Monte Carlo Simulations of the Irradiator on a Risø Reader

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Aim

The aim of this work is to develop an accurate computational model for the irradiator of a Risø DA-20 model[1], 2009, with a Eckert&Ziegler (E&Z) source of glass encapsulated Strontium (Sr) at CTN, in order to perform Monte Carlo simulations to estimate β and photon flux distributions and energy spectra at the source, and sample levels.

Introduction

Risø readers are used for measuring the absorbed dose in mineral grains and Thermoluminescence dosimeters (TLDs). The luminescence response is calibrated relative to irradiation with an internal Strontium/Yttrium (Sr/Y) β-source. For luminescence dating the mineral and grain size fraction commonly used is 100 micron diameter grains of Quartz, mounted on stainless steel discs. TLDs are commonly ca. ca. 1 mm thick 5 mm across and may be approximately biological equivalent or quartz equivalent with respect to energy absorption.

In the present work, the geometry and composition of the source, housing and castle, and sample support was built in MCNPX based on published data and inspection of the apparatus. The deposited beta and photon flux and energy spectra by means of Monte Carlo (MC) simulations was determined for dosimetric purposes. The different contributions to both the beta and gamma particle flux and energy spectra were determined and compared. This work is part of the wider research project VADOSE the aim of which is to combine experimental determinations and modelling fordosimetric evaluation of soils and sediments with different compositions.

Materials and Methods

1. The Risø Reader.

The Risø Reader (DA-20 model, 2009) at CTN consists of a cylindric castle made of Lead (Pb) which is 140 mm wide and 120 mm long. Inside it there is a stainless steel (SS) rotating weel (60 mm diameter; 20 mm width) where the samples are placed. They are irradiated by means of a Sr/Y β-source inside a perpendicular Aluminium cylinder (60 mm diameter; 15 mm width). All this is encased in Brass. The geometric details of the Reader are given in figure 1.

