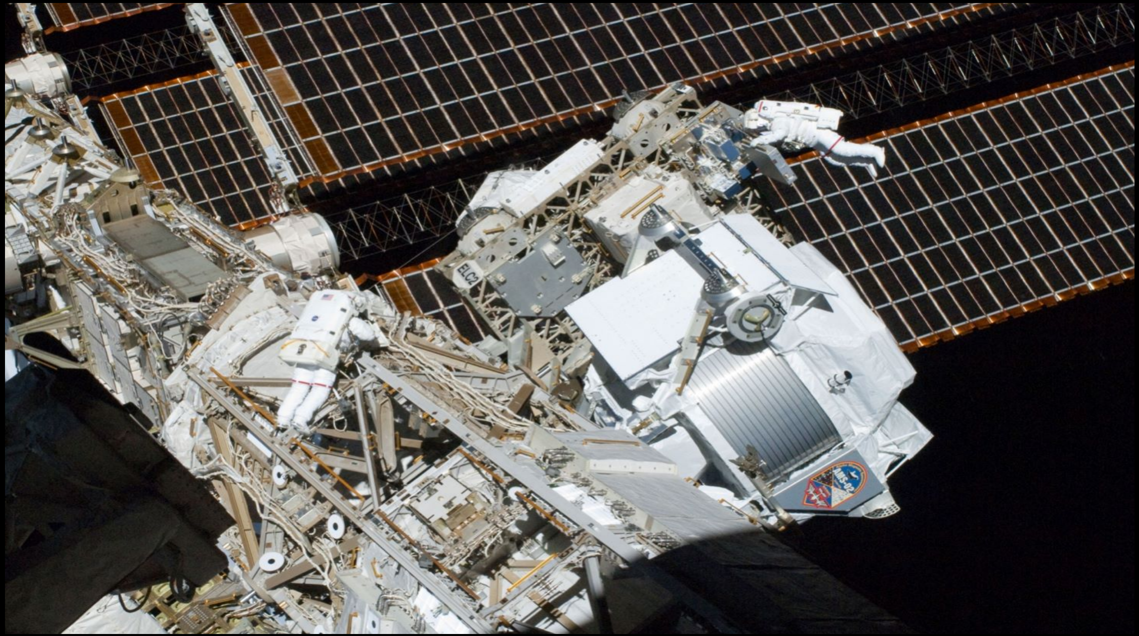
Precision Measurement of the Monthly Proton, Helium, Carbon, and Oxygen Fluxes in Cosmic Rays with the Alpha Magnetic Spectrometer on the International Space Station

