Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

Small field dosimetry for MRgRT:
Possibilities and limitations of experimental facilities

CCRI Webinar MRgRT-DOS, 12.09.2023

MRgRT-DOS
Metrology

Stephan Frick[1,2]

EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

EMPIR EURAMET
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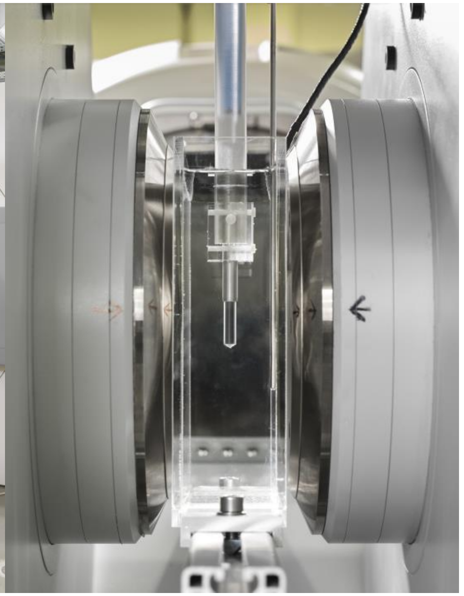
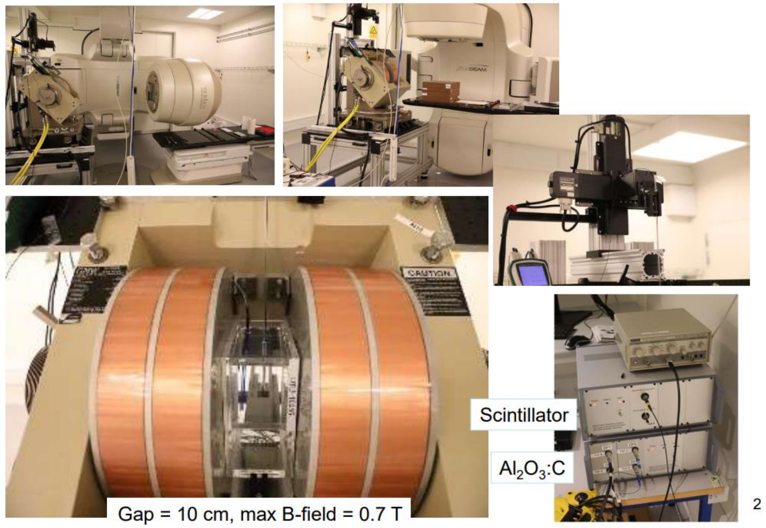
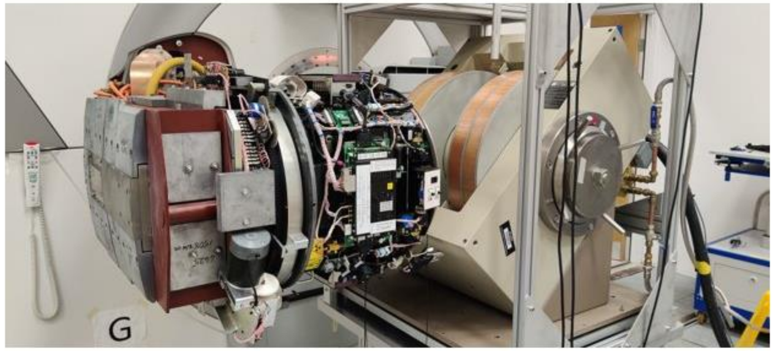
[1]Physikalisch-Technische Bundesanstalt [2]Universitätsklinikum Tübingen

I. Experimental facilities







SSD = 110 cm, z_{ref} = 10 cm
max. B-field = 1.55 T
Pole gaps = 6.5 cm
6MV, Q = 0.683

SSD = 177 cm, z_{ref} = 10 cm
max. B-field = 0.7 T
Pole gaps = 10 cm
6MV FFF, Q = 0.625

SSD = 95 cm, z_{ref} = 5 cm
max. B-field = 1.55 T
Pole gaps = 7.3 cm
6MV, Q = 0.682

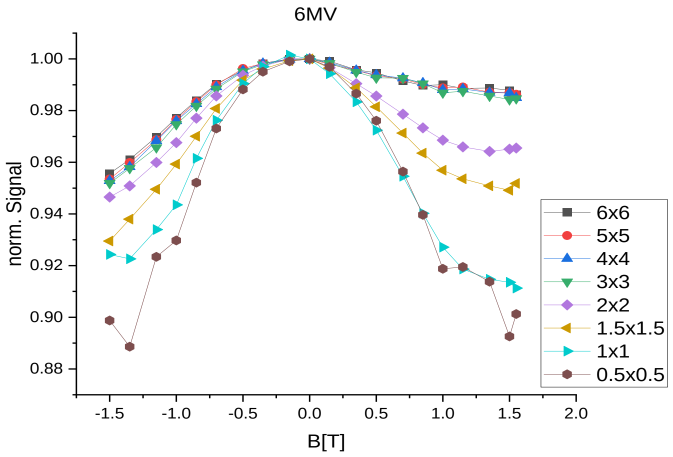
II. Possibilities

- Possibility to turn magnetic field on and off
- Different magnetic flux densities *B* (0T/0.35T/1.5T) and beam qualities *Q* possible
- (Generate experimental data, compare to Monte Carlo simulation results)
- (Research facilities:)
  - No treatment of patients → More time to measure
  - Research Environment → more Ressources

