Activation and Capture Simulations

S. Riemann, A. Schälicke, **A. Ushakov**, D. Andrienko[1]

DESY, Germany
[1]Moscow Institute of Physics and Technology, Moscow, Russia

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The Cockcroft Institute
Daresbury Laboratory

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Outline

Introduction

Remote Handling

- Activation of water
- Shielding thickness around target
- Activation of capture section
  - copper vs aluminium
  - AMD and Li lens

Li lens

- Magnetic field of lens
- Energy deposition in window

Outlook

New Fluka Release

FLUKA 2008 has been released (September 2008)

- Equivalent dose is a new “standard” detector
- New radioactive decay database now includes also conversion electron and Auger lines
- New event generator should significantly improve residual nuclei predictions

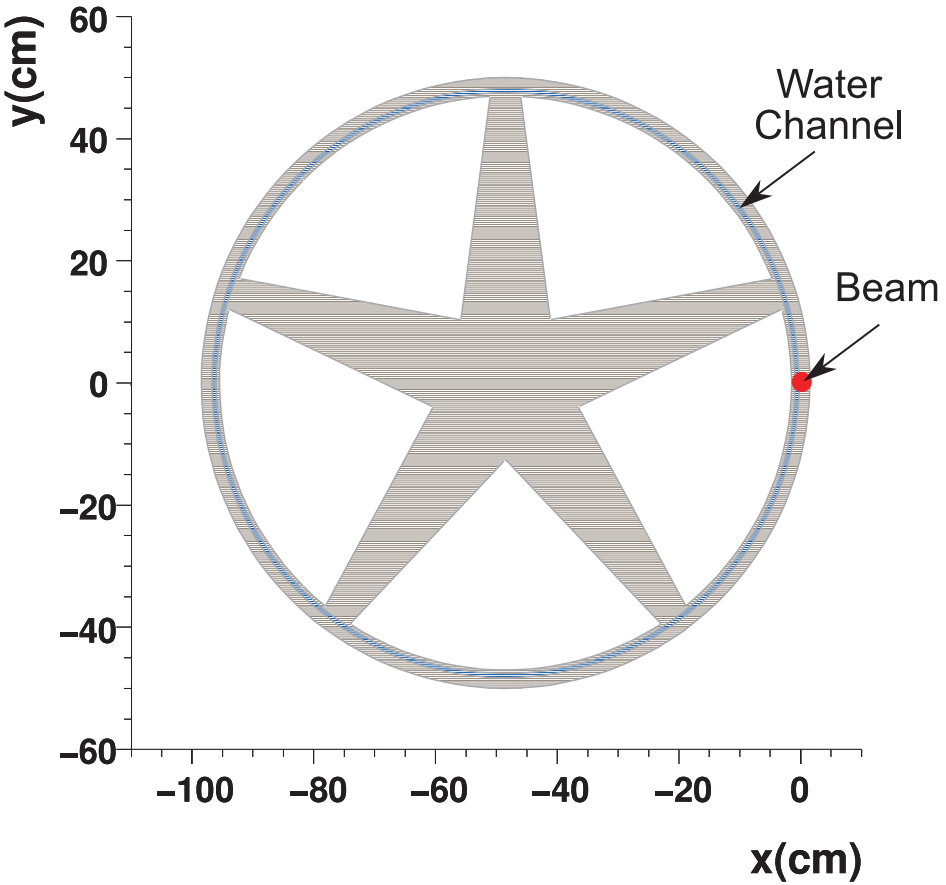
- Dose could be calculated for whole model only (contribution of different model parts into dose is not foreseen)
- Electric field is not implemented yet

General Remarks

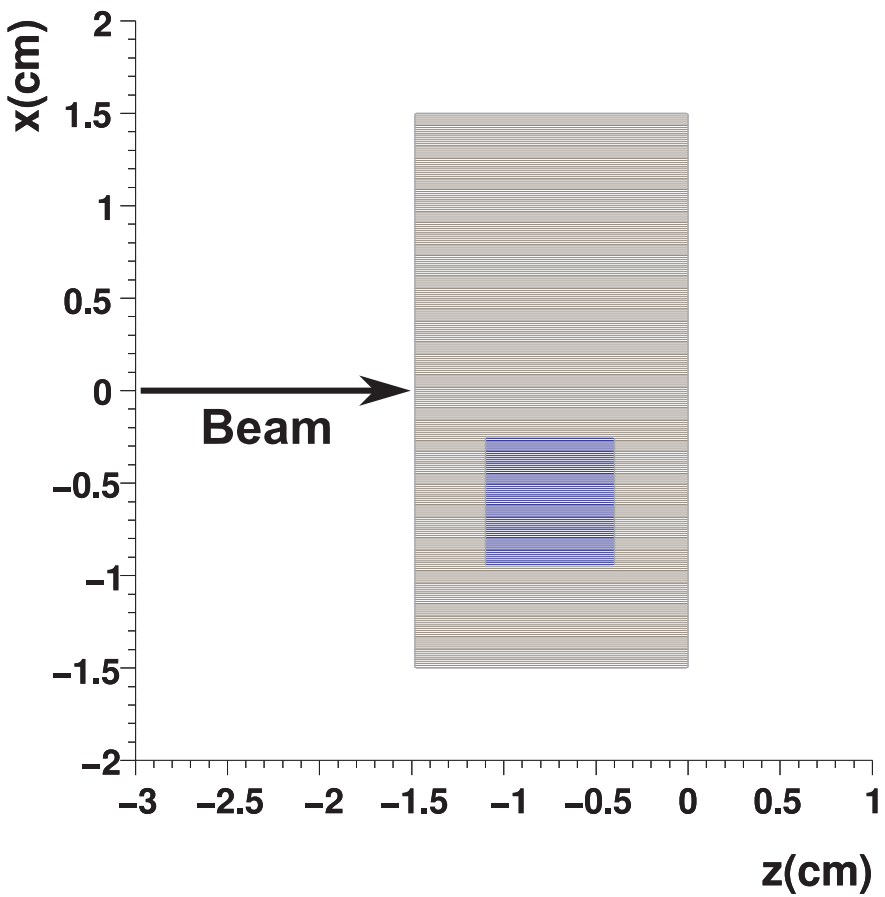
- Target material: Ti6Al4V
- Undulator: K = 0.92, period = 11.5 mm
- No photon collimator
- Number of incident on the target photons: $7 \cdot 10^{16}$ ph/s (positron capturing efficiency is 35%)

