Karlsruher Institut für Technologie

Anisotropy of particle fluxes in primary cosmic rays measured with the Alpha Magnetic Spectrometer on the ISS

July 26th, 2019

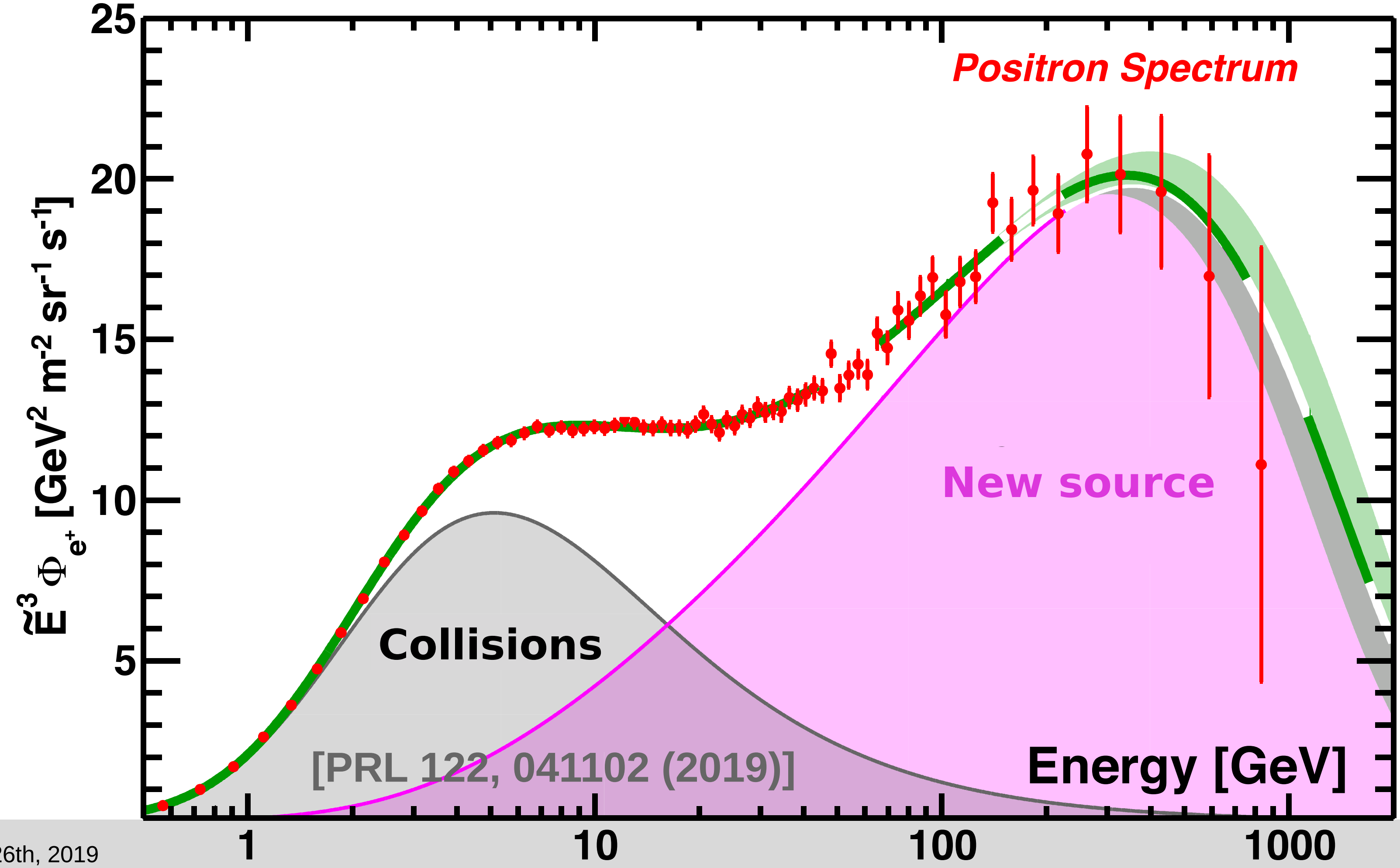
36th International Cosmic Ray Conference, Madison, WI, USA

Iris Gebauer for the AMS collaboration

INSTITUTE FOR EXPERIMENTAL PARTICLE PHYSICS

THERE IS AN UNKNOWN SOURCE OF ENERGETIC POSITRONS

See talks by
Z. Weng (CRD2h)
B. Bertucci (H9)



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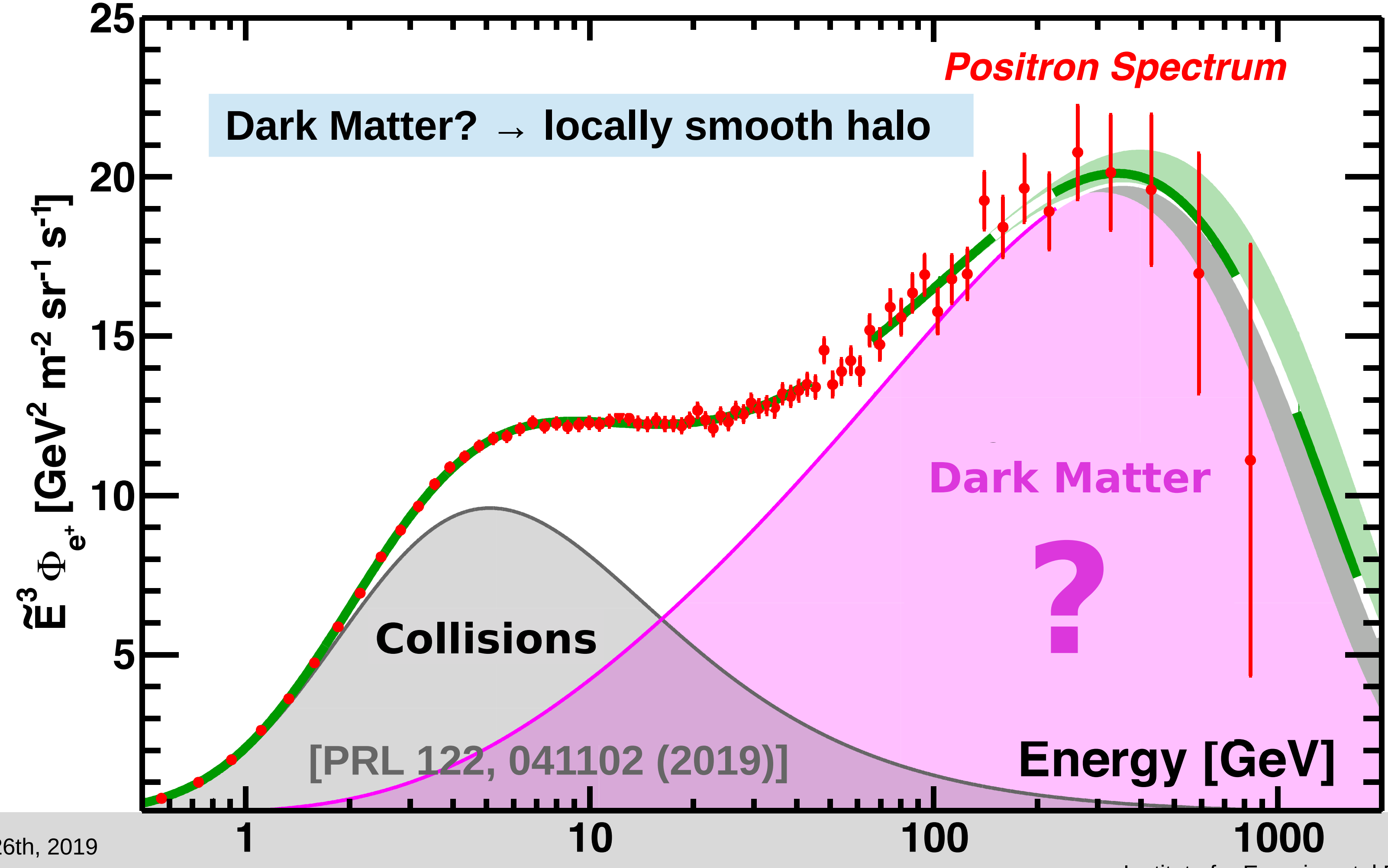

