Signal Prediction for an On-line Delivery Verification System

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Introduction

The IQM system (iRT Germany) verifies treatment delivery through unique signal measurement:

- Encodes field shape
- Segment (control point) level resolution
- Sensitive to aperture position

Requires an accurate calculation of signal to compare to measurement.

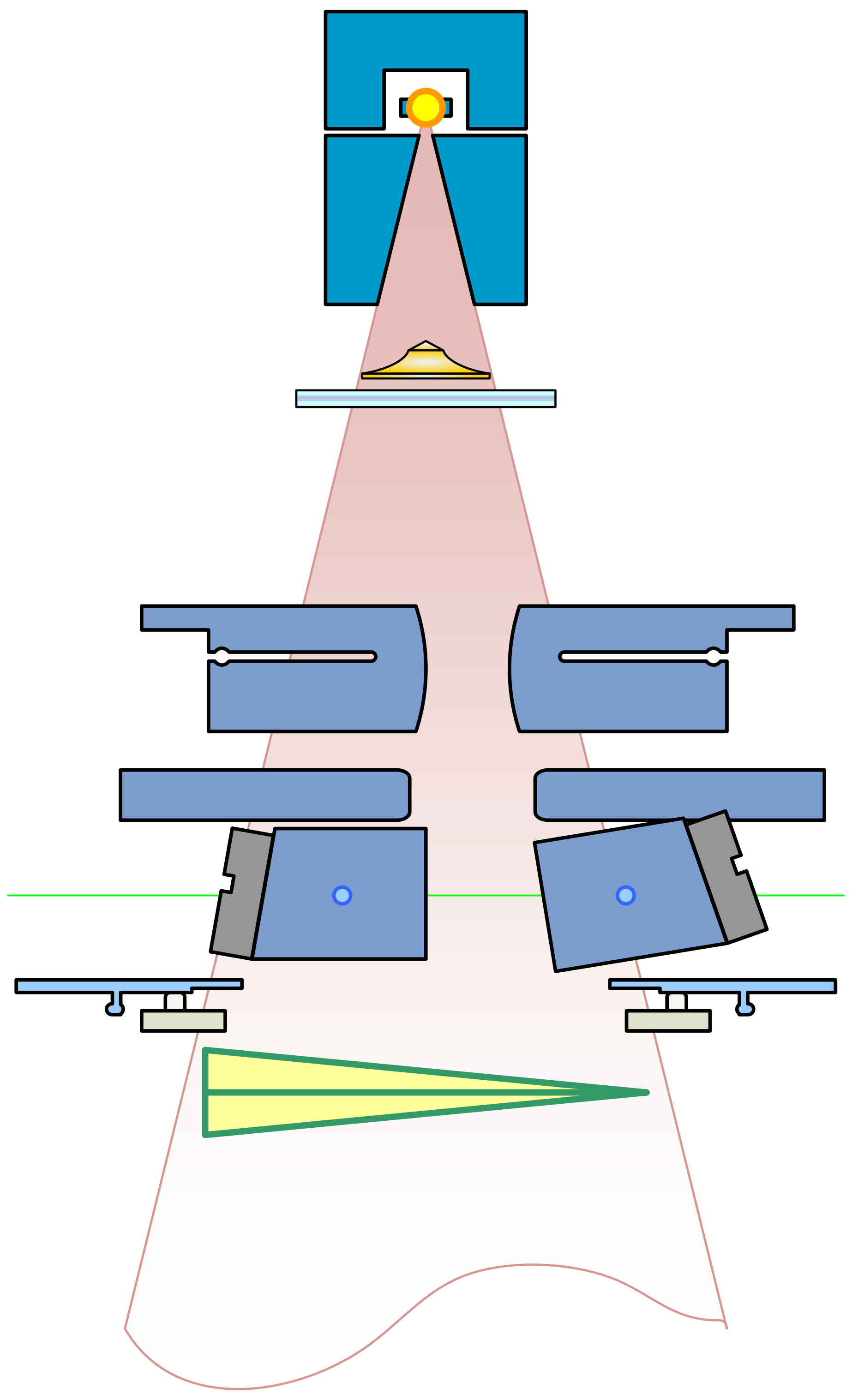


Figure 1: The IQM detector mounts below the collimator of a linear accelerator to capture a signal dependent on aperture shape and position.

