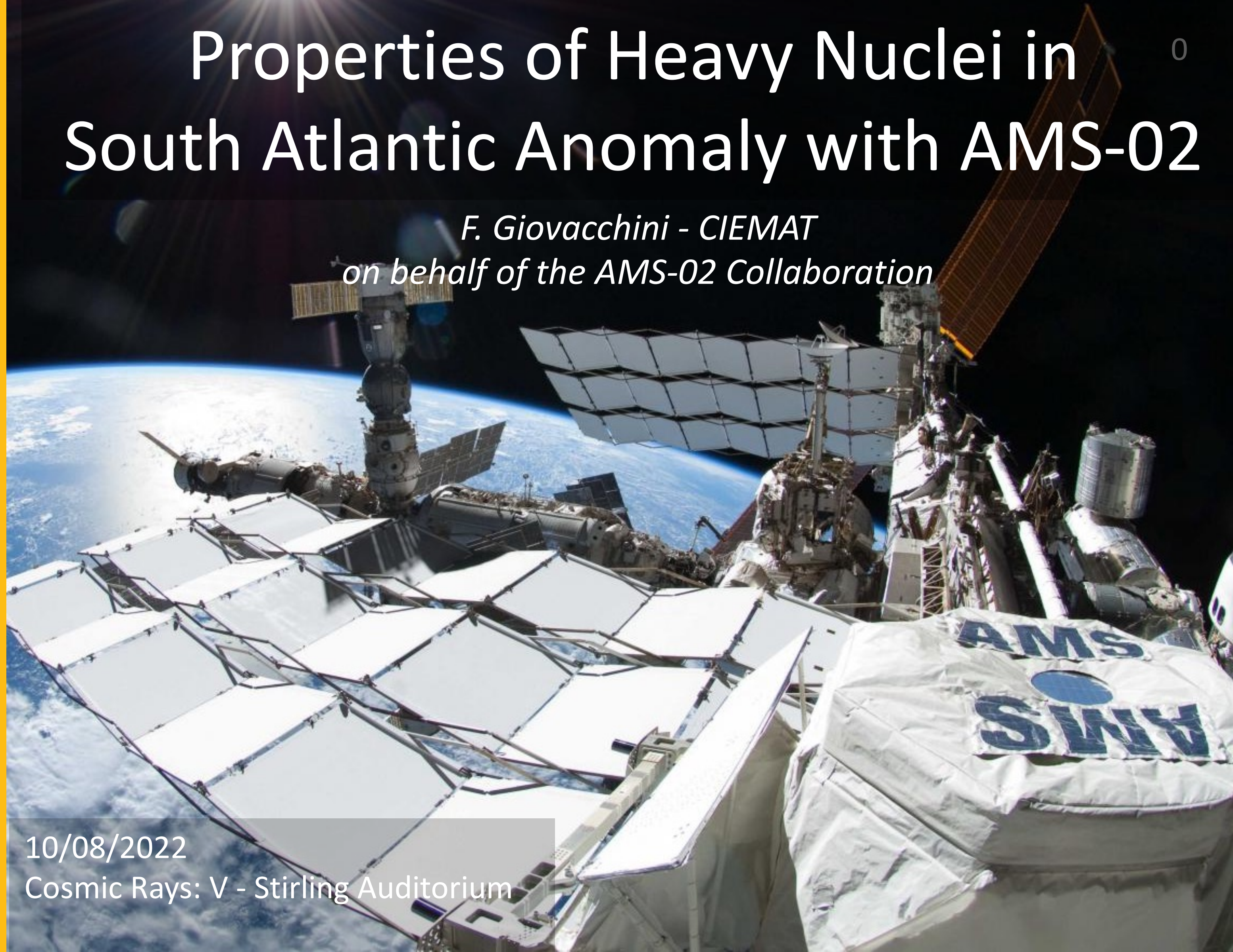
Properties of Heavy Nuclei in South Atlantic Anomaly with AMS-02

F. Giovacchini - CIEMAT
on behalf of the AMS-02 Collaboration



10/08/2022
Cosmic Rays: V - Stirling Auditorium

The Alpha Magnetic Spectrometer

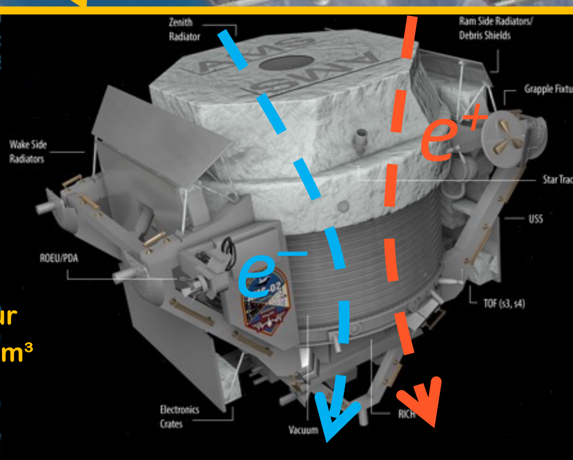
Installed in 2011 on the ISS. Takes data continuously since then.
AMS-02 collected more than **200 billion cosmic** rays up to now.

International Space Station (ISS)

