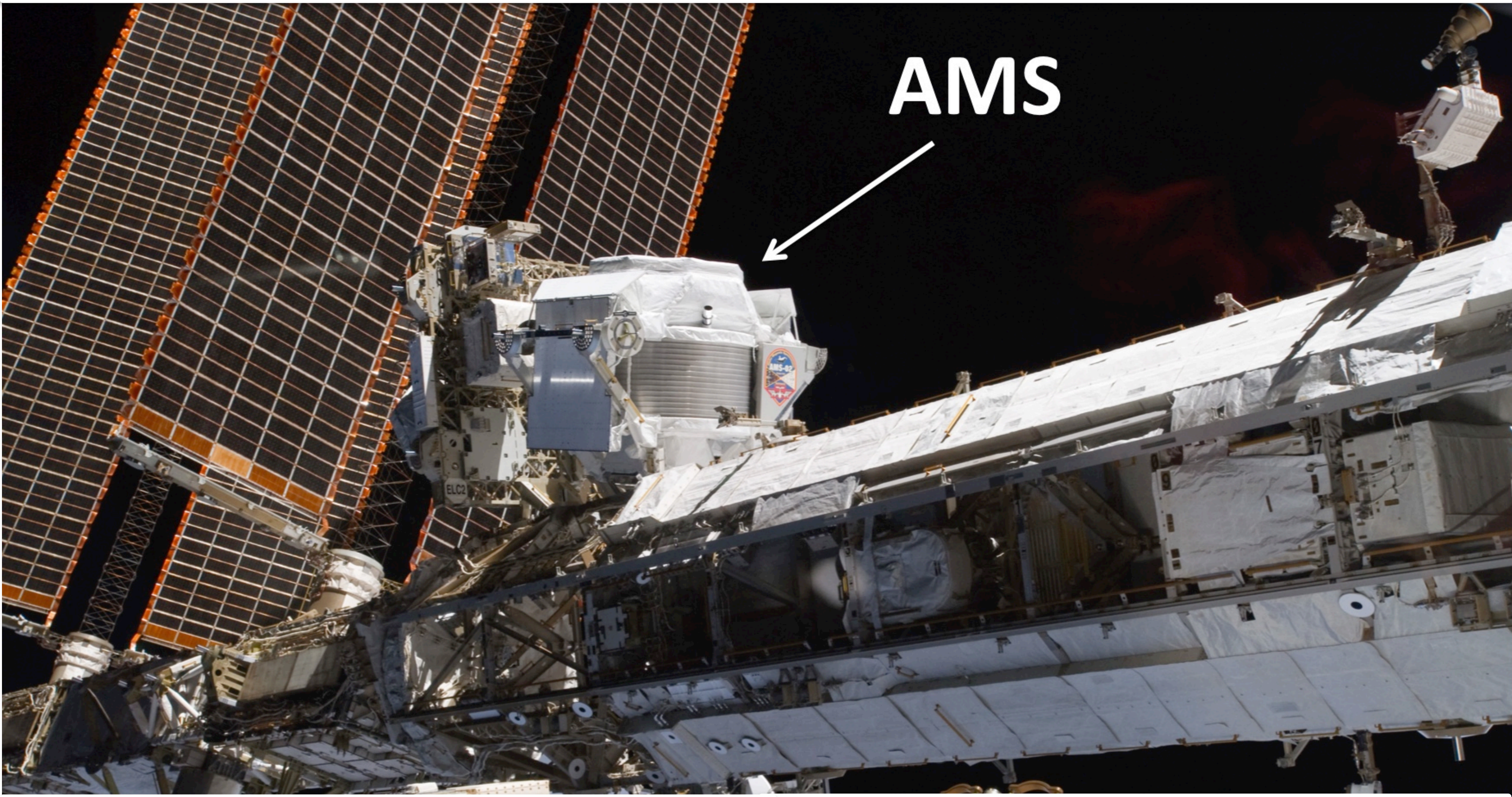
New Results from the AMS Experiment on the ISS

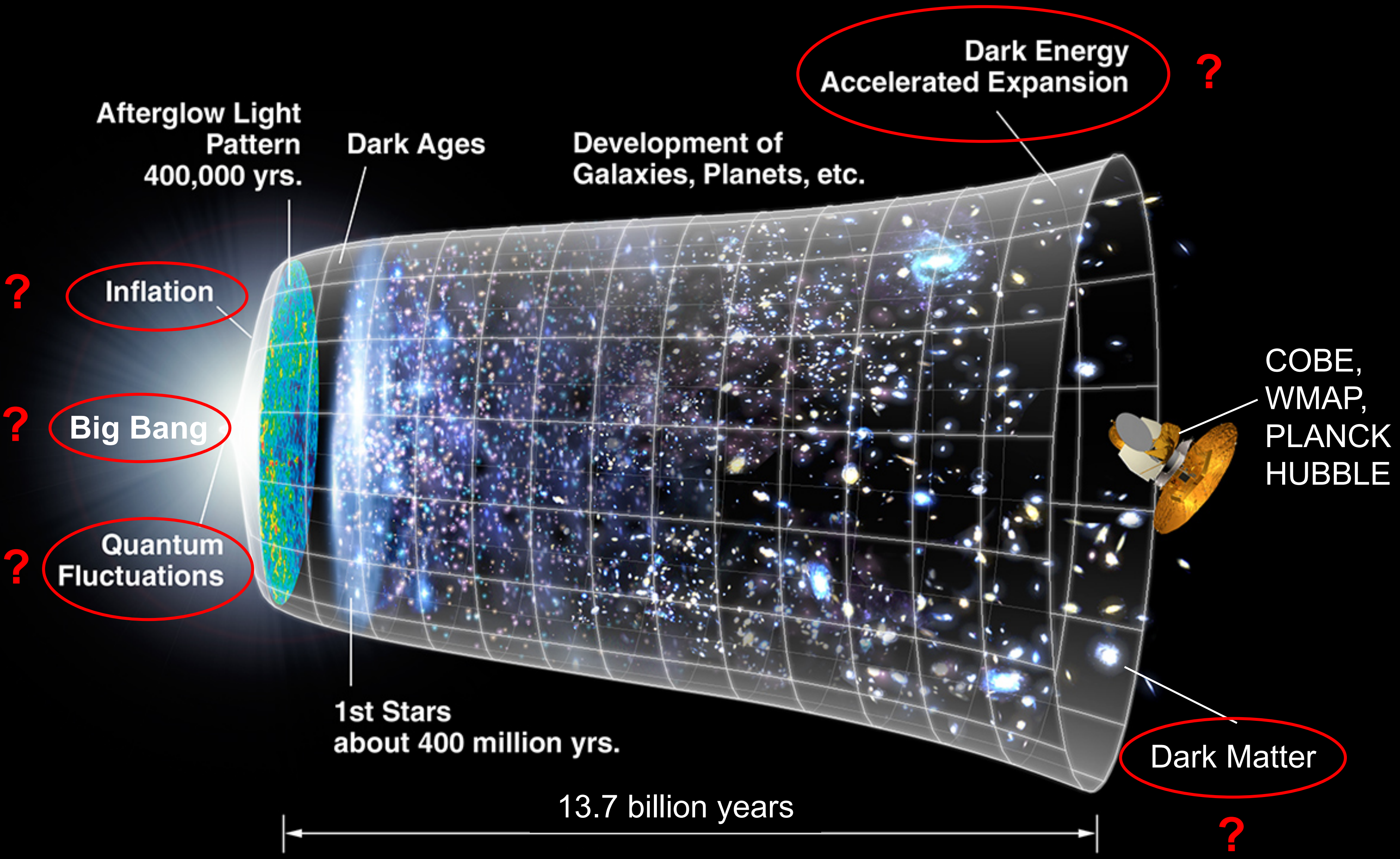


WE-Heraeus Symposium

Physikzentrum Bad Honnef

29. – 31. Oktober 2018

S. Schael, RWTH Aachen University



Dark Energy
Accelerated Expansion ?

Afterglow Light
Pattern
400,000 yrs.

Dark Ages

Development of
Galaxies, Planets, etc.

? Inflation

? Big Bang

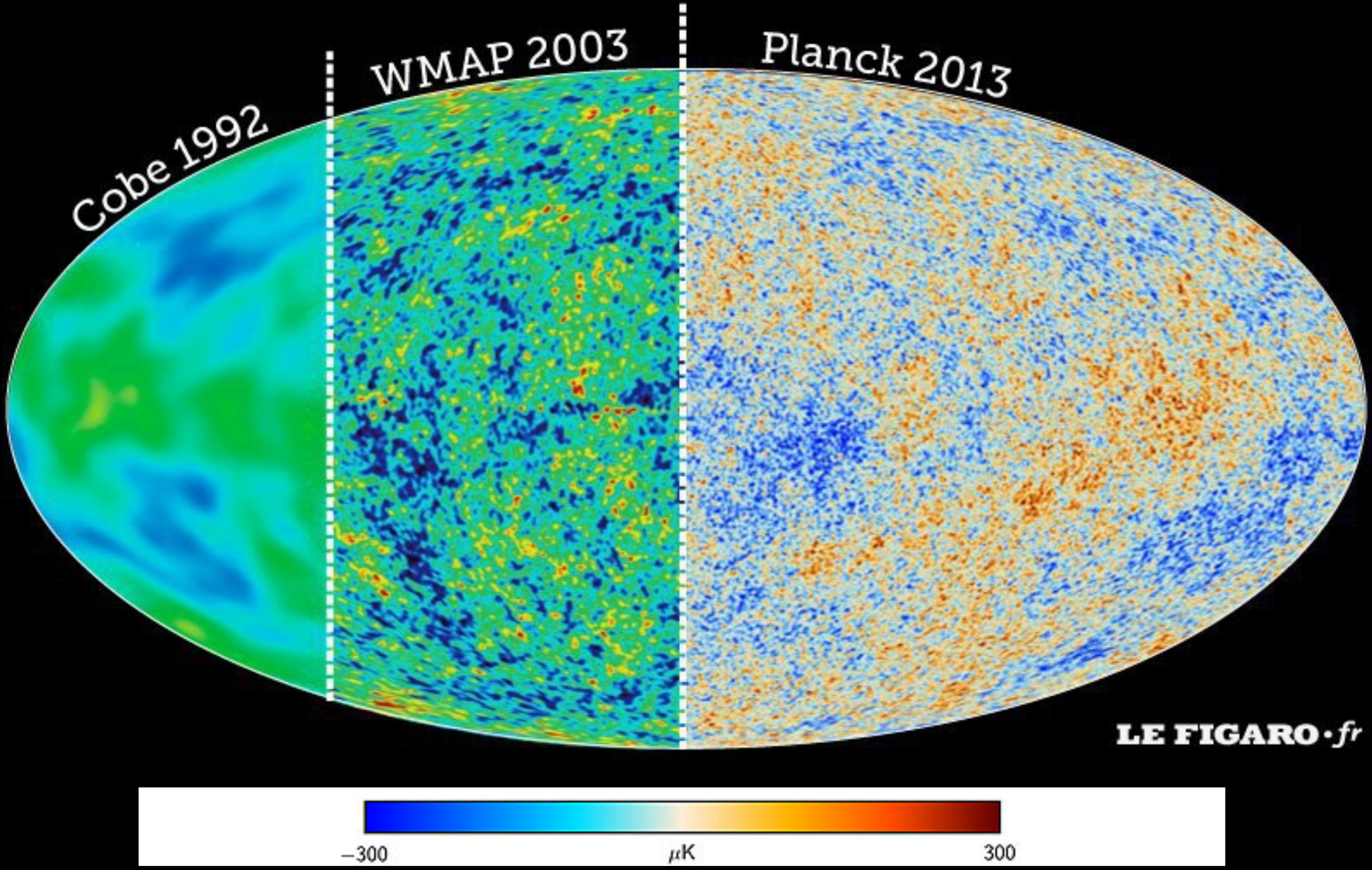
? Quantum
Fluctuations

COBE,
WMAP,
PLANCK
HUBBLE

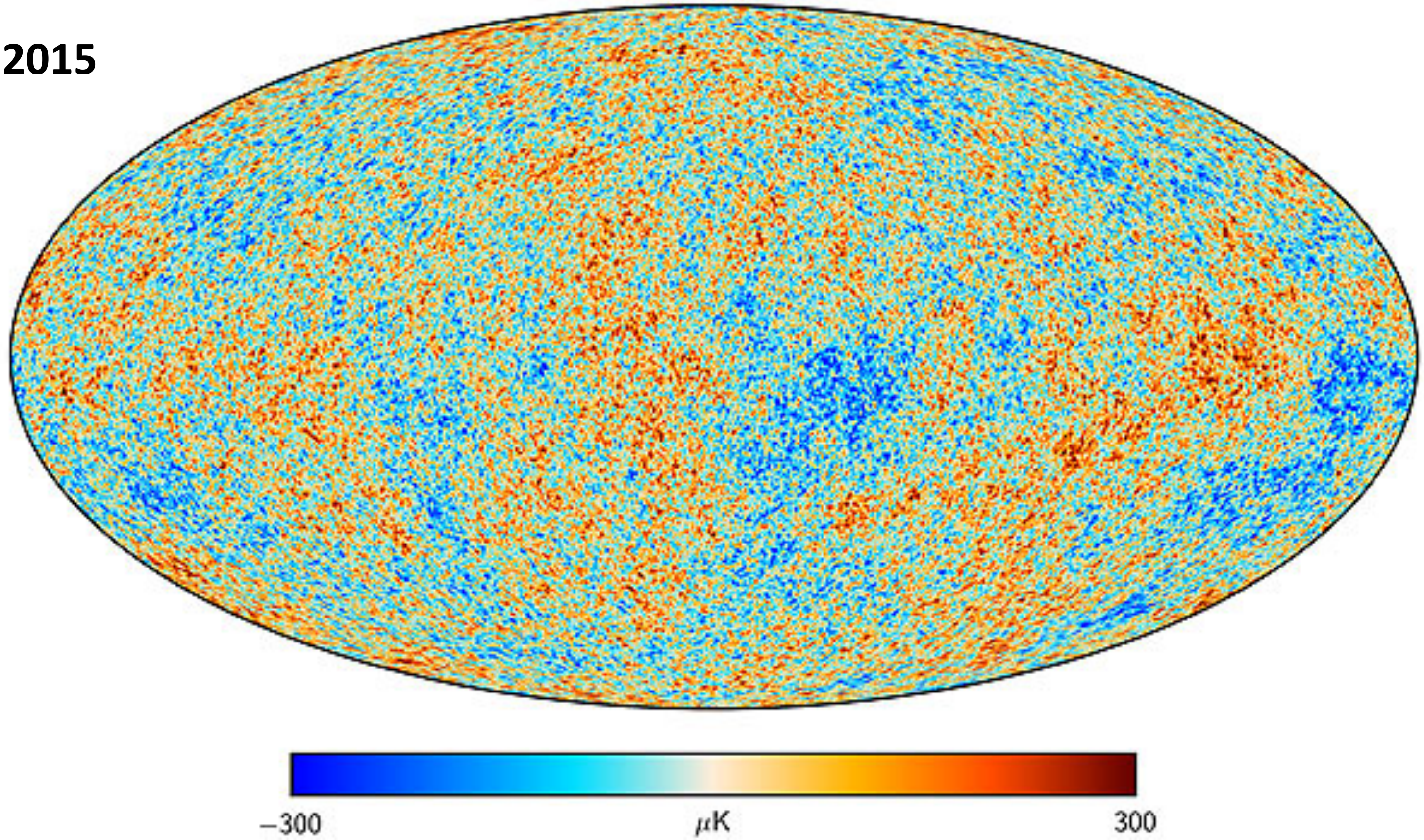
1st Stars
about 400 million yrs.

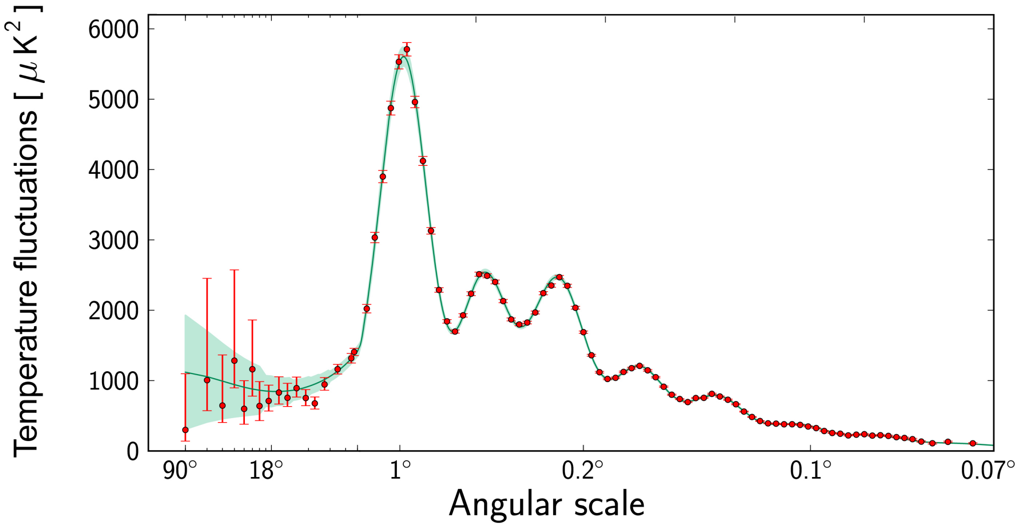
Dark Matter
?

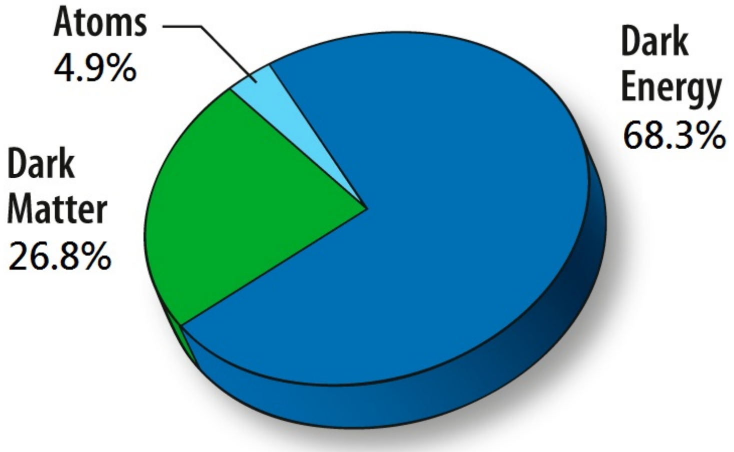
13.7 billion years

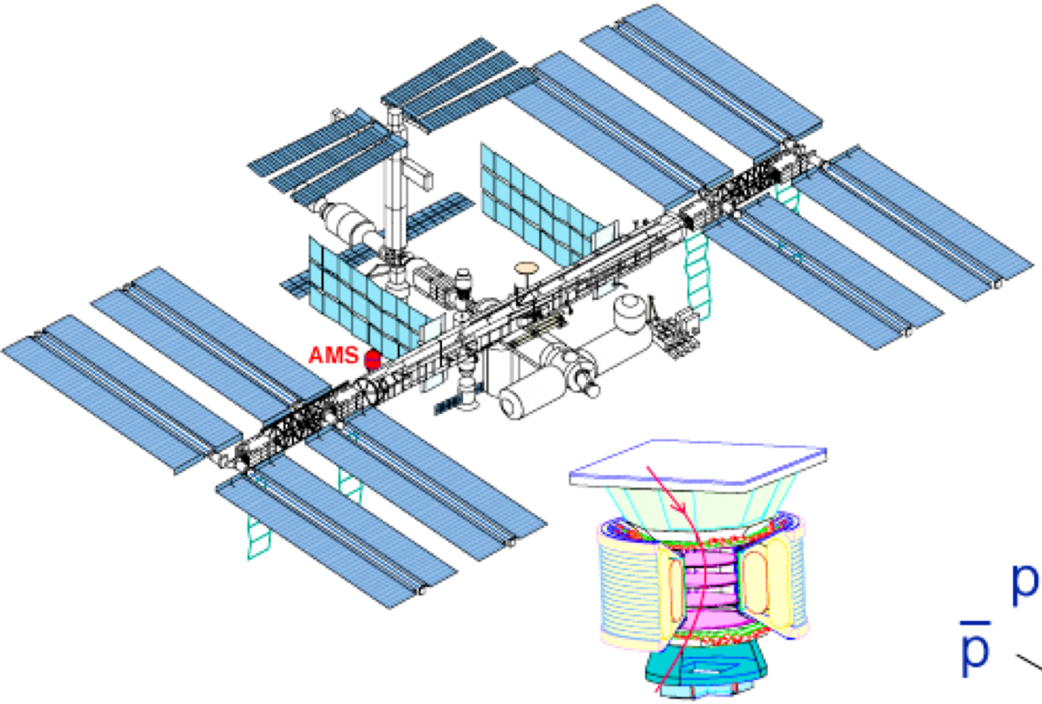

Cobe 1992
WMAP 2003
Planck 2013
LE FIGARO·fr
−300
μK
300

PLANCK 2015


−300
μK
300


Temperature fluctuations [μK²]
6000
5000
4000
3000
2000
1000
0
90°
18°
1°
0.2°
0.1°
0.07°
Angular scale


Atoms
4.9%
Dark
Energy
68.3%
Dark
Matter
26.8%



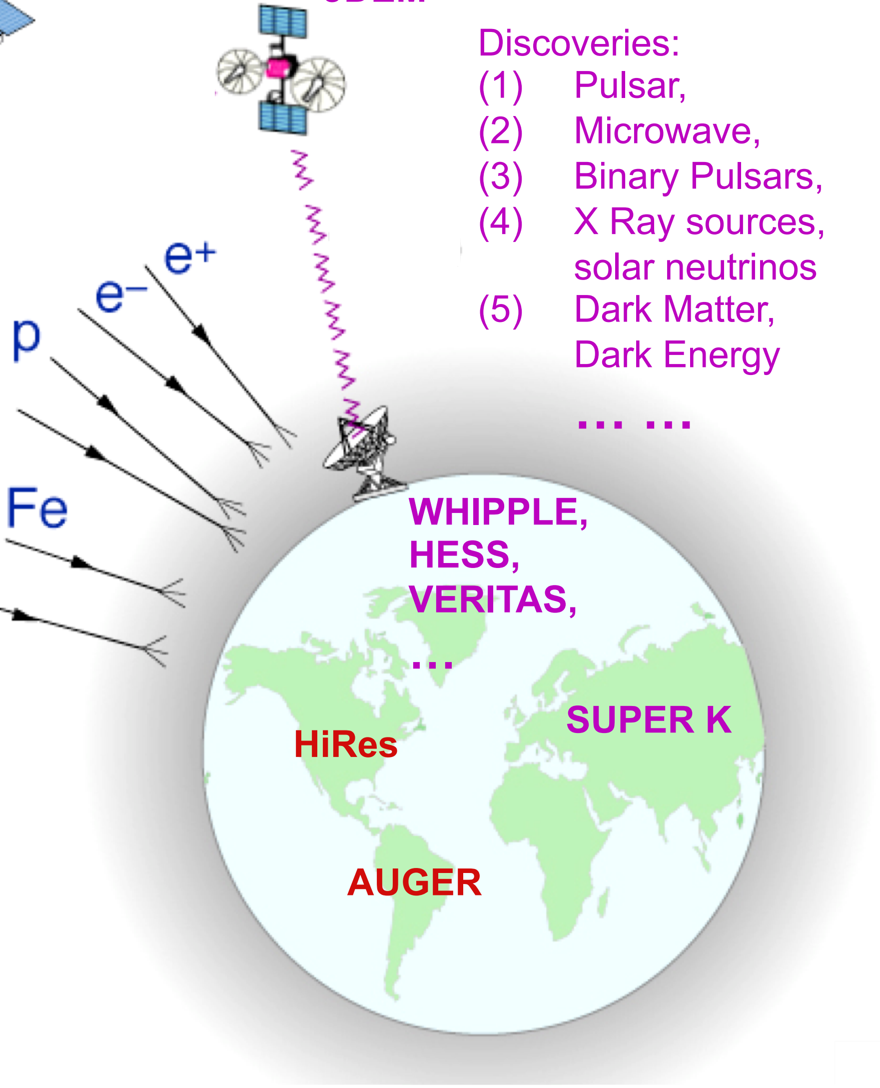
1- Neutral component:

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

$\overline{\mathrm{He}}$,

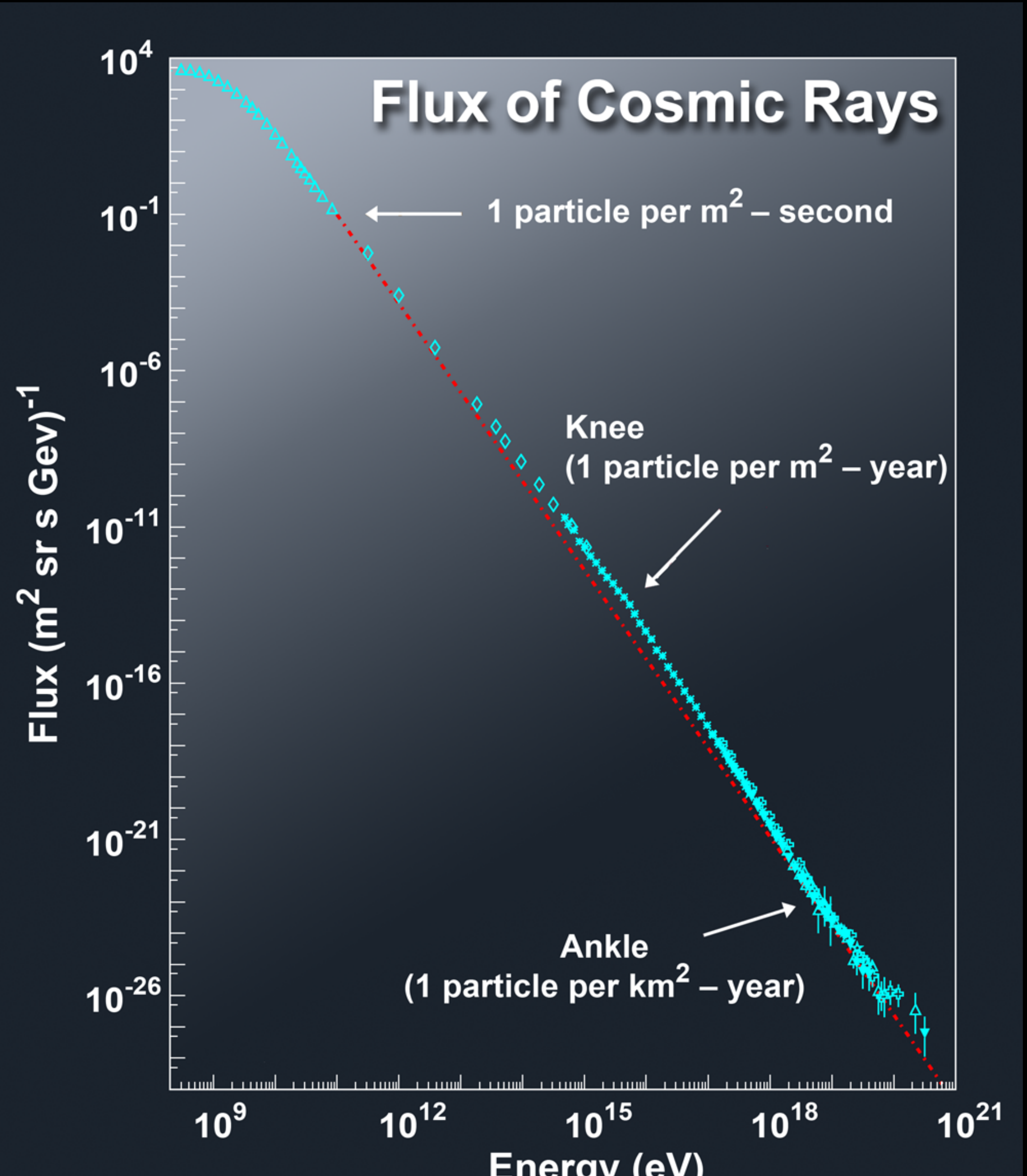
WHIPPLE, HESS, VERITAS, …

HiRes

SUPER K

AUGER

S. Ting, MIT



(source: Swordy – U.Chicago)

1 eV = 1,6 10^{-19} J

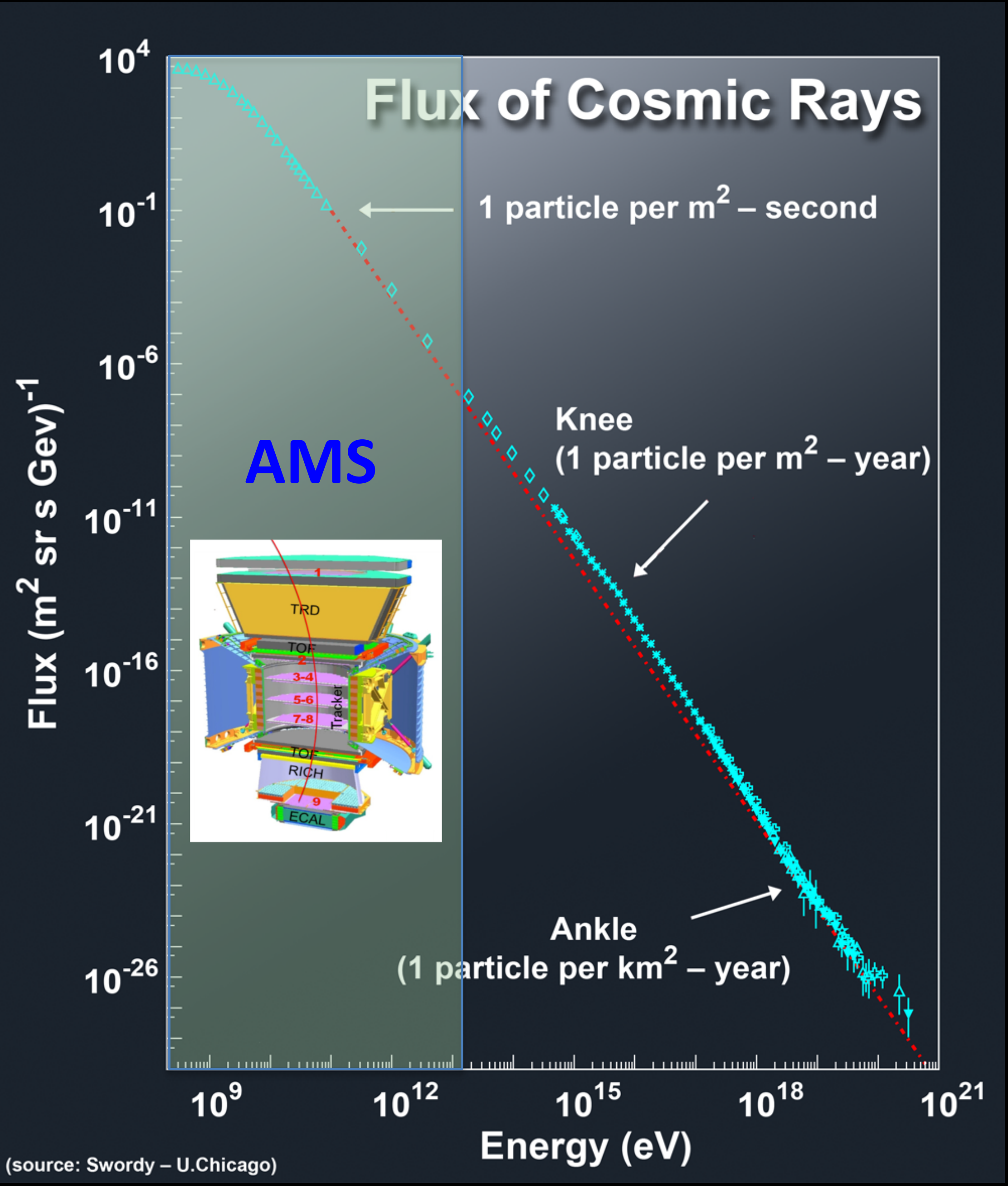
The cosmic ray flux follows a power law

$$\phi = C \cdot E^{-\gamma}$$

with $\gamma \approx 2.7$.

At low energies we see the modulation due to the solar magnetic field.

We observe spectral breaks at the “Knee” and the “Ankle”.



