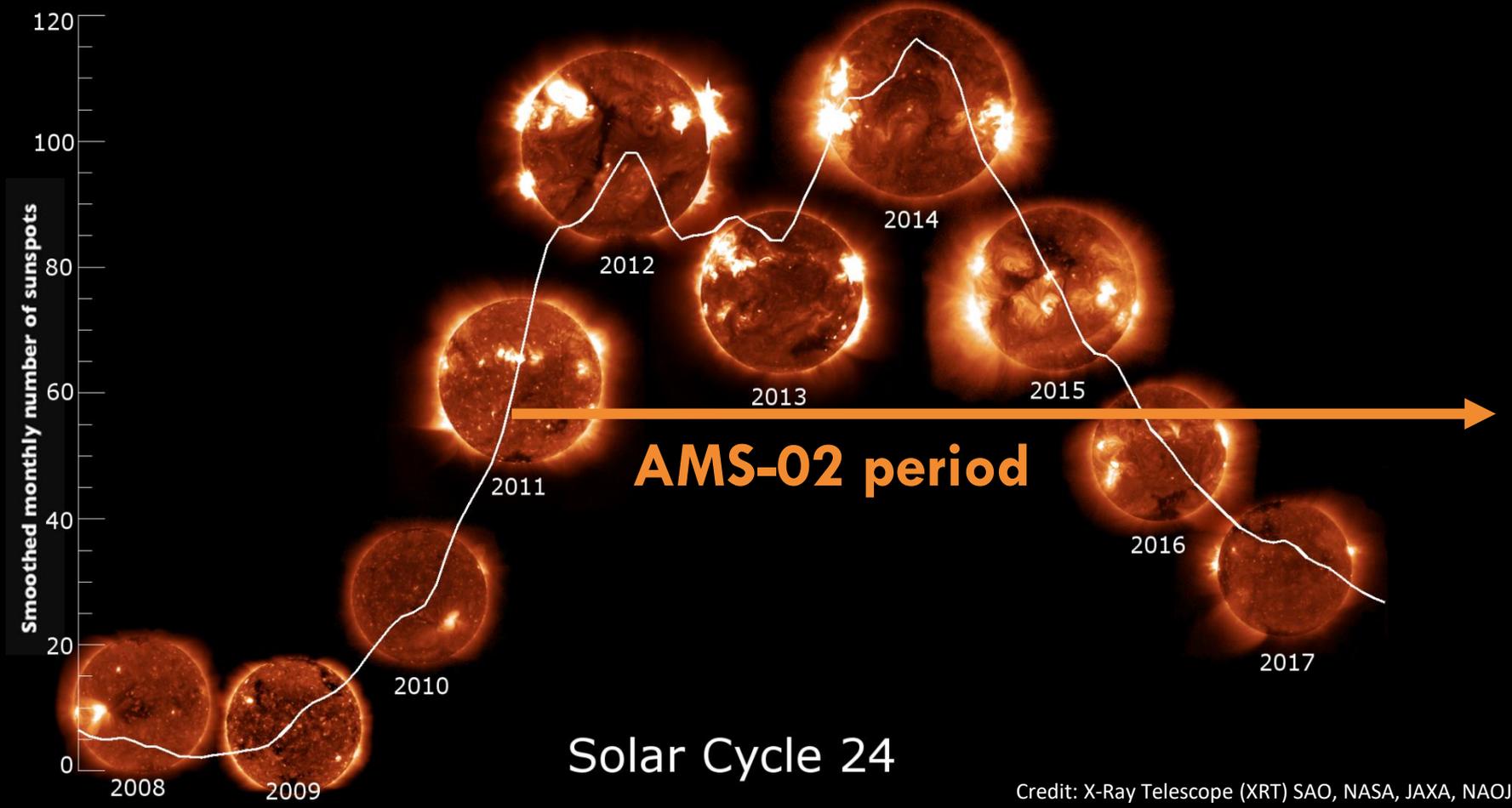
The image shows the AMS-02 detector, a large, complex piece of scientific equipment, mounted on the International Space Station (ISS). The detector is cylindrical and covered in white thermal insulation. It is surrounded by various cables and structural elements. In the background, the large, gold-colored solar panel arrays of the ISS are visible against the blackness of space. The text is overlaid on the left side of the image.

**OBSERVATION OF
COMPLEX TIME STRUCTURES
IN THE COSMIC RAY FLUXES
BY THE
ALPHA MAGNETIC
SPECTROMETER
ON THE ISS**

Davide Rozza

(INFN & University of Milano-Bicocca)
on behalf of the AMS-02 Collaboration

How does SOLAR ACTIVITY influence COSMIC RAYS?



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



>140 billion charged cosmic rays have been measured in 8 years

AMS-02 objectives

measurement of charged particles for:



Primordial **antimatter**
search with sensitivity
of 10^{-9}



Dark matter search
in antimatter channels
(e.g. antiprotons...)

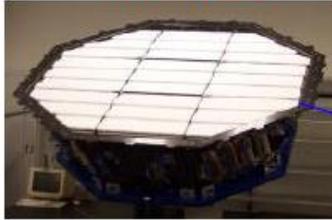


Cosmic ray
composition and
spectra analysis

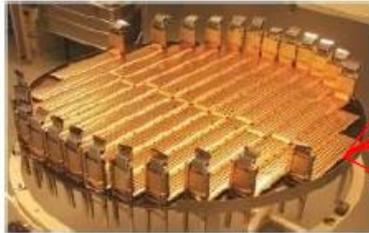
AMS-02 apparatus

Transition Radiation Detector
(TRD)

Identify e^+ , e^-

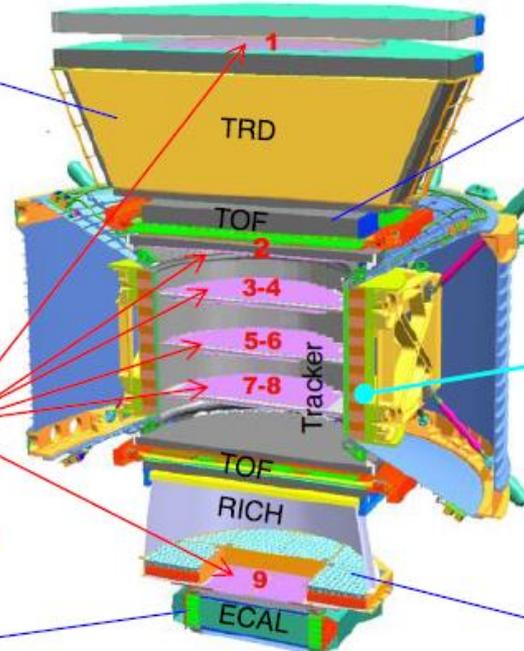


Silicon Tracker
Z, P or R=P/Z



Electromagnetic Calorimeter
(ECAL)

