Application of Monte Carlo modelling and Compton-to-peak ratio analysis of gamma spectra for the evaluation of activity before and after metallic radioactive waste decontamination procedure

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Introduction

One of the important tasks for successful nuclear power plant (NPP) decommissioning process is optimization of management of nuclear facility low-level metallic radioactive waste (MRW) by grouping and decontamination of MRW. Approximately 1000 m^3 of contaminated metal waste is generated for every 1 GW decommissioned (13% by volume) [1] during decommissioning of a nuclear facility. For efficient characterization of very low-level radioactive metallic waste, the determination of surface contamination by γ-spectrometry measurement combined with Monte Carlo simulation is being developed [2]. The aim of this work was to identify the main parameters of analysis of gamma spectra which indicates the successful removal of surface contamination from radioactive metallic waste.

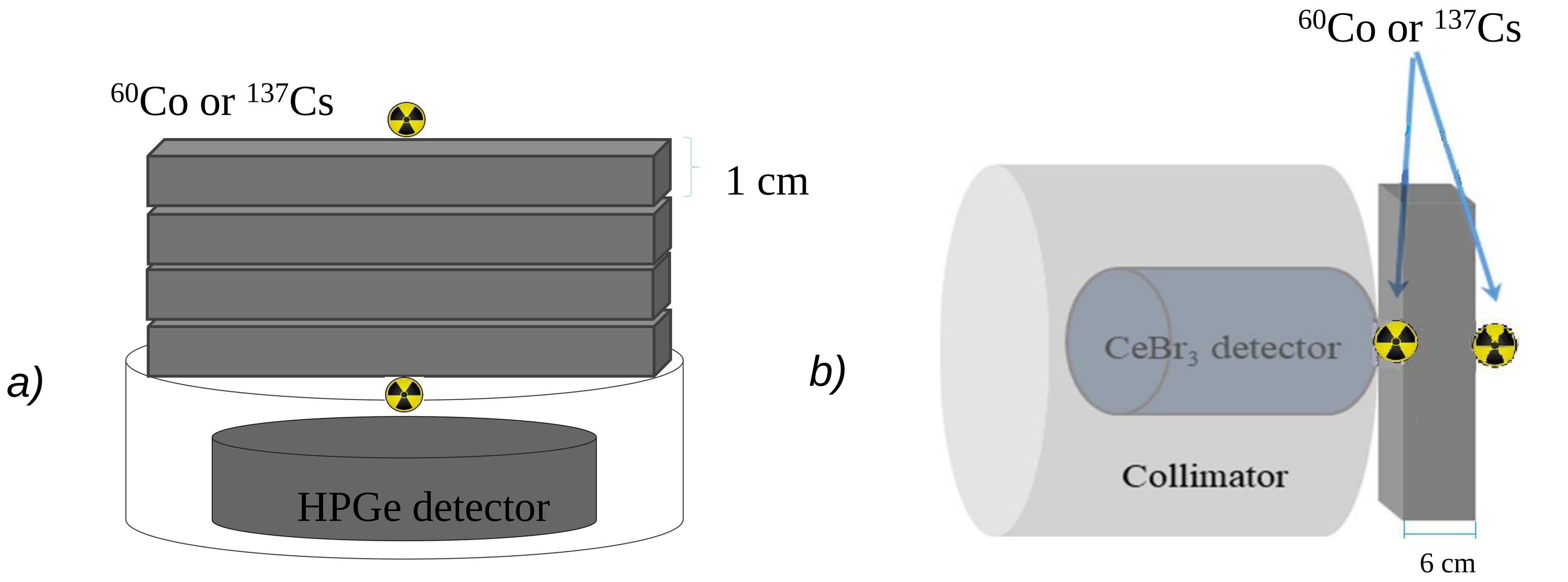

***Figure 1.** The scheme of experiment using a) HPGe detector with ^{60}Co or ^{137}Cs source in different geometry variations starting from surface source h=0 to different depths h=4 (shielded by 4 cm metal slabs) and also intermediate cases when sources are between shields (h=1… h=4 etc.); b) CeBr$_3$ detector with collimator and ^{137}Cs source behind or in front of a metal shield*

Method :

