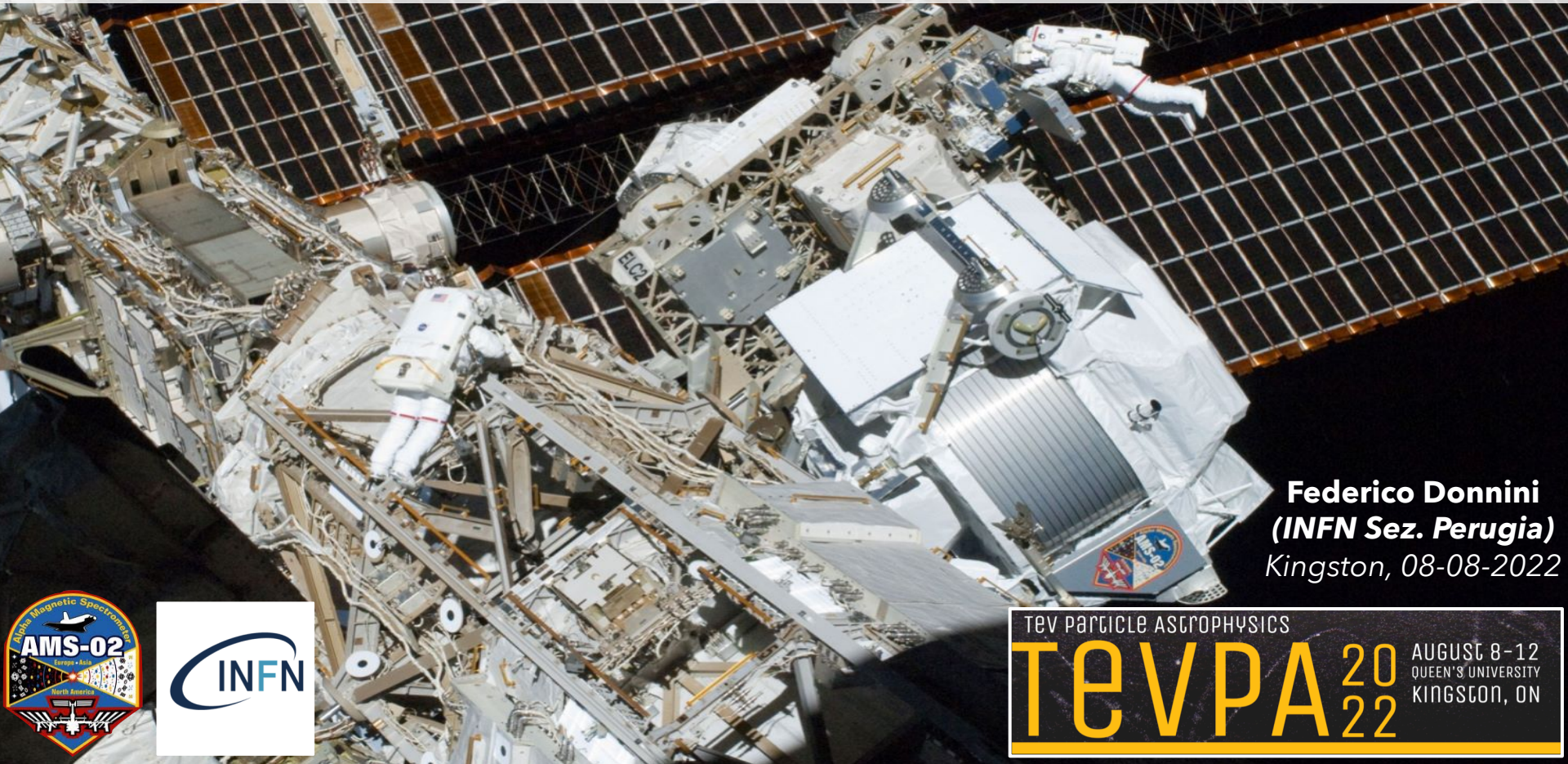
Precision measurement of the Monthly nuclei fluxes in Cosmic Rays with Alpha Magnetic Spectrometer on the International Space Station



