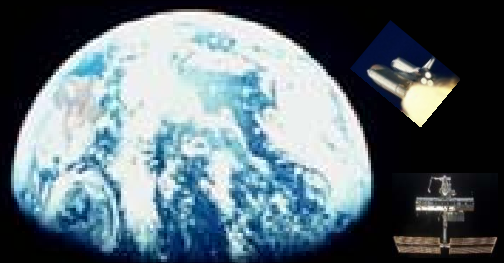
Simulations of MATROSHKA experiments at ISS using PHITS

L. Sihver [1,2], T. Sato [3], M. Puchalska [1] and G. Reitz [4]



[1] Chalmers (Sweden), [2] Roanoke College (VA, USA)
[3] JAEA (Japan), [4] German Aerospace Center (Cologne, Germany)

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

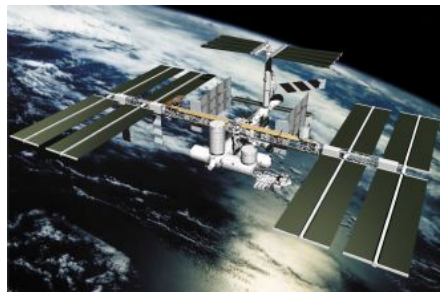
neutron, proton, meson, baryon electron, photon, nucleus

