Activation of Tritium Target Cell

George Kharashvili, Jefferson Lab Radiation Control

1 December 2014

Introduction

Jefferson Lab's Experimental Hall A plans to use a specially designed aluminum alloy target cell filled with approximately 1.1 kCi of tritium. The cell will be filled at Savanah River Site, where it will have to return after the experiment. Induced radioactivity in the target cell and the subsequent radiological concerns must be considered.

FLUKA [1] Monte Carlo code was used to calculate induced radioactivity in the target cell and the resulting equivalent dose rates during the first year after the experiment. Presented are the model details and the calculation results.

Model Description

FLUKA version 2011.2b.6 is used. The target cell is made of Al 7075 with the density of 2.8 g/cm^3 and of the following composition by mass: 0.9-Al, 0.025-Mg, 0.056-Zn, 0.0165-Cu, 0.0025-Cr. The total target cell mass is approximately 2.6 kg.

The target is modeled as tritium gas with the density of 0.0036 g/cm^3 at 20 atm. pressure. The low energy neutron cross-section of free gas tritium at 87K is assigned. The electron, positron, and photon production and transport thresholds are set at 6 MeV for the prompt radiation and at 60 keV – for the decay radiation.

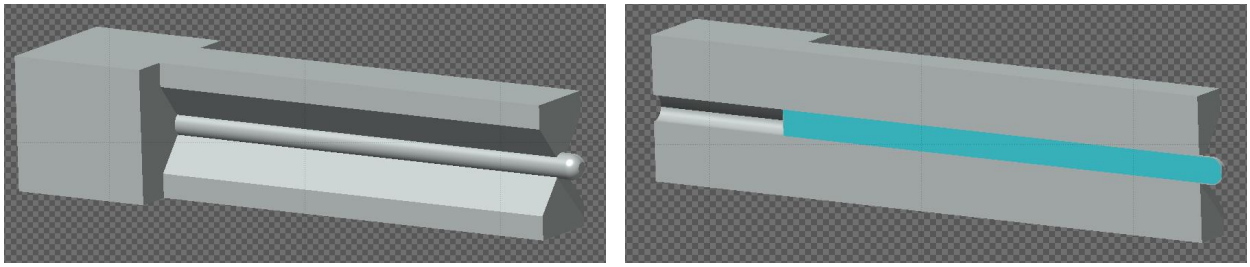

Figure 1. Modeled target cell and its vertical cross-section along the beam axis.

The model assumes 6 months-long experiment using 11 GeV electrons. The tritium target is irradiated every other week with the average beam current of 15 μA. The electron beam is replaced with a user source routine which models electronuclear interactions based on the equivalent photon approximation [2] [3].

Results

Expected equivalent dose rates at 30 cm distance from the activated target cell are presented as a function of decay time in Figure 2. The most important radionuclides are ^{22}Na, ^{24}Na, and ^{65}Zn. Expected activities of these and other significant radionuclides 1 day, 1 month, and 1 year after the end of the run are presented in Table 1.

