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HSERLAB
Human Space Exploration Radiation LAB

DOSTEL REM LIDAL intercomparison 2025

Livio Narici *on behalf of the DORELI collaboration*

WRMISS 2025 DLR :envihab, Köln Germany

NASA
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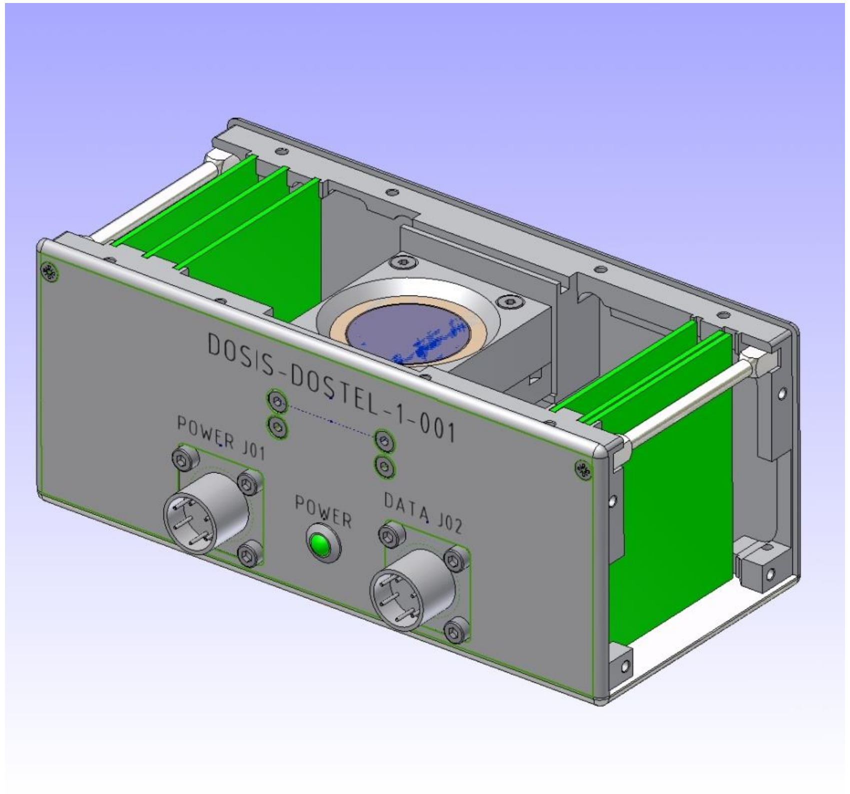
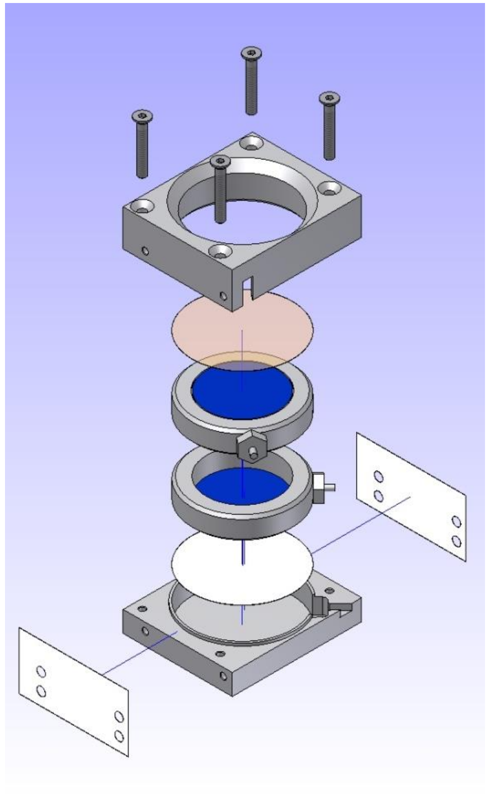
CAU
Kiel University
Christian-Albrechts-Universität zu Kiel

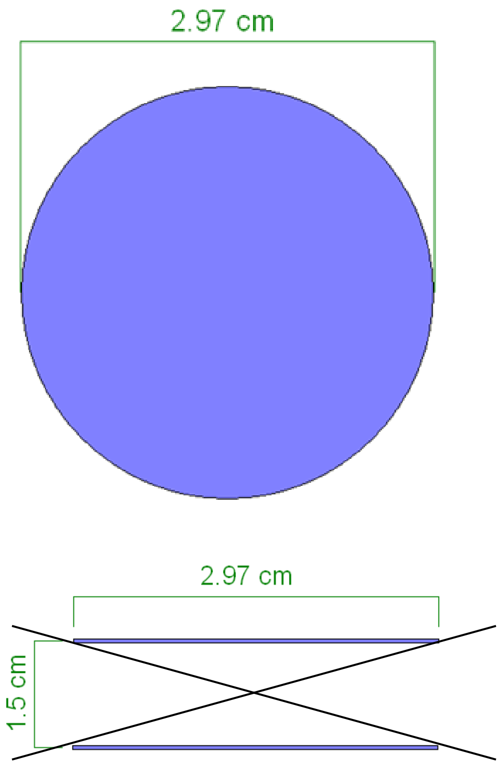
Contents

- Detectors in the comparisons
- Shield complexity
- Location
- Time of the measurements
- Field of View and energy acceptance
- Results
- Yearly results
- Discrepancies

What: DOSTEL







Each DOSTEL consits of two Canberra PIPS (Passivated Implanted Planar Silicon) sensors forming a telescope.
Each sensor has a thickness of 315 µm and an active area of 6.93 cm^2.
The distance between the two detectors of 1.5 cm defines an field of view of 120°.
Dose is measured by a single detector (opening angle 4π)

What: REM

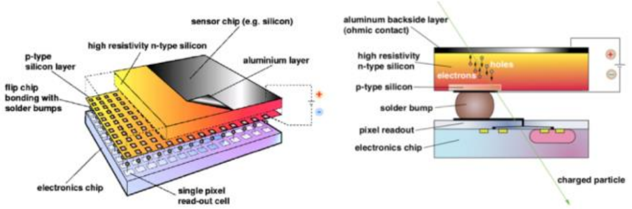
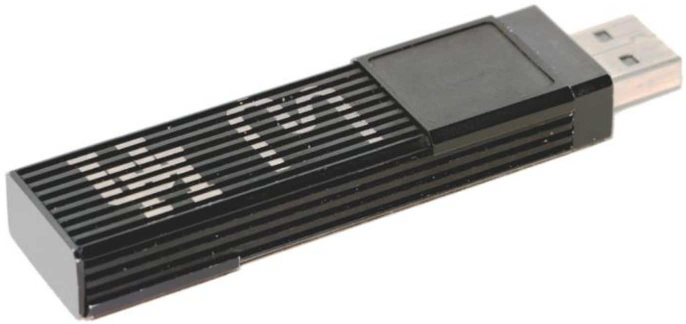


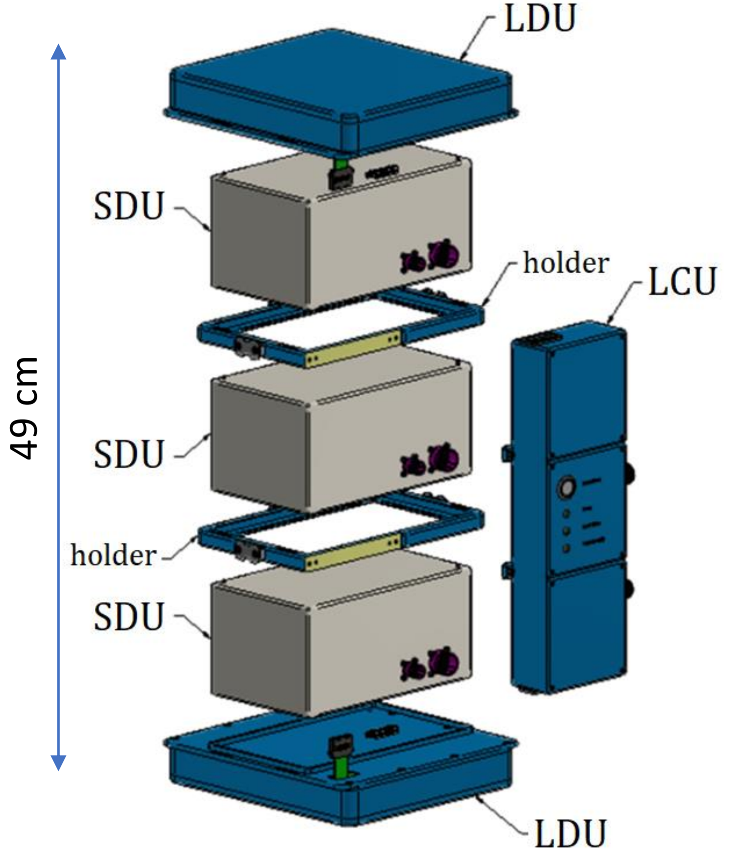
Figure 1: Medipix2 chip and Timepix assembly. (Source: CERN/Medipix.)



- Hybrid silicon pixel detector utilizing Medipix2/Timepix technology from CERN (medipix.cern.ch).
  - 256×256 pixels, each with a 55μm pitch ($1.982cm^2$).
  - Opening angle: 4π.
- Low mass/power/cost make it an ideal technology for space applications.

What: LIDAL

FoV 9° - 20°

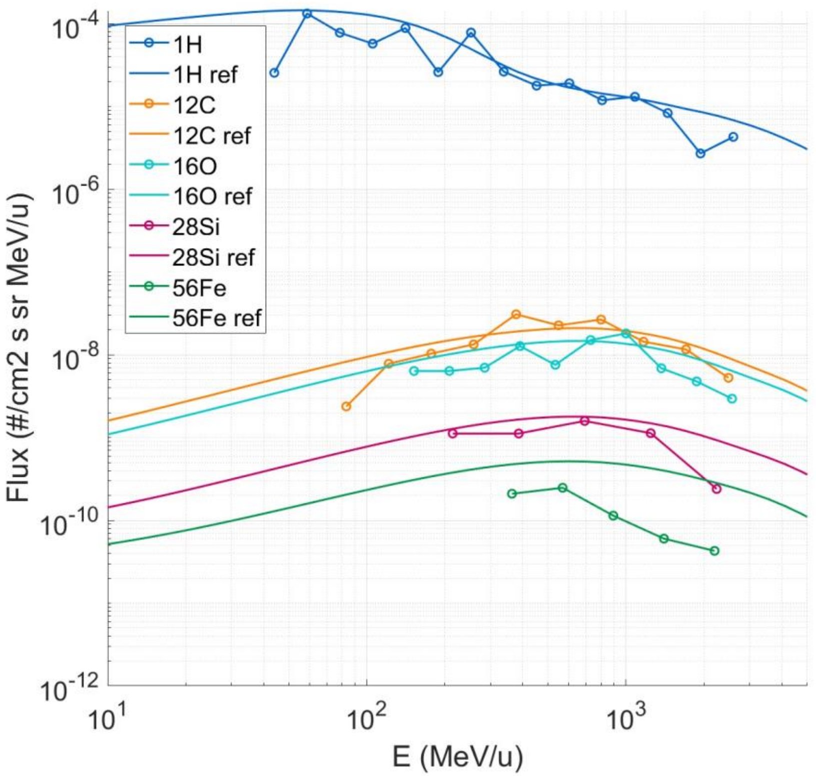


GF: $15.32\ cm^2\ sr$ (bi-directional)