from thermal up to ~ 100 GeV/u

Application Fields

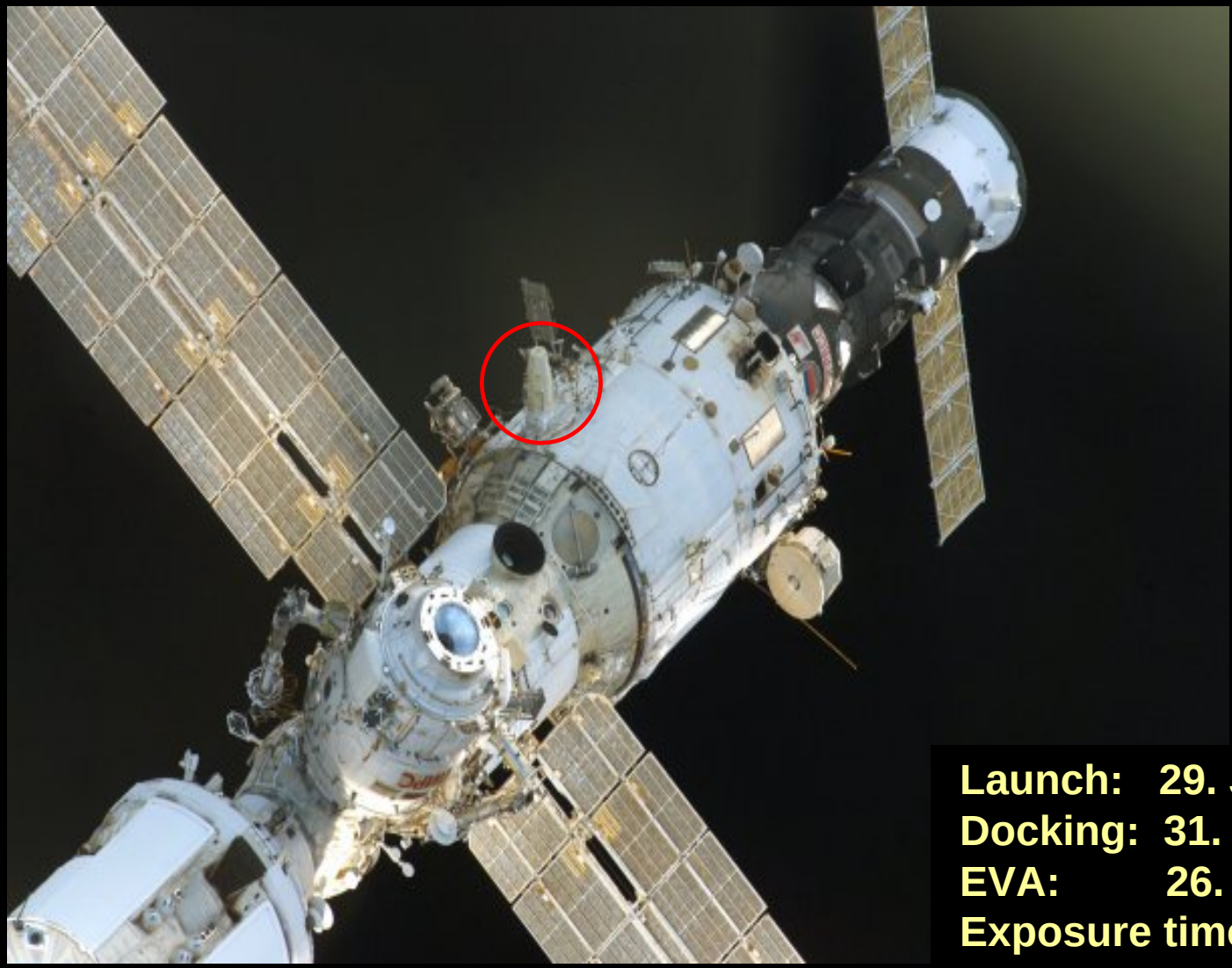
Accelerator Design

Radiation Therapy



Space Application

MATROSHKA

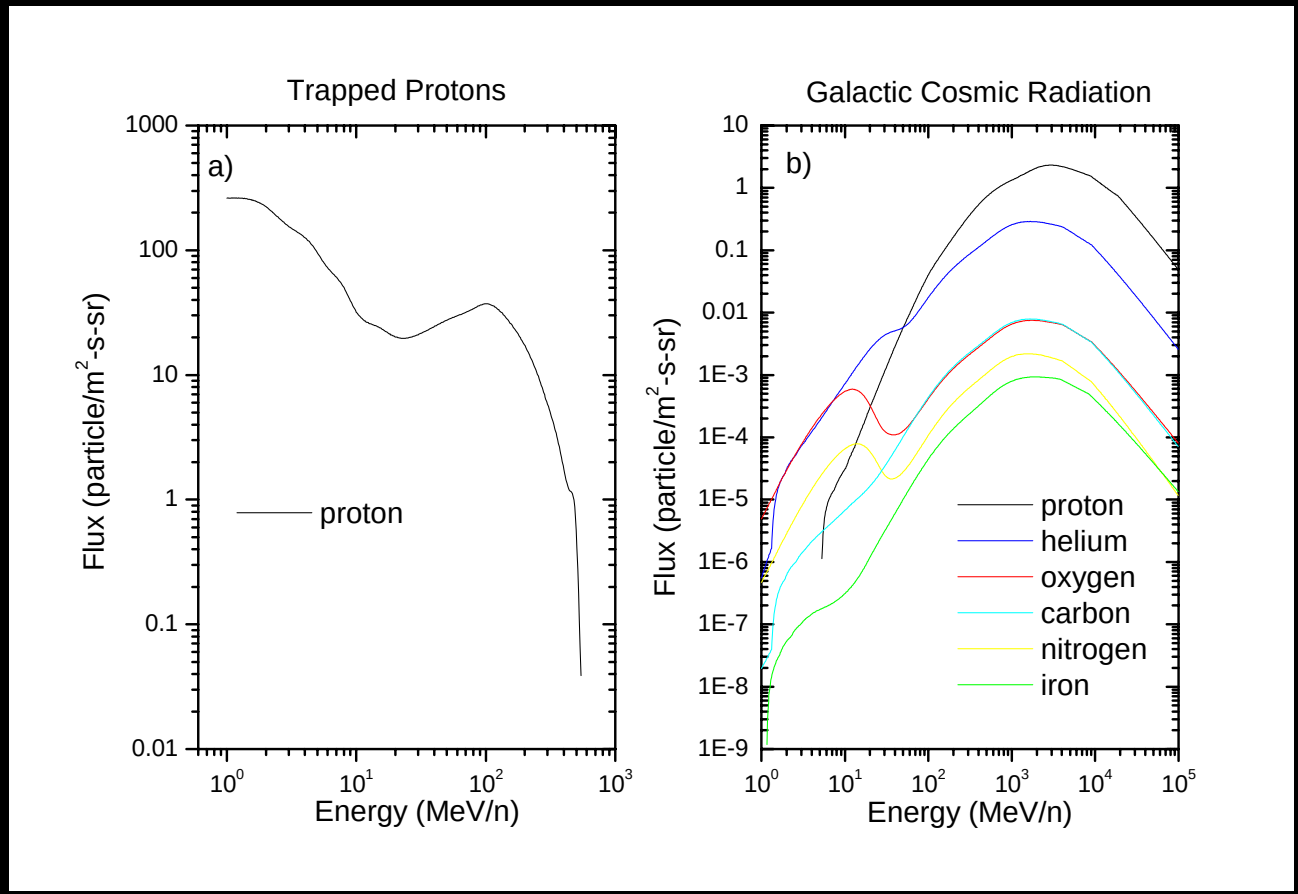


Launch: 29. January 2004
Docking: 31. January 2004
EVA: 26. February 2004
Exposure time outside: 539 days

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 o
- 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

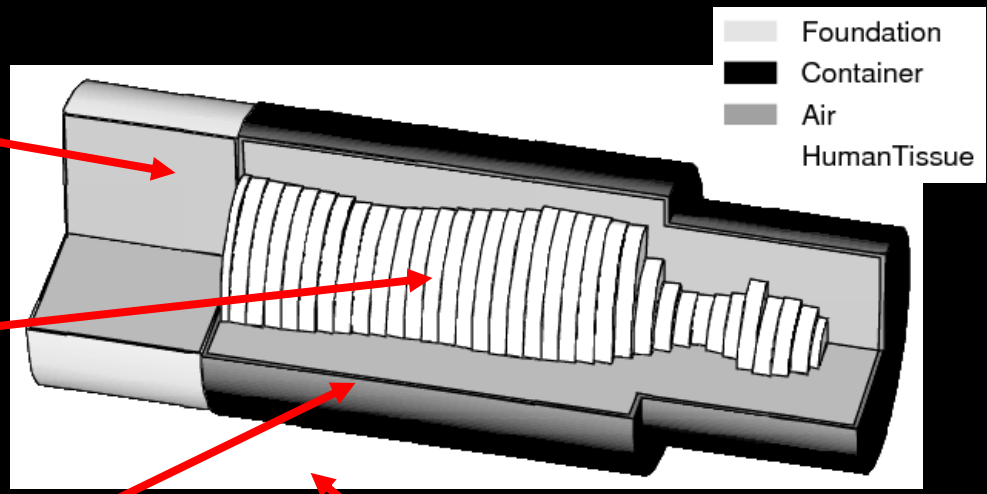
- Outside ISS
- Simplified geometry with no shielding from ISS

