Latest Results from the AMS-02 experiment

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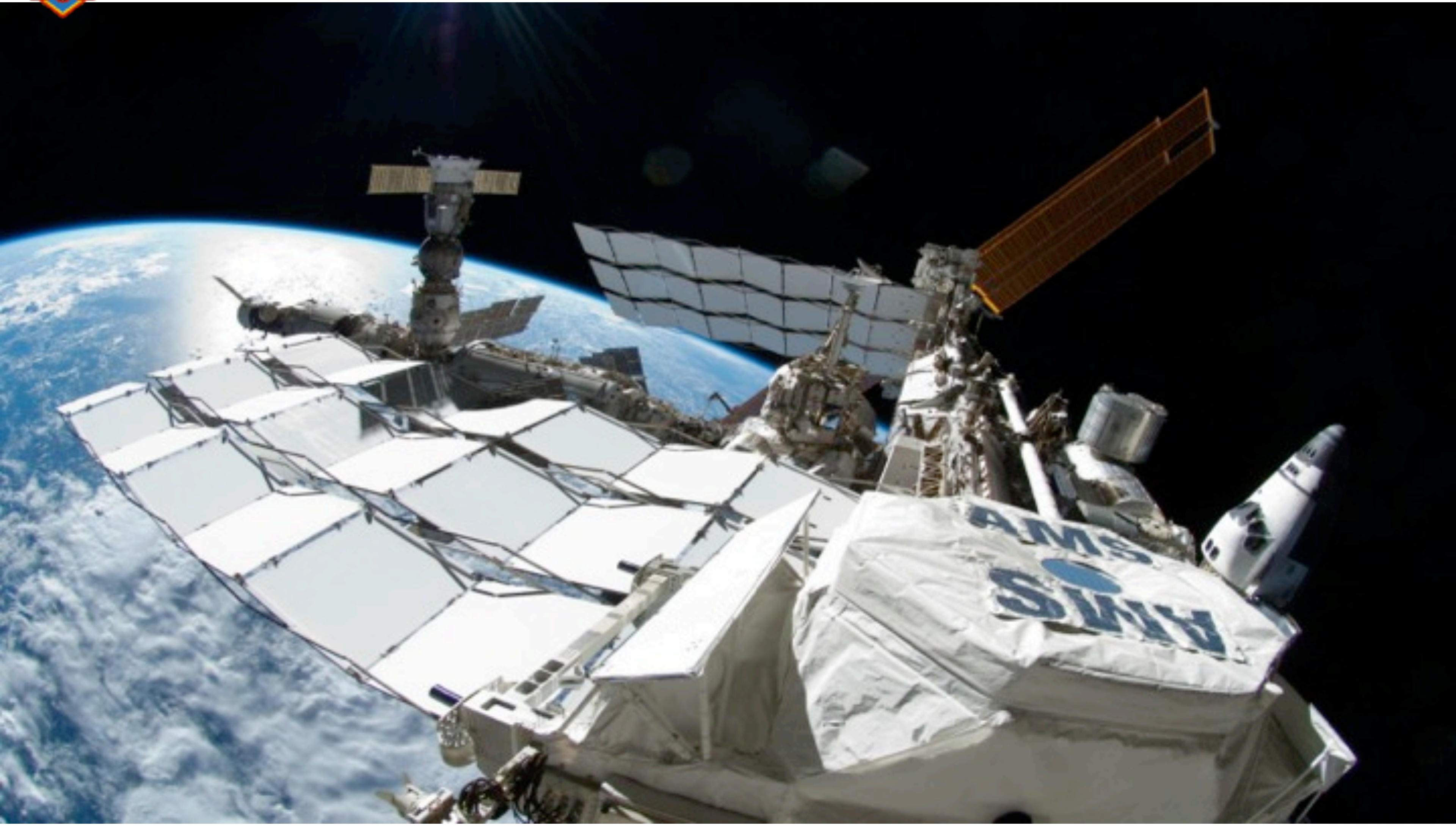
Symposium on Cosmology and Particle Astrophysics
CosPA 2013 - Honolulu, Hawaii

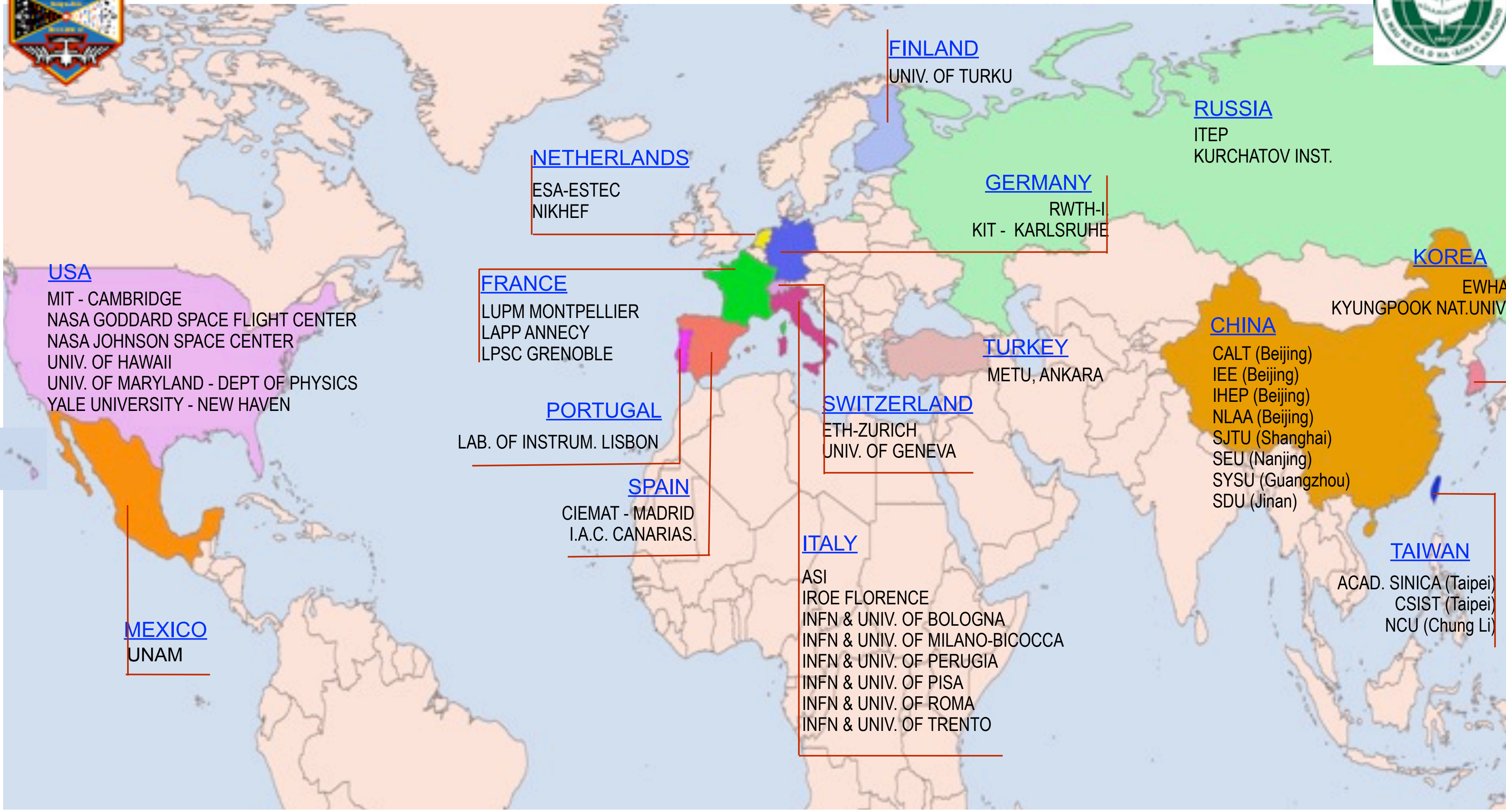
AMS is a US DOE lead International Collaboration

Spokesperson: Nobel laureate Prof. Dr. S. Ting from MIT



AMS-02 experiment has been installed
on the International Space Station on May 19th 2011

AMS collaboration



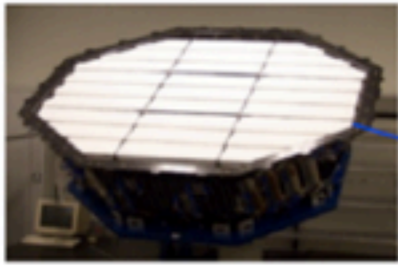
Leading International collaboration for 20 years:
15 countries, 44 institutes and 600 Physicists

95% of the ~ $2.0B to build AMS has come from international partners, 5% from US.

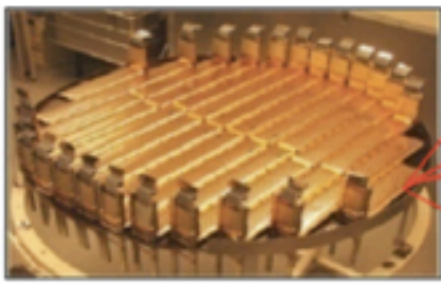
Interactions with NASA, CERN, DOE for all the logistic support

The AMS-02 detector

TRD
Identify e+, e-

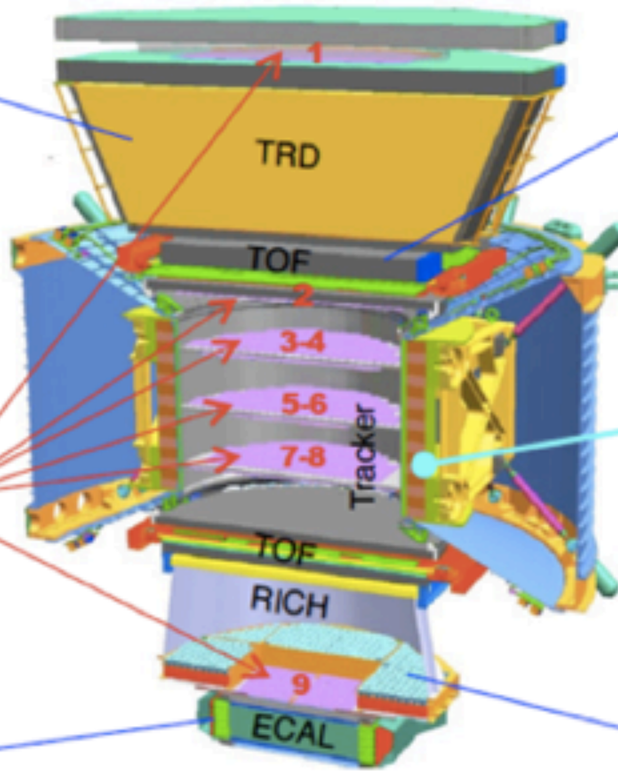


Silicon Tracker
Z, P



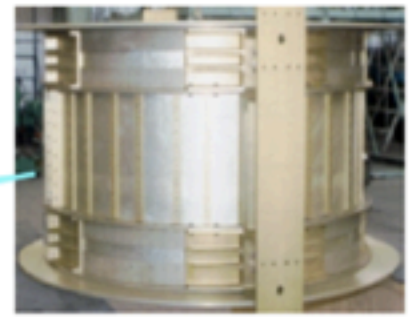
ECAL
E of e+, e-, γ

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

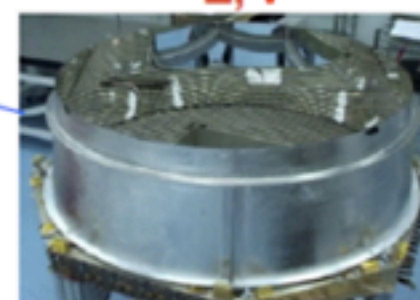


TOF
Z, V

Magnet
±Z



RICH
Z, V



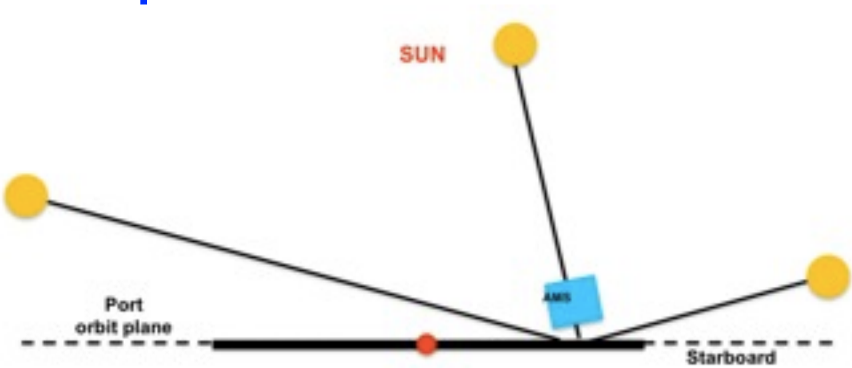
Scientific goals of AMS

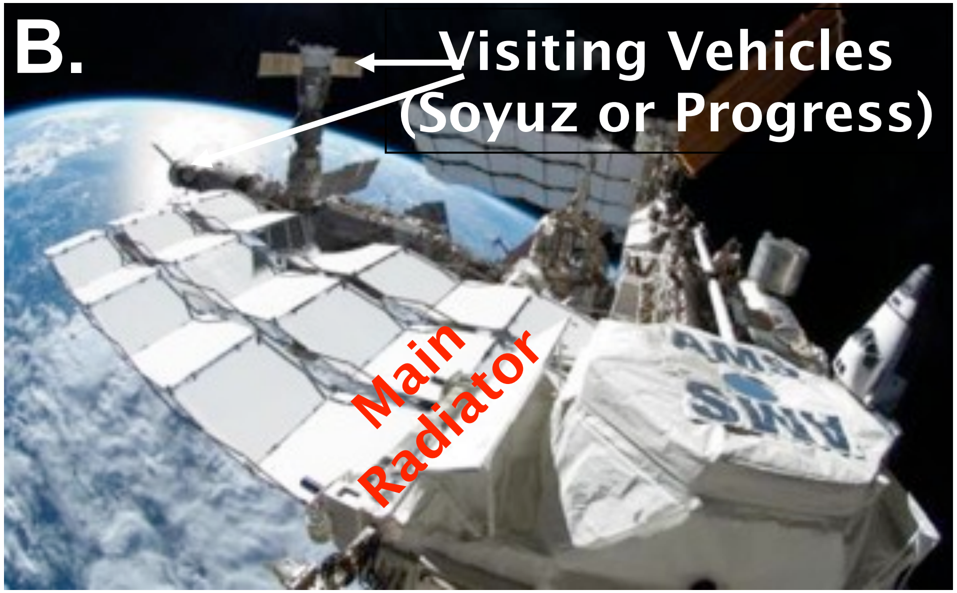
- **Measuring CR spectra up to the iron in GeV to TeV**: propagation models;
- **Indirect search of Dark Matter**: e^+, antiprotons, antideuteron, γ
- **Direct search of primordial antimatter**: Anti He, Anti C ...
- **New forms of matter**: strangelets
- **Identification of local sources of high energy photons**: SNR, Pulsars, ...
- **Solar activity and modulation**: CR spectra over 11 year solar cycle and SEPs

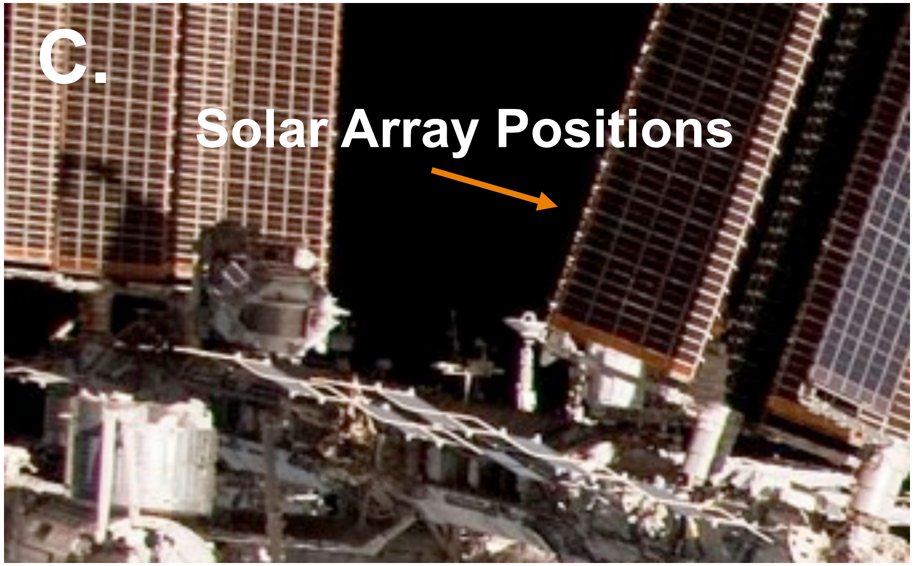
Challenges

The thermal environment on ISS is constantly changing:

A. The position of the Sun with respect to AMS







i) AMS experiences large temperature variations (tens of degrees)
ii) AMS has no control of the Space Station orientation

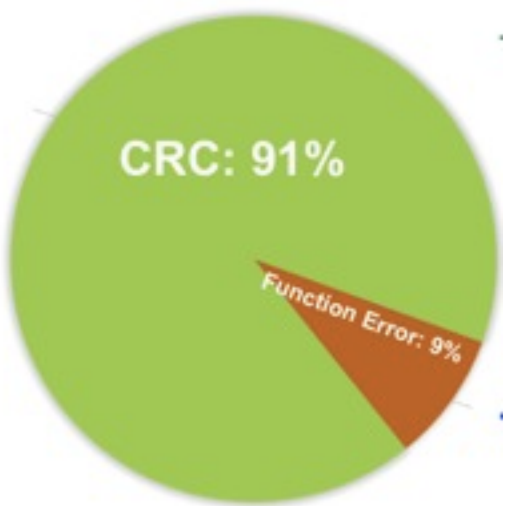
Constant monitoring of the temperature sensors, improving of the thermal models and developing of safety procedures

Challenges

A passing heavy nuclei can induce errors or damages in the electronic components

Radiation: Total dose (1 KRad/year)
Reliability: operational for 20 years.

1083 errors found in the first 26 months



Bit flip found in program memory by Cyclic Redundancy Check (CRC) which was designed according to the beam test result for the DSP chip.
This type of error is checked 4 times per orbit and can be fixed automatically by the on-board main computers.

Bit flip in DSP memories which cause functional errors.

This type of error has a different behavior each time and requires expert intervention.

