Benchmark experiment for the verification of radiation transport calculations for dosimetry in radiation therapy completed

A benchmark experiment to verify Monte Carlo calculations for the radiation transport was carried out at PTB’s research accelerator. For this purpose, fundamental characteristics of the accelerator’s electron beam had to be determined, and the experiment had to be precisely modelled in the Monte Carlo simulation. The results of the measurement and of the Monte Carlo simulation are in agreement with each other within the scope of a measurement uncertainty of approximately 1.0 %.

Monte Carlo simulations are considered to be the most accurate solution procedure for complex issues in the field of dosimetry and radiation transport. In (external) radiation therapy, they are increasingly used for the calculation of dose distributions when planning a radiation treatment. In comparison to other dose calculation algorithms, Monte Carlo methods have a great potential to increase the accuracy of the dose calculation – especially under complex conditions (e.g. consideration of inhomogeneities). However, there is a lack of information on how correct the dose distributions calculated by means of the Monte Carlo simulation are in the absolute sense. The results of Monte Carlo calculations can be checked close to practice by comparing them directly with the results of a benchmark experiment.

Such a benchmark experiment was realized at PTB. The experiment was designed in such a way that with regard to the radiation type and radiation energy used, the materials used and the detection of the absorbed dose, it exhibits parallels to external radiation therapy. To be able to carry out an absolute comparison between the results of the experiment and the Monte Carlo simulation, the characteristics of the radiation source must be very well known. However, some pieces of information on the radiation source are usually not available, as they cannot be detected experimentally, as a rule. Therefore, in most cases, the results taken from Monte Carlo calculations and experimental measurements are compared to each other only relatively. However, an almost unique radiation source in the form of a research electron accelerator is available at PTB whose electron beam can be precisely characterized. By means of various instruments for the beam diagnosis, the geometric cross section, the pulse charge and the spectral fluence of the electron beam can be determined (Figure 1).

Fig. 1: In the part of the beamline shown above, which is adjacent to the acceleration path for the electrons (behind the wall, right), the following instruments have been mounted for beam diagnosis: beam profile monitors: #1, #4, #6; beam current monitors: #2 and #5; magnetic spectrometer: #3.
The benchmark experiment was designed for high-energy photon radiation. For the conversion of the primary electron radiation into photon radiation, an X-ray target was used. The characteristics of the target – such as the composition and the density of the material as well as the thickness of the target – which can influence the dose amount, have also been precisely determined.

The absorbed dose was detected via two different types of ionization chambers which have been placed centrally in a phantom made of water-equivalent plastic at a distance of approximately 2 m to the X-ray target. The chambers are graphite cavity ionization chambers which are actually used to determine the air kerma in gamma radiation fields. The chambers were selected as dose detectors in the benchmark experiment due to the fact that the set-up and the volume of these chambers are very precisely known.

To thoroughly perform the task of verifying radiation transport calculations by means of the benchmark experiment, the benchmark experiment was modelled by means of a Monte Carlo simulation. For this purpose, the Monte Carlo program EGSnrc [1] was used which has been established in dosimetry and radiation therapy. The simulation has been set up on the basis of the experiment. The corresponding geometry is shown in Fig. 2. The experimental result and the result of the simulation were compared in an absolute way for both ionization chambers. By taking into account the respective relative uncertainty, which amounts to approximately 0.7 % for the benchmark experiment and to approximately 1.0 % for the Monte Carlo simulation, the results of the Monte Carlo simulation and of the experiment coincide in both cases (for an example, see Fig. 3).

![Simulation Geometry](image)

Fig. 2: The simulation geometry used, illustrated by means of the example of one of the two ionization chambers (so-called HRK2) used.
Fig. 3: Comparison of the benchmark experiment result and the result calculated via the Monte Carlo simulation for one of the two ionization chambers. The uncertainty assessment for the simulation made it necessary to carry out several simulations in order to be able to estimate various influences on the uncertainty.

**Literature**


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