Docking of Space Shuttle with ISS Drops down the Measured SAA Doses

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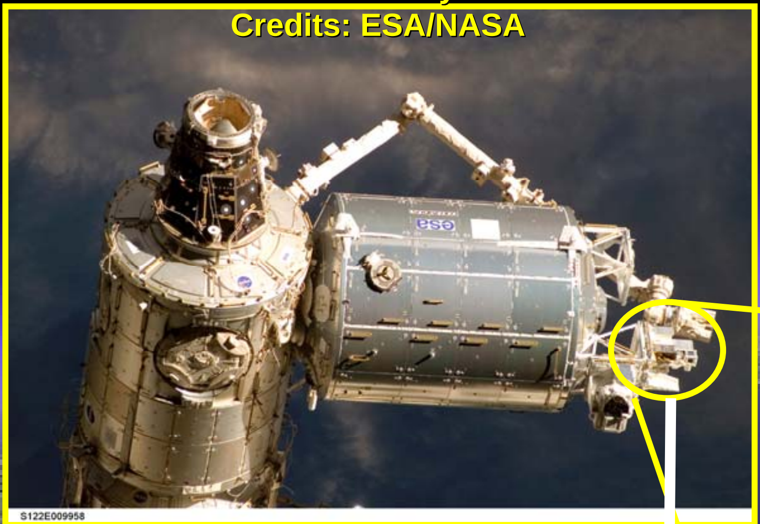
Outlook

- Instruments
- Analysis of the measured R3DE and Liulin-5 data related to the Shuttle docking
- Comparisons with other instruments on ISS
- Conclusions

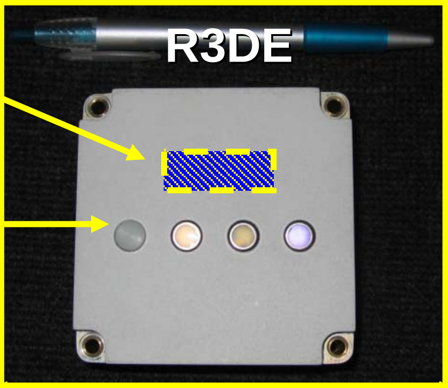
Instruments

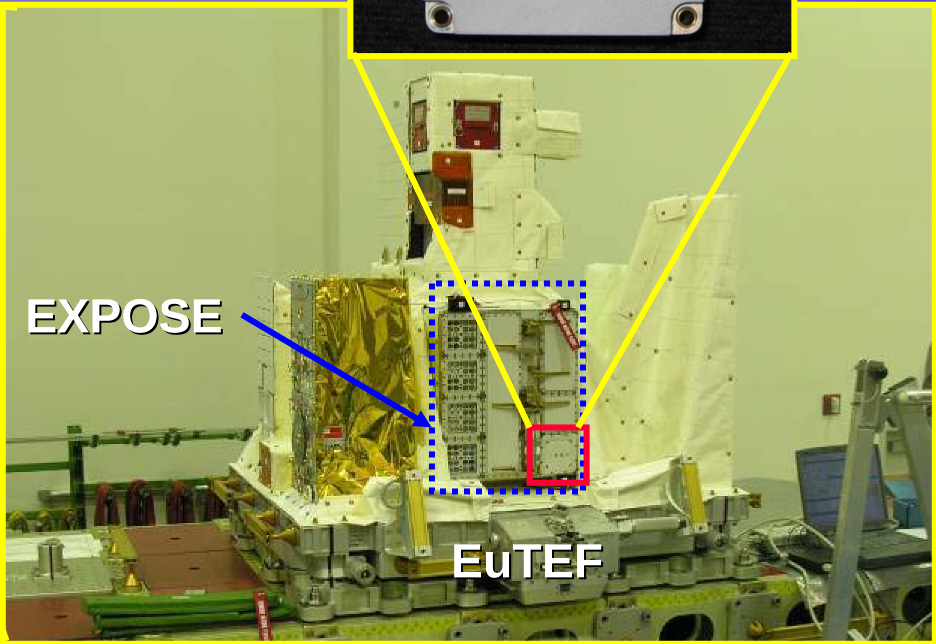
R3DE instrument, which is a part of the EXPOSE facility is working continuously on the EuTEF platform of Columbus module on International space station since February 20th 2008

A close-up view of the Columbus laboratory
Credits: ESA/NASA

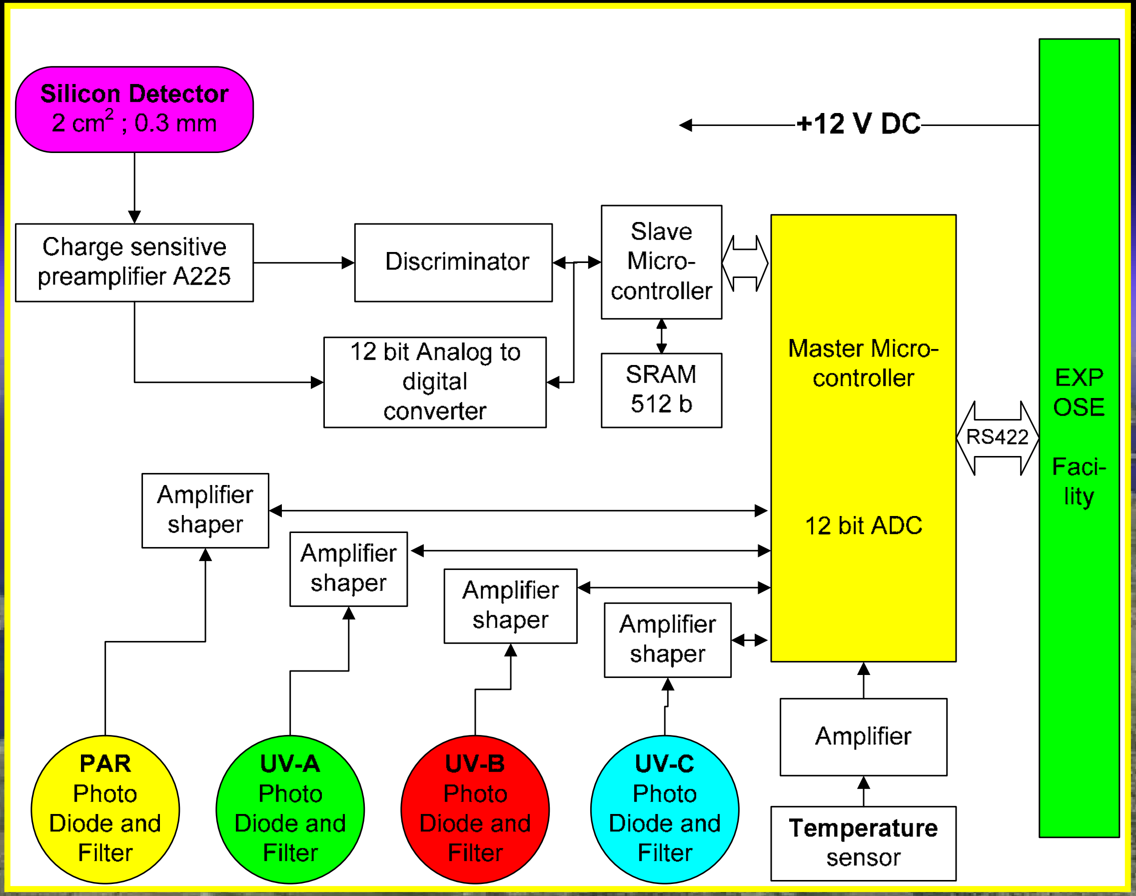


The detector of R3DE instrument is shielded by less than 0.4 g/cm^2 material including: 1 mm aluminum + 0.1 mm cuprum +0.2 mm plastic. This allows direct hits on the detector by electrons with energies higher than 0.78, MeV and protons with energies higher than 15.8 MeV





The R3DE is an active, low mass (120 g) and small consumption (150 mW) device, which measure solar radiation in 4 channels and space ionizing radiation in 256 channels. Measurements have 10 s. time resolution and are transmitted by the ISS telemetry system to the ground since 20th of February 2008. The spectrometers are mutually developed with Prof. D.-P. Haeder, University of Erlangen, Germany

