

DOSIS & DOSIS 3D on-board the ISS

Current Status / Science Overview / Work in Progress

Thomas Berger for the DOSIS & DOSIS 3D Team

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Knowledge for Tomorrow



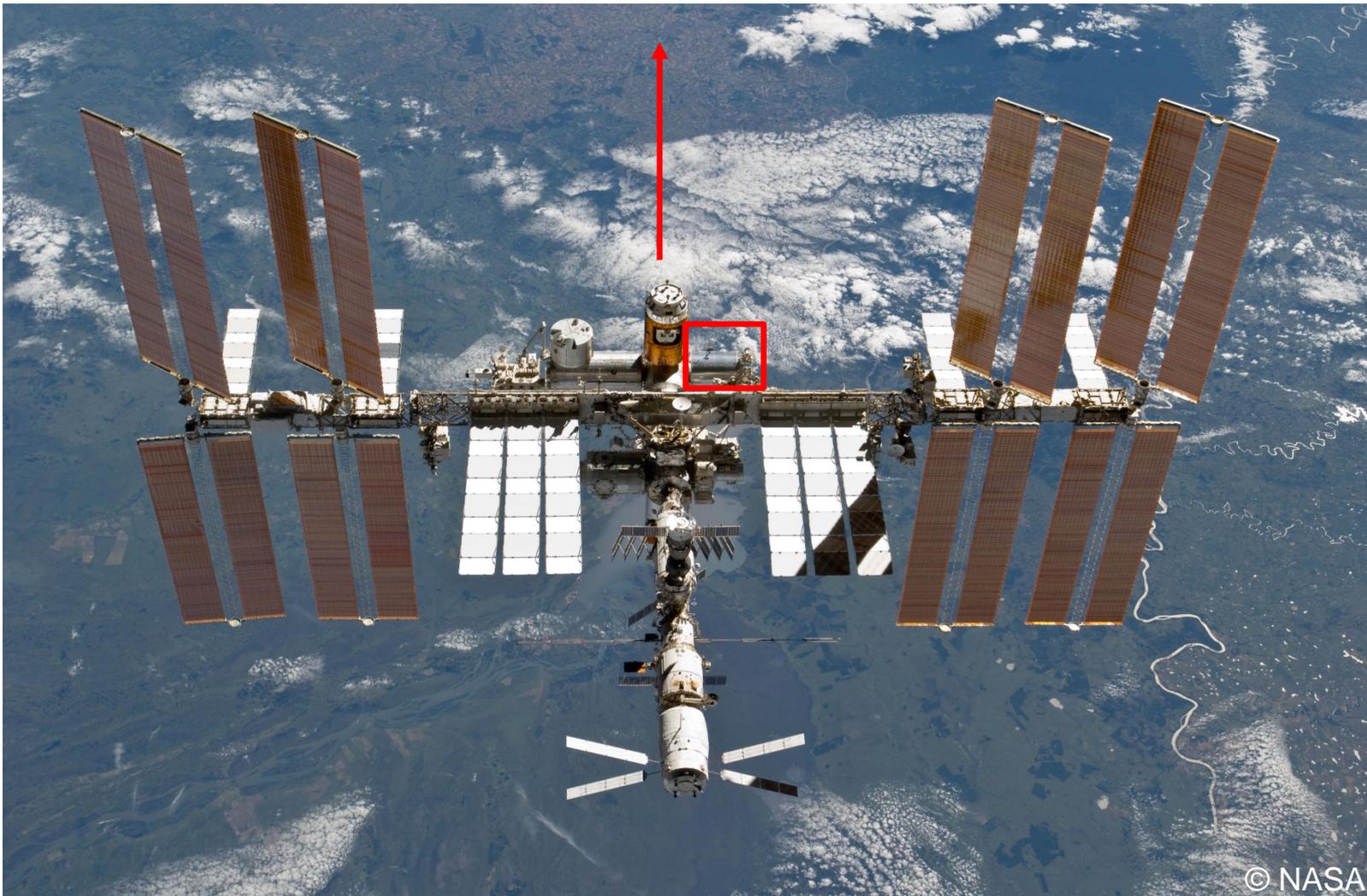
DOSIS & DOSIS 3D: Science Team

Berger Thomas¹, Przybyla Bartos¹, Matthiä Daniel¹, Aeckerlein Joachim¹, Marsalek Karel¹, Rutzynska Aleksandra¹, Reitz Günther¹, Burmeister Sönke², Bilski Pawel³, Horwacik Tomasz³, Twardak Anna³, Wojciech Gieszczyk³, Hajek Michael^{4,5}, Lembit Sihver⁵, Hofstätter Christina⁵, Manfred Fugger⁵, Palfalvi Jozsef⁶, Szabo Julianna⁶, Stradi Andrea⁶, Ambrozova Iva⁷, Kubancak Jan⁷, Pachnerova Brabcova Katerina⁷, Vanhavere Filip⁸, Cauwels Vanessa⁸, Van Hoey Oliver⁸, Werner Schoonjans Werner⁸, Parisi Alessio⁸, Gaza Ramona^{9,15}, Semones Edward⁹, Yukihiro Eduardo¹⁰, Benton Eric¹⁰, Uchihori Yukio¹¹, Kodaira Satoshi¹¹, Kitamura Hisashi¹¹, Shurshakov Vyacheslav¹², Benghin Victor¹², Lishnevskii Andrey¹², Tolocek Raisa¹², Nagamatsu Aiko¹³, Boehme Matthias¹⁴, Liesbeth De Smet¹⁶

¹ DLR	German Aerospace Center	Cologne, Germany
² CAU	Christian Albrechts Universität zu Kiel	Kiel, Germany
³ IFJ	Institute of Nuclear Physics	Krakov, Poland
⁴ IAEA	International Atomic Energy Agency	Vienna, Austria
⁵ ATI	Technical University Vienna	Vienna, Austria
⁶ MTA EK	Centre for Energy Research	Budapest, Hungary
⁷ NPI	Nuclear Physics Institute	Prague, Czech Republic
⁸ SCK•CEN	Belgian Nuclear Research Center	Mol, Belgium
⁹ NASA	Space Radiation Analysis Group	Houston, United States
¹⁰ OSU	Oklahoma State University	Stillwater, United States
¹¹ NIRS	National Institute of Radiological Sciences	Chiba, Japan
¹² IMBP	Russian Academy of Sciences	Moscow, Russia
¹³ JAXA	Japan Aerospace Exploration Agency	Tsukuba, Japan
¹⁴ OHB System AG		Bremen, Germany
¹⁵ LHM	Lockheed Martin Exploration & Mission Support	Houston, United States
¹⁶ ESA-ESTEC	European Space Agency	Noordwijk, The Netherlands



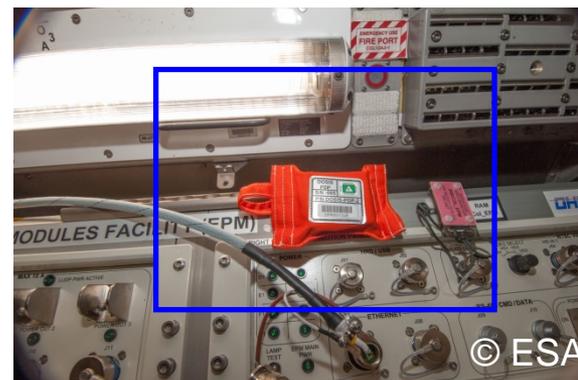
DOSIS & DOSIS 3D: Columbus



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.

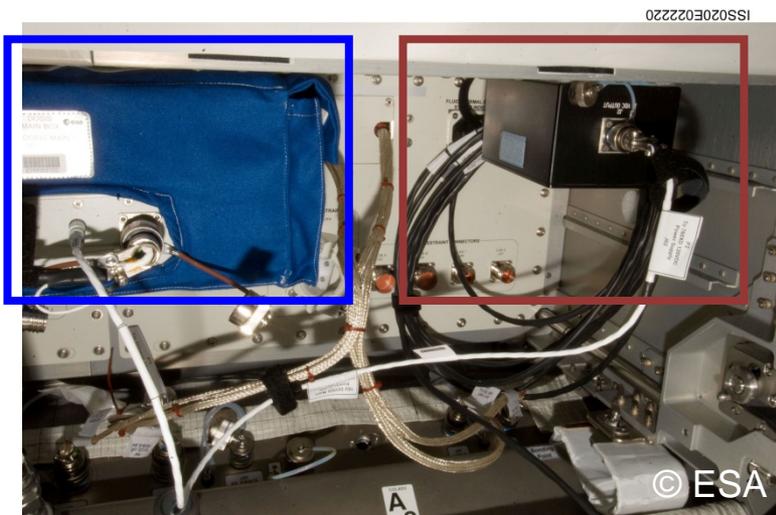
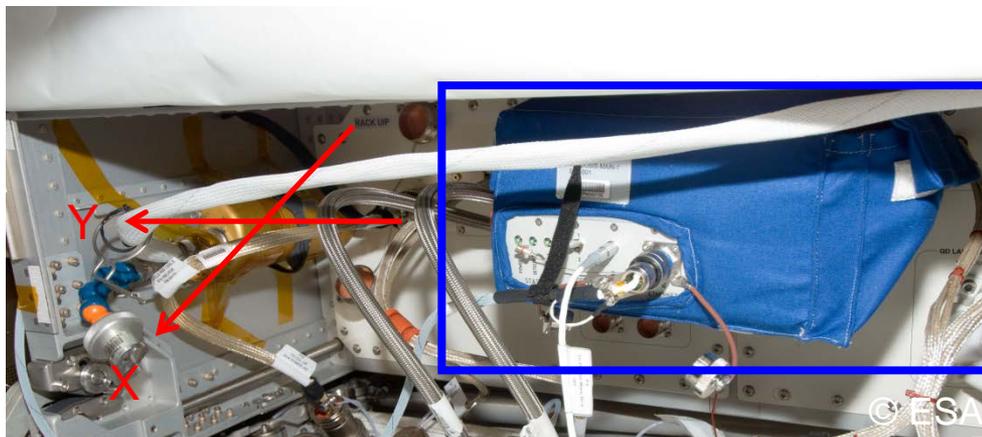
- Monitor the radiation environment inside Columbus with **active** and **passive** radiation detectors (ESA) for the determination of the temporal and spatial dose distribution
- Combine data gathered by NASA, JAXA, IMBP and ESA into a 3D radiation map of the International Space Station



DOSIS & DOSIS 3D: Active detectors (2 x DOSTEL)

Dosis Main Box
DOSIS-MAIN-1-001

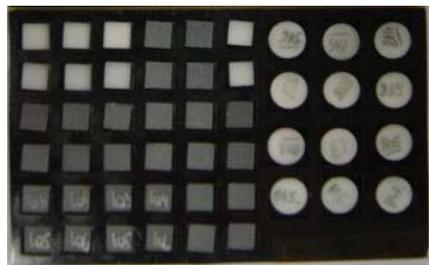
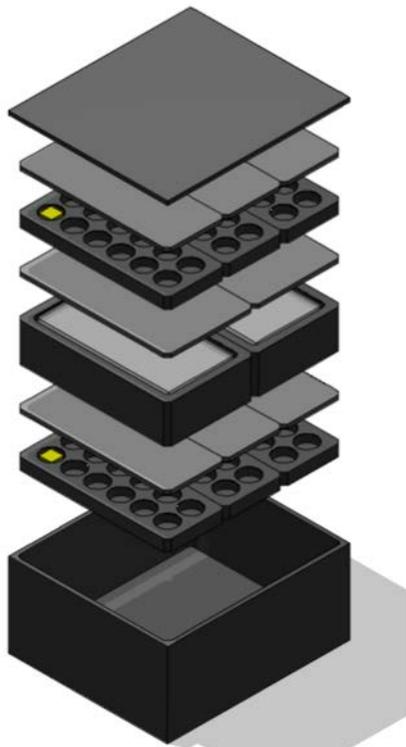
C | A | U



- Ethernet connection to EPM rack "Right Utility Distribution Panel"
- DOSIS MAIN BOX connected to EPM LAN like an external EPM instrument
- Data downlink is an EPM operation from ground performed once per month over CADMOS – COLCC – MUSC – Scientists
- Up to Sept. 2017: 61 data downlinks (**DOSIS 3D**)



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

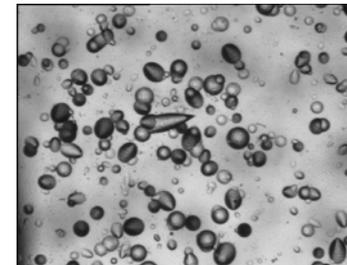


Thermoluminescence detectors (TLD) / OSLD

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 radioactive isotopes at Oak Ridge Institute for Nuclear Studies

