

The DOSIS and DOSIS 3D Experiments onboard the International Space Station – Results From the Active DOSTEL Instruments

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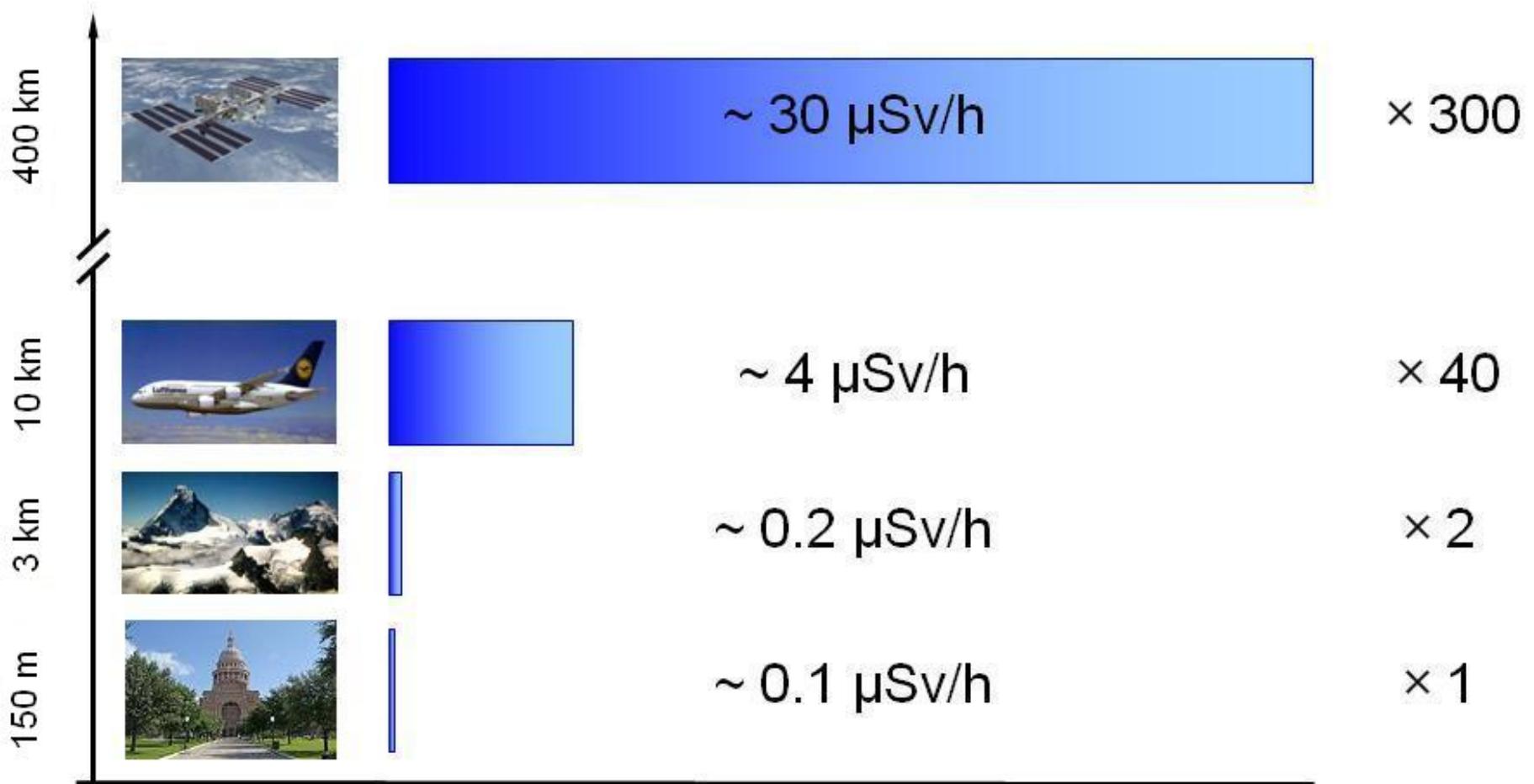
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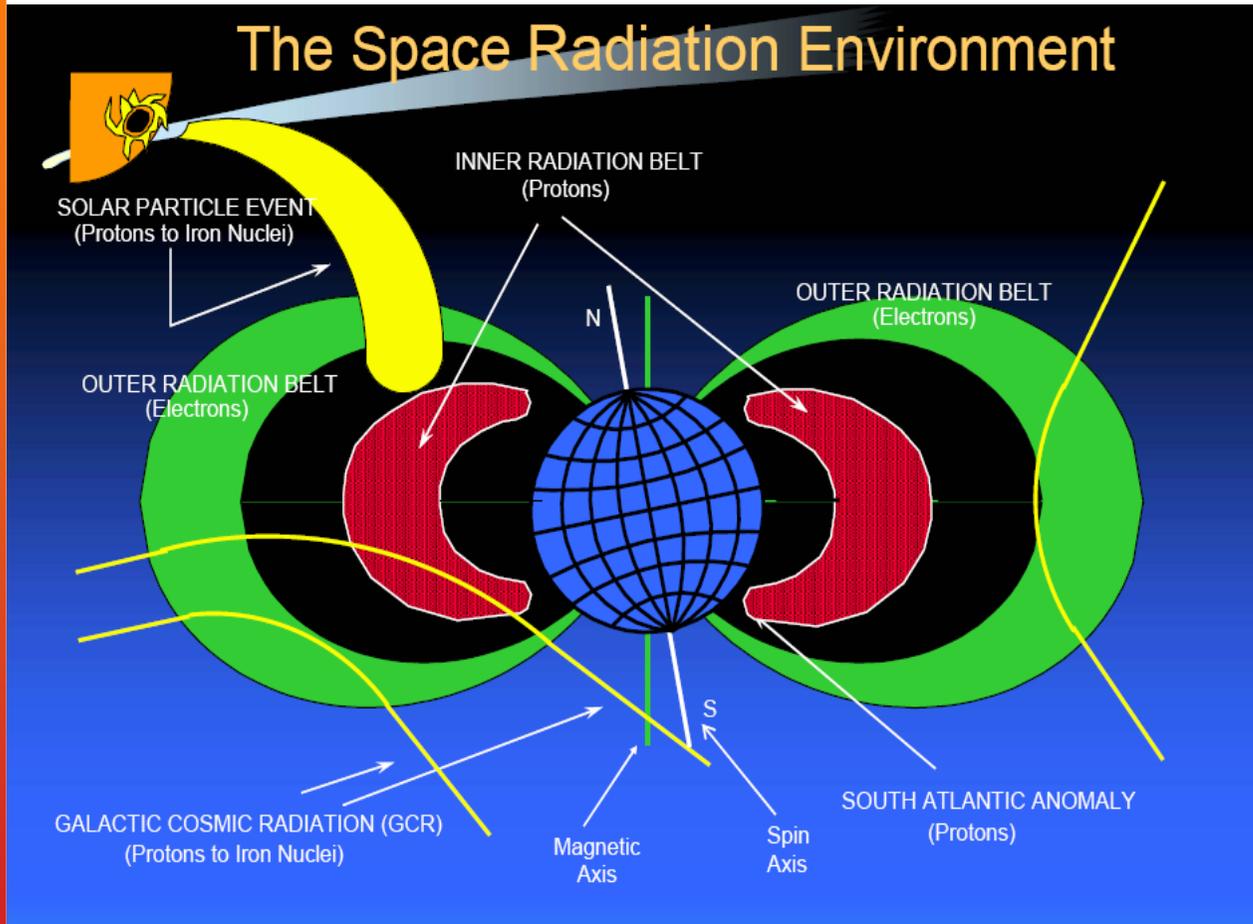
⁴ OHB Technologies, Bremen, Germany



Radiation Exposure



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 : Dose Distribution Inside the ISS

Measurement of the radiation environment inside the European Columbus Laboratory onboard the ISS ESA Proposal #ILSRA-2004-167

- 2 active radiation detectors (DOSTEL)
- 11 passive radiation detector packages (PDP) distributed within Columbus

→ July 2009 to June 2011

Reference Document:
SCI-ESA-HSF-ESR-DOSIS



DOSIS 3D - Dose Distribution Inside the ISS 3D **ESA Proposal # ILSRA-2009-0778**

The main objective of the 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) (same experiment suite as for DOSIS)

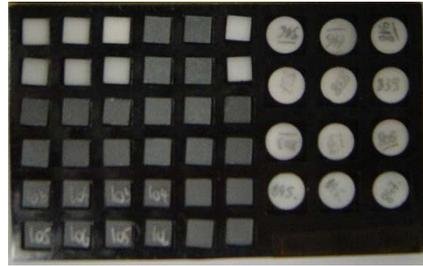
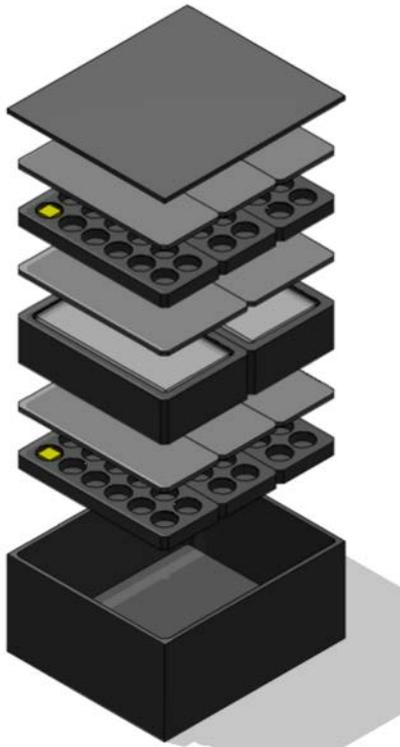
Combine data gathered by NASA; JAXA; IMBP and ESA into a 3D radiation map of the International Space Station

START: May 2012 (Soyuz 30S)

Experiment Runtime: 6 increments (up to end of 2014)

Reference Document: ESA-HSO-ESR-Dosis 3D

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

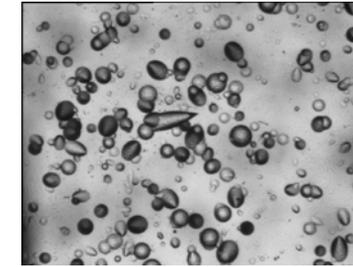


Thermoluminescence detectors (TLD)

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 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

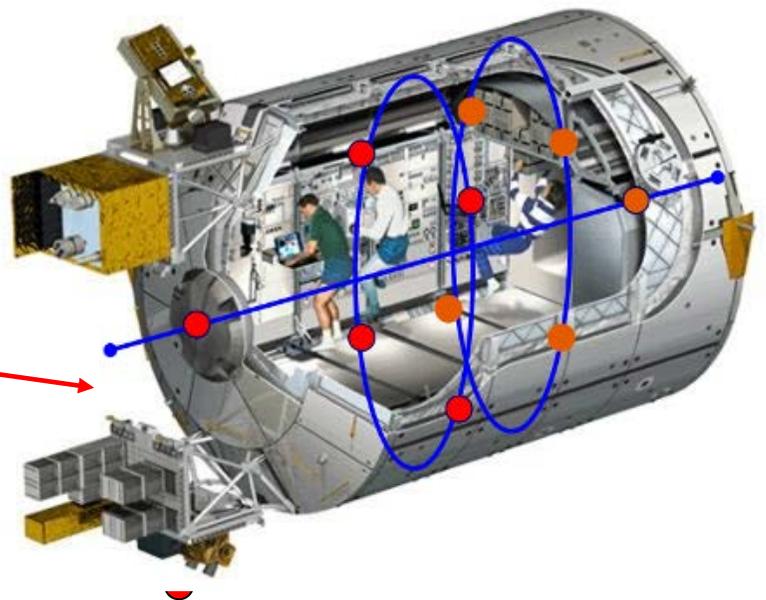
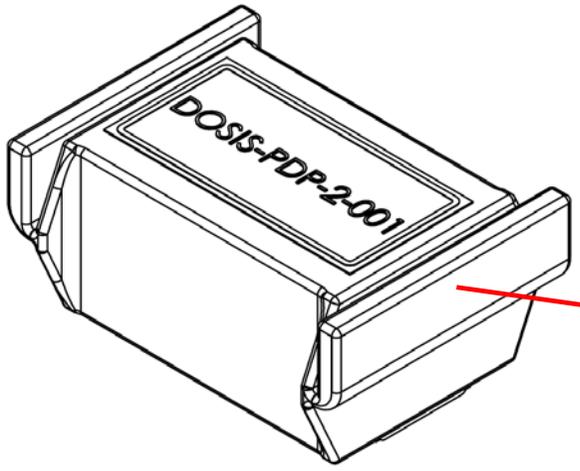
Heavy charged particles break chemical bonds in the material. This trail can be made visible by etching the material.

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

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).

DOSIS Passive Detectors

11 passive radiation detector packages (PDP) distributed within Columbus



DOSIS Passive Detector Packages (PDP)

