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ISS radiation environment anisotropies measured by ALTEA

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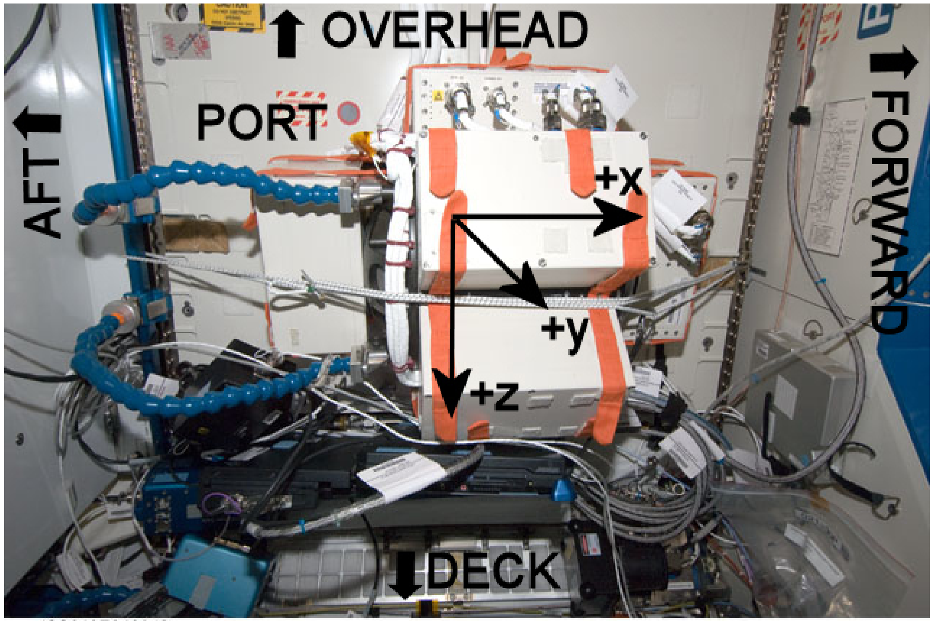
Summary

- Rationale
- ALTEA detector
- ALTEA in the ISS
- Use ALTEA as a single detector
- Results: angular distributions
- Results: spectra
- Simulation
- High-LET anisotropy
- Integrated fluxes and LET rates
- Conclusions

Rationale

- Exposure of crew to space radiation poses one of the most significant hazards to space permanence.
- Since the response of dosimeters and radiation detectors depends on their orientation respect to the impinging radiation flux, angular anisotropies of this flux cannot be ignored.
- ALTEA is an optimal device to study composition and angular anisotropies of the cosmic ray flux thanks to wide LET acceptance window (3-800 KeV/μm), large geometrical factor and full coverage of the solid angle.

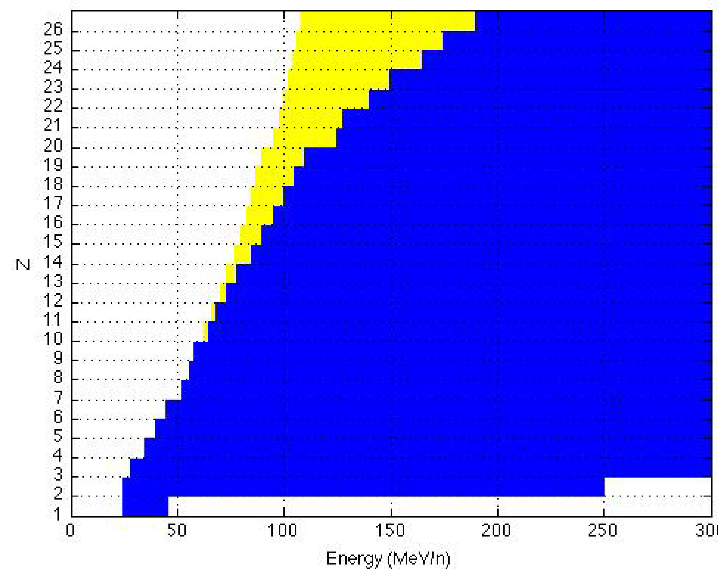
ALTEA detector



ISS018E046042

- ALTEA particle detector is composed by 6 SDUs (Silicon Detector Unit).
- Each SDU is composed by 6 silicon planes segmented alternatively along orthogonal directions.
- Each plane is 8x16 cm^2 and 380 μm thick
- Each SDU has a geometrical factor of 230 cm^{2}sr
- LET range is from 3 to 800 KeV/μm

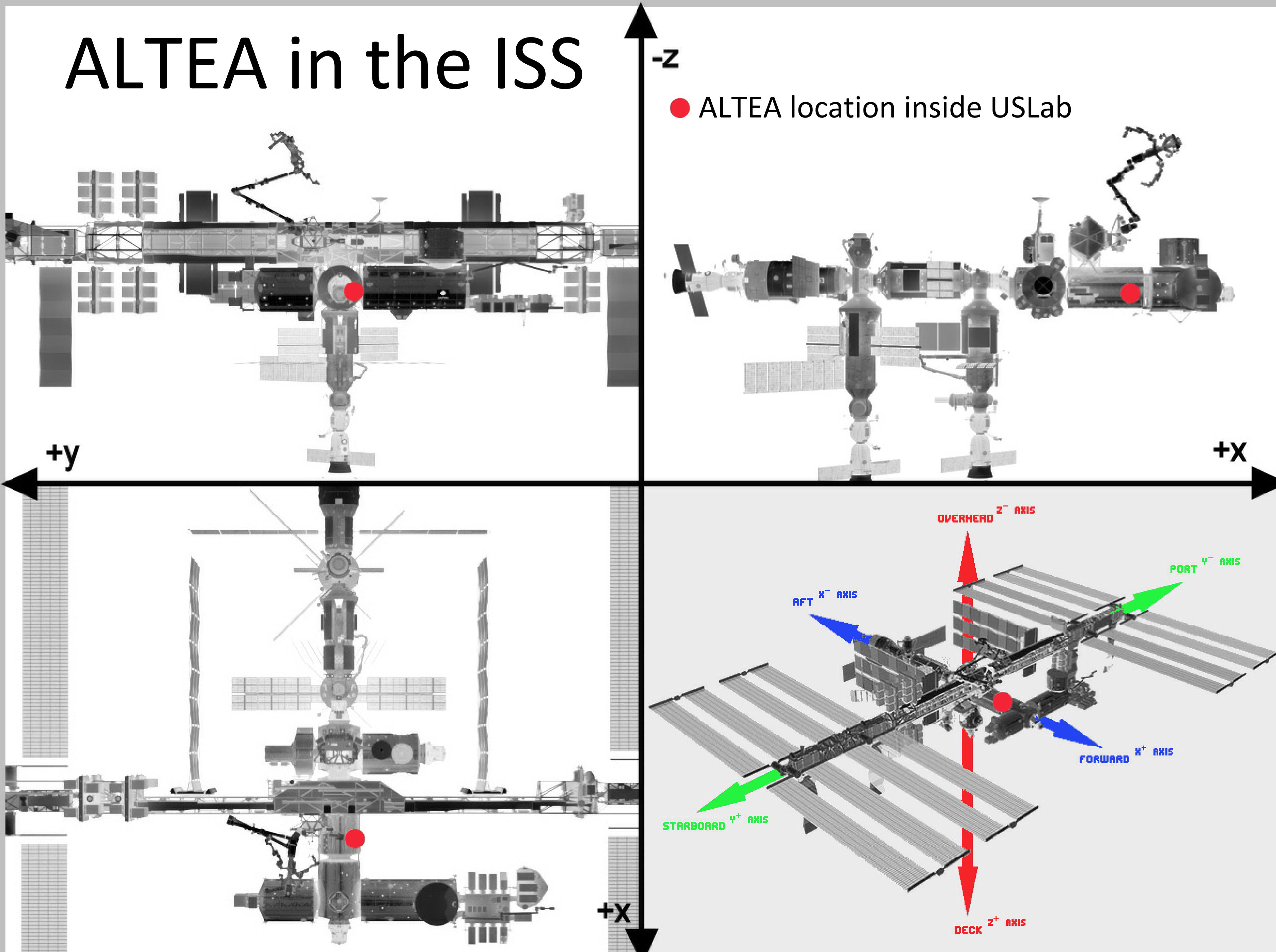
	Minimum kinetic energy (MeV/n)	Maximum kinetic energy (MeV/n)
H	25	35
^{4}He	25	250
^{56}Fe	190	> 2 GeV



