Get ready for Krakatit

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Abstract

Our task at ELI Beamlines was to design a simple shielding against ionizing radiation from three different sources - 137-Cs, 241-Am and 60-Co. First, we made this shielding in lab from materials we were given (cuboid from concrete, four steel cylinders and two lead blocks) and measured the ambient dose equivalent where needed with Geiger-Müller counter. Then we used GUI Flair for FLUKA simulation based on Monte Carlo method and plotted graphs of ambient dose equivalent as a function of its position in space. Our results match with our measurement.

1 Introduction

In case of working with a source of ionizing radiation, you have to be protected from it, so it does not cause you any harm. The rule of acting if using source of ionizing radiation is called ALARA, which says that your irradiation should be As Low As Reasonably Achievable. Three basic aspects which have influence on the amount of your irradiation are time, distance and shielding. But the only one we must influence before the work with the source of ionizing radiation is shielding. Therefore, we must design the best shielding to protect not only people, but also electronics, because ionizing radiation can also influence the way the work.

ELI Beamlines is a research centre located in Dolní Břežany which aspires to install and run the worlds most intense laser system. It is supposed that this can push the boundaries of human knowledge in astrophysics, biomedical sciences, nanotechnologies etc. Krakatit is going to be a laser with the biggest power in the world, 10 PW. This laser will be used to produce ionizing radiation so there must be shielding designed.

2 Experiment

There is no laser at ELI working yet, so we used a radioactive source of ionizing radiation for our experiment. Our task was to design a simple shielding against this radiation. Then we measured the ambient dose equivalent where needed and simulated this situation with Monte Carlo code FLUKA.

2.1 Quantities

Strength of a radioactive source is described by activity, which is defined as

$$A = N/t \quad [Bq] \tag{1}$$

where N is a number of decayed nuclei per time t. However, for evaluating how much an object has been irradiated, we use another quantity - dose - which is defined as

$$D = \varepsilon/m \quad [Gy] \tag{2}$$

where ε is energy deposited in mass m. The problem with it is that different types of radiation causes different level of damage to human tissues. Therefore, we use another quantity called effective dose

$$E = w_T \cdot w_R \cdot D_{R,T} \quad [Sv] \tag{3}$$

where w_R is the radiation weighting factor and w_T tissue radiation weighting factor. For γ rays we define

$$w_R = 1 \tag{4}$$

Effective dose describes how much have you been endangered by irradiation. Since this quantity cannot be measured by detectors, we define ambient dose equivalent rate H^* as "the effective dose you would get by standing at the place where detector is per one hour".

2.2 Results

x	y	H* Cs - sim.	meas.	H* Am - sim.	meas.	H* Co - sim.	meas.
10	0	2,52	2,88	3,64	1,00	11,72	18,51
20	0	0,71	0,97	1,04	0,25	3,33	5,58
30	0	0,32	0,59	0,45	0,14	1,56	3,73
5	-20	0,61	0,54	0,42	0,12	3,20	3,68
5	20	0,56	0,48	0,41	0,11	2,88	3,58
40	0	0,17	0,27	0,27	0,08	0,88	2,50
-20	0	0,26	0,26	0,23	0,07	1,63	2,28
-30	0	0,11	0,23	0,09	0,06	0,69	1,30
35	-20	0,19	0,23	0,27	0,05	3,20	1,28
35	20	0,18	0,21	0,27	0,04	0,88	1,27
-40	0	0,07	0,20	0,05	0,03	0,40	0,54
-40	-20	0,04	0,13	0,03	0,01	0,71	0,39
-40	20	0,04	0,11	0,03	0,00	0,72	0,40

Table 1: This table shows the difference between measured and simulated ambient dose equivalent as a function of position in space.

At figures below, you can see distribution of ambient dose equivalent on the table in lab, which we got from our FLUKA simulation.

