DOSTEL measurements as part of DOSIS/DOSIS3D: An update

Sönke Burmeister[1], Thomas Berger[2] and Daniel Matthiä[2] for the DOSIS3D team

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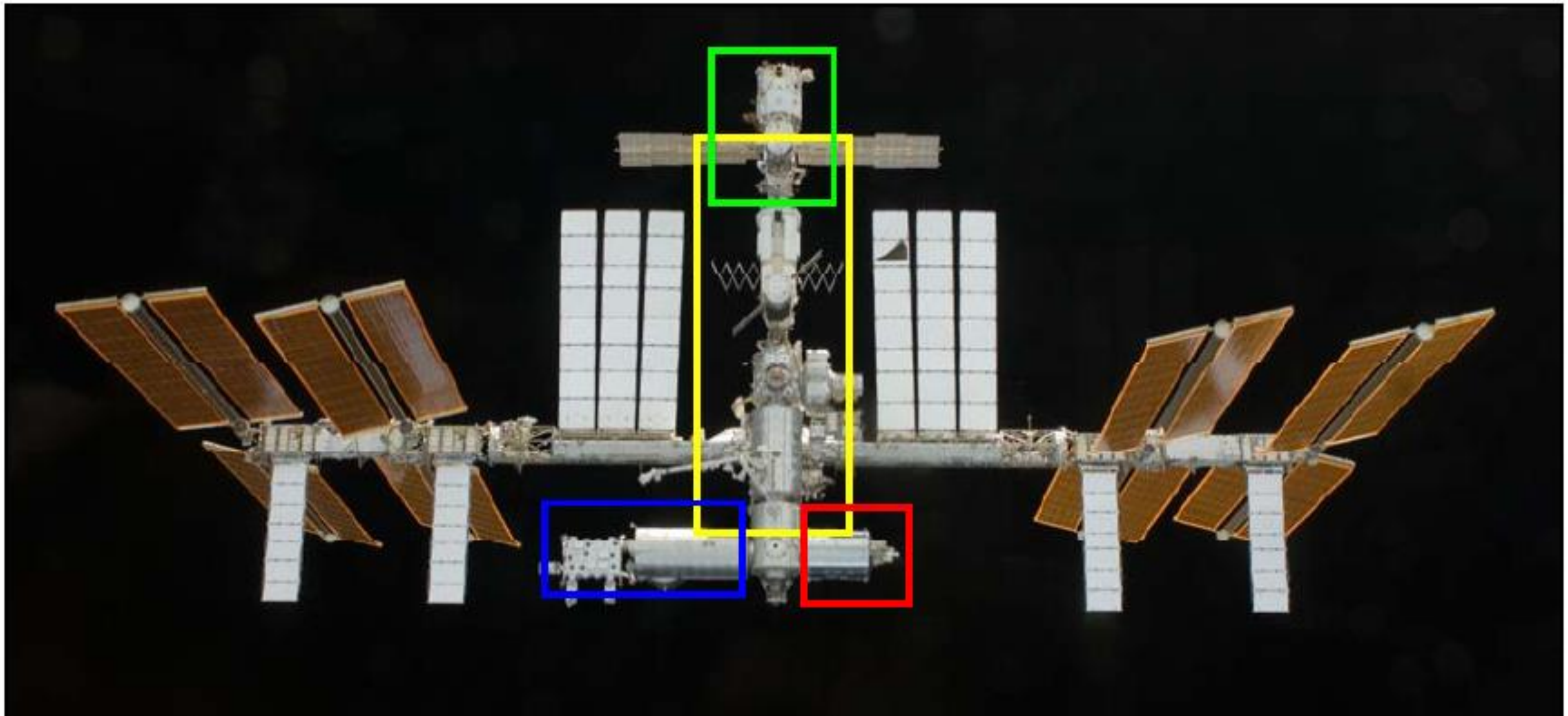
26th WRMISS, 5 – 7 September 2023, Rome, Italy

ISS020E022219

DOSIS / DOSIS 3D



Agency	*Name of the detectors*	*Quantity*	*Position on ISS*
ESA	PDP	10 + 1	Columbus (red rectangle)
NASA	RAMs	24	All over the ISS (yellow rectangle)
JAXA	PADLES	12	KIBO (blue rectangle)
IBMP	SPD	6	Russian part of the ISS (green rectangle)
	Pille	10	

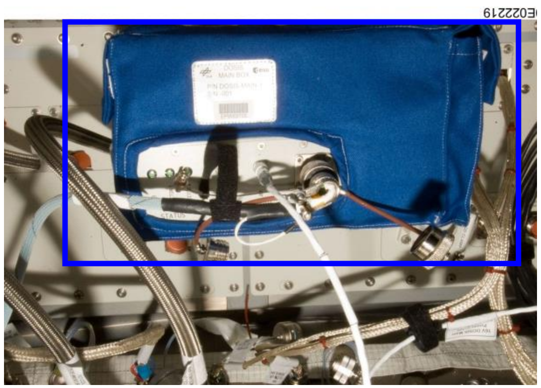
Fig. 3: Passive detectors on the ISS. The RAMs, PADLES, SPD and Pille detectors are permanently on board of the ISS. The PDPs from ESA are not. To reach the scientific goals set by Dosis 3D the PDPs shall be re-introduced on Columbus.

DOSIS & DOSIS 3D: Scientific Goals

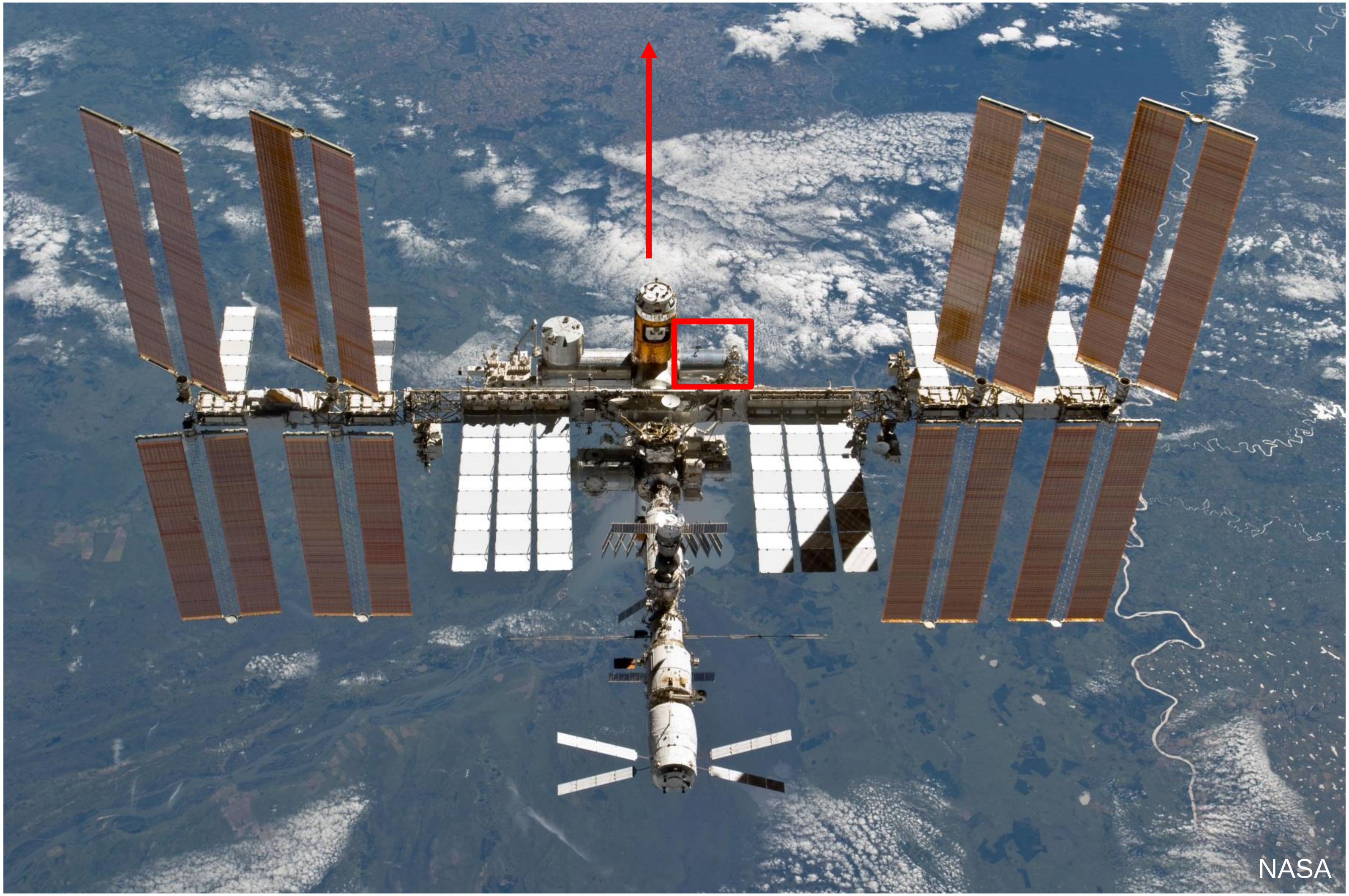
The main objective of the **DOSIS & DOSIS 3D** experiment is the determination of the absorbed dose and dose equivalent using a variety of active and passive radiation detector devices distributed throughout the ISS.

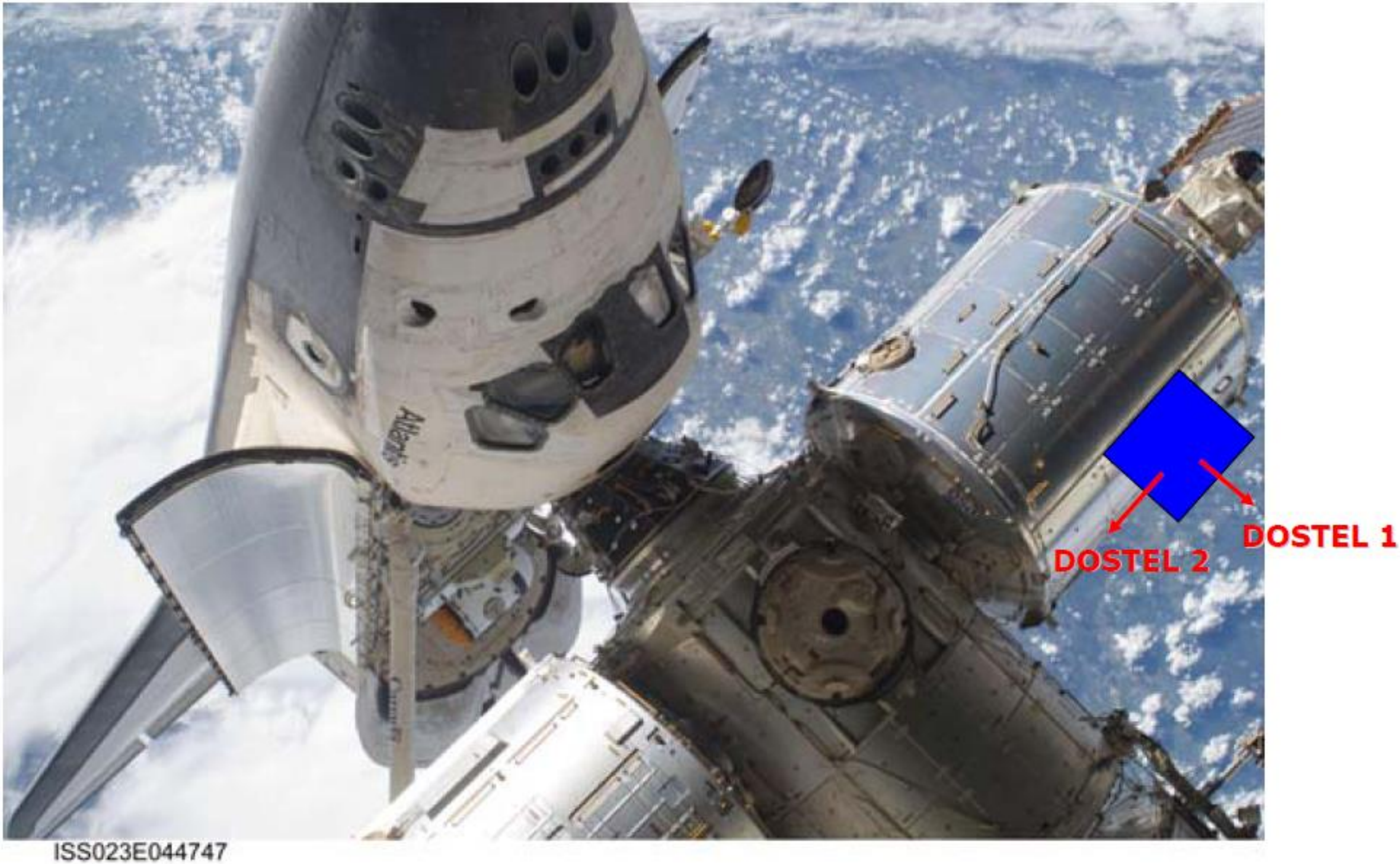
- Monitor the radiation environment inside Columbus with **active** and **passive** radiation detectors (ESA) for the determination of the temporal and spatial dose distribution

- Combine data gathered by NASA, JAXA, IMBP and ESA into a 3D radiation map of the International Space Station



DOSIS & DOSIS 3D: Measuring since 2009

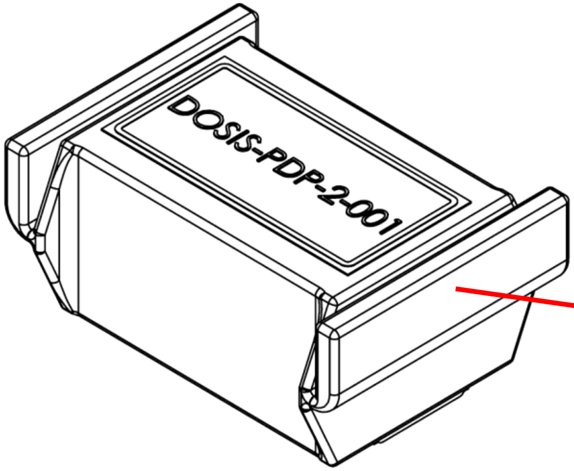


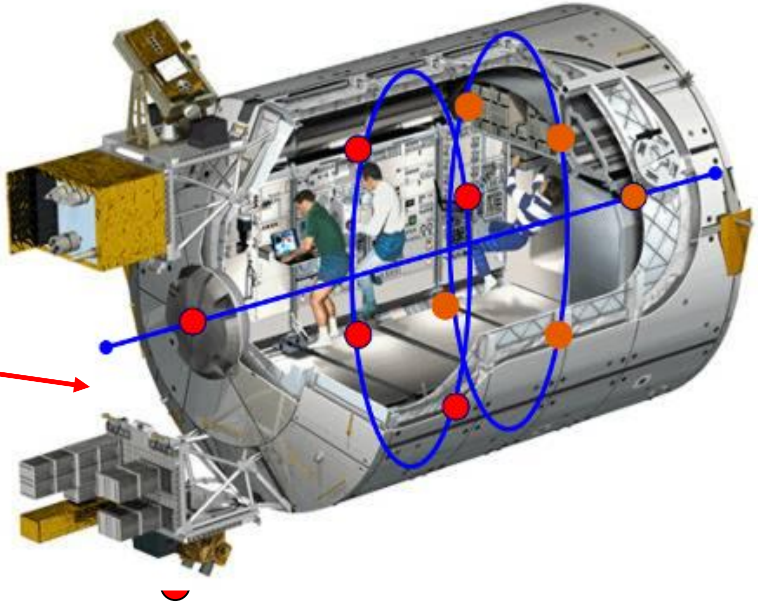

DOSTEL 1
DOSTEL 2
ISS023E044747

DOSIS Passive Detectors

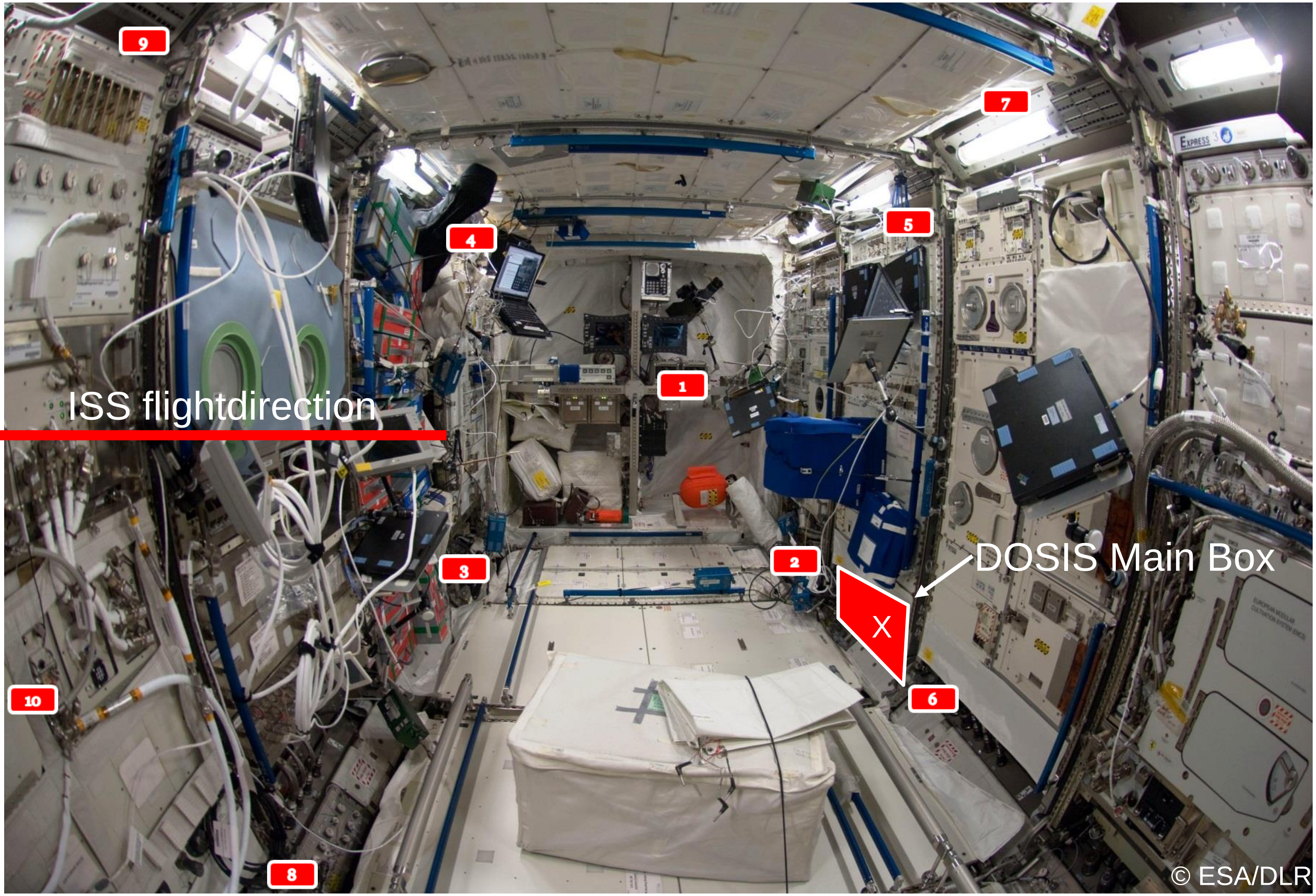
11 passive detector packages (PDPs) distributed inside COLUMBUS

Remember talk by Thomas ...

