARIAS.

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SYSU (Guangzhou)
SDU (Jinan)

TAIWAN
ACAD. SINICA (Taiwan)
AIDC (Taiwan)
CSIST (Taiwan)
NCU (Chung Li)
NCKU (Tainan)
NCTU (Hsinchu)
NSPO (Hsinchu)

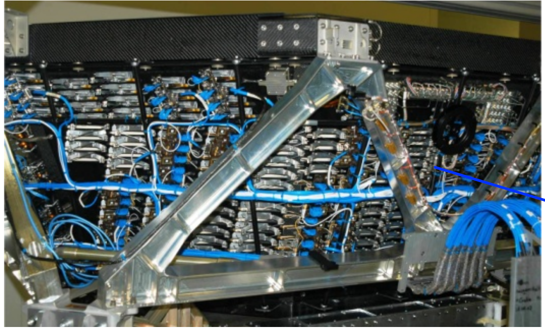
The detectors were built all over the world and assembled at CERN, near Geneva, Switzerland

AMS: A TeV precision, multipurpose spectrometer

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

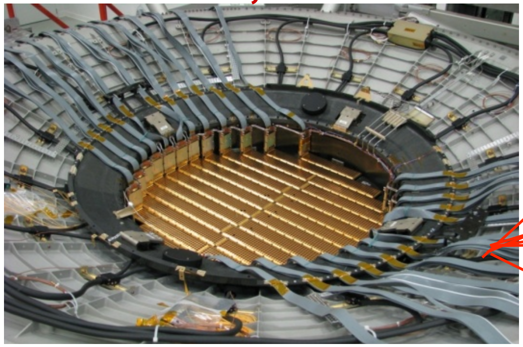
TRD

Identify e⁺, e⁻



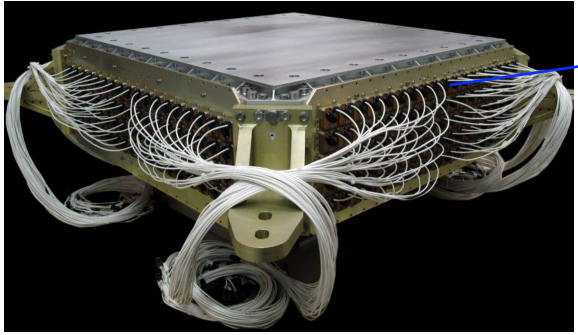
Silicon Tracker

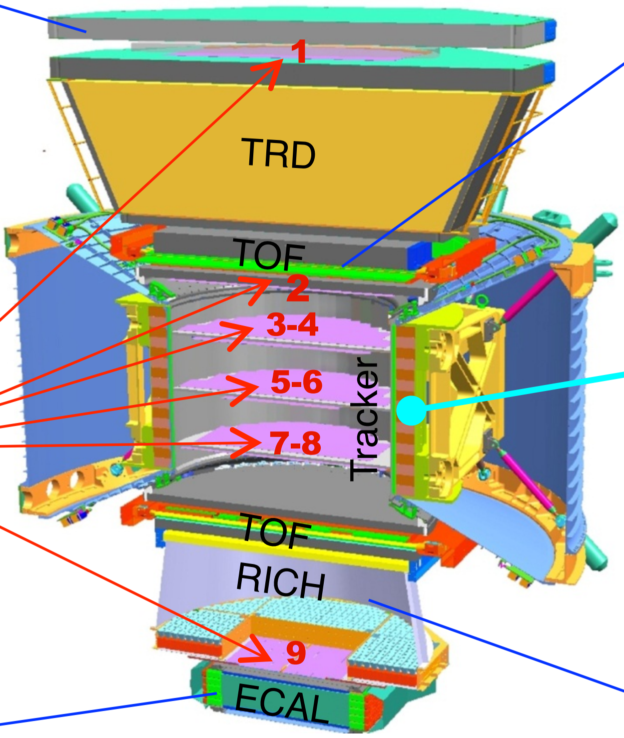
Z, P



ECAL

E of e⁺, e⁻, γ





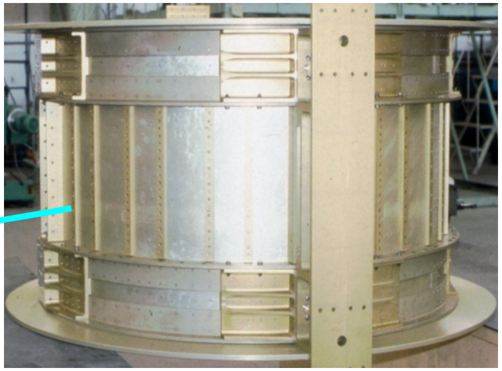
Z, P are measured independently by the Tracker, RICH, TOF and ECAL

TOF

Z, E

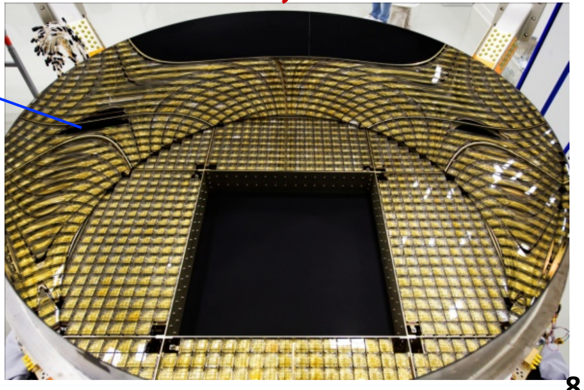
Magnet

±Z

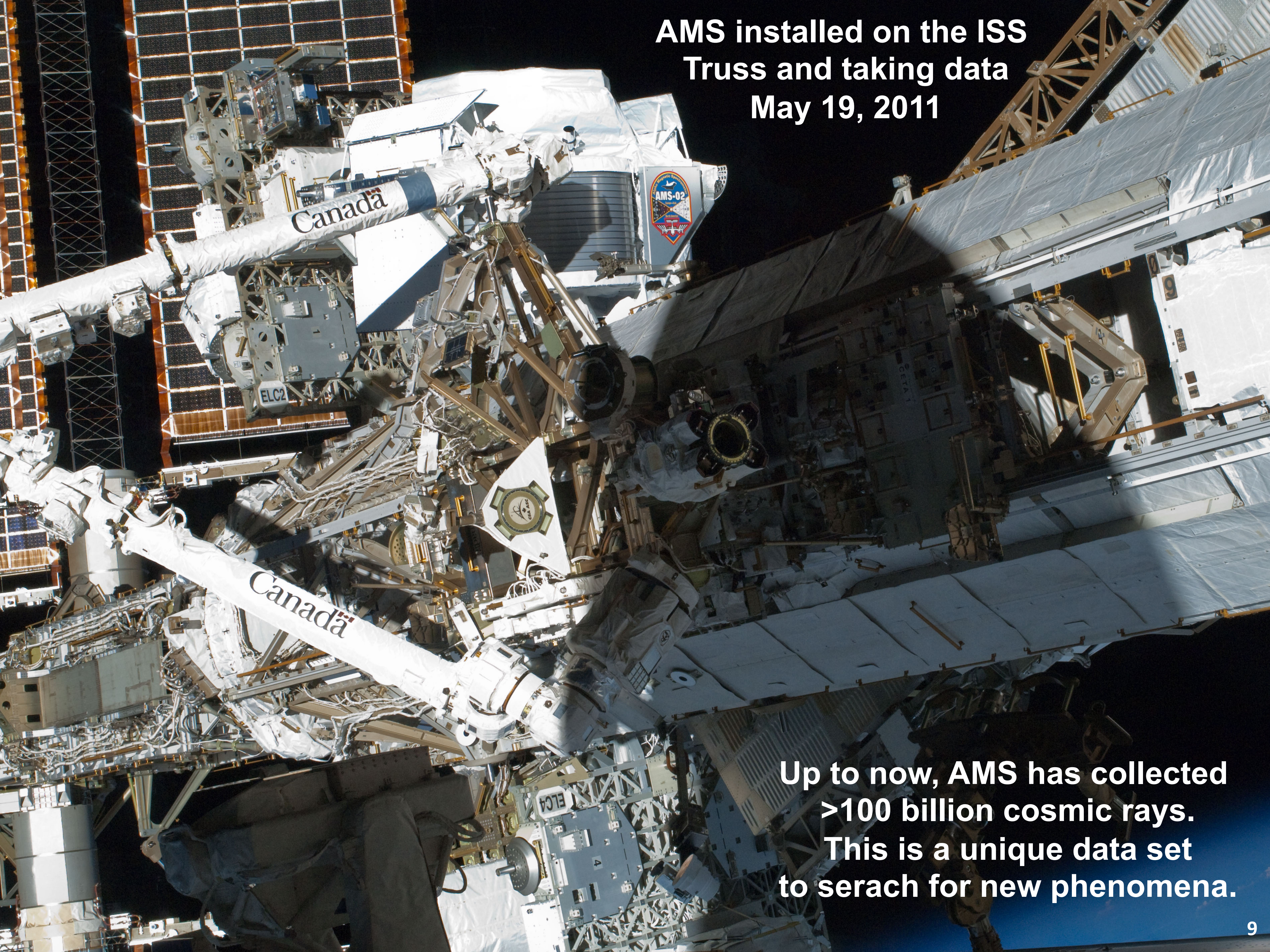


RICH

Z, E

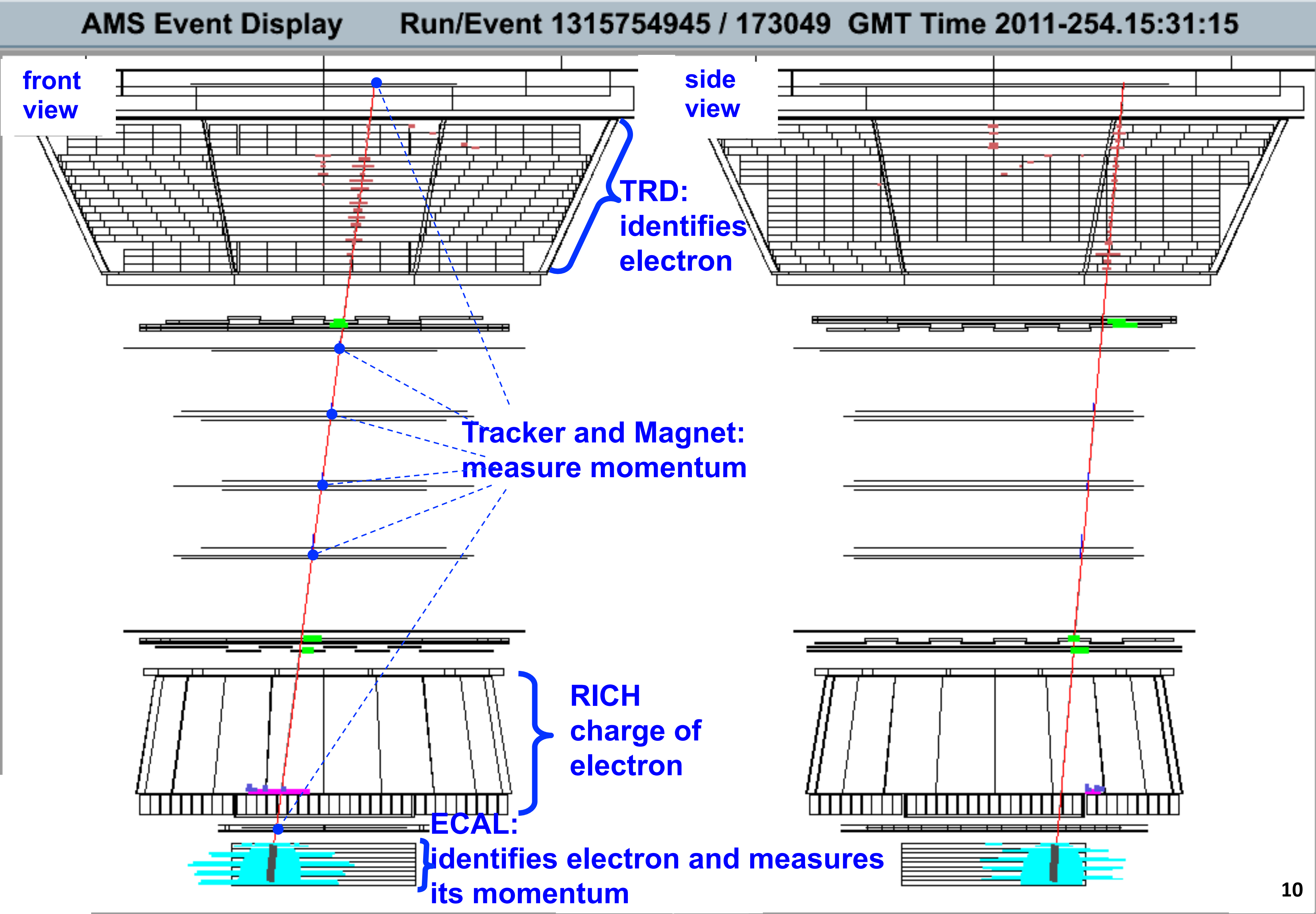


AMS installed on the ISS Truss and taking data May 19, 2011



Up to now, AMS has collected >100 billion cosmic rays.
This is a unique data set to serach for new phenomena.

1.03 TeV electron



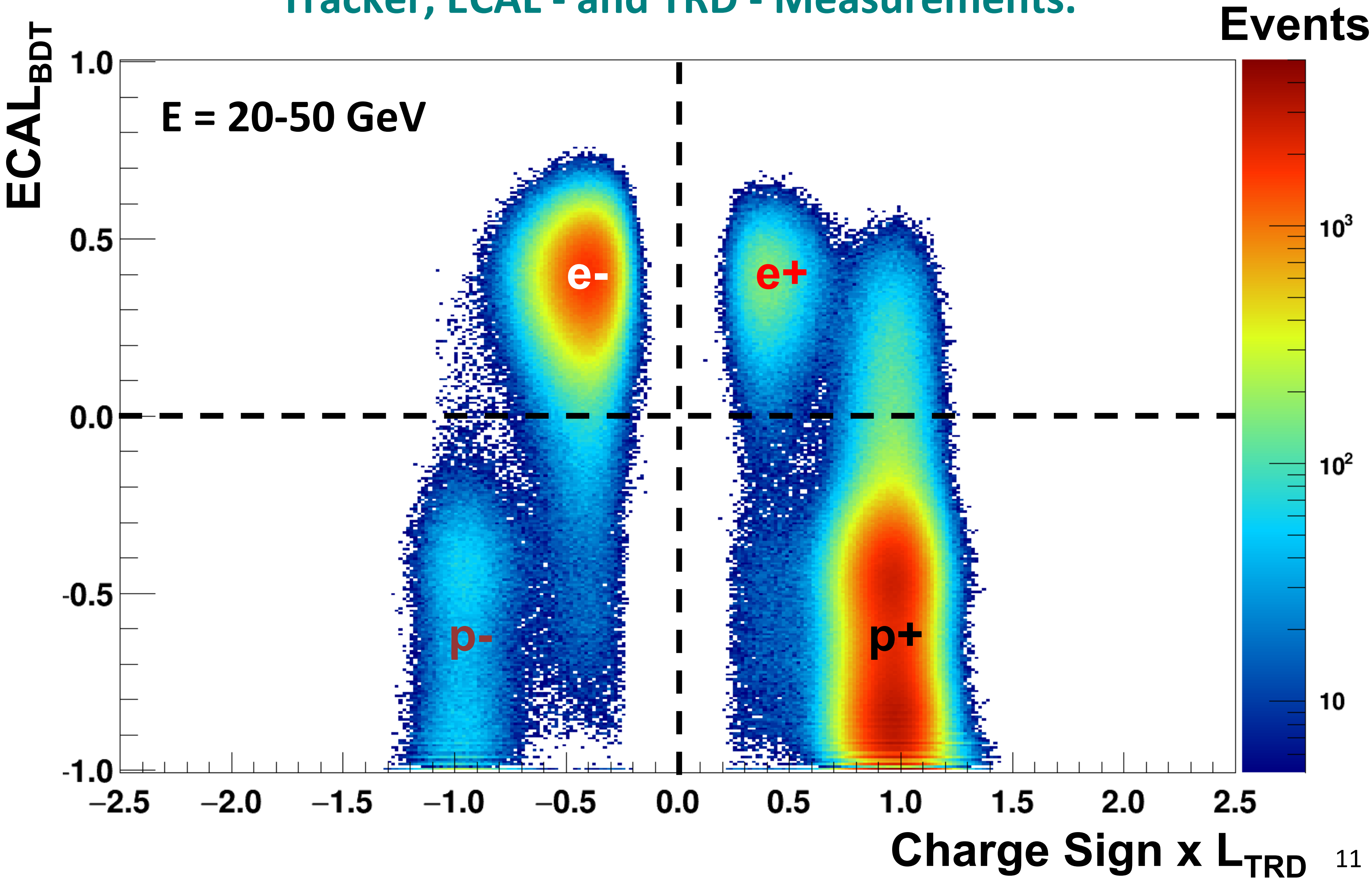
TRD: identifies electron

Tracker and Magnet: measure momentum

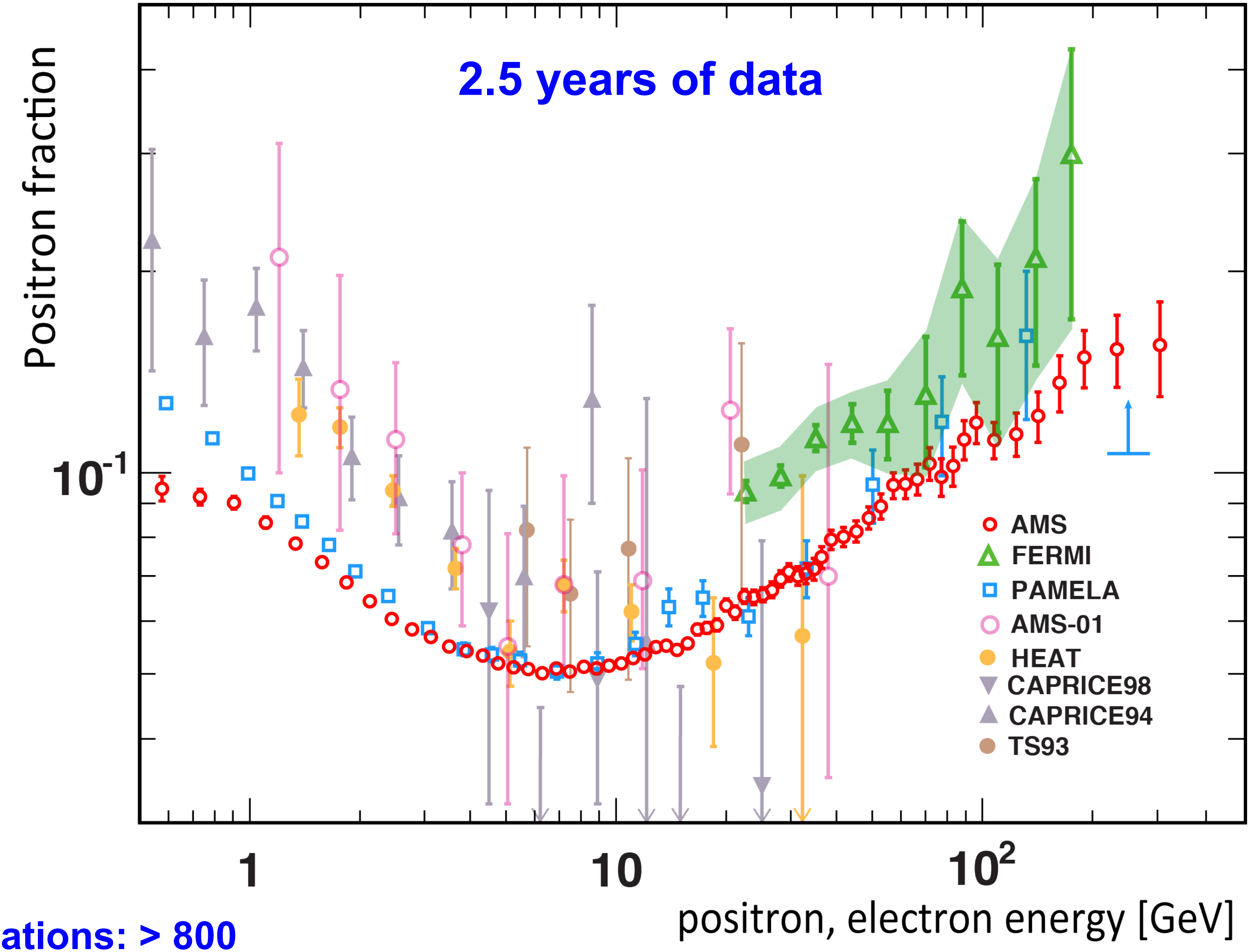
RICH charge of electron

ECAL: identifies electron and measures its momentum

Due to its magnetic spectrometer AMS can accurately identify four components combining the Tracker, ECAL - and TRD - Measurements.

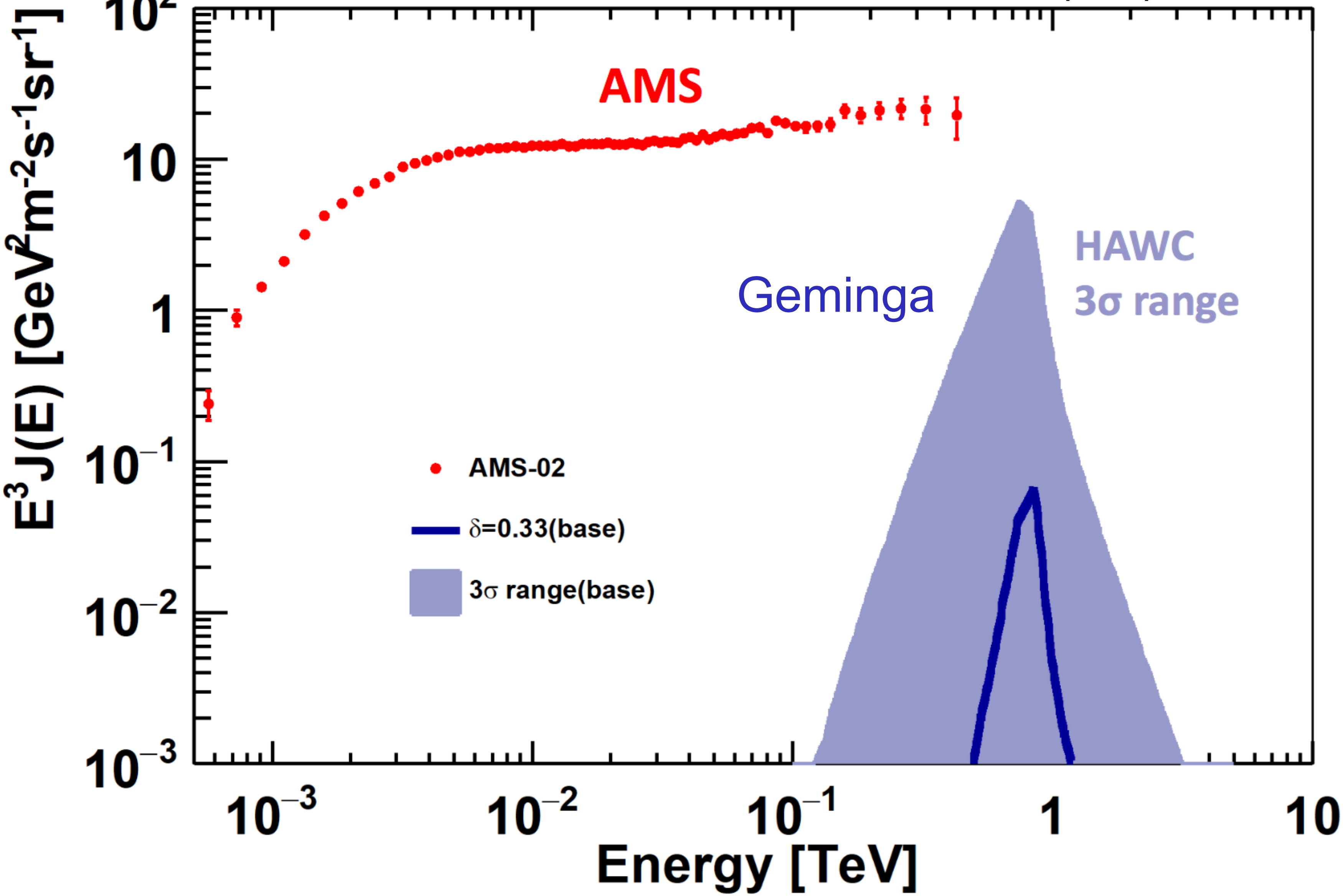


PRL **113,** 121101 (2014) PHYSICAL REVIEW LETTERS week ending 19 SEPTEMBER 2014



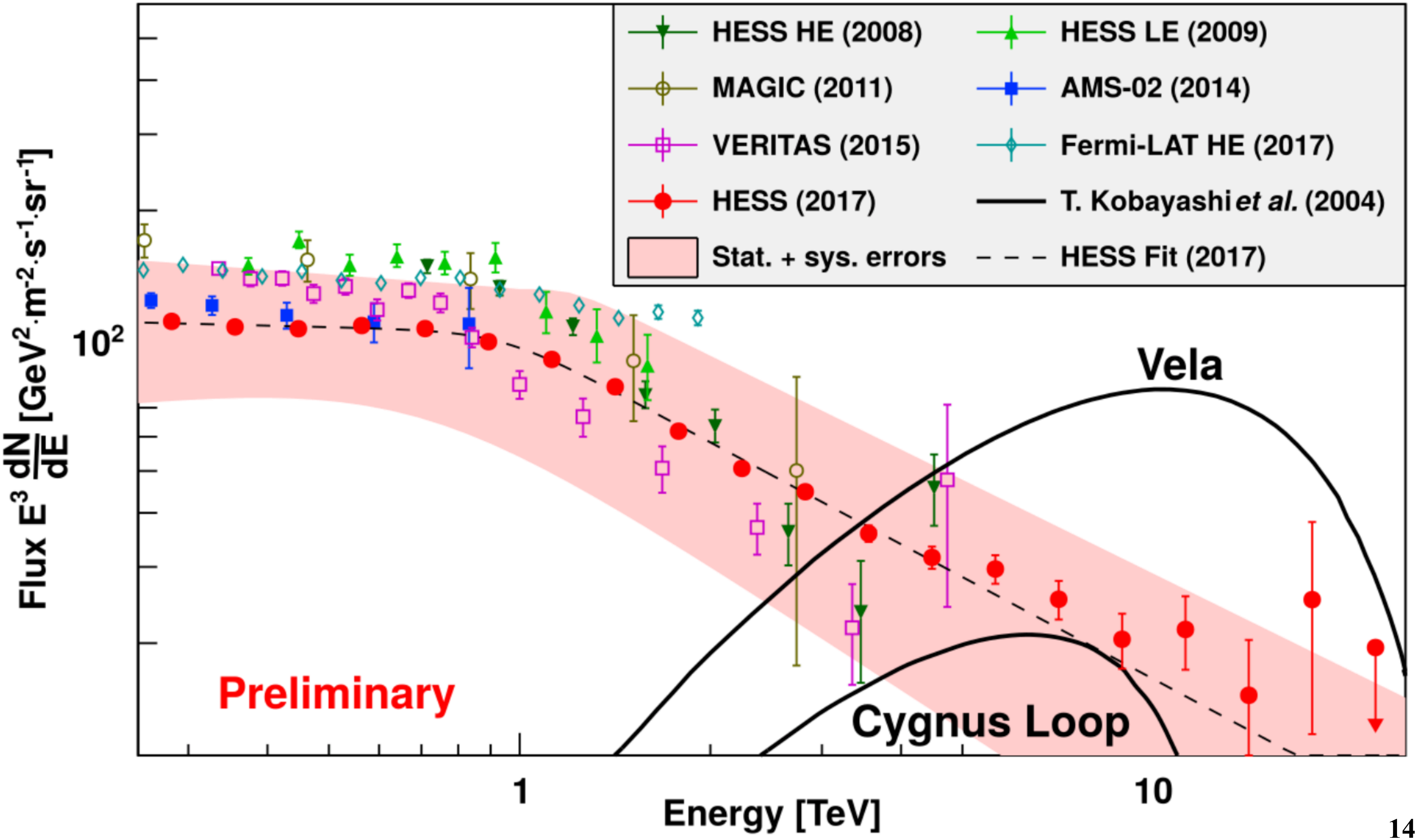
Citations: > 800

„We demonstrate that the leptons emitted by these objects are therefore unlikely to be the origin of the excess positrons, which may have a more exotic origin.“

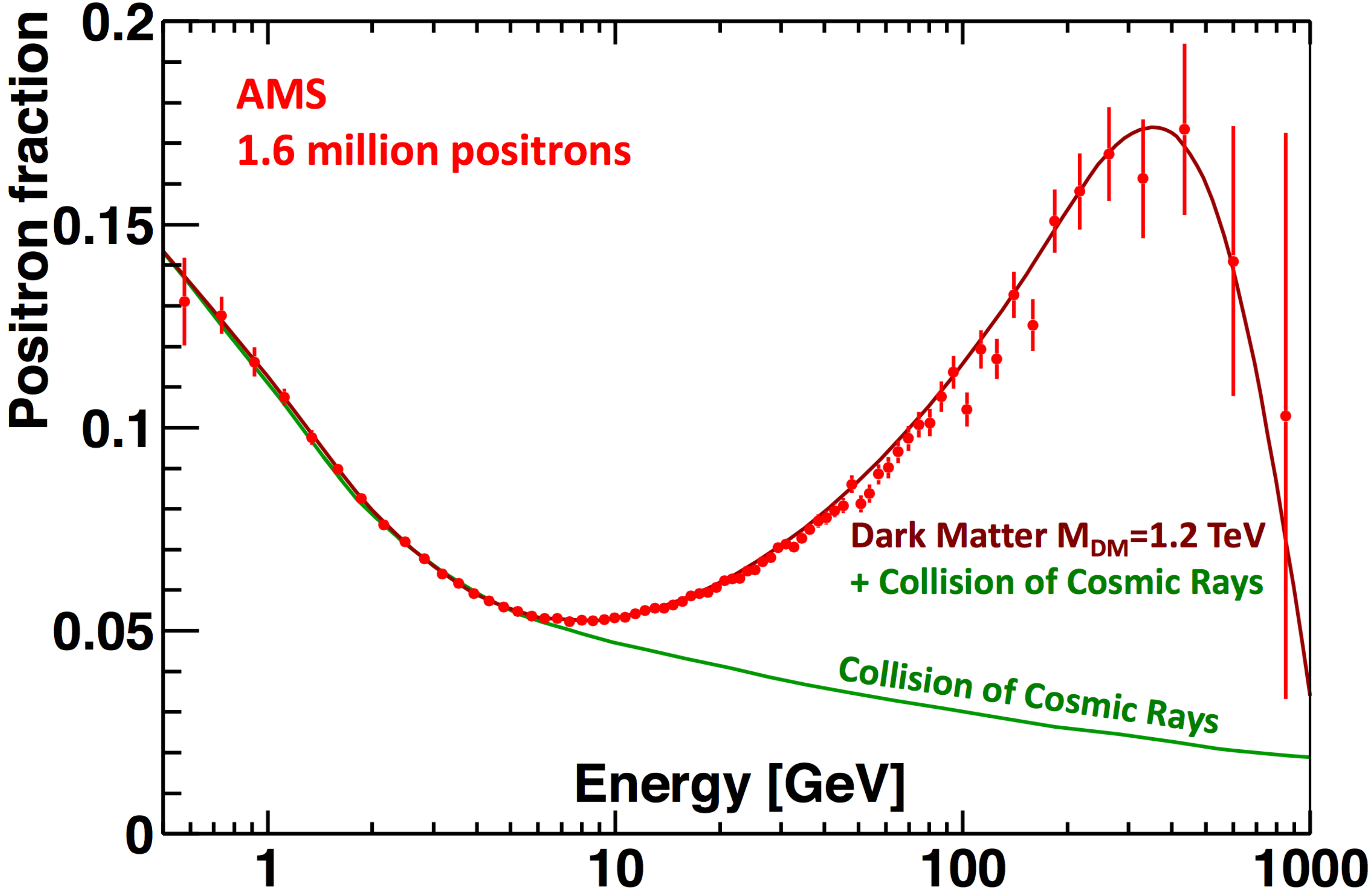

HAWC Collaboration, *Science* 358, 911-914 (2017)