DOSIS : PDP in Columbus I



DOSIS-PDP-2-001/011

ISS020E022221



DOSIS-PDP-2-004/014

ISS020E022228



DOSIS-PDP-2-007/017

ISS020E022233



DOSIS-PDP-2-002/012

ISS020E022223



DOSIS-PDP-2-005/015

ISS020E022229



DOSIS-PDP-2-008/018

ISS020E022237



DOSIS-PDP-2-003/013

ISS020E022225



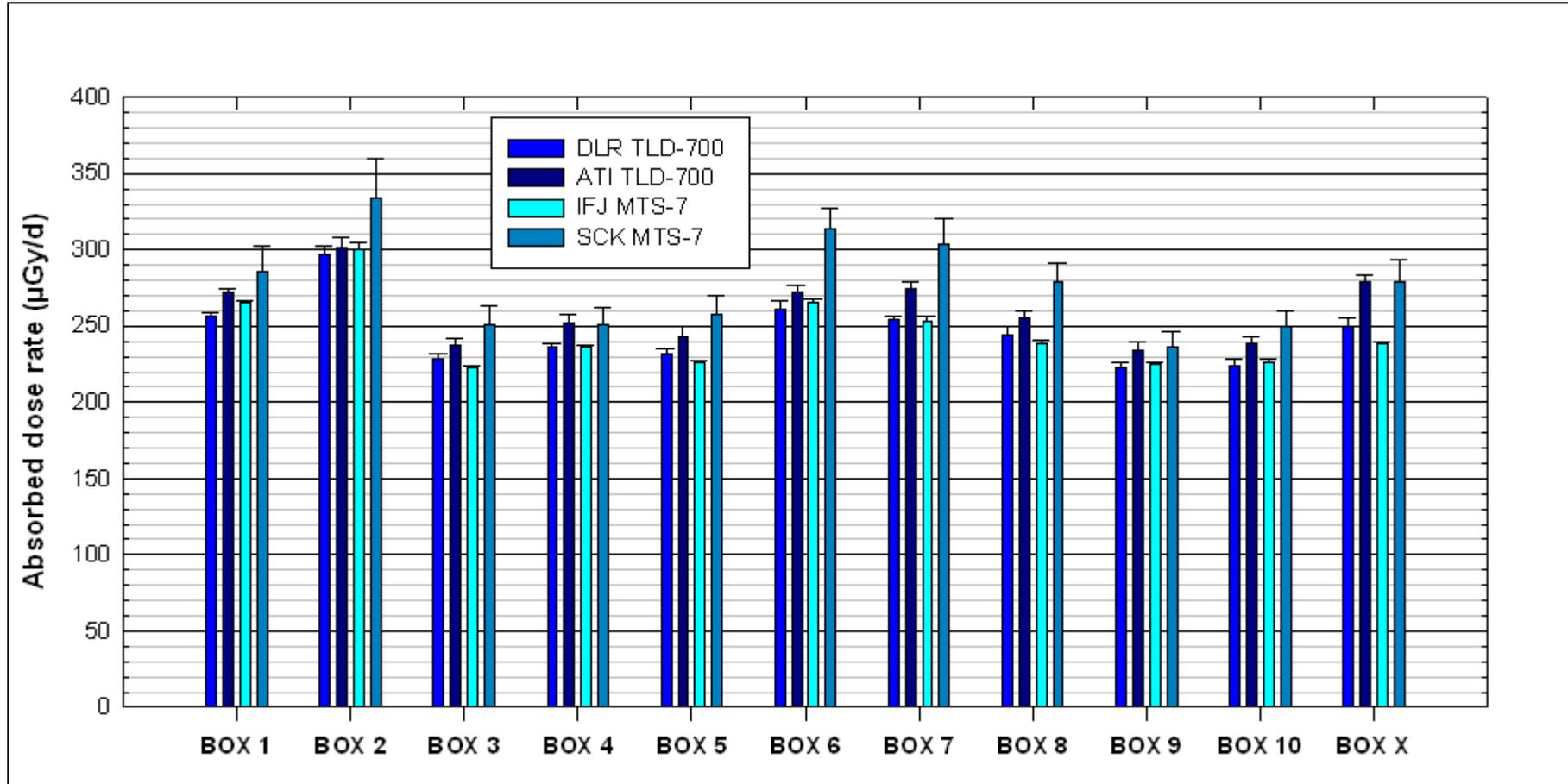
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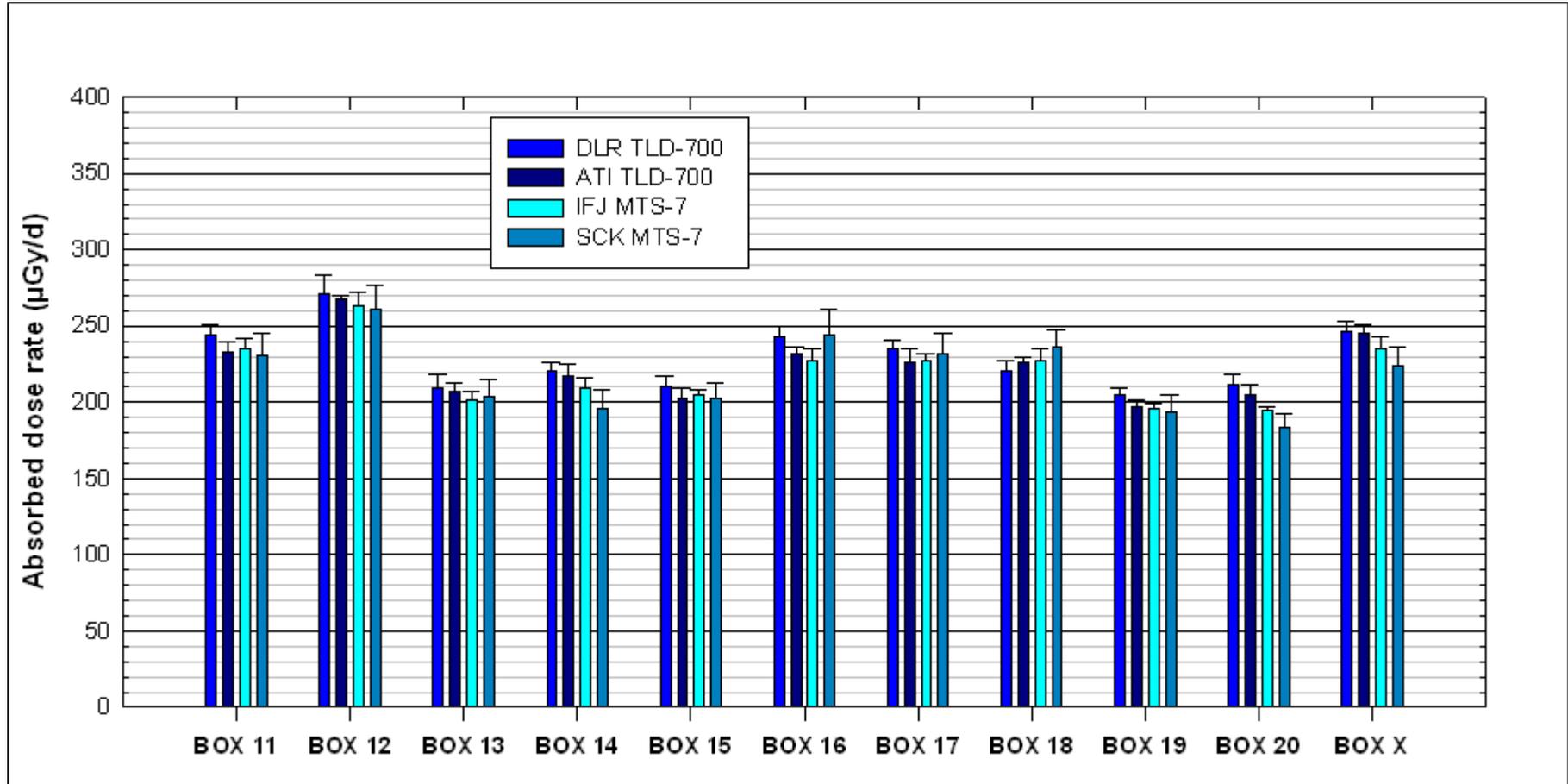
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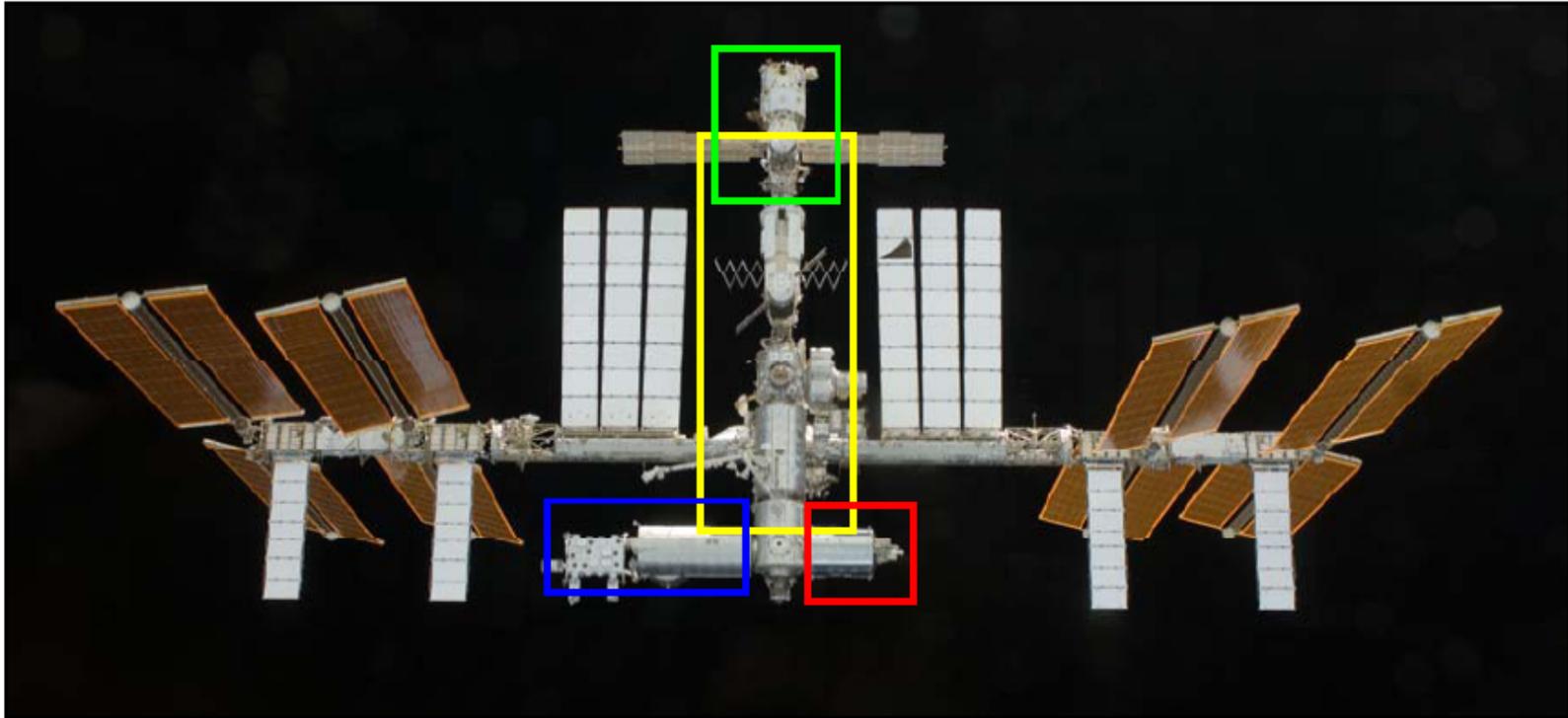
DOSIS-PDP-2-009/019

ISS020E022235

DOSIS : Results from passive TLDs Phase I (07 – 11/09)

DOSIS : Results from passive TLDs Phase II (11/09 – 05/10)

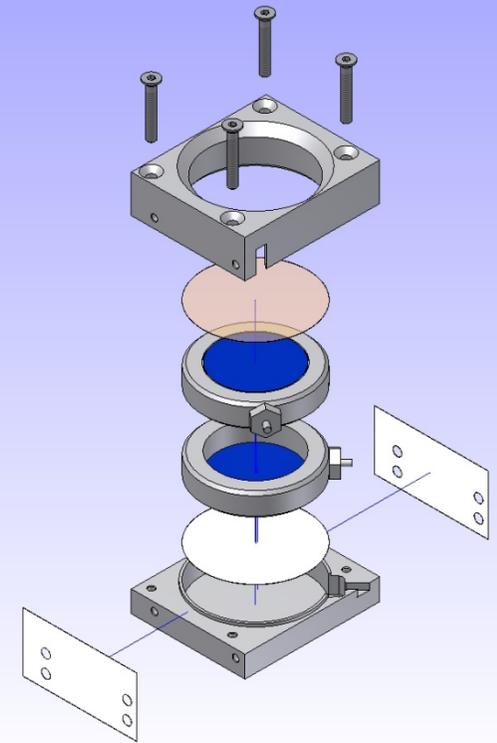
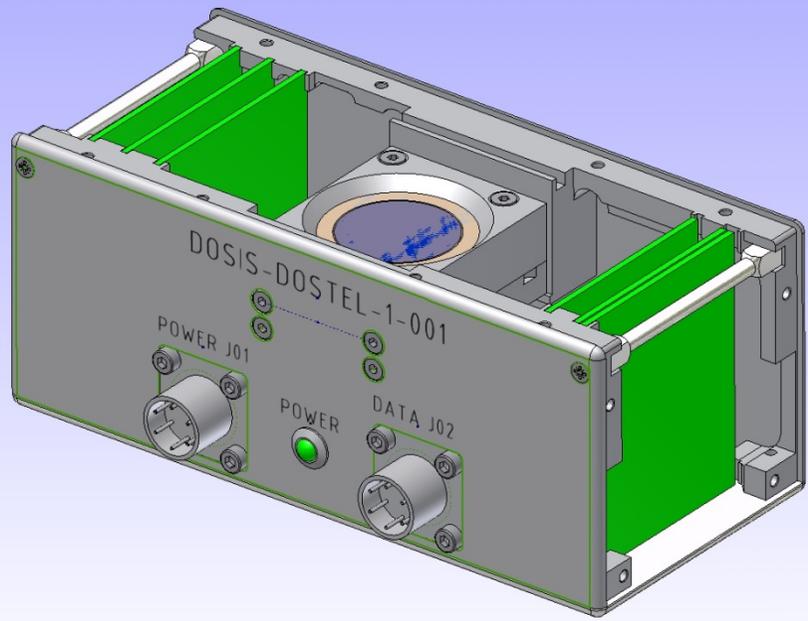
DOSIS / DOSIS 3D



<i>Agency</i>	<i>Name of the detectors</i>	<i>Quantity</i>	<i>Position on ISS</i>
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	

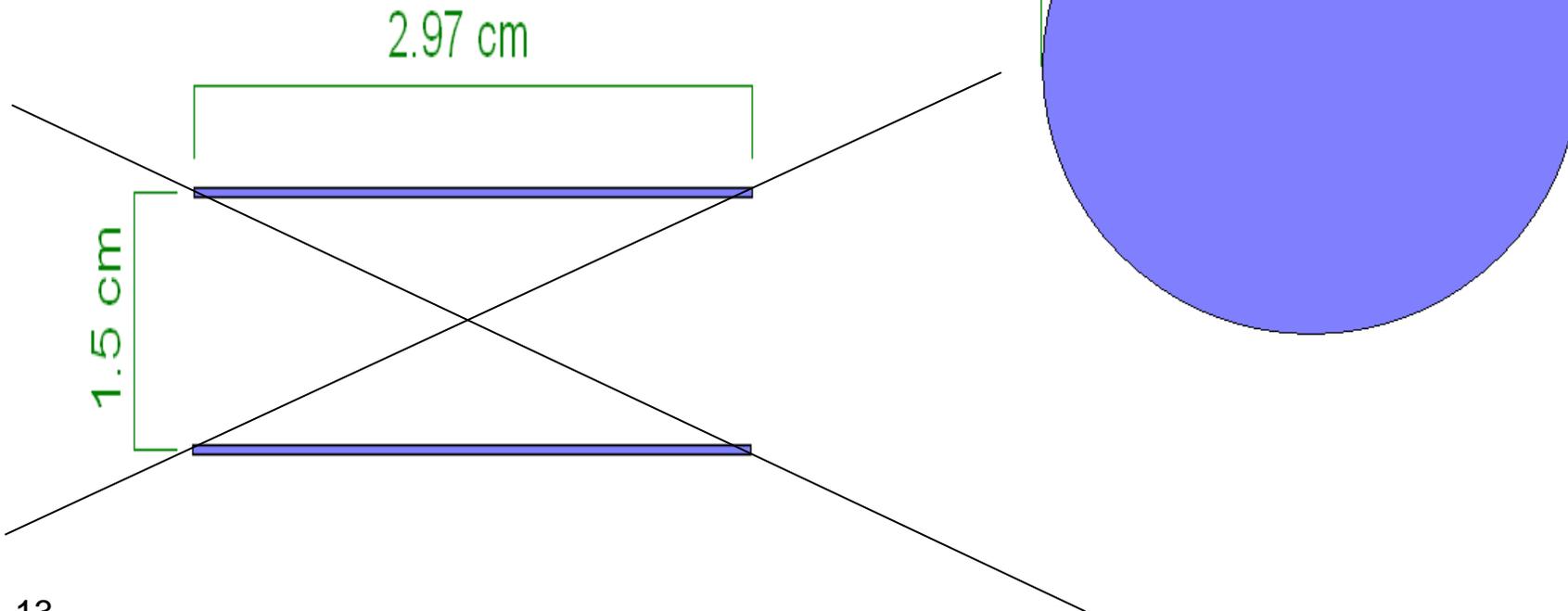
Fig. 3: Passive detectors on the ISS. The RAMs, PADLES, SPD and Pille detectors are permanently on board of the ISS. The PDPs from ESA are not. To reach the scientific goals set by Dosis 3D the PDPs shall be re-introduced on Columbus.

DOSTEL Detector



DOSTEL Detector

The DOSTEL Detector Head consists two circular PIPS detectors by Canberra. These two are forming a telescope. The active area of the detectors is 6.93 cm^2 . Mounted in a distance of 1.5 cm this leads to an opening angle of 120° .



DOSIS Main Box



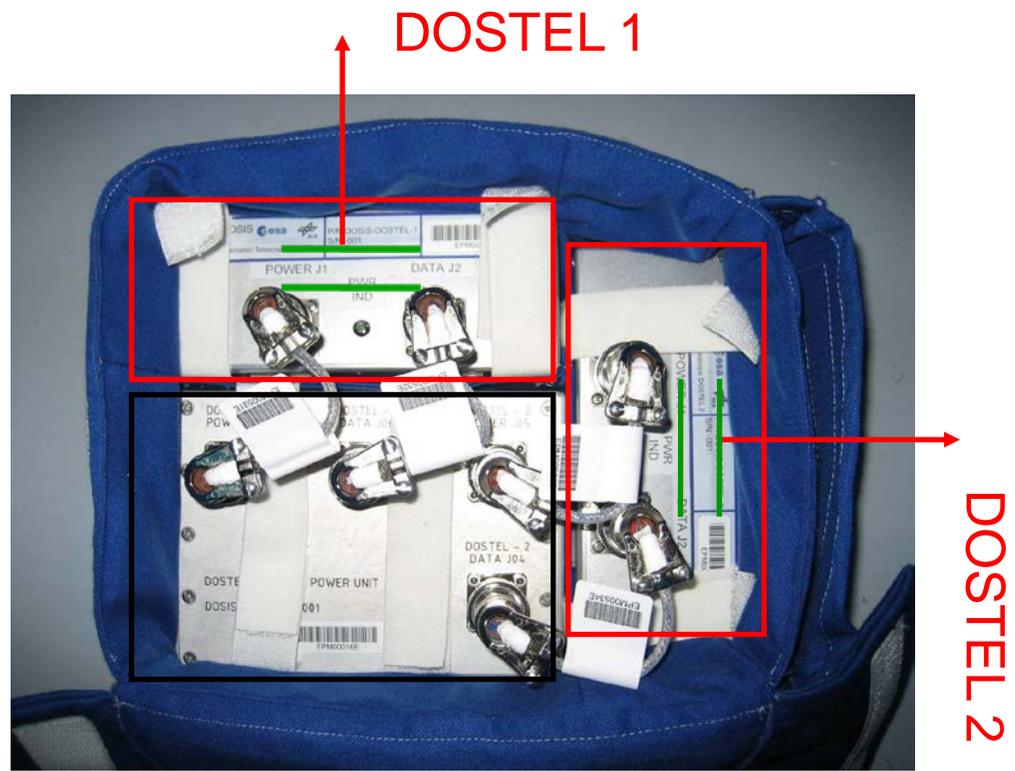
DOSTEL



DDPU
(DOSTEL Data and Power Unit)



DOSIS Main Box



DDPU – DOSTEL Data and Power Unit

DOSTEL Data

- Each DOSTEL can provide count rate profiles, dose rate profiles and energy deposition spectra
- The energy spectra can be used to obtain LET-Spectra because of the path length limitation due to its telescope geometry
- The LET spectra can be used to get information such as average quality factors which leads to dose equivalent

