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# Calcoli di radioprotezione e ottimizzazione per il centro di BNCT

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Pavia



INFN4LS – Catania – 31/01/2024

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BNCT route from neutrons to treatments

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clinical centre

radiobiology



accelerator

B measurements



treatment planning



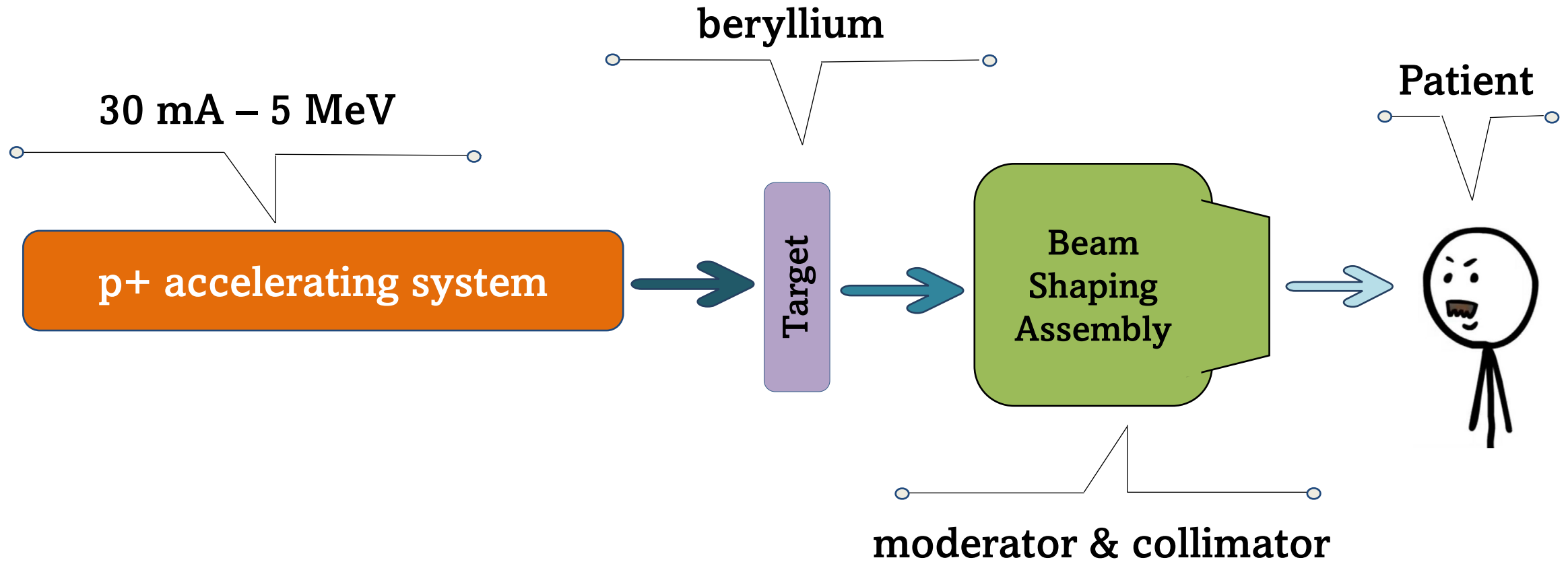
dosimetry



# BNCT route from neutrons to treatments

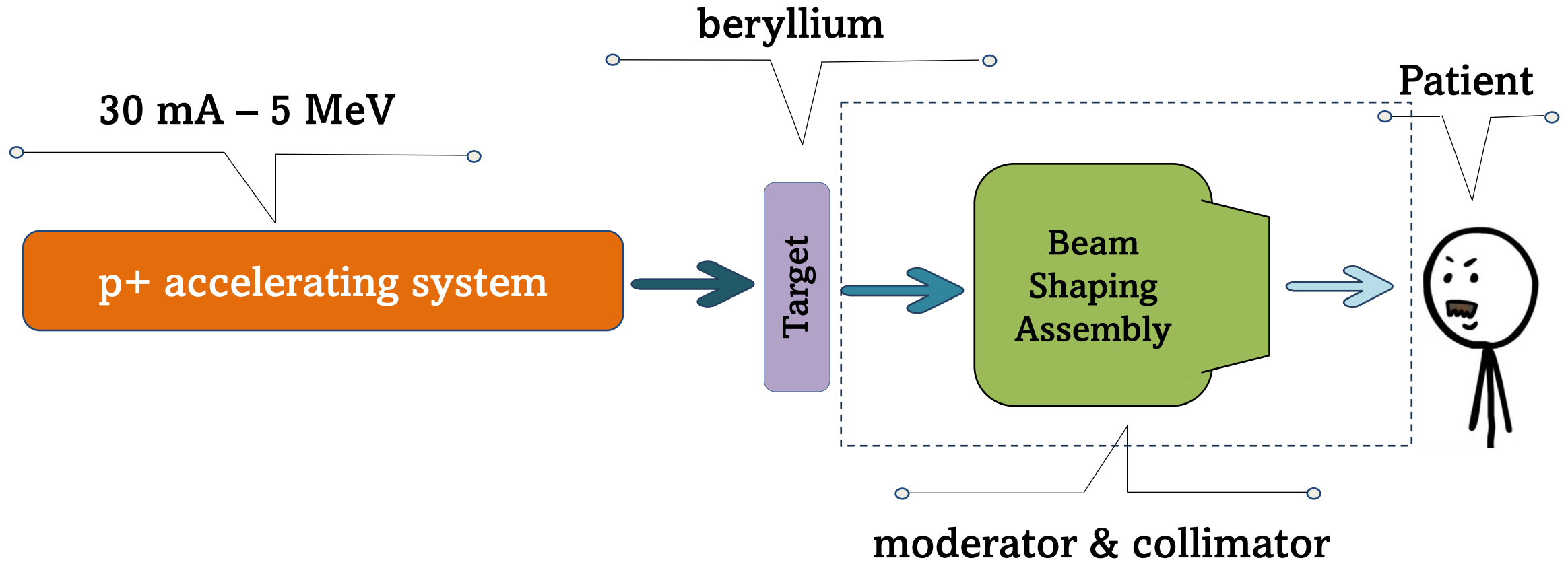
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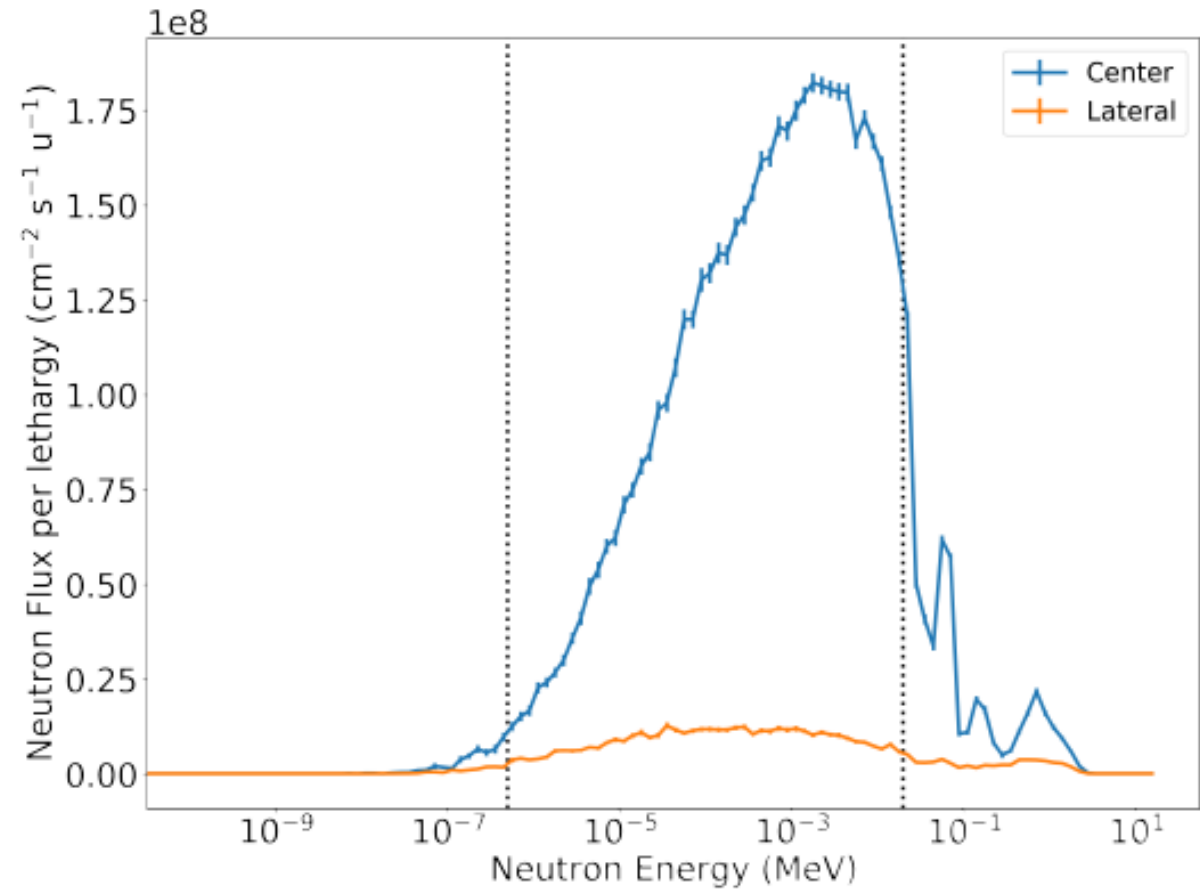
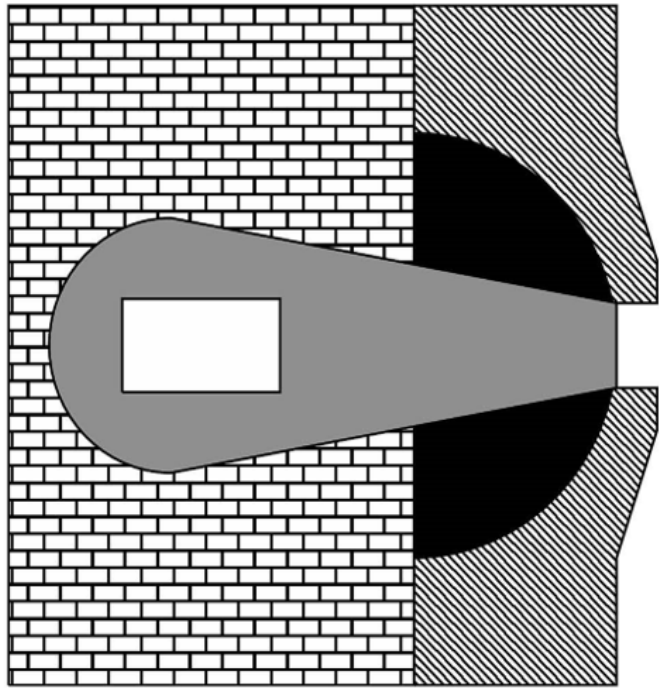
# Starting from the beginning (pre-PNRR era)

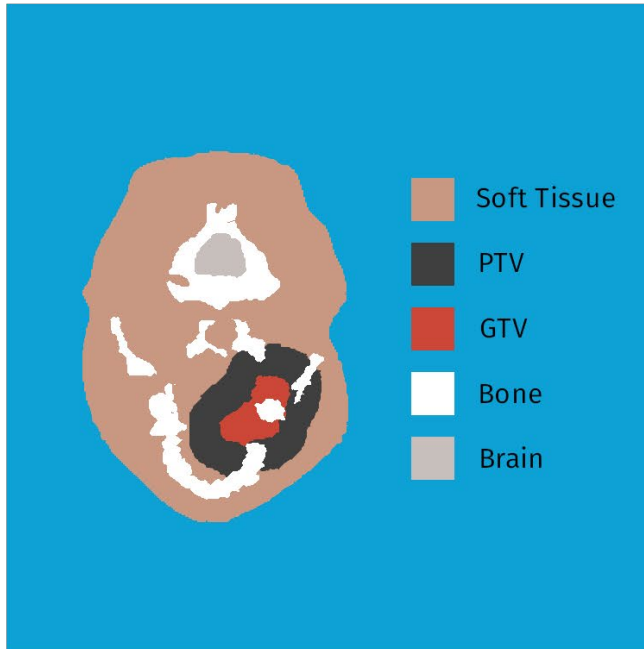


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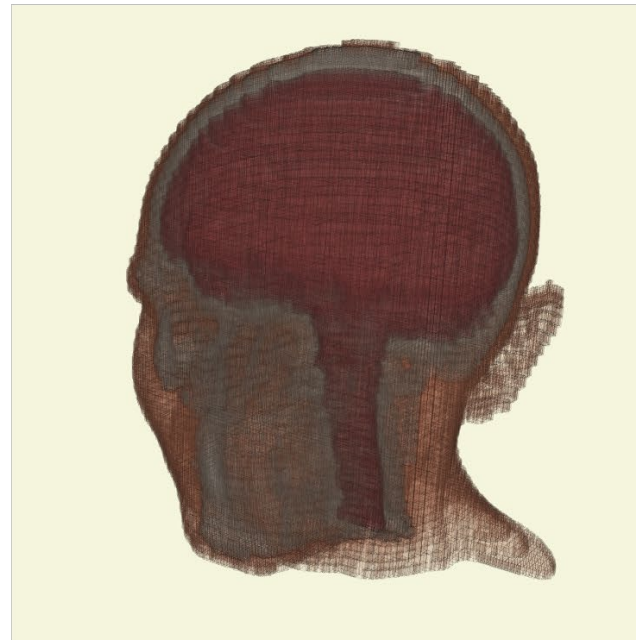
# Starting from the beginning







## Performance in real patient treatments

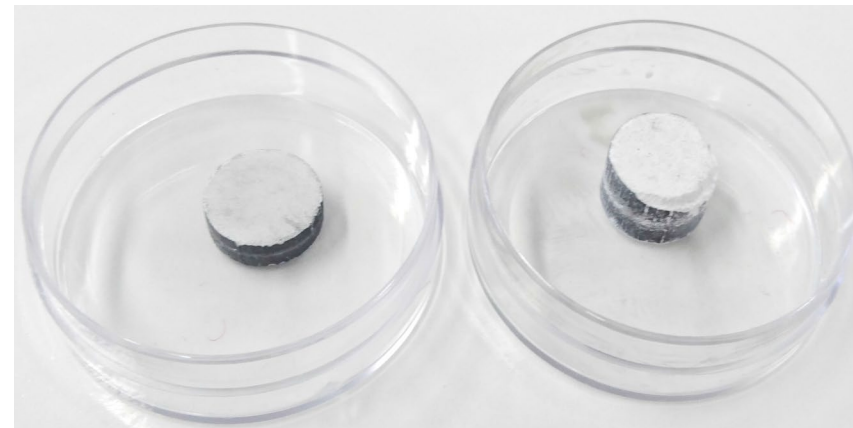
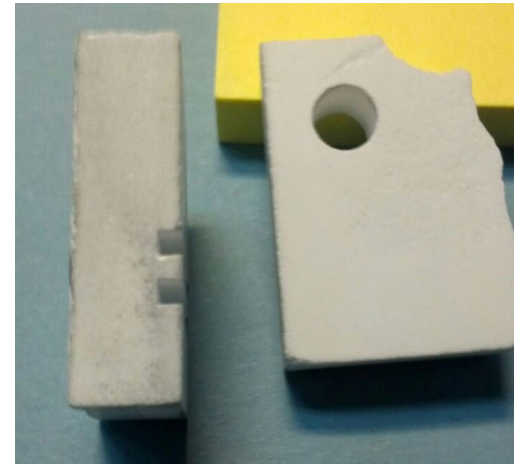
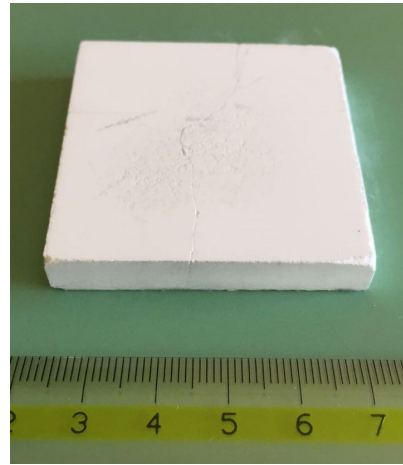


H&N patient treated in Finland, same irradiation configuration (2 fields, 2 sessions), same criterion to prescribe the irradiation time.