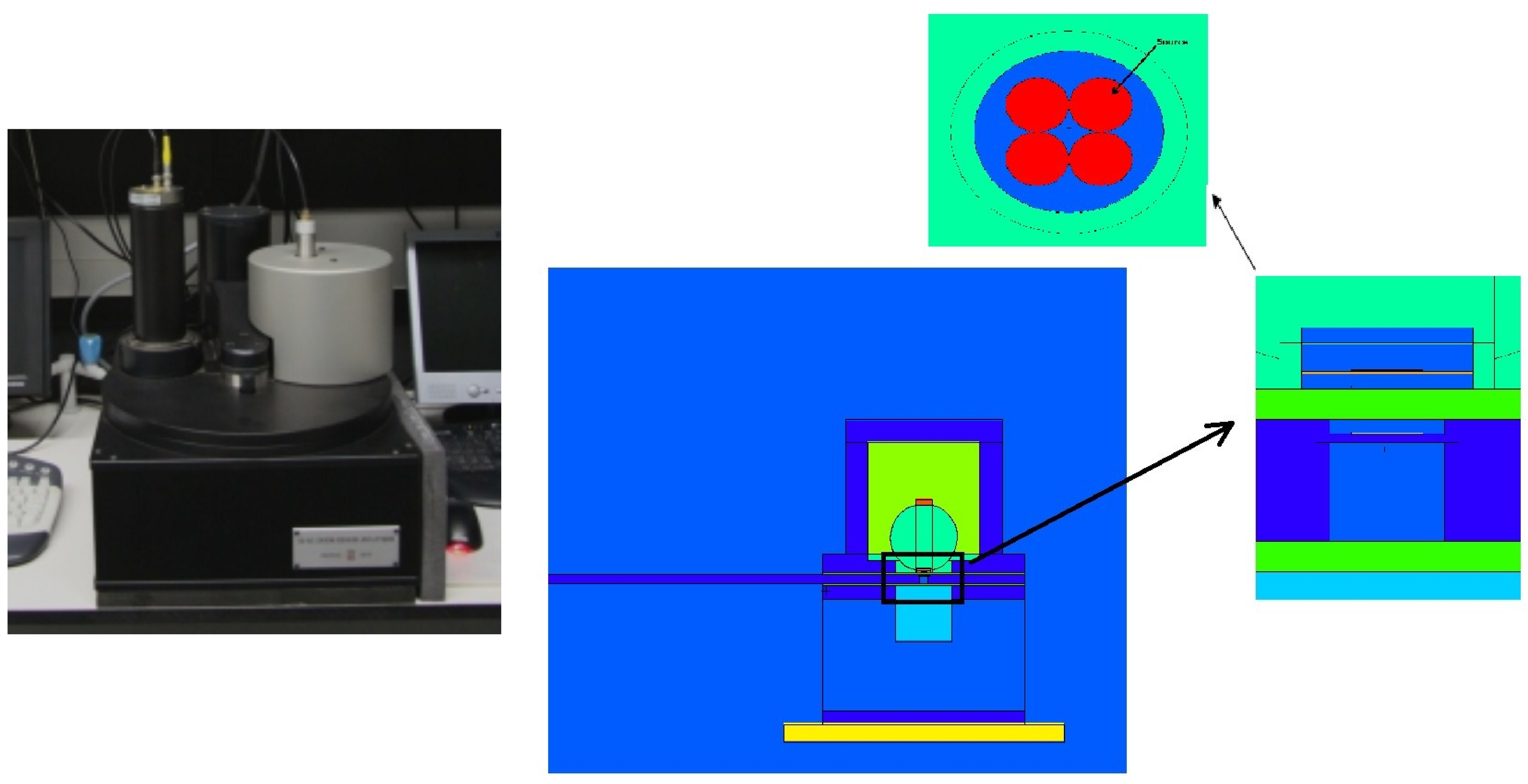

Figure 1: Geometric details of the Risø Reader as implemented in the MC Code.

2. The Monte Carlo Simulations.

2.1 The Code.

The MC code MCNPX ver 2.5f was used to perform the simulations. Electrons and photons were tracked in the simulations. The MCPLIB02 and the EL03 libraries for photon and electron cross sections, from the RSICC package DLC-200, were used. $4x10^8$ initial particles were simulated in order to obtain statistical uncertainties lower than ~5% (1σ).

2.2 The Source.

The β-source consists of four 1 mm wide, 2 mm long, Strontium cylinders emitting isotropically. There is a Be window separating the samples from the source. The energy spectrum was modeled as being the sum from the emission spectra of Sr and Y, as shown in figure 2 [2]:

Results

• The flux distributions and dose deposition of both β particles and photons were tallied in energy and spatially

• The aim was to charachterise both the source and the particles reaching the target (sample) in order to understand what happens.

• The average energy of the β particles shifts from ~800 keV to ~ 640 keV indicating the significance of the interactions in this geometry (β tracks per source particle: 74;photon tracks per source particle: 1.8);