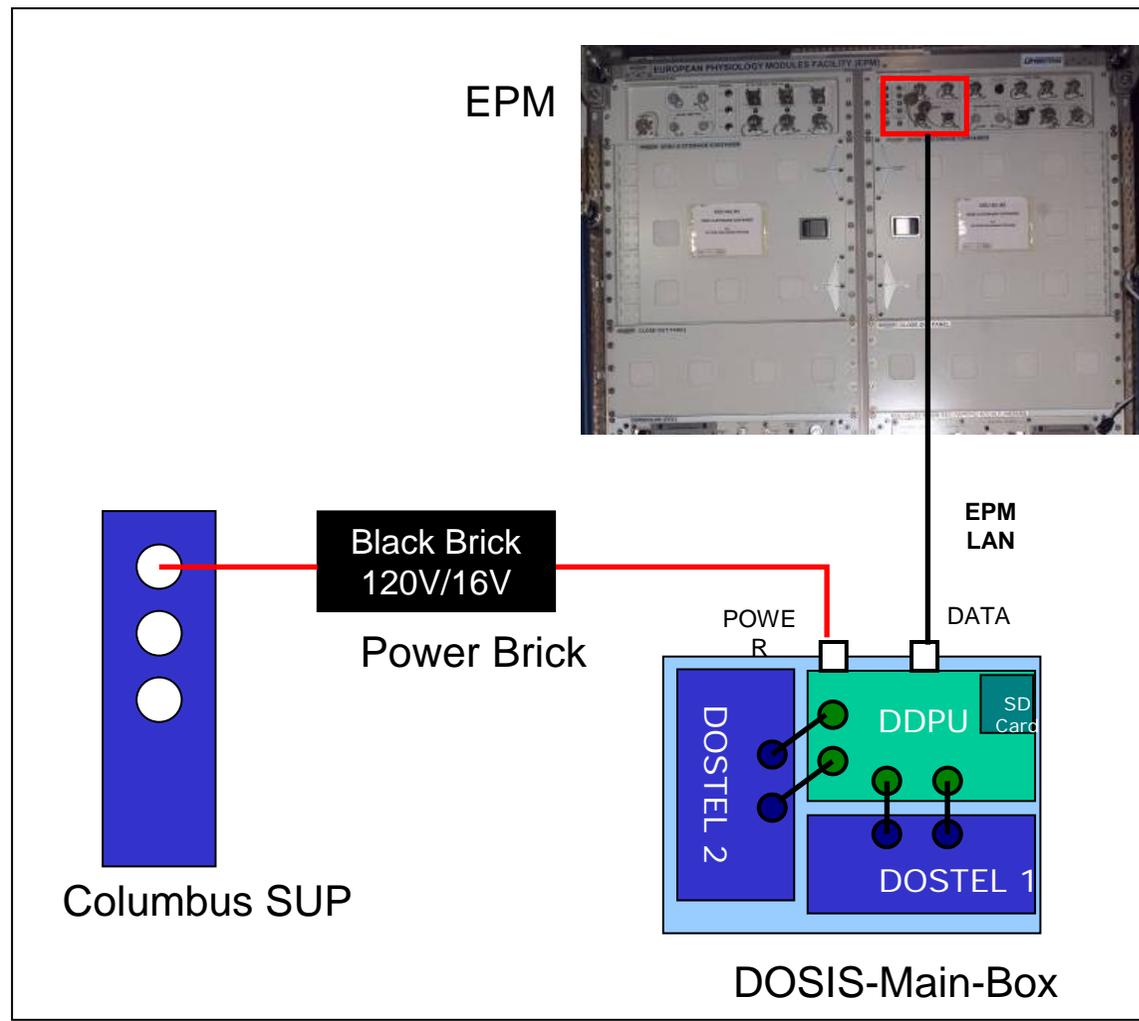
DOSIS - Launch 15.July 2009 STS-127



DOSIS 3D - Launch 15. May 2012 Soyuz TMA 04M / 30S



DOSIS Installation Inside COLUMBUS

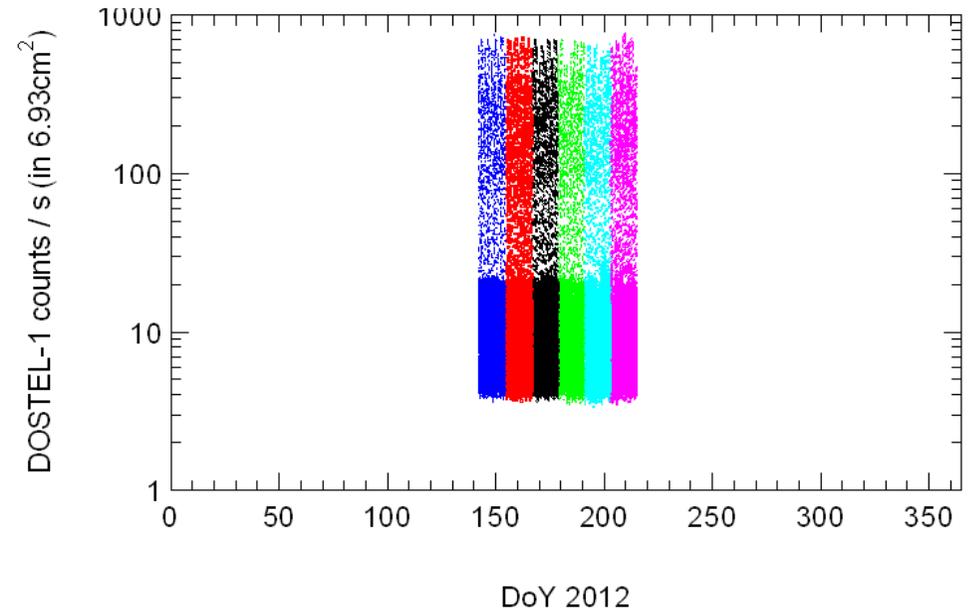
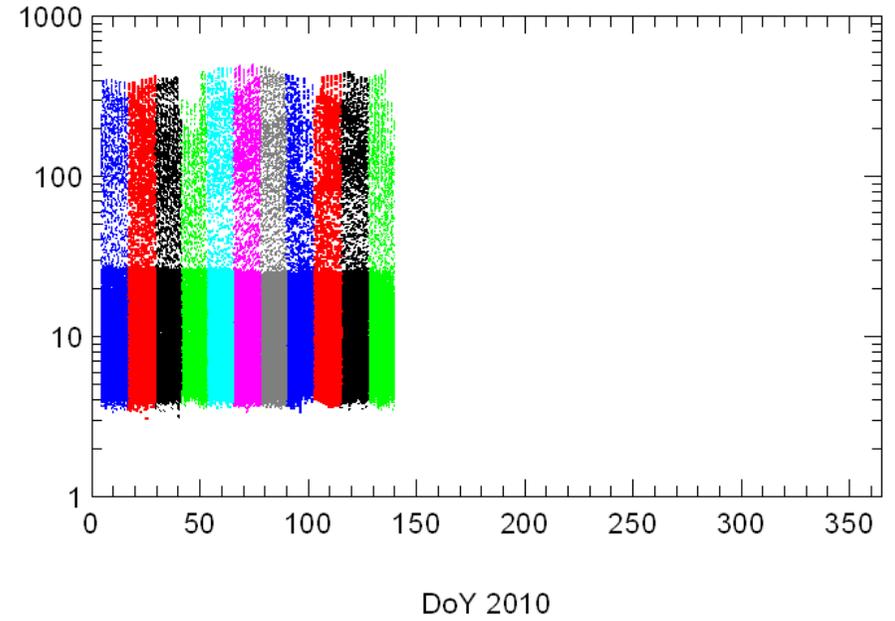
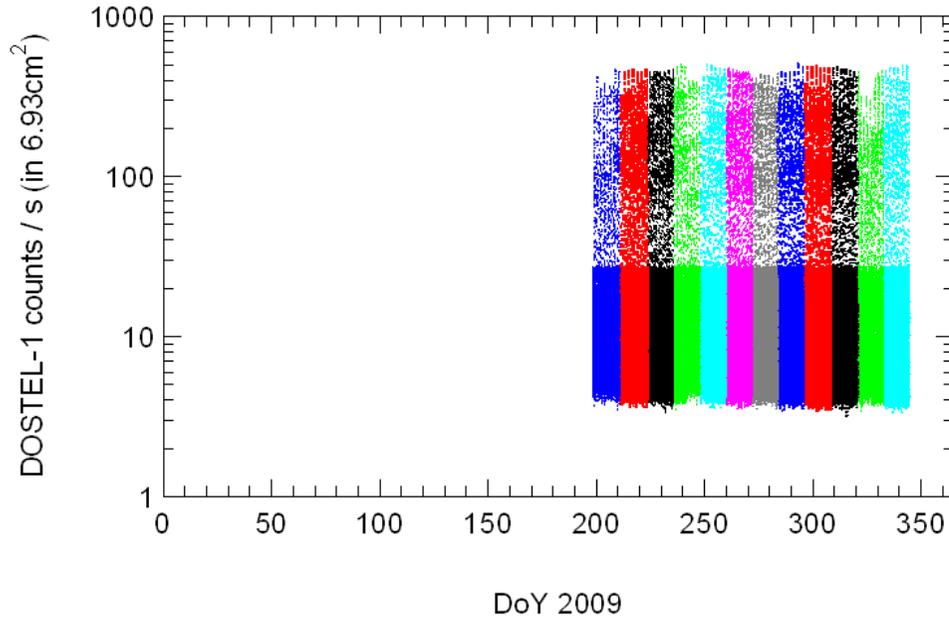


DOSIS & DOSIS 3D: DOSTEL

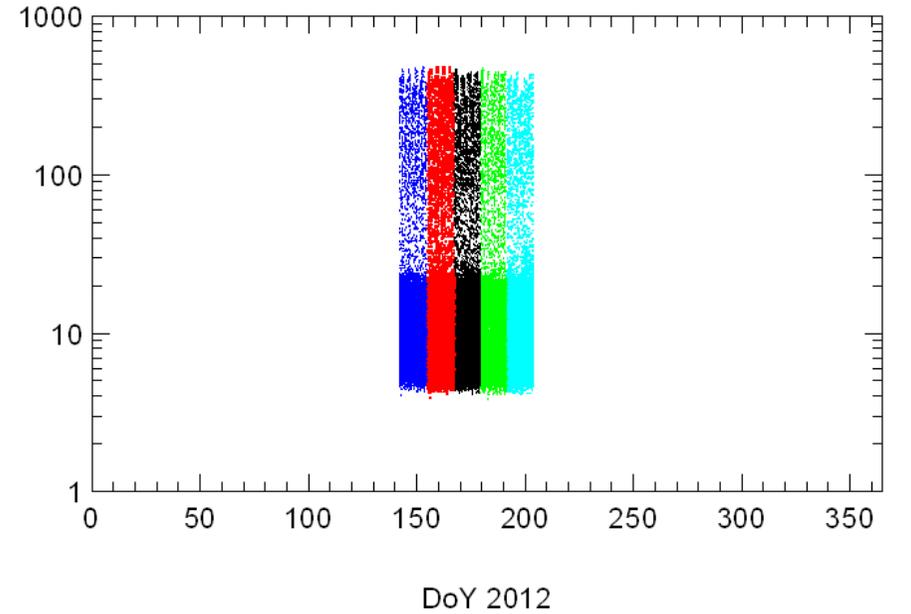
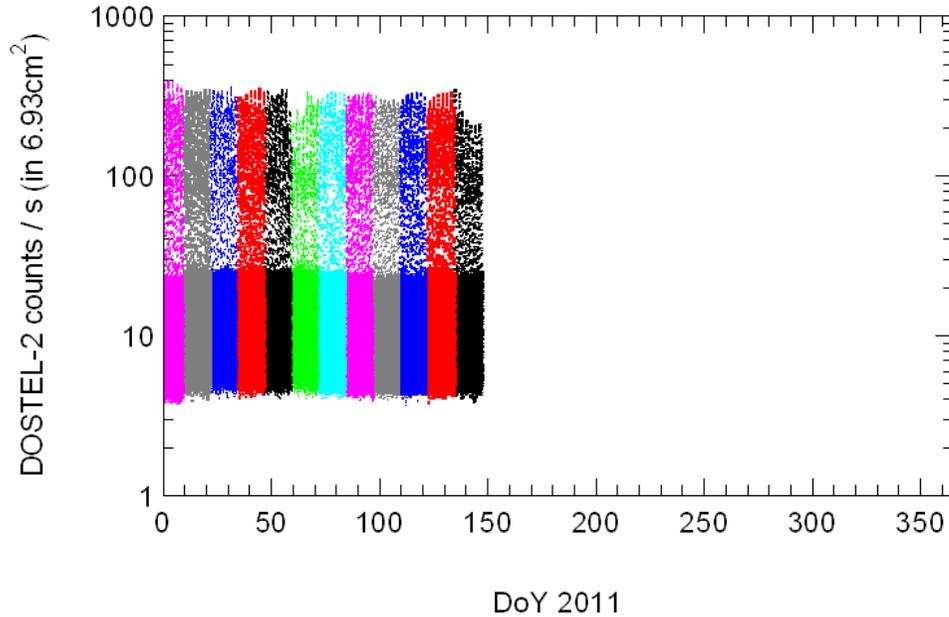
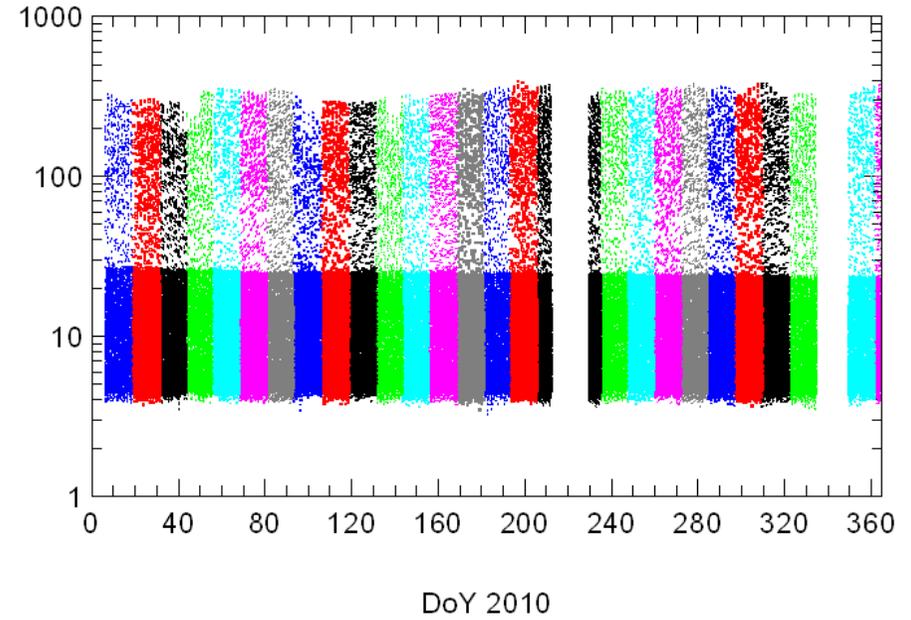
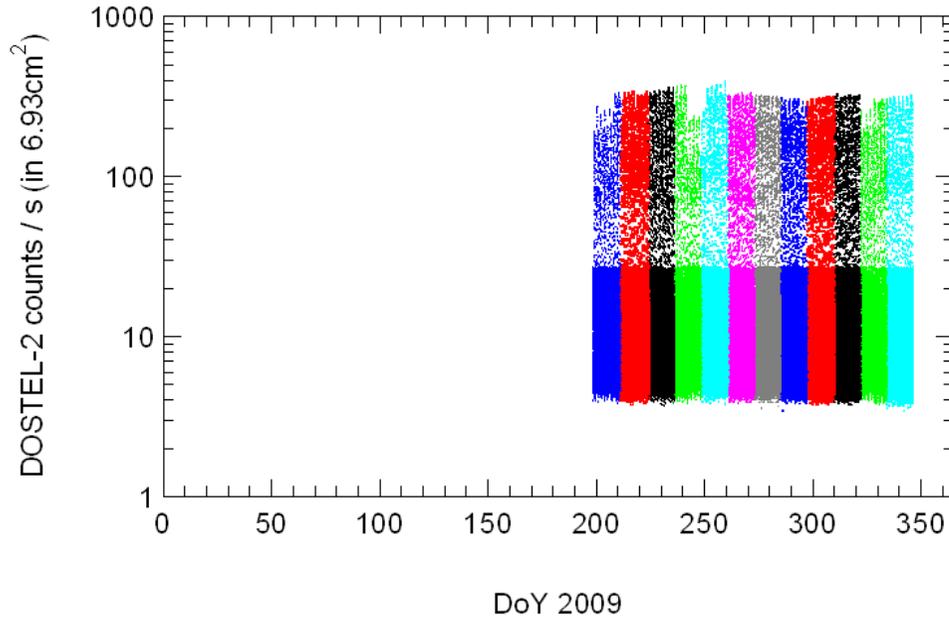


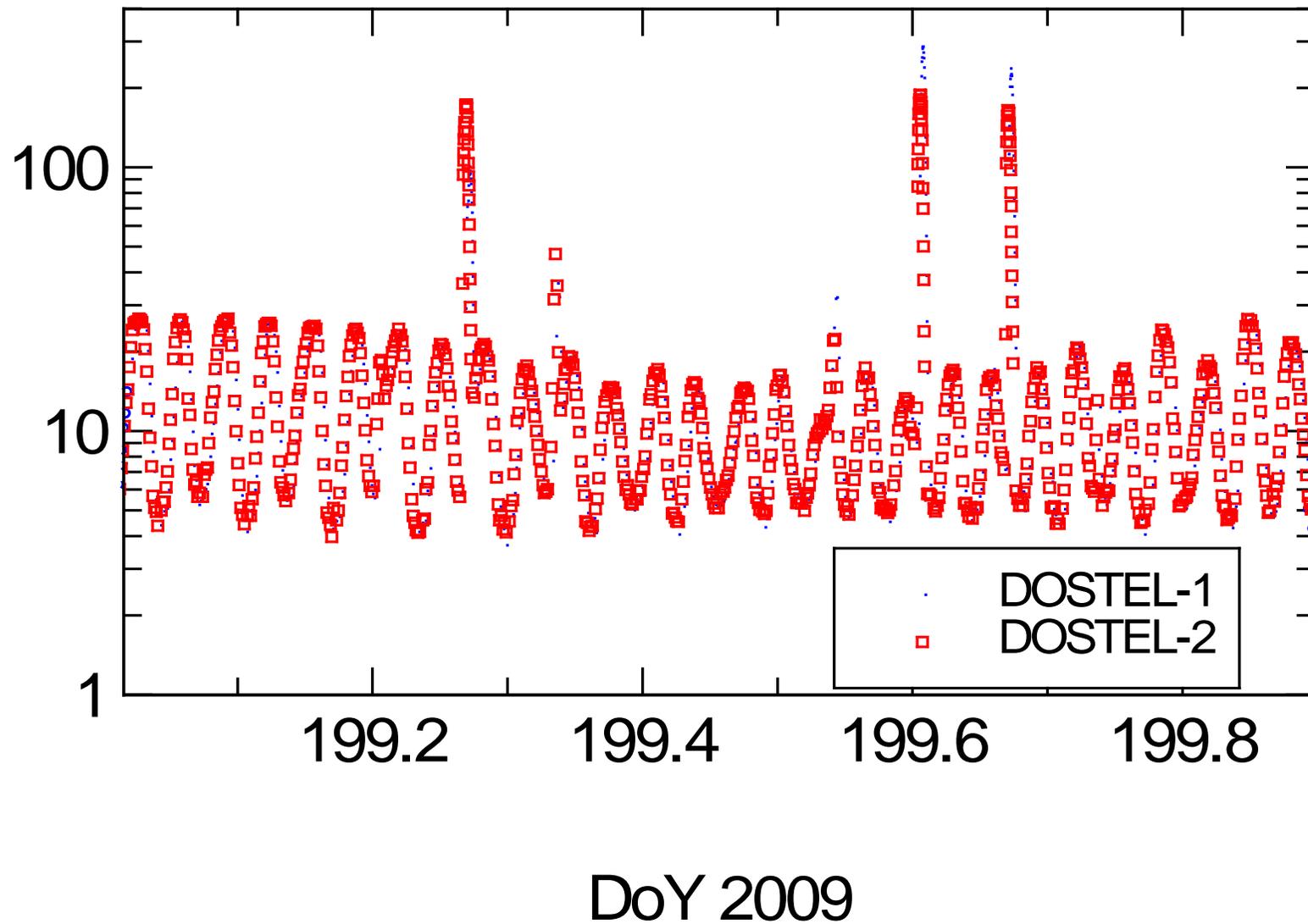
- Ethernet connection to EPM rack "Right Utility Distribution Panel"
- DOSIS MAIN BOX connected to EPM LAN like an external EPM instrument
- Data downlink is an EPM operation from ground performed once per month