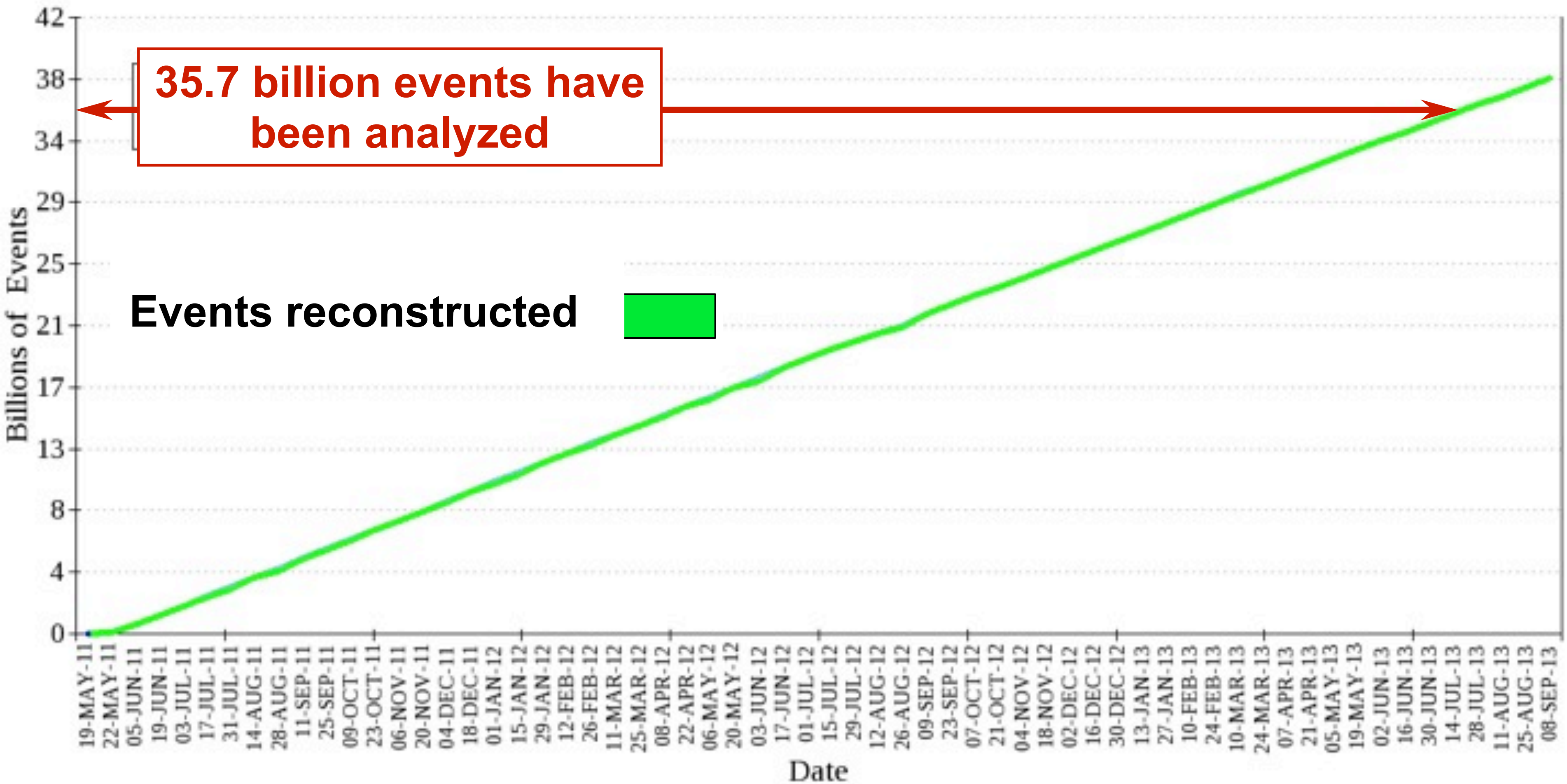
Restore nominal condition
Redundancy on the Electronics

Flight and Ground Operations

Data Reconstruction

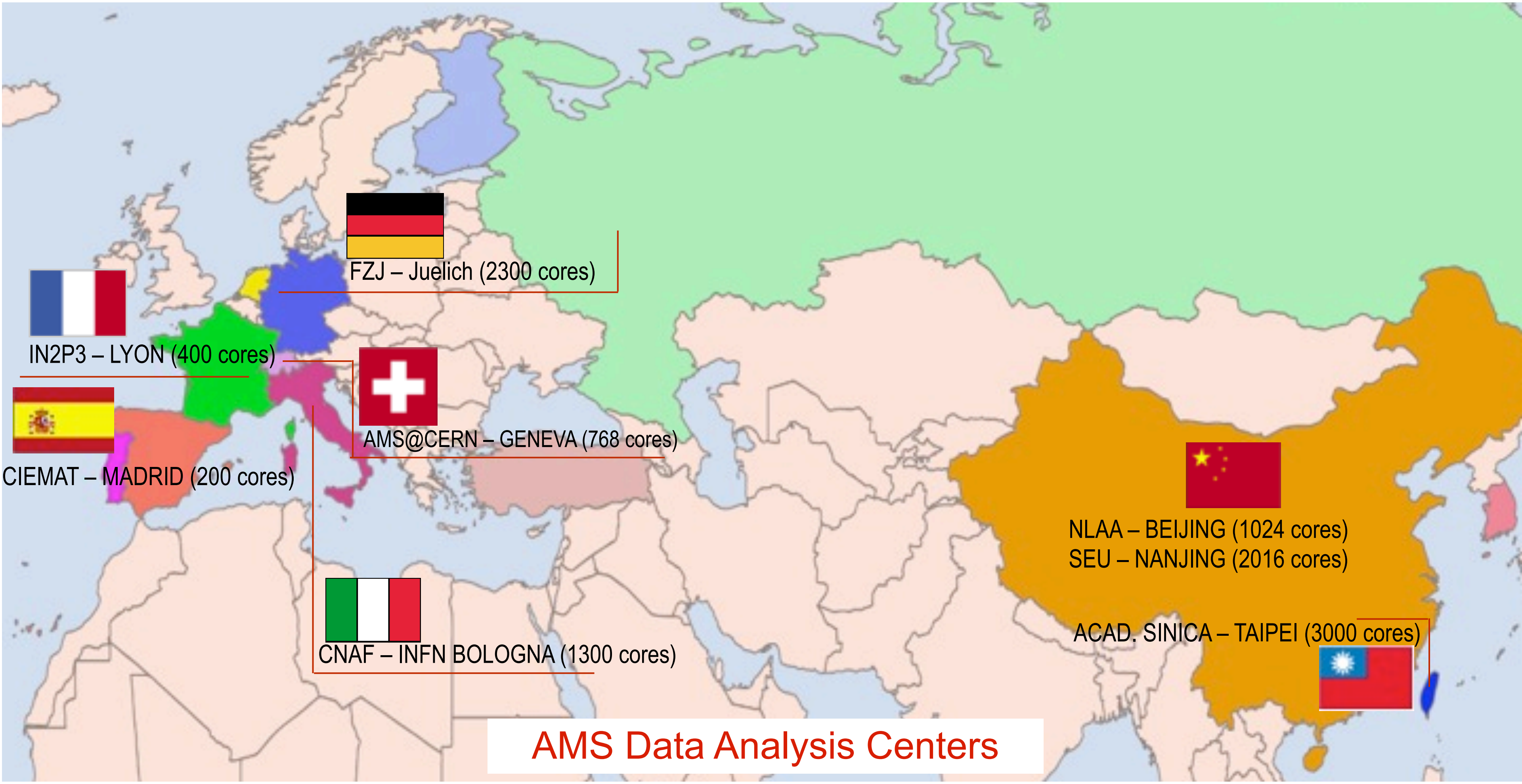
28 months of AMS operations 36 billion events

18 billion events/year



AMS Analysis

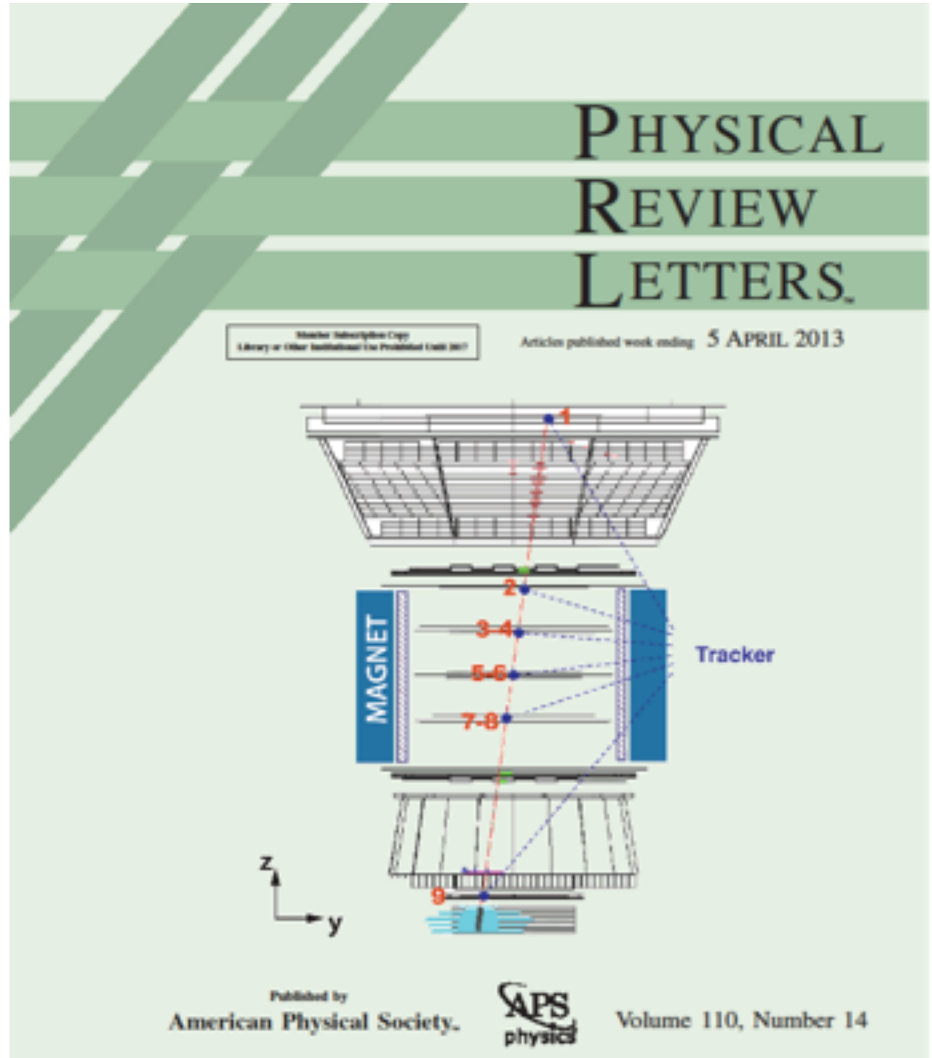
Conducted at the Science Operations Center (SOC) at CERN and in the regional centers around the world.



Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5-350 GeV

Aguilar,M. et al (AMS Collaboration) Phys. Rev. Lett. 110, 1411xx (2013)]

In the first 18 months in space, AMS has collected over 25 billion events. 6.8 million are electrons or positrons.



Positron identification and Proton rejection

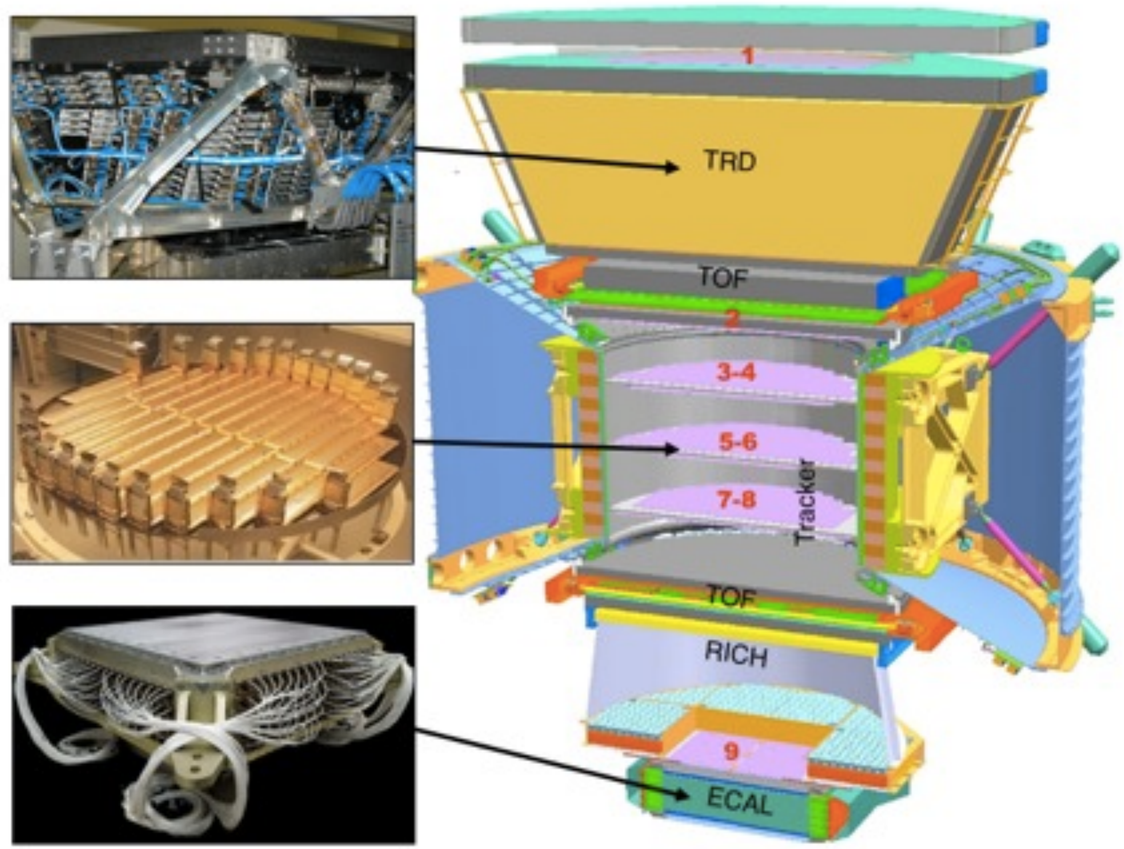
e^+ low signal and high P background: P ~ $(10^3 \div 10^4)$ e^+

P rejection factor: $10^5 \div 10^6$ to identify e^+ with an error at % level

TRD
Distinguishes between e+ and P

SILICON TRACKER + MAGNET
measure sign and momentum

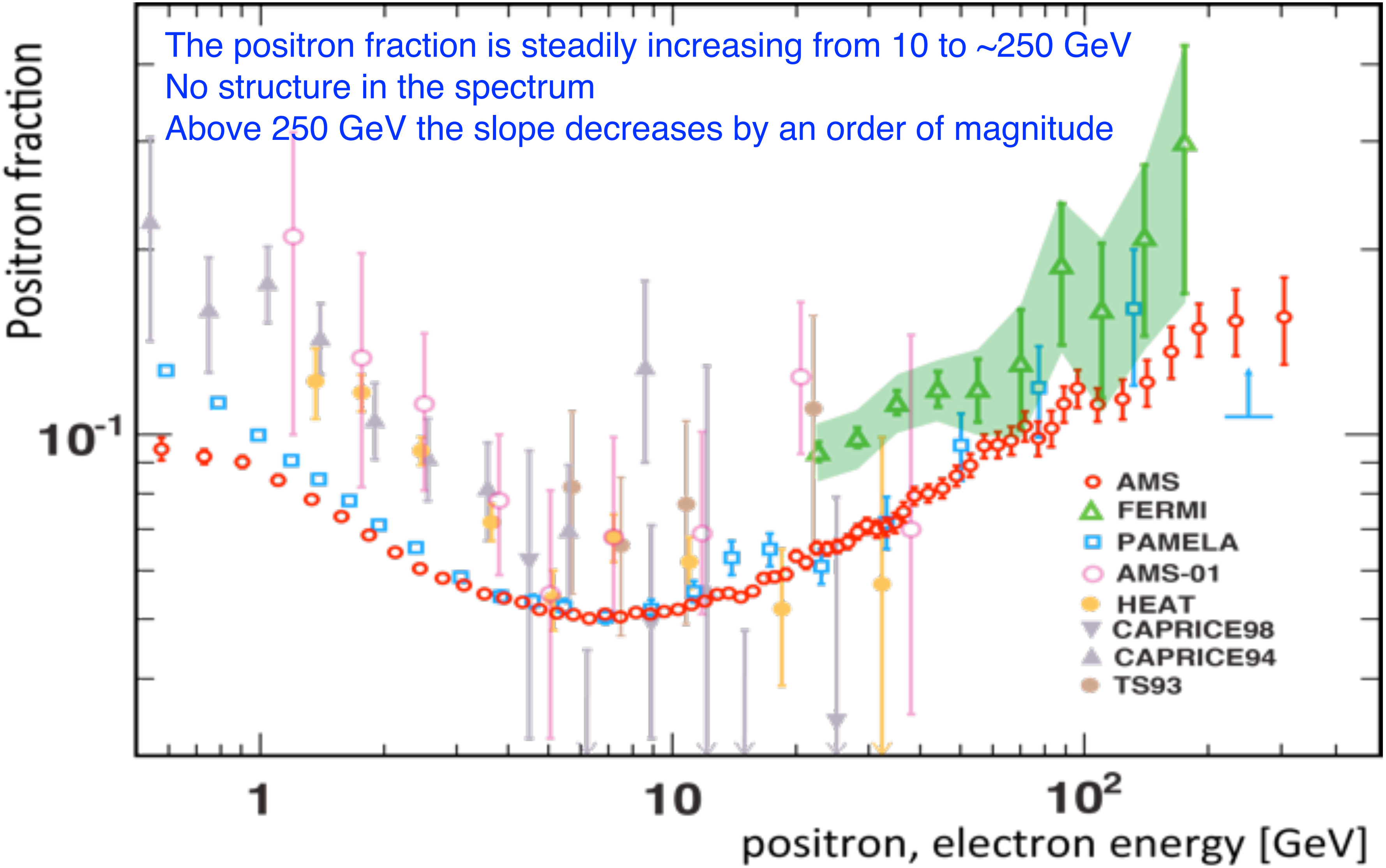
Electromagnetic CALorimeter
measures energy,
Identifies 3D positron shower and
rejects hadronic showers



Total rejection of proton 10^6

Verified in test beam at CERN

Positron Fraction



On the origin of the Positron excess

It could be New Physics:
Dark Matter Annihilation!

