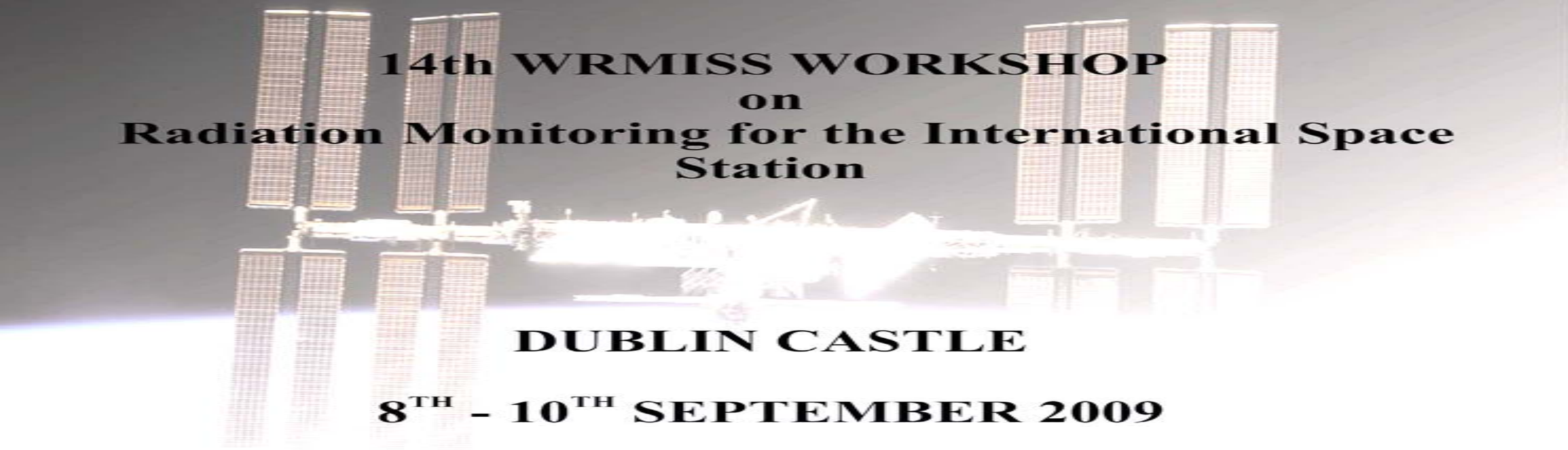
Image courtesy of NASA



14th WRMISS WORKSHOP on Radiation Monitoring for the International Space Station

DUBLIN CASTLE

8TH - 10TH SEPTEMBER 2009

HOSTED AND ORGANISED BY THE

DUBLIN INSTITUTE FOR ADVANCED STUDIES

CHAIRMAN: Guenther Reitz, DLR
LOC: Denis O'Sullivan, DIAS
Eileen Flood, DIAS
Anne Grace, DIAS

Development of a Numerical Model for the MATROSHKA Phantom

14th Workshop on Radiation Monitoring on International Space Station, Dublin, 8th – 10th September 2009

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Outline

- MATSIM – the project
- Description of the MATROSHKA model
- Photon Measurements with the MATROSHKA head
- Simulations of MATSIM head
- Comparison between measurement and simulation
- Outlook

MATSIM – the project

MATROSHKA

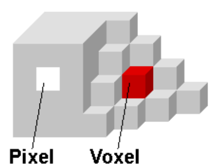
- International collaboration of >19 research institutes, ESA experiment under the scientific and project lead of „Deutsches Zentrum für Luft- und Raumfahrt“ (DLR)
- Long-term dose measurements onboard International Space Station, started in 2004

MATSIM

- carried out at the Austrian Institute of Technologies, Seibersdorf in collaboration with DLR and Atomic Institute, Vienna
- Development of a novel numerical model
- Same geometry, material and density distribution as real phantom
- Simulation of energy deposition in photon and neutron reference fields

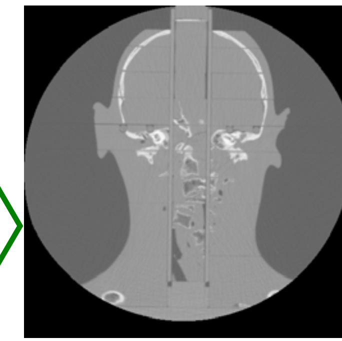
MATROSHKA - Computer Tomography Scan

- **Two CT scans of MATROSHKA provided by DLR**
  - Torso and
  - Head

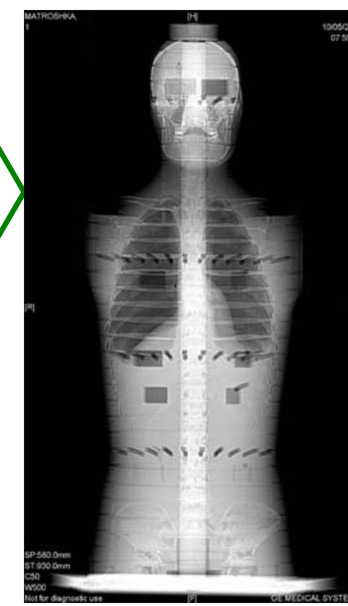


	Torso		**Head**	
Axis	**Number of pixels**	**Layer width (mm)**	**Number of pixels**	**Layer width (mm)**
X	512	0.78	512	0.62
Y	512	0.78	600	0.4
Z	278	3.125	512	0.62
	$7.3 \cdot 10^7$ voxels		**$1.6 \cdot 10^8$ voxels**	

Source: DLR



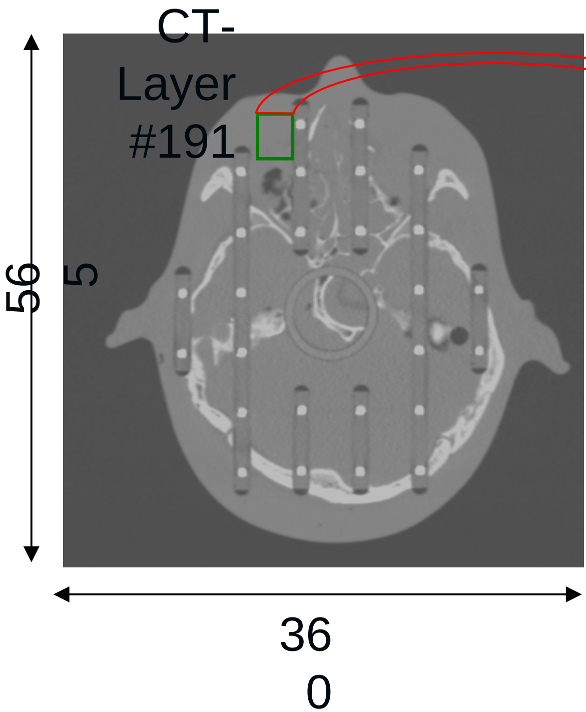
Source: DLR



Source: DLR

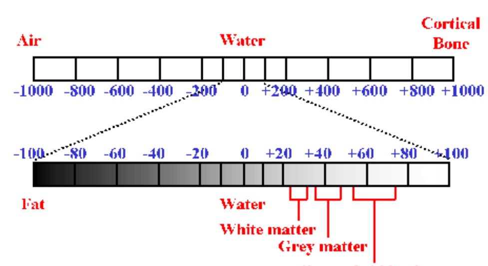
MATROSHKA CT scan – data processing

- Special software developed to read and manipulate CT data
- Definition of materials
- Append all slices to one file for Fluka



