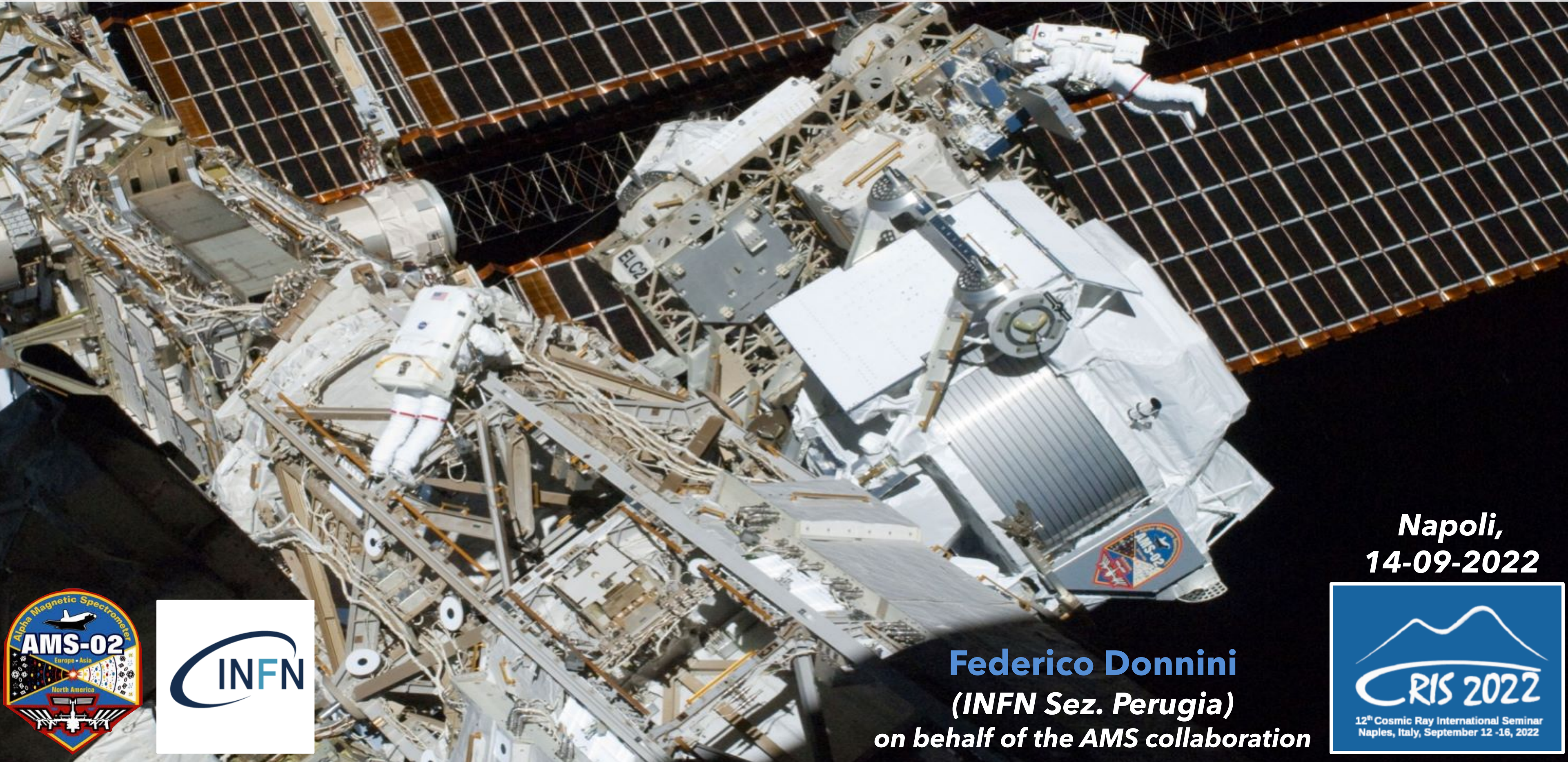
Precision measurement of the Monthly nuclei fluxes in Cosmic Rays with Alpha Magnetic Spectrometer on the International Space Station



