Small-Field Dosimetry

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NYU Langone MEDICAL CENTER

Treatment Fields

Magna-Fields

200x200 cm^2 ⟷ 40x40 cm^2 ⟷ 4x4 cm^2

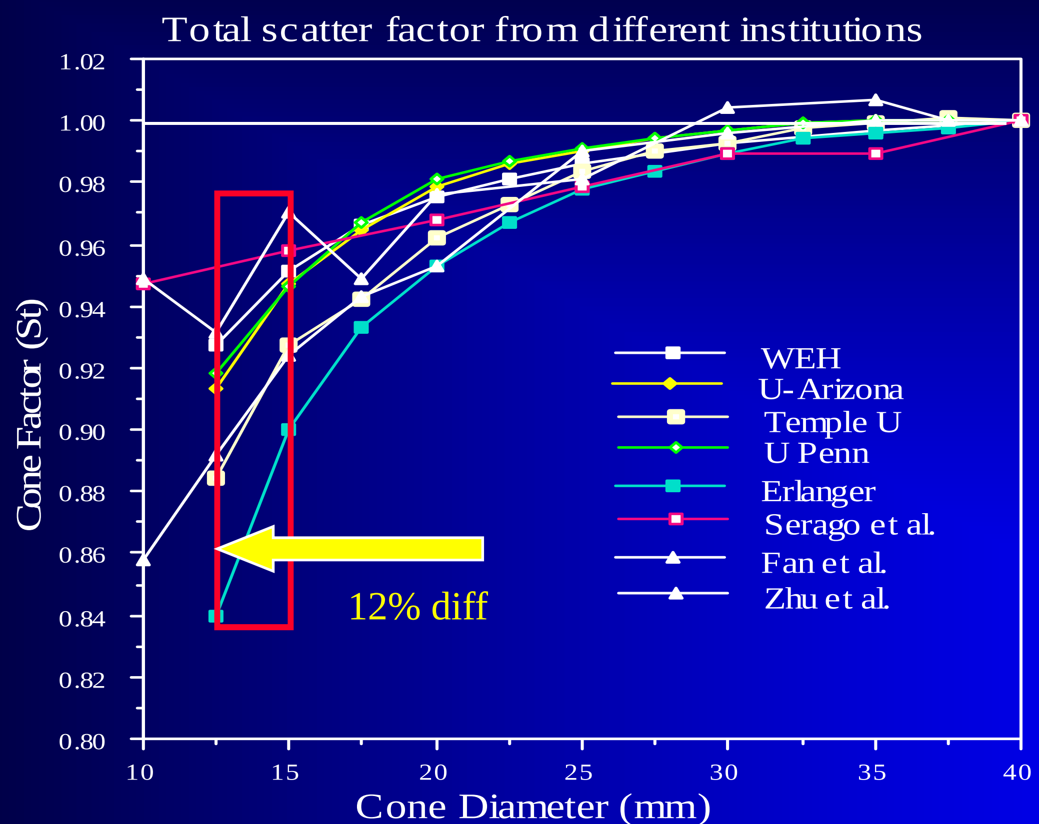
Traditional Fields

Small Field

4x4 cm^2 ⟷ 0.3x0.3 cm^2

Advance Therapy Fields
- SRS/SRT
- Gamma Knife
- Cyber-Knife
- Tomotherapy
- IMRT

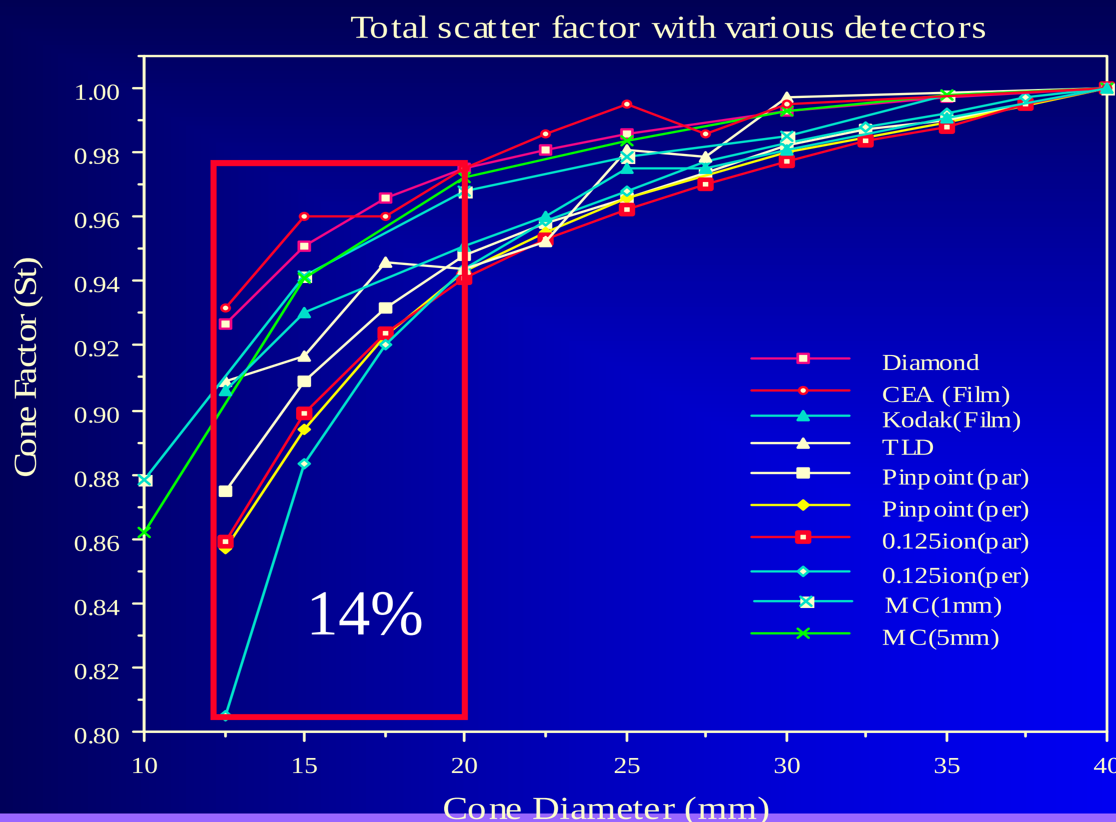
Small Field Dosimetry Problem



Institutional variability in 6 MV Radionics SRS dosimetry

Das et al, J Radiosurgery, 3, 177-186, 2000

Dosimetric Variation with Detectors



Das et al, J Radiosurgery, 3, 177-186, 2000

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Misadministration Media Coverage

Springfield Hospital Reports Radiation Overdose Administered to 76 Cancer Patients

February 26, 2010

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The New York Times reported on a recent report filed by CoxHealth medical facility in Springfield, Missouri where they admitted to over-radiating 76 cancer patients during treatment. The majority of the patients were being treated for brain cancer, and received about a 50% overdose of radiation therapy. A hospital employee improperly calibrated the machine used to administer the radiation.

The New York Times — U.S.

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH

POLITICS EDUCATION

Radiation Errors Reported in Missouri

By WALT BOGDANICH and REBECCA R. RUIZ
Published: February 24, 2010

A hospital in Missouri said Wednesday that it had overradiated 76 patients, the vast majority with brain cancer, during a five-year period because powerful new radiation equipment had been set up incorrectly even with a representative of the manufacturer watching as it was done

The hospital, CoxHealth in Springfield, said half of all patients undergoing a particular type of treatment — stereotactic radiation therapy — were overdosed by about 50 percent after an unidentified medical physicist at the hospital miscalibrated the new equipment and routine checks over the next five years failed to catch the error.

Stereotactic therapy delivers radiation in such high doses that usually only one treatment is required. It is commonly used to treat small tumors in the head, which must be firmly stabilized, allowing radiation to be delivered to a precise location.

The error was discovered in September 2009 only after a second physicist received training on the equipment, made by BrainLAB, and the hospital began questioning whether the machine had been installed correctly in 2004, in a process called commissioning.

The overdoses at CoxHealth occurred in a state where there is little or no government oversight of radiation therapy, a fact that Robert H. Bezanson, the hospital's president and chief executive, chose to emphasize.

On Wednesday, he released a letter that he wrote to the Food and Drug Administration, saying that its recent decision to toughen oversight of diagnostic radiation did not go far enough.

"The initiative should be broadened to include regulation of medical radiation therapy as well," he wrote. "We have also learned that the incident here at CoxHealth is, unfortunately, not an isolated occurrence. Rather, similar instances of medical overradiation have occurred at other hospitals throughout the country. Without increased regulation and oversight, these instances of medical overradiation will likely continue."

Wrong detector used for BrainLab cone calibration

Misadministration Media Coverage

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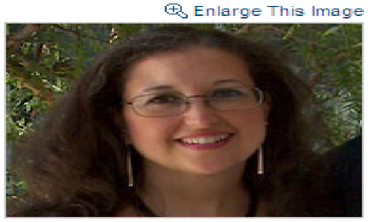
THE RADIATION BOOM

A Pinpoint Beam Strays Invisibly, Harming Instead of Healing

By WALT BOGDANICH and KRISTINA REBELO
Published: December 28, 2010

The initial accident report offered few details, except to say that an unidentified hospital had administered radiation overdoses to three patients during identical medical procedures.

Enlarge This Image



Marci Faber is nearly comatose after a treatment mistake.

It was not until many months later that the full import of what had happened in the hospital last year began to surface in urgent nationwide warnings, which advised doctors to be extra vigilant when using a particular device that delivers high-intensity, pinpoint radiation to vulnerable parts of the body.

Marci Faber was one of the three patients. She had gone to Evanston Hospital in Illinois seeking treatment for pain emanating from a nerve deep inside her head. Today, she is in a nursing home, nearly comatose, unable to speak, eat or walk, leaving her husband to care for their three young daughters.

The Radiation Boom

Missing the Target

Articles in this series examine issues arising from the increasing use of medical radiation and the new technologies that deliver it.

Previous Articles in the Series »

Well

Tara Parker-Pope on Health

...herapy for Depression
..., 2011, 4:15 PM

...g Profits Before Patients
..., 2011, 2:10 PM

...ies: Garlic for Athlete's Foot
..., 2011, 10:07 AM

...u Be Addicted to Foods?
..., 2011

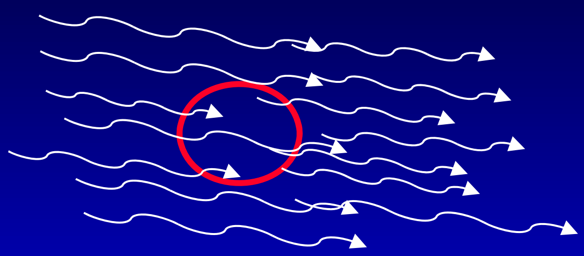
...d: Does Exercising Make You Drink More ...l?
..., 2011

What is a Small Field?

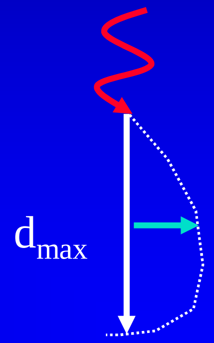
- Lack of charged particle
  - Dependent on the range of secondary electrons
  - Photon energy
- Collimator setting that obstructs the source size
- Detector is comparable to the field size

CPE & Electron Range

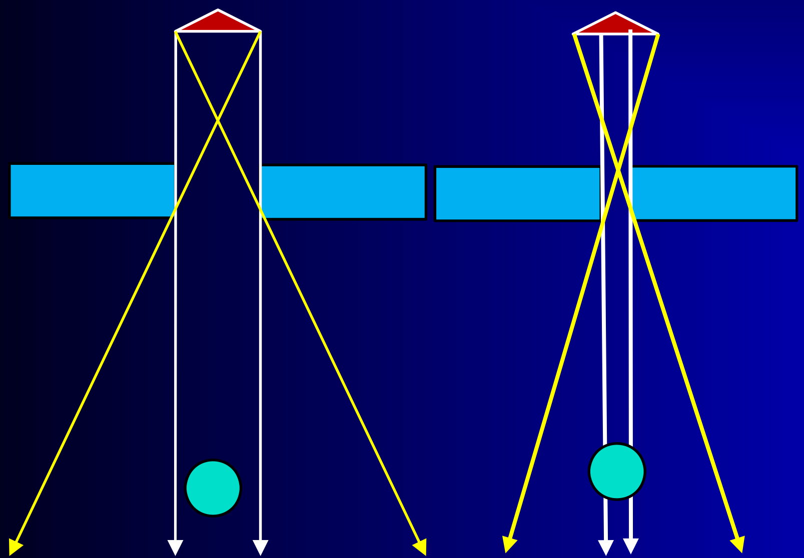
- CPE, Charged Particle Equilibrium

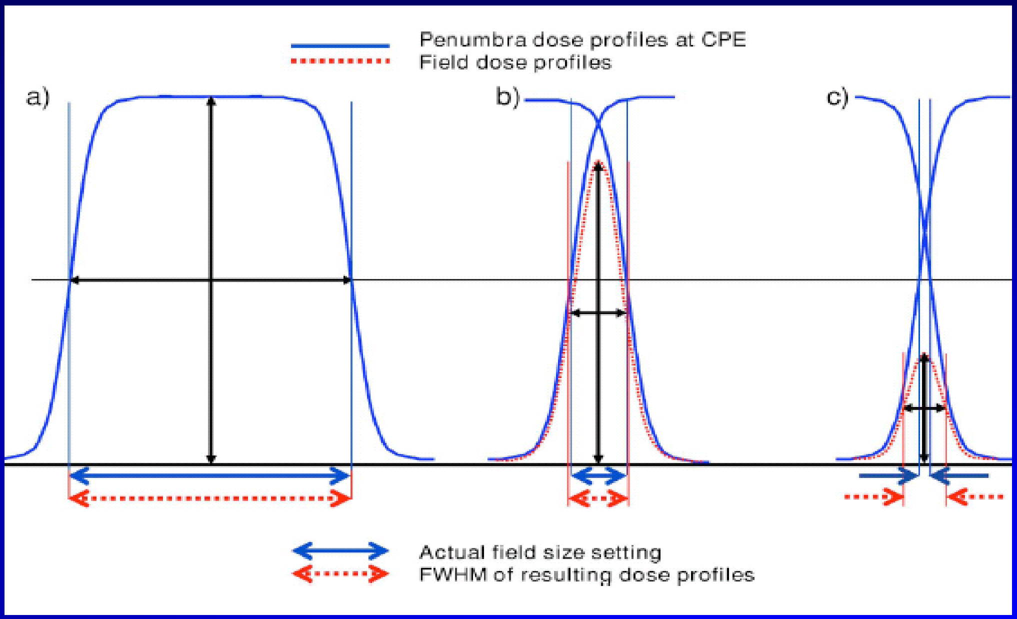


- Electron range= d_{max} in forward direction
- Electron range in lateral direction
  - Nearly energy independent
  - Nearly equal to penumbra (8-10 mm)
- Field size needed for CPE
  - Lateral range
  - 16-20 mm



