Properties of Heavy Nuclei in South Atlantic Anomaly with AMS-02

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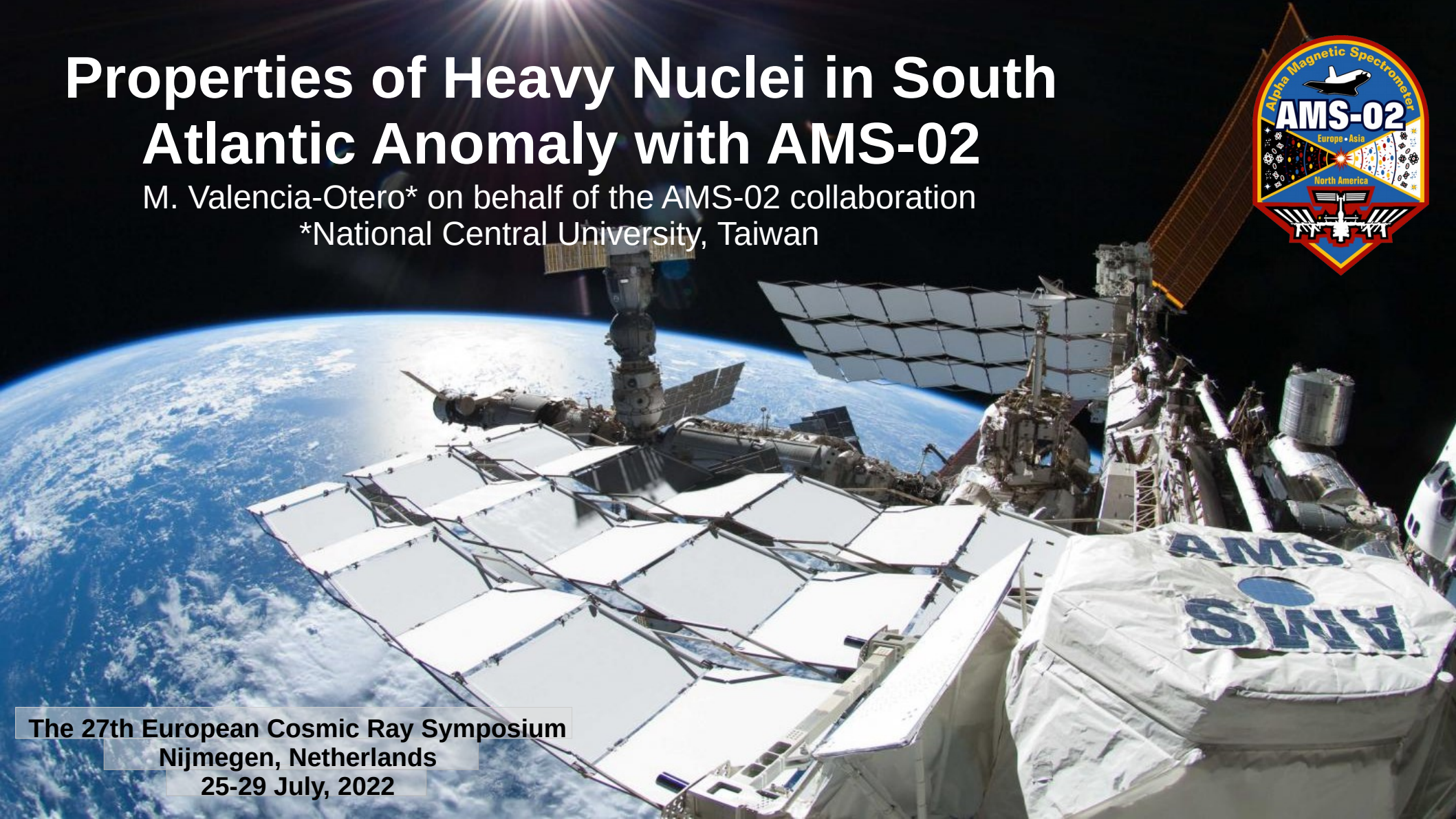


The 27th European Cosmic Ray Symposium
Nijmegen, Netherlands
25-29 July, 2022

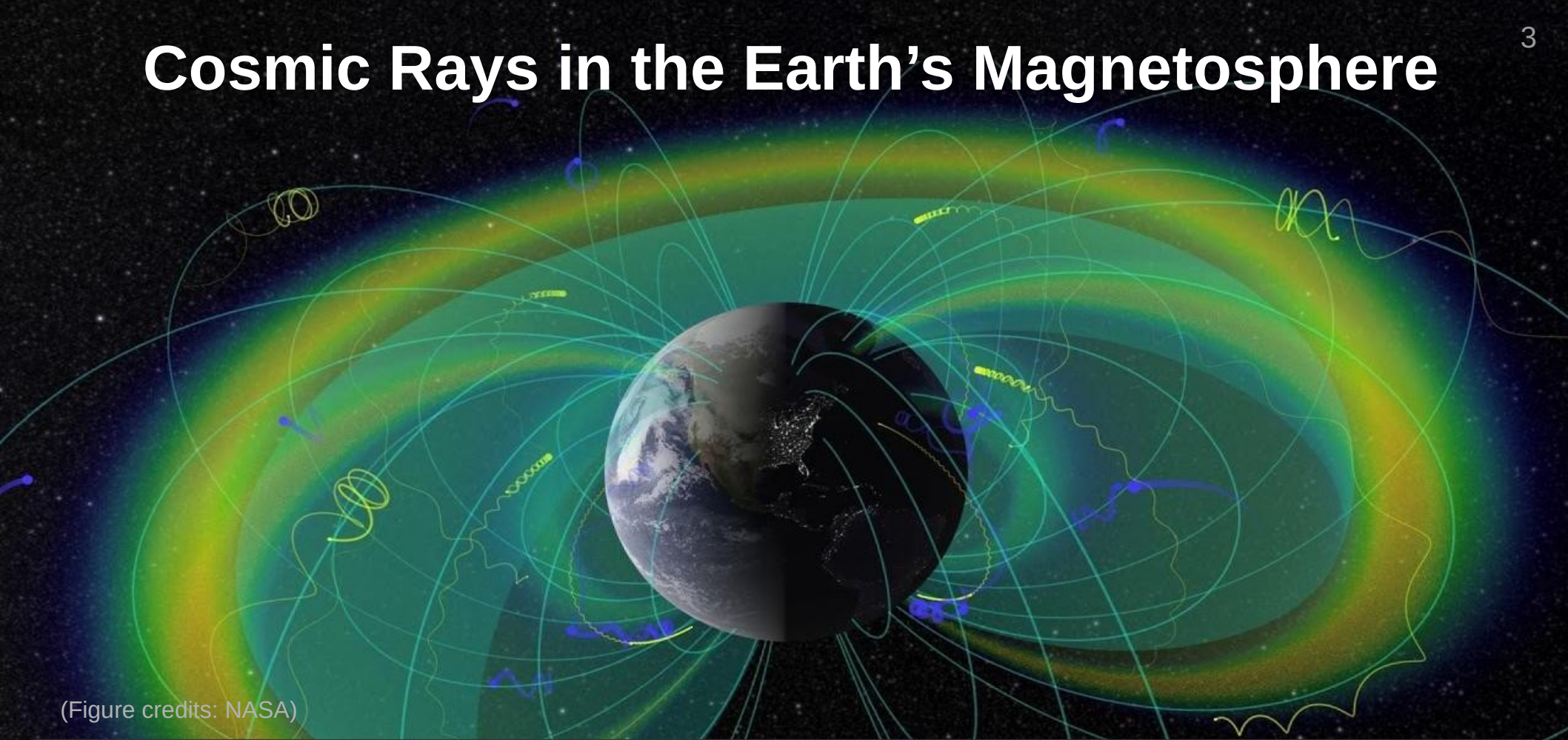
The Alpha Magnetic Spectrometer

- Onboard ISS since 2011.
- On continuous operation.
- More than 200 billion events so far.