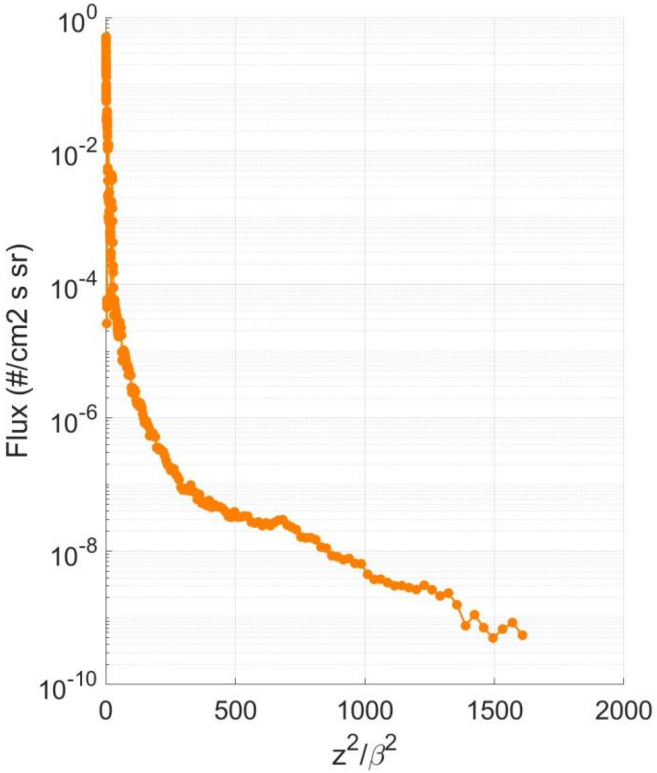
18 Si planes: [0.038 x (2 x 8) x 8] cm^3

2 Scint. planes.: [0.4 x (8 x 2) x 8] cm^3

First detector measuring ToF in a space habitat



First Kinetic energy spectra

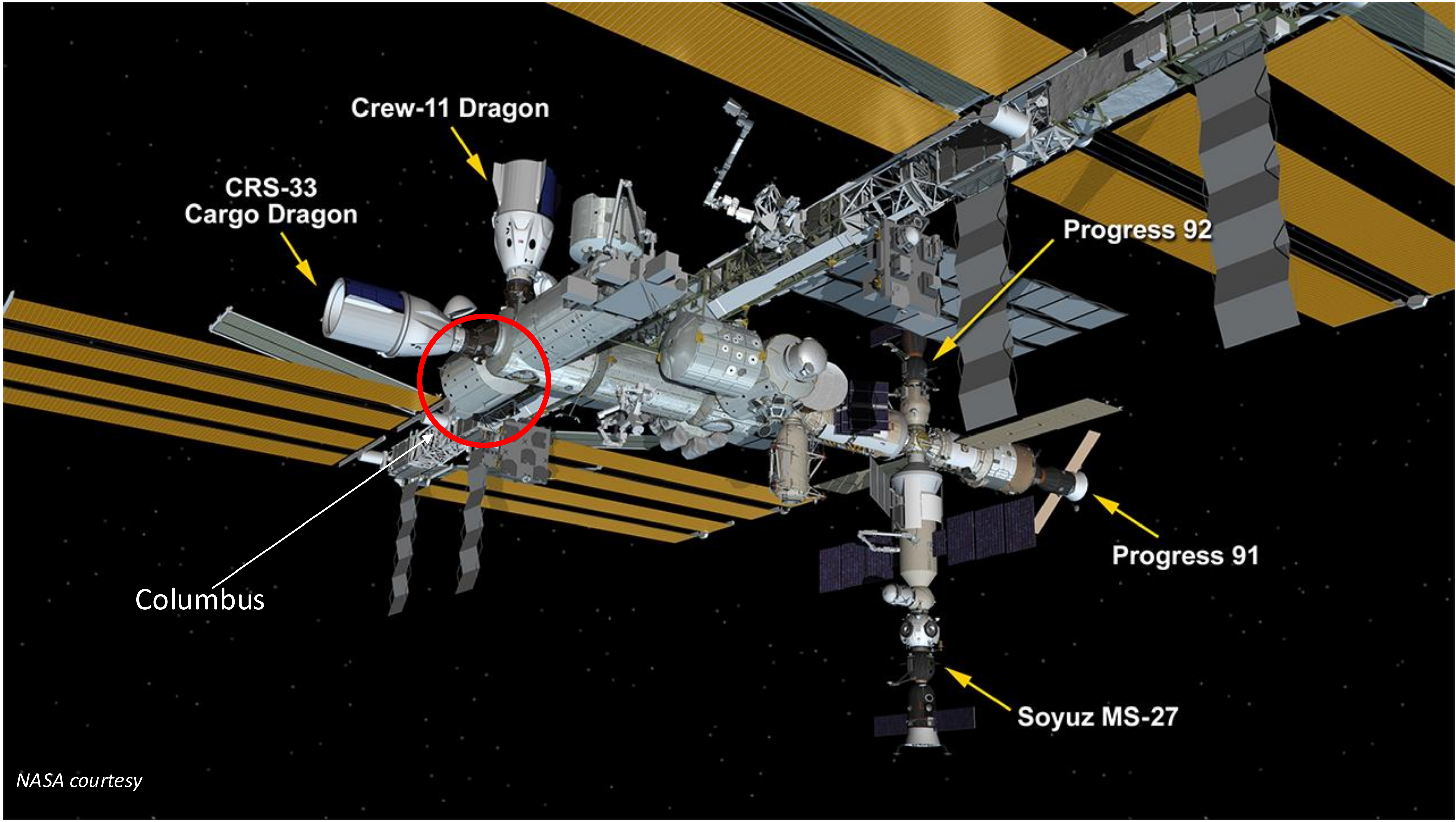


First Z^2/β^2 spectra
→ measurement of NASA Q

Shield complexity

Shielding complexity for the ISS.

Situation on August 25 2025: one week ago



Shield complexity

Shielding complexity within Columbus:

NASA astronaut Josh Cassada performs sets of movements for GRIP

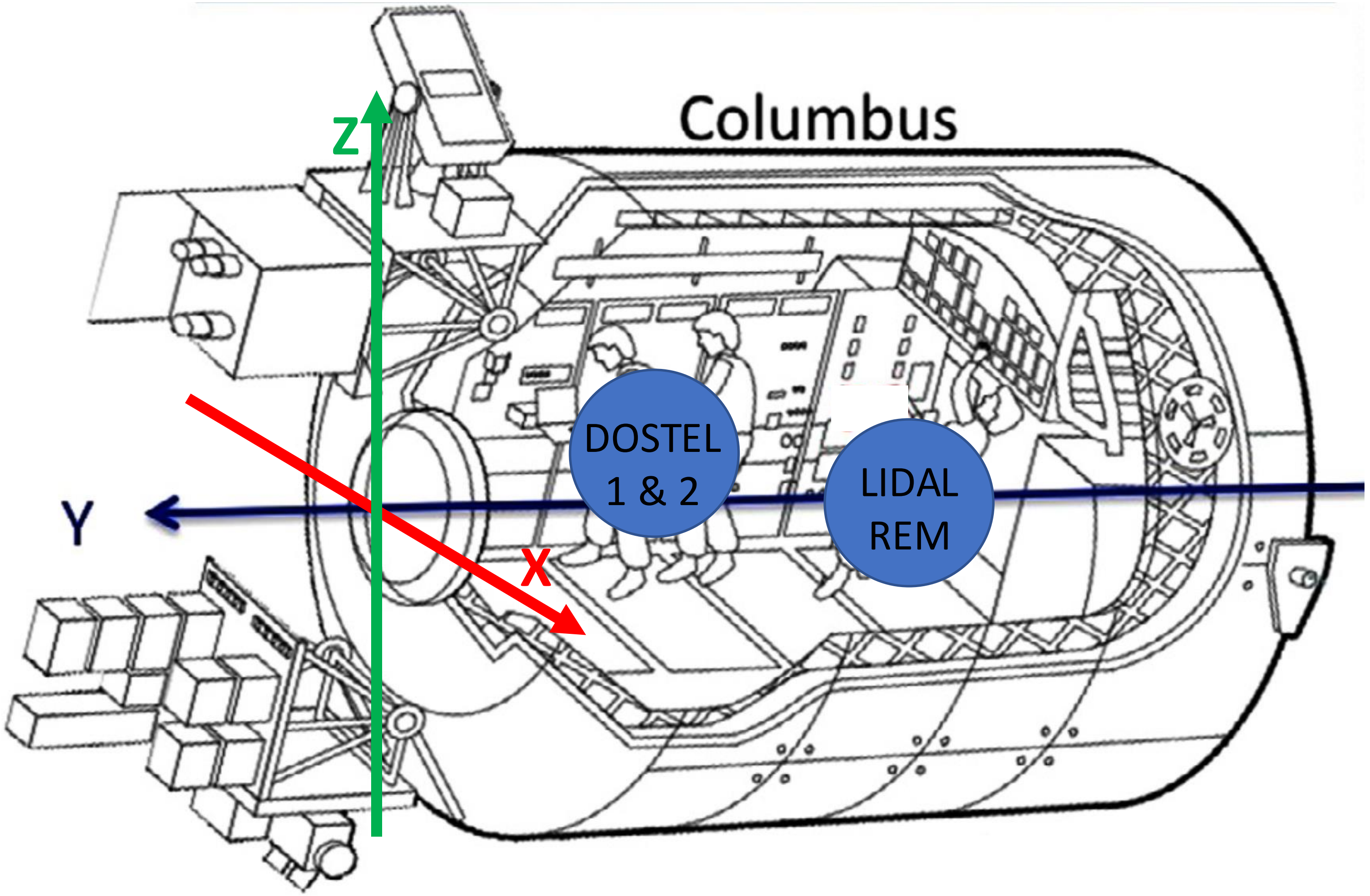
LIDAL-REM assembly

DOSTELs

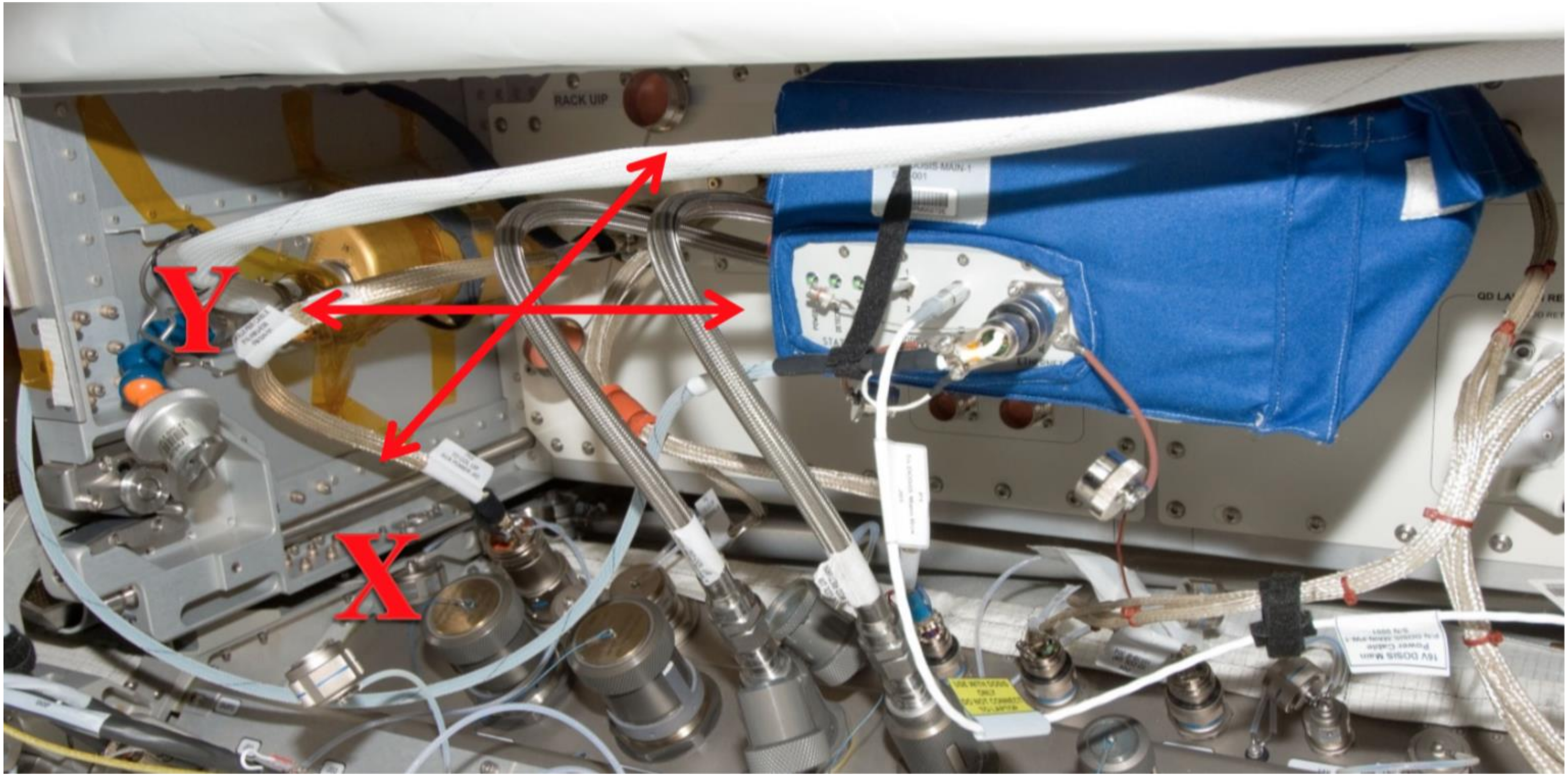
Where

Comparative studies of the measurements from four silicon detectors in Columbus:

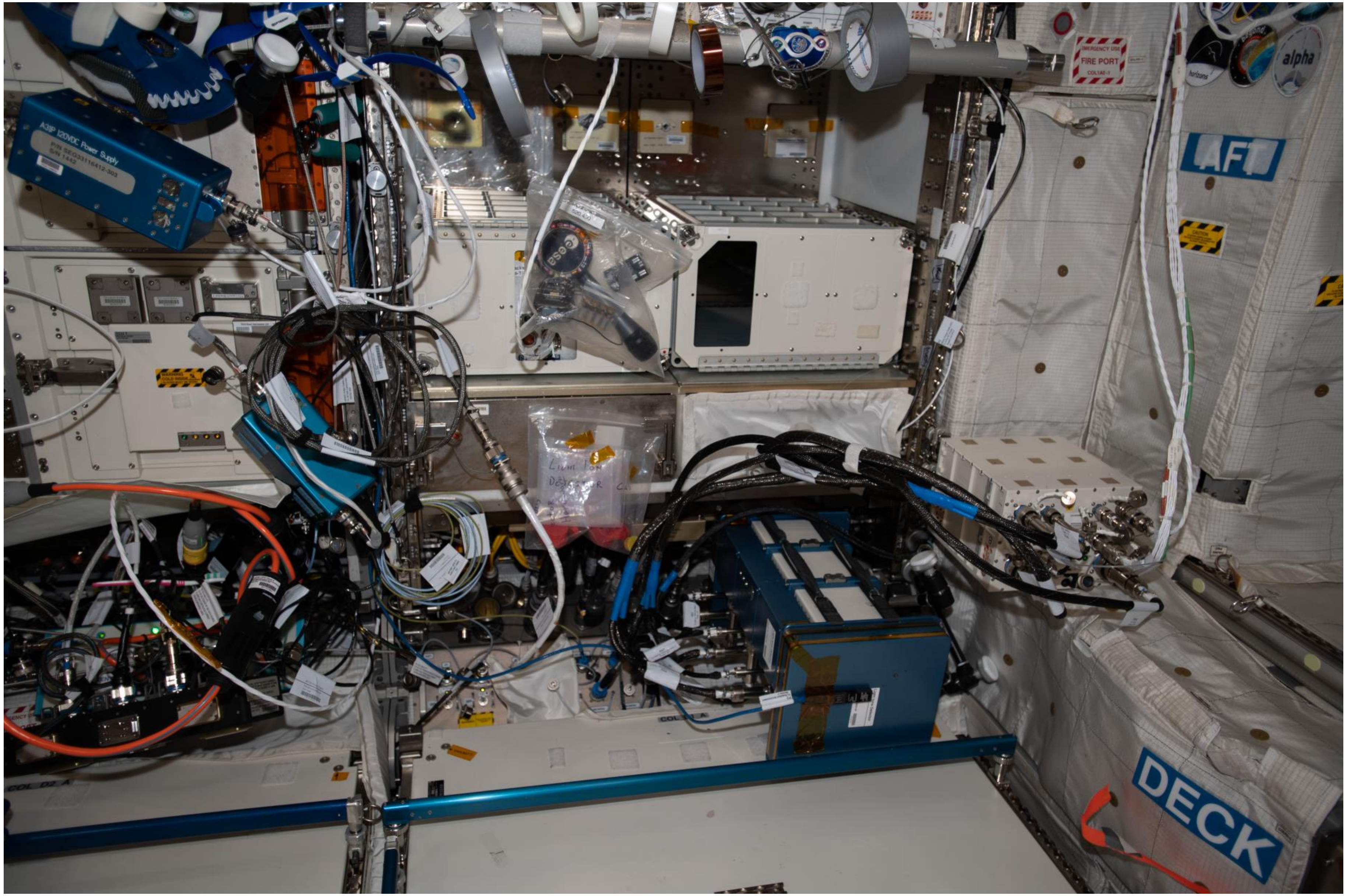
DOSTEL 1 & 2
REM
LIDAL



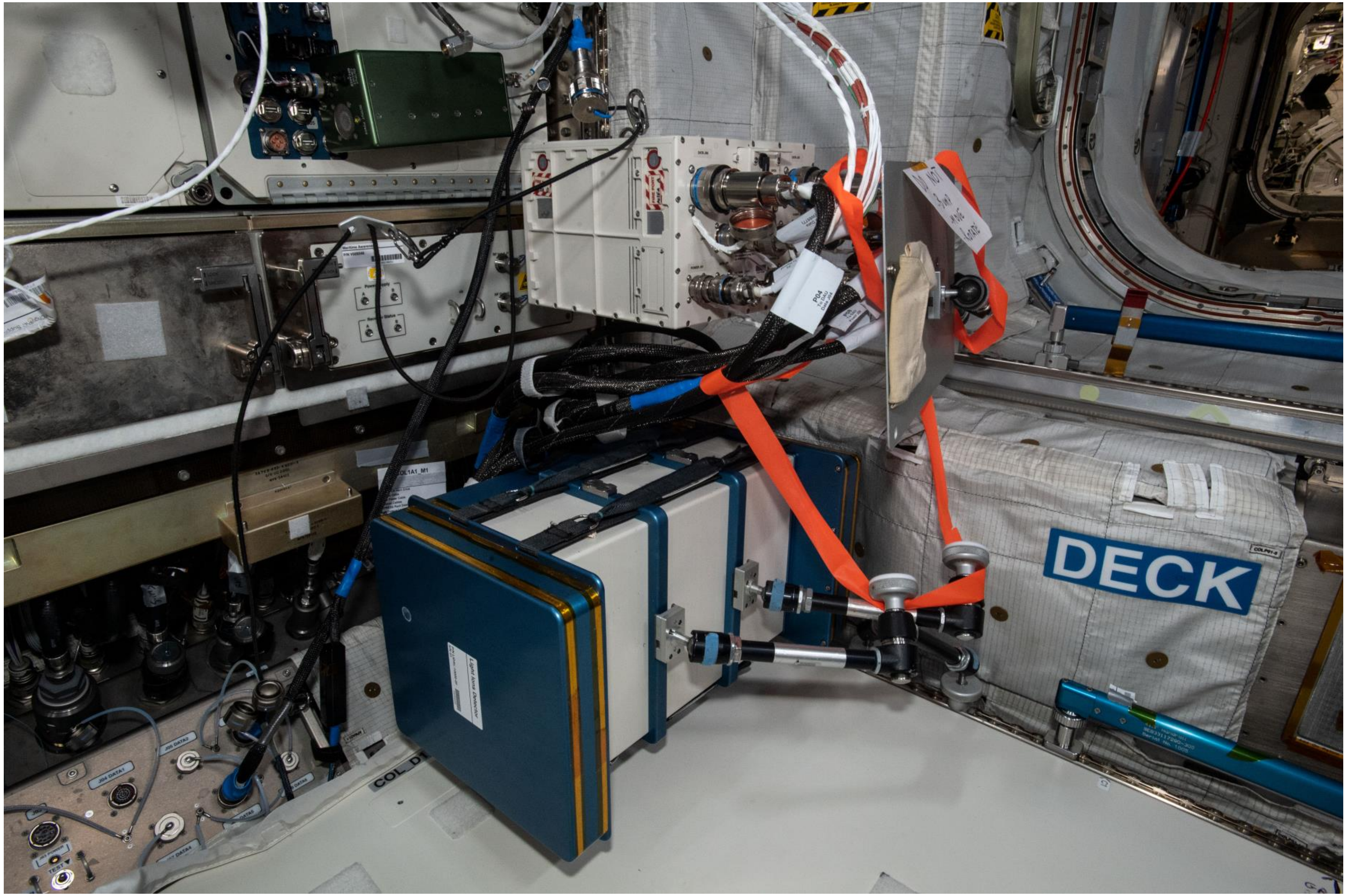
Where: DOSTEL site (fixed)