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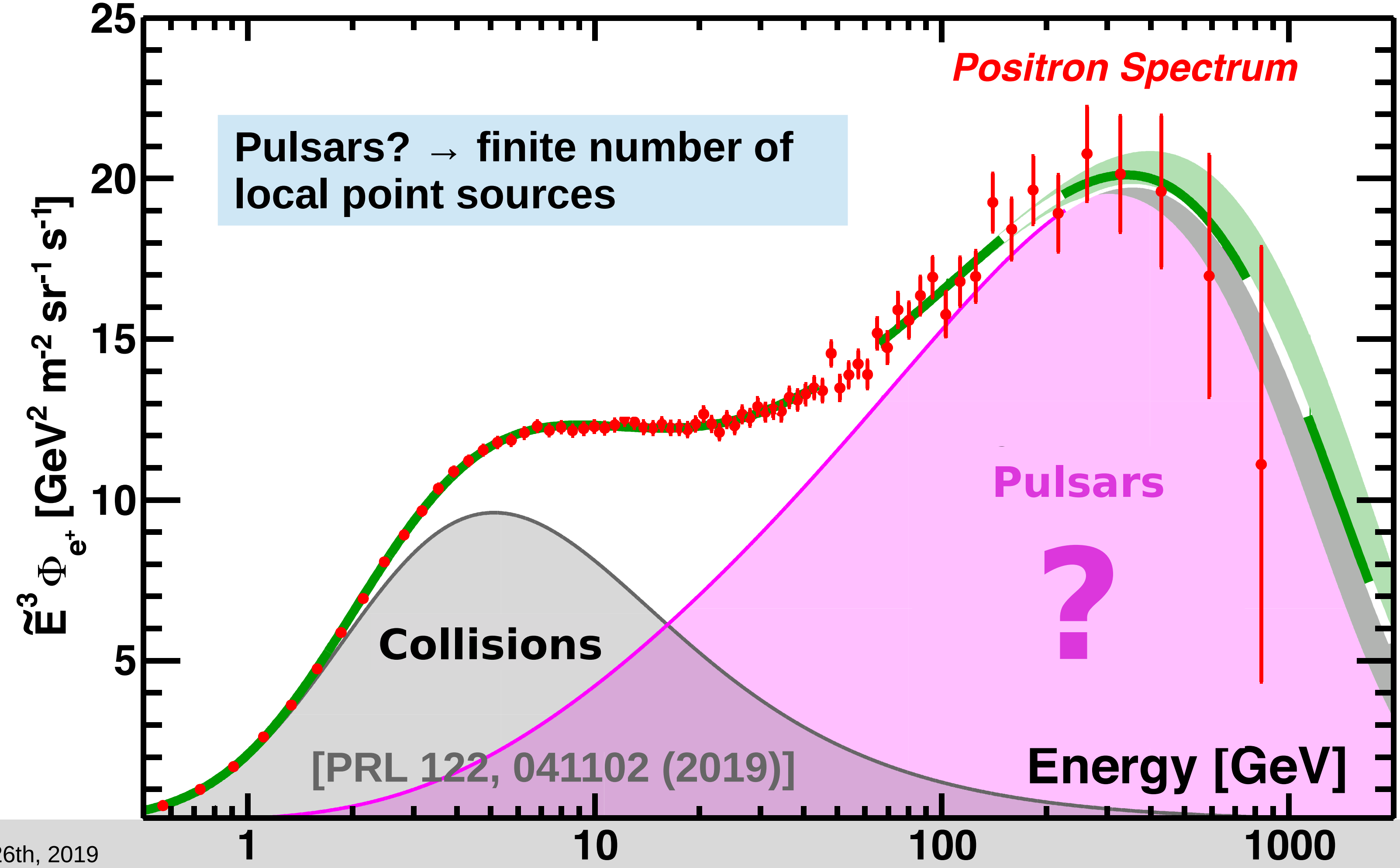
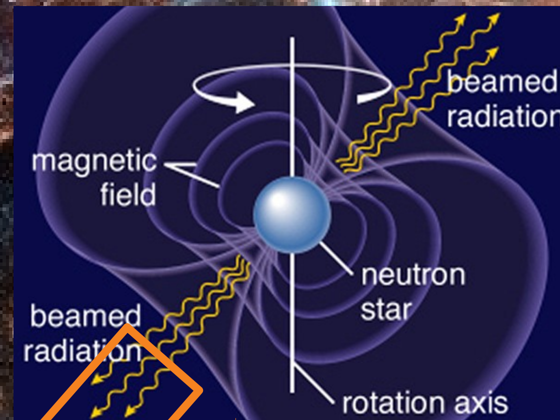


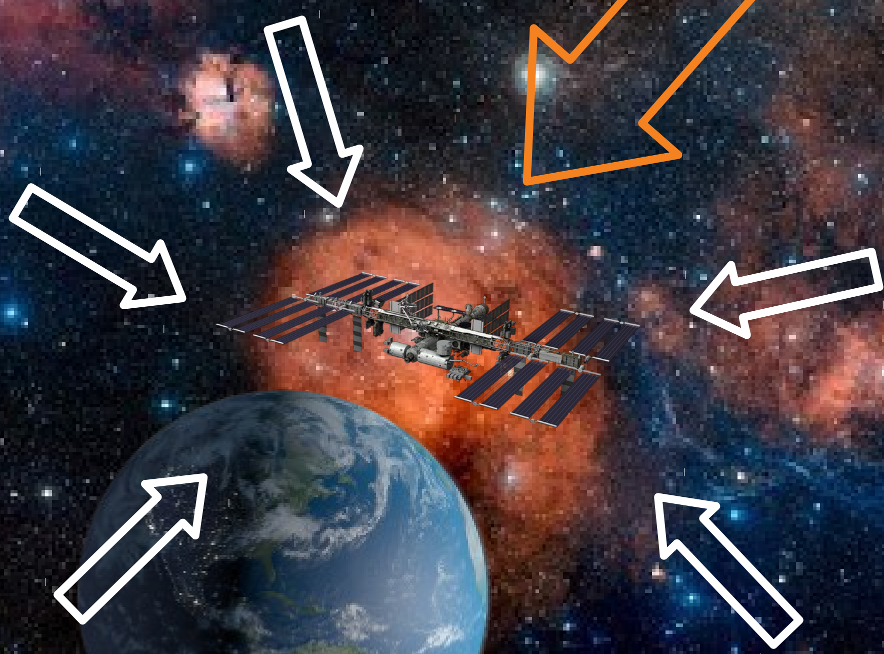
DO WE LIVE CLOSE TO A LOCAL POSITRON SOURCE?

Expectation for pulsars: δ ~1%

[D. Hooper, P. Blasi & P. D. Serpico, JCAP 0901(2009)]