International space station (ISS)

- Altitude ~400km
- Inclination 51°
- Period 93 min

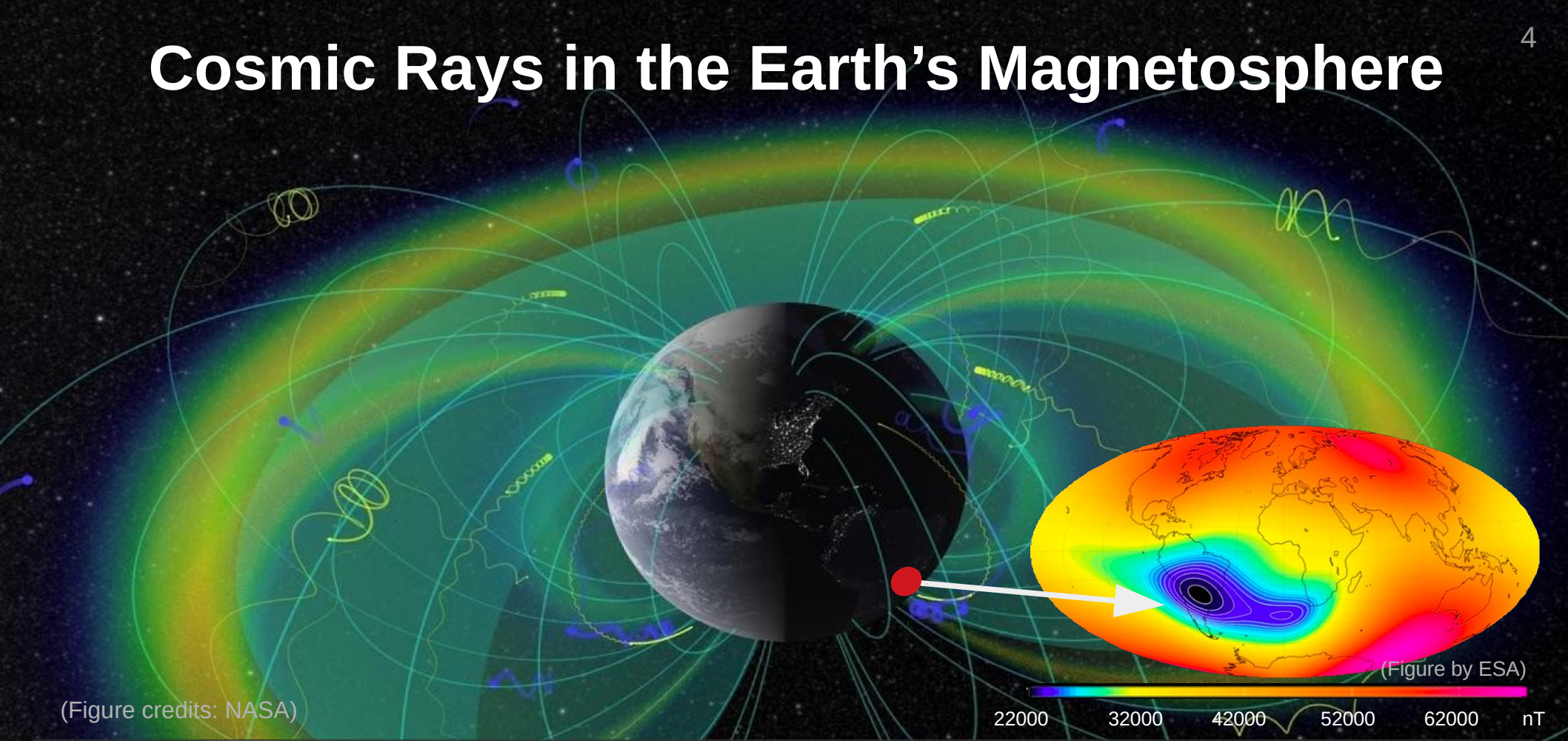
Cosmic Rays in the Earth's Magnetosphere



(Figure credits: NASA)

Particles **trapped** in the Earth's magnetic field create regions of **high radiation** called **Van Allen belts**.

Cosmic Rays in the Earth's Magnetosphere

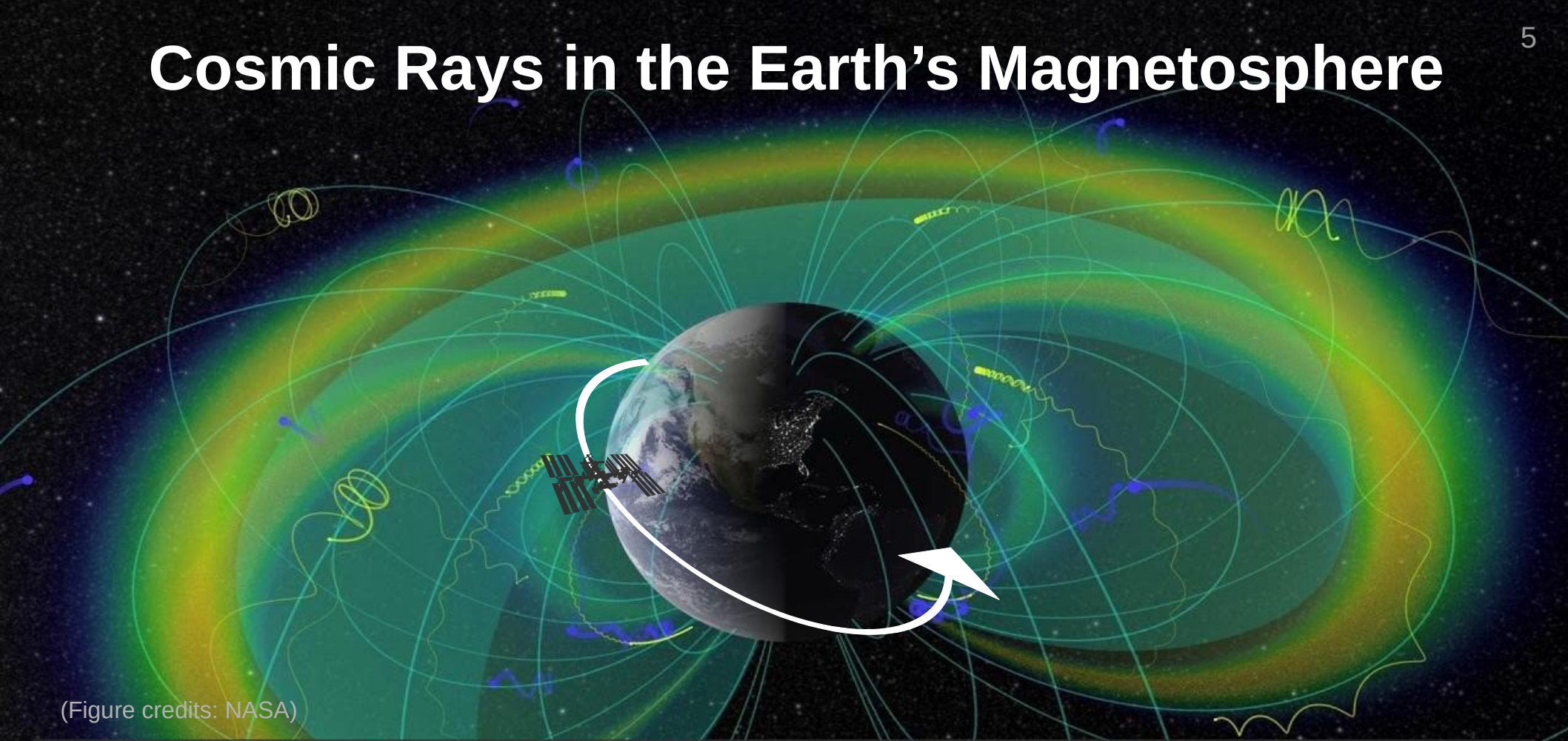


(Figure credits: NASA)

(Figure by ESA)

Particles **trapped** in the Earth's magnetic field create regions of **high radiation** called **Van Allen belts**. The **South Atlantic Anomaly (SAA)** is an area over South America where the inner belt dips down to an altitude of 200 km.