Calculation Theory

The IQM detector is a transmission chamber that fully encompasses the radiation beam. The signal is comprised of contributions from open regions of the field as well as attenuated radiation passing through beam collimating elements. For a beam segment of U monitor units, signal contributions across the area of the chamber is given by the equation:

$$C_{IQM} = U \cdot AOF(x,y) \cdot \frac{N_{IQM}}{n \times m} \cdot \sum_{i,j}^{n,m} S_{IQM}(i,j) \cdot I_{ij}$$

$$= U \cdot AOF(x,y) \cdot \frac{N_{IQM}}{n \times m} \cdot \sum_{i,j}^{n,m} S_{IQM}(i,j) \cdot \big((1-f_S)I_P + f_S I_S\big)$$

Where (i,j) are positional indices in an $n \times m$ calculation array:

- S_{IQM} = relative chamber response map
- I_P = primary fluence intensity
- I_S = secondary fluences intensity
- f_S = relative secondary fluence strength
- N_{IQM} = chamber specific normalization factor
- $AOF(x,y)$ = machine output factor parameter for an $x \times y$ field.

Component Characterization

S_{IQM} – the polarizing plate separation changes across the chamber to generate a spatially encoded signal. The CSM is measured by moving the chamber across a narrow field.

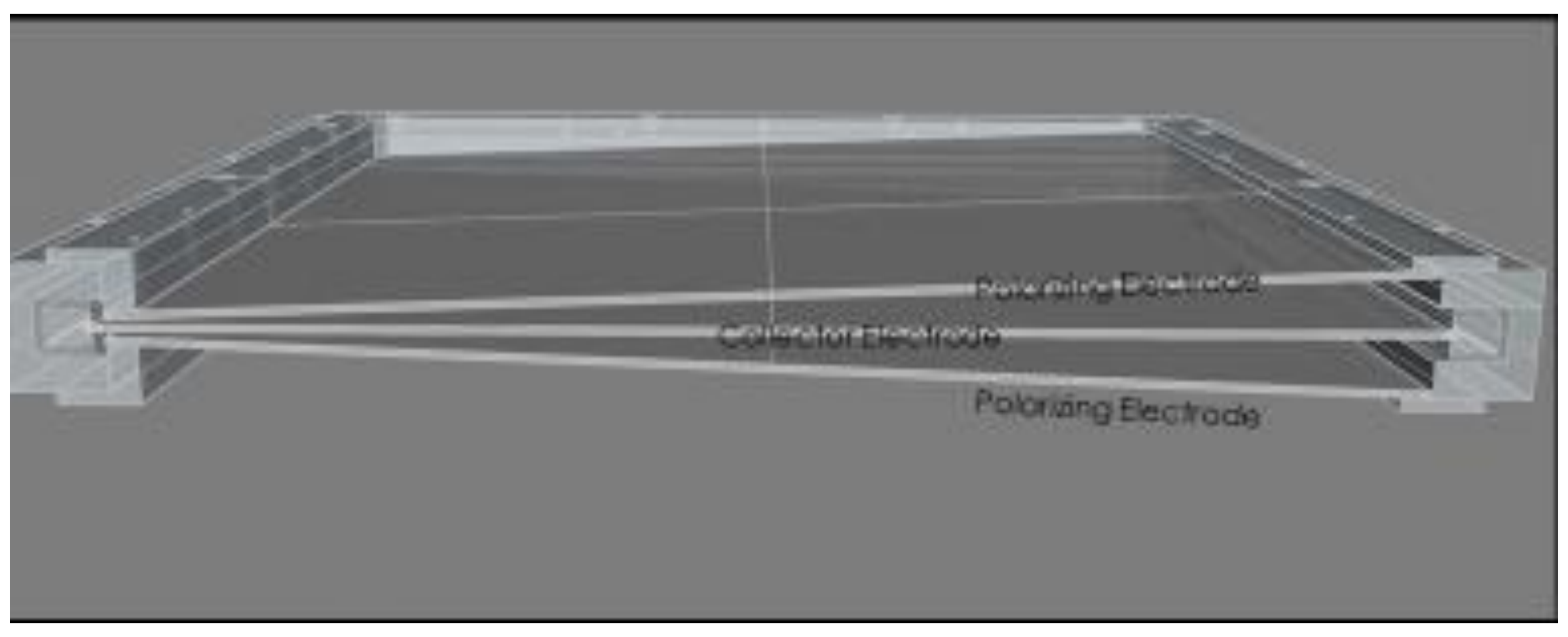


Figure 2: IQM chamber cross section showing the variation of plate separation.

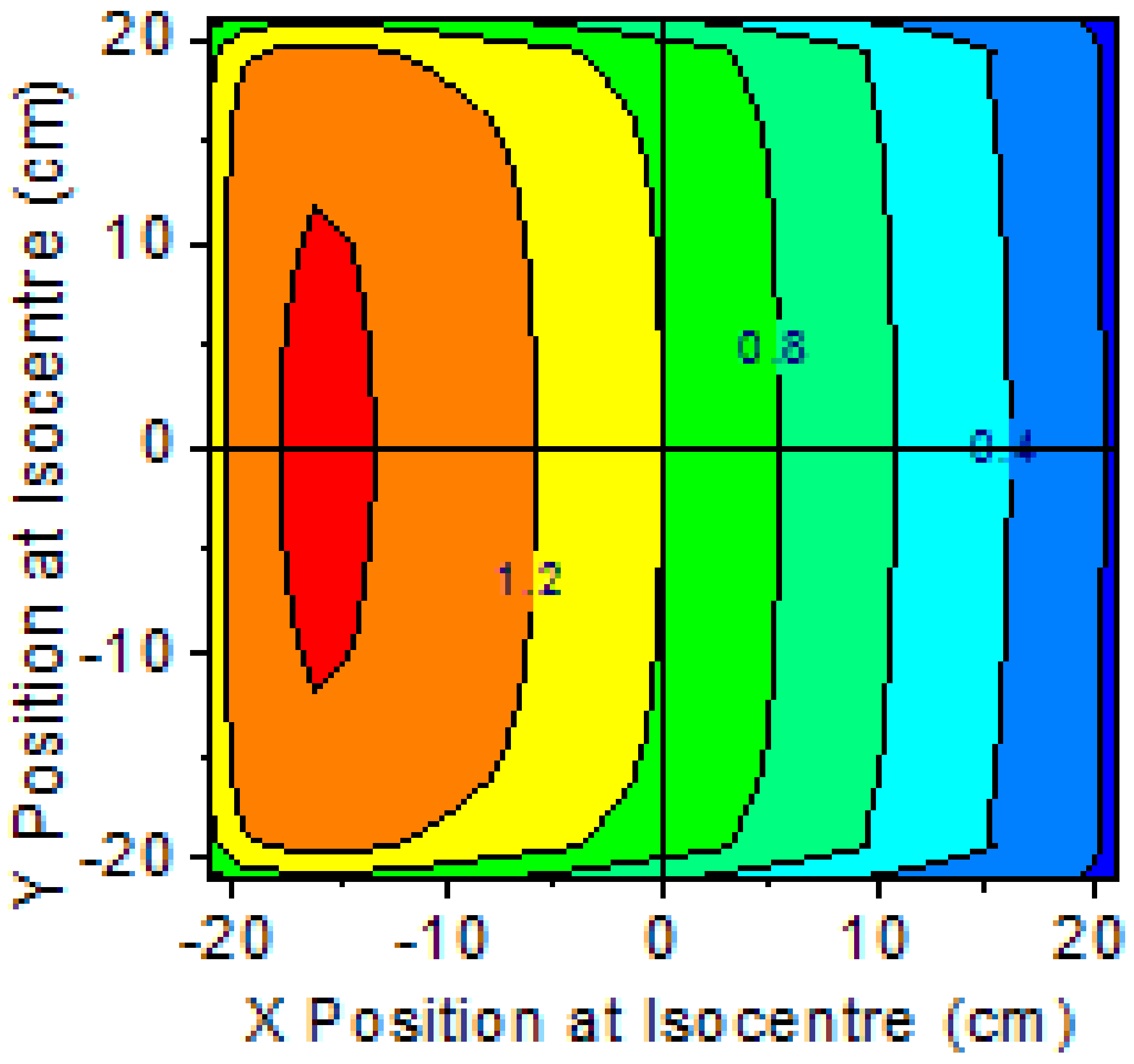


Figure 3: IQM chamber signal gradient from narrow field measurements.

