Latest AMS-02 results

on behalf of the AMS Collaboration

B. Bertucci

University of Perugia

& INFN, ASI-SSDC

ICRC2019 36th International Cosmic Ray Conference - Madison, WI, USA
THE ASTROPARTICLE PHYSICS CONFERENCE

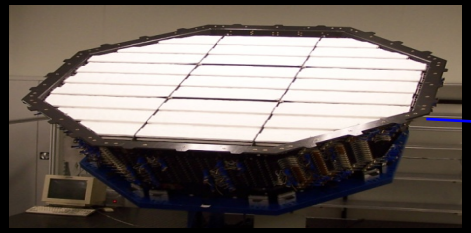
Alpha Magnetic Spectrometer

One-of-a kind instrument measuring with unprecedented precision different components of the charged cosmic rays up to few TeVs

- Fundamental physics: anti-particles in the CR flux
- Origin and propagation of galactic cosmic rays: CR chemical/isotopic composition and spectral features
- Heliospheric effects on cosmic rays and solar physics: time dependence of different CR components related to Sun activity

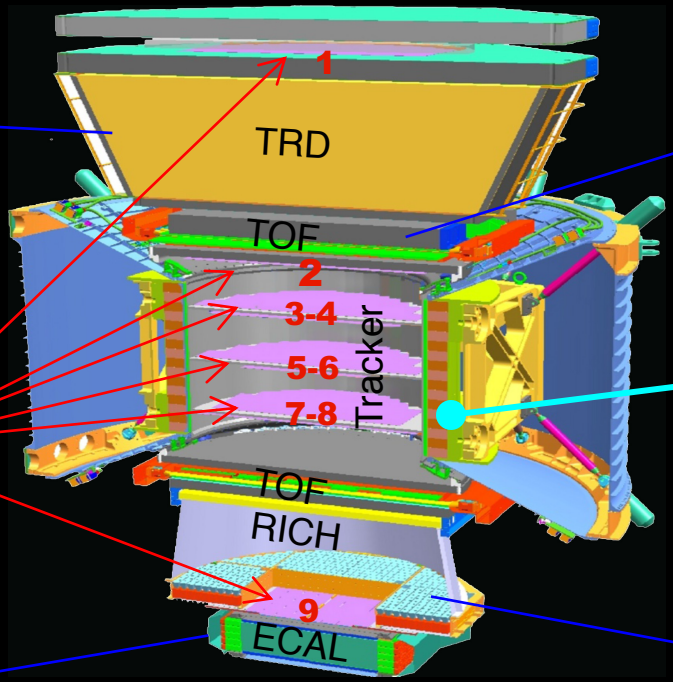
A HEP particle Detector in space

Transition Radiation Detector (TRD)



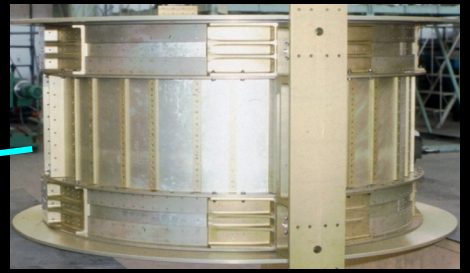
Silicon Tracker

Electromagnetic Calorimeter (ECAL)

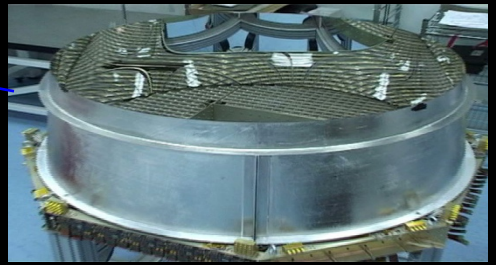


Time of Flight Detector (TOF)

Magnet

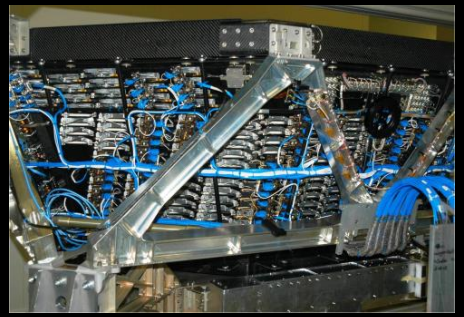


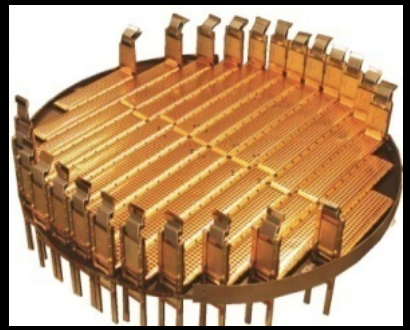
Ring Imaging Cherenkov (RICH)

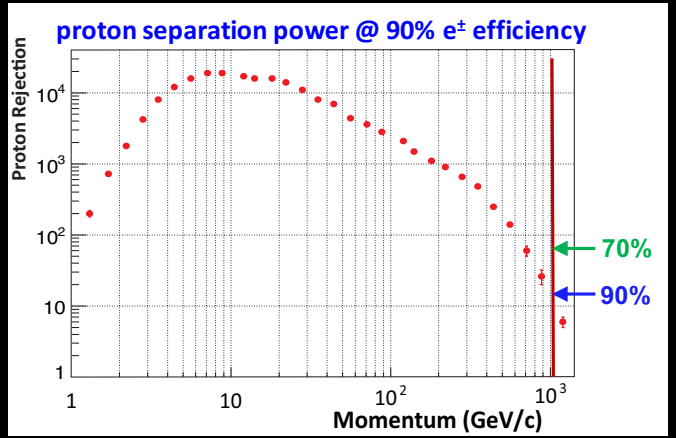


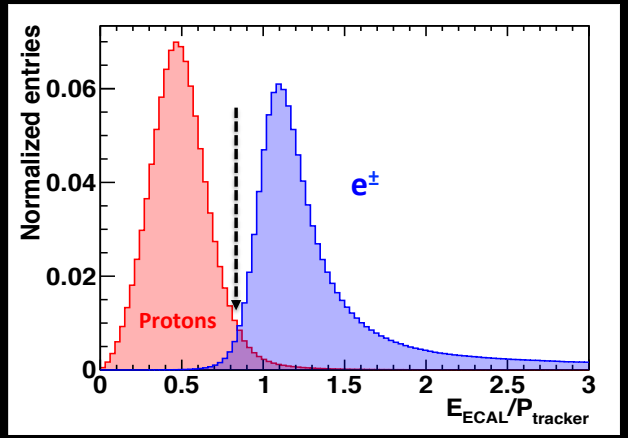
300,000 electronic channels,
650 fast microprocessors
size: 5m x 4m x 3m weight: 7.5 tons

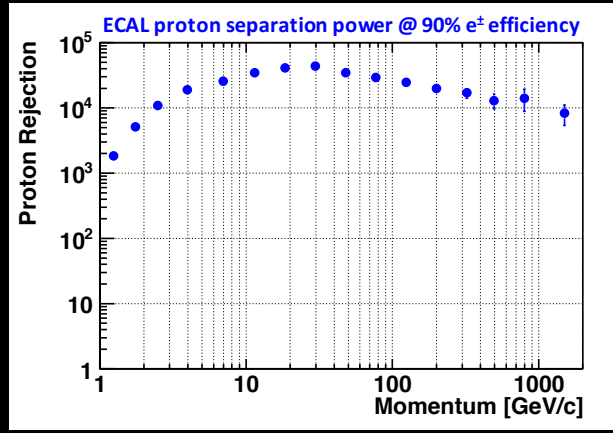
e/p separation





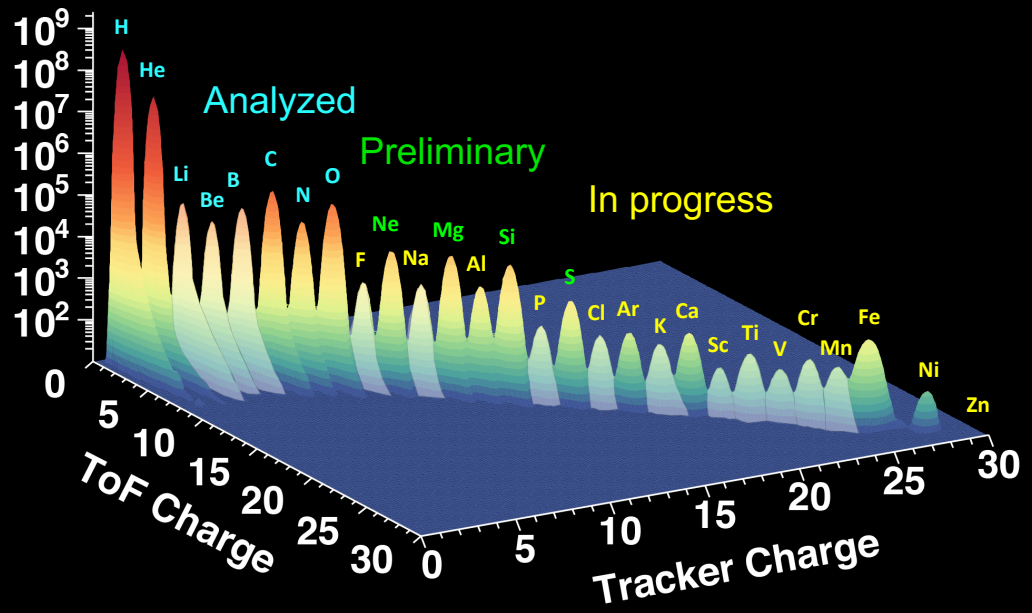




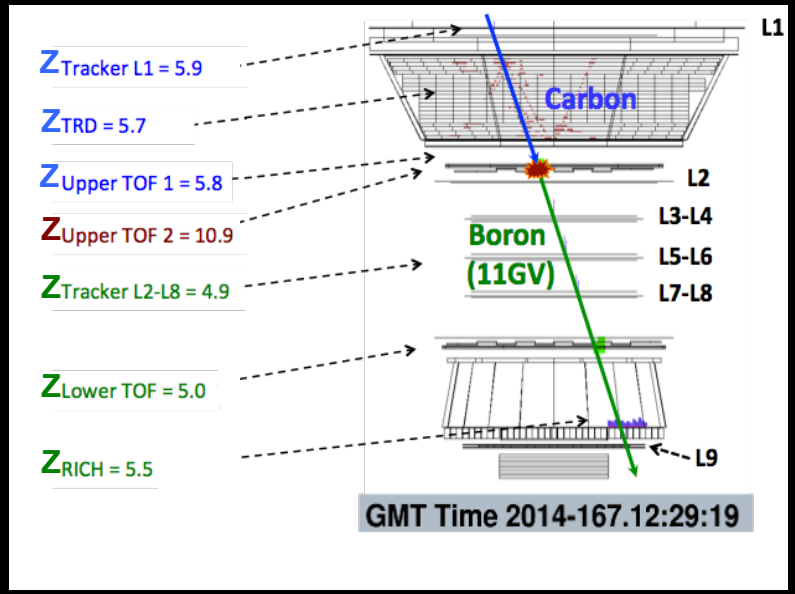


Z measurement

CR Nuclei: Primaries and Secondaries



Seven independent measurements of Z



Z measurement

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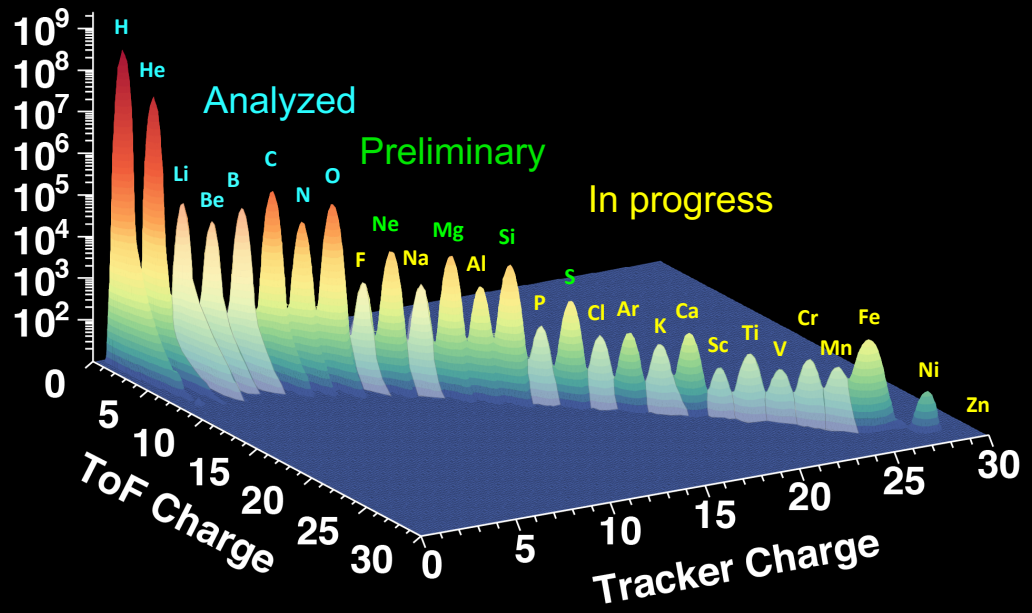
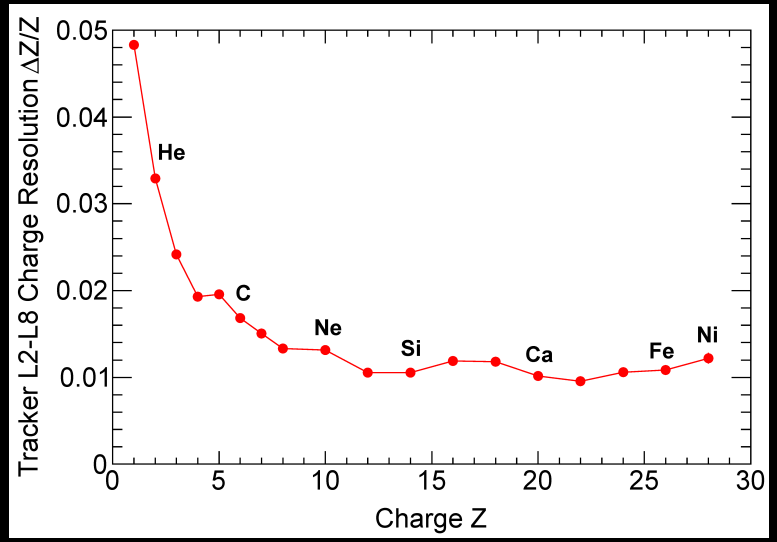
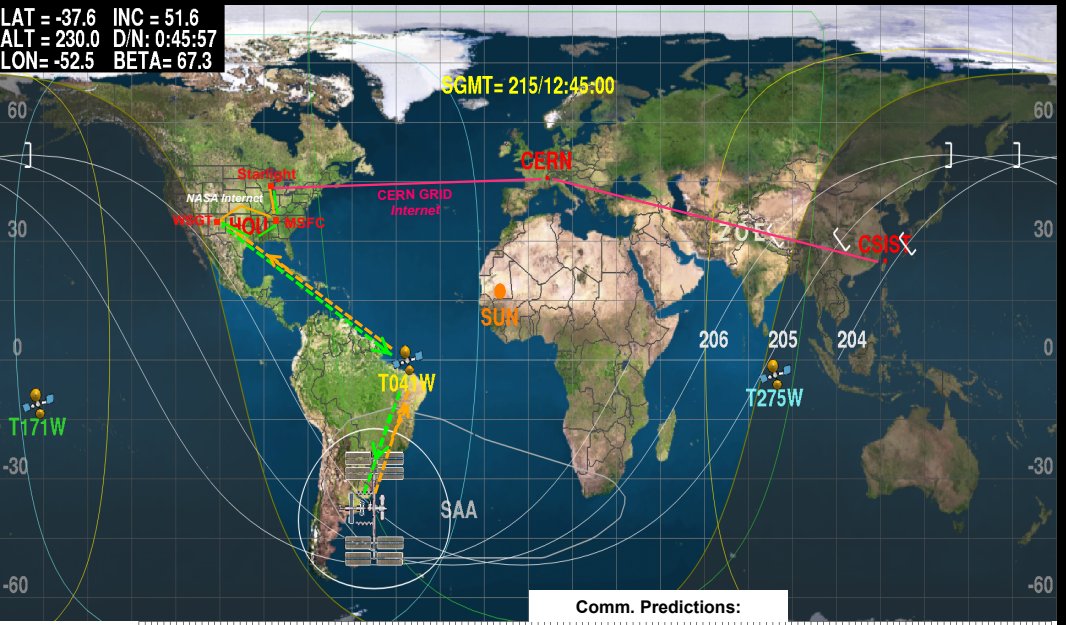
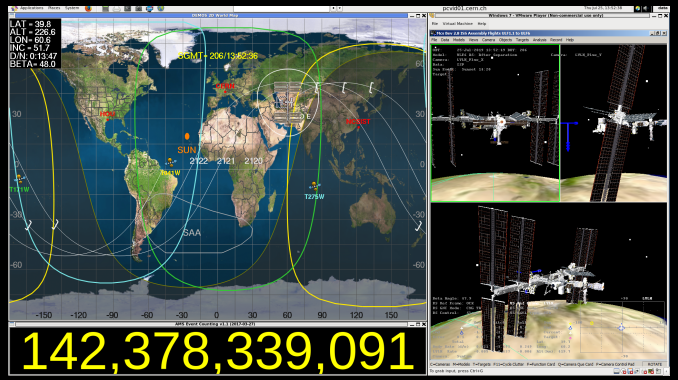