Al foundation

Density: 2.7 g/cm^3
Thickness: 1 g/cm^2

MATROSHKA phantom

Polyurethane
Density: 1 g/cm^3

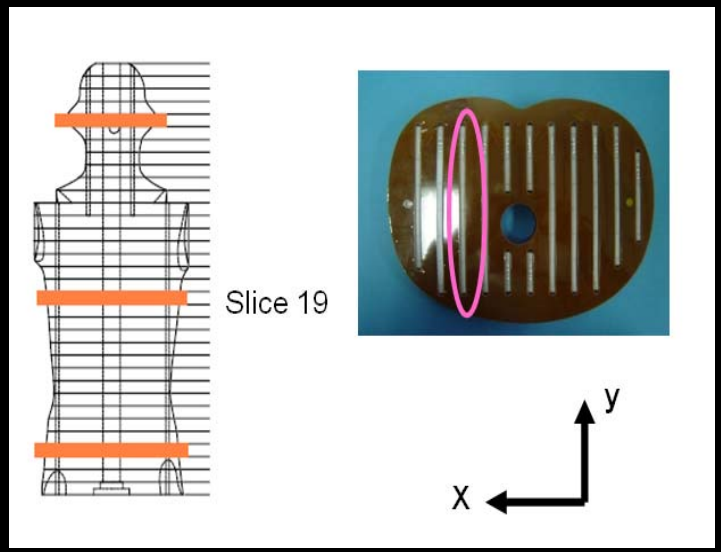


Container

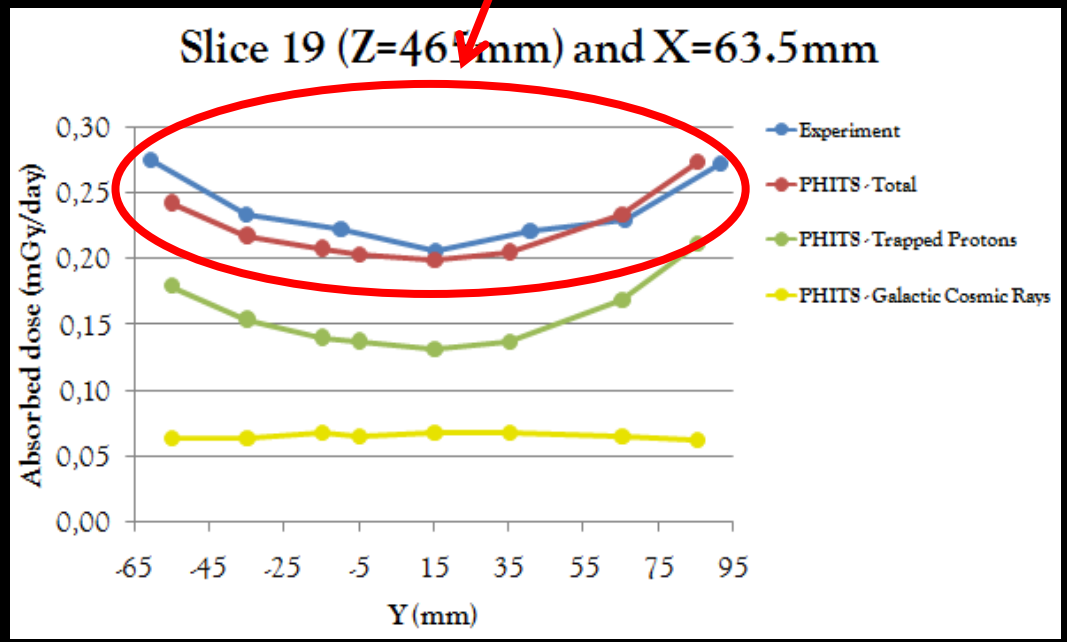
Carbon fiber
Density: 1 g/cm^3
Thickness: 1 g/cm^2

Vacuum

MATROSHKA simulations - no shielding from ISS

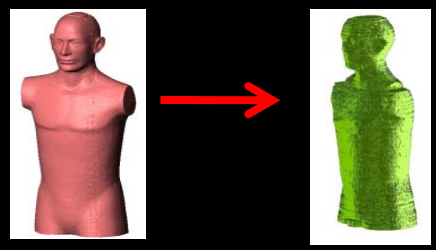


Good agreement!



Next step:

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



MATROSHKA simulations

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

Al foundation

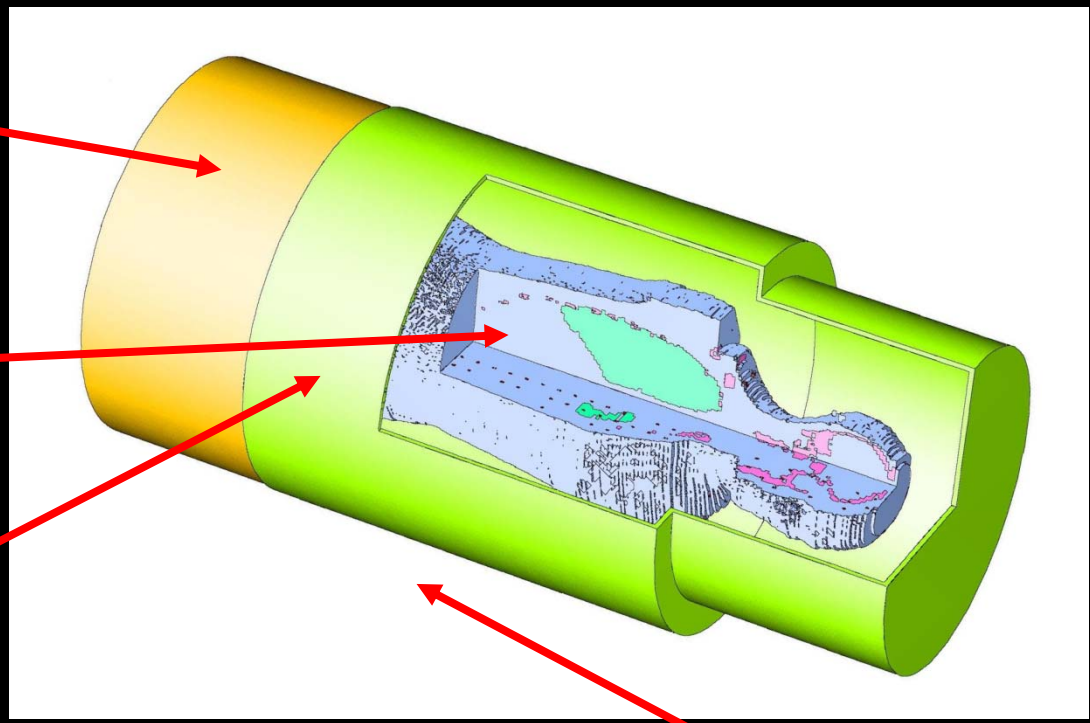
Density: 2.7 g/cm^3
Thickness: 1.35 g/cm^2