DOSIS DOSTEL-1 Count Rates

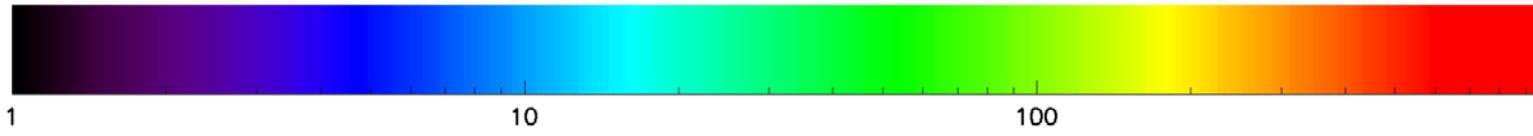


DOSIS DOSTEL-2 Count Rates

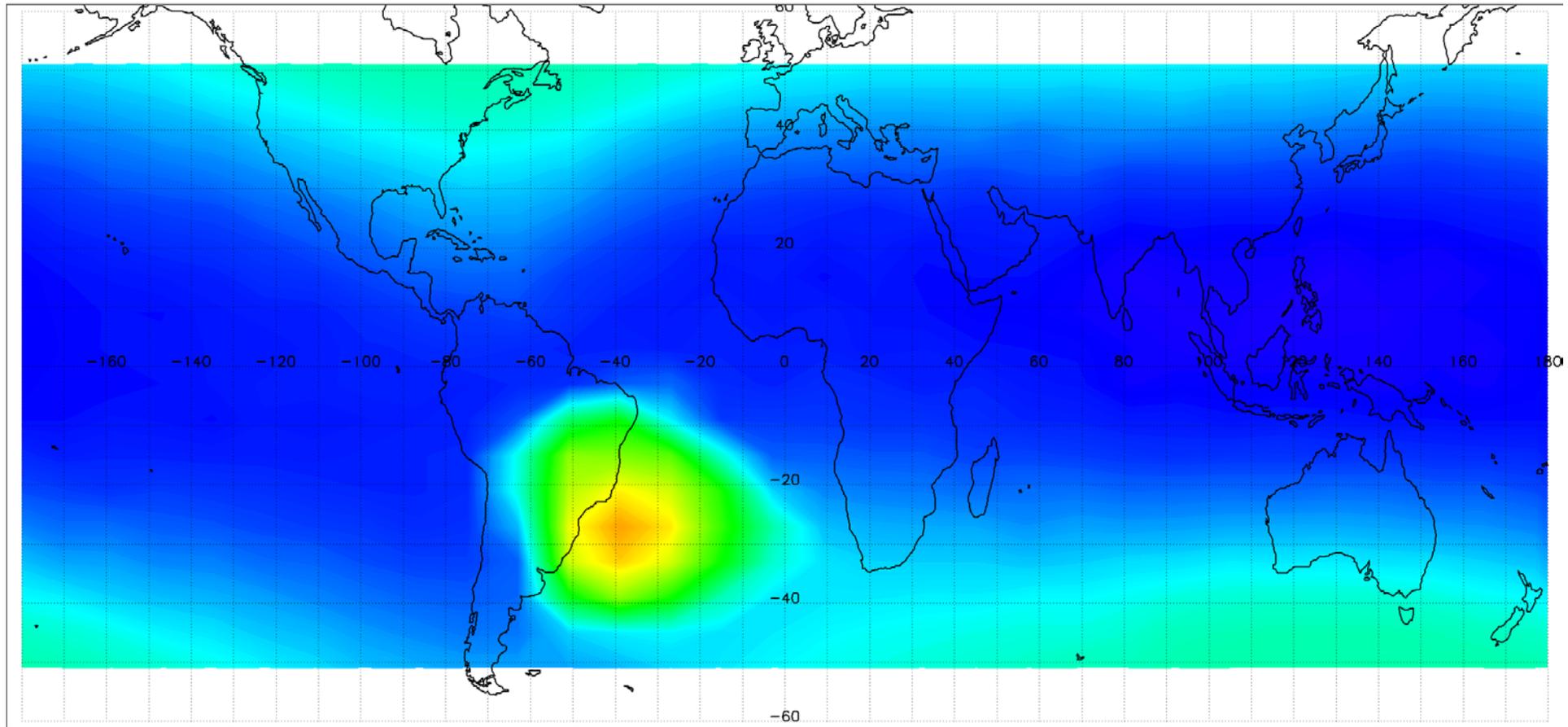


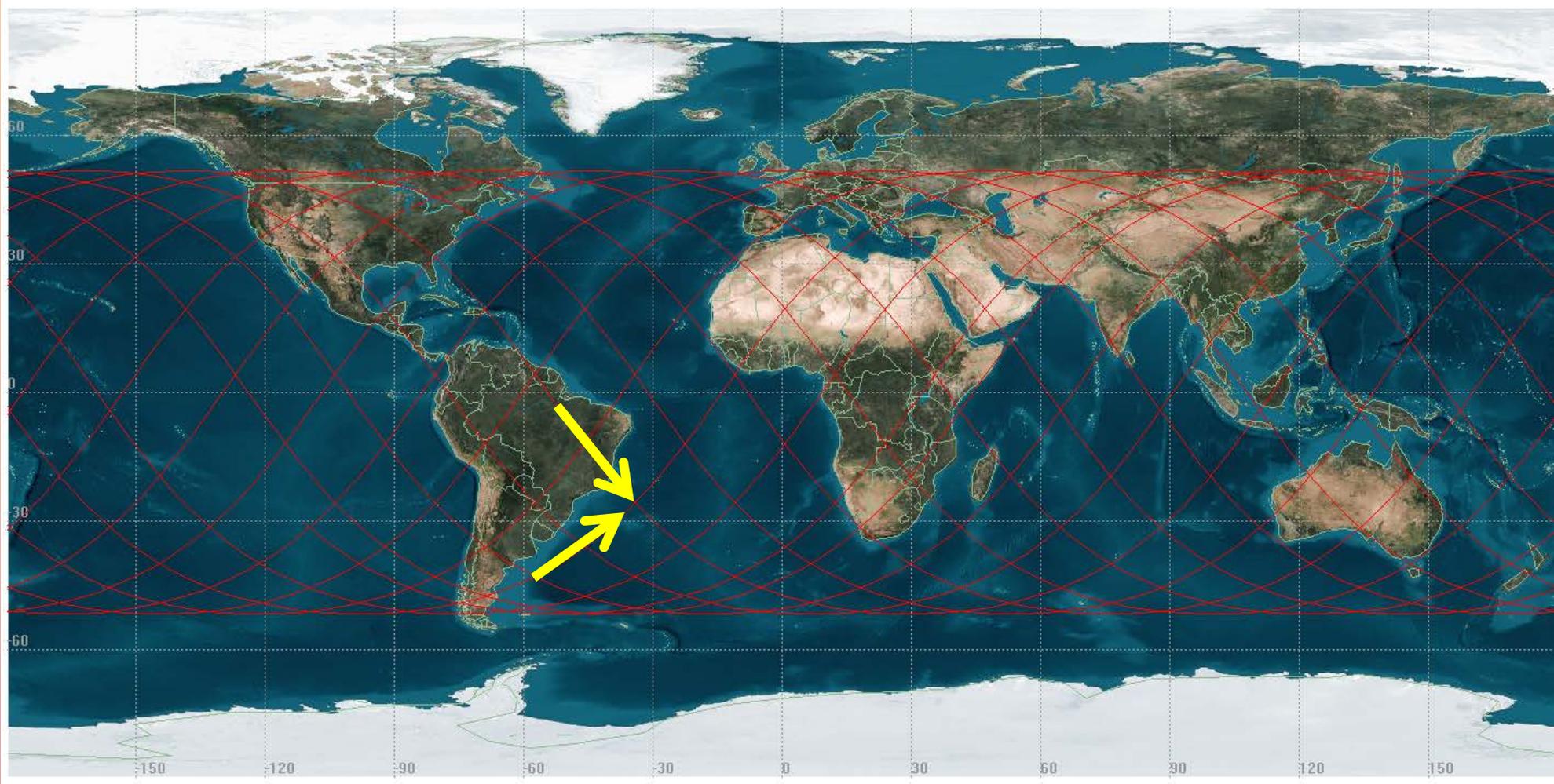
1 counts/s in 6.93cm²

DOSIS - DOSTEL

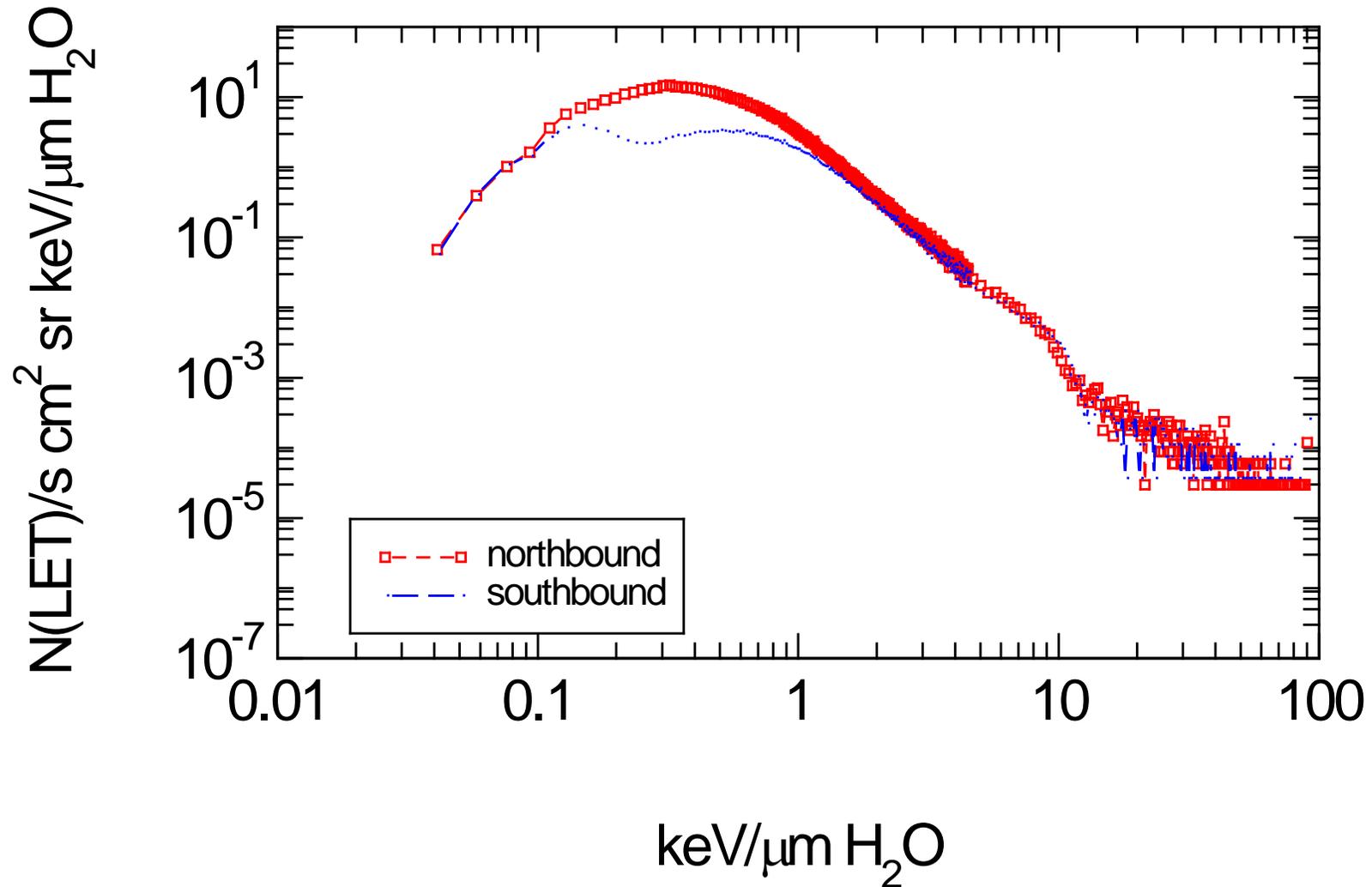


counts/s DOSIS July 2010

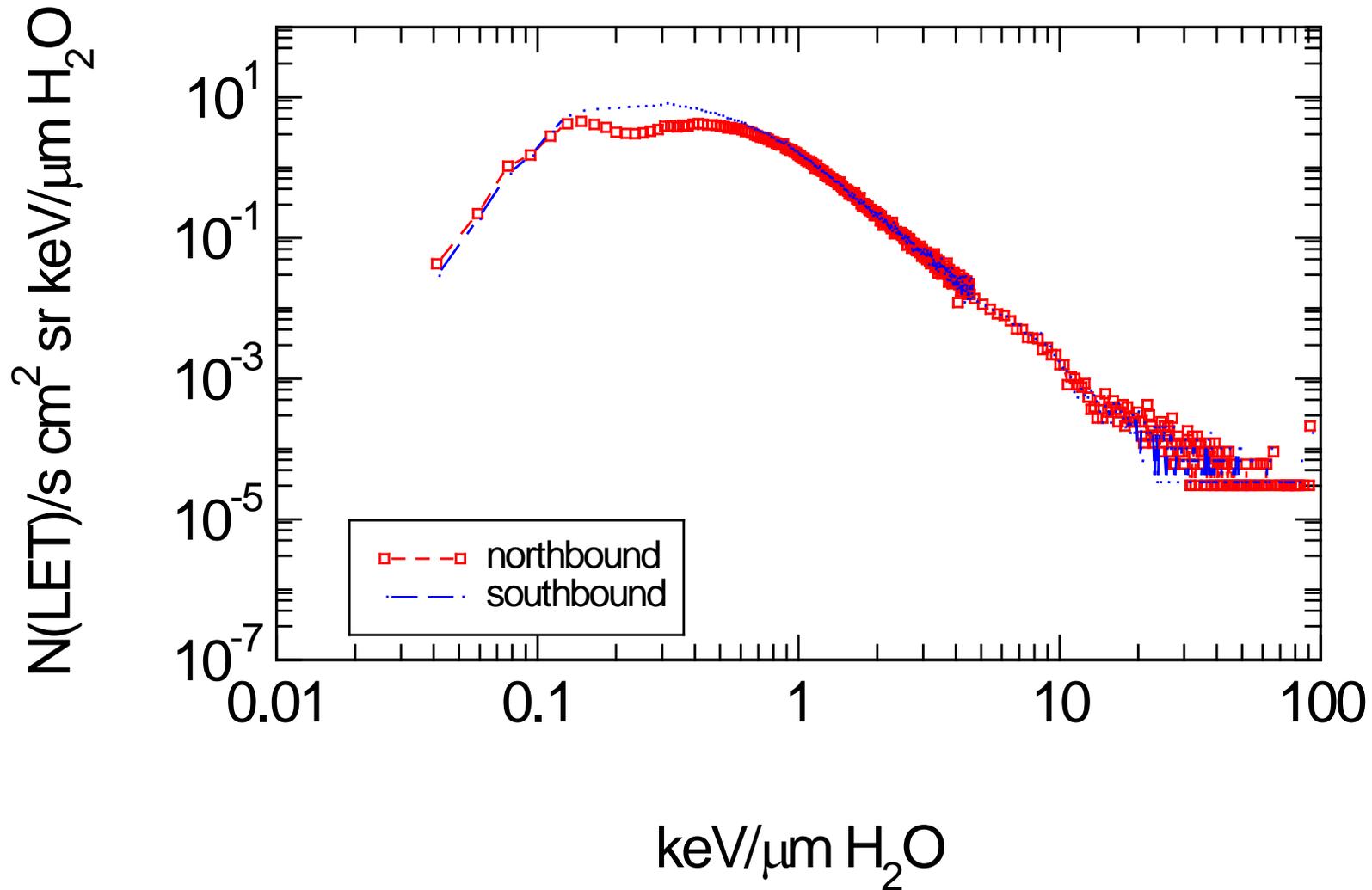