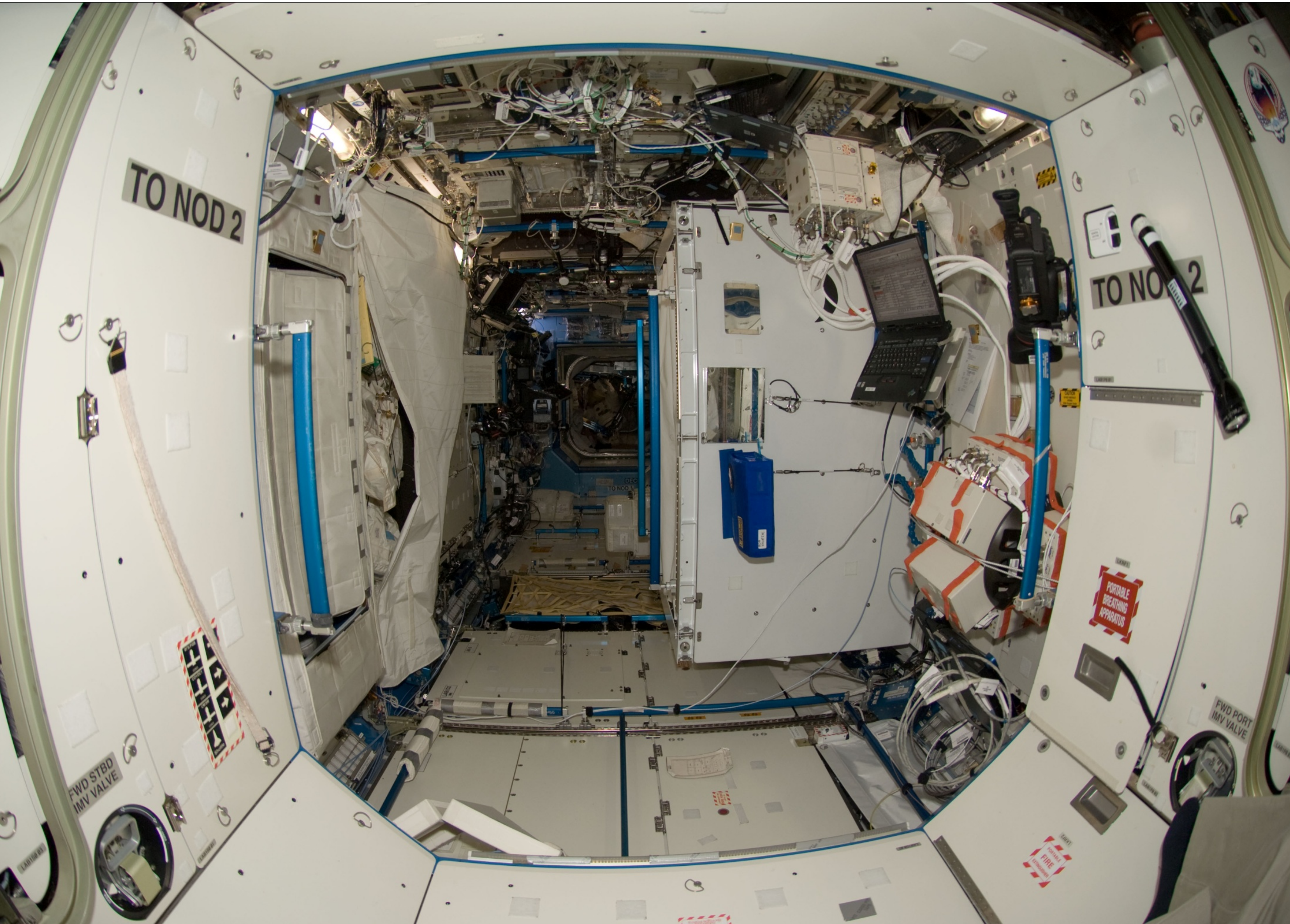
Observation period: ~ 74 effective days
01/06/2009 – 28/09/2009

	Time (s)	Triggers (part.)
Mean	6.40 * 10^6	4.95 * 10^7
Poles	1.89 * 10^6	1.69 * 10^7
Equator	3.80 * 10^6	1.87 * 10^7
SAA	7.03 * 10^5	1.39 * 10^7

ALTEA in the ISS



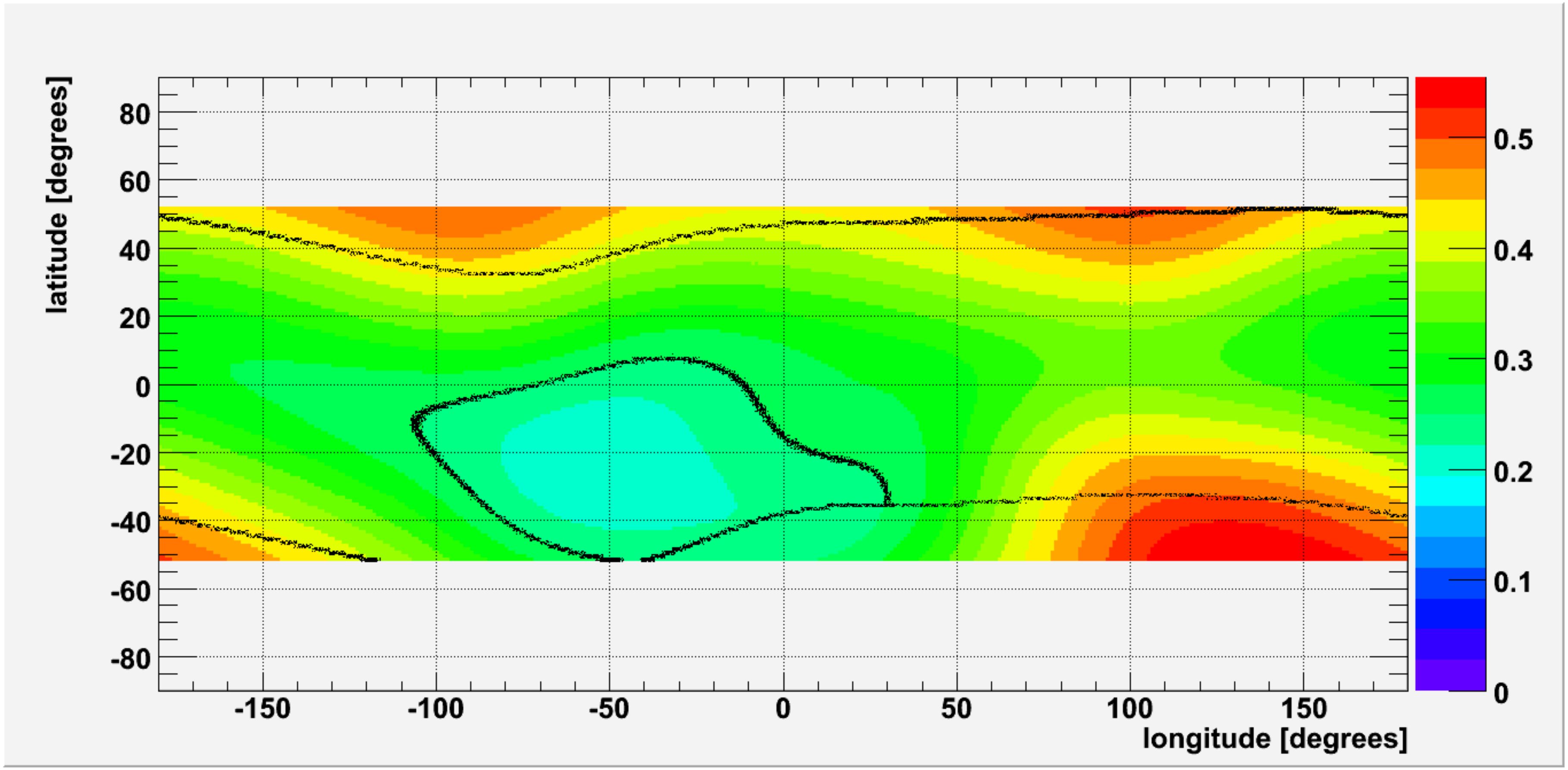
3D model courtesy of NASA – Adapted and Rendered by Riccardo Rossi – www.isaa.it



