FLUKA Simulations of Radiation Field in Second Accelerator Tunnel

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Content

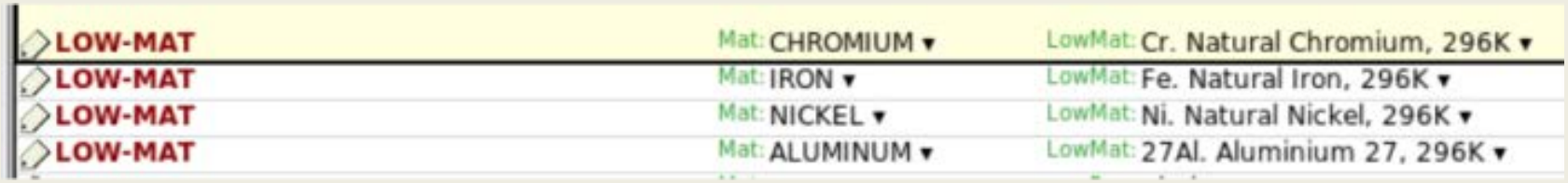
The purpose of this study is to calculate the produced radiation dose rates and define an appropriate radiation shielding in order to ensure that no radiation exits the accelerator area, i.e. dose level is below 3 **µSv/h** (controlled area limit)

- Using the FLUKA code to model the radiation field is necessary
  - ✓ Define the geometry
  - ✓ Define FLUKA cards
- Using the FLUKA code were obtained the following results
  - ✓ The equivalent dose distribution in the tunnel
  - ✓ Dose rate distribution for different shielding configuration

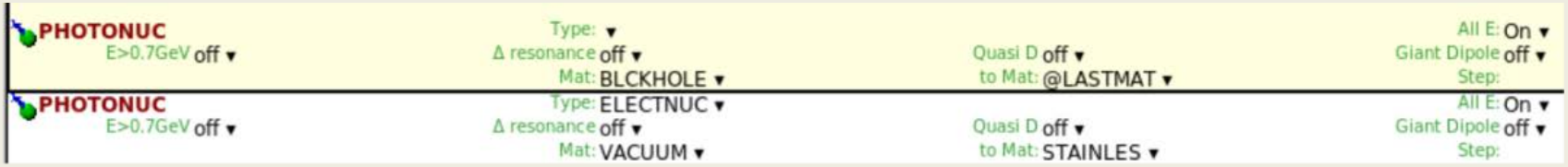
Define FLUKA cards

Some FLUKA cards are used for simulations:

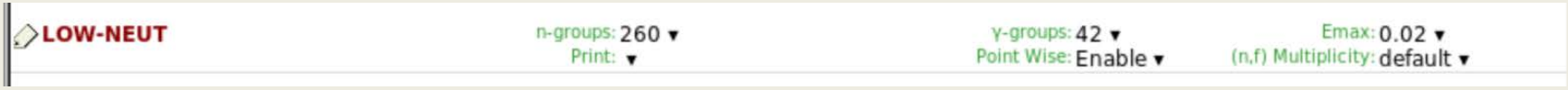
- LOW-MAT: Correspondence between FLUKA materials and low energy neutron cross sections:



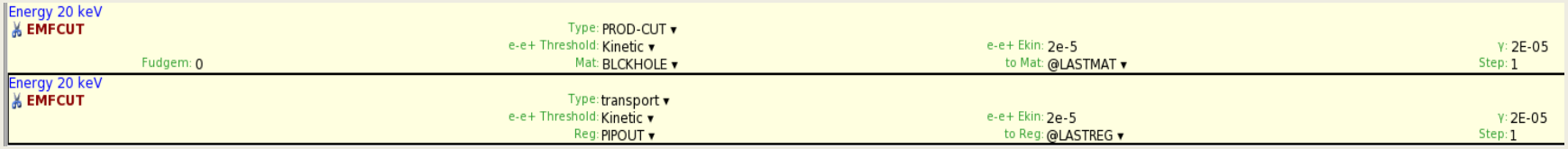
- PHOTONUC: Activate photonuclear interaction



- LOW-NEUT: Activates low-energy neutron transport



- EMFCUT: Energy threshold production: 20 keV for photon and 20 keV for electron and positron



Define the Geometry

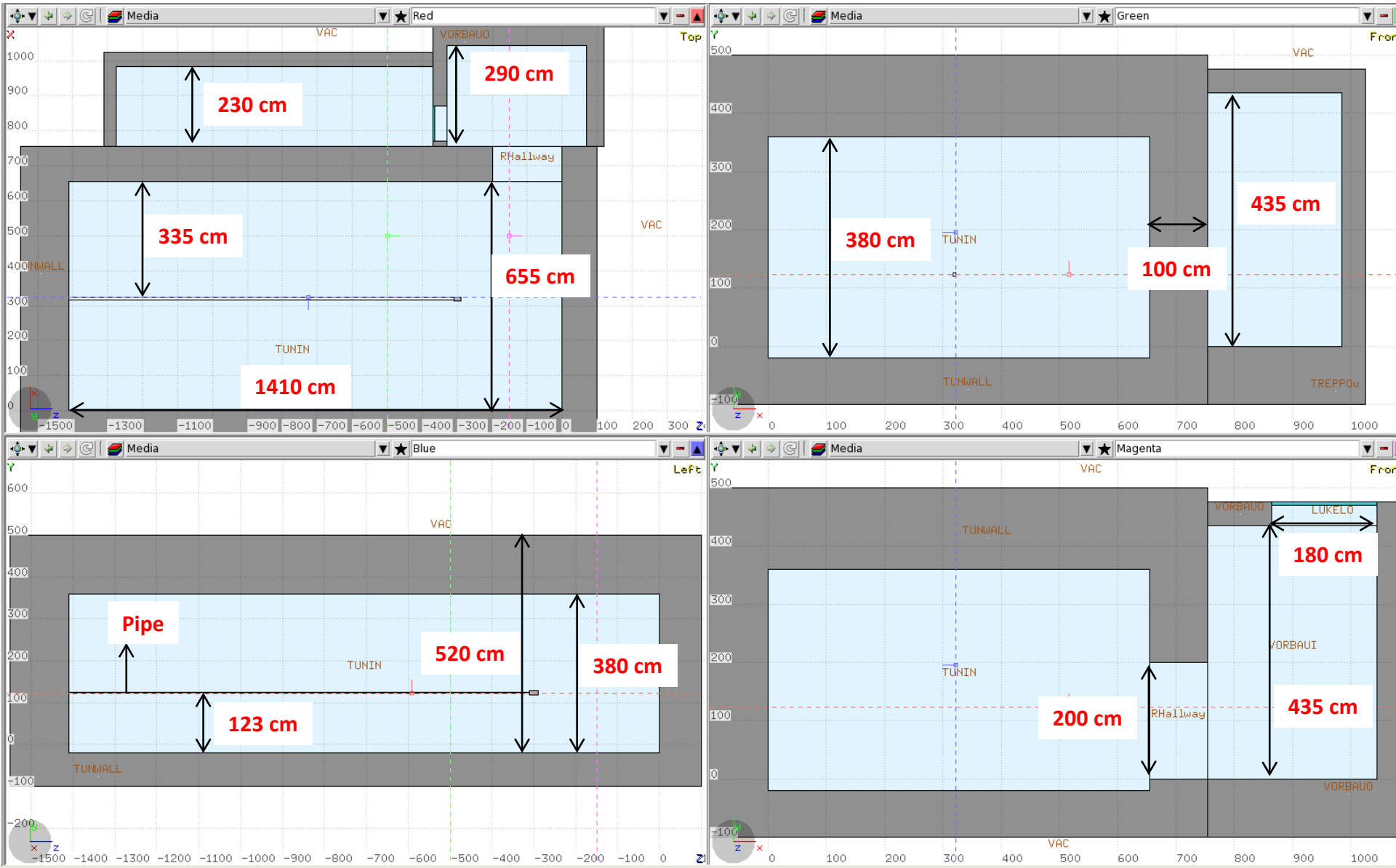


Diagram of the tunnel hall in the XZ and YX planes around the pipe.

Define the Geometry

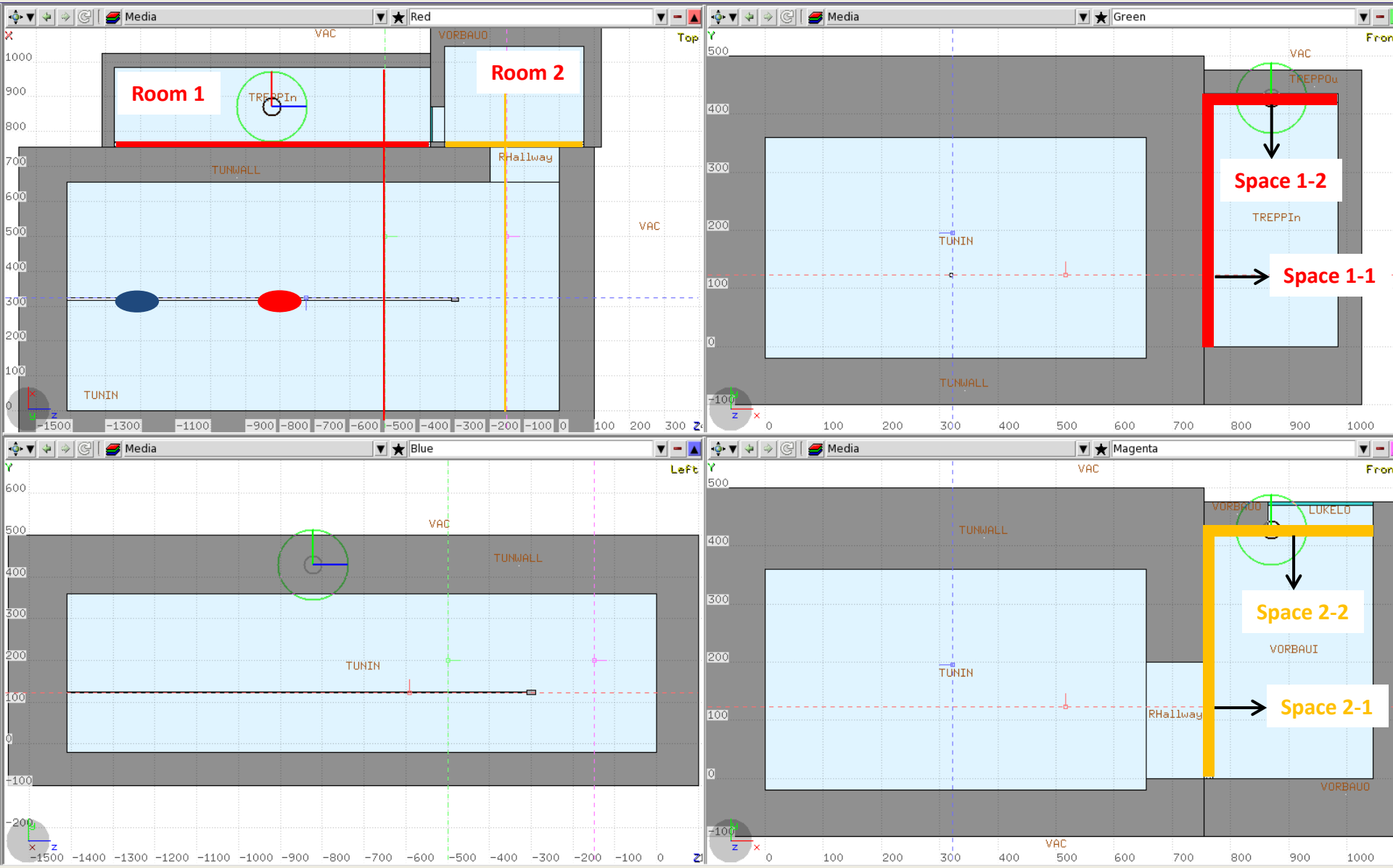
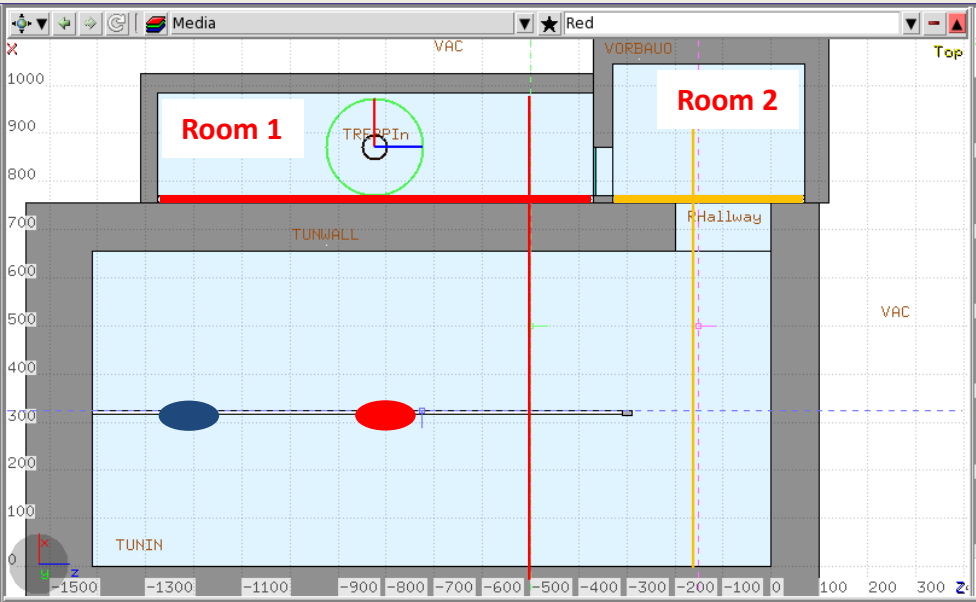
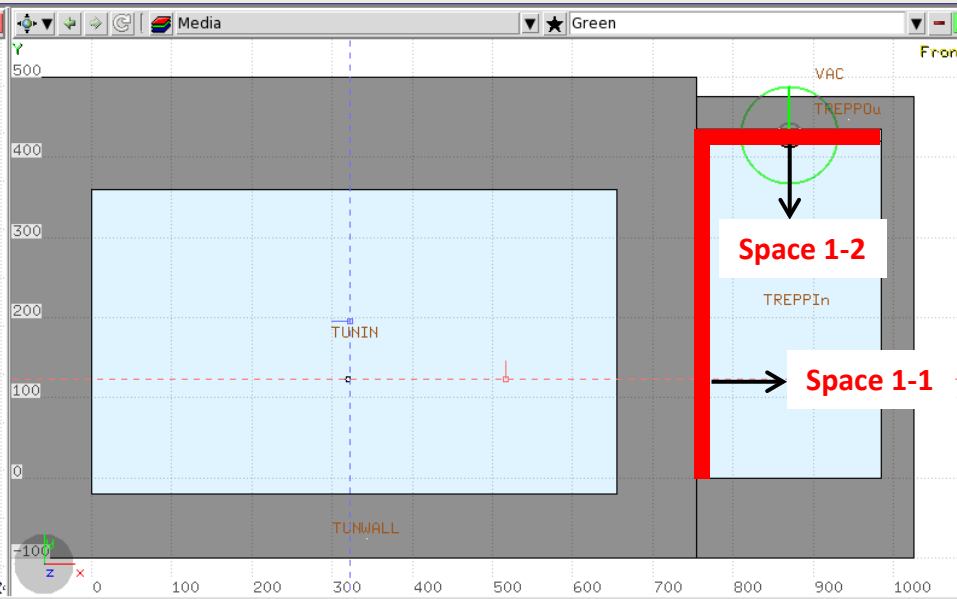
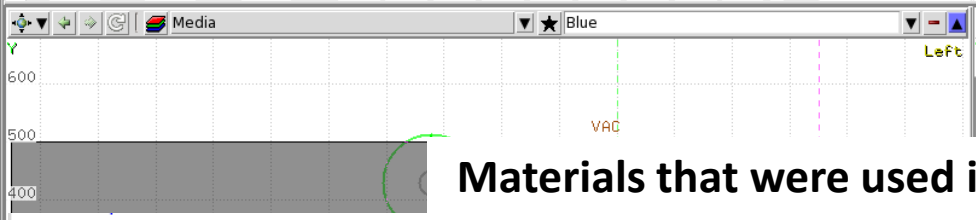


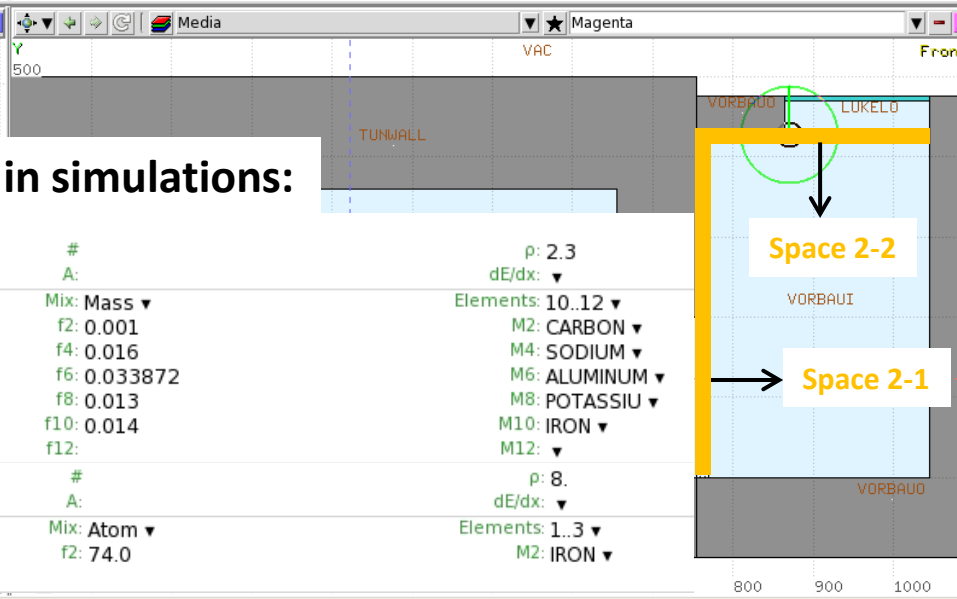
Diagram of the tunnel hall in the XZ and YX planes around the pipe.

Define the Geometry





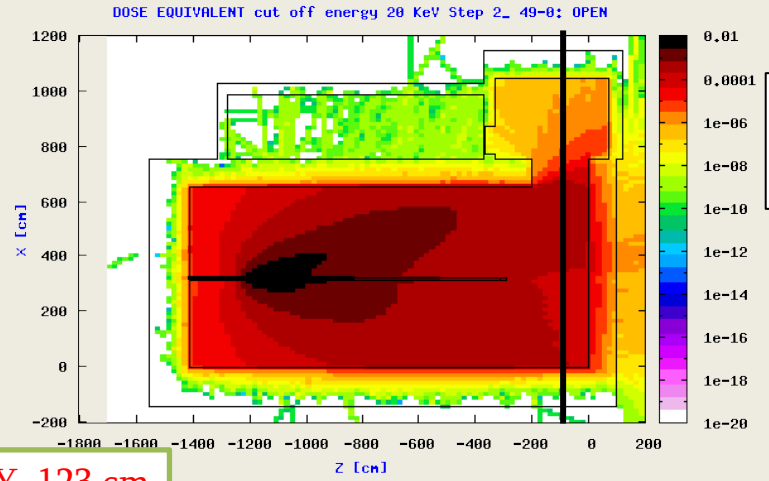




Materials that were used in simulations:

MATERIAL		Name:	PORTLAND	#		ρ:	2.3
	Z:	Am:		A:		dE/dx:	
COMPOUND		Name:	PORTLAND	Mix:	Mass	Elements:	10..12
	f1: 0.01	M1:	HYDROGEN	f2:	0.001	M2:	CARBON
	f3: 0.529107	M3:	OXYGEN	f4:	0.016	M4:	SODIUM
	f5: 0.002	M5:	MAGNESIU	f6:	0.033872	M6:	ALUMINUM
	f7: 0.337021	M7:	SILICON	f8:	0.013	M8:	POTASSIU
	f9: 0.044	M9:	CALCIUM	f10:	0.014	M10:	IRON
	f11:	M11:		f12:		M12:	
MATERIAL		Name:	STAINLES	#		ρ:	8.
	Z:	Am:		A:		dE/dx:	
COMPOUND		Name:	STAINLES	Mix:	Atom	Elements:	1..3
	f1: 18.0	M1:	CHROMIUM	f2:	74.0	M2:	IRON
	f3: 8.0	M3:	NICKEL				

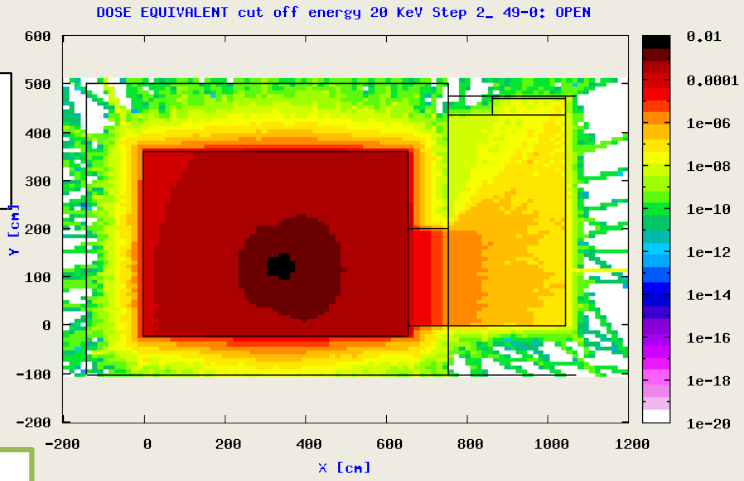
Equivalent Dose Distribution [pSv per electron]



Y=123 cm

Step 1

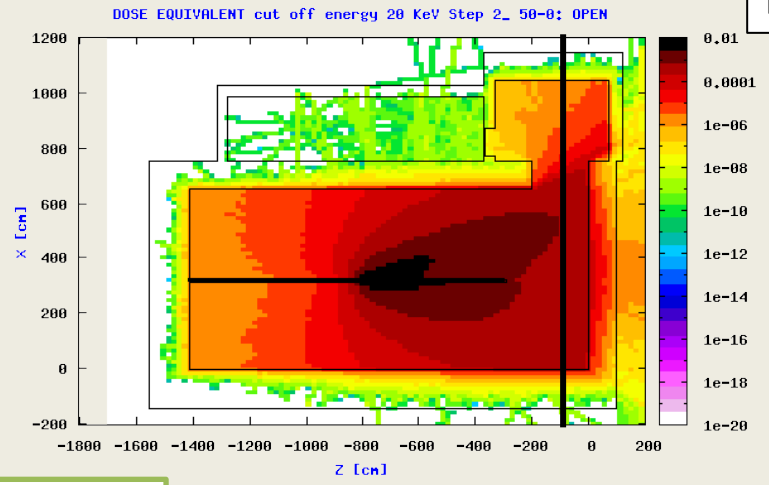
Dose EQ: 312600 pSv



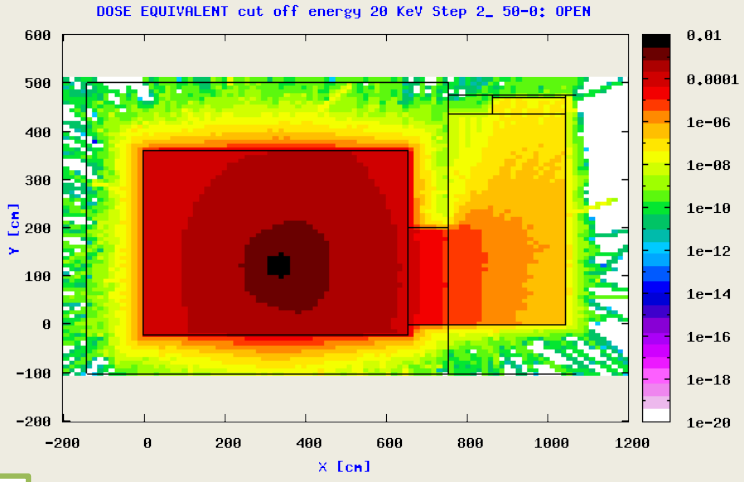
Z=-50cm

Step 2

Dose EQ: 403136 pSv

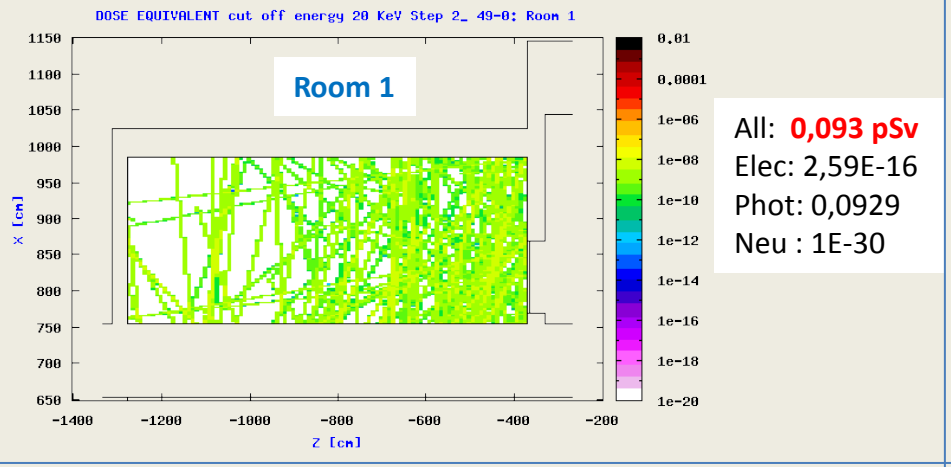


Y=123 cm

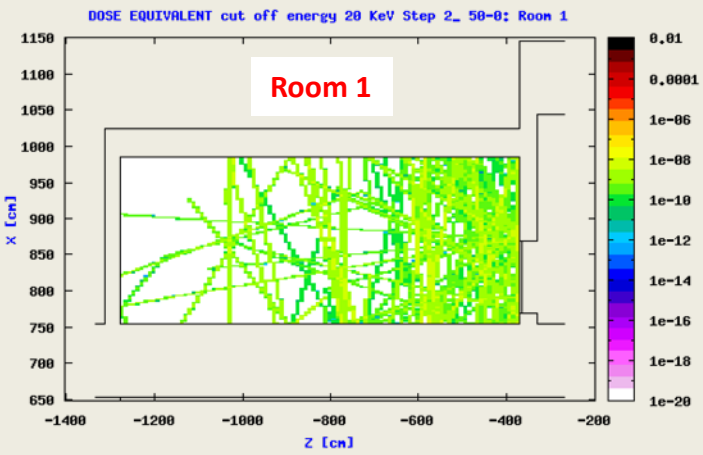


Z=-50cm

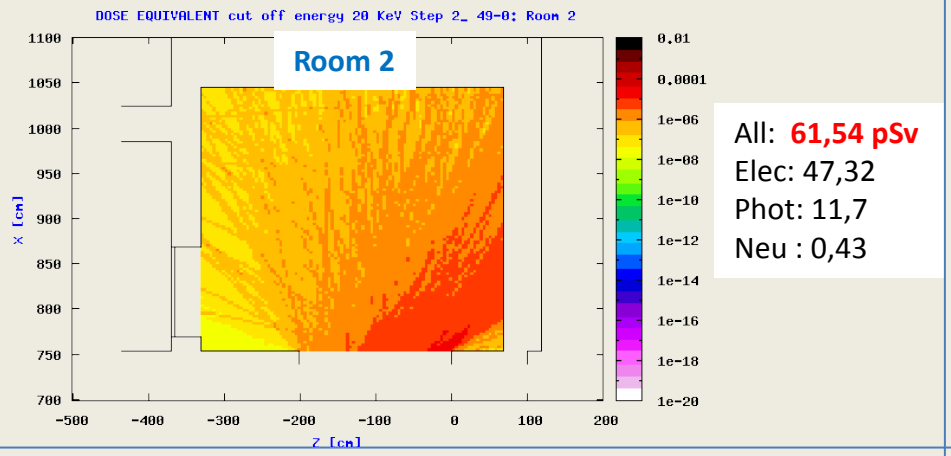
Equivalent dose distribution in XZ and YX plans in the tunnel hall (pSv per electron). a) interacts with the pipe in the position 1 b) interacts with the pipe in the position 2



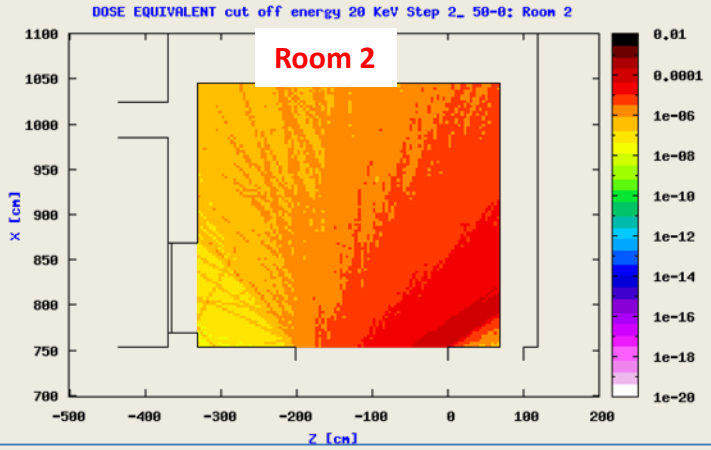
All: **0,093 pSv**
Elec: 2,59E-16
Phot: 0,0929
Neu : 1E-30



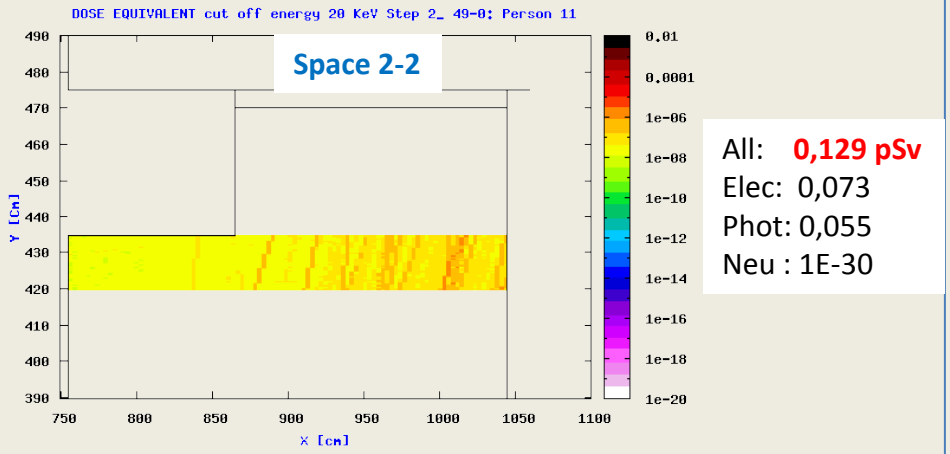
All: **0,05 pSv**
Elec: 1,31E-17
Phot: 0,05
Neu : 1E-30



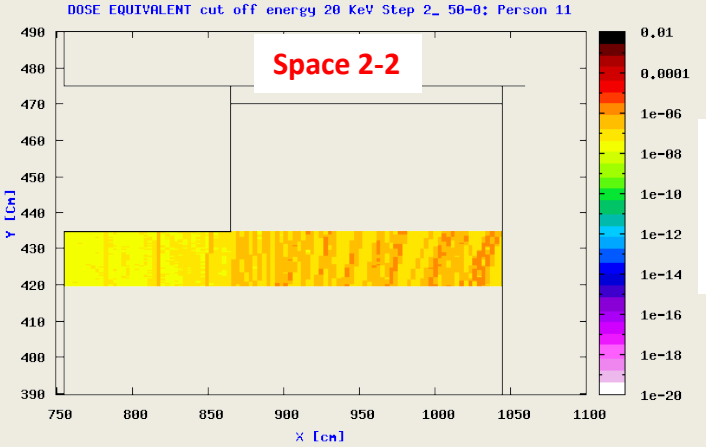
All: **61,54 pSv**
Elec: 47,32
Phot: 11,7
Neu : 0,43