Matrix with Hounsfield numbers (HU)

.	.	.	.	.	.	.	.
.	.	21	13	4	−6	.	.
.	−65	−10	20	16	14	10	.
.	−112	31	28	−25	−37	41	.
.	−264	3	47	2	−15	−2	.
.	−472	3	−68	−2	5	−7	.
.	.	−133	−154	−7	20	.	.
.	.	.	.	.	.	.	.



build regions
(e.g. tissue from -80 to 80)

implement in Monte Carlo code

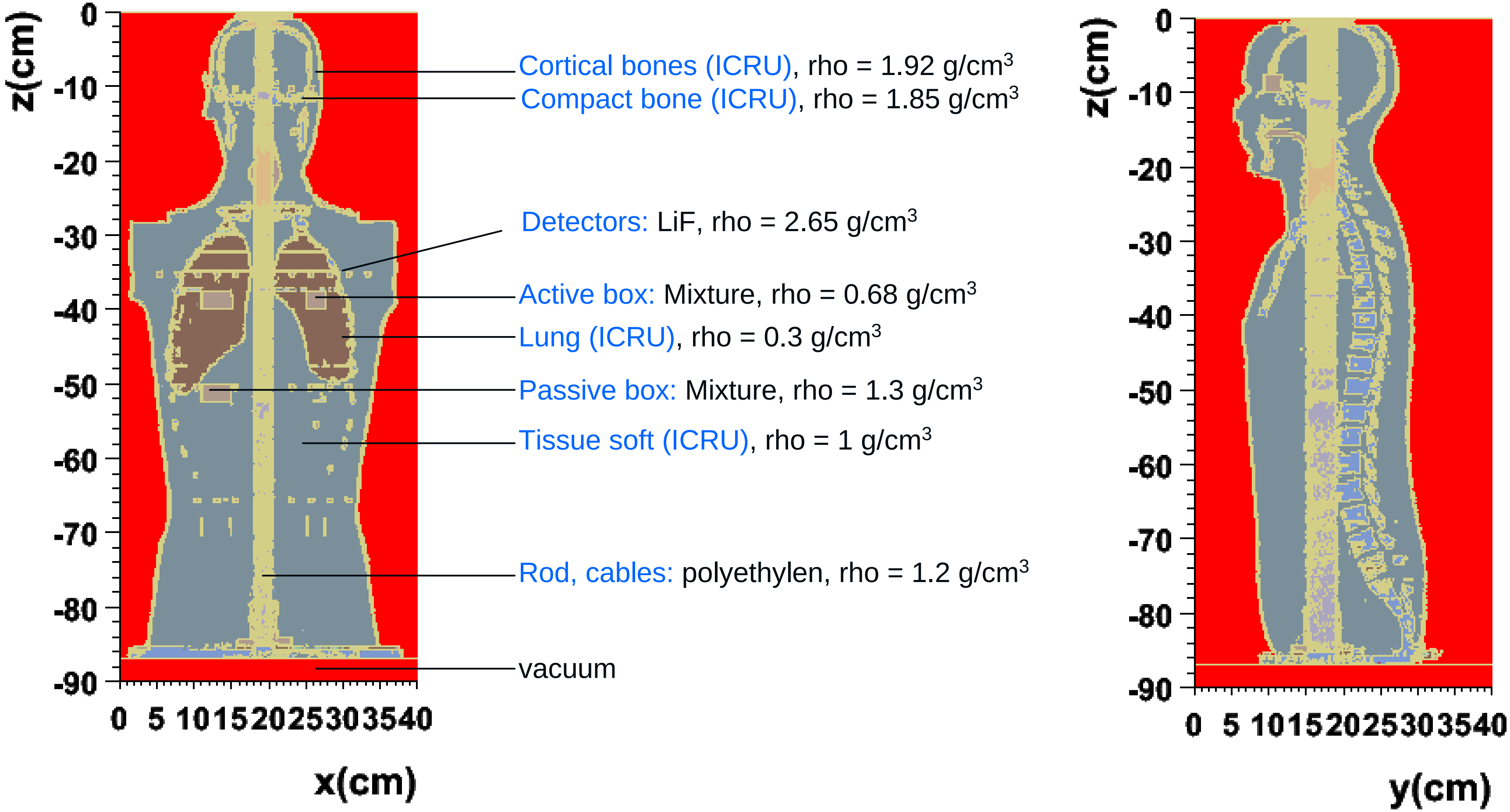
geometry model with assigned materials

Monte Carlo Code FLUKA

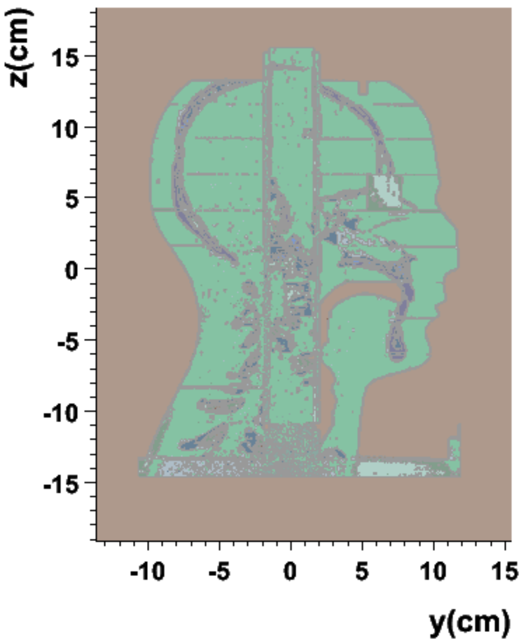
- Particle transport and interaction with matter
- 60 different particles
  - photons and electrons from 1 keV to thousands of TeV
  - muons of any energy, hadrons up to 20 TeV
  - neutrons down to thermal energies and heavy ions.
- Optimized computer algorithms
- high energy experimental physics and engineering, accelerator shielding, detector design, cosmic ray studies, dosimetry and micro-dosimetry, medical physics and radiobiology, neutrino physics
- **Voxel geometry**: translate a CT scan into a dosimetry model

FLUKA geometry – MATSIM Torso

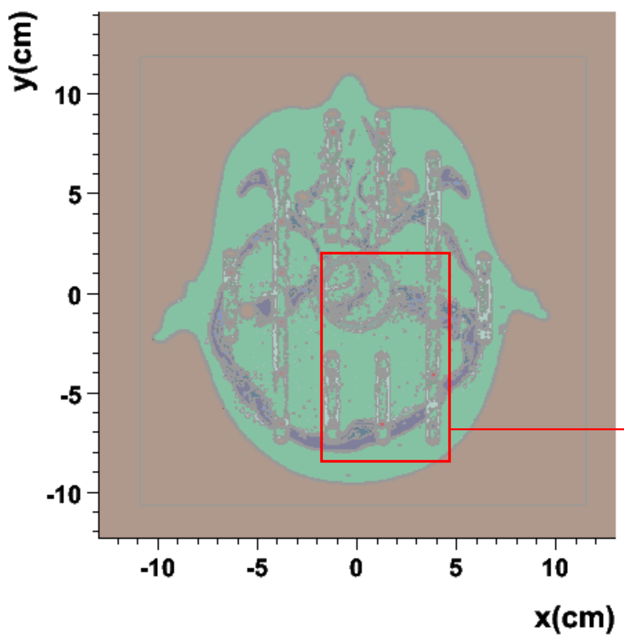
vertical cut from the front (left) and from the side (right)



