

# Characterisation of the half-field beam penumbra for a variety of blocking set-ups

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**Abstract.** Measurements of half-field beam penumbra were taken using EBT2 film for a variety of blocking techniques. It was shown that minimizing the SSD reduces the penumbra as the effects of beam divergence are diminished. The addition of a lead block directly on the surface provides optimal results with a 10-90% penumbra of  $0.53 \pm 0.02$  cm. To resolve the uncertainties encountered in film measurements, future Monte Carlo measurements of half-field penumbras are to be conducted.

## 1. Introduction

In the development of new gel dosimeters, several characterisation studies are generally undertaken, including dose response and stability, manufacturing conditions, calibration effects and spatial stability [1-7]. To characterise the rate of diffusion in gel dosimeter candidates, dose gradients are measured across the edge of a half-blocked field at varying, post-irradiation intervals. In other words, the experimentally determined diffusion coefficient [8] is a calculation of the loss of edge sharpness as a function of time after irradiation [9].

However, when conducting half-field irradiations, it is apparent that scatter from shielding lead blocks together with beam divergence could contribute to an inherent beam penumbra. In turn, this penumbra may appear to be diffusion of the dose distribution recorded in a gel. Thus, to ensure accurate measurements, the width of the penumbra should be minimized. Across the numerous diffusion studies that have been performed, no consistent irradiation technique has been used to maximize the sharpness of the half-field edge [8-15]. And, although a protocol has been developed which minimizes the effects of initial penumbra [10], it may still be useful to determine how best to produce a half-blocked field using a 6 MV linear accelerator. This work aims to achieve this by establishing the inherent penumbra shape and width, for various field-blocking techniques.

