Gamma Blockers
Radiation studies

NATIONAL CENTRE FOR NUCLEAR RESEARCH ŚWIERK

Karol Szymczyk

17-11-2017

Overview

09:00 - 09:15 Committee discussion (closed) 15'

09:15 - 09:35 Gamma Blockers overview and schedule 20’ Karol Szymczyk

09:35 - 09:55 Requirements and interfaces 20’ Marcin Wojciechowski

09:55 - 10:35 Radiation studies 40’ Karol Szymczyk

10:35 - 10:50 Coffee break

10:50 - 11:30 Mechanical design 40’ Marcin Wojciechowski

11:30 - 11:45 Safety, Machine Protection and RAMI 15’ Marcin Wojciechowski

11:45 - 12:00 Quality and Verification plans 15’ Karol Szymczyk

12:00 - 13:30 Lunch

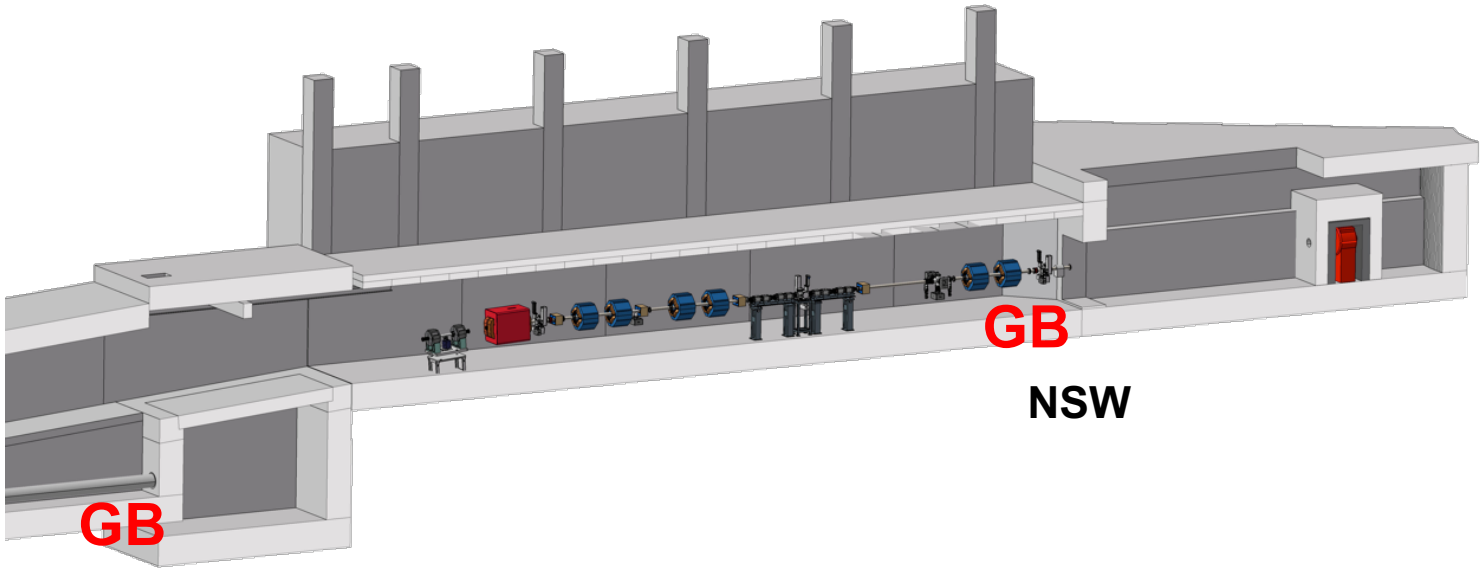
13:30 - 14:30 Committee deliberations (closed) 1h0'

14:30 - 15:00 Closeout 30'

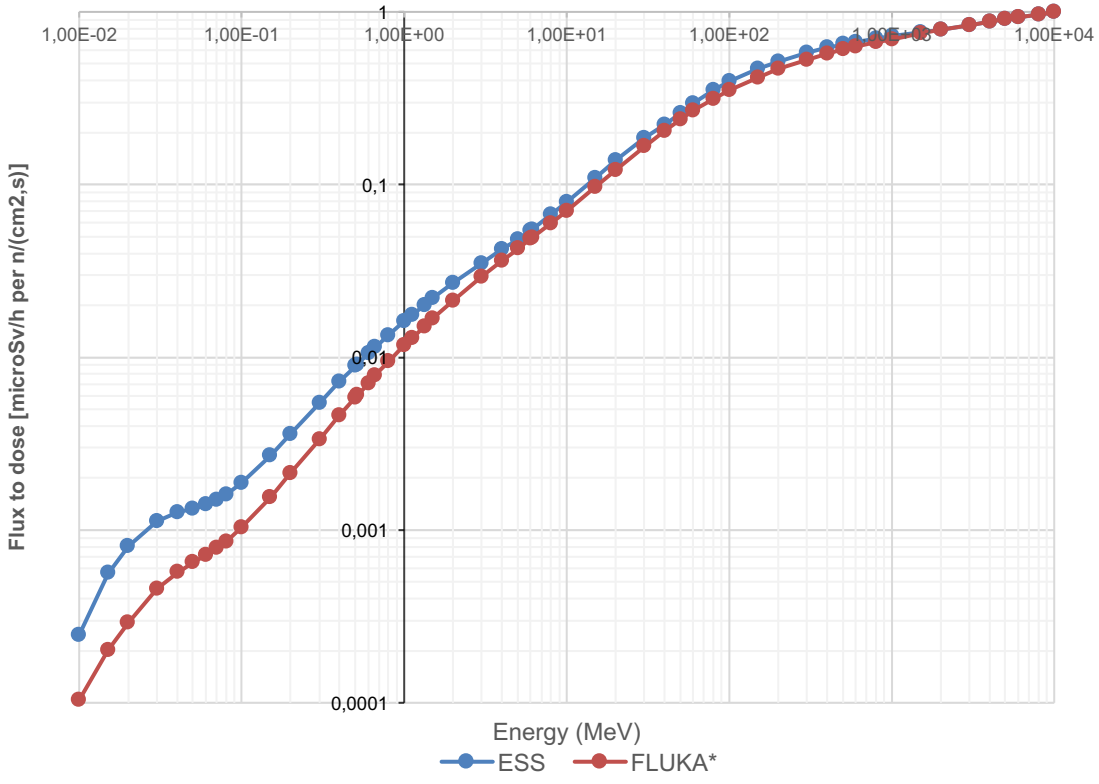
Gamma Blocker

"Absorb gamma radiation from the target or beam dump, during maintenance periods."

- Gamma blocker consists of: shield plate, movement mechanism, vaccum chamber, CF beam line flanges, actuator(s),



Flux to dose conversion factors for external radiation



Energy Energy	Flux to dose [µSv/h per n/(cm2,s)]	
Energy [MeV]	ESS	FLUKA*
1,00E-02	2,47E-04	1,04E-04
1,50E-02	5,62E-04	2,02E-04
2,00E-02	8,10E-04	2,92E-04
3,00E-02	1,13E-03	4,57E-04
4,00E-02	1,26E-03	5,69E-04
5,00E-02	1,33E-03	6,48E-04
6,00E-02	1,40E-03	7,16E-04
7,00E-02	1,49E-03	7,85E-04
8,00E-02	1,60E-03	8,60E-04
1,00E-01	1,87E-03	1,03E-03
1,50E-01	2,69E-03	1,54E-03
2,00E-01	3,60E-03	2,12E-03
3,00E-01	5,44E-03	3,36E-03
4,00E-01	7,20E-03	4,61E-03
5,00E-01	8,89E-03	5,87E-03
5,11E-01	9,07E-03	6,01E-03
6,00E-01	1,05E-02	7,09E-03
6,62E-01	1,14E-02	7,81E-03
8,00E-01	1,34E-02	9,43E-03
1,00E+00	1,62E-02	1,17E-02
1,12E+00	1,76E-02	1,30E-02
1,33E+00	2,01E-02	1,51E-02
1,50E+00	2,20E-02	1,68E-02
2,00E+00	2,69E-02	2,12E-02
3,00E+00	3,51E-02	2,91E-02
4,00E+00	4,21E-02	3,60E-02
5,00E+00	4,82E-02	4,25E-02
6,00E+00	5,40E-02	4,86E-02
6,13E+00	5,47E-02	4,93E-02
8,00E+00	6,70E-02	5,98E-02
1,00E+01	7,92E-02	7,06E-02
1,50E+01	1,09E-01	9,65E-02
2,00E+01	1,38E-01	1,22E-01
3,00E+01	1,85E-01	1,66E-01
4,00E+01	2,23E-01	2,05E-01
5,00E+01	2,60E-01	2,38E-01
6,00E+01	2,95E-01	2,67E-01
8,00E+01	3,52E-01	3,14E-01
1,00E+02	3,96E-01	3,51E-01
1,50E+02	4,68E-01	4,18E-01
2,00E+02	5,15E-01	4,68E-01
3,00E+02	5,80E-01	5,29E-01
4,00E+02	6,19E-01	5,72E-01
5,00E+02	6,48E-01	6,05E-01
6,00E+02	6,70E-01	6,26E-01
8,00E+02	7,02E-01	6,66E-01
1,00E+03	7,24E-01	6,95E-01
1,50E+03	7,63E-01	7,49E-01
2,00E+03	7,92E-01	7,85E-01
3,00E+03	8,35E-01	8,35E-01
4,00E+03	8,75E-01	8,75E-01
5,00E+03	9,04E-01	9,04E-01
6,00E+03	9,29E-01	9,29E-01
8,00E+03	9,65E-01	9,65E-01
1,00E+04	9,94E-01	9,94E-01