Cosmic Rays in the Earth's Magnetosphere

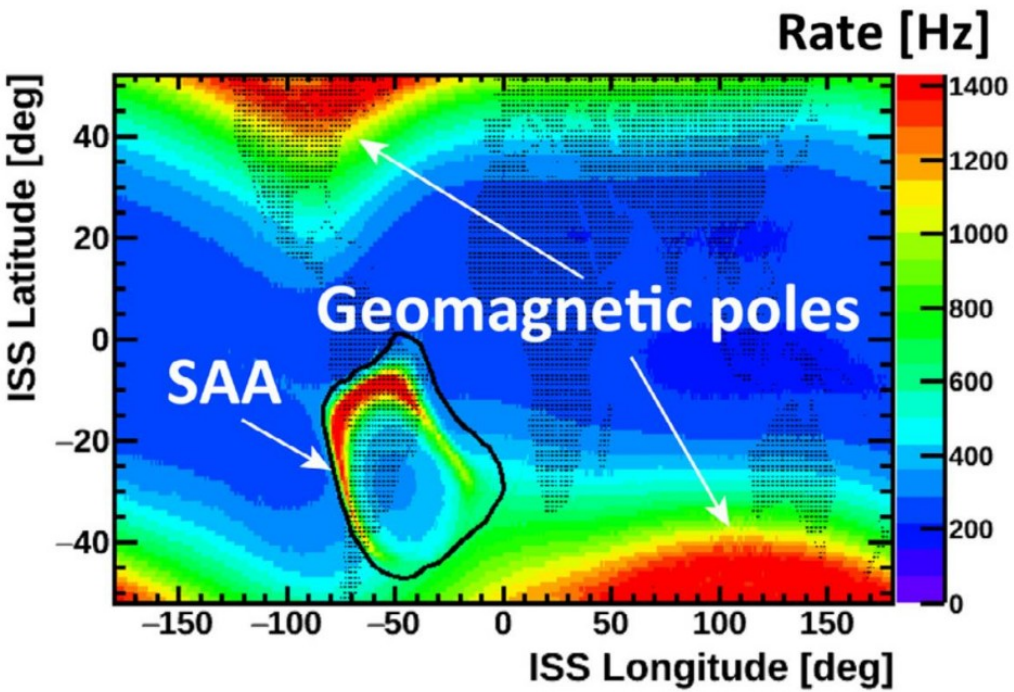


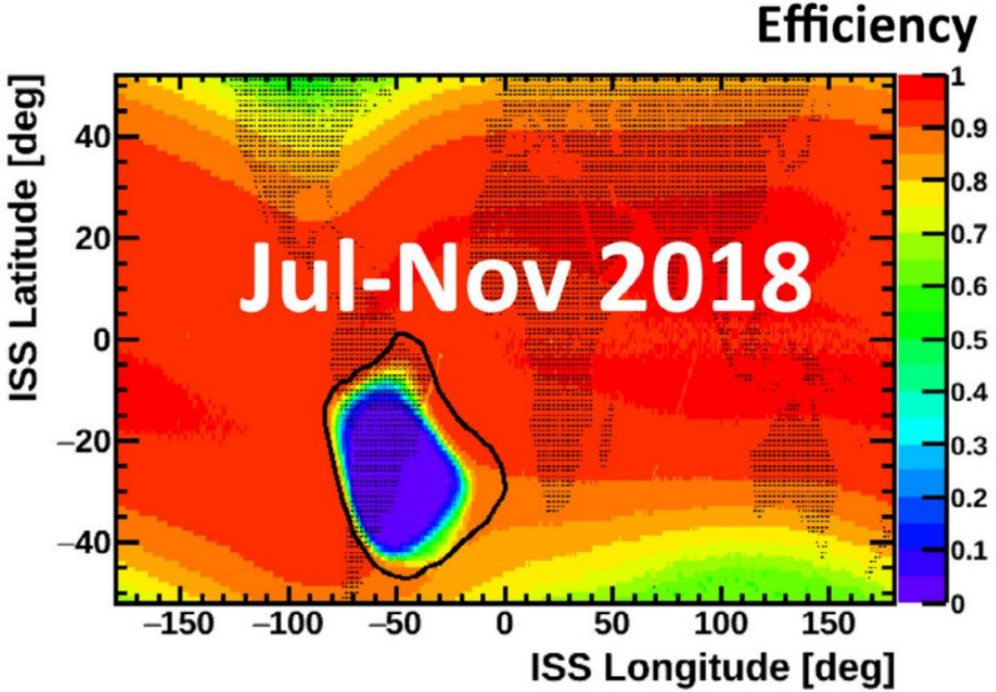
(Figure credits: NASA)

Particles **trapped** in the Earth's magnetic field create regions of **high radiation** called **Van Allen belts**. The **South Atlantic Anomaly (SAA)** is an area over South America where the inner belt dips down to an altitude of 200 km. The ISS crosses this region, causing a sudden increase of the observed radiation.

South Atlantic Anomaly as seen by AMS

Incoming particle rate at the poles and in the SAA is high.
This causes low collection efficiency, mostly in the inner part of the SAA.
However, the efficiency is high on the external sides of the SAA.

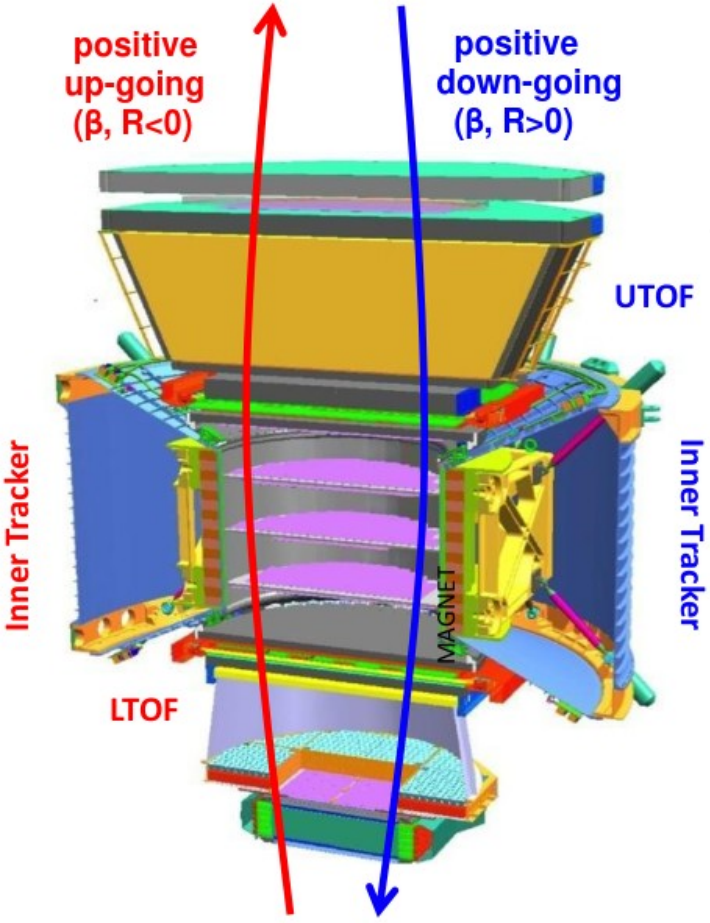




Energetic particle with charge up to 2 are known to exist in this region.
While there is no previous observation of energetic (R>1GV) Z>2 particles inside SAA.

Trapped Nuclei Search

- AMS largest field of view (defined by Inner Tracker).
- Only nuclei with Z>2 considered.
- Including both incoming directions **down-going** and **up-going**.
- Good quality criteria on track, velocity, rigidity and charge reconstruction.
- Globally pre-selection includes 80 milion events in the down-going direction and 3 million for up-going.



Charge identification, Z,
with Inner Tracker (ΔZ/Z≈2% for Z=6)
and UTOF or LTOF (ΔZ/Z≈4% for Z=6).

Velocity, β, and direction
measured with TOF
(Δβ≈1% at β=1 and Z=6).