unknown source

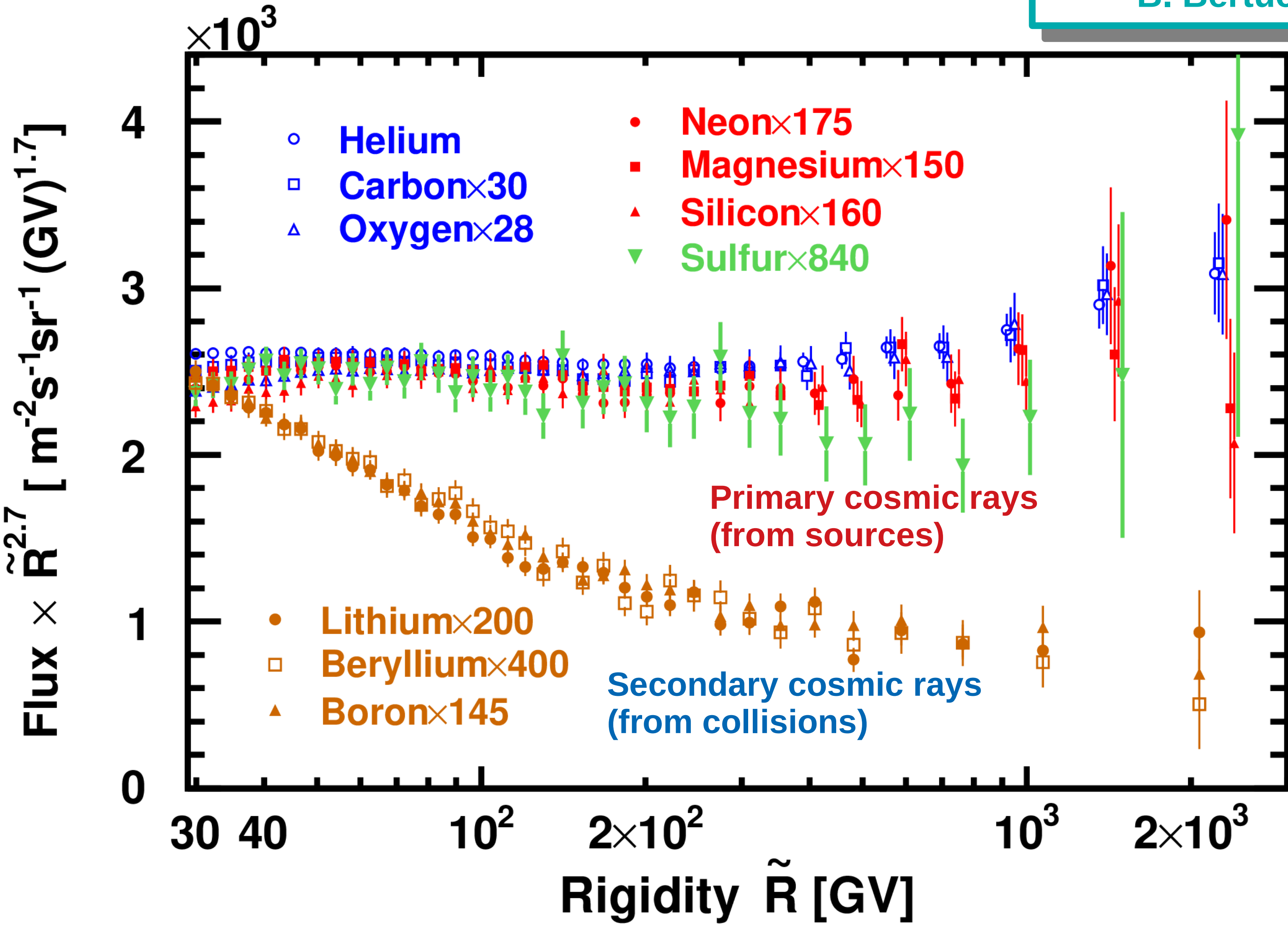


cosmic ray collisions

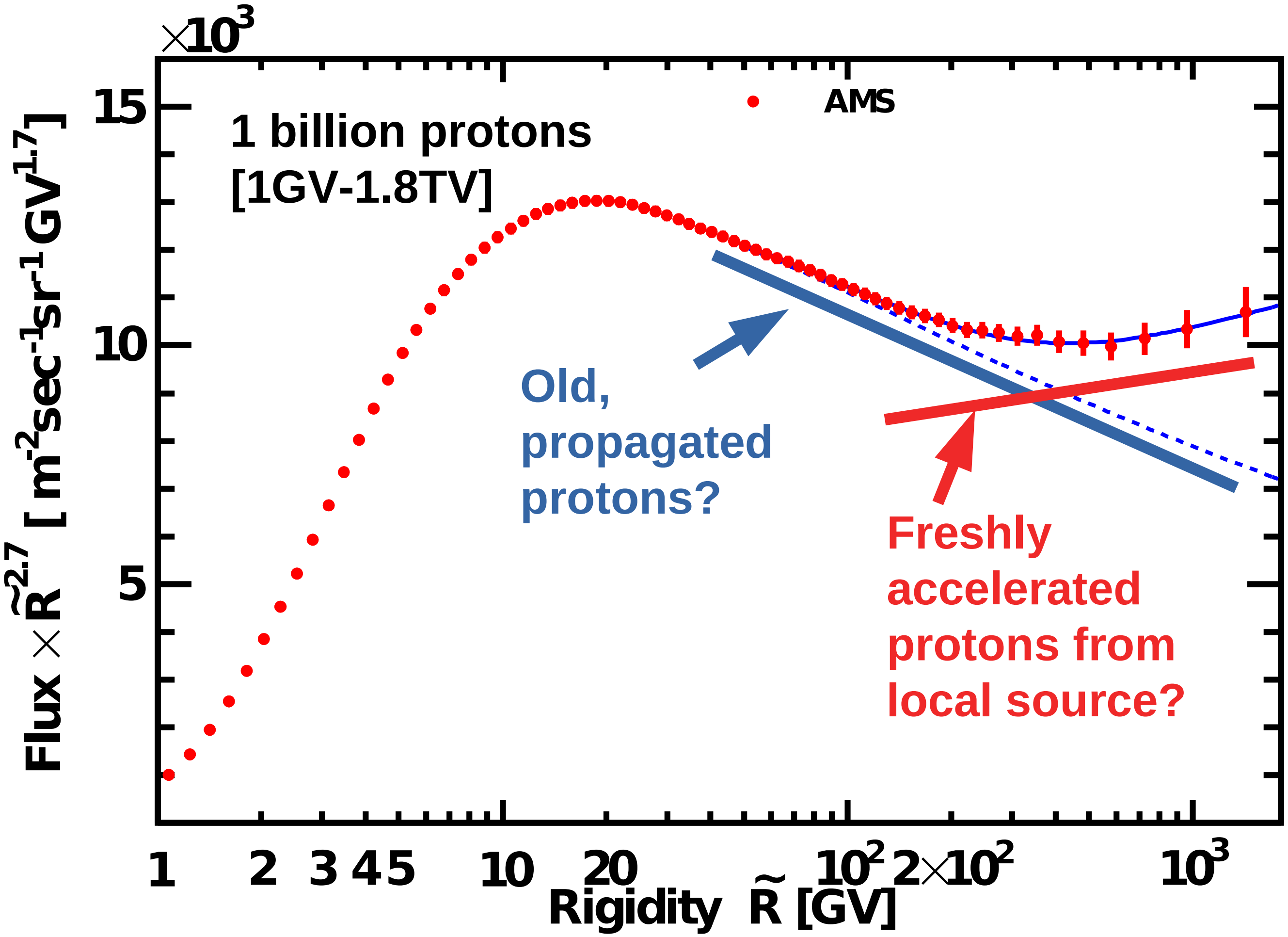
[Digitized Sky Survey, ESA/ESO/NASA FITS Liberator, Davide De Martin]

WHAT IS THE ORIGIN OF THE SPECTRAL BREAK IN NUCLEI?

See talks by
A. Oliva (CRD6b)
Q. Yan (CRD7a&8b)
B. Bertucci (H9)



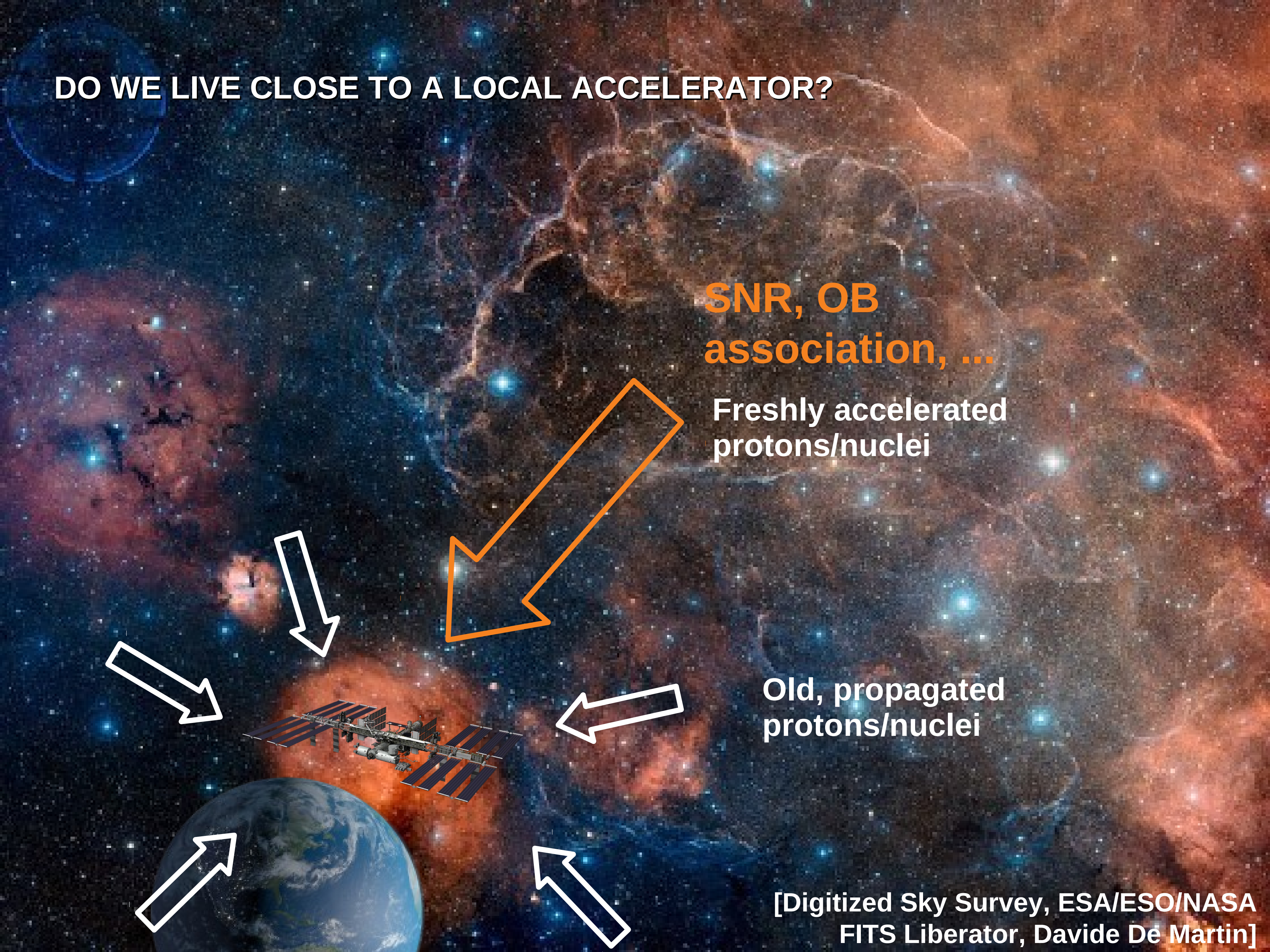
DO WE LIVE CLOSE TO A LOCAL ACCELERATOR?



