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Comparative investigation of beam quality index Q on flattening filter and flattening filter free 6 and 15 MV photon beams of an medical linear accelerator

Abstract: An Elekta Synergy LINAC was used to investigate the beam quality index Q and the beam quality correction factor k_Q, which is used for absolute dosimetry, in off-axis photon fields. It was found that the beam quality index Q of the photon energies with flattening filter decreases with increasing distance to the central axis, at 6 MV by 4.27% and at 15 MV by 3.98% inside a range of 15 cm off-axis. The beam quality index for flattening filter free photon fields also decreases with increasing distance to the central axis. In this case Q changed only by 1.01% inside the above range.

Keywords: beam quality index, flatting and flattening filter free, off-axis

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1 Introduction

The beam quality index Q is used for absolute dosimetry of high energy photon radiation with ionization chambers, to correct the spectral difference between the spectrum of the calibration radiation ^{60}Co and the spectrum of therapeutic radiation. The measurement is usually done on the central axis in 10 cm and 20 cm depth of water with a source surface distance of 100 cm and a field size of 10x10 cm^2. With the obtained beam quality index a chamber specific correction factor can be determined by tables.

Former own investigations [1] with a Siemens Primus LINAC and comparable investigations in literature [3,4,5] showed a change in the spectrum and thus in the beam quality index with increasing lateral distance to the central axis. The change of the beam quality index is connected to a change in the beam quality correction factor k_Q. This can cause a dosimetric error up to 1%.

In this study the change of the beam quality index was investigated with an Elekta LINAC for different photon energies with and without flattening filter and compared to former investigations.

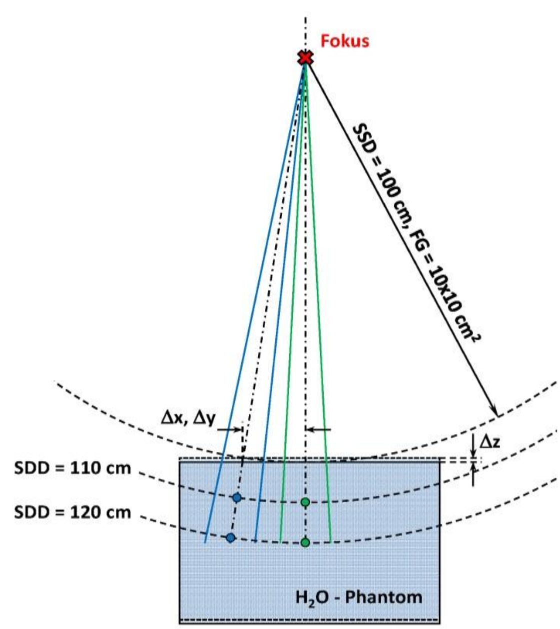

Figure 1: measurement setup

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2 Methods and material

The determination of the beam quality index Q was performed under the conditions defined by DIN 6800-2:2008-03 [2] on the central axis and off-axis in distances of 5, 10, 15 cm in cross-plane and in-plane direction relative to the central axis. Measurements were done with an ionization chamber TM60012-0021 (PTW-Freiburg) for energies of 6 MV and 15 MV with flattening filter and 6 MV flattening filter free with an Elekta Synergy Linac. The setup of the measurements is shown in **Figure 1**. To ensure the 10 cm and 20 cm depths of measurement in off-axis photon fields, a divergence compensation was carried out. From the measured ionizations $I(SDD_{110})$ and $I(SDD_{120})$ at source detector distance 110 cm and 120 cm the beam quality factor Q was calculated according to the formula:

$Q = 1{,}2661 * (I(SDD_{120}) / I(SDD_{110})) – 0{,}0595$. [2]

3 Results

Results showed a decrease of the beam quality index for photon energies with flattening filter with increasing distance to the central axis. A decrease of 4.27% for 6 MV at 15 cm distance and 3.98% for 15 MV at 15 cm distance was observed. The relative percentage change dependens on the distance to the central axis for 6 MV is shown in **Figure 2** and for 15 MV in **Figure 3**.

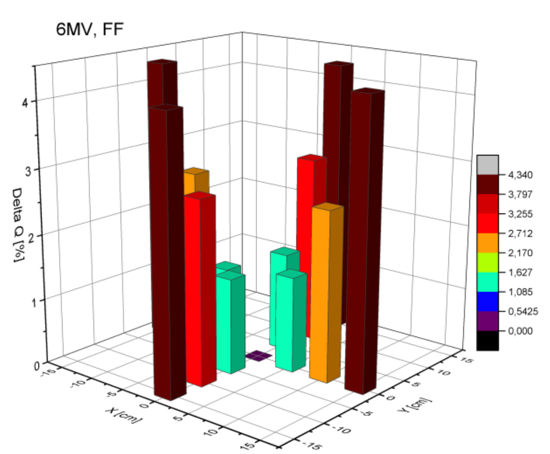

Figure 2: relative change of the beam quality index in percent as a function of the distance from the central axis for 6 MV FF

The decrease of the beam quality index was symmetrical to the central axis within the measurement uncertainty for both energies along both x- and y-directions. Therefore an averaging was performed over the positions on the x- and y-axis. The beam quality index and the beam quality correction factor and their change at a given distance from the central axis for both energies with flattening filter are shown in **Table 1**.