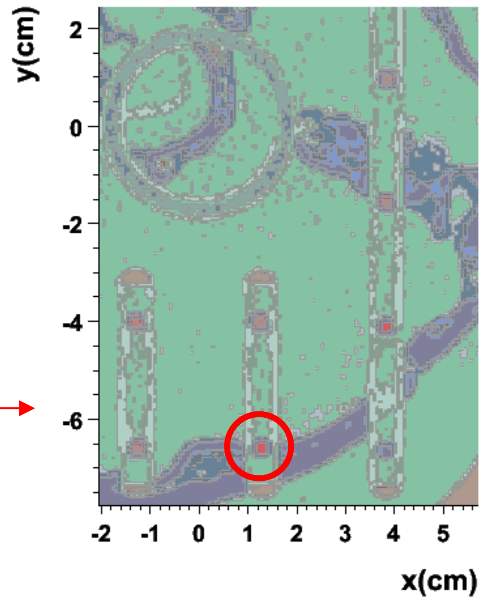
FLUKA geometry – MATSIM Head



vertical center cut
from the side



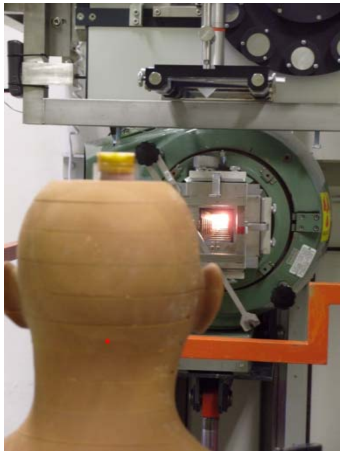
horizontal cut in slice # 4
from the top



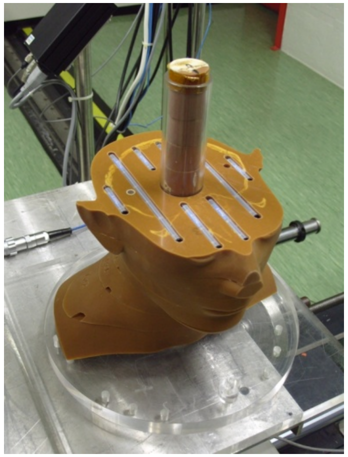
detector location in
slice #4

Reference measurements - Co-60 photons

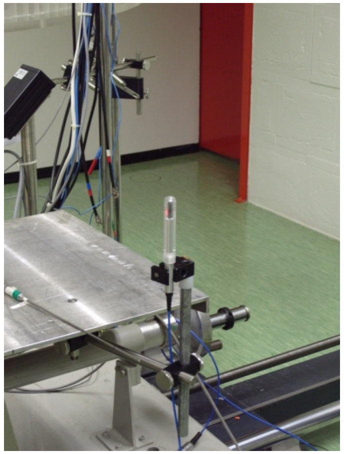
- Reference Point: rod center, slice #5
- Distance Source – Head: 450 cm, field size: 27 x 27 cm
- K_{Air} = 200mGy, $\dot{K}_{Air}$ = 159.5 µGy/s
- Beam incidence: front, omni directional (30° steps)