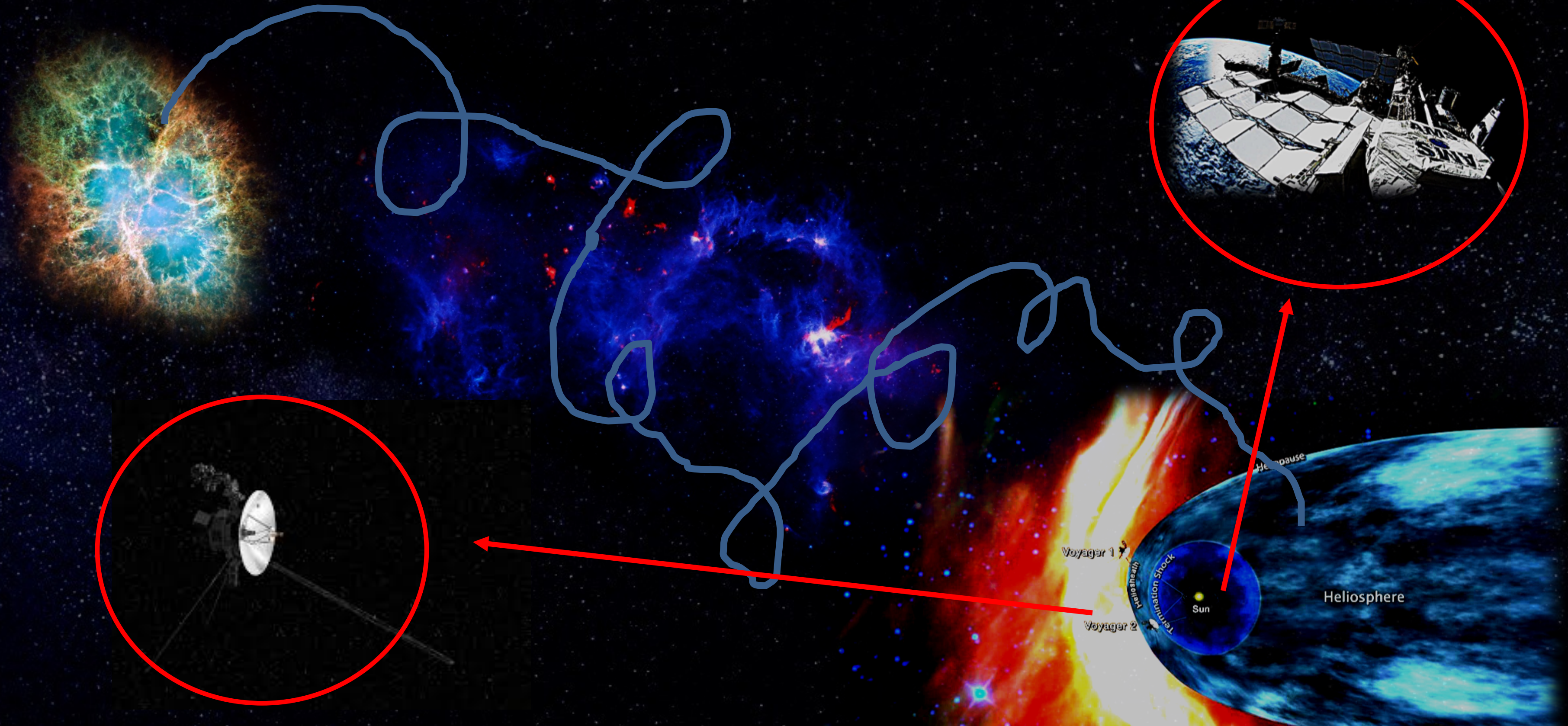
Behrouz Khiali
(ASI-SSDC, INFN di Roma Tor Vergata)

On behalf the AMS-02 Collaboration



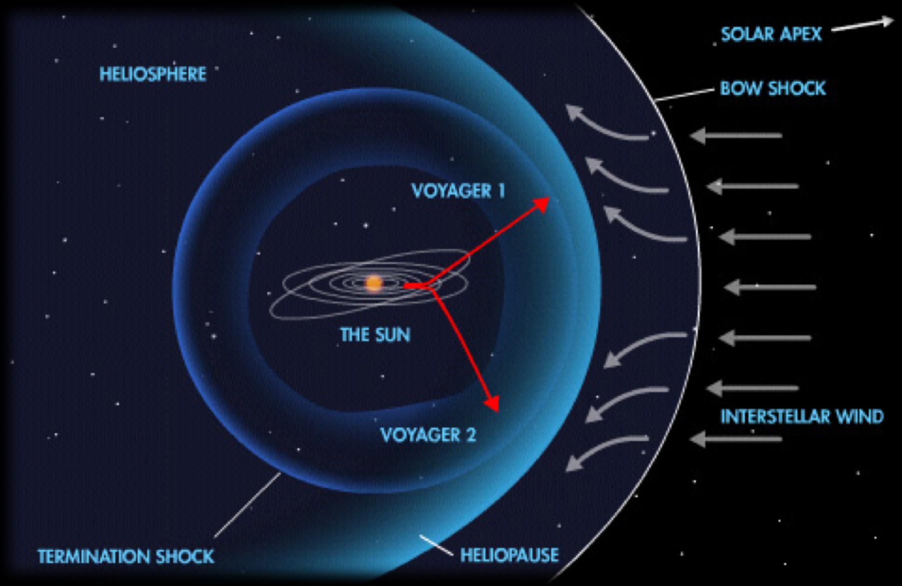
ECRS 2022
Nijmegen, 28-July-2022

Galactic Cosmic Rays



The galactic cosmic rays enter the heliosphere through a combination of diffusion (random walk) and drift

