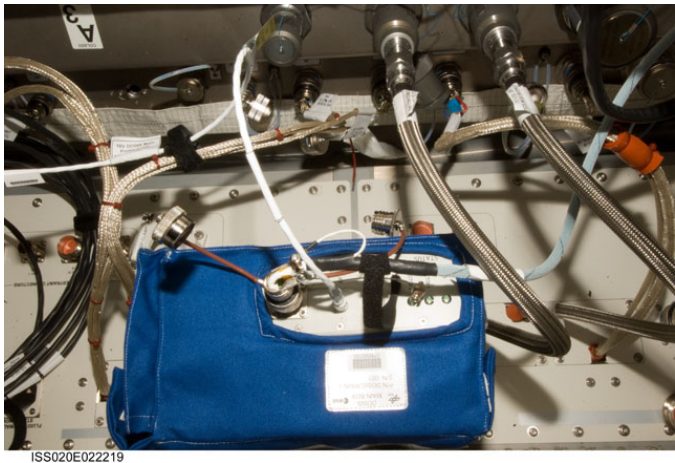
20th WRMISS, Cologne, Germany, September 8 – 10, 2015

The DOSIS and DOSIS 3D experiments on-board the International Space Station – Current Status and Latest Data from the DOSTELs as Active Instruments

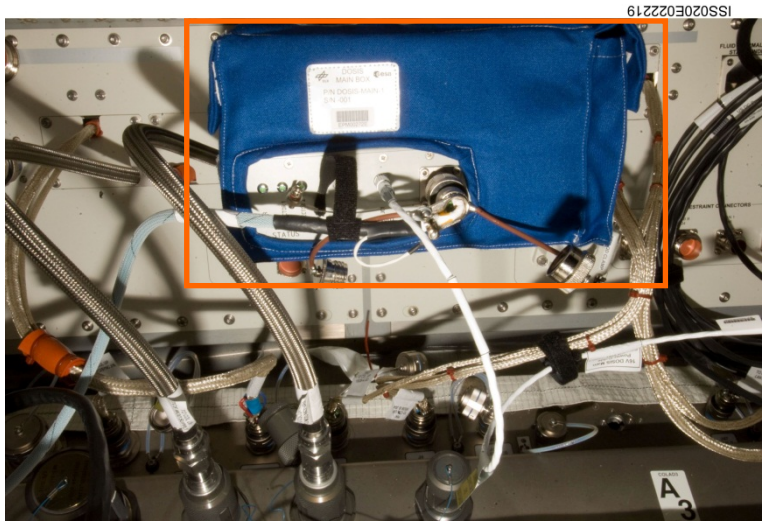
Soenke Burmeister[1], Thomas Berger[2], Johannes Labrenz[1], Matthias Boehme[3], Lutz Haumann[3] and Guenther Reitz[2]

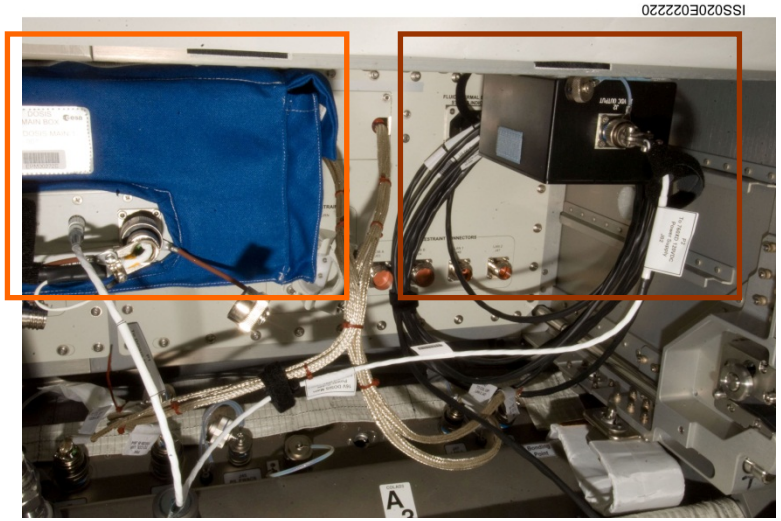
[1] Institute for Experimental and Applied Physics, Kiel University, Kiel, Germany
[2] German Aerospace Center, DLR, Institute for Aerospace Medicine, Cologne, Germany
[3] OHB Technologies, Bremen, Germany



ISS020E022219

DOSIS & DOSIS 3D: DOSTEL





ISS020E033064

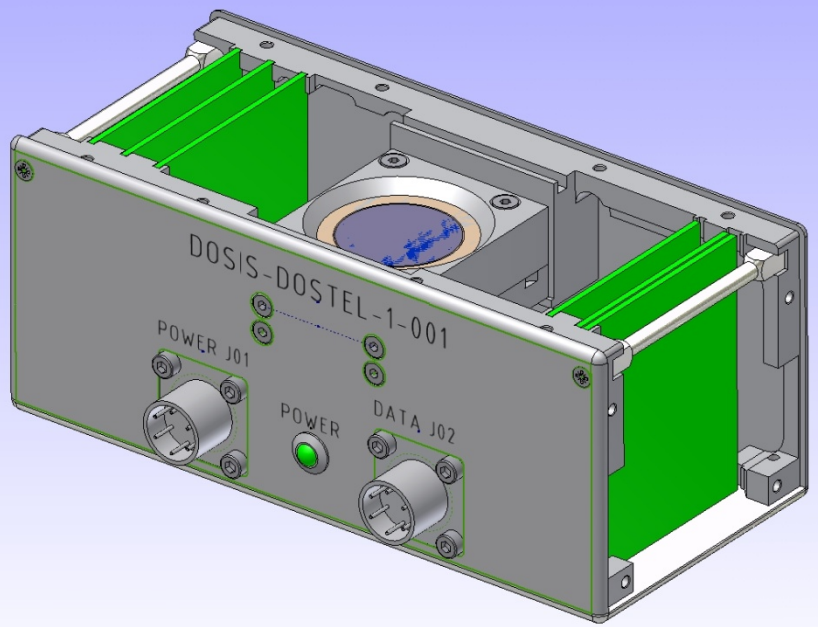
- Ethernet connection to EPM rack "Right Utility Distribution Panel“
- DOSIS MAIN BOX connected to EPM LAN like an external EPM instrument
- Data downlink is an EPM operation from ground performed once per month

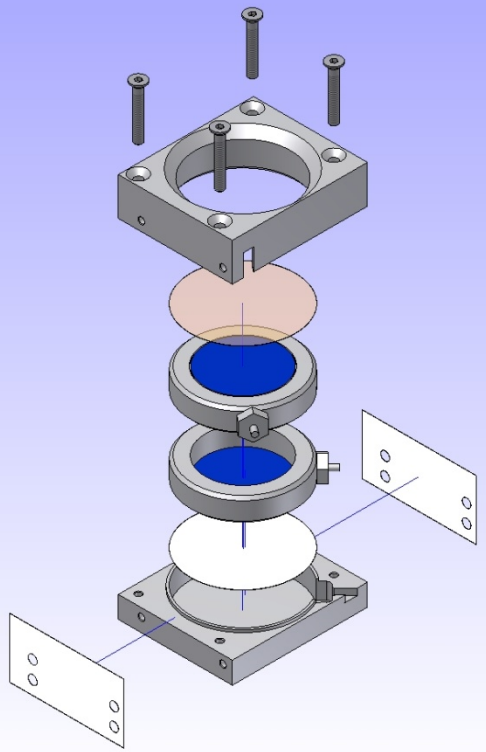
DOSIS Main Box

DOSTEL

DDPU
(DOSTEL Data and Power Unit)

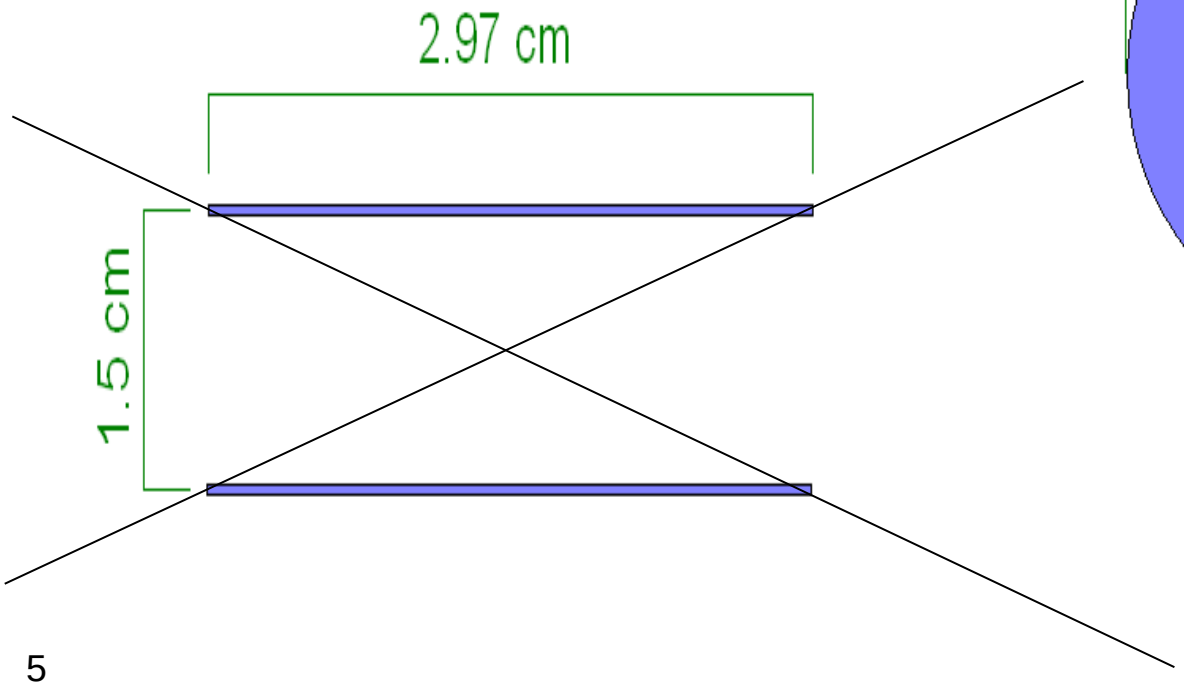
DOSTEL Detector

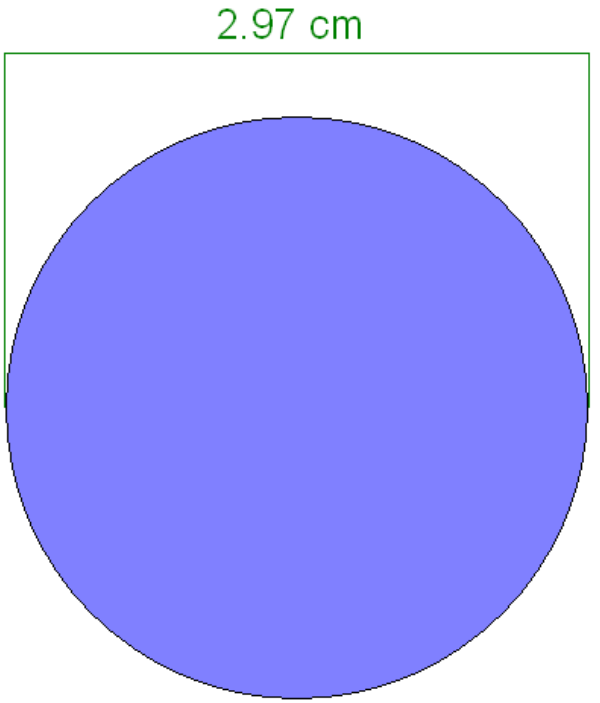




DOSTEL Detector

The DOSTEL Detecor Head consists two circular PIPS detectors by Canberra. These two are forming a telescope. The active area of the detectors is 6.93 cm². Mounted in a distance of 1.5cm this leads to an opening angle of 120°.





DOSTEL Data

- Each DOSTEL can provide count rate profiles, dose rate profiles and energy deposition spectra
  - Dose rate and count rate are measured by the single detectors
  - The count rate and dose rate is counted in 100s intervals during GCR and in 20s during SAA passages
  - Coincident triggers are used to sum up the energy deposition spectra
  - Integration times for the energy spectra are adapted automatically to measure over half orbits
  - Energy deposition spectra measured in the region of the SAA are integrated separately; this is done by a threshold for the gradient of the count rate

DOSTEL Data

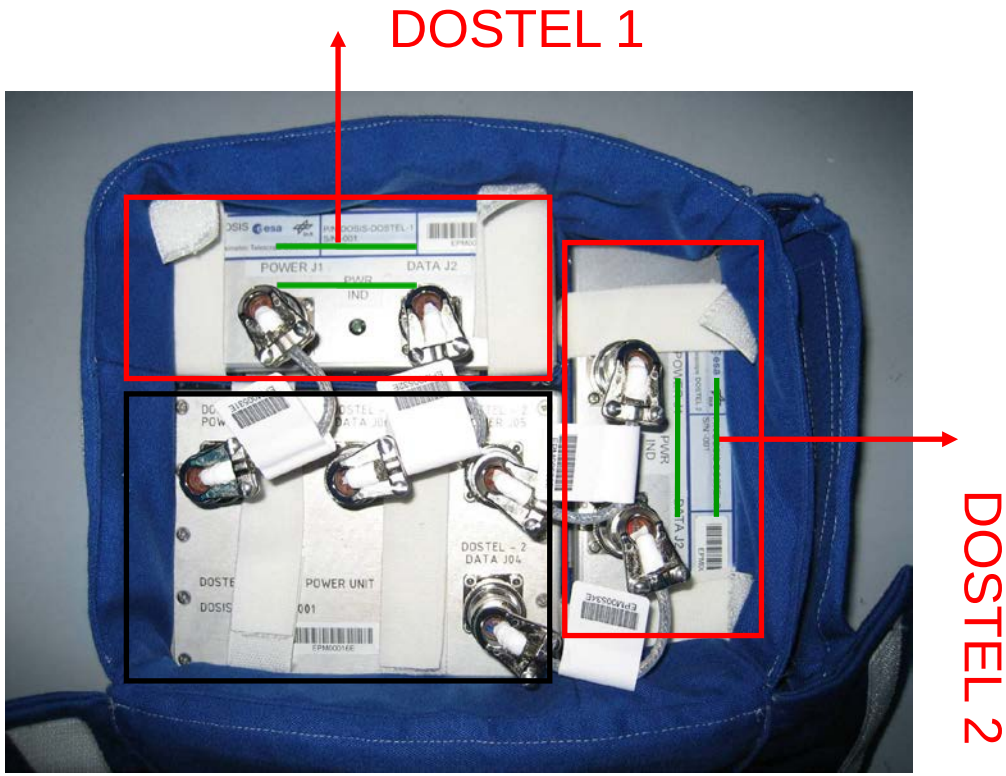
- The energy spectra can be used to obtain LET-Spectra because of the path length limitation due to its telescope geometry
- The LET spectra can be used to get information such as average quality factors which leads to dose equivalent
- DOSTEL-1 has an additional mode 2 where the PHA data for every single particle is taken

DOSTEL Data

- DOSTEL energy range
  - ΔE 69 keV – 165 MeV in Si for D1
  - ΔE 48 keV – 66 MeV in Si for D2
  - For dose measurements all energy deposition measurements exceeding the upper limit ΔE_{max} are taken as ΔE_{max}.

- DOSTEL LET range
  - 0.1-240 keV/µm for D1
  - 0.07-95 keV/µm for D2
  - For dose measurements all LET values exceeding the upper limit LET_{max} are taken as LET_{max}.

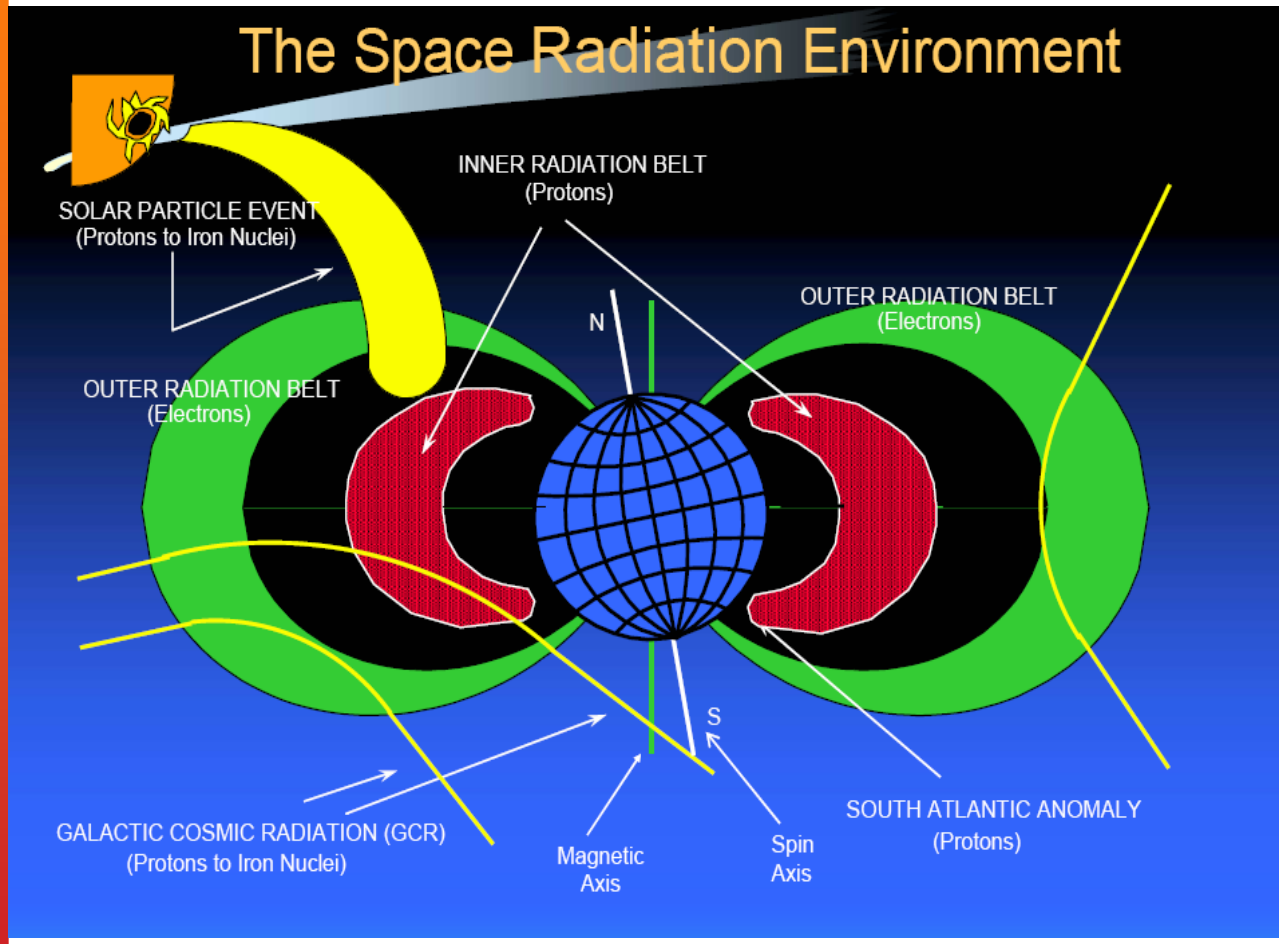
DOSIS Main Box



DDPU – DOSTEL Data and Power Unit


DOSTEL 2
DOSTEL 1
ISS023E044747

Radiation Environment in Space



Galactic Cosmic Rays (GCR)

- Ions from protons to iron

Trapped Radiation (Van Allen Belts)

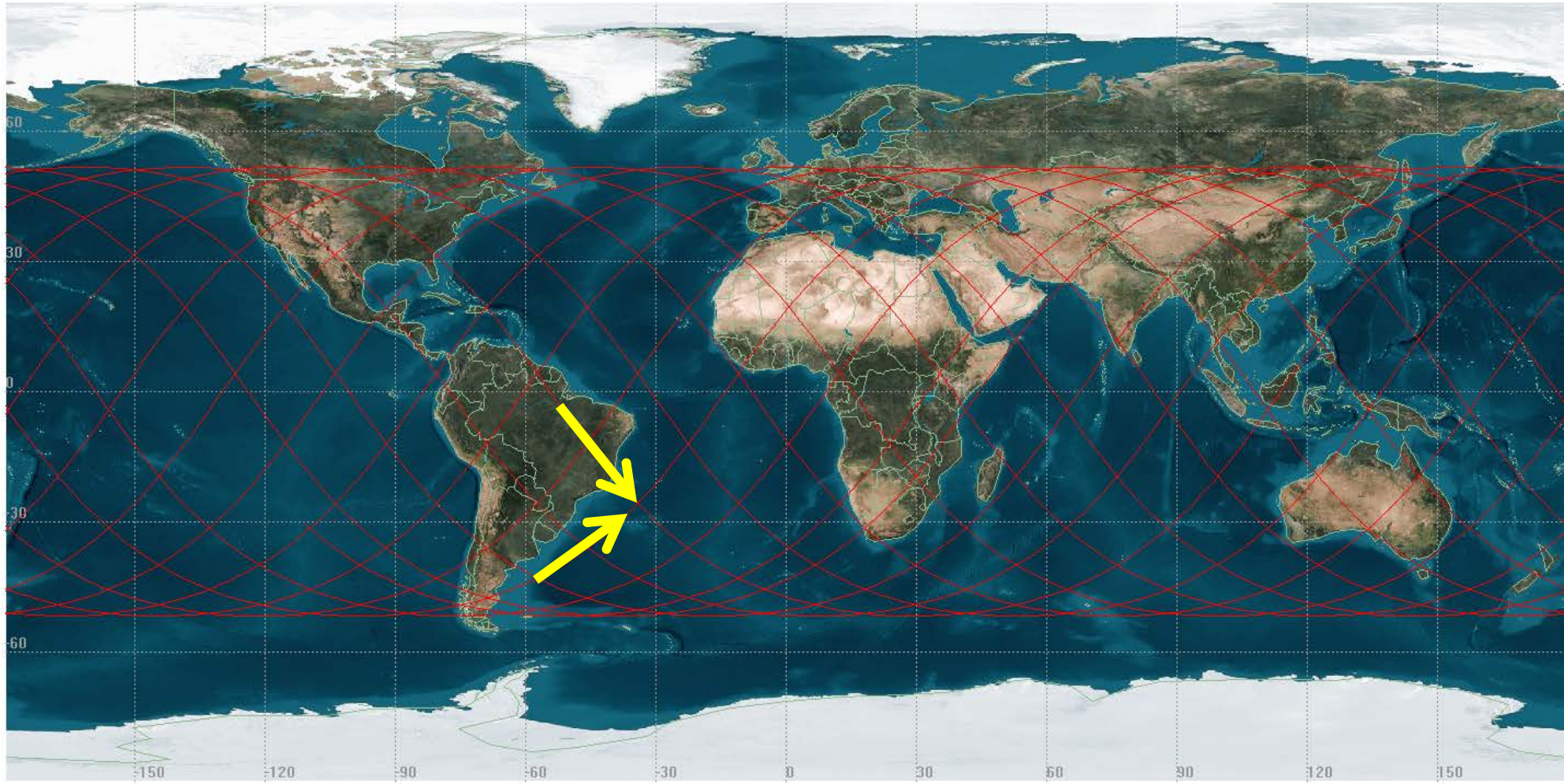
- Low energy protons and electrons

Solar particle events

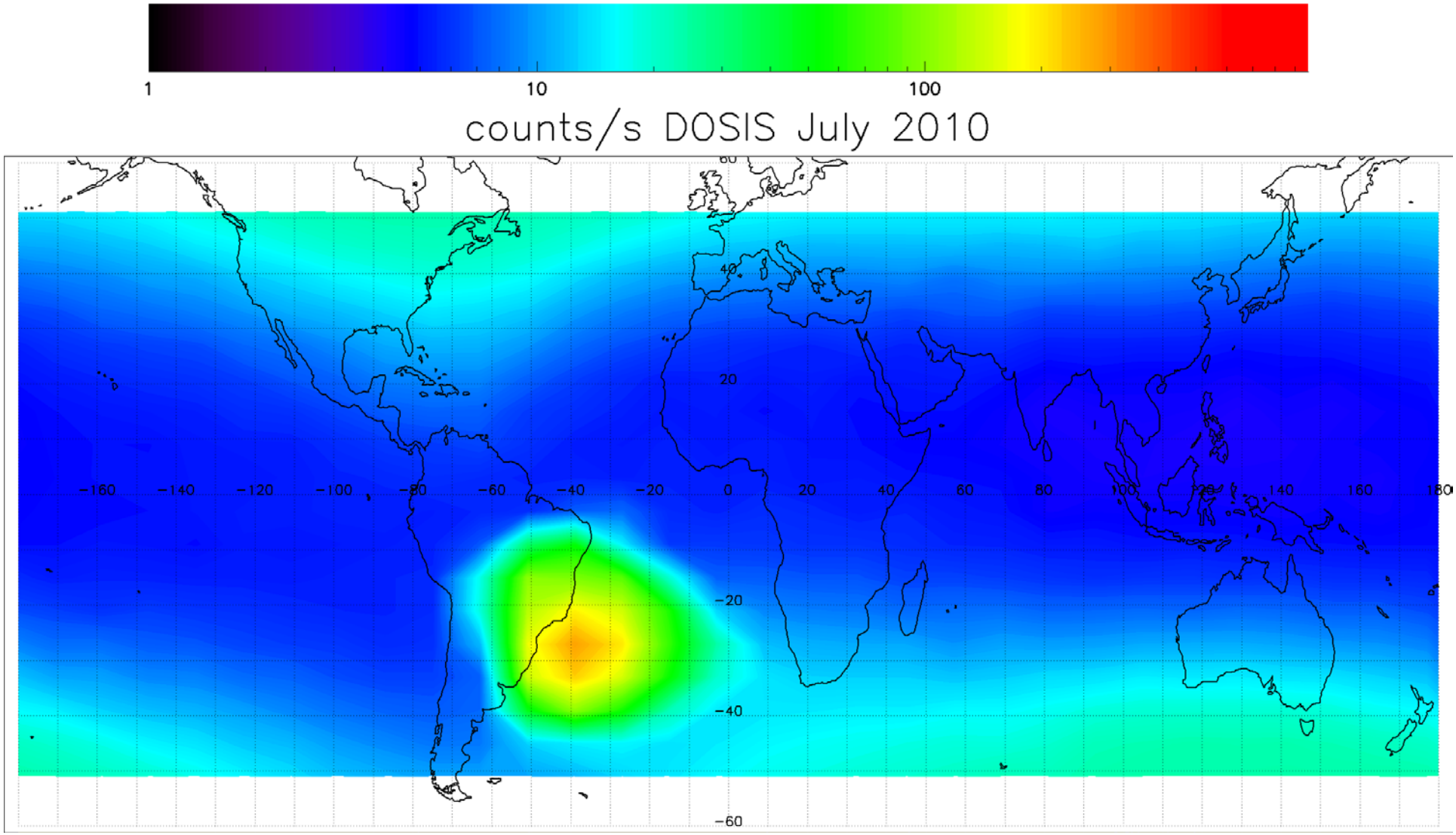
- Protons (in dependence of the solar cycle)