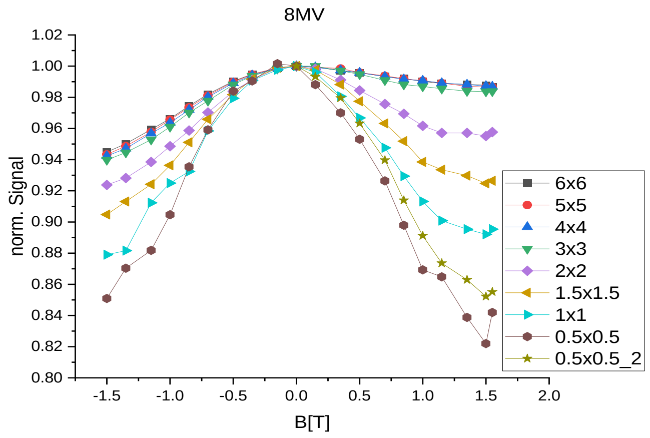
→ Possibility to not only measure correction factors for different *B* and *Q*, but also investigate general behavior and physical proberties

II. Possibilities: general proberties of $k^{B}_{Q_{clin}}$

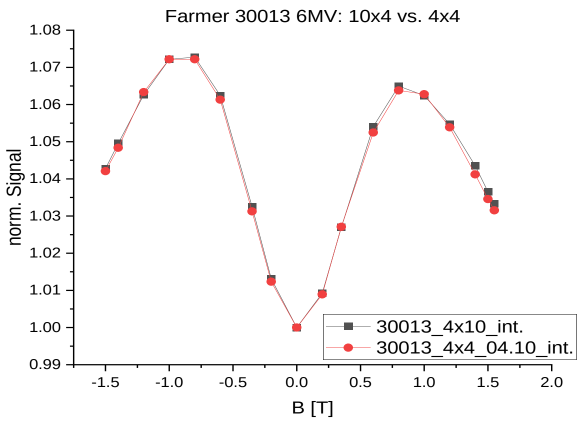
Semiflex 31021 6MV CAX (perpendicular)

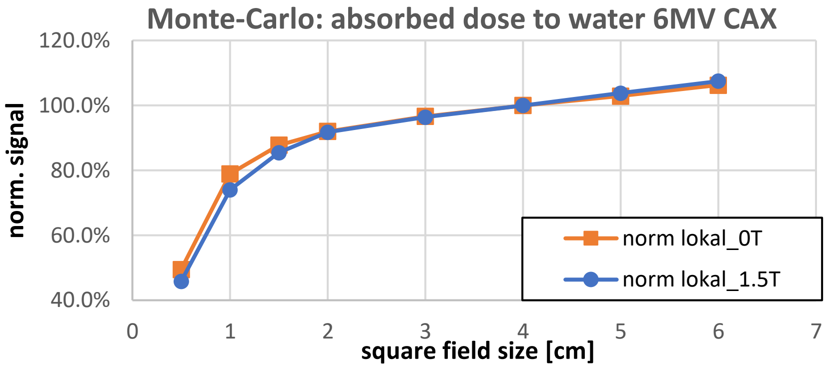


Semiflex 31021 8MV CAX (perpendicular)



Farmer 30013 6MV CAX (perpendicular)