Combined ($e^+ + e^-$) Spectrum

https://www.mpi-hd.mpg.de/hfm/HESS/pages/home/som/2017/09/

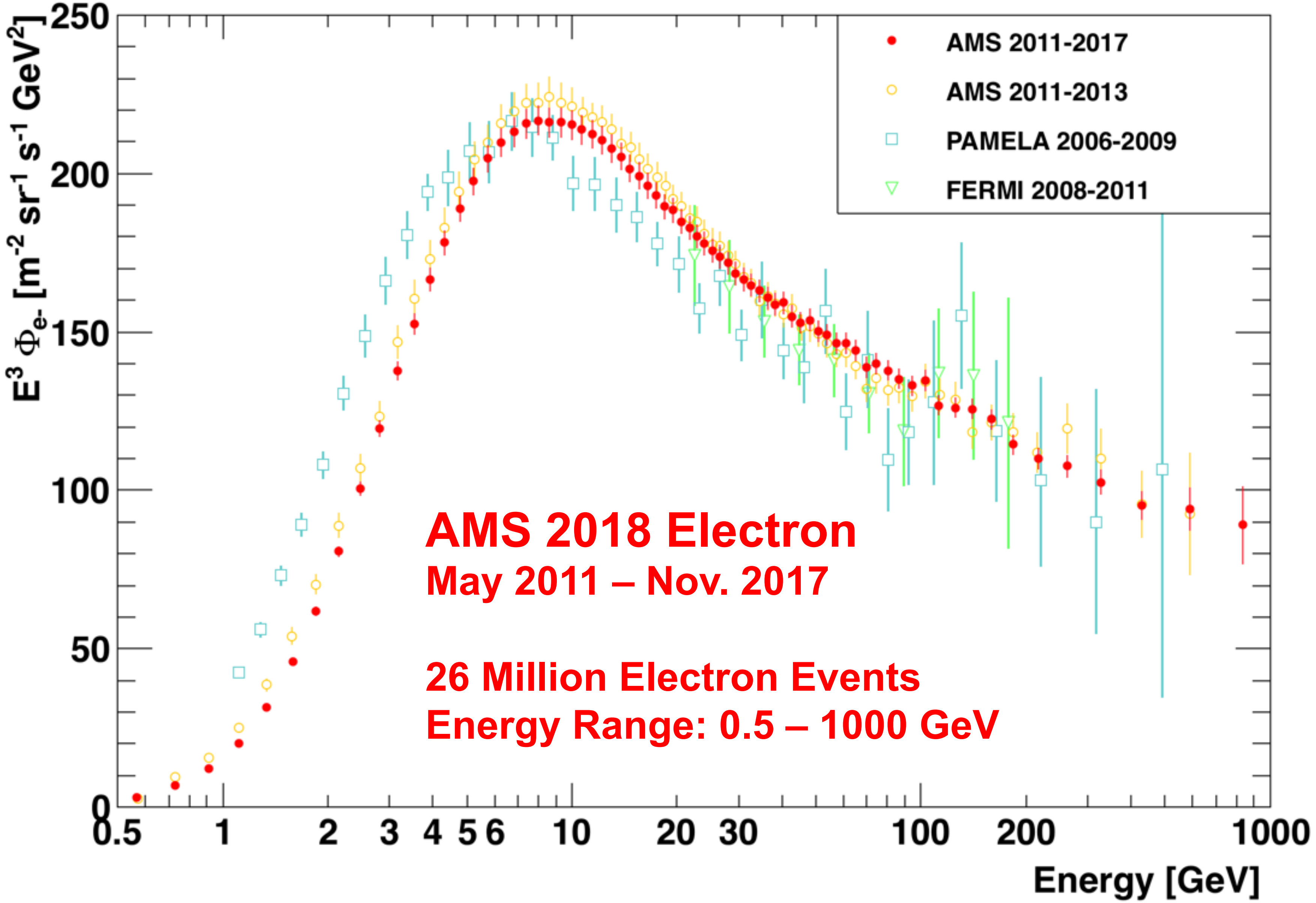


AMS results on the Positron Fraction



Dark Matter model is based on J. Kopp, Phys. Rev. D 88, 076013 (2013).

Recent Electron Flux Measurements

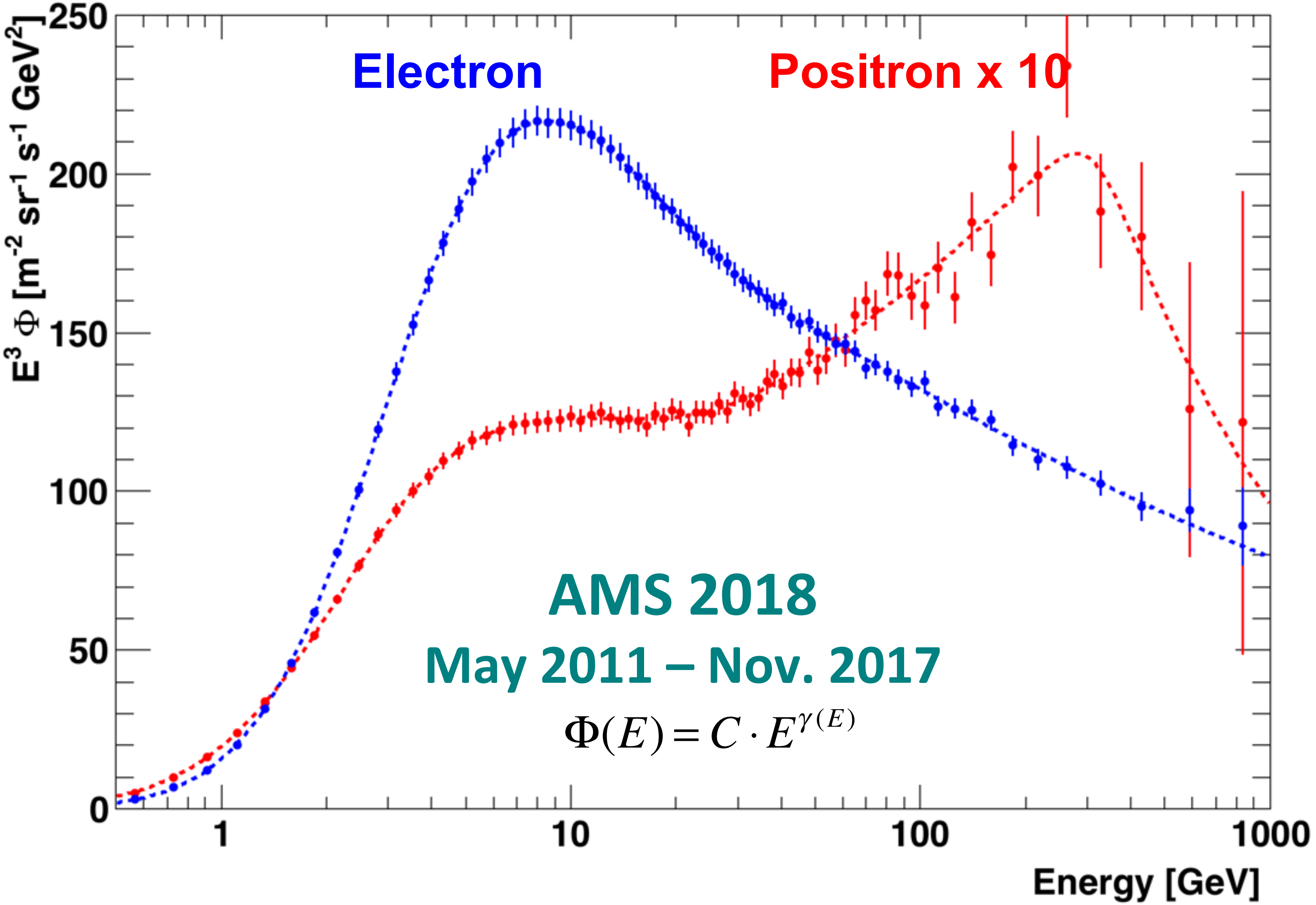


AMS 2018 Electron
May 2011 – Nov. 2017

26 Million Electron Events
Energy Range: 0.5 – 1000 GeV

AMS Measurements of the Electron and Positron spectra

The data are well described by a combination of smoothly broken power laws.

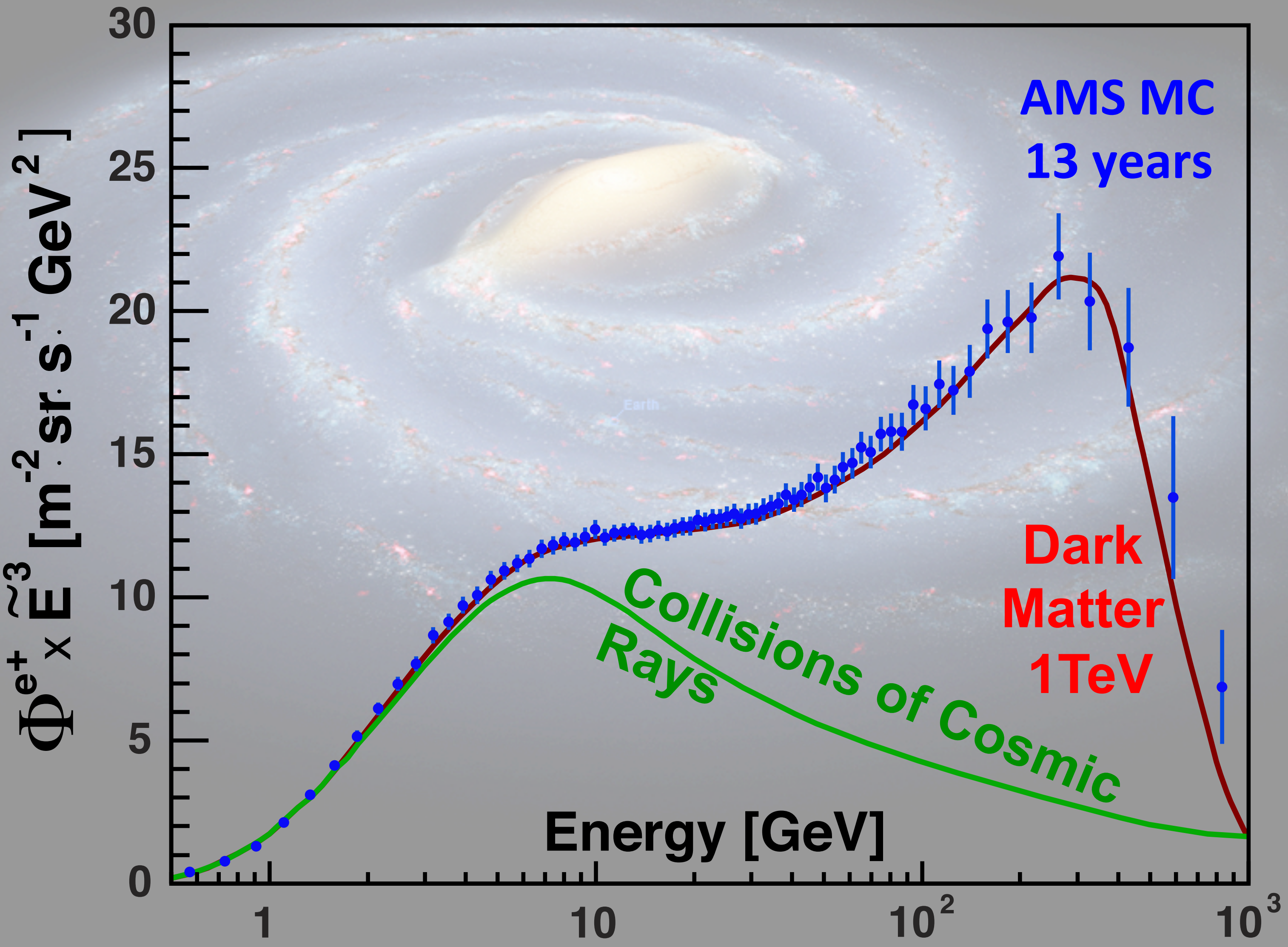


AMS 2018

May 2011 – Nov. 2017

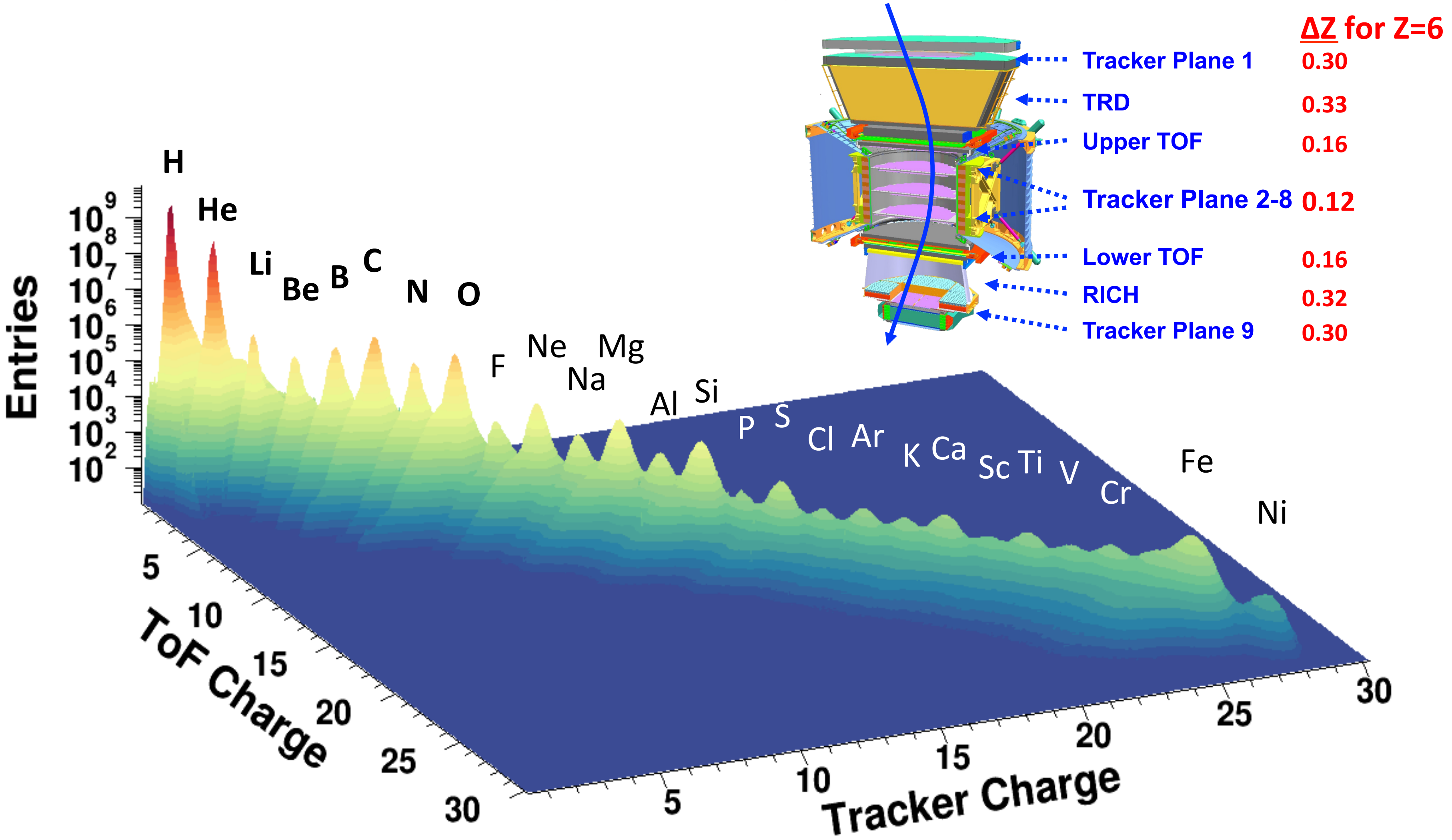
$$\Phi(E) = C \cdot E^{\gamma(E)}$$

2024: Extend measurement to 1 TeV



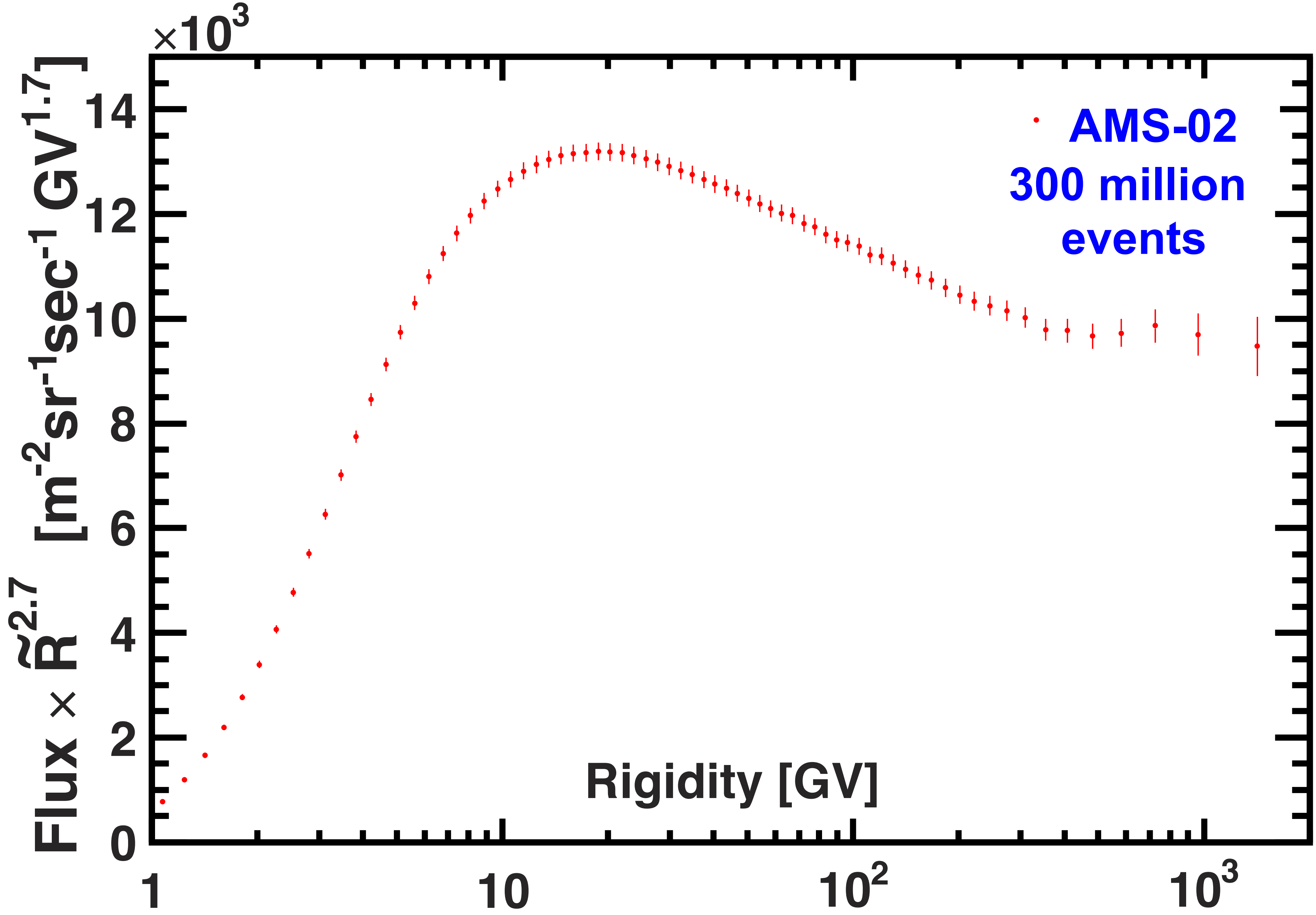
Cosmic Nuclei

AMS has seven instruments which independently identify different elements

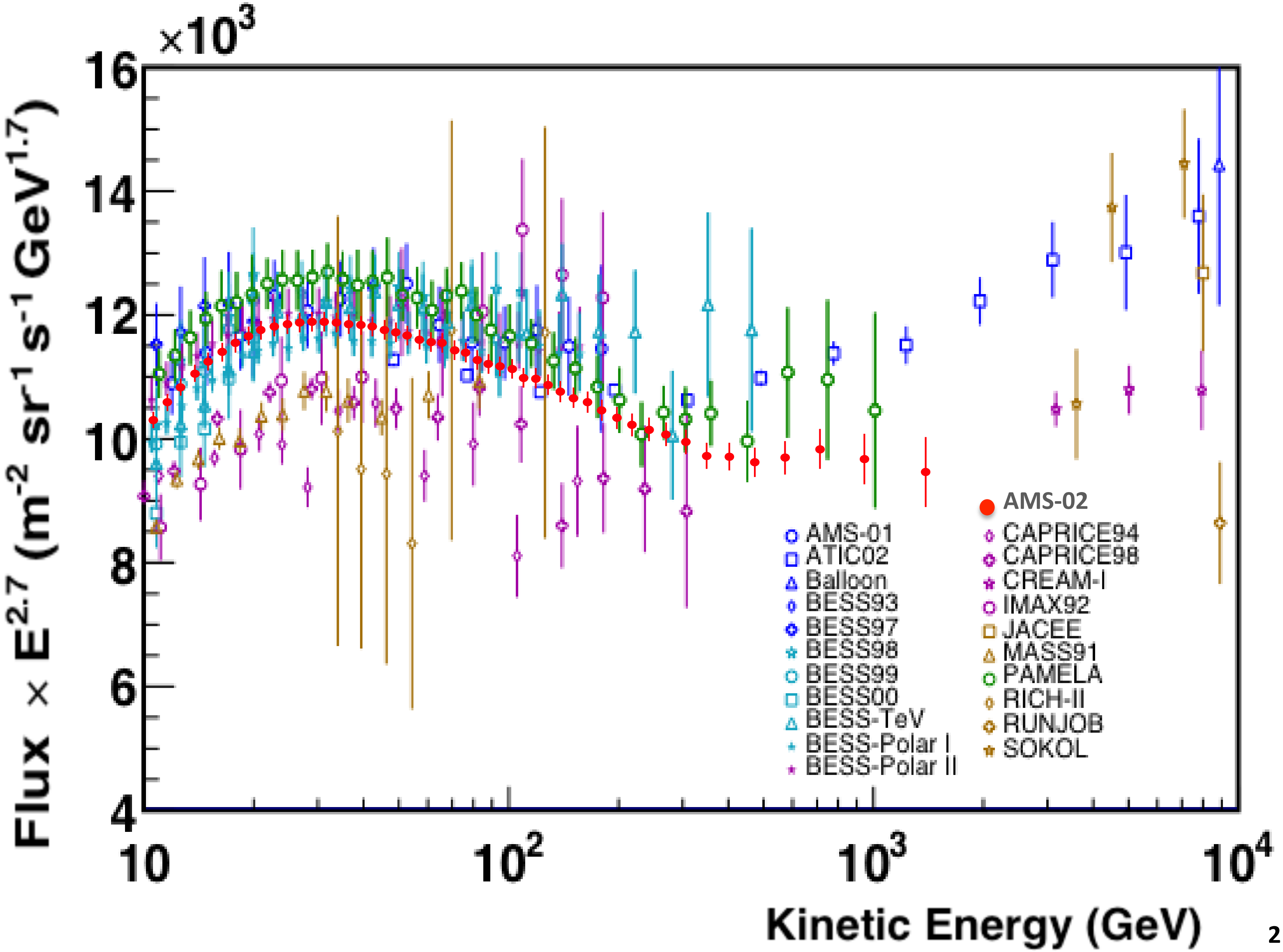


	ΔZ for Z=6
Tracker Plane 1	0.30
TRD	0.33
Upper TOF	0.16
Tracker Plane 2-8	0.12
Lower TOF	0.16
RICH	0.32
Tracker Plane 9	0.30

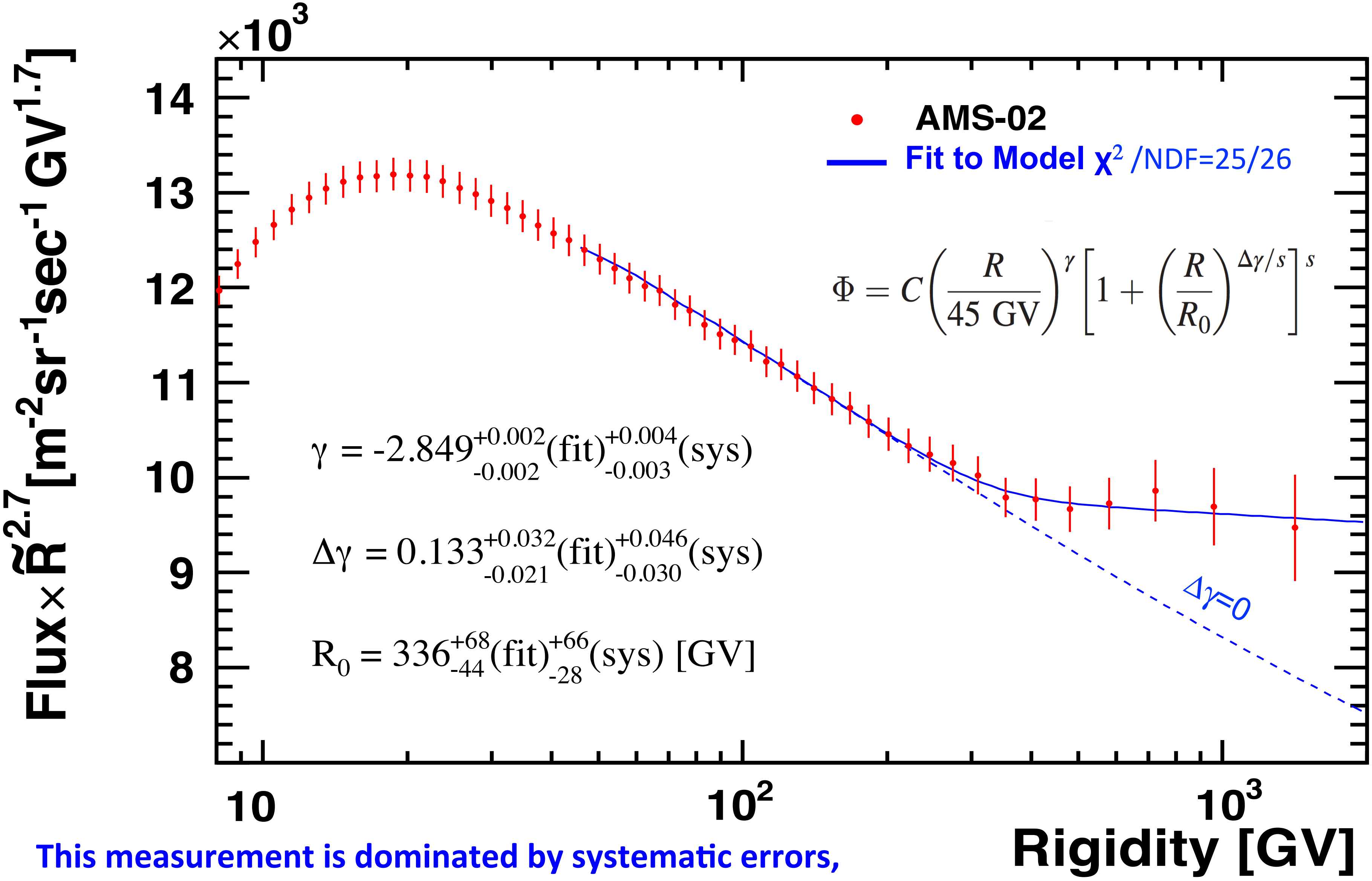
AMS Proton Flux, accuracy 1%



M. Aguilar *et al.*, Phys. Rev. Lett. **114**, 171103 (2015)


×10^3
16
14
12
10
8
6
4
Flux × E^2.7 (m^-2 sr^-1 s^-1 GeV^1.7)
10
10^2
10^3
10^4
Kinetic Energy (GeV)
AMS-02
AMS-01
ATIC02
Balloon
BESS93
BESS97
BESS98
BESS99
BESS00
BESS-TeV
BESS-Polar I
BESS-Polar II
CAPRICE94
CAPRICE98
CREAM-I
IMAX92
JACEE
MASS91
PAMELA
RICH-II
RUNJOB
SOKOL

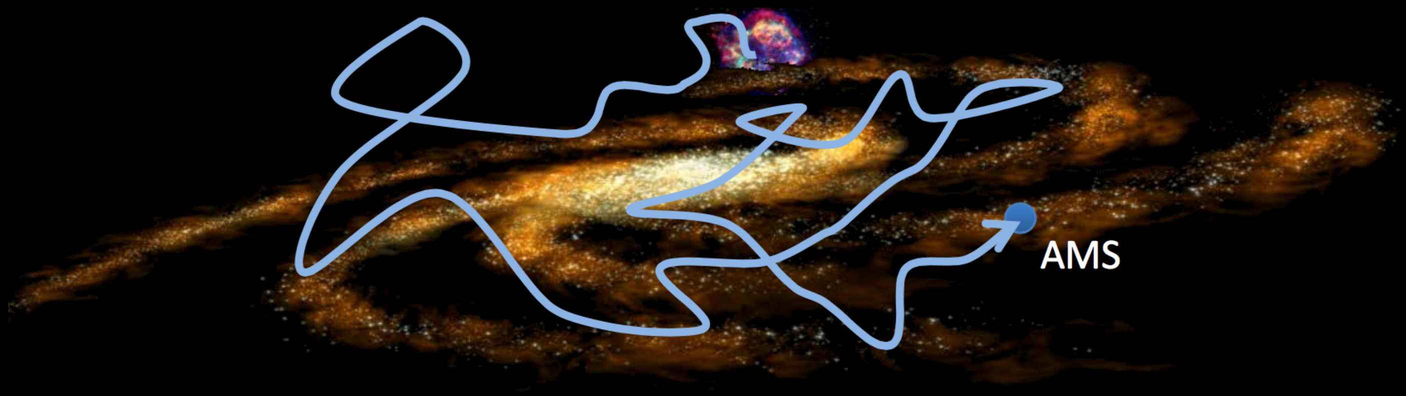
It was expected that the proton flux could be described with a single power law with spectral index γ=-2.7.