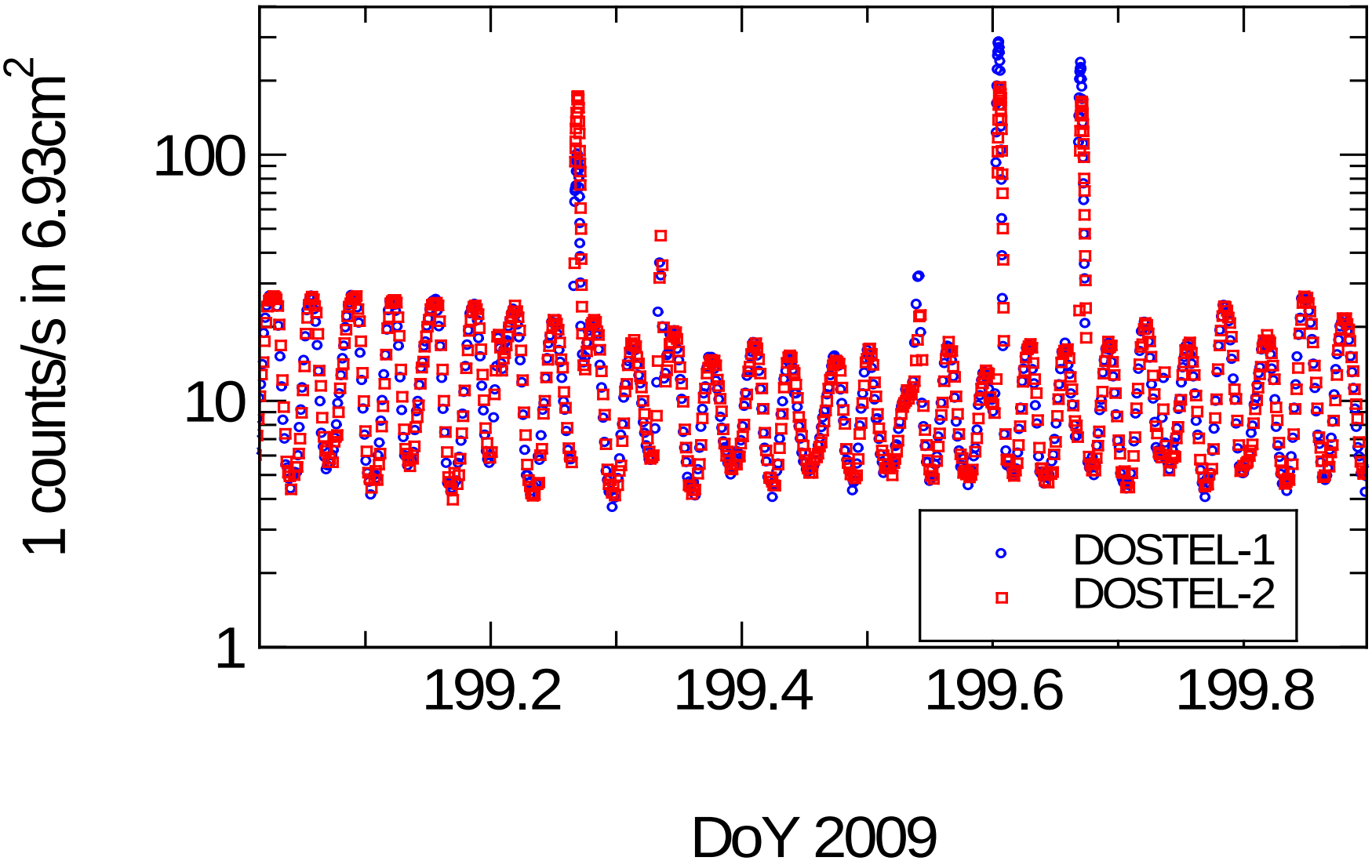
Variation of the radiation load onboard the ISS with altitude, latitude and time

ISS Orbit

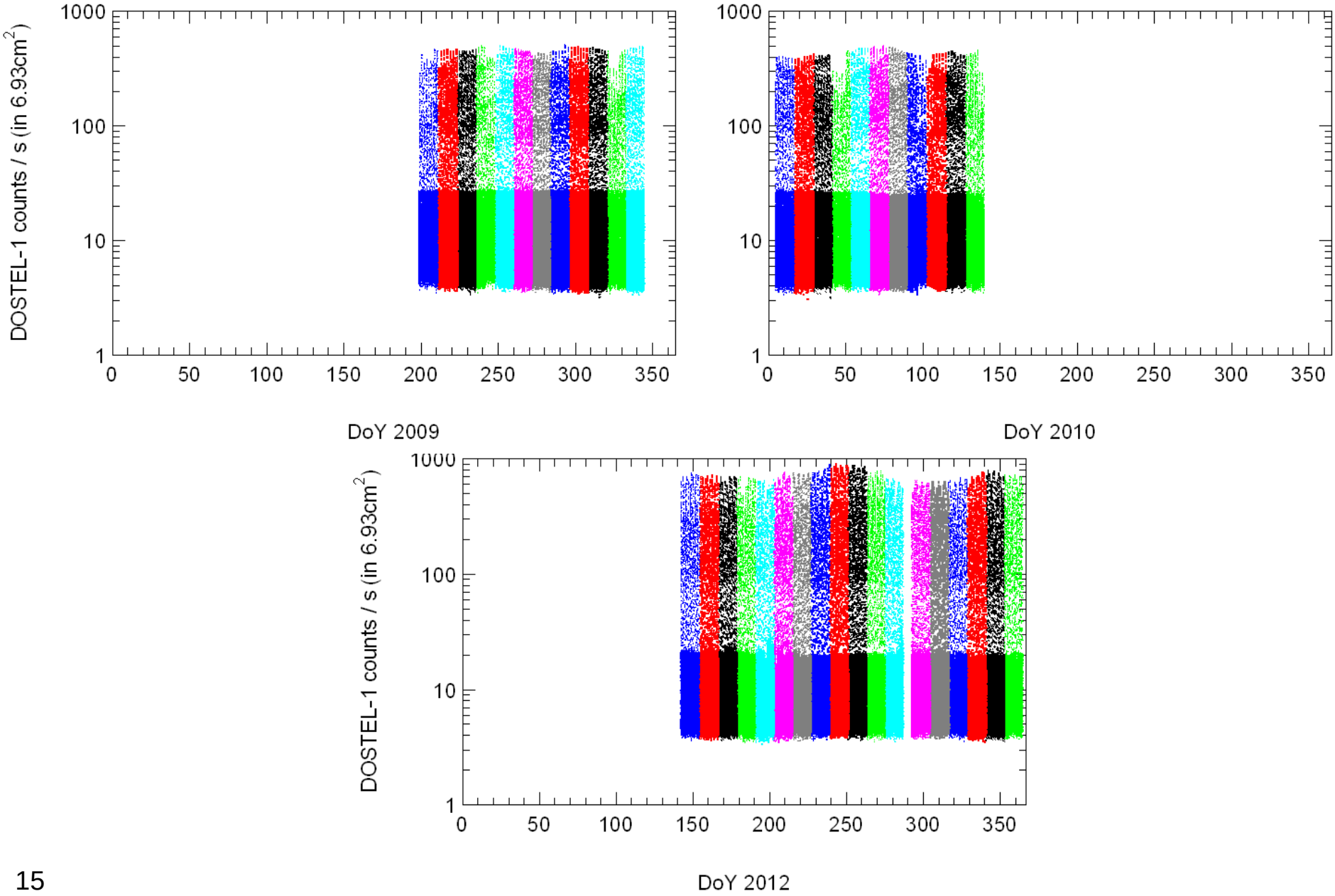


DOSIS - DOSTEL

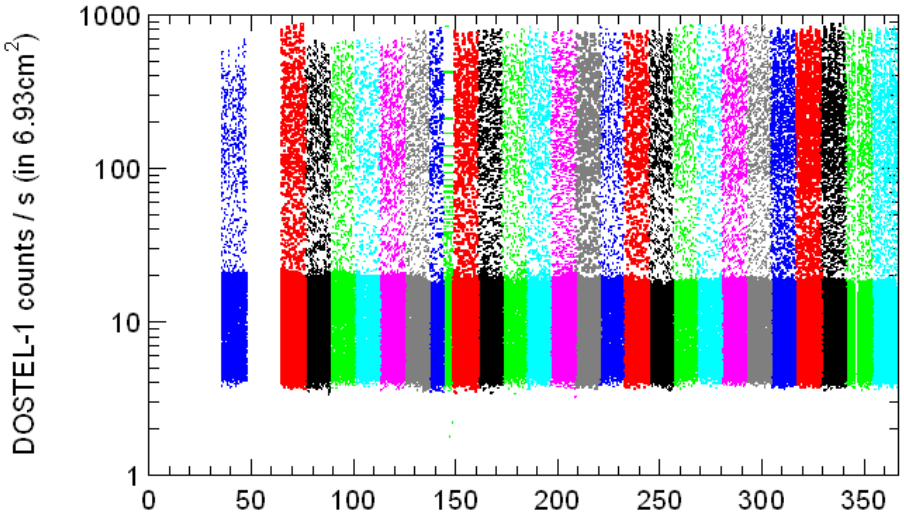


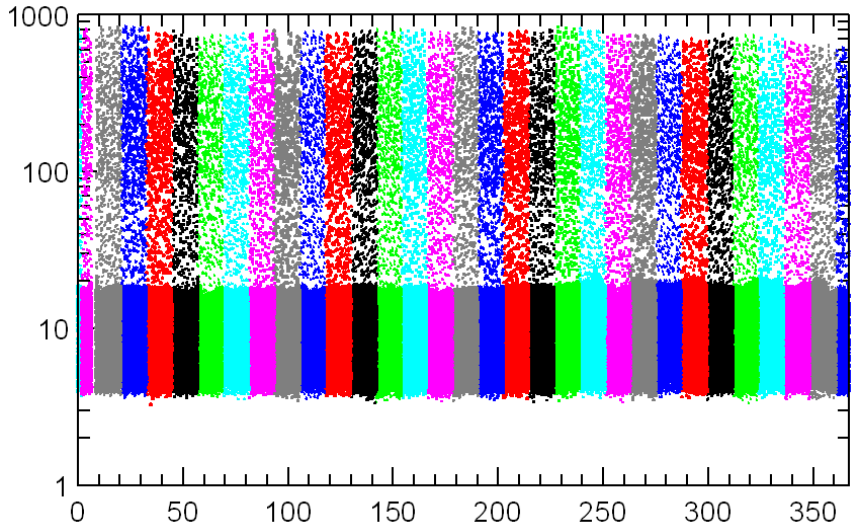

1 counts/s in 6.93cm2
100
10
1
199.2
199.4
199.6
199.8
DoY 2009
DOSTEL-1
DOSTEL-2