MATROSHKA head in front of the irradiation facility, reference point is marked

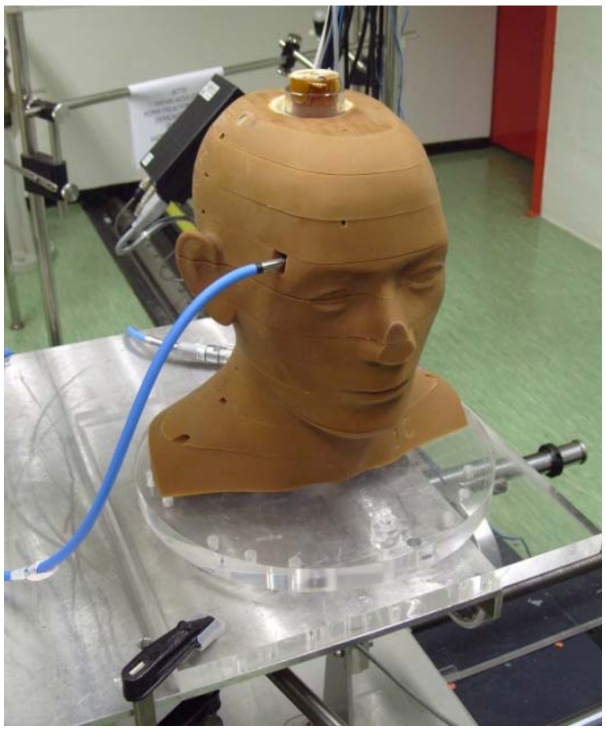


TLD set in slice#4

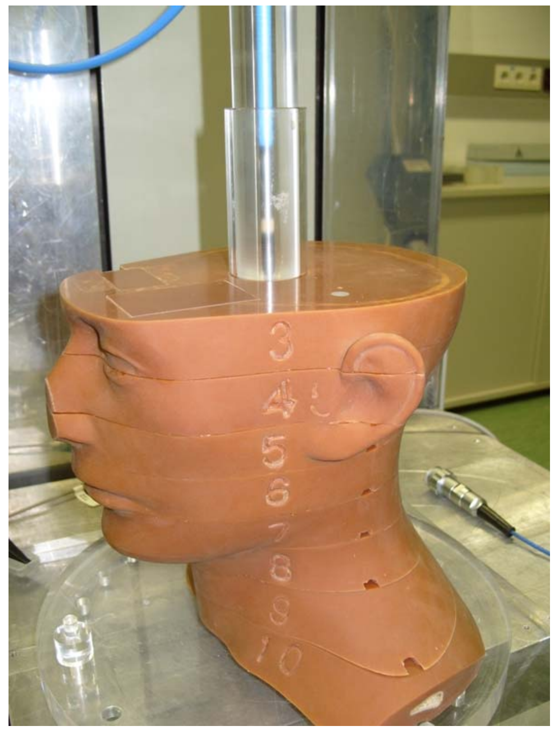


Ionization chamber

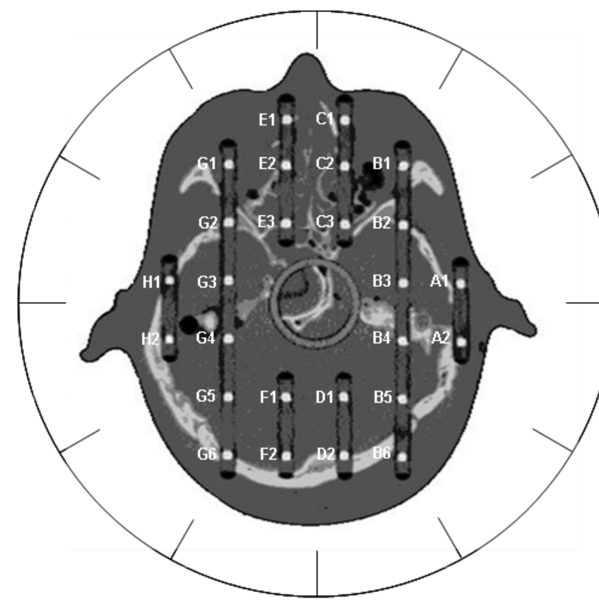
Reference measurements - Co-60 photons



Active box eye



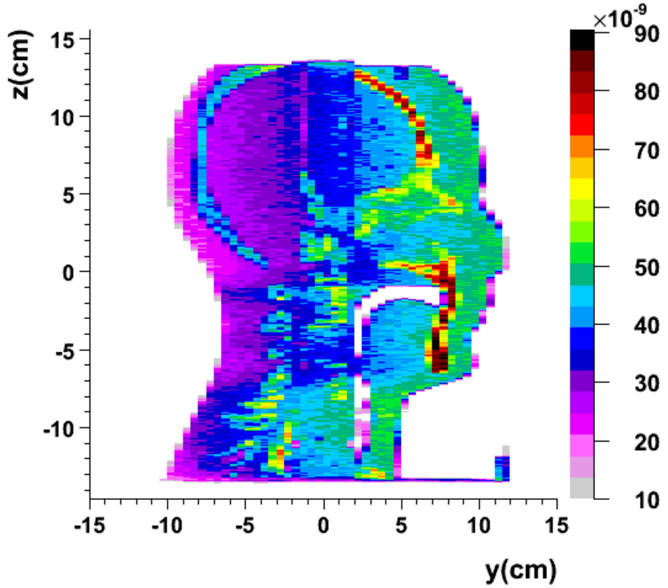
Chamber in PMMA rod , slice #2



Experimental set-up:
TLD numbering and beam incidence (30 degree steps)

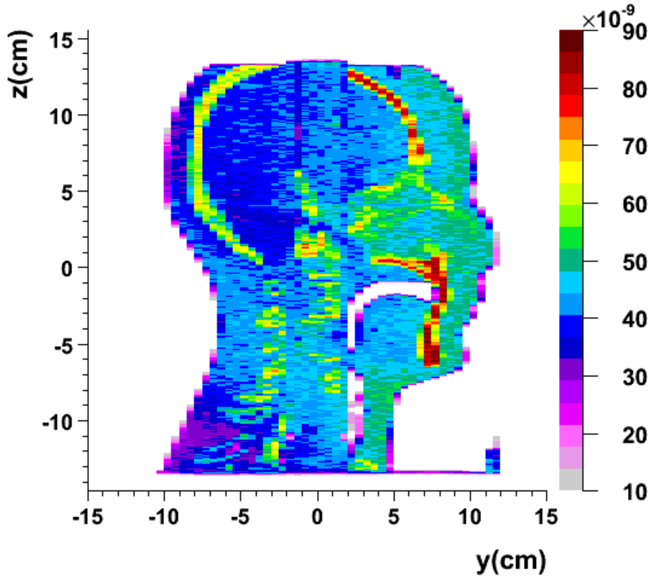
MATSIM Head Simulation of the Energy Density due to ^{60}Co

Front beam incidence



Deposited spatial energy density (GeV/cm^3) in the head, side view.

60 degree beam incidence



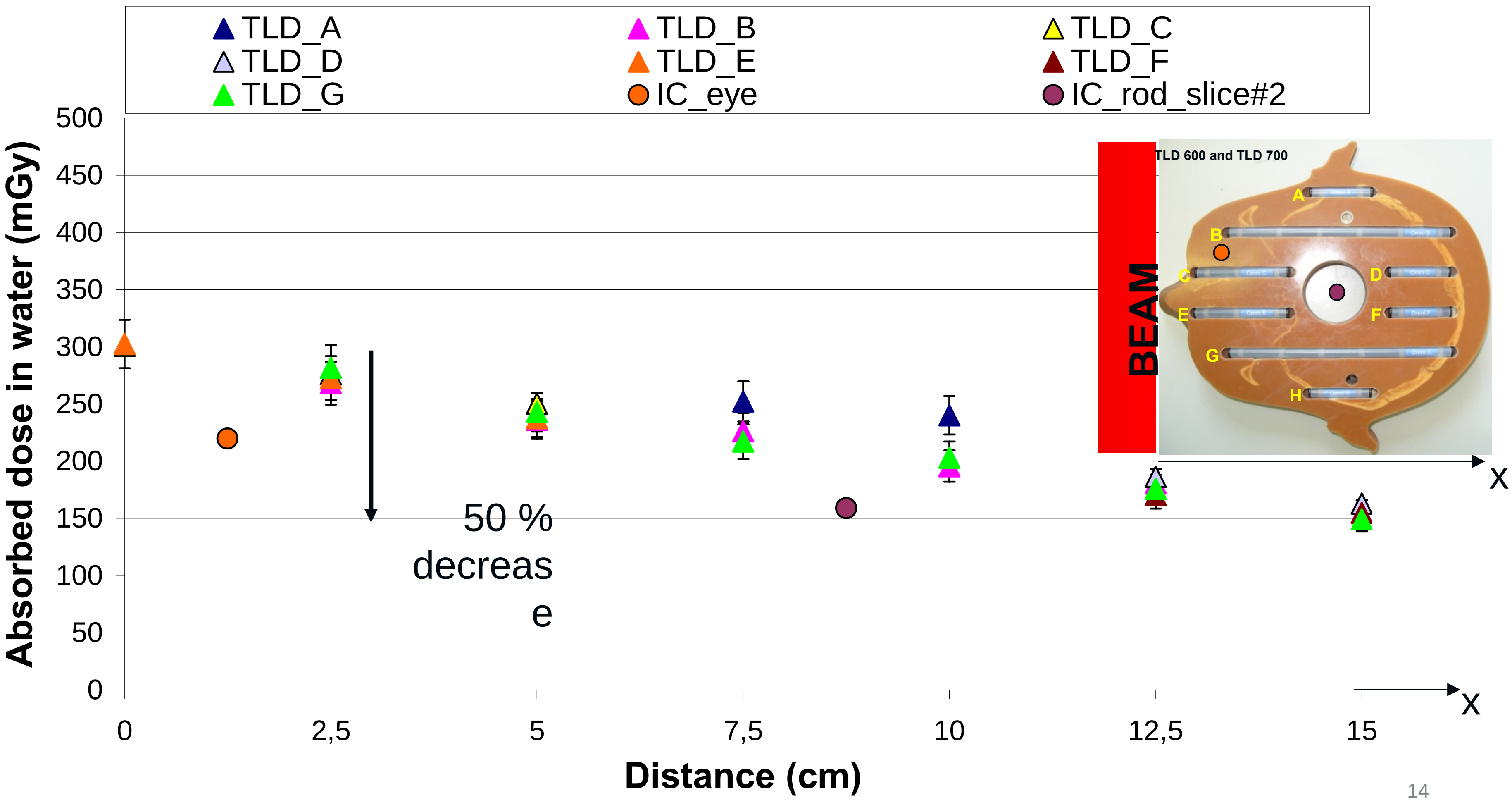
Deposited spatial energy density (GeV/cm^3) in the head´, side view.