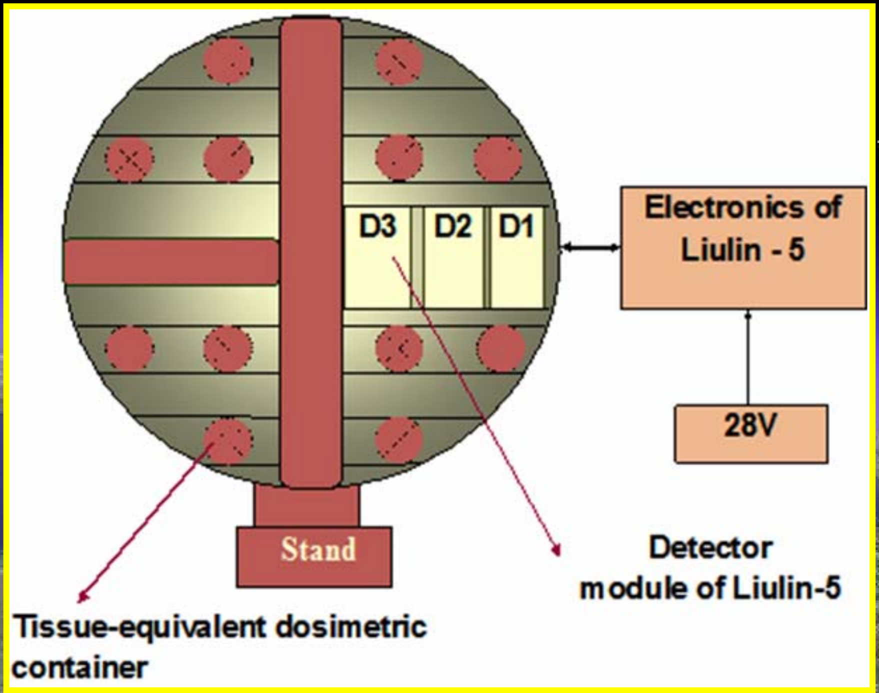


Block schema of the R3DE device

Liulin-5 Instrument and places of the detectors inside of the phantom

Monitoring unit

Detectors module



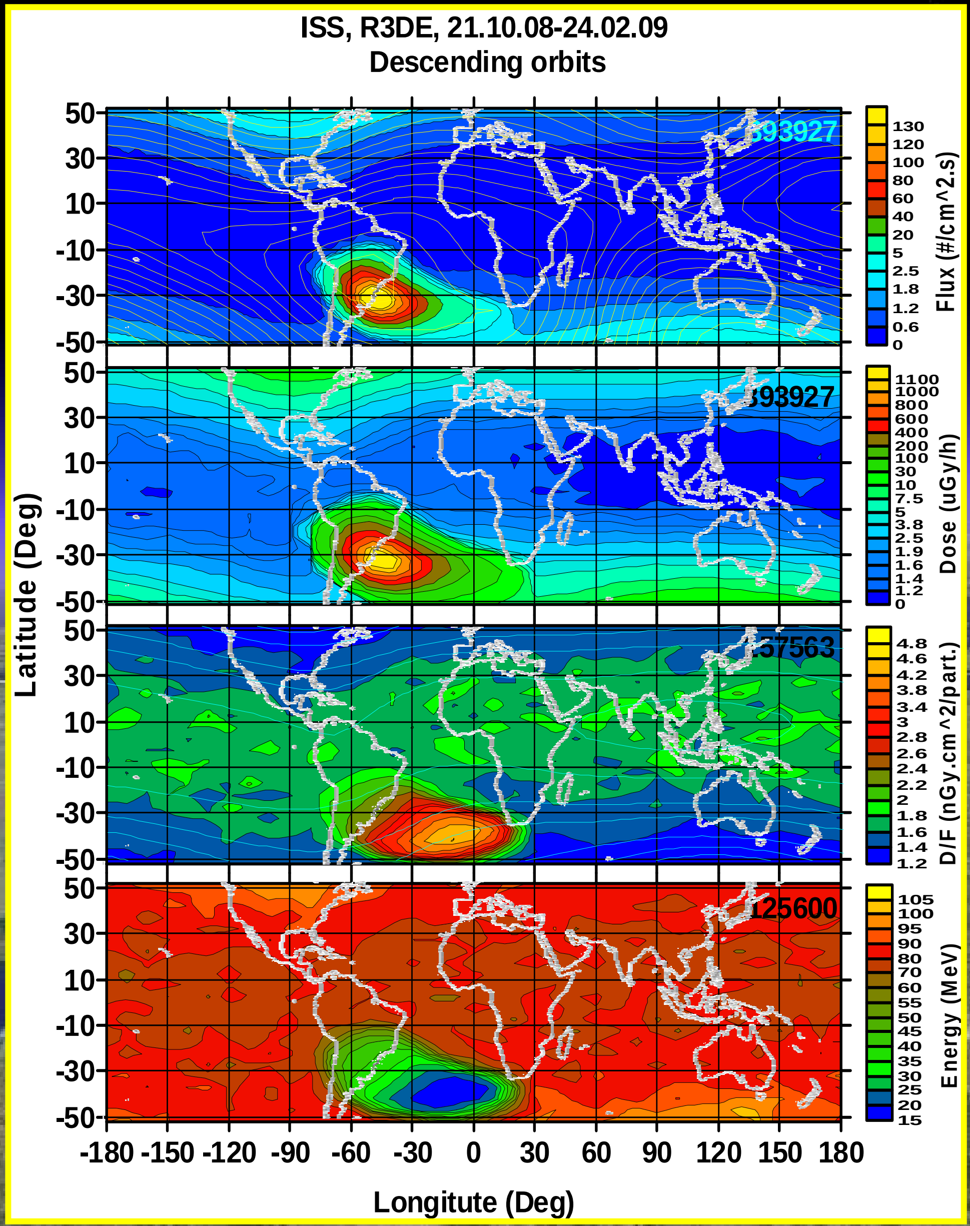
Place of the Phantom in the PIERS module of Russian segment of ISS and place of Liulin-5 in it

Analysis of the measured R3DE and Liulin-5 data related to the Shuttle docking

Global distribution of the R3DE descending orbits data for about 4 months including incident proton energy in SAA

B-values (Gauss)

L-values



1. Isolines follow well the shape of L-value;

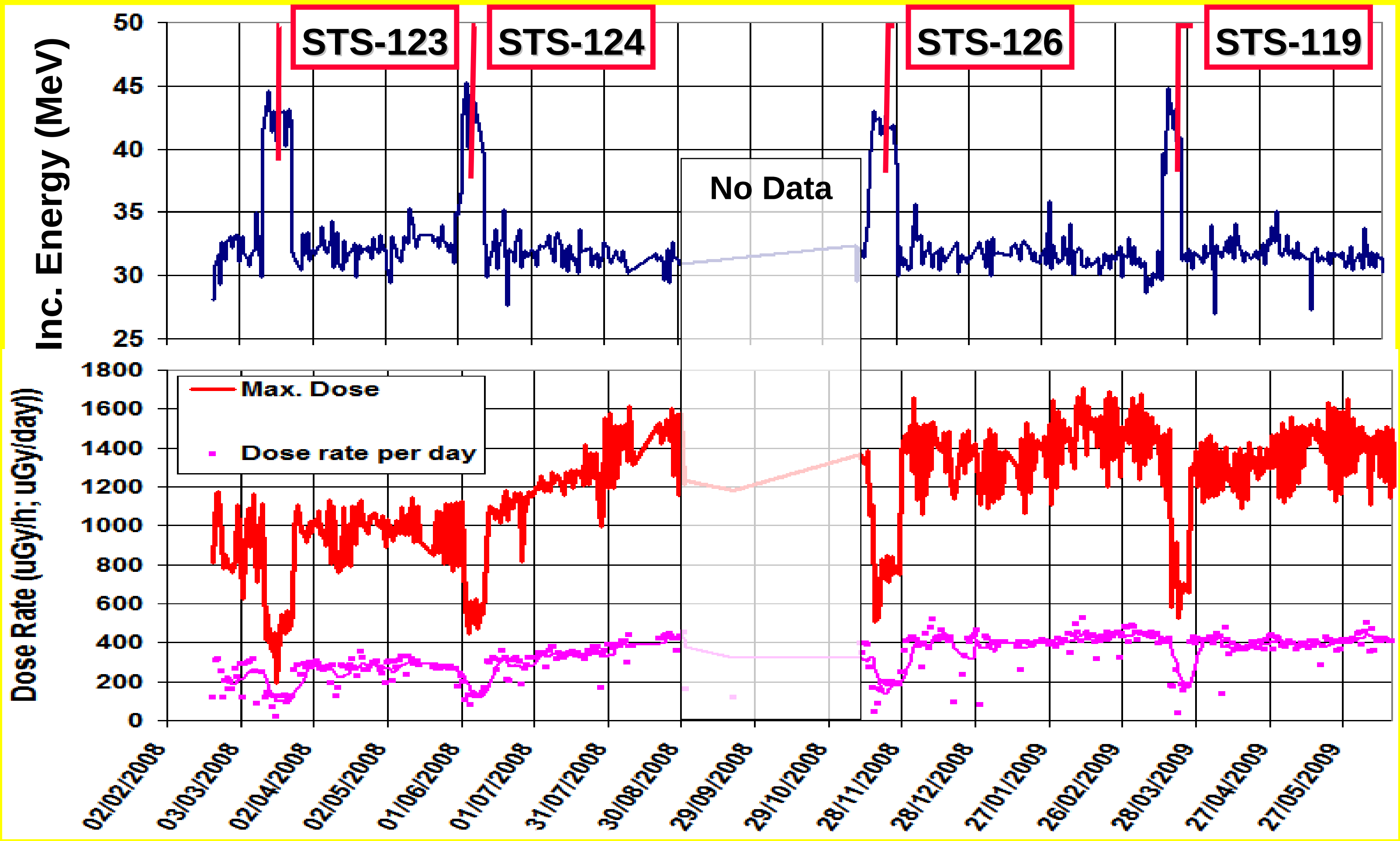
2. SAA Dose maximum is displaced according to the flux maximum.

3. Procedure for calculation of the proton energy in the region of SAA :
The incident energy (MeV) of the protons normally to the detector is calculated by using of the experimental formula described by (Haffner, 1971):

$$D/F(E_p) = 4.10^8 E_p^{-0.8} - 0.8.10^6 E_p^{0.85}$$

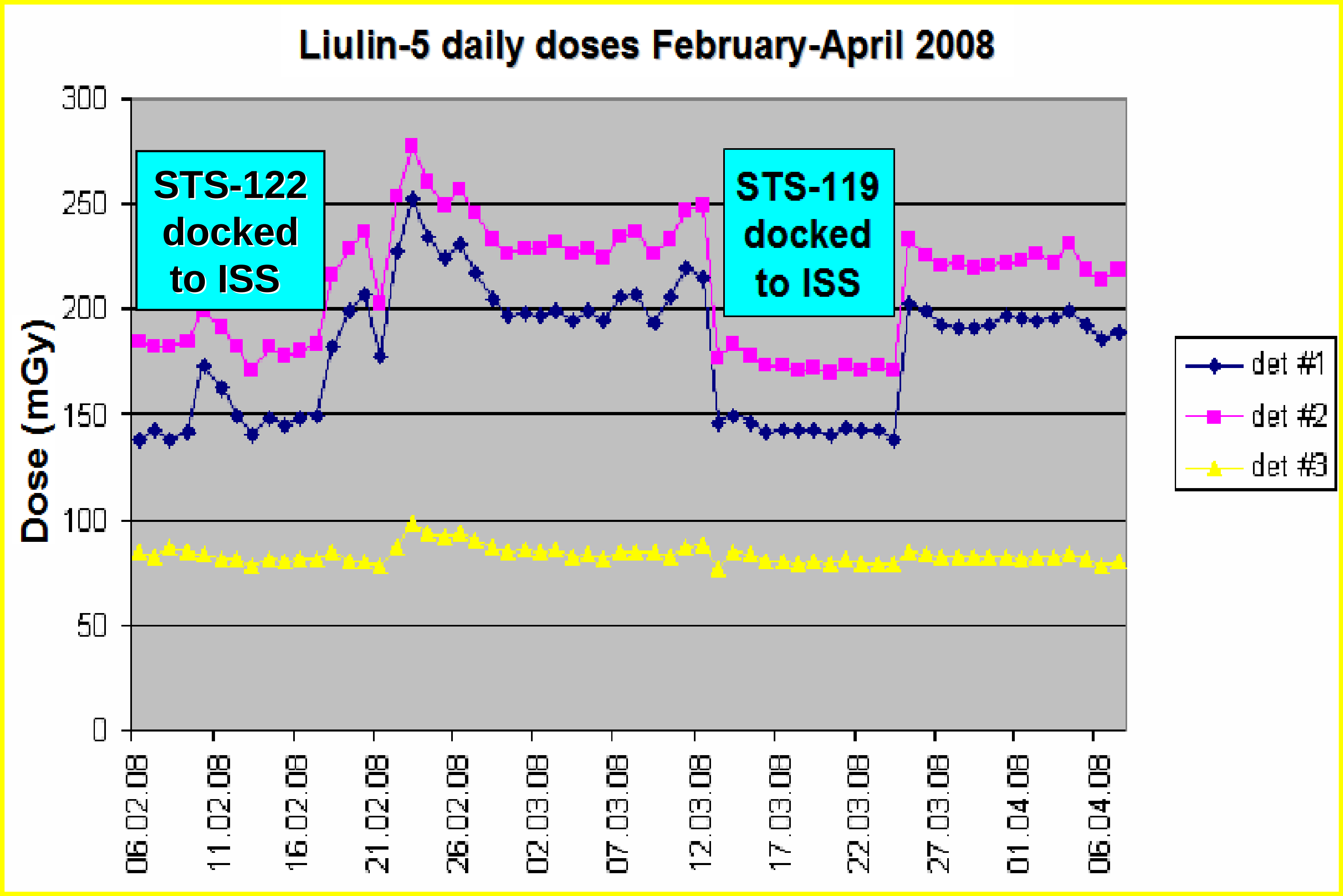
where E_p is the energy of the protons. D/F ratio is obtained from the measured independently dose rate and flux.