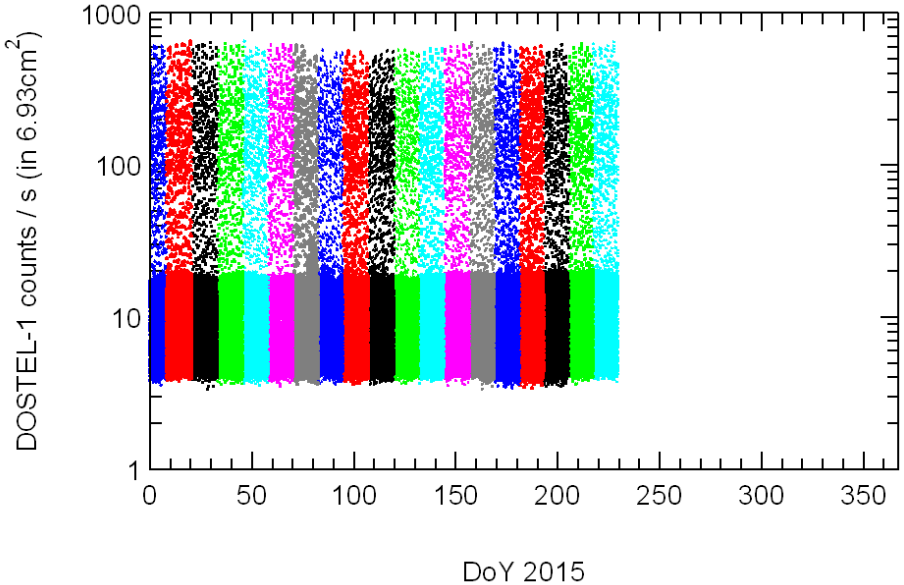
DOSIS / DOSIS3D DOSTEL-1 Count Rates



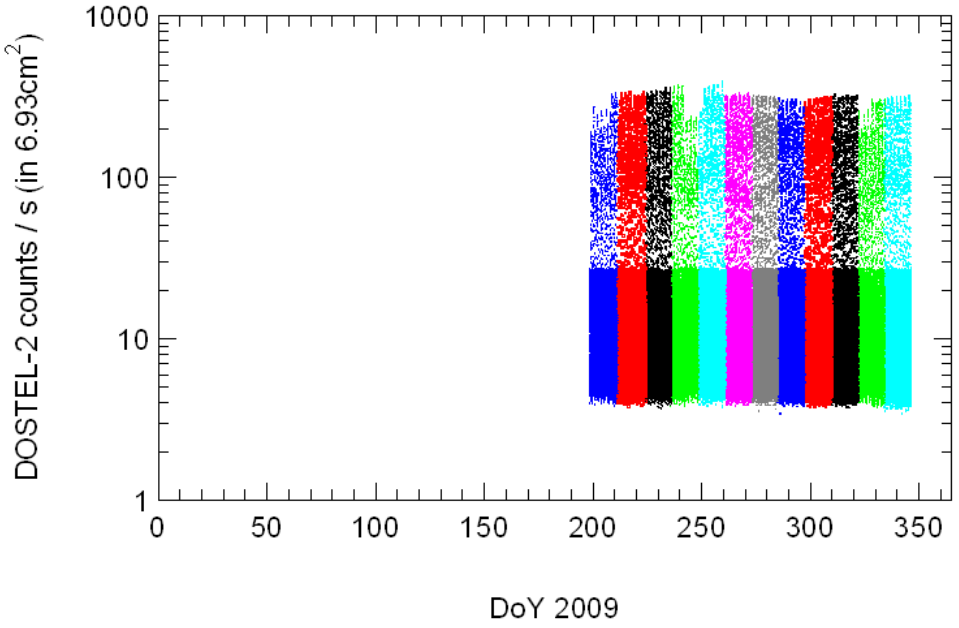
DOSIS / DOSIS3D DOSTEL-1 Count Rates

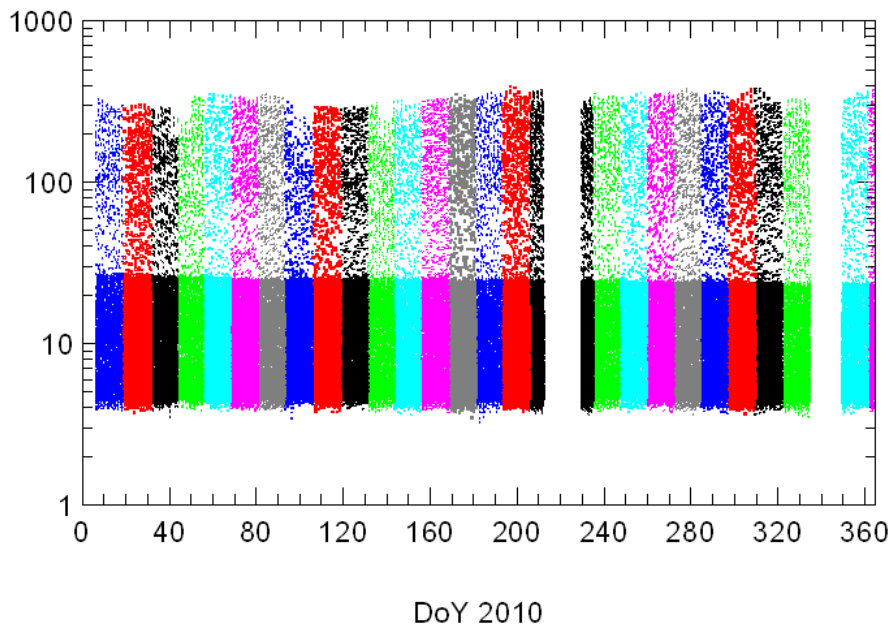


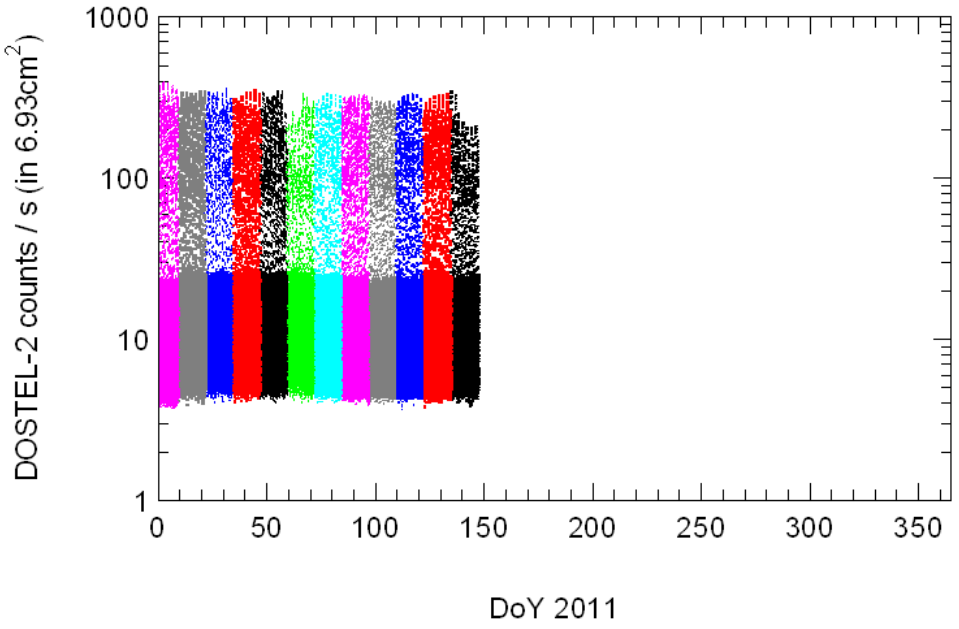


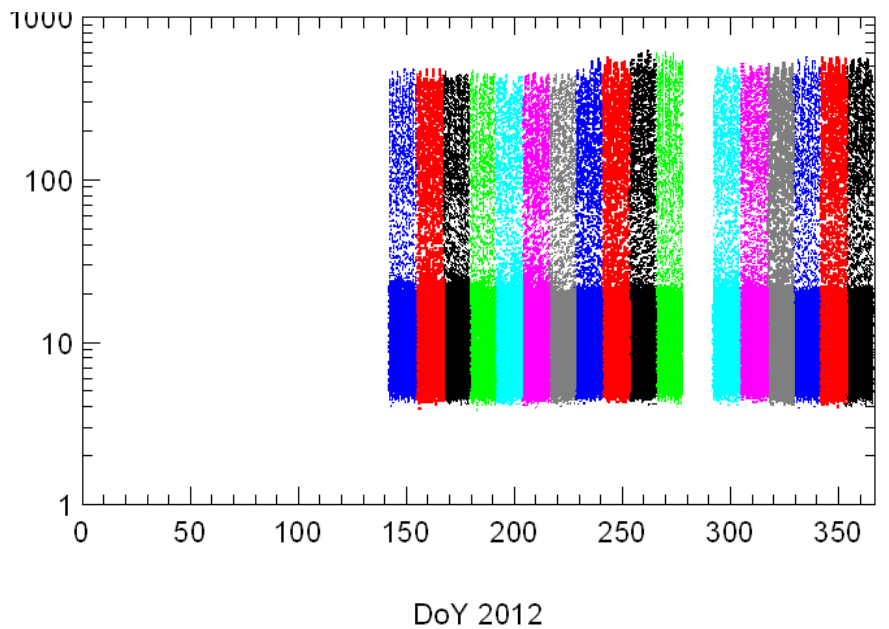


DOSIS / DOSIS3D DOSTEL-2 Count Rates

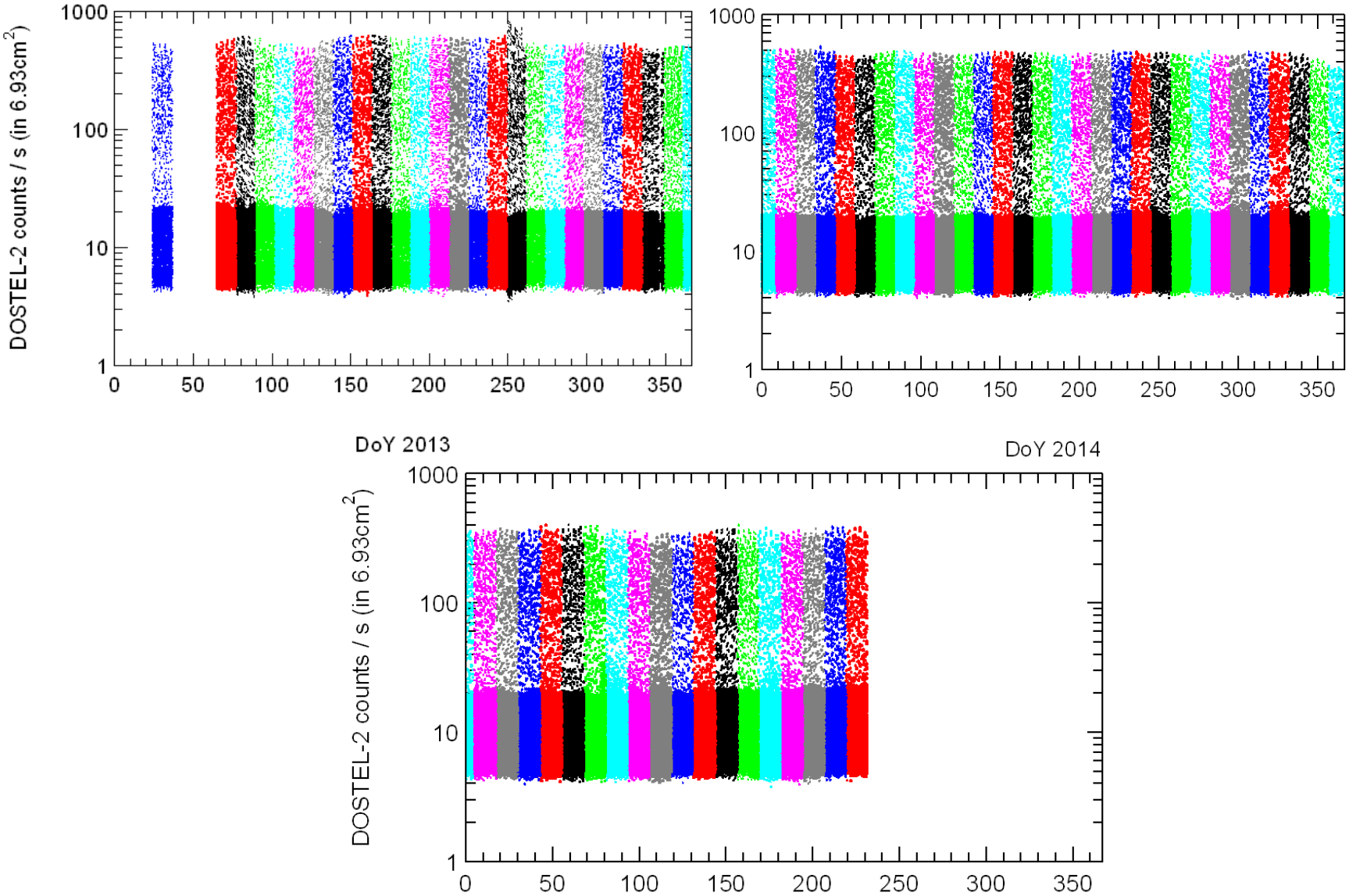




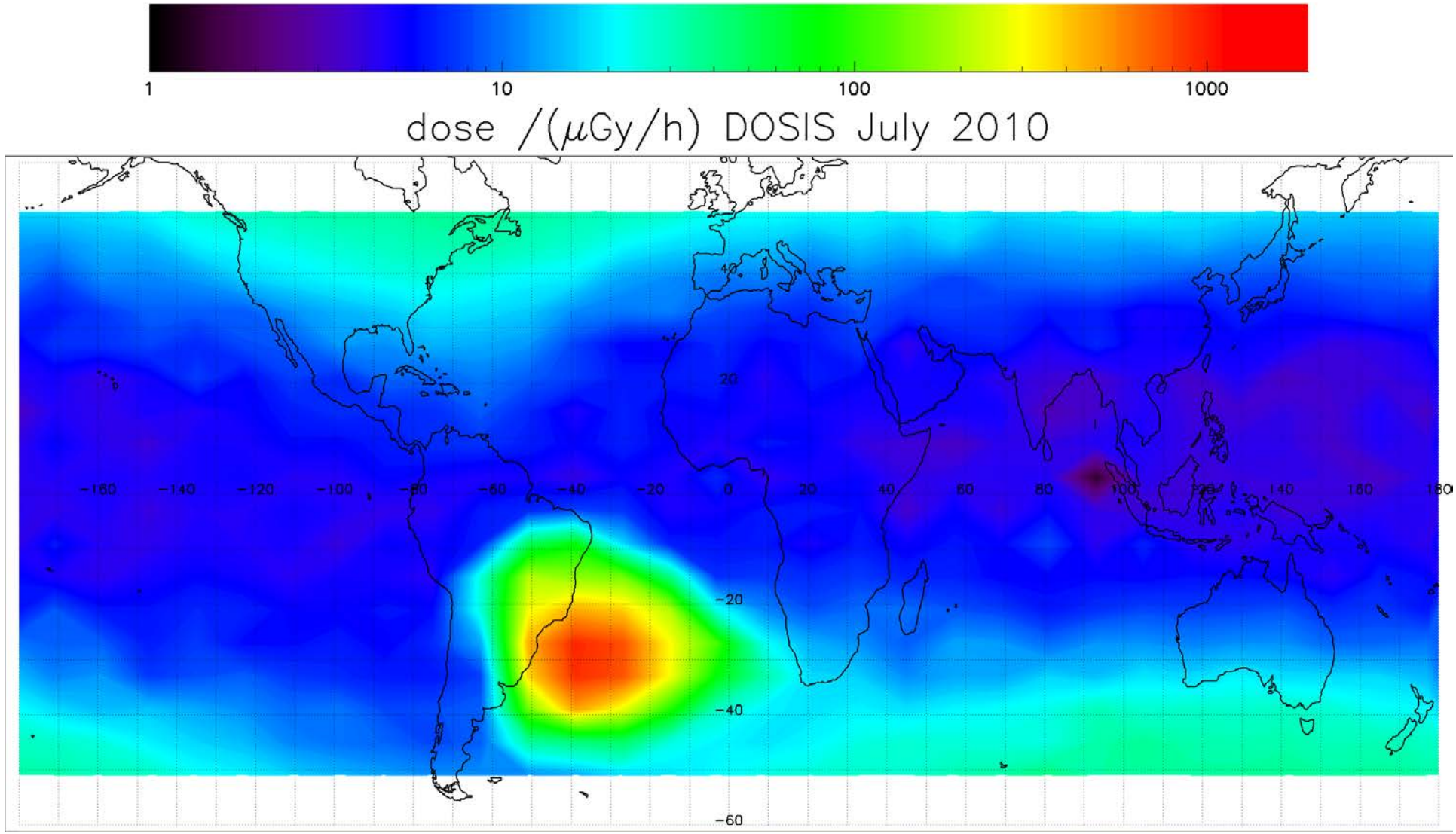


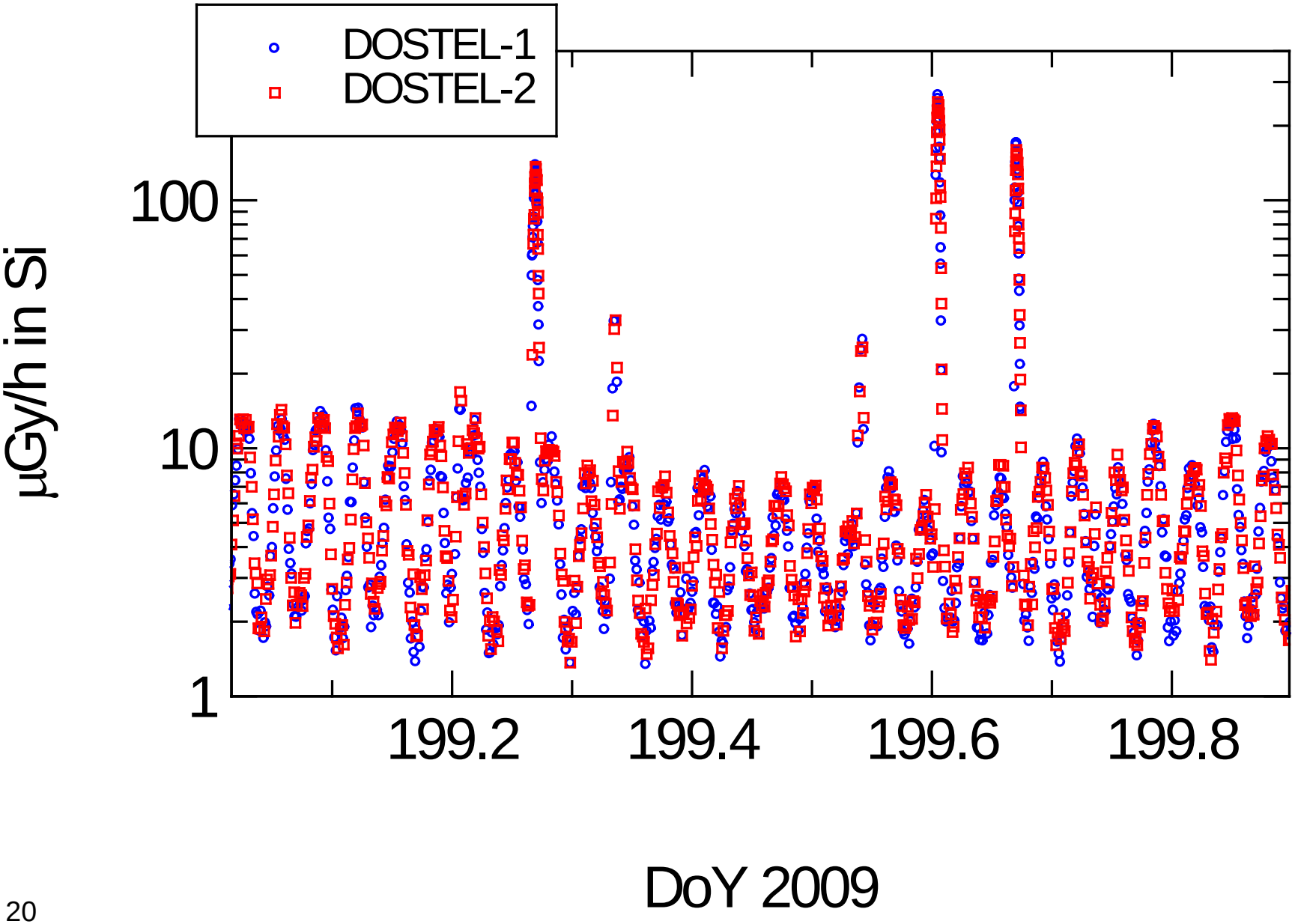


DOSIS / DOSIS3D DOSTEL-2 Count Rates

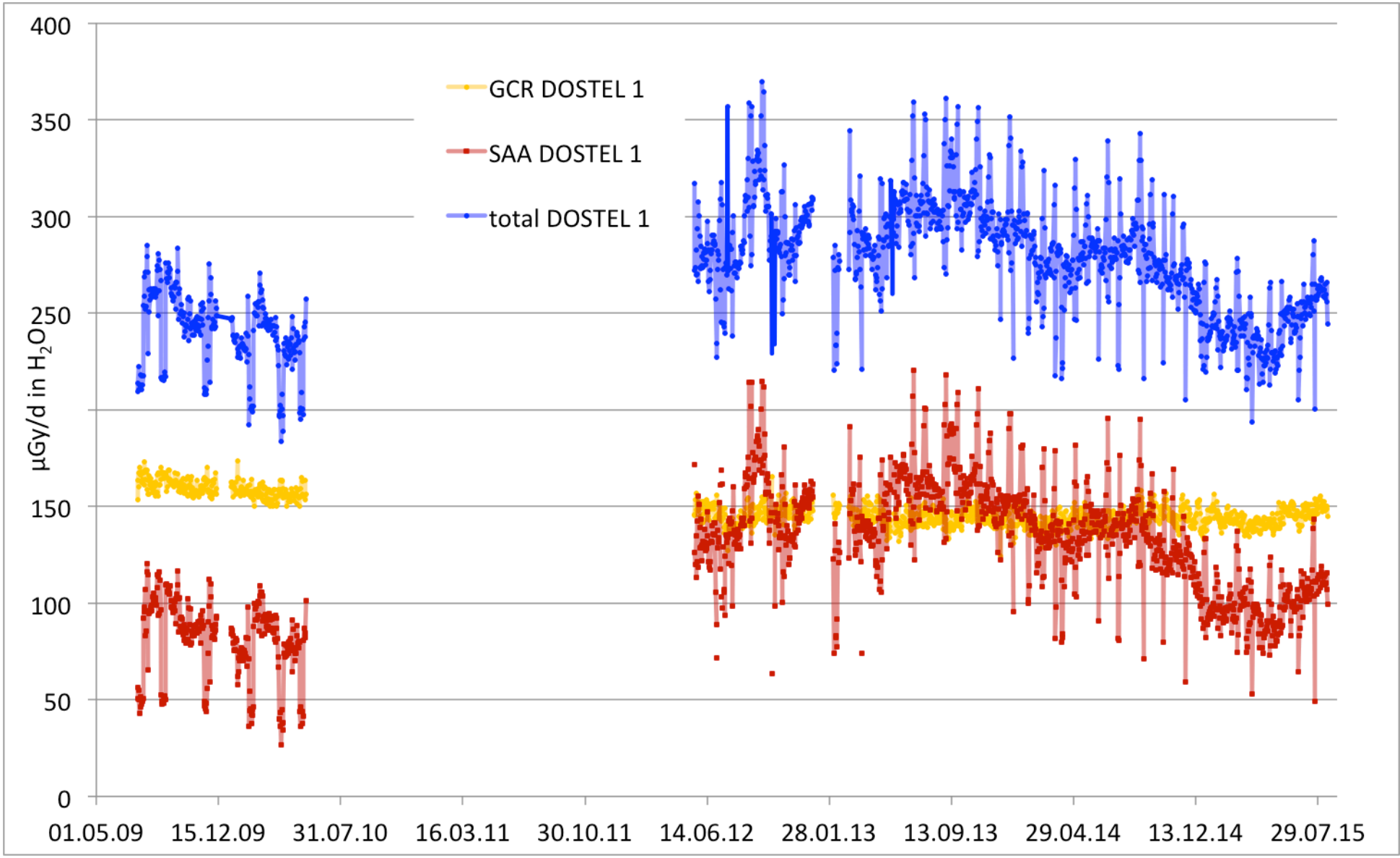


DOSIS - DOSTEL

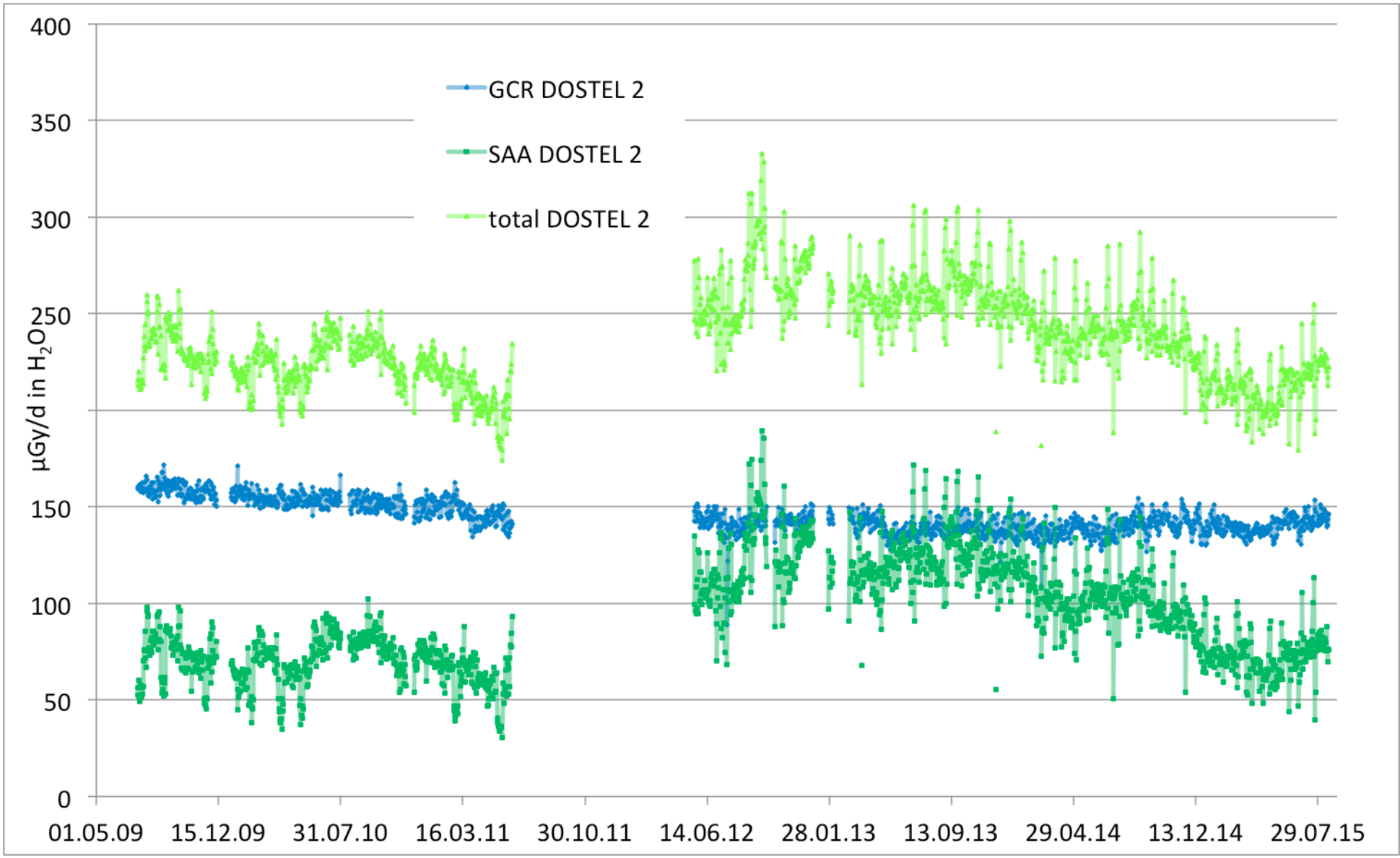



DOSTEL-1
DOSTEL-2
100
10
1
µGy/h in Si
199.2
199.4
199.6
199.8
DoY 2009

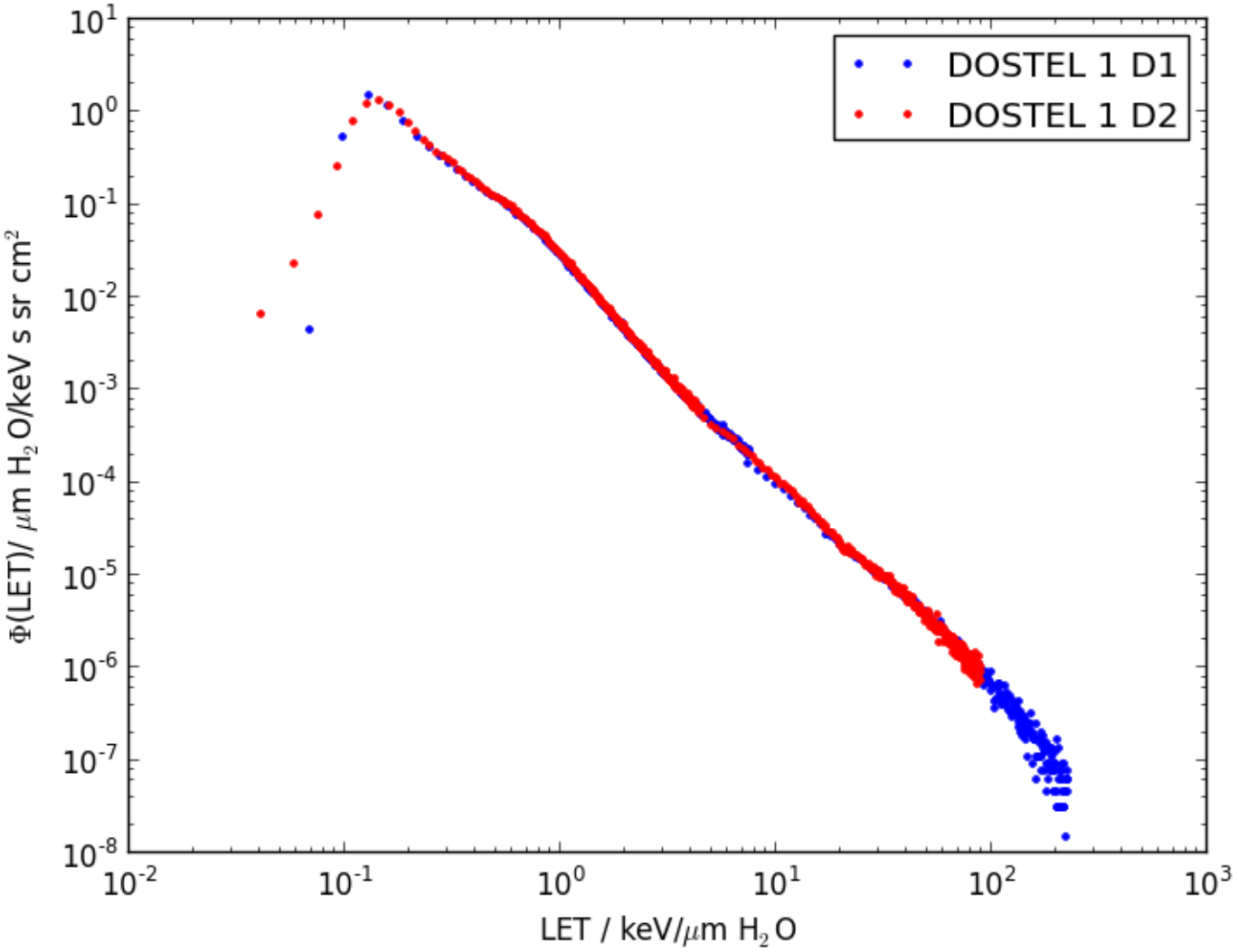
Absorbed Dose Rates DOSTEL 1



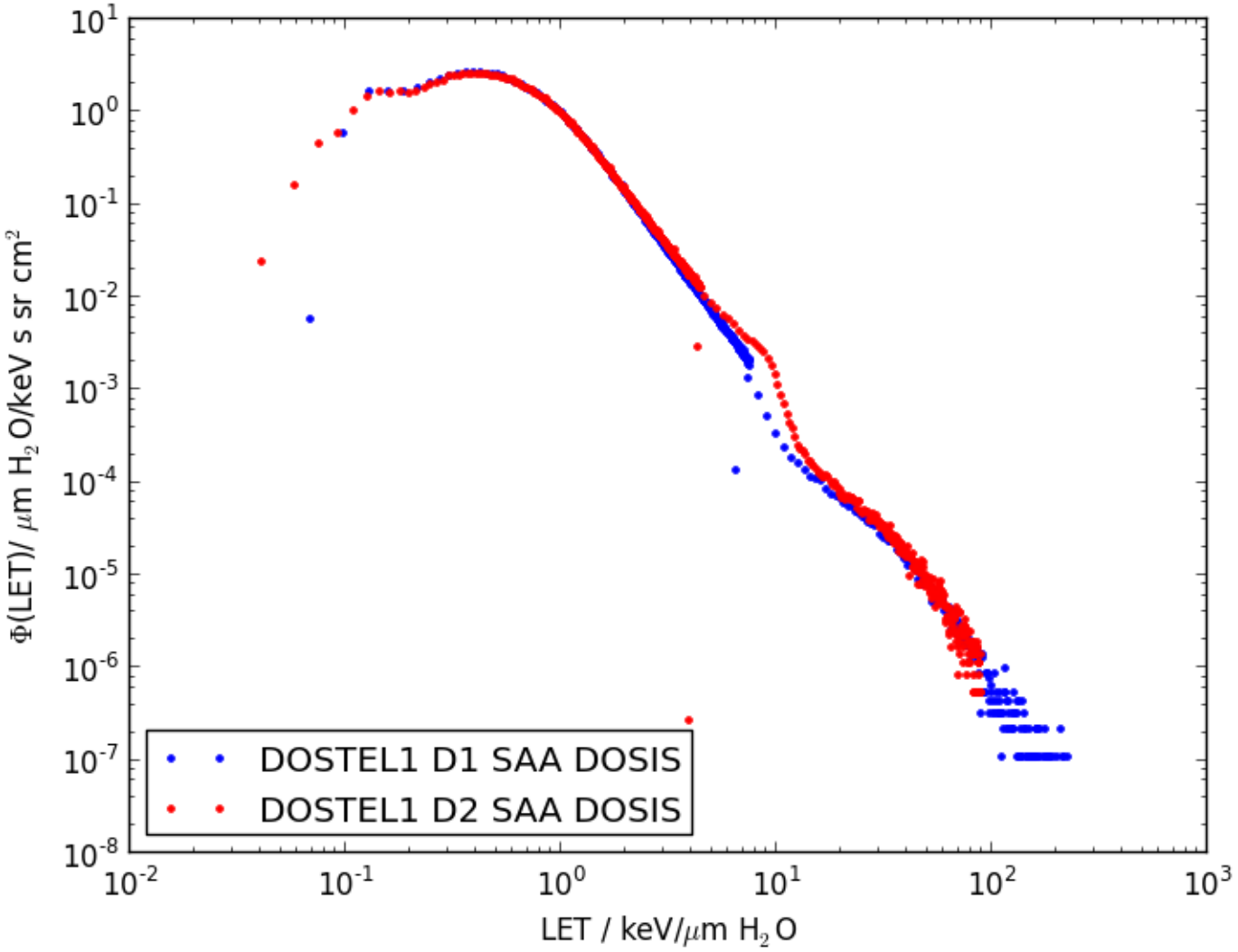
Absorbed Dose Rates DOSTEL 2



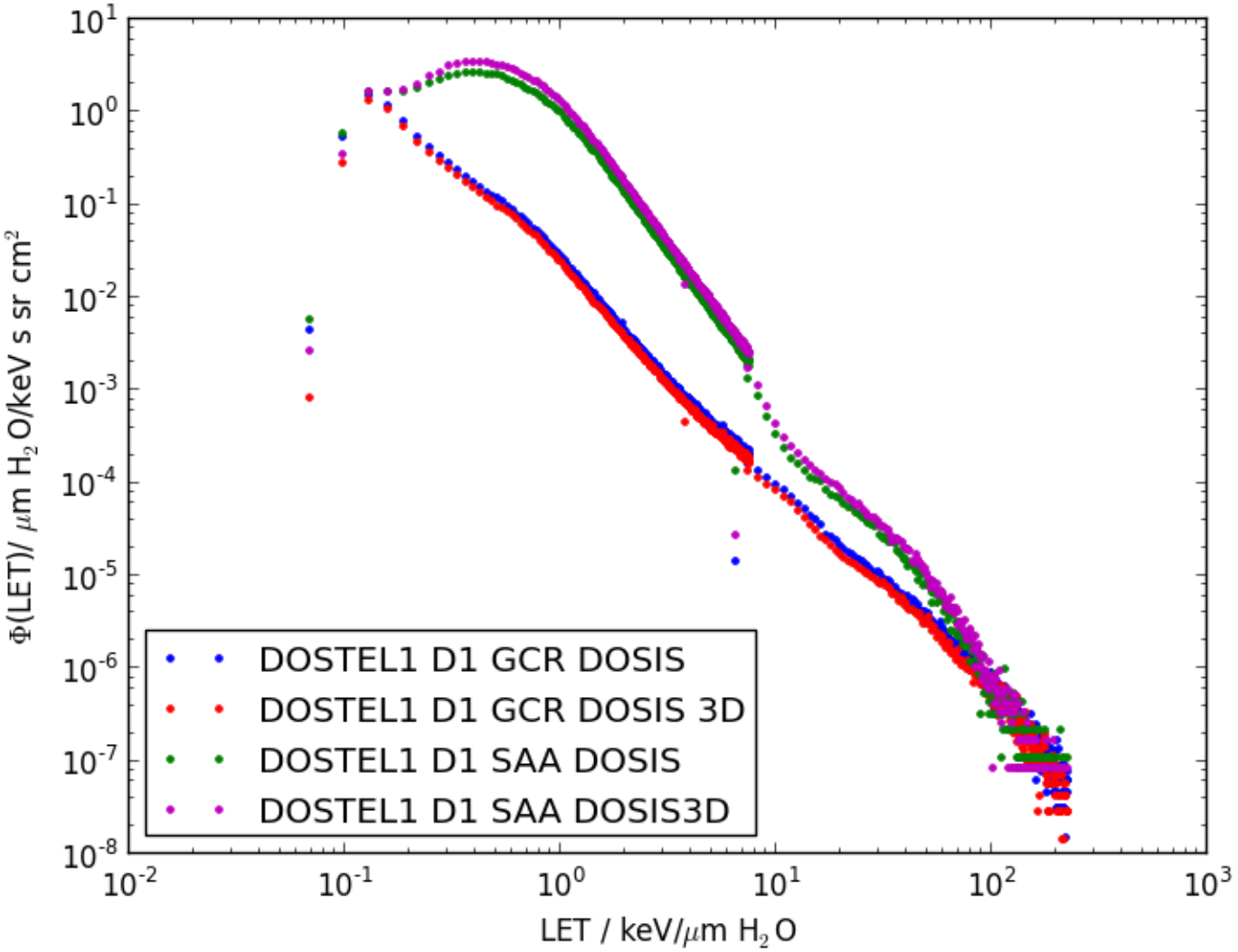
DOSIS GCR LET Spectra DOSTEL-1



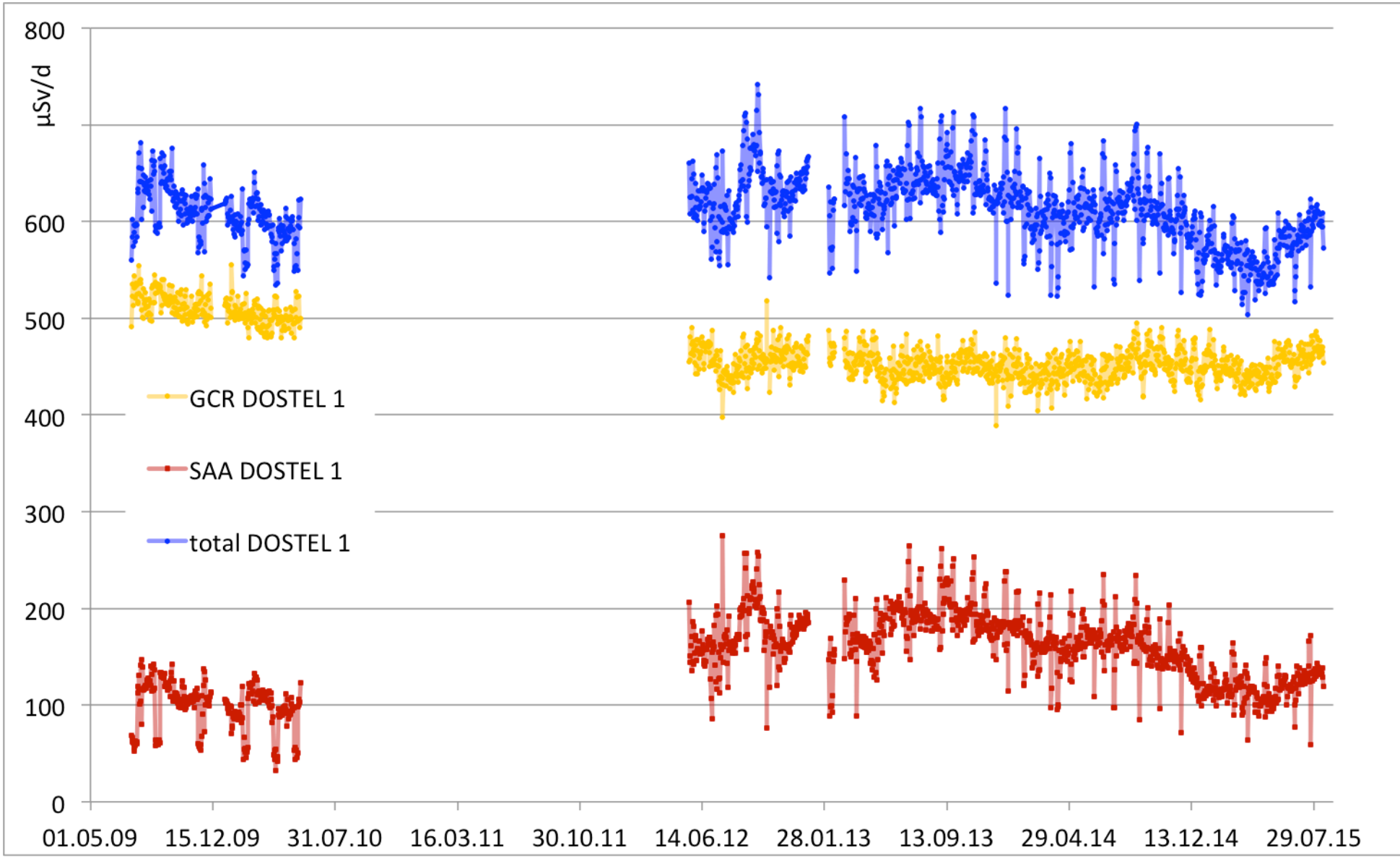
DOSIS SAA LET Spectra DOSTEL-1



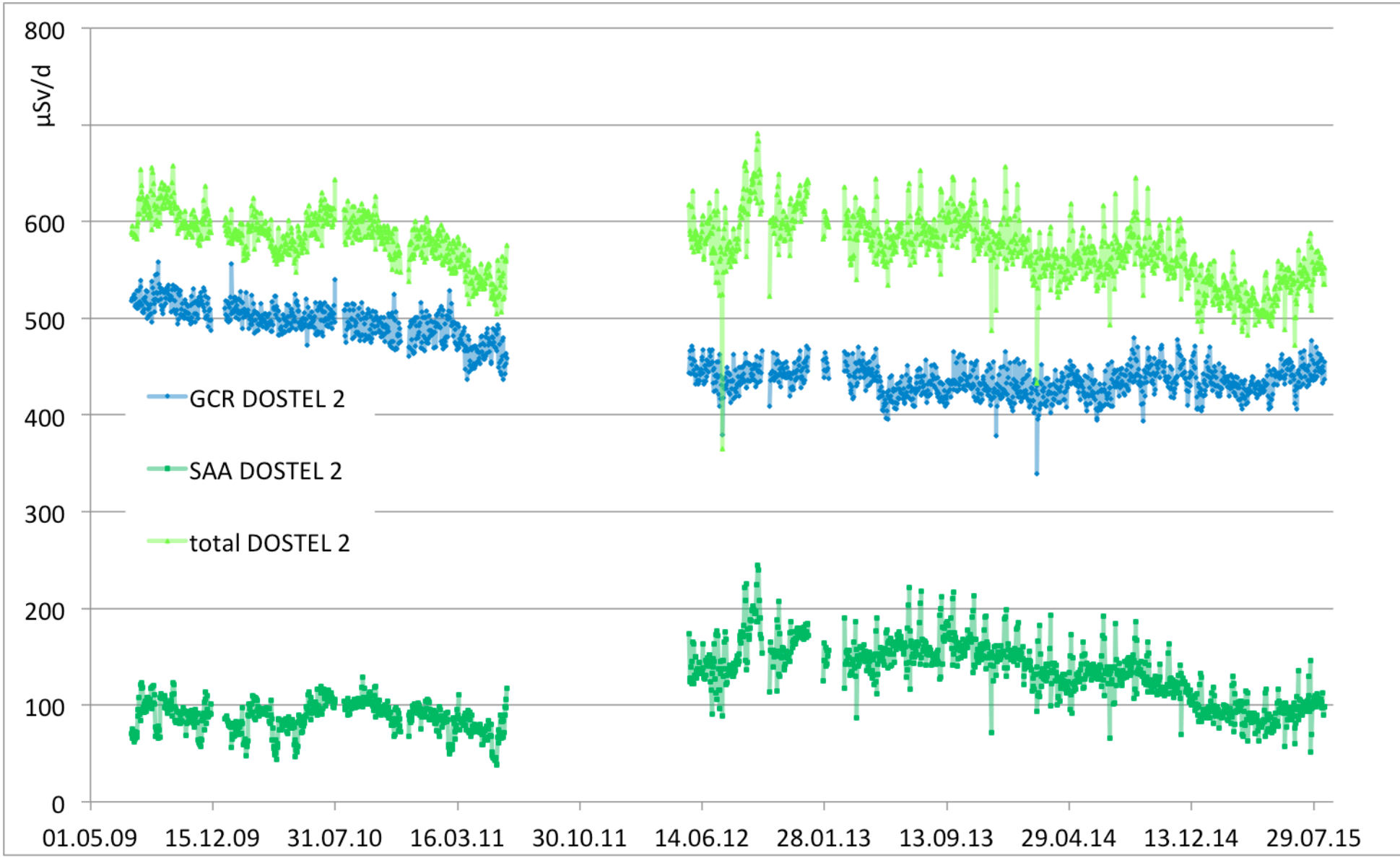
LET Spectra DOSTEL-1 Detector 1



Dose Equivalent Rates DOSTEL 1



Dose Equivalent Rates DOSTEL 2



DOSIS / DOSIS 3D Results

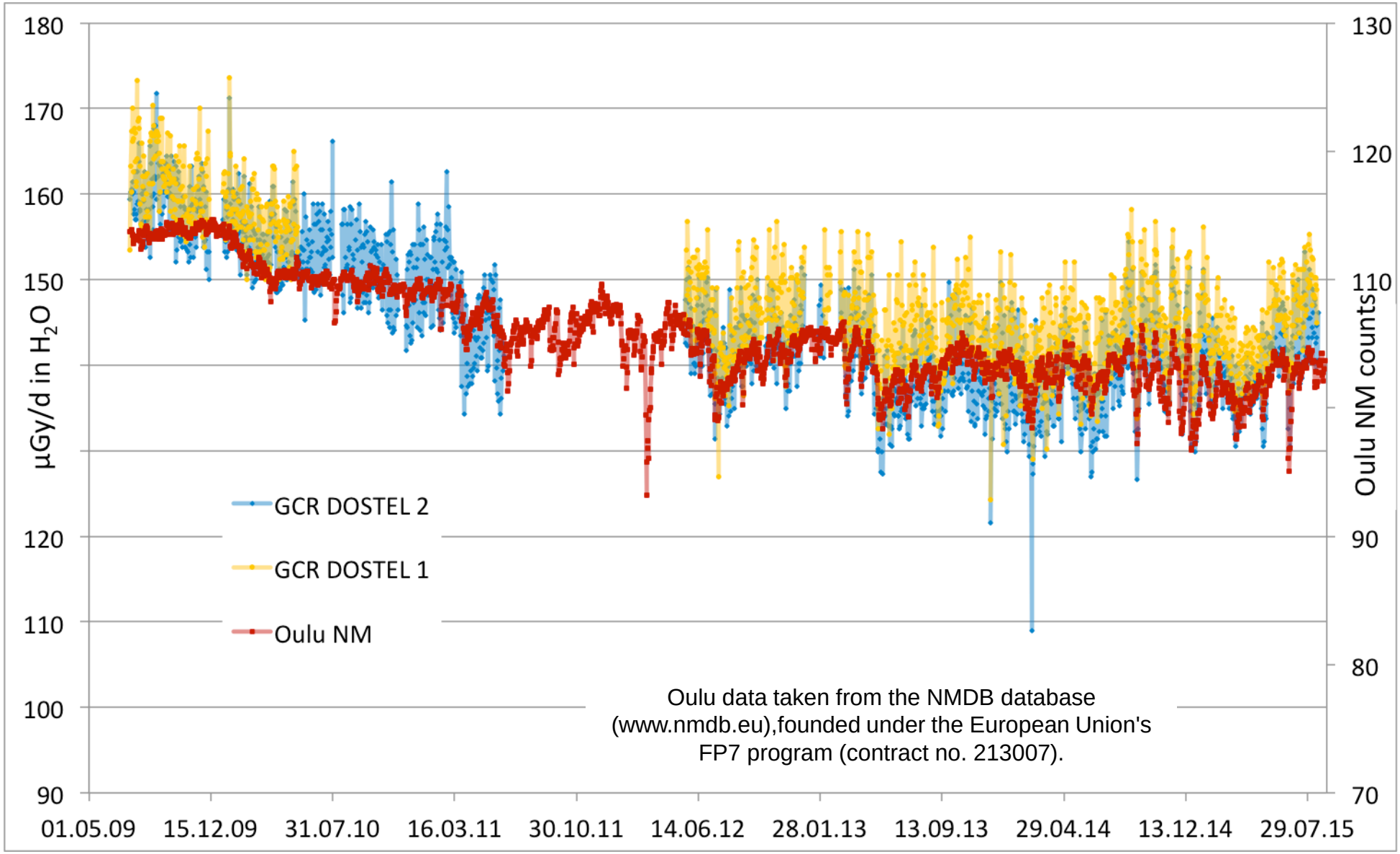
DOSTEL-1: July 18, 2009 - May 28, 2010