E of e^+ , e^-



Z and P, E or R are
measured independently by Tracker,
ECAL, TOF and RICH

Time of Flight
(TOF)
Z, E



Magnet
 $\pm Z$



Ring Imaging Cherenkov
(RICH)
Z, E



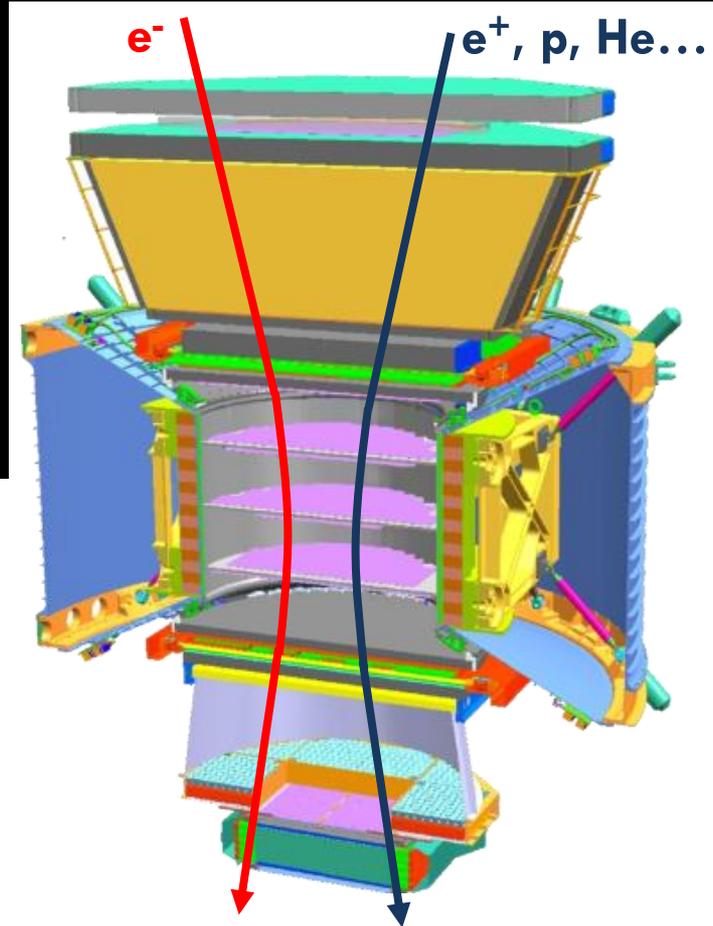
AMS-02 particle identification

CHARGE SIGN

matter to anti-matter
separation

e/p SEPARATION AT THE 10^6 LEVEL

combining TRD,
TRACKER and ECAL
measurements



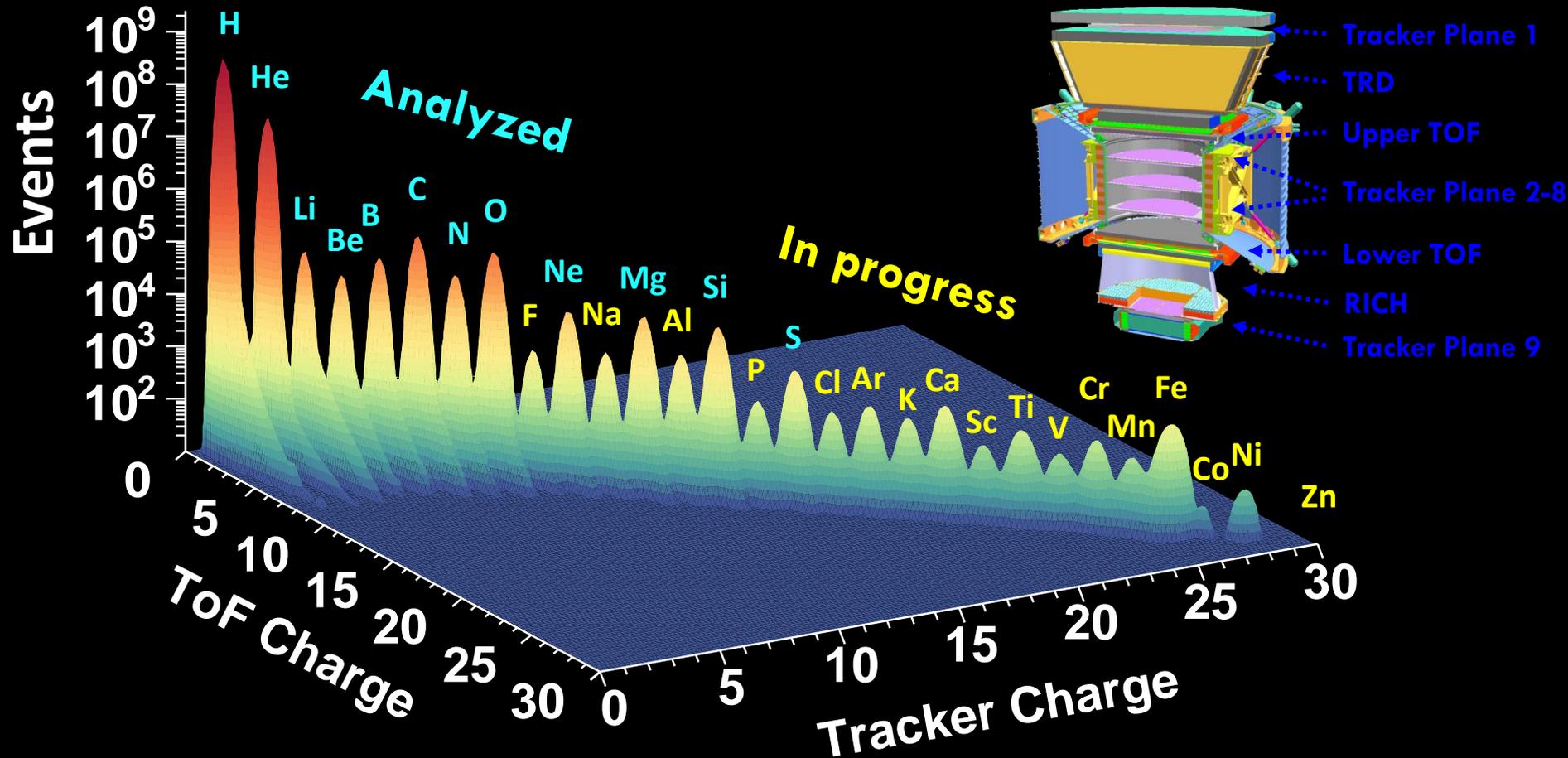
HIGH ENERGY

identification up to TeV
energy region

NUCLEI MEASUREMENTS

Z redundant measurements to
evaluate fragmentation along
the detector

AMS has seven instruments which independently measure charge



AMS-02

an high statistics precision, multipurpose spectrometer



**WIDE
ENERGY RANGE**

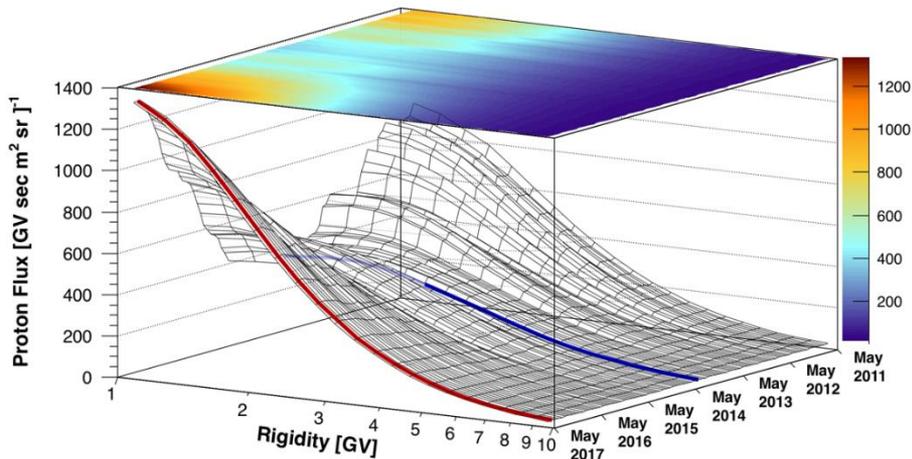


**LARGE
ACCEPTANCE**



**LONG
EXPOSURE TIME**

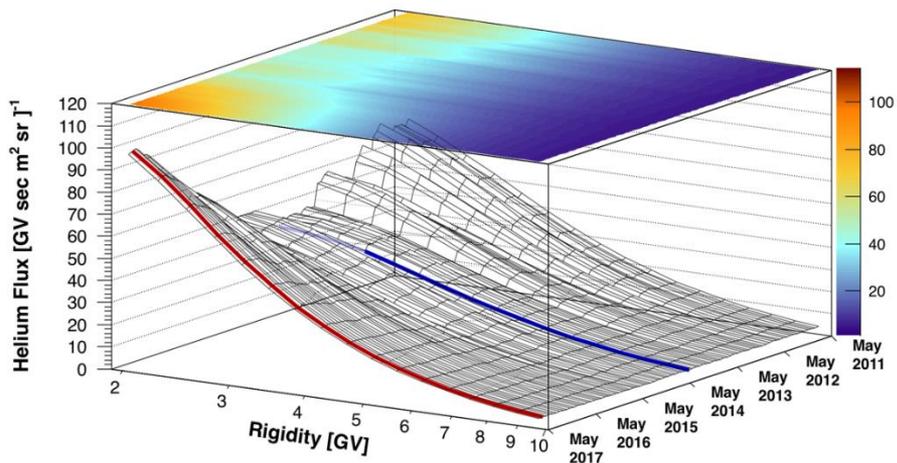
Proton



Proton Flux [$\text{GV sec m}^2 \text{sr J}^{-1}$]