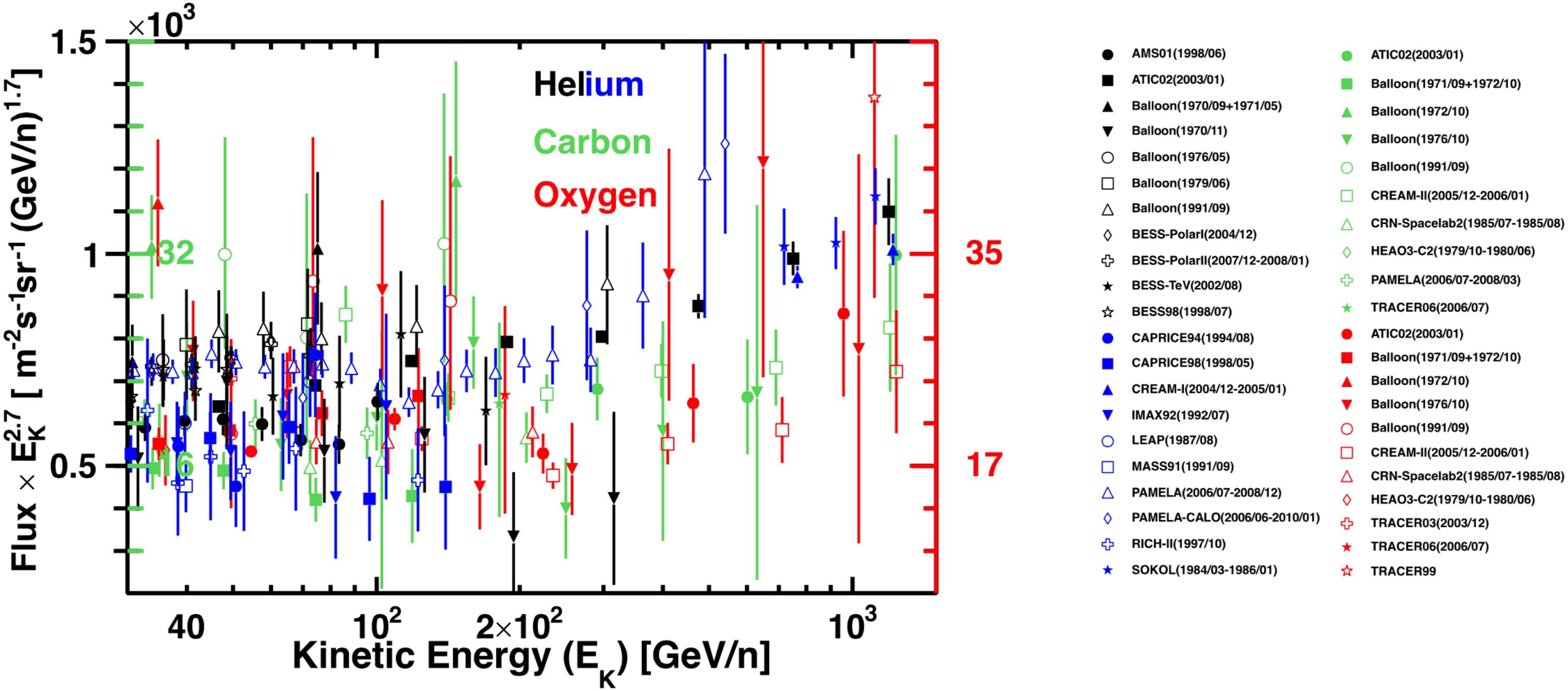
This measurement is dominated by systematic errors, we will therefore not be able to improve it.

Traditionally, there are two prominent classes of cosmic rays:

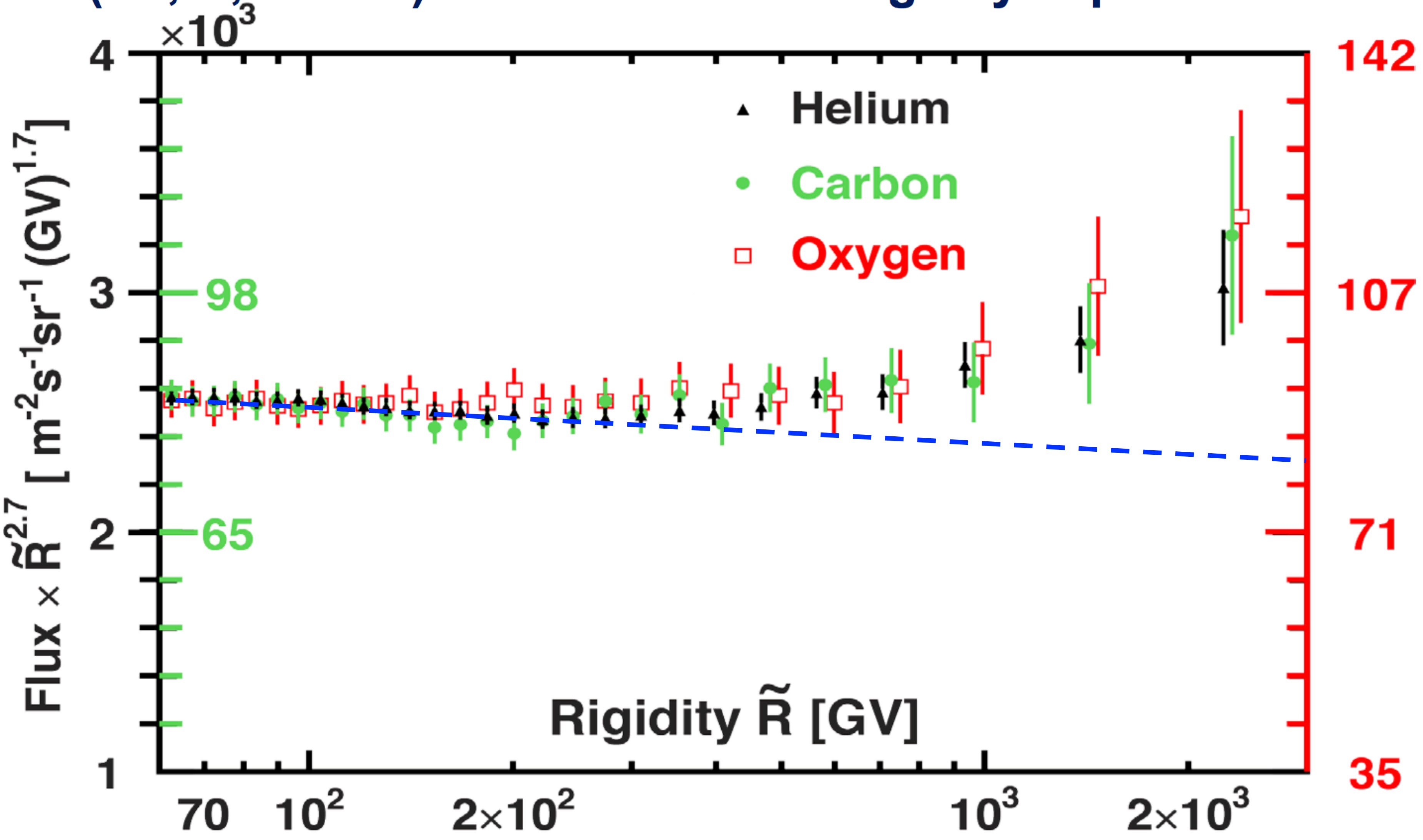
Primary Cosmic Rays (p, He, C, O, …)
are produced at their source and travel through space and are directly detected by AMS. They carry information on their sources and the history of travel.



Before AMS: results on Primary Cosmic Rays (Helium, Carbon, Oxygen) from balloon and satellite experiments

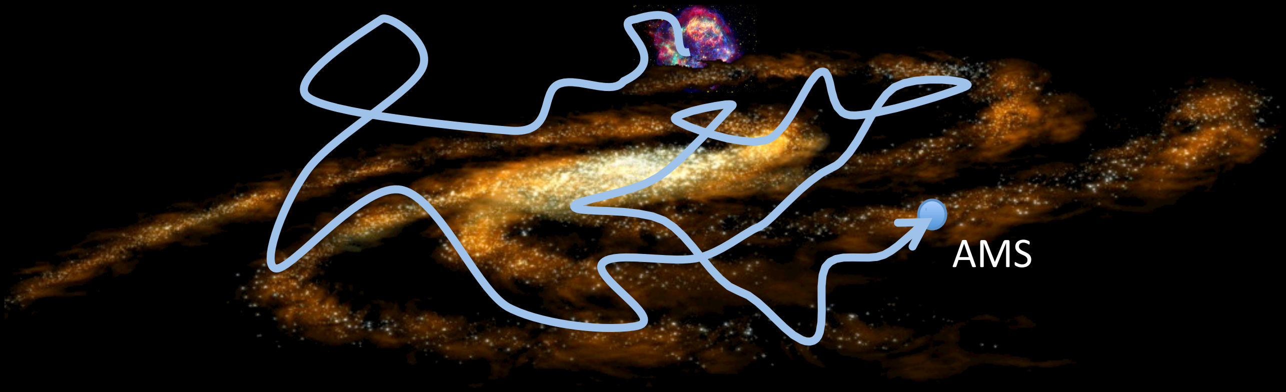


The AMS results show that the primary cosmic rays (He, C, and O) have an identical rigidity dependence.

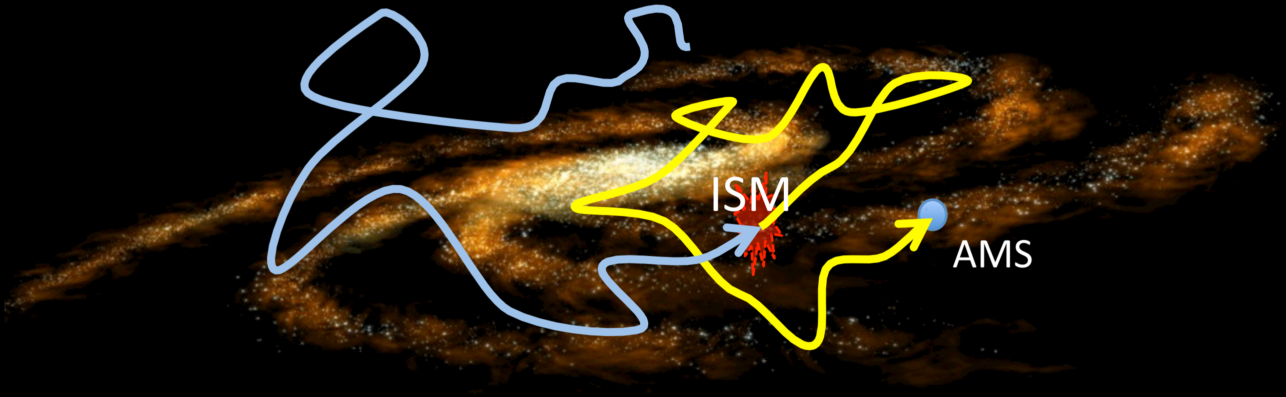


Above 200 GV the data all increase in identical way.

Primary Cosmic Rays (p, He, C, O, …)

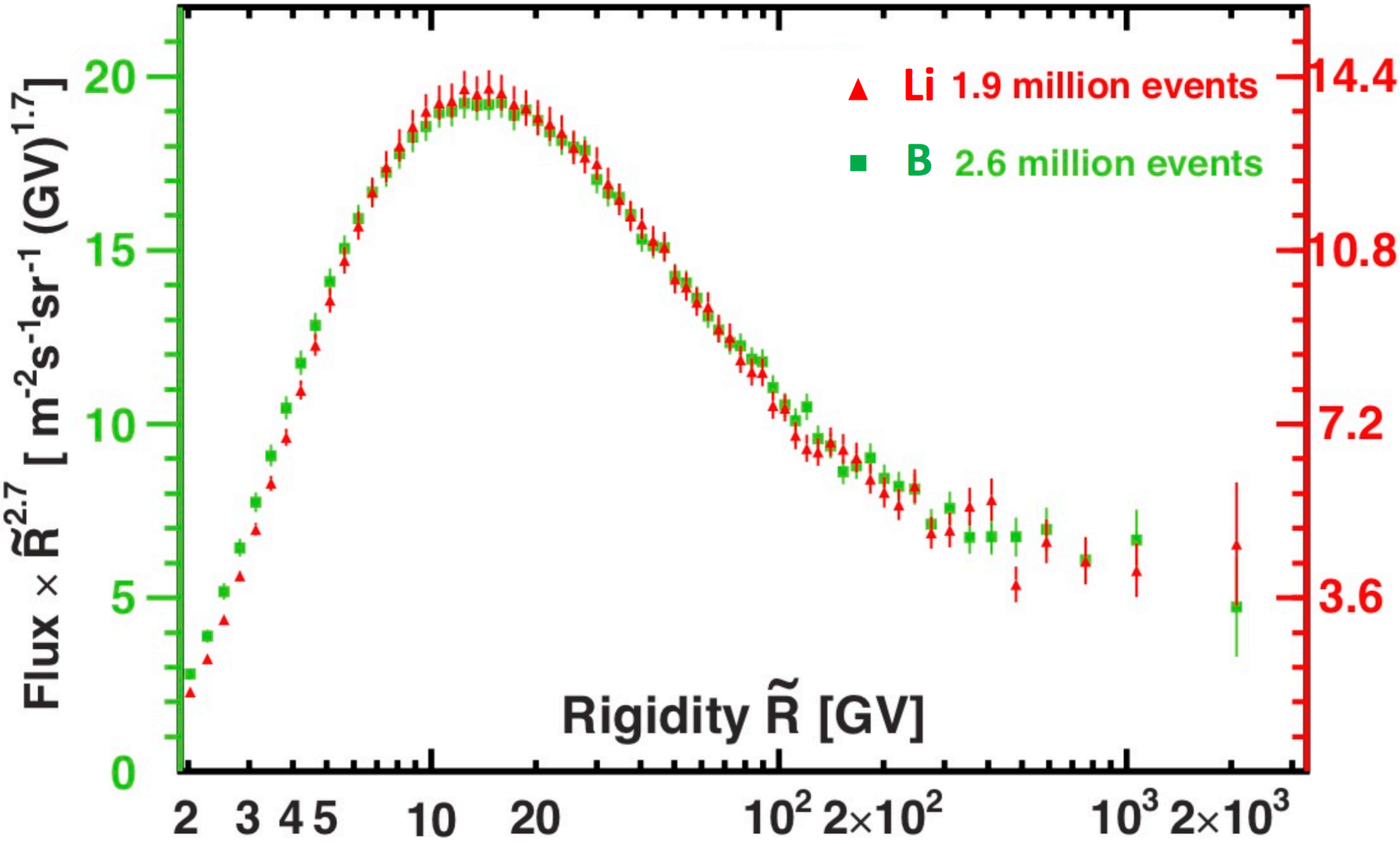


Secondary Cosmic Rays (Li, Be, B, …)



Secondary Cosmic Rays: Lithium and Boron

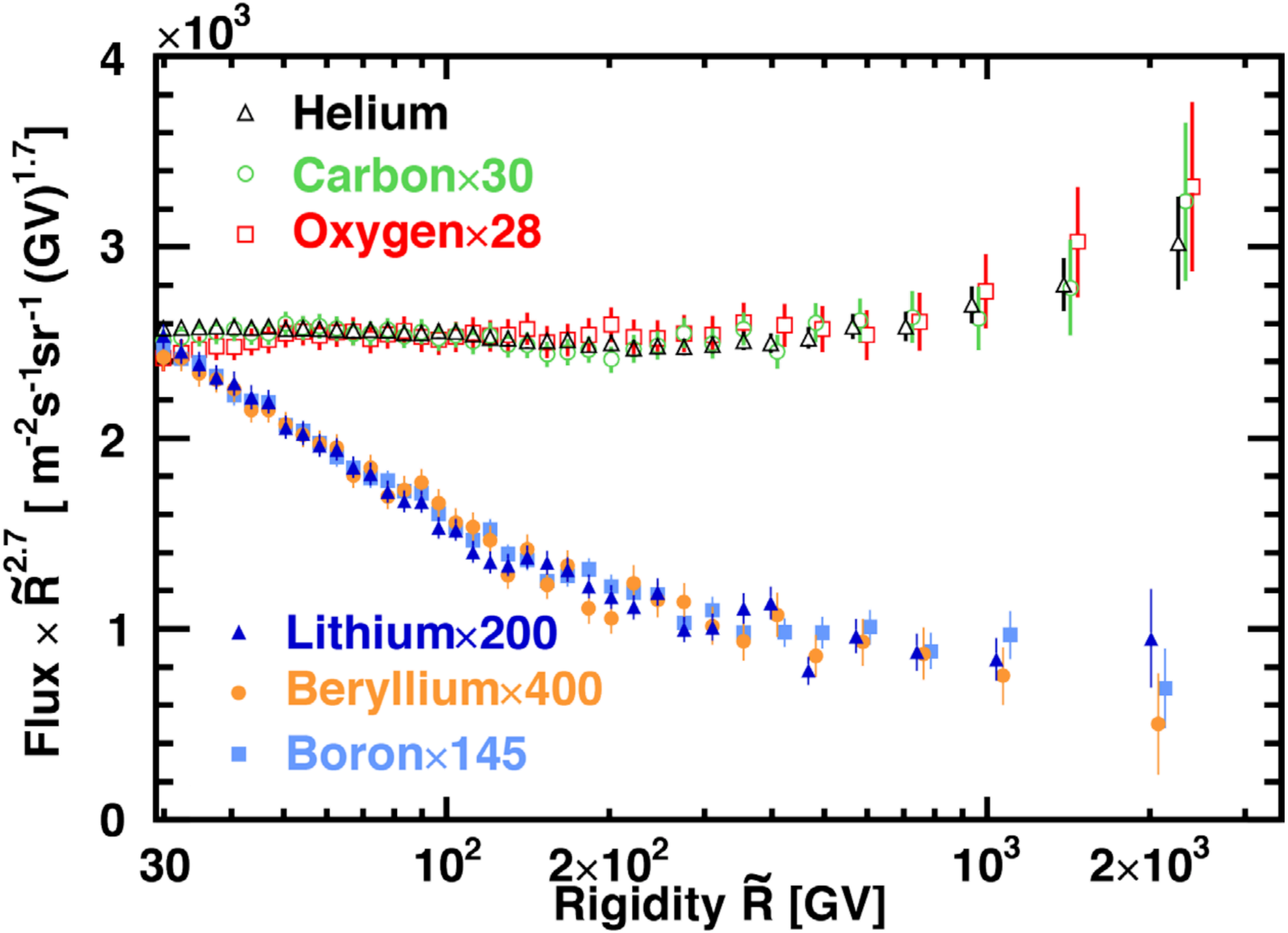
Above 7 GV Li and B have identical rigidity dependence



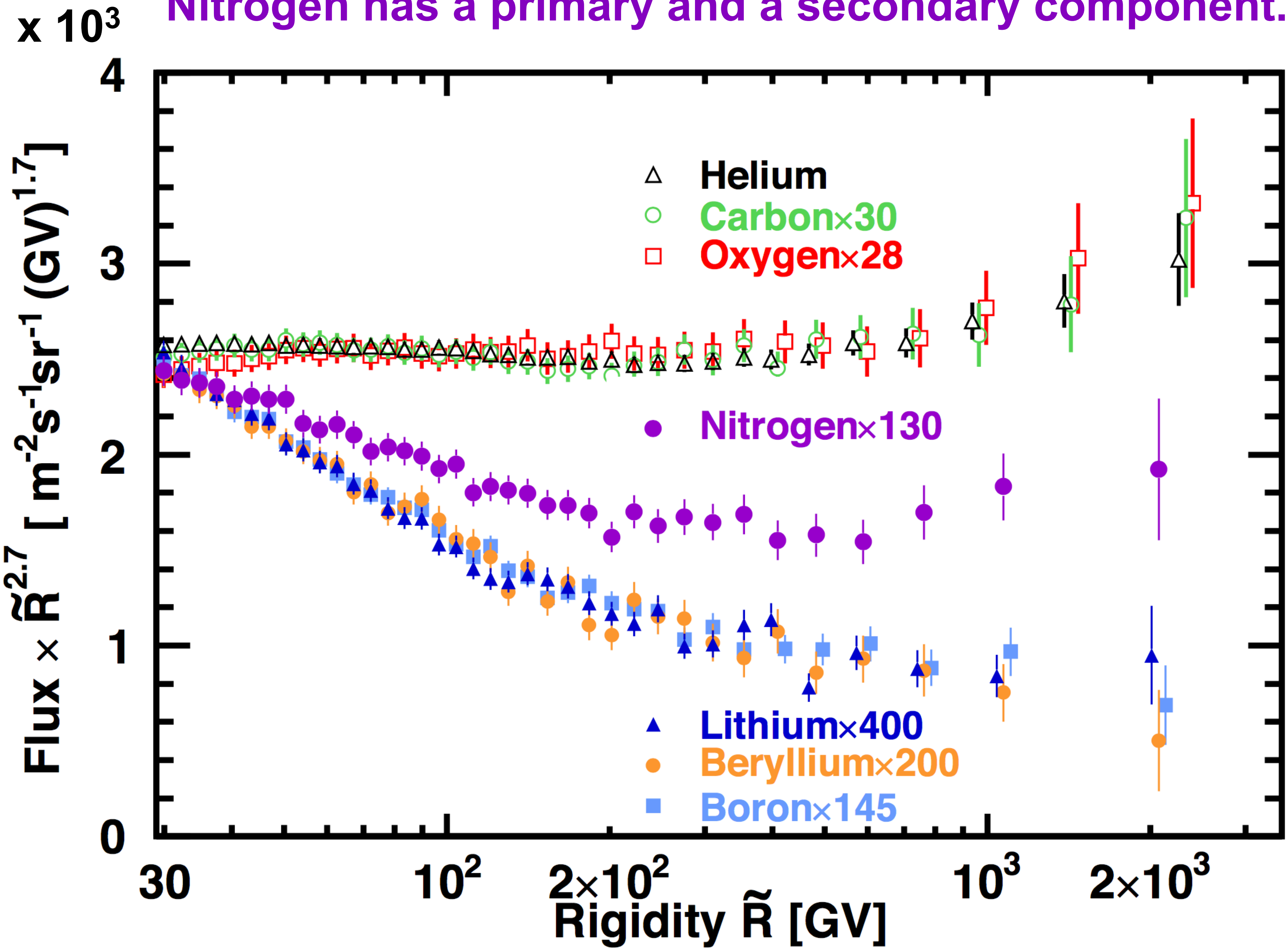
Rigidity dependence of Primary and Secondary Cosmic Rays

Both deviate from a traditional single power law above 200 GeV.

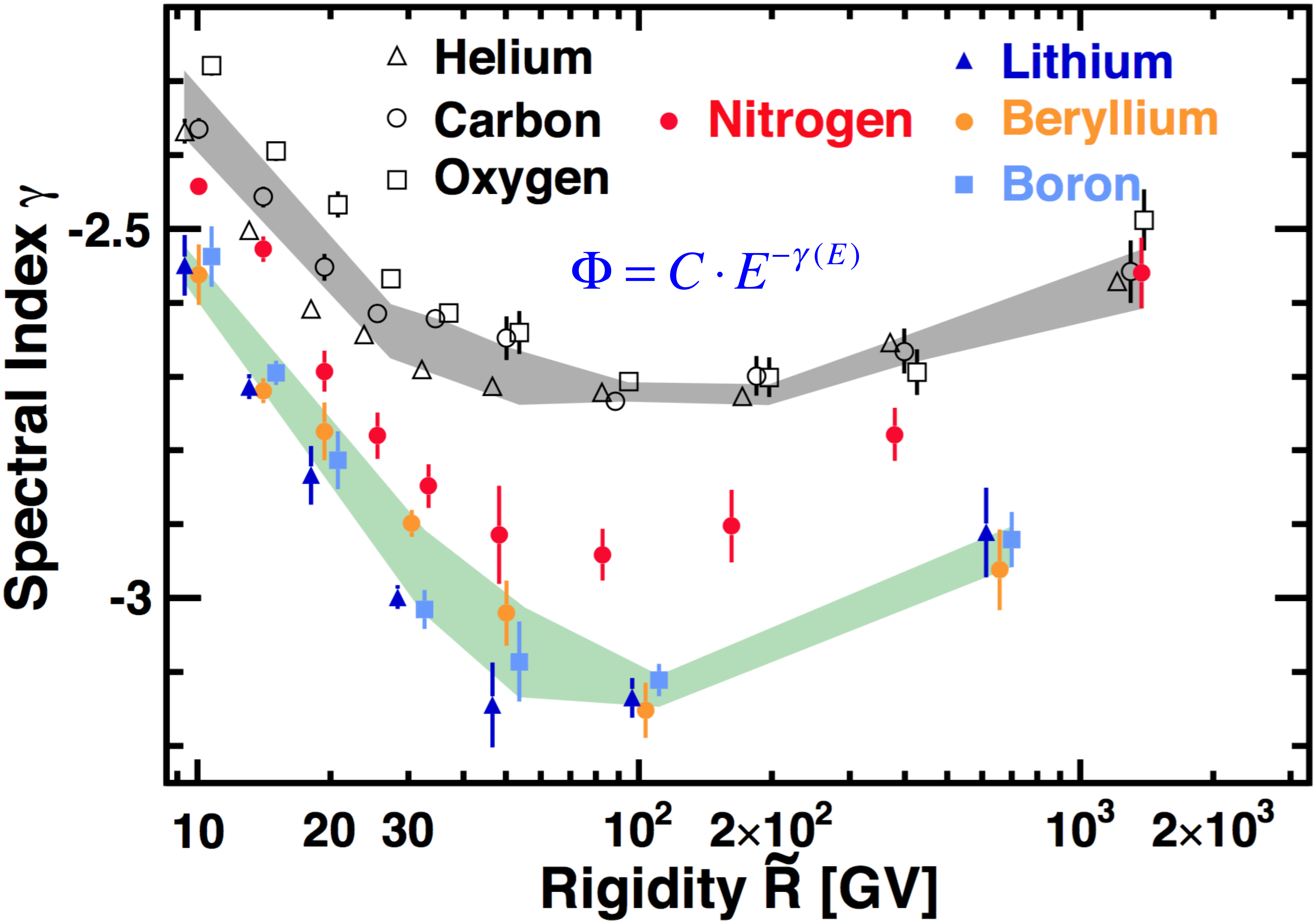
But their momentum dependences are distinctly different.



Nitrogen has a primary and a secondary component.



The hardening of the spectral index is stronger for the secondary particles.

