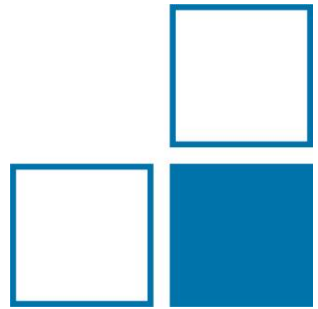
Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

Extending TRS-483 to small fields in MRgRT

Ralf-Peter Kapsch



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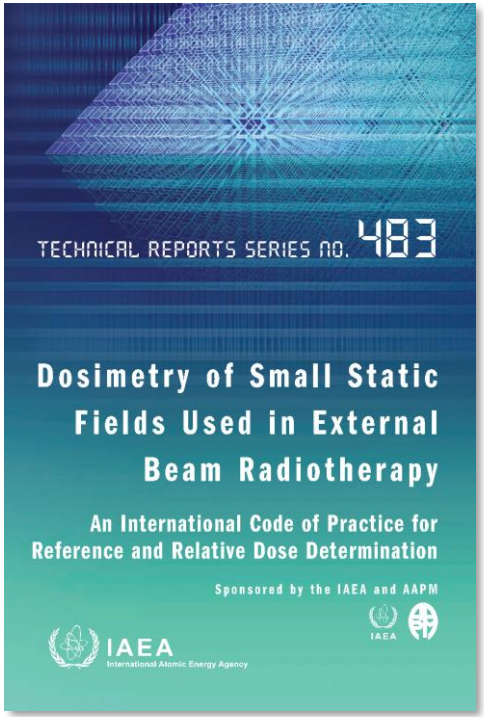


MRgRT-DOS Metrology

EURAMET

Traceable Dosimetry for Small fields in MR-guided RadioTherapy

D2: Report on the modifications needed to extend the methodology of IAEA/AAPM TRS-483 to small field dosimetry in MRgXT with a target uncertainty of 2.0 % (k = 1)

Project:	19NRM01 – MRgRT-DOS
Lead partner:	PTB
Deliverable due on:	April 2023
Submission date:	31 May 2023