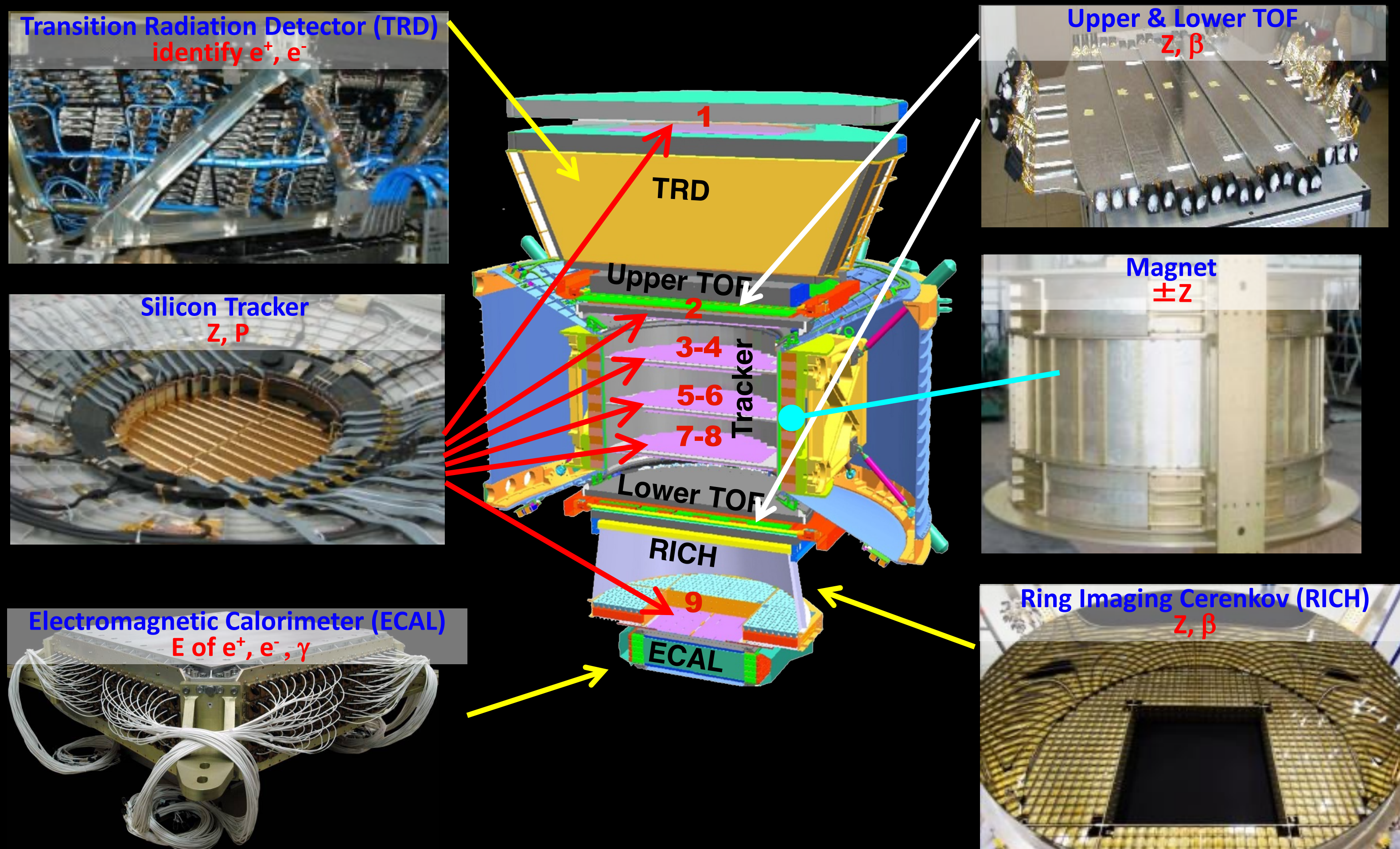
Altitude	~ 400 km
Inclination	51°
Period	93 min
Construction	1998 - …
Dimensions	73×109 m^2
Weight	420 t

AMS-02

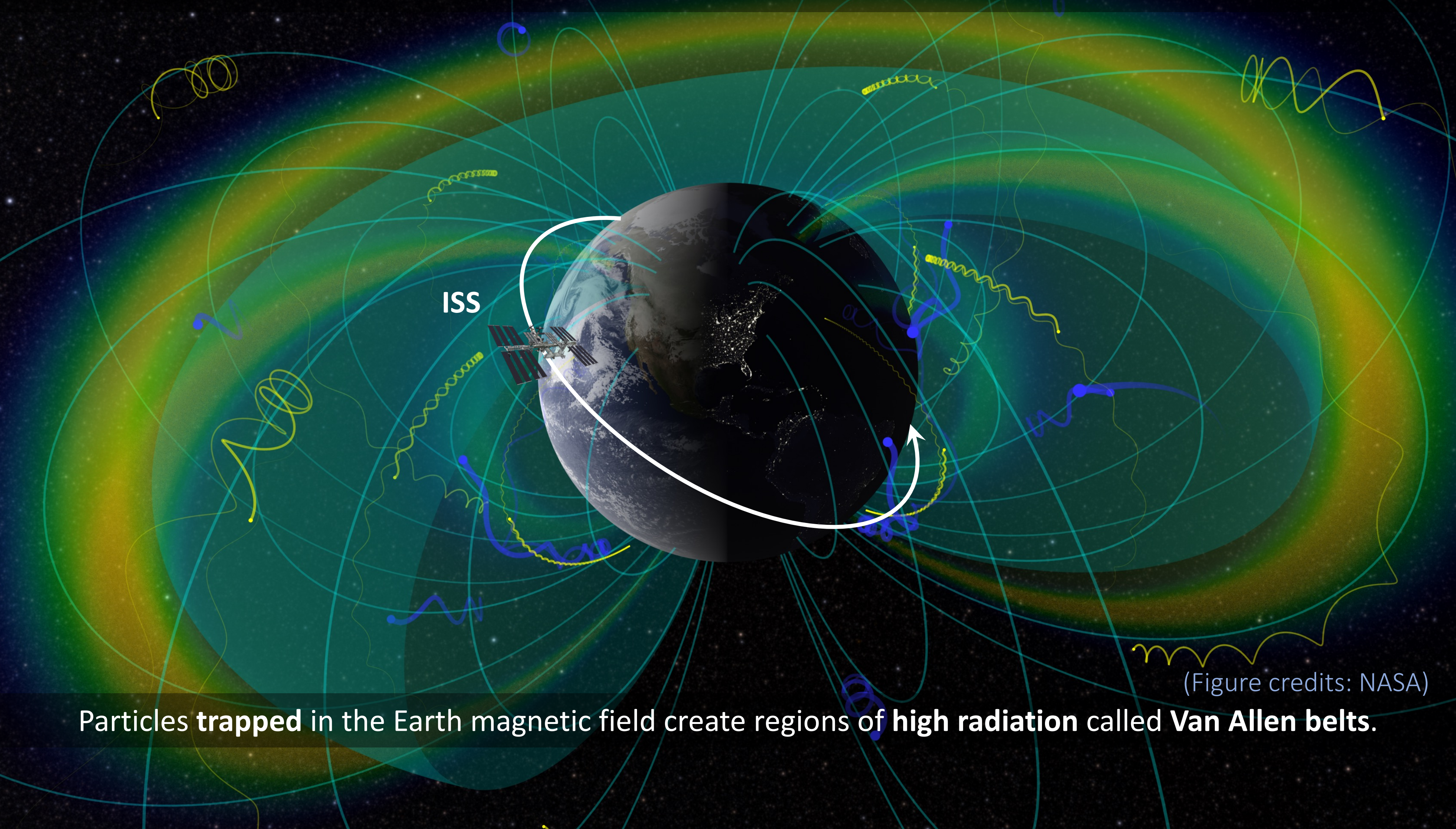
Launch	16/5/2011
	STS-134
	Endeavour
Dim.	$3 \times 4 \times 5$ m^3
Weight	7.5 t
Power	2500 W