based on $8.46 \cdot 10^8$
events

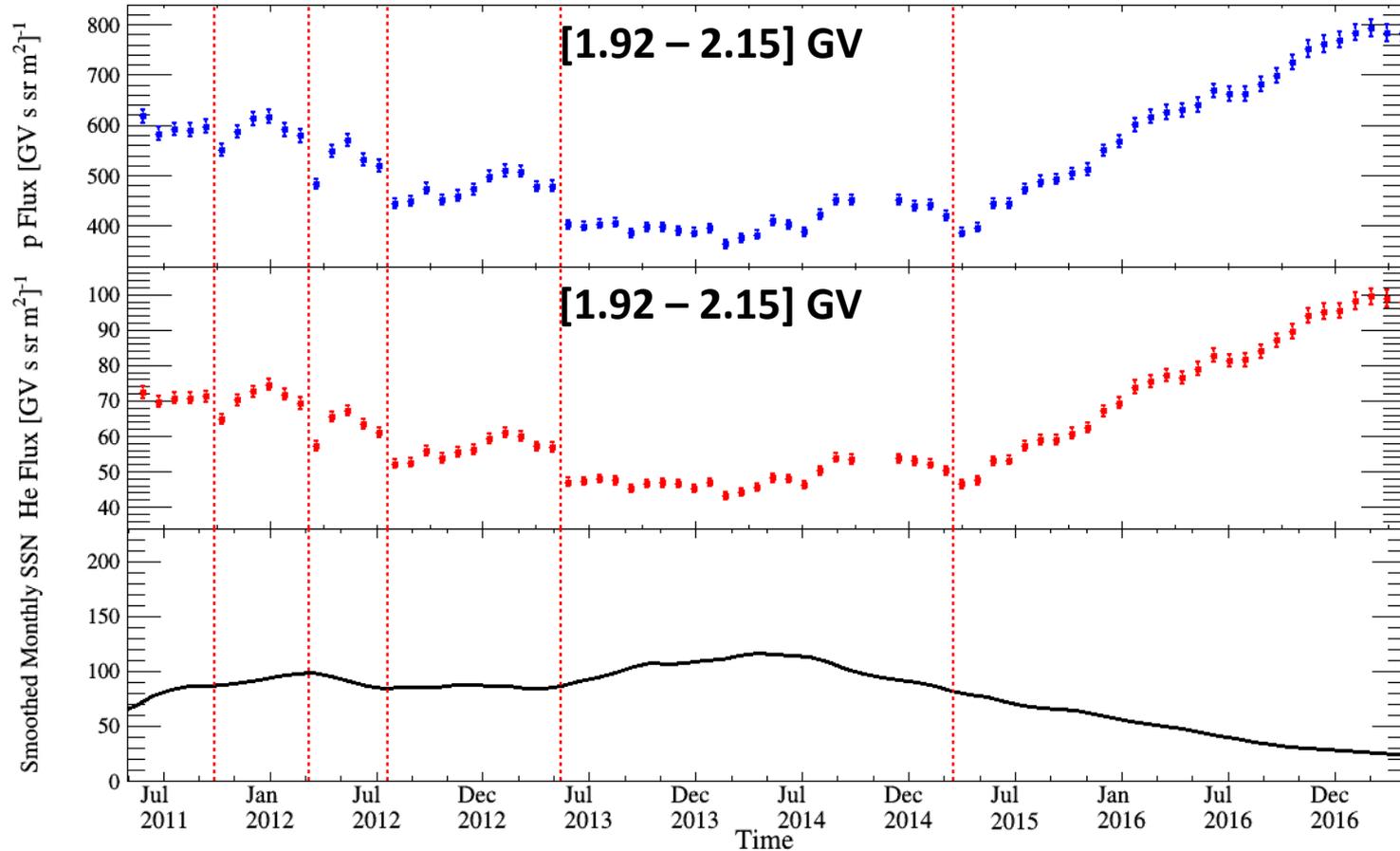
Helium



Helium Flux [$\text{GV sec m}^2 \text{sr J}^{-1}$]

