Geant4 high-accuracy simulations of the ISS radiation environment

and comparison to astronaut dosimetry

Progress Report

10/05/2012

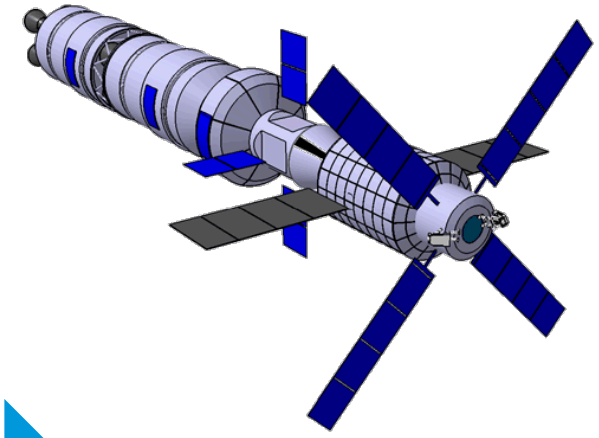
Outline

1. Motivation, background of project: manned interplanetary missions
2. The radiation environment and ISS
3. Geant4 modelling of ISS:
    a. MULASSIS
    b. SSAT / Shieldose2
    c. SSAT / MULASSIS
4. Comparison to astronaut dosimetry
5. Conclusions and applications to interplanetary missions

Motivation and background

ISS

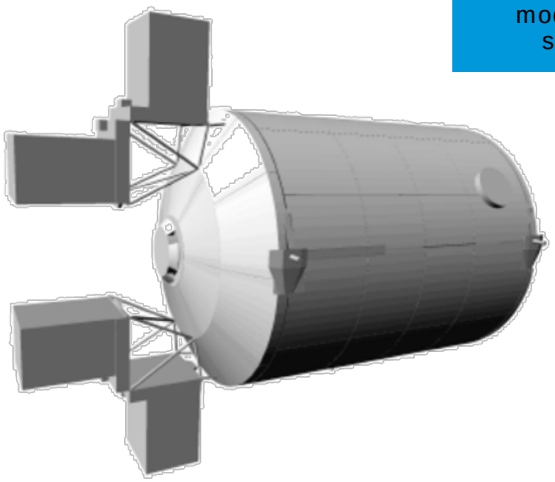
Interplanetary mission

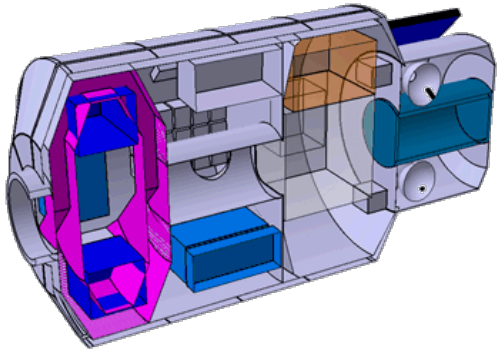


Accurately model manned spacecraft

Validate models with dosimetry

Model new manned missions





Ex: NEMS, EML-2

The radiation environment and setups

1. MULASSIS was used to simulate
    a. GCRs with the ISO-15390 model
    b. Trapped protons with the AP-8 model
    c. SPEs with ESP-PSYCHIC model

2. DOSIS I: DLR project, cross-comparison across many instruments
    a. Thermo Luminescence Detectors (TLD)
    b. Columbia Resin No. 39 (CR-39)

3. ISS: 350 km, Columbus module, summer 2009, 136 days

Experimental setup: MULASSIS

1. MULASSIS v1.22 compiled with Geant4.9.5.p01, physics scenario "hadron-em-ln "
2. Geometry from Ersmark (2006), with some modification from TAS
3. Small statistical scatter (100 000 events)