EMPIR EURAMET

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

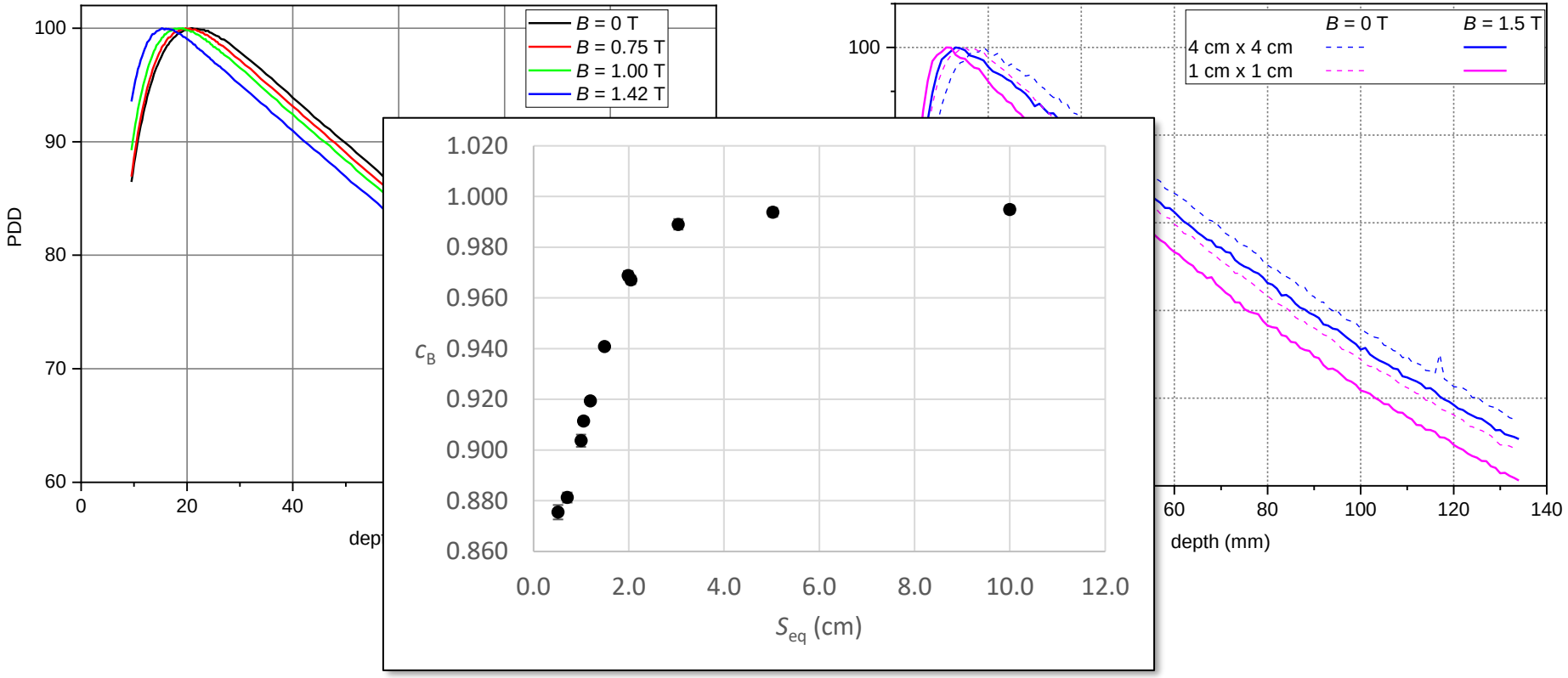
MRgRT-DOS Metrology

EURAMET

1 Contents

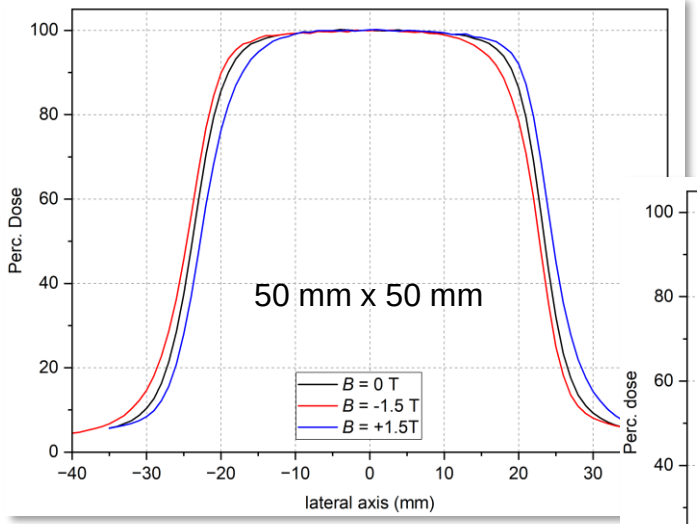