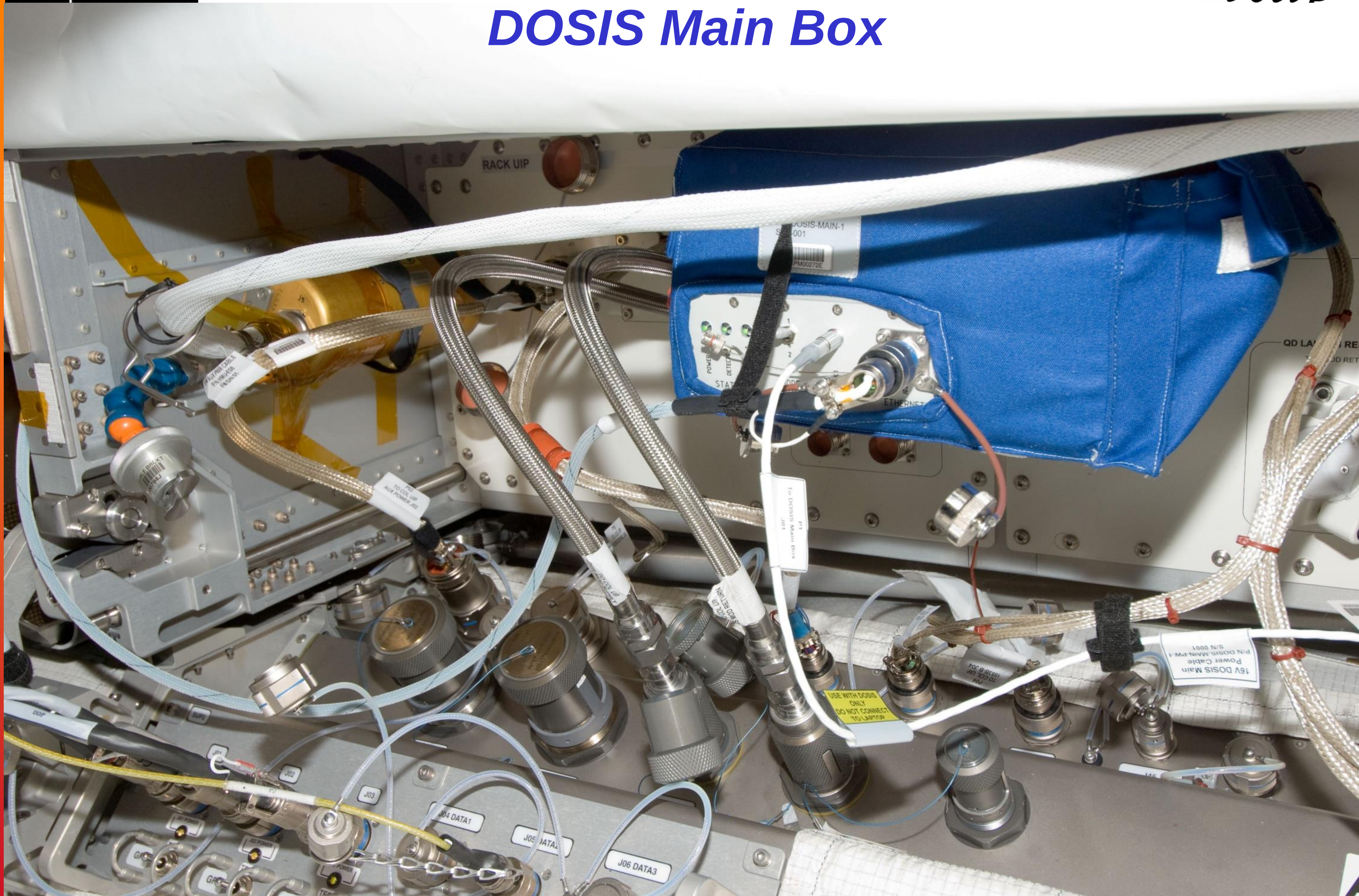




DOSIS & DOSIS 3D: PDP + DOSTEL Positions



DOSIS Main Box



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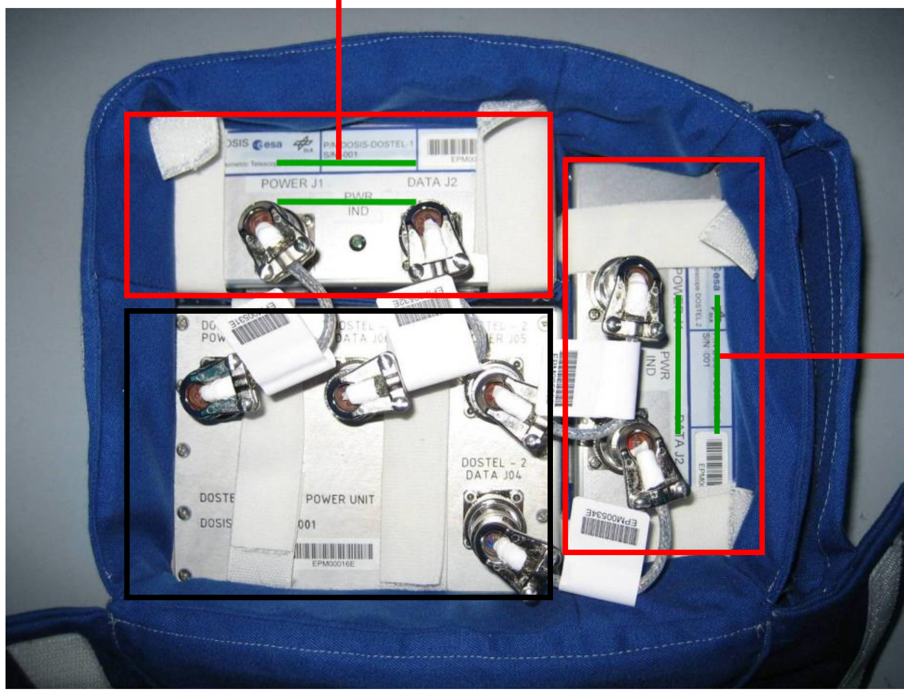
DOSIS Main Box

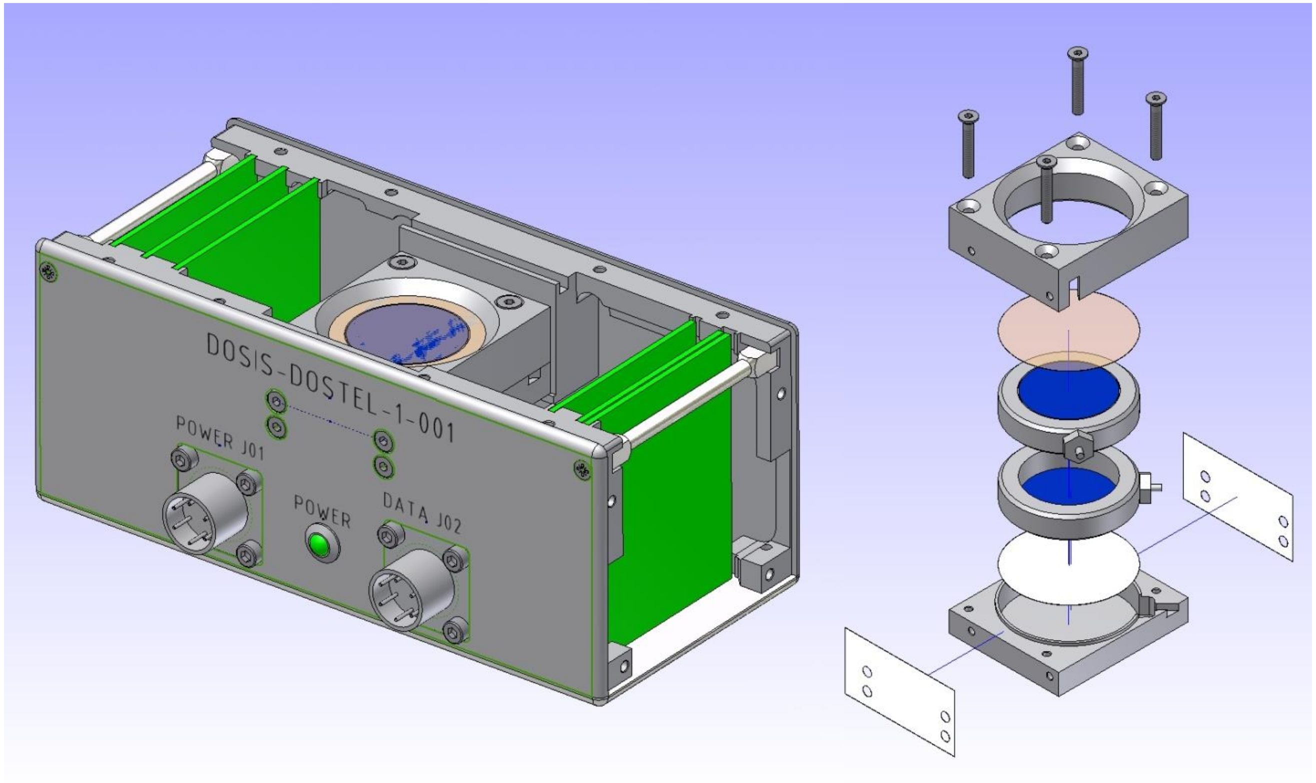
DOSTEL 1

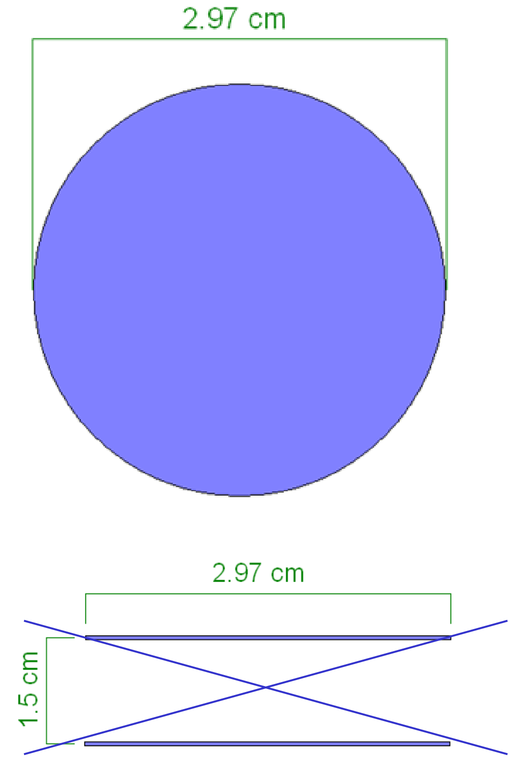


DOSTEL 2

DDPU – DOSTEL Data and Power Unit

DOSTEL Design

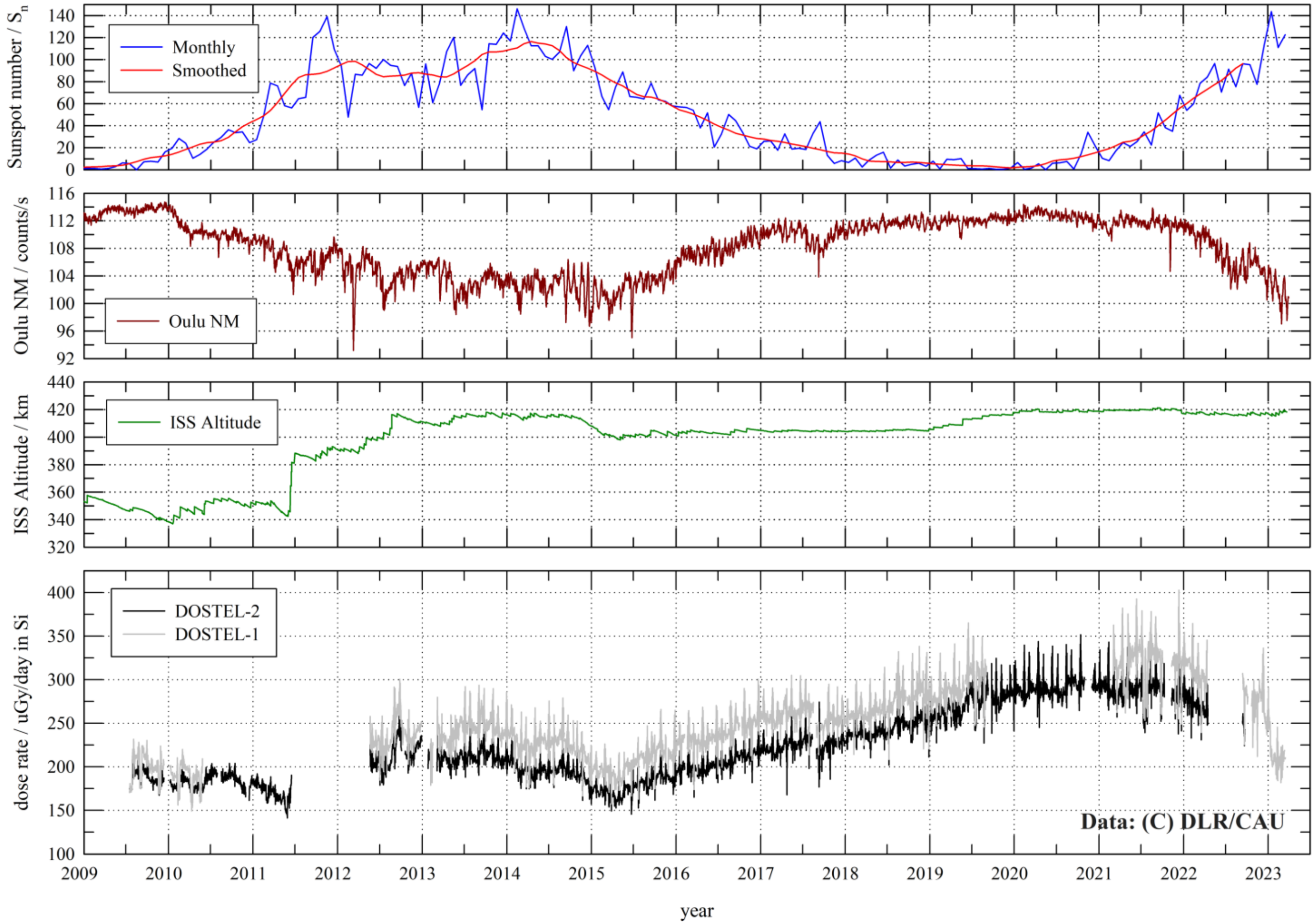




The DOSTEL instruments consist of two Canberra PIPS (Passivated Implanted Planar Silicon) detectors, forming a particle telescope.
The detectors have a thickness of 315 µm and an actice area of 6.93 cm^2.
A distance of 1.5 cm between the two detectors leads to an opening angle of 120°.

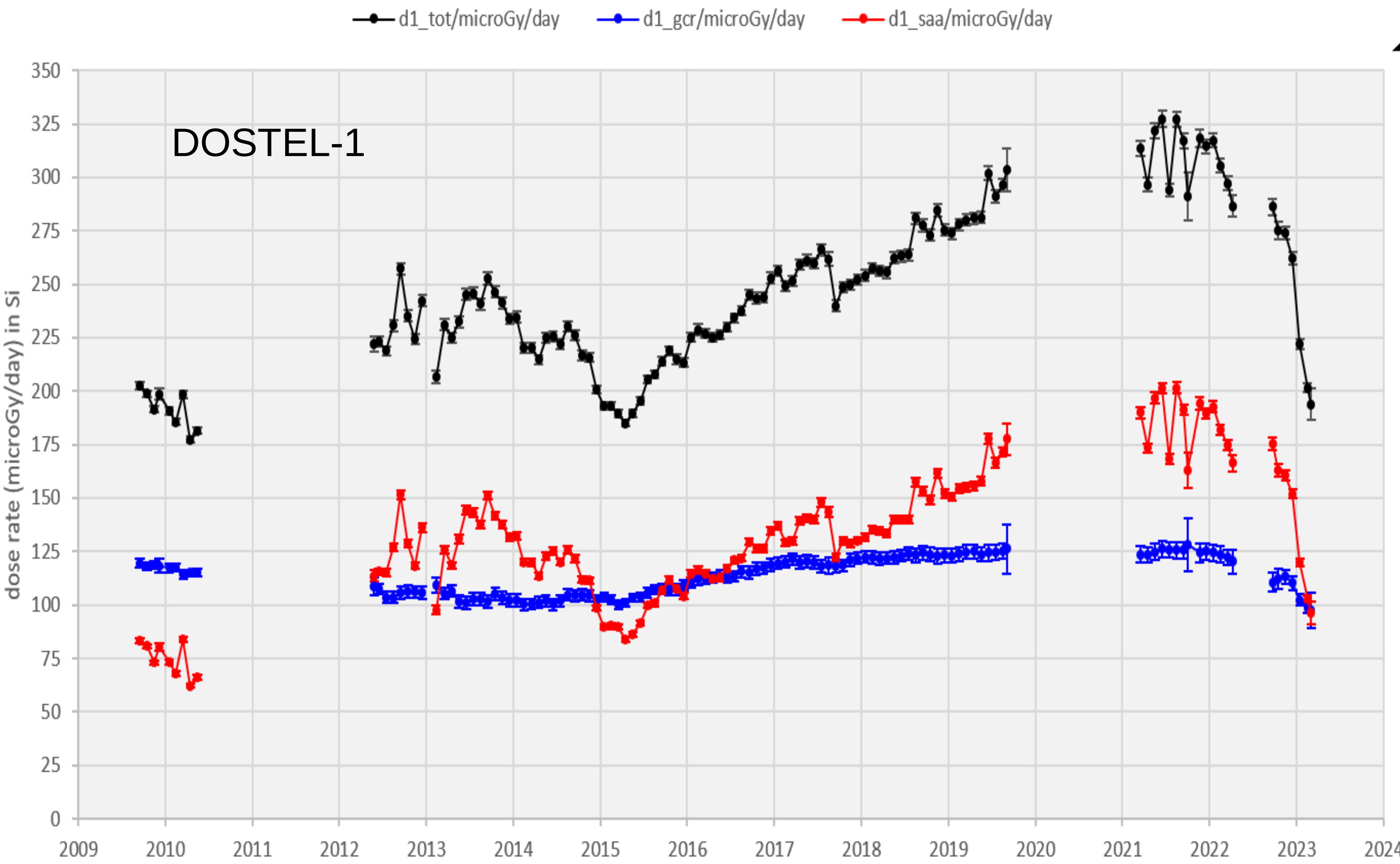
DOSIS-DOSTEL during the solar cycle

- Data since 2009
- More than one (half) cycle (#24)
  - 2 solar minima (2009 und 2020)
  - 1 solar maximum (~2014)