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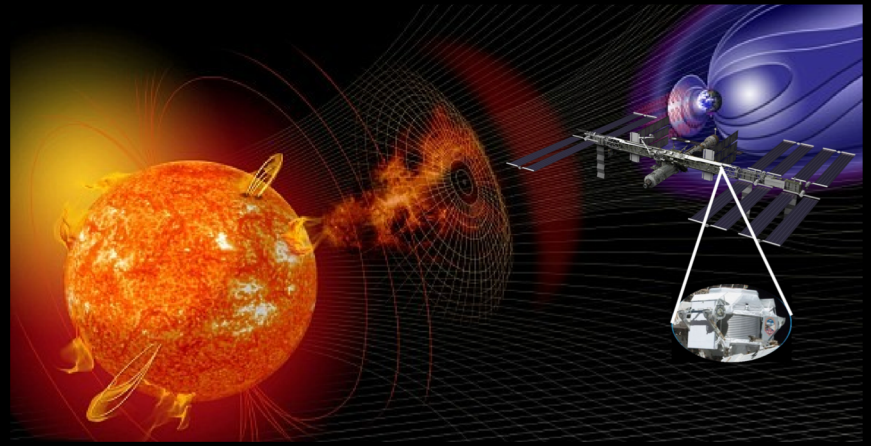
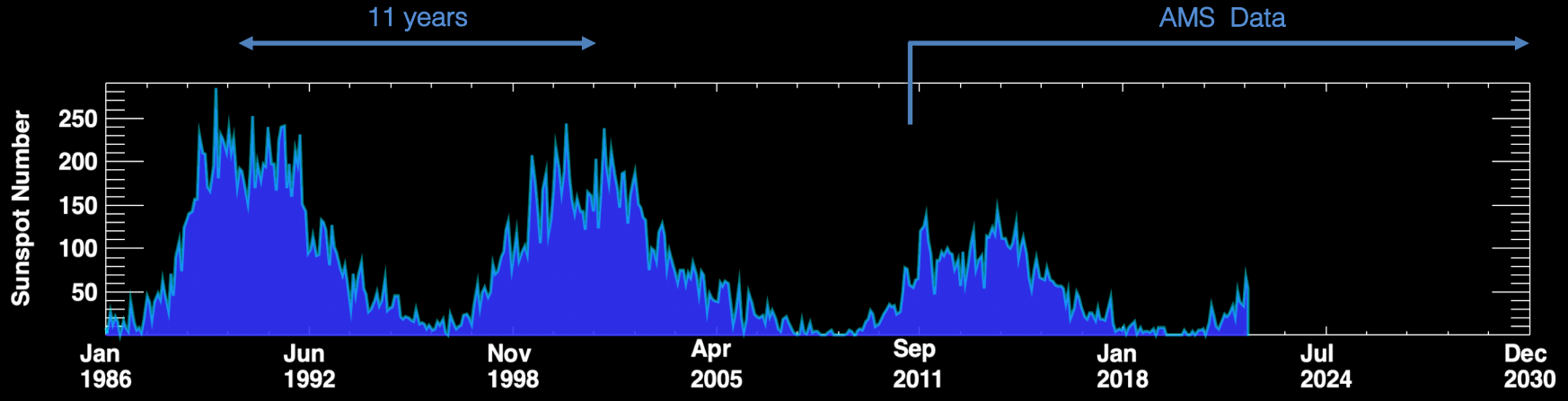
TeV Particle Astrophysics TeVPA 2022 August 8-12 Queen's University Kingston, ON

Solar physics with AMS-02

- **Large time scale effects** (~years):
  - intensity variation of CRs
  - charge sign dependence:
    - at solar maximum: diffusion
    - at solar minimum: diffusion + magnetic drift
- **Small time scale effects** (~days):
  - Forbush decrease & Solar Energetic Particles (SEP)





Solar physics with AMS-02: Nuclei

The Cosmic Rays propagation in the heliosphere is described by Parker equation:

Particle density in phase space

$$\frac{\partial f}{\partial t} = -\vec{V}_{SW} \cdot \vec{\nabla} f + \vec{\nabla} \cdot (\mathrm{K} \cdot \vec{\nabla} f) + \frac{1}{3} \vec{\nabla} \cdot \vec{V}_{SW} \frac{\partial f}{\partial lnR}$$