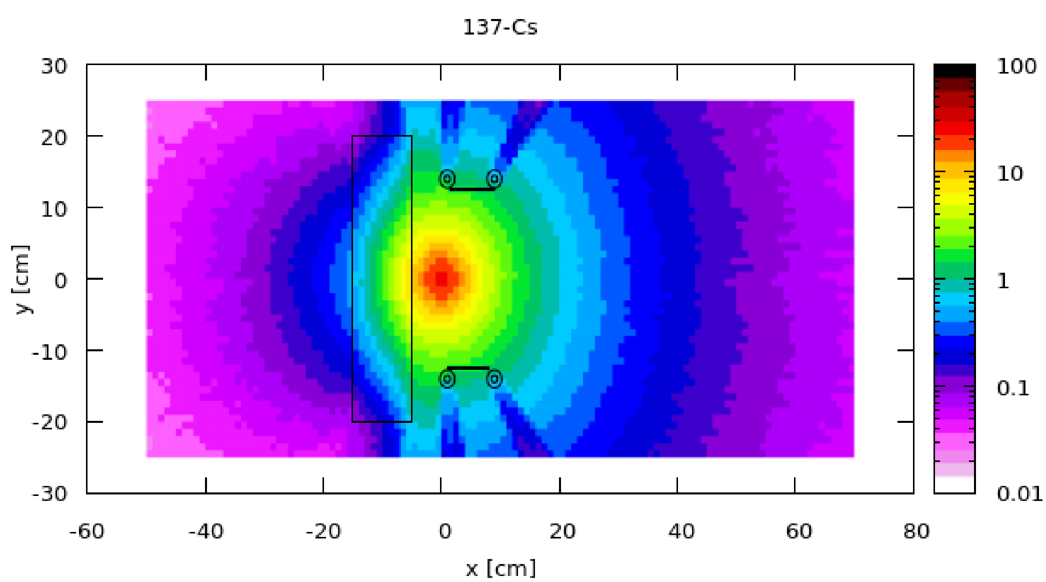

Figure 1: 2D distribution of ambient dose equivalent as a function of position in space for 137-Cs

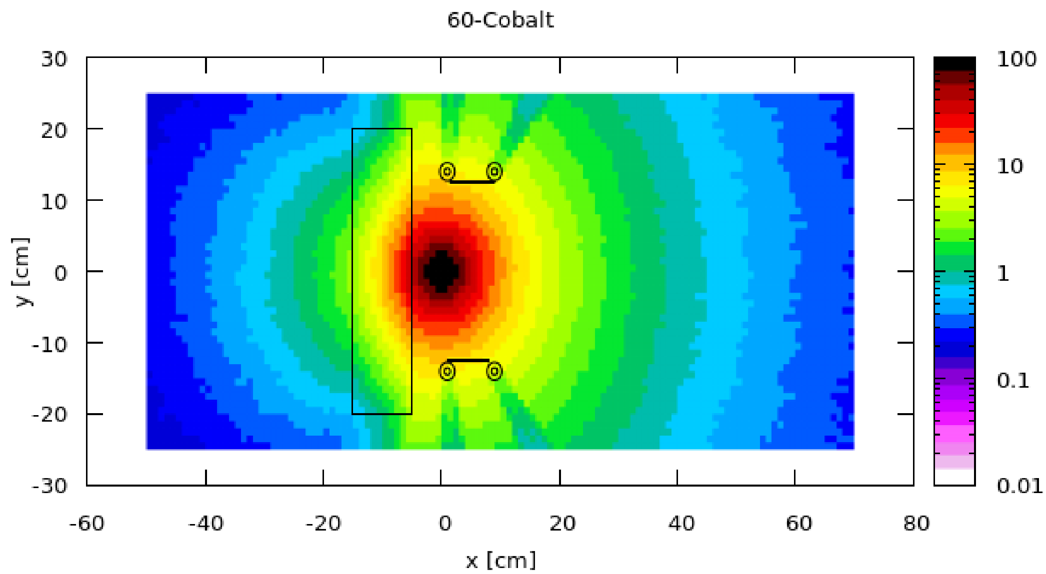

Figure 2: 2D distribution of ambient dose equivalent as a function of position in space for 60-Co

