

# Quality Assurance of Radiotherapy using Scattered X-ray

## SYSTEM DESIGN

The design of the system is depicted in Figure 1. The system comprises two parts: 1) The simulation of a MV x-ray beam transport through a phantom and the registration of the photons in a scoring volume; 2) The scattered photons' transfer from the scoring volume to a photon counting detector and the relation of the detector signal to the delivered radiation dose. The first part should be done using the gDPM Monte Carlo simulation package<sup>1,2</sup>, while the second part must be implemented in MATLAB.

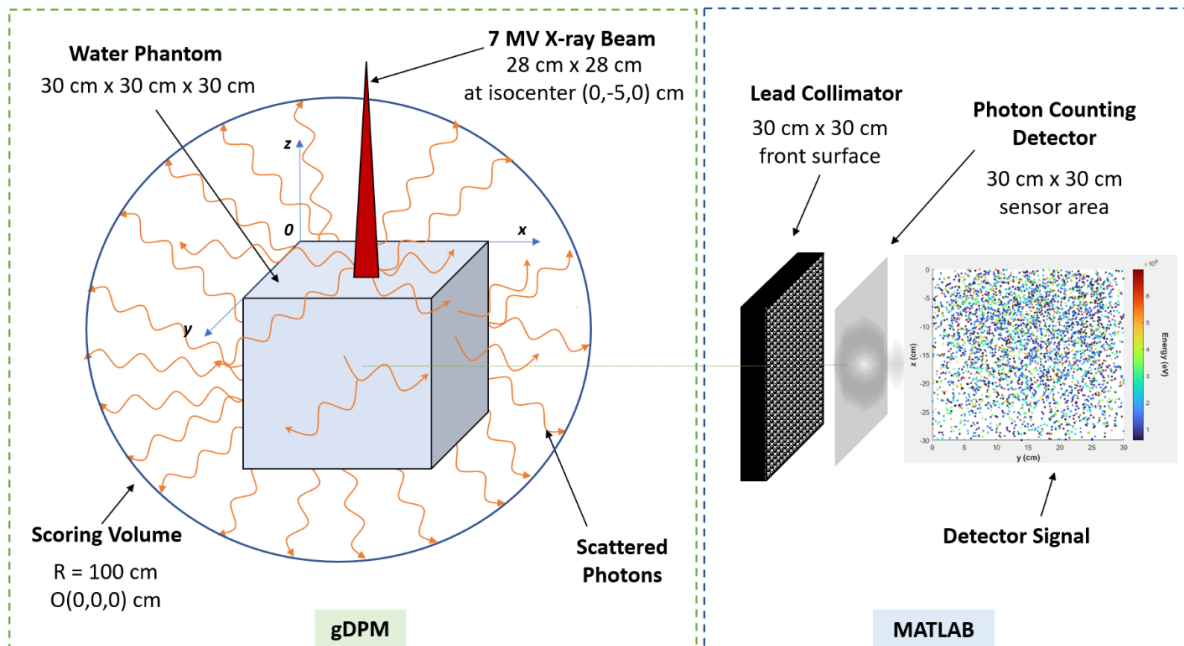


Figure 1. System design

### The description and characteristics of the system units

1. **A 7 MV x-ray beam** is a beam of electromagnetic radiation with the maximum energy of 7 megavolts (MV) which corresponds to the voltage used to accelerate electrons in a linear accelerator. In the system, the beam is diverging and has a 28 cm x 28 cm cross-section at the isocenter located inside the phantom at (0, 0, -5) cm. The beam source is 100 cm away from the isocenter.
2. **A phantom** is an object used as stands-in for human tissue to study radiation deposition when it is targeted with a radiation beam. In minimum and expected deliverables, a phantom made of water should be used while in maximum deliverables, heterogeneous

phantoms (a water phantom with a piece of bone and an air cavity, a phantom with bone and lung pieces) must be considered to mimic the heterogeneous density of a real human body. The default gDPM water phantom is cube-shaped with a 30 cm side length. The design of heterogeneous phantoms can be borrowed from a similar study carried out by other researchers<sup>3</sup>.

3. **Scattered photons** are photons which, upon collision with the matter, scatter in a different direction. In the case of MV x-rays, the phenomenon is mainly referred to as the Compton process<sup>4</sup> where an incident photon collides with a planetary electron having a low binding energy. The photon gives a part of its energy to the electron as kinetic energy. Then, it deflects from its initial path, proceeds with reduced energy, and gets involved in further interactions.
4. **A scoring volume** is a sphere constructed in the gDPM around the phantom to record information on the photons passed through the phantom, including their energy, momentum direction and position (x, y, z- coordinates and radius). If a photon gave up all its energy while interacting with the matter and thus, in theory, it “disappeared” inside the phantom, then its registered position, momentum direction and energy are the ones the photon had right before its death. By default, in the gDPM, the sphere radius is 100 cm, and the sphere center is at the furthest top left phantom corner. These parameters can be modified as needed.
5. **A collimator** is a device that filters the scattered photons approaching the detector sensor by letting pass the ones that would fall on the sensor at approximately right angle. The system uses a multi-hole collimator with hexagonal holes. The collimator is made of lead, its size and the vertices’ coordinates should match the corresponding parameters of the facing phantom side. The collimator thickness should be set to 3.5 cm, the distance between two opposite hole faces to 1.5 mm, and the distance between two adjacent holes to 0.2 mm.
6. **A photon counting detector**<sup>5</sup> is a device that converts the x-ray photon energy to an electrical signal and counts those photons whose charge is greater than a specified energy threshold. The detector sensor area should match the phantom dimensions to obtain optimal results. Different energy thresholds should be explored, and the most appropriate ones are to be determined in the project.
7. **A detector signal** – a two-dimensional plot with the coordinates of the photons registered by the photon counting detector.

The most appropriate distance between the phantom and the collimator/detector sensor area are to be determined in the project.

## References

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3. Cunha, M., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: Concept and simulation study. *IEEE Transactions on Nuclear Science*, 60(4), p. 3119-3126
4. Hall, E.J. (2000). *Radiobiology for the radiologist*. 5th edition. Philadelphia, PA: Lippincott Williams & Wilkins.
5. VAREX Imaging (n.d.). Photon counting. Retrieved from <https://www.vareximaging.com/photon-counting/#:~:text=Photon%20Counting%20Technology,-Photon%20counting%20detectors&text=The%20use%20of%20direct%20conversion,into%20light%20through%20a%20scintillator>