Solar wind convection | Diffusion and Drifts | Adiabatic energy losses

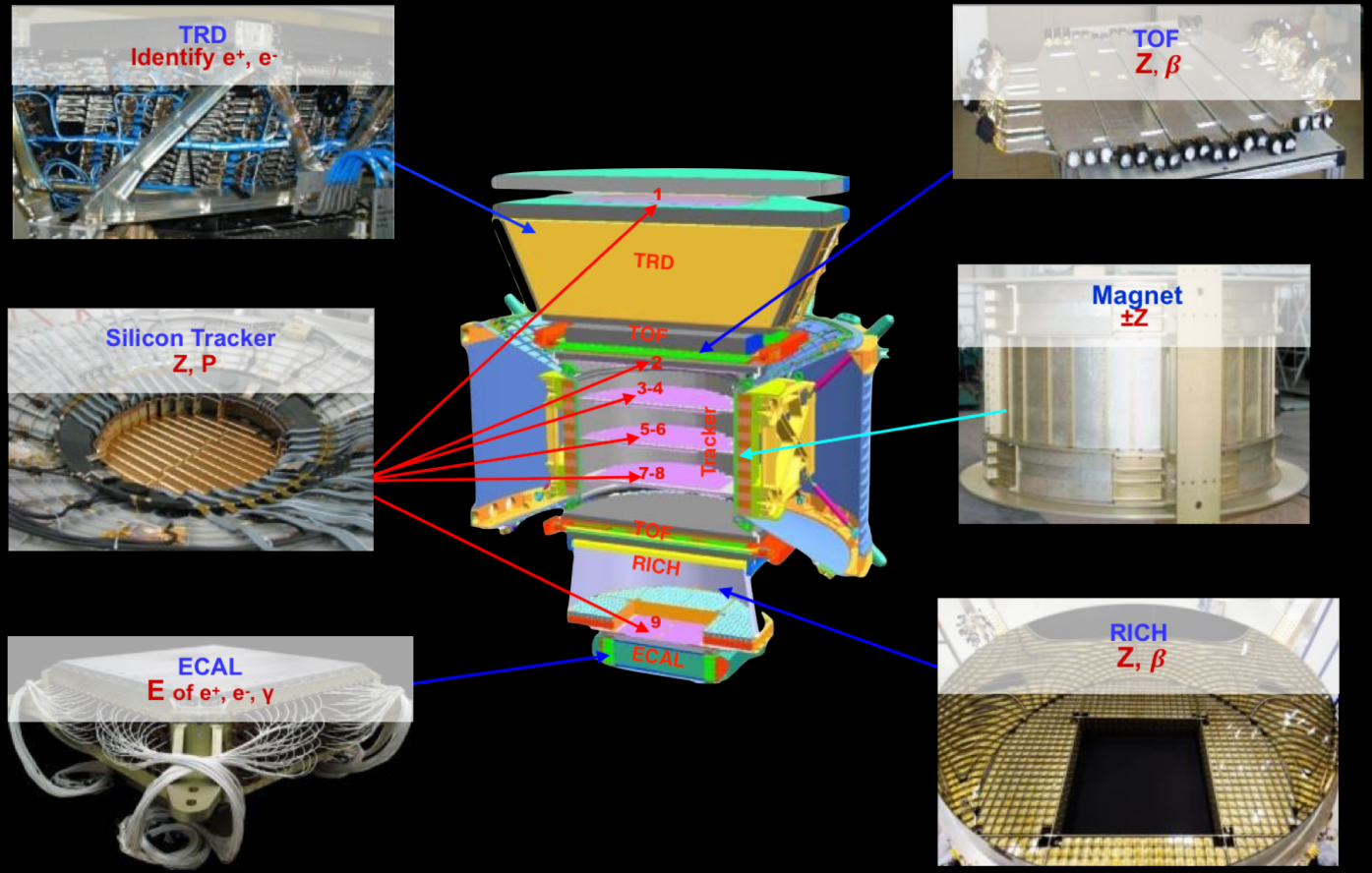
- Velocity dependence of the diffusion tensor: the velocity induces changes in this term for nuclei with different A/Z since $\beta(R) = \frac{R}{\sqrt{R^2 + (A/Z)^2 (mc)^2}}$
- Difference in spectral shape: the adiabatic energy losses term depends on the spectral shape. If two nuclei have different spectral shape outside the heliosphere (LIS), the last term will be different.

→ **Nuclei with different A/Z or with different LIS have different propagation in the Heliosphere**