A % charge resolution for Z> Ne



Uninterrupted data taking since May 2011

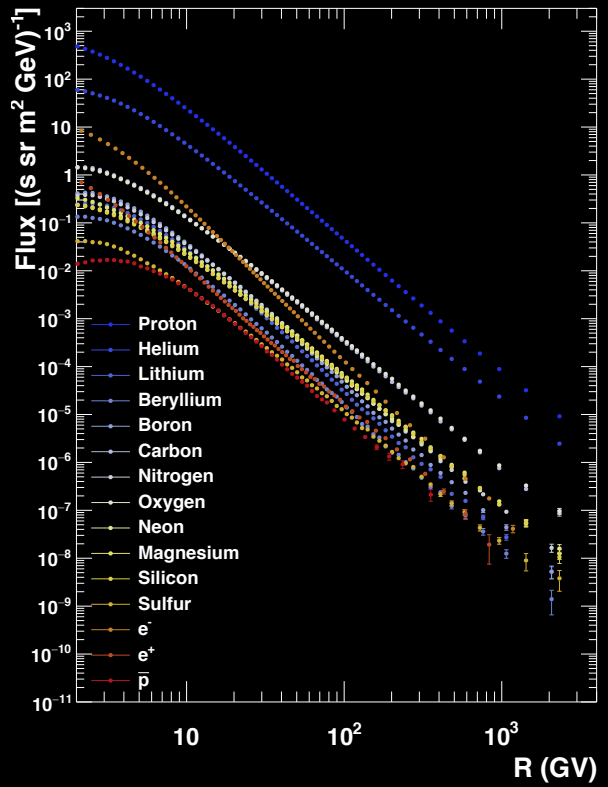


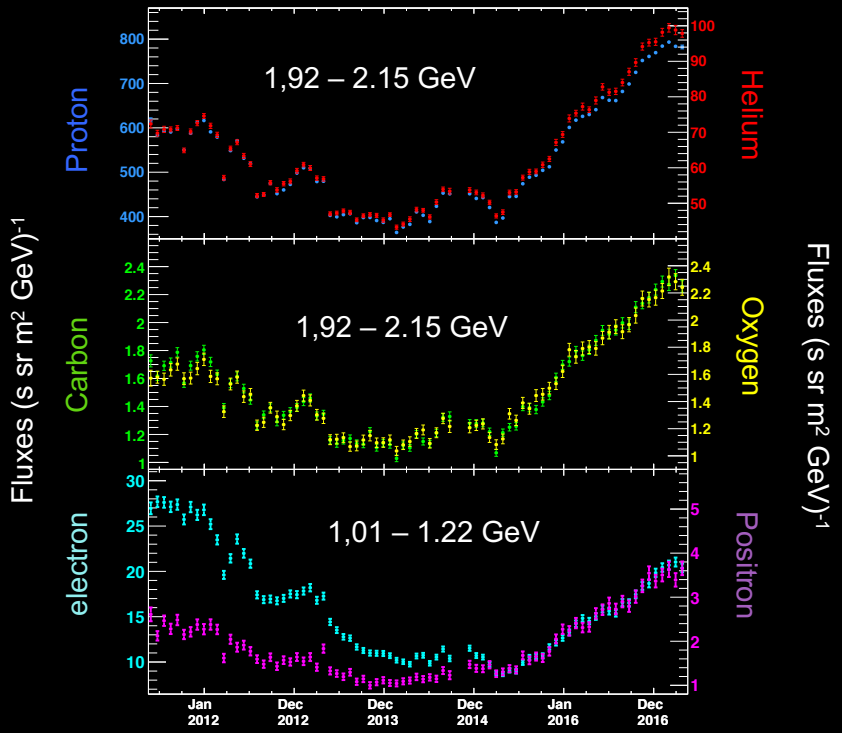


S-band Low Rate
AMS Commanding: 1 Kbit/s (up)
AMS No Ku: 10 bits/s (down)
Duty Cycle: 75-95%

Ku-band High Rate (down)
AMS Events <10Mbit/s>
AMS Monitoring: 30 Kbit/s
Duty Cycle: 50-85%

Cosmic rays measurements with AMS





First and only instrument providing simultaneous measurements of particles/anti-particles, chemical composition up to Zn in an extended energy range and over a solar cycle

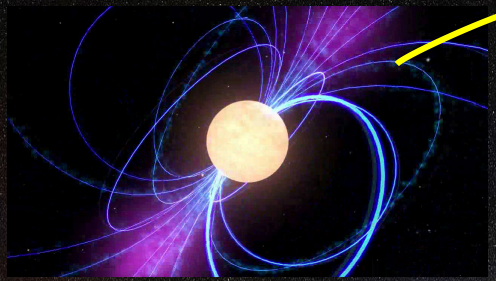
AMS-02 publications in PRL

1. *First Result from the AMS on the ISS: Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5–350 GeV (2013)*
2. *Electron and Positron Fluxes in Primary Cosmic Rays Measured with the AMS on the ISS (2014)*
3. *High Statistics Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5–500 GeV with the AMS on the ISS (2014)*
4. *Precision Measurement of the $e^+ + e^-$ Flux in Primary Cosmic Rays from 0.5 GeV to 1 TeV with the AMS on the ISS (2014)*
5. *Precision Measurement of the Proton Flux in Primary Cosmic Rays from Rigidity 1 GV to 1.8 TV with the AMS on the ISS (2015)*
6. *Precision Measurement of the He Flux in Primary Cosmic Rays of Rigidities 1.9 GVto 3 TV with the AMS on the ISS (2015)*
7. *Antiproton Flux, Antiproton-to-Proton Flux Ratio, and Properties of Elementary Particle Fluxes in Primary Cosmic Rays Measured with the AMS on the ISS (2016)*
8. *Precision Measurement of the B to C Flux Ratio in Cosmic Rays from 1.9 GV to 2.6 TV with the AMS on the ISS (2016)*
9. *Observation of the Identical Rigidity Dependence of He, C, and O Cosmic Rays at High Rigidities by the AMS on the ISS (2017)*
10. *Observation of New Properties of Secondary Cosmic Rays Lithium, Beryllium, and Boron by the AMS on the ISS (2018)*
11. *Observation of Fine Time Structures in the Cosmic Proton and Helium Fluxes with AMS on the ISS (2018)*
12. *Observation of complex time structures in the cosmic-ray electron and positron fluxes with the AMS on the ISS (2018)*
13. *Precision measurement of cosmic-ray nitrogen and its primary and secondary components with AMS on the ISS (2018)*
14. *Towards Understanding the Origin of Cosmic-Ray Positrons (2019)*
15. *Towards Understanding the Origin of Cosmic-Ray Electrons (2019)*

… "Helium Isotopes in the Cosmos "
… "Rigidity Dependence of Ne, Mg, and Si Cosmic Rays"
…

-- Editor's suggestion

On the Origins of Cosmic Electrons and Positrons



Electrons/Positrons
from Pulsars

Electrons

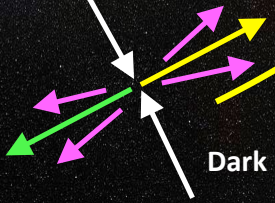
Protons,
Helium, ...

Interstellar
Medium

Positrons / Electrons
from Collisions

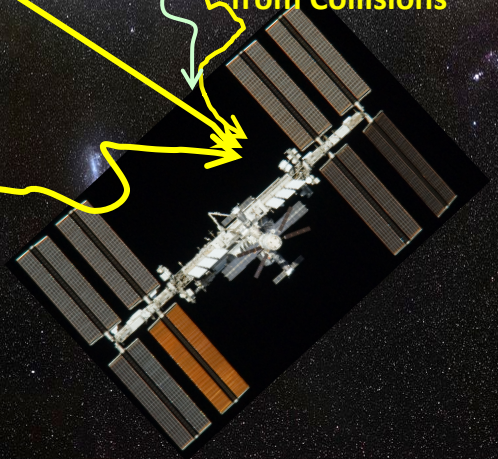
Electrons/Positrons
from Dark Matter

Dark Matter



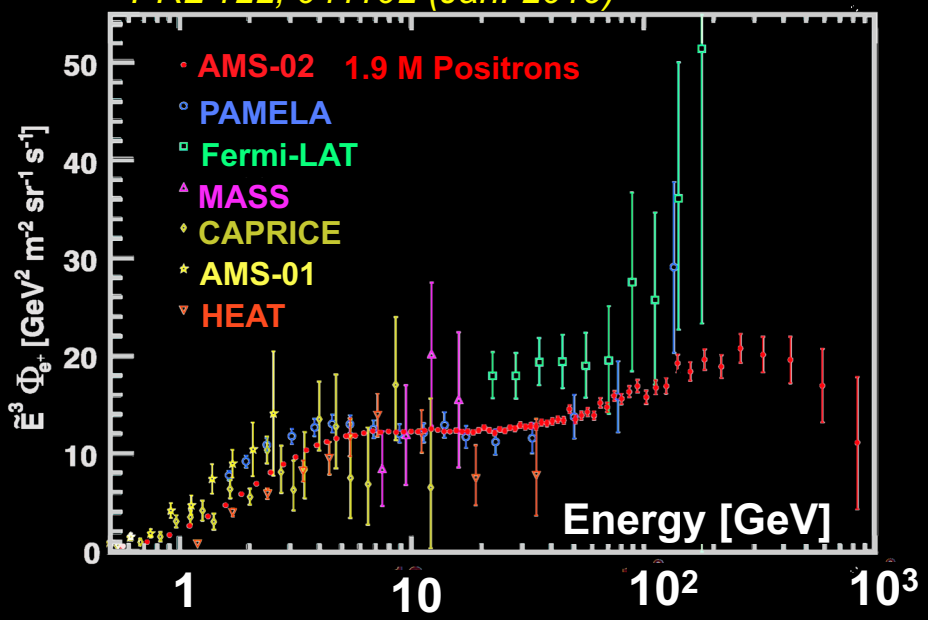
Electrons

Dark Matter

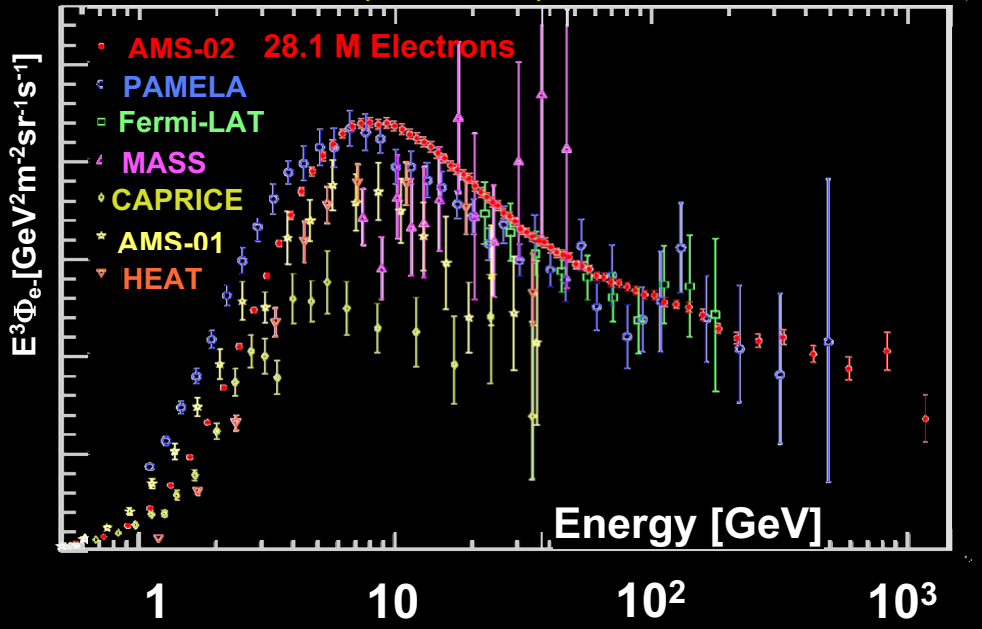


Positron and Electron fluxes

PRL 122, 041102 (Jan. 2019)

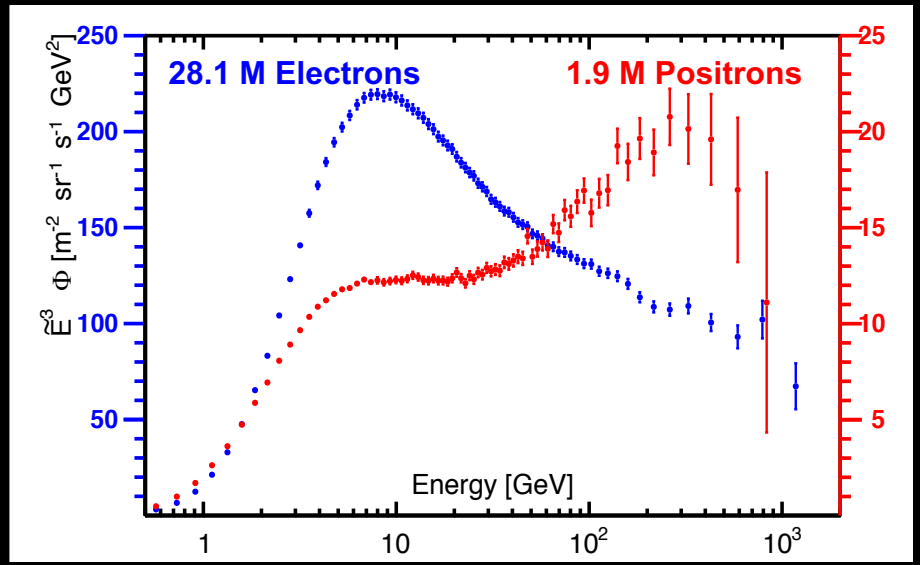


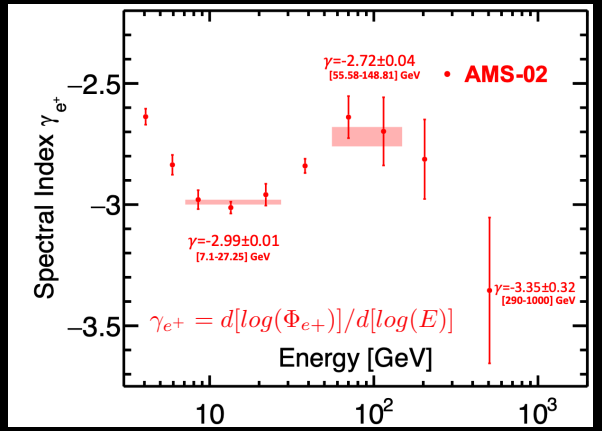
PRL 122, 101101 (Mar. 2019)