DOSTEL-2: July 18, 2009 - June 16, 2011

DOSIS	Total				GCR				SAA			
	µGy/d in Si	µGy/d in tissue	Q	µSv/d	µGy/d in Si	µGy/d in tissue	Q	µSv/d	µGy/d in Si	µGy/d in tissue	Q	µSv/d
DOSTEL-1	195	240	2.5	609	130	159	3.2	510	66	81	1.22	99
DOSTEL-2	181	222	2.6	584	124	153	3.3	497	57	70	1.26	88

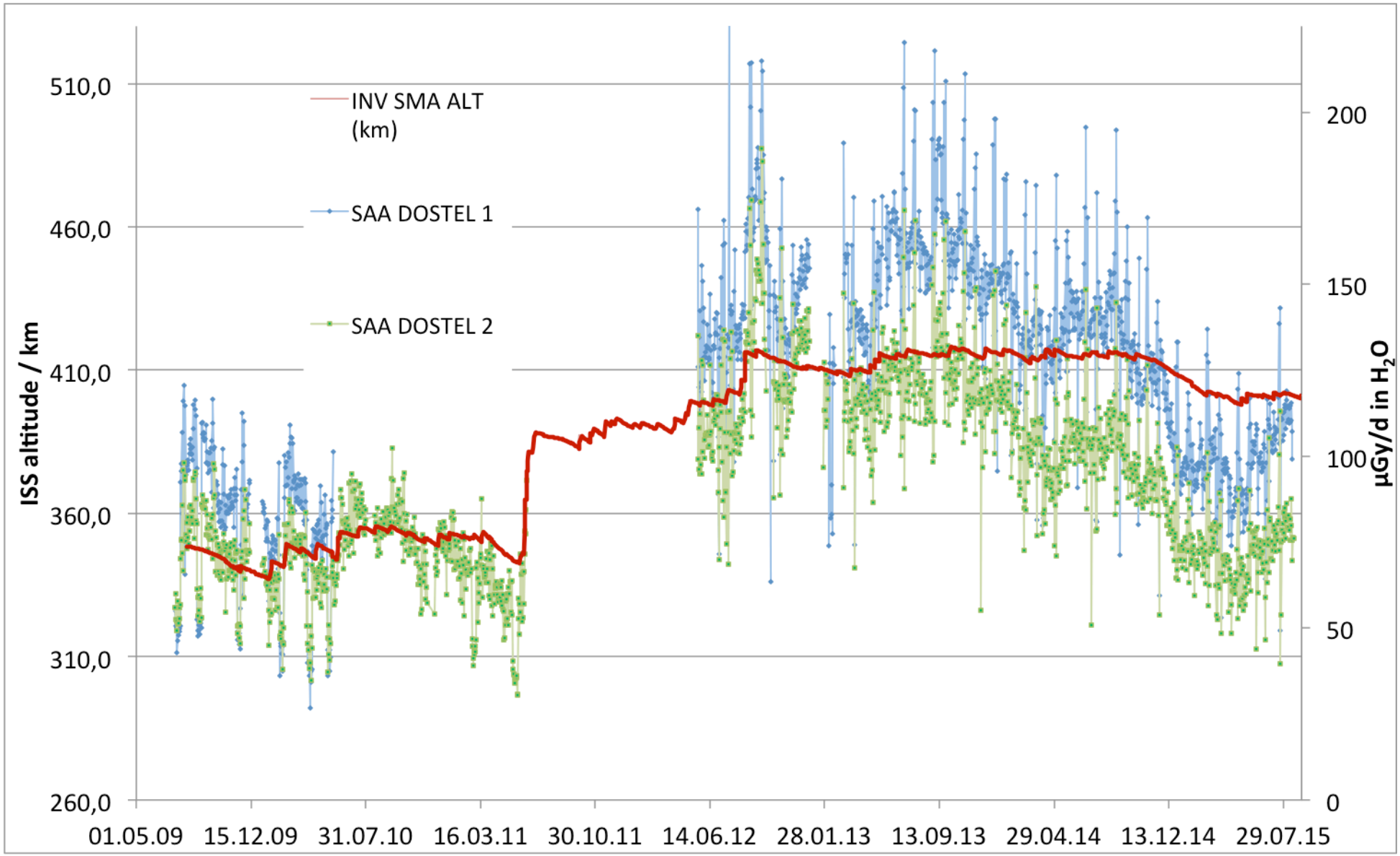
DOSIS 3D	Total				GCR				SAA			
	µGy/d in Si	µGy/d in tissue	Q	µSv/d	µGy/d in Si	µGy/d in tissue	Q	µSv/d	µGy/d in Si	µGy/d in tissue	Q	µSv/d
DOSTEL-1	227	279	2.2	613	117	144	3.1	452	109	134	1.20	161
DOSTEL-2	199	244	2.3	570	114	140	3.1	435	85	105	1.29	135

DOSTEL-1: May 21, 2012 – August 17, 2015
DOSTEL-2: May 21, 2012 – August 19, 2015

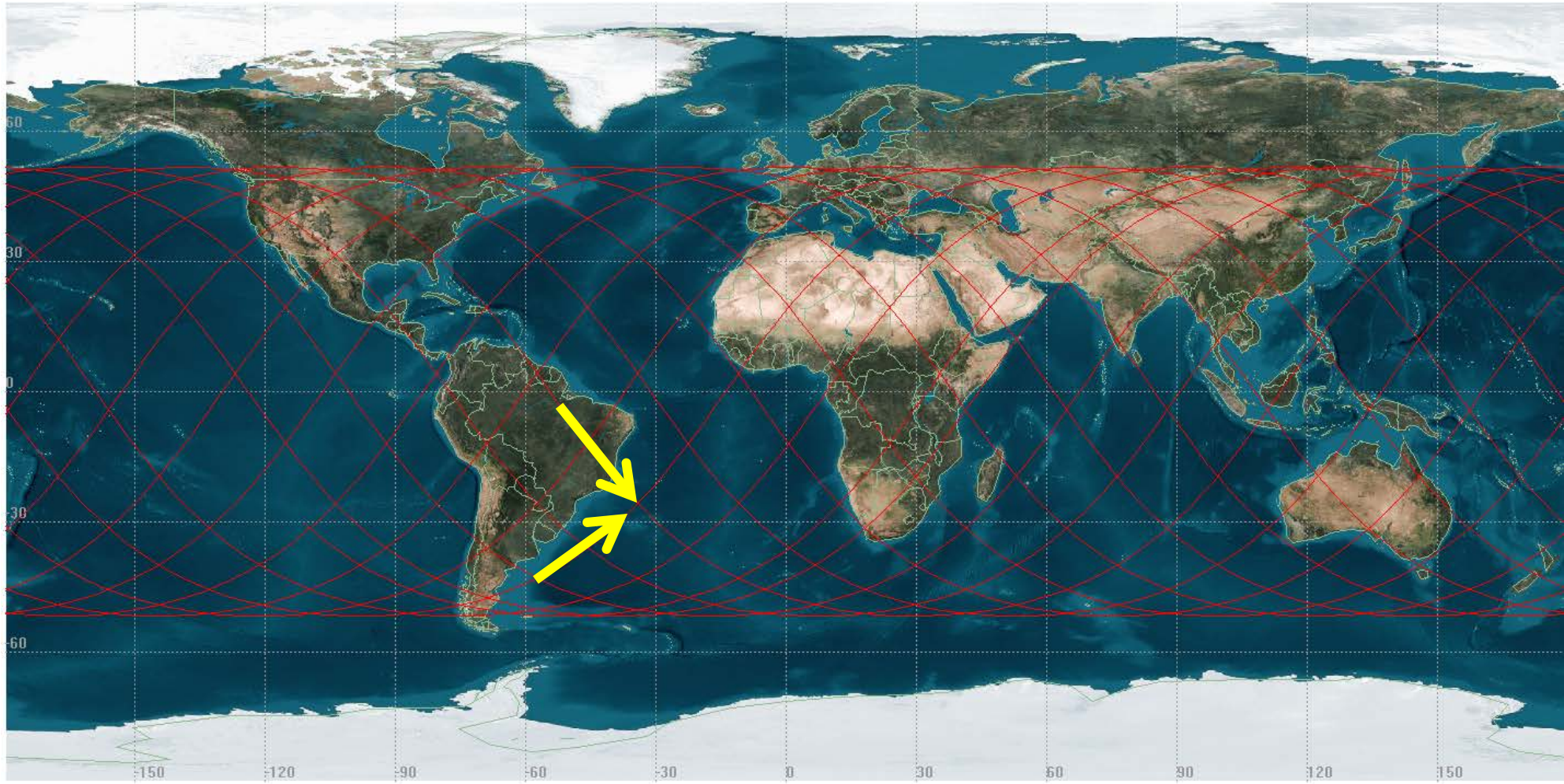
GCR Dose Rates



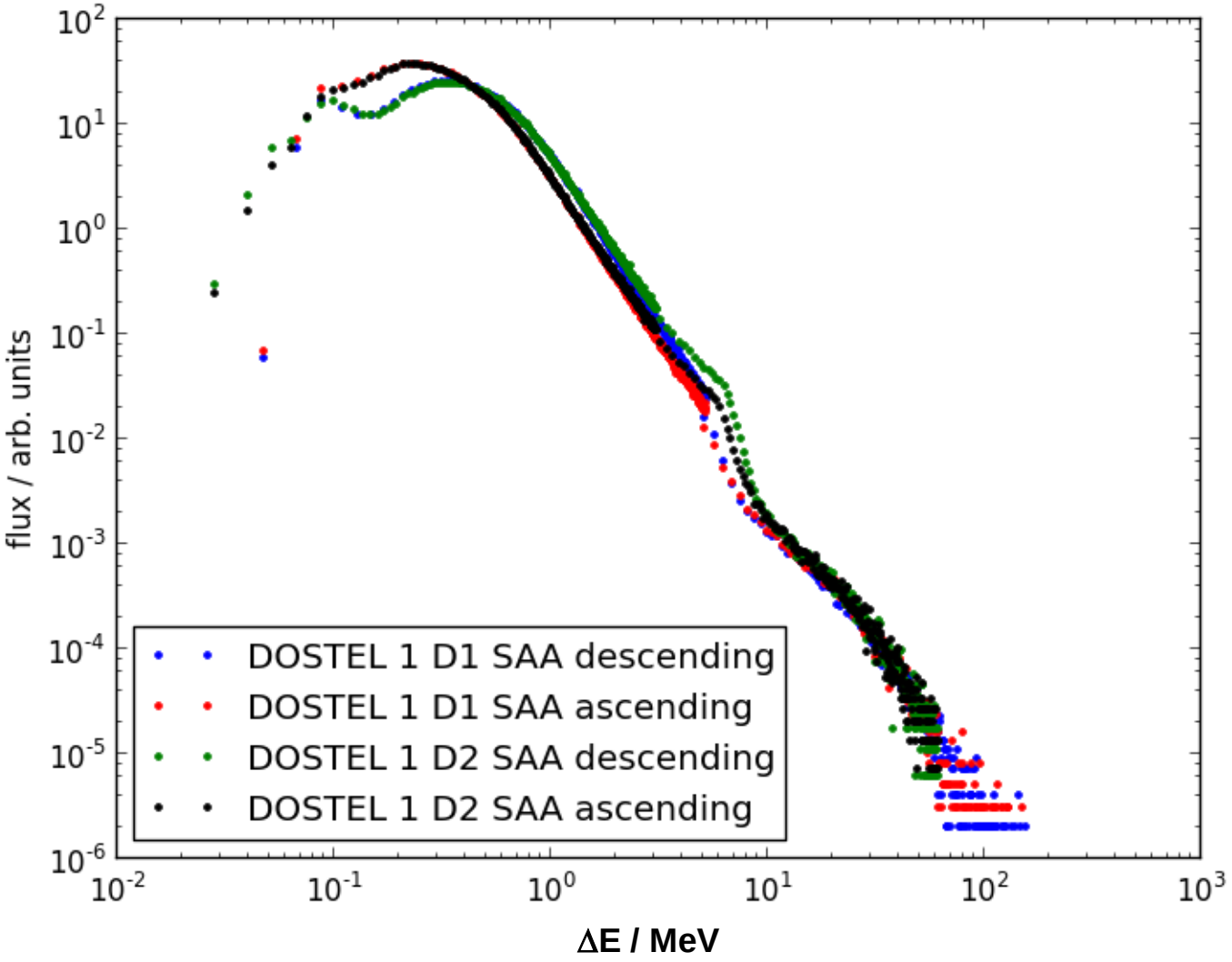
SAA Dose Rates



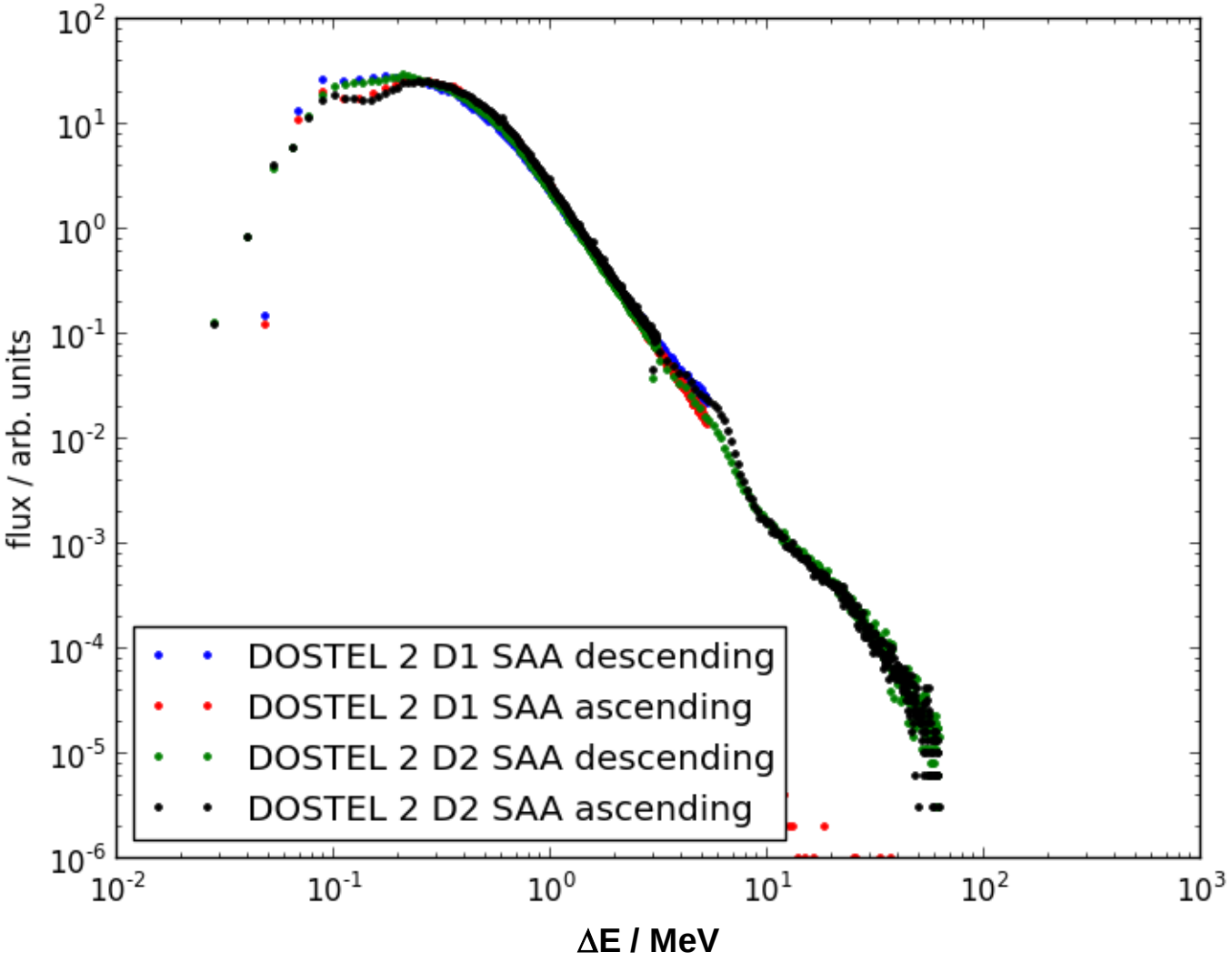
ISS Orbit



DOSIS SAA Energy Deposition Spectra



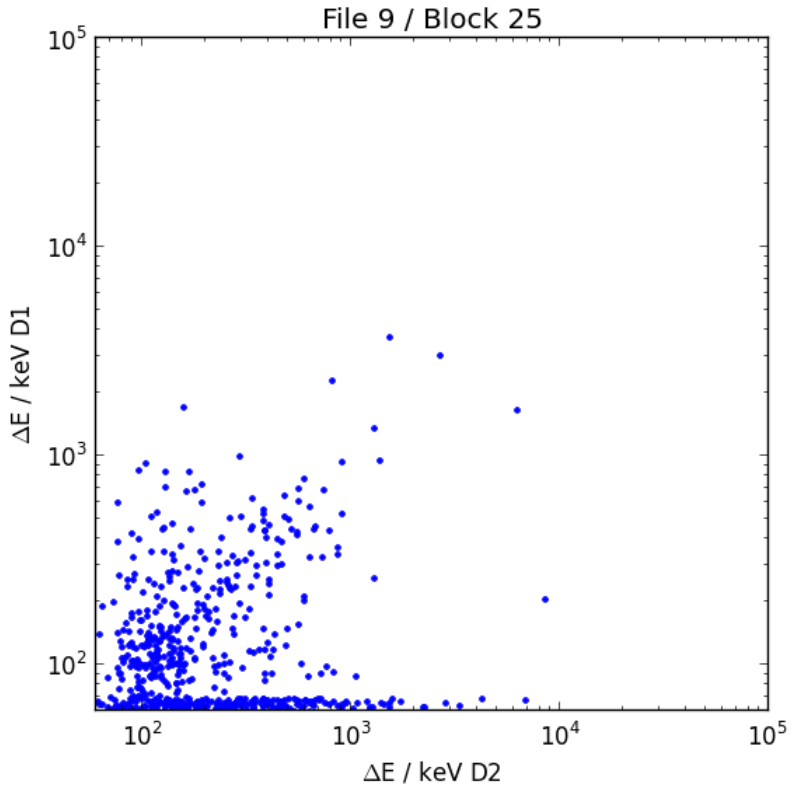
DOSIS SAA Energy Deposition Spectra

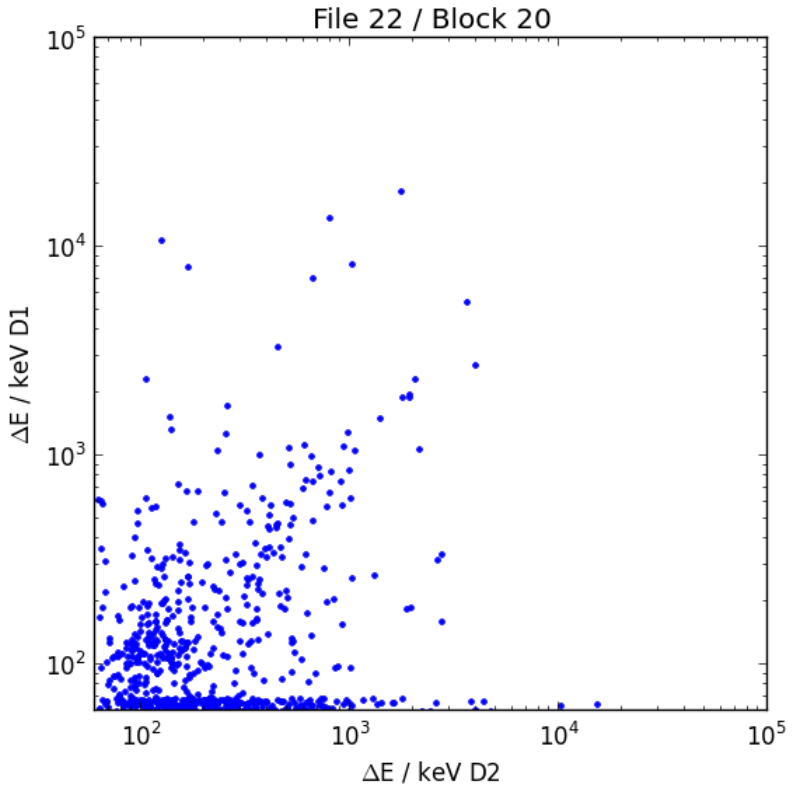


DOSIS 3D SAA Mode 2 Data - SAA

ascending

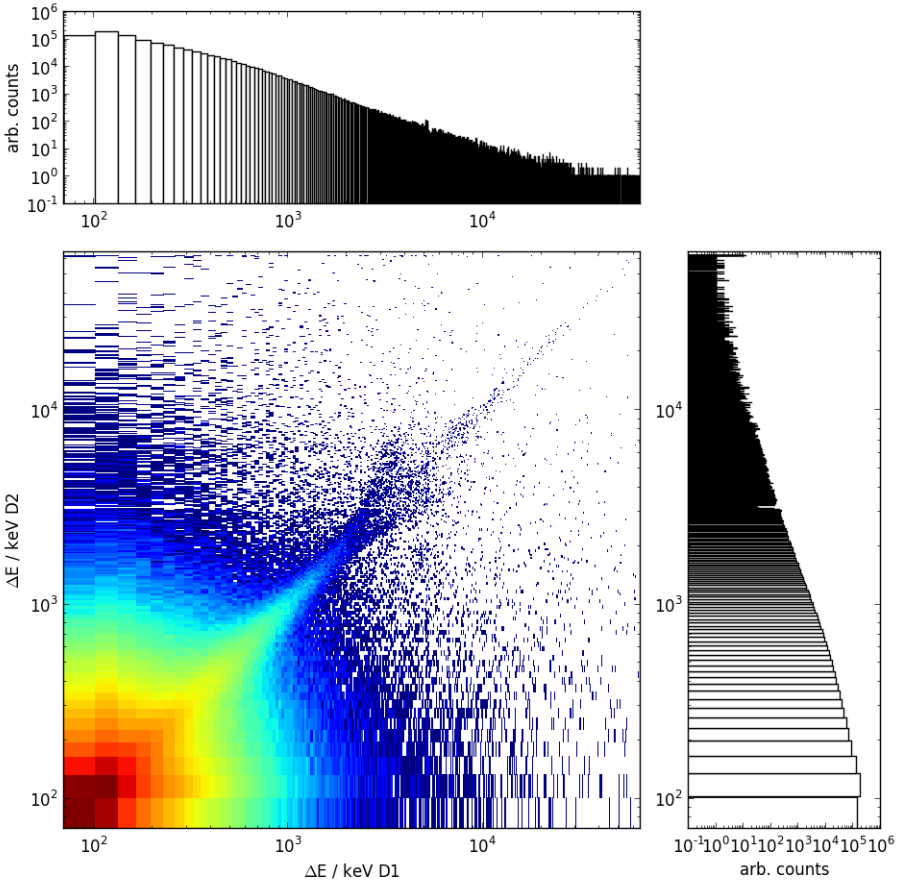
descending



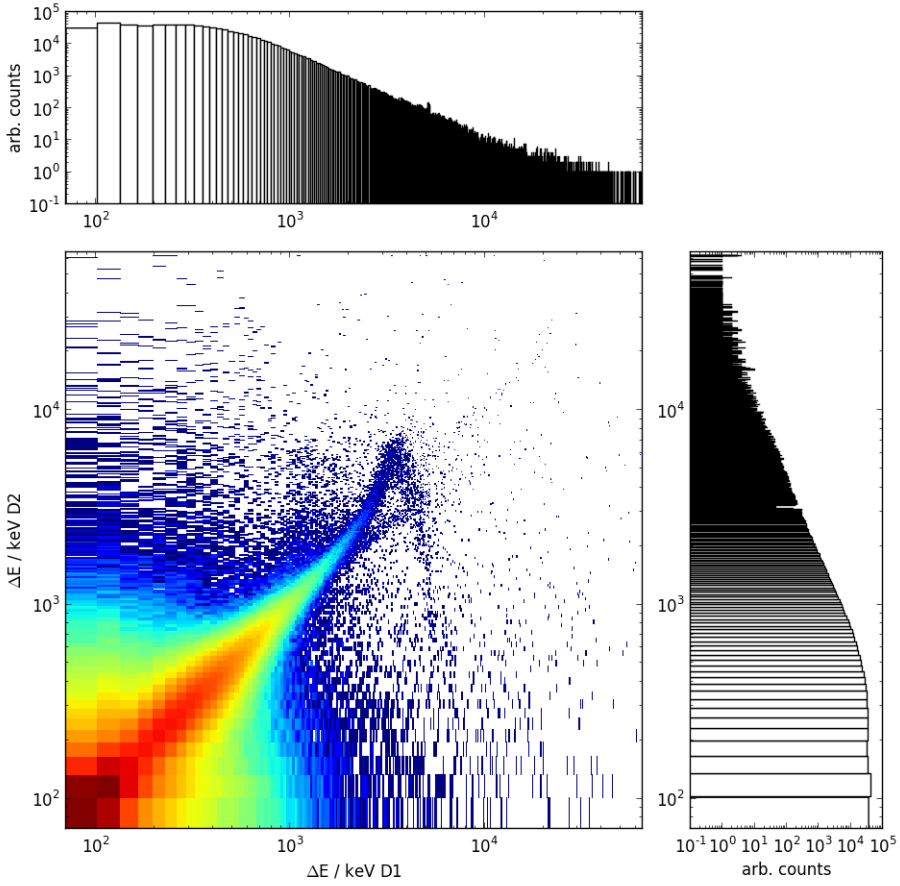


DOSIS 3D SAA Mode 2 Data - SAA

GCR (mainly)