Bernard et al., A&A 555, A48 (2013)

Ptuskin et al., APJ 763, 47 (2013)

+ many more excellent papers

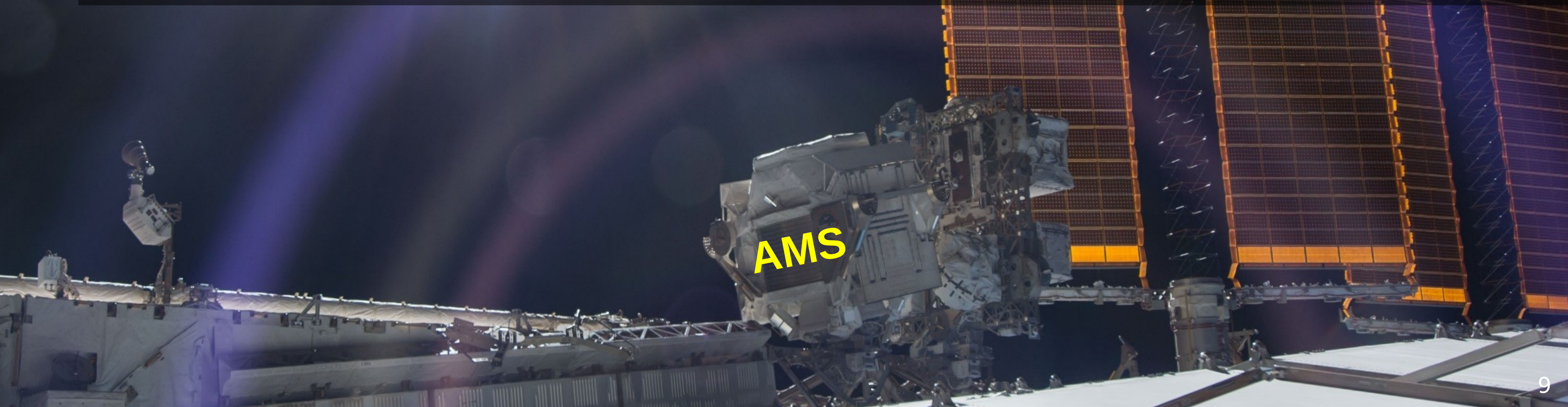

DO WE LIVE CLOSE TO A LOCAL ACCELERATOR?
SNR, OB association, ...
Freshly accelerated protons/nuclei
Old, propagated protons/nuclei
[Digitized Sky Survey, ESA/ESO/NASA FITS Liberator, Davide De Martin]

SEARCH FOR ANISOTROPIES IN NUCLEI

We have searched for dipole anisotropies in the arrival directions of protons, Helium, Carbon and Oxygen.

The search for dipole anisotropies requires

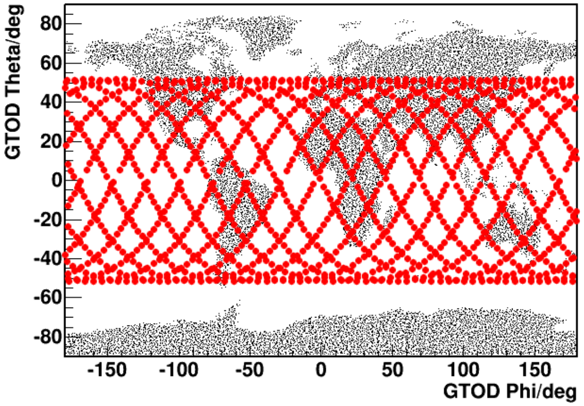
- **knowledge of the isotropic arrival directions as they would be measured by AMS.**
- **an understanding of the detector to the level of the reconstructed dipoles**



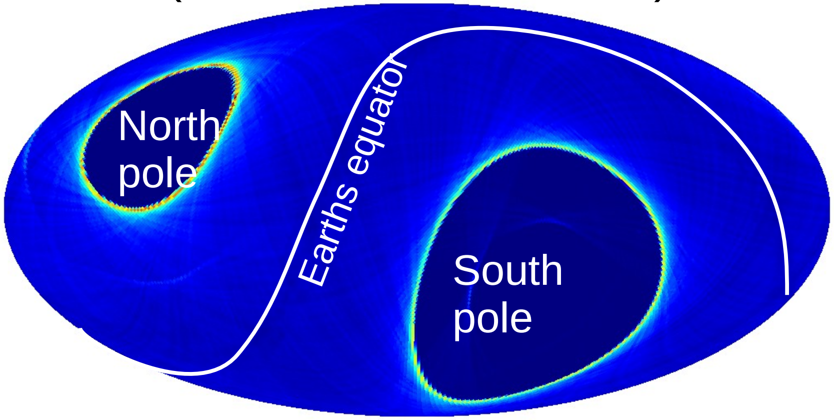
WHAT DOES AN ISOTROPIC SKY LOOK LIKE?

AMS-02 does not scan the galactic sky uniformly.

ISS global position 1 day



AMS-02 galactic pointing direction 2.5 years (**Galactic coordinates**)



Iris Gebauer
Institute for Experimental Particle Physics

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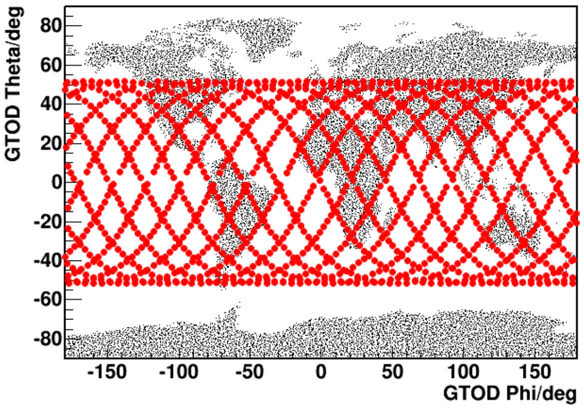
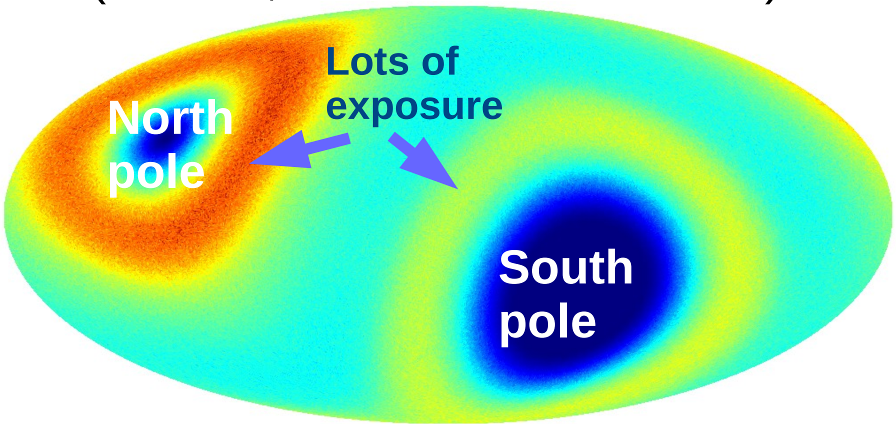


AMS-02 proton sky
(>40 GV, **Galactic coordinates**)



Opening angle:
~ 40 degs for protons
~ 25 deg for electrons

On top of that we have:

- **Geomagnetic cutoff → high rate of low energy particles at poles → trigger busy**
- **Position dependent efficiencies**

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REFERENCE MAPS FOR ANISOTROPY SEARCHES

Reference map: best guess for an image of an isotropic sky measured by AMS-02 in the respective data taking period. Any deviation from this reference map might be detected as a signal.

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REFERENCE MAPS FOR ANISOTROPY SEARCHES

Reference map: best guess for an image of an isotropic sky measured by AMS-02 in the respective data taking period. Any deviation from this reference map might be detected as a signal.

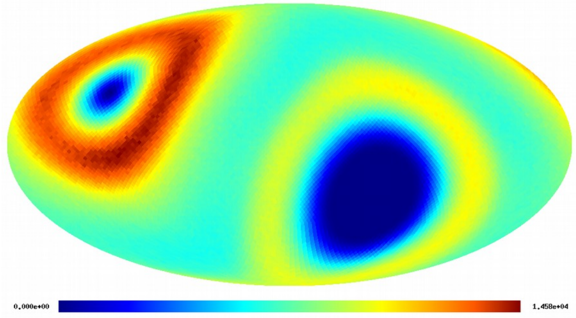
Choices for reference maps:

I) other cosmic ray species (e.g. protons used for positrons)

II) *same* cosmic ray species (at different energy)

Methods discussed in:
PoS(ICRC2017)186
PoS(ICRC2017)202
PoS(ICRC2015)408

III) **absolute anisotropies:** simulation of an isotropic sky **from data**



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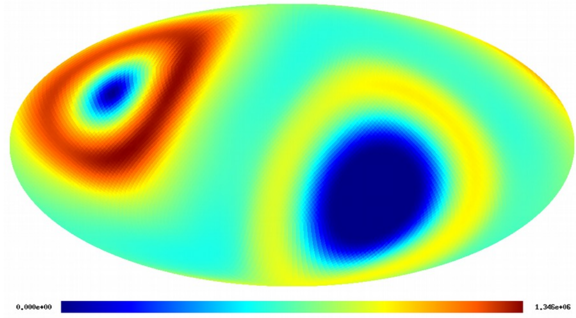

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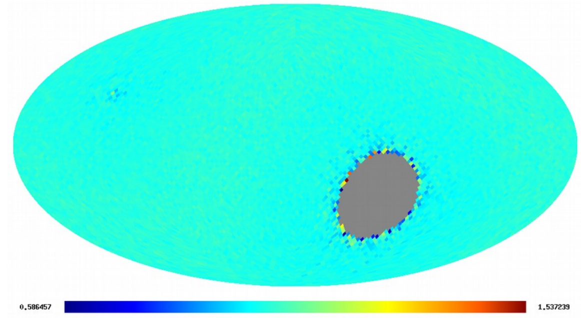

40 GV-1.8 TV protons

40 GV-1.8 TV Reference map

Ratio (proton/reference)