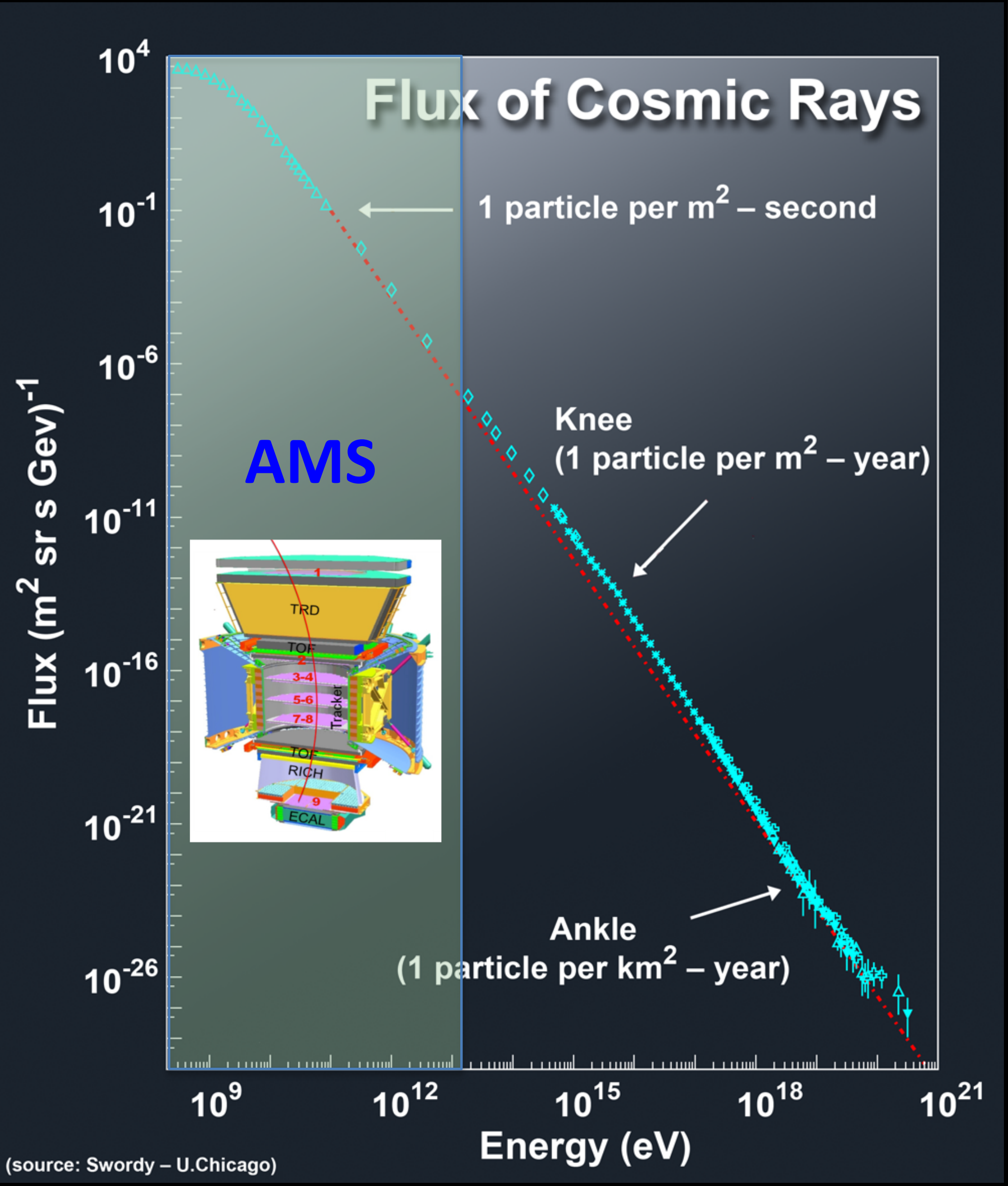
1 particle per m^2 – second

Knee
(1 particle per m^2 – year)

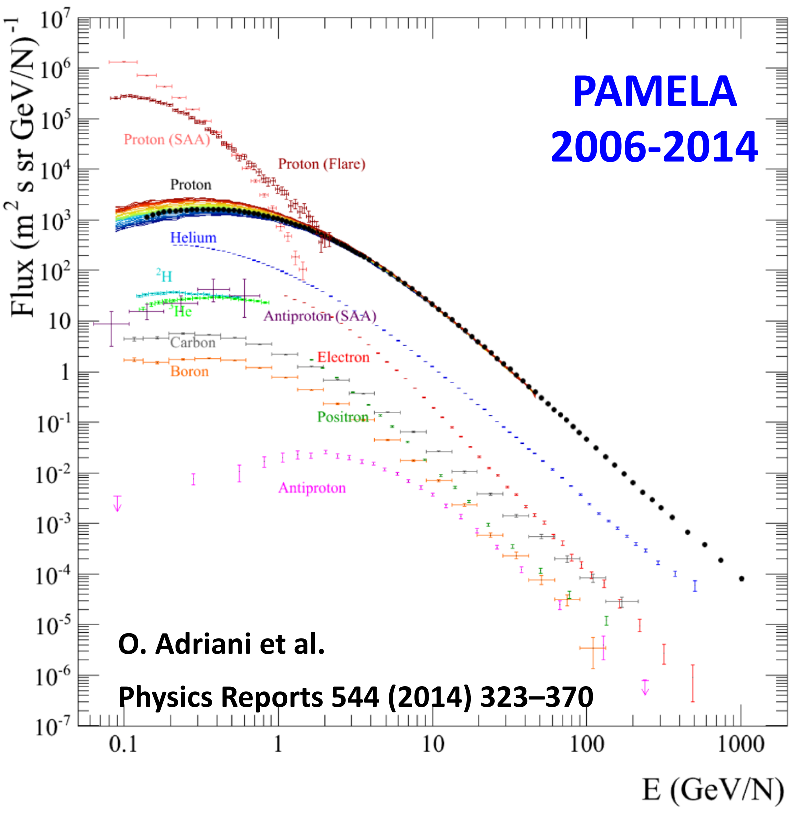
Ankle
(1 particle per km^2 – year)

(source: Swordy – U.Chicago)

1 eV = 1,6 10^{-19} J



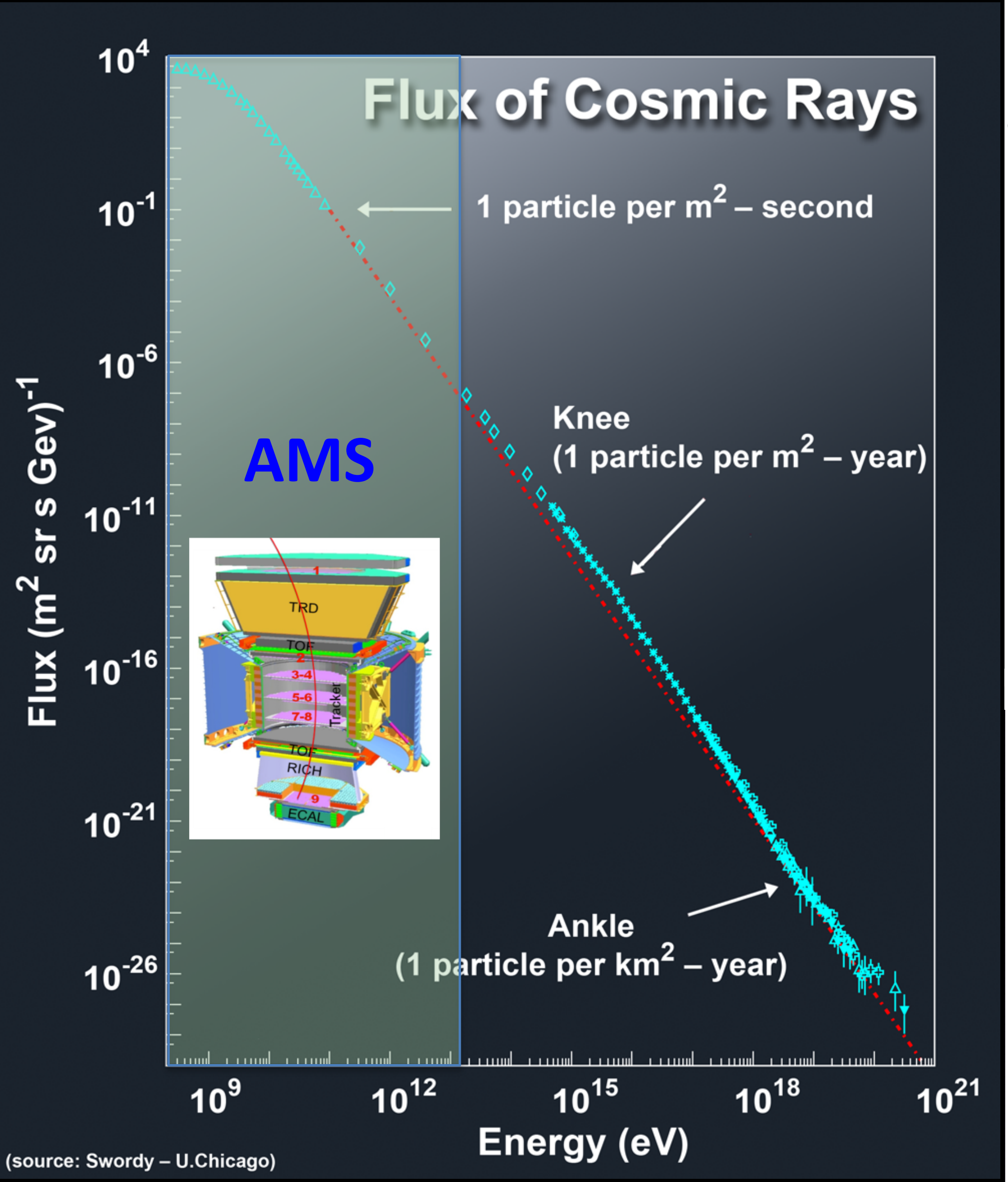
(source: Swordy – U.Chicago)



O. Adriani et al.

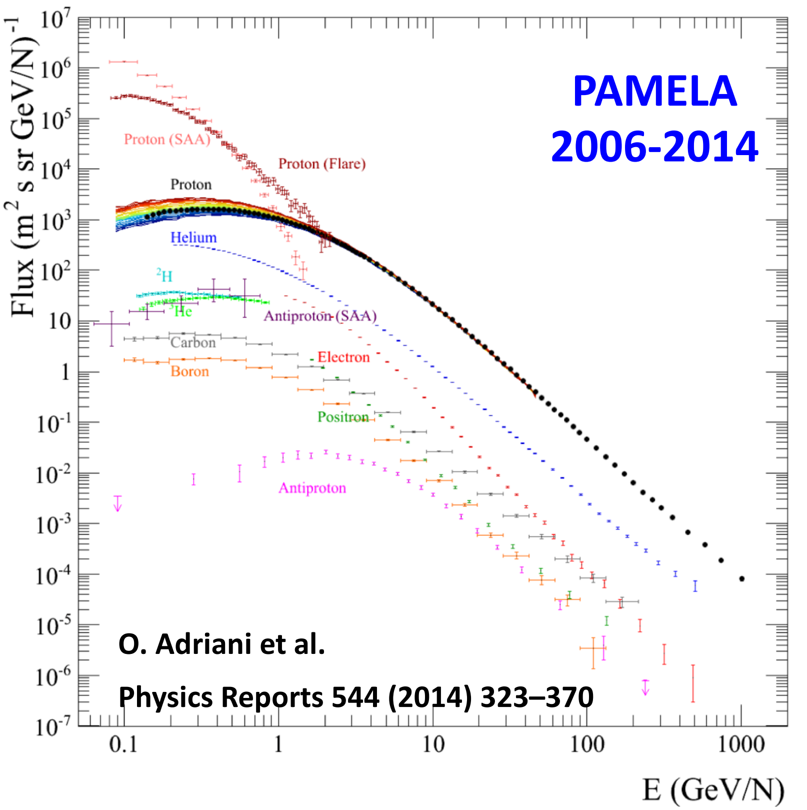
Physics Reports 544 (2014) 323–370

1 eV = 1,6 10^{-19} J



(source: Swordy – U.Chicago)

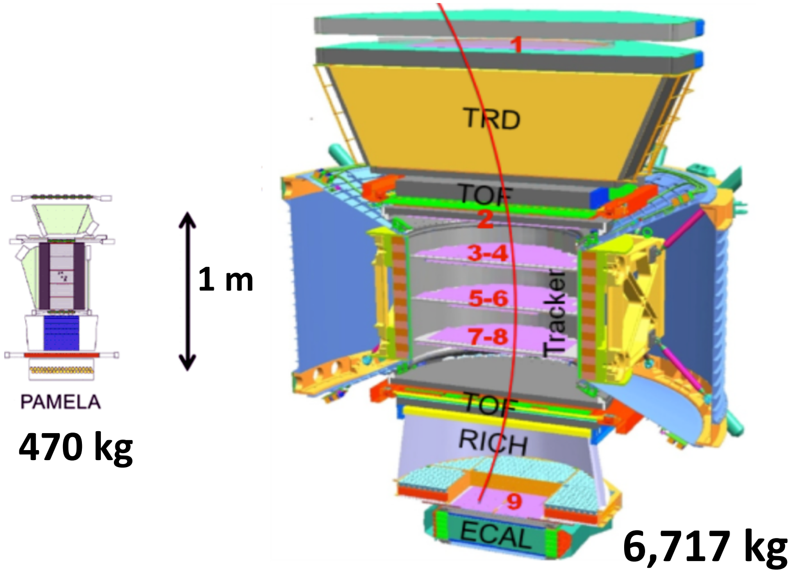
1 eV = 1,6 10^{-19} J



PAMELA
2006-2014

O. Adriani et al.

Physics Reports 544 (2014) 323–370

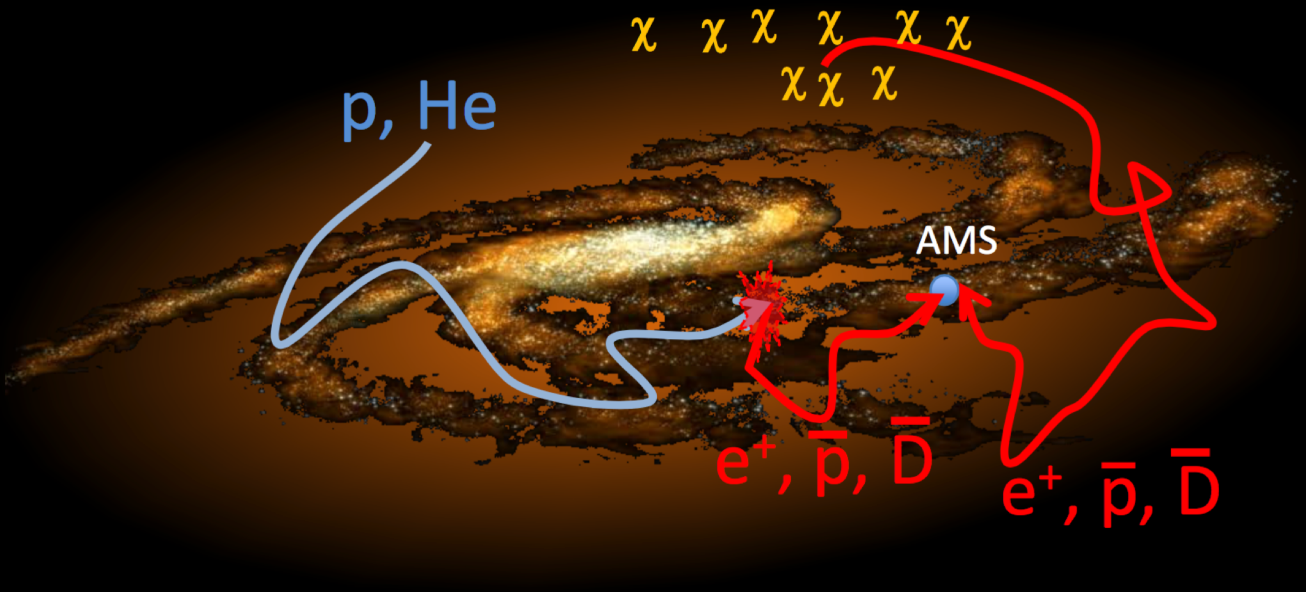


Dark Matter

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



Dark Matter

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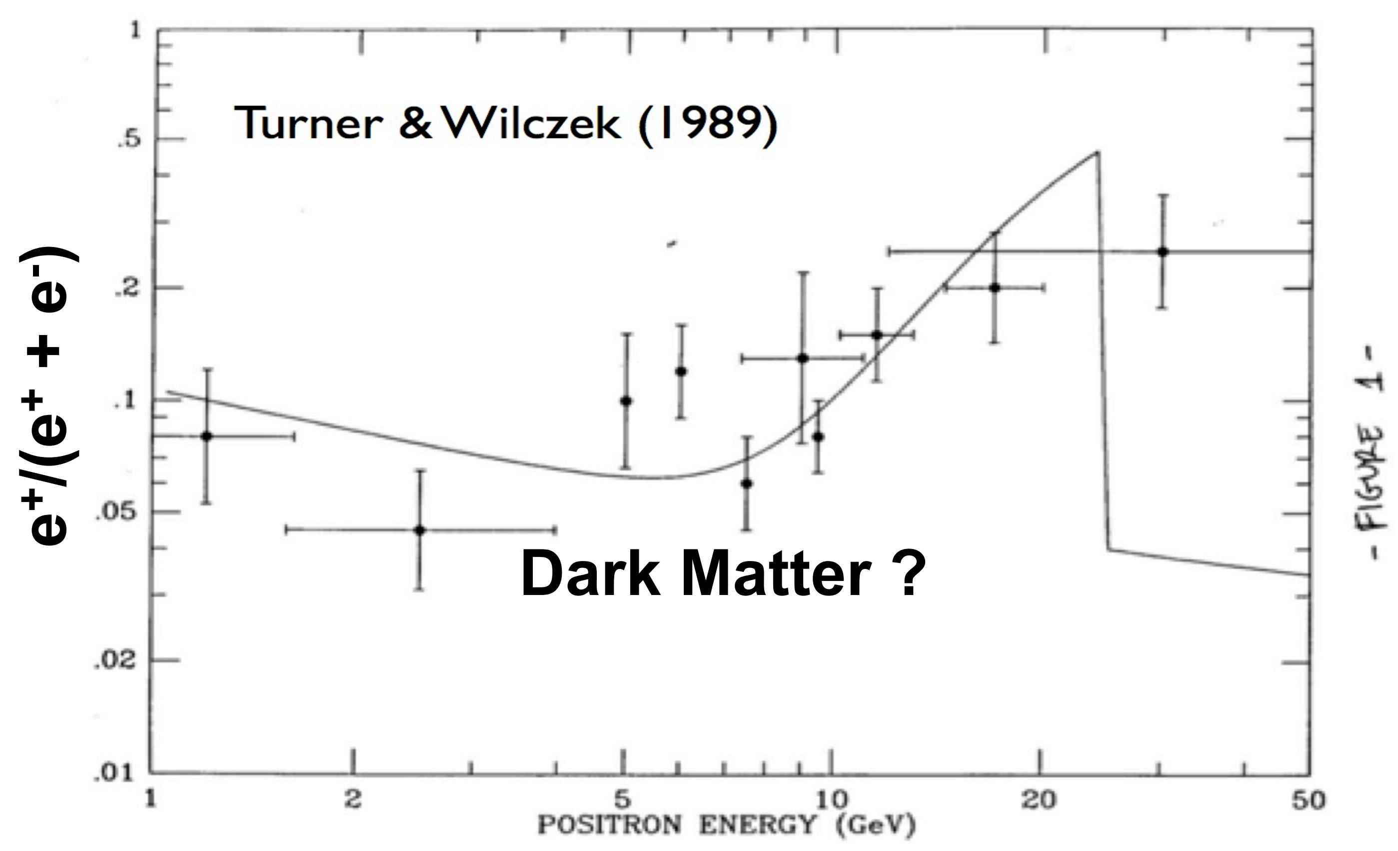
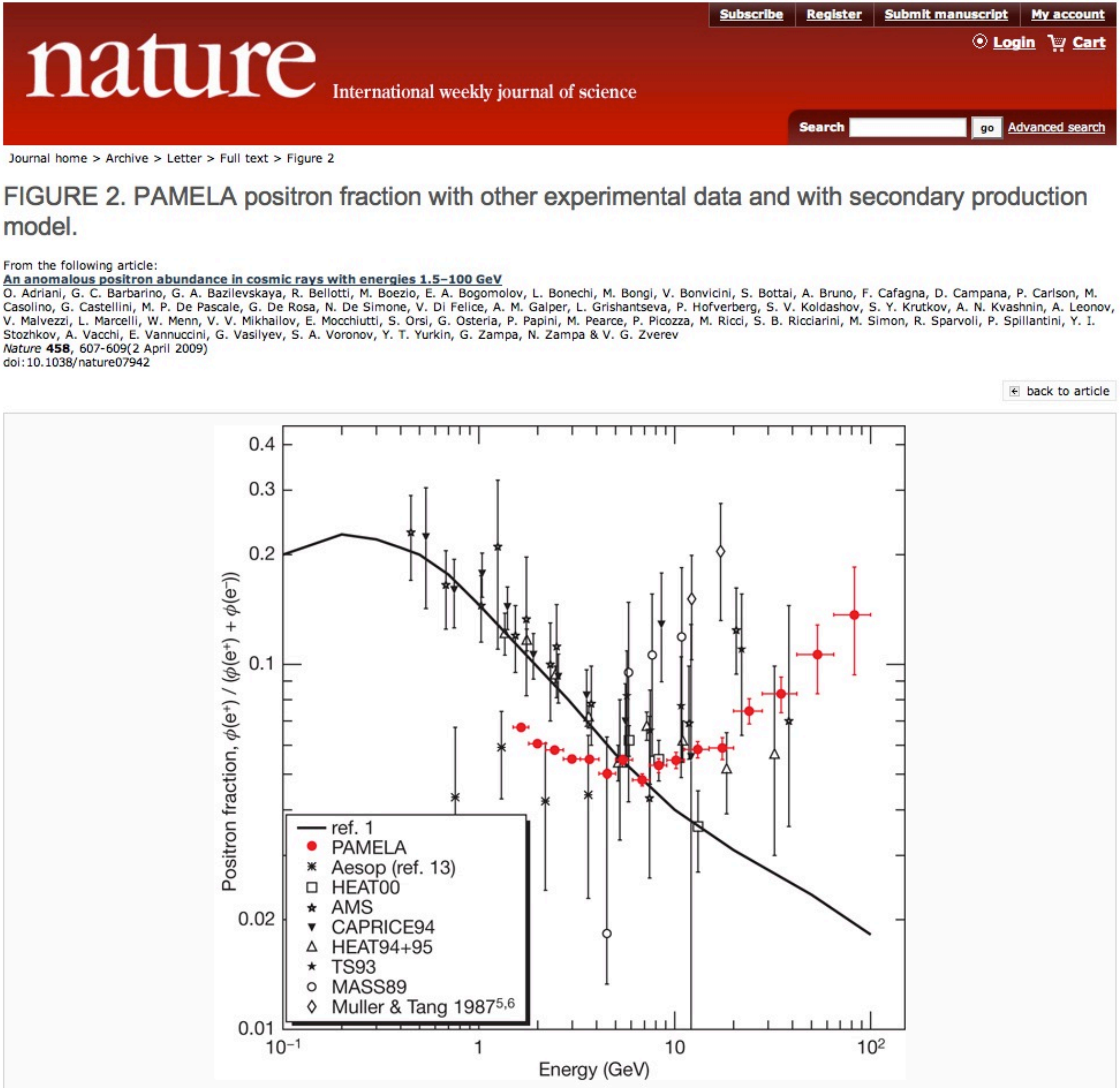
The excess of e^+, $\bar{p}$, $\bar{D}$ from Dark Matter annihilations can be measured by AMS





Journal home > Archive > Letter > Full text > Figure 2

FIGURE 2. PAMELA positron fraction with other experimental data and with secondary production model.

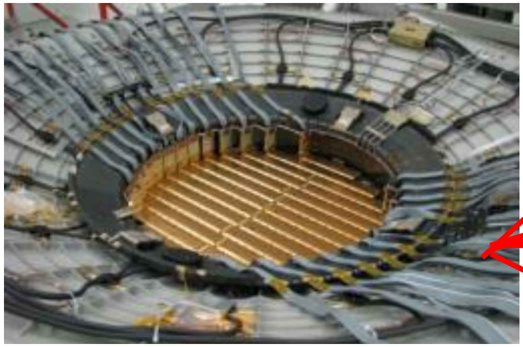
From the following article:
An anomalous positron abundance in cosmic rays with energies 1.5–100 GeV
O. Adriani, G. C. Barbarino, G. A. Bazilevskaya, R. Bellotti, M. Boezio, E. A. Bogomolov, L. Bonechi, M. Bongi, V. Bonvicini, S. Bottai, A. Bruno, F. Cafagna, D. Campana, P. Carlson, M. Casolino, G. Castellini, M. P. De Pascale, G. De Rosa, N. De Simone, V. Di Felice, A. M. Galper, L. Grishantseva, P. Hofverberg, S. V. Koldashov, S. Y. Krutkov, A. N. Kvashnin, A. Leonov, V. Malvezzi, L. Marcelli, W. Menn, V. V. Mikhailov, E. Mocchiutti, S. Orsi, G. Osteria, P. Papini, M. Pearce, P. Picozza, M. Ricci, S. B. Ricciarini, M. Simon, R. Sparvoli, P. Spillantini, Y. I. Stozhkov, A. Vacchi, E. Vannuccini, G. Vasilyev, S. A. Voronov, Y. T. Yurkin, G. Zampa, N. Zampa & V. G. Zverev
Nature **458**, 607-609(2 April 2009)
doi:10.1038/nature07942

AMS: a unique TeV precision, accelerator-type spectrometer in space

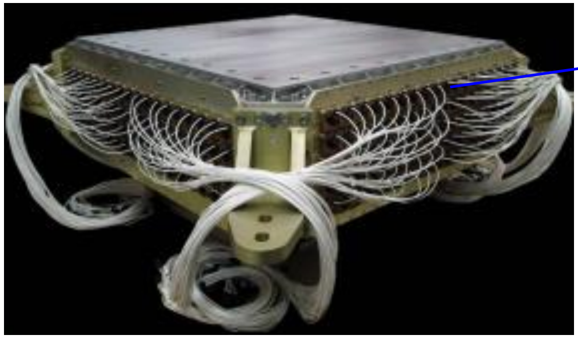
Particles and nuclei are defined
by their charge (Z)
and energy (E)
or momentum (P).
Rigidity R = P/Z

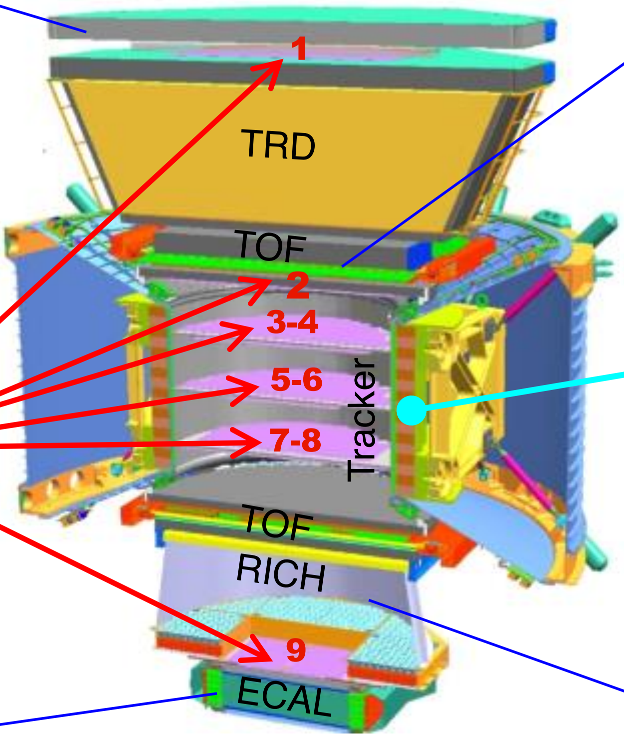
TRD: Identify e^+, e^-, Z

Silicon Tracker: Z, P



ECAL: E of e^+, e^-



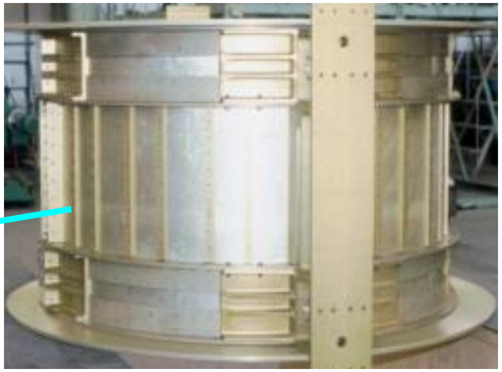


Z and P

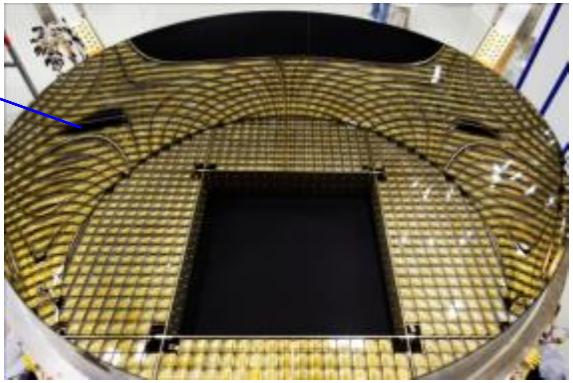
are measured independently by the
Tracker, RICH, TOF and ECAL

TOF: Z, E

Magnet: ±Z

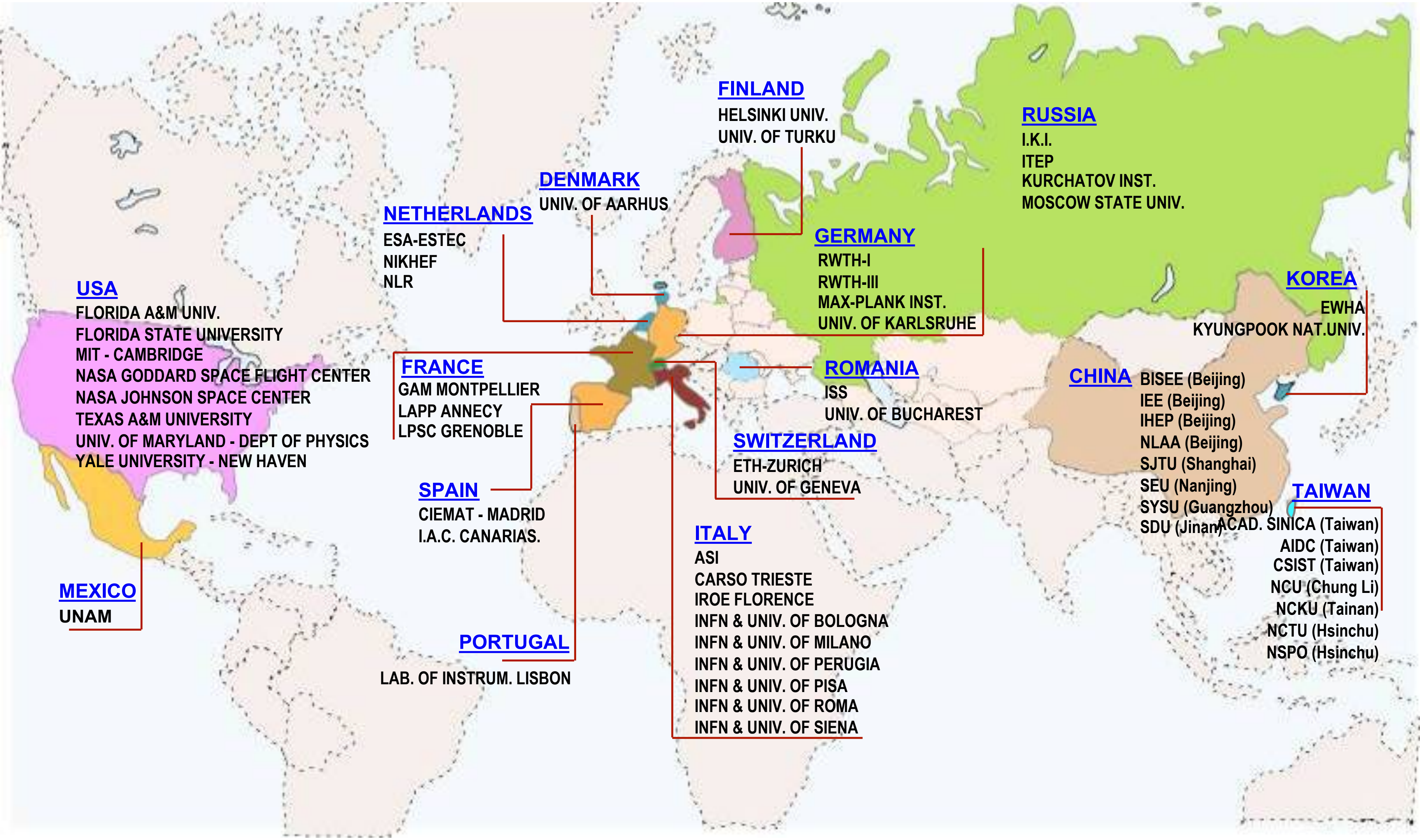


RICH: Z, E



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.

PORTUGAL
LAB. OF INSTRUM. LISBON

GERMANY
RWTH-I
RWTH-III
MAX-PLANK INST.
UNIV. OF KARLSRUHE

ROMANIA
ISS
UNIV. OF BUCHAREST

SWITZERLAND
ETH-ZURICH
UNIV. OF GENEVA

ITALY
ASI
CARSO TRIESTE
IROE FLORENCE
INFN & UNIV. OF BOLOGNA
INFN & UNIV. OF MILANO
INFN & UNIV. OF PERUGIA
INFN & UNIV. OF PISA
INFN & UNIV. OF ROMA
INFN & UNIV. OF SIENA

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SYSU (Guangzhou)
SDU (Jinan)

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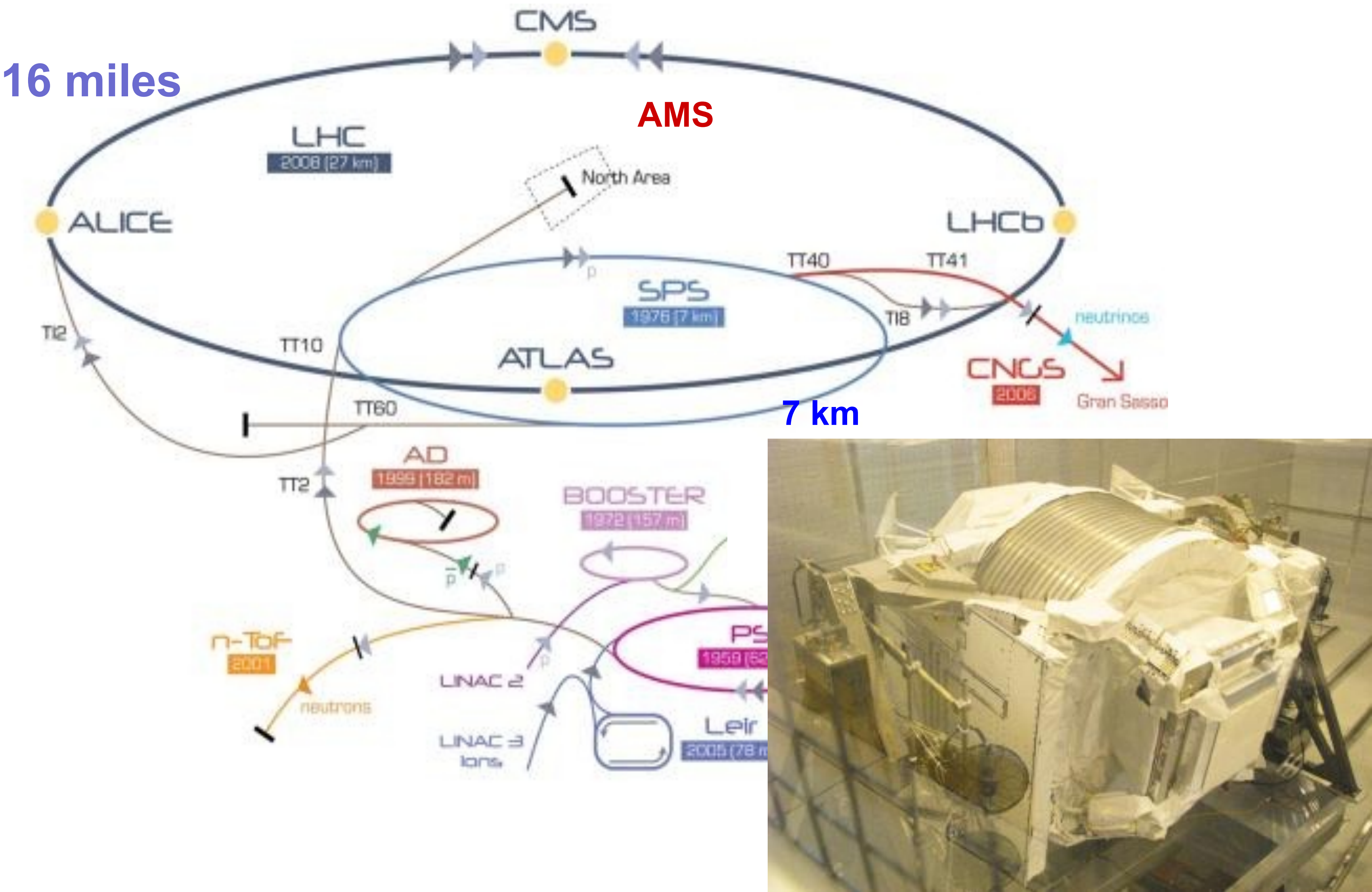
EWHA
KYUNGPOOK NAT.UNIV.

