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Use of organic plastic scintillators for determination of the beam quality correction factor for flattening filter free photon beams.

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INTRODUCTION

Flattening filters free (FFF) MV photon beams are increasingly used in the clinic. Due to the sharpen profile of these FFF beams, compared to with flattening filter (wFF) beams, it is possible to deliver the dose to small target volumes without the need of modulation [1]. Since the flattening filter for these beams is removed, the dose rate that can be delivered is higher than conventional beams and therefore the treatment can be delivered in less time. However, due to the non-homogeneity of the dose profile, an extra volume correction factor is required in order to account for the detector`s reading averaged over its sensitive volume in a non-uniform radiation condition [2]. Detectors with a small sensitive volume are therefore good candidates for evaluating the changes between FFF and WFF beams.

Fiber-coupled plastic organic scintillators can be built with small sensitive volume while maintaining a good signal-to-noise ratio. Due to the water equivalence of this scintillator material they provide an almost direct measurement of the dose to a point in water [3]. These detectors have, however, problems in the creation of the signal due to the ionization quenching effect and in the transport of the signal through the fiber due to Cerenkov parasite signal (stem effect). The latter can be suppressed by several methods whereas the ionization quenching effect has not been taken into account before for this particular application. This effect appears for low energy electrons (~100keV) and results in a loss of signal. Birks et al (4) proposed a formalism for the relationship between the light yield and the ionization density.

The purpose of this study was to use organic plastic scintillators for determination of the beam quality correction factor (k_{Q,Q_0}) for flattening filters free photon beams increasingly used in modern radiotherapy. The values were compared with those recommended in the recent TRS-483 code of practice from the International Agency of Atomic Energy [5].

METHODS

1- According to the TRS-483 the beam quality corrrection factor for FFF beams can be computed ass follows:

$$k^{f_{ref}}_{Q^{FFF},Q_0} = \frac{N^{f_{ref}}_{D,w,Q^{WFF}_{ref}}}{N^{f_{ref}}_{D,w,Q_0}} \quad \frac{N^{f_{ref}}_{D,wFQ^{FFF}_{ref}}}{N^{f_{ref}}_{D,w,Q^{WFF}_{ref}}} = \frac{D^{f_{ref}}_{w,Q^{WFF}_{ref}} \Big/ M^{f_{ref}}_{Q^{WFF}_{ref}}}{D^{f_{ref}}_{w,Q_0} \Big/ M^{f_{ref}}_{w,Q_0}} \quad \frac{D^{f_{ref}}_{w,Q^{FFF}_{ref}} \Big/ M^{f_{ref}}_{Q^{FFF}_{ref}}}{D^{f_{ref}}_{w,Q^{WFF}_{ref}} \Big/ M^{f_{ref}}_{Q^{WFF}_{ref}}} \qquad (1)$$

The $M^{f_{ref}}_{Q_x}$ represents the corrected ionization chamber response for a given quality Q_x [6]. A farmer type ionization chamber FC-65G (IBA) calibrated for WFF beams qualities was used for this study, therefore, the left term in the right part of equation 1 was directly measured. The last term in equation was determined as follows

$$D^{f_{ref}}_{w,Q_x} \simeq D^{f_{ref}}_{scintillator,Q_x}\, k_{ioq} \qquad (2)$$

Where k_{ioq} is the ionization quenching correction factor.

2- Birks formalism relates the light yield per path unit with the ionization density:

$$\frac{dL}{dx} = \frac{A\frac{dE}{dx}}{1+kB\frac{dE}{dx}} \quad (3) \longrightarrow \quad L(E) = \int_{E}^{E+\Delta E} \frac{A}{1+kB\frac{dE}{dx}}\, dE \qquad (4)$$

Where A is the scintillator efficiency and kB is the quenching parameter.

3- The Monte Carlo based software EGSnrc was developed in order to output the scintillator light yield instead of the absorbed dose taking into account Birks formalism and the quenching parameters reported by Boivin et al [7].