*This beam has the same therapeutic effect as the one in Finland*



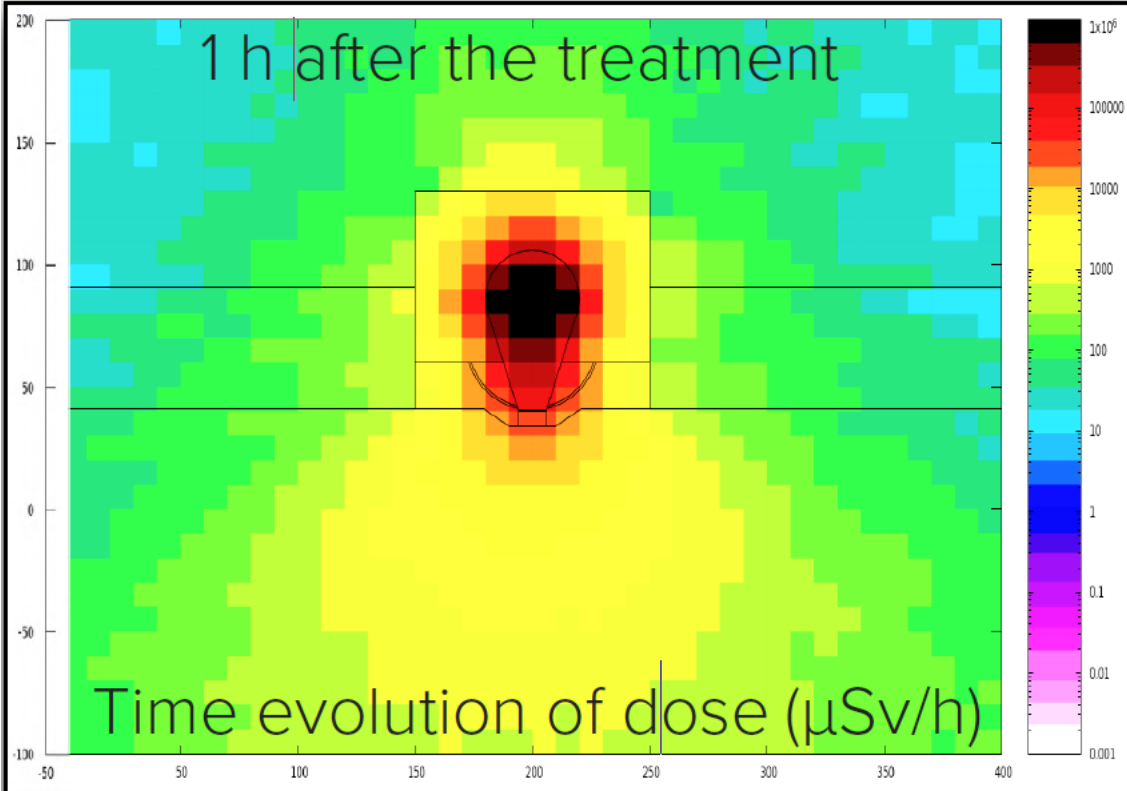
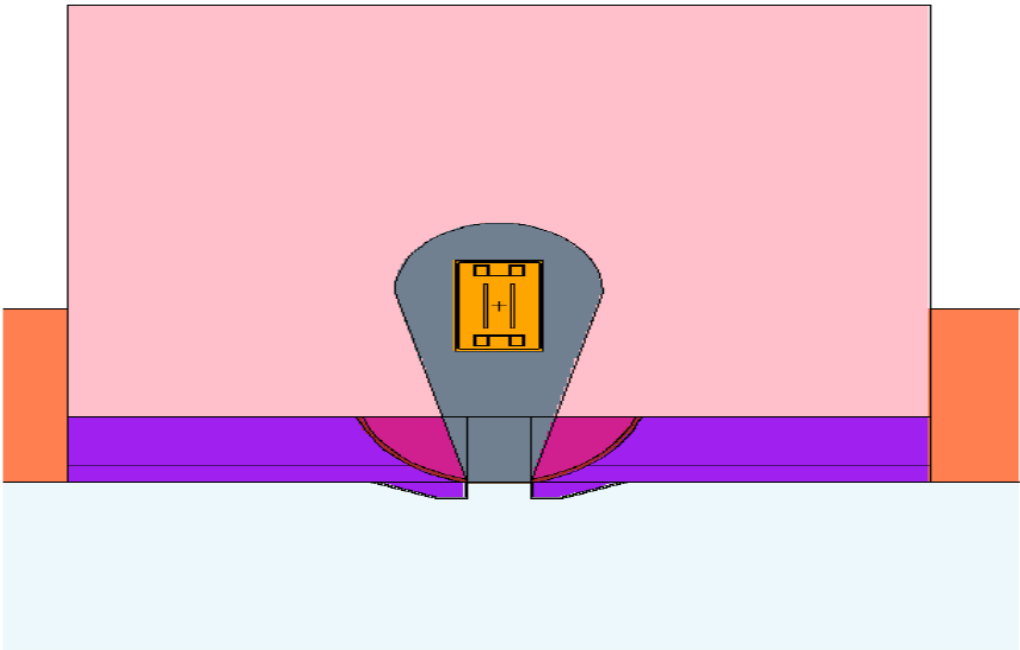
Densified  $\text{AlF}_3$  and  $\text{AlF}_3 + 2\% \text{LiF}$   
High density ( $\sim 100\%$ )

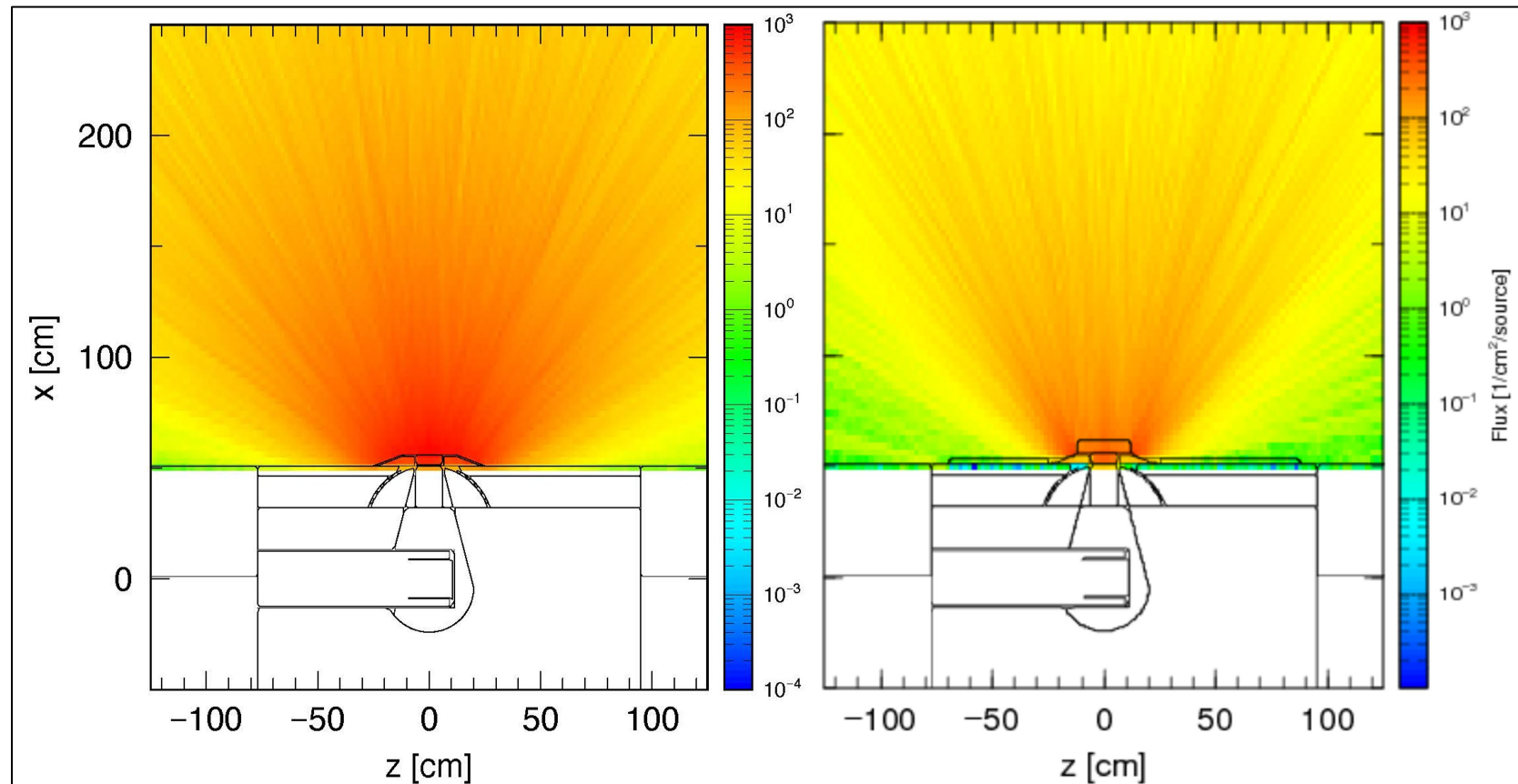


Study of mechanical properties ongoing



Real composition by NAA  
at the TRIGA reactor

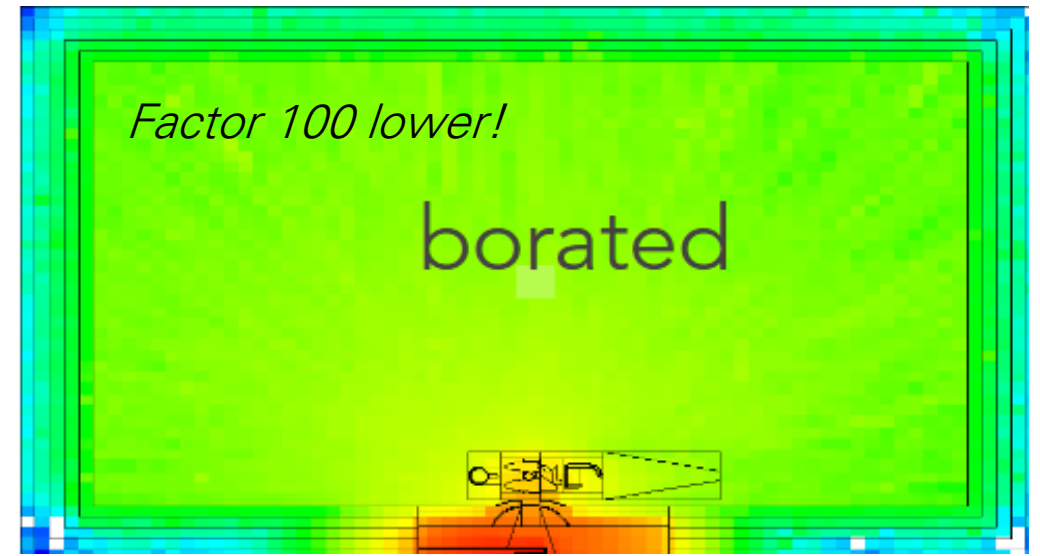
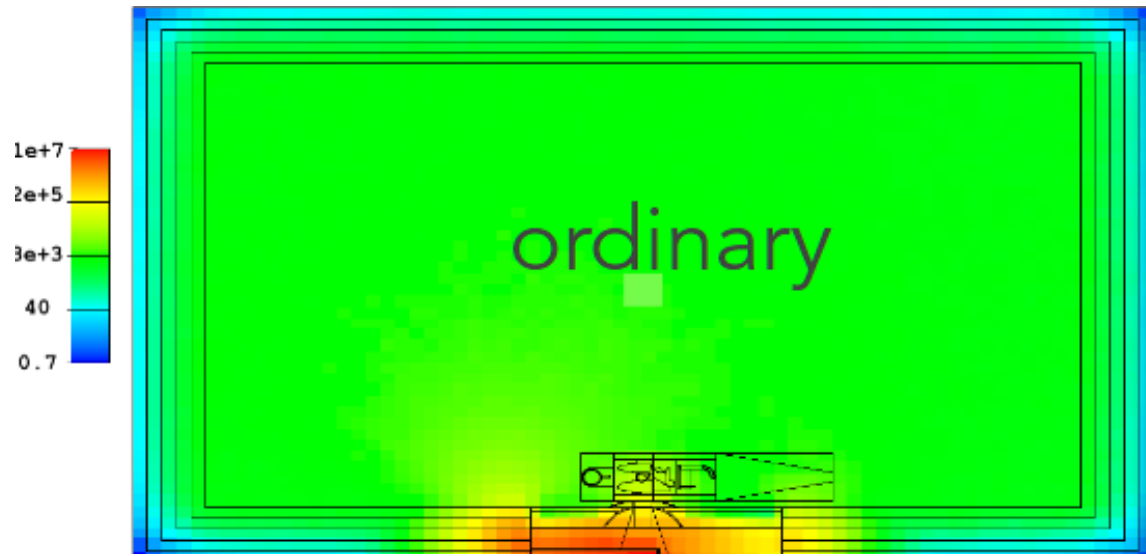




Distribution of the rate of ambient dose equivalent, 5 min after the end of the treatment, due to the radioactivity induced in the BSA (left) and in presence of the lead shield on the BSA walls (right).

