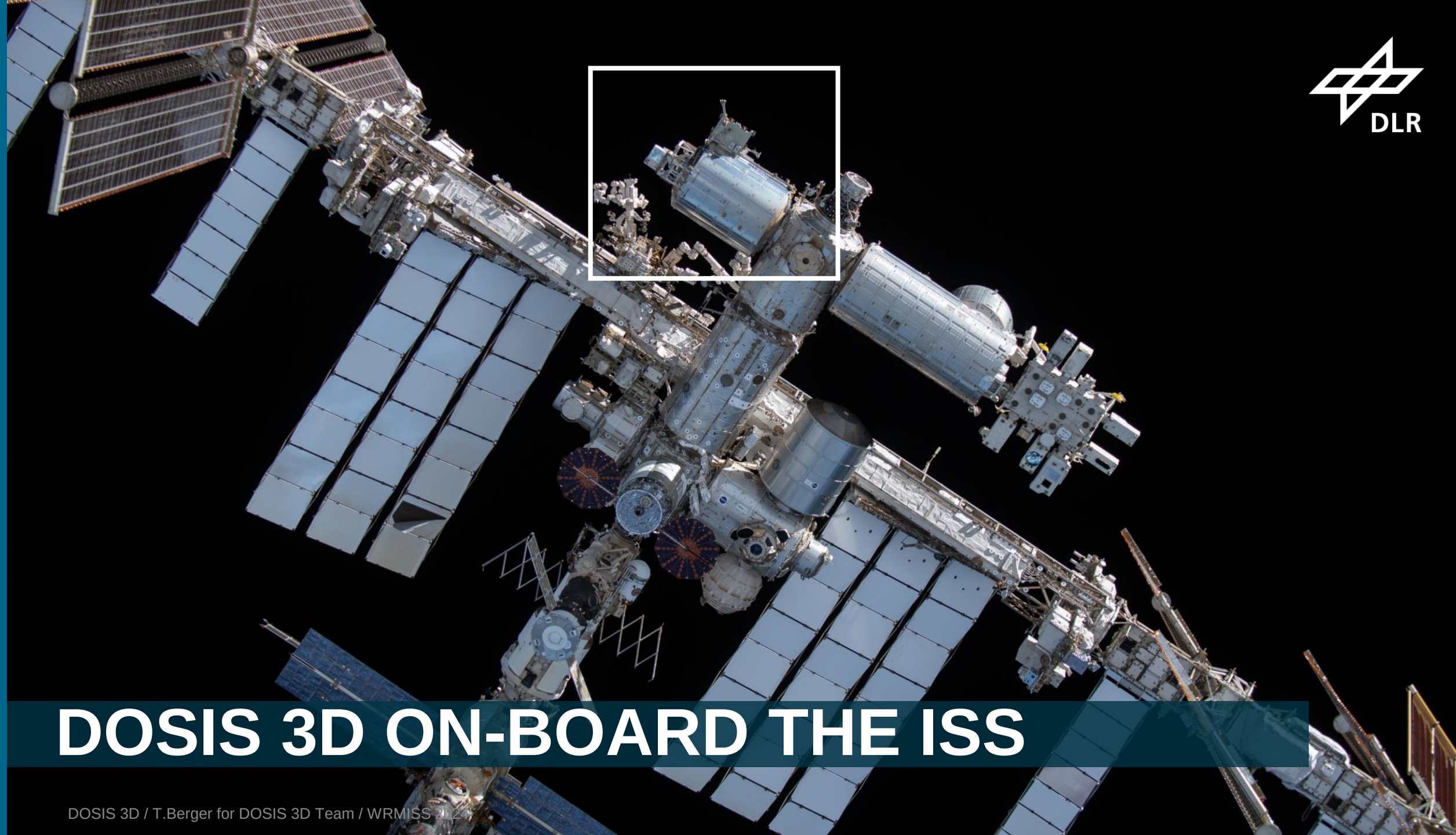
DOSIS AND DOSIS 3D – ACTIVE AND PASSIVE RADIATION MEASUREMENTS IN COLUMBUS FROM 2009 - 2024

WRMISS 27
SEPTEMBER 3 – 5, 2024, BOULDER, USA

Thomas Berger for the DOSIS 3D Team

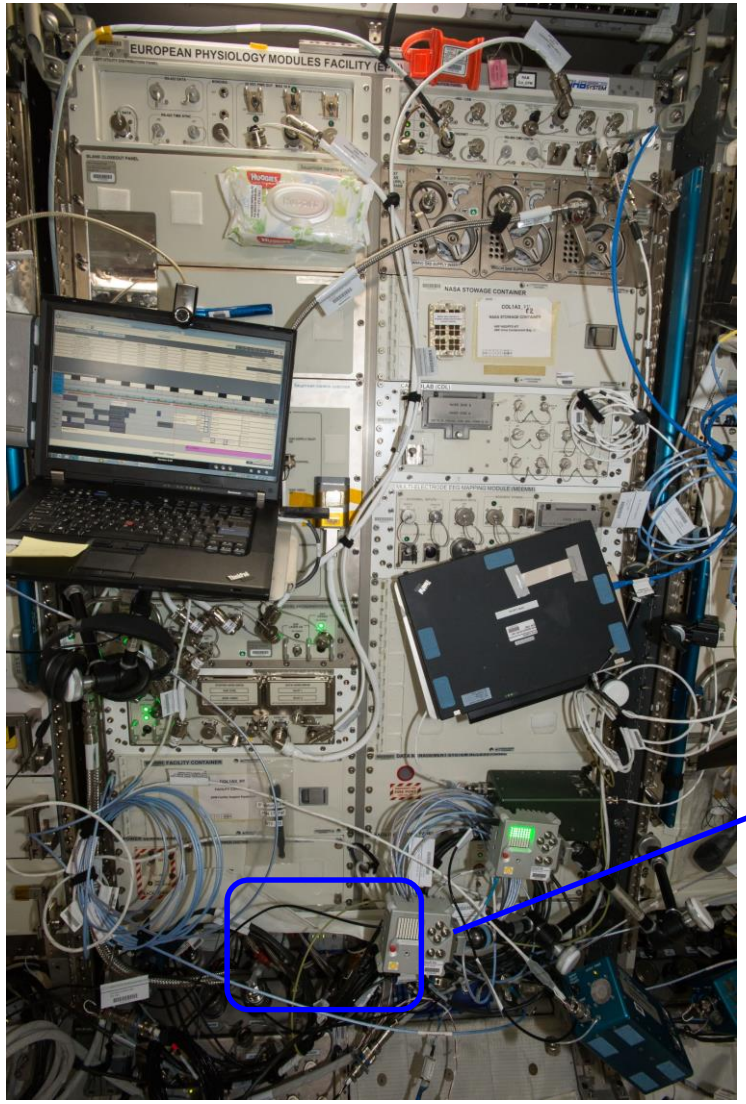
Improving Health Span in Space and on Earth



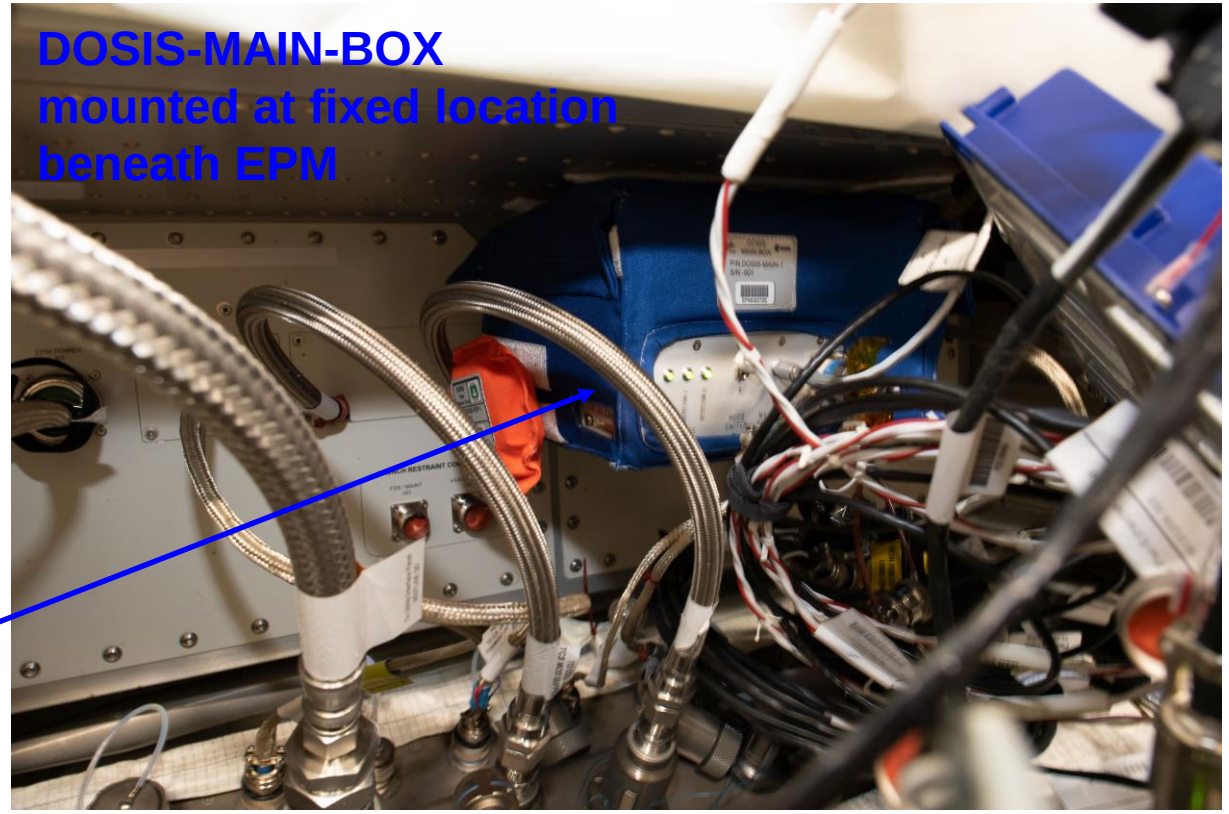
DOSIS 3D ON-BOARD THE ISS

DOSIS 3D: Dose Distribution Inside the ISS 3D

Experiment aim: to measure the radiation dose in Columbus with **two active (DOSTEL-1/-2)** and eleven passive radiation detectors (PDP) and combine/compare with data from other instruments

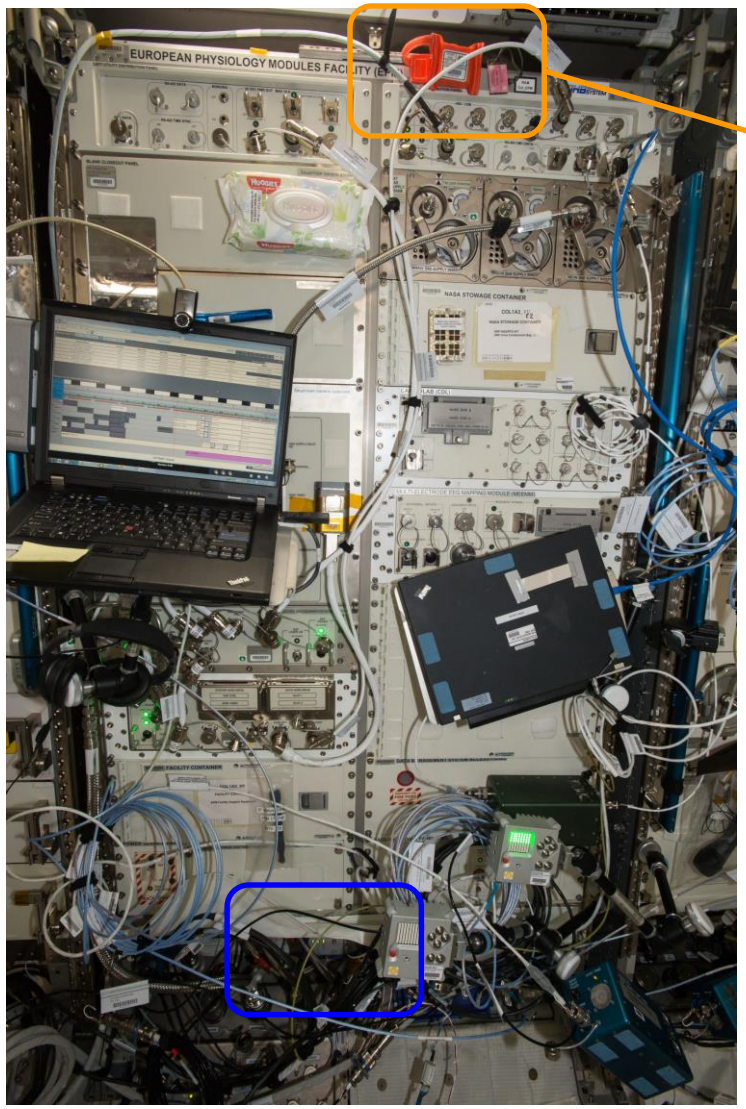


7882 days of data for DOSTEL-1 and DOSTEL-2



DOSIS 3D: Dose Distribution Inside the ISS 3D

Experiment aim: to measure the radiation dose in Columbus with **two active (DOSTEL-1/-2)** and **eleven passive radiation detectors (PDP)** and combine/compare with data from other instruments



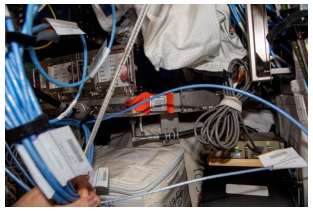
26 x PDP
⇑⇓
(up/down)

Currently Crew-8

https://www.esa.int/ESA_Multimedia/Images/2020/10/Hidden_science

DOSIS 3D: Dose Distribution Inside the ISS 3D - Timeline

Eleven passive radiation detectors (PDP)

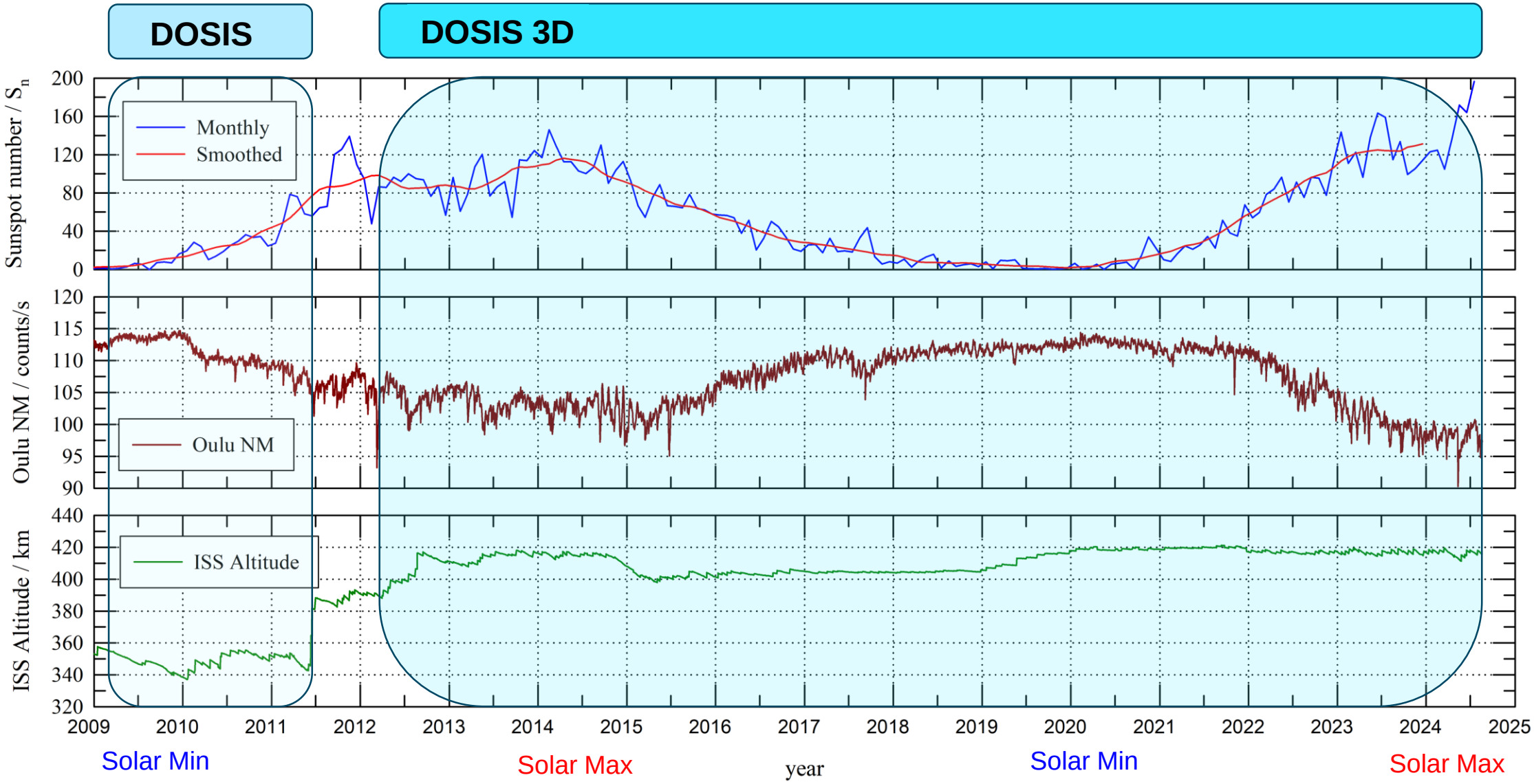


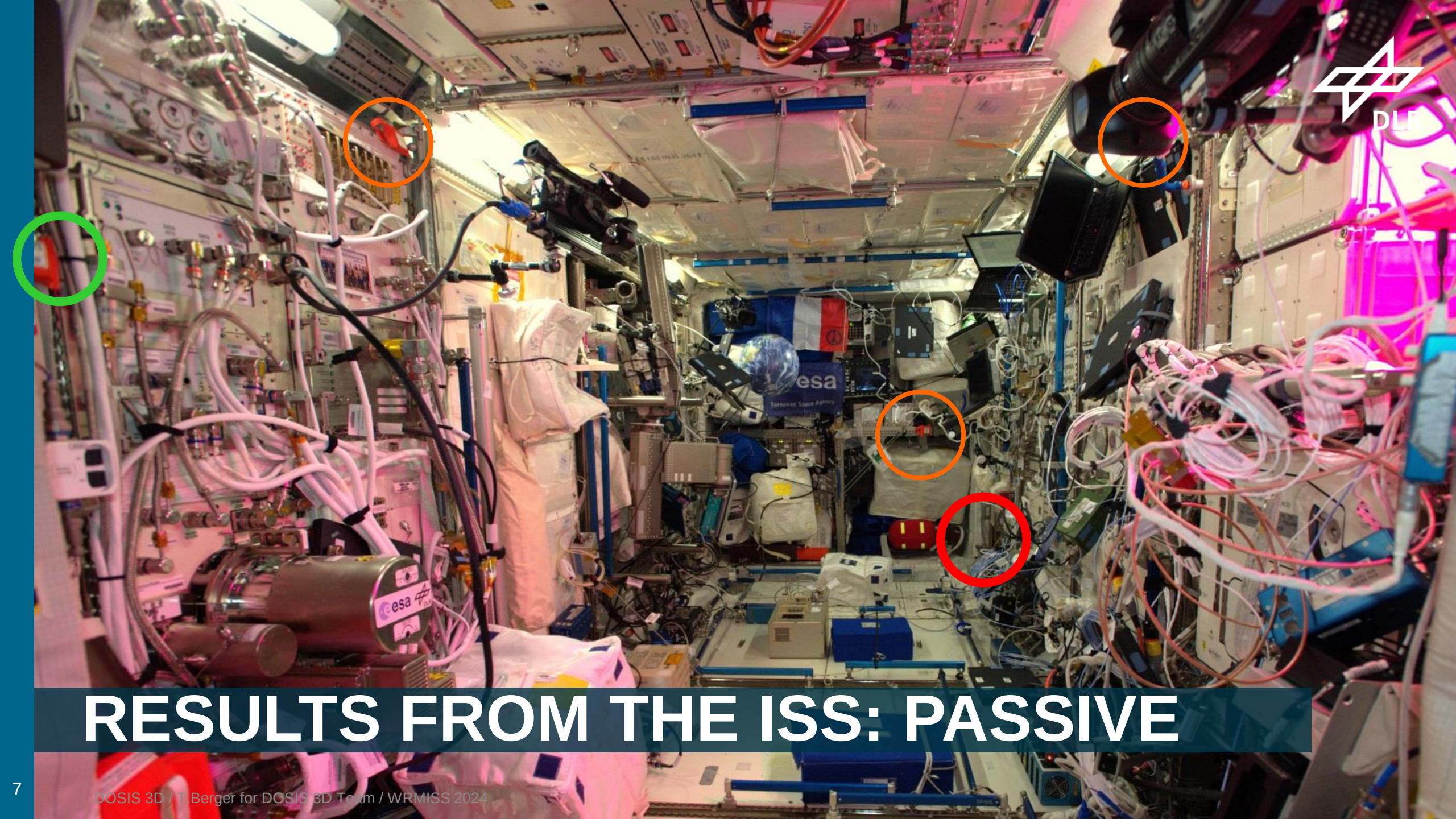
Up to Crew-7 4874 days in space

	#	Spacecraft	⇑ Up ⇓ Down	Launch	Installation	Deinstallation	Landing	Duration [days]	Installed [days]	Installed [%]
DOS	01	STS-127	⇑	15.07.2009	18.07.2009	-	-	-	-	-
		STS-129	⇓	-	-	21.11.2009	27.11.2009	136	127	93.3
	02	STS-129	⇑	16.11.2009	21.11.2009	-	-	-	-	-
		STS-132	⇓	-	-	18.05.2010	26.05.2010	191	178	93.2
D3D	01	30S	⇑⇓	15.05.2012	21.05.2012	11.09.2012	17.09.2012	125	113	90.4
	02	32S	⇑⇓	23.10.2012	27.10.2012	13.03.2013	16.03.2013	144	137	95.1
	03	34S	⇑⇓	28.03.2013	03.04.2013	06.09.2013	11.09.2013	167	156	93.4
	04	36S	⇑⇓	25.09.2013	01.10.2013	06.03.2014	11.03.2014	167	156	93.4
	05	38S	⇑⇓	25.03.2014	28.03.2014	05.09.2014	11.09.2014	170	161	94.7
	06	40S	⇑⇓	26.09.2014	29.09.2014	09.03.2015	12.03.2015	167	161	96.4
	07	42S	⇑	27.03.2015	29.03.2015	-	-	-	-	-
		43S	⇓	-	-	10.12.2015	11.12.2015	259	256	98.9
	08	45S	⇑⇓	15.12.2015	18.12.2015	15.06.2016	18.06.2016	186	180	96.8
	09	47S	⇑⇓	07.07.2016	09.07.2016	26.10.2016	30.10.2016	115	109	94.8
	10	49S	⇑⇓	17.11.2016	21.11.2016	01.06.2017	02.06.2017	197	192	97.5
	11	51S	⇑⇓	28.07.2017	30.07.2017	12.12.2017	14.12.2017	139	135	97.1
	12	53S	⇑⇓	17.12.2017	20.12.2017	30.05.2018	03.06.2018	168	161	95.8
	13	552	⇑⇓	06.06.2018	11.06.2018	03.12.2018	20.12.2018	197	175	88.8
	14	57S	⇑⇓	03.12.2018	04.12.2018	19.06.2019	24.06.2019	203	197	95.8
	15	59S	⇑⇓	20.07.2019	22.07.2019	31.01.2020	06.02.2020	201	193	96.0
	16	SpX-20	⇑	07.03.2020	11.03.2020	-	-	-	-	-
		62S	⇓	-	-	16.10.2020	21.10.2020	228	224	98.3
	17	63S	⇑⇓	14.10.2020	16.10.2020	16.04.2021	17.04.2021	185	182	98.4
	18	Crew-2	⇑⇓	23.04.2021	25.04.2021	05.11.2021	08.11.2021	199	194	97.5
	19	Crew-3	⇑⇓	11.11.2021	15.11.2021	26.04.2022	06.05.2022	176	162	92.5
	21	Crew-4	⇑⇓	27.04.2022	02.05.2022	12.10.2022	14.10.2022	170	163	95.9
	22	Crew-5	⇑⇓	05.10.2022	12.10.2022	08.03.2023	12.03.2023	158	147	93.0
	23	Crew-6	⇑⇓	02.03.2023	08.03.2023	31.08.2023	03.09.2023	185	176	95.1
	24	Crew-7	⇑⇓	26.08.2023	31.08.2023	06.03.2024	12.03.2024	199	188	94.5

DOSIS & DOSIS 3D: Radiation data over one full solar cyle

Data: DOSIS (2009 – 2011) / DOSIS 3D (since 2012)