With the computed light yield using equation 4, the ionization quenching correction factor can be computed as follows:

$$k_{ioq} = \left[\frac{L(E)_{ideal}}{L(E)_{quench}}\right]^{Q} \qquad (5)$$

This parameter gives an idea of how much signal is lost because of ionization quenching for a specific beam quality.

4- For all the experimental measurements as well as the Monte Carlo calculations, both the plastic scintillatos and the ionization chambers were placed in a water phantom of 30cmx30cmx30cm at 10cm depth in an isocentric configuration. The radiation source was the Varian TrueBeam and for the Monte Carlo calculations the Varian Truebeam phase spaces (phsp) where downloaded from the Varian website. The used energies and the beam qualities are shown in the following table.

Energy	Co60	6FFF	6MV	10FFF	10MV
TPR20_10	Co60	0.632	0.666	0.707	0.738

RELSULTS AND DISCUSSION

Ionization quenching correction factor

Figure 1 shows the ionization quenching correction factors for the studied beam qualities. The uncertainties of the computed values are less than 0.15% in all cases. The relative difference between 6MV and 6FFF is approximately 0.61% whereas between 10MV and 10FFF is 0.35%.

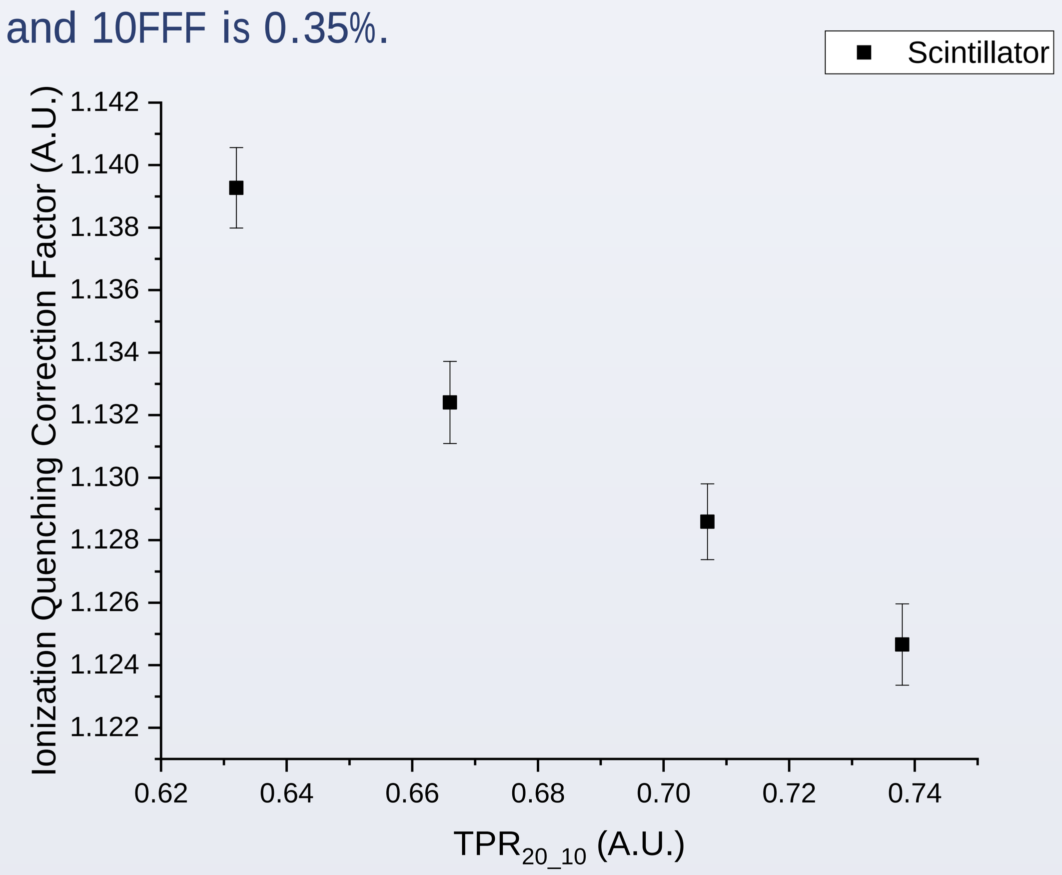

Figure 1. Ionization quenching correction factors.