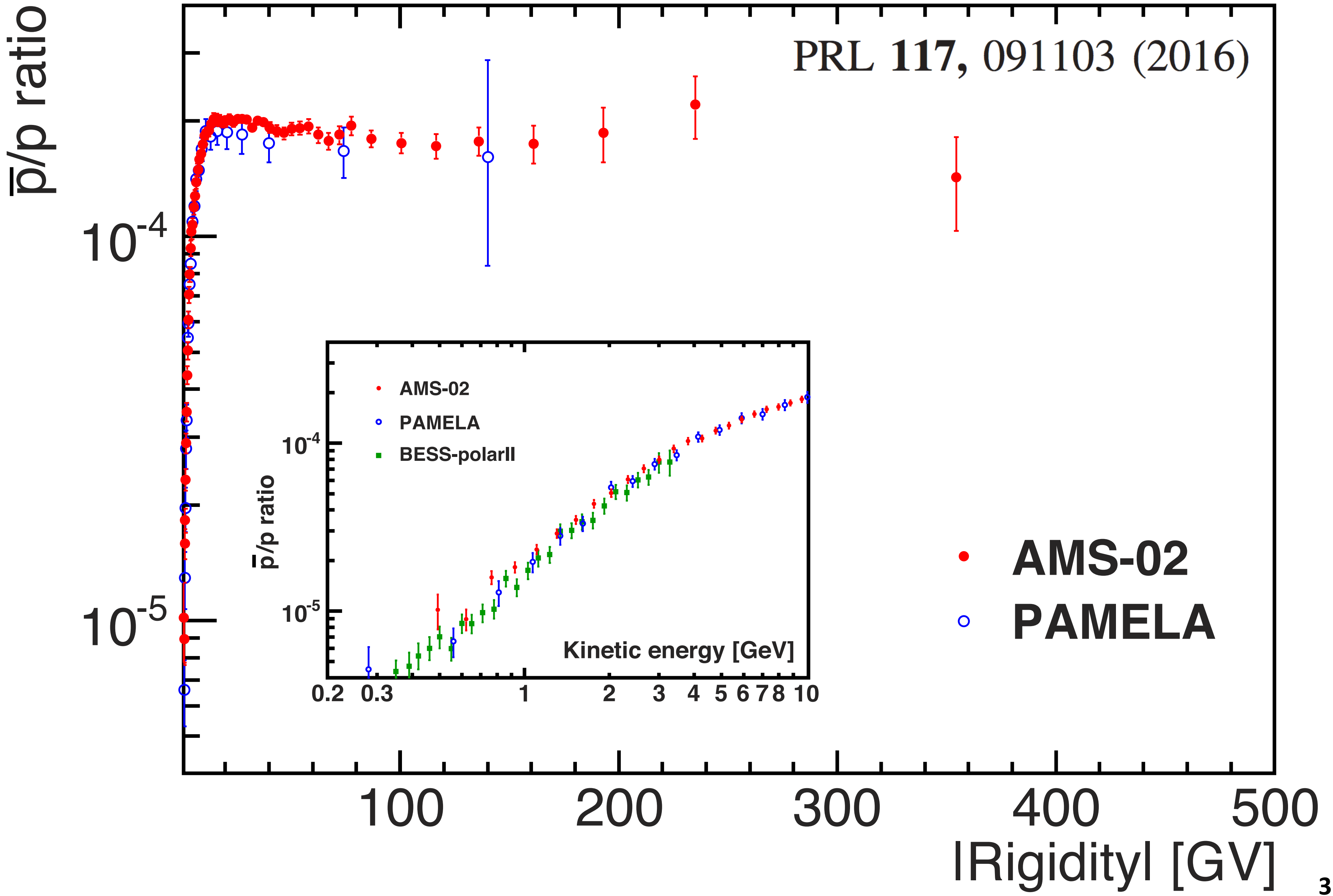


Measurement of Antiproton flux

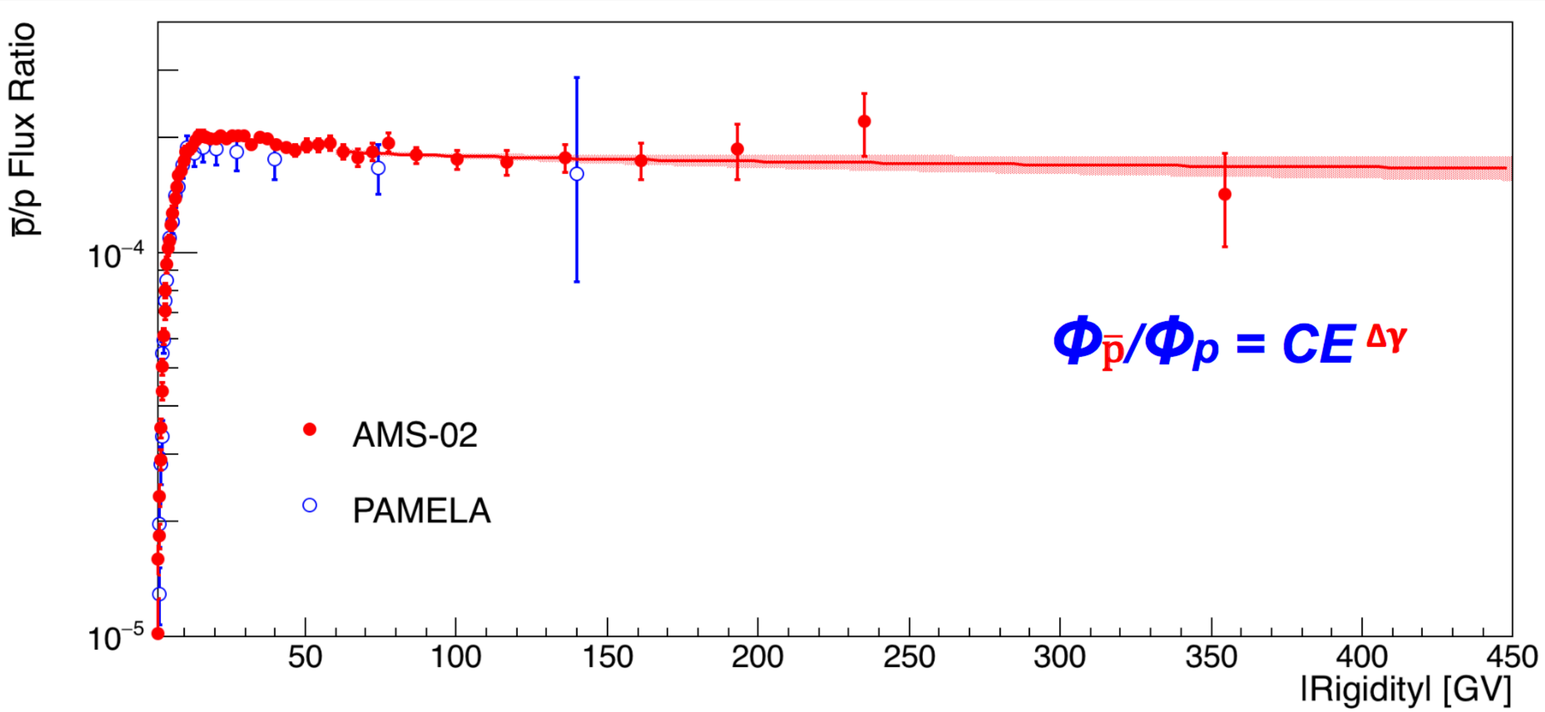
Physics importance

- Antiprotons : Only $\sim 10^{-4}$ of cosmic ray particles
- Produced by cosmic ray collisions
  e.g. $pN \rightarrow \bar{p}$...
- Probe of indirect Dark Matter detection
  e.g. $\chi\chi \rightarrow \bar{p}$...
  Complementary to $\chi\chi \rightarrow e^{+}$...

AMS results on the $\bar{p}/p$ flux ratio

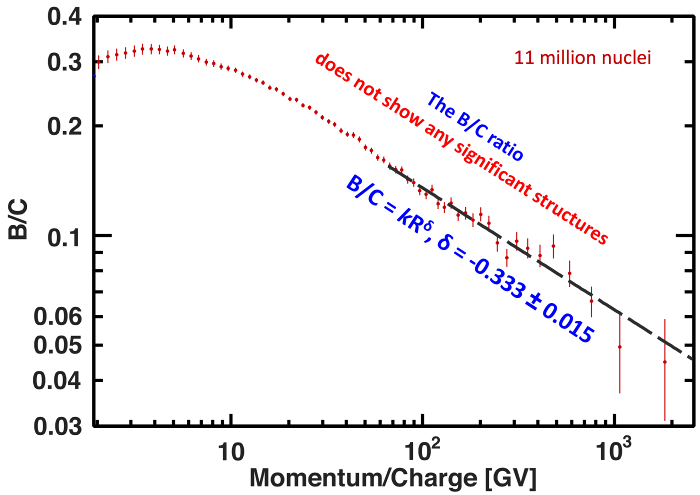


Antiproton-to-Proton flux ratio

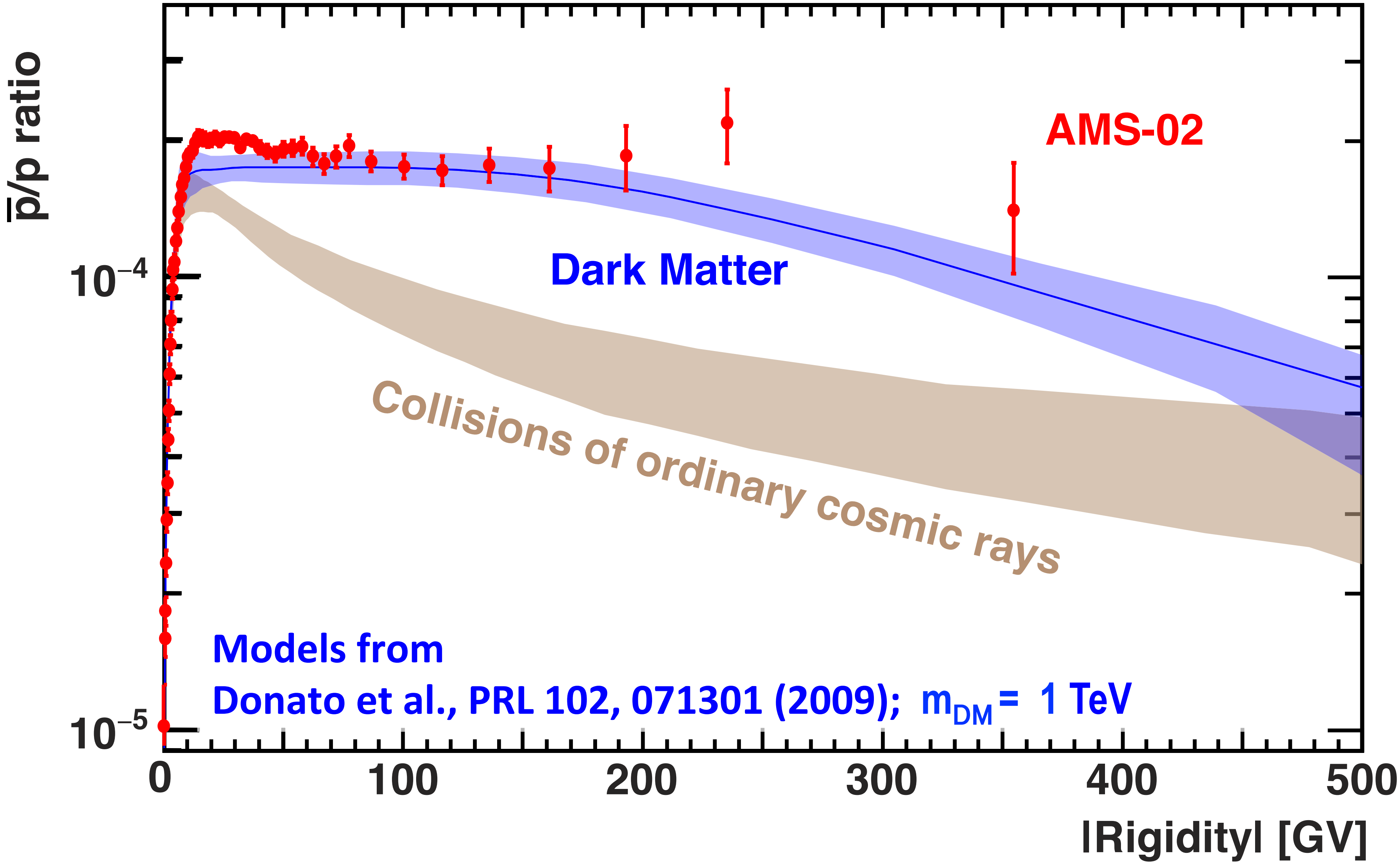


$$\Phi_{\bar{p}}/\Phi_{p} = CE^{\Delta\gamma}$$

- The AMS measurement of $\bar{p}/p$ flux ratios shows that starting from 60GeV, the flux ratio is surprisingly flat up to 450GV.
- Fit to a power law in the range [60,450] GV shows that the difference between the power law index of proton and antiproton is 0.05±0.06, consistent with 0.
- This is distinctly different than the flux ratio of secondary/primary nuclei. Traditional models predict a falling $\bar{p}/p$with power law index 0.2 - 0.3



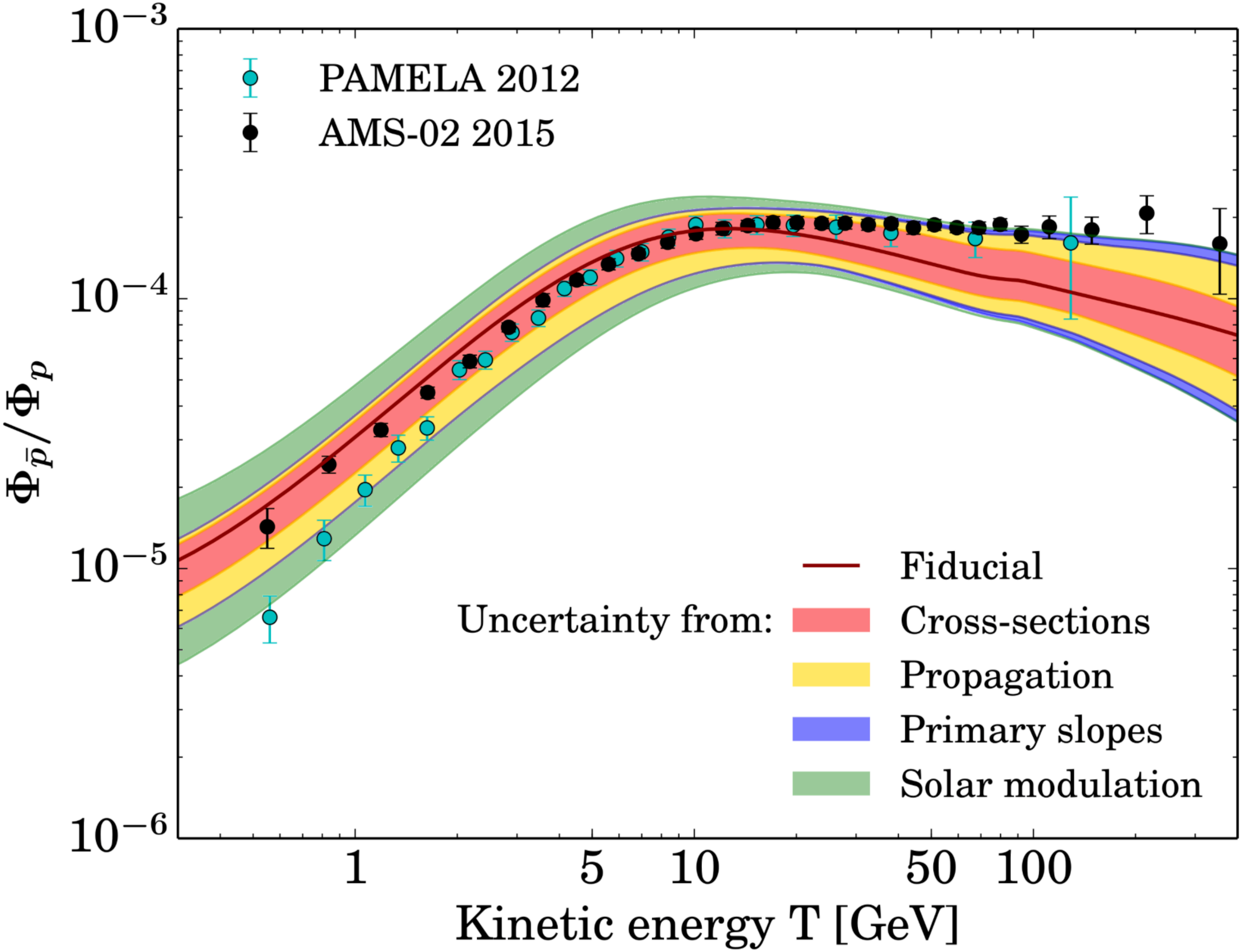
AMS $\bar{p}/p$ results and modeling



Models from

Donato et al., PRL 102, 071301 (2009); m_{DM} = 1 TeV

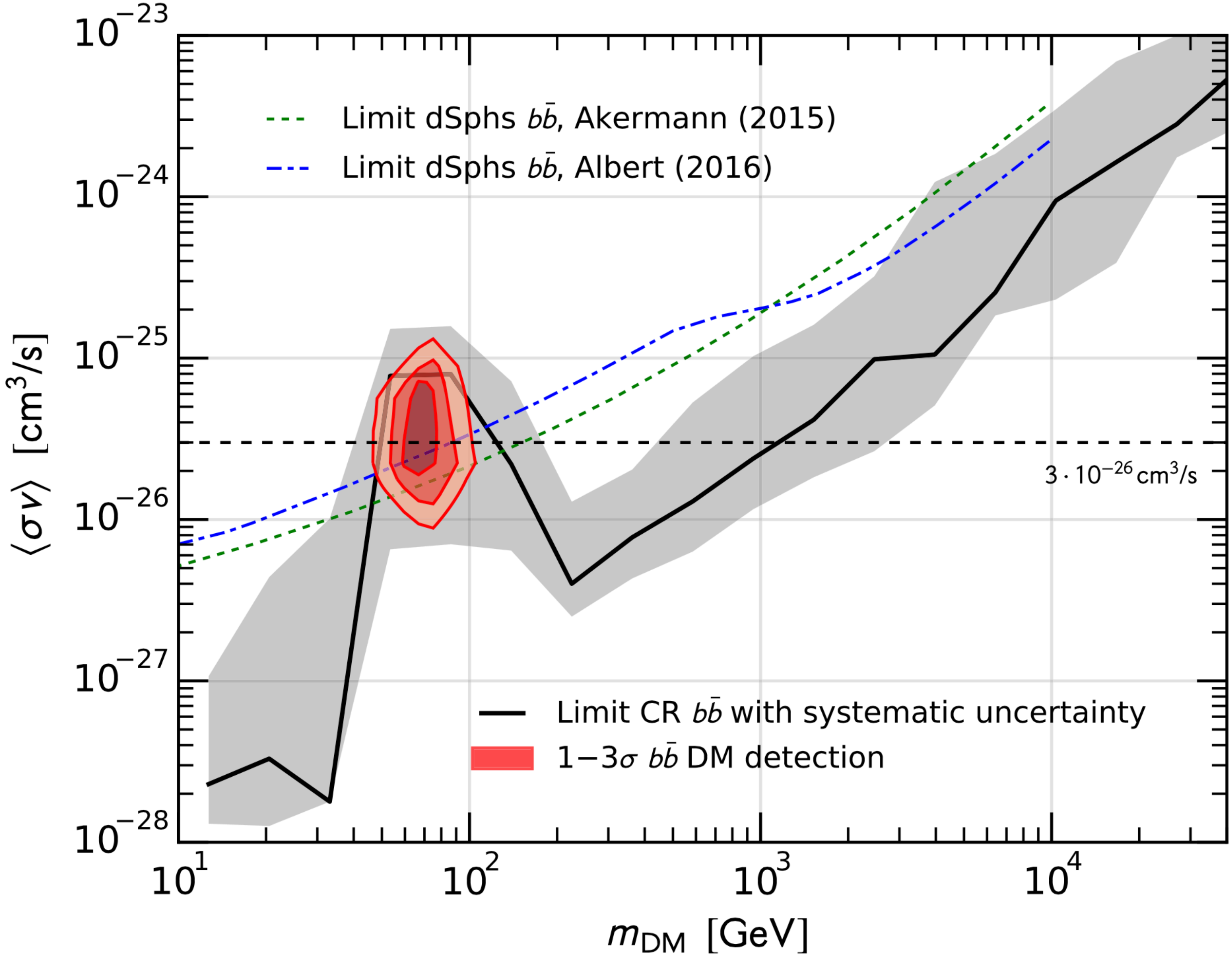
G.Giesen et al., JCAP09(2015) 023



PRL **118,** 191102 (2017) PHYSICAL REVIEW LETTERS week ending 12 MAY 2017

Novel Dark Matter Constraints from Antiprotons in Light of AMS-02

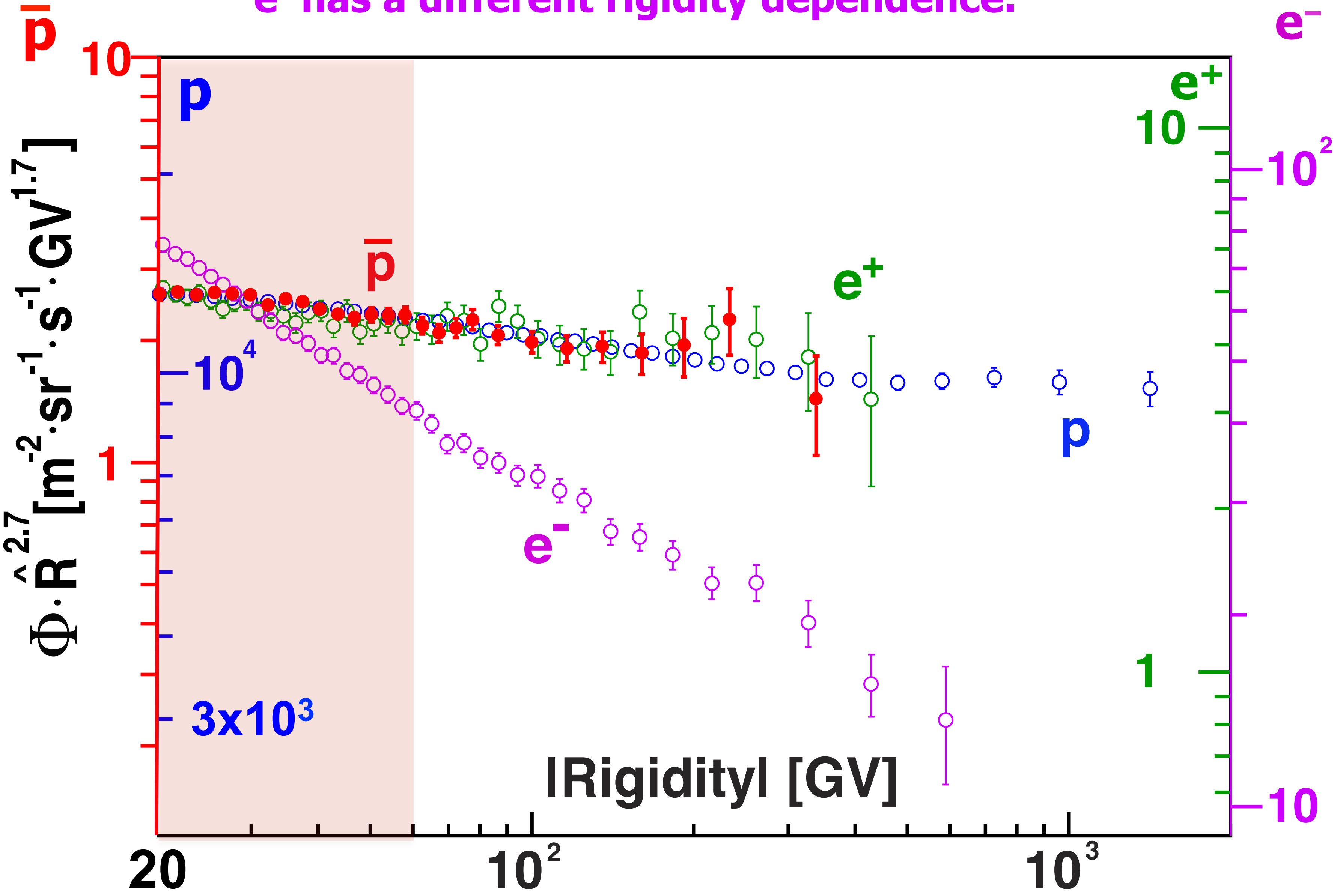
Alessandro Cuoco,[*] Michael Krämer,[†] and Michael Korsmeier[‡]



The Rigidity Dependence of Elementary Particles

e^+, $\bar{p}$, p are identical from 60-500 GV.

e^- has a different rigidity dependence.



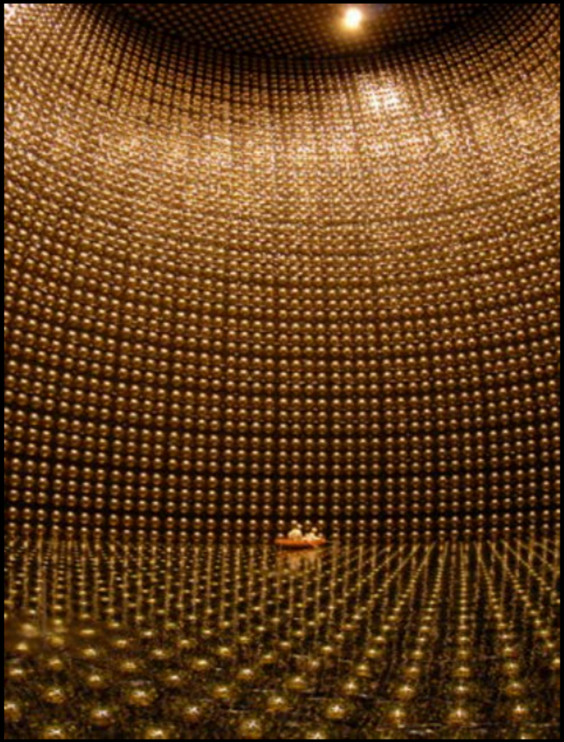
M. Aguilar *et al.*, Phys. Rev. Lett. **117,** 091103 (2016)

Experimental work on Antimatter in the Universe

Search for Baryogenesis

New symmetry breaking

Proton has finite lifetime



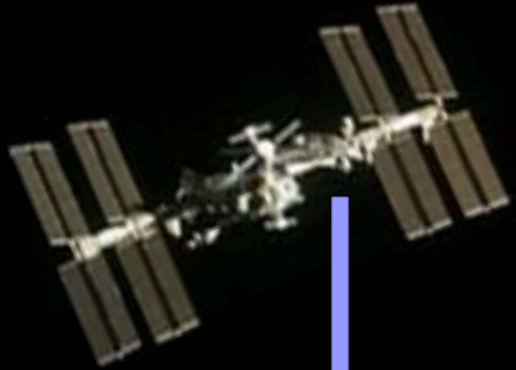
LHC-b, ATLAS,CMS

Super Kamiokande

$\tau_p > 6.6 * 10^{33}$ years

No explanation found for the absence of antimatter (no reason why antimatter should not exist)

Direct search

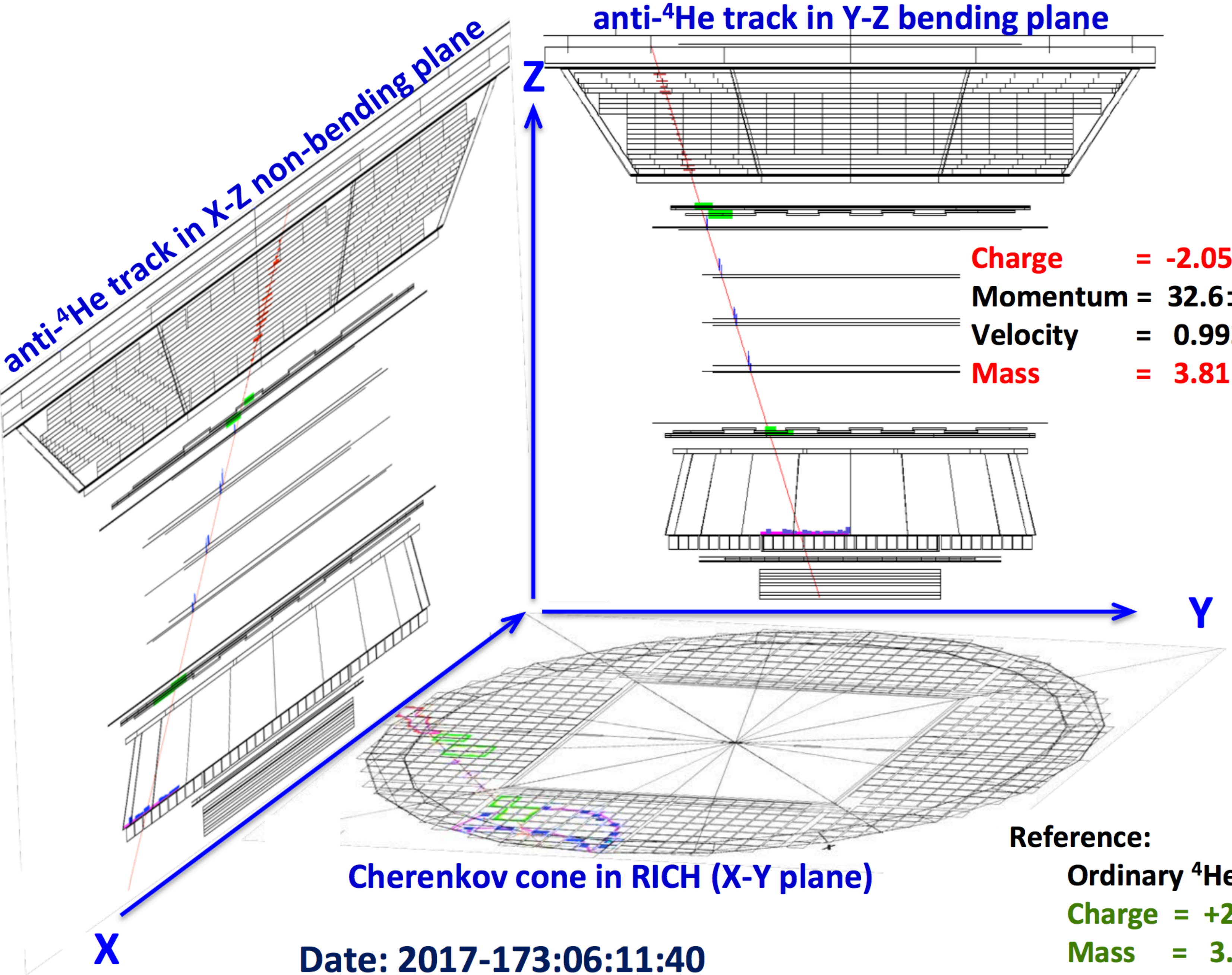


AMS

Increase in sensitivity: x $10^3 - 10^6$

Increase in energy to ~TeV

Observation of anti-He events



anti-^{4}He track in X-Z non-bending plane

anti-^{4}He track in Y-Z bending plane

Cherenkov cone in RICH (X-Y plane)

Charge = -2.05 ± 0.05

Momentum = 32.6±2.5 GeV/c

Velocity = 0.9930±0.0007 c

Mass = 3.81± 0.29 GeV/c^2

Reference:

Ordinary ^{4}He:

Charge = +2

Mass = 3.73 GeV/c^2

Date: 2017-173:06:11:40

Status of the AMS complex antimatter analysis

To date we have observed eight Z = -2 events with mass around He.

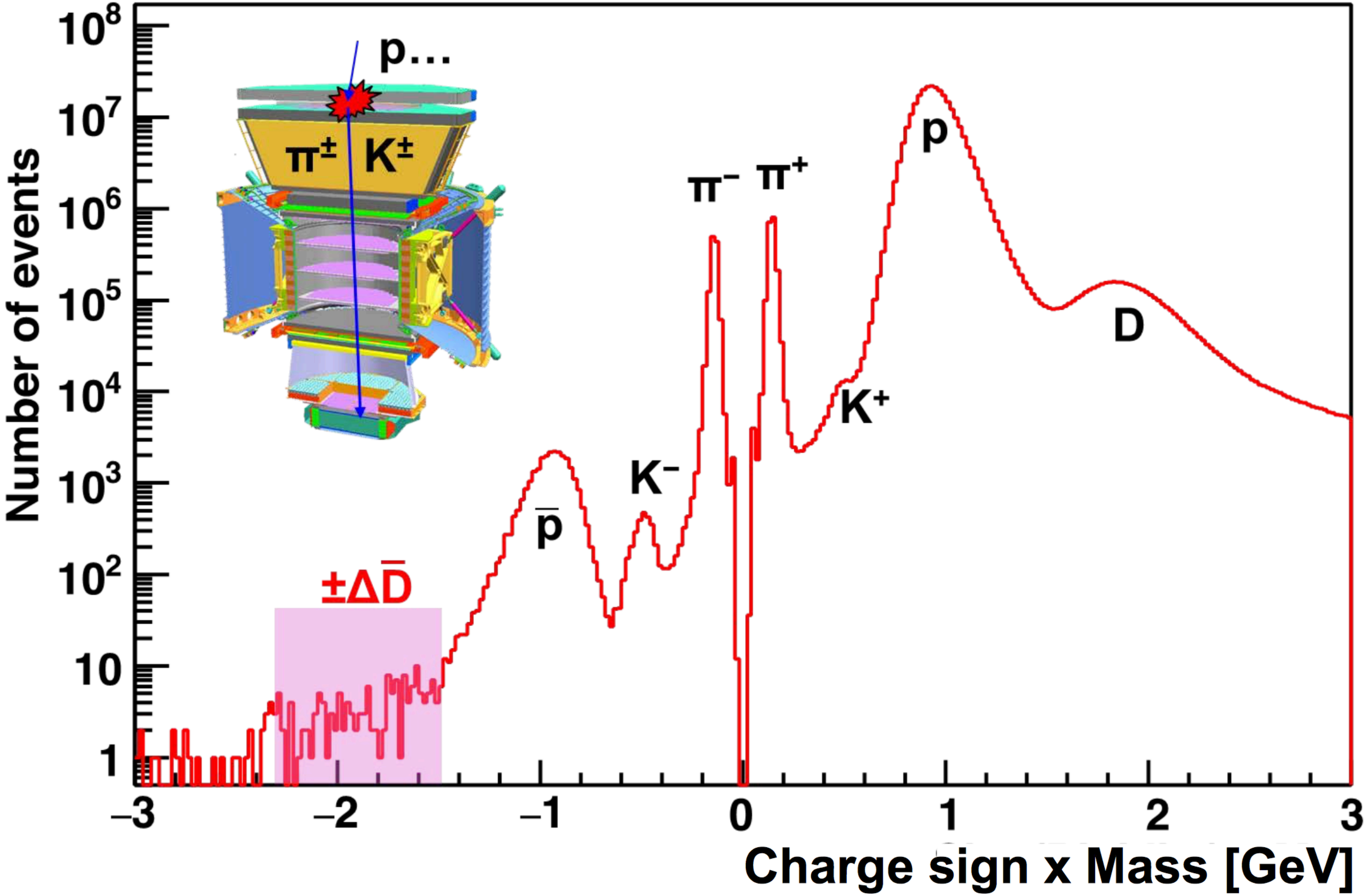
The corresponding sample with Z = +2 amounts to one billion helium events.