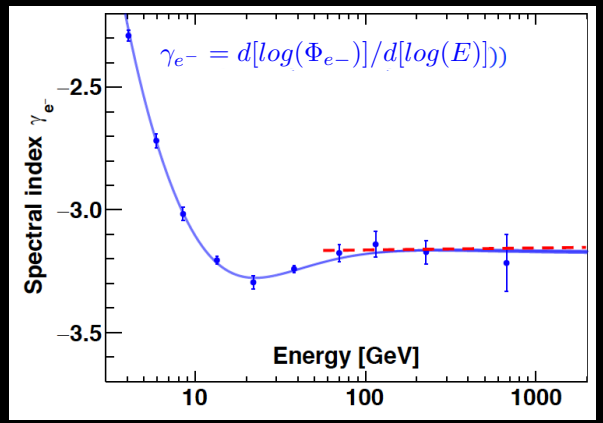


Accuracy & energy as  **towards understanding**

Distinct (and different) features



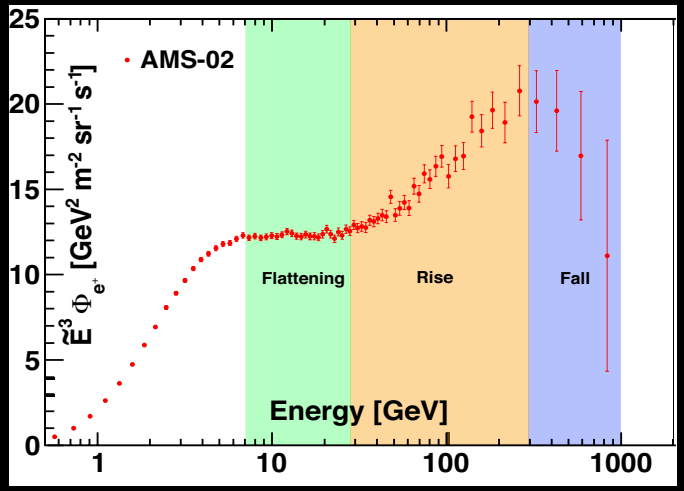


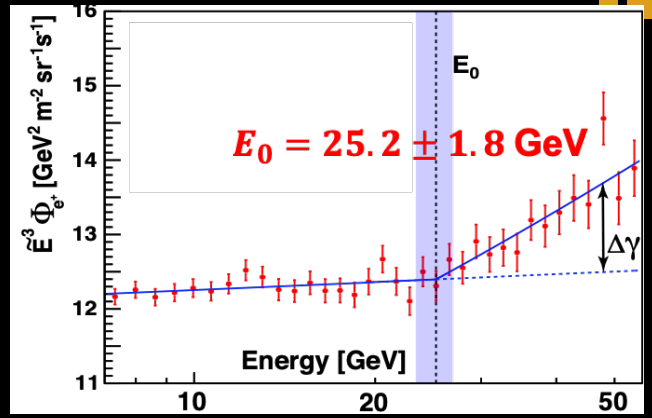


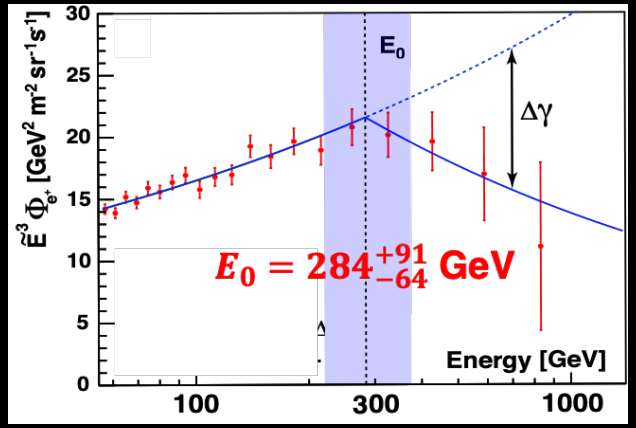
Pub on:
PRL 122, 041102 (Jan. 2019)
PRL 122, 101101 (Mar. 2019

@ ICRC Jul 25
CRD2b: Towards Understanding the Origin of Cosmic-Ray Electrons W.Xu
CRD2h: Towards Understanding the Origin of Cosmic-Ray Positrons Z.Weng

The complex energy dependence of e+





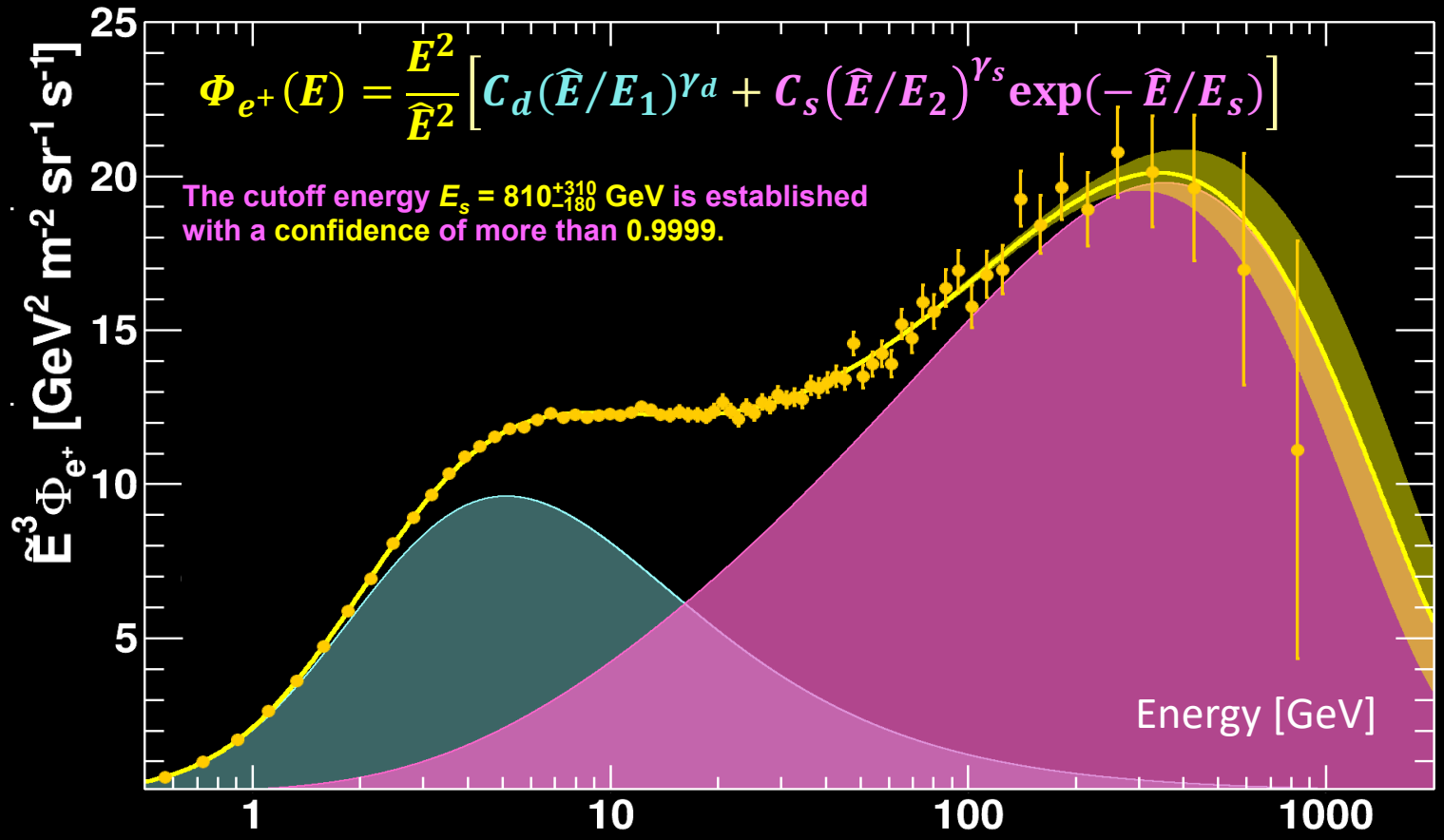


Fit of the data to define the transition Energy E0 between different regions

$$\Phi_{e^+}(E) = \begin{cases} CE^{\gamma}, & E \leq E_0; \\ CE^{\gamma}(E/E_0)^{\Delta\gamma}, & E > E_0. \end{cases}$$

Positron flux:

described with two components with a cutoff at high energy

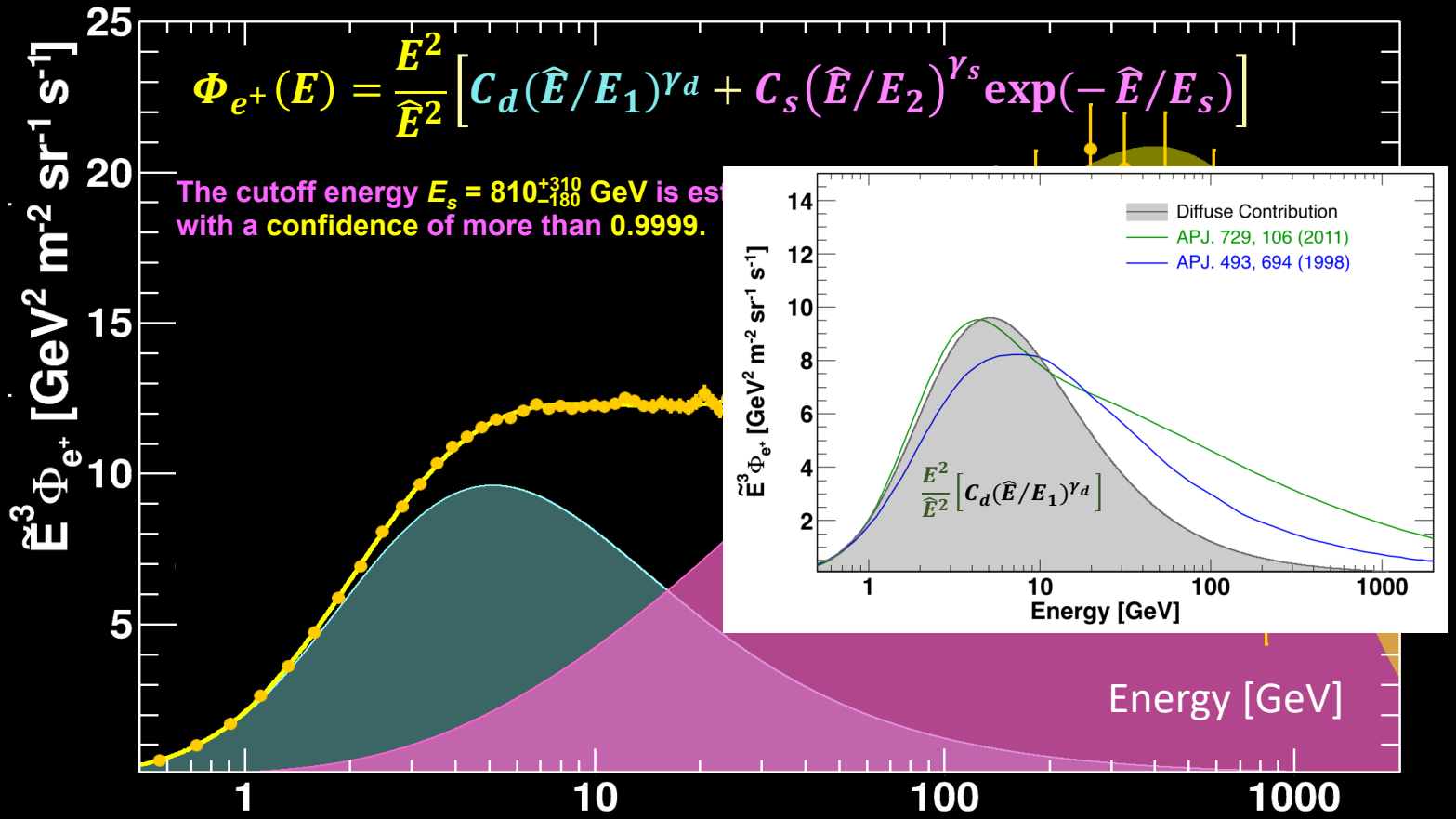


Positron flux:

described with two components with a cutoff at high energy

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

The cutoff energy $E_s = 810^{+310}_{-180}$ GeV is est
with a confidence of more than 0.9999.



Positron flux:

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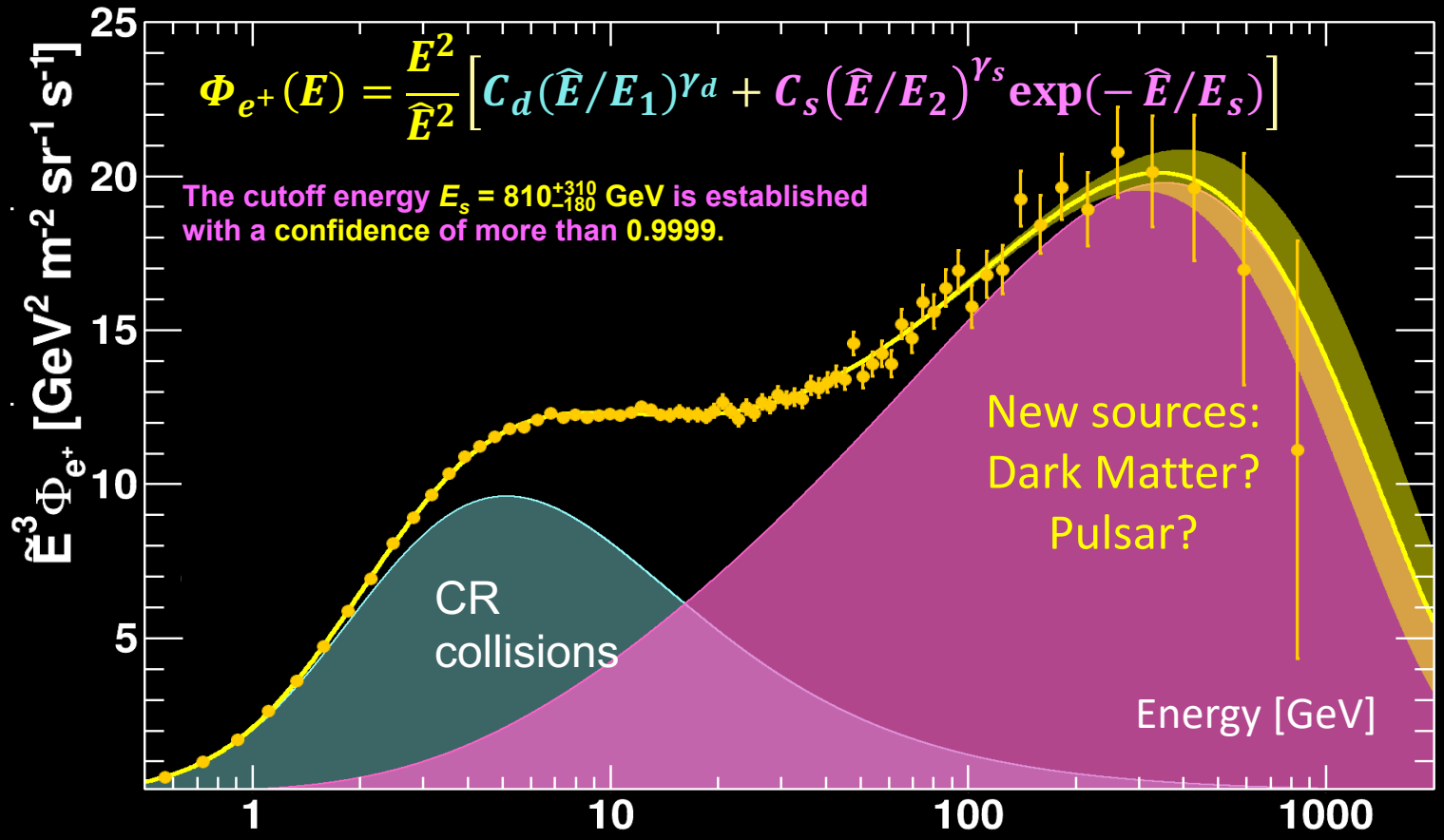
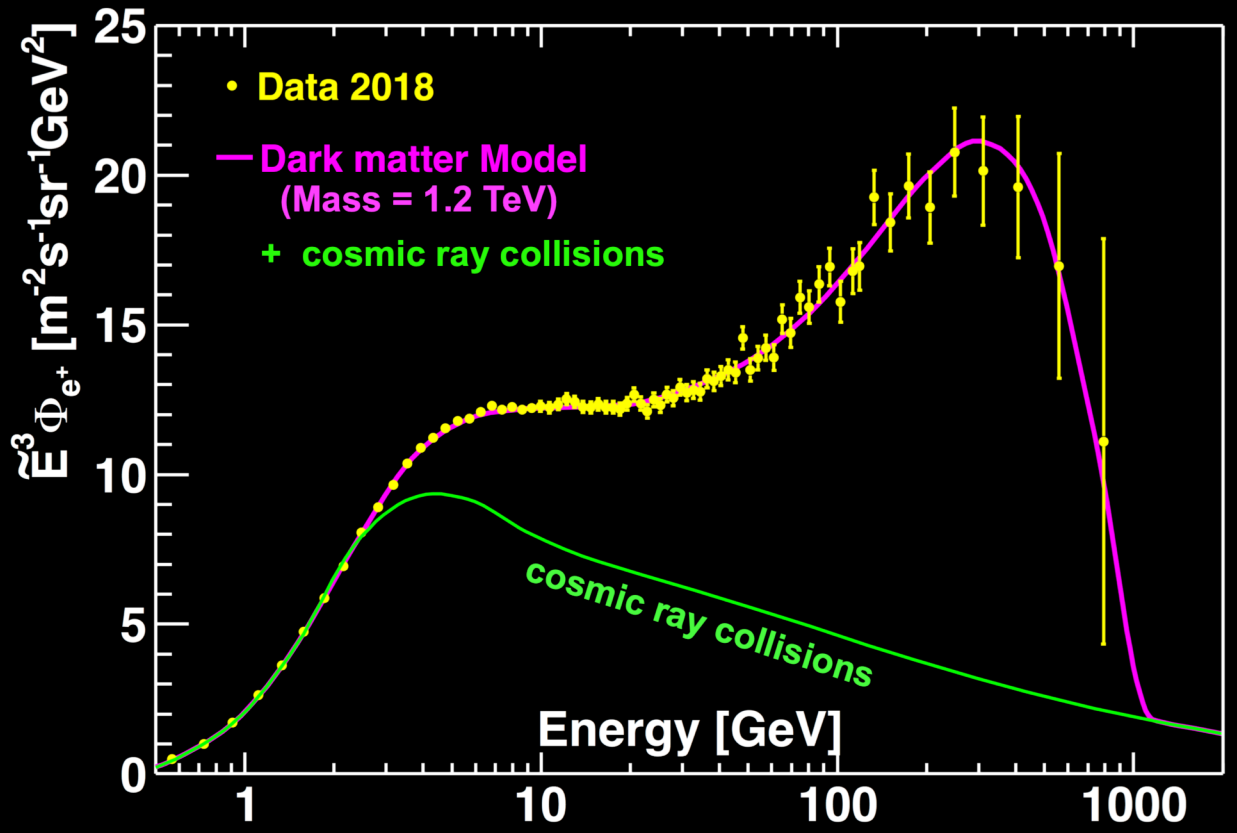
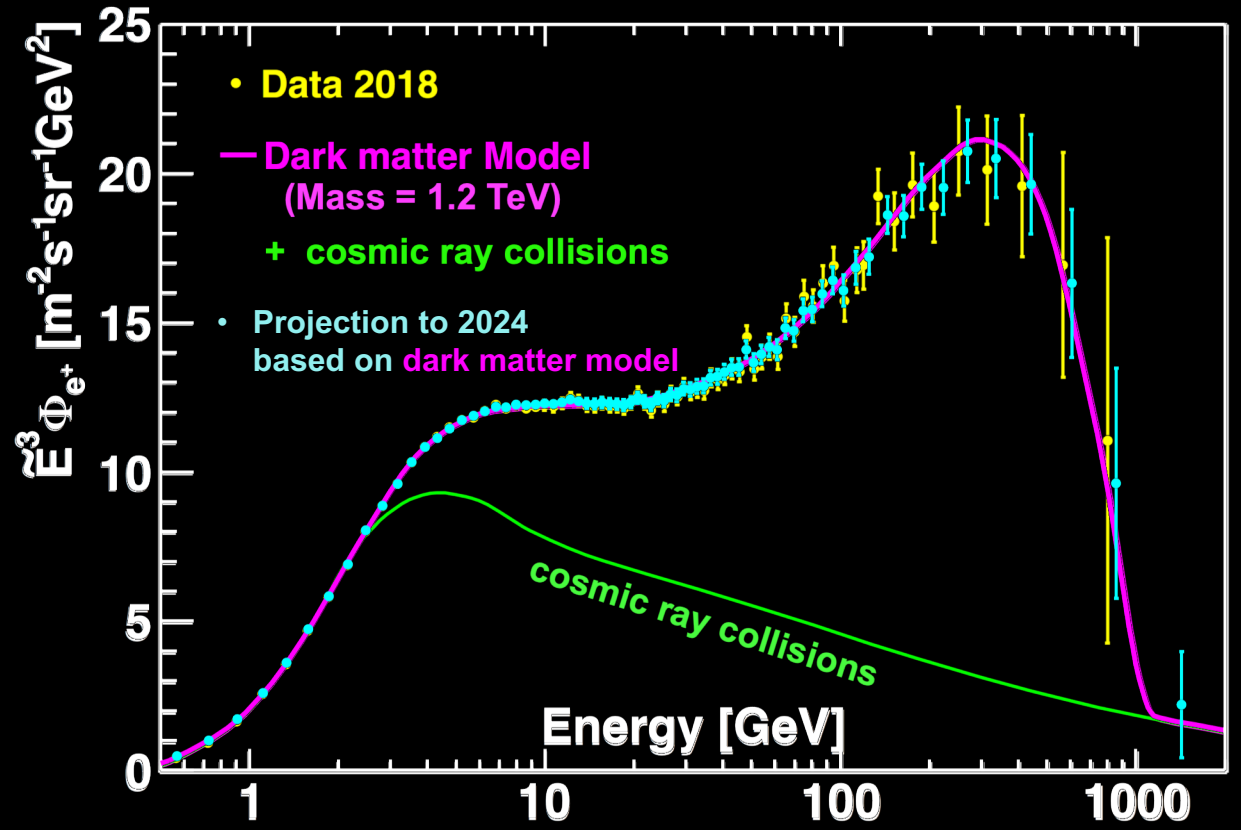


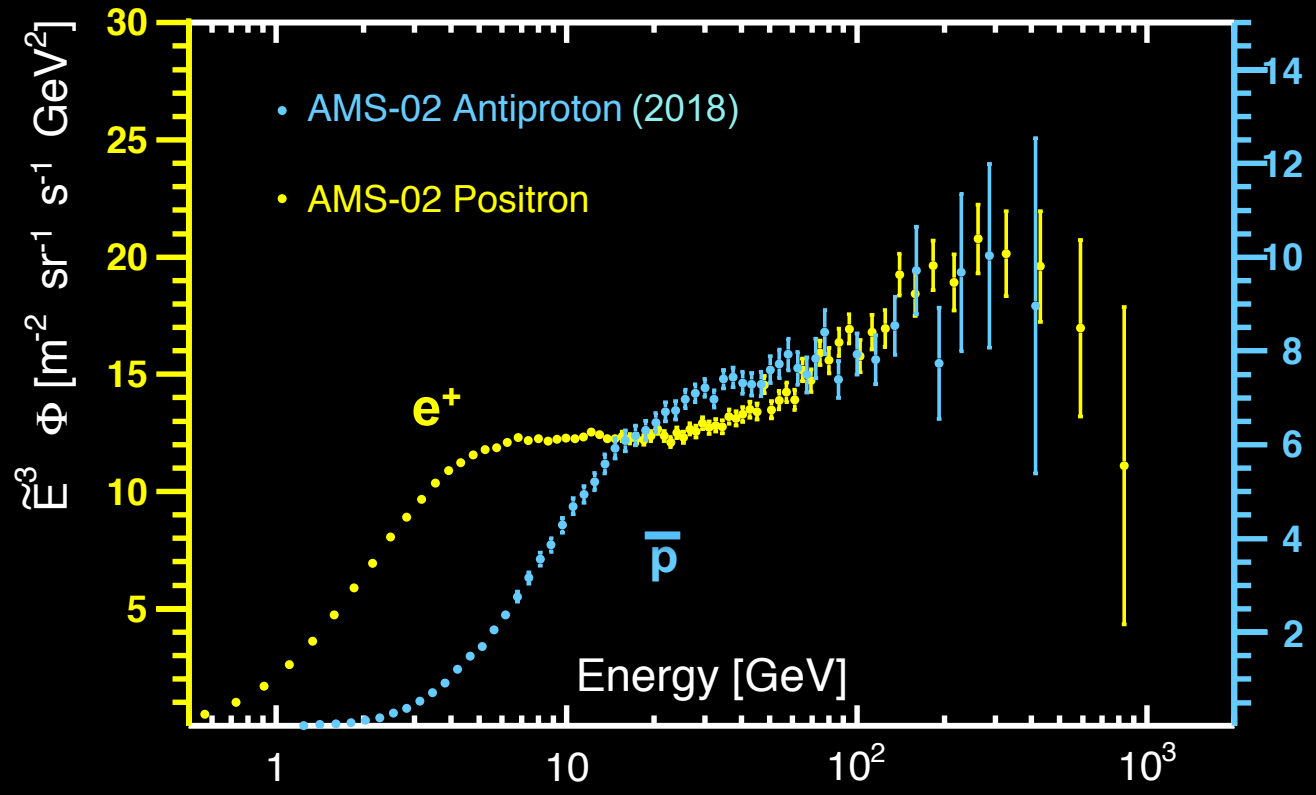
Positrons and a Dark matter model



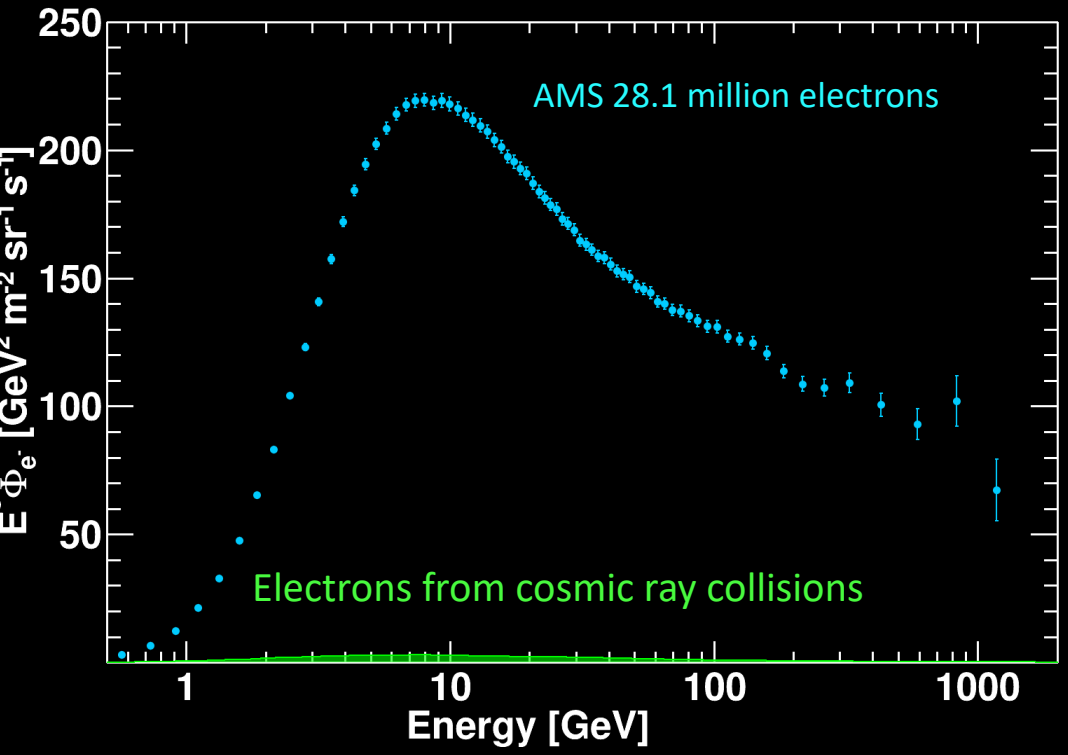
Positrons and a Dark matter model



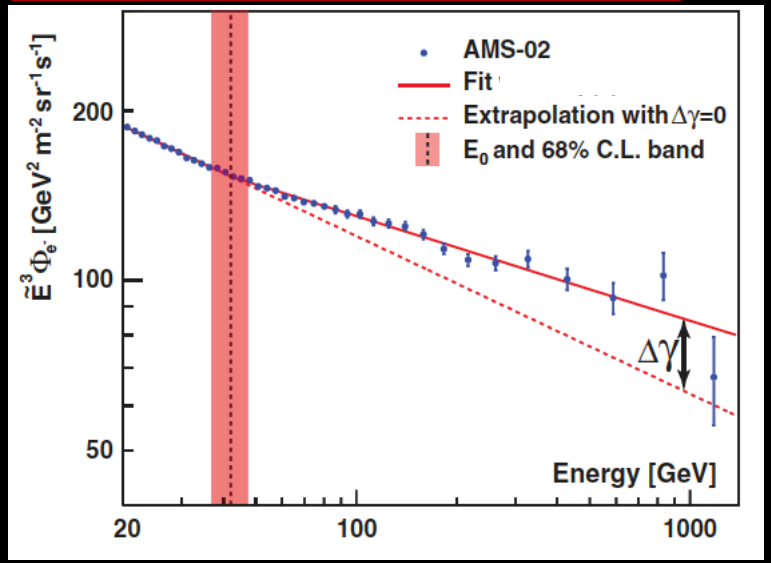
Antiprotons exhibits same trend as positrons …but cannot come from pulsars



The origin of cosmic electrons:



$$\Phi_{e^-}(E) = \begin{cases} C(E/20.04\ \mathrm{GeV})^{\gamma} & E \le E_0 \\ C(E/20.04\ \mathrm{GeV})^{\gamma} & (E/E_0)^{\Delta\gamma} E > E_0 \end{cases}$$



