3D Dose Distribution Measurements by Passive Detectors in the Columbus Module

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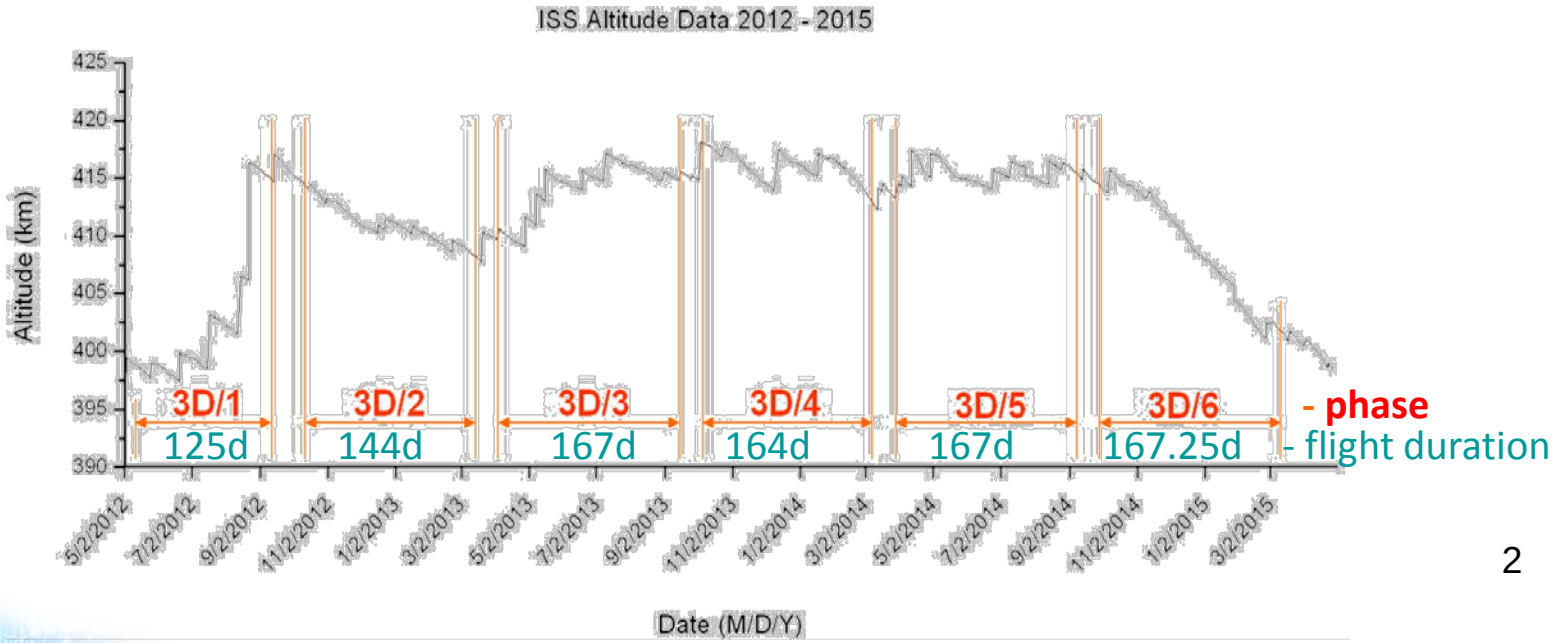
20th WRMISS 8–10 September 2015, Cologne, Germany

