Simulations of MATROSHKA-R experiment 2006 at the ISS using PHITS

Z. Kolísková (Mrázová)[1,2], I. Ambrožová[1], L. Sihver[3,4,5,6], T. Sato[7] and V.A. Shurshakov[8]

[1]NPI AS CR, Czech Republic, [2]CTU in Prague, Czech Republic, [3]Chalmers, Sweden, [4]Roanoke College, Virginia, USA, [5]TEXAS A&M, College Station, USA, [6]University of Houston, USA, [7]JAEA, Japan, [8]IBMP, Russia

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Content

- Brief introduction of PHITS, MATROSHKA-R experiment and geometry of simulations
- Comparison of experimental and simulated data of MATROSHKA-R experiment 2006
- Results of simulations using 3 g/cm^2 and 5 g/cm^2 Al as the ISS shielding

PHITS

- Three-dimensional Monte Carlo Particle and Heavy Ion Transport code System
- Developed by JAEA, RIST, KEK and Chalmers
- Complex models for high energy heavy ions transport calculations based on the JQMD model
- Nucleus 0 $\sim$ 100 GeV/u, neutrons 10^{-5} eV $\sim$ 200 GeV, protons 0 $\sim$ 200 GeV, photons and electrons 1 keV $\sim$ 1 GeV, baryons, mesons . . .

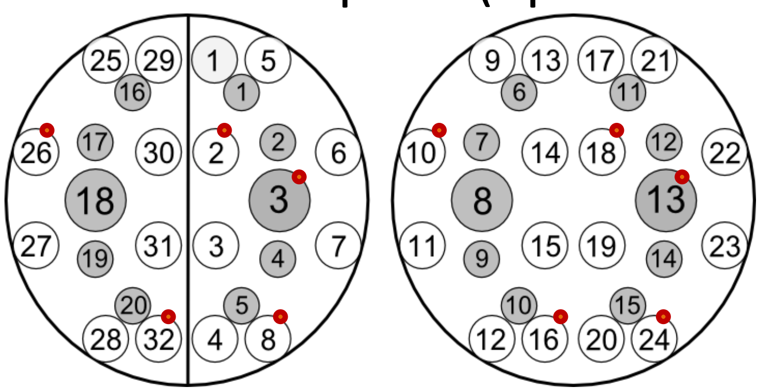
MATROSHKA-R

Russian tissue-equivalent (TE) spherical phantom

- Diameter of phantom 35 cm, mass 32 kg, cavity of diameter of 10 cm inside the phantom
- 32 pockets on the surface of the phantom
- 4 equatorial thick and 16 thin containers inside the phantom (detectors can be placed in various depths)

Matroshka-R experiment 2006

- Onboard Russian Service module Zviezda, at the ISS from Dec. 21, 2005 to Sept. 20, 2006 (273 days)
- Dose in water measured by combination of thermoluminescent (TLD) and plastic nuclear track detectors (PNTD)
- NPI measured dose in 8 pockets on the surface of the phantom and in 10 depths (up to 9.5 cm) of two equatorial containers



- The left hemisphere was oriented towards the inside of the ISS, the right hemisphere towards the wall of the ISS
- Detectors placed in:
  Pockets no. 2, 8, 10, 16, 18, 24, 26, 32
  Containers no. 3 and 13

Gray filled circles represent the containers, non-filled circles the pockets.

More about the experimental results:

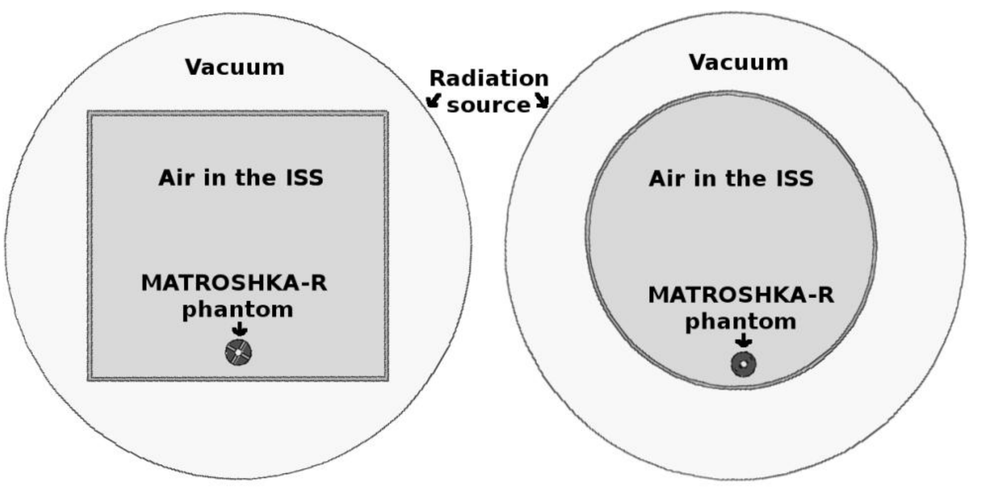
- *Jadrníčková, et al. Dose characteristics and LET spectra on and inside the spherical phantom onboard of ISS, Radiation Measurements 45, 1536-1540, 2010.*

