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

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Context and objectives

- Online verification of dose delivery during radiotherapy treatments has become essential in order to ensure that the dose planned by the treatment planning system (TPS) is delivered as accurately as possible and to detect possible deviations.
- One strategy using EPIDs for dosimetric verification consists in comparing predicted dose images with acquired portal images before and/or during treatment [1].
- Our goal is twofold:
  - demonstrate that the Monte-Carlo (MC) simulation code PENELOPE [2] can be used to compute reliably predicted dose images,
  - develop and optimize a MC model of an EPID and validate it against measurements.

Measurements

Description of the experimental setup

- Saturne 43 Linac (GEMS)
  - 12 MV photons, 200 UM (1,7 Gy/min at 100 cm),
  - field sizes: 4x4, 10x10 and 15x15 cm².
- Fluoroscopic EPID (Lynx 2D, Fimel, France)
  - fluorescent screen (1 mm copper coated with a GOS fluorescent layer) viewed by a CCD camera via a mirror tilted at an angle of 45°,
  - active area: 30x30 cm²,
  - pixel size: 0.5x0.5 mm² (600x600 pixels).

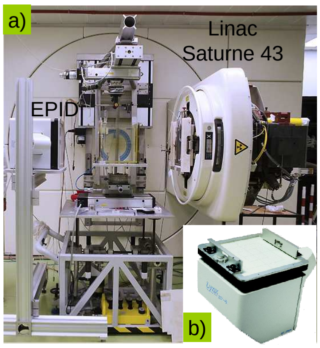


***Fig. 1**: a) Experimental setup and b) fluoroscopic EPID*

Acquisitions

- Source-to-isocenter = 100 cm; source detector distance (SDD) = 150 cm,
- Phantom: 30x30x30 cm³ water tank (entrance face at 90 cm from the source),
- Each acquired image formed by averaging 15 images of 10 s each,
- Acquisition of open-field portal images with and without the phantom in the beam ("in-air" images), for the three fields sizes (4x4, 10x10 and 15x15 cm²)

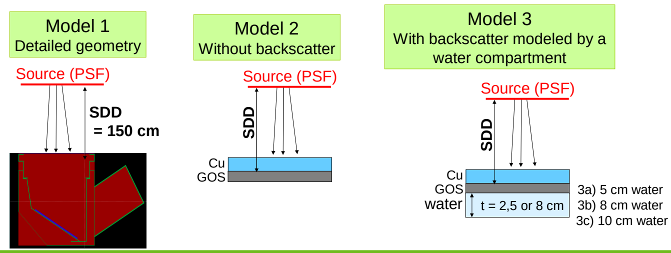
Monte Carlo simulations

Computation of Monte-Carlo portal images in two steps

- **Step 1**: computation of a phase-space file (PSF) storing data about particles exiting the linac (150 million), using a MC commissioned model [3]
- **Step 2**: computation of a 150x150 portal image (pixel size: 2 mm) using the PSF as input data by scoring the energy deposit in the GOS layer
  - photon and electron/positron cut-offs set to 0.01 MeV and 0.70 MeV.

Investigated EPID models and simulated configurations

- Optimal EPID model determined by simulating 10x10 cm² open fields for different models



Results

Determination of the optimal EPID model

- Determination of the backscatter compartment thickness:
  - calculation of the experimental ratio R defined by: $R_{exp} = I_{exp}^{10x10\ cm^2} / I_{exp}^{15x15\ cm^2}$ (with I: average value in a 6x6 cm² central area of the image),
  - variation of the backscatter compartment tickness until the simulated R value matches the experimental R value.
- Validation (Fig. 2):

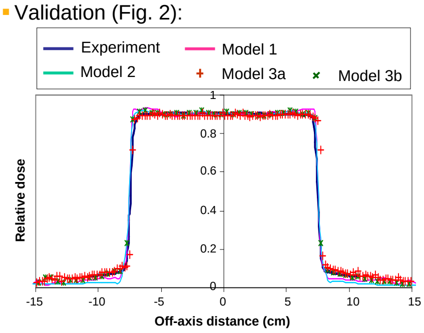


***Fig. 2**: Comparison of the measured profile with simulated profiles for the four tested EPID models, for a 10x10 cm² field.*

- a backscatter compartment must be included in the EPID model,
- the optimal model was obtained with a 8 cm water backscatter compartment,
- the EPID signal is not significantly affected by the mirror and the shielding (profiles for models 1 and 2 almost identical),
- the EPID signal is increased by optical photons backscattering within the EPID structure.

Validation of the EPID model

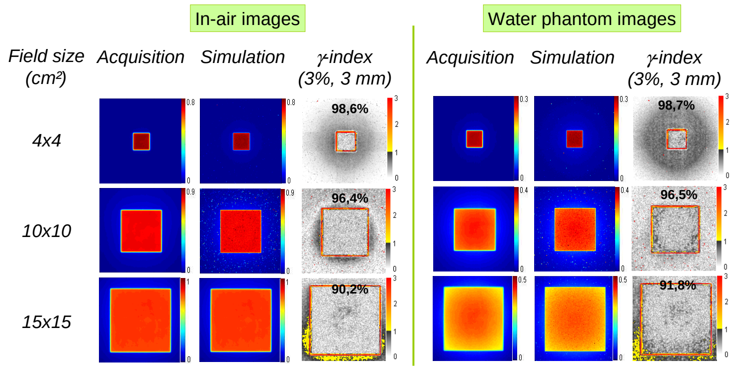


***Fig. 3**: Measured, simulated and 2D gamma-index images obtained without phantom and with the water phantom*

- γ-index < 1 for 90% of the pixels for large field sizes and <1 for 96% of the pixels for fields of size 10×10 cm² or less,
- results a little bit degraded outside the field for large field sizes because the cross-talk effect is not corrected in the measured portal images.

Conclusions and perspectives

- Portal images can be computed accurately, with and without phantom in the beam, by implementing with the MC code PENELOPE a 3-layer EPID model including a backscatter compartment, whose thickness must be adjusted carefully,
- This model will be used to compute MC predicted portal images for pre-treatment or online verification in radiotherapy.

References

[1] W. van Elmpt et al., 2008 Radioth. Oncol. 88 289-309
[2] J. Baro et al., 1995 Nucl. Instr. and Meth. B 100 31-46
[3] B. Habib et al., 2009 Physica Medica in press