Photo by Samantha Cristoforetti

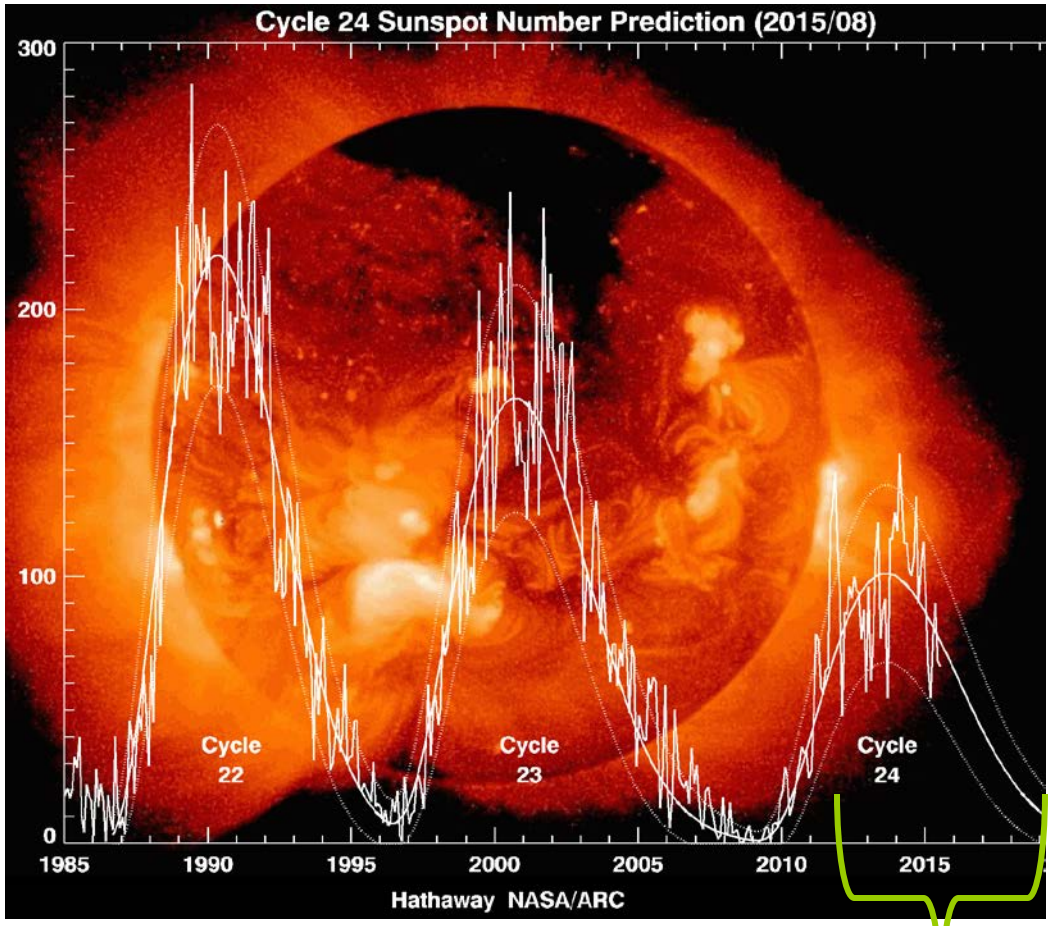
Introduction – DOSIS-3D

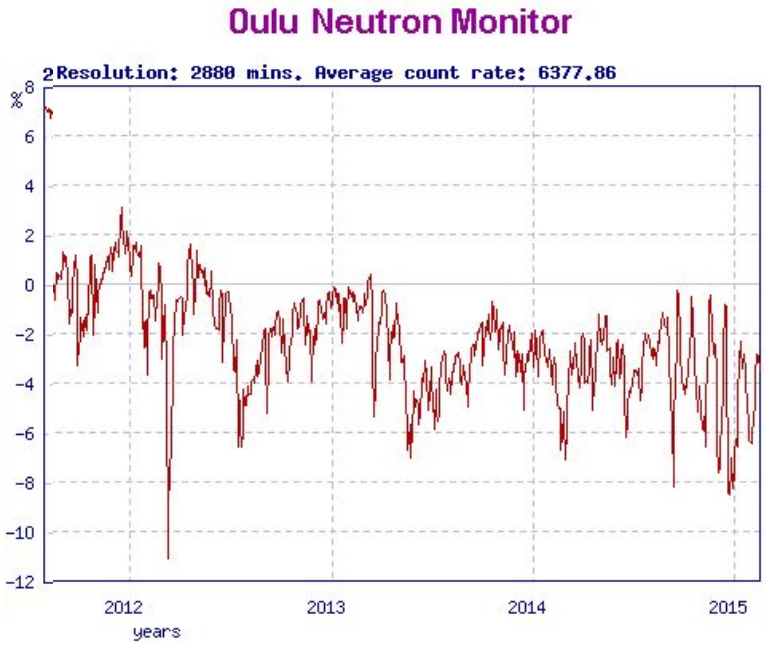
- Follow up experiment of the Dosis Project (2009-2011)
- Goal: obtaining 3 dimensional dose distribution information at different locations and shielding conditions
- ➢ Active parts: DOSTEL-1 and DOSTEL-2 dosimetry telescopes
- ➢ Combined passive detector packages at 11 locations

  (TLDs: low LET radiation, SSNTDs: high LET radiation >10 keV/µm)
- 6 completed phases since 2012



Introduction – Space Weather





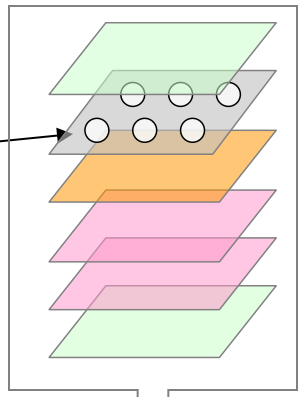
Dosis-3D

- Systematic decrease of neutron count rate → decreasing number of high LET GCR particles
- Increased solar activity between 2014 and 2015

Detector Packages

MTA EK stack 1

- 6 pcs of *TLD*s (3 x ^{6}LiF, 3 x ^{7}LiF)
- 2 layer of *SSNTD*s

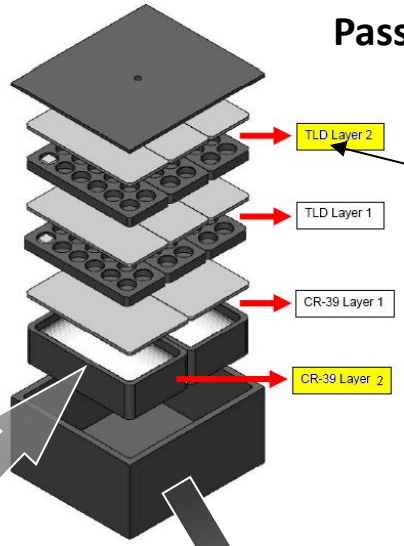


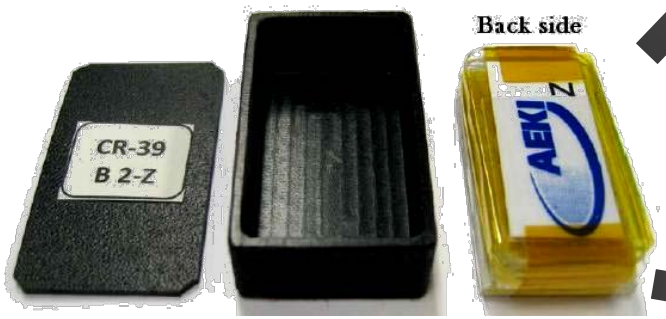
Passive Detector Package 2

MTA EK stack 2

- 8 pcs of *TLD*s (4 x ^{6}LiF, 4 x ^{7}LiF)