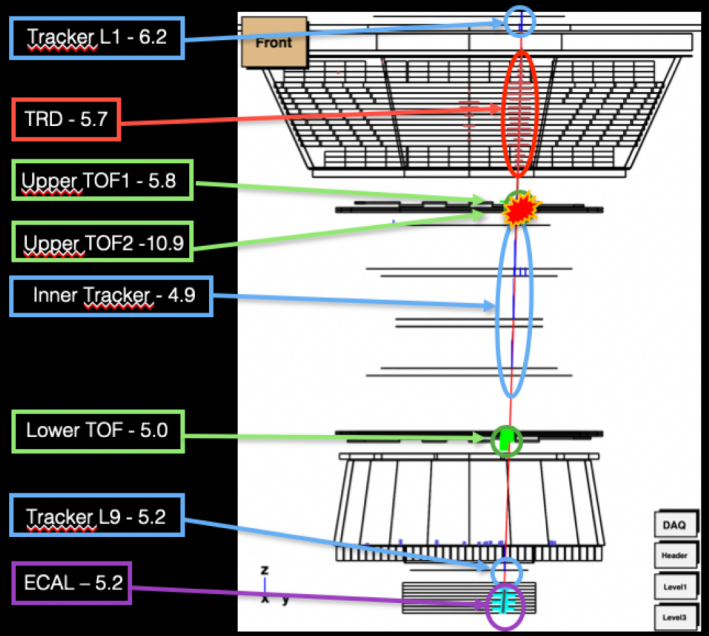
AMS-02 detector

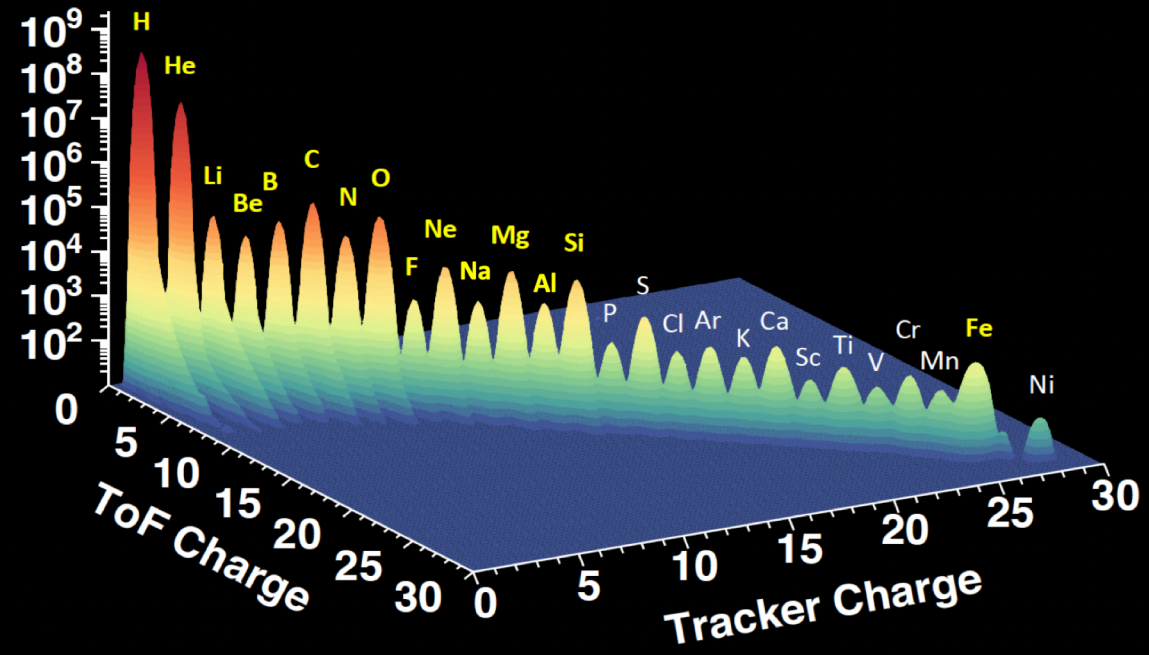
Particles and nuclei are defined by their charge (**Z**) and energy (**E ~ P**)

Both quantities are measured redundantly and independently by the *Tracker, TOF, RICH* and/or *ECAL*



AMS-02 Charge Measurement





Status of the Nuclei Analysis in AMS

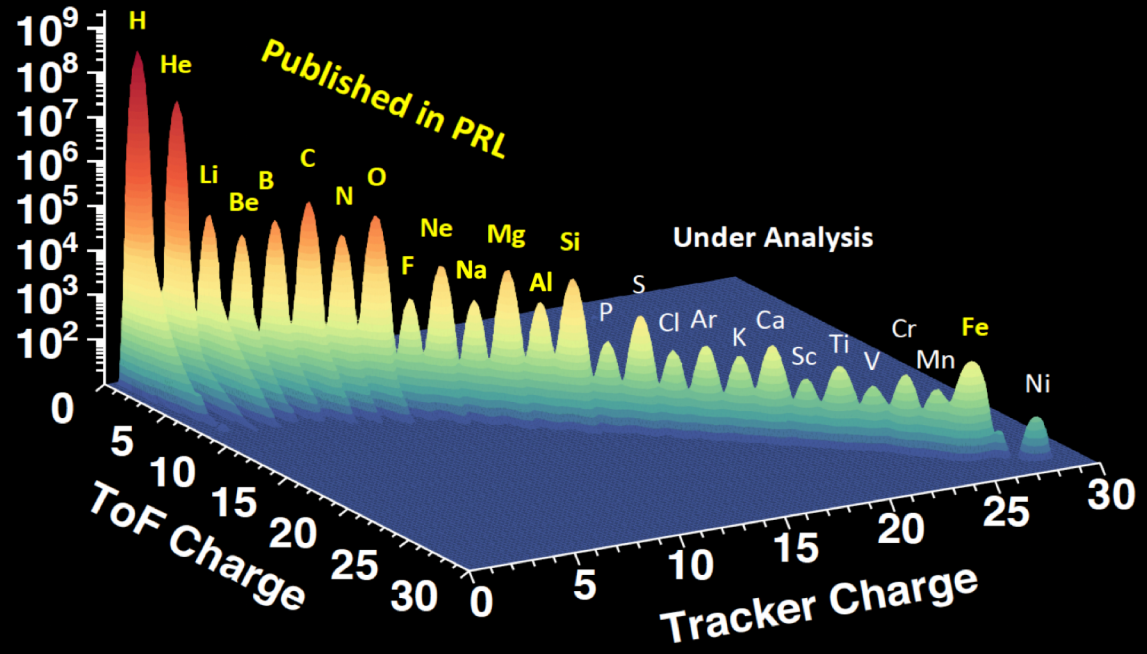
Nuclei spectra from p to Si, and Fe published on PRL