All: **255,1 pSv**
Elec: 221,5
Phot: 23,92
Neu : 1,01



All: **0,129 pSv**
Elec: 0,073
Phot: 0,055
Neu : 1E-30



All: **0,35 pSv**
Elec: 0,24
Phot: 0,096
Neu : 0,01

Shielding Design

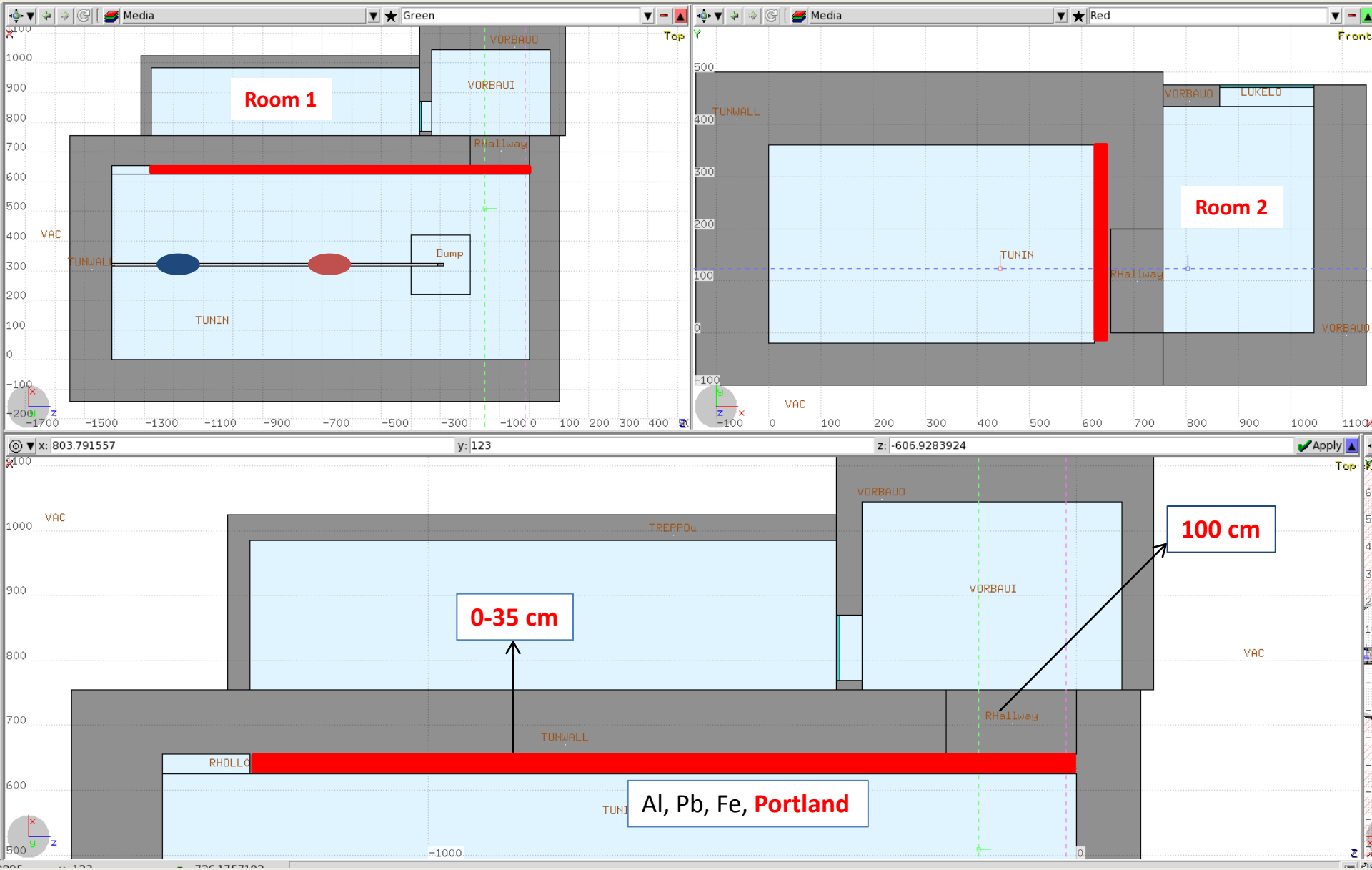
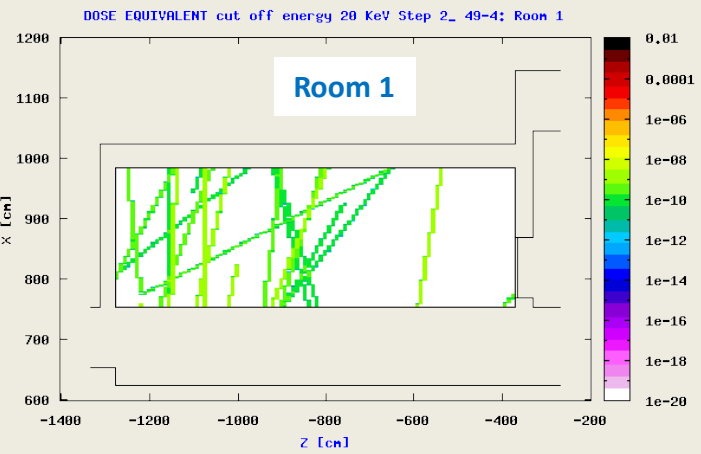


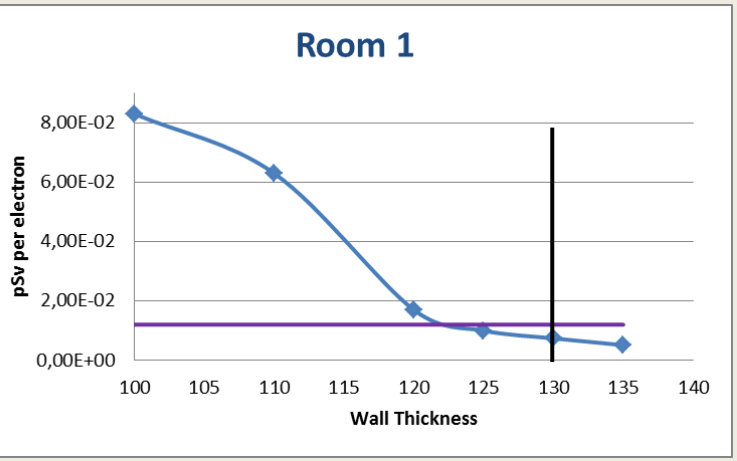
Diagram of the tunnel hall in the XZ and YX planes around the pipe.

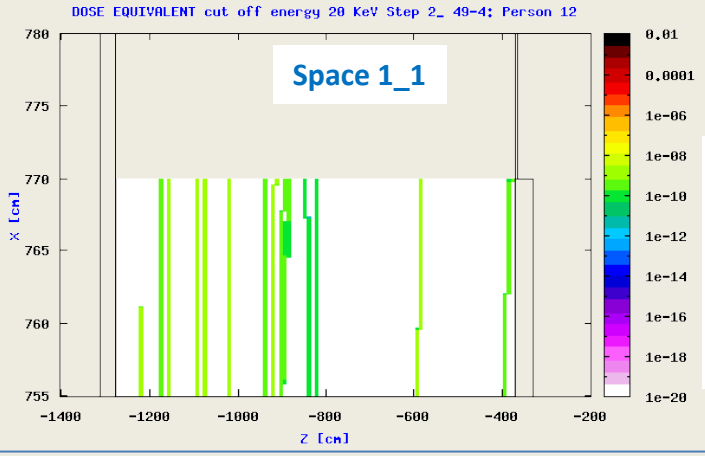


30 cm

0,012 pSv

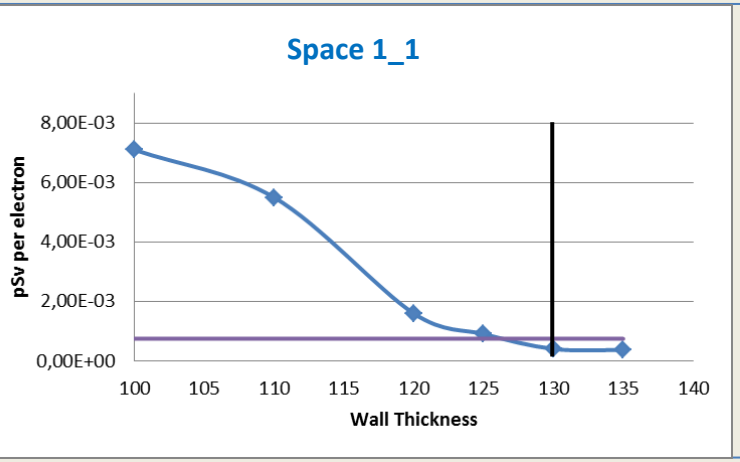
All: **0,0074 pSv**
Elec: 9,8E-13
Phot: 0,0064
Neu : 1E-30

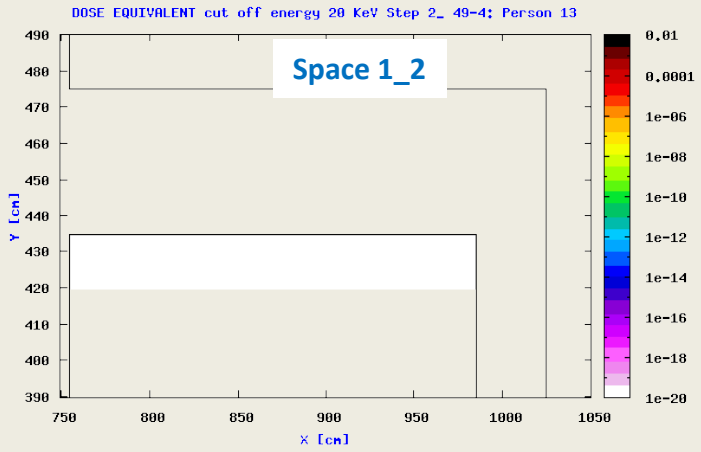




0,00075 pSv

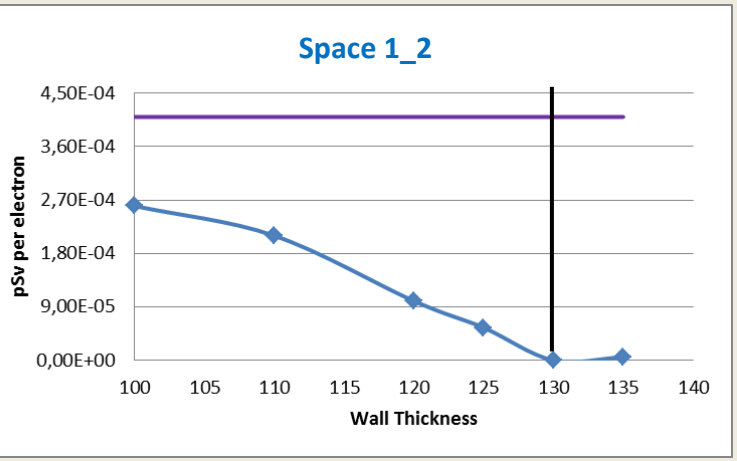
All: **0,00041 pSv**
Elec: 9,4E-13
Phot: 0,00046
Neu : 1E-30

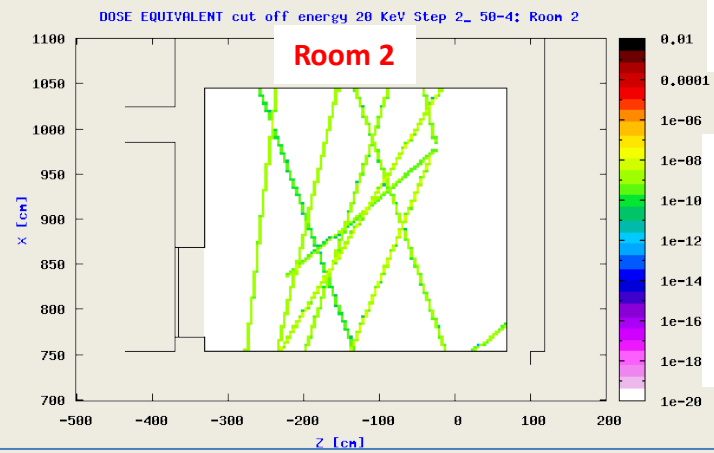




0,00041pSv

All: **1E-30**
Elec: 1E-30
Phot: 1E-30
Neu : 1E-30

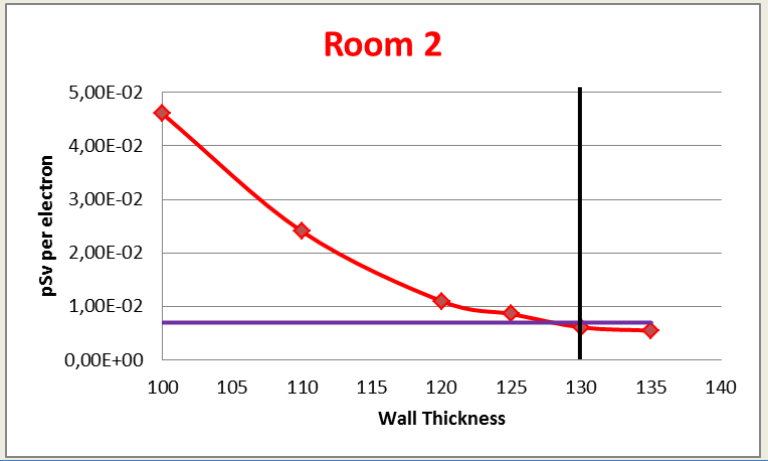


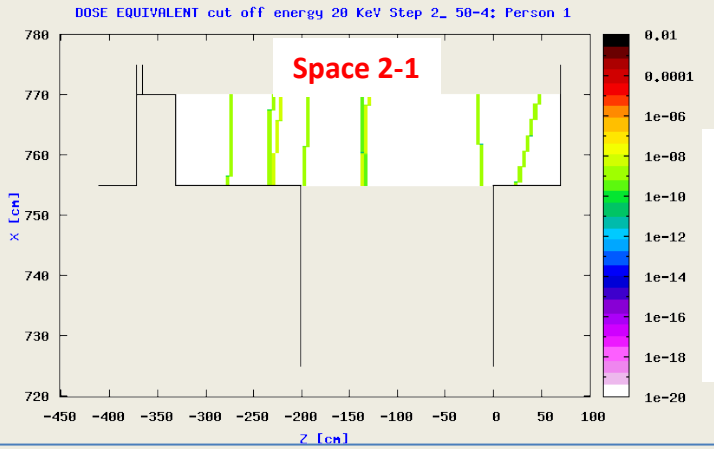


30 cm

0,007 pSv

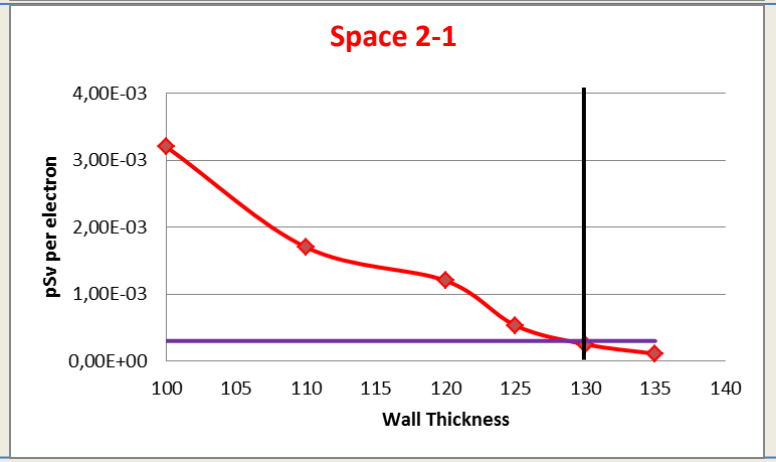
All: **0,0061 pSv**
Elec: 1E-30
Phot: 0,0061
Neu : 1E-30

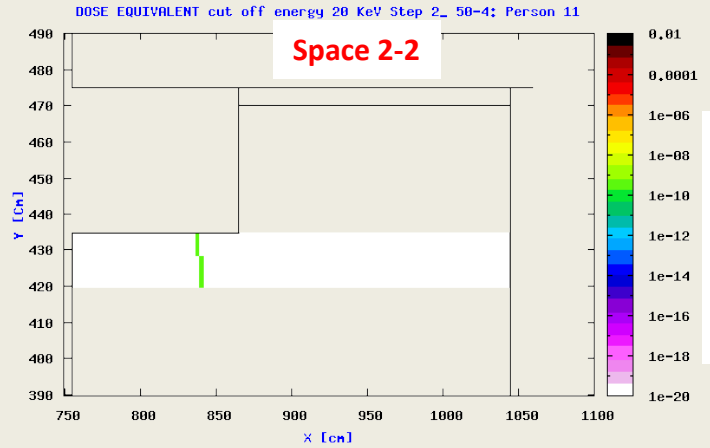




0,0003 pSv

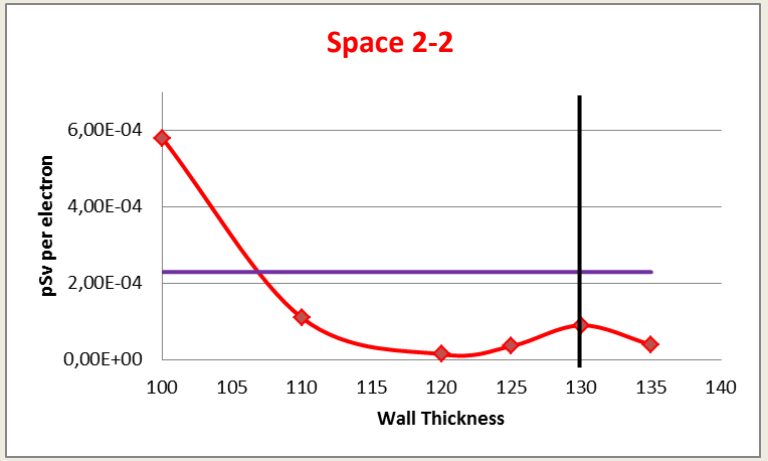
All: **0,00025 pSv**
Elec: 1E-30
Phot: 0,00025
Neu : 1E-30



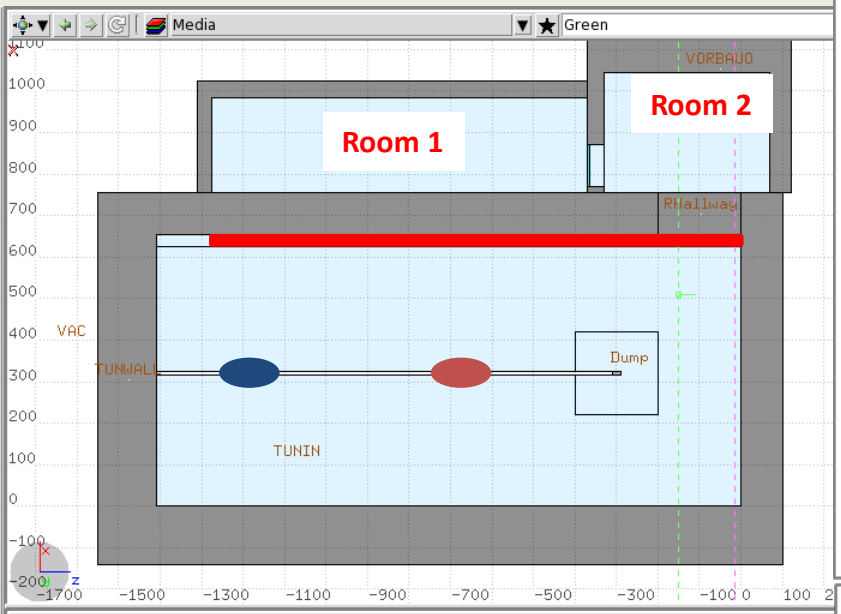


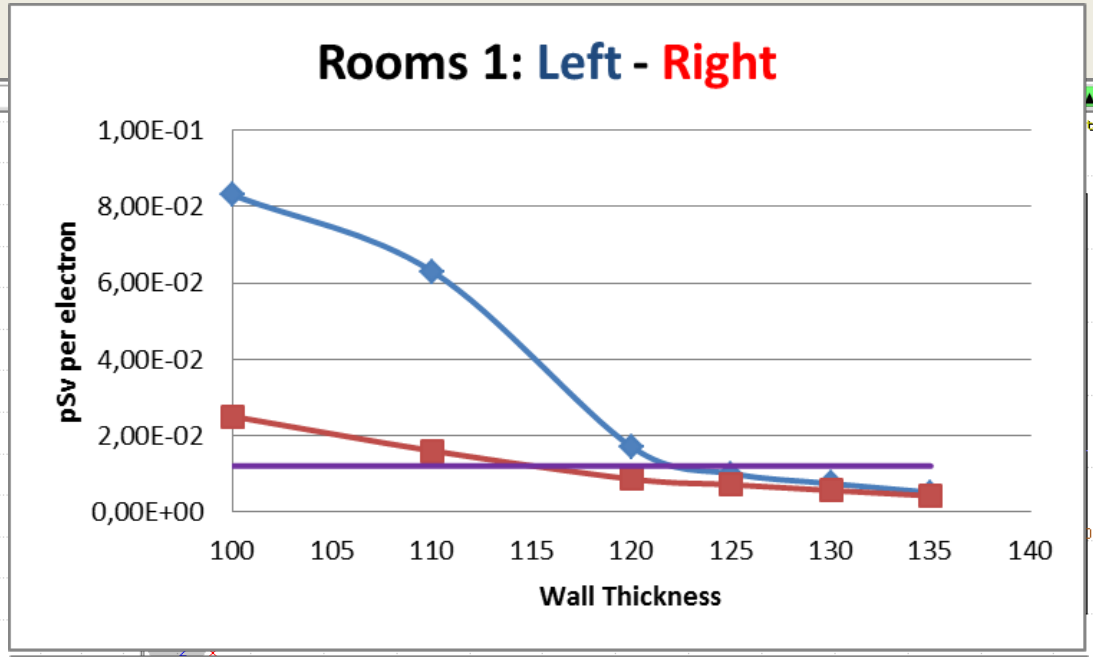
0,00023 pSv

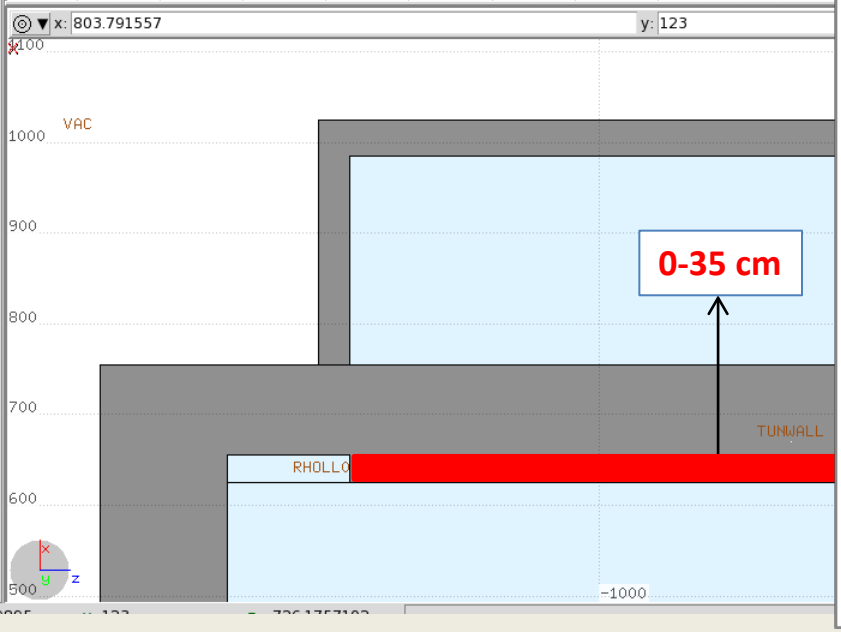
All: **9.61E-5 pSv**
Elec: 1E-30
Phot: 9.61E-5
Neu : 1E-30

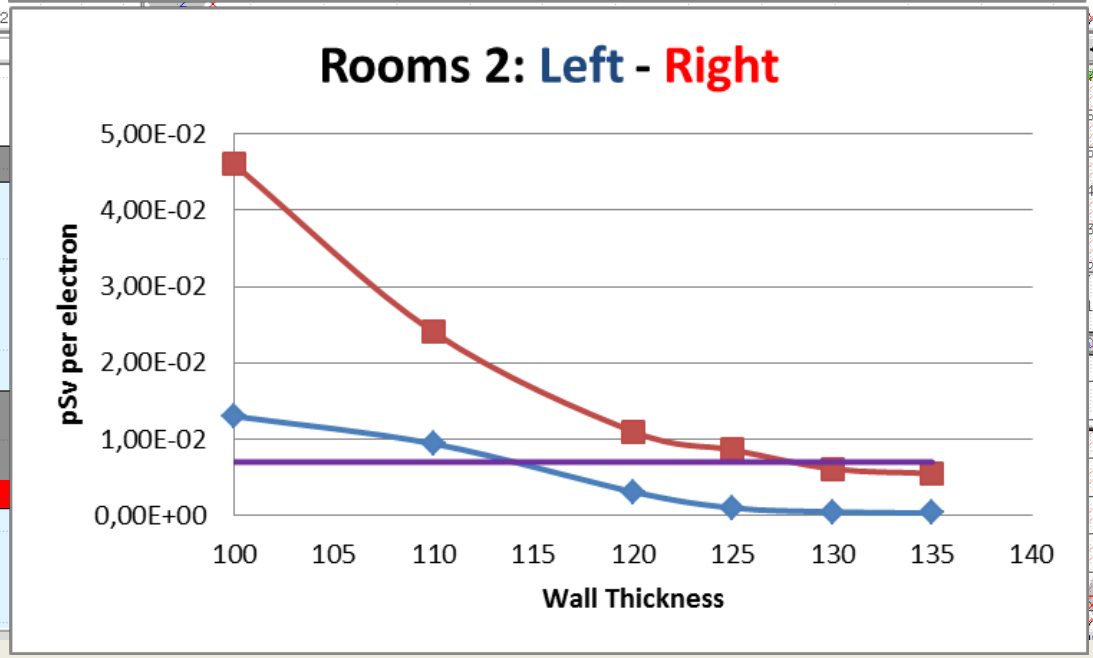


12


Media
Green
Room 1
Room 2
VORBAUO
RHallway
VAC
TUNWALL
Dump
TUNIN


Rooms 1: Left - Right
pSv per electron
1,00E-01
8,00E-02
6,00E-02
4,00E-02
2,00E-02
0,00E+00
100
105
110
115
120
125
130
135
140
Wall Thickness


x: 803.791557
y: 123
VAC
0-35 cm
TUNWALL
RHOLLO


Rooms 2: Left - Right
pSv per electron
5,00E-02
4,00E-02
3,00E-02
2,00E-02
1,00E-02
0,00E+00
100
105
110
115
120
125
130
135
140
Wall Thickness

Shielding Design

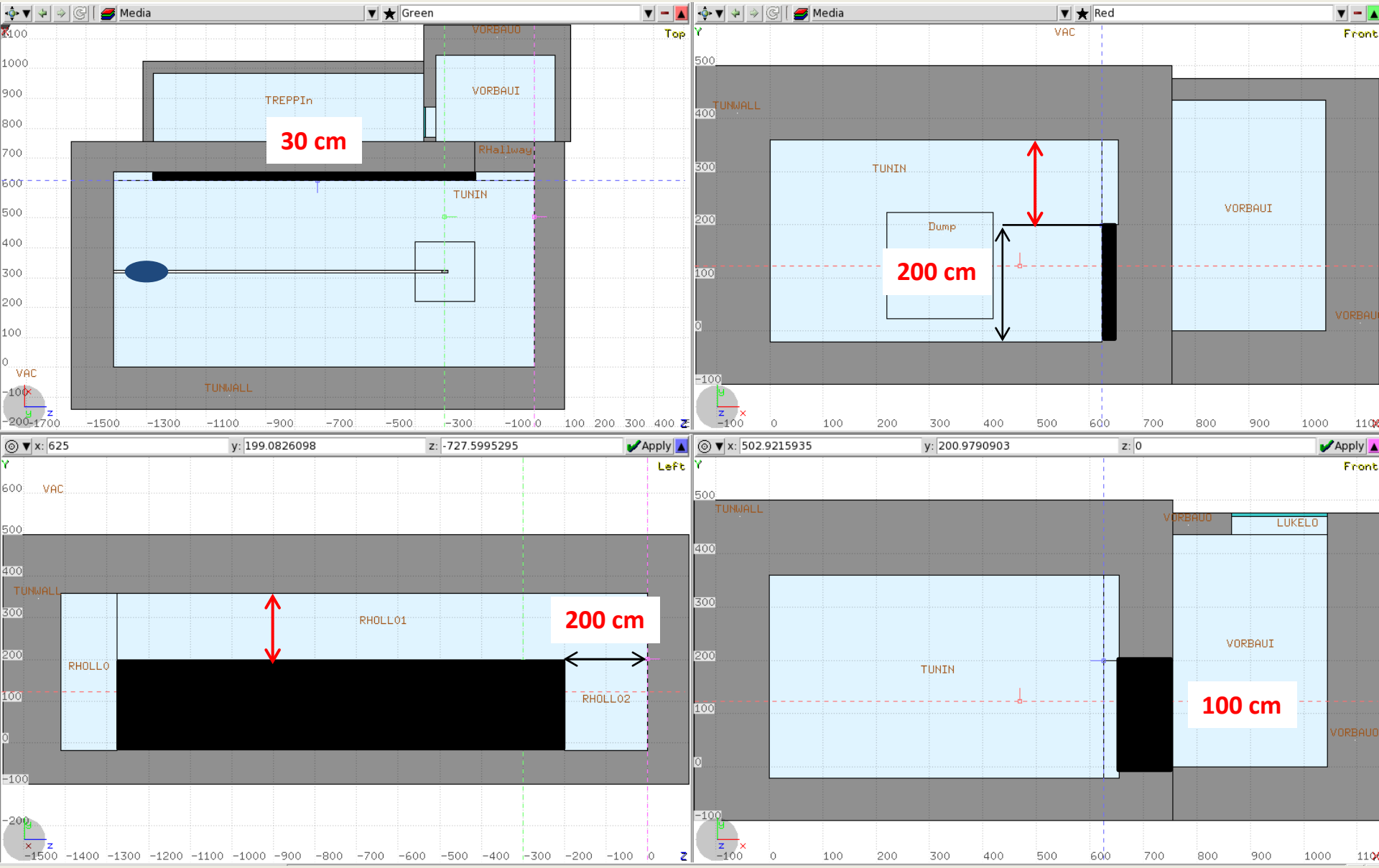
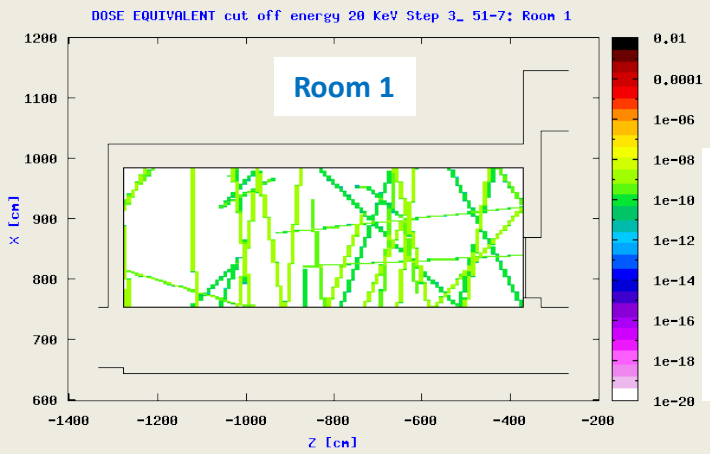


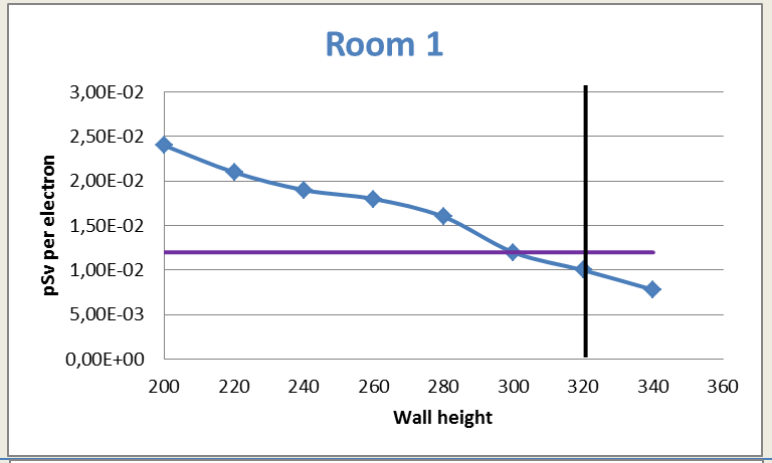
Diagram of the tunnel hall in the XZ and YX planes around the pipe.