F. Daniels *Science* 117, 343, 1953

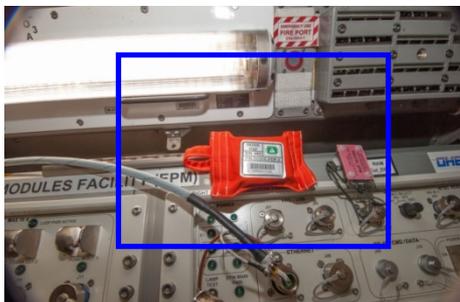


Nuclear Track Etch Detectors (CR-39)

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



TLD/OSLD + CR-39 → Absorbed dose + Dose Equivalent

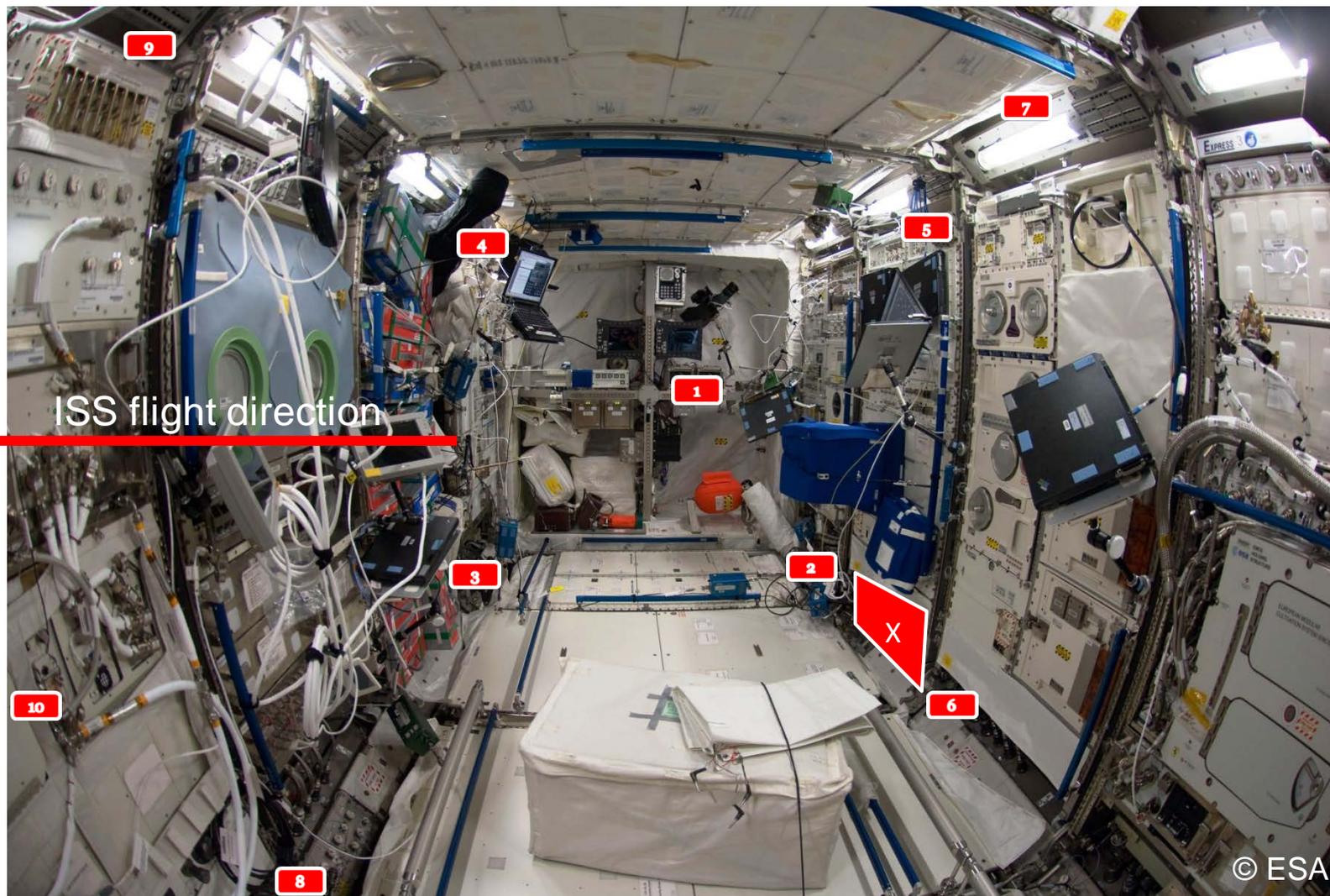


DOSIS & DOSIS 3D: PDP Positions

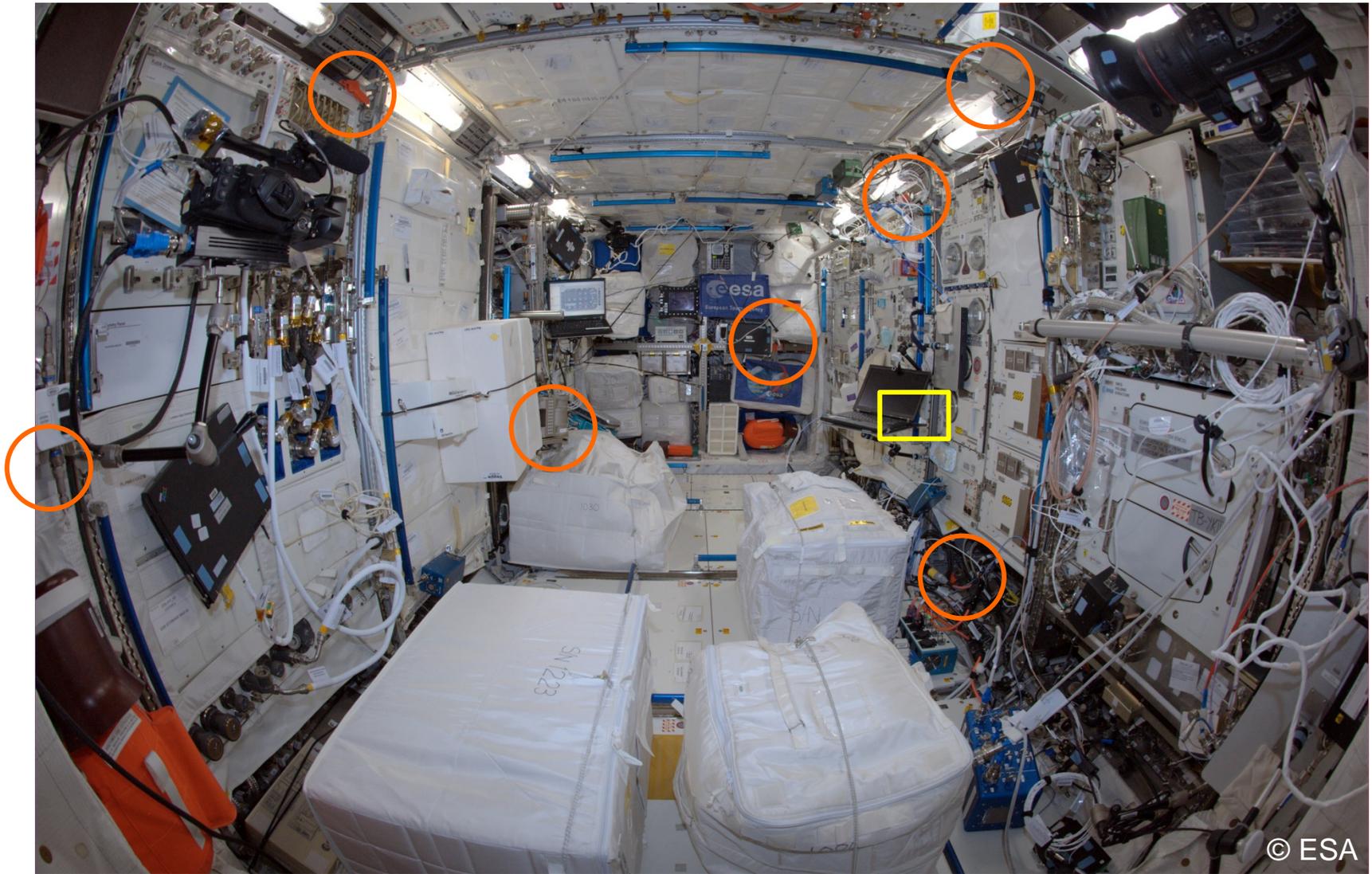
PDP Nr	Columbus Location	Related Rack	Position	Columbus coordinate system [cm]			
				X	Y	Z	
1	Star Cone	-	Behind bend in right cone structure	Aft	681	-57	0
2	A4 UIP	HRF 2	Left side on UIP next to Vacuum connector	Aft	665	-123	-93
3	F4 UIP	HRF 1	Left side on UIP next to Vacuum connector	Forward	570	123	-93
4	B1 HRF 1	HRF 1	Front panel of Cooling Stowage Drawer	Forward	600	104	60
5	A3 EPM	EPM	410 mm left from upper right edge	Aft	463	-104	93
6	A2 UIP	BLB	Left side on UIP next to Vacuum connector	Aft	436	-123	-93
7	O2 UIP	-	Left side on UIP next to Vacuum connector	Aft	436	-101	106
8	F1 UIP	EDR	Left side on UIP next to Vacuum connector	Forward	243	123	-93
9	F1 EDR	EDR	77 mm left from upper right edge	Forward	333	104	93
10	End Cone	-	On PBA Cover	Forward	221	95	85
X	DOSIS-MAIN-BOX	EPM	On the left side of the DOSIS-MAIN-BOX	Aft	516	-116	-60



DOSIS & DOSIS 3D: PDP Positions



DOSIS & DOSIS 3D: PDP Positions



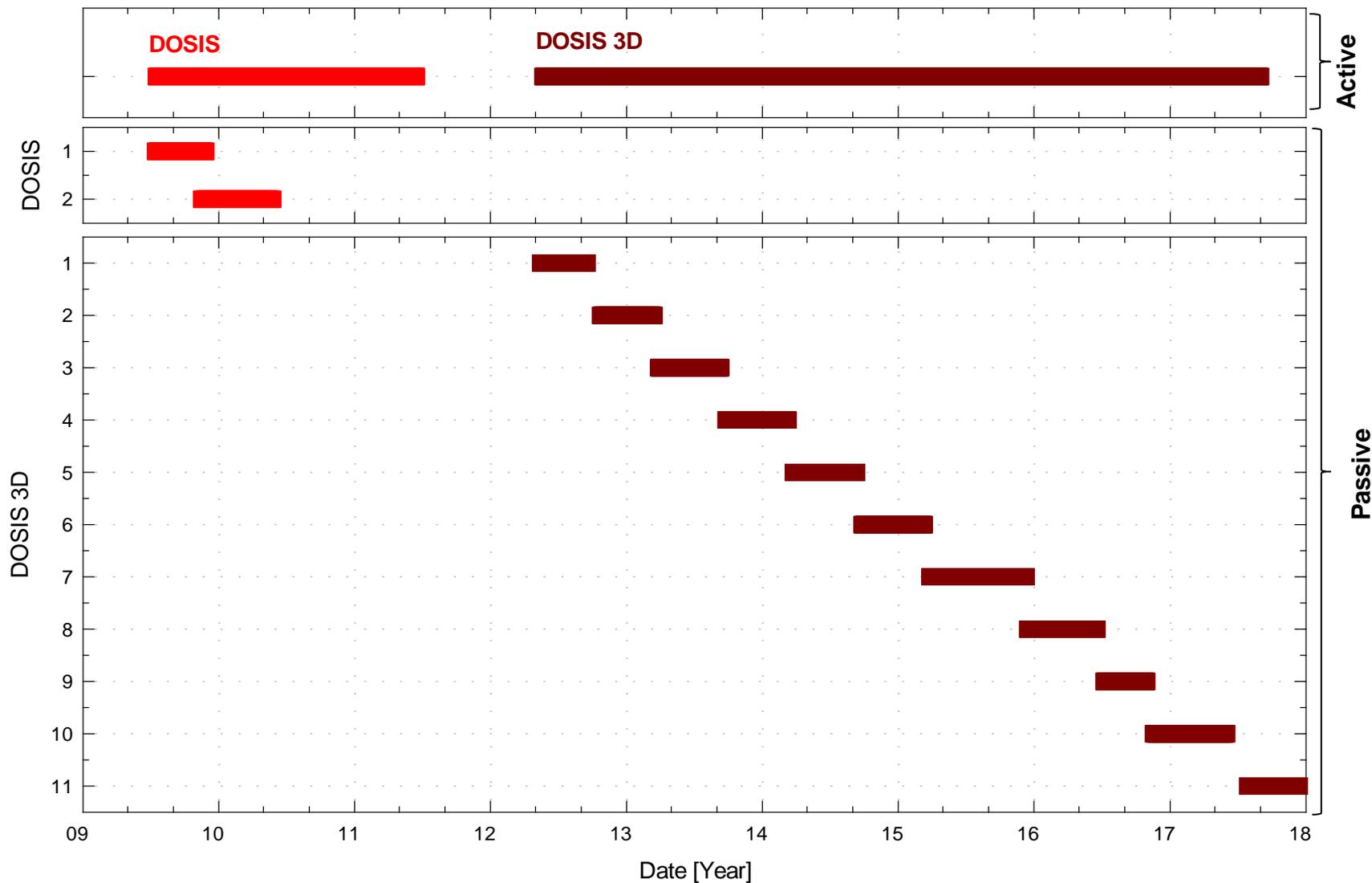
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DOSIS & DOSIS 3D: PDP Positions