Activation of Water. Geometry of Target

Target Rim. XY-Plane



Target Rim. ZX-Plane



Activity of Target and Cooling Water after 5000 h of Irradiation and 0 s of Cooling Time

Activity of Target

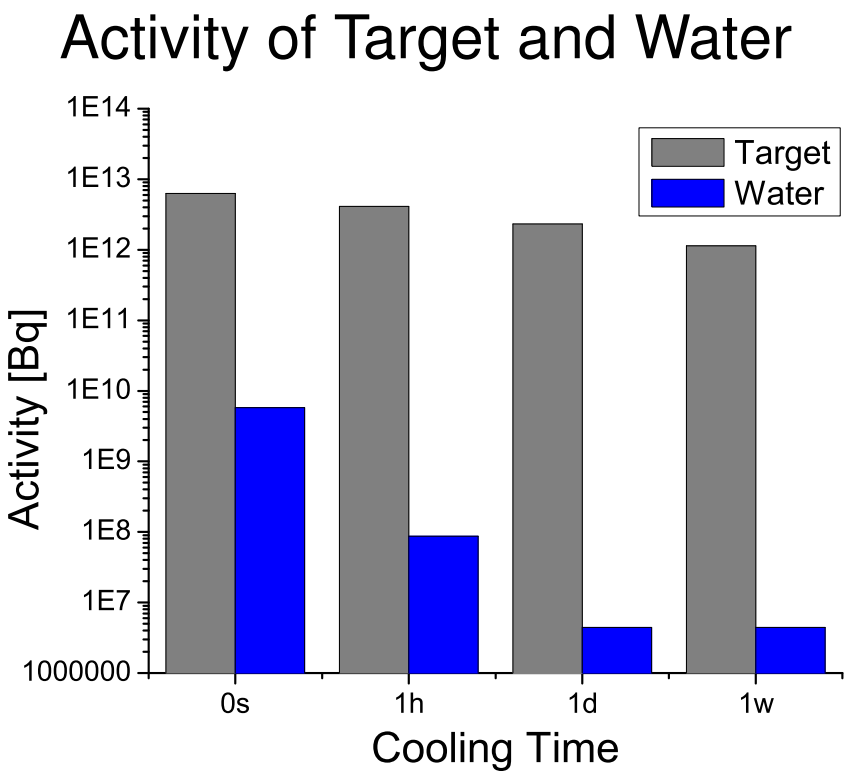
El.	Z	A	A_{+0s} [Bq]	Err. %	Frac. %
Ti	22	45	$1.7 \cdot 10^{12}$	0.5	26.4
Sc	21	47	$1.6 \cdot 10^{12}$	0.5	26.1
Sc*	21	45	$1.0 \cdot 10^{12}$	0.4	16.3
Sc	21	46	$6.3 \cdot 10^{11}$	0.5	10.0
Al*	13	26	$3.9 \cdot 10^{11}$	0.2	6.2
Sc*	21	46	$3.8 \cdot 10^{11}$	0.5	6.1
Sc	21	44	$2.0 \cdot 10^{11}$	1.5	3.2
...					
$\sum$			$6.3 \cdot 10^{12}$		

Activity of Water

El.	Z	A	A_{+0s} [Bq]	Err. %	Frac. %
O	8	15	$4.9 \cdot 10^{9}$	8.9	85.1
C	6	11	$6.2 \cdot 10^{8}$	15.4	10.7
N	7	13	$1.4 \cdot 10^{8}$	31.6	2.4
N	7	16	$6.7 \cdot 10^{7}$	46.8	1.2
O	8	14	$2.8 \cdot 10^{7}$	99.9	0.5
H	1	3	$4.4 \cdot 10^{6}$	31.6	0.1
C	6	14	$2.5 \cdot 10^{4}$	31.3	<0.1
$\sum$			$5.7 \cdot 10^{9}$		