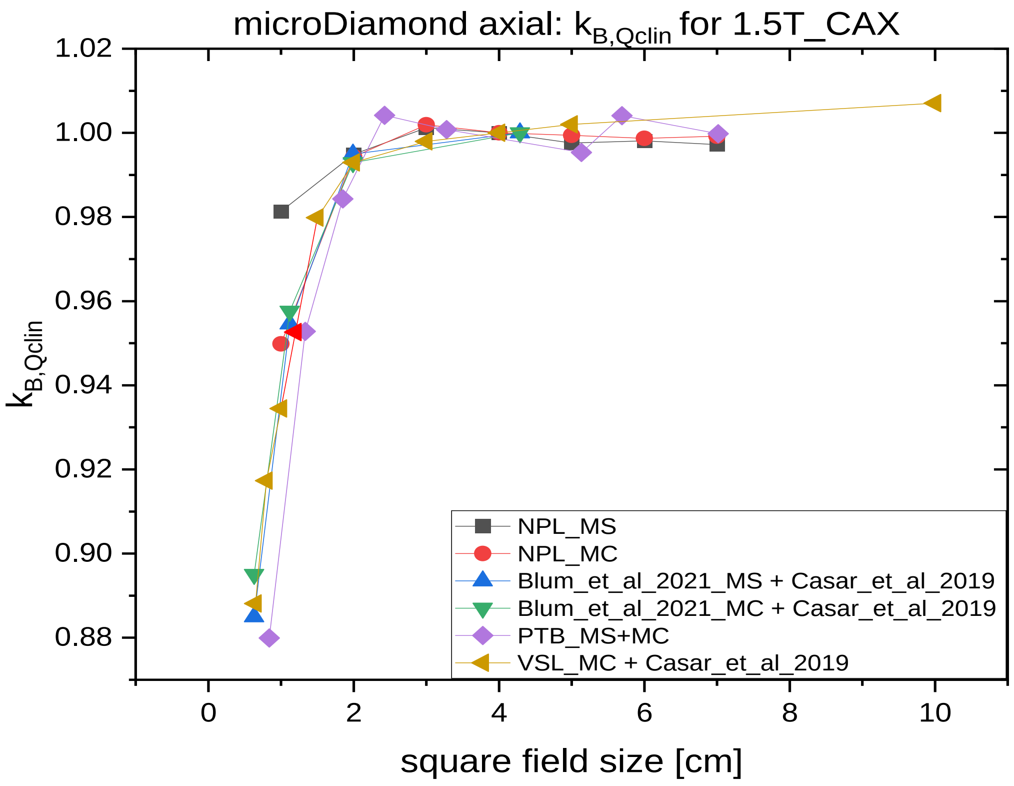




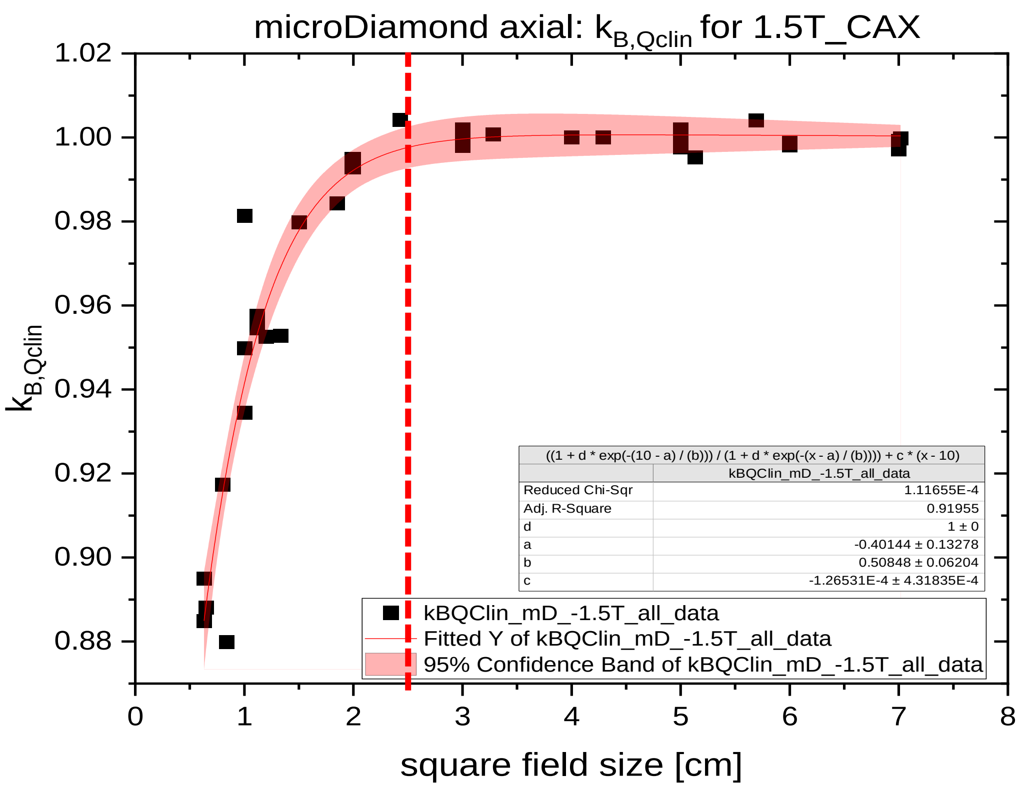
$$k^{B}_{Q_{clin}} = \left[\frac{k^{B}_{Q_{small}}}{k^{B}_{Q_{msr}}} * k_{Q_{clin}}\right]$$

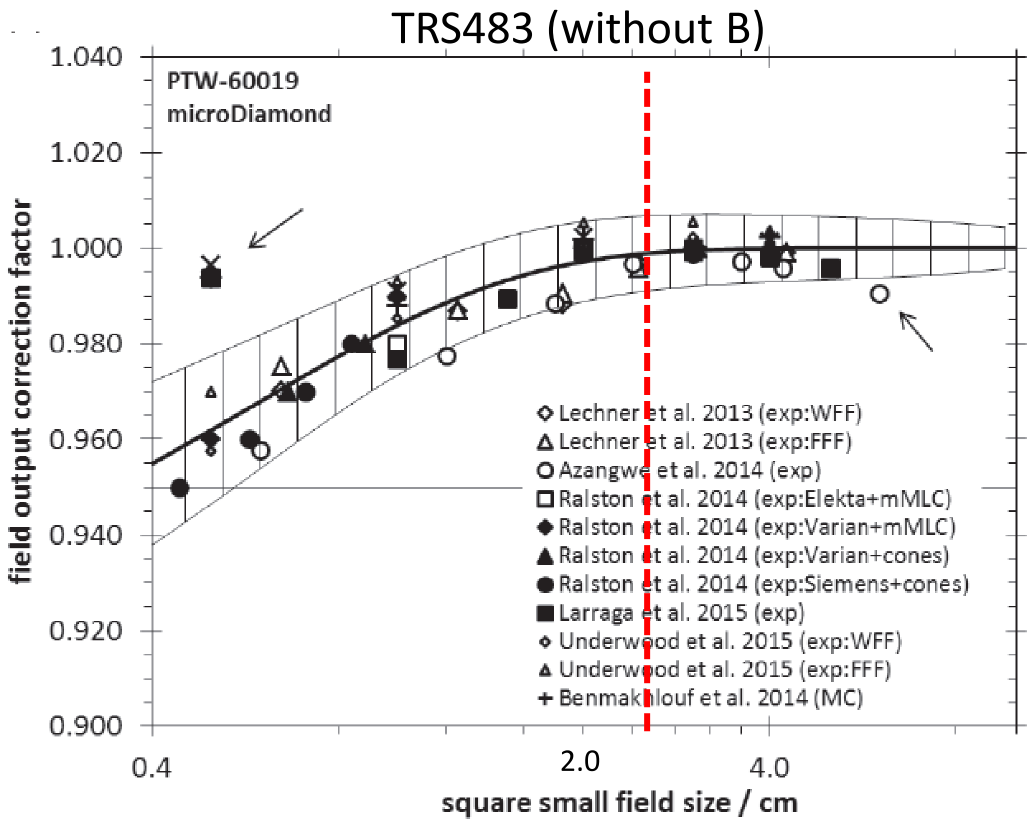
$$\rightarrow k^{B}_{Q_{clin}} = k_{Q_{clin}}$$