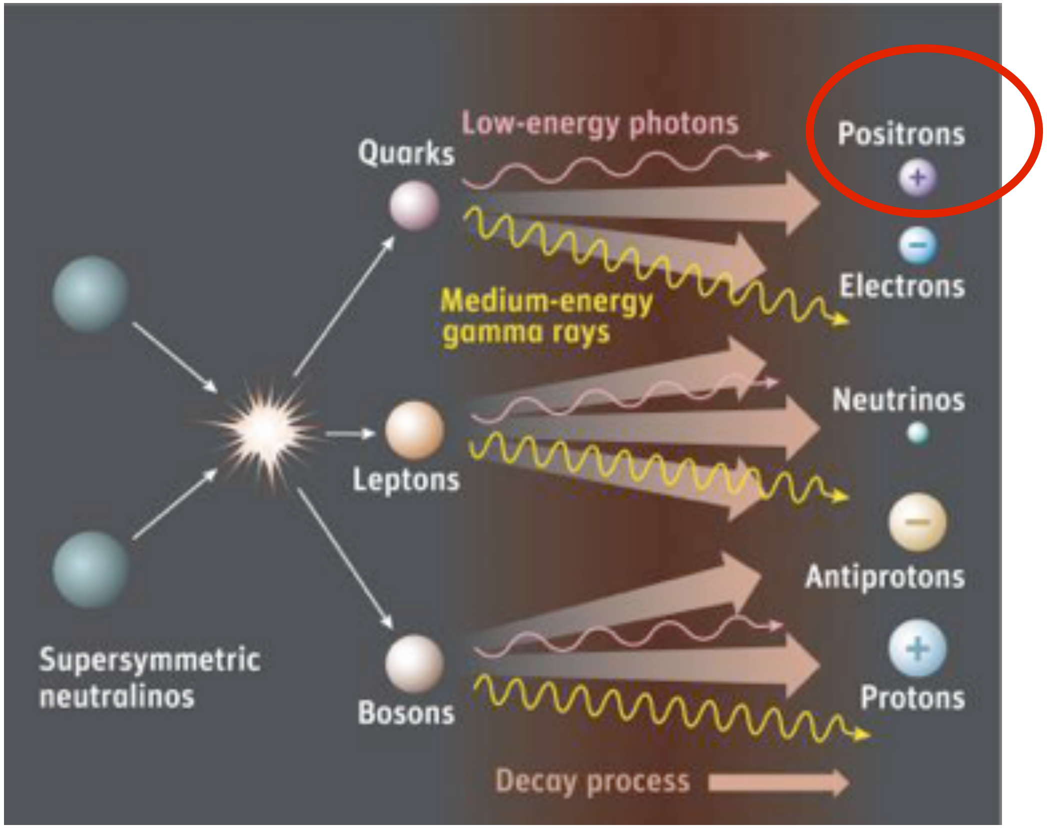


Image Credit: NASA/GLAST collaboration

On the origin of the Positron excess

~ 900/1000 papers advocate Dark Matter
…despite some significant issues:

(i) Need very large annihilation rates

$(\langle\sigma v\rangle \sim 10^2\text{-}10^3 \times 10^{-26}\,\mathrm{cm}^3/\mathrm{s})$

(ii) Need rather large masses (~TeV)

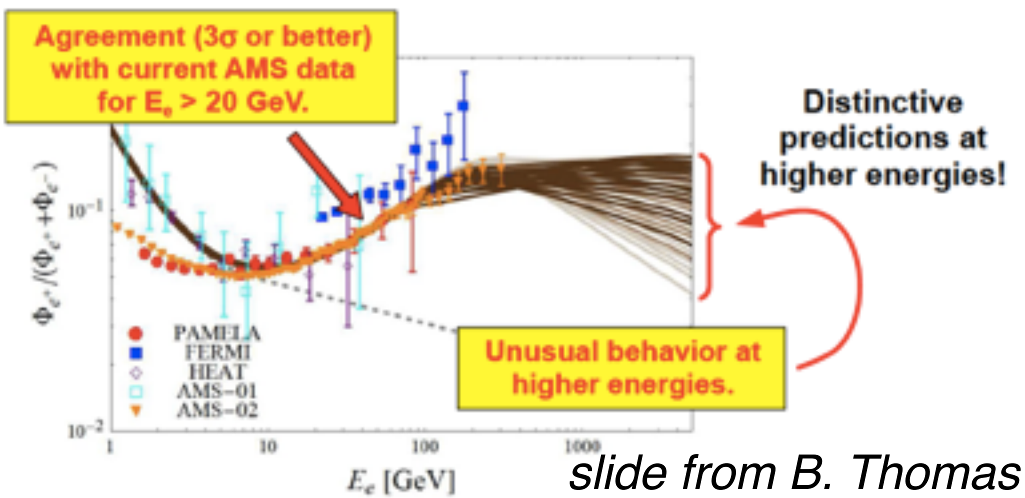
(iii) Need special annihilation or decay modes
(suppress antiprotons)

slide from S. Profumo

The Positron excess could be explained by DM

as example:

Positron Fractions from DDM Ensembles



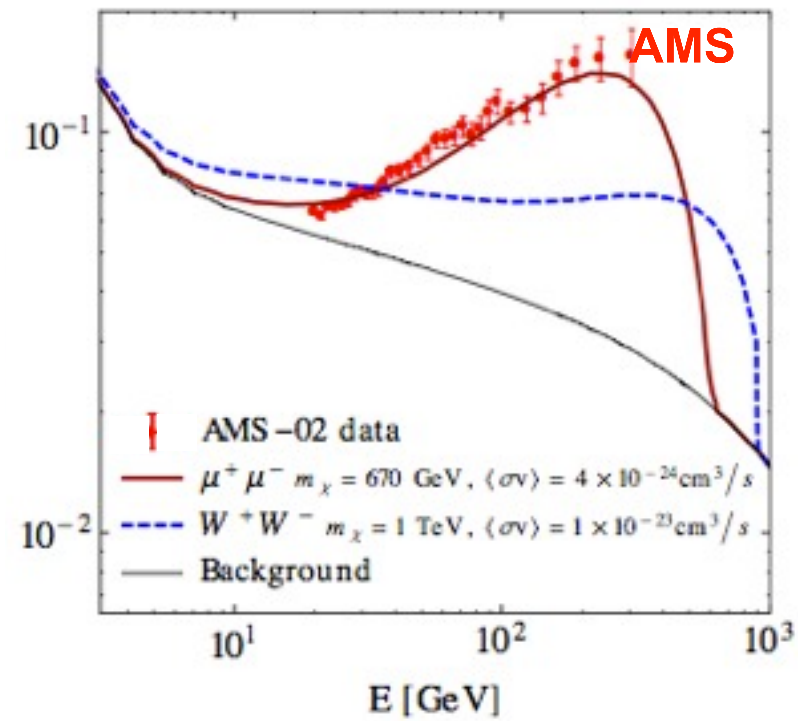
slide from B. Thomas

The positron-fraction curves associated with DDM models in the continuum regime yield a concrete prediction for the positron fraction at $E_{e^\pm} < 350$ GeV :

In stark contrast to the pronounced downturn anticipated for typical dark-matter models, DDM models in this regime predict a plateau or a gradual decline in the positron fraction at high energies.

K. R. Dienes, J. Kumar, B.Thomas [arXiv:1306.2959]

Kopp hep-ph/1304.1184



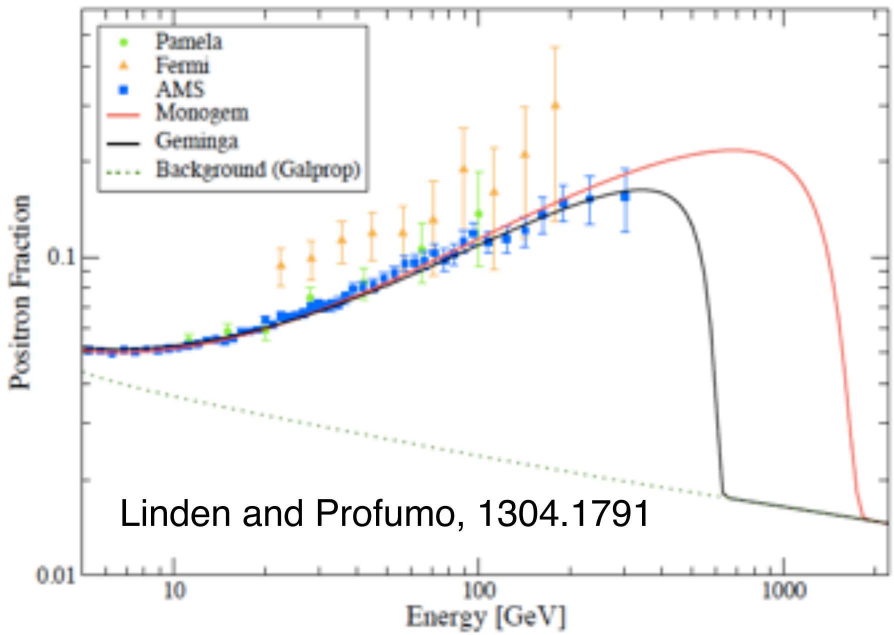
The Positron excess could be explained by DM

It could be New Physics:

Dark Matter Annihilation!

... or not!

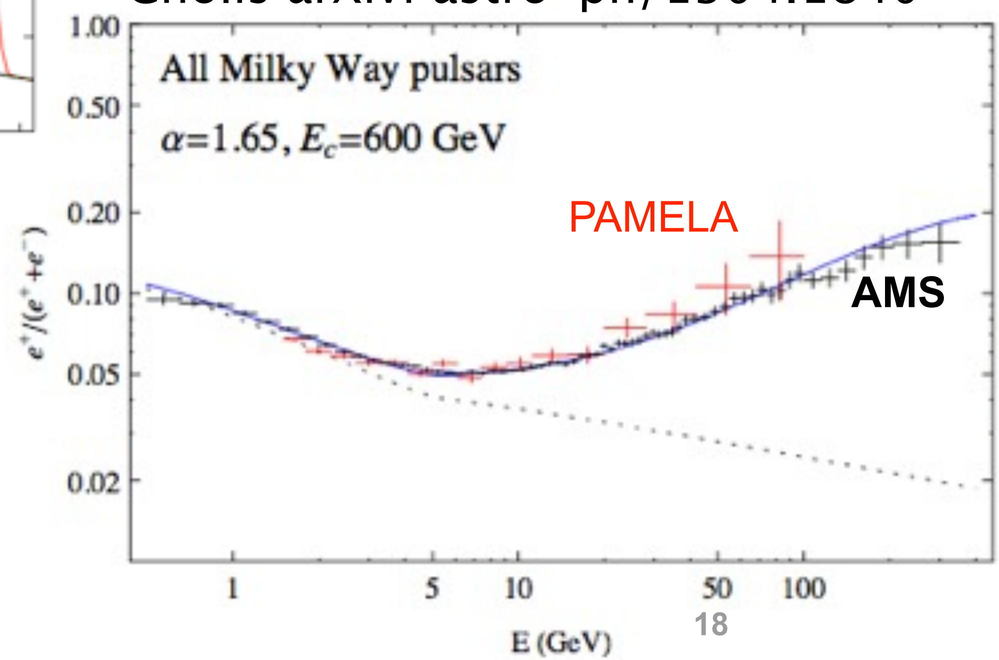
The Positron excess could be explained by an astrophysical source



Distance and Age from observation (set the cutoff)

Injection Spectrum: ~ E^{-2} (Fermi 1st order)

Cholis arXiv: astro-ph/1304.1840



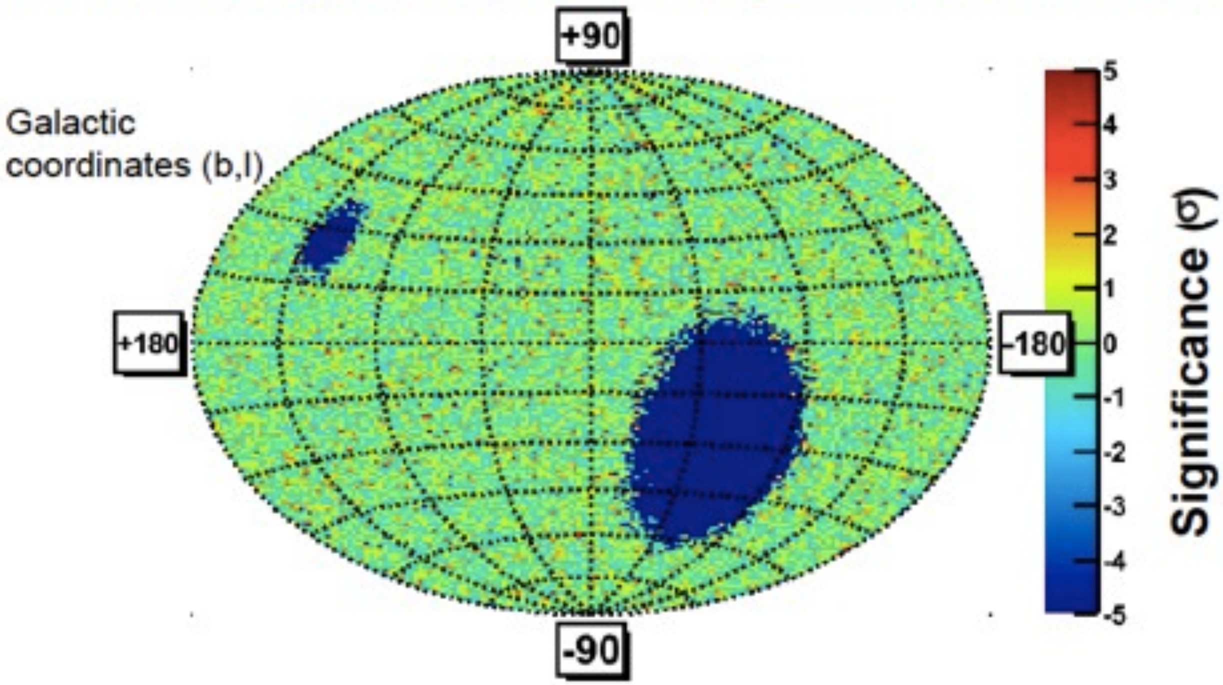
Can we discriminate between dark matter and pulsars?

On the origin of the Positron excess

Nearby **Pulsar** → Anisotropy in the arrival direction *(sufficient, not necessary)*

Dark Matter → Diffuse secondary component

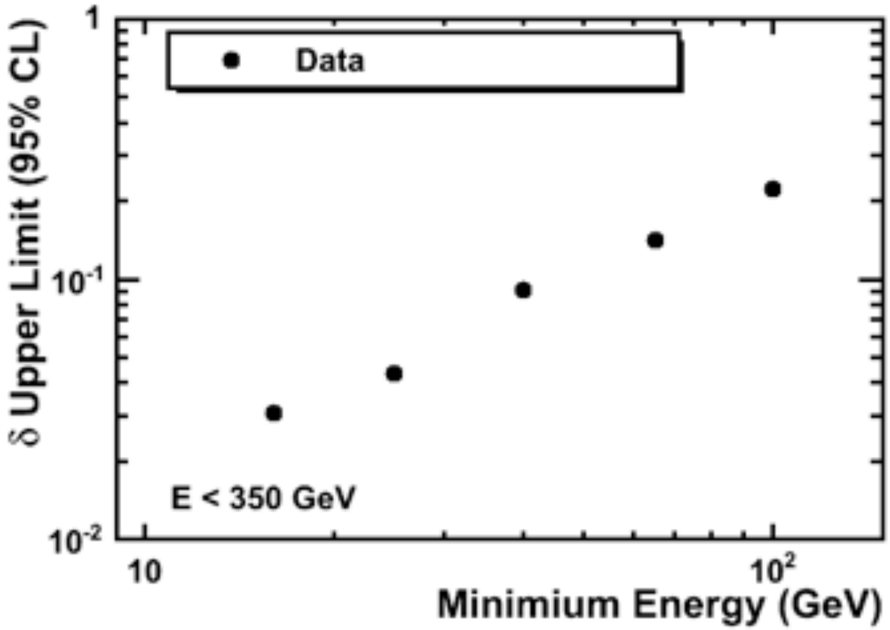
New results from the first 2 years of AMS: On the origin of excess of positrons

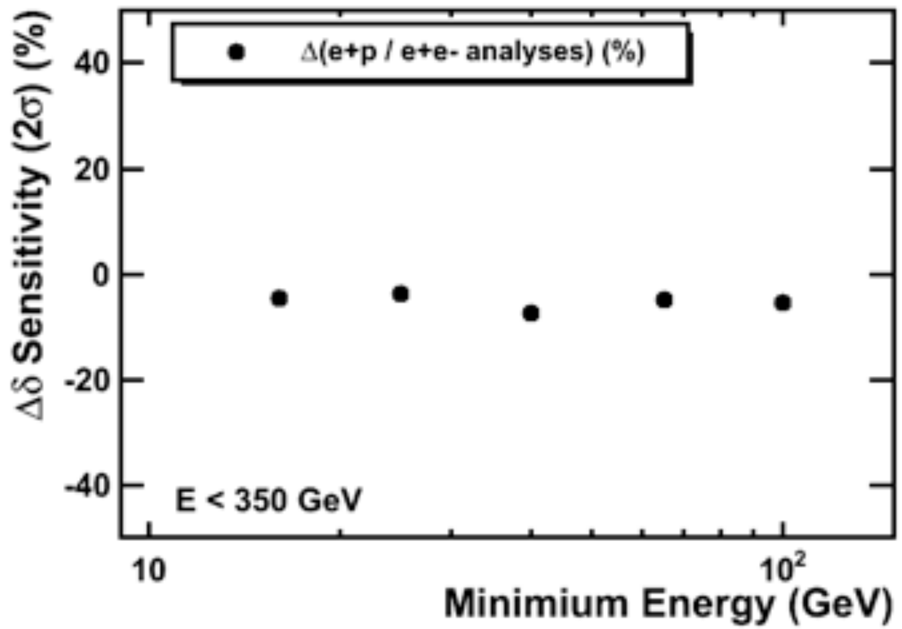


The fluctuations of the positron ratio e^+/e^- are isotropic

The relative fluctuations of the positron ratio across the observed sky map show no evident pattern.