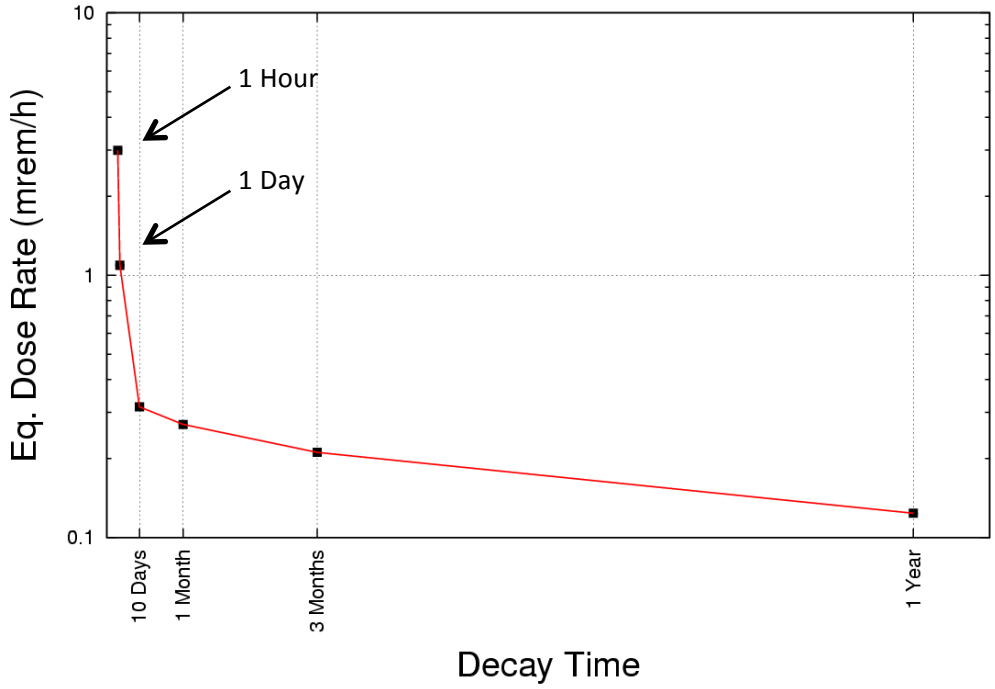

Figure 2. Expected equivalent dose rates at 30 cm distance from activated target cell (statistical error bars are too small to view on this scale).

Radionuclide	$T_{1/2}$ (days)	A_{1day} (Bq)	A_{1month} (Bq)	A_{1year} (Bq)
^{22}Na	950	6.02×10^5	5.89×10^5	4.61×10^5
^{24}Na	0.625	2.15×10^6	N/A	N/A
^{65}Zn	244.3	1.01×10^6	9.32×10^5	3.6×10^5
^{51}Cr	27.7	6×10^5	2.9×10^5	65.7
^{7}Be	53.1	2.38×10^6	1.62×10^6	2.08×10^4
^{57}Co	271.8	1.73×10^5	1.61×10^5	6.86×10^4
^{58}Co	70.9	3.7×10^5	2.78×10^5	1.05×10^4

Table 1. Induced radioactivity in the target cell.

Radionuclide inventory in the target cell and the subsequent photon spectra at 10 cm distance after 1 day, 1 month, and 1 year decay times are presented in Figures 3 – 8. Short term radiological conditions are dominated by the decay of ^{24}Na, while ^{22}Na is the most significant long-term contributor.