Rigidity, R=p/Z, and charge sign
with Inner Tracker
(ΔR/R≈10% at R=2 GV).

Mass identification, m,
by combination of β and R.

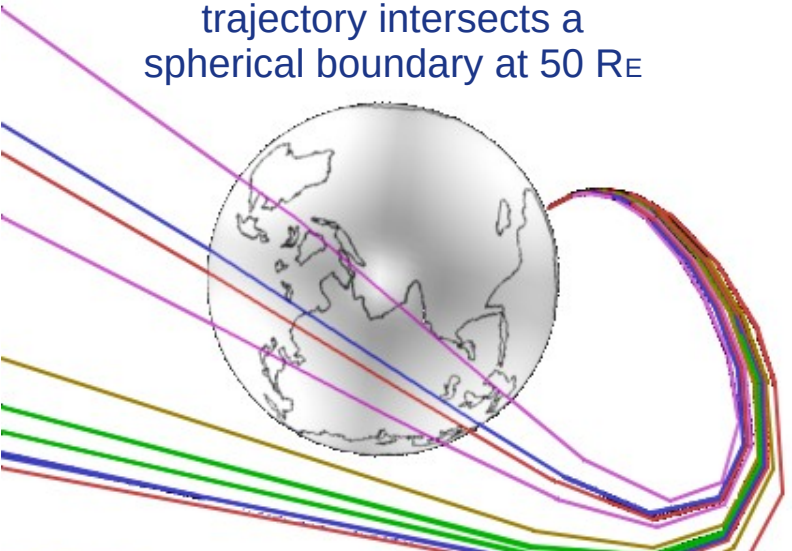
Backtracing Procedure

A **backtracing** algorithm is used to understand the **origin** of the particle. It reconstructs the particle's trajectory in the **Earth's magnetic field** (implements the International Geomagnetic Reference Field, IGRF-13).

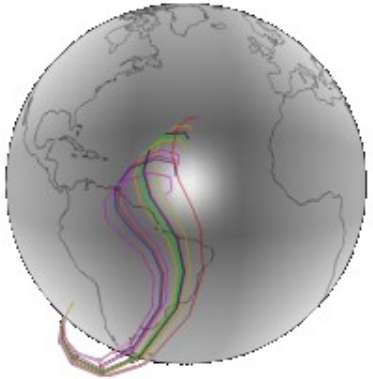
To account for systematic uncertainties in the AMS measurement and trajectory reconstruction, the backtracing was performed sevetal times varying:

- Arrival direction with a spread of $\Delta\theta = 0.2°$.
- Rigidity estimation with a resolution of $\Delta R/R = 10\%$.
- ISS orbit coordinates on time with a $\Delta t = 50$ms variation.

Primary: the particle's trajectory intersects a spherical boundary at 50 R_E

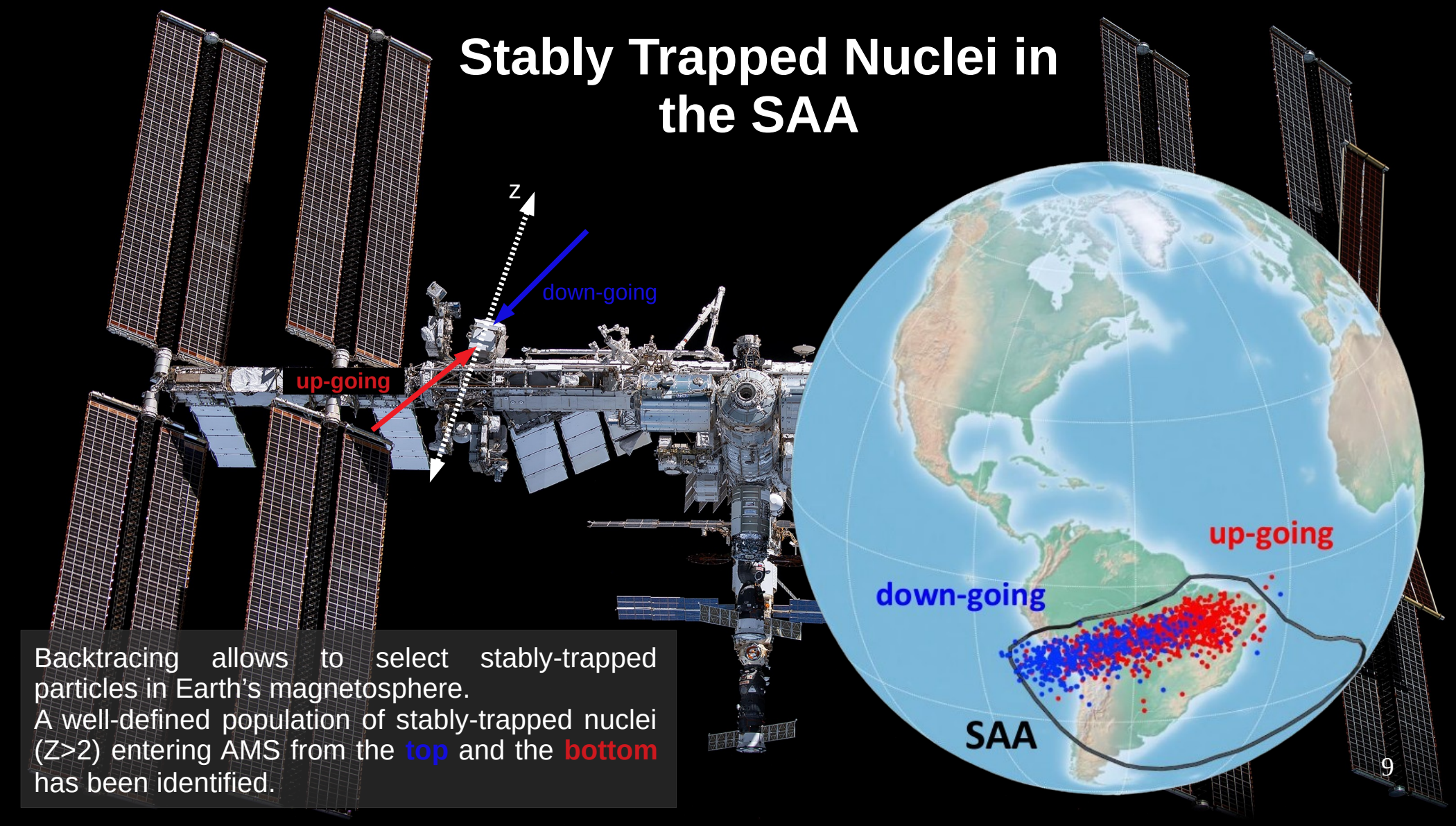


Secondary: the trajectory intersects a spherical a boundary at 100 km from the Earth's surface.



Stably-Trapped: particle is neither primary nor secondary, bounded in trajectories around the Earth.