New results from the first 2 years of AMS: AMS upper limits on dipole anisotropy





Limits on the amplitude of a dipole anisotropy in any axis in galactic coordinates on the positron to electron ratio in the energy range from 16 GeV to 350 GeV

The sensitivity to a dipole anisotropy using the positron to proton ratio is consistent with the one obtained on the positron to electron analysis

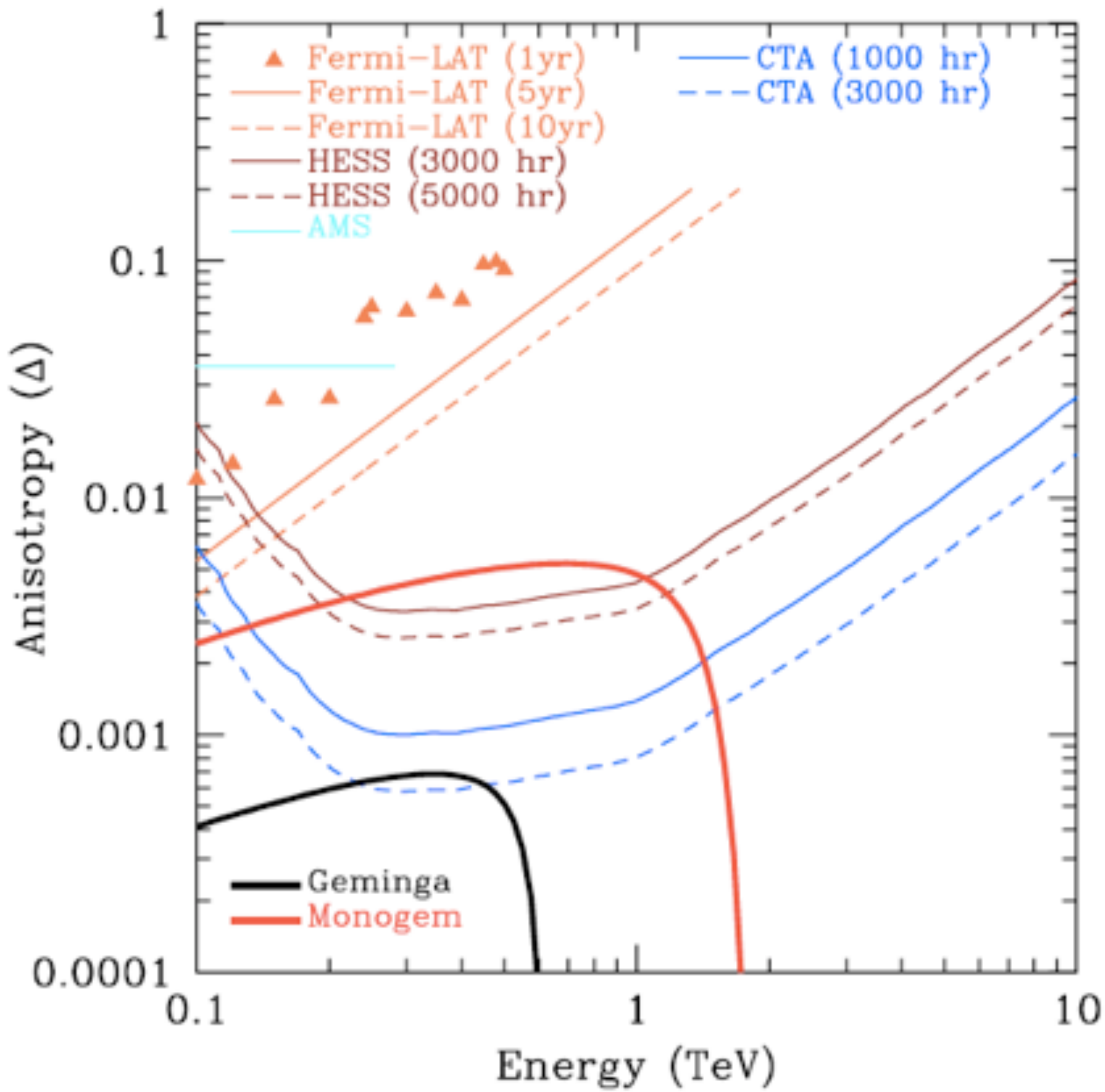
δ <0.030 for 16<E<350GeV

On the origin of the Positron excess

Nearby **Pulsar** → **Anisotropy in the arrival direction** *(sufficient, not necessary)*

Can be ruled out the pulsars scenario?

Pulsar interpretation consistent with all data



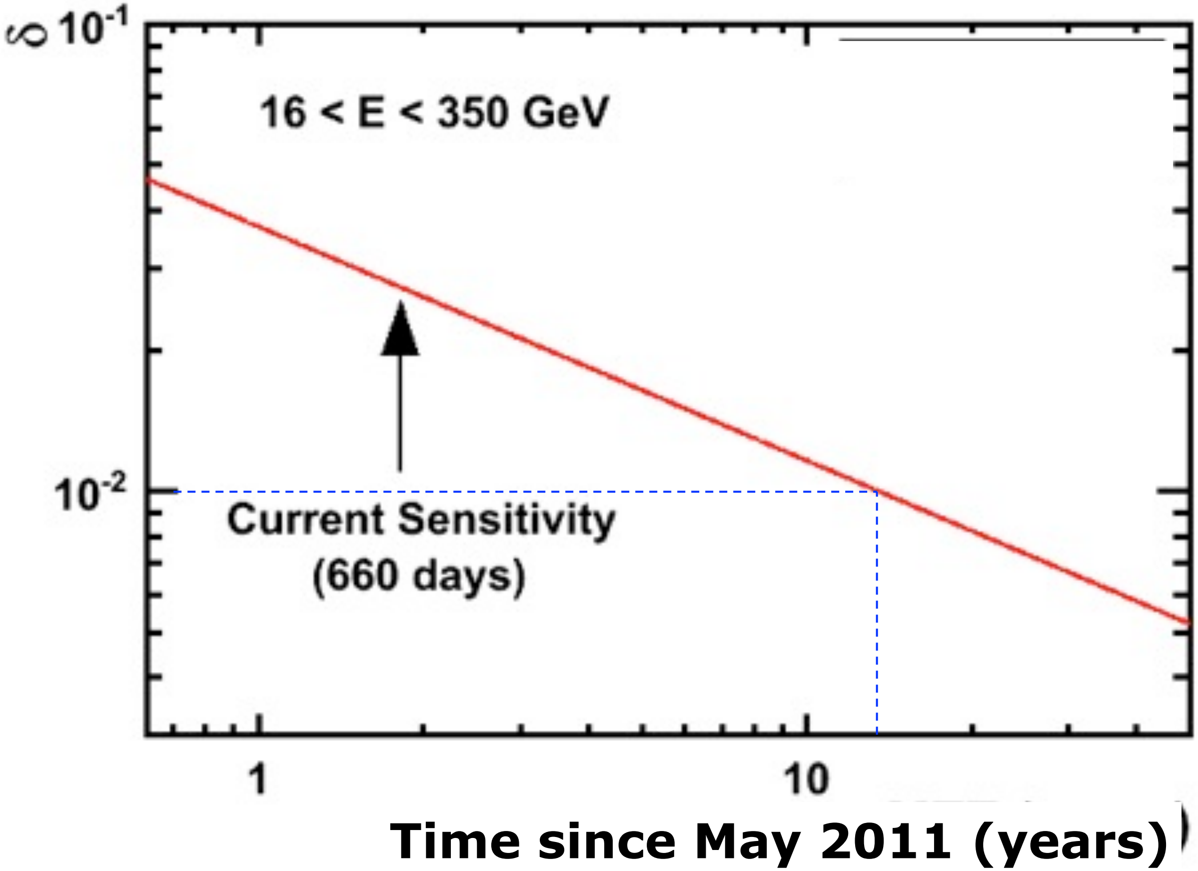
Linden and Profumo, Astroph. J (2013) 1304.1791

Anisotropy on e^+/e^-: Projected sensitivity

In 10 more years, AMS will reach a sensitivity of

δ = 0.010 at 95% C.L.

for a dipole anisotropy in the positron to electron ratio

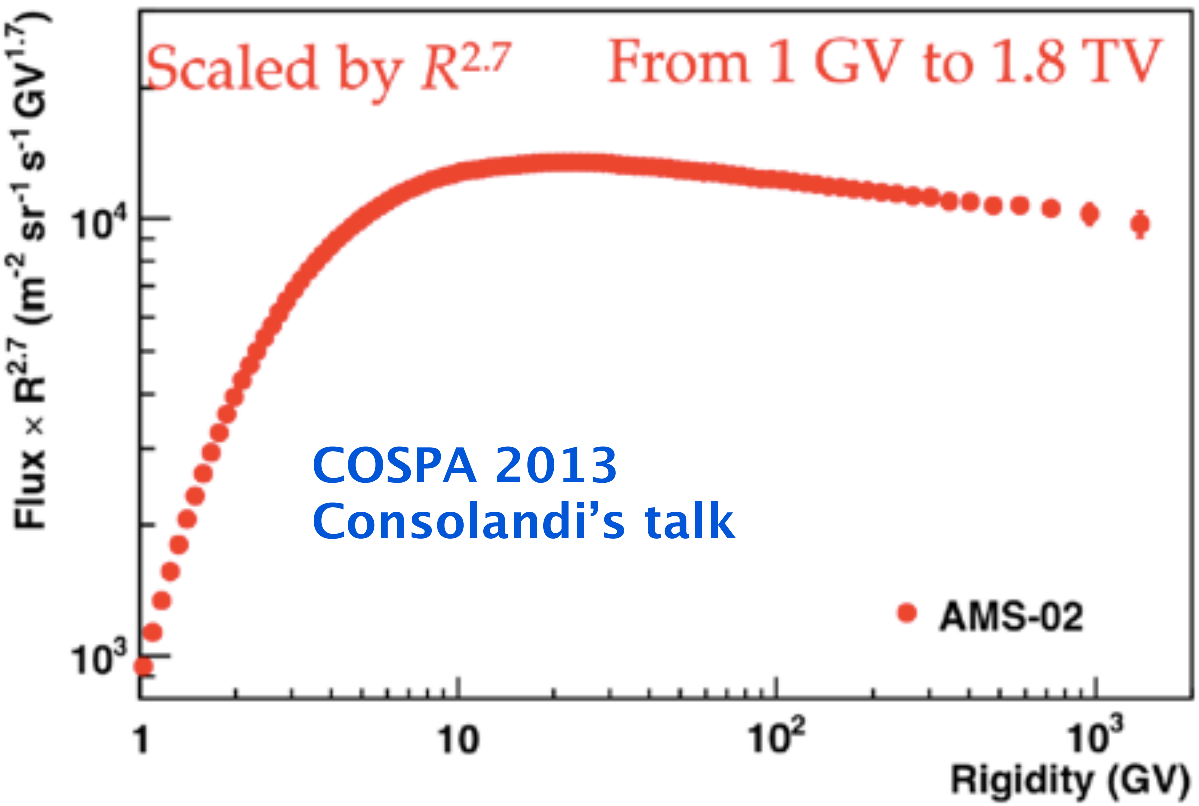


New results from the first 2 years of AMS

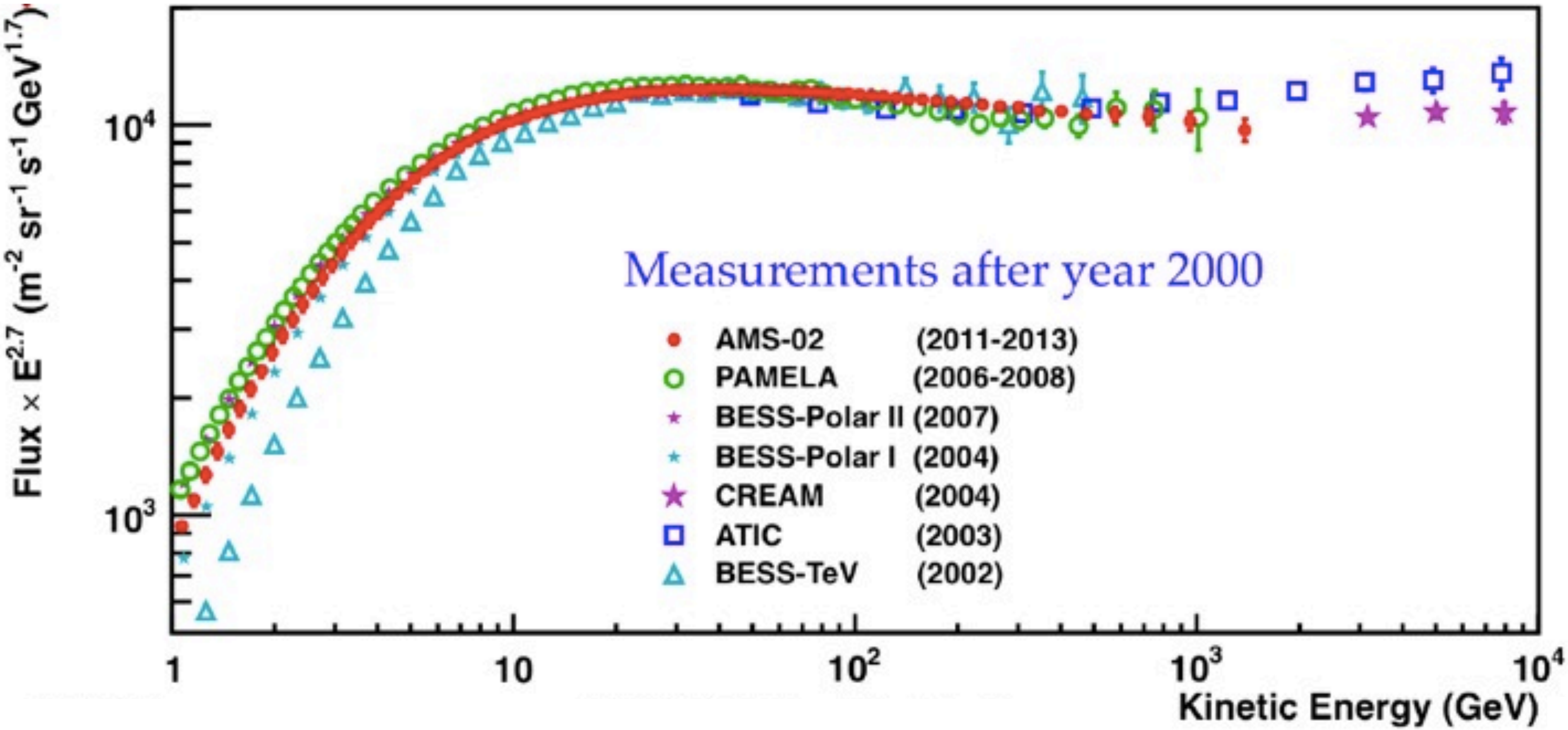
- e^+, e^- fluxes
- p, He fluxes
- B/C ratio

New results from the first 2 years of AMS: Proton flux (May 2011 / May 2013)

- The proton flux (multiplied by $R^{2.7}$) measured from 1 GV to 1.8 TV
- In the low rigidity region (R < 20 GV) the flux is determined every day with < ~ 1% stat. errors
- In the high rigidity region (R >100 GV) the spectrum is consistent with a single power law, no fine structures nor break were found on the spectrum