Galactic CRs arrived in the heliosphere …

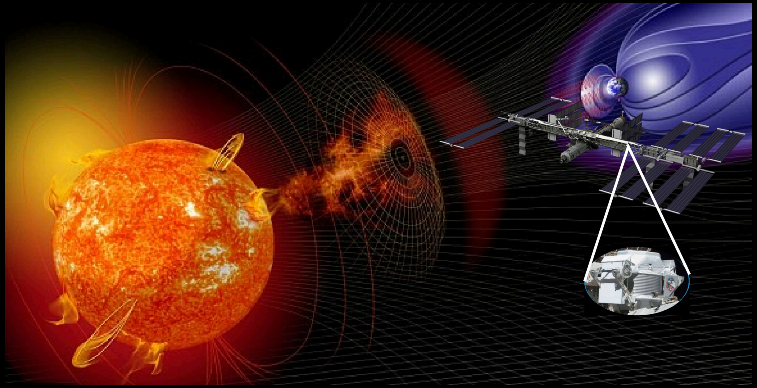


- Galactic cosmic rays encounter a turbulent solar wind with an embedded heliospheric magnetic field when entering the heliosphere.
- This leads to significant global and temporal variations in their intensity and in their energy as a function of position inside the heliosphere.
- This process is identified as the **solar modulation** of cosmic rays .

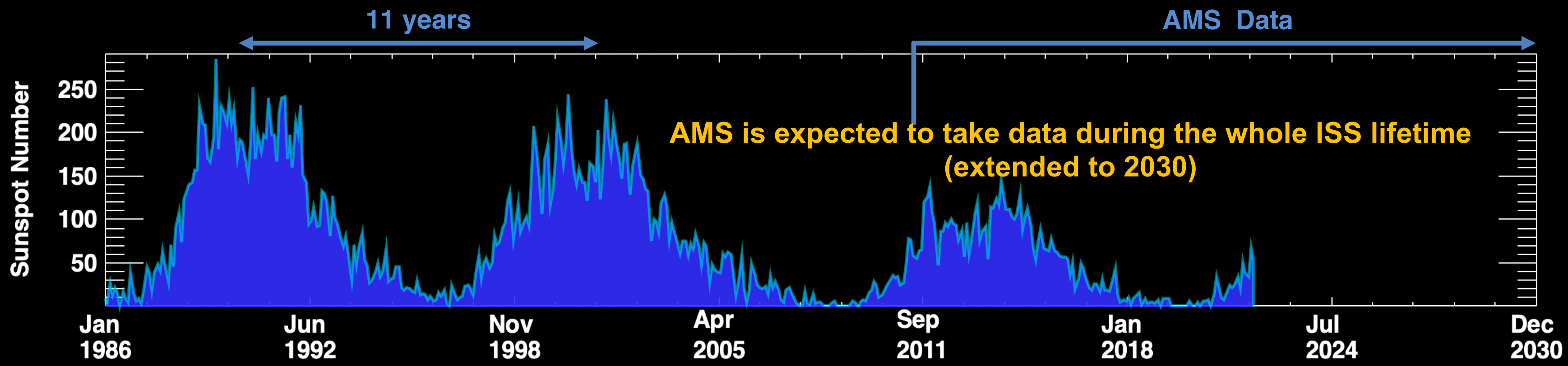
The Golden Age:

Data from Interstellar medium taken by Voyager 1 & 2

Solar physics with AMS-02

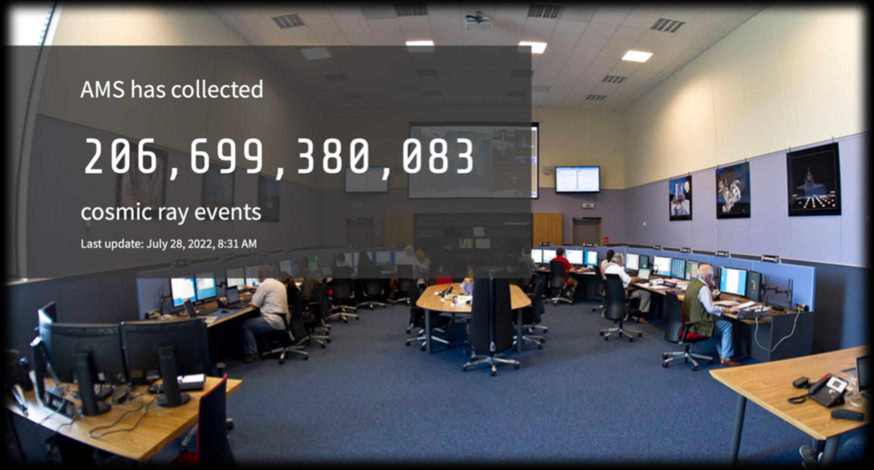


Among the physics goals of AMS are measuring GCR fluxes and their time variation, to study solar modulation effect and short-term solar during both periods of maximum and minimum of solar activity