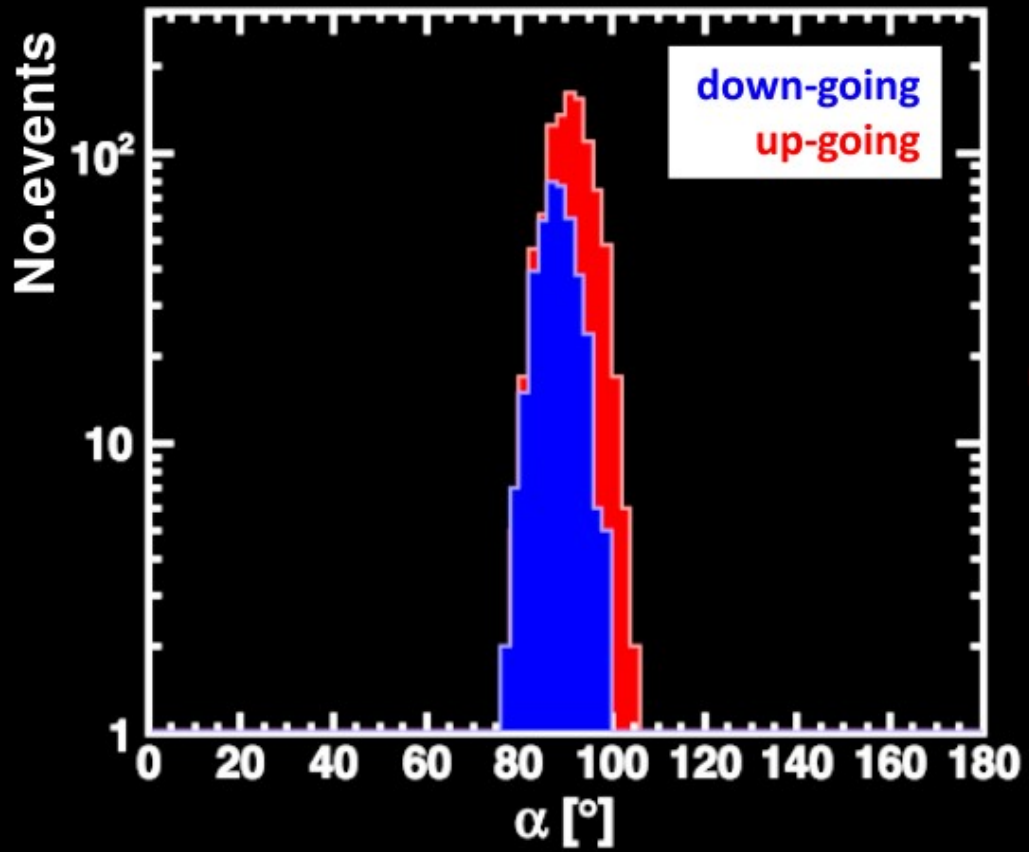
Stably Trapped Nuclei in the SAA

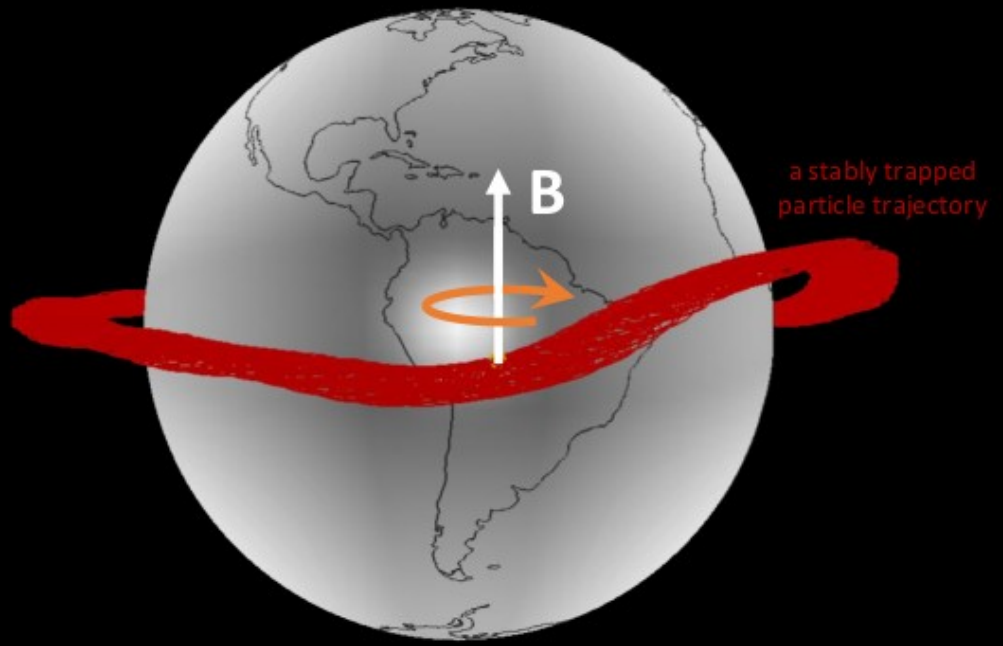


Backtracing allows to select stably-trapped particles in Earth's magnetosphere.
A well-defined population of stably-trapped nuclei (Z>2) entering AMS from the **top** and the **bottom** has been identified.

Stably Trapped Nuclei in the SAA: Pitch Angle Distribution

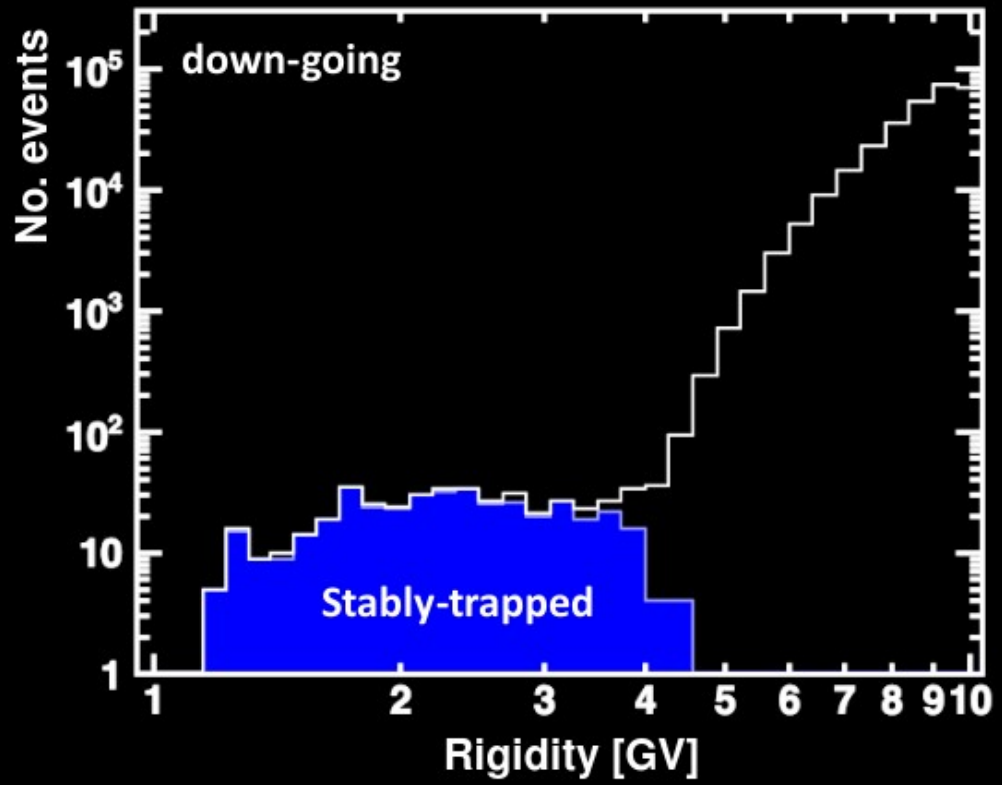
Pitch angle is the angle between particle and magnetic field.
All stably-trapped ions have a pitch angle of about 90°.