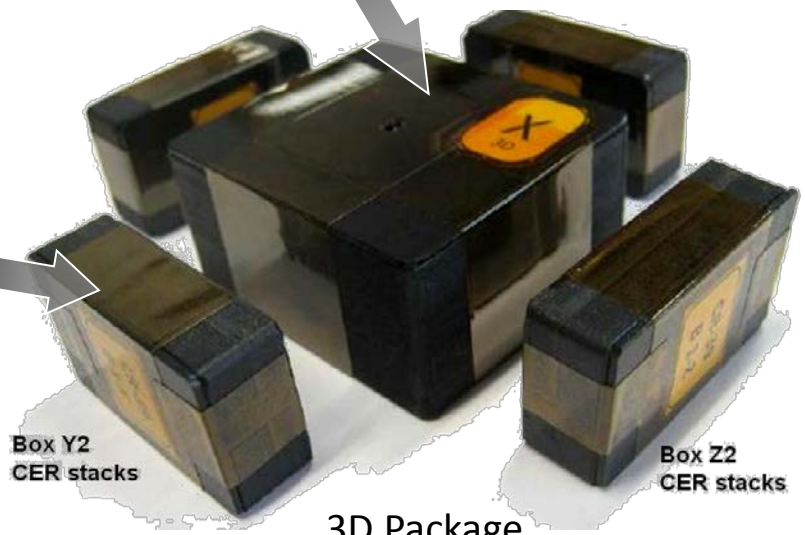
at 10 locations + x





Passive Detector Package 1

at 10 locations + x, y, z



3D Package

Detector Packages - Locations

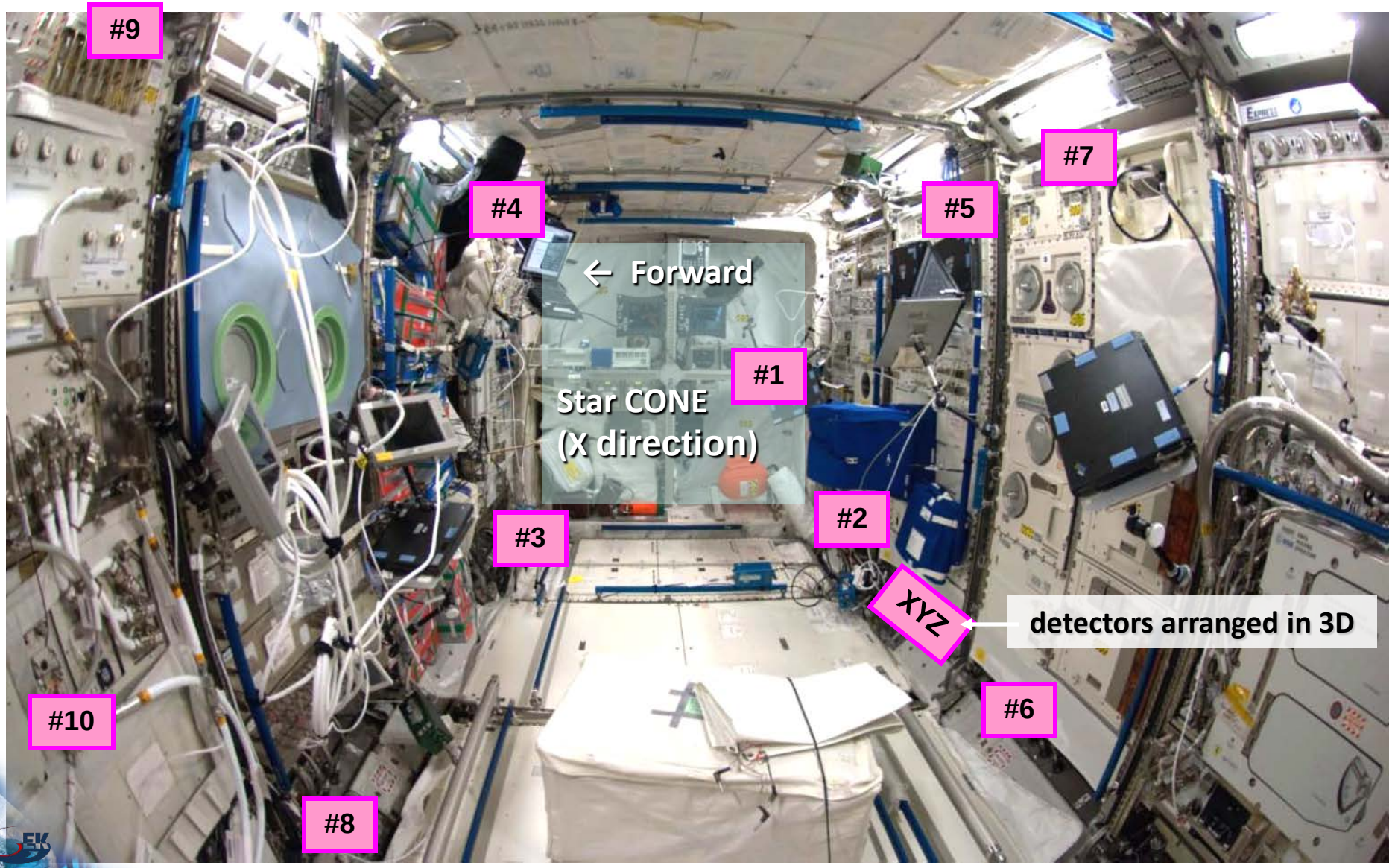


Photo: ESA/NASA

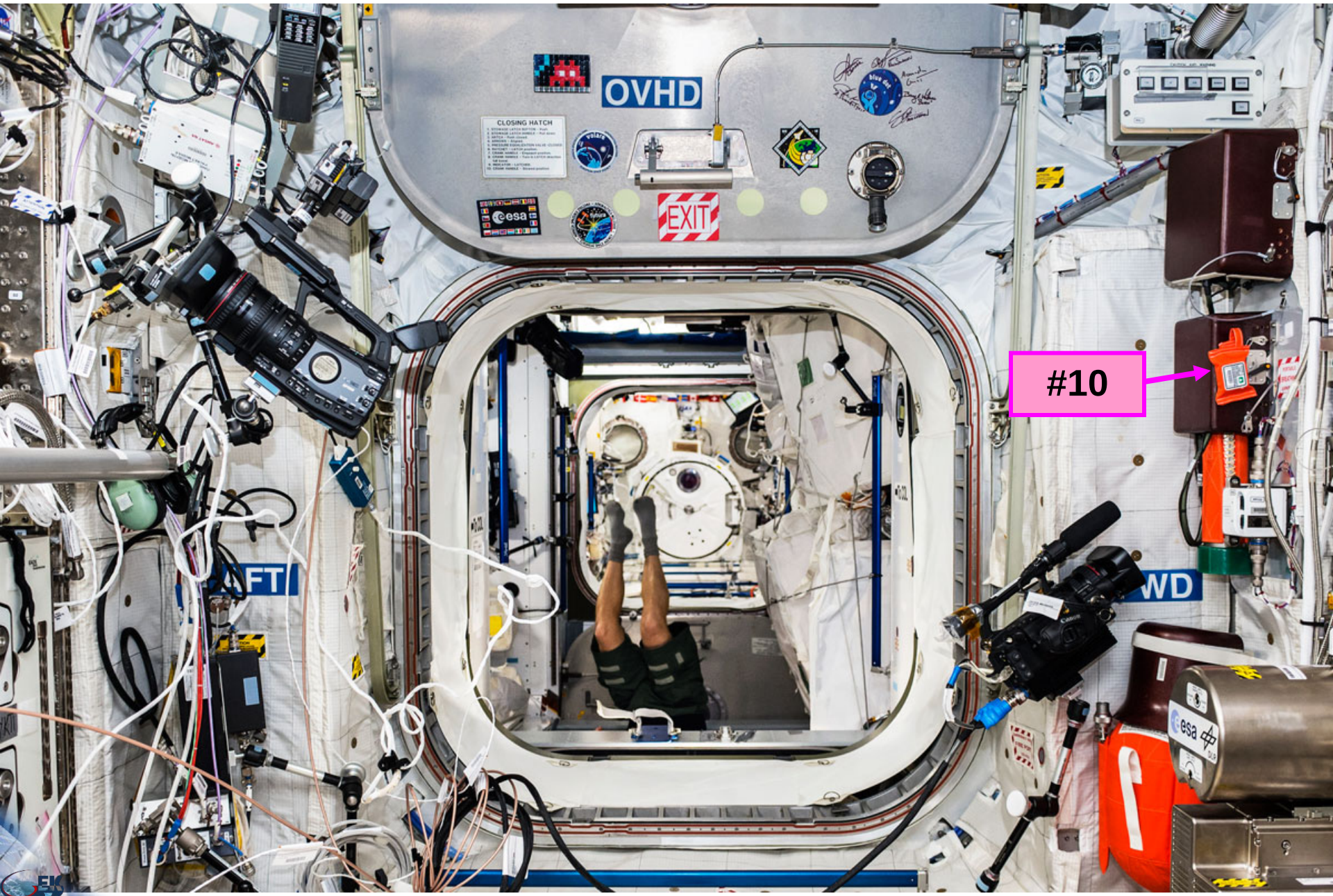


Photo: ESA/NASA

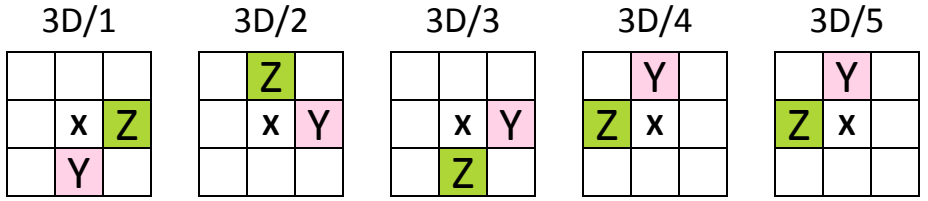
Method

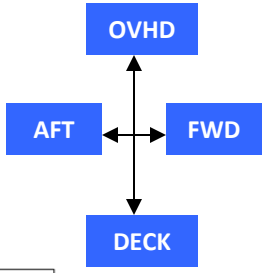
- **SSNTD**: etching in 2 steps in 6 N NaOH solution at 70 °C
  (TASTRAK material, produced by TASL, Bristol, U.K.)
  - pre-exposure irradiation (^{210}Po) → etched off layer
  - **6 h etching**: high LET particle tracks become visible
    (circular and elliptical tracks measurted automatically + HZE tracks measured manually)
  - **15 h etching**: low LET particle tracks become visible
    (only circular and elliptical tracks measurted automatically)
    → final LET spectra obtained from the combined 6h & HZE & 15h results