Matthiä, D., Burmeister, S., Przybyla, B., Berger, T. (2023) Active radiation measurements over one solar cycle with two DOSTEL instruments in the Columbus laboratory of the International Space Station. *Life Sciences in Space Research* https://doi.org/10.1016/j.lssr.2023.04.002

Absorbed dose rate (µGy/day) in Si



Berger T, Matthiä D, Burmeister S, Zeitlin C, Rios R, Stoffle N, Schwadron NA, Spence HE, Hassler DM, Ehresmann B, Wimmer-Schweingruber RF, (2020) Long term variations of galactic cosmic radiation on board the International Space Station, on the Moon and on the surface of Mars. J. Space Weather Space Clim. 10:34 https://doi.org/10.1051/swsc/2020028

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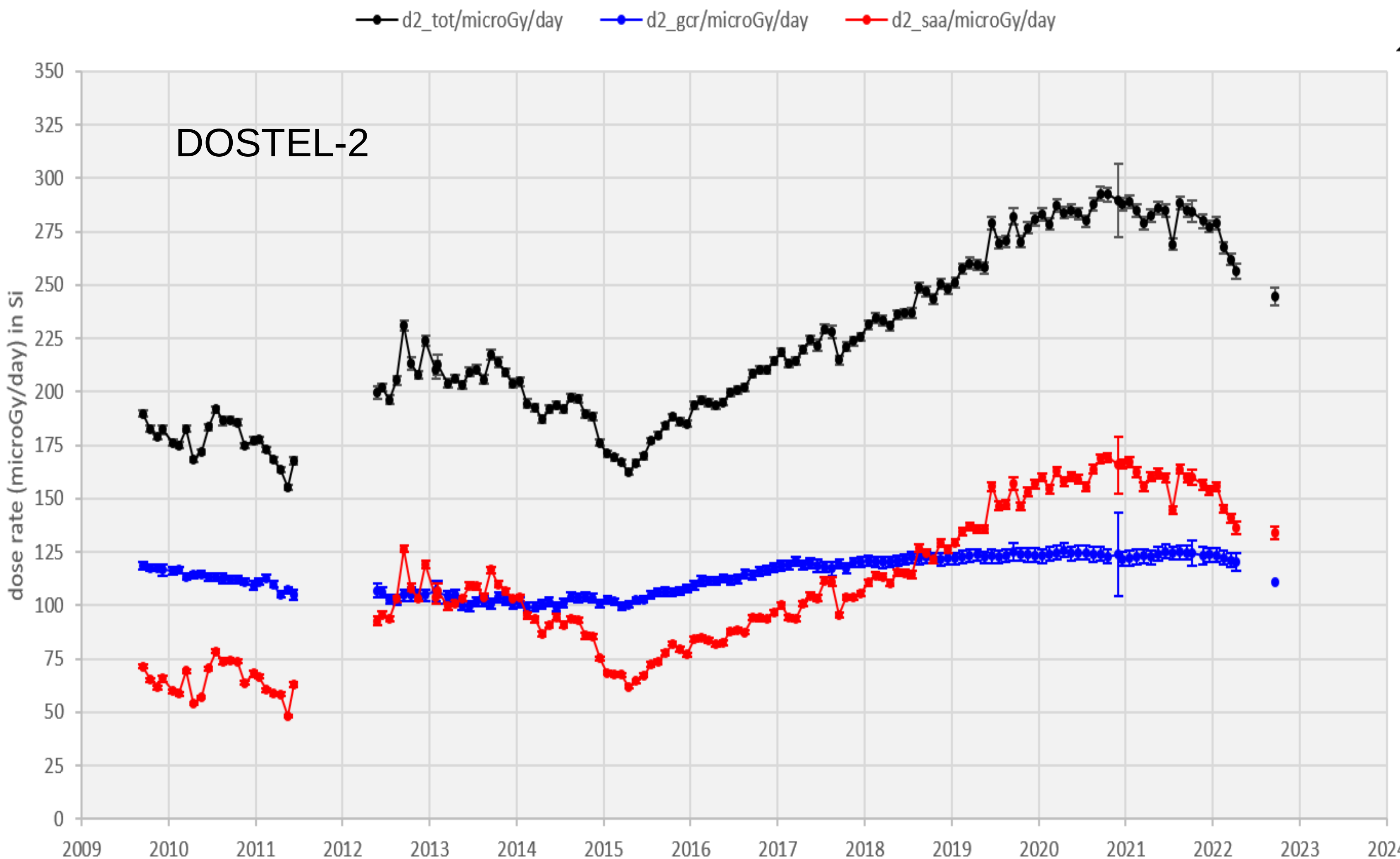

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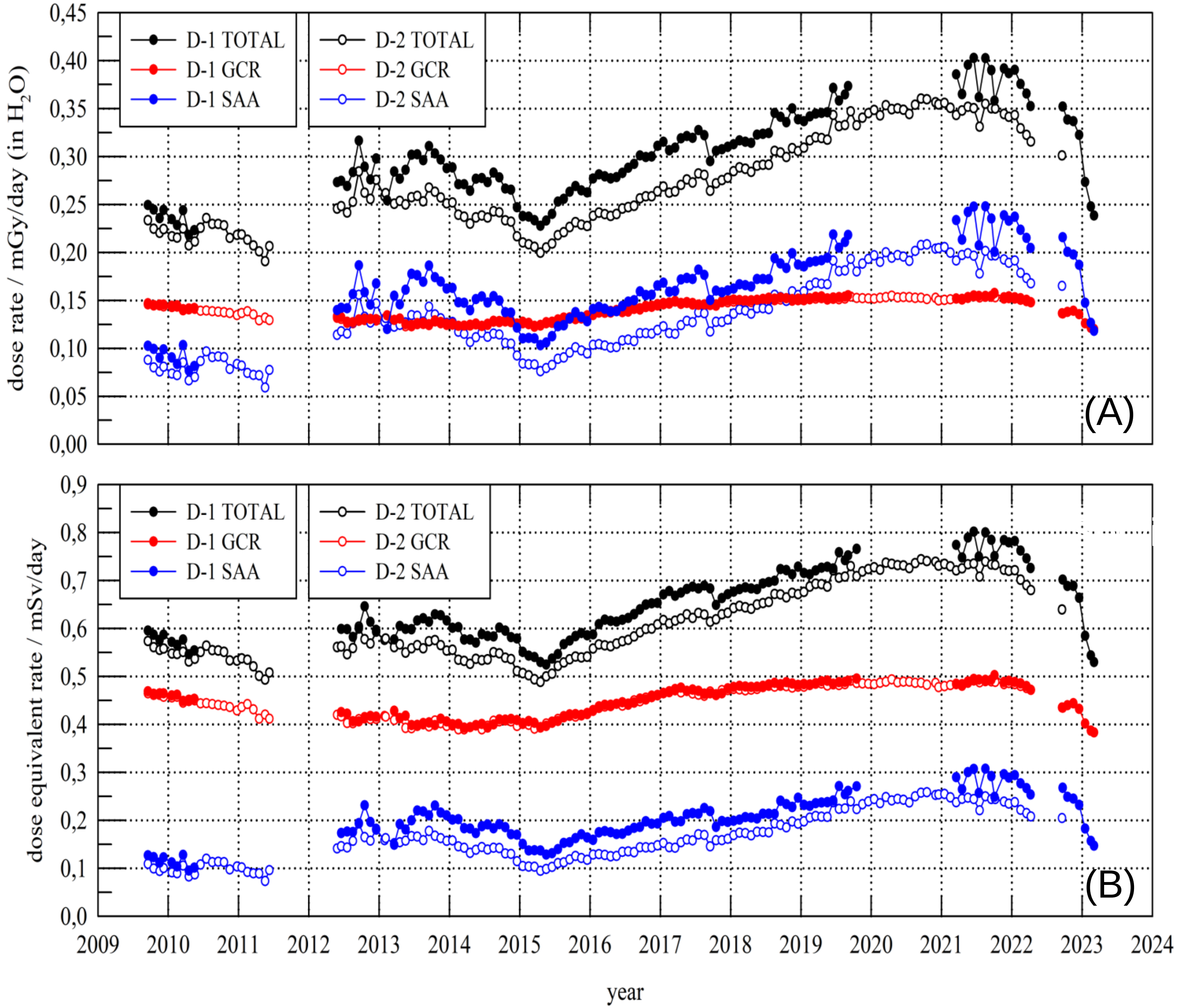
Dose and dose equivalent

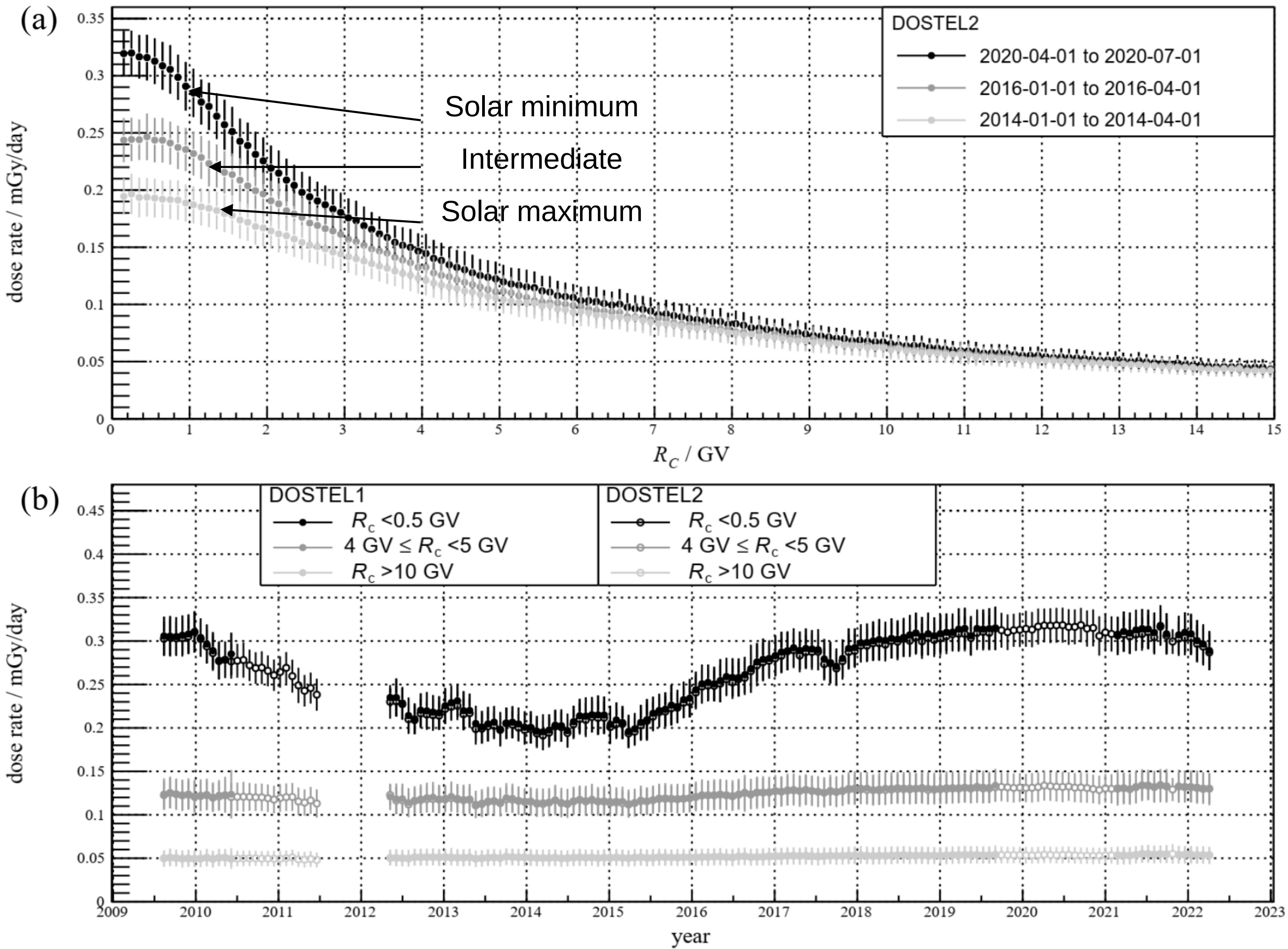


(A) mGy/day

(B) mSv/day

Matthiä, D., Burmeister, S., Przybyla, B., Berger, T. (2023) Active radiation measurements over one solar cycle with two DOSTEL instruments in the Columbus laboratory of the International Space Station. *Life Sciences in Space Research* https://doi.org/10.1016/j.lssr.2023.04.002

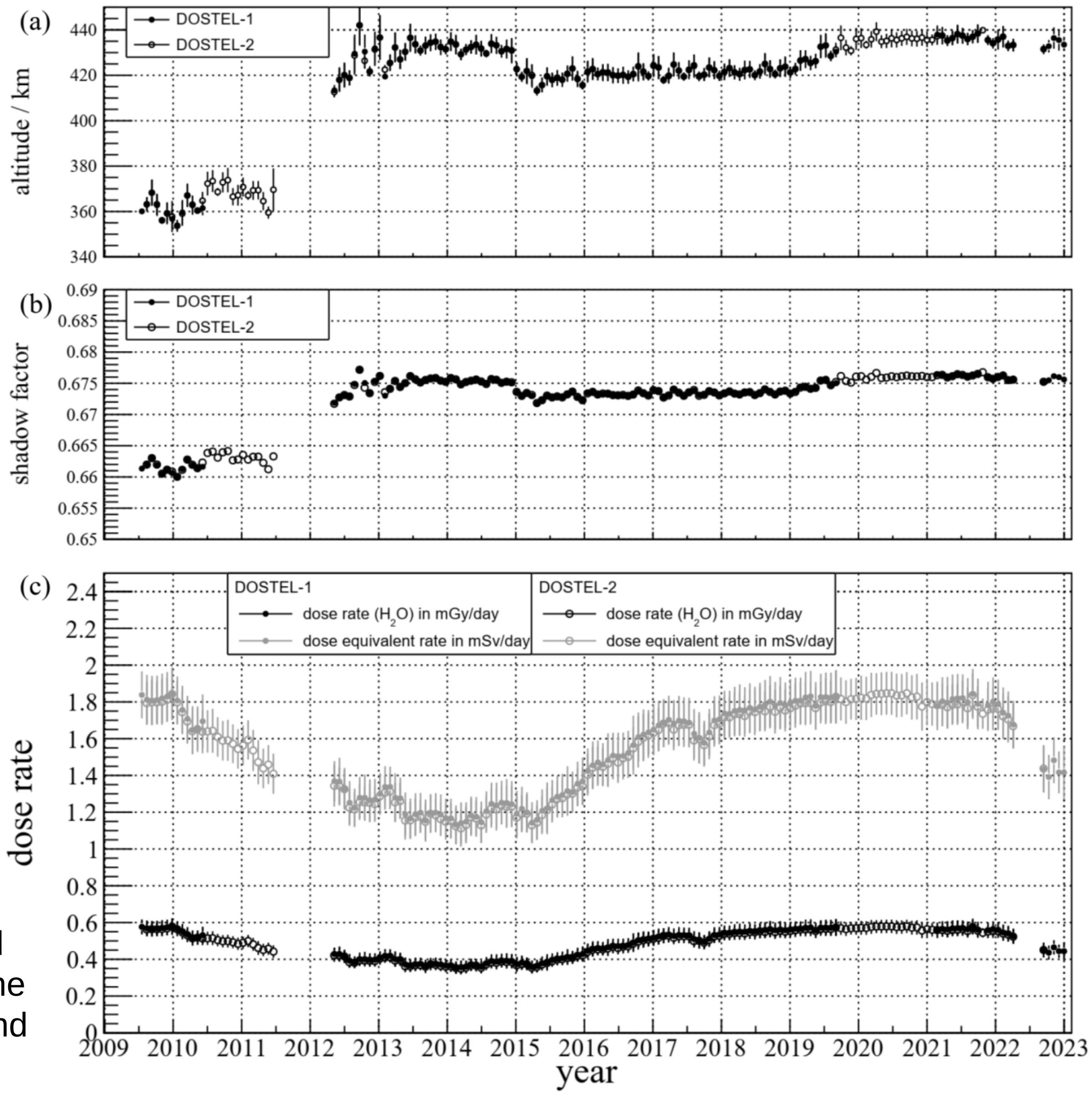
Cutoff (R_C) dependence of the dose rate



Extrapolation to Interplanetary Space

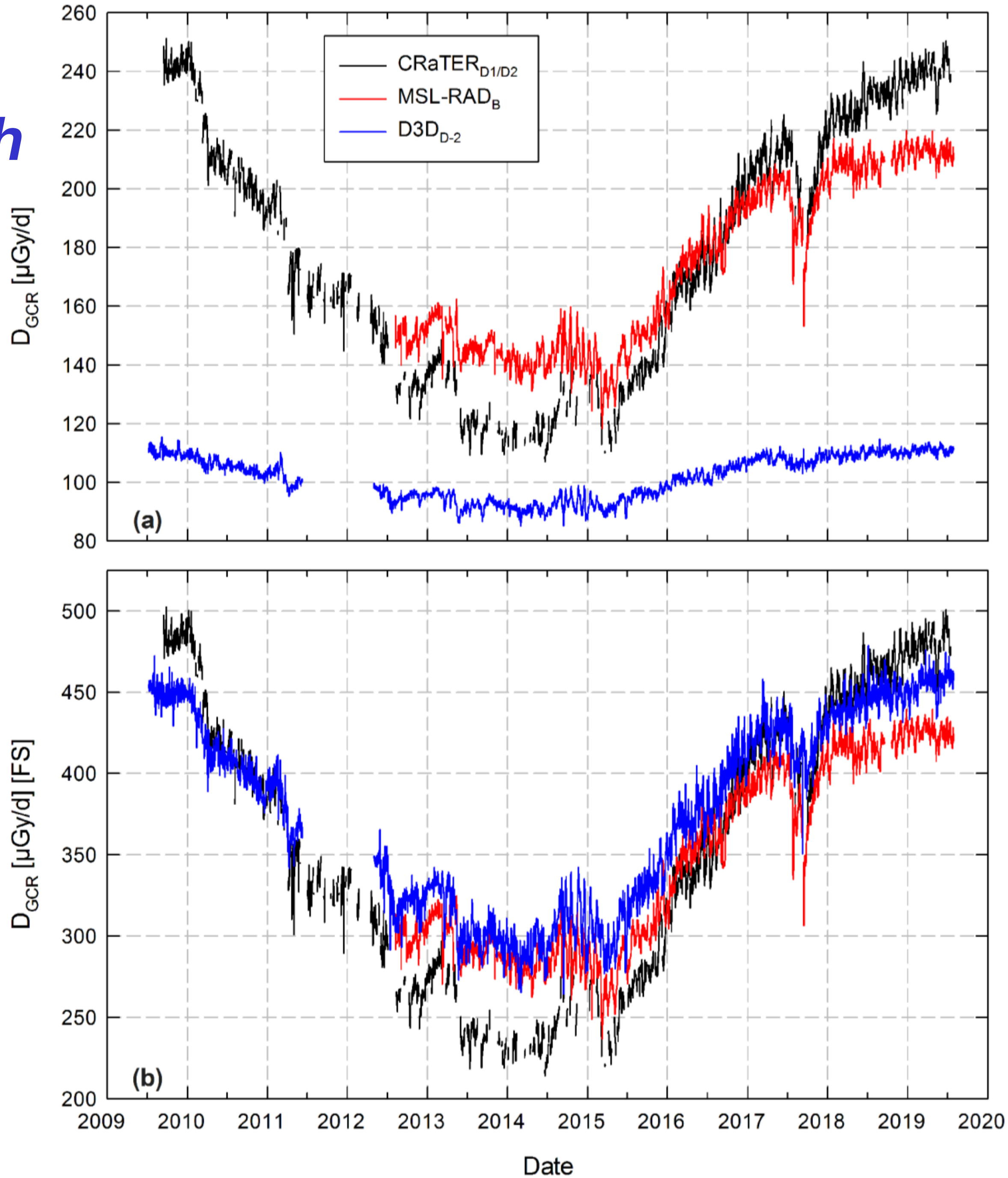
- Calculation of mean altitude
- Calculation of shadowing factor s
- Si dose to dose in H_2O: 1.23
- $d_{H2O}^{interplanetary} = 1.23 \cdot d_{Si}^{ISS}$
- $h = Q \cdot d$
  quality factor 3.3 (*Kollhoff 2015*, R_C=0-5GV)
- 350µGy/d (2014-2015) to 570 and 580 µGy/d (2009/2020)
- 1.2 mSv – 1.9 mSv

Work done by Daniel Matthiä



27-day averages of the altitude (a) and corresponding shadow factors (b) and the resulting estimated dose rate in water and dose equivalent rate in **free space** (c).

