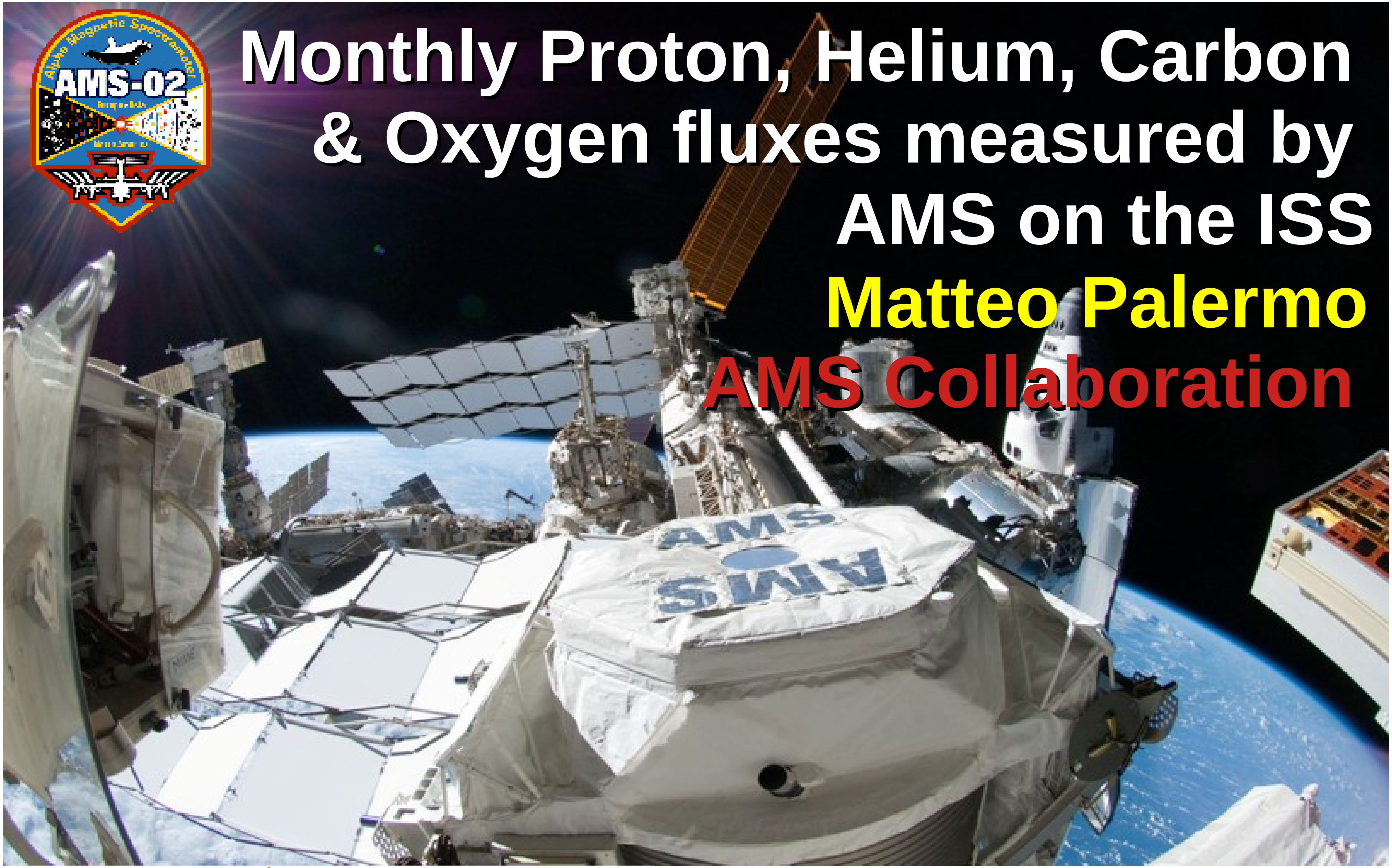


Monthly Proton, Helium, Carbon & Oxygen fluxes measured by AMS on the ISS

Matteo Palermo

AMS Collaboration

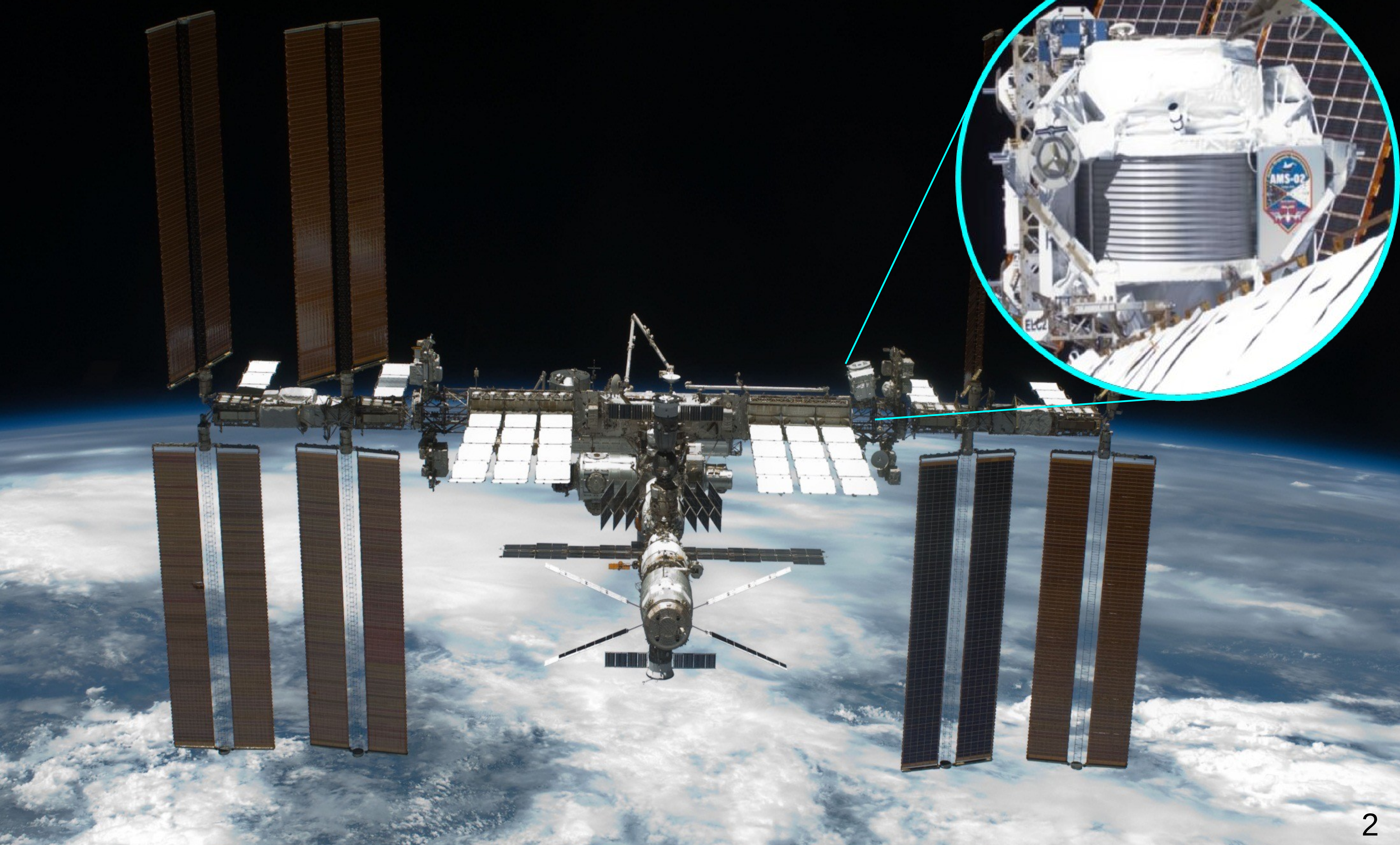
ONLINE ICRC 2021
THE ASTROPARTICLE PHYSICS CONFERENCE
Berlin | Germany