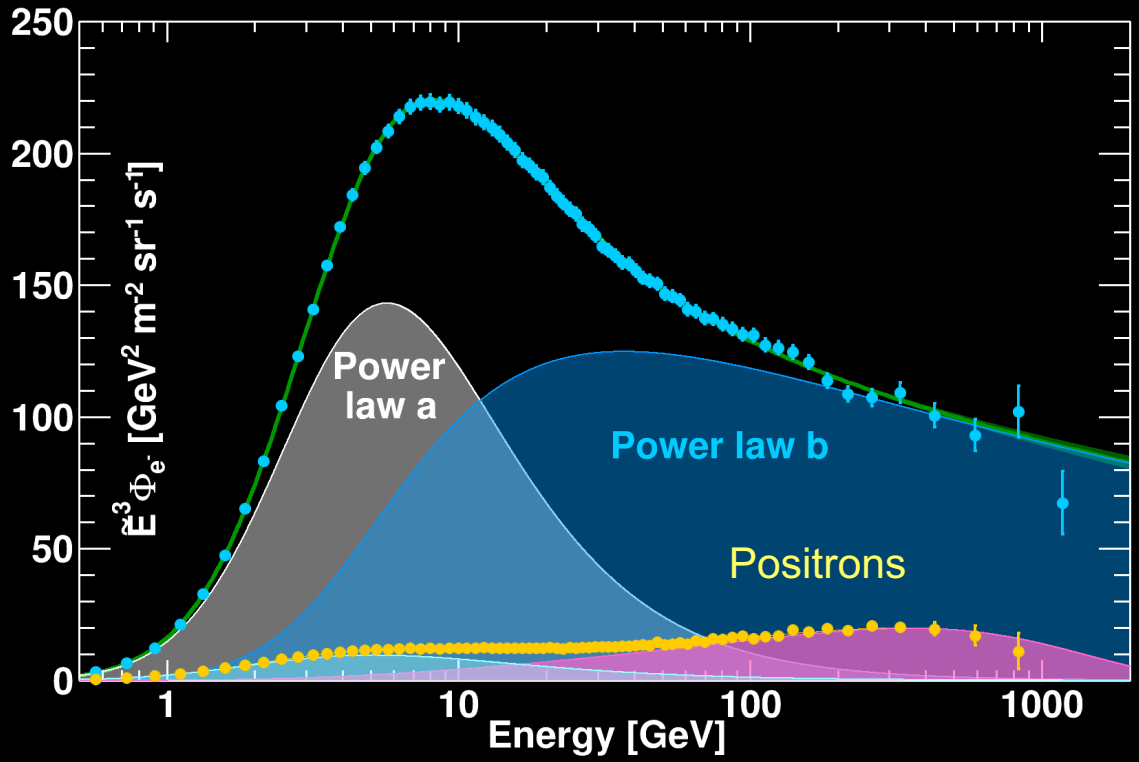
$$E_0 = 42.1^{+5.4}_{-5.2} GeV$$

$$\gamma = -3.280^{+0.014}_{0.016}$$

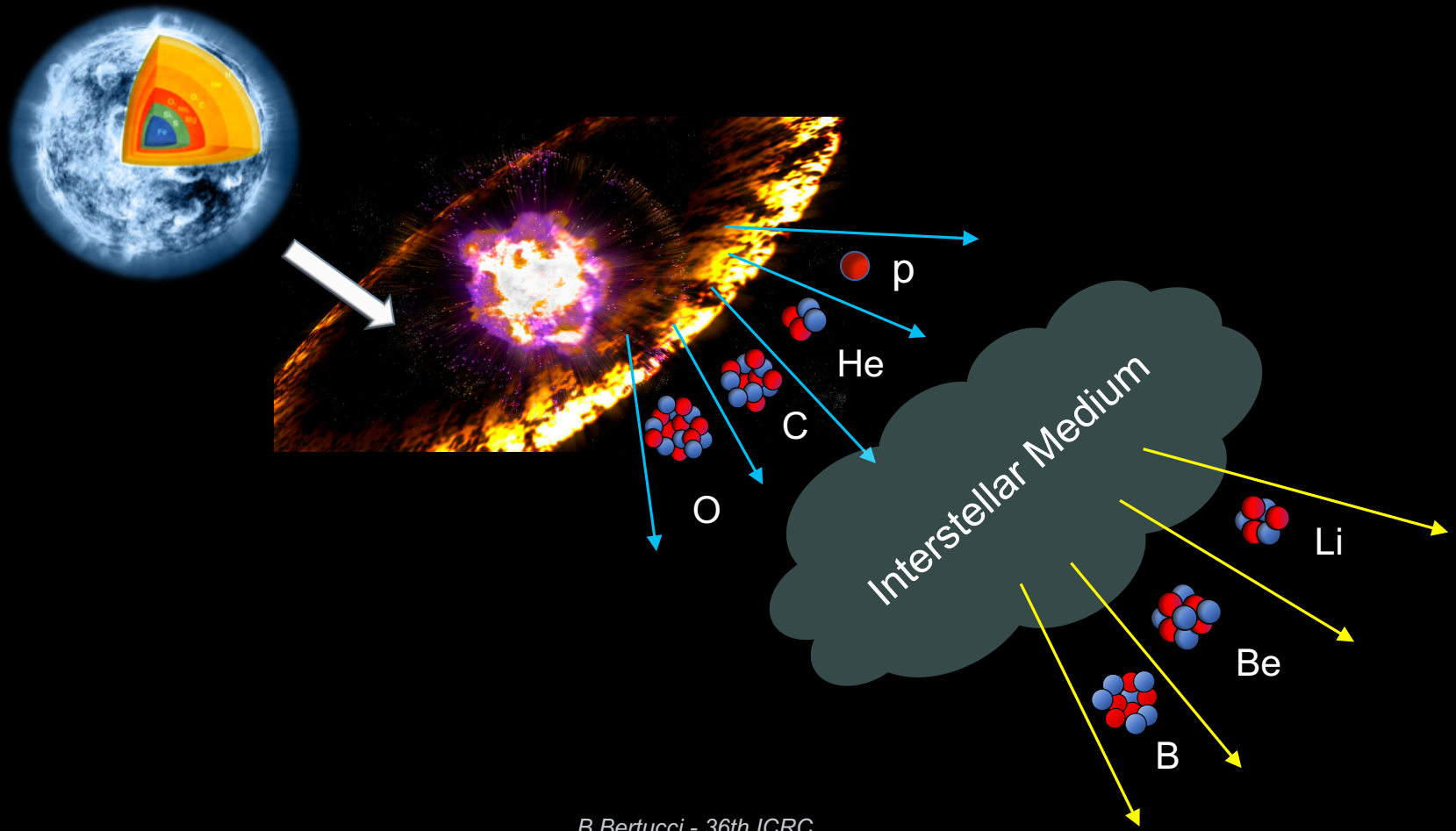
$$\Delta\gamma = 0.094 \pm 0.014$$

The origin of cosmic electrons:

$$\Phi_{e^-}(E) = \frac{E^2}{\hat{E}^2}\left[1 + \left(\hat{E}/E_t\right)^{\Delta\gamma_t}\right]^{-1}\left[C_a\left(\hat{E}/E_a\right)^{\gamma_a} + C_b\left(\hat{E}/E_b\right)^{\gamma_b}\right]$$

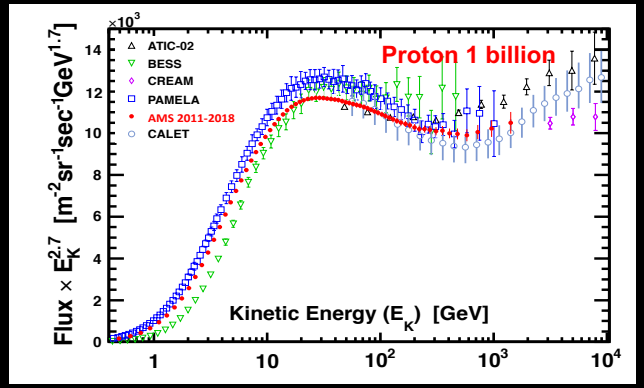


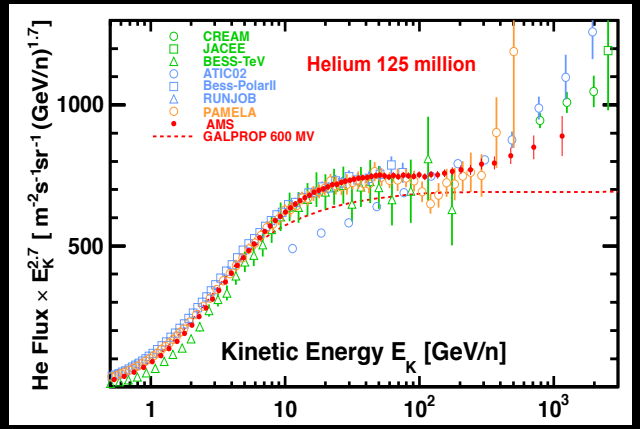
Primary and Secondary CR in the Galaxy

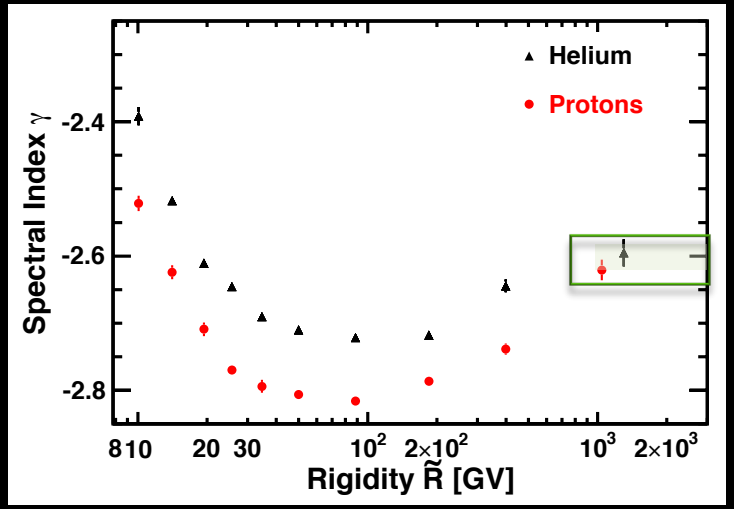


Primary cosmic rays: Proton and Helium

updated measurements with 7 years of data





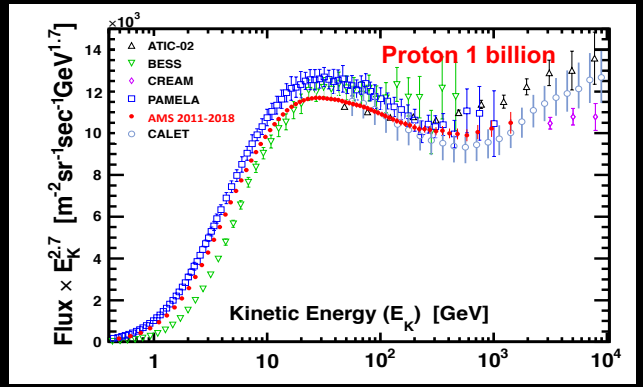


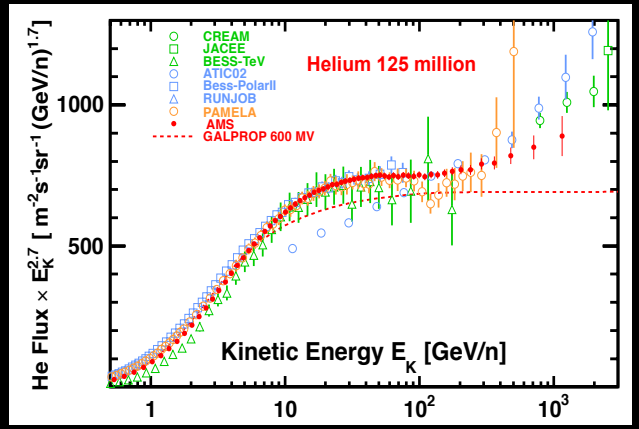
Common spectral index at high R ?

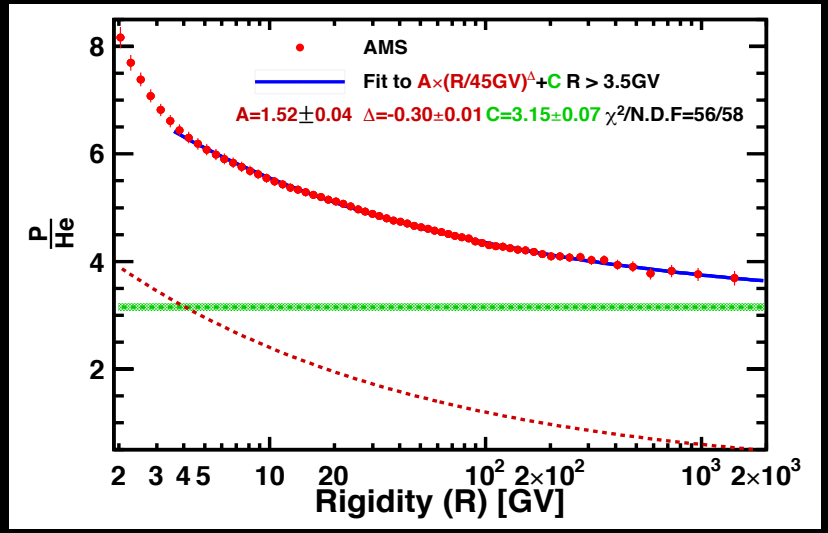
More details in the talk of Q.Yan on Jul. 30th, session CRD8b

Primary cosmic rays: Proton and Helium

updated measurements with 7 years of data



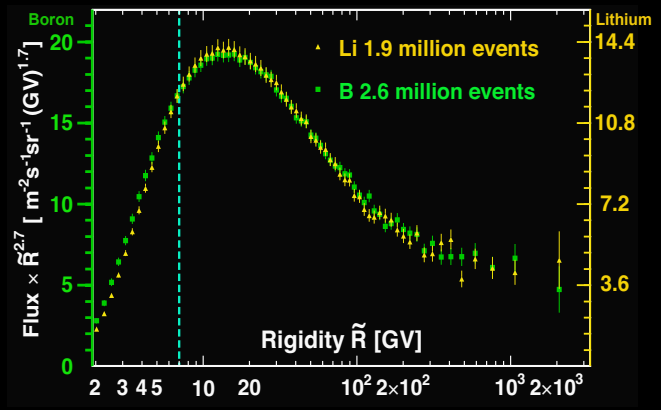


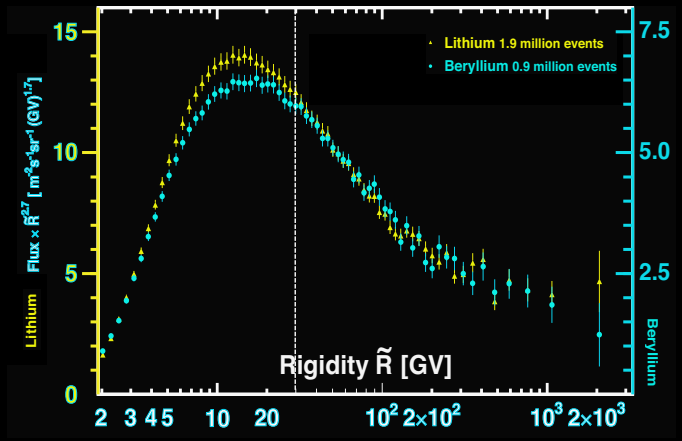


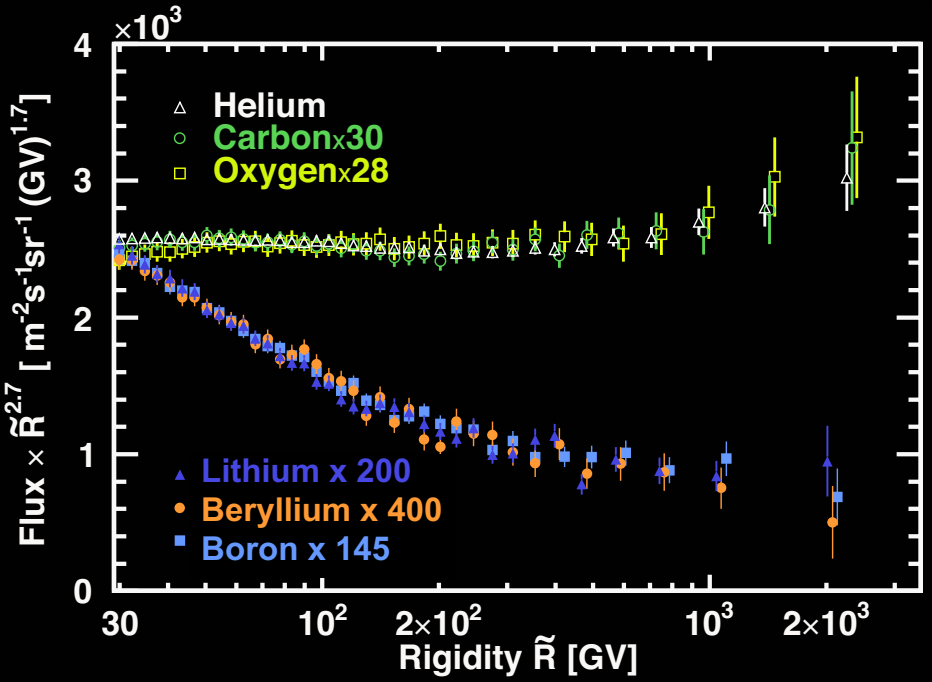
The p/He ratio at R> 45 GeV is well described by the sum of a power law + constant