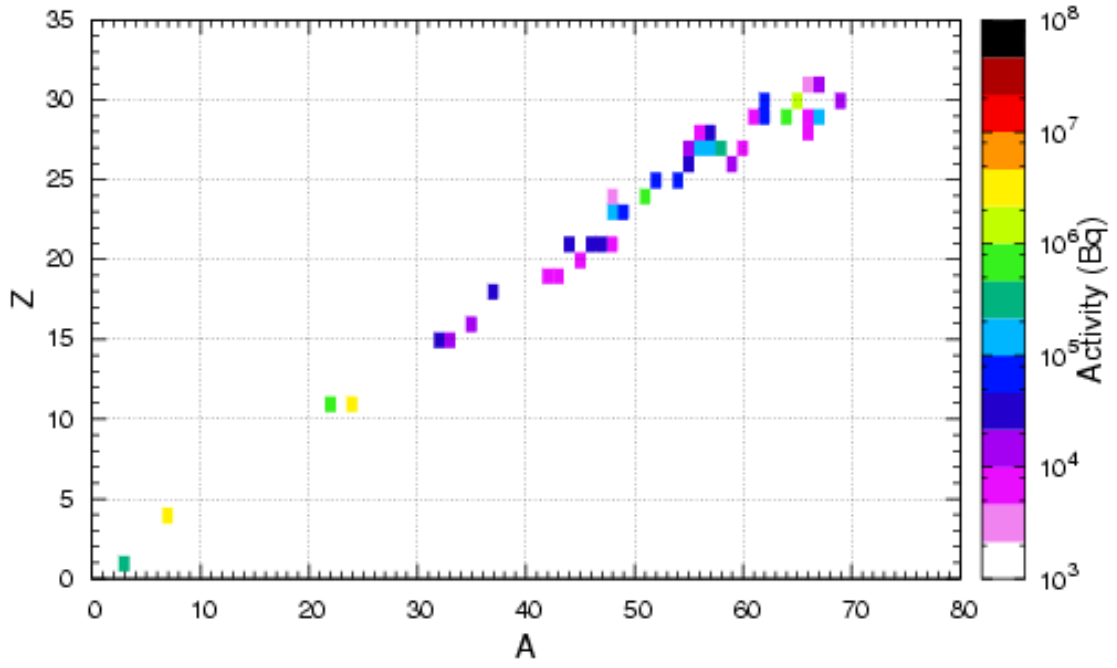

Figure 3. Radionuclide inventory in the target cell after 1 day of decay.

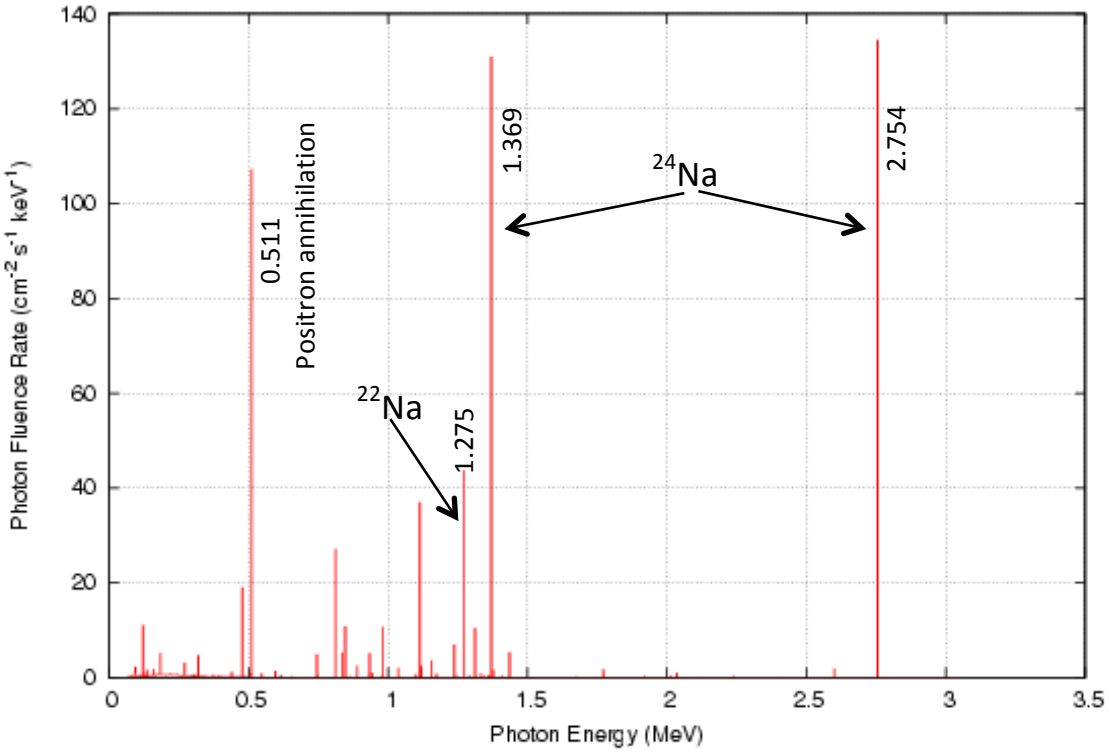

Figure4. Photon spectrum 10 cm from the target cell after 1 day of decay.