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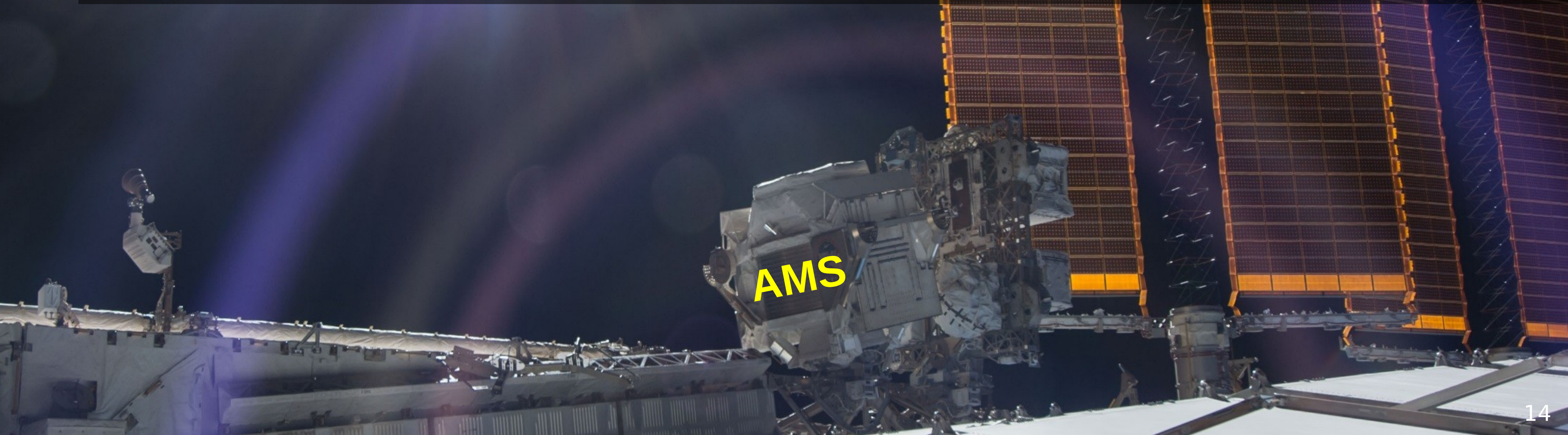
The results presented here are absolute anisotropies.

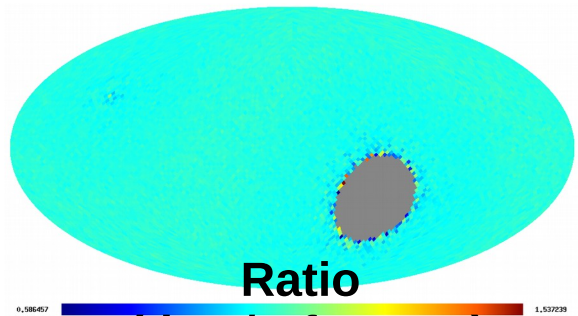
Other methods, if applicable, are used for internal cross checks and to control systematics of the method.

All methods yield consistent results.



EXTRACTING DIPOLE COMPONENTS FROM DATA

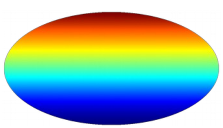
A likelihood fit procedure is used to expand the normalized ratio of data and reference map into spherical harmonics.



Ratio (data/reference)

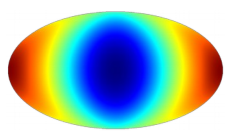
$$f(\theta,\phi)=\sum_{l=0}^{\infty}\sum_{m=-l}^{l} a_{lm} Y_l^m(\theta,\phi)$$

North-South:



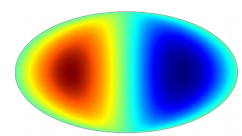
$$\rho_{NS} = \sqrt{\frac{3}{4\pi}} a_{10}$$

Forward-Backward:



$$\rho_{FB} = \sqrt{\frac{3}{4\pi}} a_{11}$$

East-West:



$$\rho_{EW} = \sqrt{\frac{3}{4\pi}} a_{1-1}$$

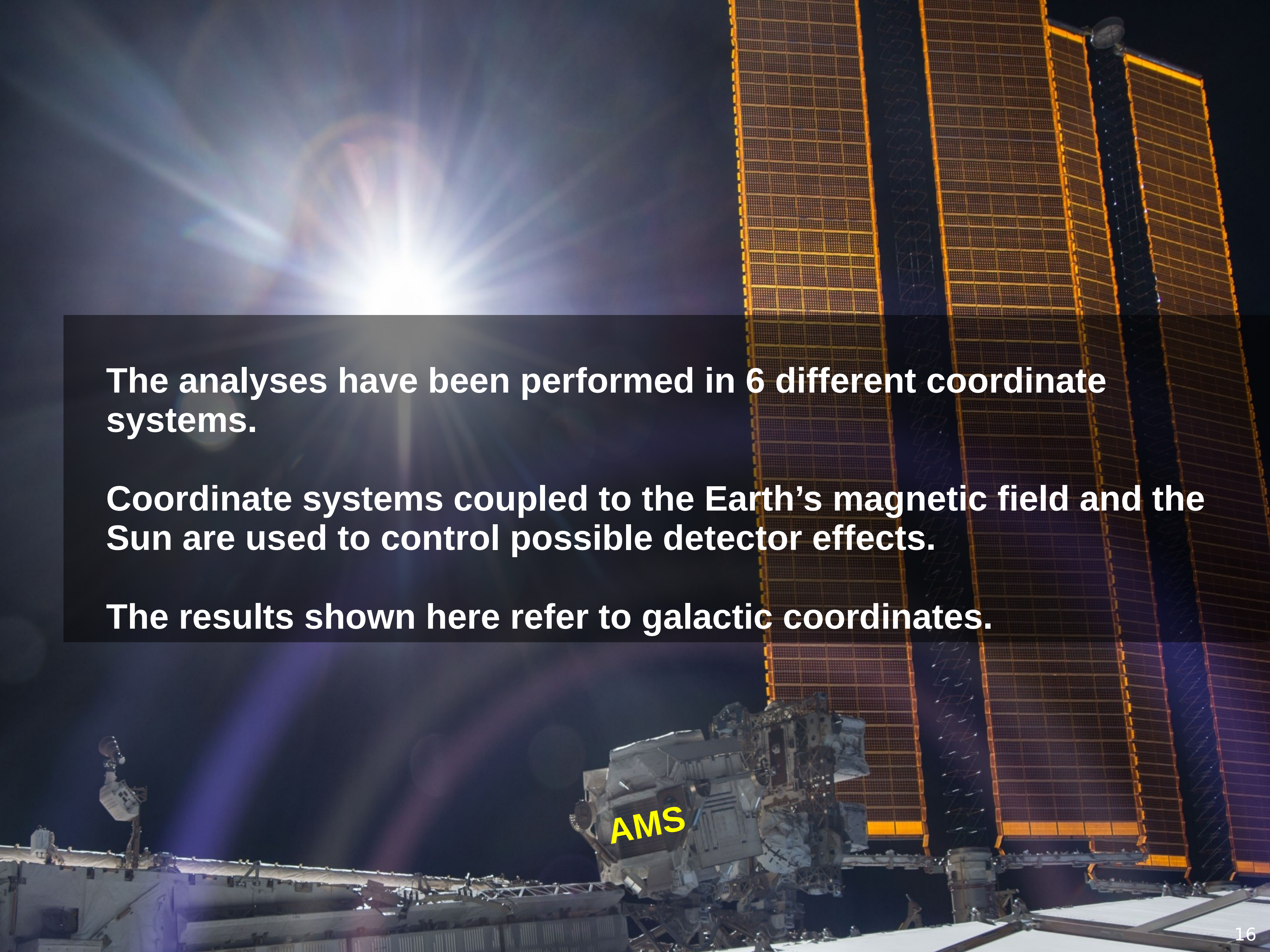
Dipole amplitude: $\delta = \sqrt{\rho_{NS}{}^2 + \rho_{FB}{}^2 + \rho_{EW}{}^2}$

Analysis is performed for any coordinate system of interest.

The analyses have been performed in 6 different coordinate systems.

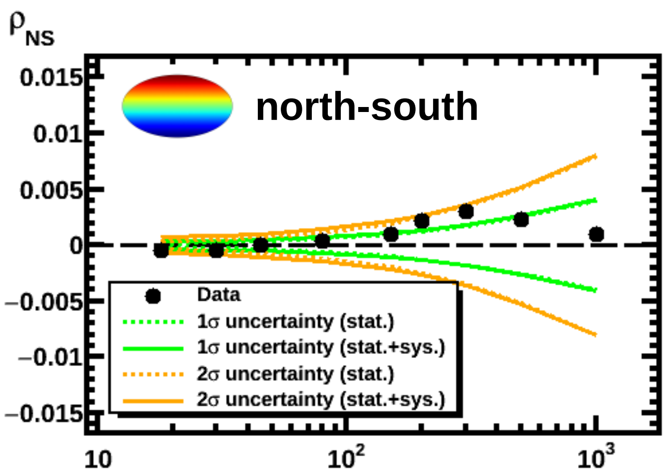
Coordinate systems coupled to the Earth's magnetic field and the Sun are used to control possible detector effects.