- Daily fluxes: p and He
  Phys. Rev. Lett. 127, 271102 (2021)

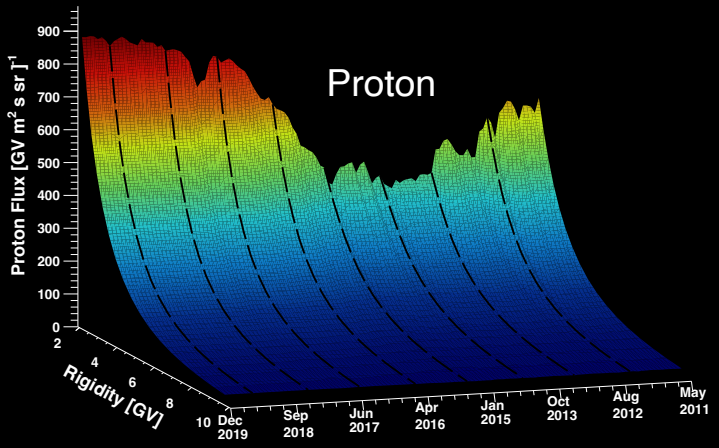
  Phys. Rev. Lett. 128, 231102 (2022)

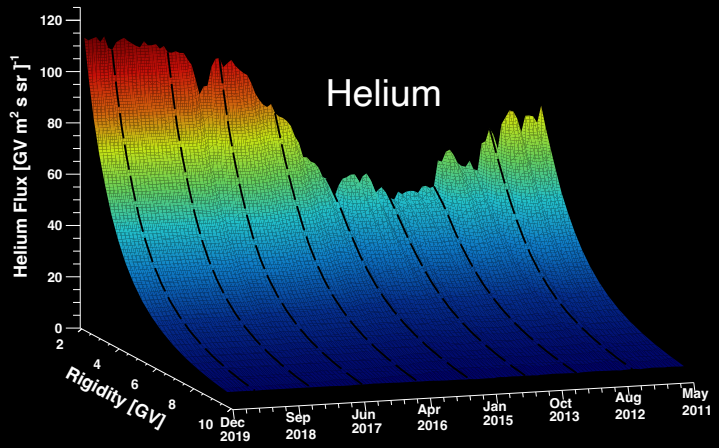
- Monthly fluxes: p and He
  Phys. Rev. Lett. 121, 051101 (2018)

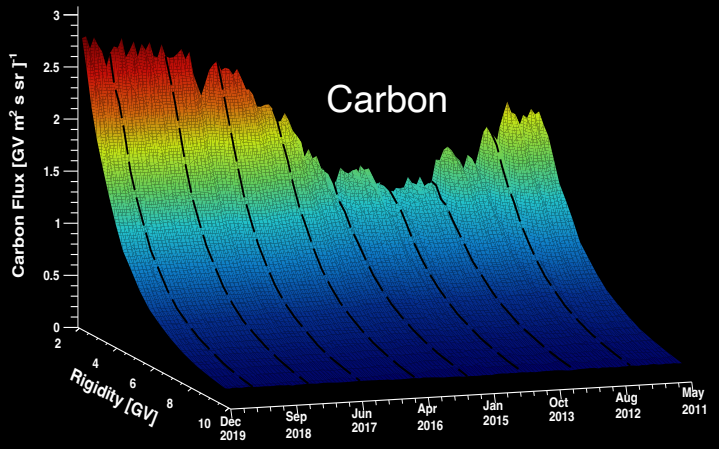
- Current Monthly fluxes: p and He (update), C and O (preliminary)