37th International Cosmic Ray Conference
12–23 July 2021

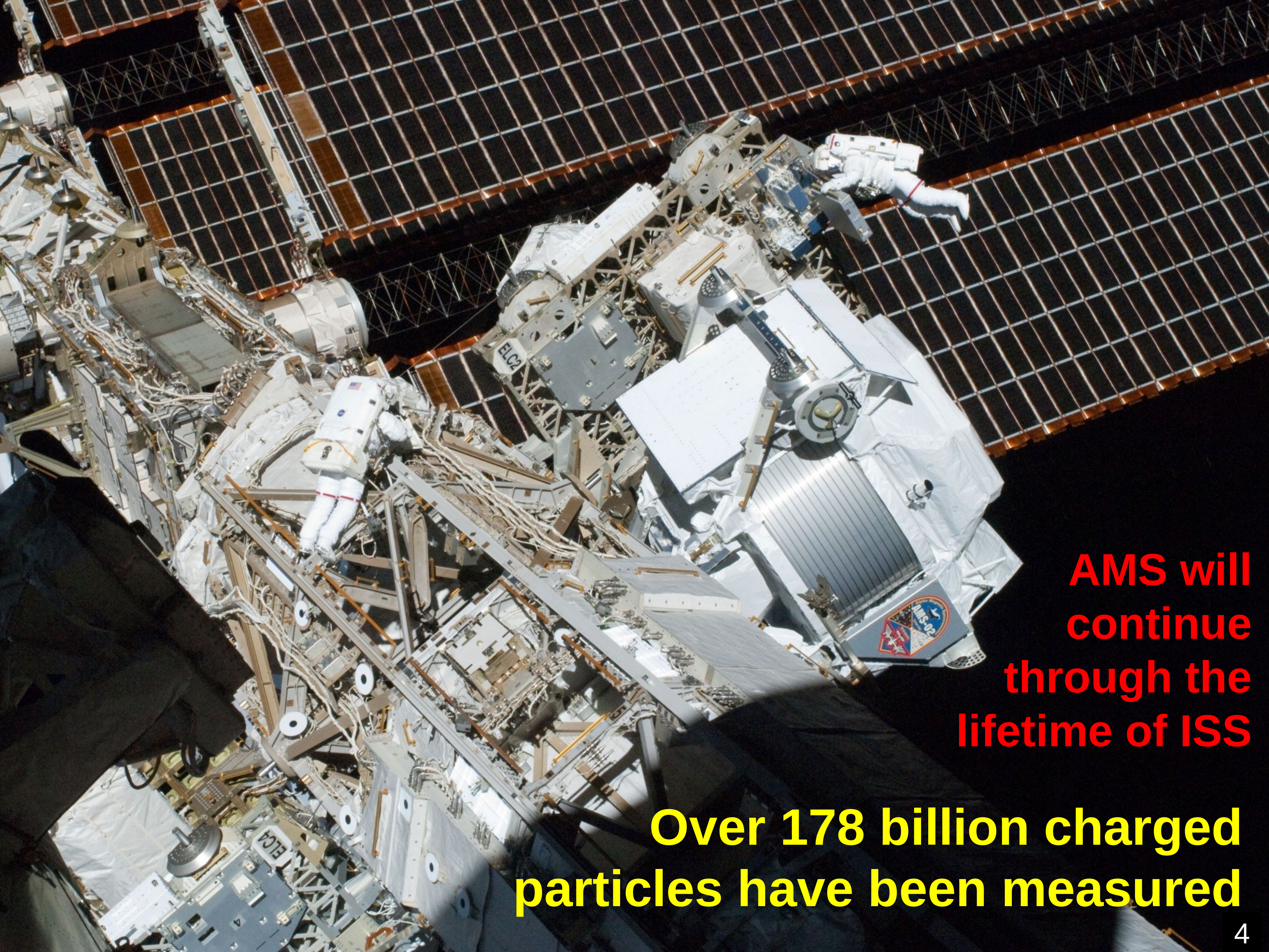
Physics and Astronomy Department
University of Hawaii at Manoa
Honolulu, Hawaii, US

ISS
Altitude: ~400 km
Orbit: 90 minutes
Size: 70m x 110m x 20m

AMS-02
Size: 5m x 4m x 3m
Weight: 7.5 ton
Power: 2.4 kW




AMS on the ISS
10-th Year Anniversary
May 16, 2011: AMS Flight, Space Shuttle Endeavor