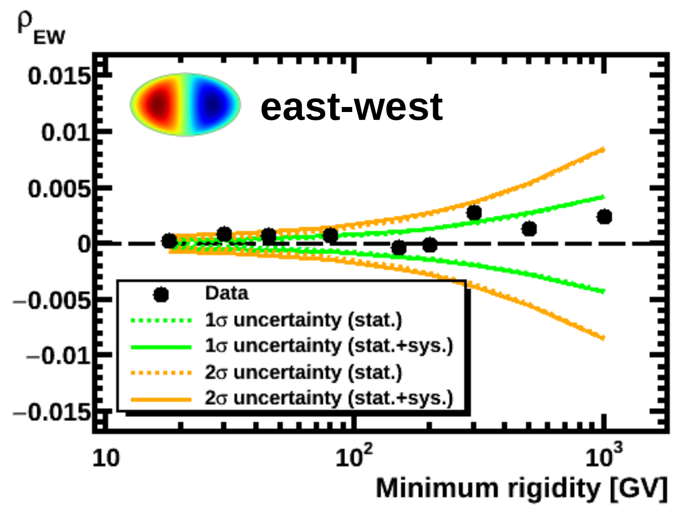
The results shown here refer to galactic coordinates.

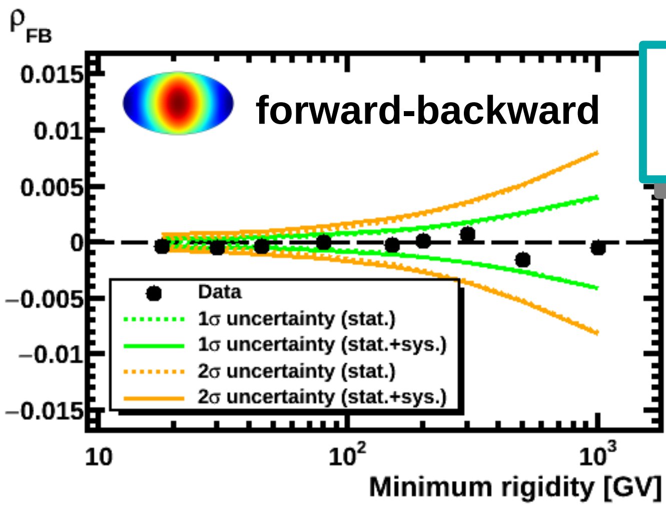


DIPOLE COMPONENTS:
PROTONS

Selected events are grouped into 9 cumulative rigidity bins with minimum rigidites 18, 30, 45, 80, 150, 200, 300, 500 and 1000 GV.







consistent with isotropy

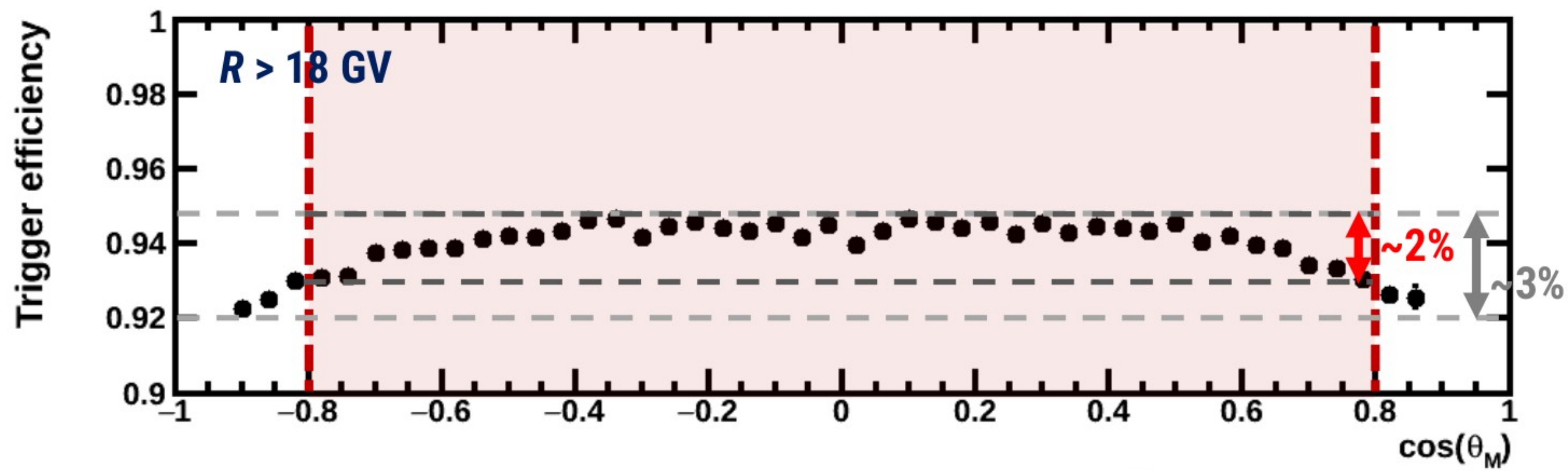
Dipole amplitude:

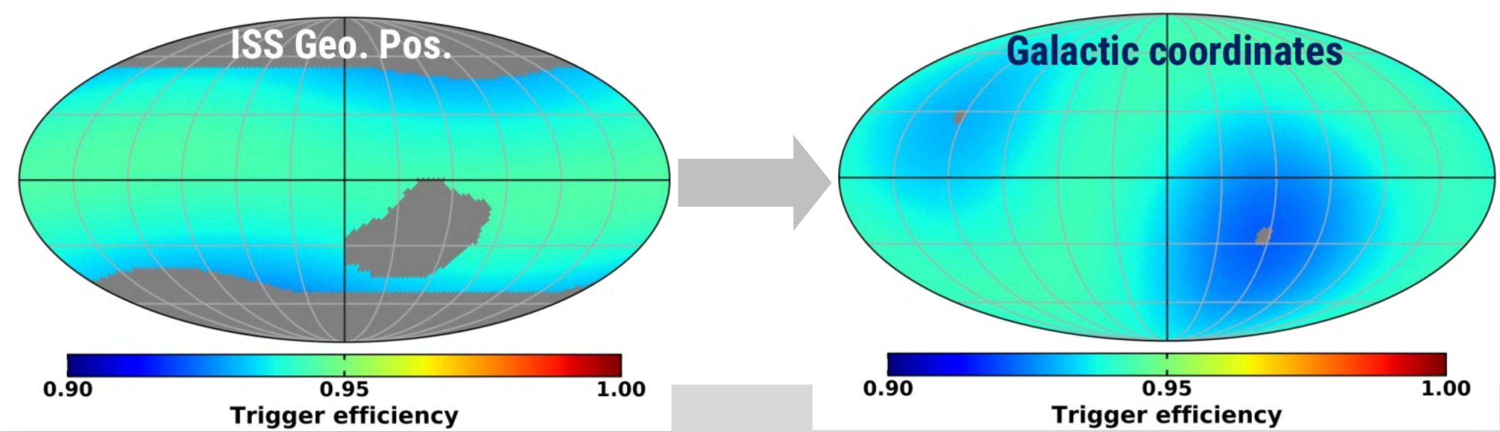
$$\delta = \sqrt{\rho_{NS}{}^2 + \rho_{FB}{}^2 + \rho_{EW}{}^2}$$

7.5 years
total exposure time: 1.72×10^8 s

EFFICIENCY CORRECTIONS

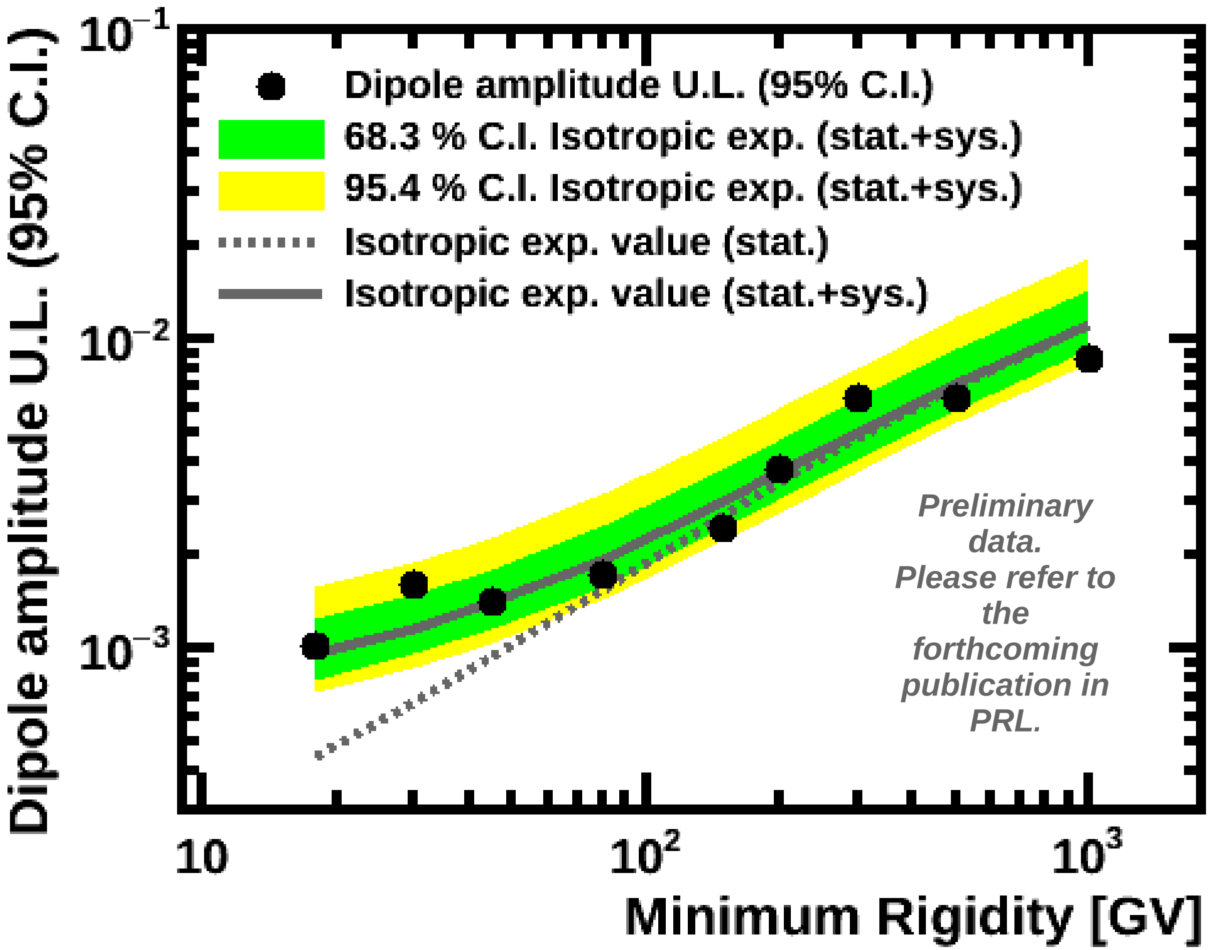
To search for dipole components on the sub-percent level, requires to understand the detector to at least the same level.