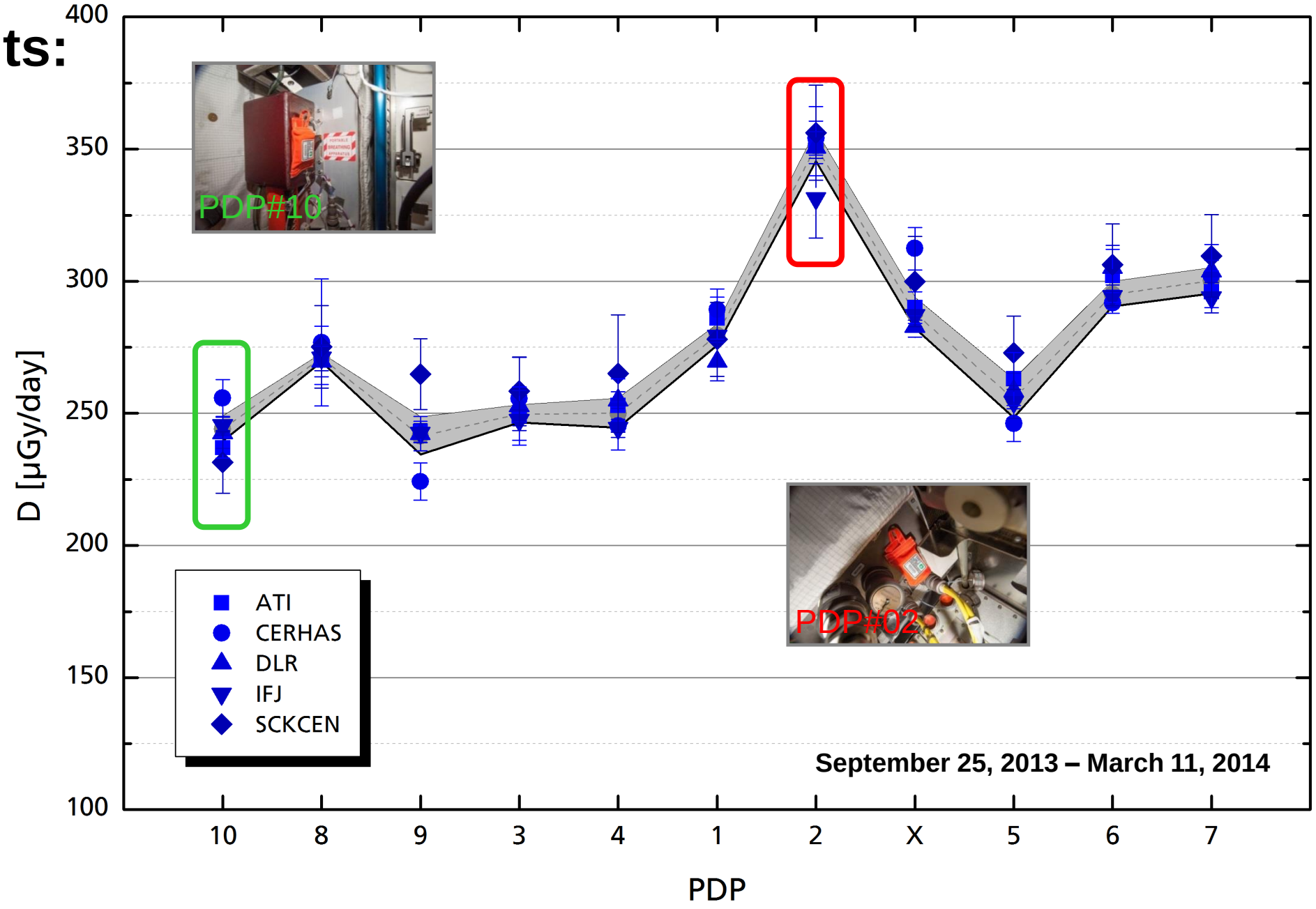




RESULTS FROM THE ISS: PASSIVE

Results:

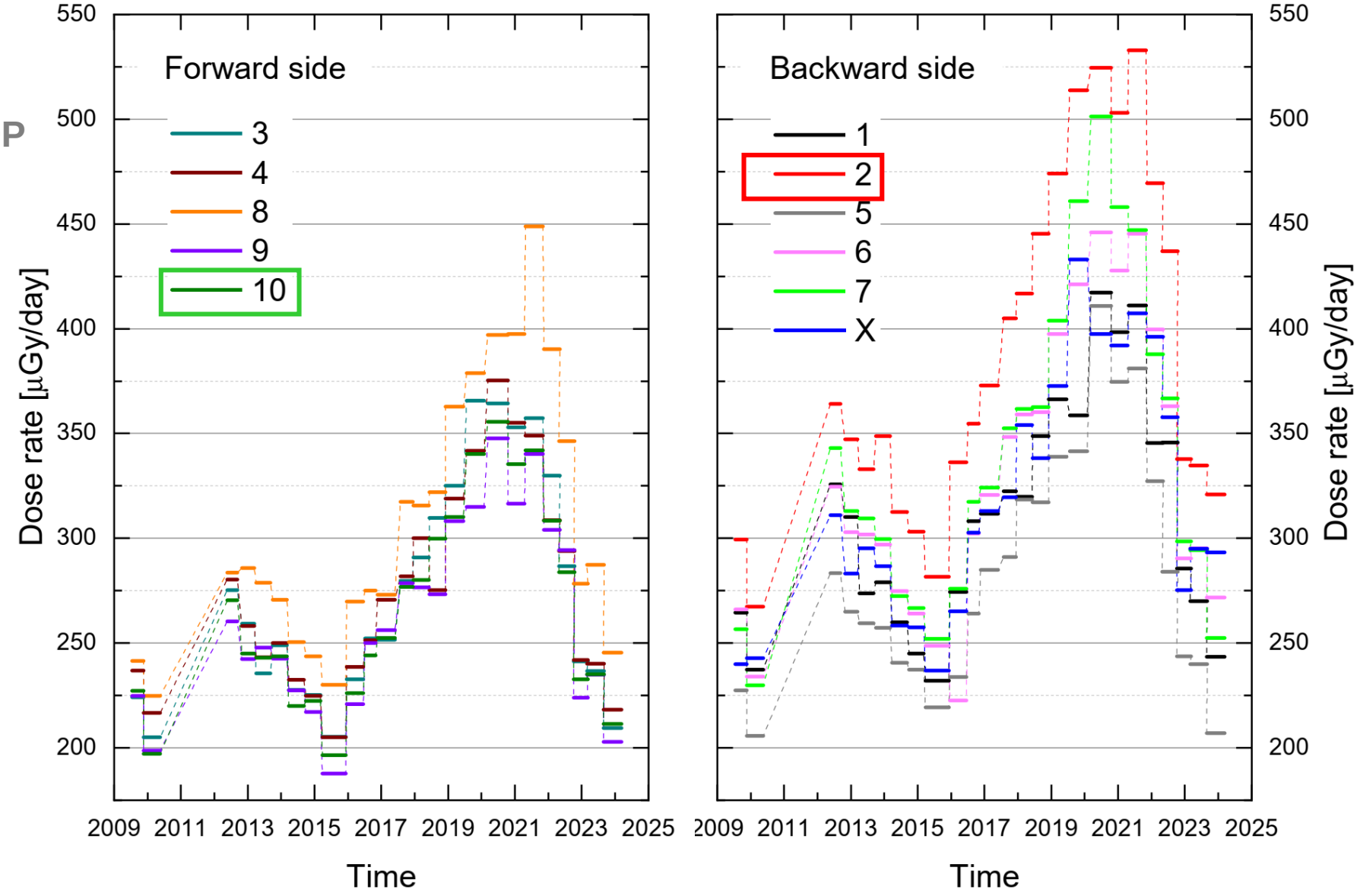
PDP
D3D04



Results:

DOSIS PDP
DOS01/02
+
DOSIS 3D PDP
D3D01 – 24

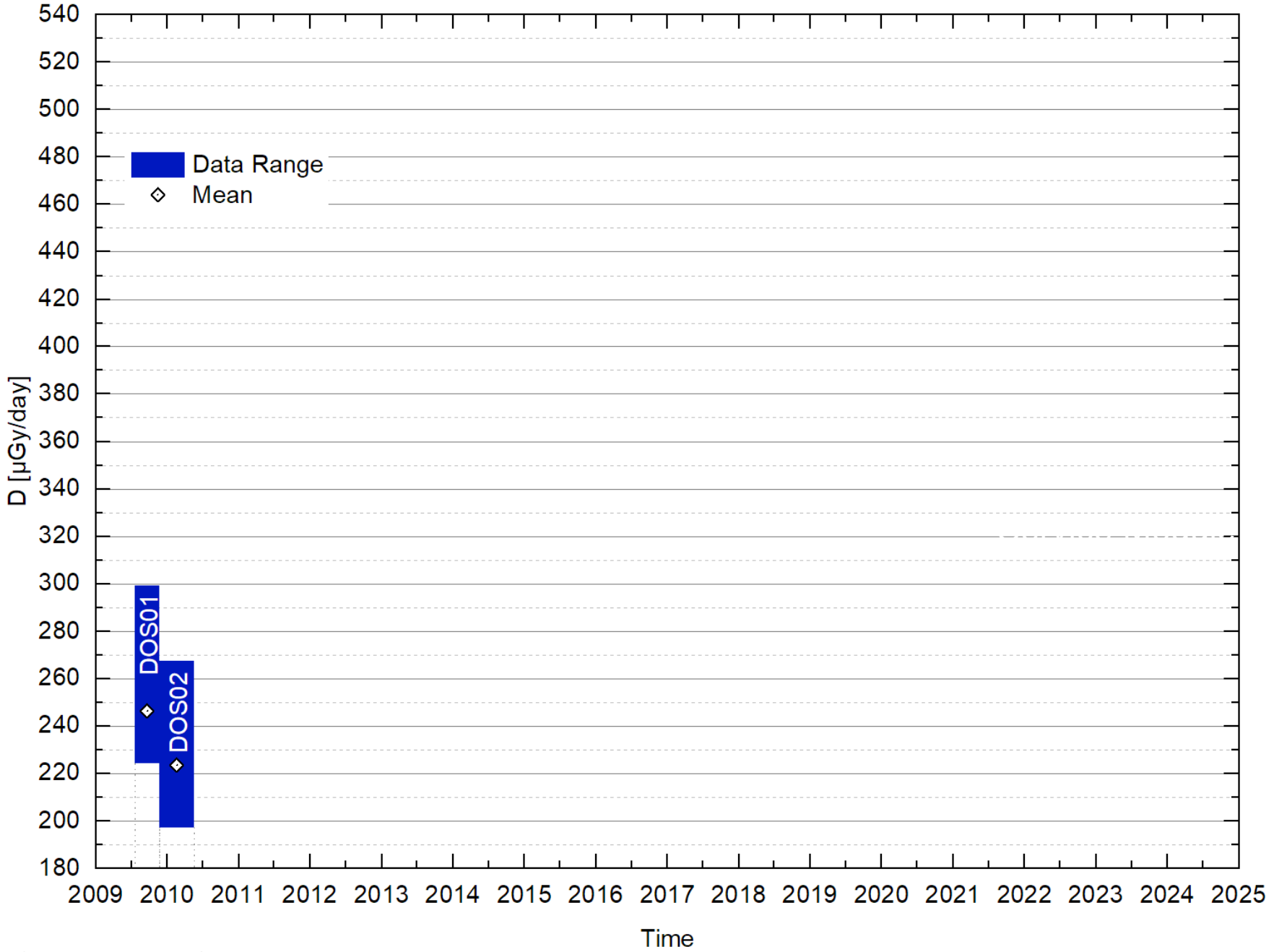
Forward
Backward



Results:

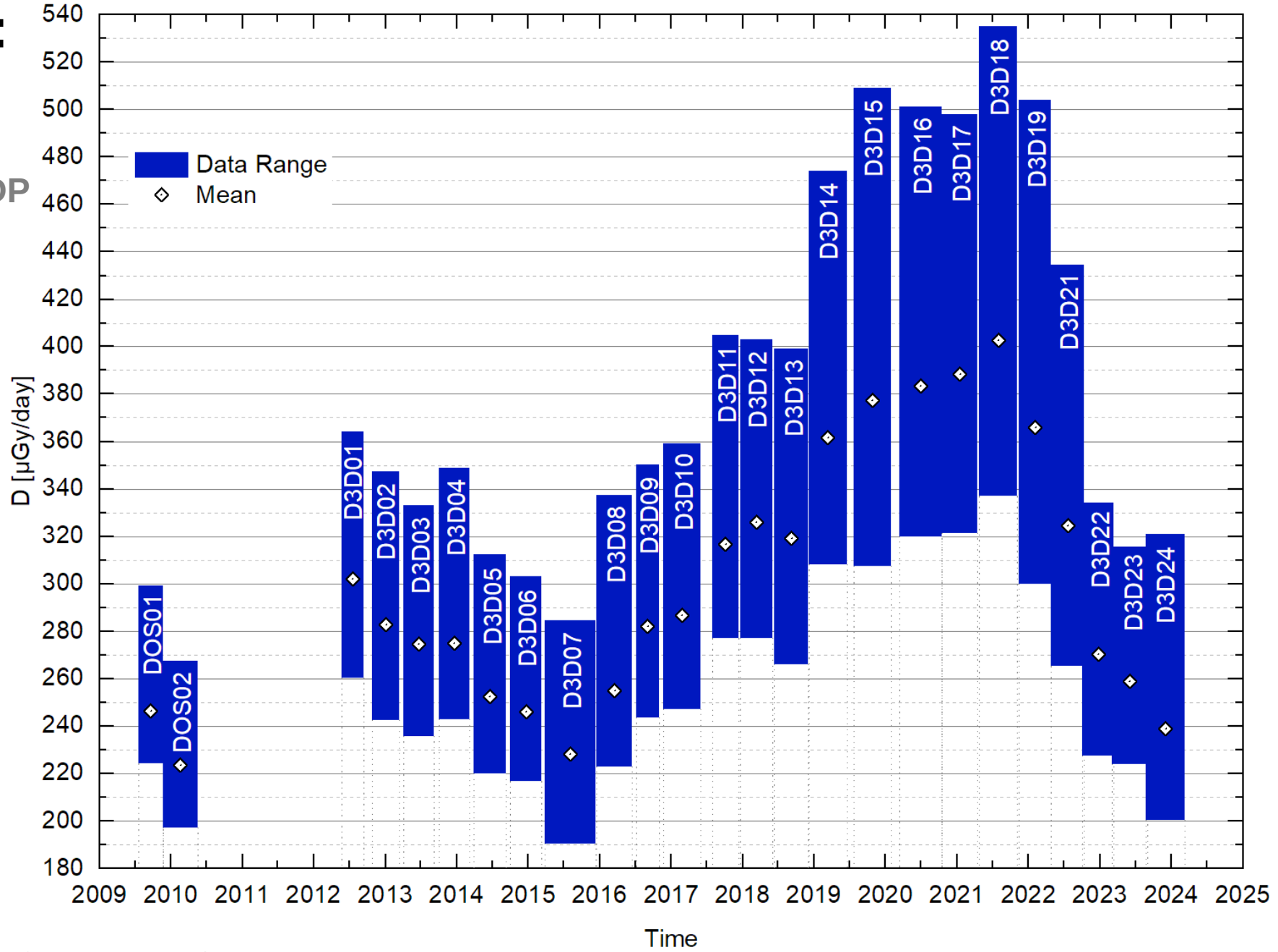
DOSIS PDP

DOS01/02



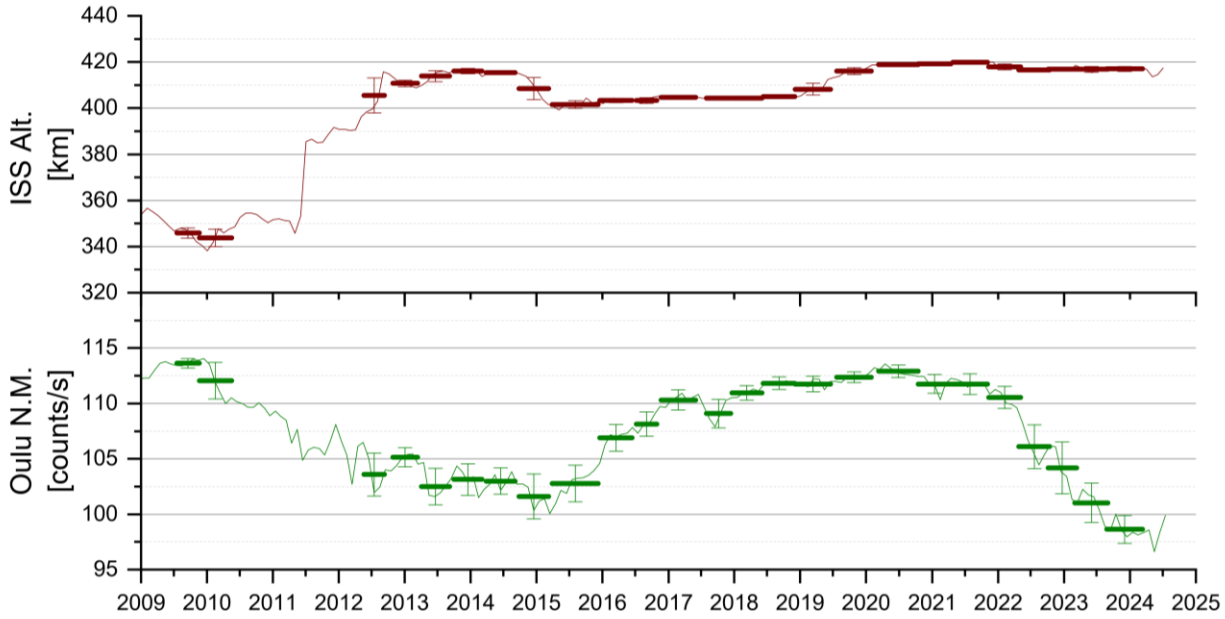
Results:

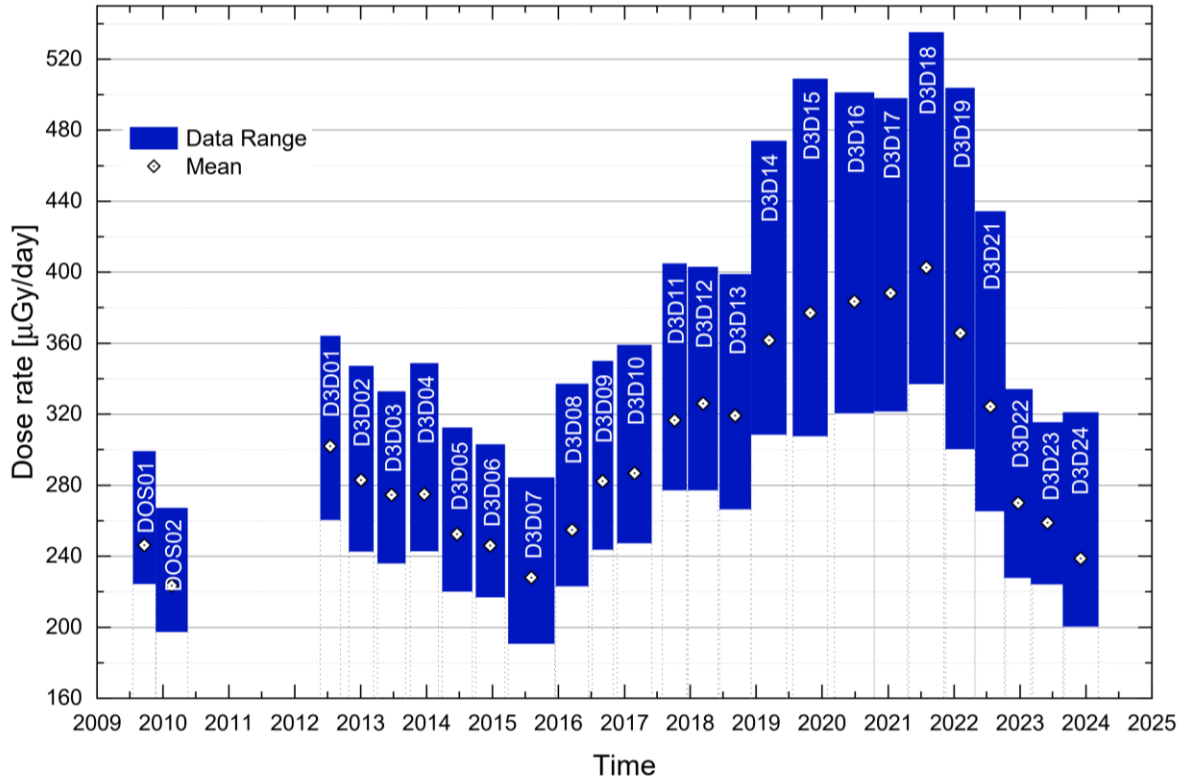
DOSIS PDP
DOS01/02
+
DOSIS 3D PDP
D3D01 - 24



Results:

DOSIS PDP
DOS01/02
+
DOSIS 3D PDP
D3D01 - 24

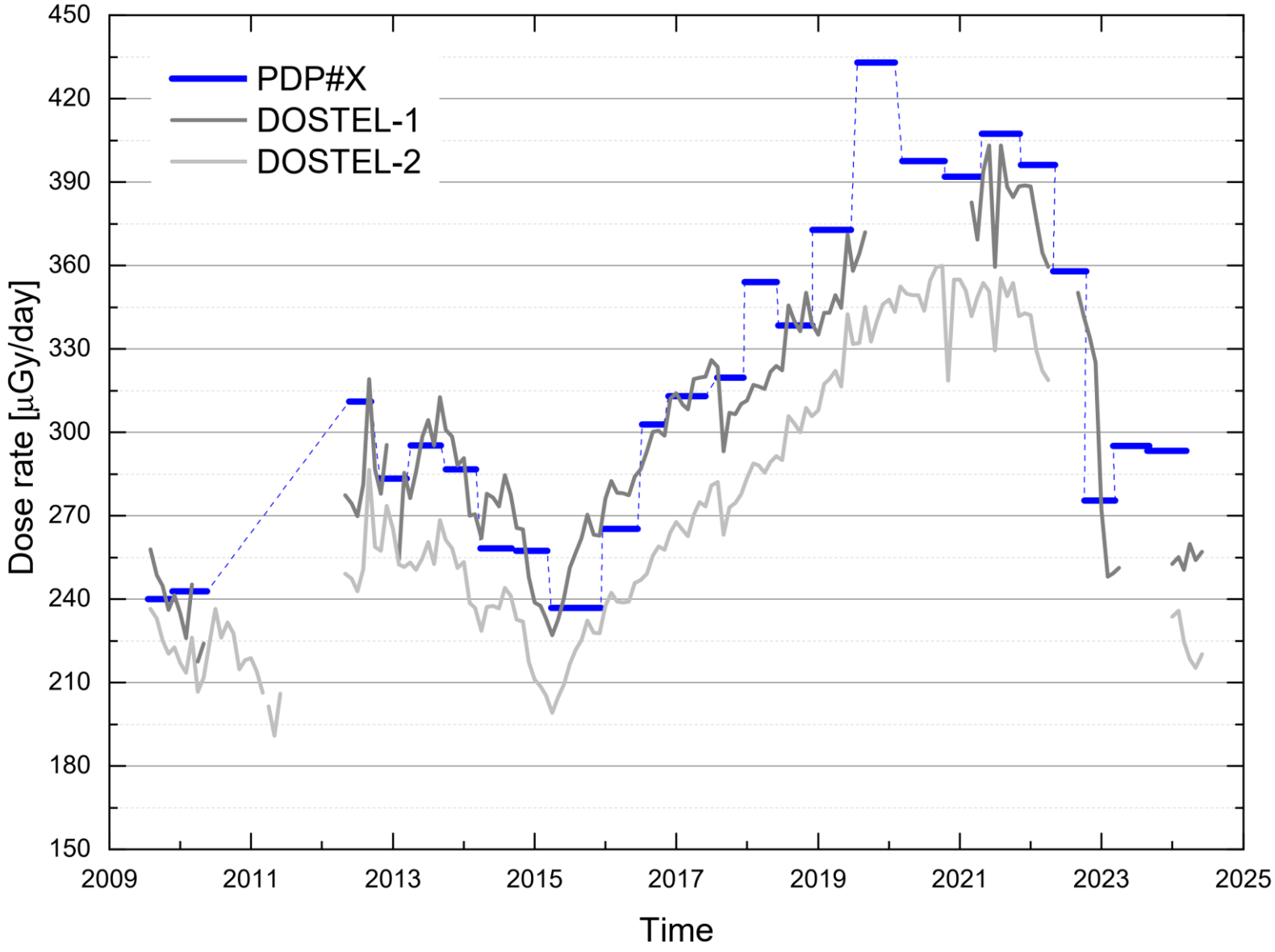


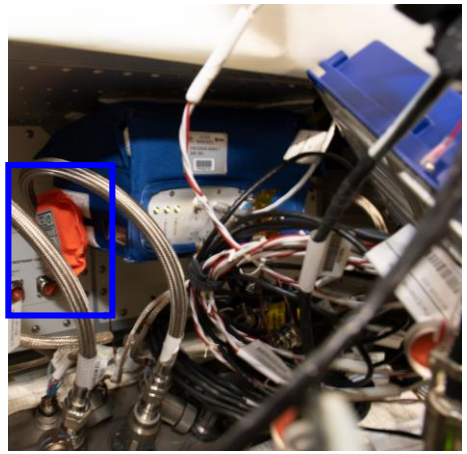


Results:

DOSIS PDP
DOS01/02
+
DOSIS 3D PDP
D3D01 – 24

PDP#X
DOSTEL-1
DOSTEL-2
(Monthly)

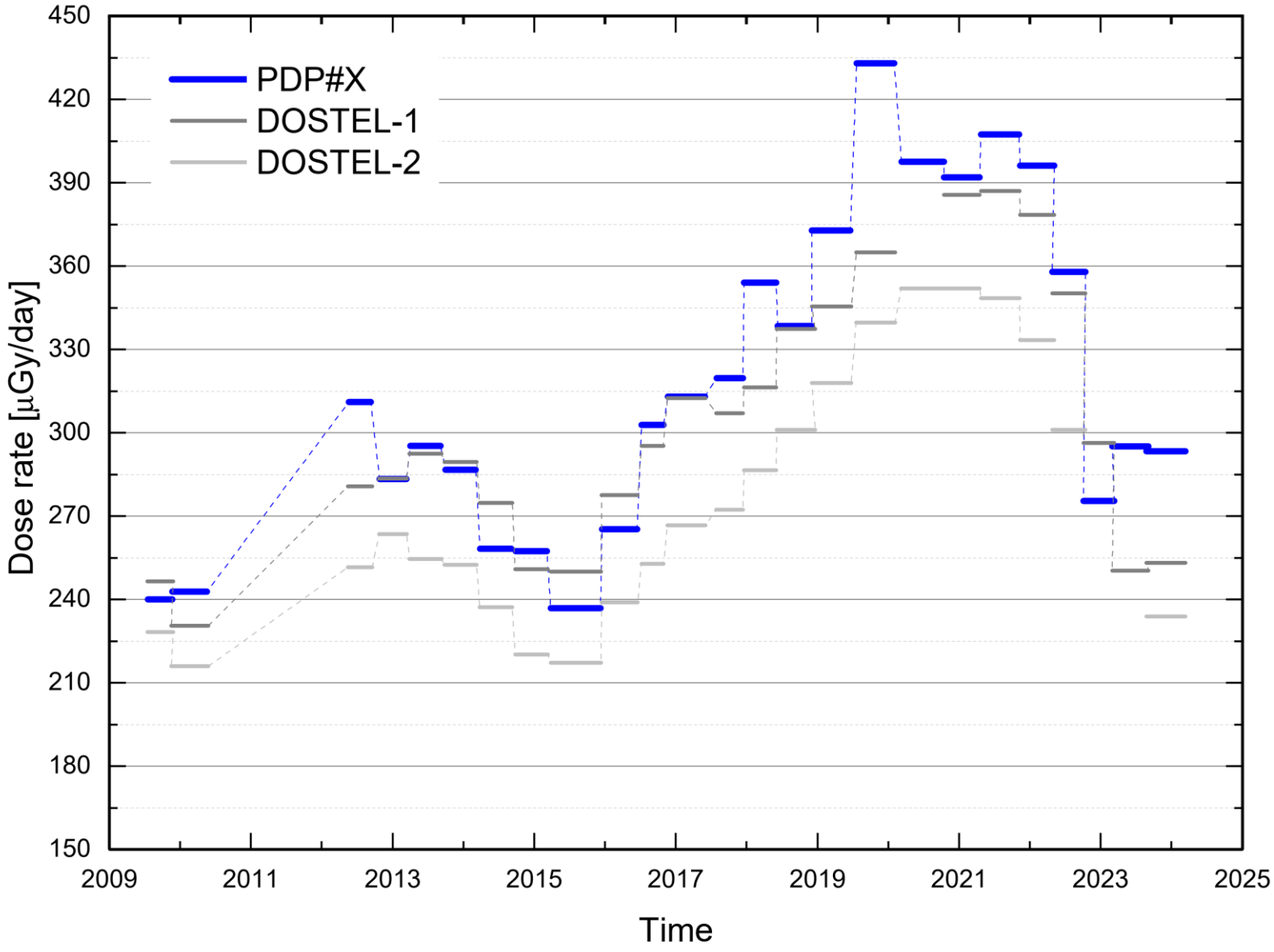


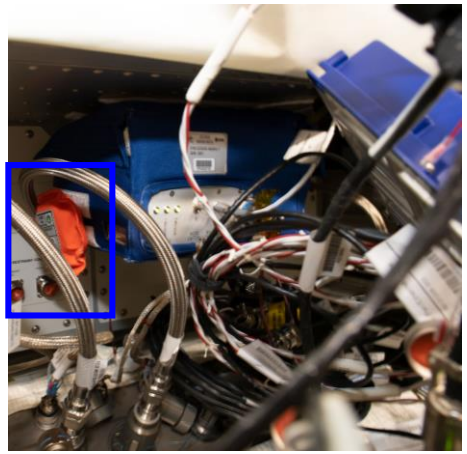


Results:

DOSIS PDP
DOS01/02
+
DOSIS 3D PDP
D3D01 – 24

PDP#X
DOSTEL-1
DOSTEL-2
(PDP Time)

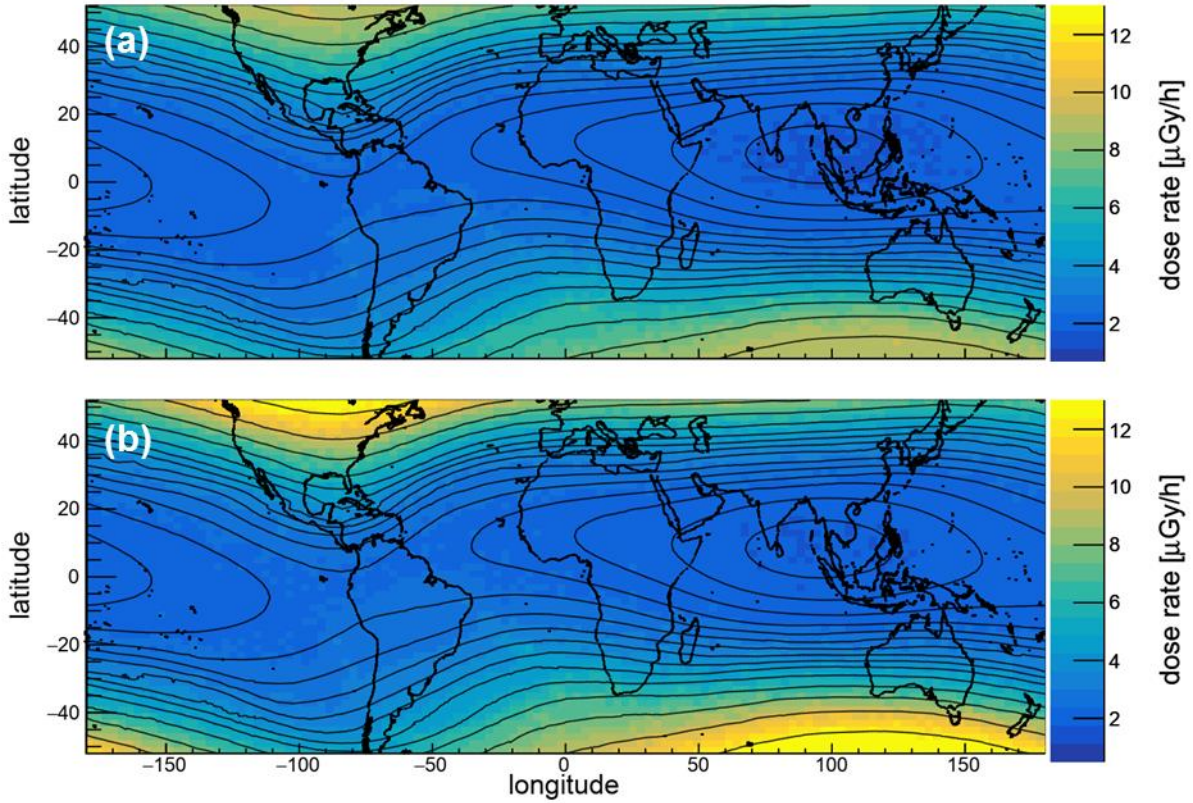




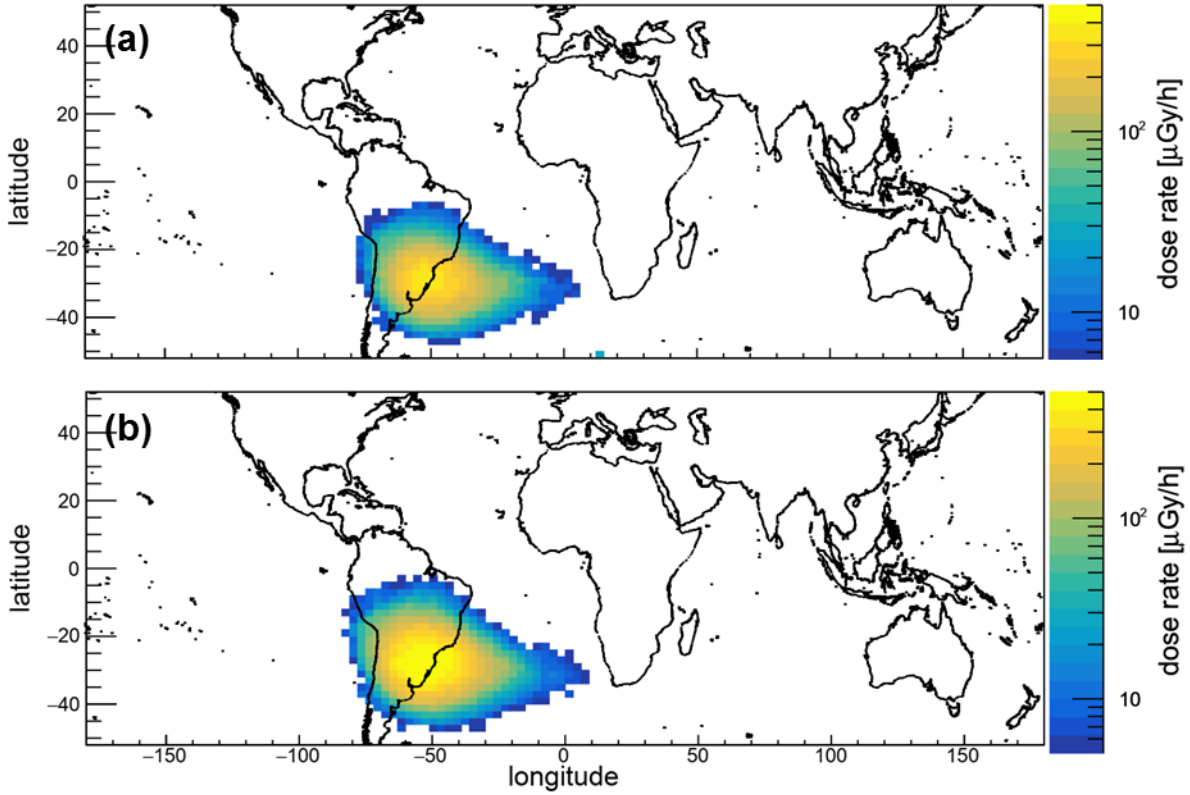
Results:

DOSTEL
GCR/SAA Separation
#07: 27.03.2015 – 11.12.2015 (solar max)
#14: 03.12.2018 – 24.06.2019 (approaching solar min)

GCR: D3D Phase 07 (a) and Phase 14 (b)



SAA: D3D Phase 07 (a) and Phase 14 (b)



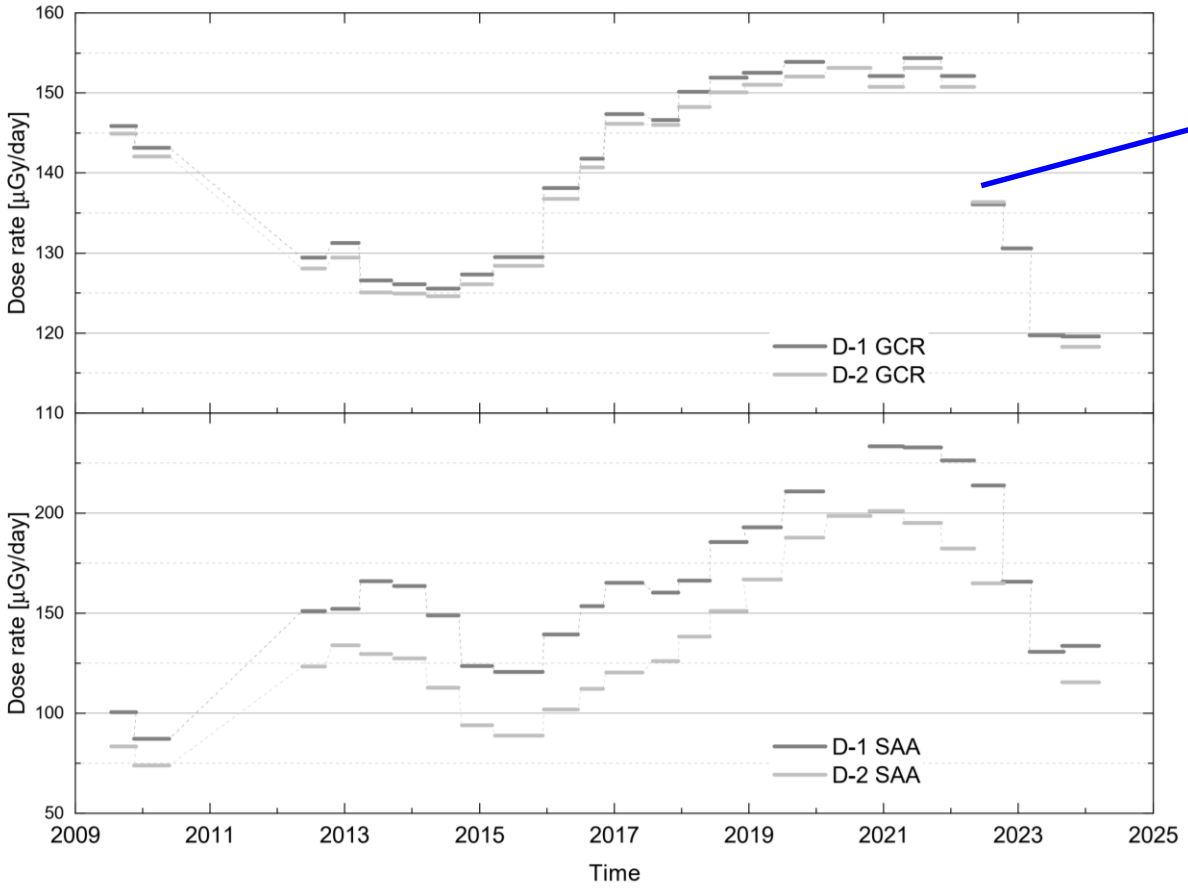
Results:

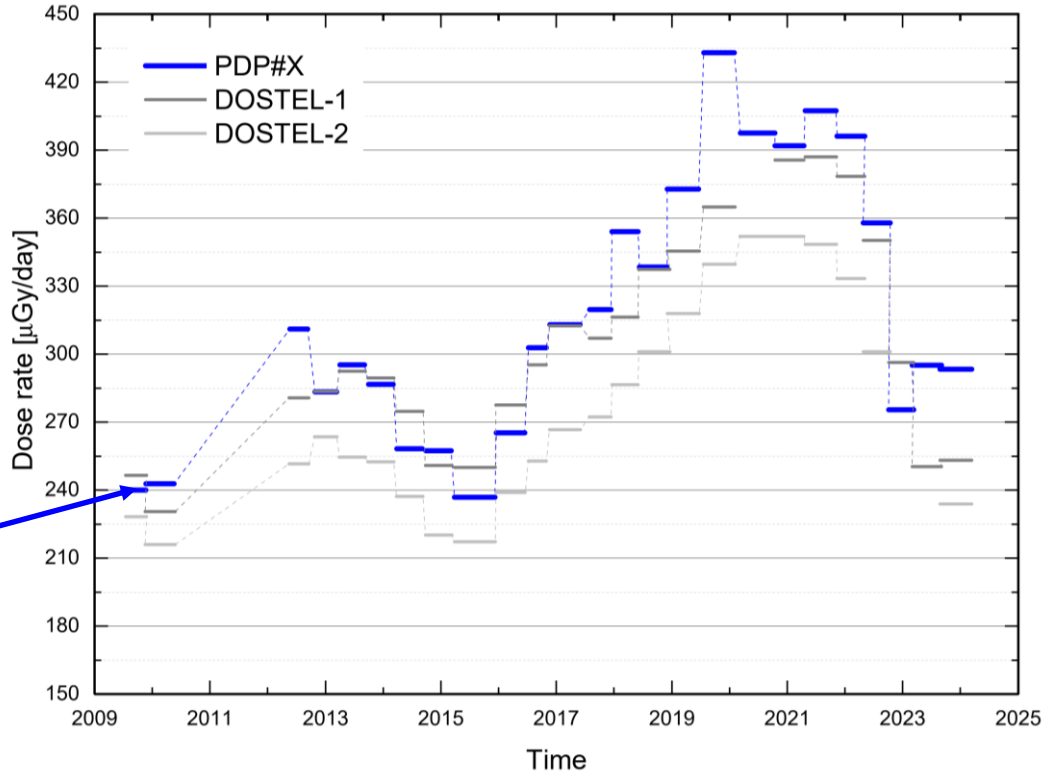
DOSTEL

GCR/SAA Separation

#07: 27.03.2015 – 11.12.2015 (solar max)

#14: 03.12.2018 – 24.06.2019 (approaching solar min)





- **D-1 and D-2 GCR over PDP time**
- **Subtraction of D-1 GCR from PDP-X**

→ **PDP-X SAA**

→ **Subtraction of D-1 GCR from PDP-02 (max)**

→ **Subraction of D-1 GCR from PDP-10 (min)**

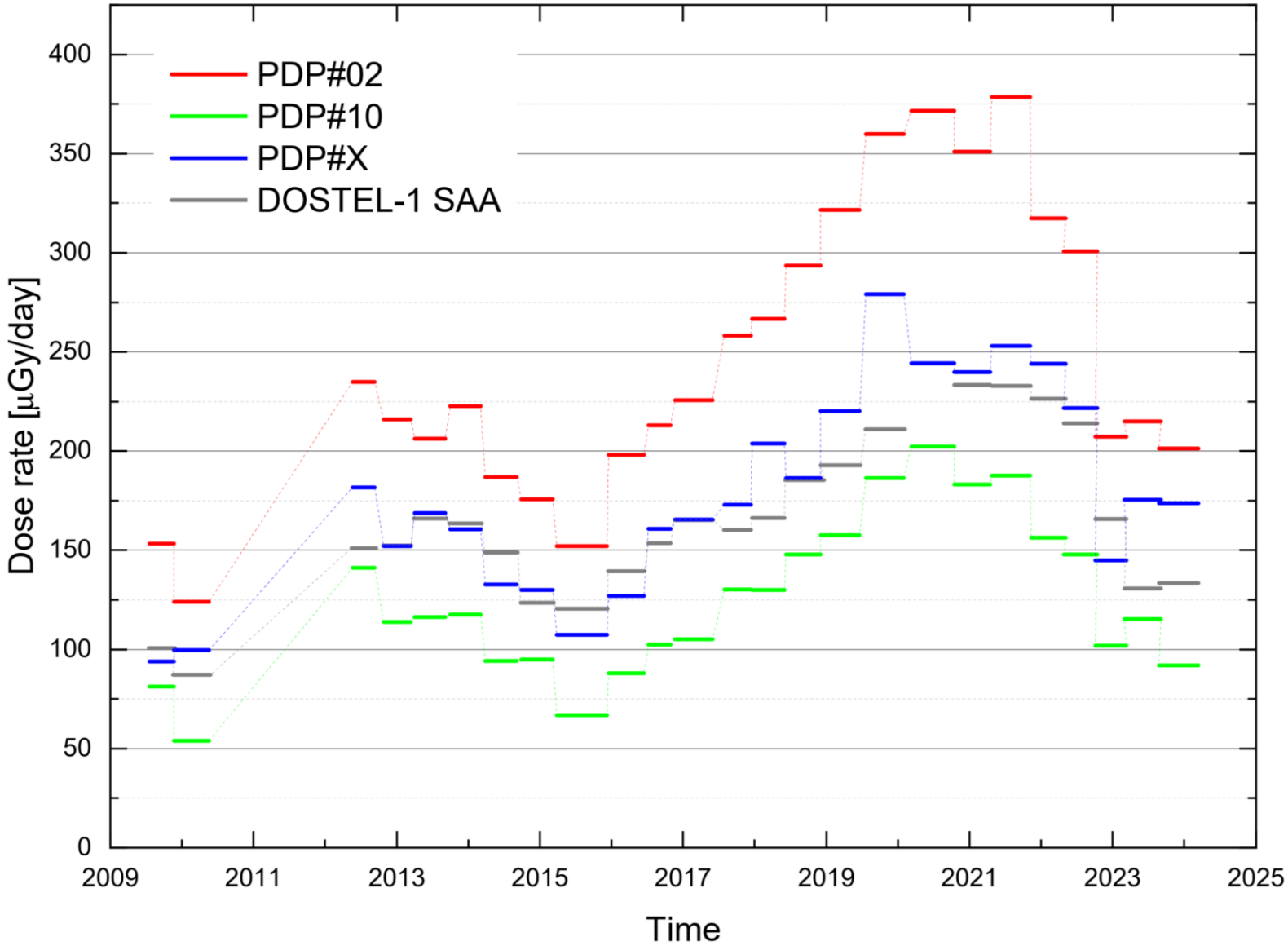
→ **<u>SAA Dose over time in Columbus</u>**

Results:

DOSIS PDP
DOS01/02
+
DOSIS 3D PDP
D3D01 – 24

SAA over time

GCR DOSTEL-1 subtracted

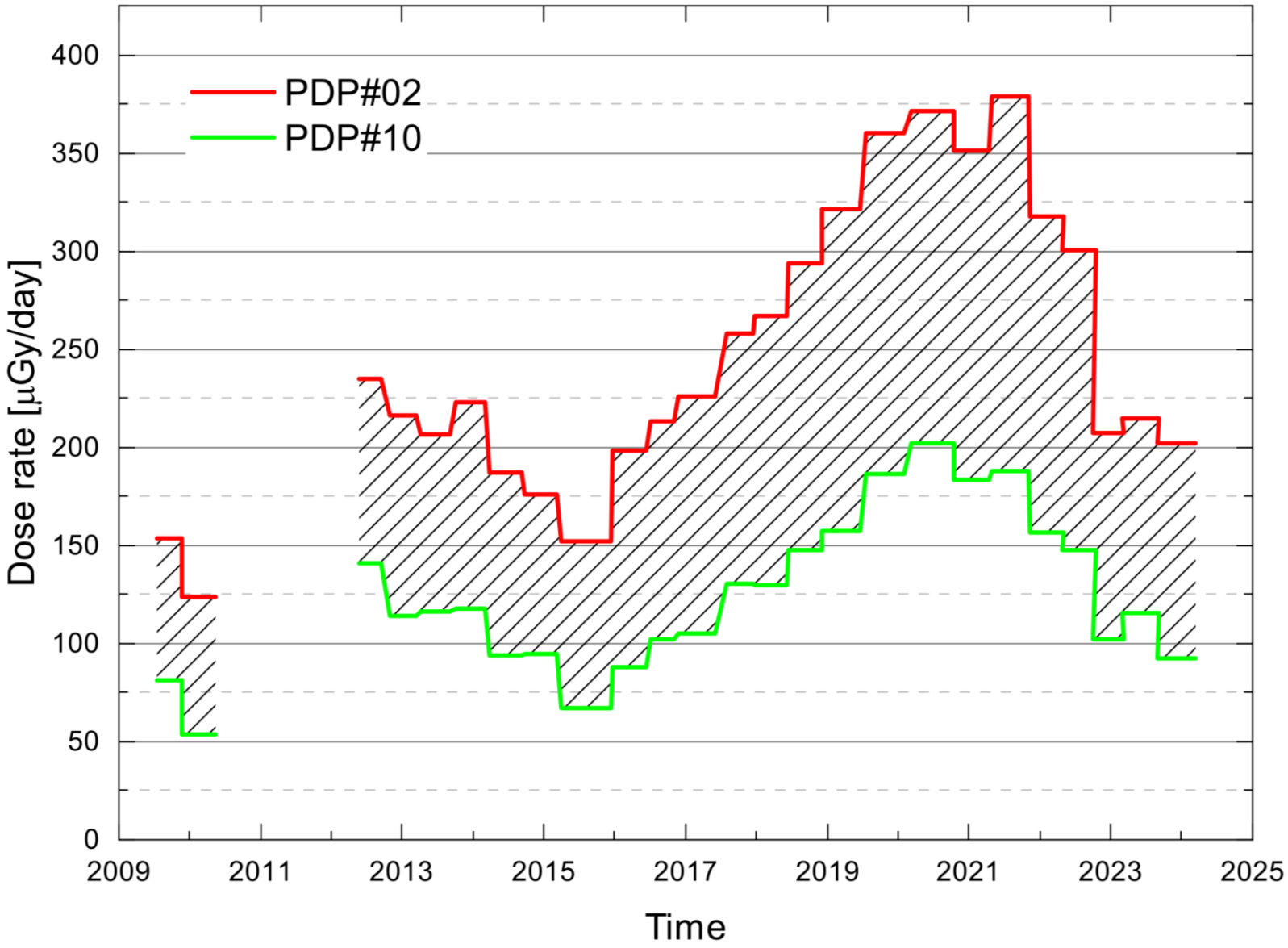


Results:

DOSIS PDP
DOS01/02
+
DOSIS 3D PDP
D3D01 – 24

SAA over time

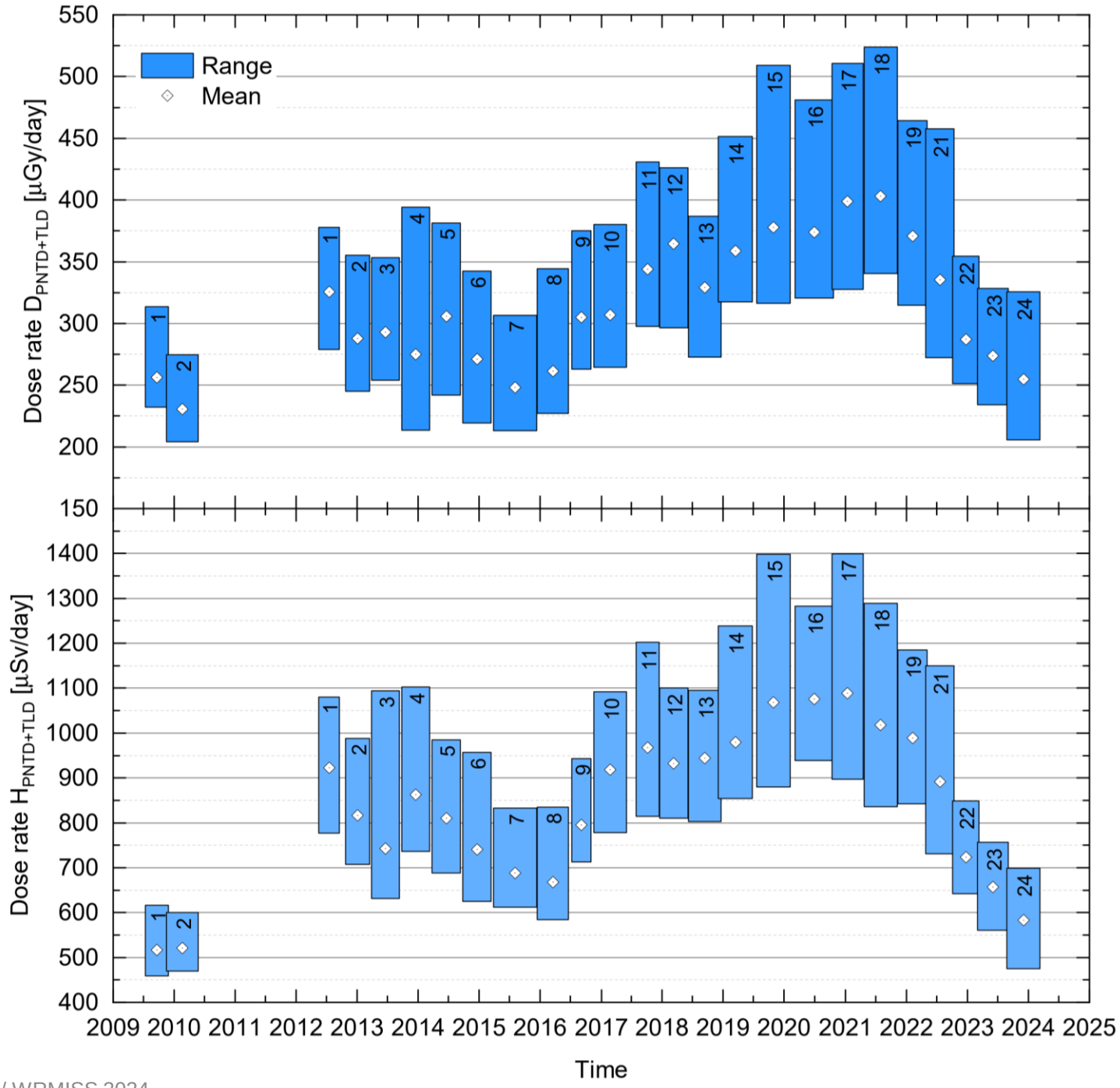
GCR DOSTEL-1 subtracted



Results:

DOSIS PDP
DOS01/02
+
DOSIS 3D PDP
D3D01 – 24

TLD+CR-39



01.01.2020 00:00

RESULTS FROM THE ISS: ACTIVE

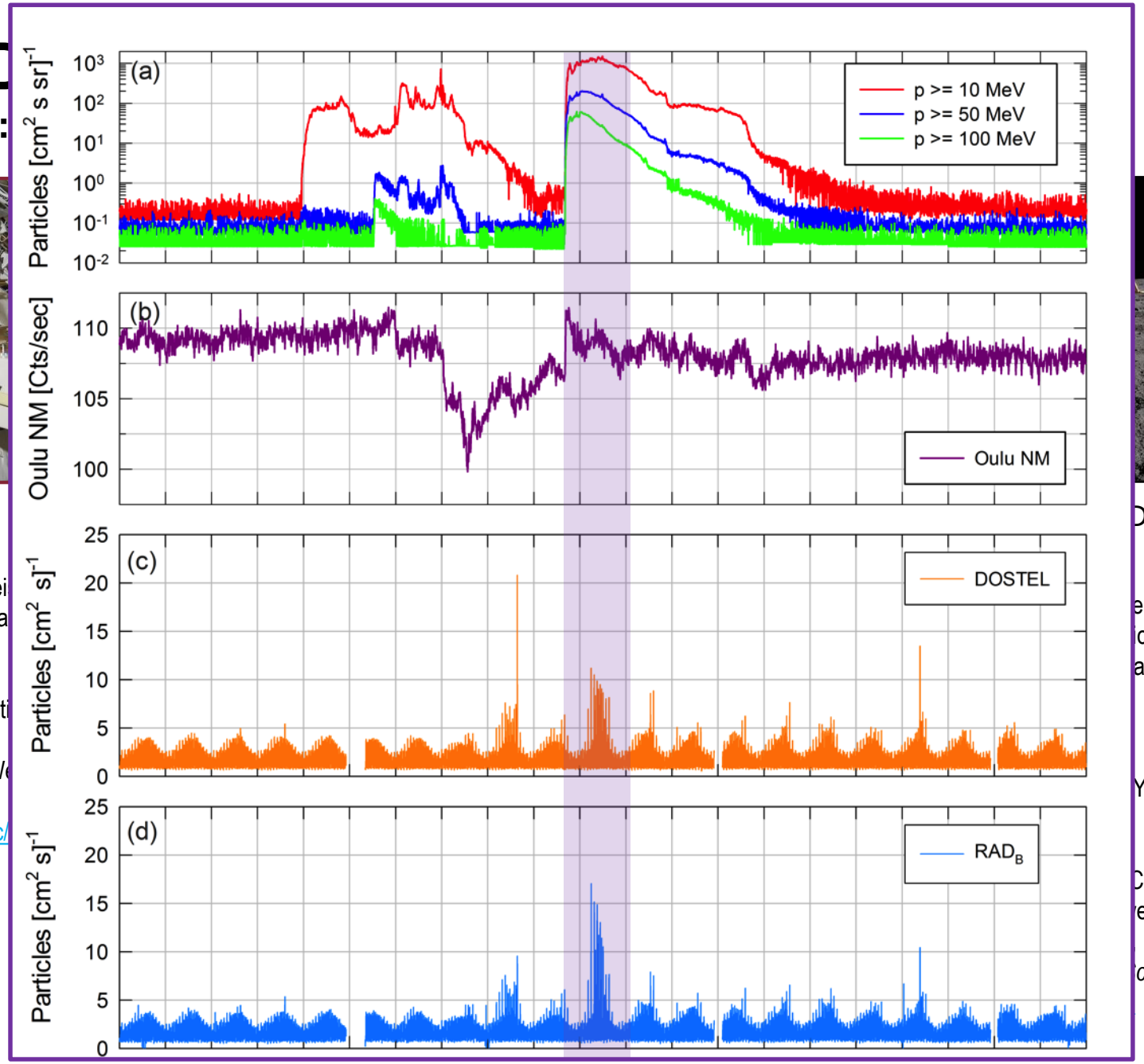
DOSIS 3D DOSTEL-2 Count rates 2020

DOSIS 3D

Experiment aim:

ASI ALTEA

Narici, L., Berger, T., Burmei
S. et al. Exploiting different a
silicon detectors in the
International Space Station:
ALTEA and DOSTEL Galacti
Cosmic Radiation (GCR)
measurements. J. Space We
Space Clim. 7, A18, 2017,
https://doi.org/10.1051/swsc/
16

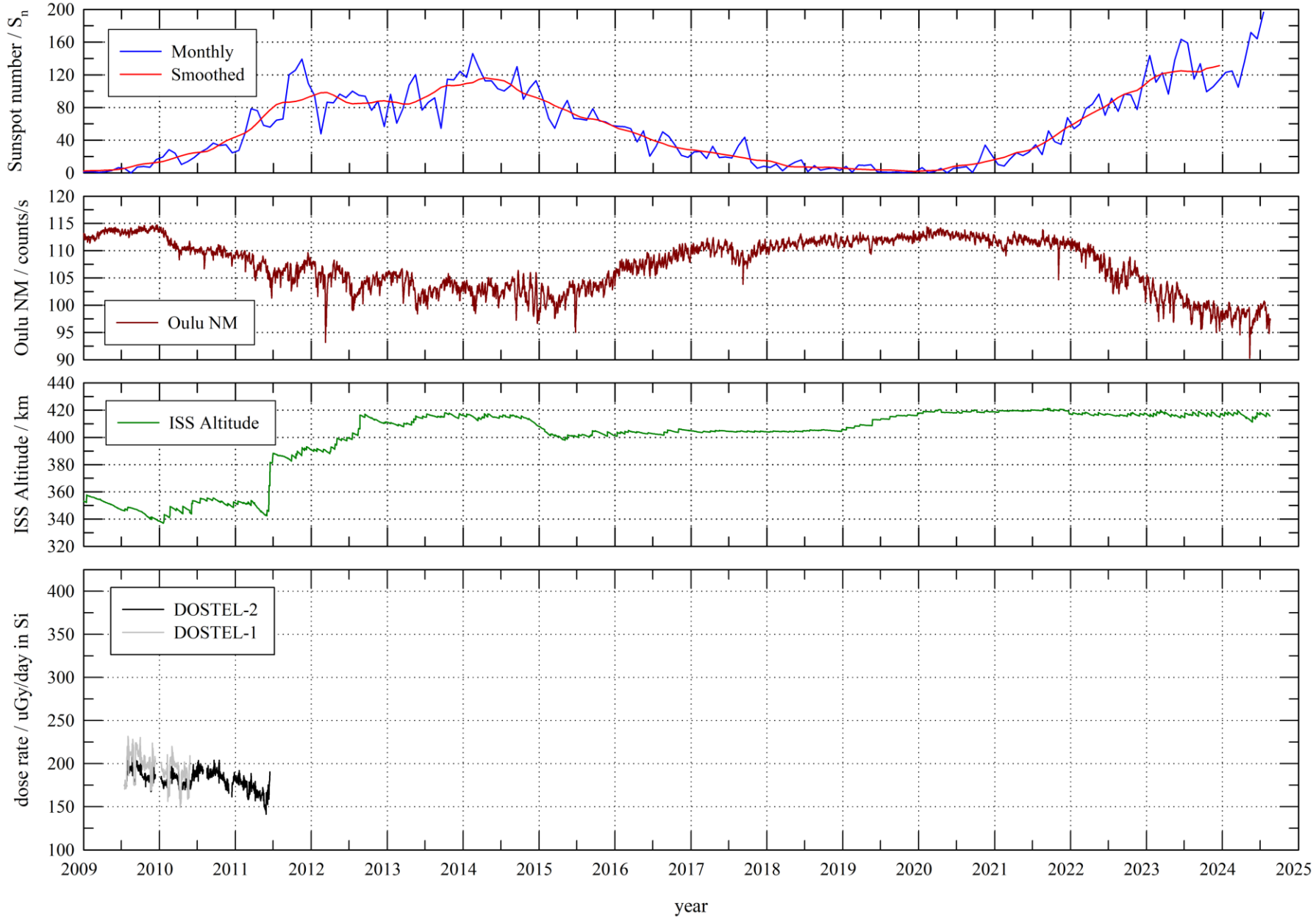


ESA EAD

Straube, U., Berger, T., Dieckmann, M. (2023) The ESA Active Dosimeter (EAD) system onboard the International Space Station (ISS). Zeitschrift für Medizinische Physik https://doi.org/10.1016/j.zemedi.2023.03.001

Results:

DOSIS
DOSTEL-1
DOSTEL-2

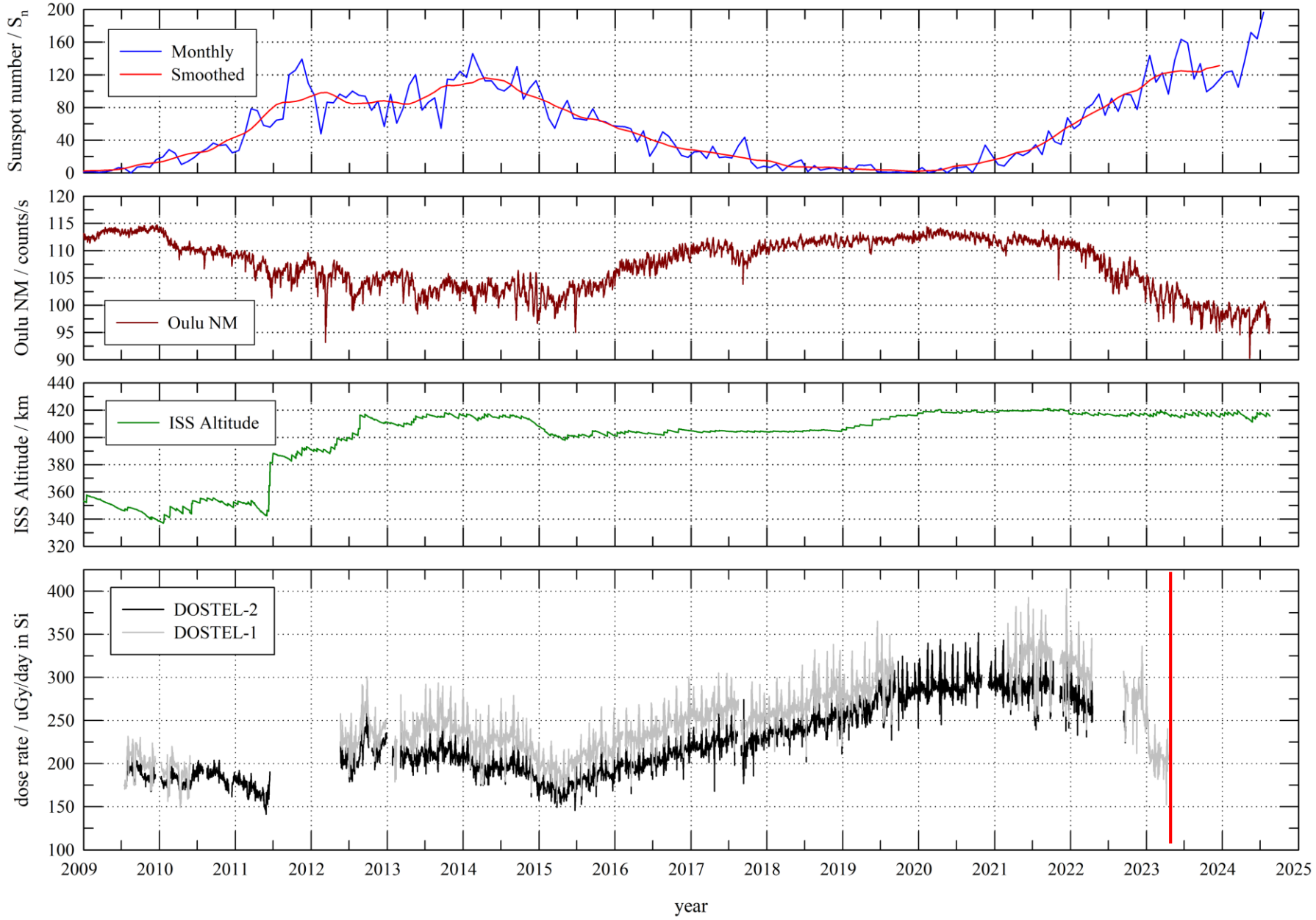


Absorbed dose rate (µGy/day) in Si

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, 39, 14-25. https://doi.org/10.1016/j.lssr.2023.04.002

Results:

DOSIS
DOSTEL-1
DOSTEL-2
+
DOSIS 3D
DOSTEL-1
DOSTEL-2



Absorbed dose rate (µGy/day) in Si

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, 39, 14-25. https://doi.org/10.1016/j.lssr.2023.04.002

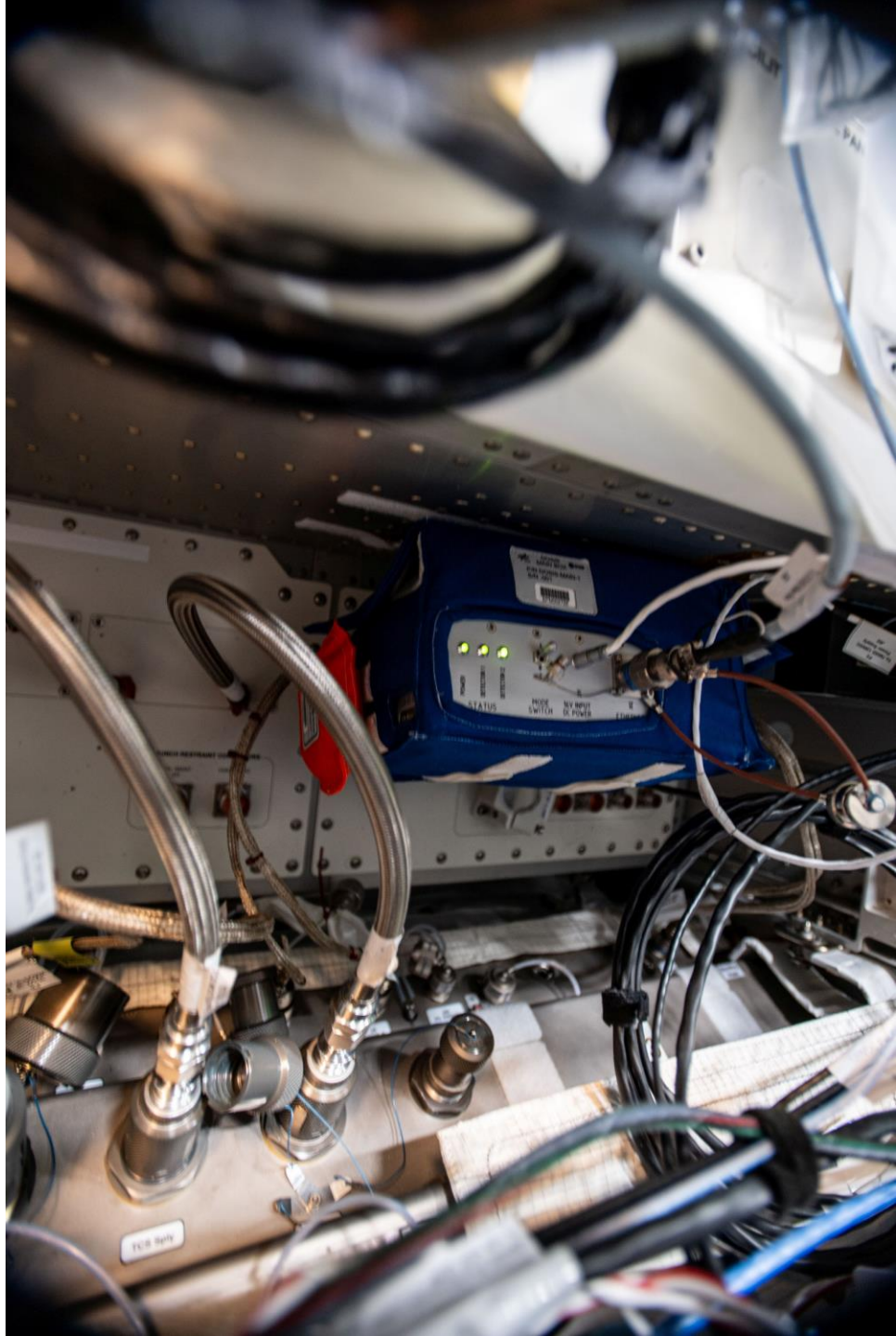
Intermezzo: DOSIS-MAIN-BOX ⇓⇑

23 April 2023 – 24 January 2024

⇓ **DOWN:** SPX-28 (30 June 2023)

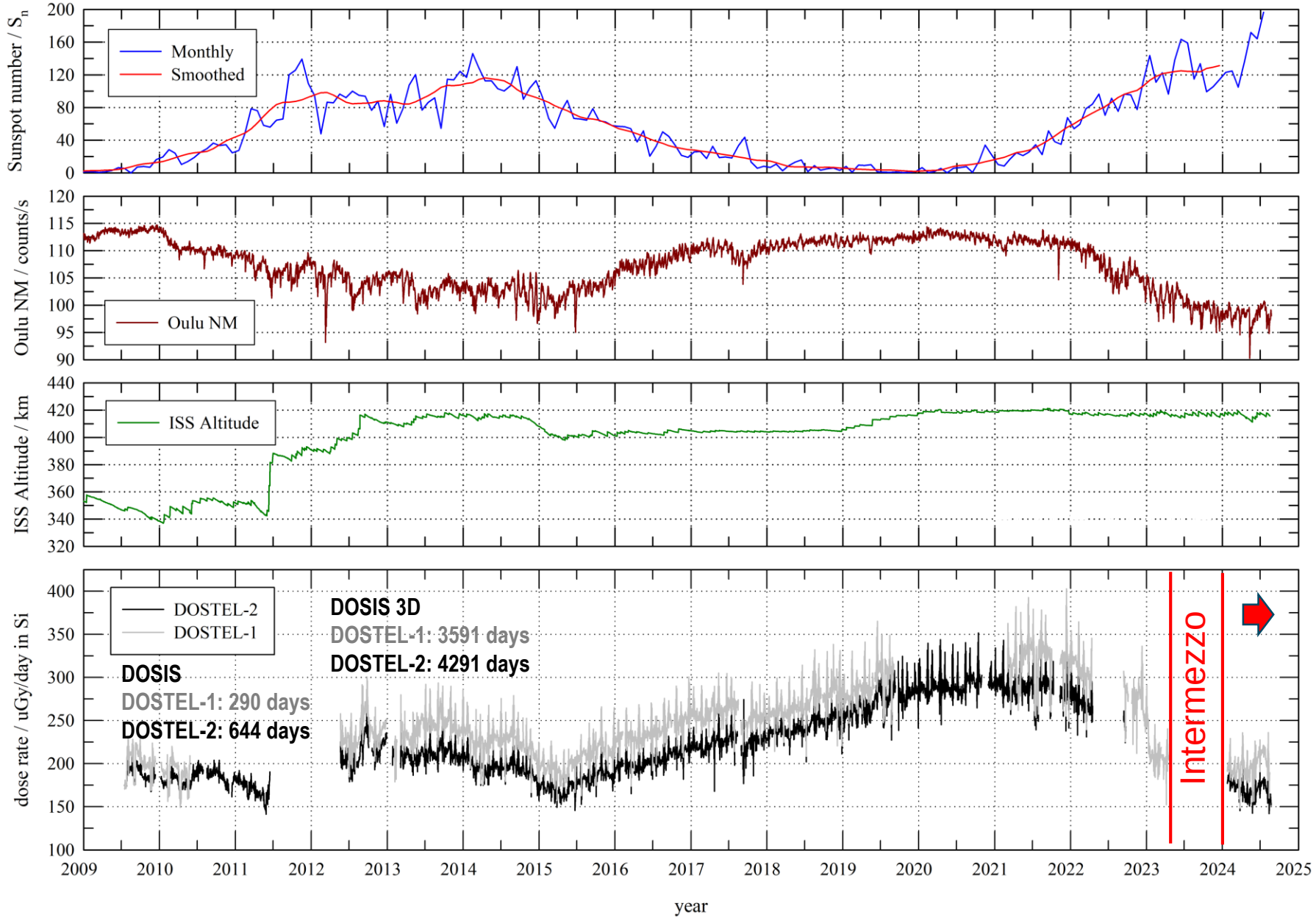
⇑ **UP:** AXIOM-3 (18 January 2024)

