Determination of small field output factors, advantages and limitations of Monte Carlo simulations

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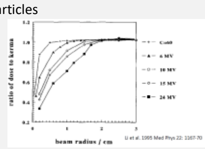
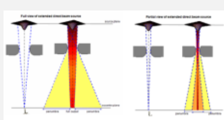
Introduction
Methods
Results
Conclusions

- Non lateral equilibrium of charged particles



- Partial occlusion of the target.



- Detector dimensions same order than field size.

What "small field" means?

Das, I. J et al (2008) *Med. Phys. 35*(1), 206.

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Formalism for absorbed dose determination in reference conditions

$$D_{w,Q} = M_Q \cdot N_{D,w,Q_o} \cdot k_{Q,Q_0}$$

Formalism for reference dosimetry of small and nonstandard fields

Alfonso, R et al (2008). Med. Phys, 35(11),5179

$$D_{w,Q_{msr}}^{f_{msr}} = M_{Q_{msr}}^{f_{msr}} \cdot N_{D,w,Q_0} \cdot k_{Q,Q_o} \cdot k_{Q_{msr},Q_{ref}}^{f_{msr},f_{ref}}$$

$$k_{Q_{msr},Q}^{f_{msr},f_{ref}} = \frac{D_{w,Q_{msr}}^{f_{msr}} / M_{Q_{msr}}^{f_{msr}}}{D_{w,Q}^{f_{ref}} / M_{Q}^{f_{ref}}}$$

Factor that corrects for the differences between the conditions of field size, geometry, phantom material, and beam quality of the conventional reference field f_{ref} and the machine-specific reference field f_{msr}

Formalism

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Relative dosimetry. FOF; OR

$$D_{w,Q_{msr}}^{f_{msr}} = M_{Q_{msr}}^{f_{msr}} \cdot N_{D,w,Q_0} \cdot k_{Q,Q_o} \cdot k_{Q_{msr},Q_{ref}}^{f_{msr},f_{ref}}$$

$$[\cdots]$$

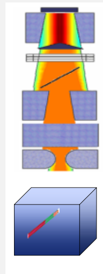
$$D_{w,Q_{clin}}^{f_{clin}} = D_{w,Q_{msr}}^{f_{msr}} \cdot \Omega_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$$

$$[\cdots]$$

$$\Omega_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}} = \frac{M_{Q_{clin}}^{f_{clin}}}{M_{Q_{msr}}^{f_{msr}}} \cdot k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$$

$$OR_{f_{msr}}^{f_{clin}} = \frac{M_{Q_{clin}}^{f_{clin}}}{M_{Q_{msr}}^{f_{msr}}}$$

$$FOF_{f_{clin}} = OR_{10x10}^{f_{clin}} \cdot k_{Q_{clin},Q_{10x10}}^{f_{clin},10x10}$$



Formalism

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In 2010 Varian (Varian Medical Systems, Palo Alto, CA, USA) launched the TrueBeam, a new linear accelerator (LINAC) designed to irradiate using flattened (FF) and flattening filter-free (FFF) beams

Objectives

Experimental and MC determination of FOF for small fields (smaller than 2 cm x 2 cm)

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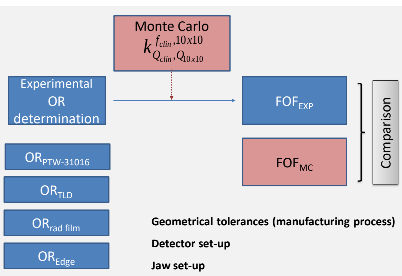

Geometrical tolerances (manufacturing process)
Detector set-up
Jaw set-up

3 main source of uncertainty

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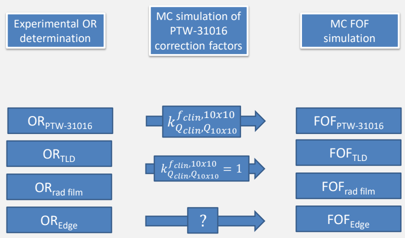

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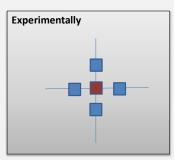
Detector set-up

Active detector is situated on the position that maximise the reading

Jaw set-up

Tolerance in jaws set-up of 0.5 mm



Detector set-up and jaw set-up influence

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MonteCarlo

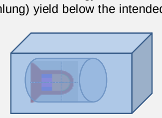
PENELOPE code system using PenEasy (2009) as the main program.