Napoli,
14-09-2022

Federico Donnini
(INFN Sez. Perugia)
on behalf of the AMS collaboration

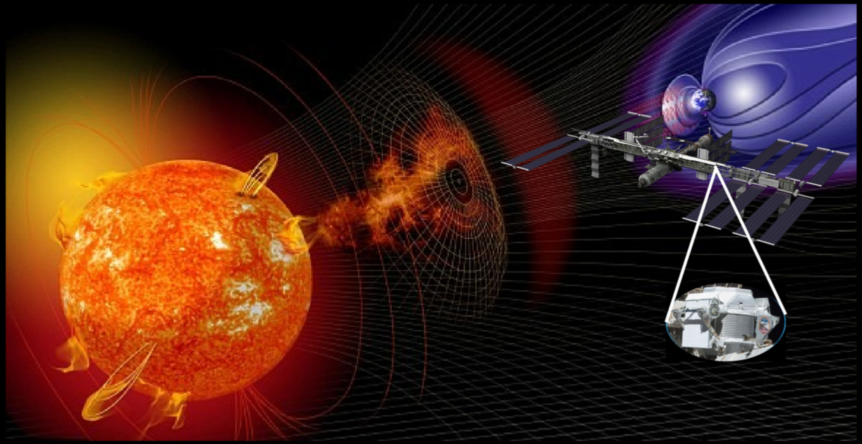
Alpha Magnetic Spectrometer AMS-02

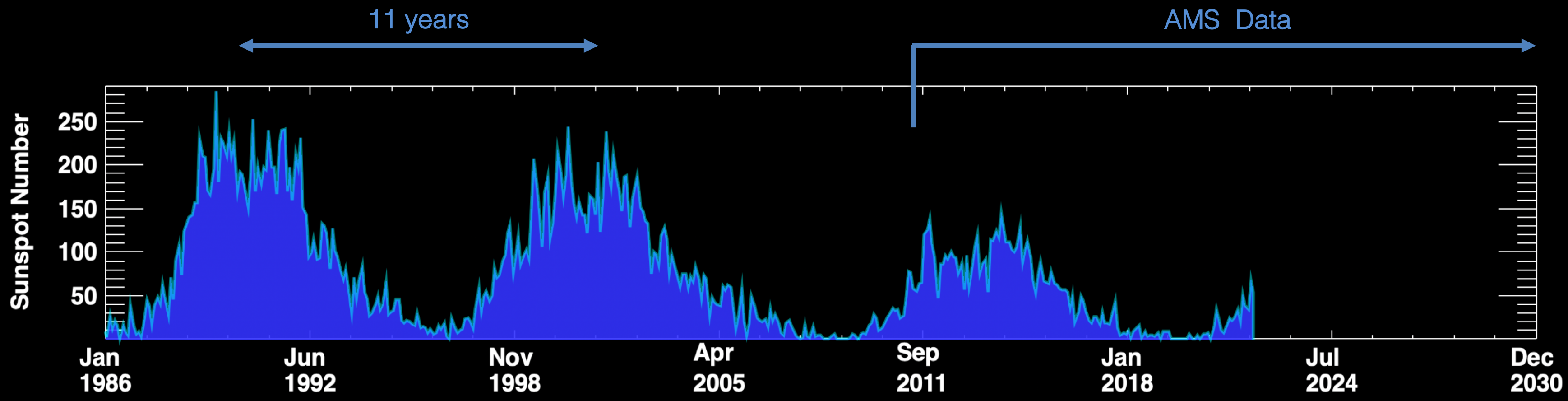
CRIS 2022
12th Cosmic Ray International Seminar
Naples, Italy, September 12 -16, 2022

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:

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

Particle density in phase space ($\frac{\partial f}{\partial t}$) — **Solar wind convection** ($-\vec{V}_{SW} \cdot \vec{\nabla} f$) — **Diffusion and Drifts** ($\vec{\nabla} \cdot (\mathrm{K} \cdot \vec{\nabla} f)$) — **Adiabatic energy losses** ($\frac{1}{3} \vec{\nabla} \cdot \vec{V}_{SW} \frac{\partial f}{\partial lnR}$)