INSTALLATION: 24 January 2024 (ESA Project Astronaut Marcus Wandt (AXIOM-3)



Results:

DOSIS
DOSTEL-1
DOSTEL-2
+
DOSIS 3D
DOSTEL-1
DOSTEL-2

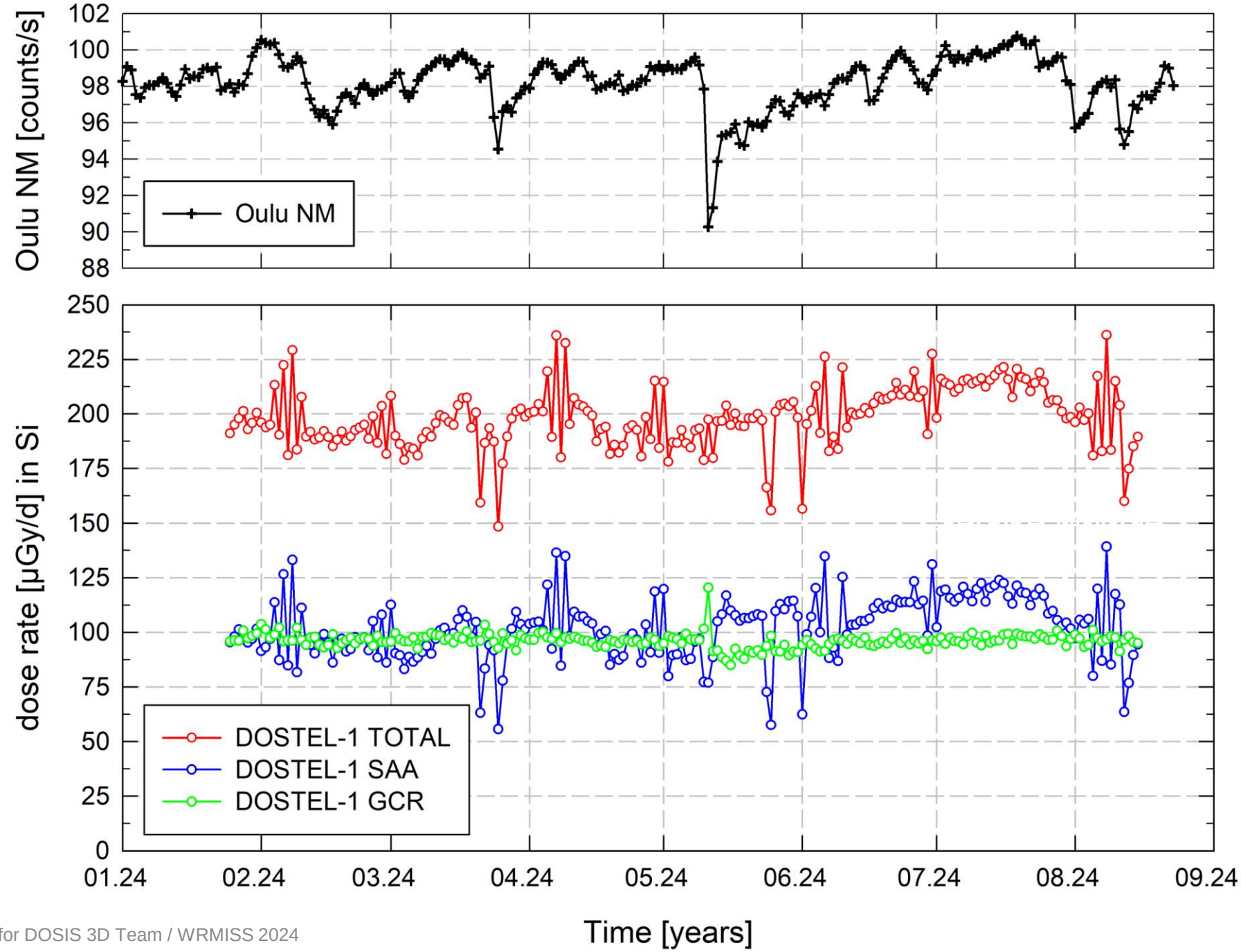


Absorbed dose rate (µGy/day) in Si

Results:

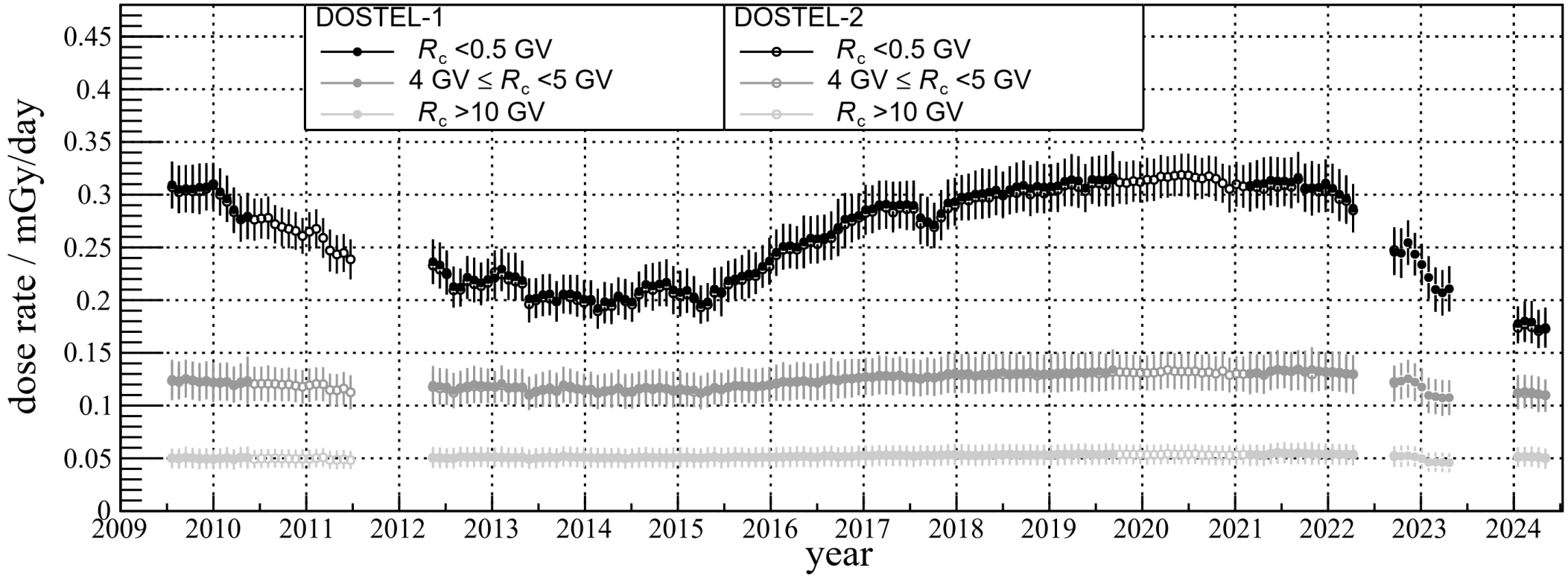
DOSIS 3D
DOSTEL-1
DOSTEL-2

2024



Results:

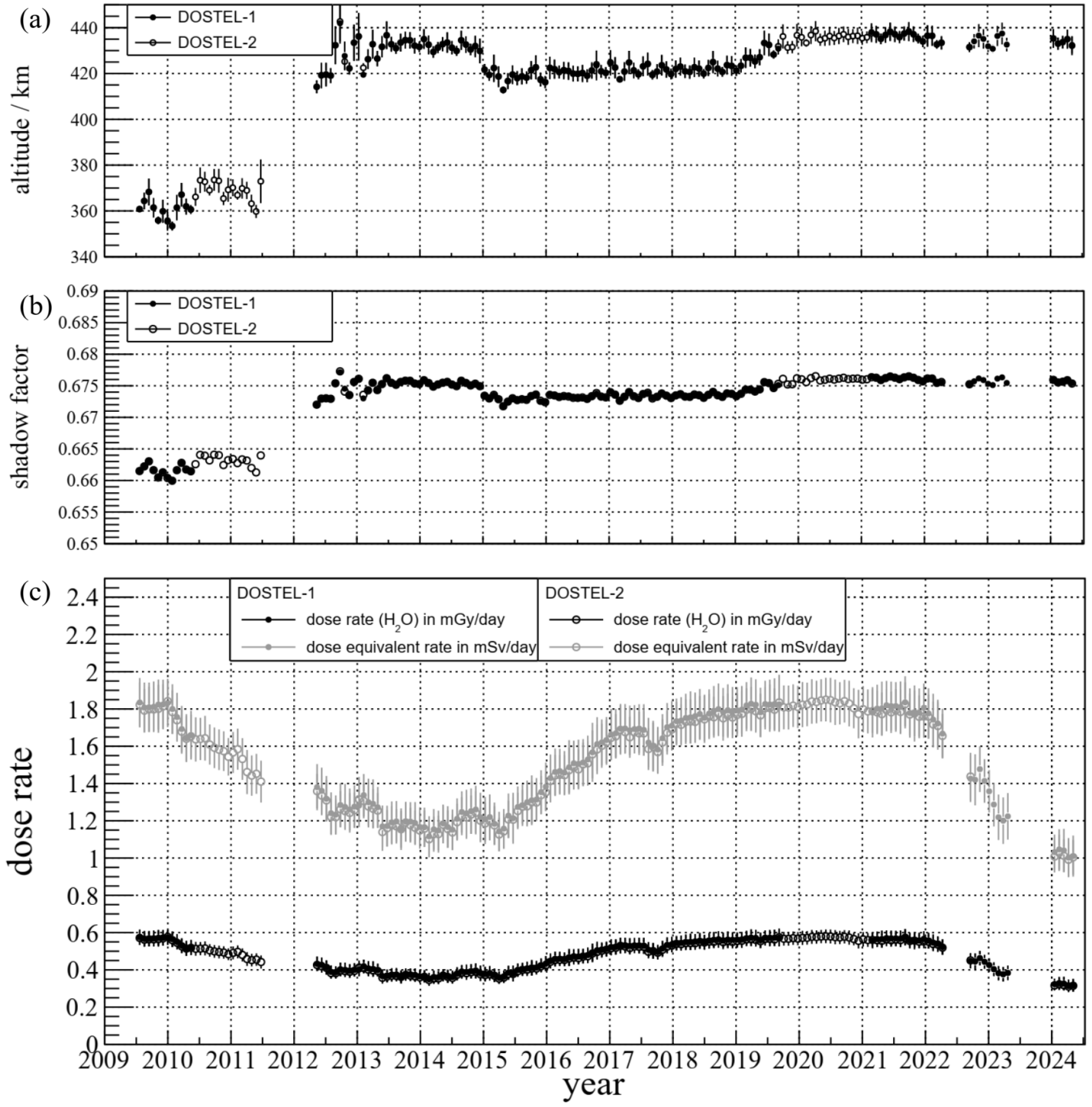
DOSIS
DOSTEL-1
DOSTEL-2
+
DOSIS 3D
DOSTEL-1
DOSTEL-2



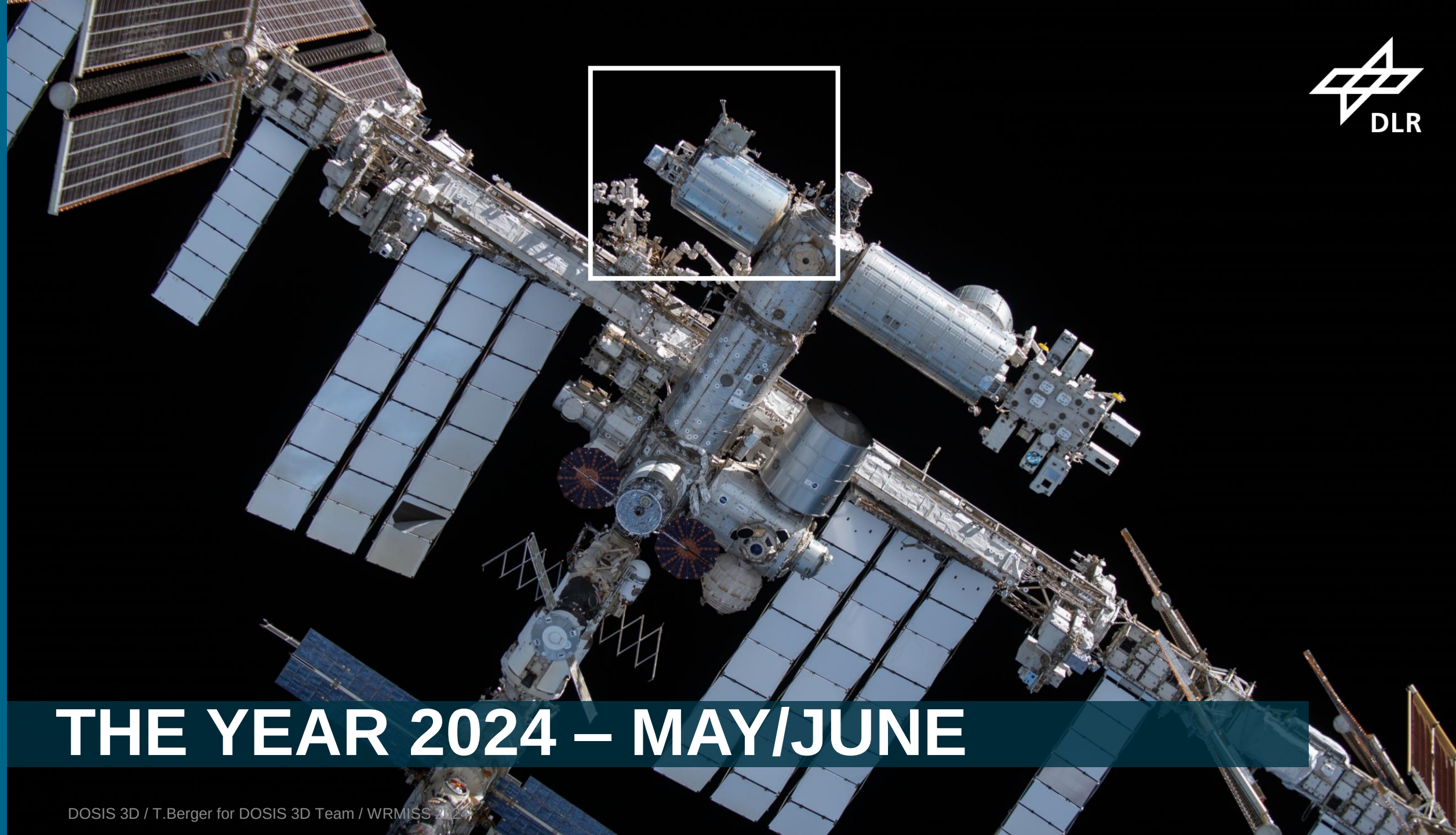
Matthiä, D., Burmeister, S., Przybyla, B., Berger, T. (2023) Active radiation measurements over one solar cycle with two DOSTEL instruments in the Columbus laboratory of the International Space Station. Life Sciences in Space Research, 39, 14-25. https://doi.org/10.1016/j.lssr.2023.04.002

Results:

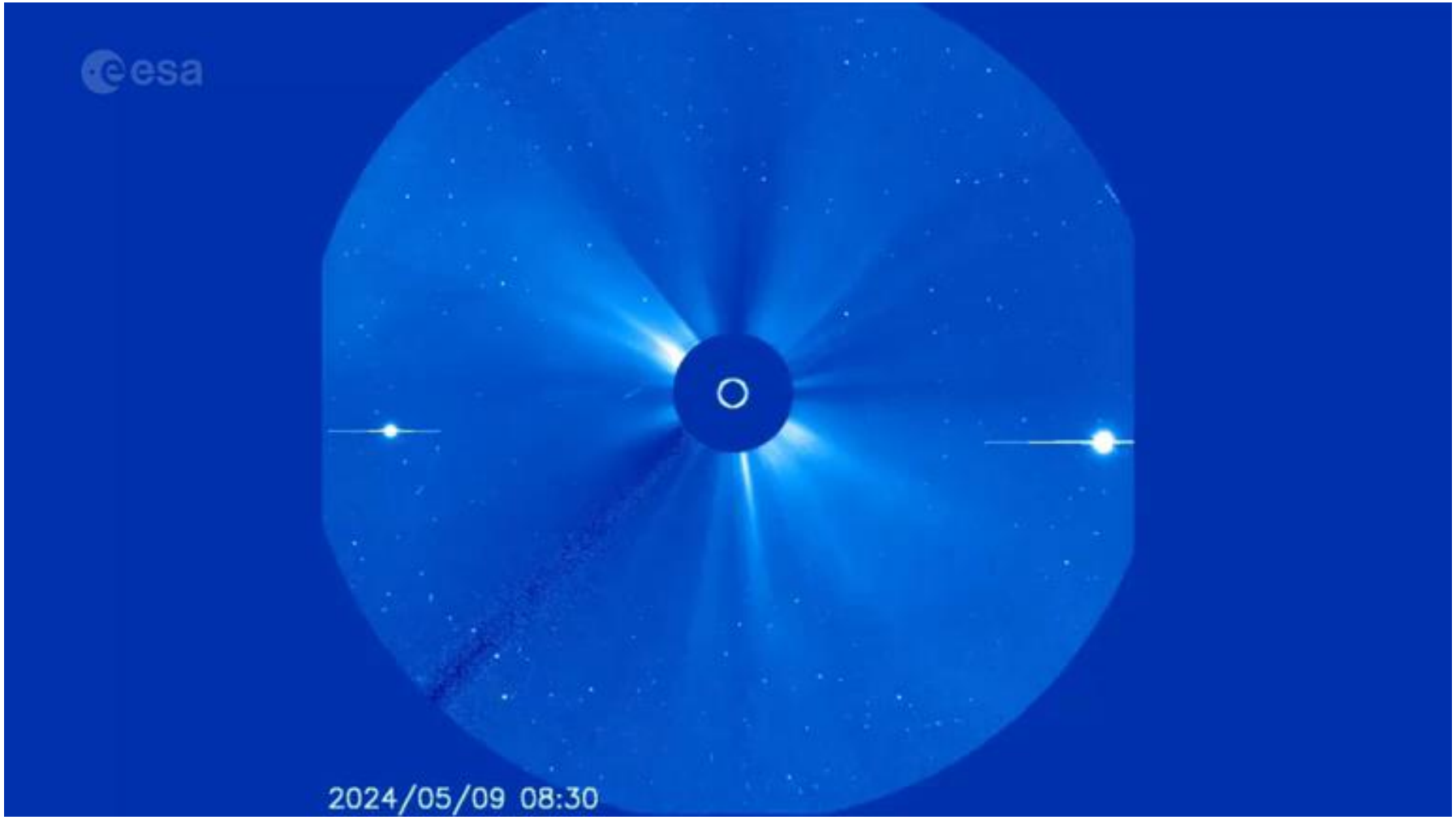
DOSIS
DOSTEL-1
DOSTEL-2
+
DOSIS 3D
DOSTEL-1
DOSTEL-2



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, 39, 14-25. https://doi.org/10.1016/j.lssr.2023.04.002

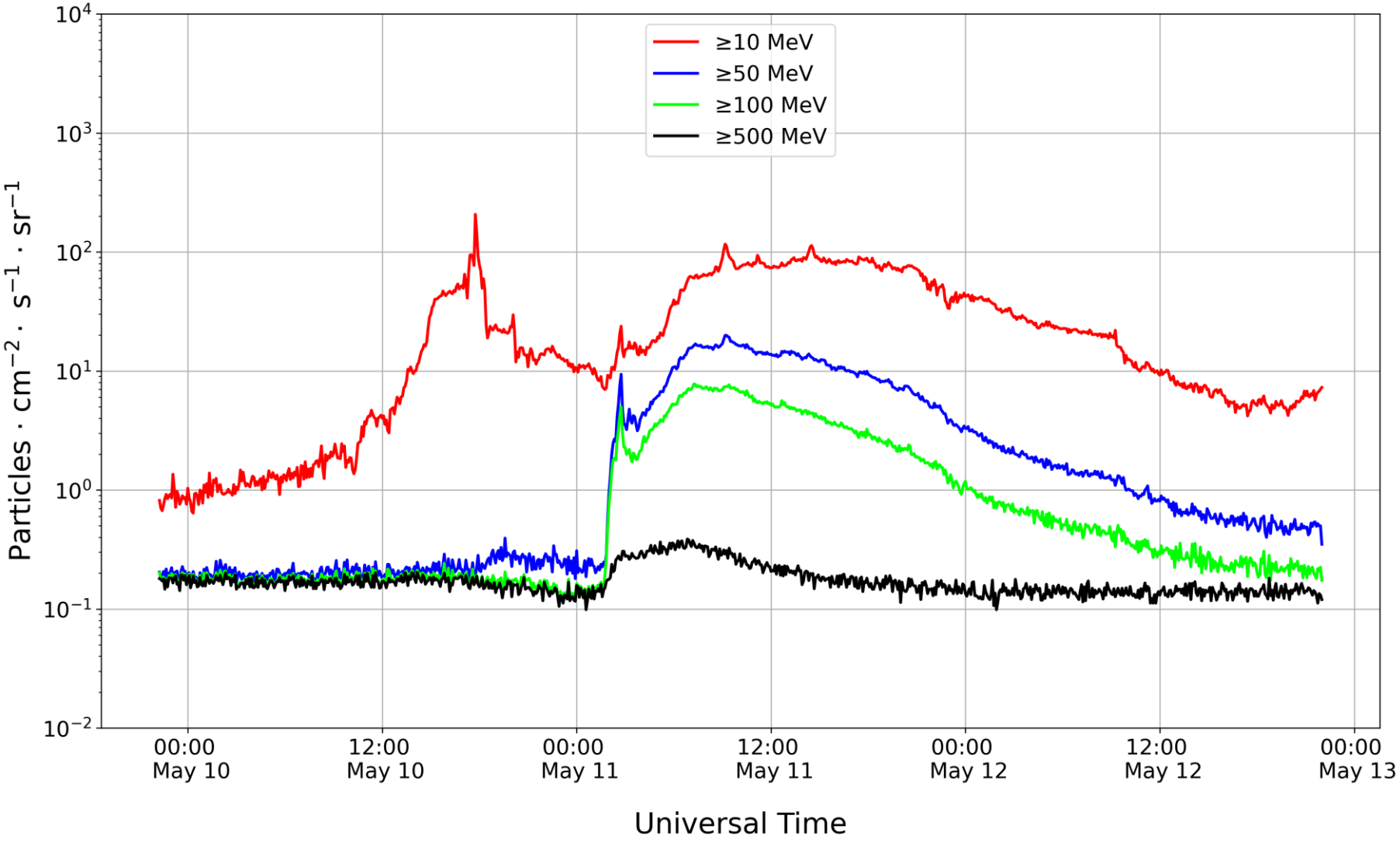


THE YEAR 2024 – MAY/JUNE



https://www.esa.int/Space_Safety/Space_weather/The_May_2024_solar_storm_your_questions_answeredEvents