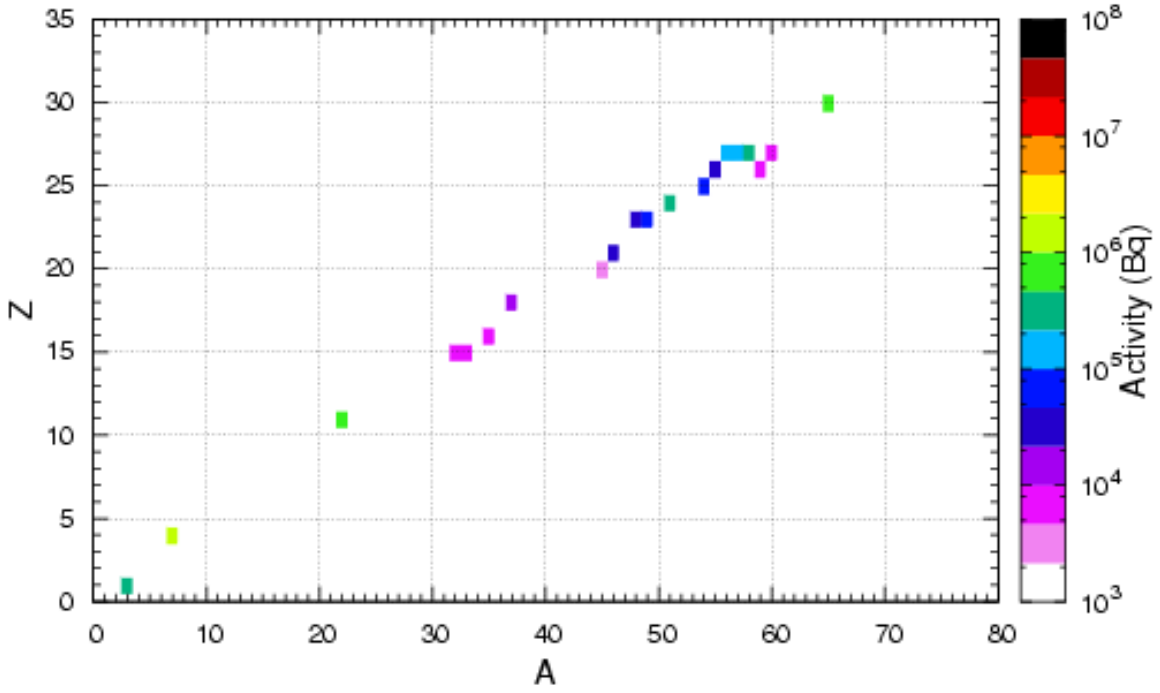

Figure 5. Radionuclide inventory in the target cell after 1 month of decay.