Comparison with measurements



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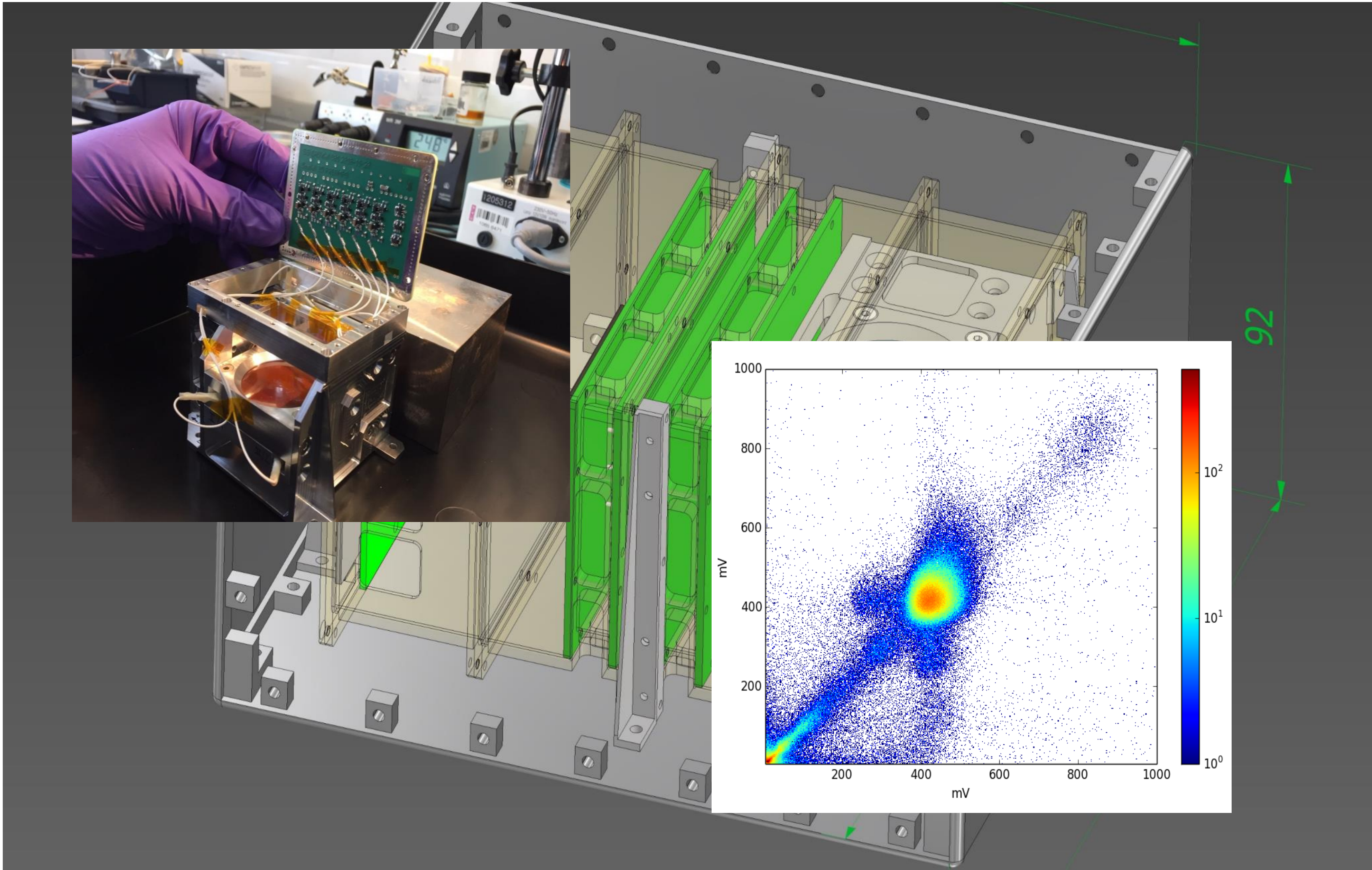
Conclusions

- monthly und orbital mean dose rate (H_2O):
  SAA: 60 µGy/d - 250 µGy/d, 80 µSv/d – 300 µSv/d
  GCR: 120 µGy/d – 160 µGy/d, 380 µSv/d – 490 µSv/d

- Dose rate estimation for interplanetary space (based on R_c<0.5GV measurements and correction for shadowing effect by earth):
  - 350 µGy/d (2014-2015) to 570 and 580 µGy/d (2009/2020)
  - 1.2 mSv/d to 1.9 mSv/d

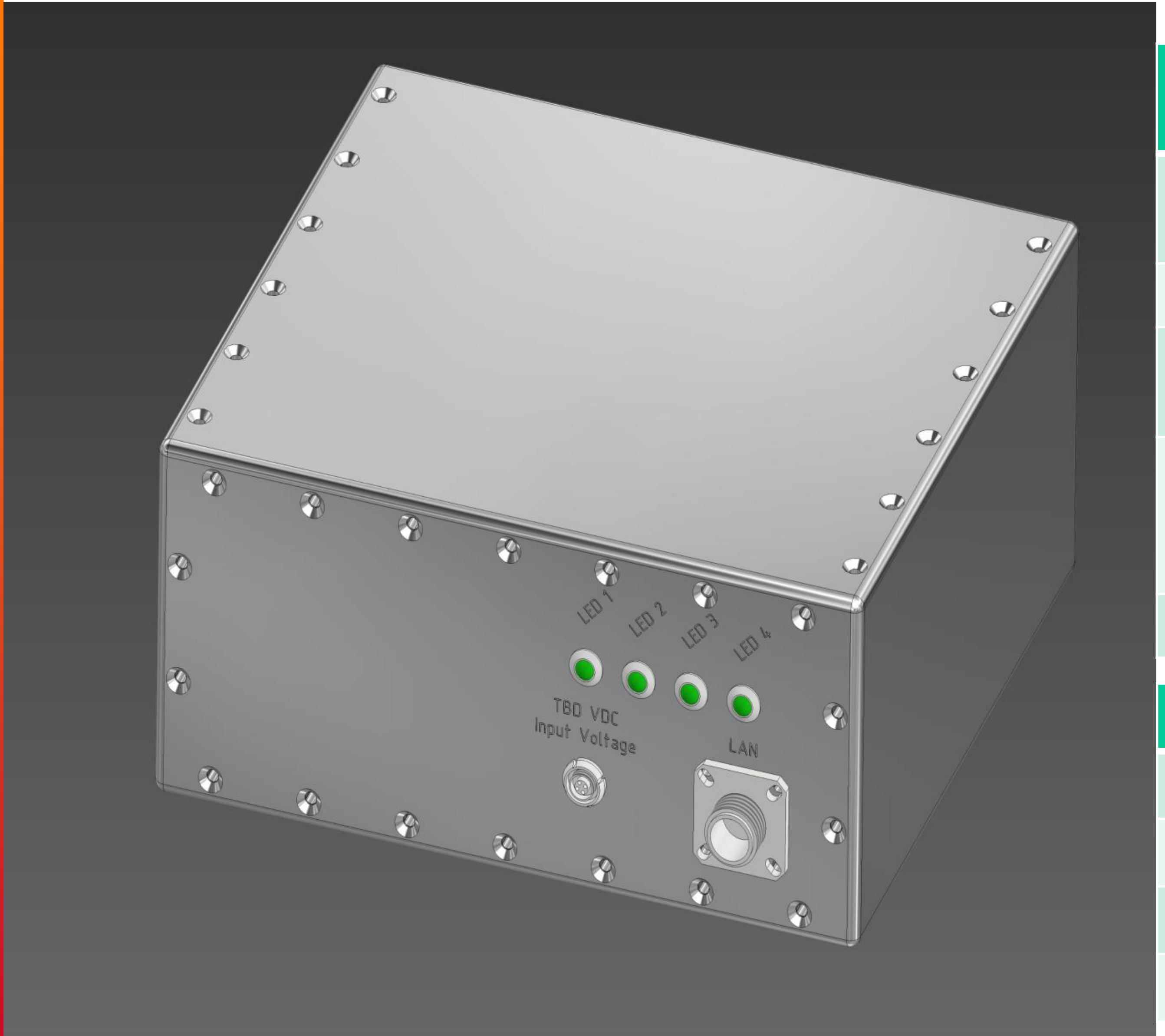
  - models, solar minimum:
    - Without neutrons: ~ 560 µGy/d or 1.3 mSv/d
    - Including neutrons: ~ 600 µGy/d or 1.9 mSv/d

Future Plan: DOSTEL 3D



DOSIS 3D: DOSTEL 3D

Concept design: a new DOSTEL 3D instrument



DOSTEL 3D	
Dimension	180 x 92 x 226 mm^3
Mass	~1.7 kg
Power input	16V – 28V
Power consumption	~6-10W
Data	Ethernet

DOSTEL 3D	
LED 1	POWER
LED 2	DOSTEL X Status
LED 3	DOSTEL Y Status
LED 4	DOSTEL Z Status

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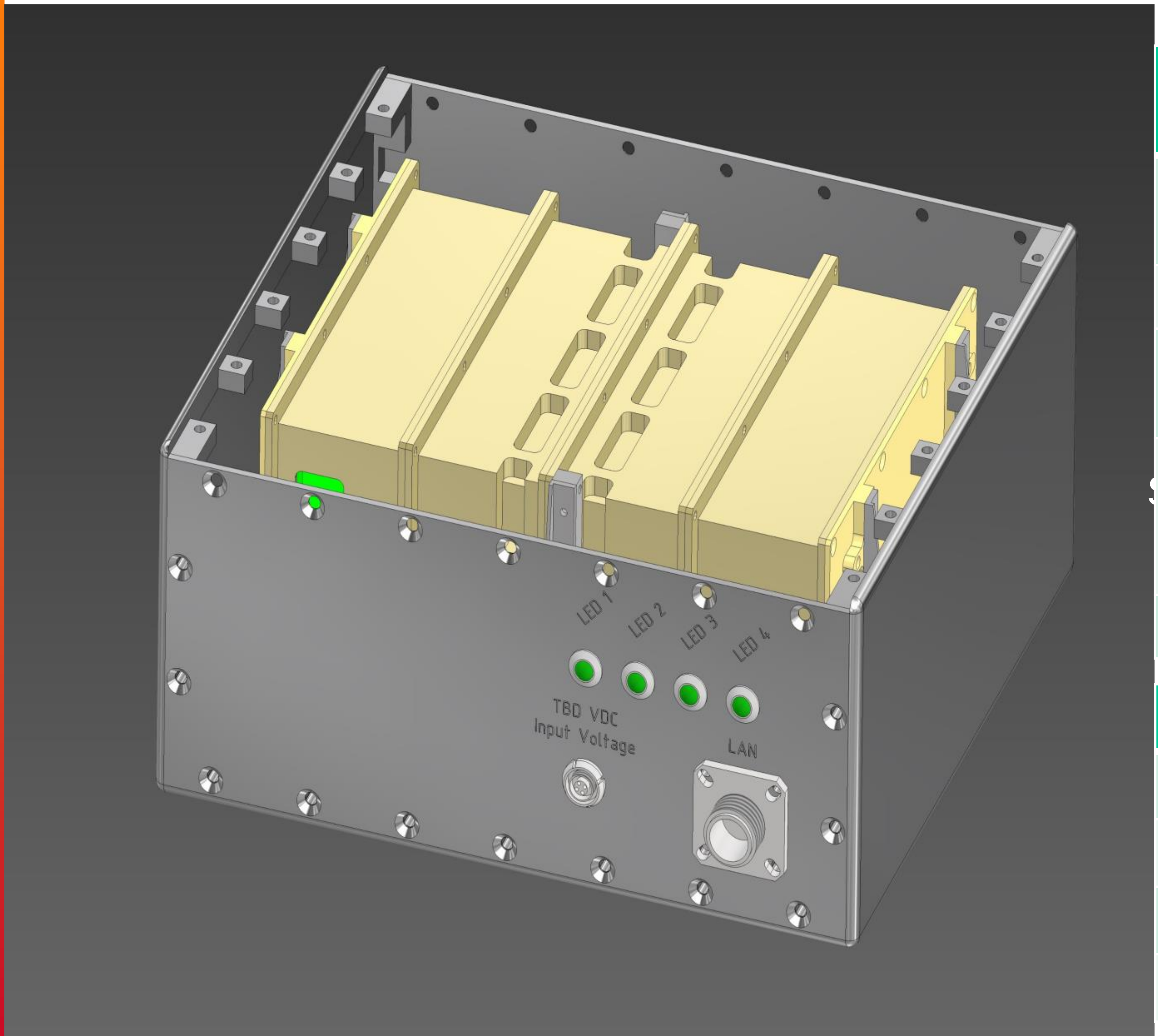

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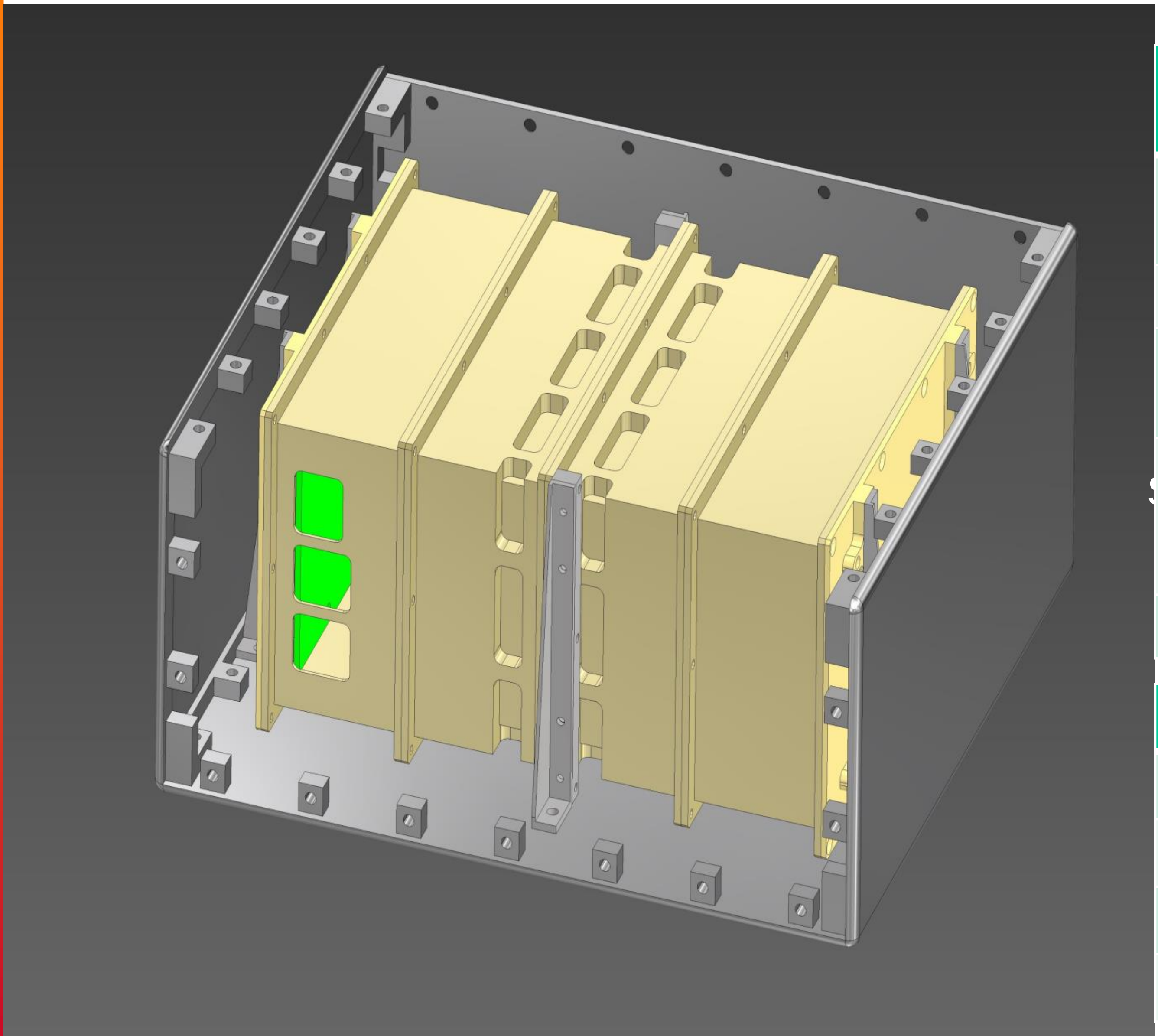