# Activation of walls (Ca)

1%  $^{10}\text{B}$  in weight

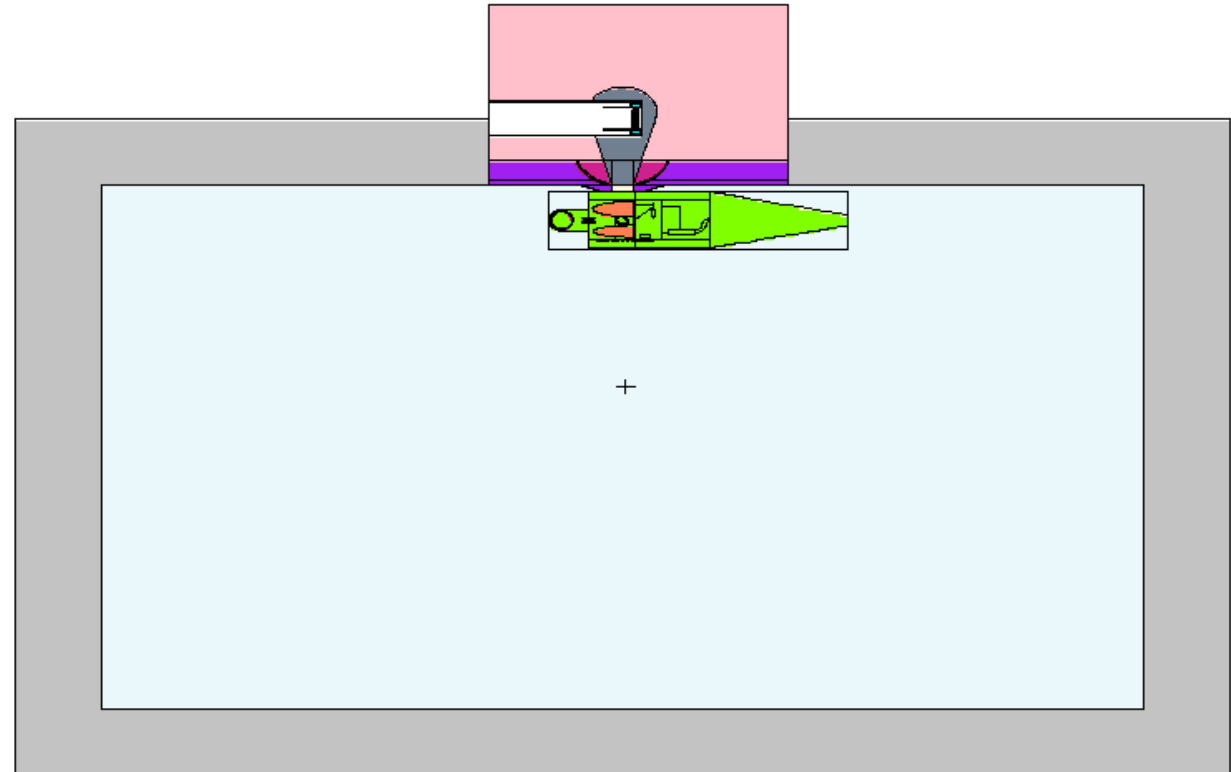
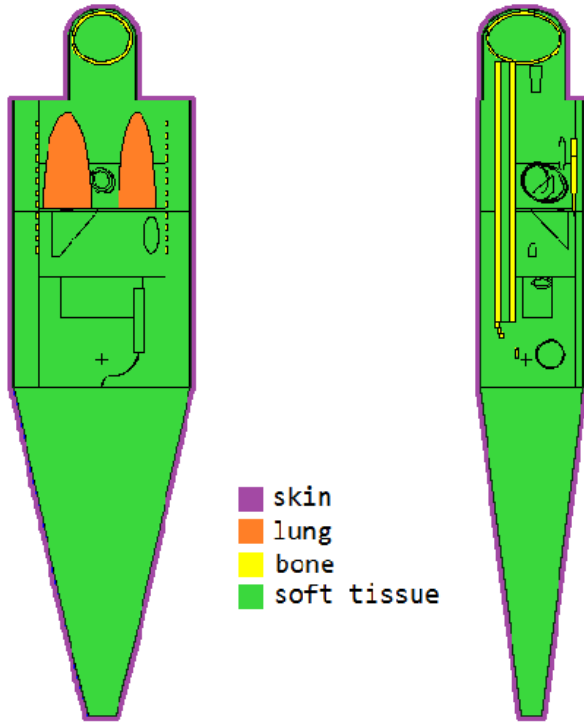


Reac/cm<sup>3</sup> s

	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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# Activation of the patient



# Depending on irradiation position

Isotope	Half-life	Head and Neck		Thorax		Lower Limb	
		$A_{ORD}$ [Bq/g]	$A_{BOR}$ [Bq/g]	$A_{ORD}$ [Bq/g]	$A_{BOR}$ [Bq/g]	$A_{ORD}$ [Bq/g]	$A_{BOR}$ [Bq/g]
Cl-38	37.24 min	23.5	14.3	23.5	8.88	24.7	9.48
K-42	12.360 h	1.68	0.73	1.68	0.68	1.76	0.72
Fe-59	44.503 d	$2.7 \cdot 10^{-4}$	$1.4 \cdot 10^{-4}$	$2.7 \cdot 10^{-4}$	$1.3 \cdot 10^{-4}$	$2.8 \cdot 10^{-4}$	$1.4 \cdot 10^{-4}$

Residual specific activities of the soft tissue elements, at the end of a 2-hours irradiation

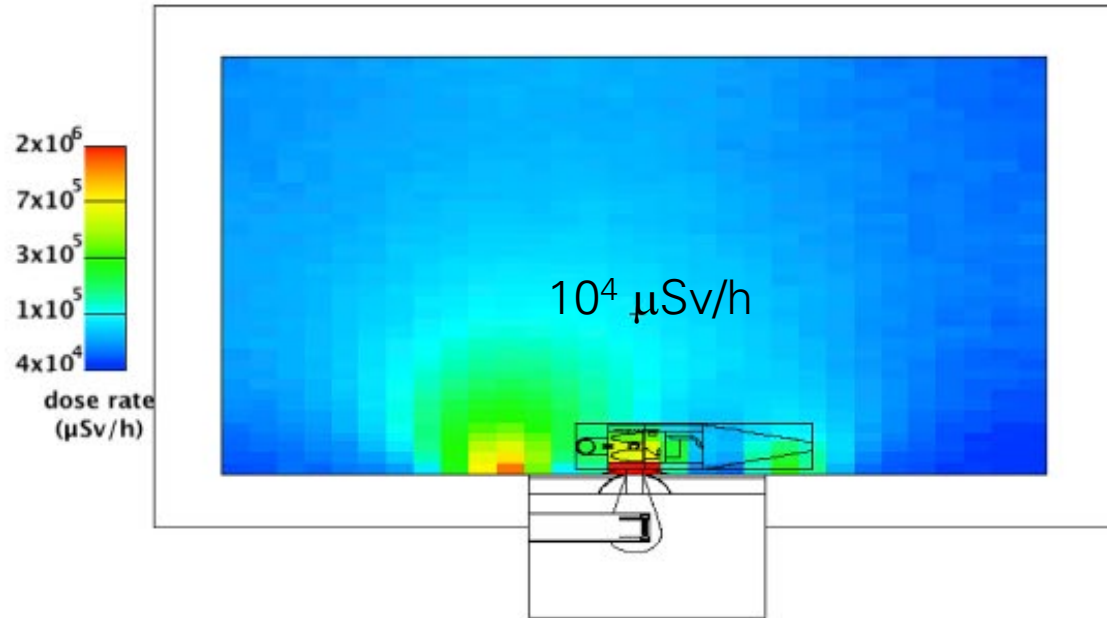
Head and Neck		Thorax		Lower Limb	
$A_{ORD}$ [Bq/g]	$A_{BOR}$ [Bq/g]	$A_{ORD}$ [Bq/g]	$A_{BOR}$ [Bq/g]	$A_{ORD}$ [Bq/g]	$A_{BOR}$ [Bq/g]
22.7	3.0	36.5	22.3	46.9	17.9



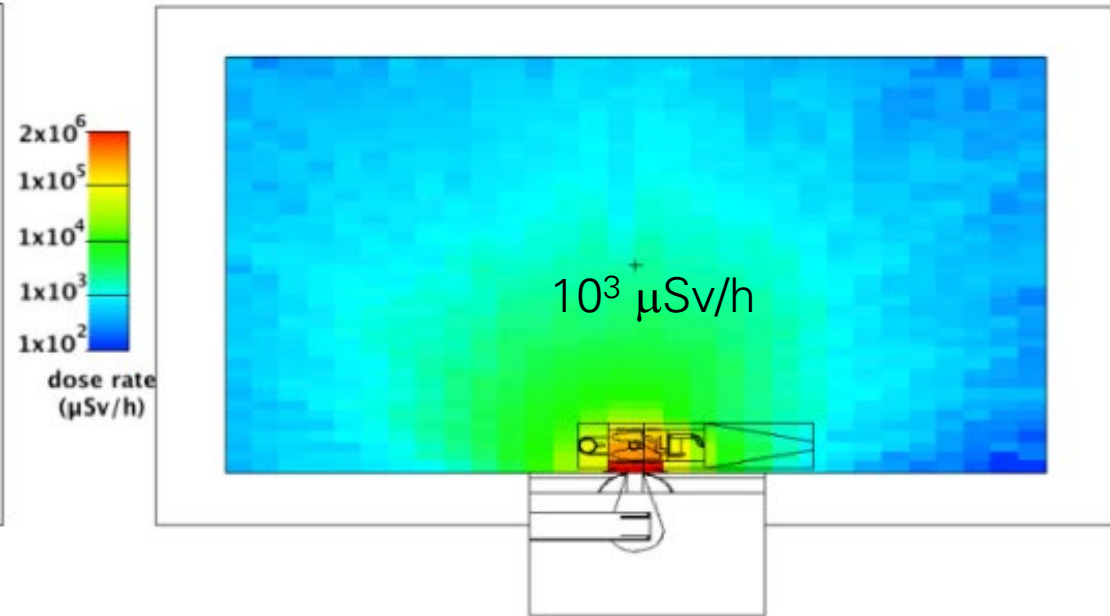
Residual specific activities of the urine, at the end of a 2-hours irradiation

# Ambient dose equivalent during irradiation

concrete

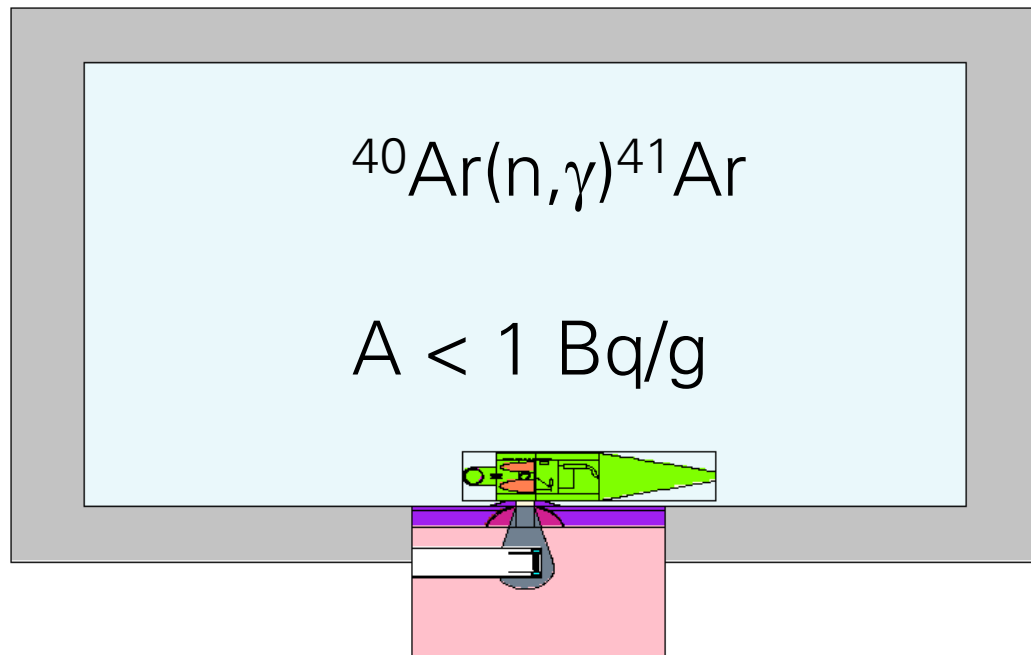


borated concrete



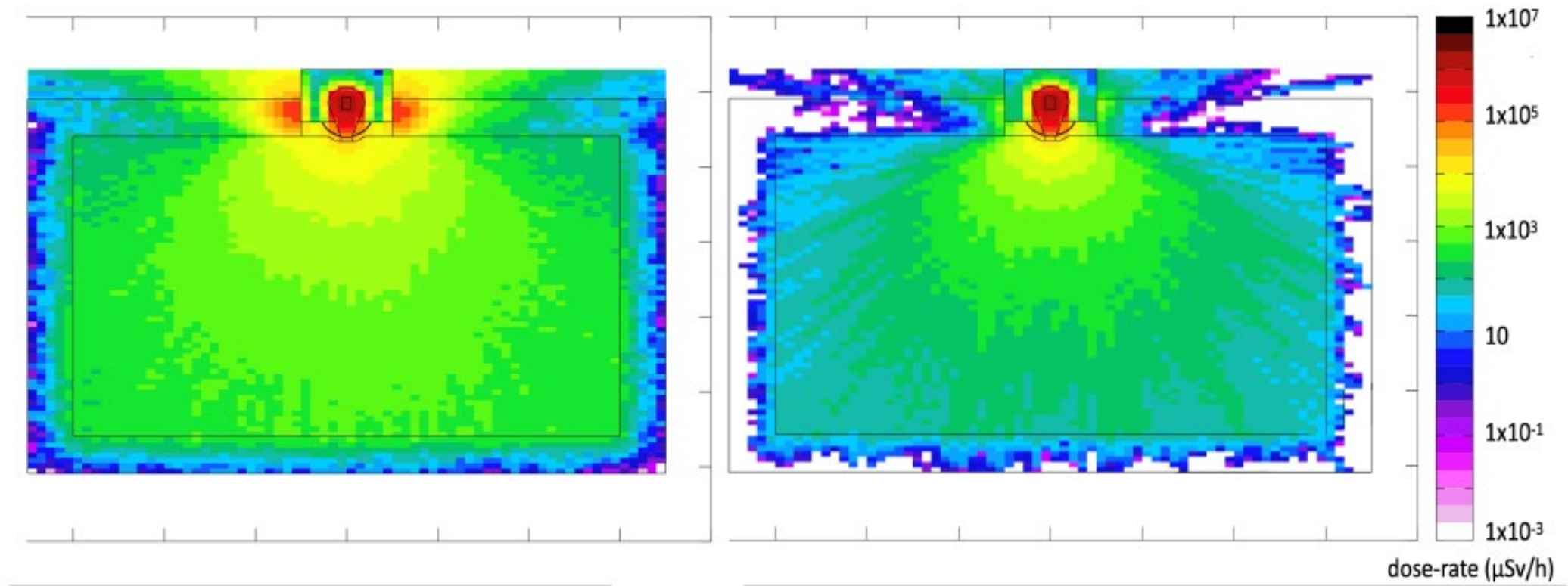
$H^*(10)$

# Air activation



Walls composition	a [Bq/g]
concrete	5.6
concrete + boron	0.07
polyethylene	2.6
polyethylene + lithium	0.22

# Dose in air



Distribution of the rate of ambient dose equivalent from the overall induced radioactivity, 5 min after a 2-hour irradiation, walls of ordinary concrete (left) and borated concrete (right)

