ABSORBED-DOSE ENERGY DEPENDENCE FOR LUMINOPHORE MATERIALS: A MONTE CARLO INTERCOMPARISON

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In this study, Monte Carlo methods were used to estimate the absorbed-dose energy dependency of 4 widely used optically and thermally stimulated luminescence materials: $CaSO_4$, LiF, BeO, $Al2O_3$. The examined X-ray / photon energy range was 20 keV to 400 MeV. Three well-known general-purpose Monte Carlo codes were used: FLUKA.CERN, GEANT4, and PHITS. The results obtained from these completely independent codes are directly compared to each other and presented in this paper for the first time. Their excellent agreement is shown.

INTRODUCTION

The ratio between the dose to the medium at the point of measurement, but in absence of the detector, D_{med} and the dose to the sensitive material of the detector, D_{det} , is defined as the absorbed-dose energy dependence:

$$f(E) = \frac{\mathrm{D}_{med}}{D_{det}}. \qquad \text{(eq. 1)}$$

As its name suggests, this quantity is a function of the energy, E, of the impinging radiation, i.e. the photon beam in the case at hand. The importance of determining $f(E)$ cannot be overstated. It is a key ingredient to link the measurement from a dosimeter to the actual dose to the medium. Since detectors are calibrated against a reference energy, the relative absorbed-dose factor, R, is a more interesting and meaningful parameter. For this study, the reference beam energy was 1.25 MeV, the effective energy of Co-60.

$$R(E) = \frac{\left({}^{D_{med}}/_{D_{det}}\right)_{1.25MeV}}{\left({}^{D_{med}}/_{D_{det}}\right)_{E}}. \qquad \text{(eq. 2)}$$

MATERIALS

- **Luminescence** is the emission of light by a substance whose atoms have been previously excited by any process other than heating
  - If the emitted light is stimulated by thermal energy, it is called **thermoluminescence** (TL).
  - If it is stimulated by optical energy, it is known as **optically stimulated luminescence** (OSL).
- Interest in luminescence dosimetry is multidisciplinary: radiation protection, radiobiology, environmental and archaeological sciences, medical physics, accident and epidemiological studies, and in industrial applications.

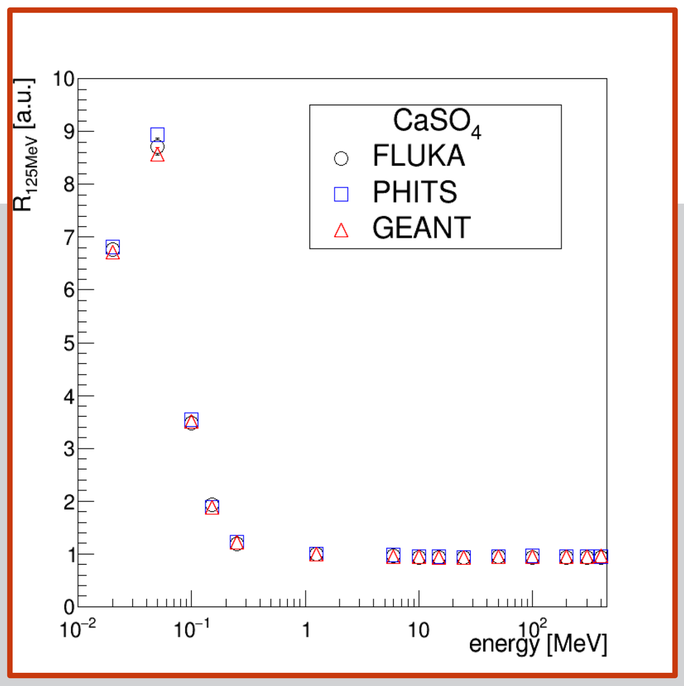
Material	Density [g/cm³]
$CaSO_4$	2.96
LiF	2.635
BeO	2.85
Al_2O_3	3.97
water	1.0