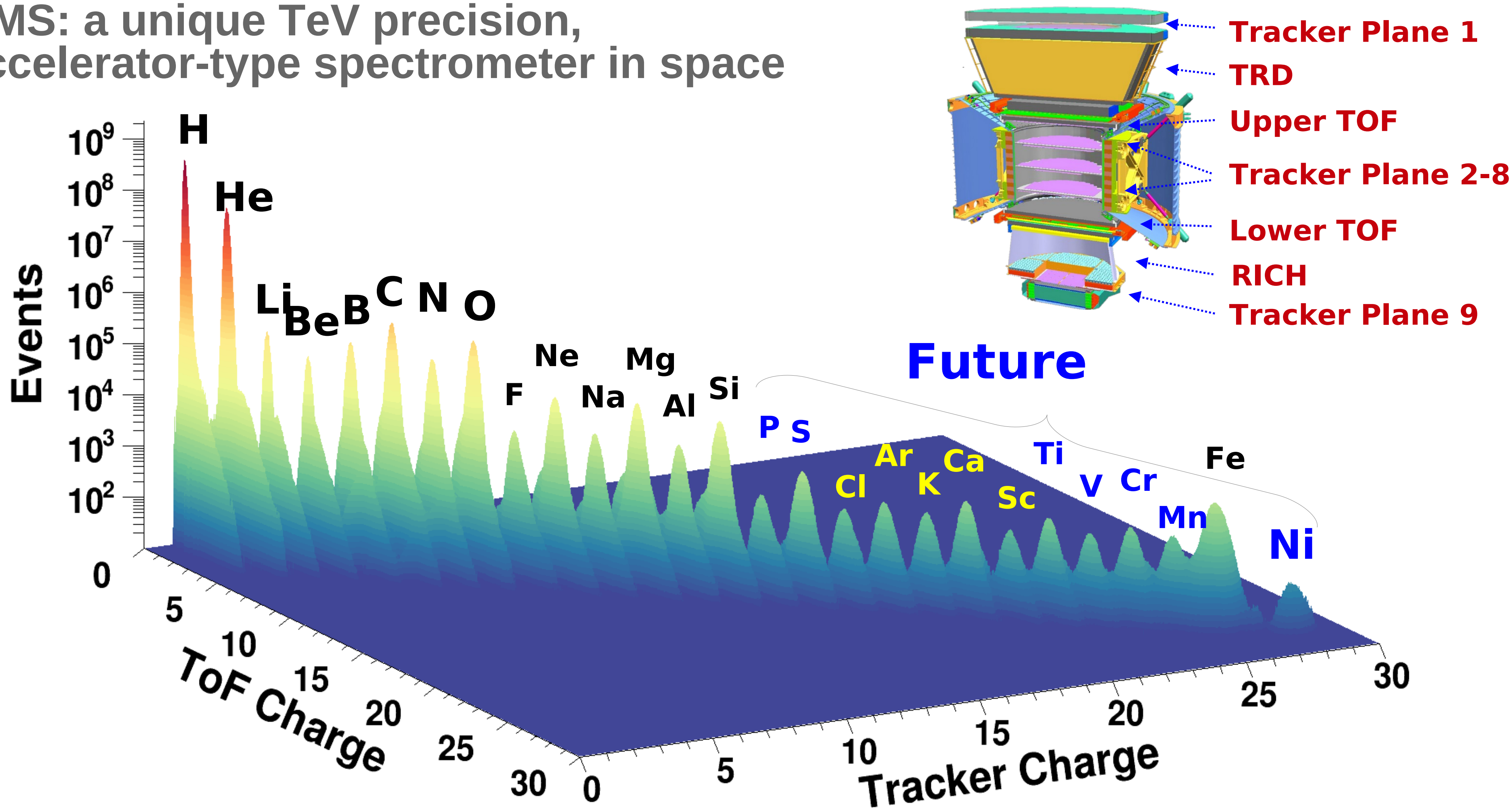


AMS will continue through the lifetime of ISS

Over 178 billion charged particles have been measured

Precision Measurements of Cosmic Rays

AMS: a unique TeV precision, accelerator-type spectrometer in space



AMS has 7 instruments which independently measure Cosmic Nuclei

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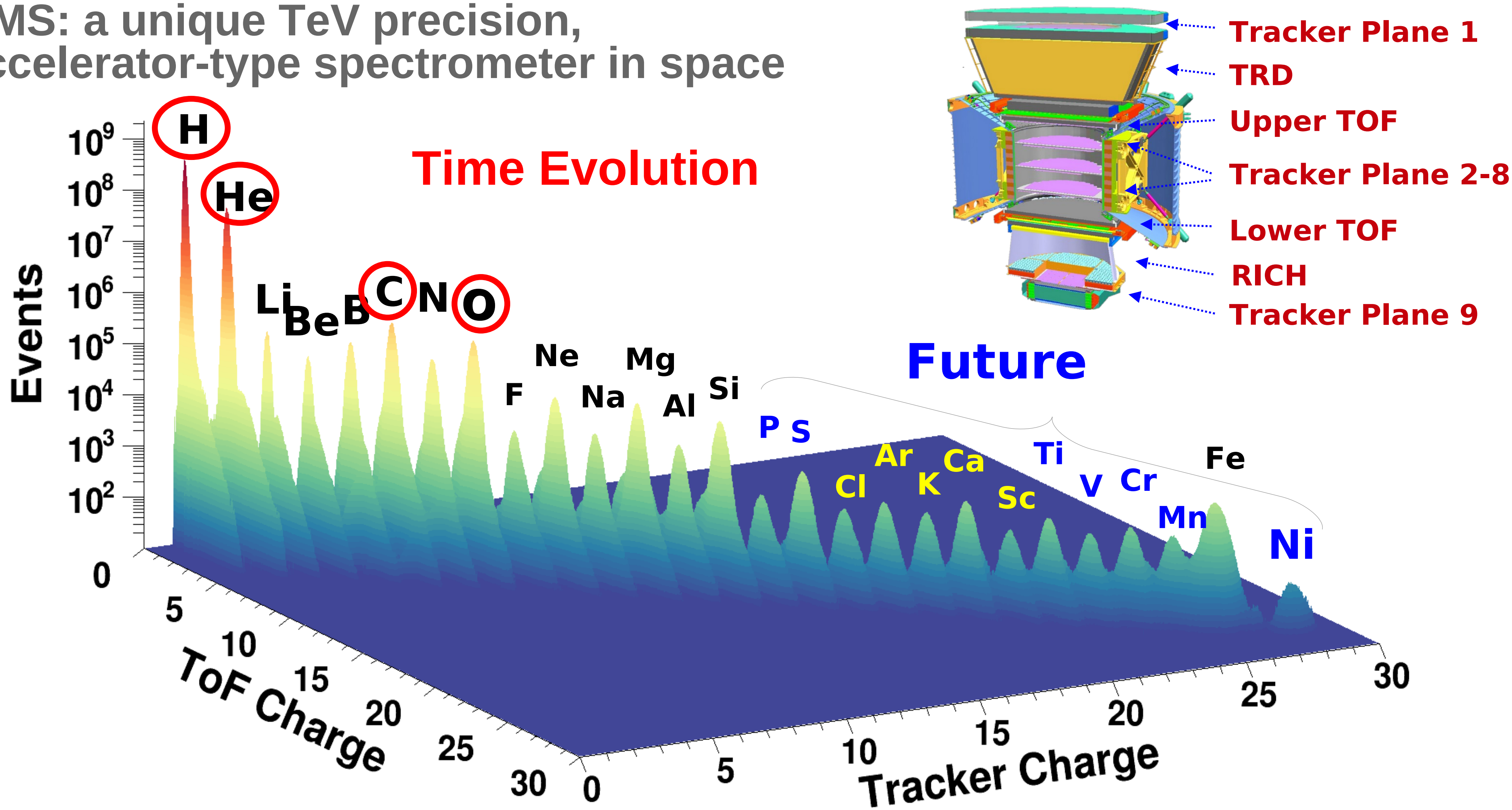
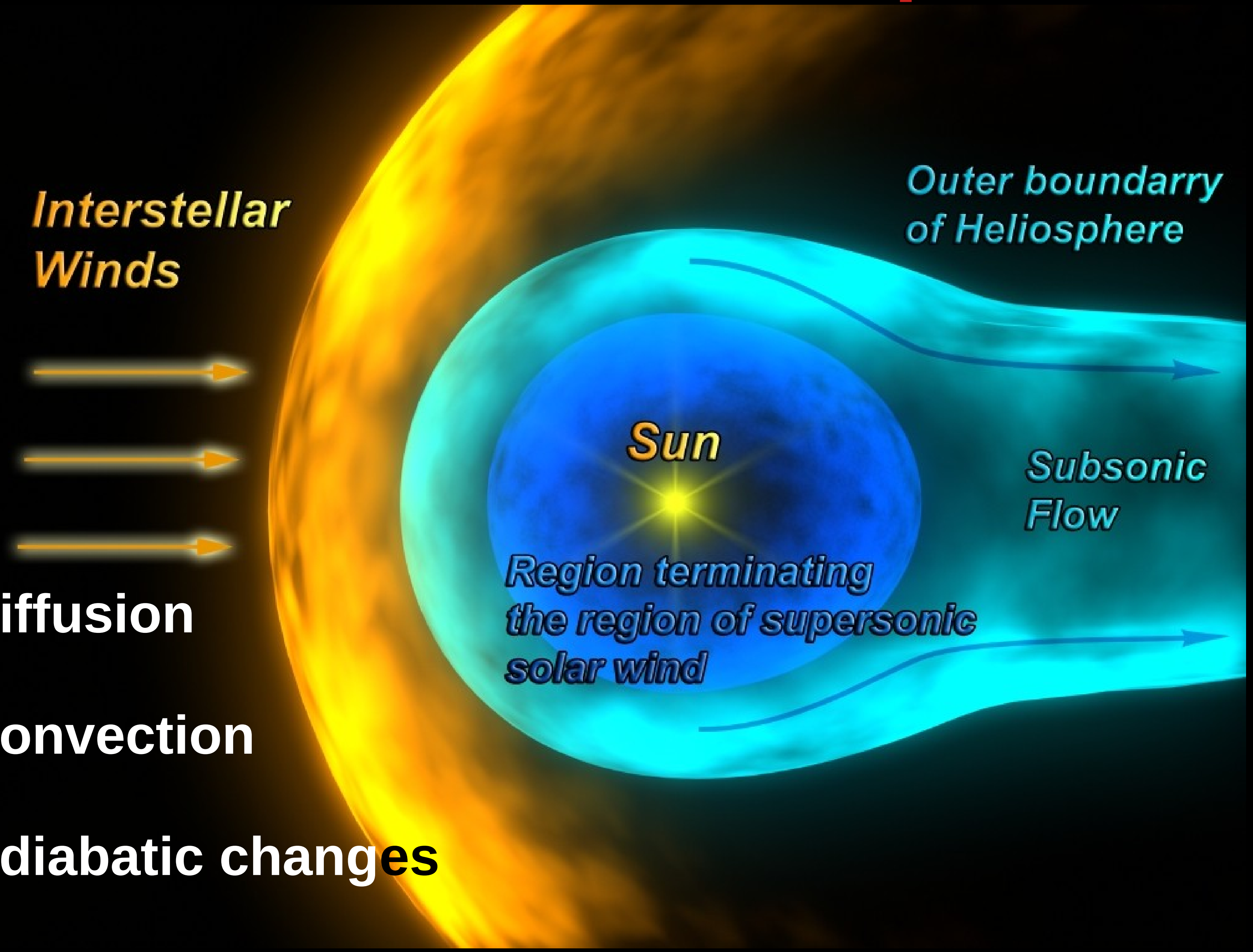