Simulation geometry

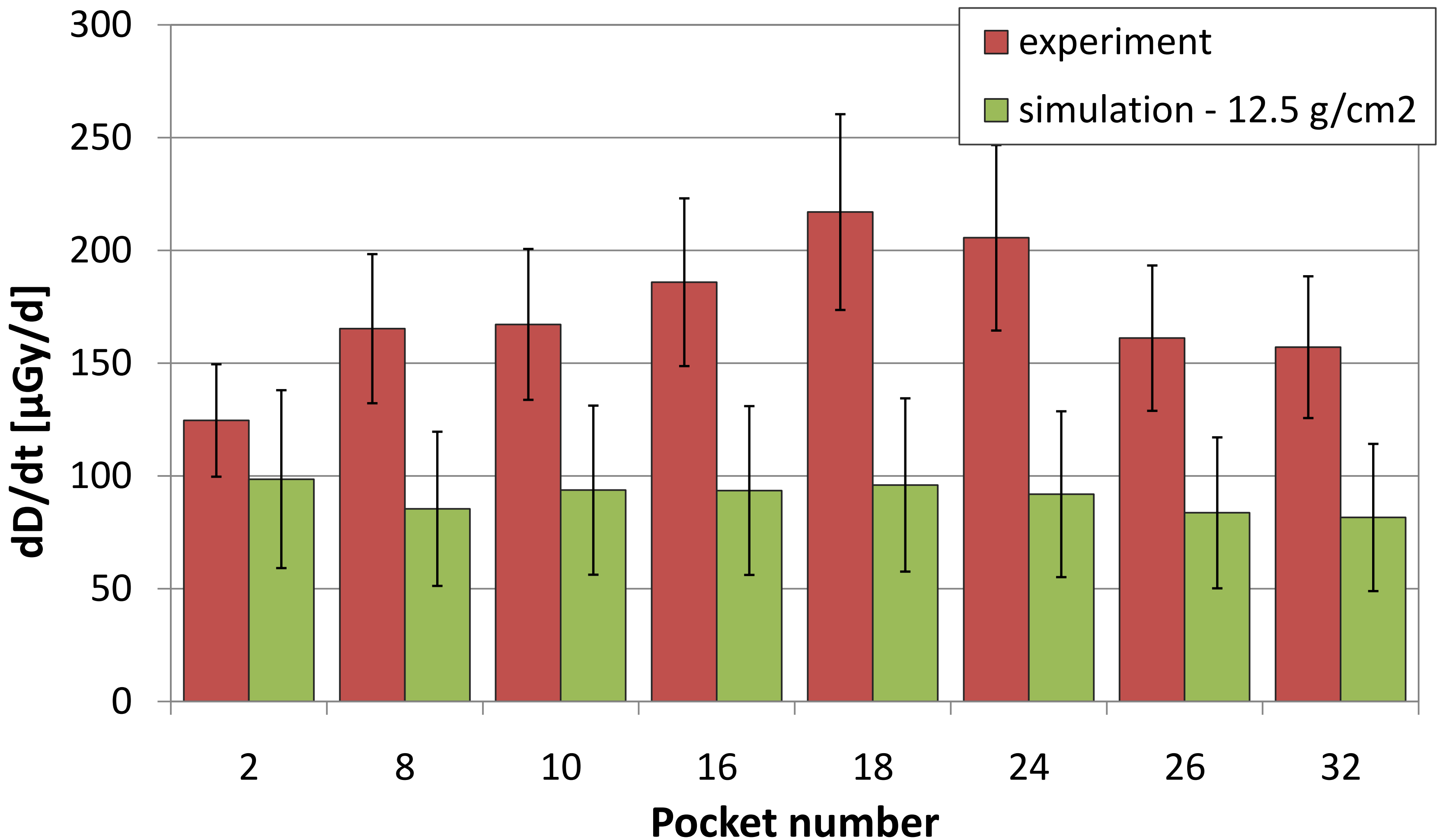
- Phantom - TE sphere of a diameter of 35 cm with spherical air cavity of a diameter of 10 cm, covered by TE jacket with pockets
- ISS - Al cylinder of a length of 400 cm and a diameter of 400 cm, of a mass thickness of 3 g/cm^2 , 5 g/cm^2 and 12,5 g/cm^2
- Isotropic radiation source