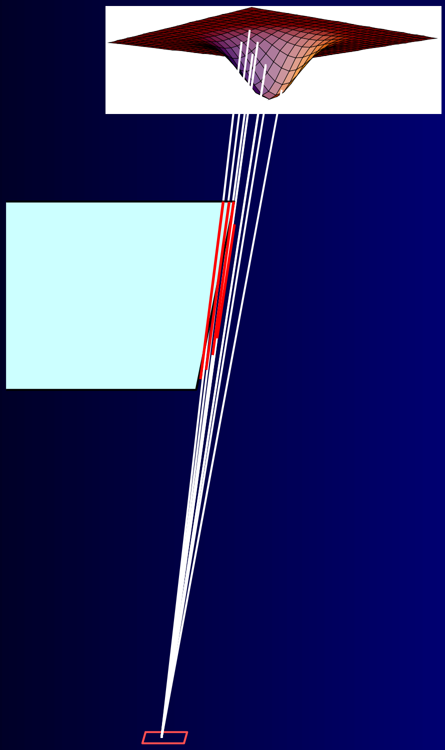
Definition of Small Fields

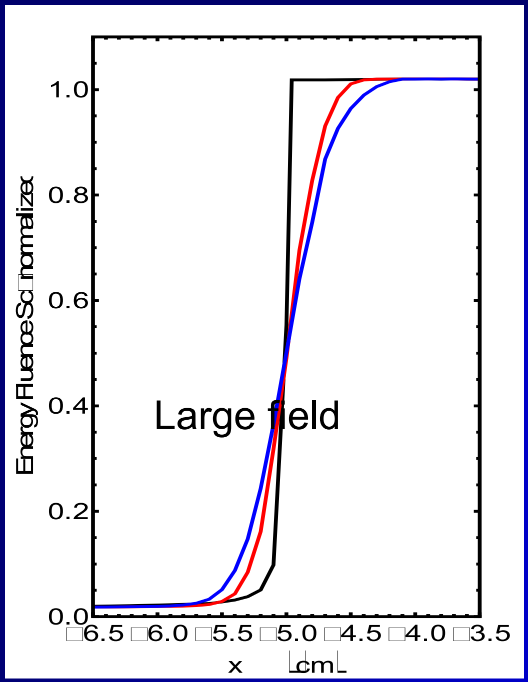


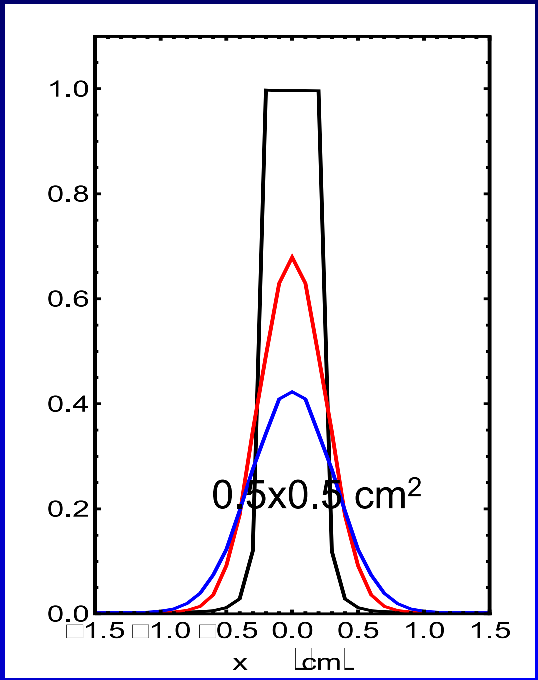


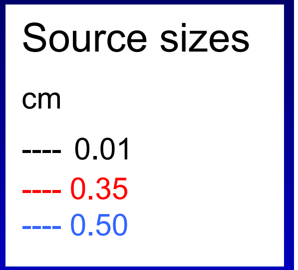
Das et al, Med. Phys. 35, 206-215, 2008

Energy Fluence Penumbra/Output





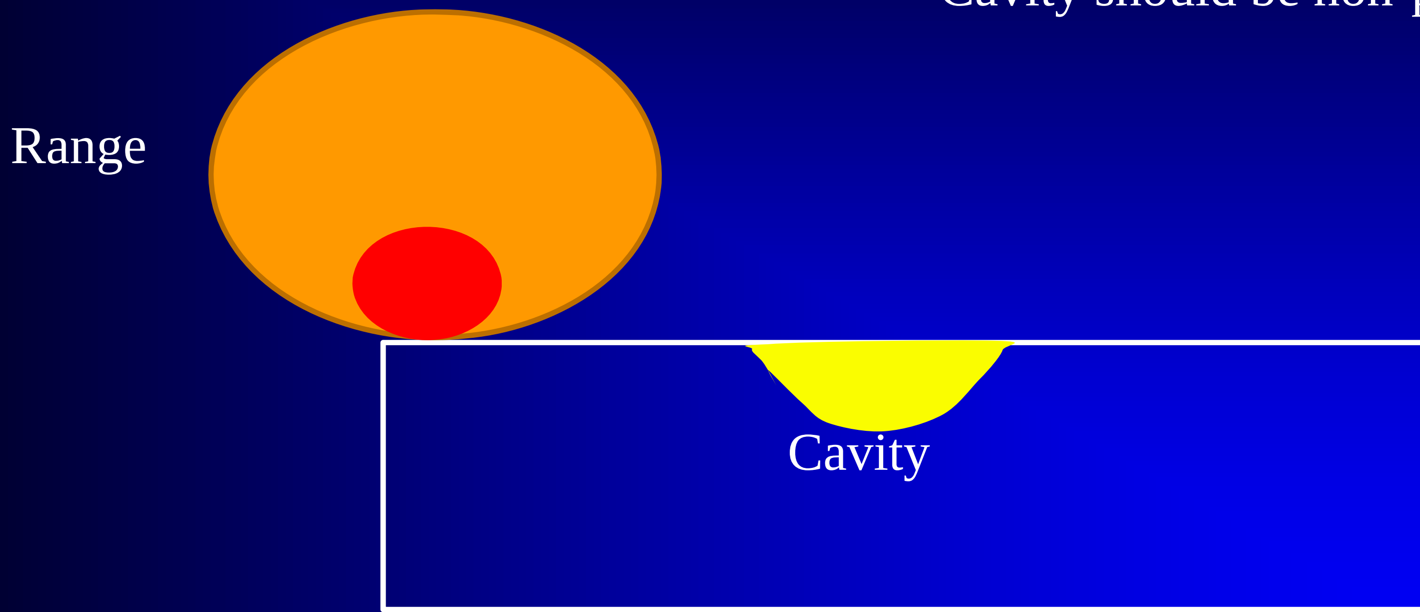




Nyholm *et al* Radiother Oncol 78, 347, 2006 and Phys Med Biol 51,6245, 2006

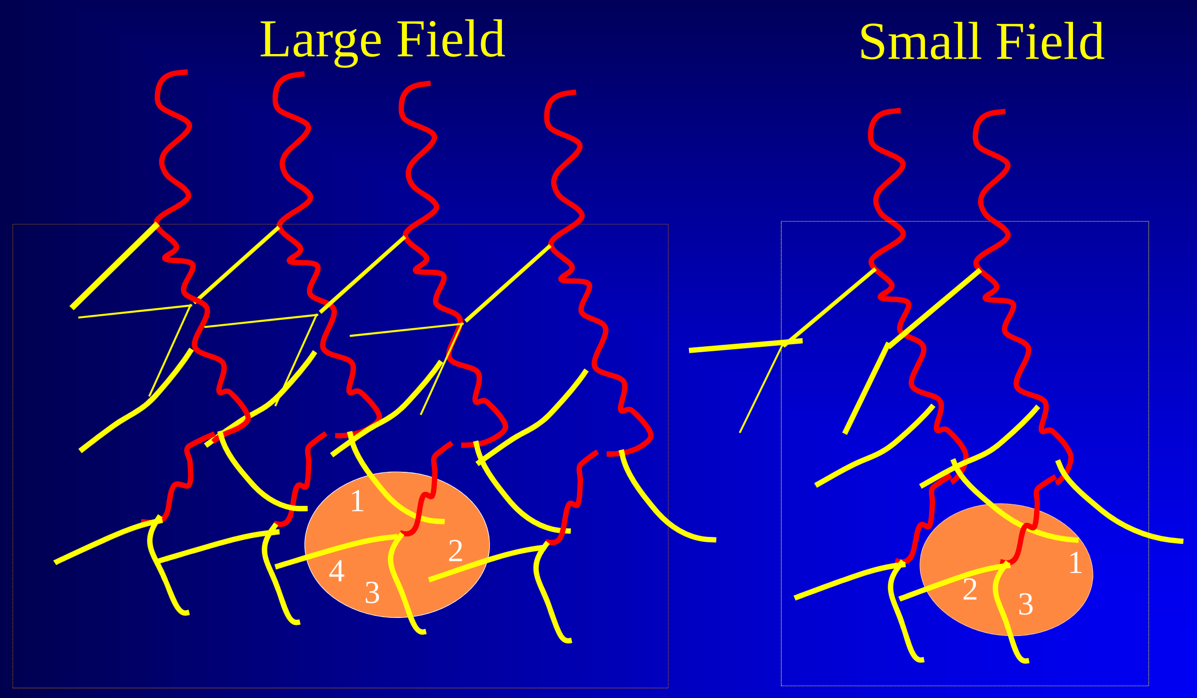
Bragg-Gray Cavity: Range and Cavity Size

Dose is calculated only by charged particle crossers in the cavity & Cavity should be non-perturbing

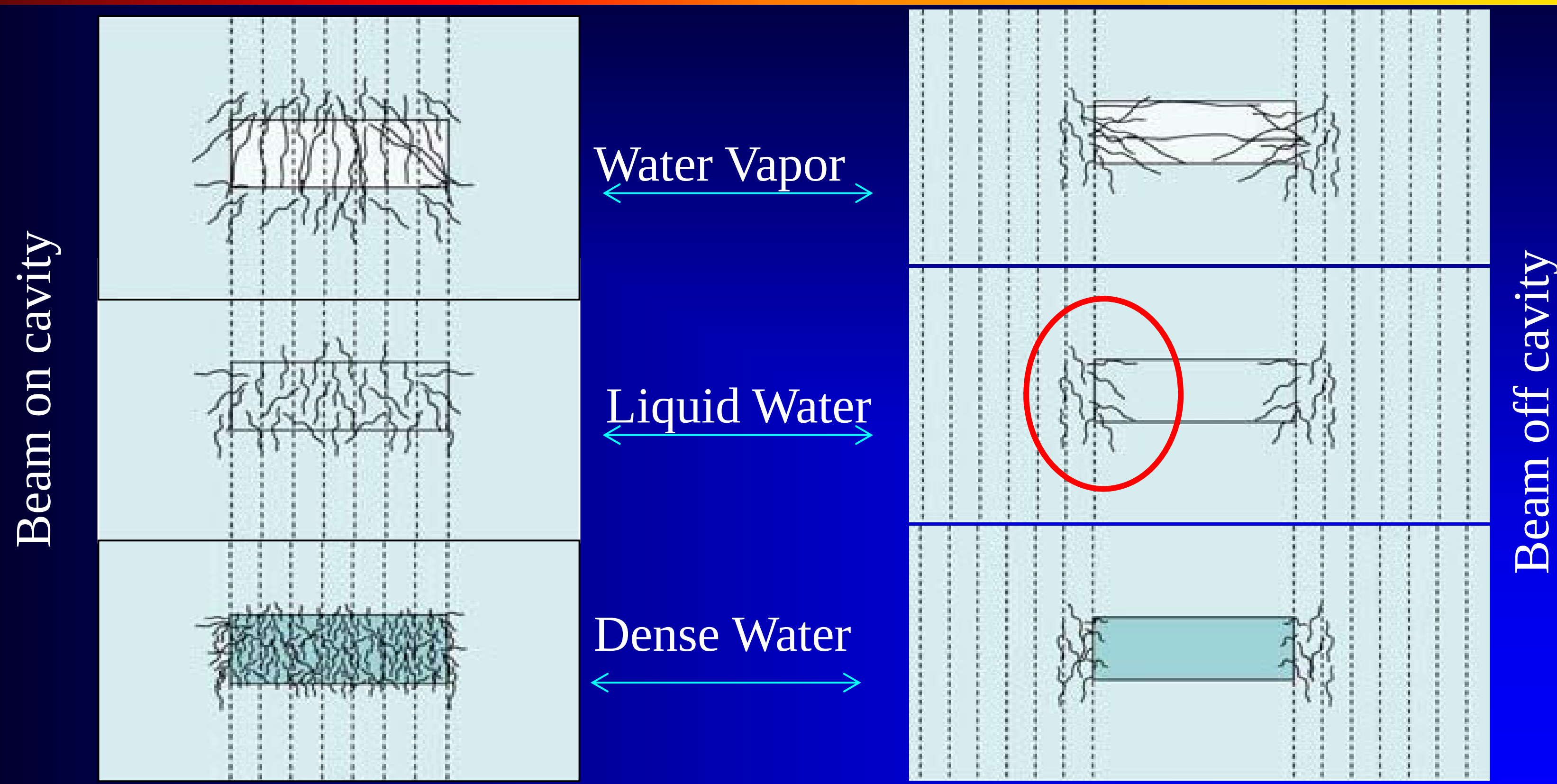


$$\text{Dose} = \phi.S/\rho = (\text{number/cm}^2)(\text{MeVcm}^2/\text{g}) = \text{MeV/g} = \text{J/kg (Gy)}$$

Lateral Electronic Equilibrium, LEE

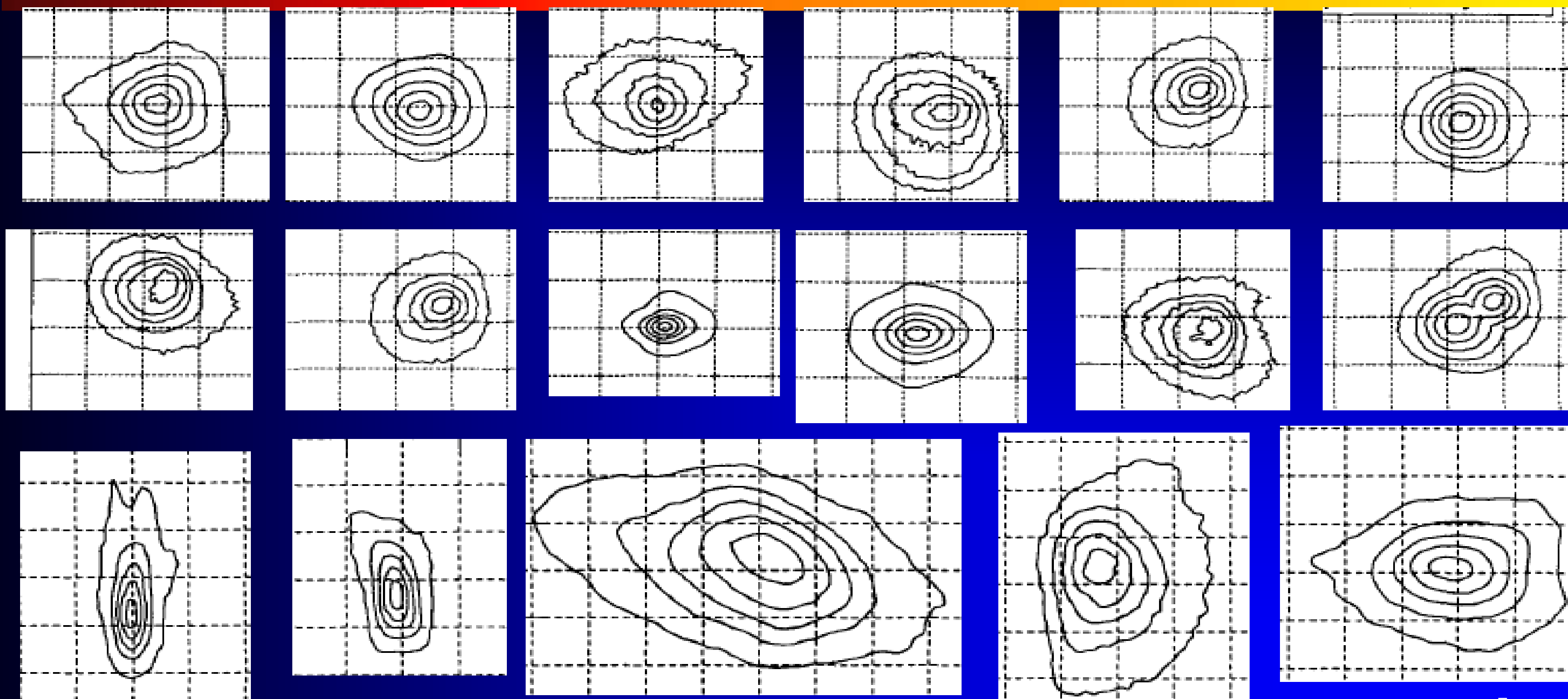


Density Effect



Bouchard et al, Med Phys, 42, 6063-6047, 2015

Source Size

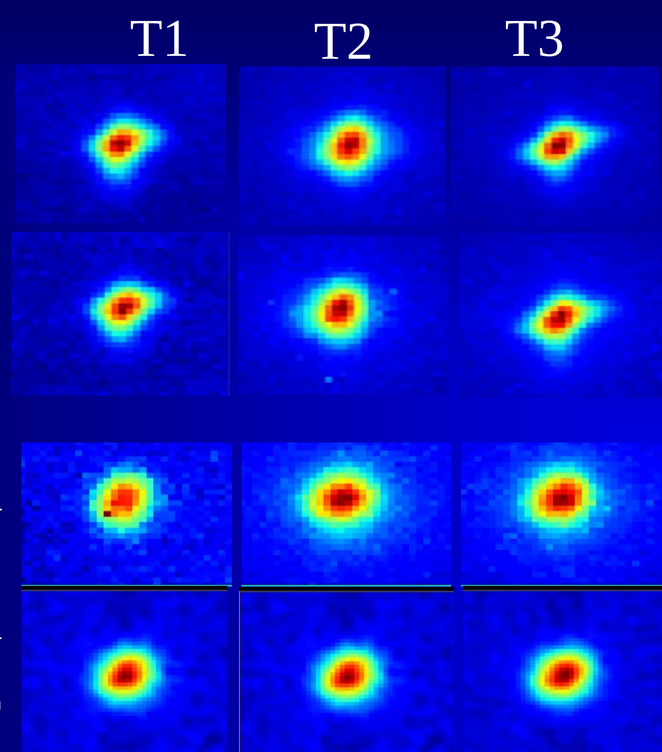


90%, 70%, 50%, 30%, 10% iso-intensity line

Jaffray et al, Med Phys 20, 1417-1427 (1993)