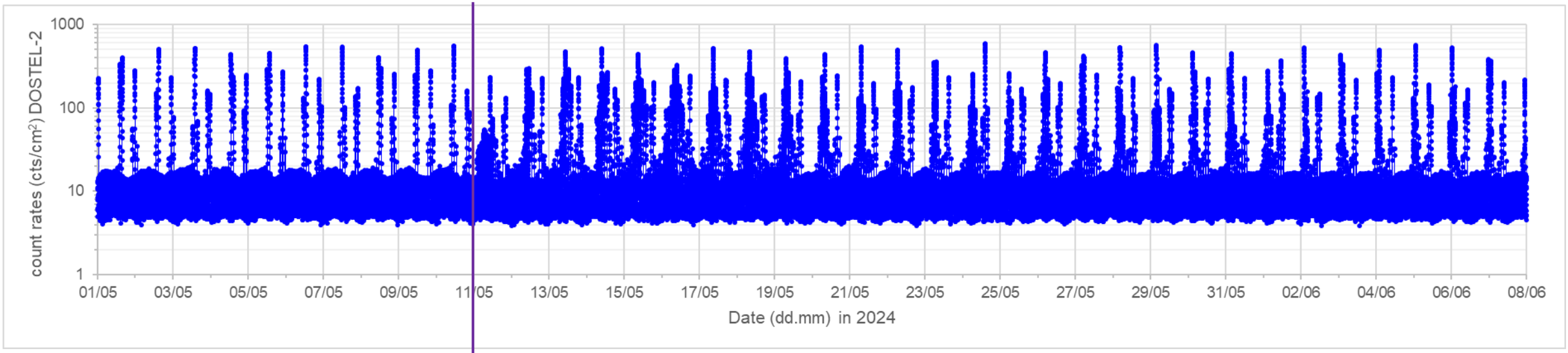
11TH MAY 2024

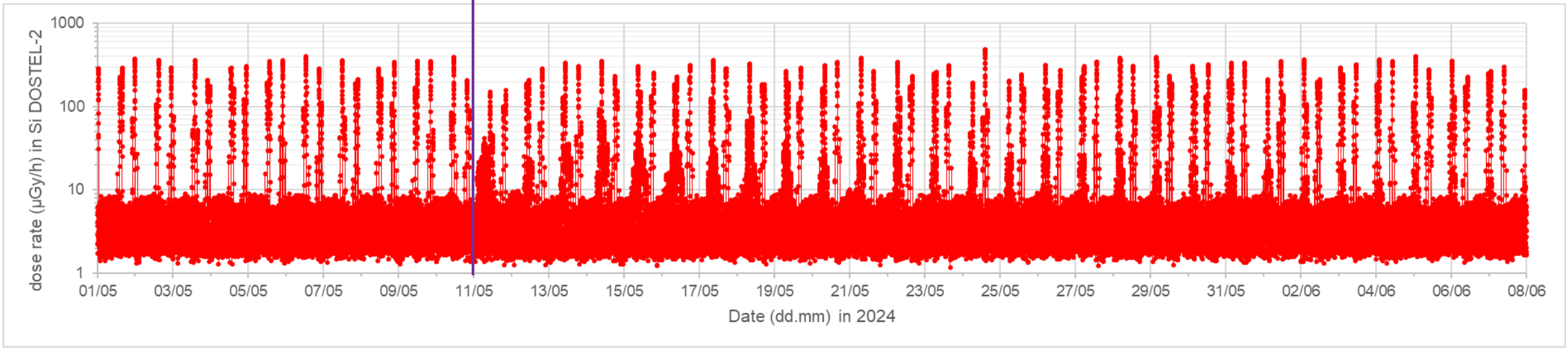


11TH MAY 2024

Results: count rate / dose rate vs. Time

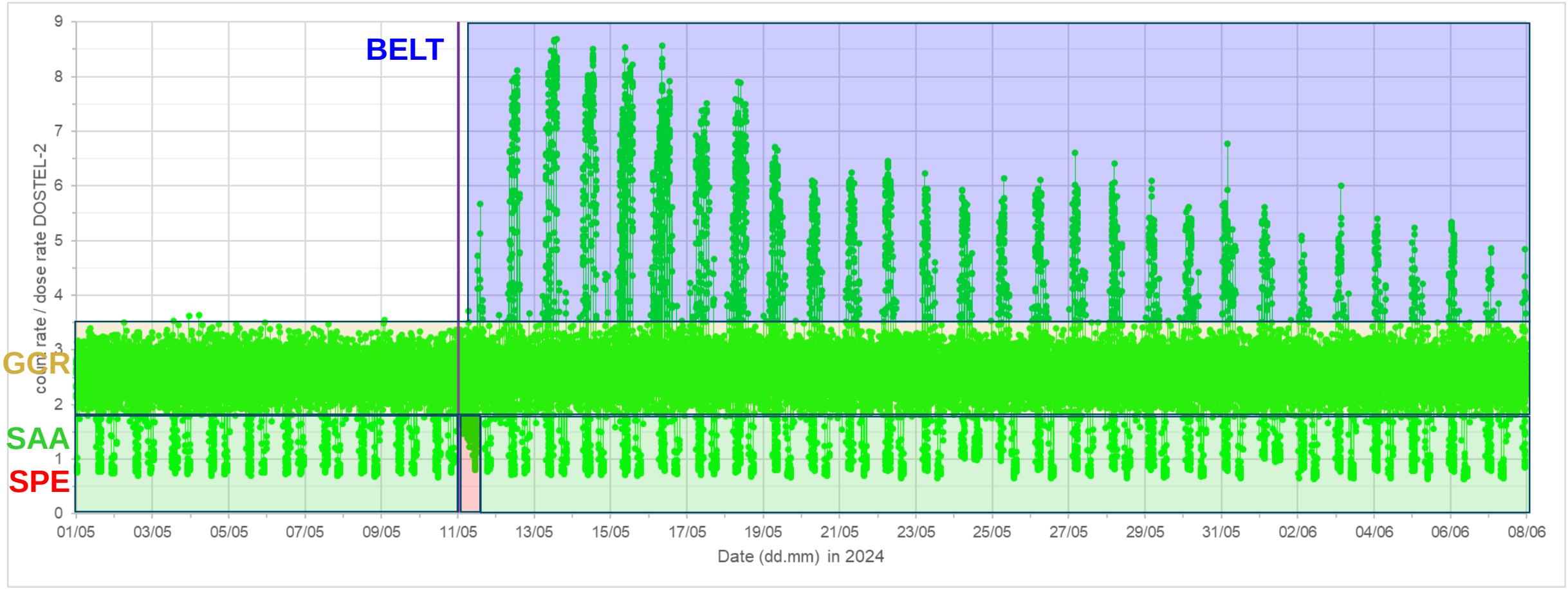
DOSTEL-2





Results: count rate/dose rate vs. Time

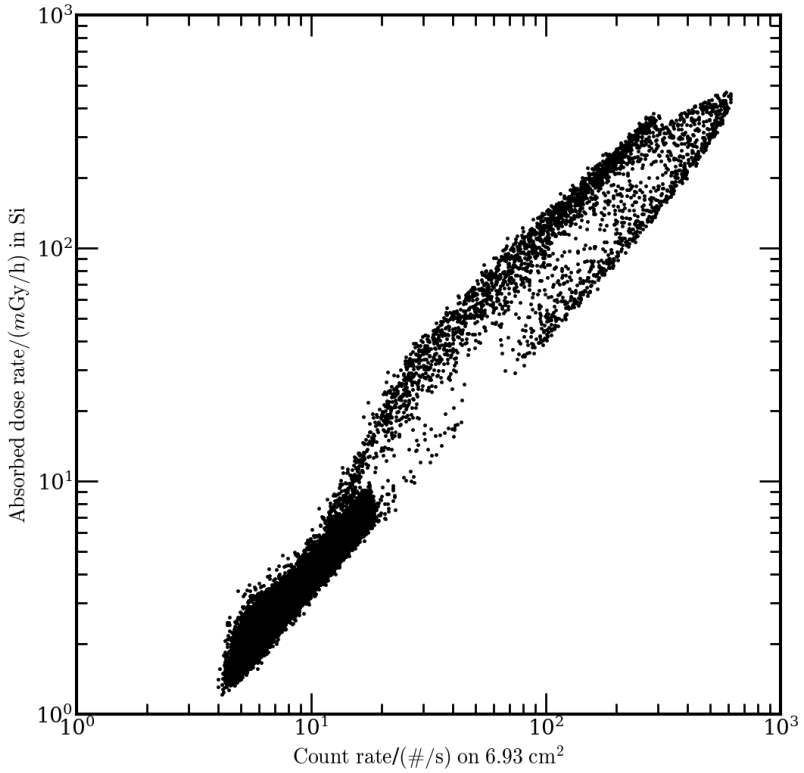
DOSTEL-2



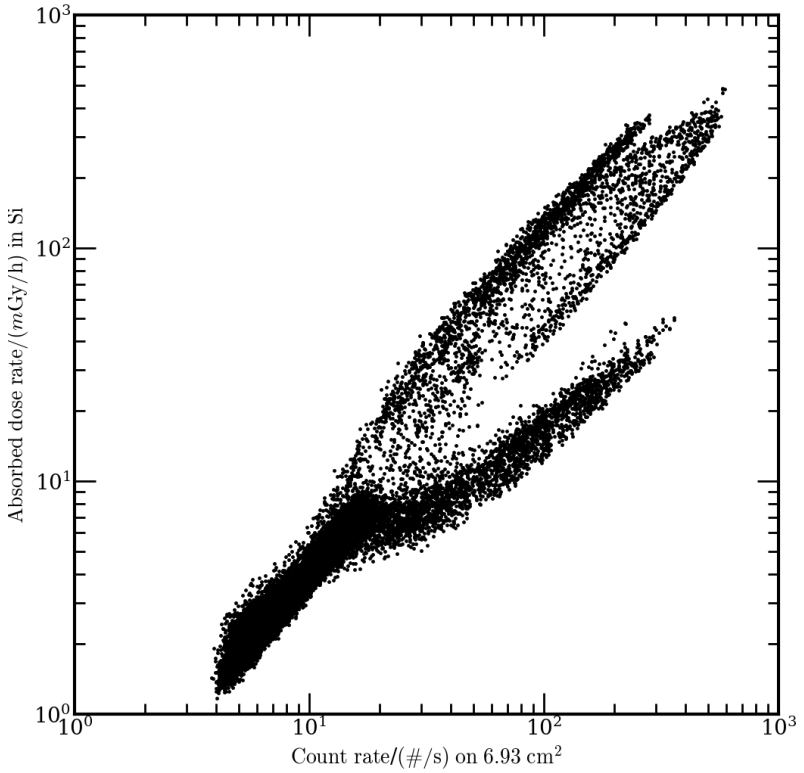
Results: count rate/dose rate vs. Time

DOSTEL-2

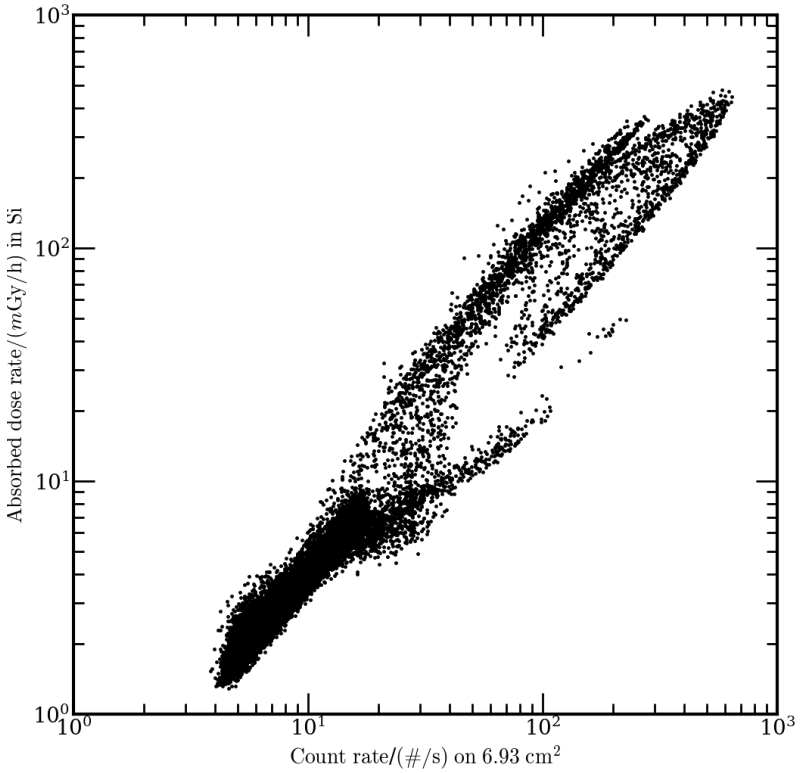
DOSTEL-2 D2, 01.04.2024 to 01.05.2024



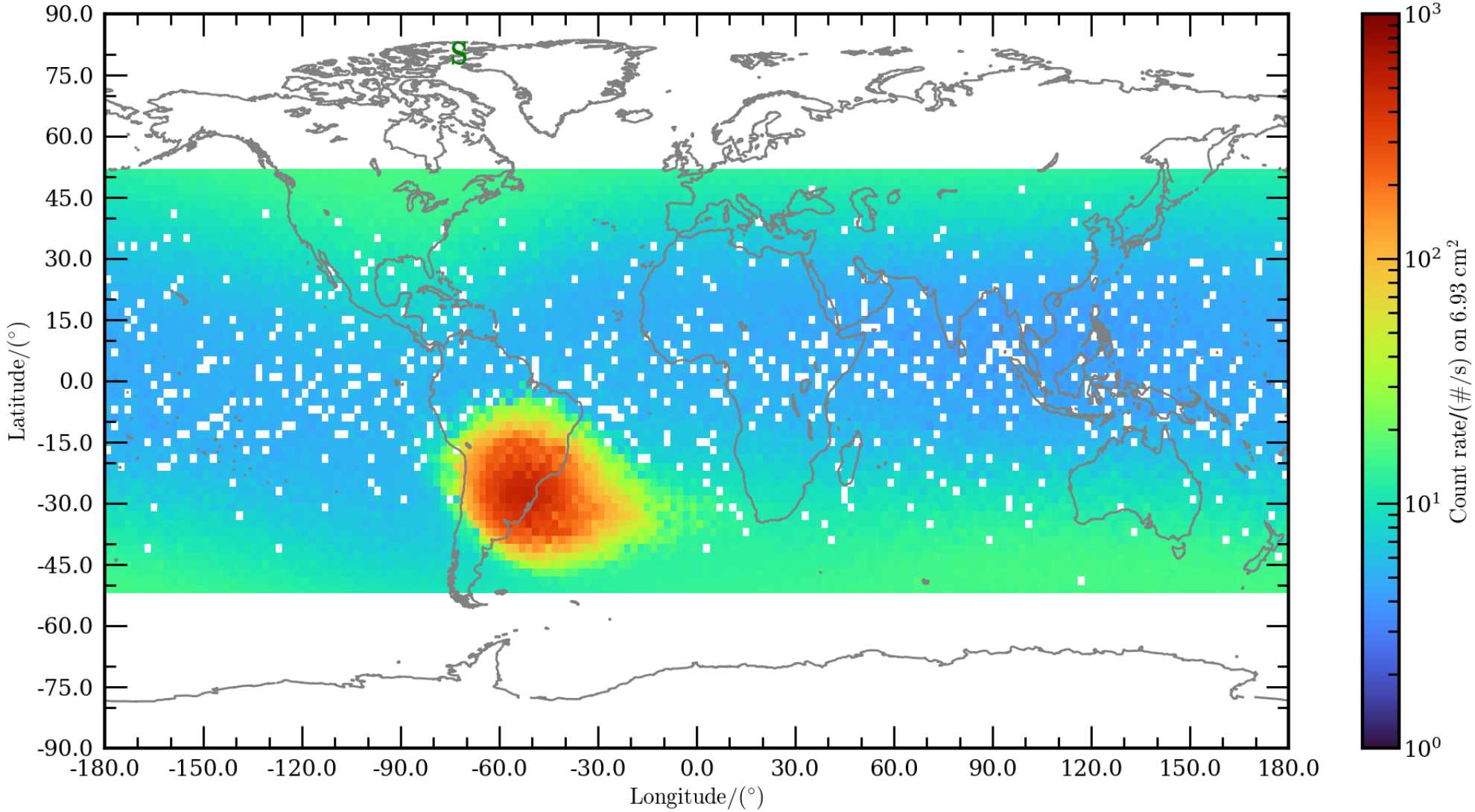
DOSTEL-2 D2, 01.05.2024 to 01.06.2024



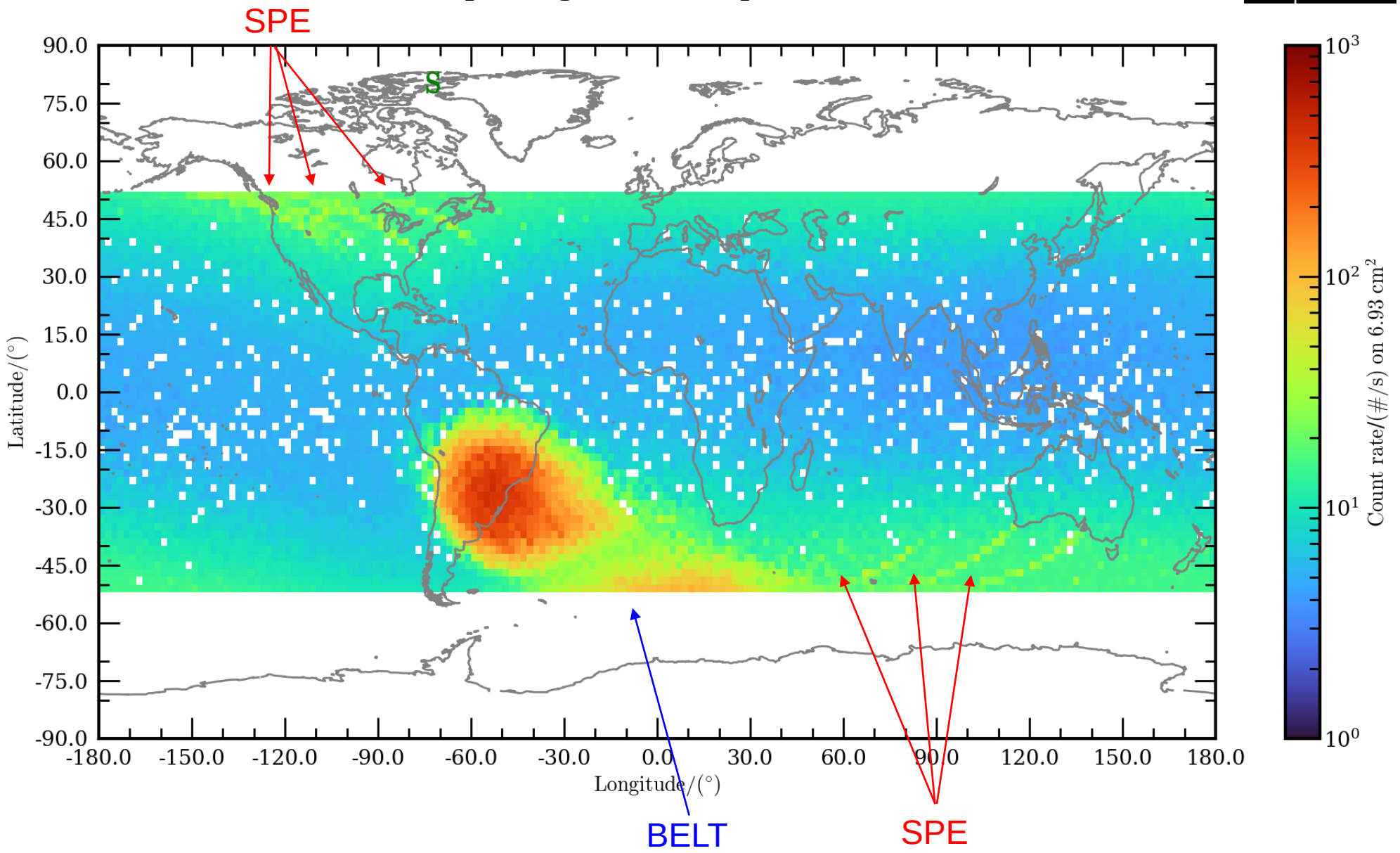
DOSTEL-2 D2, 01.06.2024 to 01.07.2024



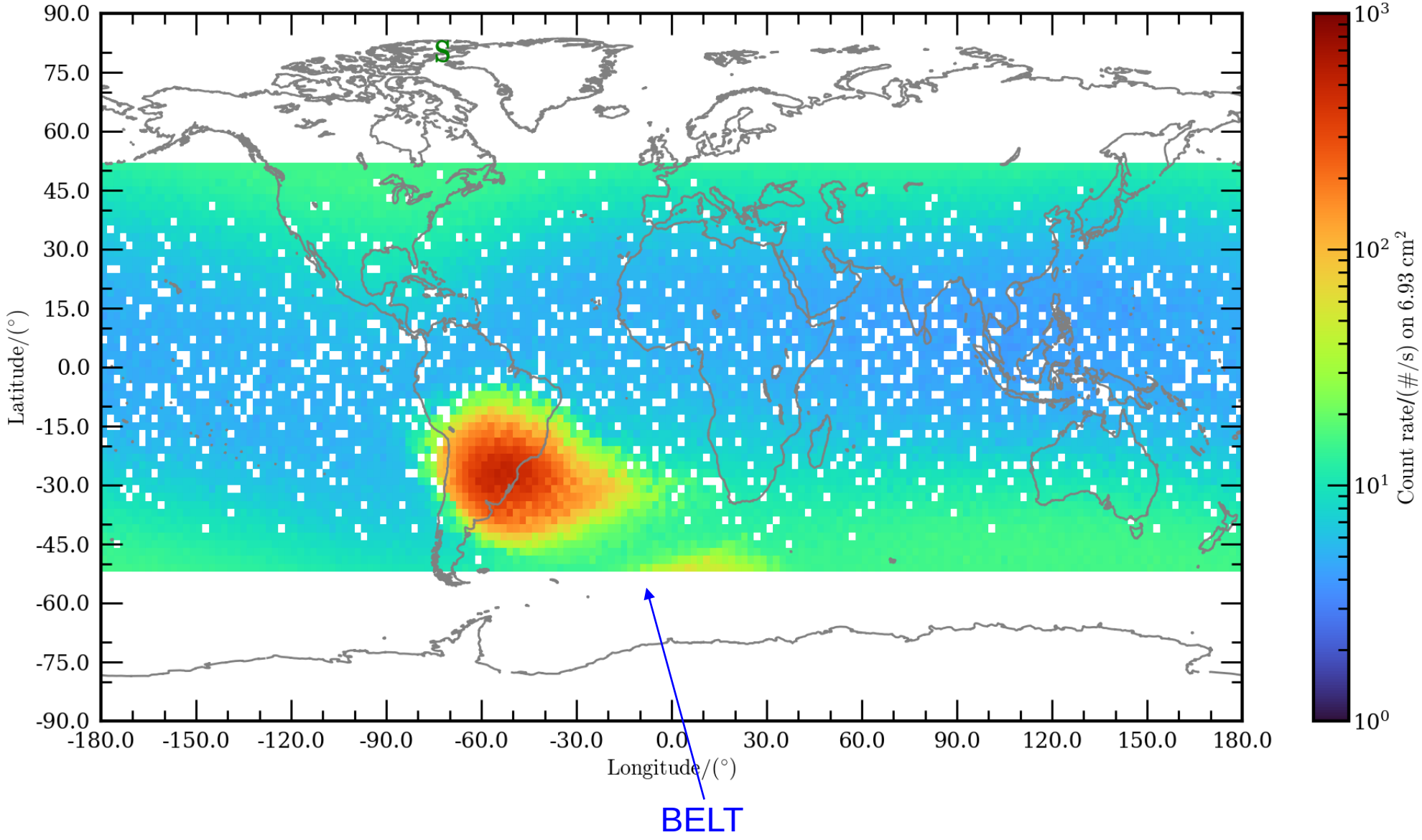
Results: count rates (April 2024)



