

# Quality Assurance of Radiotherapy using Scattered X-ray

## SYSTEM TESTING

### 1. Photon Trajectory Management

To verify the management of photon trajectory, we defined three photons by assigning them a position in 3D space and a momentum direction. The photons started at the point  $[0,0,0]$  and traveled along the positive directions of x-, y- and z-axes, and thus had momentum directions  $[1,0,0]$ ,  $[0,1,0]$  and  $[0,0,1]$ . The photons were subject to travel a distance of 1 meter, and, thus were supposed to obtain the final positions of  $[100,0,0]$ ,  $[0,100,0]$  and  $[0,0,100]$ , respectively. To facilitate the verification procedure, an animation of the photon movement was created which is presented in Figure 1 below.

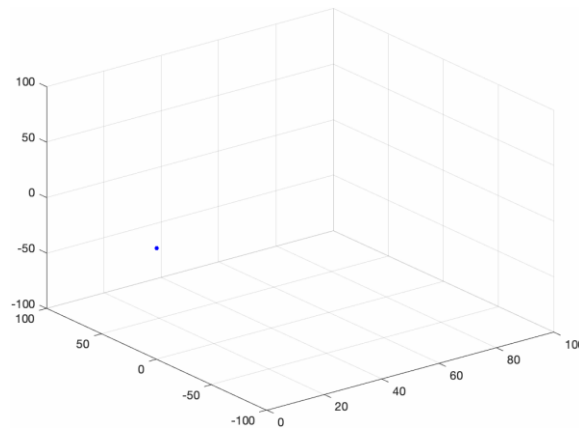


Fig. 1. Photon movement animation

As the animation shows, the photons start at the origin and traverse along their assigned axes. The result of the test indicates that our management of photon movement is correct and we are ready to work with photons scattering outside of a phantom as they pass through the matter.

## 2. Photon Registration on the Detector Sensor

We defined a detector sensor area such that its bottom corner was at  $[100, 0, 0]$  and its top corner was at  $[100, 30, -30]$ . Then, we defined two photons at positions  $[0, 10, -10]$  and  $[0, -1, 0]$ , both traveling in the same direction  $[1, 0, 0]$ . The first photon was expected to collide with the detector sensor while the other one was not due to its initial position. The presented below animation was created to facilitate the verification procedure.

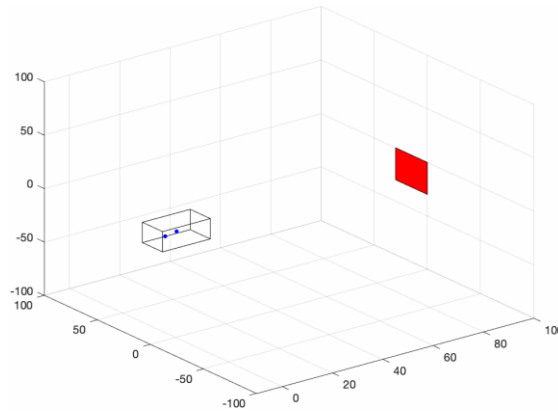


Fig. 2. Animation of photon interaction with the detector sensor

As the animation shows, only one photon interacts with the detector while the other one narrowly misses it. The test result indicates that we correctly handle the photon registration on the detector sensor.

## 3. Energy Filtering

We defined three photons with energies  $10^5$  eV,  $10^3$  eV, and  $10^7$  eV, respectively. We set the detector energy threshold to  $10^4$  eV. If the algorithm worked correctly, the second photon would not be recorded on the detector sensor. Figure 3 below shows the obtained detector response which indicates the correctness of our program.

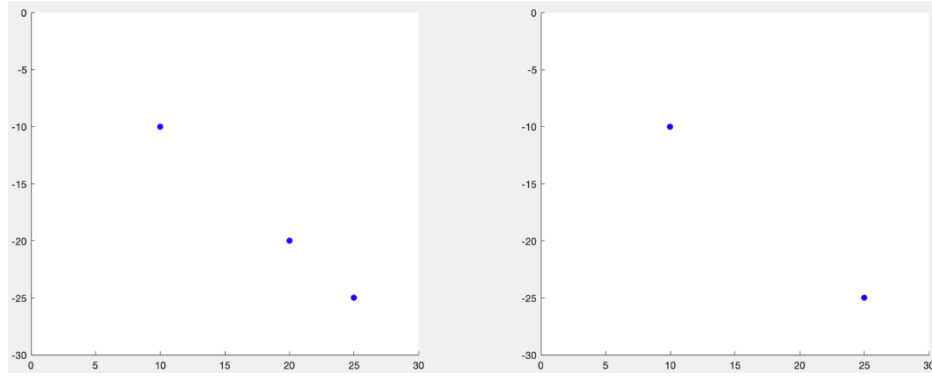


Fig. 3. Photons on detector face (left); photons registered on the detector sensor (right).

#### 4. 3D Collimator Design Confirmation

A small collimator was built to verify the correctness of its shape and dimensions. The geometrical parameters of the hexagonal holes were intentionally increased to make the visualization clearer. Figure 4 depicts nicely interlocking hexagonal holes confirming the correctness of the collimator construction.

