Activation analysis in the BNCT irradiation room

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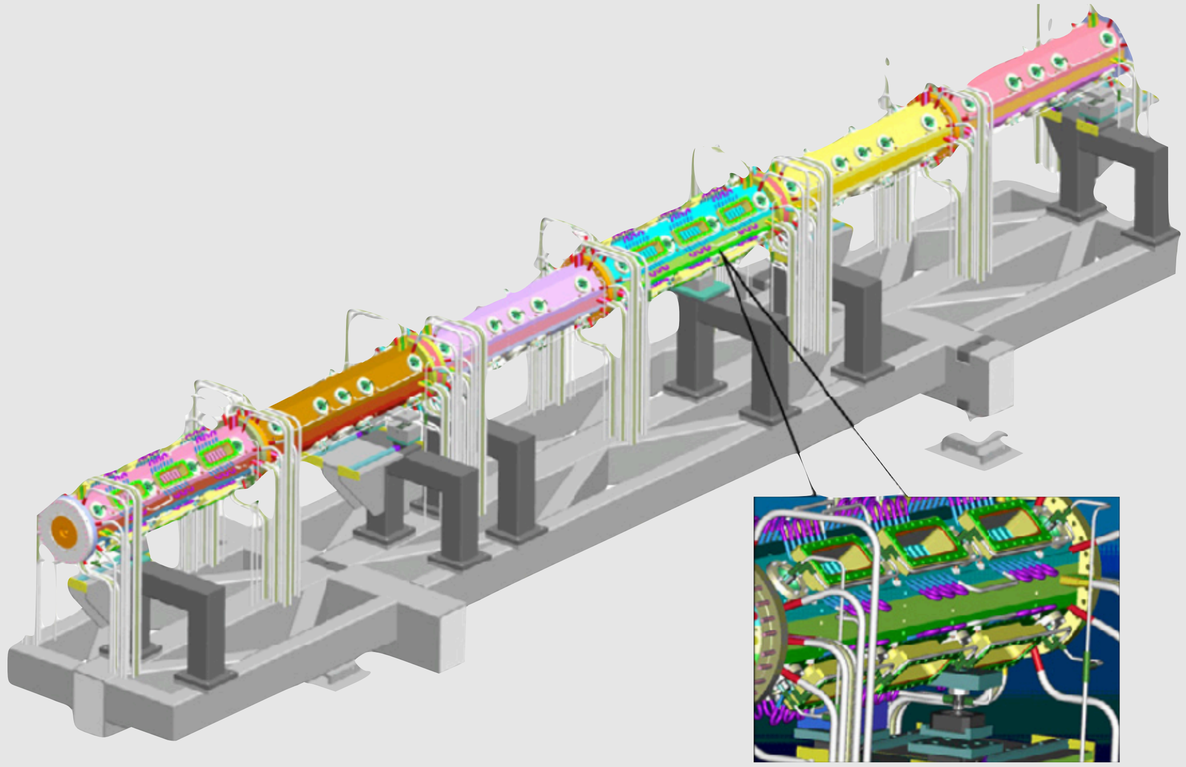
RFQ proton accelerator (5 MeV, 30 mA) + Beryllium target

+ Beam Shaping Assembly



→ epithermal neutron beam

OUTLINE

Neutron flux ~ 10^9 cm^{-2} s^{-1} → issue of neutron activation

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- BSA activation
- Activation of air (Ar-40)
- Activation of walls
- Activation of patient (urine, soft tissue)

BSA

peak @ 1-10 keV → main constituent: AlF_3

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composition with
NAA @ research nuclear
reactor “TRIGA Mark II”

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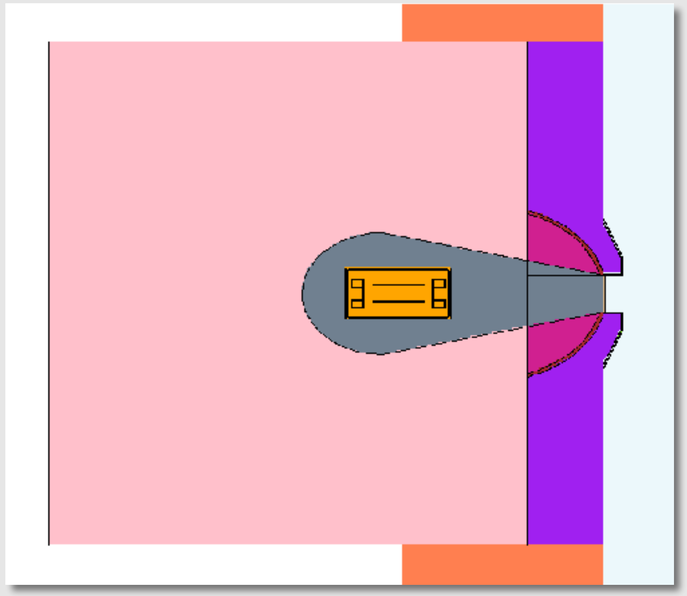

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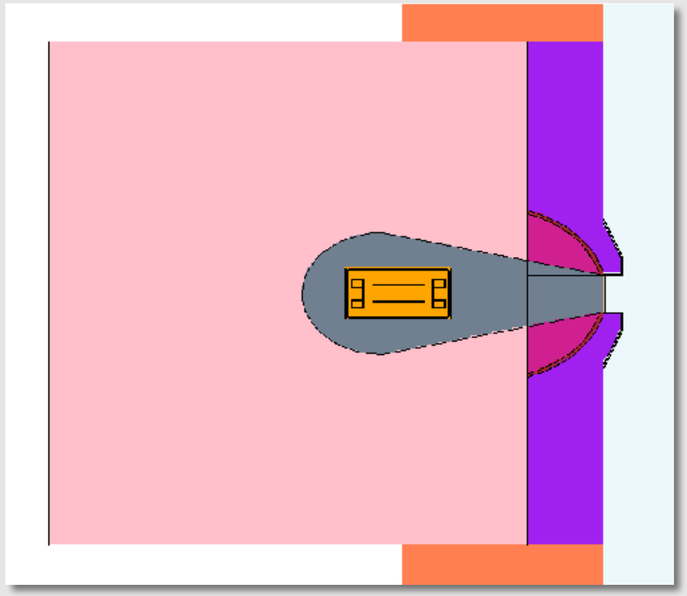

composition with
NAA @ research nuclear
reactor "TRIGA Mark II"

residual activity after irradiation

Nuclide	a [Bq/g]
Al-28	$(2.9\pm0.3)\cdot10^{6}$
As-76	$(7.7\pm1.5)\cdot10^{3}$
Br-82	15 ± 3
Co-60	$(4.8\pm1.0)\cdot10^{-1}$
Fe-59	$(2.4\pm0.5)\cdot10^{-2}$
Ga-72	$(4.0\pm0.8)\cdot10^{2}$
Mg-27	$(6.6\pm1.3)\cdot10^{4}$
Na-24	$(9.5\pm1.9)\cdot10^{2}$
Sb-122	3.2 ± 0.6
Sb-124	$(2.4\pm0.5)\cdot10^{-1}$
Sc-46	$(3.0\pm0.6)\cdot10^{-3}$
Zn-65	$(2.3\pm0.4)\cdot10^{-1}$

Ongoing studies:

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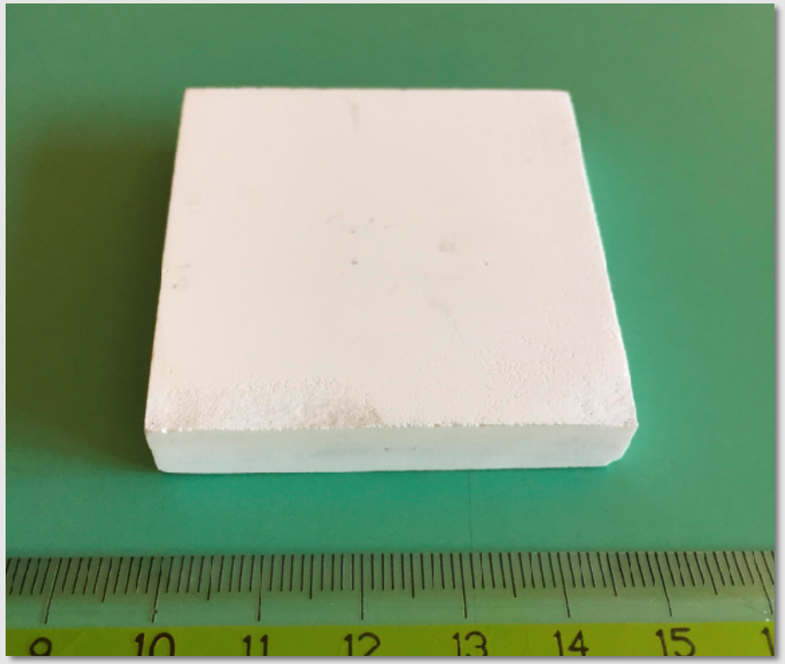
- sintered AlF_3



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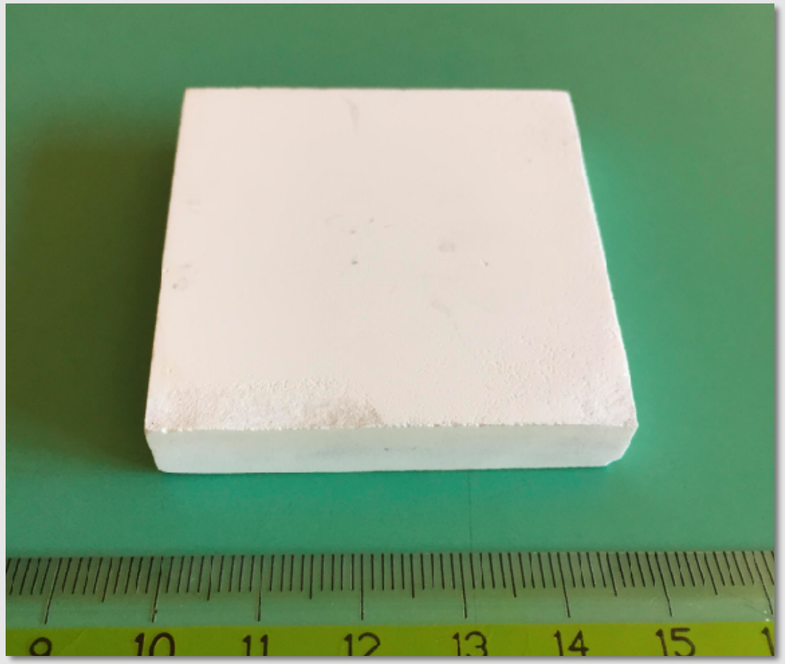

- other facility elements (patient coach…)

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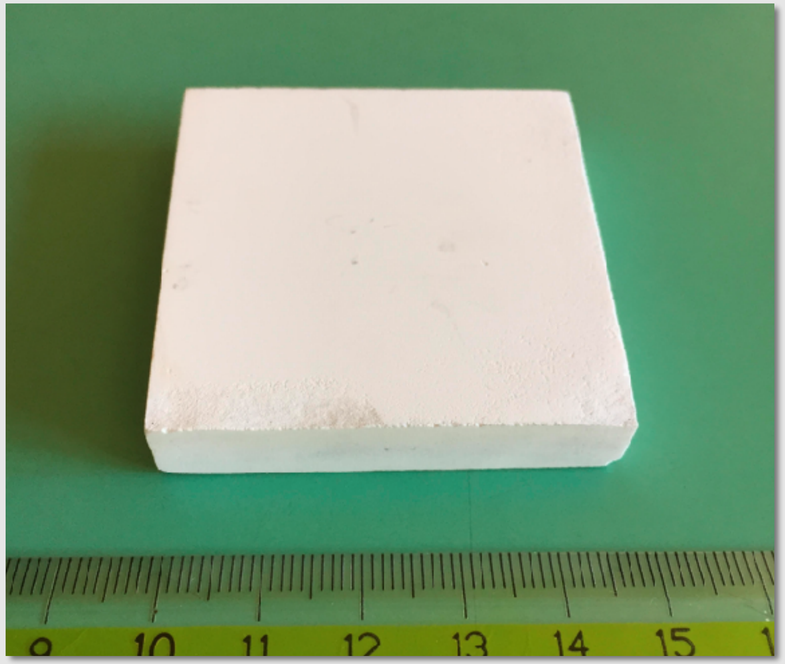