With the anti-Helium to Helium ratio of less than 1 in 100 million, detailed understanding of the instrument is required.

S. Ting, La Palma, Spain, April 2018:

We are performing final detector verifications before announcing the results

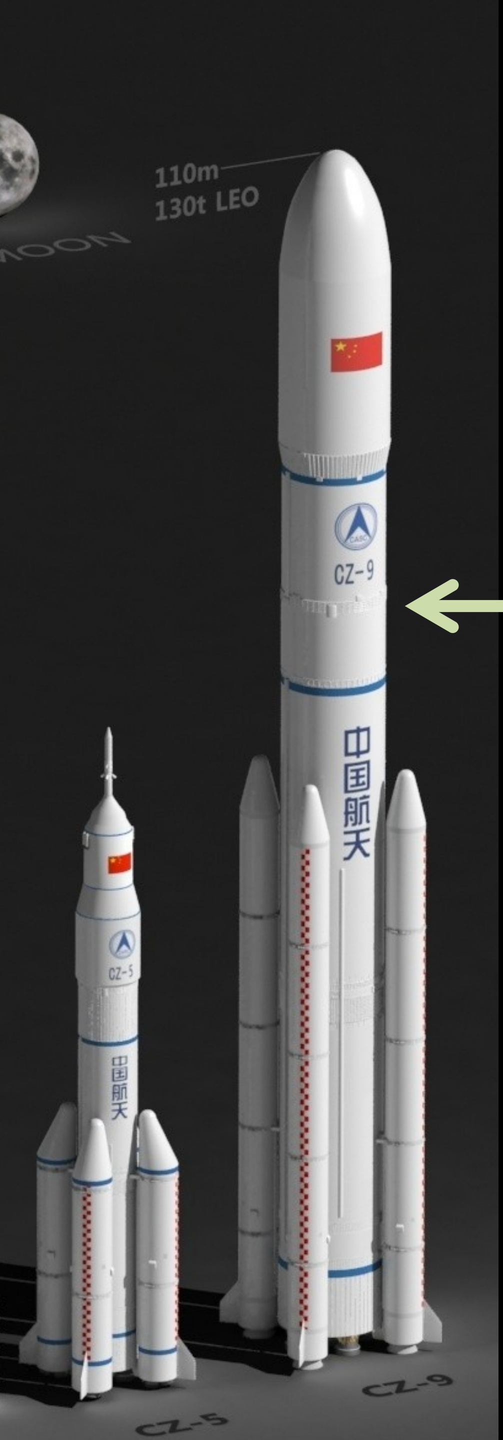
Anti-Deuteron



AMS-100 -
A Magnetic Spectrometer at Lagrange Point 2

- AMS-02 is an excellent experiment on the Space Station. It is now operational since 7 years. We plan to operate it till the end of the lifetime of the ISS in 2024.

- Is is now time to think about the next step!



Current and upcoming rockets

Name	LEO [kg]	other [kg]	First flight	
Ariane 5	21,000	10,730 GTO	2002	ESA
Falcon Heavy	63,800	26,700 GTO	2018	SpaceX
Long March 5	25,000	8,000 TLI	2016	CALT
Long March 9	130,000	50,000 TLI	2025	CALT
SLS Block 1B	105,000	39,100 TLI	2022	NASA
SLS Block 2	130,000	45,000 TLI	2025	NASA

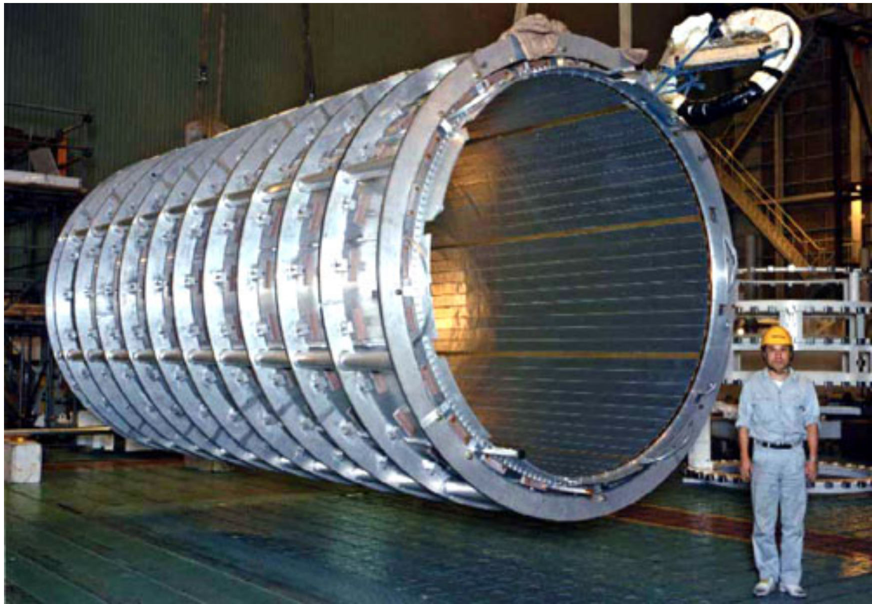
Operational
Under development

LEO: Low Earth orbit
GTO: Geostationary transfer orbit
TLI: Trans-lunar injection

ATLAS Central Solenoid Magnet

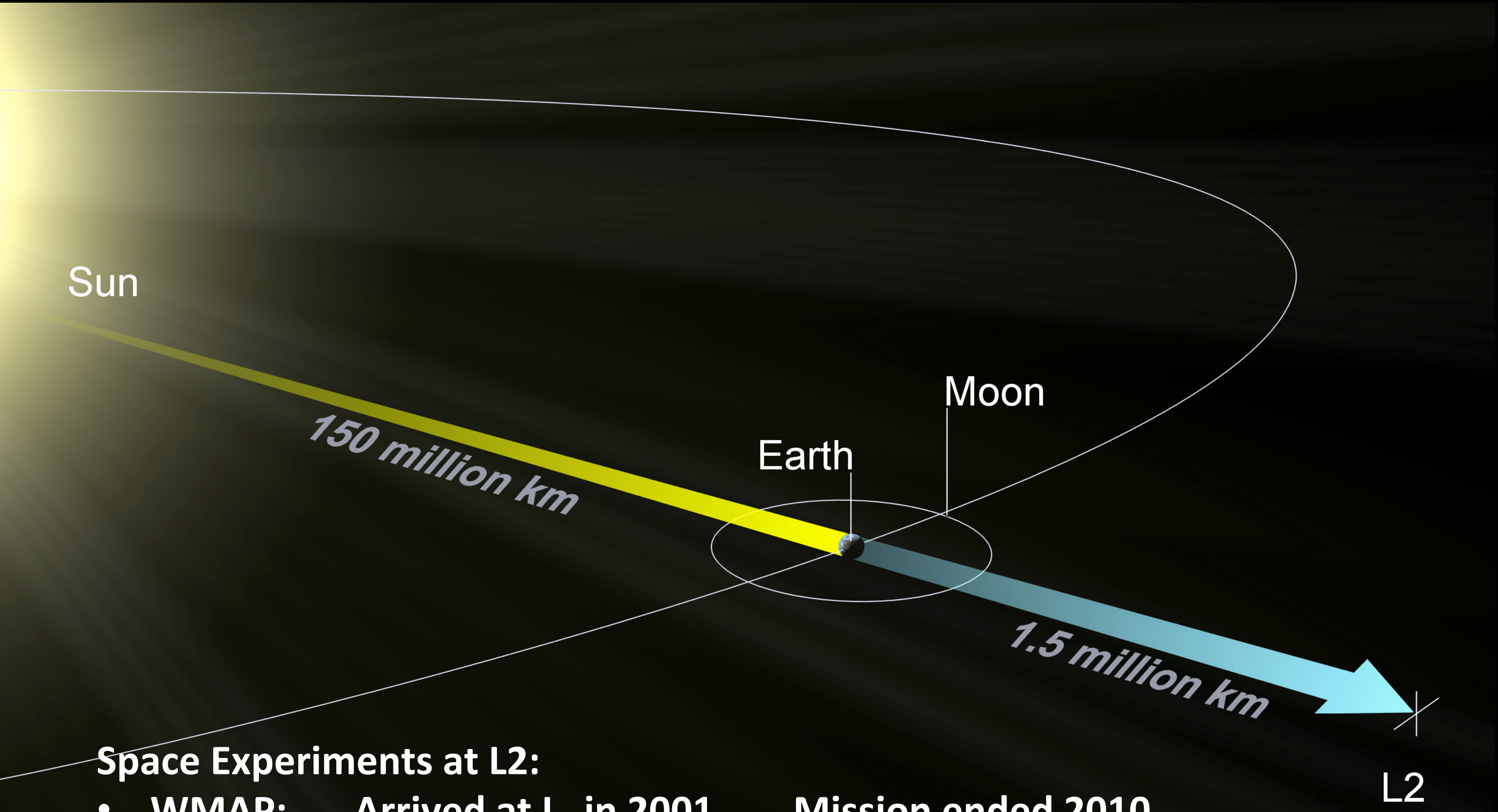
- **only 0.66 radiation lengths X0 thick**
- **made from aluminium enforced Nb/Ti conductor**
- **operation temperature 4.5 K**

- 5.3 long, 2.4 m diameter, 4.5 cm thick
- 5 tonne weight
- 2 tesla (T) magnetic field with a stored energy of 38 megajoules (MJ)
- 9 km of superconducting wire
- Nominal current: 7.73 kiloampere (kA)



AMS-100: Operation at Lagrange Point 2

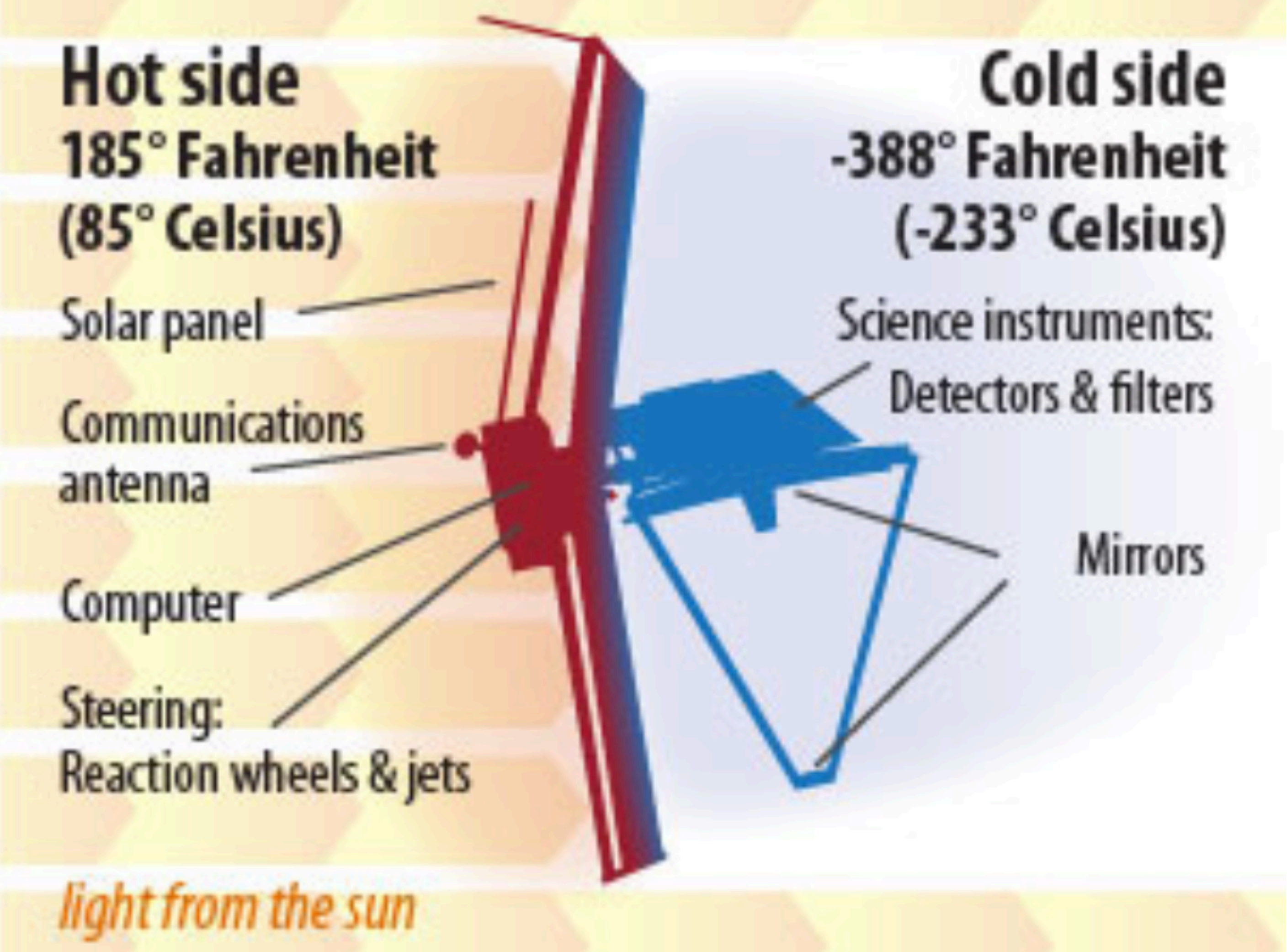
Due to earth magnetic field a cryogenic solenoid magnet can only be operated at L2.



Space Experiments at L2:

- **WMAP:** Arrived at L_2 in 2001. Mission ended 2010
- **Herschel:** Arrived at L_2 July 2009. Ceased operation on 29 April 2013
- **Planck:** Arrived at L_2 July 2009. Mission ended on 23 October 2013
- **Chang'e 2:** Arrived in August 2011 after completing a lunar mission before departing en route to asteroid 4179 Toutatis in April 2012.

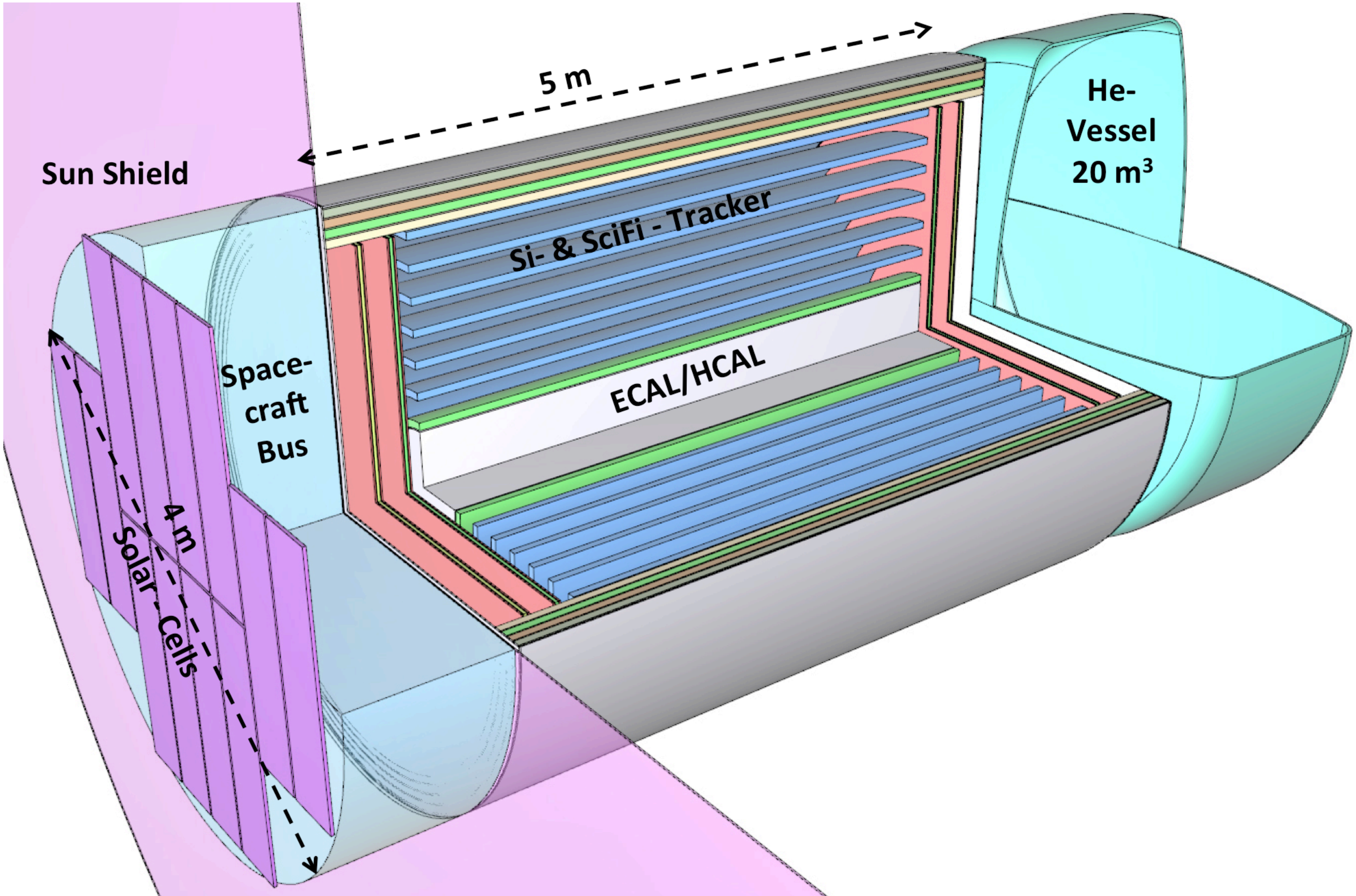
James Webb Telescope -
a space telescope at Lagrange Point 2



The science phase of the mission is expected to start in 2018 and to last for 10.5 years.

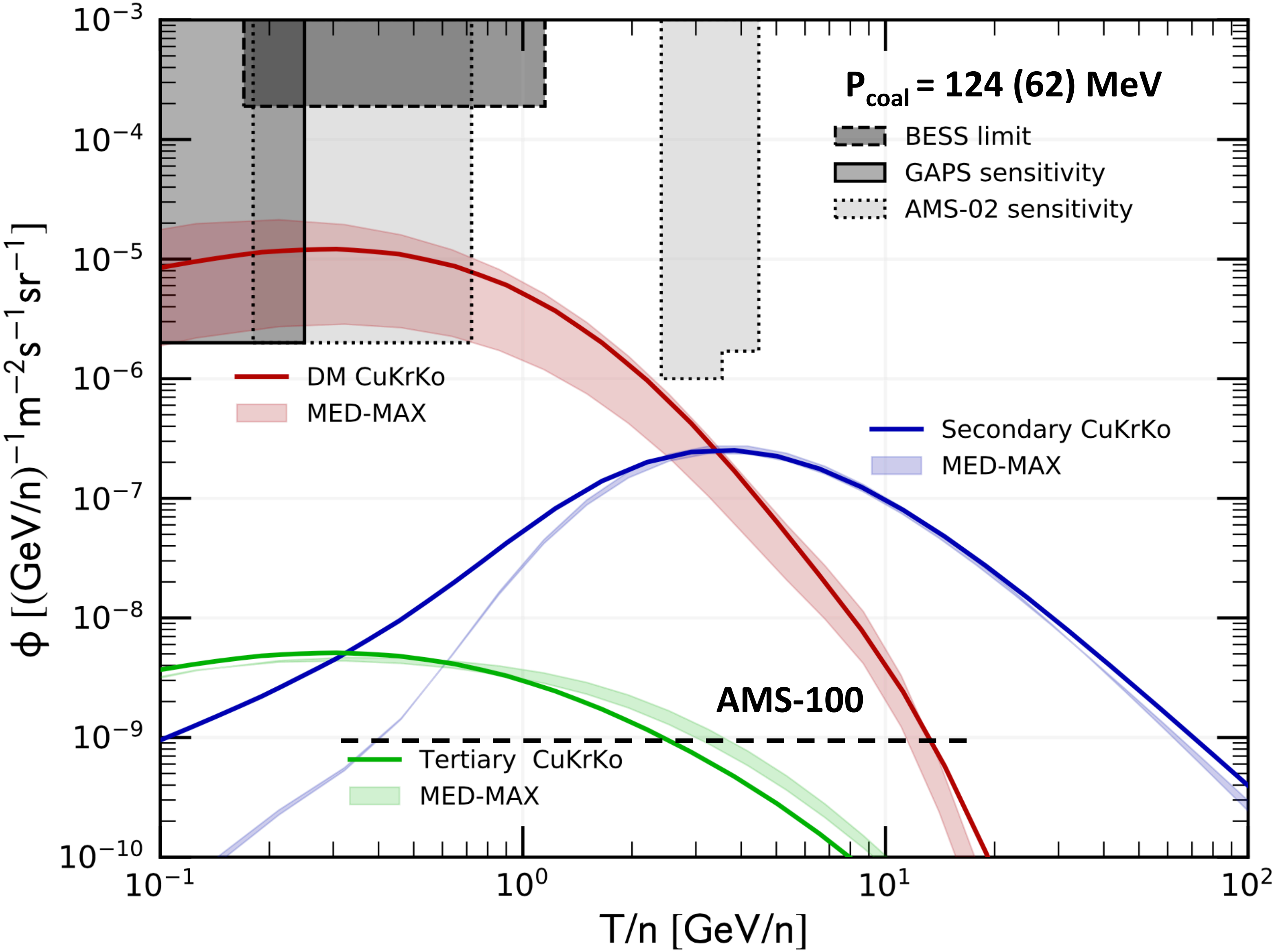
AMS-100: A Magnetic Spectrometer at LP-2

Weight: 43 t
MDR: 100 TeV
Readout-Channels: 4 10^6
Acceptance: 100 m^2 sr
Power: 40 kW
B-Field: 1 Tesla
Trigger Rate: 1 MHz

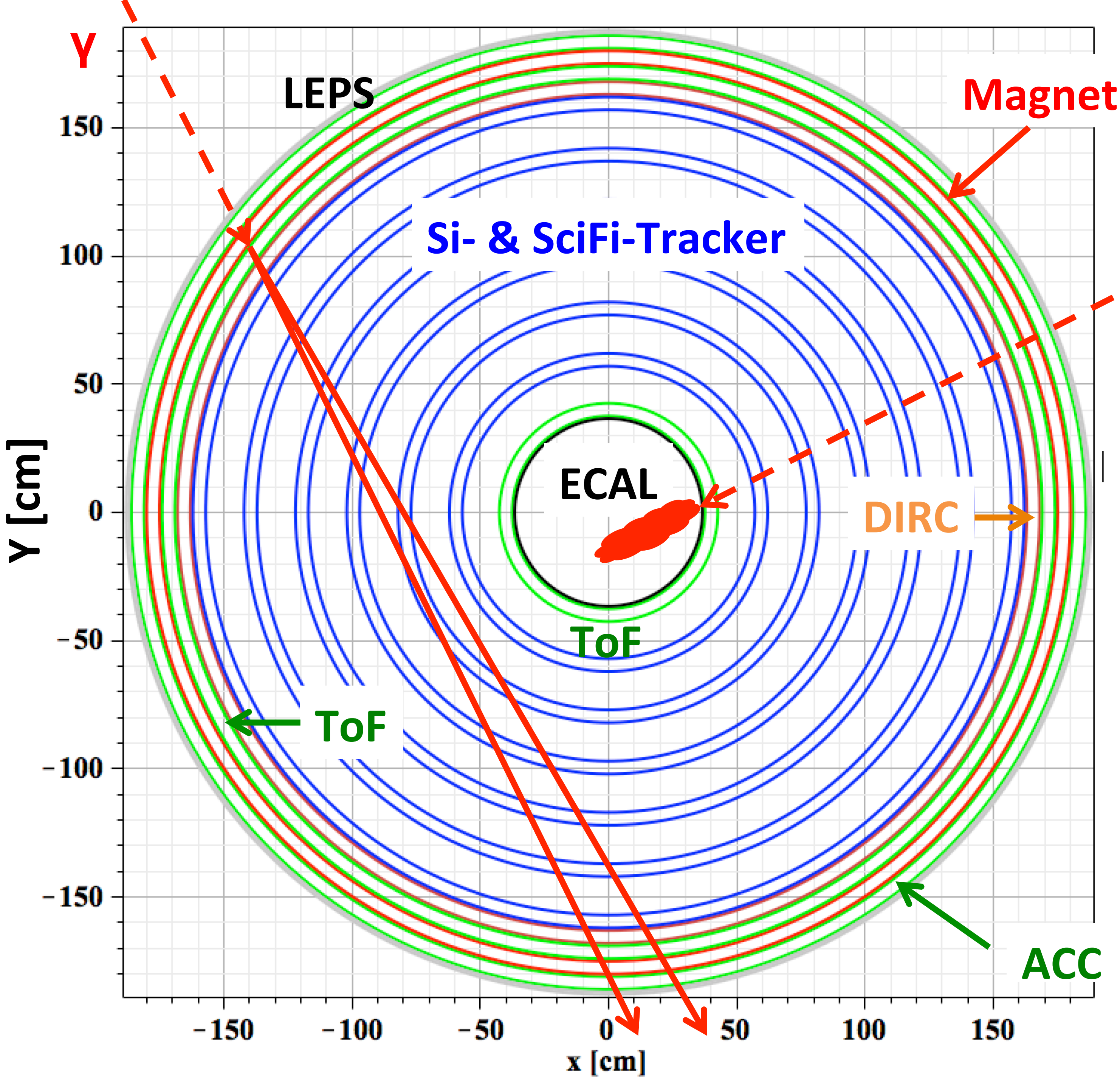


Anti-Deuteron and Anti-Helium

If AMS-02 finds Anti-Deuteron and/or Anti-Helium AMS-100 would detect thousands of such events.

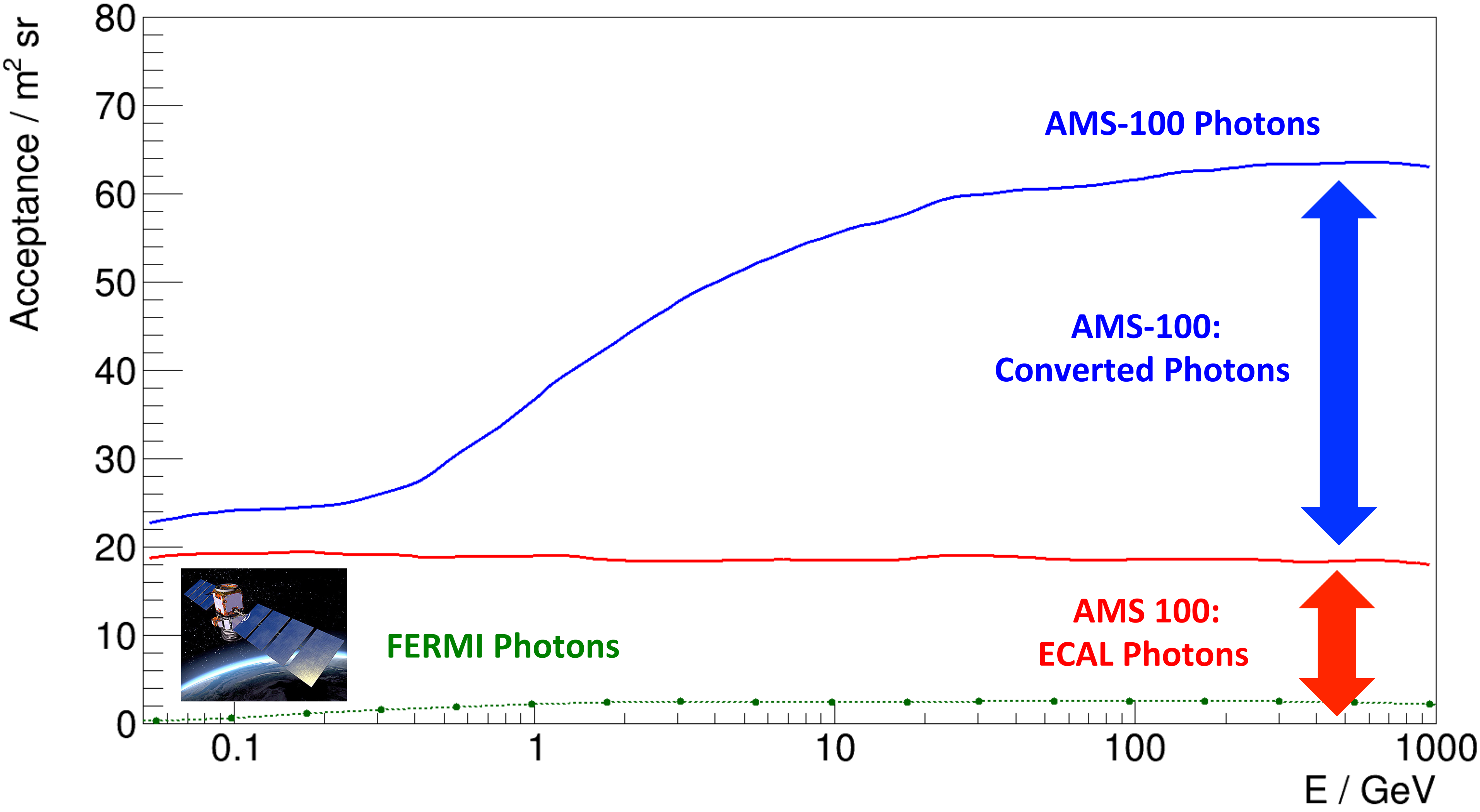


F. Donato, Fornengo, Korsmeier, 1711.08465 subm. PRD


γ
LEPS
Magnet
Si- & SciFi-Tracker
γ
ECAL
DIRC
ToF
ToF
ACC
Y [cm]
x [cm]
150
100
50
0
−50
−100
−150
−150
−100
−50
0
50
100
150

AMS-100 will monitor the whole sky continously.