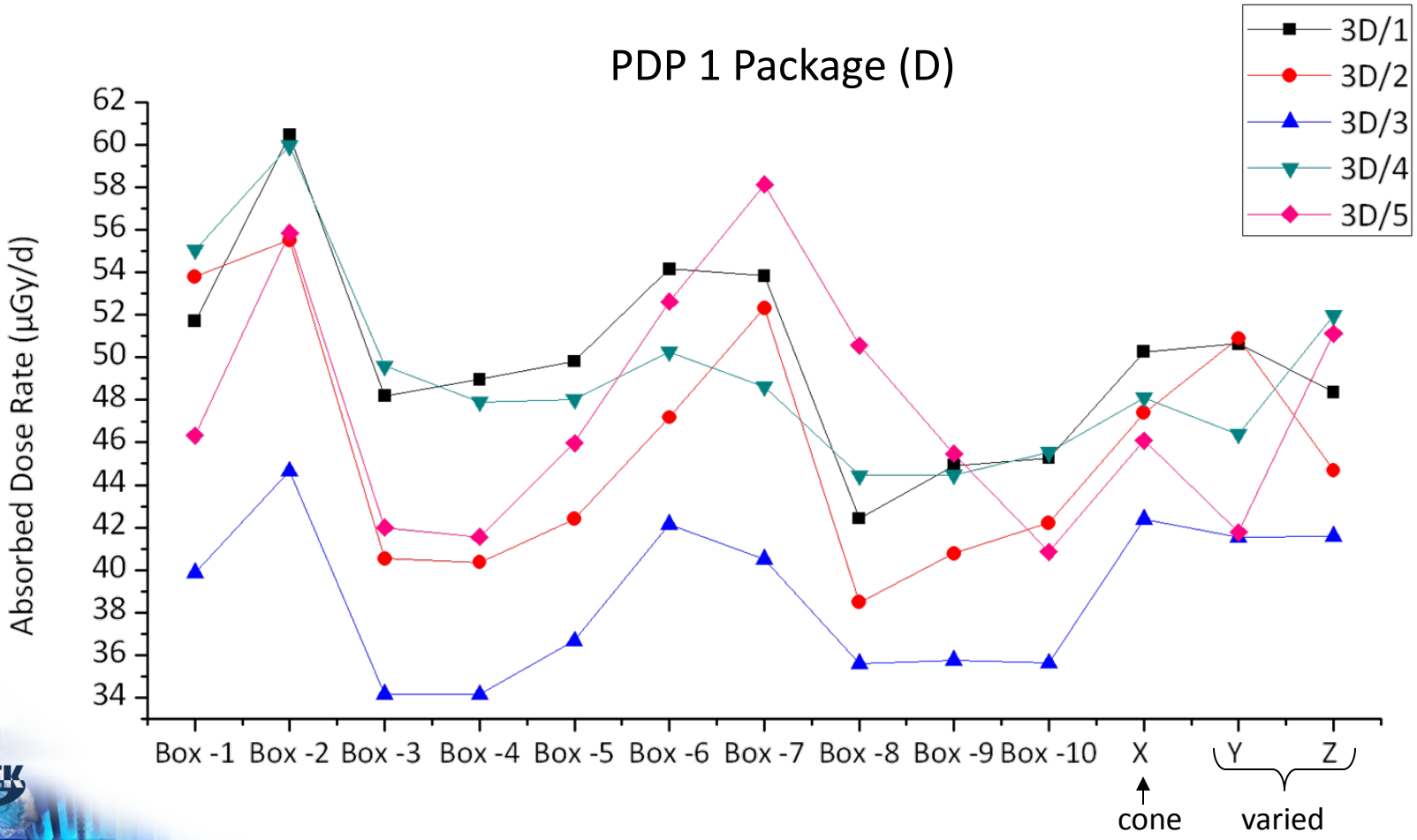
- **TLD**:
  (MTS-N, MTS-6, MTS-7)
  - pre-exposure annealing at 400 °C (1 h) and 100 °C (2 h)
  - readout by a Harshaw 2000 instrument
    (evaluation based on the dosimetric (5th) peak)
  - post-exposure annealing at 400 °C (1 h) and 100 °C (2 h)
  - detectors individually calibrated using a ^{137}Cs source

Results – Track Detectors (D)

