Contributed Oral presentation
Parallel Session 3
14:45

# Evaluation of body dose through Geant4 simulation

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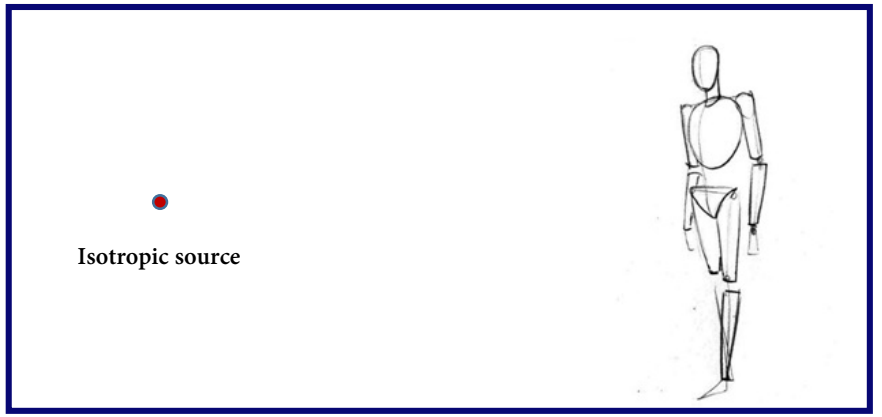
# Outline

# Introduction

## Scenario

- A person is at a distance r from a point source. Given the **activity A, the time t, the area of the person** facing the source Area and the mass m.
- The distance, activity and time were fixed for all models to r = 3.5 m, A = 1 mCi and t = 1 h respectively.

Reference [1]




- The absorbed dose was calculated for each model with four different radioactive isotopes; Na-22, Co-60, Cs-137 and Am-247 .

**The aim of this application is** :

- Calculate the absorbed dose that the person receives by analytical approach and Geant4 simulation (simplified geometry).
- Highlight the difference between the two methods, and the parameters that could impact the absorbed dose by a person.
- The more accurate and realistic method to estimate the absorbed dose in real scenarios.

| | Na-22 | Co-60 | Cs-137 | Am-241 |
|---|---|---|---|---|
| Gamma particle energy (KeV) | 511<br>511<br>1275 | 1173<br>1332 | 661.7 | 59.54 |
| MAC ($cm^2/g$) | 0.09593,<br>0.009593,<br>0.06262 | 0.06262<br>0.0626 | 0.08870 | 0.2025 |

Table1: Gamma particle energy and MAC of the studied isotopes in "Tissue, Soft (ICRU Four-Component) Reference [2].

# Absorbed dose by analytical approach

- In the analytical approach the person is supposed to be a box with 3different dimensions:

| | Height | Width | Depth |
|---|---|---|---|
| Person 1 | 173 cm | 37.5 cm | 20 cm |
| Person 2 | 173cm | 22.0 cm | 20 cm |
| Person 3 | 173 cm | 37.5 cm | 11.7 cm |

Table 2 : Dimensions of the 3 different persons,

The average mass and the height are from 2019 NCD Risk factor Collaboration for an adult Moroccan male.
M= 76kg
Height=173 cm

Reference [3]

- The absorbed dose is defined by :

$$D(Gy) = \frac{E}{m}, \quad (1,1)$$

With:

$$E(J) = \Omega . N . E_\gamma . f_\gamma, \quad (1,2)$$

$$\Omega = \frac{S\,(area)}{R^2}, \quad (1,3)$$

$$N = A . t, \quad (1,4)$$

$$f_\gamma = 1 - e^{-\frac{\mu}{\rho}\rho . T} \quad (1,5)$$

$$\rho = \frac{m}{V},$$

$$depth = \frac{mass}{width . height . density}$$

$$width = \frac{mass}{depth . height . density}$$

$\rho = 1 g/cm^3$
For soft tissue
(ICRU four-component)
Reference [4]