TO NOD 2
TO NOD 2
PORTABLE BREATHING APPARATUS
FWD STBD IMV VALVE
FWD PORT IMV VALVE
PORTABLE FIRE EXTINGUISHER

7E011093

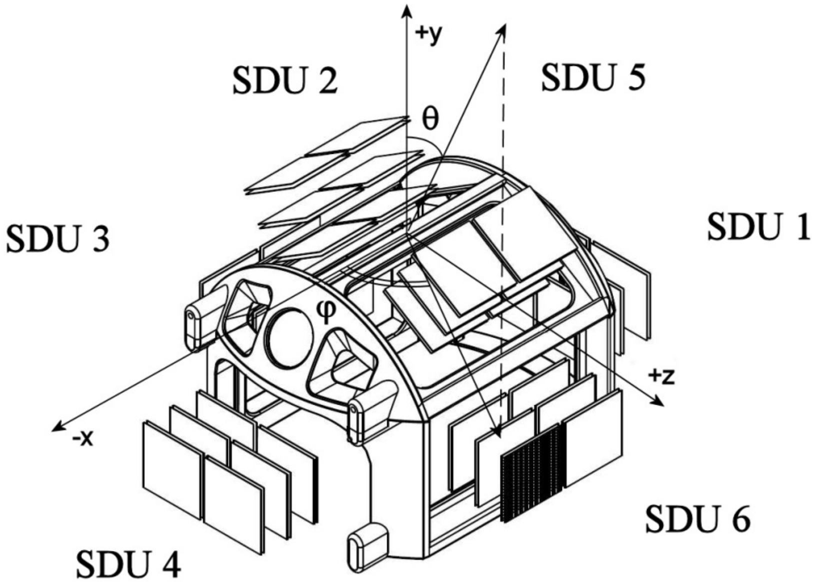
GeoZones

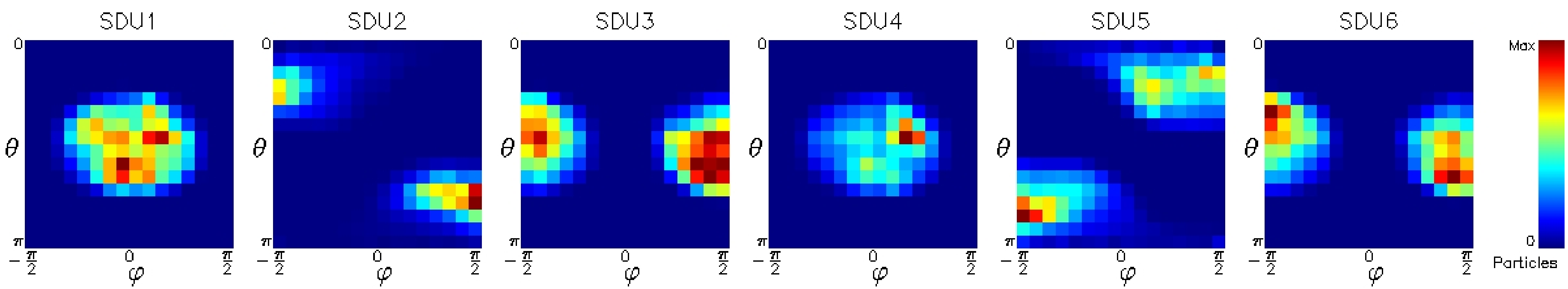


Zone	B	L
Poles	Any	≥ 2
Equator	≥ $2.5*10^{-5}$ T	< 2
SAA	< $2.5*10^{-5}$ T	< 2

Use ALTEA as a single detector (1)

In a spherical coordinate system we defined 16x16 (θ–φ) histograms with a square bin of π/16 x π/16 size.
Particle flux anisotropy in raw angular flux distribution is masked by SDU angular acceptance.
We need to calculate the geometrical factor for each (θ–φ) bin in order to normalize histograms to absolute fluxes.
We must take into account the overlap between different SDUs.





Orthogonal projection of SAA angular distributions

Note: <u>ALTEA is not able to discriminate between forward and backward moving particles</u>, so solid angle is limited to **θ = [0, π] ; φ = [–π/2, π/2]**

Use ALTEA as a single detector (2)

A Montecarlo simulation of an isotropic flux was used to obtain each SDU angular acceptance. To use ALTEA as a single detector we sum all the SDUs to obtain the angular acceptance of the whole ALTEA detector - R(θ,φ).

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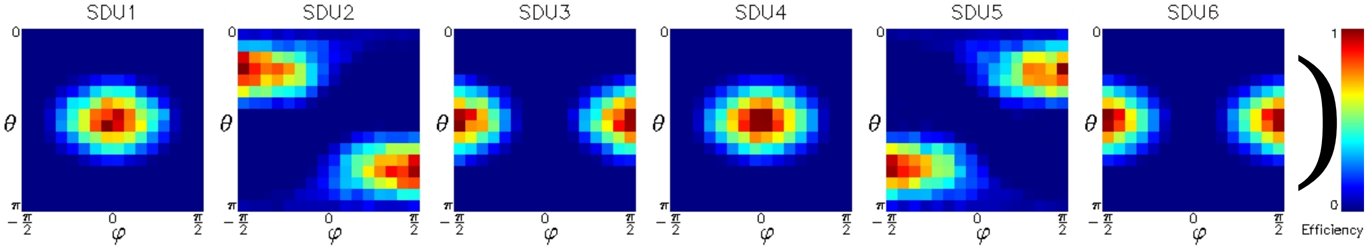

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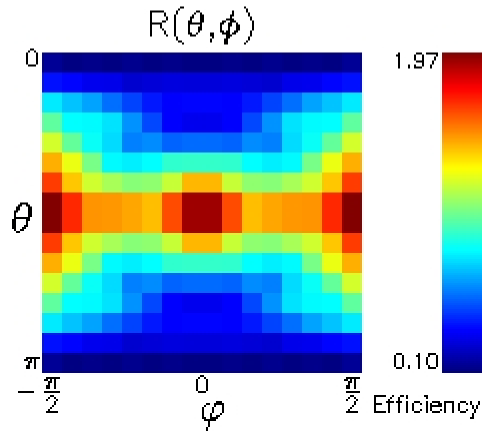
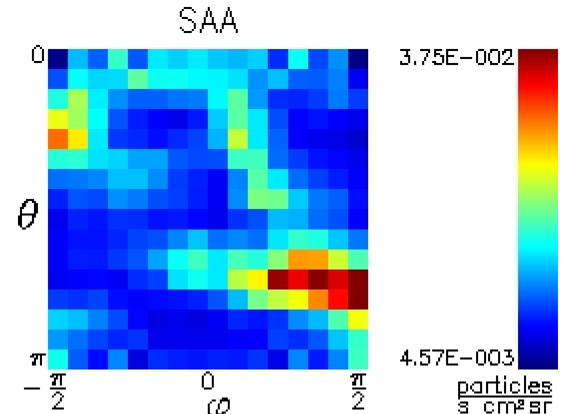


The maximum value of almost 2 means that each particle in each direction is counted twice (by two different SDUs); efficiency is never less than 10% meaning that ALTEA is able to detect particle coming from any direction.

We use R(θ,φ) to calculate angular geometrical factor GF(θ,φ) for the whole ALTEA detector.

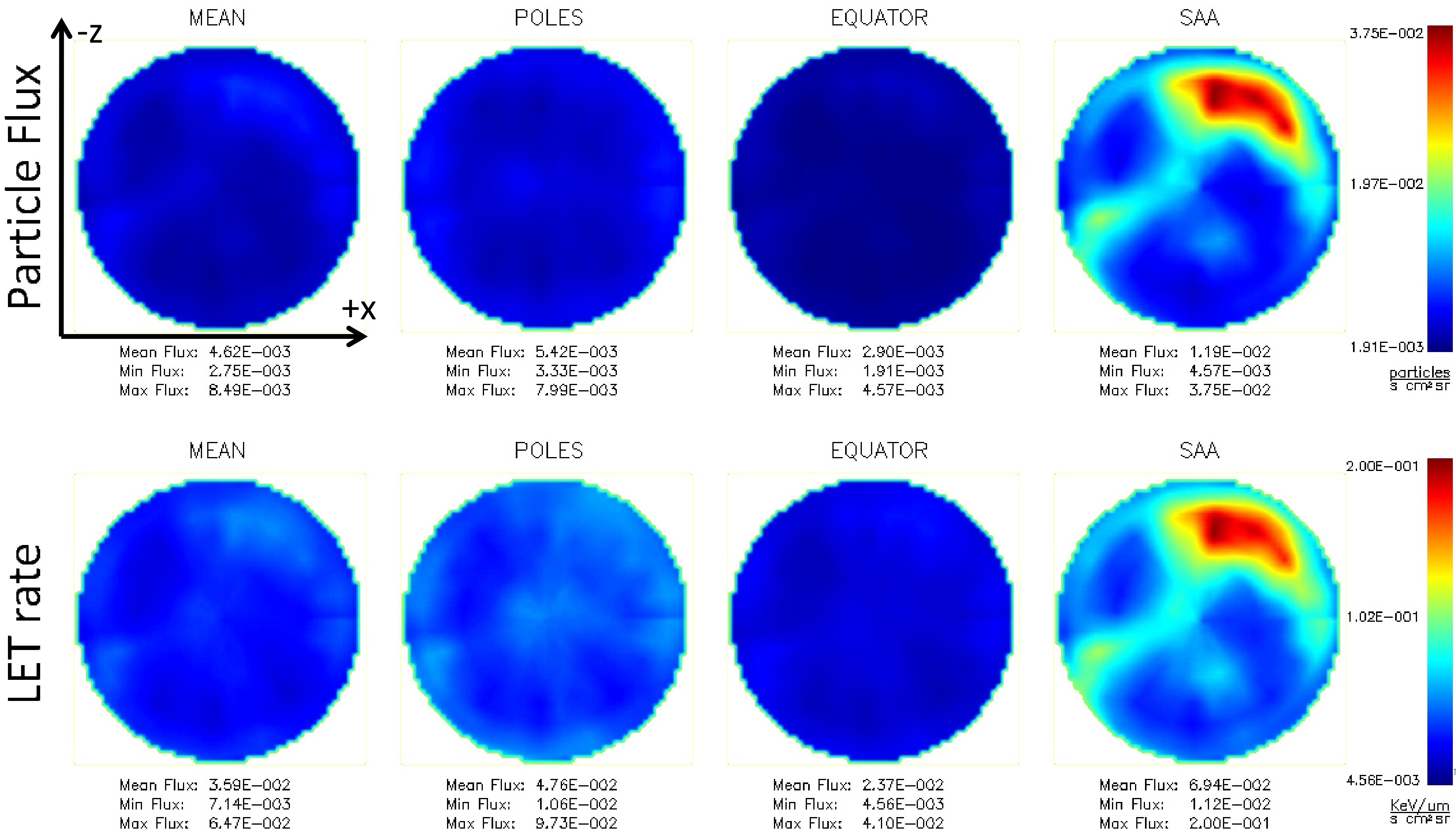


GF(θ,φ) is used to normalize raw flux to absolute flux

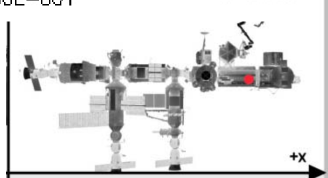
$$GF(\theta,\varphi) = \frac{R(\theta,\varphi)}{\sum_{\theta,\varphi} R(\theta,\varphi)} * GF$$

$$\Phi(\theta,\varphi) = \sum_{SDU} \frac{n_{SDU}(\theta,\varphi)}{t_{SDU}} \frac{1}{GF(\theta,\varphi)} \frac{part}{s * cm^2 sr}$$