DOSIS & DOSIS 3D: Timeline



DOSIS & DOSIS 3D: Timeline → Active

Experiment	Detector	Timeline	Measurement period	Data [days]	ISS altitude [km]	
DOSIS (Active)	DOSTEL-1	Launch (STS-127)	July 15, 2009	July 18, 2009 - May 28, 2010	290	337-350
		Installation	July 18, 2009			
		Activation	July 18, 2009			
		Retrieval	April 21, 2011			
		Return (Soyuz-25S)	May 24, 2011			
	DOSTEL-2	Launch (STS-127)	July 15, 2009	July 18, 2009 - June 16, 2011	645	337-375
		Installation	July 18, 2009			
		Activation	July 18, 2009			
		Retrieval	June 17, 2011			
		Return (STS-135)	July 21, 2011			
DOSIS 3D (*) (Active)	DOSTEL-1	Launch (Soyuz-30S)	May 15, 2012	May 21, 2012 – August 16, 2017	1849	398-418
	DOSTEL-2	Installation	May 21, 2012			
		Activation	May 21, 2012	May 21, 2012 – August 22, 2017	1843	

(*) up to last data downlink performed August 31st 2017



Experiment	Phase	Timeline	Duration [days]	Installed [days]	Installed [%]	ISS altitude [km]	
DOSIS (Passive)	1	Launch (STS-127) Installation Retrieval Return (STS-129)	July 15, 2009 July 18, 2009 November 21, 2009 November 27, 2009	136	127	93	339-348
	2	Launch (STS-129) Installation Retrieval Return (STS-132)	November 16, 2009 November 21, 2009 May 18, 2010 May 26, 2010	191	178	93	337-349

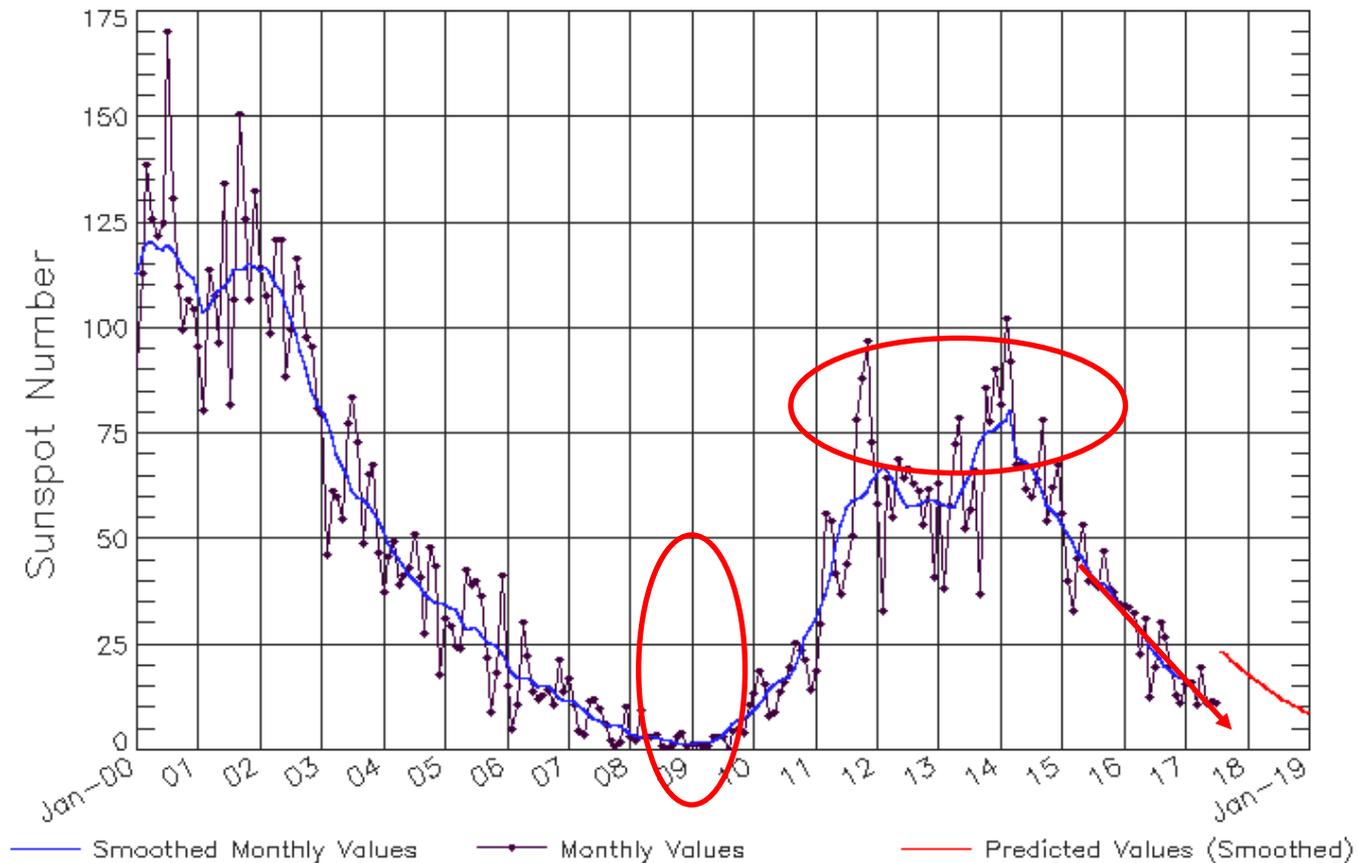


Experiment	Phase	Timeline	Duration [days]	Installed [days]	Installed [%]	ISS altitude [km]	
DOSIS 3D (Passive)	1	Launch (Soyuz 30S) Installation Retrieval Return (Soyuz 30S)	May 15, 2012 May 21, 2012 September 11, 2012 September 17, 2012	125	113	90	397-417
	2	Launch (Soyuz 32S) Installation Retrieval Return (Soyuz 32S)	October 23, 2012 October 27, 2012 March 13, 2013 March 16, 2013	144	137	95	407-416
	3	Launch (Soyuz 34S) Installation Retrieval Return (Soyuz 34S)	March 28, 2013 April 03, 2013 September 06, 2013 September 11, 2013	167	156	93	409-417
	4	Launch (Soyuz 36S) Installation Retrieval Return (Soyuz 36S)	September 25, 2013 October 01, 2013 March 06, 2014 March 11, 2014	167	156	93	413-418
	5	Launch (Soyuz 38S) Installation Retrieval Return (Soyuz 38S)	March 25, 2014 March 28, 2014 September 05, 2014 September 11, 2014	170	161	95	413-417
	6	Launch (Soyuz 40S) Installation Retrieval Return (Soyuz 40S)	September 26, 2014 September 27, 2014 March 09, 2015 March 12, 2015	167	161	96	401-416
	7	Launch (Soyuz 42S) Installation Retrieval Return (Soyuz 43S)	March 27, 2015 March 28, 2015 December 10, 2015 December 11, 2015	259	256	99	398-405
	8	Launch (Soyuz 45S) Installation Retrieval Return (Soyuz 45S)	December 15, 2015 December 18, 2015 June 15, 2016 June 18, 2016	186	161	97	401-405
	9	Launch (Soyuz 47S) Installation Retrieval Return (Soyuz 47S)	July 07, 2016 July 09, 2016 October 26, 2016 October 30, 2016	115	109	95	401-406
	10	Launch (Soyuz 49S) Installation Retrieval Return (Soyuz 49S)	November 17, 2016 November 21, 2016 June 01, 2017 June 02, 2017	197	192	97	403-406
	11	Launch (Soyuz 51S) Installation Retrieval Return (Soyuz 51S)	July 28, 2017 July 30, 2017 TBD December 14, 2017	139	TBD	TBD	TBD

DOSIS & DOSIS 3D: Solar Cycle

ISES Solar Cycle Sunspot Number Progression

Observed data through Jul 2017



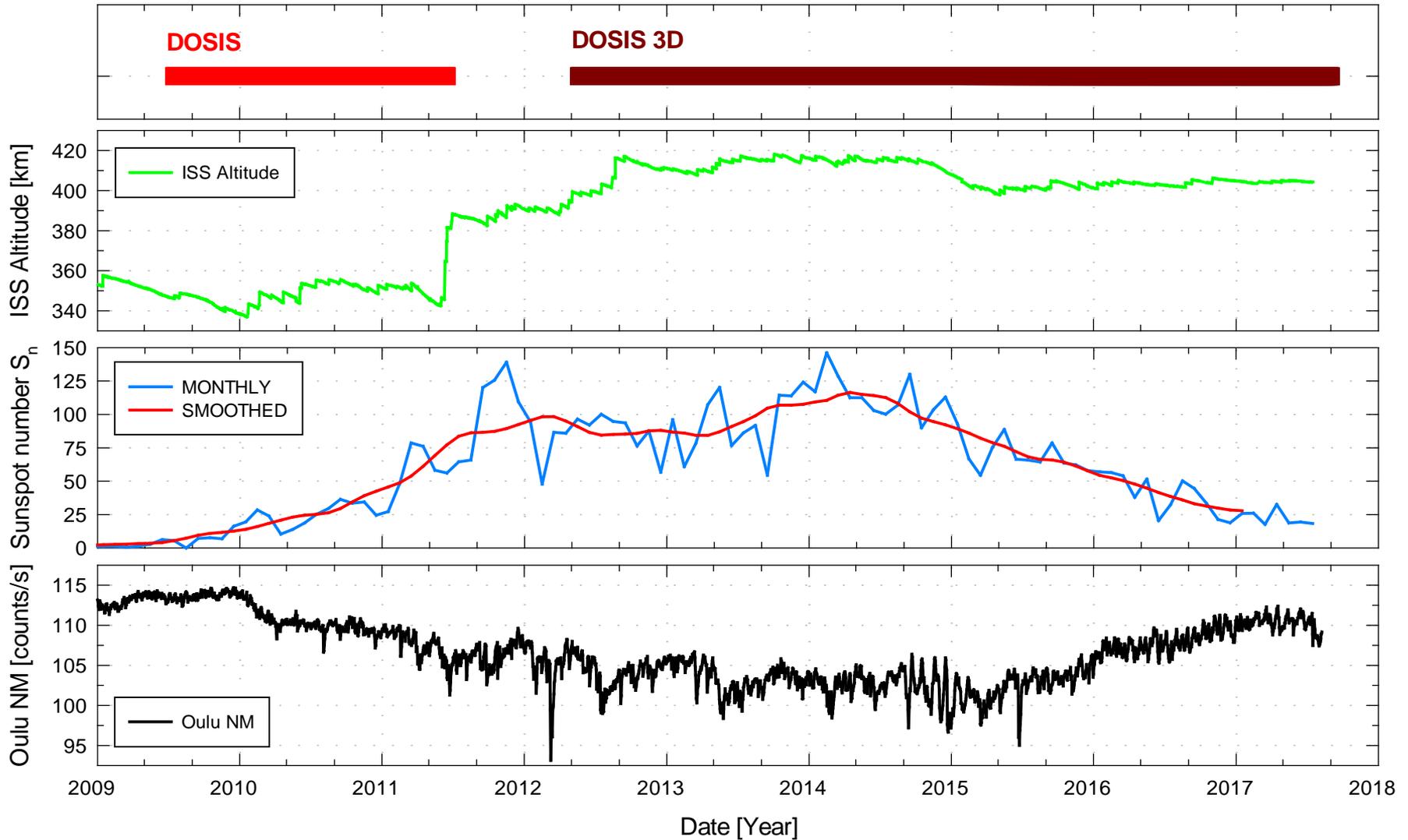
Updated 2017 Aug 7

NOAA/SWPC Boulder, CO USA

<http://www.swpc.noaa.gov/products/solar-cycle-progression>



DOSIS & DOSIS 3D: Timeline / ISS Altitude / S_n / Oulu NM



DOSIS & DOSIS 3D: PDP – Results



DOSIS & DOSIS 3D: PDP – Results

Experiment	Phase	Timeline	Duration [days]	Installed [days]	Installed [%]	ISS altitude [km]
DOSIS (Passive)	1	July 15, 2009 – November 27, 2009	136	127	93	339-348
	2	November 16, 2009 – May 26, 2010	191	178	93	337-349
DOSIS 3D (Passive)	1	May 15, 2012 – September 17, 2012	125	113	90	397-417
	2	October 23, 2012 – March 16, 2013	144	137	95	407-416
	3	March 28, 2013 – September 11, 2013	167	156	93	409-417
	4	September 25, 2013 – March 11, 2014	167	156	93	413-418
	5	March 25, 2014 – September 11, 2014	170	161	95	413-417
	6	September 26, 2014 – March 12, 2015	167	161	96	401-416
	7	March 27, 2015 – December 11, 2015	259	256	99	398-405
	8	December 15, 2015 – June 18, 2016	186	161	97	401-405
	9	July 07, 2016 – October 30, 2016	115	109	95	401-406
	10	November 17, 2016 – June 02, 2017	197	192	97	403-406