# Absorbed dose by analytical approach

| | Na-22 | Co-60 | Cs-137 | Am-241 |
|---|---|---|---|---|
| **Person 1 dose (Gy)** | **2.11 E-6** | **2.12 E-6** | **6.50 E-7** | **6.92 E-8** |
| **Person 2 dose (Gy)** | **1.24 E-6** | **1.24 E-6** | **3.81 E-7** | **4.05 E-8** |
| **Person 3 dose (Gy)** | **1.60 E-6** | **1.54 E-6** | **5.06 E-7** | **6.39 E-8** |

Table 2 : **Results from analytical calculations**

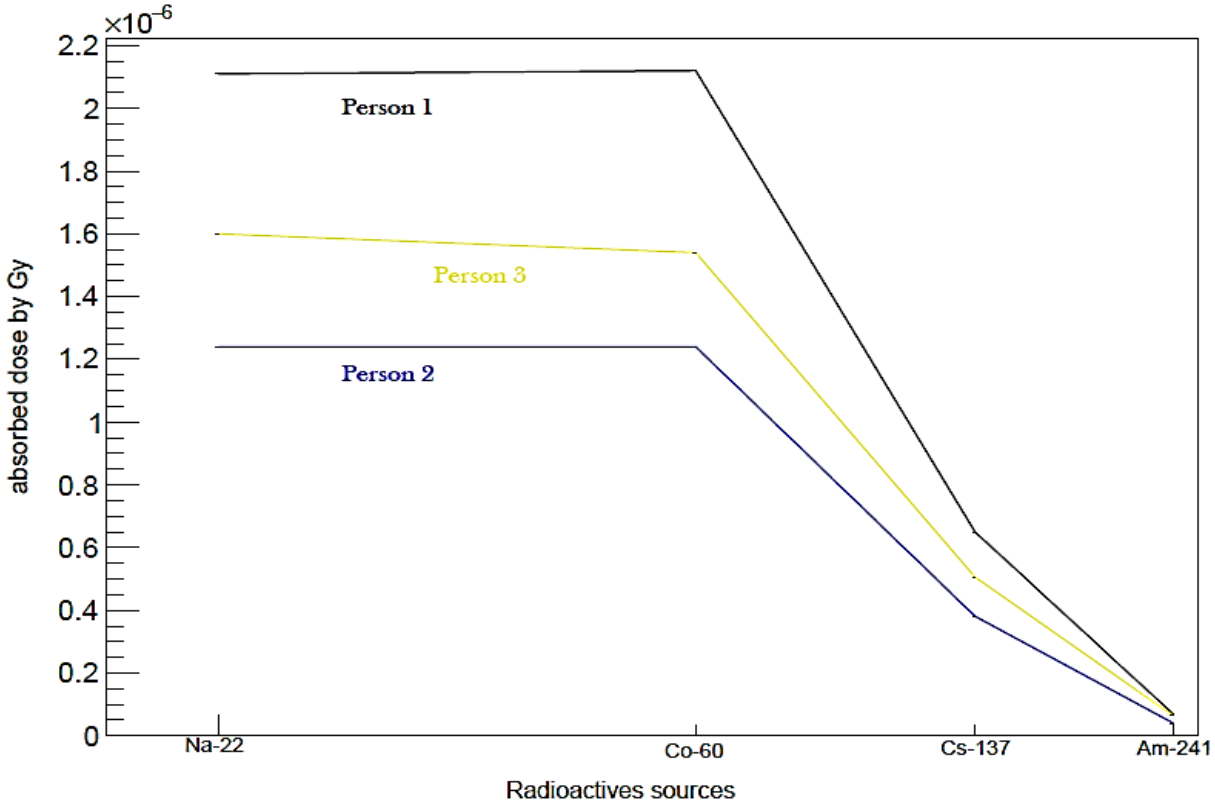



Figure 1 : **Absorbed dose for the three person calculated analytically (Gy)**

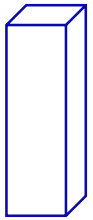
- D(Na-22) , D(Co-60) > D(Cs-137), D(Am-241).
- Person 1 received the highest dose.