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

5m x 4m x 3m
7 tons

Calibration at CERN
AMS in test beam 4-8. Feb. and 8-20. Aug., 2010



16 miles

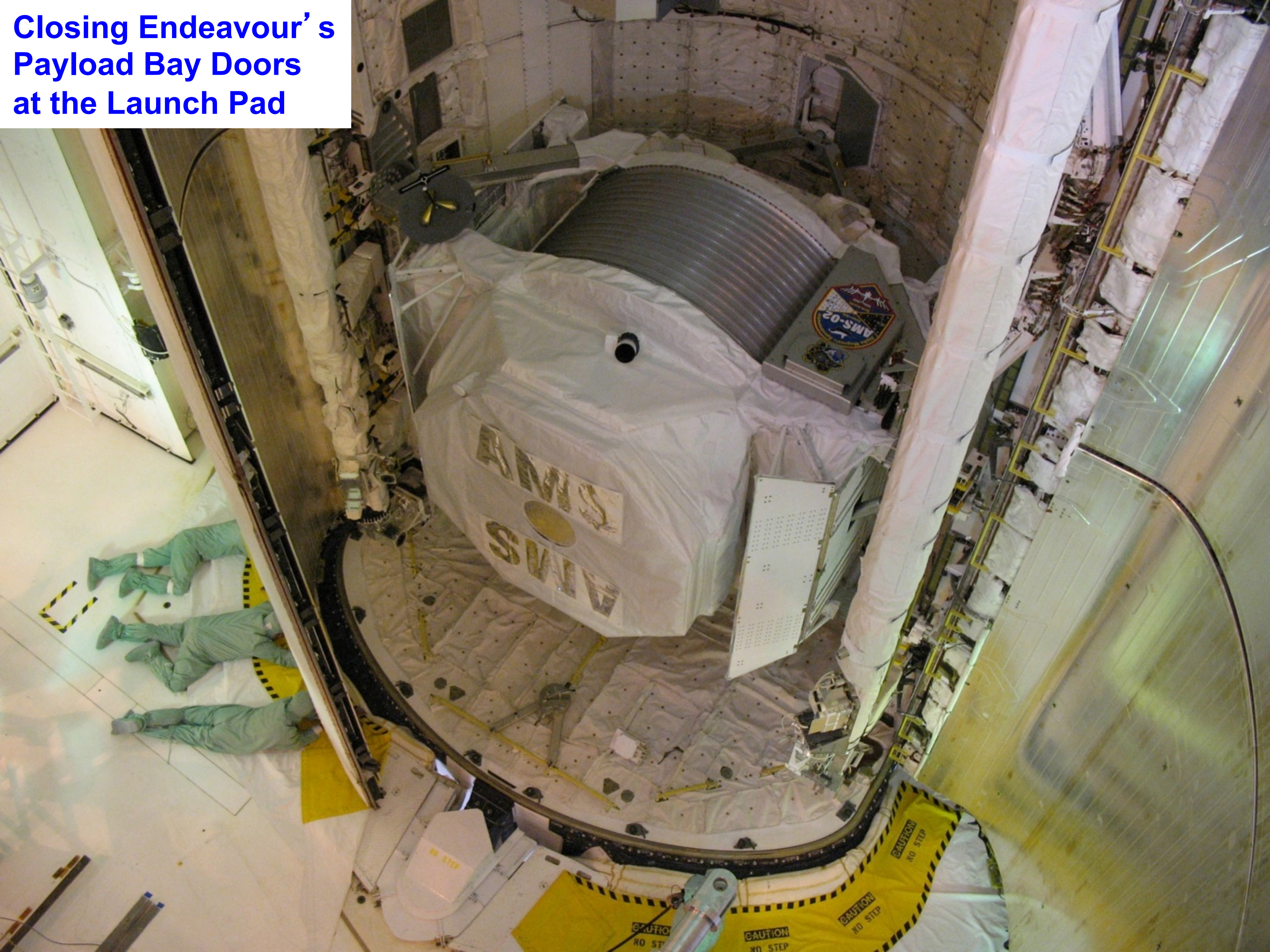
AMS

7 km

A US Air Force C-5 Galaxy
has been used for transport
from Geneva to KSC
25. August 2010

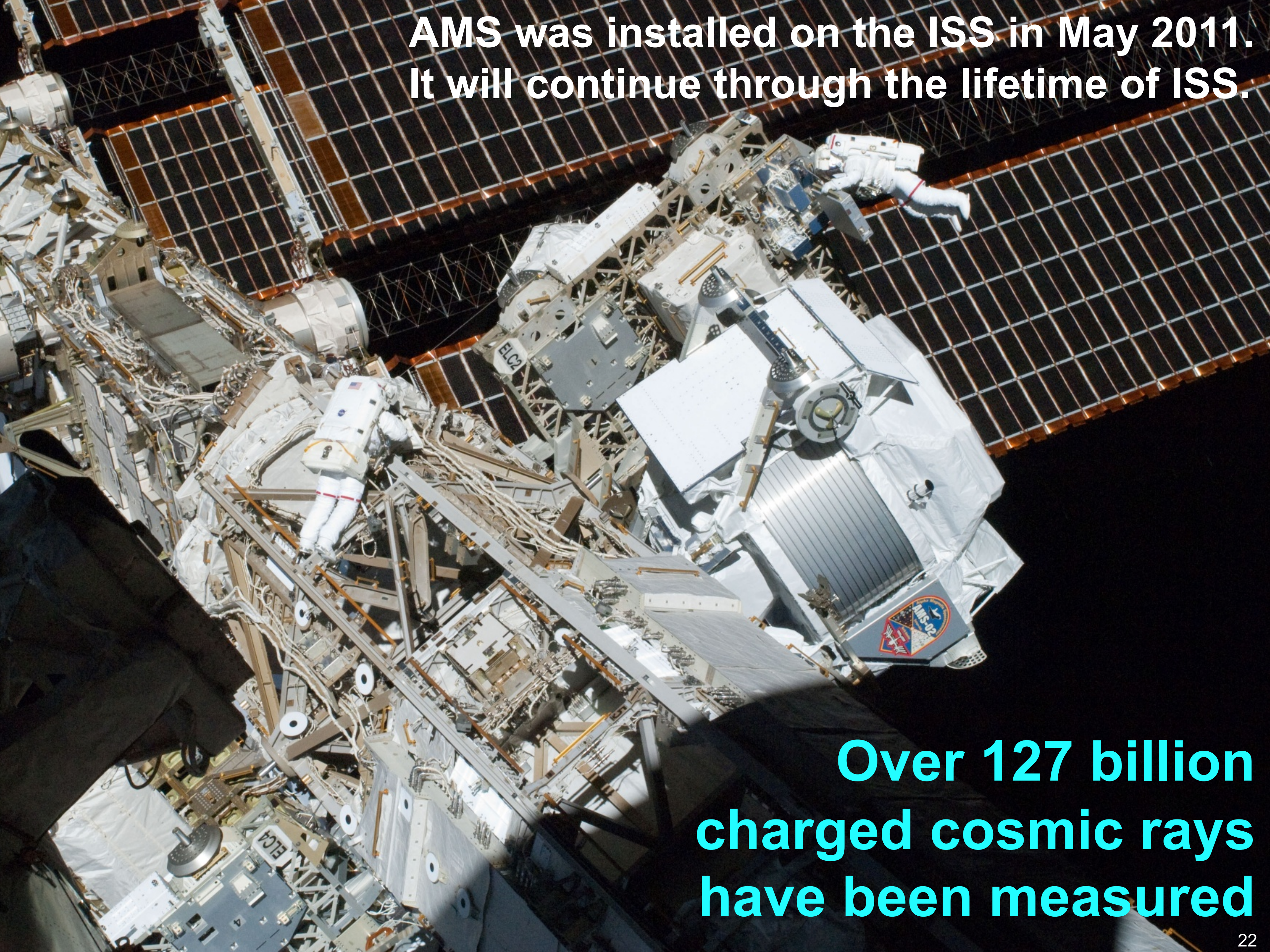

AMS

Closing Endeavour's Payload Bay Doors at the Launch Pad



STS-134 launch   May 16, 2011 @ 08:56 AM

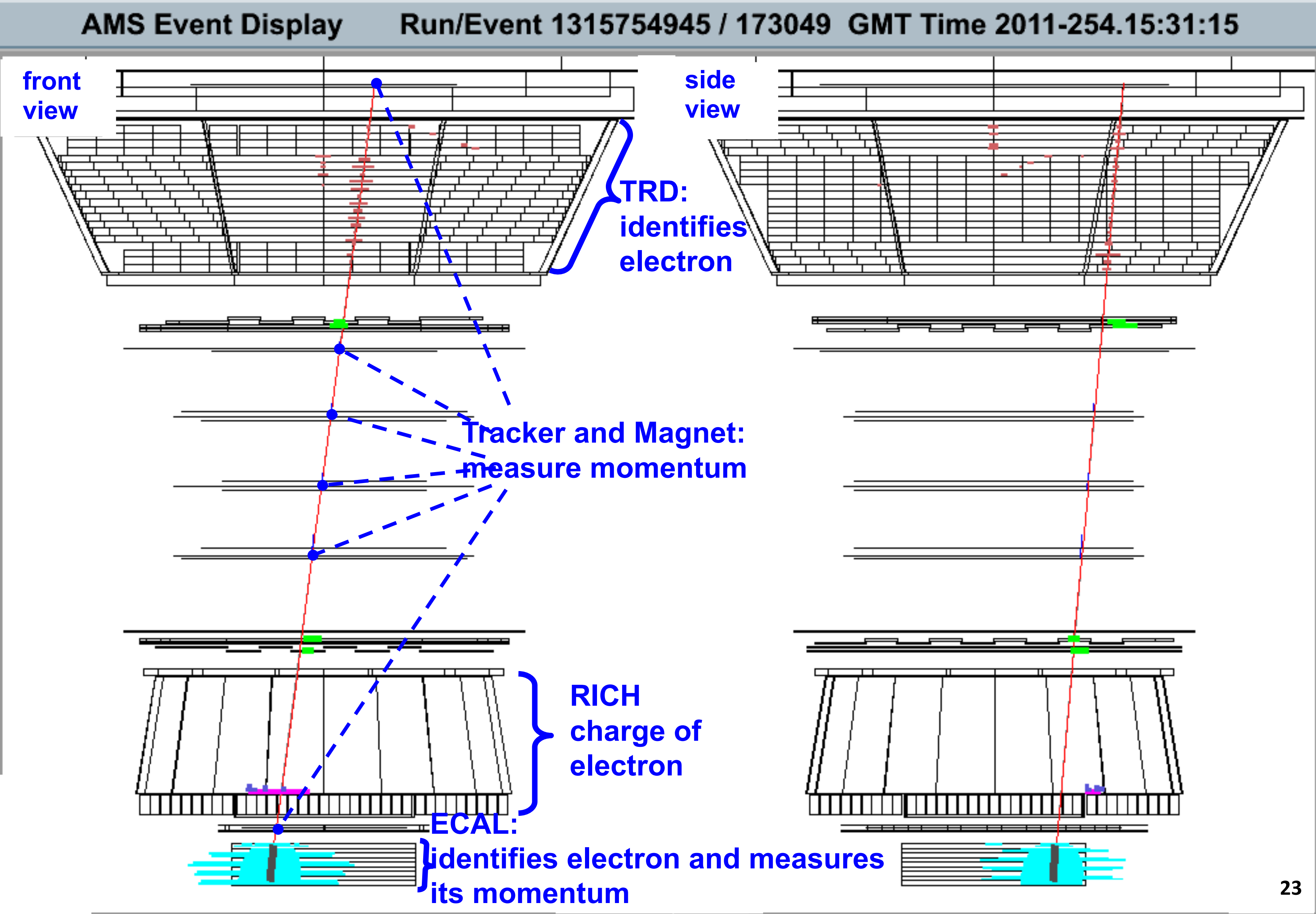
Endeavour approaches the International Space Station



AMS was installed on the ISS in May 2011.
It will continue through the lifetime of ISS.

Over 127 billion
charged cosmic rays
have been measured

1.03 TeV electron



front view

side view

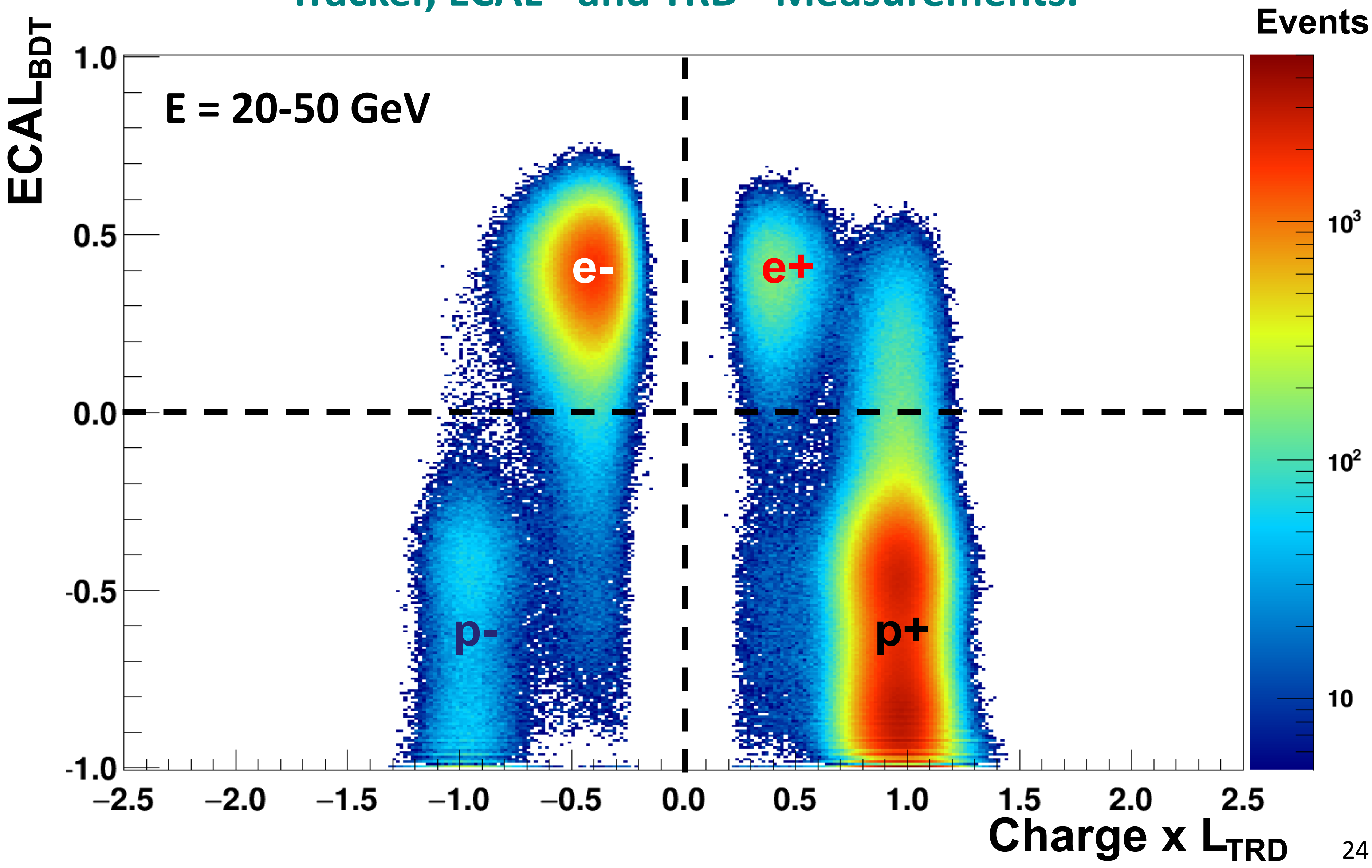
TRD: identifies electron

Tracker and Magnet: measure momentum

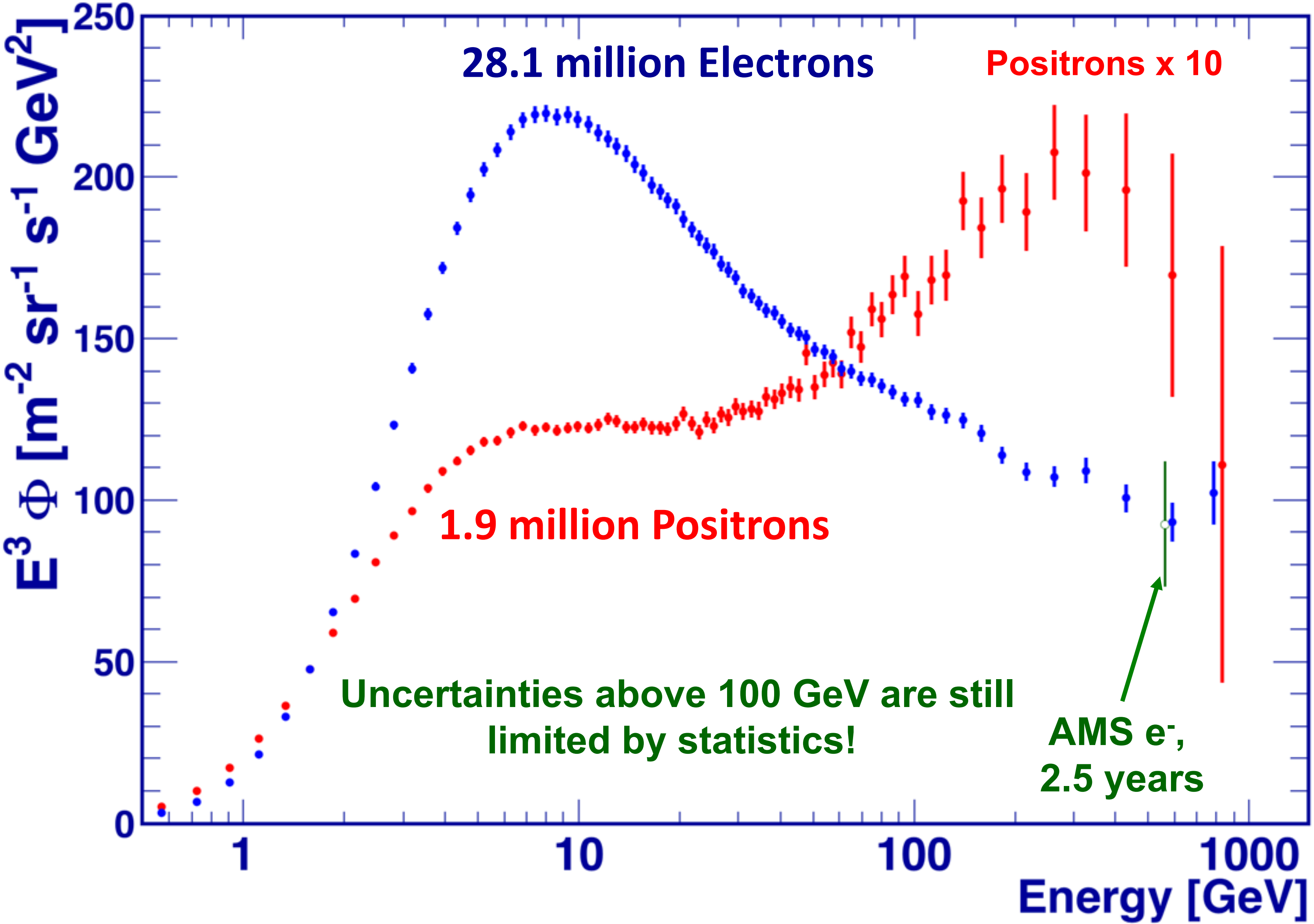
RICH charge of electron

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.



AMS results on Positron and Electron fluxes from 6.5 years

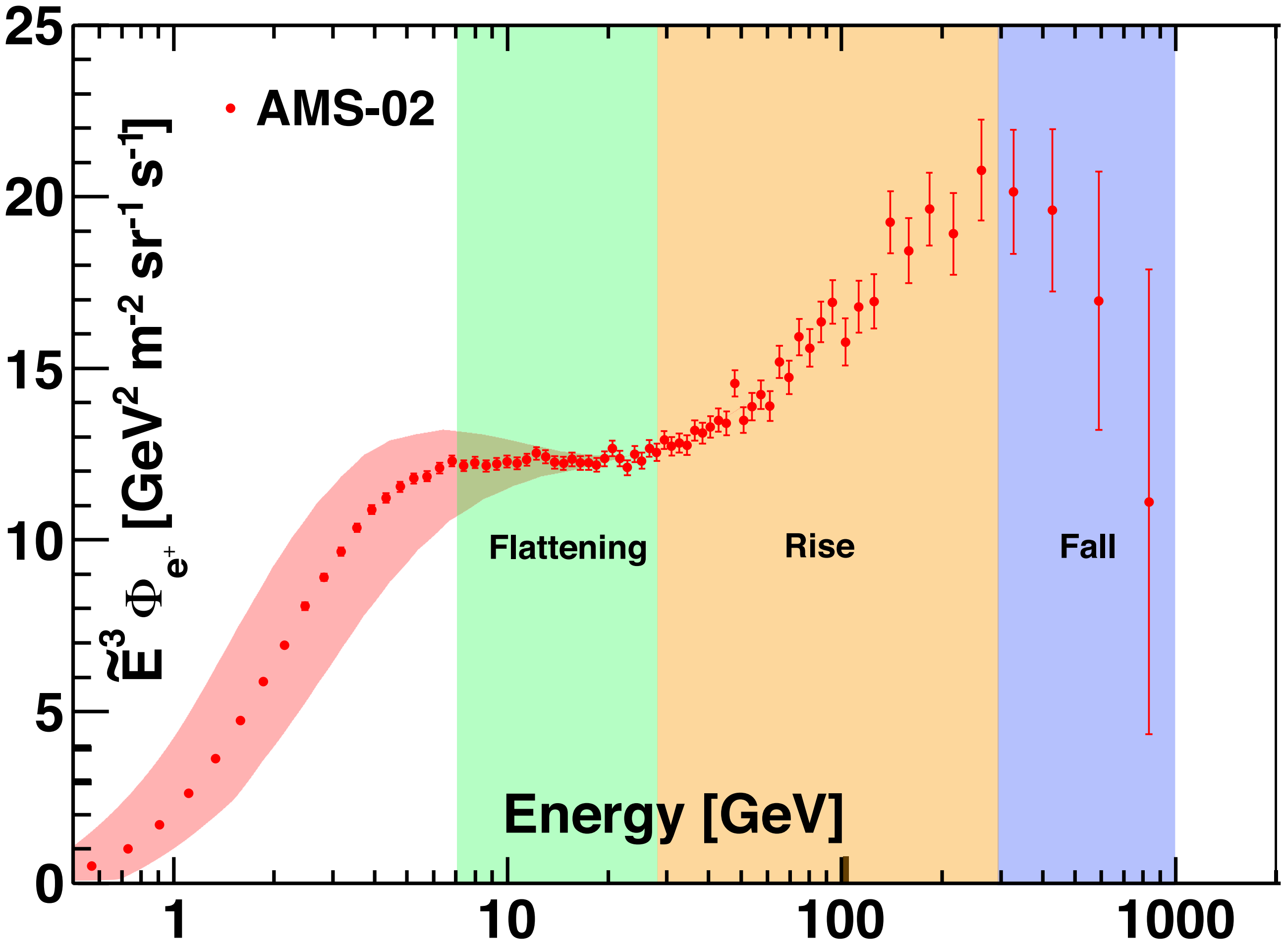


Origins of Cosmic Positrons

Submitted to Phys. Rev. Lett.

Based on 1.9 million positrons with energies from 0.5 GeV to 1 TeV

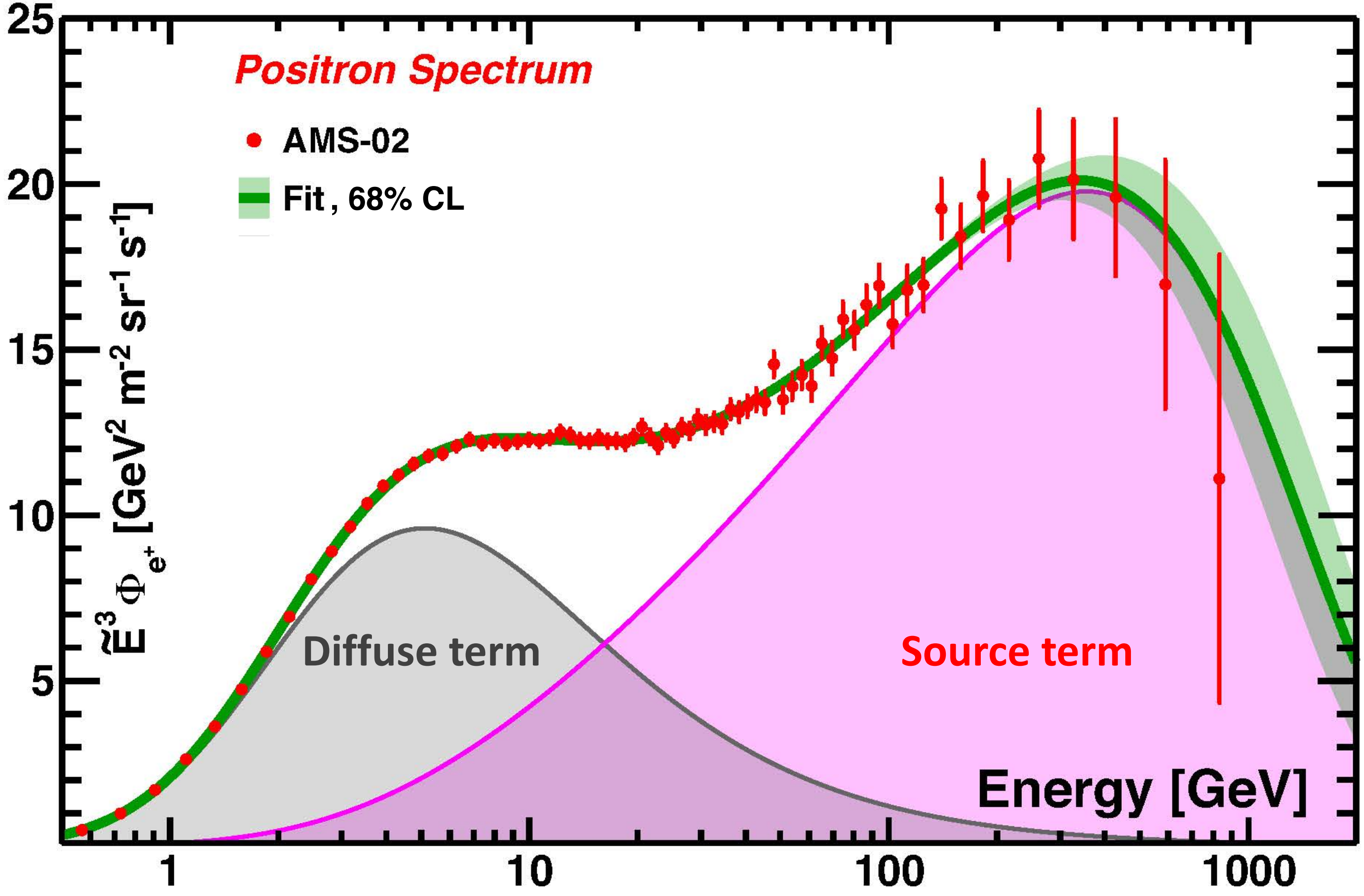
The positron flux, Φ_{e^+}. The variation of the flux due to solar modulation is indicated by the red band. The vertical color bands indicate the energy ranges corresponding to changing behavior of the spectrum: flattening, rising, and falling spectrum.



In the entire energy range the positron flux is well described by the sum of a diffuse term associated with positrons produced in the collision of cosmic rays, which dominates at low energies and a new source term of positrons, which dominates at high energies

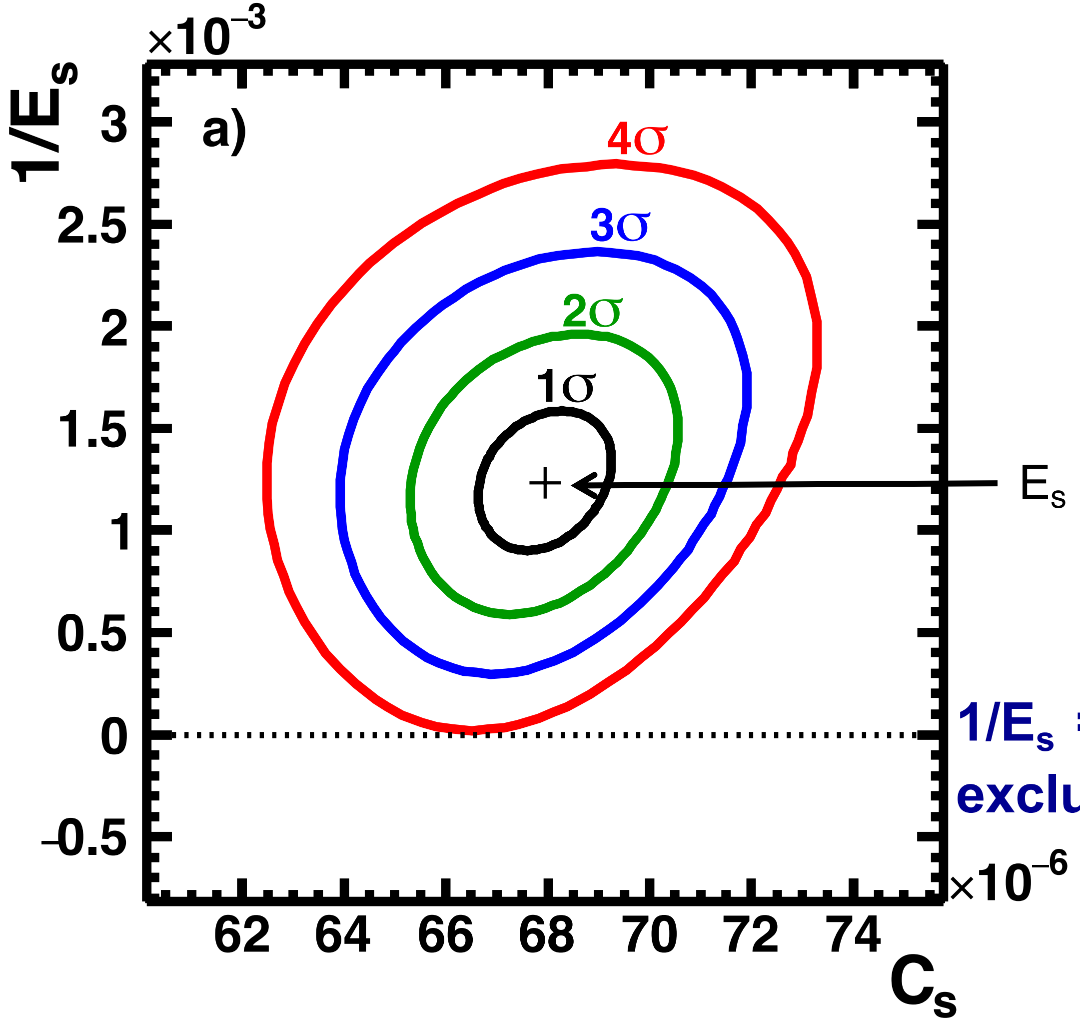
$$\Phi_{e^+}(E) = \frac{E^2}{\hat{E}^2}[C_d\,(\hat{E}/E_1)^{\gamma_d} + C_s\,(\hat{E}/E_2)^{\gamma_s}\exp(-\hat{E}/E_s)]$$

Diffuse term　　　　Source term



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

$$\Phi_{e^+}(E) = \frac{E^2}{\hat{E}^2}[\underbrace{C_d(\hat{E}/E_1)^{\gamma_d}}_{\text{Diffuse term}} + \underbrace{C_s(\hat{E}/E_2)^{\gamma_s}\exp(-\hat{E}/E_s)}_{\text{Source term}}]$$