* Isomers

Activity of Target and Cooling Water after 1 h, 1 day and 1 week



Activity of Water

after 1 week of cooling time

El.	Z	A	$T_{0.5}$	A_{+1w} [Bq]	Err. %	Frac. %
H	1	3	12.3 y	$4.4 \cdot 10^6$	31.6	99.4
C	6	14	5700 y	$2.5 \cdot 10^4$	31.3	0.6

Shielding around Target

Modification of Model:

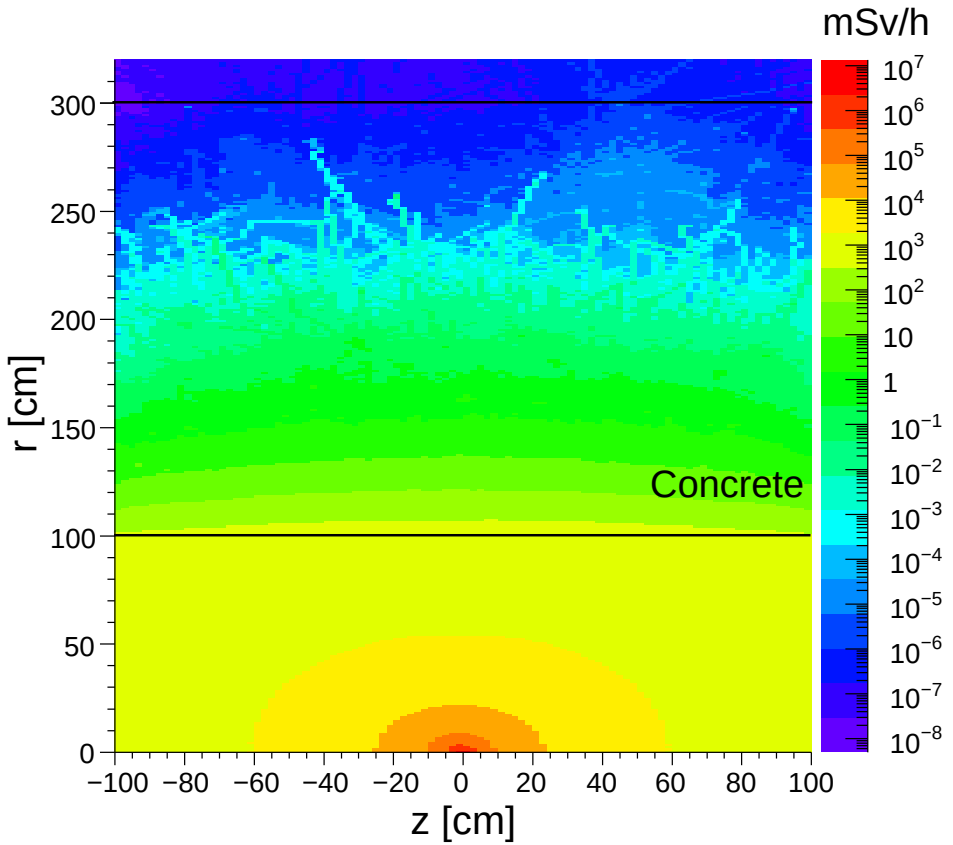
- 2m concrete wall has been added
- Target rim has been changed to the disk with radius of 1.5 cm
- Cooling water channel has been removed

Composition of Concrete ($2.34\ g/cm^3$)