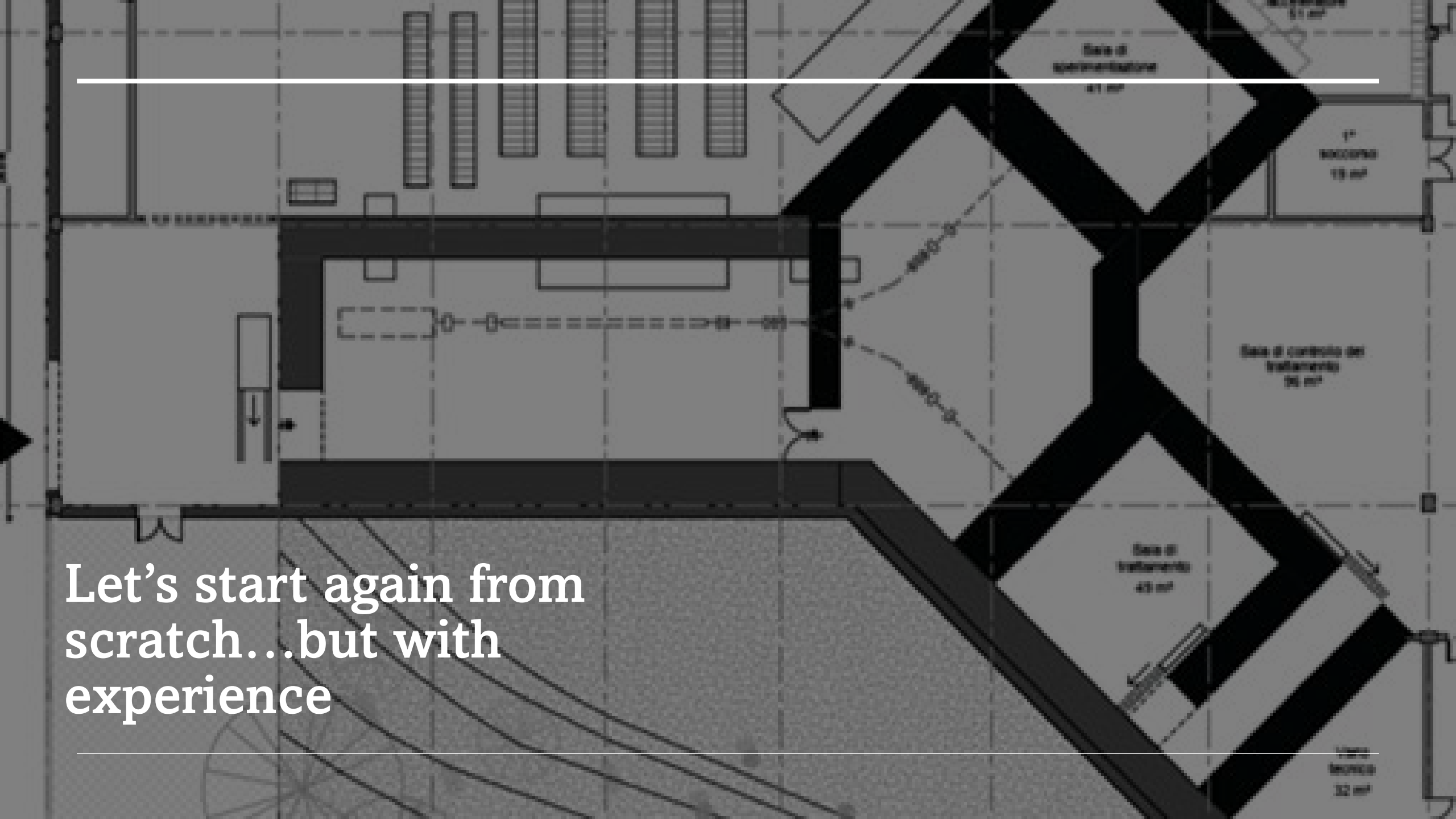




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Let's start again from  
scratch...but with  
experience

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shape and dimensions by LNL & To

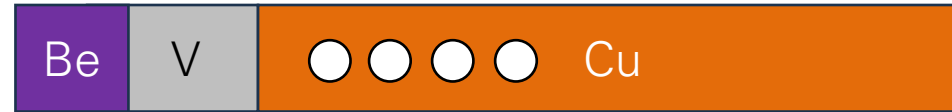
walls materials & thickness?

doors?

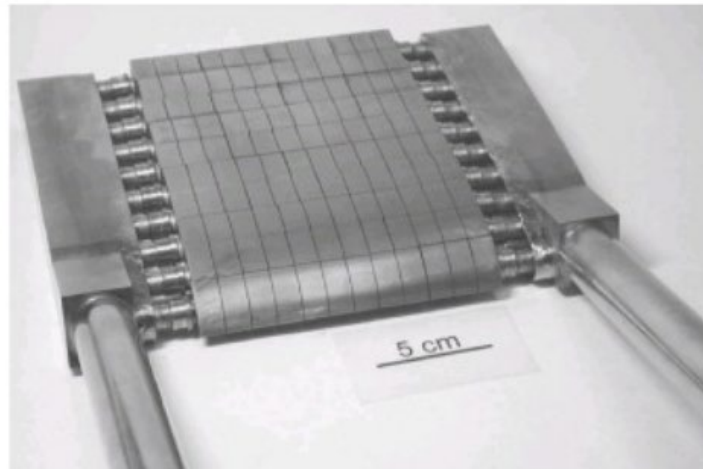
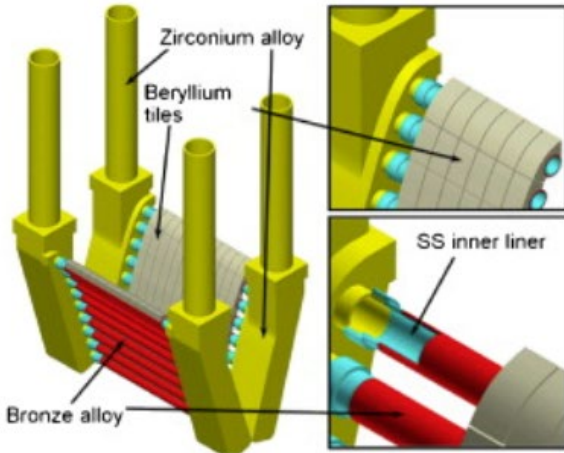
maze shape?

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# New target, new BSA

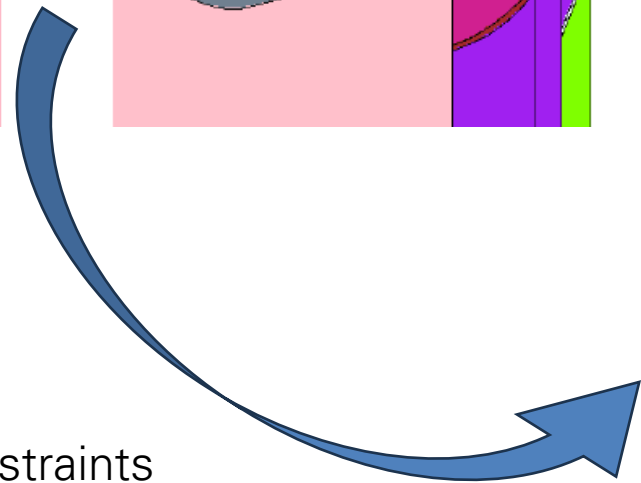
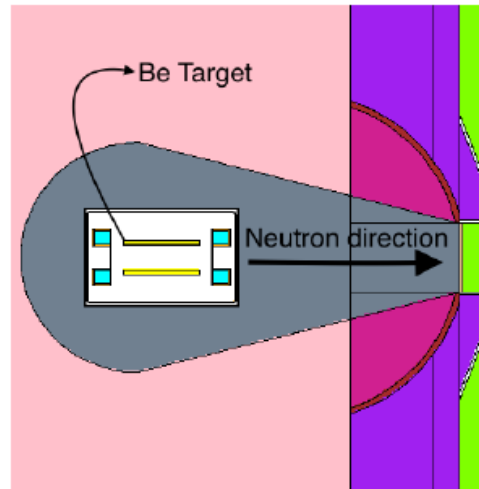
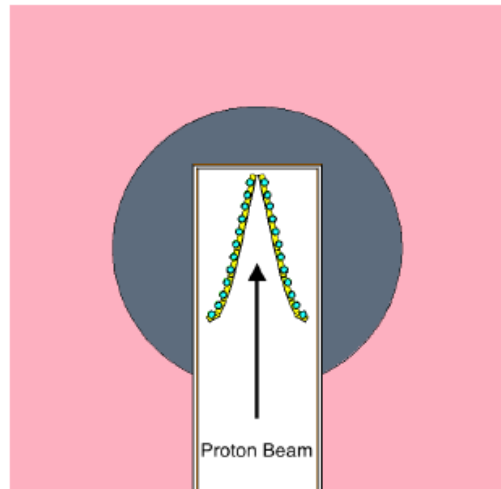


0.15mm 0.2mm 20-30mm

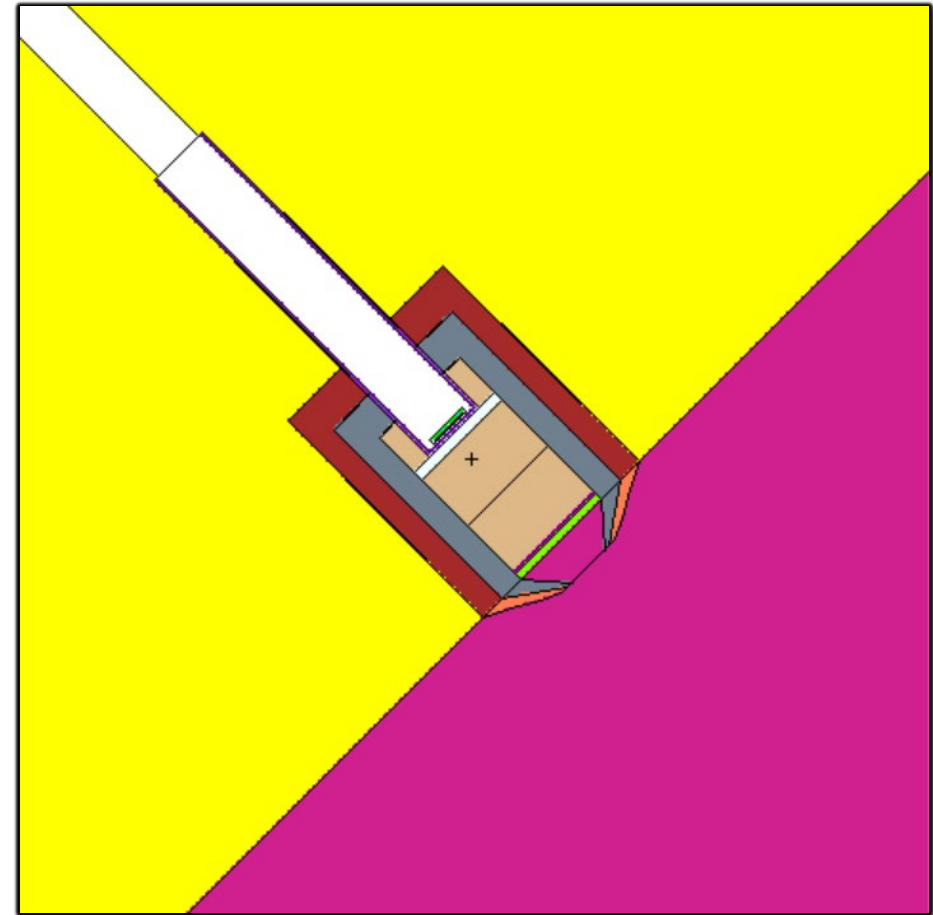
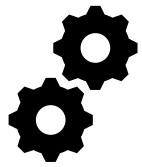


Planar, 20x20 cm  
Perpendicular to the p+ beam

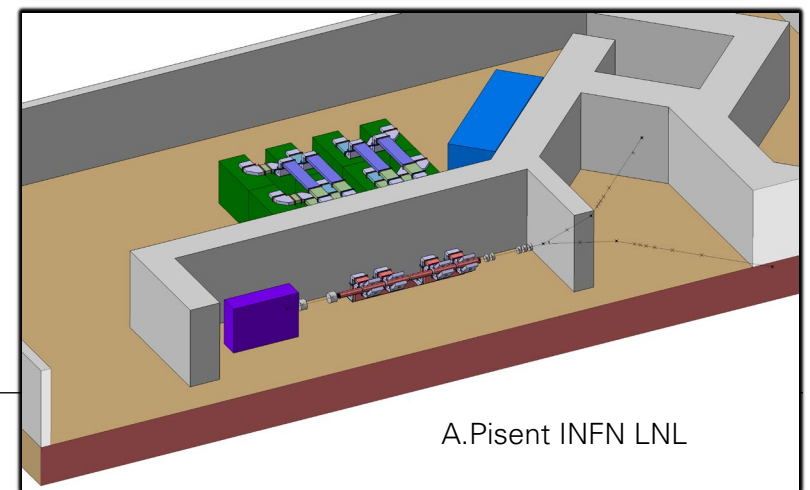
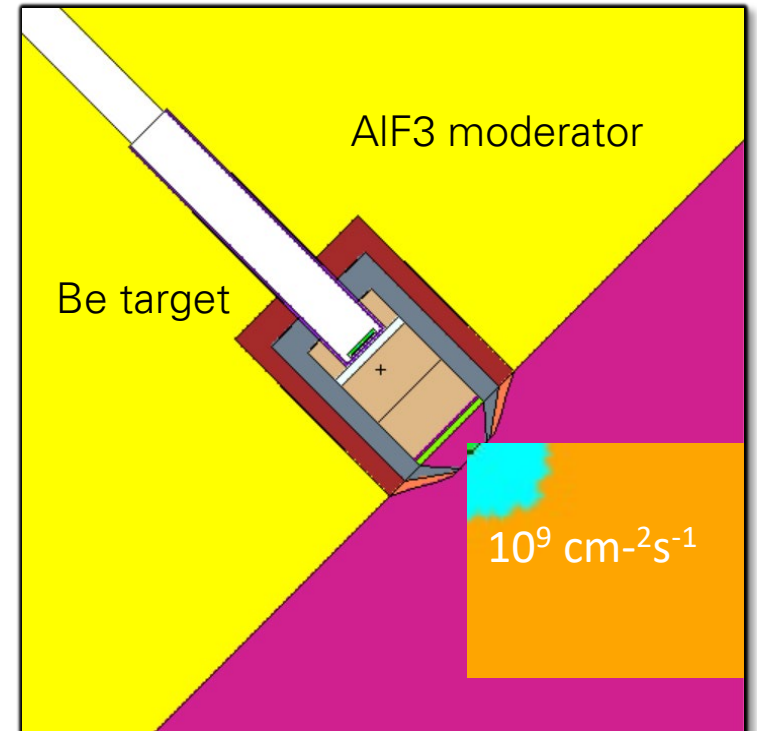
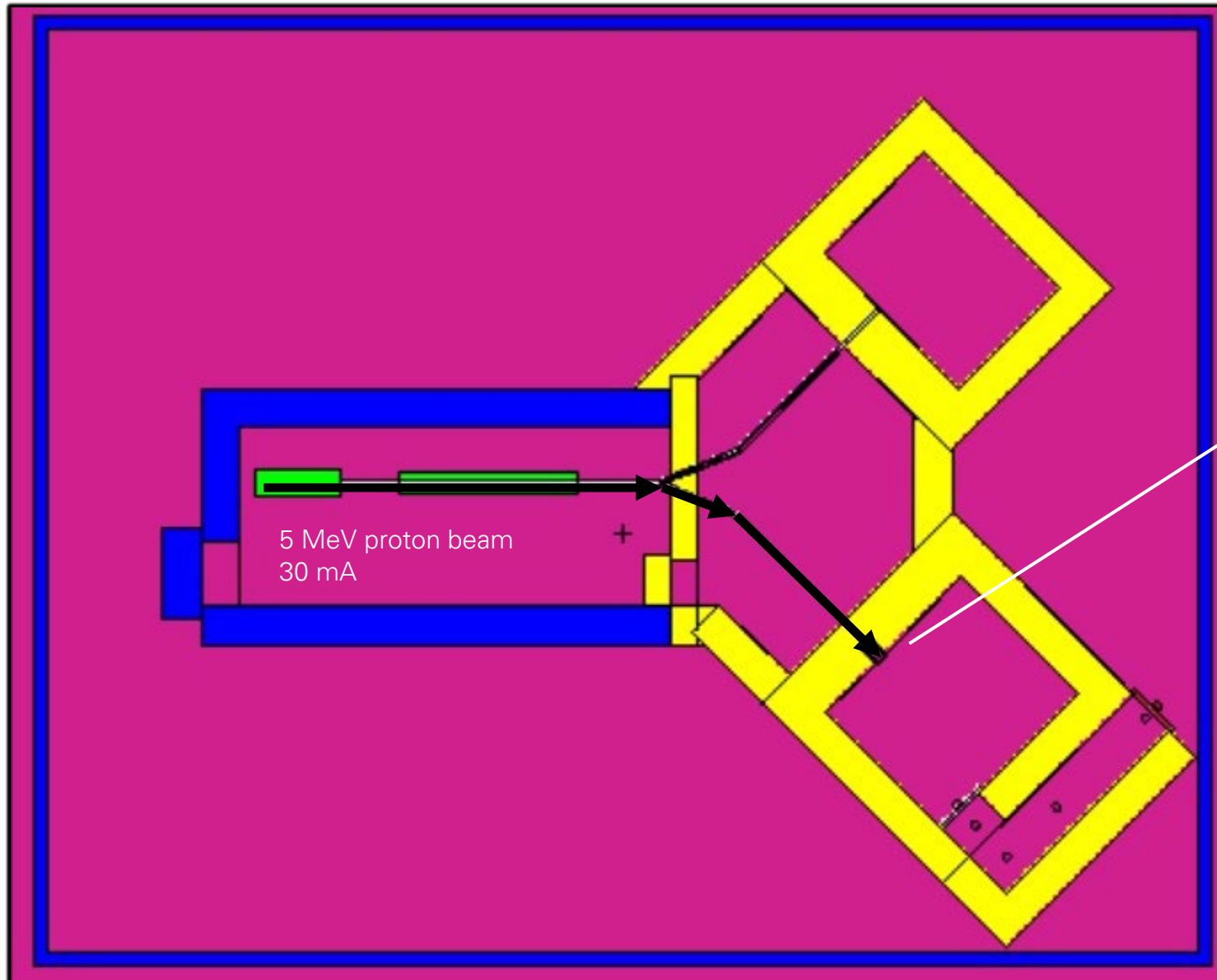
# BSA to be constructed