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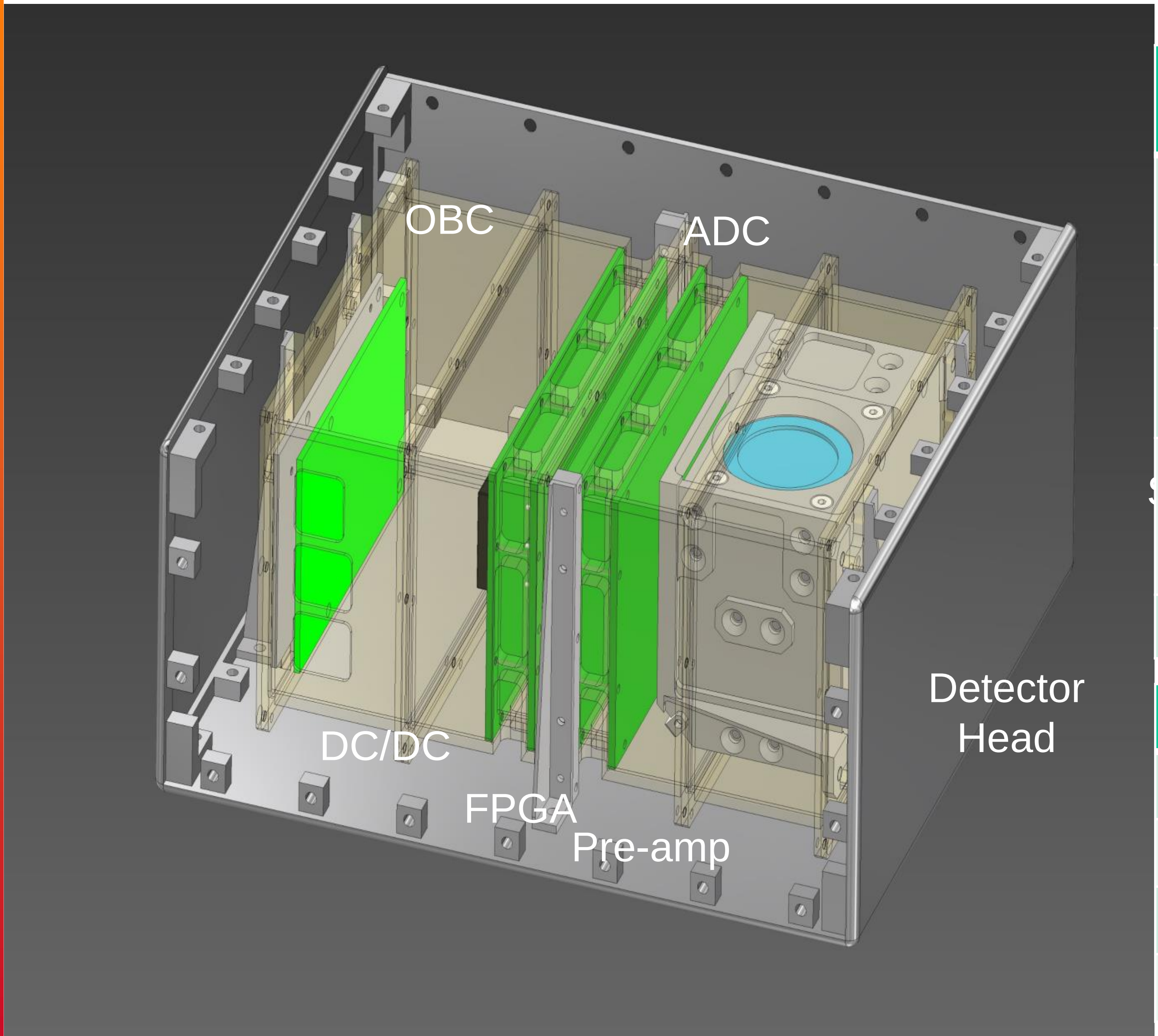

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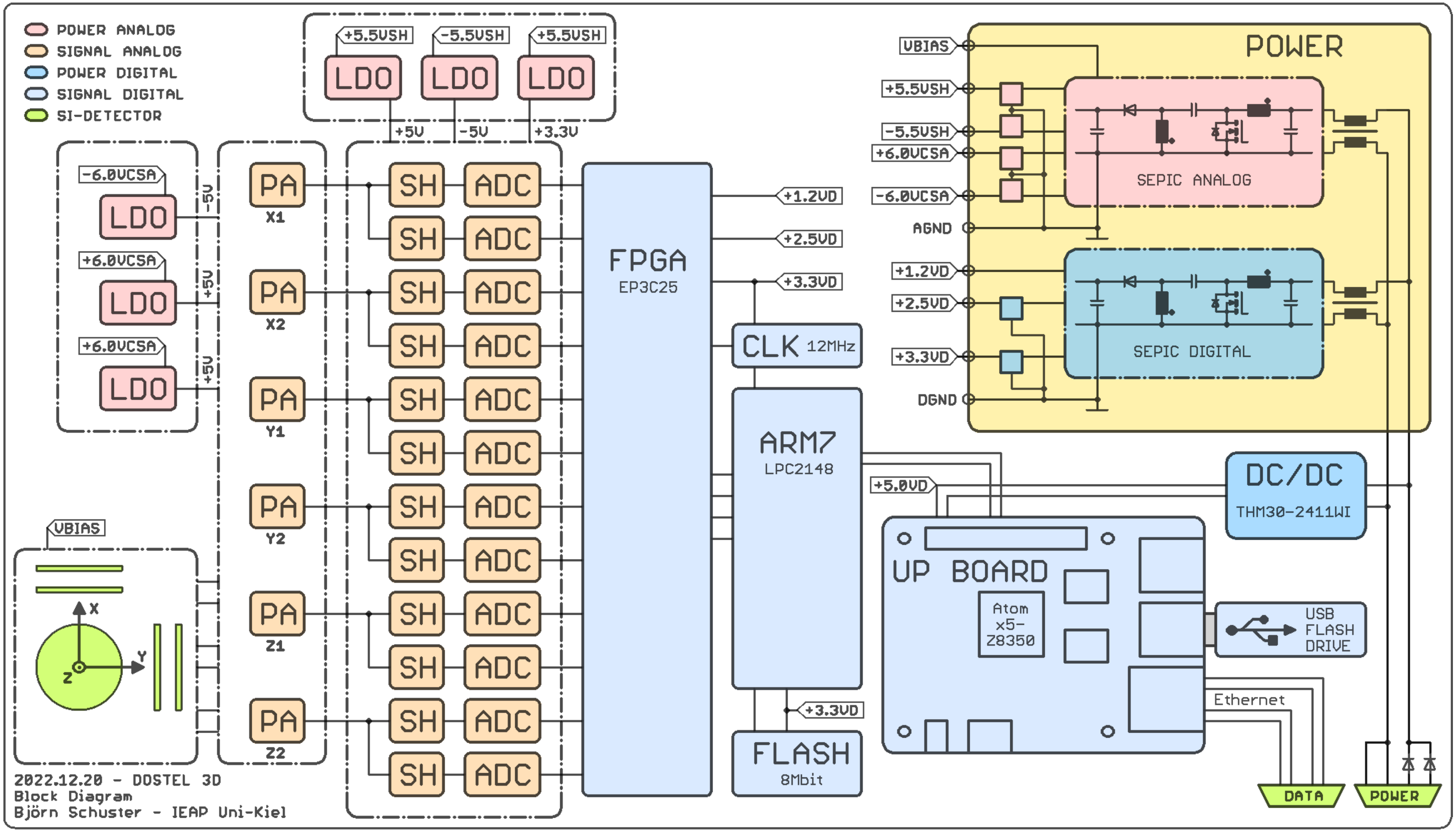
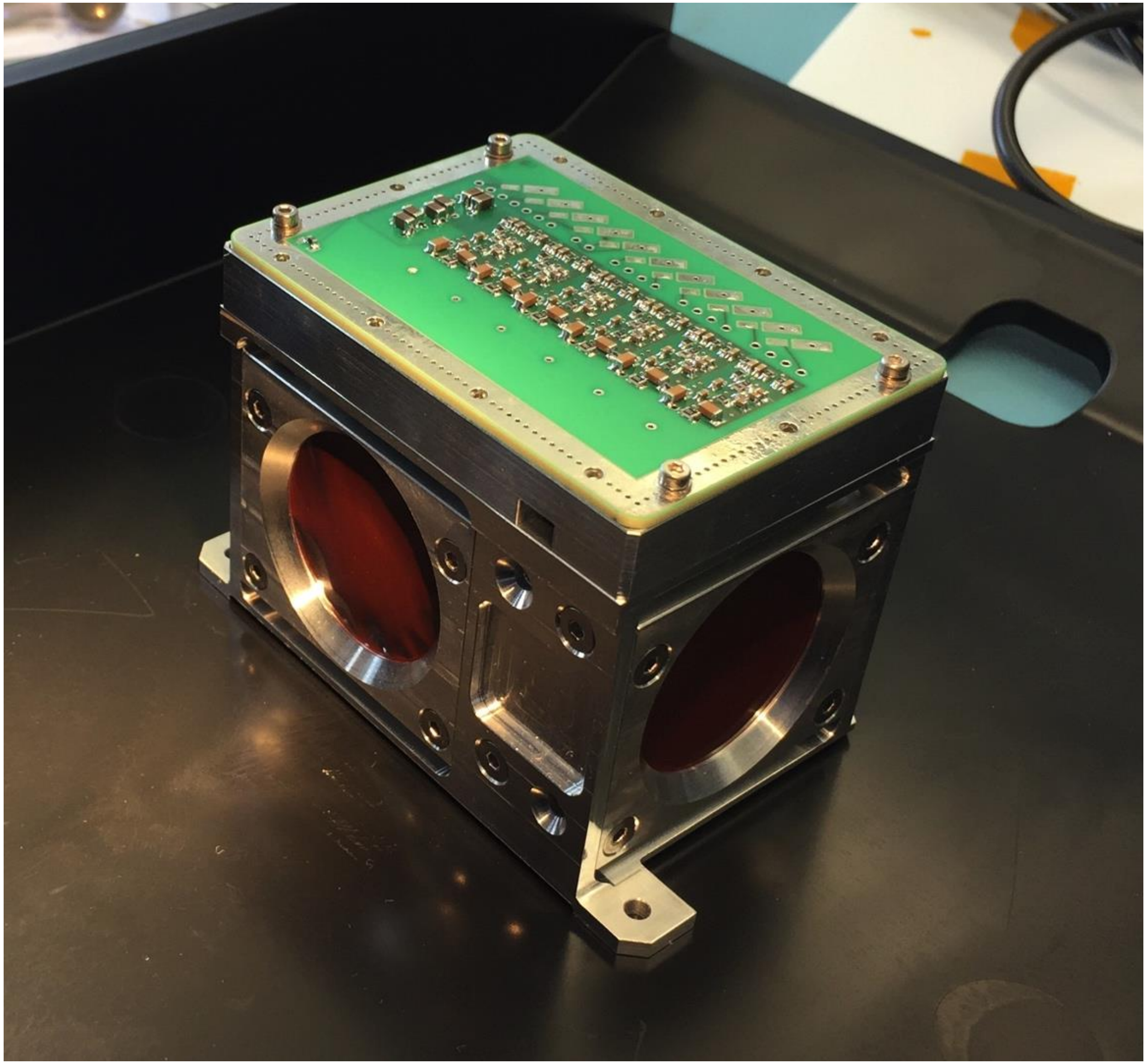
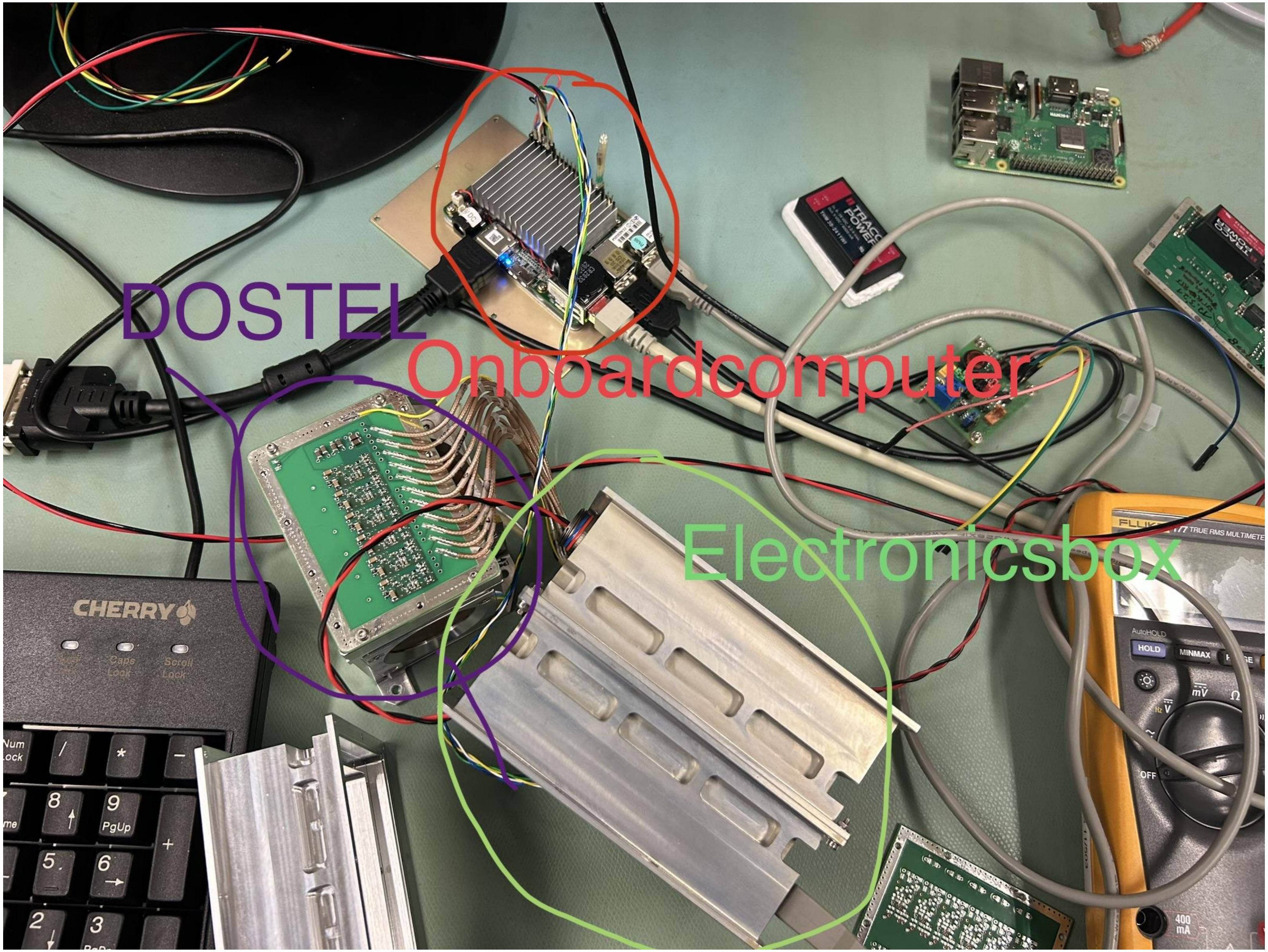
DOSTEL3D Electronics



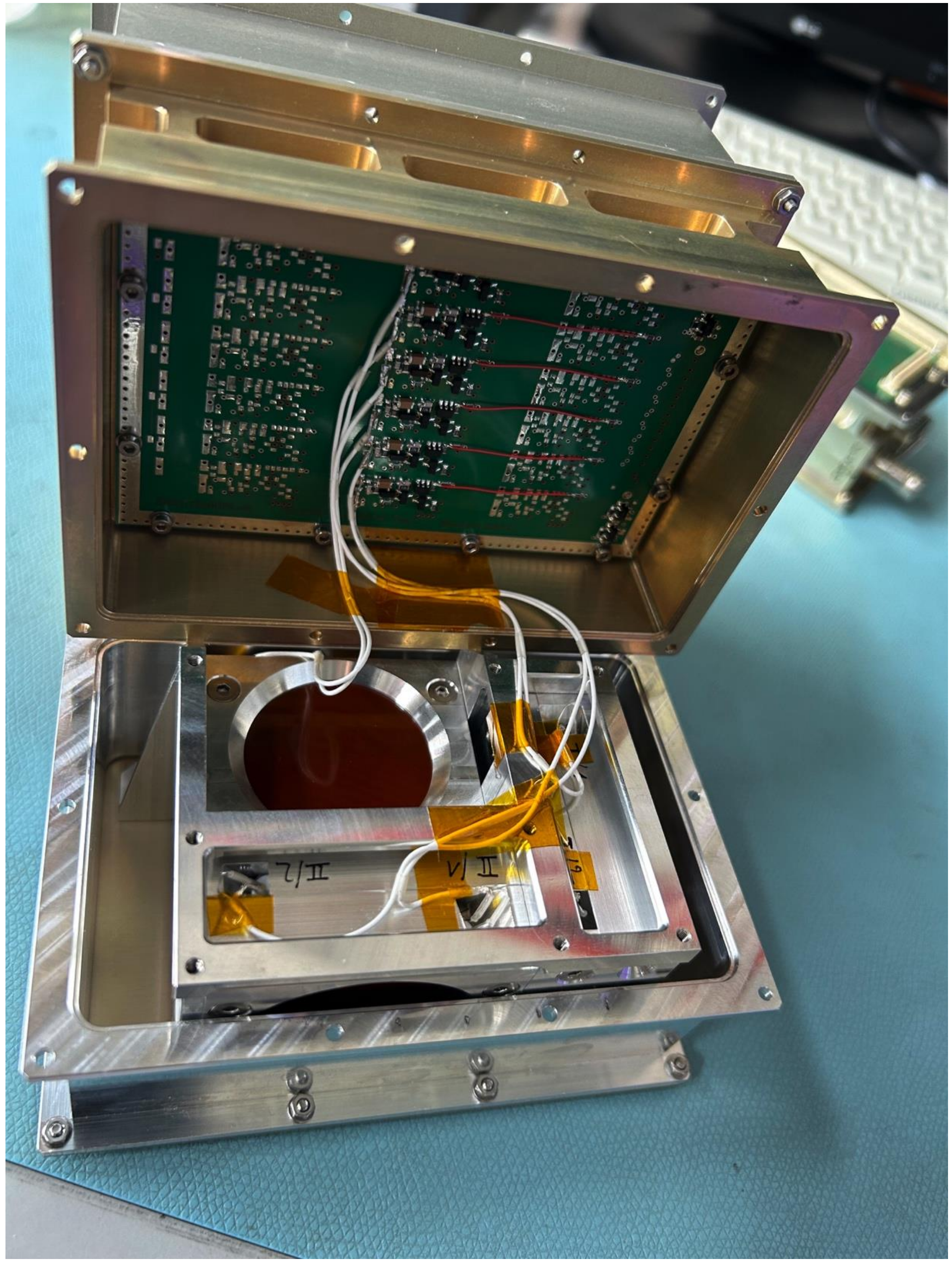
DOSTEL3D



DOSTEL3D



DOSTEL3D



26th WRMISS, 5 – 7 September 2023, Rome, Italy

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Acknowledgement

- The CAU work on DOSIS/DOSIS3D has been supported under grants 50WB0826, 50WB1026, 50WB1232, 50WB1533 und 50WB1817 by Federal Ministry of Economics and Technology