AMS: a high energy physics detector in space



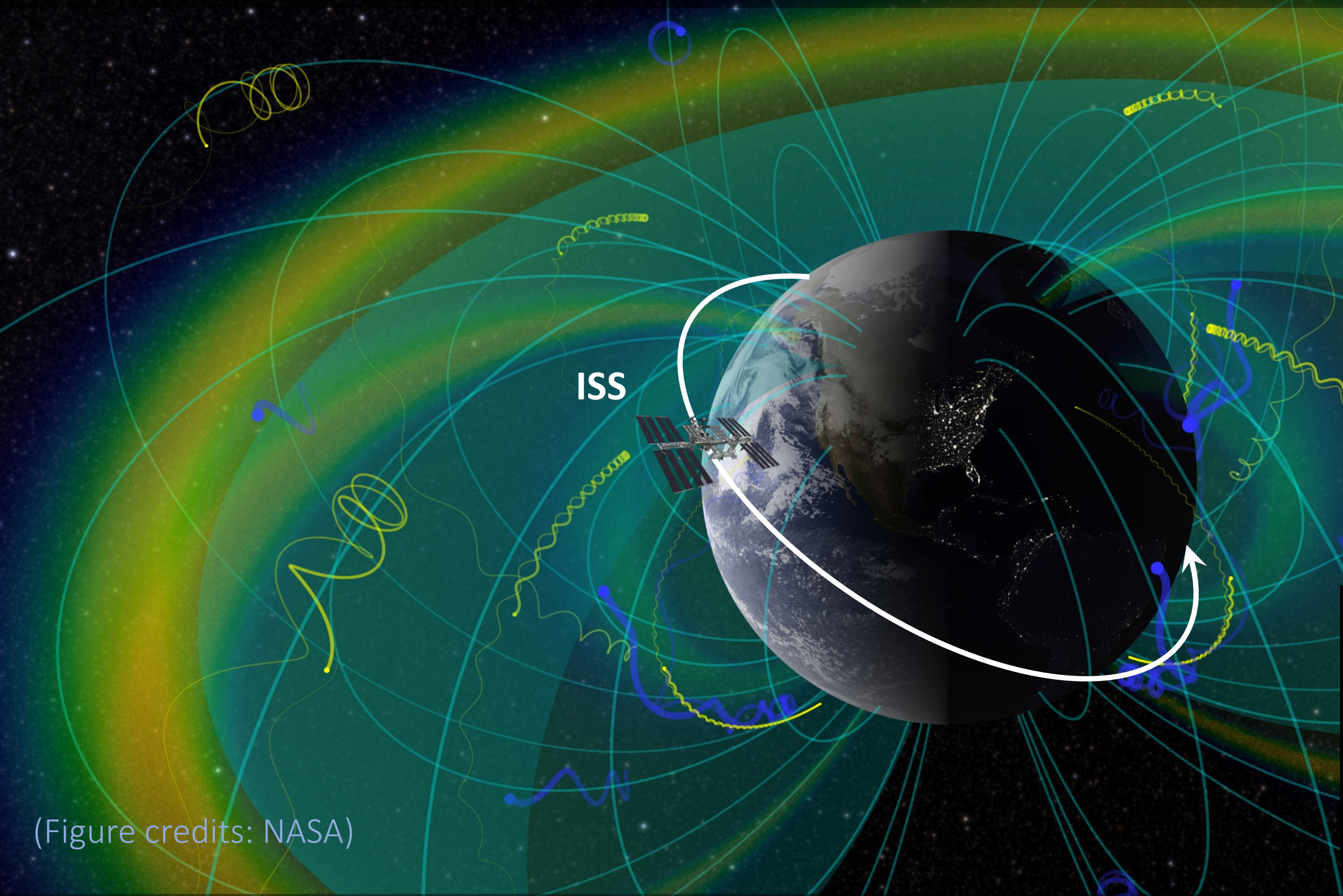
Cosmic Rays in the Magnetosphere



(Figure credits: NASA)

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

Cosmic Rays in the Magnetosphere



(Figure credits: NASA)