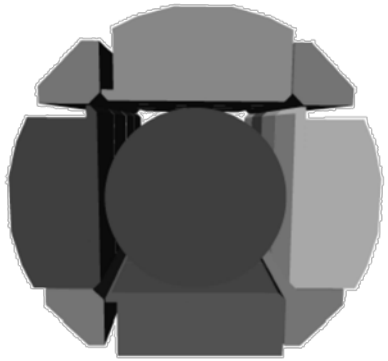
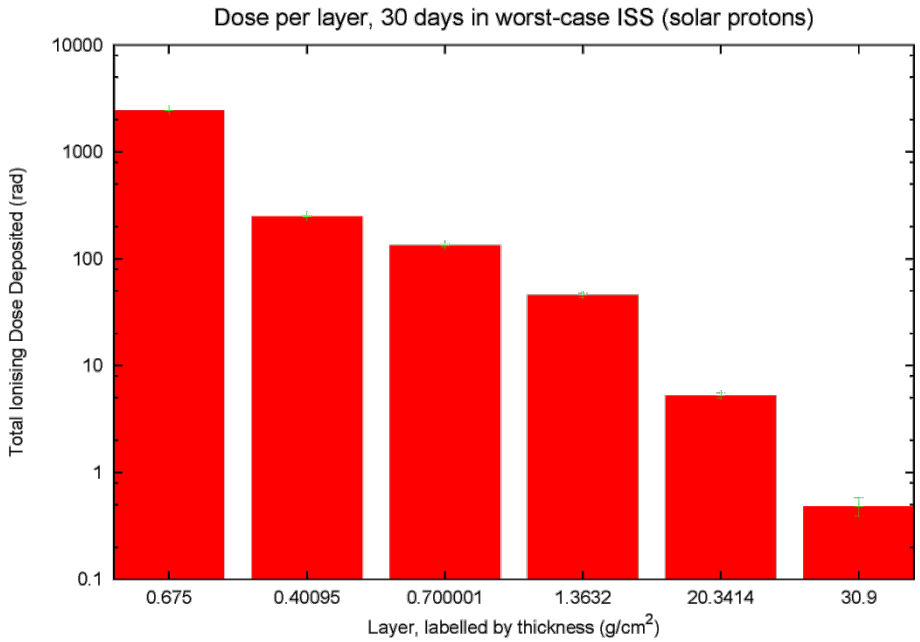


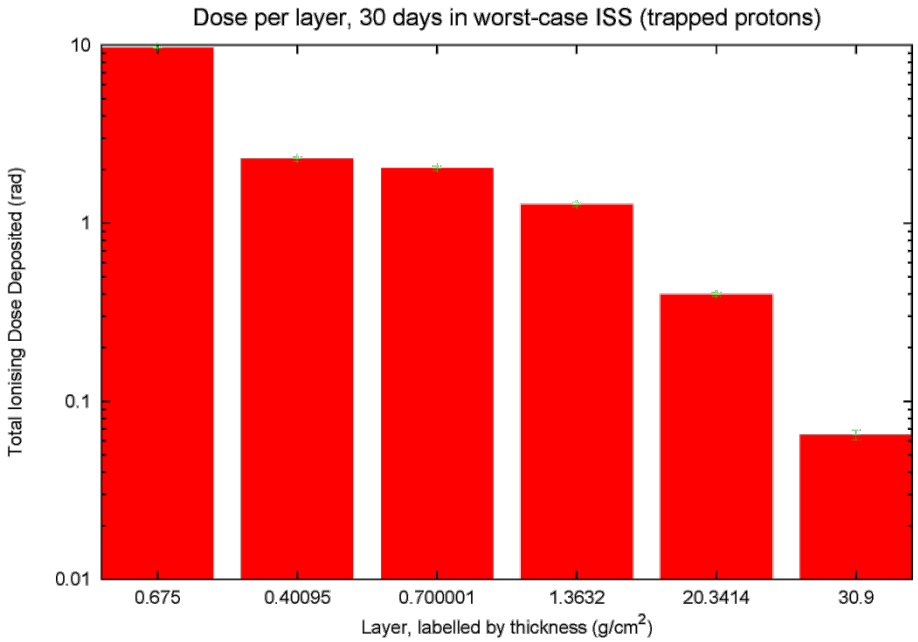
Table 1: Composition of slab model, and most of shell of 3-D model of Columbus

Material	aluminium	Nextel cloth	Kevlar + MLI	aluminium	equipment racks	phantom
Thickness (cm)	0.25	0.55	0.48	0.50	100	30

MULASSIS results 1

- Shielding characteristics of ISS:
- Very effective shielding of SPE flux
- Note the effect of the equipment racks