AMS has 7 instruments which independently measure Cosmic Nuclei

GCR in the Heliosphere



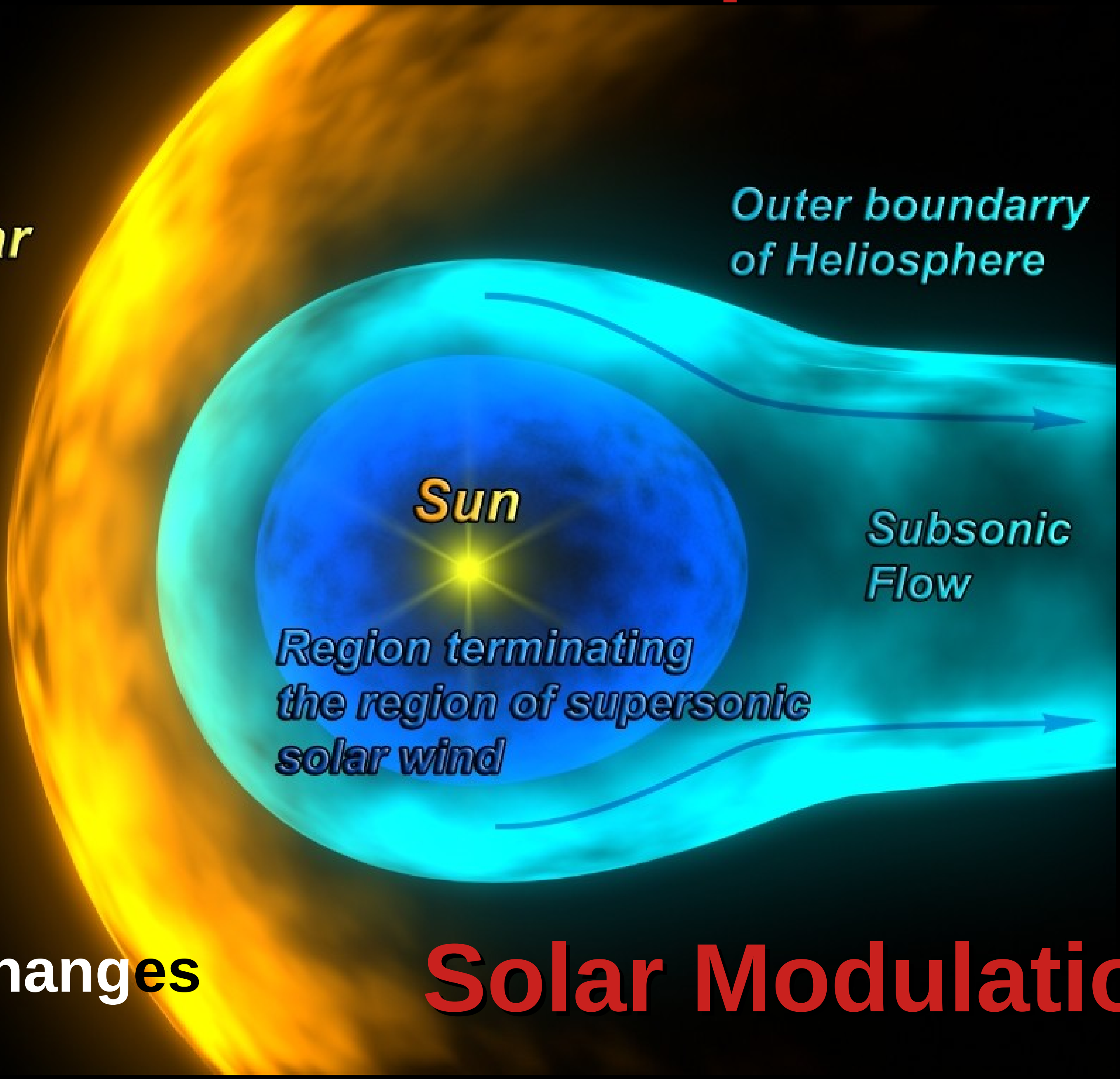
GCRs

- **Diffusion**
- **Convection**
- **Adiabatic changes**
- **Magnetic drift**

GCR in the Heliosphere

Interstellar Winds

GCRs



- **Diffusion**
- **Convection**
- **Adiabatic changes**
- **Magnetic drift**

Solar Modulation

GCR in the Heliosphere

The Cosmic Ray propagation in the Heliosphere is described by the **Parker Equation:**

$$\frac{\partial f}{\partial t} + \underbrace{\vec{V}_{sw} \cdot \vec{\nabla} f}_{\text{Solar wind plasma convection}} - \underbrace{\vec{\nabla} \cdot (K \cdot \vec{\nabla} f)}_{\text{Diffusion and drifts}} - \underbrace{\frac{1}{3} \vec{\nabla} \cdot \vec{V}_{sw} \frac{\partial f}{\partial \ln R}}_{\text{Adiabatic energy losses and gains}} = 0$$

GCR in the Heliosphere

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Phase space distribution function of GCRs

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- **Time Evolution**

Solar wind plasma convection

Diffusion and drifts

Adiabatic energy losses and gains

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- **Time Evolution**

- **Velocity dependence of the diffusion tensor:**

$$k(r, R) = \beta k_1(r) k_2(R)$$

Nuclei with distinct A/Z result in different velocity, hence a different behavior

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Diffusion and drifts

Adiabatic energy losses and gains

- **Velocity dependence of the diffusion tensor:**

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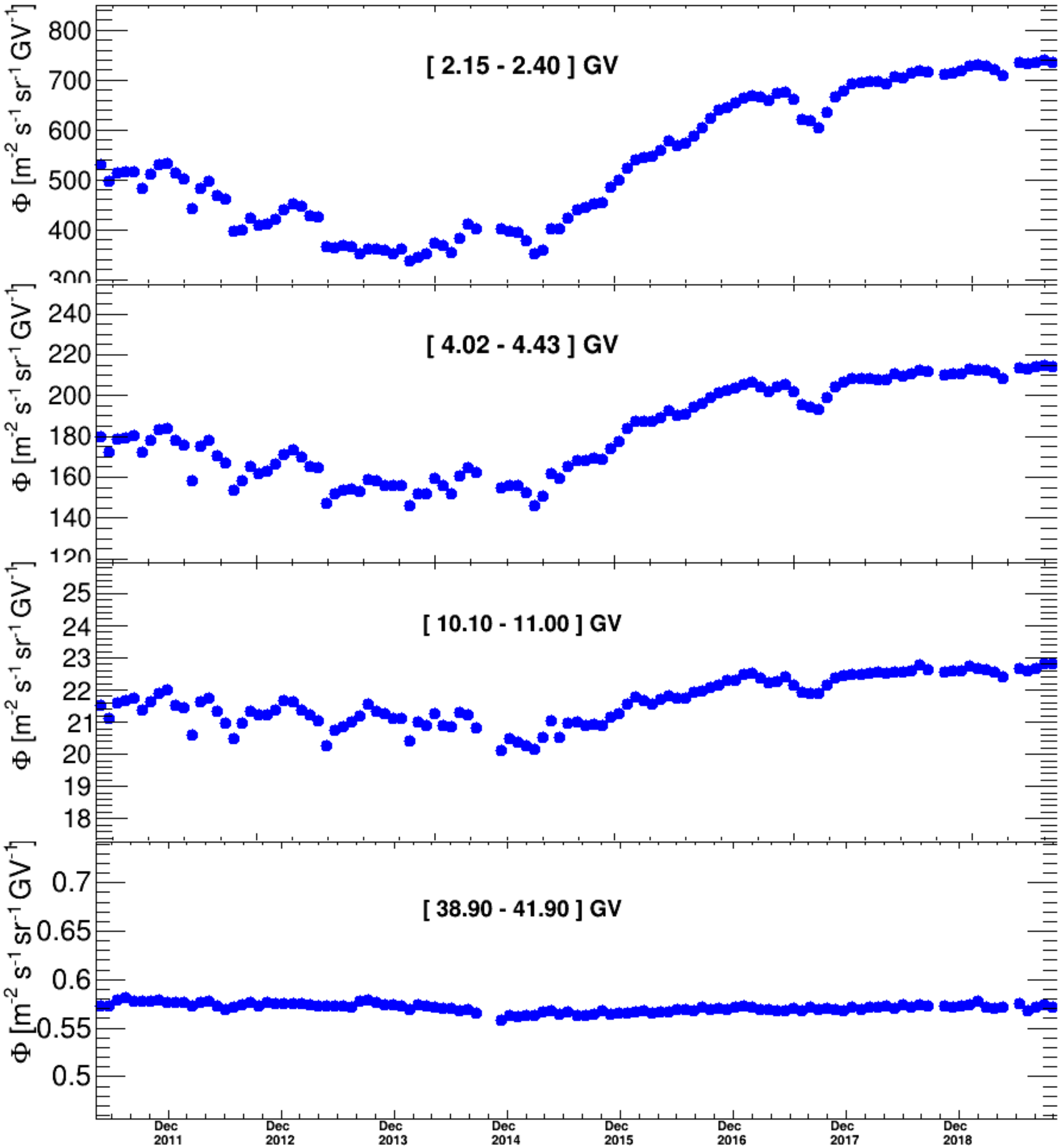
Nuclei with distinct A/Z result in different velocity, hence a different behavior

- **Difference in the spectral shape outside the heliosphere (Local Interstellar Spectrum, LIS):**

the adiabatic energy changes term depends on the LIS shape, hence nuclei with different LIS behave differently.