* Annals of the ICRP ICRP PUBLICATION 116 Conversion Coefficients for Radiological Protection Quantities for External Radiation Exposures Editor C.H. CLEMENT Authors on behalf of ICRP N. Petoussi-Henss, W.E. Bolch, K.F. Eckerman, A. Endo, N. Hertel, J. Hunt, M. Pelliccioni, H. Schlattl, M. Zankl

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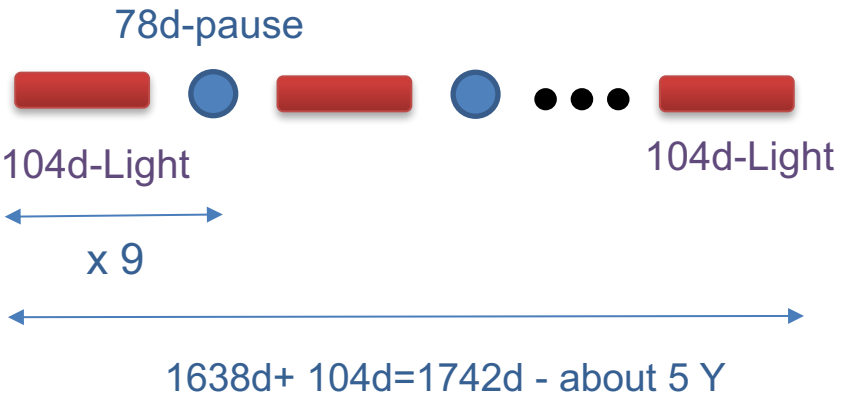
Calculations

Recommendation of design criteria for the radiation level upstream of the GB which was presented in the document "Considerations for Gamma Blocker design related to radiation safety: ESS-0087526" [7], were taken into account during this design.

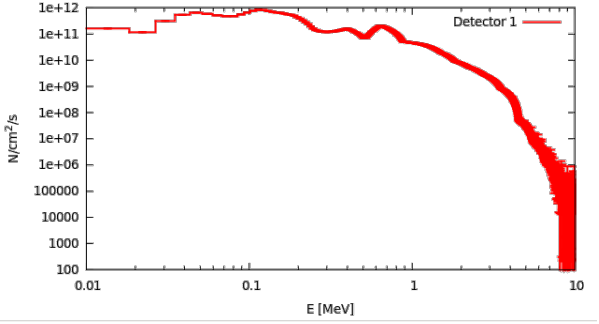
“For gamma blocker in the line of target: 100 μSv/h on contact for 5 years of irradiation of target (max 2 GeV, 5 MW beam) and no cool-down.
For gamma blocker in the line of beam dump: 100 μSv/h on contact for 50 years of irradiation of beam dump (max 2 GeV, 12 kW beam) and no cool-down.”

With regard to the ESS Documents "ESS Procedure for designing shielding for safety", in all particle transport code calculations, the safety factor of 2 was applied.

A2T section
Input file



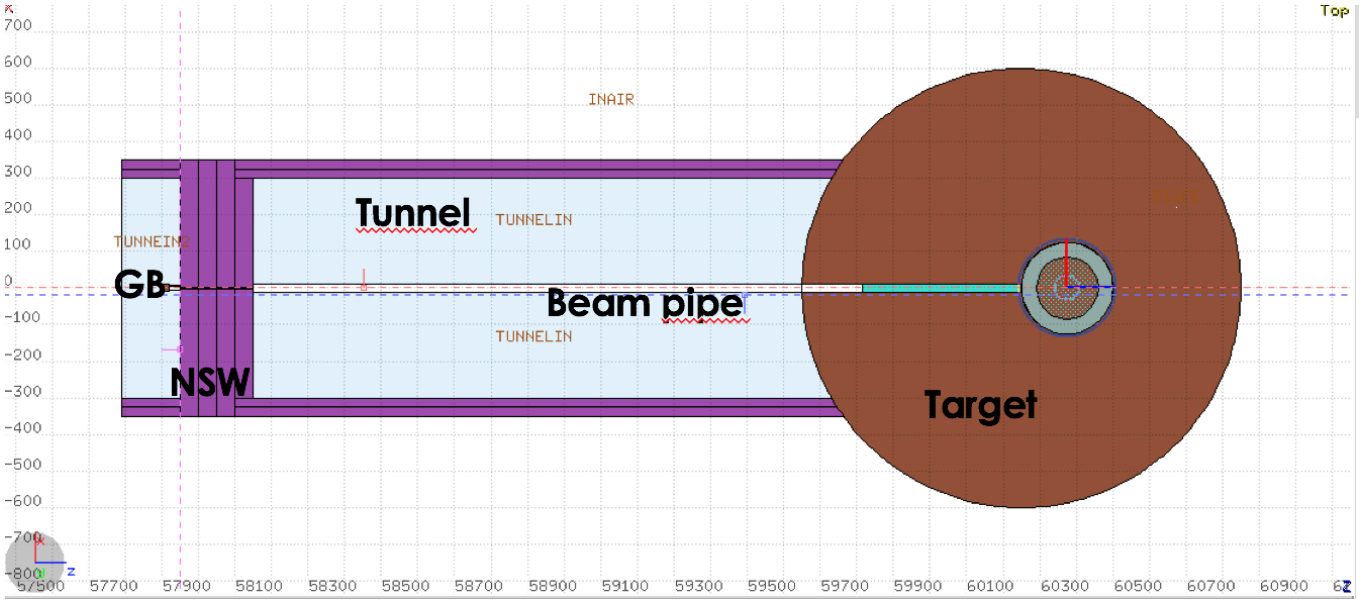
For gamma blocker in the line of target: 100 μSv/h on contact for 5 years of target irradiation (2 GeV, 5 MW proton beam, ~6000 hours of annual operation) and no cool-down.