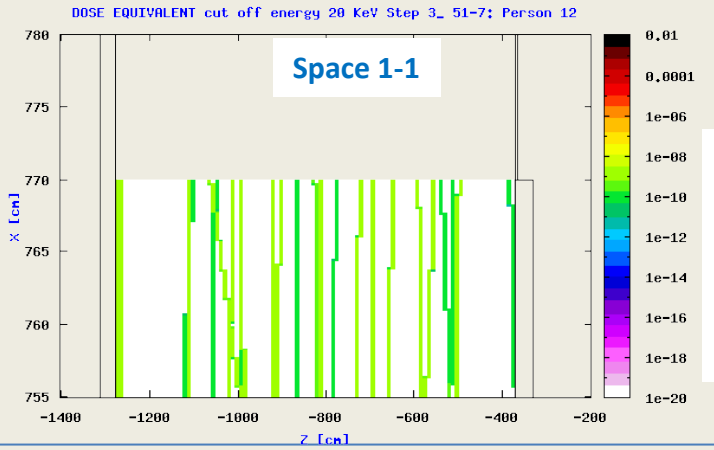


320 cm

0,012 pSv

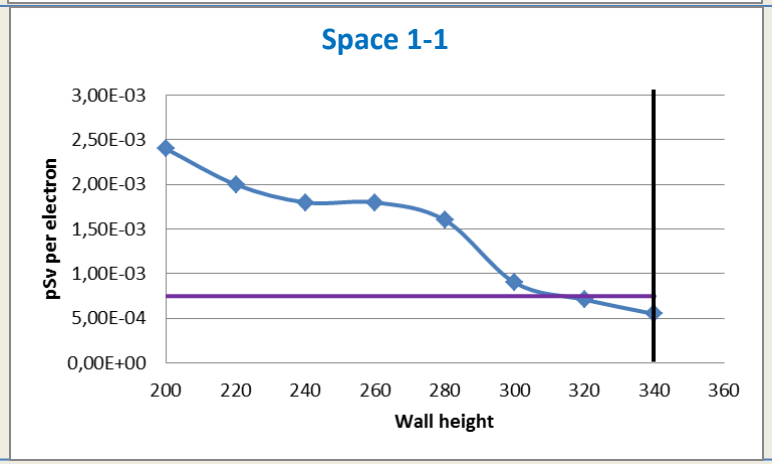
All: **0,01 pSv**
Elec: 1E-30
Phot: 0,01
Neu : 1E-30

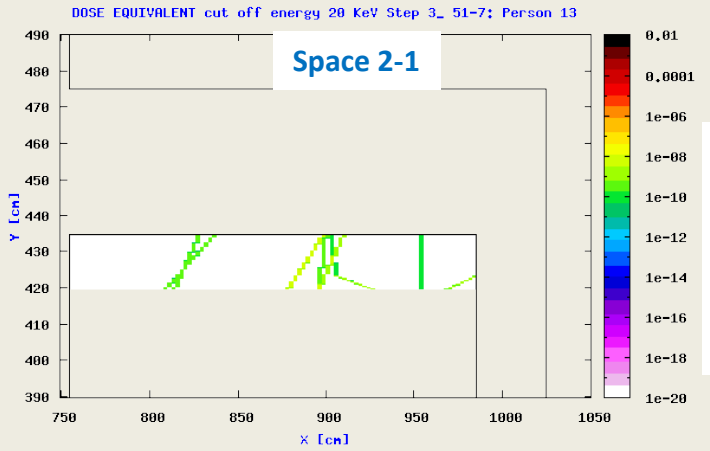




0,00075 pSv

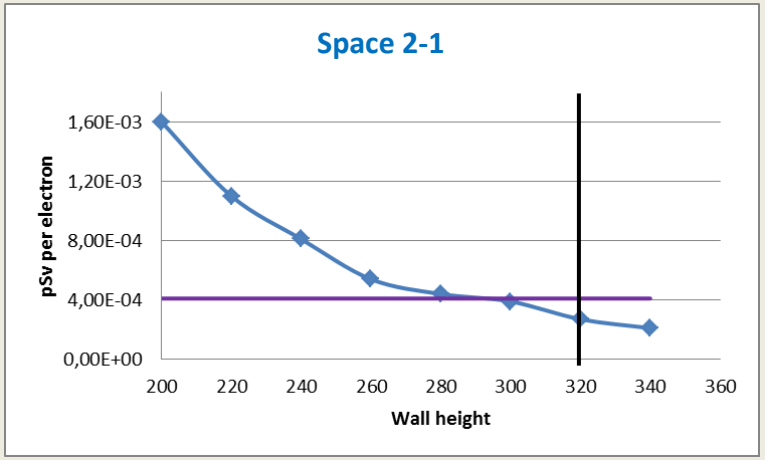
All: **0,00071 pSv**
Elec: 1E-30
Phot: 0,00071
Neu : 1E-30





0,00041 pSv

All: **0,00027 pSv**
Elec: 1E-30
Phot: 0,00027
Neu : 1E-30



Design of Shielding 1-0

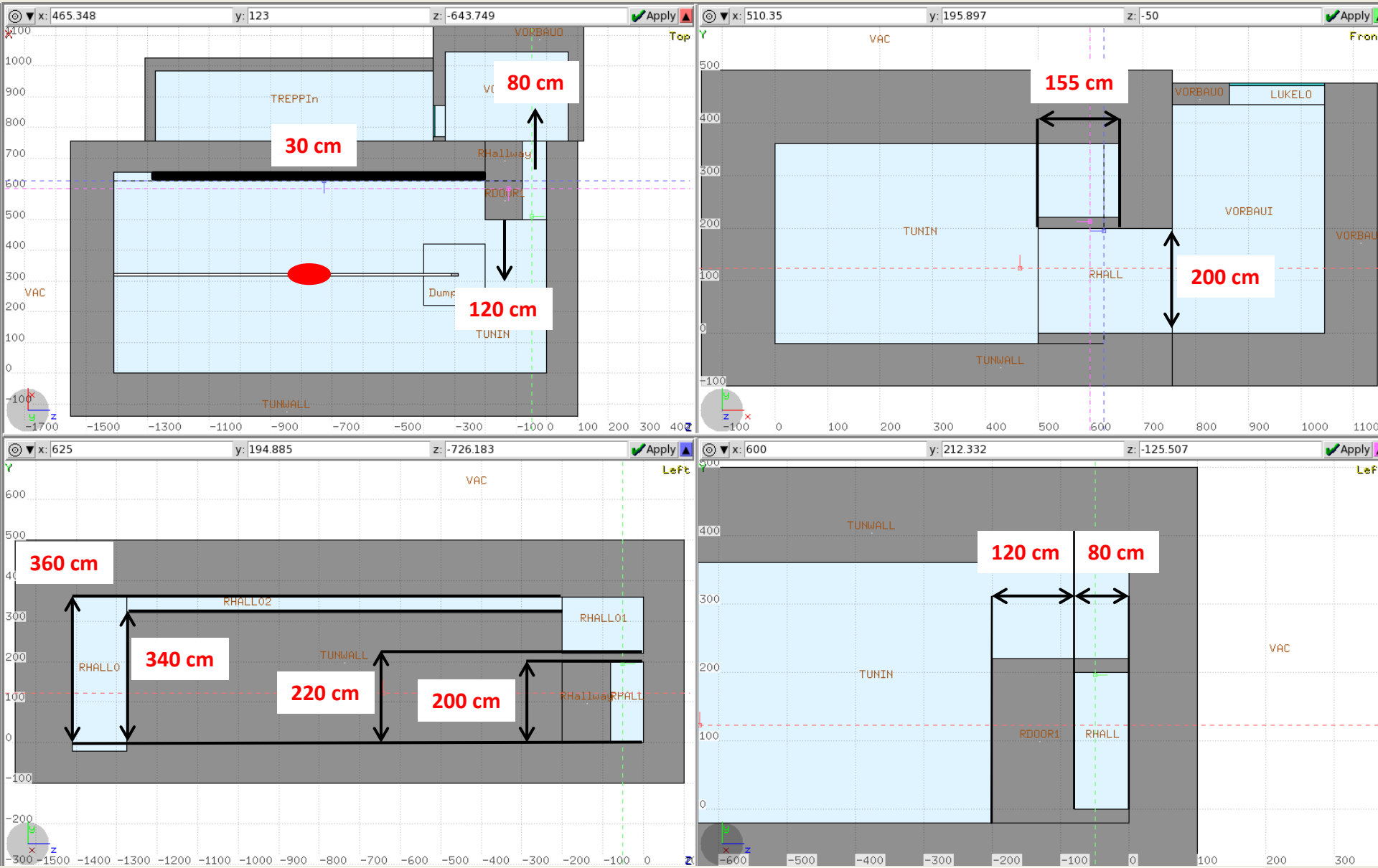
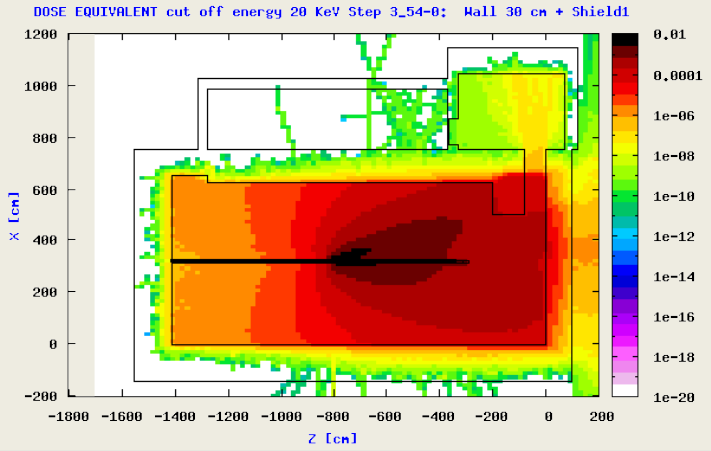
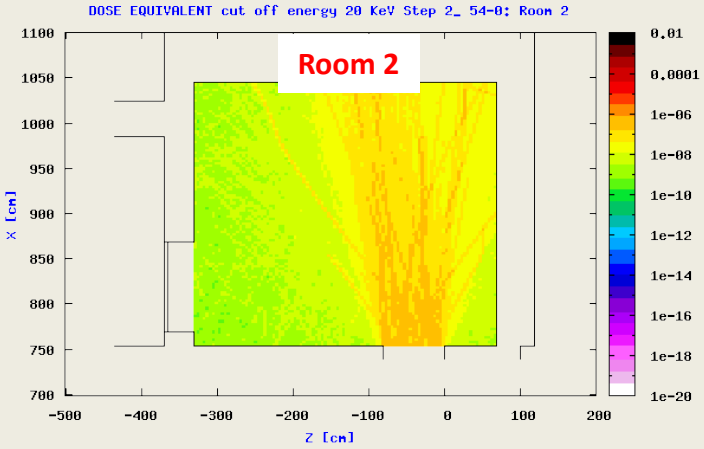
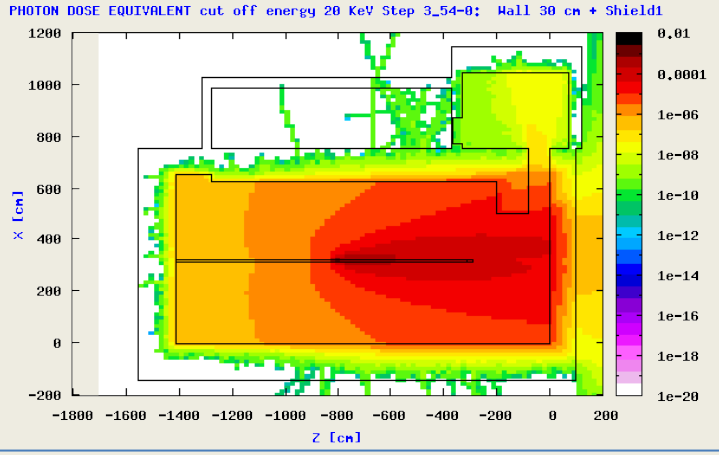


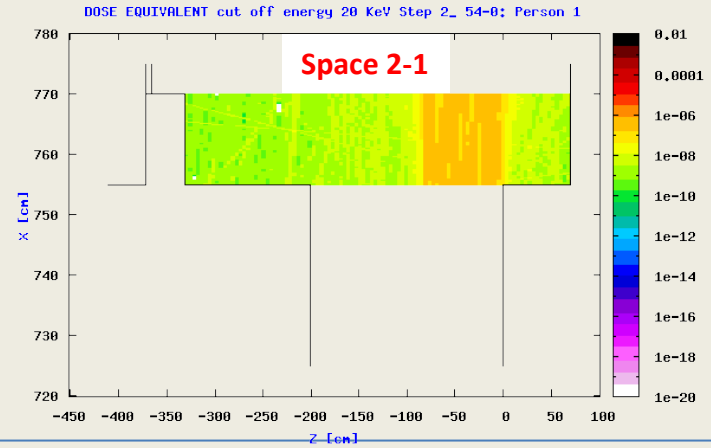
Diagram shielding 1-0 of the tunnel hall in the XZ and YX planes around the pipe.



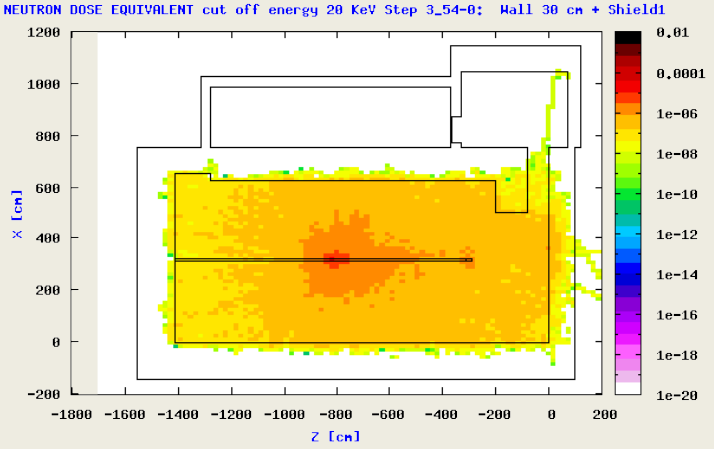


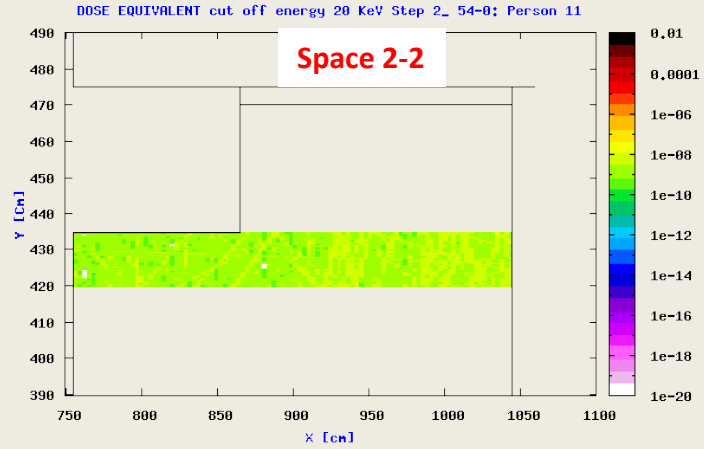
0,007
All: 2,238
Elec: 0,95
Phot: 1,13
Neu : 0,048





0,0003
All: 0,14
Elec: 0,064
Phot: 0,068
Neu : 0,0022





0,00023
All: 0,0036
Elec: 3,76E-17
Phot: 0,0036
Neu : 1E-30

Design of Shielding 1-0 With Doors

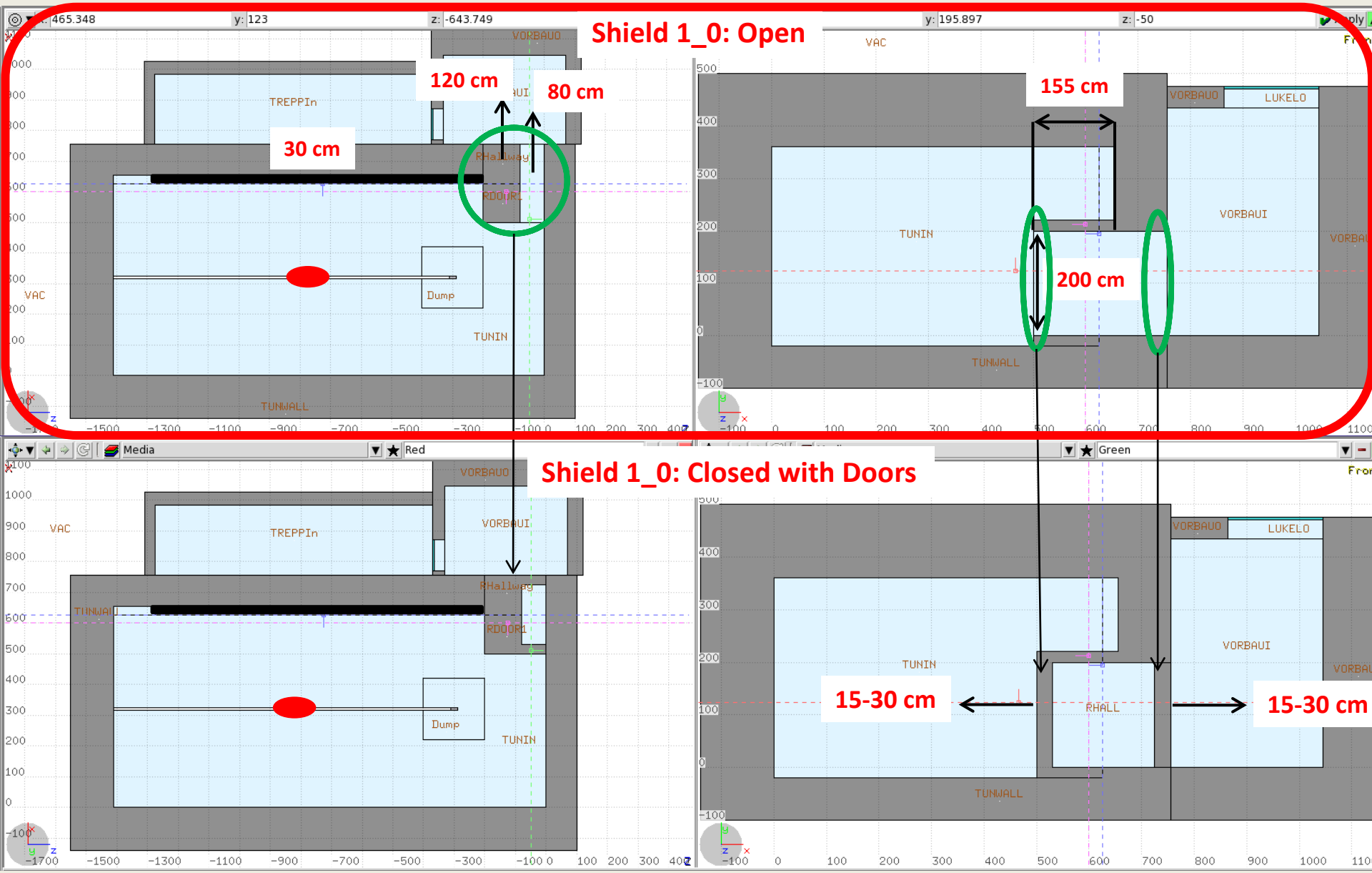
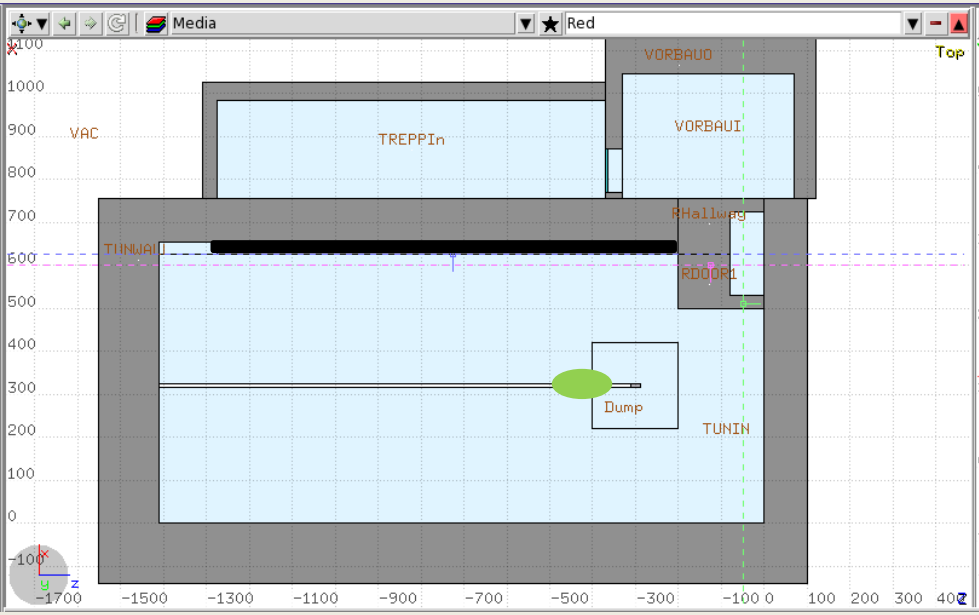
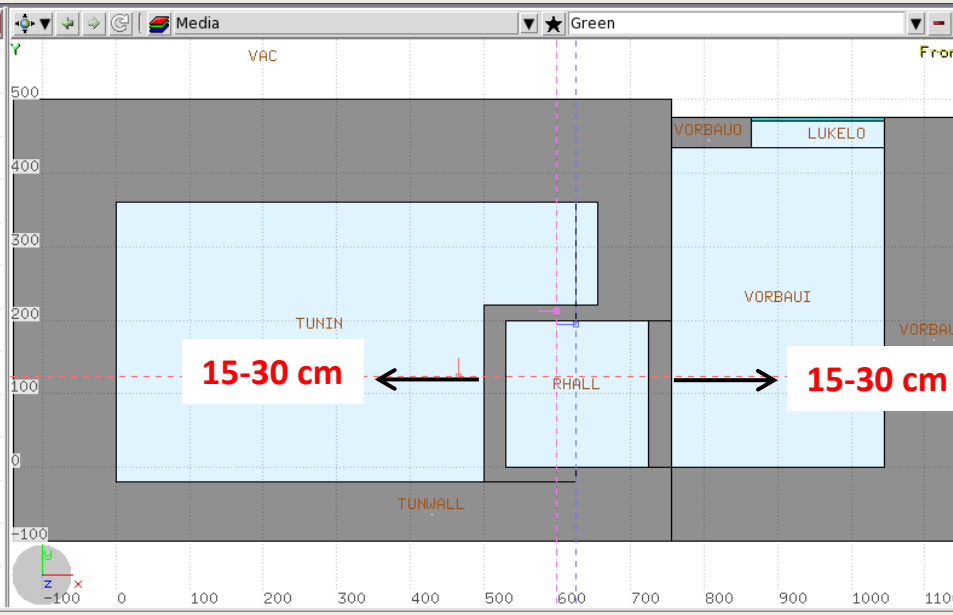
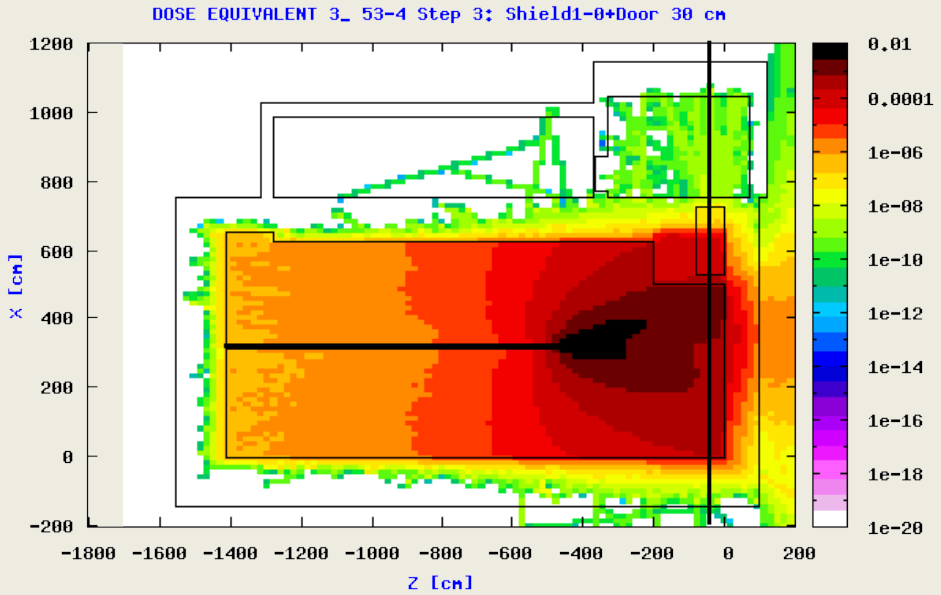


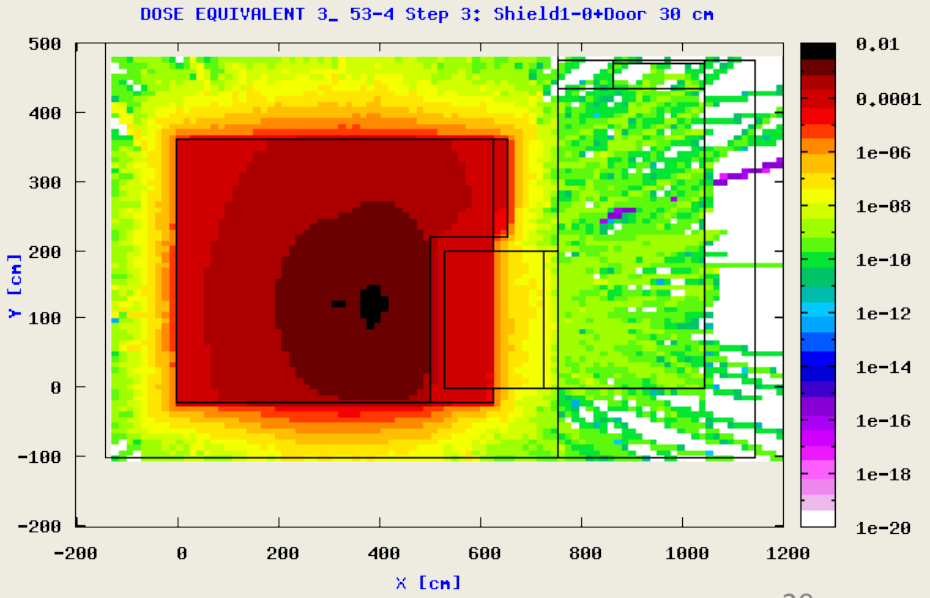
Diagram shielding 1-0 of the tunnel hall in the XZ and YX planes around the pipe.

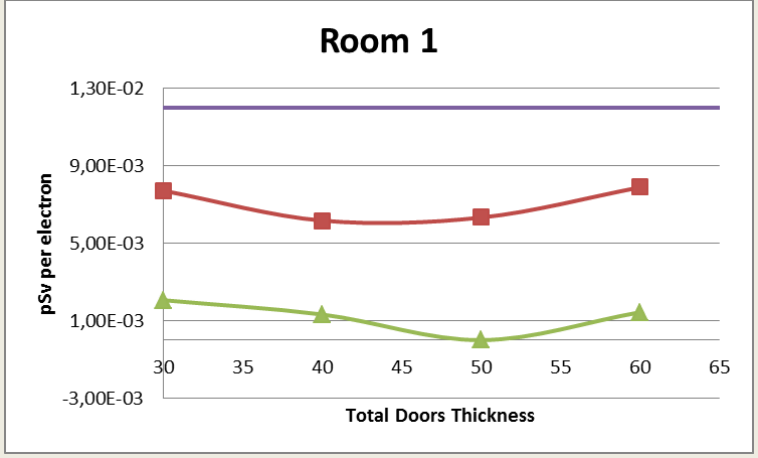
Design of Shielding 1-0 With Doors

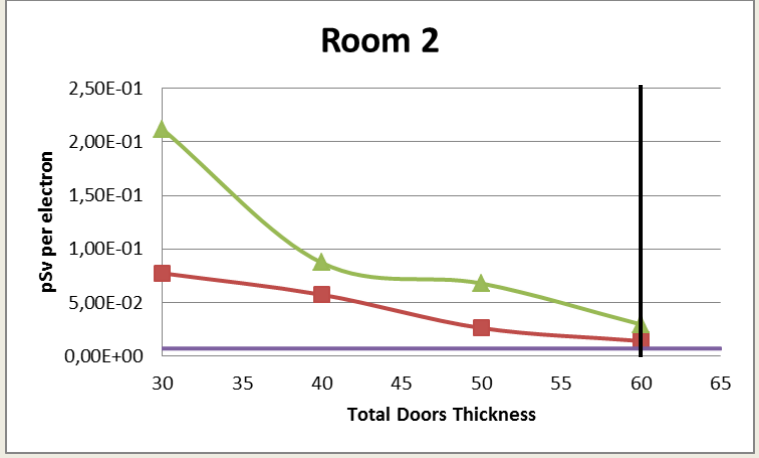


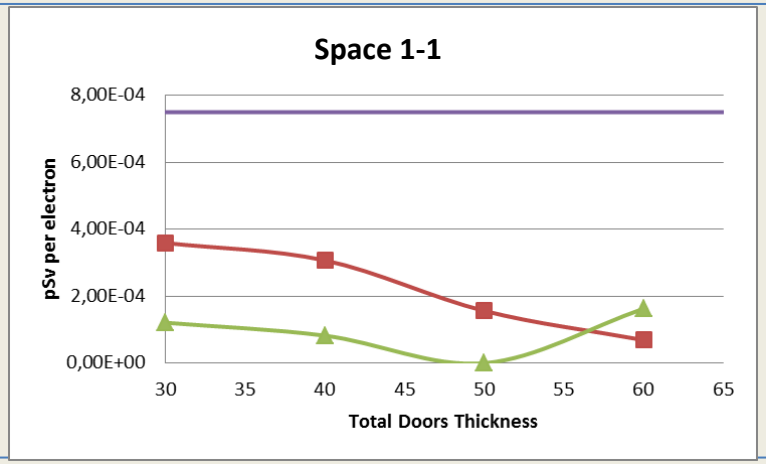


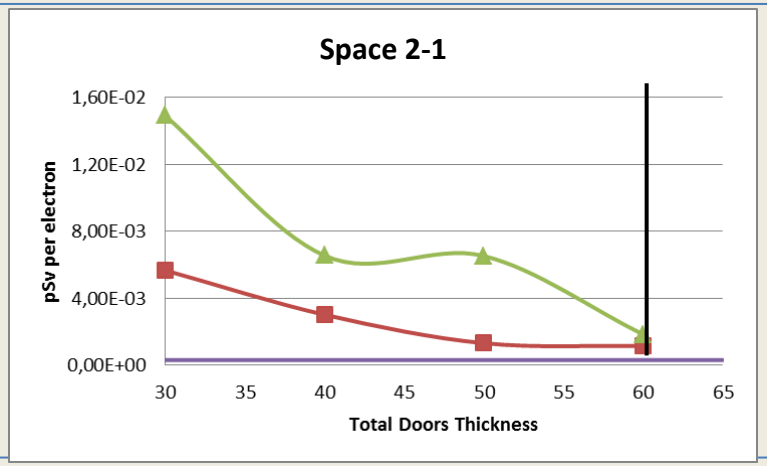


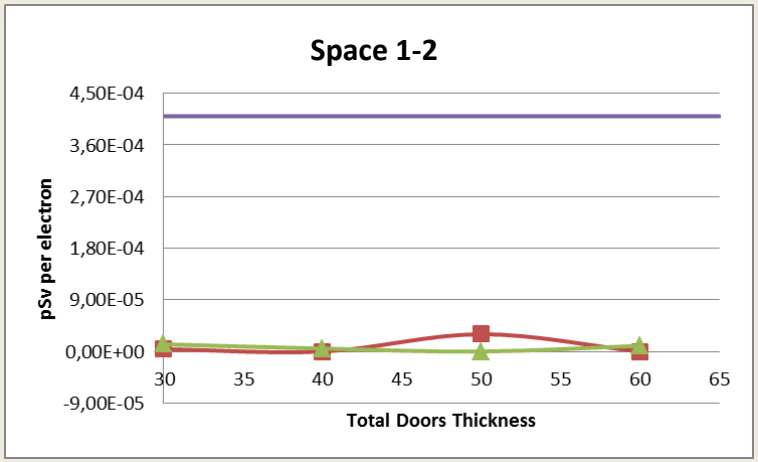


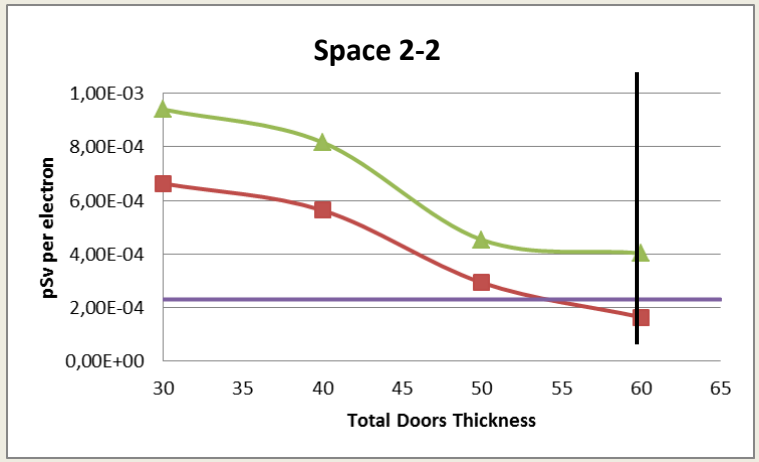

Room 1
1,30E-02
9,00E-03
5,00E-03
1,00E-03
-3,00E-03
pSv per electron
30 35 40 45 50 55 60 65
Total Doors Thickness