Berger et al. SWSC 6, A39, 2016



DOSIS & DOSIS 3D: PDP – Results → Publication

J. Space Weather Space Clim., 6, A39 (2016)
DOI: 10.1051/swsc/2016034
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RESEARCH ARTICLE

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DOSIS & DOSIS 3D: long-term dose monitoring onboard the Columbus Laboratory of the International Space Station (ISS)

Thomas Berger^{*1}, Bartos Przybyla¹, Daniel Matthiä¹, Günther Reitz¹, Sönke Burmeister², Johannes Labrenz², Pawel Bilski³, Tomasz Horwacik³, Anna Twardak³, Michael Hajek^{4,5}, Manfred Fugger⁵, Christina Hofstätter⁵, Lembit Sihver^{5,6}, Jozsef K. Palfalvi⁷, Julianna Szabo⁷, Andrea Stradi⁷, Iva Ambrozova⁸, Jan Kubancak⁸, Katerina Pachnerova Brabcova⁸, Filip Vanhavere⁹, Vanessa Cauwels⁹, Olivier Van Hoey⁹, Werner Schoonjans⁹, Alessio Parisi⁹, Ramona Gaza^{10,11}, Edward Semones¹⁰, Eduardo G. Yukihara¹², Eric R. Benton¹², Brandon A. Doull¹², Yukio Uchihori¹³, Satoshi Kodaira¹³, Hisashi Kitamura¹³, and Matthias Boehme¹⁴

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⁸ Nuclear Physics Institute of the CAS (NPI), Department of Radiation Dosimetry, Na Truhlárce 39/64, 180 00 Prague, Czech Republic

⁹ Belgian Nuclear Research Center (SCK-CEN), Boeretang 200, 2400 Mol, Belgium

¹⁰ NASA, Space Radiation Analysis Group (NASA/SRAG), Houston, TX 77058, USA

¹¹ Leidos, Exploration & Mission Support, 2400 NASA Pkwy, Houston, TX 77058, USA

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¹³ National Institute of Radiological Sciences (NIRS), National Institutes for Quantum and Radiological Science and Technology (QST), 4-9-1 Anagawa, Inage, 263-8555 Chiba, Japan

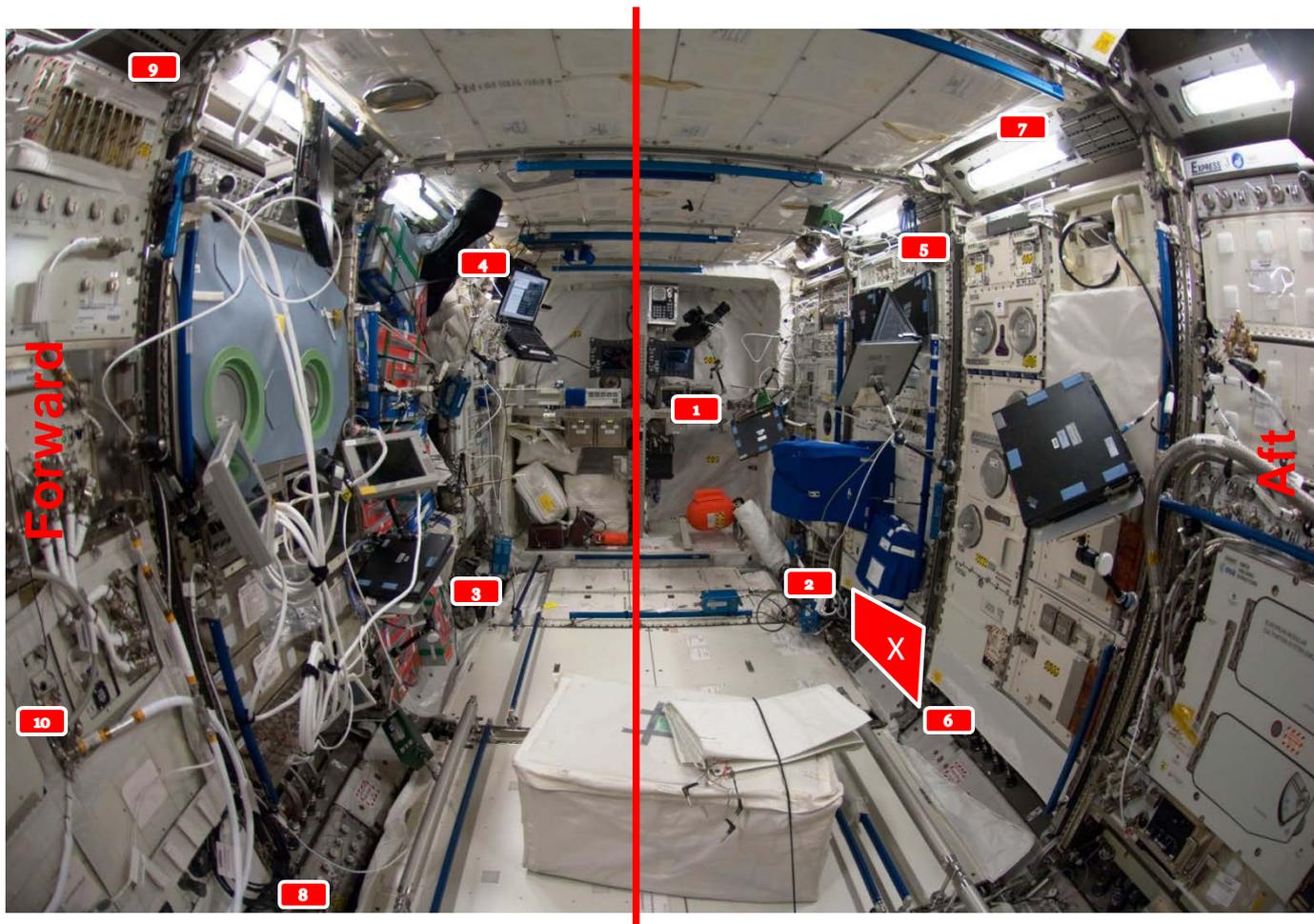
¹⁴ OHB System AG, Universitätsallee 27-29, 28359 Bremen, Germany

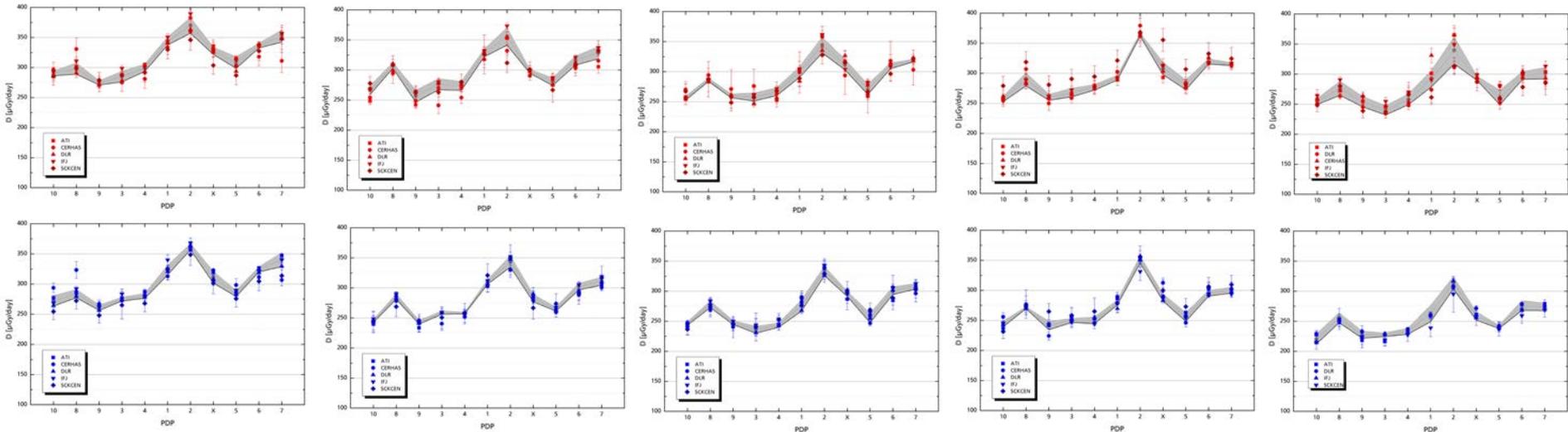
Received 26 July 2016 / Accepted 19 September 2016

https://www.swsc-journal.org/articles/swsc/full_html/2016/01/swsc160033/swsc160033.html



DOSIS & DOSIS 3D: PDP – Results (Selected)