Effects of magnetic fields

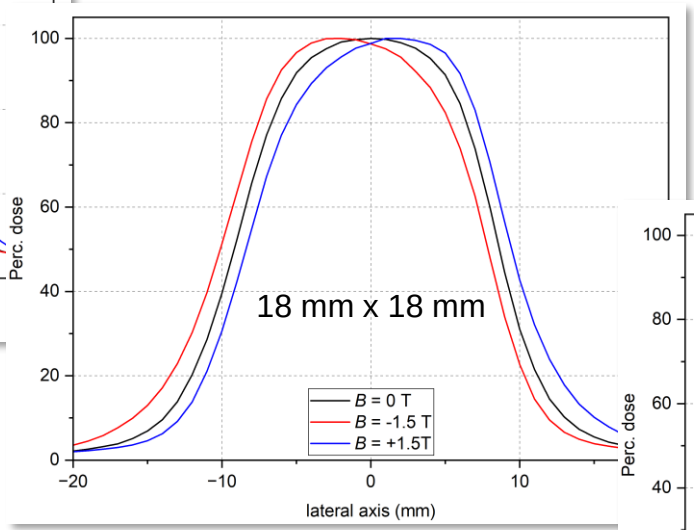
Depth dose curves

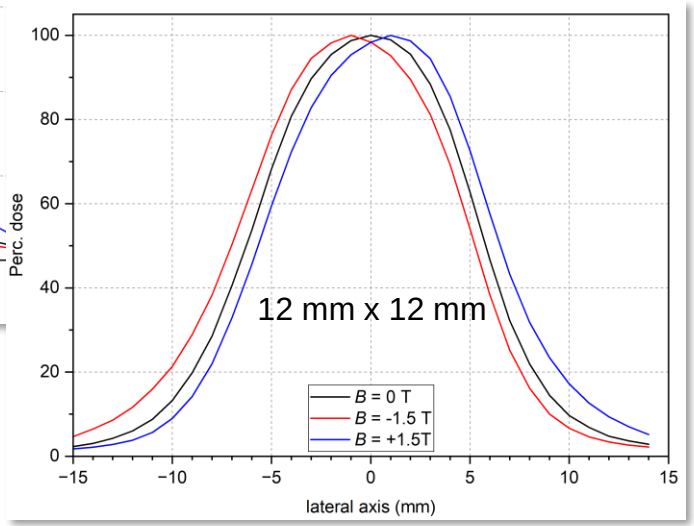


Effects of magnetic fields