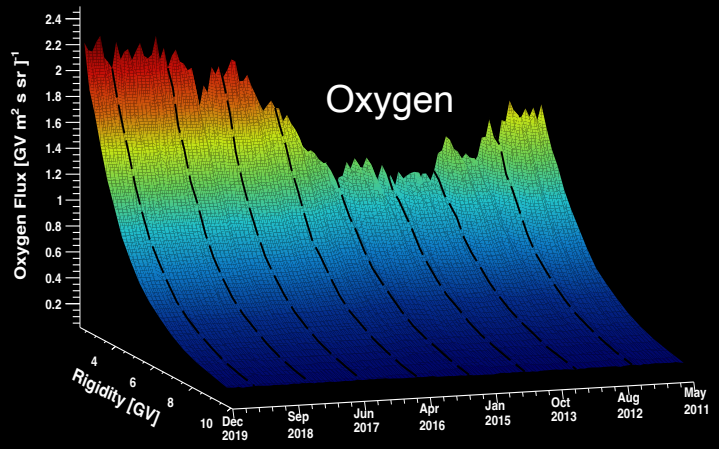


p, He, C and O fluxes







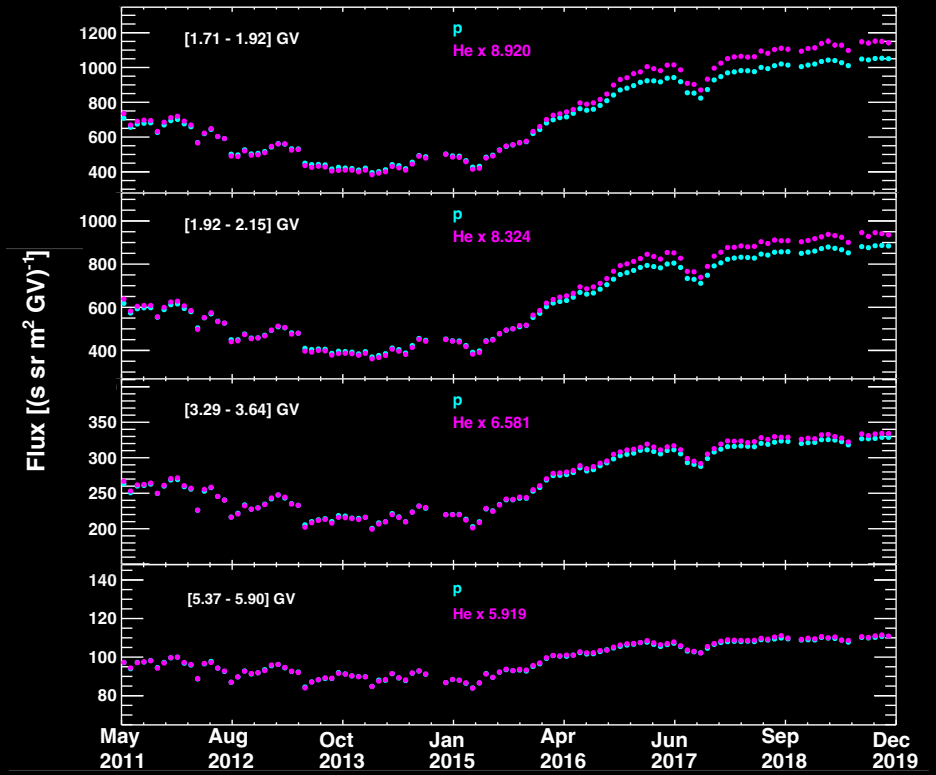


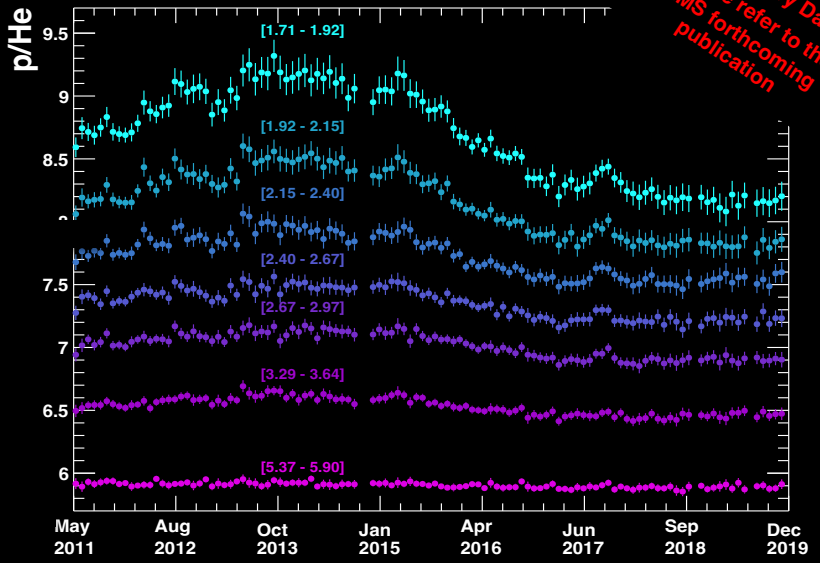
Time Evolution from May 2011 up to Nov 2019.

The time interval is 27 days (Bartels Rotation)

