

INVESTIGATION OF CYLINDRICAL IONIZATION CHAMBER RESPONSE IN THE PENUMBRA REGION OF HIGH-ENERGY RADIOTHERAPY PHOTON BEAMS

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Presented at the second European Congress of Medical Physics

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Keywords: Ionization chamber dosimetry, non-reference conditions, Monte Carlo simulations, radiotherapy

Purpose

To experimentally and theoretically investigate the response of the cylindrical ionization chamber CC13 in non-reference conditions using 6 MV photon beams with focus on the penumbra region and the depth of maximum dose.

Conclusions

An uncorrected chamber response would result in an under- or overestimation of the absorbed dose to water at positions inside or outside of the beam close to the penumbra for small, (20×20 mm²), as well as large, (100×100 mm²), fields. The correction factors obtained can be applied to measurements using CC13 ionization chambers in non-reference conditions.

Methods

Scan and point measurements in a 3D water phantom and Monte Carlo calculations are carried out using a Varian iX linear accelerator with field sizes of 20×20 mm², 20×100 mm² and 100×100 mm² at the depths of 15 mm and 100 mm. A Monte Carlo model of a CC13 chamber is developed within the egs_chamber user code in the EGSnrc package. Conversion factors for different chamber positions and field sizes are calculated relating *absorbed dose to air* in the chamber air cavity to *absorbed dose to water*: (a) using water volume equal to the air cavity of the chamber ($f_{w/chamber}$), (b) using 1×1×1 mm³ water voxel representing a point dose ($f_{w,point/chamber}$). The following correction factors (C),

$$C_{w/chamber} = f_{w/chamber}^{(non-ref)} / f_{w/chamber}^{(ref)}$$

$$C_{w,point/chamber} = f_{w,point/chamber}^{(non-ref)} / f_{w,point/chamber}^{(ref)}$$

are determined to quantify the variations of the conversion factors in non-reference conditions compared to the reference geometry.

Results

An overall agreement within 3.5% and a distance-to-agreement of less than 0.5 mm is obtained between the experimental measurements and the corresponding Monte Carlo calculations of the chamber response. The correction factors for a chamber position at the central axis of the beam and at the center of the field penumbra are between 0.98 and 1.02 for all field sizes and depths examined. The largest corrections are obtained for the off-axis chamber position 3 mm beyond the penumbra center, $C_{w,point/chamber}$ varies between 0.54 and 0.71 for the depth of 100 mm and between 0.45 and 0.58 for the depth of 15 mm. $C_{w,point/chamber}$ factors up to 1.27 are obtained in regions close to the penumbra inside the 20×20 mm² and 20×100 mm² fields. The maximum variation of the $C_{w/chamber}$ factors is between 0.70 and 1.06 for the 20×20 mm² field at the depth of 15 mm (see Figure and Table).