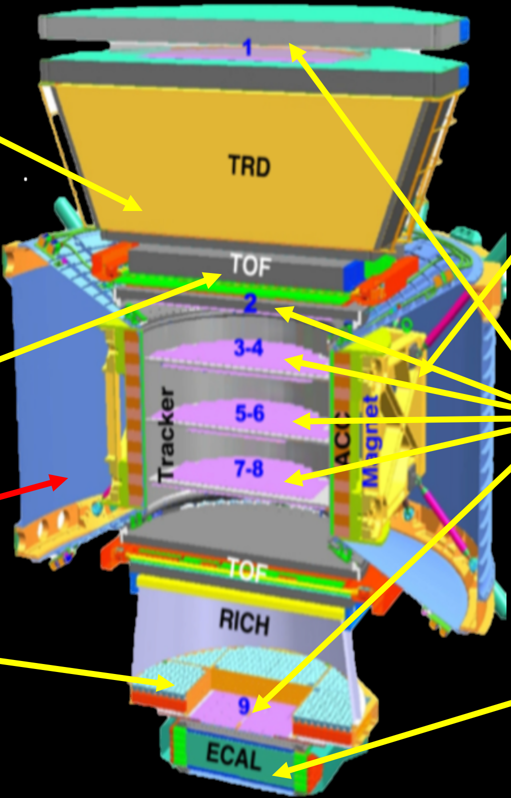
AMS-02 Detector

https://ams02.space



- AMS-02 is a large-acceptance high-energy magnetic spectrometer able to perform precision measurements of particles in the GeV-TeV energy range.

AMS-02 Detector



TRD:
Identify e+, e-, Z

TOF:
Z, E

RICH:
Z, E

Magnet:
±Z

Silicon Tracker:
Z, P

ECAL:
E of e+, e-

Particles and nuclei are measured by their charge (Z), energy (E), momentum (P) or Rigidity R = P/Z

Z and P are measured independently by the Tracker, RICH, TOF and ECAL

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

Particle density in phase space

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

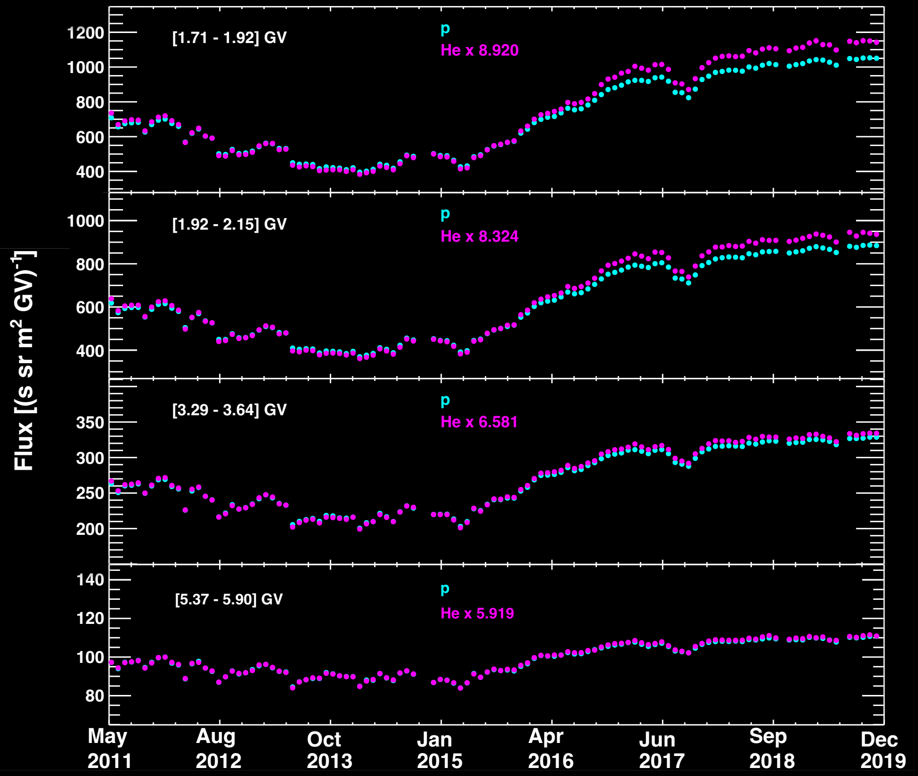
Solar wind convection | **Diffusion and Drifts** | **Adiabatic energy losses**