based on $1.12 \cdot 10^8$
events

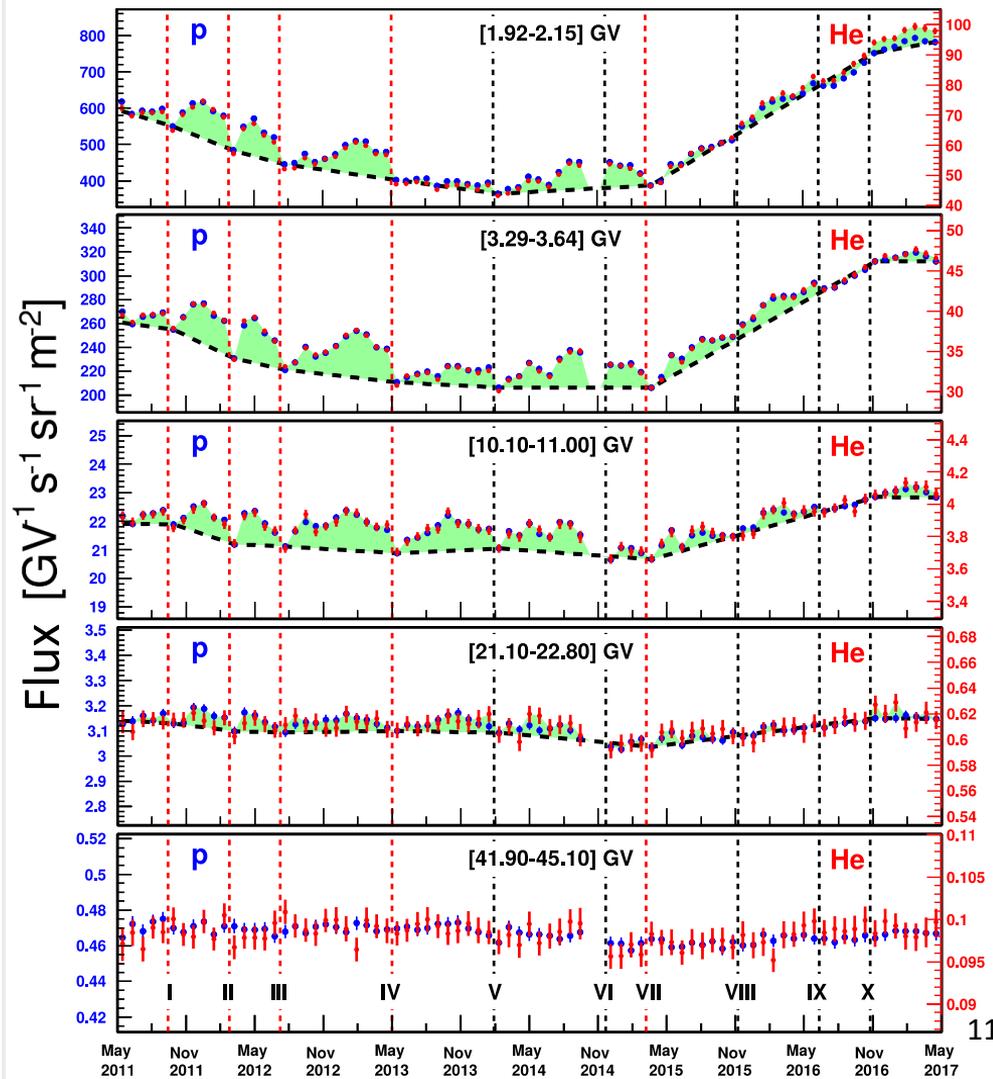
AMS-02 during Solar Cycle 24



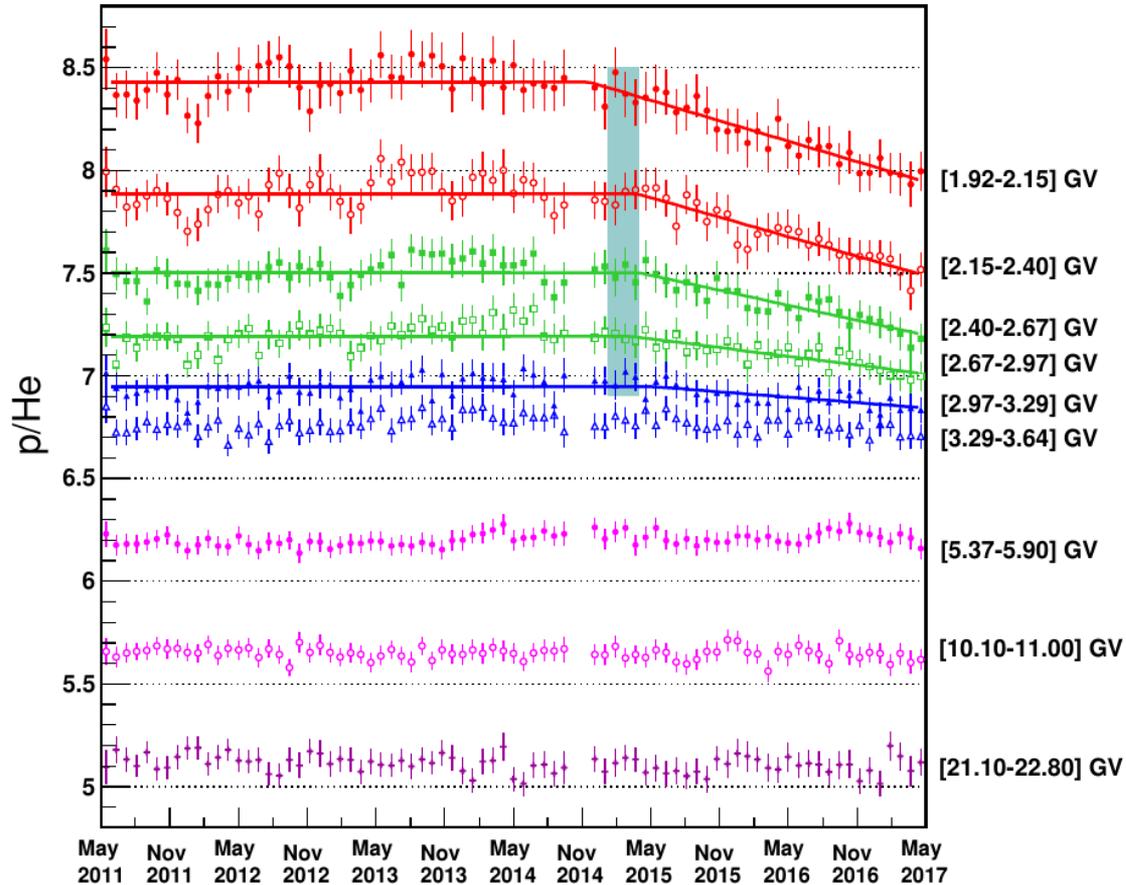
STRUCTURES BELOW 40 GV
(green shading and dashed lines to guide the eye)

THE AMPLITUDE OF THE STRUCTURES DECREASES WITH INCREASING RIGIDITY

SIMILAR STRUCTURES OBSERVED ALSO IN e^+ & e^- MEASUREMENTS
(indicated here by red dashed lines)