From figure 1 can be appreciated that the quenching effect should not be neglected and therefore the correction for this effect should be applied.

Beam quality correction factor

Figure 2 shows the beam quality correction factors both, estimated and recommended by the TRS-483, for the FFF beams as well as the relative discrepancies between them. As can be seen in figure 2 the uncertainty for the estimated values are less than 0.9% mainly because of the calibration coefficient of the ionization chamber. The figure shows that the relative discrepancies between the estimated and the recommended values by the TRS-483 are less than 0.3 %.

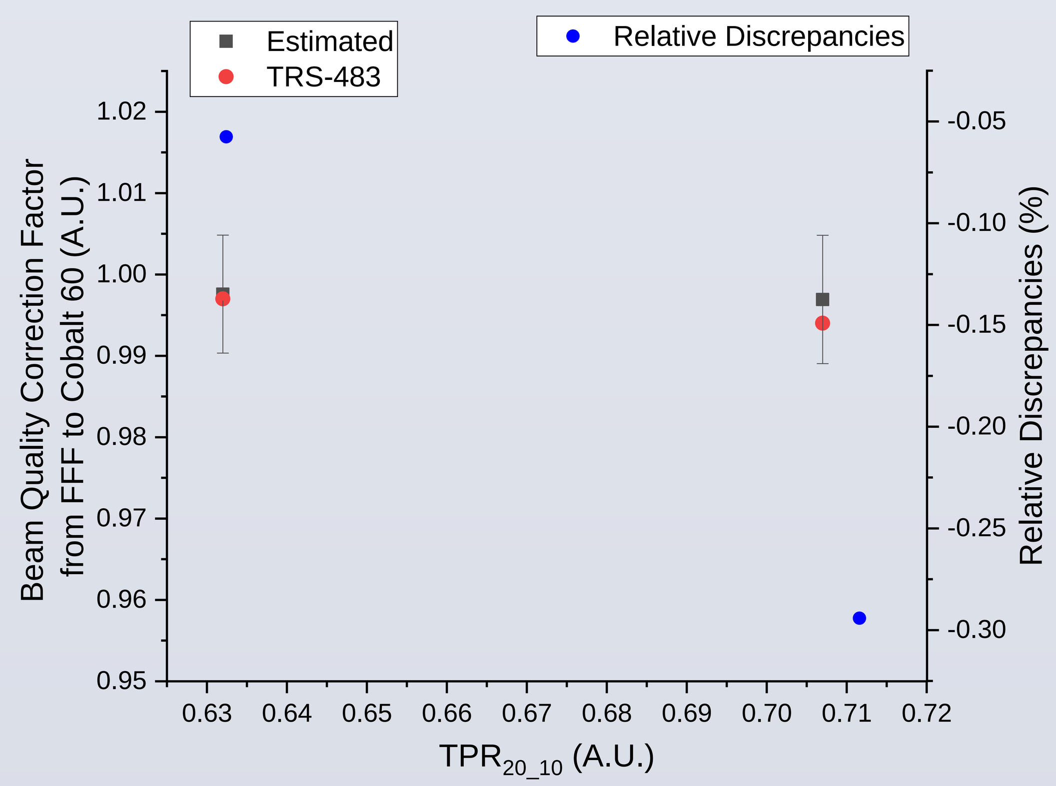

Figure 2. Beam quality correction factors for FFF beams as well as relative discrepancies.

CONCLUSIONS

An experimental investigation for determining the beam quality correction factor for FFF to WFF was carried out. The study supports that organic plastic scintillators can be used as a perturbation-free detector in MV photon beams. However, considerations should be given to the change in quenching when spectrally different beams are involved such as when computing the dose ratio for WFF and FFF beams in the TRS-483 formula for beam quality correction factor.

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