Energies: Phase space files (PSF). 6 MV FF & FFF, 10 MV FF & FFF

Determinations in water: 0.5 mm radius

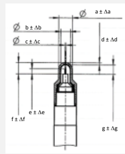
Determinations in the chamber air cavity:
Geometry split into two regions. 2 cm ROI, a cut-off energy of 10 keV was selected for the charged particles, outside the ROI, a cut-off energy of 200 keV was applied in order to satisfy a radiation (bremsstrahlung) yield below the intended uncertainty of the calculations, 0.15%

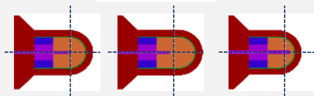
$$k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}} = k_{Q_{clin},Q_{ref}}^{f_{clin},f_{ref}} = \frac{D_w^{f_{clin}} / D_w^{10x10}}{\overline{D}_{air}^{f_{clin}} / \overline{D}_{air}^{10x10}}$$



Remove the possible backscatter influence

PTW-31016 -0.016 cm³



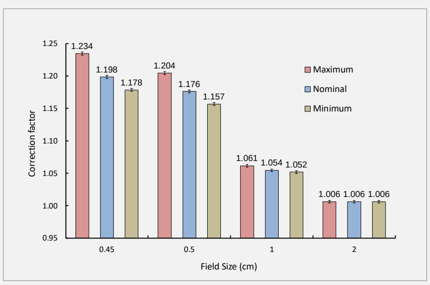


Nominal Maximum Minimum

PTW31016
Correction Factors

Up to 2cm

Det-det Up to 1cm



Geometric inaccuracies effect + Jaw set-up

PTW31016
Correction Factors

Up to 2cm

Det-det Up to 1cm

Main Inf Jaw

Experimentally , the active detector is situated on the position that maximise the reading

Tolerance in jaws set-up of 0.5 mm

Ion Manufacturing

Ion Set-up

Jaw LINAC Set-up

	Nominal field size (cm)			
	0.5 cm x 0.5 cm		0.45 cm x 0.45 cm	
	Origin	0.3 mm	Origin	0.3 mm
Nominal	1.186	1.176	1.212	1.198
Maximum	1.204	1.211	1.234	1.234
Minimum	1.176	1.157	1.200	1.178

	Nominal field size (cm)					
	0.5		1		2	
$k_{Q_{clin},Q_{10x10}}^{f_{clin},10x10}$	1.17	±2.8%	1.054	±0.6%	1.006	±0.2%

Geometric inaccuracies effect + Jaw set-up+ detector set-up

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PTW31016
Correction Factors
Up to 2cm
Det-det Up to 1cm
Main Inf Jaw

Detectors

Ionization Chamber

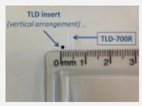
PTW-31016 0.016 cm^3
(cavity : radius 1.45 mm; length 2,9 mm)

Diode

Edge SunNuclear side = 0.8 mm
t = 0.03 mm

TLDs

TLD-700R ^{7}LiF:Mg,Ti rods
radius= 0.5 mm t = 6 mm



Radiochromic film

EBT2

Experimental determinations

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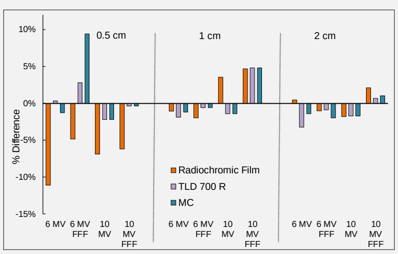

FOF differences. Reference $FOF_{PTW-31016}$

Experimental determinations

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Det-det Up to 1cm
Main Inf Jaw

FOF
Main Inf Jaw ?