A method for analysing the gamma spectra of metallic radioactive waste before and after the decontamination procedure, when only part or all of the surface contamination (^{137}Cs) is removed from the MRW in the presence of volume activation of same or other gamma emitter sources (i.e. ^{60}Co or ^{137}Cs) is being developed. To simulate the successful decontamination procedure of metallic radioactive waste, the comparison of two the same geometry gamma spectra have to be performed and evaluation of change in Compton-to-peak ratio will show which part of contaminants have been removed. The experiments were carried out with laboratory samples and removable sources of different activities of ^{137}Cs and ^{60}Co, using stationary semiconductor detectors HPGe (with 26.2 % relative efficiency and resolution ~1.76 keV/1.33 MeV (Canberra Industries, USA) (Fig.1a, Fig.3) and portable scintillation detectors CeBr$_3$ (scintillation detector 51B51/2M-CEBR-X (Scionix, Netherlands) with (Fig.1b, Fig.6) and without collimators.

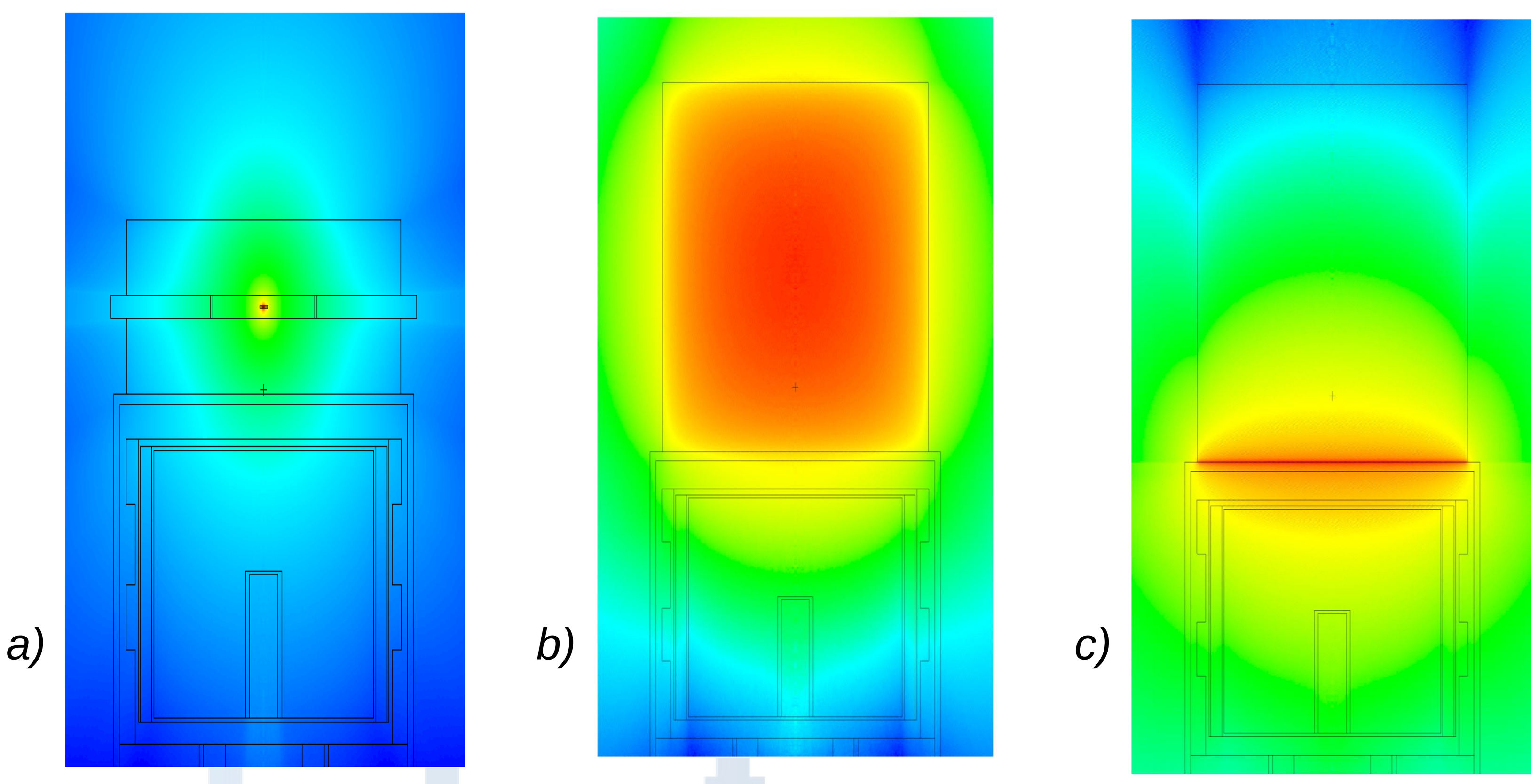

***Figure 2.** Modelled ^{137}Cs photon flux for different geometry sources: (a) HPGe detector and the point source in an Al disk, between 1cm steel slabs; (b) HPGe detector and the homogeneously distributed volume source; (c) HPGe detector and the planar source on the surface*