Fluence Intensity Calculation

I_P:

- Assumes a primary point source
- Incorporates off-axis intensity variation
- Accounts for simultaneous dynamic motion of collimating elements during beam delivery

I_S:

- Assumes an extended source
- Approximated by a Gaussian source shape
- Accounts for oblique ray-line paths through collimating elements
- Incorporates a Compton scatter emission distribution

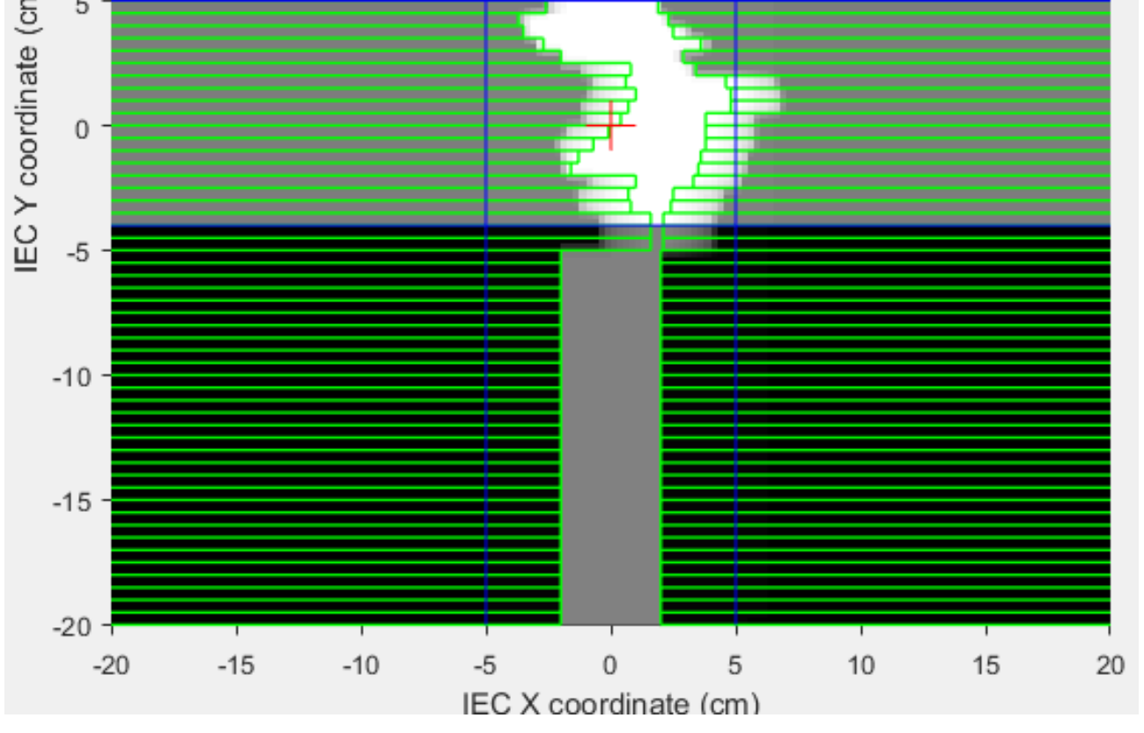


Figure 4a: Gray-scale primary fluence I_P for a dynamic segment. Intensity is shown in logarithmic scale, with end collimation shown. Leaf motion during the segment gives rise to intensity under the leaves.