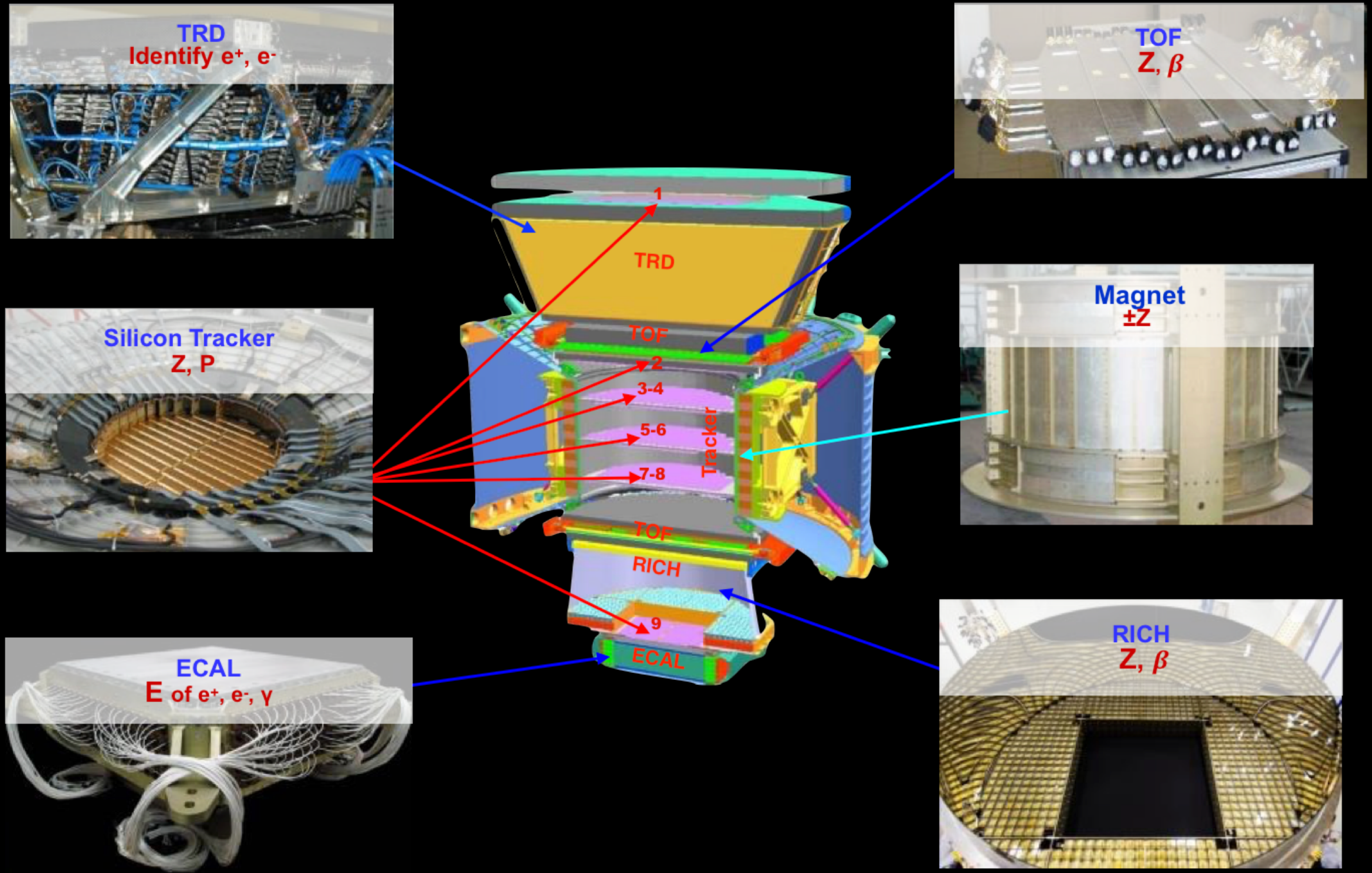
- Velocity dependence of the diffusion tensor: the velocity induces changes in this term for nuclei with different A/Z since $\beta(R) = \frac{R}{\sqrt{R^2+(A/Z)^2(mc)^2}}$
- Difference in spectral shape: the adiabatic energy losses term depends on the spectral shape. If two nuclei have different spectral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