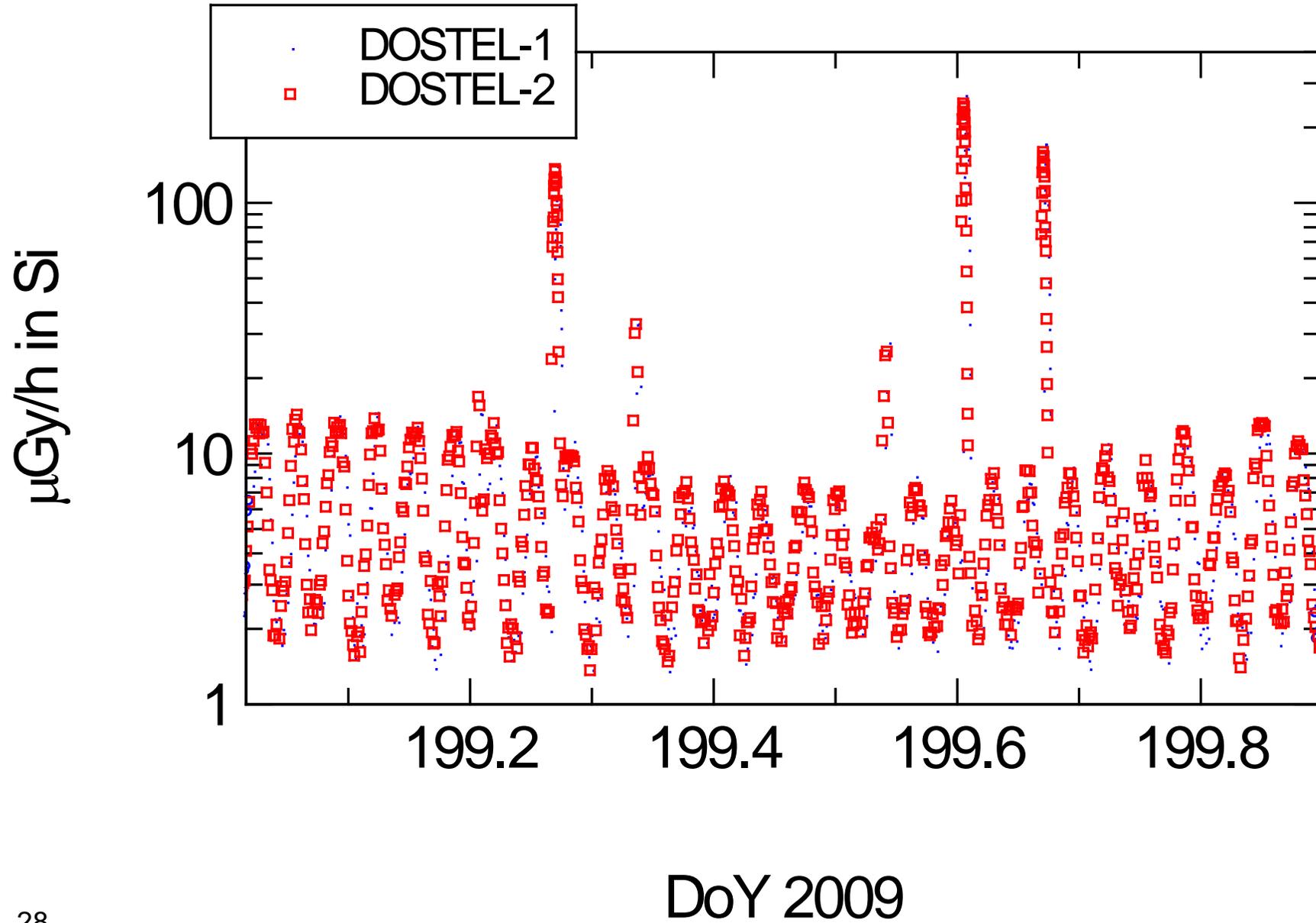


DOSTEL-1

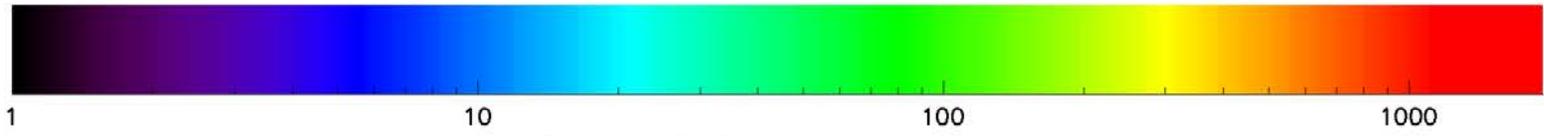


DOSTEL-2

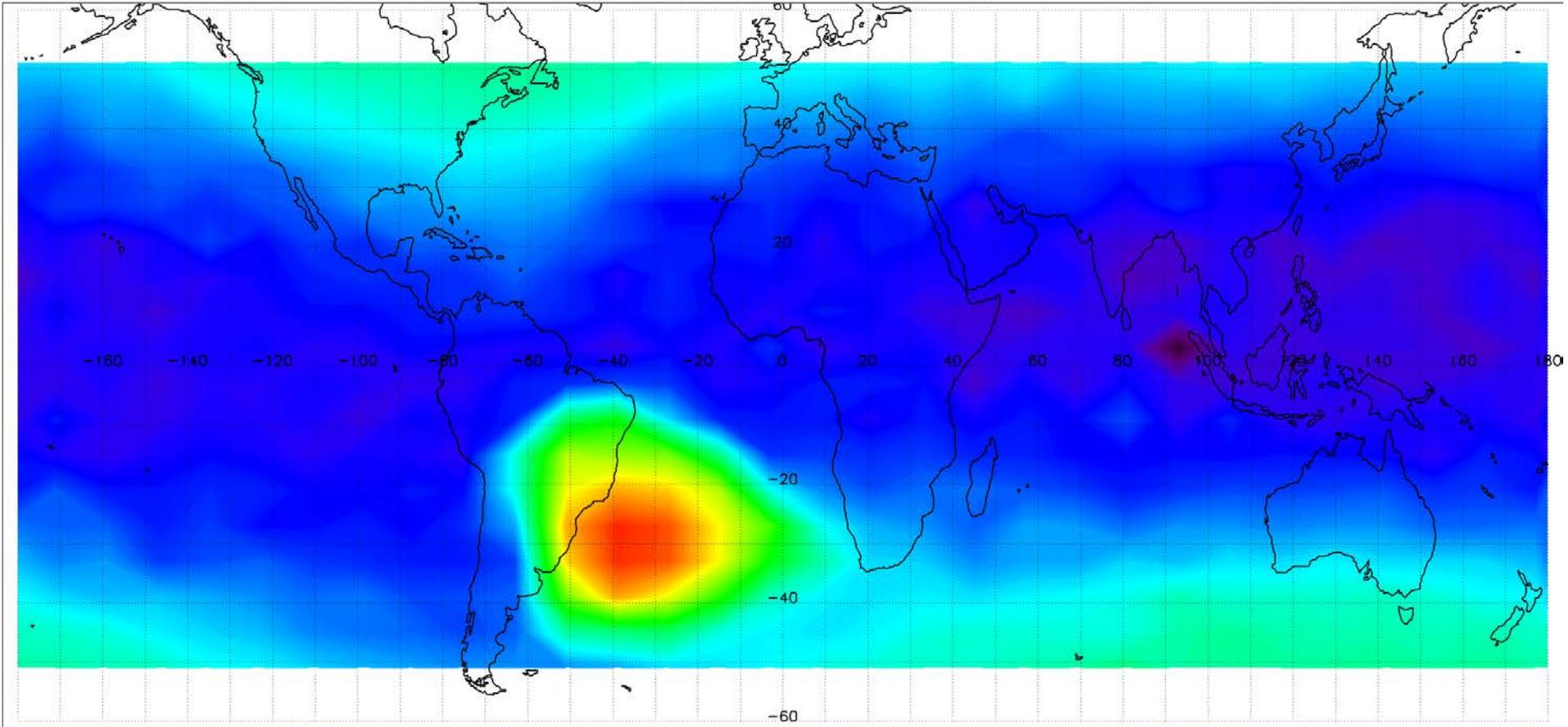




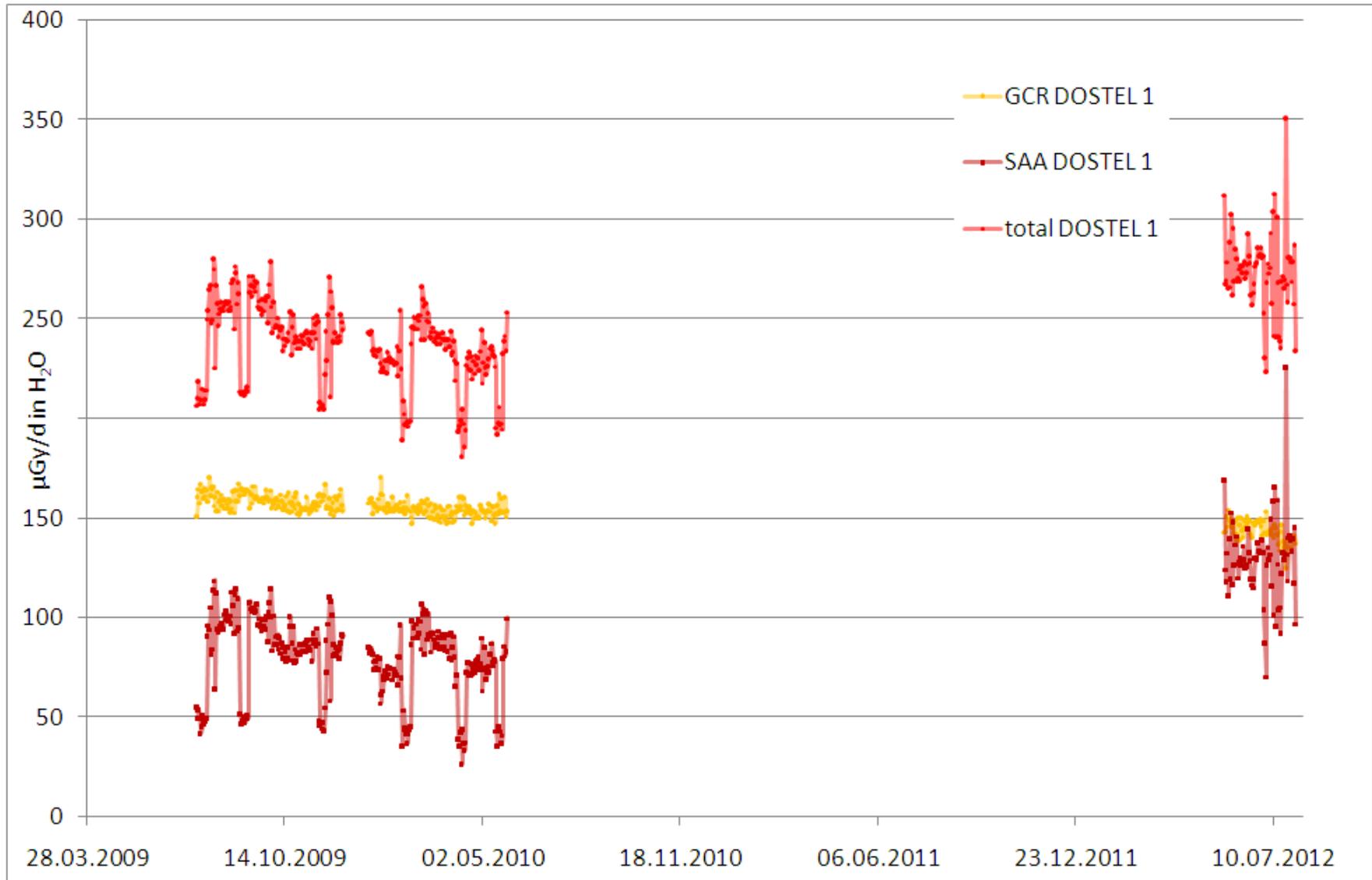
DOSIS - DOSTEL



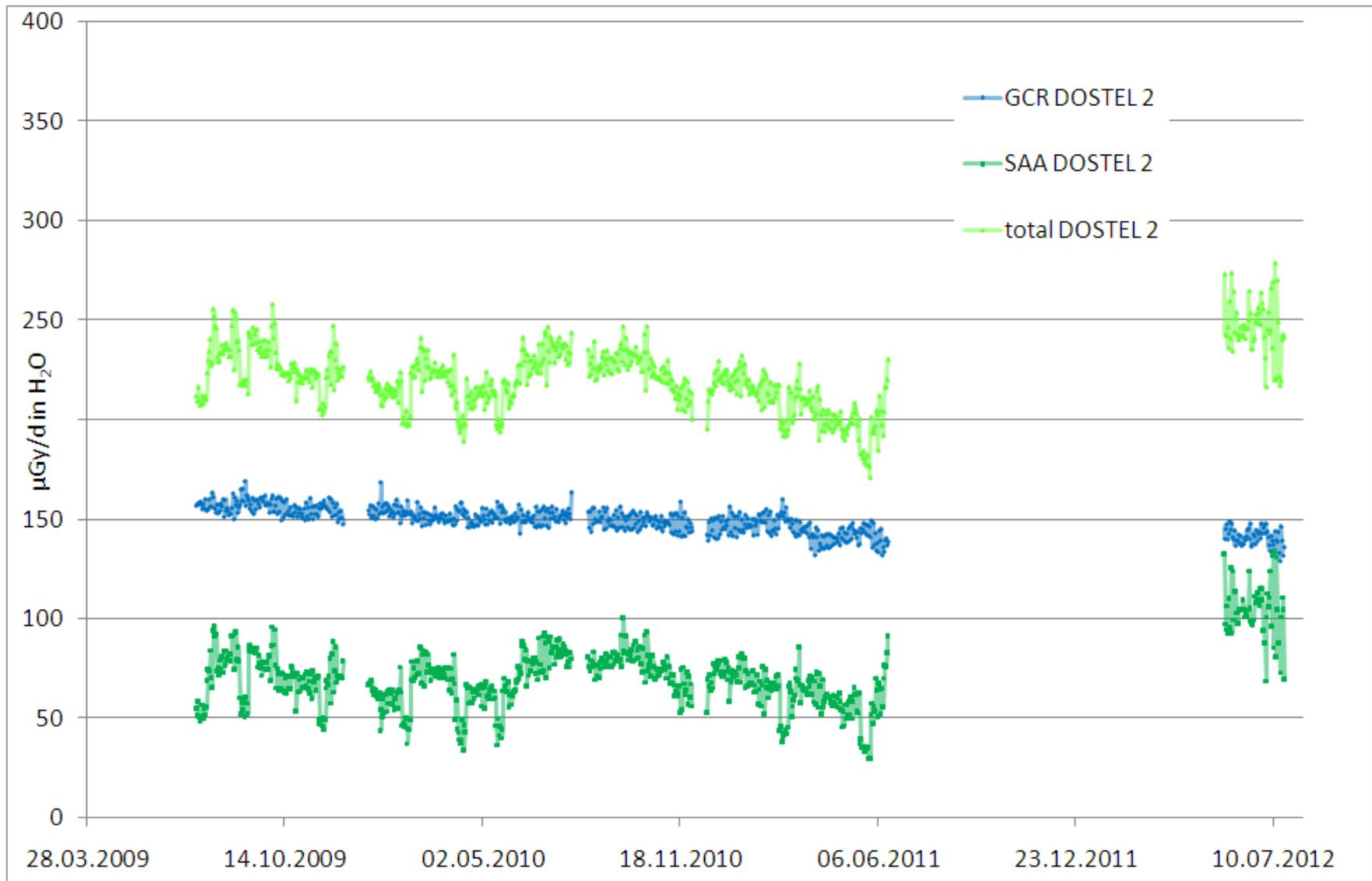
dose / ($\mu\text{Gy/h}$) DOSIS July 2010