II. Possibilities: general proberties of $k^{B}_{Q_{clin}}$



II. Possibilities: general proberties of $k^{B}_{Q_{clin}}$

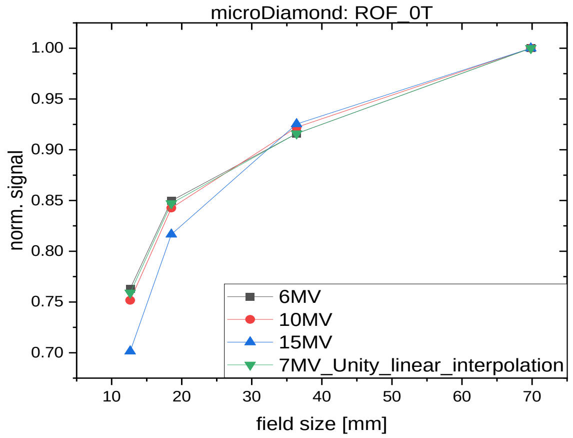


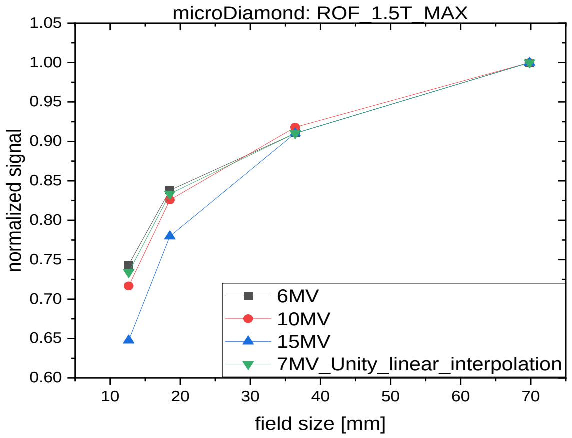


microDiamond ≥2.5x2.5 cm^2 : $k^{B}_{Q_{clin}} = k_{Q_{clin}}$

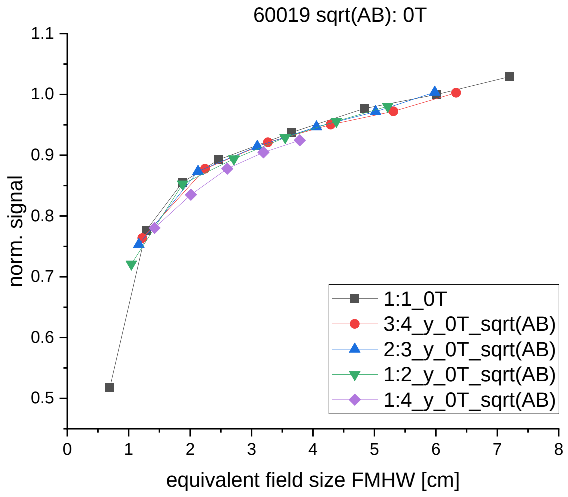
II. Possibilities: other examples

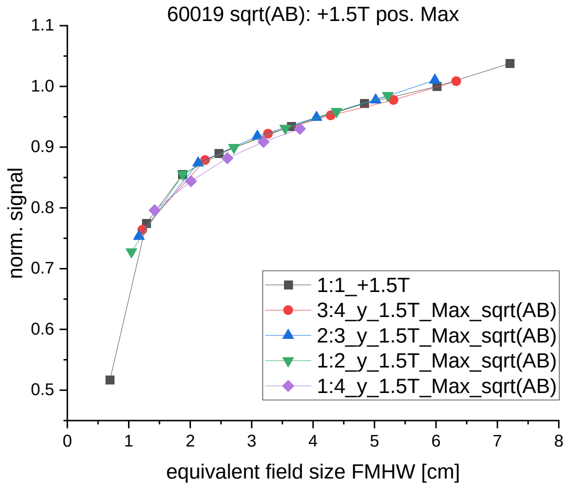
- Energy depence of OFs





- Equivalent square field size formula in magnetic fields: Compare to 0T