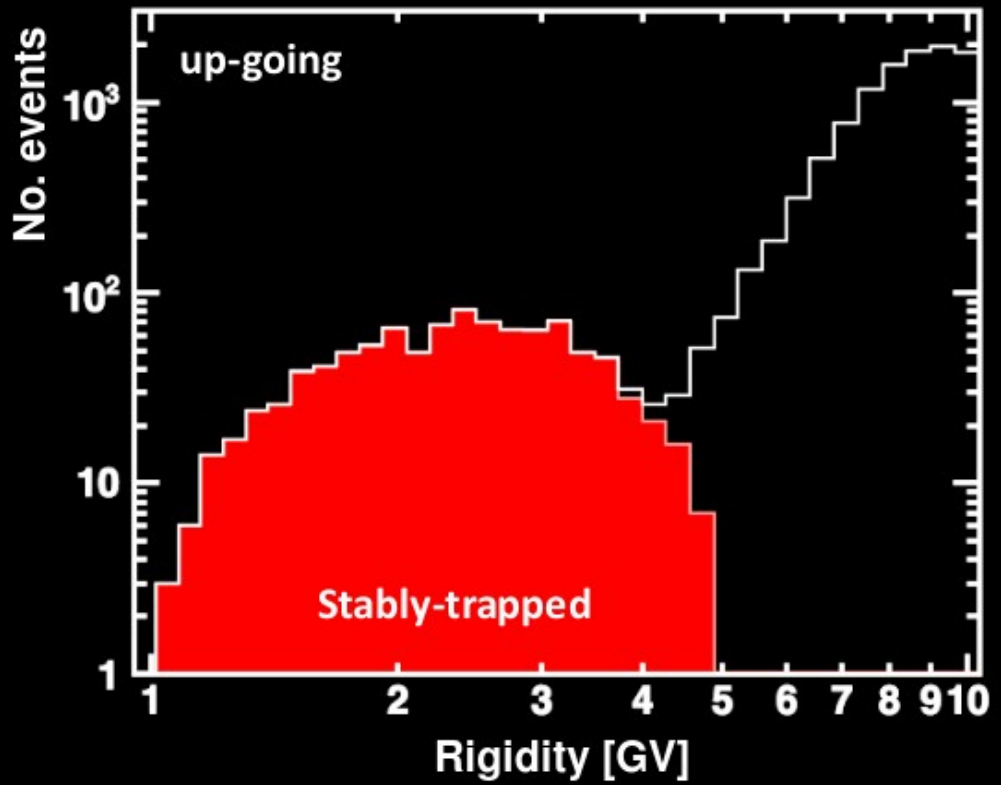




Stably Trapped Nuclei in the SAA: Rigidity Distribution

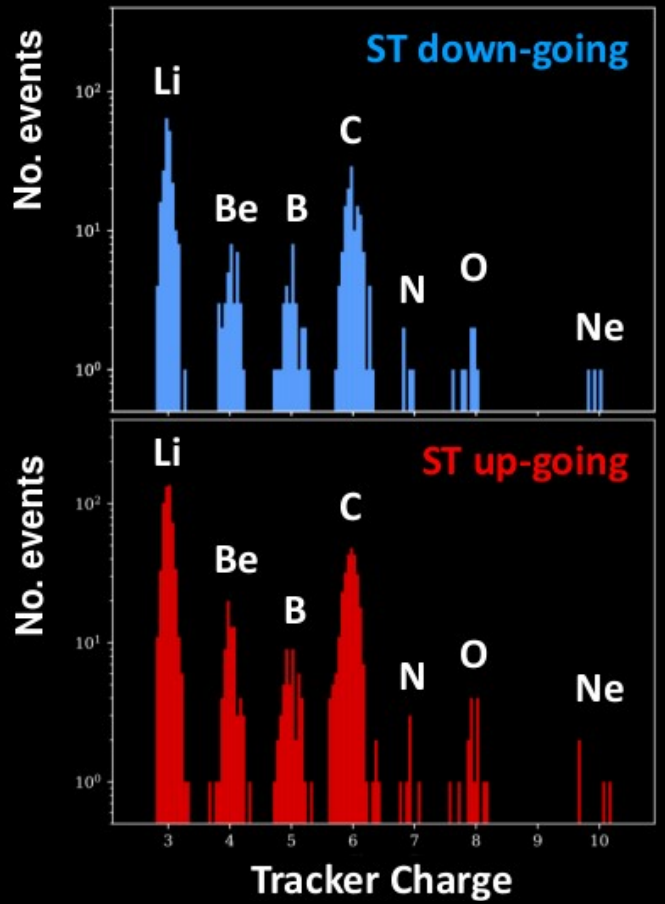
Selecting North SAA ($-20<\theta_M<10$, $-10<\varphi_M<50$).
Rigidity spectra extends from 1 to 5 GV.
These populations are below the geomagnetic cutoff.

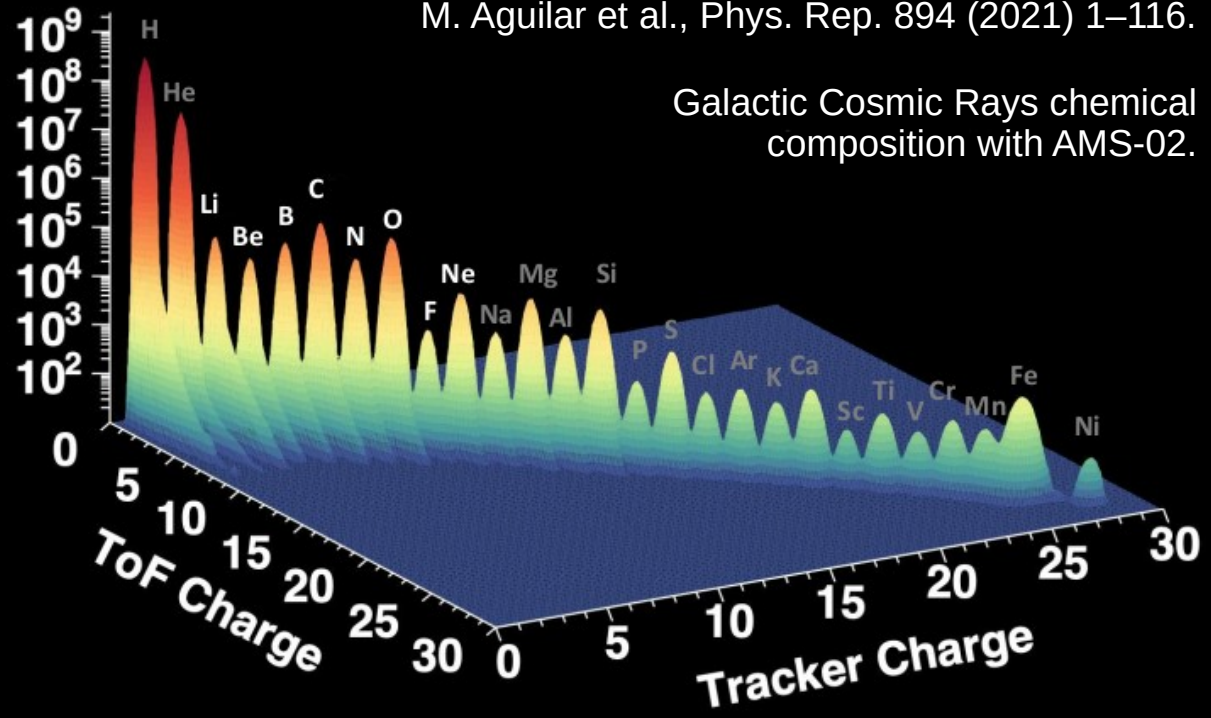




Stably Trapped Nuclei in the SAA: Chemical composition

The chemical composition of up-going and down-going is similar.
The charge distribution of stably trapped nuclei and GCRs is different (Li>C>O, while in GCRs O∼C>Li)