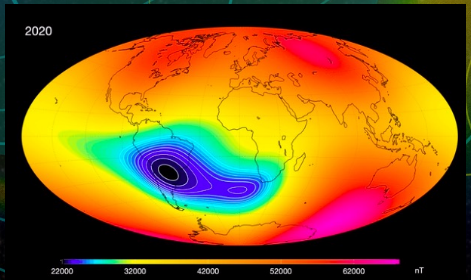
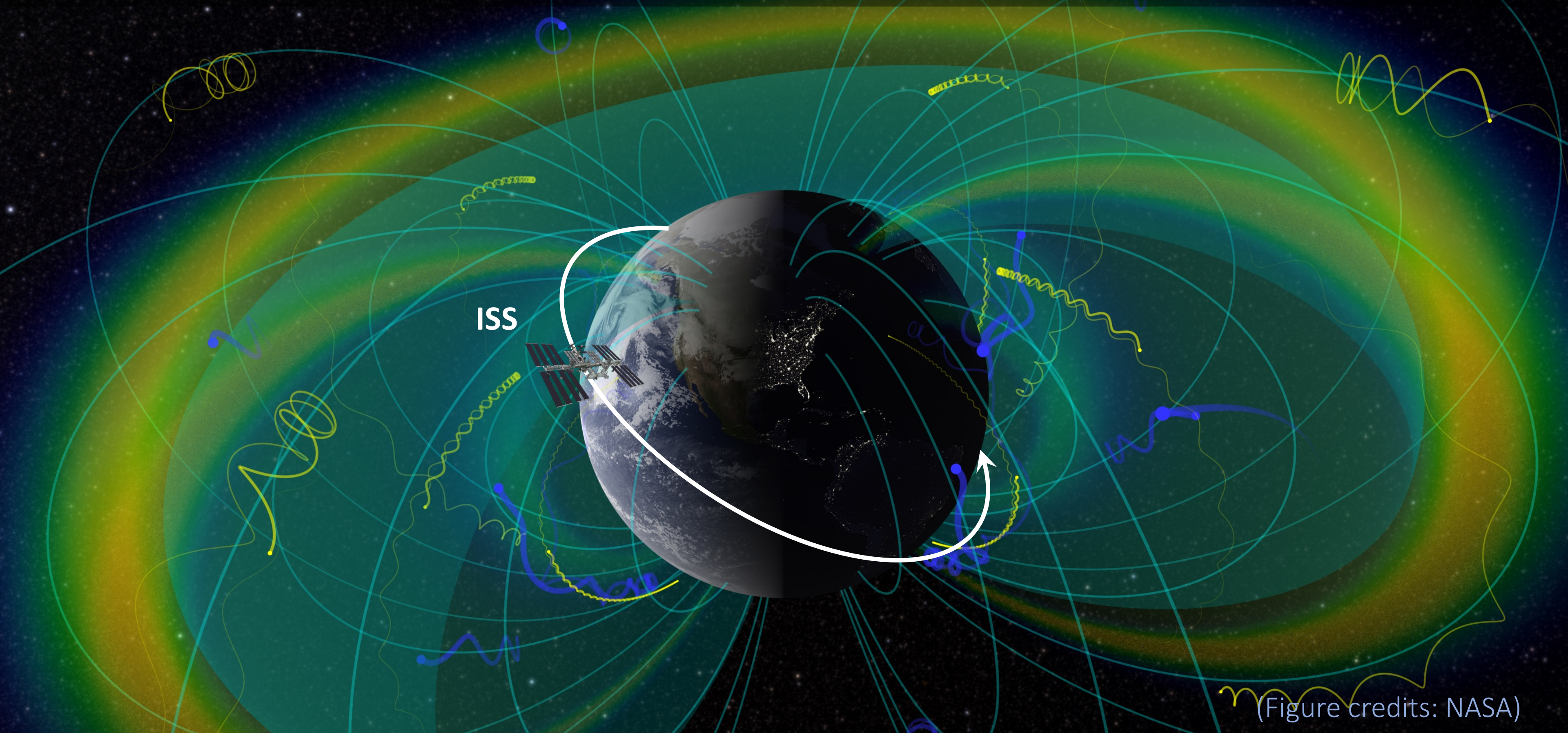


Figure credits: ESA

Particles **trapped** in the Earth 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 Magnetosphere

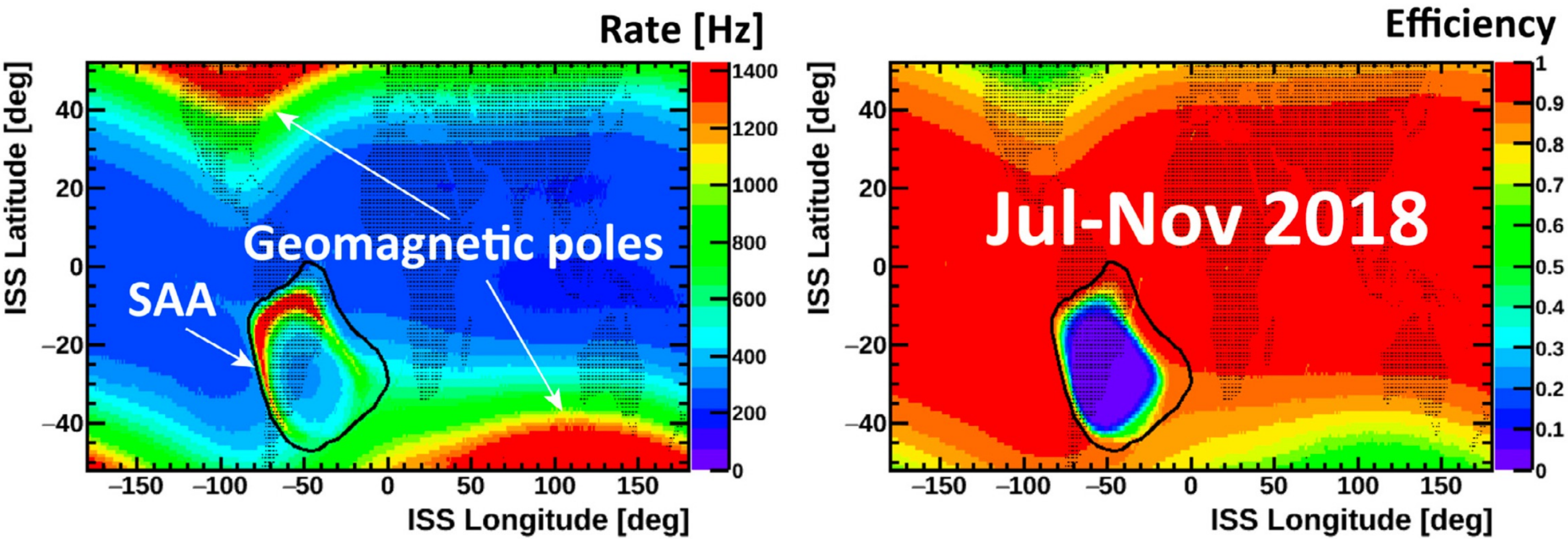


(Figure credits: NASA)

Particles **trapped** in the Earth 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.

The 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.

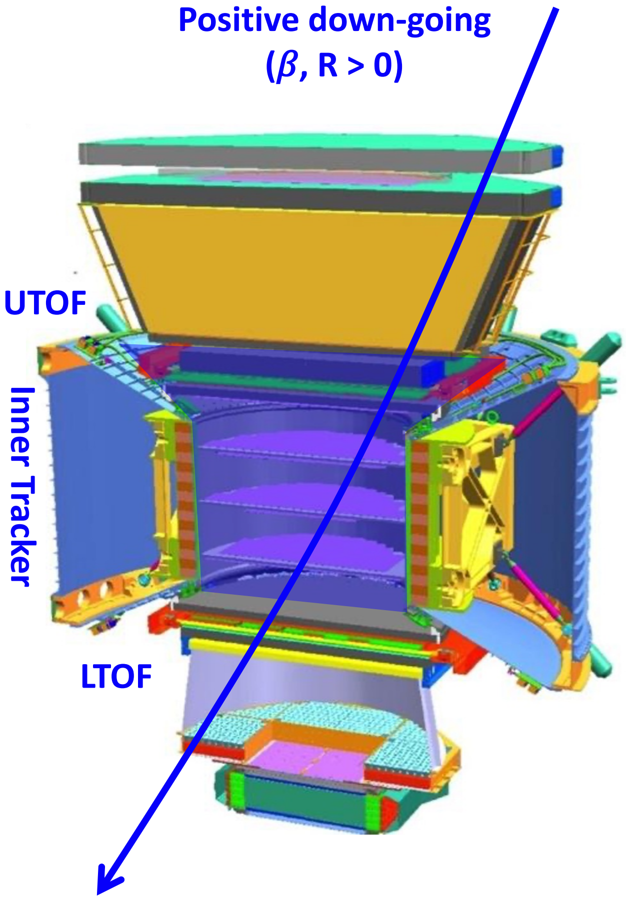


M. Aguilar et al., Phys. Rep. **894** (2021) 1–116.

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

Since trapped particles are expected to enter from all directions, the analysis is performed in the largest field of view (defined by inner tracker) and all available directions including both **down-going** and **up-going** events.
Only nuclei with **Z>2** considered.