MATROSHKA phantom

Polyurethane
Density: lungs – 0.35 g/cm^3
bones – 1.3 g/cm^3
rest - 1 g/cm^3

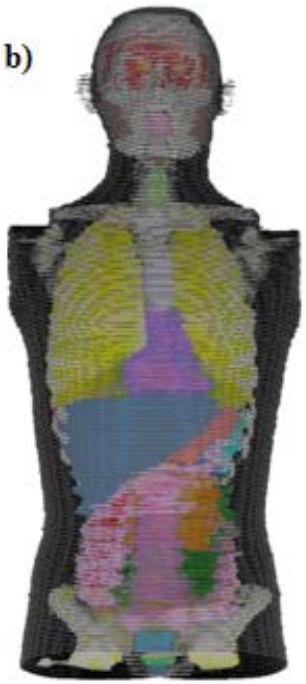
Container

Carbon fiber
Density: 0.35 g/cm^3
Thickness: 0.35 g/cm^2



Vacuum

The voxel phantom “NUNDO” (Numerical RANDO)*



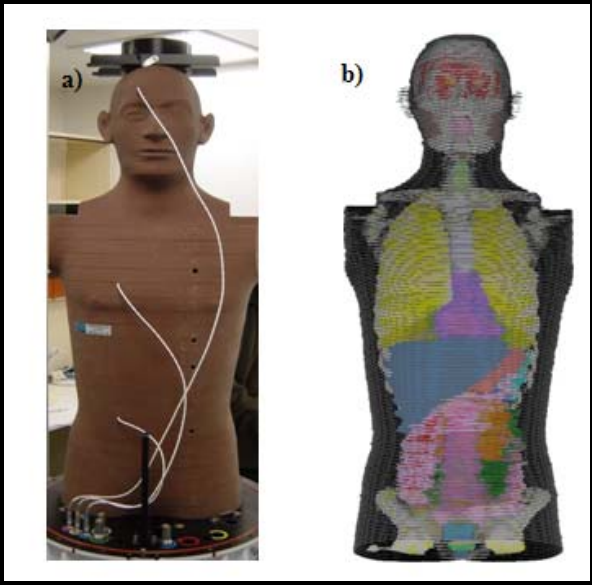
Front view of the RANDO® phantom a) and the numerical voxel model NUNDO b)

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

Element	Percentage in soft tissue	Percentage in lungs
Carbon	67.78	70.74
Oxygen	20.31	21.28
Hydrogen	9.18	5.97
Nitrogen	2.50	1.9
Antimony	0.22	0.1
The density [g/cm^3]	0.997	0.352

* Puchalska, M. et al., 2009. Radiation hazard to astronauts outside the International Space Station – the effective dose calculations, Radiat. Meas. (in press)

The voxel phantom “NUNDO” (Numerical RANDO)*

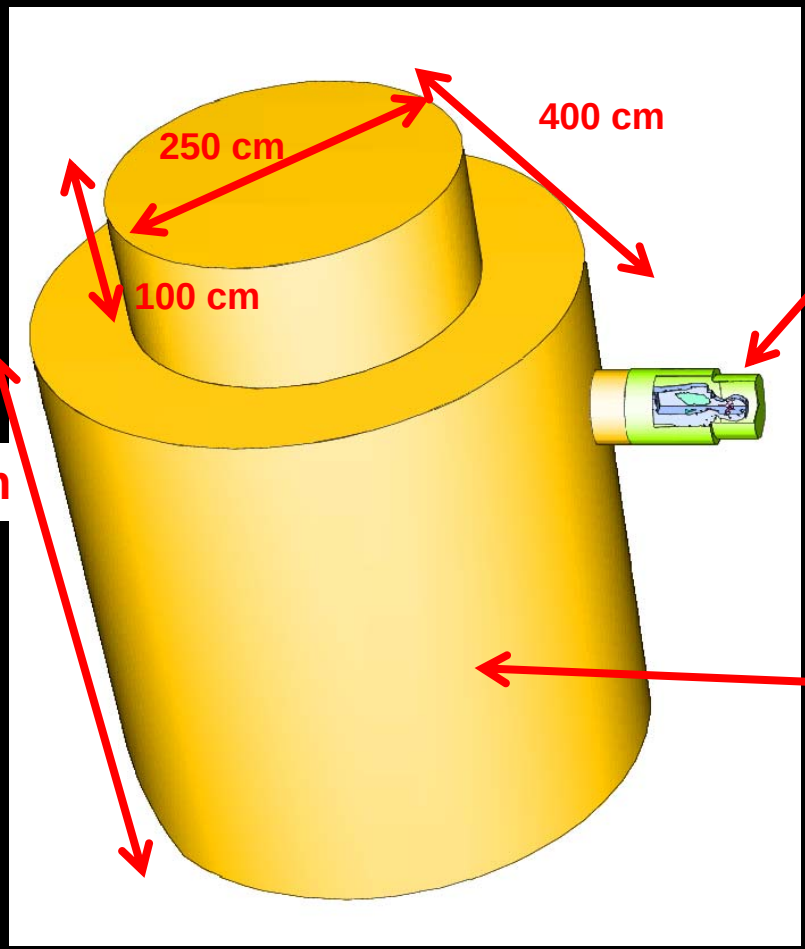


- NUNDO was constructed on base of the CT scans of the RANDO® phantom
- Model used in calculations consists of 16,335,540 voxels