- The Y and Z orientations were not constant

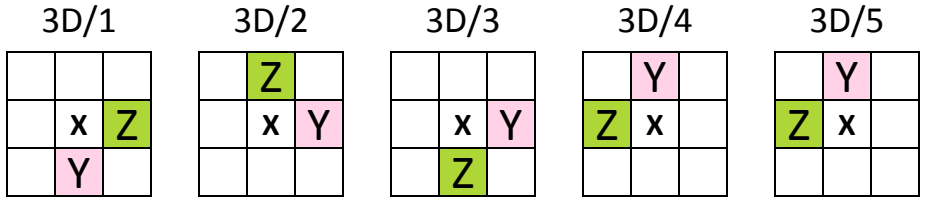


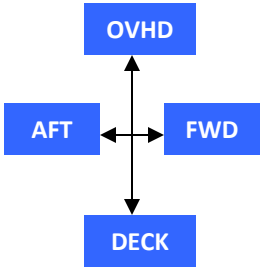


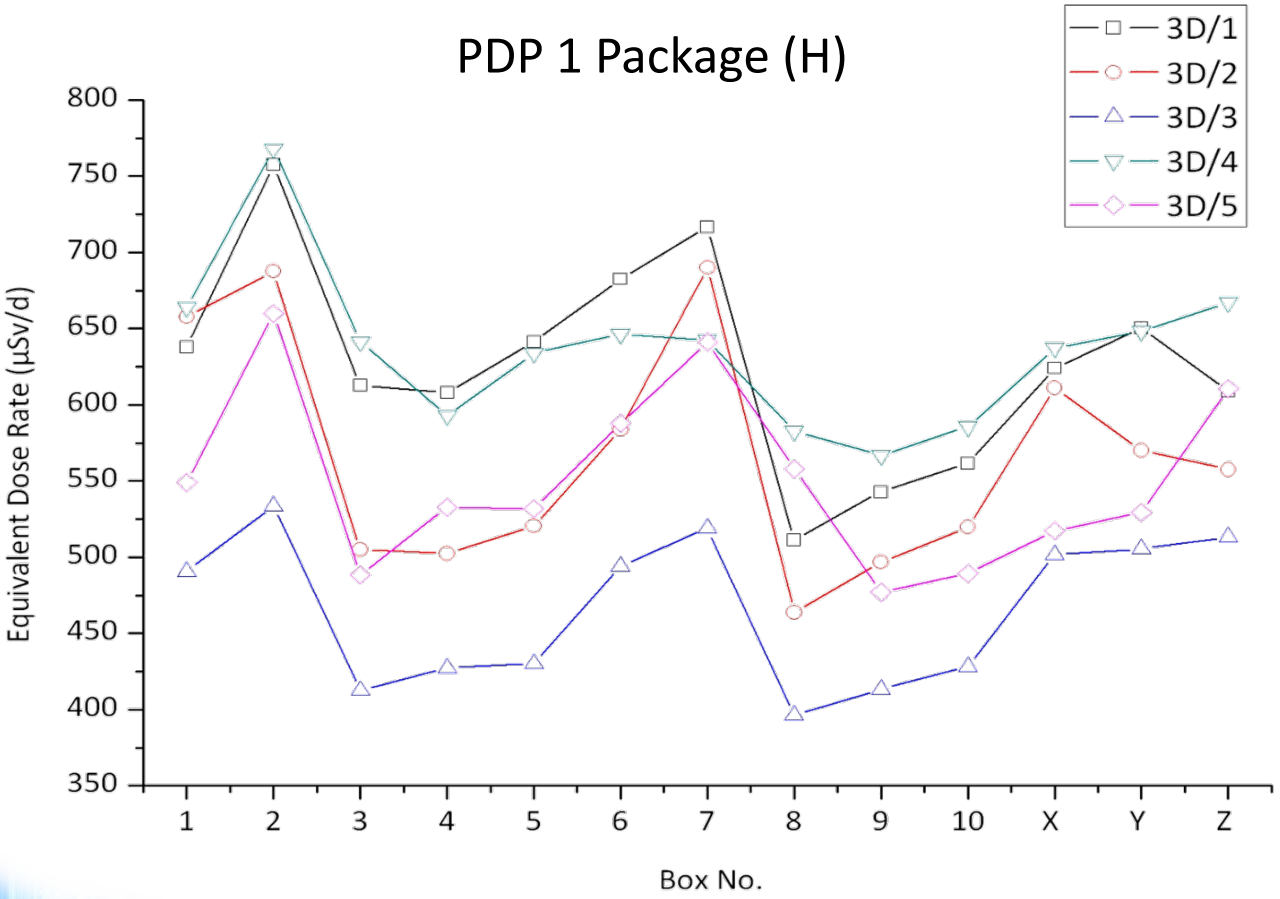


Results – Track Detectors (H)

- The Y and Z orientations were not constant



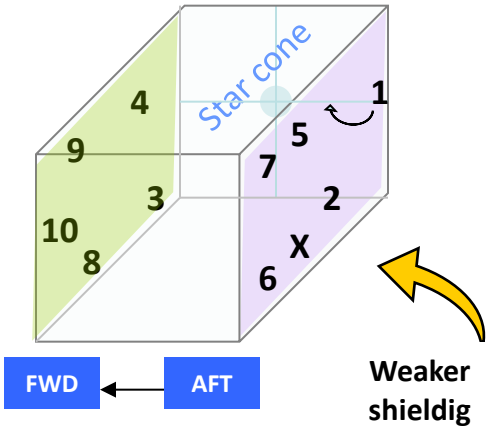




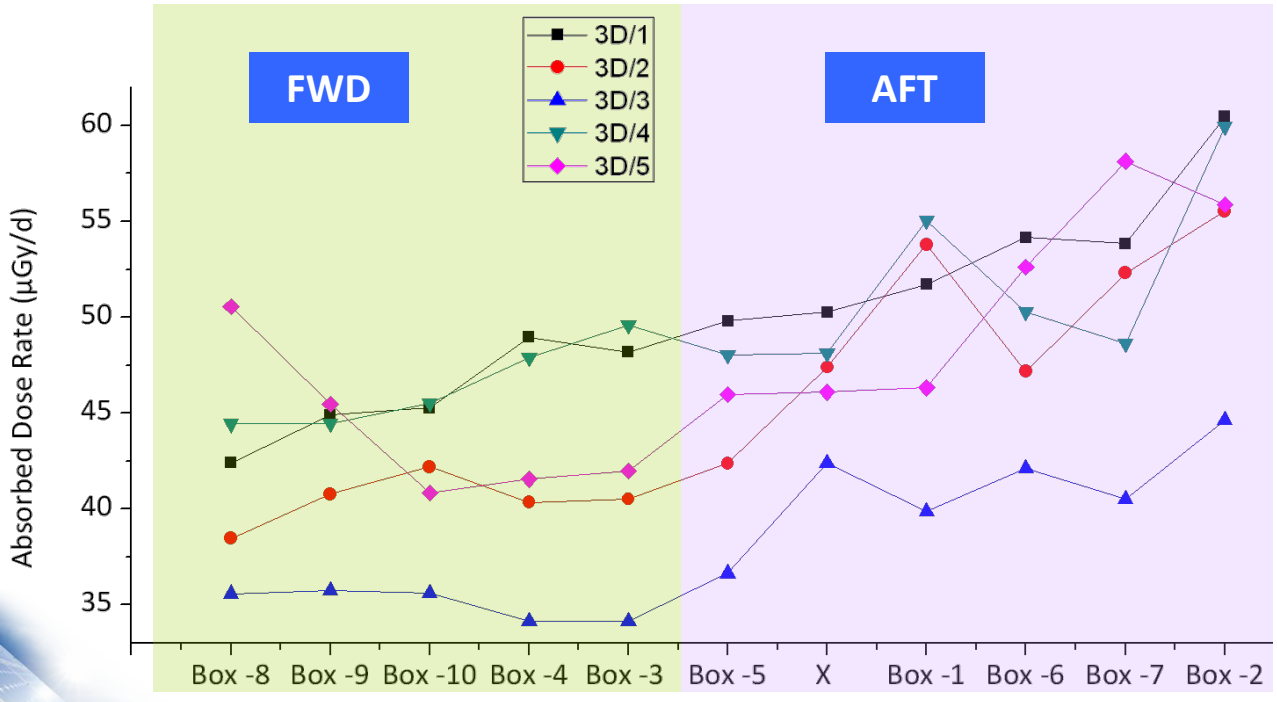
Results – Track Detectors (D)

- $D_{fwd} < D_{aft}$ tendency in most phases

Schematic view of Columbus module:

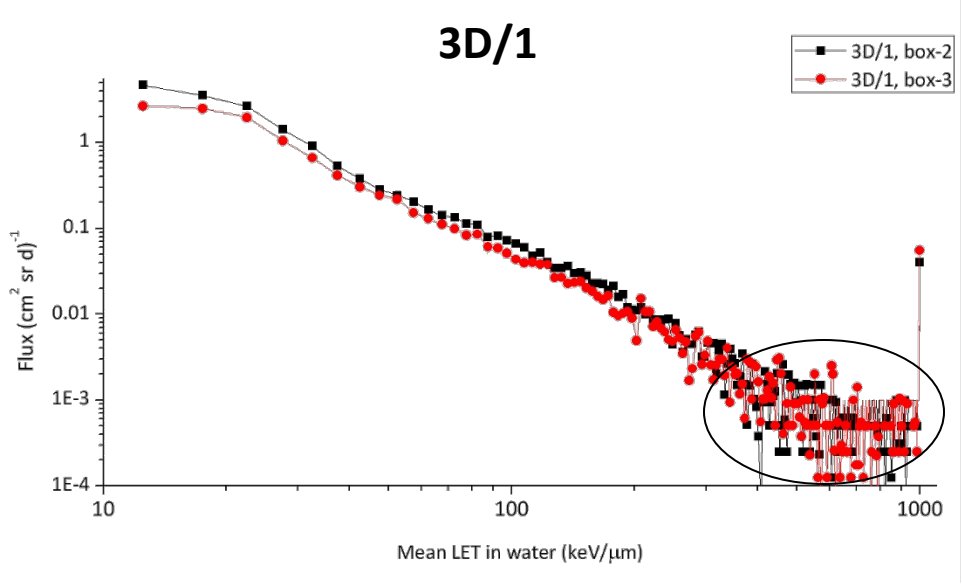


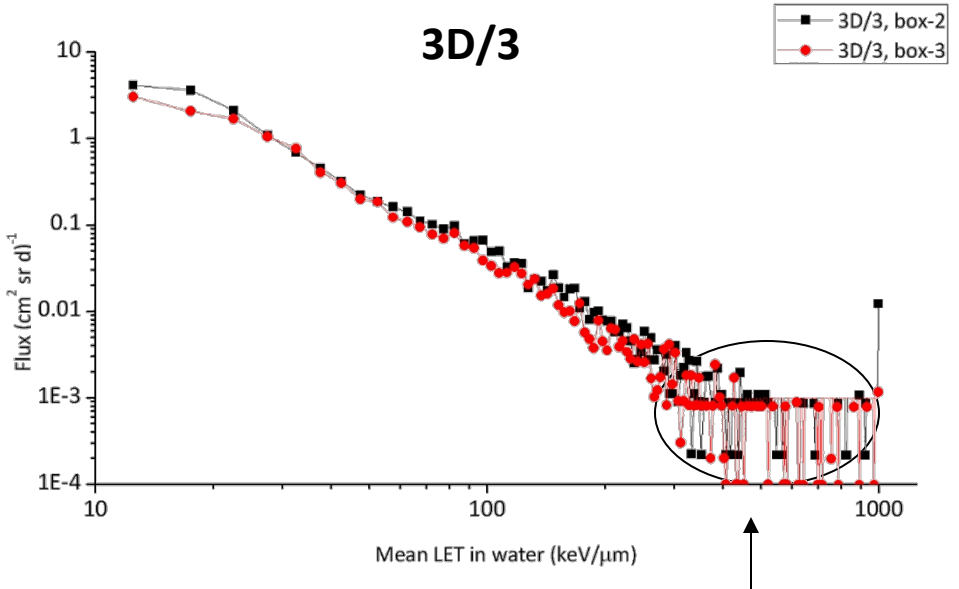
PDP 1 Package (D)



Boxes listed according to increasing D

Results - LET spectra





3D/1: highest overall dose rate
box-2: highest dose rate
box-3: lowest dose rate

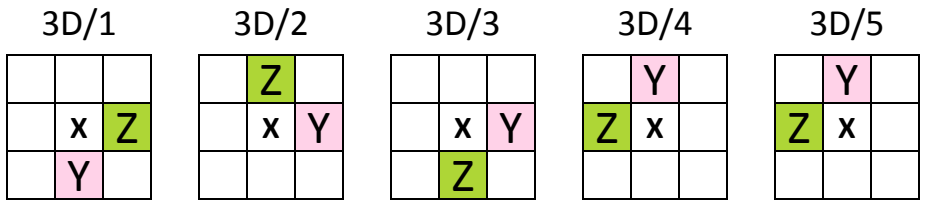
3D/3: lowest overall dose rate
box-2: highest dose rate
box-3: lowest dose rate

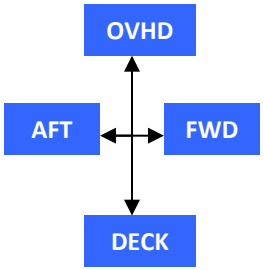
Very few particles over 200 keV/µm

- Space weather conditions were the same in average
- ~ 5 km higher altitude during 3D/3
- Differences in shielding?