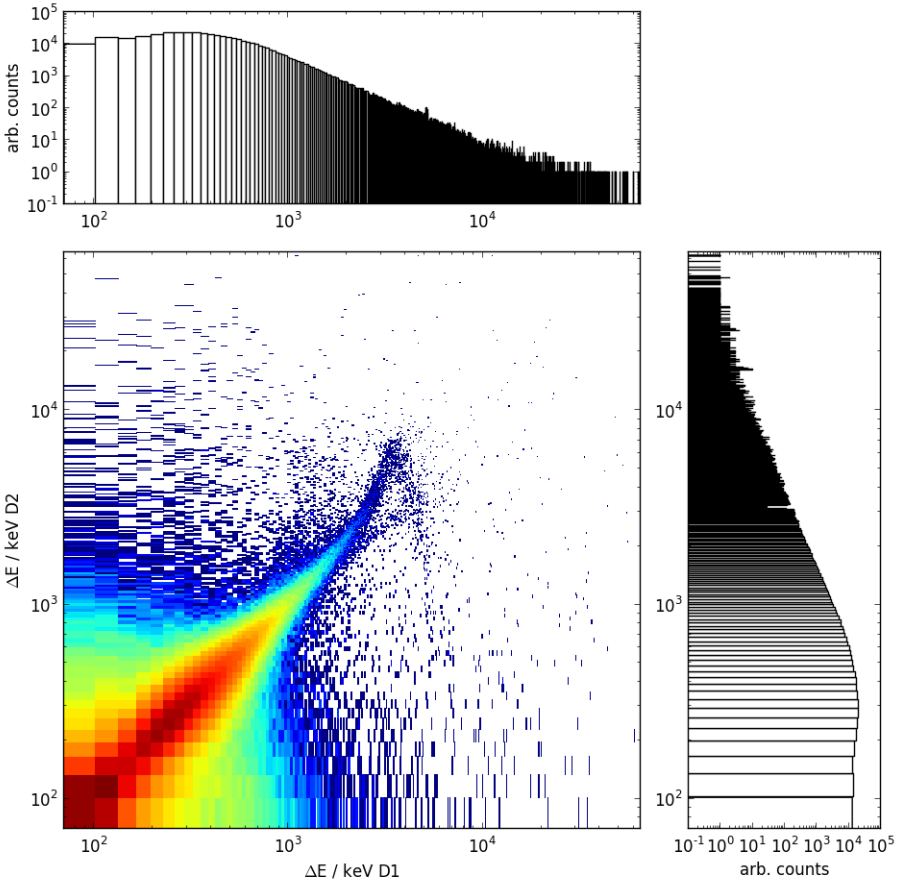


SAA (mainly)

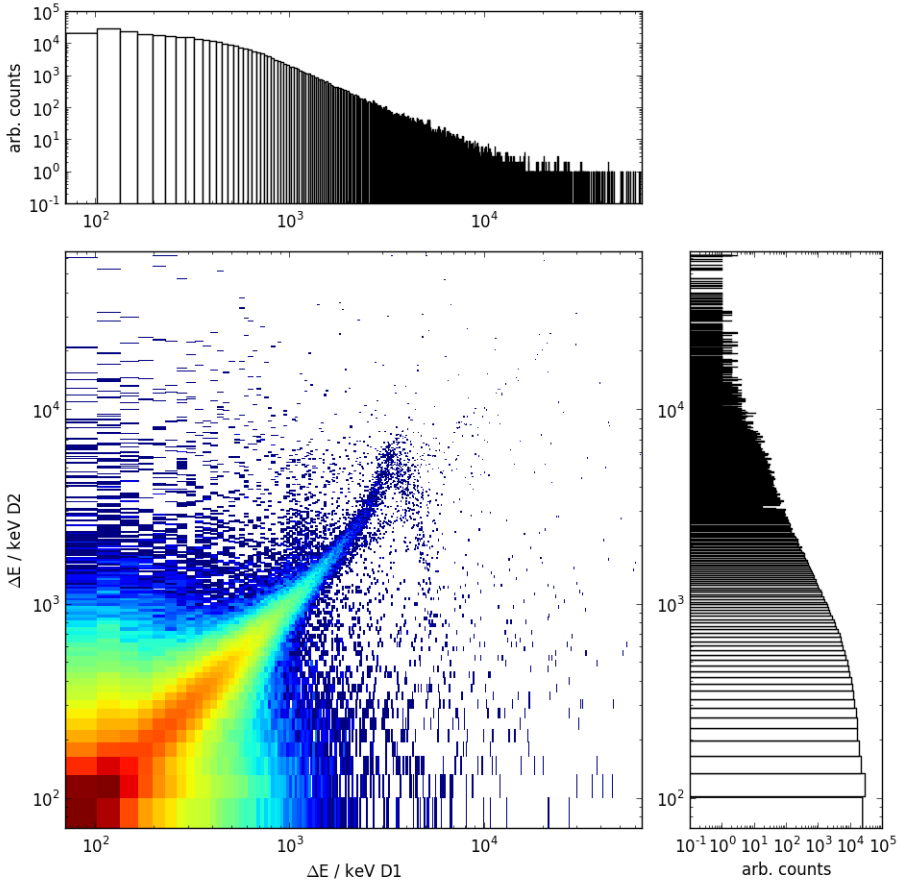


DOSIS 3D SAA Mode 2 Data - SAA

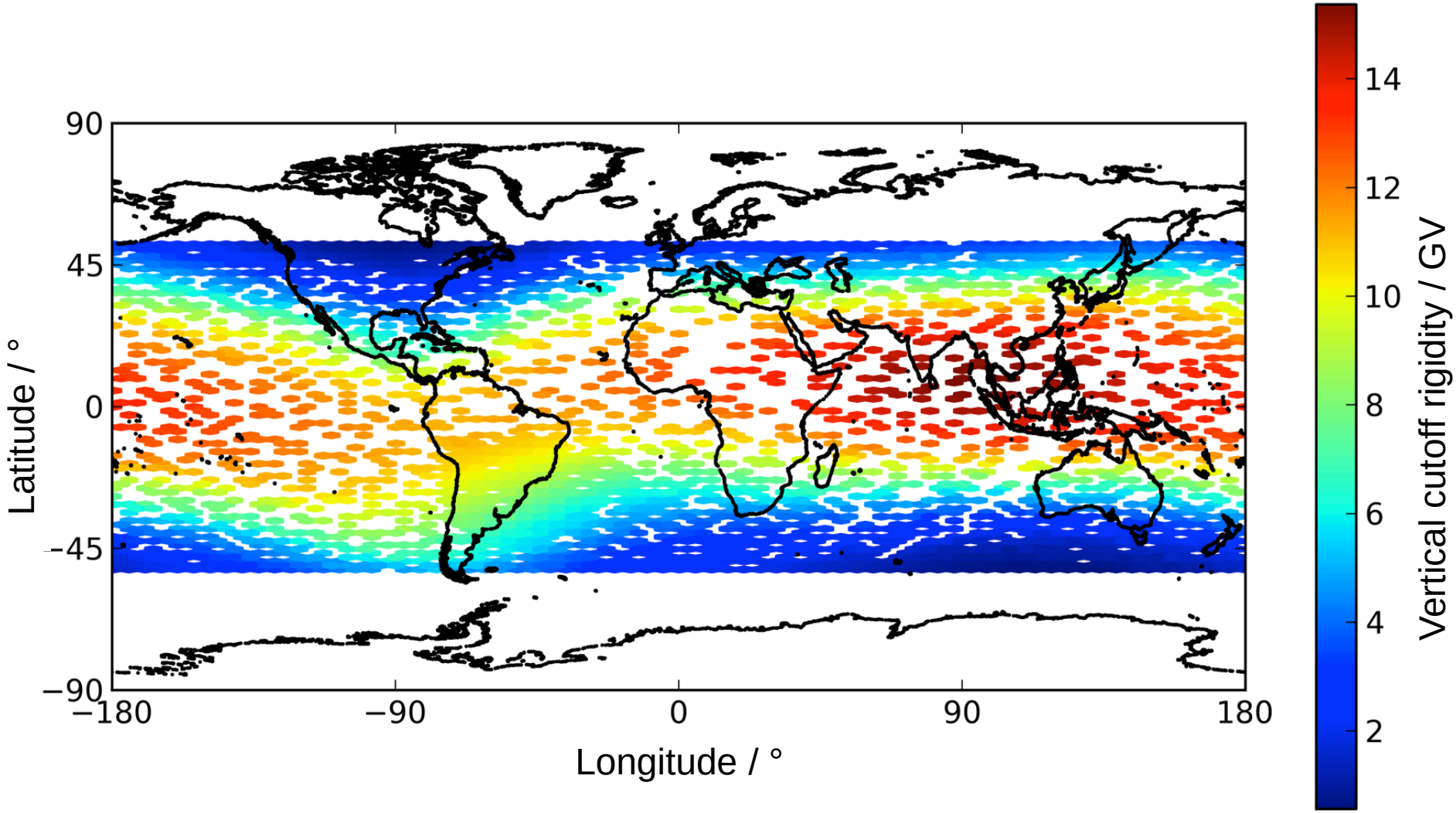
Ascending SAA (mainly)



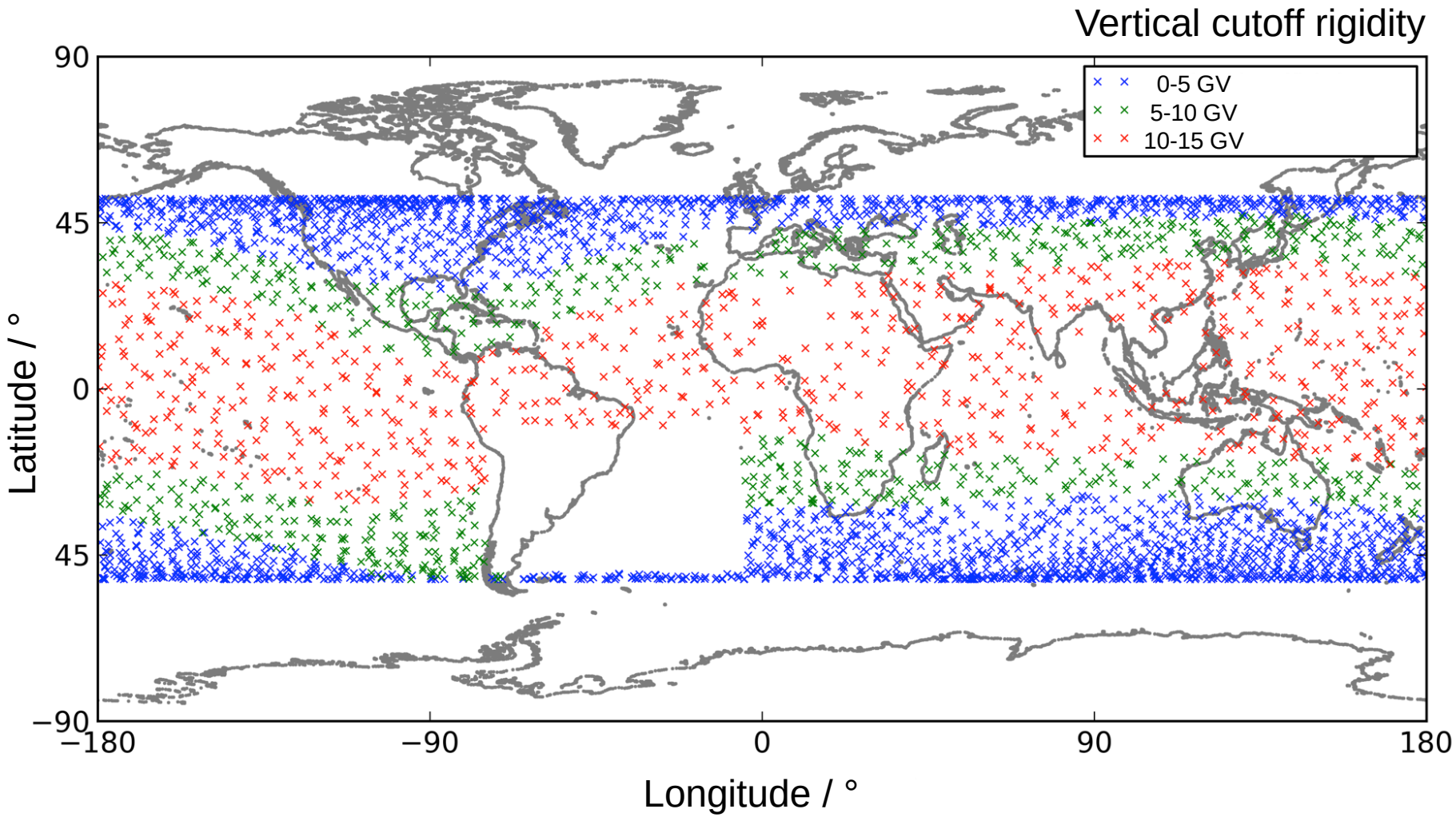
Descending SAA (mainly)



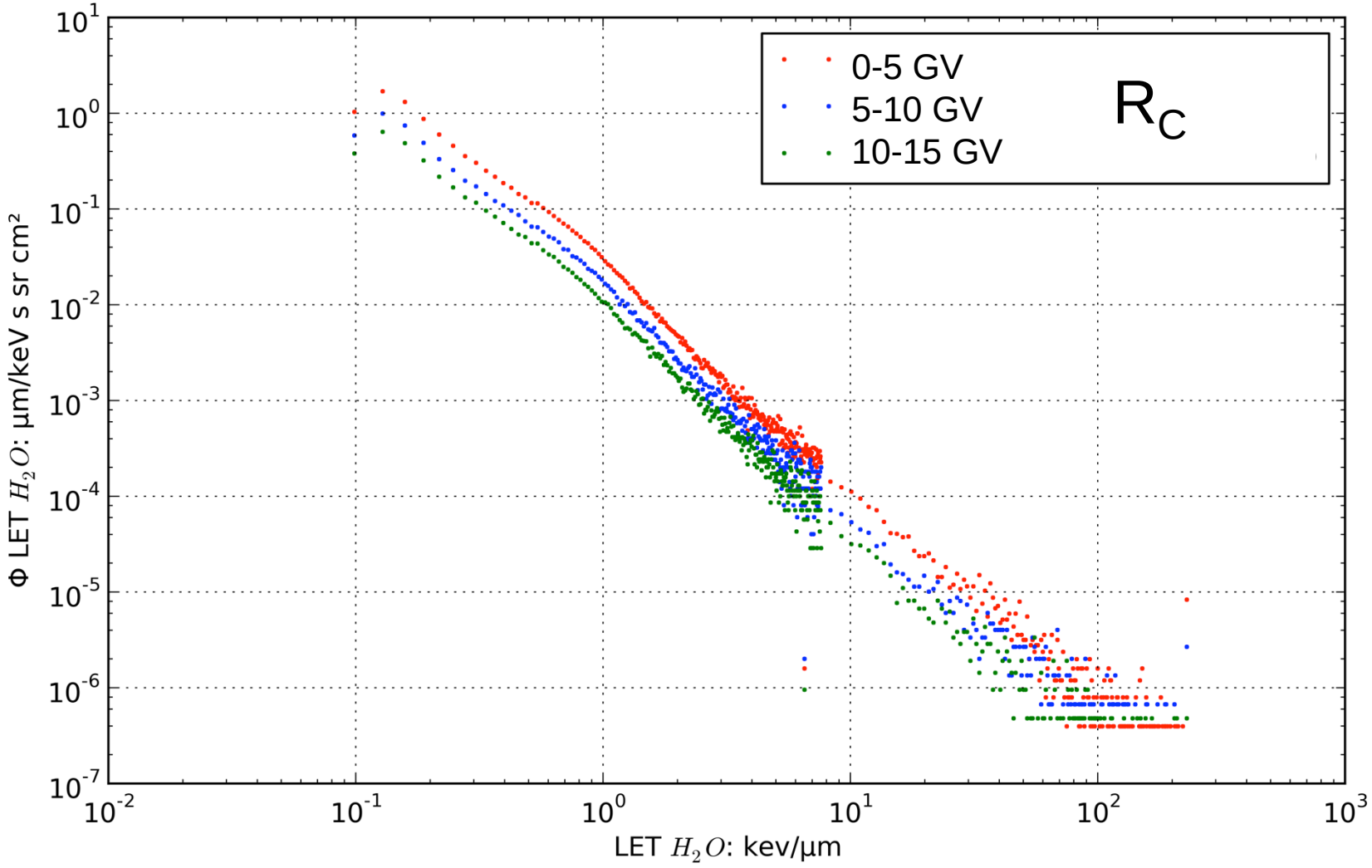
DOSIS 3D SAA Mode 2 Data



DOSIS 3D SAA Mode 2 Data - GCR



DOSIS 3D SAA Mode 2 Data - GCR



DOSIS 3D SAA Mode 2 Data - GCR

Dependence of mean Q on vertical cutoff rigidity

Cutoff region	Mean Q from LET according ICRP60
0-15 GV	3.2 ± 0.38
0-5 GV	3.3 ± 0.39
5-10 GV	3.0 ± 0.36
10-15 GV	2.7 ± 0.34

Conclusions

- Up to now we have data for 1758 days of measurement with DOSTEL-2 (DOSTEL-1: 1414d)

- During the passes of the SAA region stopping Protons can clearly be seen in the second detector of DOSTEL-1, i.e. protons mainly reaching the DOSTEL-1 telescope from aft direction

- LET spectrum dependence on geomagnetic latitude / vertical cutoff rigidity could be observed but better statistics is required for verification

Acknowledgements

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

Supported by:

on the basis of a decision
by the German Bundestag

- under grants 50WB0826, 50WB1026, 50WB1232 and 50WB1533

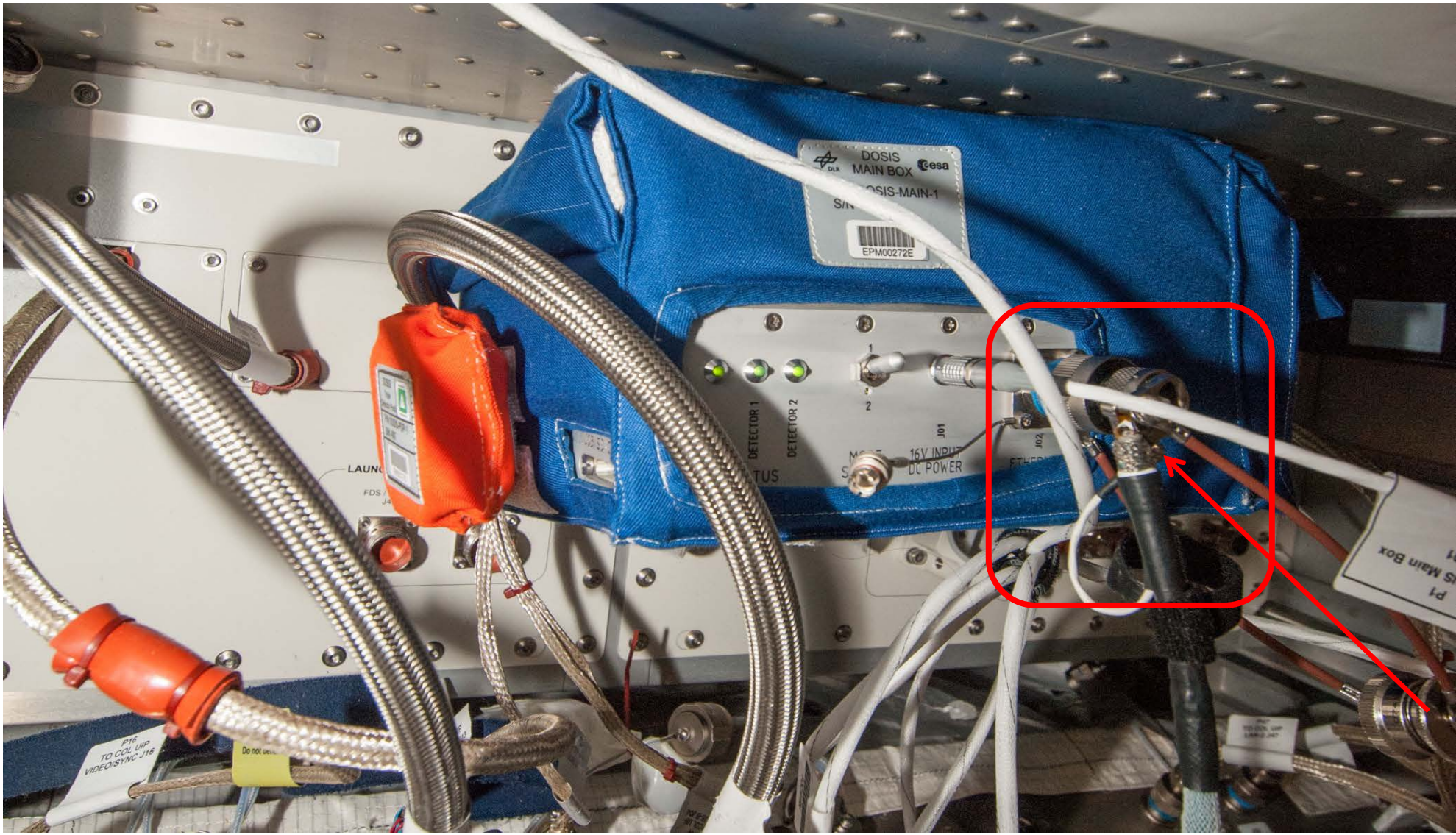
- Thank you very much for your attention!