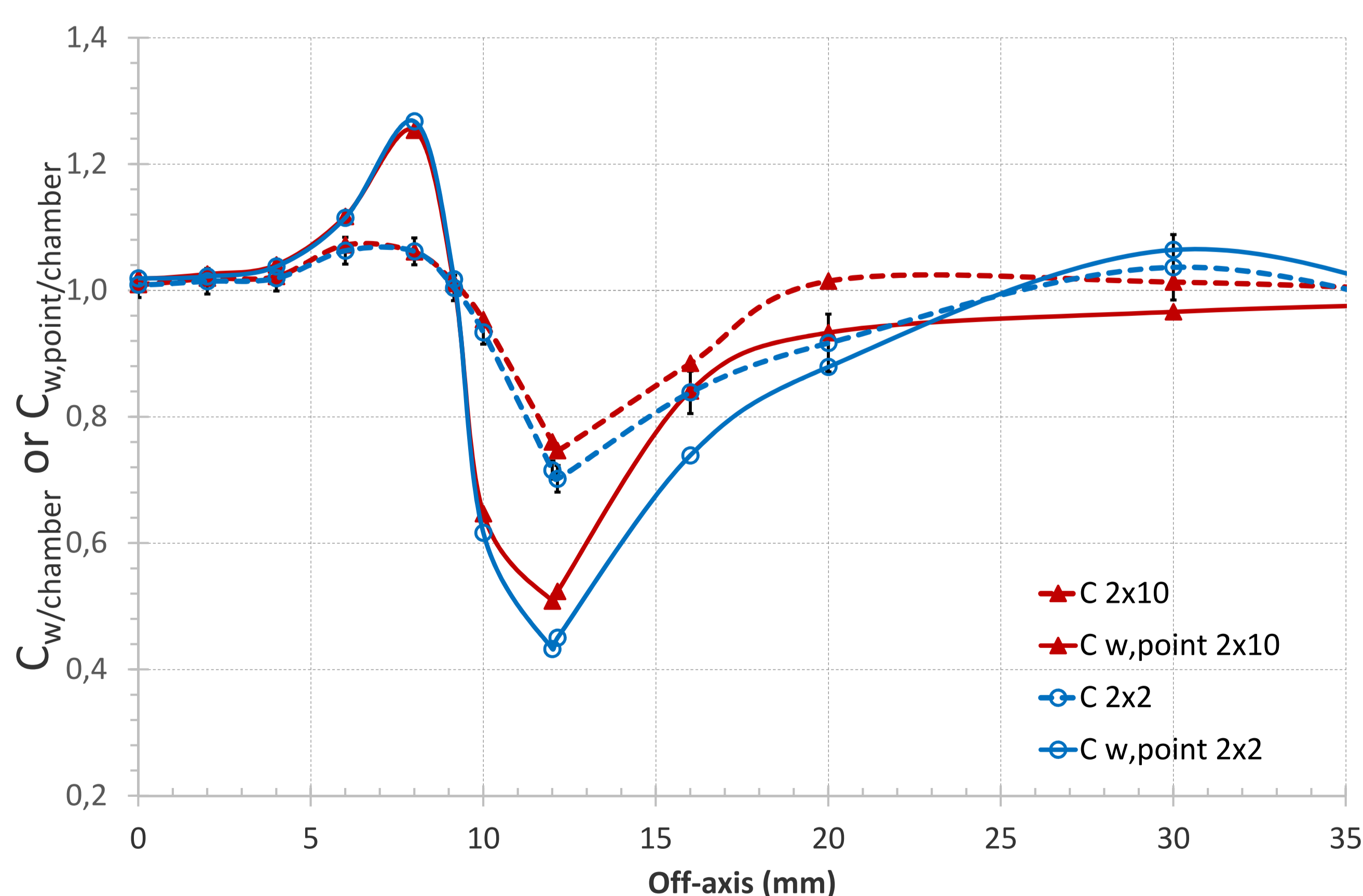


Figure. Correction factors as a function of off-axis distances for the 20×20 mm² and 20×100 mm² fields, 15 mm depth. $C_{w/chamber}$ corrections (dashed lines) and $C_{w,point/chamber}$ corrections (continuous lines). The circle symbols are related to the 20×20 mm² beam and the triangle symbols to the 20×100 mm² beam. The error bars are shown for $C_{w/chamber}$ with the 20×20 mm² beam (representative for the other data). The penumbra center is at 9.15 mm.

Field size, (mm ²)	Position	$f_{w,chamber}$	$C_{w,chamber}$	$f_{w,point,chamber}$	$C_{w,point/chamber}$	$C_{w,chamber}$
						$C_{w,point/chamber}$
100×100	d100, CAX	1,117	1,000	1,112	1,000	1,000
	d100, PNB	1,110	0,994	1,115	1,003	0,991
	d100, PNB3	0,949	0,849	0,794	0,714	1,190
100×100	d15, CAX	1,121	1,004	1,128	1,014	0,991
	d15, PNB	1,113	0,997	1,093	0,983	1,014
	d15, PNB3	0,867	0,776	0,649	0,583	1,331
20×20	d100, CAX	1,121	1,004	1,125	1,012	0,993
	d100, PNB	1,120	1,003	1,110	0,998	1,005
	d100, PNB3	0,841	0,753	0,596	0,536	1,405
20×20	d15, CAX	1,127	1,009	1,133	1,019	0,991
	d15, PNB	1,121	1,004	1,131	1,017	0,987
	d15, PNB3	0,777	0,696	0,496	0,446	1,560
20×100	d100, CAX	1,120	1,003	1,125	1,011	0,992
	d100, PNB	1,134	1,016	1,116	1,003	1,012
	d100, PNB3	0,921	0,825	0,719	0,647	1,276
20×100	d15, CAX	1,129	1,011	1,134	1,020	0,991
	d15, PNB	1,133	1,015	1,126	1,013	1,002
	d15, PNB3	0,838	0,751	0,585	0,526	1,426

Table. Conversion ($f_{w,chamber}$ and $f_{w,point,chamber}$) and correction ($C_{w/chamber}$ and $C_{w,point/chamber}$) factors for different field sizes and chamber positions. CAX denotes a chamber position at the central axis of the beam; PNB and PNB3 denote chamber positions at the penumbra center and at 3 mm distance beyond the penumbra center, respectively; d15 and d100 denote positions at depths of 15 mm and 100 mm, respectively.