Source Size, Modern Machines

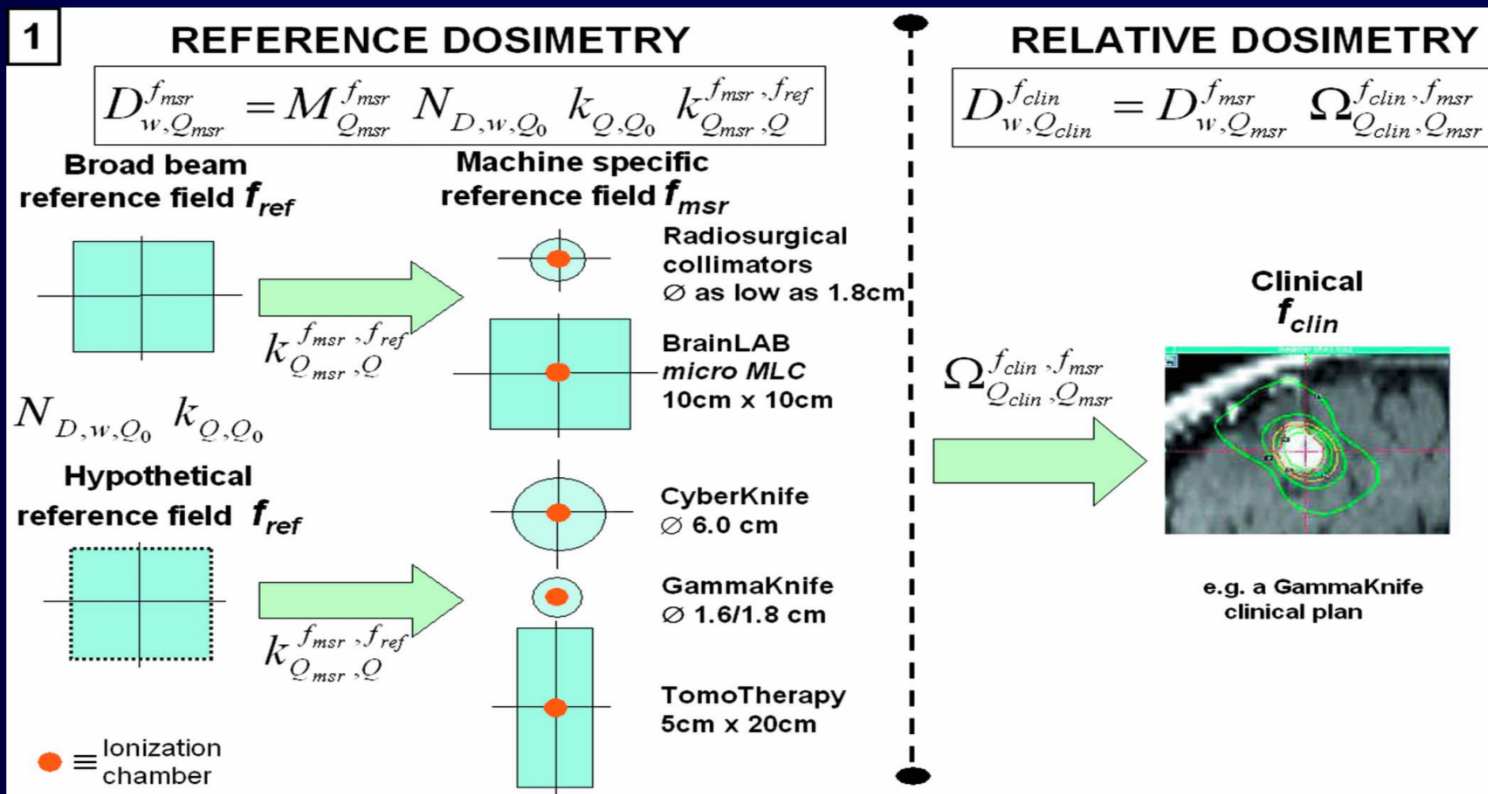
Varian TrueBeam



	Dimensions x, y (mm)
6 MV	0.9, 0.7
6 MV FFF	0.8, 0.7
10 MV	0.9, 0.9
10 MV FFF	0.9, 0.8

Sawkey et al, Med Phys, 40, 332, 2013

IAEA/AAPM Proposed Pathway



Alfonso, et al. Med Phys ***35****, 5179-5186 (2008)*

Why So Much of Fuss?

- Reference (ref) conditions cannot be achieved for most SRS devices (cyberknife, gammaknife, tomotherapy etc)
- Machine Specific reference (msr) needs to be linked to ref
- Ratio of reading (PDD, TMR, Output etc) is not the same as ratio of dose

$$\frac{D_1}{D_2} \neq \frac{M_1}{M_2}$$

$$\frac{D_1}{D_2} = \frac{M_1}{M_2} \bullet \left[k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}} \right]$$

$$k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}} = \frac{D_1}{D_2} \bullet \frac{M_2}{M_1}$$

Alfonso et al. Med Phys 35, 5179-5186 (2008)

Relative Dosimetry

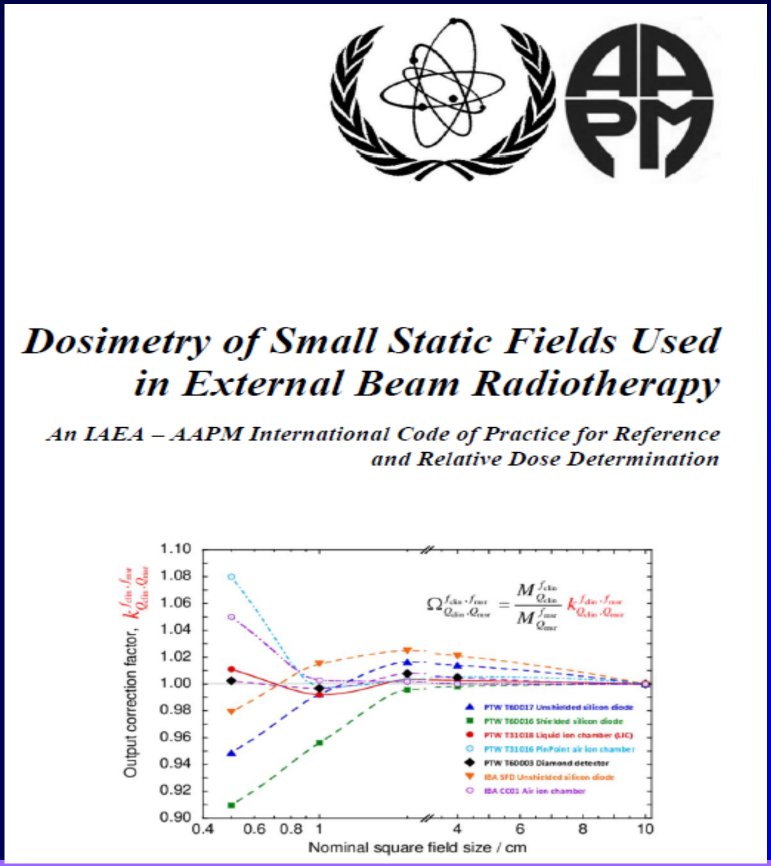
$$D_{w,Q_{msr}}^{f_{msr}} = M_{Q_{msr}}^{f_{msr}} N_{DW,Qo} k_{Q,Qo} k_{Q_{msr},Q}^{f_{msr},f_{ref}}$$

$$\Omega_{Q_{clin}Q_{msr}}^{f_{clin}f_{msr}} = \frac{M_{Q_{clin}}^{f_{clin}}}{M_{Q_{msr}}^{f_{msr}}}\left[\frac{\left(D_{w,Q_{clin}}^{f_{clin}}\right)/\left(M_{Q_{clin}}^{f_{clin}}\right)}{\left(D_{w,Q_{msr}}^{f_{msr}}\right)/\left(M_{Q_{msr}}^{f_{msr}}\right)}\right] = \frac{M_{Q_{clin}}^{f_{clin}}}{M_{Q_{msr}}^{f_{msr}}} k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$$

$$k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}} = \frac{\left(D_{w,Q_{clin}}^{f_{msr}}\right)/\left(M_{w,Q_{clin}}^{f_{clin}}\right)}{\left(D_{w,Q_{msr}}^{f_{clin}}\right)/\left(M_{w,Q_{msr}}^{f_{clin}}\right)} = \frac{(Output)_{rel}}{(Reading)_{rel}}$$

$$k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}} = \frac{(S_{w,air})_{fclin} \cdot P_{fclin}}{(S_{w,air})_{fmsr} \cdot P_{msr}}$$

Small Field Dosimetry Publications



+ TG-155 (AAPM)

Relative dosimetry

IAEA-TRS 483, 2017

Meaning of k in Micro-Chambers

$$k_{Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{msr}}} = \frac{[s_{\mathrm{w,det},\Delta}^{\mathrm{SA}} \times (p_{\Phi})_{\mathrm{det}}^{\mathrm{w}}]_{Q_{\mathrm{clin}}}}{[s_{\mathrm{w,det},\Delta}^{\mathrm{SA}} \times (p_{\Phi})_{\mathrm{det}}^{\mathrm{w}}]_{Q_{\mathrm{msr}}}}$$

Kumar et al, PMB, 60, 8187, 2015

$$k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}} = \frac{\left[\left(\frac{\overline{L}}{\rho}\right)_{air}^{w} \cdot P_{fl} \cdot P_{grad} \cdot P_{stem} \cdot P_{cell} \cdot P_{wall}\right]_{f_{clin}}}{\left[\left(\frac{\overline{L}}{\rho}\right)_{air}^{w} \cdot P_{fl} \cdot P_{grad} \cdot P_{stem} \cdot P_{cell} \cdot P_{wall}\right]_{f_{msr}}}$$

Bouchard et al, Med Phys, 36, 4654, 2009

Stopping Power Ratio

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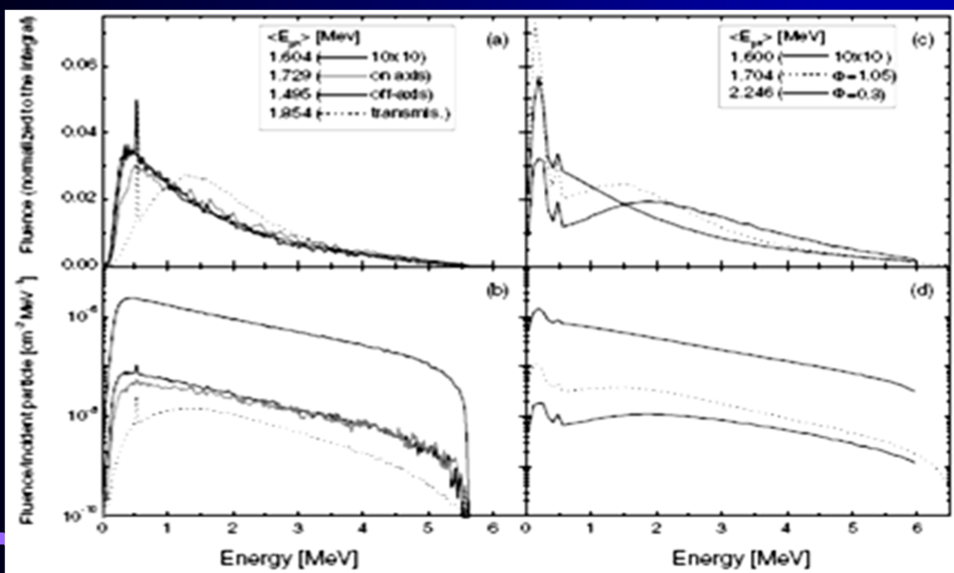
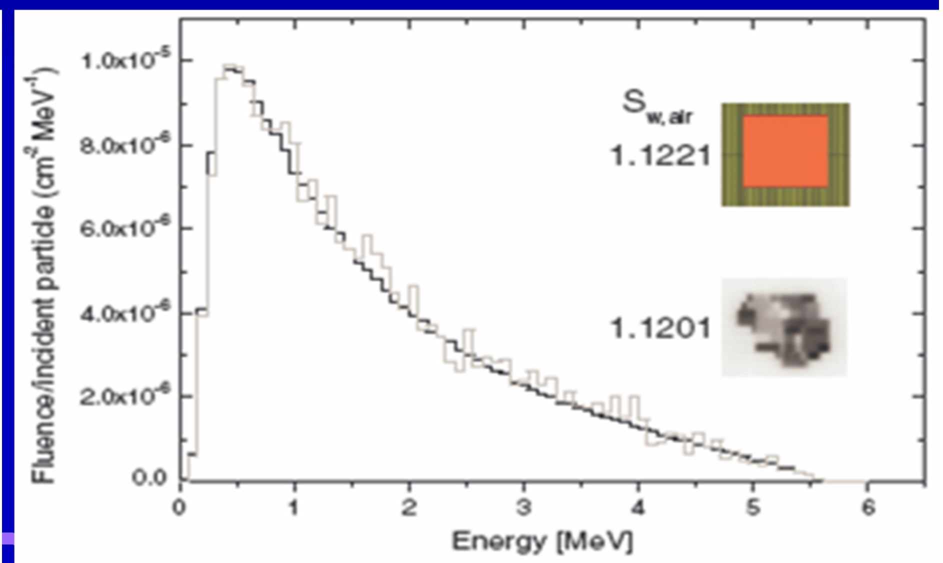
Phys. Med. Biol. 48 (2003) 2081–2099 PII: S0031-9155(03)61152-8

Ionization chamber dosimetry of small photon fields: a Monte Carlo study on stopping-power ratios for radiosurgery and IMRT beams

F Sánchez-Doblado[1,2], P Andreo[3], R Capote[1,2], A Leal[1,2], M Perucha[2], R Arráns[1], L Núñez[4], E Mainegra[5], J I Lagares[1,2] and E Carrasco[1,2]





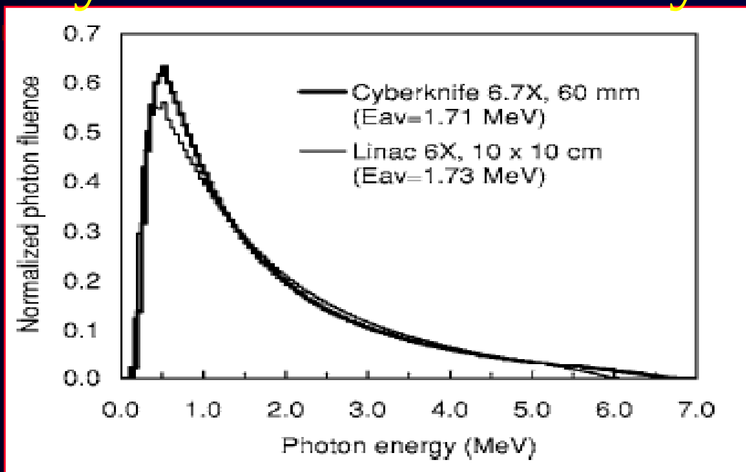
Radiological Parameters

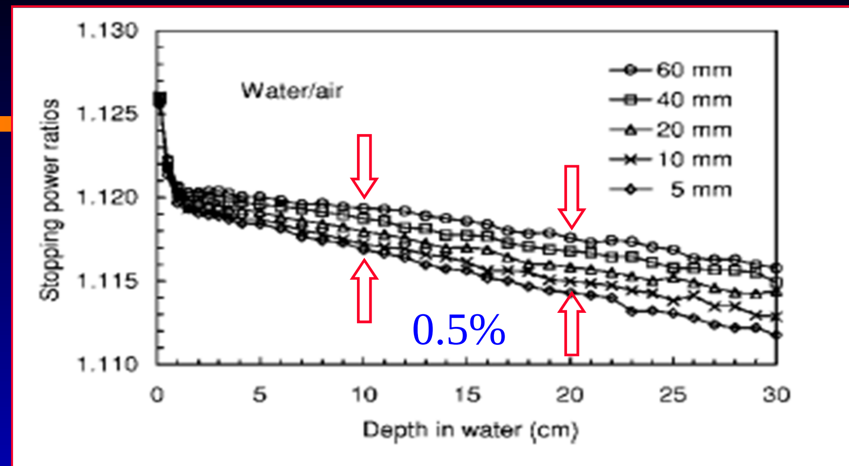
6 MV beams	Beam quality ($TPR_{20,10}$)	$s_{w,air}$ Andreo (1994)[a]	$s_{w,air}$ This work	$s_{w,air}$ Ratio this work/ Andreo	$s_{PMMA,air}$ Andreo (1994)[a]	$s_{PMMA,air}$ This work	$s_{PMMA,air}$ Ratio this work/ Andreo	Configuration
Elekta SL-18 radiosurgery								
10 × 10 cm^2	0.690	1.1187	1.1188	1.000	1.0853	1.0856	1.000	figure 1(a)
1.0 cm diameter			1.1155	0.997		1.0819	0.997	figure 1(b)
0.3 cm diameter			1.1153	0.997		1.0817	0.997	figure 1(c)
Siemens Primus MLC								
10 × 10 cm^2	0.677	1.1213	1.1221	1.001	1.0880	1.0892	1.001	figure 1(d)
2 × 2 cm^2 irregular on-axis			1.1203	0.999		1.0870	0.999	figure 1(e)
2 × 2 cm^2 irregular 8 cm off-axis			1.1250	1.003		1.0922	1.004	figure 1(f)
MLC transmission			1.1300	1.008				figure 1(i)
IMRT beam (10 × 10 cm^2 approx)			1.1201	0.999				figure 12

[a] These are the values in the IAEA TRS-398 code of practice (Andreo *et al* 2000).