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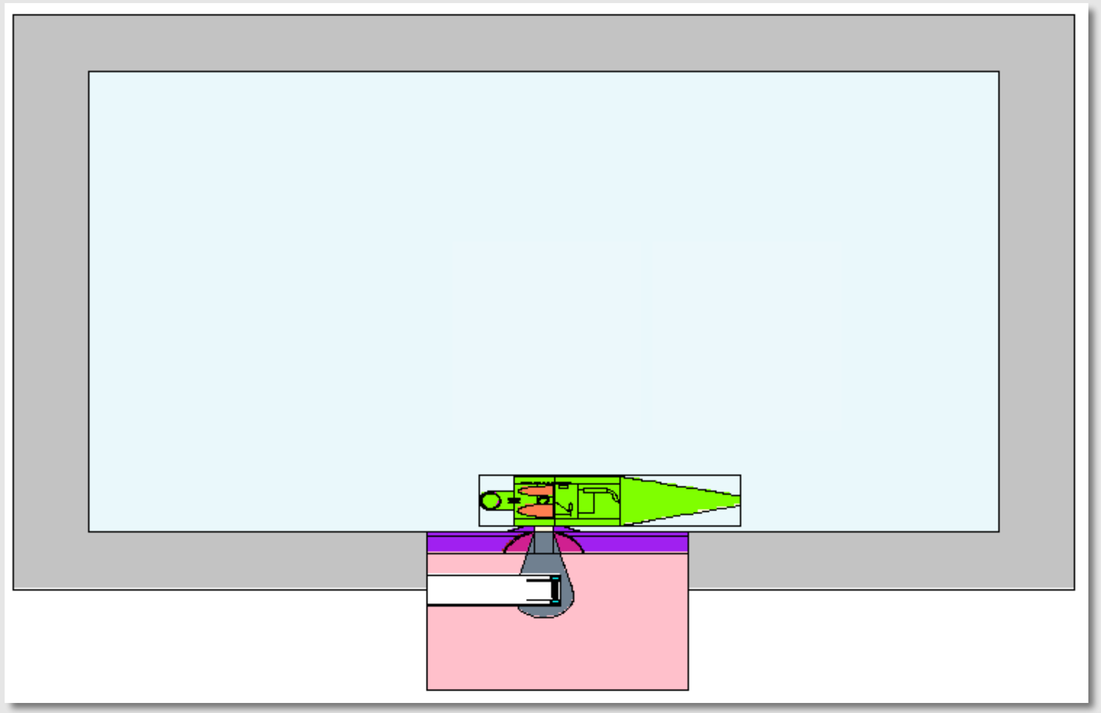
TREATMENT ROOM



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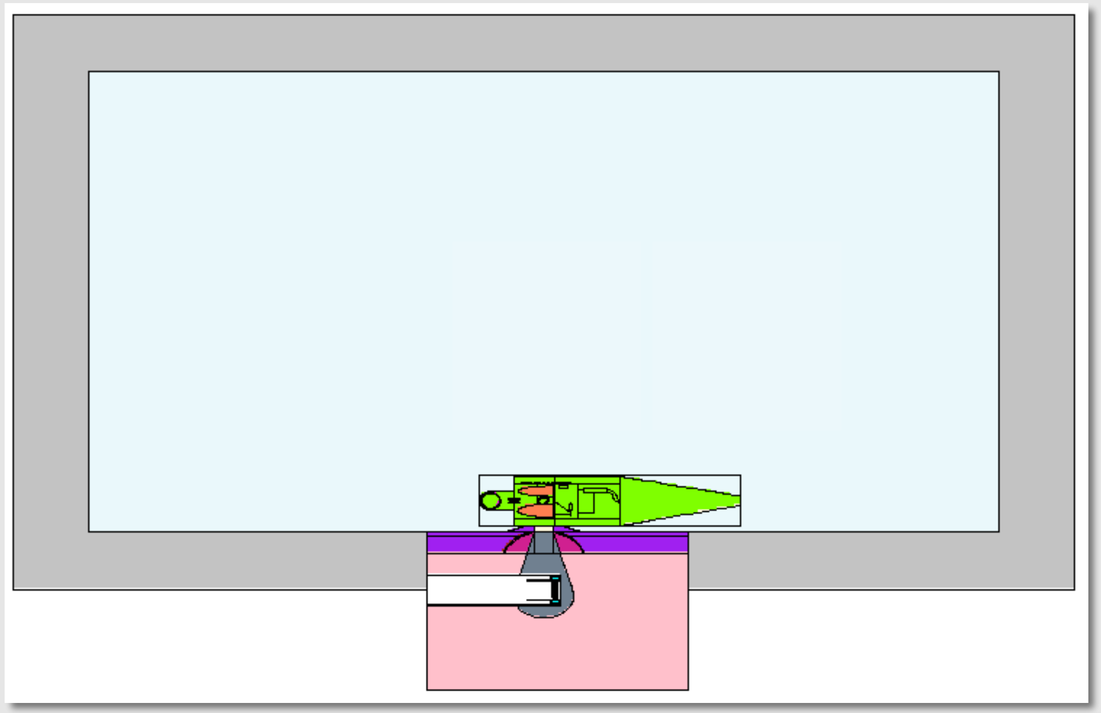
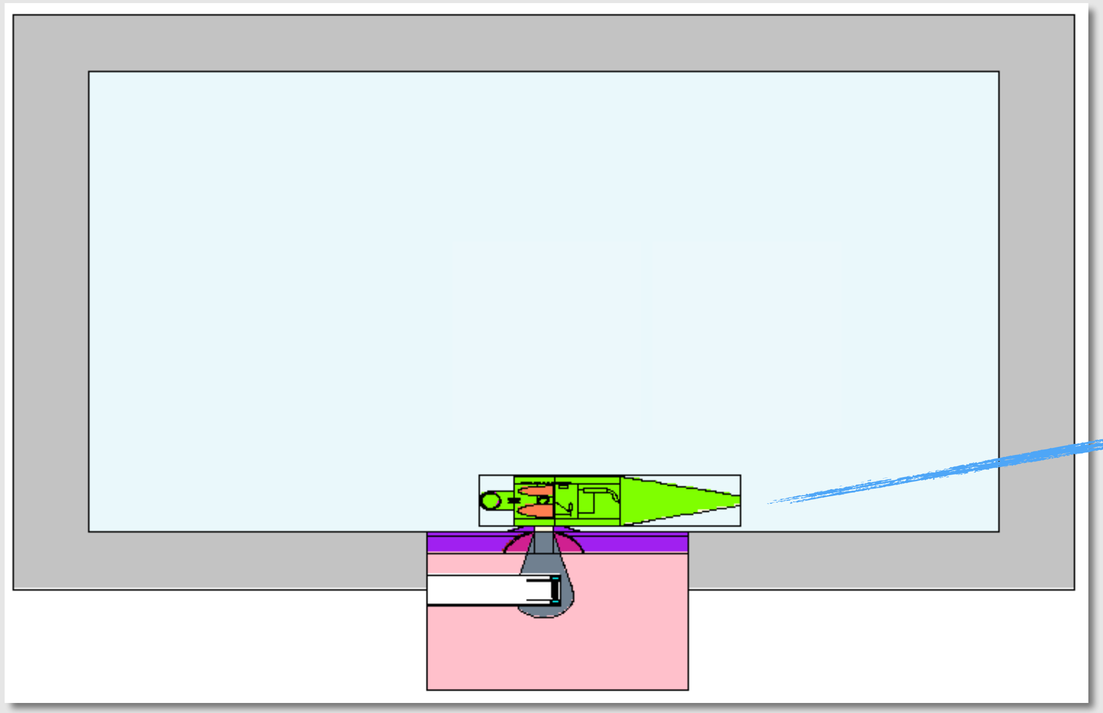


3.3x4x6 m^3

TREATMENT ROOM



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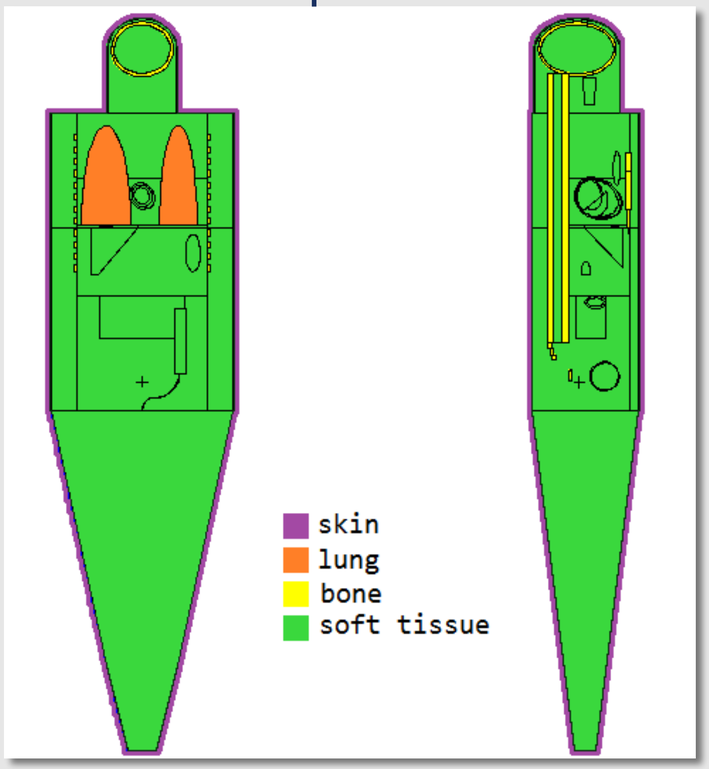
MIRD phantom



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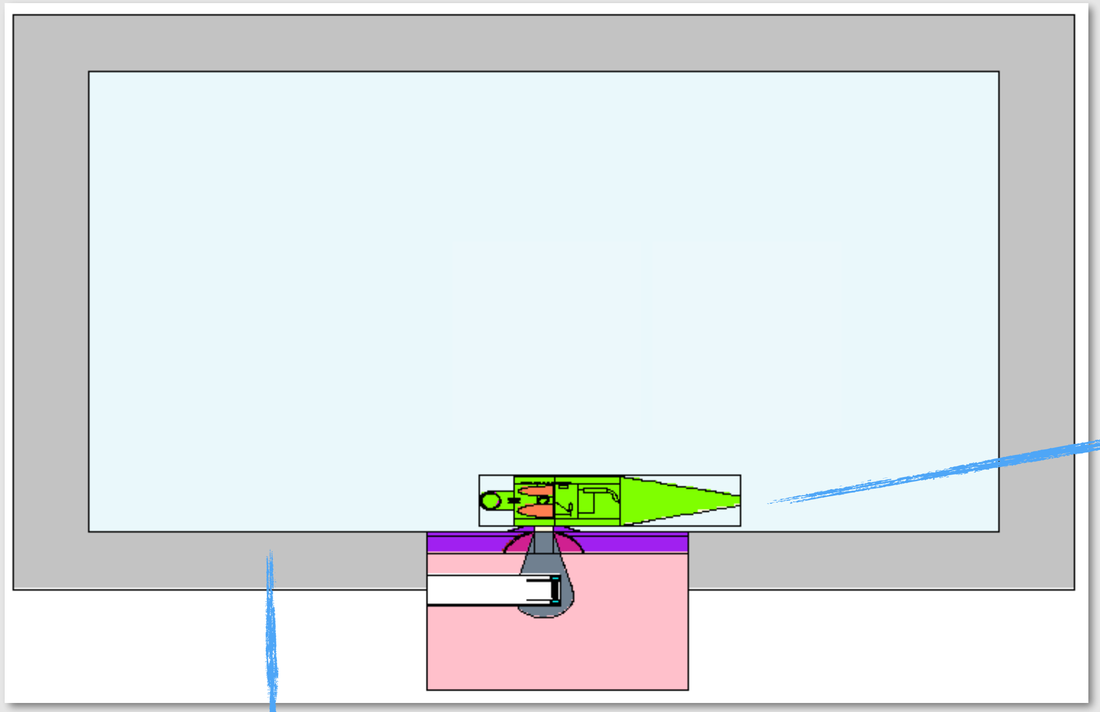