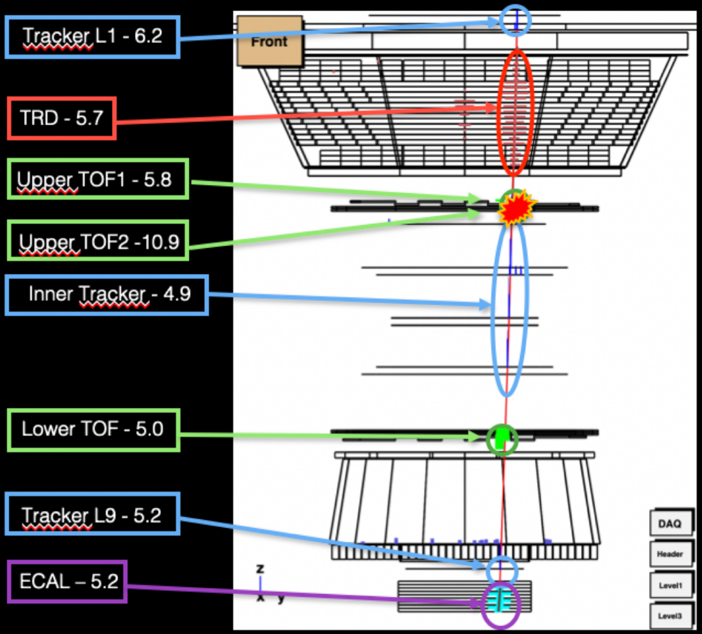
AMS-02 detector

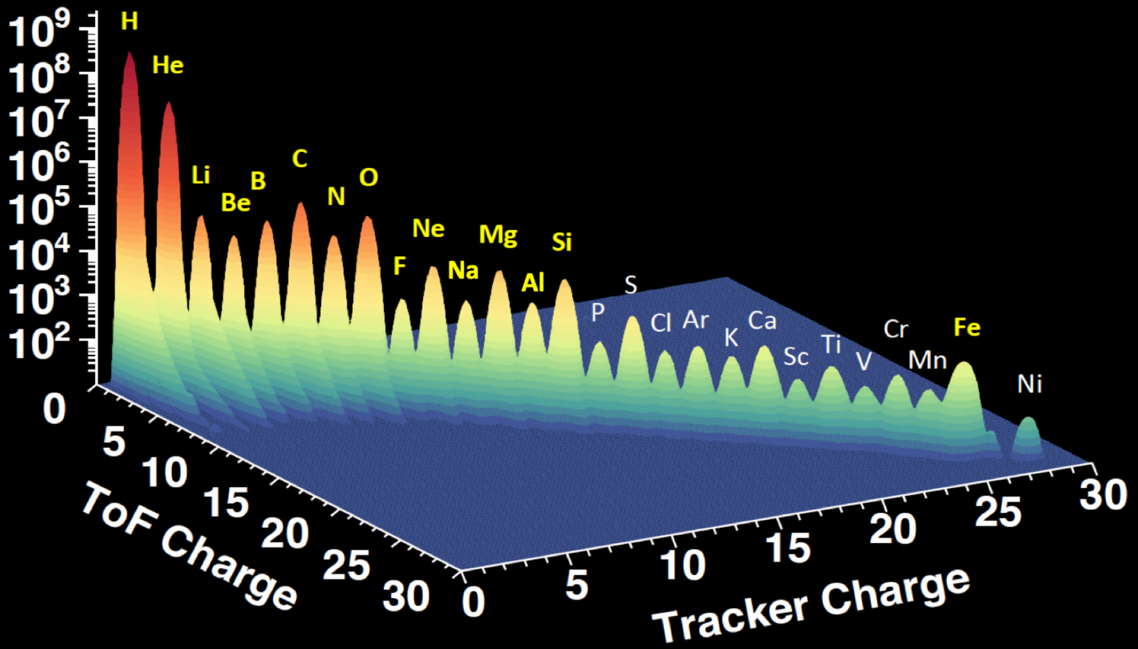
Particles and nuclei are defined by their charge (**Z**) and energy (**E ~ P**)