AMS-02 p/He ratio



BELOW 3 GV

the p/He flux ratio has a long-term decrease



Differences in p and He diffusion coefficients

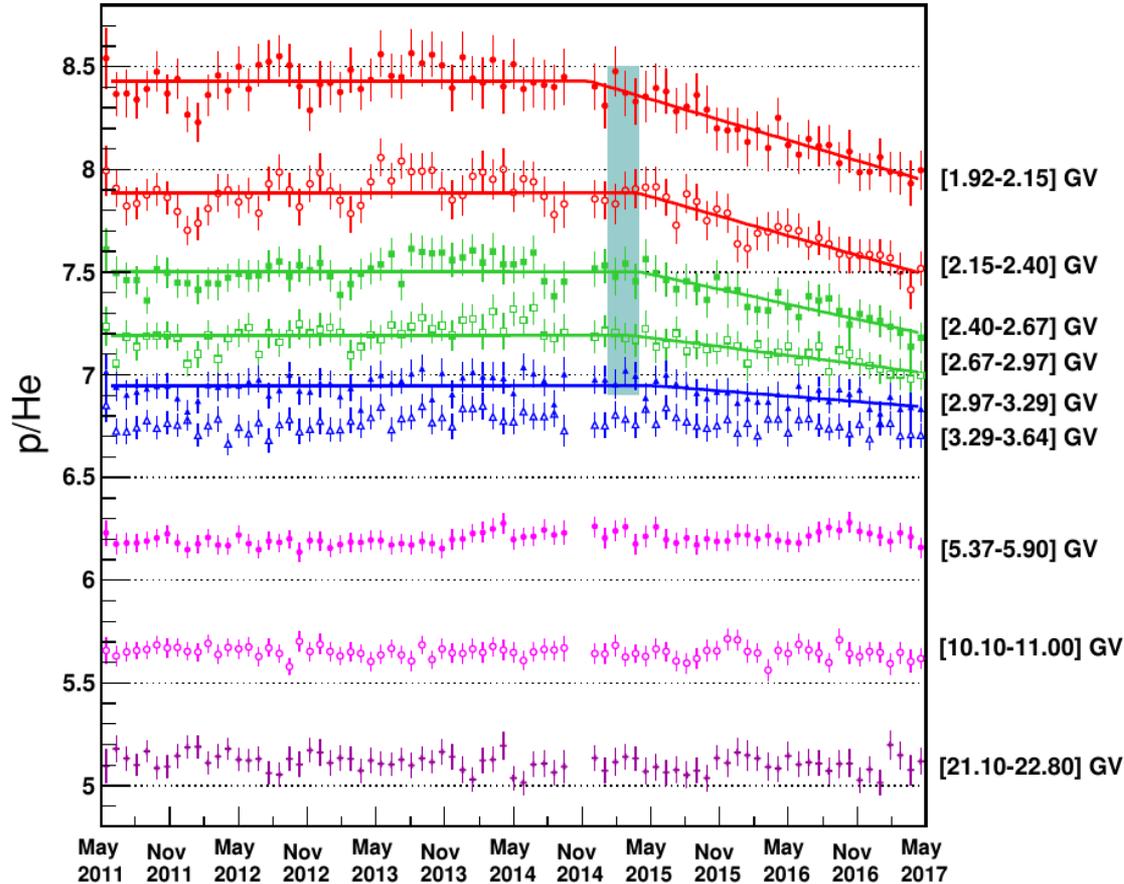


Differences in the local interstellar spectra of p and He



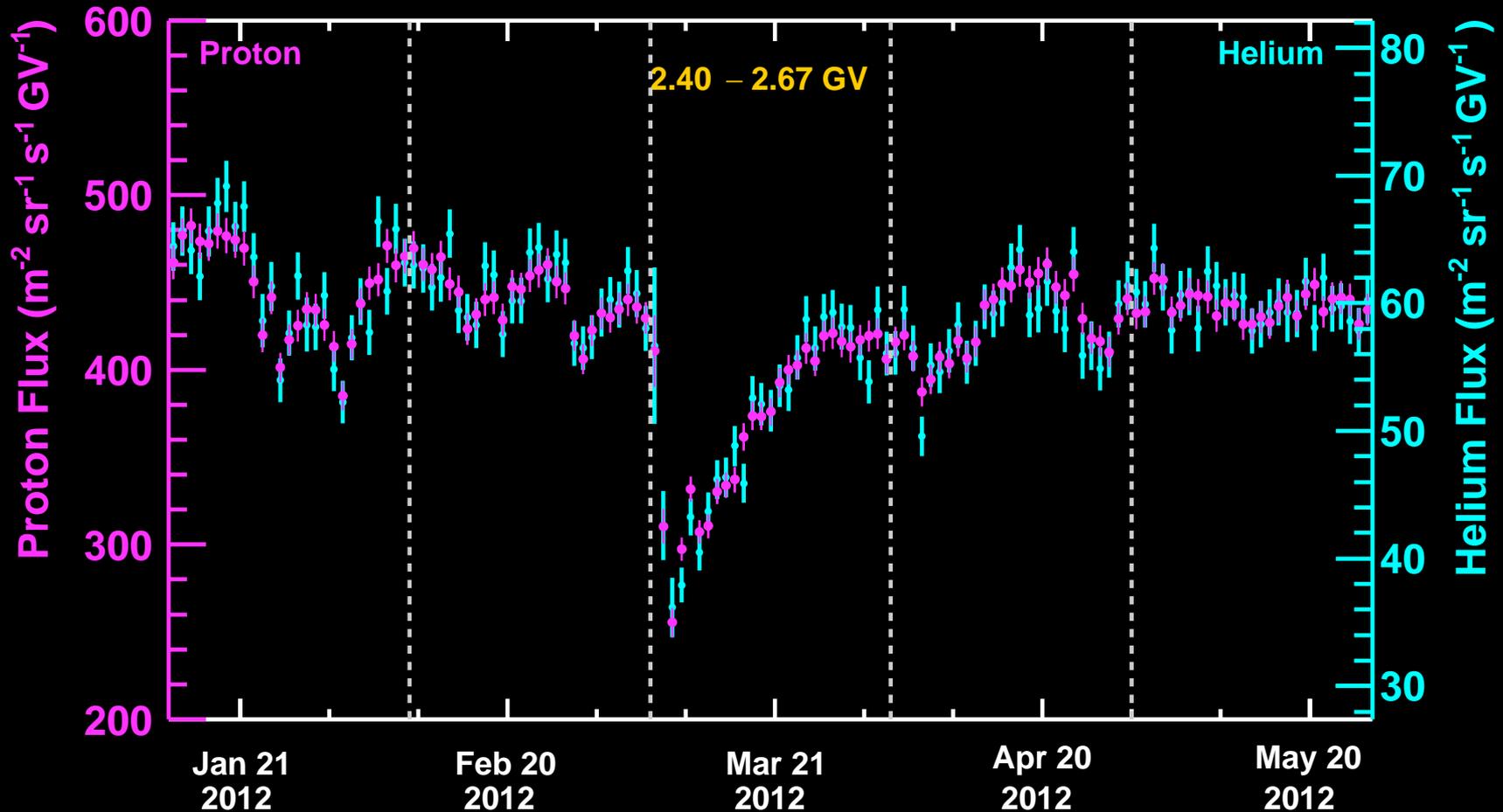
^3He and ^4He isotopic composition

AMS-02 p/He ratio

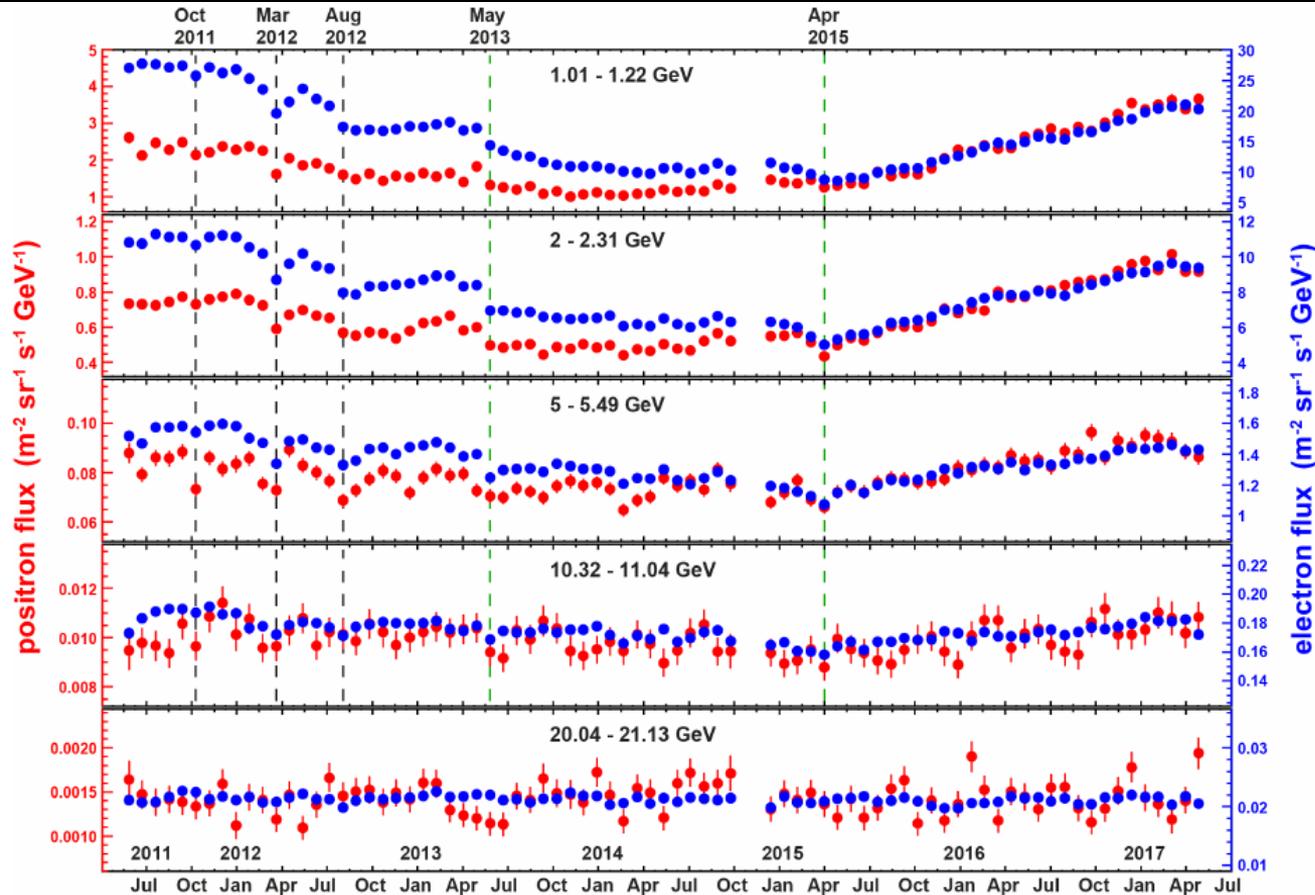


ABOVE 3 GV
the p/He flux ratio
is time-independent

IDENTICALLY DAILY time variation of the p, He fluxes



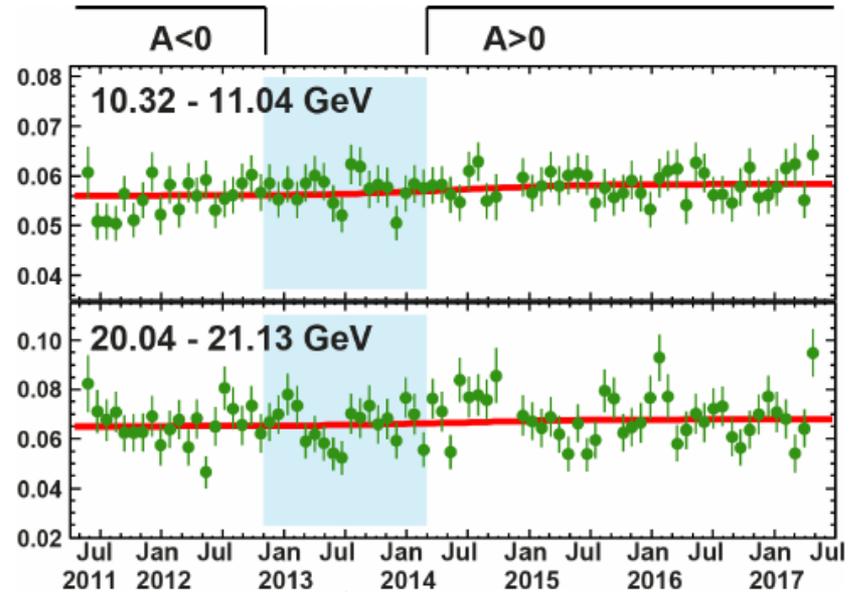
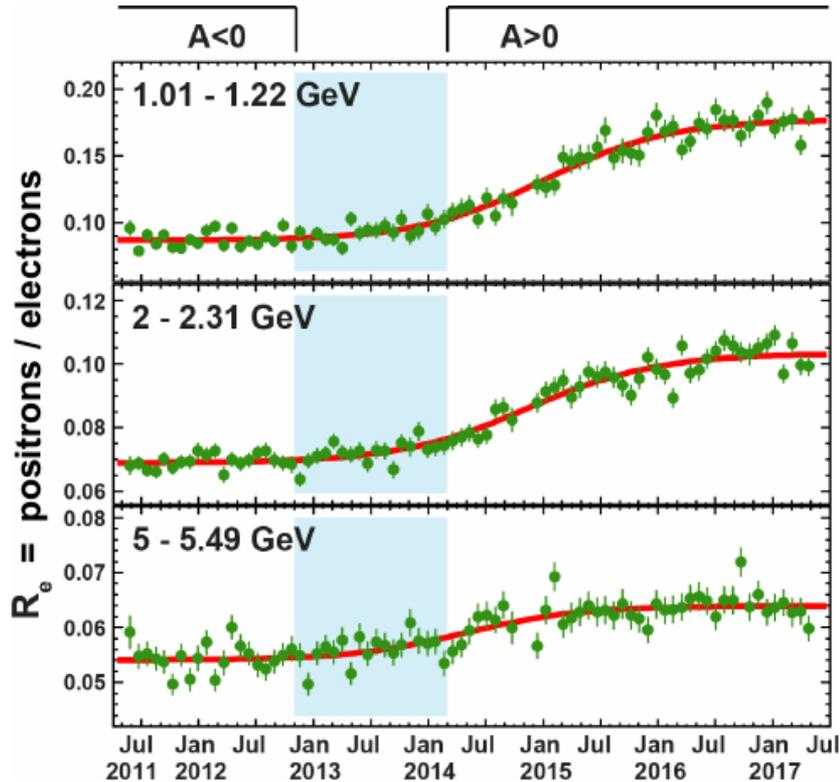
AMS-02 electron and positron fluxes



Prominent and distinct **TIME STRUCTURES** visible in both e^+ and e^- spectrum and at different energies (marked by dashed vertical lines)

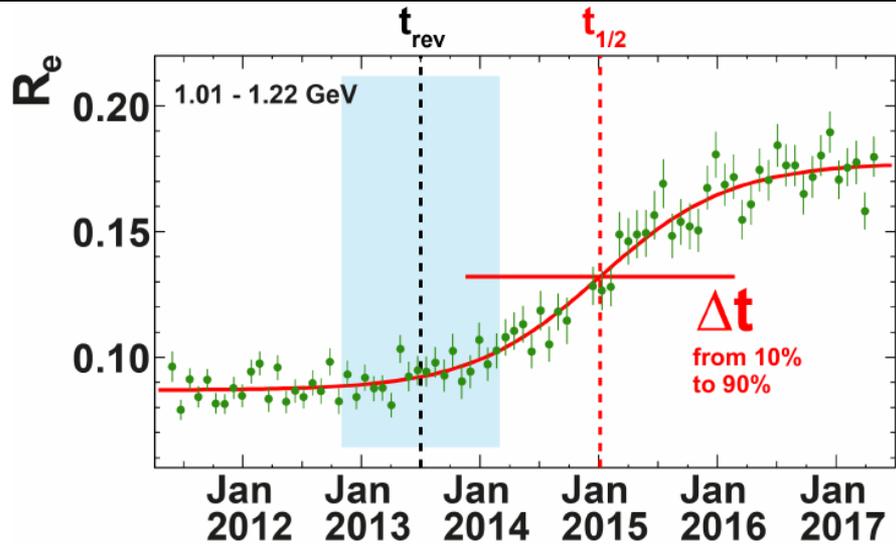
Based on $23.5 \cdot 10^6$ events

AMS-02 e^+/e^- ratio



↑
Polarity reversal of solar magnetic field in 2013.

AMS-02 e^+/e^- ratio

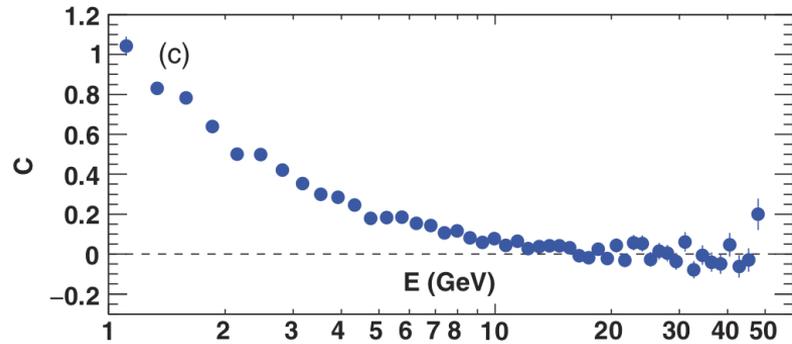
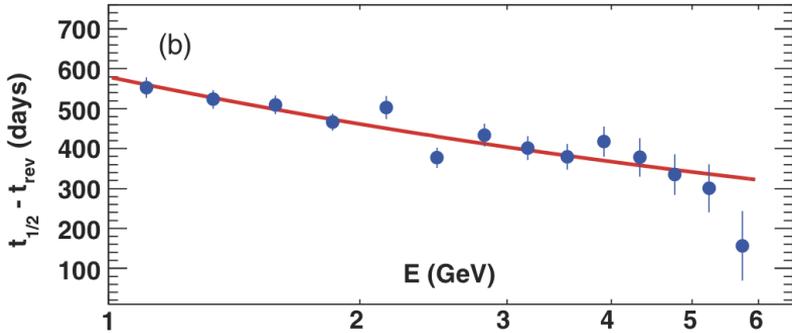