- Scenario illustration by Geant4:

Geant4 (for GEometry ANd Tracking) is a platform for "the simulation of the passage of particles through matter" using Monte Carlo methods.
Reference [ 5]

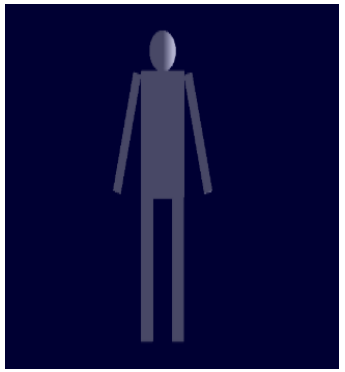
- **Detector Construction class**
- **Primary Generator Class**
- **Physic Lists Class**

- Case 1 : The person is simulated as a box (like analytical method with 3 different dimensions (G4_TiSSUE_ SOFT_ICRU-4)



**Simplified geometry**

- Case 2 : The person is simulated as human like model with soft tissue (G4_TiSSUE_ SOFT_ICRU-4)



**Human like model geometry**

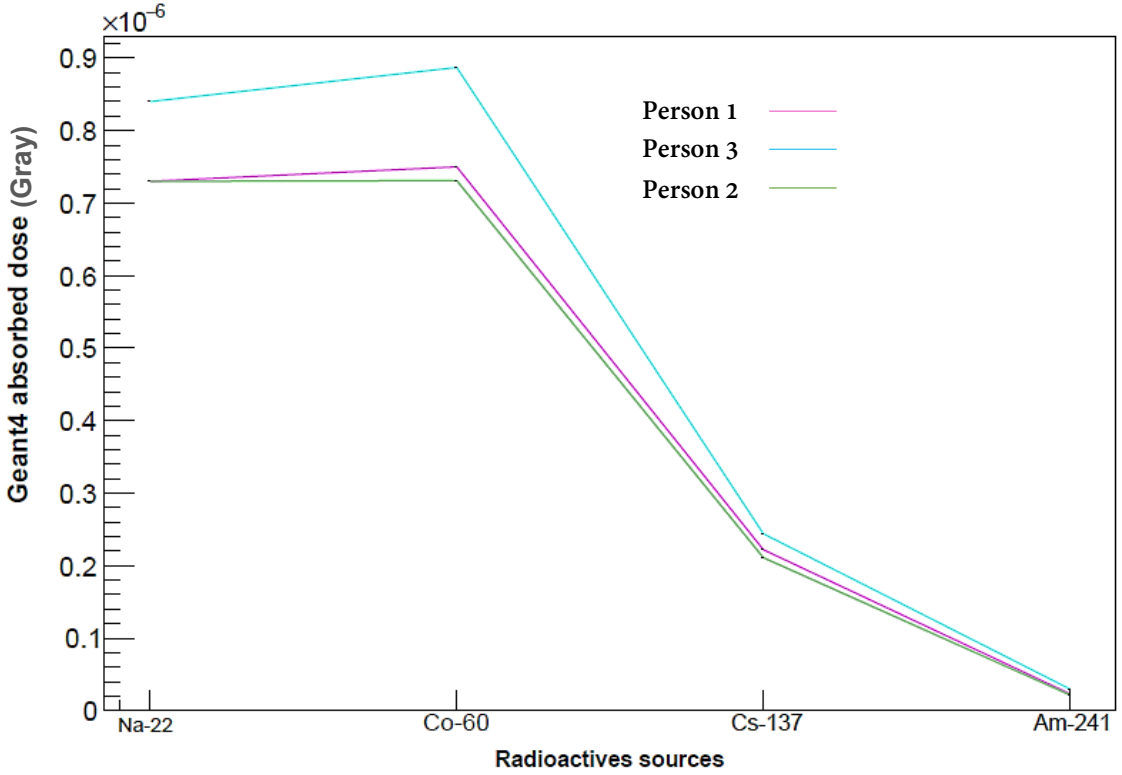



Figure 2: Absorbed dose by Geant 4( case 1) (Gy)