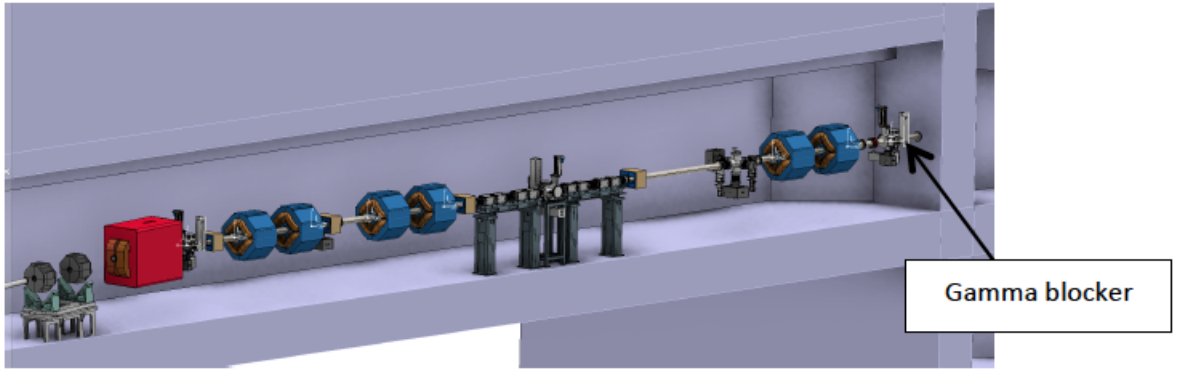


Used Gamma Spectrum after 5 Years operation time

		0s cooling time	1h cooling time	4h cooling time	1m cooling time
Emin (MeV)	Emax (MeV)	photons/cm3/s	photons/cm3/s	photons/cm3/s	photons/cm3/s
0,00E+00	1,00E-02	4,05E+11	1,05E+11	8,60E+10	3,34E+10
1,00E-02	3,00E-02	5,69E+10	5,04E+10	4,43E+10	3,43E+09
3,00E-02	6,00E-02	7,77E+11	2,87E+11	2,31E+11	7,49E+10
6,00E-02	1,00E-01	3,22E+11	1,70E+11	1,48E+11	1,86E+10
1,00E-01	2,00E-01	2,26E+11	9,93E+10	8,09E+10	8,09E+09
2,00E-01	3,00E-01	5,43E+10	3,56E+10	2,67E+10	2,97E+09
3,00E-01	5,00E-01	1,73E+11	1,42E+11	1,25E+11	7,86E+09
5,00E-01	5,25E-01	6,58E+10	2,59E+10	1,50E+10	3,96E+08
5,25E-01	7,50E-01	2,38E+11	2,17E+11	1,95E+11	3,28E+09
7,50E-01	1,00E+00	5,78E+10	4,38E+10	3,68E+10	3,07E+09
1,00E+00	1,33E+00	4,42E+10	3,12E+10	2,45E+10	6,82E+09
1,33E+00	1,66E+00	2,19E+10	1,31E+10	9,21E+09	4,97E+08
1,66E+00	2,00E+00	1,03E+10	6,84E+09	5,11E+09	2,34E+08
2,00E+00	2,50E+00	5,93E+09	3,96E+09	3,08E+09	5,63E+07
2,50E+00	3,00E+00	3,17E+09	2,38E+09	1,96E+09	4,17E+06
3,00E+00	4,00E+00	9,45E+08	4,54E+08	3,34E+08	3,01E+05
4,00E+00	5,00E+00	5,92E+07	1,37E+07	5,16E+06	4,22E+03
5,00E+00	6,00E+00	9,95E+06	1,04E+05	7,84E+01	6,43E+00
6,00E+00	7,00E+00	2,58E+06	1,57E+04	8,84E+00	0,00E+00
7,00E+00	8,00E+00	4,85E+05	5,51E+02	3,11E-01	0,00E+00
8,00E+00	9,00E+00	1,21E+05	2,07E+00	1,17E-03	0,00E+00
9,00E+00	1,00E+01	3,92E+04	9,96E-04	7,24E-18	0,00E+00
1,00E+01	1,20E+01	1,56E+04	3,59E-04	2,61E-18	0,00E+00
1,20E+01	1,70E+01	1,21E+03	8,91E-06	6,48E-20	0,00E+00
1,70E+01	3,00E+01	0,00E+00	0,00E+00	0,00E+00	0,00E+00

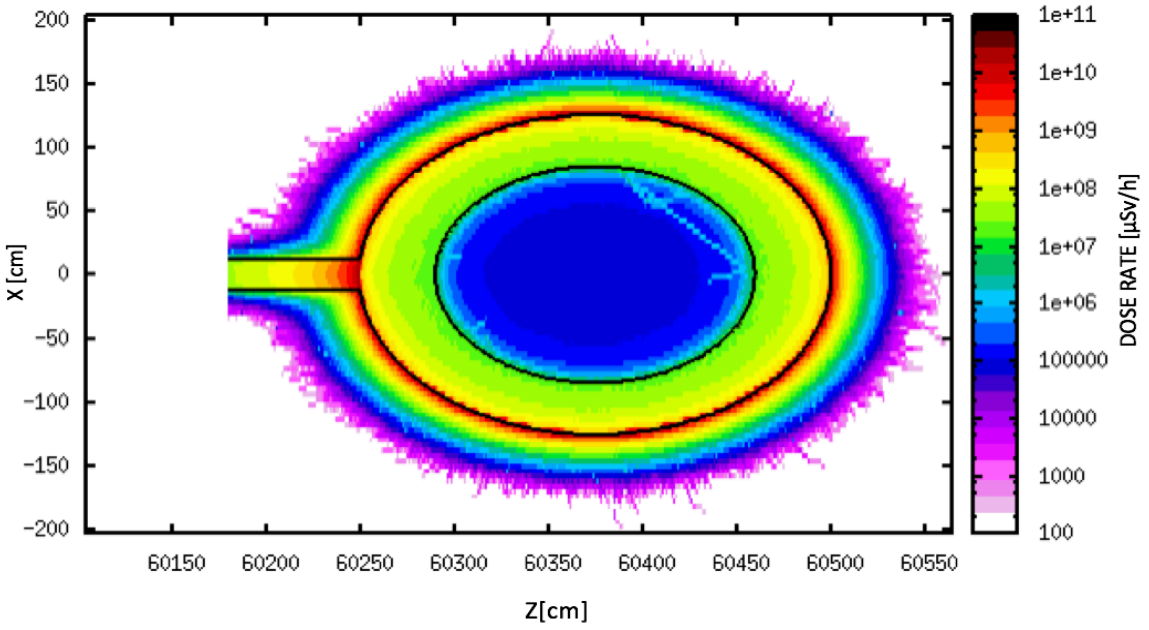
A2T section
Input file





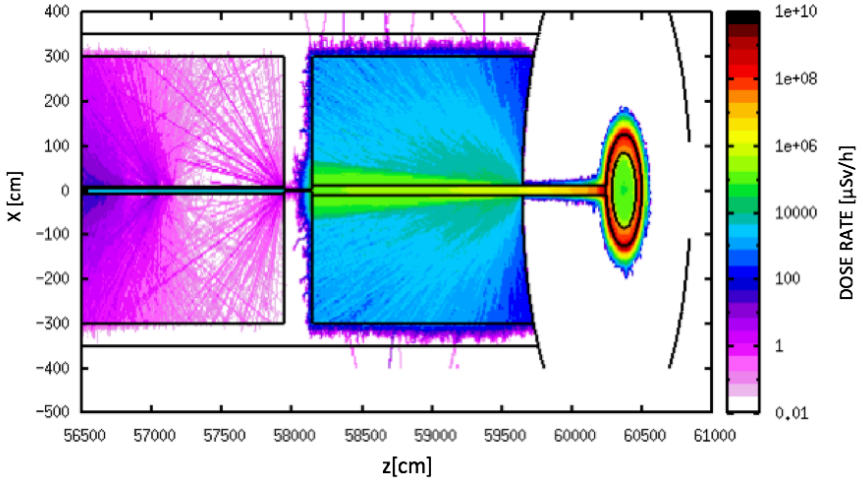
A2T section
Input file

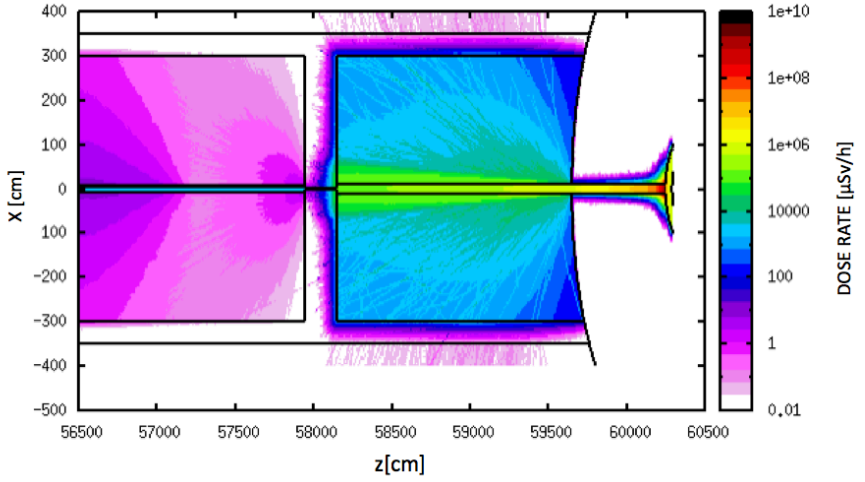
An isotropic source on the surface was designed with special geometry for the target wheel and Beam dump.. The gamma energy was always randomised from the field spectrum with the right probabilities.



A2T section
Input file

To speed up the simulation time, only a part of target wheel in the neighborhood of the beam pipe was taken as an isotropic source of radiation. The final results are exactly the same (see Figure 2), and the simulation time, is several times shorter.