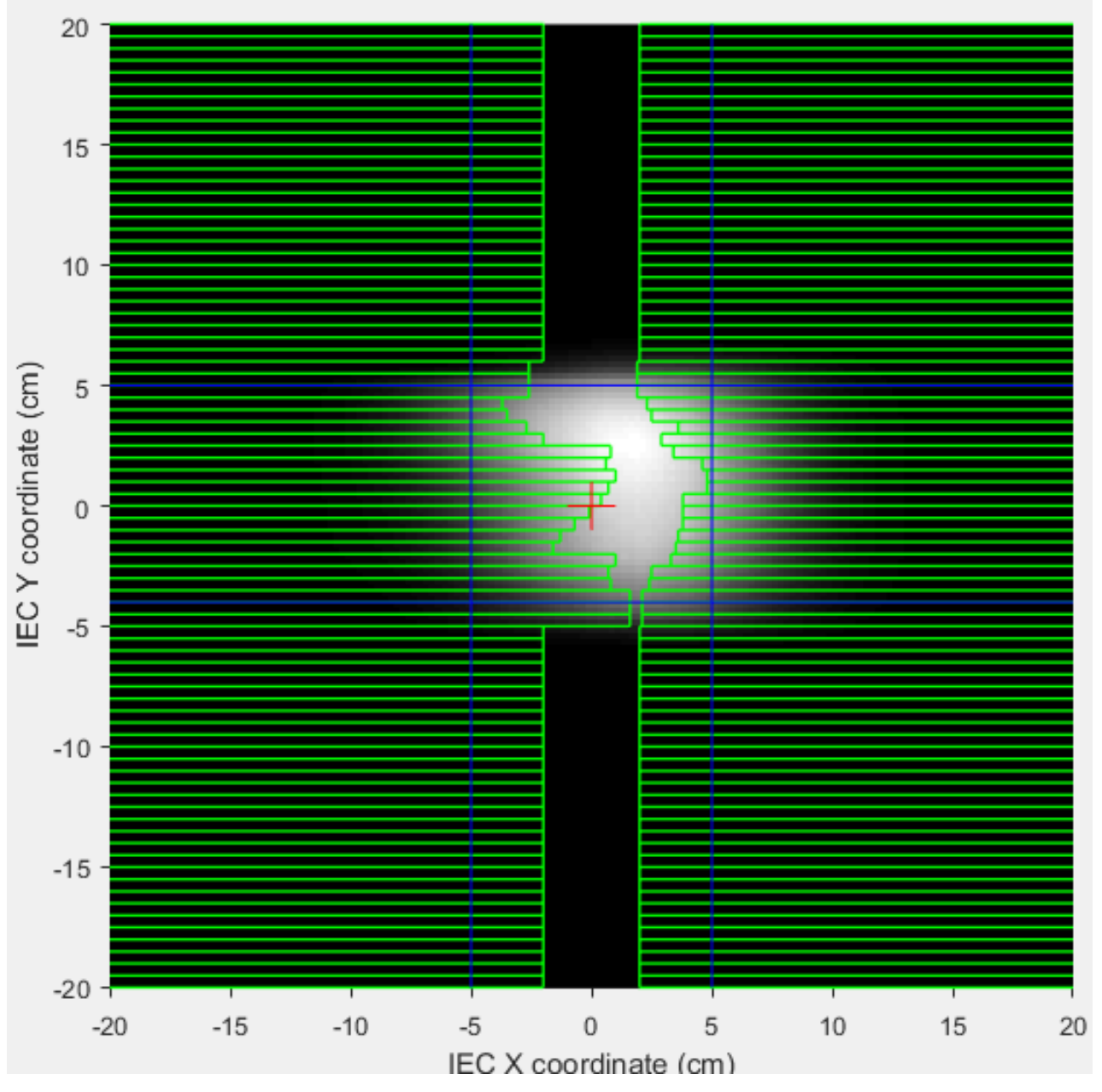


Figure 4b: Gray-scale secondary fluence I_S for a dynamic segment. Intensity is shown in a linear scale, with source size effects generating intensity under collimation edges.