Backup slides…

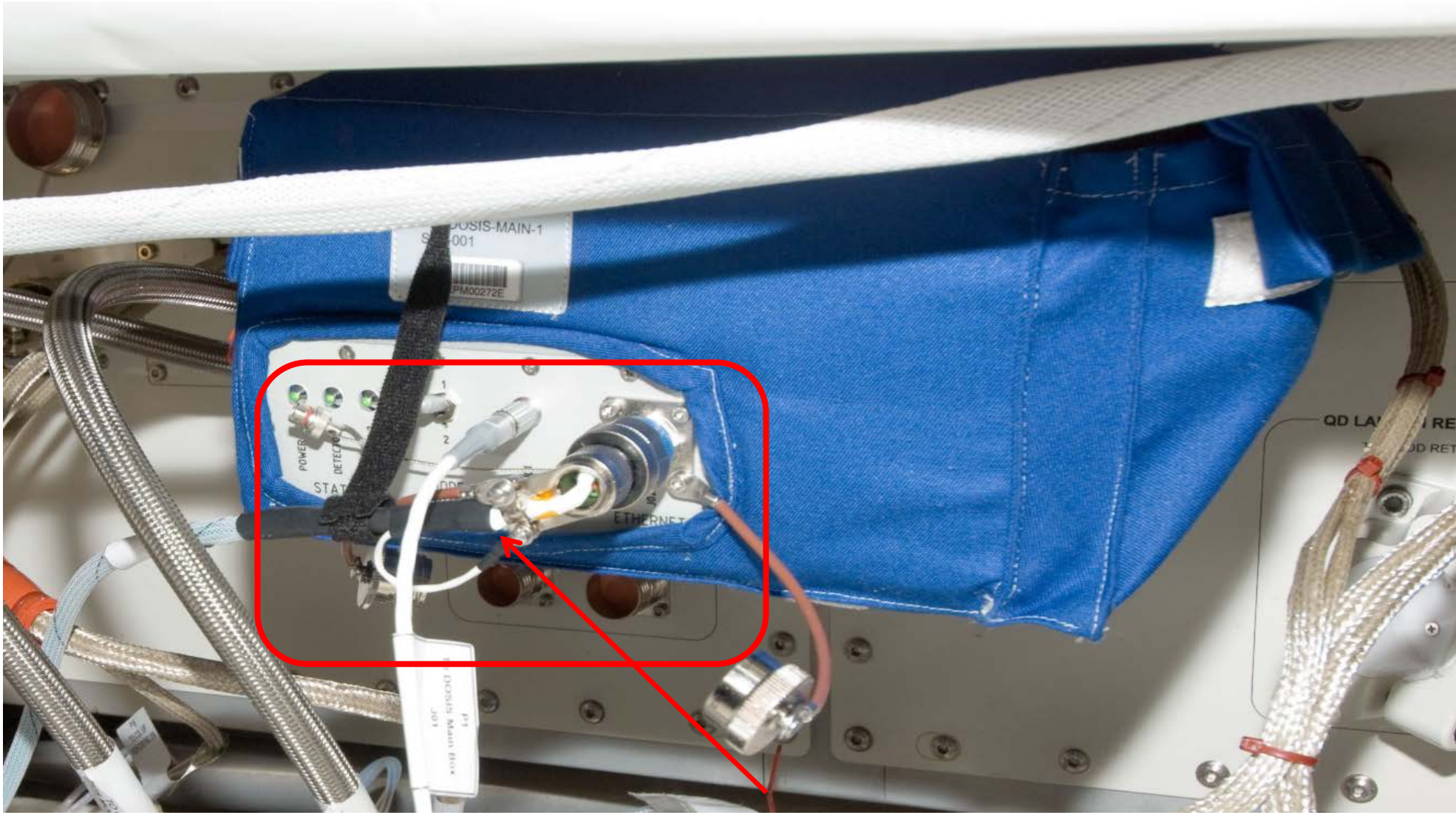
C | A | U

ieap
INSTITUT FÜR EXPERIMENTELLE UND ANGEWANDTE PHYSIK

DOSIS 3D: 38S



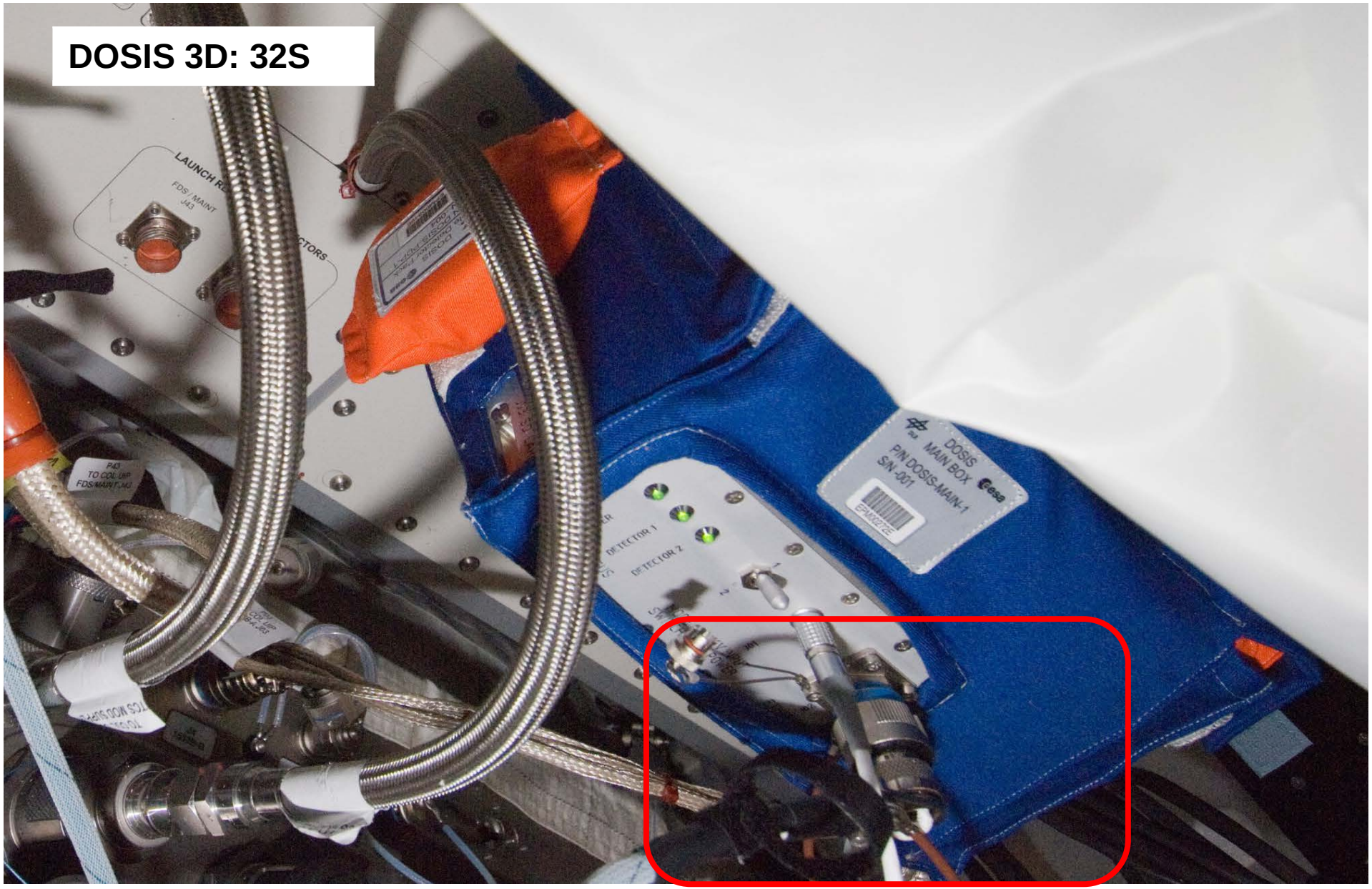
DOSIS: 2009



DOSIS 3D: 30S


DOSIS
MAIN BOX
P/N DOSIS-MAIN-1
S/N -001
EPM00272E
POWER
DETECTOR 1
STATUS
1
2

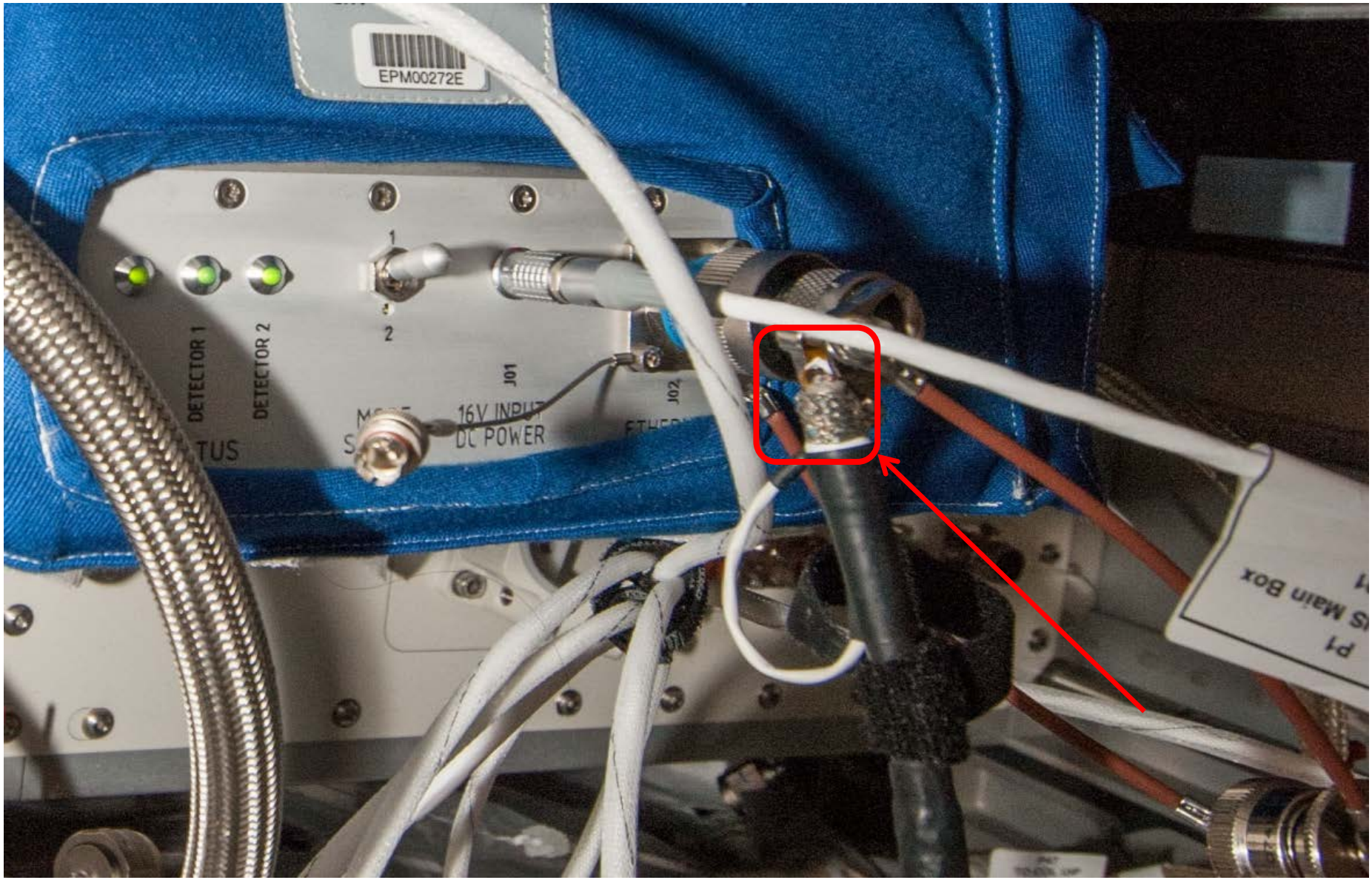
DOSIS 3D: 32S



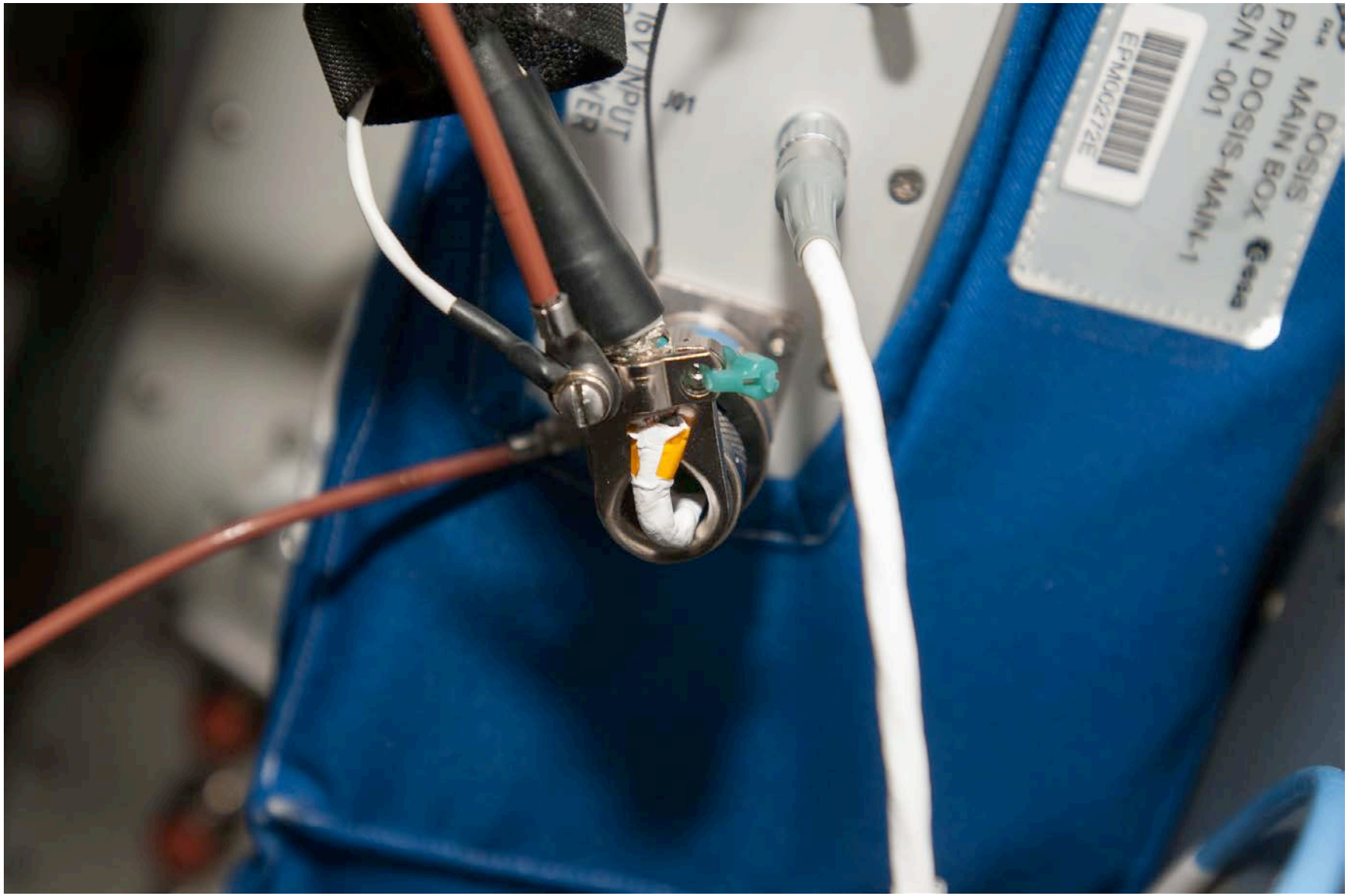
DOSIS 3D: 36S


DOSIS
MAIN BOX
esa
P/N DOSIS-MAIN-1
S/N -001
EPM00276E
DOSIS
Triple Detector Pack
esa
P/N DOSIS-PDP-1
S/N -006
EPM00715E