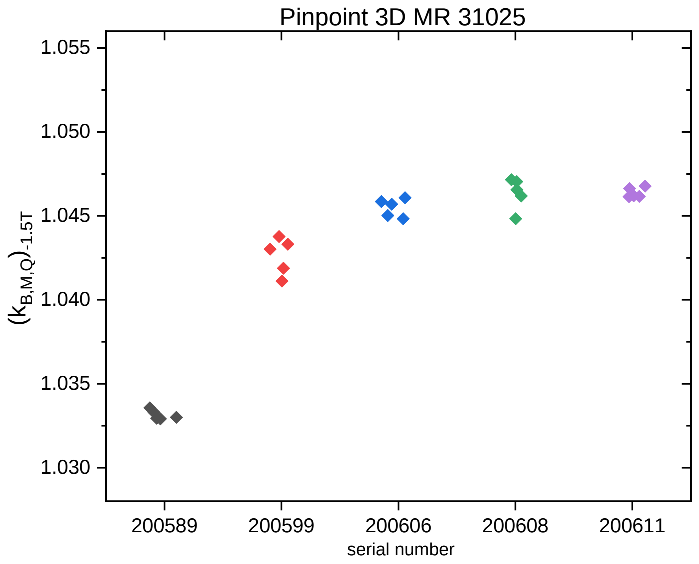
II. Possibilities: other examples

- intra-type variation

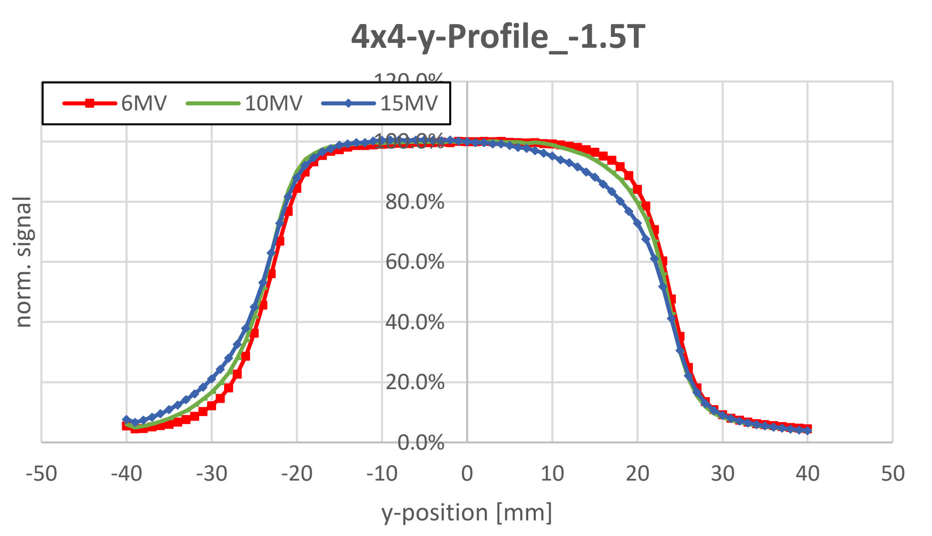
microDiamond intra-type variation (normalized to 4x4)

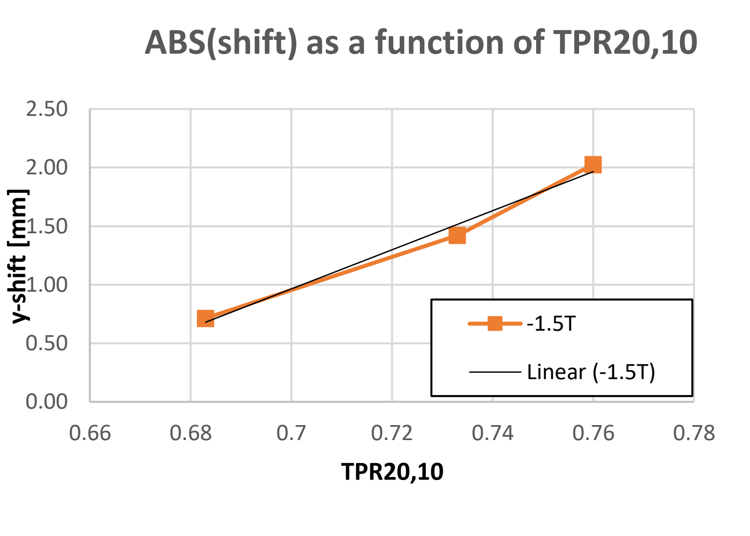
0T	mean	STD
1x1	79.99%	0.24%
0.5x0.5	50.95%	0.94%

-1.5T	mean	STD
1x1	77.92%	0.15%
0.5x0.5	49.09%	0.82%



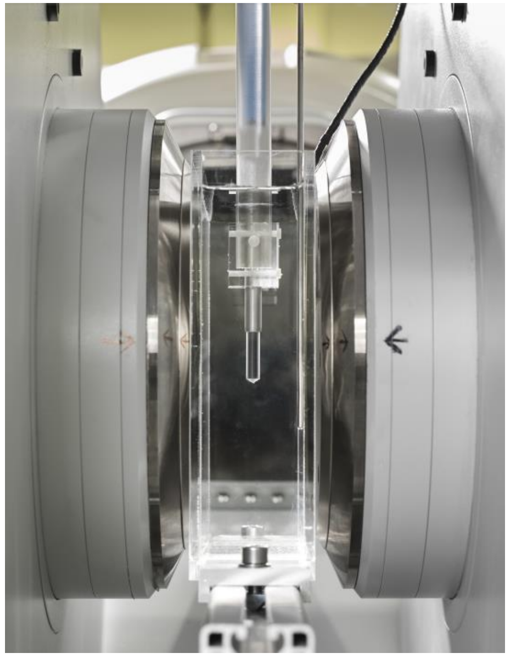
- Investigate profiles for different *Q* and *B*
- Angular dependence of OFs (NPL)
- Correction factors of plastic scintillator (DTU)