E_s = 810 GeV

$1/E_s$ = 0 or $E_s = \infty$ excluded at 4.07σ

A sample of papers on AMS data from more than 2300 publications

1) J. Kopp, Phys. Rev. D 88, 076013 (2013);
2) L. Feng, R.Z. Yang, H.N. He, T.K. Dong, Y.Z. Fan and J. Chang Phys.Lett. B728 (2014) 250
3) M. Cirelli, M. Kadastik, M. Raidal and A. Strumia ,Nucl.Phys. B873 (2013) 530
4) M. Ibe, S. Iwamoto, T. Moroi and N. Yokozaki, JHEP 1308 (2013) 029
5) Y. Kajiyama and H. Okada, Eur.Phys.J. C74 (2014) 2722
6) K.R. Dienes and J. Kumar, Phys.Rev. D88 (2013) 10, 103509
7) L. Bergstrom, T. Bringmann, I. Cholis, D. Hooper and C. Weniger, PRL 111 (2013) 171101
8) K. Kohri and N. Sahu, Phys.Rev. D88 (2013) 10, 103001
9) A. Ibarra, A.S. Lamperstorfer and J. Silk, Phys.Rev. D89 (2014) 063539
10) Y. Zhao and K.M. Zurek, JHEP 1407 (2014) 017
11) C. H. Chen, C. W. Chiang, and T. Nomura, Phys. Lett. B 747, 495 (2015)
12) H. B. Jin, Y. L. Wu, and Y.-F. Zhou, Phys.Rev. D92, 055027 (2015)
13) A. Reinert and M. W. Winkler JCAP 01 (2018) 055

and many other excellent papers **…**

Dark Matter explaining the AMS e+ data

---

1) R.Cowsik, B.Burch, and T.Madziwa-Nussinov, Ap.J. 786 (2014) 124
2) K. Blum, B. Katz and E. Waxman, Phys.Rev.Lett. 111 (2013) 211101
3) R. Kappl and M. W. Winkler, J. Cosmol. Astropart. Phys. 09 (2014) 051
4) G.Giesen, M.Boudaud, Y.Gènolini, V.Poulin, M.Cirelli, P.Salati and P.D.Serpico, JCAP09 (2015) 023;
5) C.Evoli, D.Gaggero and D.Grasso, JCAP 12 (2015) 039.
6) R.Kappl, A.Reinert, and M.W.Winkler, arXiv:1506.04145 (2015)

and many other excellent papers …

New Propagation Models explaining the AMS e+ data

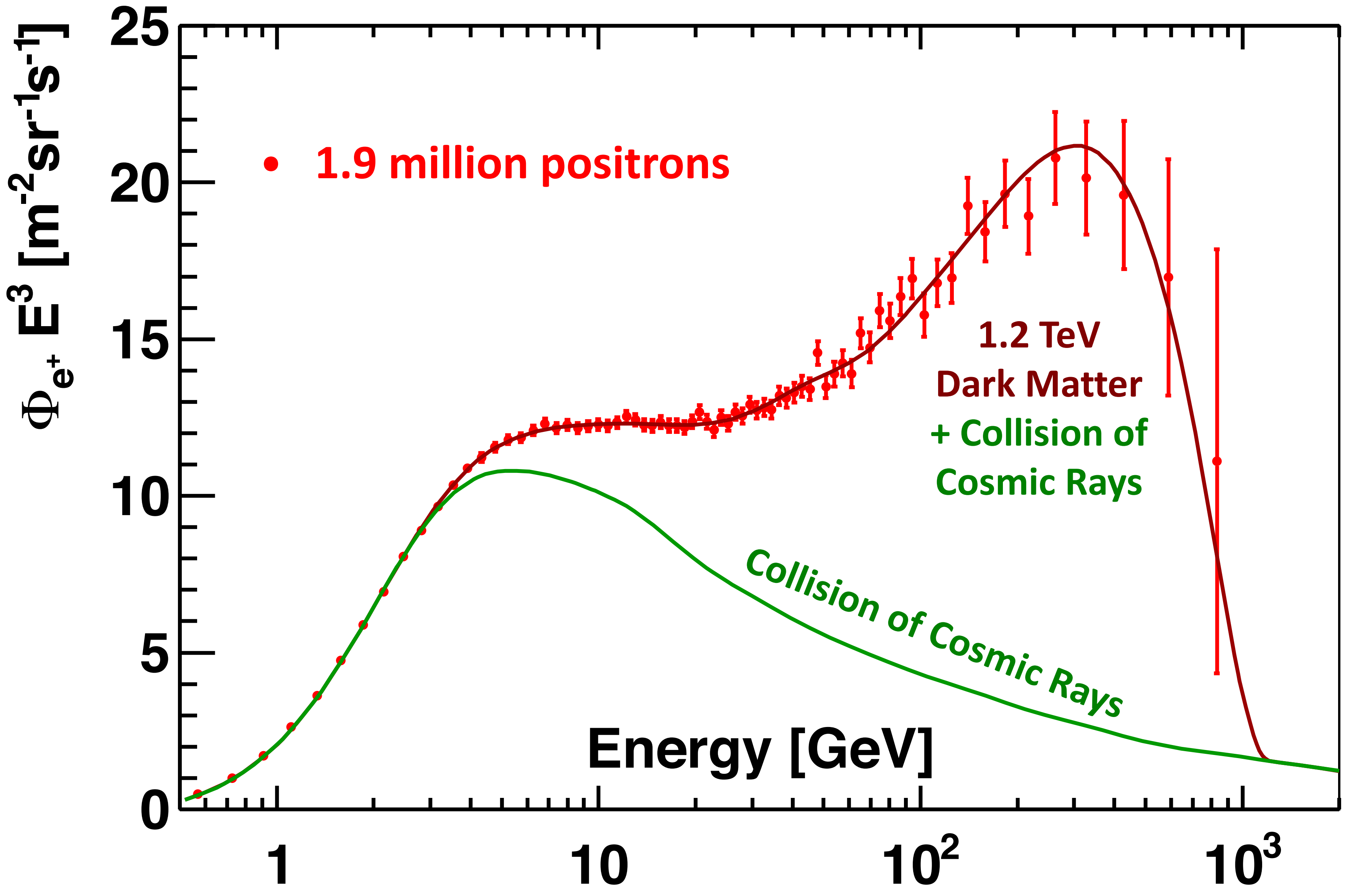
---

1) T. Linden and S. Profumo, Astrophys.J. 772 (2013) 18
2) P. Mertsch and S. Sarkar, Phys.Rev. D 90 (2014) 061301
3) I. Cholis and D. Hooper, Phys.Rev. D88 (2013) 023013
4) A. Erlykin and A.W. Wolfendale, Astropart.Phys. 49 (2013) 23
5) P.F. Yin, Z.H. Yu, Q. Yuan and X.J. Bi, Phys.Rev. D88 (2013) 2, 023001
6) A.D. Erlykin and A.W. Wolfendale, Astropart.Phys. 50-52 (2013) 47
7) E. Amato, Int.J.Mod.Phys.Conf.Ser. 28 (2014) 1460160
8) P. Blasi, Braz.J.Phys. 44 (2014) 426
9) D. Gaggero, D. Grasso, L. Maccione, G. DiBernardo and C Evoli, Phys.Rev. D89 (2014) 083007
10) M. DiMauro, F. Donato, N. Fornengo, R. Lineros and A. Vittino, JCAP 1404 (2014) 006
11) K. Kohri, K. Ioka, Y. Fujita, and R. Yamazaki, Prog. Theor. Exp. Phys. 2016, 021E01 (2016)

and many other excellent papers …

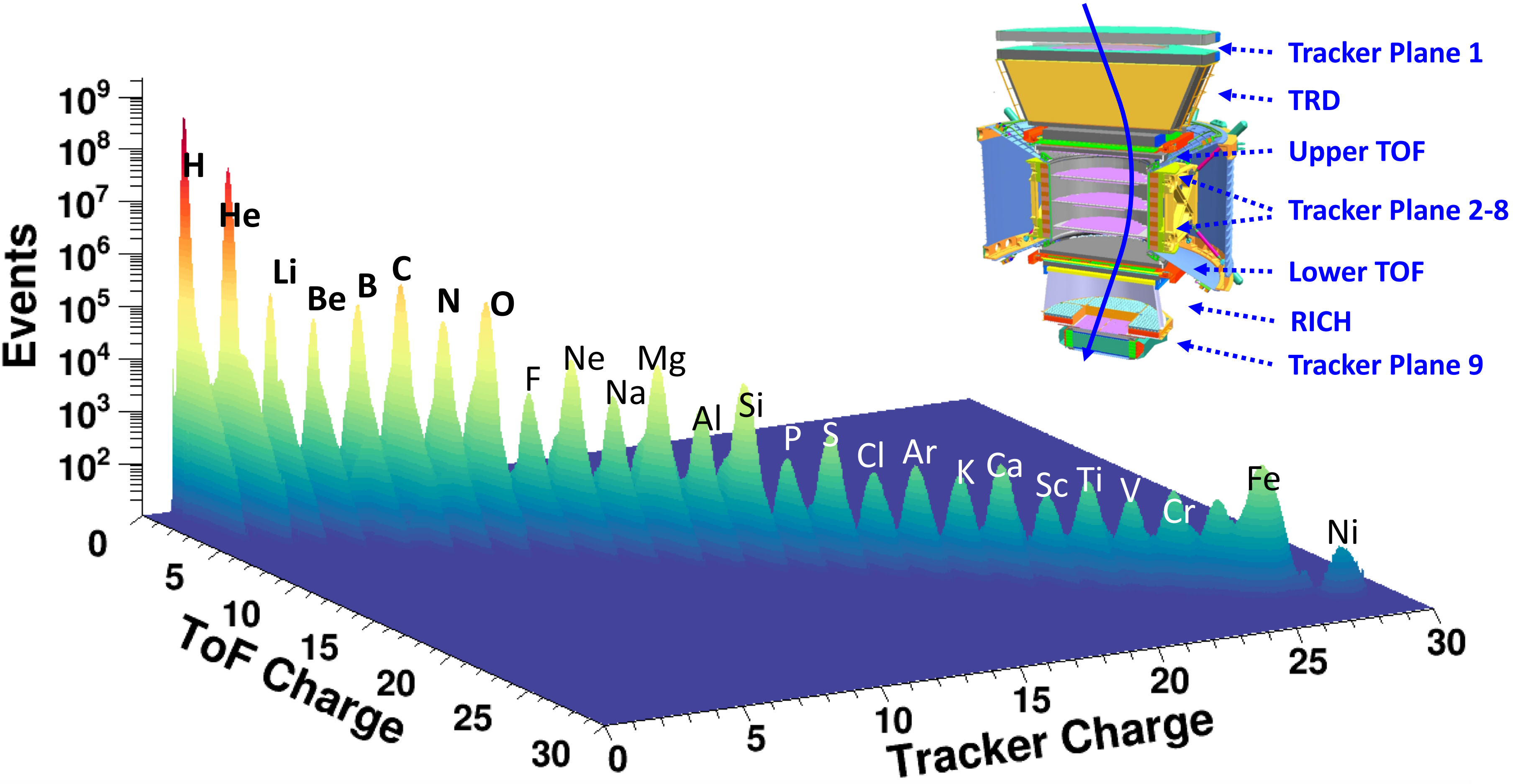
New Astrophysical Sources explaining the AMS e+ data

The positron flux appears to be in agreement with predictions from a 1.2 TeV Dark Matter model (J. Kopp, Phys. Rev. D 88, 076013 (2013))



Precision Measurements of Cosmic Rays:

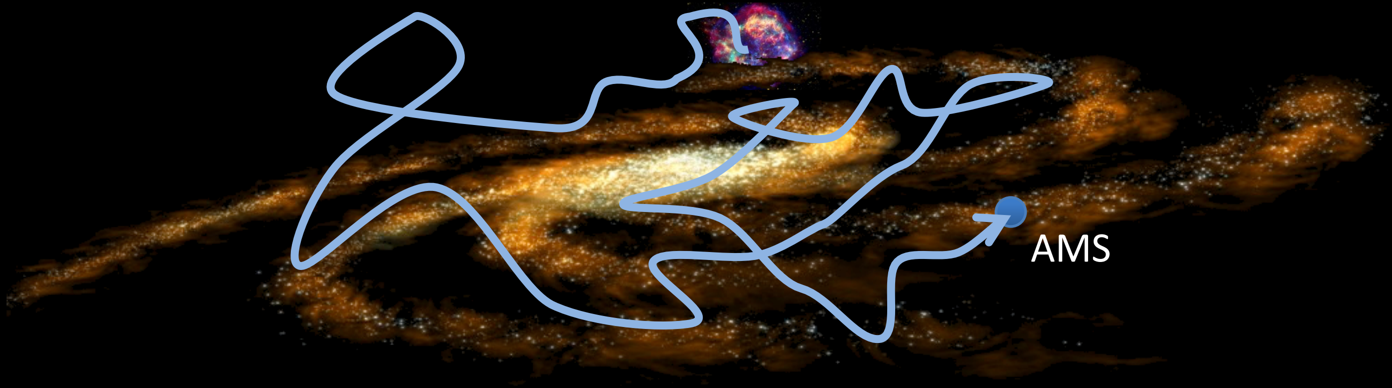
AMS has seven instruments which independently measure Cosmic Nuclei



Traditionally, there are two prominent classes of cosmic rays:

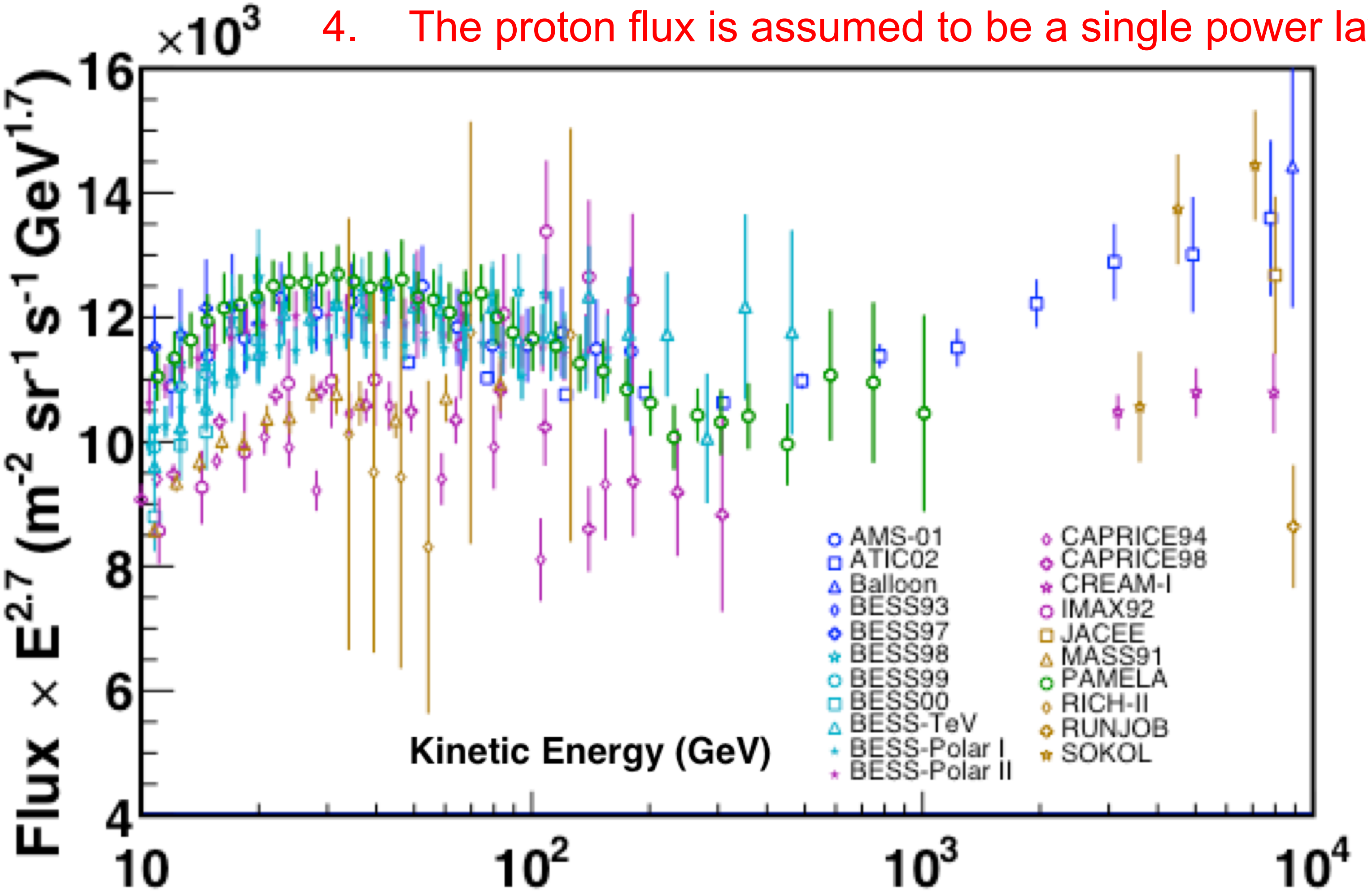
Primary Cosmic Rays (p, He, C, O, …)

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.

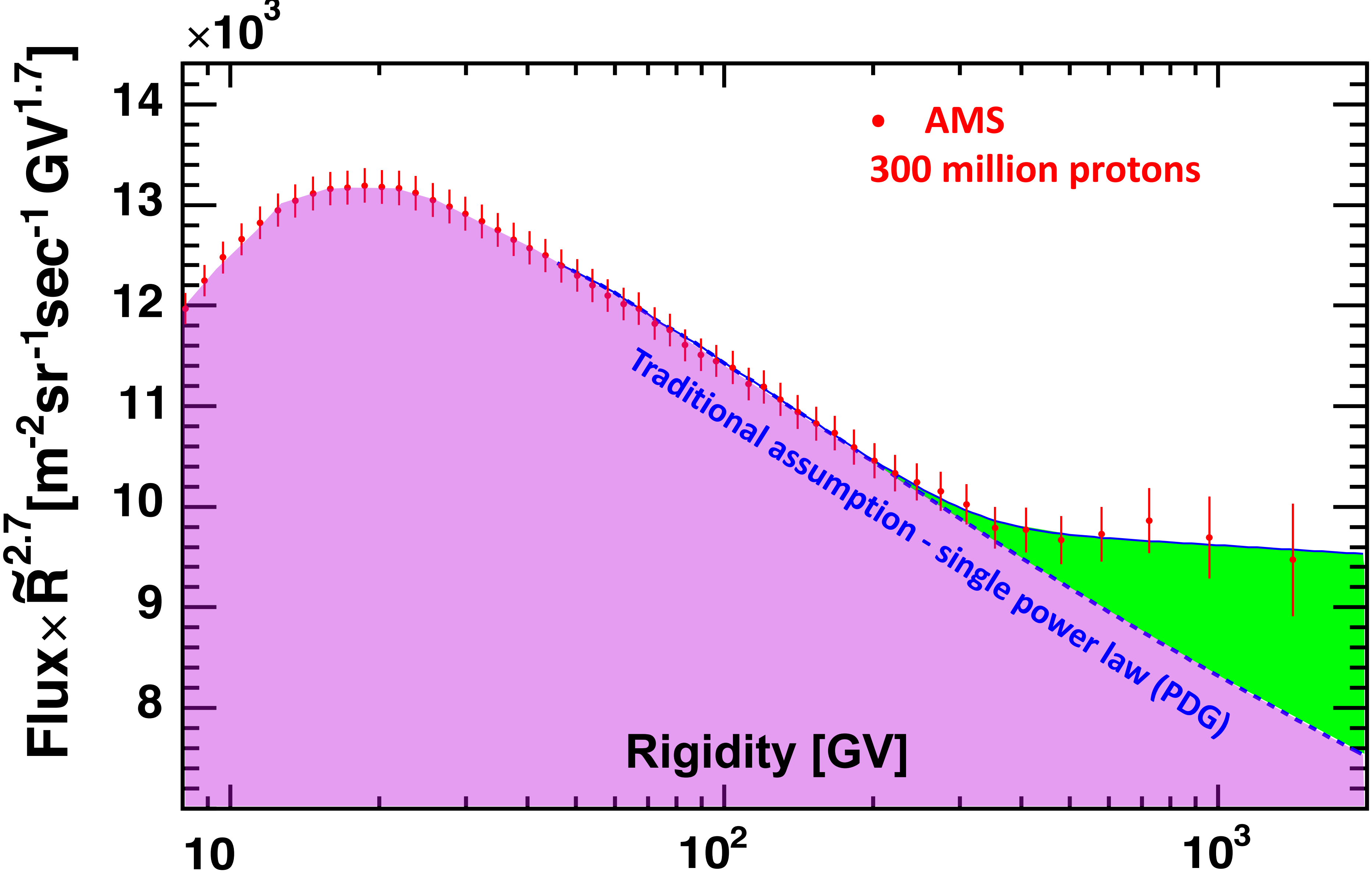


Measurements of proton spectrum before AMS

1. Protons are the most abundant charged cosmic rays.
2. Before AMS, there were many measurements but the data have large errors and are inconsistent.
3. These data limit the understanding of the production, acceleration and propagation of all cosmic rays.
4. The proton flux is assumed to be a single power law = CR^{γ}



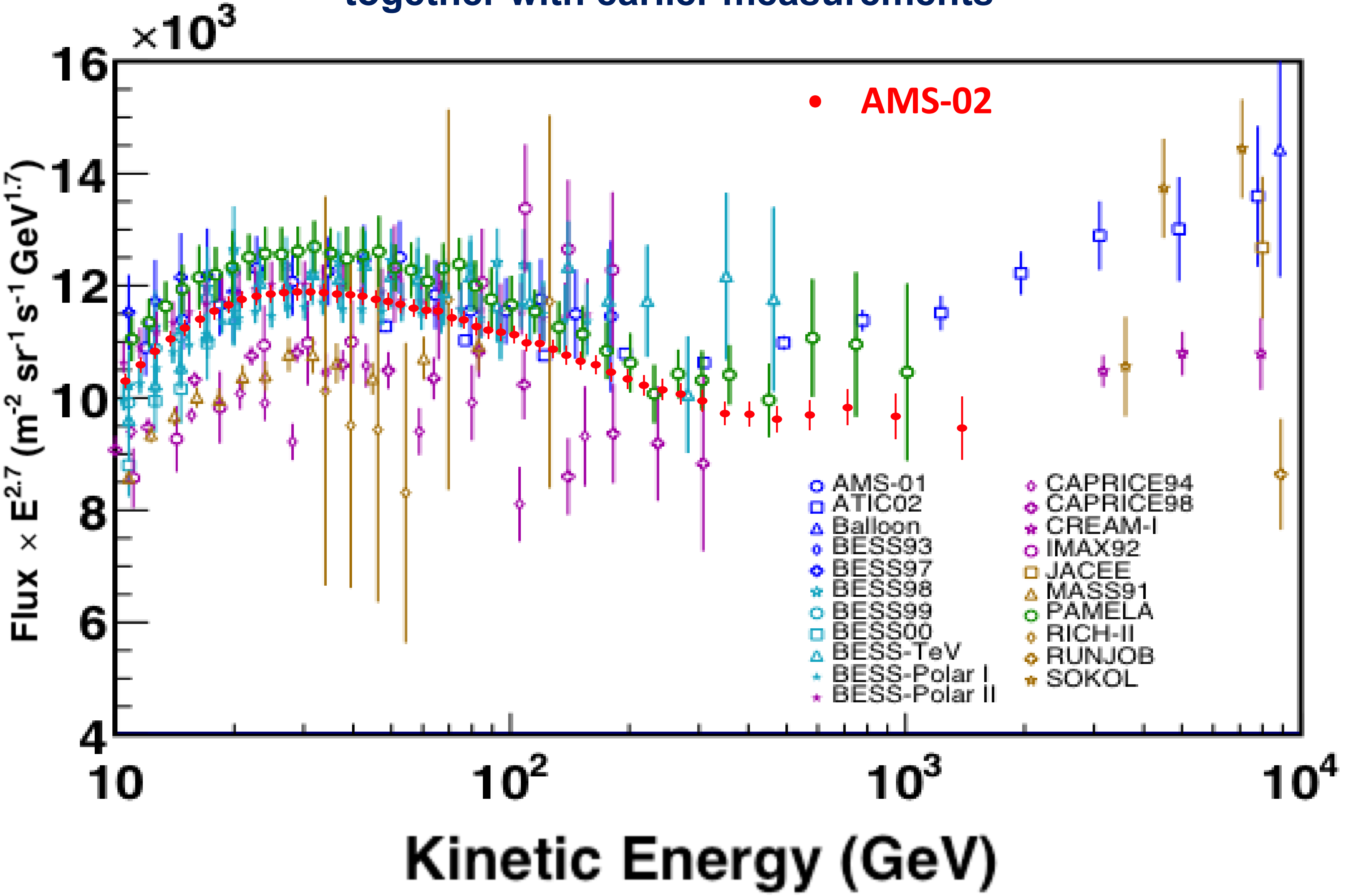
AMS results on the proton flux



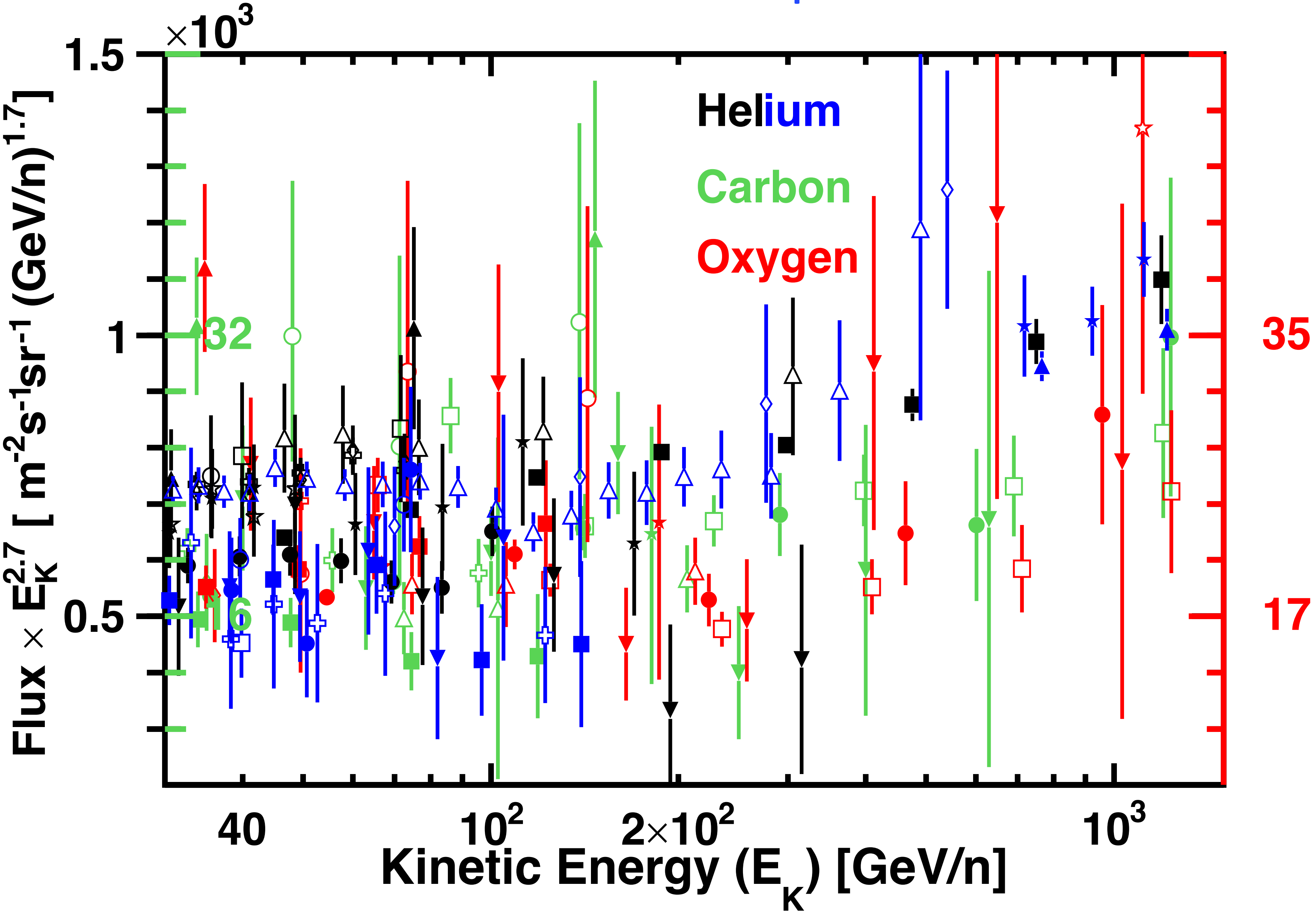
The proton flux **cannot** be described by a single power law = CR^{γ}

AMS Measurement of the proton spectrum

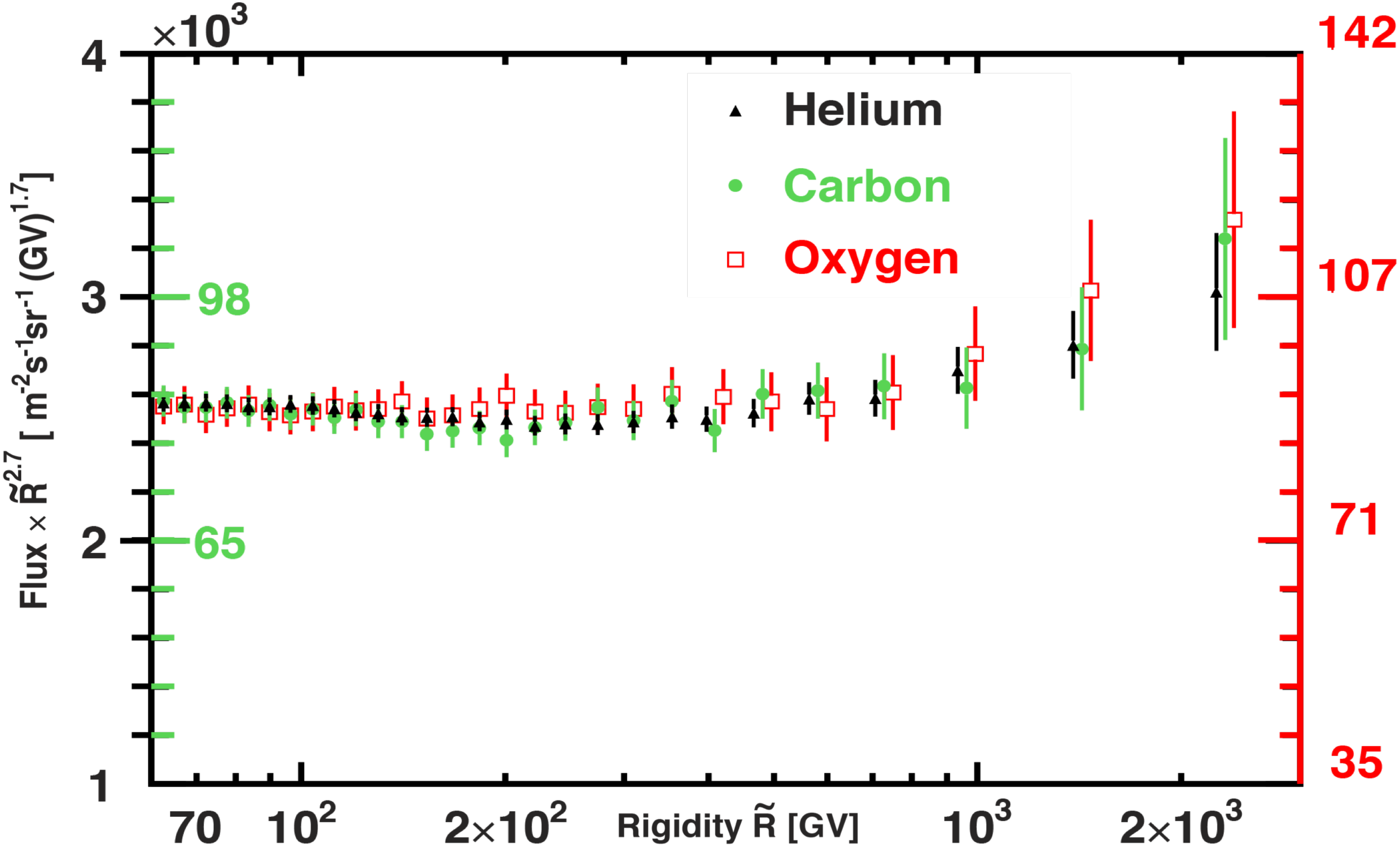
together with earlier measurements



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 identical rigidity dependence.

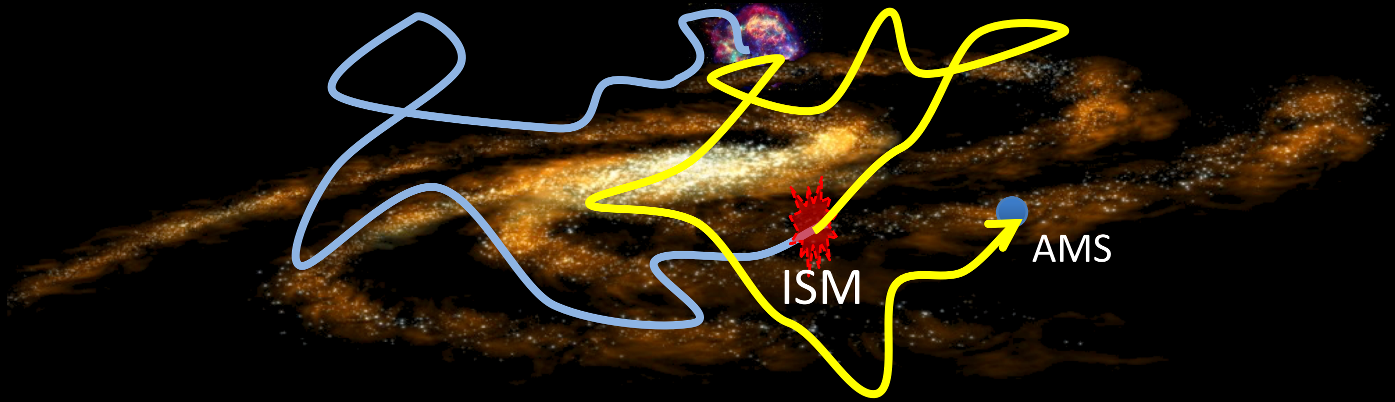


Above 200 GV the data all increase in identical way.

This is unexpected.

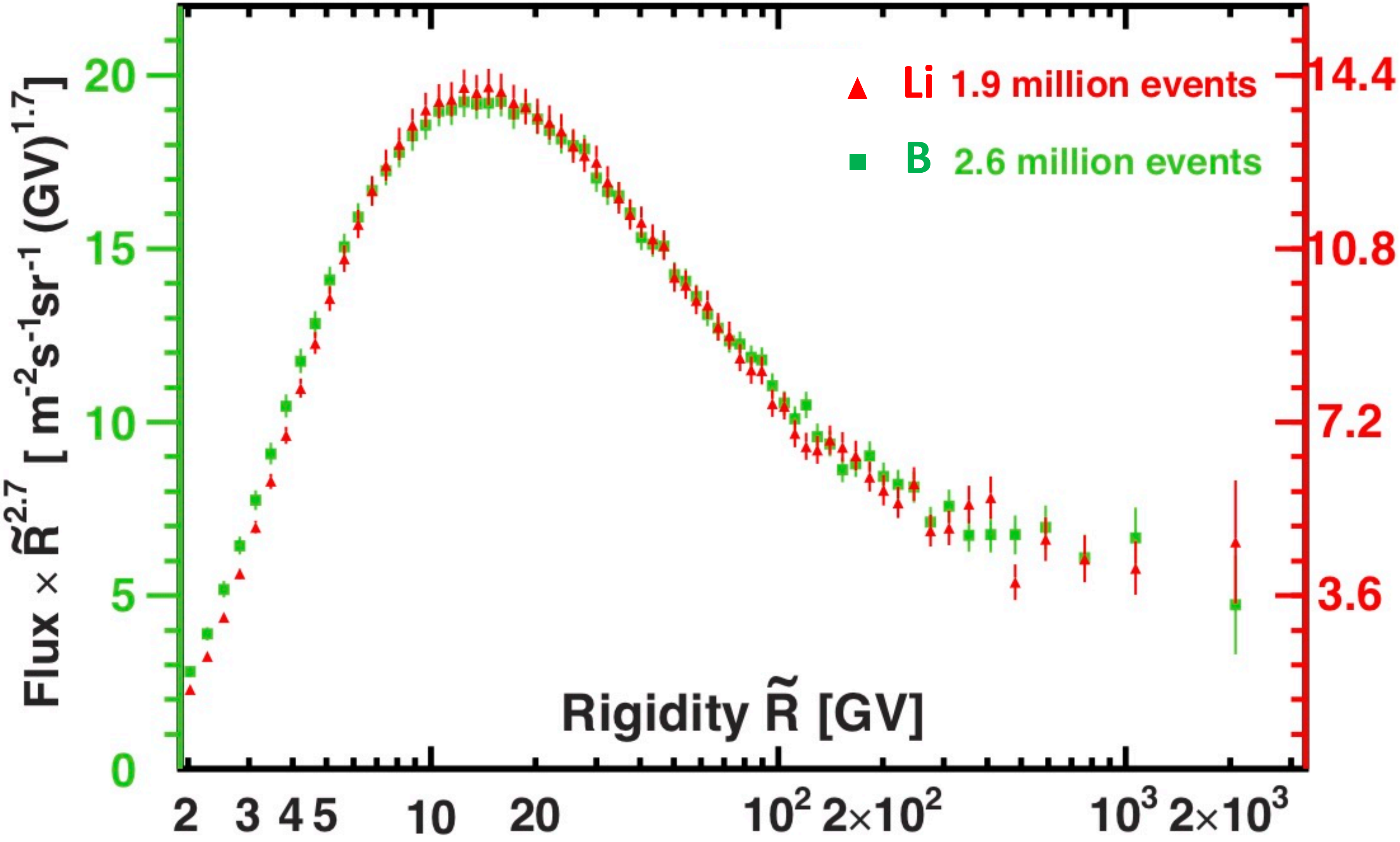
Secondary Cosmic Rays (Li, Be, B, …)

are produced in the collisions of primary cosmic rays. They carry information on the history of the travel and on the properties of the interstellar matter.