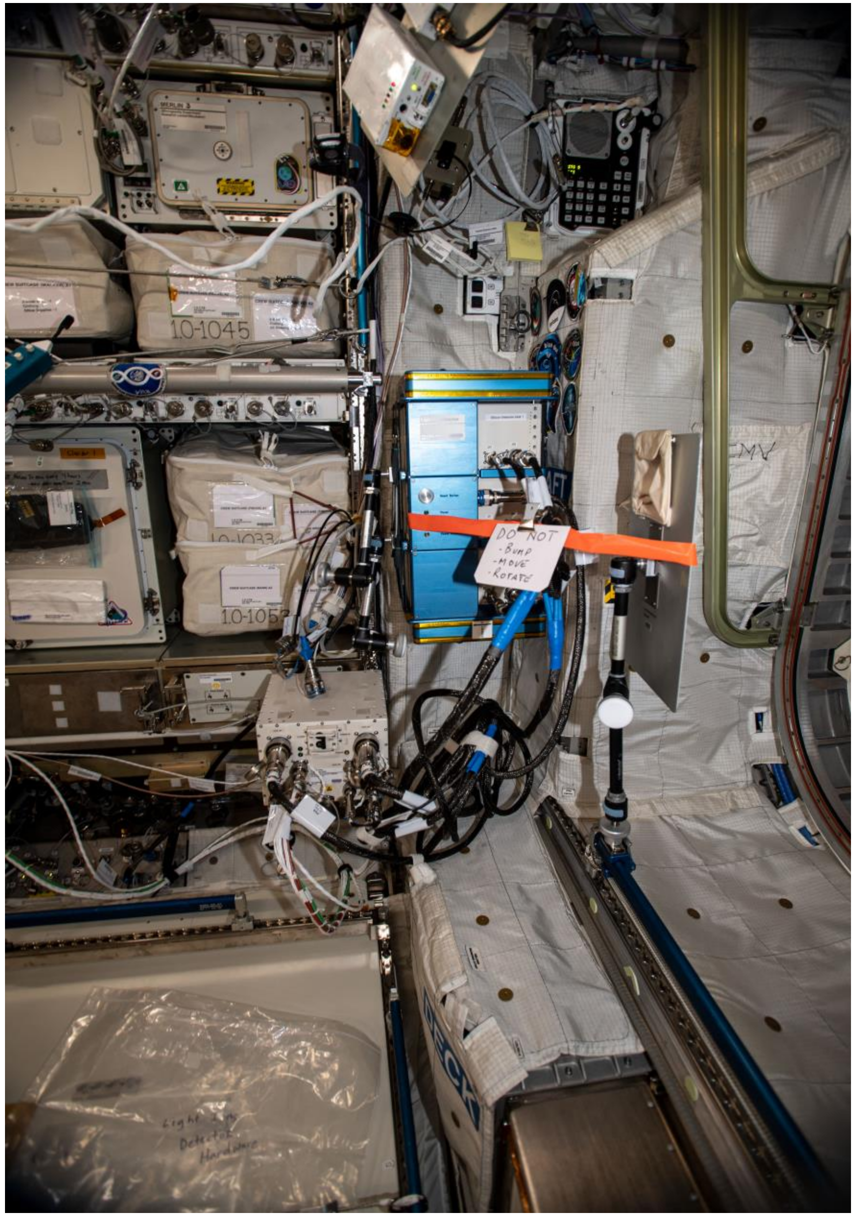
Where: LIDAL X / REM



Where: LIDAL Y



Where: LIDAL Z/REM



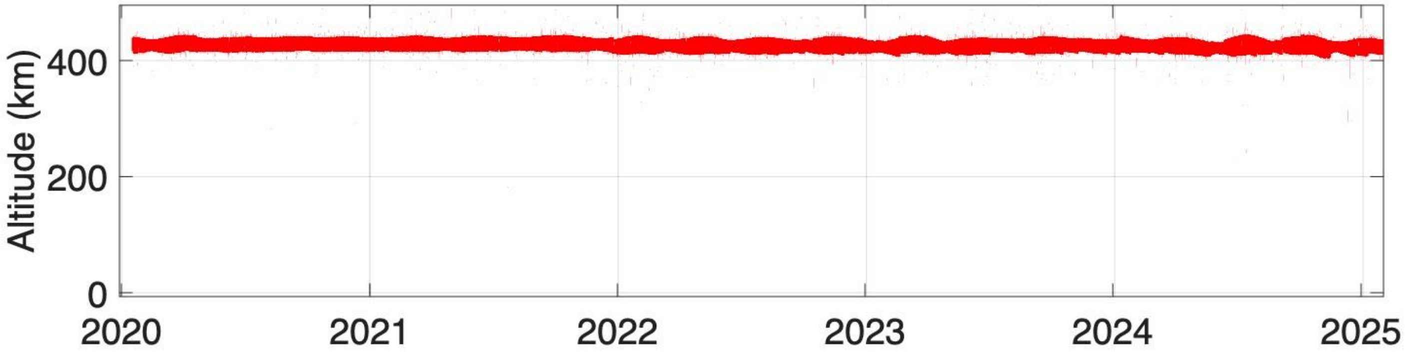
When

Measurement times

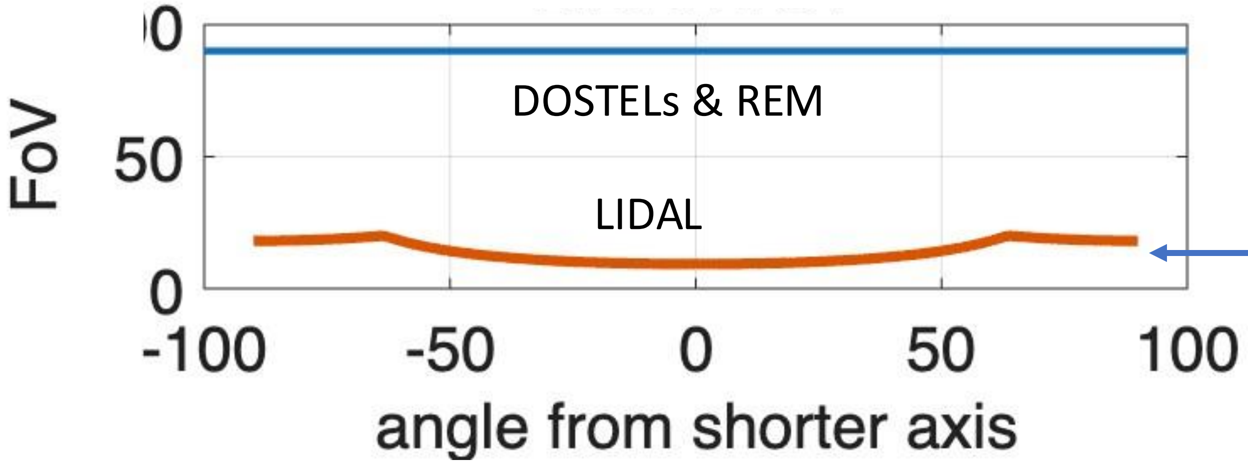
Detector	from	to*
LIDAL	2020 Jan 19th	2025 Feb 23rd
DOSTEL1	2021 Mar 4th	2024 Sep 22nd
DOSTEL2	2020 Jan 1st	2024 Sep 17th
REM	2021 Sep 17th	2025 Feb 23rd

* All four detectors are still running and acquiring data. The 'to' date refers to the data shown here

ISS altitude would not be an issue during the considered period:



Field of View (FoV)

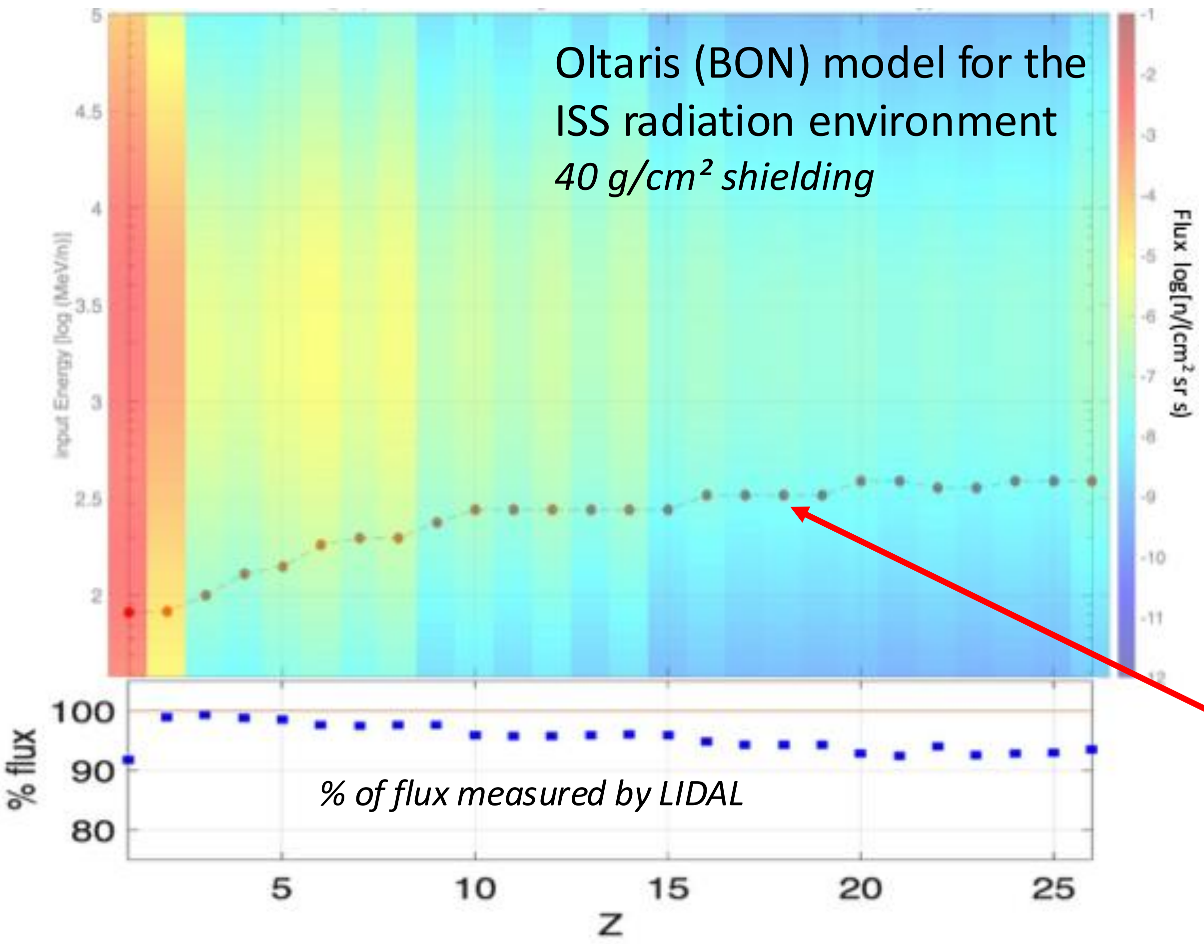


DOSTEL and REM are 4π detectors

LIDAL mean: 14°

- DOSTEL and REM have a cosinusoidal modulation of the efficiency in detection within the FoV
- REM corrects this modulation to become a ‘spherical’ detector
- Within the FoV LIDAL efficiency is modulated by the energy acceptance of the telescope