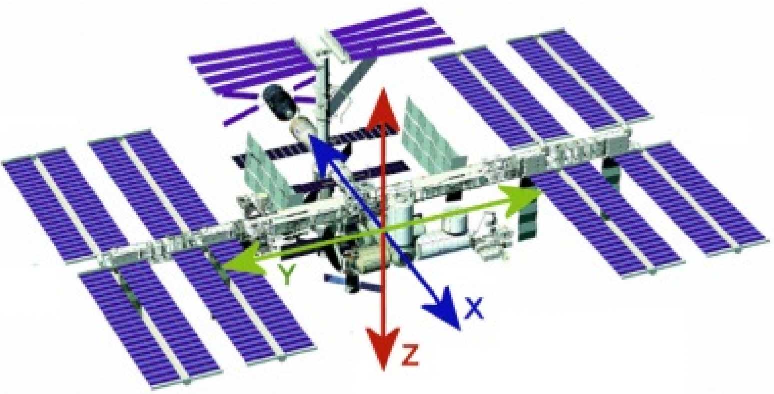
Results – All particles (LET > 3 Kev/μm)

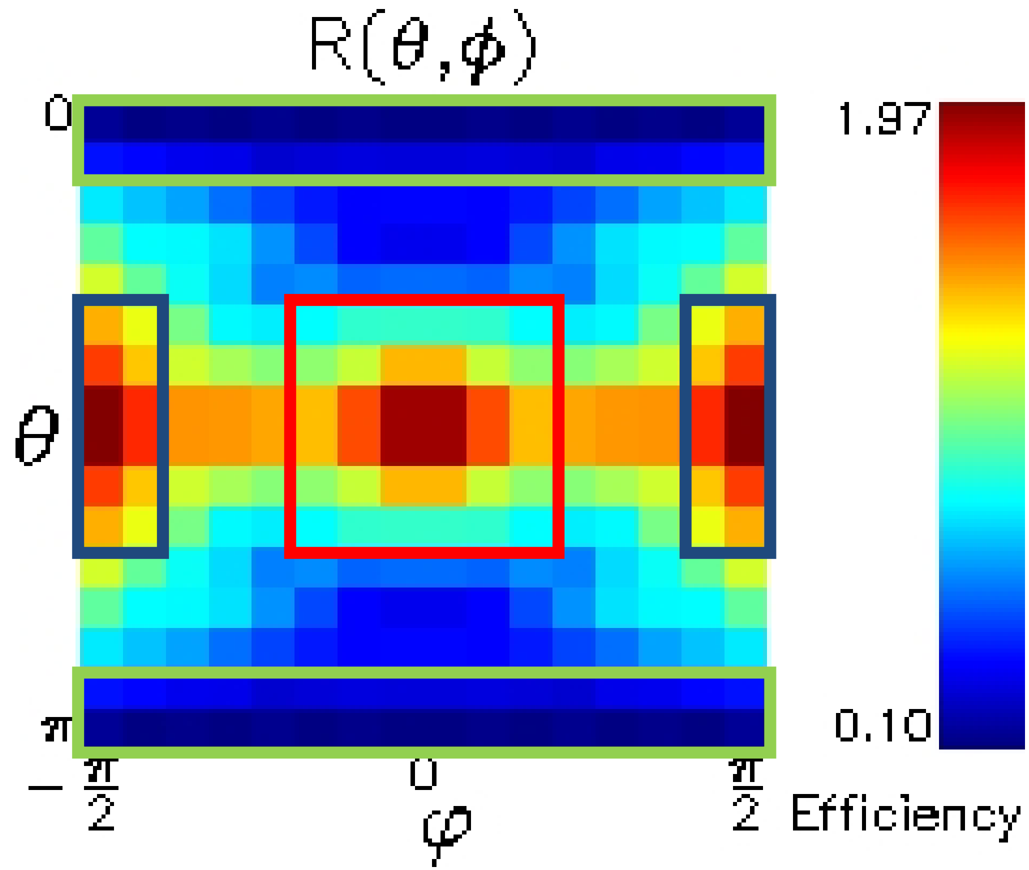


Spherical projection of angular distributions over different geomagnetic regions



LET spectra integrated over angular sectors



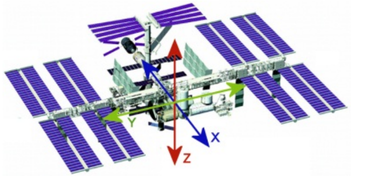


X direction

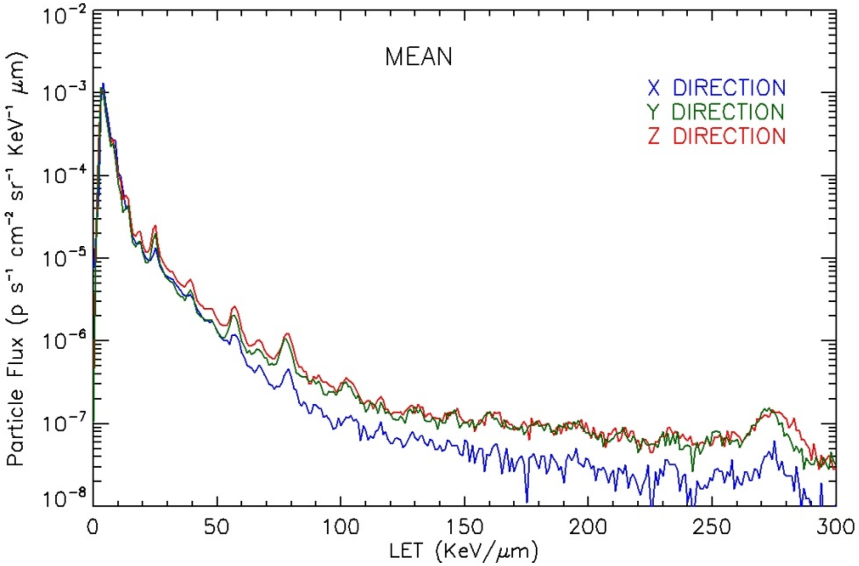
Y direction

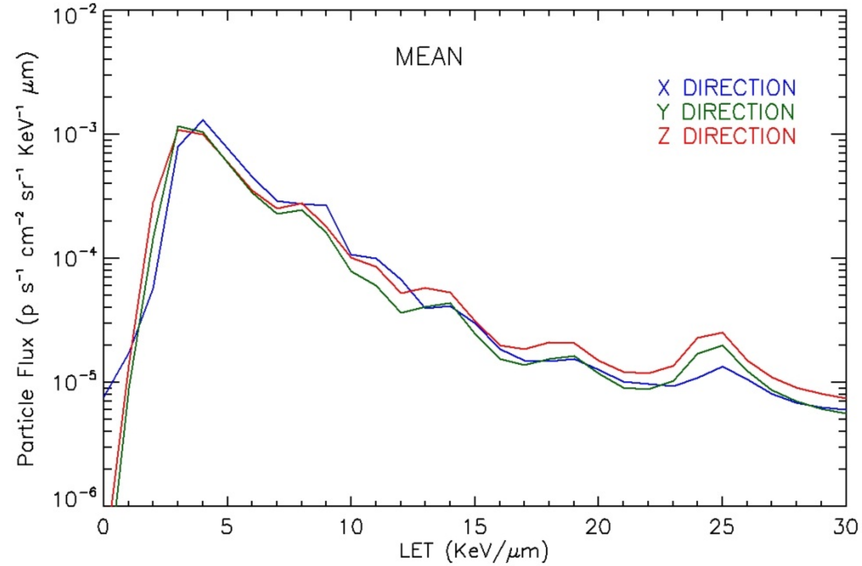
Z direction

Mean Spectra

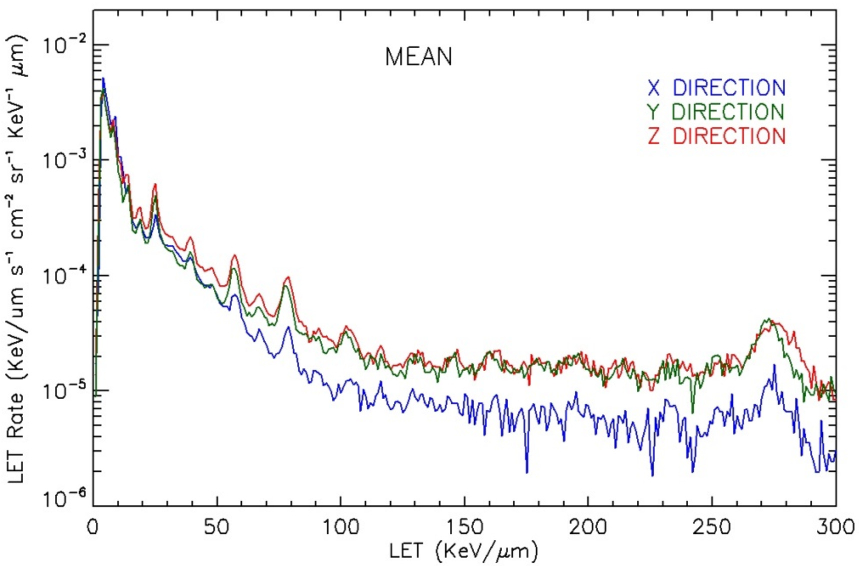


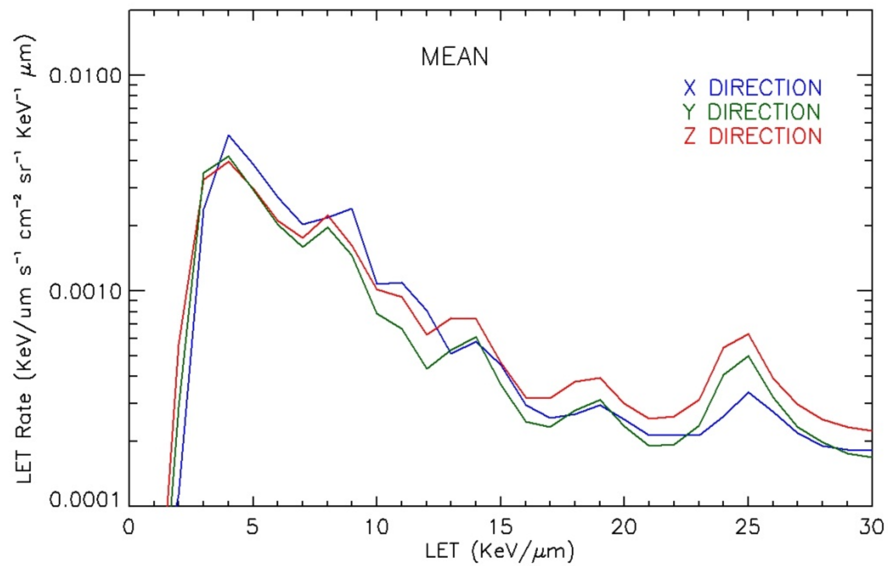
Particle Flux