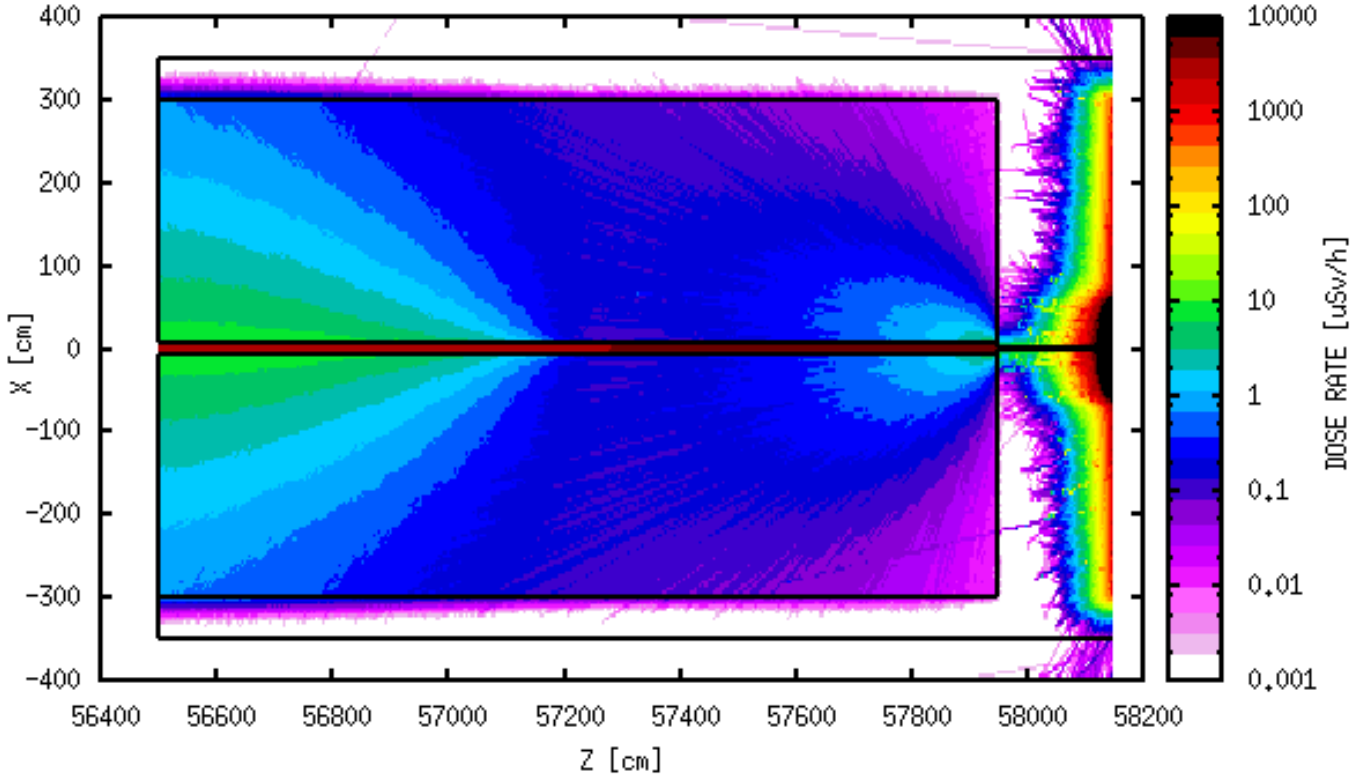




A) Implemented isotropic source on the whole target wheel surface.

B) Implemented isotropic source only on the target wheel surface in the beam pipe line-of-sight

A2T section
Dose rate



Residual dose rate after 5 years of exposure and no cooling times

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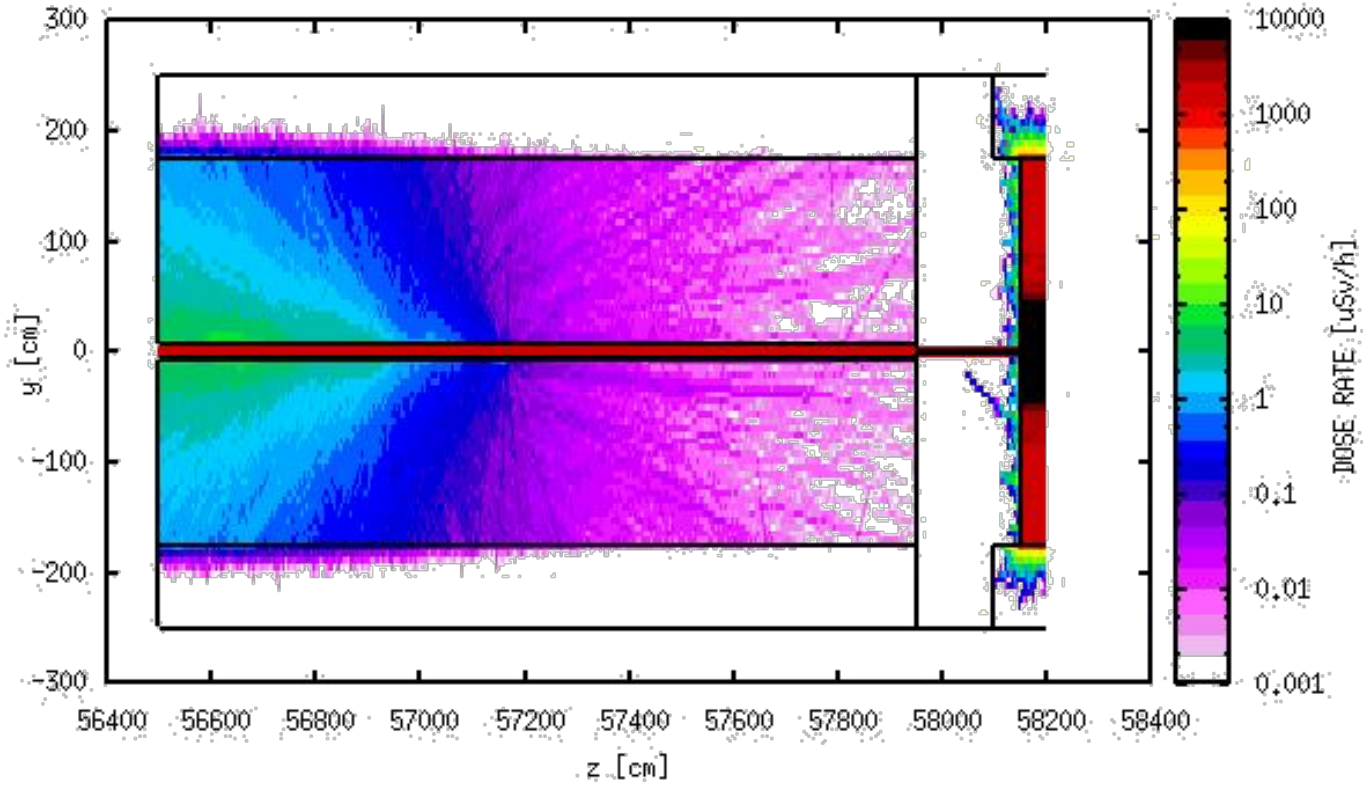
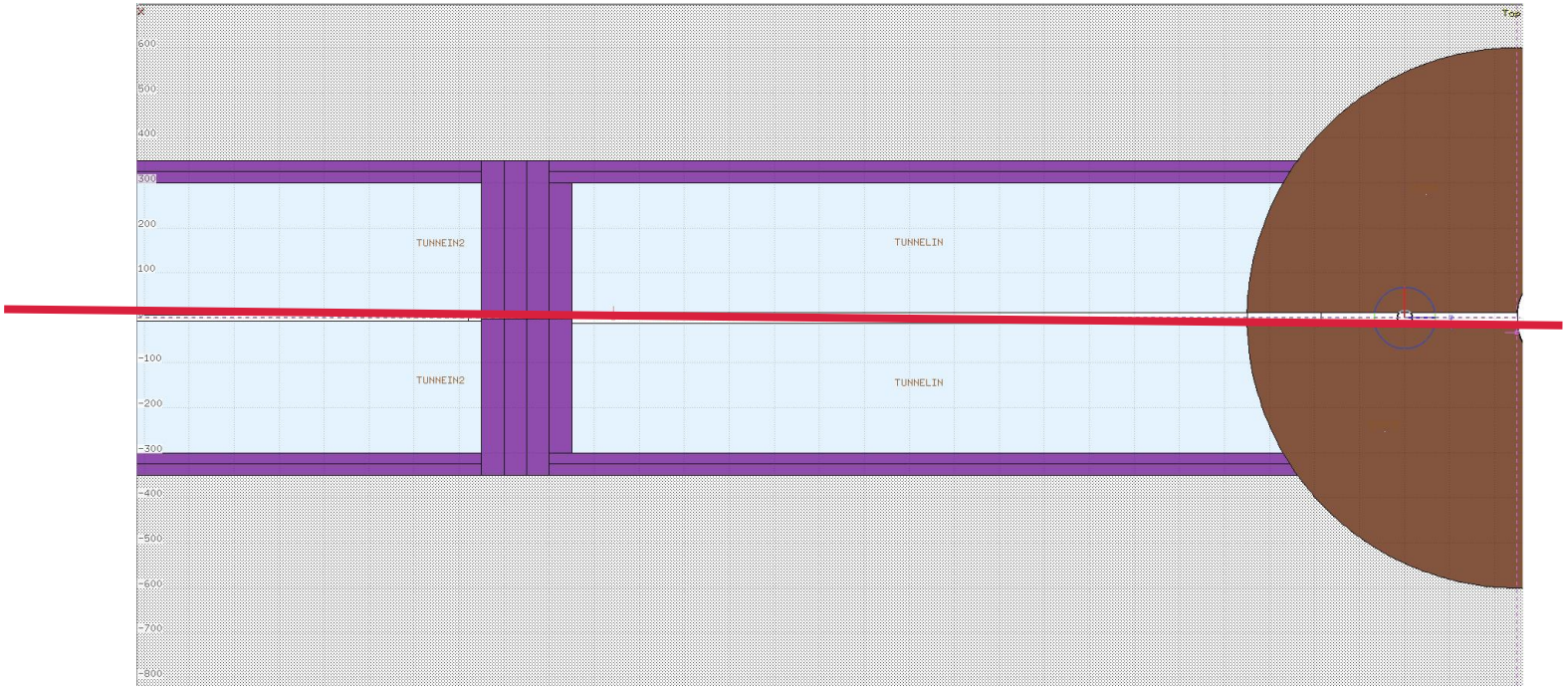
A2T section
Dose rate