Time Evolution

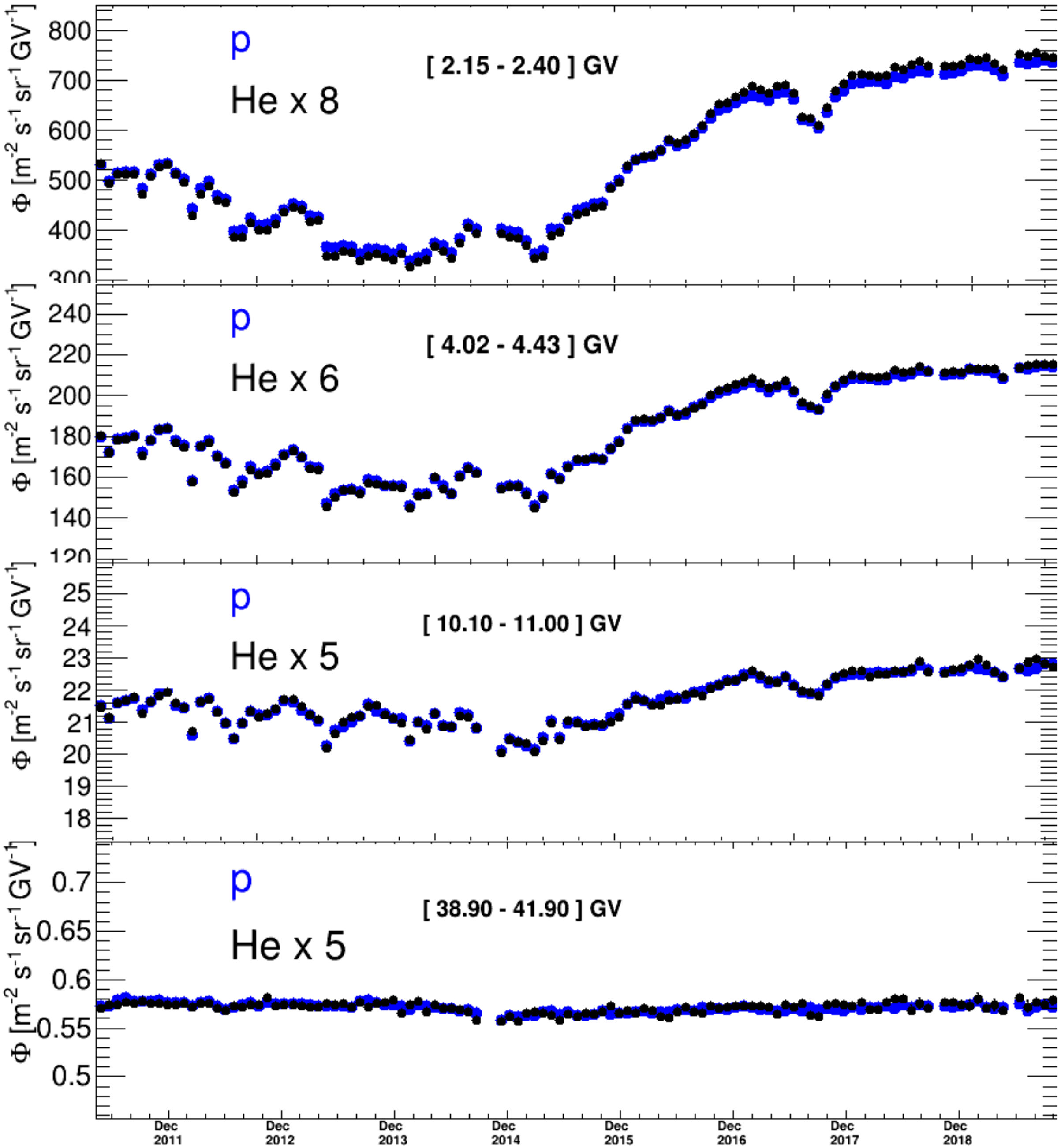


Preliminary Data
Please refer to the AMS forthcoming publication in PRL

- **proton**, fluxes **from May 2011 to Oct. 2019**, in 27 days time interval (Bartels rotations)

- Rigidity ranges:
  [1 , 60] GV for p

Time Evolution



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- **proton, Helium,** fluxes **from May 2011 to Oct. 2019**, in 27 days time interval (Bartels rotations)

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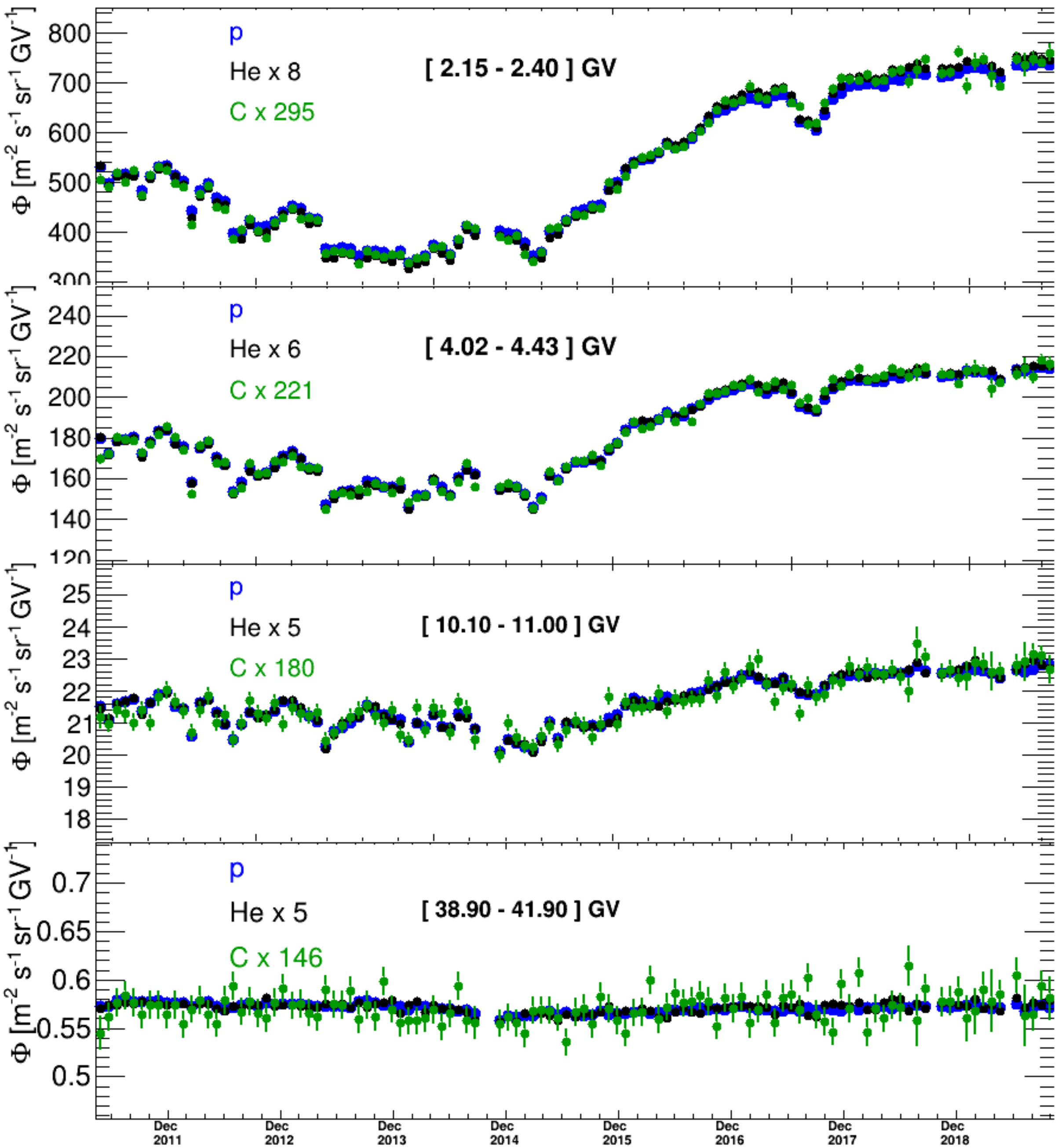
Time Evolution



Preliminary Data
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- **proton, Helium, Carbon** fluxes **from May 2011 to Oct. 2019**, in 27 days time interval (Bartels rotations)

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  - [1.7, 60] GV for He
  - [1.9 , 60] GV for C

Time Evolution

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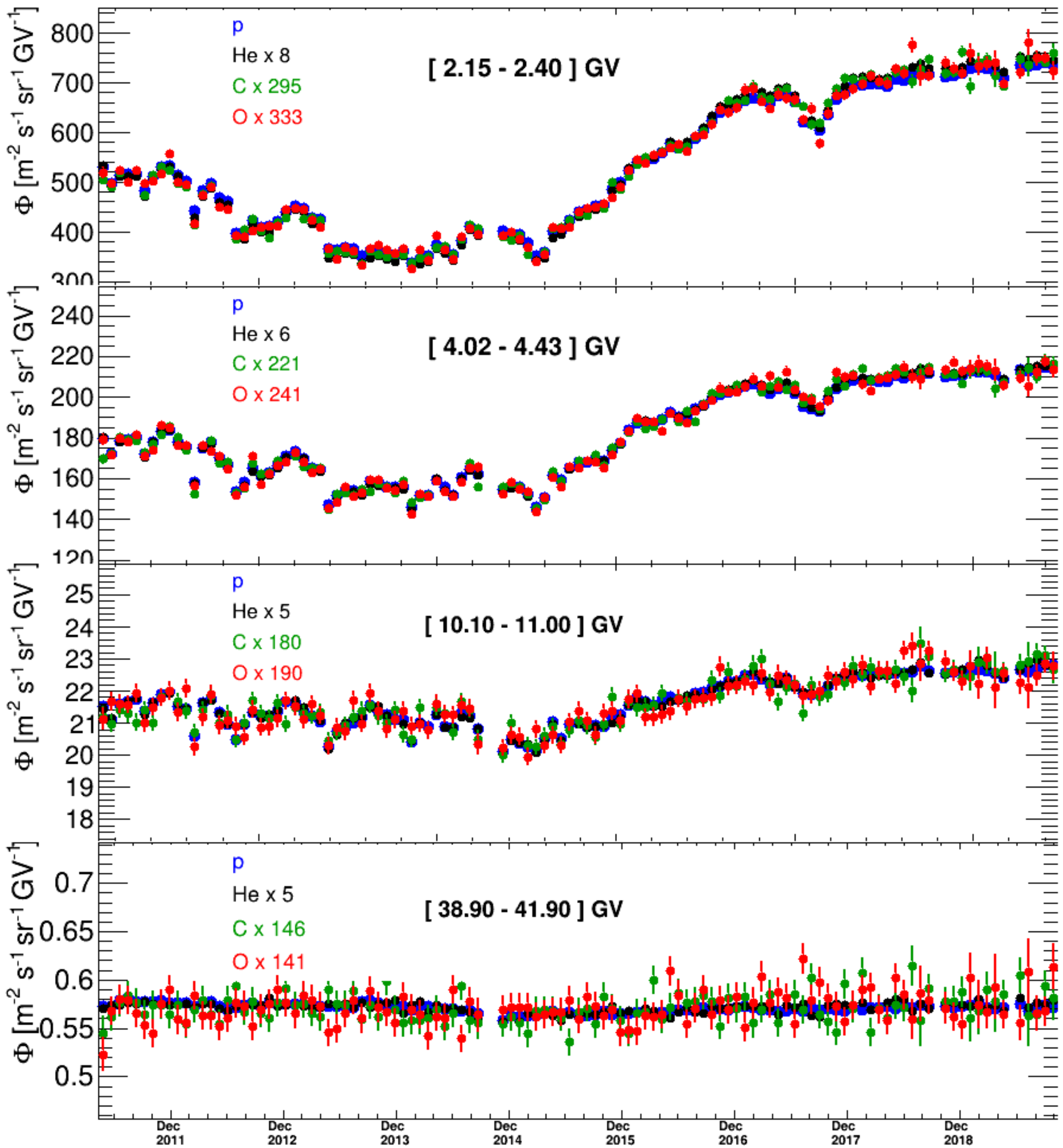