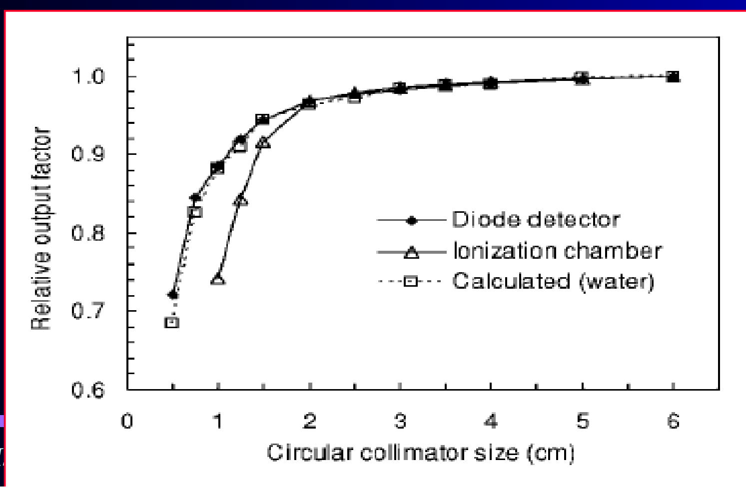
Sanchez-Deblado et al, Phy. Med. Biol., 48, 2081, 2003

Cyber Knife Dosimetry





Machine type	%dd(10)$_x$	$(\bar{\mu}_{en}/\rho)^{w}_{wall}$
		Wall=C-552
Linac	66.3	1.1091
Cyberknife	60.8	1.1088
		Wall=Carbon
Linac	66.3	1.1144
Cyberknife	60.8	1.1144
		Wall=PMMA

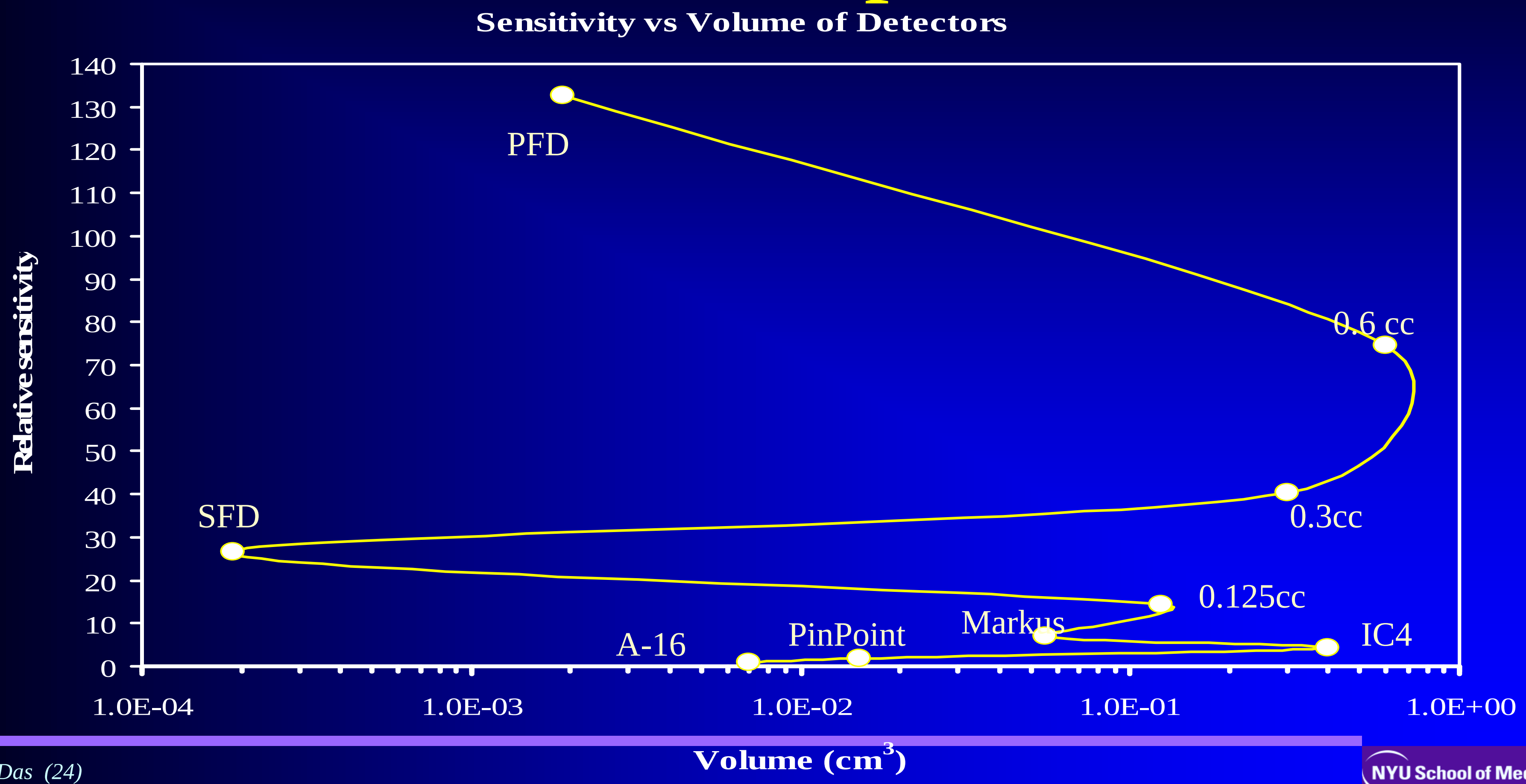


Machine type	%dd(10)$_x$	$(\bar{L}/\rho)^{m}_{air}$			
		Water	PMMA	Carbon	C-552
Linac	66.3[a]	1.1208	1.0878	0.9876	0.9836
Cyberknife	60.8[b]	1.1194	1.0859	0.9854	0.9817

[a]For a 10×10 cm^2 field at 100 cm SSD from a Varian 6 MV-linear accelerator.
[b]For a 60 mm circular collimator at 80 cm SSD from a Cyberknife system.

F. Araki, Med. Phys. 33, 2955-2963 (2006).

Detector Response



Correction Factors

Correction Factor depends on:

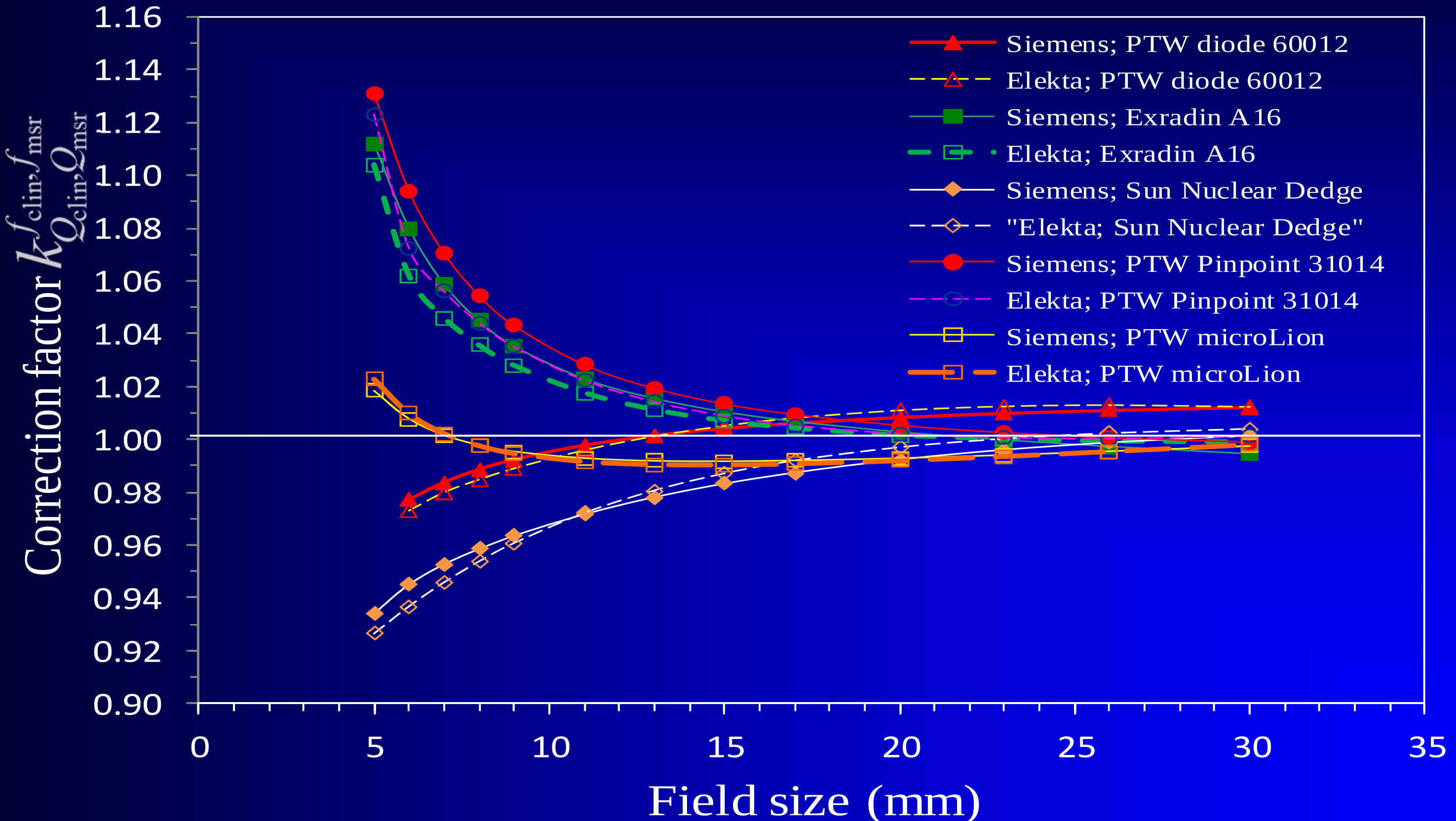
- Field size
- Source size (FWHM; machine type)
- Detector type

TABLE VII. F_{corr} of the four detectors for the 5, 7.5, and 10 mm collimators, as a function of the FWHM.

Detector	FWHM (mm)	F_{corr} 5 mm coll	F_{corr} 7.5 mm coll	F_{corr} 10 mm coll
A16	1.4	1.067	1.021	1.008
	1.8	1.087	1.017	1.007
	2.2	1.102	1.020	1.012
	2.6	1.112	1.027	1.010
Pin Point	1.4	1.082	1.025	1.017
	1.8	1.099	1.024	1.013
	2.2	1.110	1.025	1.013
	2.6	1.124	1.037	1.016
Diode	1.4	0.953	0.966	0.978
	1.8	0.955	0.966	0.978
	2.2	0.957	0.967	0.978
	2.6	0.940	0.967	0.978
Diamond	1.4	1.066	1.001	1.001
	1.8	1.093	1.007	1.000
	2.2	1.107	1.010	0.999
	2.6	1.123	1.012	1.001

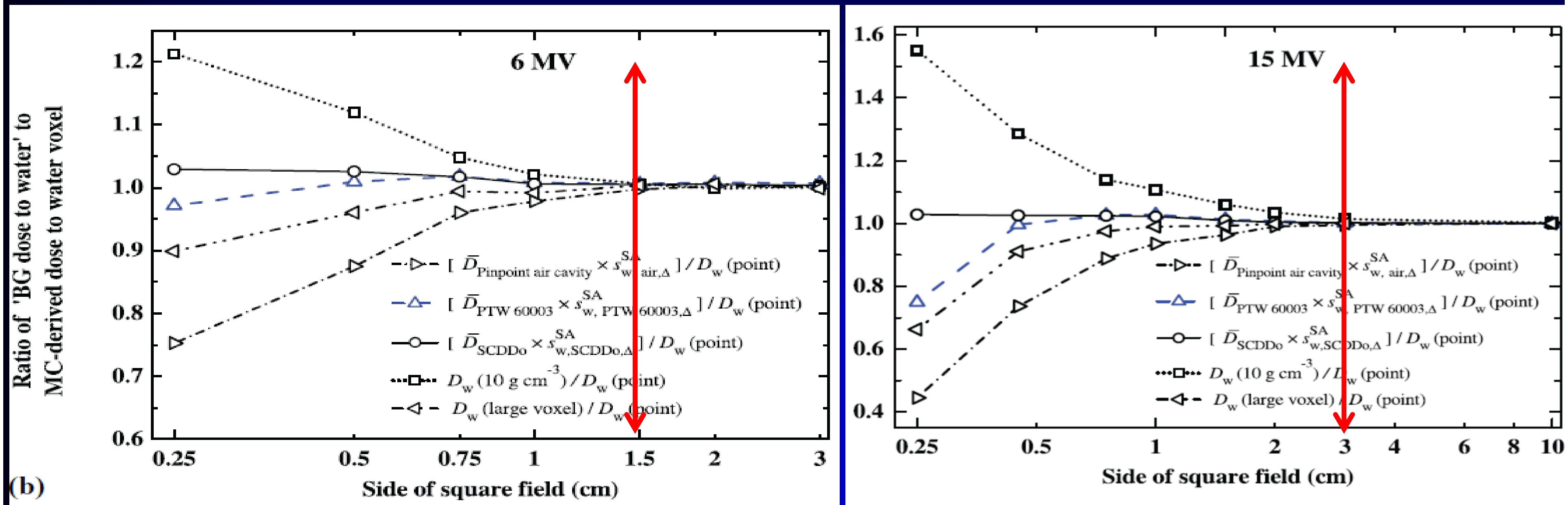
Francescon, et al Med Phys 35, 504, 2008

Published data on $k_{Q_{\text{clin}},Q_{\text{msr}}}^{f_{\text{clin}},f_{\text{msr}}}$



Francescon et al Med Phys,38, 6513, 2011

Monte Carlo Derived $k^{f_{clin},f_{msr}}_{Q_{clin},Q_{msr}}$



Kumar et al, PMB, 60, 8187, 2015

$k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ of Linear Accelerators (Varian)

Implementing a newly proposed Monte Carlo based small field dosimetry formalism for a comprehensive set of diode detectors

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Med. Phys. 38 (12), 6992, 2011

$k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ of Linear Accelerators

Calculation of $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ for several small detectors and for two linear accelerators using Monte Carlo simulations

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Med. Phys. 38 (12), 6513-6527, 2011

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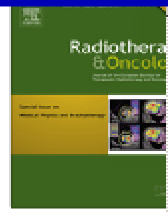

Experimental small field 6 MV output ratio analysis for various diode detector and accelerator combinations

Gavin Cranmer-Sargison [a,b,*], Steve Weston [b,c], Narinder P. Sidhu [a,d], David I. Thwaites [b,e]

Radiotherapy and Oncology 100 (2011) 429–435

$k^{f_{clin},f_{msr}}_{Q_{clin},Q_{msr}}$ Cyber Knife

Detector	5 mm		7.5 mm		10 mm	
	$M^{f_{clin}}_{Q_{clin}} / M^{f_{msr}}_{Q_{msr}}$	$k^{f_{clin},f_{msr}}_{Q_{clin},Q_{msr}}$	$M^{f_{clin}}_{Q_{clin}} / M^{f_{msr}}_{Q_{msr}}$	$k^{f_{clin},f_{msr}}_{Q_{clin},Q_{msr}}$	$M^{f_{clin}}_{Q_{clin}} / M^{f_{msr}}_{Q_{msr}}$	$k^{f_{clin},f_{msr}}_{Q_{clin},Q_{msr}}$
A16	0.626 (15)	1.089 (3)	0.811 (10)	1.018 (3)	0.866 (6)	1.010 (3)
PinPoint	0.620 (17)	1.101 (3)	0.801 (7)	1.024 (3)	0.862 (5)	1.015 (3)
Diode 60008	0.726 (1)	0.943 (3)	0.873 (1)	0.949 (3)	0.912 (1)	0.964 (3)
Diode 60012	0.705 (1)	0.956 (3)	0.847 (2)	0.966 (3)	0.891 (1)	0.978 (3)
EDGE	0.726 (1)	0.948 (3)	0.864 (1)	0.955 (3)	0.906 (1)	0.966 (3)
Alanine	0.544 (8)	1.249 (8)	0.785 (12)	1.059 (4)	0.855 (13)	1.019 (3)
TLD	0.668 (4)	···	0.809 (6)	···	0.880 (8)	···
EBT films	0.659 (17)	···	0.811 (16)	···	0.853 (18)	···
Polymer gels[a]	0.702 (21)	···	0.872 (27)	···	0.929 (29)	···

Pantelis et al, Med Phy. 37, 2369-2379, 2010

Output correction factors for nine small field detectors in 6 MV radiation therapy photon beams: A PENELOPE Monte Carlo study