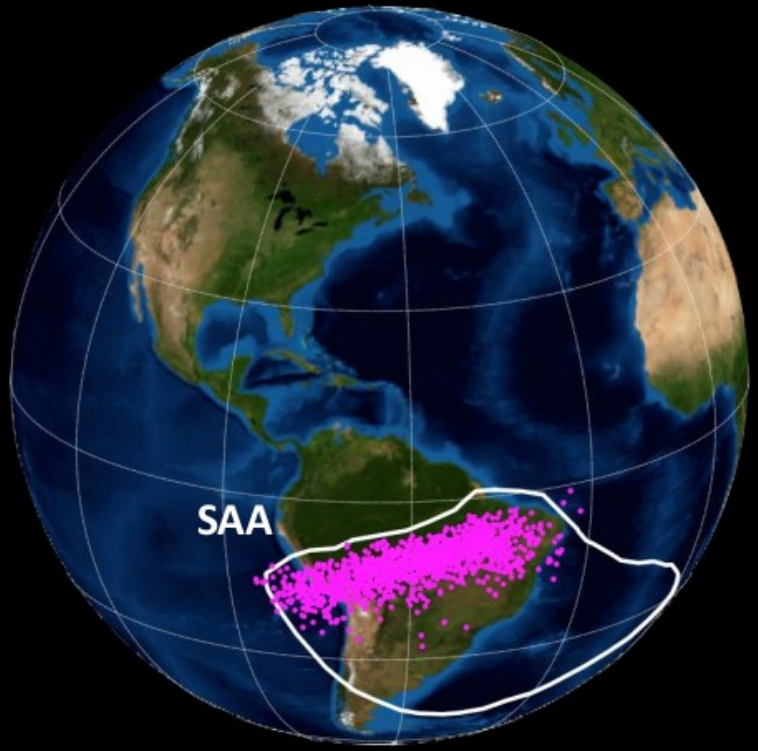


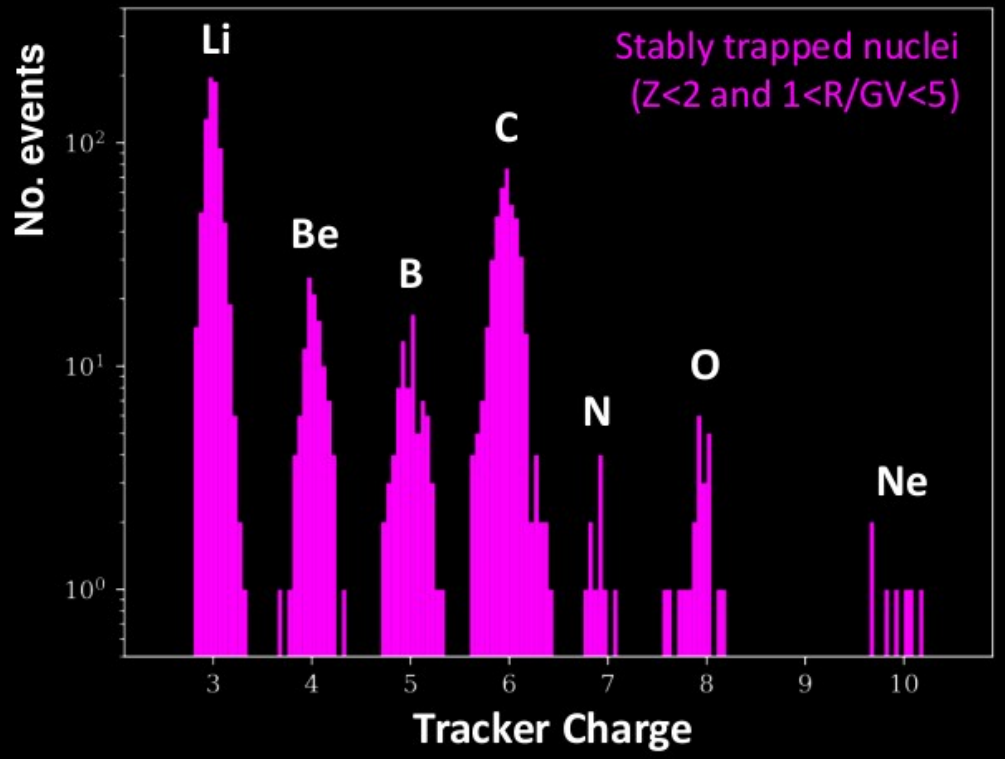


M. Aguilar et al., Phys. Rep. 894 (2021) 1–116.

Galactic Cosmic Rays chemical composition with AMS-02.

Conclusions





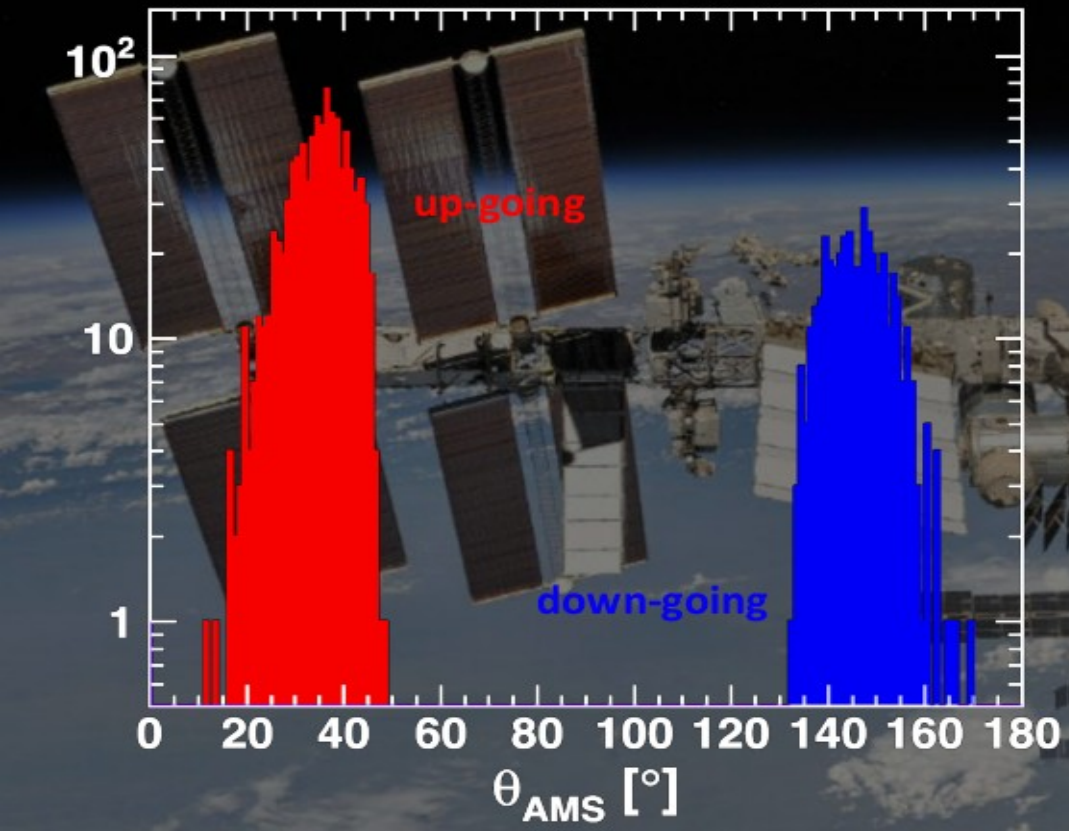
- 10 years of AMS-02 data have been used to look for ions below geomagnetic cutoff with Z>2.
- A **stably trapped** population has been clearly identified below 5 GV in the SAA region.
- This population has properties (rigidity, charge, arrival direction) distinctly different from GCRs.
- This is a high-Z, high-energy population (up to 5 GV) never observed before.