Lateral beam profiles

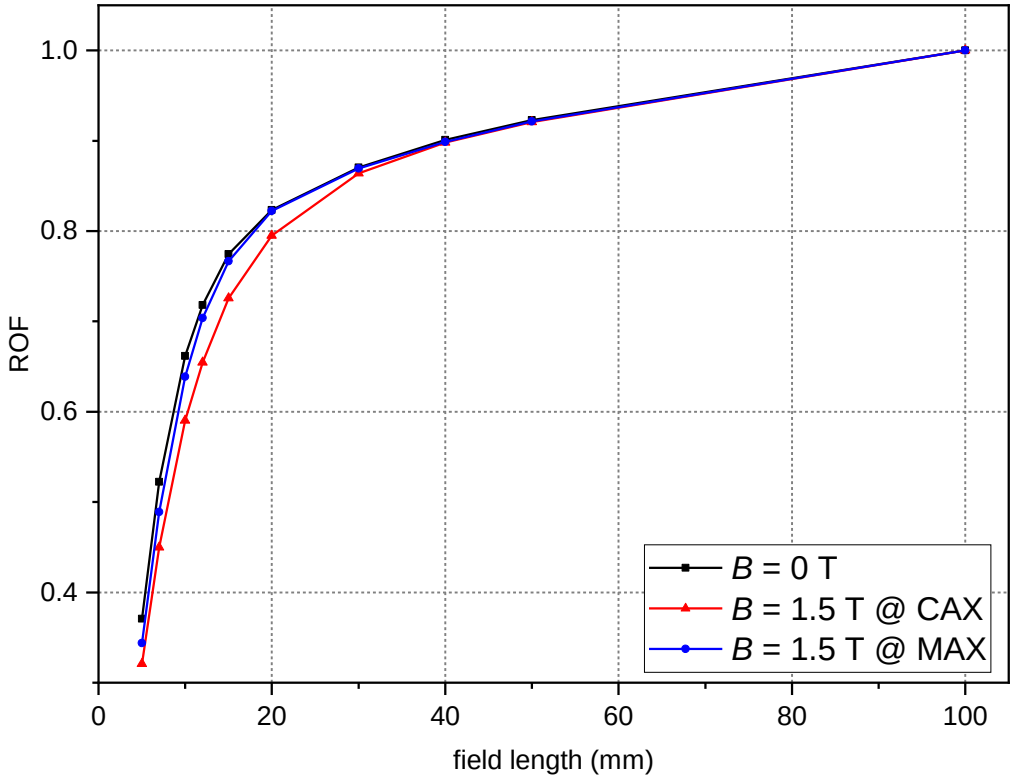


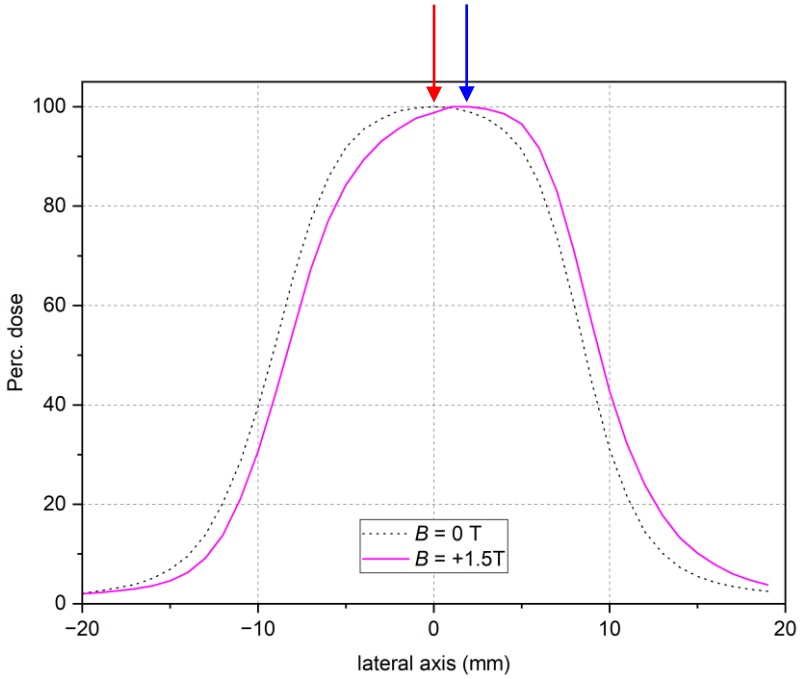




Effects of magnetic fields

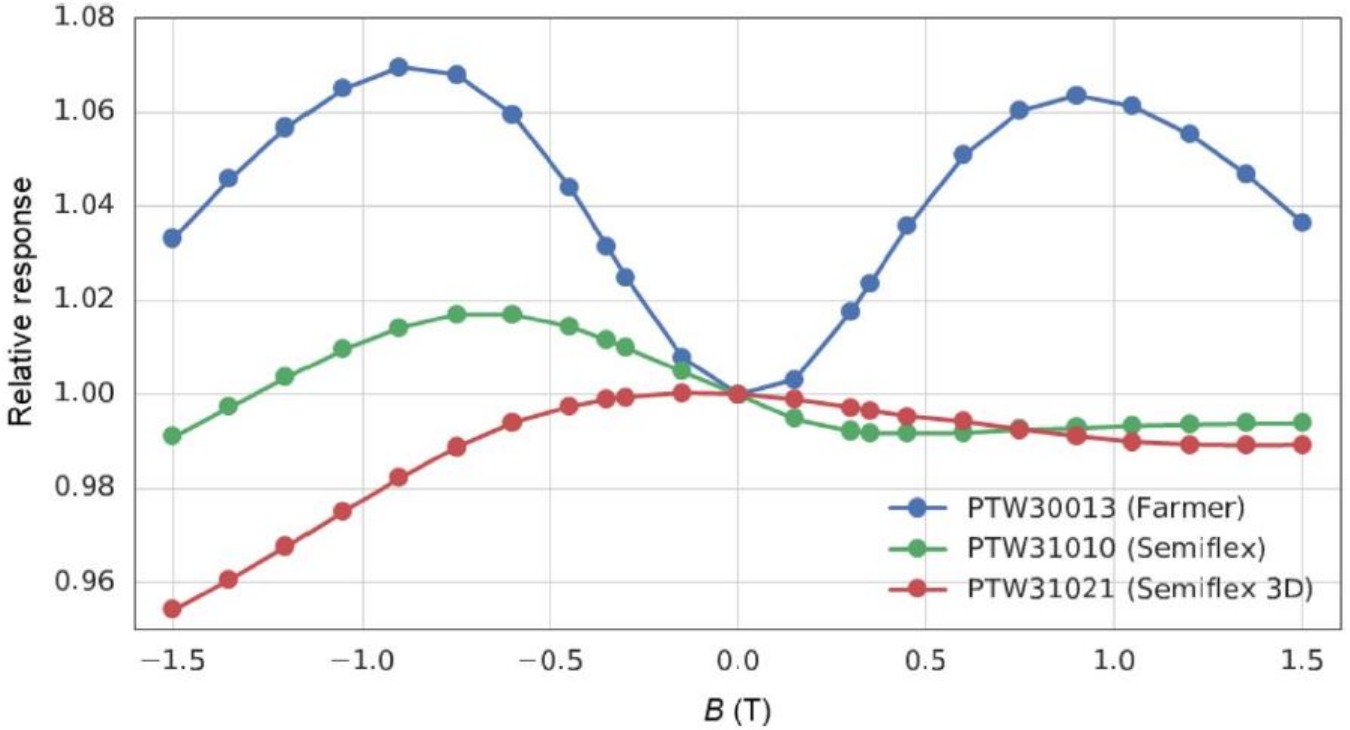