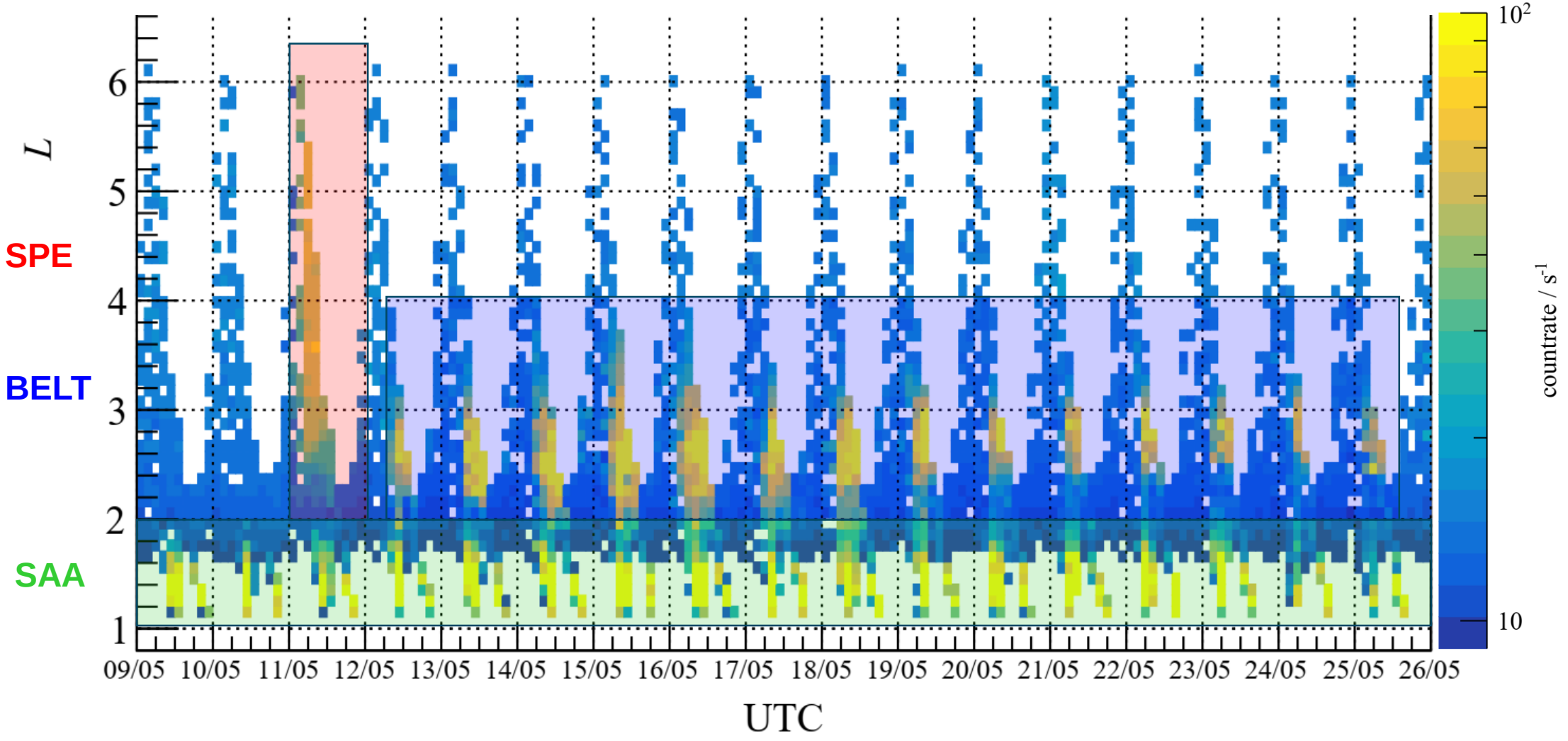
Results: count rates (May 2024)



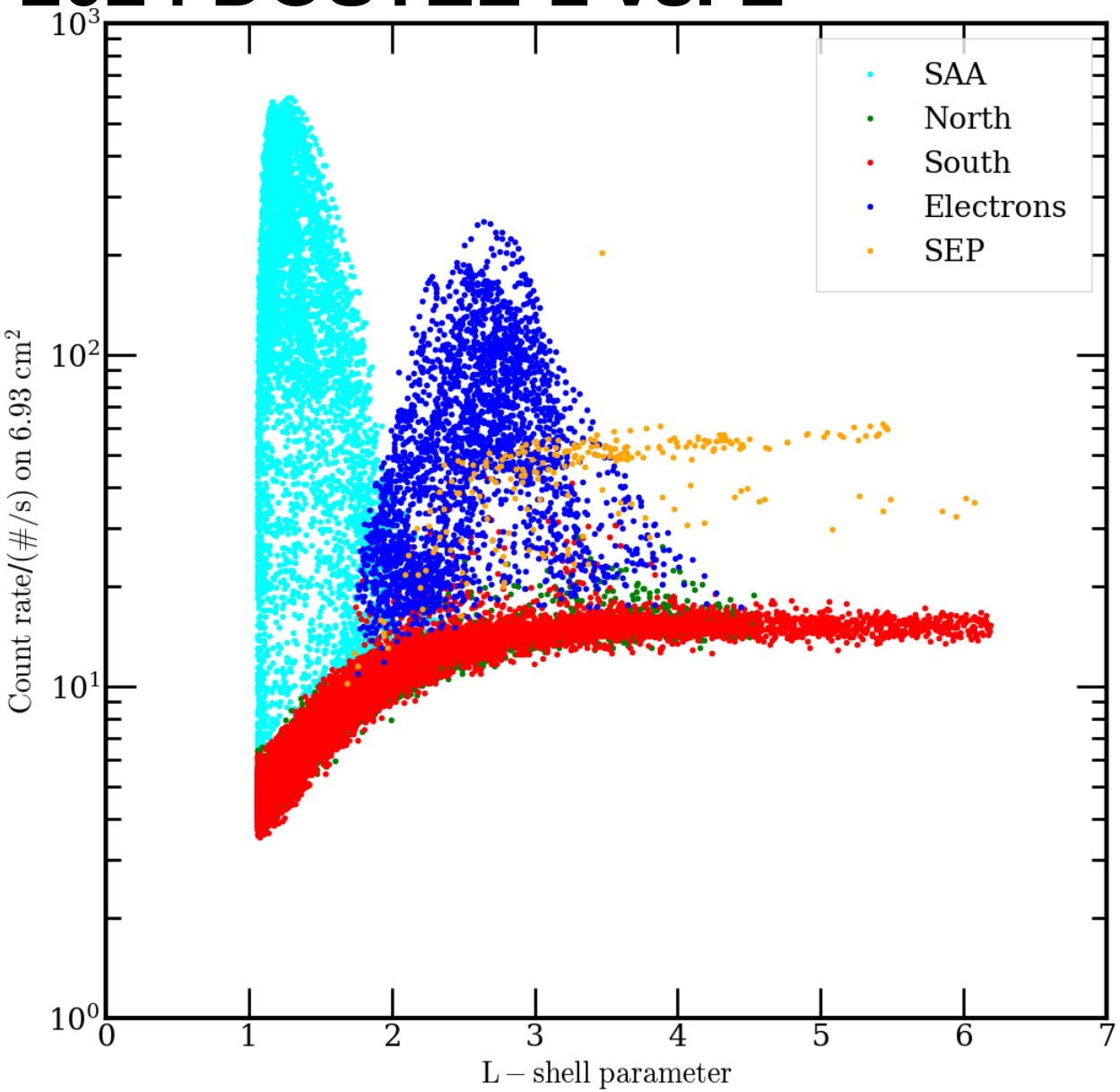
Results: count rates (June 2024)