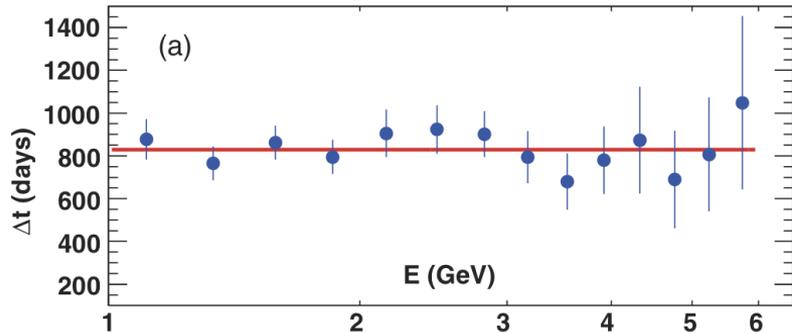


Midpoint of the transition

Amplitude of the transition

$$R_e(t, E) = R_0(E) \left[1 + \frac{C(E)}{\exp\left(-\frac{t-t_{1/2}(E)}{\Delta t(E)/\Delta_{80}}\right) + 1} \right]$$

Duration of the transition



DURATION of transition is energy independent
 The ratio exhibits a **SMOOTH TRANSITION** over **830±30 DAYS** from one value to another

MIDPOINT ($t_{1/2}$) and **AMPLITUDE** (C) of the transition are energy dependent

Midpoint shift of 260±30 days

$t_{rev} = 01/July/2013$, time of the solar magnetic field reversal

C consistent with 0 for $E > 20$ GeV

AMS-02 measured
p, He, e⁺, e⁻ monthly fluxes
during Solar Cycle 24
(ascending phase, its maximum and toward its minimum)

PhysRevLett.121.051101

(p and He)

PhysRevLett.121.051102

(e⁻ and e⁺)

Editors' suggestion

Observation of Fine Time Structures in the Cosmic Proton and Helium Fluxes with the Alpha Magnetic Spectrometer on the International Space Station