UPPER LIMITS ON DIPOLE AMPLITUDE: PROTONS

$$\delta = \sqrt{{\rho_{NS}}^2 + {\rho_{FB}}^2 + {\rho_{EW}}^2}$$



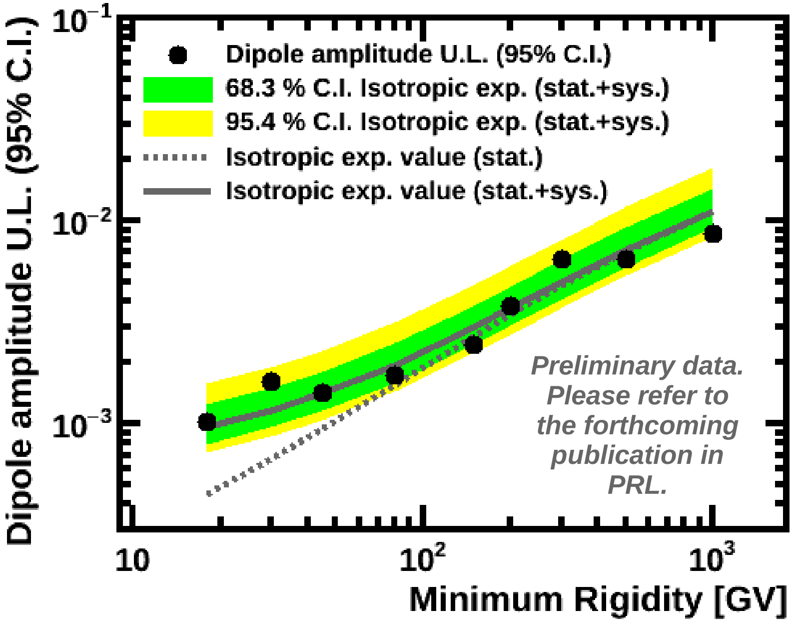
- **High rigidities:** For R>70 GV the measurement is limited by statistics.
- **Low rigidities:** Systematics on efficiency corrections **limit the sensitivity** at low R to **0.1%**.
- **Upper limit on dipole amplitude:** **δ_p(>200 GV) < 0.38% at 95% C.I.**

UPPER LIMITS ON DIPOLE AMPLITUDE:
PROTONS AND HELIUM

Karlsruhe Institute of Technology

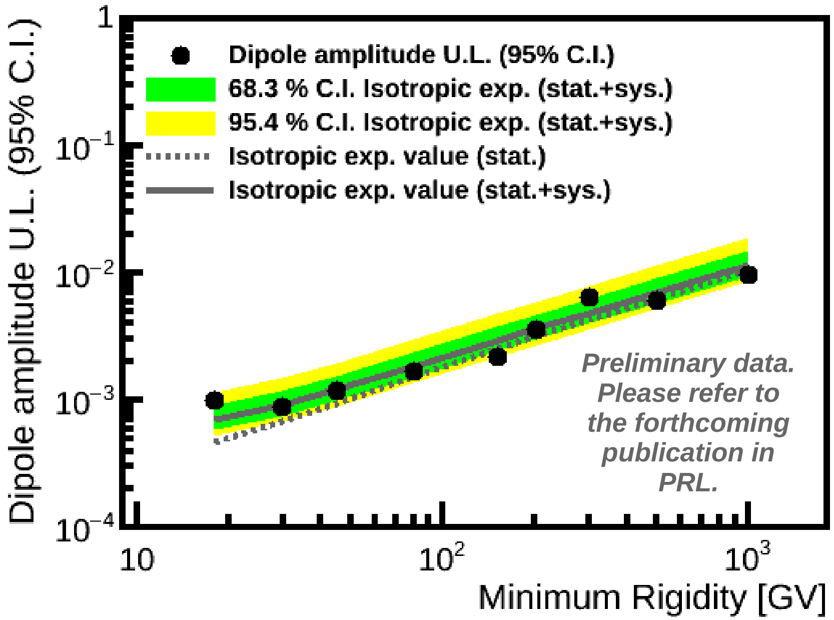
Protons

1.2 x 10^8 events, R>18 GV



Helium

1.0 x 10^8 events, R>18 GV



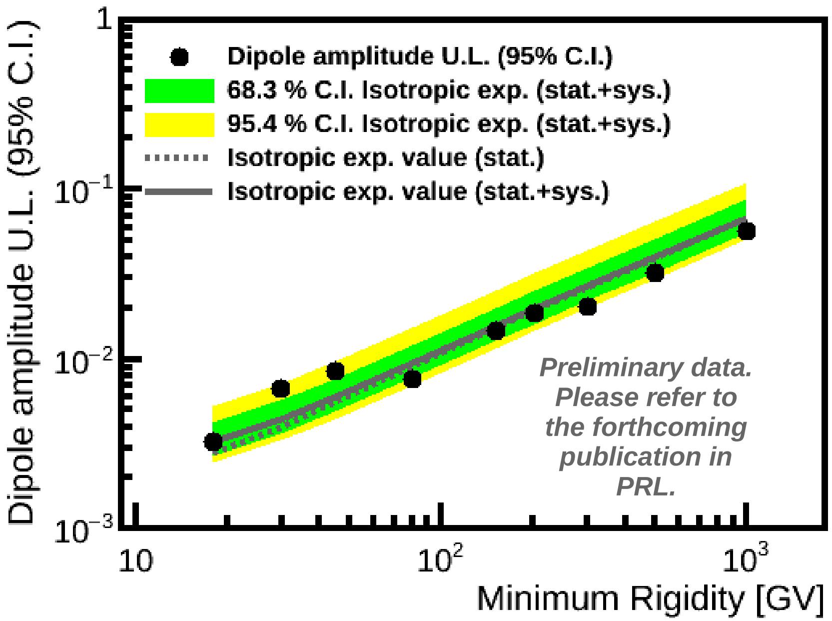
Upper limit on dipole amplitude:
δ_p(>200 GV) < 0.38% at 95% C.I.

Upper limit on dipole amplitude:
δ_{He}(>200 GV) < 0.36% at 95% C.I.

UPPER LIMITS ON DIPOLE AMPLITUDE:
CARBON AND OXYGEN

Carbon

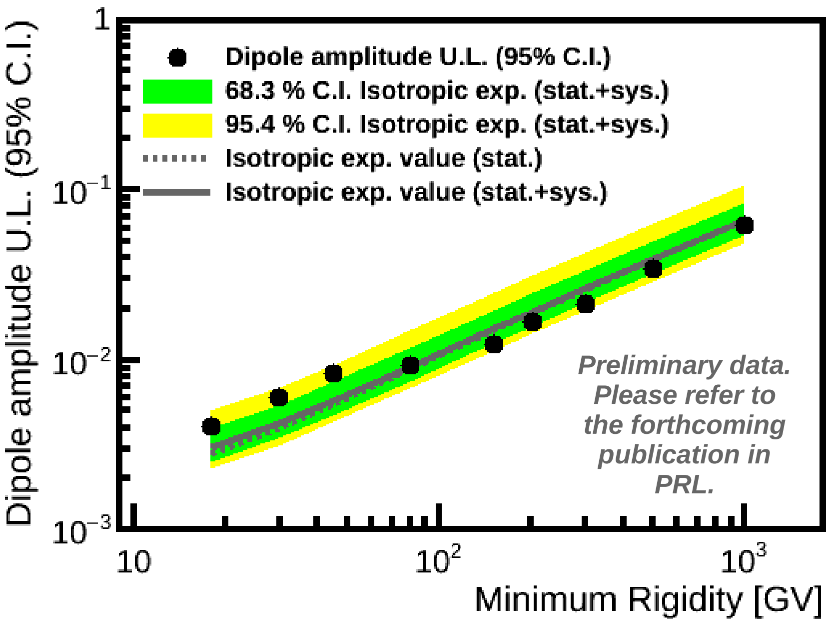
2.9 x 10^6 events, R>18 GV



Upper limit on dipole amplitude:
δ_c(>200 GV) < 1.9% at 95% C.I.