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



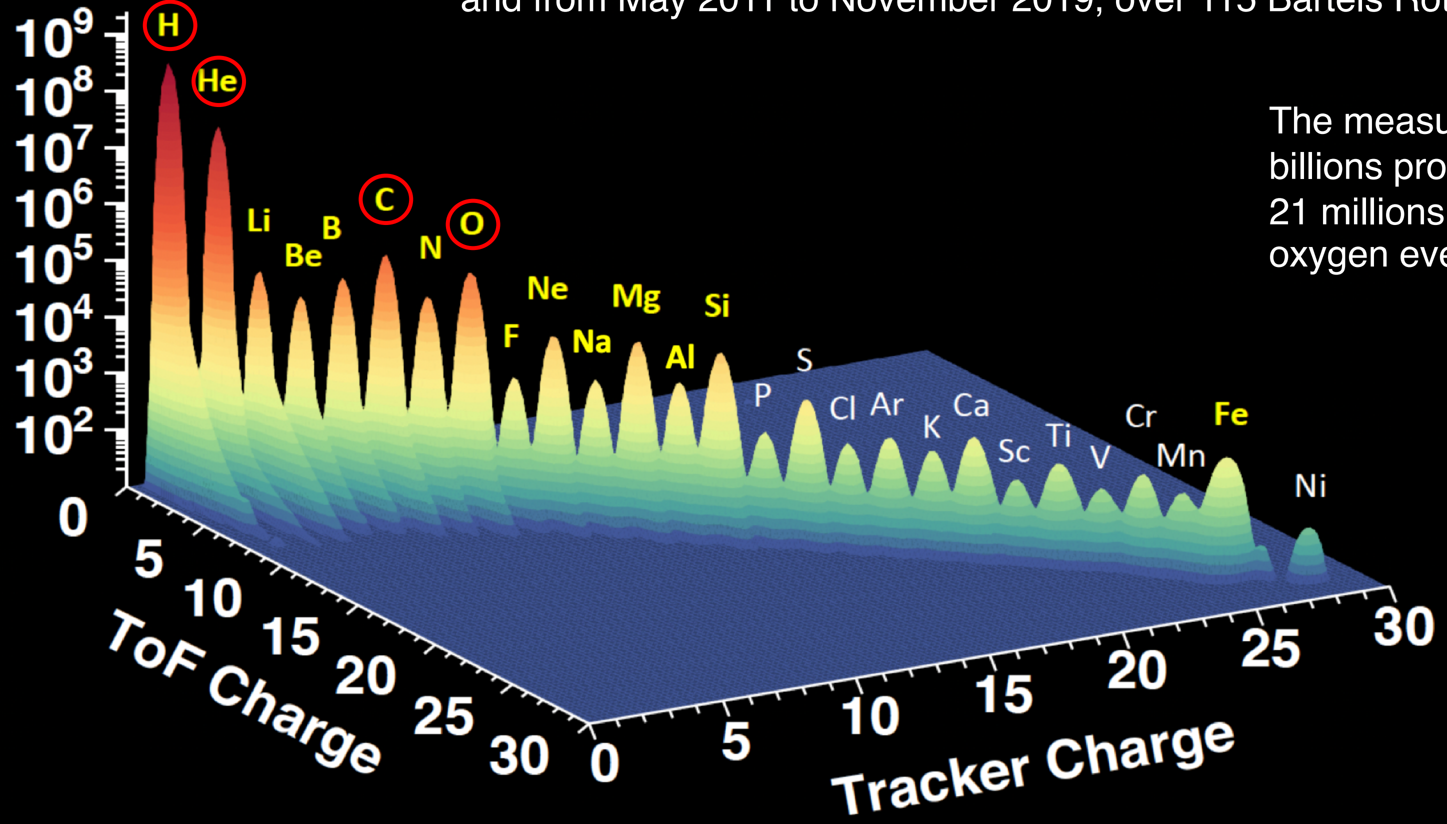
AMS-02 Charge Measurement





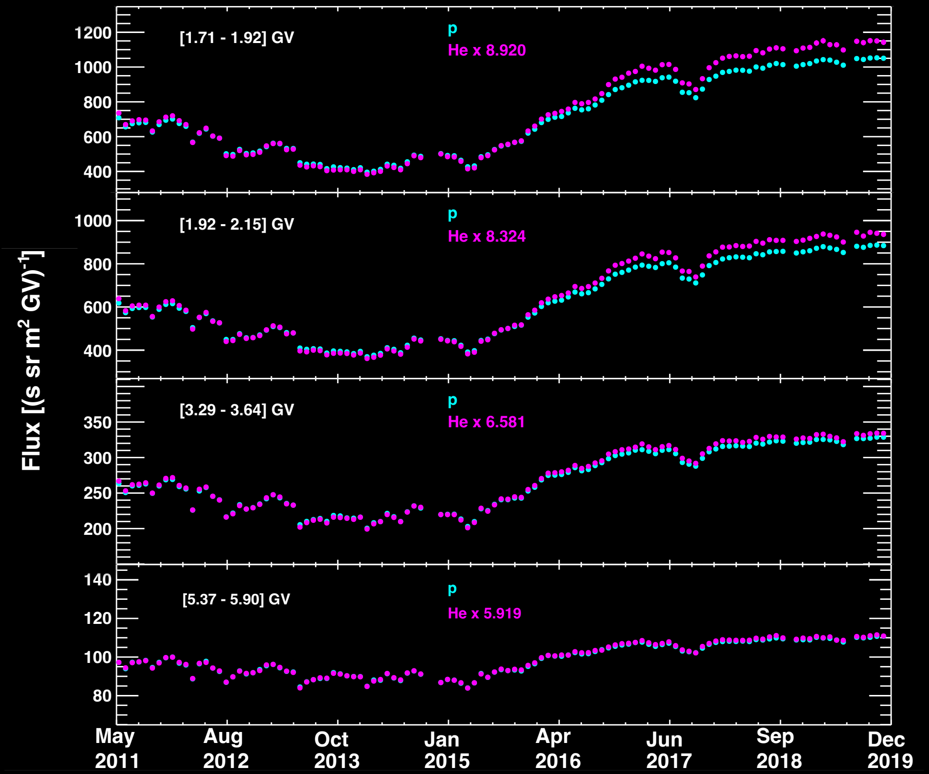
AMS Periodic Table

