

## Geant4 simulation of ion chambers response to $^{60}\text{Co}$ spectrum of LNMRI/IRD Shepherd 81-14D Radiator

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**Abstract:** The National Ionizing Radiation Metrology Laboratory of the Radioprotection and Dosimetry Institute (LNMRI / IRD) has recently acquired a Shepherd 81-14D Radiator. In this work we simulate, using Geant4, the behavior with the inverse square law radiation of the distance for 3 models of PTW spherical chambers used in radioprotection, a relevant information to planning the measurements. We did the corrections for the attenuation and scattering in the air for each distance, where we used the  $^{60}\text{Co}$  spectrum simulated previously.

**Keywords:** Monte Carlo simulation; inverse square law radiation;  $^{60}\text{Co}$  source; ion chambers

### 1. INTRODUCTION

Recently the LNMRI / IRD acquired a Shepherd 81-14D irradiator with  $^{137}\text{Cs}$  sources with activity of 54 Ci and  $^{60}\text{Co}$  with activity of 5 Ci, for the facilities of the Radioprotection Laboratory. The laboratory has been carrying out measurements and characterized the beams of  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  in a previous work [1]. The spectra of the  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  were simulated in another work [2] and used in our simulations.

It is necessary to carry out Monte Carlo simulations to know in more detail the behavior of the measurement system [3-6]. Therefore, we simulated the complete irradiator as well as three PTW spherical chambers with distinct sensitive volumes: 27.9 cm<sup>3</sup>, 1 liter and 10 liters. In this work we simulate the behavior with the inverse square law radiation to the beam of the  $^{60}\text{Co}$  spectrum generated after crossing the structure of

the irradiator. The attenuation and scattering effects were obtained in the air to correct the results. The simulations, using the Monte Carlo method, were performed with the Geant4 Program version 10.02 [7].

### 2. METODOLOGY

The source of  $^{60}\text{Co}$  J. L. Shepherd & Associates Model No. 7810-150 is in the form of solid metal pellets occupying a cylindrical volume with double encapsulation of 304 stainless steel.

We extracted from the previous paper [2] the simulated spectrum of the  $^{60}\text{Co}$  source after the exit of the collimation system. It will be used in the simulations and can be seen in figure 1.

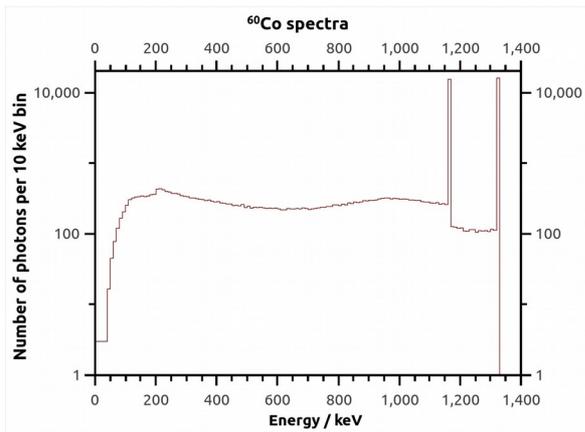


Figure 1. Distribution of the simulated spectrum of the  $^{60}\text{Co}$  source.

The LNMRI / IRD ionization chambers are the PTW type 32005, 32002 and 32003 models shown below.