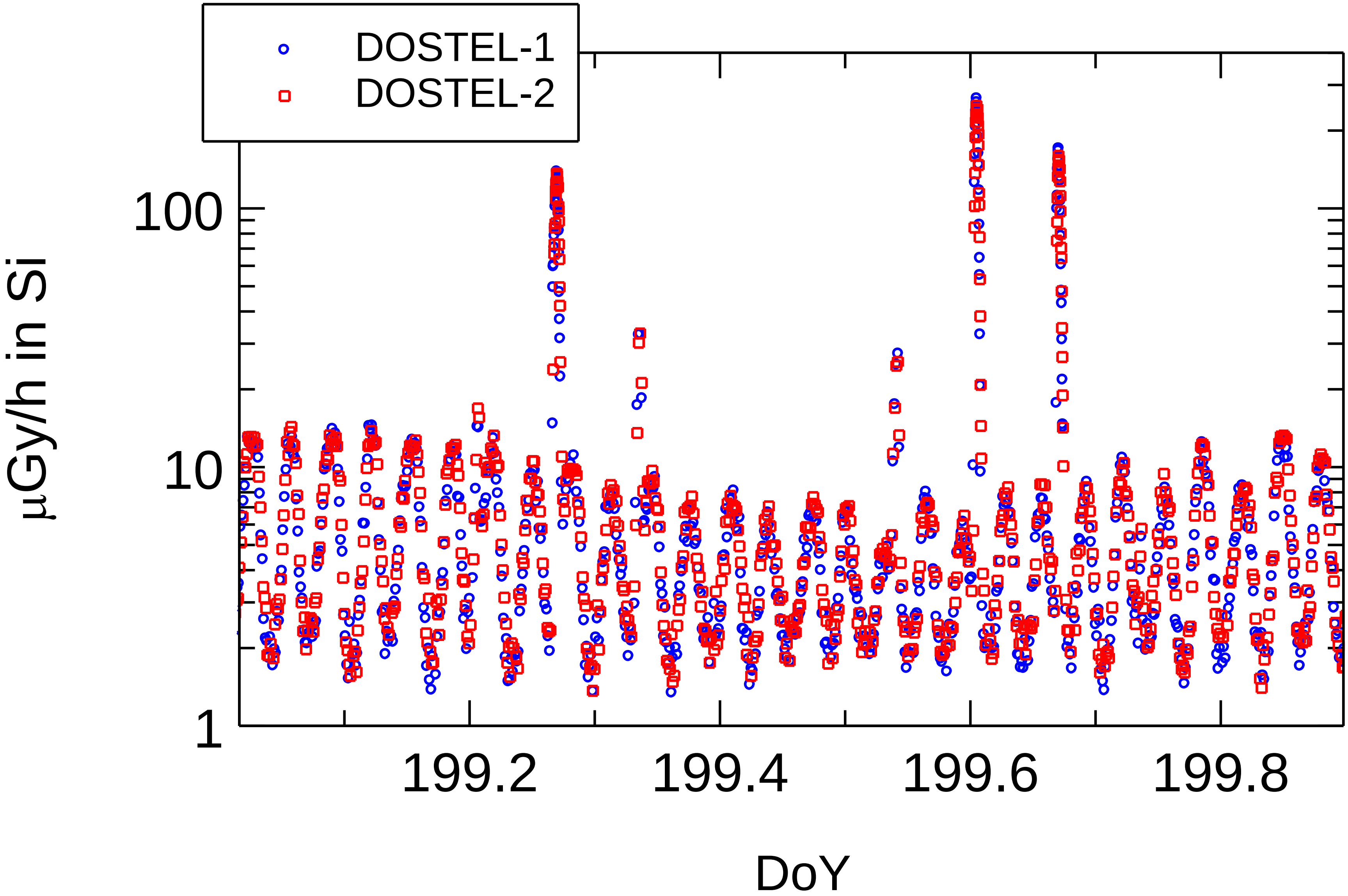
Supported by:

Federal Ministry of Economics and Technology

on the basis of a decision by the German Bundestag

- Thanks for patience and attention!

Backup slides…


DOSTEL-1
DOSTEL-2
µGy/h in Si
100
10
1
199.2
199.4
199.6
199.8
DoY

Unterstützung biologischer Experimente

Experiment	On-orbit	Report	Submission
Endothelial Cells	4.-11. September 2015	DOSIS-3D-DLR-REP-BIO-001	01-03-2016
Extremophiles	May – August 2017	DLR-ME-SBA-DOSIS 3D - BIO-Extremophiles-2017	12-02-2018
ARTHROSPIRA-B	15.12.2017 – 24.01.2018	DLR-ME-SBA-DOSIS 3D - BIO-2018	12-02-2018
BIOROCK	30.7. 2019 - 20.8.2019	DOSIS-3D-DLR-REP-BIOROCK-001	17-10-2019
Rotifer B1	9 – 16 December 2019	DOSIS-3D-DLR-REP-ROTIFER-B1-001	10-03-2020
BioAsteroid	8 to 19 December 2020	DOSIS-3D-DLR-REP-BioAsteroid-001	26-04-2021
Rotifer B2	20th December 2020 - 8th January 2021	DOSIS-3D-DLR-REP-Rotifer B2-001	26-04-2021
CANES	03rd March 2020 - 12th January 2021	DOSIS-3D-DLR-REP-CANES-001	27-04-2021
MOLECULAR MUSCLE 2	05th - 11th June 2021.	DOSIS-3D-DLR-REP-MOLECULAR MUSCLE 2-001	05-07-2021
BIOFILMS	29th August - 30th September 2021	DOSIS-3D-DLR-REP-BIOFILMS-001	11-02-2022
Thermo Mini	06.12.2021 17:18 – 08.12.2021 10:18 22.11.2021 07:50 – 24.11.2021 08:05 15.11.2021 17:37 – 17.11.2021 08:00	DOSIS-3D-DLR-REP-ThermoMini-001	21-02-2022
EVOOS	Crew-4		
Epigenetic Adaptation	Crew-4		

DOSIS/DOSIS3D DOSTEL Dosisleistung (Monatsmittel)

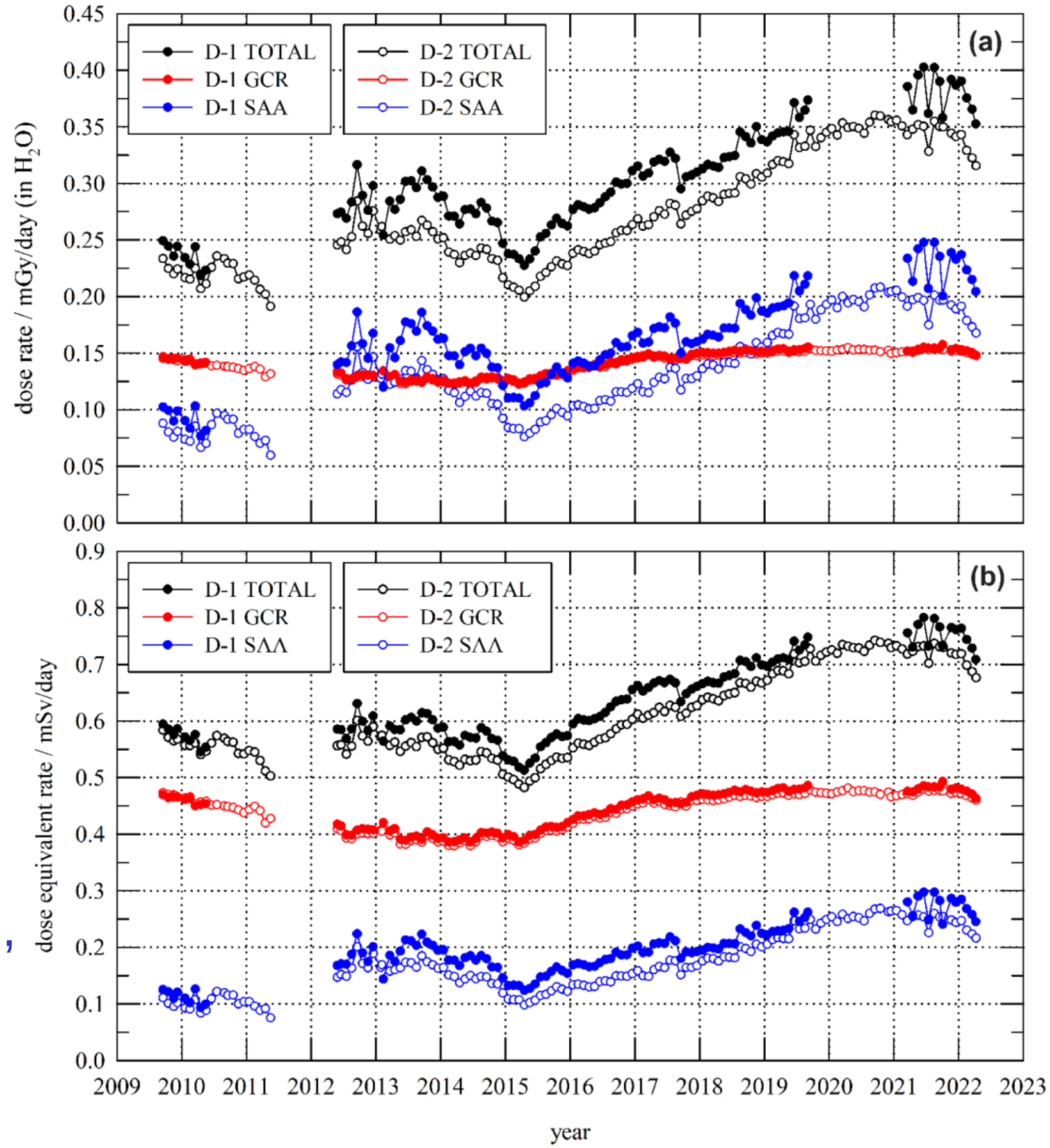
- Dosisleistung sortiert nach SAA/non-SAA (GCR)

- Umrechnungsfaktor Dosis in Silizium zu Dosis in Wasser: 1.23

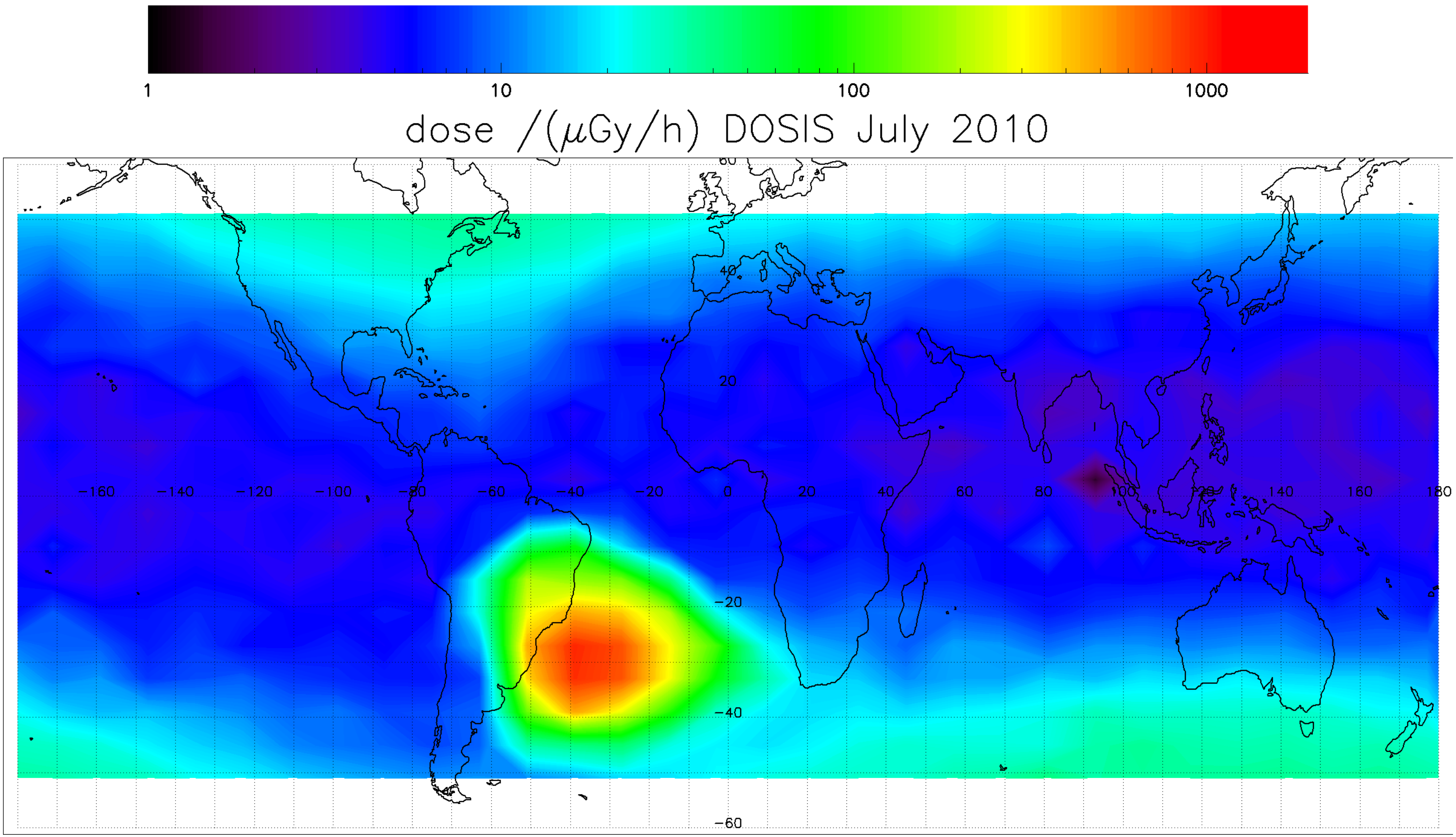
- Q (GCR) = 3.1 – 3.3
- Q (SAA) = 1.2 – 1.3

- SAA: 60 µGy/d - 250 µGy/d, 80 µSv/d – 300 µSv/d

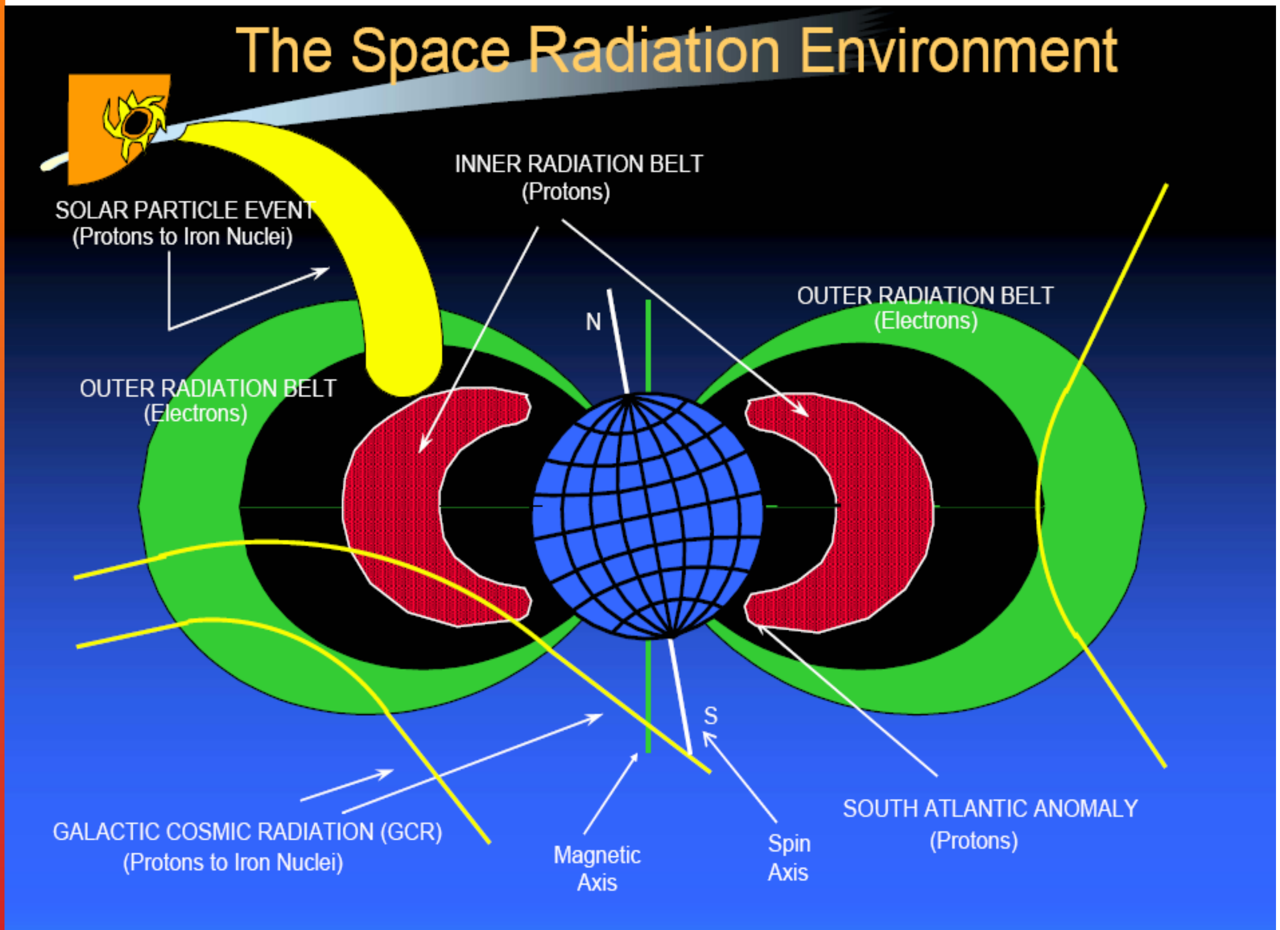
- GCR: 120 µGy/d – 160 µGy/d, 380 µSv/d – 490 µSv/d



DOSIS - DOSTEL



Radiation Environment in Space



Galactic Cosmic Rays (GCR)

- Ions from protons to iron

Trapped Radiation (Van Allen Belts)