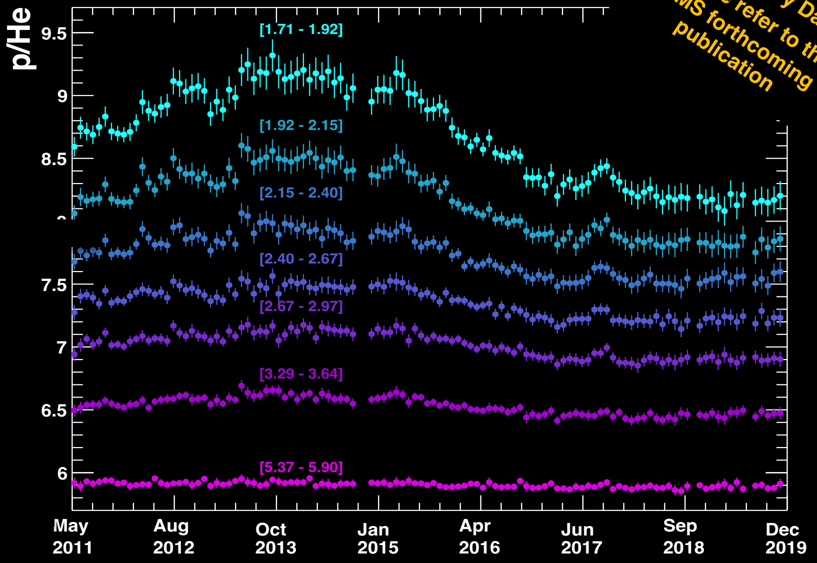
Time evolution of the proton, helium, carbon, and oxygen fluxes from 1 GV to 60 GV, and from May 2011 to November 2019, over 115 Bartels Rotation (27 days)