Secondary Cosmic Rays: Lithium and Boron

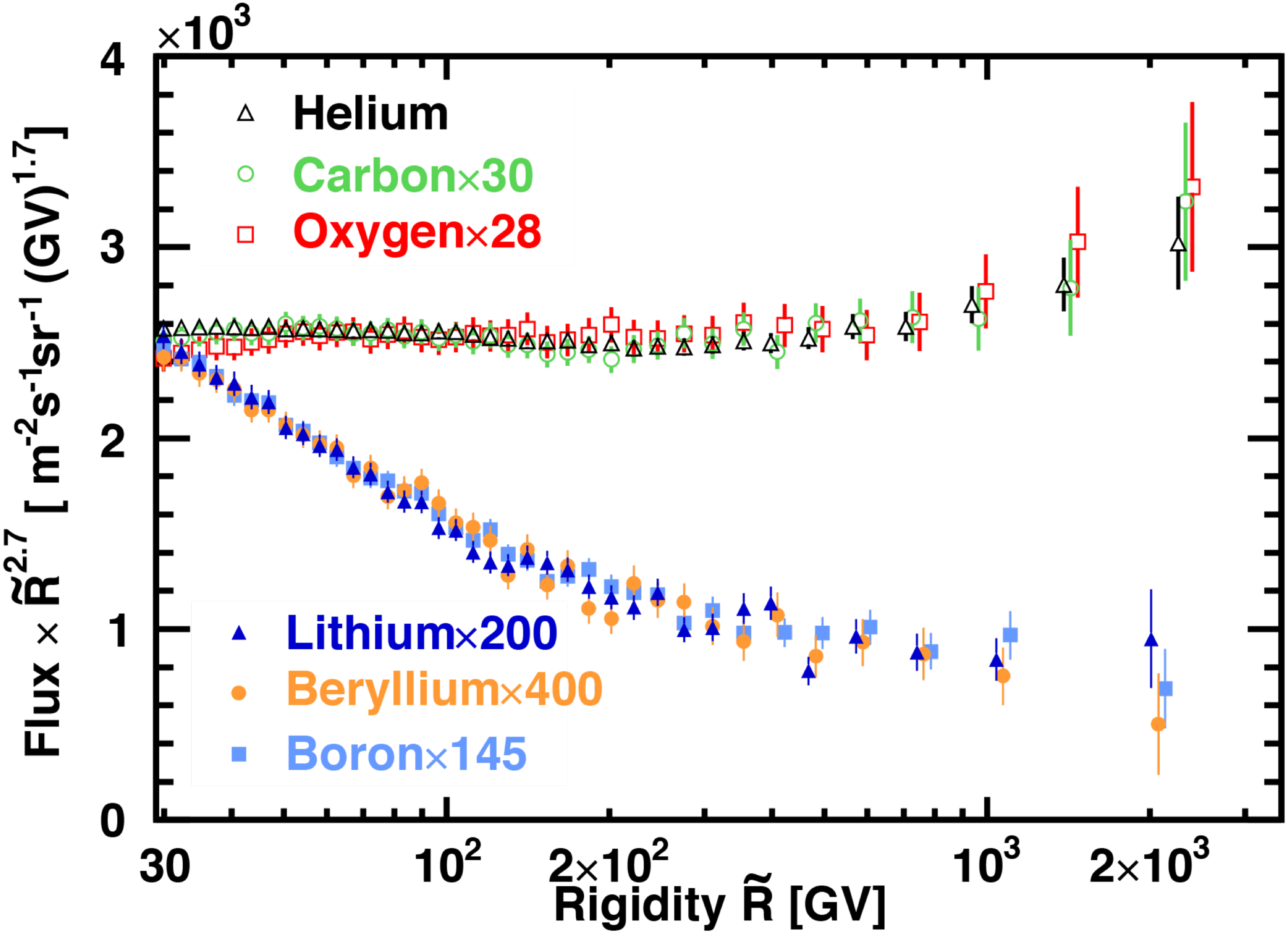
Above 7 GV Li and B have identical rigidity dependence



Rigidity dependence of Primary and Secondary Cosmic Rays

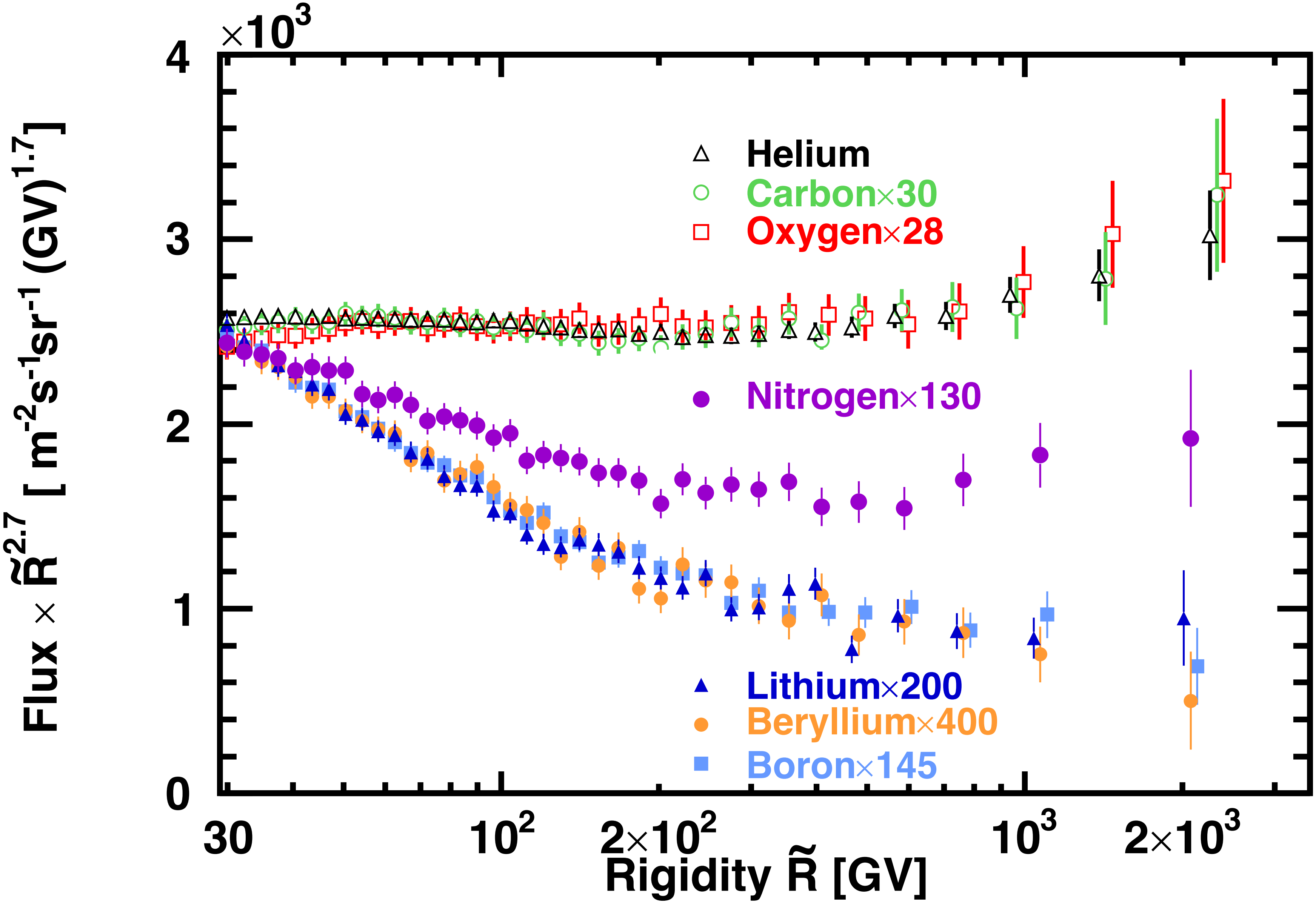
Both deviate from a traditional single power law above 200 GeV.

But their rigidity dependences are distinctly different.



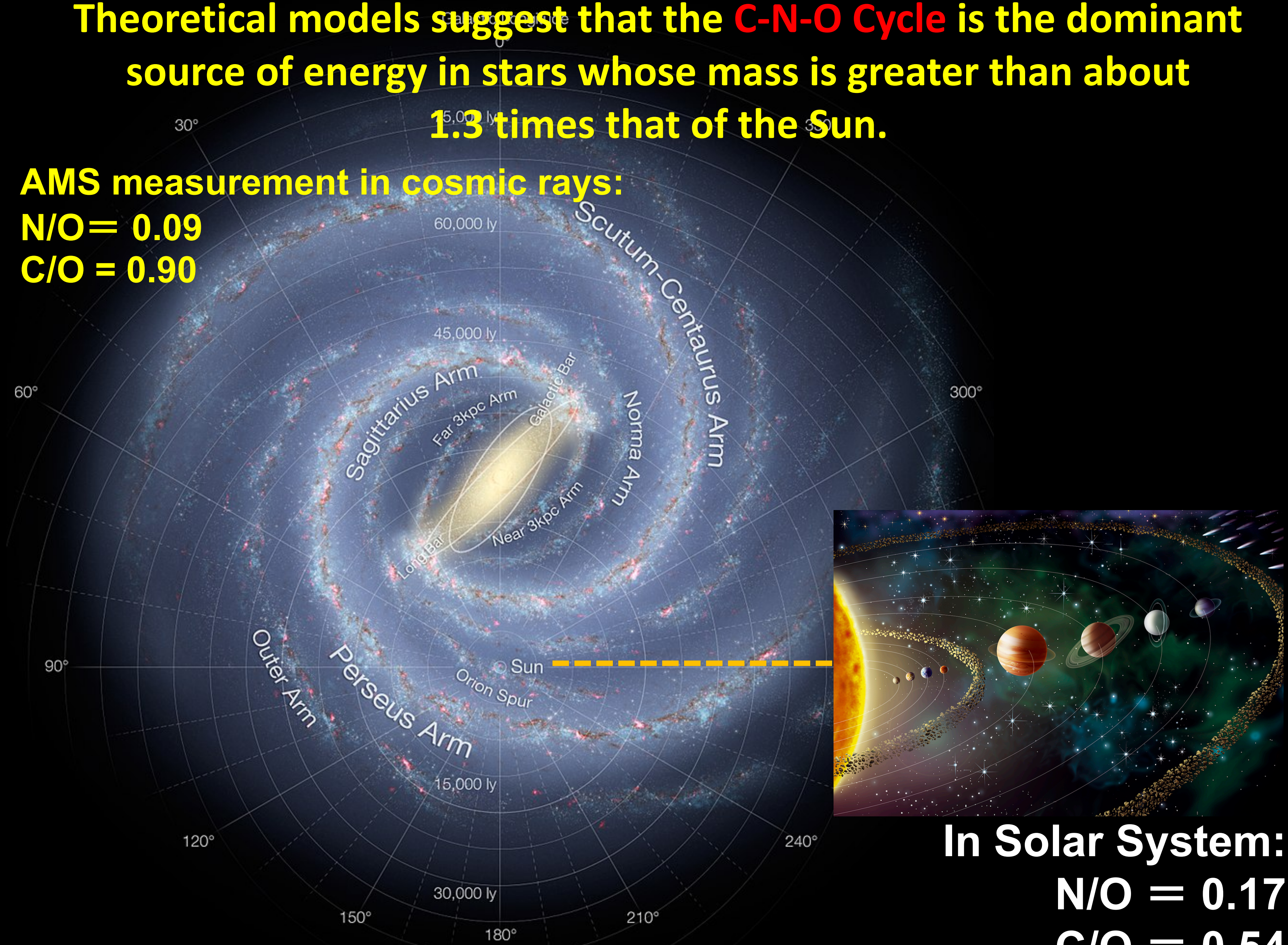
PRL **120**, 021101 (2018), **Editor's Suggestion**

The AMS measurements of the primary cosmic ray fluxes and the secondary cosmic rays fluxes with the nitrogen flux.



Theoretical models suggest that the C-N-O Cycle is the dominant source of energy in stars whose mass is greater than about 1.3 times that of the Sun.

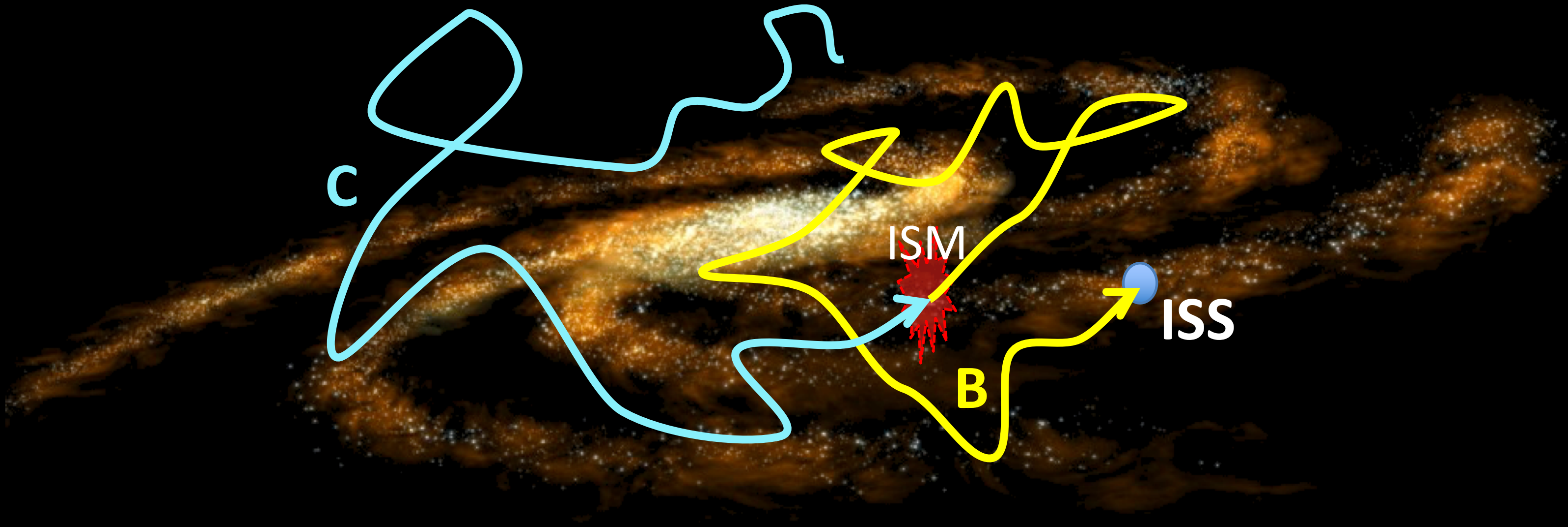
AMS measurement in cosmic rays:
N/O = 0.09
C/O = 0.90



In Solar System:
N/O = 0.17
C/O = 0.54

Abundances of the Elements in the Solar System, Cameron, A. G. W., Space Science Reviews, 15, 121 (1970)

The flux ratio between primaries (C) and secondaries (B) provides information on propagation

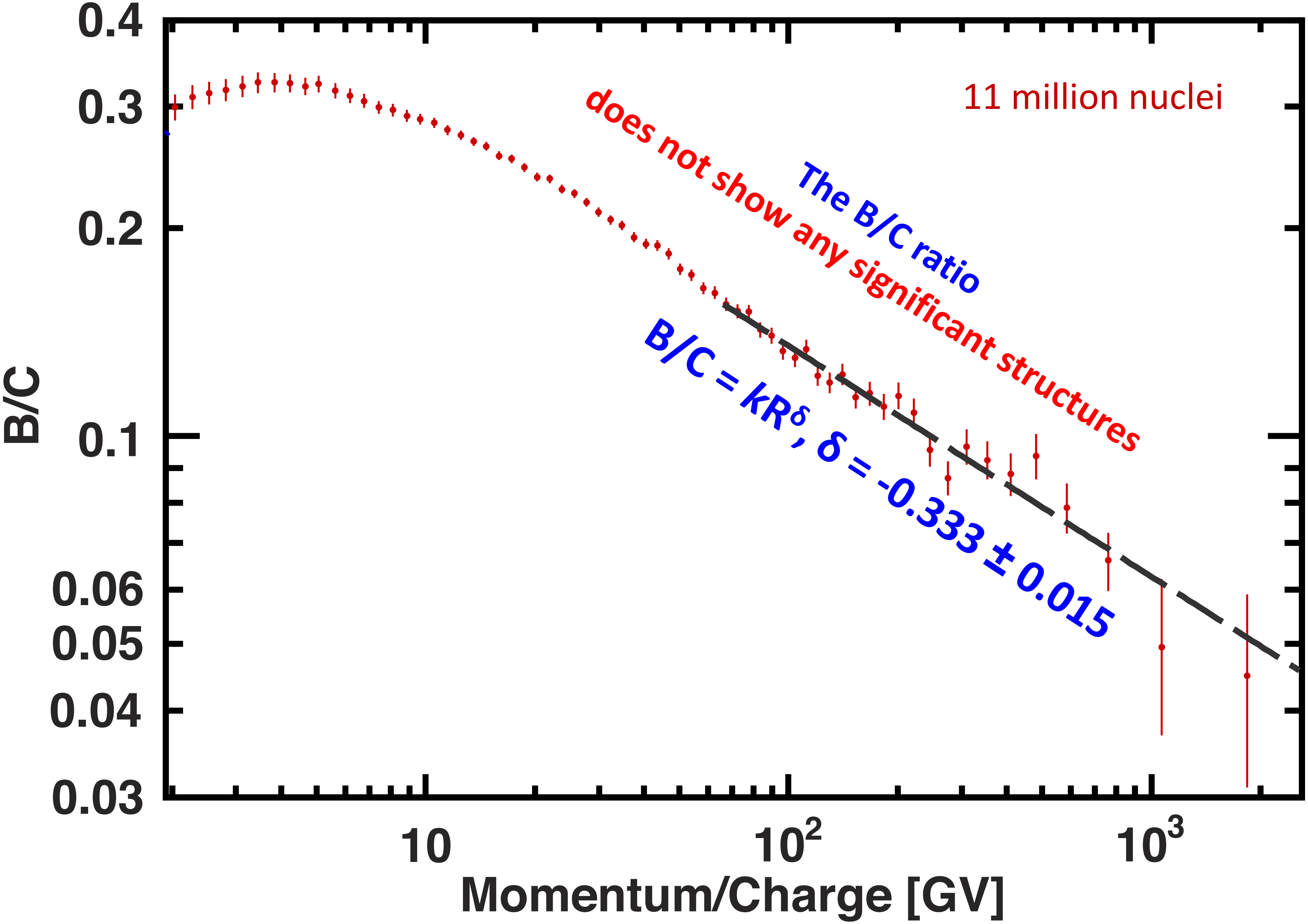


Cosmic ray propagation is commonly modeled as a fast moving gas diffusing through a magnetized plasma.

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

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

The AMS Boron-to-Carbon (B/C) flux ratio



11 million nuclei

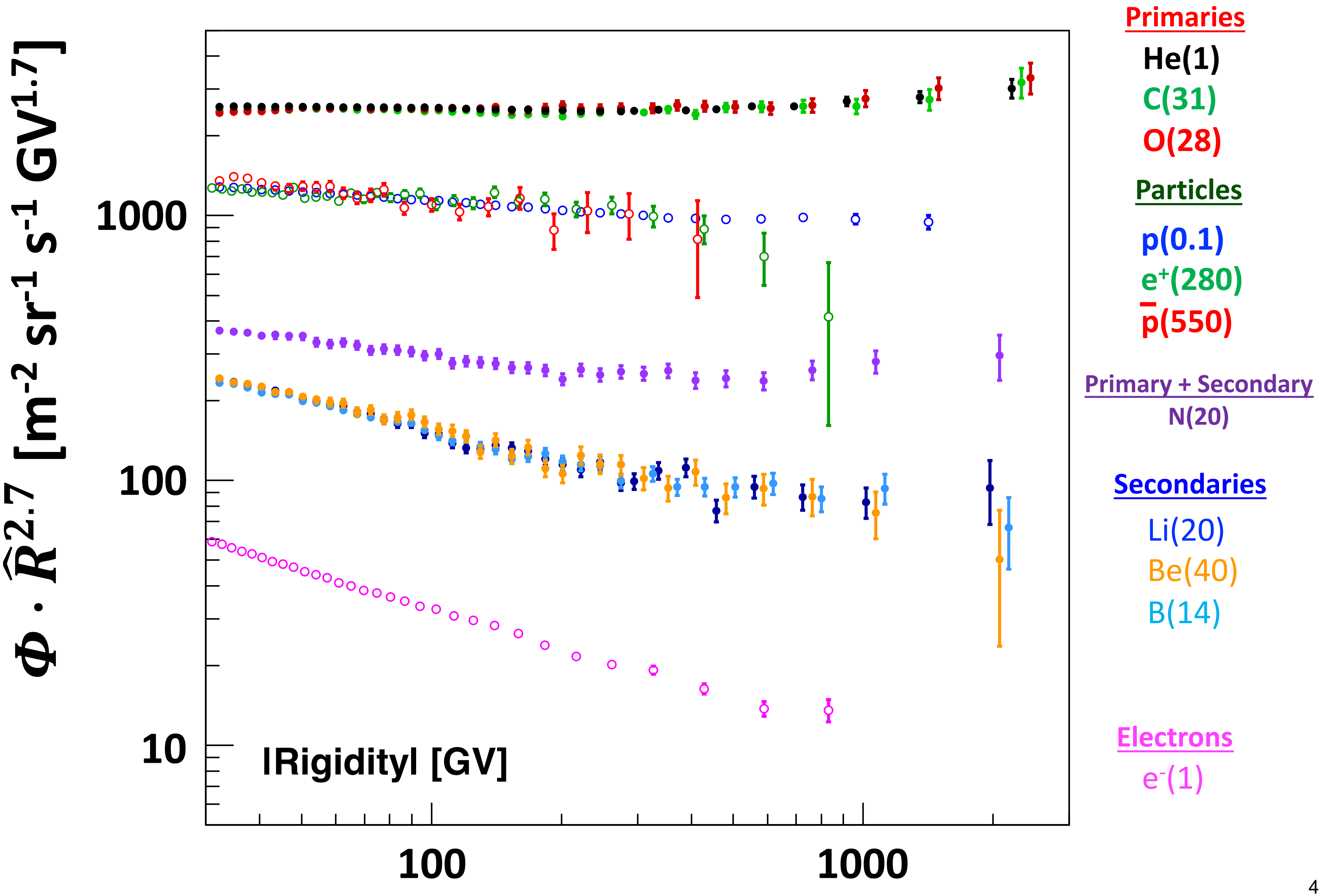
The B/C ratio does not show any significant structures

$B/C = kR^{\delta}$, $\delta = -0.333 \pm 0.015$

M. Aguilar *et al.*, Phys. Rev. Lett. **117,** 231101 (2016)

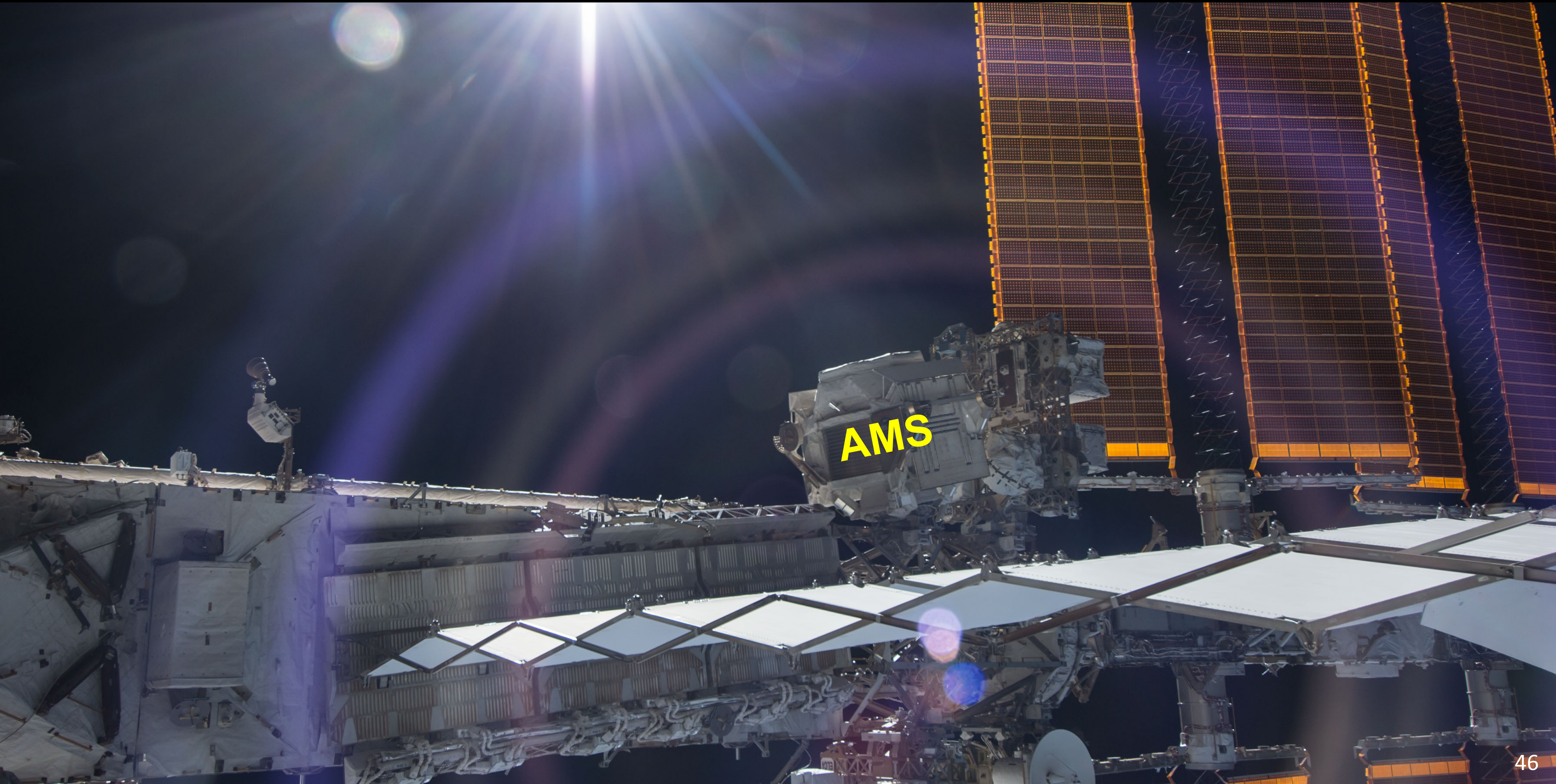
Summary of AMS results on Cosmic Ray Fluxes

High energy cosmic ray fluxes have 5 classes of rigidity dependence.

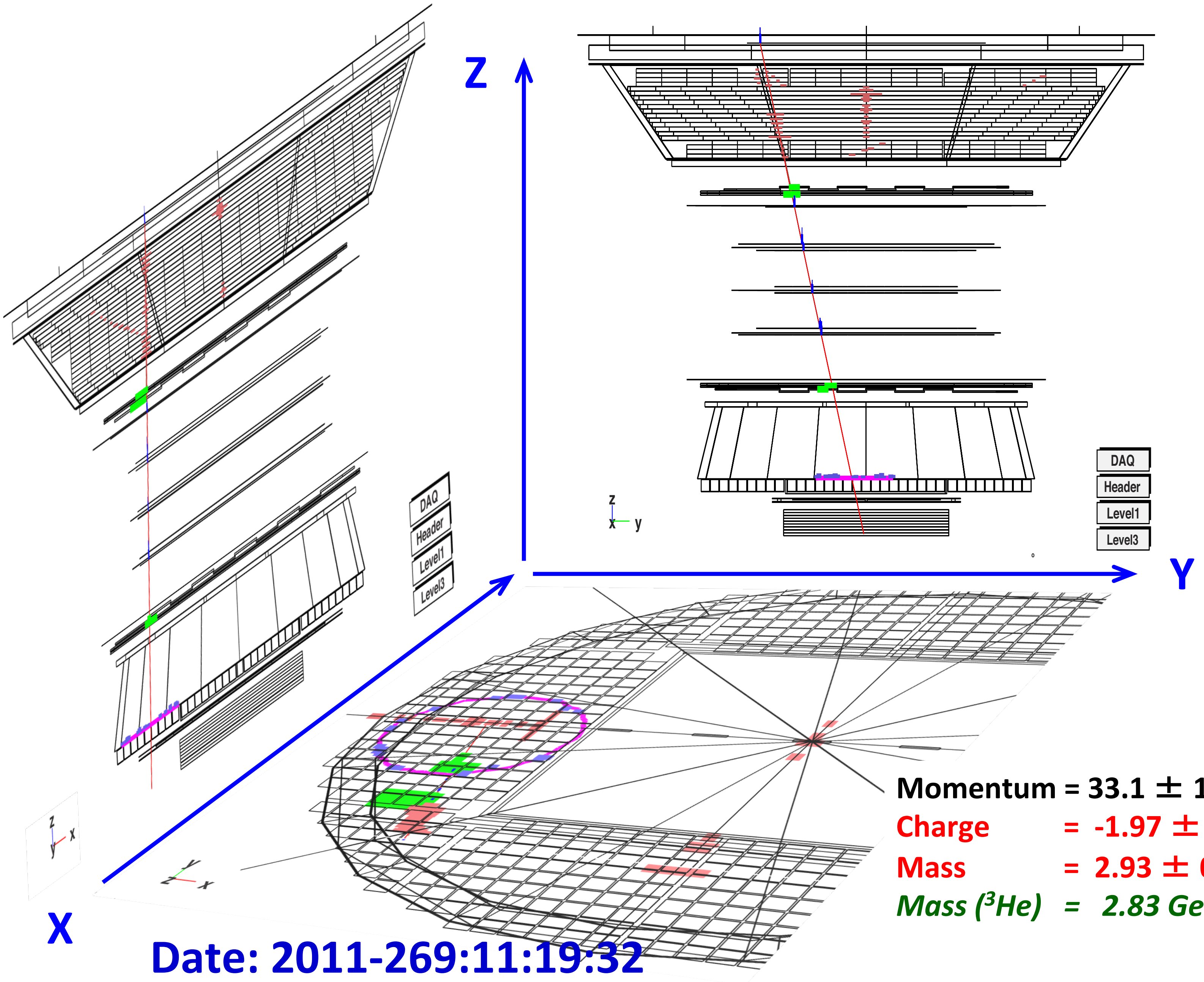


Physics of AMS through the lifetime of the Space Station

Examples: Complex anti-matter – $\overline{\mathrm{He}}$, $\overline{\mathrm{C}}$, $\overline{\mathrm{O}}$
Positrons and Dark Matter
Anisotropy and Dark Matter
High Z cosmic rays



Physics of AMS on ISS: Complex anti-matter $\overline{\text{He}}$



Momentum = 33.1 ± 1.6 GeV/*c*

Charge = -1.97 ± 0.05

Mass = 2.93 ± 0.36 GeV/c^2

Mass (^{3}He) = 2.83 GeV/c^2

Date: 2011-269:11:19:32

Physics of AMS on ISS: Study of complex anti-matter
$\overline{\text{He}}$, $\overline{\text{C}}$, $\overline{\text{O}}$

$^{3}\overline{\text{He}}$/He flux ratio predictions

From the collision of cosmic rays:

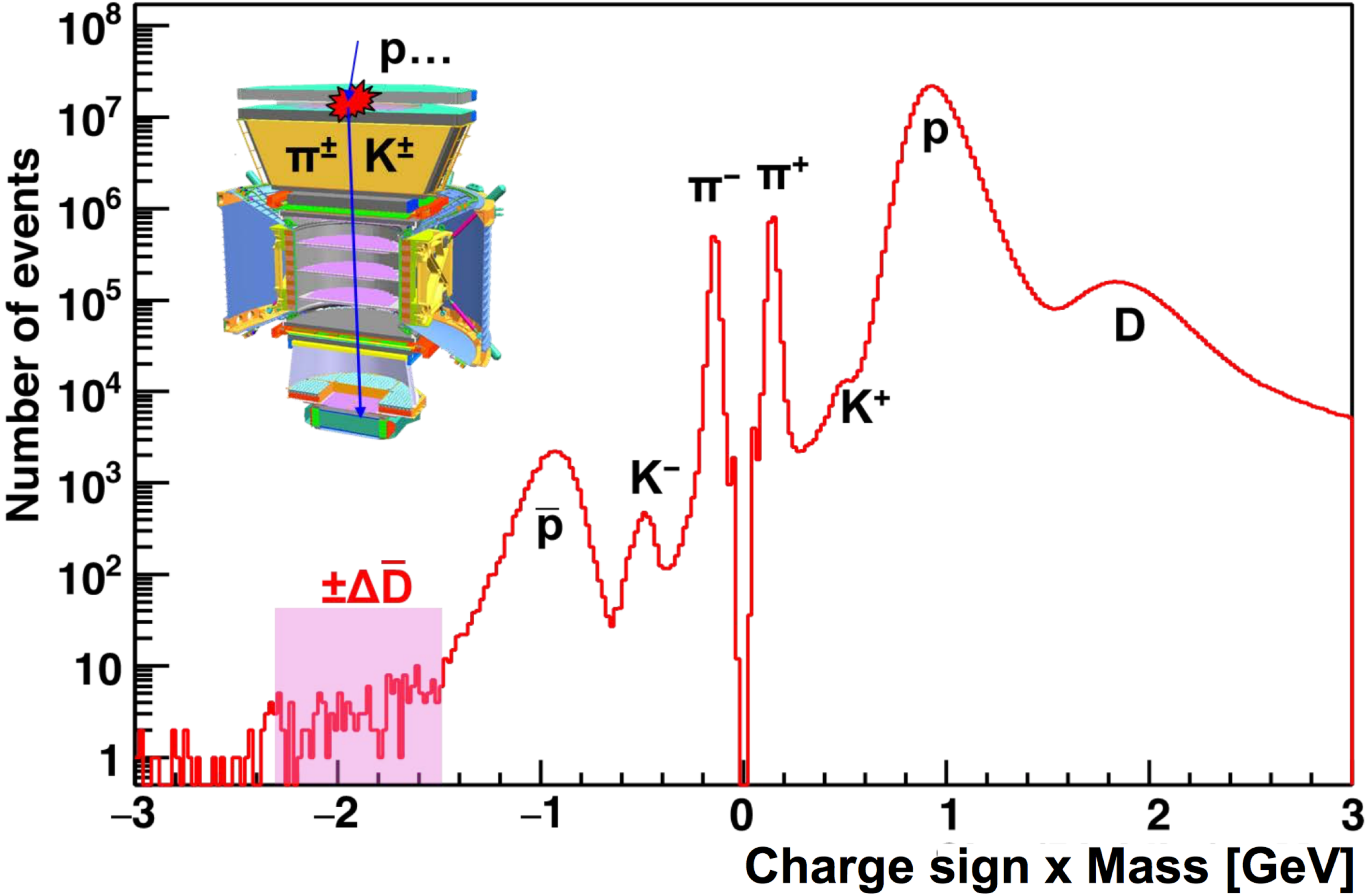
R. Duperray et al., Phys. Rev. D **71**, 083013 (2005)	**$^{3}\overline{\text{He}}$/He[8-40]GV = 6 X 10^{-12}**
M. Cirelli et al., JHEP **8**, 9 (2014):	**$^{3}\overline{\text{He}}$/He[8-40]GV = 3 X 10^{-11}**
K. Blum et al., Phys. Rev. D **96**, 103021 (2017)	**$^{3}\overline{\text{He}}$/He[8-40]GV = 6 X 10^{-10}**
E. Carlson et al., Phys. Rev. D **89**, 076005 (2014)	**$^{3}\overline{\text{He}}$/He[8-40]GV = 1.4 X 10^{-9}**
A. Coogan et al., Phys. Rev. D **96**, 083020 (2017)	**$^{3}\overline{\text{He}}$/He[8-40]GV ~ 2 X 10^{-8}**
AMS Measurement:	**$^{3}\overline{\text{He}}$/He[8-40]GV = 2 X 10^{-8}**

There are large uncertainties in models to ascertain the origin of $^{3}\overline{\text{He}}$

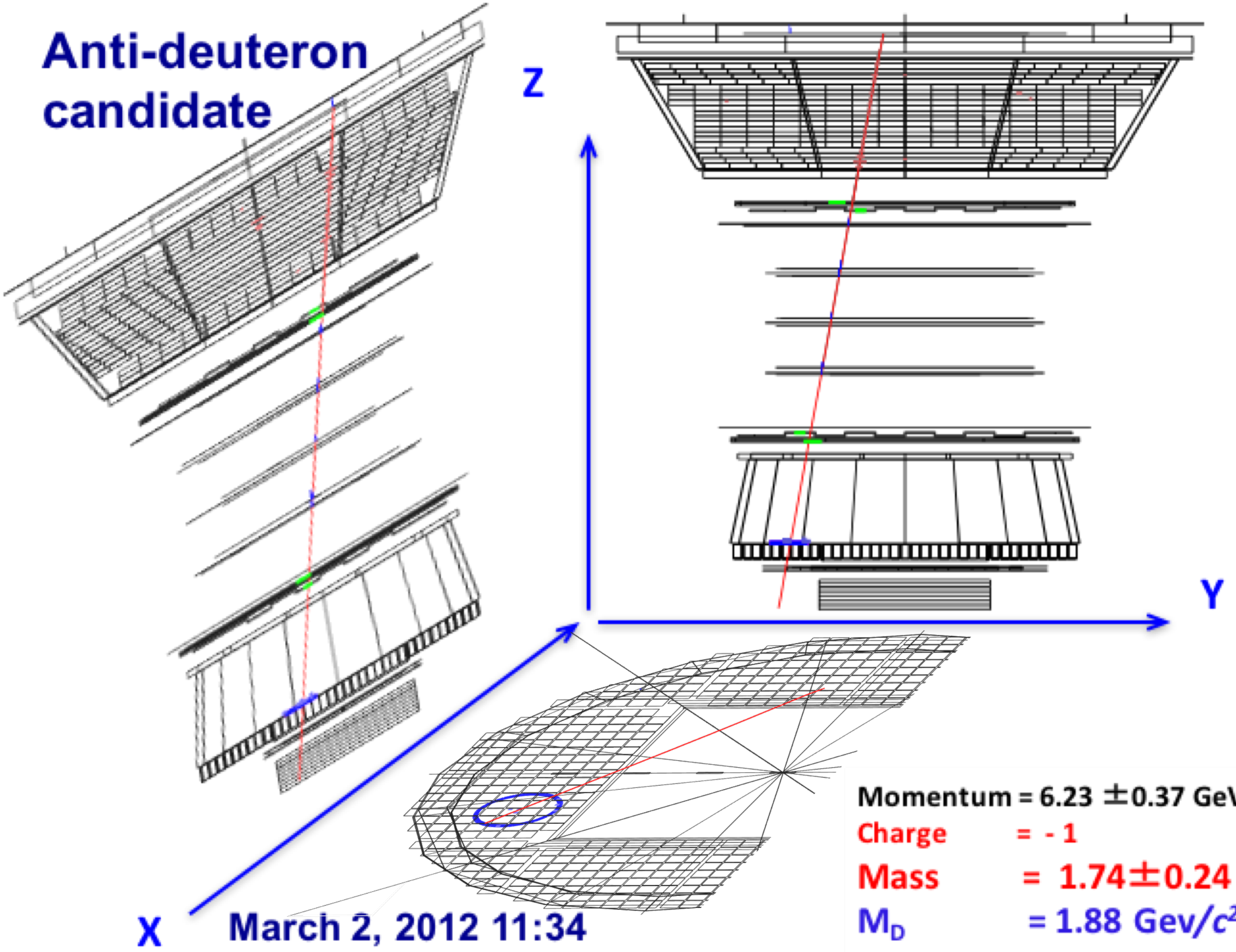
We have also observed two $^{4}\overline{\text{He}}$ candidates.