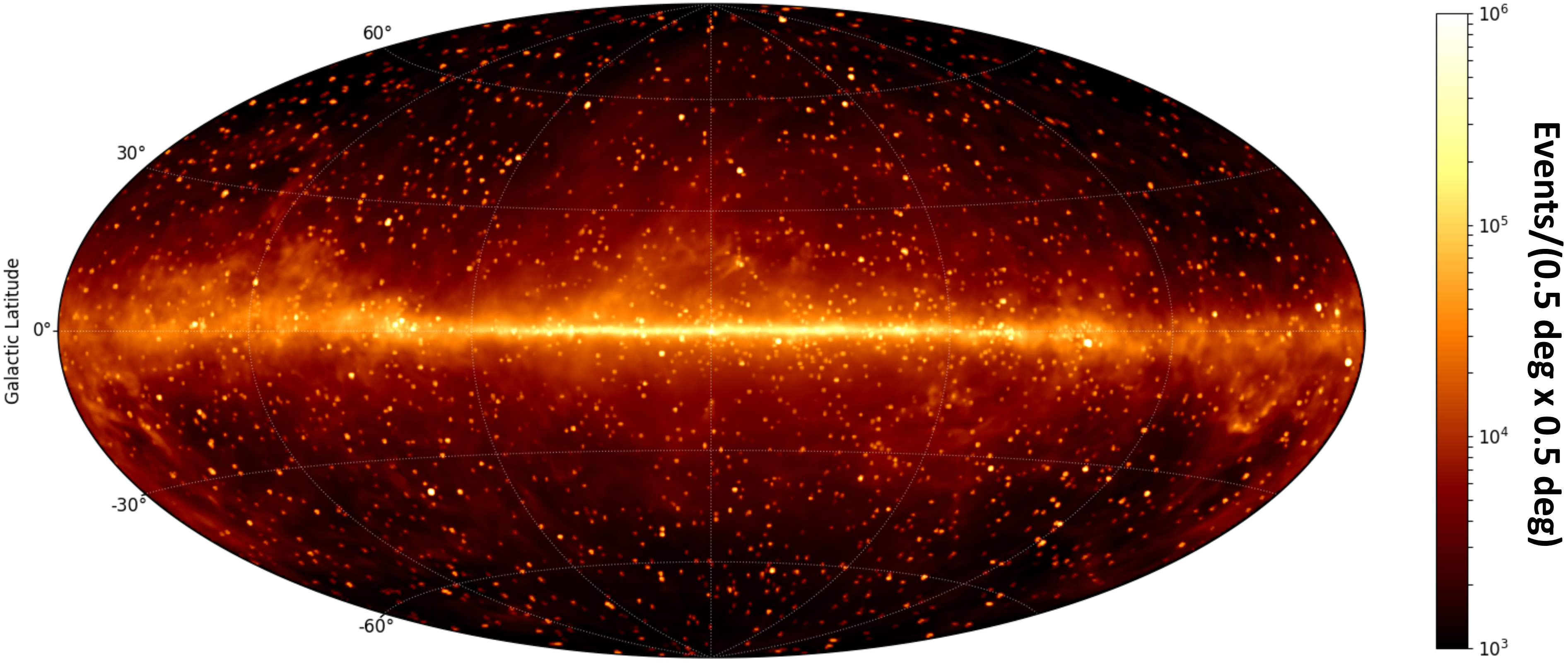
The acceptance for photons is up to 65 m^2 sr compared to FERMI 2.5 m^2 sr.



The angular Resolution for converted photons is 0.005 mm/3.5m = 1 10^{-4} deg and will be up to ~1,000 better than the FERMI resolution.

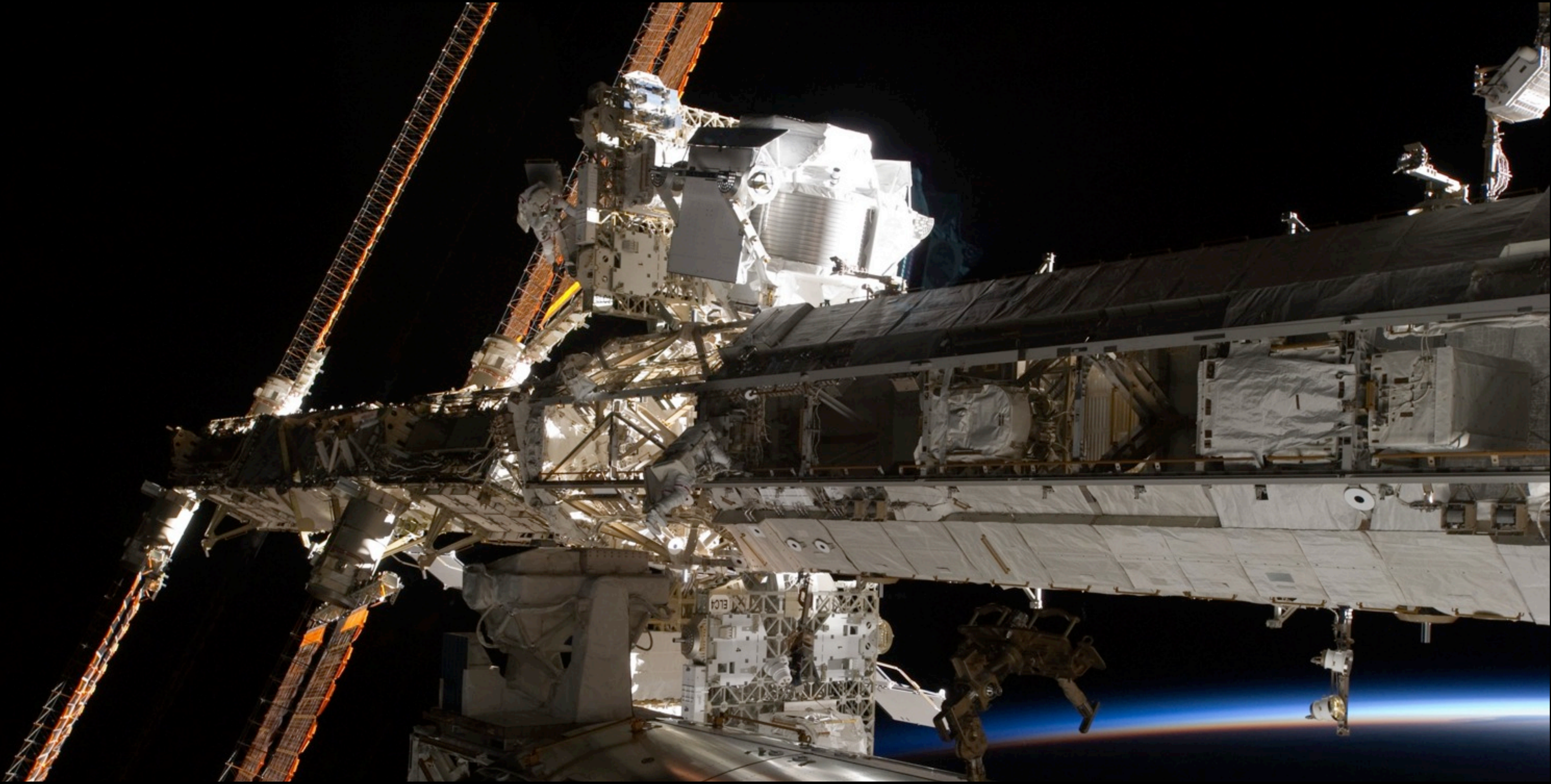
The 3. FERMI catalog includes 3033 sources above 4 sigma significance.

AMS-100: Expected counts for 5 years for E=50 MeV – 1 TeV



- For every source in the 3. FERMI catalog we expect at least 1,000 events in AMS-100.
- We expect to see 10,000 new sources in AMS-100.

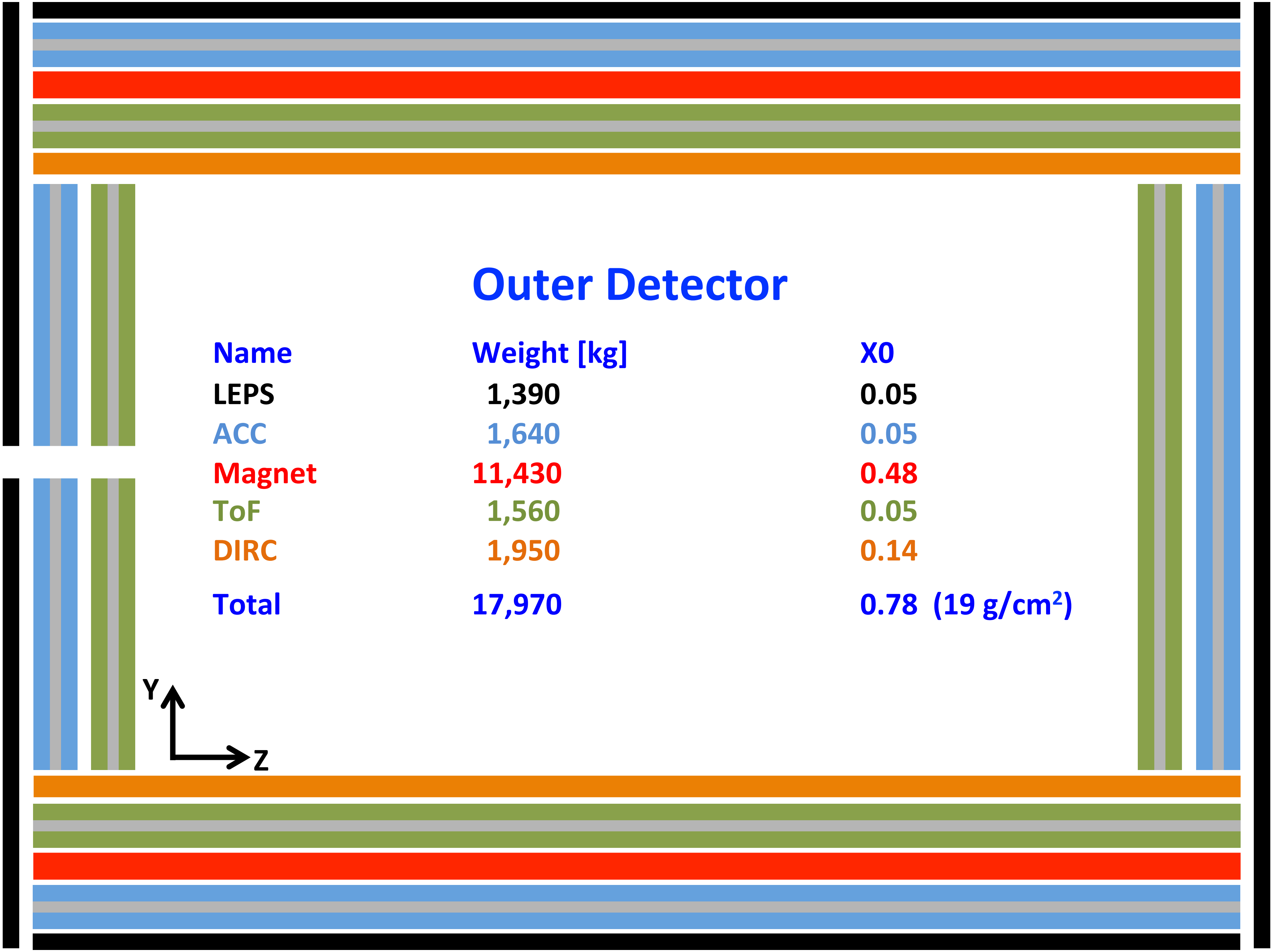
The Space Station has become a unique platform for precision physics research.



*"The most exciting objective of AMS is to probe the unknown;
to search for phenomena which exist in nature
that we have not yet imagined nor had the tools to discover."*

S. Ting

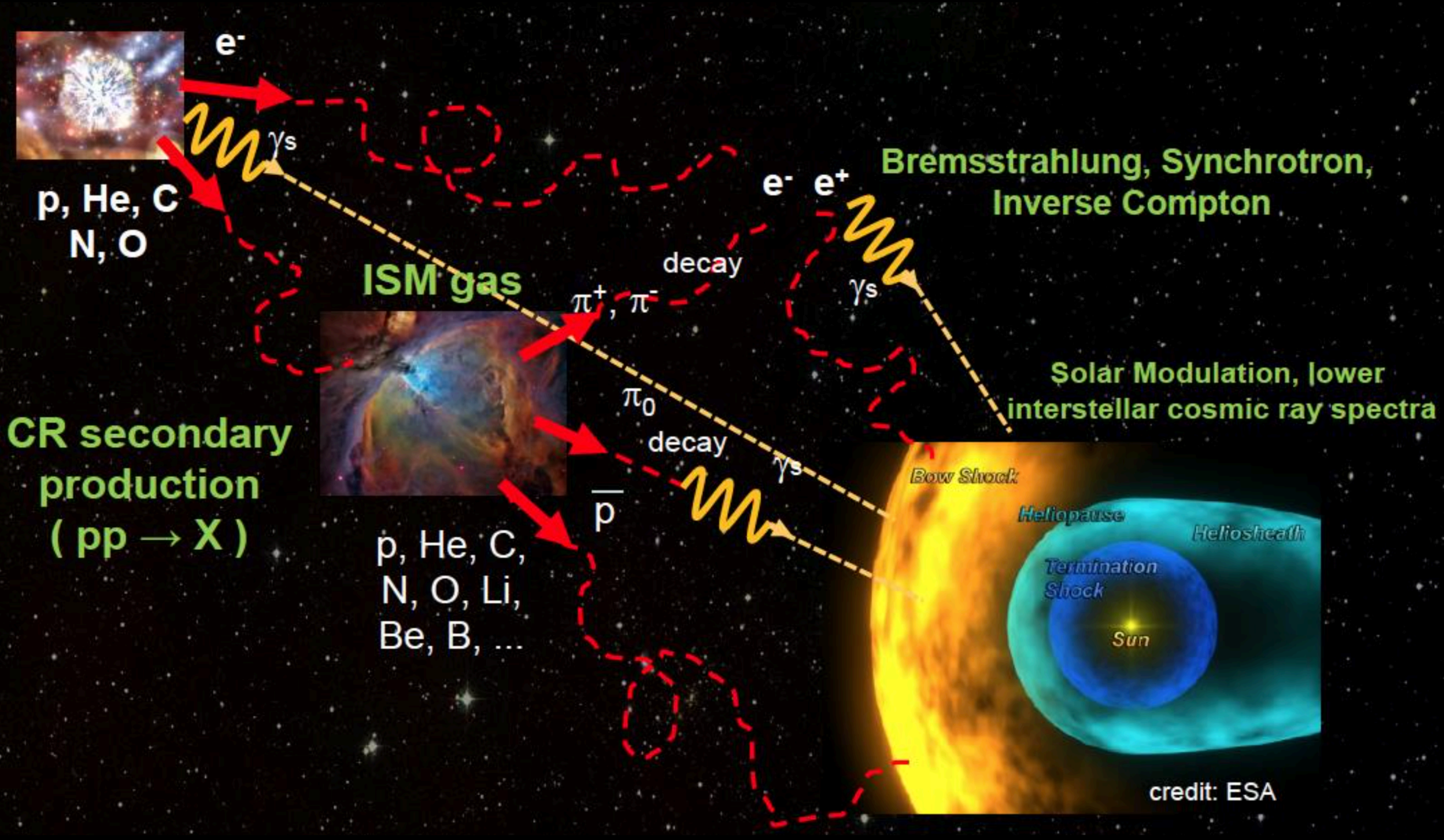
Backup



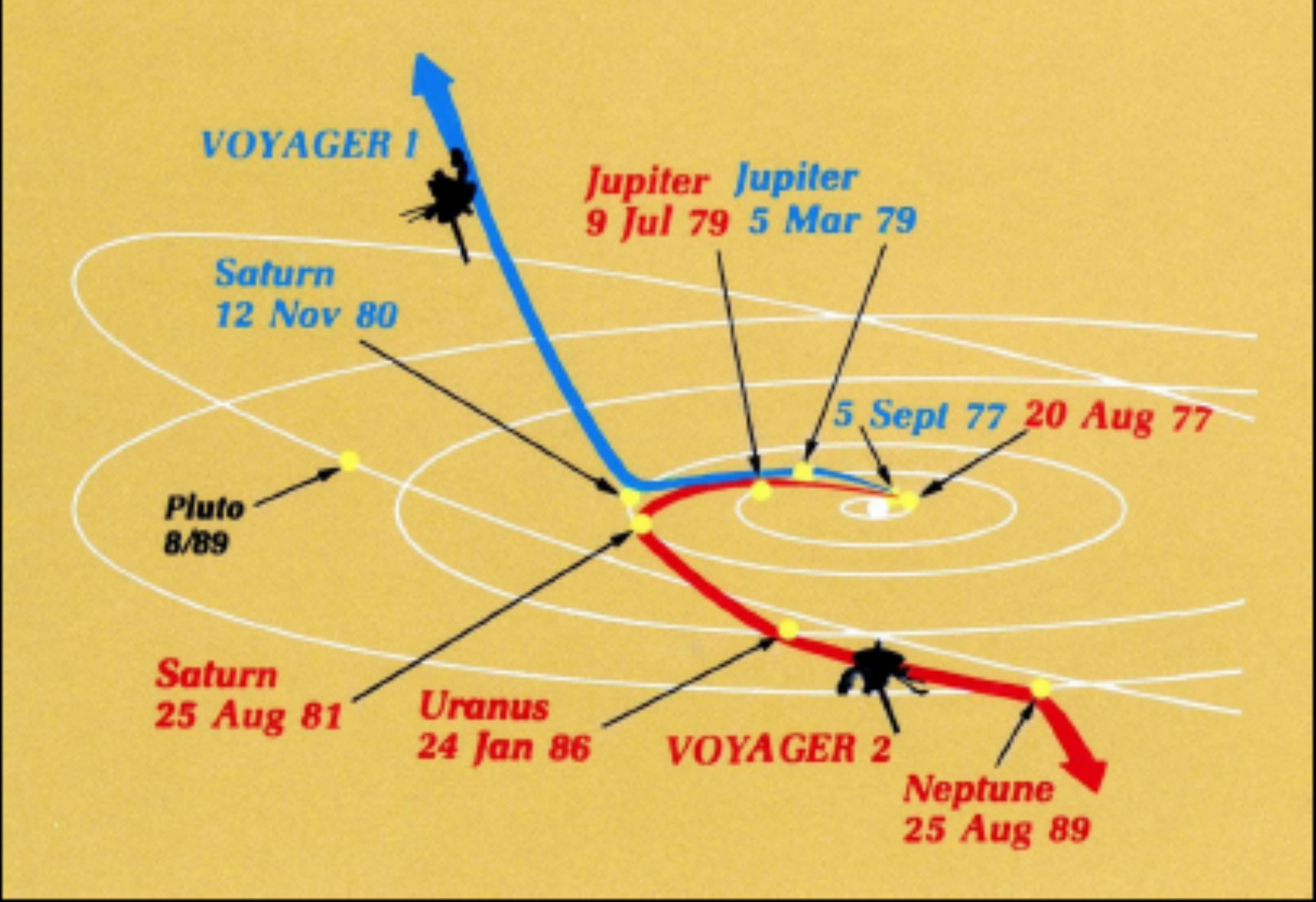
Outer Detector

Name	Weight [kg]	X0
LEPS	1,390	0.05
ACC	1,640	0.05
Magnet	11,430	0.48
ToF	1,560	0.05
DIRC	1,950	0.14
Total	17,970	0.78 (19 g/cm^2)

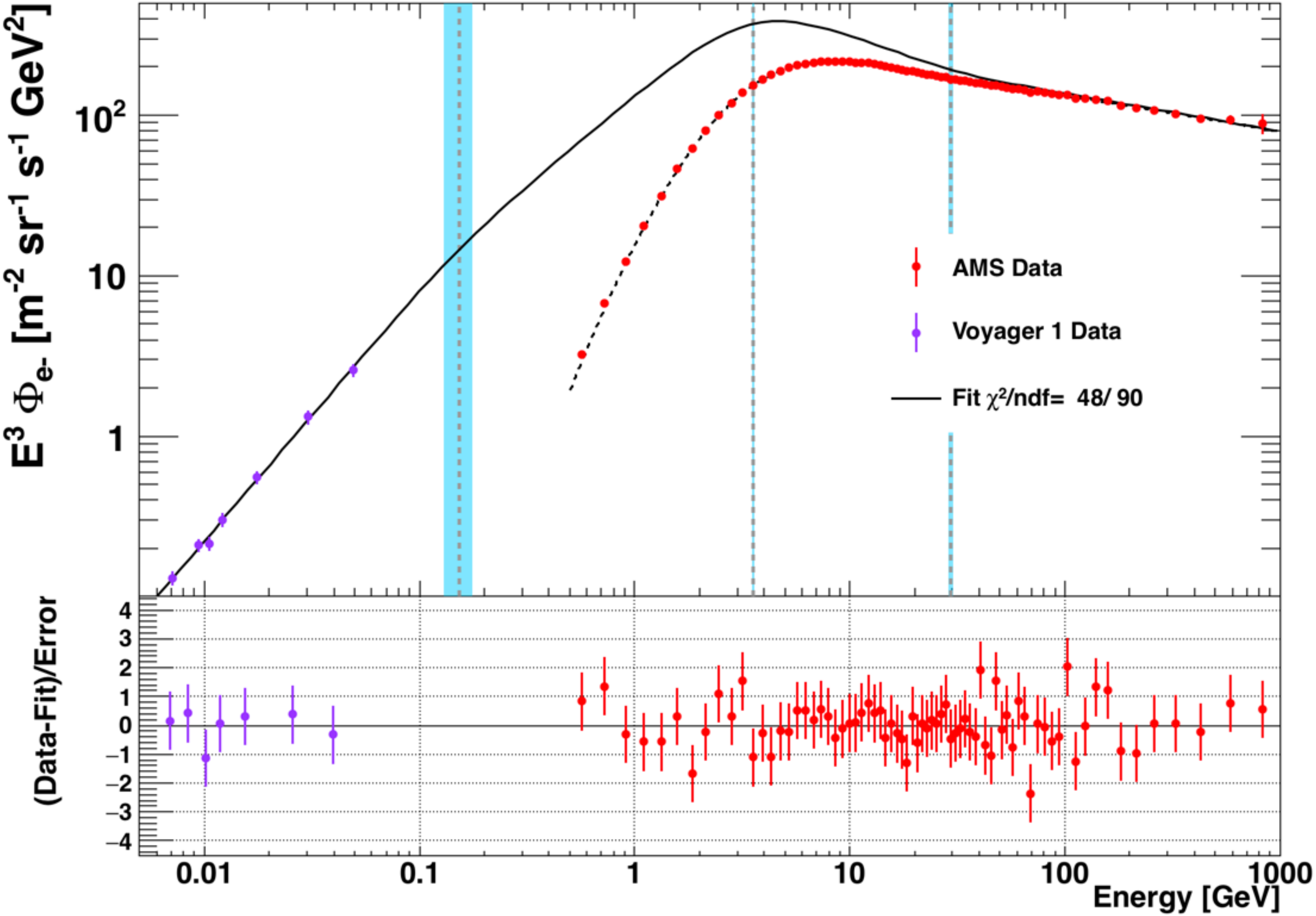
Light primary cosmic ryas: p, He, C, N, O and e^-, ...



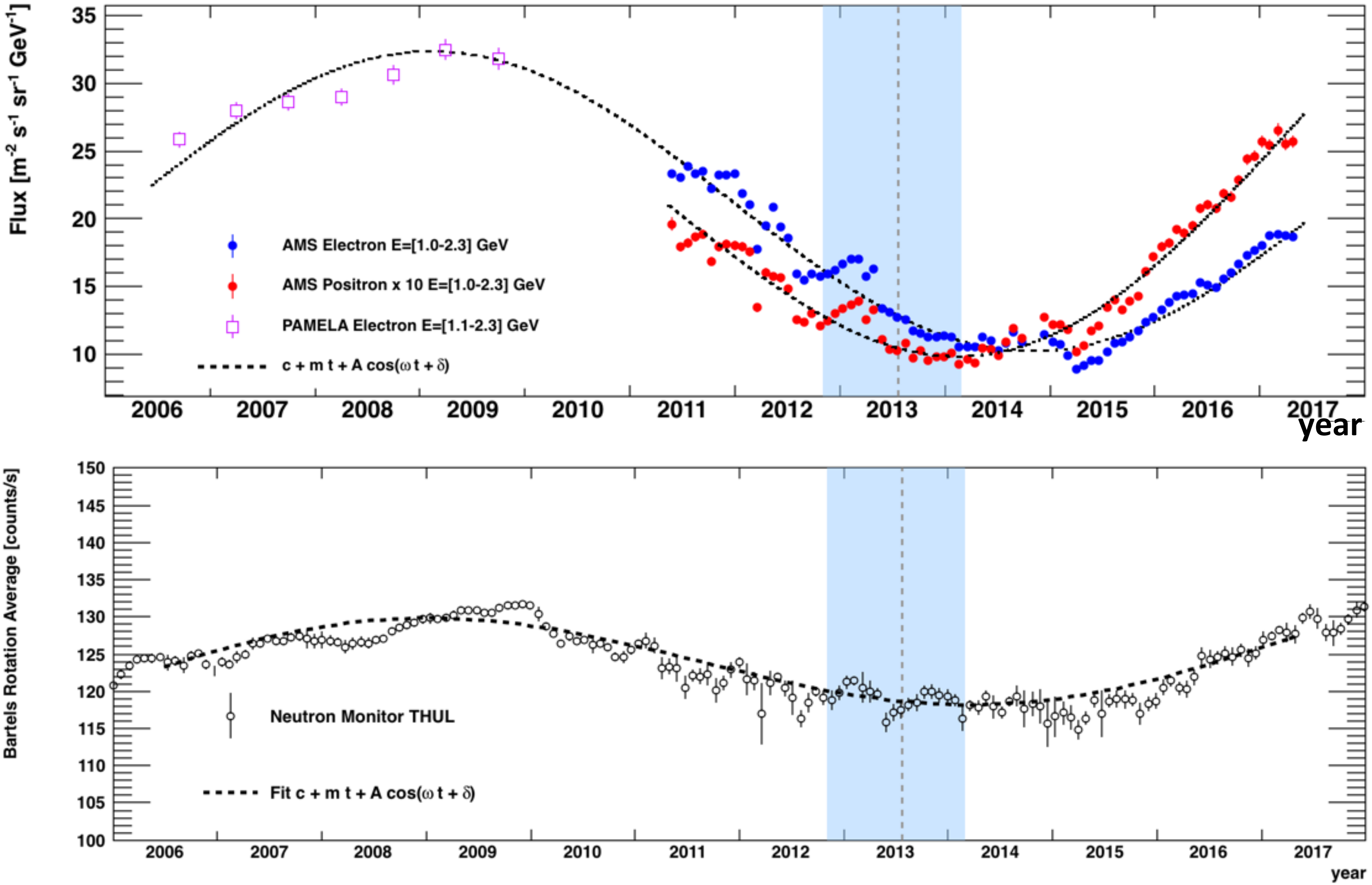
Light secondary cosmic ryas: Li, Be, B and $e^{+,}$ $\bar{p}$, ...



Once every 176 years the giant planets are lined up for a Grand Tour, and in 1977 the Voyagers were launched on humankind's longest journey


$E^3\ \Phi_{e-}$ [m^{-2} sr^{-1} s^{-1} GeV^2]
10^2
10
1
AMS Data
Voyager 1 Data
Fit χ^2/ndf= 48/ 90
(Data-Fit)/Error
4
3
2
1
0
−1
−2
−3
−4
0.01
0.1
1
10
100
1000
Energy [GeV]

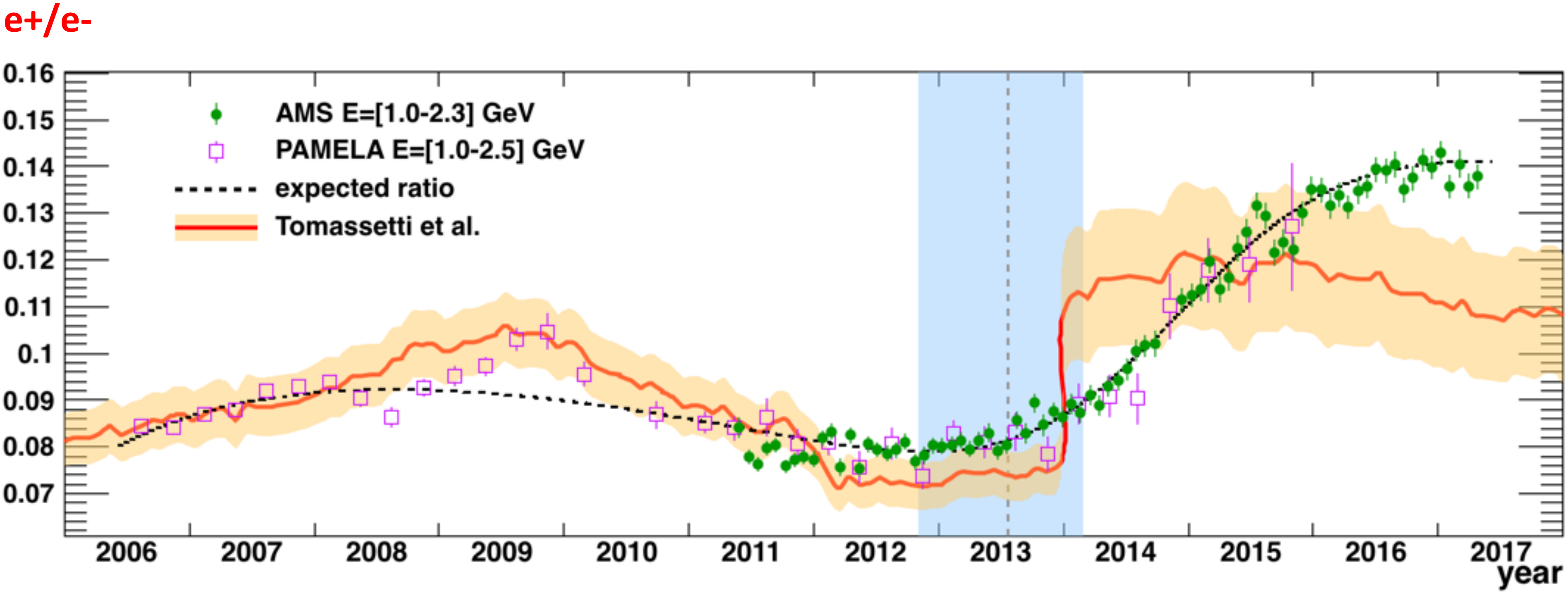
Similar to the neutron monitor count rates the general long-term trend of both the electron and the positron flux follows on average smooth periodic functions with a cycle of 11 years for the data considered here.