Preliminary Data.
Please refer to the AMS forthcoming publication

Time evolution: protons and Helium

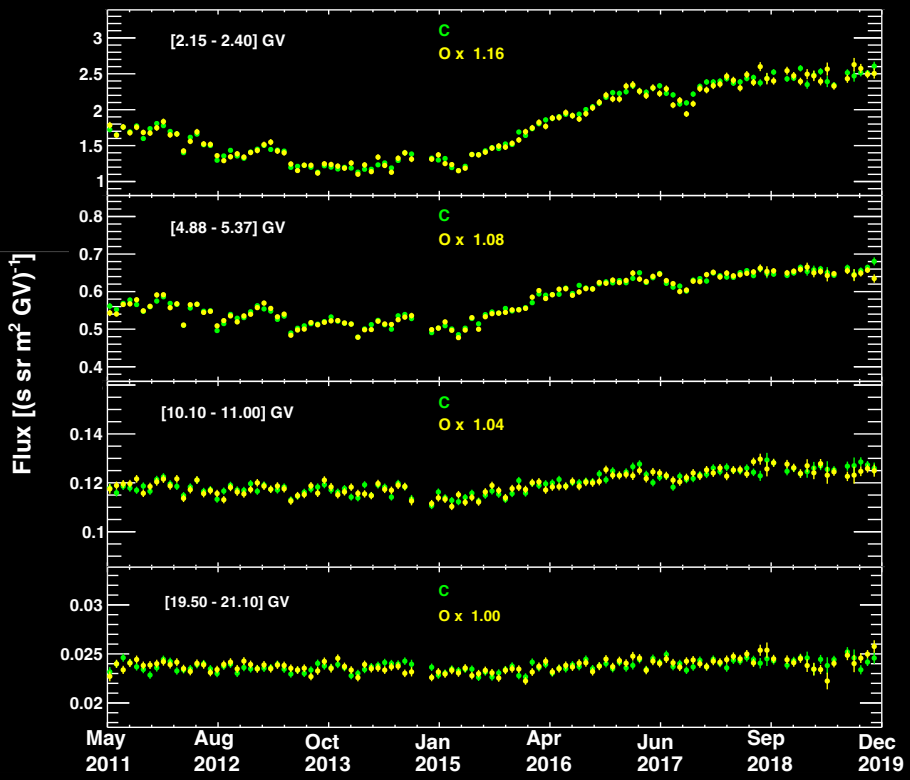


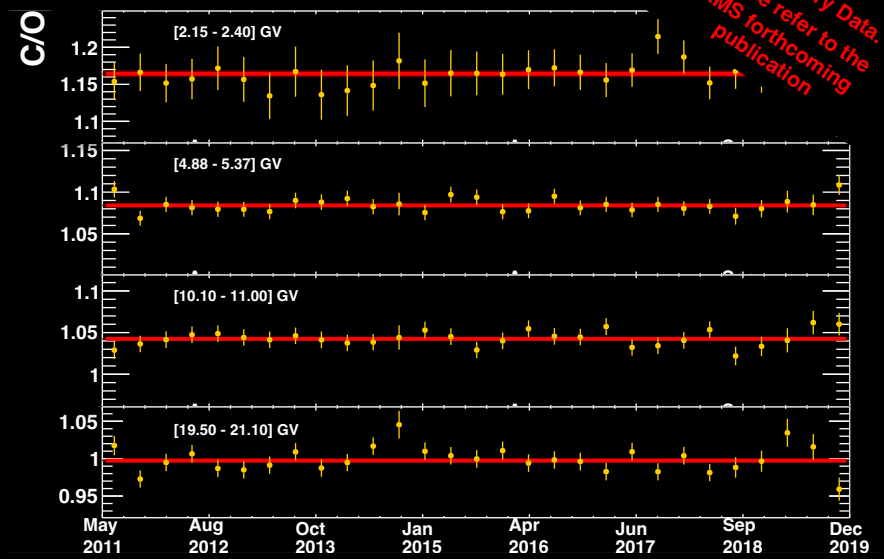


- p and He fluxes present short and long term variations
- He flux more modulated with respect p flux

- **p/He: different velocity**
  from numerical model the velocity difference is the main contribution to the time dependence