Oxygen

2.9 x 10^6 events, R>18 GV



Upper limit on dipole amplitude:
δ_o(>200 GV) < 1.7% at 95% C.I.

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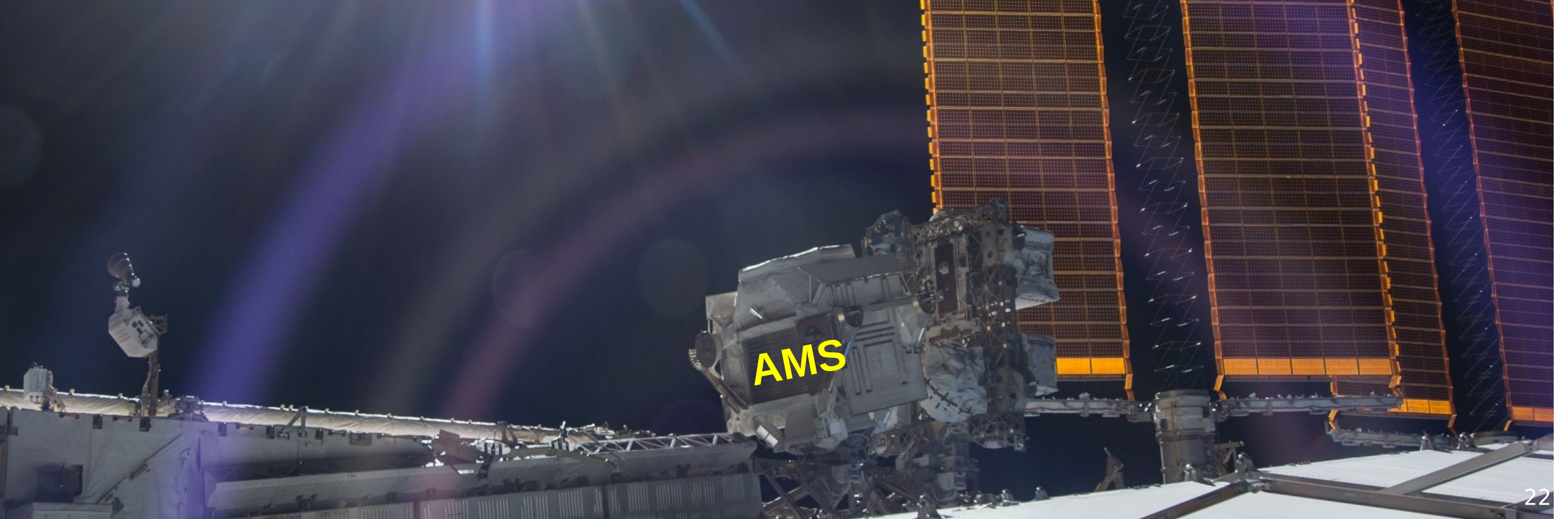
SEARCH FOR ANISOTROPIES IN POSITRONS

Is the source of the energetic positrons a local point source?

Selected events are grouped into 5 cumulative energy ranges: 16-350, 25-350, 40-350, 65-350 and 100-350 GeV.

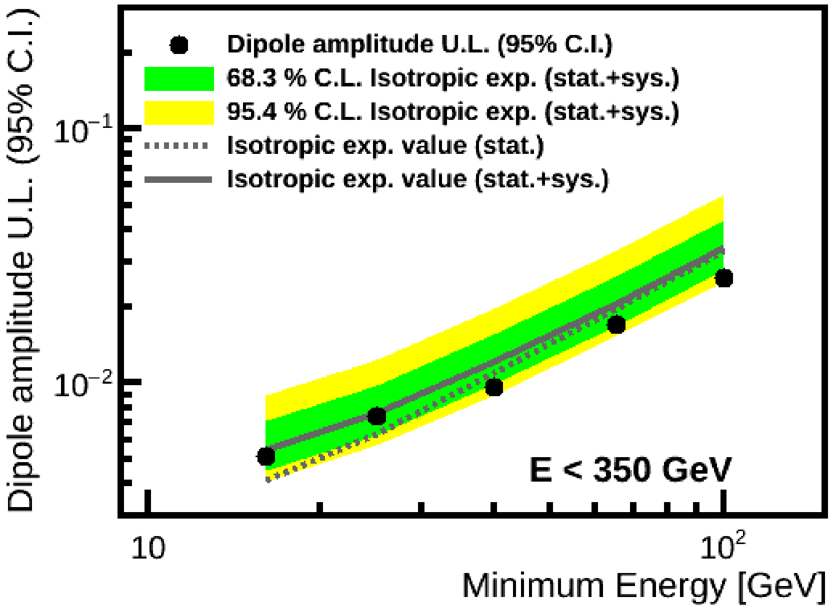
6.5 years: total exposure time 1.48 x 10^8 s



UPPER LIMITS ON DIPOLE AMPLITUDE:
ELECTRONS AND POSITRONS

Electrons

1.3 x 10^6 events, 16 GeV<E<350 GeV



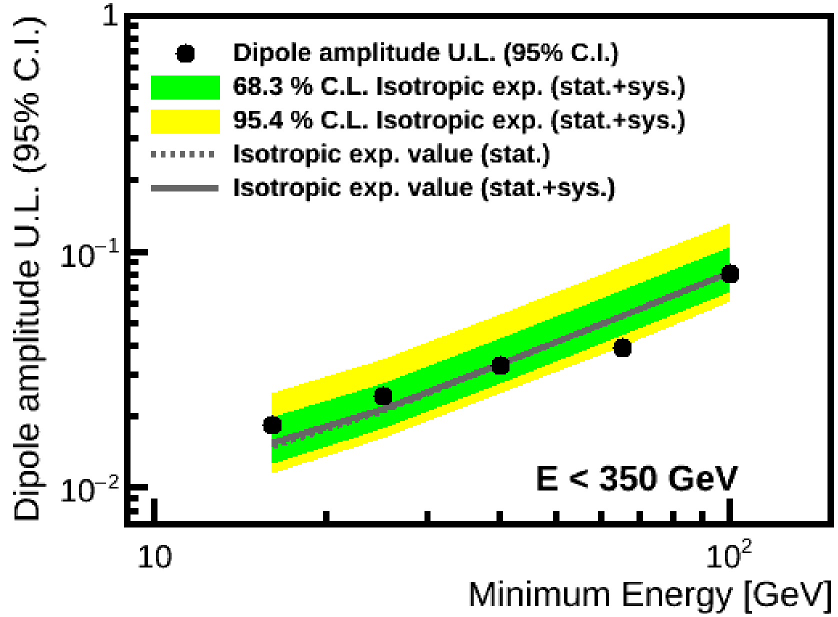
Upper limit on dipole amplitude:

δ_{e-}(>16 GeV) < 0.5% at 95% C.I.

[Phys. Rev. Lett. 122, 101101]

Positrons

9.9 x 10^4 events, 16 GeV<E<350 GeV



Upper limit on dipole amplitude:

δ_{e+}(>16 GeV) < 1.9% at 95% C.I.

[Phys. Rev. Lett. 122, 041102]

SUMMARY

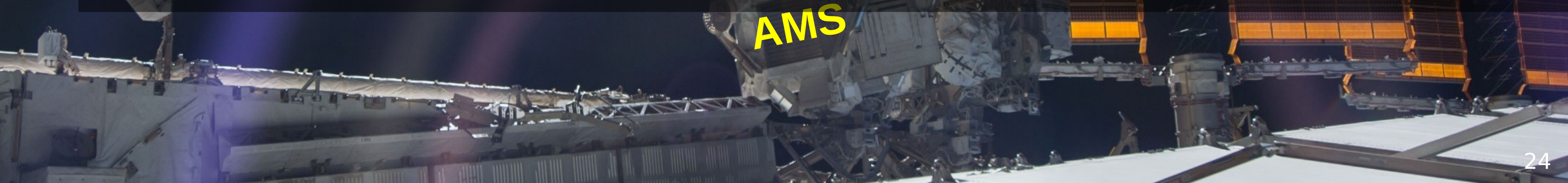
- The near to full sky coverage, long exposure and high particle identification capabilities of AMS allow us to search for 3D dipole anisotropies in the arrival directions of individual charged cosmic rays.
  The latter may be directly related to the origin of some of the unexplained features observed by AMS.

- A search for anisotropies in the arrival directions of cosmic ray protons, helium, carbon, oxygen, positrons and electrons was performed:

  No significant deviation from isotropy was observed in any observable and any coordinate system.

- Upper limits on the 3D absolute anisotropies were set.

  AMS will continue to take data until the end of ISS operation, currently 2024. By that time positron statistics will allow us to reach the 1% level expected for pulsars.



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AMS

CRA2019
COSMIC RAY ANISOTROPY WORKSHOP
October 7th - 11th 2019
GSSI L'Aquila Italy
http://indico.gssi.it/e/CRA2019