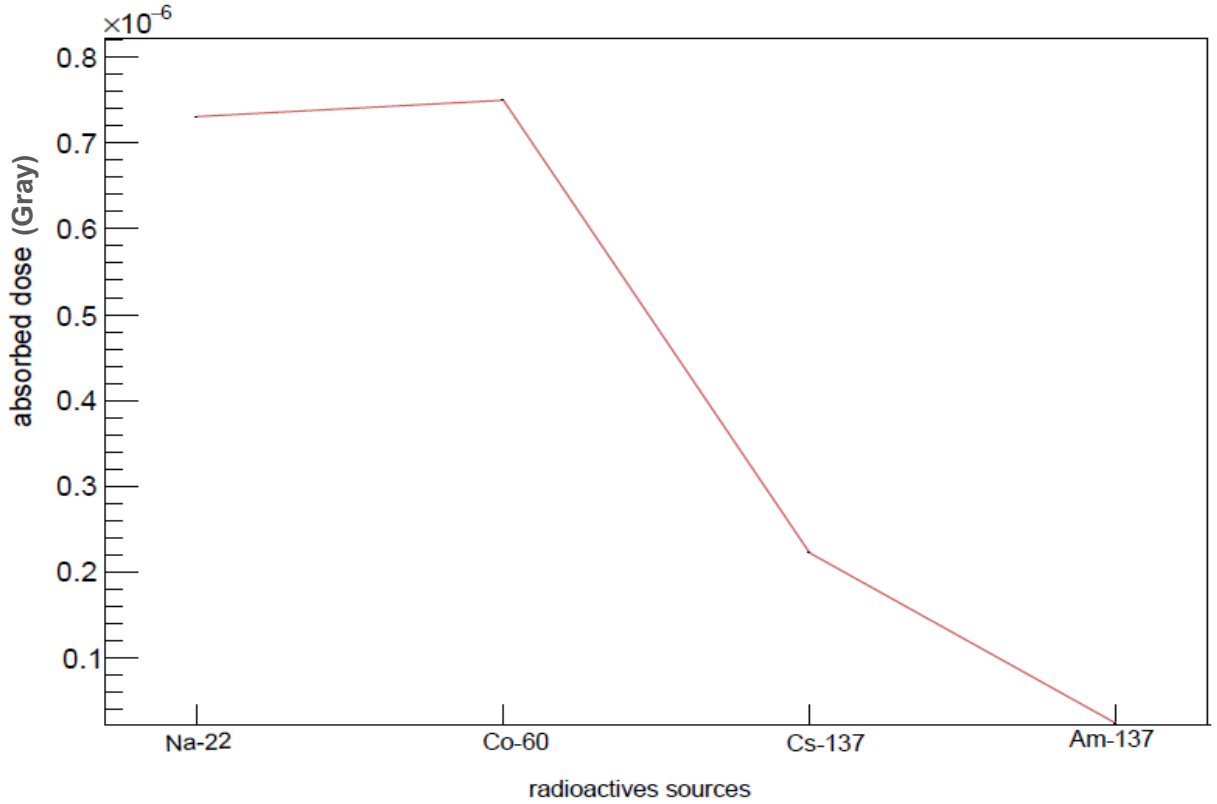



Figure 3: Absorbed dose by Geant4 ( case 2) (Gy)

- **The absorbed dose by Geant4 appears to be lower than the absorbed dose calculated by analytical method .**

- **The absorbed dose by human like model is approximately the same like the results giving by the person 2**
- **The absorbed dose giving by the case 2 seems to be the closet to the realistic approximation of the absorbed dose.**