MULASSIS results 2: GCRs

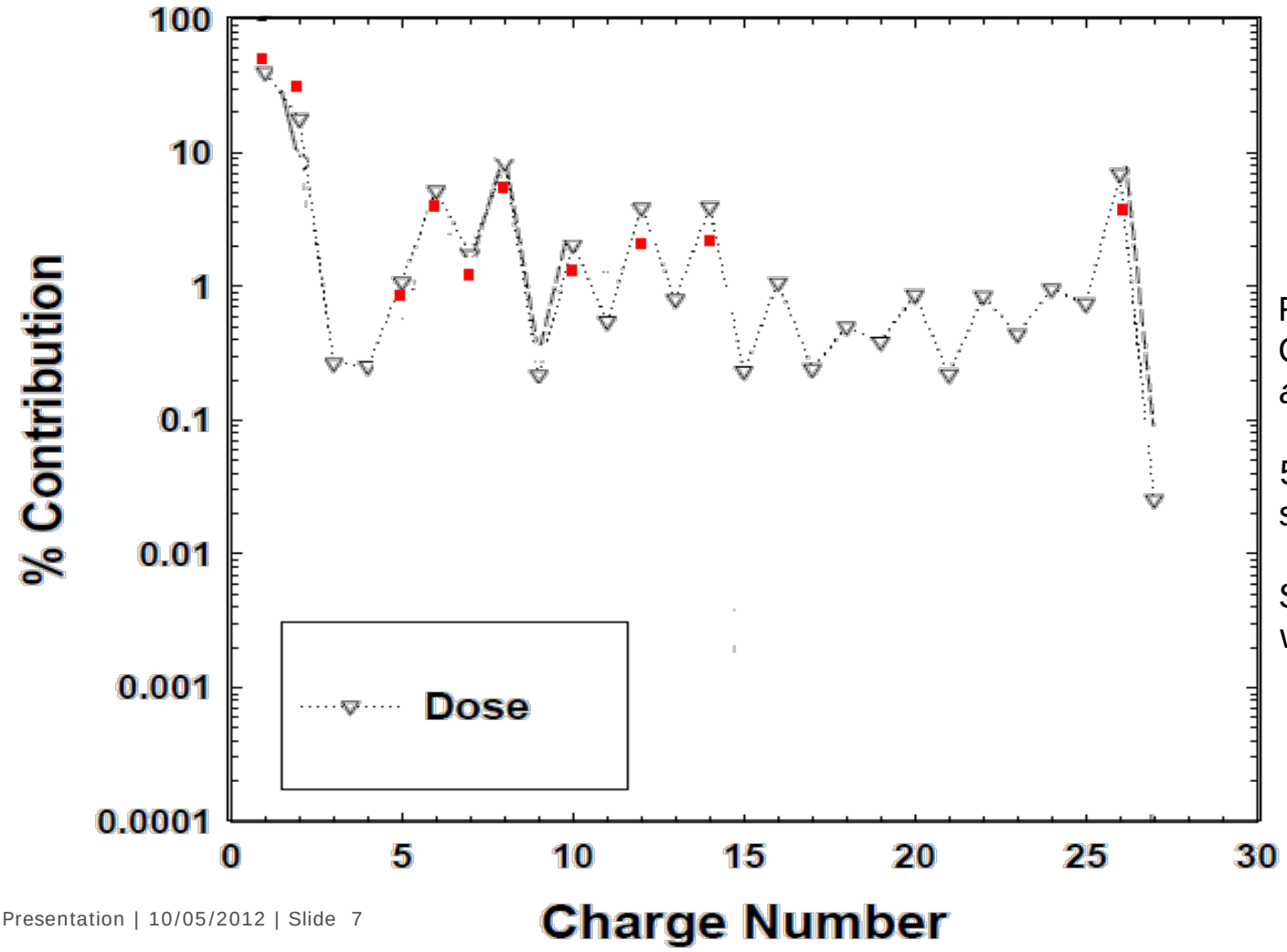
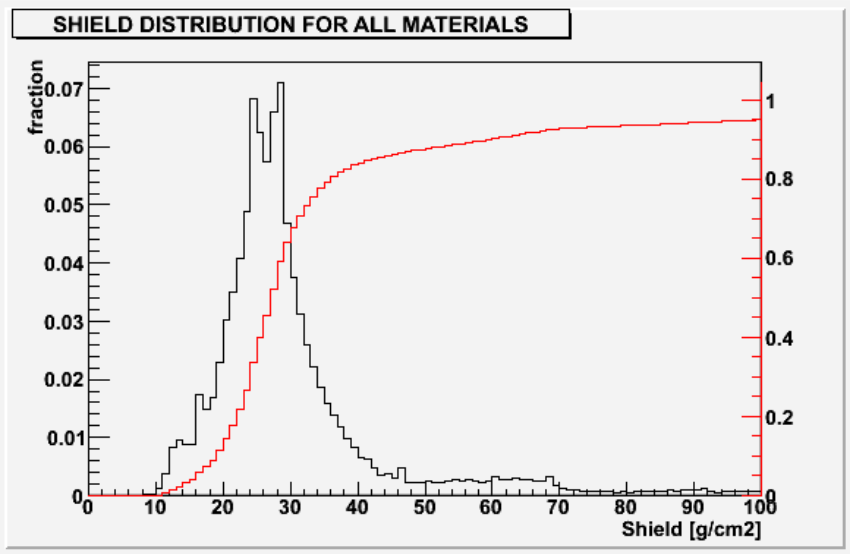