M. Aguilar,²⁷ L. Ali Cusumano,¹ B. Alpat,²⁸ G. Ambrosi,²⁷ L. Arrabé,²⁷ N. Arbib,²⁷ S. Augé,¹⁹ P. Azziello,¹⁷ A. Bacalchuez,¹⁷ F. Barao,²⁵ A. Barrán,¹⁸ L. Barrán,¹⁶ A. Baroni,¹⁶ L. Basam,²⁵ S. Bazilevich,²⁵ M. Battarbee,⁴⁰ R. Battiston,^{28,30} U. Becker,¹⁰ M. Behlmann,⁴⁰ B. Beiswenger,¹ J. Bergho,²⁷ B. Bertucci,^{23,33} K. F. Binko,²³ V. Bindi,²⁰ W. de Boer,²³ K. Bollweg,²¹ V. Bonnavanti,¹⁸ B. Borgia,^{33,38} M. J. Boschini,²⁸ M. Boudspain,¹⁷ F. F. Busno,¹⁹ J. Burger,¹⁰ F. Cadoux,¹⁷ X. D. Cai,¹⁰ M. Capelli,¹⁰ S. Caroff,⁷ J. Casari,²⁷ G. Castellini,¹⁰ F. Cervelli,²⁰ M. J. Chae,⁴⁰ Y. H. Chan,⁴¹ A. I. Chen,¹⁷ G. M. Chen,⁶ H. S. Chen,^{6,7} Y. Chen,¹⁷ L. Cheng,⁴ H. Y. Chou,¹¹ E. Choumilov,¹⁰ V. Chourko,¹⁰ C. H. Chung,⁴ C. Clark,²¹ R. Clavero,²⁴ G. Coignet,¹ C. Concolandi,²⁰ A. Cozzini,⁴⁹ C. Corti,²⁰ W. Crans,⁴⁸ M. Crispoltoni,^{32,37} Z. Cui,⁴¹ K. Dadzie,¹⁰ Y. M. Dai,⁴ A. Datta,²⁷ C. Delgado,²⁷ S. Della Torre,²⁷ M. B. Demirköz,²⁷ L. Derome,¹⁸ S. Di Falco,²⁸ F. Dimiccoli,^{35,6} C. Diaz,²⁷ P. von Doetinchem,²⁰ F. Dong,³ F. Donnini,^{32,33} M. Duranti,¹² D. D'Urso,^{32,6} A. Egorov,⁴⁸ A. Elisei,¹⁸ T. Eronen,²⁷ J. Feng,²⁵ E. Fiorini,^{32,33} P. Fisher,¹⁰ V. Forman,⁷ Y. Galaktionov,¹⁰ G. Gallucci,²⁴ R. J. García-López,²⁷ C. Gargiulo,¹⁶ H. Gaut,¹ J. Gebauer,²⁷ M. Gervasi,^{20,20} A. Gholi,¹⁹ F. Giovinetti,²⁷ D. M. Gómez-Costá,²⁷ J. Gong,³ C. Gong,³ V. Grady,²⁸ D. Gmadi,²⁸ M. Graziani,²³ K. H. Guo,¹⁹ S. Haini,¹⁹ K. C. Han,²⁸ Z. H. He,¹⁹ M. Heil,¹⁰ J. Hoffman,²⁰ T. H. Hoeh,¹⁰ H. Huang,^{44,6} Z. C. Huang,¹⁹ C. Huh,¹⁴ M. Inagaki,³⁴ M. Ionica,³² W. Y. Jung,¹⁴ Y. Ju,¹⁰ H. Jinchi,²⁸ S. C. Kang,¹⁴ K. Kanibekov,^{28,40} B. Khiali,⁴¹ G. N. Kim,¹⁴ K. S. Kim,¹⁴ Th. Kim,¹ C. Konak,² O. Koumina,¹⁰ A. Kourina,¹⁰ V. Kousenko,¹⁰ A. Kulomoinen,¹⁰ G. La Vecchia,²⁰ E. Laus,¹⁶ G. Laurenti,⁴ I. Lazzarini,^{35,36} A. Lebedev,¹⁰ H. T. Lee,⁴³ S. C. Lee,⁶ C. Leluc,¹⁷ H. S. Li,⁶ J. Q. Li,²¹ Q. Li,²¹ T. X. Li,¹⁹ Z. H. Li,² Y. Li,^{44,6} C. Light,²⁰ S. Lim,⁴ C. H. Lin,⁴⁸ P. Lipari,²⁷ T. Lippert,²³ D. Liu,¹¹ Hui Liu,^{40,6} V. D. Lortello,²⁸ S. Q. Lu,^{44,6} Y. S. Lu,⁶ K. Lueholsmeyer,¹ F. Luo,⁴¹ J. Z. Luo,²¹ X. Luo,² S. S. Lysa,¹⁹ F. Machacek,¹ C. Masti,²⁷ J. Marin,²⁷ T. Marin,²¹ G. Martínez,²⁷ N. Masi,⁴ D. Maurin,¹⁸ A. Mendonça Rocha,²⁸ Q. Meng,¹ V. M. Mikumi,²⁰ D. C. Mo,¹⁹ P. Moré,²¹ T. Nelson,²⁰ J. Q. Ni,¹⁹ N. Nikonorov,¹ F. Nozzoli,^{32,7} A. Oliva,²⁷ M. Orcinari,²⁸ M. Palermo,²⁰ F. Palmonari,⁴⁹ C. Palomares,²⁷ M. Panizza,¹⁷ M. Pauluzzi,^{32,33} S. Penucci,^{20,20} C. Perrina,¹⁷ H. D. Phan,¹⁰ N. Picot-Clemente,¹⁹ F. Pilo,¹ C. Pizzolotto,^{32,6} V. Plyuskin,¹⁰ M. Pohl,¹⁷ V. Poireau,¹ A. Popkova,²⁰ L. Quadt,¹⁰ X. M. Qiu,¹⁹ X. Qin,¹⁹ Z. Y. Qu,^{40,6} T. Räihä,¹ P. G. Ranonirina,¹⁰ D. Rapin,¹⁹ J. S. Ricoil,¹⁸ S. Roiser-Loeb,¹ A. Rozhnov,¹ D. Rozza,^{20,20} R. Sagdeev,¹⁹ S. Schadi,¹ S. M. Schmidt,²⁷ A. Schulz von Dratz,¹ G. Schwering,¹ E. S. Seo,¹³ B. S. Shari,¹ Y. Shi,¹ T. Siedelbach,² D. Sin,¹⁹ J. W. Song,¹ M. Taroni,^{20,20} X. W. Tang,² Z. C. Tang,² D. Toccani,²⁸ Samuel C. C. Ting,^{43,6} S. M. Ting,⁴³ M. Tomasini,^{23,33} J. Tor,⁴² C. Turokhan,² T. Urban,²¹ V. Vagstad,^{23,6} E. Valente,^{37,38} E. Valtonen,⁴⁵ M. Vázquez Acosta,²⁴ M. Vecchi,²⁰ M. Velasco,¹⁷ J. P. Valle,¹ Q. Wang,⁴¹ N. H. Wang,⁴¹ Q. L. Wang,⁴ X. Wang,¹⁰ X. Q. Wang,^{6,7} Z. X. Wang,¹⁹ C. C. Wei,⁴⁴ Z. L. Wong,⁴¹ K. Whitman,²⁰ H. Wu,³¹ X. Wu,¹⁷ R. Q. Xiong,²¹ W. Xu,¹⁰ Q. Yan,¹⁰ J. Yang,¹⁰ M. Yang,⁶ Y. Yang,⁴³ H. Yi,¹¹ Y. Yu,¹ Z. Q. Yu,¹ M. Zannoni,²⁰ S. Z. Seidel,²³ C. Zhang,⁶ F. Zhang,¹⁶ J. H. Zhang,³¹ S. W. Zhang,^{6,7} Z. Zhang,¹⁰ Z. M. Zheng,⁴ H. L. Zhuang,⁴ V. Zhukov,¹ A. Zichichi,⁴⁵ N. Zimmermann,¹ and P. Zuccon⁴⁰

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FLUX RATIO (p/He)

above 3 GV is time independent
below 3 GV has long-term decrease

FIRST accurate measurement of

both e⁻ and e⁺ fluxes over time

SHORT-TERM STRUCTURES

coincident in both fluxes and are not

visible in the e⁺/e⁻ flux ratioFLUX RATIO (e⁺/e⁻)

smooth transition over 830±30 days

midpoint of the transition shows an energy

dependent delay relative to the reversal and

changes by 260±30 days from 1 to 6 GeV.