Room 2
2,50E-01
2,00E-01
1,50E-01
1,00E-01
5,00E-02
0,00E+00
pSv per electron
30 35 40 45 50 55 60 65
Total Doors Thickness

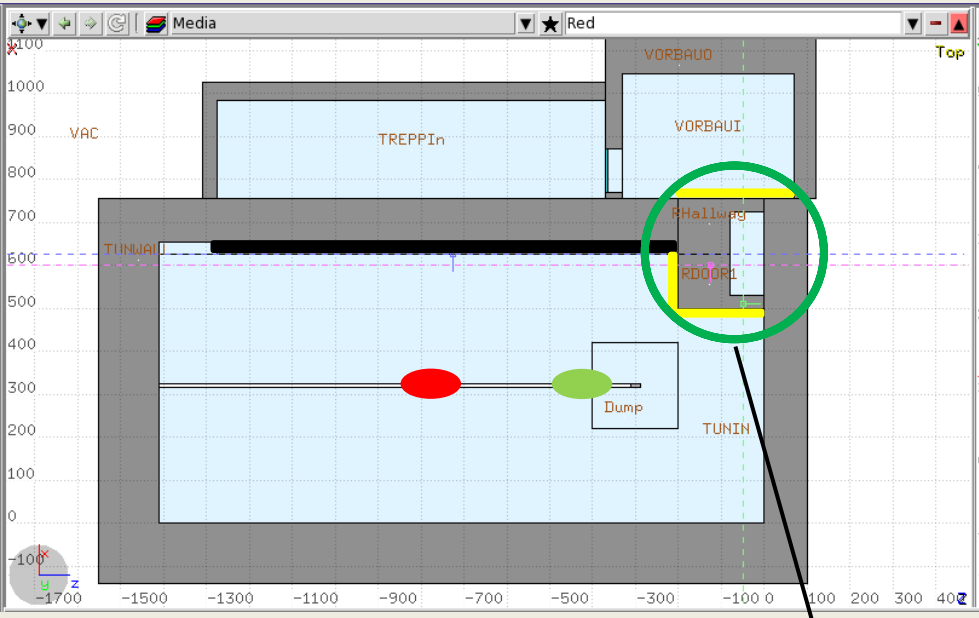

Space 1-1
8,00E-04
6,00E-04
4,00E-04
2,00E-04
0,00E+00
pSv per electron
30 35 40 45 50 55 60 65
Total Doors Thickness

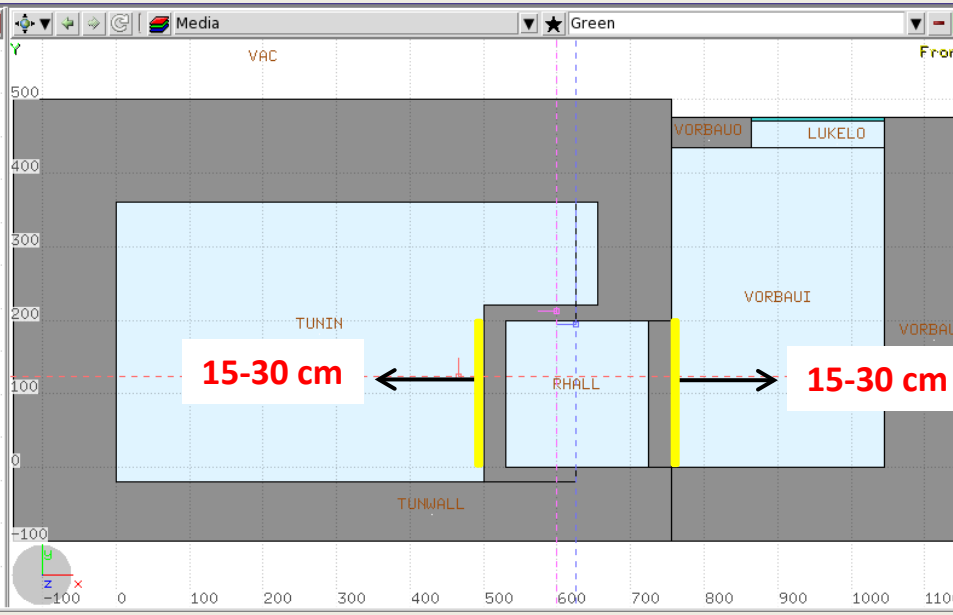

Space 2-1
1,60E-02
1,20E-02
8,00E-03
4,00E-03
0,00E+00
pSv per electron
30 35 40 45 50 55 60 65
Total Doors Thickness


Space 1-2
4,50E-04
3,60E-04
2,70E-04
1,80E-04
9,00E-05
0,00E+00
-9,00E-05
pSv per electron
30 35 40 45 50 55 60 65
Total Doors Thickness


Space 2-2
1,00E-03
8,00E-04
6,00E-04
4,00E-04
2,00E-04
0,00E+00
pSv per electron
30 35 40 45 50 55 60 65
Total Doors Thickness

Design of Shielding 1-0 With Doors and Sandwich





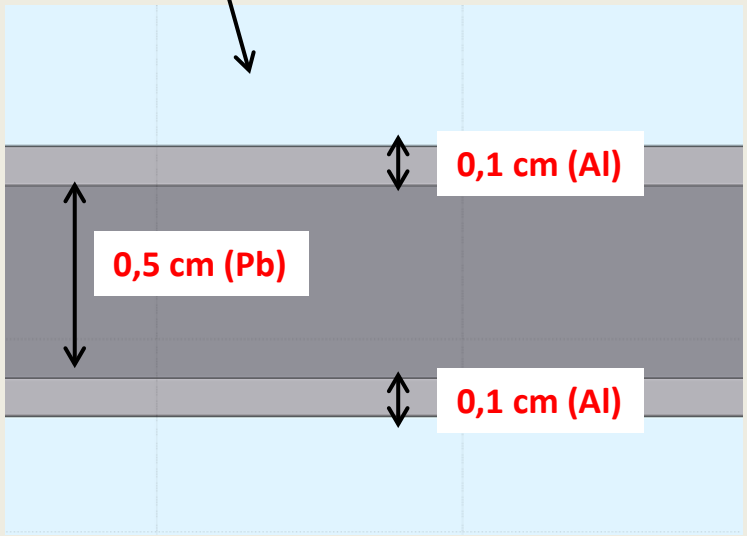
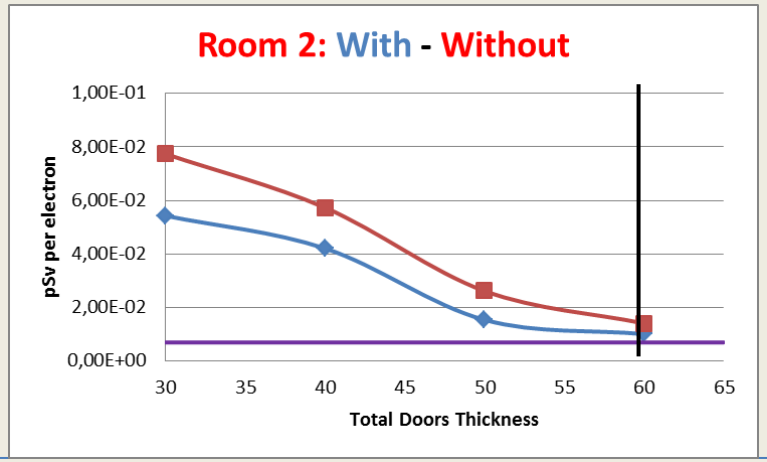
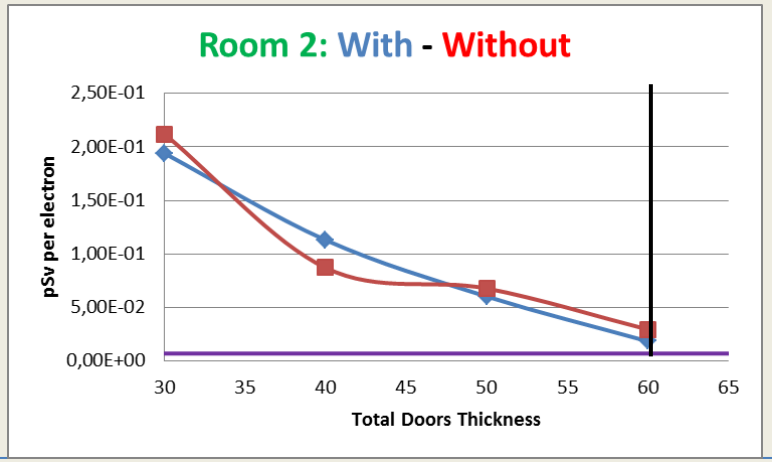
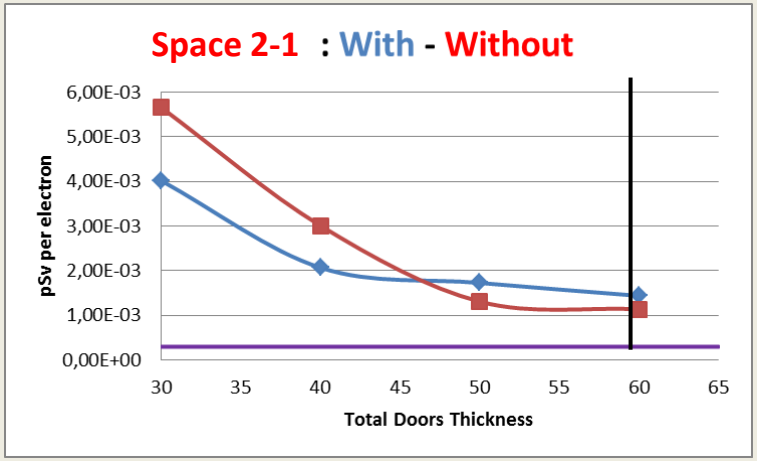
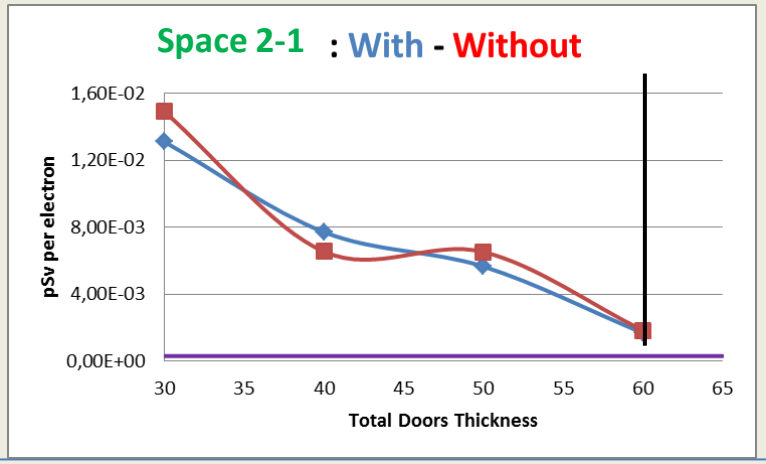


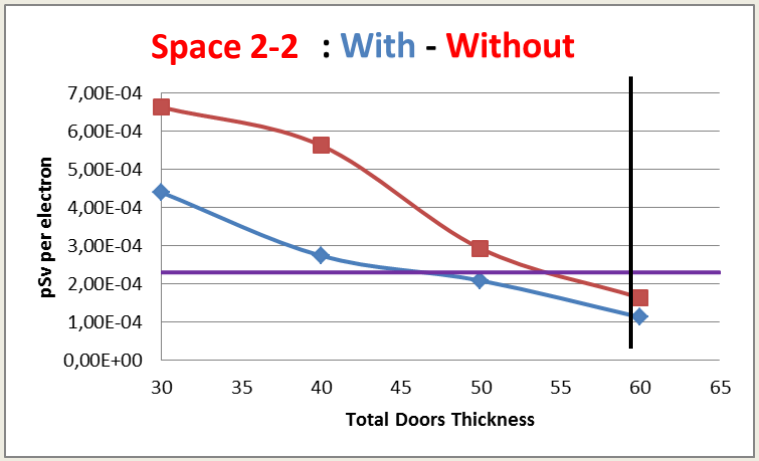
Diagram shielding 1-0 of the tunnel hall in the XZ and YX planes around the pipe.

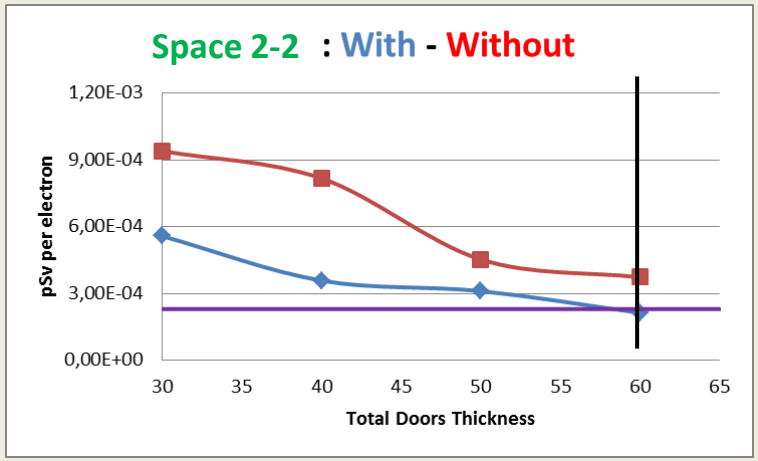

Room 2: With - Without
1,00E-01
8,00E-02
6,00E-02
4,00E-02
2,00E-02
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness


Room 2: With - Without
2,50E-01
2,00E-01
1,50E-01
1,00E-01
5,00E-02
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness

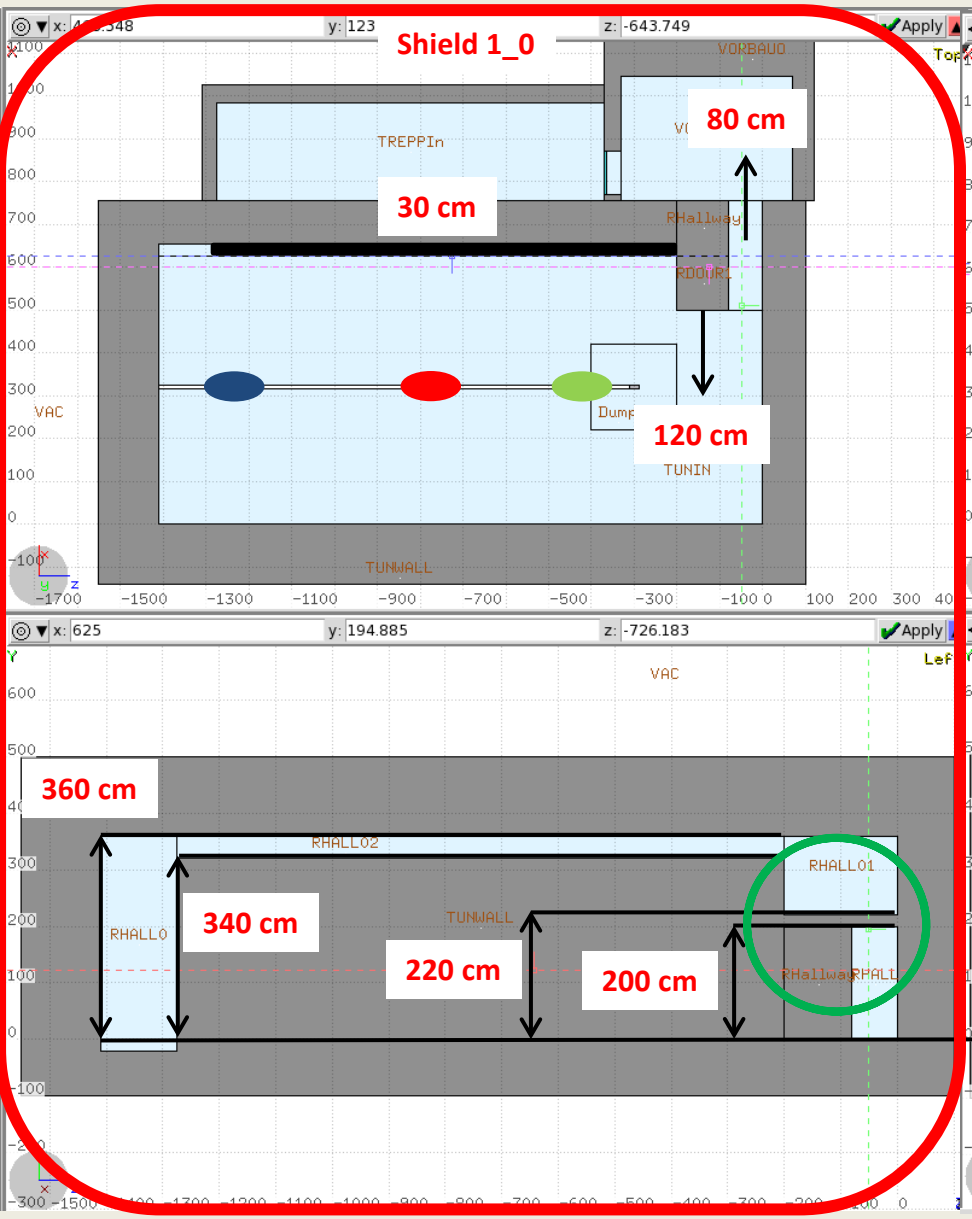

Space 2-1 : With - Without
6,00E-03
5,00E-03
4,00E-03
3,00E-03
2,00E-03
1,00E-03
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness

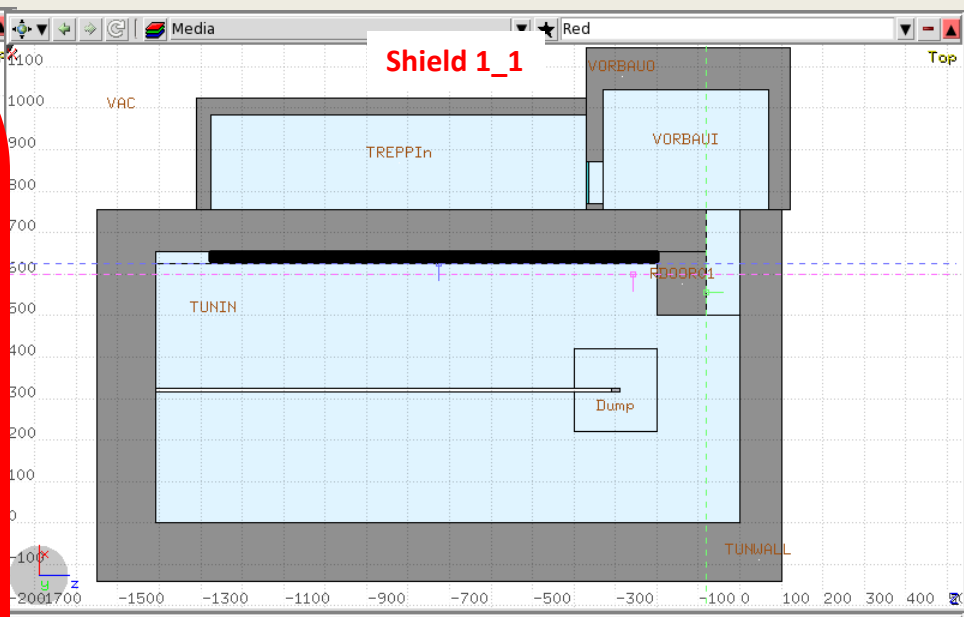

Space 2-1 : With - Without
1,60E-02
1,20E-02
8,00E-03
4,00E-03
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness

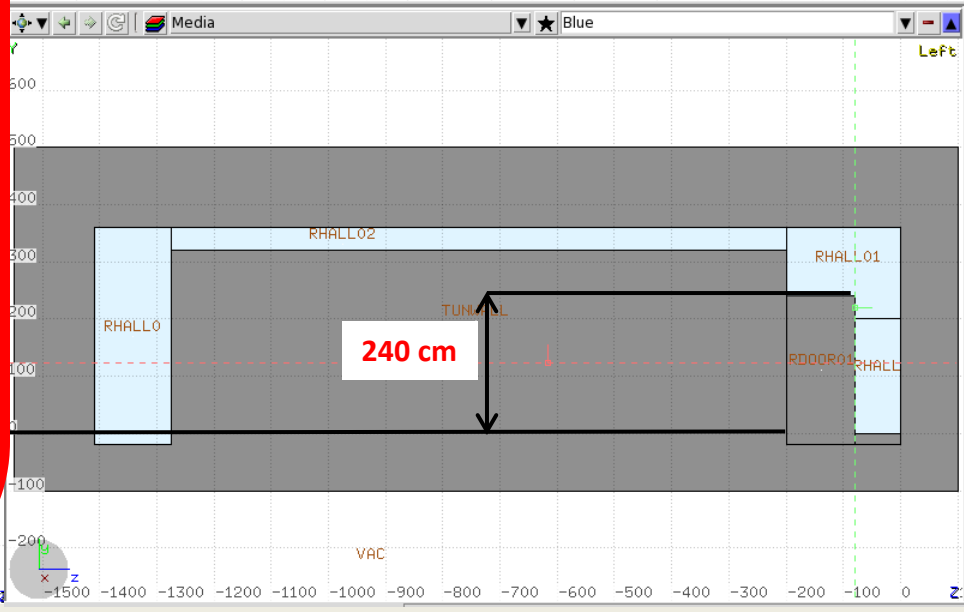

Space 2-2 : With - Without
7,00E-04
6,00E-04
5,00E-04
4,00E-04
3,00E-04
2,00E-04
1,00E-04
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness


Space 2-2 : With - Without
1,20E-03
9,00E-04
6,00E-04
3,00E-04
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness

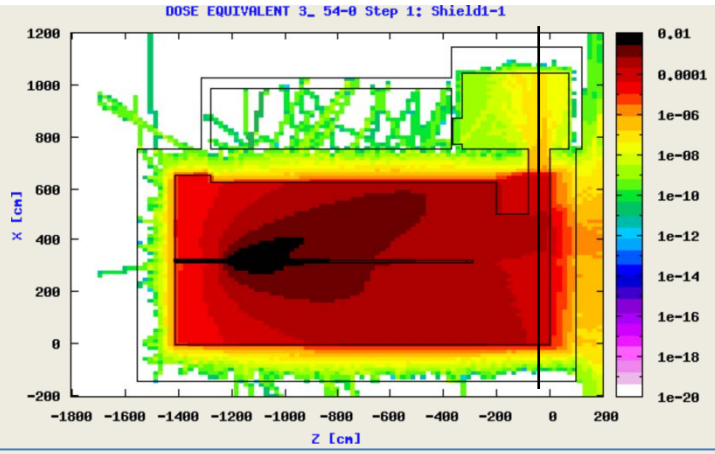
Shield 1-1: Open





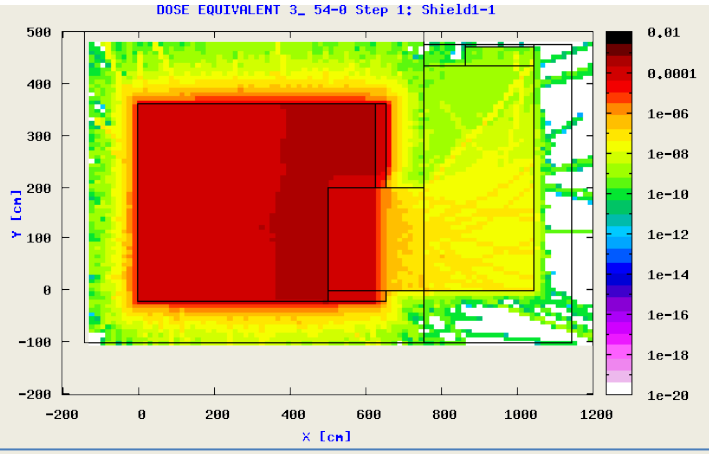


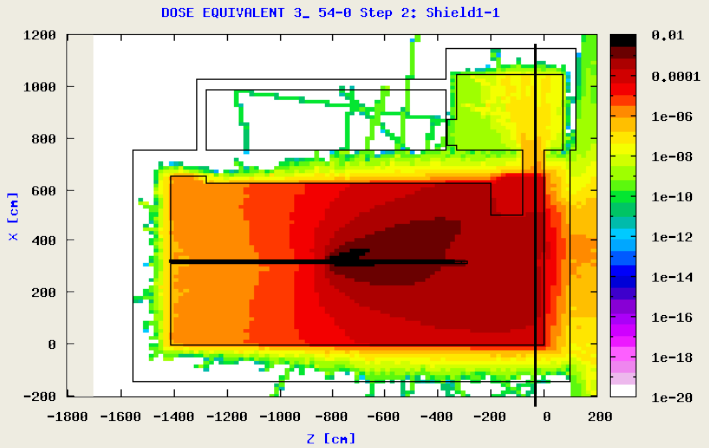
Equivalent Dose Distribution [pSv per electron]



Step 1

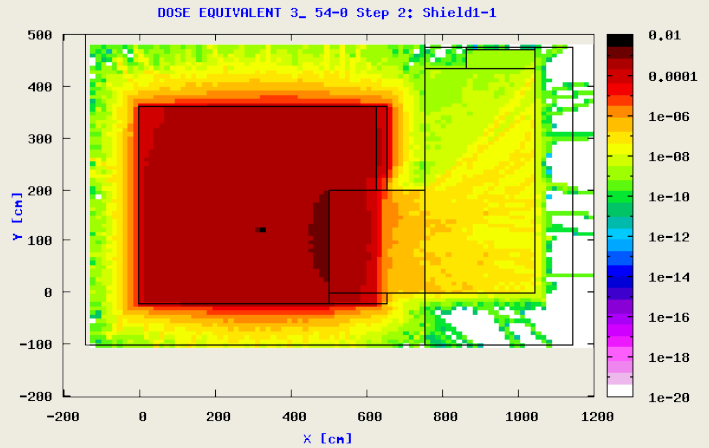
Dose: 305202

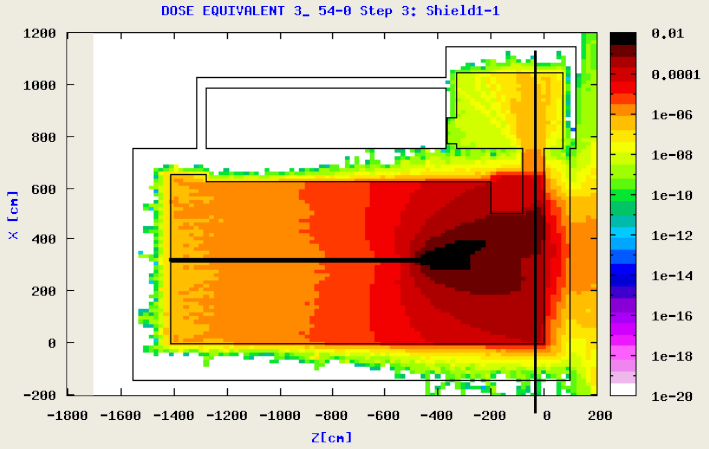




Step 2

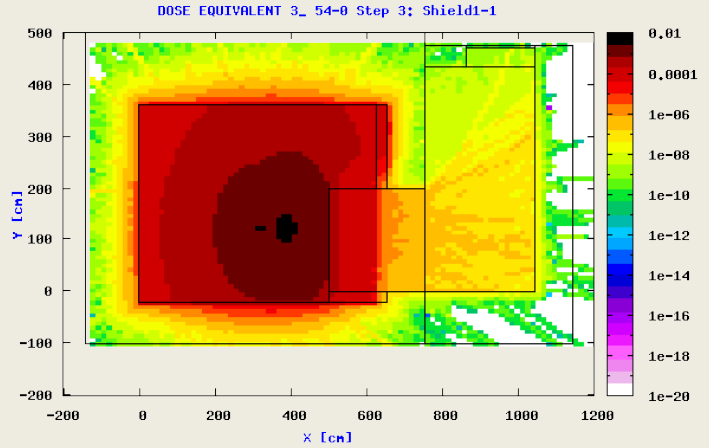
Dose: 394993

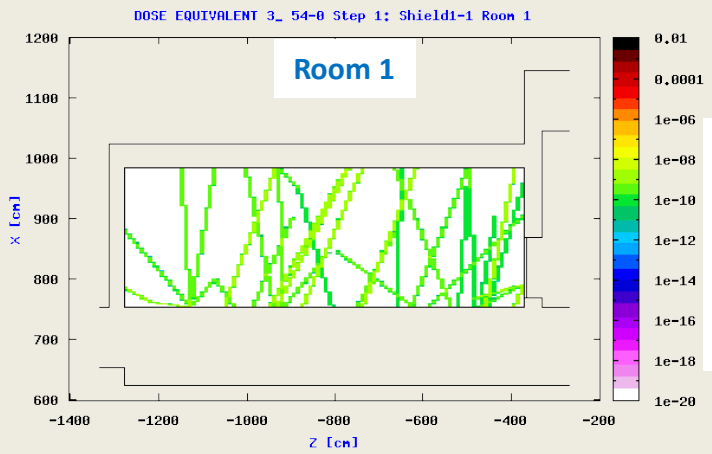




Step 3

Dose: 414217

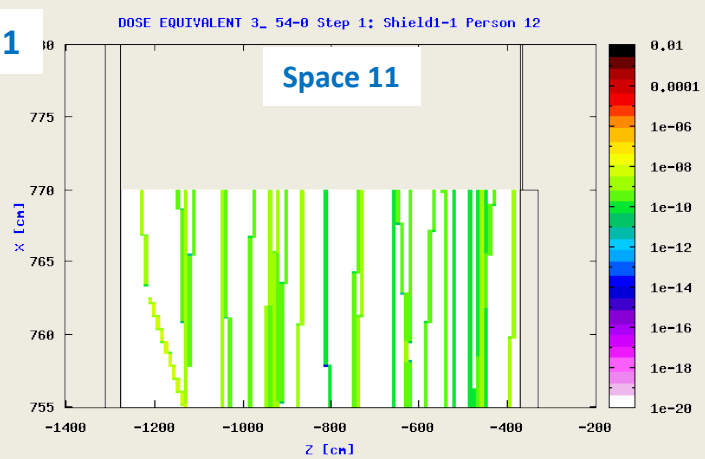




Step 1: Room 1

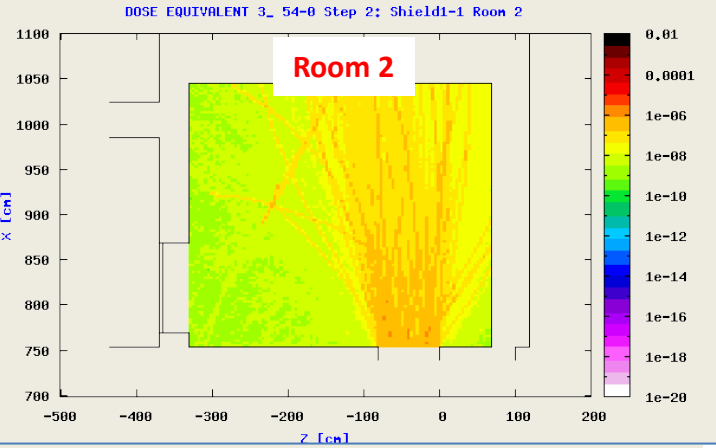
0,012 pSv/h

All: **0,0097 pSv**
Elec: 1E-30
Phot: 0,0097
Neu : 1E-30



0,00075 pSv/h

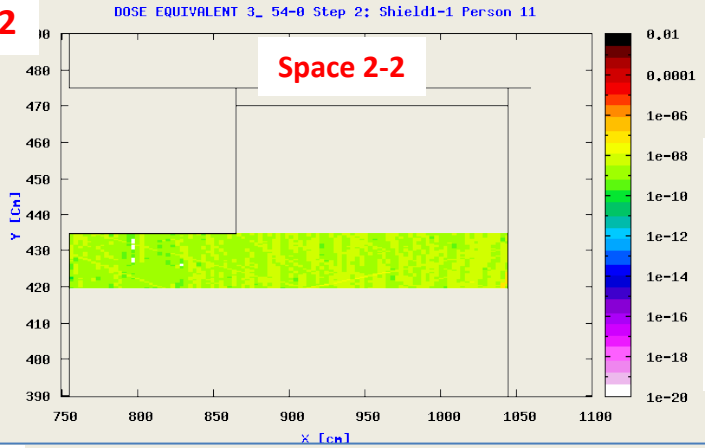
All: **0,00068 pSv**
Elec: 1E-30
Phot: 0,00068
Neu : 1E-30