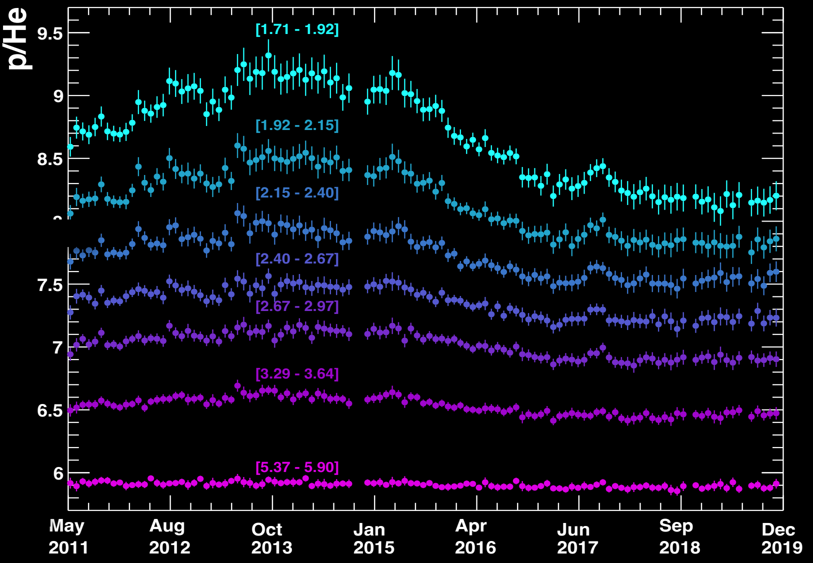
- Velocity dependence of the diffusion tensor: $\mathrm{K}(\vec{r}, R) = \beta \mathrm{K}_1(\vec{r})\, \mathrm{K}_2(R)$
  the velocity induces changes in this term for nuclei with different A/Z $\beta(R) = \frac{R}{\sqrt{R^2+(A/Z)^2(mc)^2}}$.

- 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

Time evolution: protons and Helium (8.5 Years, 115 Bartels rotation)