Variations of SAA dose rate per day (μGy/day), maximum dose (μGy/h), and Incident Energy from 22/02/2008 to 23/06/2009

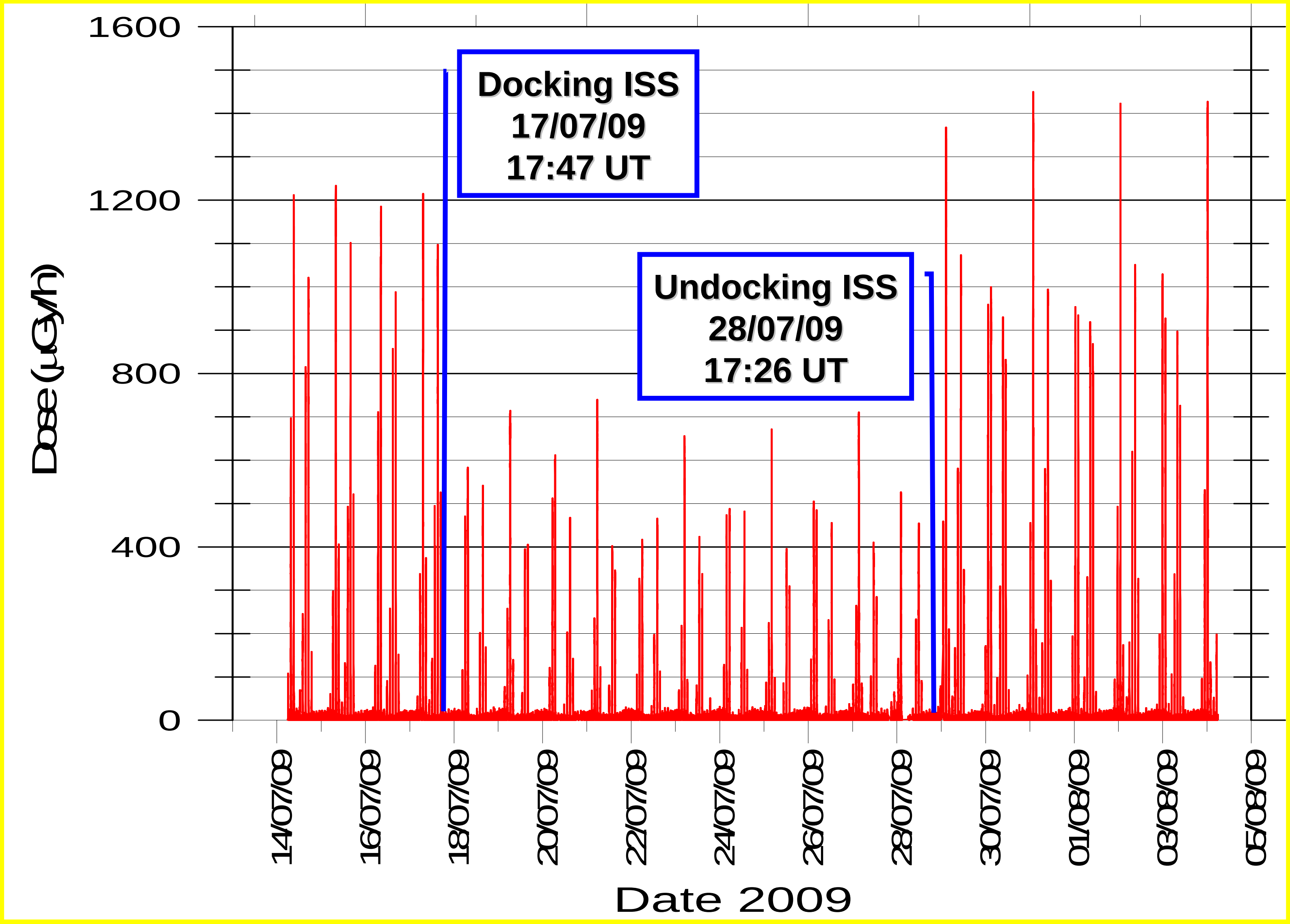


- SAA (trapped) average and maximum dose rates decrease during Shuttle docking time;
- Calculated incident proton energy increase;

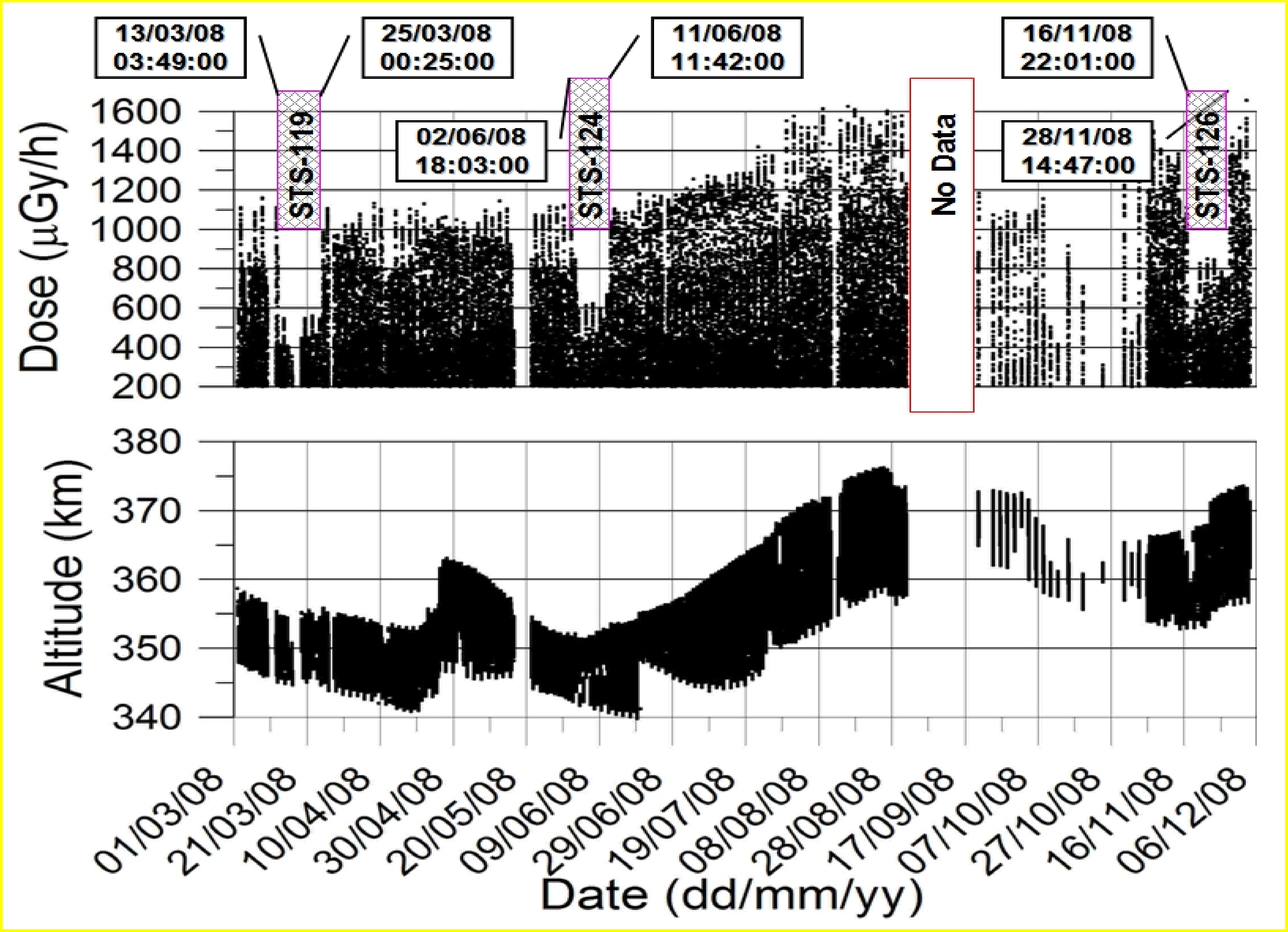
The 2 Liulin-5 external detectors daily doses decrease by factor of 1.3 during the time of docking of STS-122 and 119. The heavy shielded 3th detector response is very small



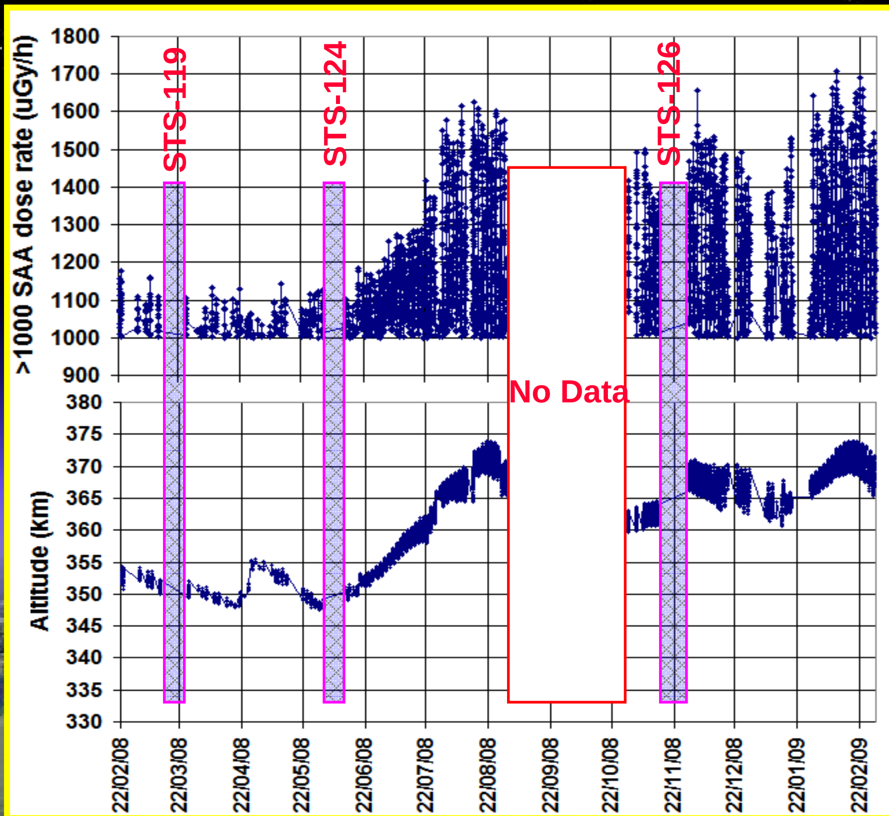
STS-127 Dose history in July 2009 as observed by R3DE instrument