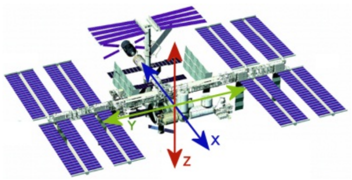


LET rate

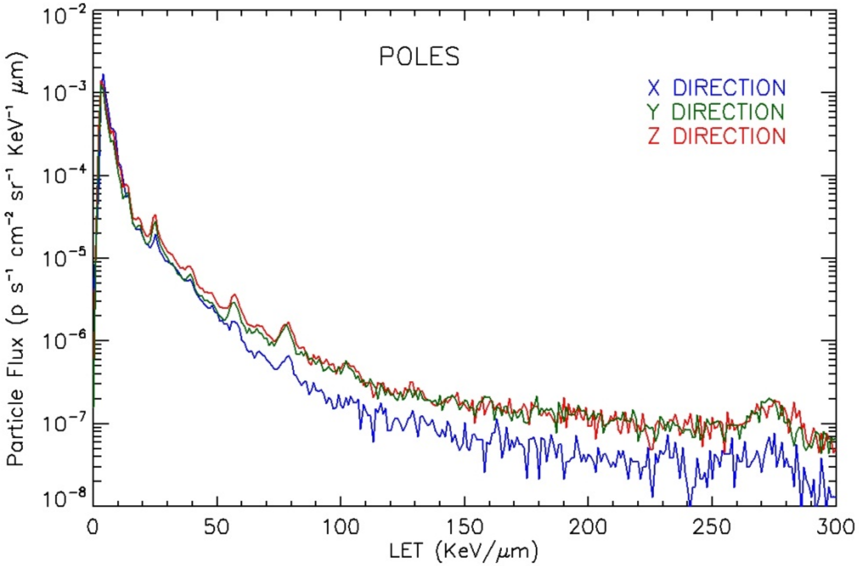


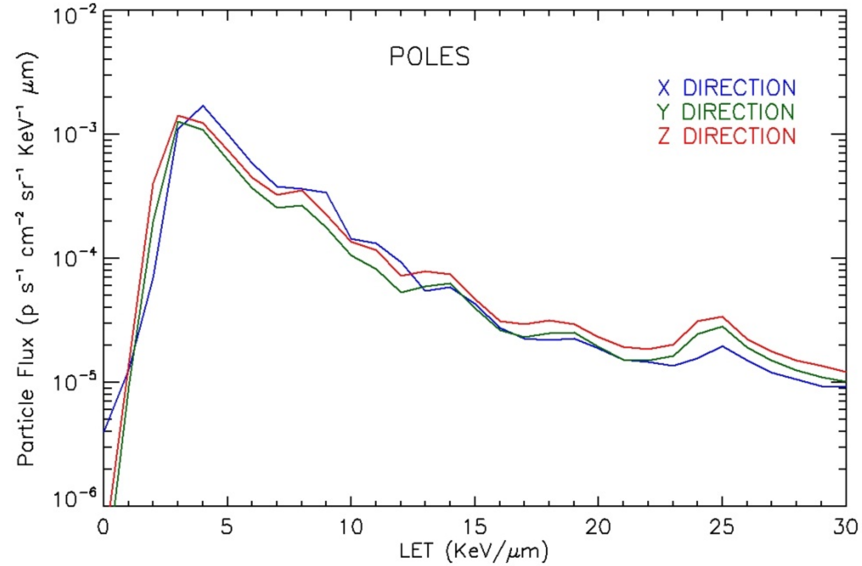


Poles Spectra

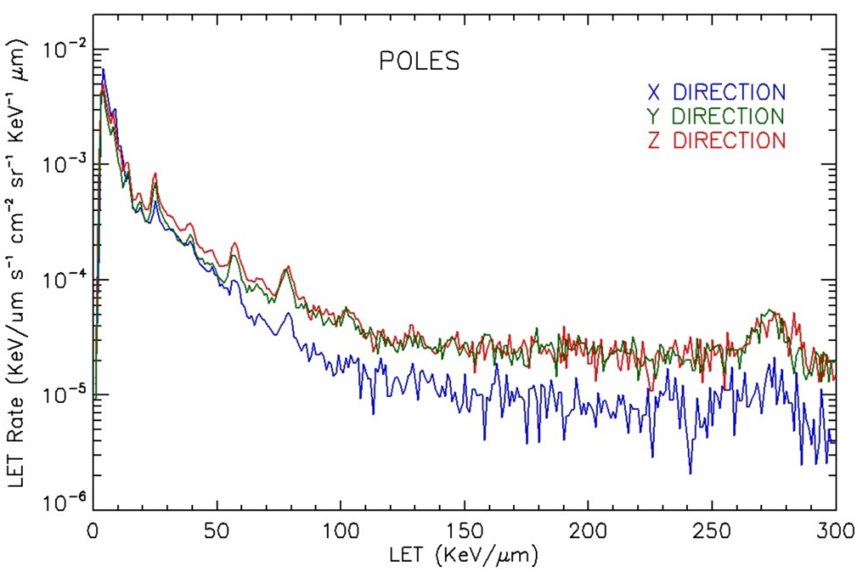


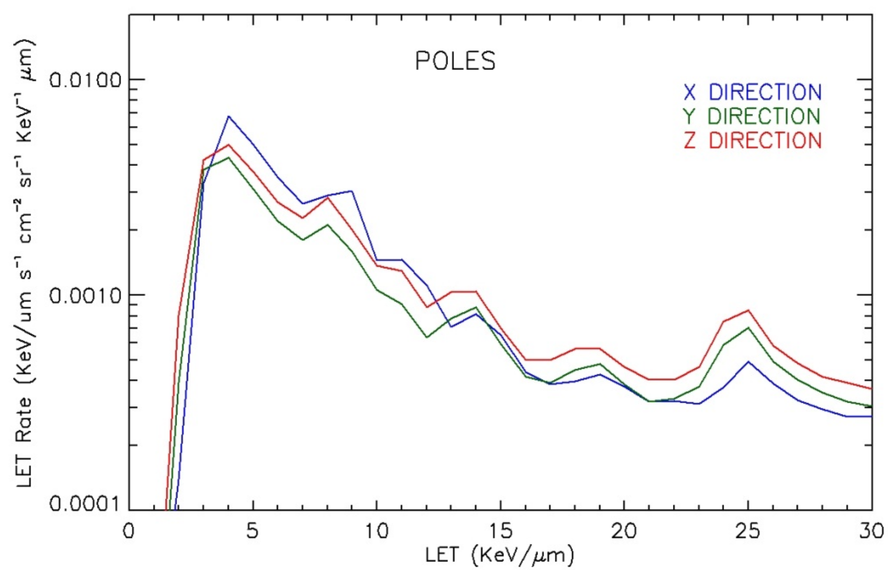
Particle Flux



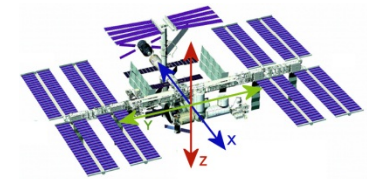


LET rate

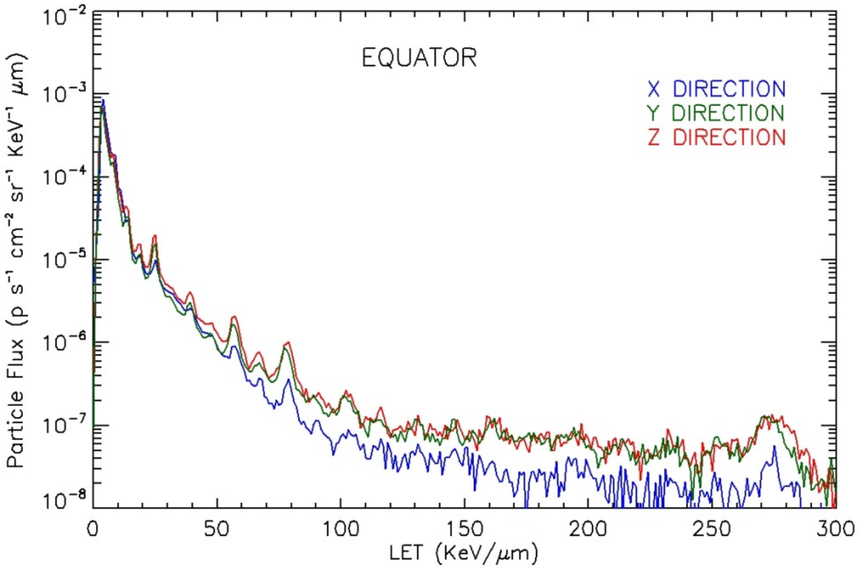


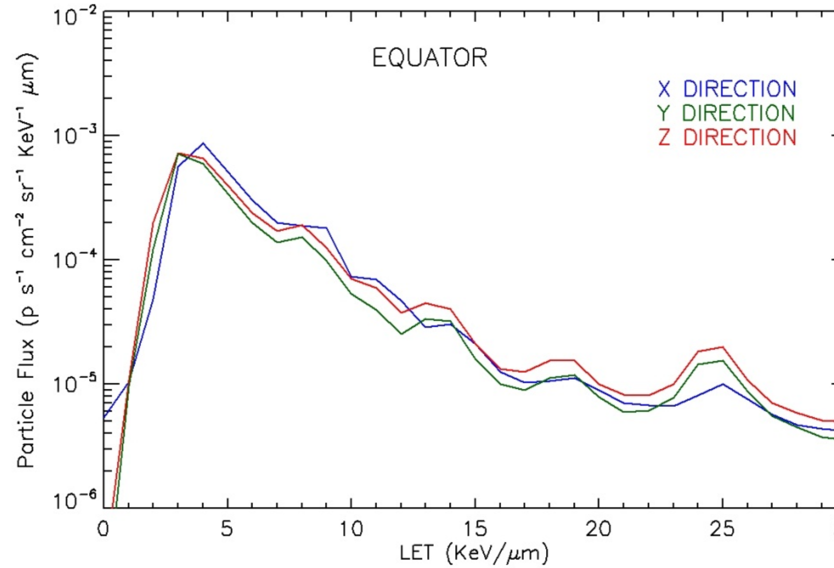


Equator Spectra

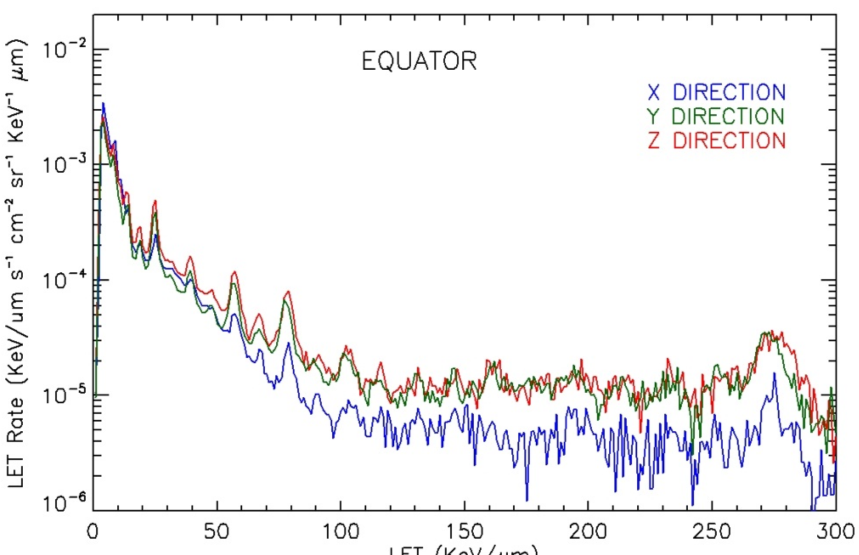


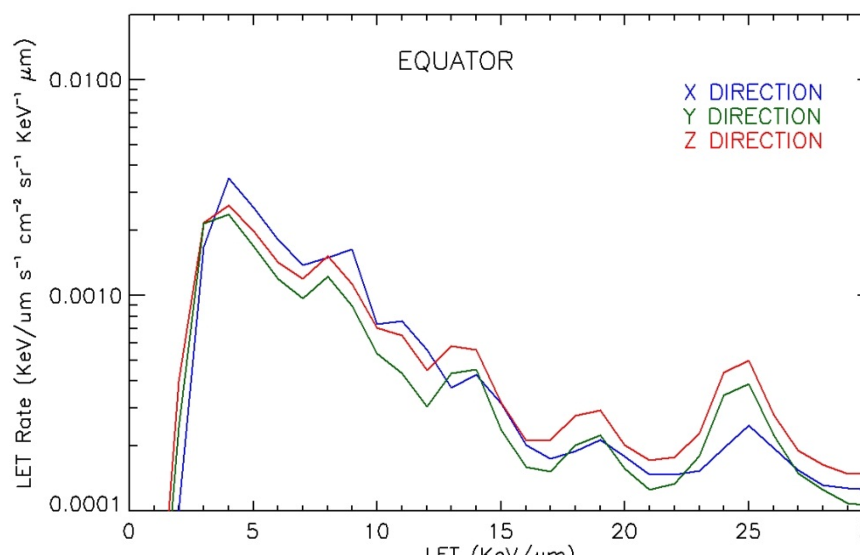
Particle Flux



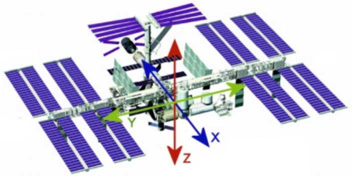