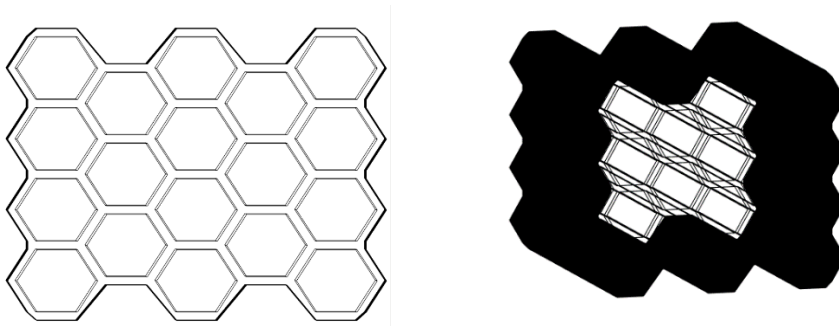


Fig. 4. Collimator top view (left); collimator isometric view (right)

## 5. Photon Filtering by 3D Collimator

To simplify real radiation physics processes, a decision was made to record only those photons that passed through the collimator holes without touching the collimator material. To test the collimator filtering function, a collimator with a single hexagonal hole was created (Figure 5).

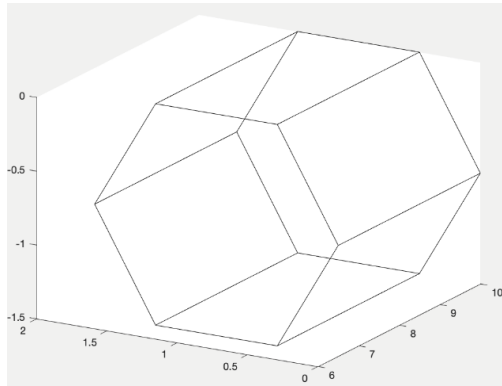


Fig. 5. Single Hexagonal Hole Collimator

Then, we defined three photons with the starting positions at  $[0, 0.8, -0.8]$ ,  $[0, 0, 0.8]$  and  $[0, 0.75, -1.6]$  and having momentum directions  $[1, 0, 0]$ ,  $[0.98, 0, -0.18]$  and  $[1, 0, 0]$ , respectively. The first photon was supposed to pass straight through the collimator hole, the second photon was supposed to collide with the wall inside the hexagonal hole, and the last one was supposed to collide with the detector face. Thus, if the algorithm worked correctly, only the first photon would be recorded on the detector sensor. And that was the result we obtained when executing our program, ensuring its validity.

## 6. gDPM Output Files Size Reduction

When reducing the size of the gDPM output files, we forced the simulation to record the information on only those photons that would scatter towards the detector sensor based on the x-coordinate of their momentum direction. To make sure that we did not filter out useful information, we run a single simulation with  $10^8$  histories and recorded both the original (full-size) and reduced output files to then compare their results to each other. Thus, once the both files were obtained, we

processed them through our MATLAB code and visualized the resulting longitudinal profiles of the simulated dose and photon counts (Fig.6). The results looked identical indicating the validity of our reduction method. The file reduction decreased the space usage on Google Colab from 1.52 GB to 54.9 MB allowing us to run simulations with  $10^{10}$  histories.

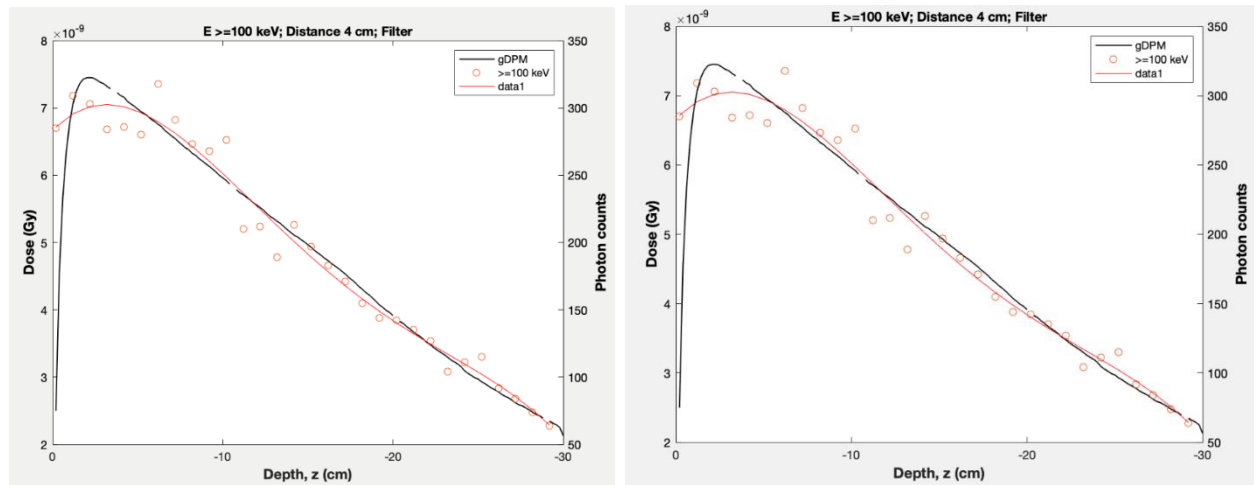


Fig. 6. Longitudinal profiles of the simulated dose and photon counts obtained with original full-size gDPM output files (left) and reduced gDPM output files (right)