El.	Frac. %
H	10
C	23
O	40
Mg	2
Si	12
Ca	12

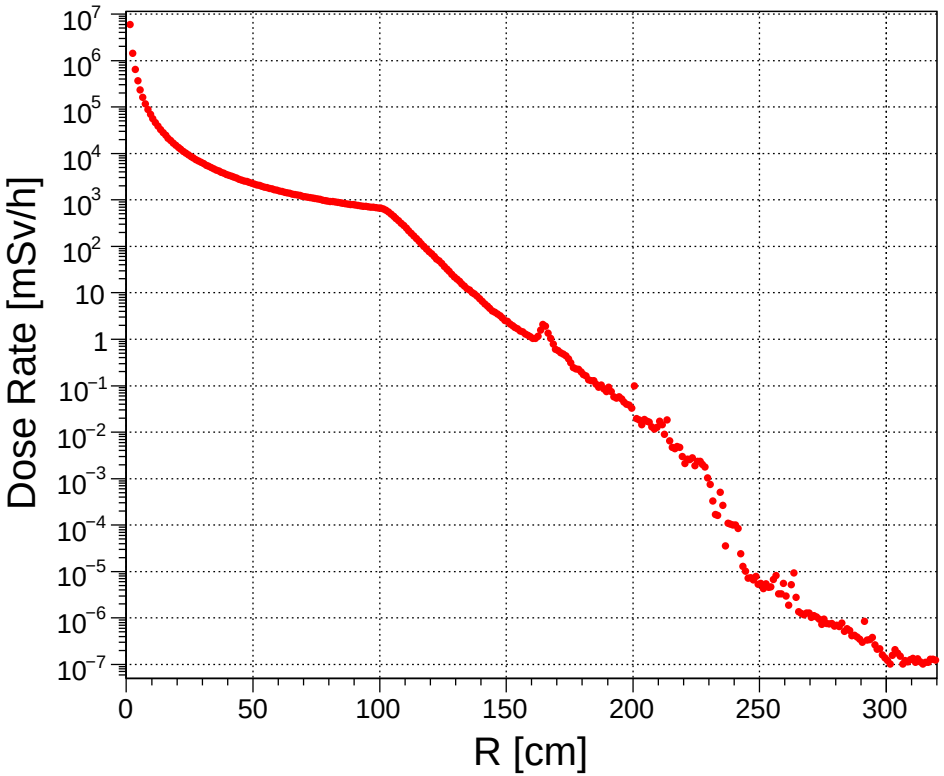
Dose Rate

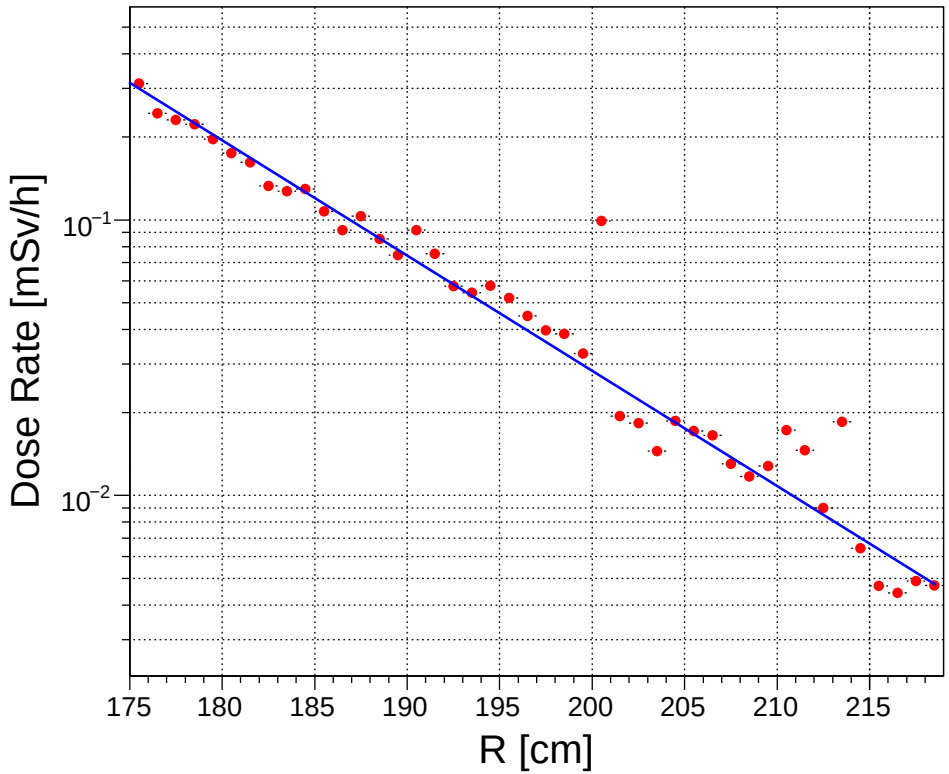
after 5000 h of irradiation and 0 s of cooling time



Required Thickness of Shielding

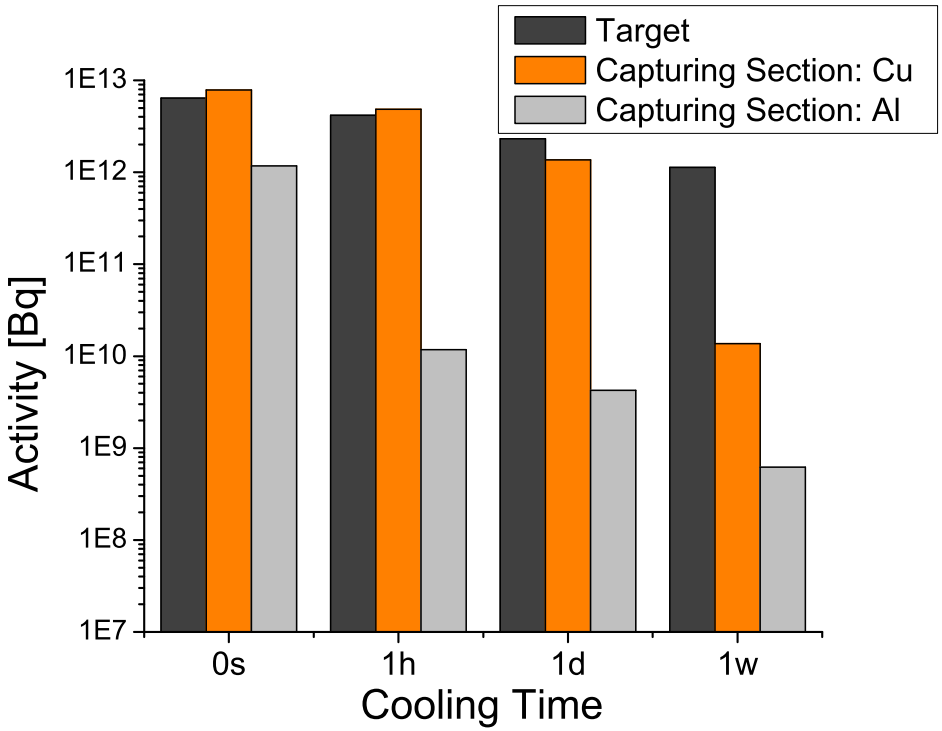
Personal dose: 20 mSv/year; 2000 h/year $\mapsto$ $\dot{D}_{max}$ = 0.01 mSv/h