LET rate

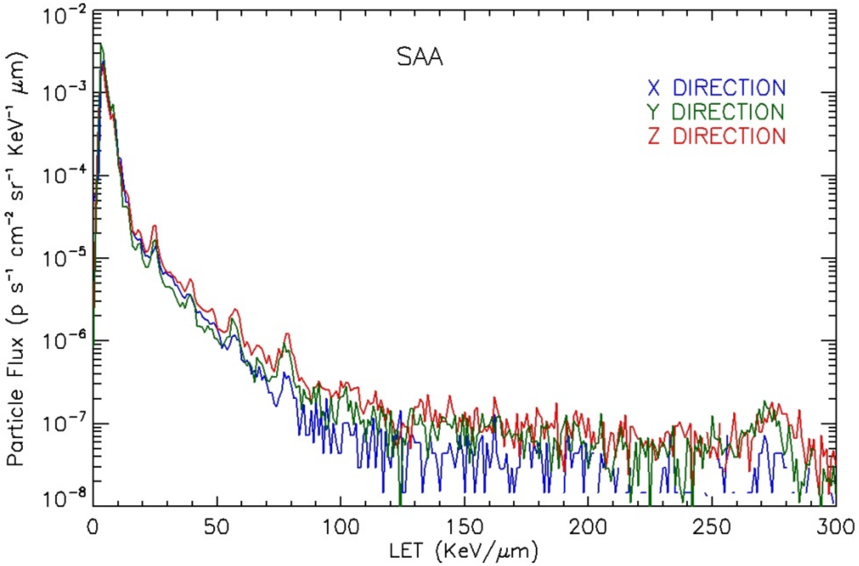


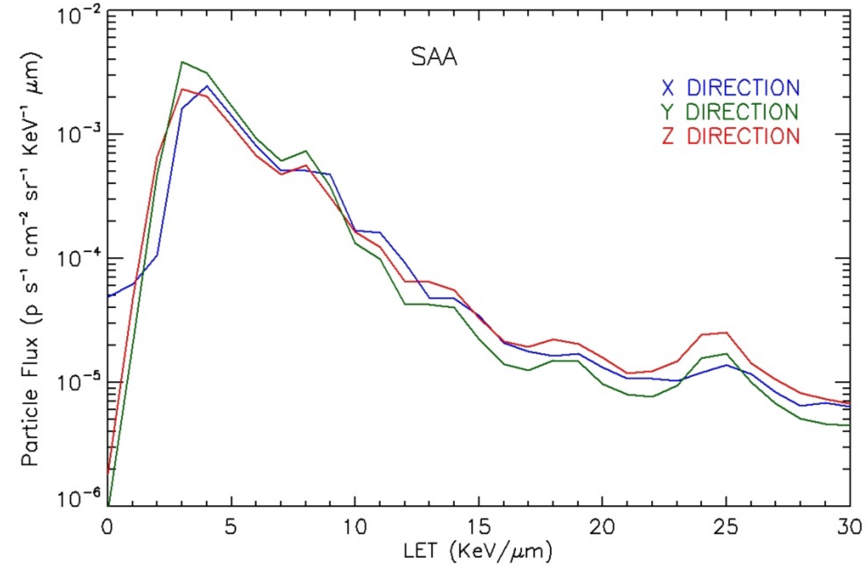


SAA Spectra

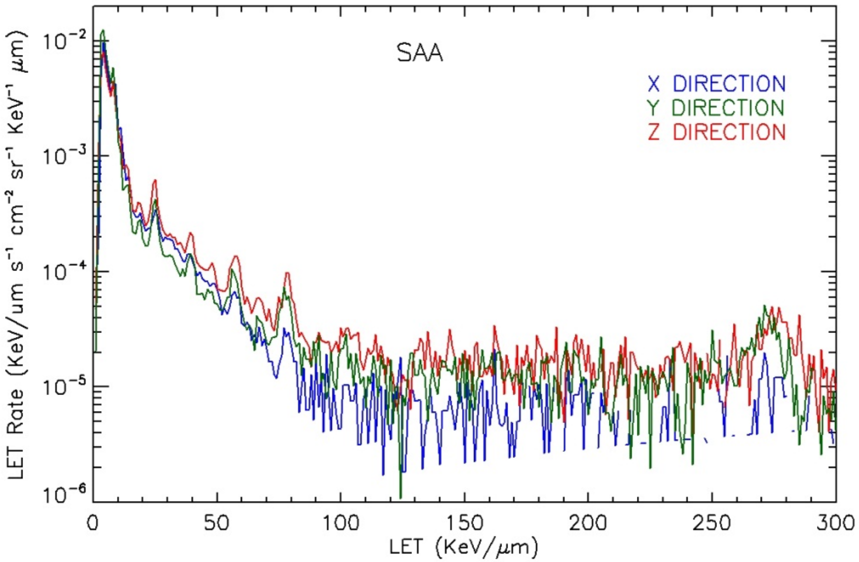


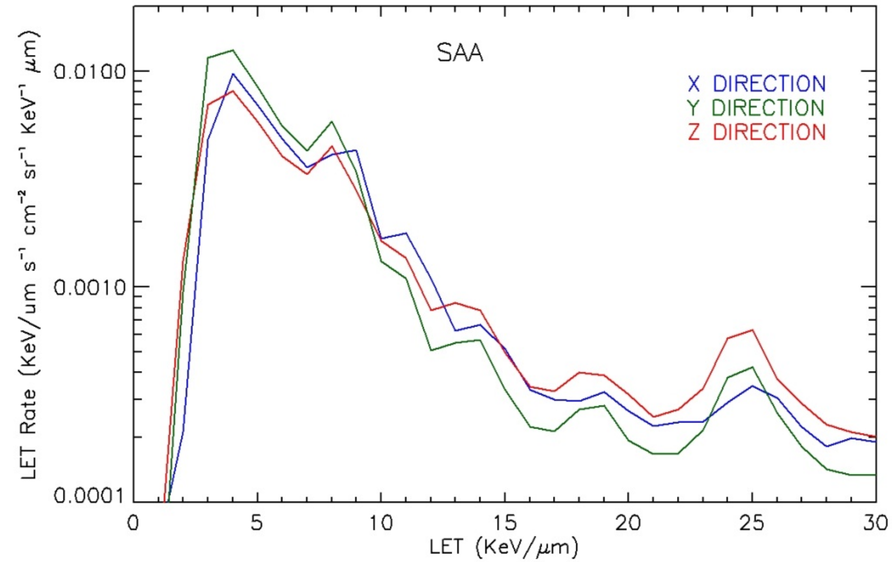
Particle Flux



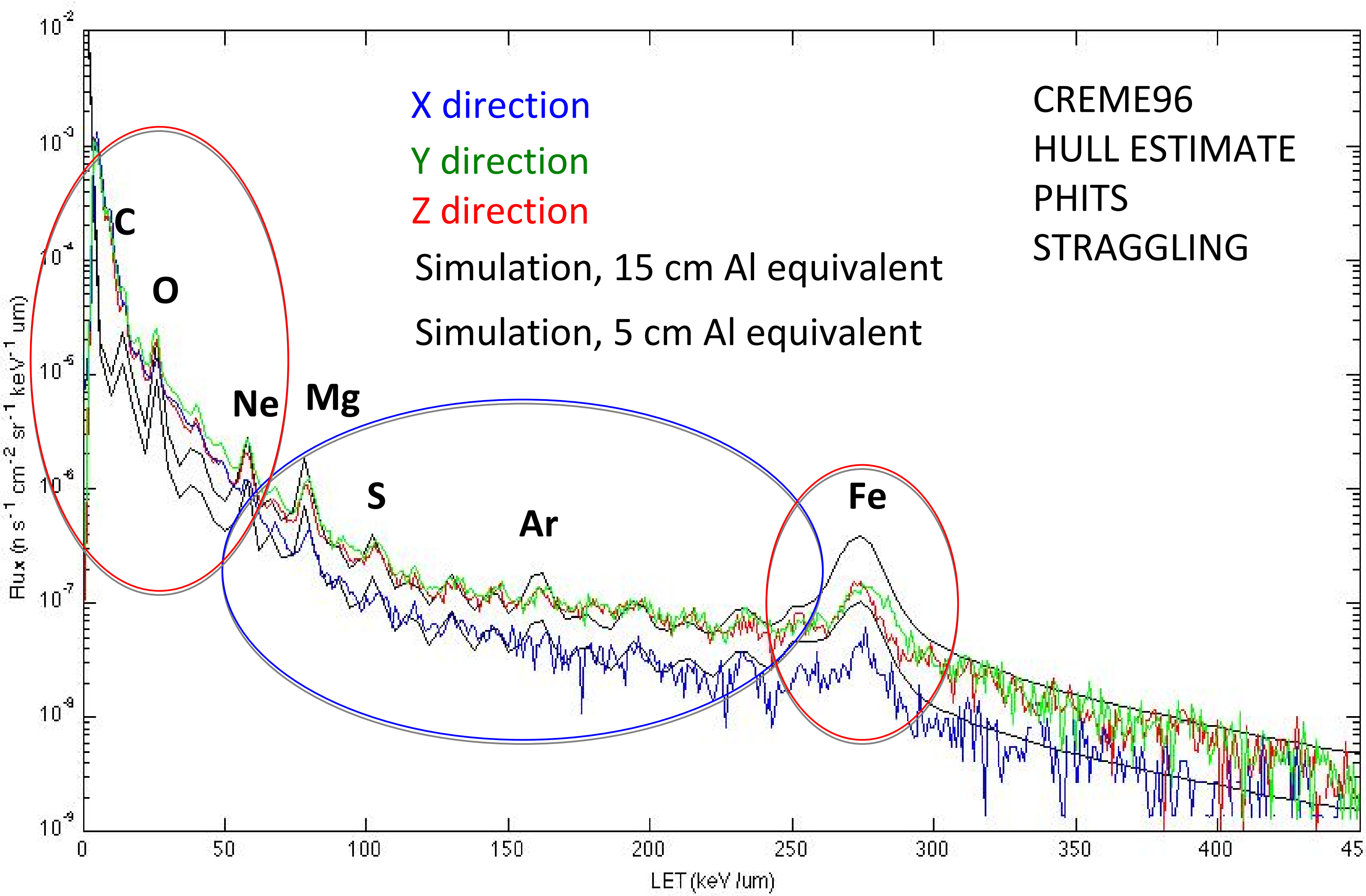


LET rate





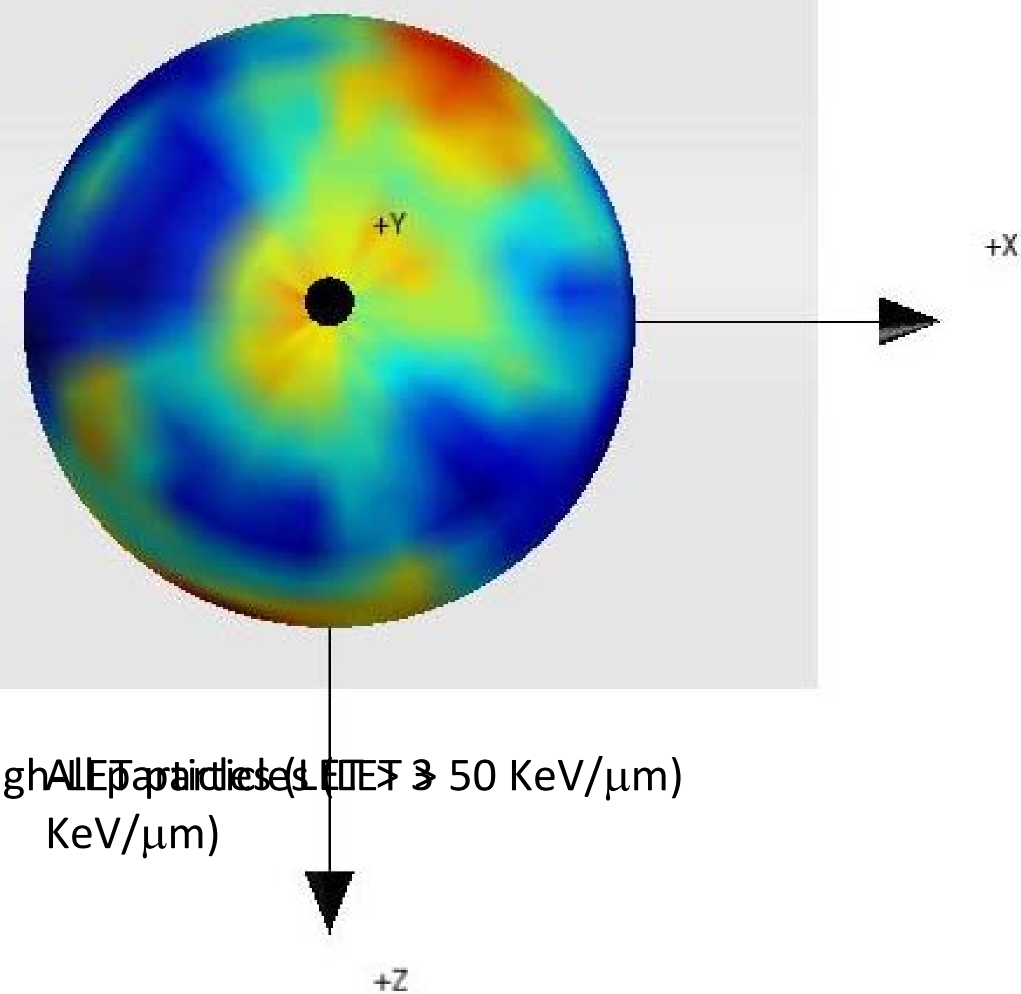
Understanding Anisotropy: simulation



Flux Anisotropy for High-LET particles
(LET > 50 KeV/μm)

Mean distribution

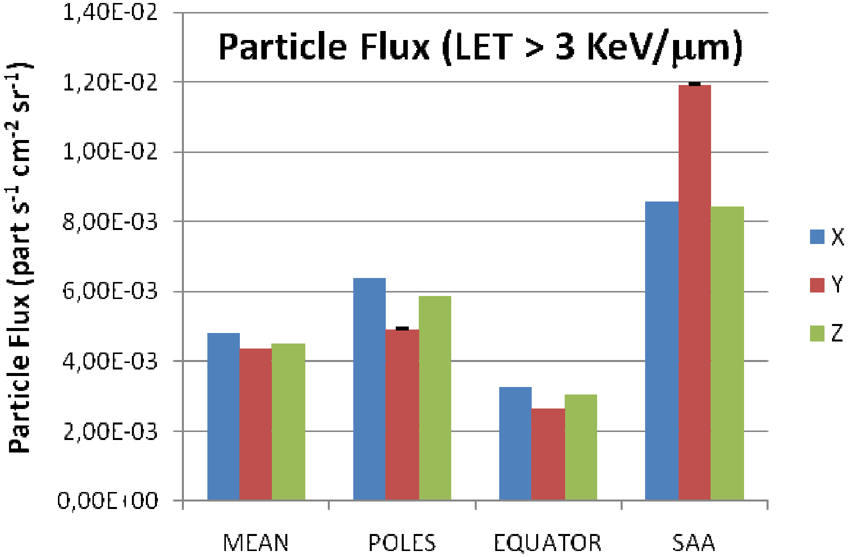
- Quite isotropic for all particles (LET > 3 KeV/μm)