The rate of anti-helium production is typically 1 in 100 million helium.
More events are necessary to confirm that there are no backgrounds.

Anti-Deuteron



Anti-deuteron candidate



March 2, 2012 11:34

Momentum = 6.23 ±0.37 GeV/*c*

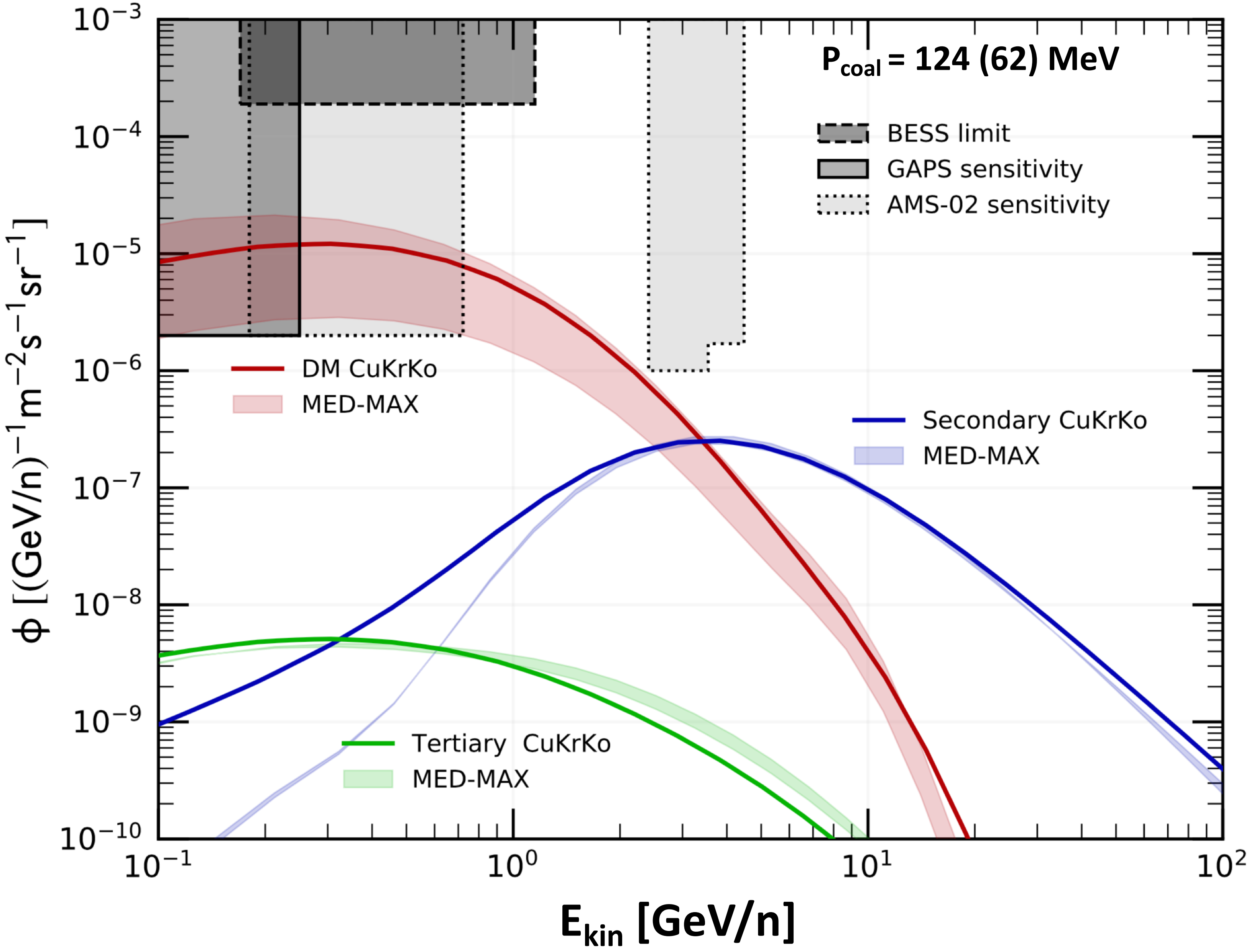
Charge = - 1

Mass = 1.74±0.24 GeV/c^2

M_D = 1.88 Gev/c^2

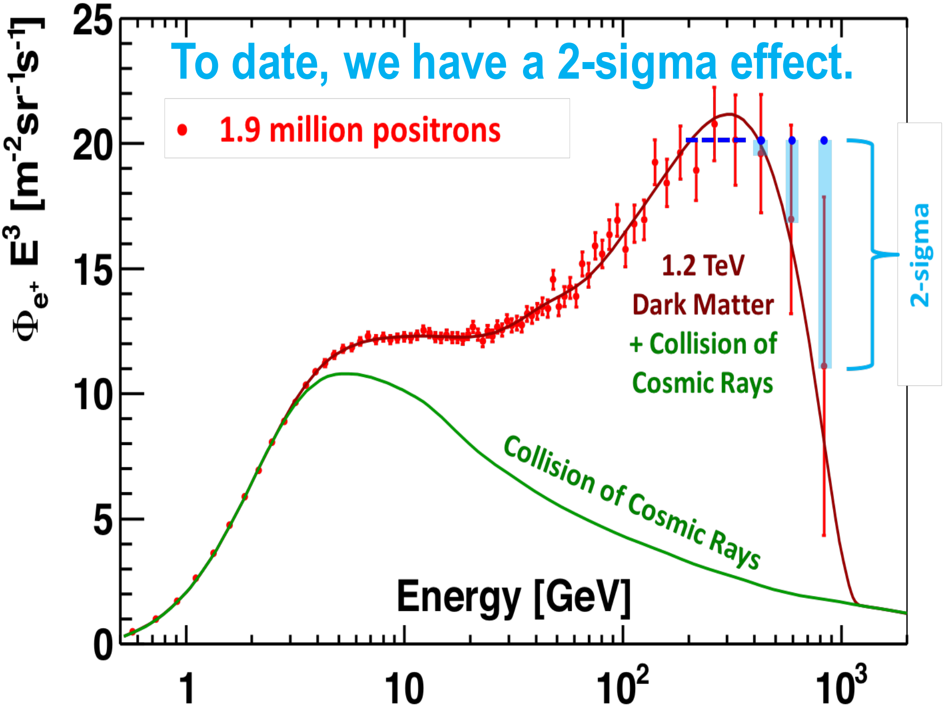
Example: Sensitivity to Anti-Deuteron in Cosmic Rays

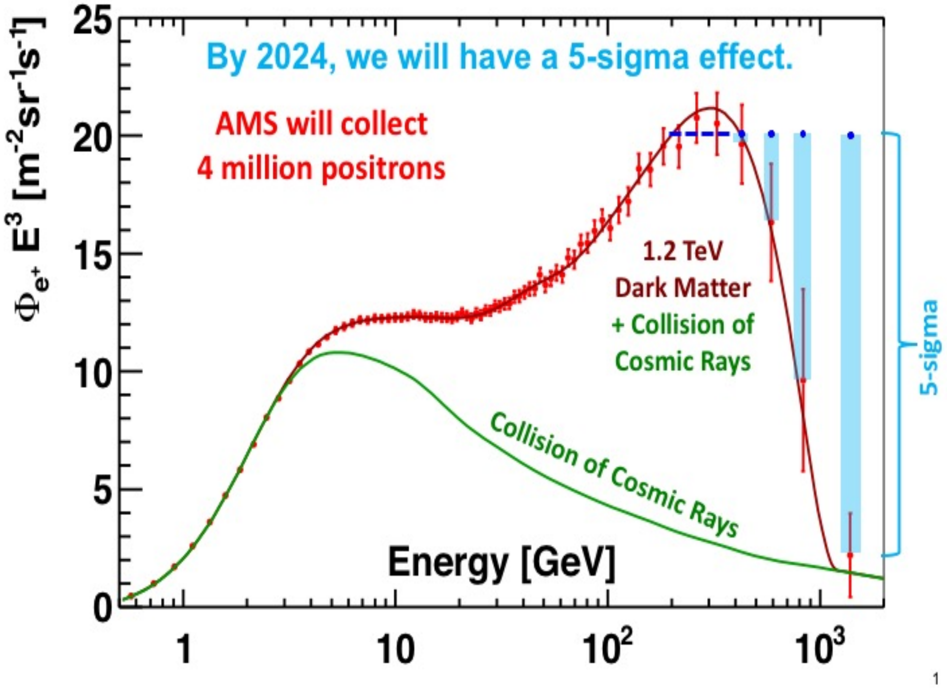
F. Donato, Fornengo, Korsmeier, 1711.08465 subm. PRD



Physics of AMS on ISS: Positrons and Dark Matter

Extend the measurements to 2 TeV and determine the sharpness of the drop off.





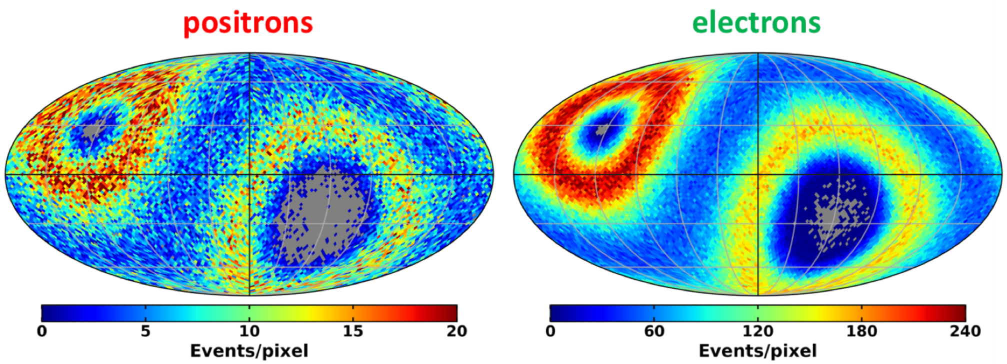
Currently, the approved ISS lifetime is until 2024.
The incremental gain between now and 2024 is from 2-sigma to 5-sigma.

Physics of AMS on ISS: Anisotropy and Dark Matter

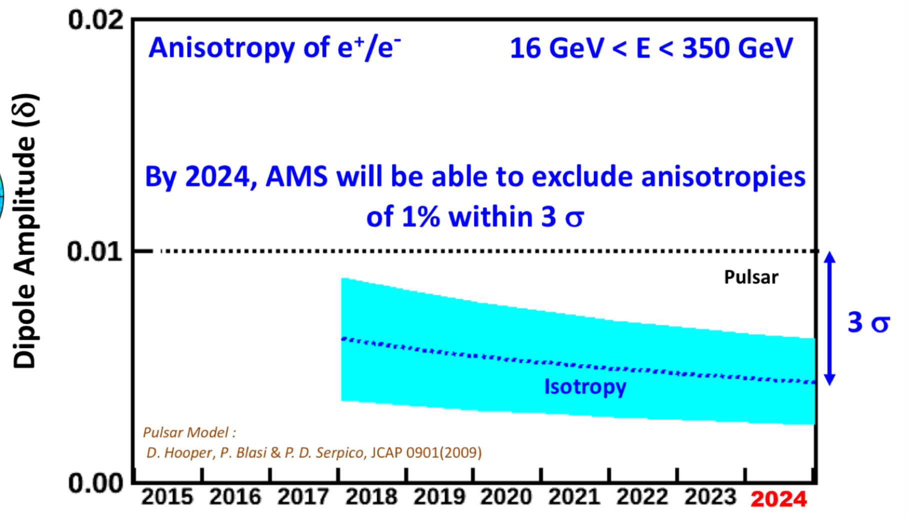
Astrophysical point sources like pulsars will imprint a higher anisotropy on the arrival directions of energetic positrons than a smooth dark matter halo.

The anisotropy in galactic coordinates

$\delta = 3\sqrt{C_1/4\pi}$ C_1 is the dipole moment

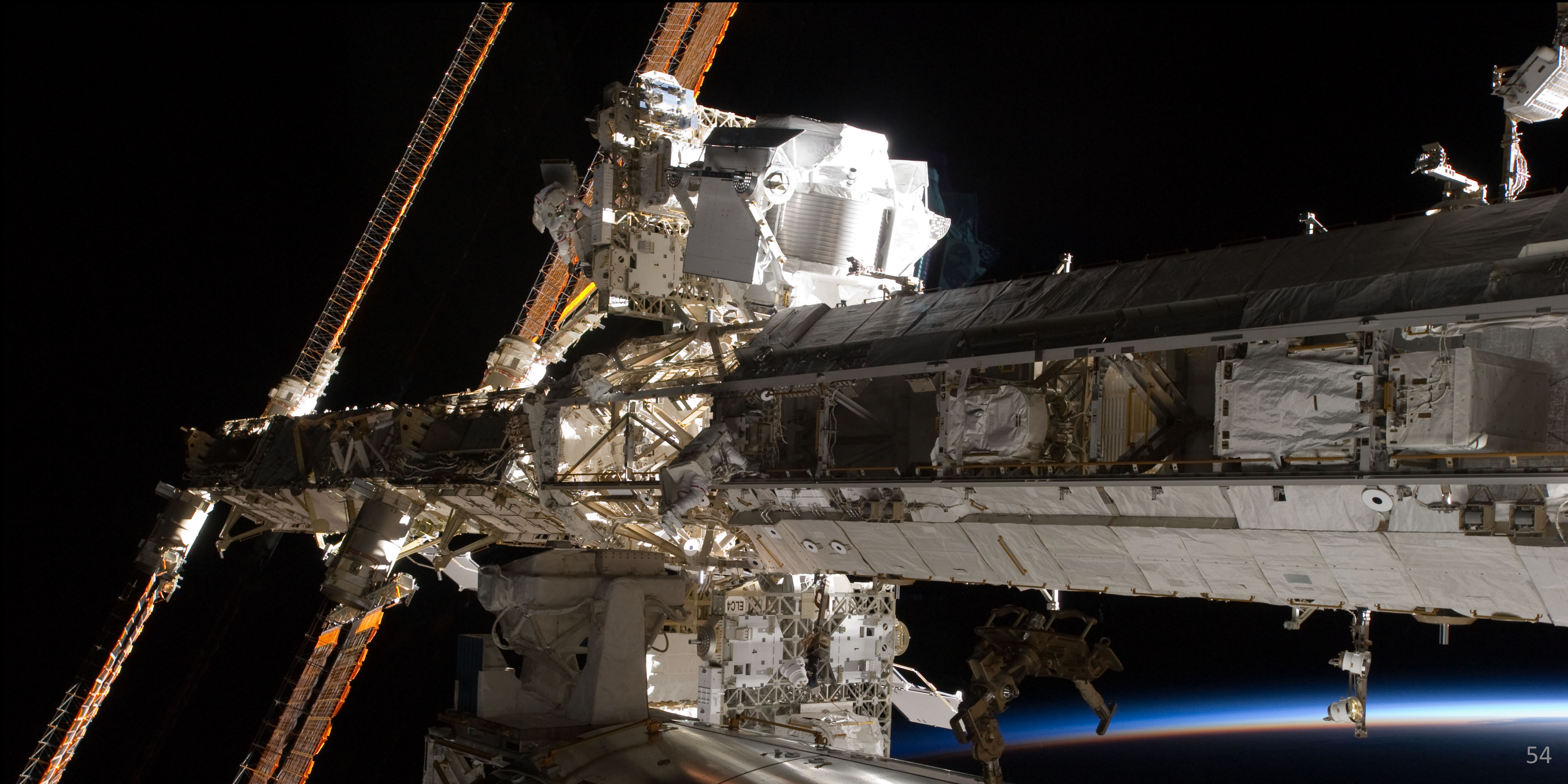


Projected amplitude of the dipole anisotropy

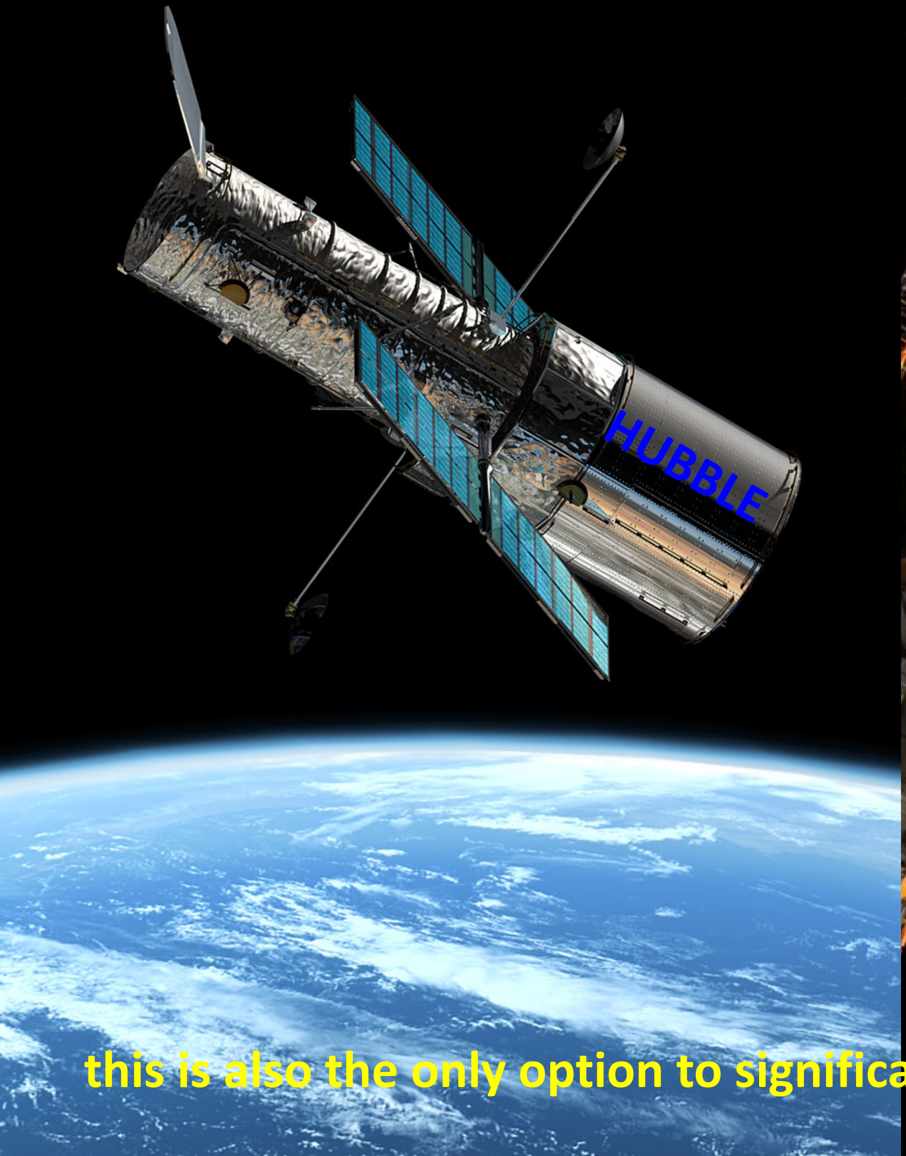


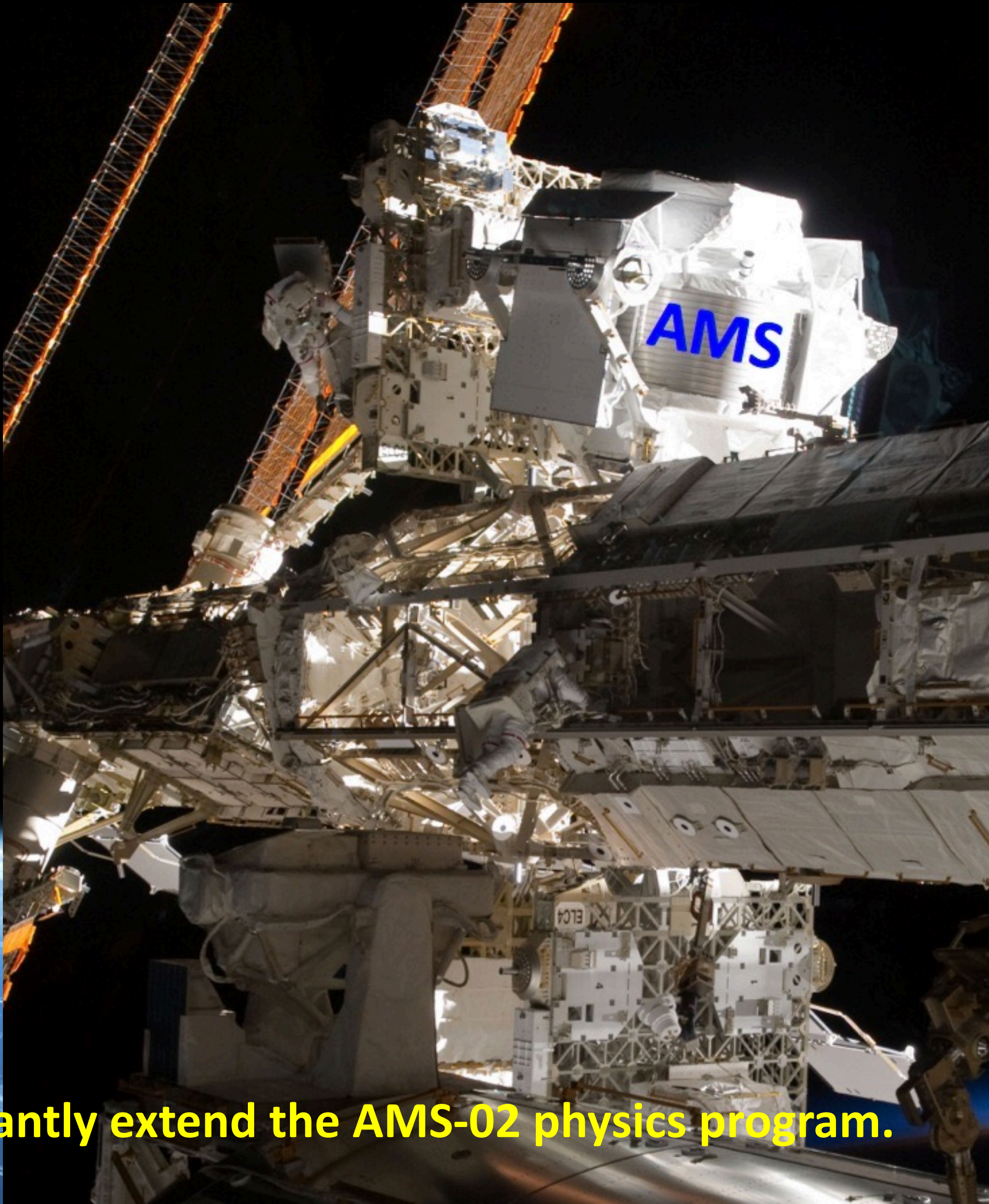
The observation of isotropy is important to understand the origin of the excess in the positron flux.

- AMS has collected more than 125 Billion cosmic rays since 2011 and is a unique scientific instrument on board the ISS.
- The high precision cosmic ray flux measurements from AMS present challenges to the present understanding of the nature of cosmic rays and are of fundamental importance for deciphering the properties of Galactic cosmic rays.
- AMS will have collected 240 Billion cosmic rays by 2024 and will continue to take data through the lifetime of the ISS.



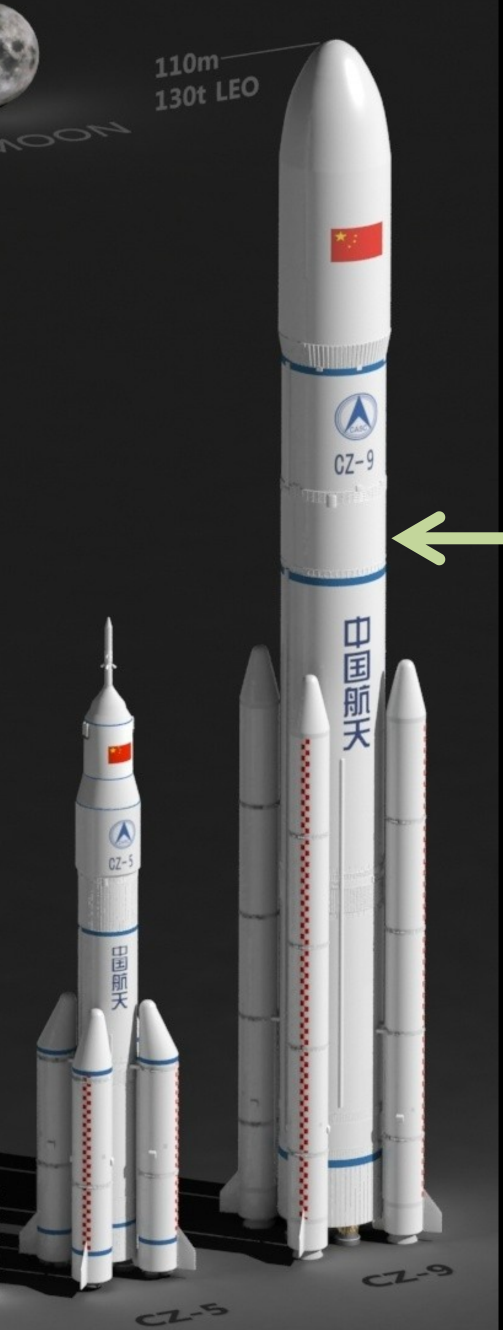
The next generation space telecope will be operated at Lagrange Point 2,





this is also the only option to significantly extend the AMS-02 physics program.

The next generation of Cosmic Ray Experiments



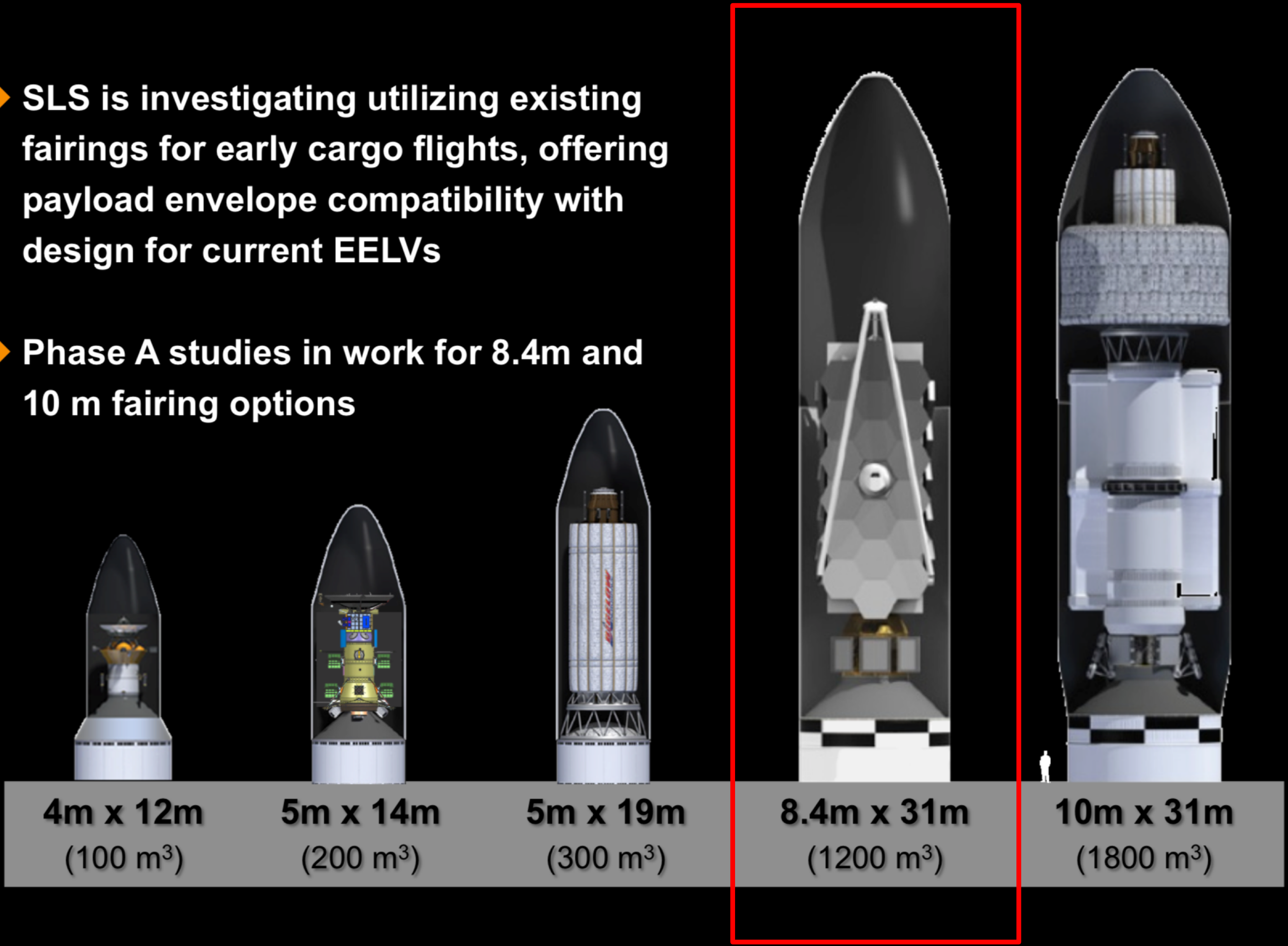
Current and upcoming rockets

Name	LEO [kg]	other [kg]	First flight	
Ariane 5	21,000	10,730 GTO	2002	ESA
Falcon Heavy	63,800	26,700 GTO	2017	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

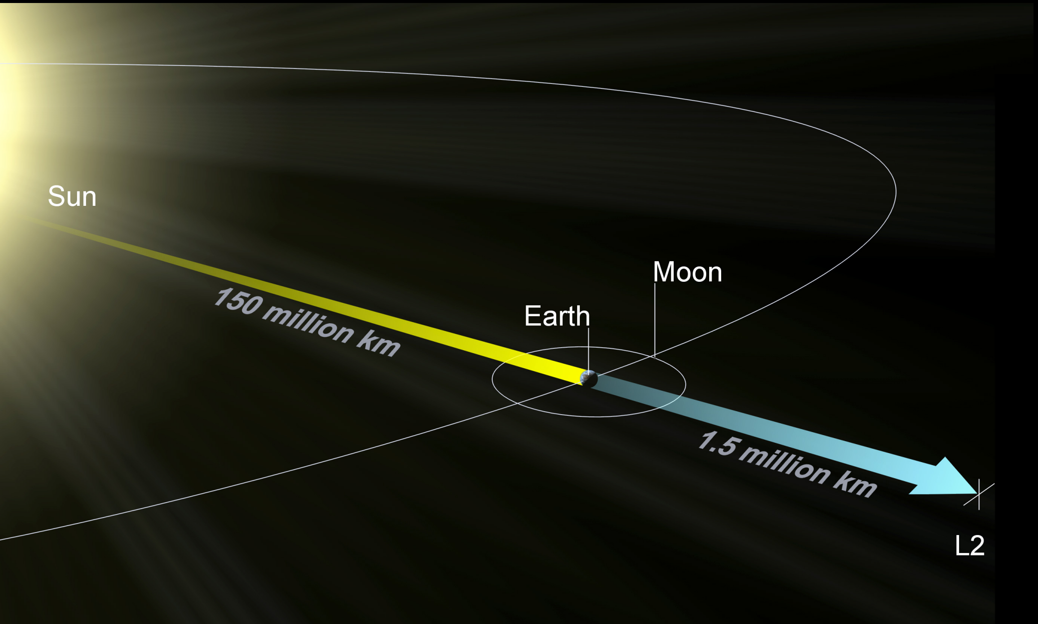
LEO:	Low Earth orbit
GTO:	Geostationary transfer orbit
TLI:	Trans-lunar injection