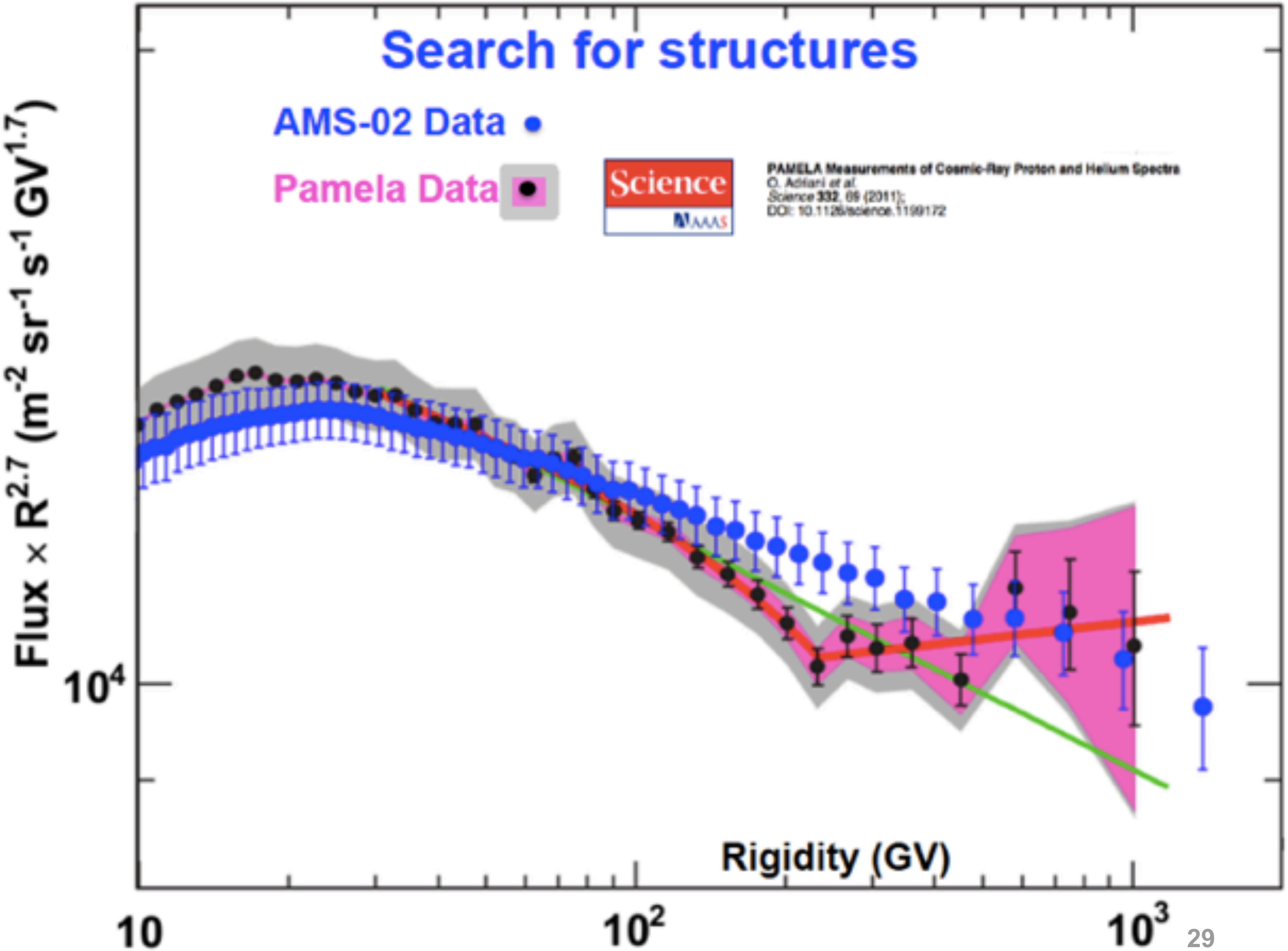


Proton flux:
Comparison with past measurements



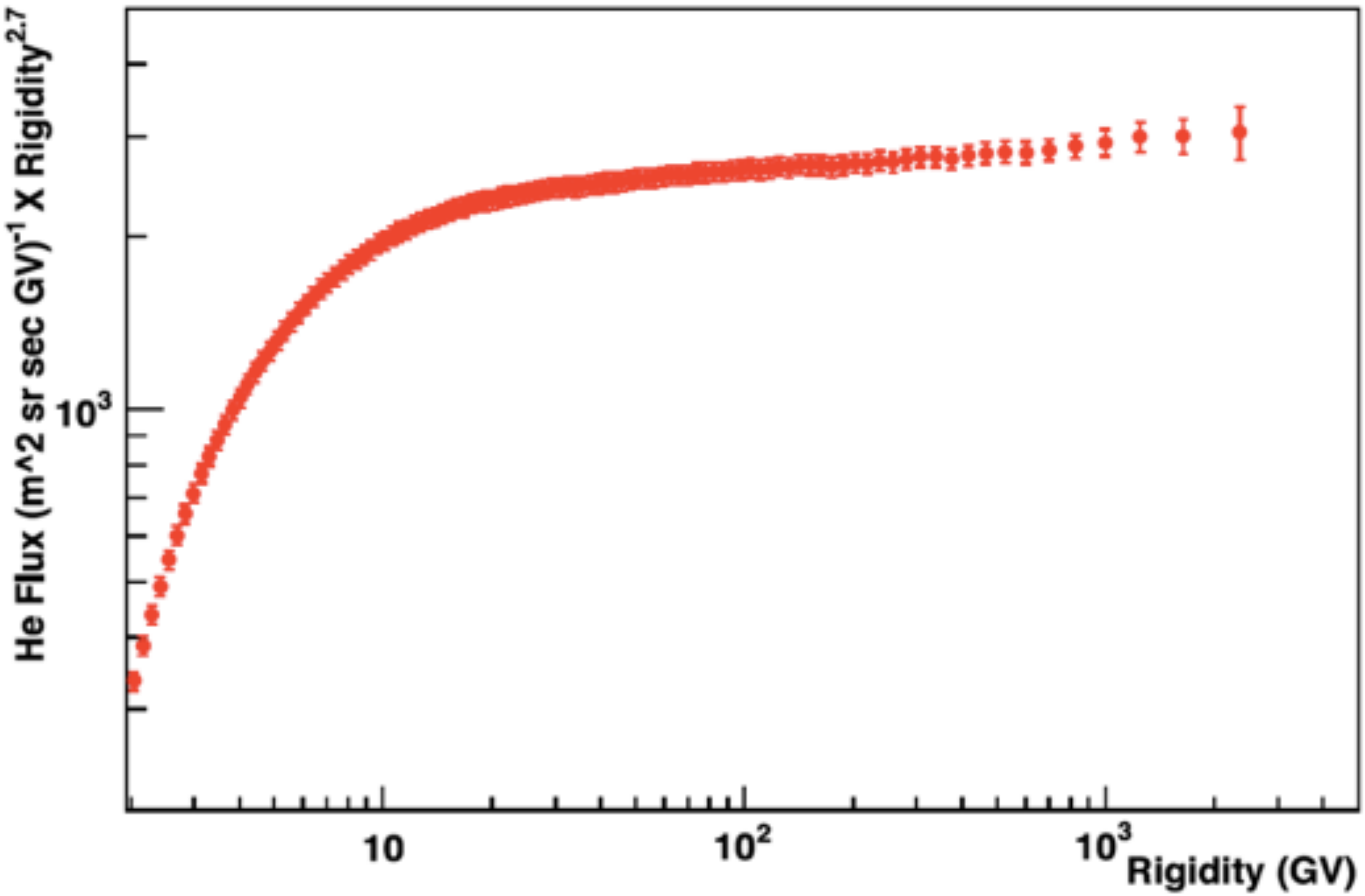
Comparison with latest measurements

Proton flux:
Comparison with Pamela

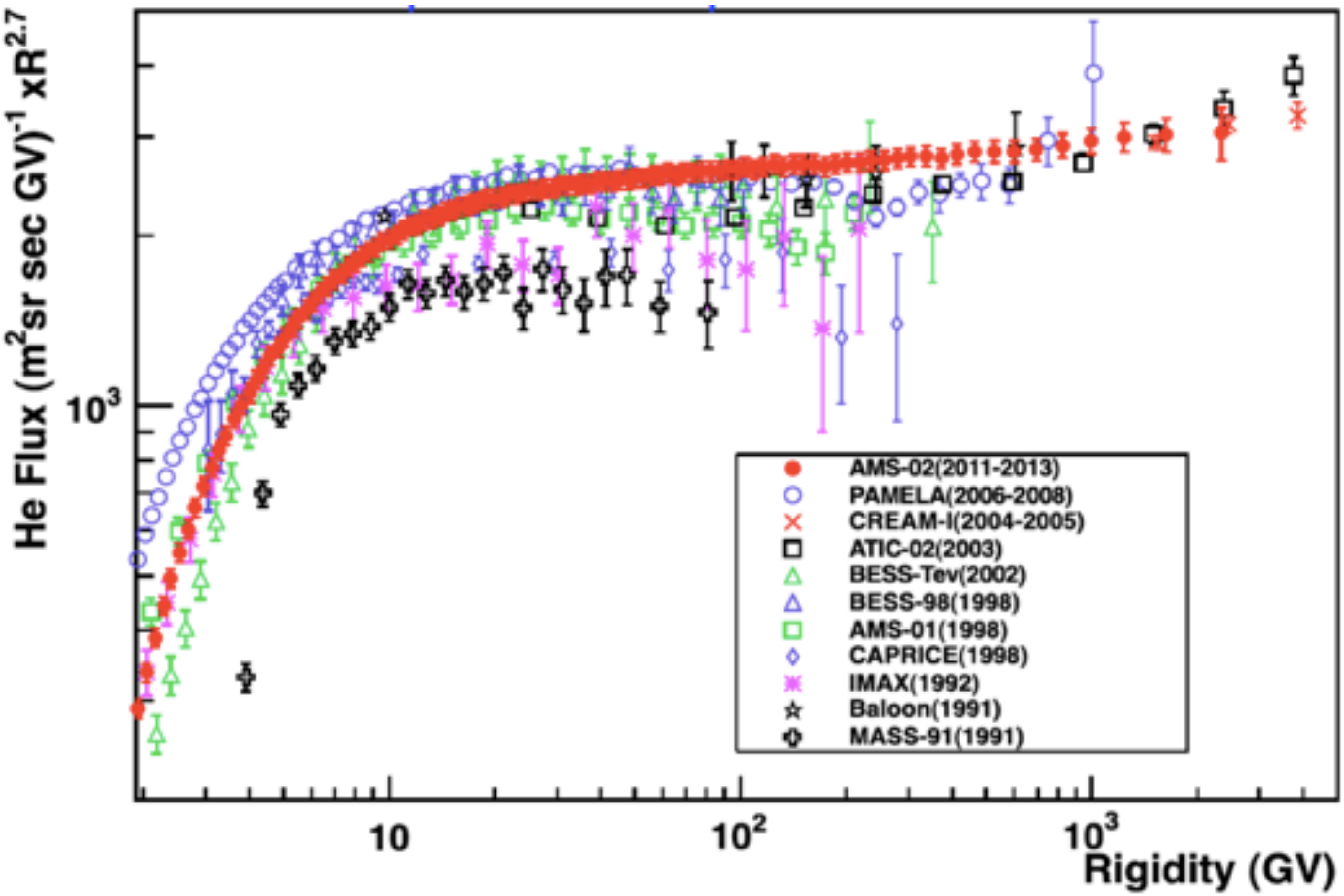


New results from the first 2 years of AMS: Helium flux (May 2011 / May 2013)

- The helium flux (multiplied by $R^{2.7}$) measured from 2 GV to 3.2 TV
- Above 10 GV the spectrum can be parametrized by a single power law
- No fine structures were found on the spectrum

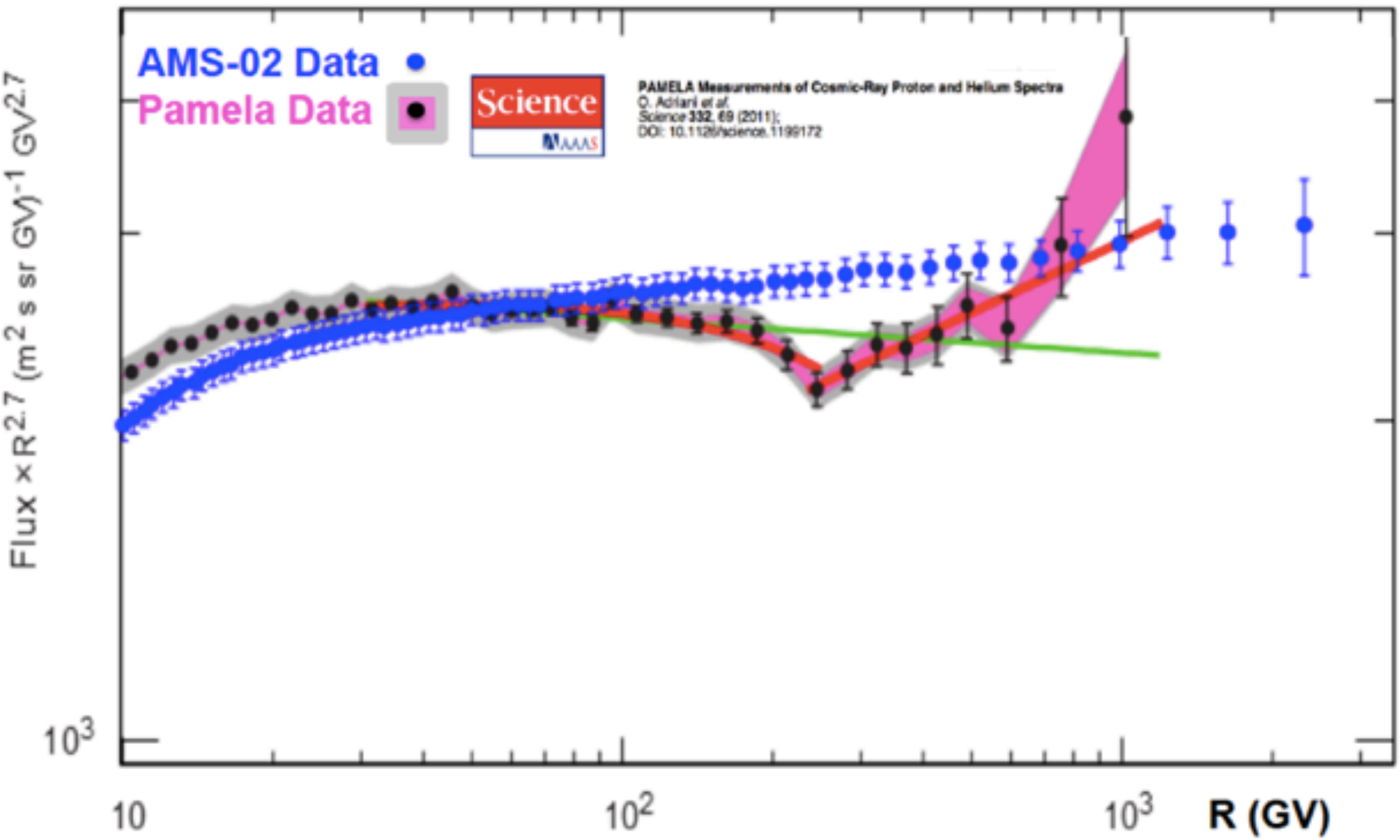


New results from the first 2 years of AMS: Helium flux (May 2011 / May 2013)



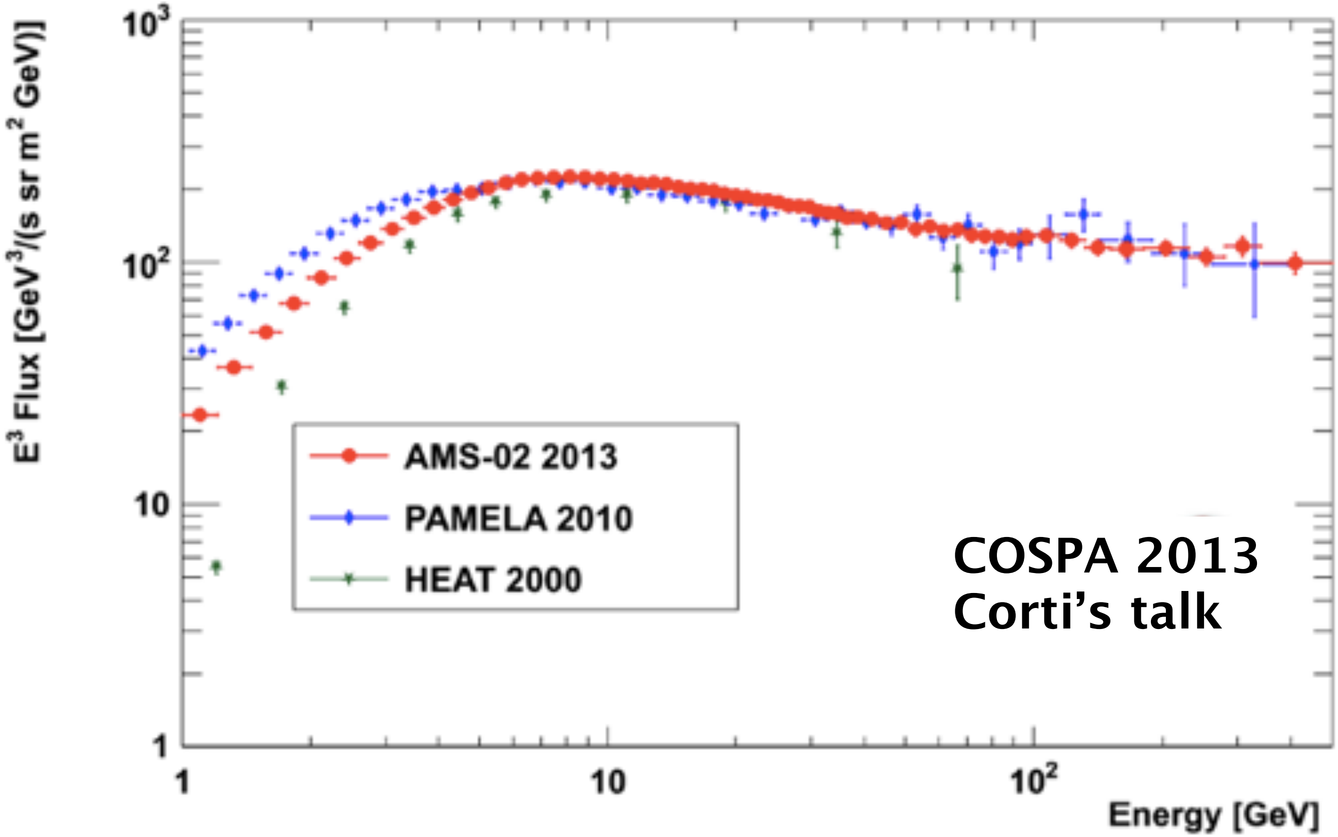
Comparison with past measurements

Helium flux: Comparison with Pamela



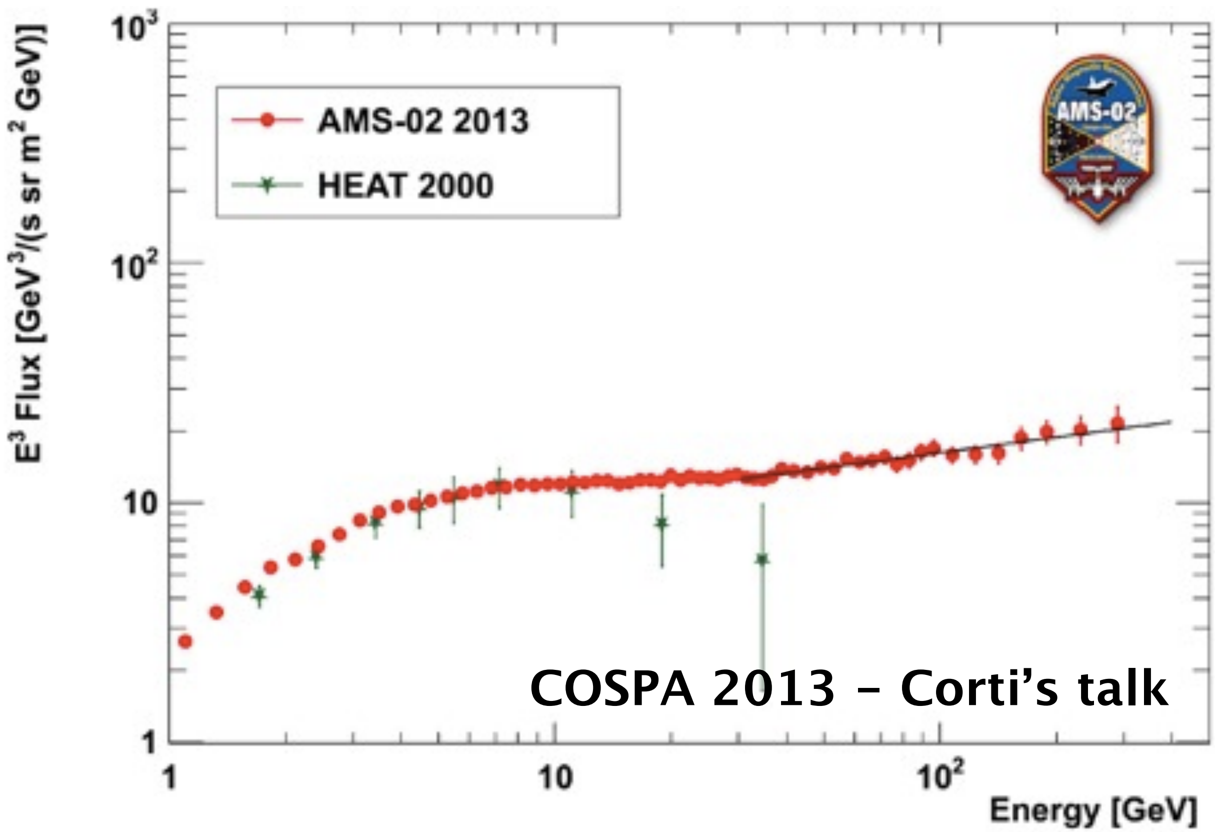
New results from the first 2 years of AMS: Electron flux (May 2011 / May 2013)

- The electron flux (multiplied by E^3) up to 500 GeV
- It is rising up to 10 GeV and appears to be on a smooth, slowly falling curve above.
- The measurement is in good agreement with the previous data.
- The differences at low energies can be attributed to the effect of the solar modulation.



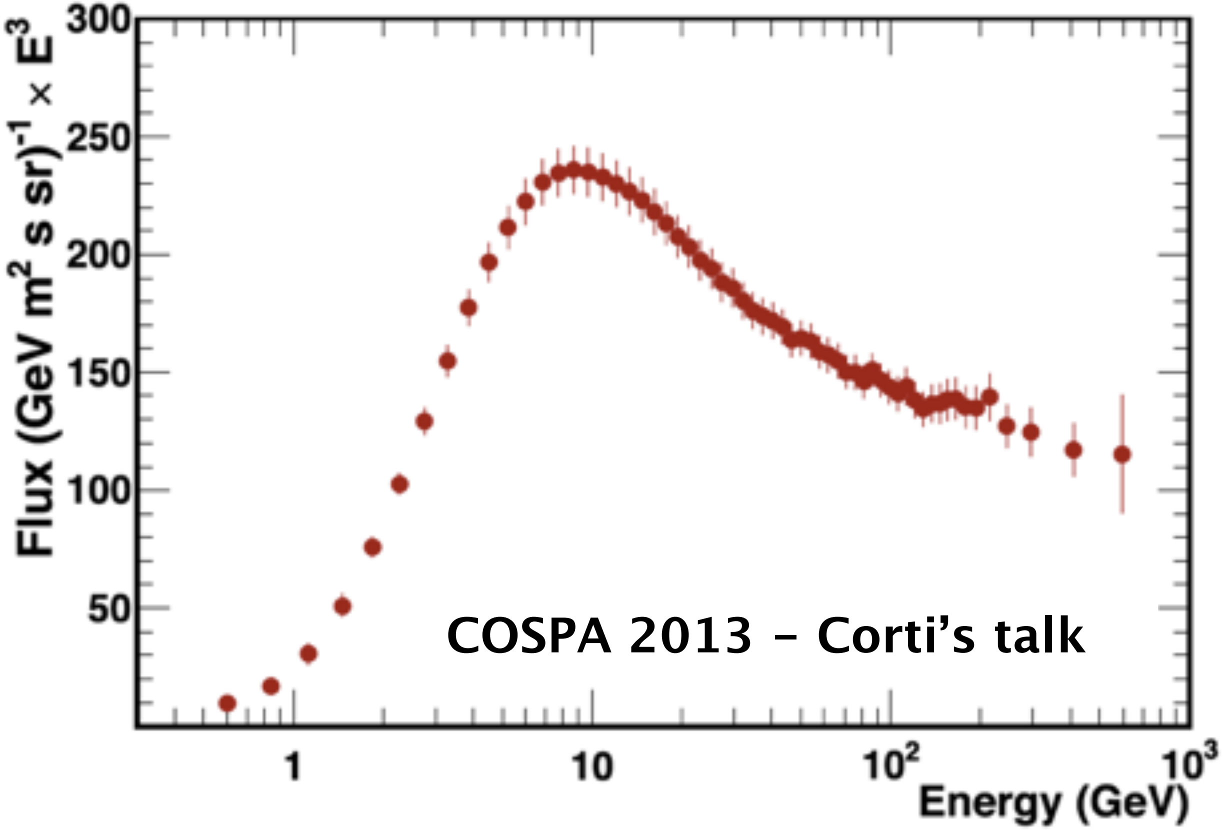
New results from the first 2 years of AMS: Positron flux (May 2011 / May 2013)

- The positron flux (multiplied by E^3) measured up to 350 GeV.
- It is rising up to 10 GeV, from 10 to 30 GeV the spectrum is flat and above 30 GeV again rising as indicated by the black line in the figure.
- The spectral index and its dependence on energy is clearly different from the electron spectrum.
- In the low energy range the agreement with HEAT results is good.