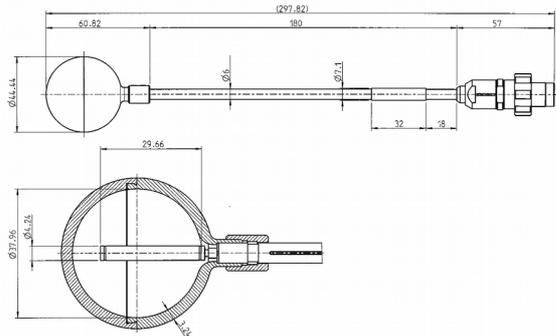


Figure 2. Spherical Ionization Chamber TK-30 32005 of PTW

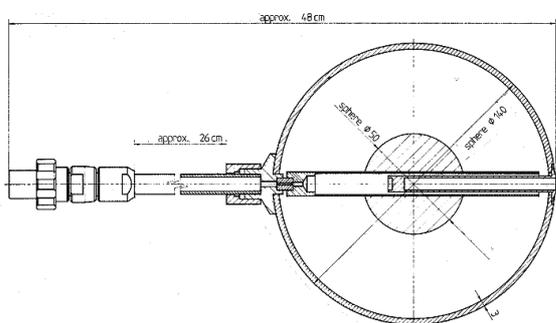


Figure 3. 1 Liter Spherical Ionization Chamber 32002 of PTW

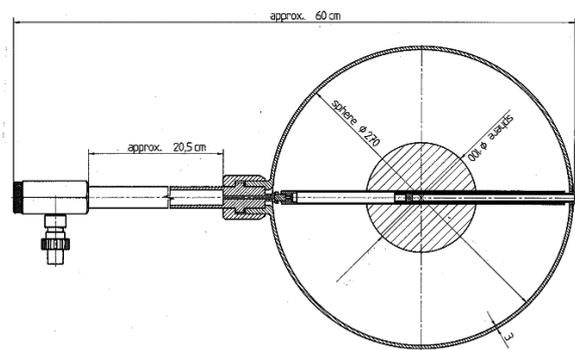


Figure 4. 10 Liter Spherical Ionization Chamber 32003 of PTW

The technical information of the simulated cameras was taken from the Ionizing Radiation Detectors catalog of PTW [8]. The chambers are spherical with a long metal rod, suitable for use in radioprotection measurements. The spherical wall surrounding the sensitive volume of the 3 chambers has a thickness of 3 mm of graphite polyoxymethylene. The chamber of  $27.9 \text{ cm}^3$  has a sensitive volume with a radius of 22 mm and a cylindrical central electrode attached to the rod made of graphite coated with PMMA with 4.2 mm in diameter. The 1 and 10 liter chambers have a spherical central electrode, made of PMMA coated graphite, with diameters of 50 mm and 100 mm, respectively, and a sensitive volume consisting of a spherical shell with a thickness between the diameter of the electrodes and the diameters of the 140 mm and 276 mm cameras, respectively.

The three camera models were simulated with their centers distant 1 m, 2 m, 3 m and 4 m from the center of the cobalt source.

Ideally, the calculated doses should decrease proportionally to the inverse square law radiation. However, we know that some effects contribute to change this result. In this work we eliminate, through simulation, the effects of the interaction of the  $^{60}\text{Co}$  photon spectrum with the air layer between the irradiator and the chambers.

Although we know that this spectrum interacts very little with air and that the attenuation and scattering factors compete with each other to further diminish its effect, it should not be neglected. For this we made a correction for the attenuation and scattering in the air. In addition, the larger the diameter of the chambers, the greater the effect of their geometry. 10 billion events were simulated for the smaller camera and 1 billion events for the 1 liter and 10 liter cameras at the four distances.

### 3. RESULTS

The factors obtained for the four distances and three ionization chamber geometries are shown in tables 1, 2 and 3.

**Table 1.** Attenuation and scattering effects for 27.9 cm<sup>3</sup> chamber.

Distance (m)	factor	Uncertainty (%)
1	1.004	0.18
2	1.019	0.54
3	1.014	0.92
4	1.01	0.98

**Table 2.** Attenuation and scattering effects for 1 liter chamber.

Distance (m)	factor	Uncertainty (%)
1	1.002	0.15
2	1.007	0.32
3	1.013	0.60
4	1.014	0.64

**Table 3.** Attenuation and scattering effects for 10 liter chamber.

Distance (m)	factor	Uncertainty (%)
1	1.005	0.11
2	1.009	0.16
3	1.010	0.29
4	1.024	0.27

We can observe that the factors obtained are very small since they combine the effects of attenuation and scattering. The factors of the chamber of 27.9 cm<sup>3</sup> are larger than those of the 1 liter chamber which undergoes a greater compensation of the scattering due to its larger volume. The same behavior can be seen for the 10 liter chamber relative to the 1 liter chamber. Table 4 shows the values of the ratio between the doses in the chambers with the distance, corrected by the attenuation factor and the scattering factor.

**Tabela 4.** Comparison between simulation and the inverse square law radiation.

Distance ratio d <sub>i</sub> /d <sub>r</sub>	Dose ratio D <sub>i</sub> /D <sub>r</sub>	Uncertainty (%)	Percent deviation (%)	Volume (cm <sup>3</sup> )
1/2	3,99	0,44	0,27	27,9
1/3	9,02	0,85	0,24	27,9
1/4	16	0,81	0,23	27,9
2/4	4,02	0,90	0,50	27,9
1/2	4,03	0,25	0,76	1000
1/3	9,05	0,34	0,56	1000
1/4	16,1	0,47	0,63	1000
2/4	4,00	0,51	0,12	1000
1/2	3,635	0,12	9,12	10000
1/3	8,21	0,23	8,80	10000
1/4	14,59	0,22	8,79	10000
2/4	4,02	0,23	0,36	10000

We can observe that the inverse square law radiation was respected. As expected, the percentage deviation between the simulated result and the inverse square law radiation increased with the volume of the chambers. This is because the effect of the geometry of the chambers increases with the chamber diameter. Consequently, we also observe that as distances increase this effect decreases. This is clearly observed by comparing the values of the percentage deviation for each of the chambers, and we can particularly highlight the deviation of the ratio between doses at 1 m and 2 m for each chamber and between doses at 2 m and 4 m for the 10 liter chamber.

#### 4. CONCLUSIONS

We simulated irradiation of the 3 PTW chamber models used in radioprotection with the simulated spectrum for the LNMRI / IRD Shepherd 81-14D Irradiator with the  $^{60}\text{Co}$  source. The chambers were positioned at 4 distances where the doses were corrected for the air attenuation and scattering effects. We show the behavior of each camera in relation to the inverse square law radiation.

We observe, through the percentage deviation, that our results respect the inverse square law radiation. The percentage deviation to the mentioned law, as expected, increases with the increase of the dimensions of the chambers, as well as with the greater proximity between camera and source. The next step will be the calculation of wall chamber correction factors.

#### 5. REFERENCES

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