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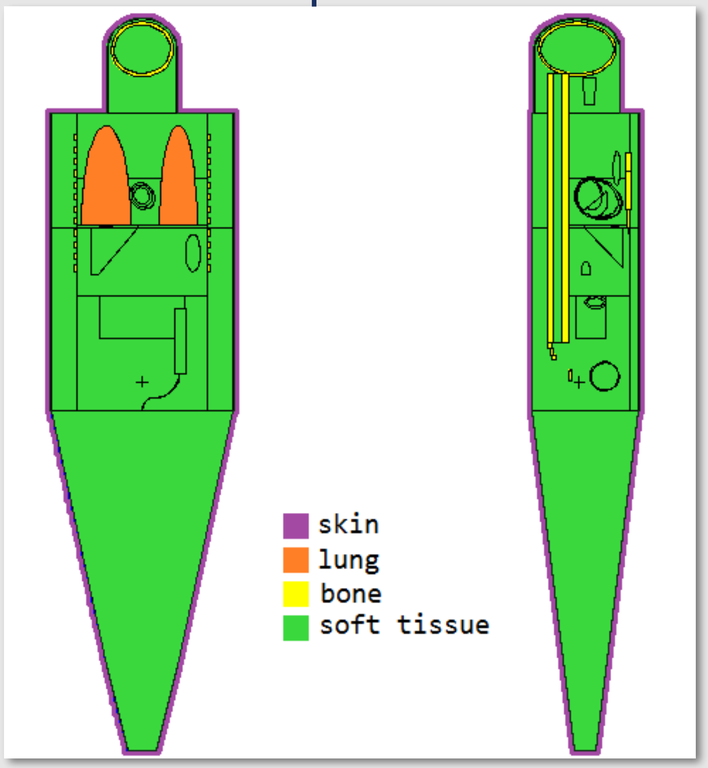
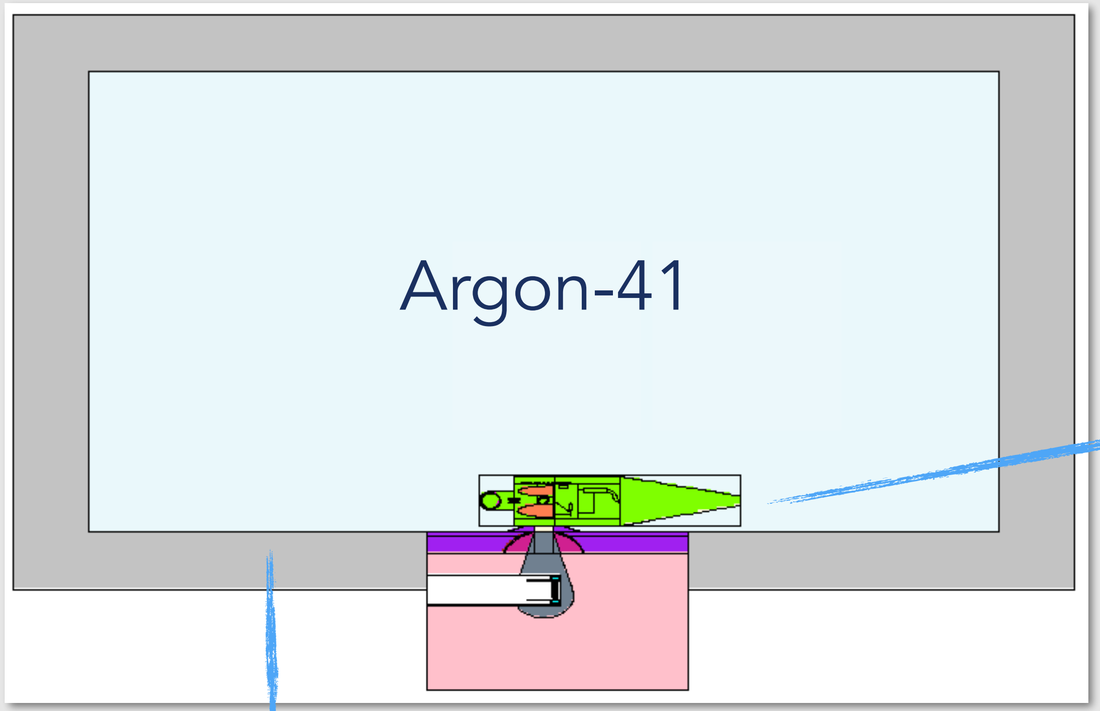


- concrete
- borated concrete
- polyethylene
- lithiated polyethylene

TREATMENT ROOM



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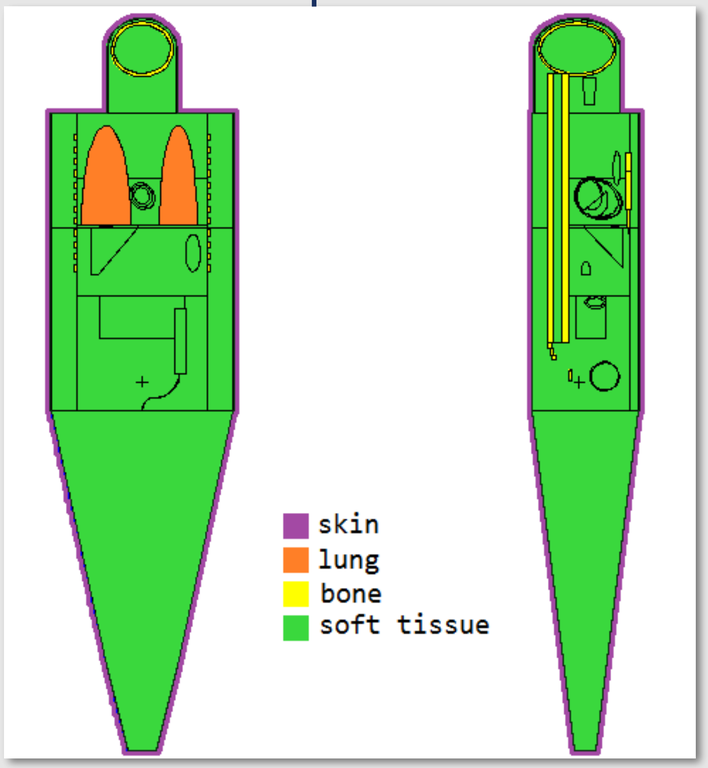

AIR ACTIVATION

$$\frac{dA}{dt} = R\lambda_{phys} - (\lambda_{phys} + \lambda_{air})A$$

$$a = \frac{R\lambda_{phys}}{m\lambda_{air}}$$

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Walls composition	R [s^{-1}]	a [Bq/g]
concrete	2.1×10^7	5.6
concrete + boron	2.6×10^5	0.07
polyethylene	9.7×10^6	2.6
polyethylene + lithium	8.3×10^5	0.22

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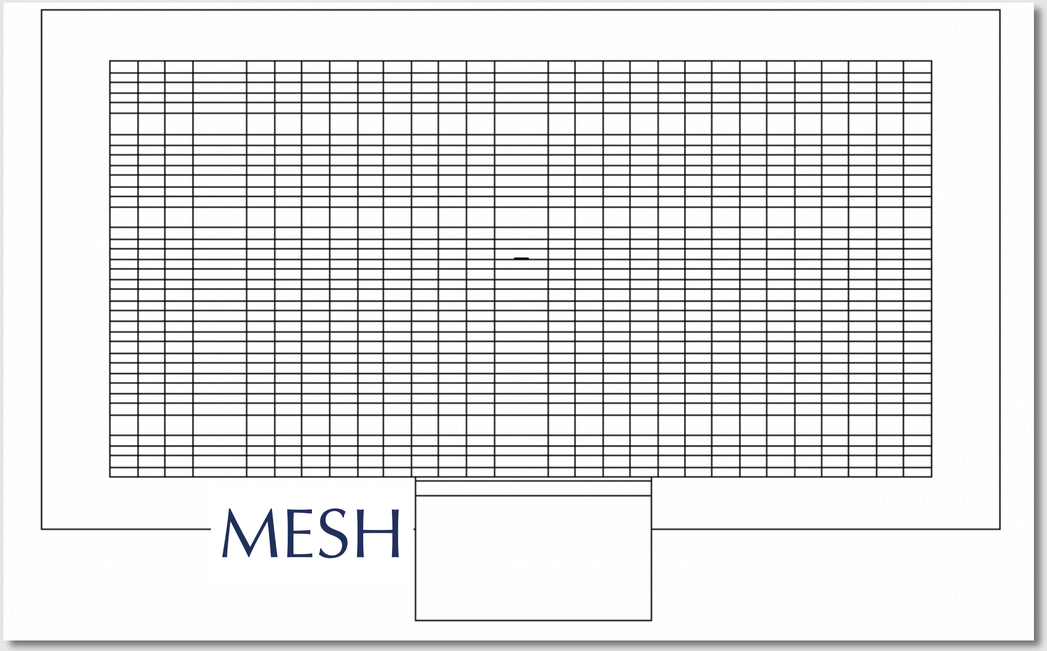
γ shielding, ✓ easy to produce

ROOM DOSIMETRY



Absorbed dose

Equivalent dose

Ambient dose equivalent

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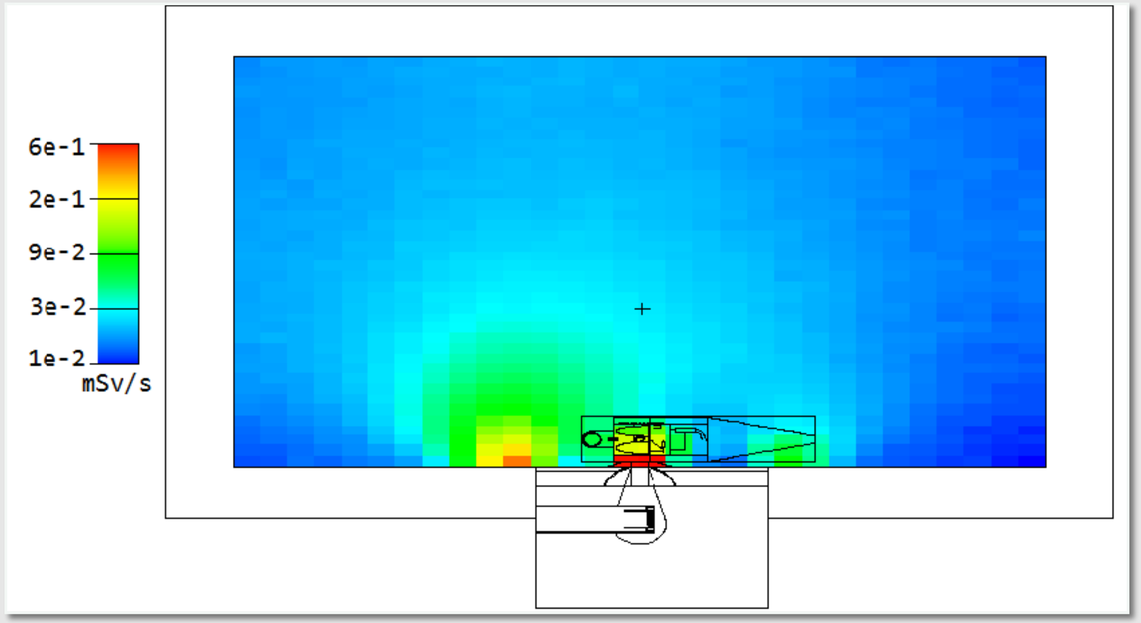