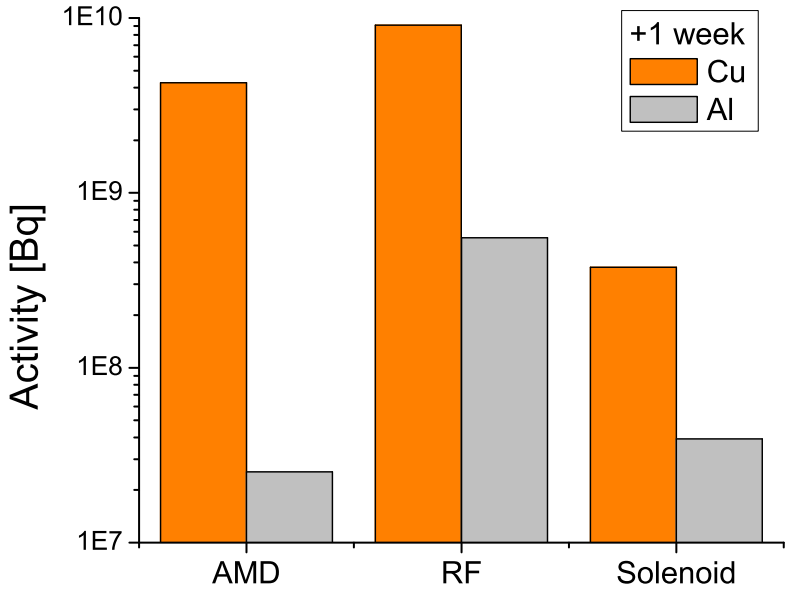




Activation of Capturing Section. Cu vs Al

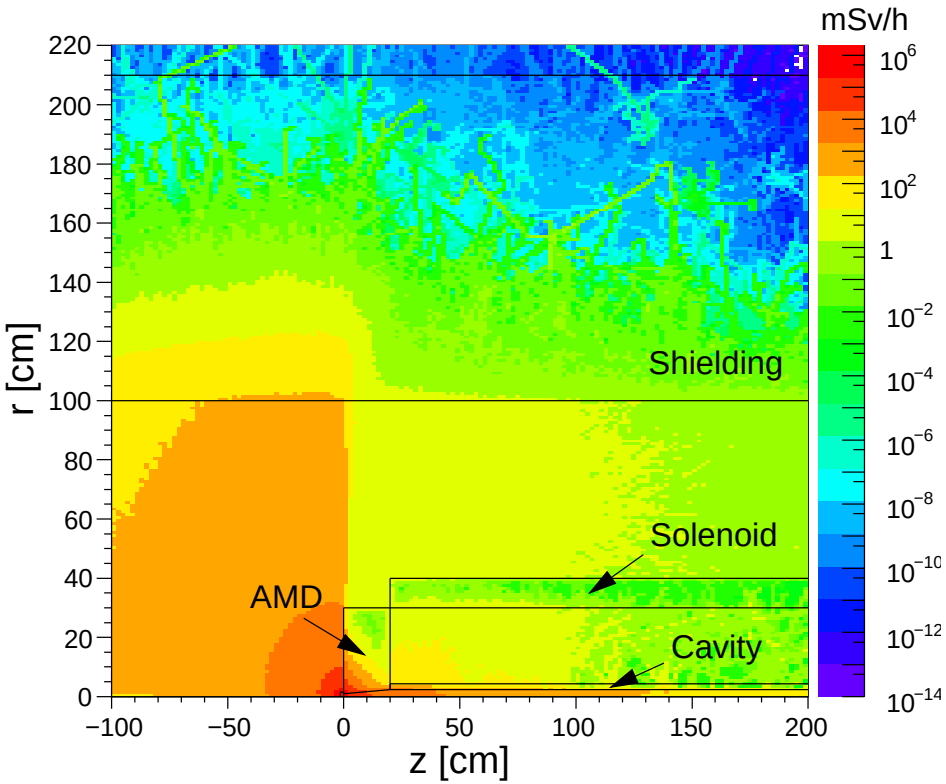
Capturing Secting: AMD + RF Structure (1.8 m) + Solenoid (1.8 m)