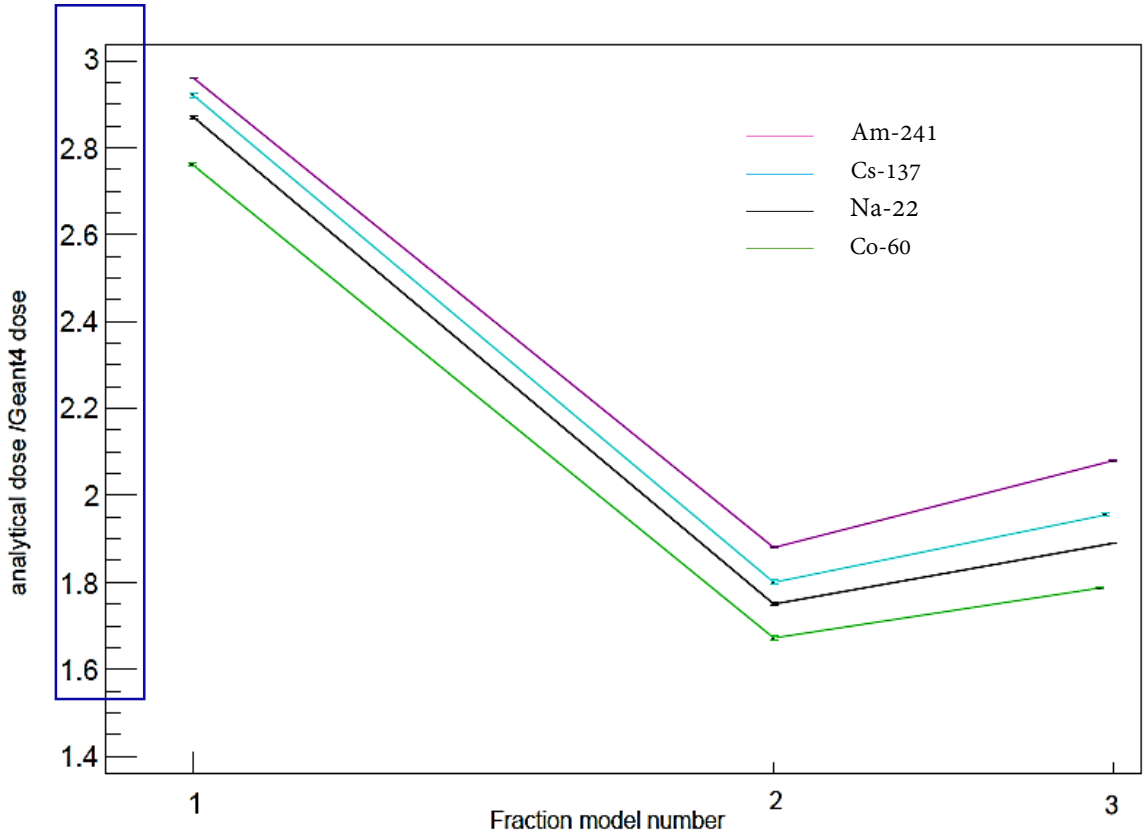



**Figure 4**: The ratio between Analytical results and Geant4 results for the three boxes (case 1) ( example : Person 1 analytical/person 1 geant4)

- The analytical dose varies from a factor 1.6 to 3 larger than the Geant4 simulated .