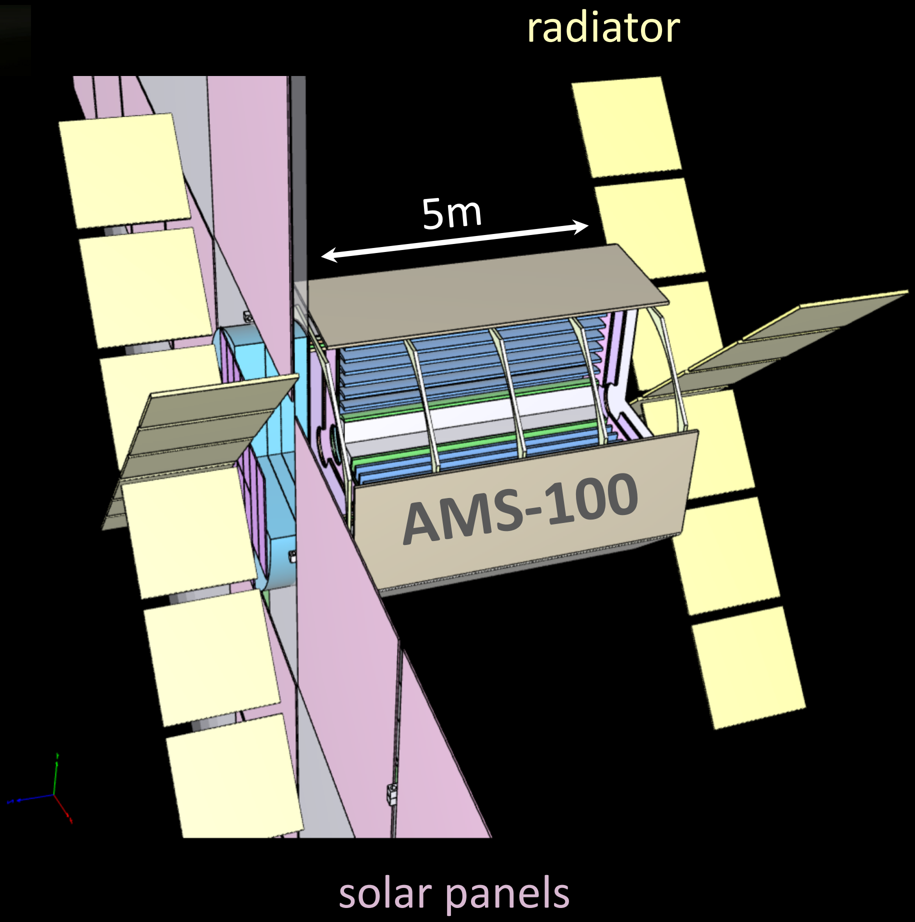
- **SLS is investigating utilizing existing fairings for early cargo flights, offering payload envelope compatibility with design for current EELVs**
- **Phase A studies in work for 8.4m and 10 m fairing options**



AMS-100: A Magnetic Spectrometer

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

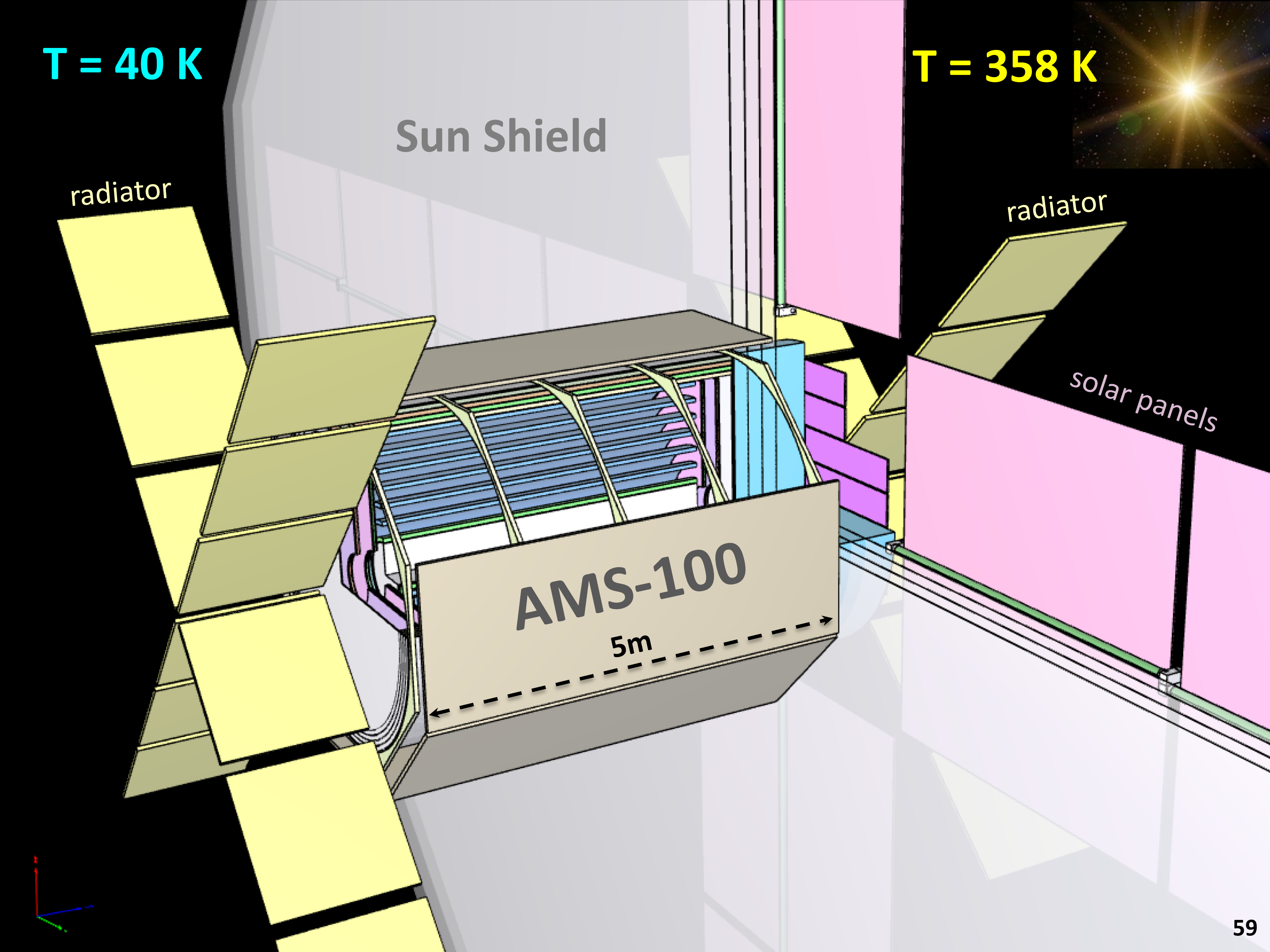




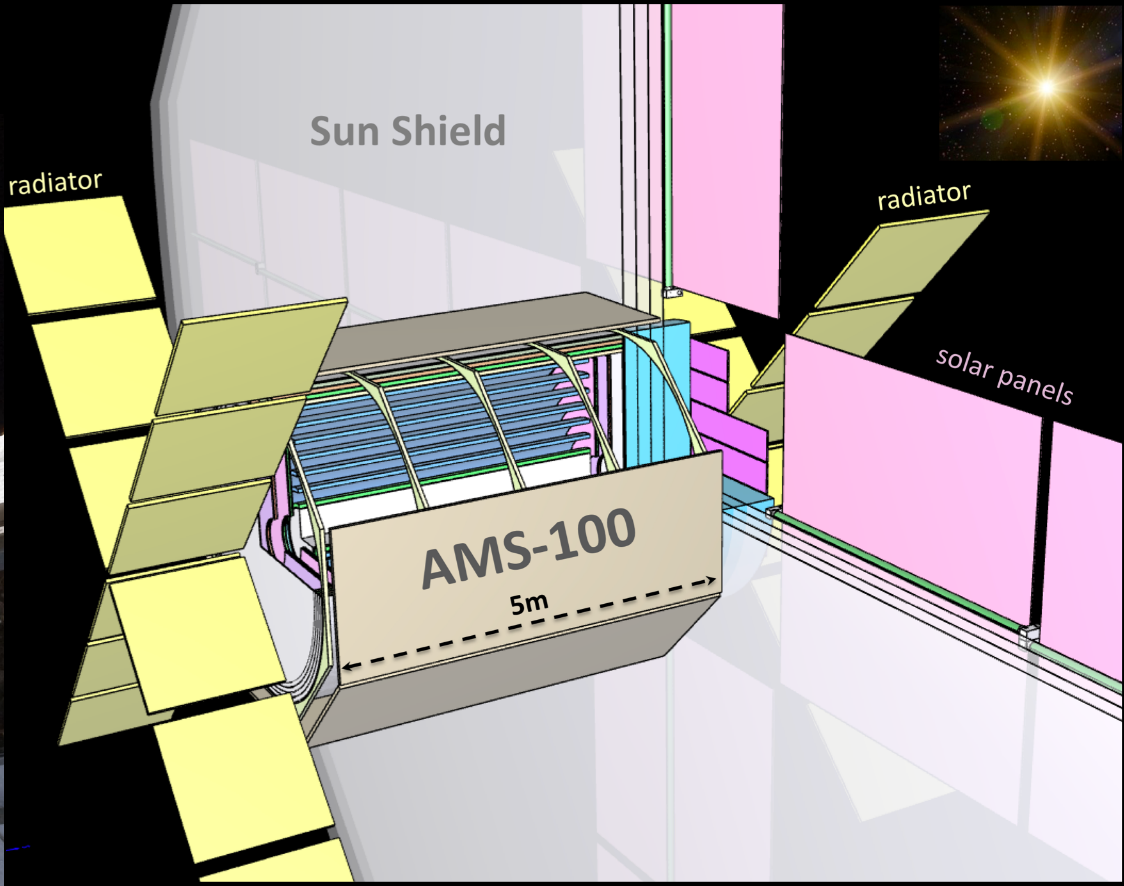
Thin coil Solenoid, HTS Wire, $T \approx 60K$, field 1 T
Silicon and Scintillating Fiber tracker
Calorimeter – 80 X_0, 4λ

Acceptance 100m^2 sr
MDR 100 TV, nuclei up to the ``knee''
Anti-protons, positrons up to 10 TeV

Weight: 40 t


T = 40 K
Sun Shield
T = 358 K
radiator
radiator
solar panels
AMS-100
5m

AMS-02



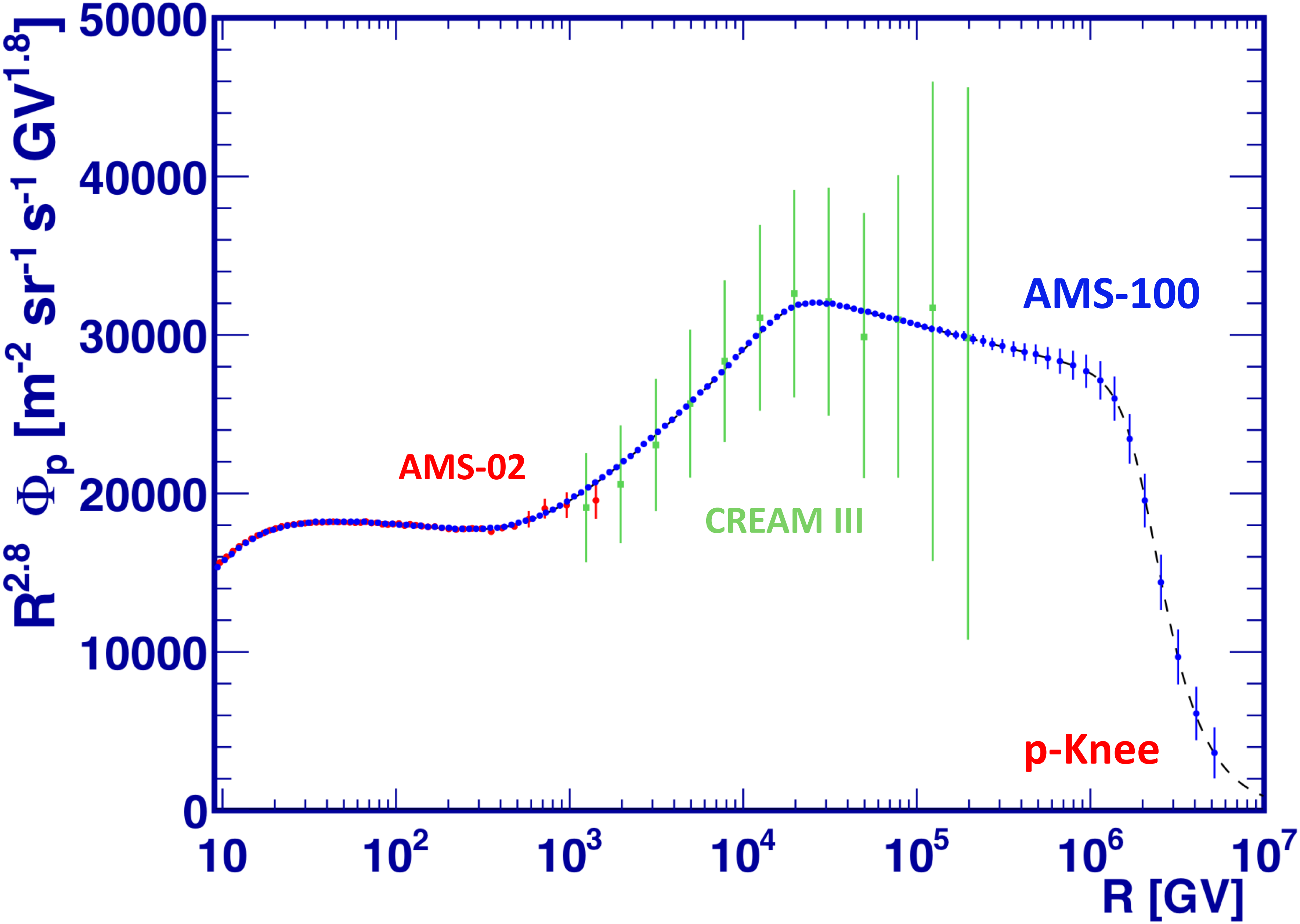
Operational on the ISS since 2011

Weight:	7 t
Permanent Magnet:	$BL^2=0.15\ Tm^2$
Acceptance:	$0.1\ m^2sr$
MDR:	2 TV
Calorimeter:	$17\ X_0,\ 1.7\lambda$

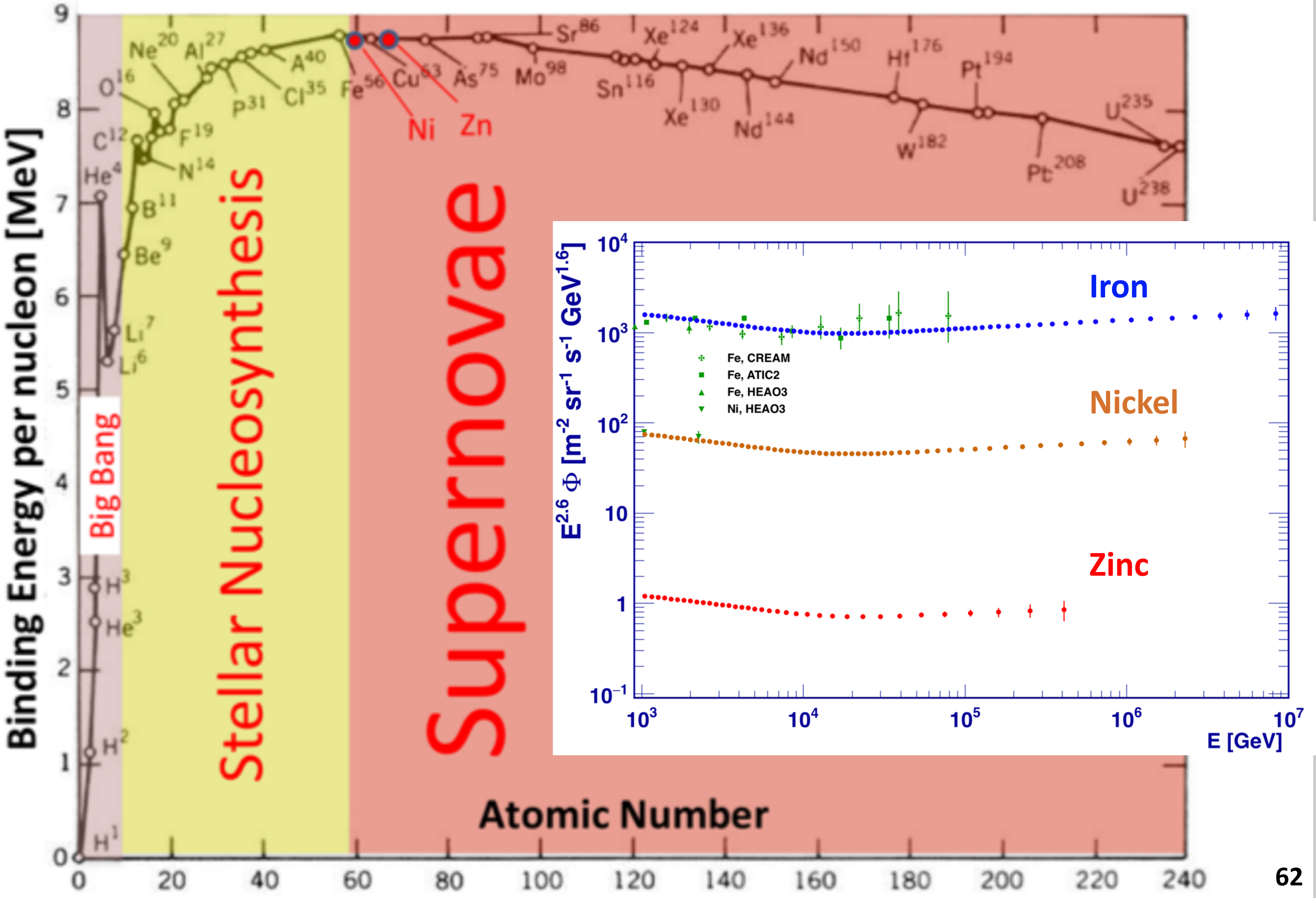
Lagrange-Point 2

Weight:	40 t
Thin coil Solenoid :	$BL^2=13\ Tm^2$
Acceptance:	$100\ m^2sr$
MDR:	100 TV
Calorimeter:	$80\ X_0,\ 4\lambda$

Protons in Cosmic Rays

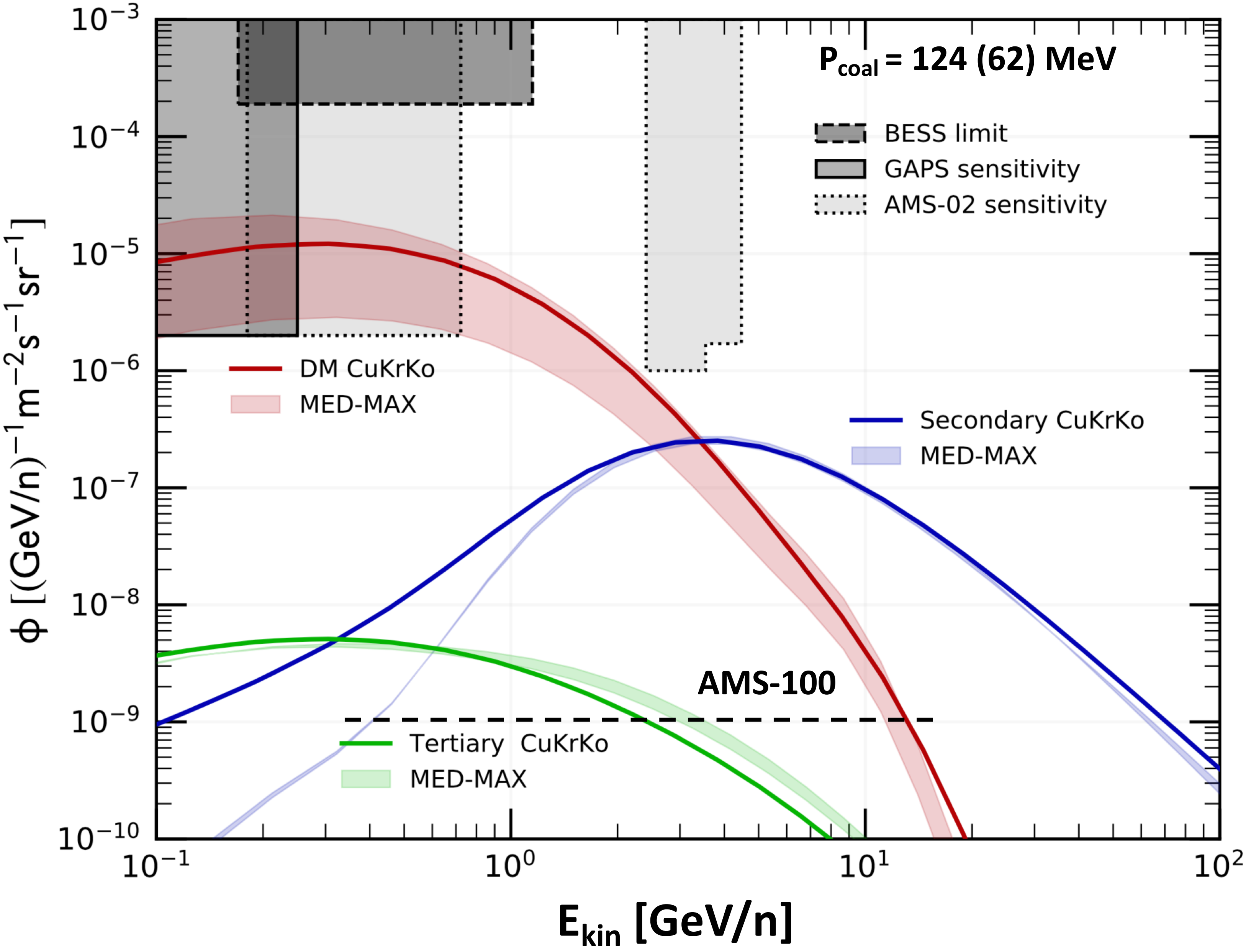


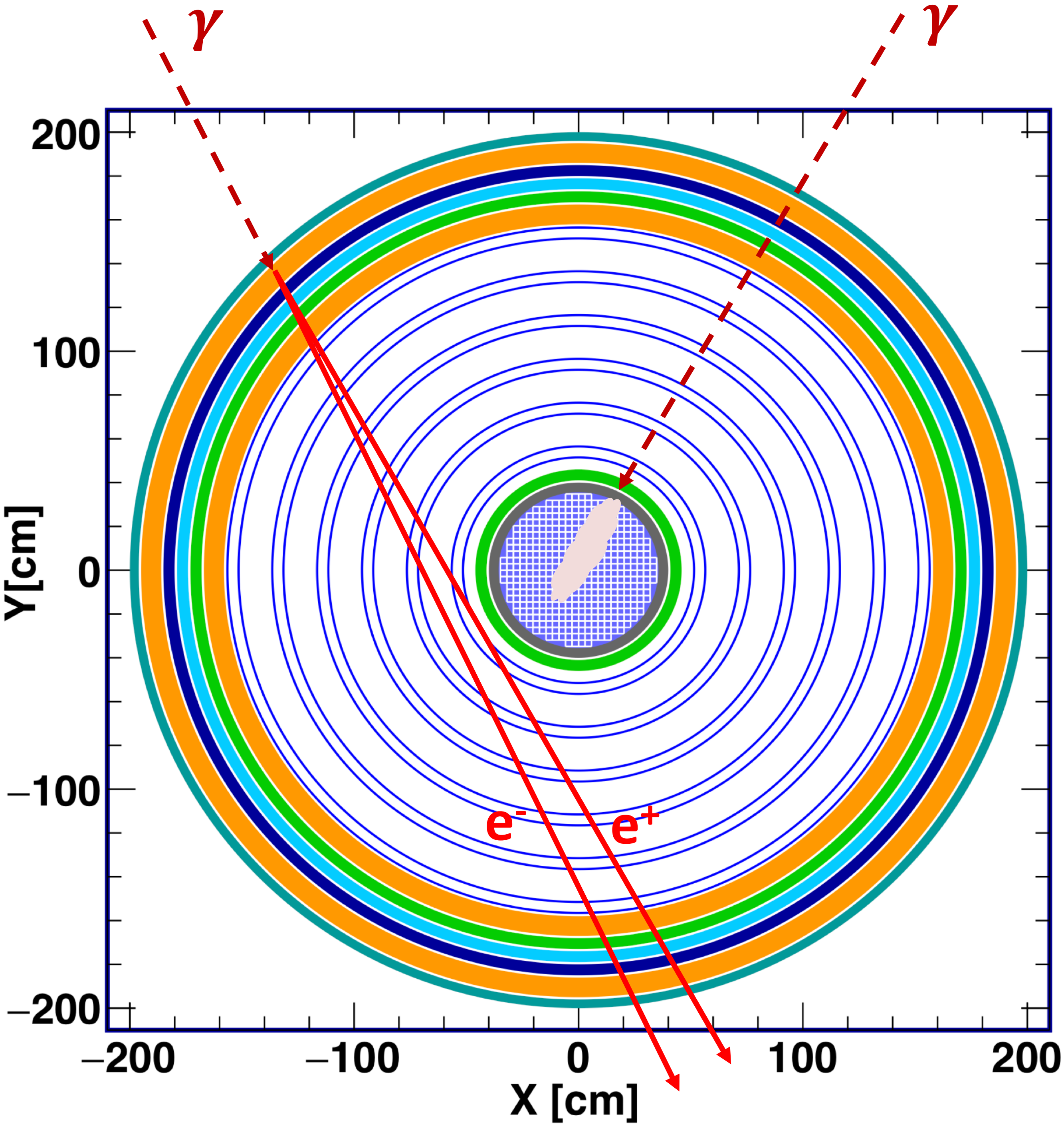
The lightest elements created by supernova are Nickel and Zinc. AMS-100 will be able to study their detailed properties and compare them with elements produced by stellar nucleosynthesis.



Example: Sensitivity to Anti-Deuteron in Cosmic Rays

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



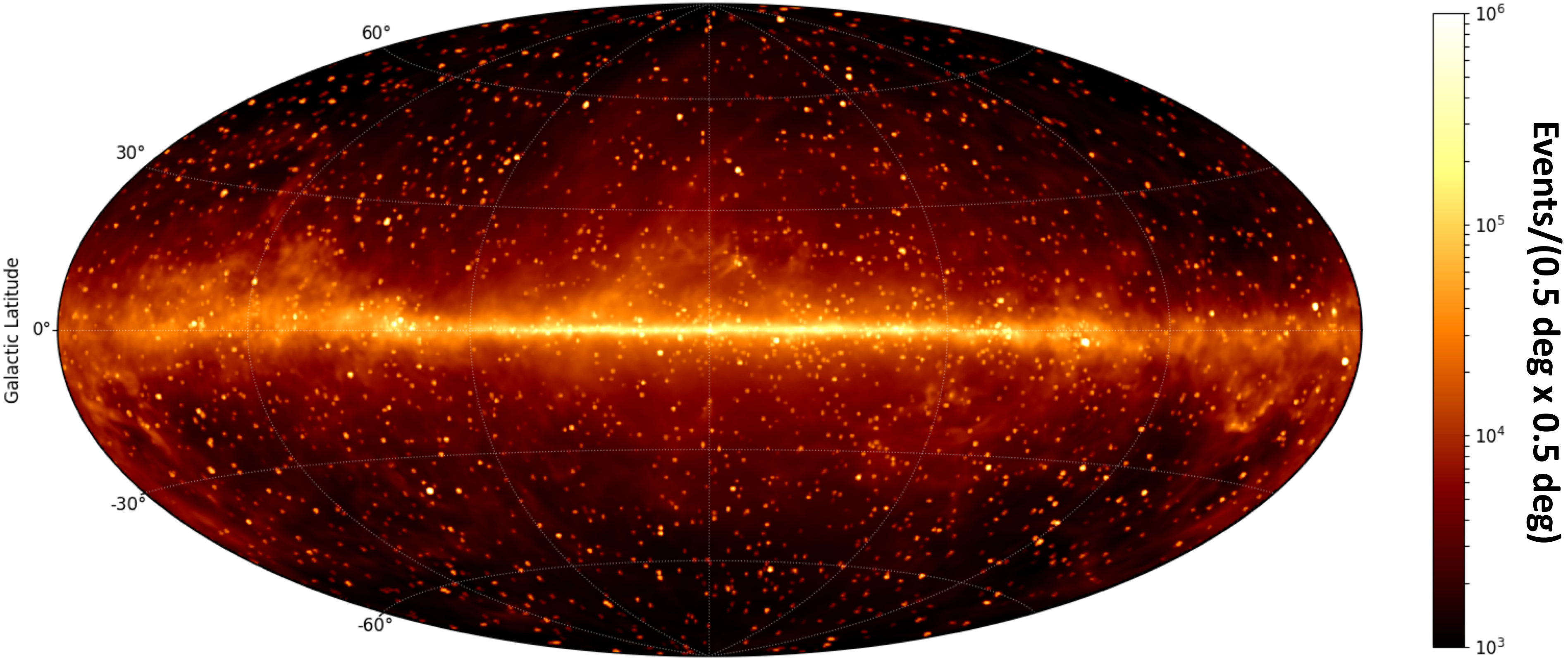


- **The magnet coil is a well localized converter for photons.**
- **The angular resolution for converted photons is ~1000 times better than FERMI‘s and the acceptance of AMS-100 is 25 times larger.**

1. Radiator
2. Outer SciFi-Tracker
3. **Magnet**
4. DIRC
5. Outer ToF
6. Inner SciFi-Tracker
7. Si-Tracker
8. Inner ToF
9. Pre-Shower
10. LYSO-Calorimeter

AMS-100 will monitor the whole sky continously.

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



We expect to see 10,000 new sources with AMS-100.

AMS-100: A Magnetic Spectrometer at LP-2

- A large scale superconducting magnet in space has large implications for human space exploration.

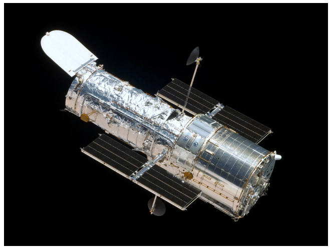
1990
Hubble

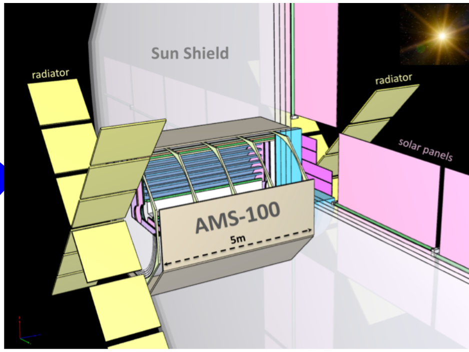
2008
FERMI

2011
AMS-02

2020
James Webb

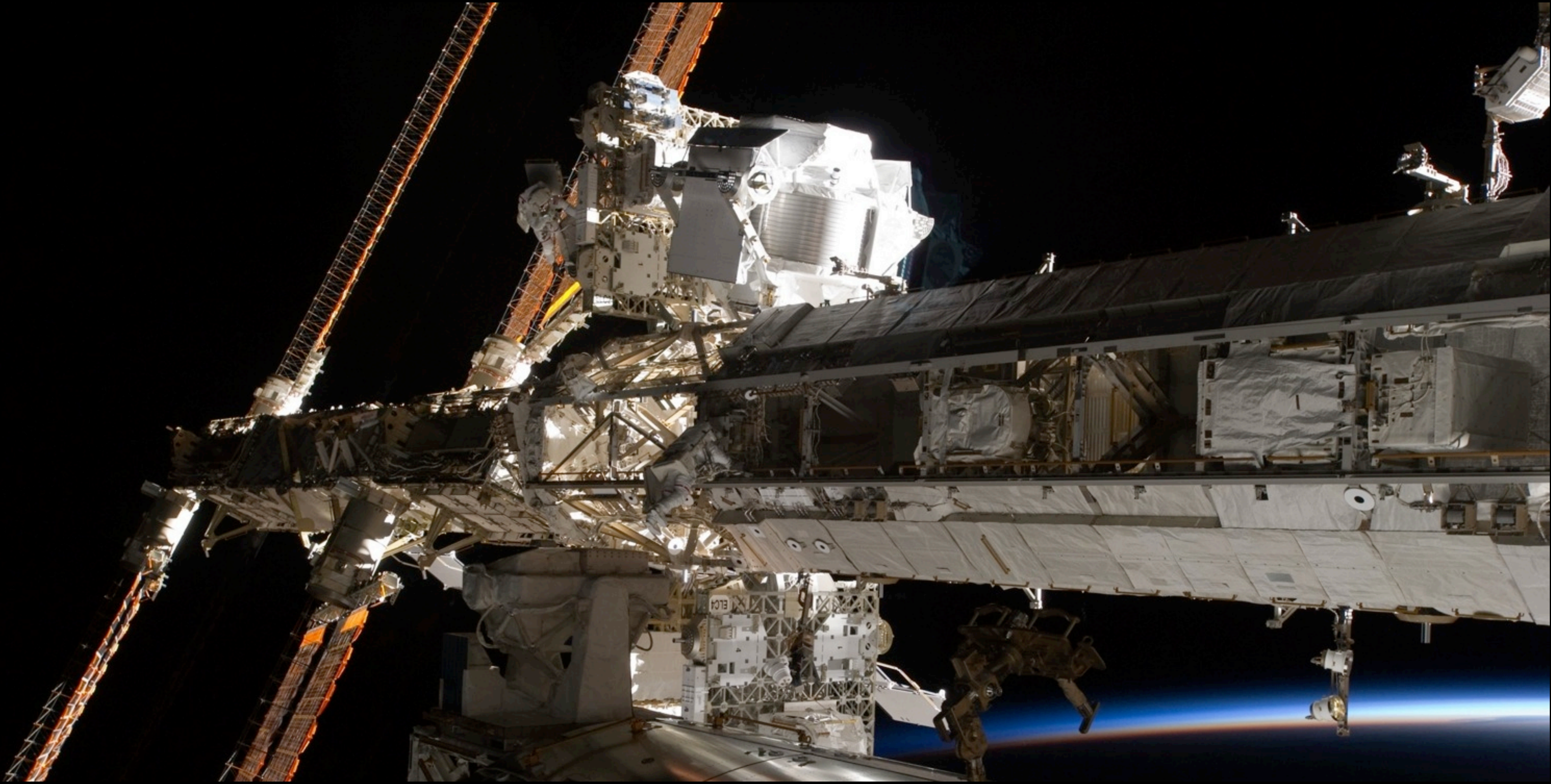
2030
AMS-100





- AMS-100 would open a new window to explore the universe.