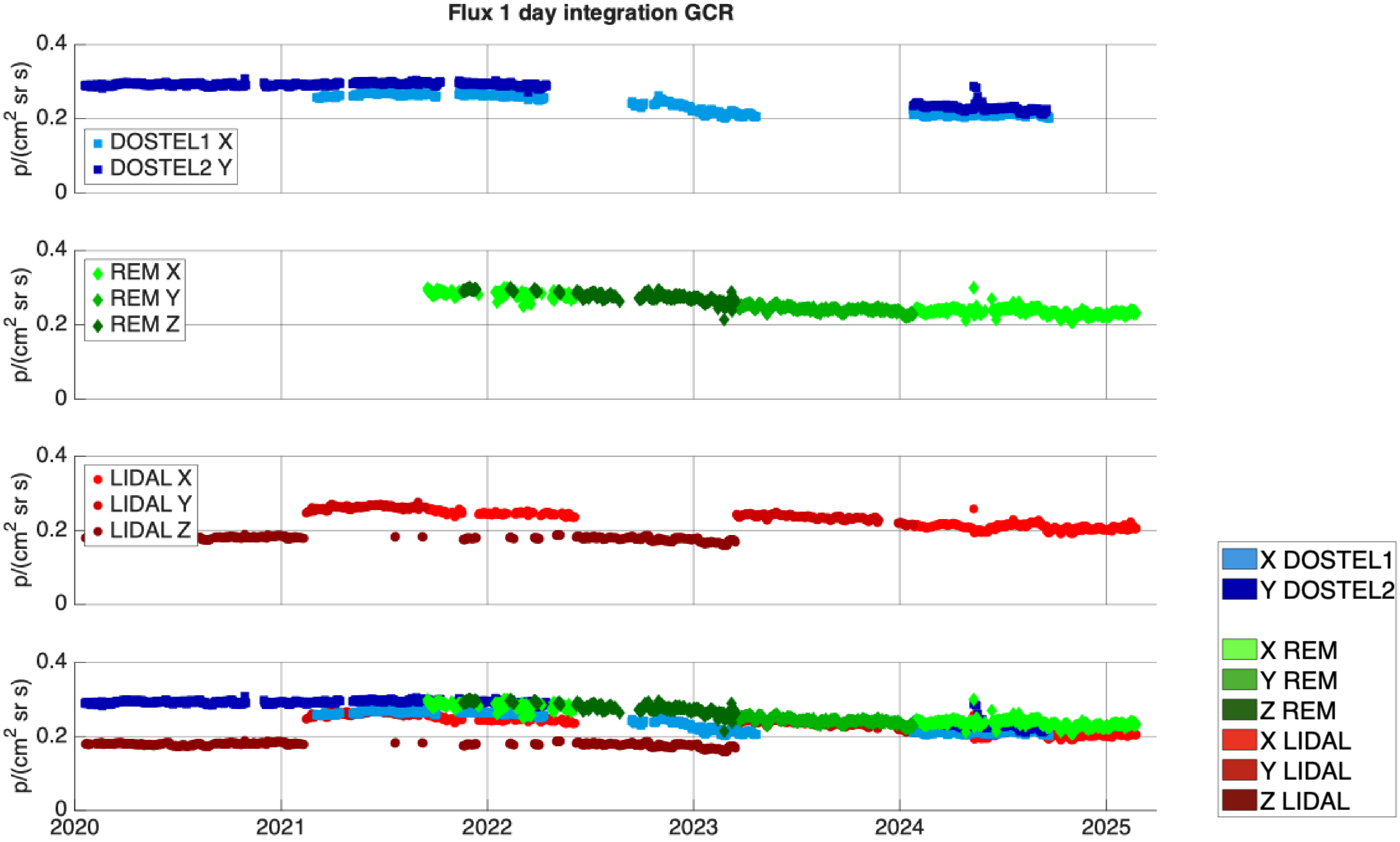
Energy acceptance for LIDAL



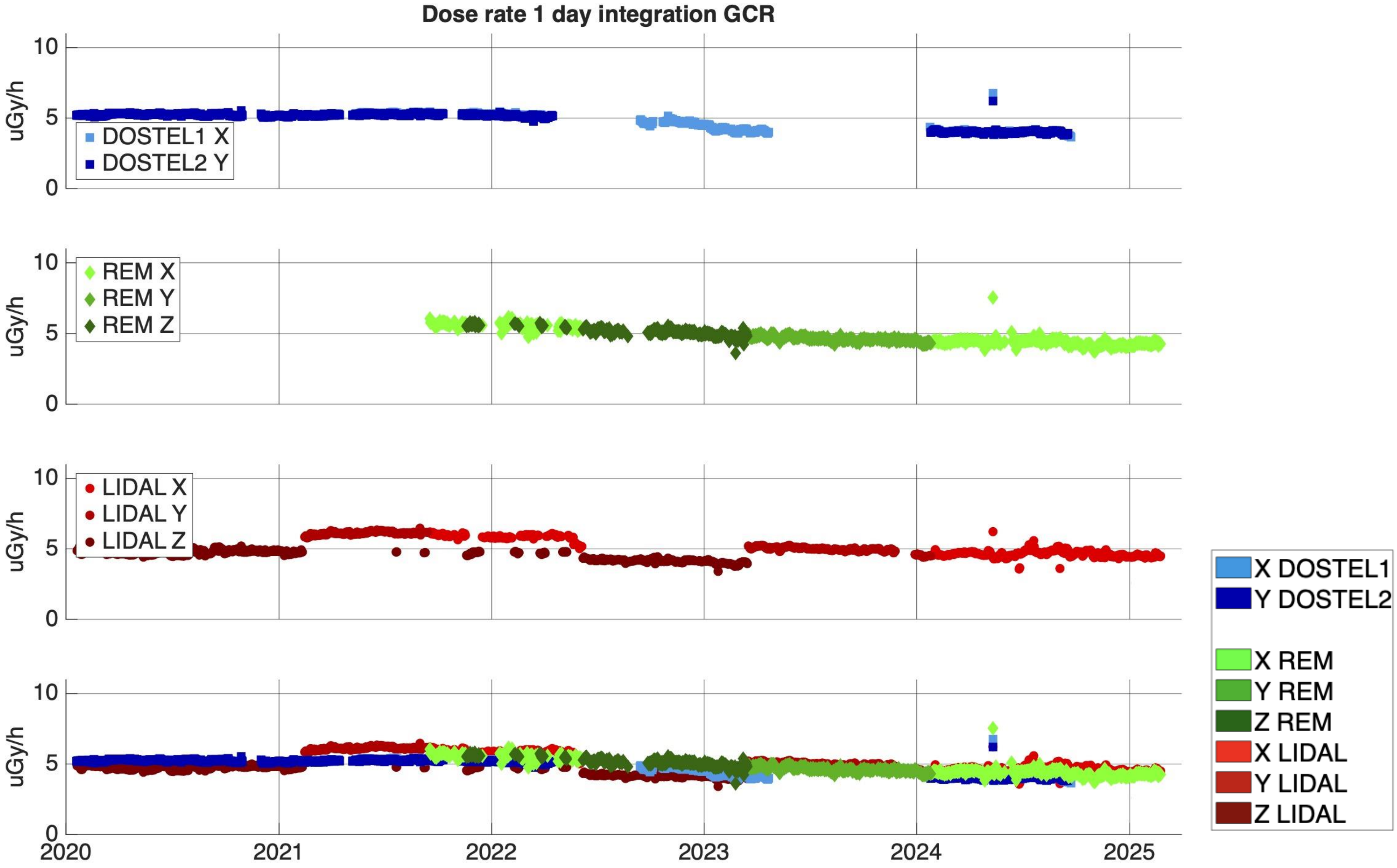
FLUKA Monte Carlo simulation of LIDAL determines the energy thresholds for each Z