Step 2: Room 2

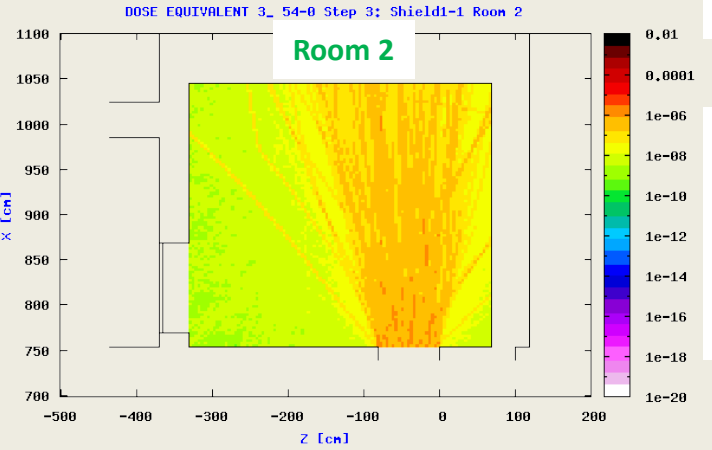
0,007 pSv/h

All: **3,02 pSv**
Elec: 1,63
Phot: 1,35
Neu : 0,014



0,00023 pSv/h

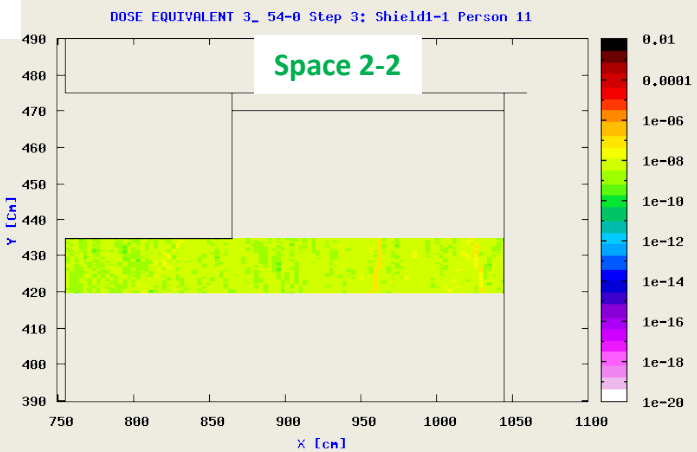
All: **0,0047 pSv**
Elec: 1E-30
Phot: 0,0047
Neu : 1E-30



Step 3: Room 2

0,007 pSv/h

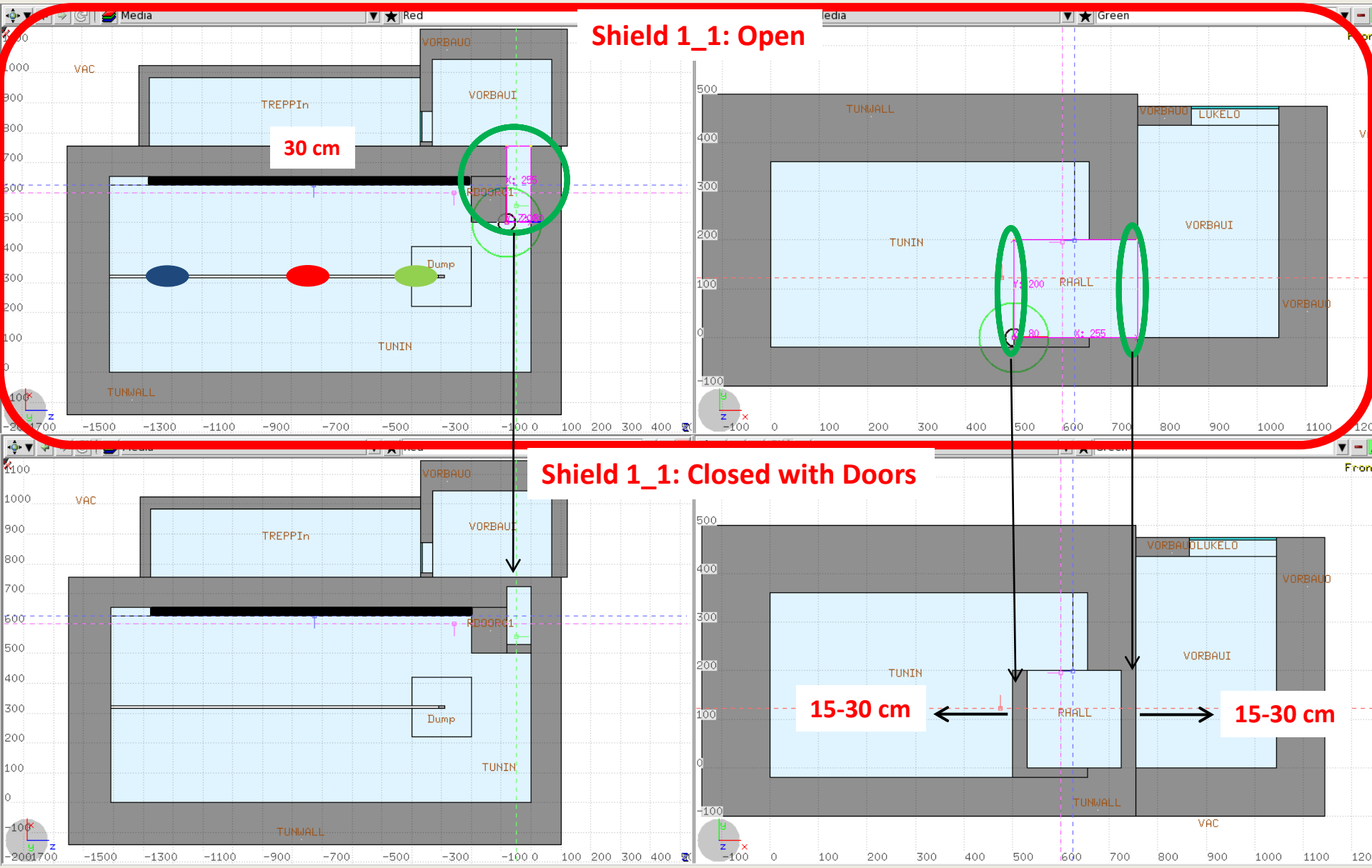
All: **5,51 pSv**
Elec: 3,31
Phot: 2,08
Neu : 0,12

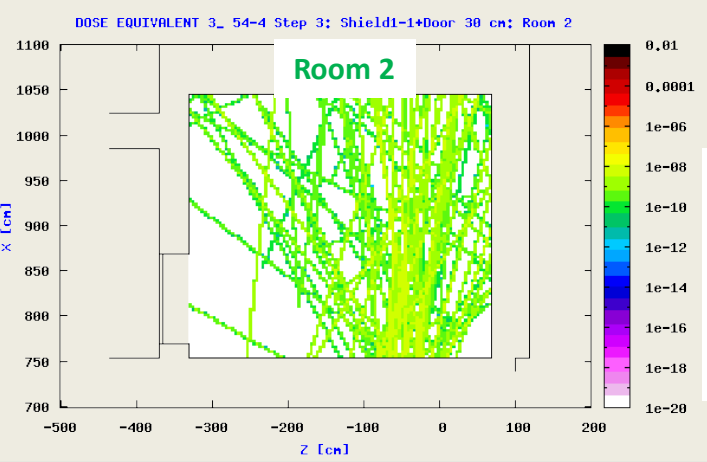


0,00023 pSv/h

All: **0,0099 pSv**
Elec: 0,0024
Phot: 0,0068
Neu : 0,00062

Shield 1-1: Closed With Doors

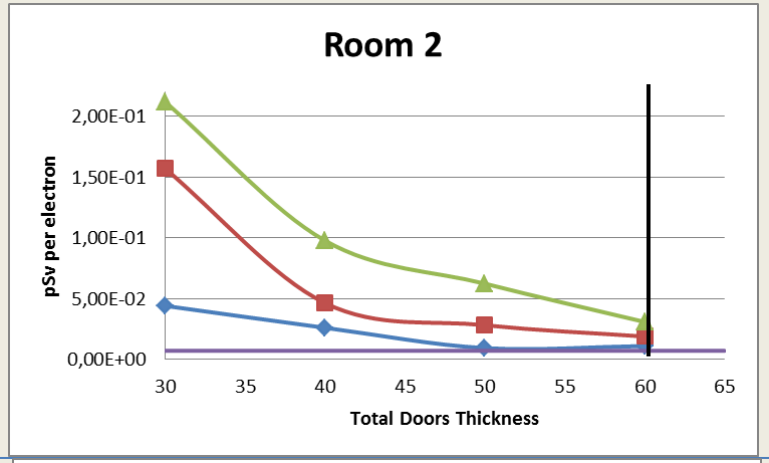


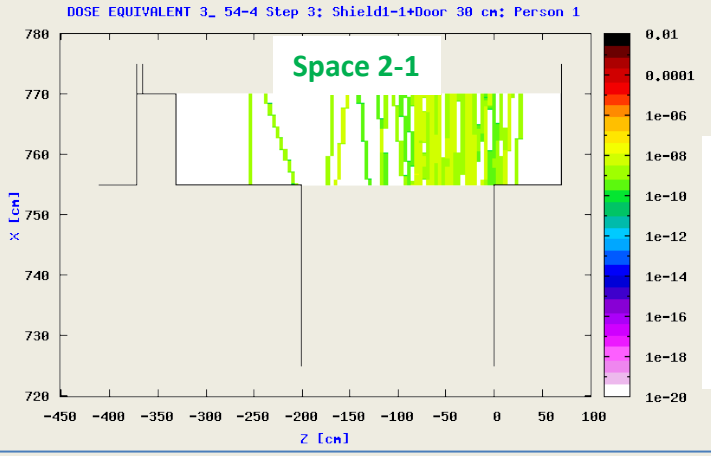


30 cm

0,007 pSv/h

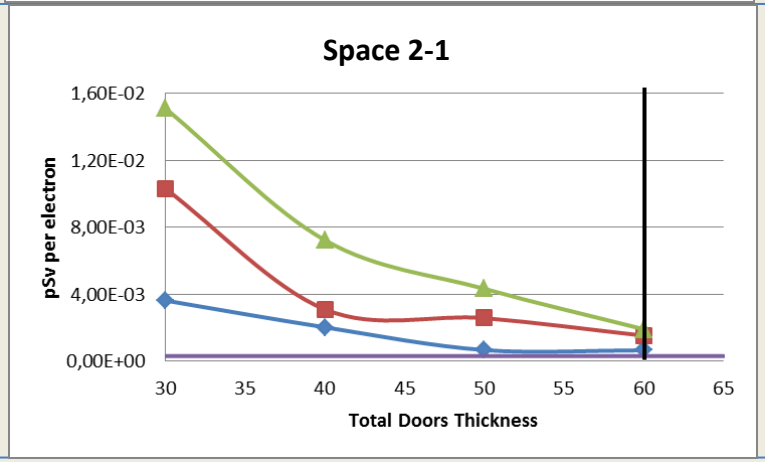
All: **0,031 pSv**
Elec: 5,19E-17
Phot: 0,0308
Neu : 1E-30

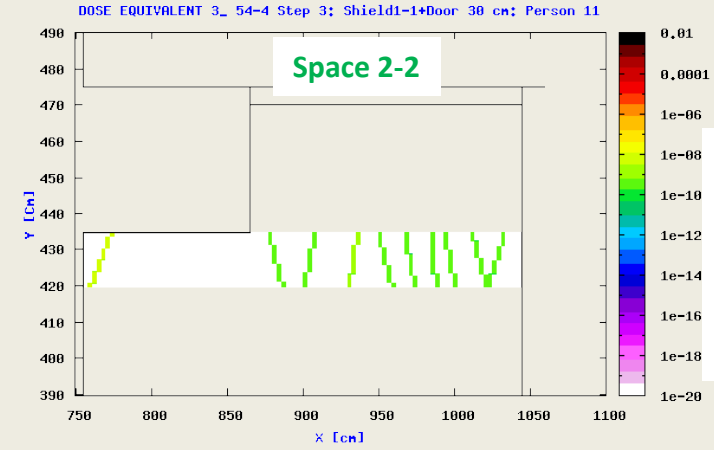




0,0003 pSv/h

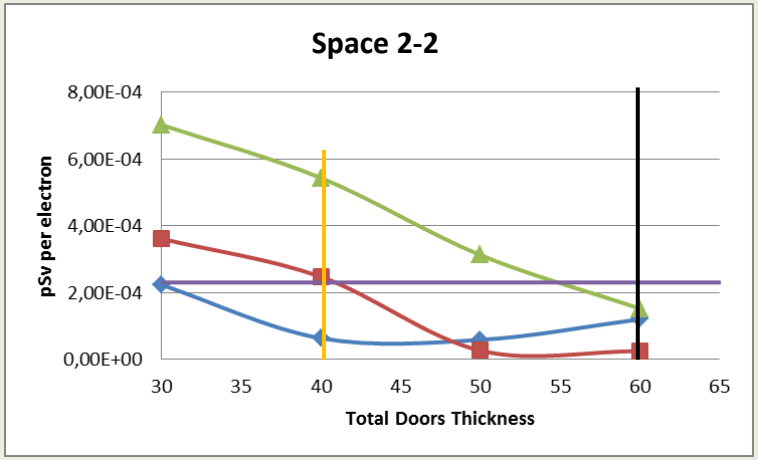
All: **0,0019 pSv**
Elec: 1E-30
Phot: 0,00197
Neu : 1E-30



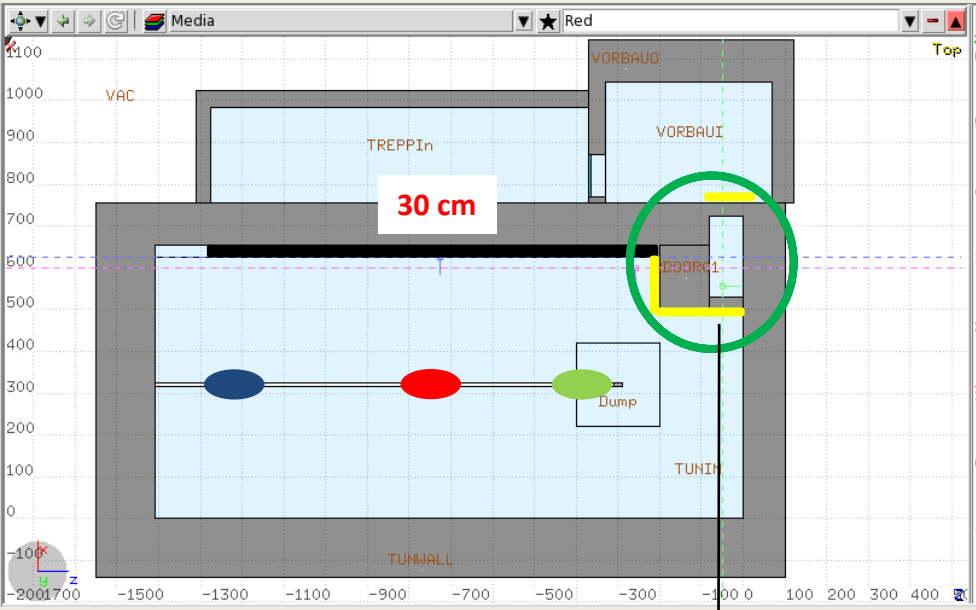


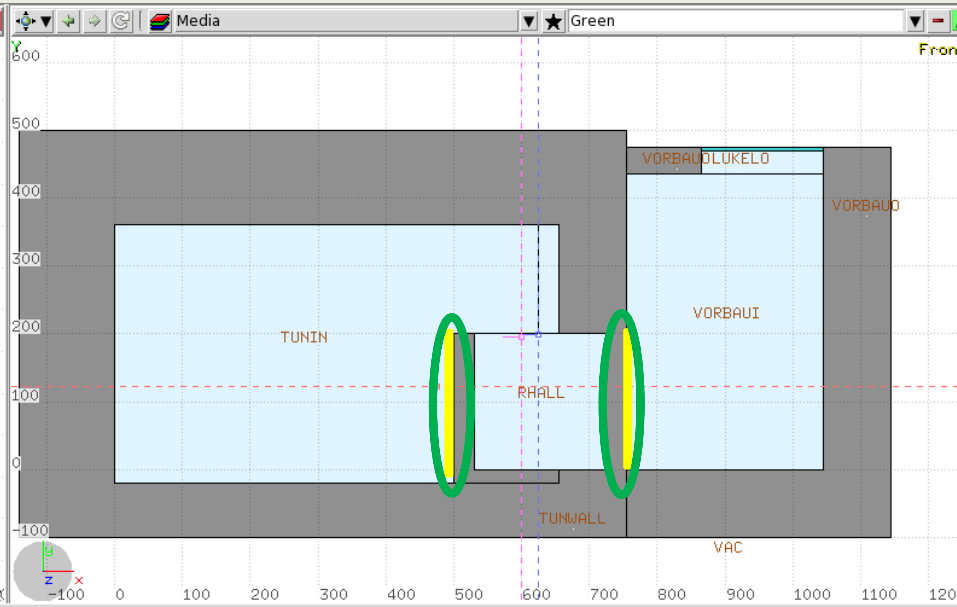
0,00023 pSv/h

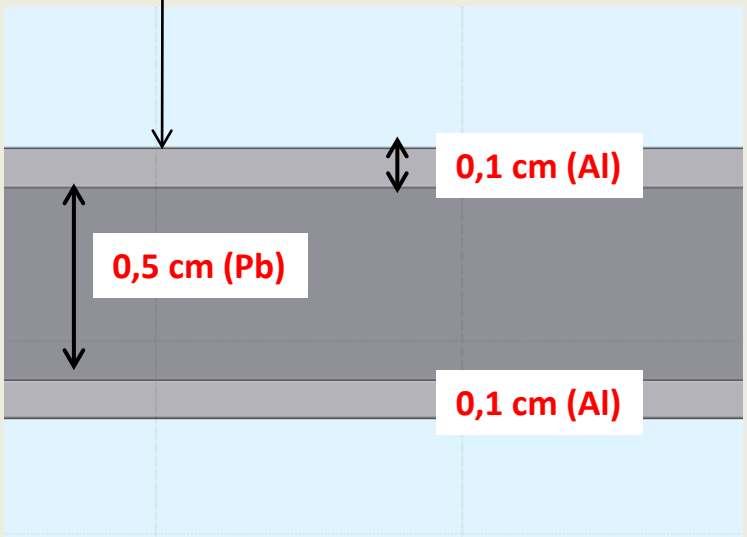
All: **0,00015 pSv**
Elec: 1E-30
Phot: 0,00015
Neu : 1E-30

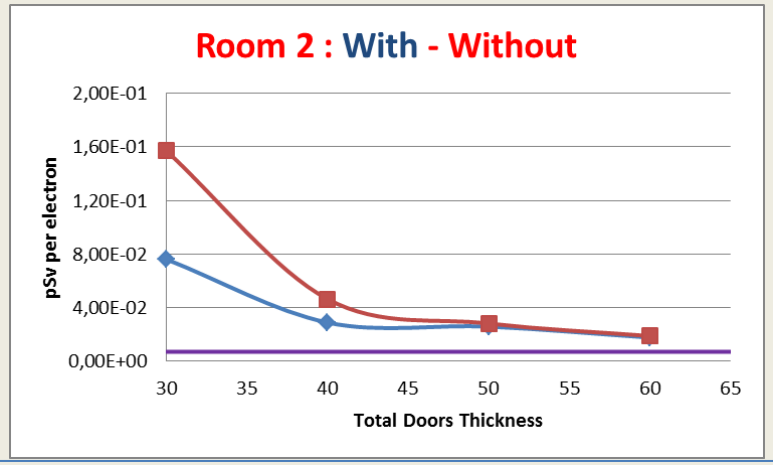


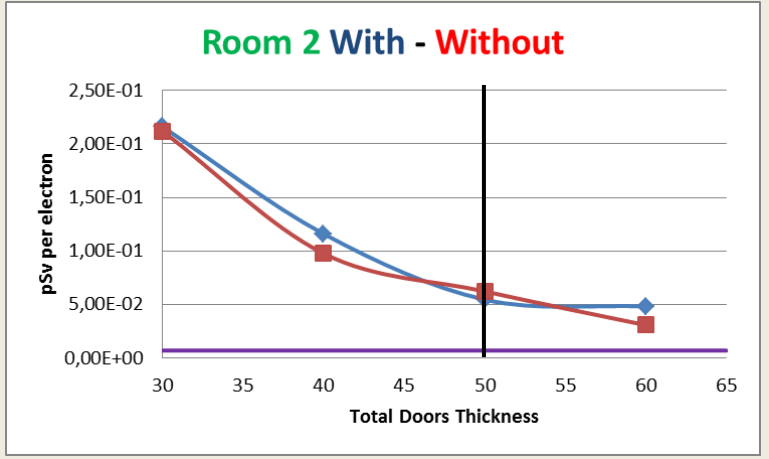
Shield 1-1: Closed With Doors and Sandwich

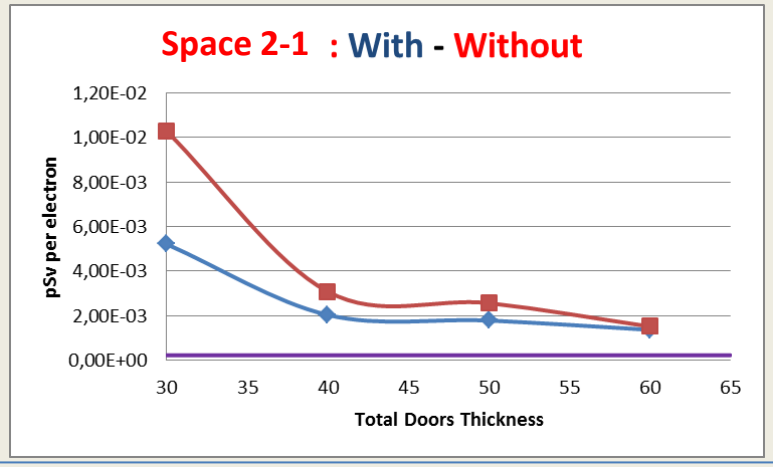


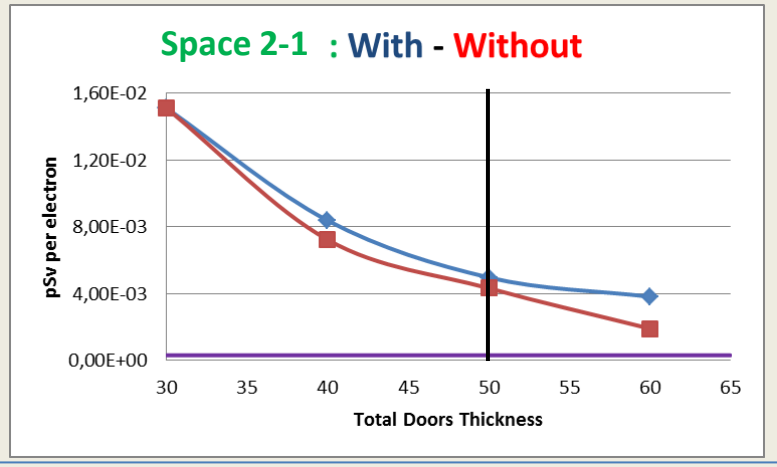


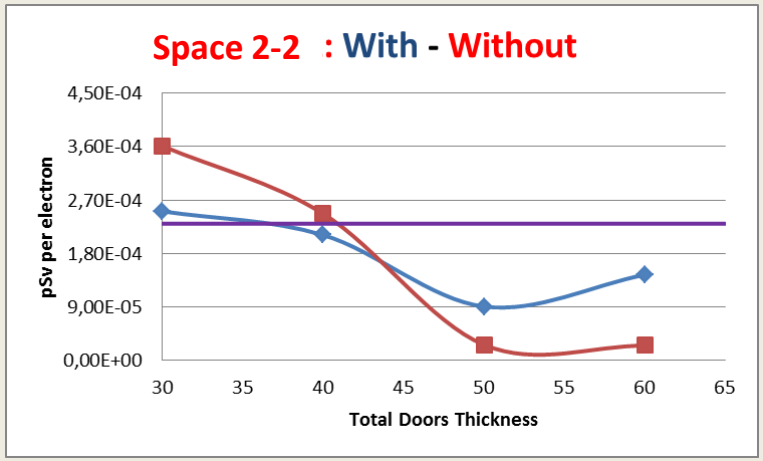


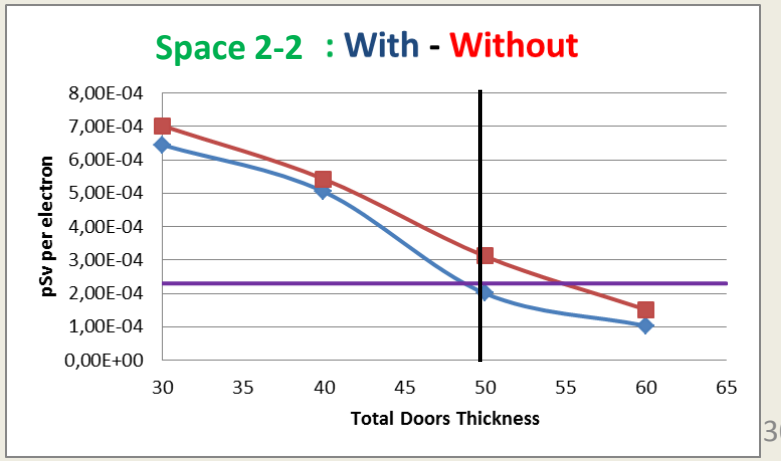

Room 2 : With - Without
2,00E-01
1,60E-01
1,20E-01
8,00E-02
4,00E-02
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness

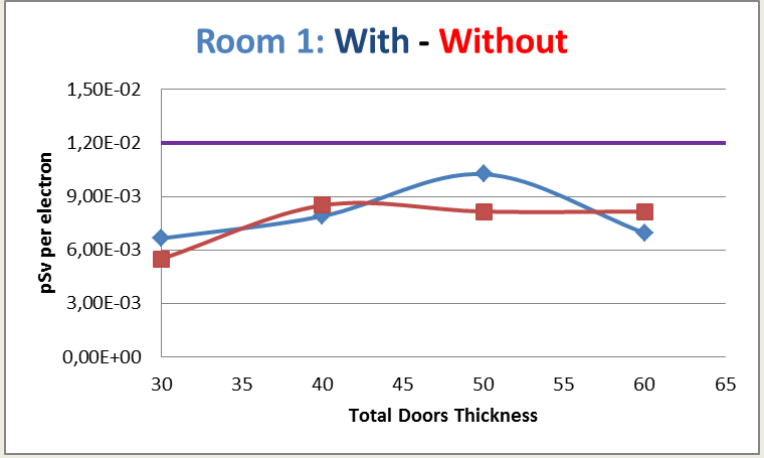

Room 2 With - Without
2,50E-01
2,00E-01
1,50E-01
1,00E-01
5,00E-02
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness

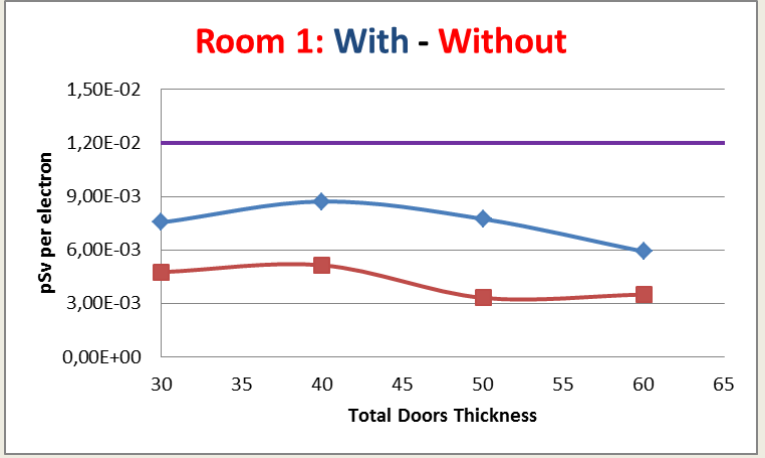

Space 2-1 : With - Without
1,20E-02
1,00E-02
8,00E-03
6,00E-03
4,00E-03
2,00E-03
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness

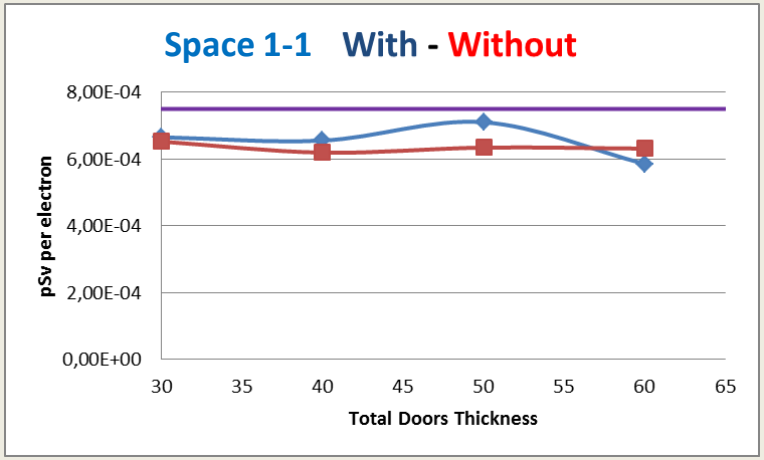

Space 2-1 : With - Without
1,60E-02
1,20E-02
8,00E-03
4,00E-03
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness

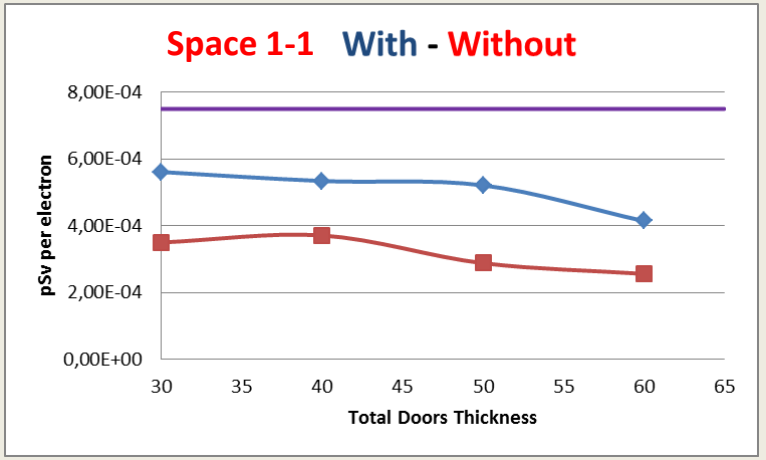

Space 2-2 : With - Without
4,50E-04
3,60E-04
2,70E-04
1,80E-04
9,00E-05
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness

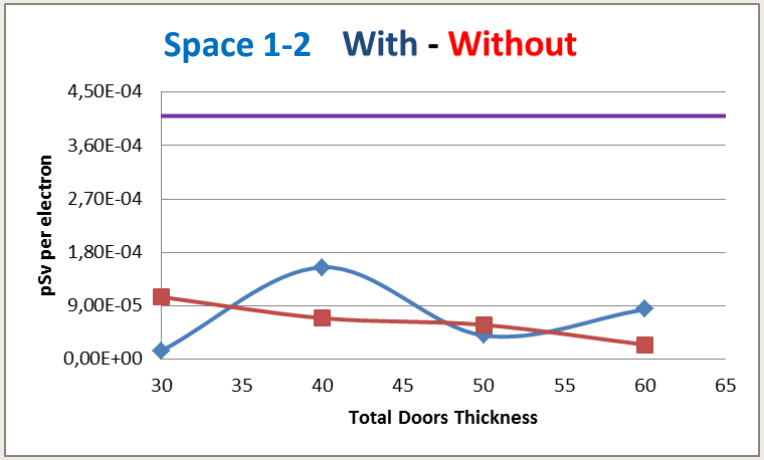

Space 2-2 : With - Without
8,00E-04
7,00E-04
6,00E-04
5,00E-04
4,00E-04
3,00E-04
2,00E-04
1,00E-04
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness

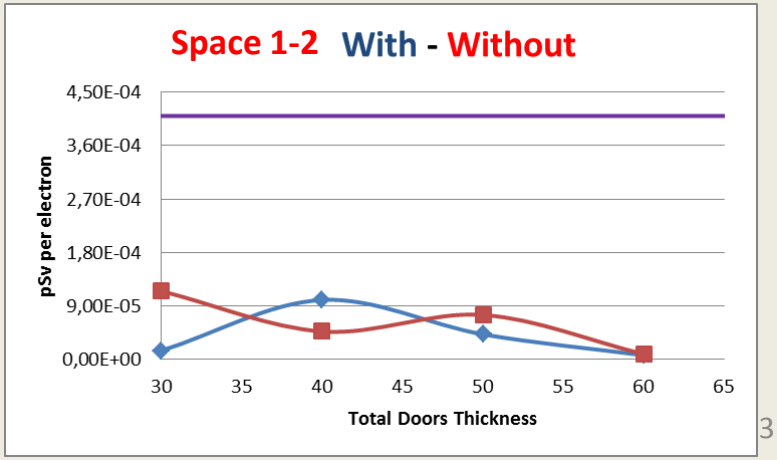

Room 1: With - Without
1,50E-02
1,20E-02
9,00E-03
6,00E-03
3,00E-03
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness


Room 1: With - Without
1,50E-02
1,20E-02
9,00E-03
6,00E-03
3,00E-03
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness

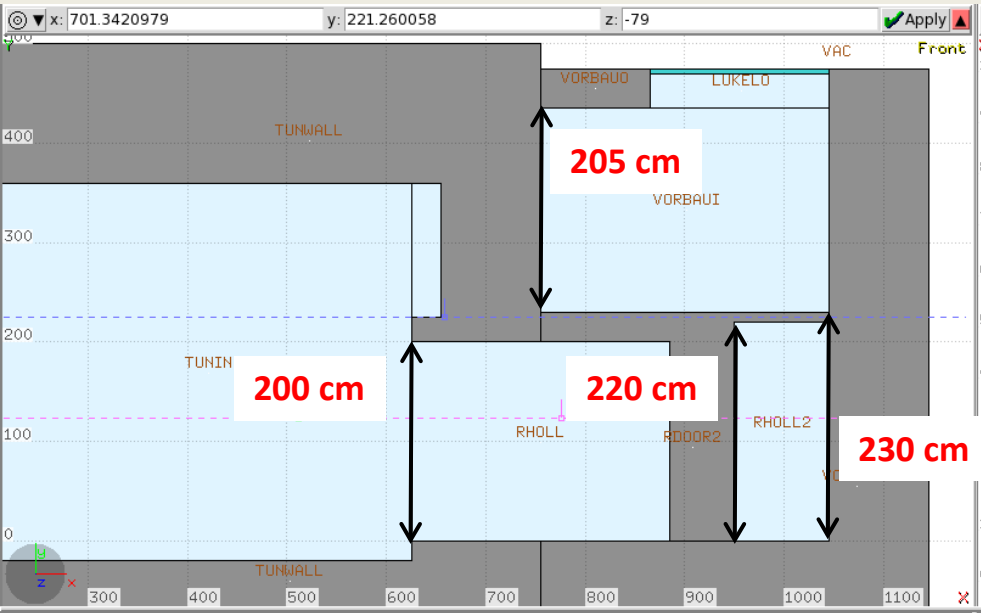

Space 1-1 With - Without
8,00E-04
6,00E-04
4,00E-04
2,00E-04
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness

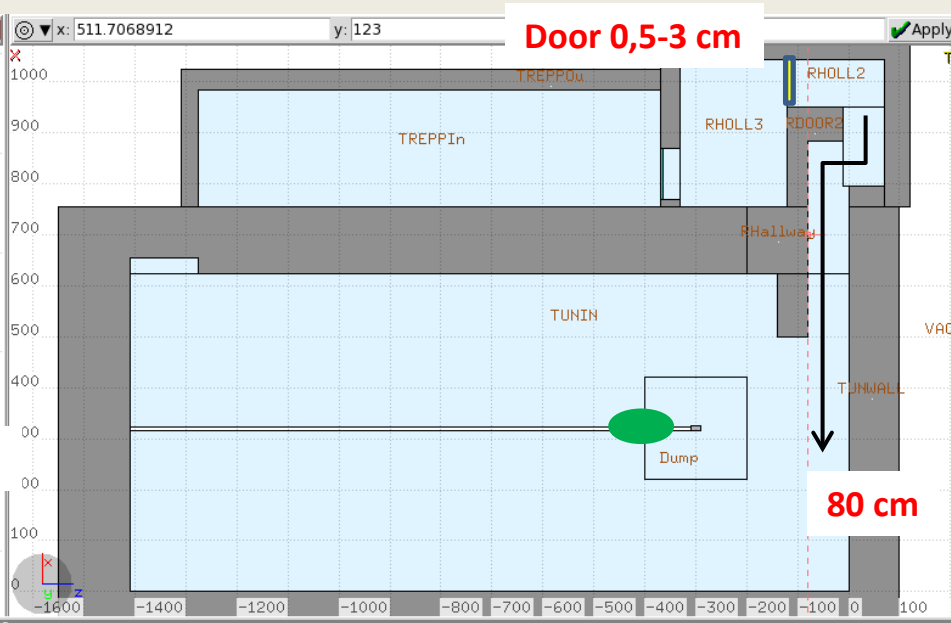

Space 1-1 With - Without
8,00E-04
6,00E-04
4,00E-04
2,00E-04
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness

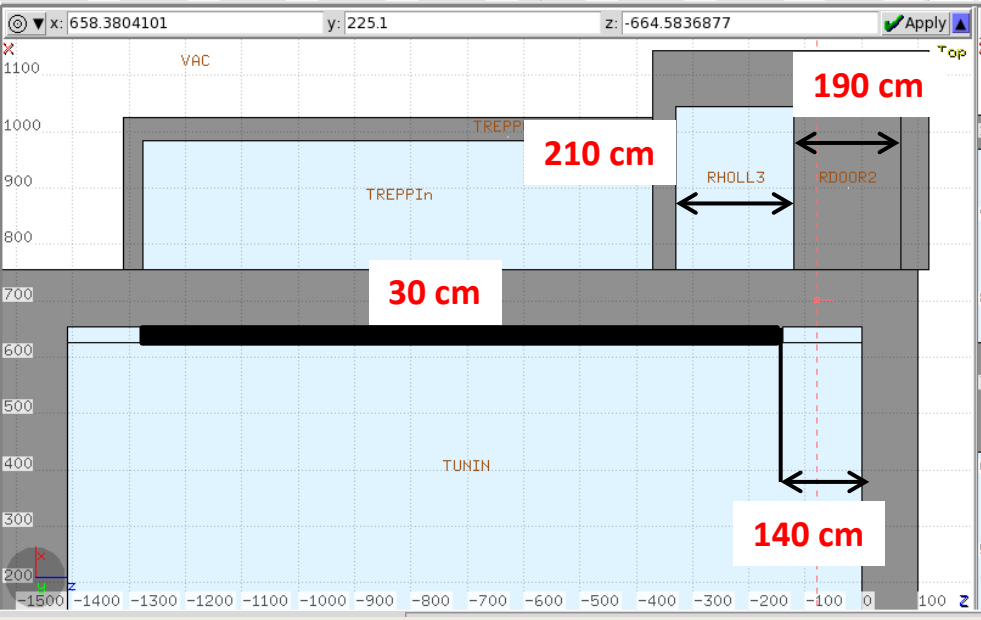

Space 1-2 With - Without
4,50E-04
3,60E-04
2,70E-04
1,80E-04
9,00E-05
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness

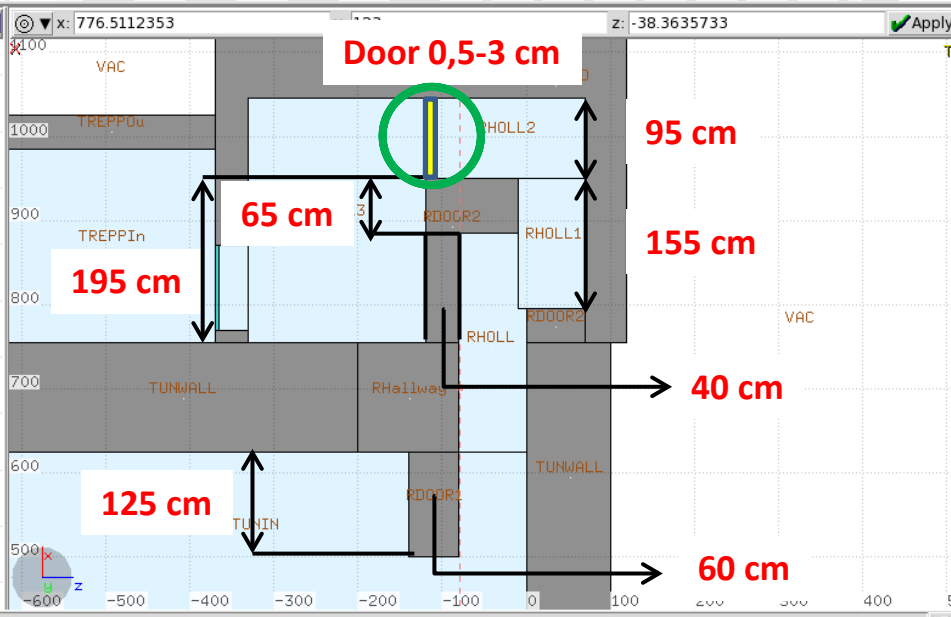

Space 1-2 With - Without
4,50E-04
3,60E-04
2,70E-04
1,80E-04
9,00E-05
0,00E+00
pSv per electron
30
35
40
45
50
55
60
65
Total Doors Thickness

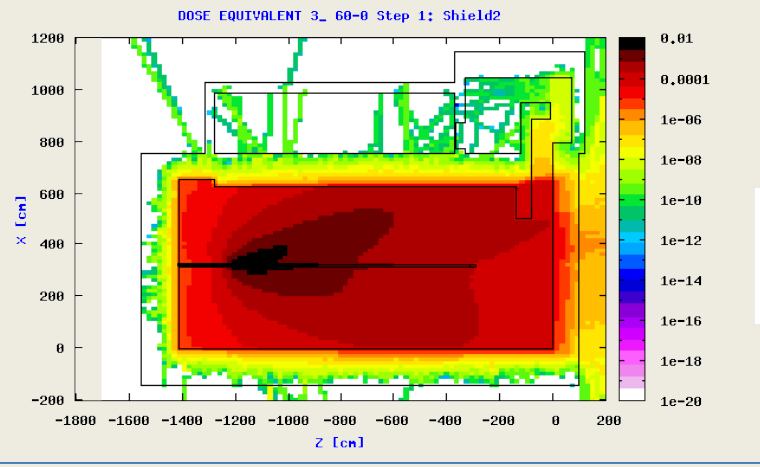
Design of Shielding 2-0





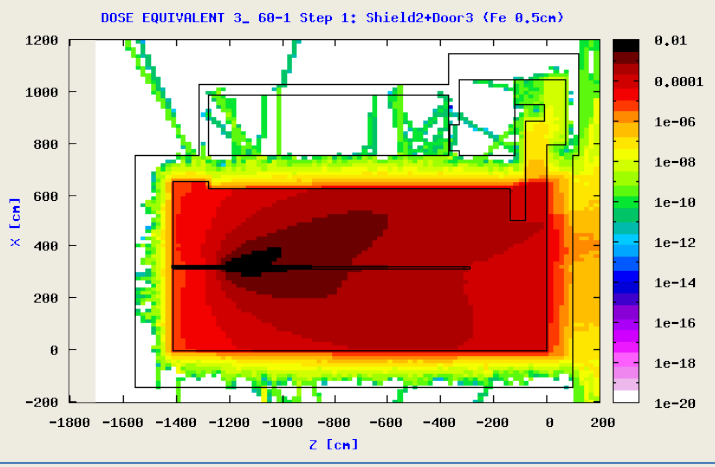






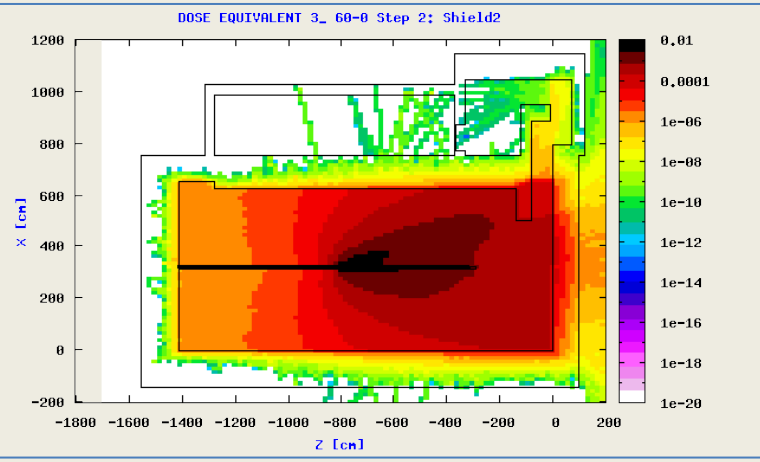
Step 1

Shield 2

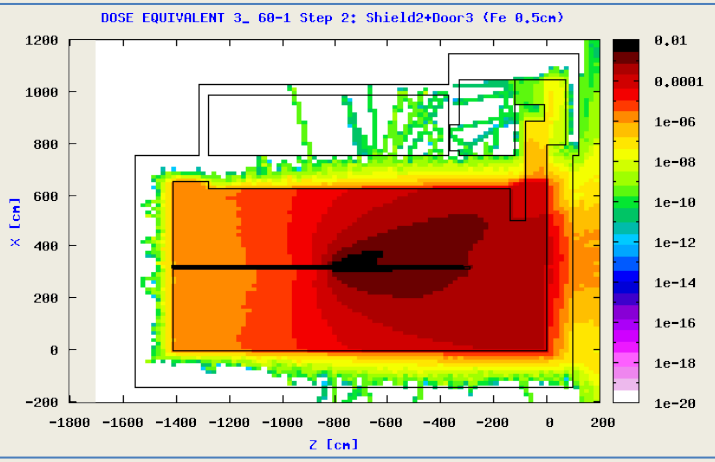


Step 1

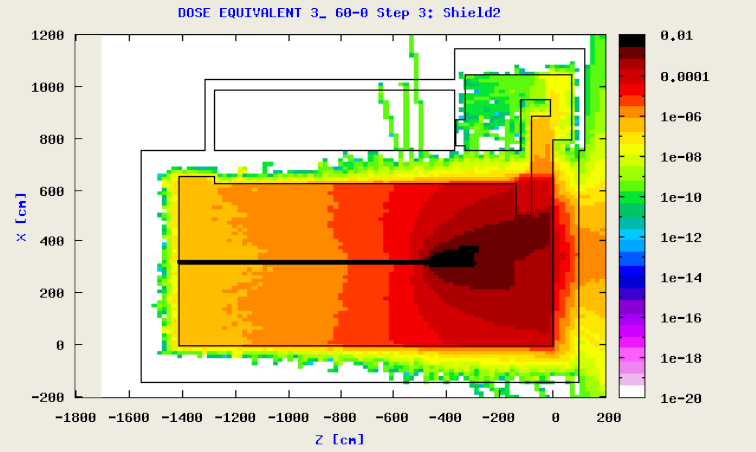
Shield 2+Door



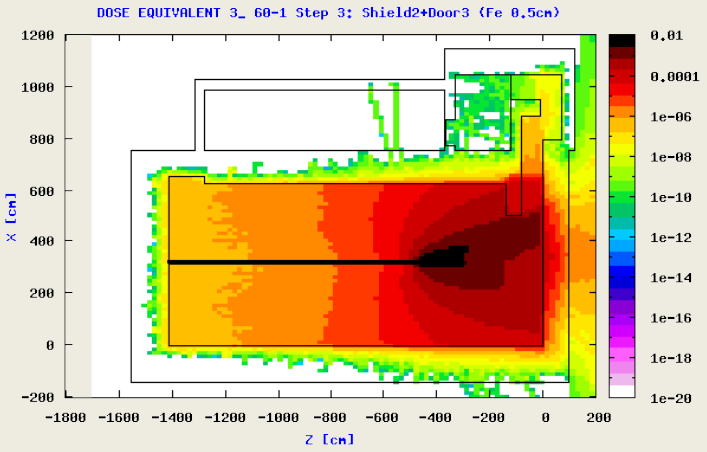
Step 2



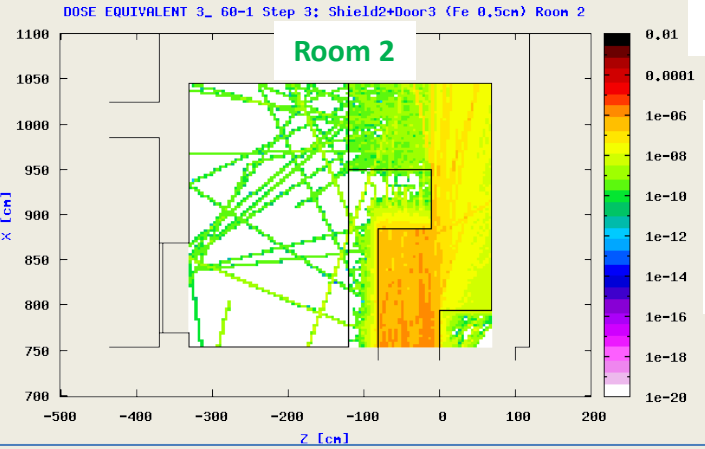
Step 2



Step 3

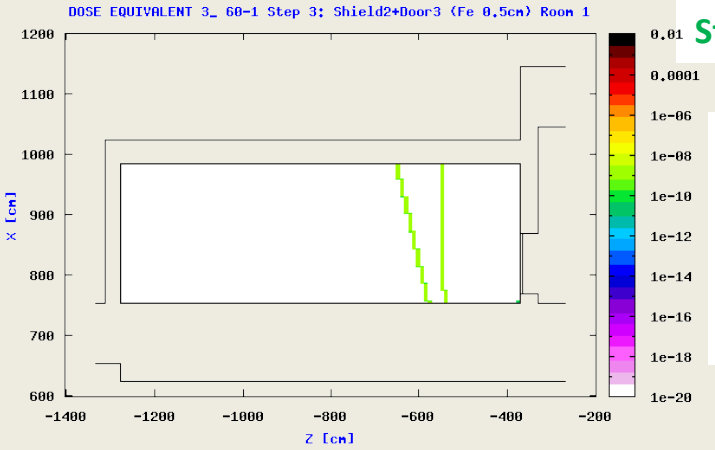


Step 3



Step 3: Room 2

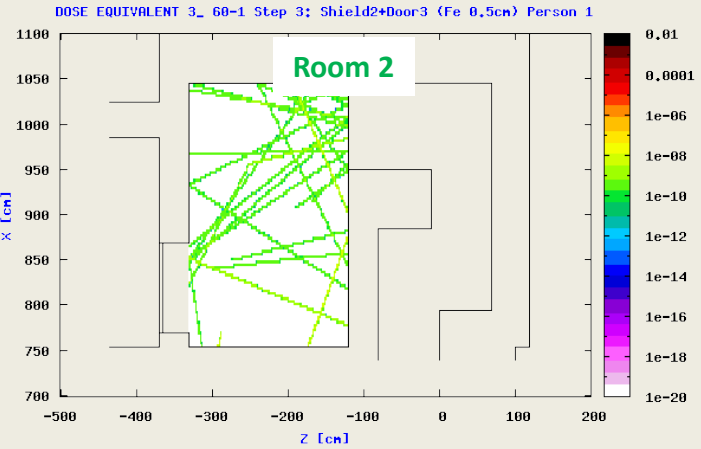
All: **2,72 pSv**
Elec: 1E-30
Phot: 2,72
Neu : 1E-30



Step 3: Room 1

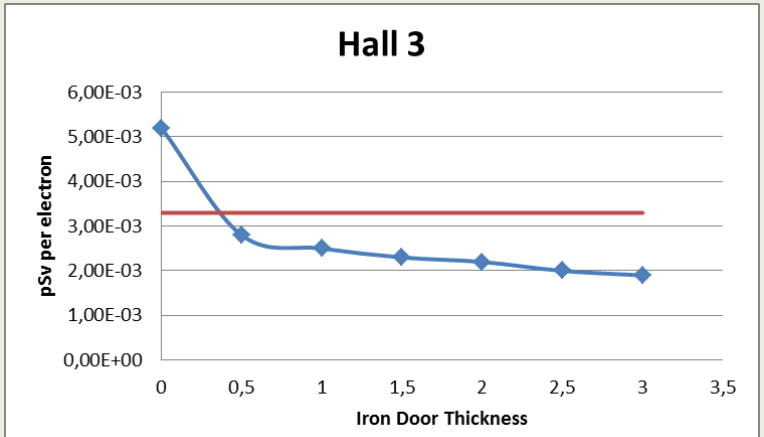
0,012 pSv/h

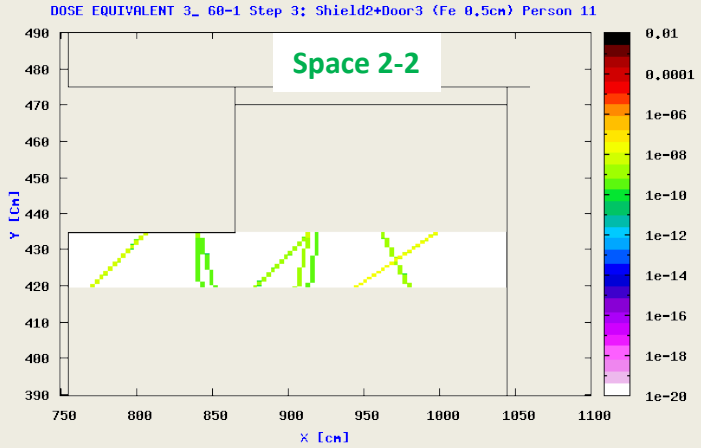
All: **0,0018 pSv**
Elec: 1E-30
Phot: 0,0027
Neu : 1E-30



0,0033 pSv

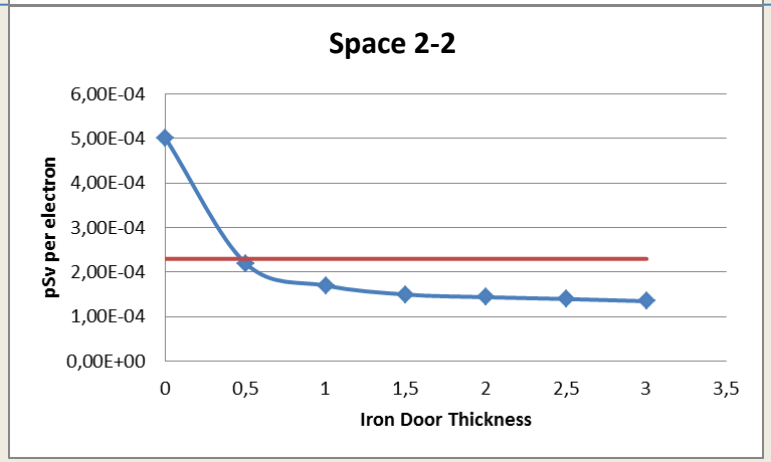
All: **0,0028 pSv**
Elec: 1E-30
Phot: 0,0028
Neu : 1E-30



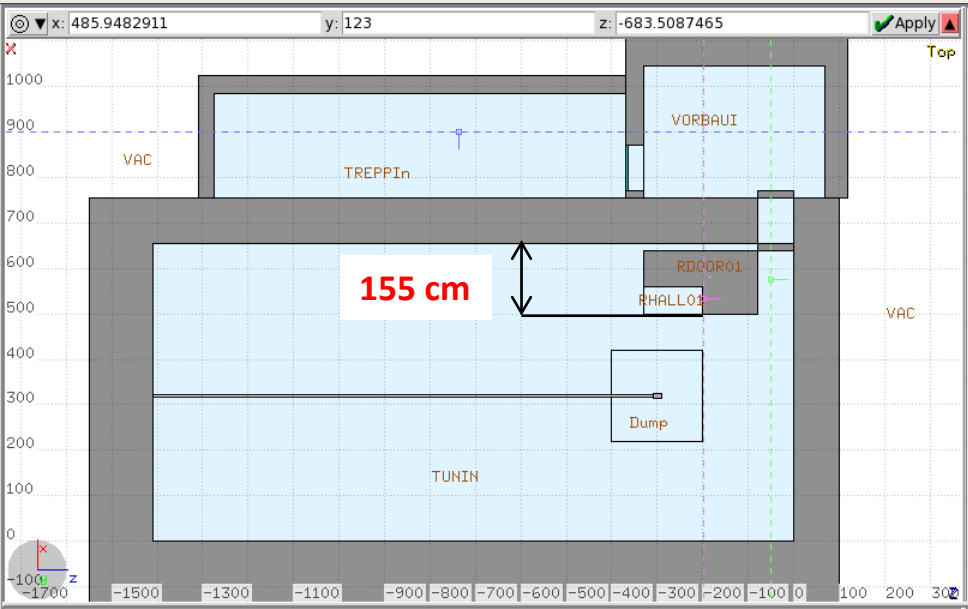


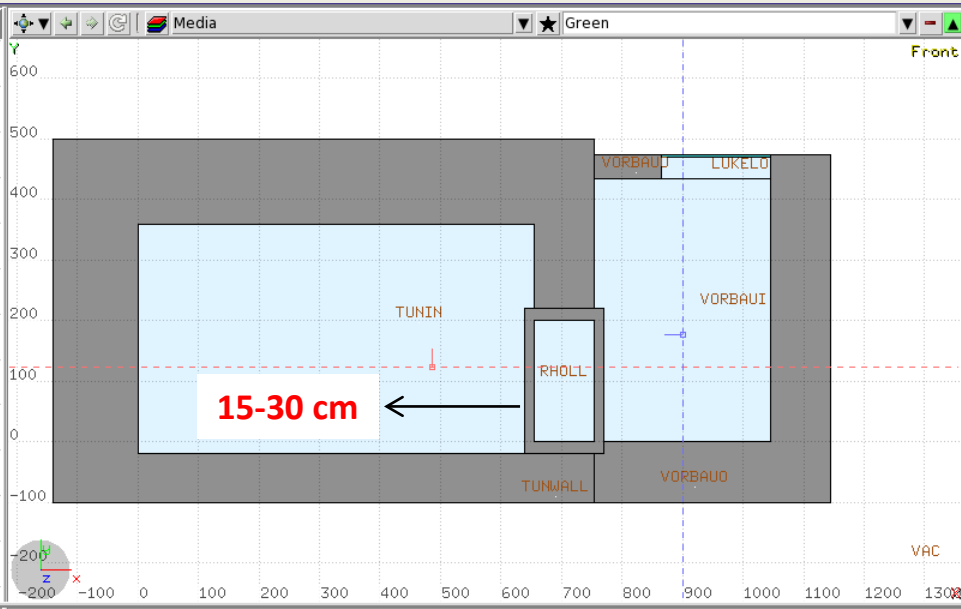
0,00023 pSv

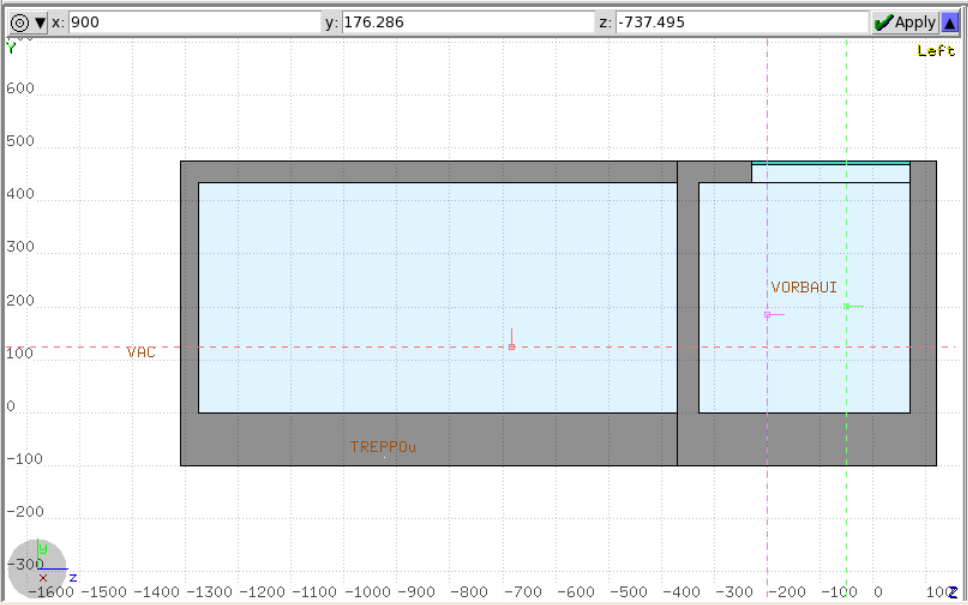
All: **0,00022**
Elec: 1E-30
Phot: 0,00022
Neu : 1E-30