Table 1: absolute and relative (compared to the central axis) change of the beam quality index Q and beam quality correction factor kQ for 6 MV FF and 15 MV FF at distance □□X,Y) to the central axis

Energie [MV]	Δ(X,Y) [cm]	Q	ΔQ [%]	k_Q	Δk_Q [%]
6	0	0,685	0	0,9880	0
	5	0,6753	1,44	0,9896	0,16
	10	0,6662	2,75	0,9910	0,30
	15	0,6558	4,27	0,9925	0,46
15	0	0,7597	0	0,9704	0
	5	0,7518	1,04	0,9728	0,25
	10	0,741	2,46	0,9759	0,57
	15	0,7295	3,98	0,9788	0,87

For 6MV FFF the beam quality index also decreases also with increasing distance symmetrically to the central axis at maximum by 1.01% at 15cm distance. This leads to a change in k_Q of 0.1%. (shown in **Figure 4**)

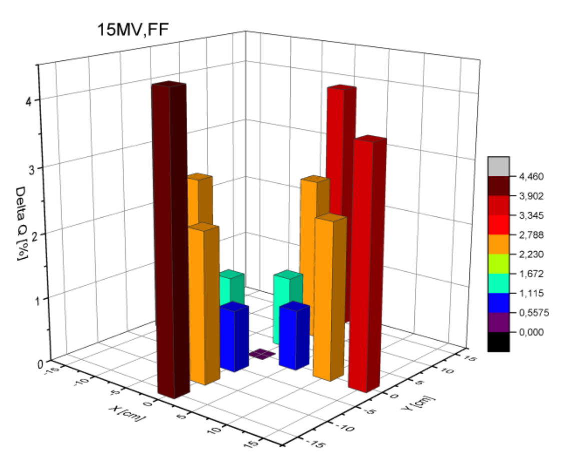

Figure 3: relative change of the beam quality index in percent as a function of the distance from the central axis for 15 MV FF

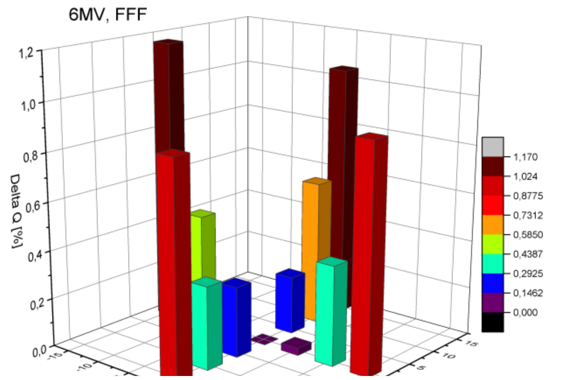

Figure 4: relative change of the beam quality index in percent as a function of the distance from the central axis for 6 MV FFF

Discussion

The decrease of the beam quality index for 6 MV and 15 MV photon energies with flattening filter with increasing distance to the central axis is in agreement with former investigations with a Siemens Primus LINAC. Even though the design of the flattening filters is different for both investigated types of LINACs, the percentage change of the beam quality index is almost equal, which is shown in **Figure 5**.

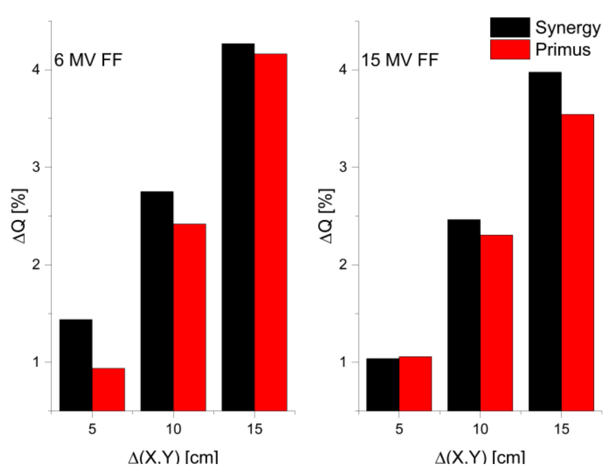

Figure 5: comparison of the relative change of the beam quality index in percent as a function of the distance to the central axis for 6 MV FF and 15 MV FF for the Elekta Synergy and Siemens Primus Linac

The decrease of the beam quality index for photon energies with flattening filter is caused by a shift and broadening of the energy spectrum towards lower energies due to radial reduction of the absorption thickness of the flattening filter.

Without flattening filter the slighter decrease of the beam quality index can be explained by interaction processes of electrons during the bremsstrahlung production in the target. With increasing depth in the target the scattering angle increases and the electron energy is reduced. [6] This results in photons with lower energies, when the distance to the central axis is increased, which leads to a broadening of the energy spectrum towards lower energies.

To verify the measurement results a monte-carlo-simulation was performed. In **Figure 6** the calculated mean energy in the isocenter plane, normalized to the energy on the central axis, is shown against on the distance to the central axis for 6 MV photon energies with and without flattening filter. The only interaction object for flattening filter free simulations is the target. The mean energy decrease with increasing distance to the central axis is much stronger pronounced for 6 MV with flattening filter compared to 6 MV flattening filter free. This finding is confirmed by the measurement results.

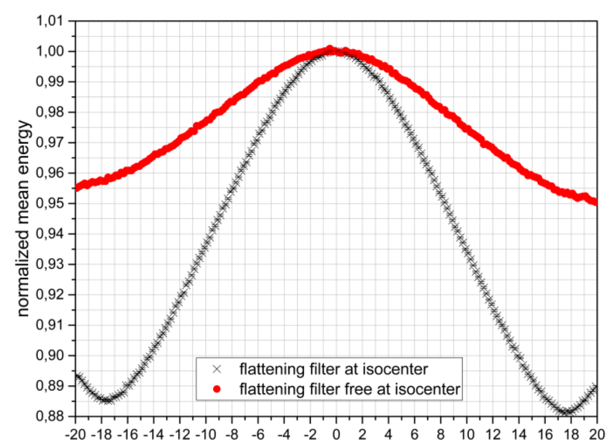

Figure 6: mean energy against distance to the central axis in the isocenter plane for 6 MV FF and 6 MV FFF

Author's Statement

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