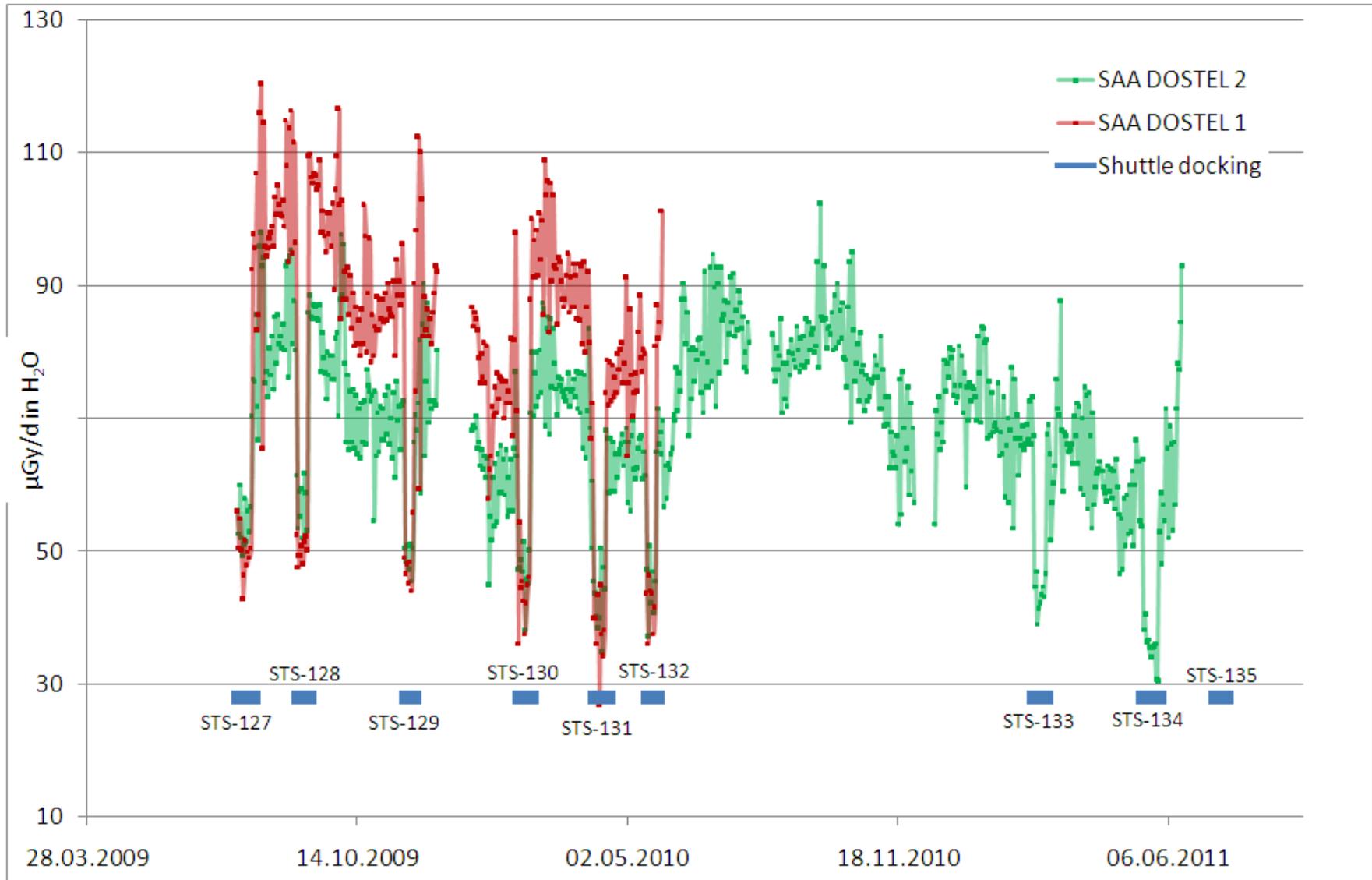
Absorbed Dose Rates DOSTEL 1



Absorbed Dose Rates *DOSTEL 2*



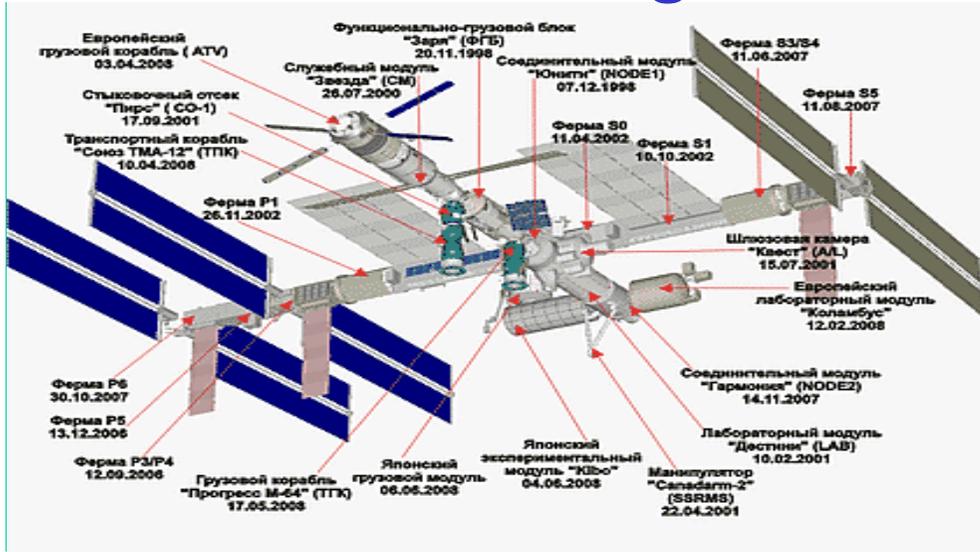
Absorbed Dose Rates SAA



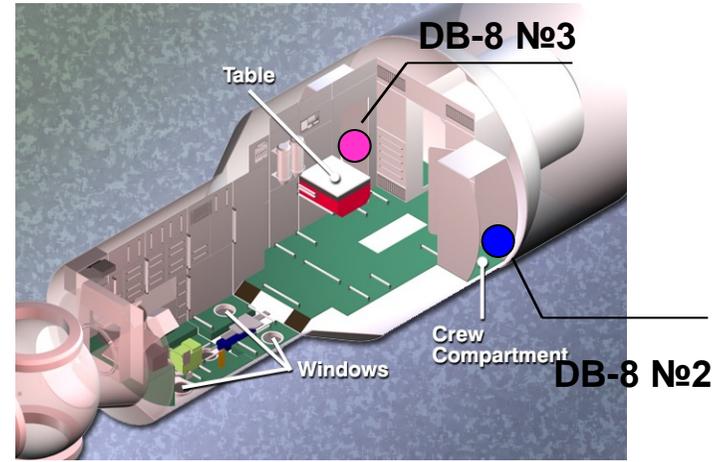


ISS023E044747

ISS configuration



Service Module



Thanks to S.G. Drobyshev, V.V. Benghin

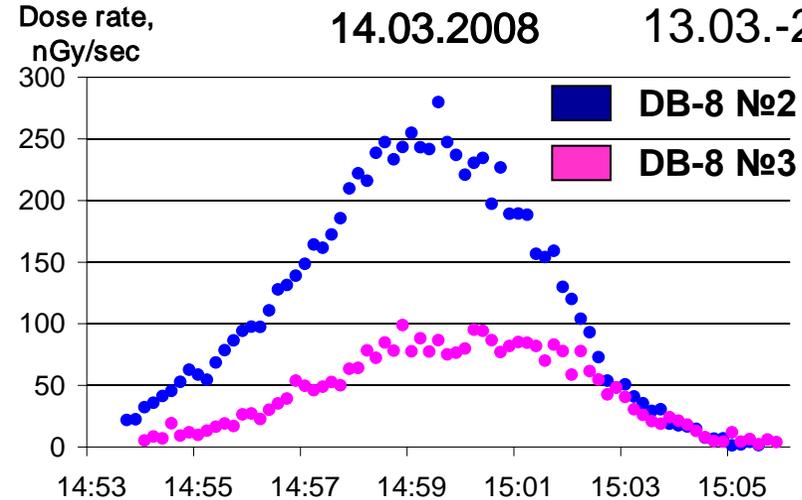
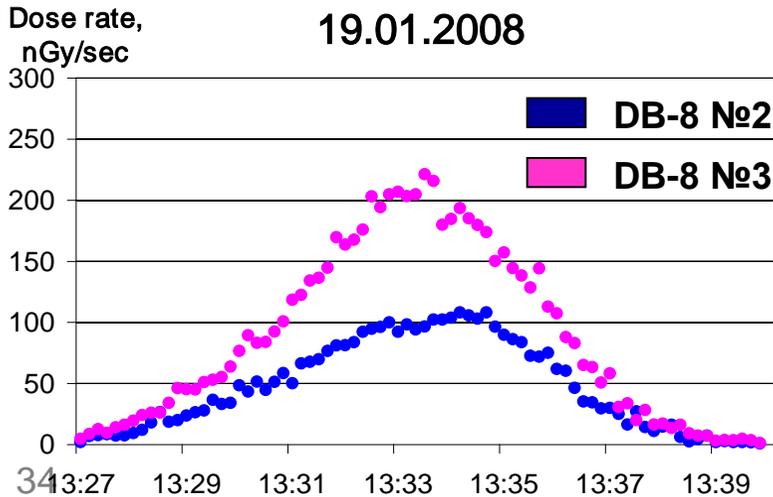


19.01.2008

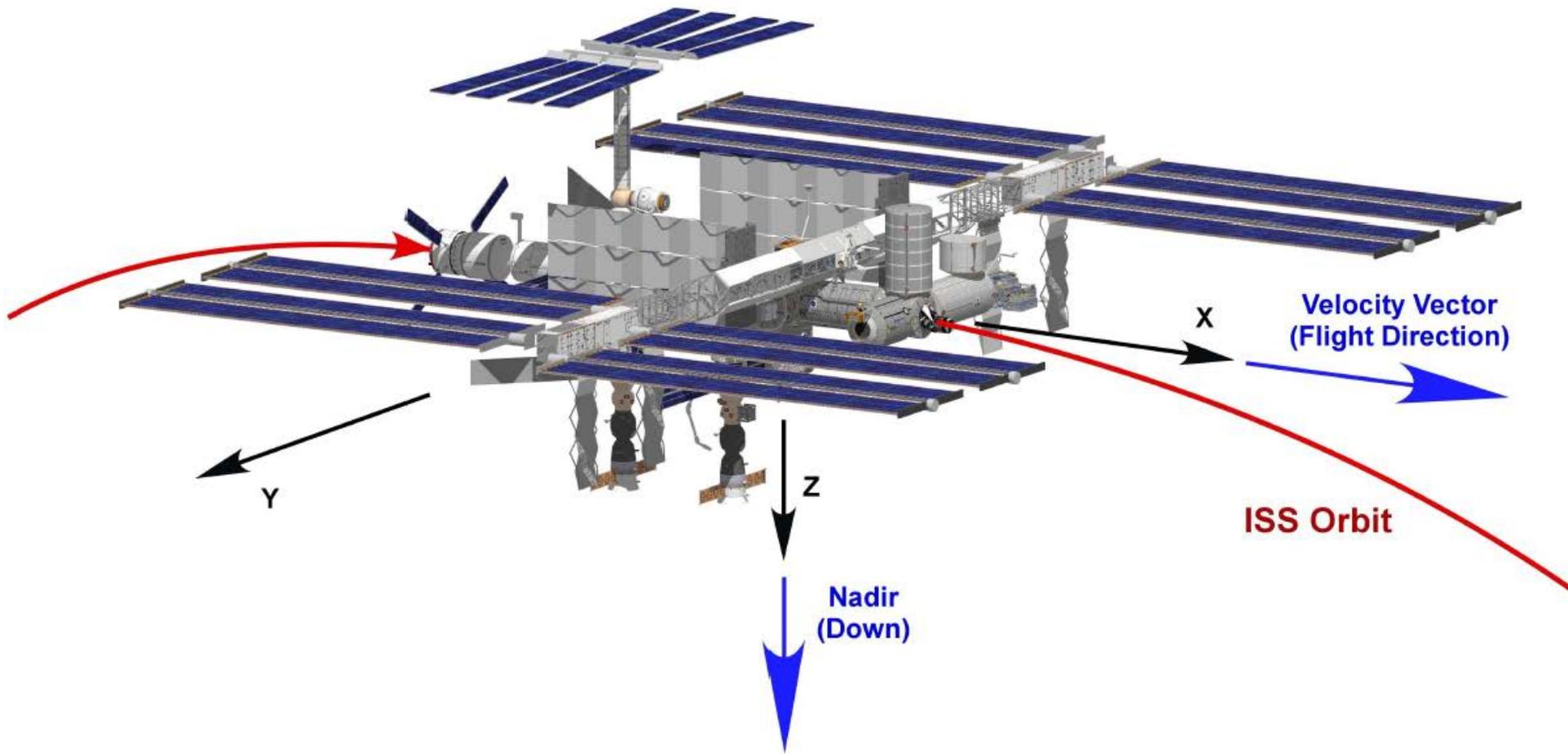


14.03.2008

STS-123 docking: 13.03.-25.03.08

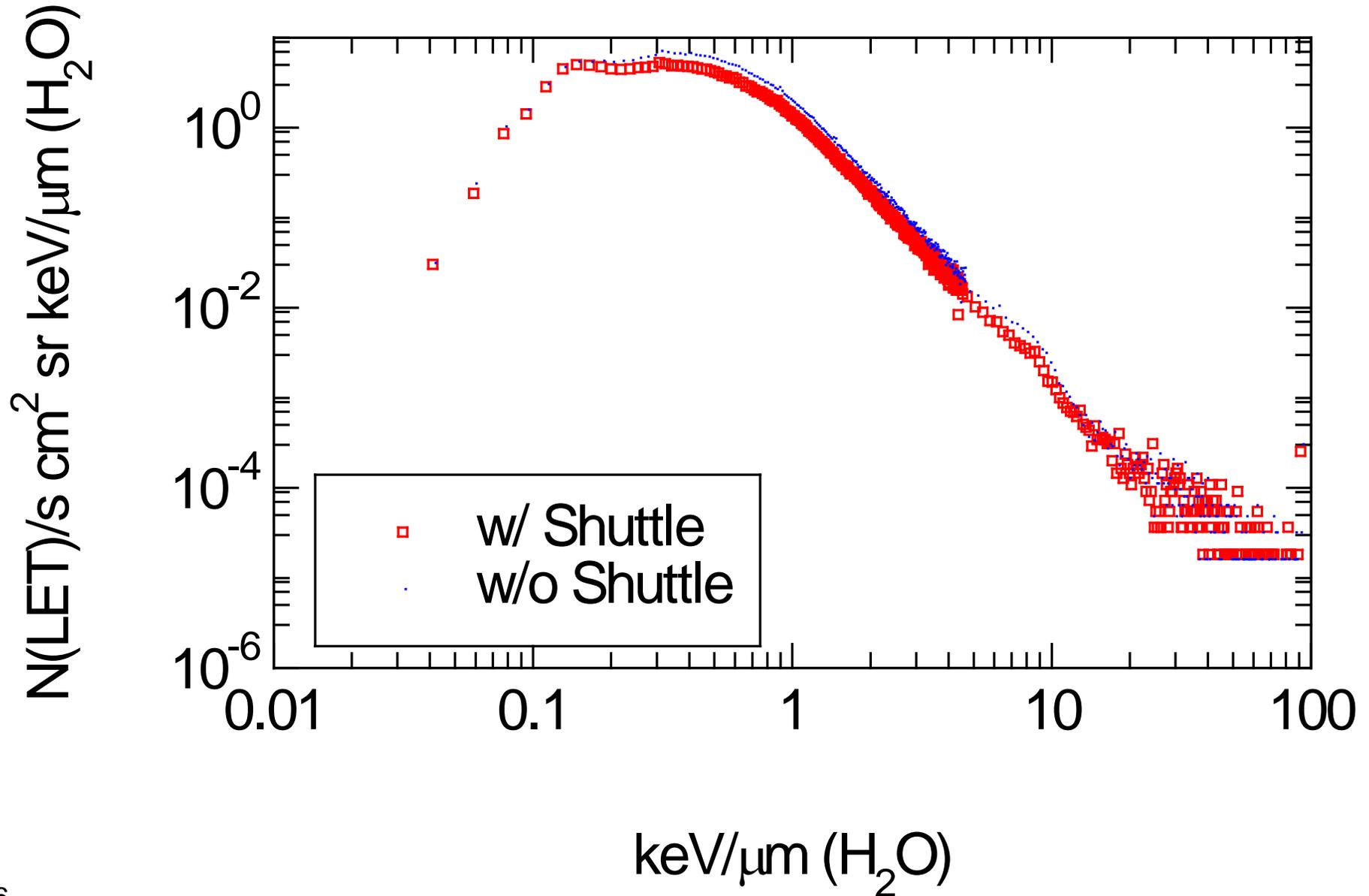


ISS +Xvv Attitude



[European Users Guide to Low Gravity Platforms, UIC-ESA-UM-0001]

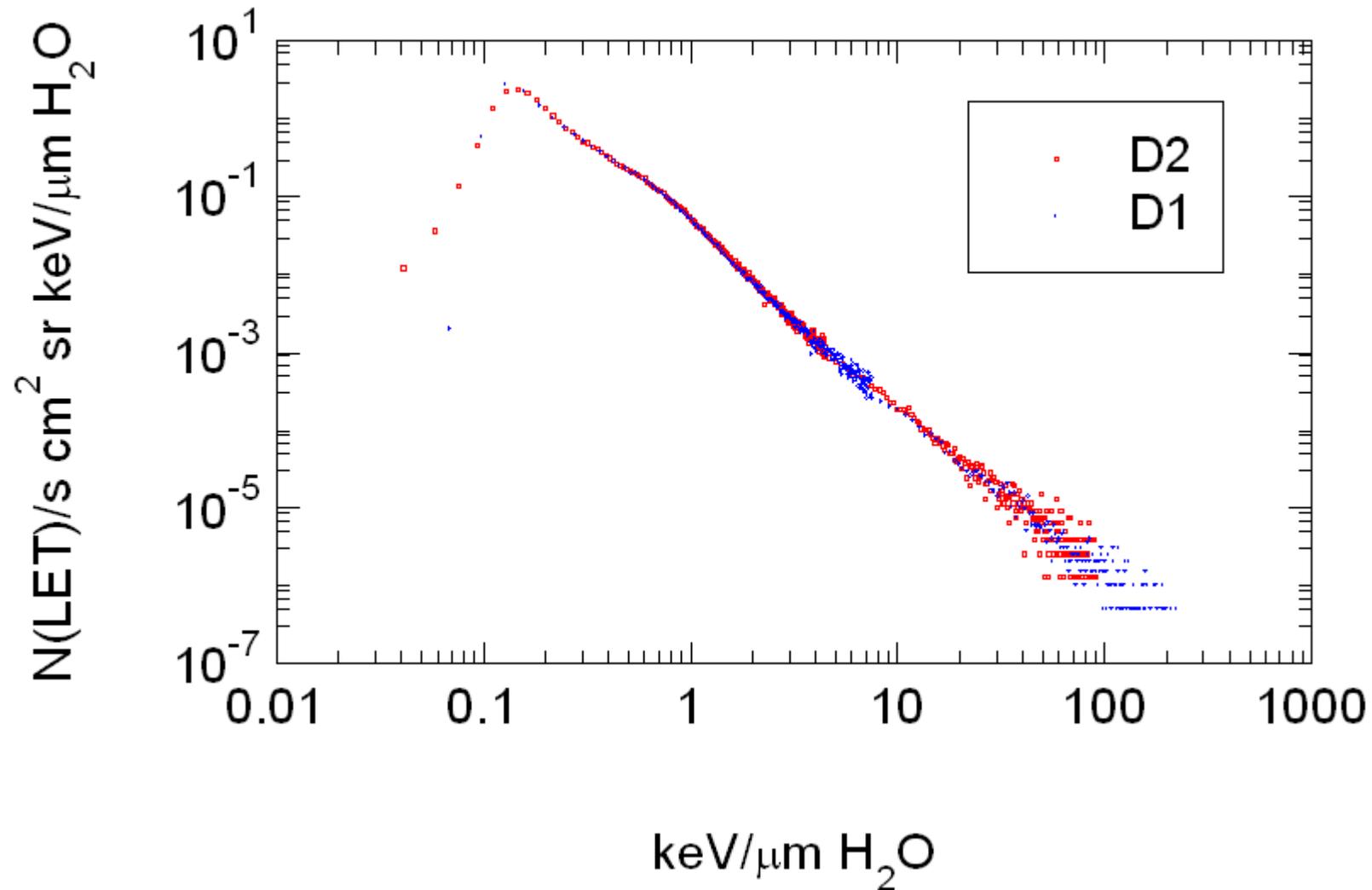
SAA LET Spectra



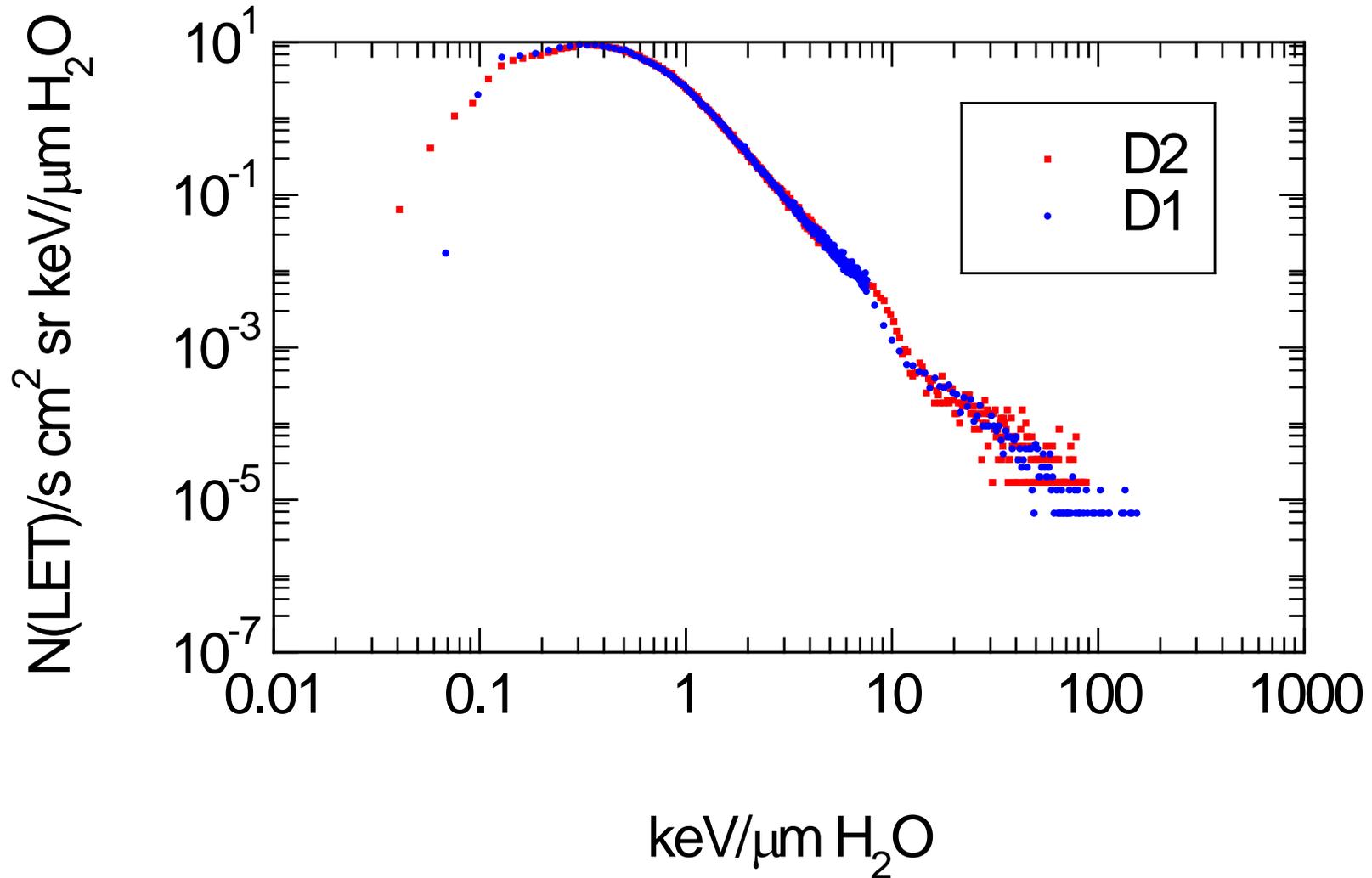
Dose Values During Shuttle Docking

- The mean contribution to the daily dose drops roughly 30-40% from $\sim 100 \mu\text{Sv/d}$ to $\sim 60\text{-}70 \mu\text{Sv/d}$ during the Shuttle docking phases
- The effect occurs mainly during the south-eastward passages through the SAA
- It is most likely due to the attitude change of the station from $+X_{\text{v}}$ to $-X_{\text{v}}$