  - Energy spectrum of GCRs (H-Ni) from CREME96 and TPs using AP8-min model, both for an altitude of 345 km

  - SPEs and TEs not considered

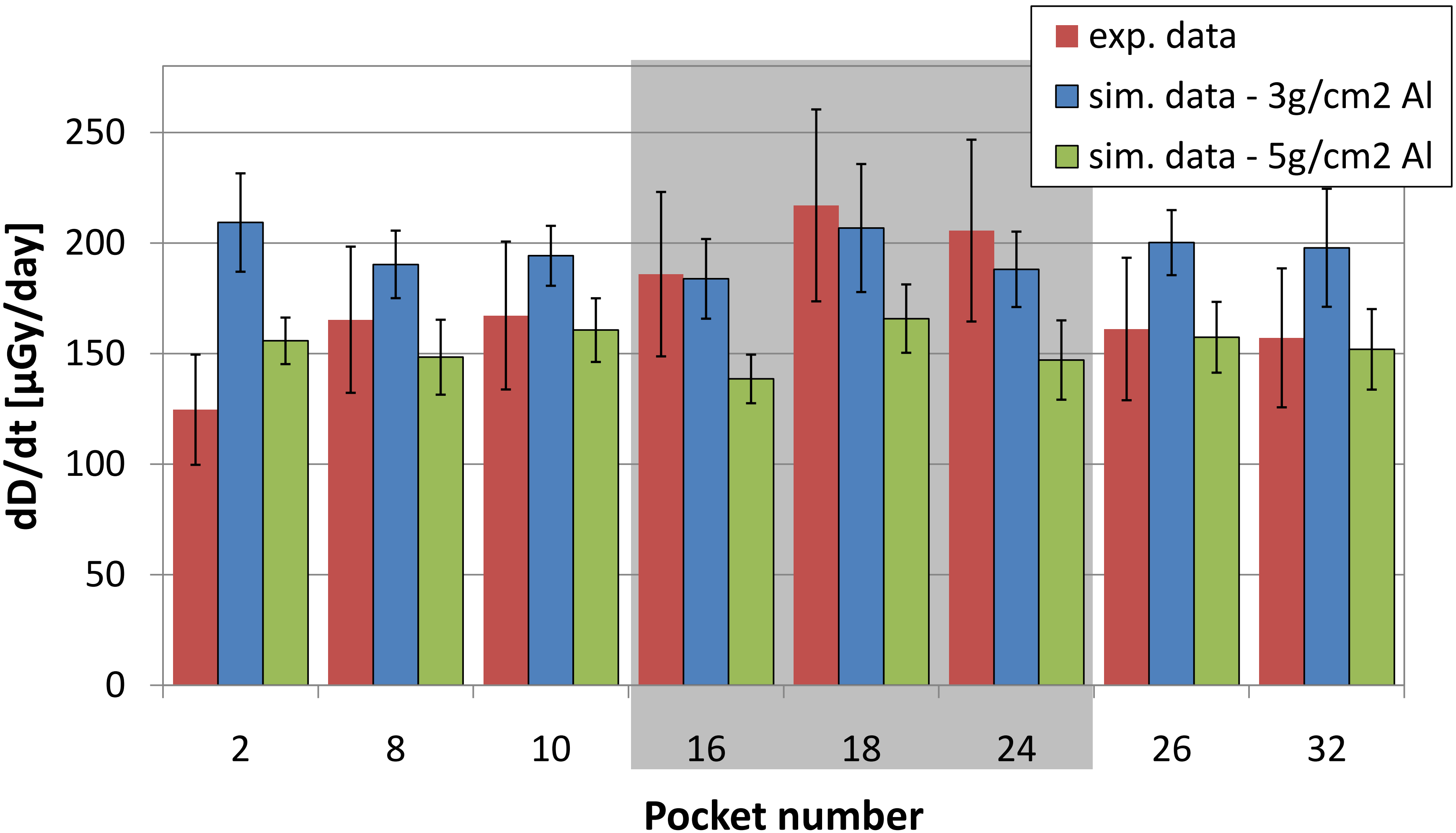


Comparison of calculated and measured abs. doses in 8 pockets of Matroshka-R phantom



Only statistical uncertainties are considered for the calculated data.