The measurement is based on 5.5 billions proton, 760 millions helium, 21 millions carbon and 17 millions oxygen events,

Time evolution: protons and Helium



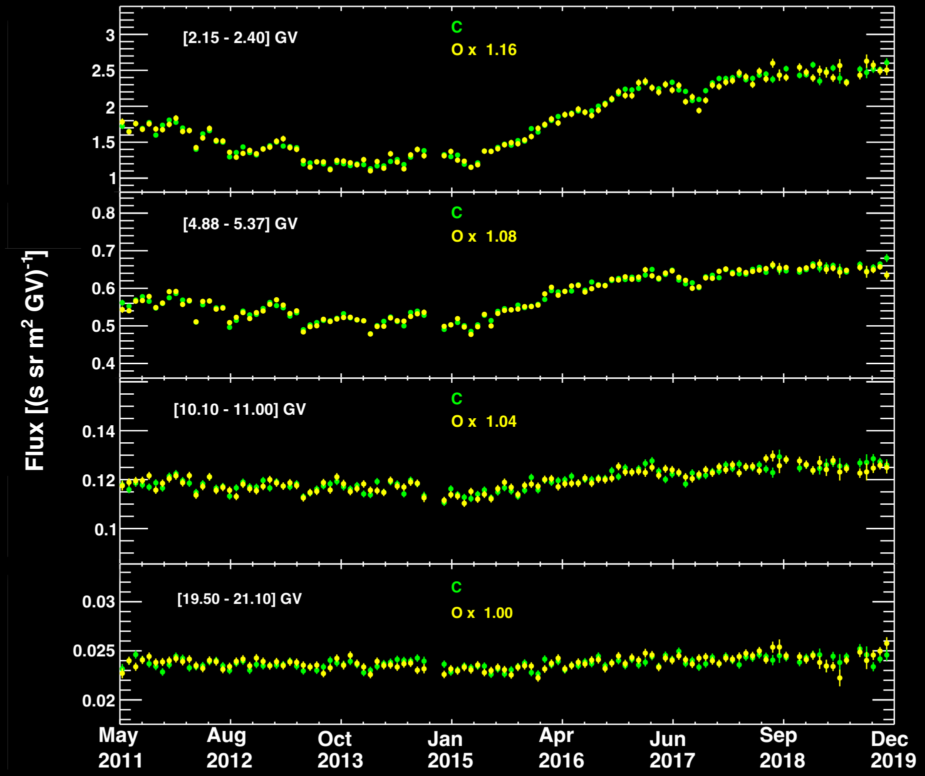


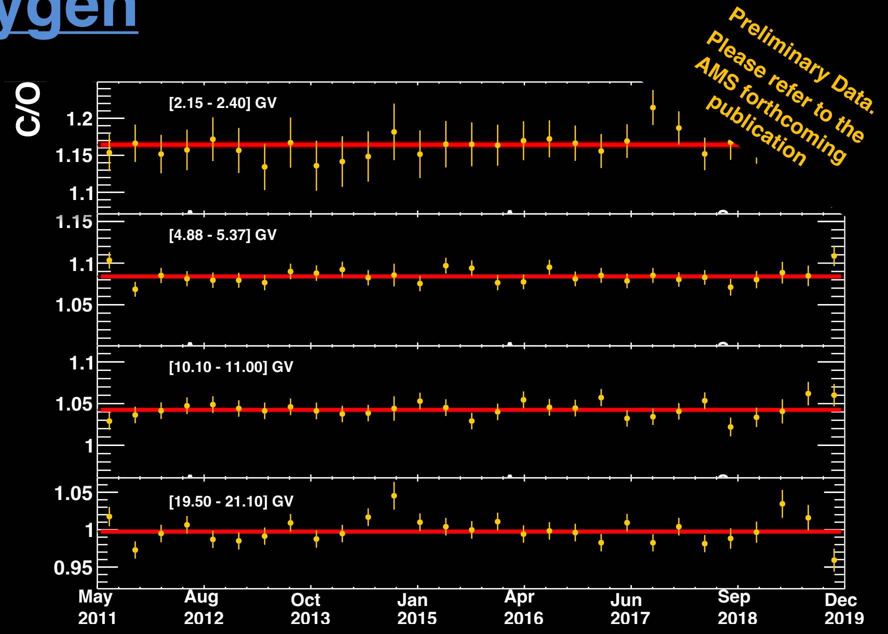
Preliminary Data. Please refer to the AMS forthcoming publication