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- similar **long-term** and **short-term** time structures

Time Evolution

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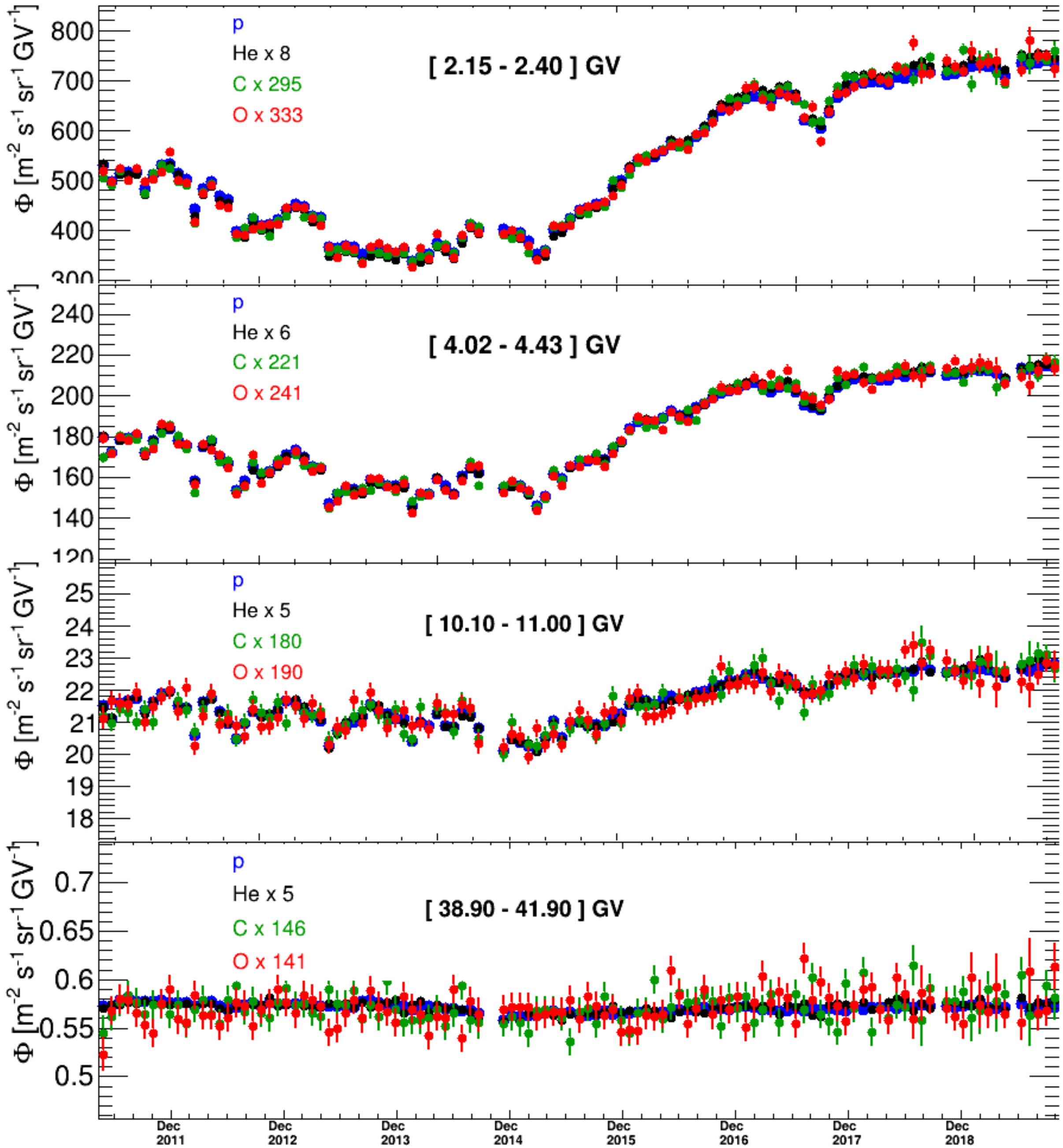

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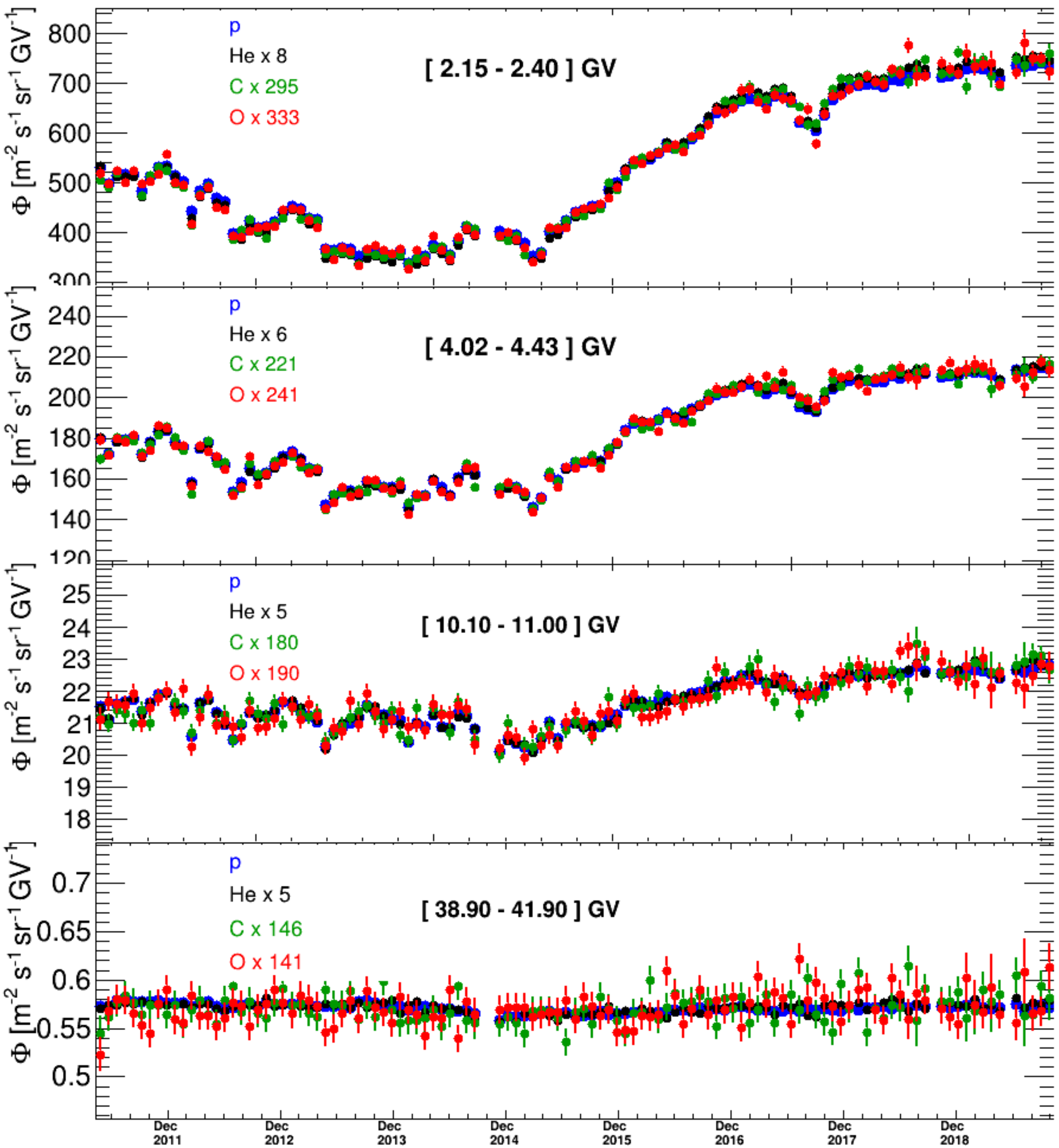
- similar **long-term** and **short-term** time structures

At ICRC2021 by AMS collab.:
- Daily p, by Y. Jia (749)
- Daily He, by C. Consolandi (1139)
- SEP, by C. Light (1003)
- FD, by S. Wang (1146)