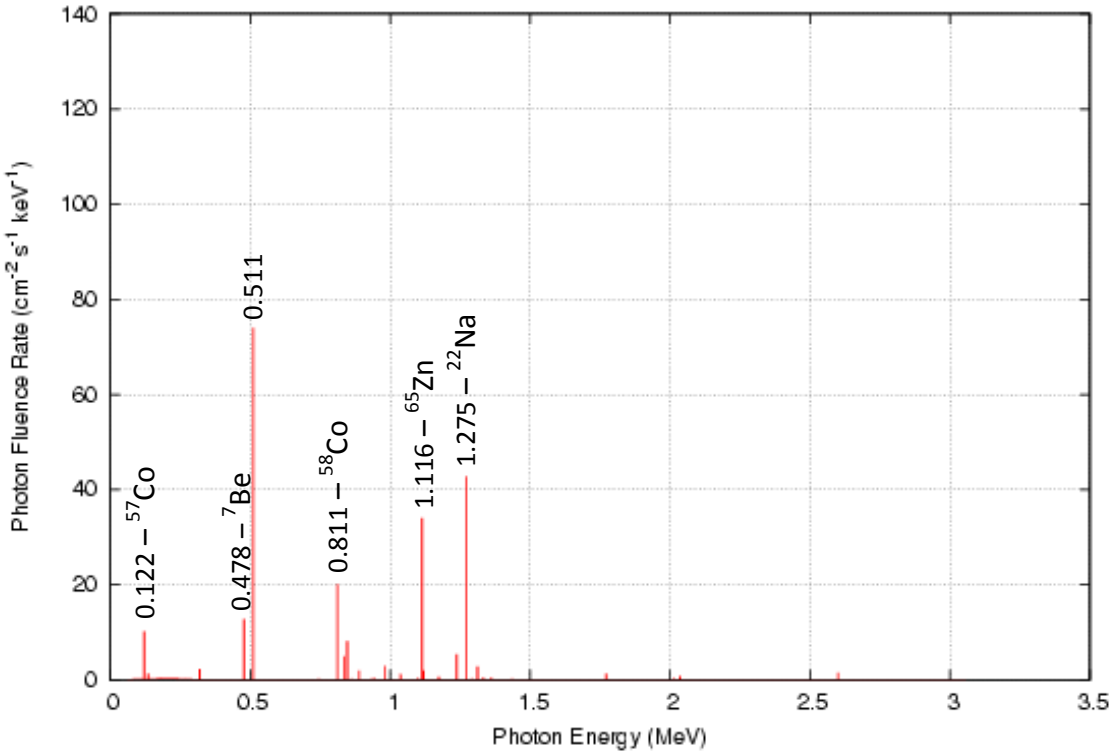

Figure 6. Photon spectrum 10 cm from the target cell after 1 month of decay.

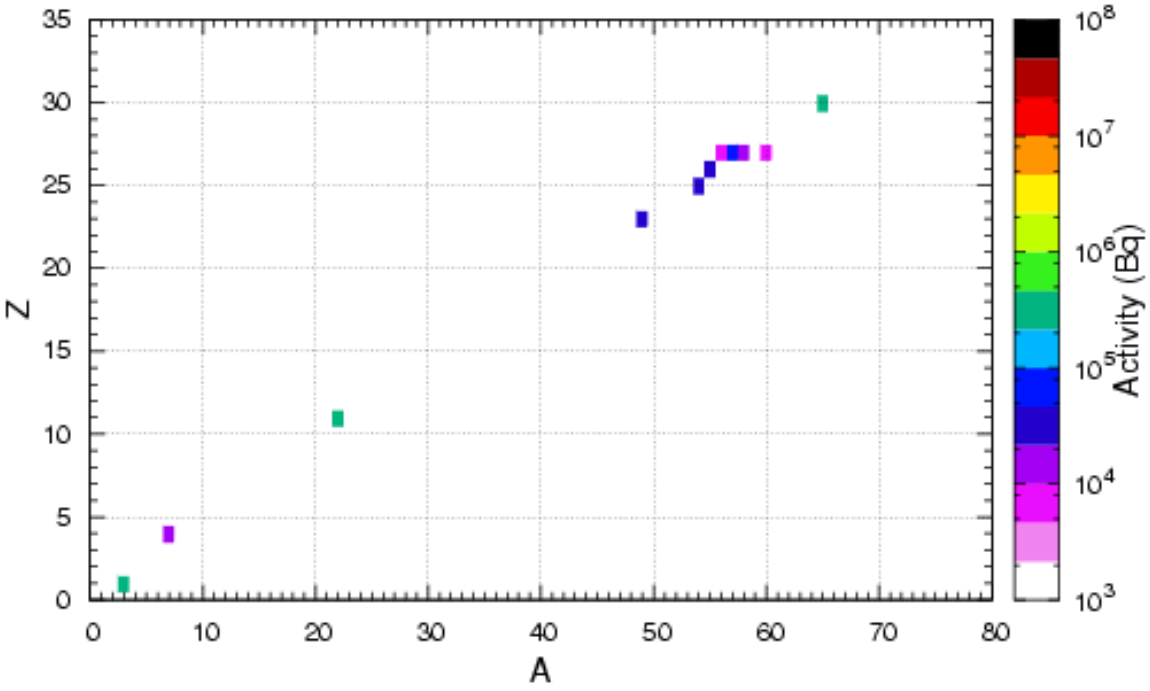

Figure 7. Radionuclide inventory in the target cell after 1 year of decay.