→ Mean LIDAL measured flux: > 92%

Daily averaged flux - GCR

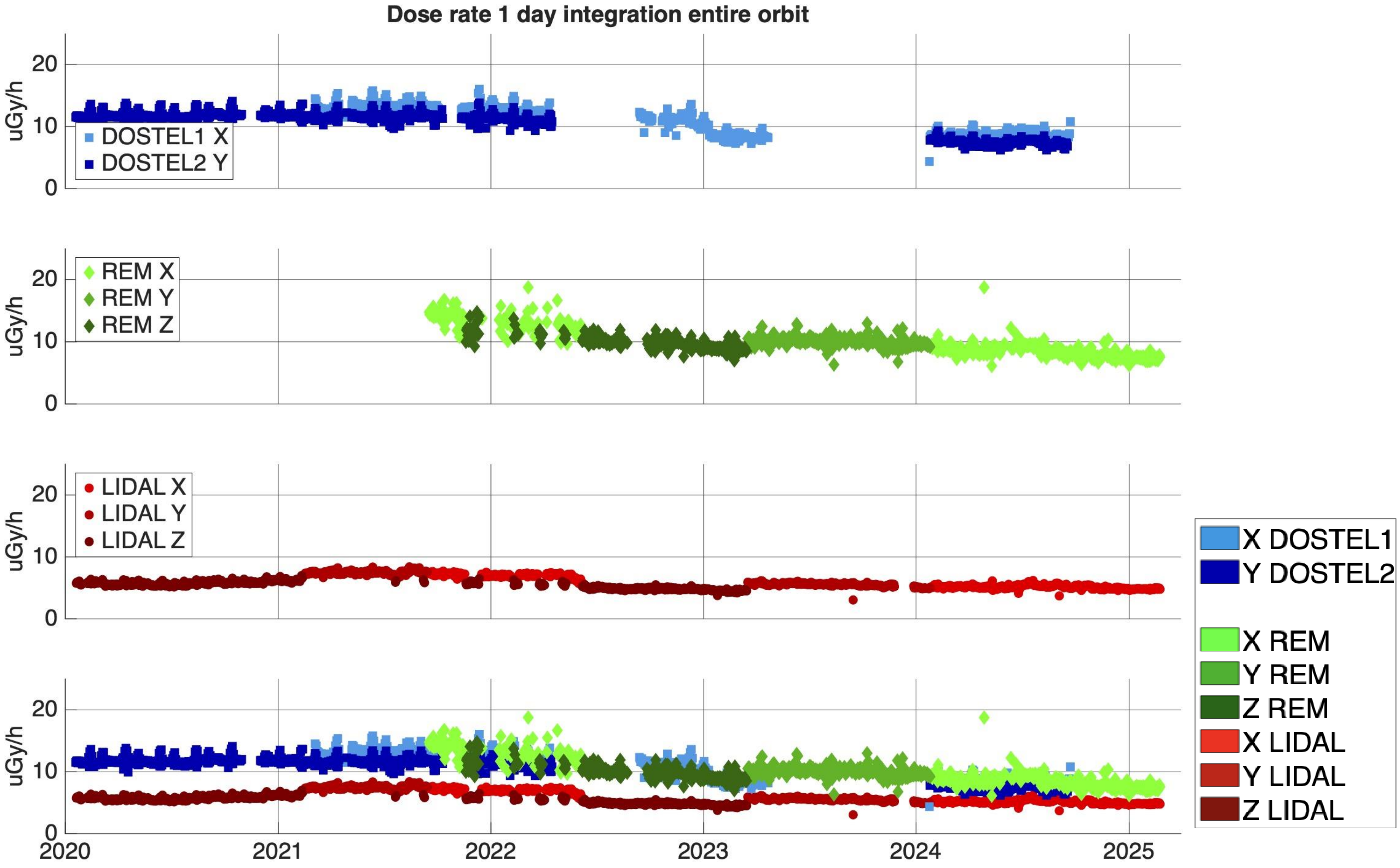


Daily averaged dose rate - GCR

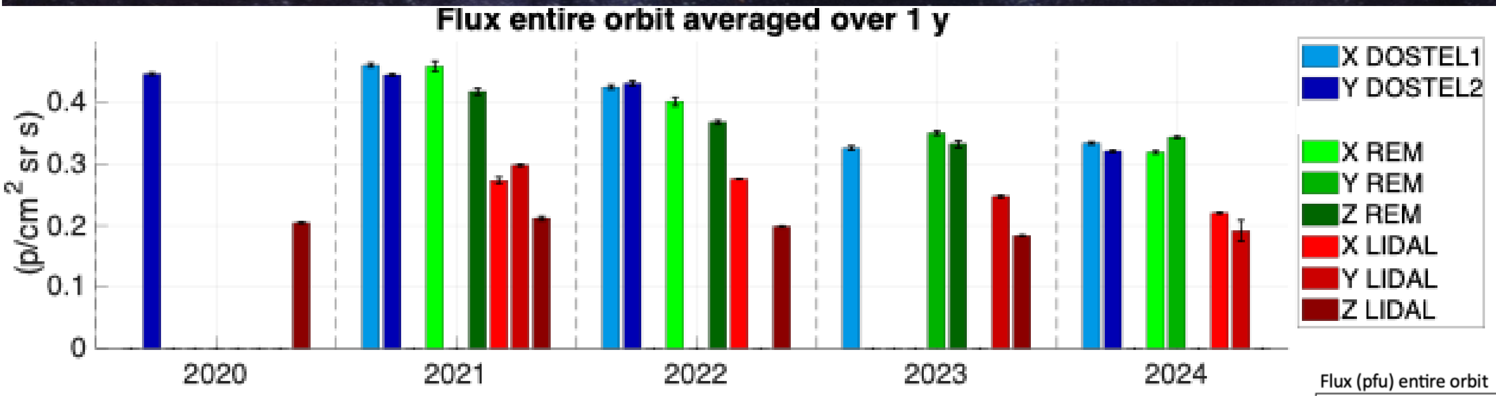


Daily averaged flux – including SAA

Daily averaged dose rate – including SAA

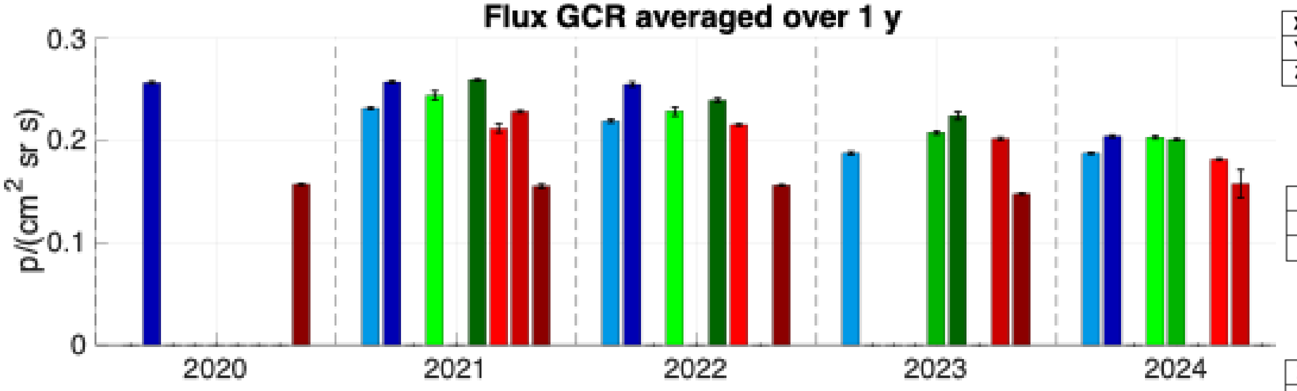


Yearly averaged flux



Flux (pfu) entire orbit

	2020			2021			2022			2023			2024		
	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL
X				0.462	0.460	0.274	0.426	0.403	0.276	0.326			0.335	0.320	0.221
Y	0.447			0.446		0.298	0.432				0.351	0.247	0.321	0.344	0.192
Z			0.205		0.419	0.212		0.368	0.198		0.333	0.184			

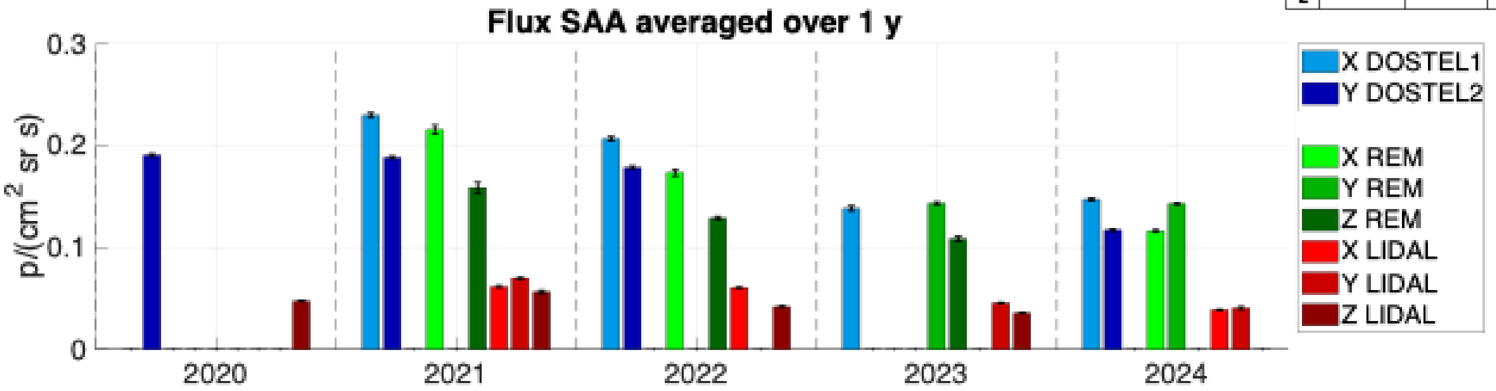


Flux (pfu) GCR

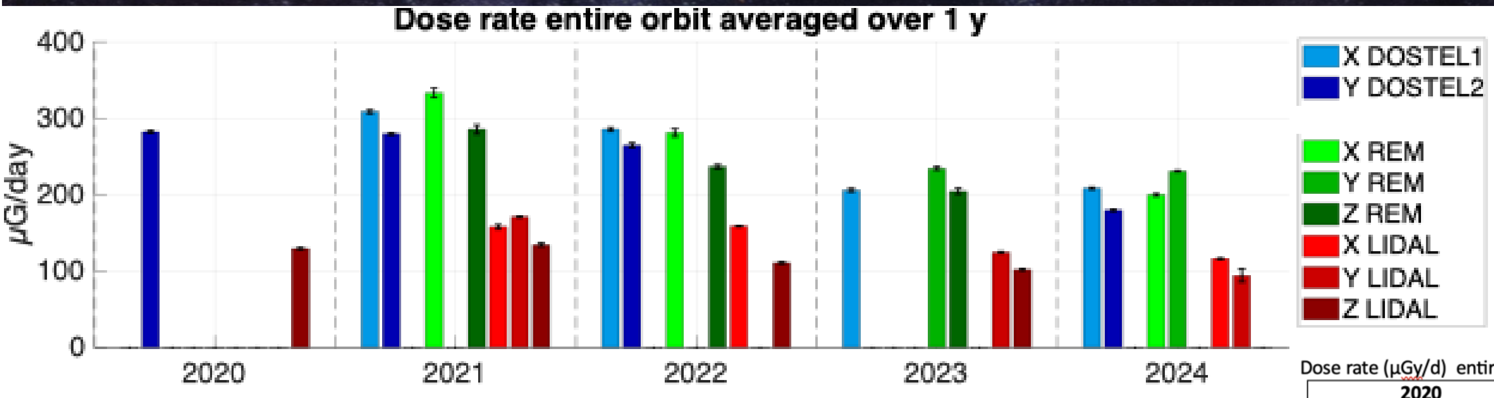
	2020			2021			2022			2023			2024		
	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL
X				0.232	0.244	0.212	0.219	0.229	0.216	0.188			0.188	0.203	0.182
Y	0.257			0.257		0.229	0.255				0.208	0.202	0.204	0.201	0.158
Z			0.157		0.260	0.155		0.240	0.156		0.225	0.148			

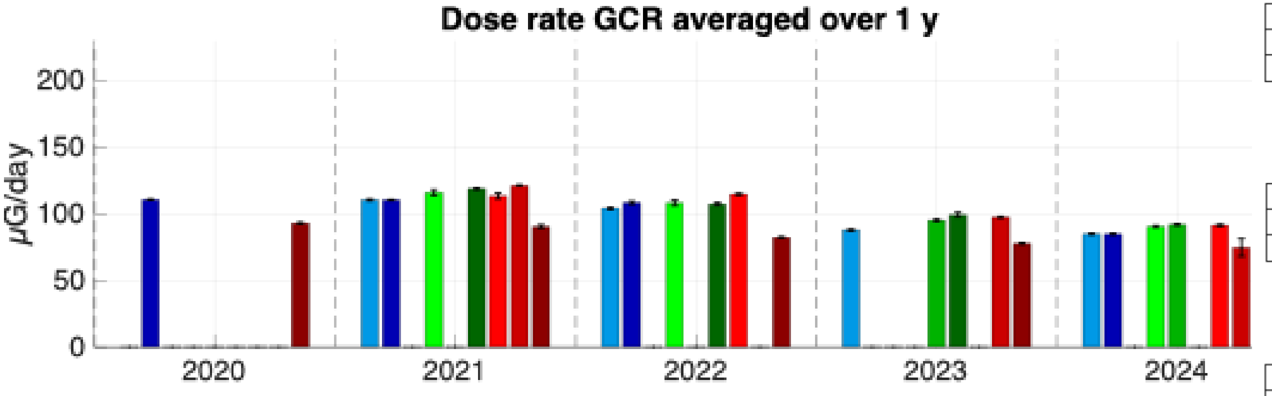
Flux (pfu) SAA

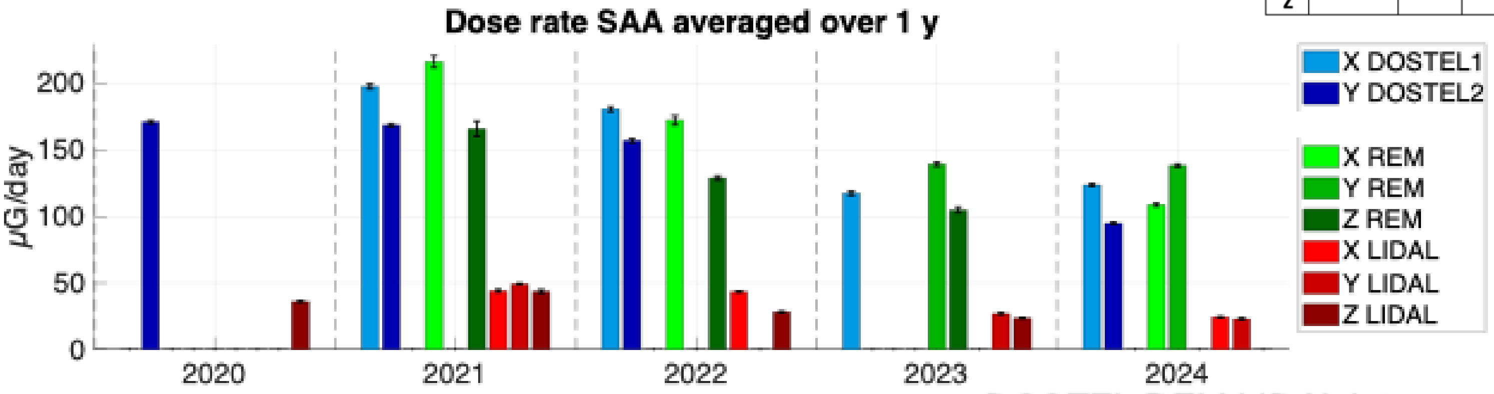
	2020			2021			2022			2023			2024		
	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL
X				0.230	0.216	0.062	0.207	0.174	0.061	0.138			0.147	0.116	0.039
Y	0.191			0.189		0.070	0.179				0.143	0.046	0.117	0.143	0.041
Z			0.047		0.159	0.056		0.129	0.042		0.109	0.036			