Beam at 0°  
Easier shapes  
Consider construction constraints



# Facility simulation



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# A special concrete by Neuboron Medtech



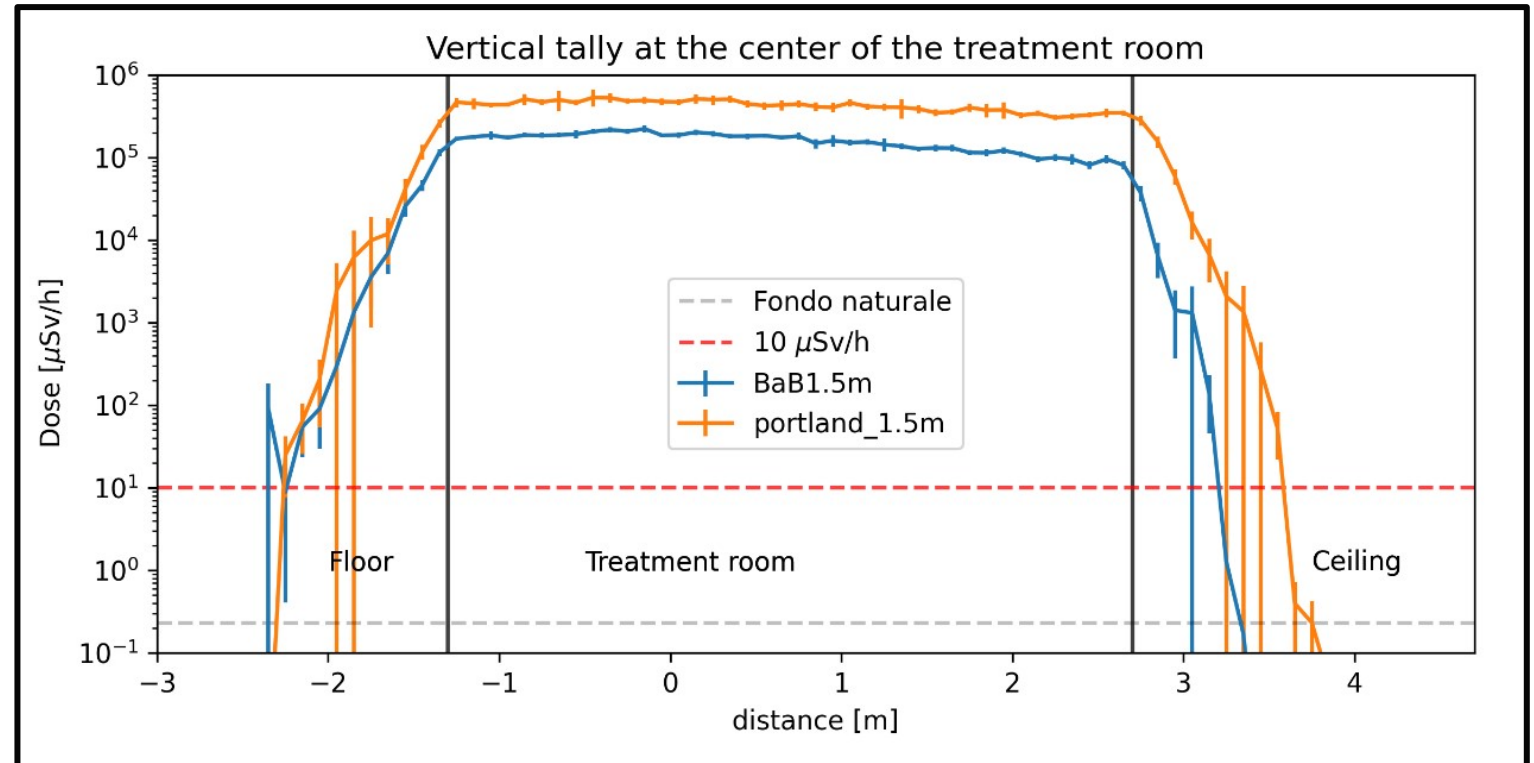
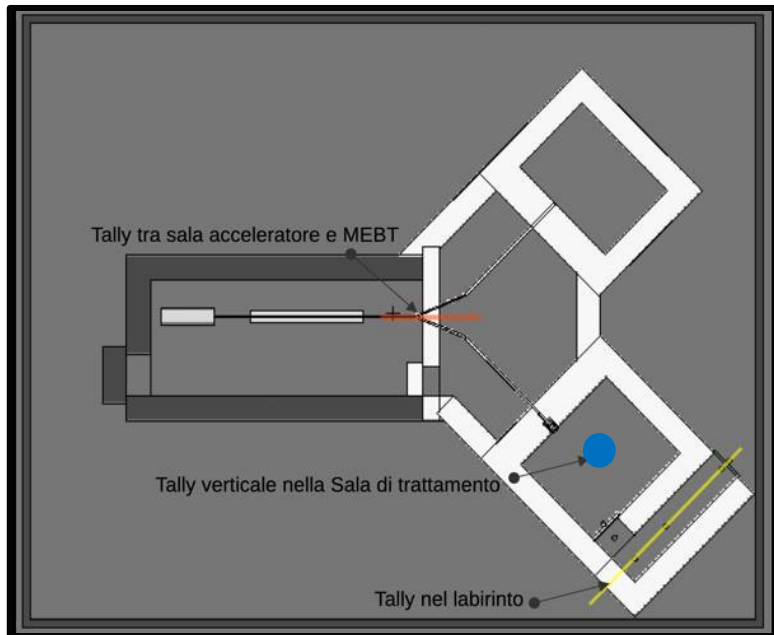
Ba + 0.5%  $^{10}\text{B}$

Recipe available under  
the agreement signed  
with Vanvitelli University



# Comparison between different materials

Borated Baritic Concrete versus Portland Concrete

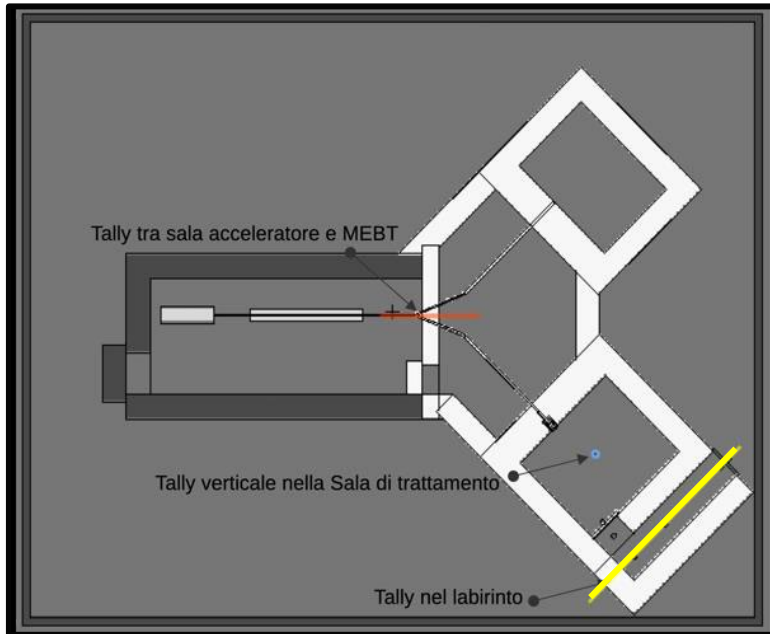


- Vertical distribution in treatment room

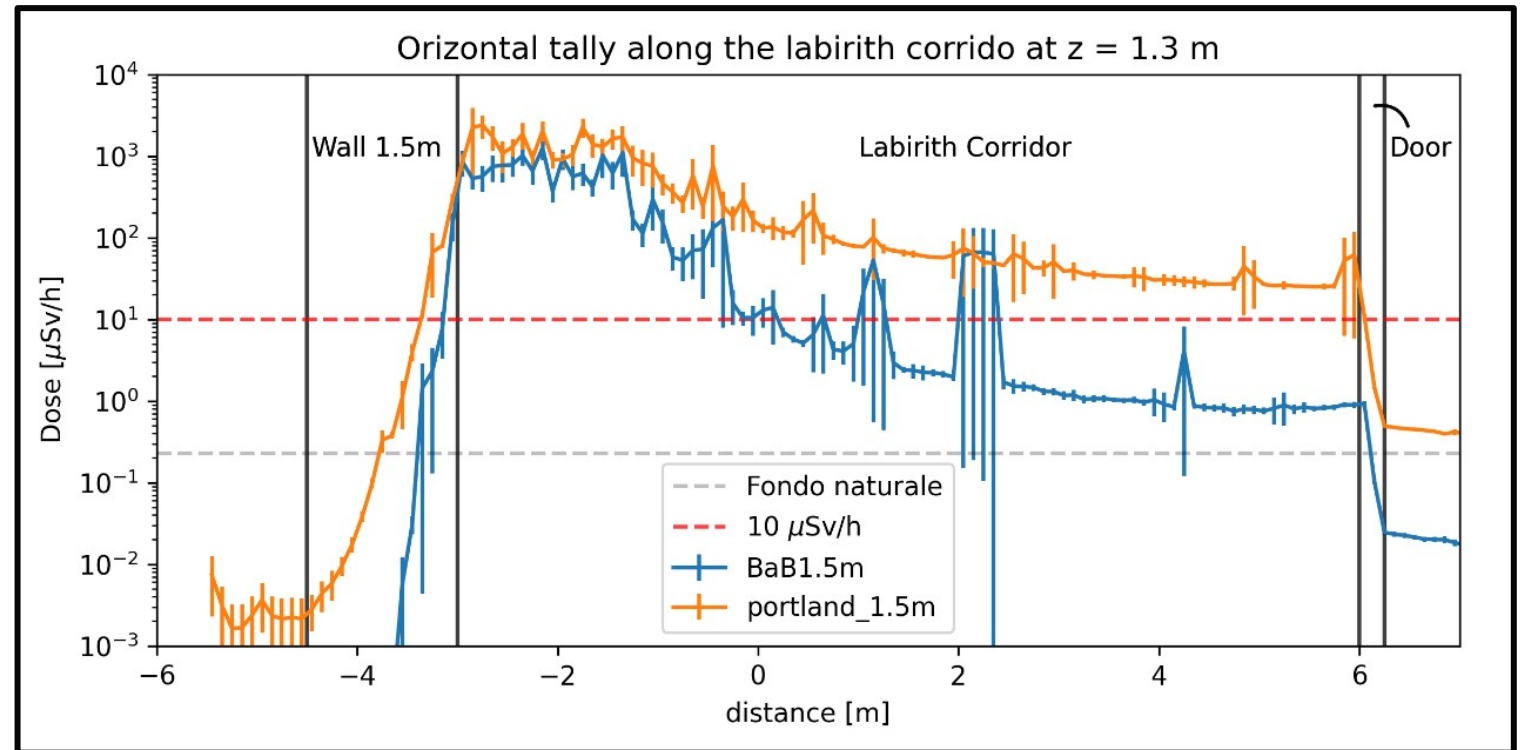


# Comparison between different materials

Borated Baritic Concrete versus Portland Concrete

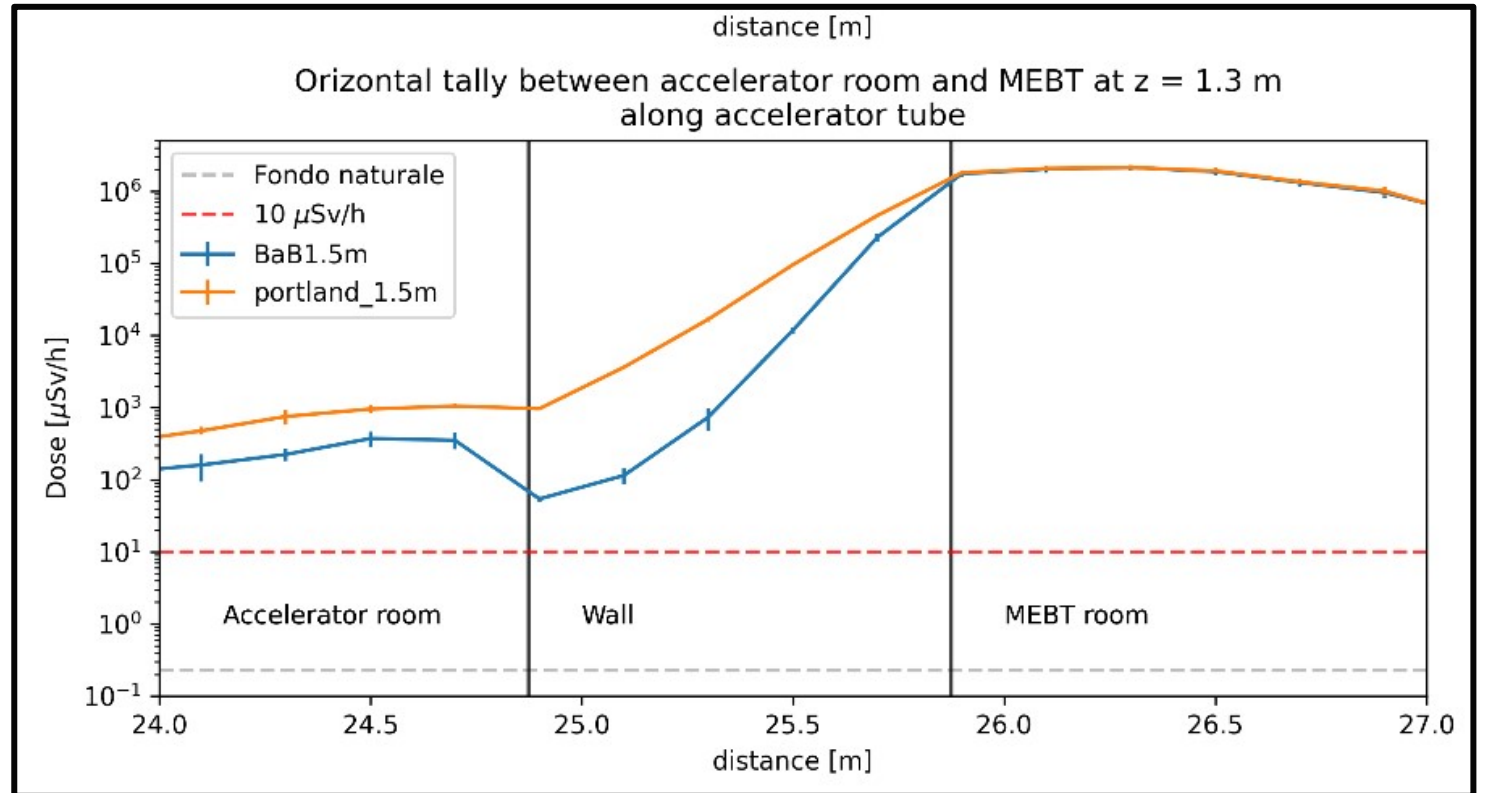
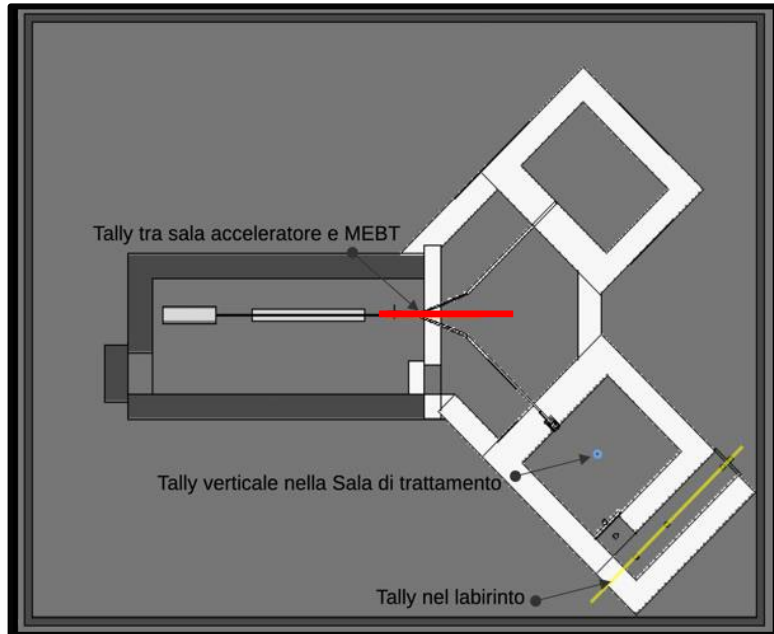