## 2. Methodology

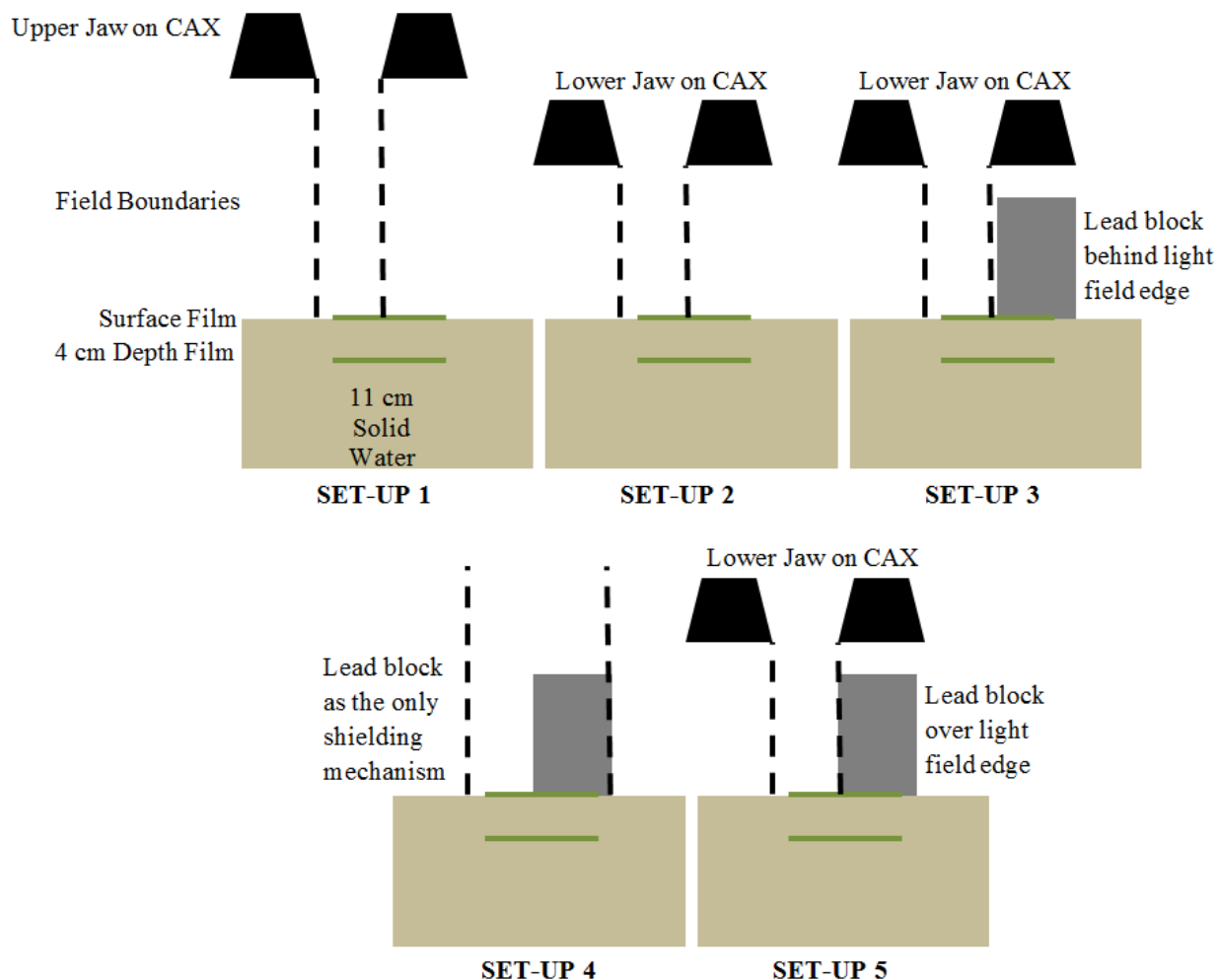
### 2.1 Half Field Blocking Set-ups

This work involved measurements of the 10-90% beam penumbra from a Varian Clinac 600C (Varian Medical Systems, Palo Alto, USA) linear accelerator using 20 pieces of EBT2 film. All irradiations used a 6 MV photon beam with an 11 cm solid water backscatter layer. The remaining film pieces were evenly separated into two groups to take measurements at 85 cm and 100 cm SSDs. At each



SSD, 100MU were applied for 5 different field-blocking set-ups with film placed on the surface and at a depth of 4 cm (figure 1). The studied techniques of half-blocking fields were:

1. Upper jaw on the central axis (CAX)
2. Lower jaw on CAX, to provide a reduction in beam divergence from setup 1
3. Lower jaw on CAX, with 10cm lead block placed 1 mm behind light field edge, to clean up the jaw penumbra
4. 10 cm Lead shield only, as utilised in a number of published diffusion studies [11-13]
5. Lower jaw on CAX, with 10 cm lead block placed 1 mm over light field edge, so lead collimates the field and jaw reduces lead transmission and scatter from setup 4.