Observation of Complex Time Structures in the Cosmic-Ray Electron and Positron Fluxes with the Alpha Magnetic Spectrometer on the International Space Station

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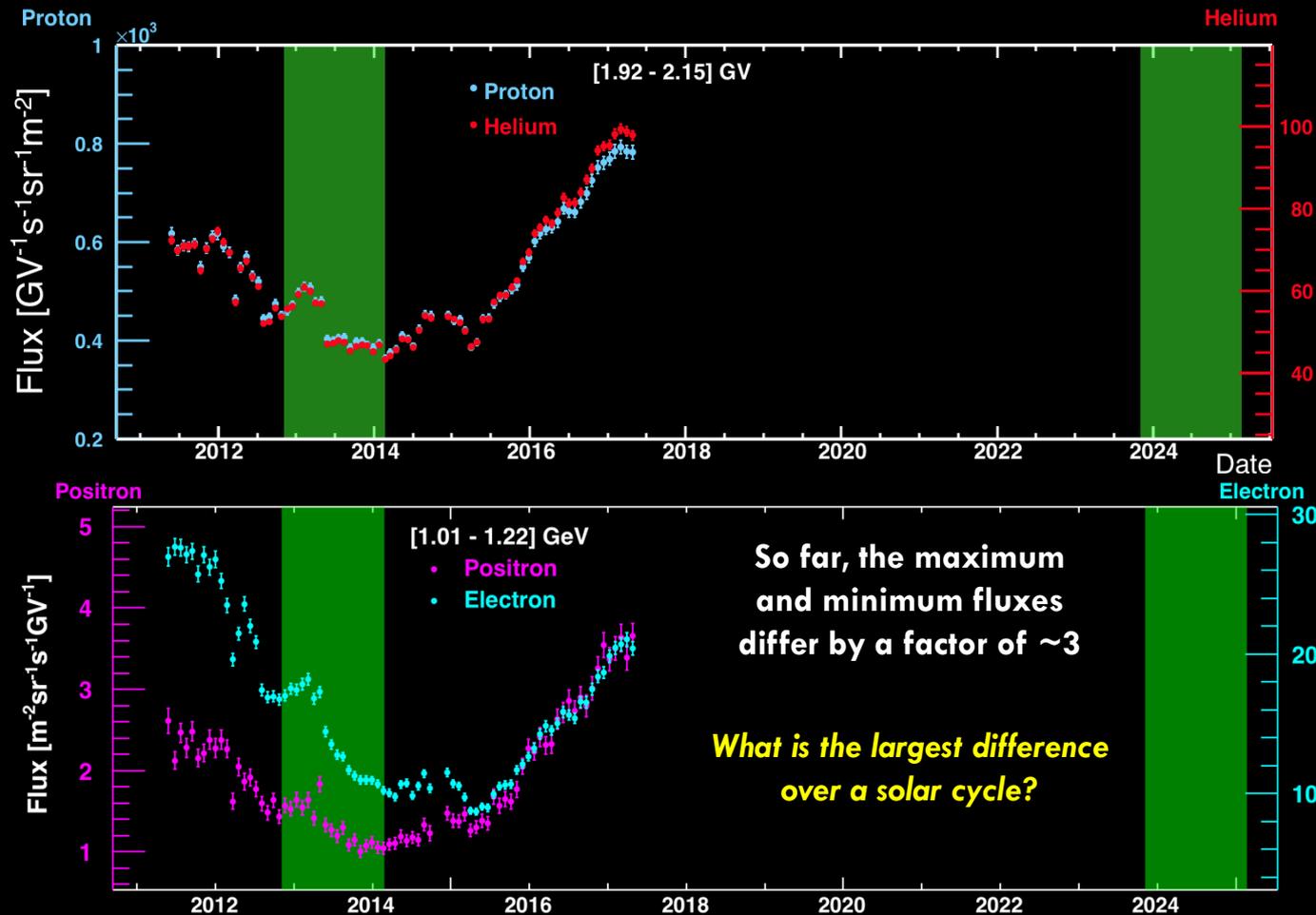
(AMS Collaboration)

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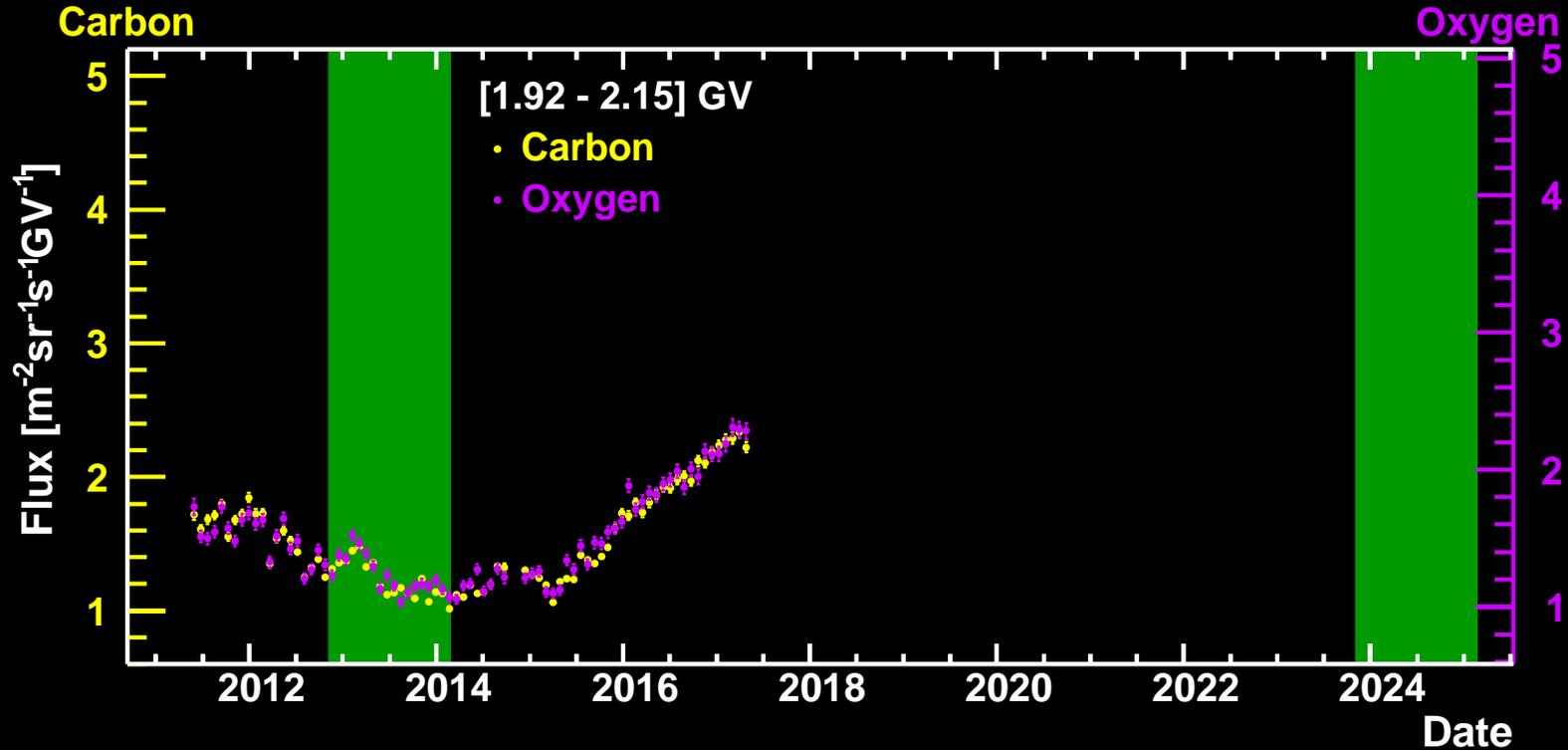
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Solar physics over a complete 11-year solar cycle



Solar physics over a complete 11-year solar cycle



The maximum and minimum fluxes differ by a factor of ~ 3

What is the largest difference over a solar cycle?

**AMS is measuring solar effects for all nuclei,
particle and anti-particle fluxes
in the present and next solar cycle**

Refer to the AMS forthcoming publication in PRL

