# Development of an Accurate Monte Carlo Model of an Electronic Portal Imaging Device (EPID) Towards Improved EPID Calibration Methodology

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## Background

### Introduction

- EPIDs provide high-resolution, fast imaging with a large field of view, allowing for treatment verification through routine in-vivo dosimetry [1]

### Problem:

- Non-trivial dose calibration due to multi-stage EPID signal processing
- Conventional calibration requires an independent set of measurements for each correction factor

$$\frac{primary}{dose\ to\ EPID} = \left(\frac{corrected}{pixel\ value} \cdot \frac{dose}{calibration\ coefficient} \cdot \frac{Pixel}{sensitivity} \cdot \frac{Relative}{off\ axis\ ratio} * \frac{Field\ size}{kernel}\right) * \frac{Blurring}{Kernel}$$

- Direct film-based calibration methods have been proposed [2], however their dependence on EPID disassembly has limited widespread clinical uptake

### Goal

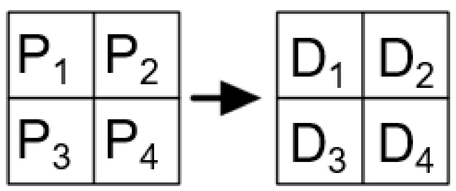
- Develop and validate a Monte Carlo model of the EPID panel to enable clinically feasible direct film-based calibration without requiring panel disassembly

### Film-based EPID calibration:

- Consolidate the dose calibration, sensitivity, and OAR into a single film measurement inside the EPID:

$$\frac{Dose\ to}{film} = \left(\frac{\frac{Calibration}{film\ dose}}{\frac{Calibration}{Pixel\ value}}\right) \cdot \frac{corrected}{pixel\ value}$$

Used to convert individual pixel signal ($P_i$) to absorbed dose ($D_i$) by mapping one matrix onto the other, yielding a direct one-to-one calibration



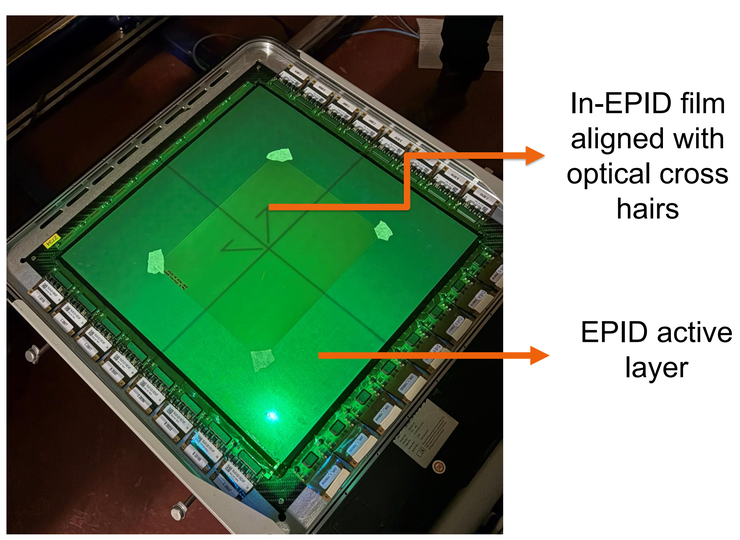




Figure 1: set up for the proposed in-EPID film calibration measurement with the film centered on top of the active layer

## Monte Carlo EPID modelling

A Monte Carlo model of the NRC Elekta Synergy and EPID (XRD 1640 AL5 P) was built using EGSnrc

EPID layer thicknesses were defined via disassembly and direct measurement of their thickness along with manufacturer specifications

EPID layer densities were measured where possible

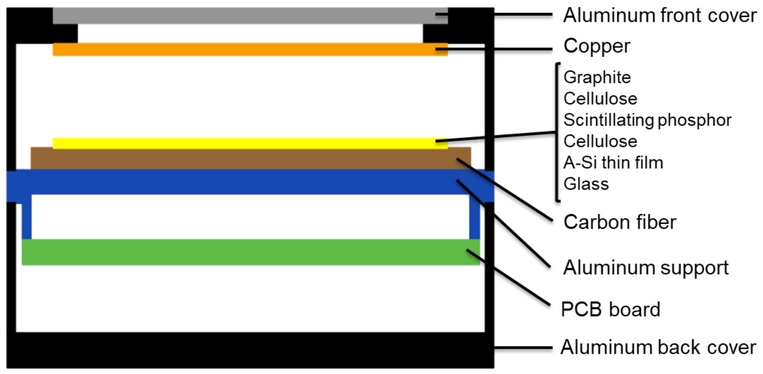



Figure 2: Compositional model of the EPID panel

## In-EPID film measurements

Film measurements were performed using EBT4 Gafchromic film at three locations:

- Top of the aluminum front cover
- Top of the graphite layer (top surface of EPID active layer)
- Bottom of the aluminum back cover

Comparison of measurements and simulations were used to validate the EPID model for a 6 MV beam with 10x10 cm$^2$ and 5x5 cm$^2$ fields