	Field size (cm)					
	2		1		0.5	
6 MV						
MC	0.840	1.5%	0.720	1.5%	0.453	1.5%
PTW-31016	0.852	0.7%	0.728	2.0%	0.459	3.6%
TLD-700R	0.825	1.0%	0.714	1.1%	0.460	2%
Rad film	0.856	1.1%	0.720	1.1%	0.408	3%
6 MV FFF						
MC	0.854	1.3%	0.780	1.3%	0.550	0.9%
PTW-31016	0.871	0.7%	0.765	1.7%	0.503	3.6%
TLD-700R	0.864	1.1%	0.761	0.6%	0.517	1.1%
Rad film	0.862	0.6%	0.750	0.6%	0.478	2.4%
10 MV						
MC	0.778	1.2%	0.594	1.3%	0.318	1.3%
PTW-31016	0.792	0.8%	0.609	1.4%	0.347	3%
TLD	0.778	1.1%	0.601	1.0%	0.339	1.2%
Rad film	0.777	0.9%	0.631	1.8%	0.323	2.4%
10 MV FFF						
MC	0.842	0.5%	0.677	0.5%	0.382	0.1%
PTW-31016	0.834	0.8%	0.658	1.7%	0.394	3%
TLD	0.839	1.5%	0.689	1.31%	0.392	0.7%
rad film	0.851	1.0%	0.689	0.96%	0.370	1.8%

SDD = 100 cm; Depth = 5 cm for 6 MV FF&FFF; Depth = 10 cm for 10 MV FF%FFF

Field Output Factors on FF and FFF beams

MC simulation or real jaw effect?

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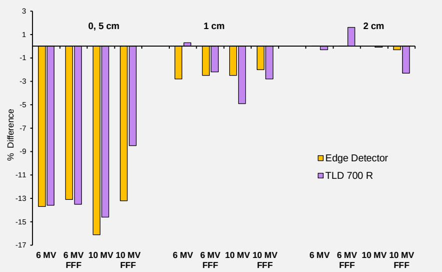
Up to 2cm
Det-det Up to 1cm
Main Inf Jaw

FOF
Main Inf Jaw X



Differences between TB_{ICO} and TB_{ECC}

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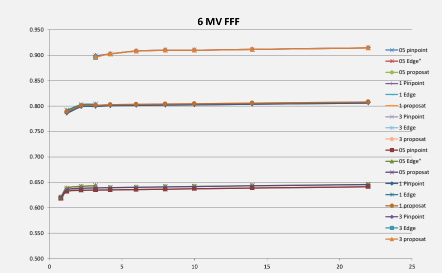
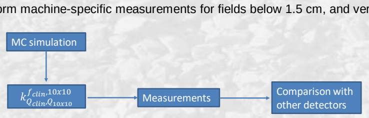
Correction Factors
Up to 2cm
Det-det Up to 1cm
Main Inf Jaw

FOF
Main Inf Jaw



New TrueBeam. Differences Between $FOF_{PTW-31016}$, FOF_{Edge} and FOF_{TLD} <2% all field sizes

- Correction $factor_{PTW-31016}$ >1
  - Due to the volume effect.
  - Affects square field sizes up to 2 cm for PTW-31016.
- Differences in PTW-31016 correction factor chamber-to-chamber for square field sizes up to 1 cm.
- Low energy dependence of $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ was verified for PTW-31016. (*Alfonso et al 2008*)
- Need to perform machine-specific measurements for fields below 1.5 cm, and verification after jaw calibration.



Thanks for your attention

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