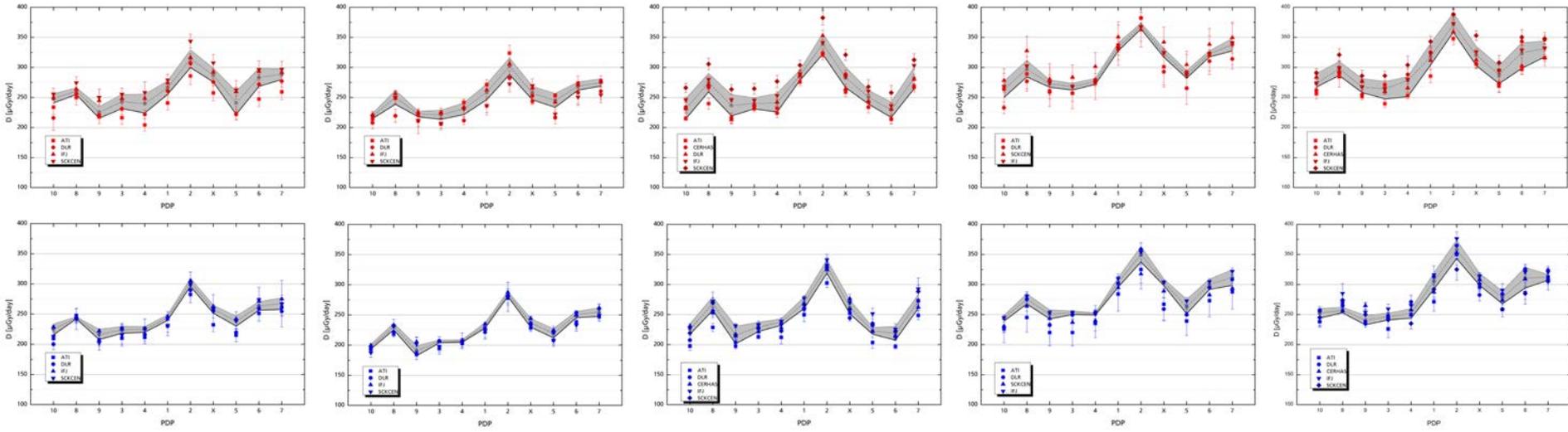




2012

2013

2014



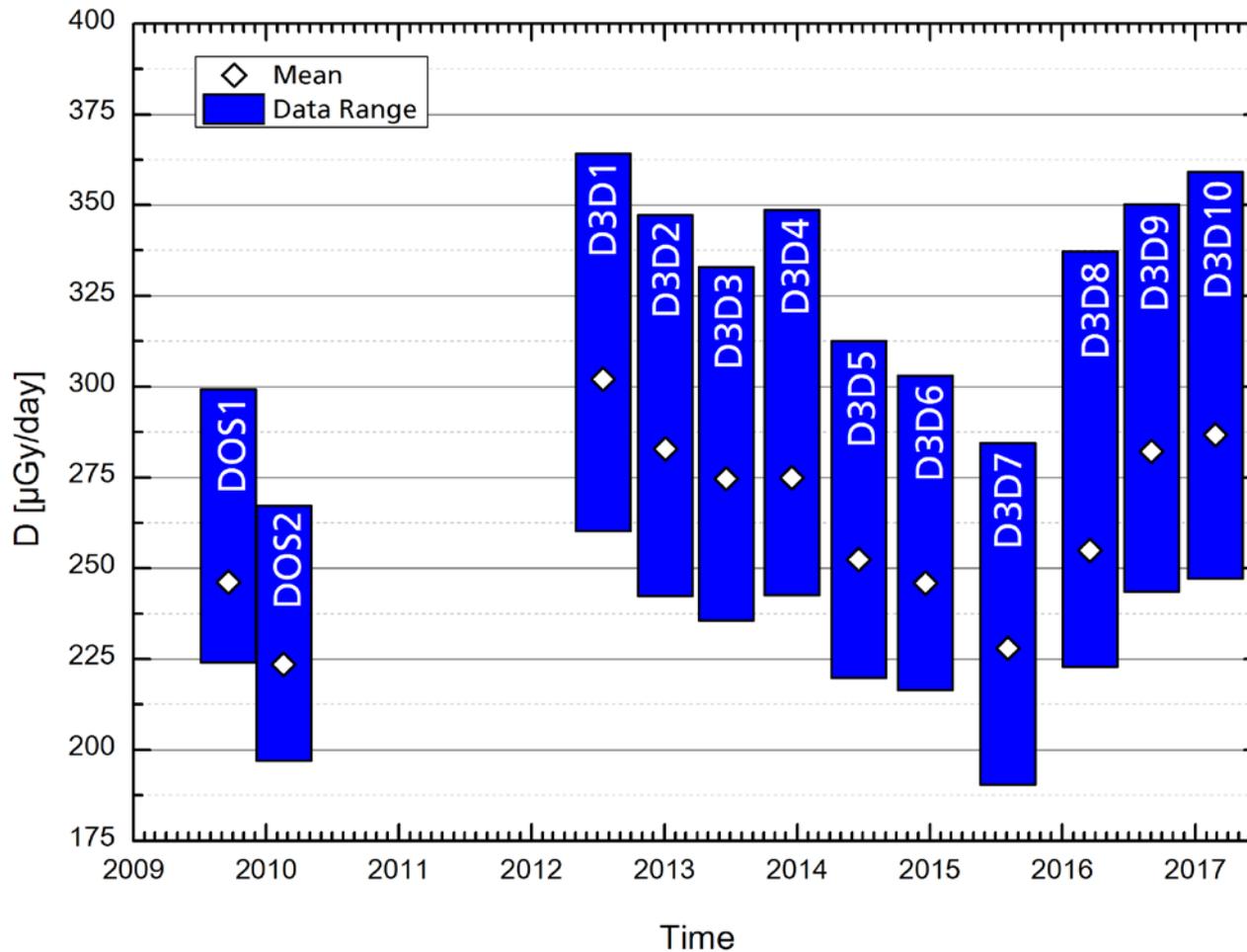
2015

2016

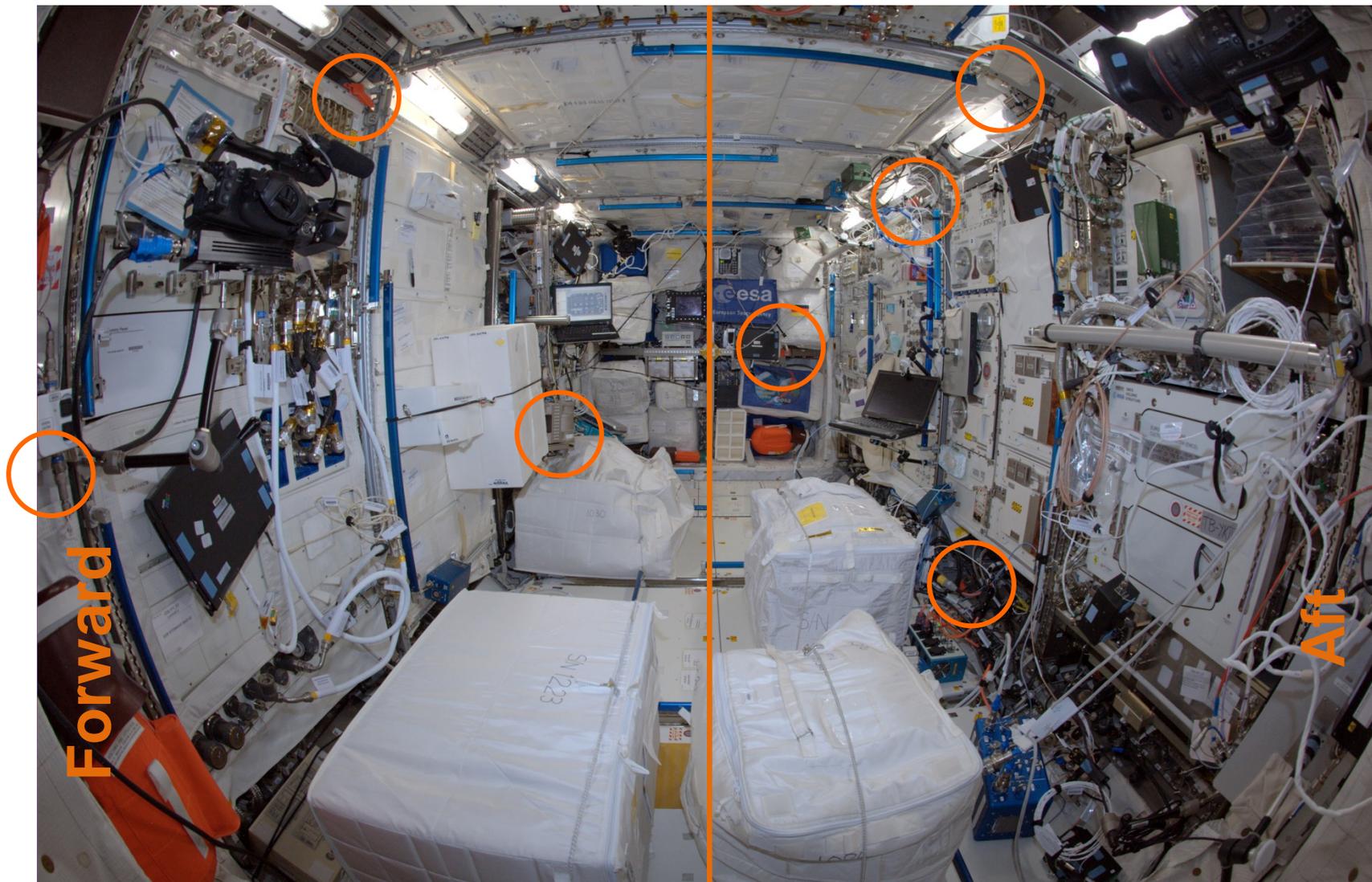
⁶LiF:Mg,Ti / ⁷LiF:Mg,Ti



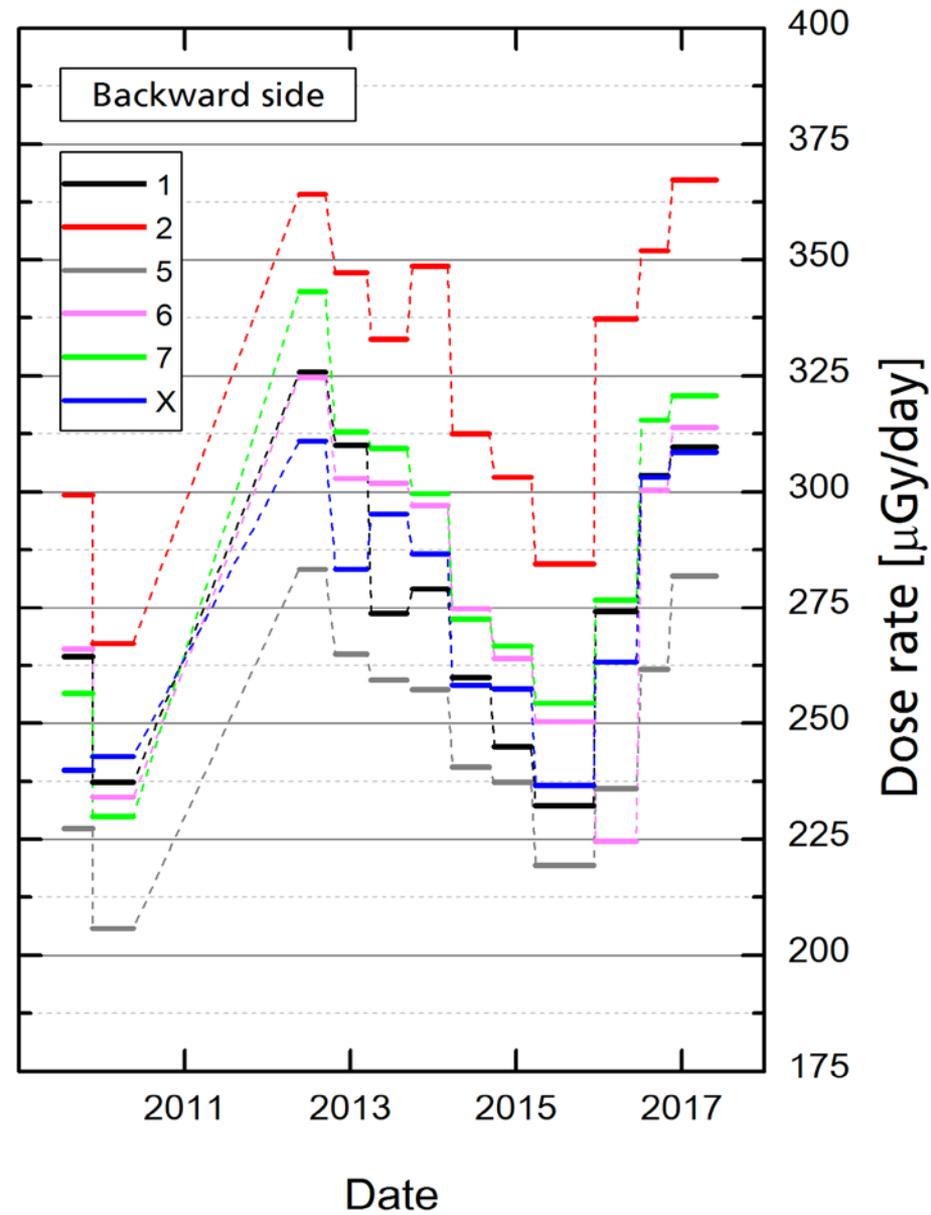
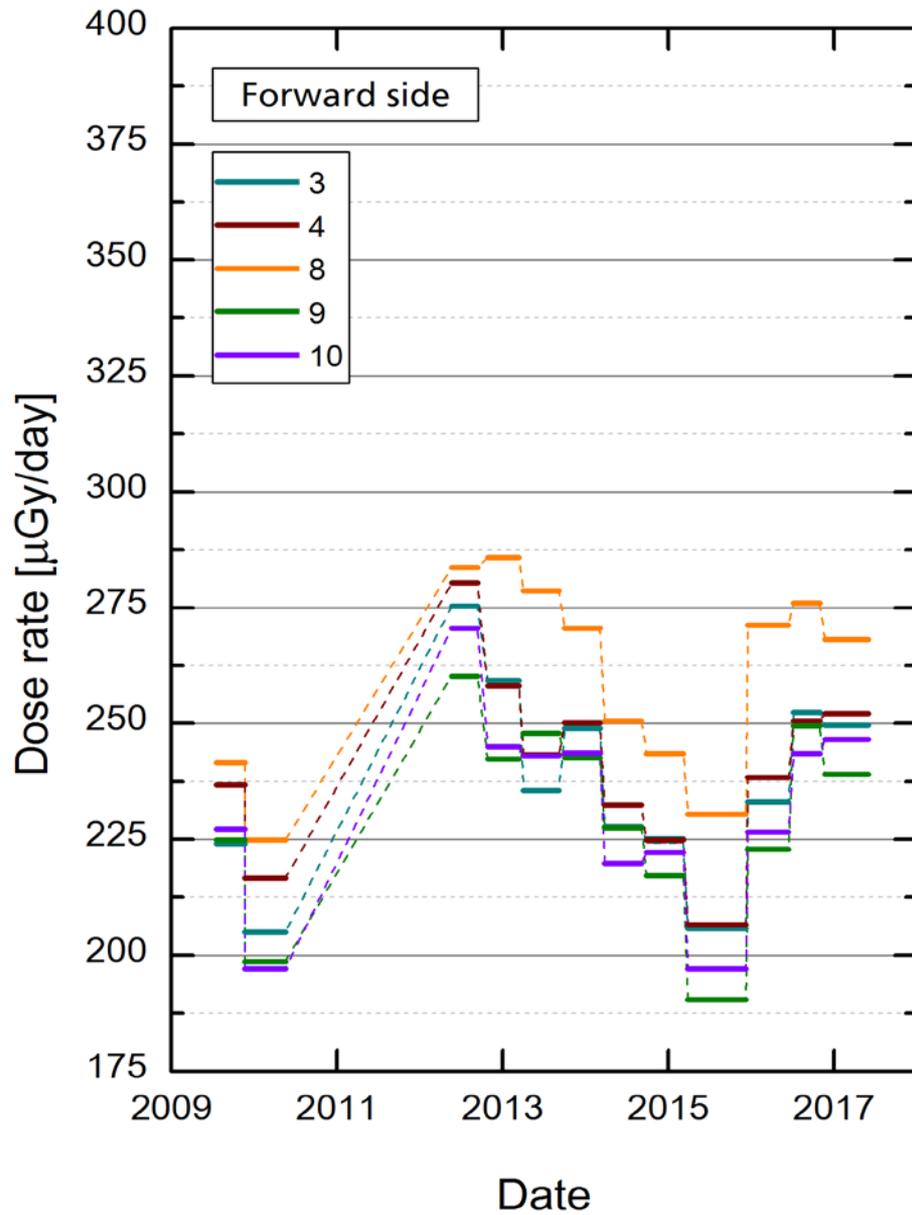
DOSIS & DOSIS 3D: PDP – Results