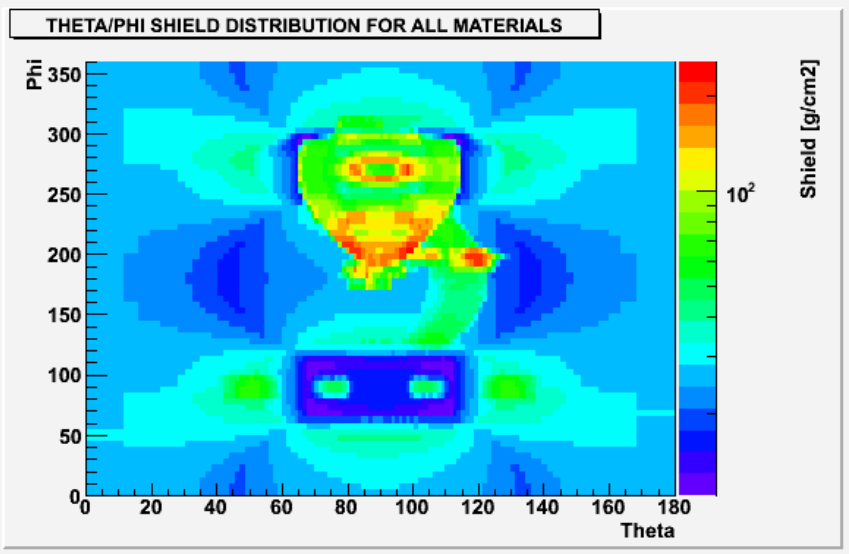
Figure from Cucinotta *et al.*, 2003

5 g/cm² shielding

Superimposed with 23 g/cm²

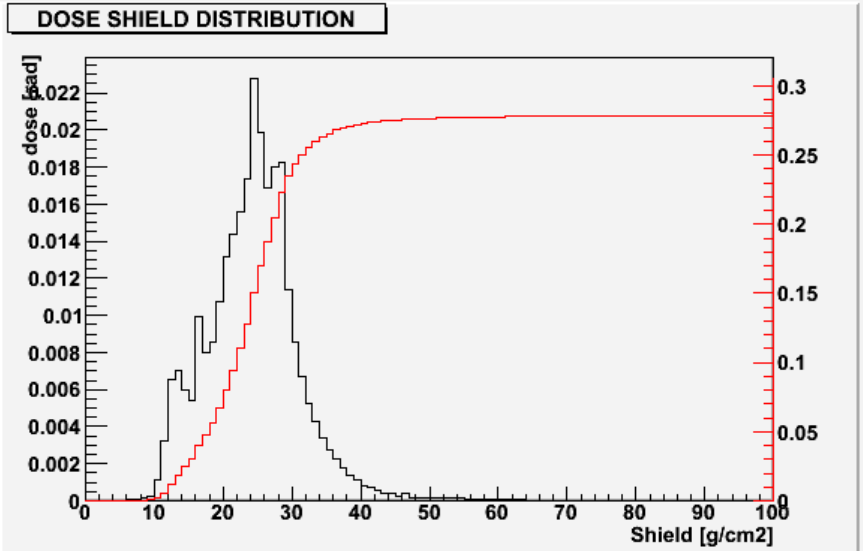
SSAT and Shieldose: Setup

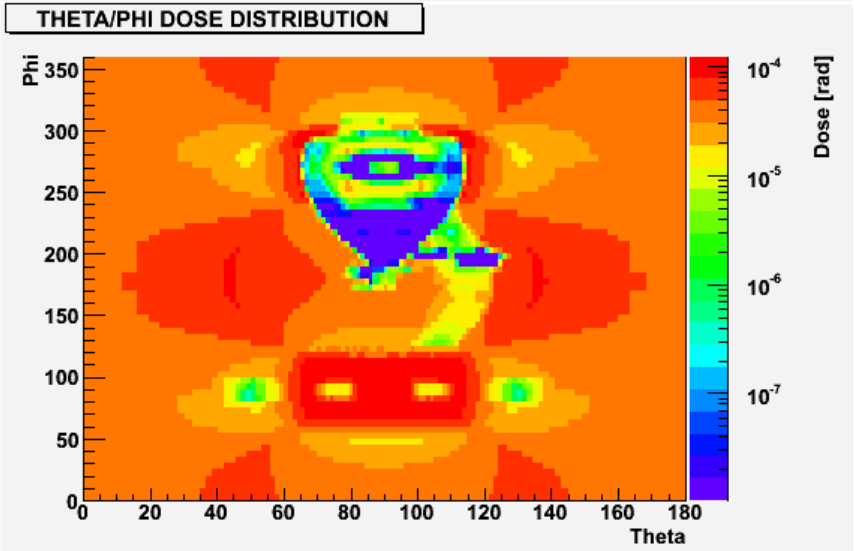




- Thick shields!
  - Minimum 10 g/cm²,
  - peak around 23 g/cm²,
  - half above 28 g/cm²
- Geometry adapted from Ersmark (2006)

