

# Validation of a Monte Carlo prediction model for portal images using PENELOPE

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## Abstract

In external beam radiotherapy, dosimetric verification is usually performed by comparing dose images provided by EPIDs with predicted images computed using Monte Carlo (MC) simulations. The goal of the present study is to develop a portal prediction model with the MC code PENELOPE and validate it against experiment. Experimental images were acquired at 12 MV using a Saturne 43 accelerator and a fluoroscopic Lynx2D EPID (SDD = 150 cm), for 4x4, 10x10 and 15x15 cm<sup>2</sup> open fields, and both without and with a 30x30x30 cm<sup>3</sup> water phantom in the beam. The accelerator and the EPID were simulated with PENELOPE. Two EPID models were implemented, one describing in details the geometry and the other being a simplified model, composed of three layers (copper, GOS and water). The water layer simulated the backscatter within the EPID and its thickness had to be adjusted. The best EPID model was found to be the simplified model including an 8 cm thick backscatter compartment. This model was then used to compute portal images with and without the water phantom in the beam and the simulated and acquired images were compared using the  $\gamma$ -analysis.  $\gamma$ -index values less than 1 were obtained for 96% of the pixels for fields of 10x10 cm<sup>2</sup> or less and for 90% of the pixels for larger field sizes. These results exhibit that a simple MC EPID model allows predicting accurately portal images for open fields, with and without object in the beam, and that PENELOPE is a reliable tool for this purpose.

## Introduction

Dose delivery in radiotherapy can be verified online by comparing images acquired using Electronic Portal Imaging Devices (EPIDs) with predicted dose images computed with Monte Carlo (MC) simulations [1]. The objective of this study is to develop a reliable prediction model of portal images using the MC code PENELOPE and to validate it against measurements.

## Material and methods

**Experiments:** Portal images were obtained using a Saturne 43 accelerator (GEMS), delivering a photon beam energy of 12 MV and equipped with a fluoroscopic Lynx2D EPID (FIMEL, France). EPID images were acquired for 4x4, 10x10 and 15x15 cm<sup>2</sup> open fields and for two configurations, one without object in the beam (in-air images) and the other with a 30x30x30 cm<sup>3</sup> water cubic phantom located at 90 cm from the source, with a source-to-isocenter distance and a source detector distance set to 100 cm and 150 cm, respectively. Each image was formed by averaging 15 images of 10 s each, at a dose rate of 200 MU/min (1.7 Gy/min) and was corrected for dark-field and flood-field.

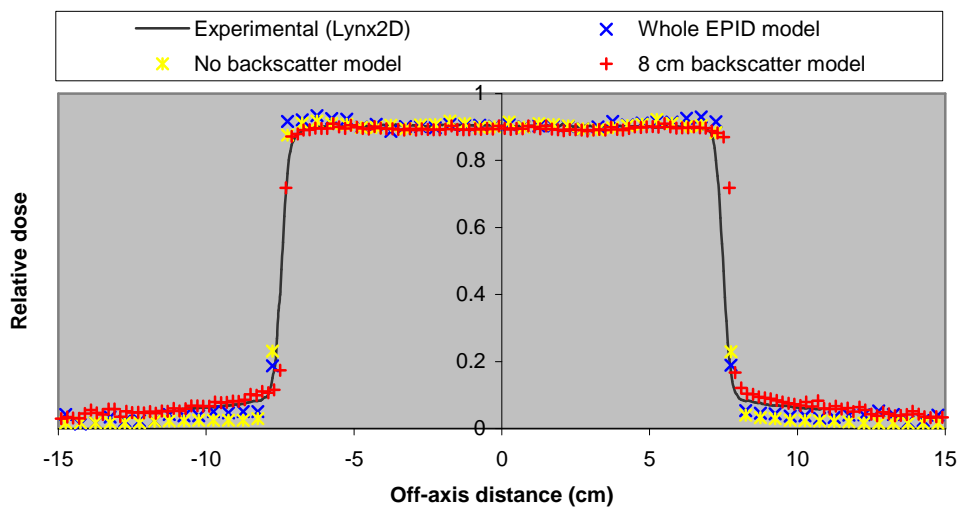
**Monte Carlo simulations:** the PENELOPE code [2] was used to develop a MC model of the accelerator and the EPID. Using this model, phase space files (storing information about 150 million particles) were generated at the exit of the accelerator head and portal images were computed by scoring the energy deposited in the GOS layer on a 150x150 pixel virtual grid, with a pixel size of 2x2 mm<sup>2</sup>. Two EPID models were tested: the first model described accurately the whole EPID geometry, following the manufacturer specifications. The second model consisted in a three-layer simplified model: the fluorescent screen was represented by a copper layer and a GOS layer, beneath them was added a uniform water slab to mimic backscatter

within the EPID. The water slab thickness was varied in simulations until values in simulated images matched those in experimental images, for the studied field sizes.

Validation of the MC prediction model: the MC prediction model was validated for both configurations (in-air and with the water phantom) by computing the gamma index on profiles and images, using 3% and 3 mm as values for dose-difference and the distance-to-agreement criteria, respectively. Simulated portal images were normalized with respect to acquired images.

## Results

Profiles computed for the different EPID models and for the 10x10 cm<sup>2</sup> field (Fig.1) demonstrate that the EPID response can be reliably predicted by a simple three-layer model, with an 8 cm thick backscatter compartment. These results also show that including in the model components such as the mirror and the shielding do not bring a lot, the EPID response being dominated by the backscattering of optical photons.



**Fig.1.** Comparison of experimental and simulated profiles obtained with different MC EPID models.

Results of the  $\gamma$ -analysis are presented in Table 1 and show a very good agreement between simulation and experiment.  $\gamma$ -index values less than 1 were obtained for 90% and 96% of the pixels for large field sizes and fields of size 10x10 cm<sup>2</sup> or less, respectively. Discrepancies are mostly observed in the steep dose gradient regions, mainly due to uncertainties in the EPID positioning, and outside the field because the cross-talk was not efficiently corrected for large field sizes.

Configuration	Field size (cm <sup>2</sup> )	2D $\gamma$ -index (%)
In-air	4x4	98.6
	10x10	96.4
	15x15	90.2
Water phantom	4x4	98.7
	10x10	96.5
	15x15	91.8

**Table 1.**  $\gamma$ -index values computed on simulated and acquired images.

## Conclusion

This study shows that a simple three-layer MC model, including a backscatter compartment and developed with the code PENELOPE, allows to predict reliably portal images, in air and with an object in the beam, for open-fields.

## References

1. W. van Elmpt et al, Radioth. Oncol. 2008, vol. 88: 289-309.
2. J. Baro et al, Nucl. Instr. and Meth. B 1995, vol. 100: 31-46.