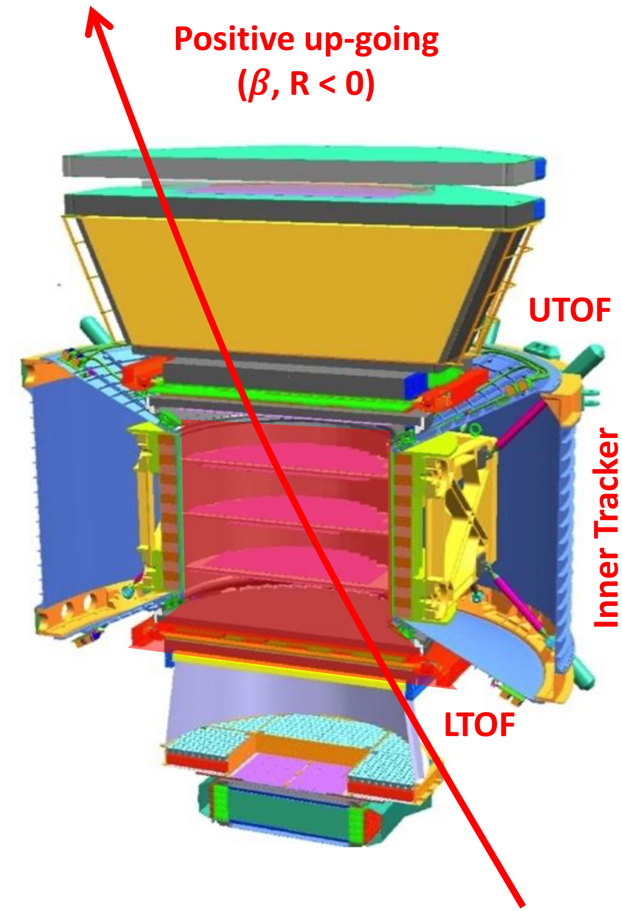


Velocity, β, and direction
measured with TOF
($\Delta\beta\approx1\%$ at $\beta=1$ and $Z=6$).

Rigidity, $R=p/Z$, and charge sign
with Inner Tracker
($\Delta R/R\approx10\%$ at $R=2$ GV).

Charge identification, Z,
with Inner Tracker ($\Delta Z/Z\approx2\%$ for $Z=6$)
and **UTOF** or **LTOF** ($\Delta Z/Z\approx4\%$ for $Z=6$).

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



Backtracing of AMS Data

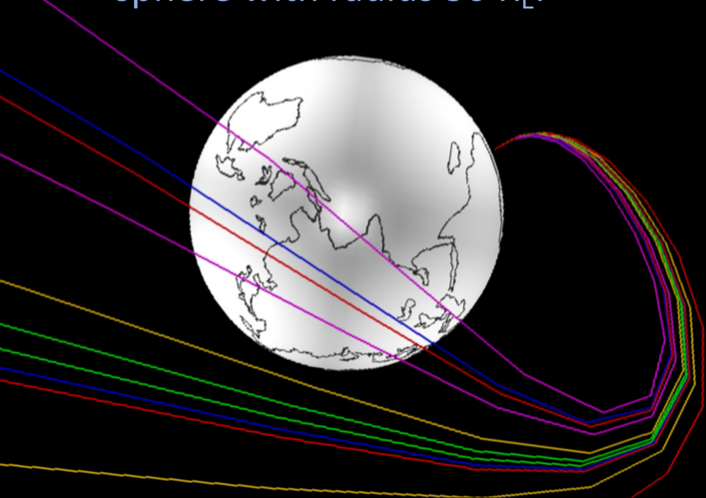
A **backtracing** is used to understand the **origin** of the particle.

It consists in **propagating backwards in time** the particle trajectory in the Earth's magnetic field (modelized using the International Geomagnetic Reference Field model, IGRF-13).

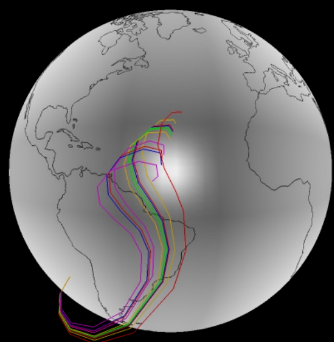
To avoid tracing instabilities and measurement systematics, the procedure is repeated several time:

- Arrival direction with a spread of $\Delta\vartheta = 0.2°$;
- Rigidity with a resolution of $\Delta R/R = 10\%$;
- ISS orbit coordinate evaluation with a time spread of $\Delta t = 50$ ms.

Primary: the particle intersects in finite time a sphere with radius 50 R_E.