***Figure 3.** HPGe detector (Canberra)*

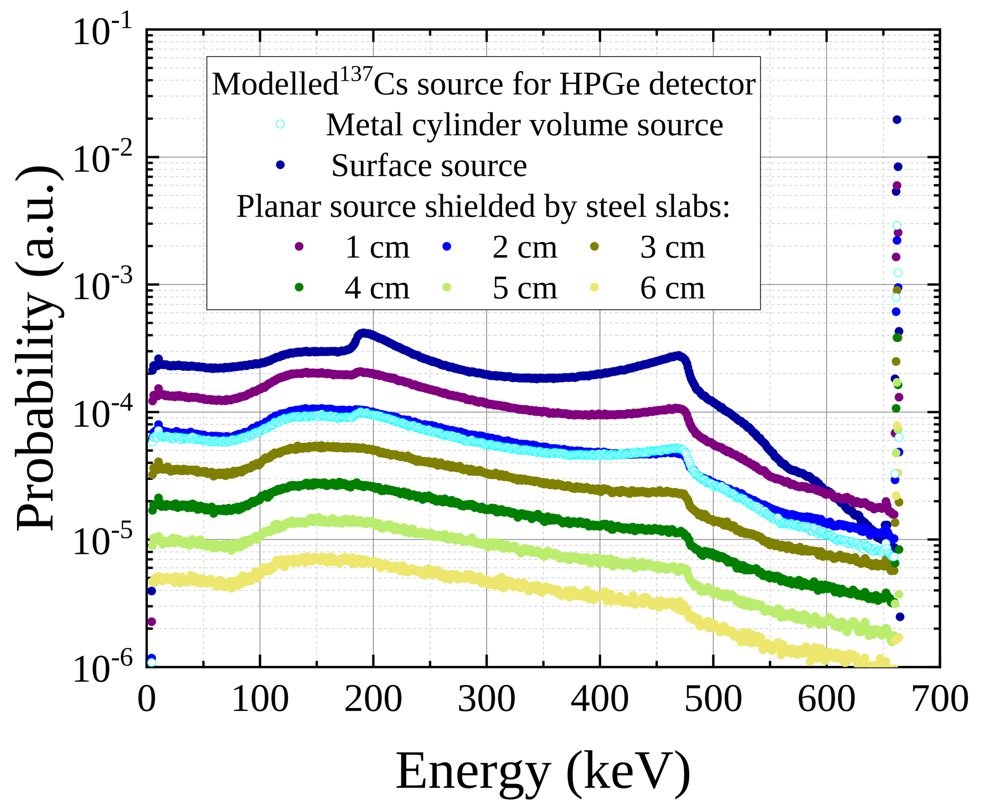

***Figure 4.** Comparison of modeled spectra of ^{137}Cs source obtained using HPGe detector*

Modeling:

MCNP6 modelling of both detectors and different sample geometries of the experiments has been carried out for comparison and method development purposes [3]. MCNP simulations of different source cases: a flat source shielded by different metal plates and a volume source showed that the ^{137}Cs surface contamination source can be distinguished from the reference source case by simulation and analysis of the measured γ-spectra and peak/intensity and Compton-to-photopeak ratio (Fig.2, Fig.4). This proves the possibility of separating surface contamination from activated heterogeneous (point/planar) or homogeneous volume distribution in the samples. Comparison of simulated and experimental γ-spectra, peak/intensity dependence and Compton-to-photopeak ratio for laboratory ^{60}Co and ^{137}Cs samples under different metal shielding conditions showed good agreement between experimental and simulated results for spectra obtained with the HPGe and CeBr$_3$ detectors, in CeBr$_3$ case using a collimator (Fig. 5 and Fig. 6).