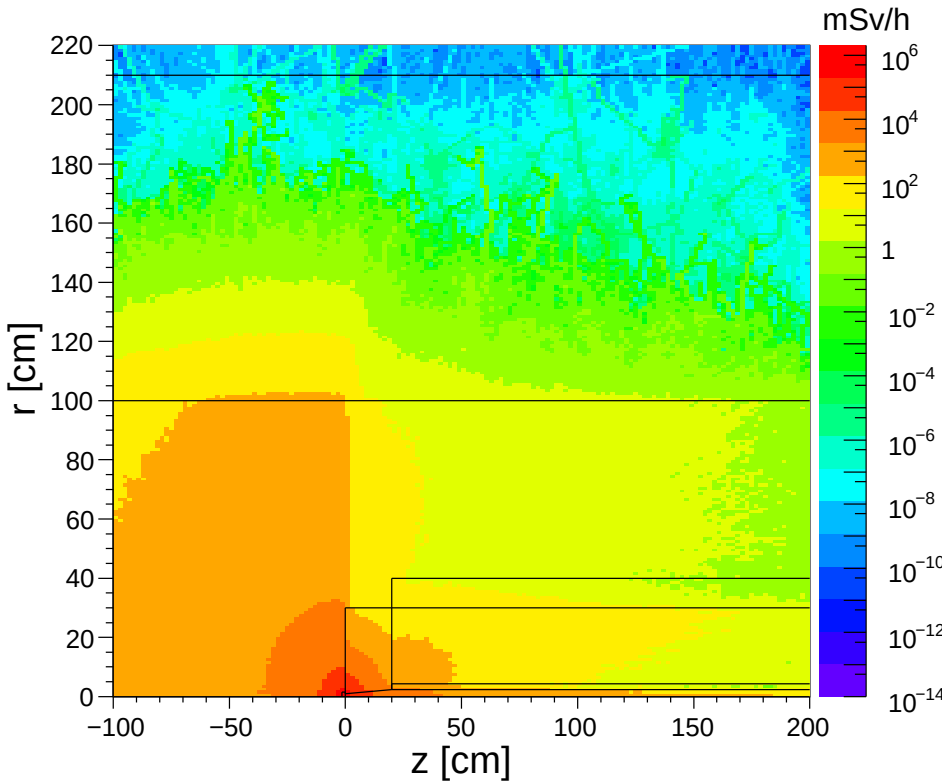


Dose Rate. Cu vs Al

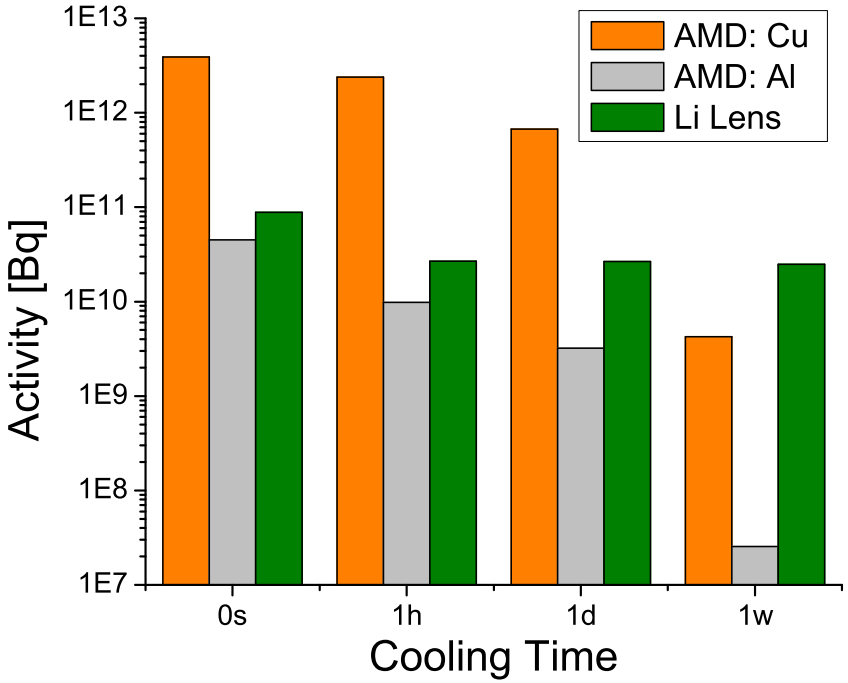
Dose Rate after 1 week (Cu)



Dose Rate after 1 week (Al)



Activation of AMD and Li Lens



Activity of Li Lens

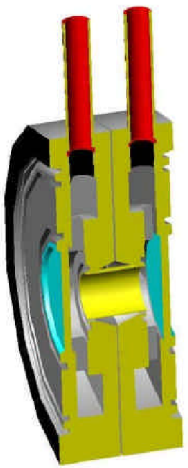
after 1 week of cooling time

El.	Z	A	$T_{0.5}$	A_{+1w} [Bq]	Err. %	Frac. %
H	1	3	12.3 y	$8.2 \cdot 10^{9}$	2.5	33.0
Be	4	7	53.2 d	$2.5 \cdot 10^{10}$	12.7	67.0