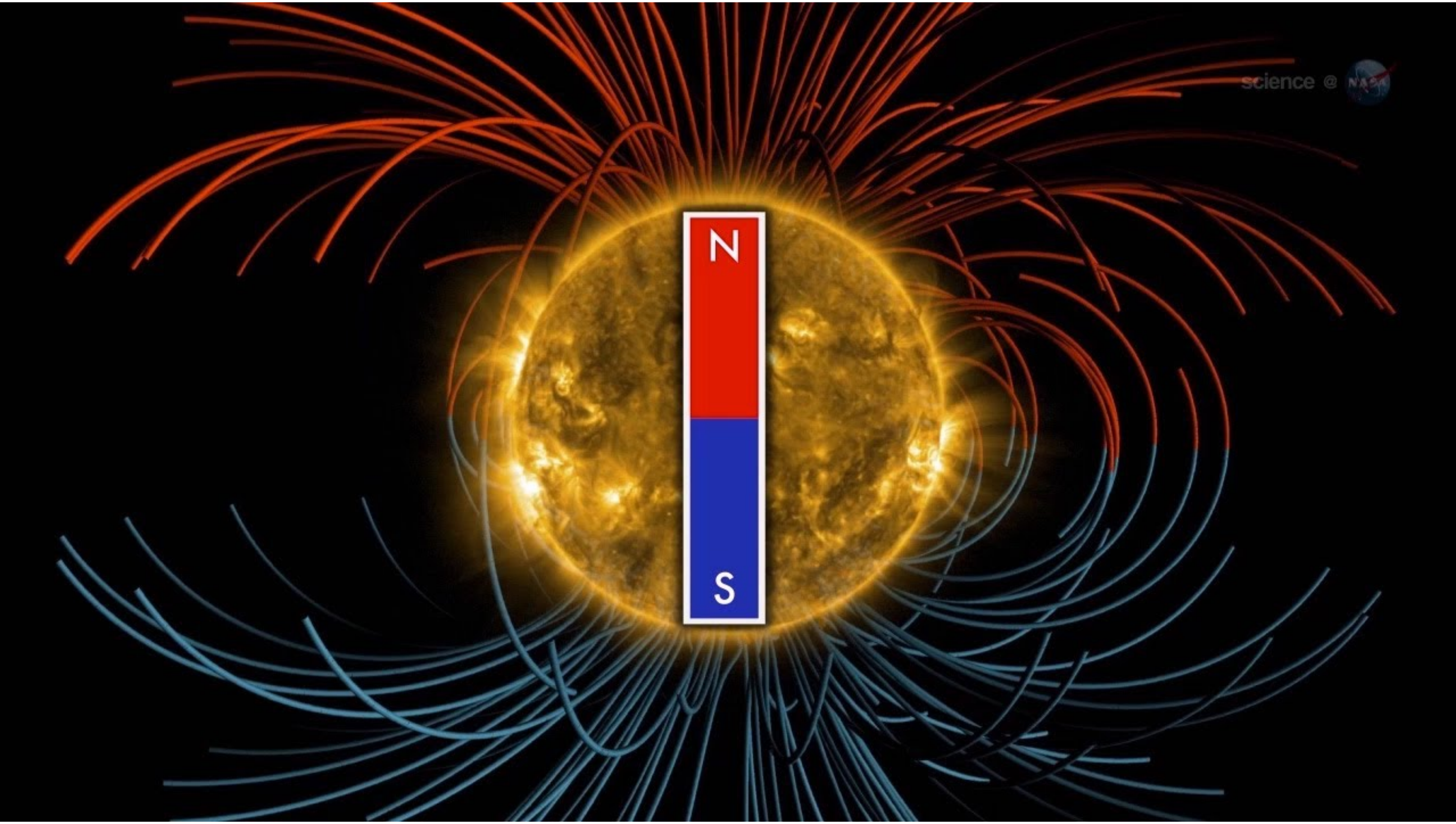
The Cosmos is the ultimate Laboratory.



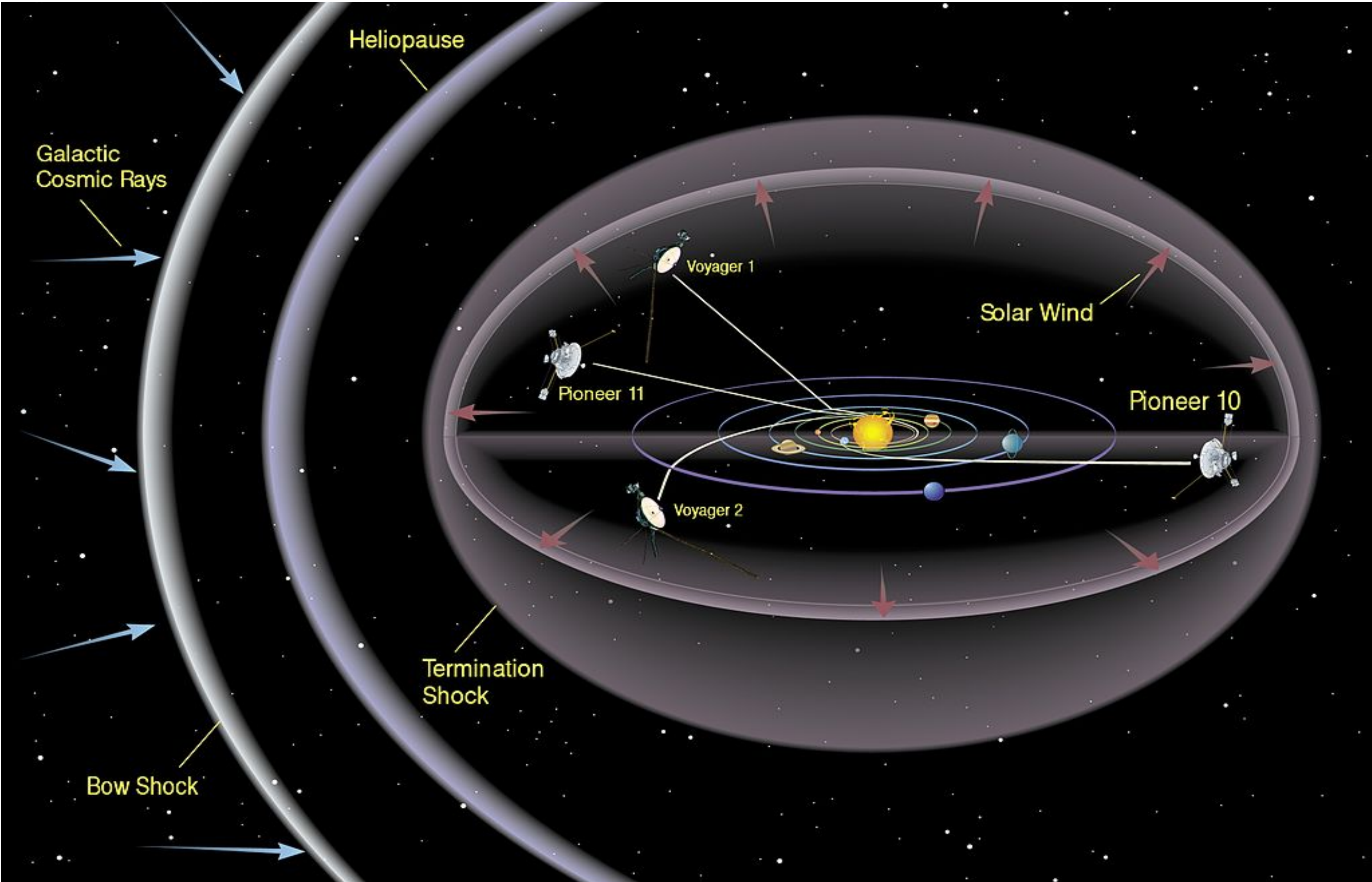
*"The most exciting objective of AMS is to probe the unknown;
to search for phenomena which exist in nature
that we have not yet imagined nor had the tools to discover."*

S. Ting

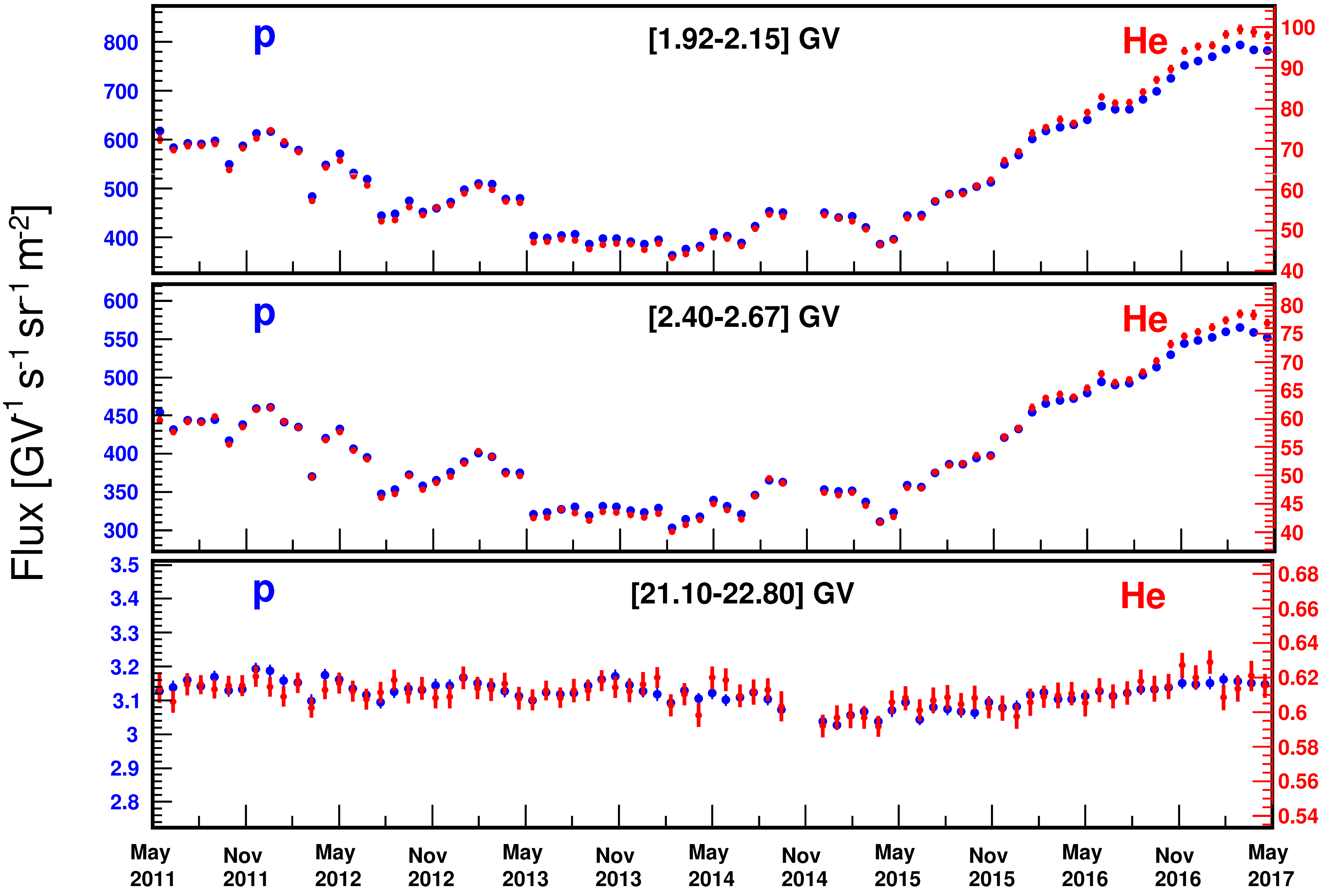
Cosmic Ray Fluxes vs Time



New observations of the monthly time variation of the e+, e-, p, and He fluxes are providing key information for studying solar physics

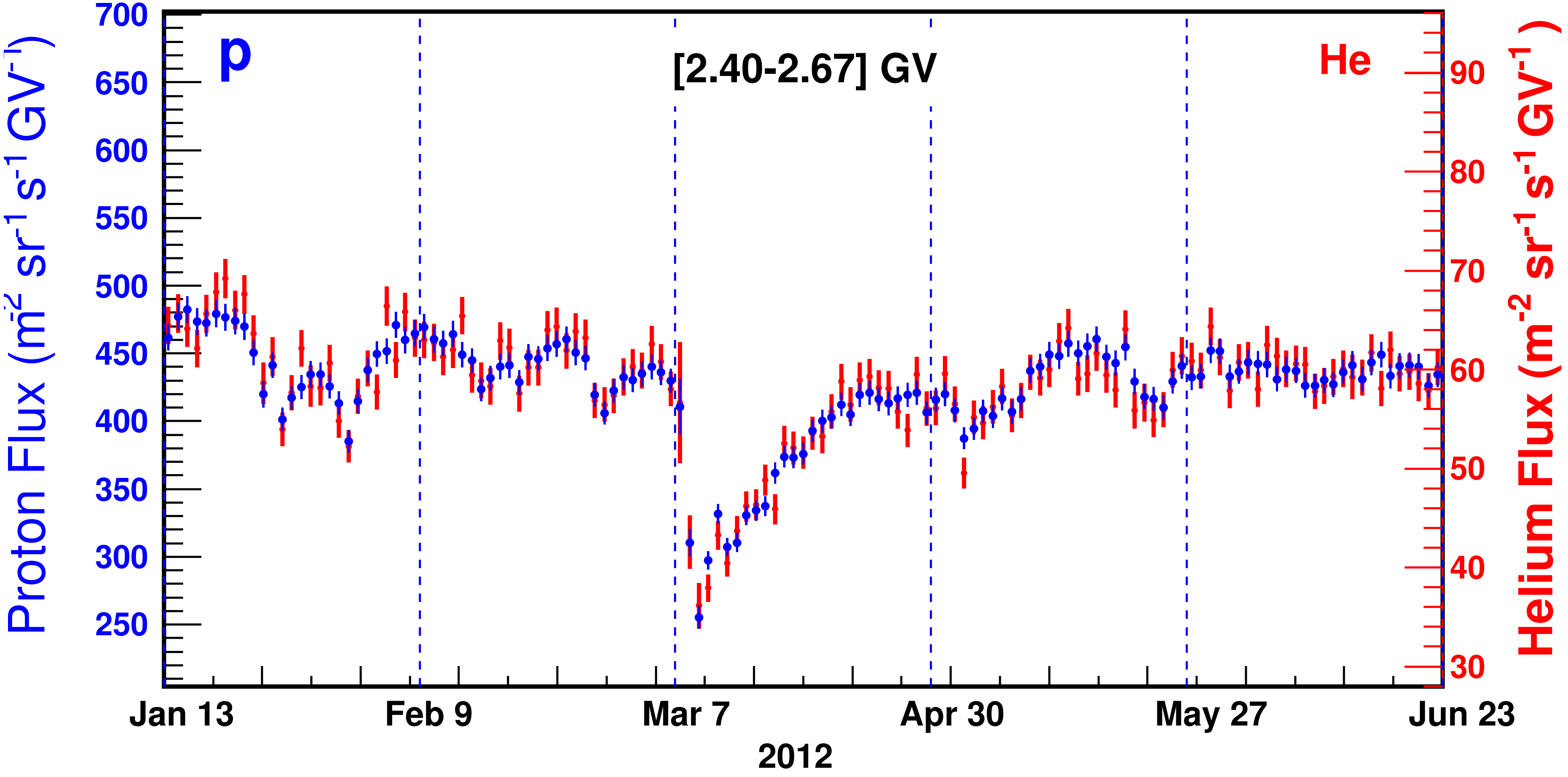


AMS observes Identical monthly time variation of the p, He fluxes

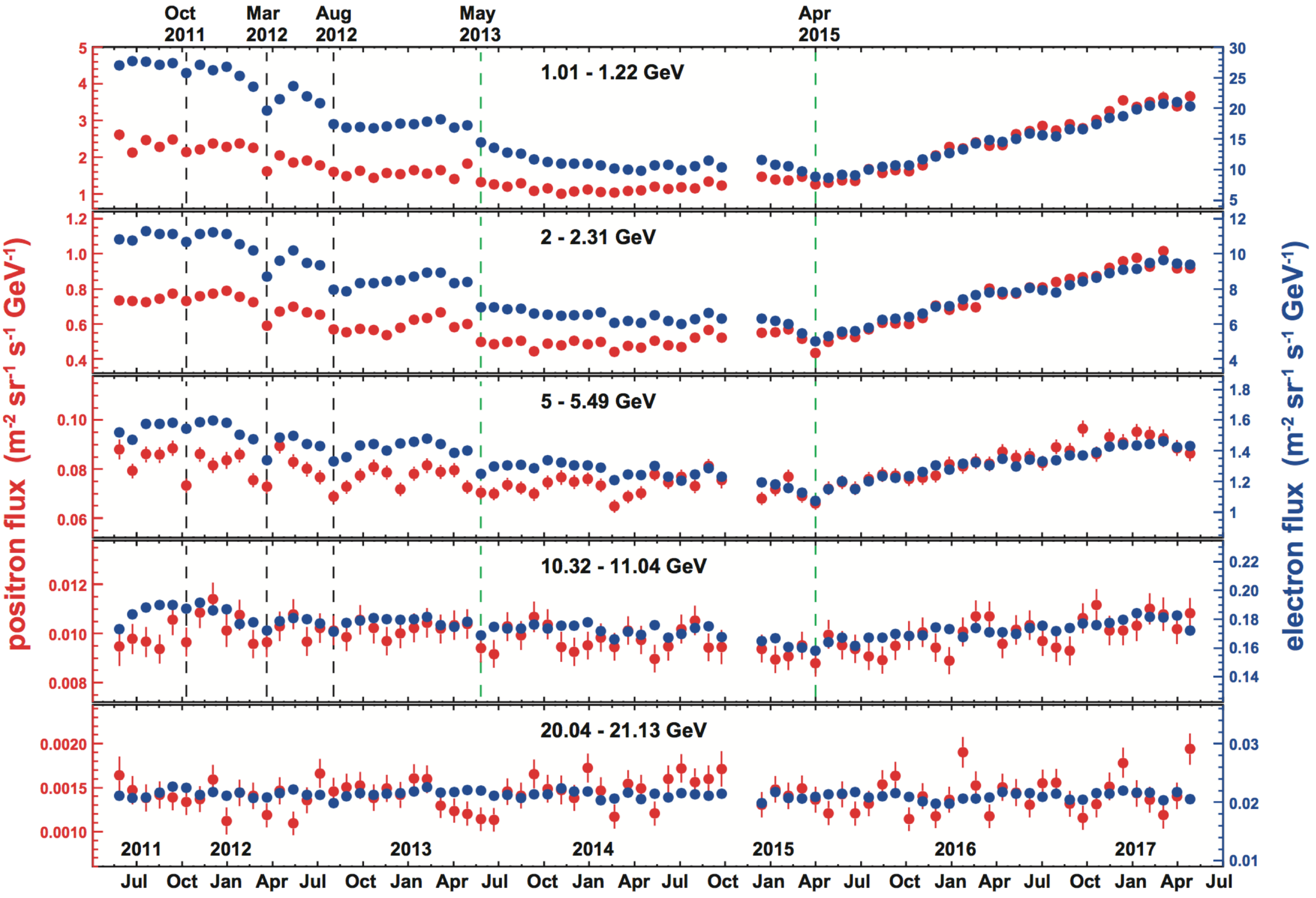


PRL **121**, 051101 (2018)

Identical **daily** time variation of the p, He fluxes

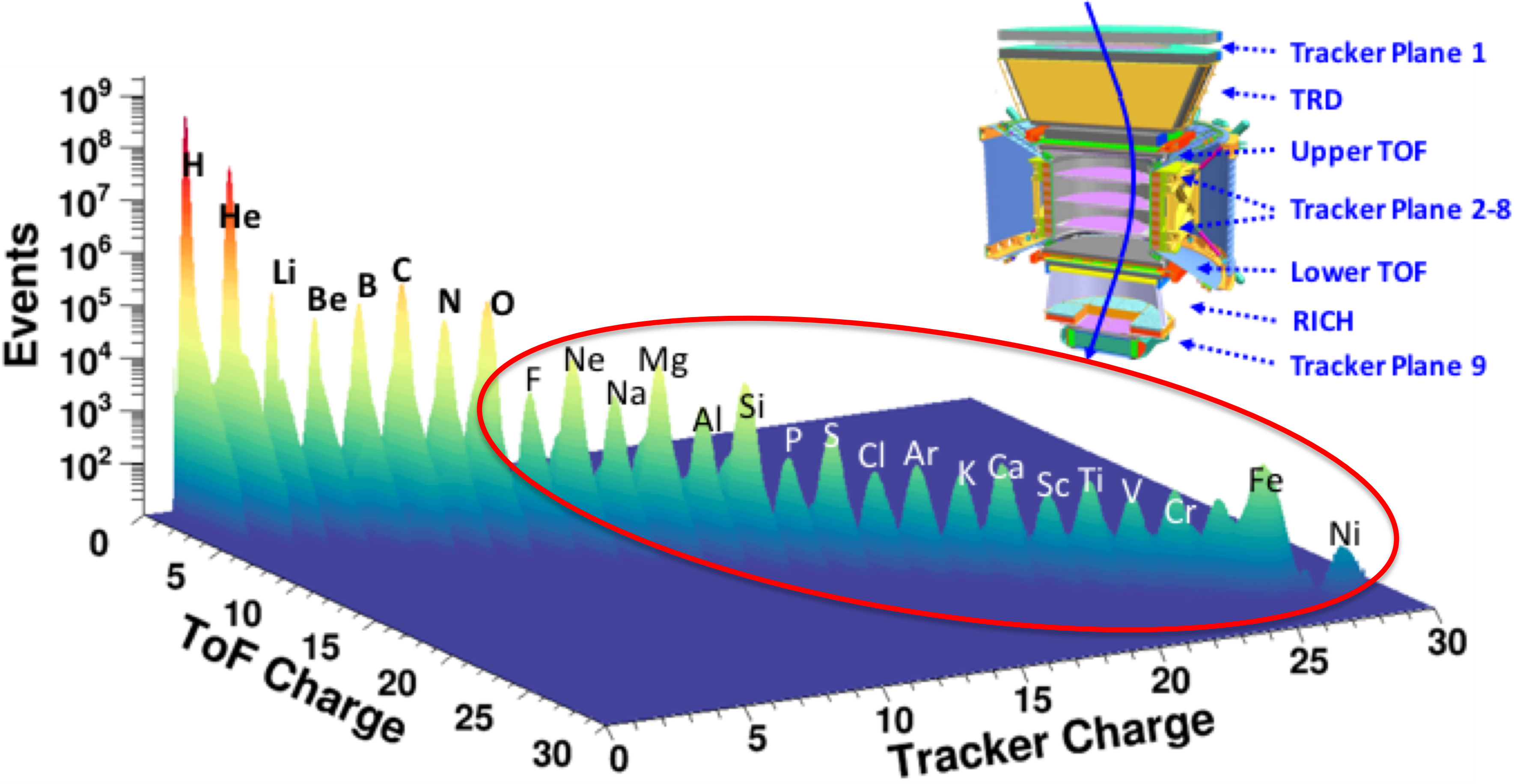


AMS continous measurement of the e+ and e- flux in the energy range 1 -50 GeV over 6 years with a time resolution of 27 days.

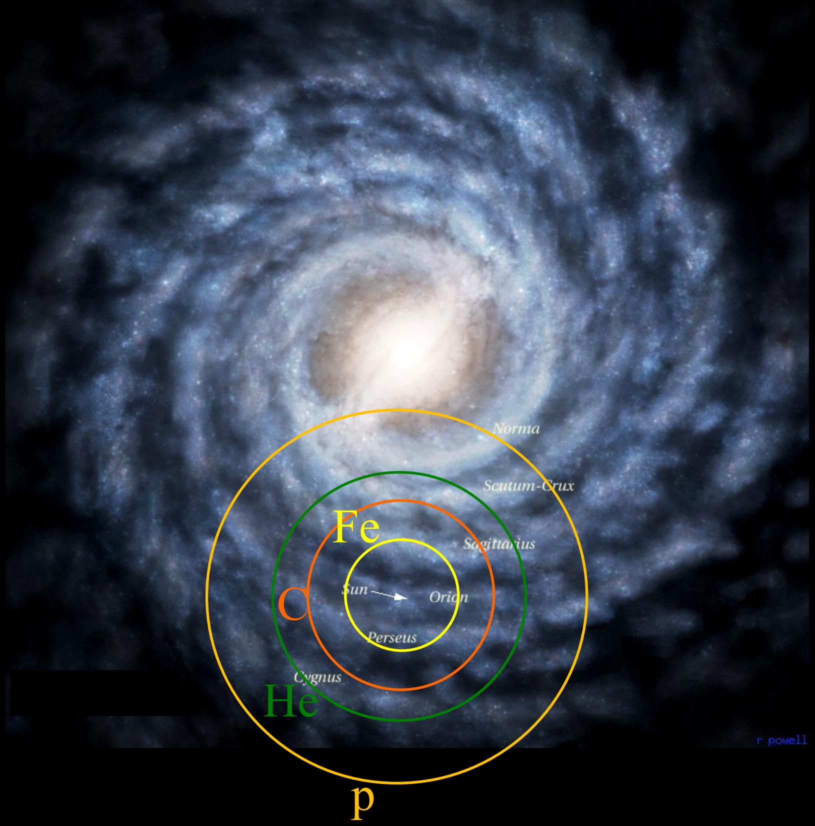


PRL **121**, 051102 (2018), Editor's Suggestion

Physics of AMS on ISS: Study high Z cosmic rays



Physics of high Z cosmic ray spectra at high energies:
Probe different galactic distances
Systematic study of propagation as function *A (Z)* and *R*.



Effective distance is shown for ~1 GV.

Effective propagation distance:

$$\langle X \rangle \sim \sqrt{6D\tau} \sim 2.7\ \mathrm{kpc}\ R^{\delta/2}\,(A/12)^{-1/3}$$

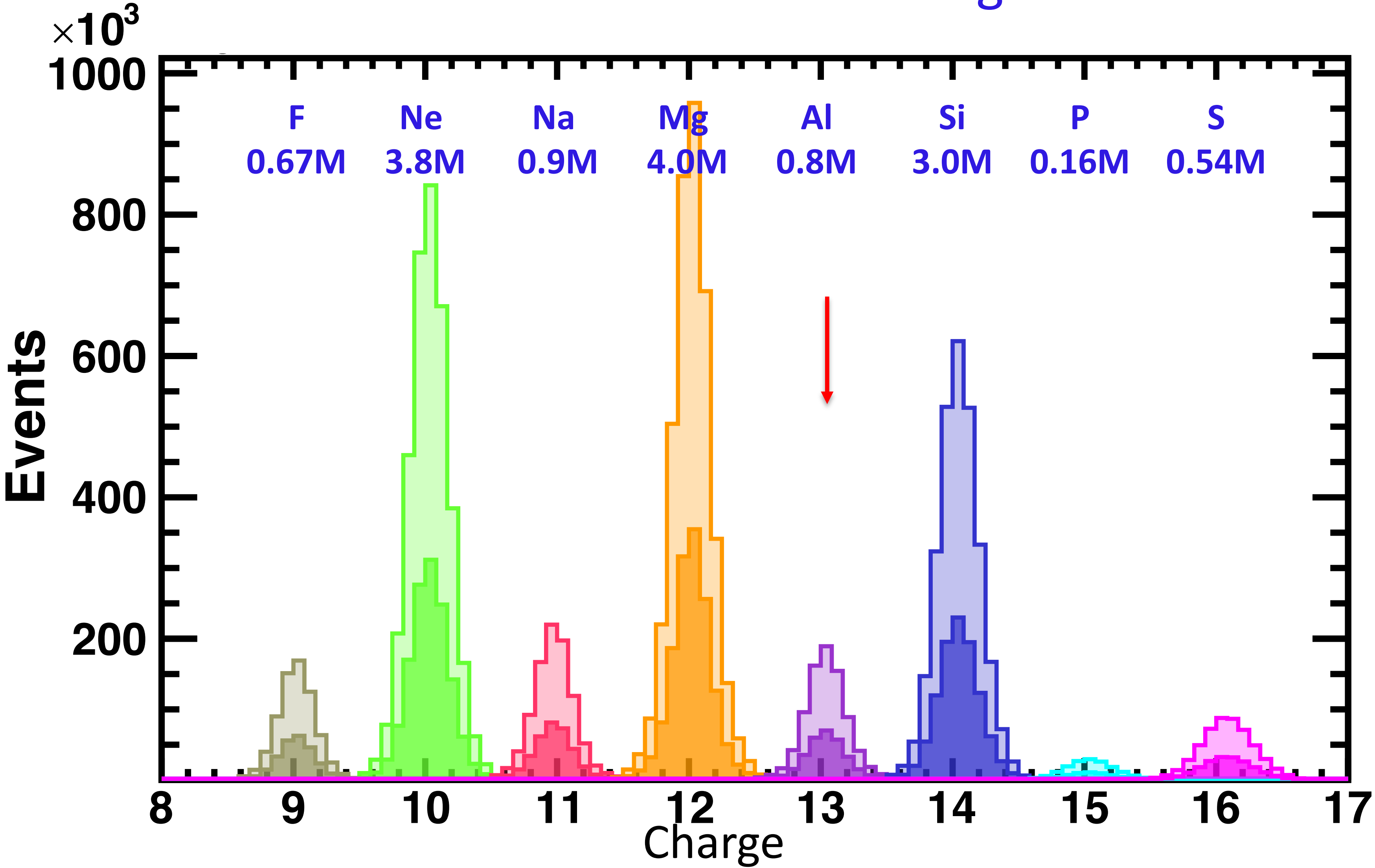
protons:	~ 5.6 kpc $R^{\delta/2}$
Helium:	~ 3.6 kpc $R^{\delta/2}$
Carbon:	~ 2.7 kpc $R^{\delta/2}$
Iron:	~ 1.6 kpc $R^{\delta/2}$

i. Different Z (or A) nuclei probe different distances.

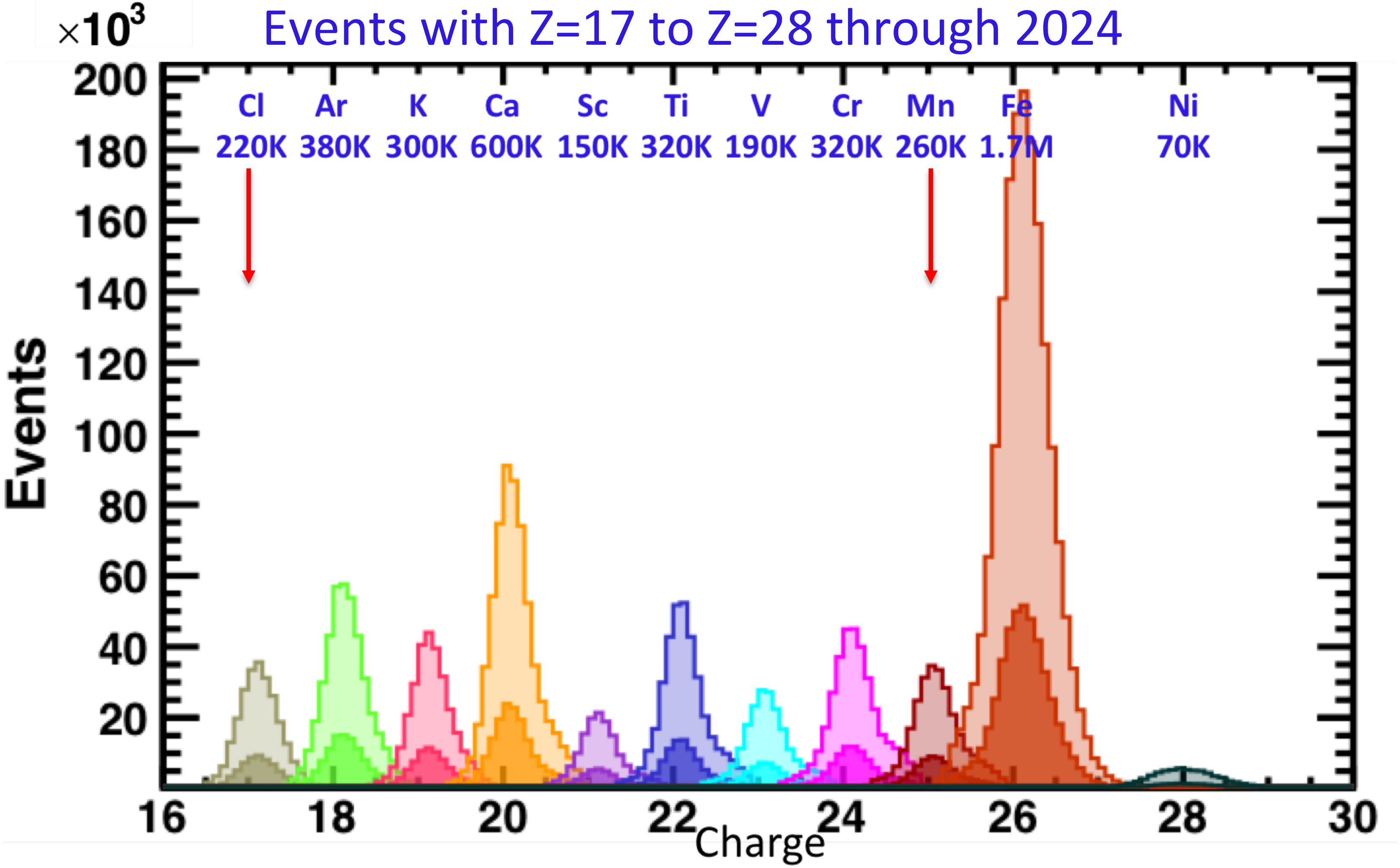
ii. Higher energies probe larger distances

AMS will obtain precise data on heavy nuclei, Z=9 to Z=28, up to the TV region. Particularly interesting is evidence of the flux break at ~200 GV. The measurements of the Aluminum, Chlorine, and Manganese spectra will precisely establish the age of cosmic rays as ^{26}Al, ^{36}Cl, ^{54}Mn are radioactive clocks.

Events with Z=9 to Z=16 through 2024



AMS will obtain precise data on heavy nuclei, Z=9 to Z=28, up to the TV region. Particularly interesting is evidence of the flux break at ~200 GV. The measurements of the Aluminum, Chlorine, and Manganese spectra will precisely establish the age of cosmic rays as ^{26}Al, ^{36}Cl, ^{54}Mn are radioactive clocks.



Events with Z=17 to Z=28 through 2024

The lightest elements created by supernova are Nickel and Zinc. AMS will be able to study their properties for the first time and compare them with elements produced by stellar nucleosynthesis.