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

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

Time evolution: Carbon and Oxygen



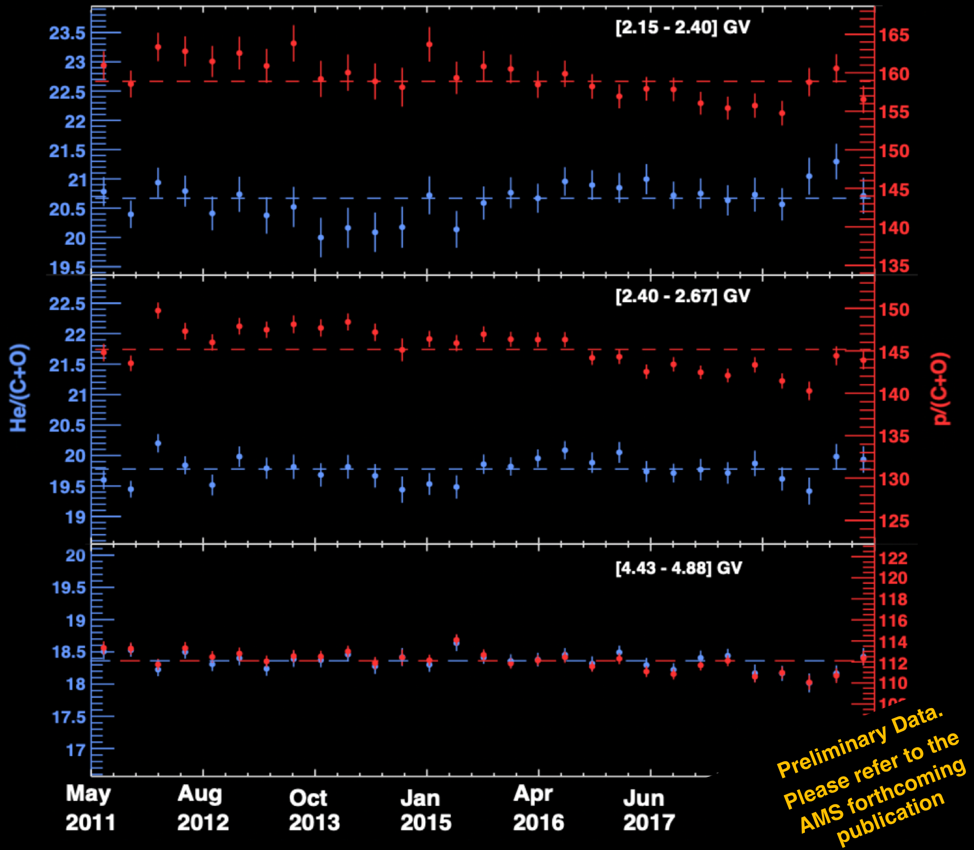


- ❑ C and O fluxes present short and long term variations as observed on p and He fluxes.
- ❑ C and O fluxes have the same time evolution above 2 GV)

- ❑ **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 (> 5σ) below 3.29 GV
- ❑ The He/(C+O) ratio show a small deviation ($\sim 3\sigma$) from a costant value below 2.4 GV
- ❑ **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)**