Thank You

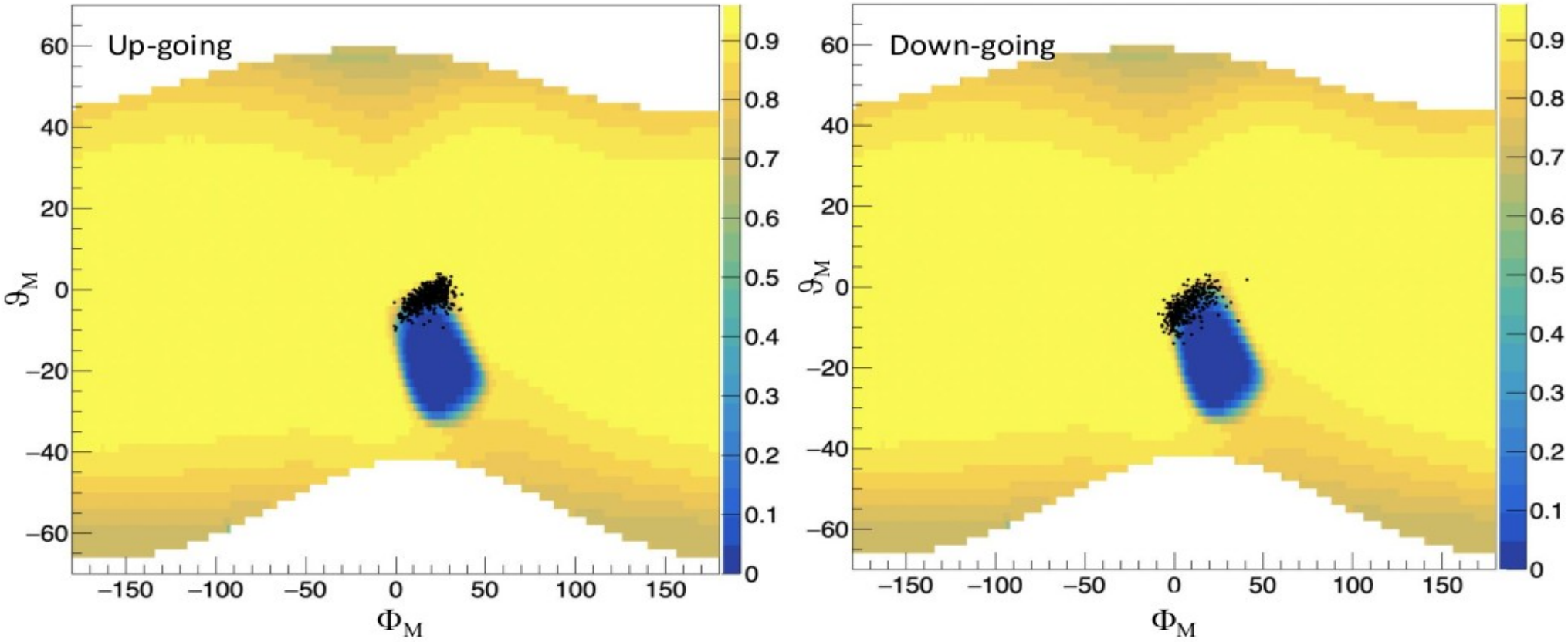
For Your Attention

Stably Trapped Nuclei in the SAA

Backtracing allows to select particles stably-trapped in Earth's magnetosphere.
A clear population of stably trapped ions (Z>2) entering in AMS
both from the **top** and the **bottom** has been identified.

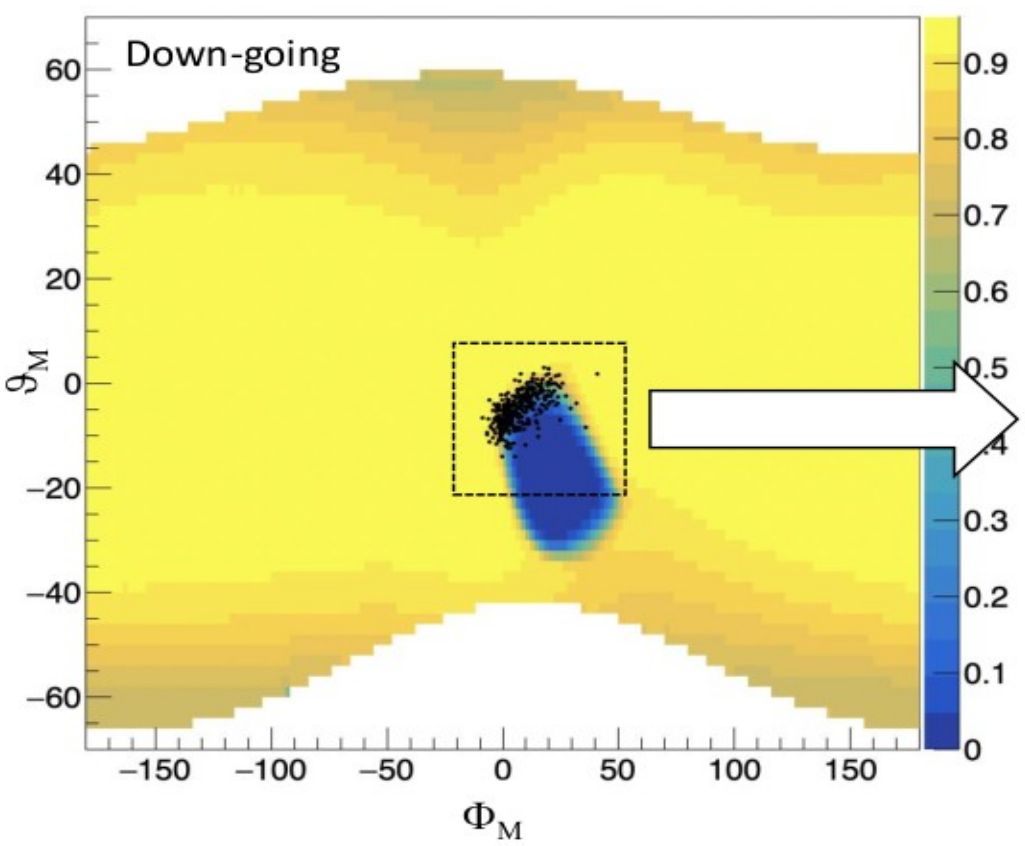


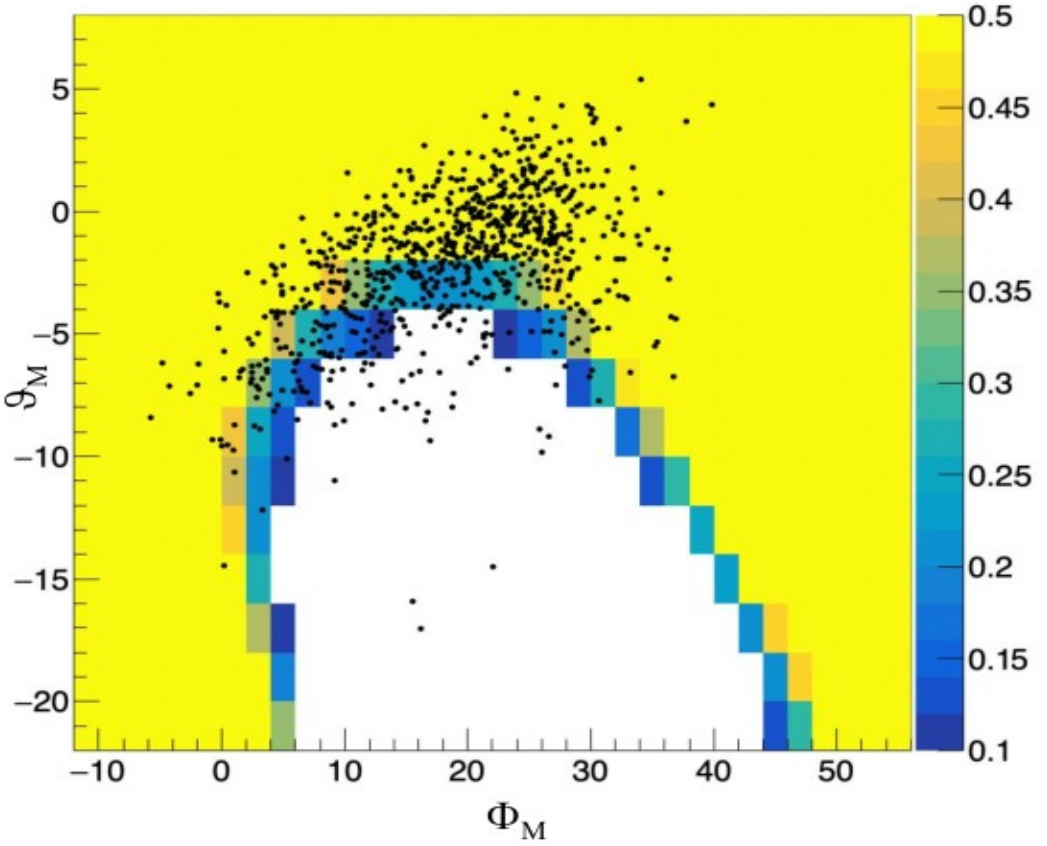
Livetime Distribution



→ At the center of SAA there are no counts due mostly to livetime.
Where we have counts, we have an approximately good livetime,
even if it's changing fast with orbit position.

Livetime Distribution





→ At the center of SAA there are no counts due mostly to small livetime.
We however have regions where livetime is good.
We can do some flux estimation as function of arrival direction (in development).

Comparison with AMS

Essentially very different picture in terms of:

- Energy range
- Charge distribution
- Geographic distribution
- Time dependence