$AOF(x,y)$:

- Captures changes in output due to field size effects
- Derived from a series of rectangular field measurements
- Treated as a residual to calculation (effects of extended secondary source explicitly in model)
- Assumed to be a function of aperture width and length

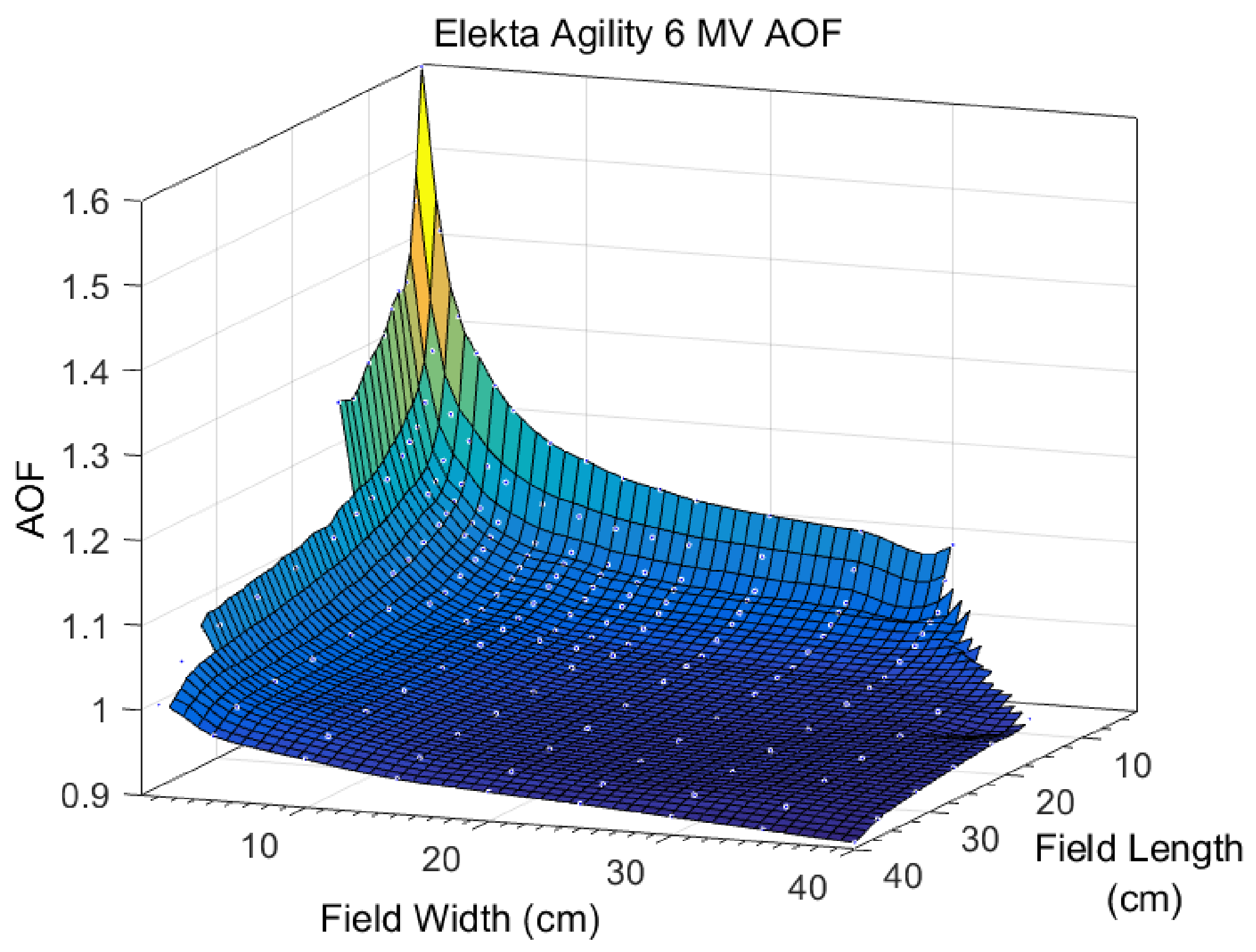


Figure 5: AOF distribution for an Elekta Agility derived from rectangular field shapes spanning from 1×1 to 40×40 cm². The circles in the plot show the measured field sizes, while the colour graded surface shows the interpolation. At the smallest field sizes large correction factors are required.