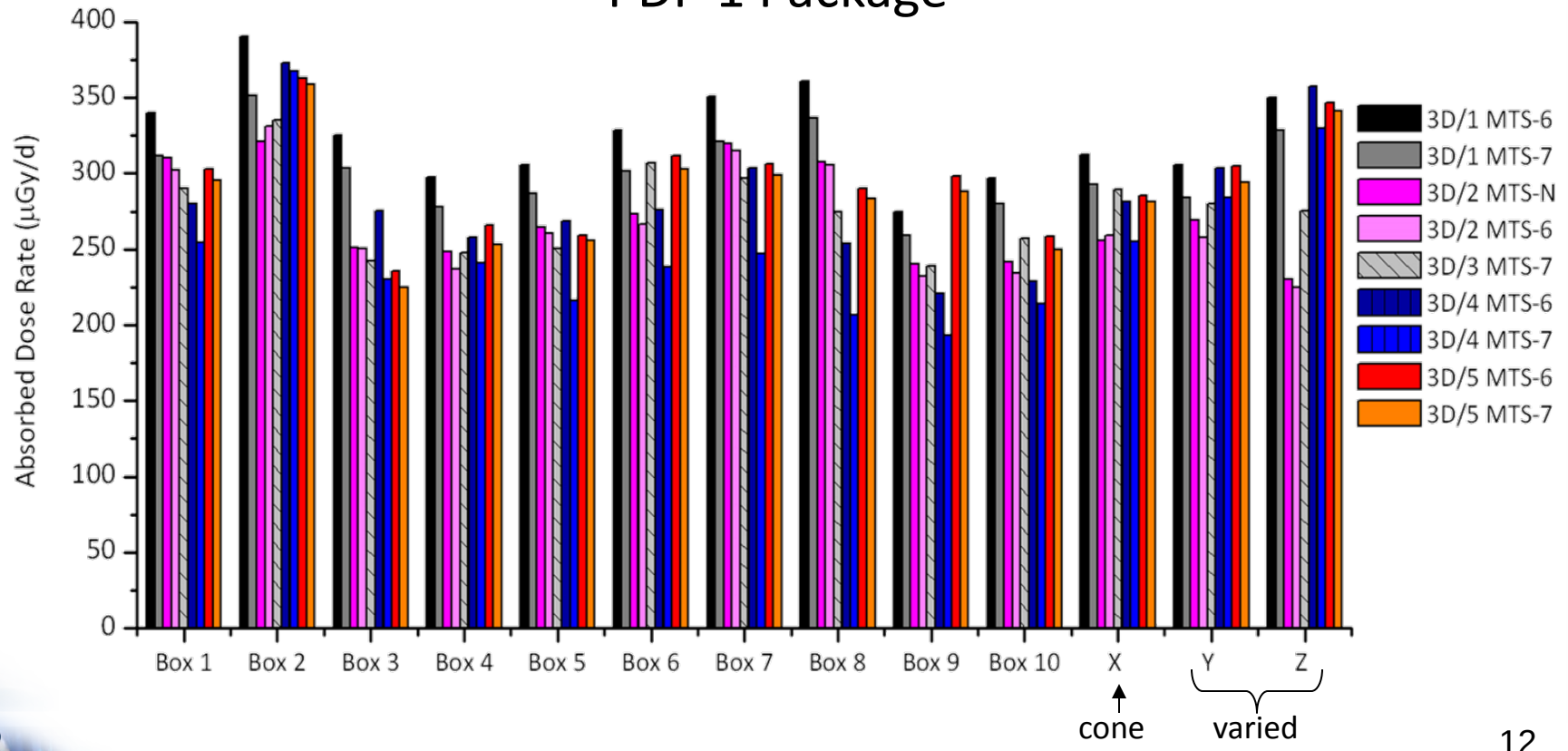
Results – Thermoluminescent Detectors

- The Y and Z orientations were not constant

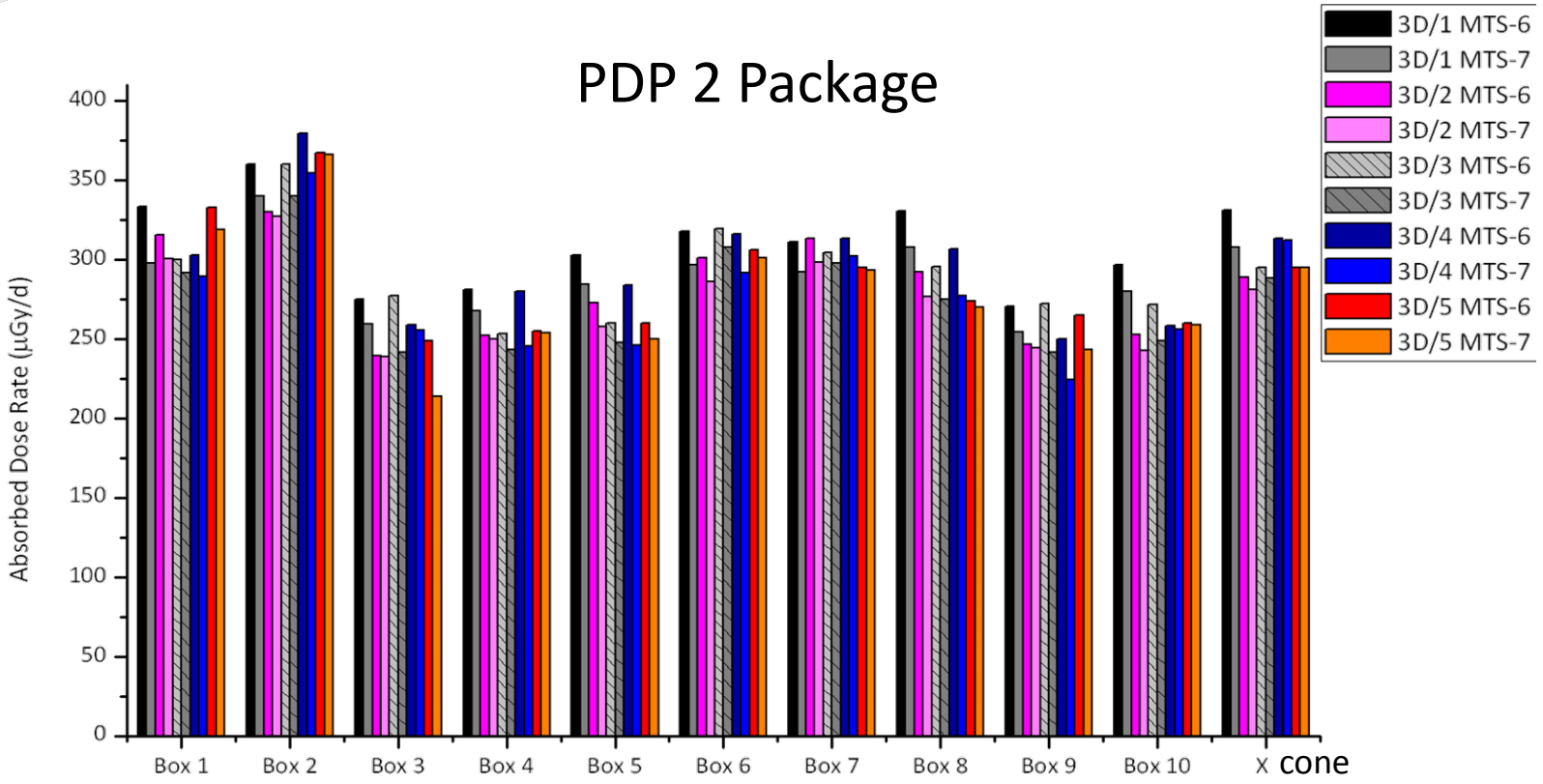




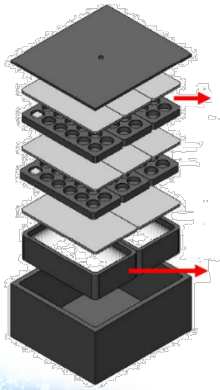
PDP 1 Package



Results – Thermoluminescent Detectors



Dosimetric package

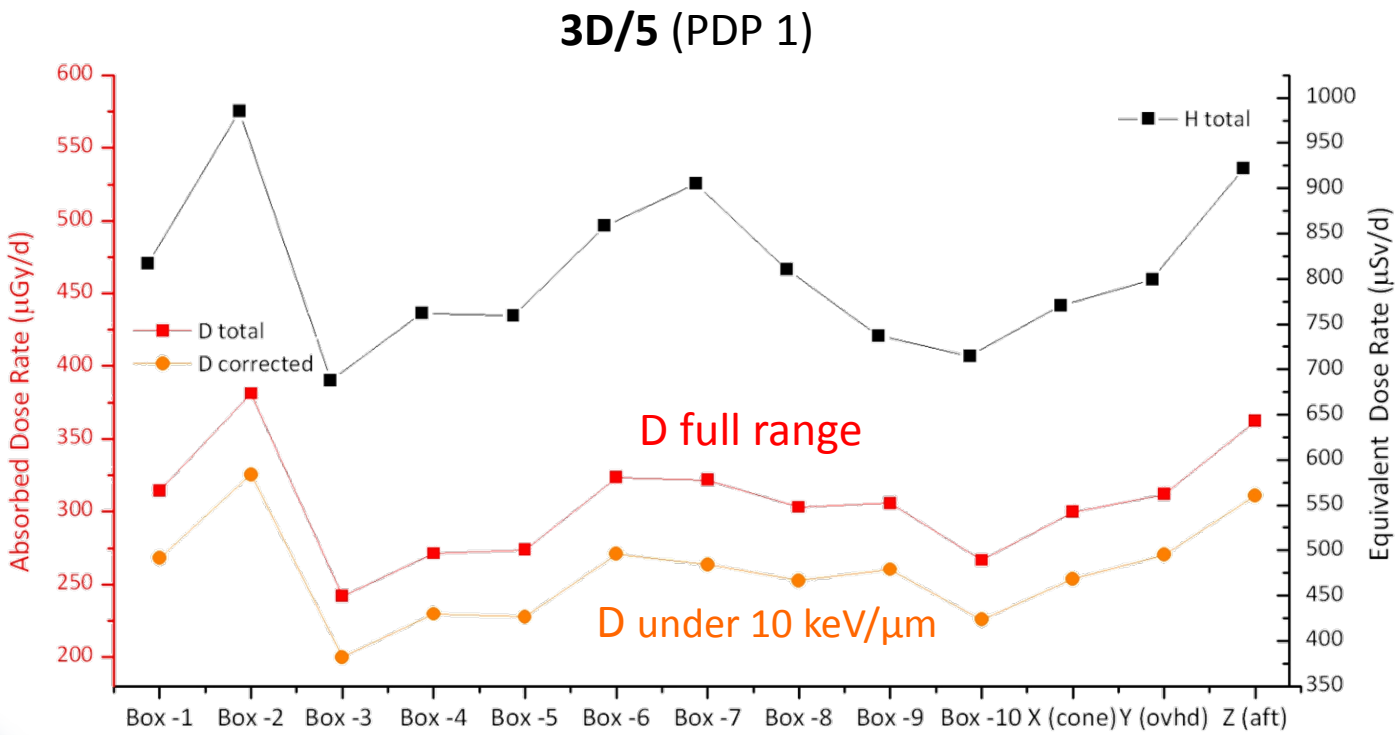


PDP 2: smaller differences of D in the successive phases
σ_D in average in the boxes: *MTS-6: ± 15 µGy/d; MTS-7: ± 12 µGy/d*

PDP 1: twice as high deviation of D
σ_D in average in the boxes : *MTS-6: ± 31 µGy/d; MTS-7: ± 27 µGy/d*

Latest Results – 3D/5 TLD & SSNTD combined

- Convolution of low LET (≤ 10 keV/µm) and high LET (≥ 10 keV/µm) portions of radiation using the TLD (MTS-7) and SSNTD results → total D, **total H**, average Q



Box No.	Average Q
1	2.60
2	2.58
3	2.85
4	2.81
5	2.77
6	2.65
7	2.81
8	2.67
9	2.41
10	2.68
X (cone)	2.57
Y (ovhd)	2.56
Z (aft)	2.54

Bilski, P., Berger, T., Hajek, M., Reitz, G., 2011. Rad.Meas. 46, 1680-1685.
Hajek, M., Berger, T., Vana, N., Fugger, M., Pálfalvi, J.K., Szabó, J., Eördögh, I., Akatov, Y.A., Arkhangelsky, V.V., Shurshakov, V.A., 2008. Rad. Meas. 43, 1231-1236.