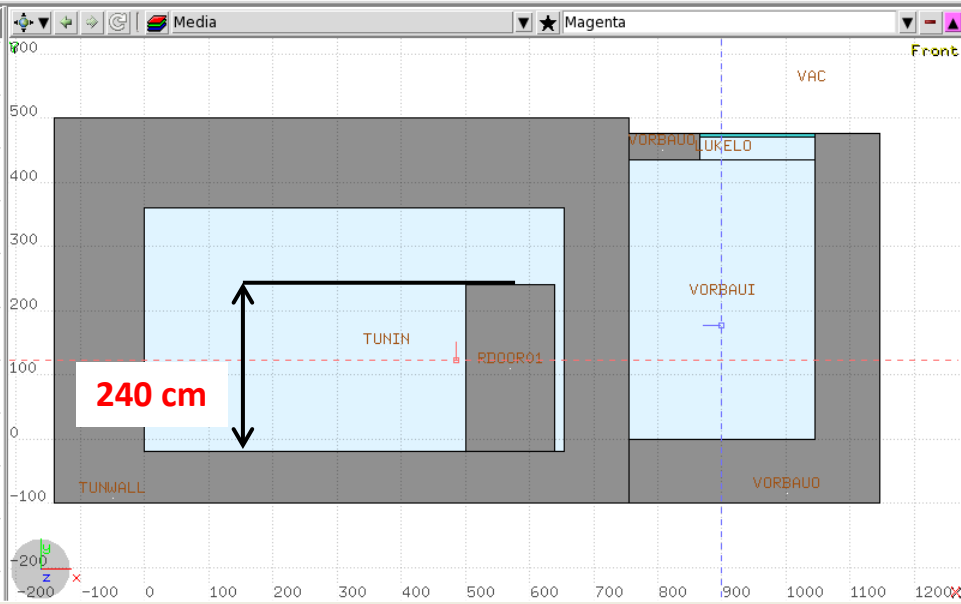


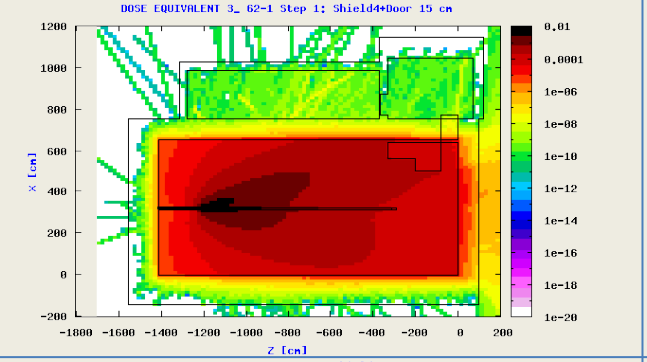
Design of Shielding 4-1

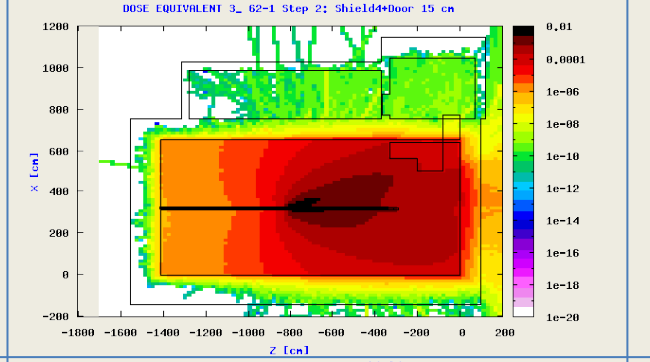


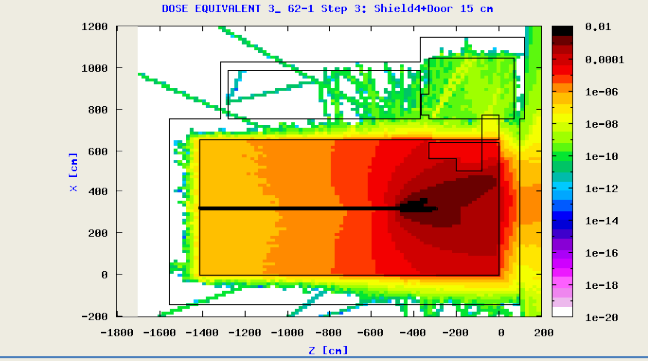


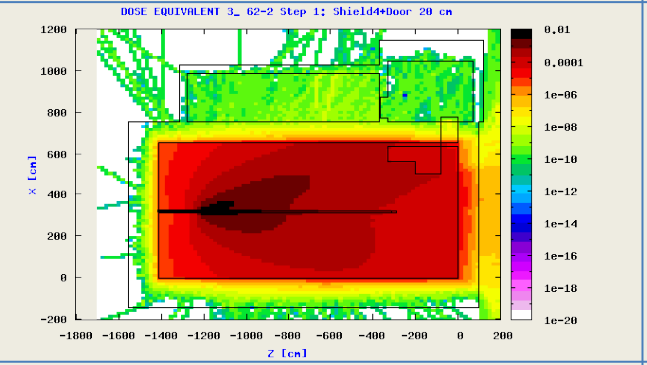


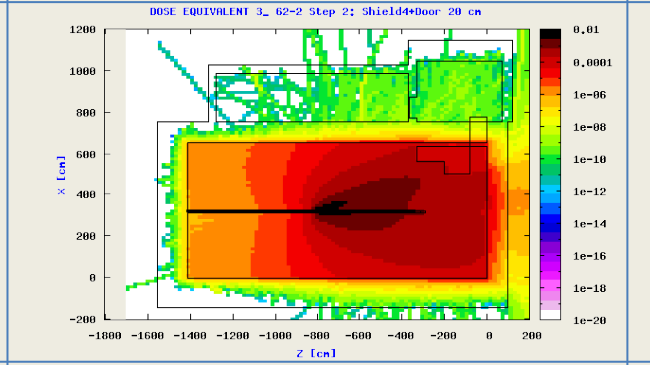


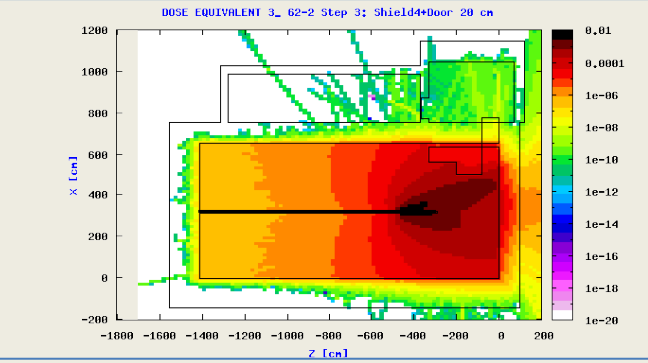

DOSE EQUIVALENT 3_ 62-1 Step 1: Shield4+Door 15 cm
X [cm]
Z [cm]

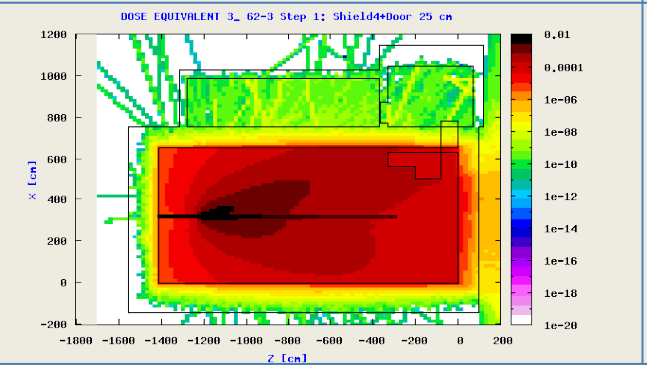

DOSE EQUIVALENT 3_ 62-1 Step 2: Shield4+Door 15 cm
X [cm]
Z [cm]

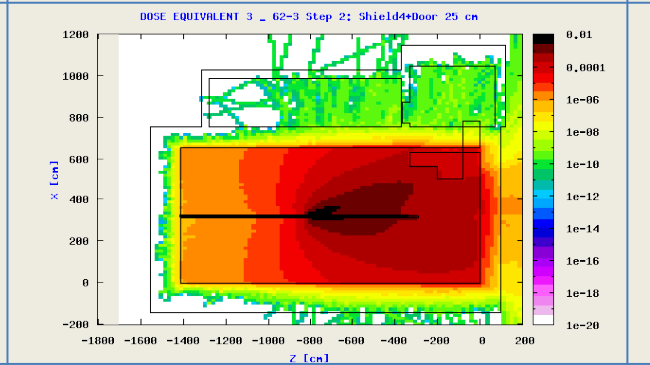

DOSE EQUIVALENT 3_ 62-1 Step 3: Shield4+Door 15 cm
X [cm]
Z [cm]

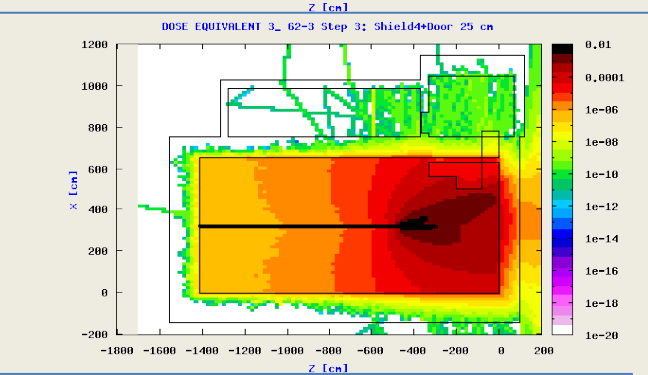

DOSE EQUIVALENT 3_ 62-2 Step 1: Shield4+Door 20 cm
X [cm]
Z [cm]

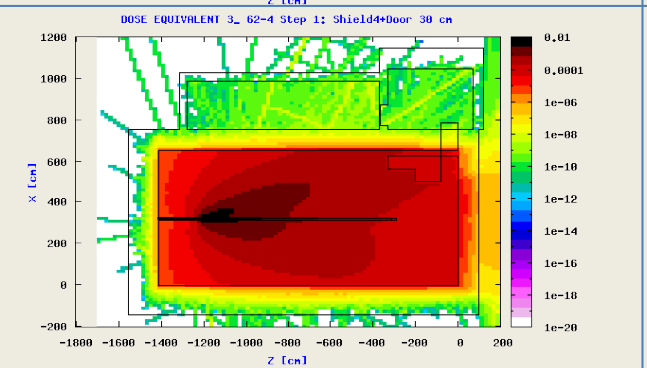

DOSE EQUIVALENT 3_ 62-2 Step 2: Shield4+Door 20 cm
X [cm]
Z [cm]

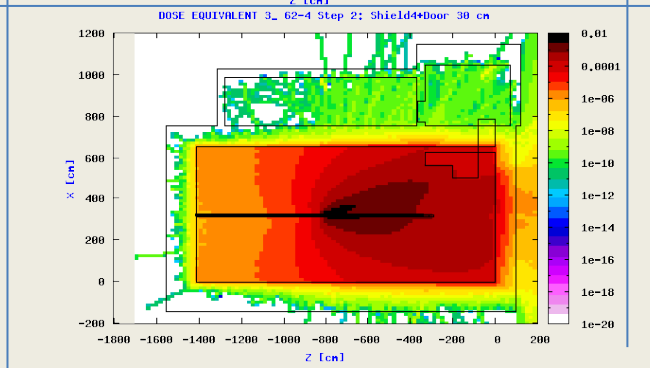

DOSE EQUIVALENT 3_ 62-2 Step 3: Shield4+Door 20 cm
X [cm]
Z [cm]

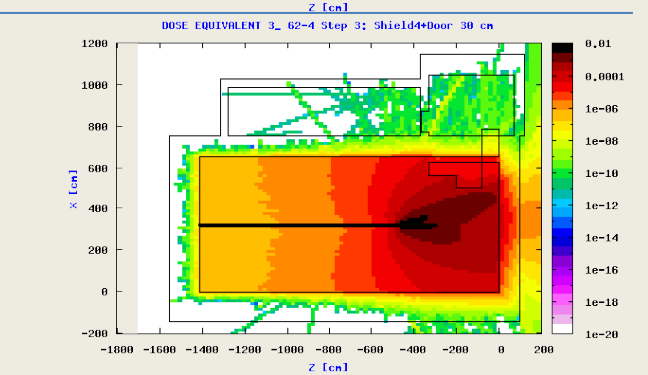

DOSE EQUIVALENT 3_ 62-3 Step 1: Shield4+Door 25 cm
X [cm]
Z [cm]

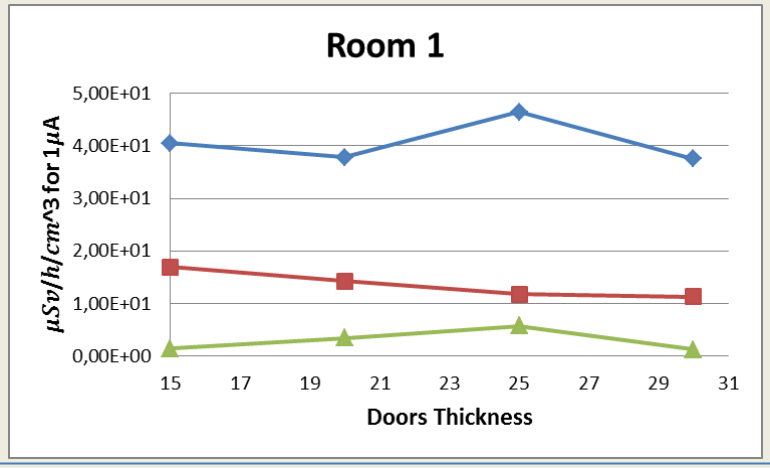

DOSE EQUIVALENT 3 _ 62-3 Step 2: Shield4+Door 25 cm
X [cm]
Z [cm]

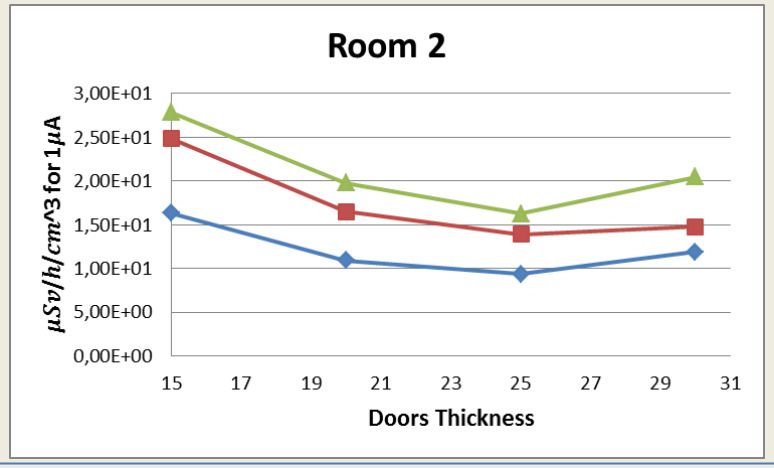

DOSE EQUIVALENT 3_ 62-3 Step 3: Shield4+Door 25 cm
X [cm]
Z [cm]

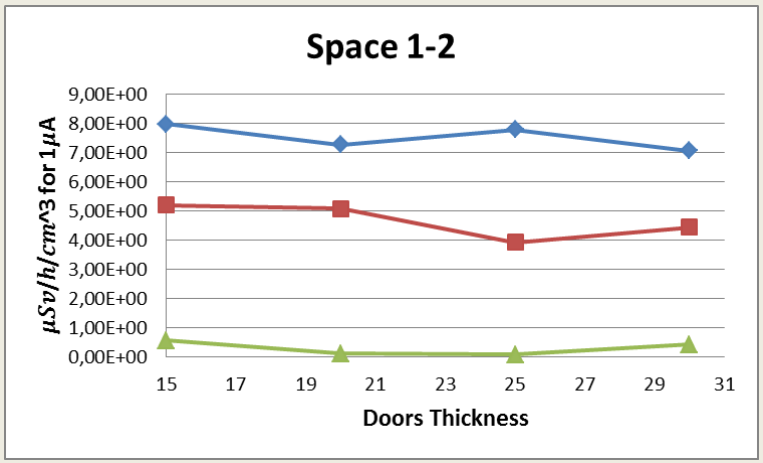

DOSE EQUIVALENT 3_ 62-4 Step 1: Shield4+Door 30 cm
X [cm]
Z [cm]

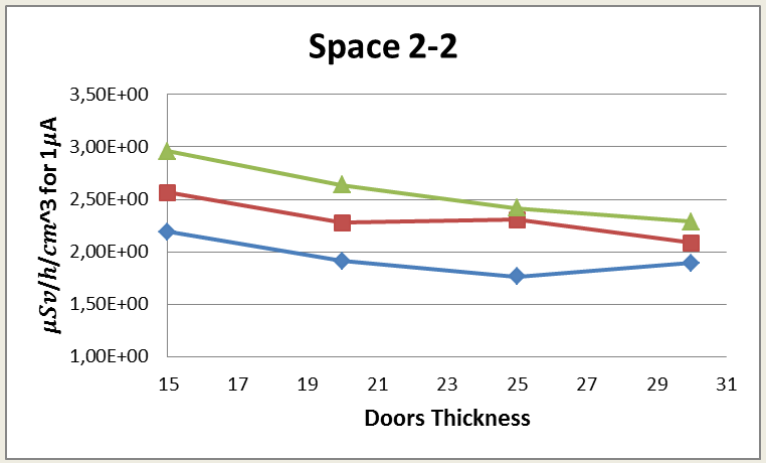

DOSE EQUIVALENT 3_ 62-4 Step 2: Shield4+Door 30 cm
X [cm]
Z [cm]

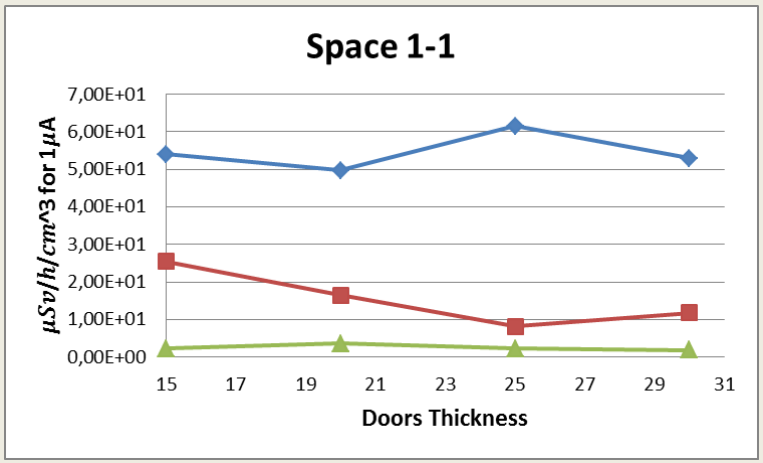

DOSE EQUIVALENT 3_ 62-4 Step 3: Shield4+Door 30 cm
X [cm]
Z [cm]

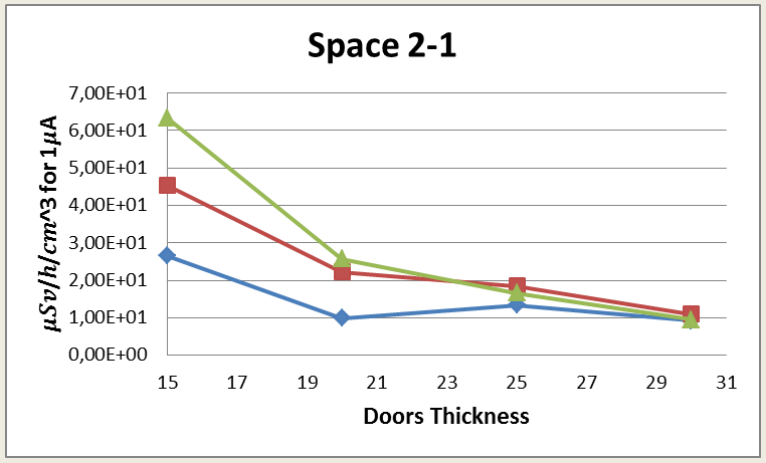

Room 1
5,00E+01
4,00E+01
3,00E+01
2,00E+01
1,00E+01
0,00E+00
μSv/h/cm^3 for 1μA
15 17 19 21 23 25 27 29 31
Doors Thickness


Room 2
3,00E+01
2,50E+01
2,00E+01
1,50E+01
1,00E+01
5,00E+00
0,00E+00
μSv/h/cm^3 for 1μA
15 17 19 21 23 25 27 29 31
Doors Thickness

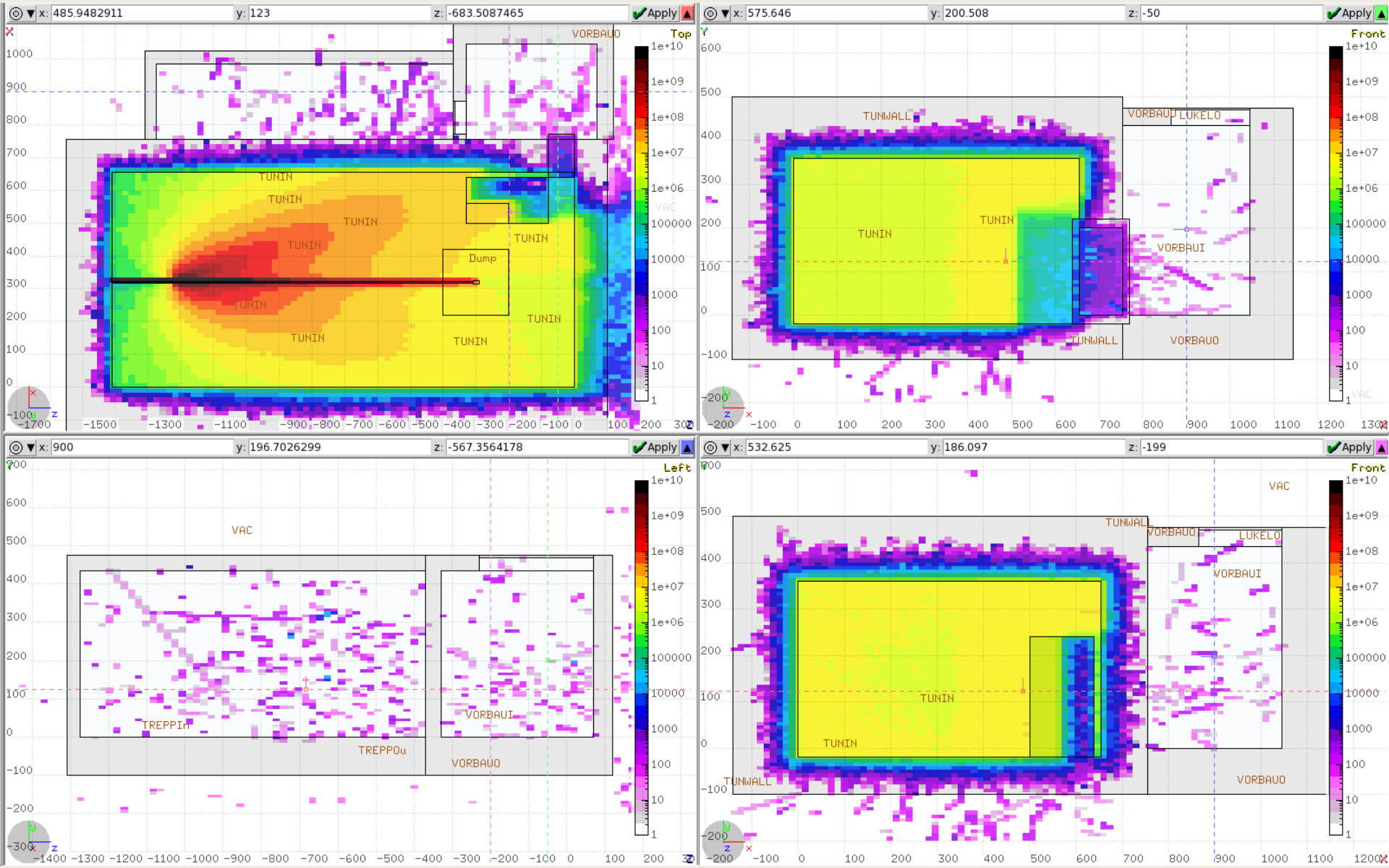

Space 1-2
9,00E+00
8,00E+00
7,00E+00
6,00E+00
5,00E+00
4,00E+00
3,00E+00
2,00E+00
1,00E+00
0,00E+00
μSv/h/cm^3 for 1μA
15 17 19 21 23 25 27 29 31
Doors Thickness


Space 2-2
3,50E+00
3,00E+00
2,50E+00
2,00E+00
1,50E+00
1,00E+00
μSv/h/cm^3 for 1μA
15 17 19 21 23 25 27 29 31
Doors Thickness

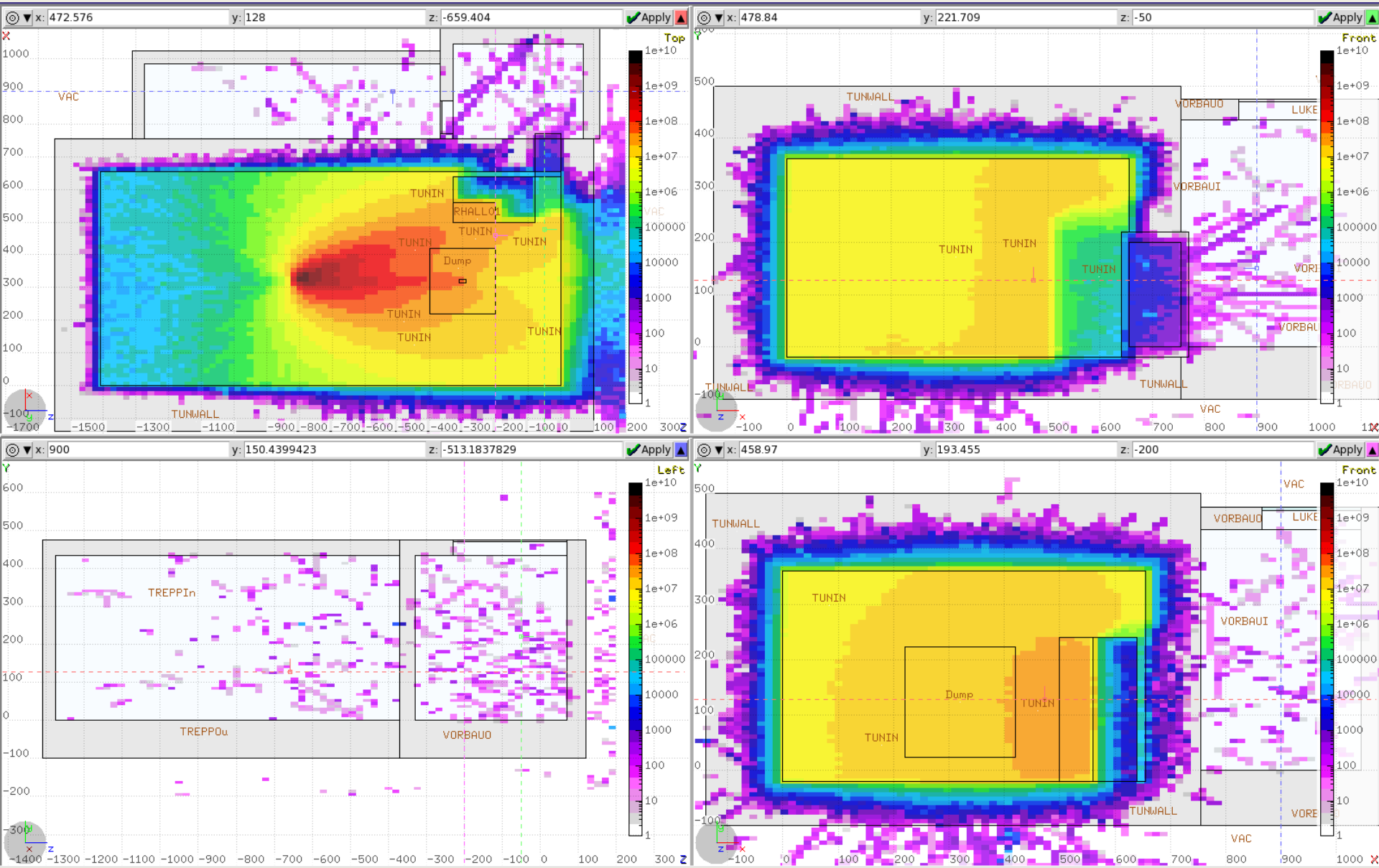

Space 1-1
7,00E+01
6,00E+01
5,00E+01
4,00E+01
3,00E+01
2,00E+01
1,00E+01
0,00E+00
μSv/h/cm^3 for 1μA
15 17 19 21 23 25 27 29 31
Doors Thickness


Space 2-1
7,00E+01
6,00E+01
5,00E+01
4,00E+01
3,00E+01
2,00E+01
1,00E+01
0,00E+00
μSv/h/cm^3 for 1μA
15 17 19 21 23 25 27 29 31
Doors Thickness

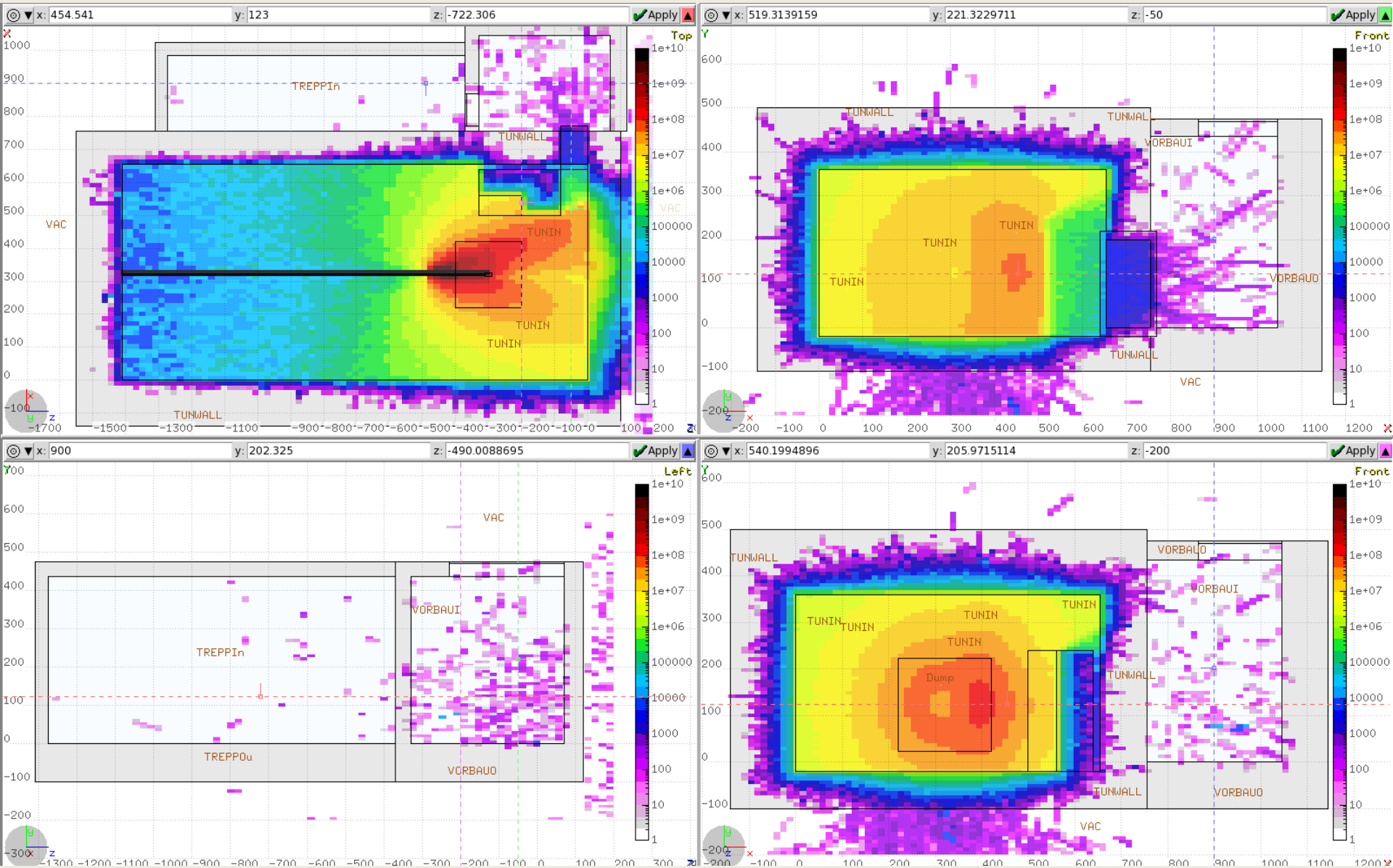
3_62-1 Step 1: Shield 4-1+ Door 15 cm



3_62-1 Step 2: Shield 4-1+ Door 15 cm



3_62-1 Step 3: Shield 4-1+ Door 15 cm



Equivalent Dose Distribution [pSv per electron]

Next Steps

- Improve simulation results using FLUKA custom routines.
  - Input the beam characteristics: energy spread, divergence, beam profile (x, y direction)
  - Repeat the simulation with the beam parameters
  - Compare the simulation results with the old one
  - Repeat the simulation with complex geometry
  - Analyzing data from mgdraw.f to find better types of shielding materials and thickness
  - Using routine source.f in input, adequate to read particle distribution provided by tracking simulations and correctly place it in the geometry.