● Maze hallway



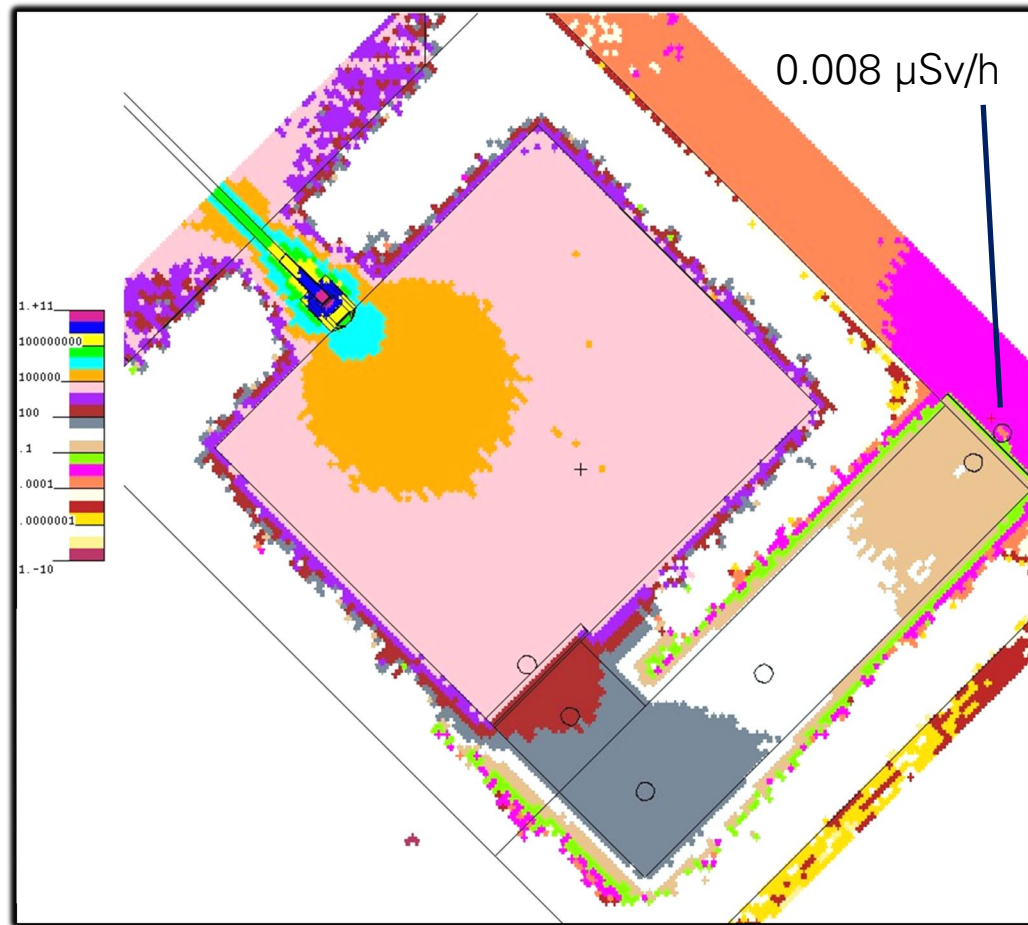
# Comparison between different materials