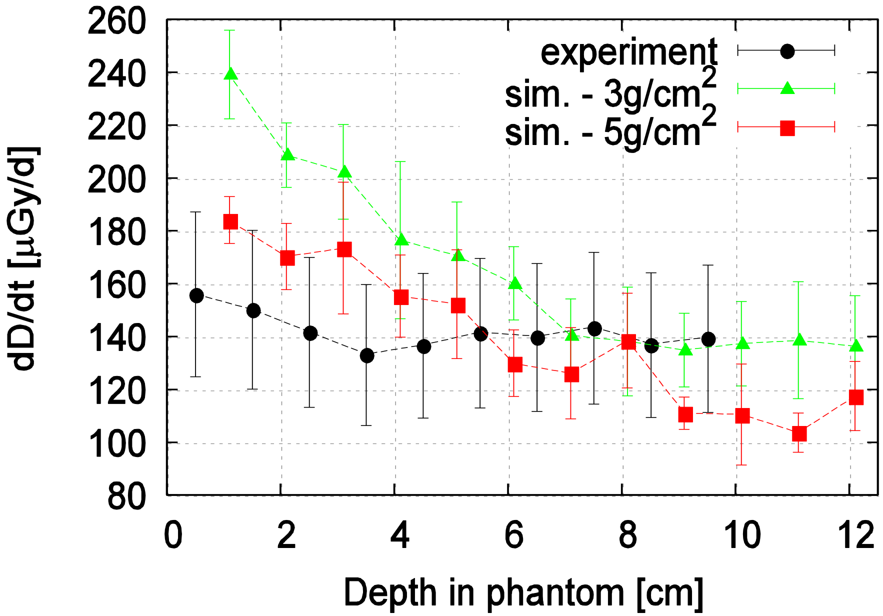
Comparison of calculated and measured abs. doses in 8 pockets of Matroshka-R phantom



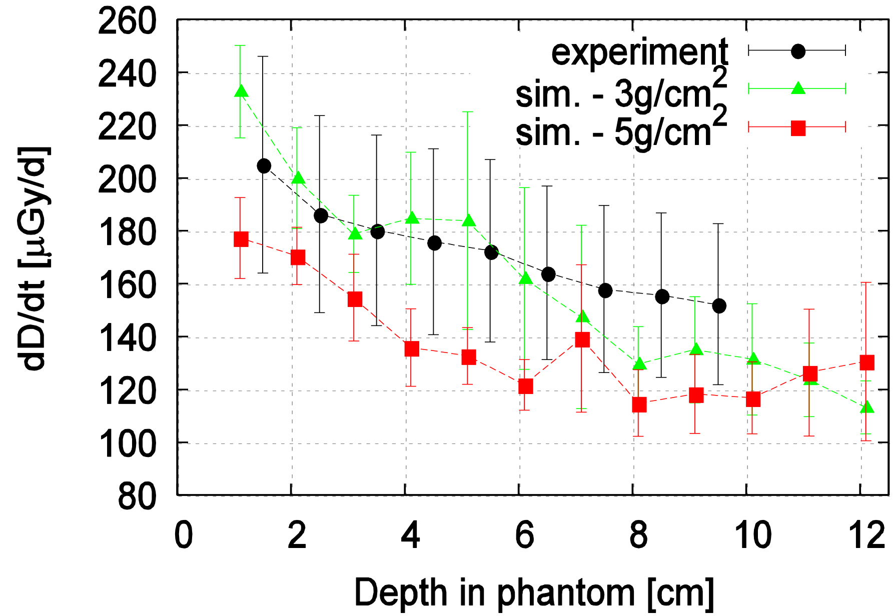
Only statistical uncertainties are considered for the calculated data.