Med Phys, 41(4), 041711, 2014

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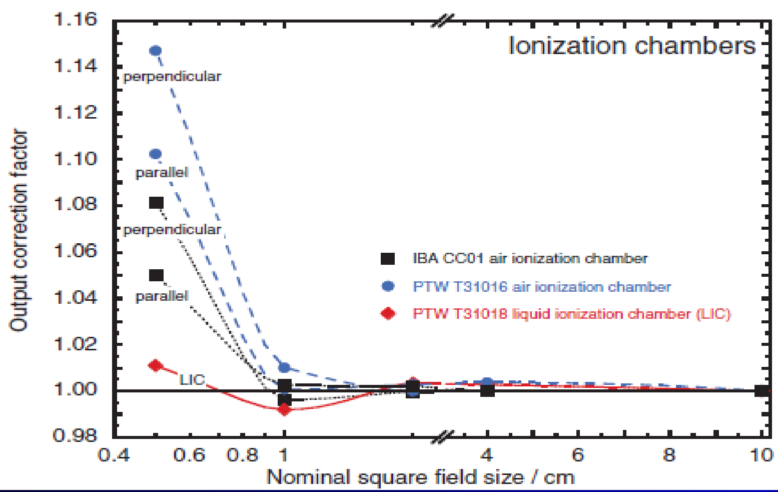

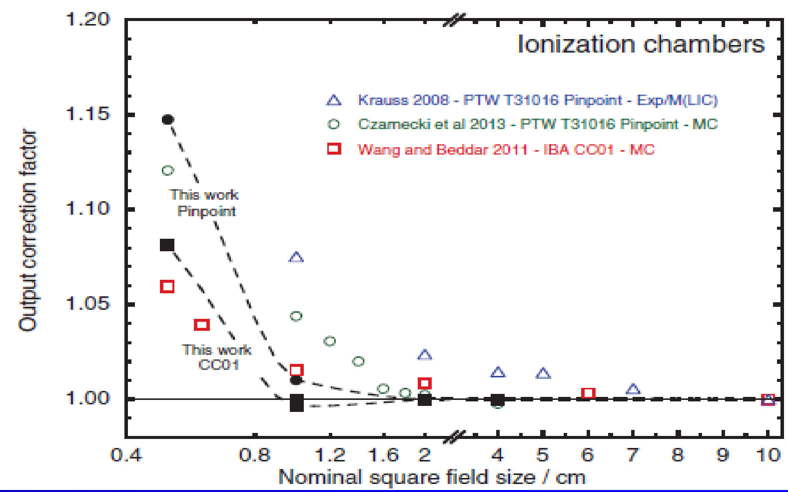

Variation of $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ for the small-field dosimetric parameters percentage depth dose, tissue-maximum ratio, and off-axis ratio

Paolo Francescon[a)]
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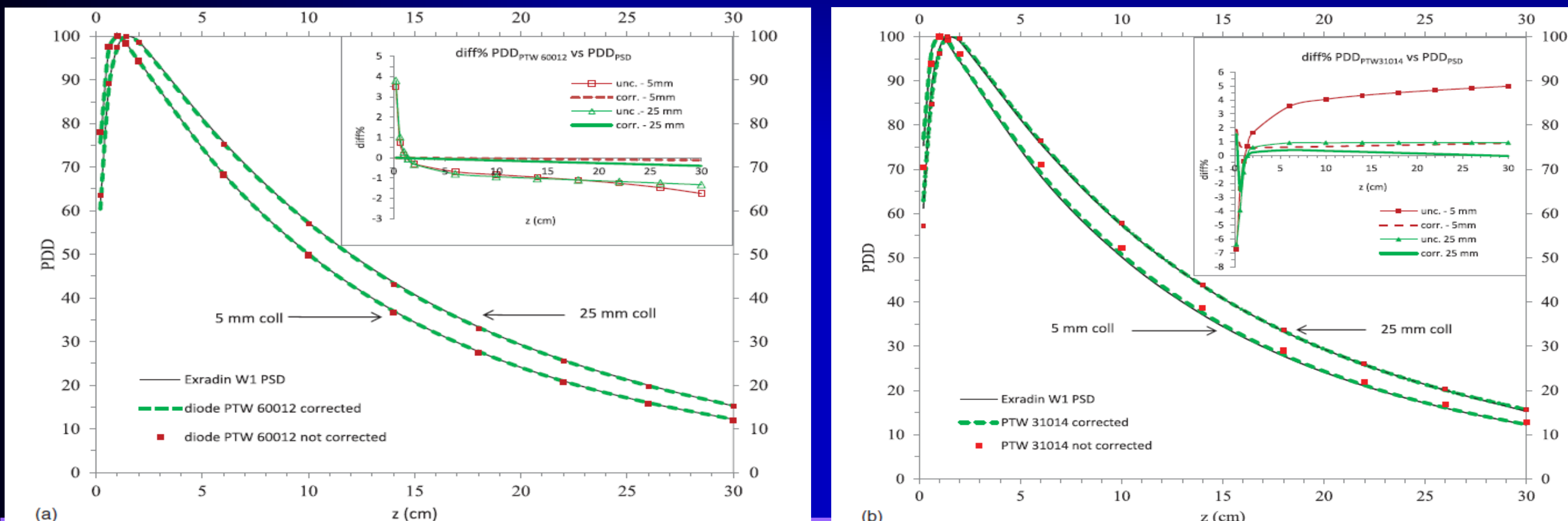
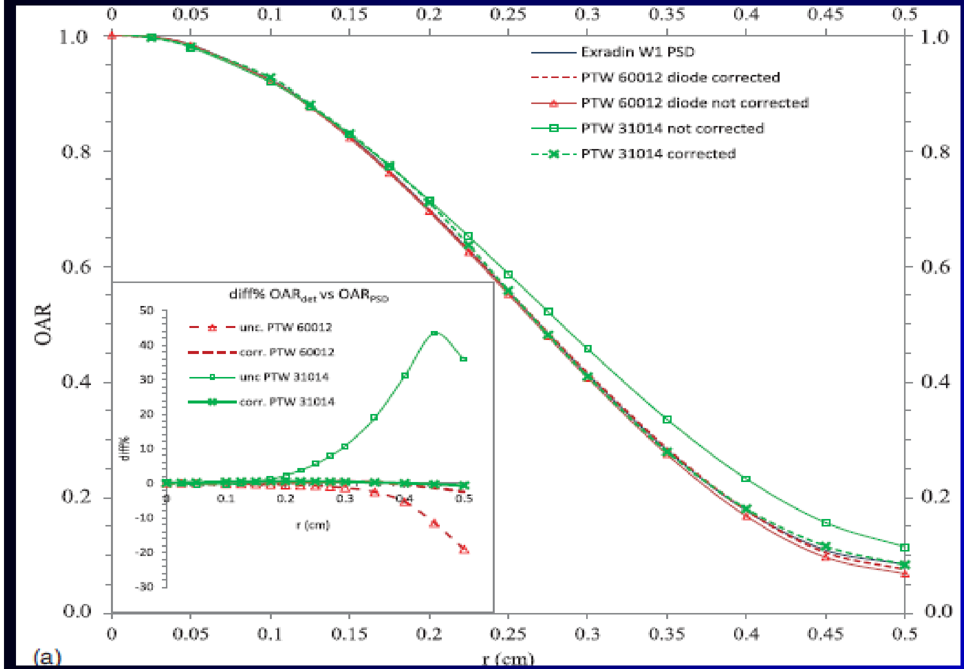
Department of Radiation Oncology, Indiana University School of Medicine, Indianapolis, Indiana 46202



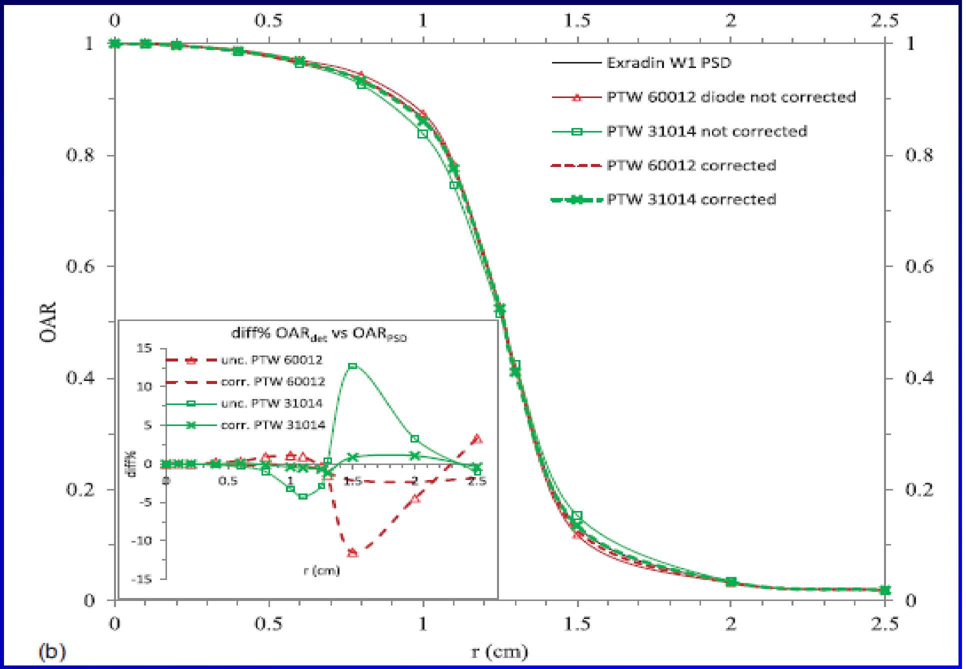
Med. Phys. 41 (10), October 2014 0094-2405/2014/41(10)/101708/

Correction in Profile (OAR)

5 mm cone

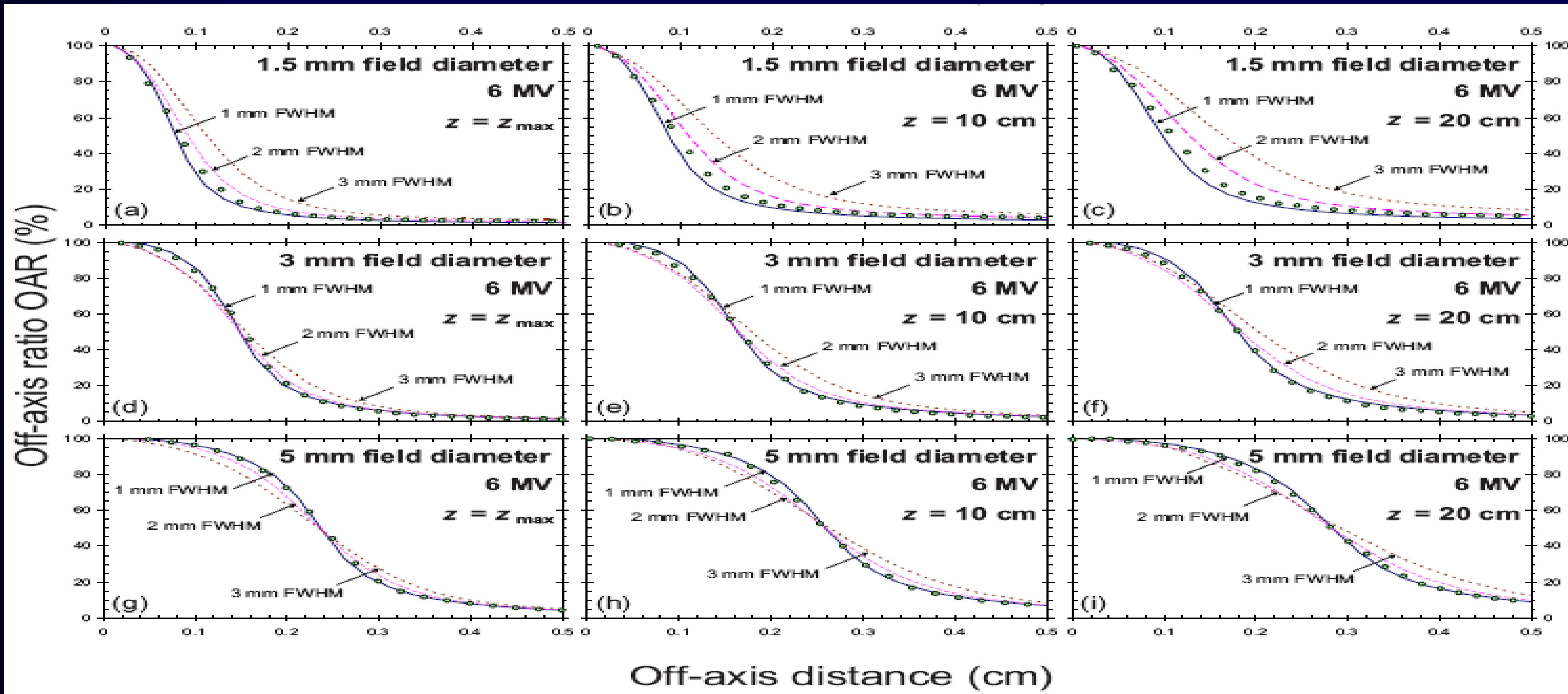


25 mm cone



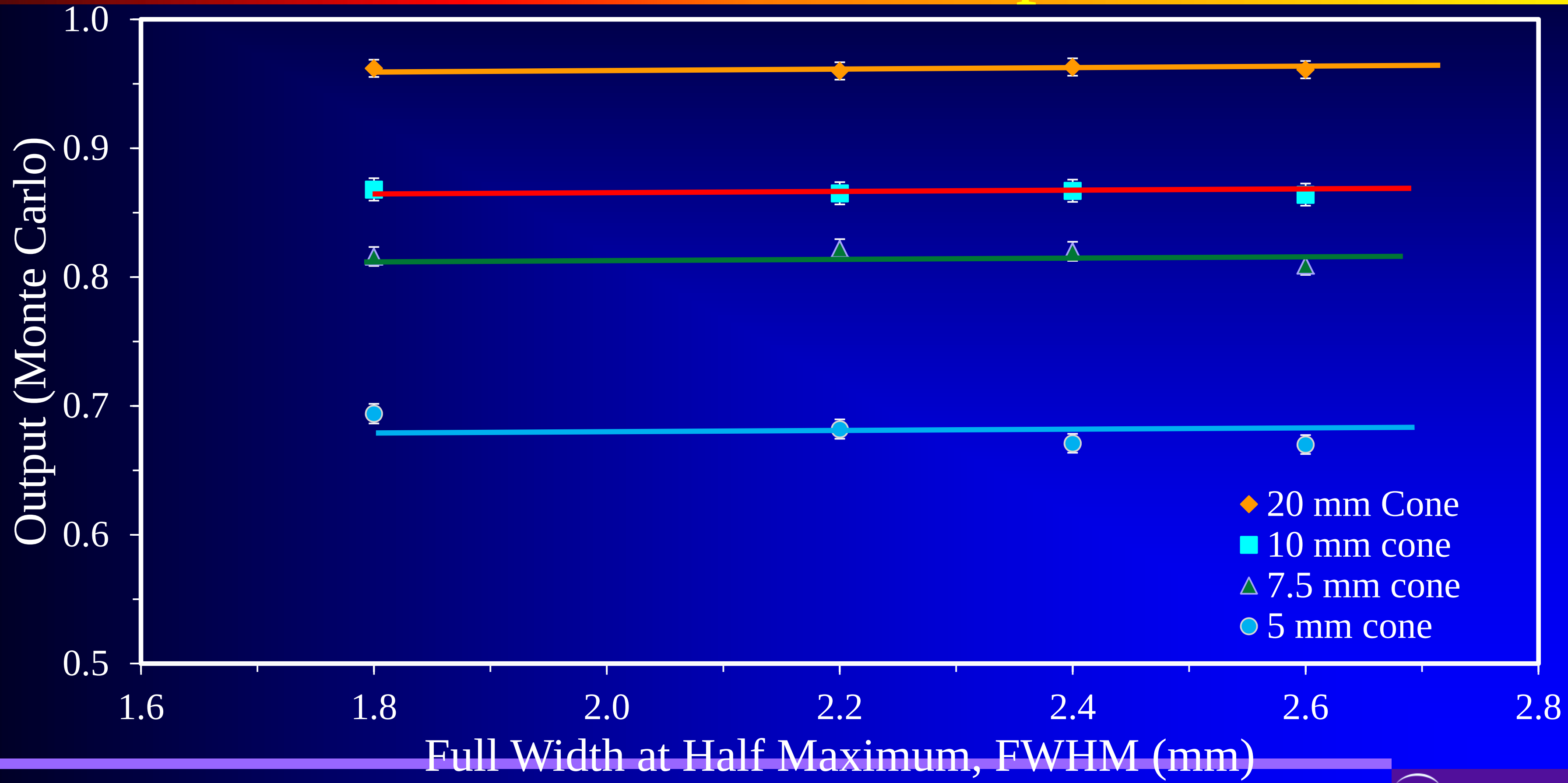
Francescon et al, Med Phys, 41(10), 101708, 2014