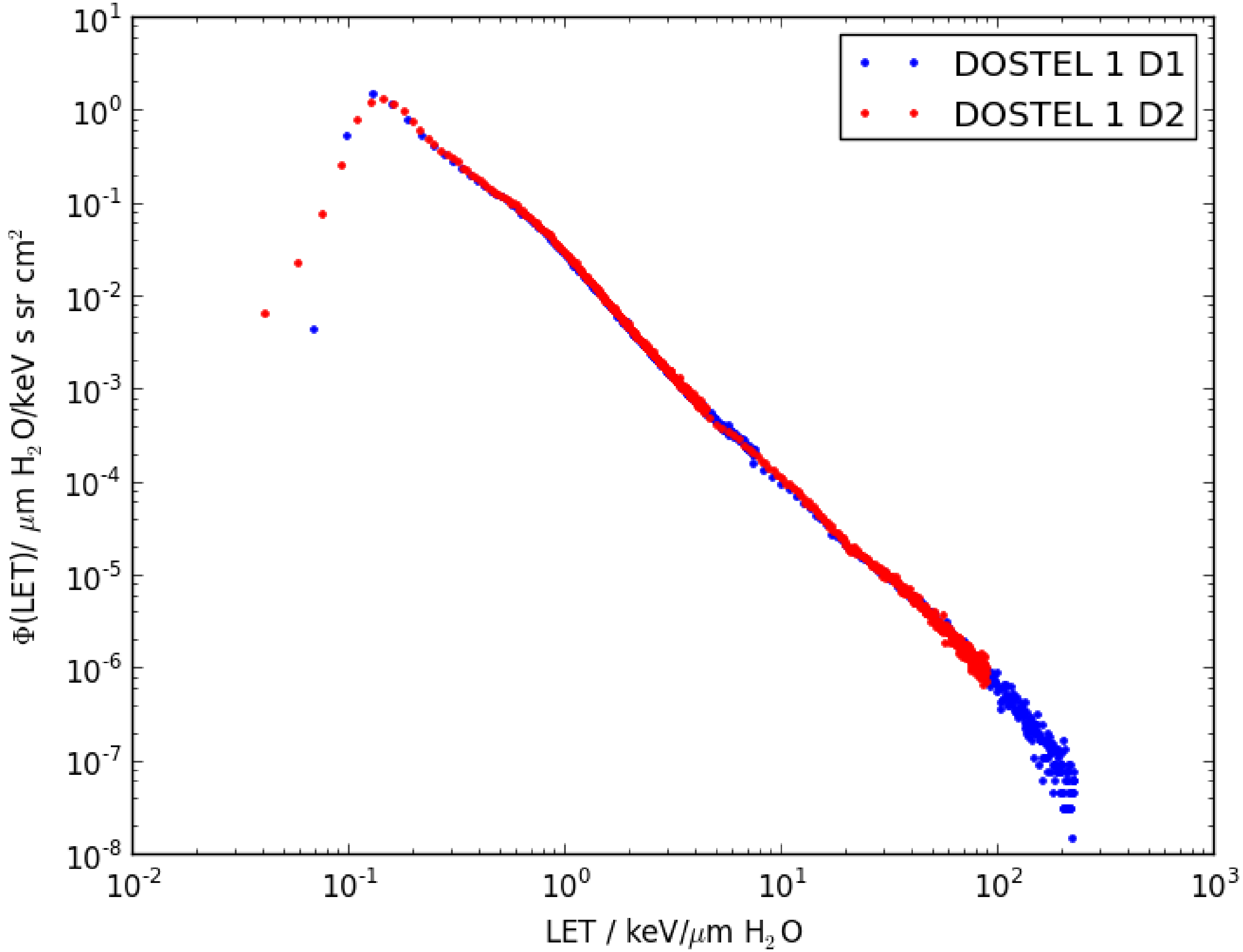
- Low energy protons and electrons

Solar particle events

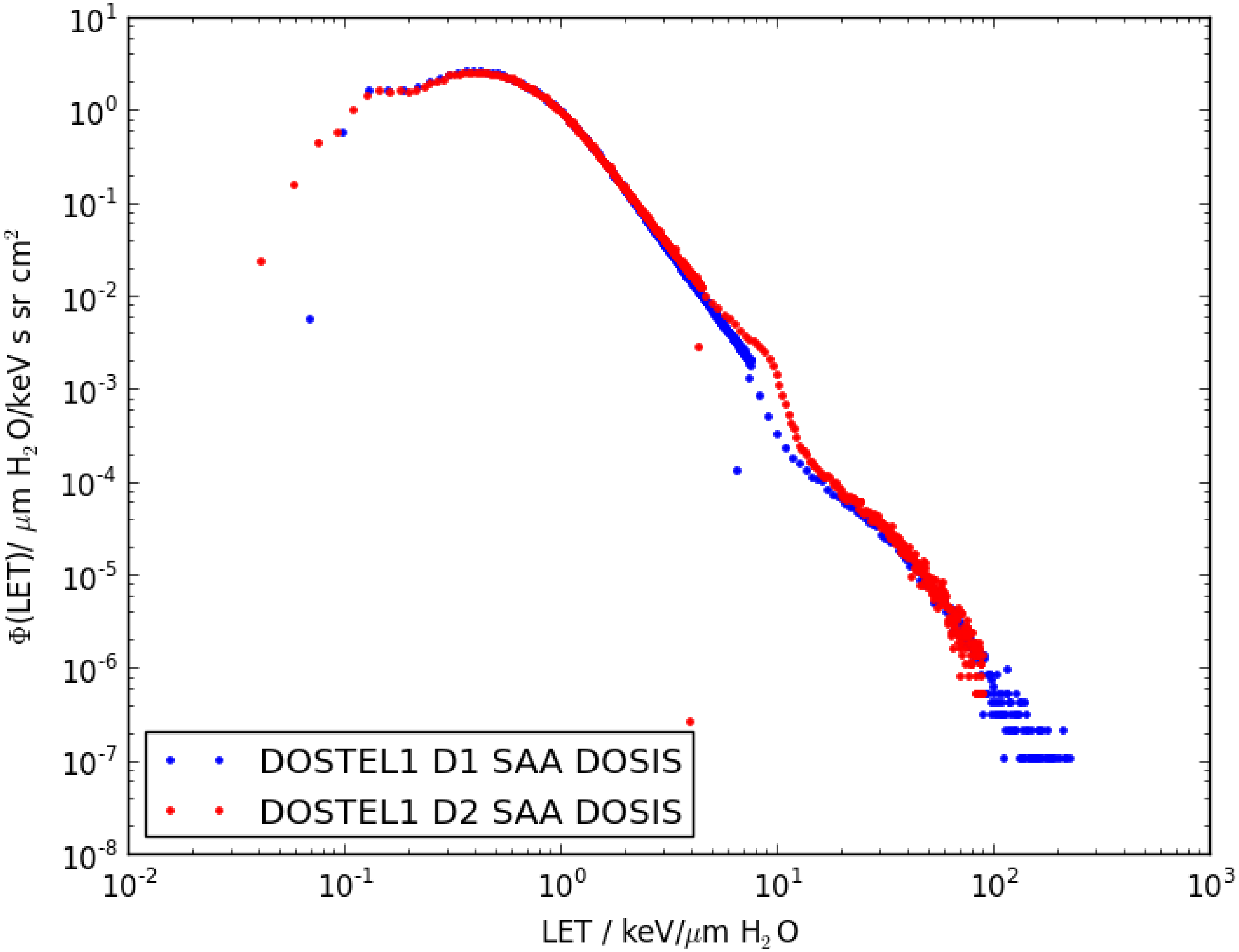
- Protons (in dependence of the solar cycle)

Variation of the radiation load onboard the ISS with altitude, latitude and time

DOSIS GCR LET Spectra DOSTEL-1

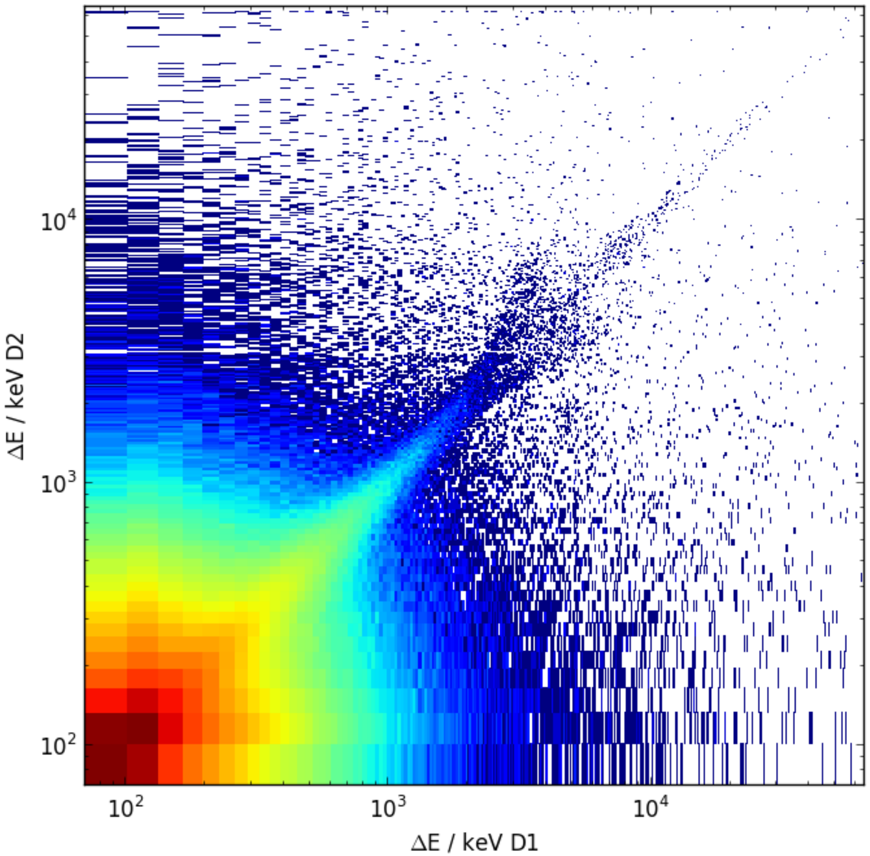


DOSIS SAA LET Spectra DOSTEL-1

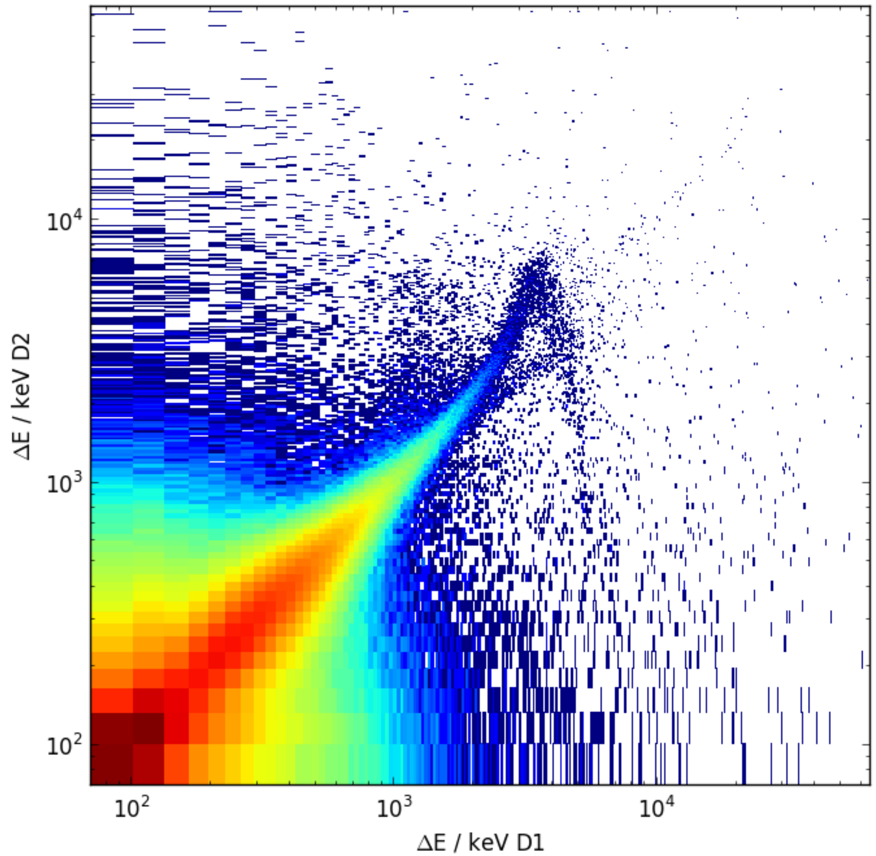


DOSIS 3D Mode 2 Data

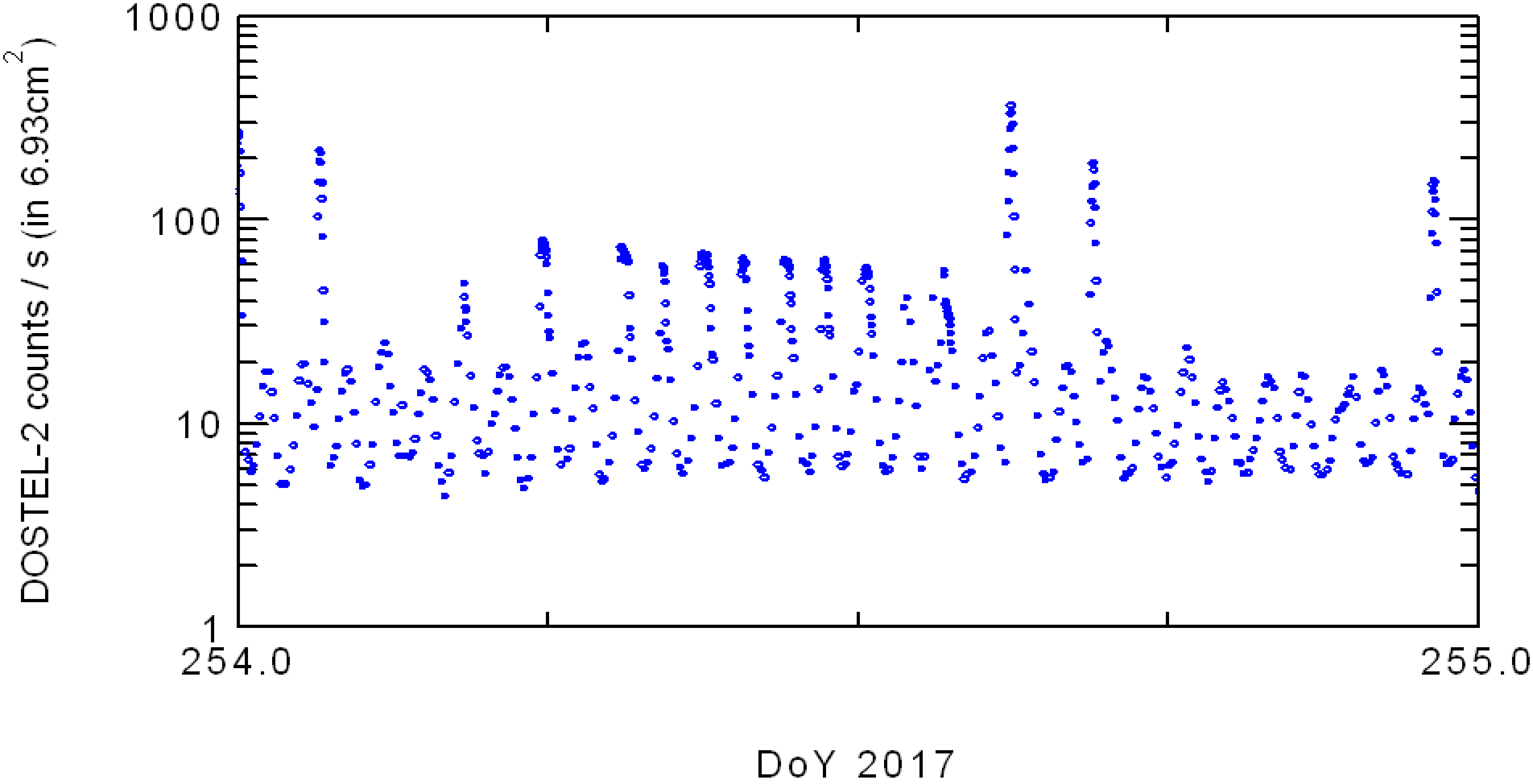
GCR (mainly)



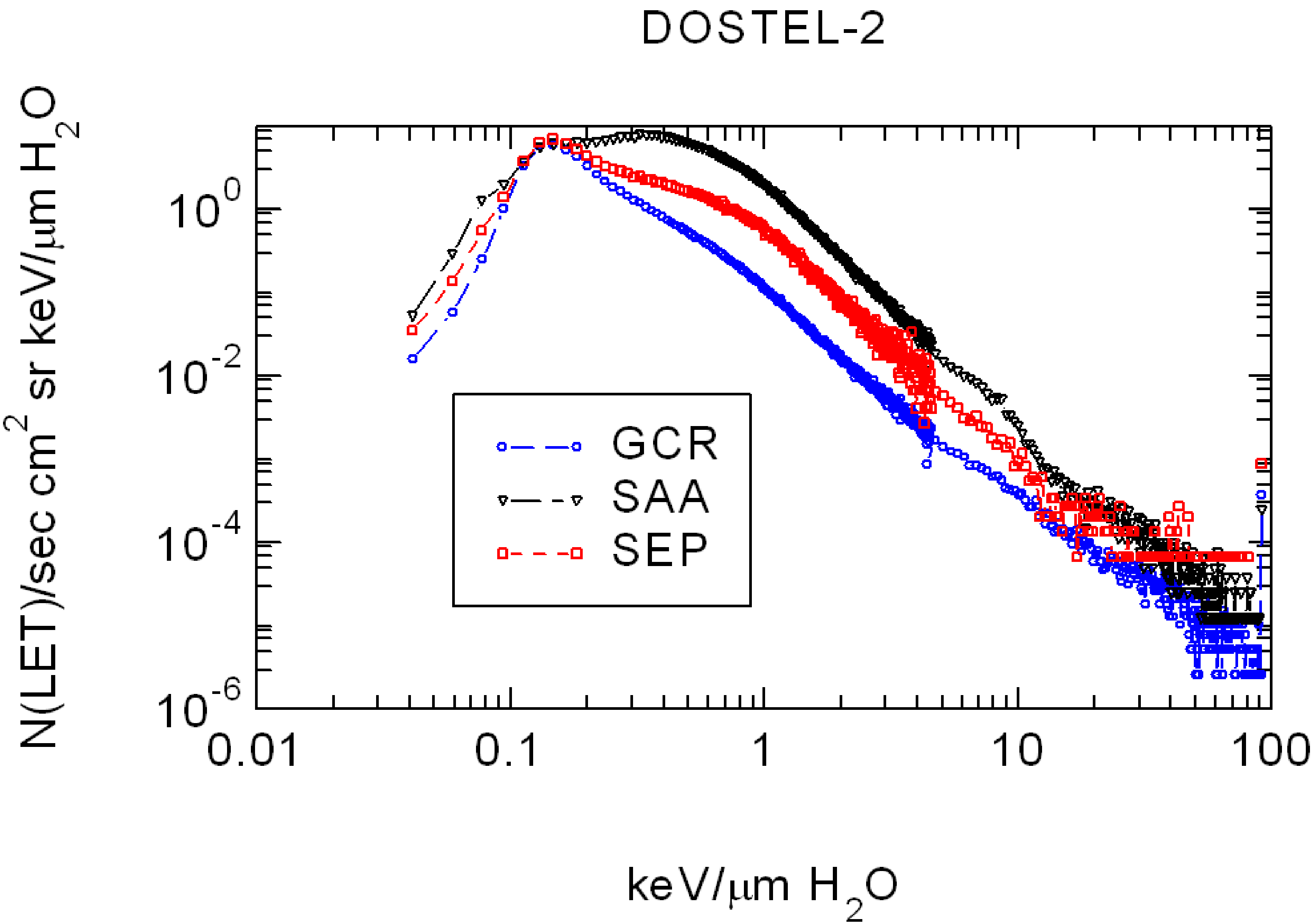
SAA (mainly)