NSW- Black Hole



Residual dose rate after 5 years of exposure and no cooling times

A2T section
Geometry



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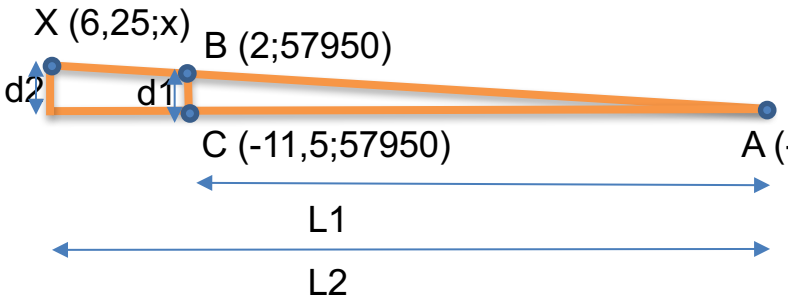
A2T section
Geometry



L1=60250-57950=231
d1=2+11,5=13,5
D2=6,25+11,5=17,75

L2/d2=L1/d1
L2=L1*d2/d1
L2=3025

x=60251-3025=**57225**

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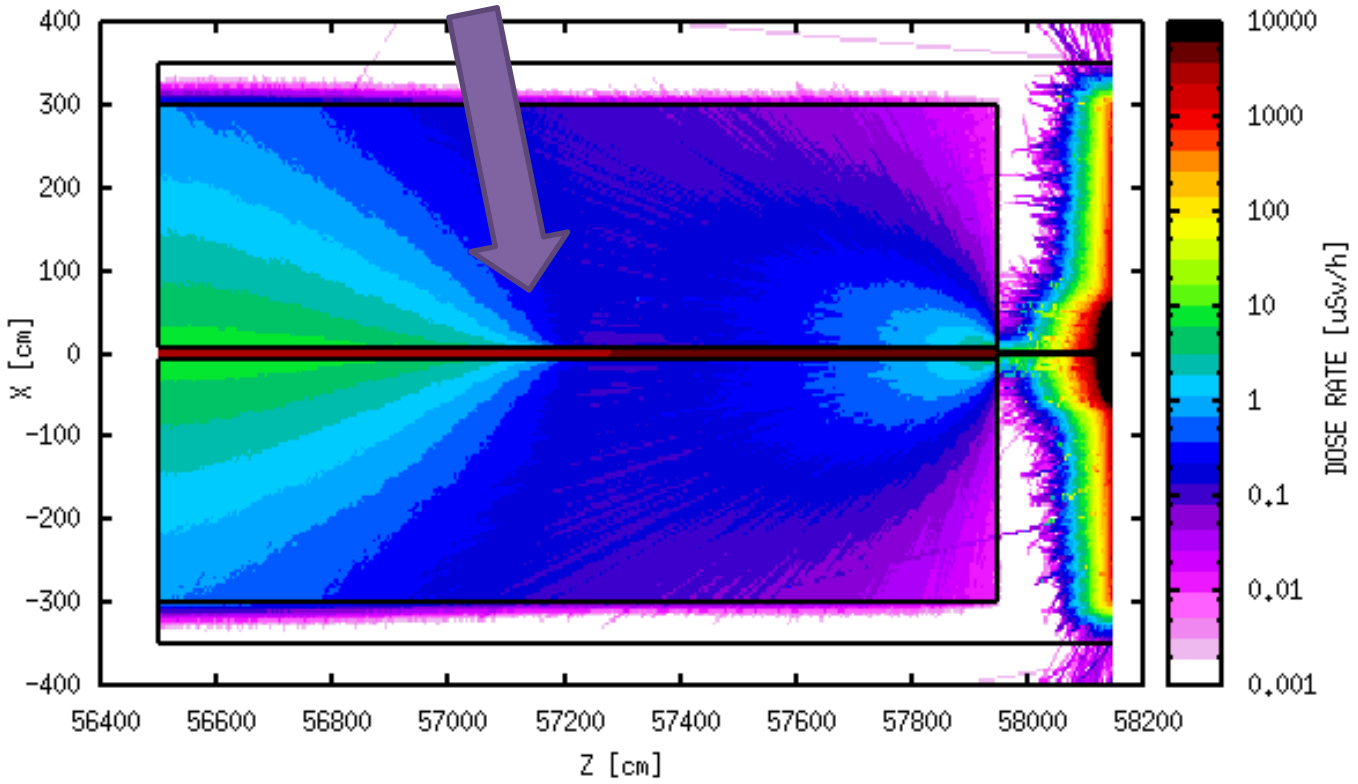
A2T section

Geometry

- x=60251-3025=**57225**



Residual dose rate after 5 years of exposure and no cooling times

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A2T section

Comparison of Dose rate for the different cooling time

The residual dose equivalent rate after 5 years of exposure and various cooling down times inside the tunnel on the NSW contact, transverse to the accelerator tunnel

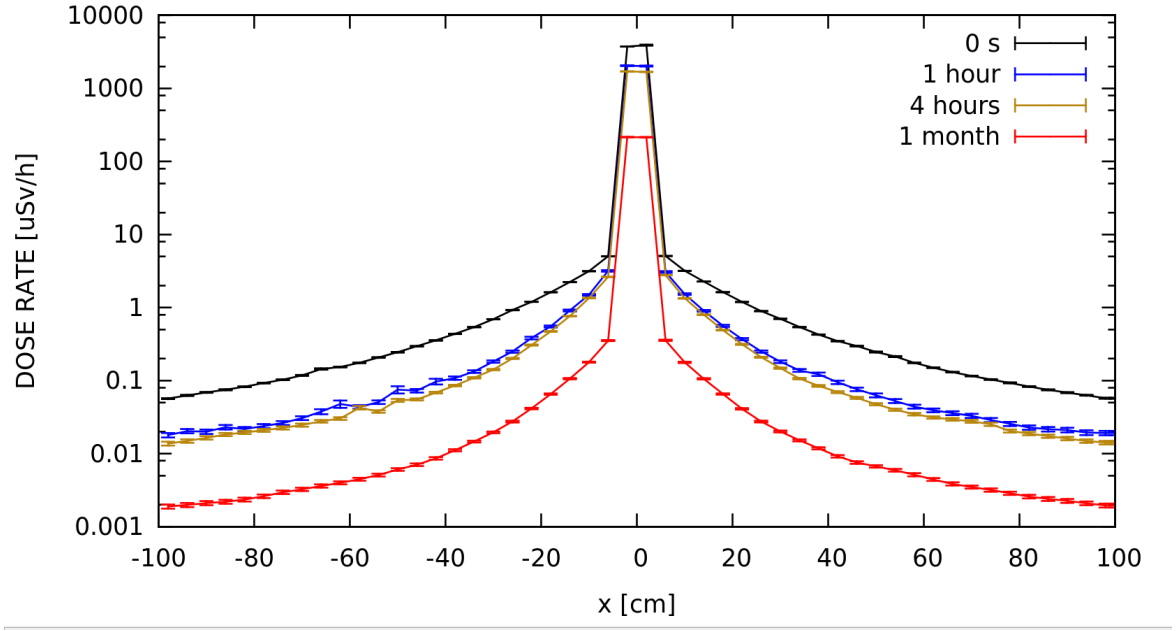

Figure 4 : Gamma radiation dose rate vs. distance from the beam pipe. Projection on X-axis. Cooling times: 0s, 1hour, 4 hours, 1 month (black). Z=57950cm