Profile & Source Size



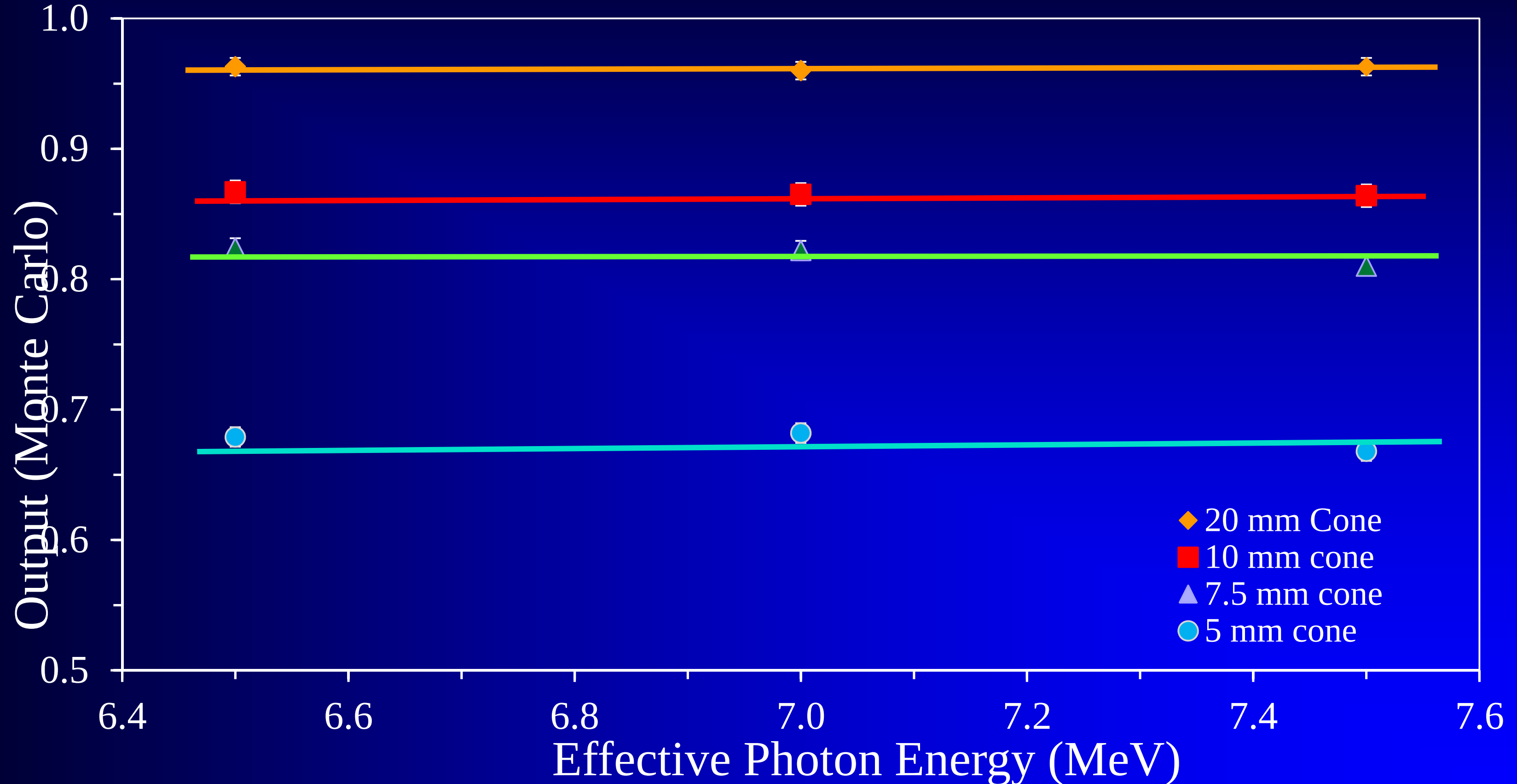
Sham et al, Med Phys, 35, 3317-3330, 2008

Effect of Focal Spot



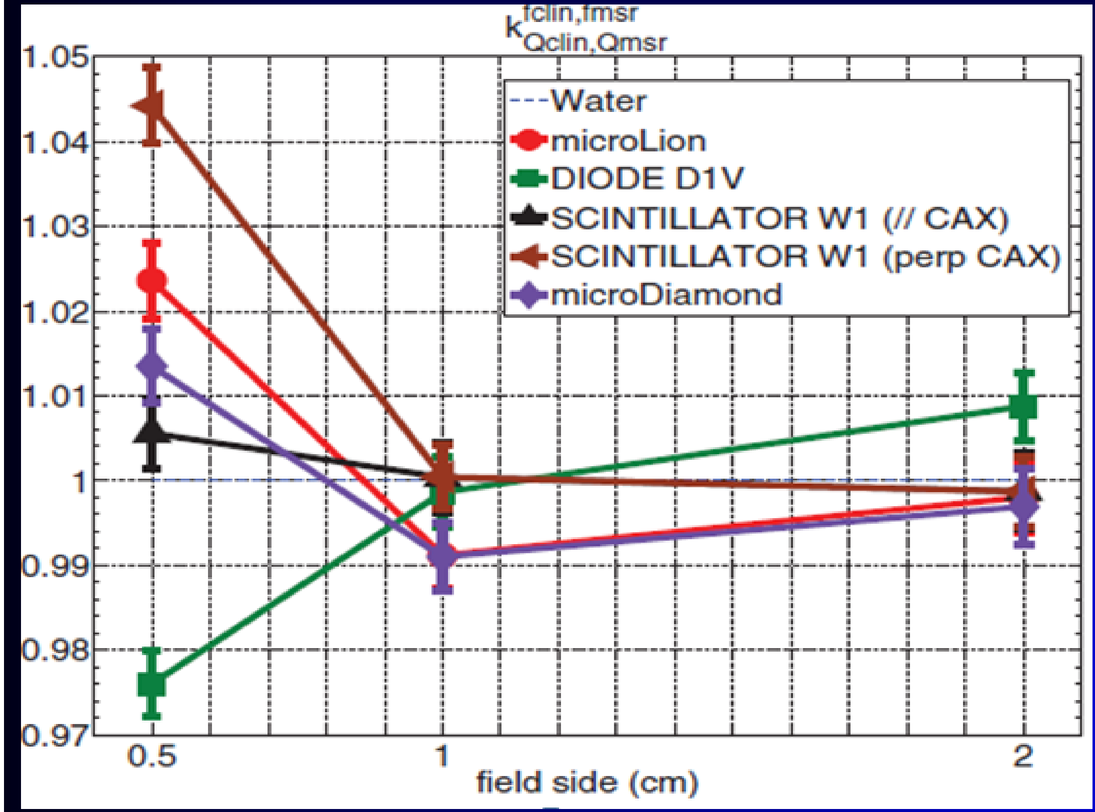
Moignier et al, Med Phys 41(7), 071702, 2014

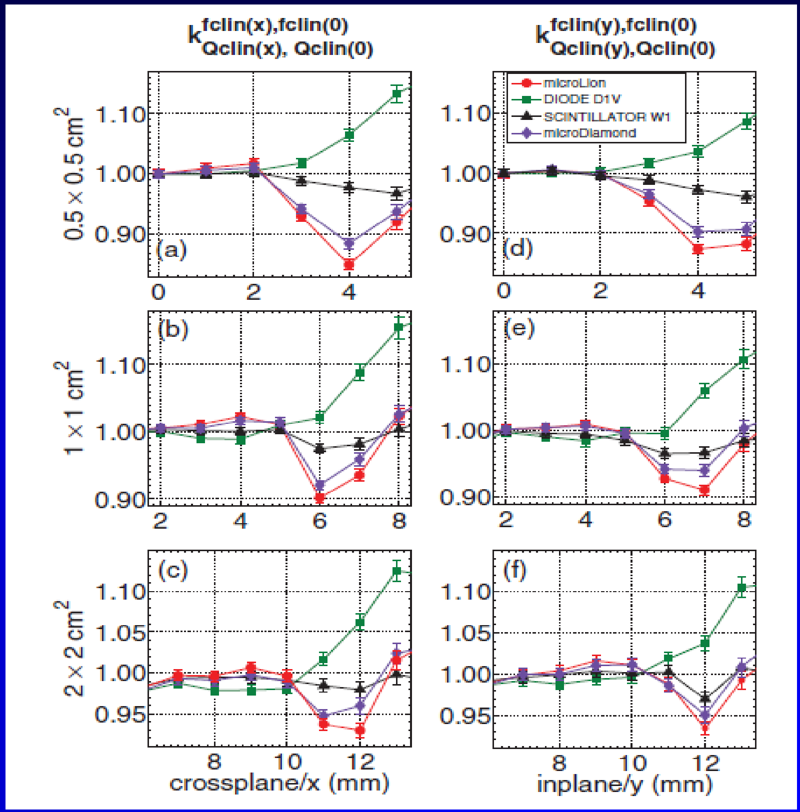
Effect of Beam Energy



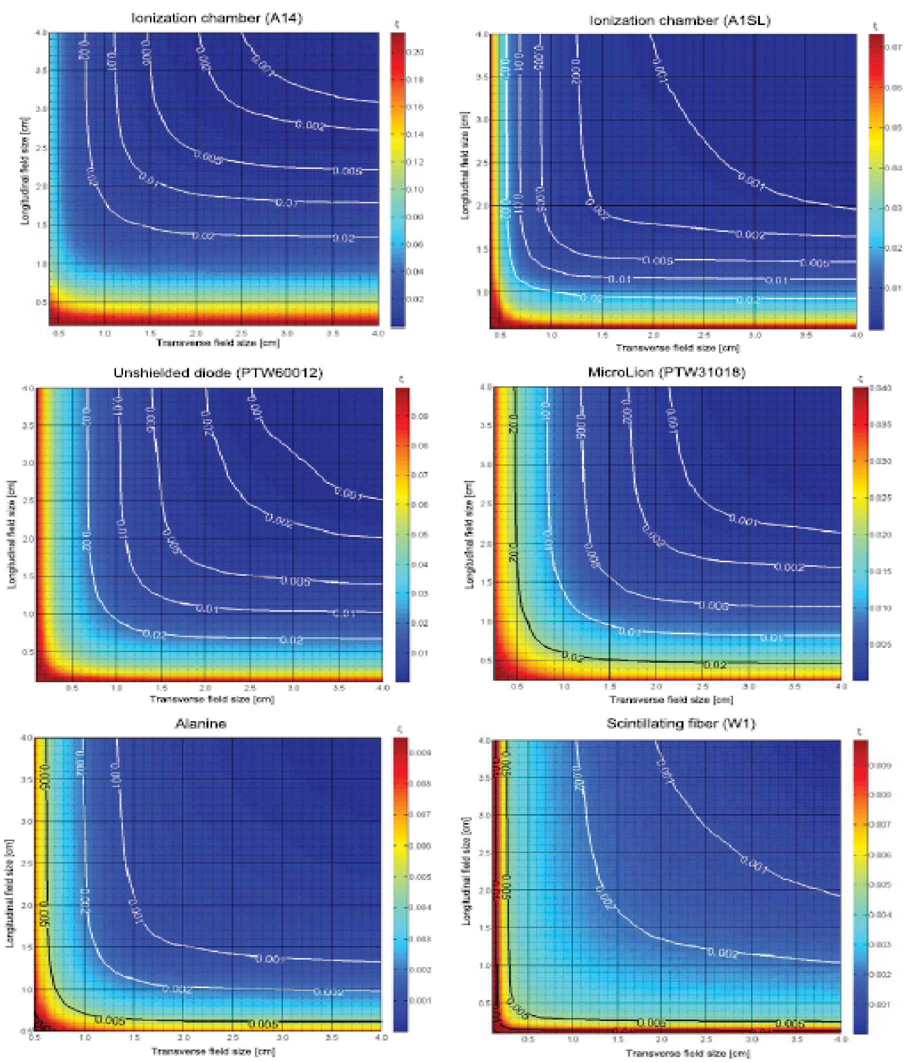
Moignier et al, Med Phys 41(7), 071702, 2014

Good News with Modern Microdetectors





Papaconstadopoulos, et al, Phys. Med. Biol. 59 (2014) 5937–5952



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Phys. Med. Biol. 59 (2014) 4973–5002 — doi:10.1088/0031-9155/59/17/4973

Correction-less dosimetry of nonstandard photon fields: a new criterion to determine the usability of radiation detectors

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6 MV

Detectors	Square field size (cm) 0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.50	3.00
MicroLion	3.1	2.0	1.3	0.8	0.5	0.3	0.2	0.1	0.1
N. Diamond	3.8	2.4	1.5	1.0	0.6	0.4	0.3	0.2	0.1
U. diode	4.9	3.0	1.9	1.2	0.8	0.5	0.4	0.2	0.1
Alanine	1.4	0.6	0.3	0.2	0.1	0.1	0.1	0.0	0.0
S. Fiber	0.5	0.4	0.3	0.3	0.2	0.2	0.2	0.1	0.1

[a]Values are rounded to the nearest 0.1%.

25 MV

Detectors	Square field size (cm) 0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.50	3.00
MicroLion	2.4	1.8	1.4	1.0	0.8	0.6	0.5	0.3	0.2
N. Diamond	3.3	2.1	1.5	1.0	0.8	0.6	0.5	0.3	0.1
U. diode	4.0	2.8	2.1	1.6	1.3	1.0	0.9	0.5	0.3
Alanine	1.5	0.8	0.6	0.4	0.3	0.2	0.2	0.1	0.1
S. Fiber	0.7	0.5	0.4	0.3	0.3	0.2	0.2	0.1	0.1

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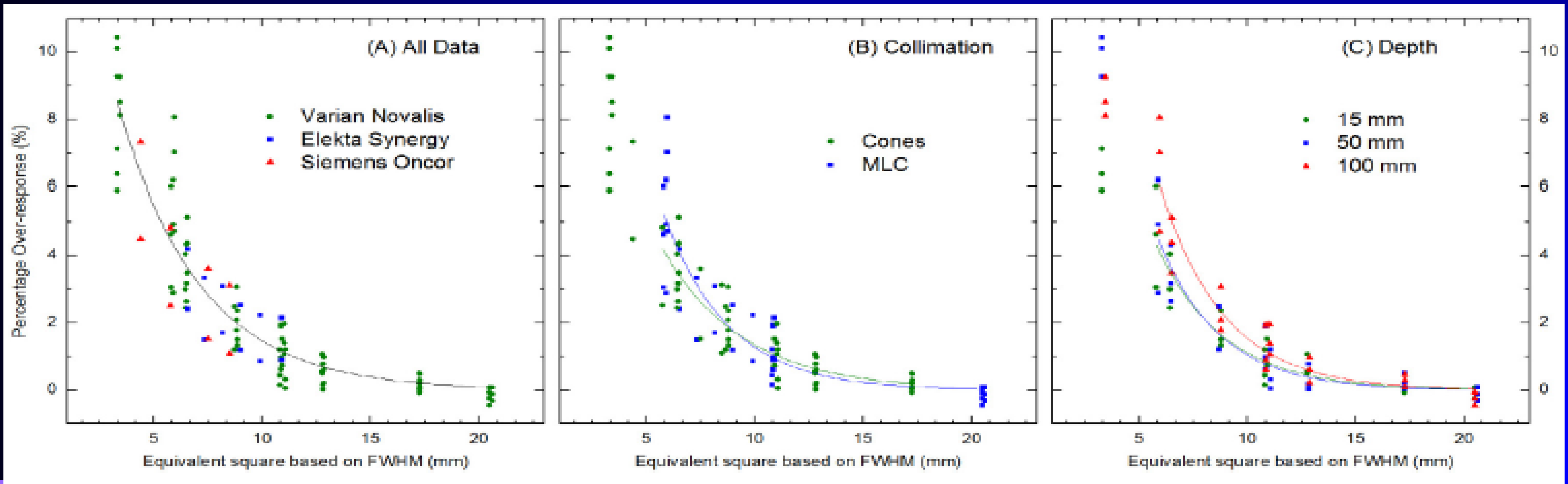
Machine, Cone & Depth?

Can small field diode correction factors be applied universally?