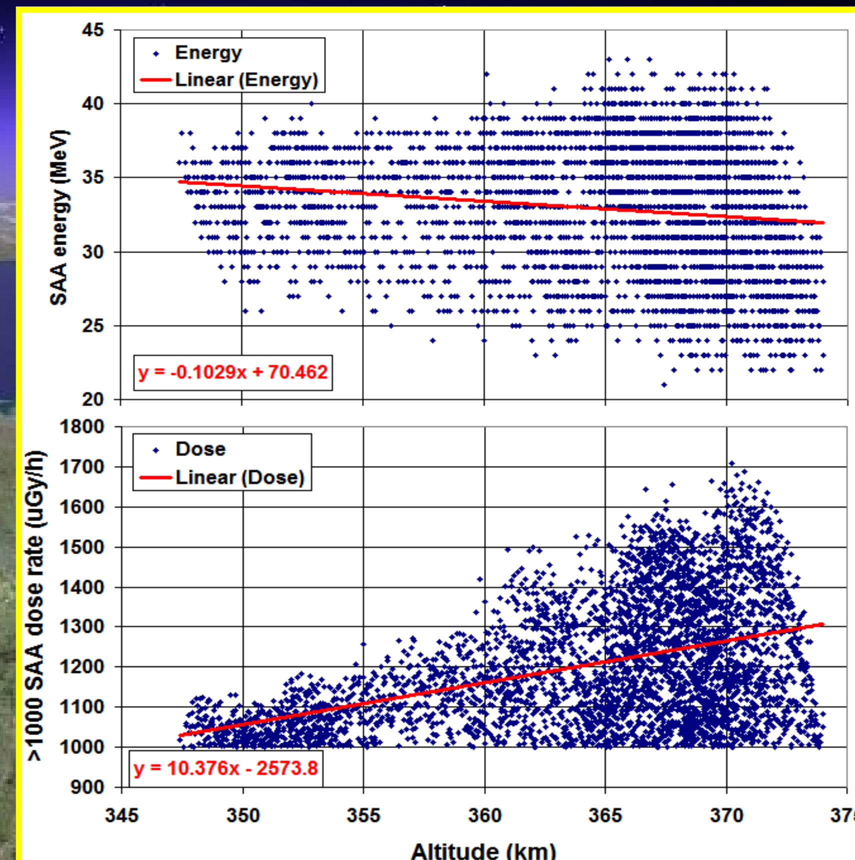
Comparison of ISS more than 200 μGy/h dose rates with the altitude of ISS



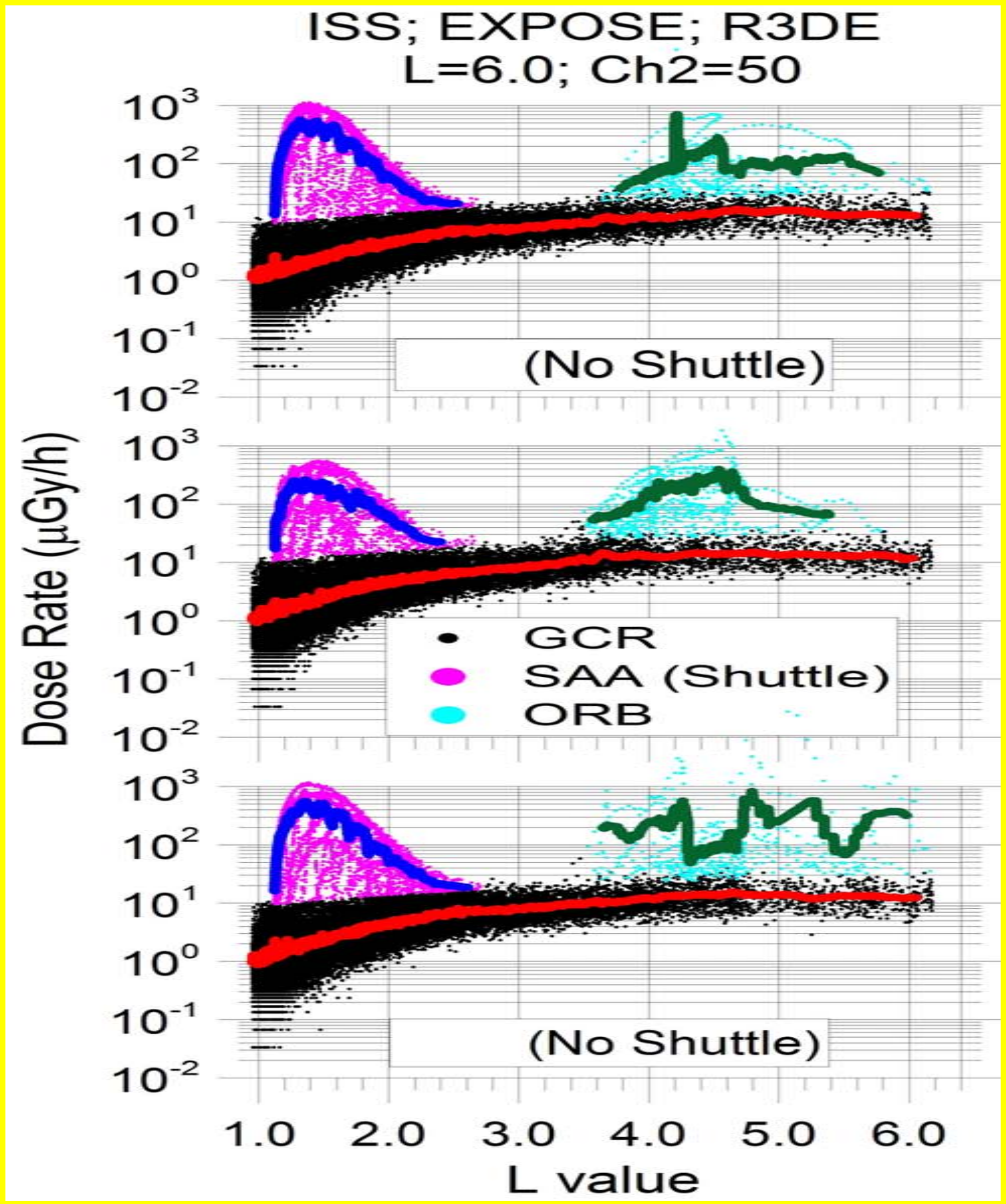
Altitudinal dependence of the SAA maximum (>1000 mGy/h) dose 22/02/2008-22/02/2009 (Descending orbits only)



In average the SAA dose rate above 1000 μGy/h rise up with 10.4 μGy/km, while the energy falls down with 0.1 MeV/km



Average dose rate distribution of separated radiation sources at ISS altitudes



Dose rate Aver. Galactic Cosmic Rays (GCR)

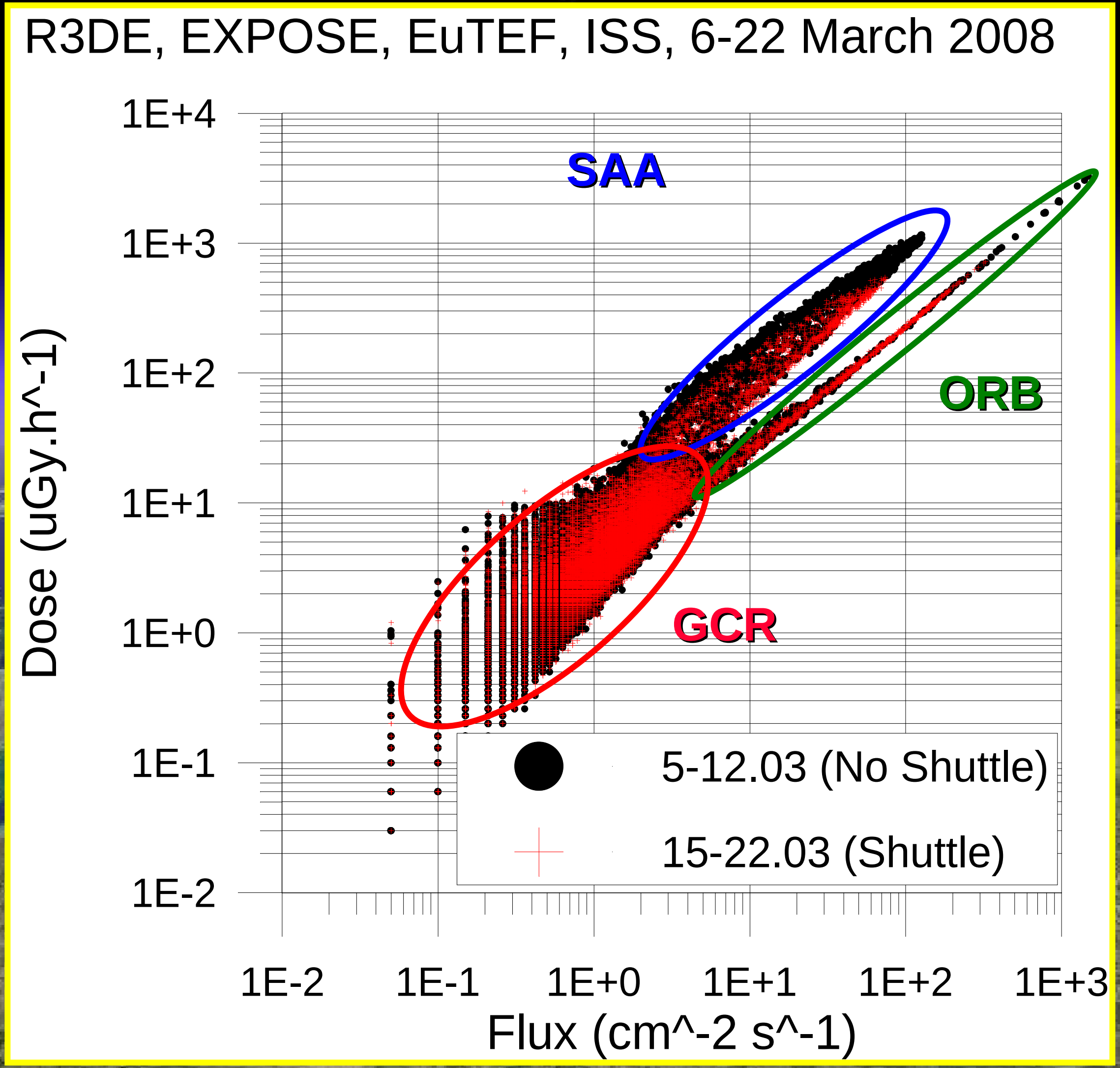
Dose rate Aver. Inner belt protons (SAA)