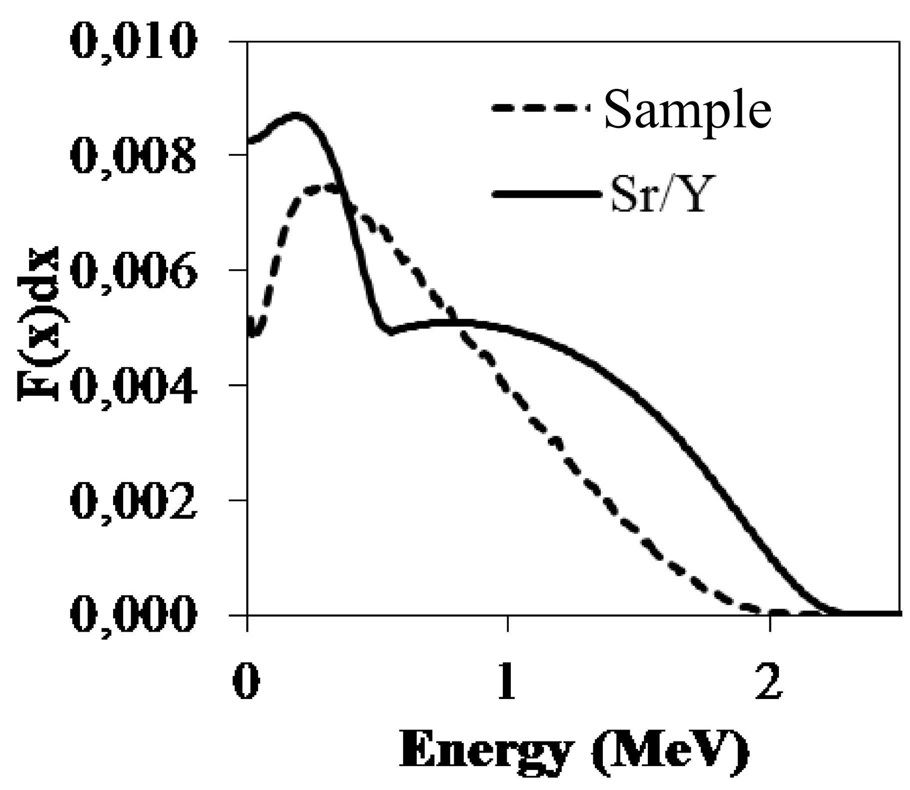

Figure 2: Normalized β particle energy distribution of Sr/Y and at the Quartz sample.

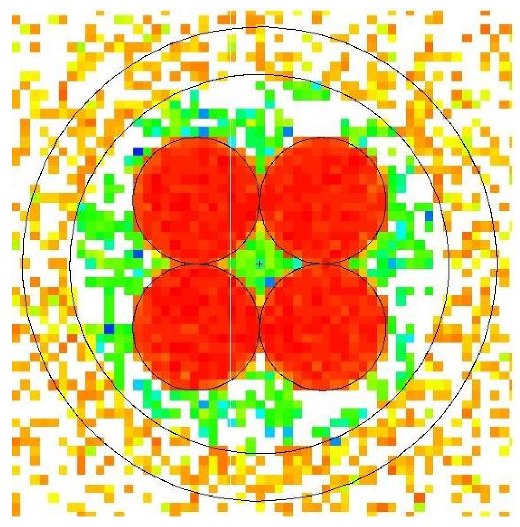

Figure 3: Energy deposition tallied around the Sr/Y source.

- The photon energy spectrum at the sample shows the main contribution to secondary photons is bremsstrahlung
- The filtering at lower energies os due to the surrounding materials
- Further studies are needed to understand the spectrum at lower energies (<100keV)

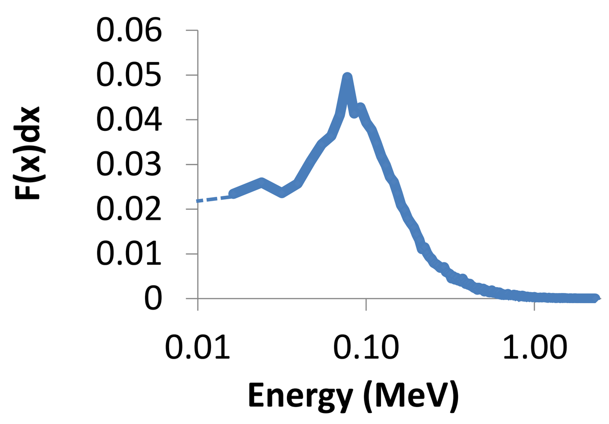

Figure 4: Photon energy distribution at the sample

Conclusions

✓Preliminary results show that this MCNPX model can accurately estimate the associated dose rate values

✓Compton recoil is very low ~0.1-1 % at the Quartz sample and

✓Brehmsstrahlung accounts for ~85% of the total number of secondary photons generated;

✓Photon electrons account for ~1% of the total number of photons arriving at the sample;

✓Preliminary dose rate calculations indicate a value of 174 mGy/s compared with an experimental value obtained using the material irradiated in [3] of 135 mGy/s.

References

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[3] Richter, D., Zink, A., Przegietka, K., Cardoso, G.O., Gouveia, M.A., Prudêncio, M.I. **2003**. Source calibrations and blind test results from the new Luminescence Dating Laboratory at the Instituto Tecnológico e Nuclear, Sacavém, Portugal. Ancient TL *21*, 1-7.

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