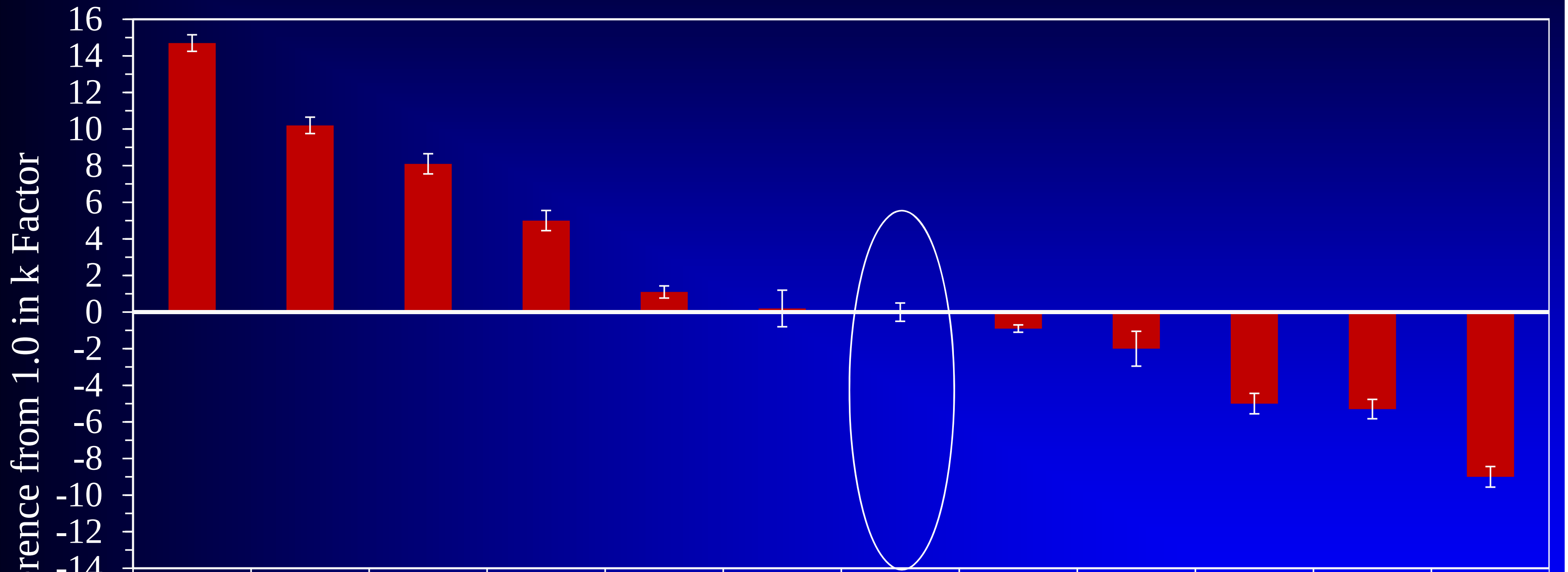
Paul Z.Y. Liu [a,b,*], Natalka Suchowerska [a,b], David R. McKenzie [a]

[a] *School of Physics, The University of Sydney; and* [b] *Department of Radiation Oncology, Chris O'Brien Lifehouse, Camperdown, Australia*

Radiotherapy Oncology, 112, 442-446, 2014



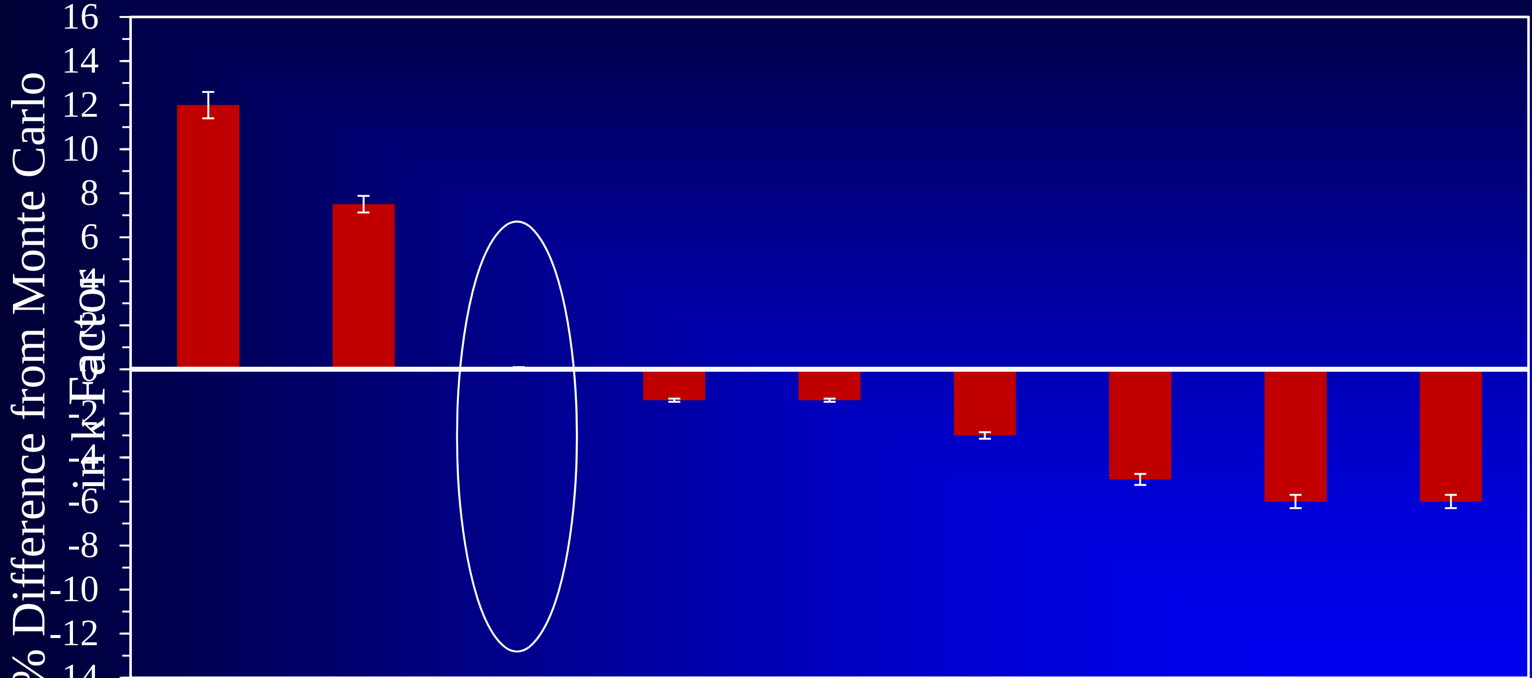
k Factor for Varian IX Machine, 5x5 mm^2 Field



	PTW-Pinpoint-per	PTW-Pinpoint-par	IBA CC01-per	IBA CC01-par	PTW-LIC	PTW-Micro Diamond	SI PSD	IBA-EFD	IBA-SFD	PTW-Unshielded Diode	IBA-PFD	PTW-Shielded Diode
Series1	14.7	10.2	8.1	5.0	1.1	0.2	0.0	-0.9	-2.0	-5.0	-5.3	-9.0

Benmakhlouf et al, Med Phys 41(4), 041711, 2014

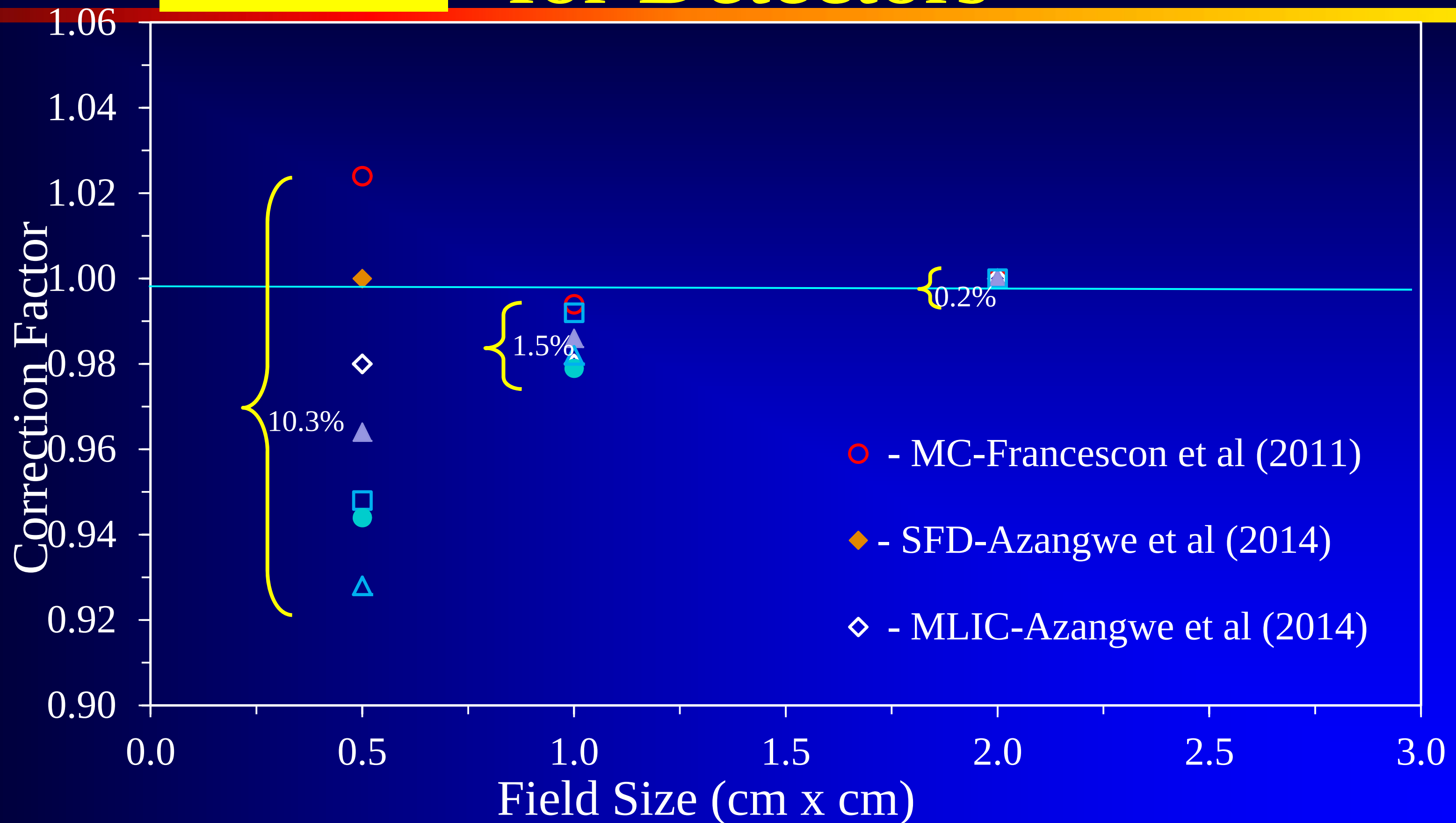
k Factor of CyberKnife 5 mm Cone



	PTW PinPoint	Diamond(old)	SI-PSD	EBT2	MicroTLD	IBA-SFD	PTW unshielded Diode	PTW shielded Diode	SN-Edge
Series1	12.0	7.5	0.1	-1.4	-1.4	-3.0	-5.0	-6.0	-6.0

Moignier et al, Med Phys 41(7), 071702, 2014

$k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ for Detectors



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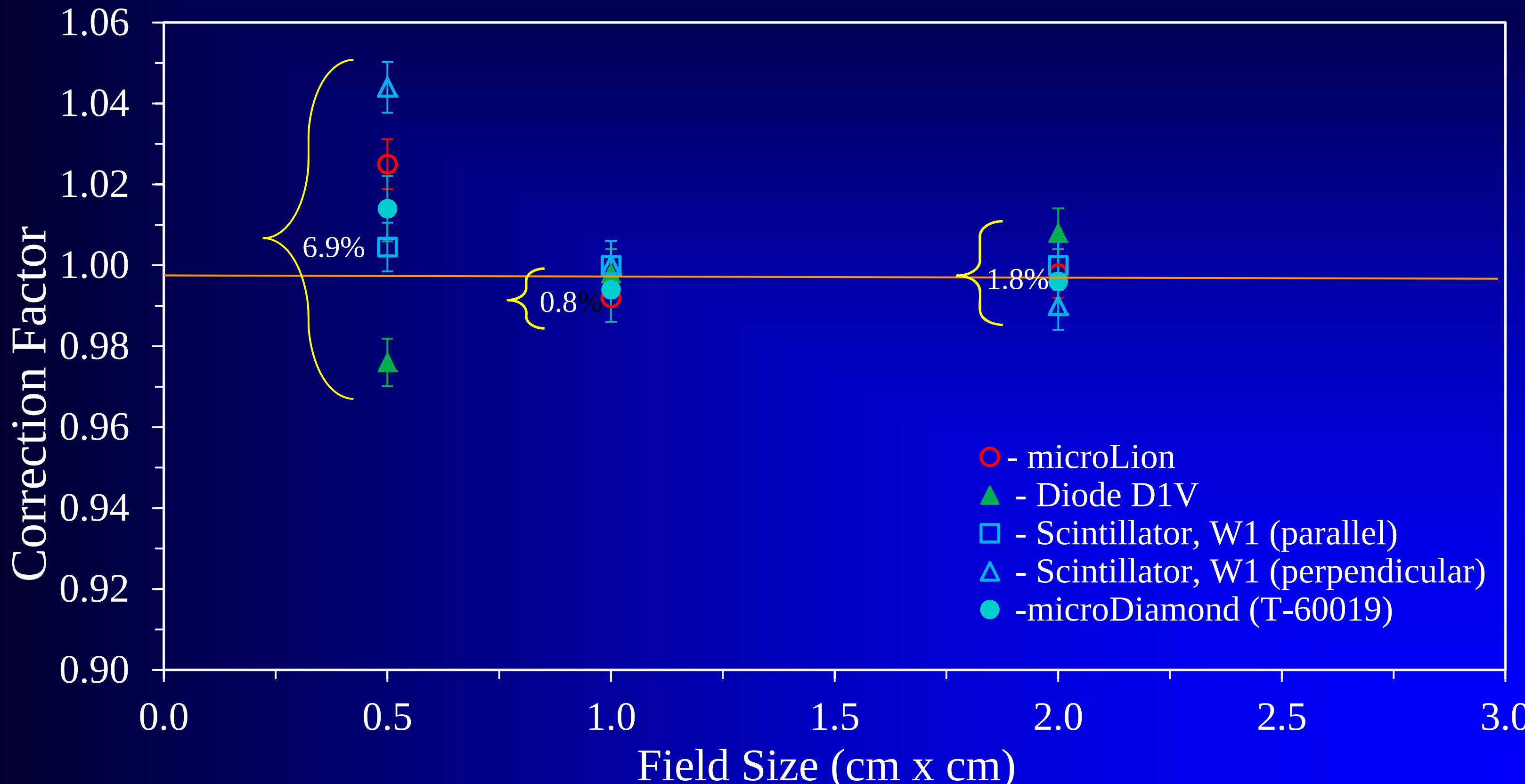
$k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ for select detectors



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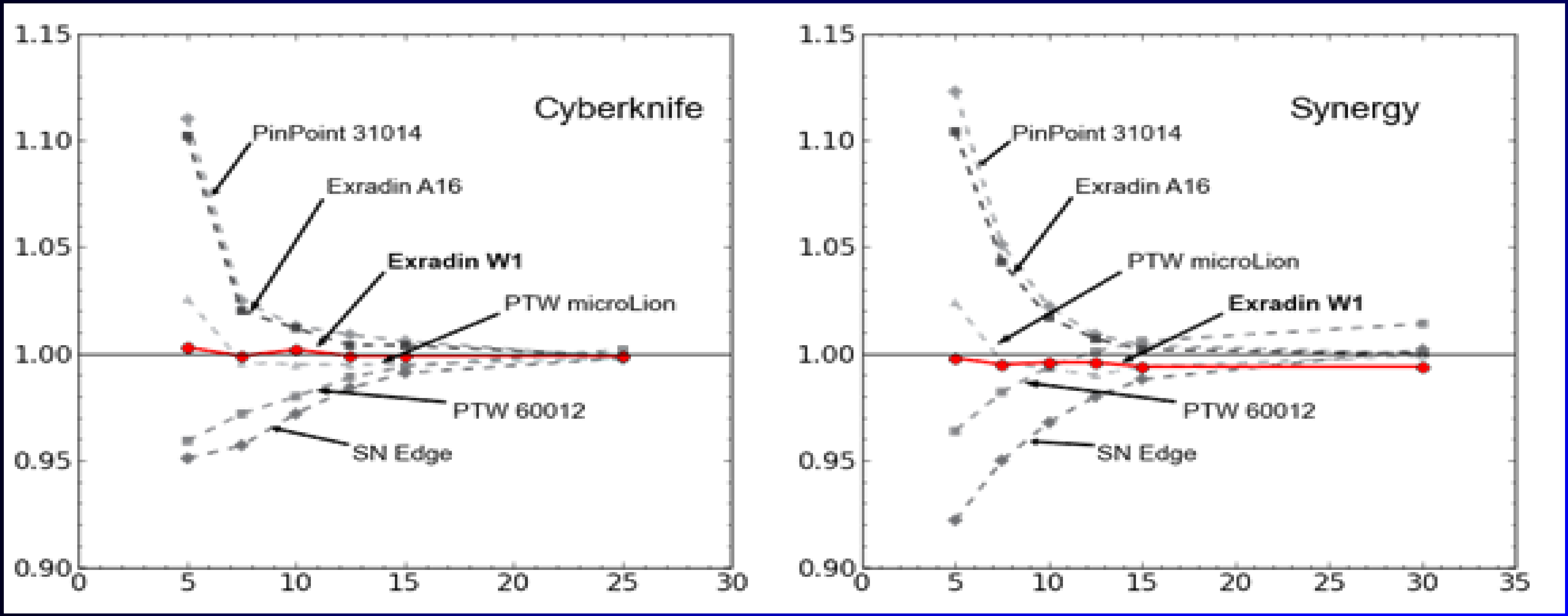
$k^{f_{clin},f_{msr}}_{Q_{clin},Q_{msr}}$ for Detectors and Devices