DOSIS & DOSIS 3D: PDP – Results 2



DOSIS & DOSIS 3D: PDP – Results 2



DOSIS 3D: Passive → **WORK IN PROGRESS**

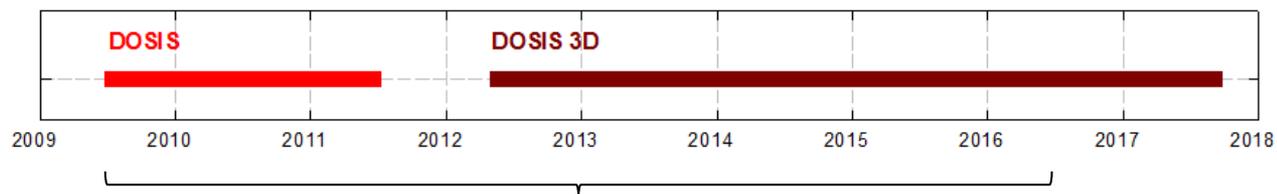
- ❖ **TLD:** Correlation of the high temperature emissions in ${}^6\text{LiF:Mg,Ti}$ with the dose rate measured in ${}^7\text{LiF:Mg,Ti}$
 - indication of thermal neutron dose in dependence on shielding inside Columbus



- ❖ **TLD/OSLD + CR-39:** TLD/OSLD + CR-39 detector final evaluation and joint publication



DOSIS & DOSIS 3D: DOSTEL – Results



Berger et al. SWSC 7, A8, 2017



DOSIS & DOSIS 3D: DOSTEL – Results → Publication

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J. Space Weather Space Clim., 7, A8 (2017)

DOI: 10.1051/swsc/2017005

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SWSC

RESEARCH ARTICLE

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DOSIS & DOSIS 3D: radiation measurements with the DOSTEL instruments onboard the Columbus Laboratory of the ISS in the years 2009–2016

Thomas Berger^{1,*}, Sönke Burmeister², Daniel Matthiä¹, Bartos Przybyla¹, Günther Reitz¹, Pawel Bilski³, Michael Hajek^{4,5}, Lembit Sihver^{5,6}, Julianna Szabo⁷, Iva Ambrozova⁸, Filip Vanhavere⁹, Ramona Gaza^{10,11}, Edward Semones¹⁰, Eduardo G. Yukihara¹², Eric R. Benton¹², Yukio Uchihori¹³, Satoshi Kodaira¹³, Hisashi Kitamura¹³, and Matthias Boehme¹⁴

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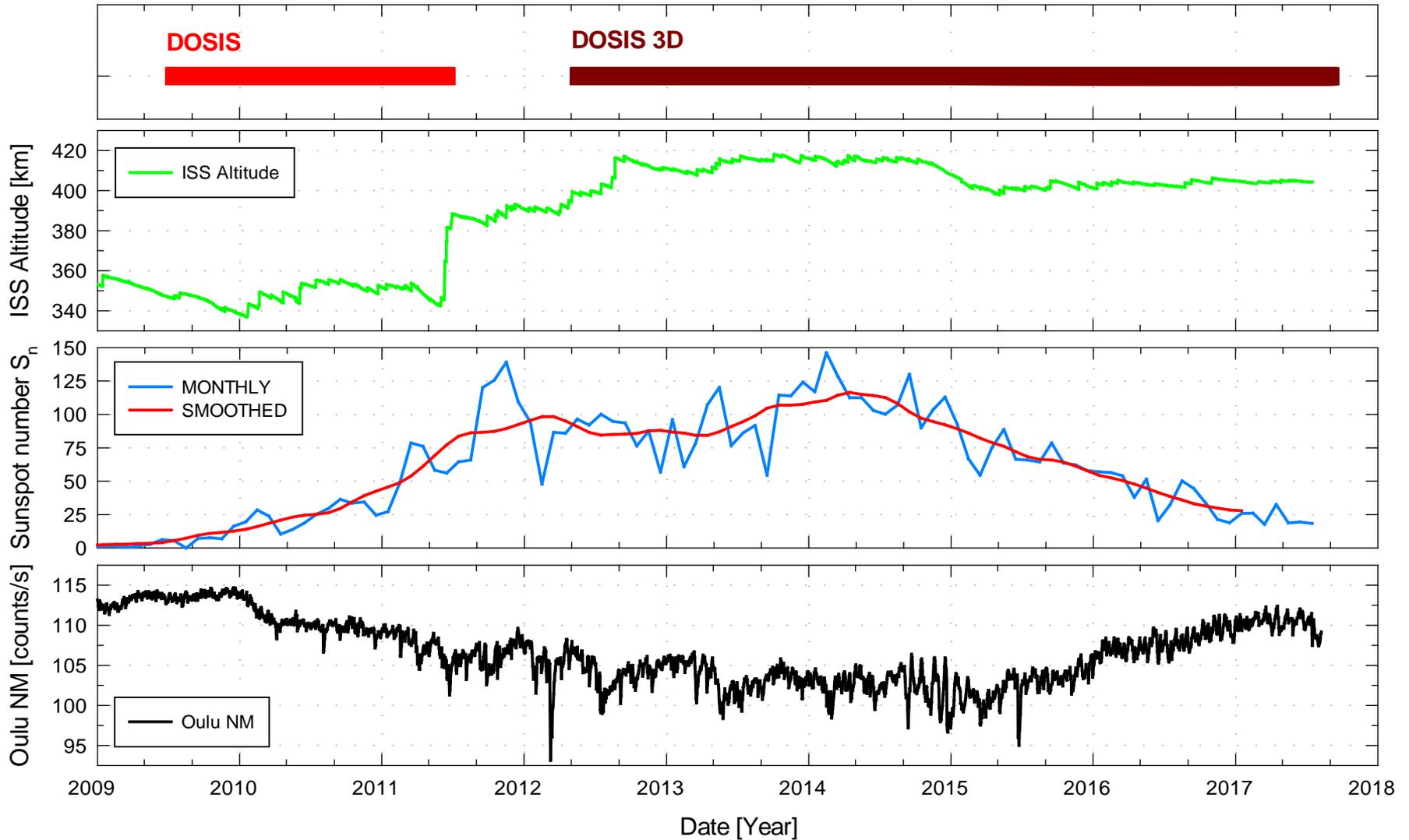
¹⁴ OHB System AG, Universitätsallee 27-29, 28359 Bremen, Germany

Received 2 November 2016 / Accepted 30 January 2017

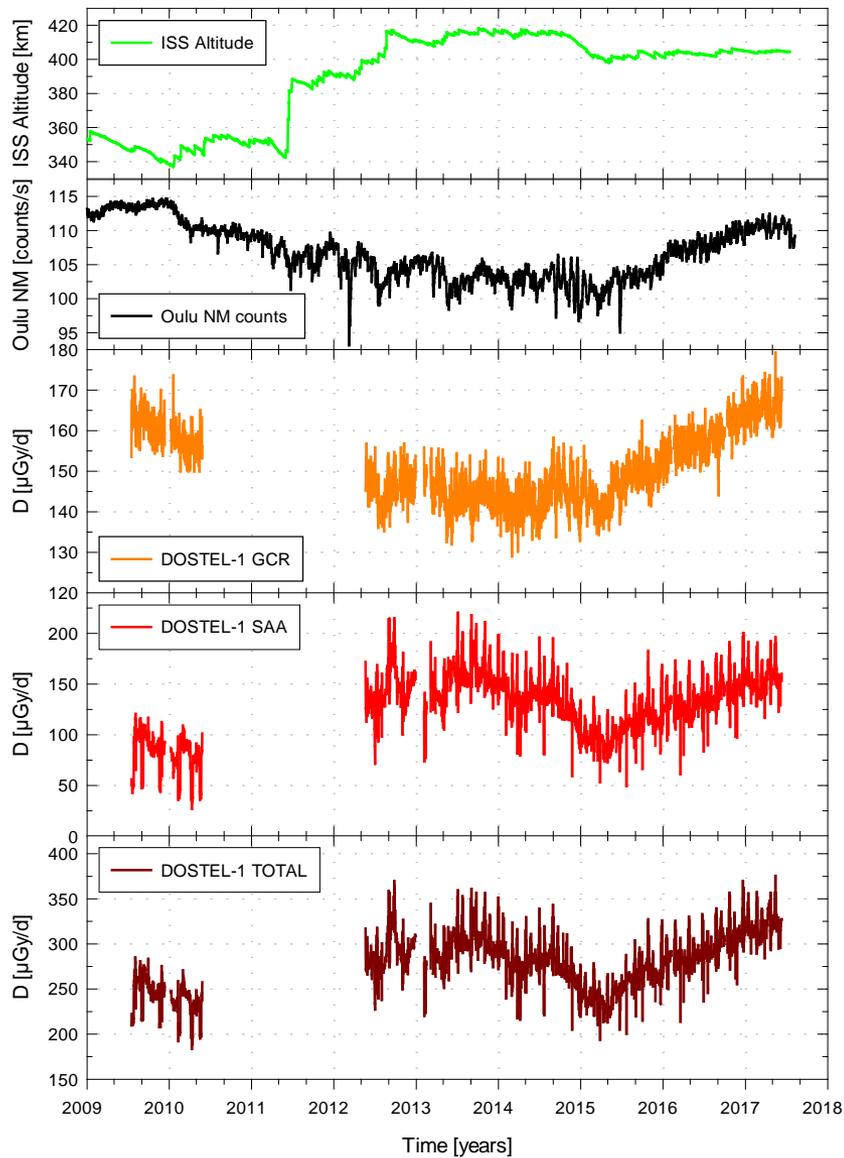
https://www.swsc-journal.org/articles/swsc/full_html/2017/01/swsc160046/swsc160046.html



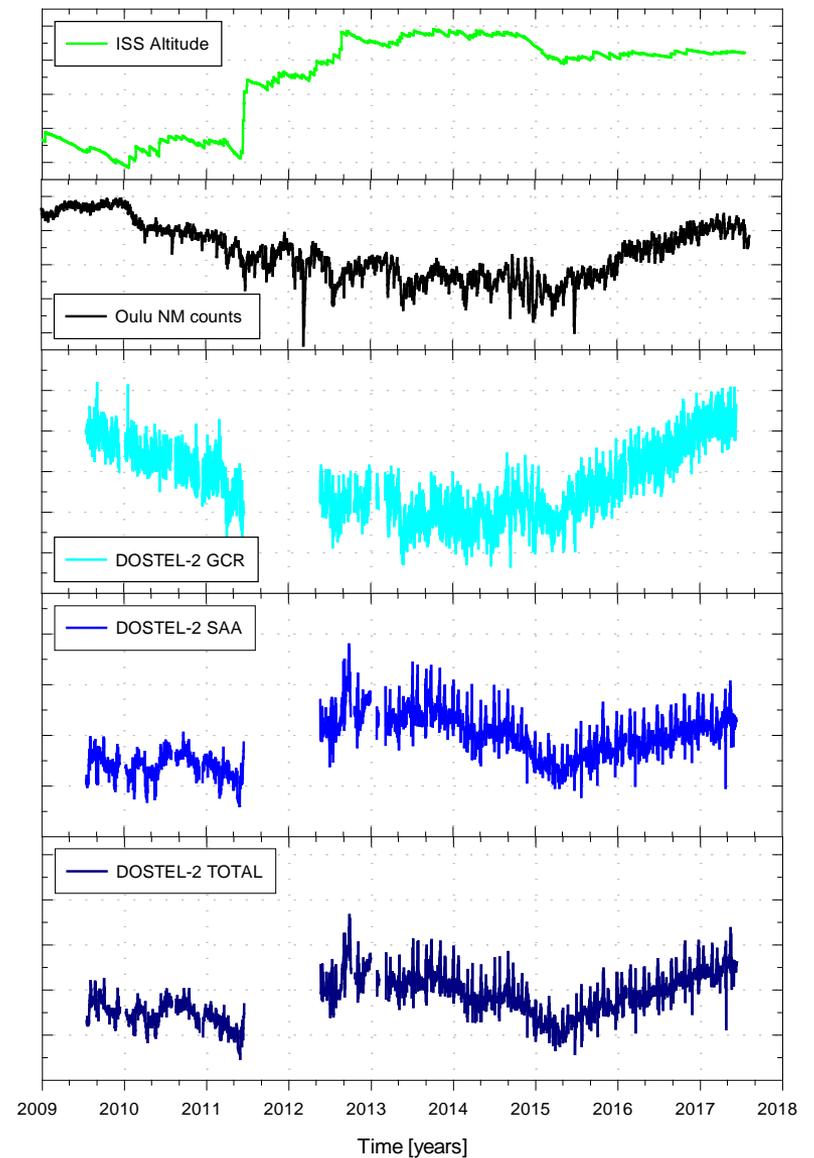
DOSIS & DOSIS 3D: Timeline / ISS Altitude / S_n / Oulu NM