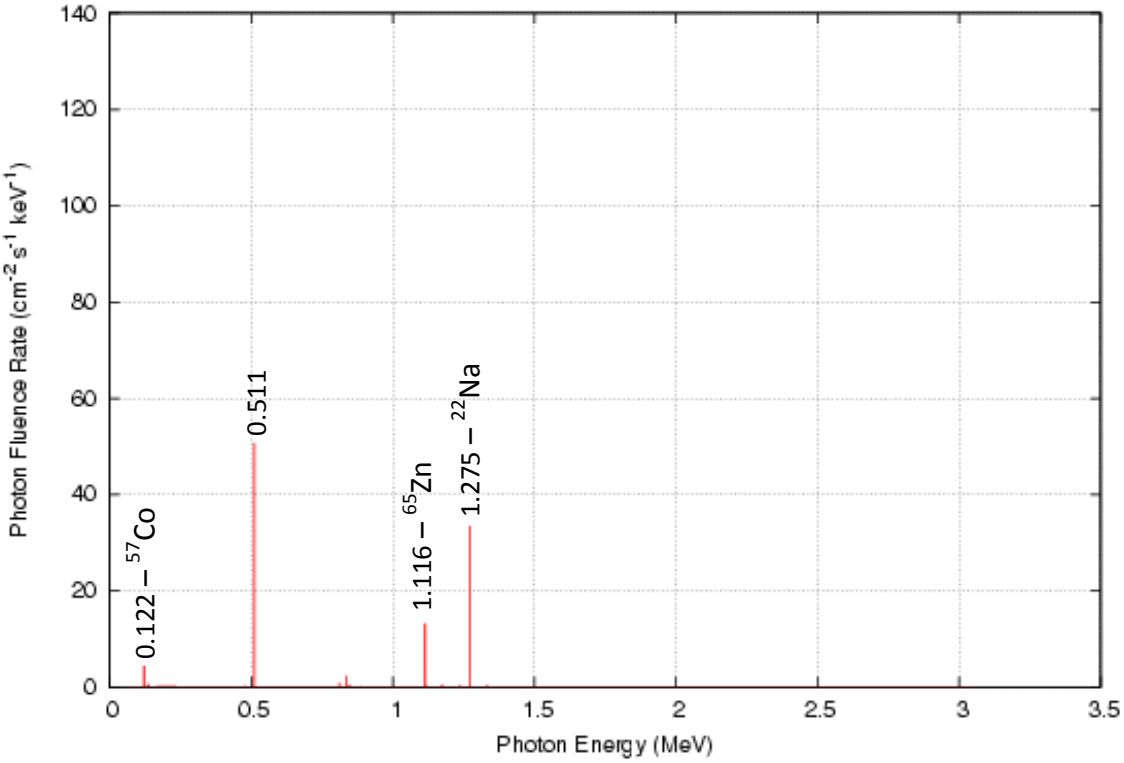

Figure 8. Photon spectrum 10 cm from the target cell after 1 year of decay.

Summary and Conclusions

Activation of the tritium target cell was evaluated using FLUKA with inclusion of the electronuclear interactions. Equivalent dose rates up to 3 mrem/h at 30 cm distance from the target cell are expected 1 hour after the end of the run. Dose rates will drop to approximately 1.1 mrem/h after 1 day of decay, to 0.3 mrem/h – after 1 month of decay, and to 0.1 mrem/h – after 1 year of decay. The short-term radiological conditions are expected to be dominated by the decay of ^{24}Na and the long-term ones – by the decay of ^{22}Na. Other notable radionuclides expected to be produced in the target cell are ^{65}Zn, ^{51}Cr, ^{7}Be, ^{57}Co, and ^{58}Co.

If at least 1 month of decay is allowed before the target cell is shipped back to the Savanah River Site the total amount of the induced radioactivity in the target cell is expected to amount to less than 0.02% of the total radioactivity of the package and therefore not have any impact on the classification for the shipping and labeling purposes.

References

[1] A. Ferrari, P. R. Sala, A. Fassò and J. Ranft, "FLUKA: a multi-particle transport code," CERN-2005-10, INFN/TC_05/11, SLAC-R-773, 2005.

[2] P. Degtiarenko, "Electronuclear Interactions in FLUKA," in *2nd FLUKA Advanced Cource and Workshop*, Vancouver https://www.fluka.org/free_download/course/triumf2012/Workshop/Degtiarenko.pdf, 2012.

[3] P. Degtiarenko and G. Kharashvili, "Contribution of the Direct Electronuclear Processes to Thin Target Activation," in *SATIF-12*, Fermi Lab, https://indico.fnal.gov/getFile.py/access?contribId=46&sessionId=8&resId=0&materialId=poster&confId=7469, 2014.