Dose rate Aver. Outer belt electrons (ORB)

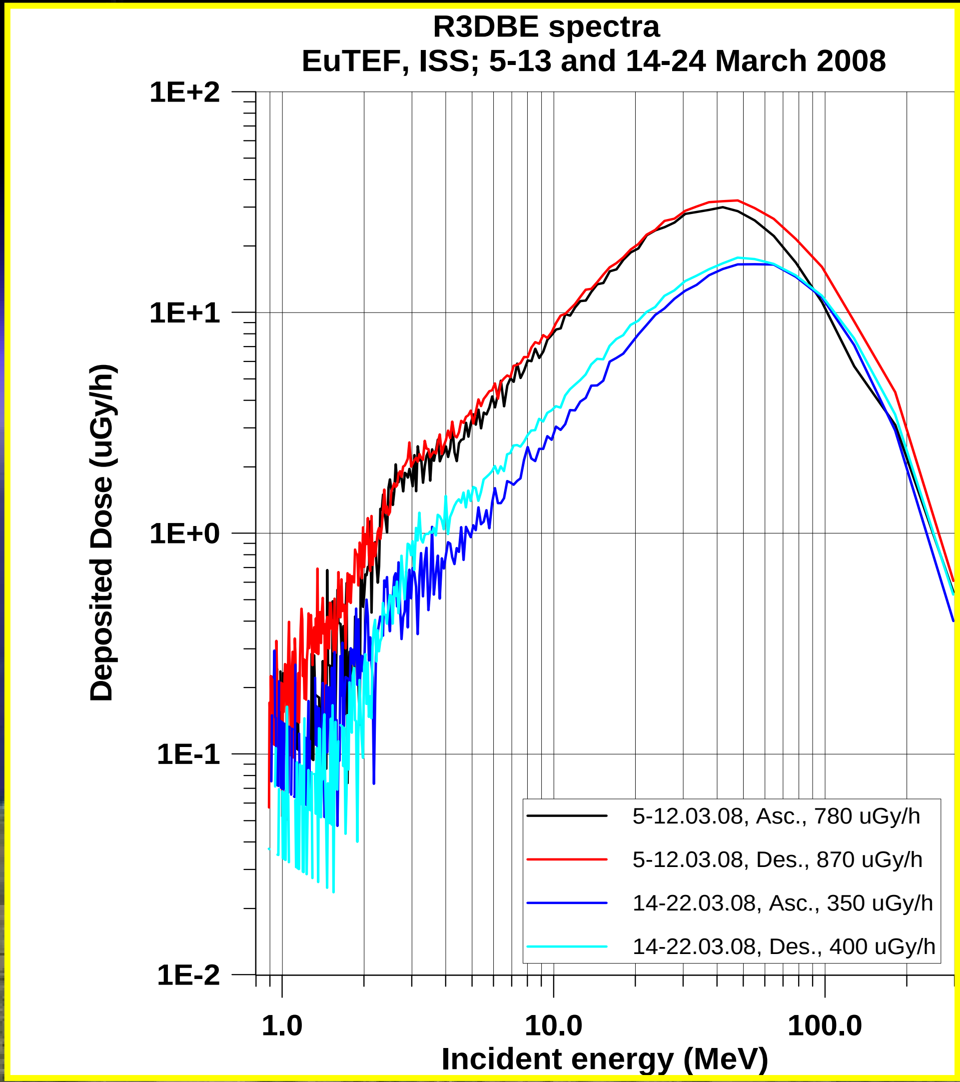
GCR and ORB electrons dose rates are practically not affected by the Space Shuttle.

SAA (proton belt) moving average doses decrease by factor of 3 for the region of the SAA maximum (L=1.4)

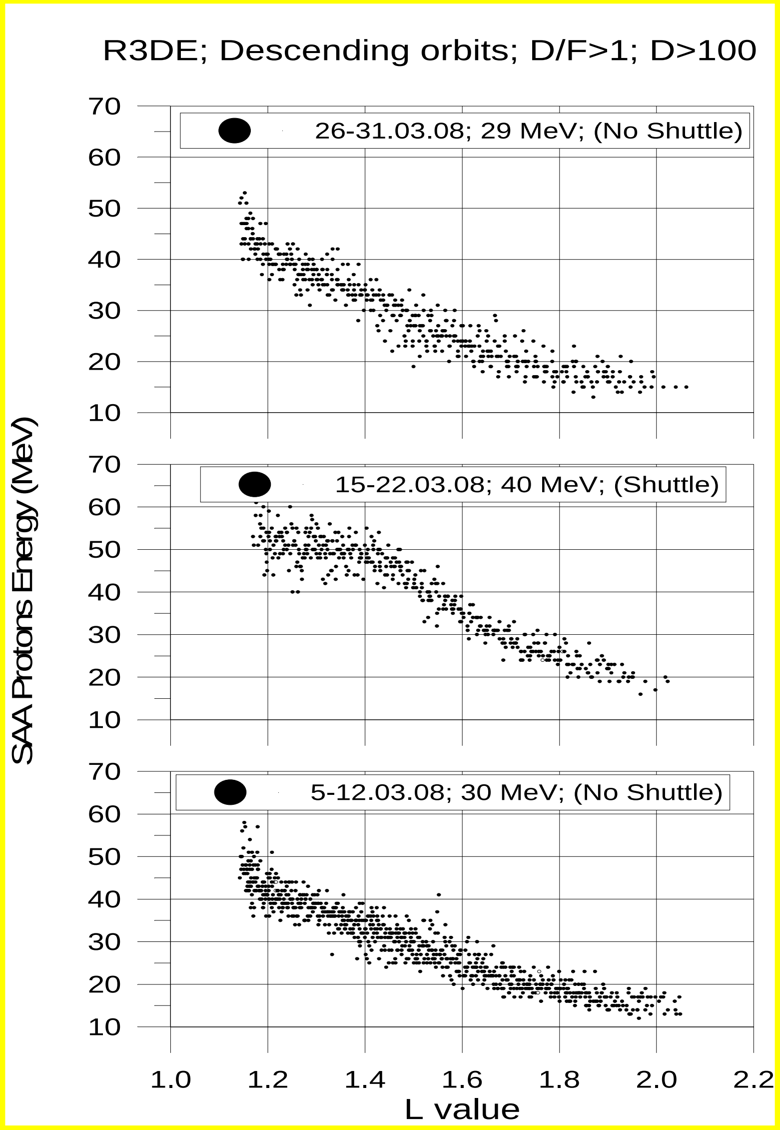
Comparison of doses and fluxes measured by R3DE before (black points) and after STS-119 docking. Well seen decrease of the red points SAA data is observed.

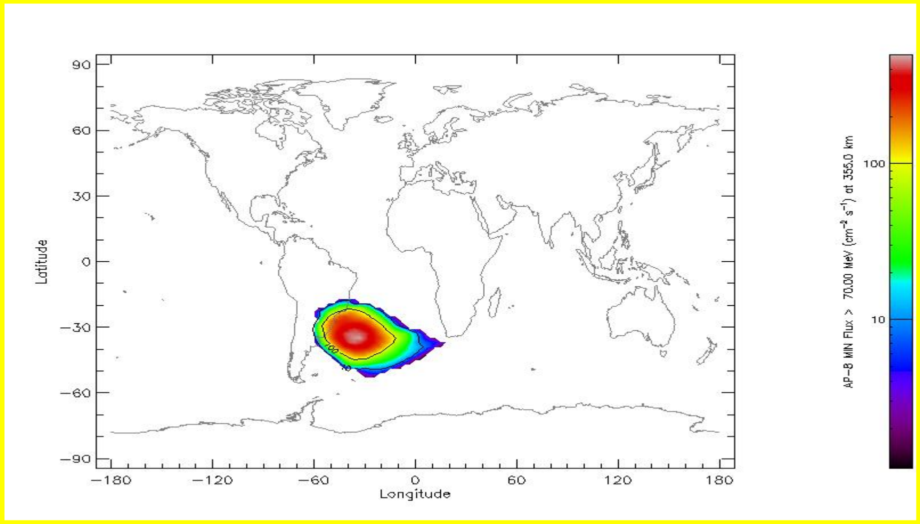


Comparison of the R3DE spectra before and after STS-119 docking. Well seen decrease of the deposited dose rates and increase of the incident energy is observed

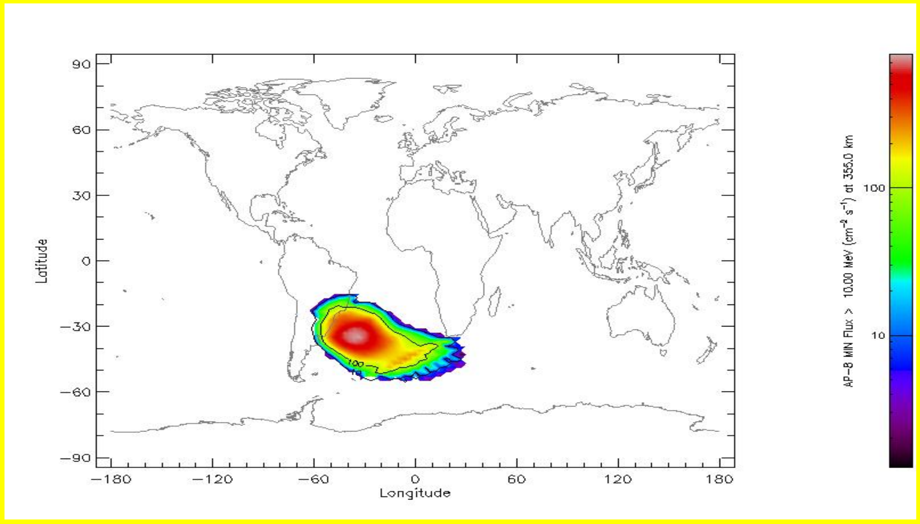


SAA protons energy decrease from 50-60 MeV at L=1.15-1.2 down to 10-20 MeV at L=2.0