III. Limitations

- Different Setups between experimental facilities caused by technical reasons or choice
  → SSD, depth, beam quality
- Different setups compared to MRLinac
  →Different beam quality/spectra, FFF vs. WFF, SSD
  →Positioning parallel to magnetic field lines often not possible due limted space between pole shoes
- Measurements with different *B*, *Q*, detectors and positioning very time consuming



→ To make results relevant for MRLinacs, every different parameter has to be investigated if it has an influence and if yes then it needs to be corrected for

III. Limitations: different beam qualities

ROF: PTB vs. MR-Linac Elekta Unity

0T

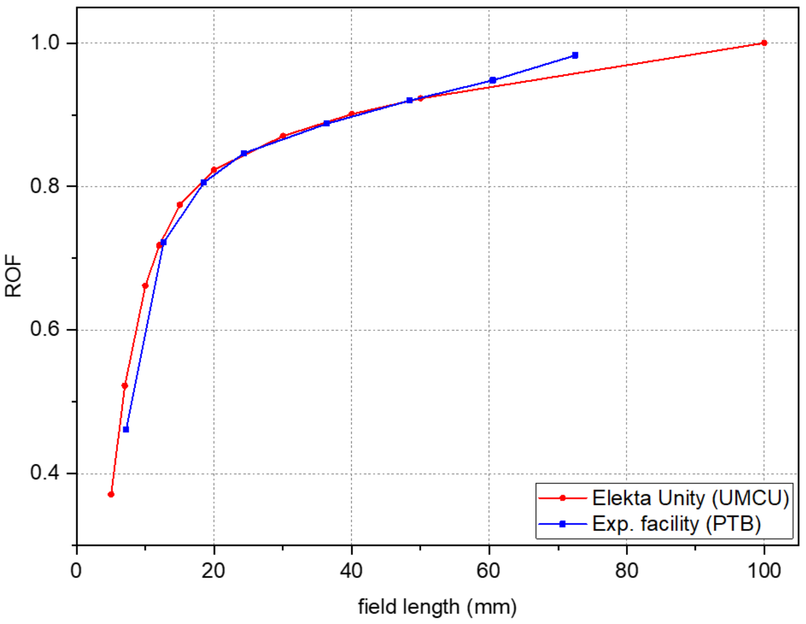


Figure 17: Comparison of the ROF curves obtained at the Elekta Unity MRI-linac and at PTB's experimental facility for an ionization chamber of type PTW 31022 positioned at CAX **without the presence of a magnetic field.**

1.5T_CAX

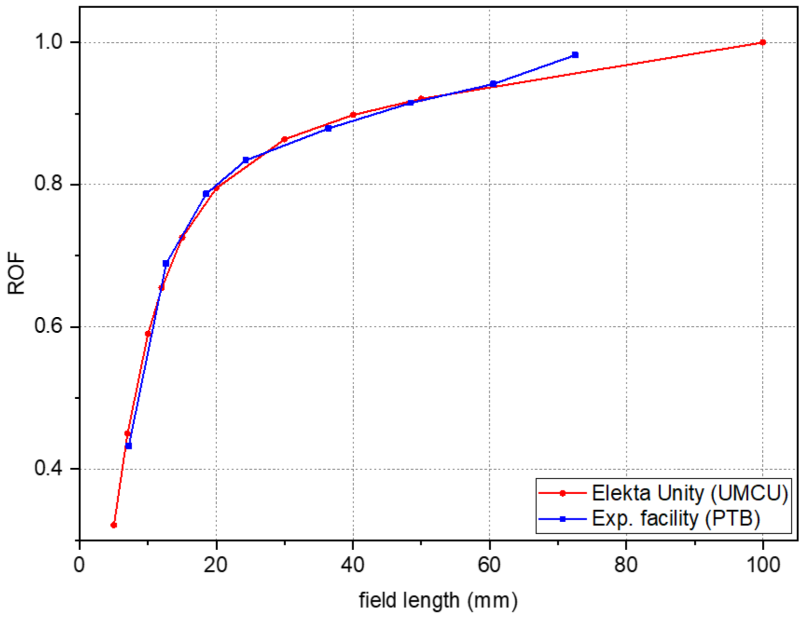


Figure 18: Comparison of the ROF curves obtained at the Elekta Unity MRI-linac and at PTB's experimental facility for an ionization chamber of type PTW 31022 **positioned at CAX** with a magnetic field B = 1.5 T.