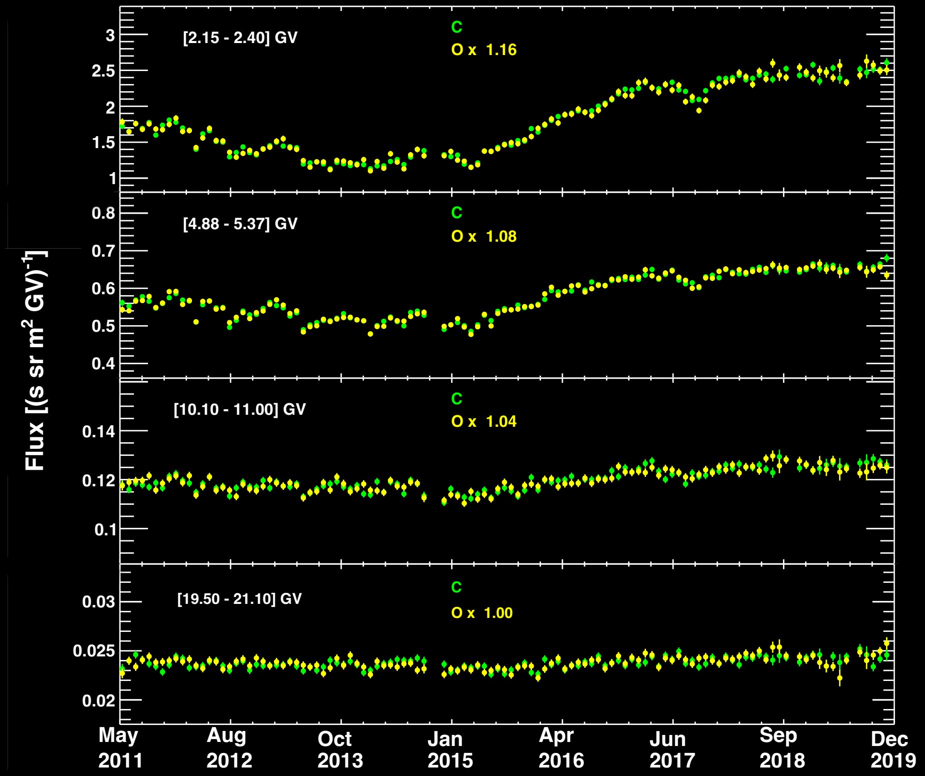


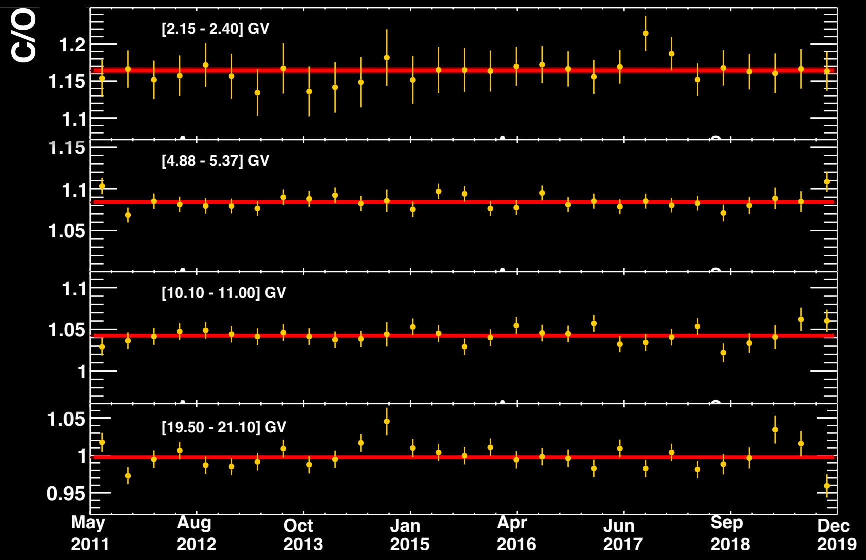


- p and He fluxes present short and long term variations
- He flux more modulated with respect p flux

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

Time evolution: Carbon and Oxygen (8.5 Years, 115 Bartels rotation)