Borated Baritic Concrete versus Portland Concrete

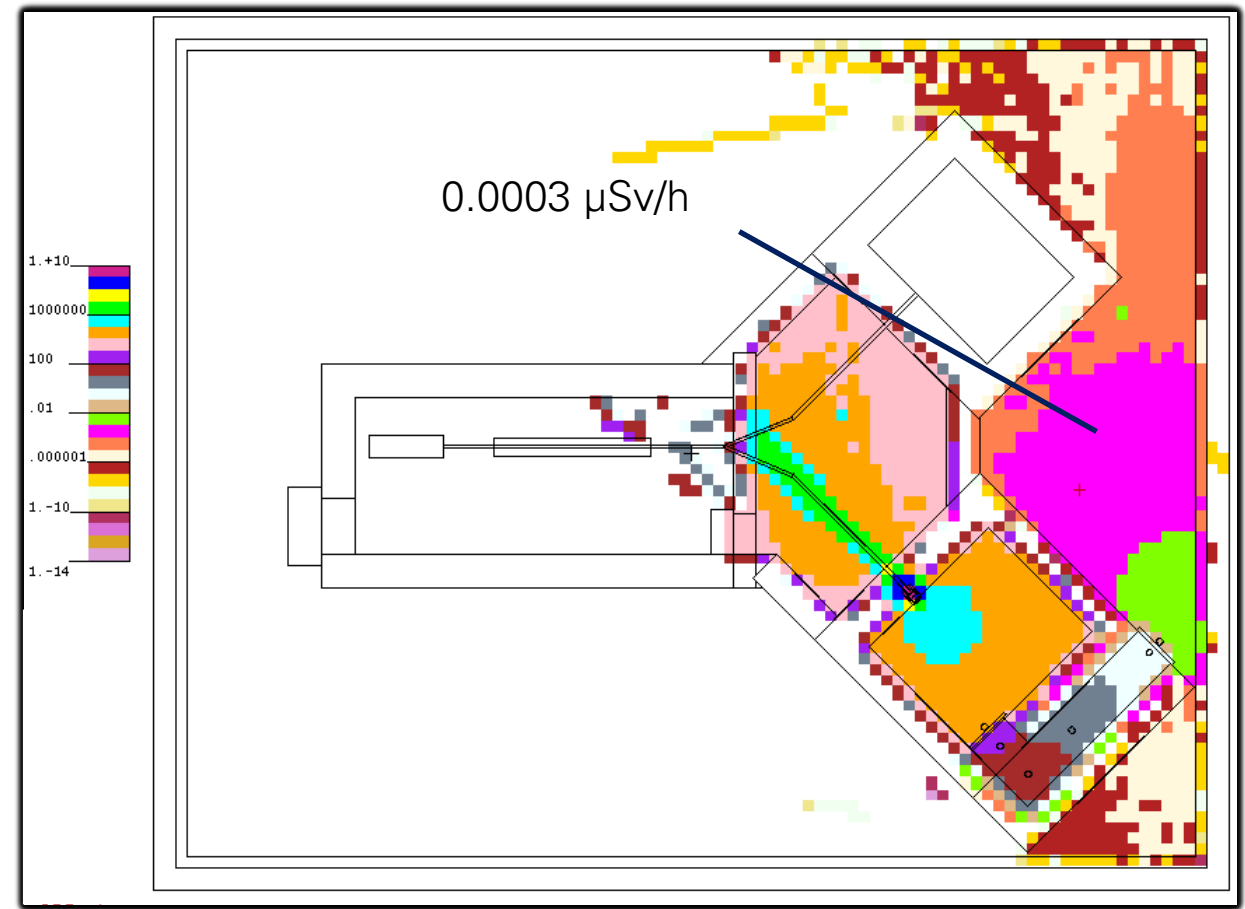


● Transition area

# Ambient Neutron Dose Equivalent

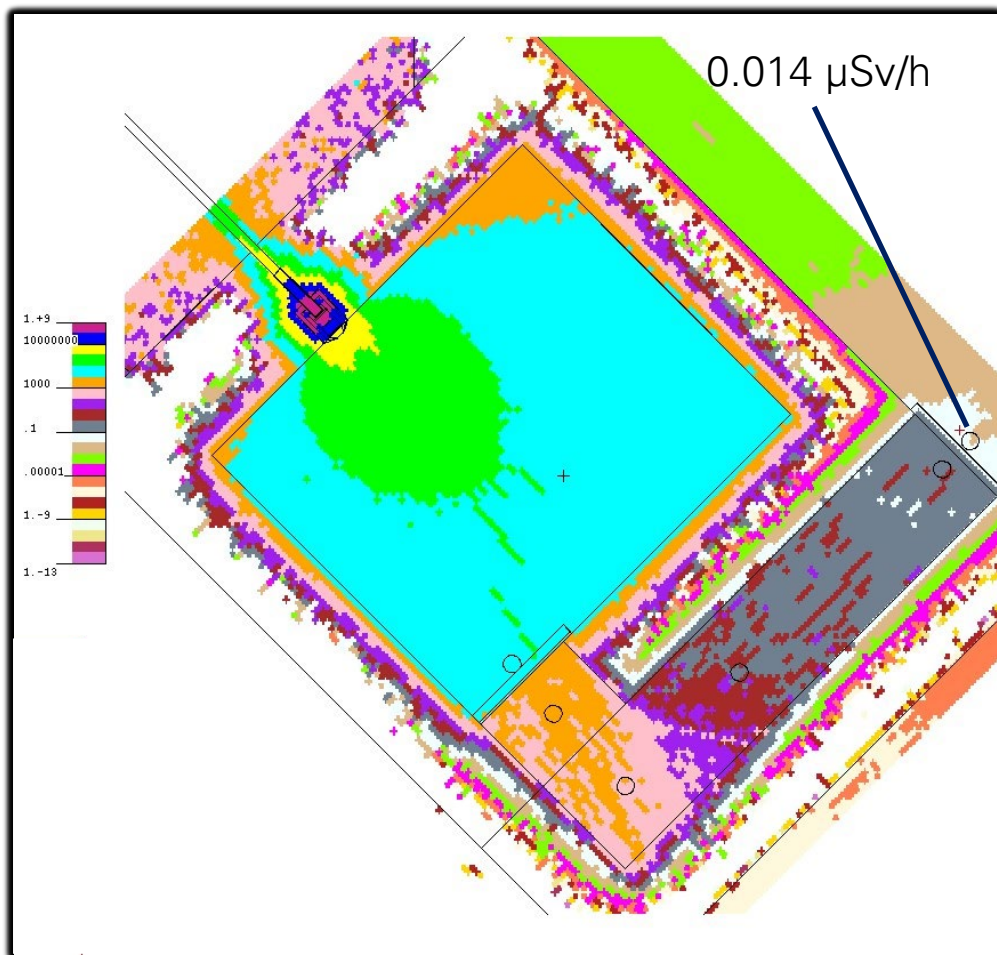


Maze

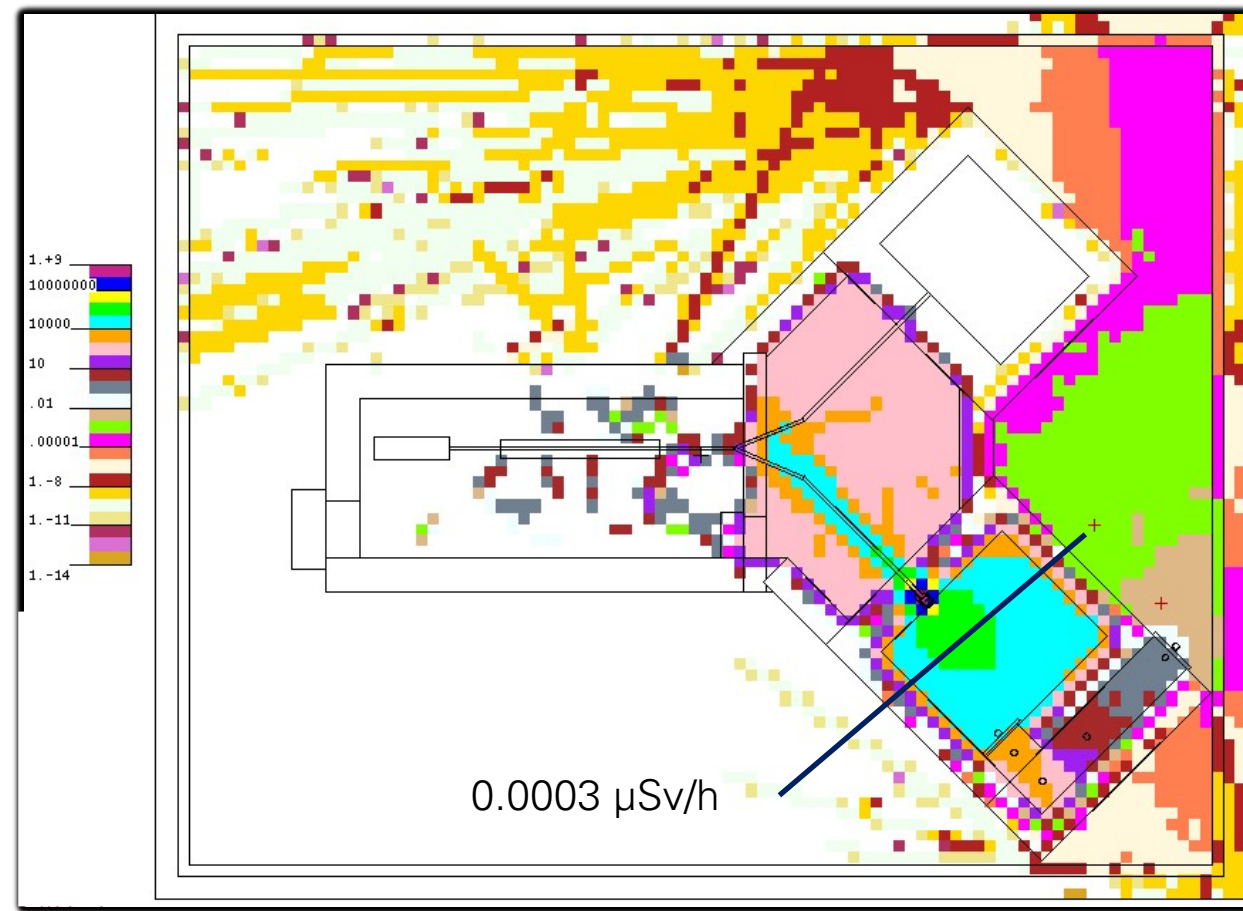


Control area

# Ambient Photon Dose Equivalent



Maze

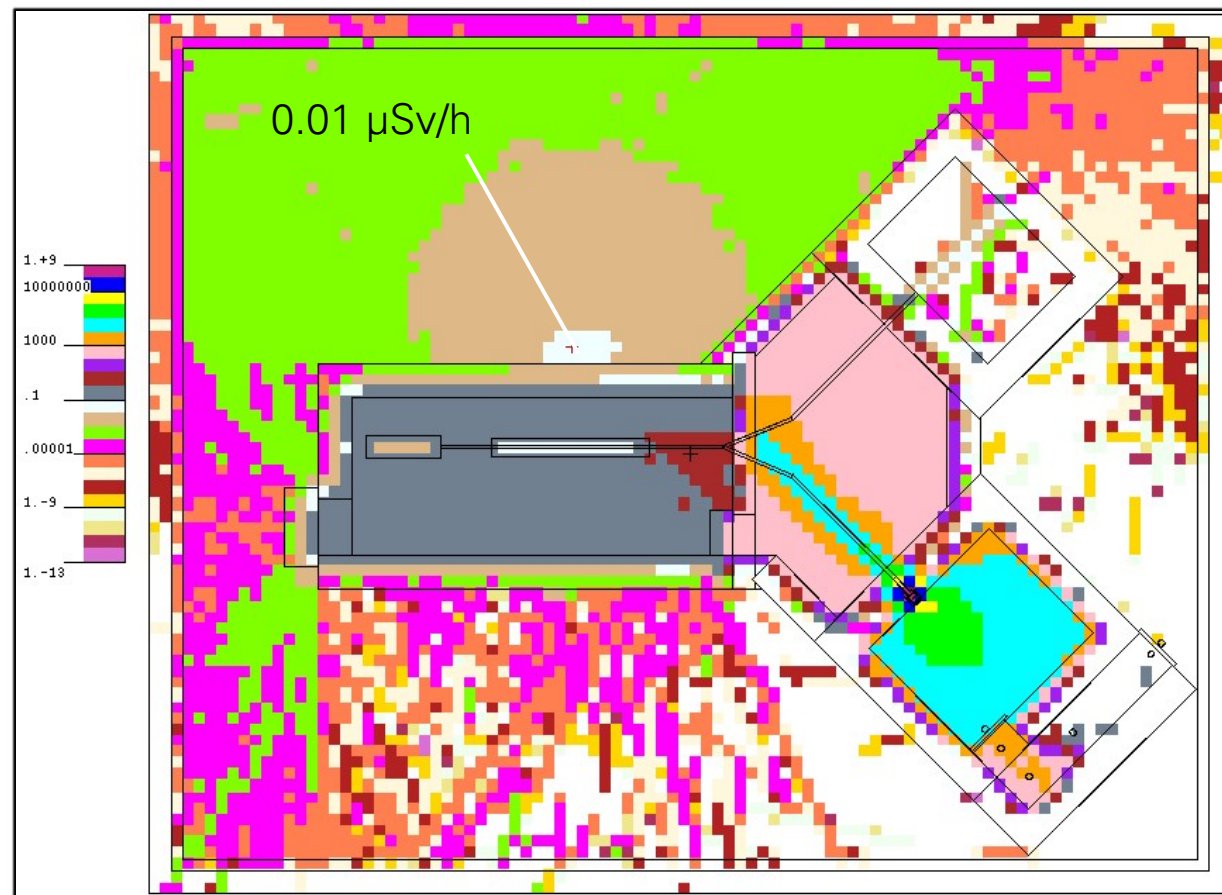
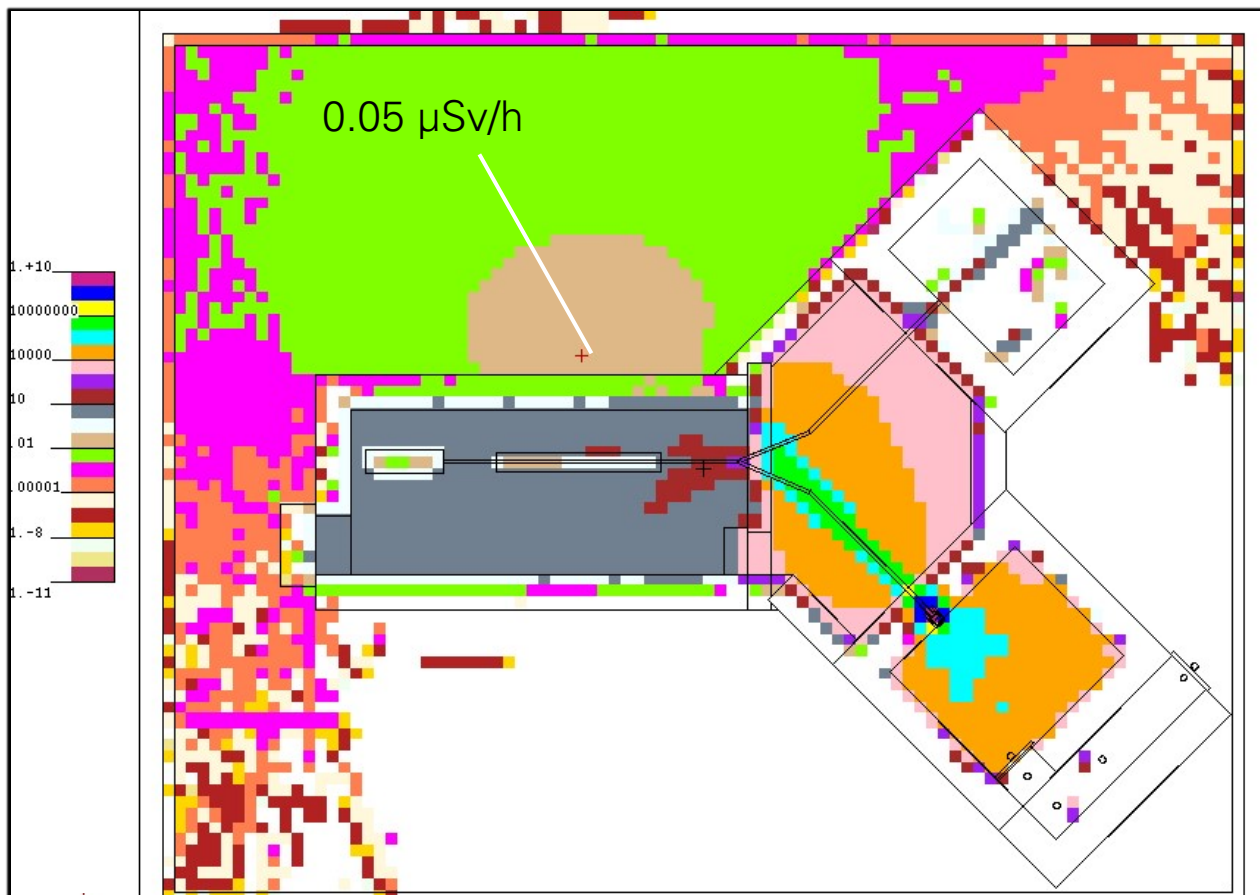


Control area

# Ambient Dose Equivalent - Accelerator area

Neutrons

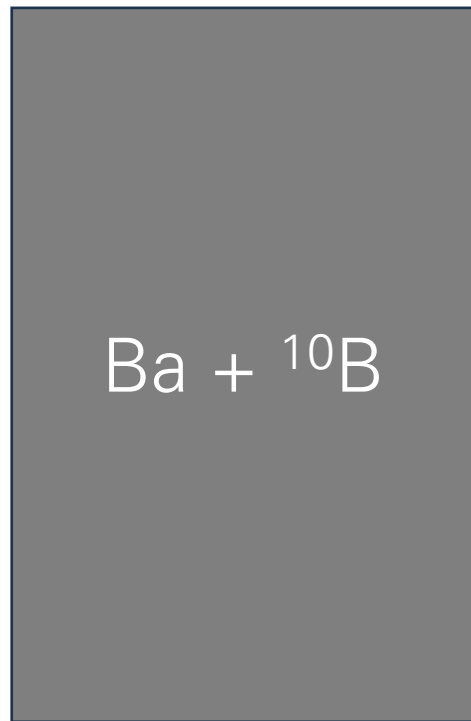
Photons



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# Cost - effectiveness

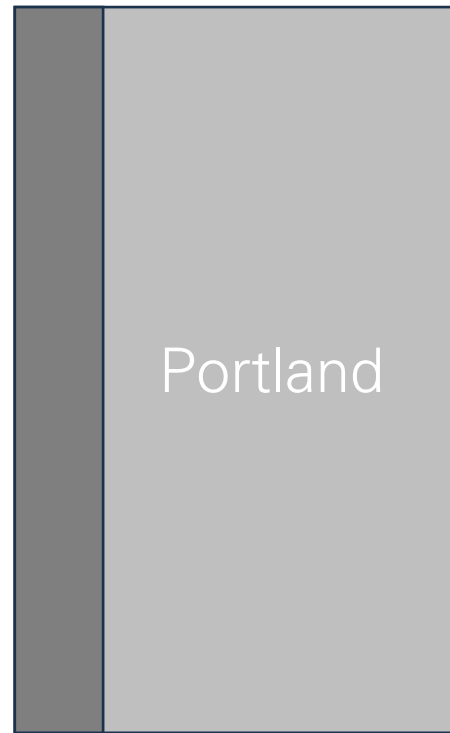
Instead of:



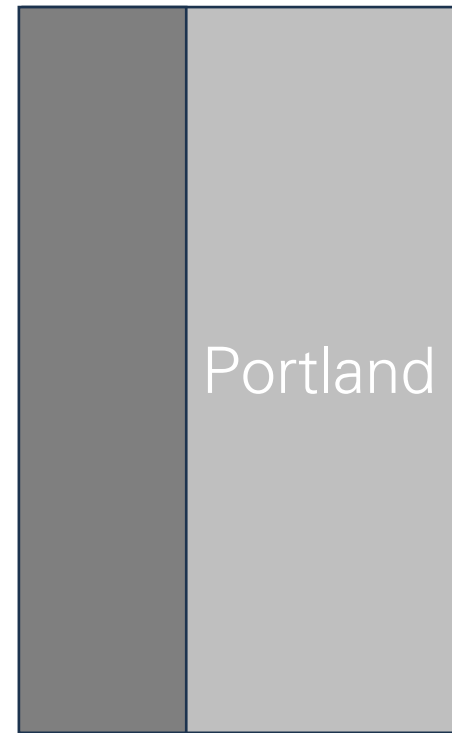
$B_a + {}^{10}B$



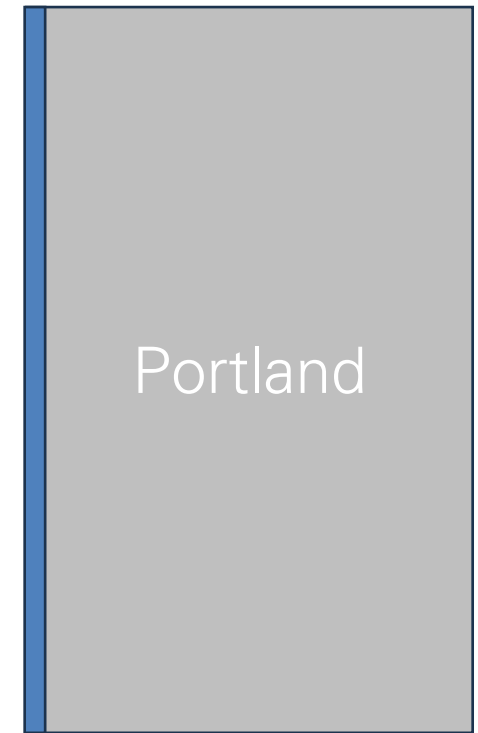
test:



Portland



Portland



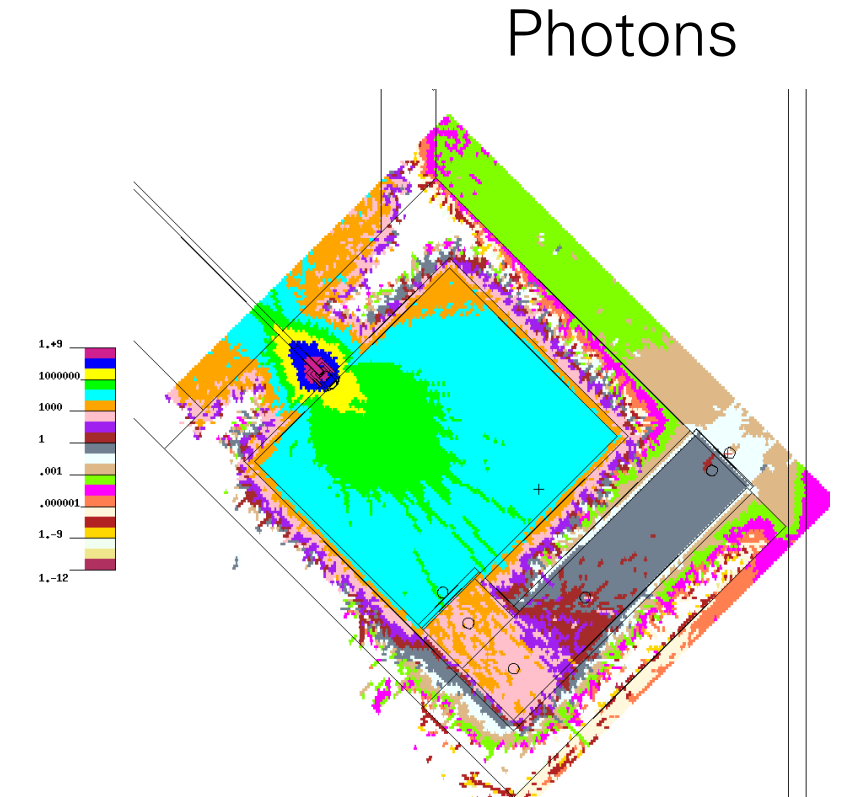
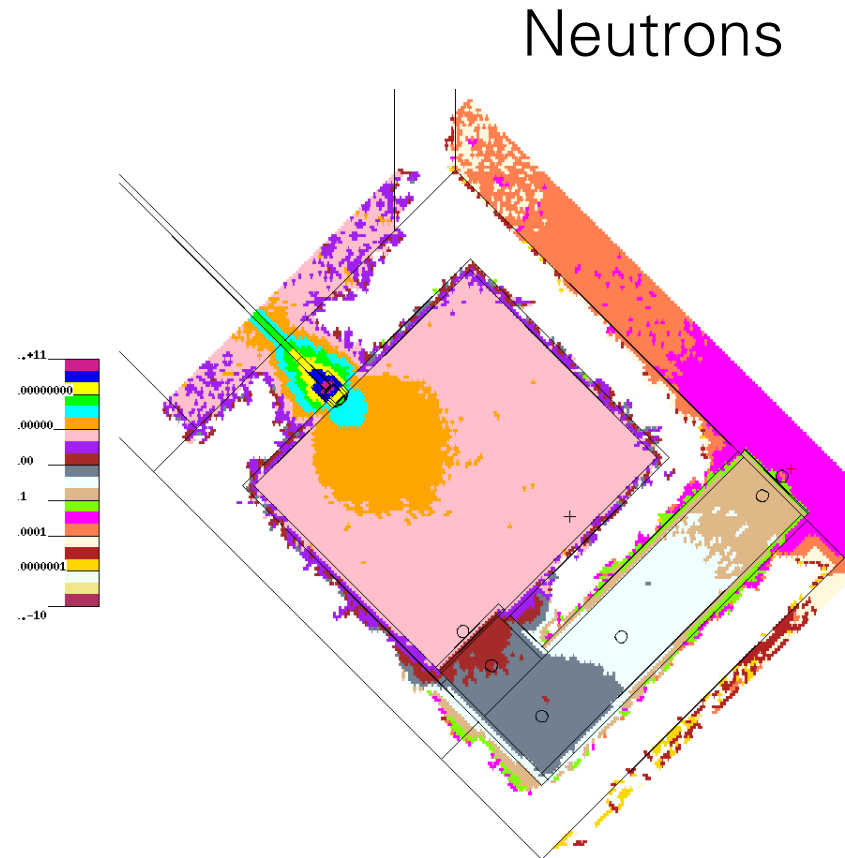
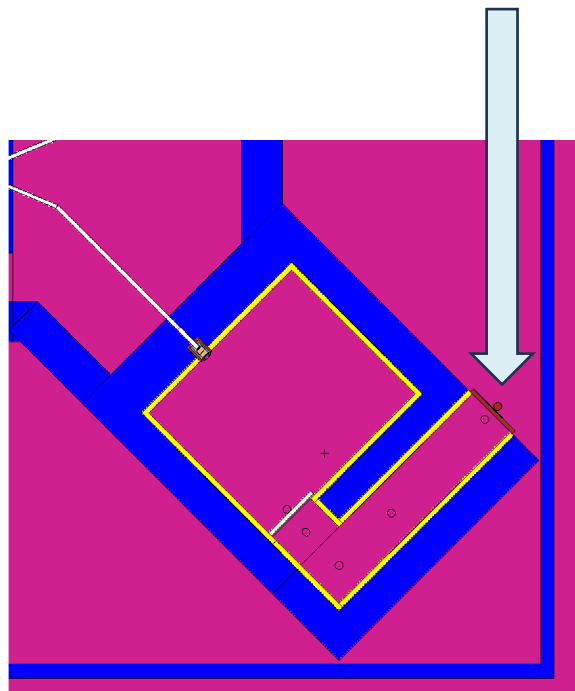
Portland

$B_4C$

?