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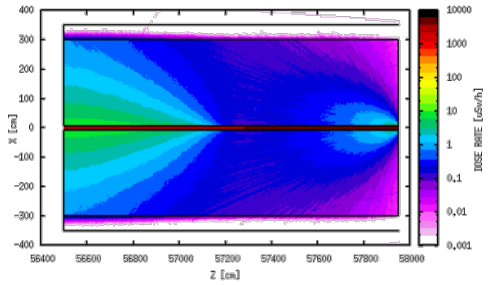
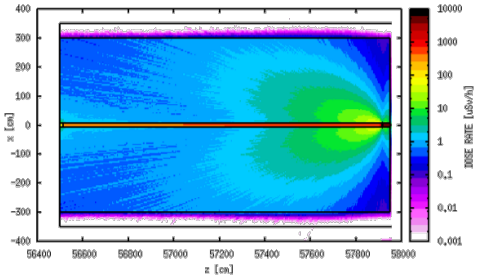
A2T section

Comparison of Dose rate for the different GB thickness

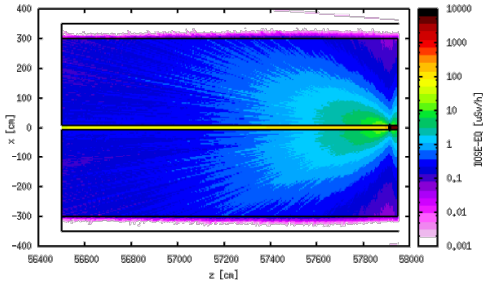
Without GB



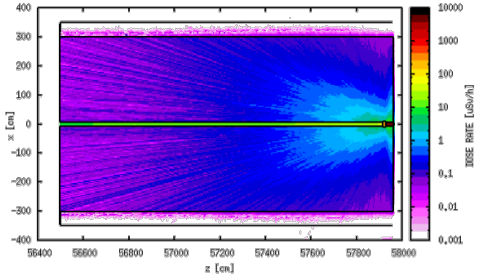
5cm GB



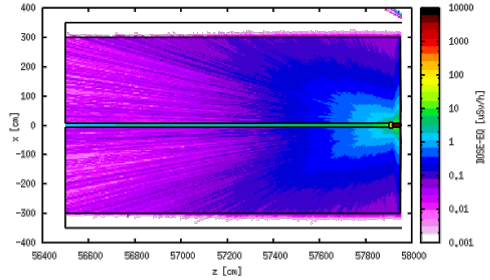
10cm GB



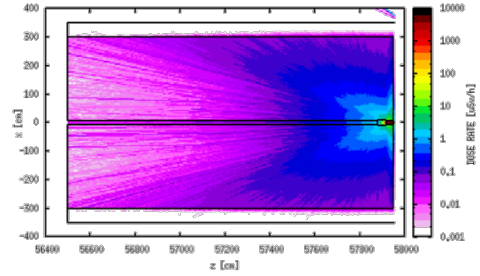
15cm GB



20cm GB



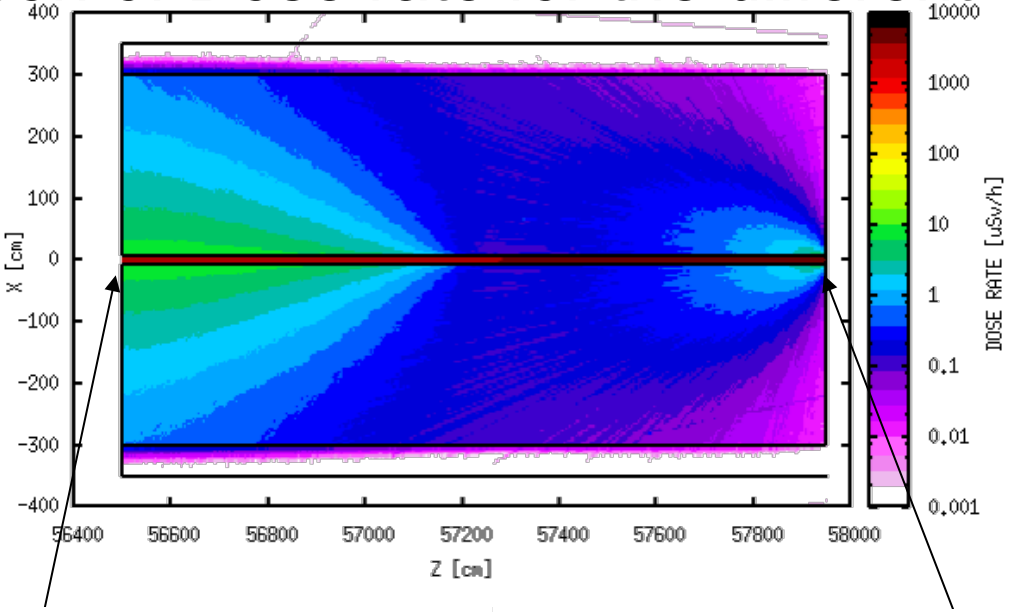
40cm GB



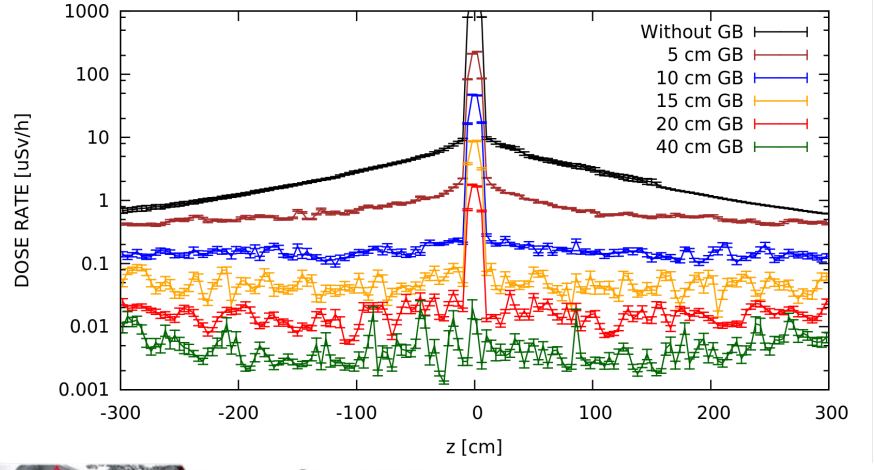
Residual dose equivalent rate after 5 years of exposure, no cooling time for different iron GB thicknesses.

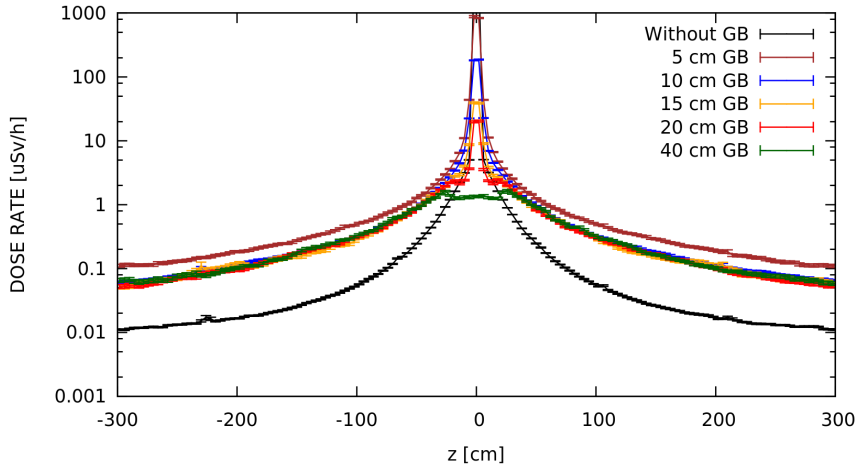
A2T section

Comparison of Dose rate for the different GB thickness



Z = on GB contact (on the NSW contact in situation without GB).