AP-8 MIN model (SPENVIS) for 70 MeV protons

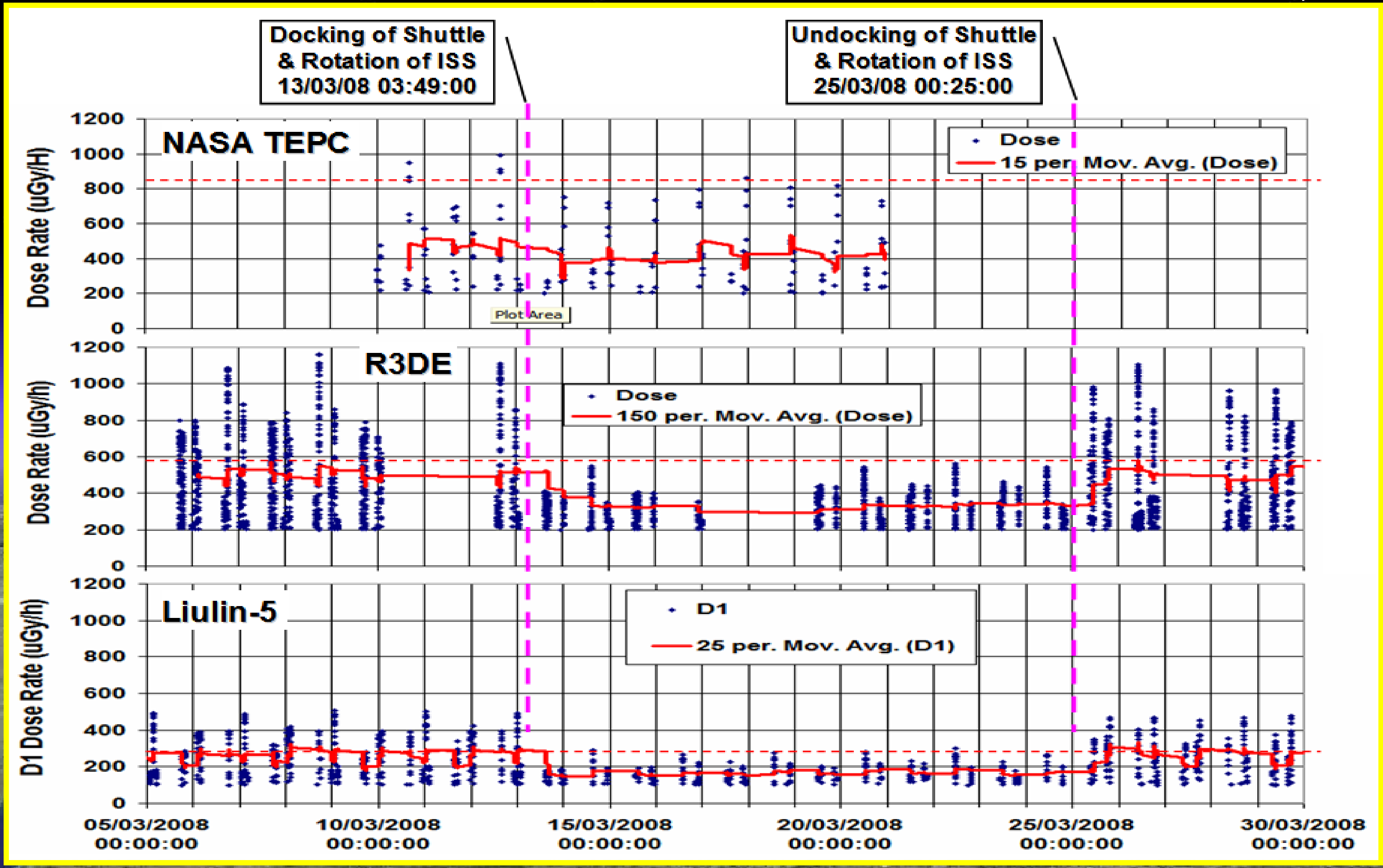


AP-8 MIN model (SPENVIS) for 10 MeV protons

Comparisons with other instruments on ISS

Variations of the dose rates by NASA TEPC, R3DE and Liulin-5 instruments close to STS-123 docking.

Authors thanks to Dr. E. Semones for the TEPC data



- All 3 instruments response by dose rate decrease during the Shuttle docking time;
- The rotation of ISS affect only the Liulin-5 SAA dose distribution by change of the place of dose rates maximum of descending and ascending orbits.

Columbus Results

(Semones, ISS TEPC Measurement Results, 13 WRMISS, 2008)

March 4 - 10

	GCR	Trapped	Total
Dose (µGy)	922.506	790.482	1712.988
Dose Eq (µSv)	2768.831	1413.807	4182.638
Particles Count	16883289	12613729	29497018
Time (minutes)	8816	626	9442
µGy/day	140.691	120.556	261.248
µSv/day	422.275	215.62	637.894

Before STS-123

March 18 – 24

	GCR	Trapped	Total
Dose (µGy)	872.357	592.419	1464.776
Dose Eq (µSv)	2571.033	1067.608	3638.642
Particles Count	16168033	9620668	25788701
Time (minutes)	8232	502	8734
µGy/day	143.828	97.674	241.502
µSv/day	423.894	176.02	599.913

During STS-123

GCR dose rates are practically not affected by the Space Shuttle, while SAA (trapped) average dose rates decrease by factor of 121/98=1.23 for the SAA region

Comparison of data between R3DE and NASA TEPC inside of Columbus module

(Semones, ISS TEPC Measurement Results, 13 WRMISS, 2008)

Instrument	Total Dose µGy/d	Total Dose µSv/d	GCR Dose µGy/d	GCR Dose µSv/d	SAA Dose µGy/d	SAA Dose µSv/d	K Tot µGy/d 4-10/ 18-24	K Tot µSv/d 4-10/ 18-24	K GCR µGy/d 4-10/ 18-24	K GCR µSv/d 4-10/ 18-24	K SAA µGy/d 4-10/ 18-24	K SAA µSv/d 4-10/ 18-24	K Tot µSv/d/ µGy/d	K GCR µSv/d/ µGy/d	K SAA µSv/d/ µGy/d
Col. TEPC March 4-10	260	637	140	422	120	215							2.45	3.01	1.79
Col. TEPC March 18-24	240	599	143	423	97	176	1.083	1.063	0.979	0.998	1.24	1.222	2.5	2.96	1.82
R3DE March 5-9	311	641	74	185	237	456							2.06	2.5	1.92
R3DE March 19-24	192	391	75	185	117	206	1.62	1.64	0.987	1.0	2.02	2.21	2.04	2.47	1.76

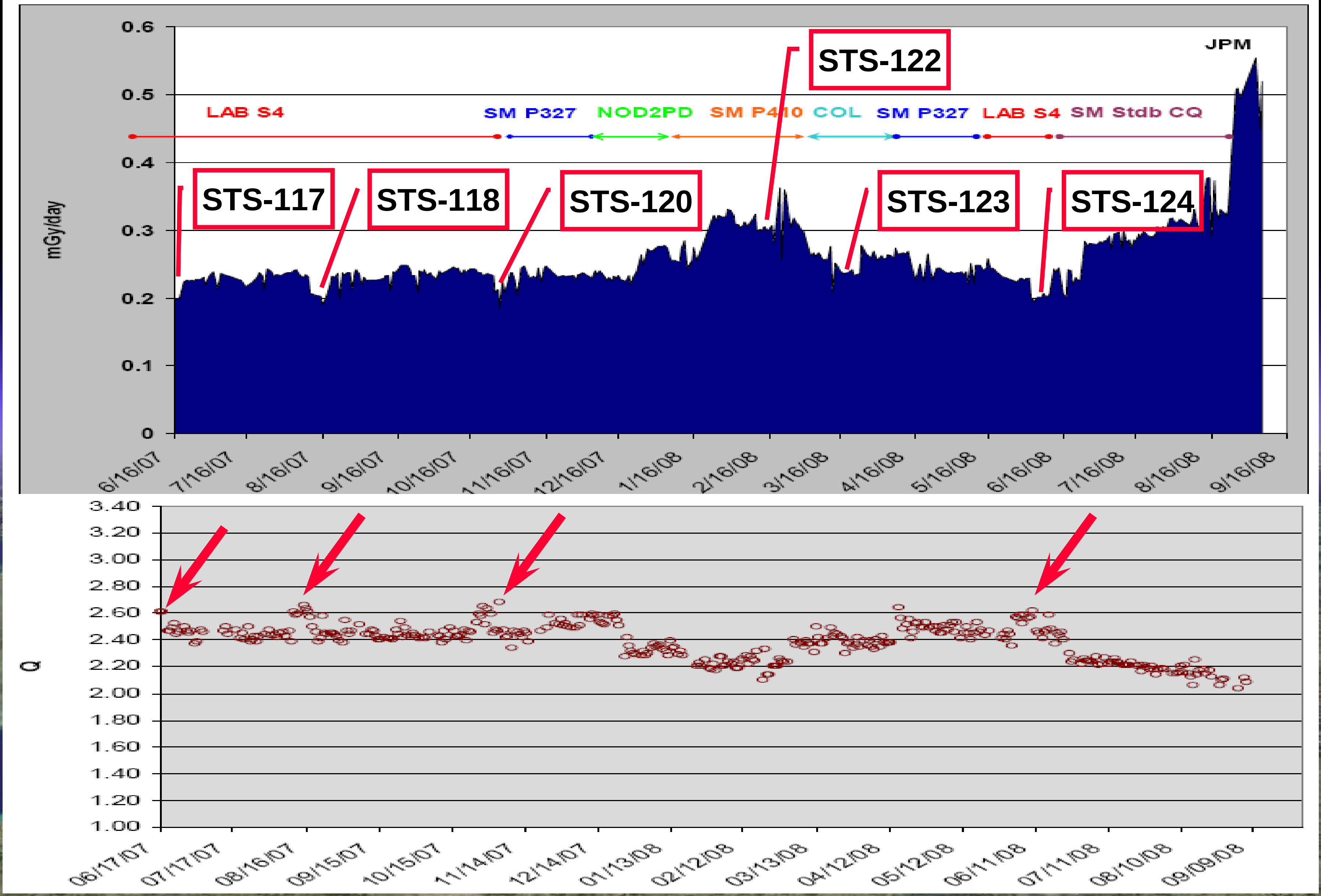
- GCR dose rates by both instruments are not affected by the Space Shuttle. Both data show small increase during the Shuttle docking by 2-7%;

- SAA dose rates measured by R3DE are 1.5-2 times higher than the TEPC dose rates because small shielding of less than 0.4 g/cm^2;