- The voxel size is equal to 1x1x5 mm^3
- In the PHITS simulations, 9x9x20 mm^3 was used
- Masses of each organs and tissues were scaled to the masses of the ICRP reference man

* Puchalska, M. et al., 2009. Radiat. Meas. (in press)

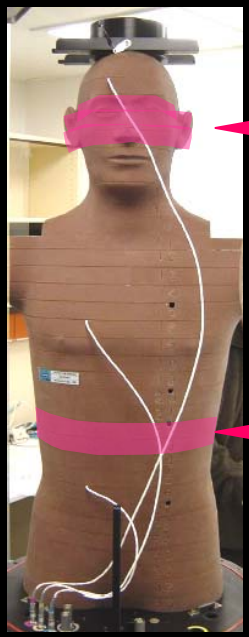
MATROSHKA simulations
- include simplified shielding from ISS



MATROSHKA phantom with container

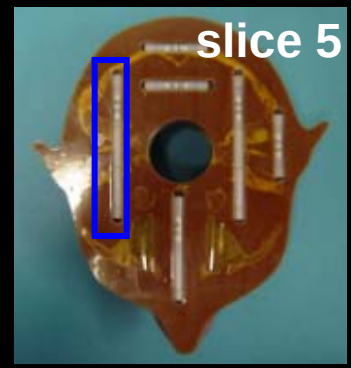
Al cylinder with wall thicknesses of 15 g/cm^2

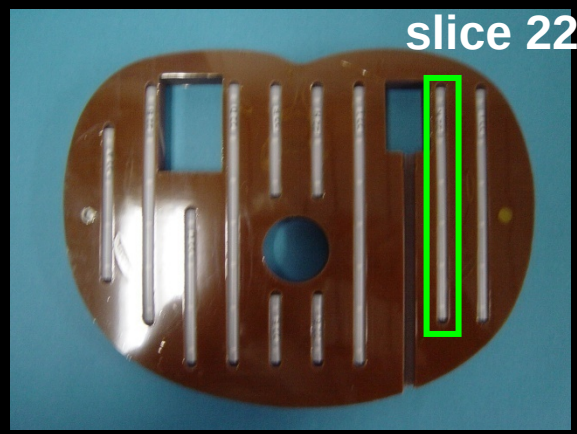
Experimental data - comparison

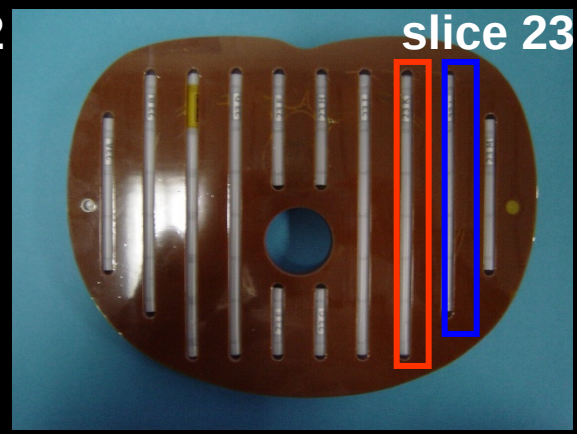


Slices 3 (ATI), 4 (IFJ) and 5 (DLR)