Charge Sign Dependent Solar Modulation

- The energy and time dependence of various cosmic ray measurements including e+/e- are well reproduced by advanced numerical solar modulation models during the extraordinary quiet solar minimum period from 2006 to 2011.

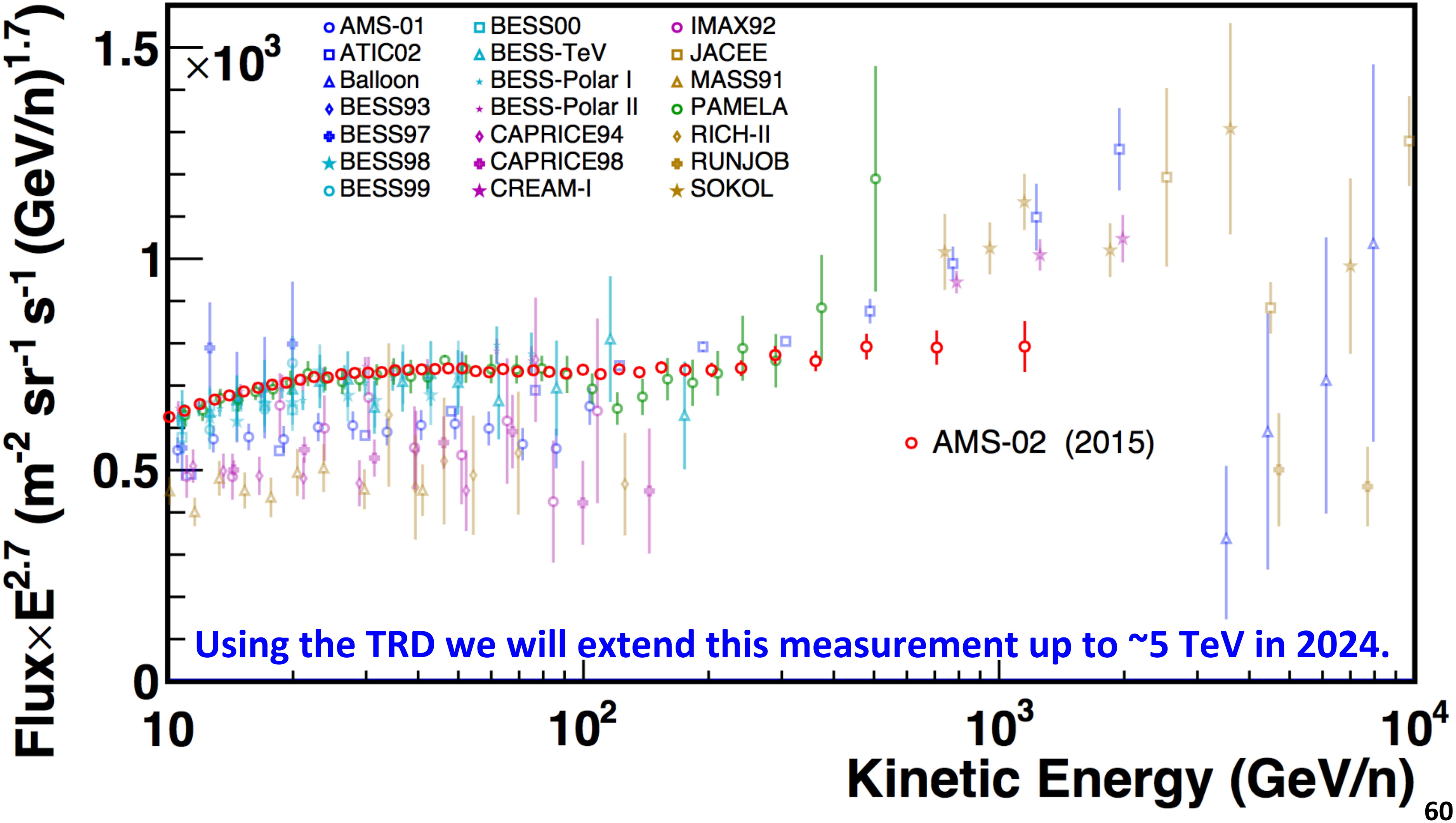
- But for the following years covered by the new AMS data important and large systematic discrepancies are observed in particular in e+/e- which is sensitive to charge sign dependent solar modulation effects.



PRL 115, 211101 (2015) PHYSICAL REVIEW LETTERS week ending 20 NOVEMBER 2015

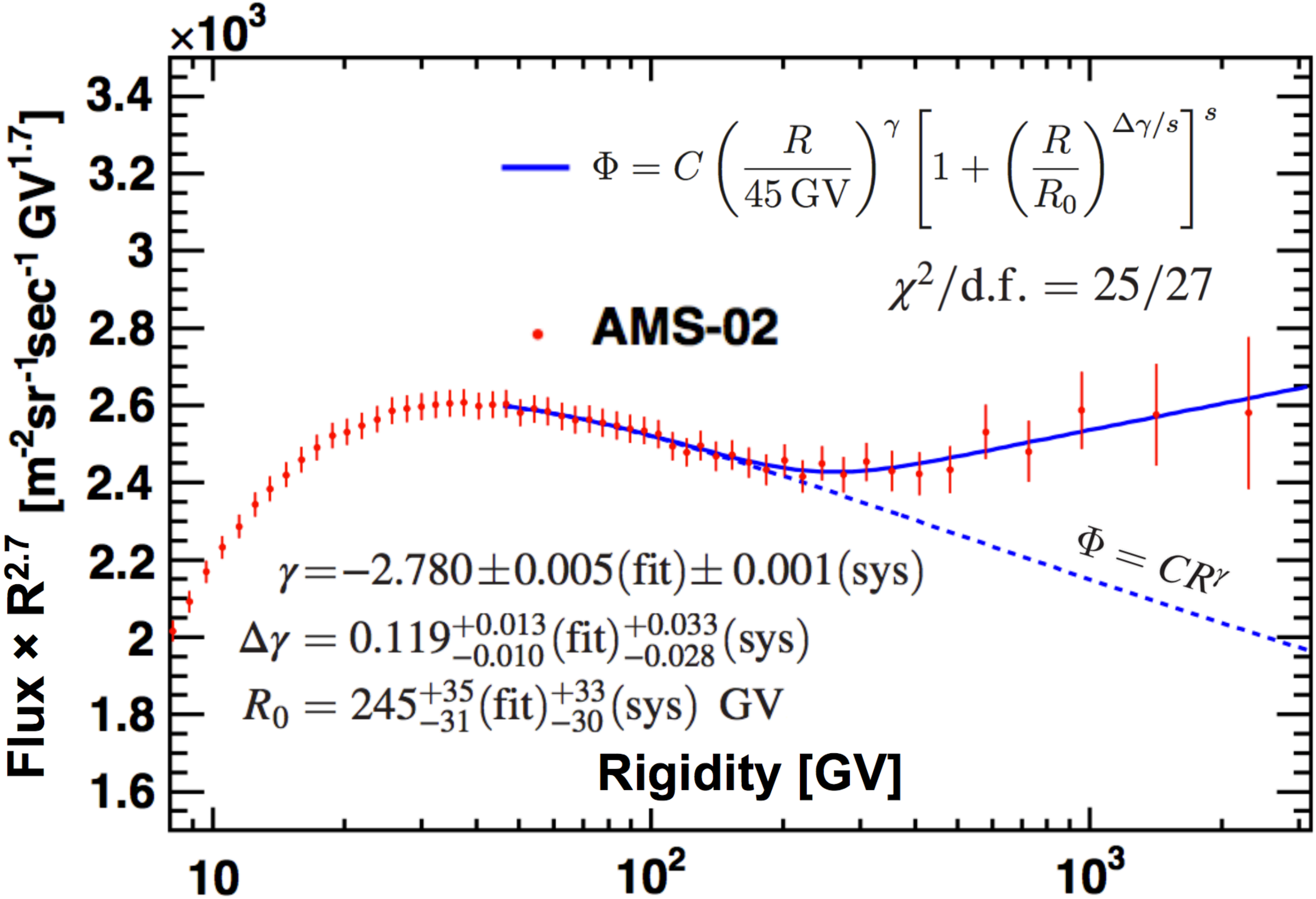
Precision Measurement of the Helium Flux in Primary Cosmic Rays of Rigidities 1.9 GV to 3 TV with the Alpha Magnetic Spectrometer on the International Space Station

50 million helium nuclei

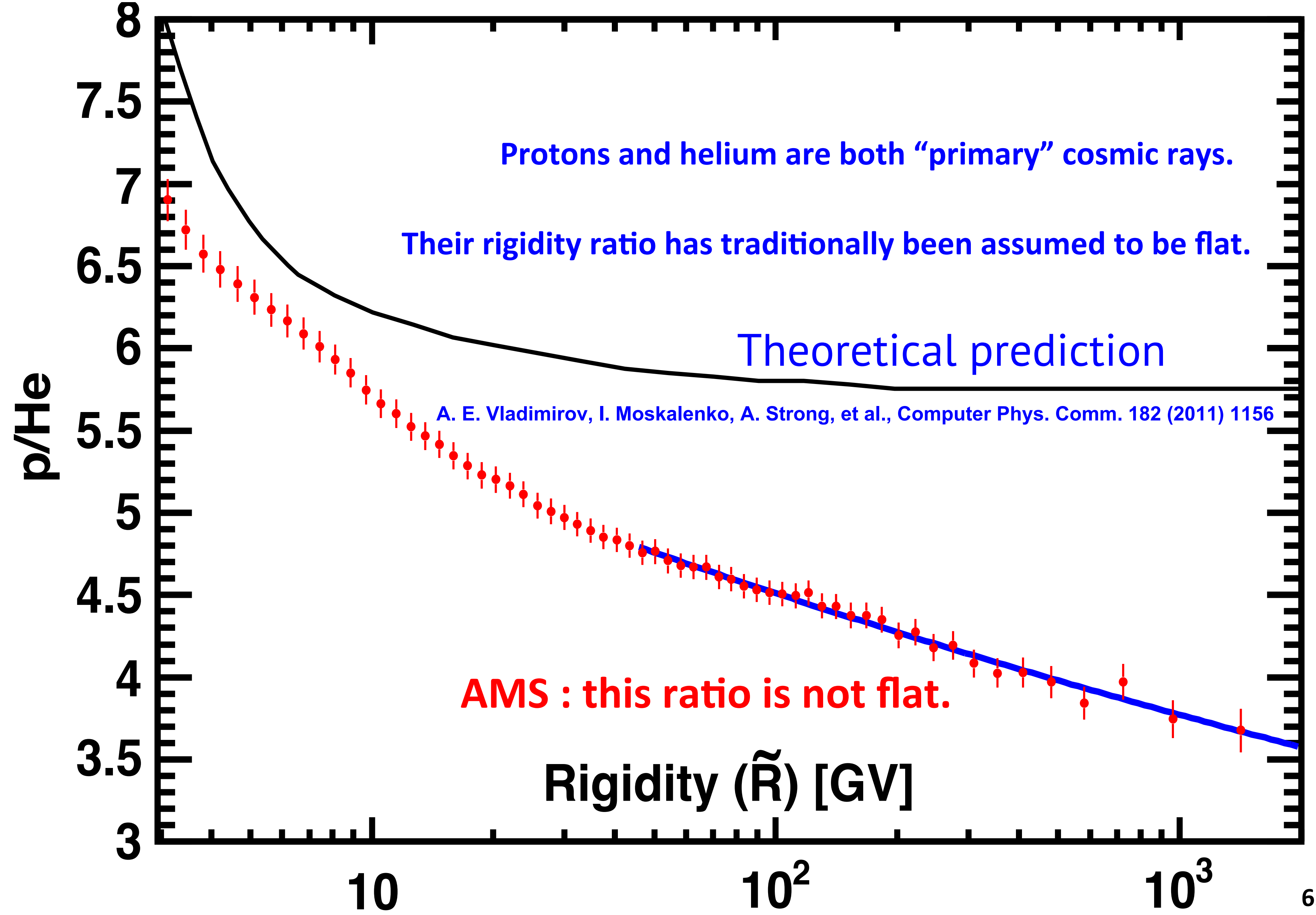


Using the TRD we will extend this measurement up to ~5 TeV in 2024.

It was expected that the He flux could be described with a single power law with spectral index γ=-2.7.



The AMS proton/helium flux ratio



Protons and helium are both “primary” cosmic rays.

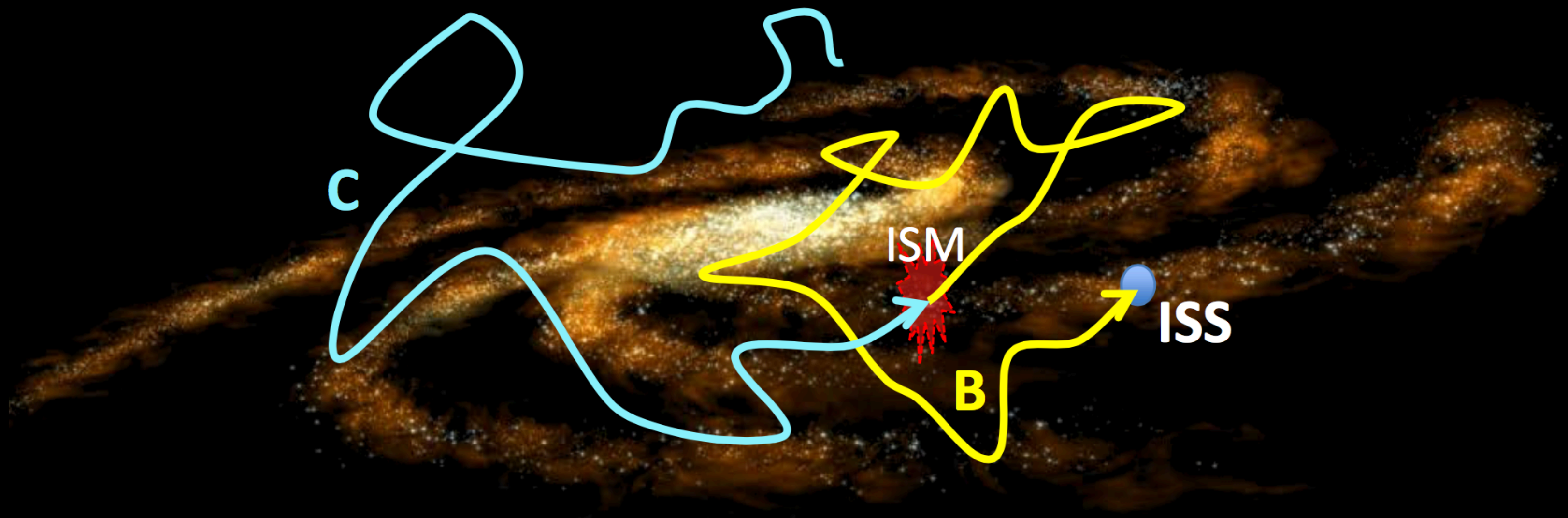
Their rigidity ratio has traditionally been assumed to be flat.

Theoretical prediction

A. E. Vladimirov, I. Moskalenko, A. Strong, et al., Computer Phys. Comm. 182 (2011) 1156

AMS : this ratio is not flat.

The flux ratio between primaries (C) and secondaries (B) provides information on propagation and on the Interstellar Medium (ISM)

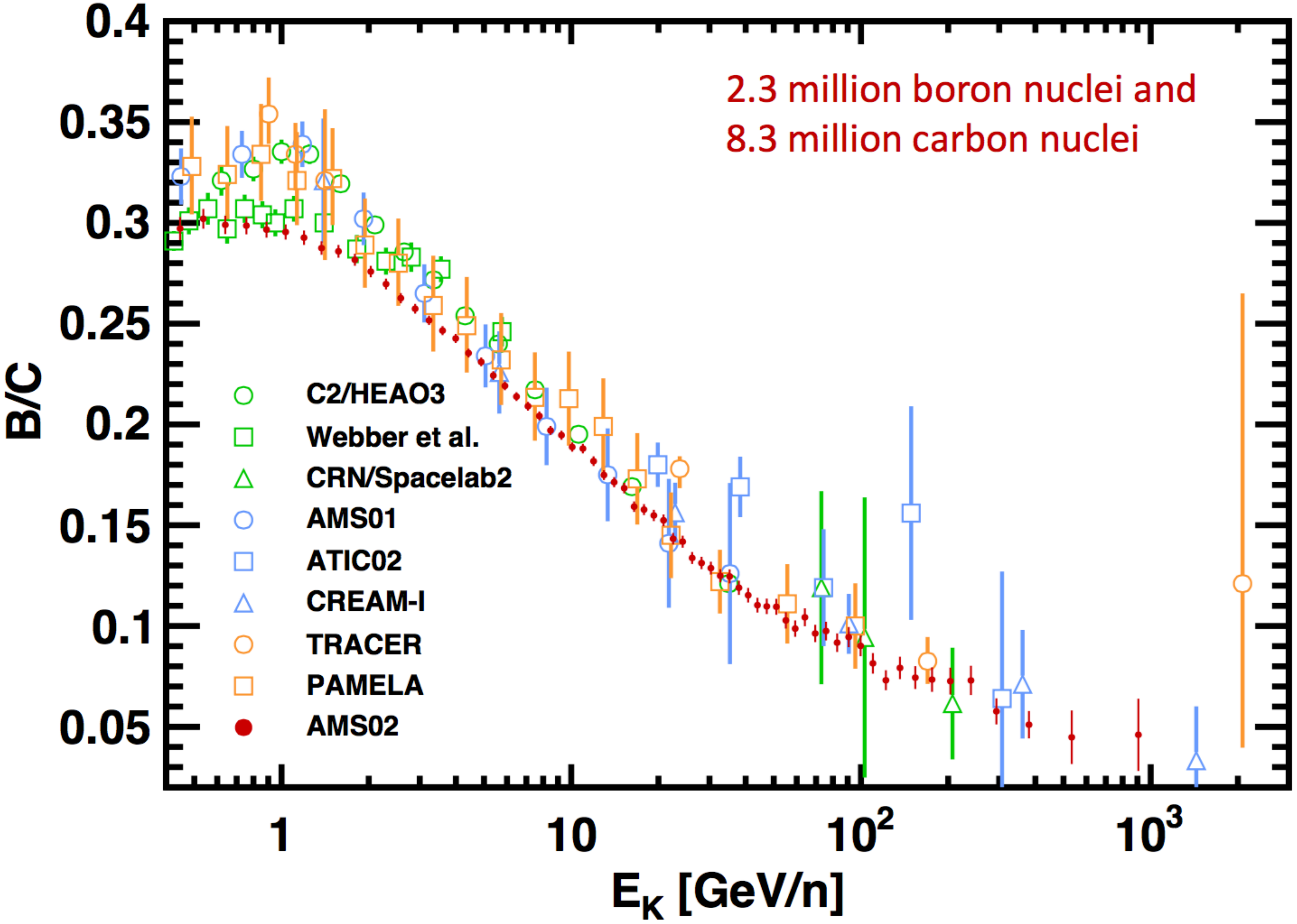


Cosmic ray propagation is commonly modeled as a fast moving gas diffusing through a magnetized plasma.

At high rigidities, models of the magnetized plasma predict different behavior for $B/C = kR^{\delta}$.

With the Kolmogorov turbulence model $\delta = -1/3$

The AMS boron-to-carbon (B/C) flux ratio



2.3 million boron nuclei and
8.3 million carbon nuclei

Theoretical models to explain the AMS positron fraction.

Among the 100’s of models there are three classes:

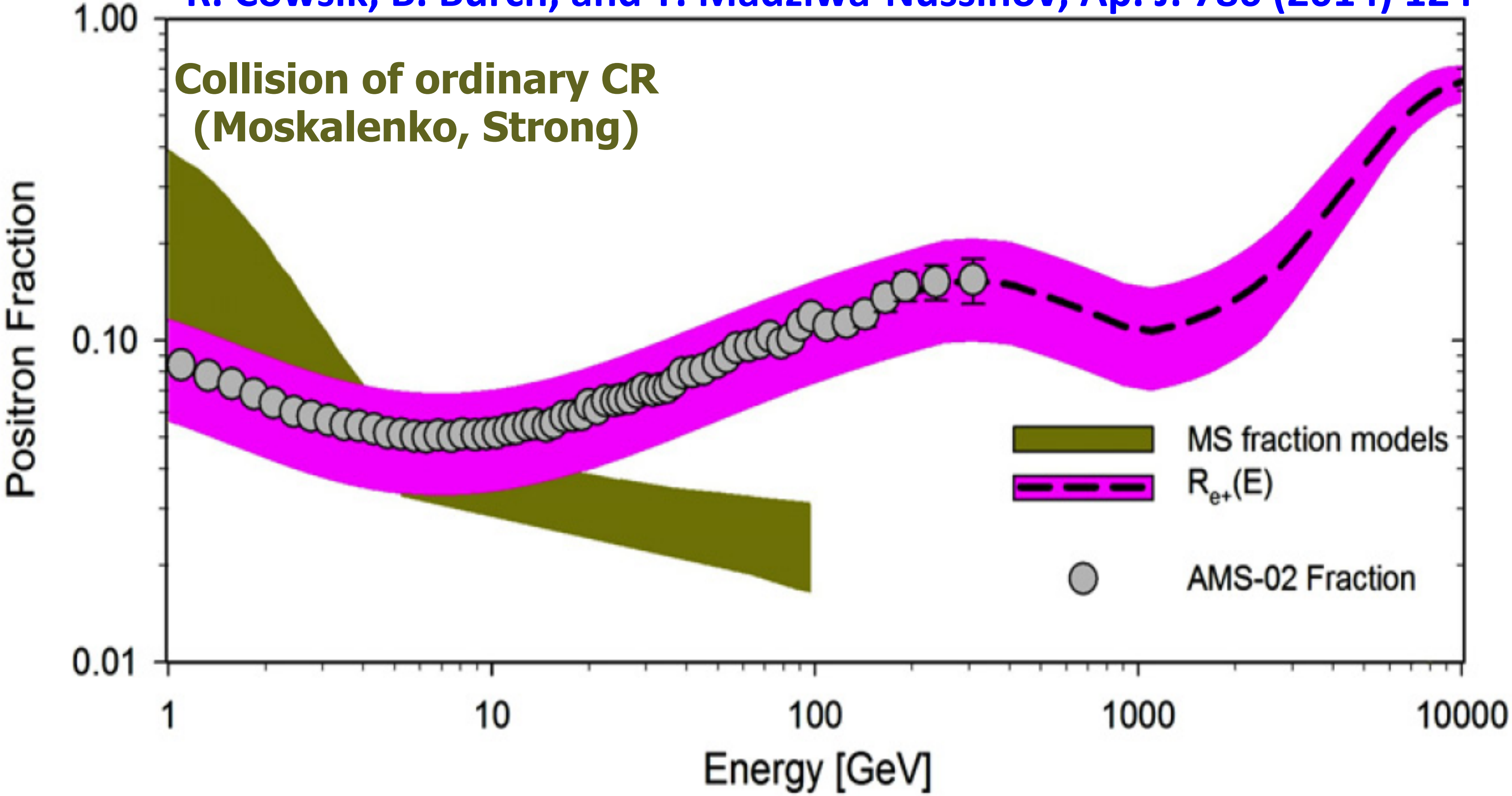
a) dark matter

b) new forms of propagation

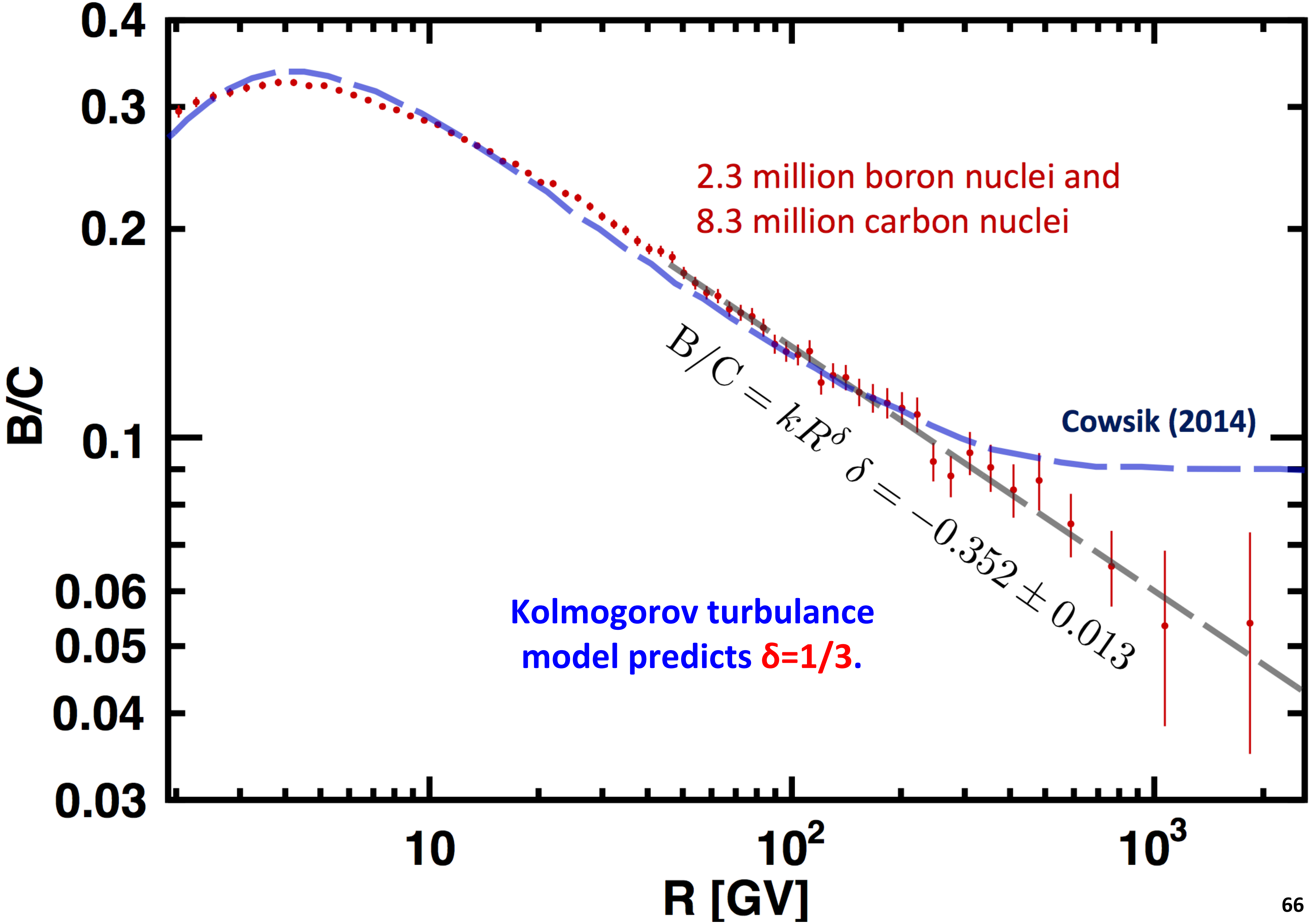
c) pulsars.

b) An example of new propagation:

R. Cowsik, B. Burch, and T. Madziwa-Nussinov, Ap. J. 786 (2014) 124



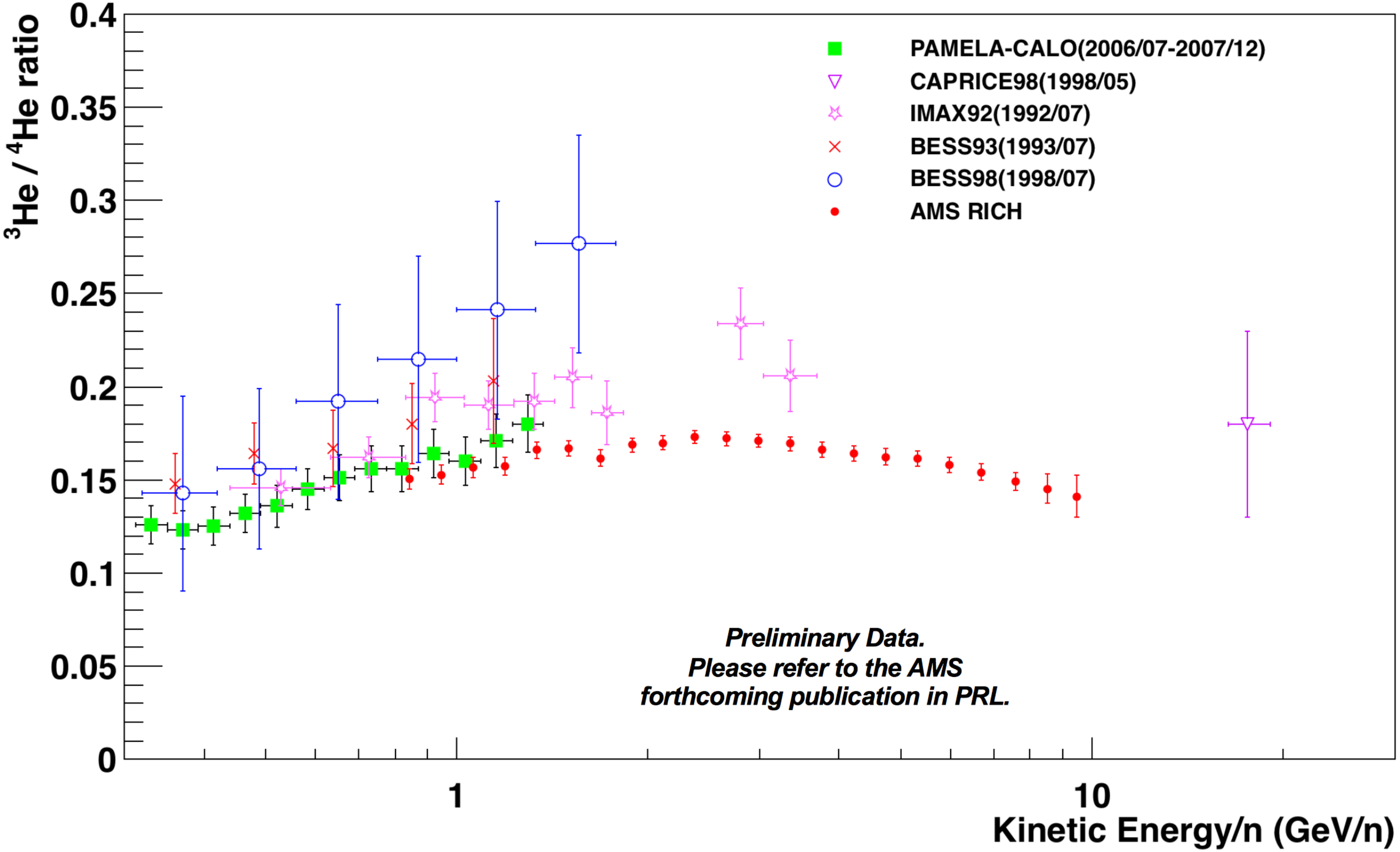
Collision of ordinary CR (Moskalenko, Strong)



2.3 million boron nuclei and
8.3 million carbon nuclei

Kolmogorov turbulance
model predicts δ=1/3.