Time Evolution



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- similar **long-term** and **short-term** time structures

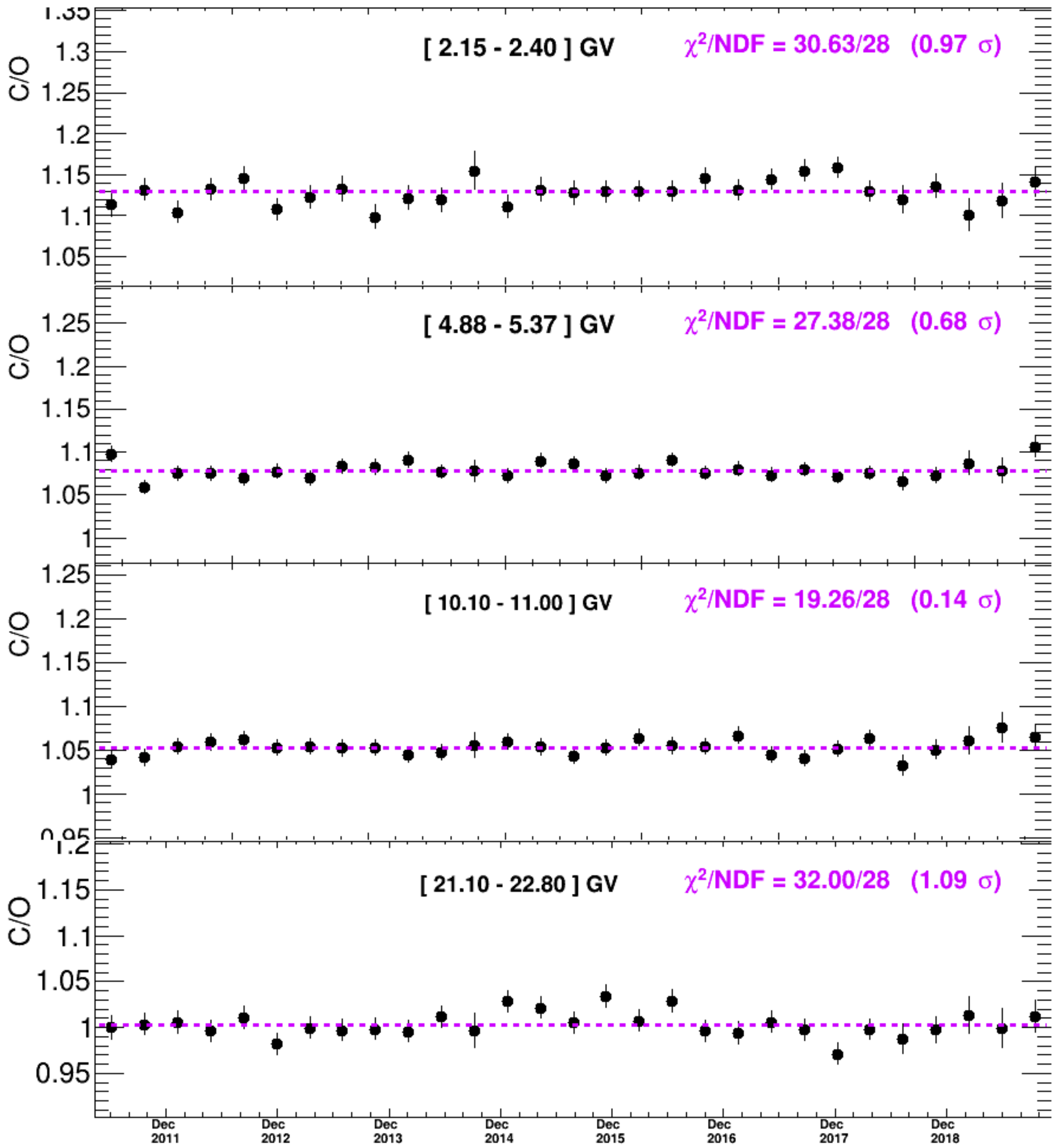
- the **amplitude** of these structures **decreases with increasing rigidity**

  and

  becomes non-observable at:
  - ~ 25 GV for C & O
  - ~ 50 GV for He

  while it's **always observable for protons** in the rigidity range analyzed.

C/O Flux Ratio



Preliminary Data
Please refer to the AMS forthcoming publication in PRL

- 4 Bartels rotations time interval

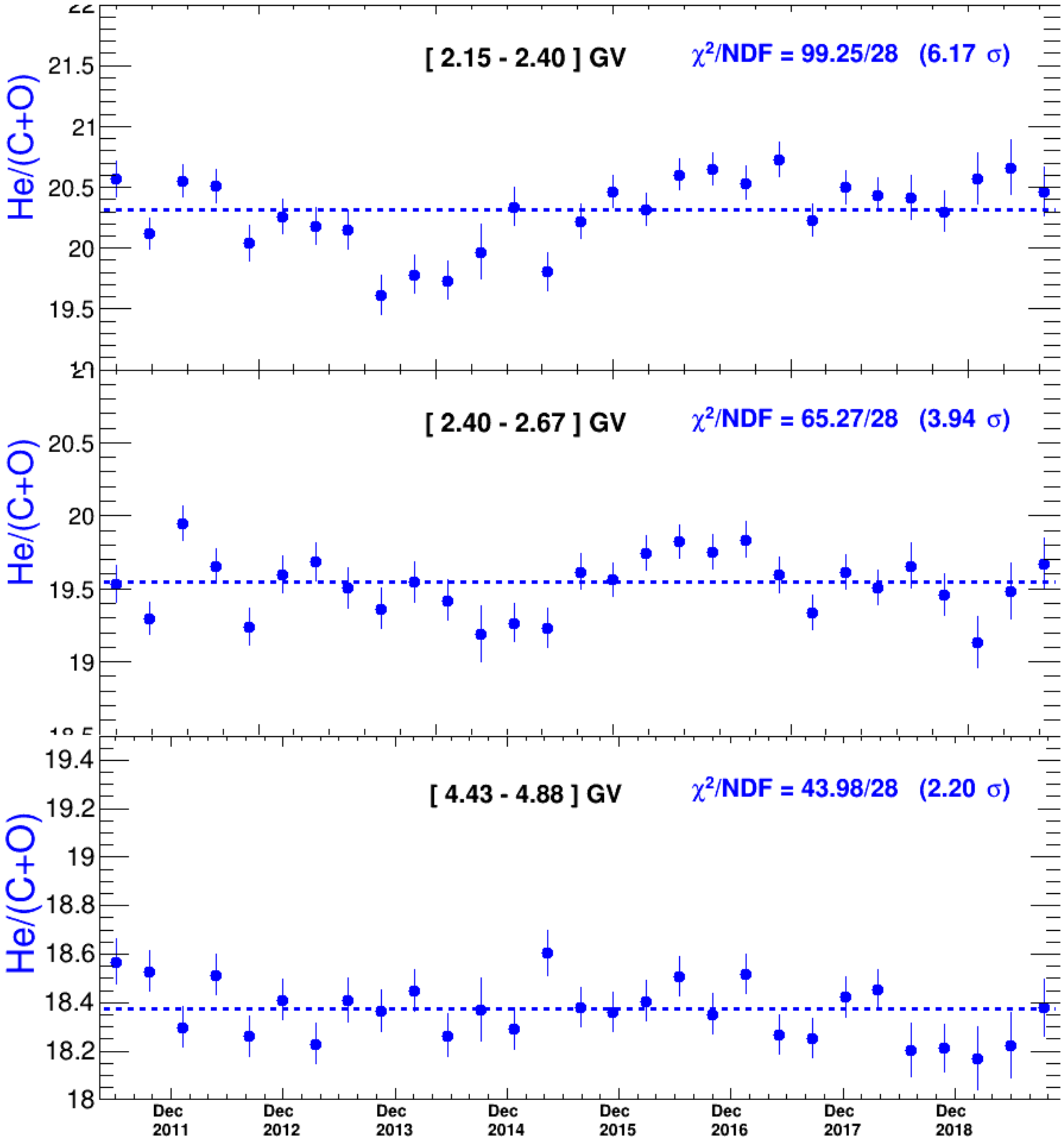
- the **first and only measurement of the time dependence** of Carbon and Oxygen fluxes **as a function of rigidity**

- **C&O have similar A/Z**, hence same velocity
→ no time dependence difference arising from the velocity

- **The C/O flux ratio is time independent** in the whole rigidity range (from 2 to 60 GV)