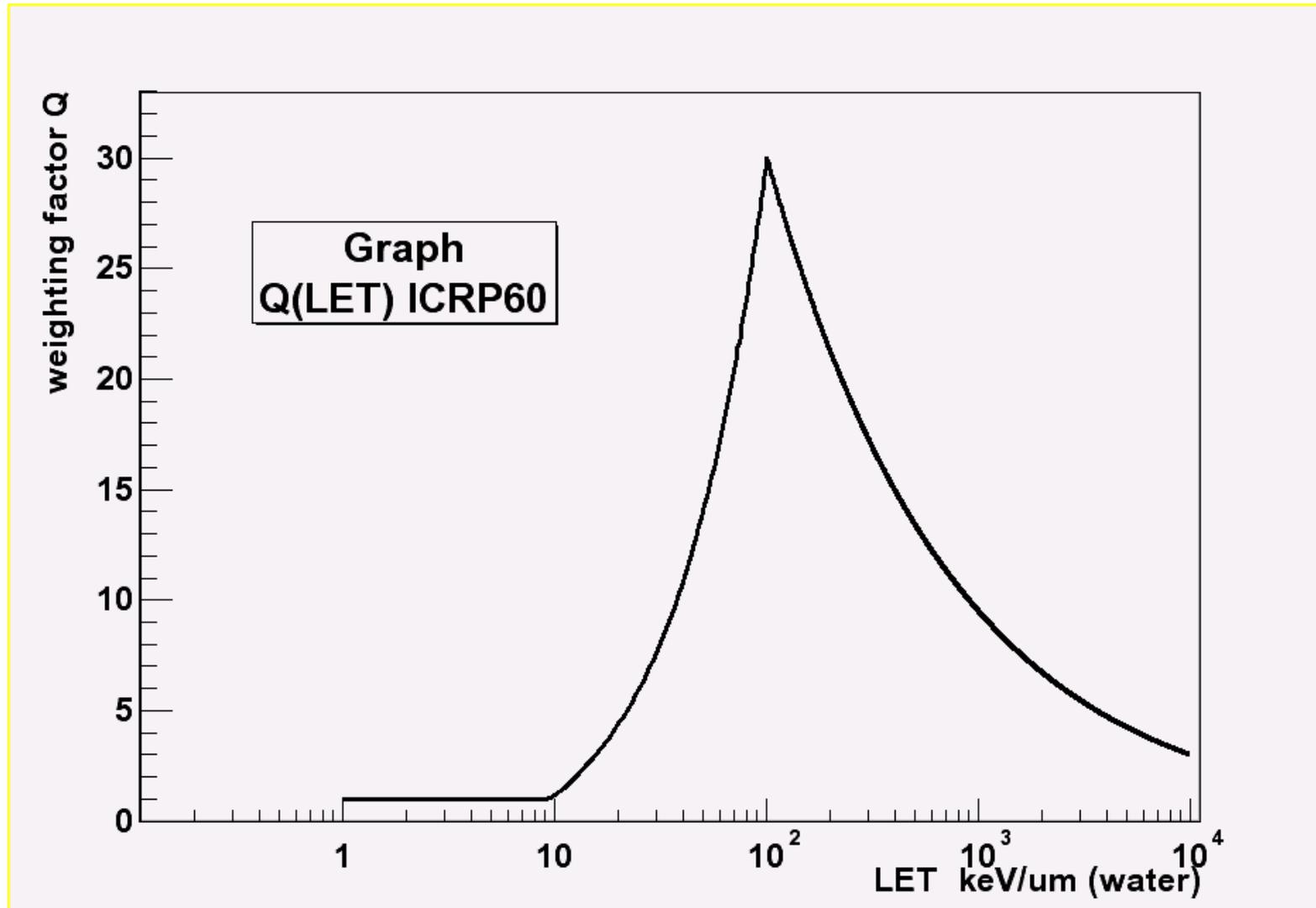
GCR LET Spectrum DOSTEL-1



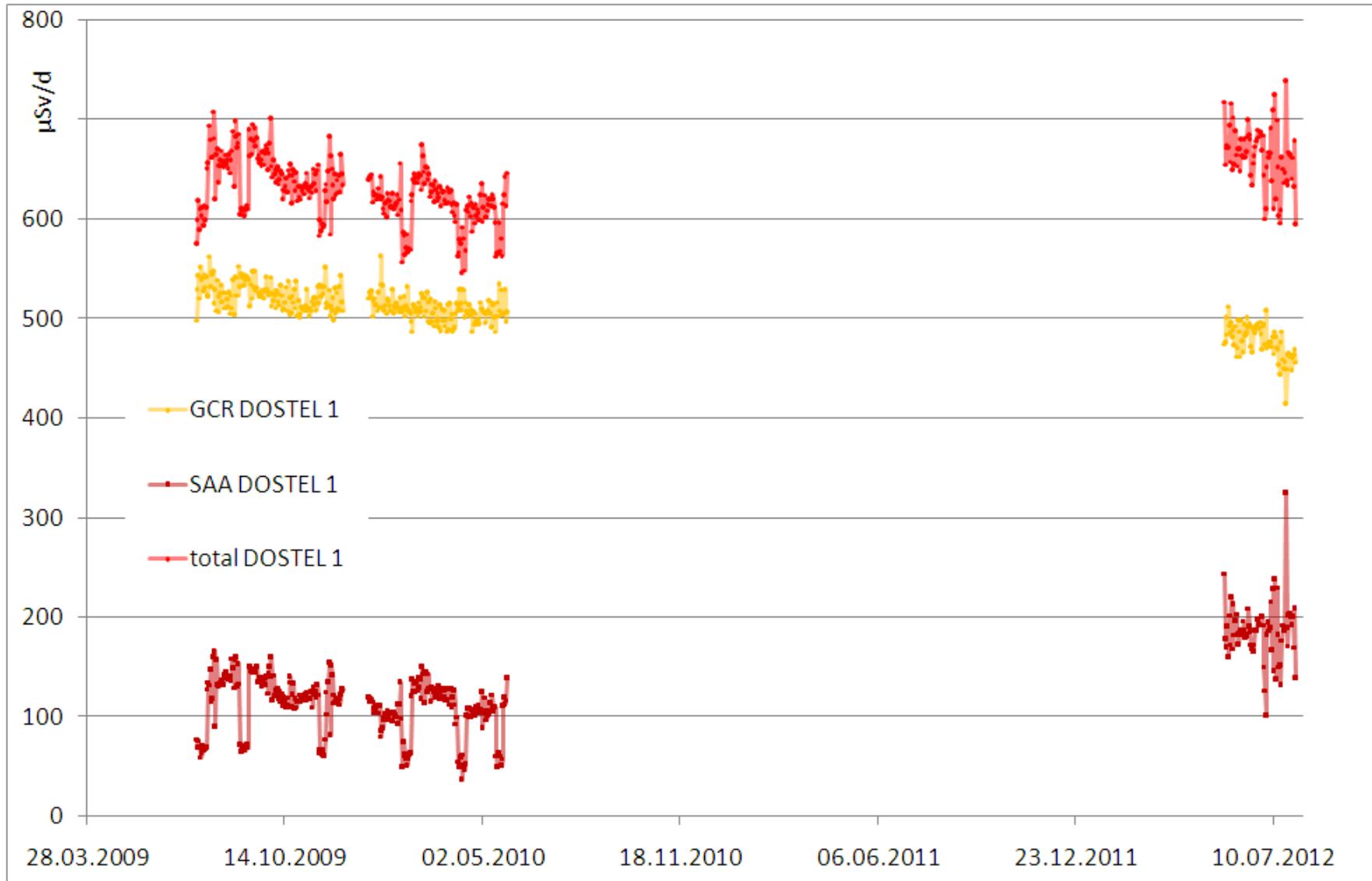
SAA LET spectrum DOSTEL-1



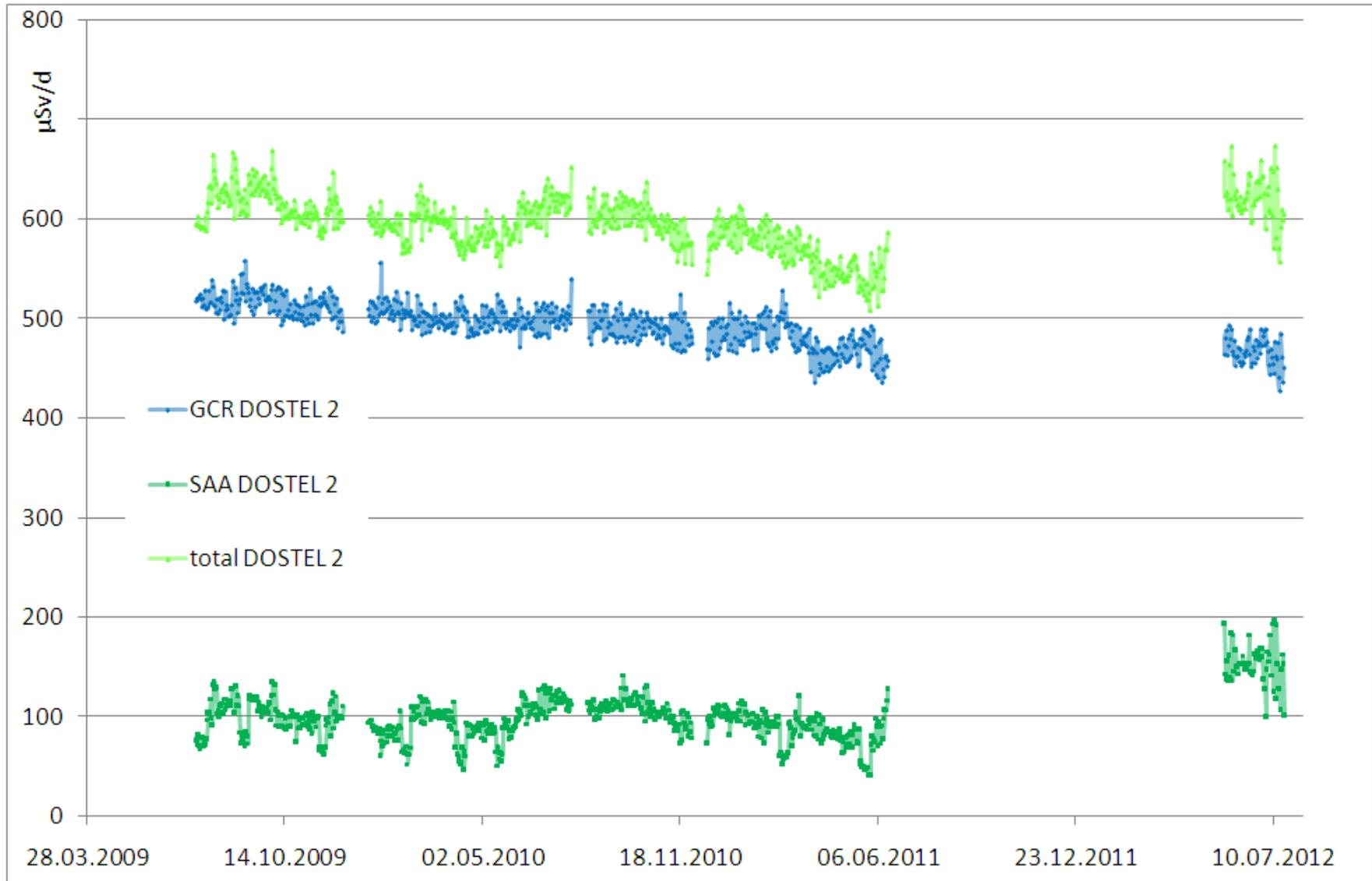
Mean Quality Factor



Dose Equivalent Rates DOSTEL 1



Dose Equivalent Rates DOSTEL 2

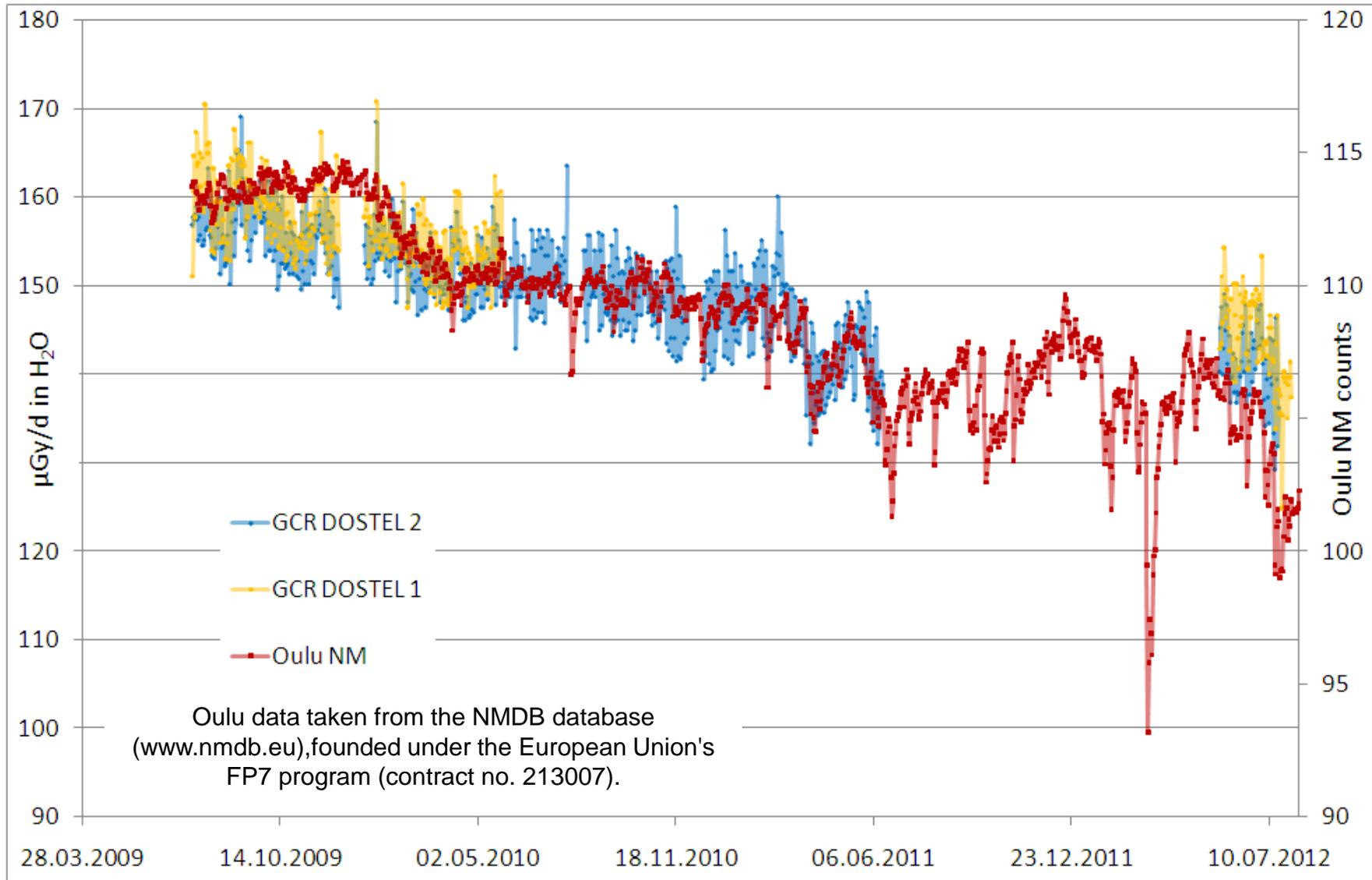


DOSIS / DOSIS 3D Results

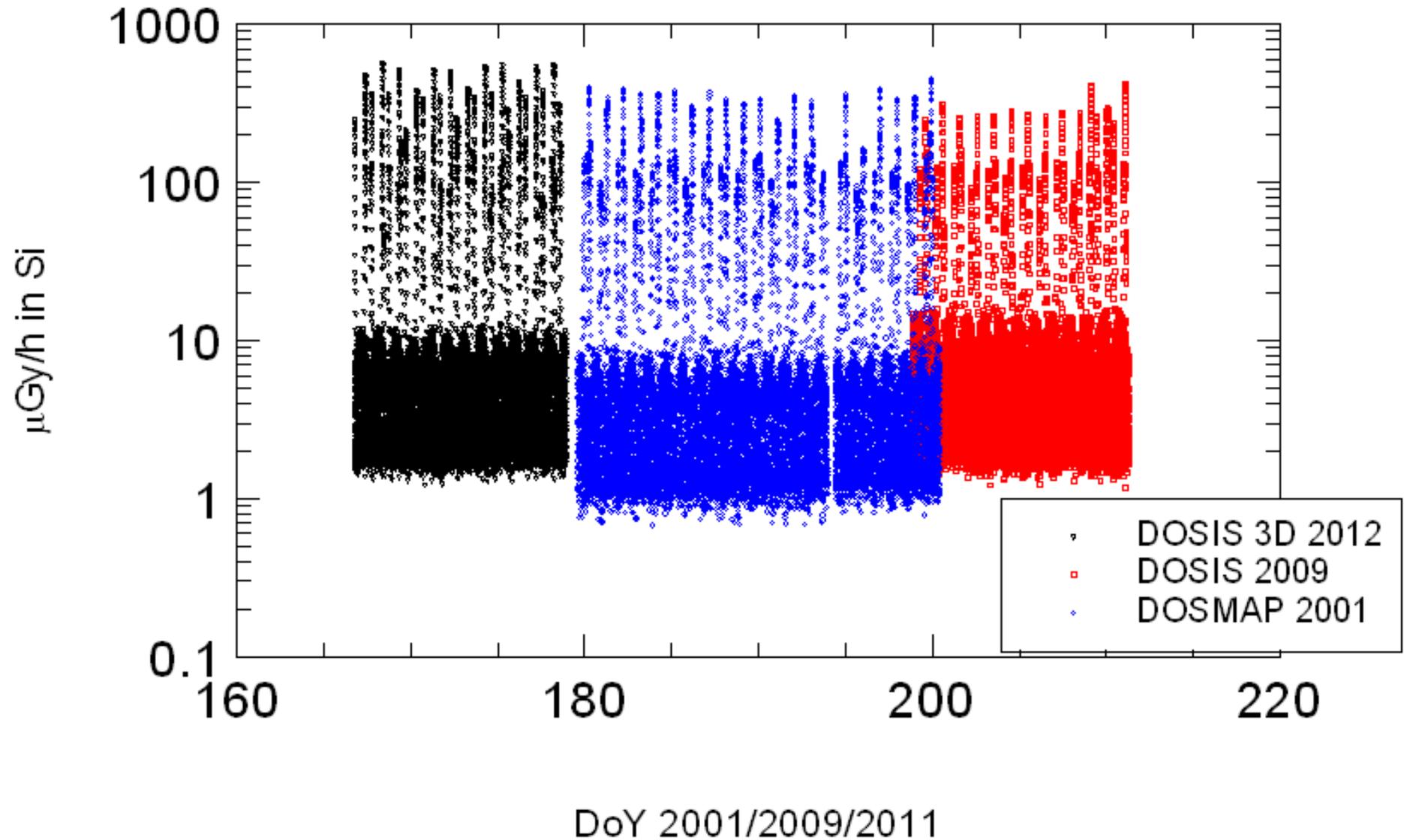
DOSIS	Total				GCR				SAA			
	$\mu\text{Gy/d}$ in Si	$\mu\text{Gy/d}$ in tissue	Q	$\mu\text{Sv/d}$	$\mu\text{Gy/d}$ in Si	$\mu\text{Gy/d}$ in tissue	Q	$\mu\text{Sv/d}$	$\mu\text{Gy/d}$ in Si	$\mu\text{Gy/d}$ in tissue	Q	$\mu\text{Sv/d}$
DOSTEL-1	195	239	2.7	637	130	159	3.3	526	66	80	1.4	112
DOSTEL-2	181	221	2.7	600	124	153	3.3	504	57	68	1.4	96

DOSIS 3D	Total				GCR				SAA			
	$\mu\text{Gy/d}$ in Si	$\mu\text{Gy/d}$ in tissue	Q	$\mu\text{Sv/d}$	$\mu\text{Gy/d}$ in Si	$\mu\text{Gy/d}$ in tissue	Q	$\mu\text{Sv/d}$	$\mu\text{Gy/d}$ in Si	$\mu\text{Gy/d}$ in tissue	Q	$\mu\text{Sv/d}$
DOSTEL-1	226	278	2.4	675	119	146	3.32	486	107	131	1.4	189
DOSTEL-2	202	249	2.5	627	116	143	3.31	472	86	106	1.5	155

GCR Dose Rates



DOSIS 3D, DOSIS and DOSMAP comparison



DOSIS / DOSIS 3D Results

DOSIS	Total				GCR				SAA			
	$\mu\text{Gy/d}$ in Si	$\mu\text{Gy/d}$ in tissue	Q	$\mu\text{Sv/d}$	$\mu\text{Gy/d}$ in Si	$\mu\text{Gy/d}$ in tissue	Q	$\mu\text{Sv/d}$	$\mu\text{Gy/d}$ in Si	$\mu\text{Gy/d}$ in tissue	Q	$\mu\text{Sv/d}$
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DOSIS 3D	Total				GCR				SAA			