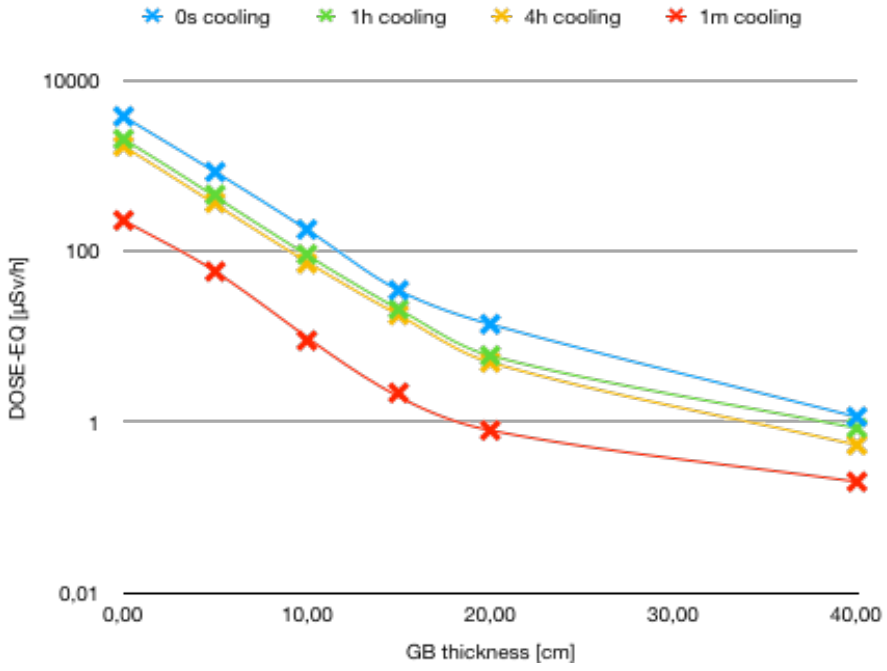




Residual dose equivalent rate vs. distance from the beam pipe. Projection on X-axis.. 5 years of exposure, cooling time 0s, GB thickness: 0cm, 5cm, 10cm, 15cm, 20cm, 40cm.

A2T section

Comparison of Dose rate for the different GB thickness



	Dose rate after 5 years of exposure at various cooling times inside the 'beam pipe' [uSv/h]			
GB thickness [cm]	0s Cooling	1h Cooling	4h Cooling	1m
0	3800	2060	1700	230
5	850	460	370	58
10	180	92	72	9
15	40	21	18	2,2
20	14	6	5	0,8
40	1,15	0,85	0,54	0,2

Residual dose equivalent rate after 5 years of exposure at various cooling times inside the 'beam pipe' as a function of GB thickness.

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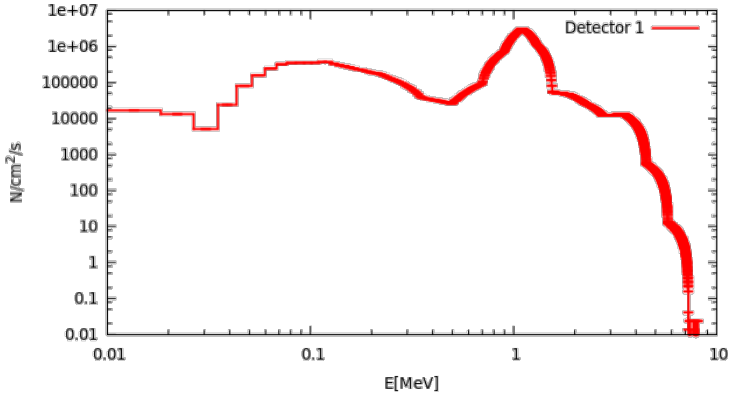
Beam dump section
The gamma spectrum

- The gamma spectrum is calculated for a 2 GeV, 12.5 kW beam operation on beam dump for a continuous 99360000 seconds.
- This corresponds to 50 years of 552 hours/year operation time.
- The decay effect during beam-off is not taken into account, which makes the data conservative. The units in column 2 is photons/cm3/second.
- For gamma blocker in the line of beam dump: 100 μSv/h on contact for 50 years of beam dump irradiation (2 GeV, 12.5 KW, ~550 hours of annual operation [3]) and no cool-down.

	0s cooling time
E (MeV)	photons/cm3/s
1,70E+01	0,00E+00
1,30E+01	0,00E+00
1,10E+01	3,15E-08
9,00E+00	1,59E-05
7,25E+00	3,56E-03
5,75E+00	1,68E+01
4,50E+00	7,37E+02
3,50E+00	1,72E+04
2,75E+00	1,59E+04
2,25E+00	3,43E+04
1,85E+00	6,17E+04
1,55E+00	7,05E+04
1,30E+00	1,47E+06
1,10E+00	4,11E+06
9,00E-01	9,65E+05
7,00E-01	1,16E+05
5,00E-01	2,73E+04
3,50E-01	4,02E+04
2,50E-01	1,36E+05
1,50E-01	2,63E+05
7,50E-02	2,63E+05
3,50E-02	9,82E+02
1,50E-02	2,85E+04
5,00E-03	7,33E-01



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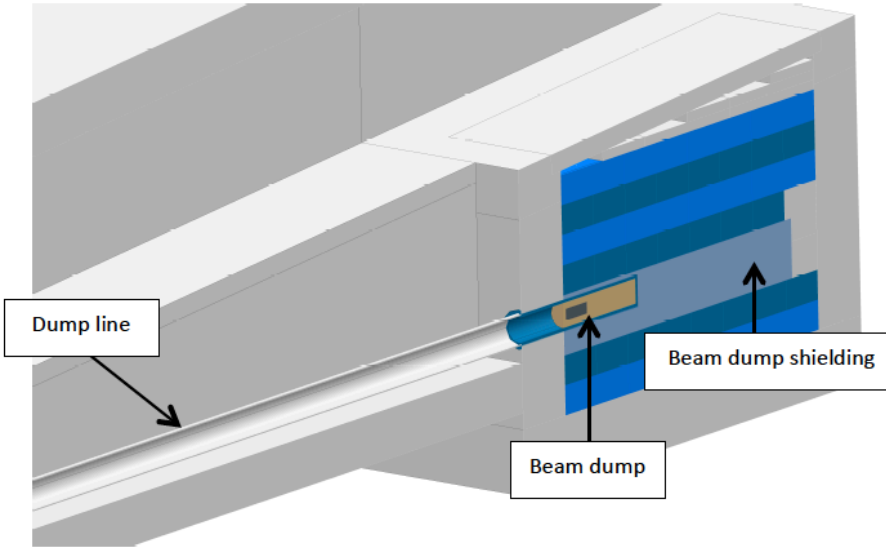
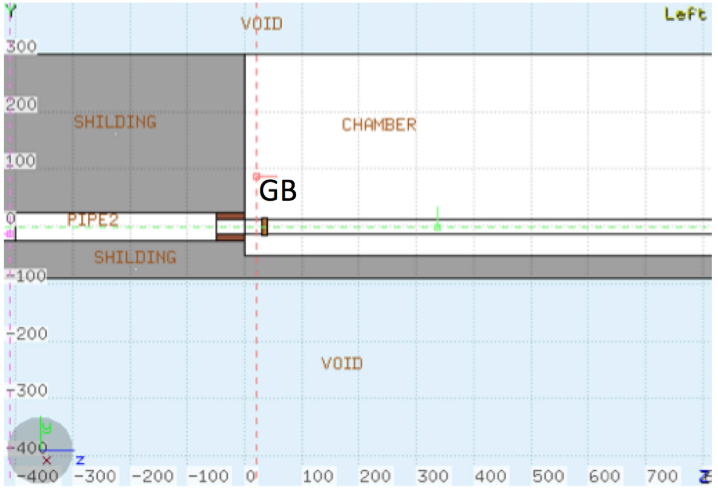
Beam dump section
Geometry