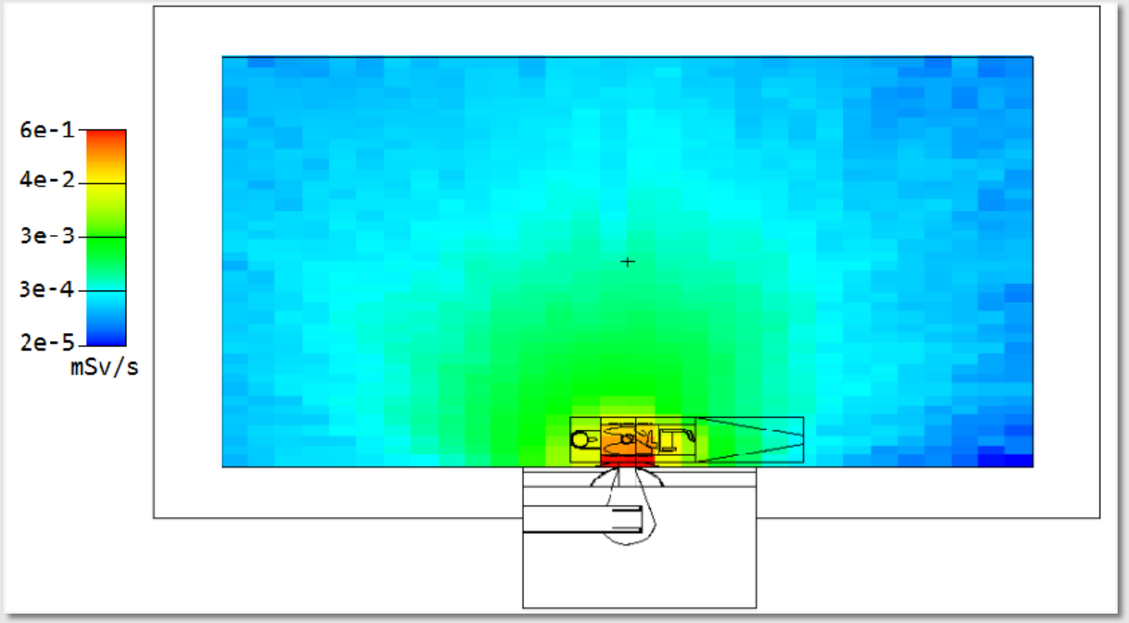
ordinary

Absorbed dose

Equivalent dose

Ambient dose equivalent

from thermal n



borated

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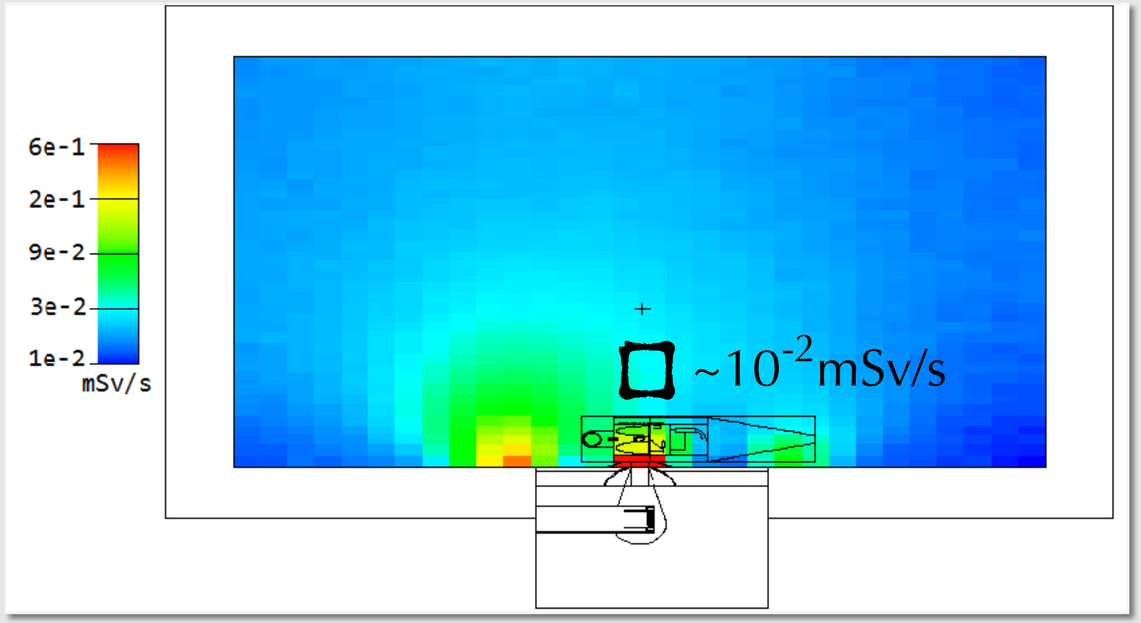

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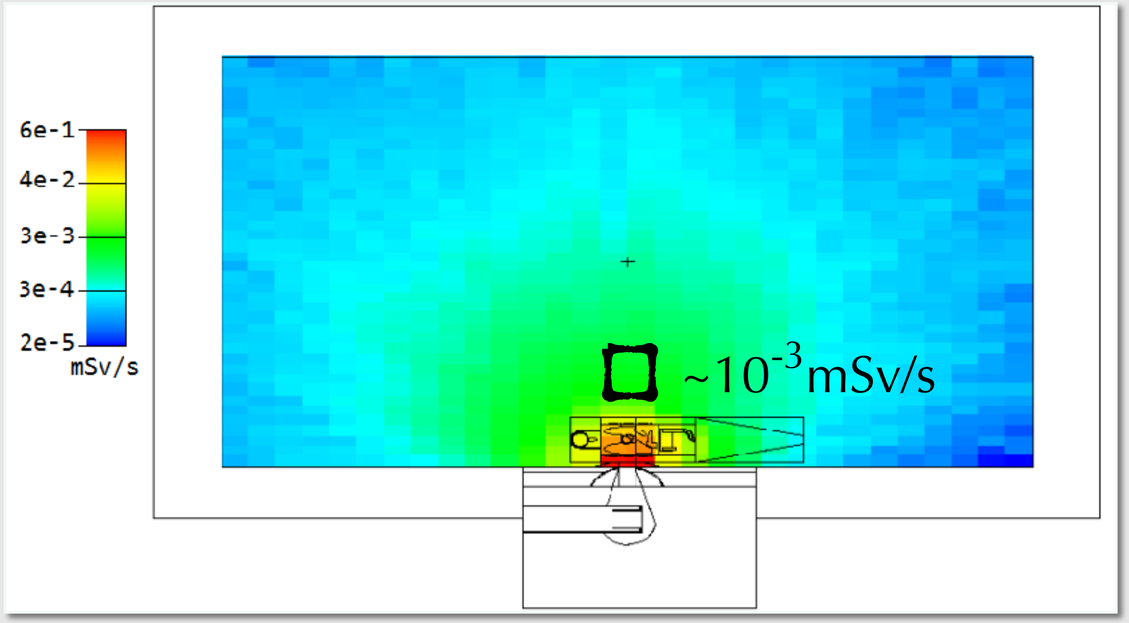
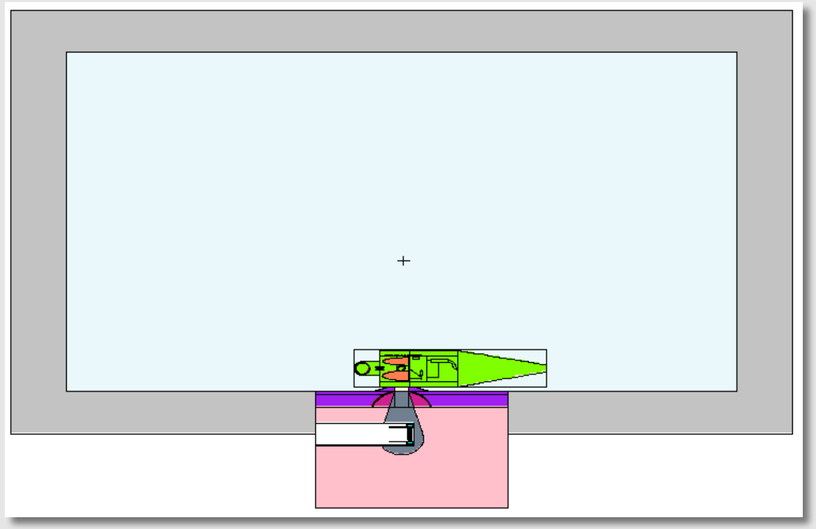


borated

PATIENT DOSIMETRY



(n,p) on N + (n,n') & (n,γ) on H + (n,α) on B

Total absorbed dose rate by main organs [μGy/s] :

brain
bladder
stomach
kidneys
intestine
lungs
liver

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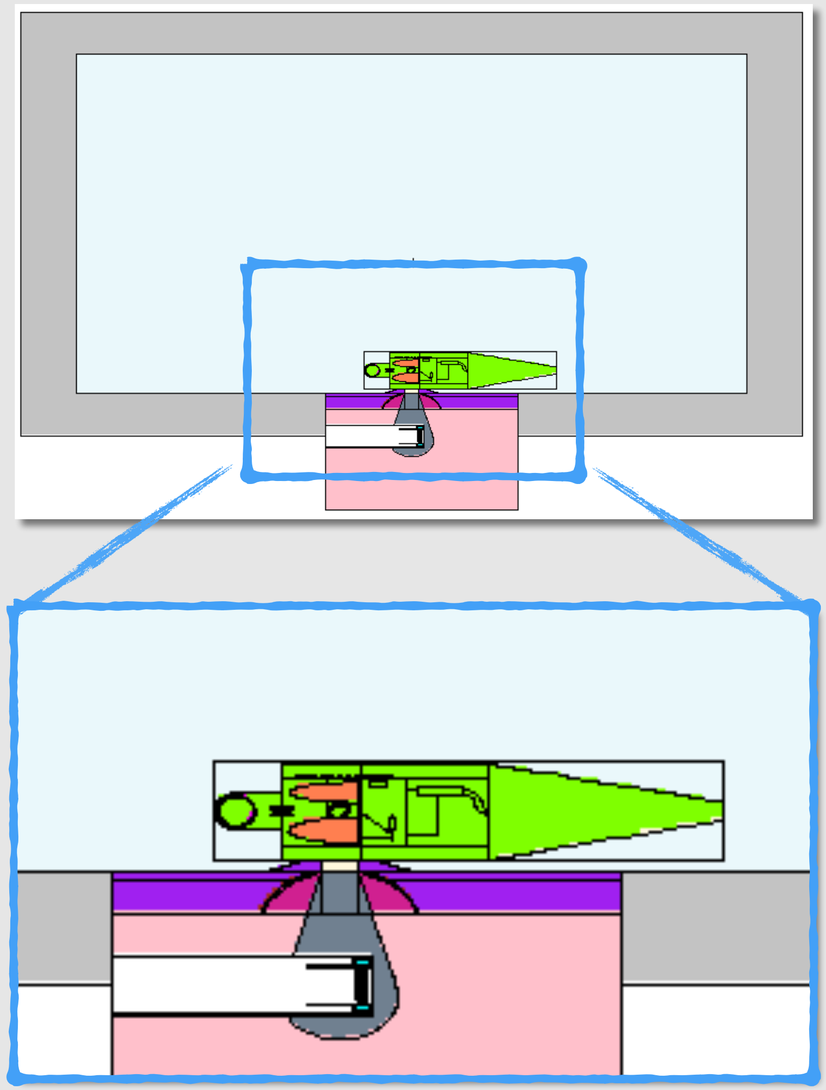