Relative Output Factors





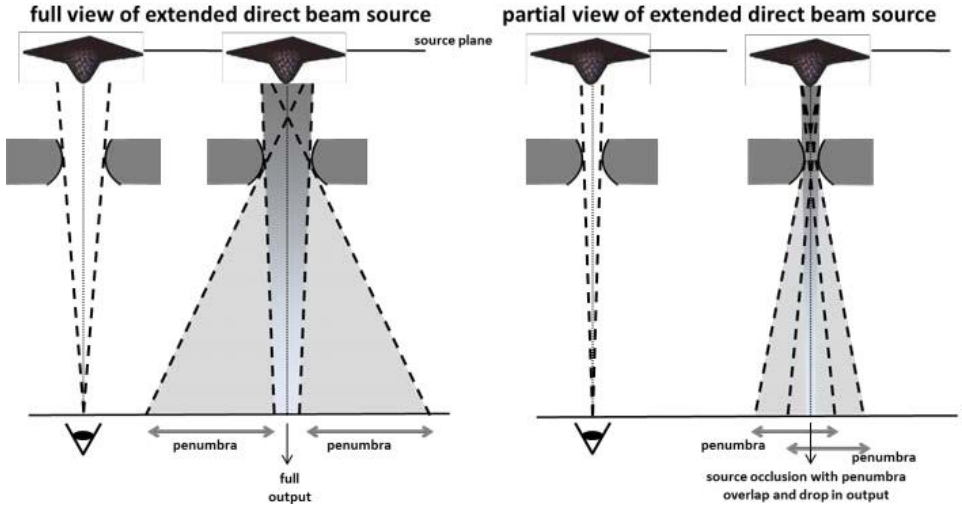
Effects of magnetic fields

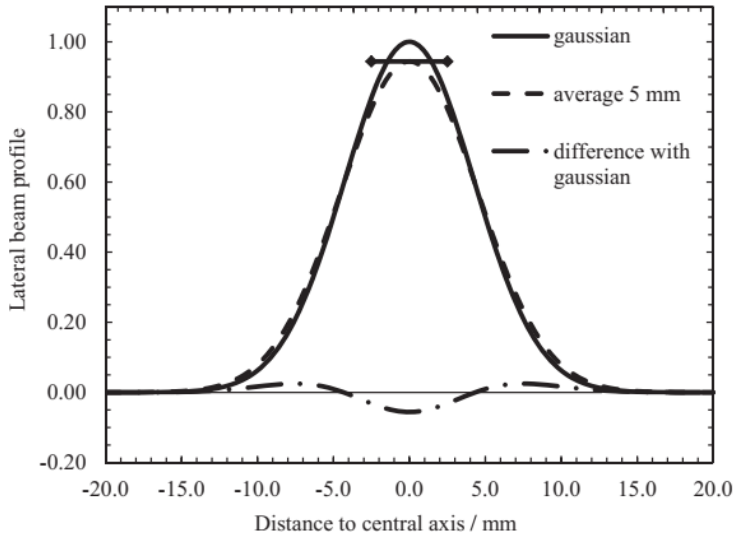
Detector response



What is a small field?