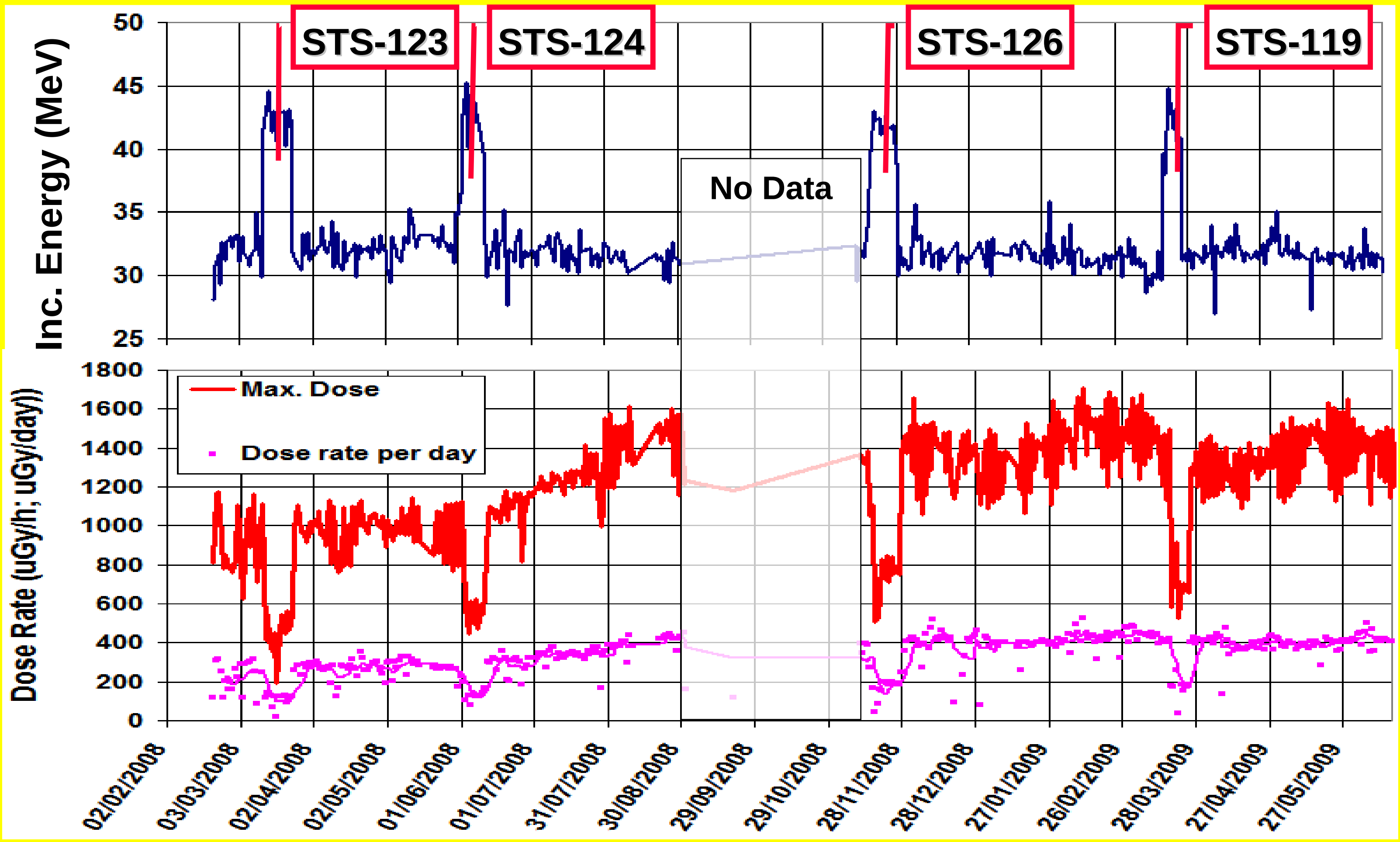
- SAA (trapped) average dose rates decrease by factor of 120/97=1.24 in TEPC and by 237/117=2.02 in R3DE data. Differences has to be attributed to shielding differences.

ISS TEPC Long Term Dose

(Semones, ISS TEPC Measurement Results, 13 WRMISS, 2008)



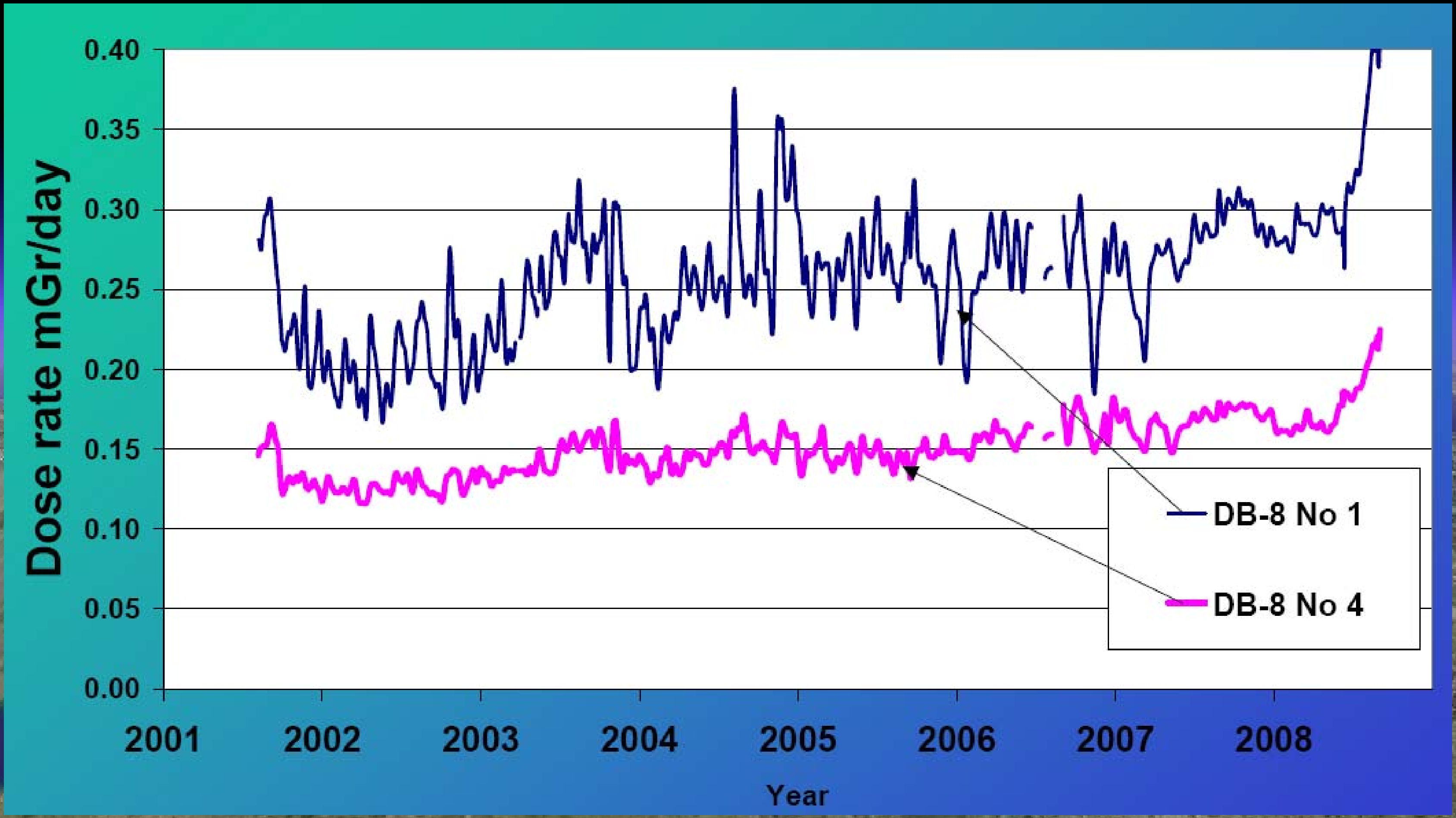
Variations of SAA dose rate per day (μGy/day), maximum dose (μGy/h), and Incident Energy from 22/02/2008 to 23/06/2009



- SAA (trapped) average and maximum dose rates decrease during Shuttle docking time;
- Calculated incident proton energy increase;

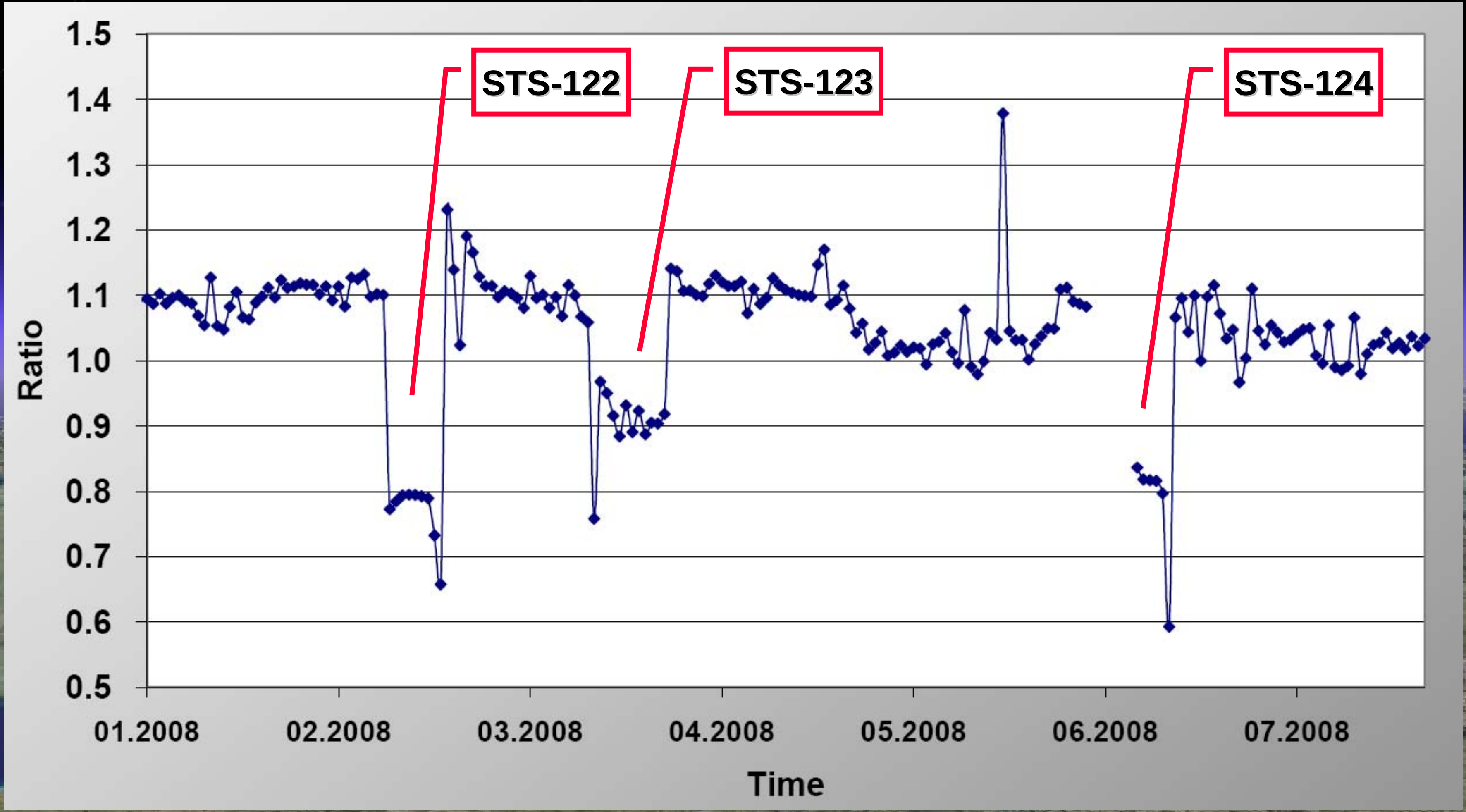
Dose rate measured from August 2001 to August 2008 with DB-8 units # 1 and # 4 unshielded detectors, SPE excluded