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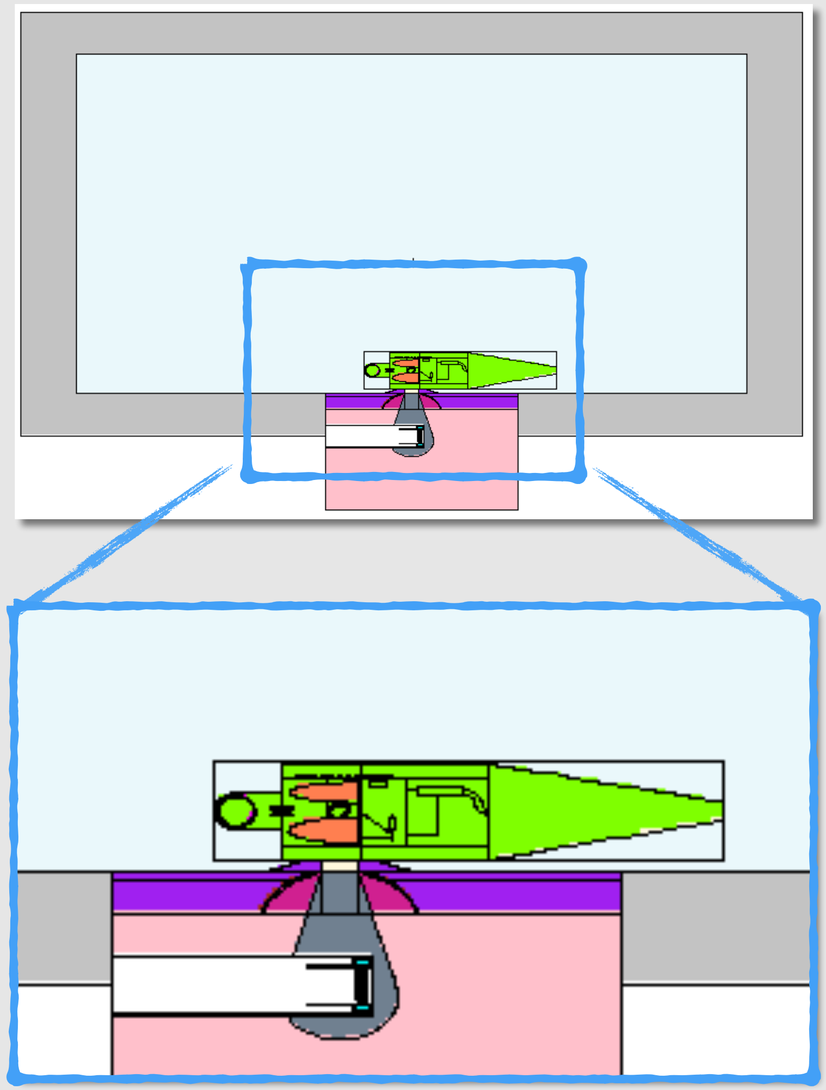

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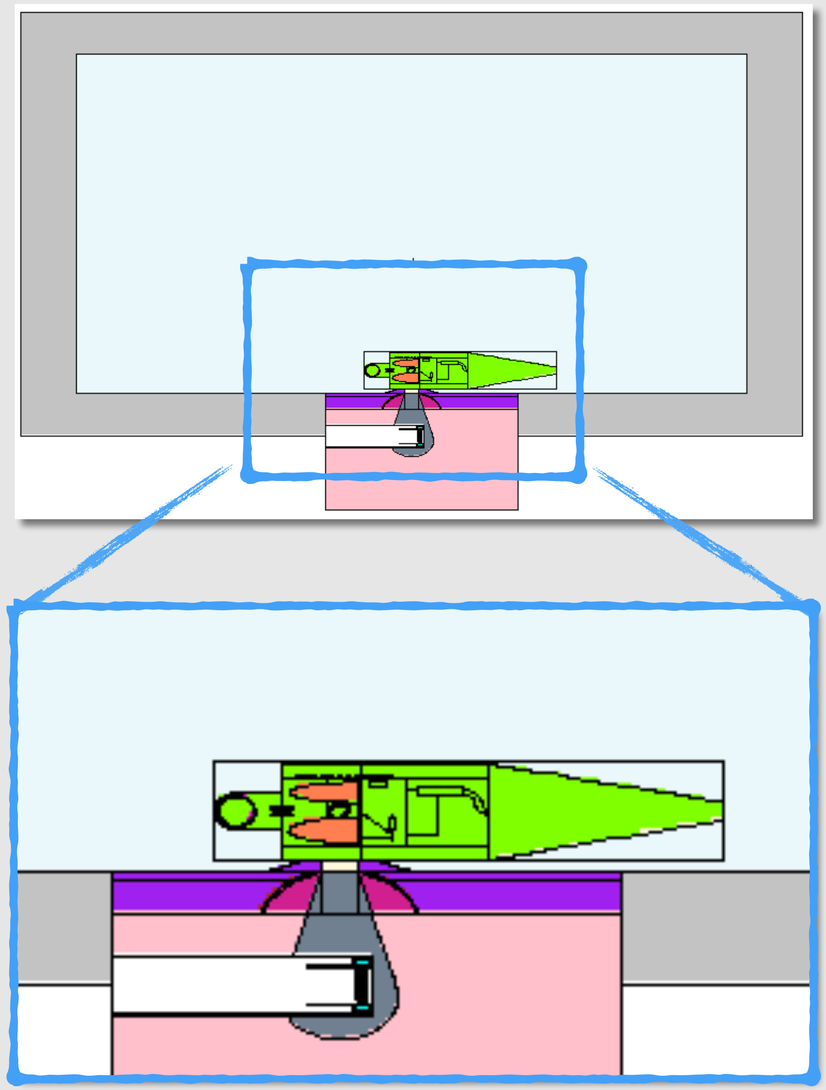
Total absorbed dose rate by main organs [μGy/s] :

	ordinary	borated
brain	213±2	158.7±1.5
bladder	114±3	90.8±1.9
stomach	113.6±1.9	98.5±1.4
kidneys	143±2	122.6±1.8
intestine	171.0±1.9	150.3±1.4
lungs	132.9±1.0	130.4±0.8
liver	330±3	311±2

PATIENT DOSIMETRY



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ordinary > borated

WALLS ACTIVATION

	O	C	Ca	Al	K	Na	Fe	H	Mg	S
%	49.56	31.35	8.26	4.56	1.92	1.71	1.22	0.56	0.24	0.11

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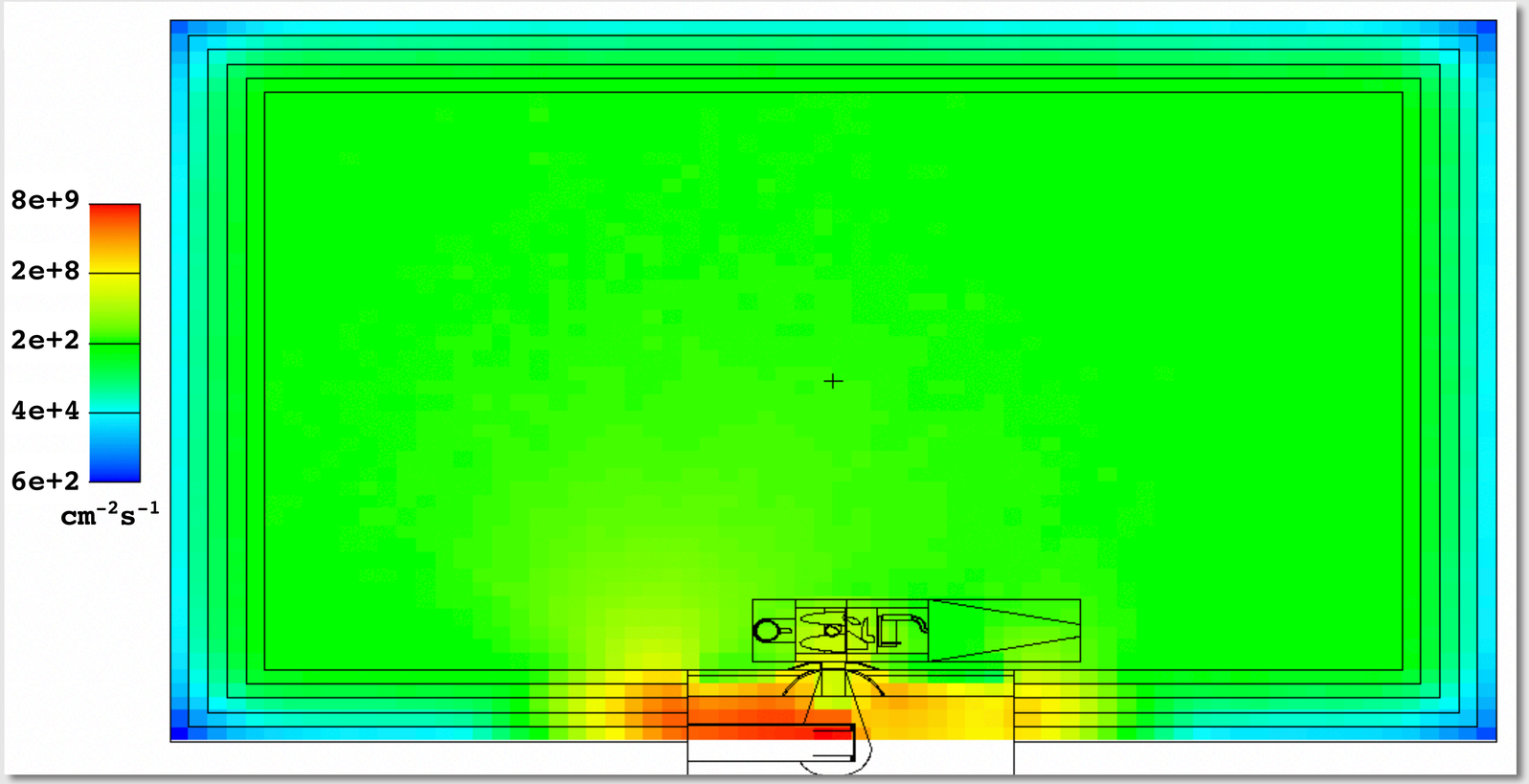
Thermal neutron flux in walls made of ordinary concrete:



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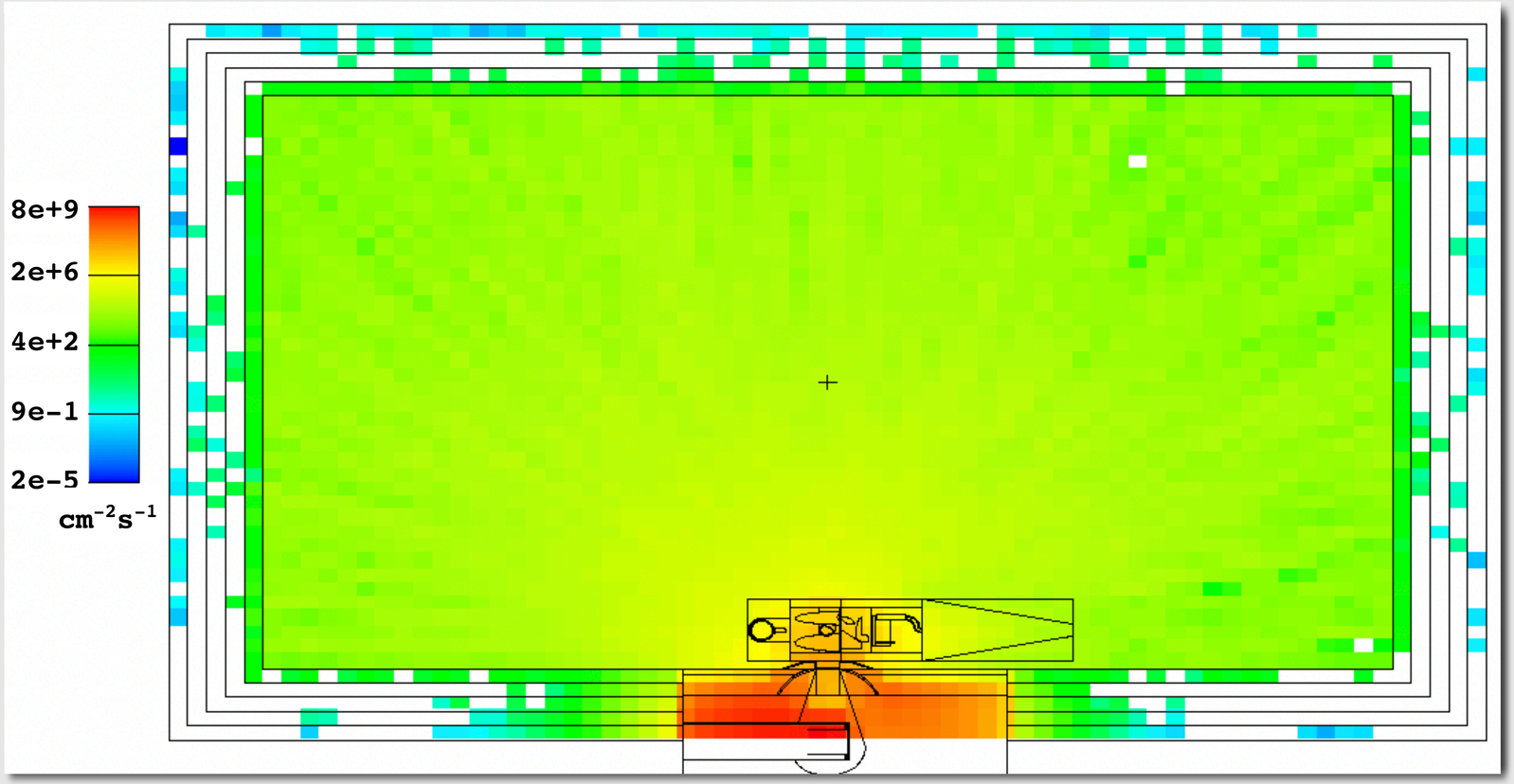
Thermal neutron flux in walls made of borated concrete:



PATIENT ACTIVATION

Urine

	O	H	N	Cl	C	Na	K	P
%	86.2	11.0	1.0	0.6	0.5	0.4	0.2	0.1

Soft tissue

	O	C	H	N	P	S	Cl	K	Fe
%	43.9	41.4	10.5	3.4	0.1	0.02	0.02	0.02	0.01

PATIENT ACTIVATION

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%	86.2	11.0	1.0	0.6	0.5	0.4	0.2	0.1

Soft tissue

	O	C	H	N	P	S	Cl	K	Fe
%	43.9	41.4	10.5	3.4	0.1	0.02	0.02	0.02	0.01

PATIENT ACTIVATION

Urine

Nuclide	Half-life [s]	a [Bq/g]	a [Bq/g]
		ordinary	borated
Cl-38	37.24 min	26.5 ± 1.3	16.1 ± 0.8
K-42	12.360 h	0.60 ± 0.03	0.36 ± 0.02
Na-24	14.9590 h	9.6 ± 0.5	5.8 ± 0.3

Soft tissue

Nuclide	Half-life [s]	a [Bq/g]	a [Bq/g]
Cl-38	37.24 min	23.53 ± 0.04	8.88 ± 0.03
K-42	12.360 h	1.680 ± 0.003	0.676 ± 0.002
Fe-59	44.503 d	$(2.712 \pm 0.007) \cdot 10^{-4}$	$(1.317 \pm 0.006) \cdot 10^{-4}$

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ordinary > borated

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PATIENT ACTIVATION

Ongoing studies:

with FLUKA: simplified phantom (soft tissue, urine & bone)

PATIENT ACTIVATION

Ongoing studies:

with FLUKA: simplified phantom (soft tissue, urine & bone)

40x15x170 cm^3

coronal section

sagittal section

H*(10): TIME EVOLUTION

H*(10) from activations as a function of cooling time:

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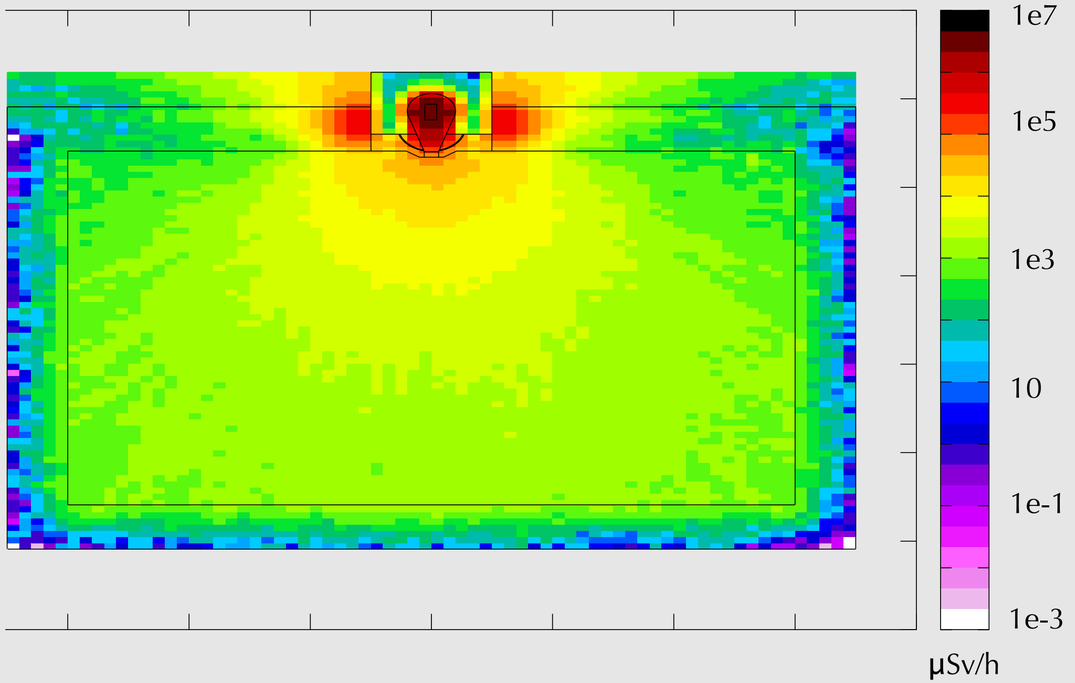
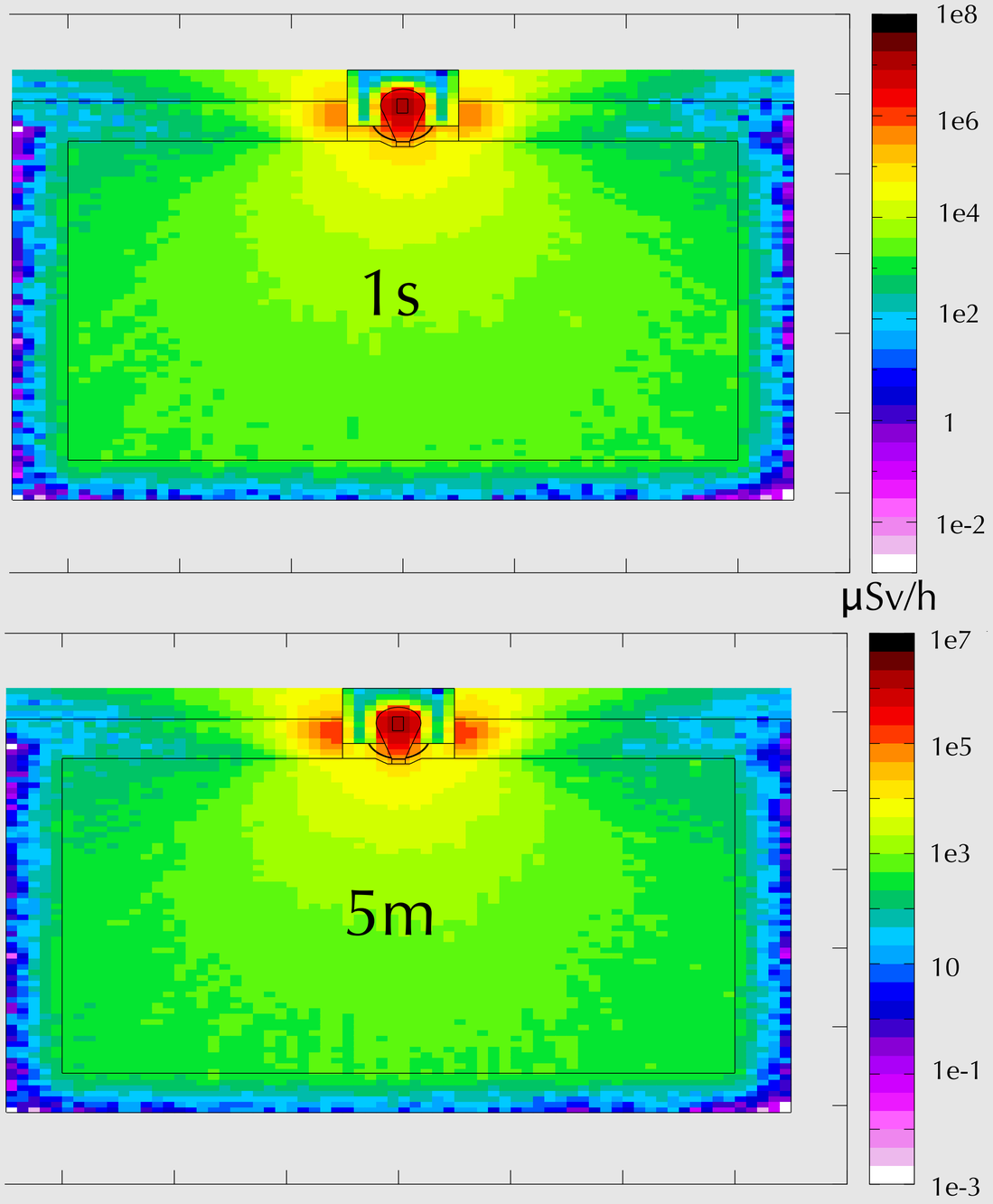
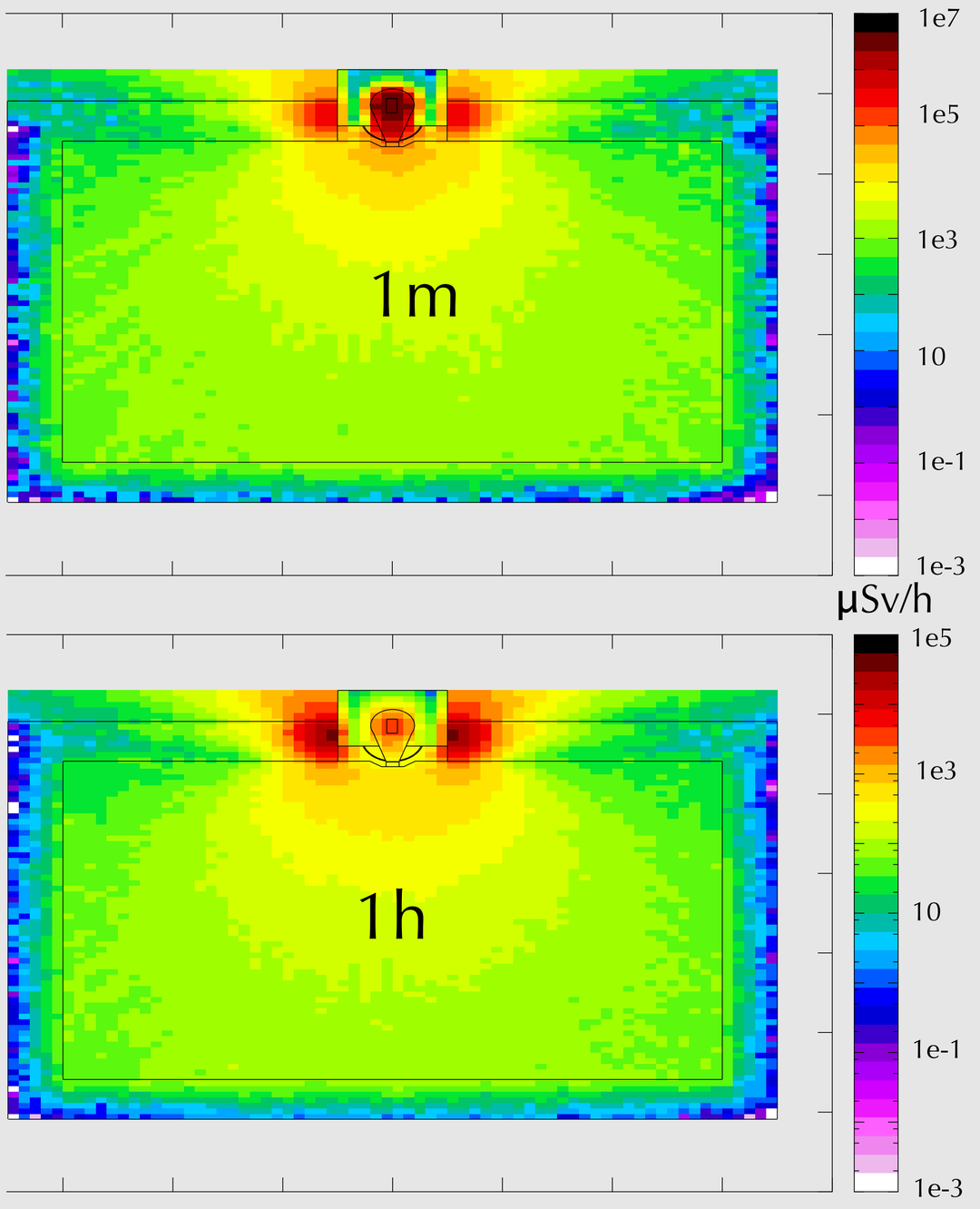
H*(10) from activations as a function of cooling time:

- in the irradiation room:

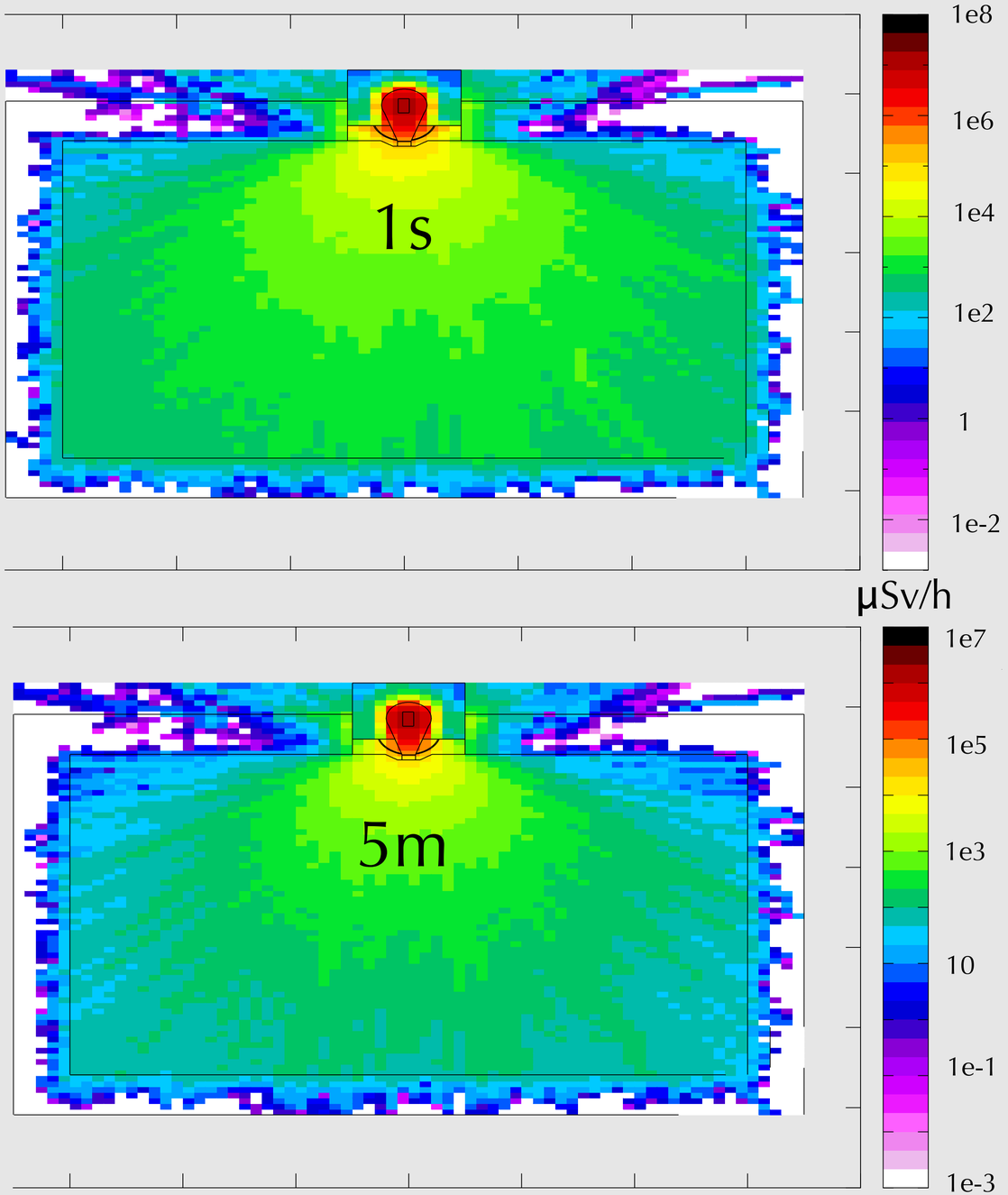



1s
1e8
1e6
1e4
1e2
1
1e-2
µSv/h


1m
1e7
1e5
1e3
10
1e-1
1e-3
µSv/h

5m
1e7
1e5
1e3
10
1e-1
1e-3

1h
1e5
1e3
10
1e-1
1e-3


1s
1e8
1e6
1e4
1e2
1
1e-2
µSv/h
1m
1e7
1e5
1e3
10
1e-1
1e-3
µSv/h
5m
1e7
1e5
1e3
10
1e-1
1e-3
1h
1e3
10
1e-1
1e-3

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H*(10) from activations as a function of cooling time:

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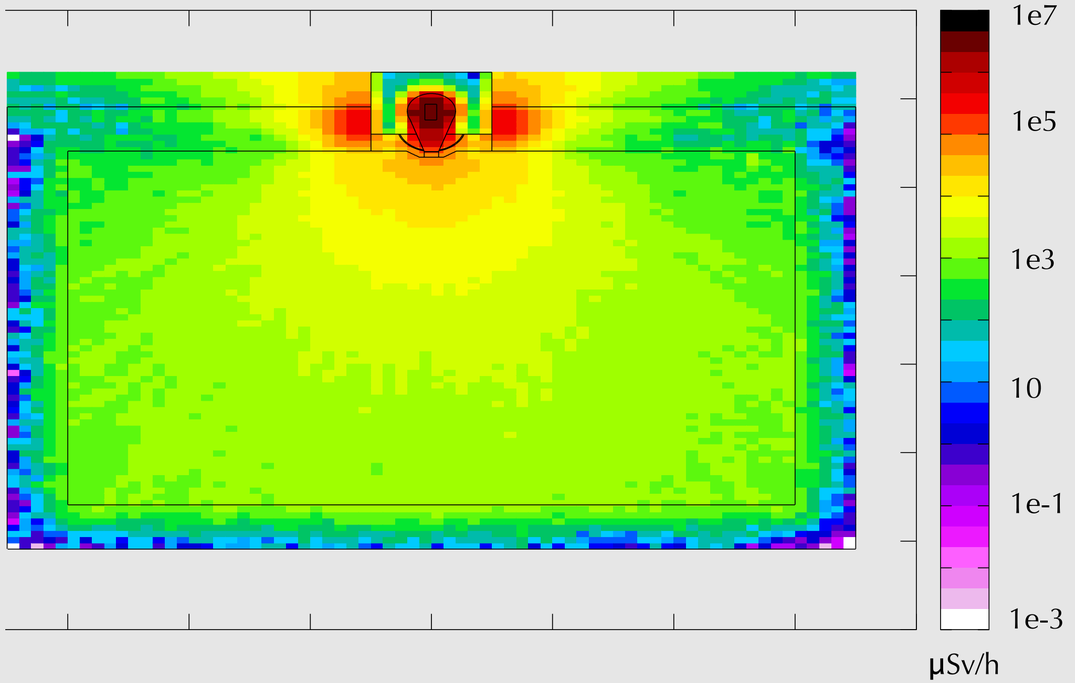
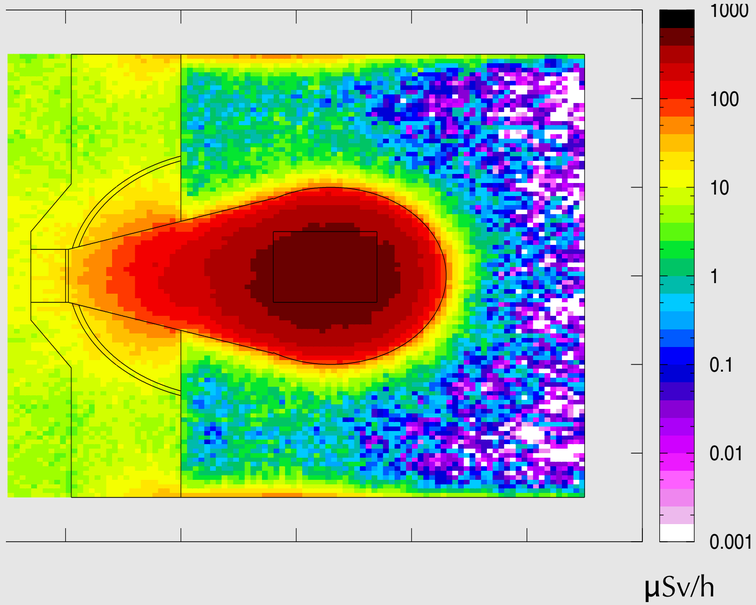