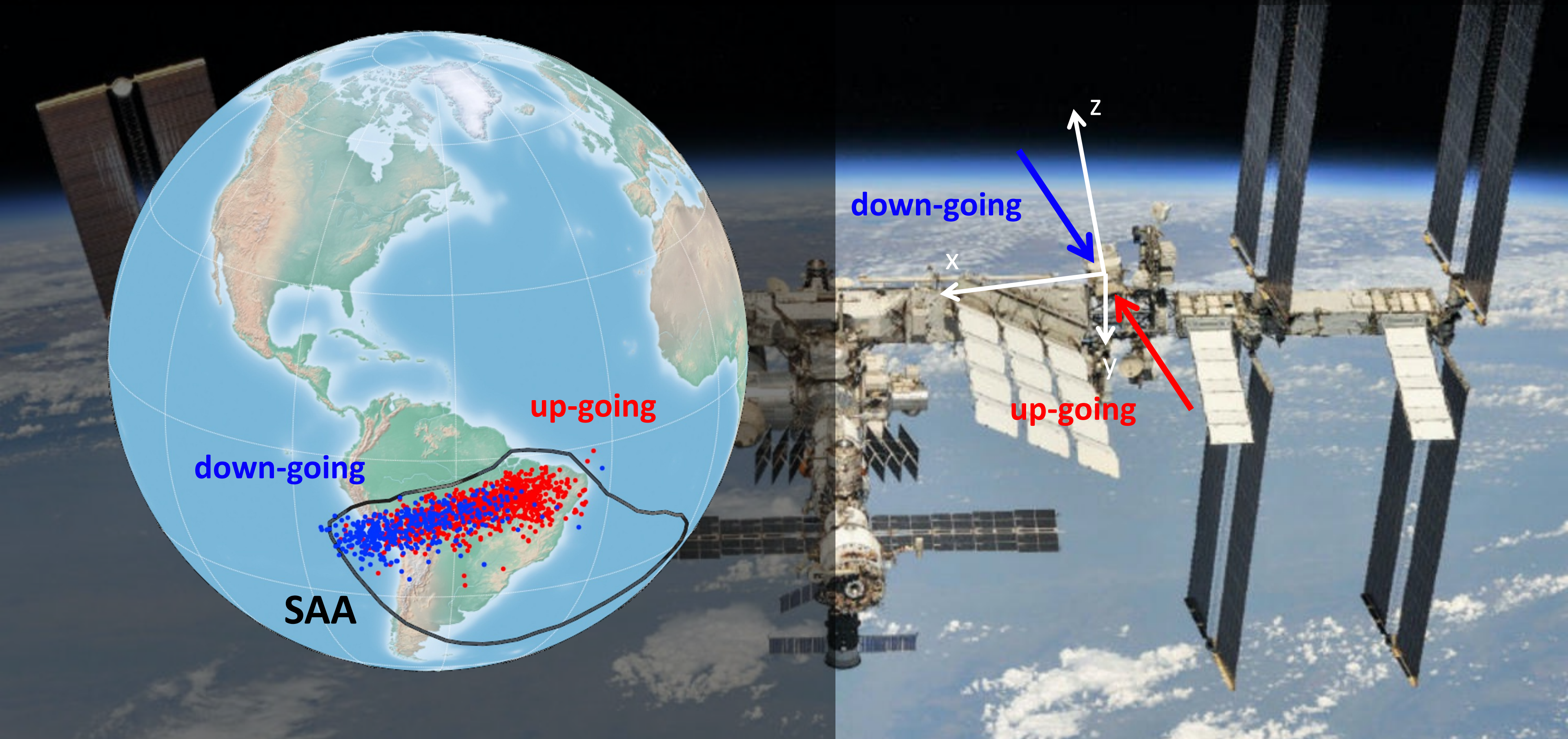
Secondary: if intersects Earth's atmosphere set at 100 km from ground.



Stably-Trapped: trajectory exceeding maximum number of laps around the Earth (10).