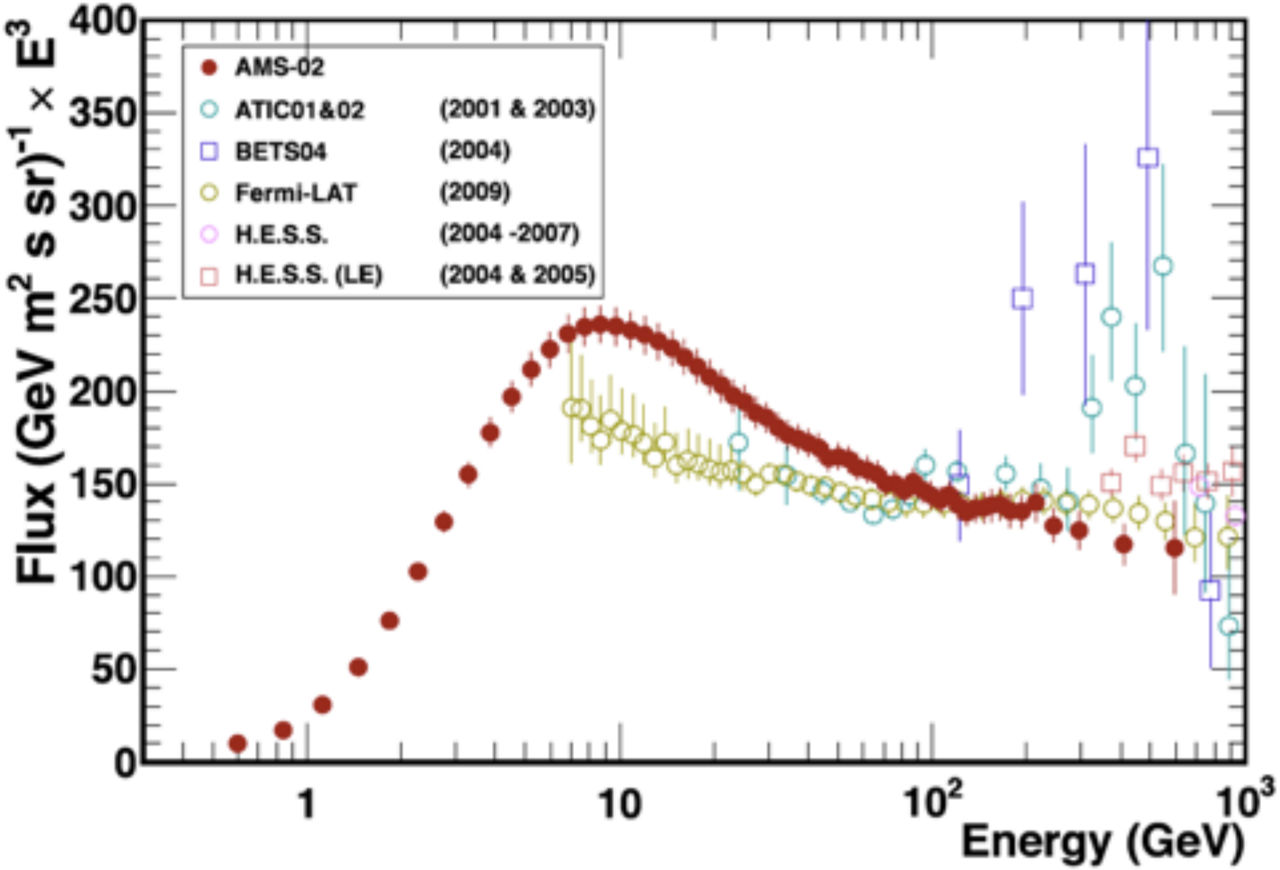


New results from the first 2 years of AMS: Electron plus Positron flux (May 2011 / May 2013)

- Electron plus positron spectrum measured up to 700 GeV and multiplied by E^3
- shows no evidence of structures.
- a change in the spectral distribution with increasing energy is seen compatible with the fraction.

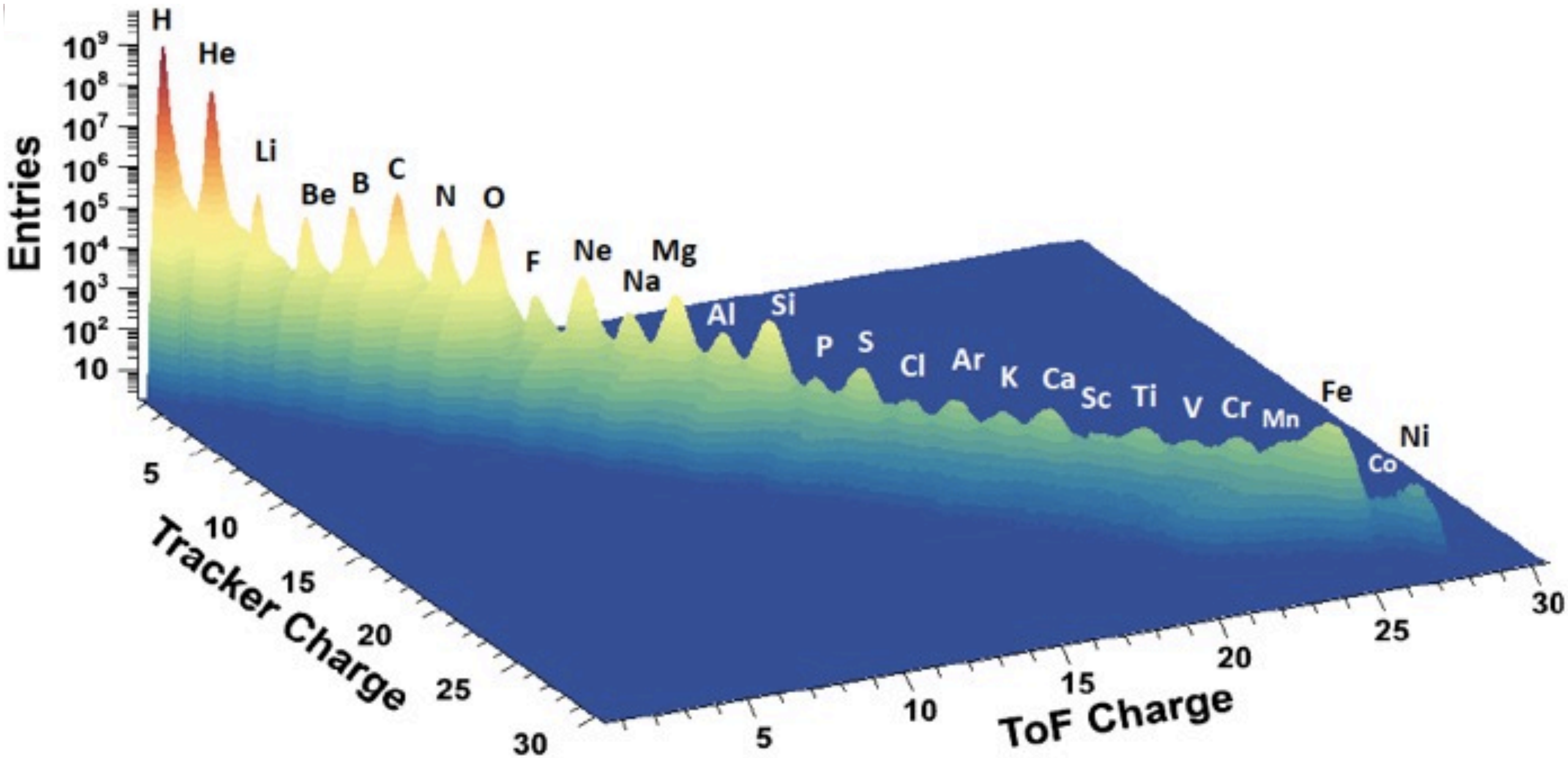


New results from the first 2 years of AMS: Electron plus Positron flux (May 2011 / May 2013)



Comparison with latest measurements

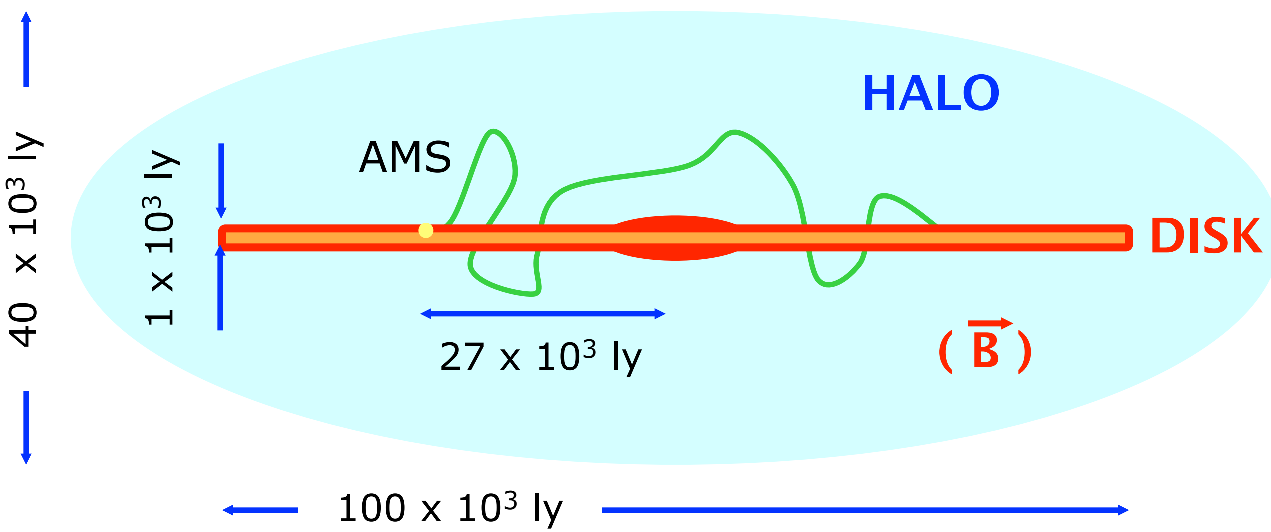
Nuclei identification in AMS



B/C ratio up to TeV

Precise measurement of the energy spectra of B/C
provides information on Cosmic Ray Interactions and Propagation

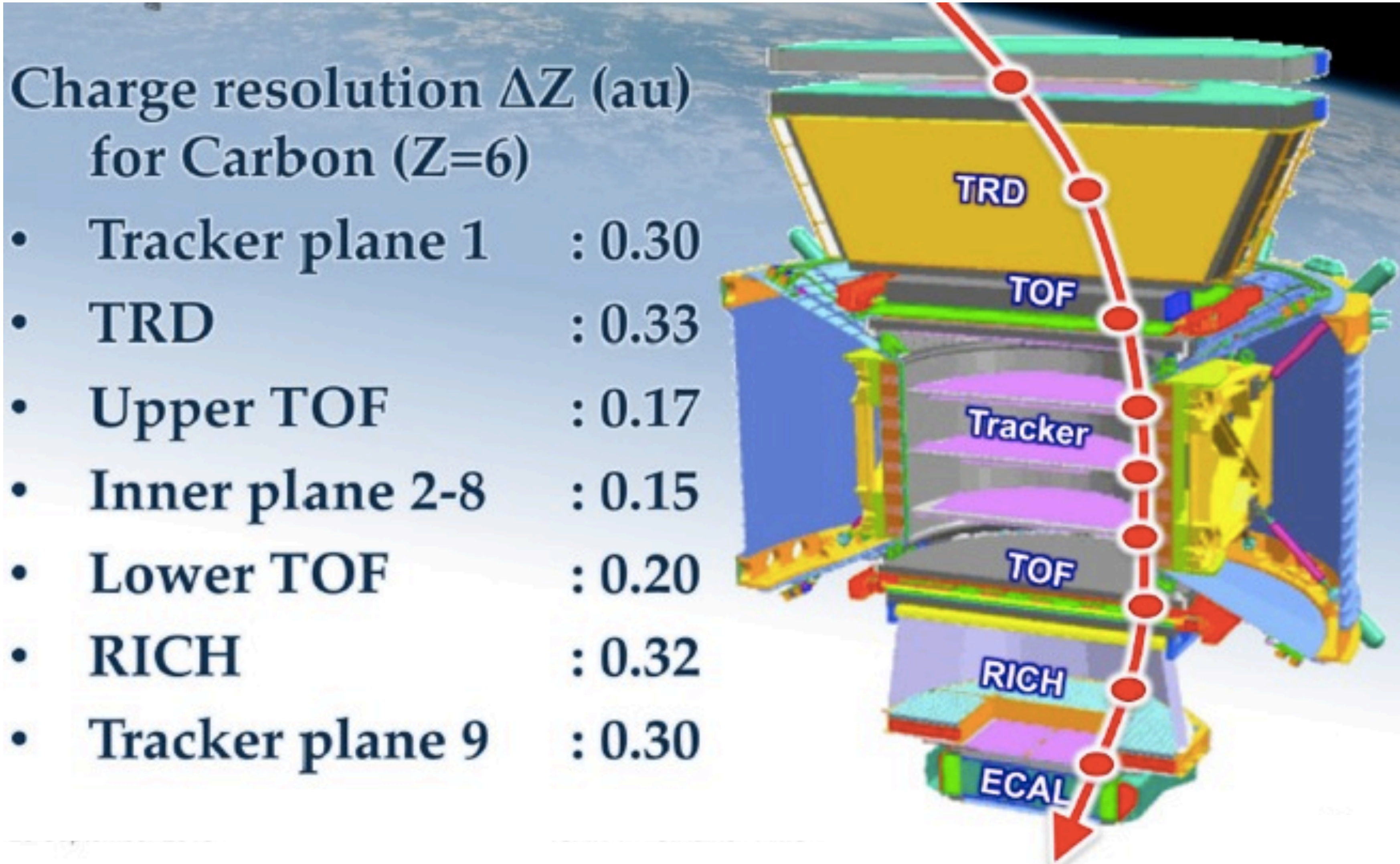
Interactions with the Interstellar Medium:
C + (p,He) → B + ...



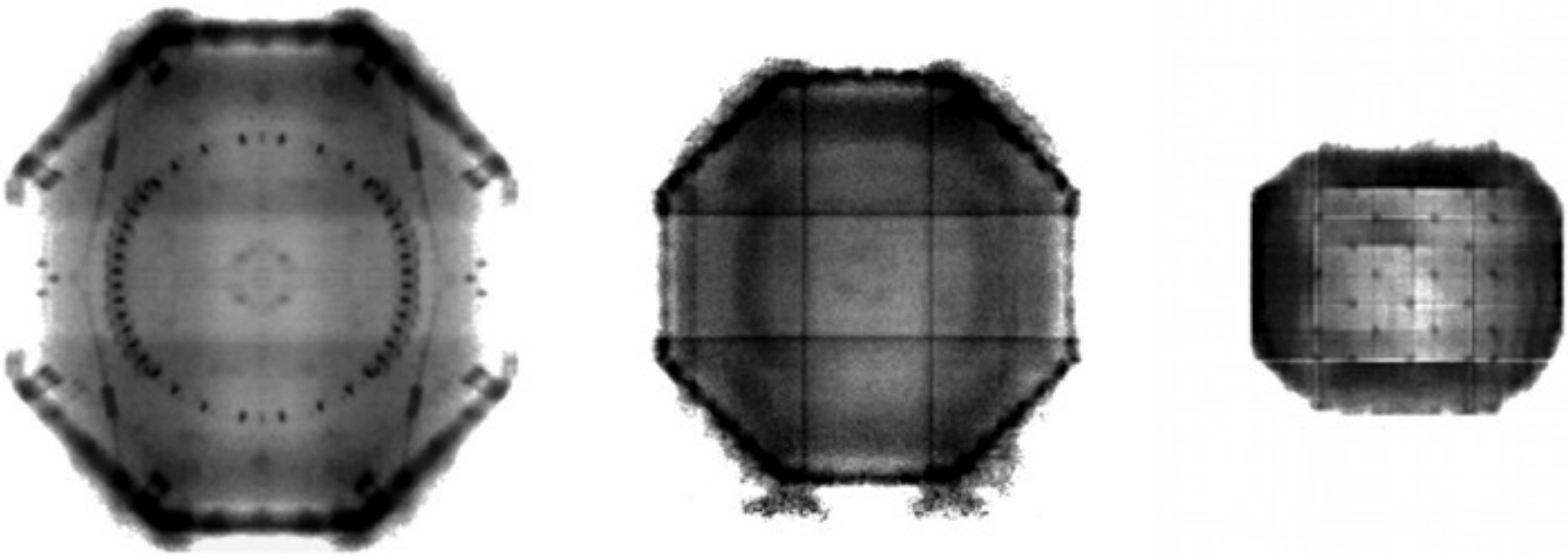
Diffusion
Convection
Reacceleration

Interactions with the Interstellar Medium (ISM):
- Fragmentation
- Secondaries
- Energy loss