- Strong anisotropy for high-LET particles (LET > 50 KeV/μm)
- Maximum along Y-Z direction (lower shielding)
- Minimum along X direction (higher shielding)

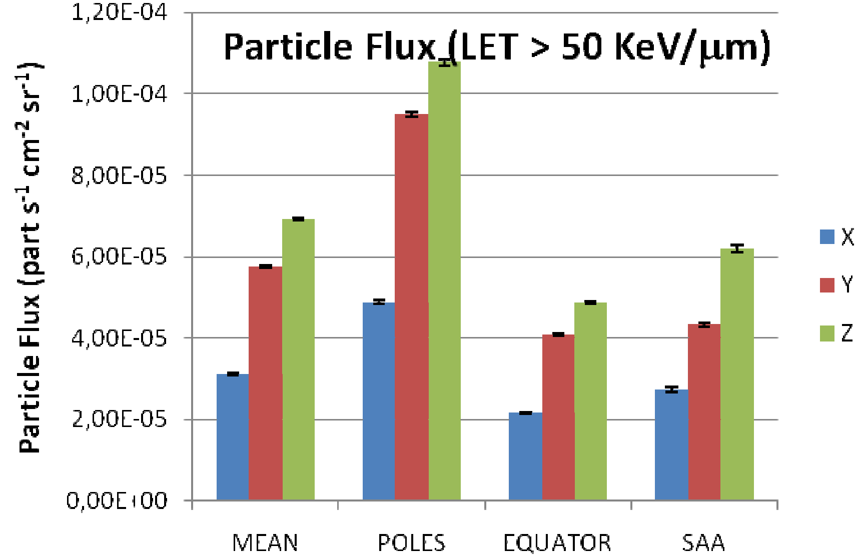


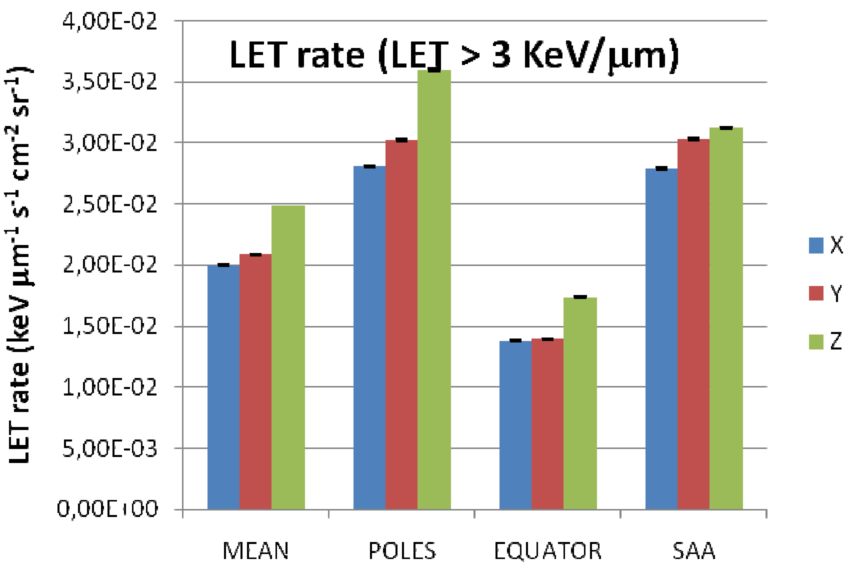
High LET particles (LET > 50 KeV/μm)

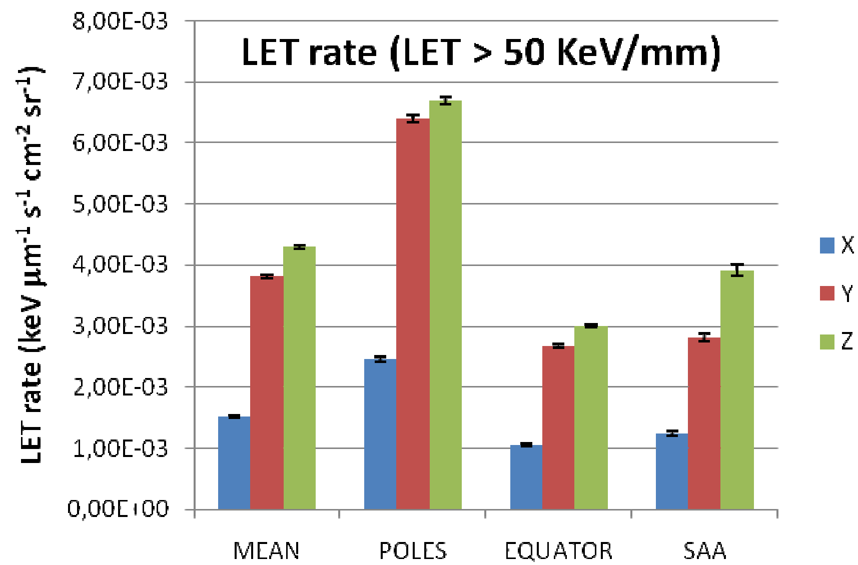
All particles (LET > 3 KeV/μm)

Integrated Particle Fluxes and LET rates









Conclusion

- Radiation in the ISS appears mostly isotropic when total LET is considered
- When considering radiation quality the radiation is strongly anisotropic:

  for LET > 50 there is almost a factor 3 difference between transversal directions (highest LET) and longitudinal one

- This measurements confirm simulations showing that increase shielding may not decrease total dose and may strongly decrease the contribution to the dose from high LET radiation
- These results should be taken into account when designing experiments sensitive to radiation quality and also should stress the importance of where and in what directions are the dosimeters/detectors positioned when attempting any comparison.