Time evolution: Carbon and Oxygen



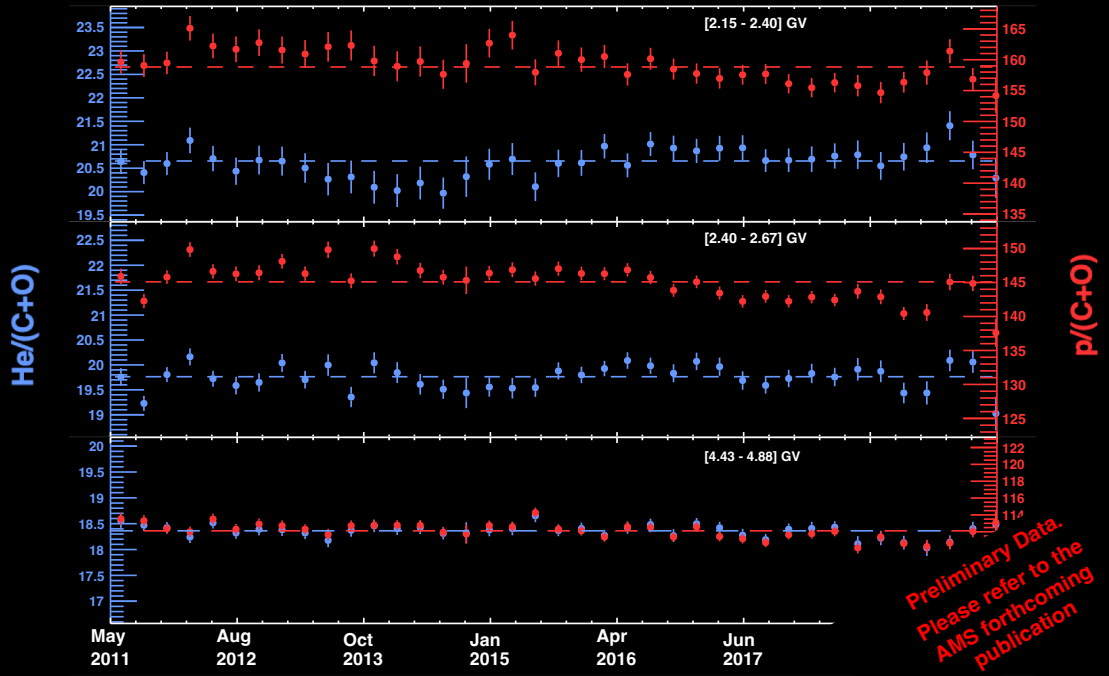


- C and O fluxes present short and long term variations as oobserved on p and He fluxes.
- C and O fluxes have the same time evolution above 2 GV)

- **C/O: same velocity, so any time dependence comes from LIS spectral shape differences the flux ratio is constant in time → C and O LIS have very similar rigidity dependence above 2 GV**

Time evolution: Fluxes comparison

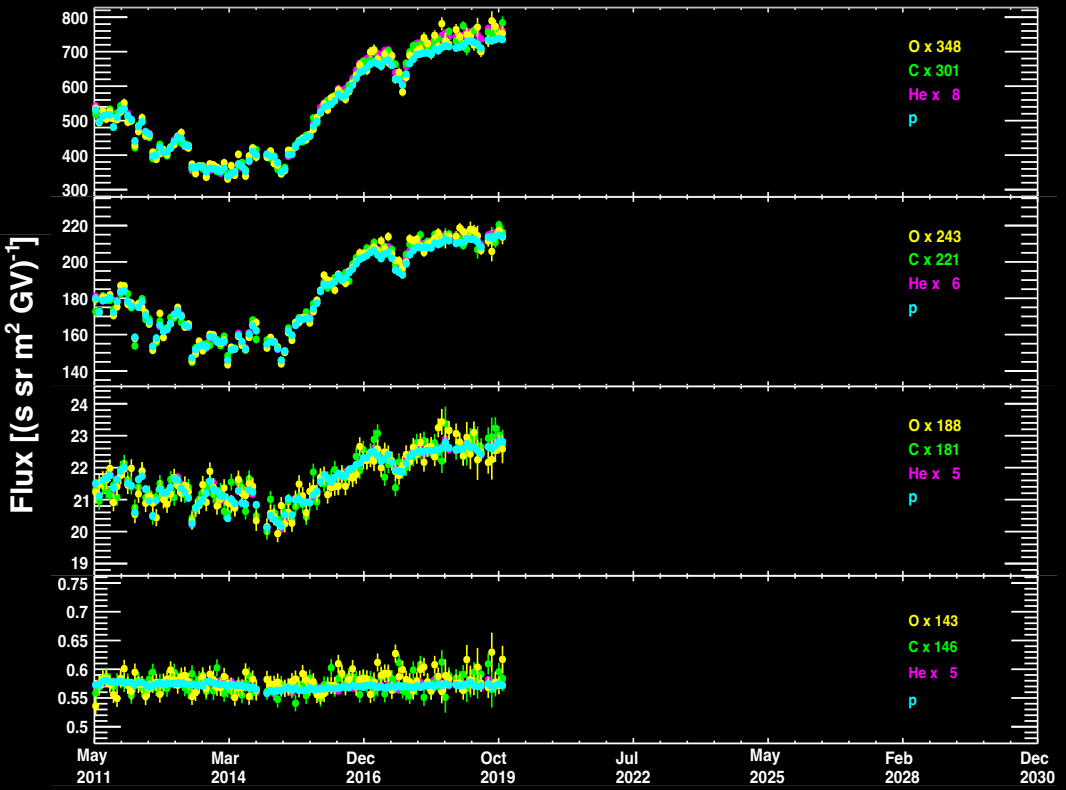
Since C and O have the same time evolution, we can perform the p/(C+O) and the He/(C+O) fluxes ratios



- The p/(C+O) flux ratio is not compatible with a constant value (dashed lines) below 3.29 GV
- the He/(C+O) ratio doesn't show any particular variation from the costant behavior in the whole rigidity range

- **p/C, p/O: numerical model needed to disentangle between velocity and LIS difference**
- **He/C, He/O: very similar velocities so any time dependence comes from spectral shape differences**

Conclusions



- AMS-02, operating onboard the International Space Station (ISS) since 2011 May 19th, is able to perform precision measurement of the CR nuclei fluxes and their time evolution
- The current measurement on p, He, C and O fluxes is based on events collected by AMS from May 2011 to Nov 2019 (115 Bartels rotation)
- The results obtained can give important informations for the development of refined solar modulation models, and for the derivation of the light nuclei LIS in a rigidity range not covered by previous experiments

- **AMS-02 will continue taking data for the entire duration of the ISS (at least up to 2030)**