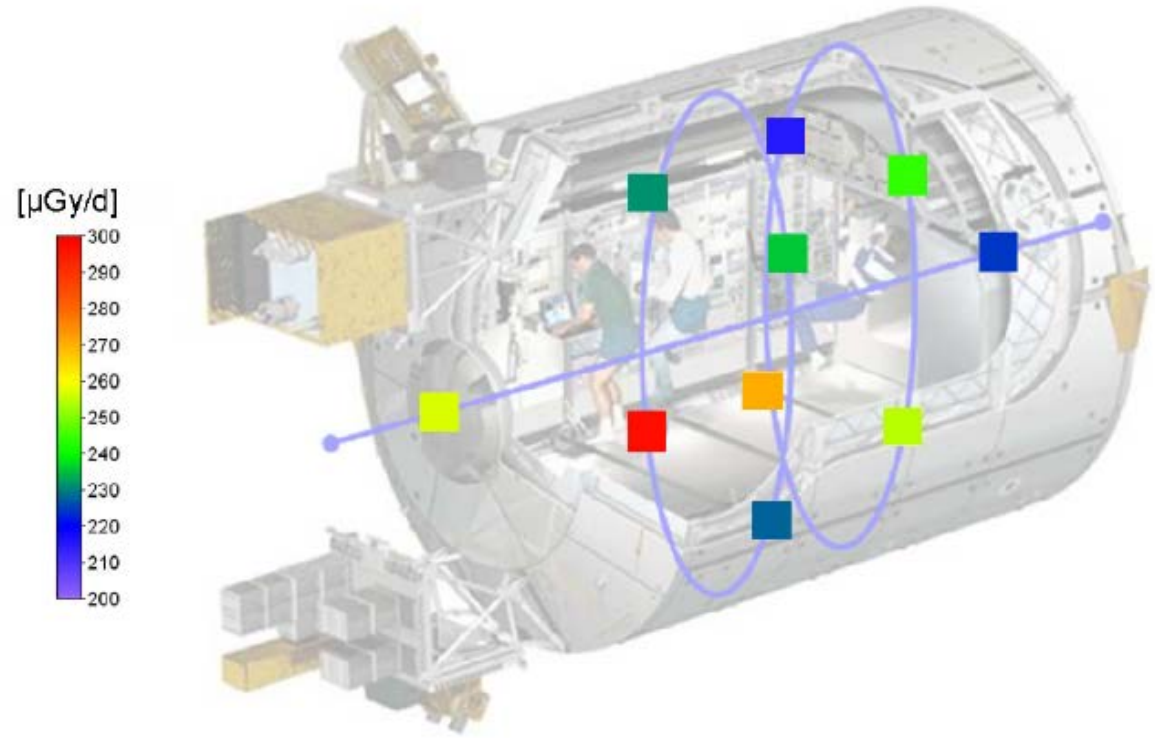
SSAT results





- SSAT folded with SHIELDOSE-2, for trapped protons
- Obtain 93 µG/d
- Note uneven shielding, which should be more
  - Dose underestimation

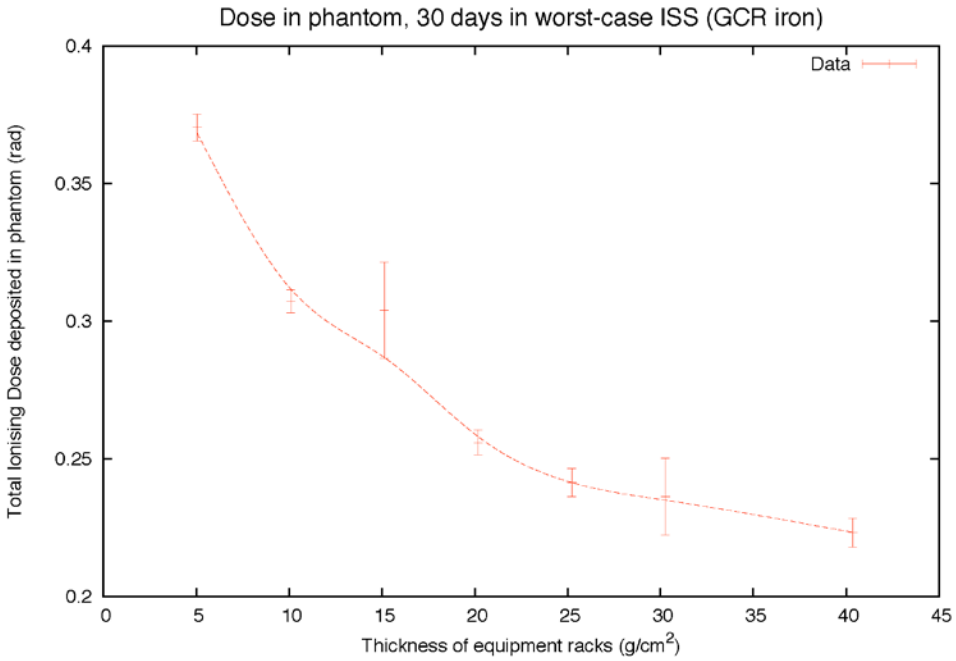
ISS dosimetry



Picture from Christine Hill's Diploma thesis (2010), DLR DOSIS I experiment

- Important variation from nearby equipment!
- Consistent with previous results (G. Reitz, 2005), which indicate 80-100 µGy/d from trapped protons, rest from GCRs

Results comparison



1. SSAT/SHIELDOSE2 within experimental scatter for trapped protons
2. Differences in spatial distribution can be accounted for partly with current models
3. Internal geometry likely accounts for rest.

Conclusions

1. First results with ISS geometry consistent with dosimetry
2. In-depth comparison of MC with dosimetry to follow
3. Next step: MULASSIS results into SSAT: GCR component; full Monte Carlo with GRAS
4. Validation of modelling tools for interplanetary missions
5. First lessons:
    a. In manned missions, internal arrangement of spacecraft can be critical
    b. Very high shielding levels are already achieved
    c. GCR long-term dose is the main challenge