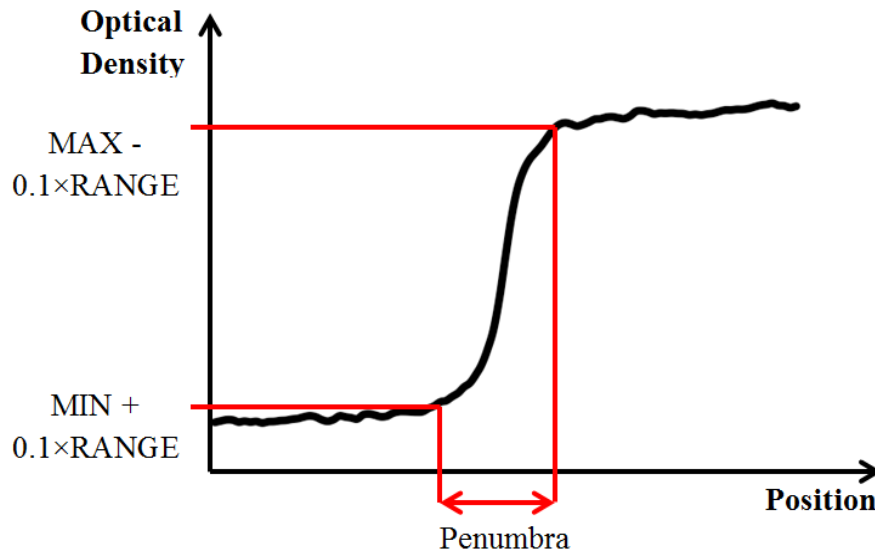


**Figure 1.** A schematic of the five half-field blocking techniques, which were investigated.

## 2.2 Penumbra Measurements

The relative dose to EBT2 film was determined according to the protocol outlined in Kairn *et al* [16] in order to minimize the effects of film heterogeneity and scanner output variations. Each piece of irradiated film was scanned before and after irradiation to correct for any film heterogeneities. To account for overall scanner output variation from one scan to the next, the ratio of the mean pixel value in an unexposed piece of film was calculated, before and after the other pieces of film were irradiated. Red channel images for the pre-scan and post-scan data were obtained and the net optical density change due to dose deposition was calculated.

From these corrected images, OD profiles were obtained across the half field dose gradient using ImageJ. To eliminate noise, a 3-point moving average was applied to each profile. The penumbra was taken as being 10% from either extent of the range of optical densities covered by the profile as demonstrated in figure 2.



**Figure 2.** A typical noise reduced half-field profile obtained from the EBT2 film. The penumbra is obtained between points, 10% of the range of OD values from the maximum and minimum.

### 3. Results and Discussion

Table 1 shows the measured 10-90% penumbra (in cm) for the 5 different half-field setups for SSDs of 85 and 100 cm at both surface and depth. Note that the uncertainty due to limitations of scanner resolution is  $\pm 0.02$  cm for all values.

**Table 1.** 10-90% penumbra measurements (cm) for the various half-field blocking set-ups investigated.

SSD (cm)	Set-up 1		Set-up 2		Set-up 3		Set-up 4		Set-up 5	
	Surface	Depth	Surface	Depth	Surface	Depth	Surface	Depth	Surface	Depth
<b>85</b>	0.95	0.67	1.24	0.67	0.56	0.56	0.53	0.53	0.64	0.56
<b>100</b>	1.31	0.71	1.24	0.74	0.99	0.64	0.92	0.53	0.88	0.56

For almost all arrangements, the penumbra at depth is less than that on the surface. This broadening effect at the surface may be attributed to electron contamination and low-energy, obliquely-scattered photons which are filtered out within the first couple of cm of water. Additionally, measurements at the lower SSD of 85 cm all yield lower penumbra widths than those at the 100 cm SSD. This is clearly a result of beam divergence, widening the field as distance to the source increases. As almost all measurements involving half-fields are taken at depth, it is prudent to compare the penumbra widths at depth to evaluate which set-up is best in practice.

Accordingly, observation of the highlighted cells shows that the blocking systems involving the lead block (i.e. 3,4, and 5) had clearly lower penumbra widths than those that did not (1 and 2). As beam divergence evidently provides a significant contribution to the penumbra, these lead blocks act to collimate the divergent photons. Beyond this, set-up 4 provides the best results for penumbra reduction using lead only with a width of  $0.53 \pm 0.02$  cm. This is somewhat counterintuitive, as it would seem that the addition of the lower jaw as in system 5, would reduce lead transmission and

scatter therefore minimizing the penumbra. However, the difference in penumbra width between set-ups 3, 4, and 5 is within the range of the combined uncertainty. Furthermore, this uncertainty cannot account for the inherent noise in OD profiles of the EBT2 film. Therefore, to consolidate these results, it is suggested that Monte Carlo measurements should be made to accurately characterize the penumbra width for these set-ups.

#### 4. Acknowledgments

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