More details in the talk of Q.Yan on Jul. 30th, session CRD8b

Primary and Secondary Cosmic Rays

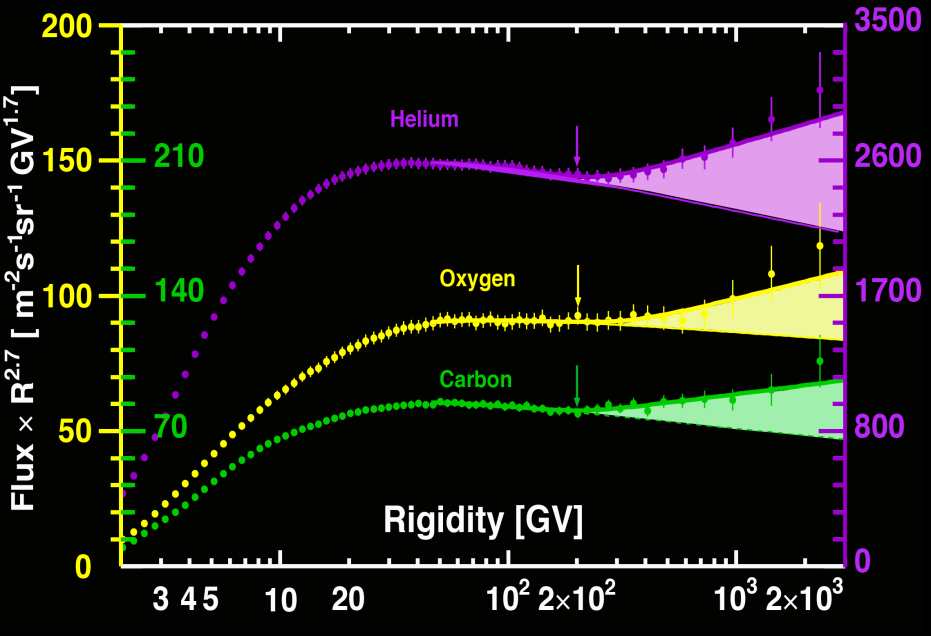


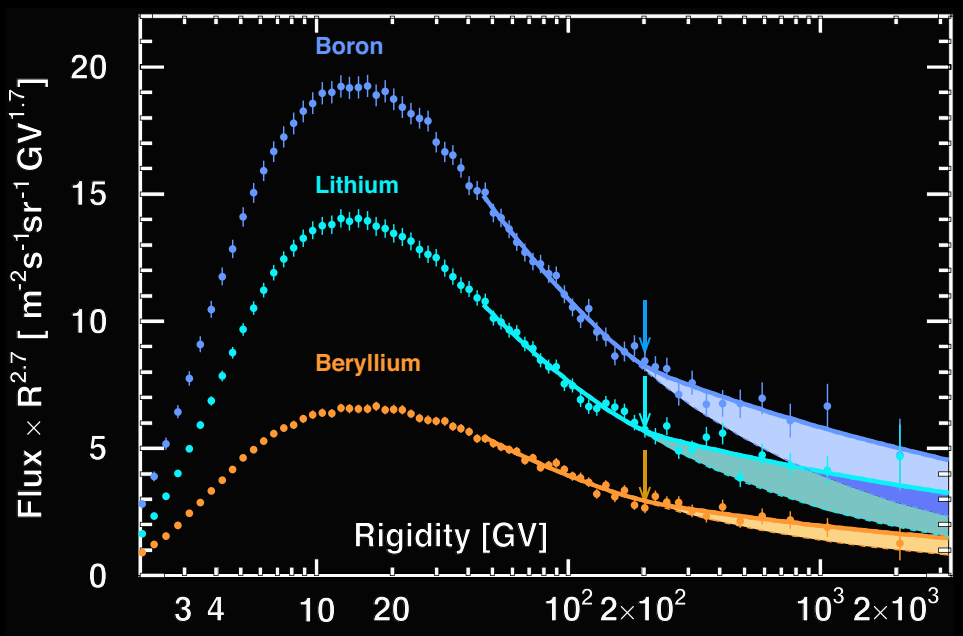




Pub. On
PRL 119 251101, (Dec 2017)
PRL 120, 021101 (Jan 2018)

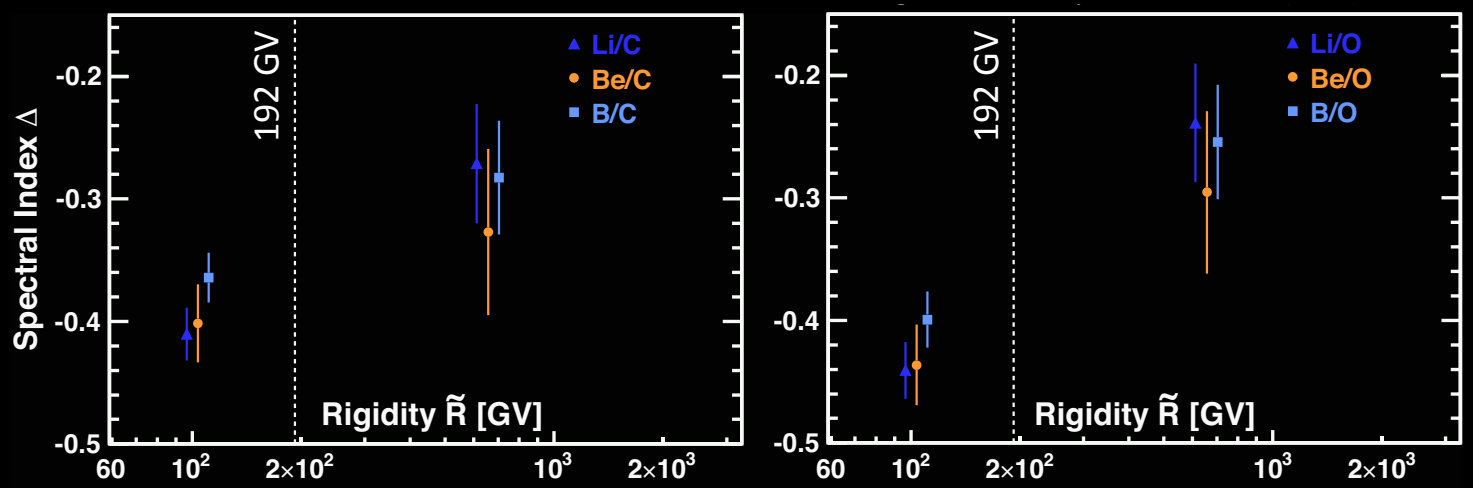
The spectral hardening > 200 GV





All measured fluxes exhibit a break ≈ 200 GeV :
injection or propagation effect?

Secondary/Primary Spectral Indices



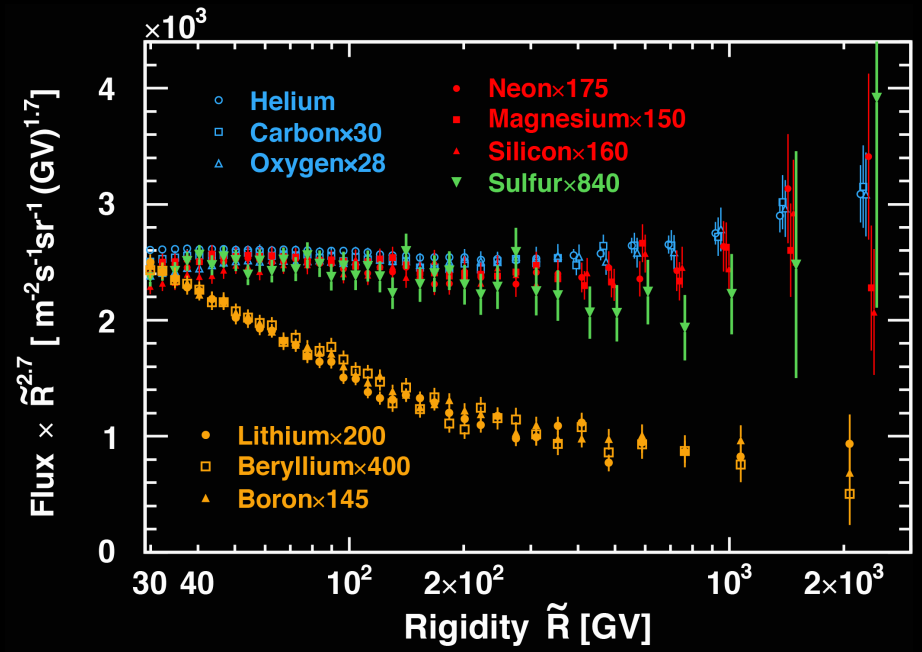
An hardening of 0.13±0.03 at 192 GV is observed combining the six secondary/primary ratios

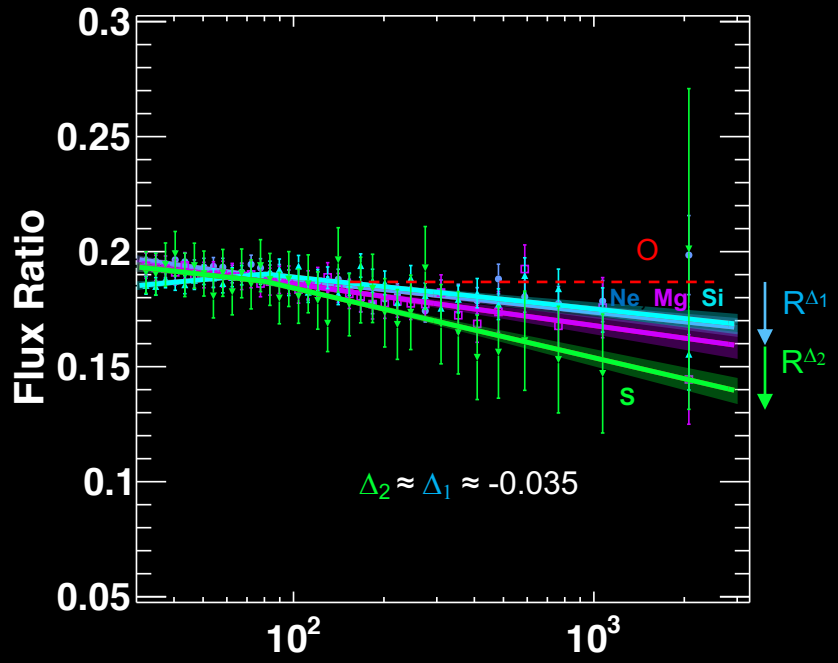
This observation favors the flux hardening as an universal propagation effect

More details in the talk of A. Oliva on Jul. 29h, session CRD6B

New results on primary CR fluxes

Progressive softening of the spectrum above 100 GeV from Oxygen to Ne,Mg,Si and then to S

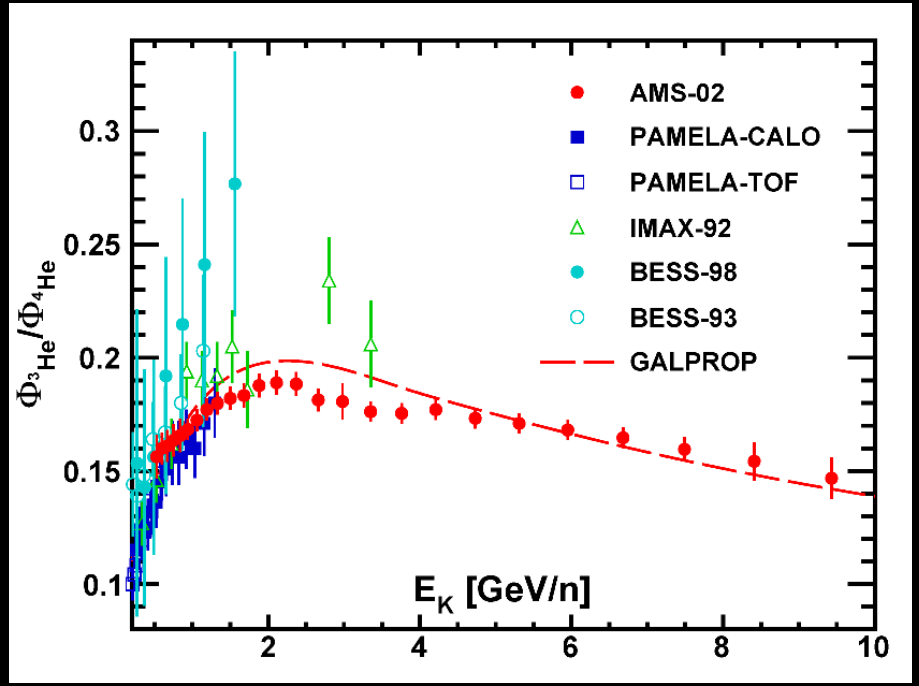




More details in the talk of Q.Yan on Jul. 30th, session CRD7A

New AMS result on ^3He / ^4He flux ratio measurement

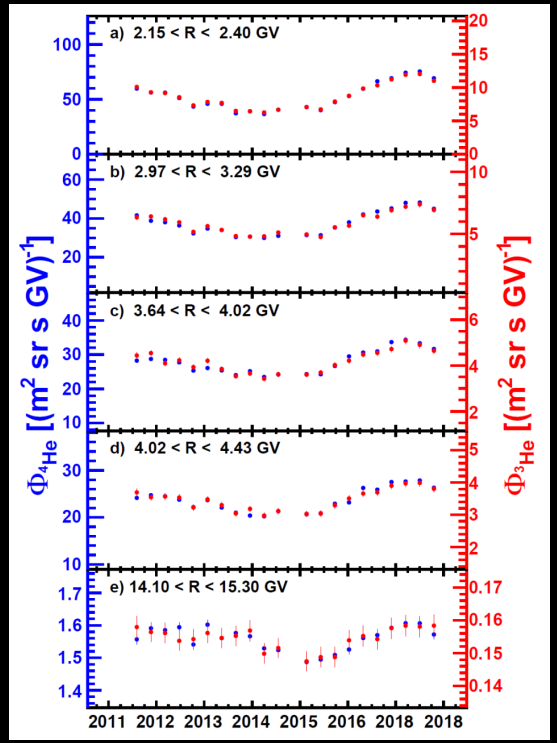
Data collected from May 2011 to Nov 2017 (6.5 y)