	$\mu\text{Gy/d}$ in Si	$\mu\text{Gy/d}$ in tissue	Q	$\mu\text{Sv/d}$	$\mu\text{Gy/d}$ in Si	$\mu\text{Gy/d}$ in tissue	Q	$\mu\text{Sv/d}$	$\mu\text{Gy/d}$ in Si	$\mu\text{Gy/d}$ in tissue	Q	$\mu\text{Sv/d}$
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DOSTEL-2	202	249	2.5	627	116	143	3.31	472	86	106	1.5	155

Conclusions

- DOSIS hardware returned to earth with the last Shuttle flight; till then one DOSTEL performed well while the other one had a hiccup since end of May 2010
- During Shuttle docking phases the flux decreased likely due to the attitude change of the station
- For DOSIS 3D the instruments have been refurbished, then brought back to the station by Soyuz 30S and reactivated on May 21st.
- Compared to DOSMAP the GCR dose is slightly higher (solar cycle) but the SAA dose dropped for DOSIS while increasing again for DOSIS 3D (altitude)

Acknowledgements

- Special Thanks to the ICCHIBAN Workinggroup and the HIMAC facility for a lot of support

Supported by:

-  Federal Ministry of Economics and Technology under grants 50WB0826, 50WB1026, and 50WB1232

on the basis of a decision
by the German Bundestag

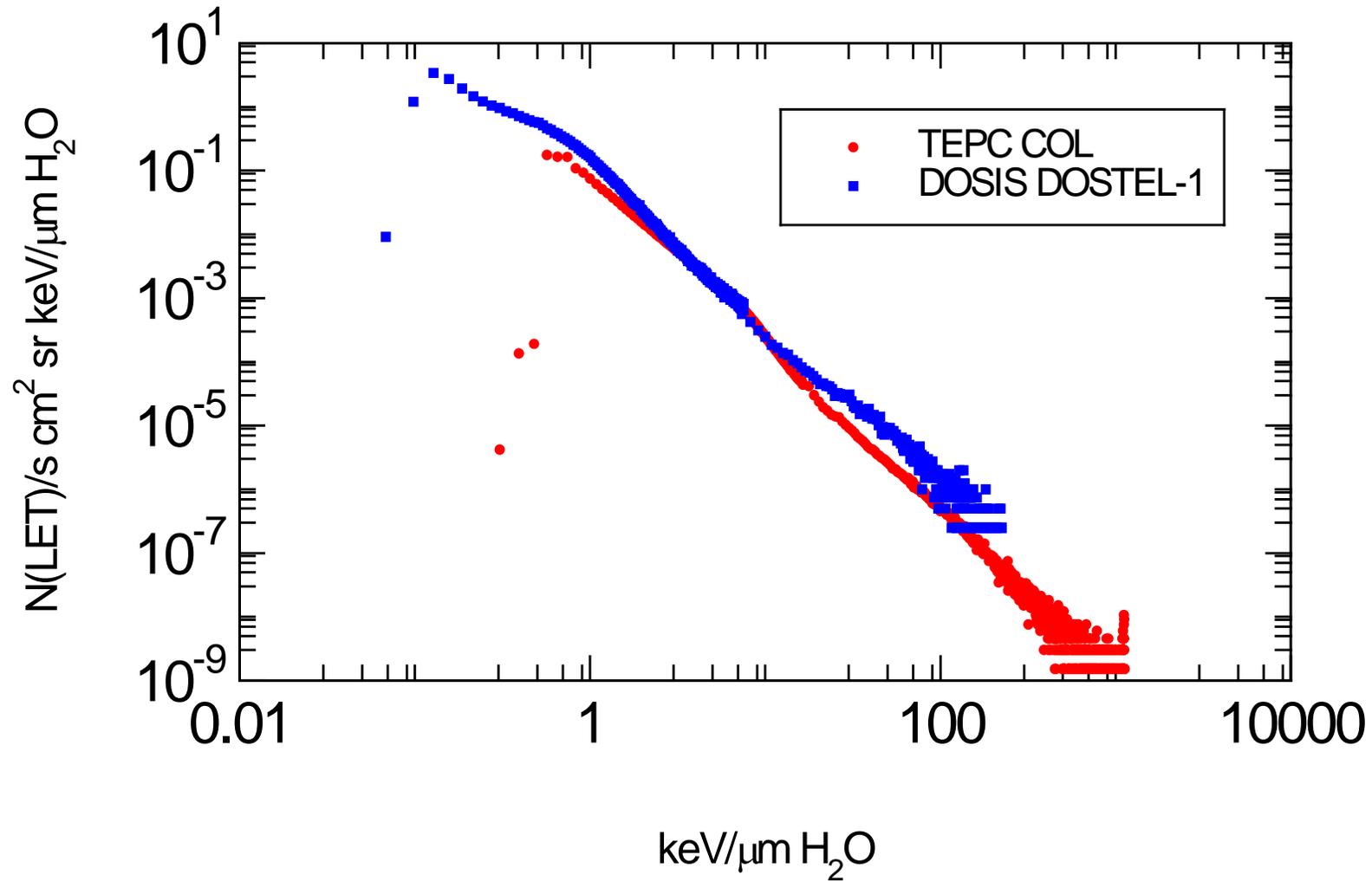
- Thank you very much for your attention!

Backup slides...

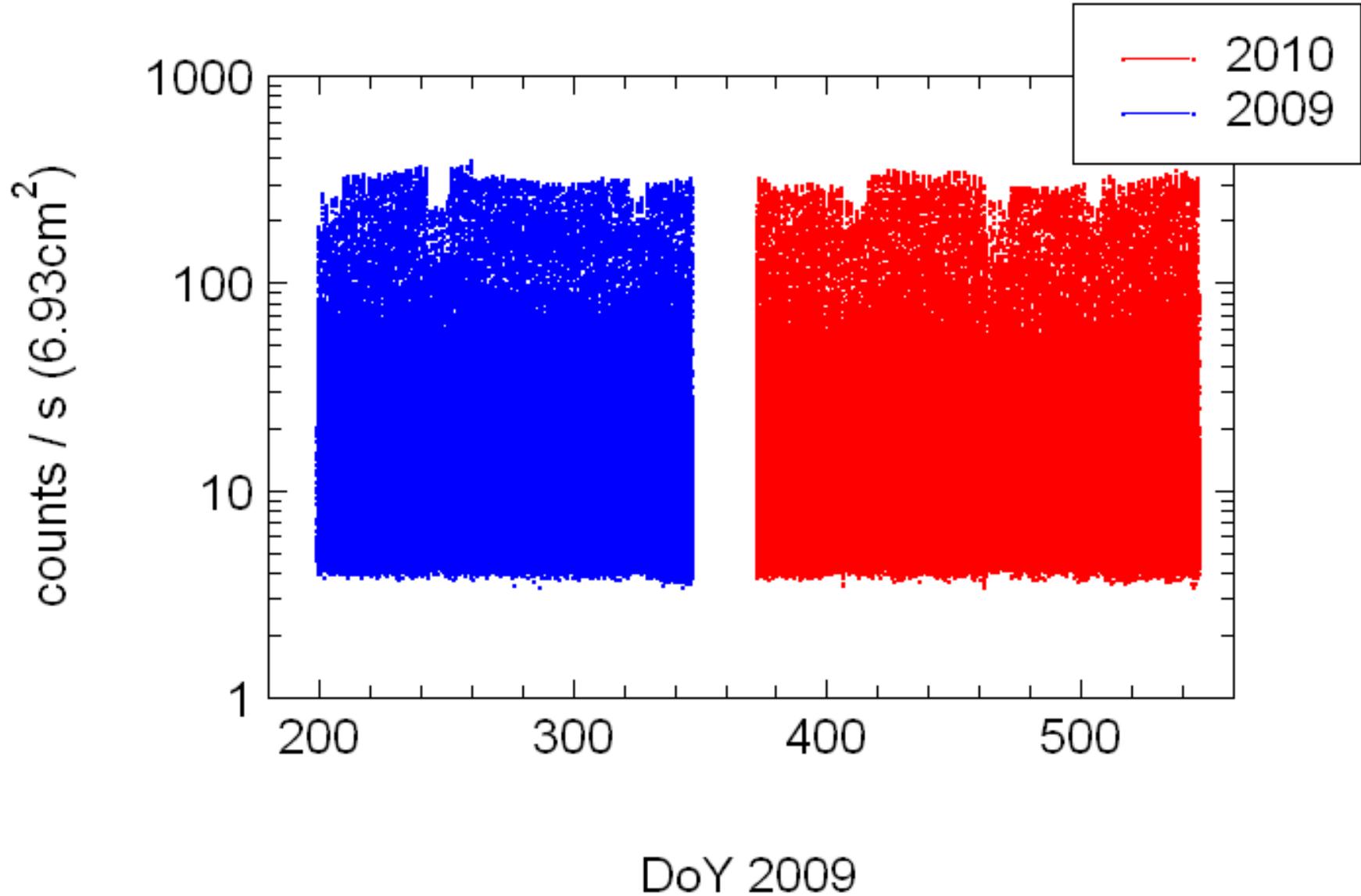
DOSIS Main Box - TEPC



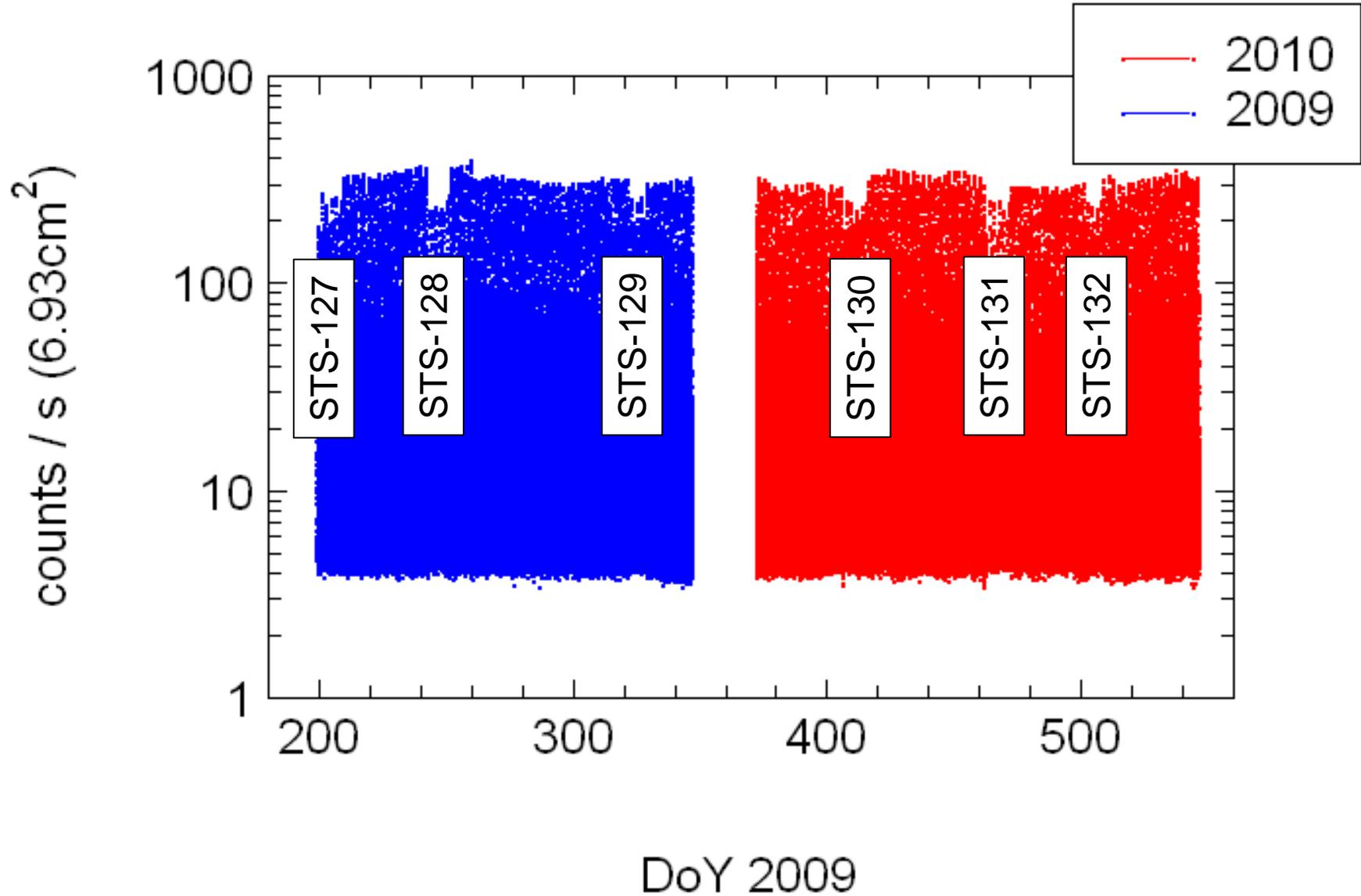
Combined LET spectra



DOSTEL-2 Count Rate Profile



DOSTEL-2 Count Rate Profile



DOSTEL GCR dose equivalent / $\mu\text{Sv/d}$
Kiel NM / arb. units

