Simulations of MATROSHKA experiments at ISS using PHITS

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Content

- Particle and Heavy Ion Transport code System – PHITS
- Simulations
- Summary and conclusions
- Ongoing activities and future plans
Introduction of PHITS
Particle and Heavy Ion Transport code System

Development
Dr. Niita of RIST (Japan)
JAEA (Japan), KEK (Japan), Chalmers Univ. Tech. (Sweden)

Capability
Transport and collision of “all” particles with wide energy range
- in 3D phase space with magnetic field & gravity
- neutron, proton, meson, baryon
- electron, photon, nucleus
- from thermal up to ~ 100 GeV/u

Application Fields
- Accelerator Design
- Radiation Therapy
- Space Application
MATROSHKA

Launch: 29. January 2004
EVA: 26. February 2004
Exposure time outside: 539 days
External particle fluxes calc. with CREME96

- During the period MTR was outside the ISS
  - 26th of February 2004 to 18th of August 2005 => 539 days
  - apogee 364 km, perigee 345 km, inclination 52 °

- A spherical radiation source, with a diameter of 345 cm, was used in the simulations

- The particles from the source were emitted inward, creating an isotropic environment inside the sphere

- Simulations were performed separately for Trapped Protons (TP) and Galactic Cosmic Radiation (GCR)
External particle fluxes calc. with CREME96

- Fluxes of the TP and the GCR used in the simulations
- Particles from p (Z=1) to Ni (Z=28) were included in the GCR
  For GCR only the fluxes of representative ions are shown
MATROSHKA simulations

- Outside ISS
- Simplified geometry with no shielding from ISS

Al foundation
Density: 2.7 g/cm³
Thickness: 1 g/cm²

MATROSHKA phantom
Polyurethane
Density: 1 g/cm³

Container
Carbon fiber
Density: 1 g/cm³
Thickness: 1 g/cm²

Vacuum
MATROSHKA simulations - no shielding from ISS

Next step:
- Include shielding from ISS
- Use a phantom based on voxel data from a CT scan of the exp. phantom

Good agreement!
MATROSHKA simulations

Using “NUNDO” constructed by M. Puchalska et al. on base of the CT scans of the RANDO® phantom

Al foundation
Density: 2.7 g/cm³
Thickness: 1.35 g/cm²

MATROSHKA phantom
Polyurethane
Density: lungs – 0.35 g/cm³
bones – 1.3 g/cm³
rest - 1 g/cm³

Container
Carbon fiber
Density: 0.35 g/cm³
Thickness: 0.35 g/cm²

Vacuum

Chalmers
The voxel phantom “NUNDO” (Numerical RANDO)*

Front view of the RANDO® phantom a) and the numerical voxel model NUNDO b)

The percentage element composition of the NUNDO phantom used in the simulations

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage in soft tissue</th>
<th>Percentage in lungs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>67.78</td>
<td>70.74</td>
</tr>
<tr>
<td>Oxygen</td>
<td>20.31</td>
<td>21.28</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>9.18</td>
<td>5.97</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>2.50</td>
<td>1.9</td>
</tr>
<tr>
<td>Antimony</td>
<td>0.22</td>
<td>0.1</td>
</tr>
<tr>
<td>The density [g/cm²]</td>
<td>0.997</td>
<td>0.352</td>
</tr>
</tbody>
</table>

The voxel phantom “NUNDO” (Numerical RANDO)*

- NUNDO was constructed on base of the CT scans of the RANDO® phantom
- Model used in calculations consists of 16,335,540 voxels

- The voxel size is equal to 1x1x5 mm³
- In the PHITS simulations, 9x9x20 mm³ was used
- Masses of each organs and tissues were scaled to the masses of the ICRP reference man

MATROSHKA simulations
- include simplified shielding from ISS

MATROSHKA phantom with container

Al cylinder with wall thicknesses of 15 g/cm²
Experimental data - comparison

Slices 3 (ATI), 4 (IFJ) and 5 (DLR)

Slices 22 (IFJ) and 23 (ATI/DLR)

With courtesy to T. Berger, M. Hajek, and P. Bilski !!!!
Experimental data - comparison

- Slices 3 (ATI), 4 (IFJ) and 5 (DLR)
- Slices 22 (IFJ) and 23 (ATI/DLR)

**Top part of the phantom: slices 3, 4 and 5**

**Middle part of the phantom: slices 22 and 23**
Comparison of experimental data and simulations, slices 3-5

Slices 3 (ATI), 4 (IFJ) and 5 (DLR)

Preliminary Data !!
Comparison of experimental data and simulations, slices 22-23

Slices 22 (IFJ) and 23 (ATI/DLR)

Preliminary Data !!

Chalmers
Summary and Conclusions

- Calculations performed **PHITS + CREME96**
- Preliminary calculations of dose distributions inside Matroshka at EVA
- Simplified shielding from ISS

Preliminary results are in rather good agreement with measurements!
Ongoing activities and future plans ???
Ongoing activities and future plans

- **Ongoing**
  - Compare simulations of more detectors with measurements from different groups
  - Calculations of organ doses and organ dose eq.

- **Future**
  - Test other radiation environment models
  - Implement more realistic shielding from the ISS
Thank you very much for your attention!!!
MATROSHKA simulations
- no shielding from ISS

Include efficiency correction for the TLD detectors in the simulations

Simulations ~ 20 - 30 % lower than exp.!