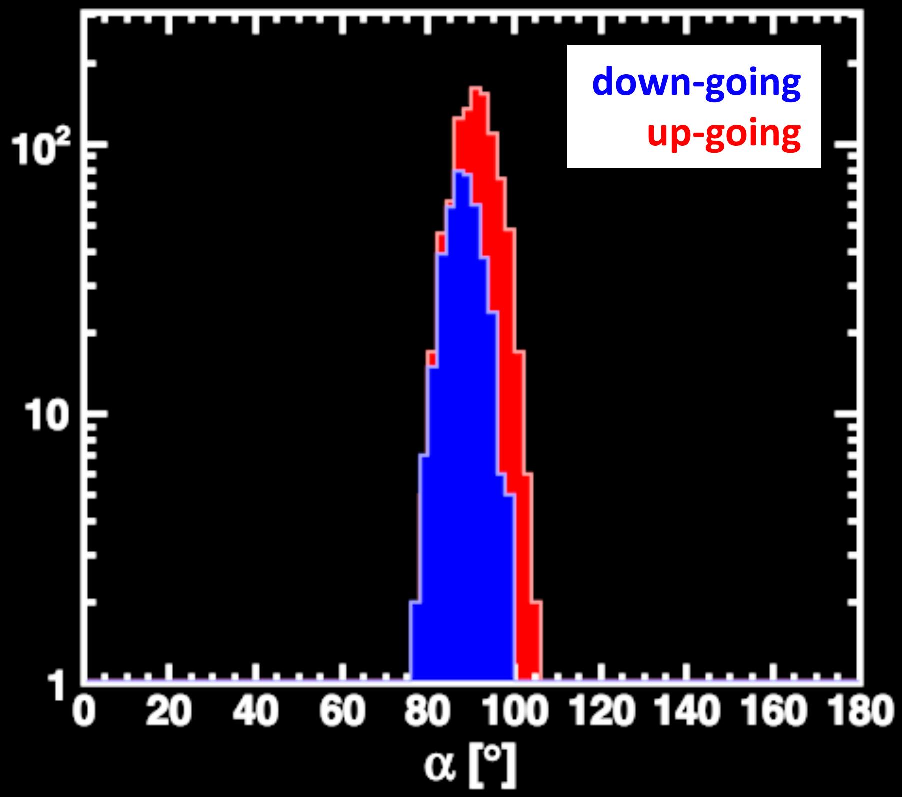
Stably Trapped Nuclei in the SAA

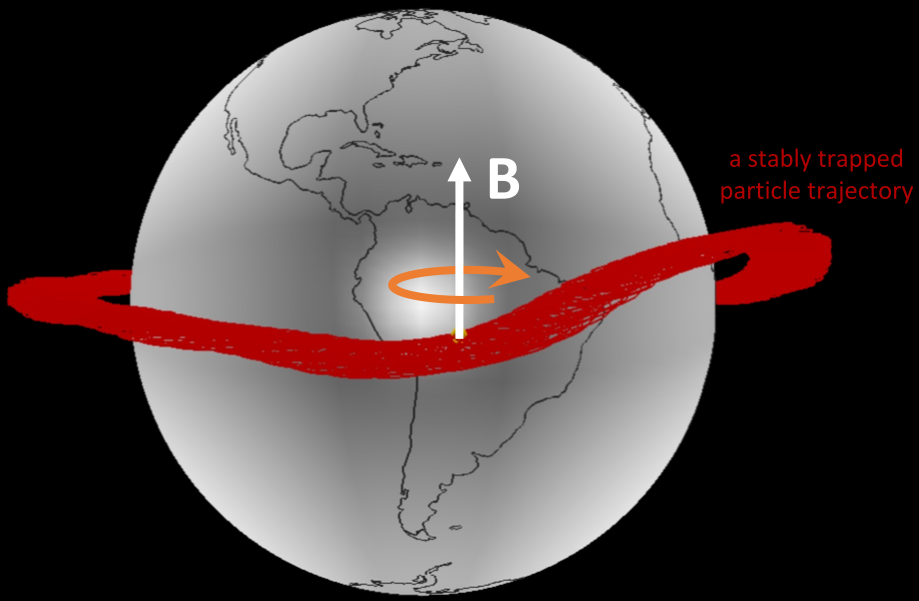
Backtracing allows to select particles stably-trapped in Earth’s magnetosphere.
A clear population of stably trapped ions (Z>2) entering in AMS
both from the **top** and the **bottom** has been identified.



Stably Trapped Nuclei in the SAA: Pitch Angle Distribution

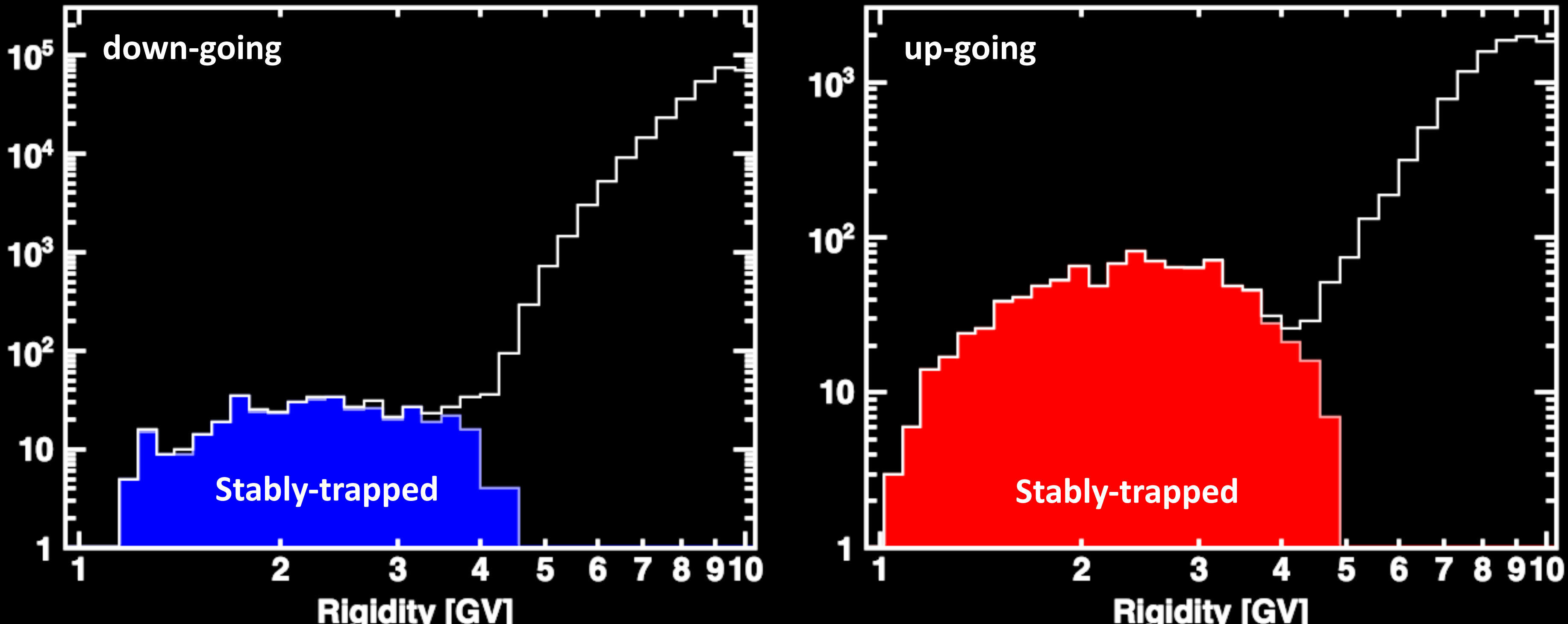
Pitch angle is the angle between particle and magnetic field.
All stably-trapped ions have a pitch angle of about 90°.





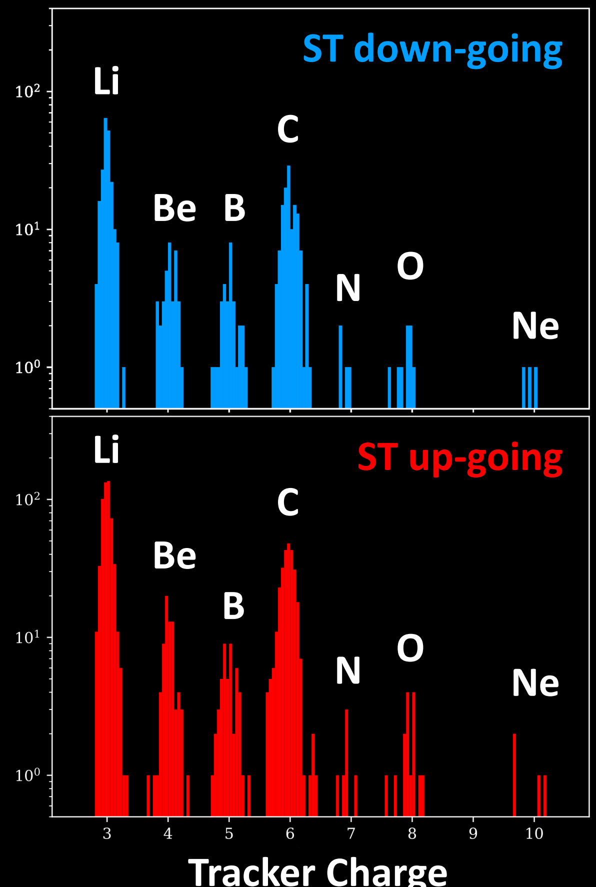
Stably Trapped Nuclei in the SAA: Geomagnetic Cutoff

Selecting North SAA ($-20<\vartheta_M<10$, $-10<\varphi_M<50$).
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)