AUSTRIAN INSTITUTE OF TECHNOLOGY

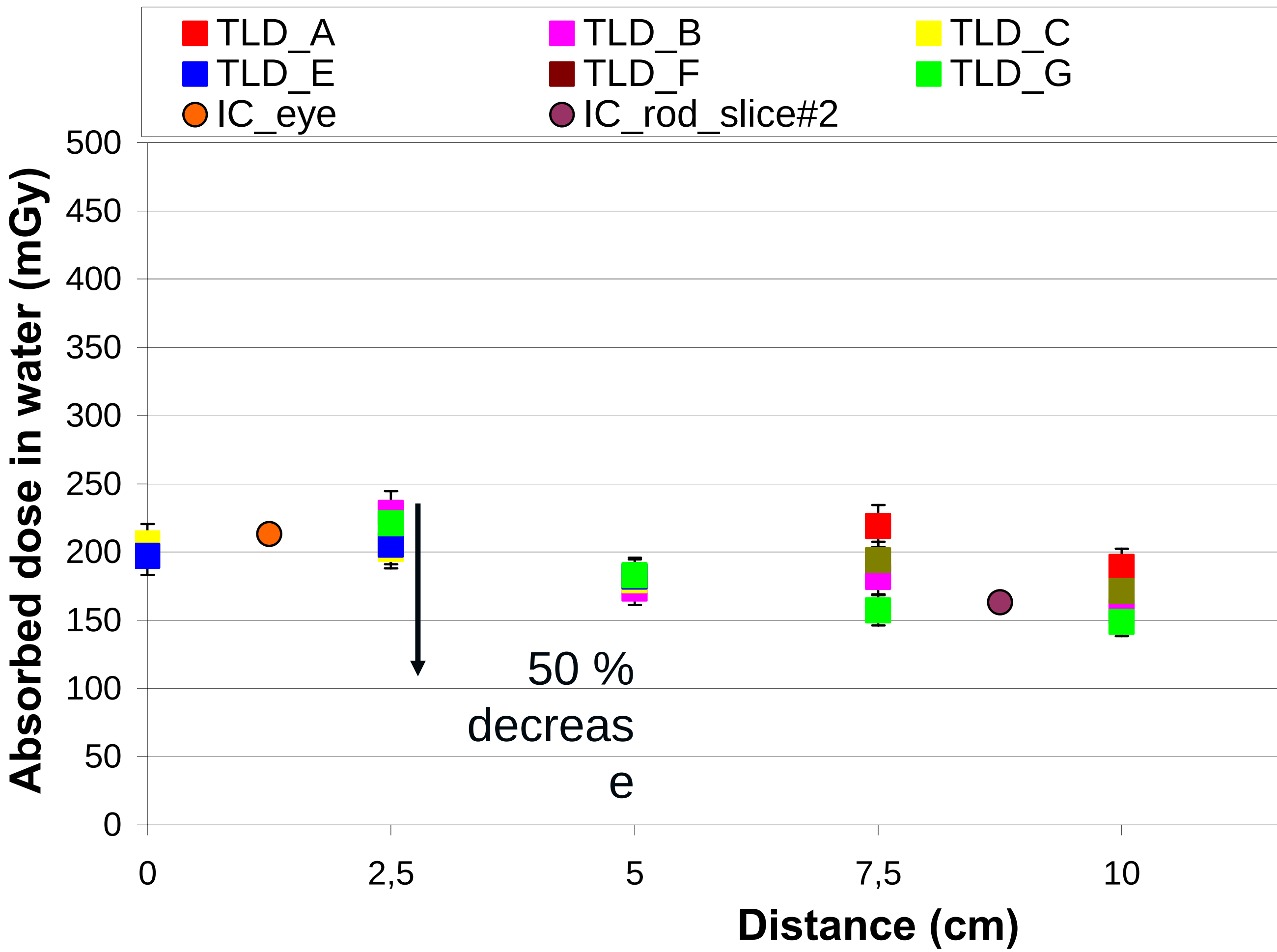
Results – Ionization chamber

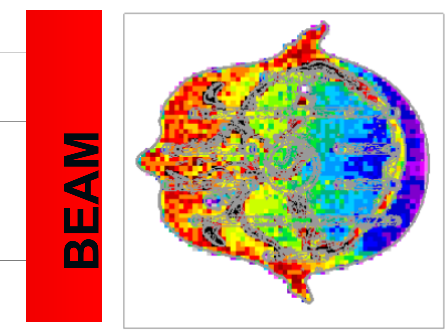
		Measurement		Simulation		
Location	**Beam incidence (°)**	**D_{Water} (mGy)**	**1σ (mGy)**	**D_{Wasser} (mGy)**	**1σ (mGy)**	**Ratio SIM / MEAS**
Eye, slice#3	**0**	219.9	0.2	213.1	0.9	**0.96**
Rod center, slice#2	**0**	159.0	± 0.6	163.0	± 0.6	**1.01**
	30	159.7	± 1.6	163.7	± 0.7	**1.05**
	60	177.7	± 1.8	180.7	± 0.8	**1.00**
	90	178.4	± 1.8	185.5	± 0.8	**1.06**
	120	169.1	± 1.7	176.7	± 1.0	**1.05**
	150	160.2	± 1.6	160.1	± 0.7	**1.00**
	180	158.6	± 1.6	164.1	± 0.9	**1.05**

Results –Measurements TLD & IC, Front Irradiation



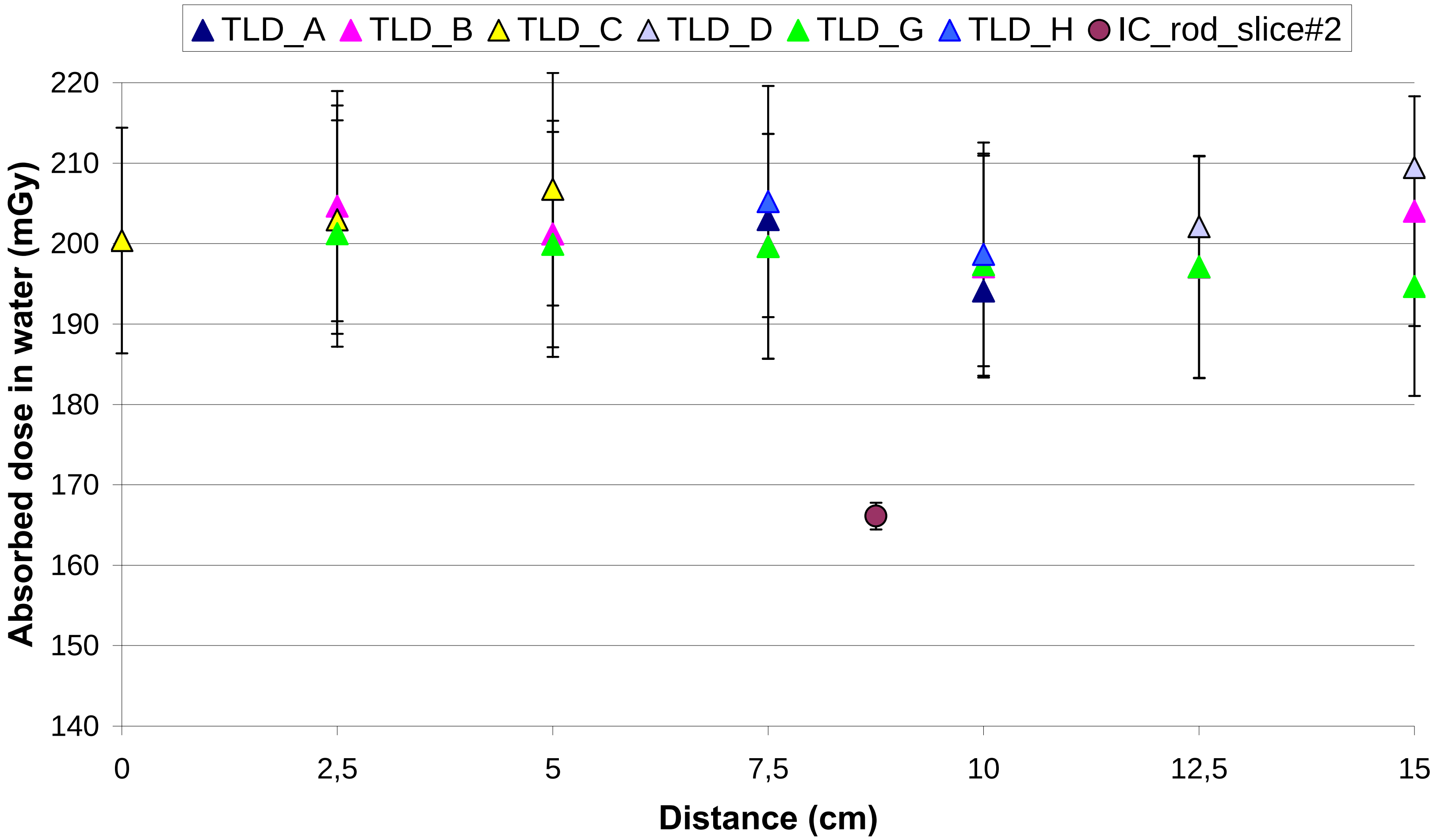
Results – Simulations TLD & IC, Front Irradiation