New results from the first 2 years of AMS: Boron to Carbon ratio

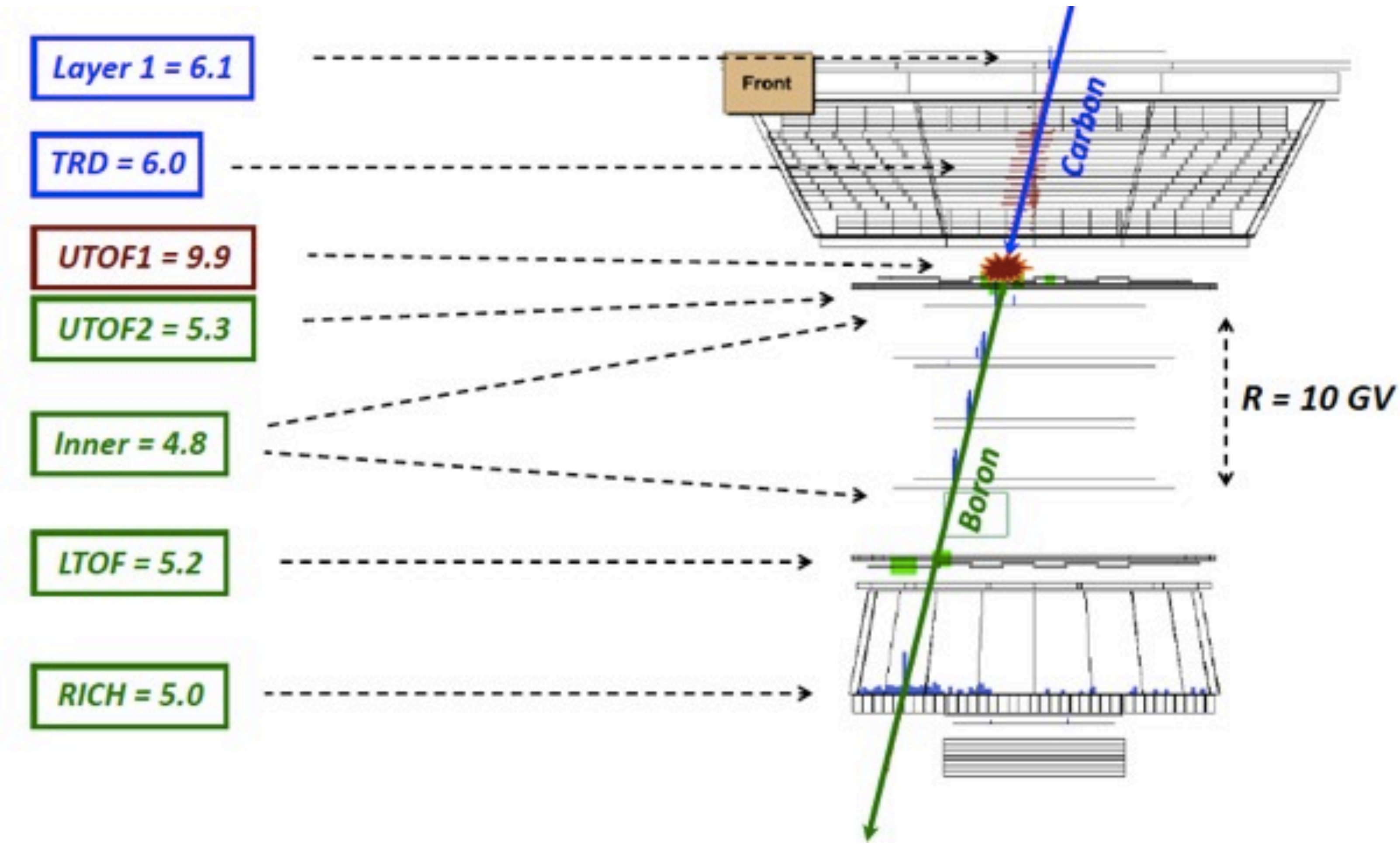


New results from the first 2 years of AMS: Boron to Carbon ratio



Tomographic reconstruction of the AMS material obtained using He/p from the cosmic rays

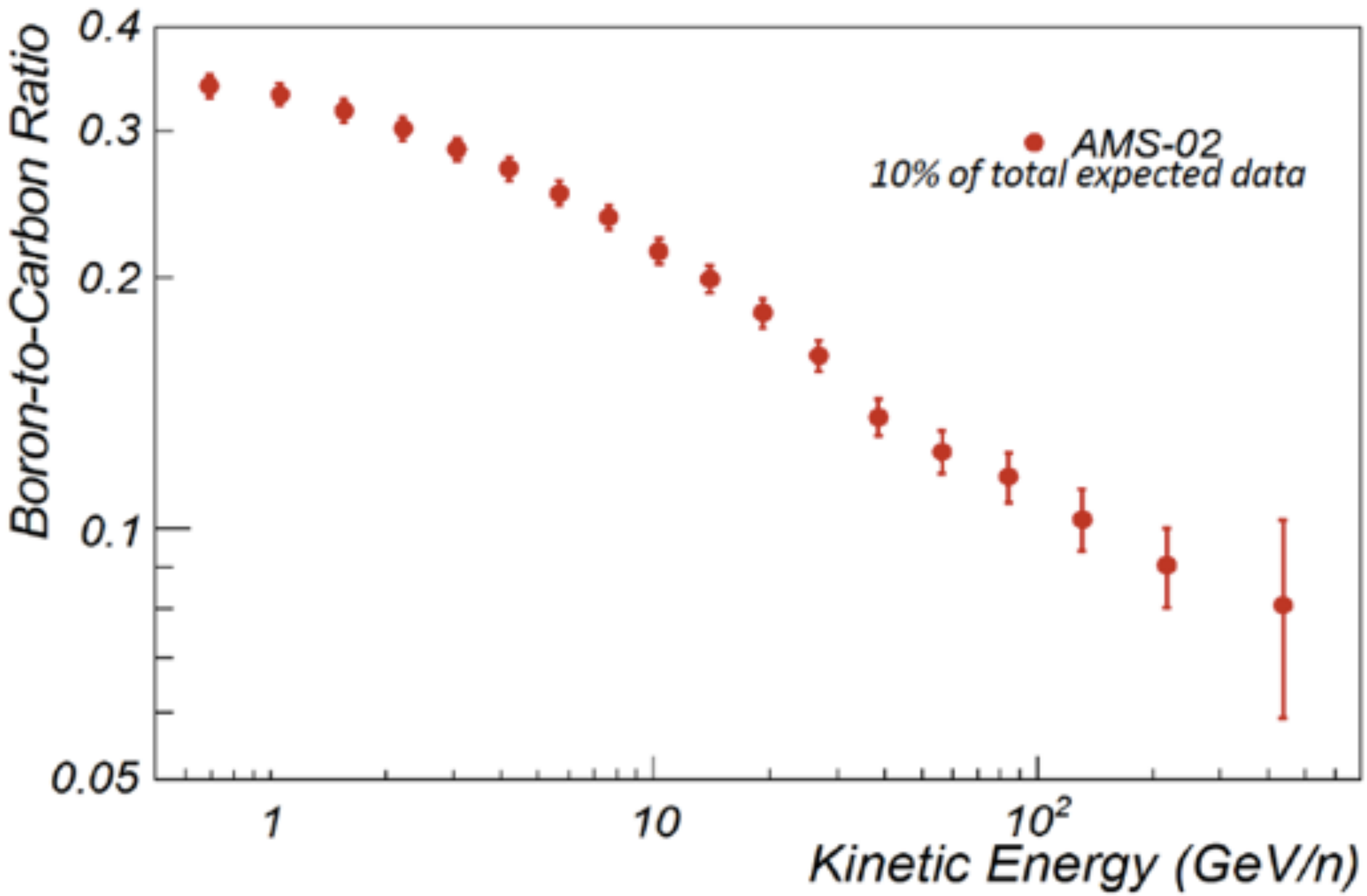
New results from the first 2 years of AMS: Boron to Carbon ratio



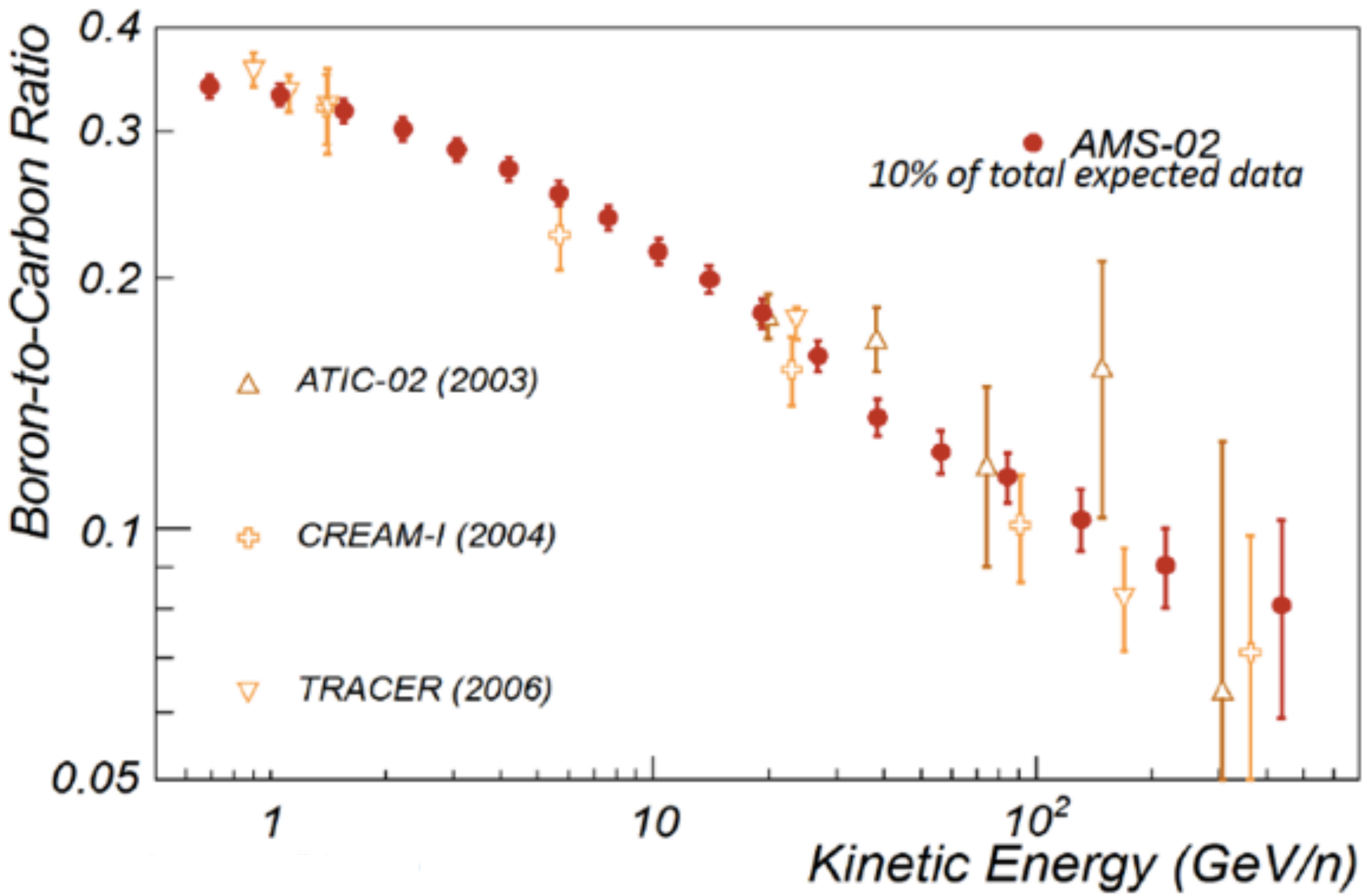
Identification of fragmentation events

New results from the first 2 years of AMS: Boron to Carbon ratio (May 2011 / May 2013)

- Measurement of the B/C between 0.5 to 670 GeV/n measured by AMS
- Statistics is the main limitation for the ratio measurement and systematics error evaluation.
- The B/C behavior at high energy will become more clear with more data

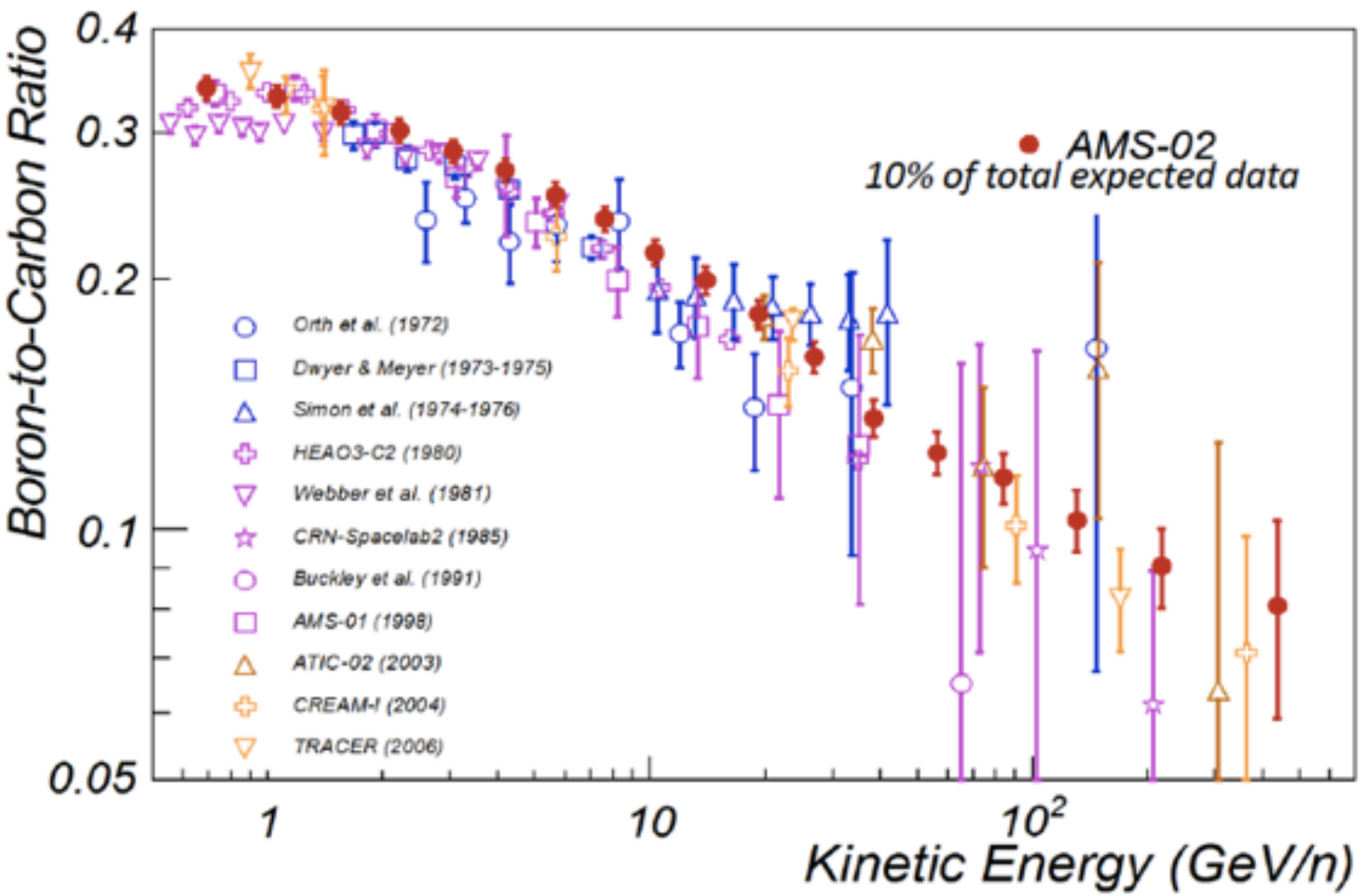


New results from the first 2 years of AMS: Boron to Carbon ratio (May 2011 / May 2013)



Comparison with latest measurements

New results from the first 2 years of AMS: Boron to Carbon ratio (May 2011 / May 2013)



Comparison with past measurements

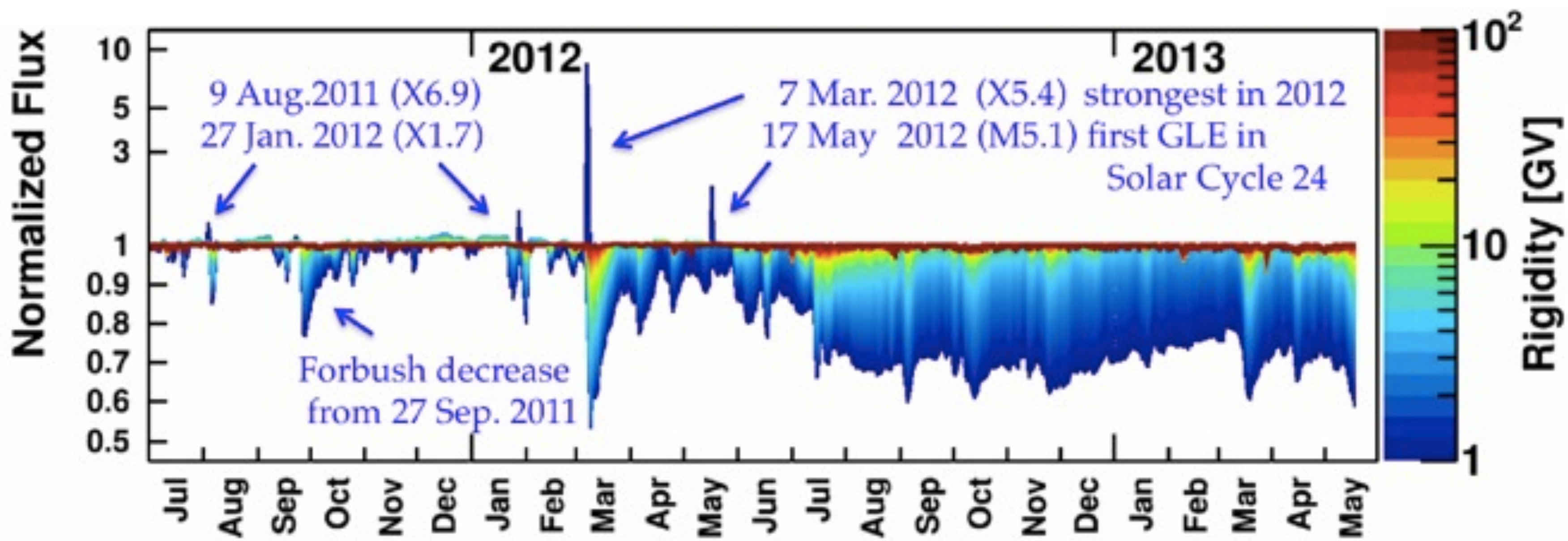
New results from the first 2 years of AMS: Study of the Solar activity

Gradual decrease effect of flux in the low rigidity region (R<10GV).