AMS-02: ^{3}He/^{4}He vs Energy



Preliminary Data.
Please refer to the AMS
forthcoming publication in PRL.

Major Experiments measureing the combined (e^+ $+e^-$)

DAMPE

TA

HAWC

Fermi

LHAASO

MAGIC

CTA

ISS
CREAM

AMS

CALET

HESS

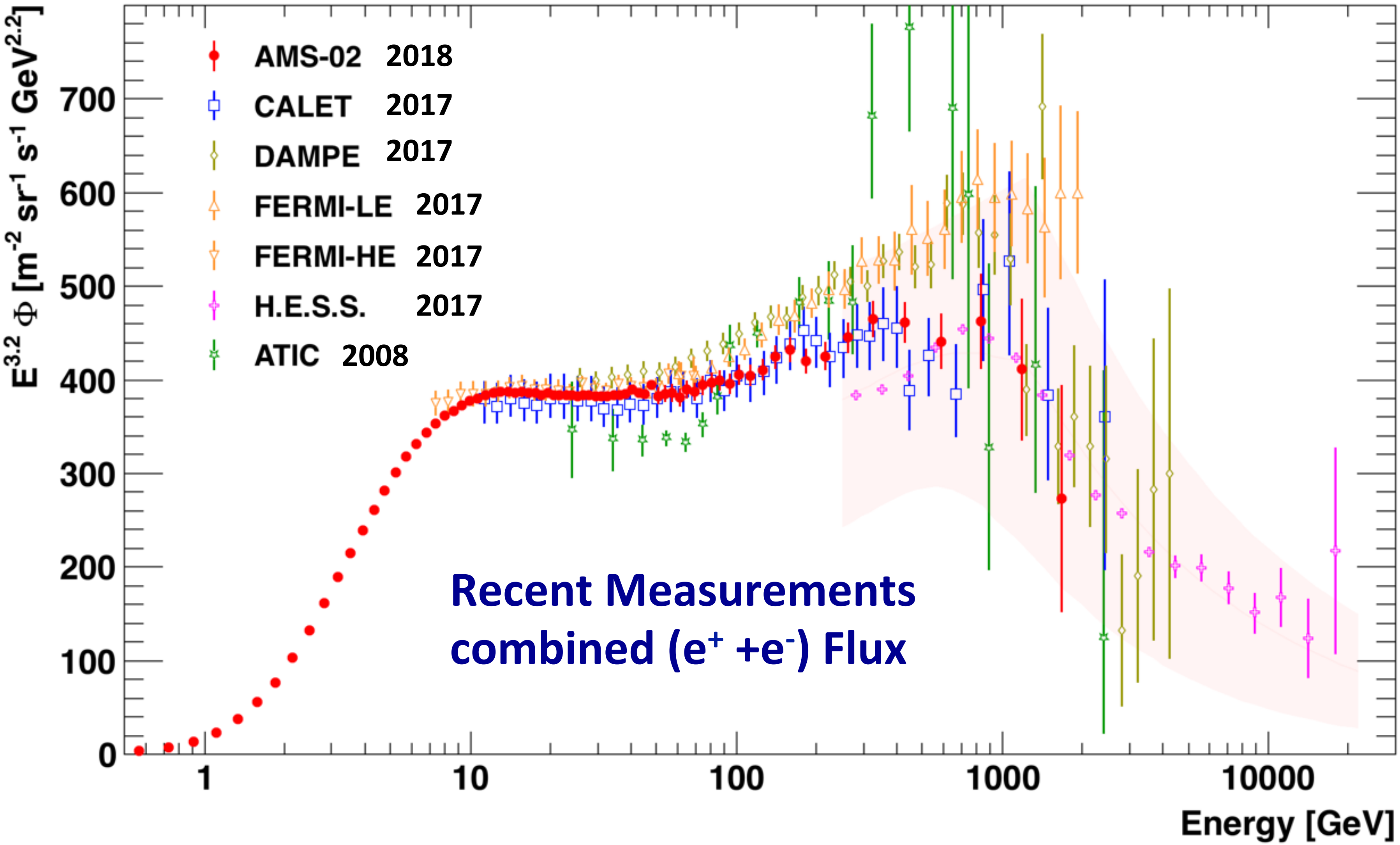
Auger

Poemma

Poemma

Experiments measureing independently
| the Electron- and Positron Flux.

- The combined ($e^+ + e^-$) Flux is a difficult measurement and difficult to interpret.
- The results of the space experiments are not consistent.
  They come in two groups: (AMS and CALET) ⇔ (FERMI and DAMPE).
- AMS and CALET are on the ISS, FERMI and DAMPE are satelite experiments.
  ISS altitude: 400 km, FERMI altitude: 550 km, DAMPE altitude: 500 km

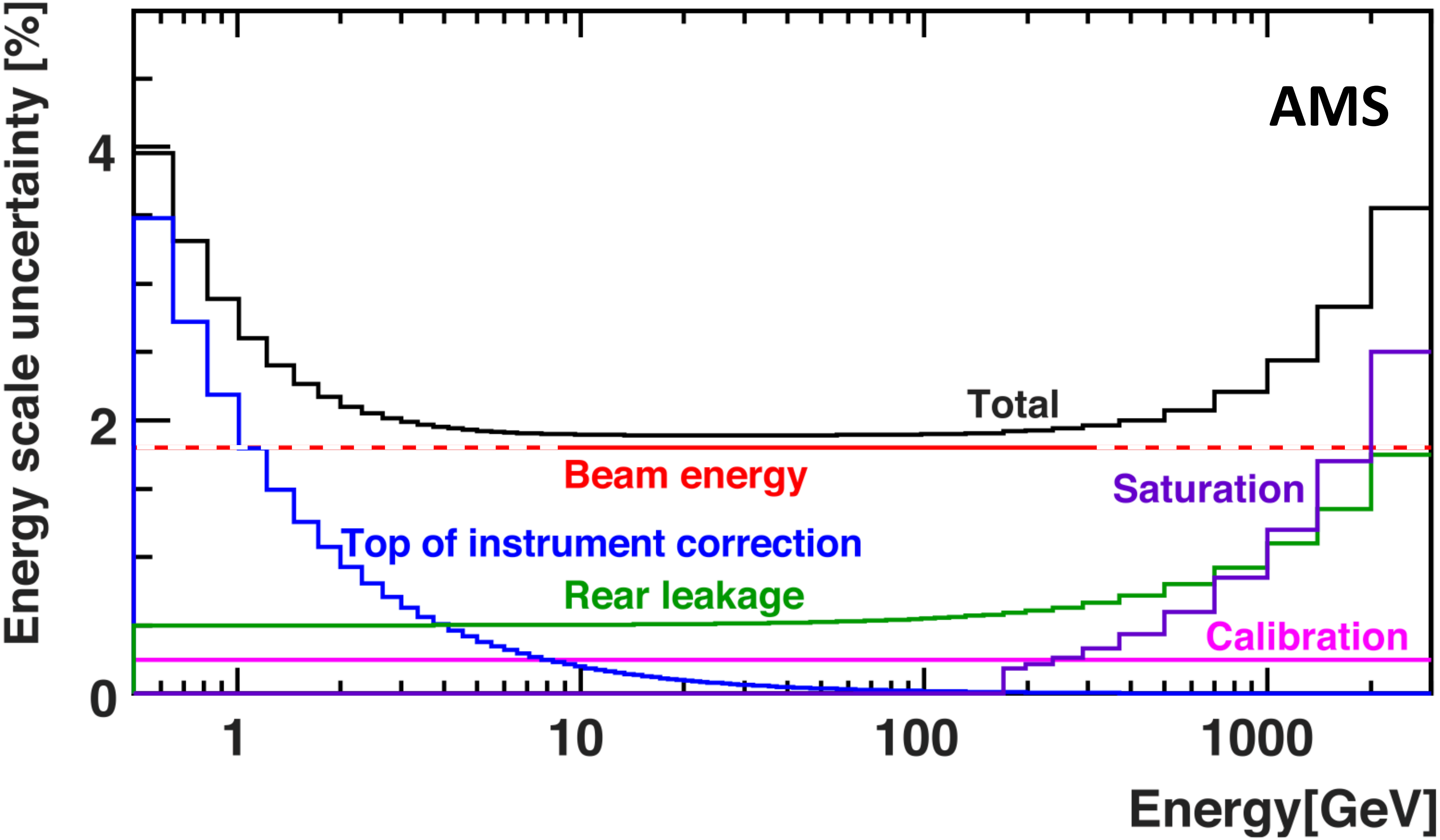


Recent Measurements combined ($e^+ + e^-$) Flux

Absolute Energy Scale for $e^{\pm}$ (at the top of AMS)

The effects which are experimentaly most difficult to control are non-linearities in the detector response, for AMS staturation effects in the ECAL fibers.

We have no test beam with 1 TeV Electrons !

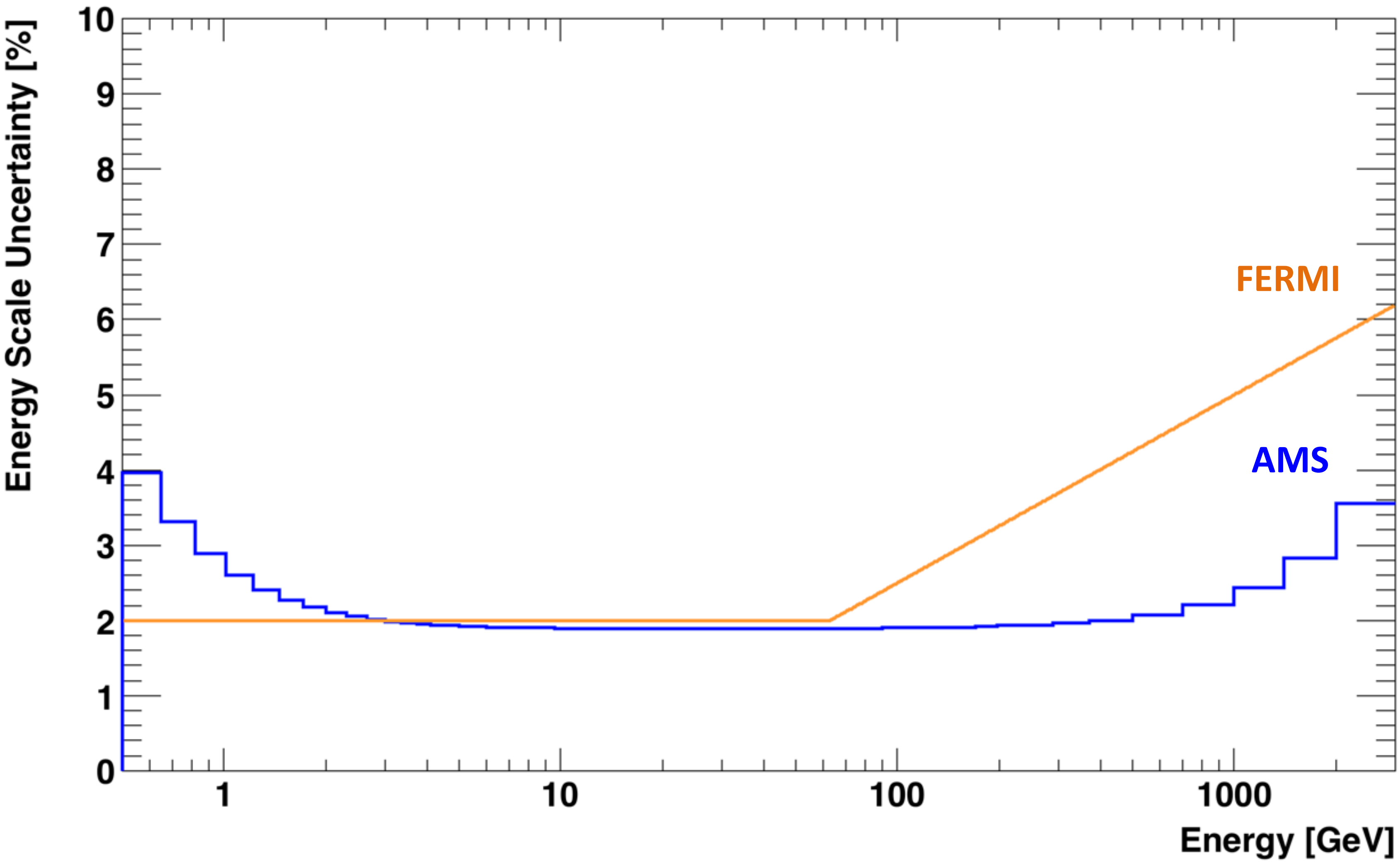


A. Kounine et al., NIM A 869 (2017) 110–117

FERMI Absolut Energy Scale , PHYSICAL REVIEW D 95, 082007 (2017):

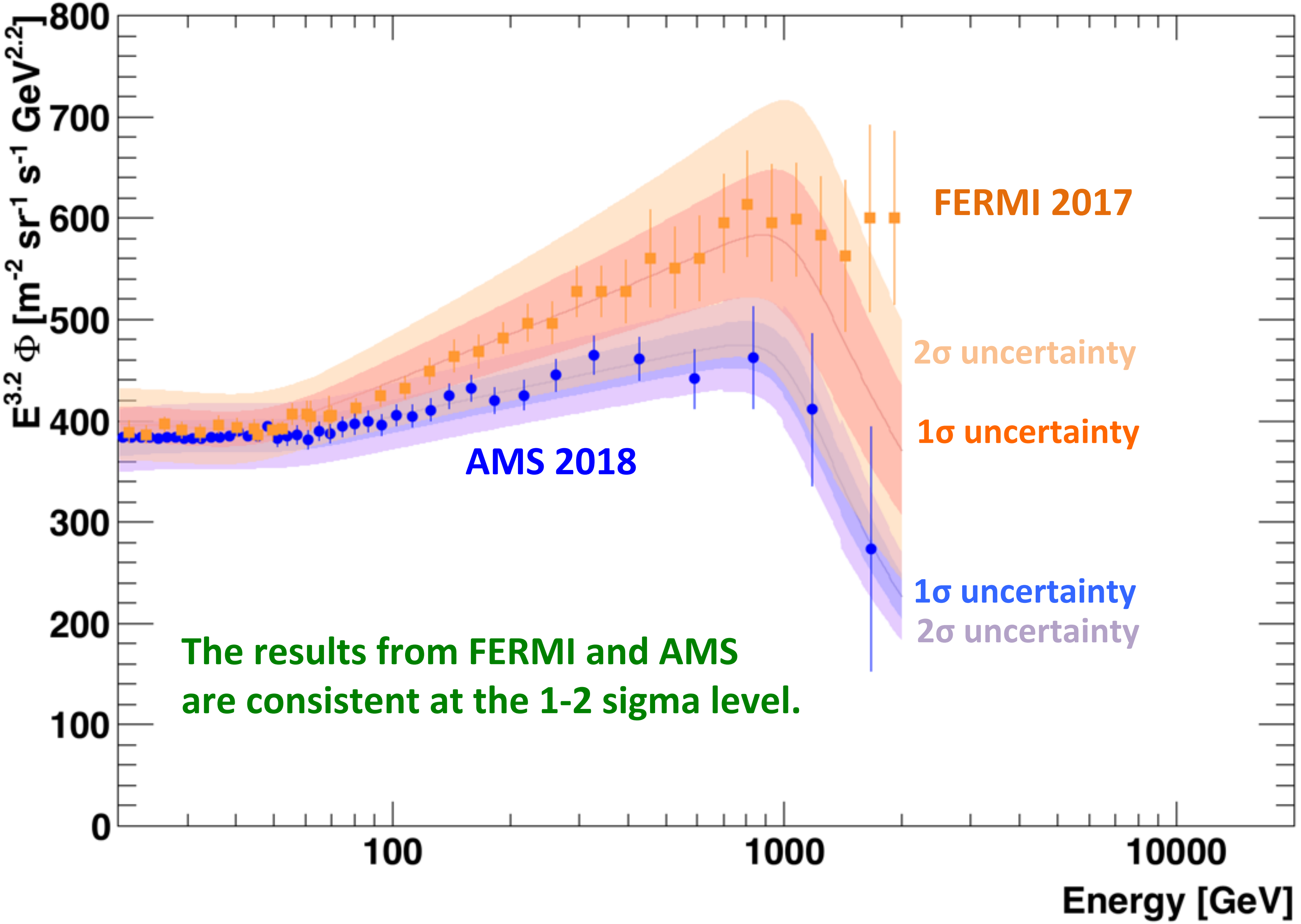
„The geomagnetic cutoff in the CRE spectrum at about 10 GeV provides a spectral feature that allows an absolute calibration of the LAT energy scale. ...
... that the systematic uncertainty on the absolute energy scale is 2%.“

„... total reconstructed energy varies linearly with log10 E as $\delta E_{rec}(E)=0.025 \log10(E/10GeV)$“.



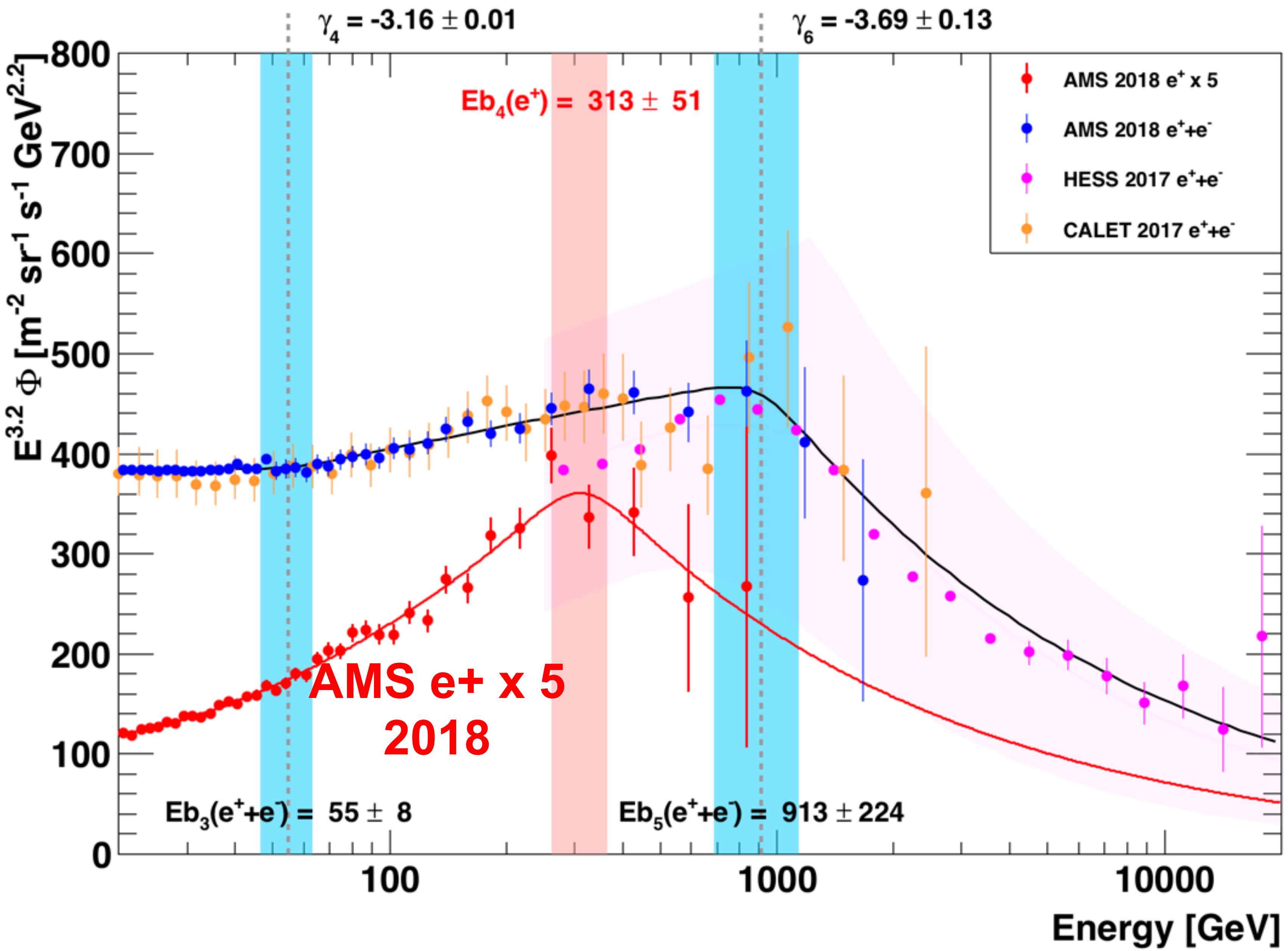
The absolute Energy Scale Uncertainty leads to an uncertainty on the Flux of:

$$\frac{\sigma(\Phi)}{\Phi} = (\gamma - 1)\frac{\sigma(E)}{E} \quad \text{for } \Phi(E) = C \cdot E^{-\gamma}$$

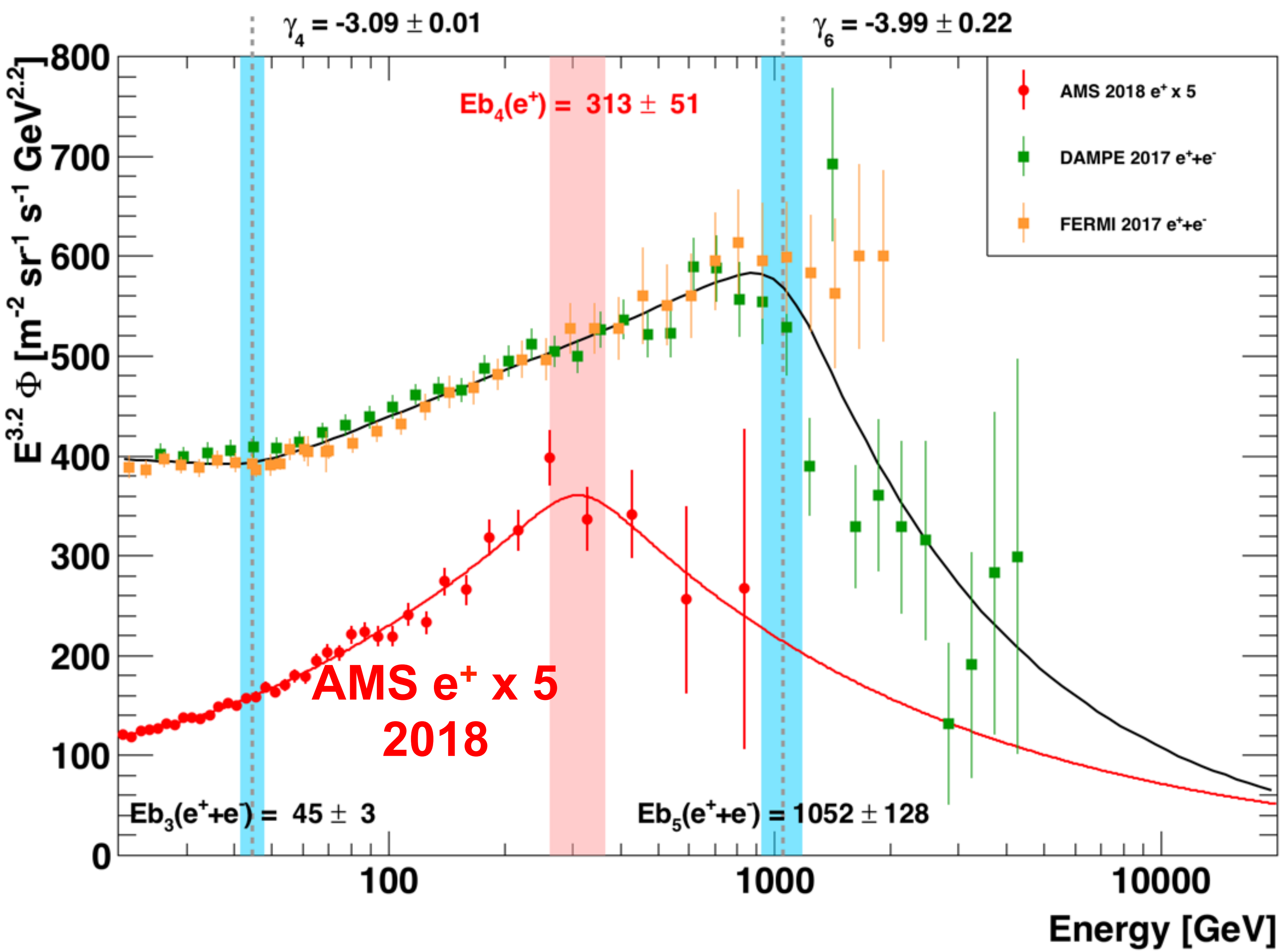


The results from FERMI and AMS are consistent at the 1-2 sigma level.

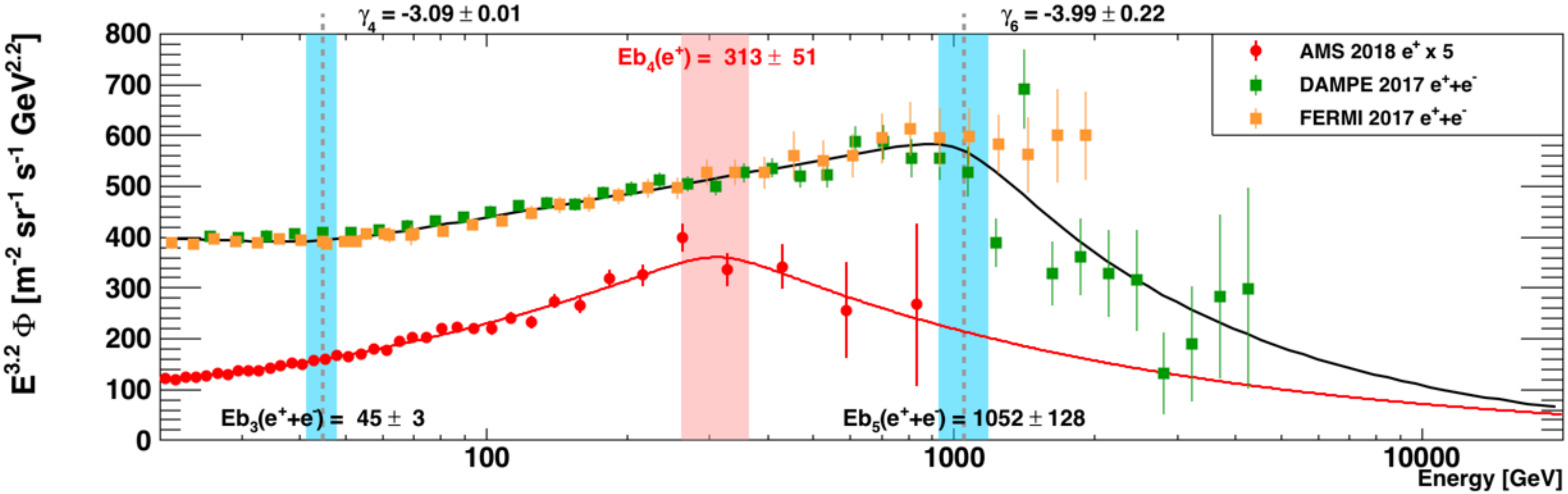
AMS e+ Data compared to AMS & HESS & CALET (e+ + e-) Data

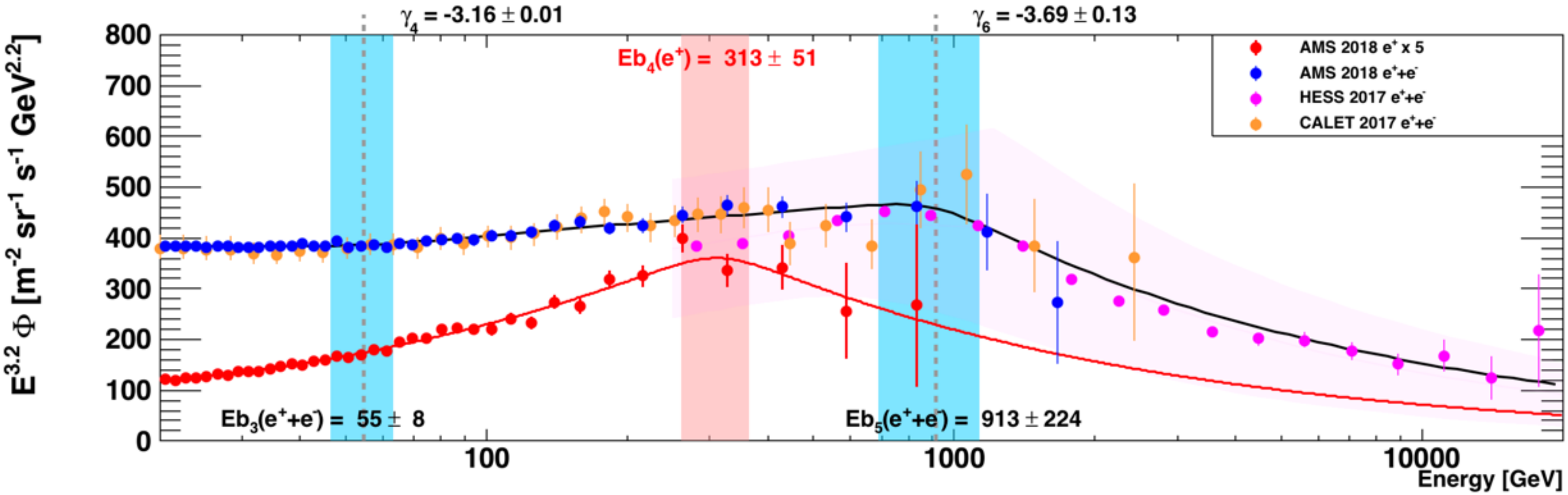


AMS e+ Data compared to DAMPE & FERMI (e+ + e-) Data



- **The energies of the two spectral breaks observed in the combined (e^++e^-) Flux are consistent between the experiments within the uncertainties.**
- **This is less clear for the spectral indices without assumptions on the energy scale uncertainties of all the experiments.**





Science

HAWC Collaboration, *Science* 358, 911-914 (2017)

Extended gamma-ray sources around pulsars constrain the origin of the positron flux at Earth

The unexpectedly high flux of cosmic-ray positrons detected at Earth may originate from nearby astrophysical sources, dark matter, or unknown processes of cosmic-ray secondary production. We report the detection, using the High-Altitude Water Cherenkov Observatory (HAWC), of extended tera–electron volt gamma-ray emission coincident with the locations of two nearby middle-aged pulsars (Geminga and PSR B0656+14). The HAWC observations demonstrate that these pulsars are indeed local sources of accelerated leptons, but the measured tera–electron volt emission profile constrains the diffusion of particles away from these sources to be much slower than previously assumed. We demonstrate that the leptons emitted by these objects are therefore unlikely to be the origin of the excess positrons, which may have a more exotic origin.