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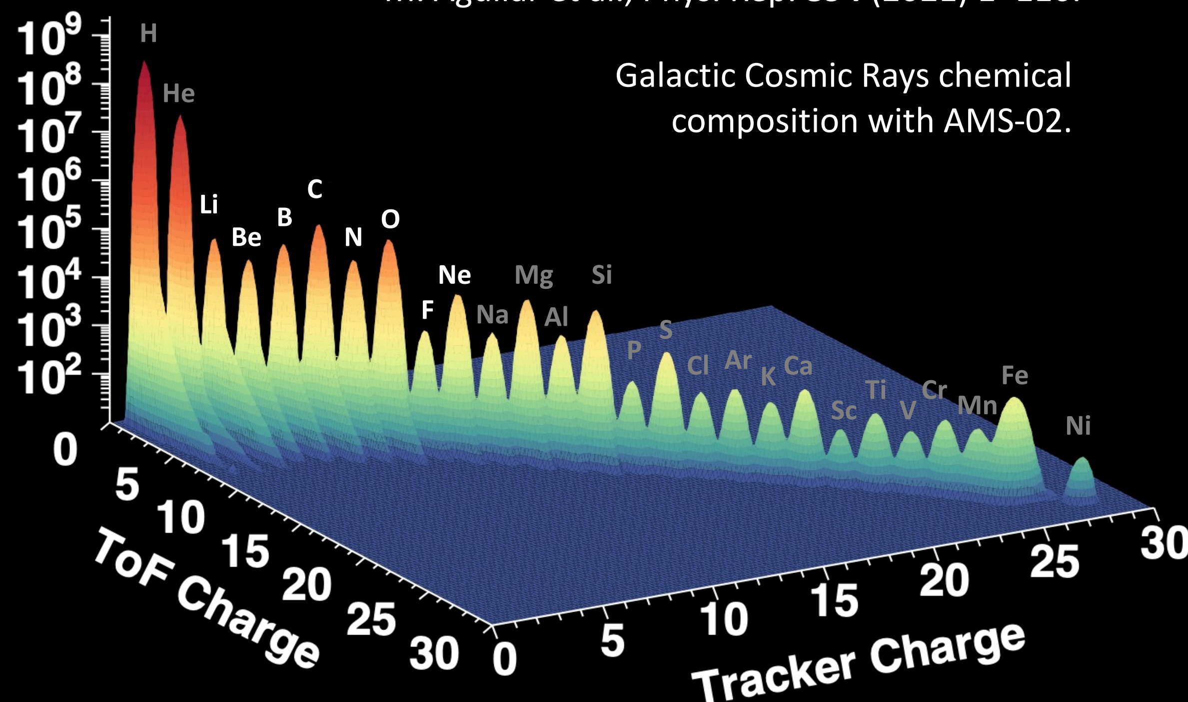
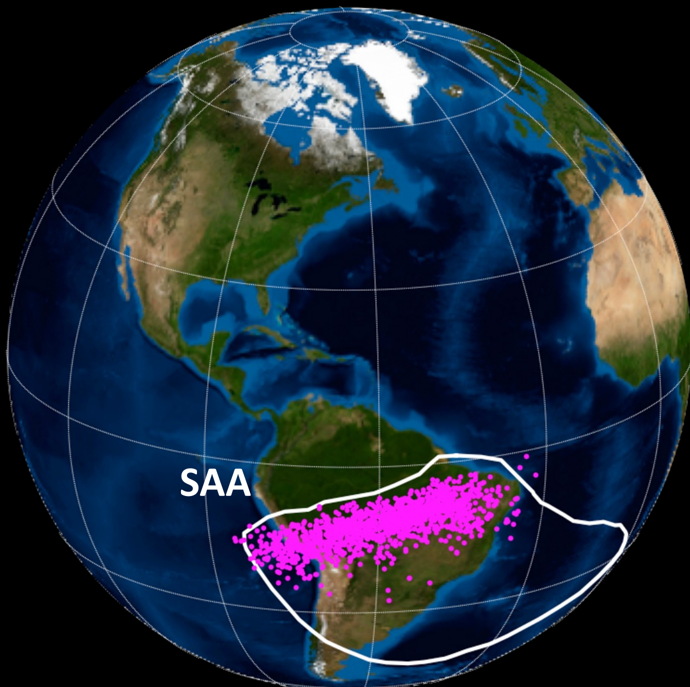
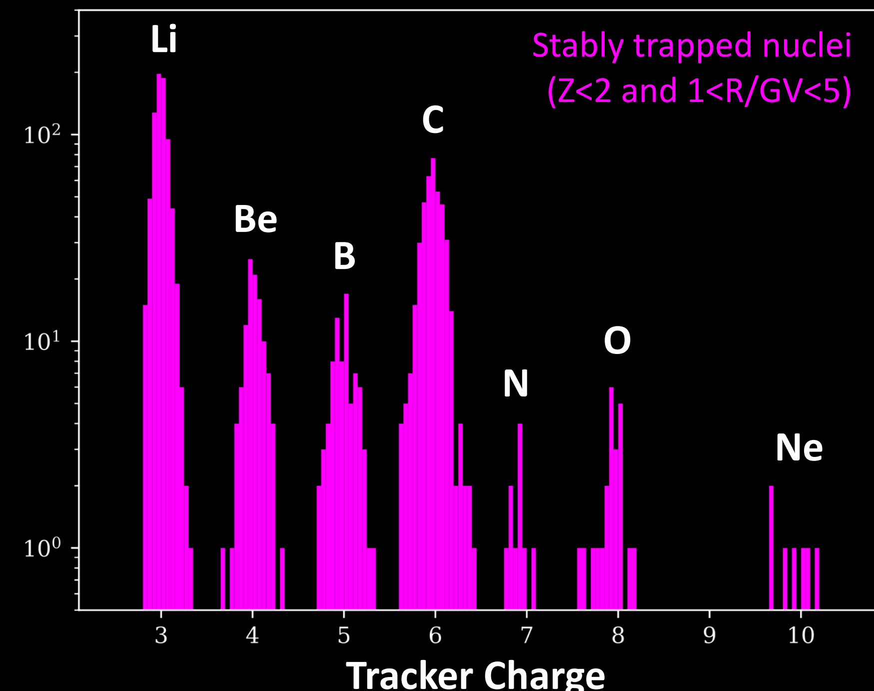


Galactic Cosmic Rays chemical composition with AMS-02.

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 !