1.5T_MAX

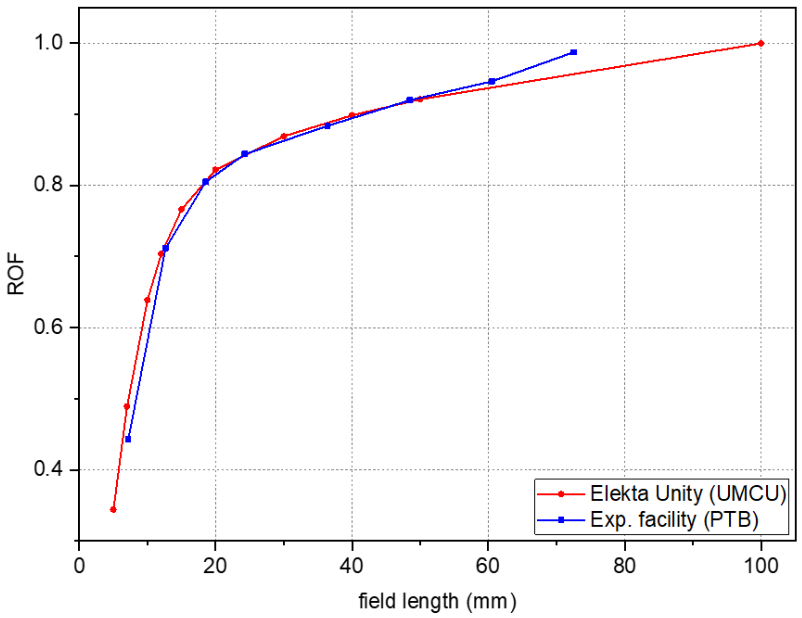


Figure 19: Comparison of the ROF curves obtained at the Elekta Unity MRI-linac and at PTB's experimenta facility for an ionization chamber of type PTW 31022 **positioned at MAX** with a magnetic field B = 1.5 T.

→ Good agreement (except 0.5x0.5cm^2)
→ PTB-Data useable from 5x5cm^2 to 1x1cm^2?

III. Limitations: different beam qualities

- In TRS483, correction factors for general energies, e.g. „6MV “

→ not corrected for different Q

  → bigger uncertainty

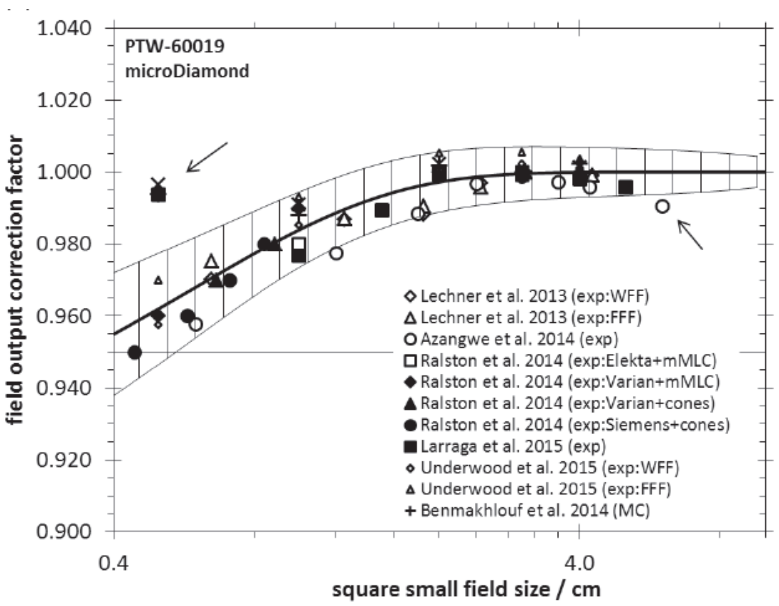


TABLE 26. FIELD OUTPUT CORRECTION FACTORS $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ FOR FIELDS COLLIMATED BY AN MLC OR SRS CONE AT 6 MV WFF AND FFF MACHINES, AS A FUNCTION OF THE EQUIVALENT SQUARE FIELD SIZE

Detector	Equivalent square field size, S_{clin} (cm)												
	8.0	6.0	4.0	3.0	2.5	2.0	1.5	1.2	1.0	0.8	0.6	0.5	0.4
Ionization chambers													
Exradin A14SL micro Shonka slimline	1.000	1.000	1.000	1.000	1.000	1.002	1.010	1.027	—	—	—	—	—
Exradin A16 micro	1.000	1.000	1.000	1.000	1.001	1.003	1.008	1.017	1.027	1.043	—	—	—
IBA/Wellhöfer CC01	1.002	1.004	1.007	1.008	1.008	1.009	1.011	1.013	1.018	1.027	1.047	—	—
IBA/Wellhöfer CC04	1.000	1.000	1.000	1.000	1.000	1.002	1.009	1.022	1.041	—	—	—	—
IBA/Wellhöfer CC13/IC10/IC15	1.000	1.000	1.000	1.001	1.002	1.009	1.030	—	—	—	—	—	—
PTW 31002 Flexible	1.000	1.000	1.001	1.004	1.009	1.023	—	—	—	—	—	—	—
PTW 31010 Semiflex	1.000	1.000	1.000	1.001	1.002	1.008	1.025	—	—	—	—	—	—
PTW 31014 PinPoint	1.000	1.000	1.000	1.002	1.004	1.009	1.023	1.041	—	—	—	—	—
PTW 31016 PinPoint 3D	1.000	1.000	1.000	1.001	1.001	1.004	1.013	1.025	1.039	—	—	—	—