Comparison of simulated and measured abs. doses in 2 Matroshka-R equatorial containers

Container no. 3: orientated toward inside of the ISS

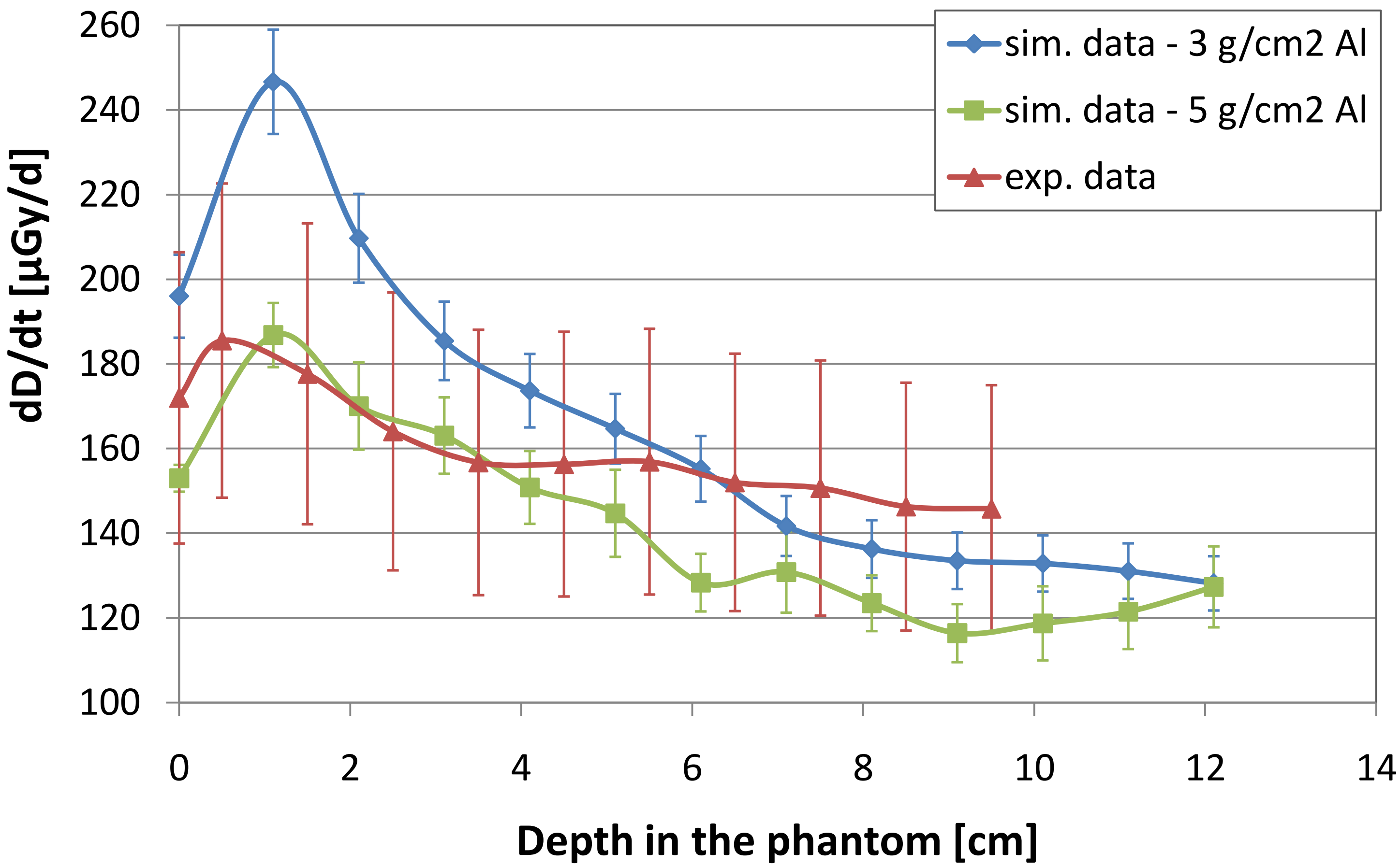


Container no. 13: orientated toward the wall of the ISS



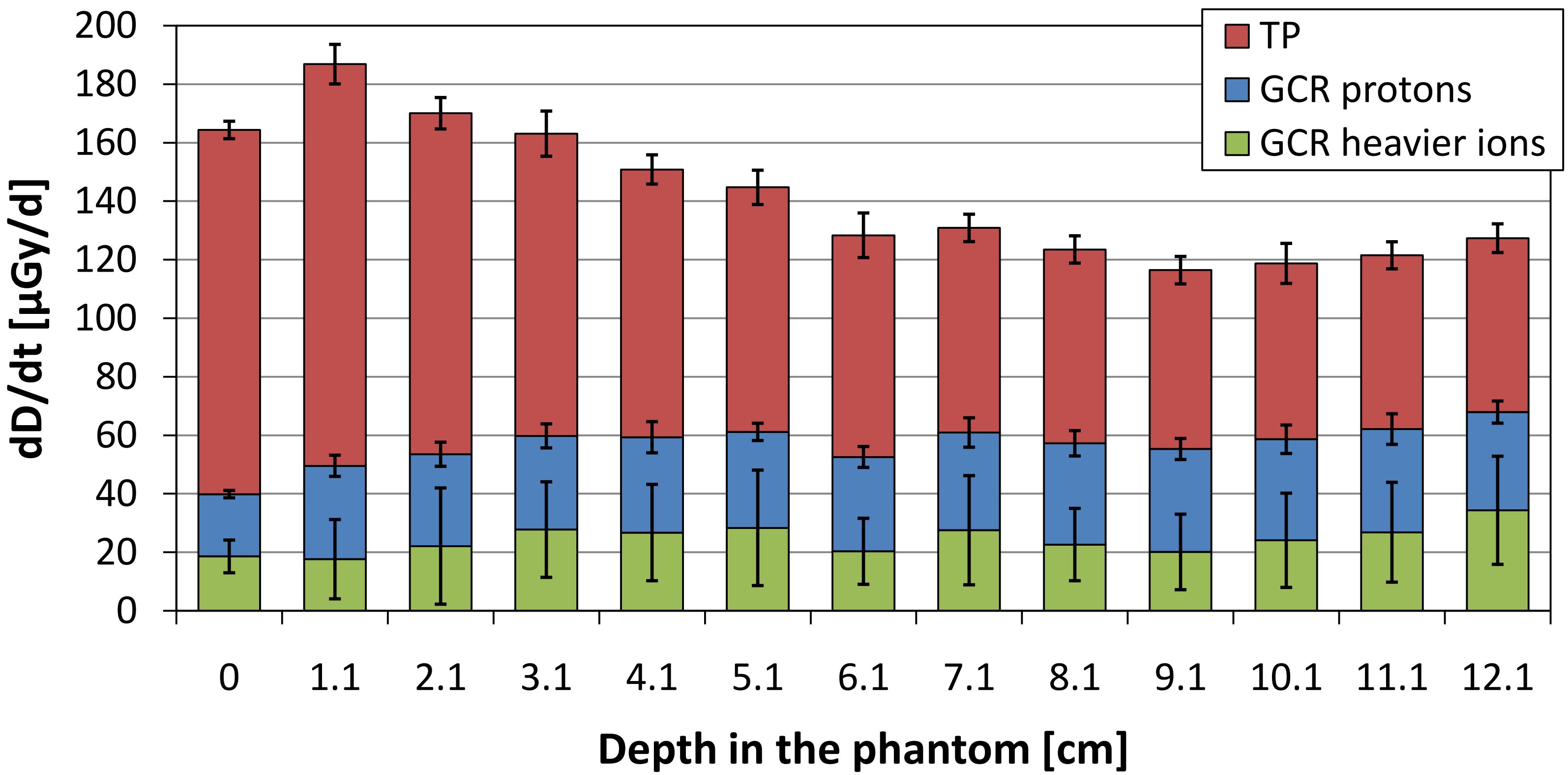
Only statistical uncertainties are displayed for simulation data.

The average absorbed dose depending on the depth in the phantom



- The minimal and maximal radiation risk of astronauts can be estimated by calculation using Al shielding of 5 and 3 g/cm^2 mass thickness.