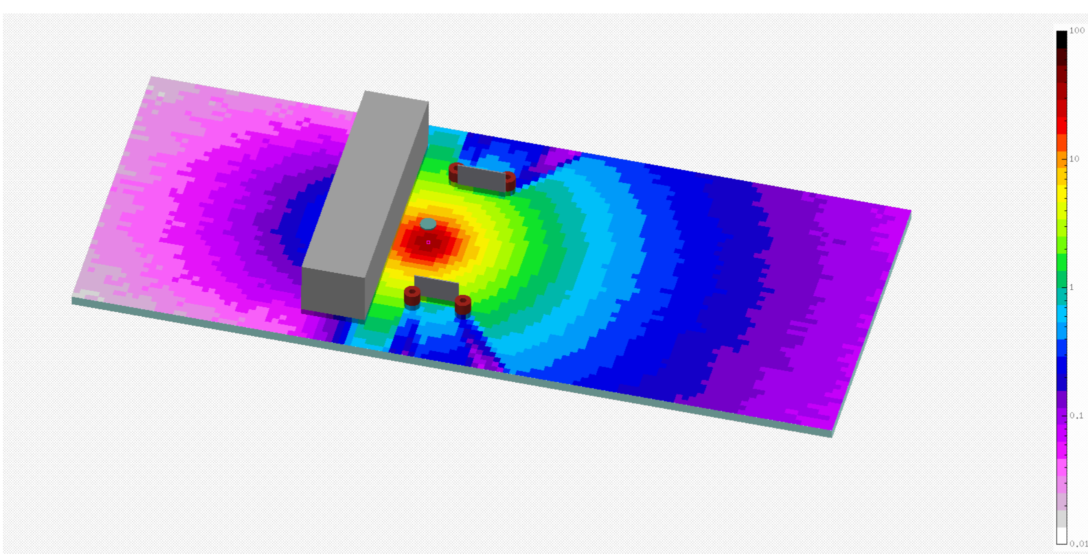

Figure 3: 3D distribution of ambient dose equivalent as a function of position in space for 241-Am

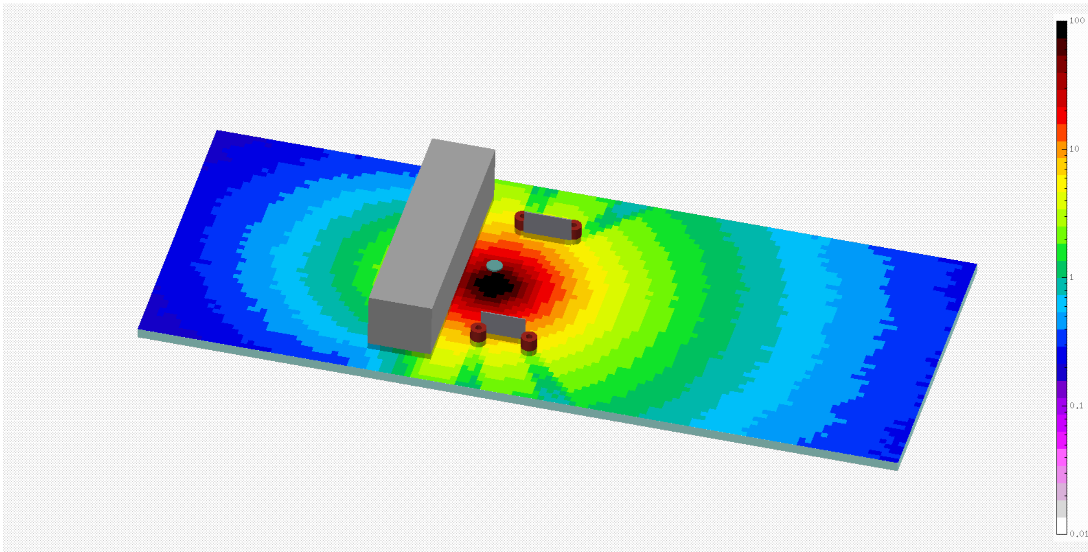

Figure 4: 3D distribution of ambient dose equivalent as a function of position in space for 60-Co

2.3 Discusion

From the results we obtained it can be seen that radiation decreases with distance. It is also obvious that concrete cuboid and the other parts of our shielding attenuate the ambient dose equivalent.

For 137-Cs, our measured results match with the simulated ones. The small difference can be caused by statistical fluctuation of detected particles.

For 241-Am, our measured results do not match at all, because the low energies of emitted photons, which did not reach the active volume of the detector.

For 60-Co, our measured and simulated results match, although there is a small difference caused by statistical fluctuation of detected particles.

Our shielding was designed for 137-Cs, which means that for 241-Am, it would be enough to use less material and on the other hand, it would have to be modified for 60-Co to fulfill the requirements.

3 Conclusion

We measured the ambient dose equivalent with Geiger-Müller counter and simulated this distribution with GUI Flair. We compared the amount of ambient dose equivalent as a function of its position in space from the simulation and measurement. Our results match with our measurement, so we managed to design a shielding which would be strong enough to protect both people and electronics.

4 Acknowledgements

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References

[1] *Online manual to FLUKA:* http://www.fluka.org/fluka.php?id=man_onl

[2] *Official ELI Beamlines website:* https://www.eli-beams.eu/en/