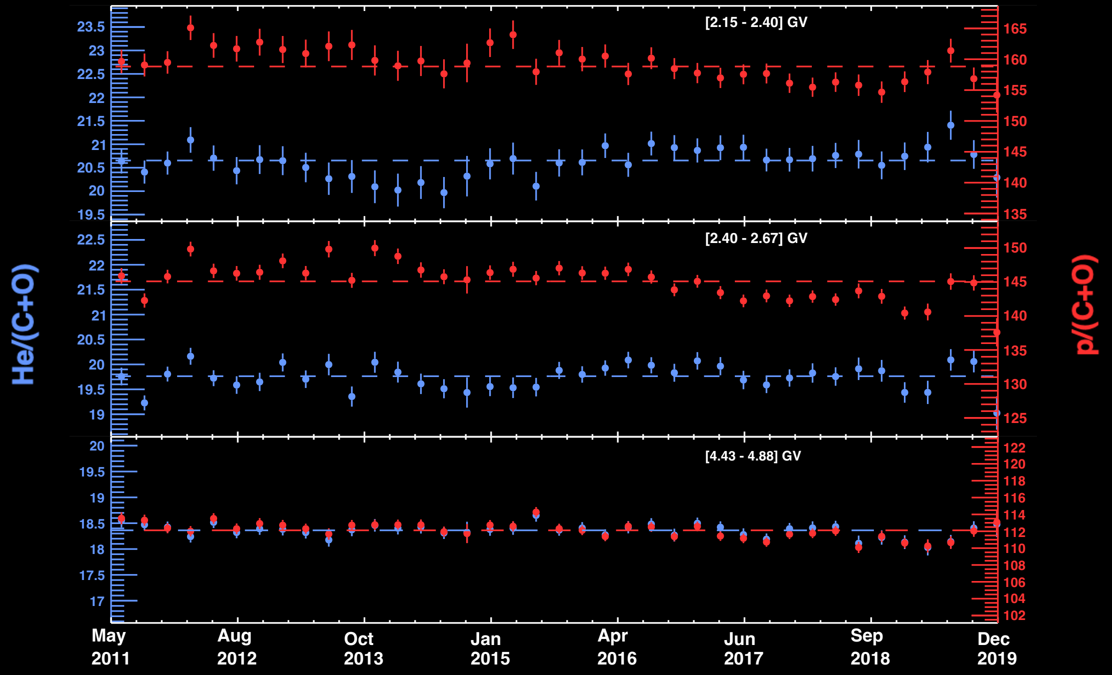


- ❑ C and O fluxes present short and long term variations as observed on p and He fluxes.
- ❑ C and O fluxes have the same time evolution above 2 GV)

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

Time evolution: Fluxes comparison

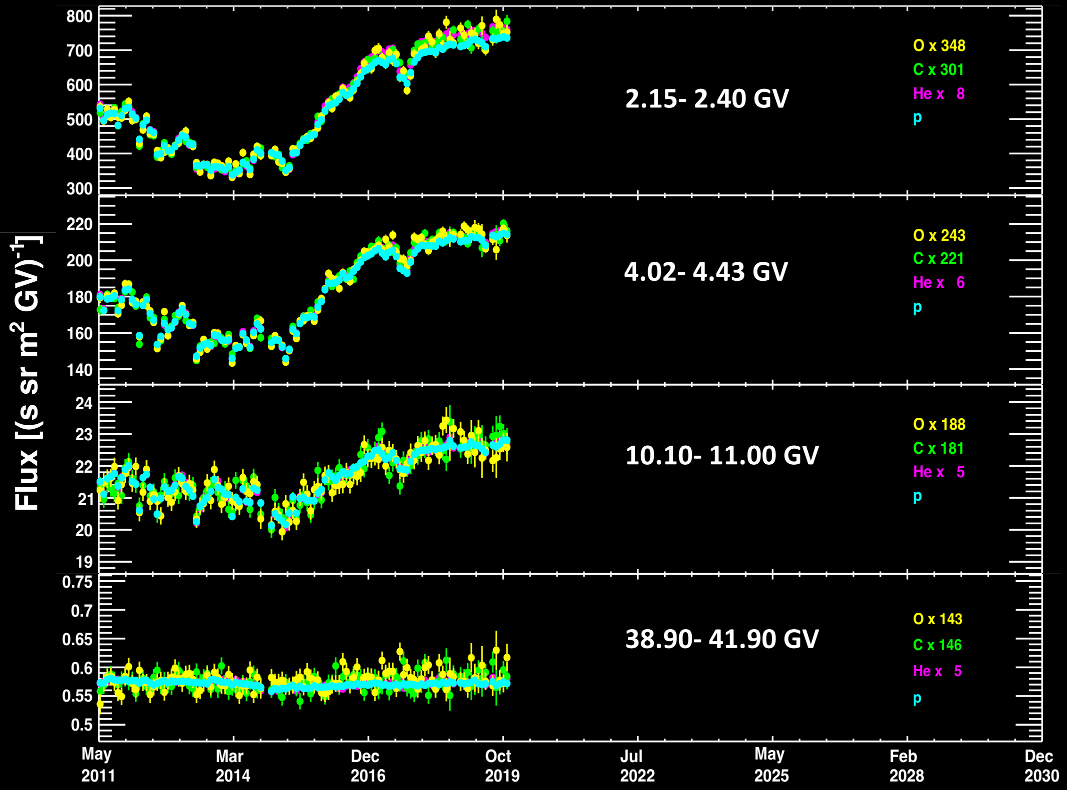
Since C and O have the same time evolution, we can perform the p/(C+O) and the He/(C+O) fluxes ratios



- ❑ 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 linear trend (i.e. constant ratio)

- ❑ **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 regarding the propagation of charged particles inside the Heliosphere

- ❑ **AMS-02 will continue taking data for the entire duration of the ISS, continuing the search for dark matter, primordial antimatter and a more detailed description of cosmic rays fluxes**