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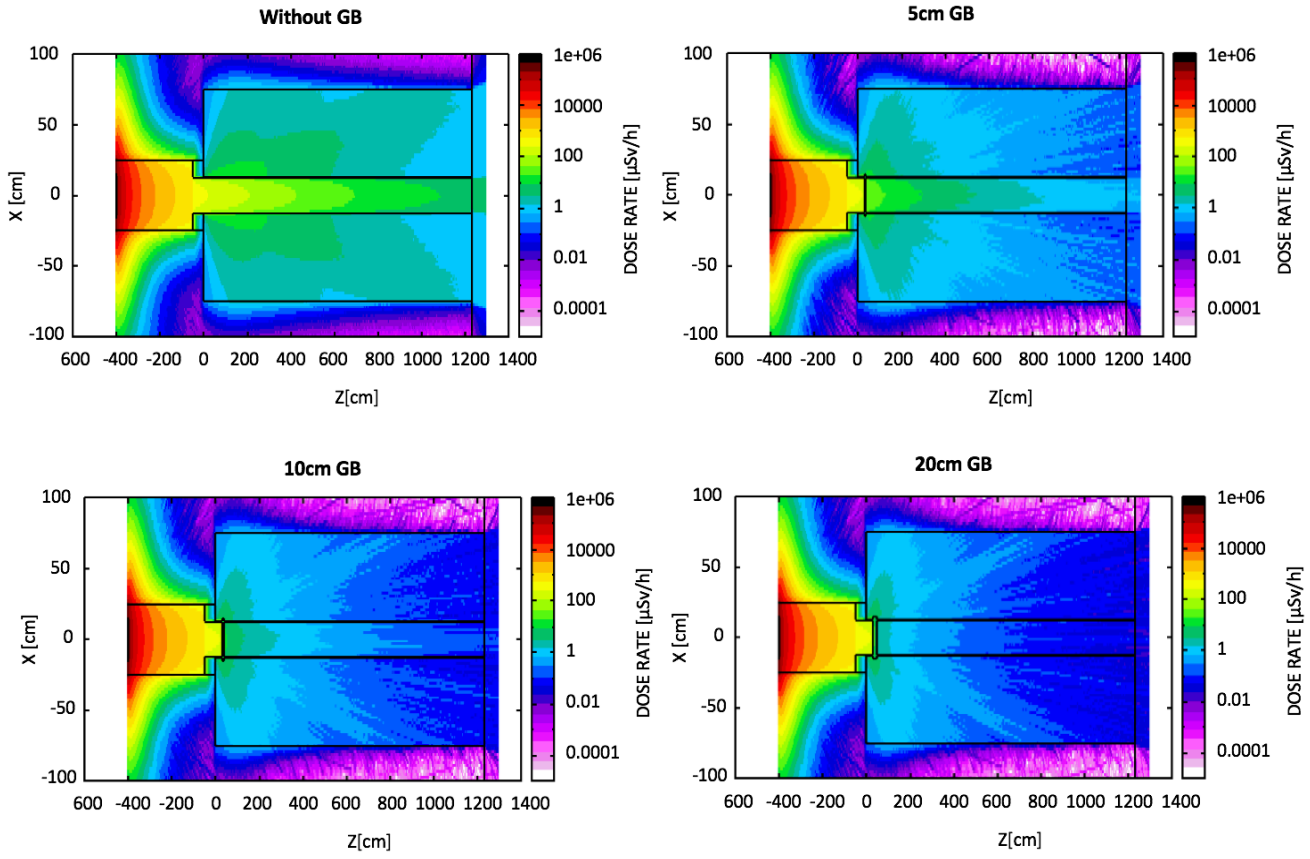
Beam dump section

Comparison of Dose rate for the different GB thickness



Dose rate after 50 years of exposure, no cooling time, without GB for different steel GB thicknesses.

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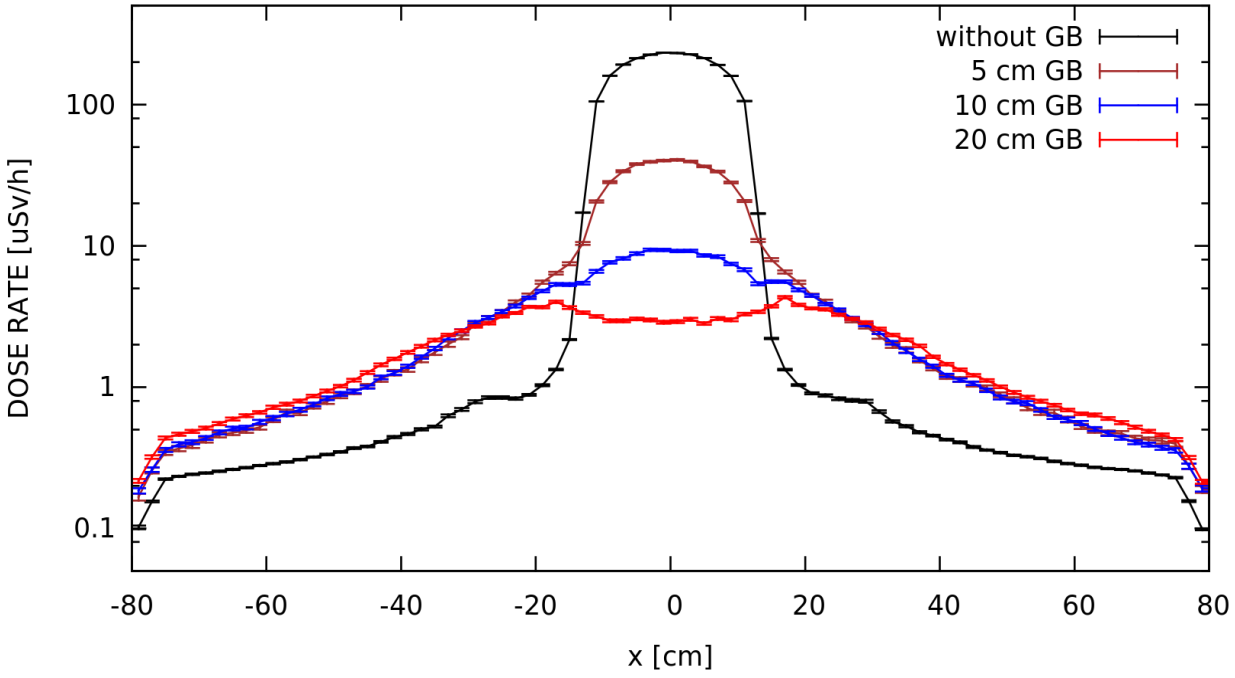
Beam dump section

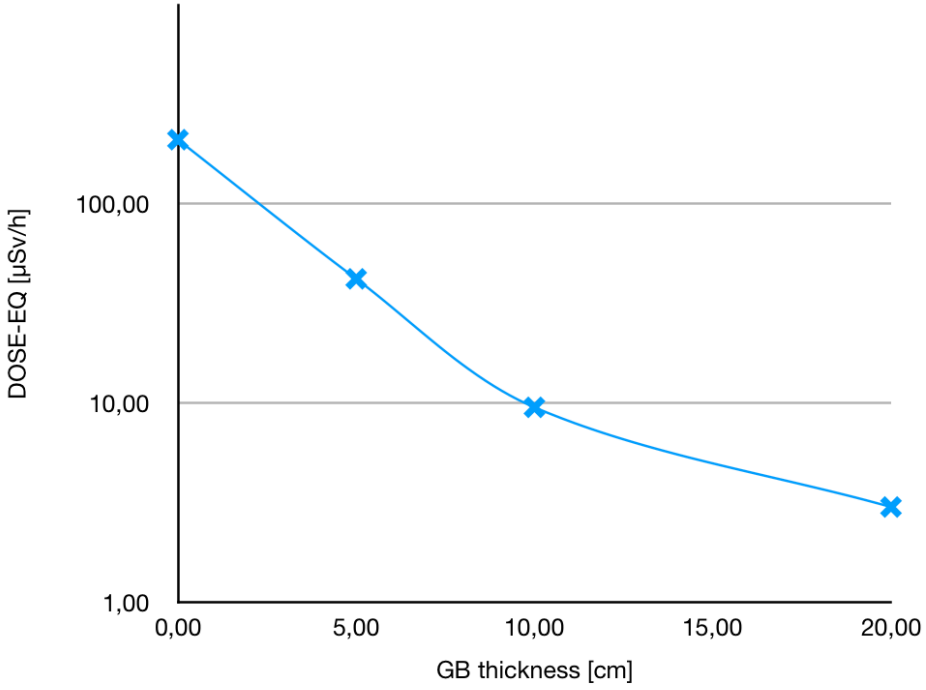
Comparison of Dose rate for the different GB thickness



Dose rate vs. distance from the beam pipe. Projection on X-axis. Z=on GB contact (on the NSW contact in situation without GB). 50 years of exposure, no cooling time, GB thickness: 0cm, 5cm, 10cm, 20cm

Beam dump section

Comparison of Dose rate for the different GB thickness



GB thickness	Dose rate after 5 years of exposure and 0 s cooling times inside the 'beam pipe' [µSv/h]
0,00	210
5,00	42
10,00	9,5
20,00	3

Dose Rate after 5 years of exposure at various cooling times inside the 'beam pipe' as a function of GB thickness.

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Summary

Based on the presented simulations and calculations,

- The Gamma blocker thickness in the A2T section must not be less than 10 cm.
- Minimum GB thickness in Beam Dump section is 5 cm.

Thank you