INSTRUMENTATION AND SIMULATION IN NUCLEAR PHYSICS AND DOSIMETRY

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In 2002 we started the study of instruments and detectors employed in nuclear and medical physics using Monte Carlo calculations. The complete description of the interaction of radiation with matter in real physical systems, like detectors, people and environment subject to radiation, is quite complex and difficult to be modelled. Difficulties in modelling such systems arise mainly due to four characteristics:

1) they are usually made of different materials;

2) they present large variety of geometrical shapes;

3) they are normally exposed to a primary radiation source of of wide energy distribution;

4) the primary radiation produces a broad spectrum of secondary radiation.

For such systems Monte Carlo methods are preferable to analytical methods, since it permits to simulate the complete history of a particle with some amount of kinetic energy until it comes to rest. Monte Carlo simulations were not widely used until some years ago because processing time was prohibitively large for common computers. Nowadays, Monte Carlo calculations of complex systems can be performed with low-cost personal computers. In this period the studies concerned mainly the following topics: production of X rays, detection of X and gamma rays, simulation of a position sensitive detector for gamma rays, dosimetry and neutron beam characterization. The GEANT4 toolkit and MCNP code for Monte Carlo calculations were employed in the simulations. X ray production - A program for simulations of X ray tubes was developed to obtain the energy distribution of photons produced by electrons impinging in tungsten targets with energies corresponding to the selected peak voltage (kVp). The filtering of the X ray spectrum was performed by another program, which allows the employment of filters made of several materials with different thickness.

Radiation detection - Programs were developed for simulation of detection of X and gamma rays by CdZnTe (CZT) solid state detectors, as well as by LiF and CaF_2 thermoluminescent dosimeters (TLDs). Fluence to effective dose conversion coefficients were calculated for high energy neutrons with voxels of an anthropomorphic phantom MAX by means of Monte Carlo simulation using the GEANT4.

Validation - Simulations were performed for spectra produced by a Philips tube, model MG 450, and for the filtering process to obtain the ISO 4037-1 narrow series (N) spectra, which are recommended for calibrations of dosimeters. (FIG.1) shows simulated spectra for kVp = 80 kV: a) unfiltered, red; b) filtered, blue. The simulation of the detection of the narrow series radiation fields (N-20 to N-100), as well as of a ^{133}Ba source field, was performed for an Amptek-CZT-100 detector.

Comparison between simulations and experimental data shows good overall agreement. Some discrepancies at the low-energy part of the spectra can be attributed to effects of incomplete charge collection in the CZT detector, which was not included in the simulations yet. Also the comparison between simulated and experimental results for for LiF and CaF_2 TLDs exposed to narrow series radiation fields (N-20 to N-300) and to the field of a ^{60}Co source was performed. Good agreement was observed and the self-absorption of light in the CaF_2 TLD could be evaluated.

These results shows that GEANT4 is a promising tool to be used in simulations of typical systems found in dosimetry, medical physics and radiation protection.

Position sensitive detector - The simulation of a Position Sensitive Detector (PSD) composed by a scintillator bar coupled to two PIN-diodes was performed. This simulation is part of a study to evaluate the response of a small detector with possible application in positron emission tomography for small animals.

A new concept of tomographic detector build from several unit of this PSD would provide images which allow the localization of positron sources in three dimension.