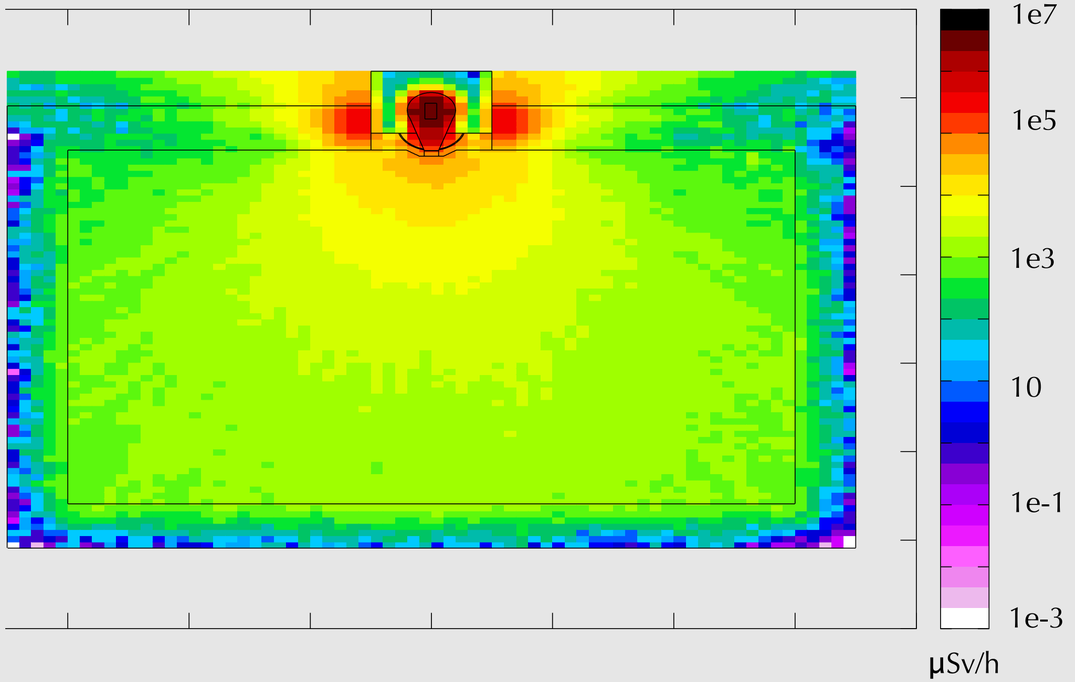
H*(10): TIME EVOLUTION

H*(10) from activations as a function of cooling time:

- in the irradiation room:

- in the BSA:





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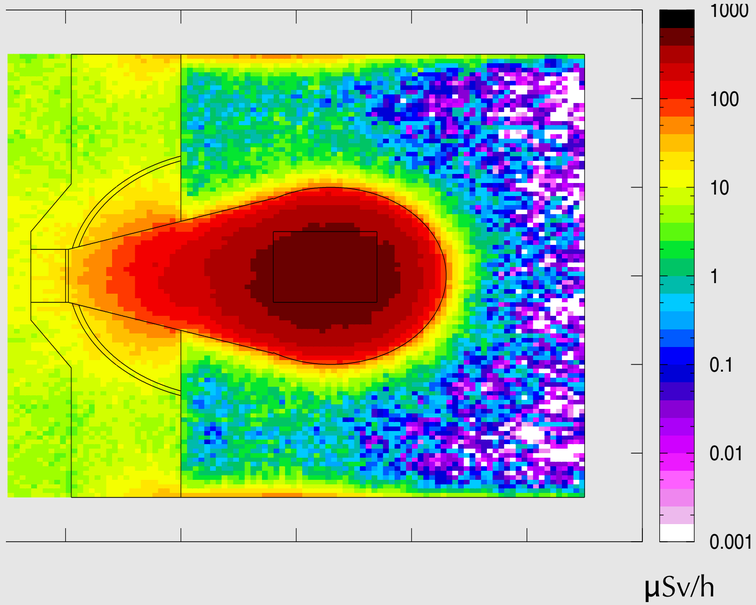

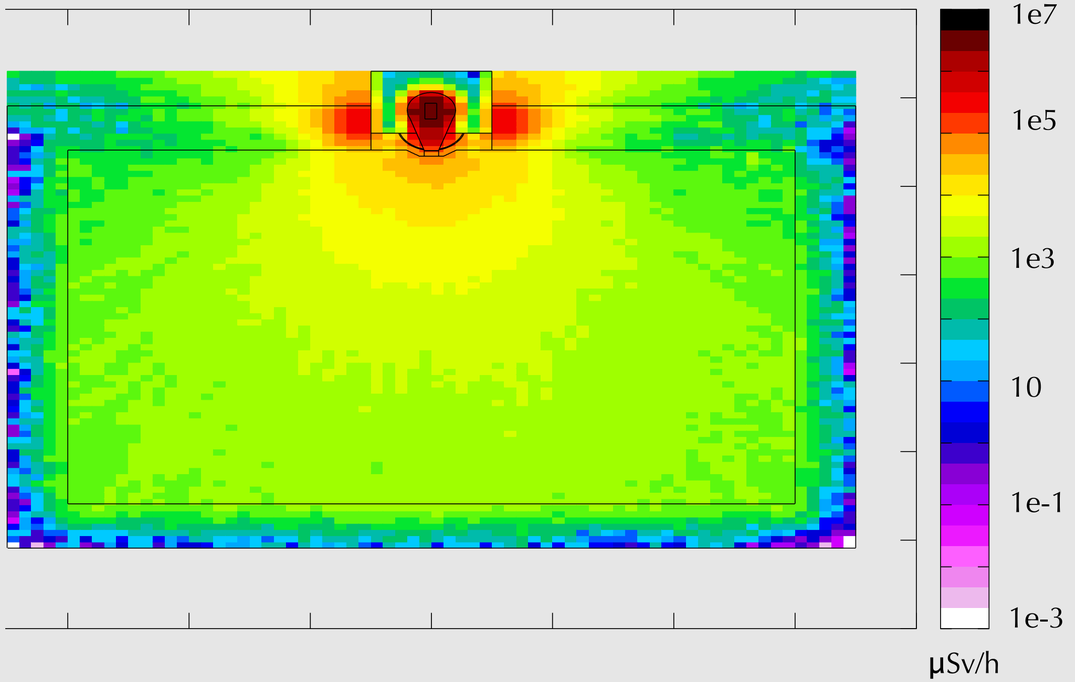

& around the patient…

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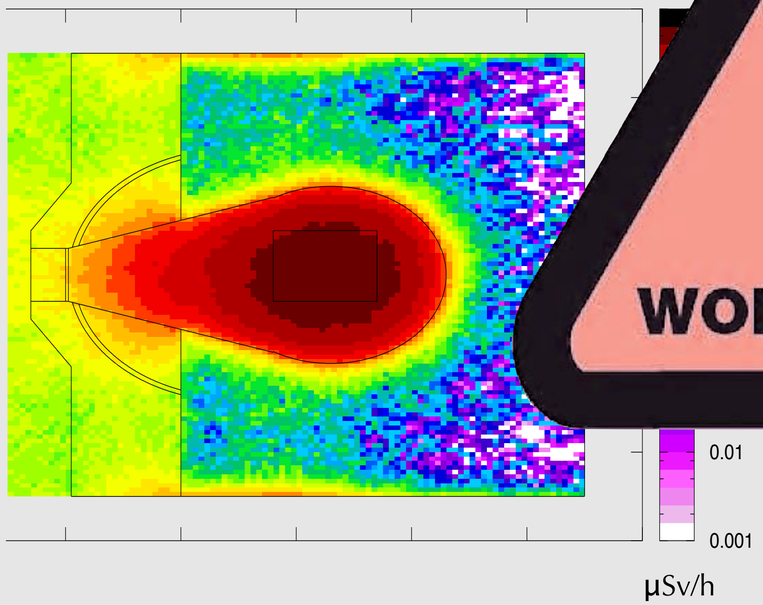
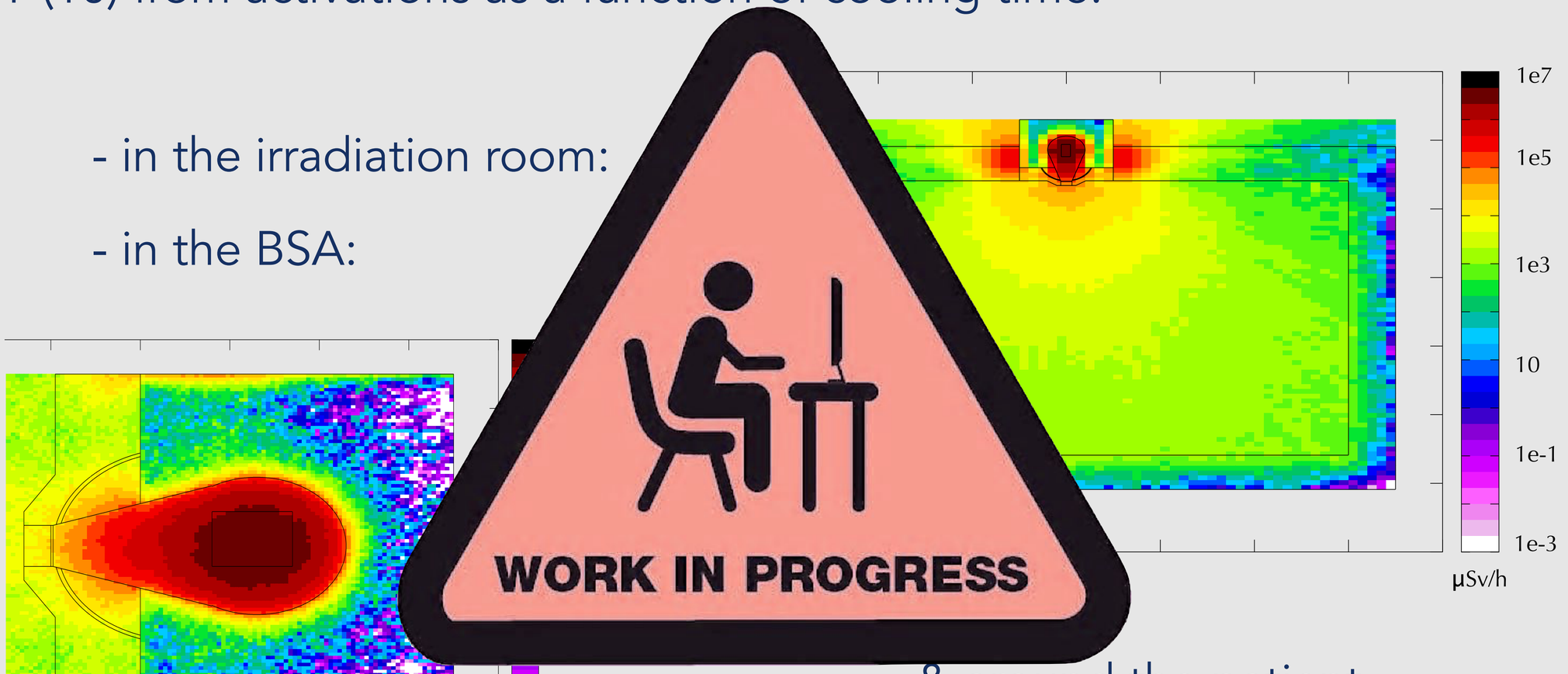
- in the BSA:





& around the patient…

CONCLUSIONS

- AlF_3 characterisation & BSA activation

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✓ feasibility of the BNCT clinical facility confirmed

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Thanks for your attention

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Composition of AlF3

Nuclide	Mass percentage
Mg-27	$1.5 \cdot 10^{-2}$
As-75	$1.1 \cdot 10^{-4}$
Na-24[2]	$1.2 \cdot 10^{-5}$
Zn-65	$1.6 \cdot 10^{-5}$
Ga-71	$5.8 \cdot 10^{-6}$
Co-59	$9.6 \cdot 10^{-6}$
Sb-121	$1.1 \cdot 10^{-7}$
Sb-123	$1.8 \cdot 10^{-7}$
Br-81	$4.3 \cdot 10^{-7}$
Fe-58	$4.3 \cdot 10^{-7}$
Sc-45	$2.1 \cdot 10^{-8}$