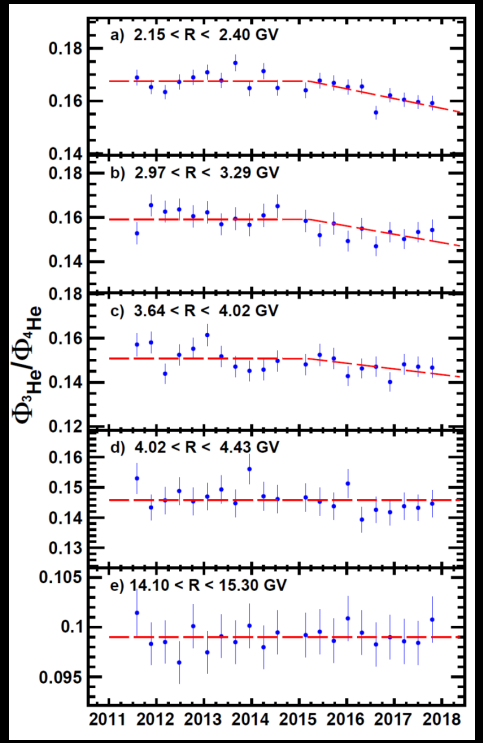


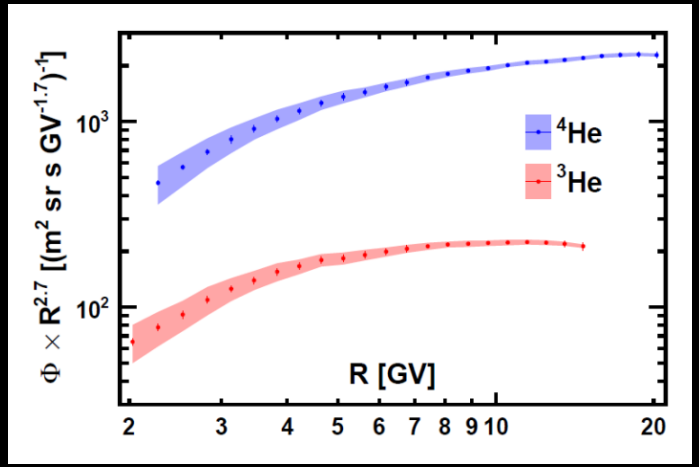
AMS ^{3}He and ^{4}He fluxes

Data collected from May 2011 to Nov 2017 (6.5 y)

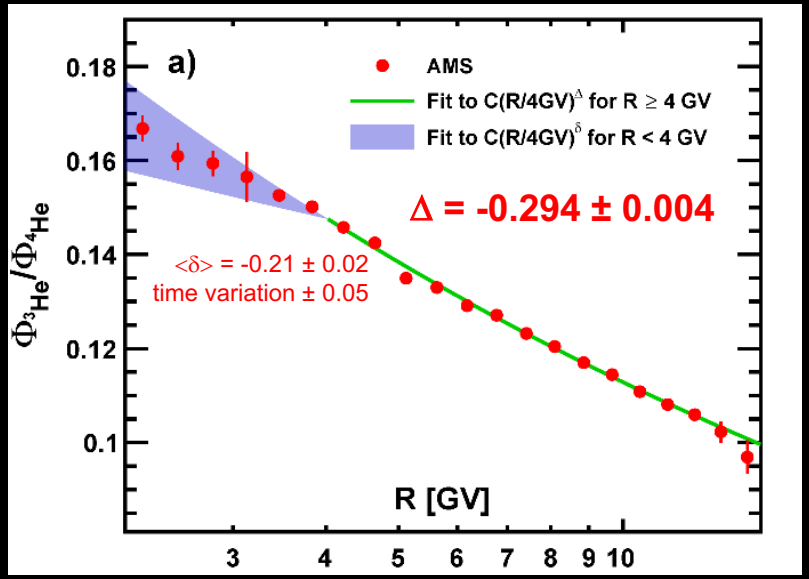
Measurements in 21 time periods of 4 Bartels rotations (108 days) each

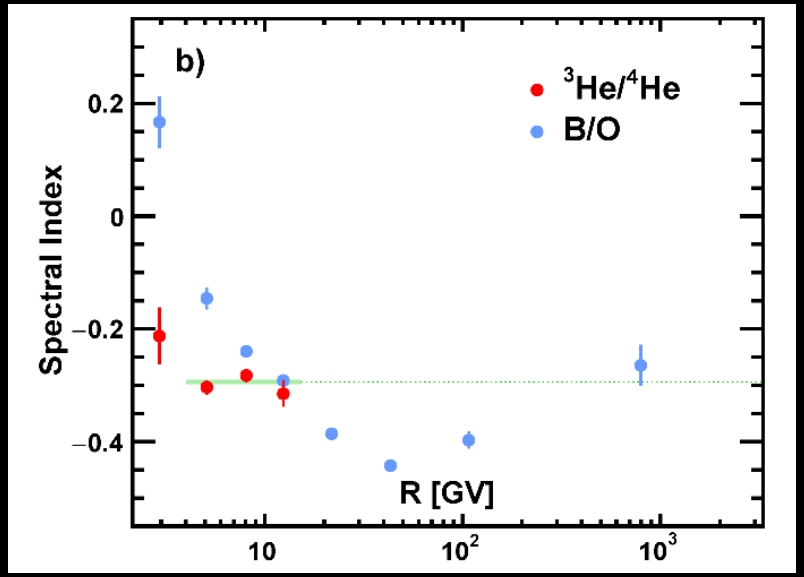






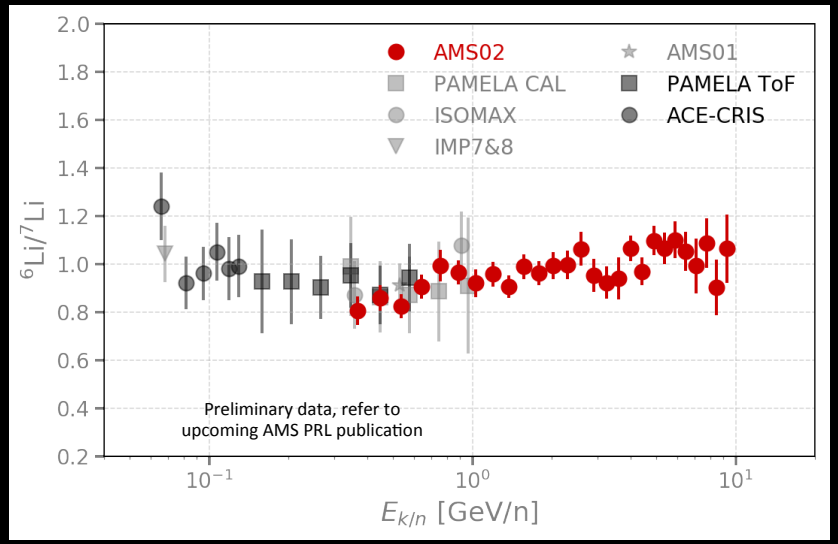
AMS $^3He/^4He$ flux ratio



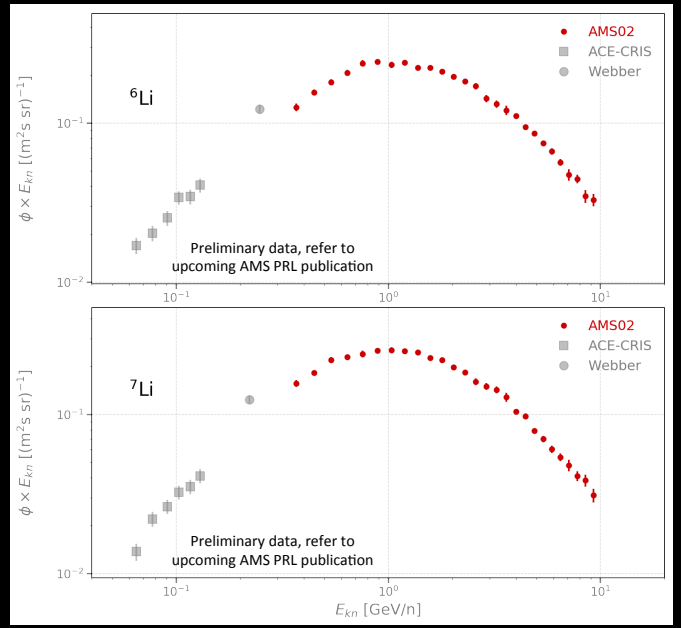


More details in the talk of C. Delgado on Jul. 29h, session CRD6C

AMS measurement of ^{6}Li and ^{7}Li



→ Extends ^{6}Li/^{7}Li ratio measurement above 1 GeV/n up to 10 GeV/n



→ First measurement of ^{6}Li and ^{7}Li fluxes above 0.3 GeV/n.

More details in the talk of L.Derome on Jul. 29^h, session CRD6D

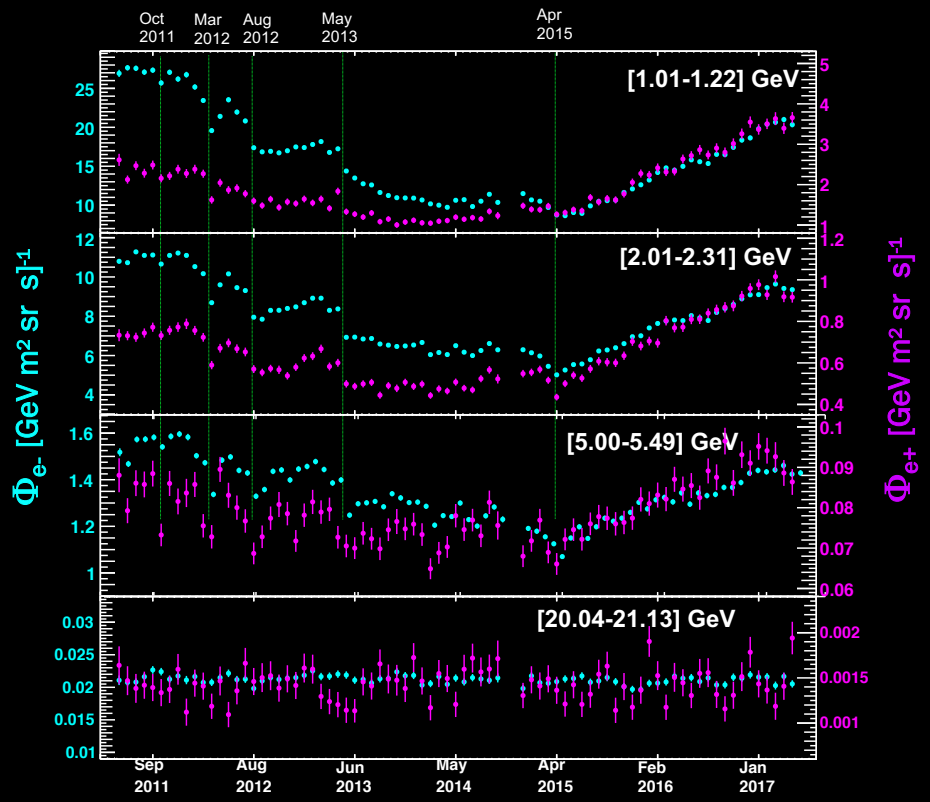
Cosmic rays & the earth-sun connection

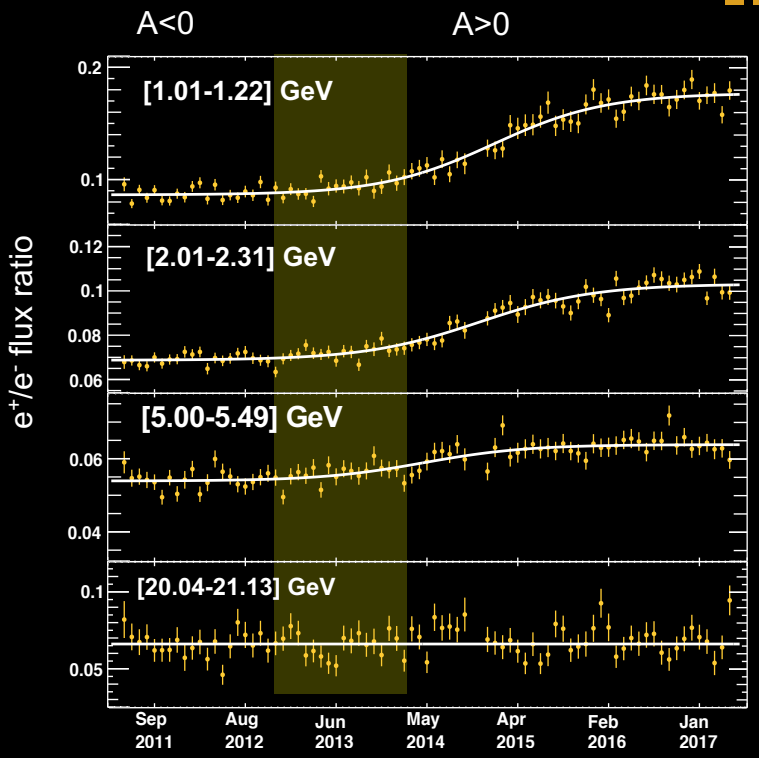
Deep understanding of solar effects is needed
to unveil the properties of the local interstellar spectrum
of galactic cosmic rays

&

… is a complex physics where AMS can
contribute with new and precise measurements
pointing to unexpected phenomena

Time dependent structures in e^+/e^- fluxes

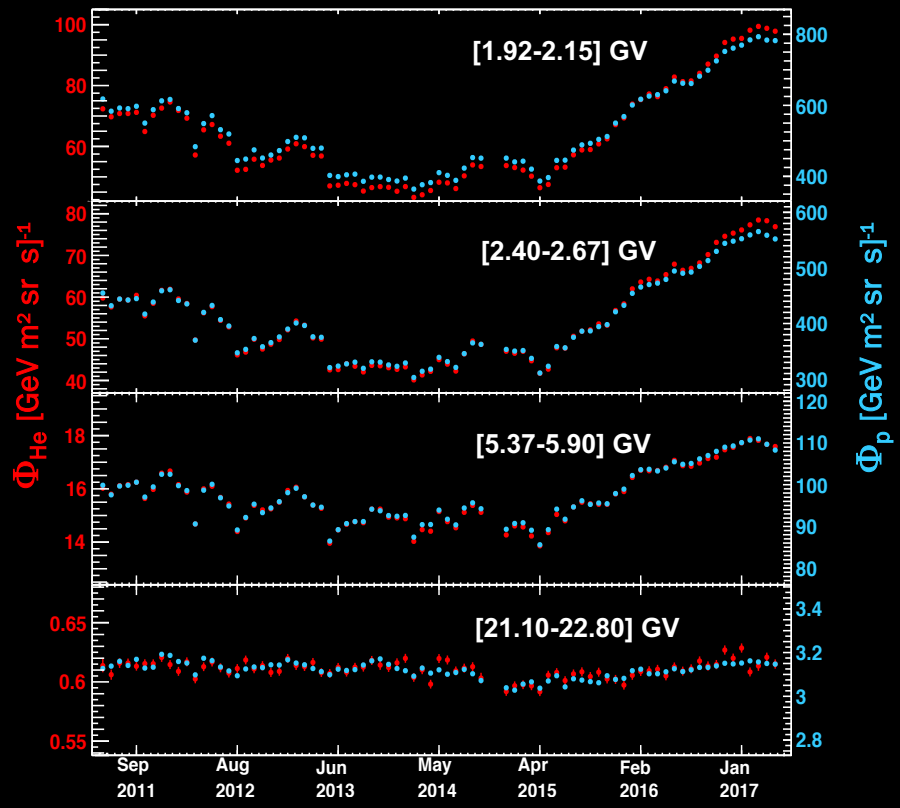


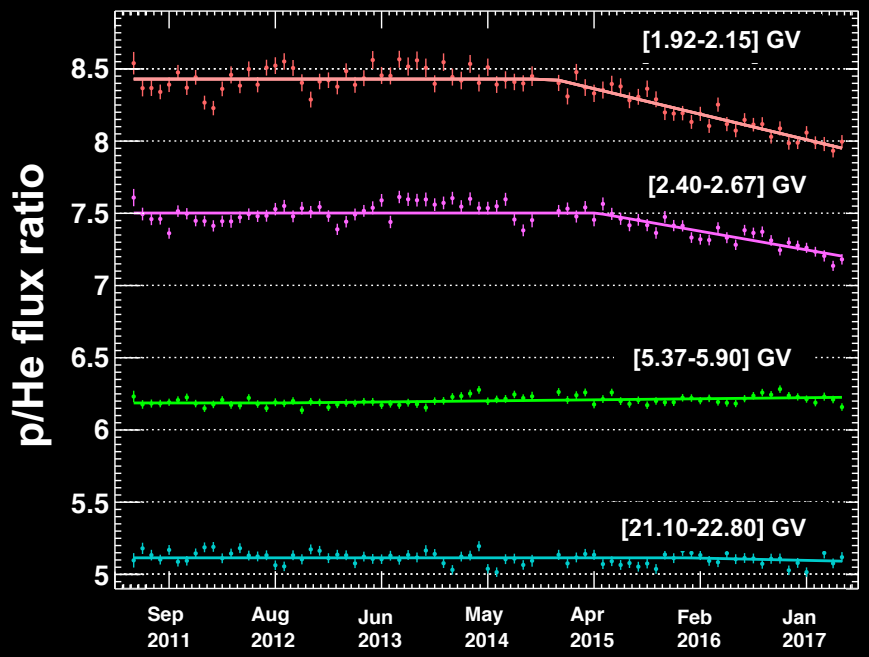


Pub. on PRL 121, 051102 (2018)