→ **the rigidity dependence of their LIS above 2 GV is very similar**

He / (C+O) Flux Ratio



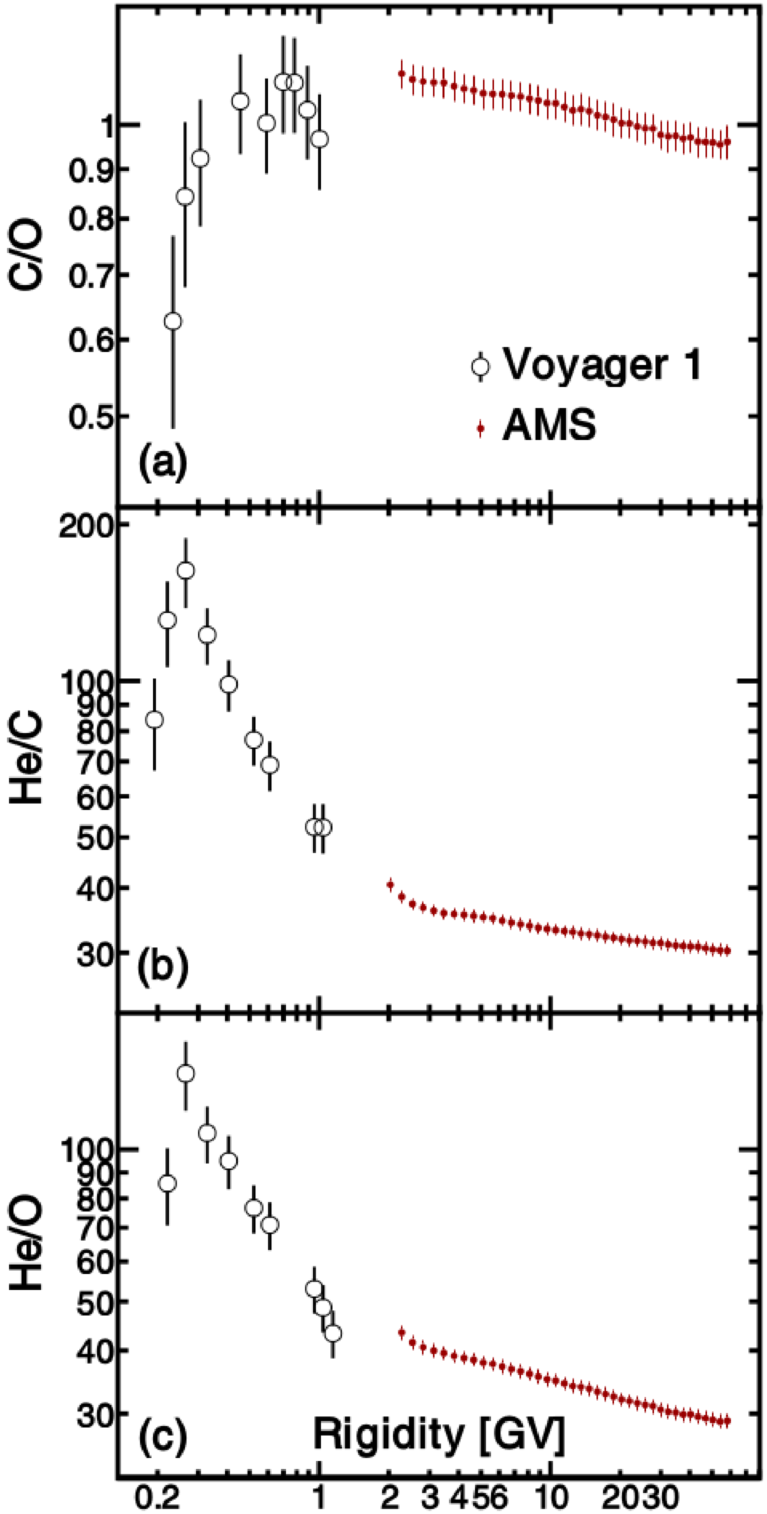
Preliminary Data
Please refer to the AMS
forthcoming publication in PRL

- 4 Bartels rotations time interval

- **He/(C+O) flux ratio exhibits a time dependence** up to ~2.5 GV

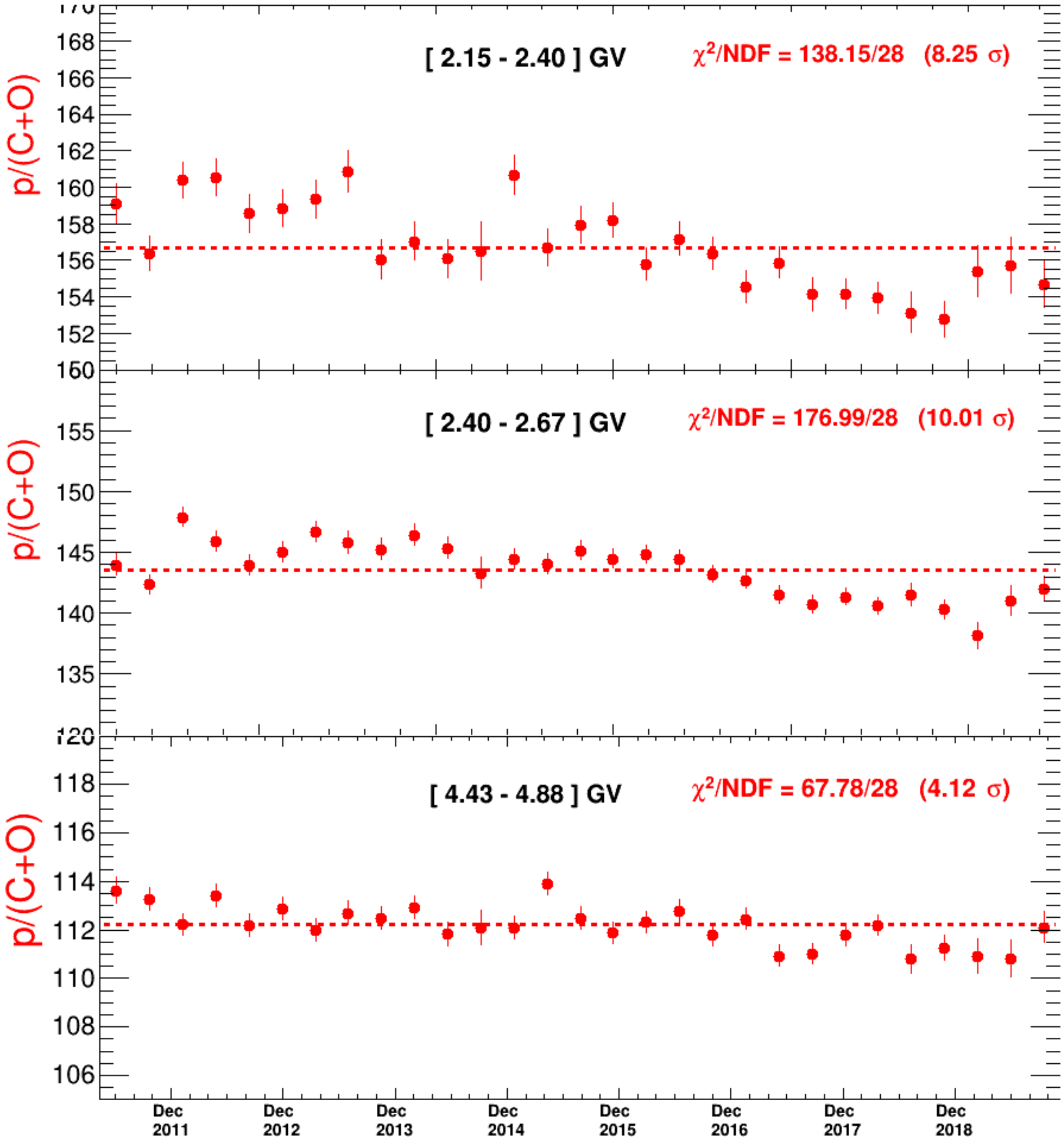
- **He, C&O have similar A/Z**
→ their **LIS have different rigidity dependence above 2 GV**

Flux Ratios Inside & Outside the Heliosphere



Smooth continuation of the flux ratios measured inside (AMS) and outside (Voyager 1) the Heliosphere

p / (C+O) Flux Ratio



Preliminary Data
Please refer to the AMS forthcoming publication in PRL

- 4 Bartels rotations time interval

- **p/(C+O) flux ratio exhibits a time dependence** up to ~4 GV

- **p, C&O have different A/Z → both LIS rigidity dependence and velocity contribute to the observed time dependence of p/(C+O)**

Summary & Conclusions

- The precision measurement of **proton, Helium, Carbon and Oxygen** fluxes in **Bartels rotations** **from May 2011 to October 2019** has been presented

- The **study of the time evolution as a function of rigidity** for different nuclei species provides unique info **to understand the contribution** of the **LIS** and of the **velocity dependence** of CR propagation in the heliosphere

- The **first and only measurement** of the **time dependence** of Carbon and Oxygen fluxes **as a function of rigidity**

- The 4 nuclei species exhibit **similar behavior** in time:

  - **C&O** have an **identical** time behavior, indicating a **very similar rigidity dependence of their LIS above ~2GV** .

  - The **He/(C+O)** flux ratio exhibit a **time dependence up to ~2.5 GV**, indicating that **their LIS has a different rigidity dependence**

  - The **p/(C+O)** flux ratio also shows a **time dependence up to ~4 GV**.
    Both LIS rigidity dependence and velocity contribute to this time behavior

Thanks For Your Attention