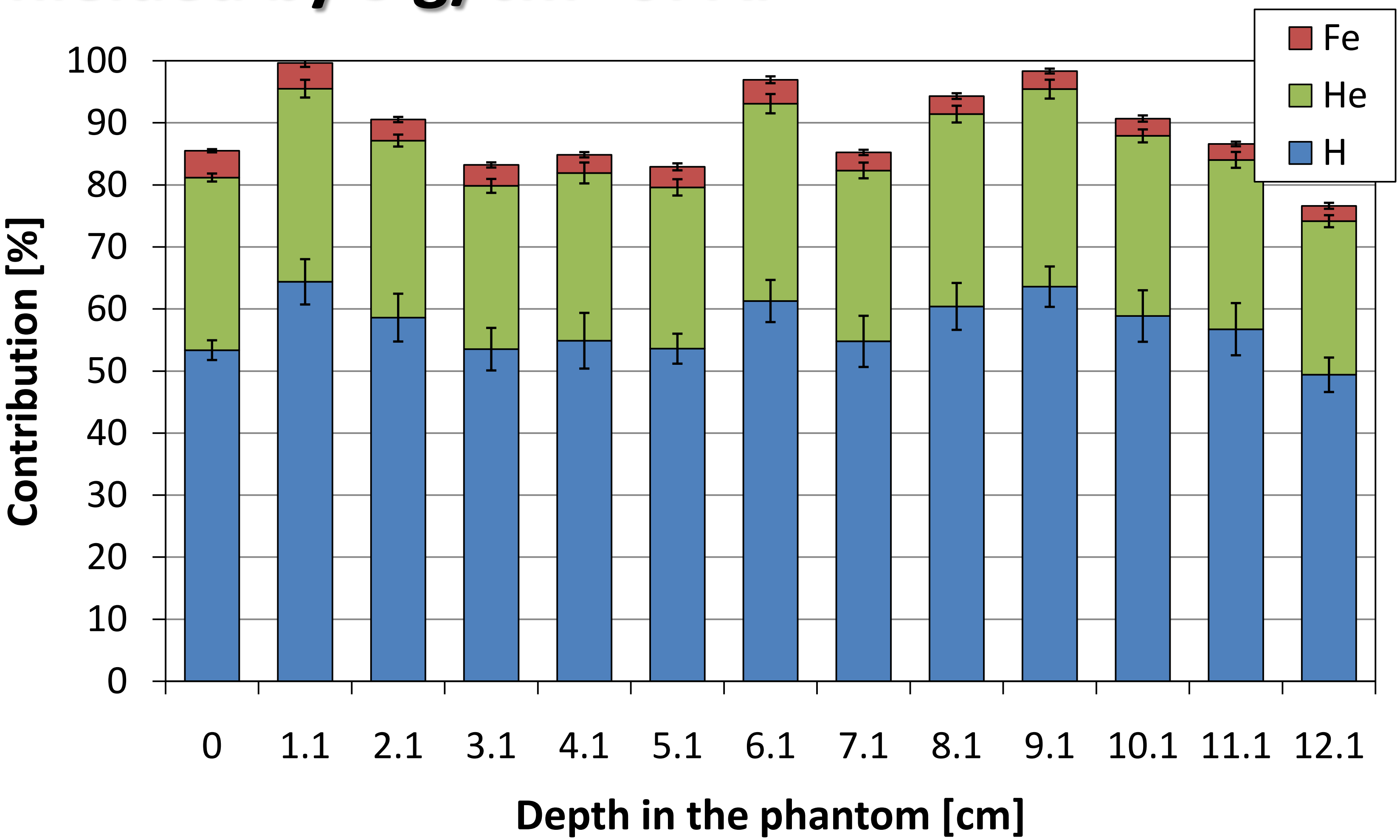
Contribution of TPs and GCRs to the total absorbed dose in the phantom shielded by 5 g/cm^2 of Al



Only statistical uncertainties are considered for the calculated data.

- 5 g/cm^2 shielding: contribution of TPs 76 -47 %, GCRs 24-53 %
- 3 g/cm^2 shielding: contribution of TPs 82 -57 %, GCRs 18-43 %

Contribution of H, He and Fe ions to the GCR absorbed dose in the phantom shielded by 5 g/cm² of Al



Only statistical uncertainties are considered for the calculated data.

Summary

- The experimental data from the Matroshka-R experiment 2006 are in best agreement with PHITS simulations using Zvezda module shielding of a mass thickness of 3-5 g/cm^2

- Simulations show that
  - contribution of the GCRs to the total absorbed dose increases with increasing depth in the phantom
  - contribution of particular GCRs ions to GCR absorbed dose remains constant with depth in phantom

- For better estimation of radiation risk inside ISS Zvezda module, more additional shielding of about 2 g/cm^2 should be added in the geometry

Q & A

Thank you for your attention.