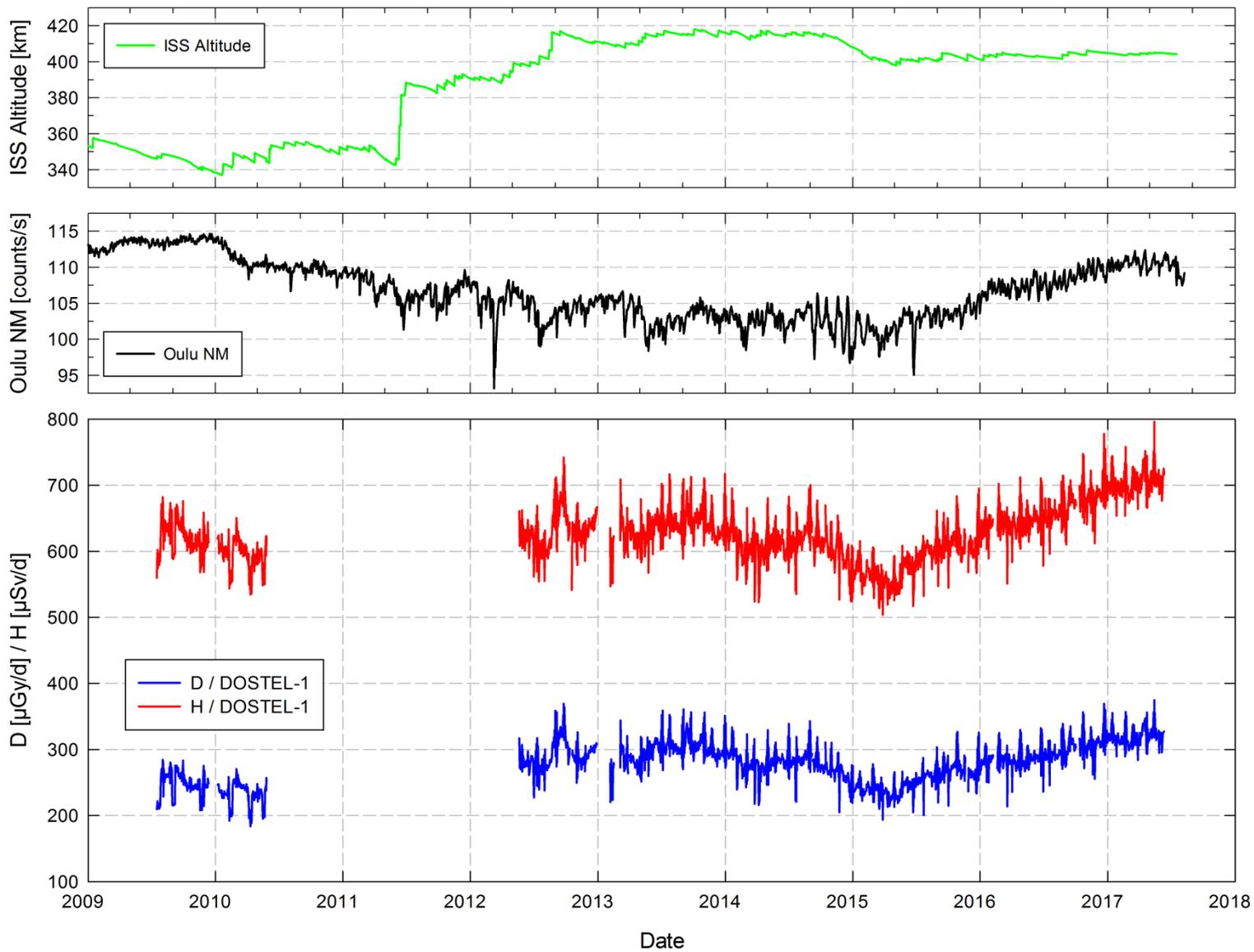
DOSTEL-1



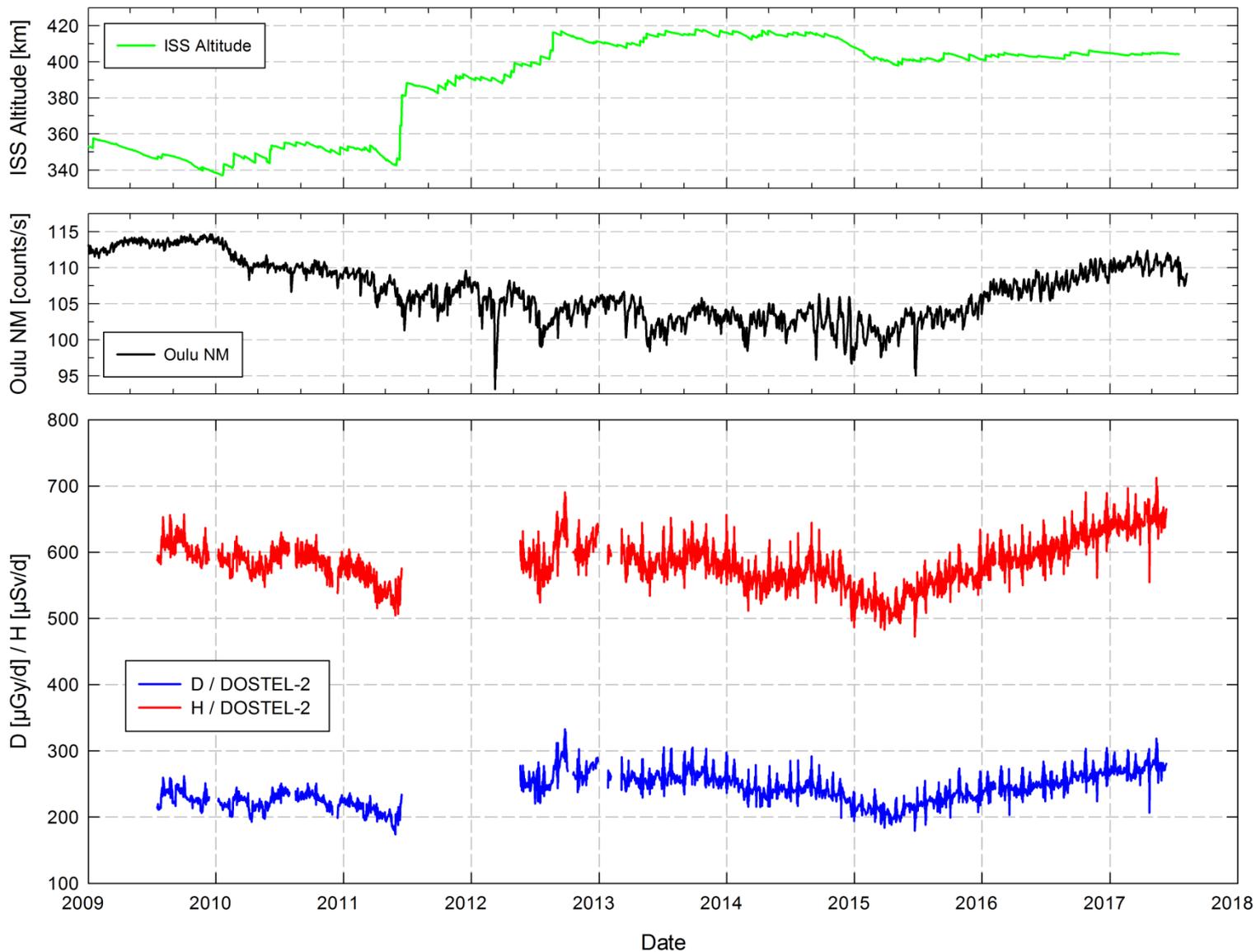
DOSTEL-2



DOSTEL-1



DOSTEL-2



DOSIS 3D: DOSTEL → **WORK IN PROGRESS**

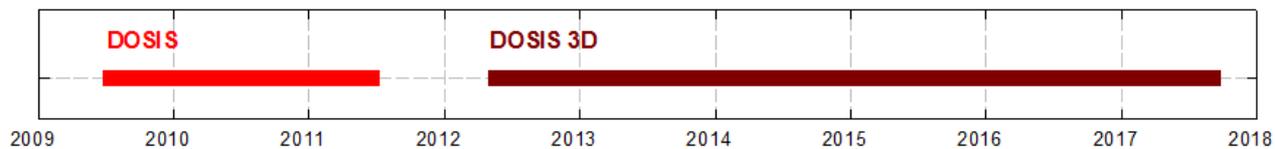
- ❖ Correlation of DOSTEL data (GCR/SAA) with ISS orbit → models for GCR and SAA dependence on solar cycle and ISS altitude (see also: WRMISS 2014 D. Matthiä)

- ❖ DOSTEL-1 Single Event Mode Data analysis → variation of GCR Quality factor with R_c

- ❖ Further work on DOSTEL comparison with other active radiation detectors onboard the ISS



DOSIS & DOSIS 3D: Active detector comparison



ALTEA



DB-8



REM

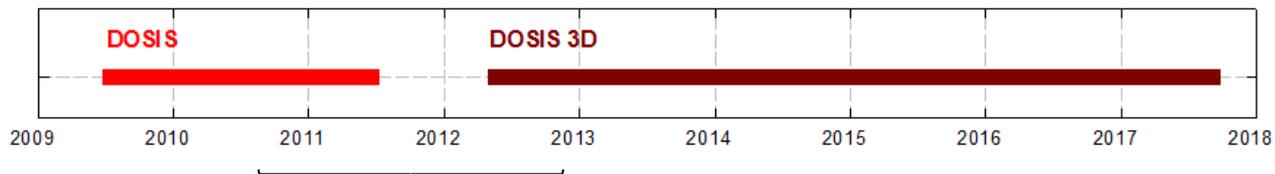


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DOSIS & DOSIS 3D: Comparison → ALTEA / DOSTEL



Narici et al. SWSC 7, A18, 2017

See: WRMISS-20 (2015) Talk L. Narici



DOSIS & DOSIS 3D: Comparison → ALTEA / DOSTEL

J. Space Weather Space Clim., 7, A18 (2017)
DOI: 10.1051/swsc/2017016
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RESEARCH ARTICLE OPEN ACCESS

Exploiting different active silicon detectors in the International Space Station: ALTEA and DOSTEL galactic cosmic radiation (GCR) measurements

Livo Narici^{1,2,*}, Thomas Berger², Sönke Burmeister³, Luca Di Fino¹, Alessandro Rizzo¹, Daniel Matthiä², and Günther Reitz²

¹ Department of Physics, University of Rome Tor Vergata & INFN – Roma 2, 00133 Rome, Italy
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Received 6 April 2017 / Accepted 19 June 2017

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DOSIS & DOSIS 3D: Comparison → ALTEA / DOSTEL

Space Weather News, Vol. 3, No. 2017
 DOI: 10.1016/j.swn.2017.05.001
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Business Model: Open Access

Exploiting different active silicon detectors in the International Space Station: ALTEA and DOSTEL galactic cosmic radiation (GCR) measurements

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Received 9 April 2017 / Accepted 09 June 2017