Conclusions

- *Space weather*: increasing solar activity between 2014 and 2015 decreasing neutron monitor signal (Oulu) → decreasing number of high LET GCR particles
- *Changes in the altitude*
  3D/1→2: + 10 km
  3D/3, 4, 5 → ± 5 km
- The dosimetric values are influenced by the different shielding conditions of the boxes (*same tendency of dose rates at the locations* in all phases)
- The orientation of the 3D package was not constant → difficult to correlate the observed results
- Dose rates were *tendentiously lower in the forward direction* than in the aft in most phases (presumably due to the shielding diffetencies)
- Open question: 3D/3 – very few high LET particles (→ low D)?

Thank you for your attention!

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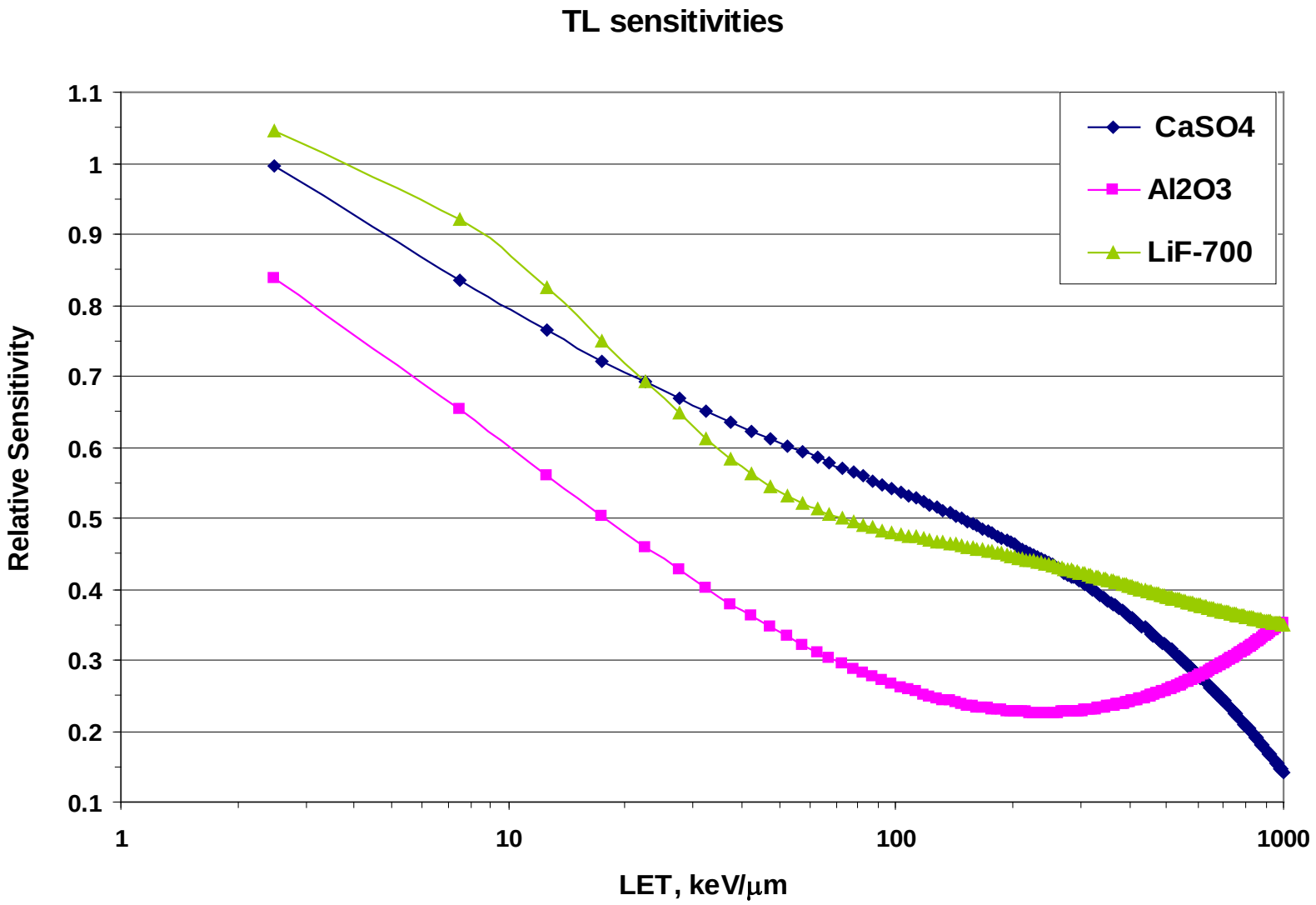
Photo by Samantha Cristoforetti

Backup


TL sensitivities
Relative Sensitivity
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
10
100
1000
LET, keV/μm
CaSO4
Al2O3
LiF-700