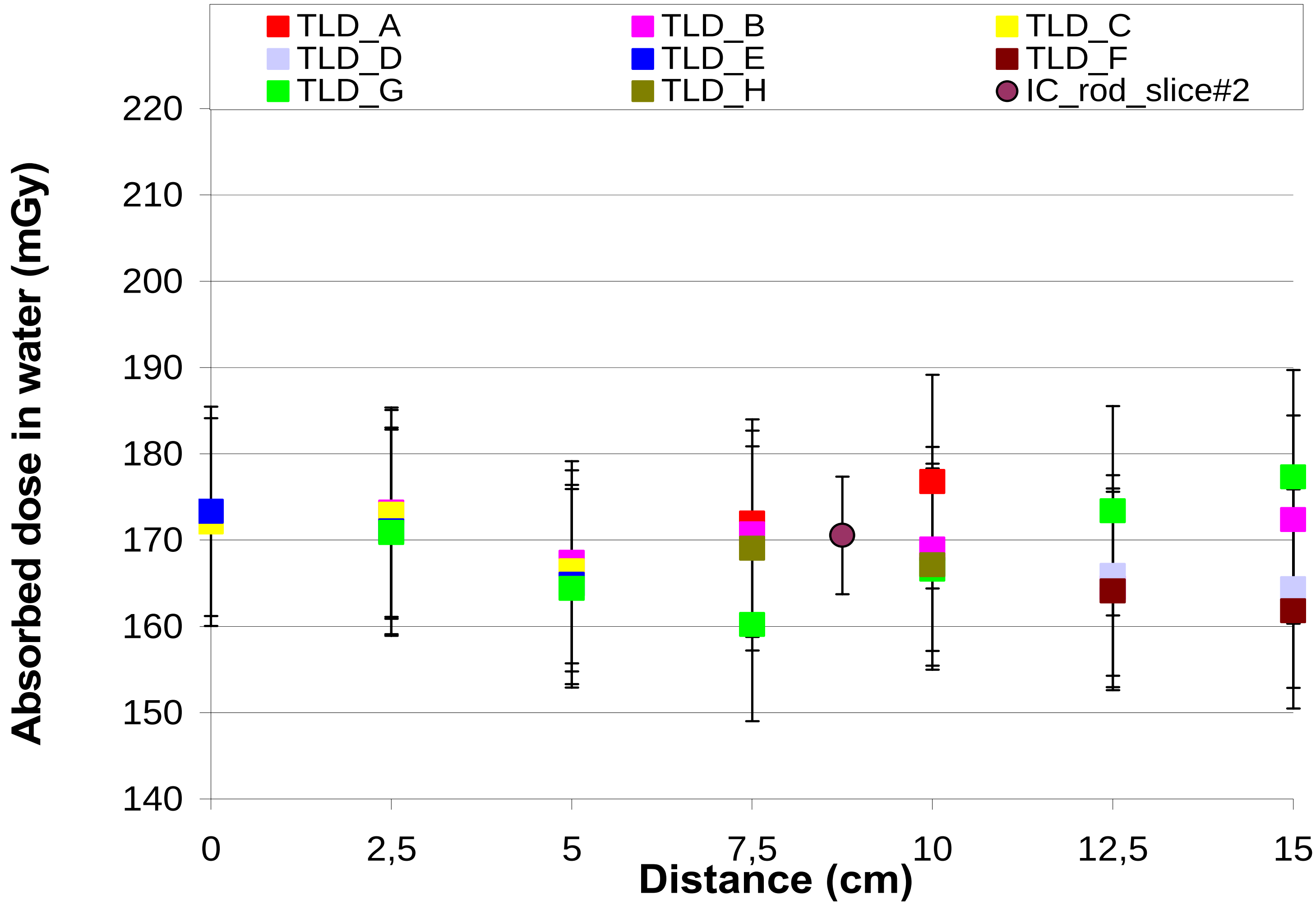


Deposited spatial energy density (GeV/cm^3) in slice #4 in the head.

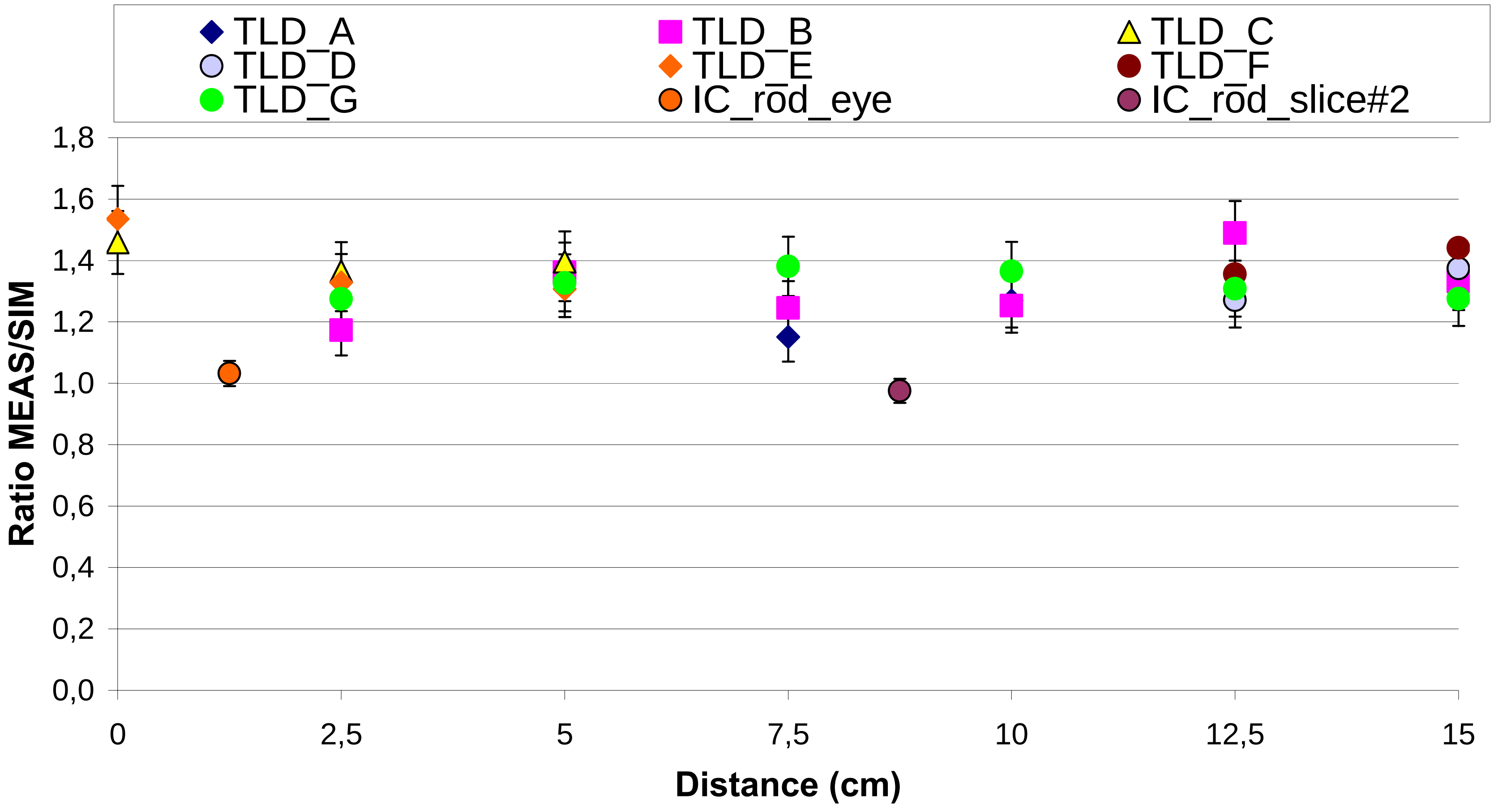
Results – Measurements TLD & IC, Omni directional