Magnetic Field of Li Lens

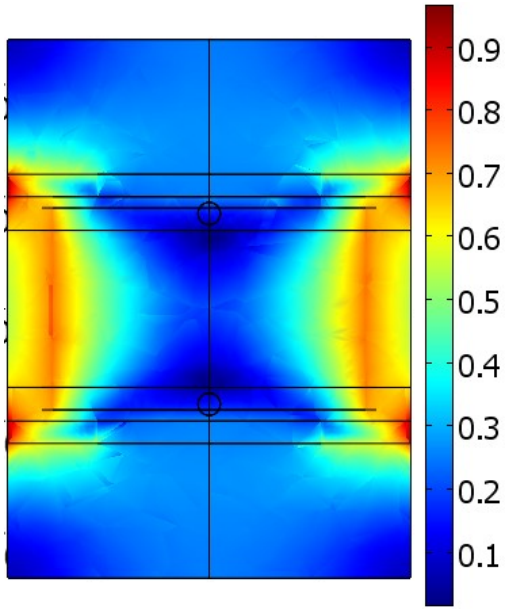
COMSOL Simulation, Daniil

Model

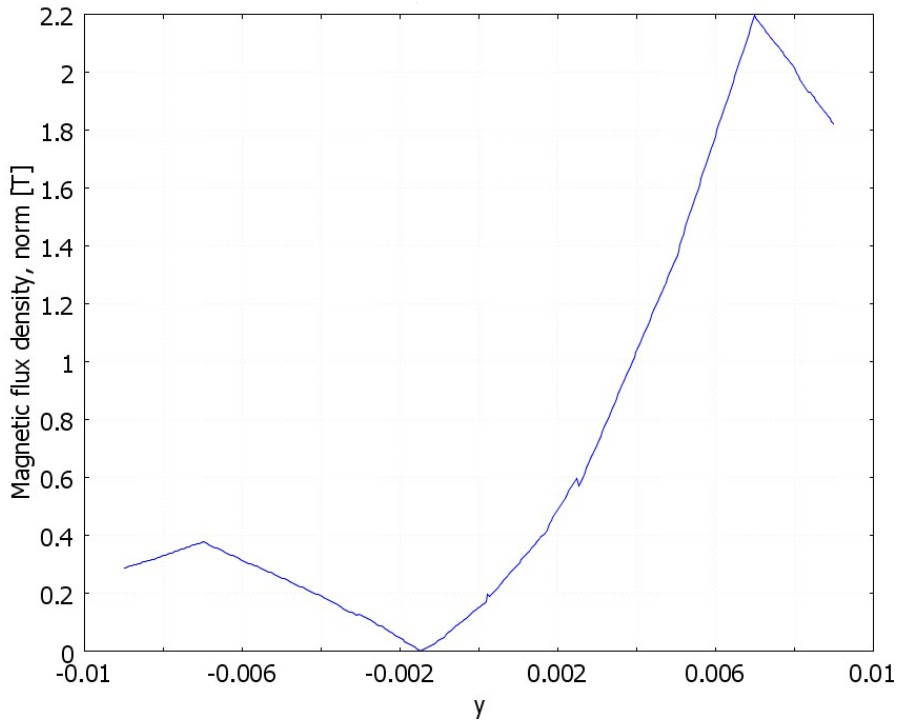


Field Map

in Horizontal Plane (XZ)