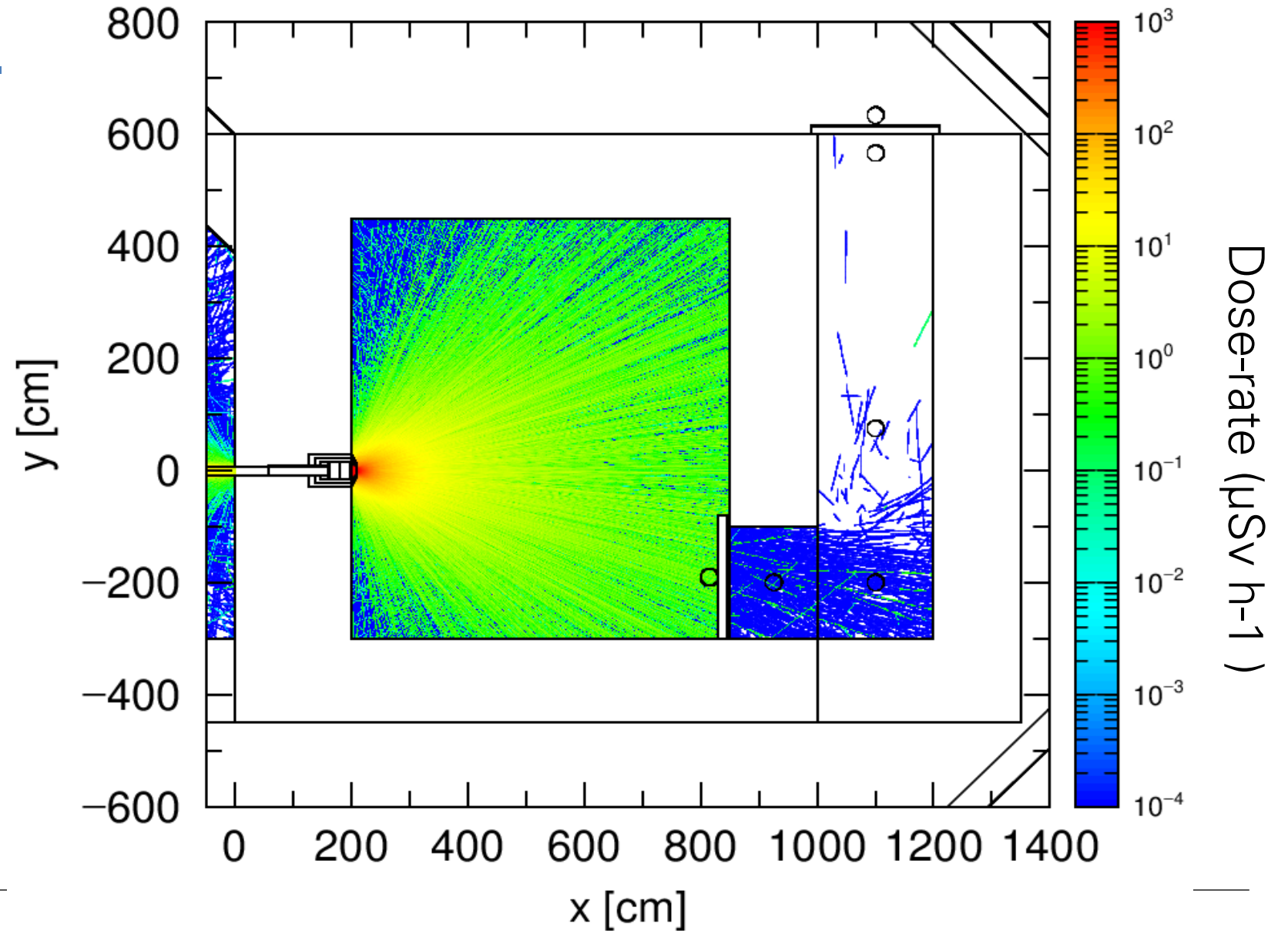
# Example of results (20 cm of Ba+<sup>10</sup>B)



Same values as full thickness of Ba+<sup>10</sup>B!

# Activation of BSA - Dose rate $H^*(10)$

15 min after  
shutdown





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# Activity of walls - Radioactive isotopes

1 sec after shutdown

Ba-139 (82%), Al-28 (7%), Mn-56 (3.5%)

15 min after shutdown

Ba-139 (92%), Mn-56 (4%), Si-31 (1%)

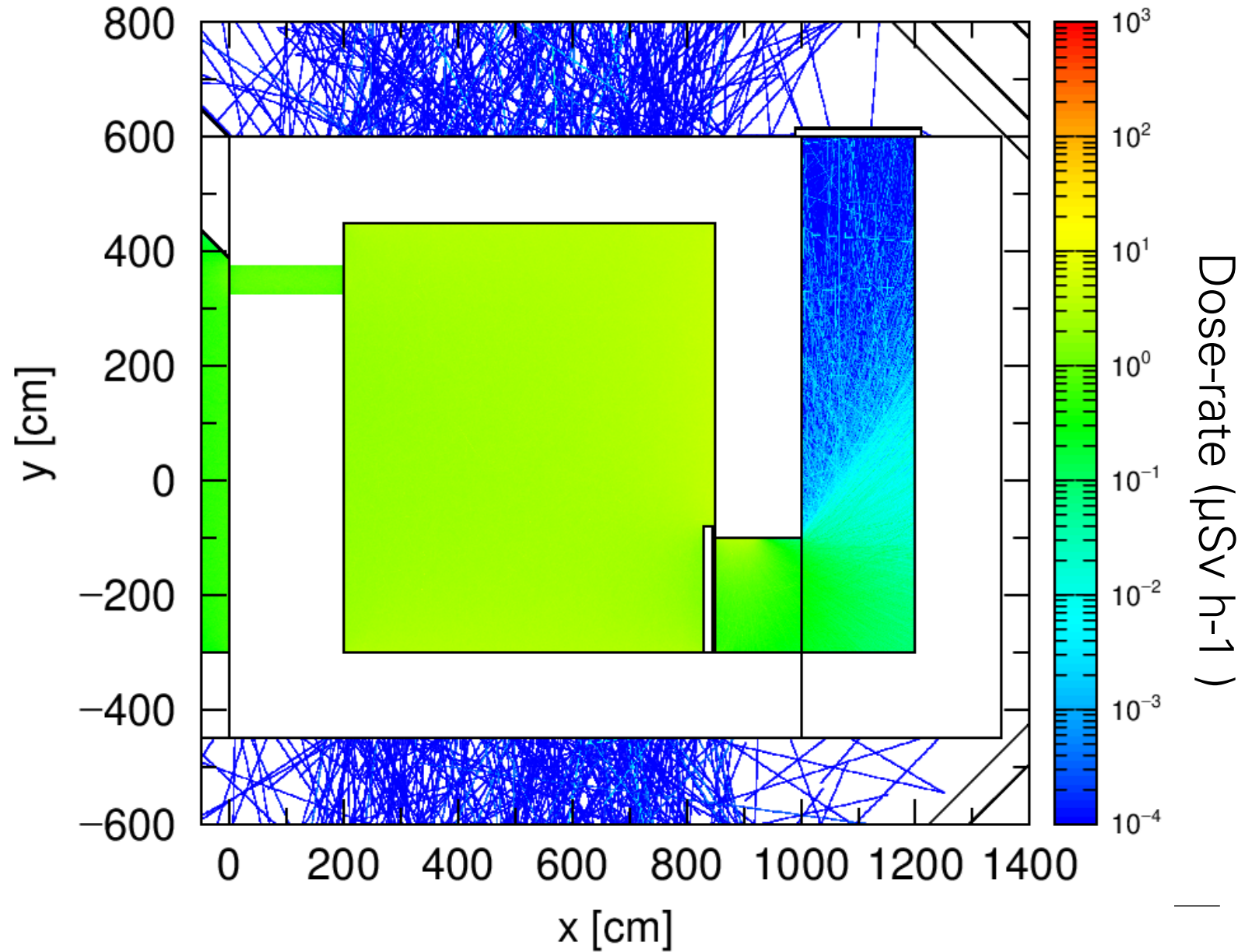
24 h after shutdown

Ba-135m (70%), K-40 (15%), P-32 (6.5%)

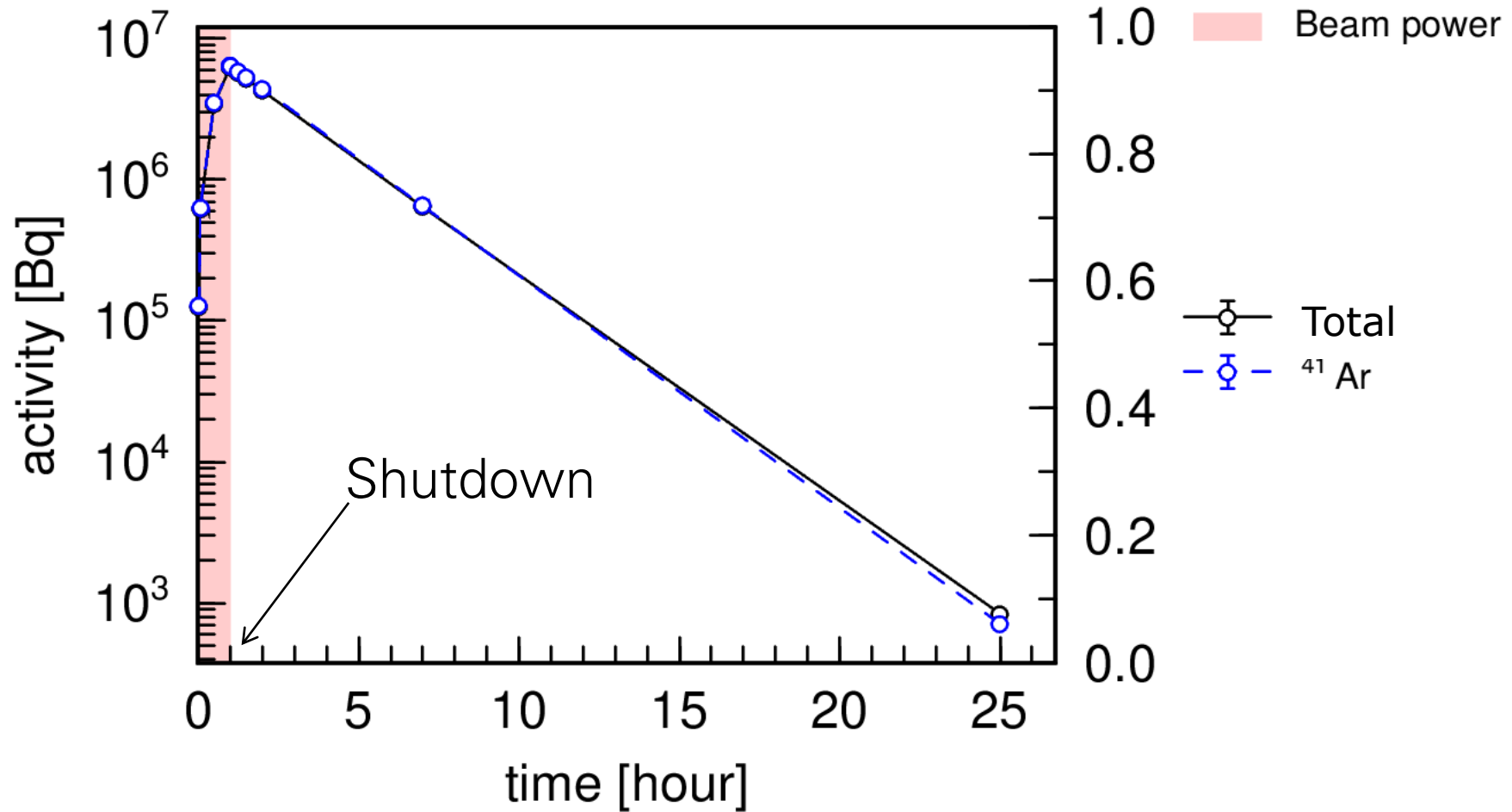
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# Activation of walls - Dose rate $H^*(10)$

15 min after  
shutdown



# Air activity - $^{41}\text{Ar}$



$^{41}\text{Ar}$  specific activity 15 min after shutdown: 24,8 Bq/g

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## Work in progress

15 minutes after shutdown:

- the activation of BSA represents the principal source for the  $H^*(10)$  dose-rate → Optimization of the BSA + shutter.
- the principal radioactive isotopes in the walls are Ba-139 (92%), Mn-56 (4%), Si-31 (1%). However,  $H^*(10)$  due to walls  $\ll H^*(10)$  due to BSA.

The specific activity of  $^{41}\text{Ar}$  15 min after shutdown is 24.8 Bq/g

→ Filtration and recirculation of air must be included. Calculation of Ar-41 activity outside the chimney

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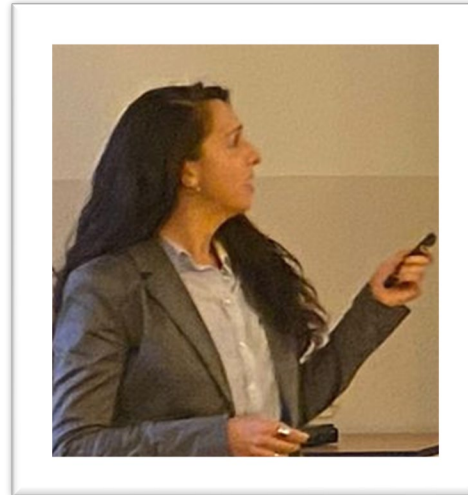
# Workforce for radioprotection calculations

Ian Postuma



Ricardo Ramos

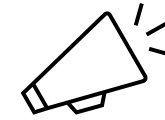
Setareh Fatemi



Laura Bagnale  
PhD student



Chiara Magni  
Advisor  
(master radioprotection)



Giovanni Garini  
MSc student  
*just recruited*

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You tell what  
we need to  
calculate...  
and we do it!

Thank you for your attention  
[silva.bortolussi@pv.infn.it](mailto:silva.bortolussi@pv.infn.it)