Results: ratio count rate vs. Time & L

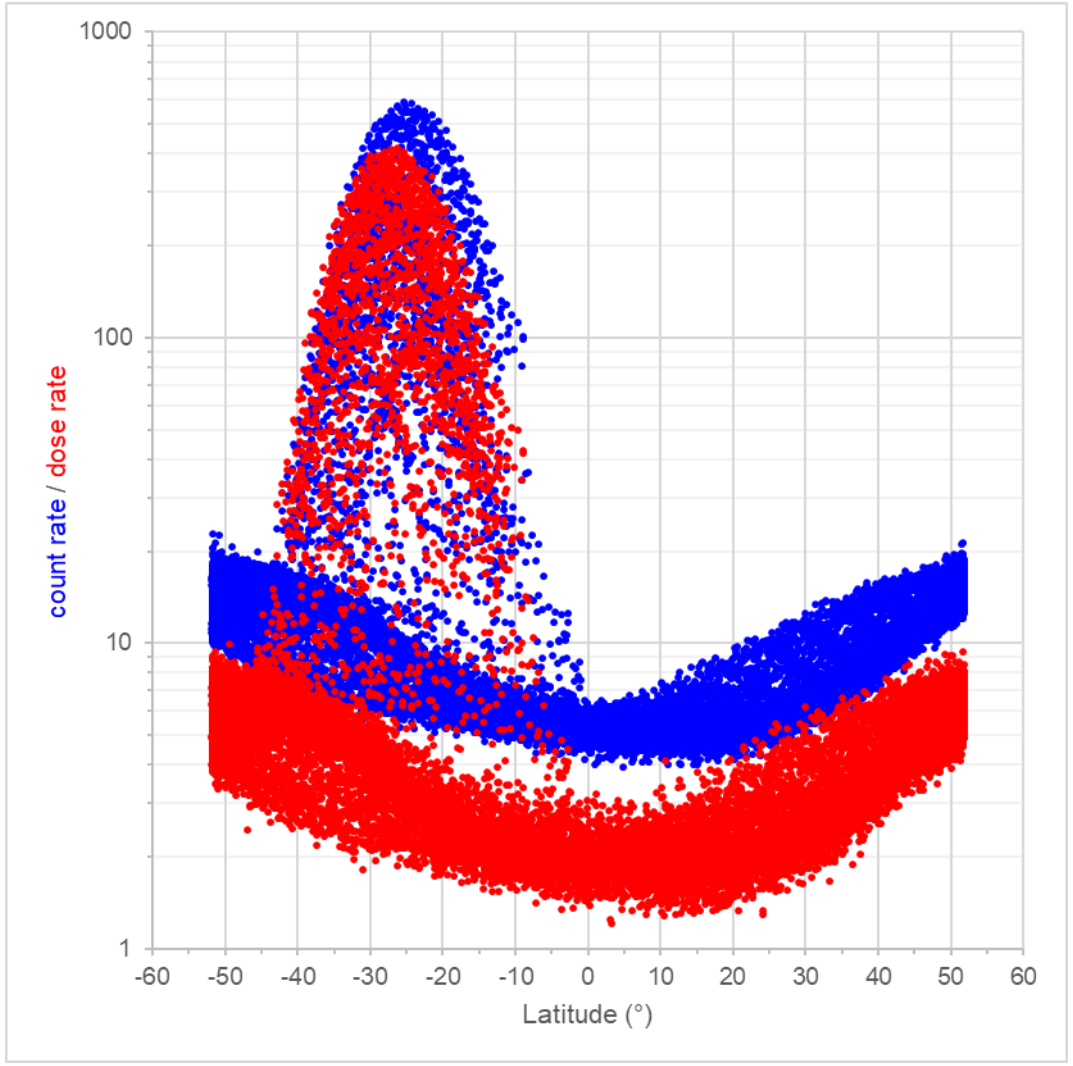


Results: May 2024 DOSTEL-1 vs. L

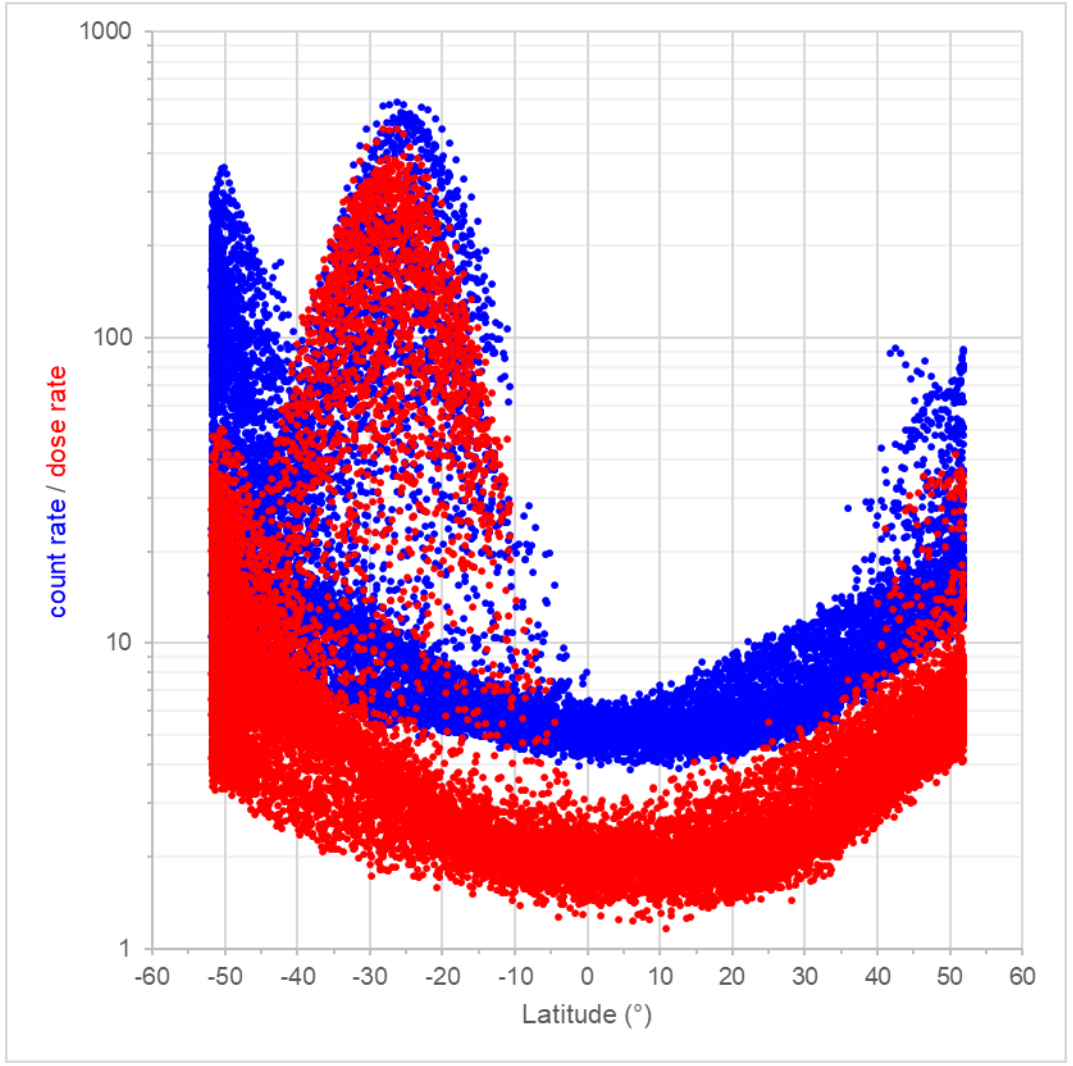


Results: count rate / dose rate vs. Latitude

DOSTEL-2: before 11th May 2024

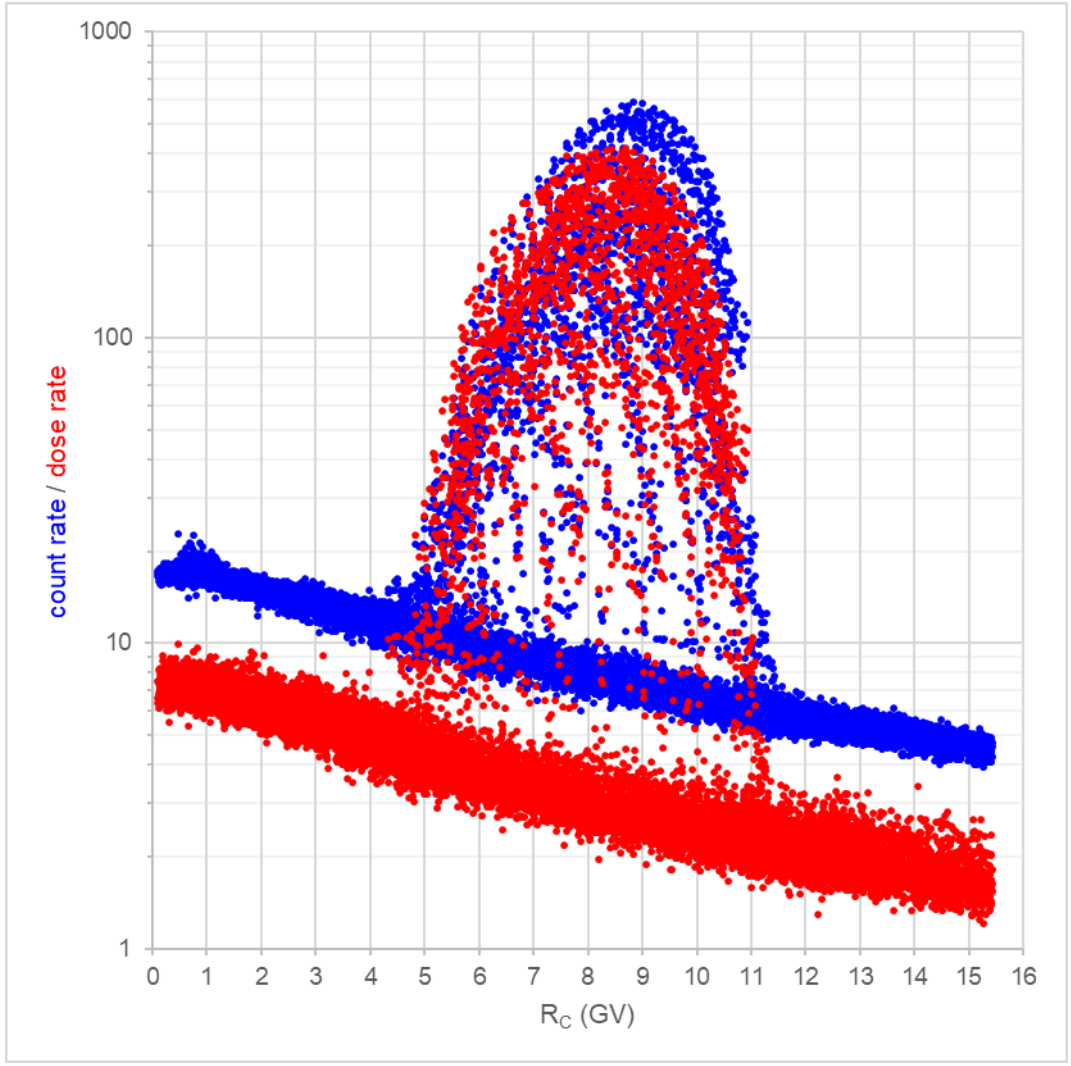


DOSTEL-2: after 11th May 2024

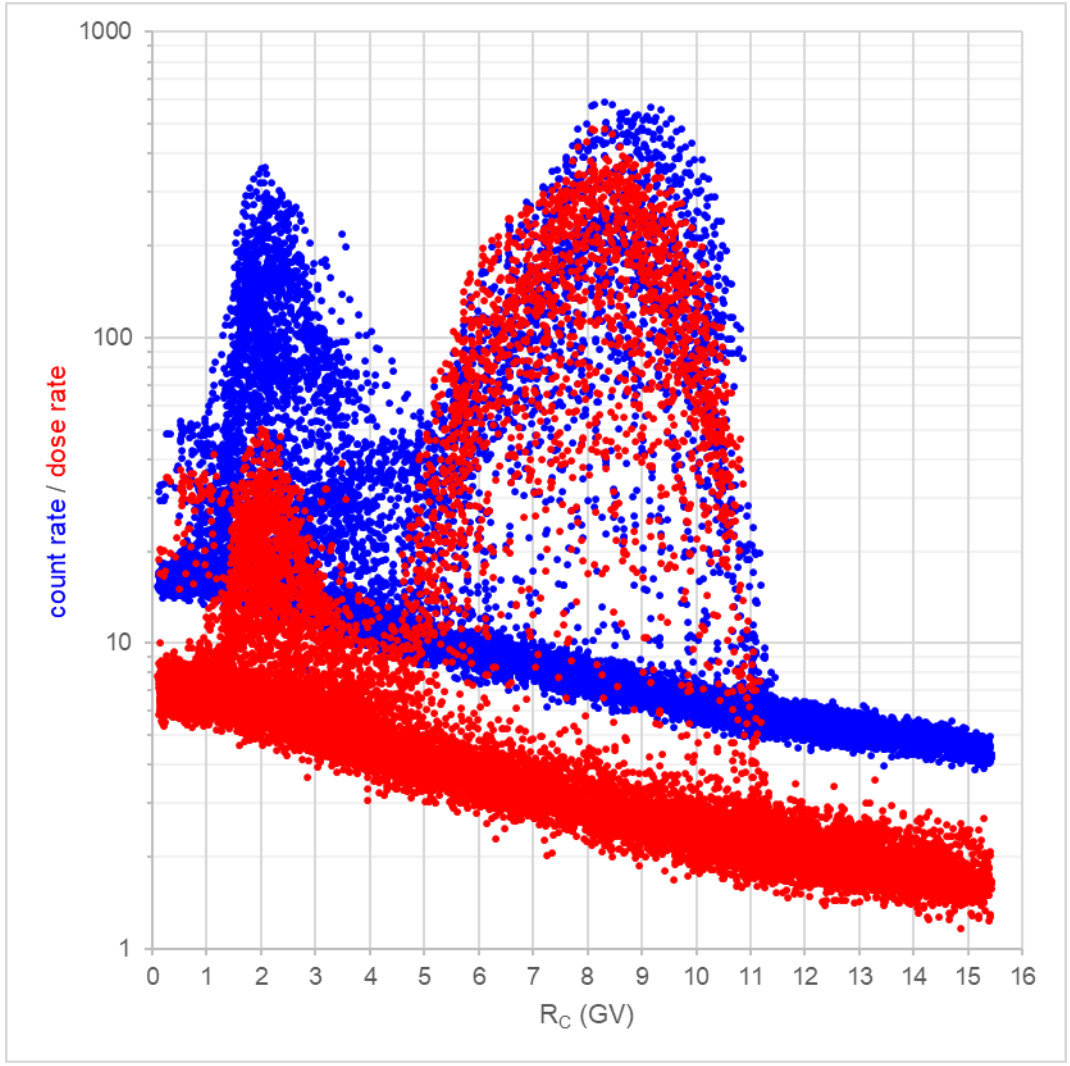


Results: count rate / dose rate vs. R_C

DOSTEL-2: before 11th May 2024

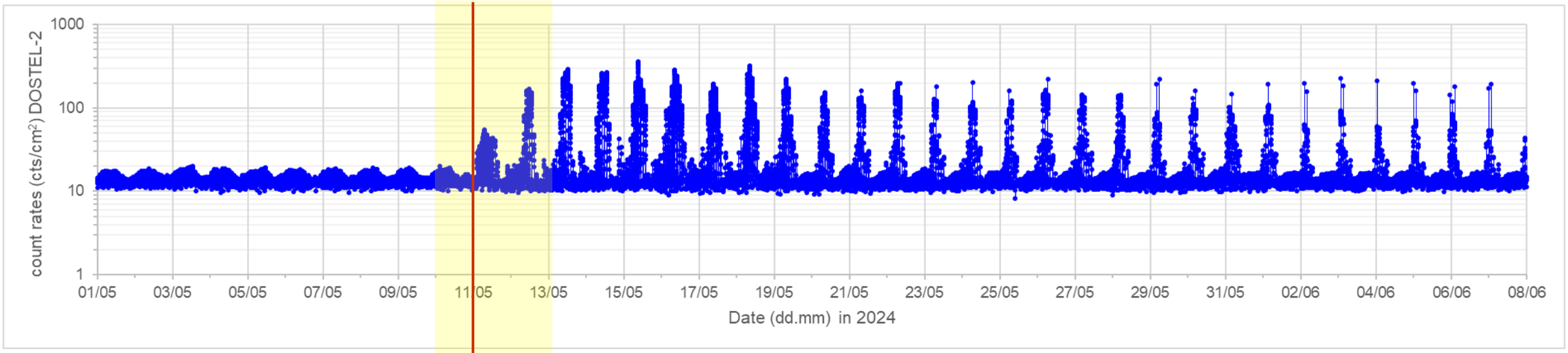


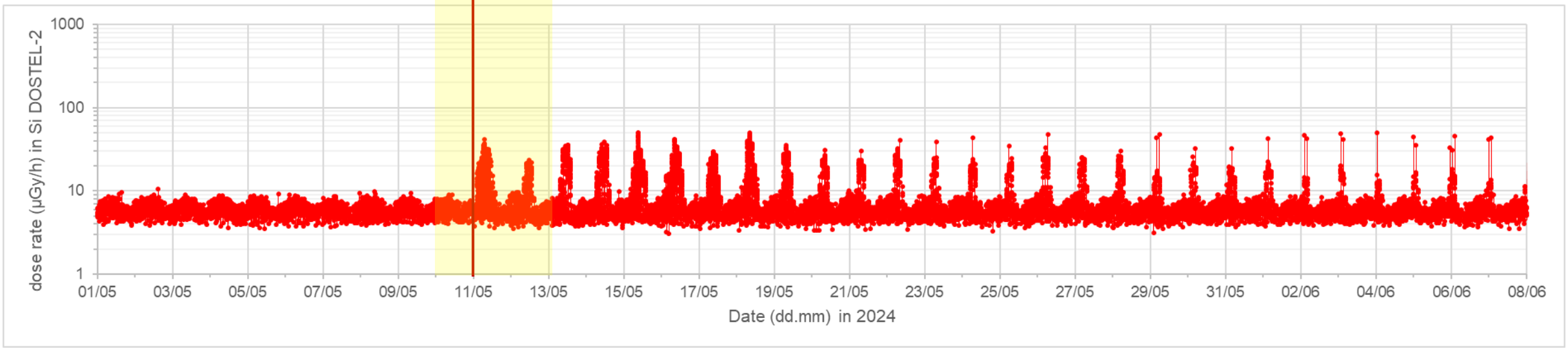
DOSTEL-2: after 11th May 2024



Results: count rate / dose rate vs. Time

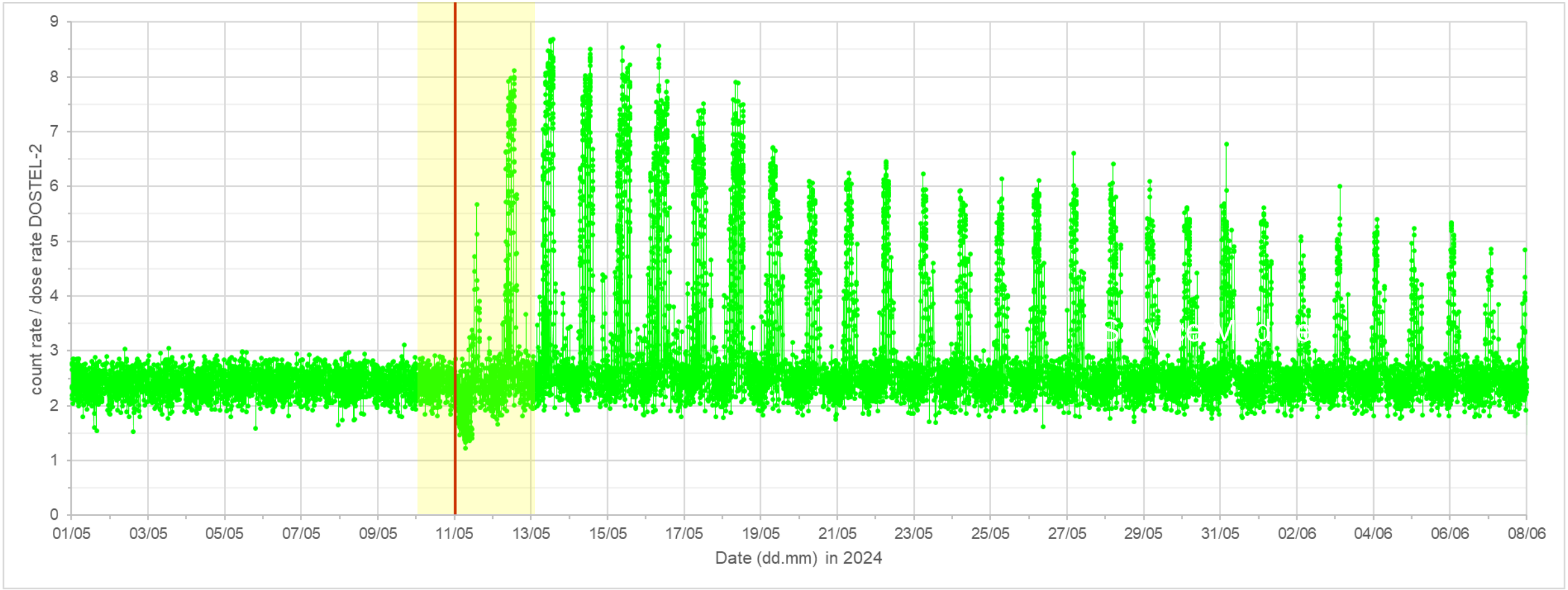
DOSTEL-2 R_C < 4.5 GV



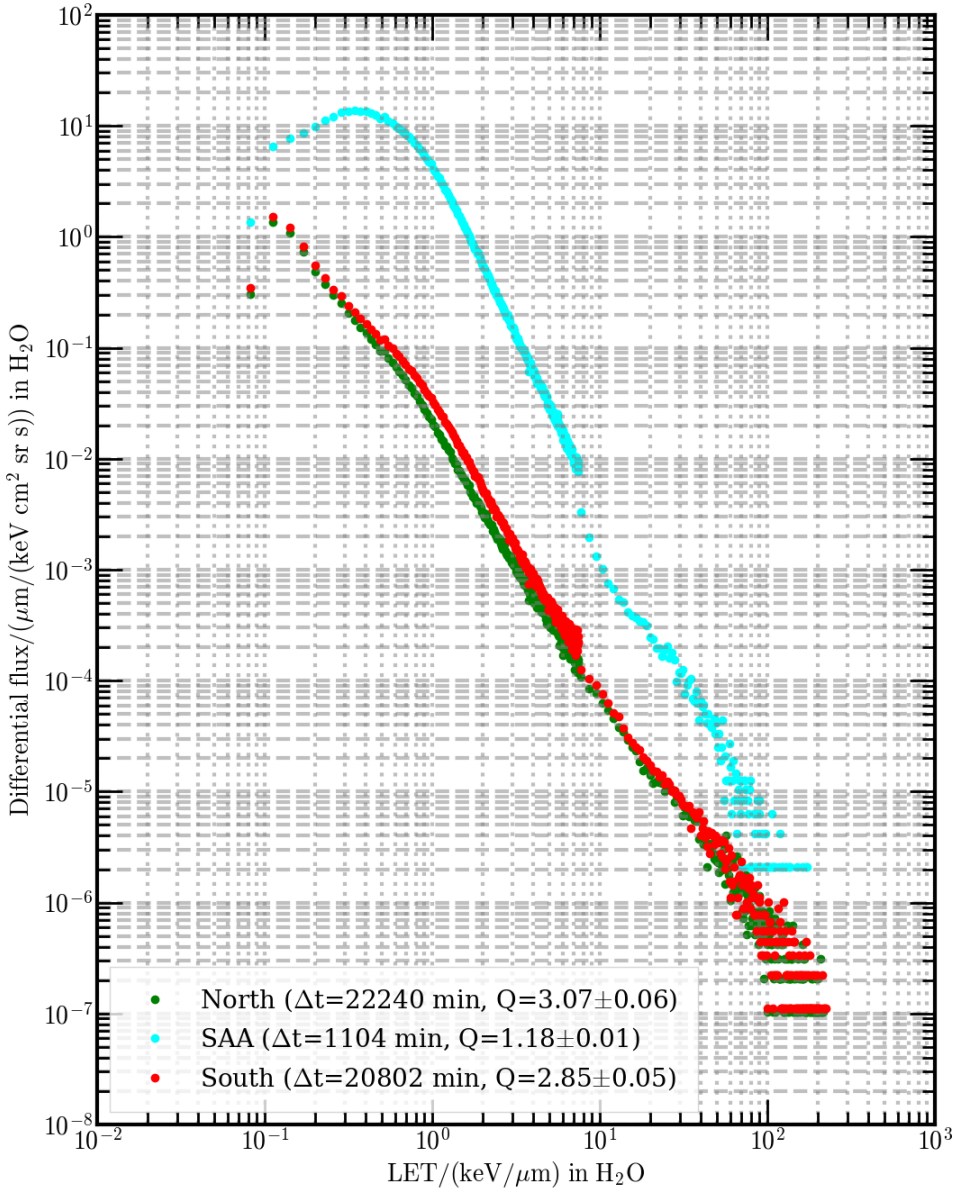


Results: count rate/dose rate vs. Time

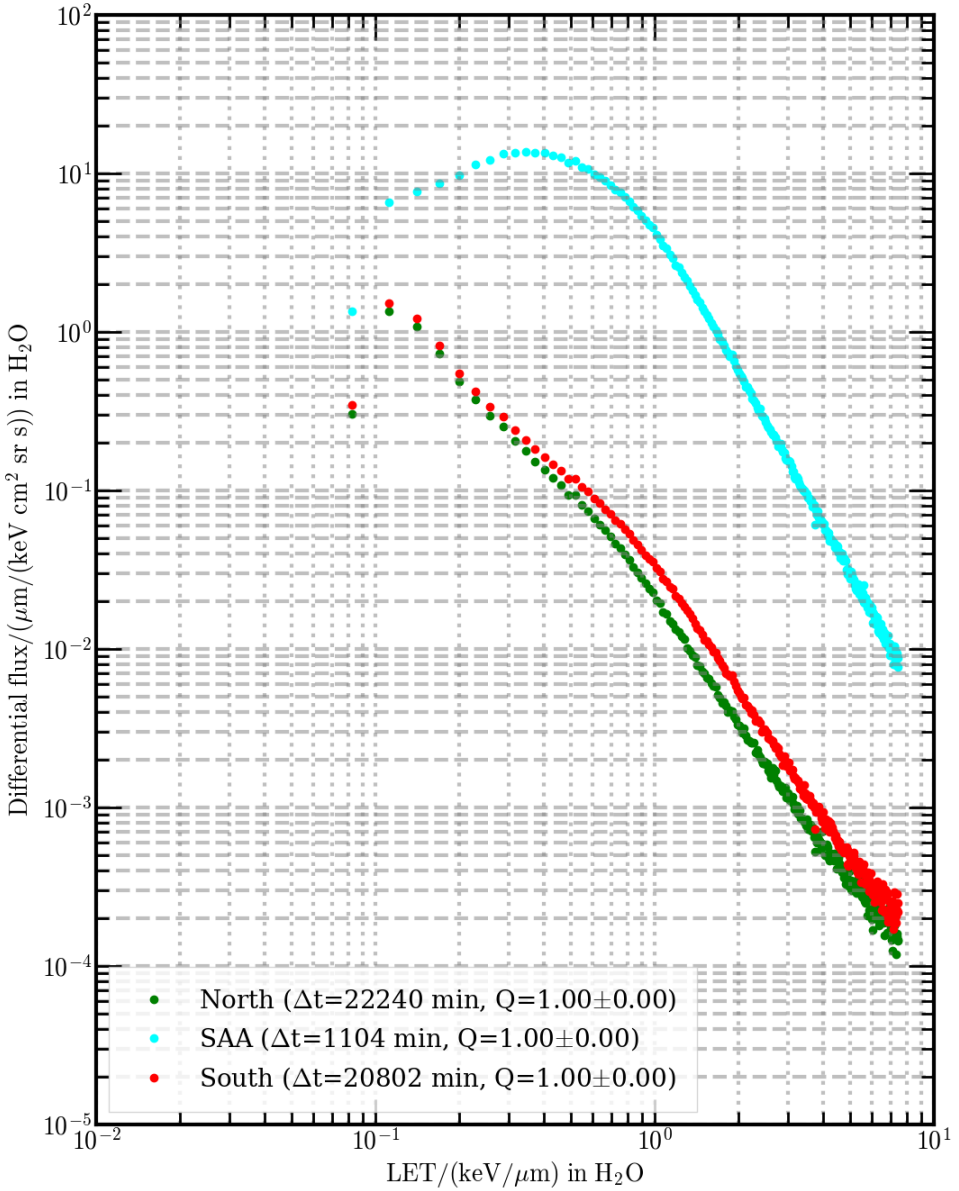
DOSTEL-2 R_C < 4.5 GV



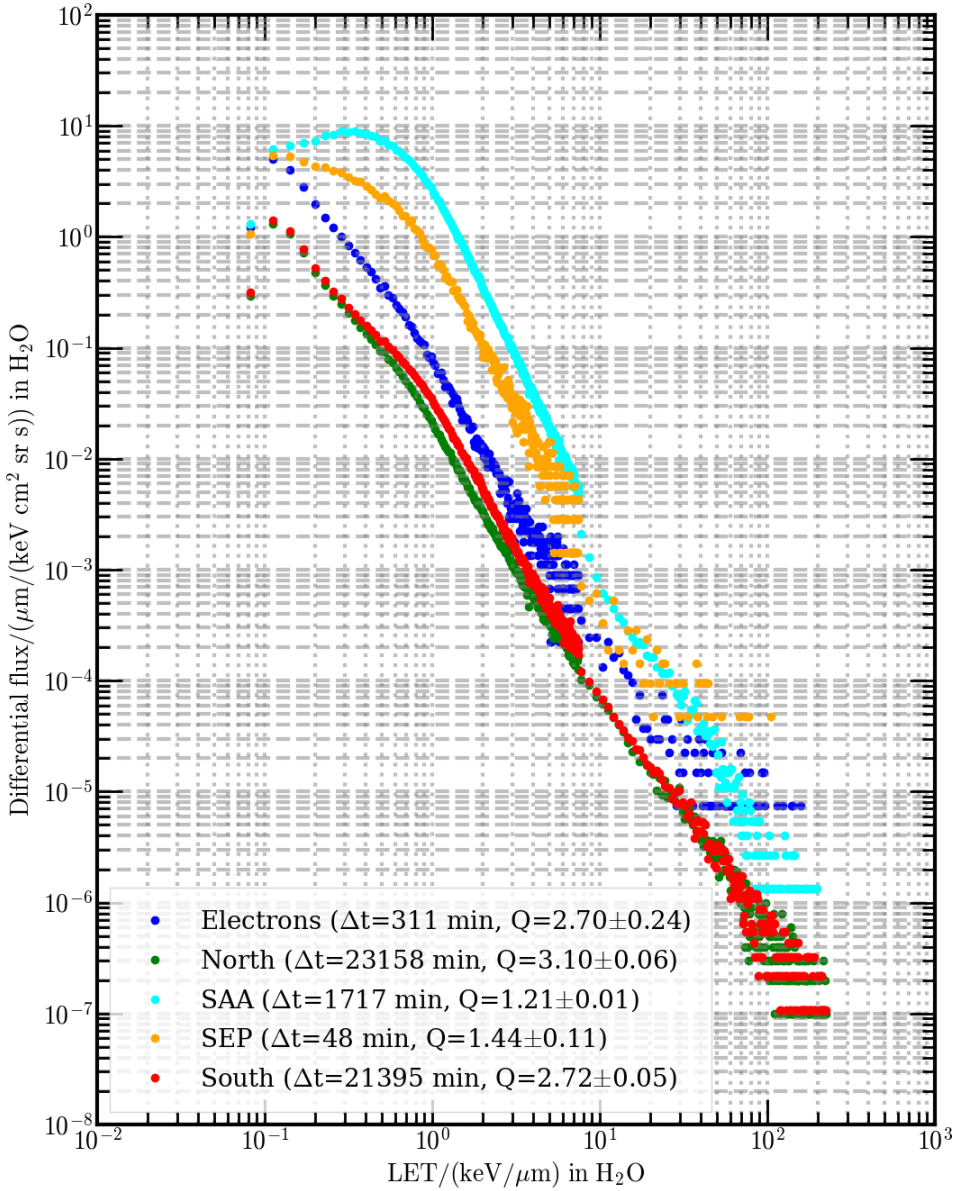
DOSTEL-1 D-1 LET-spectra 2024-04-01 to 2024-04-30



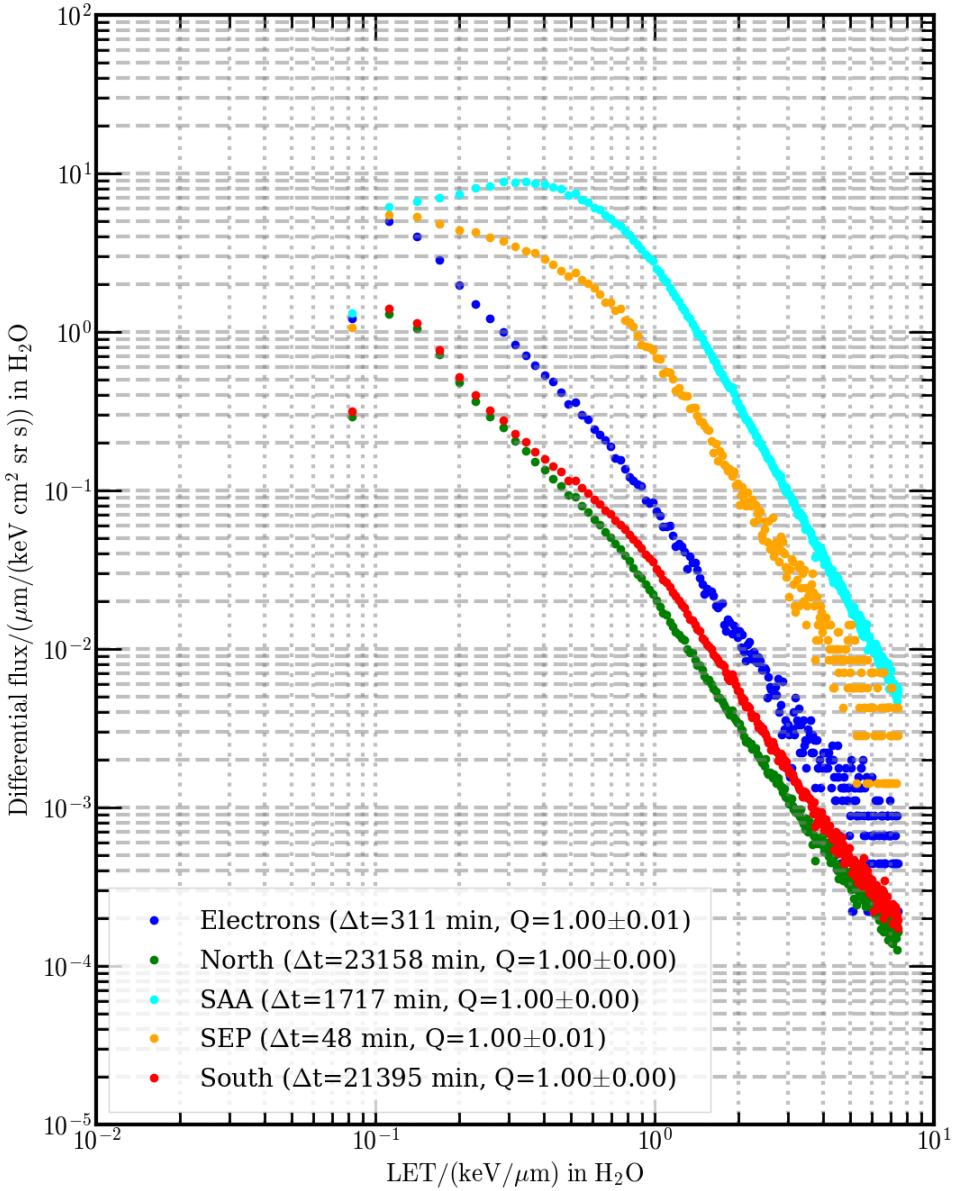
DOSTEL-1 D-1 LET-spectra 2024-04-01 to 2024-04-30

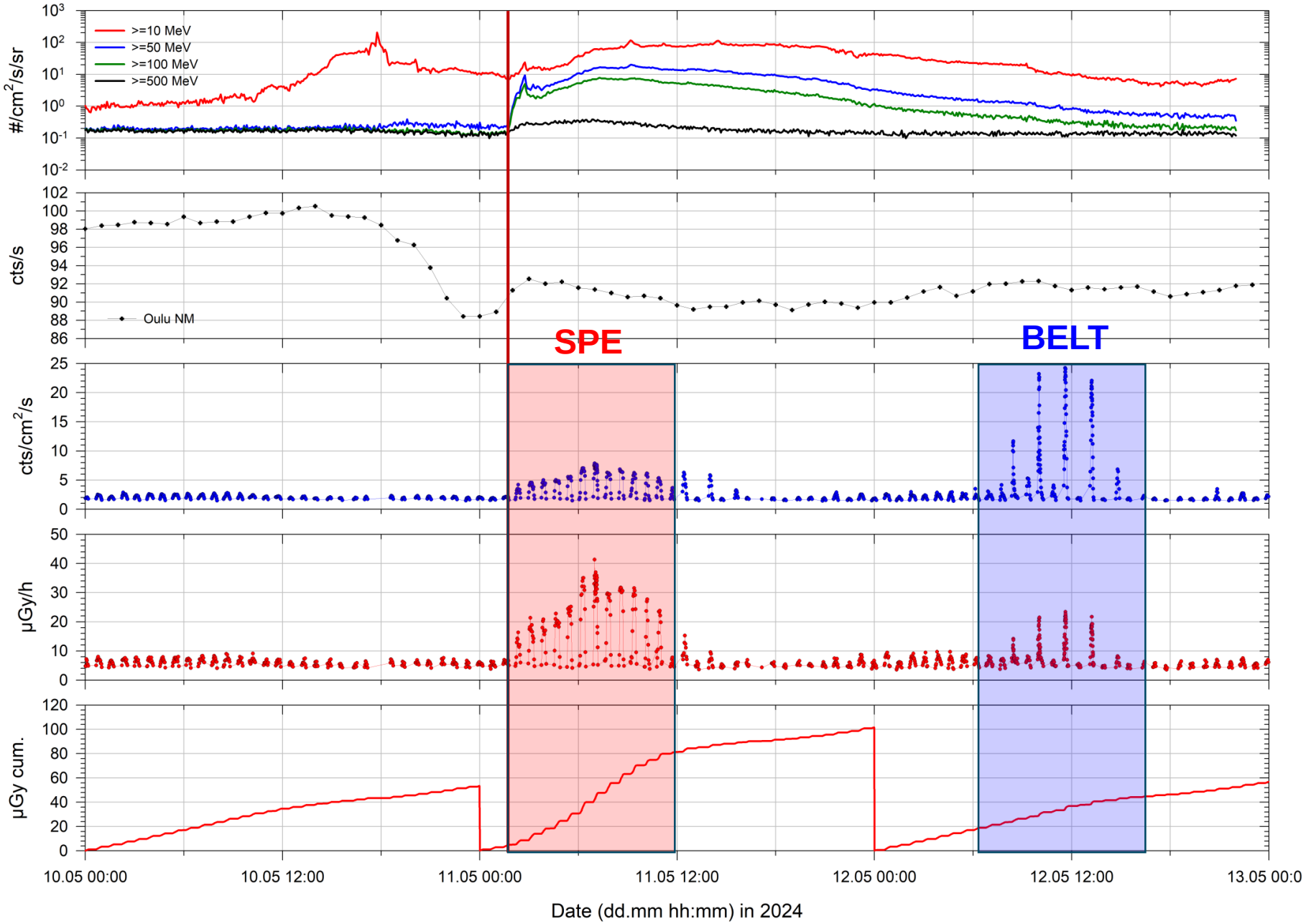


DOSTEL-1 D-1 LET-spectra 2024-05-01 to 2024-05-31



DOSTEL-1 D-1 LET-spectra 2024-05-01 to 2024-05-31





RESULTS
DOSTEL-2
Rc < 4.5 GV
10 – 13 May 2024

SPE Dose values

~ 60 µGy (in Si)

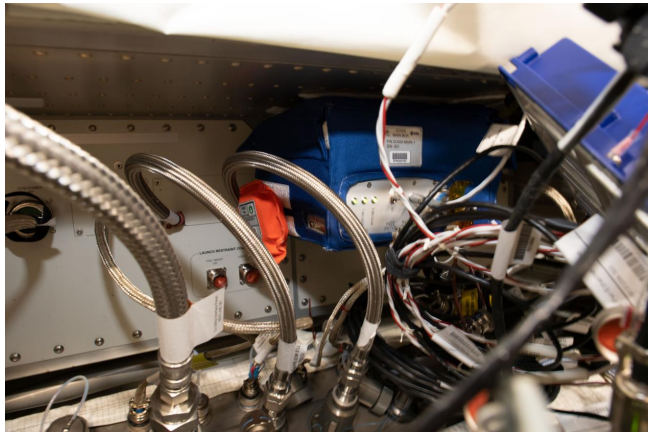
DOSIS & DOSIS 3D: Summary and Outlook

PDP

- 26 x PDP ⇑⇓
- DOSIS 3D MINI outside Columbus
- Crew-8 launched 04th March 2024
- **4874 days of measurements**
- All missions fully successful
- Next publication in preparation

DOSTEL

- Data from 2009 – 2011 and from 2012 onwards
- 7882 days of science data
- DOSIS-MAIN-BOX launched again with AXIOM-3 (18th January 2024)
- **New SPE in May 2024 + Electron belt**



DOSIS & DOSIS 3D: Acknowledgements

ESA/CADMOS/DLR-MUSC/OHB

- We gratefully acknowledge the steady help and support of ESA, especially Jason Hatton, Rene Demets, Chiara Lombardi, Christiane Hahn, Lukas De Smet, Christopher Puhl, Andrea Kurtinovic as well as all the work performed by colleagues from CADMOS, Toulouse, France, DLR-MUSC (→ DOSIS-OPS), Cologne, Germany and colleagues from OHB, Bremen, Germany.

ASTRONAUTS

- DOSIS and DOSIS 3D would not have been possible without all the support and work performed by the astronauts on-board the ISS: Frank de Winne, Tracy Caldwell-Dyson, Shannon Walker, Ron Garan, Mike Fossum, Andre Kuipers, Joe Acaba, Sunita Williams, Chris Hadfield, Chris Cassidy, Luca Parmitano, Michael Hopkins, Rick Mastracchio, Koichi Wakata, Alexander Gerst, Samantha Cristoforetti, Scott Kelly, Timothy Peake, Jeffrey Williams, Takuya Onishi, Thomas Pesquet, Jack Fischer, Mark Vande Hei, Norishige Kanai, Andrew Feustel, Matthias Maurer, Anton Schkaplerow, Denis Matveyev, Andreas Mogensen, Marcus Wandt

Impressum

Topic:	**DOSIS and DOSIS 3D – active and passive radiation measurements in Columbus from 2009 - 2024**
Date:	WRMISS 27 September 3 – 5, 2024, Boulder, USA
Authors:	Thomas Berger for the DOSIS 3D team
Institute:	Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany
Credits:	NASA, ESA, „DLR (CC BY-NC-ND 3.0)“