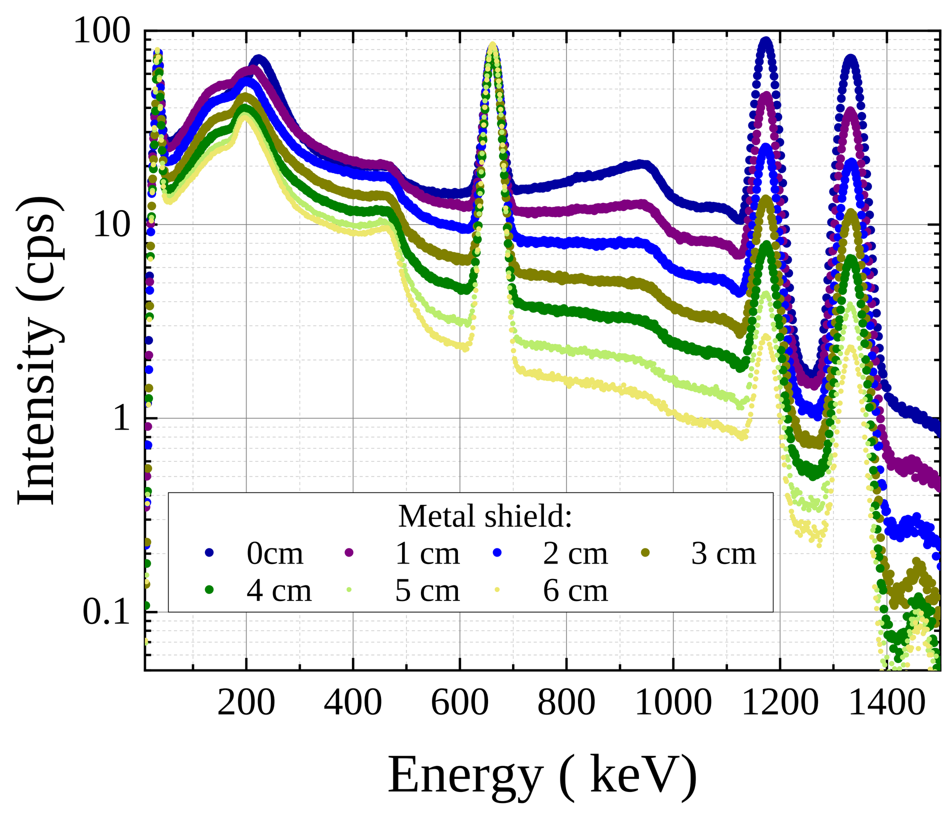

***Figure 5.** Measured spectra of different thickness metal shield with surface ^{137}Cs and heterogeneous (point) volume ^{60}Co sources obtained using CeBr$_3$ detector with collimator.*

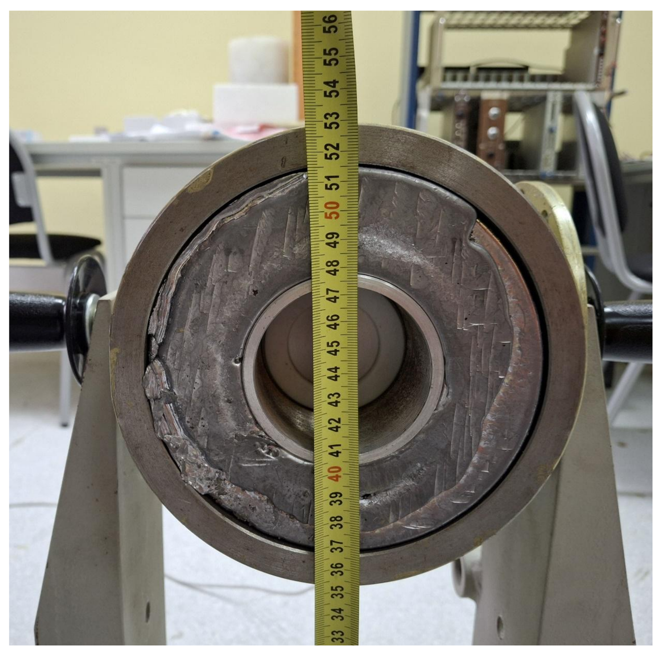

***Figure 6.** CeBr$_3$ detector inside the collimator*

Conclusions:

- Modelling, inter-comparison of γ-spectra, and analysis of the nuclide Compton-to-peak ratios for samples with different activity distribution of ^{137}Cs and ^{60}Co sources in established iron shielding conditions have been investigated to mimic the decontamination procedure of the metallic radioactive waste.
- The method by comparing the Compton-to-peak ratio of two the same geometry gamma spectra will show which part of contaminants have been removed.
- The method will be tested in radioactive metallic waste laser ablation decontamination procedure.

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