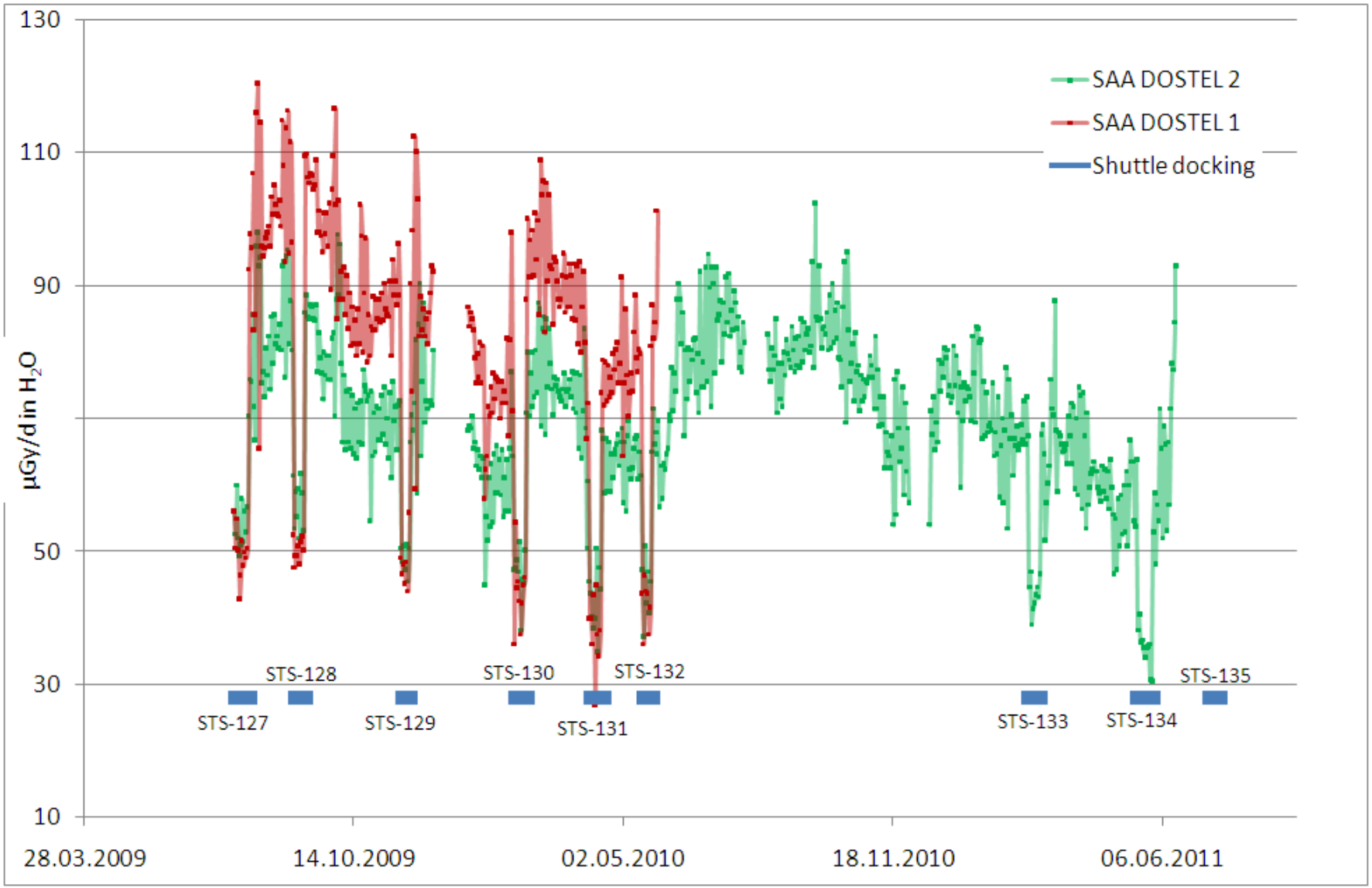
DOSIS 3D: 38S


EPM00272E
DETECTOR 1
DETECTOR 2
J01
J02
16V INPUT
DC POWER
TUS

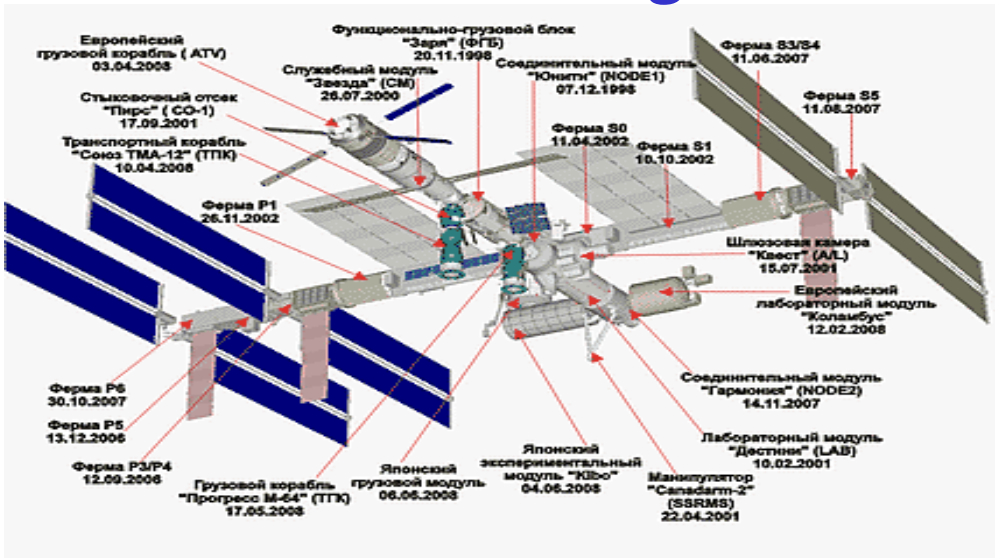

MODE
SWITCH


DOSIS
MAIN BOX
P/N DOSIS-MAIN-1
S/N -001
EPM004172

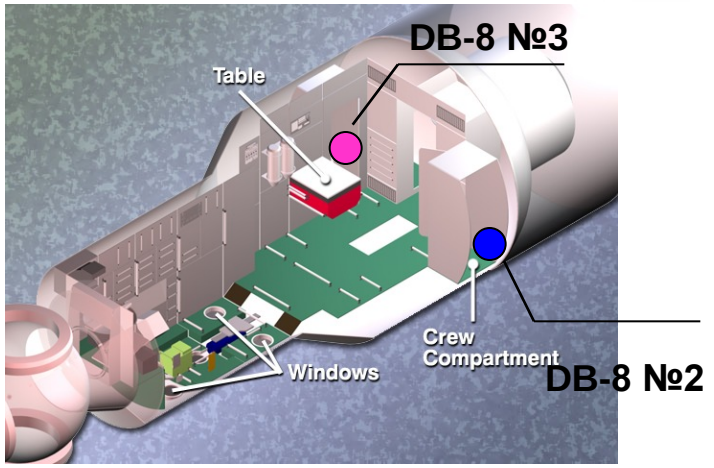
Absorbed Dose Rates SAA



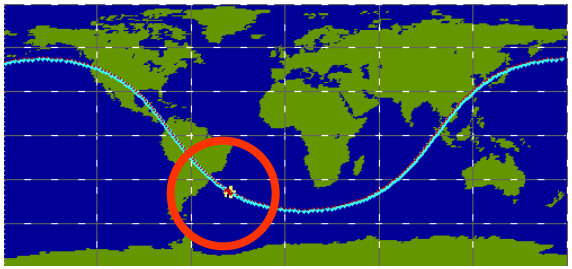
ISS configuration



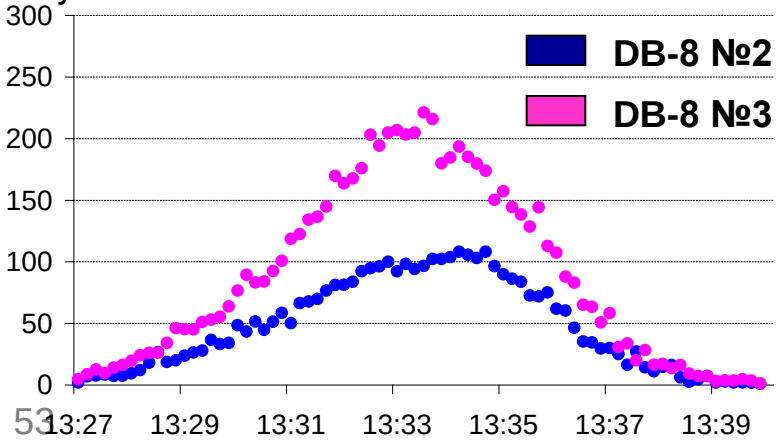
Service Module

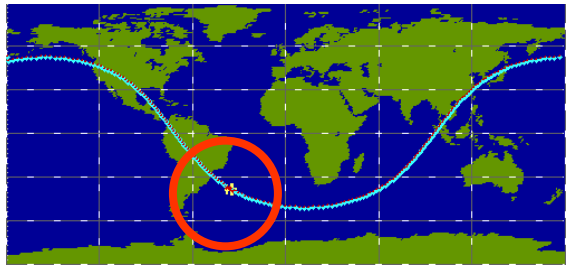


Thanks to S.G. Drobyshev, V.V. Benghin



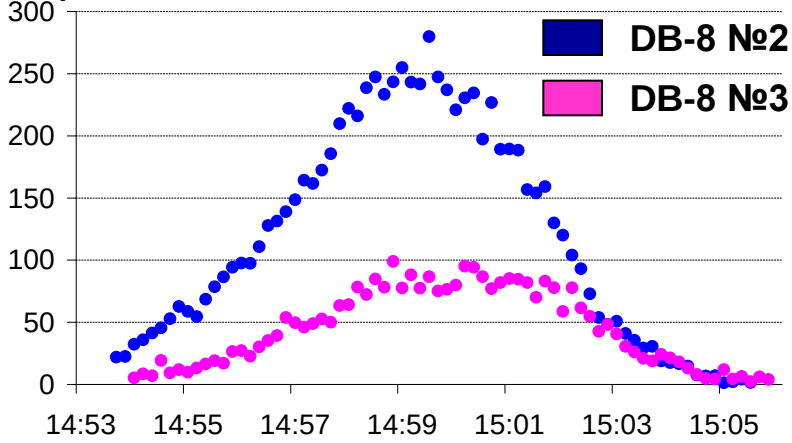
19.01.2008



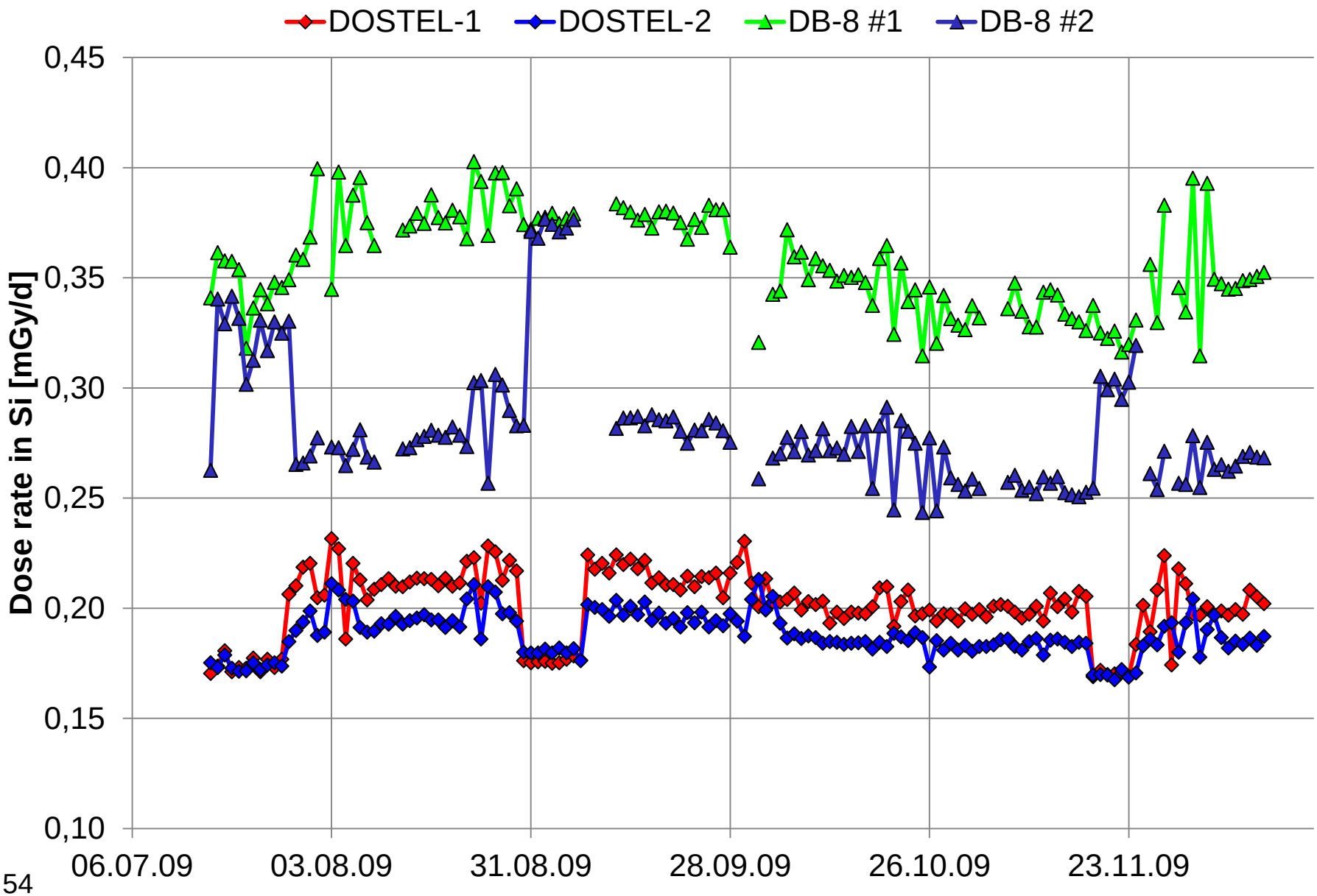


14.03.2008

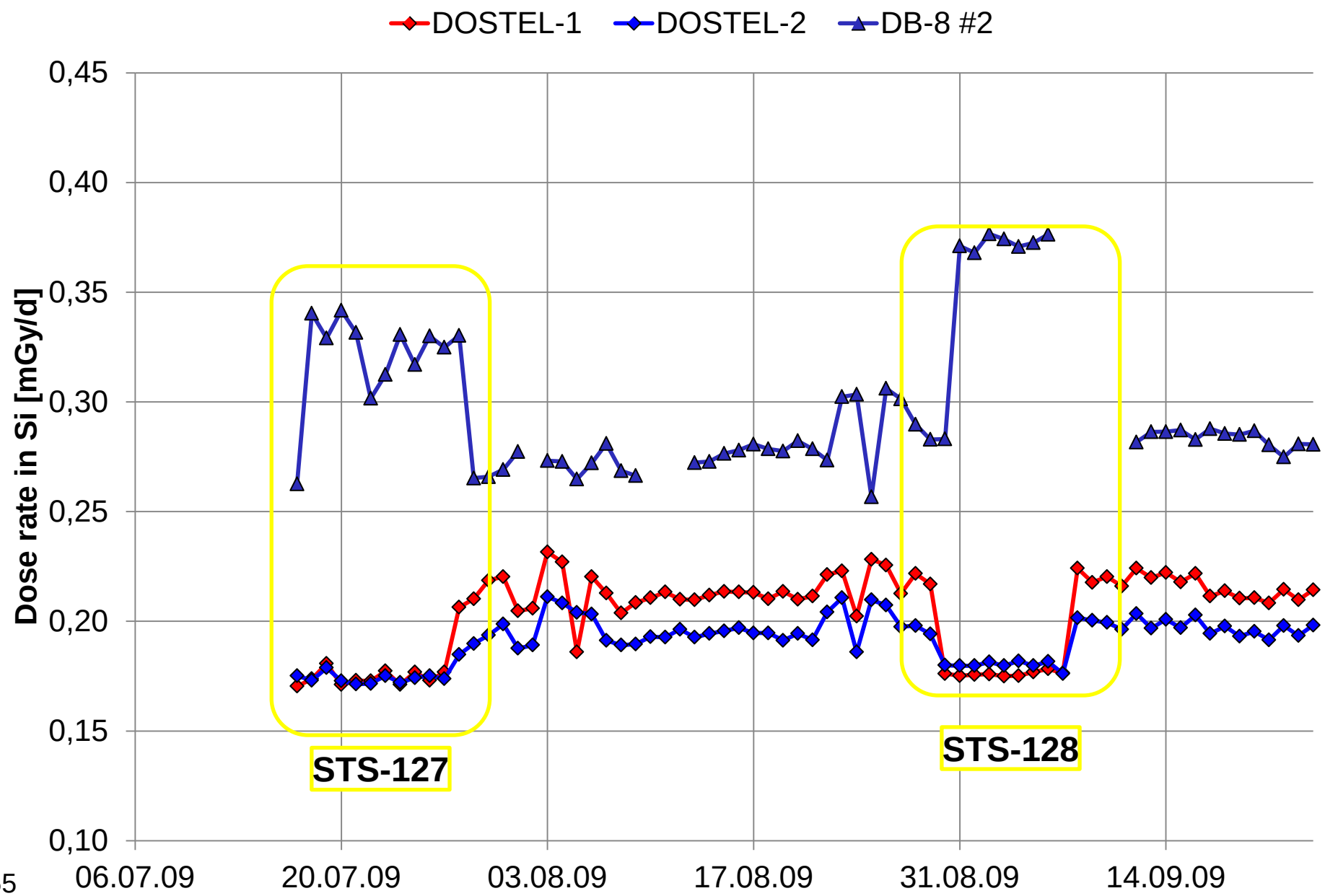
STS-123 docking: 13.03.-25.03.08



Shuttle Docking



Shuttle Docking



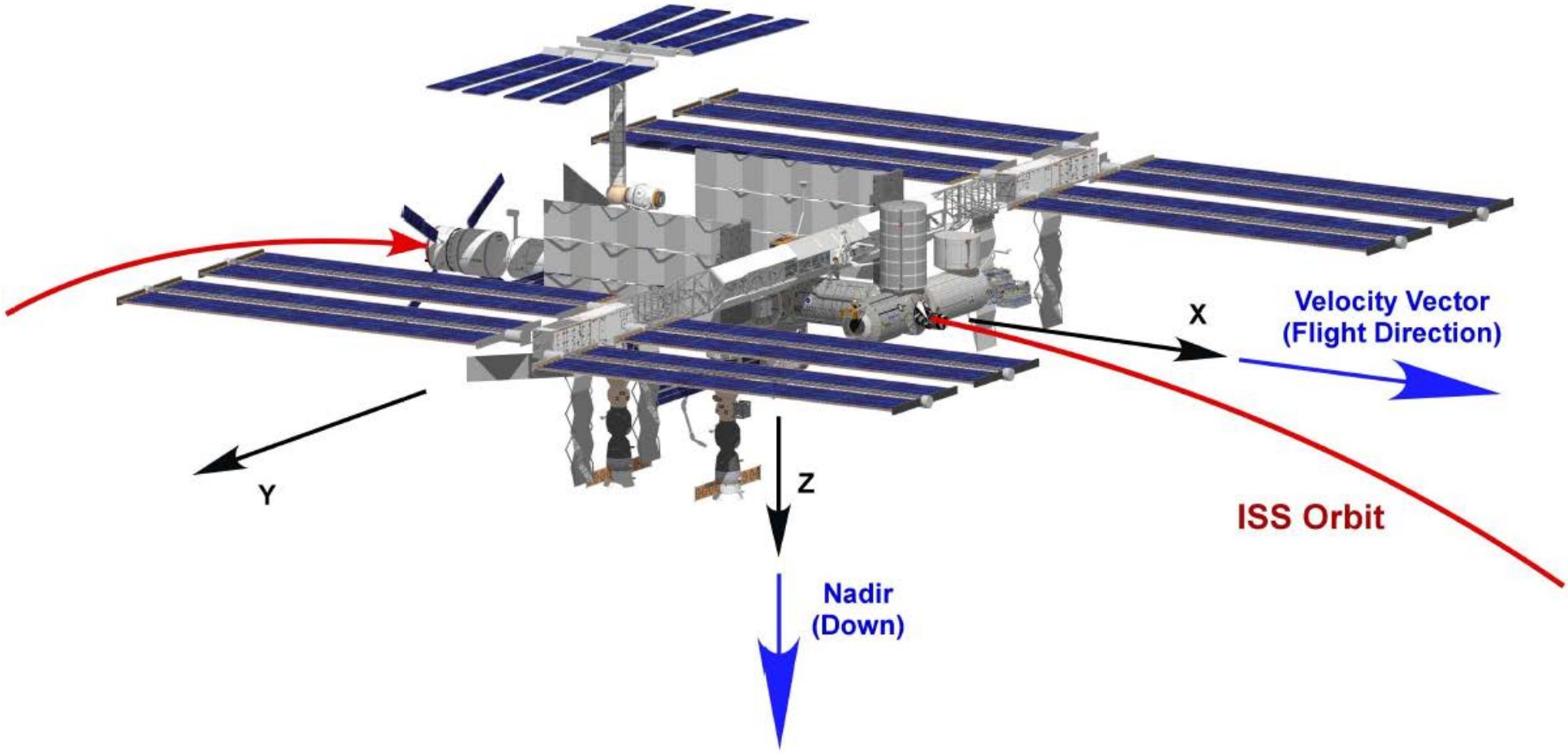
Dose Values During Shuttle Docking

- The mean contribution to the daily dose drops roughly 30-40% from ~100 µSv/d to ~60-70µSv/d during the Shuttle docking phases

- The effect occurs mainly during the south-eastward passages through the SAA

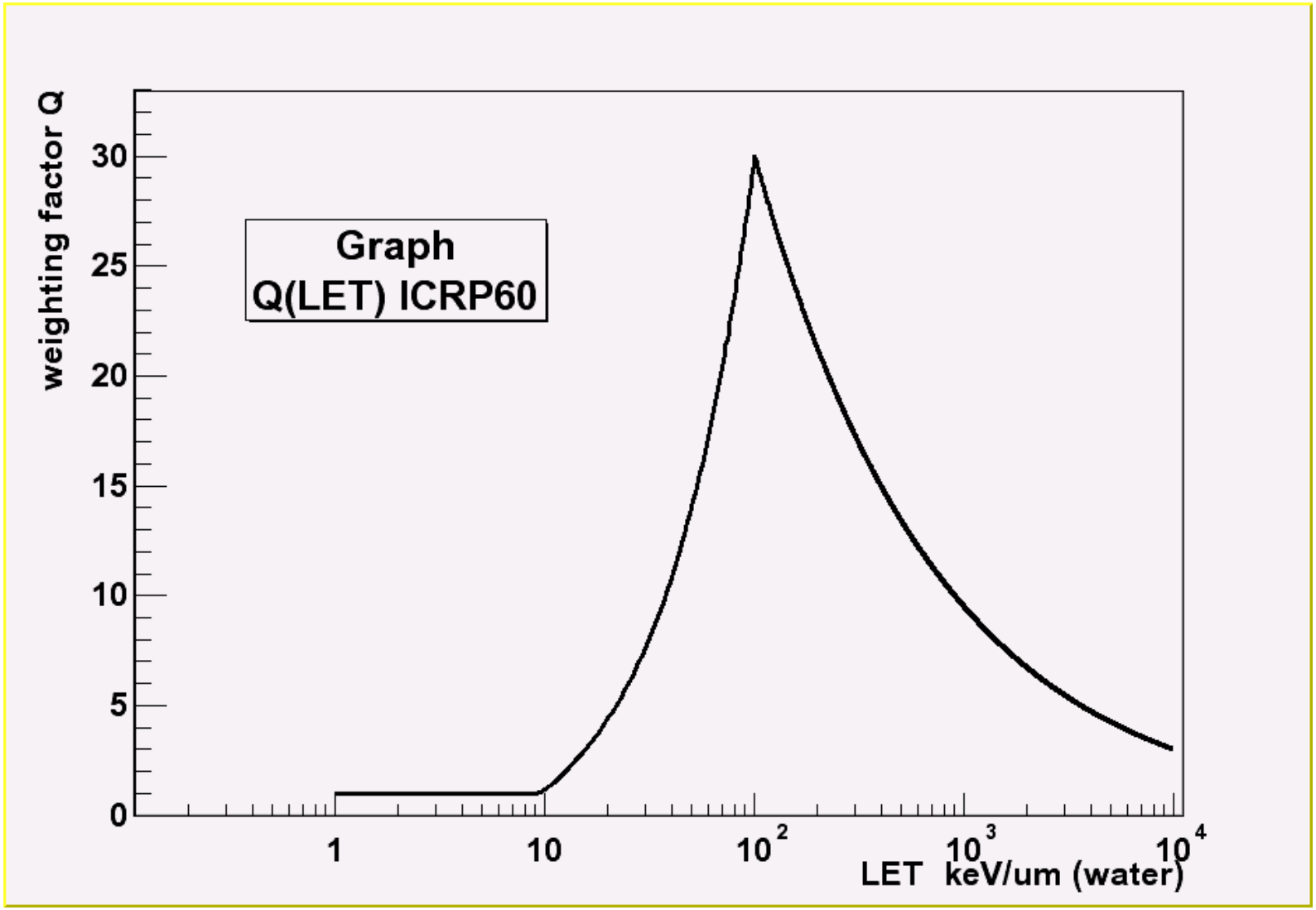
- It is most likely due to the attitude change of the station from +Xvv to -Xvv

ISS +Xvv Attitude

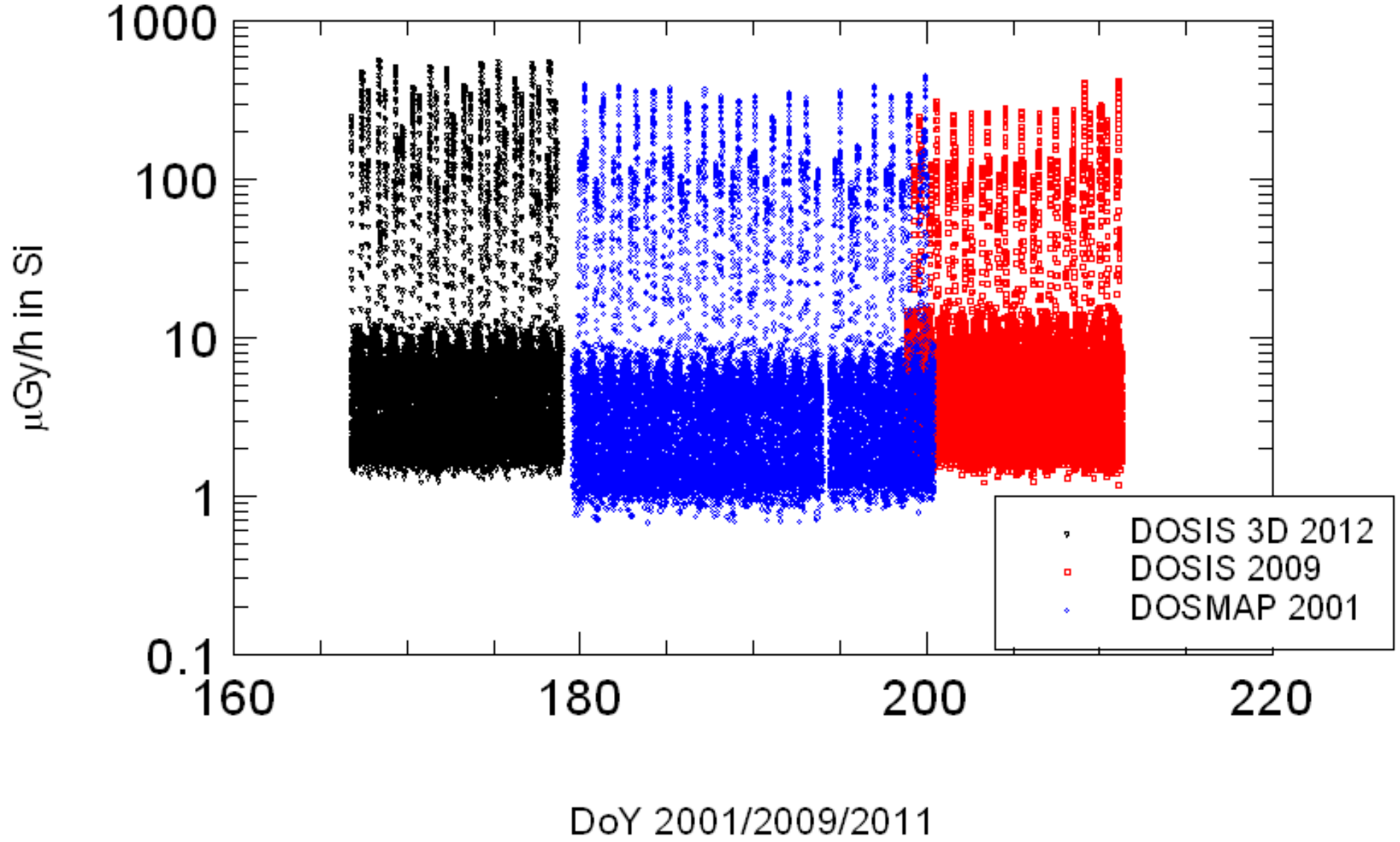


[European Users Guide to Low Gravity Platforms, UIC-ESA-UM-0001]