Yearly averaged dose rate







Dose rate (μGy/d) entire orbit

	2020			2021			2022			2023			2024		
	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL
X				308	333	158	285	281	158	205			208	199	116
Y	282			279		171	264				234	124	179	230	94
Z			129		285	134		236	111		204	101			

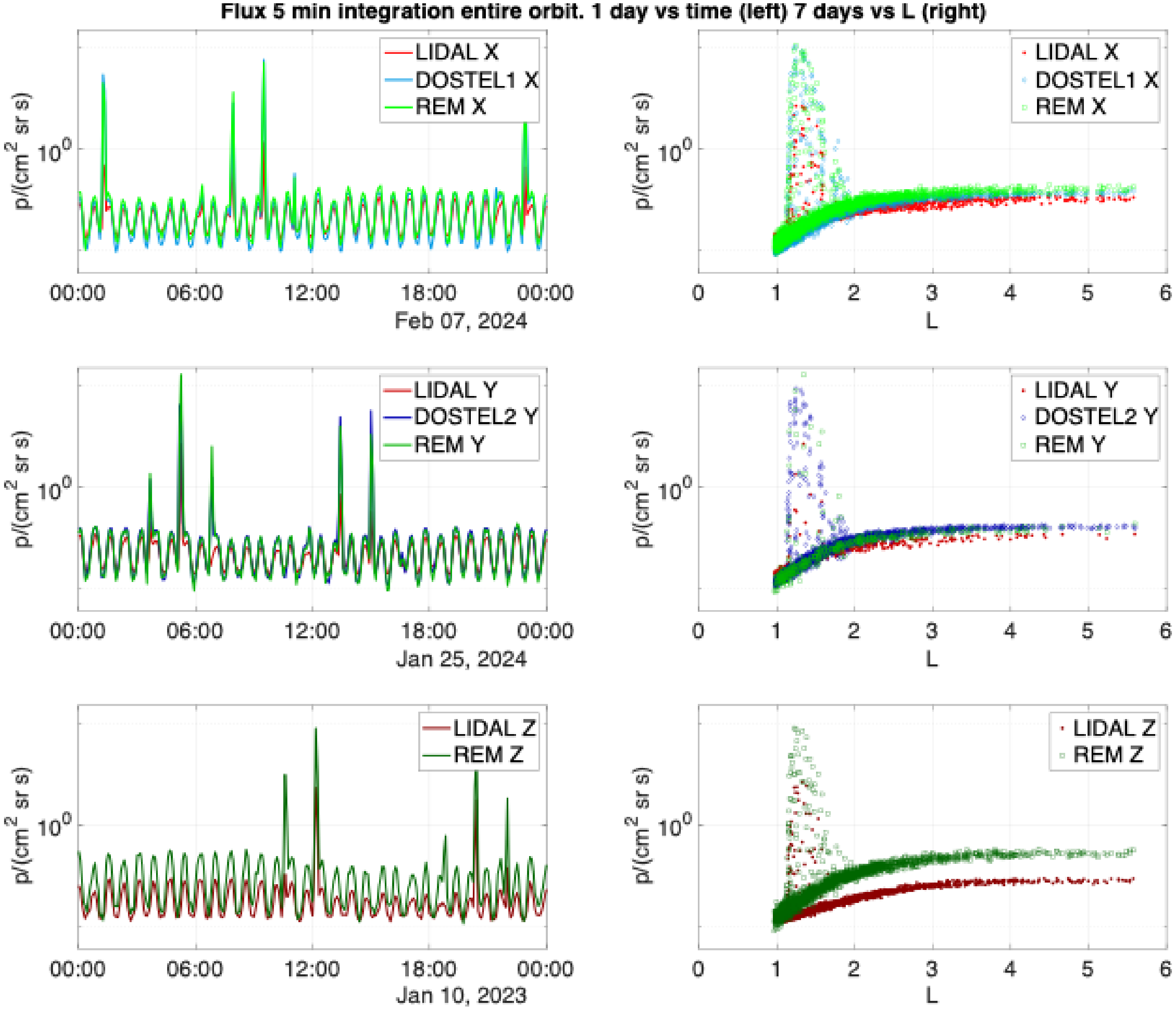
Dose rate (μGy/d) GCR

	2020			2021			2022			2023			2024		
	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL
X				111	116	114	104	108	115	88			85	91	92
Y	111			110		121	109				95	98	85	92	75
Z			93		119	91		107	82		99	78			

Dose rate (μGy/d) SAA

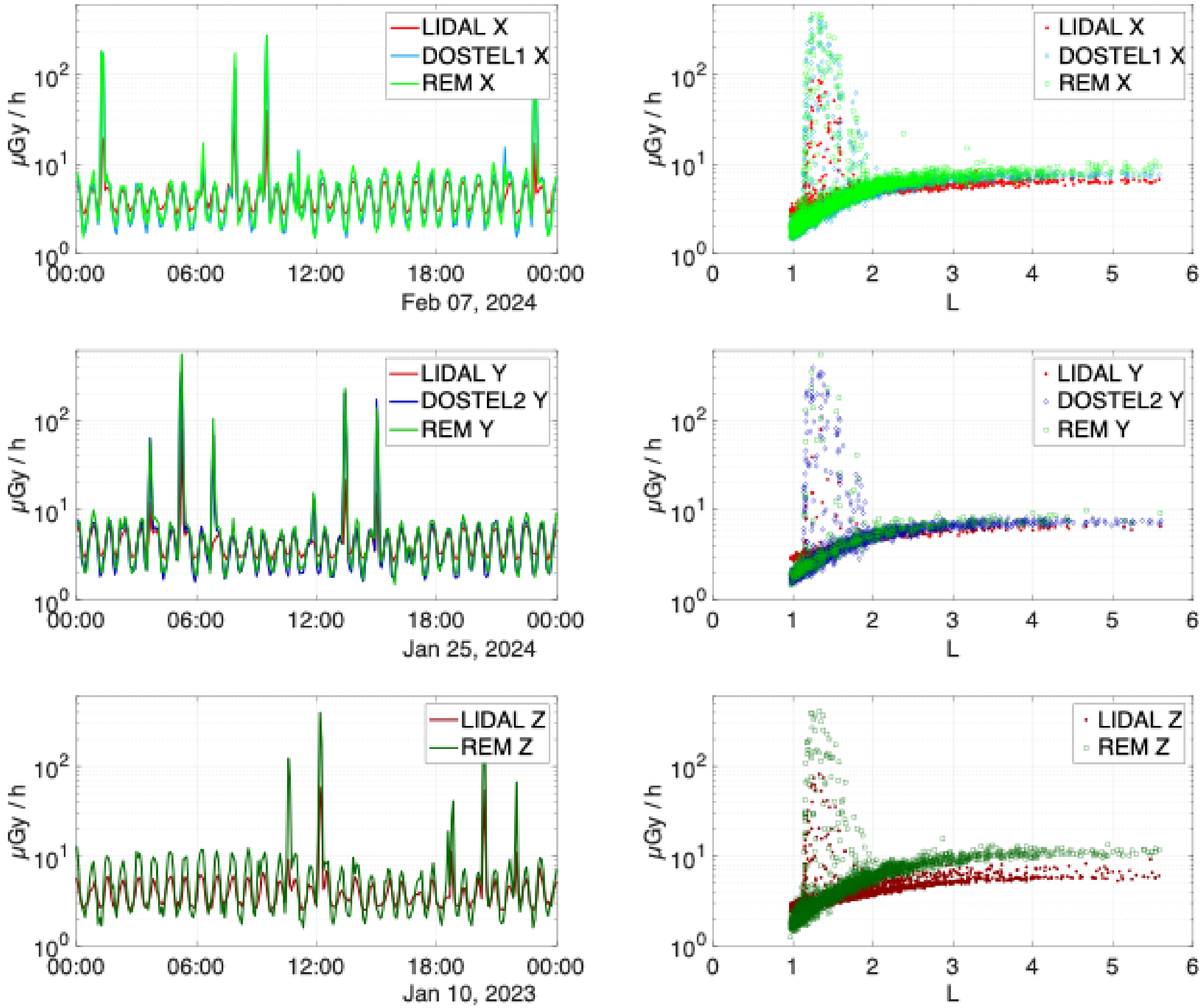
	2020			2021			2022			2023			2024		
	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL	DOSTEL	REM	LIDAL
X				198	217	44	181	172	43	118			124	109	24
Y	171			169		49	157				139	27	95	138	23
Z			36		166	44		129	28		105	24			

5 minutes integrated flux – example



5 minutes integrated dose rate – example

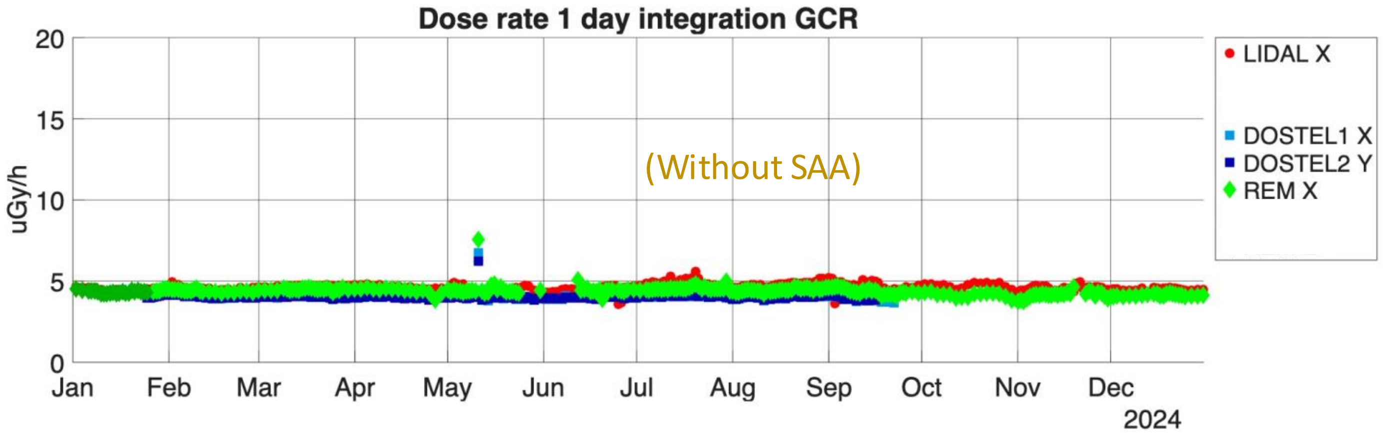
Dose rate 5 min integration entire orbit. 1 day vs time (left) 7 days vs L (right)

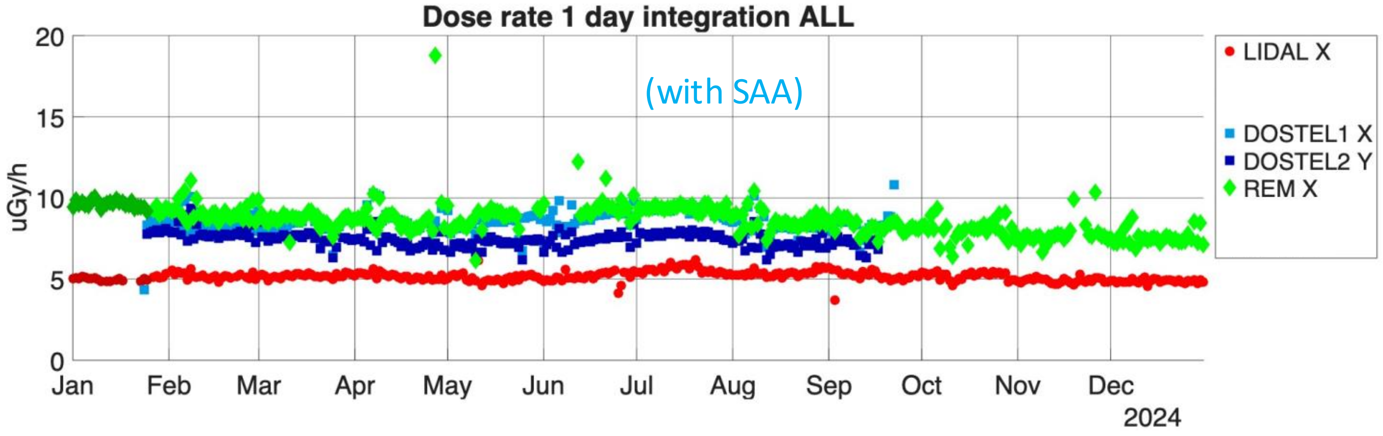


Discrepancy study

If we 'carefully select'* the datasets , the data show good agreements.
We can compute the average and the standard deviation of the dose rate values across detectors each day.