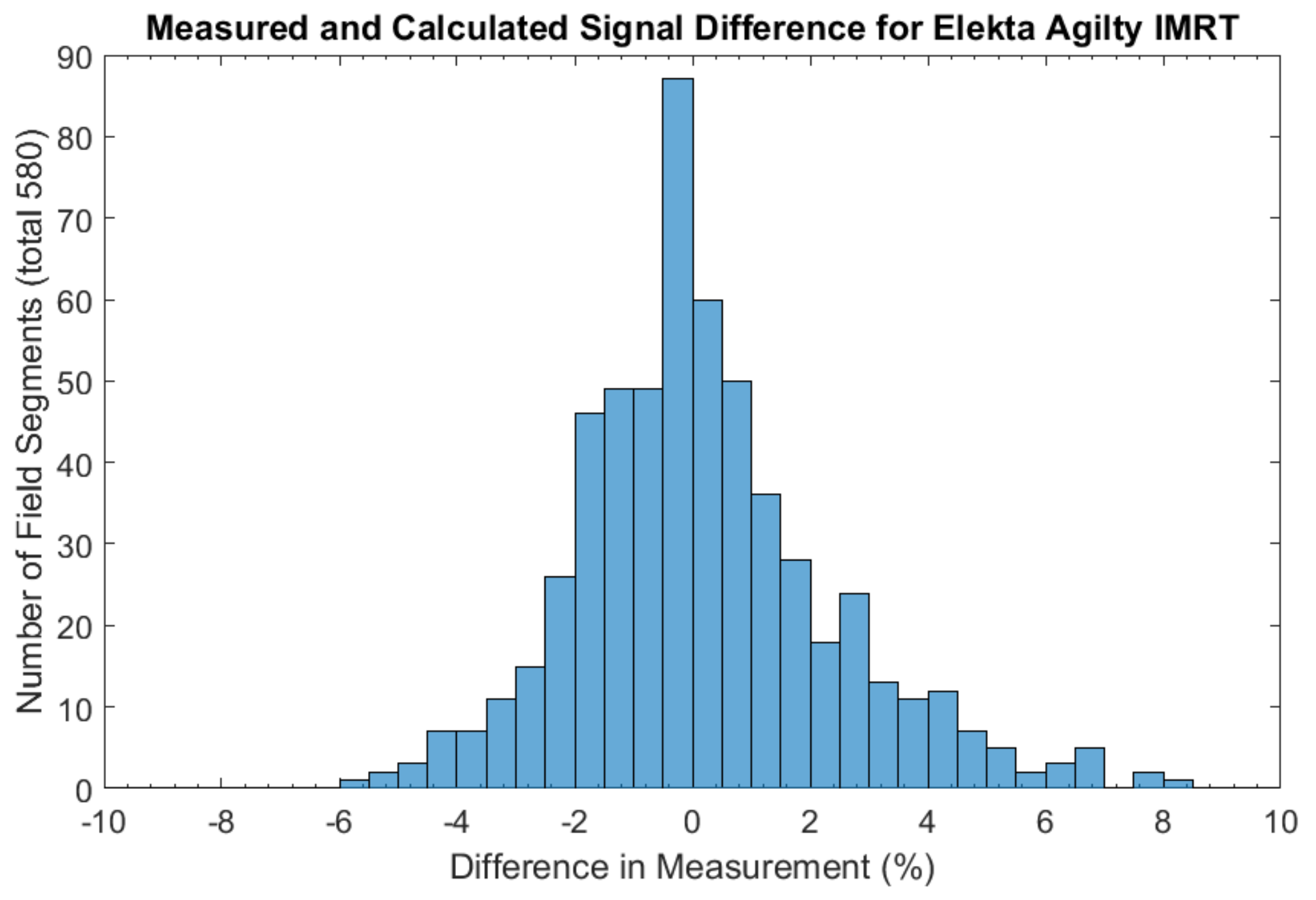
IMRT Results

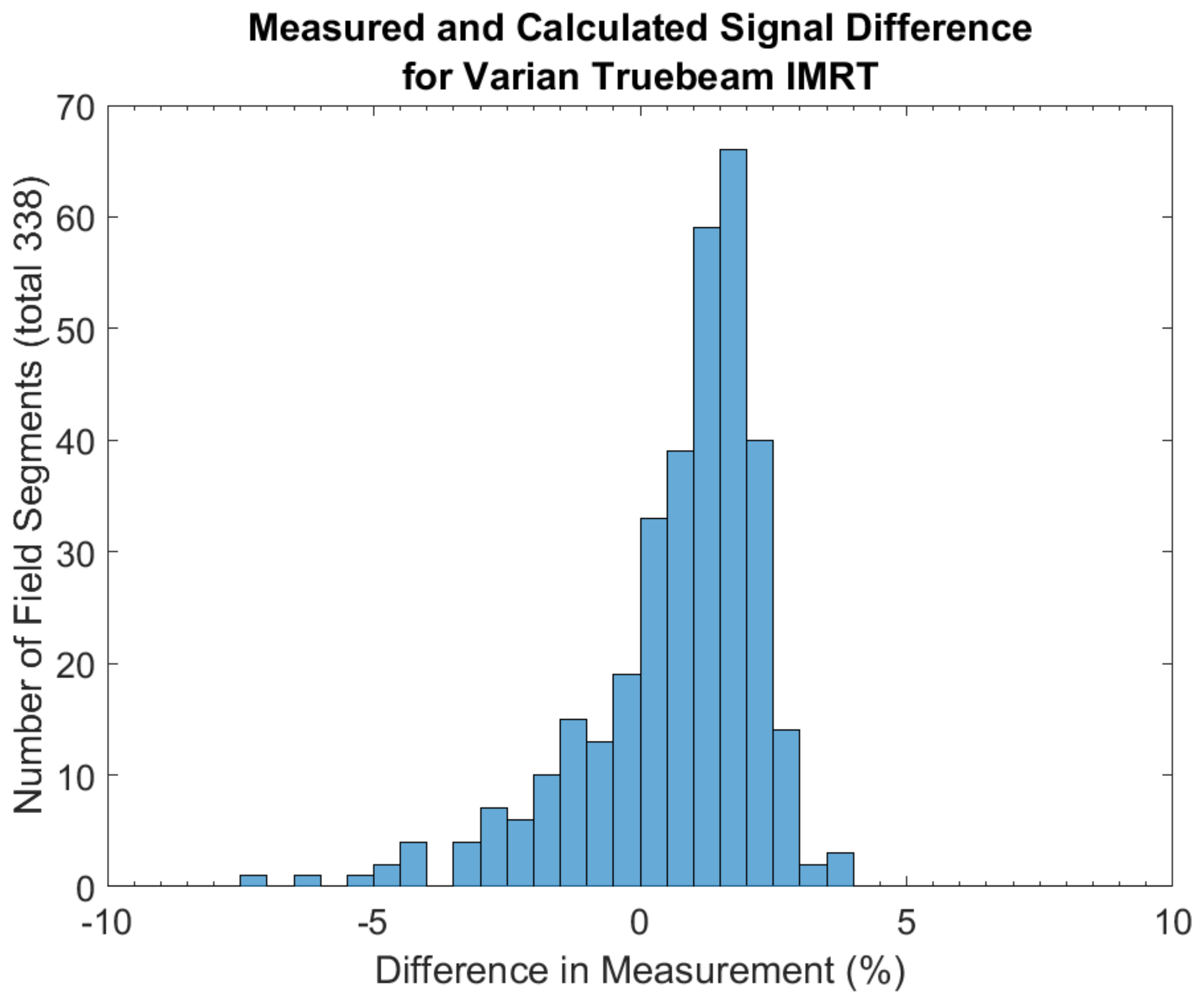
Measurement compared to calculation:

- 580 apertures on Elekta Agility
- 338 apertures on Varian Truebeam

➢ Agreement within ±4% for 95% of segments

➢ Outliers associated with small area segments





Conclusions

A calculation method has been developed to predict the measured IQM signal within a reasonable tolerance for clinical IMRT fields.