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

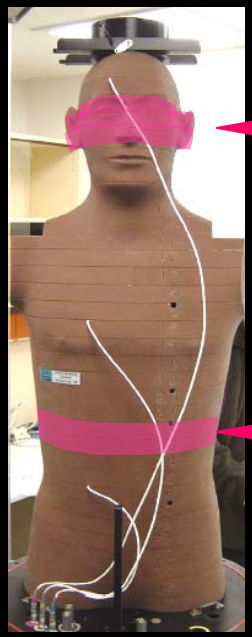






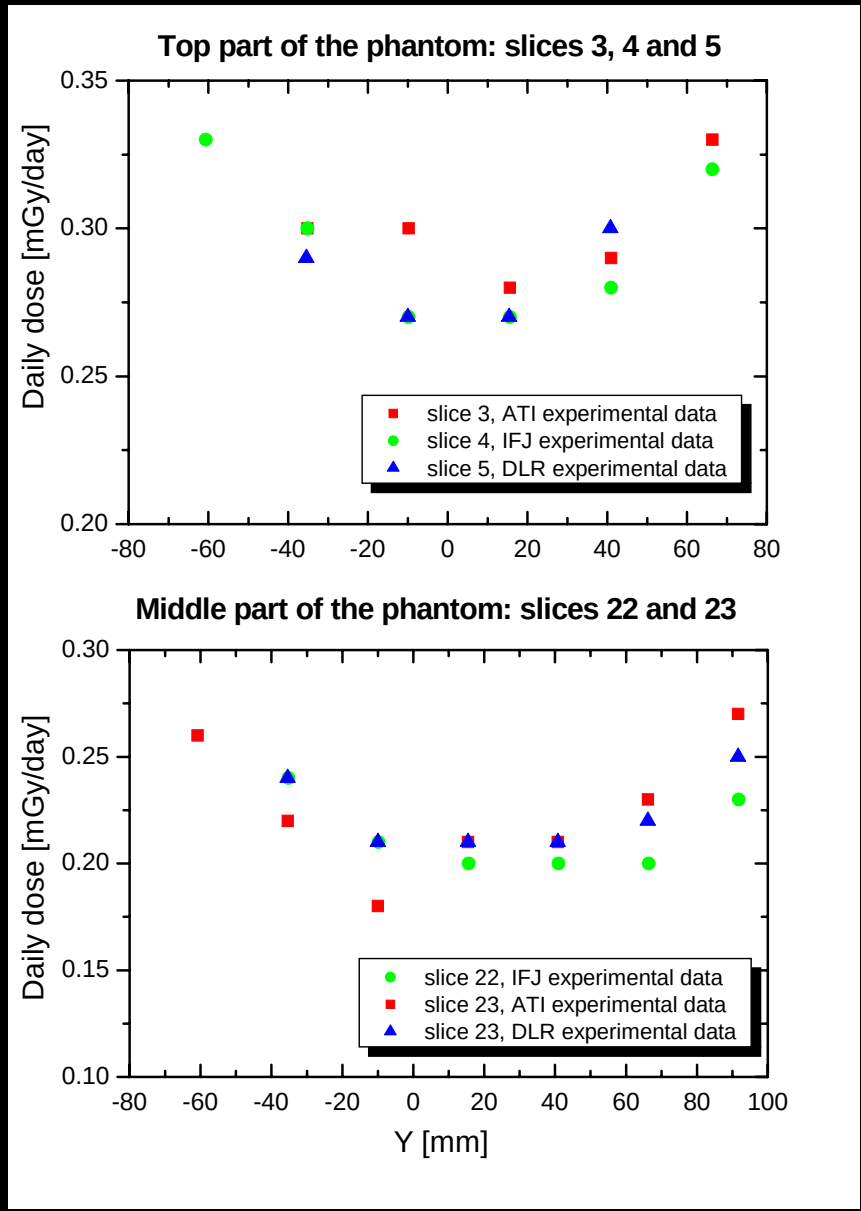
With courtesy to T. Berger, M. Hajek, and P. Bilski !!!!

Experimental data - comparison

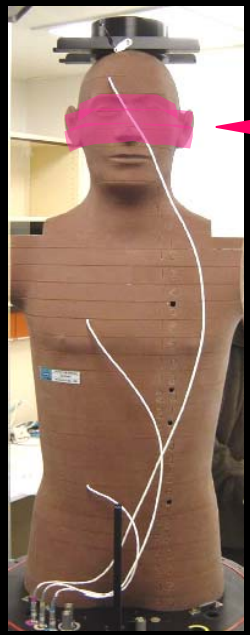


Slices 3 (ATI), 4 (IFJ) and 5 (DLR)