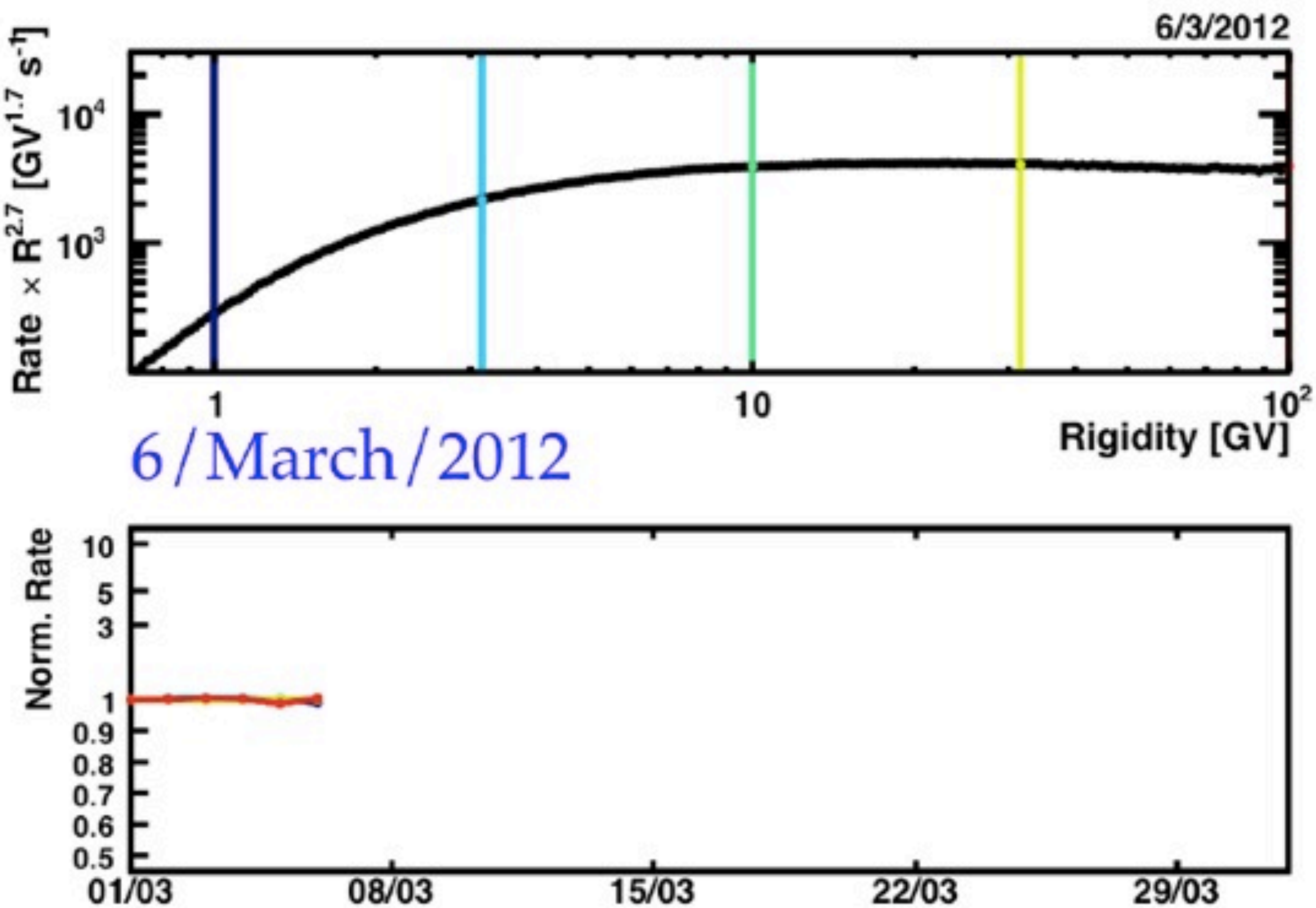
Spikes corresponds to solar events.

Forbush decrease in the observed GCR intensity following a CME due to the magnetic field of the plasma solar wind.

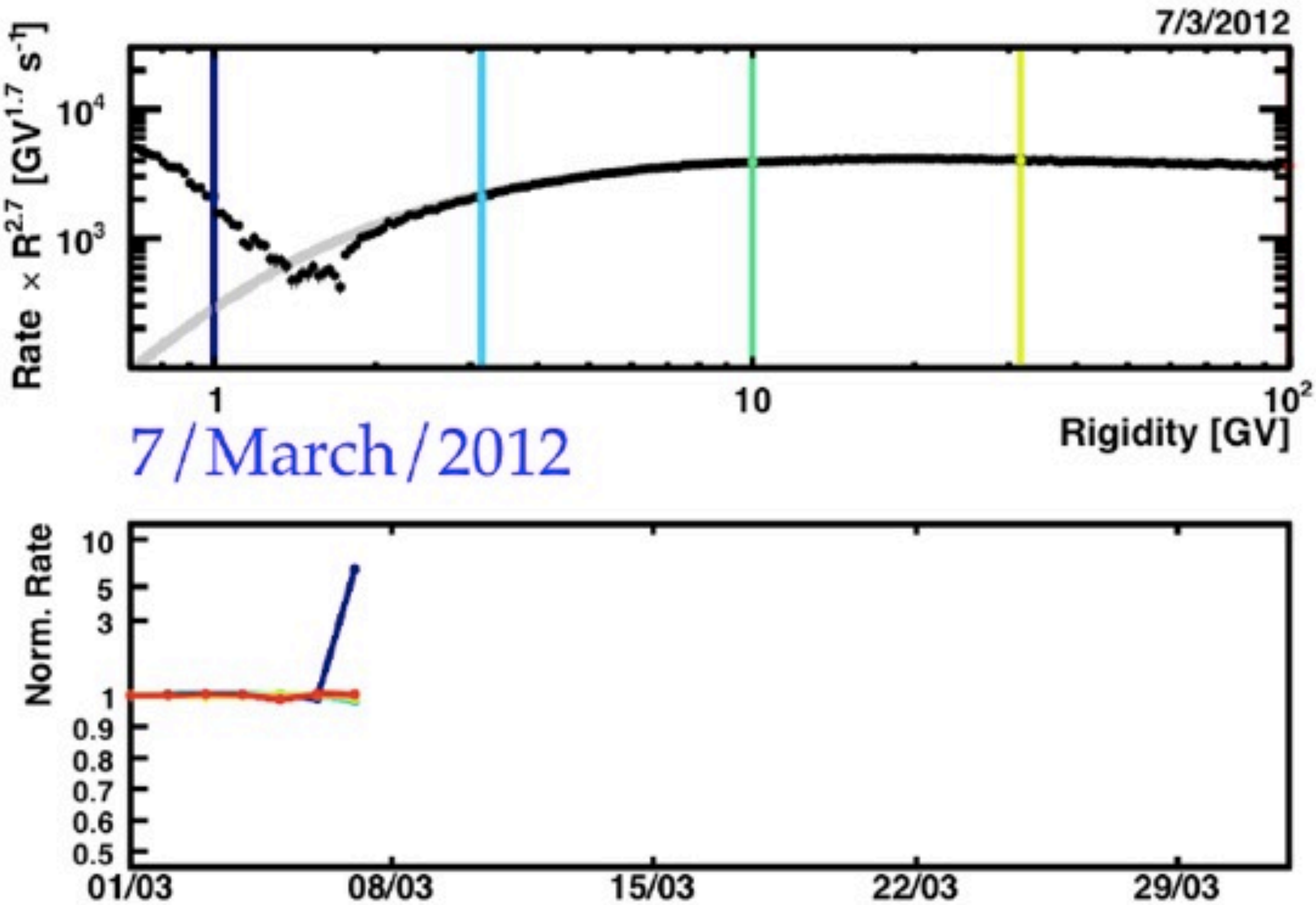
COSPA 2013 – Consolandi's talk



New results from the first 2 years of AMS: March 2012 Solar event



New results from the first 2 years of AMS: March 2012 Solar event



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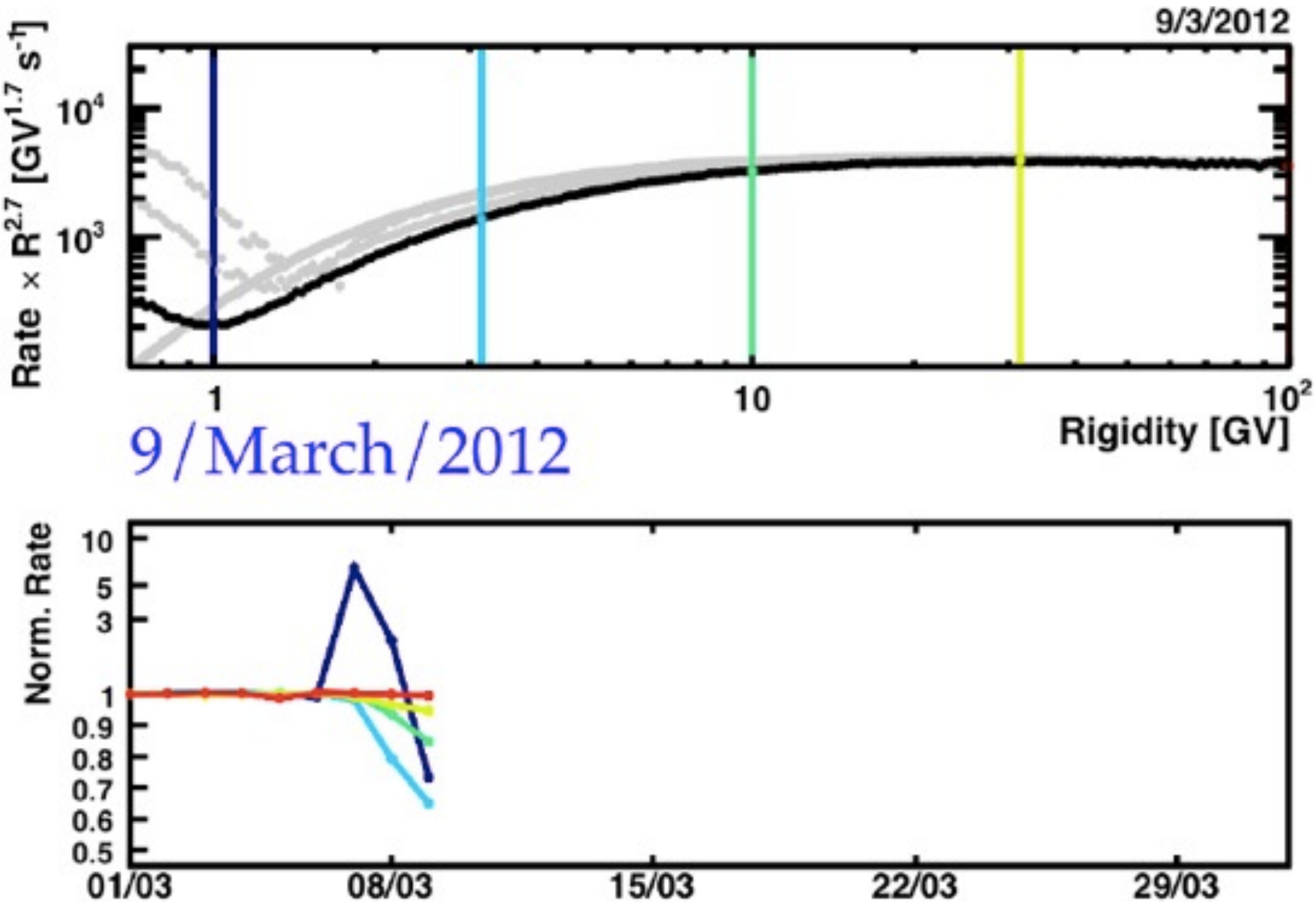

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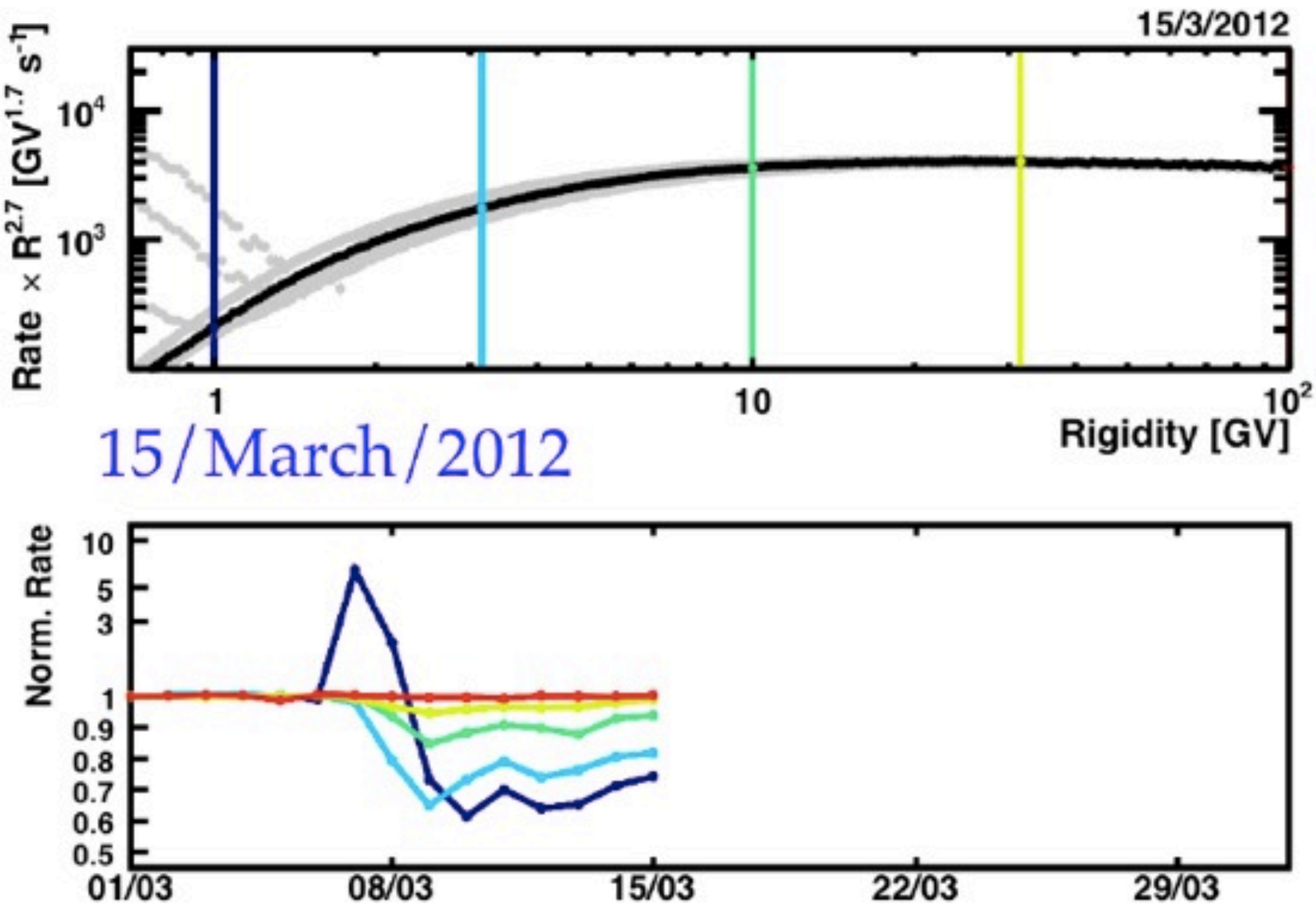
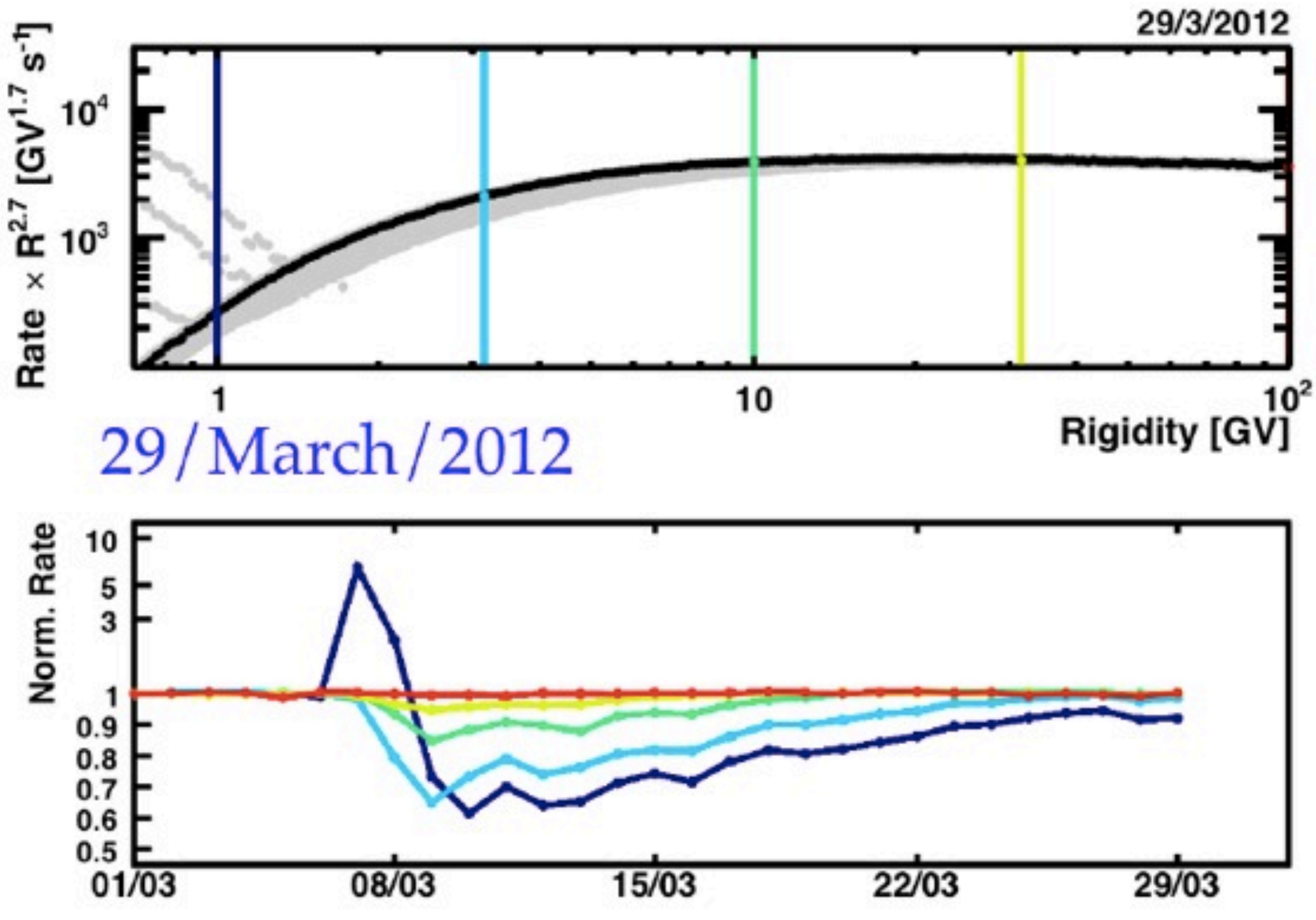


New results from the first 2 years of AMS: March 2012 Solar event



Conclusions

•The AMS positron fraction (0.5 to 350 GeV) shows a clear steady increase above 10 GeV. More statistics is necessary to clarify the behavior above 250 GeV.

•Anisotropy studies indicate that the positron to electron ratio and the positron to proton ratio are consistent with isotropy, pulsars scenario cannot be excluded.

•The AMS Proton flux (1.8TV), Helium flux (3.2TV) and electron flux (500 GeV) are consistent at high energy with a single power law with no fine structures nor break. Systematics still under study.

•Preliminary Electron + Positron spectrum (700 GeV) shows no evidence of structures. A change in the spectral distribution with increasing energy is seen compatible with the fraction and with the positron flux (350 GeV). Details of the systematic errors are under investigations.

•Measurements of the B/C (670 GeV/n) has been presented, the behavior at high energy will become more clear with more data.

• Solar activity (CR modulation and SEP) can be studied with AMS.

Thank you

More science coming soon! Stay tuned!!!