III. Limitations: high Uncertainties for field sizes <1cm²

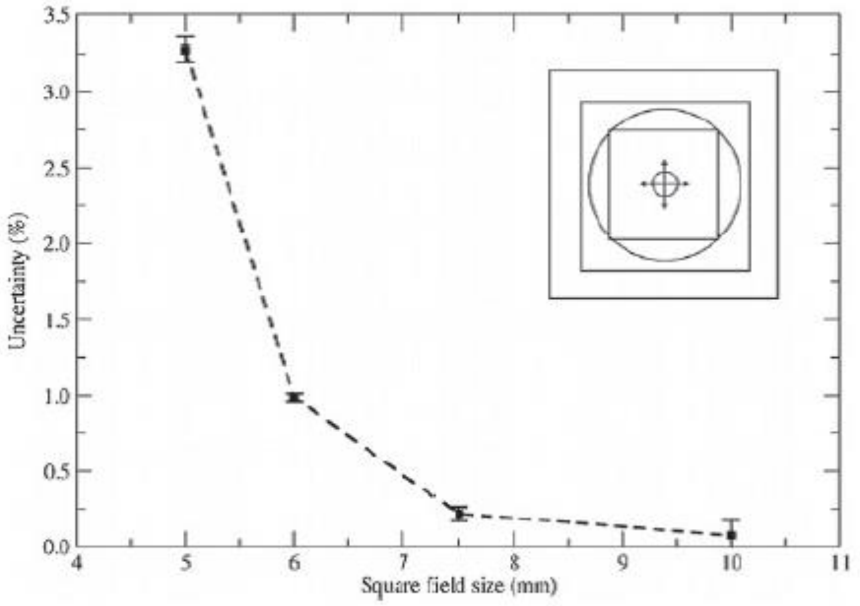


FIG. 7. Uncertainty contribution to the absorbed dose determination using a PTW 60012 diode due to a uniformly distributed displacement error of 1 mm in all directions perpendicular to the beam axis only calculated by Monte Carlo (reproduced from Ref. [46] with the permission of IOP Publishing).

TRS 483, Dosimetry of Small Static Fields Used in External Beam Radiotherapy , Vienna, 2017

PTW 60019 microDiamond detector

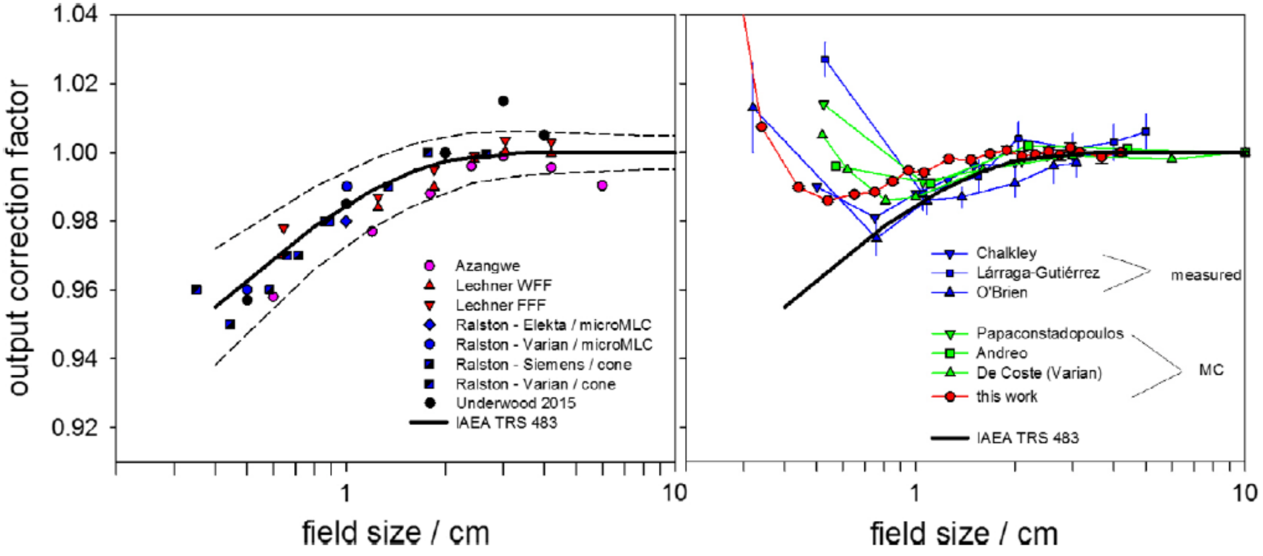


FIG. 11. Summary of recently published data on the microDiamond output correction factor referring to a depth of 5 cm in 6 MV small field photon beams. left: output correction factors taken into account in the international document IAEA TRS 483[1] (redrawn for a depth of 5 cm); the thick continuous line represents a fit to all data. right: data on the output correction factor from a variety of publications showing a clear increase with decreasing field size (right side); with the exception of the data by Poppinga et al.[14], all reference detector data have been obtained by a MC simulation; blue: diamond data have been measured; green: diamond data have been obtained by a MC simulation; red: results of this work; thick continuous line identical to the fit in the left figure. [Color figure can be viewed at wileyonlinelibrary.com]

Hartmann and Zink, A Monte Carlo study on the PTW 60019 microDiamond detector, Med. Phys. 46 (11), November 2019

→ Better data with slightly different parameters then no data!

IV. Summary

- **Possibilities:** Experimental Facilities can measure with different *B* and *Q*, therefore investigate general behavior and physical proberties of correction factors, profiles, PDDs etc. in more detail
- **Limitation:** Measurements not at an MRLinac, different setup parameters has to be considered
- Work in progress: EMPIR-data needs to be further evaluated

Physikalisch-Technische Bundesanstalt
Bundesallee 100
38116 Braunschweig

Stephan Frick
Phone: 0531 592-6422
E-Mail: Stephan.Frick@ptb.de
www.ptb.de