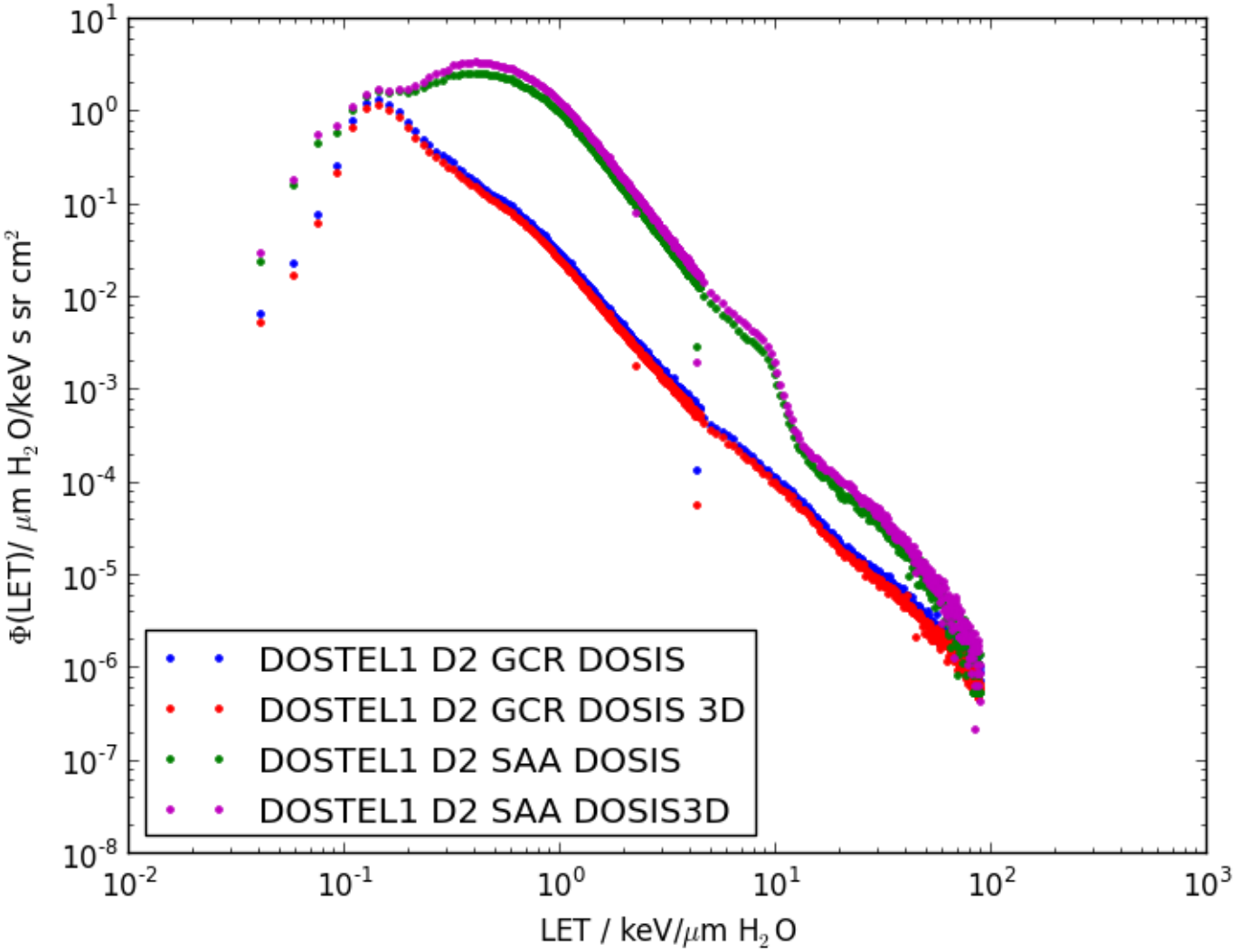
Mean Quality Factor



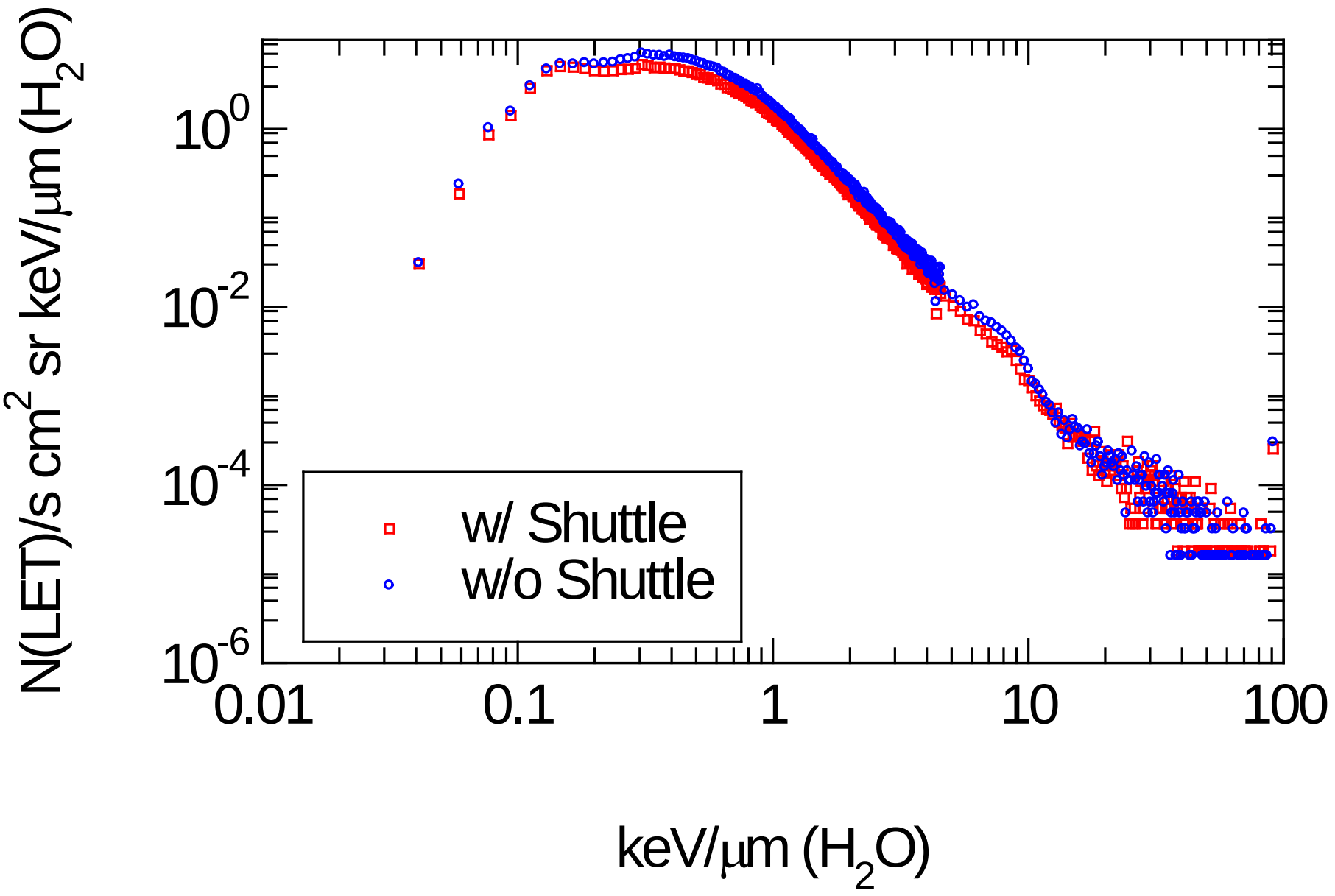
DOSIS 3D, DOSIS and DOSMAP comparison



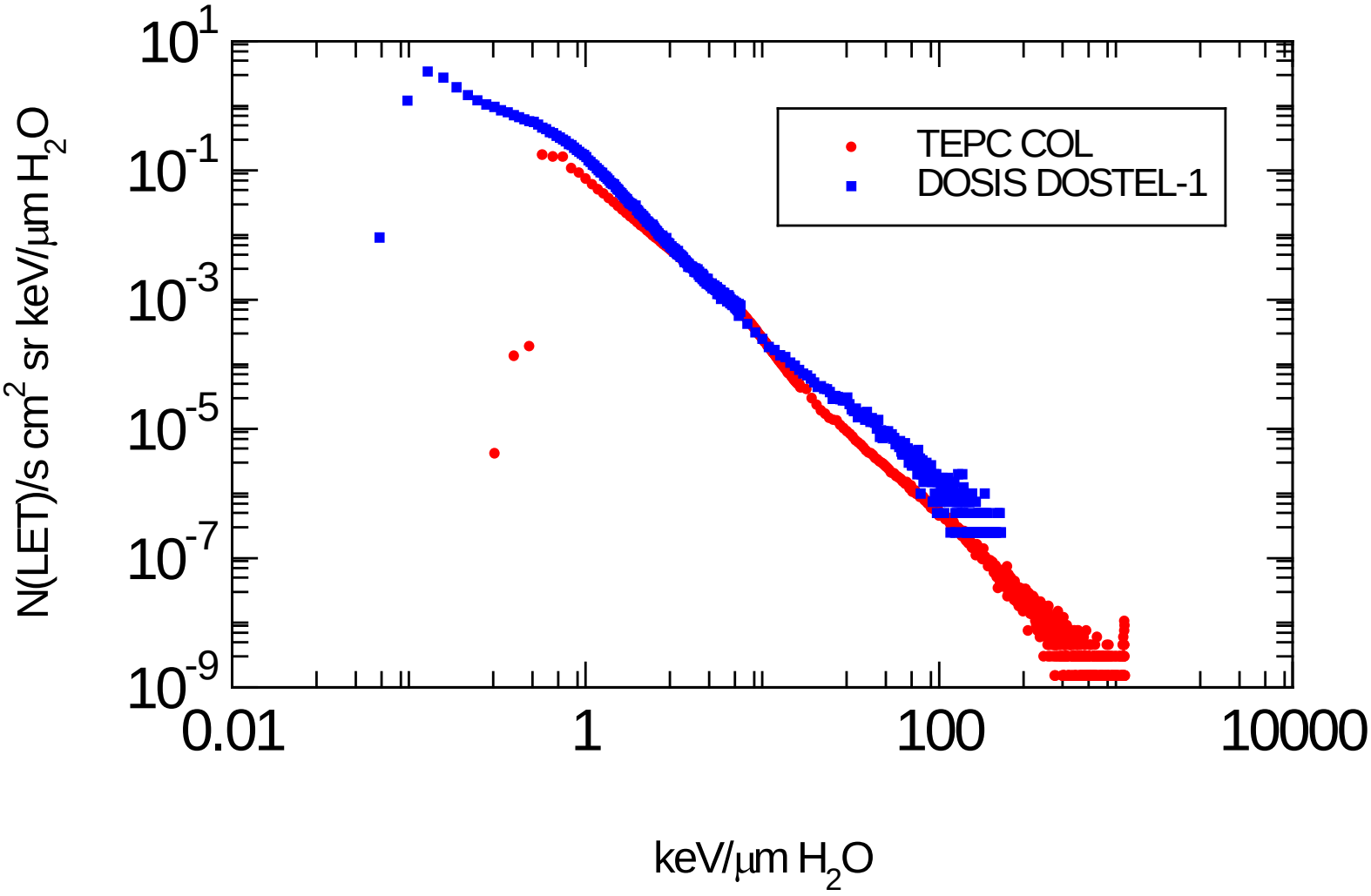
LET Spectra DOSTEL-1 Detector 2



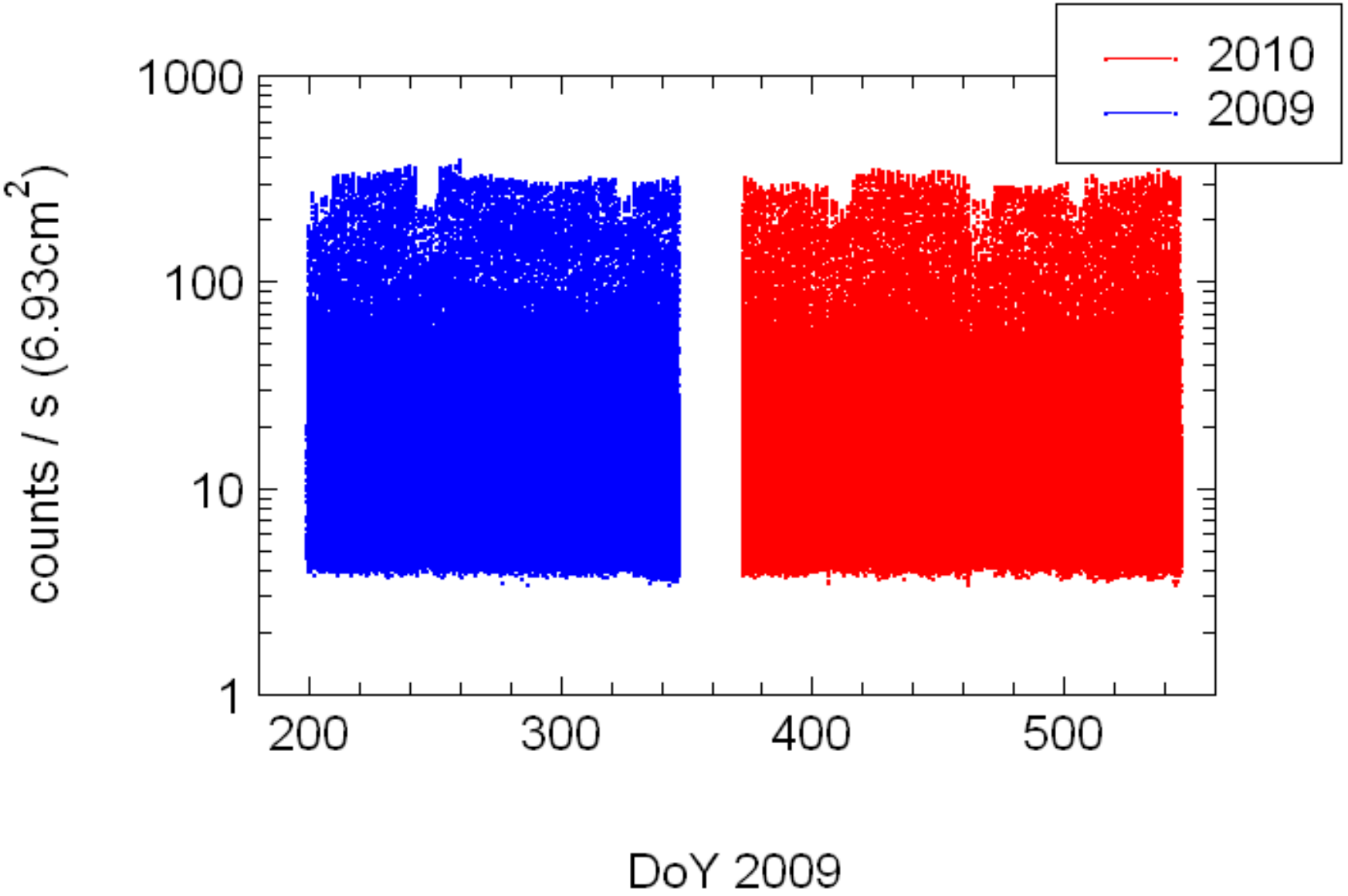
SAA LET Spectra



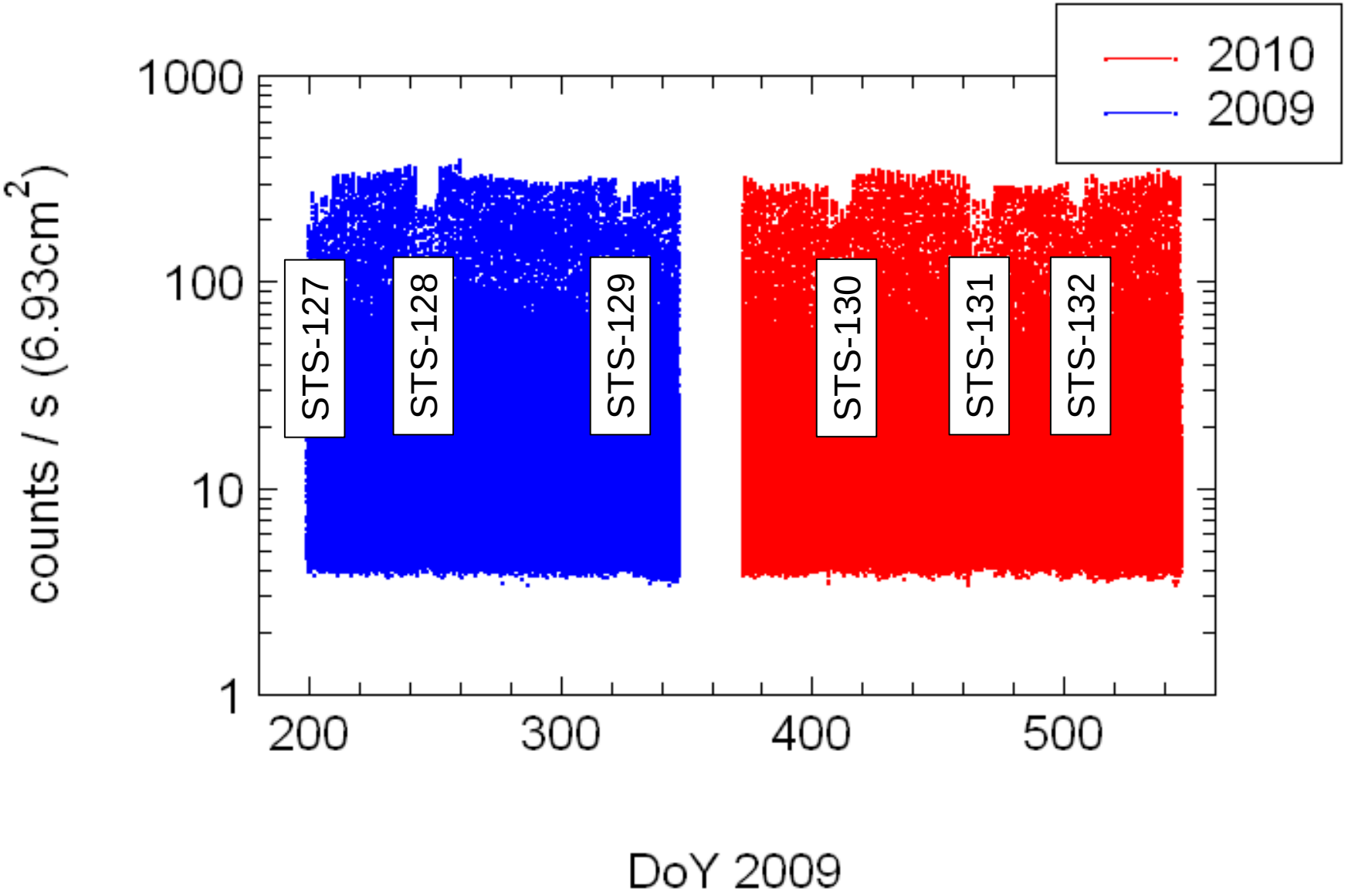
Combined LET spectra

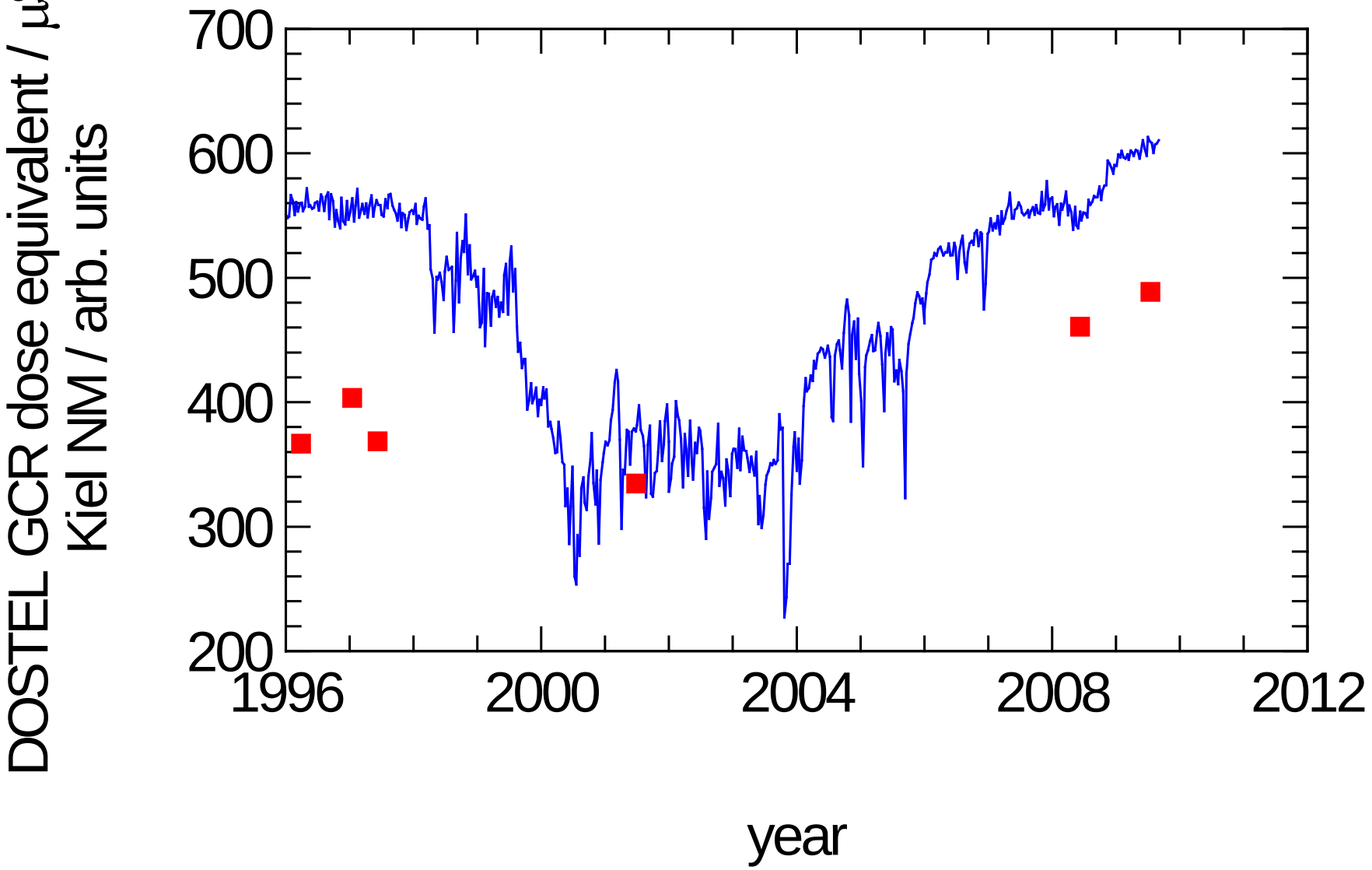


DOSTEL-2 Count Rate Profile



DOSTEL-2 Count Rate Profile



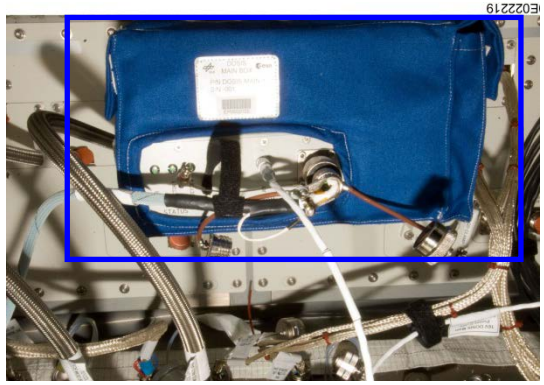

DOSTEL GCR dose equivalent / µSv/d
Kiel NM / arb. units
700
600
500
400
300
200
1996
2000
2004
2008
2012
year

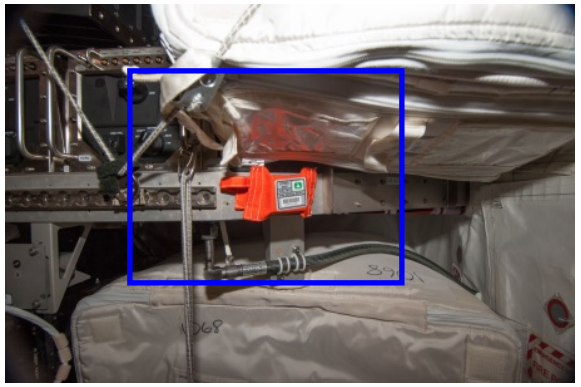
DOSIS & DOSIS 3D: Scientific Goals

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.

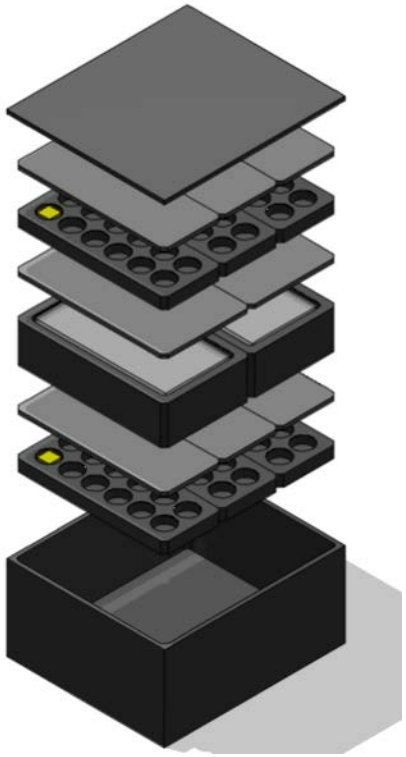
- Monitor the radiation environment inside Columbus with **active** and **passive** radiation detectors (ESA) for the determination of the temporal and spatial dose distribution

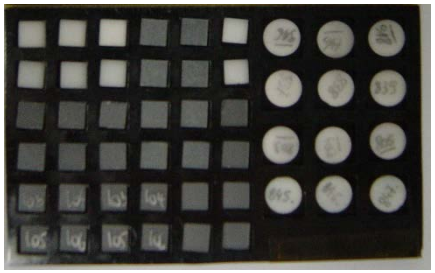
- Combine data gathered by NASA, JAXA, IMBP and ESA into a 3D radiation map of the International Space Station





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



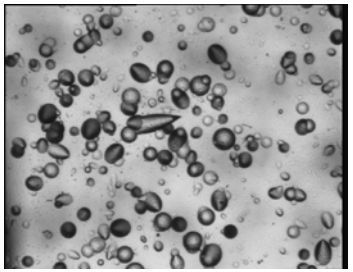


Thermoluminescence detectors (TLD)

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

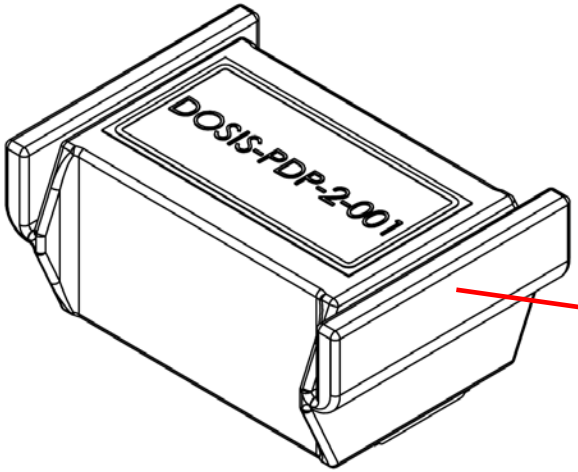
Heavy charged particles break chemical bonds in the material.This trail can be made visible by etching the material.

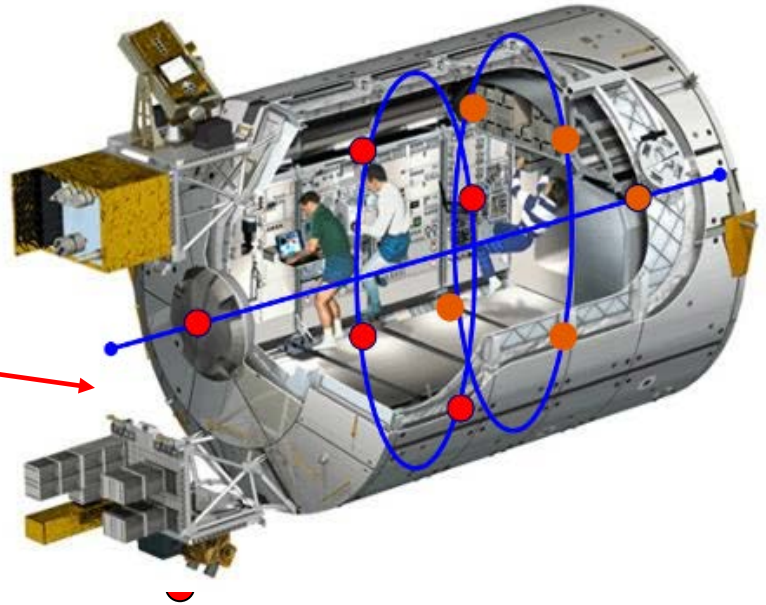
R. P. Henke and E. V. Benton, Nucl.Instr.Meth. 97 (**1971**) 483-9

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).

DOSIS Passive Detectors

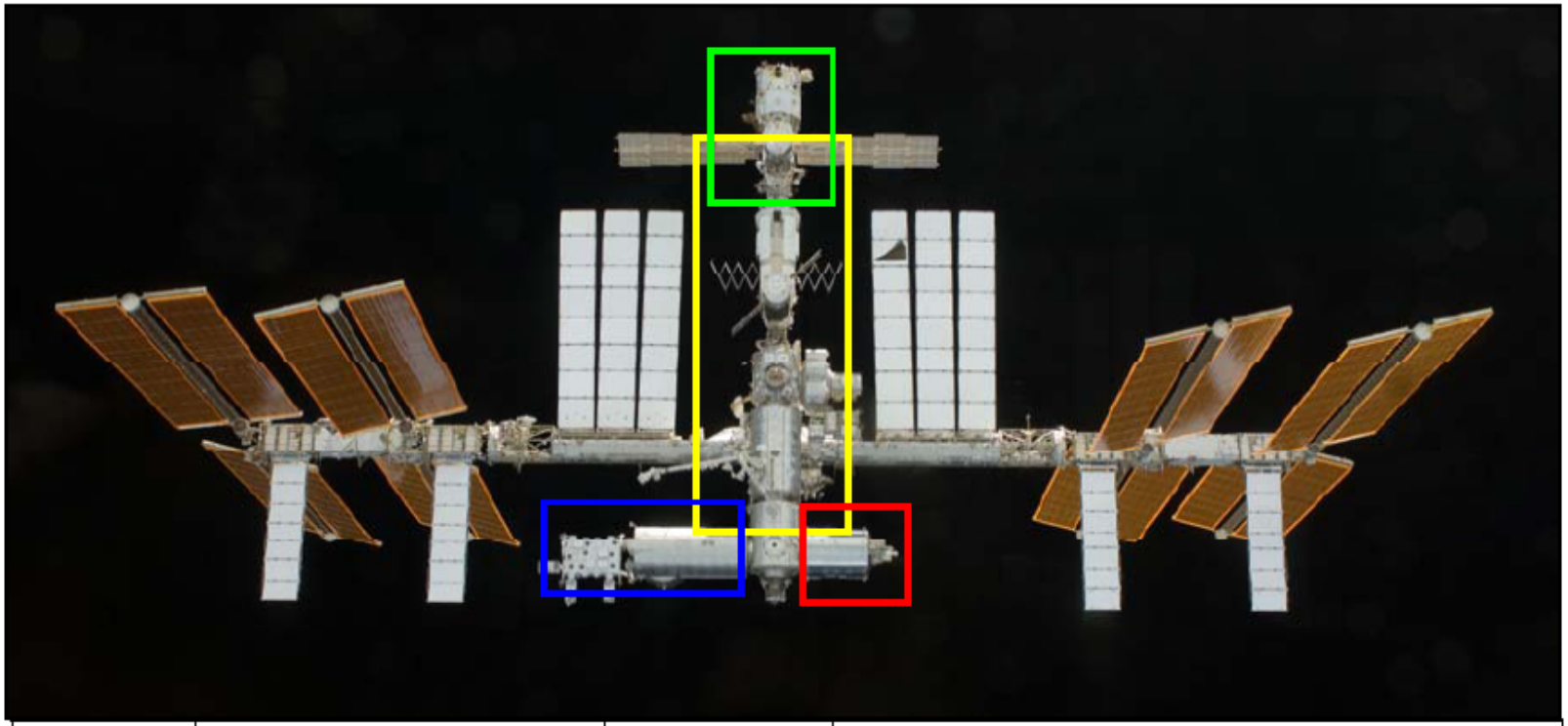
11 passive radiation detector packages (PDP) distributed within Columbus





DOSIS Passive Detector Packages (PDP)

DOSIS / DOSIS 3D



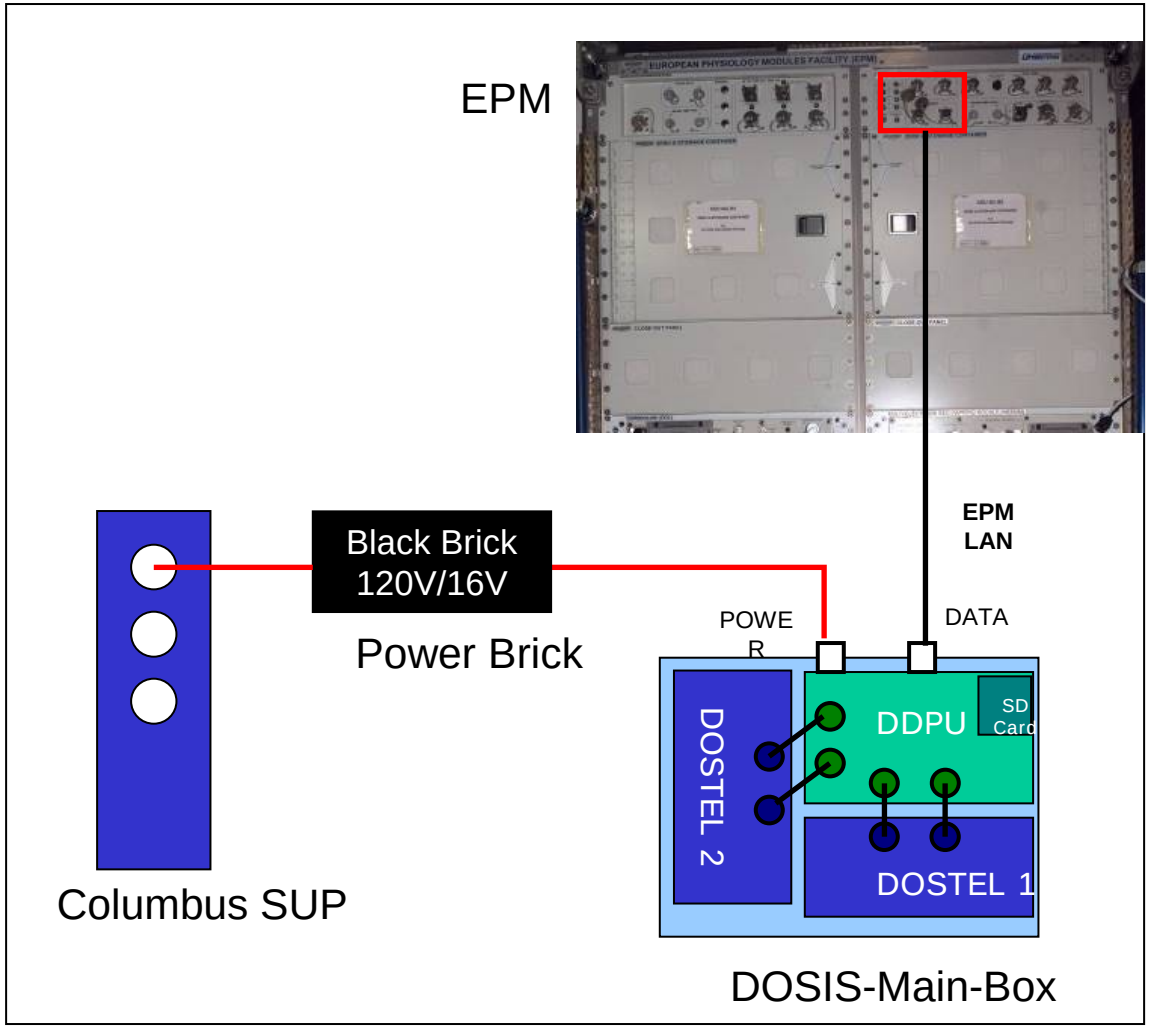
Agency	*Name of the detectors*	*Quantity*	*Position on ISS*
ESA	PDP	10 + 1	Columbus (red rectangle)
NASA	RAMs	24	All over the ISS (yellow rectangle)
JAXA	PADLES	12	KIBO (blue rectangle)
IBMP	SPD	6	Russian part of the ISS (green rectangle)
	Pille	10	

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 - Launch 15.July 2009 STS-127

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

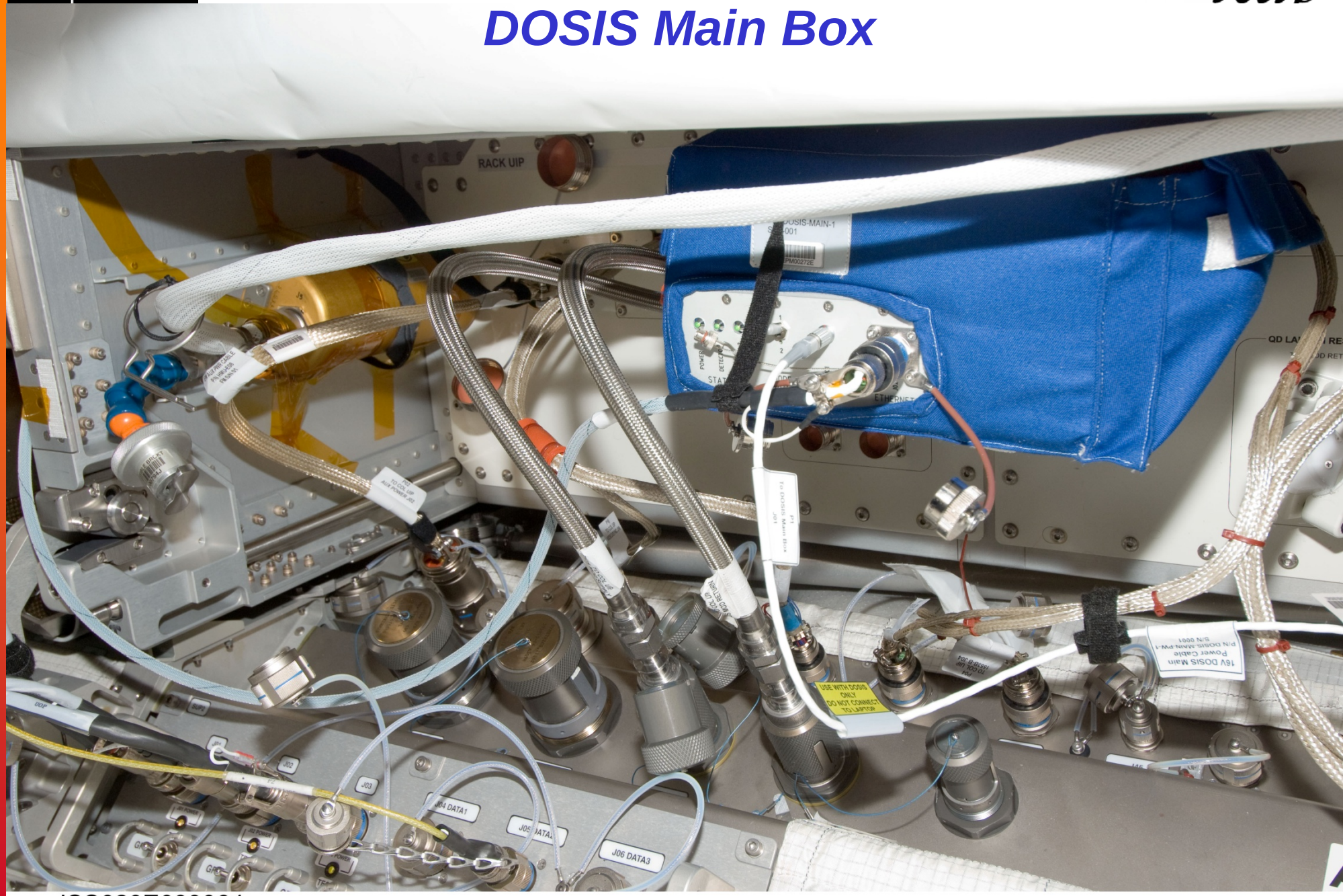
DOSIS Installation Inside COLUMBUS



C | A | U

ieab

DOSIS Main Box



ISS020E033064