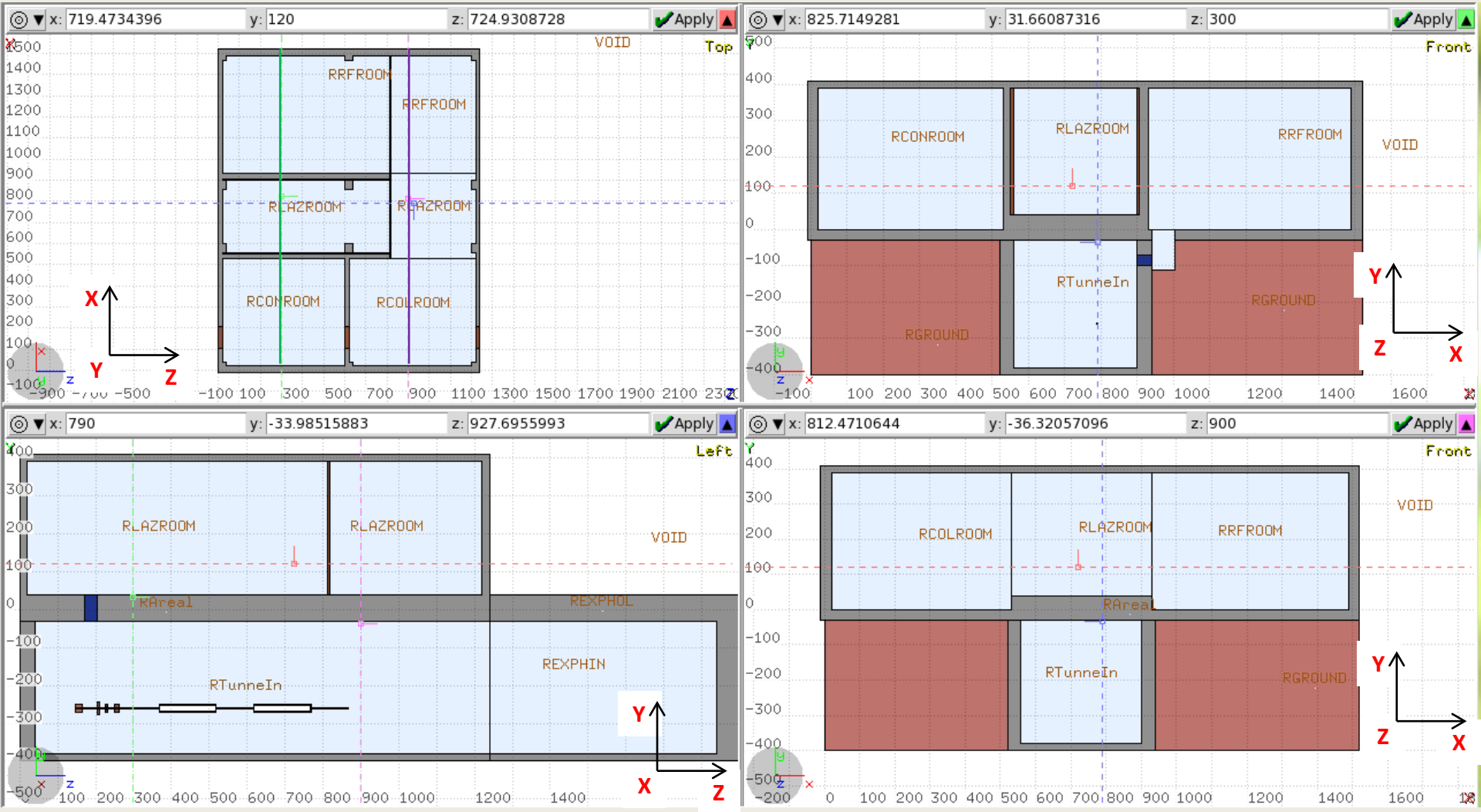
Conclusion

- For 1 μA beam a feasible section was found. For 75 μA (operation permission) this does not work
- Shielding 1-0: in order to have dose less than 3 **μ**Sv/h on ceiling of the room 2, 30 cm door with sandwich should be used.
- Shielding 1-1: only door 30 cm or 25 cm door with sandwich should be used.
- Shielding 2: the room 2 is not controlled area.

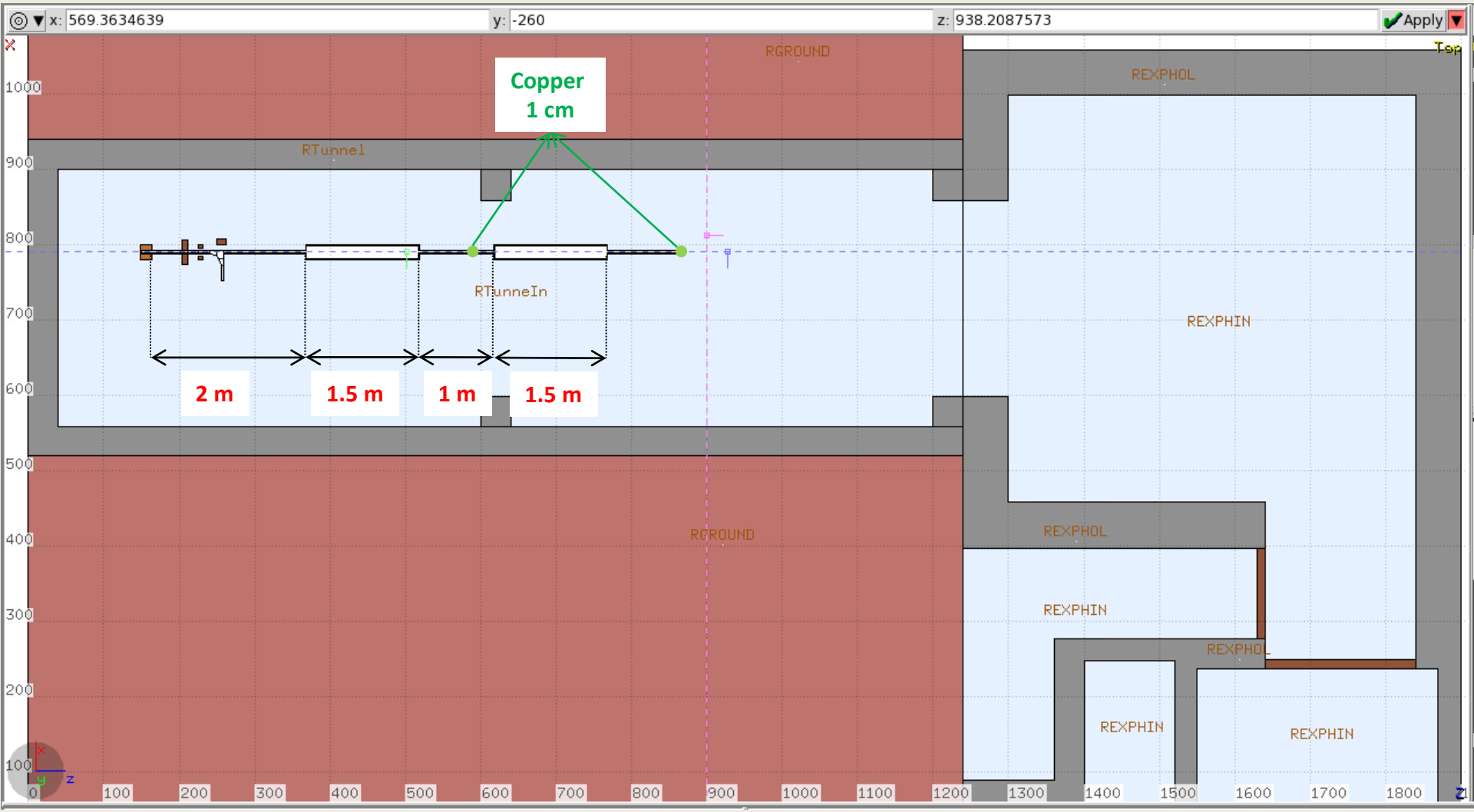
Alternatively

- Some area have to be declared as 'controlled area' with levels of 30-50 **μ**Sv/h during operation with 1 μA beams
- For higher beam current operation the dose levels have to be monitored

AREAL Geometry

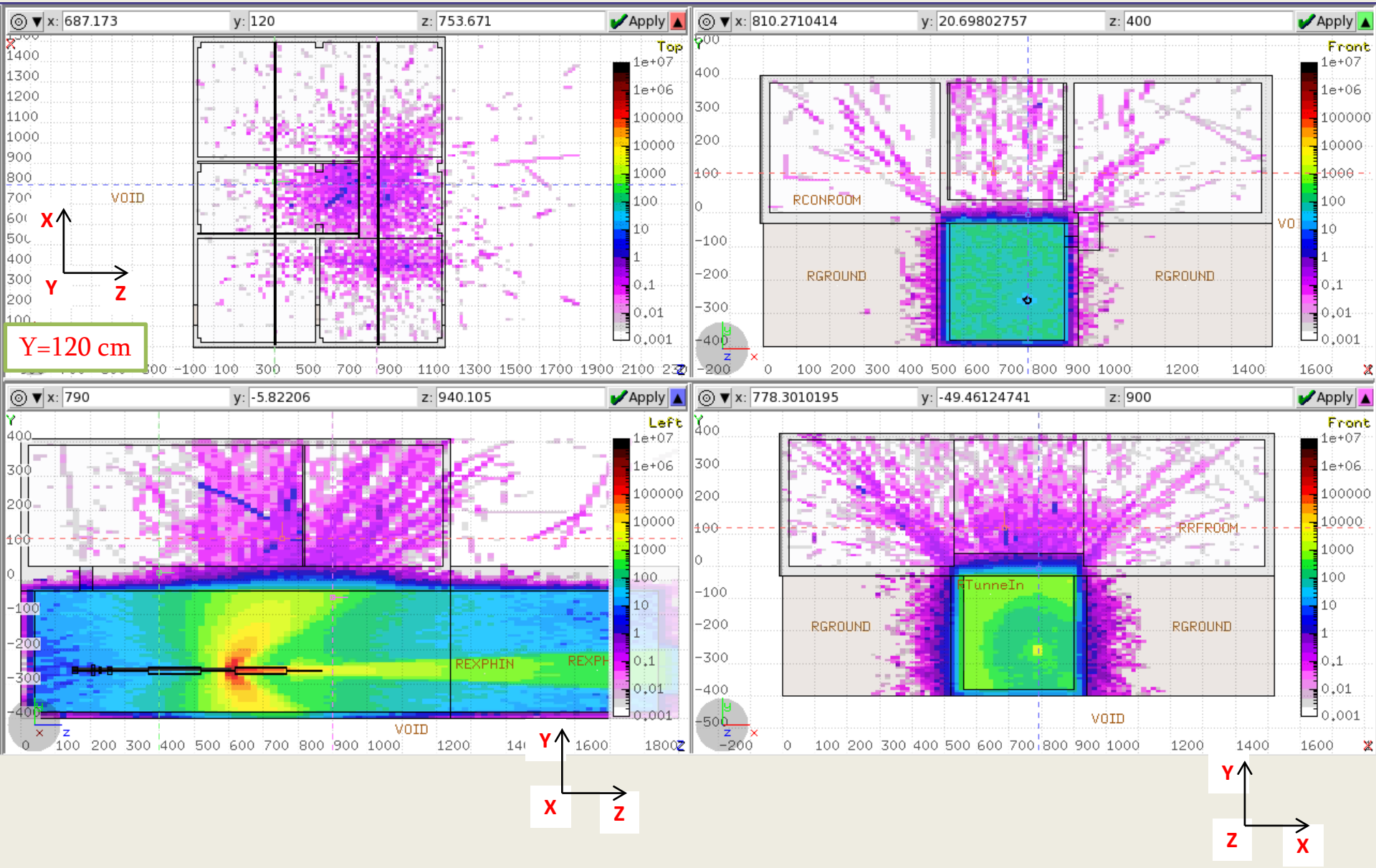


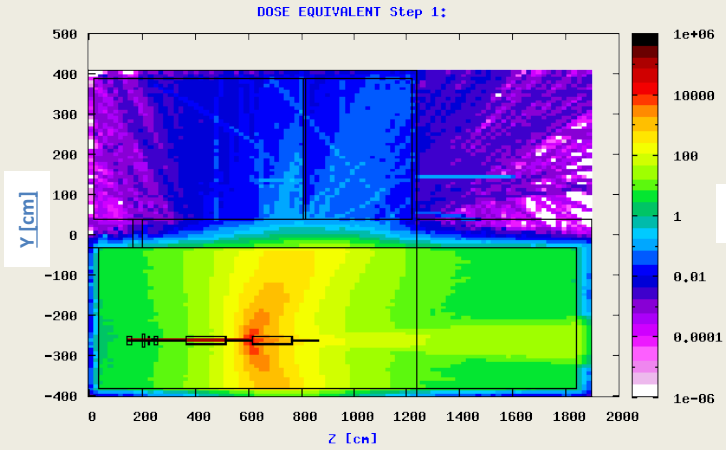
Define the Geometry



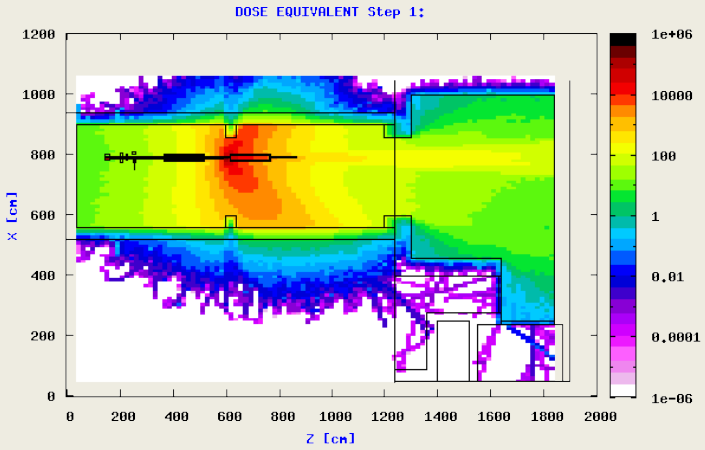
Equivalent Dose Distribution [μSv /h]

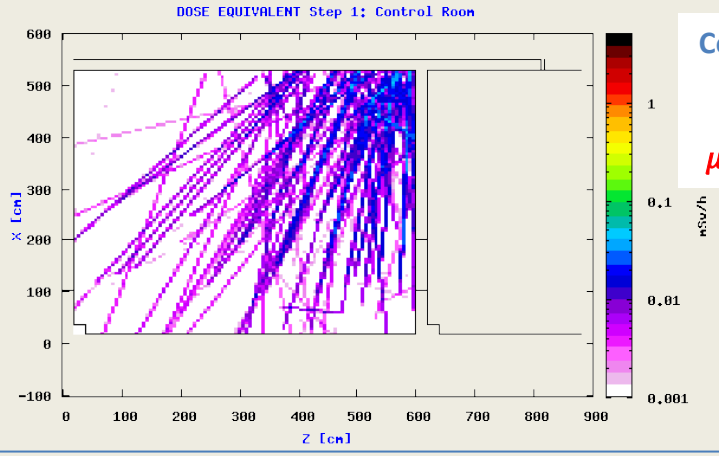
E = 25 MeV





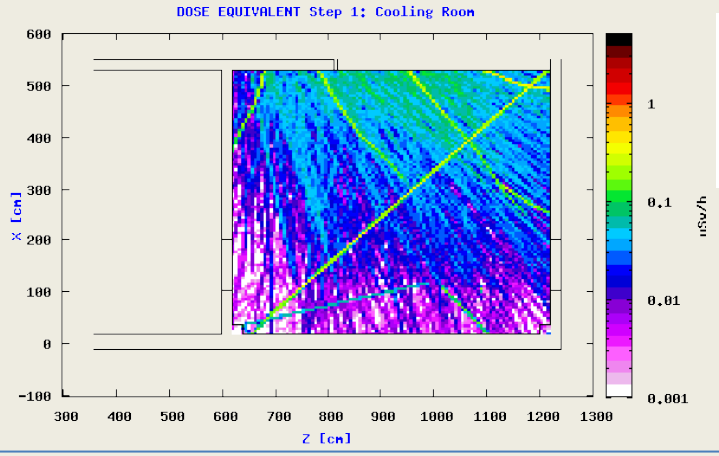
E= 25 MeV





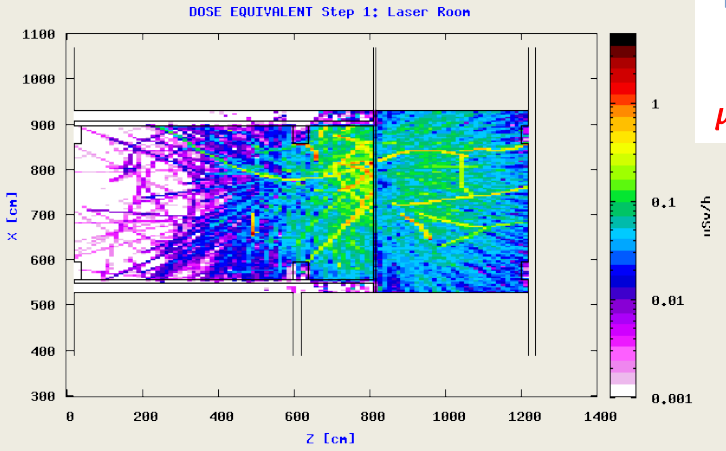
Control Room

0.0035
μSv/h/cm^3



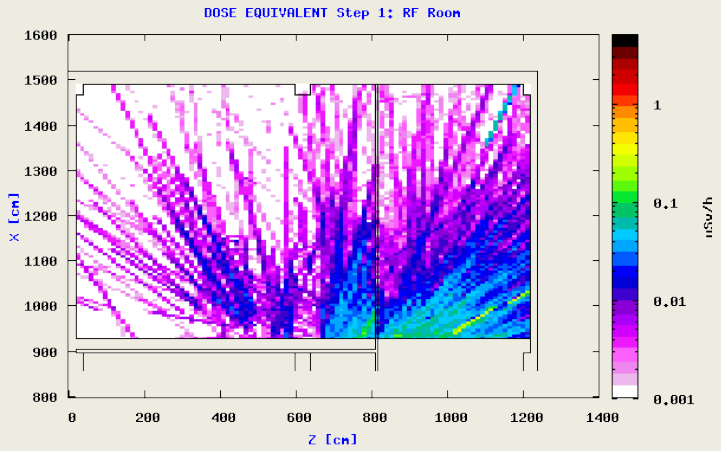
Cooling Room

0.031
μSv/h/cm^3



Laser Room

0.12
μSv/h/cm^3

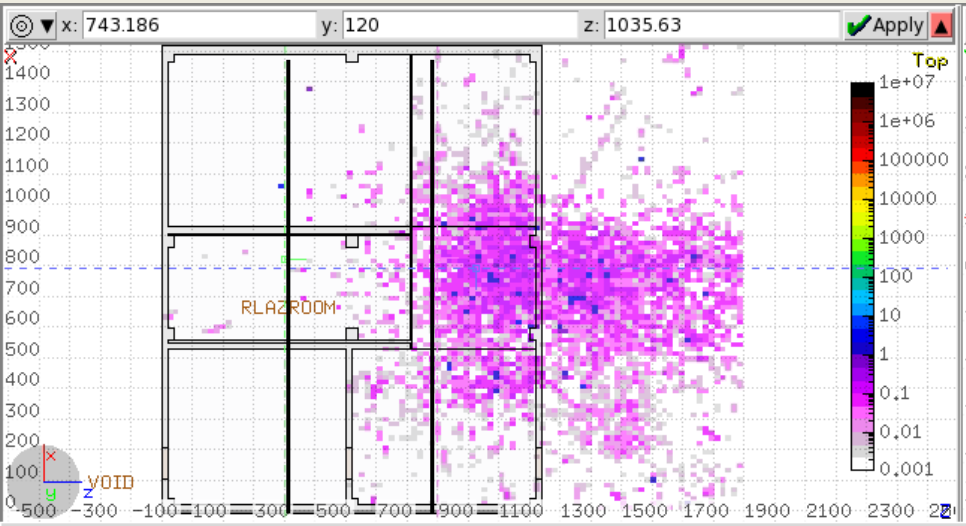


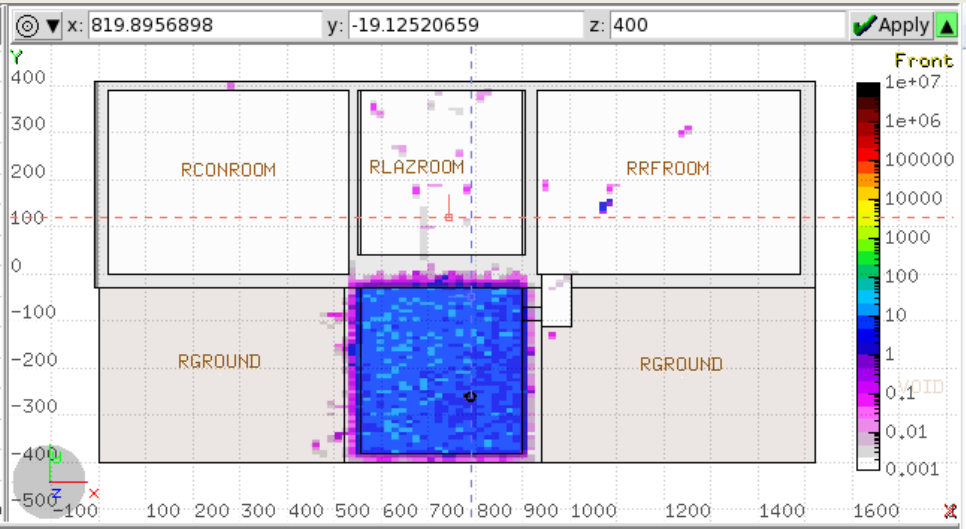
RF Room

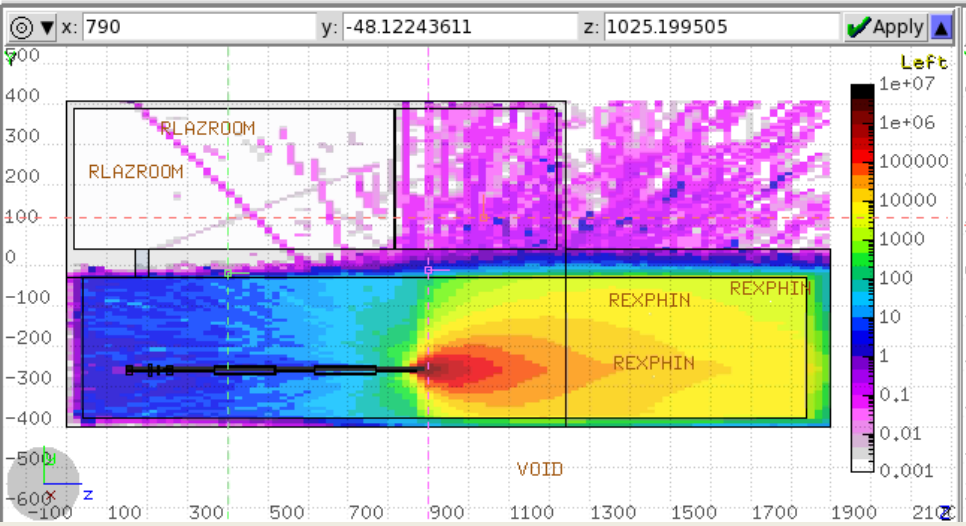
0.0081
μSv/h/cm^3

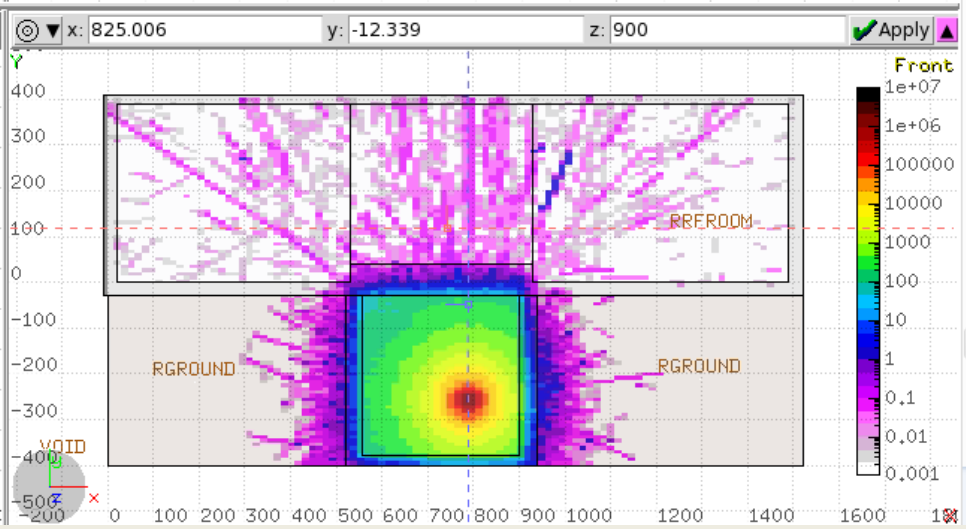
Equivalent Dose Distribution [μSv /h]

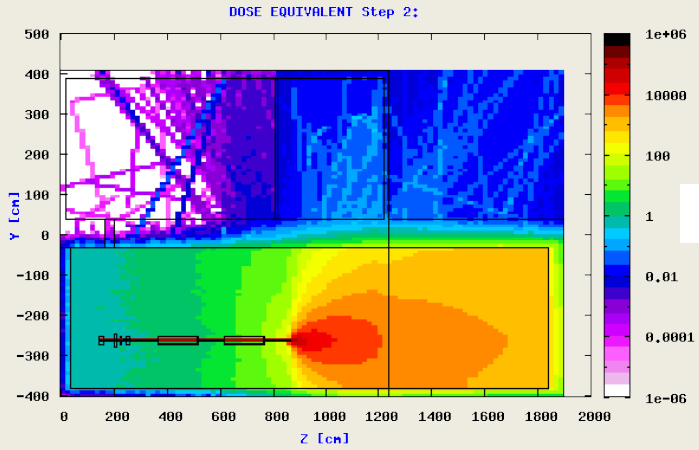
E = 50 MeV



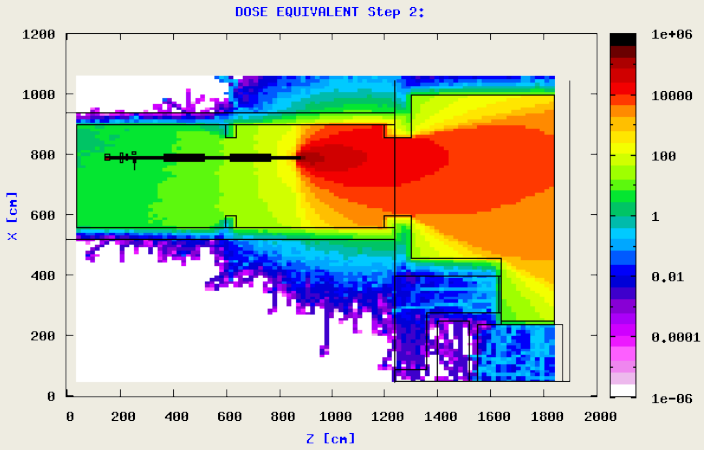


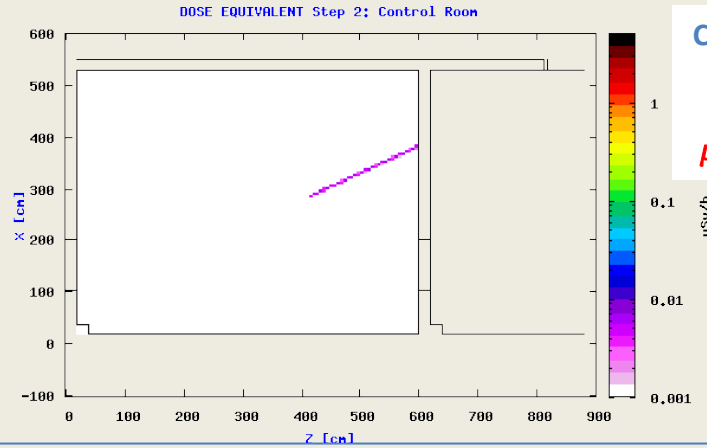






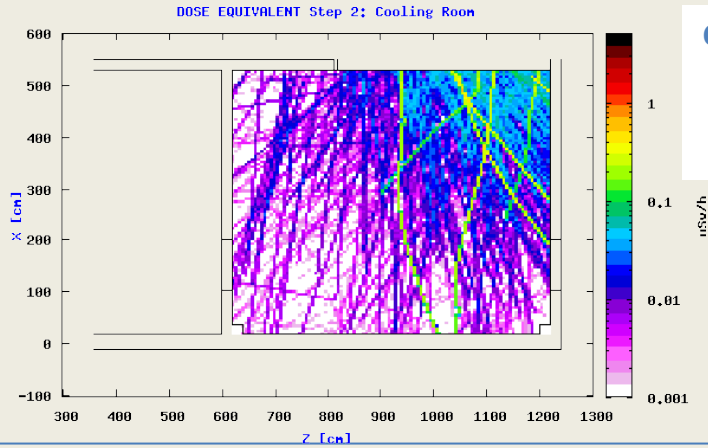
E= 50 MeV





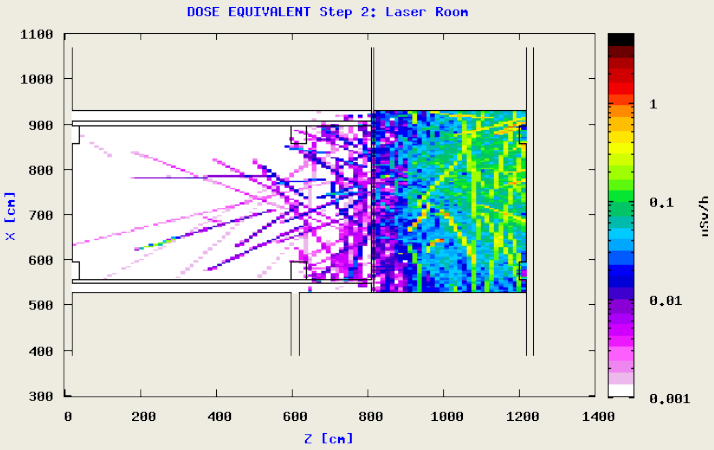
Control Room

2.29E-5
μSv/h/cm^3



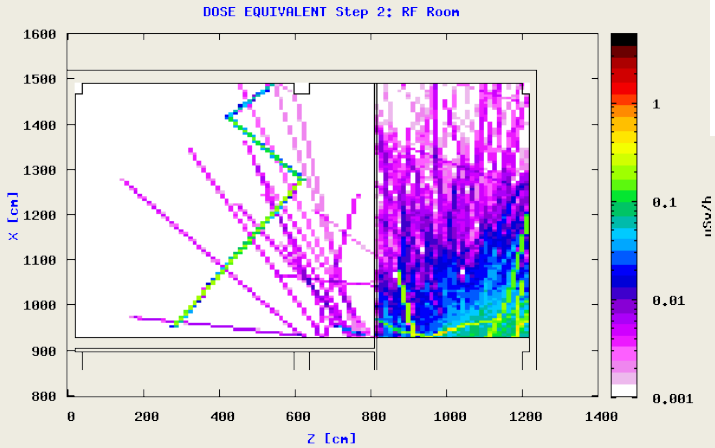
Cooling Room

0.018
μSv/h/cm^3



Laser Room

0.057
μSv/h/cm^3



RF Room

0.0092
μSv/h/cm^3

Thank You for Attention !