M.Duranti @ CRD2a

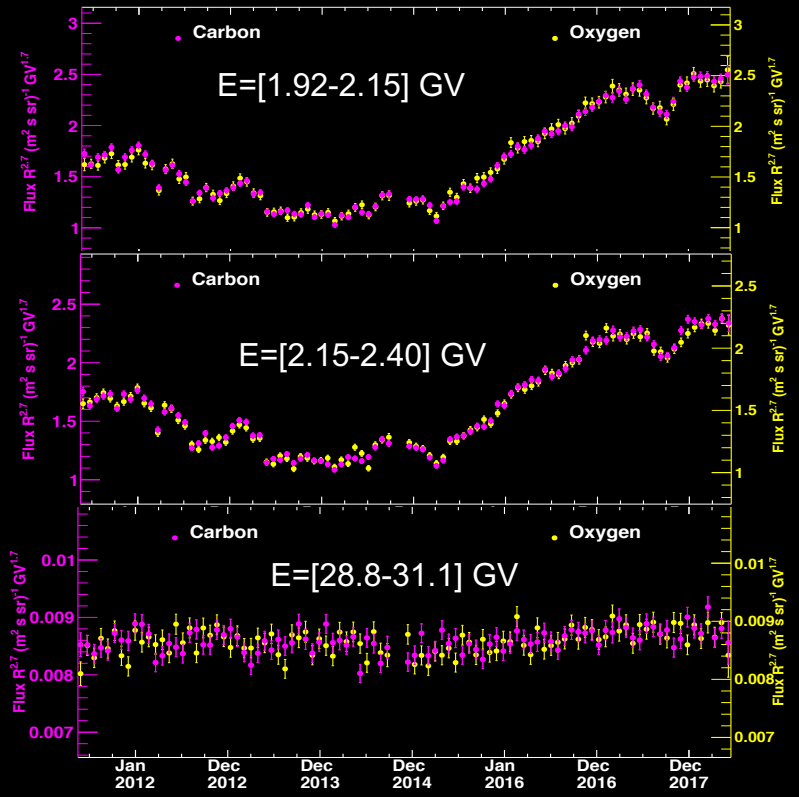
Time dependent structures in p/He

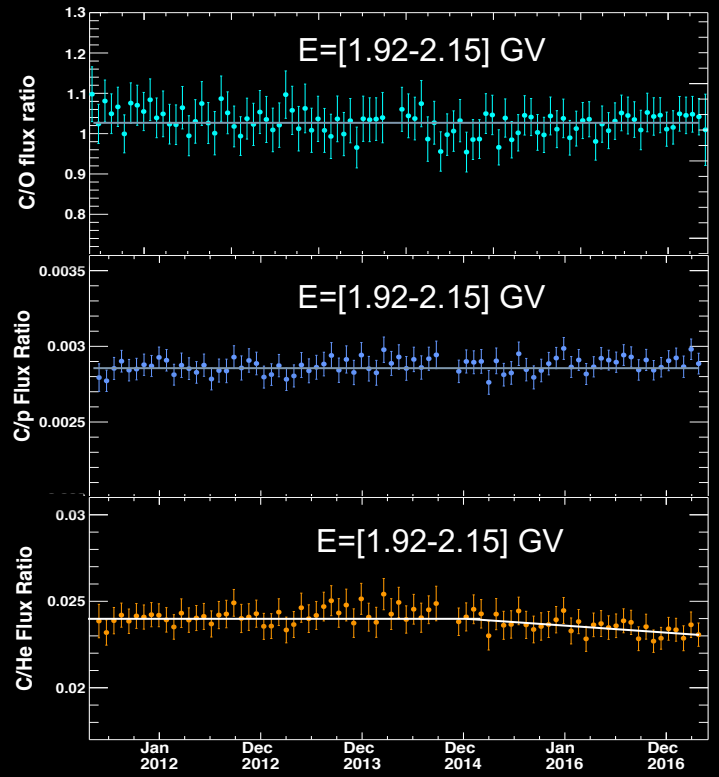




Pub. on PRL 121, 051101 (2018)

Time dependent structures in C, O

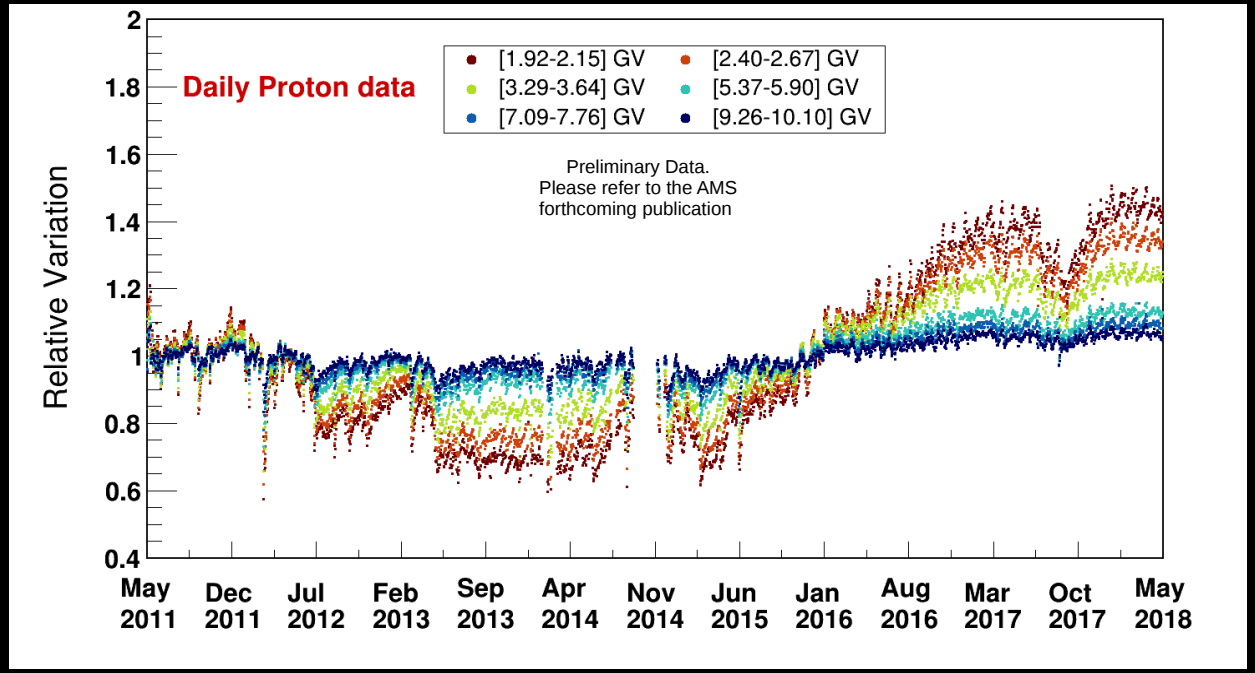




Preliminary

More details in the talk of F. Donnini on Jul. 30th, session CRD8A

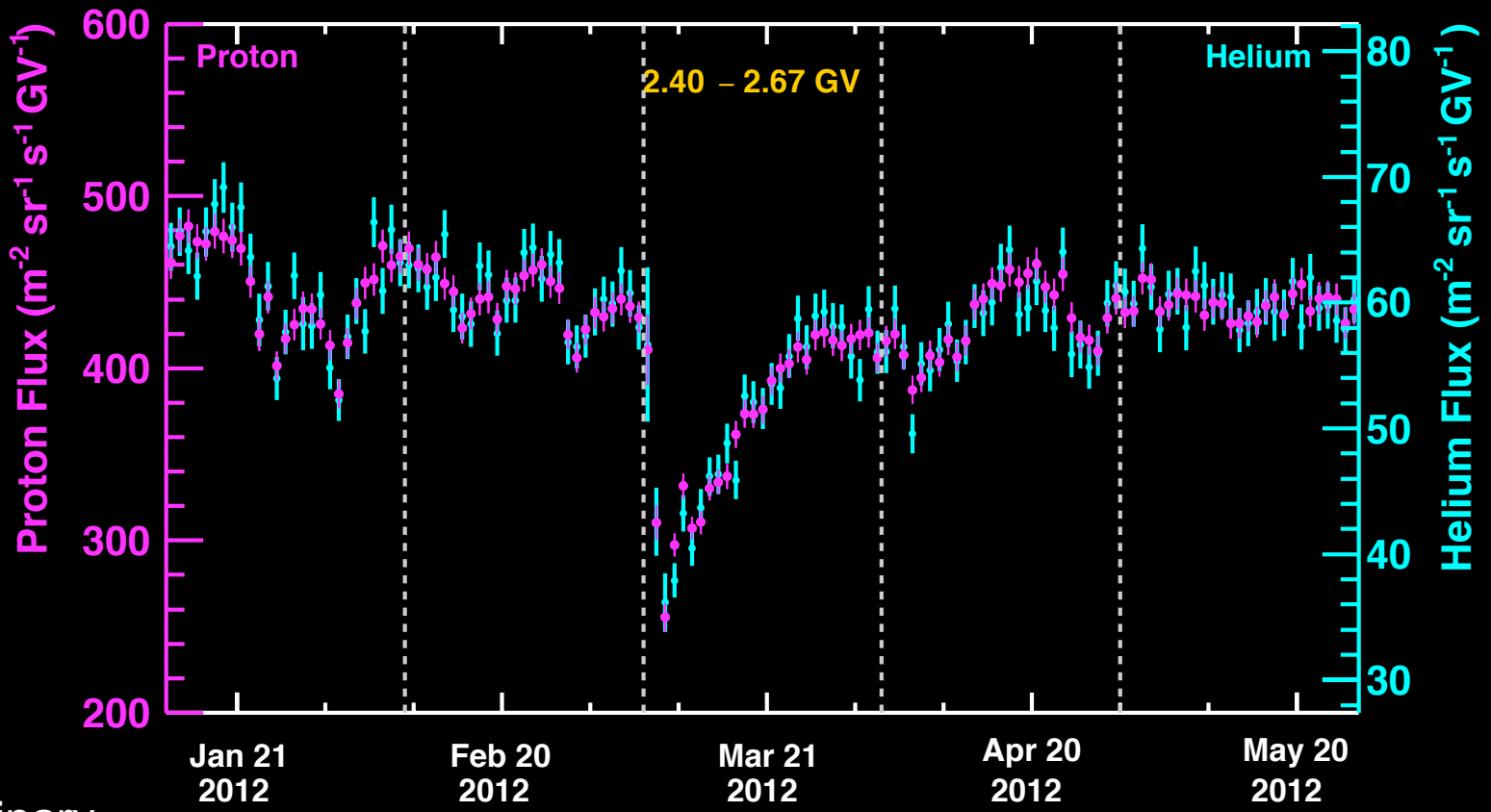
Daily relative variation of the proton flux at different energies May 2011- May 2018



Preliminary

More details in the talk of C. Consolandi on Jul.30th, session CRD8C

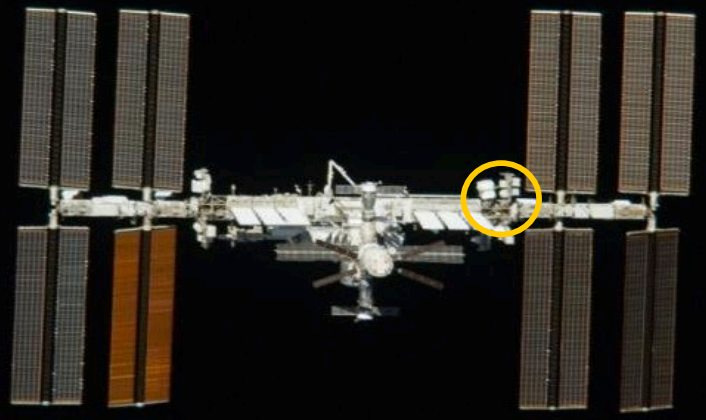
Daily variation of fluxes : e.g. Proton and Helium



Preliminary

Conclusions

- AMS is providing simultaneous measurements of different cosmic ray species with O(%) accuracy in an extended energy range
- new phenomena are being highlighted by these measurements whose nature will be further clarified as more data will be collected by the experiment.
- AMS will match the lifetime of the Space Station: stay tuned !



..more on AMS-02@ ICRC2019

36th International Cosmic Ray Conference - Madison, WI, USA
THE ASTROPARTICLE PHYSICS CONFERENCE

Jul 25-26

- CRD1a: Antiproton Flux and Properties of Elementary Particle Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the ISS *Z.Tang*
- CRD2a: Observation of Complex Time Structures in the Cosmic-Ray Electron and Positron Fluxes by the Alpha Magnetic Spectrometer on the ISS *M.Duranti*
- CRD2b: Towards Understanding the Origin of Cosmic-Ray Electrons *W.Xu*
- CRD2h: Towards Understanding the Origin of Cosmic-Ray Positrons *Z.Weng*
- CRD4a: Anisotropy of Elementary Particle Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the ISS, *I.Gebauer*

Jul 29

- SH5f: Solar Energetic Particles measured by the Alpha Magnetic Spectrometer on the International Space Station during solar cycle 24 *C.Light*
- CRD6b: Properties of Secondary Cosmic Rays Lithium, Beryllium and Boron Measured by the Alpha Magnetic Spectrometer on the International Space Station *A. Oliva*
- CRD6c: Cosmic-Ray Helium Isotopes with the Alpha Magnetic Spectrometer *C. Delgado*
- CRD6d: Cosmic-Ray Lithium Isotopes with the Alpha Magnetic Spectrometer *L. Derome*

Jul 30

- CRD7a: Properties of Primary Cosmic Rays Neon, Magnesium and Silicon Measured with the Alpha Magnetic Spectrometer on the ISS, *Q. Yan*
- CRD8a: Precision Measurement of the Monthly Carbon and Oxygen Fluxes in Cosmic Rays with the Alpha Magnetic Spectrometer on the International Space Station, *F. Donnini*
- CRD8b: Properties of Primary Protons, Helium, Carbon and Oxygen Nuclei Measured with the Alpha Magnetic Spectrometer on the ISS *Q.Yan*
- CRD8c: Precision Measurement of the Daily Proton and Helium Fluxes in Cosmic Rays with the Alpha Magnetic Spectrometer on the International Space Station *C. Consolandi*
- CRD8d: Precision Measurement of the Monthly Proton and Helium Fluxes in Cosmic Rays with the Alpha Magnetic Spectrometer on the International Space Station, *N. Tomassetti*

Thanks

The AMS-02 Collaboration