Mechanistic Model of Collimator Scatter in External Radiotherapy

Master project physics

Supervisors: Dr. Pascal Hauri, Prof. Dr. Uwe Schneider
Location: Radiotherapy Hirslanden, Zürich and
Department of Physics, University of Zürich, Switzerland

Contact: Pascal Hauri, Email: pascal.hauri2@uzh.ch

1. Motivation

The intention of radiotherapy is to control or cure local diseases while avoiding or minimizing early and late effects caused by radiation. Cancer cure rats are staidly increasing resulting in an increasing number of long term survivors of cancer who are at risk of late effects. If the patients were treated with radiation, second cancers can be one of these side effects. As a consequence, it is important to model the whole-body dose. Furthermore, for pregnant patient it is crucial to know the dose to the fetus. Commercial treatment planning systems (TPS) accurately calculate the dose in the treatment region where the tumor is located. However, outside the target region the dose is underestimated by orders of magnitude by the TPS.

To calculate the whole-body dose for a patient resulting from external radiotherapy, our group developed a general model of stray dose [1]. The dose outside the primary beam was modeled according to its three major components. The components are shown in Figure 1). The primary photon bema produced in the gantry head is collimated to the size of the tumor resulting in a specific field size. This collimation result in scatter of photons in the linear accelerator referred to as collimator scatter. The magnitude of patient scatter and collimator scatter strongly depend on the field shape. For photons scattered in the patient a mechanistic model was introduced in [1] which is able to calculate patient scatter for any field shape. For collimator scatter a strict empirical approach was utilized. To calculate the dose resulting from collimator scatter a library consisting of reference dose curves for different field sizes was used. Constructing this library of collimator scatter is time consuming and leads to an error in dose since not all field shapes are represented.

2. Aim of the project

The aim of this master project is develop a mechanistic model for collimator scatter. In a first step, a simple geometrical model of the gantry head with its major beam collimation components is constructed. The photon scatter caused by Compton interactions of the primary bema in the gantry head is represented by ionizing radiation point sources. These point sources are distributed in the gantry head leading to a mechanistic representation of collimator scatter.

In a second step, experiments should be designed to extract the magnitude of scatter arising from the different collimation components. This is done by a systematic variation of the collimation of the primary beam. Collimator scatter is measured using an ionization chamber or thermoluminescent dosimeters. The mechanistic model is then tested with already existing data of collimator scatter for simple field shapes.

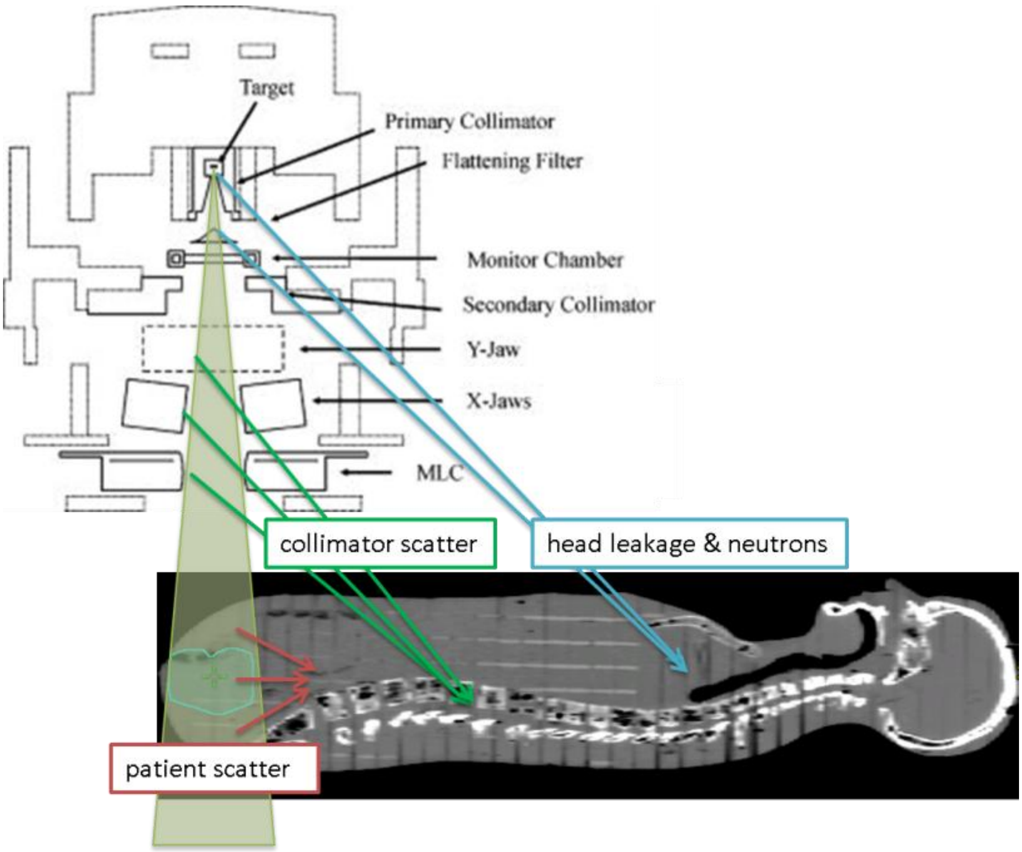
A protocol shall be designed to generalize the model to other photon beam energies and flattening filter free beams. The protocol should be utilizing measurements in simple geometries. Using the protocol the model is generalized to nominal bema energies of 6 MV, 10 MV, and 15 MV. Furthermore, flattening filter free beams are modeled.

In a fourth step, the model is included in an existing whole-body dose algorithm. Whole-body doses are recalculated for real patient treatments and compared to existing whole-body dose measurements.

3. Research Plan

The Master thesis is a nine month project.

(1) Literature study (1-2 weeks).
(2) Implementing a geometrical representation of the scatter components (1 month).
(3) Extract the collimator scatter components with measurements (2-3 months).
(4) Fit parameters of the mechanistic model of collimator scatter (1-2 months).
(5) Design a protocol and generalize the model (1-2 months).
(6) Implement the model in an existing whole-body dose algorithm and test it compared to the old algorithm (1-2 months).
(7) Develop a mechanistic model for head leakage (optional 2 months).
(8) Writing thesis and preparing a final presentation (1-2 months).



(9) **Figure 1) Schematic view of a patient treatment in radiotherapy and the major out-of-field dose contributions. The primary beam is collimated in the gantry head to a field size matching the tumor size. The outline of the tumor can be seen in the hip region.**

[1] P. Hauri, R.A.. Hälg, J. Besserer and U. Schneider. A general model for stray dose calculation of static and intensity-modulated photon radiation. Medical Physics (2016).