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

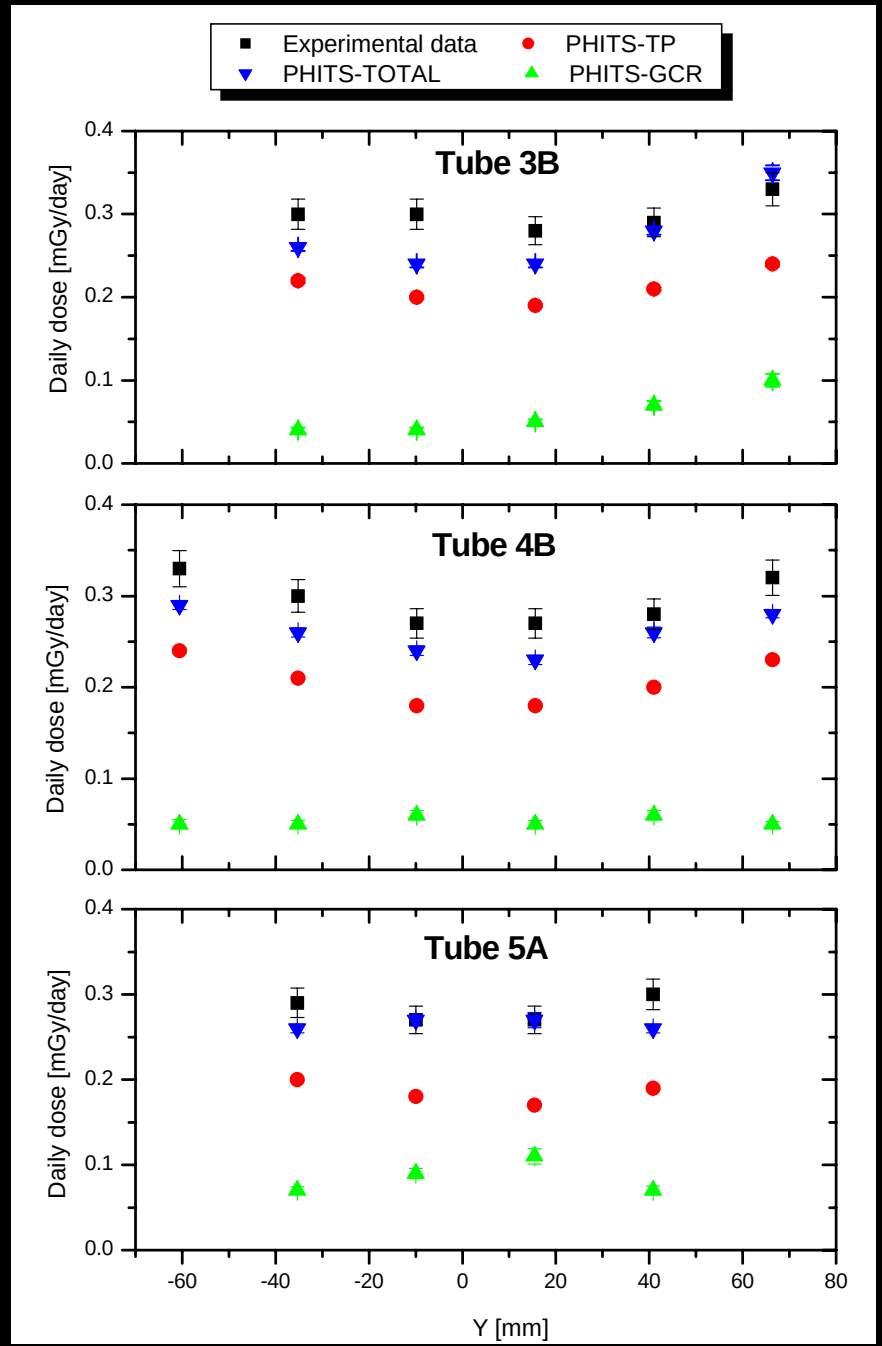


Comparison of experimental data and simulations, slices 3-5

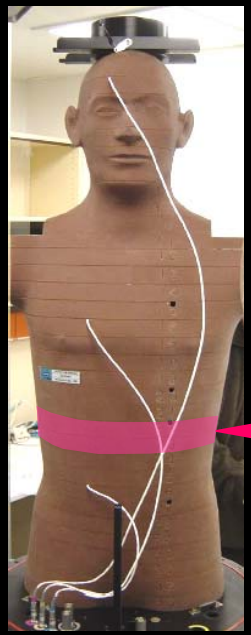


Slices 3 (ATI),
4 (IFJ) and 5 (DLR)

Preliminary Data !!

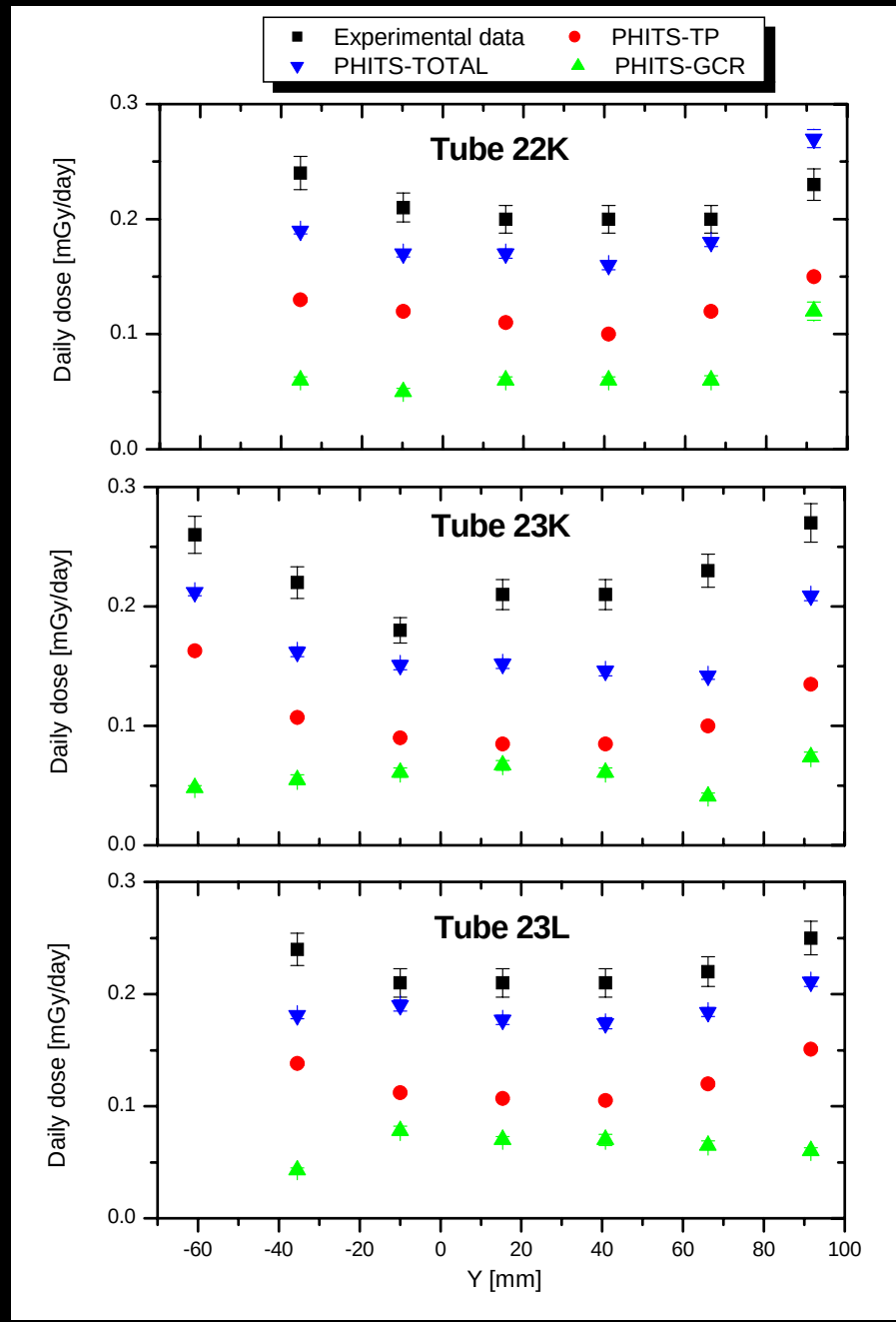


Comparison of experimental data and simulations, slices 22-23



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

Preliminary Data !!