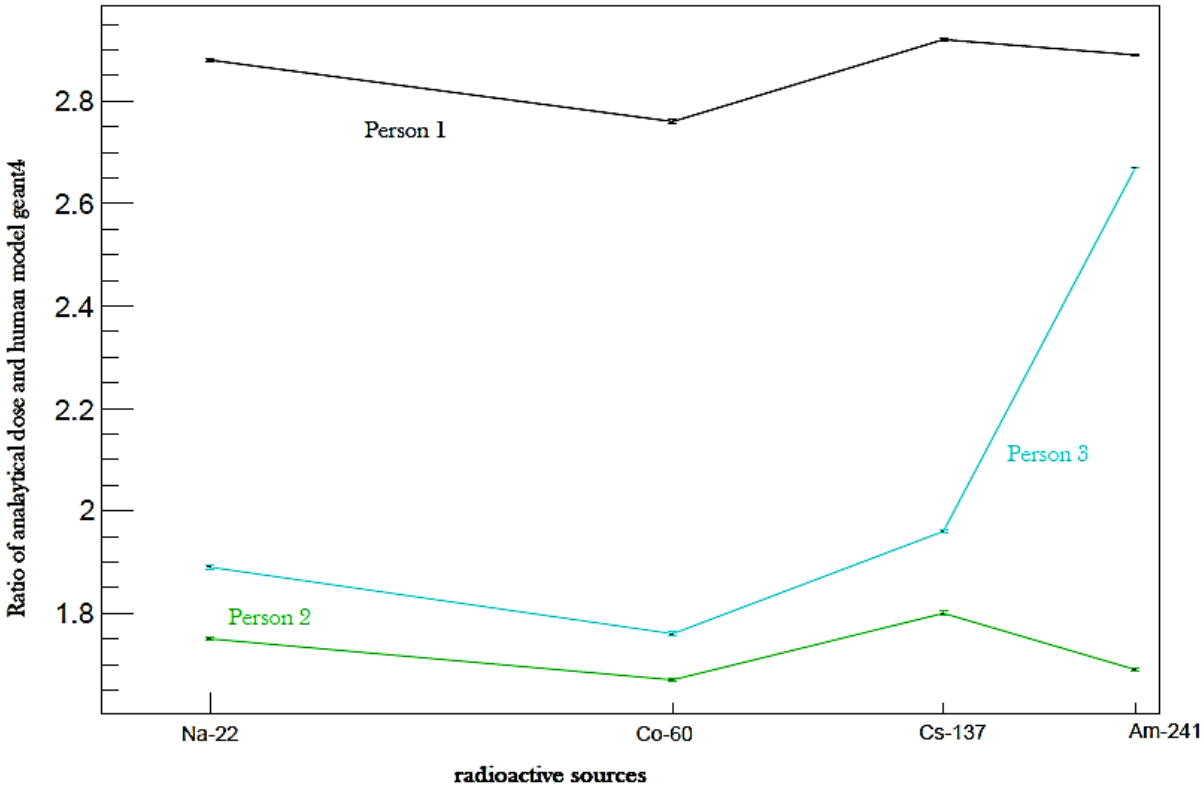



**Figure 5**: The ratio between analytical dose and dose calculated by geant4 human model (case 2)

- The closet analytical model to the human like model : Person 2

## 1. Geant4 VS Analytical method :

- Geant4 method gives a lower dose than the analytical method could be a result of energy being Compton or Rayleigh scattered out of the body or because Geant4 has a different absorption coefficient .
- In the Geant4 simulation, the dose increased as the depth of the model decreased / Analytical method the energy decreases ⟹ the dose decreases.

## 2.Isotopes VS fraction:

- Am-241 seems to have the largest factor and this is because it has the lowest Eγ.
- The analytical method assumes vacuum between the source and model/ In Geant4 however, air is simulated between the source and model

## 3. Errors sources

- In Geant4 simulation: A number of $10^7$ decays were simulated ⟶ The calculated dose was multiplied by $1.332.\ 10^4$ .
- The error from the first $10^7$ decays was less than 1% and thus the error from the N was also less than 1%.

The differences in doses is an effect of Compton/Rayleigh scattering, which is not taken into account for the analytical calculations.

In order to estimate the absorbed dose that a person can receive = Geant4 simulation must be used

- **Future improvements :**

  - Human like model with soft tissue ➡ Using the developed human like model offered by Geant4 simulation ( **advanced examples** ) which simulate the different parts and compounds of human body.
  - Simulate the Gamma particles with its appropriate energies ➡ simulate radioactive sources directly by using G4Radioactive decay.
  - Elaborate an advanced theoretical model

# References


[1] Radiation Protection, Dosimetry, and Detectors, Torbjörn Bäck, version 1.8, 2019- 05-23

[2] E. Browne, J. K. Tuli. Nuclear Data Sheets 114, 1849 (2013). Nudat. https://www.nndc.bnl.gov/nudat2/. (Accessed 2020-05-17)

[3] NCD-RISK Data Visualisation “Body-mass index and average height”,2019

[4] ICRP, 2009. Adult Reference Computational Phantoms. ICRP Publication 110. Ann. ICRP 39 (2). (Accessed 2020-05-17)

[5] Site Official de Geant4 CERN https://geant4.org/

# Thank you for your attention