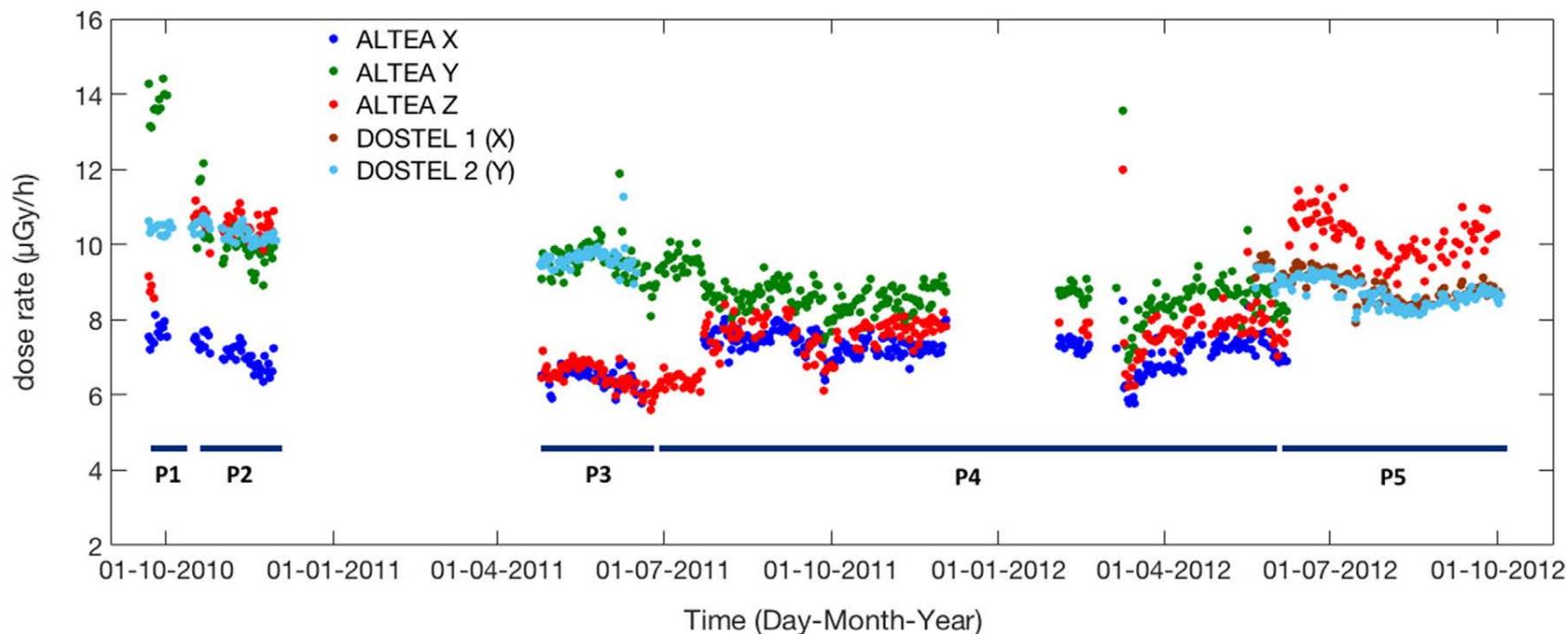
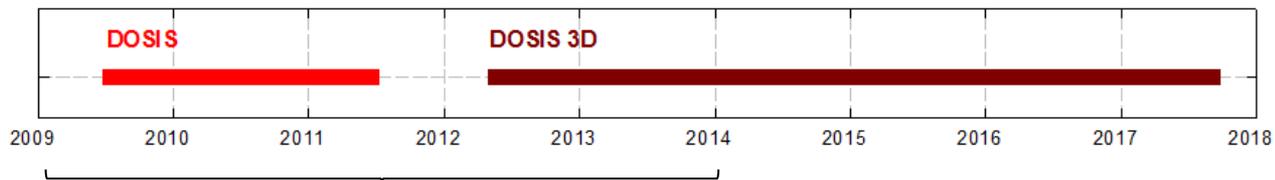


Fig. 11. Dose rate as measured by ALTEA and the two DOSTELs over the whole investigated period. **McIlwain $L > 3$** . Data are averaged over each day. In the bottom, the indication of the positions of the ALTEA system is shown (see also Fig. 1). The March 2012 SPE has been cut to improve readability of the rest of the data. Note: GCR data only (SAA data have been removed.)



DOSIS & DOSIS 3D: Comparison → DOSTEL / DB-8



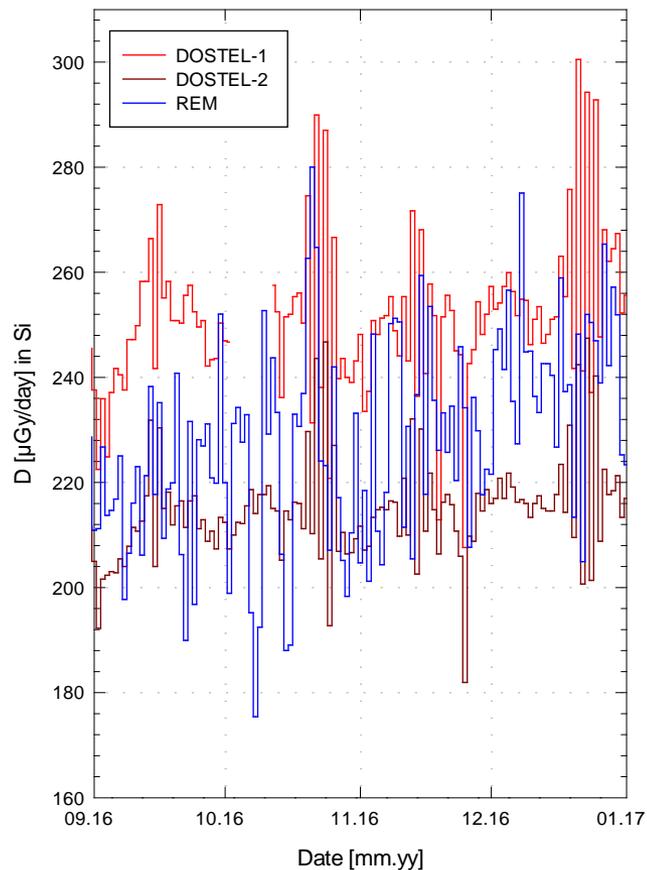
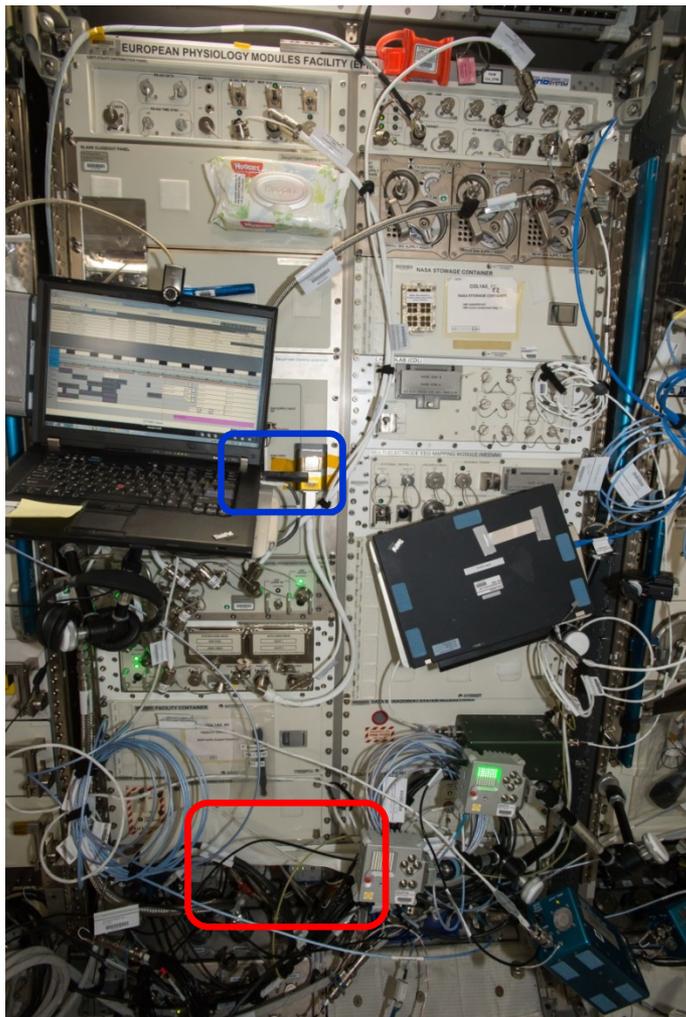
Berger et al. LSSR 2017 (under review)



See: WRMISS-19 (2014) Talk T. Berger
LSSR (paper under review) (2017)



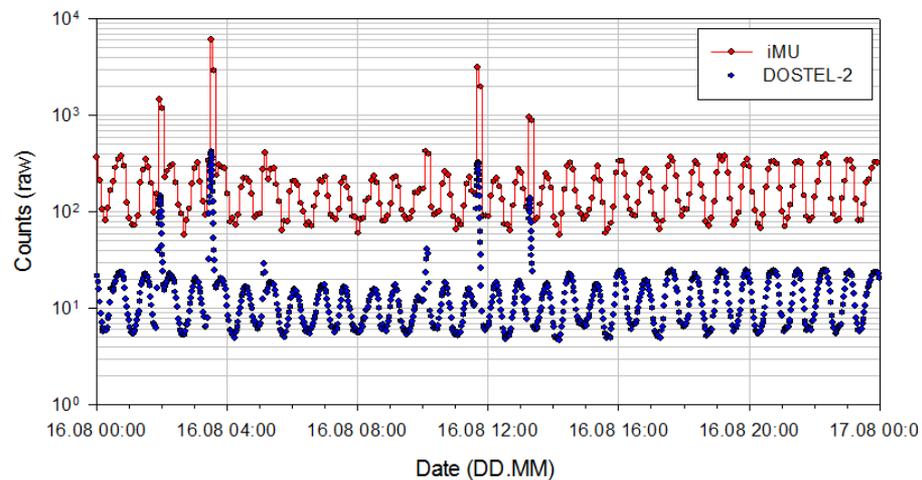
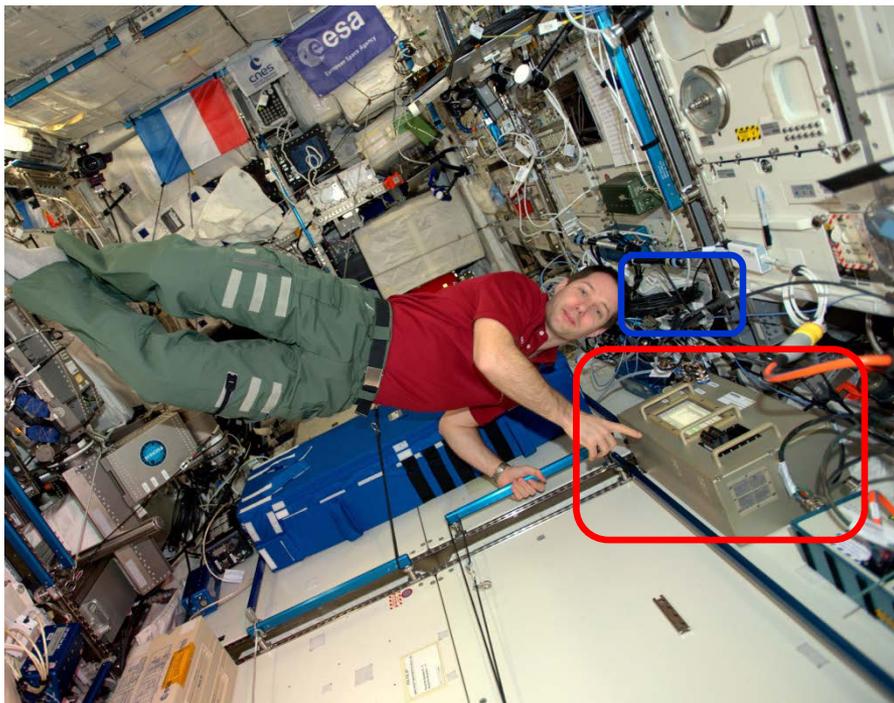
DOSIS & DOSIS 3D: Comparison → DOSTEL / REM



See: **WRMISS-22 (2017) Talk R. Rios**



DOSIS & DOSIS 3D: Comparison → DOSTEL / EAD



See: WRMISS-22 (2017) Talk T. Berger



DOSIS & DOSIS 3D: Summary

- DOSIS & DOSIS 3D:

- DOSTEL-1 2140 days of data
- DOSTEL-2 2488 days of data

- DOSIS & DOSIS 3D:

- DOSIS 2 long term PDP exposures
- DOSIS 3D 10 long term PDP exposures
PDP XI currently onboard ISS
PDP XII to be launched with 53S

- DOSIS 3D:

- Into depth comparison of data (as given before) is in progress / publications are in work



DOSIS & DOSIS 3D: Acknowledgements

We gratefully acknowledge the support of the European Space Agency (ESA) especially Jason Hatton, Rene Demets, Chiara Lombardi and Liesbeth De Smet as well as colleagues from CADMOS, Toulouse, France and DLR-MUSC, Cologne, Germany.

All of this experiments would not be possible without the help of all the astronauts working on the DOSIS and DOSIS 3D experiment: **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**



The participation of the Technische Universität Wien, Atominstitut (ATI), Vienna, Austria in the DOSIS-1 and -2 experiments was supported by the Austrian Space Applications Programme (ASAP) under contract no. 819643.

The Polish contribution for the Institute of Nuclear Physics (IFJ), Krakow, Poland was supported by the National Science Center (project No DEC-2012/06/M/ST9/00423).

MTA EK greatly acknowledges the possibility to participate in the project to the DLR and to the ESA PECS for the financial grant No. PECS4000108464.

The participation of the Nuclear Physics Institute of the Czech Academy of Sciences (NPI) has been supported by the grant of Czech Science Foundation (GACR) No. 15-16622Y.

CAU, Kiel was supported by DLR under grants 50WB0826, 50WB1026, 50WB1232 and 50WB1533.