Field along Y Axis



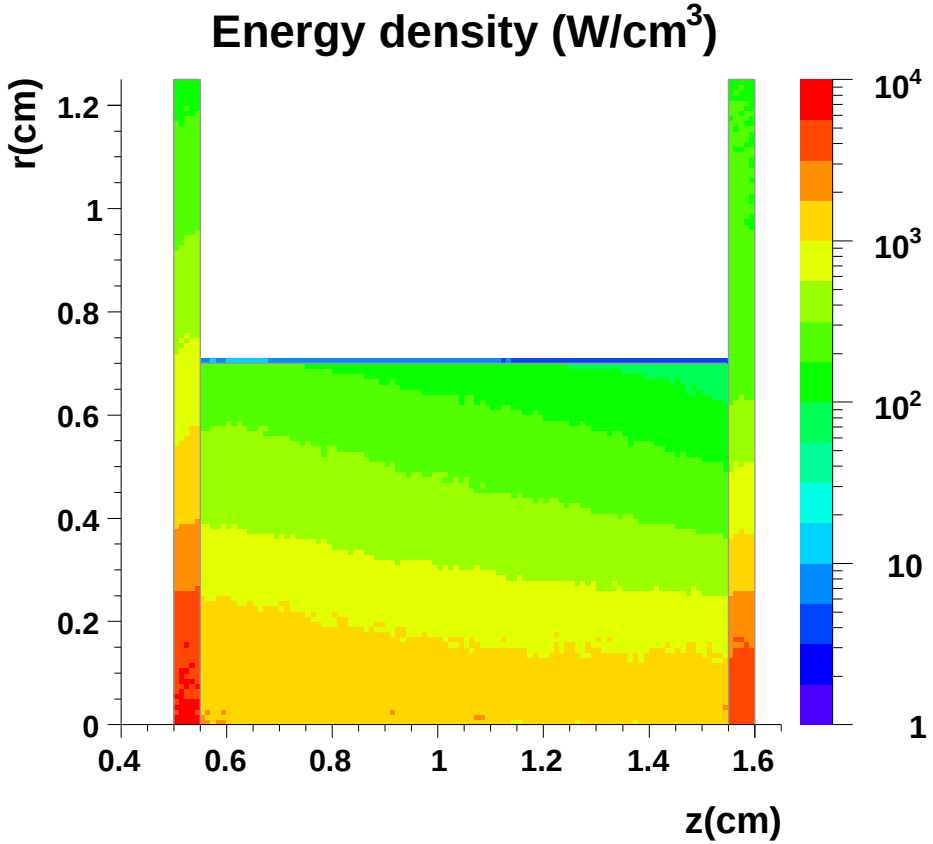
Energy Deposition in Li Lens

Deposited Energy per Photon

Part	E [keV/ph]
Target	803.2
Be window (left)	11.6
Li	37.9
Be window (right)	6.5

$\langle E_{ph} \rangle$ = 10.4 MeV

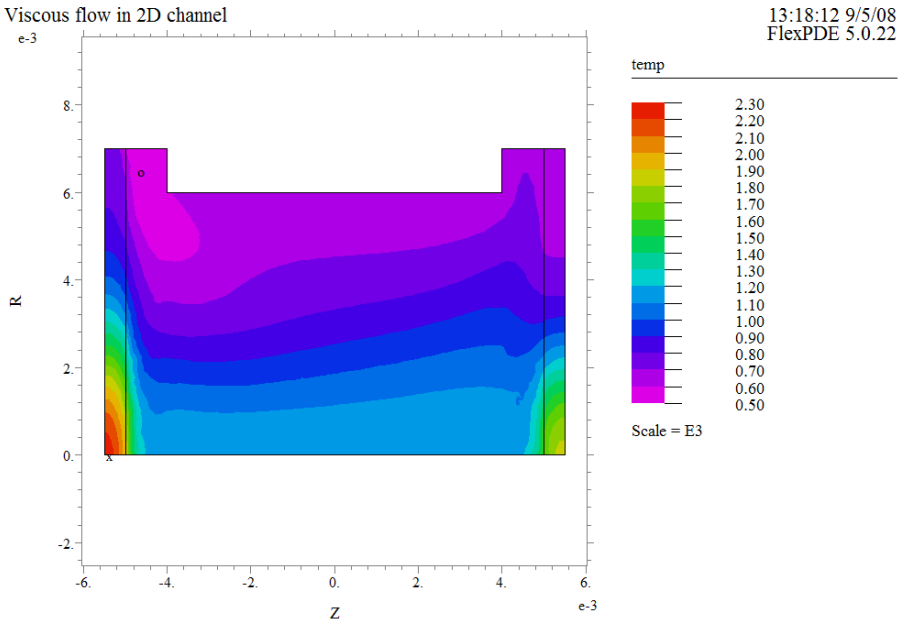
Undulator Length = 131.6 m



Heat Dissipation in Li Lens (FlexPDE Calculations, Daniil)

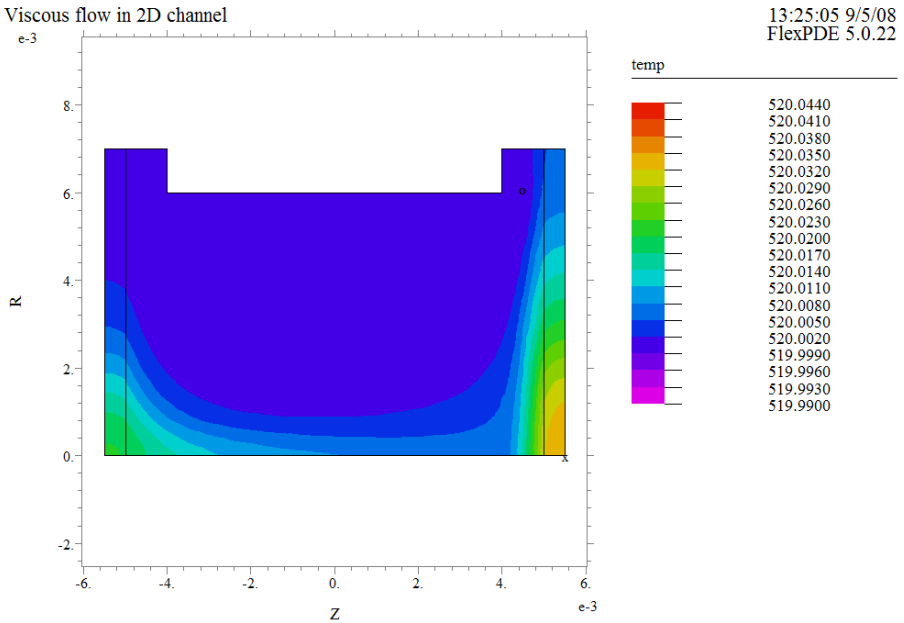
Model assumption: Li laminar flow (10 m/s)

Temperature Map after Fist Pulse



Full: Cycle=51 Time= 1.0000e-3 dt= 5.7499e-5 P2 Nodes=483 Cells=218 RMS Err= 6.6e-4
Vol_Integral= 1.067437e-3

Temperature Map before Second Pulse



Full: Cycle=321 Time= 0.2000 dt= 8.8378e-4 P2 Nodes=693 Cells=320 RMS Err= 4.7e-4
Vol_Integral= 7.106305e-4

Summary

- Activation of water is about 5 GBq that is 3 order of magnitude less then activation of the target (for short time after source switch off)
- Main contribution in activity and dose rate of water for relatively long cooling times make the tritium (half-life is 12.3 y)
- 1.1 m concrete is required to reduce dose down to 0.01 mSv/h
- Al is preferable material for the capture section but dose is strongly dominated by activation of the target. Therefore, capture section made from Al could not help much.
- Activation of Li lens has been estimated
- Current feeds have significant impact on lens field
- Preliminary estimation shows that entrance lens window will not survive first beam pulse (at least for 10 m/s Li flow). More sophisticated heat transfer modeling is required