2. *Linac related:* Partial occlusion of the source by the collimating system
3. *Detector related:* Detector size similar to beam dimensions

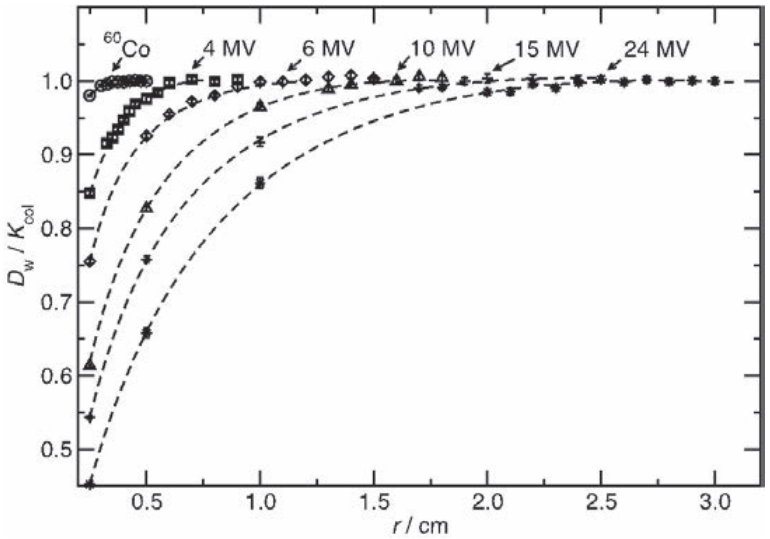




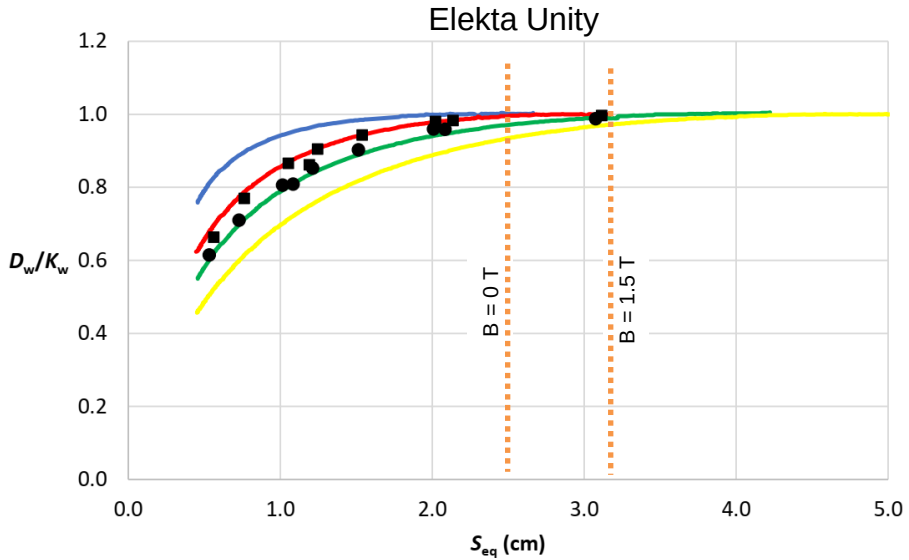
IAEA TRS-483 (2017)

What is a small field?

1. ***Beam related:*** **Loss of LCPE on the beam axis**
2. *Linac related:* Partial occlusion of the source by the collimating system
3. *Detector related:* Detector size similar to beam dimensions