** No Z direction, possibly no SAA*

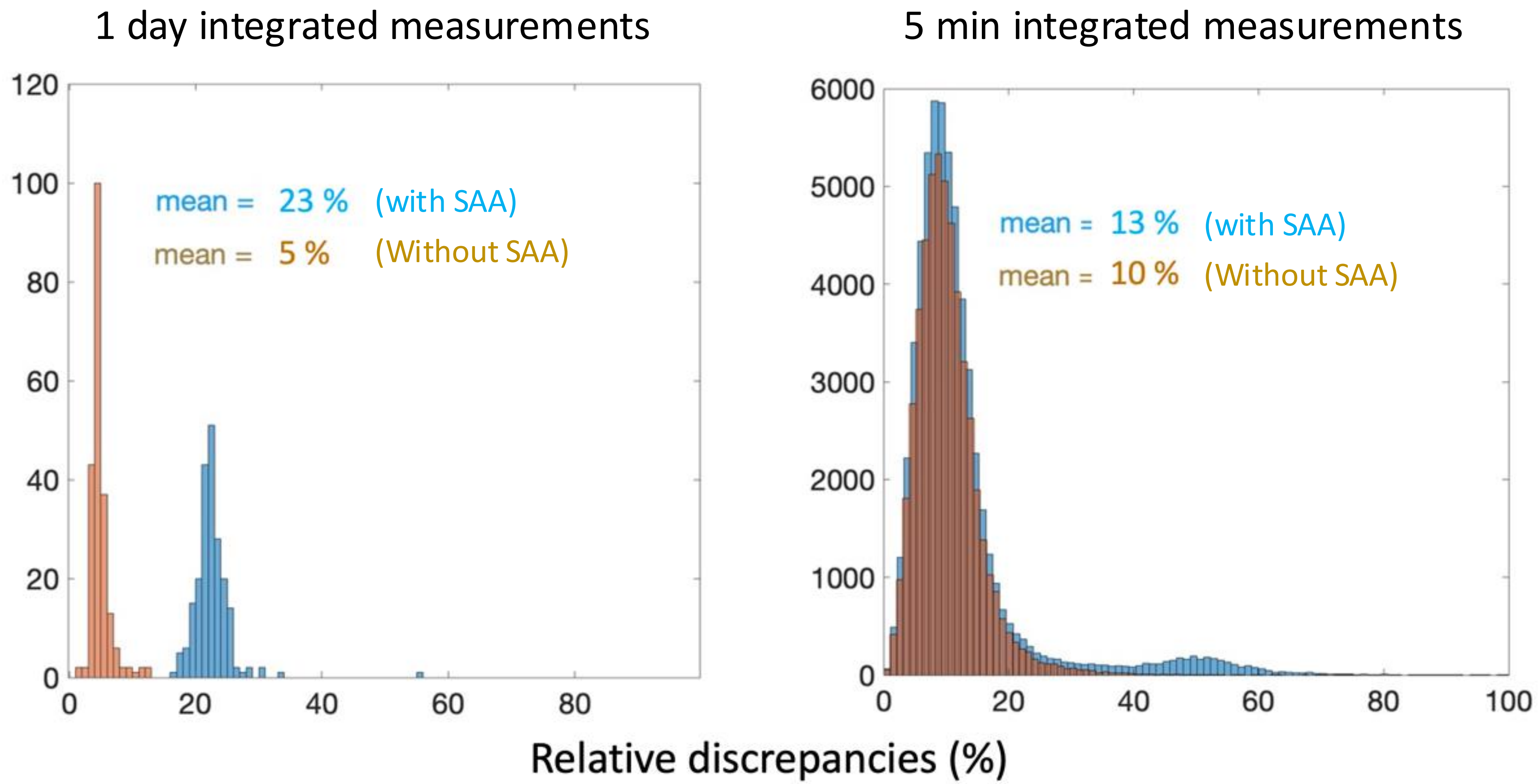




Year 2024 data
(all X, DOSTEL2 Y)

Discrepancy study

Computing the average and the standard deviation of the dose rate values across detectors, the standard deviations distribute as follows (brown plot just GCR, blue plot including SAA). Same for 5 min integrated data at right.



Year 2024 data
(all X, DOSTEL2 Y)

With SAA → bio exp. In ISS
Without SAA ~ Deep pace?

NOTE: number of detectors and experimental 'set up' do not allow for 'real' statistical meaning of these numbers: they are just approximate evaluations for a complex habitat

Discrepancy study

Models may have similar uncertainties …

Table 3 | Comparison of measured silicon dose-rates (mGy/day) to model calculations for ISS (Cupola and US lab), Orion (HPU, HSU1, HSU2), BioSentinel (BPD), and the surface of Mars (MSLRAD) during the Artemis-I mission

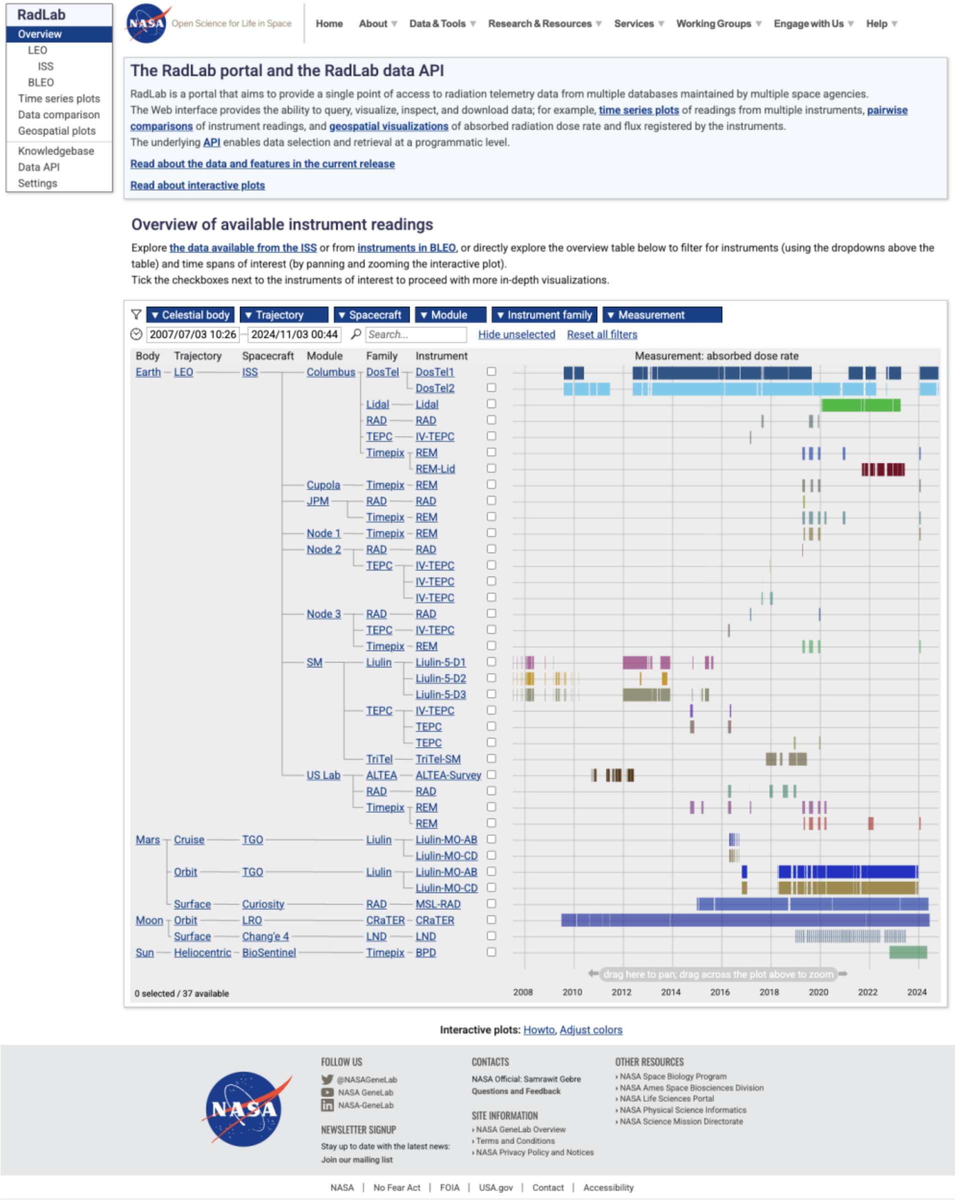
Location	Vehicle	Silicon dose-rate (mGy/day)			
		Detector	Measurement	Model	Model (G4)
LEO	ISS	US lab	0.132	0.101 (-24)	0.105 (-21)
		Cupola	0.115	0.102 (-12)	0.106 (-8)
Free space	Orion	HPU	0.336	0.345 (3)	0.346 (3)
		HSU1	0.328	0.340 (4)	0.340 (4)
		HSU2	0.320	0.330 (3)	0.329 (3)
	BioSentinel	BPD	0.276	0.287 (4)	0.282 (2)
Mars	Curiosity	MSLRAD	0.167	0.155 (-7)	0.147 (-12)

(Slaba et al. NPJ Micrograv 2025)

- Uncertainties in replicating measurement data from models seem to be roughly equivalent.

But … relying on models may cost much more (than measuring)

RadLab



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https://visualization.osdr.nasa.gov/radlab/gui/overview/

Take home messages

- Comparison among almost co-located detectors are quite useful for final calibrations and tunings.

For interested space experimental biologists:

- The overall shielding, the local shielding, the differences in detectors functioning provide apparent discrepancies in the measurements.
- Earth shadow effects heavily depends by the FoV of the detectors.
- Carefully selecting the data daily dose may be accurate within ~23% in ISS and ~13% in 'deep space' (GCR)
- You may rely on models, at a cost (→ measurements in this moment are cheaper)

For the modelists:

- In complex habitat the need of accurate knowledge of the radiation field also relies on models (and CAD availability).
- → Need of an open CAD database!

The DORELI collaboration

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* Not anymore in the collaboration

Thank you for your attention