Summary and Conclusions

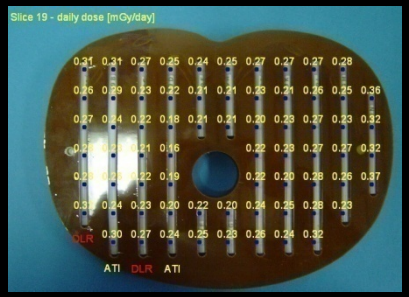
- Calculations performed PHITS + CREME96
- Preliminary calculations of dose distributions inside Matroshka at EVA
- Simplified shielding from ISS

Preliminary results are in rather good agreement with measurements !

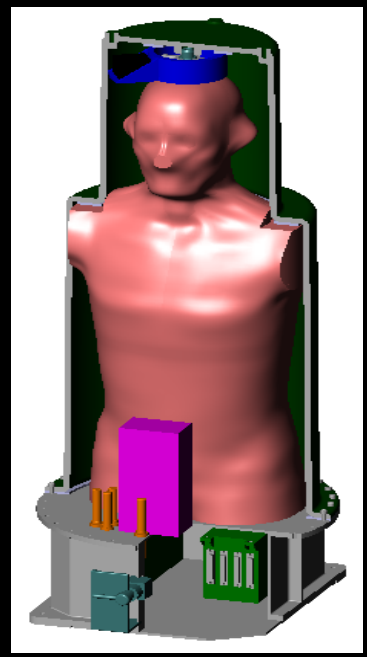
Ongoing activities and future plans ???

Ongoing activities and future plans !!!

- **Ongoing**
  - Compare simulations of more detectors with measurements from different groups



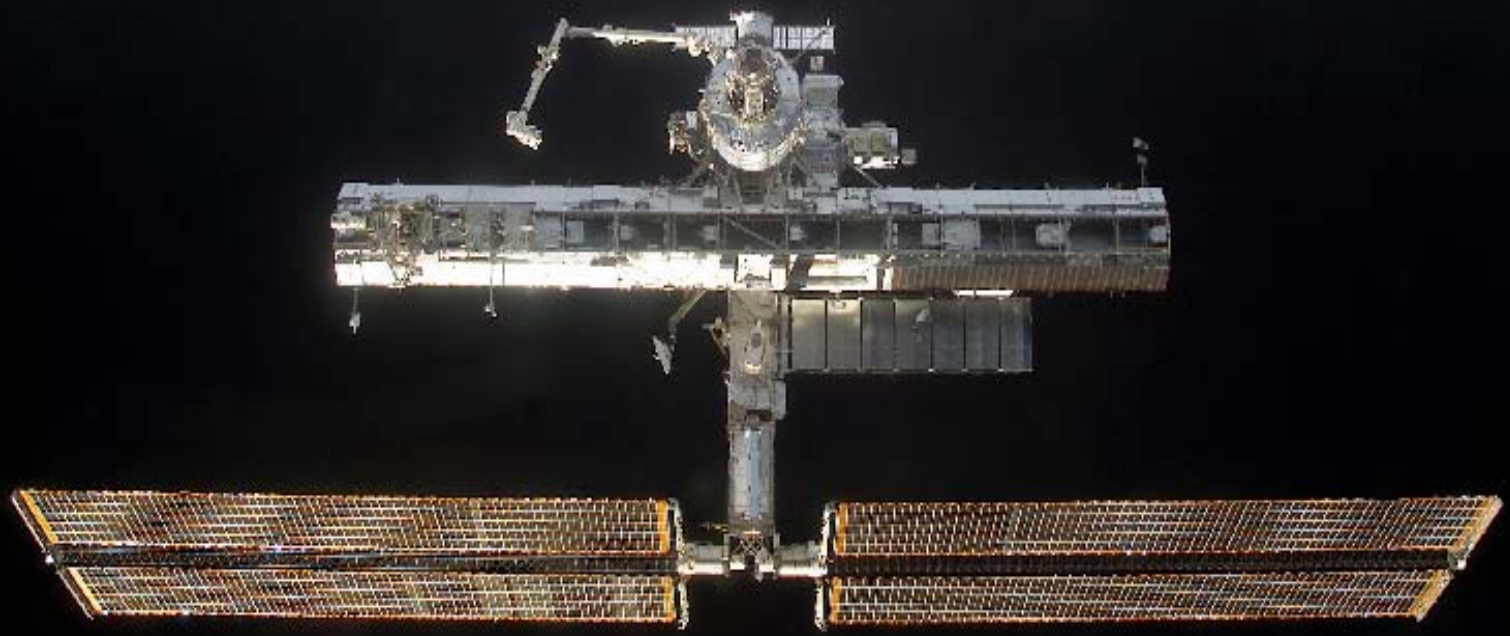
  - Calculations of organ doses and organ dose eq.



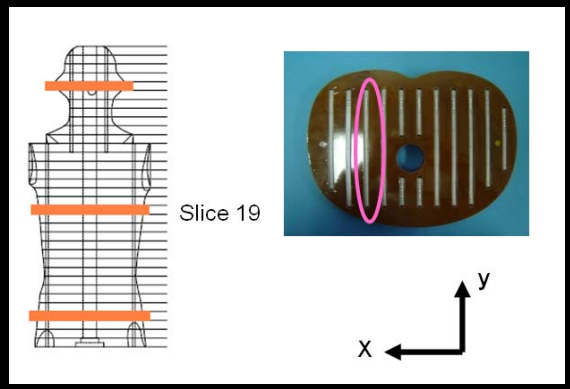
Matroshka

- **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