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

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Radiation Exposure

- 400 km: ~30 μSv/h \(\times 300\)
- 10 km: ~4 μSv/h \(\times 40\)
- 3 km: ~0.2 μSv/h \(\times 2\)
- 150 m: ~0.1 μSv/h \(\times 1\)
Variation of the radiation load onboard the ISS with altitude, latitude and time

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)
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
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 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.


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 / DOSIS 3D

![Image of the International Space Station (ISS) with marked detectors.](image)

<table>
<thead>
<tr>
<th>Agency</th>
<th>Name of the detectors</th>
<th>Quantity</th>
<th>Position on ISS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESA</td>
<td>PDP</td>
<td>10 + 1</td>
<td>Columbus (red rectangle)</td>
</tr>
<tr>
<td>NASA</td>
<td>RAMs</td>
<td>24</td>
<td>All over the ISS (yellow rectangle)</td>
</tr>
<tr>
<td>JAXA</td>
<td>PADLES</td>
<td>12</td>
<td>KIBO (blue rectangle)</td>
</tr>
<tr>
<td>IBMP</td>
<td>SPD</td>
<td>6</td>
<td>Russian part of the ISS (green rectangle)</td>
</tr>
<tr>
<td></td>
<td>Pille</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

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.
The DOSTEL Detector Head consists of 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 1.5 cm this leads to an opening angle of 120°.
DOSTEL Detector
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.

- DOSTEL-1 has an additional mode 2 where the PHA data for every single particle is taken.
DOSIS 3D - Launch 15. May 2012 Soyuz TMA 04M / 30S
DOSIS Installation Inside COLUMBUS

Columbus SUP

Black Brick 120V/16V

Power Brick

EPM

DOSIS-Main-Box

DDPU

DOSTEL 2

DOSTEL 1

SD Card

DATA

POW

EPM LAN
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

The graph shows the count rates per second for DOSTEL-1, with the y-axis representing the counts per square centimeter (counts/s in 6.93cm²). The x-axis represents the day of the year (DoY) for the years 2012 and 2013.
DOSIS - DOSTEL

counts/s DOSIS July 2010
1 counts/s in 6.93 cm$^2$

DoY 2009

- DOSTEL-1
- DOSTEL-2
DOSIS SAA spectra
DOSIS SAA spectra

\[ \Delta E / \text{MeV} \]

\[ \text{flux / arb. units} \]

- DOSTEL 1 D1 SAA descending
- DOSTEL 1 D1 SAA ascending
- DOSTEL 1 D2 SAA descending
- DOSTEL 1 D2 SAA ascending
DOSIS SAA spectra

\[ \Delta E / \text{MeV} \]

![Graph showing DOSIS SAA spectra with different data points and lines representing different conditions.](image)
DOSIS 3D SAA Mode 2 Data

ascending

Descending

File 9 / Block 25

File 22 / Block 20
DOSIS 3D Mode 2 Data

GCR (mainly)

SAA (mainly)
DOSIS - DOSTEL

dose / (μGy/h) DOSIS July 2010
Absorbed Dose Rates DOSTEL 1

- GCR DOSTEL 1
- SAA DOSTEL 1
- total DOSTEL 1

μGy/di H₂O

01.05.2009 17.01.2010 05.10.2010 23.06.2011 10.03.2012 26.11.2012 14.08.2013
Absorbed Dose Rates DOSTEL 2

GCR DOSTEL 2
SAA DOSTEL 2
Total DOSTEL 2

Gy/hr
Gy/Ah
01.05.2009 17.01.2010 05.10.2010 23.06.2011 10.03.2012 26.11.2012 14.08.2013
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.
DOSIS GCR LET Spectra DOSTEL-1

\[ \Phi(LET)/\mu m \ H_2O/keV \ s \ cm^2 \]

- DOSTEL 1 D1
- DOSTEL 1 D2

LET / keV/\mu m H_2O
DOSIS SAA LET Spectra DOSTEL-1
LET Spectra DOSTEL-1 Detector 1
LET Spectra DOSTEL-1 Detector 2
Mean Quality Factor

Graph
Q(LET) ICRP60
Dose Equivalent Rates DOSTEL 1

Graph showing dose equivalent rates with data points from 01.05.2009 to 14.08.2013.
Dose Equivalent Rates DOSTEL 2
### DOSIS / DOSIS 3D Results

<table>
<thead>
<tr>
<th>DOSIS</th>
<th>Total</th>
<th>GCR</th>
<th>SAA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>µGy/d in Si</td>
<td>µGy/d in tissue</td>
<td>Q</td>
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<tr>
<td>DOSTEL-1</td>
<td>195</td>
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<td>2.5</td>
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<td>µGy/d in tissue</td>
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GCR Dose Rates

Oulu data taken from the NMDB database (www.nmdb.eu), founded under the European Union's FP7 program (contract no. 213007).
SAA Dose Rates

Graph showing SAA Dose Rates with different markers for ISS altitude and time periods.
DOSIS 3D, DOSIS and DOSMAP comparison

μGy/h in Si


DOSIS 3D 2012
DOSIS 2009
DOSMAP 2001
Conclusions

- Up to now we have 1023 days of measurement with DOSTEL-2 (DOSTEL-1: 677d)

- 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

- Contribution of GCR to the dose rate is obviously correlated with the GCR flux measured by NM while the contribution of trapped particles is correlated with the stations altitude
Acknowledgements

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on the basis of a decision by the German Bundestag

- Thank you very much for your attention!
Backup slides…
## DOSIS / DOSIS 3D Results

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<tbody>
<tr>
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<td>µGy/d in Si</td>
<td>µGy/d in tissue</td>
<td>µSv/d µGy/d in Si</td>
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<th>Total</th>
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<tr>
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<td>µGy/d in tissue</td>
<td>µSv/d µGy/d in Si</td>
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<tr>
<td>DOSTEL-1</td>
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<tr>
<td>DOSTEL-2</td>
<td>212</td>
<td>261</td>
<td>593</td>
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ISS +Xvv Attitude

SAA LET Spectra

N(LET)/s cm$^2$ sr keV/µm (H$_2$O)

keV/µm (H$_2$O)
Combined LET spectra

\( N(\text{LET})/s \cdot \text{cm}^2 \cdot \text{sr} \cdot \text{keV/\mu m H}_2\text{O} \)

- TEPC COL
- DOSIS DOSTEL-1
DOSTEL-2 Count Rate Profile

counts / s (6.93cm²)

DoY 2009

2010
2009
DOSTEL-2 Count Rate Profile

counts / s (6.93 cm$^2$)

DoY 2009

STS-127  STS-128  STS-129
STS-130  STS-131  STS-132

2010  2009
DOSTEL GCR dose equivalent / µSv/d

Kiel NM / arb. units

year