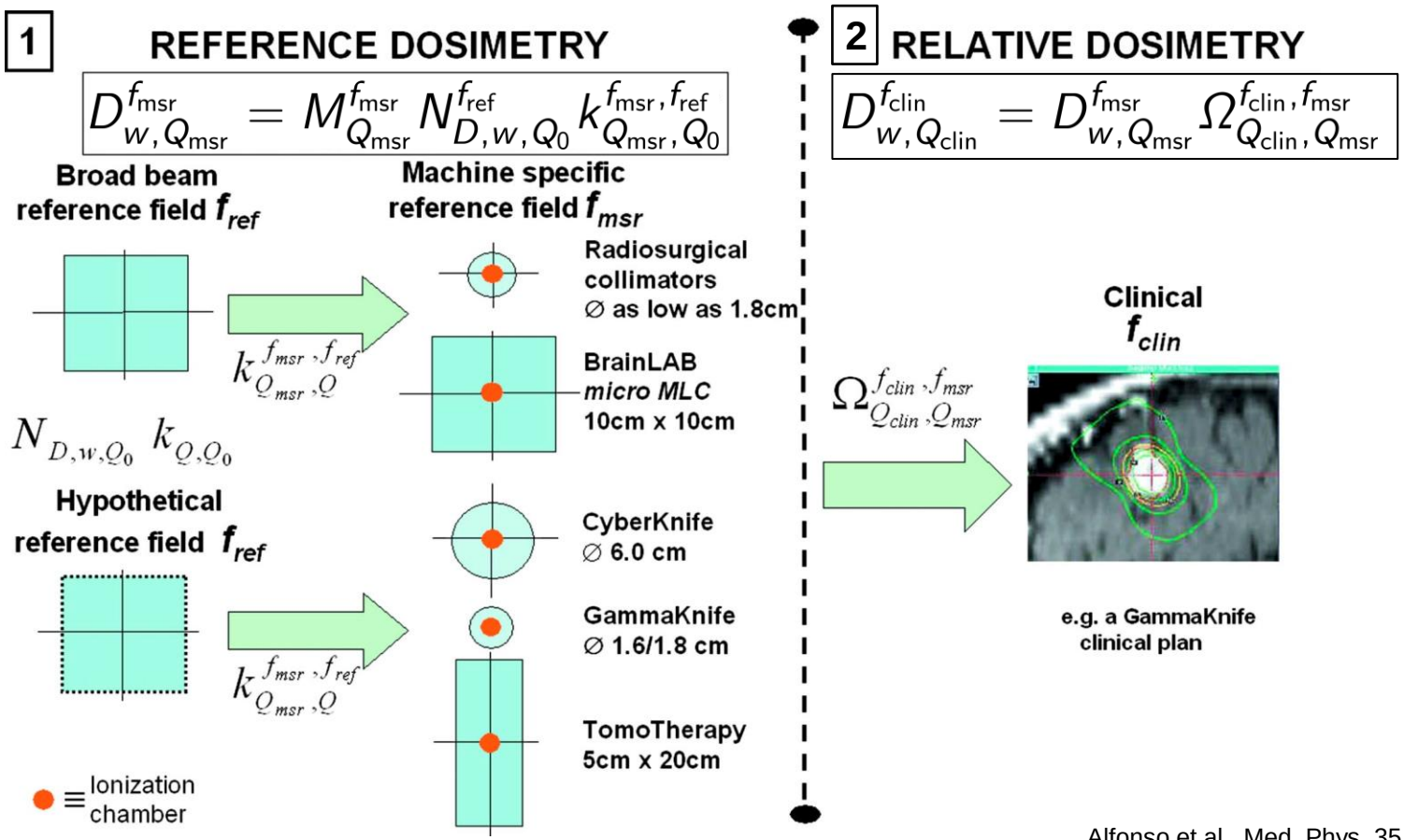


IAEA TRS-483 (2017)



courtesy of Jacco de Pooter

Recap: Formalism of TRS-483 (without $\vec{B}$)



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

Recap: Formalism of TRS-483 (without $\vec{B}$)

1. Reference dosimetry of machine specific reference (msr) fields

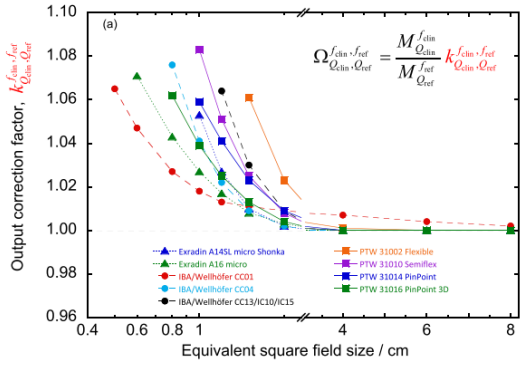
$$D_{w,Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}} = M_{Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}} N_{D,w,Q_0}^{f_{\mathrm{ref}}} k_{Q_{\mathrm{msr}},Q_0}^{f_{\mathrm{msr}},f_{\mathrm{ref}}}$$