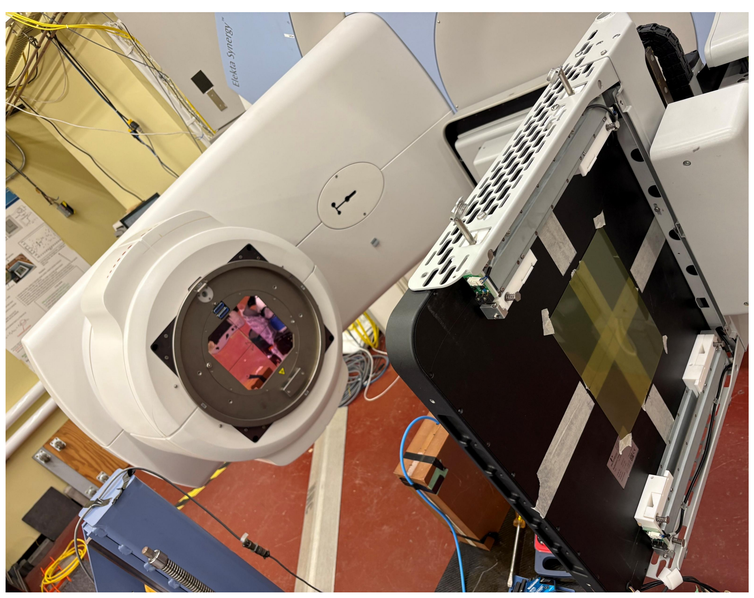


Figure 3: In-EPID film measurements set up showing the film on the back cover

References:

1. Dogan N, *et al. Med Phys.* **2023**;50:e865–e903.
2. Renaud J, Muir B. *Med Phys.* **2022**;49:1238–1247.

## EPID model validation

- Simulated normalized dose profiles were found to agree with experiment within 4%
- The relative dose response between layers was validated through ratios of upstream and downstream dose profiles

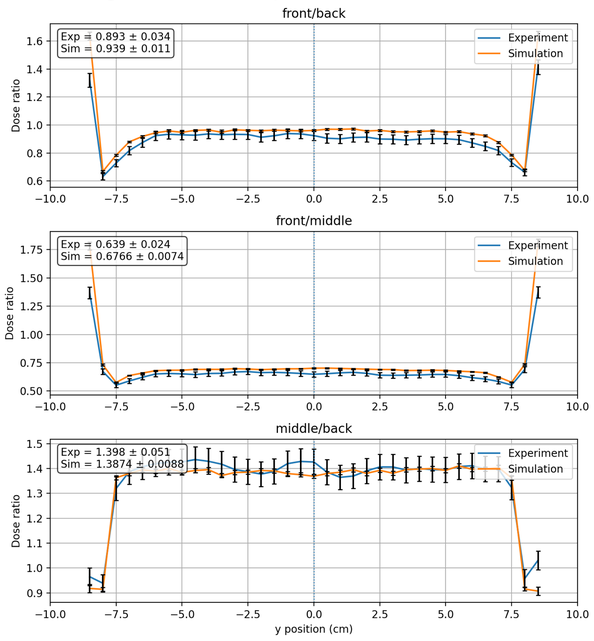



Figure 4: Validation of the EPID model for a 6 MV 10x10 cm$^2$ beam through the ratio of upstream and downstream dose profiles along the gun-target direction

The range used for analysis (ratios in boxes on figure 4 and the relative RMSE values in figure 5) is defined by the expected divergence of the field at the EPID surface:

- -7.5 cm to 7.5 cm for 10x10 cm$^2$
- -3.5 cm to 3.5 cm for 5x5 cm$^2$

Figure 5 compares the relative RMSE values across two EPID panels and two field sizes, which highlights the high sensitivity of the front film.

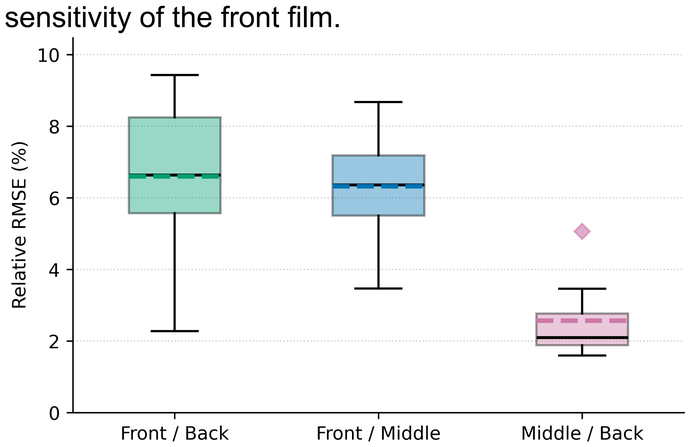



Figure 5: Whisker plot summarizing the distributions of the relative RMSE values between the simulated and measured ratios across 10x10 cm$^2$ and 5x5 cm$^2$ fields, in both directions for two EPID panels. In these plots, the horizontal black lines in the boxes represent the medians, while the dashed lines represent the mean of the distributions

## Conclusions

- Ratios involving the front surface film showed significant discrepancies likely due to the high sensitivity in the build up region
- Using buildup material in front of the EPID panel will mimic clinical workflows and move the front film out of the steep buildup dose gradient, making results less sensitive to exact EPID layer thicknesses and material densities

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