Francescon, Beddar & Das, ESTRO, 2014

$k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ of Different Devices and Selected Detectors

Cyber Knife

Field size (cm)

Detector	5.0	4.0	3.5	3.0	2.5	2.0	1.5	1.2	1.0	0.8	0.6	0.5
PTW-60019 CVD diamond	1.000	1.000	1.000	0.999	0.999	0.998	0.995	0.991	0.988	0.984	0.978	0.975
PTW-31018 liquid ion chamber	1.000	0.999	0.999	0.999	0.998	0.998	0.998	0.998	0.999	1.002	1.010	1.019
Sun Nuclear Edge Detector	1.000	1.000	1.000	0.999	0.998	0.995	0.989	0.982	0.975	0.966	0.954	0.946
Standard Imaging W1 plastic scintillator	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Tomotherapy

PTW-60019 CVD diamond	1.000	1.000	1.000	1.000	0.999	0.997	0.993	0.989	0.984	0.977	0.968	0.962	0.955
PTW-31018 liquid ion chamber	0.997	0.995	0.994	0.994	0.993	0.992	0.991	0.991	0.992	0.994	1.003	1.015	1.038
Sun Nuclear Edge Detector	1.000	1.000	1.000	0.999	0.998	0.994	0.986	0.976	0.966	0.951	-	-	-
Standard Imaging W1 plastic scintillator	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

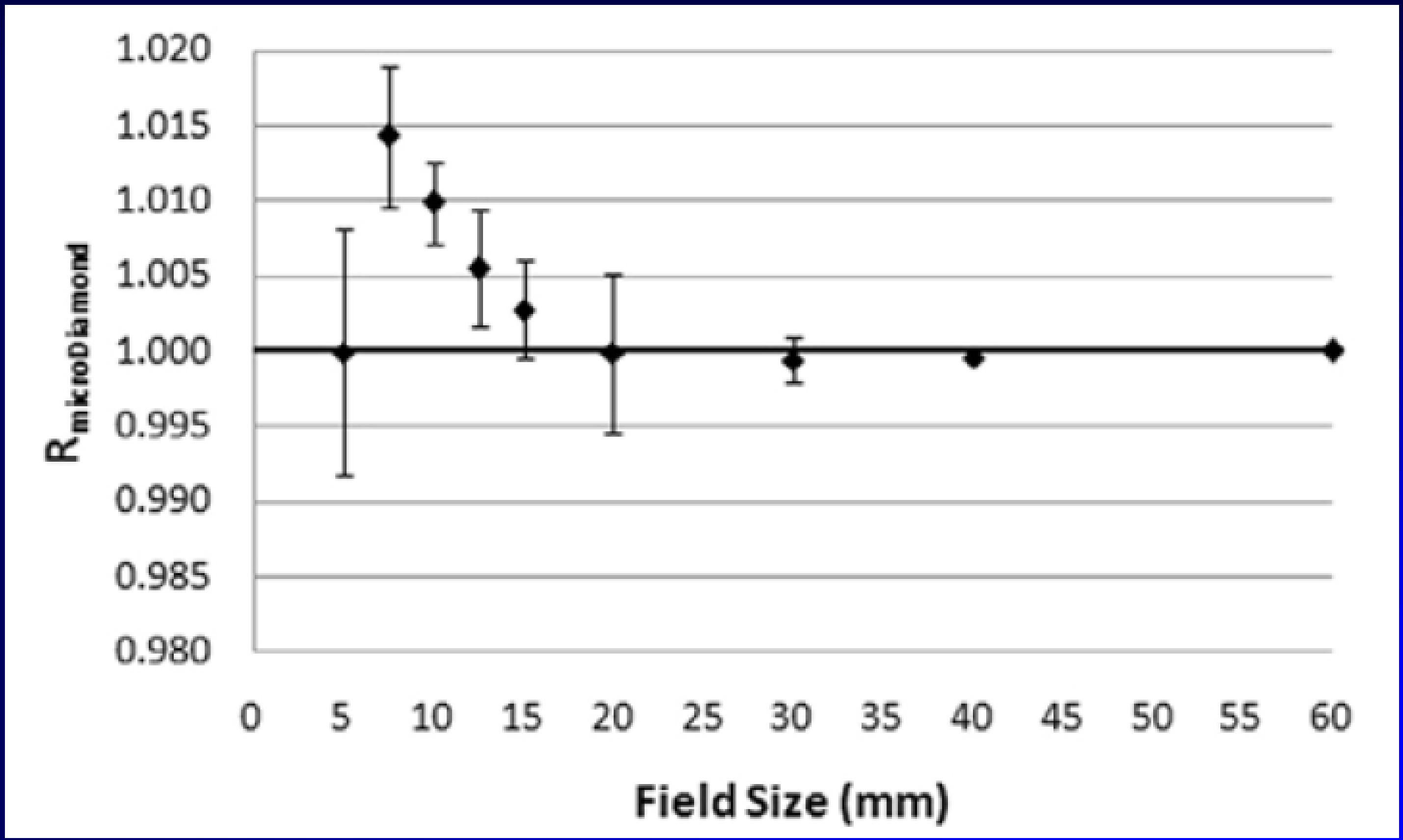
MLC, Linac

PTW-60019 CVD diamond	1.000	1.000	1.000	1.000	0.999	0.997	0.993	0.989	0.984	0.977	0.968	0.962	0.955
PTW-31018 liquid ion chamber	0.998	0.996	0.994	0.994	0.993	0.993	0.992	0.992	0.993	0.995	1.005	1.017	1.039
Sun Nuclear Edge Detector	1.000	1.000	1.000	0.999	0.998	0.994	0.986	0.976	0.966	0.951	-	-	-
Standard Imaging W1 plastic scintillator	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

TRS-483, 2016

MicroDiamond-Multi-institution

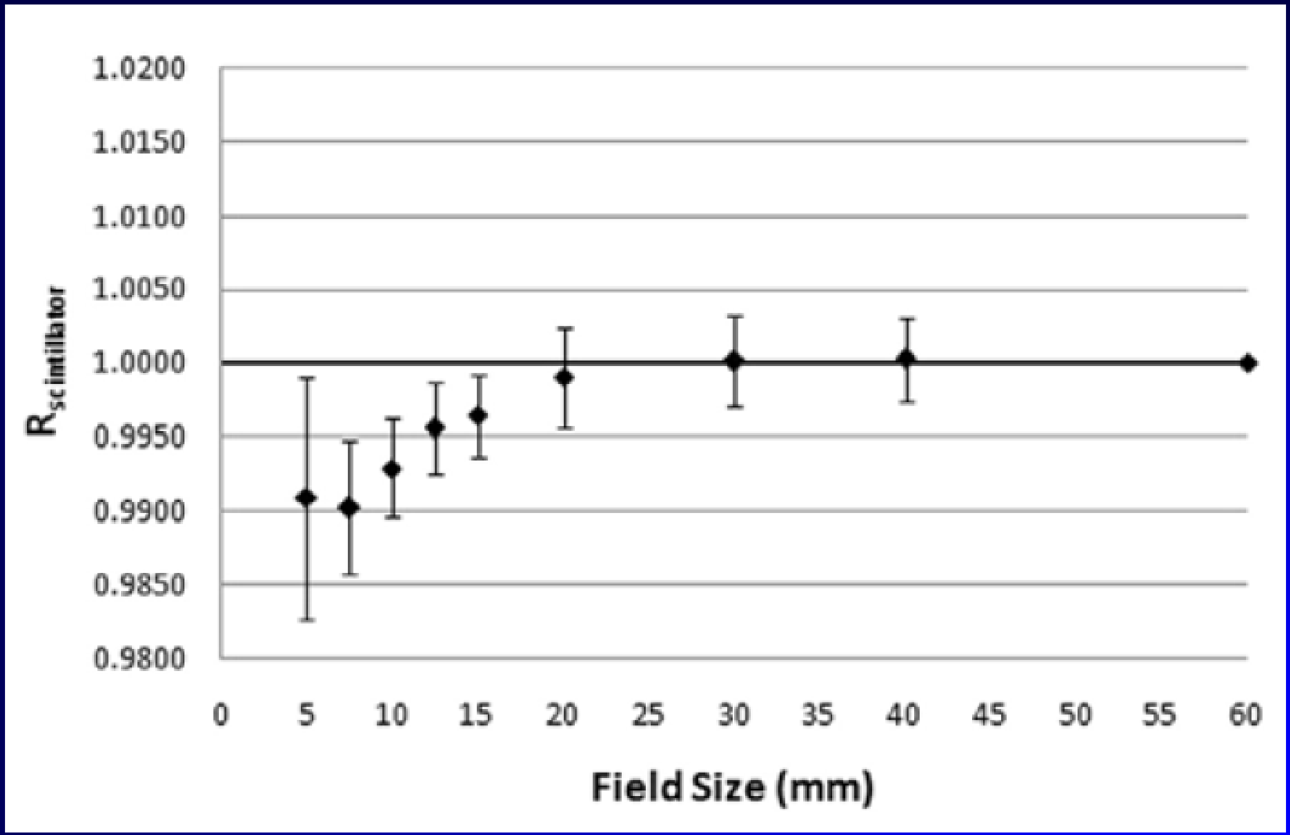
CyberKnife



Masi et al, Physica Medica,32, 1637-1643, 2016

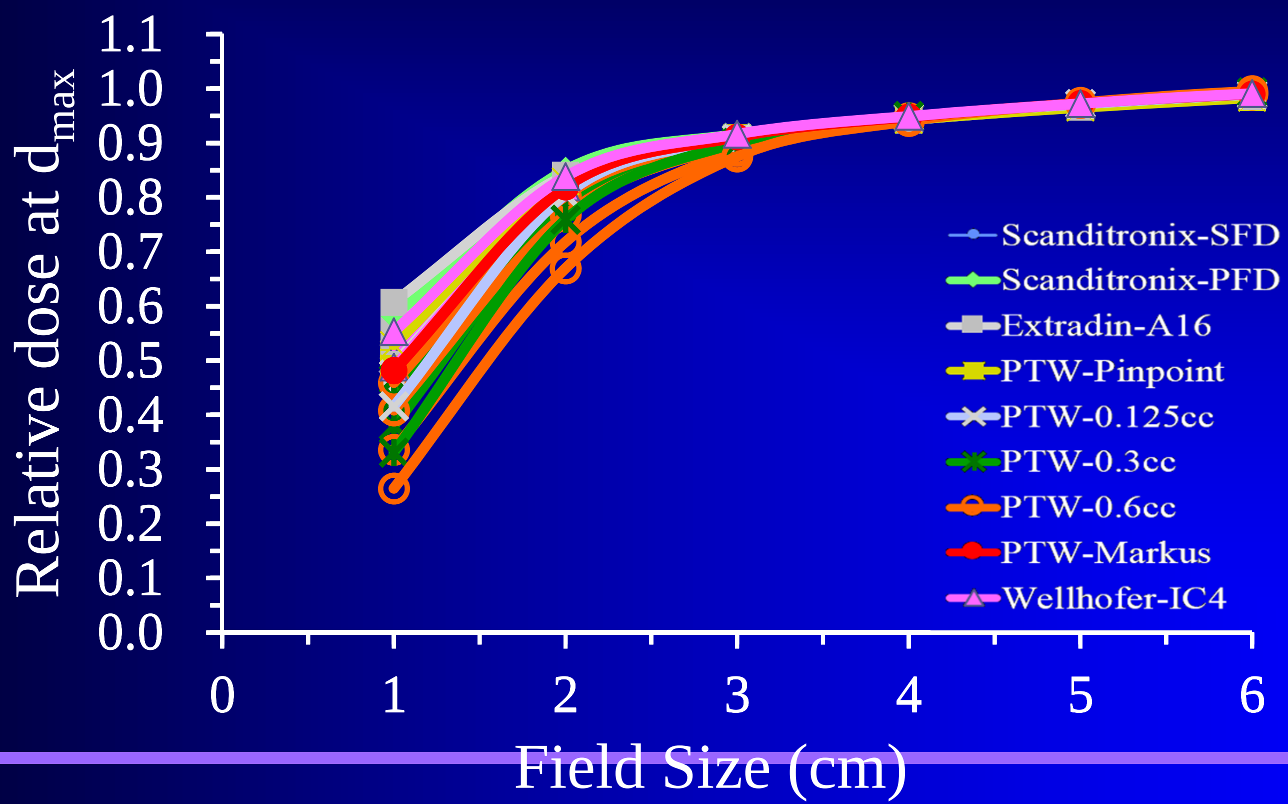
Plastic Scintillator-Multi-institution

CyberKnife



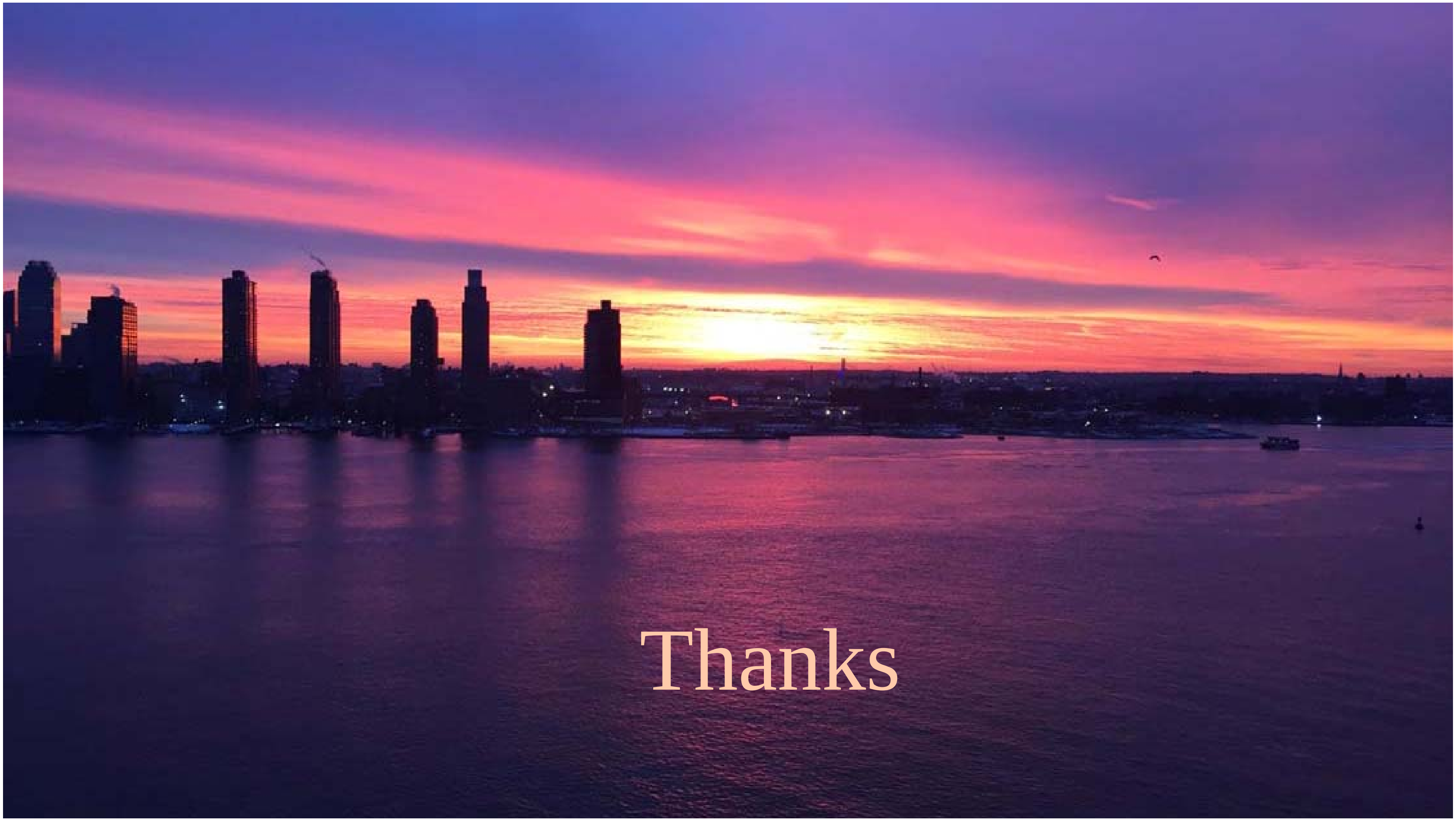
Masi et al, Physica Medica,32, 1637-1643, 2016

Validity of Proposed Method



Summary

- Understand the limit of small field, in terms of focal spot & spectral issues
- Detectors that are water equivalent like, MicroLion, MicroDiamond, Plastic Scintillators and EBT are best suited
- Use proper correction factors to correct detector response to correct for the dose
- Use data from for IAEA TRS-483 and TG-155 guidelines when published


Thanks