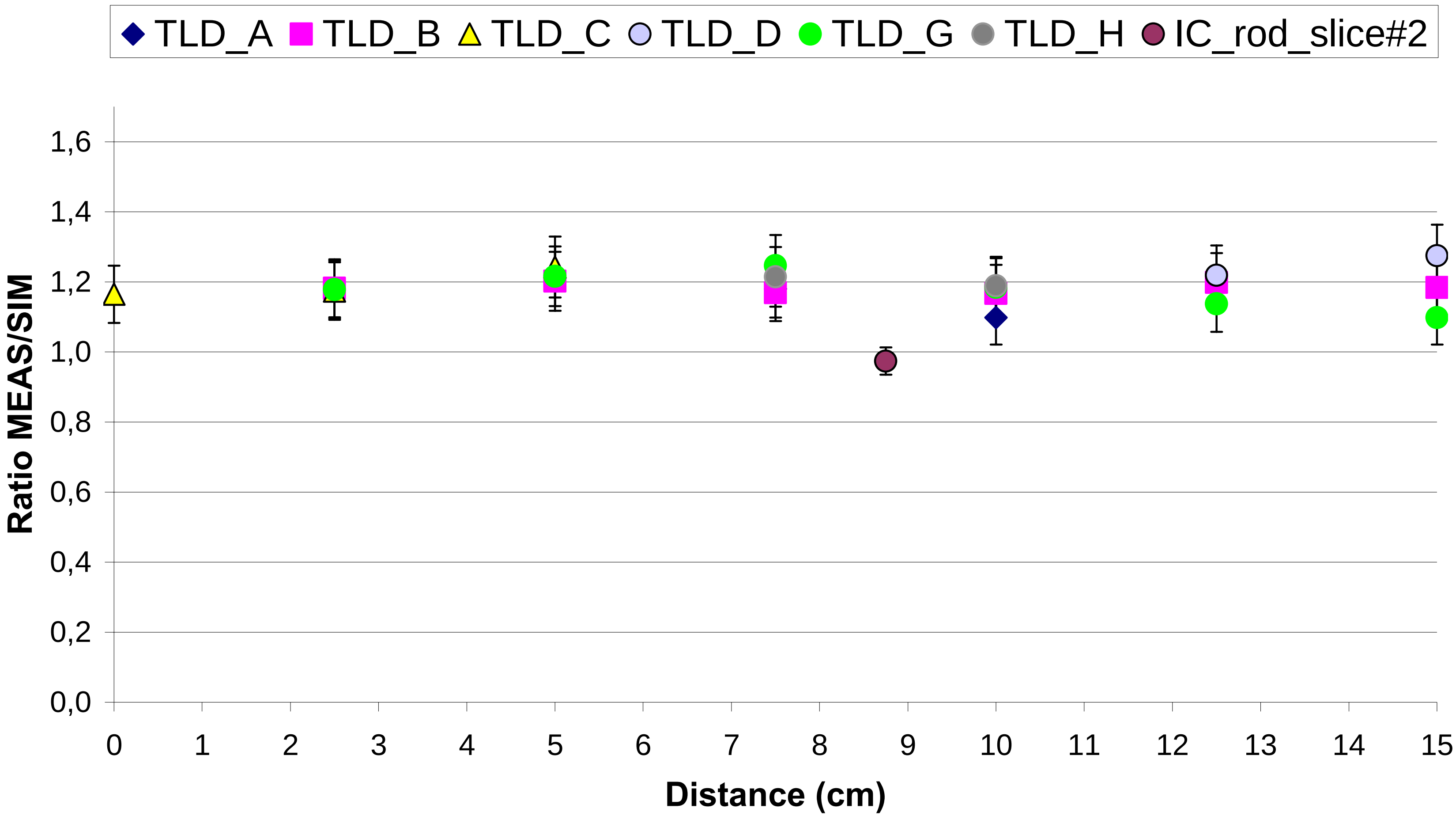
Results - Simulations TLD & IC, Omni directional Irradiation



Comparison Measurements and Simulations, Front Irradiation



Comparison Measurements and Simulation, Omni directional Irradiation



Conclusion: Co-60 Measurement and Simulation

Ionization chamber

- Good agreement between measurements and simulation (within 5%)
- Agreement compared to TLD measurements within 20-30%