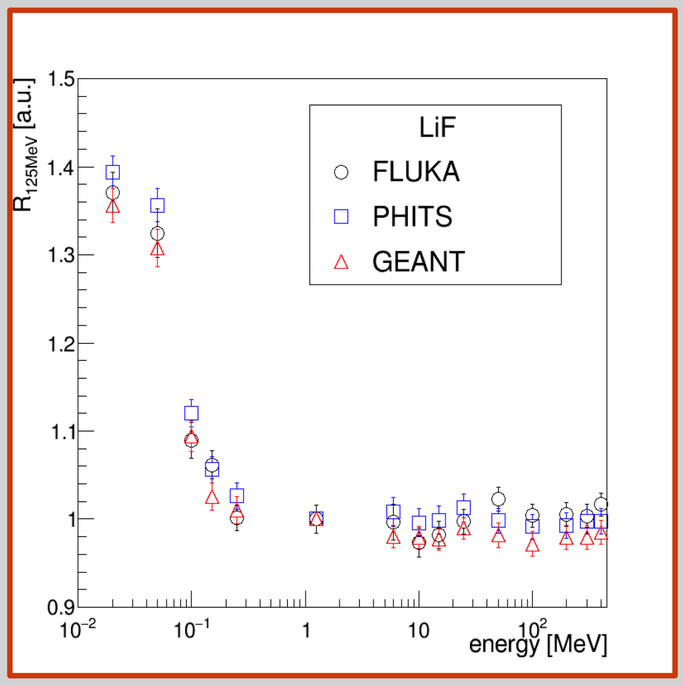
SIMULATION SETUP

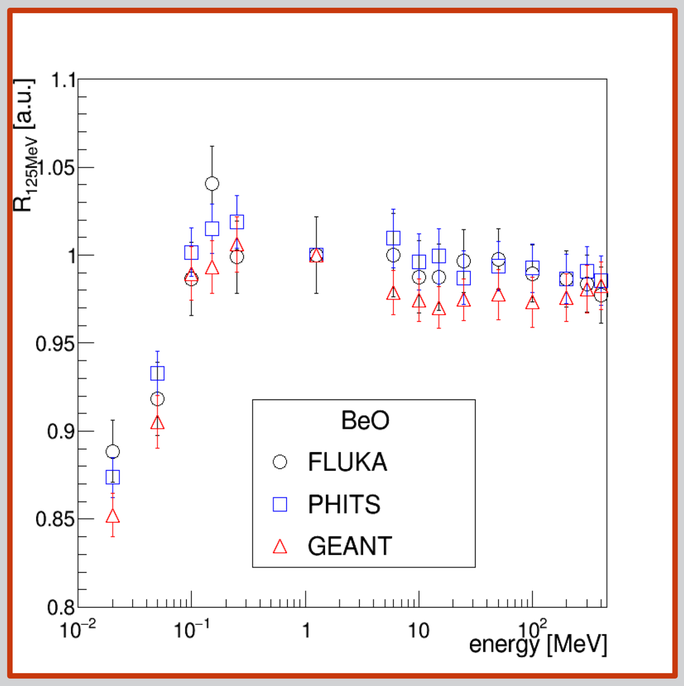
- Three different Monte Carlo codes:
  - **FLUKA.CERN**: 4-2.1
  - **GEANT4**: 10.07.p02
  - **PHITS**: 3.26
- Absorbed dose was scored in the volume occupied by the detector
- Total number of primary photons → statistical uncertainty 1% or better on the simulated absorbed dose.
- Geometry
  - ISO slab phantom (ISO 4037-3:2019(E)) placed in air
  - Solid state dosimeters chips
    - (4.7 x 4.7 x 0.5 mm³) were placed
    - at a depth of 2 cm for <1MeV and at a depth of 10 cm for higher energies (absolute dosimetry protocol)
- Beam
  - 10 x 10 cm² photon beam (IAEA code of practice for dose to water calibrations)
  - No angular divergence was added
  - An extended energy rage was investigated

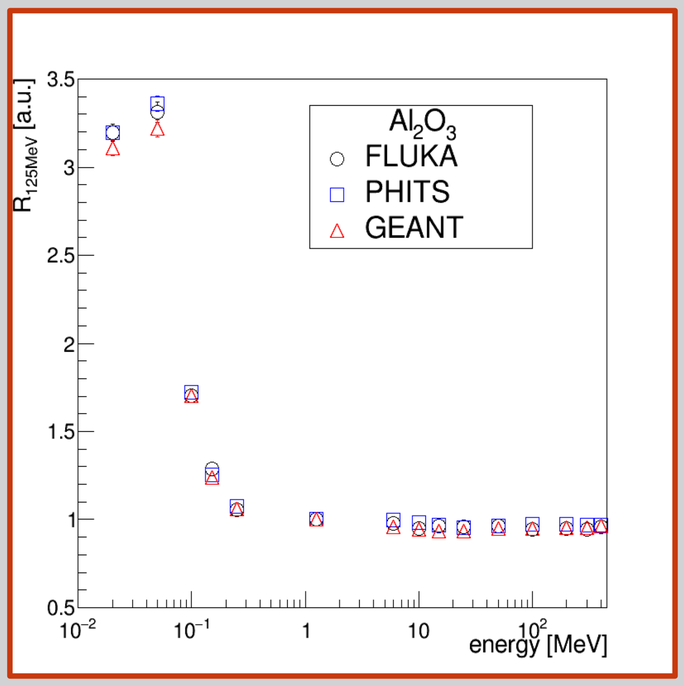
RESULTS & DISCUSSION

- The 3 Monte Carlo codes show excellent agreement throughout the investigated energy range for all materials.
- For all materials, the results are compatible within one and two standard deviation.
- The excellent agreement among the codes used confirms the reliability and robustness .









Relative absorbed-dose factor as defined in equation 2. Values are shown for 3 Monte Carlo codes: FLUKA.CERN, PHITS, and GEANT4. The error bars represent the statistical uncertainty, between 1-2%. Where non visible, they are small enough to be fully contained in the markers

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