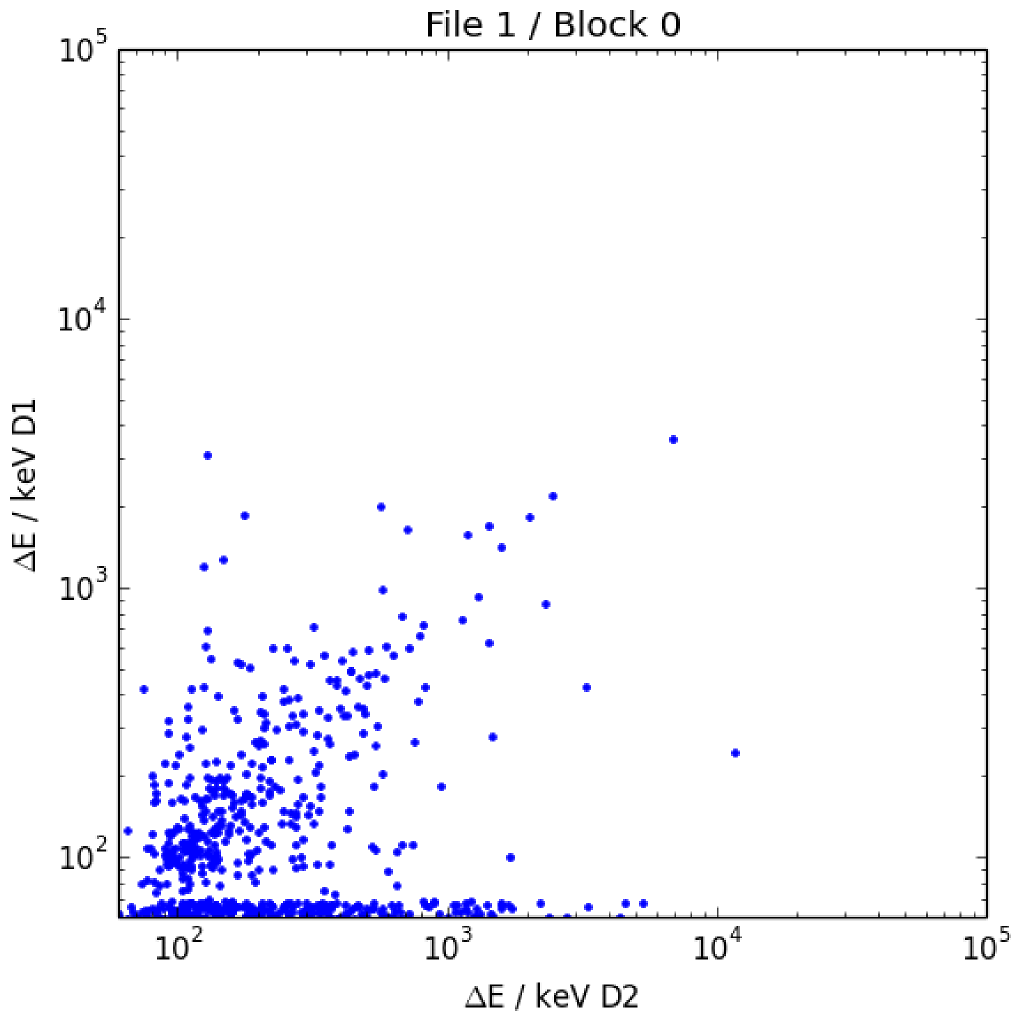
DOSIS 3D Sept 2017 SPE

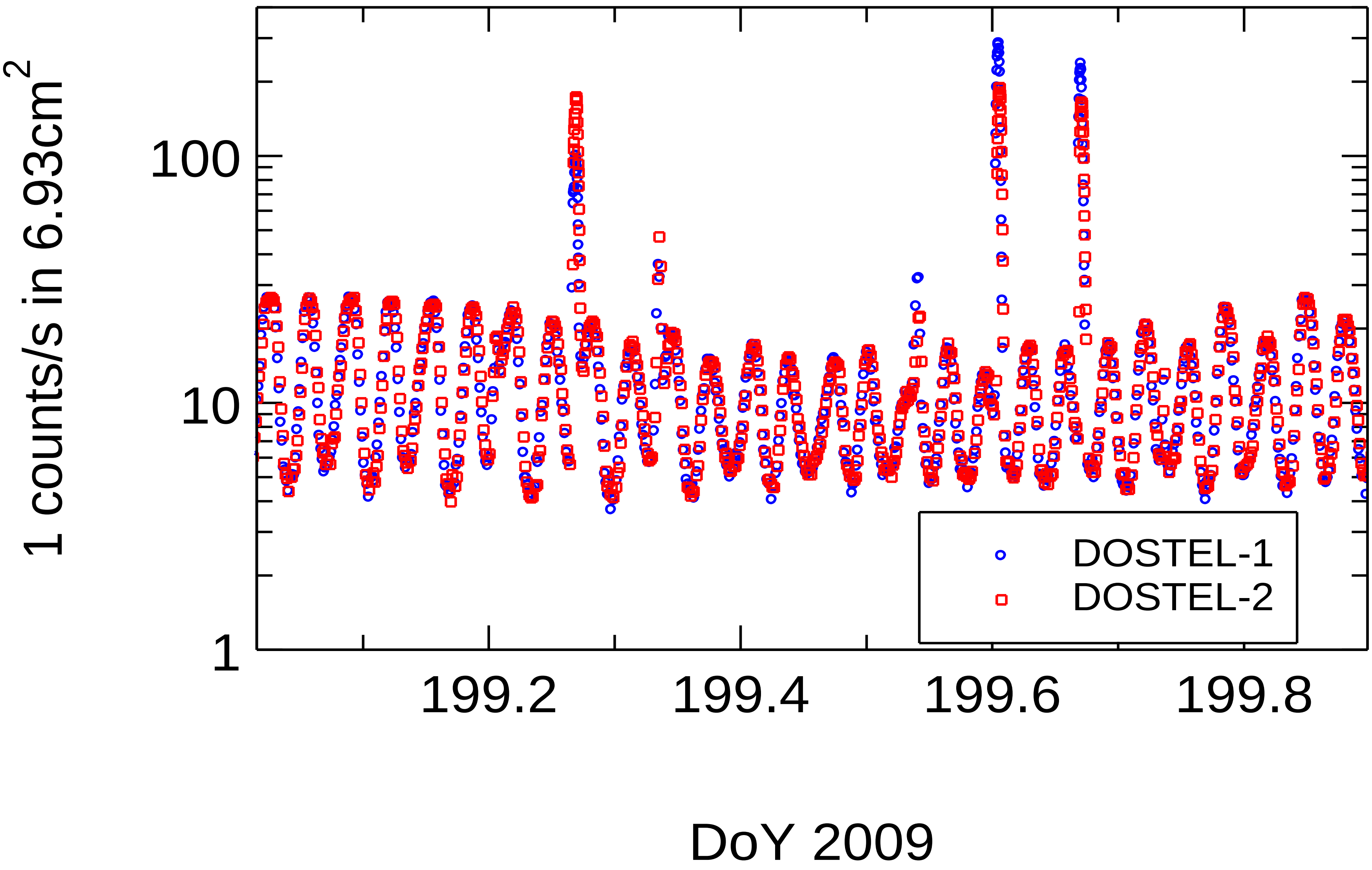


DOSIS 3D Sept 2017 SPE



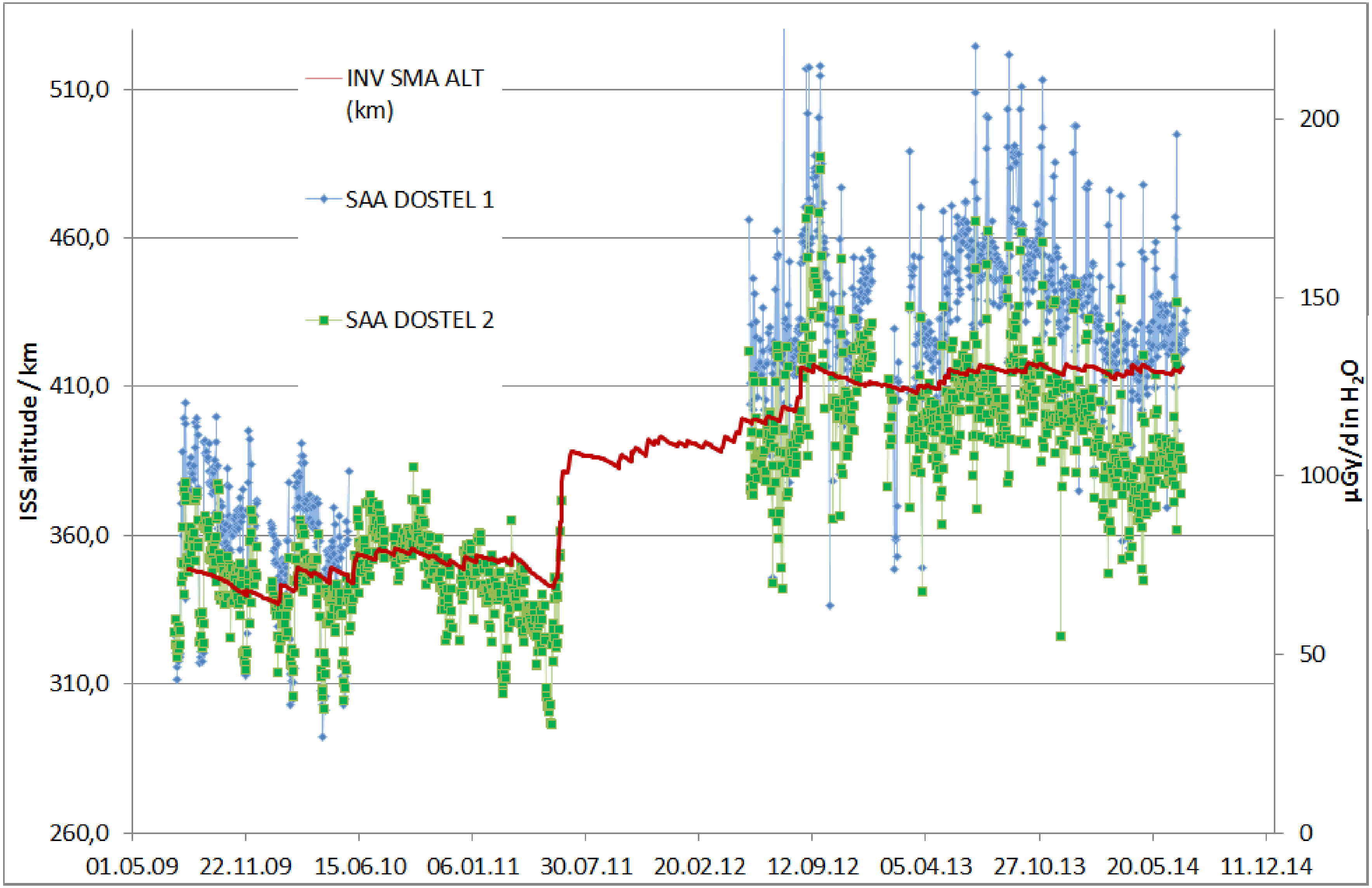
DOSIS 3D Sept 2017 SPE



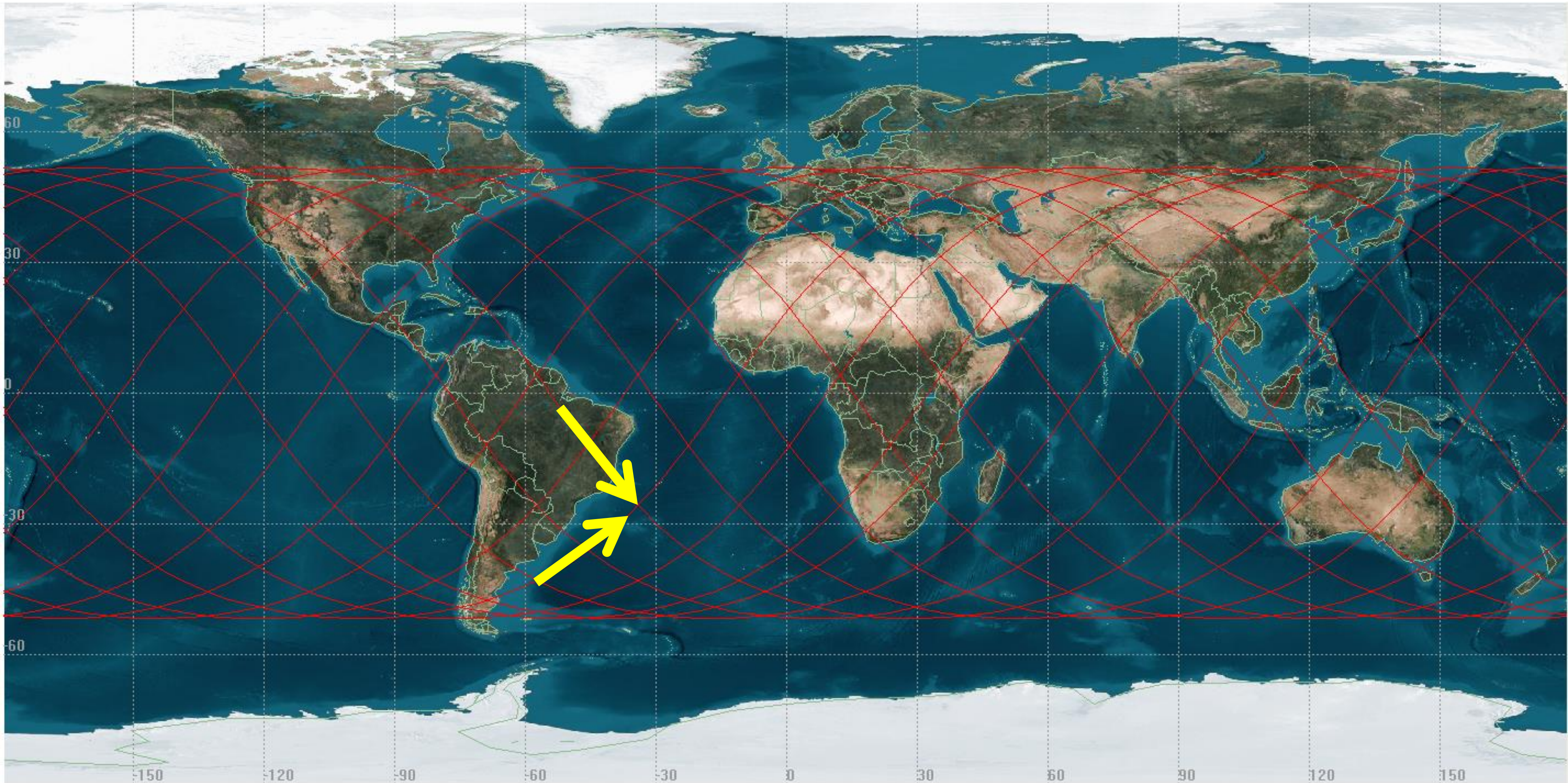


1 counts/s in 6.93cm^2
100
10
1
199.2
199.4
199.6
199.8
DoY 2009
DOSTEL-1
DOSTEL-2

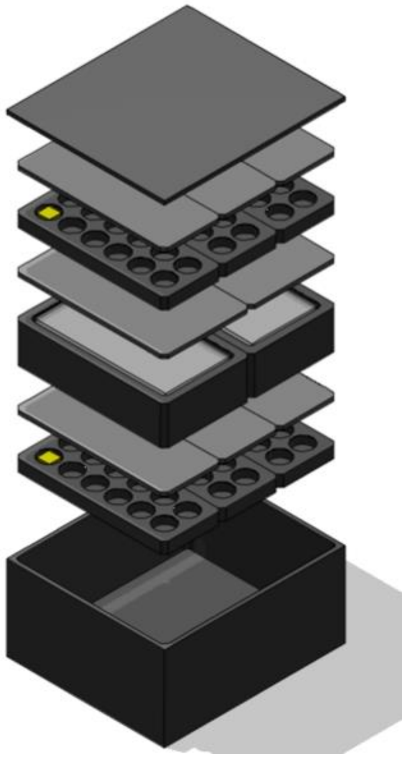
SAA Dose Rates

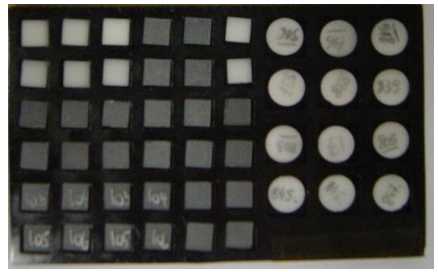


ISS Orbit



DOSIS & DOSIS 3D : Passive Detector Packages (PDP)



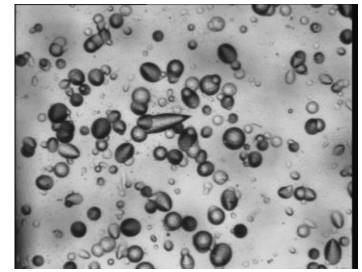


Thermoluminescence detectors (TLD)

First usage of LiF (Lithiumfluoride) for the measurement of radiation following an atomic weapon test

Measurement of internal radiation dose received by cancer patients treated with radioactiv isotopes at Oak Ridge Institute for Nuclear Studies

F. Daniels *Science* **117**, 343, **1953**



Nuclear Track Etch Detectors (CR-39)

Material : CR-39 = allyl diglycol carbonate

Heavy charged particles break chemical bonds in the material.This trail can be made visible by etching the material.

R. P. Henke and E. V. Benton, Nucl.Instr.Meth. 97 (**1971**) 483-9

The combination of passive thermoluminescence detectors and nuclear track etch detectors allows to determine the absorbed dose (in Gray) and the dose equivalent (in Sievert).