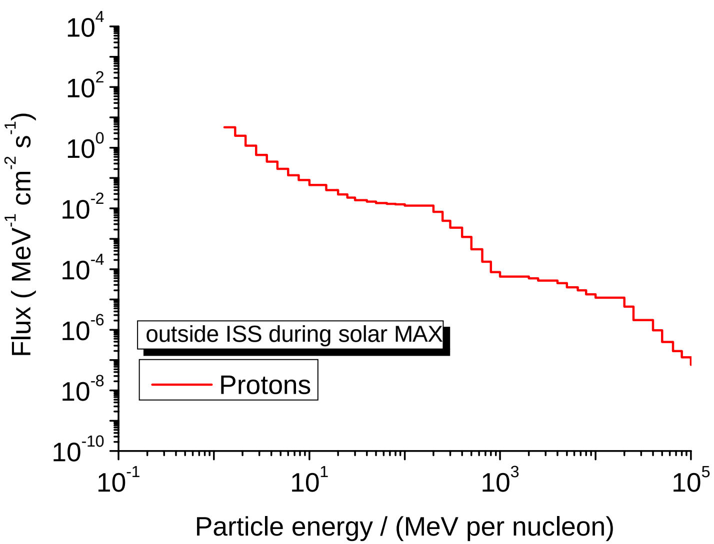
Thermoluminescence dose meters

- Agreement for omni directional irradiation within 10%
- For front within 35%

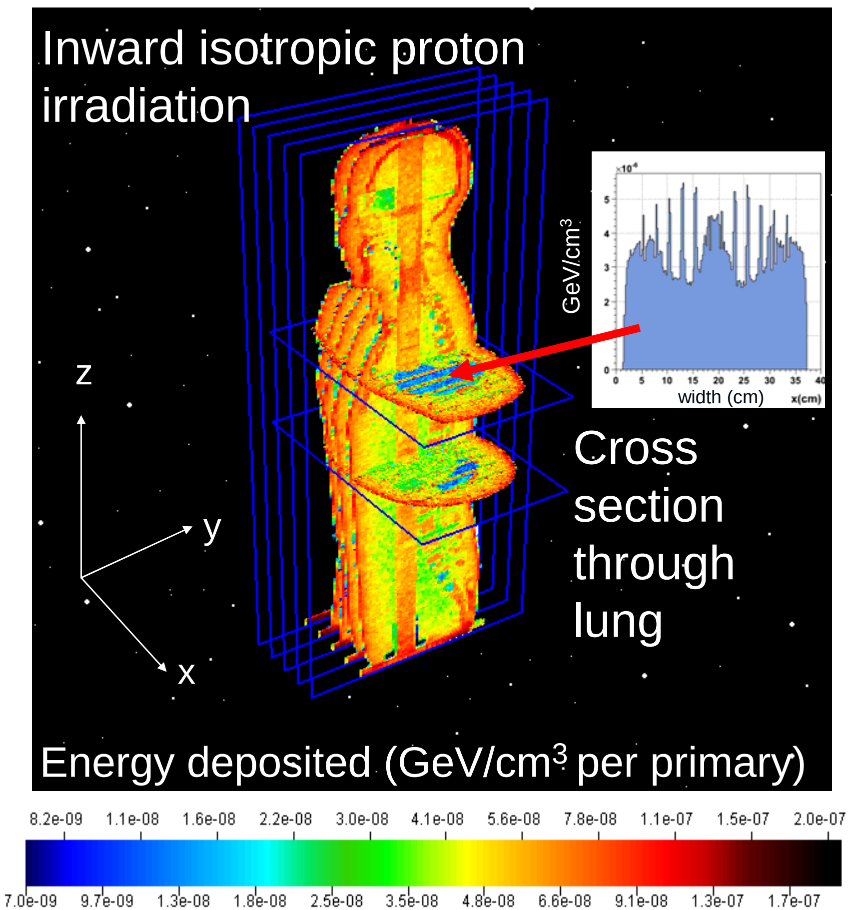
Next steps

- Detectors of the scan geometry will be adapted to the actual measurements
- Detectors will be simulated for LiF as well as for tissue and/or water
- Investigations of the electron spectrum within TLD detectors
- Investigation of the TLD calibration
- Reference measurements and simulations with neutrons, protons, and heavy ions

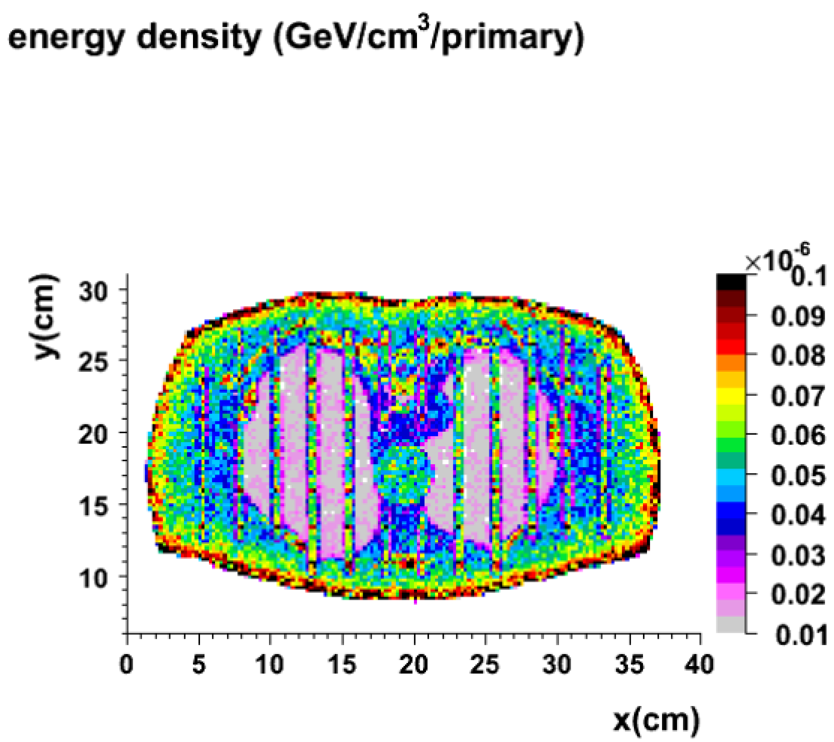
Outlook: MATSIM Investigations in Space Radiation Environment

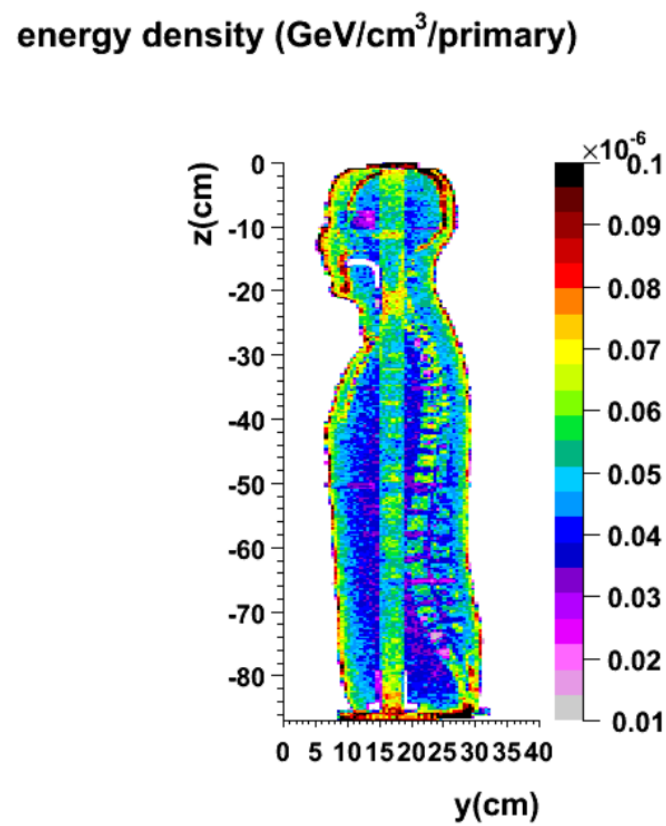


Fluence proton spectrum, outside ISS during solar maximum at 400 km (Armstrong, 1998)



Outlook: MATSIM Investigations in Space Radiation Environment





Isotropic proton irradiation
Cross section through the lung, MATSIM torso slice 15

Isotropic proton irradiation
Cross section center MATSIM to

Acknowledgments

The funding and the support by the Austrian Space Applications Programme (ASAP) and the MATROSHKA consortium is acknowledged.

Many thanks to DLR for providing the MATROSHKA phantom and the CT scans.

Many thanks also to ATI for the quick analysis of the TLD data during vacation time!

Thank you for your attention!