(Benghin, Results of the Radiation Monitoring System Onboard The Service Module of ISS, 13 WRMISS, 2008)

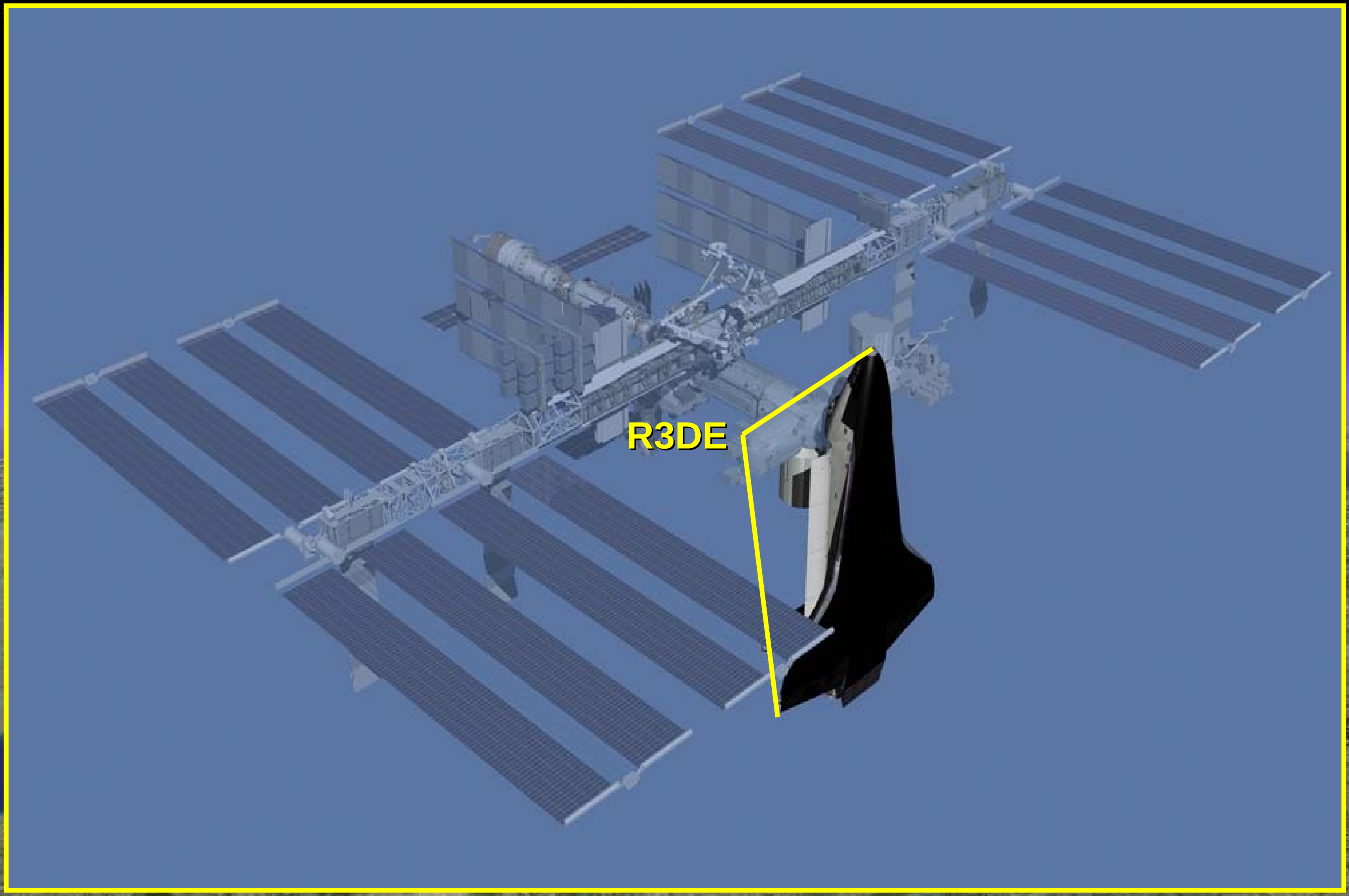


Ratio of daily dose for unshielded detectors DB-8 #3/DB-8#2

(Benghin, Results of the Radiation Monitoring System Onboard The Service Module of ISS, 13 WRMISS, 2008)



The docked Space Shuttle shields large part of the R3DE angle of view, which is the reason for the dose decreases in the SAA region



Conclusions

The long-term analysis of the Liulin type instruments data on ISS shows:

- The docking of Space Shuttle to ISS reduce the SAA maximum dose rates by factor of 3. The averaged per day dose rates decrease by factor of 2. The mean energy of the SAA protons increase from about 30 to 40 MeV;

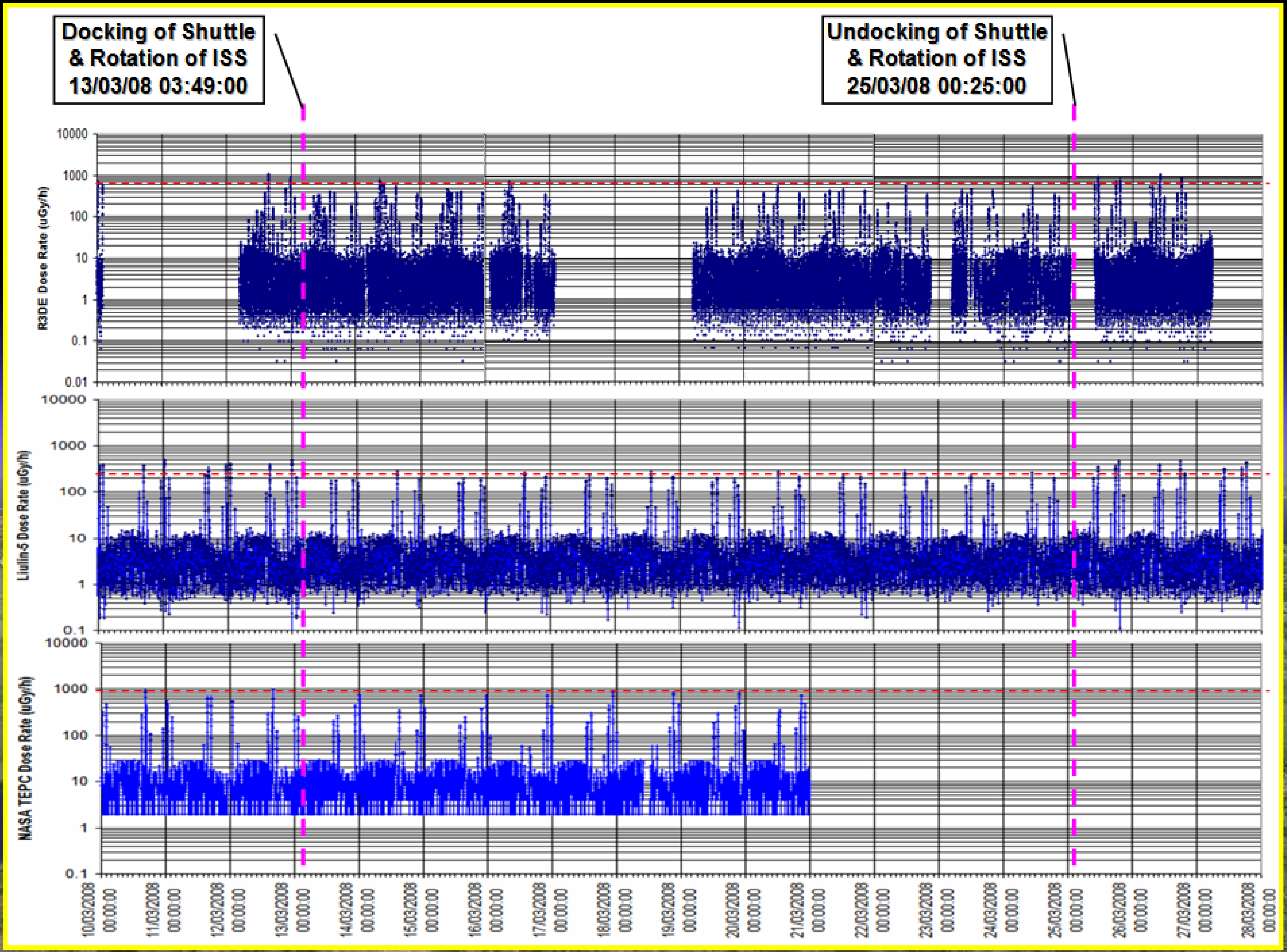
- GCR dose rates are not affected;

- Outer radiation belt relativistic electron dose rate are not affected;

The explanation of the effect on the SAA dose rates is connected with the additional shielding, which Shuttle provides to the instruments.

Further precise modeling of the ISS SAA radiation environment are necessary to confirm this hypothesis.


Thank you



Docking of Shuttle
& Rotation of ISS
13/03/08 03:49:00
Undocking of Shuttle
& Rotation of ISS
25/03/08 00:25:00
R3DE Dose Rate (uGy/h)
Liulin-5 Dose Rate (uGy/h)
NASA TEPC Dose Rate (uGy/h)
10000
1000
100
10
1
0.1
0.01
10/03/2008 00:00:00
11/03/2008 00:00:00
12/03/2008 00:00:00
13/03/2008 00:00:00
14/03/2008 00:00:00
15/03/2008 00:00:00
16/03/2008 00:00:00
17/03/2008 00:00:00
18/03/2008 00:00:00
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