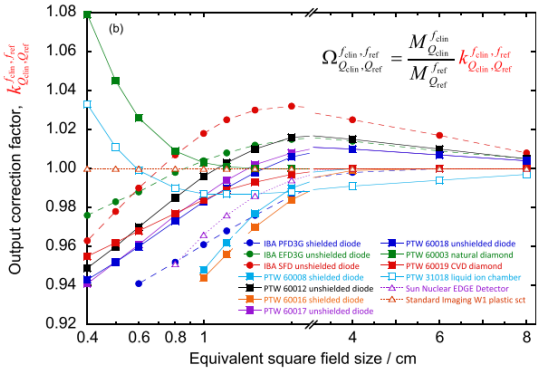
2. Relative dosimetry of small fields (clin)

$$\Omega_{Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{msr}}} = \frac{D_{w,Q_{\mathrm{clin}}}^{f_{\mathrm{clin}}}}{D_{w,Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}}} = \frac{M_{Q_{\mathrm{clin}}}^{f_{\mathrm{clin}}}}{M_{Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}}} k_{Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{msr}}}$$

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

$$D_{w,Q_{\mathrm{clin}}}^{f_{\mathrm{clin}}} = M_{Q_{\mathrm{clin}}}^{f_{\mathrm{clin}}} N_{D,w,Q_0}^{f_{\mathrm{ref}}} k_{Q_{\mathrm{msr}},Q_0}^{f_{\mathrm{msr}},f_{\mathrm{ref}}} k_{Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{ref}}}$$





Andreo, Rad. Onc. 126 (2018), 205

Extended Formalism (with $\vec{B}$)

1. Reference dosimetry of machine specific reference (msr) fields

$$D^{f_{\mathrm{msr}}}_{w,B,Q_{\mathrm{msr}}} = M^{f_{\mathrm{msr}}}_{B,Q_{\mathrm{msr}}} N^{f_{\mathrm{ref}}}_{D,w,Q_0} k^{f_{\mathrm{msr}},f_{\mathrm{ref}}}_{Q_{\mathrm{msr}},Q_0} k^{f_{\mathrm{msr}}}_{B,Q_{\mathrm{msr}}}$$

$$k^{f_{\mathrm{msr}}}_{B,Q_{\mathrm{msr}}} = \frac{N^{f_{\mathrm{ref}}}_{D,w,B,Q_0}}{N^{f_{\mathrm{ref}}}_{D,w,Q_0}} = \frac{D^{f_{\mathrm{msr}}}_{w,B,Q_{\mathrm{msr}}}}{D^{f_{\mathrm{msr}}}_{w,Q_{\mathrm{msr}}}} \cdot \frac{M^{f_{\mathrm{msr}}}_{Q_{\mathrm{msr}}}}{M^{f_{\mathrm{msr}}}_{B,Q_{\mathrm{msr}}}}$$

$$= c_B \cdot k_{B,M,Q}$$

de Pooter et al:
Reference dosimetry in MRI-linacs: evaluation of available protocols and data to establish a Code of Practice,
Phys. Med. Biol. 66 (2021), 05TR02

Extended Formalism (with $\vec{B}$)

1. Reference dosimetry of machine specific reference (msr) fields

$$D_{w,B,Q_{\text{msr}}}^{f_{\text{msr}}} = M_{B,Q_{\text{msr}}}^{f_{\text{msr}}} N_{D,w,Q_0}^{f_{\text{ref}}} k_{Q_{\text{msr}},Q_0}^{f_{\text{msr}},f_{\text{ref}}} k_{B,Q_{\text{msr}}}^{f_{\text{msr}}}$$

2. Relative dosimetry of small fields (clin)

$$\Omega_{B,Q_{\text{clin}},Q_{\text{msr}}}^{f_{\text{clin}},f_{\text{msr}}} = \frac{D_{w,B,Q_{\text{clin}}}^{f_{\text{clin}}}}{D_{w,B,Q_{\text{msr}}}^{f_{\text{msr}}}} = \frac{M_{B,Q_{\text{clin}}}^{f_{\text{clin}}}}{M_{B,Q_{\text{msr}}}^{f_{\text{msr}}}} k_{Q_{\text{clin}},Q_{\text{msr}}}^{f_{\text{clin}},f_{\text{msr}}} \frac{k_{B,Q_{\text{clin}}}^{f_{\text{clin}}}}{k_{B,Q_{\text{msr}}}^{f_{\text{msr}}}}$$

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

$$D_{w,B,Q_{\text{clin}}}^{f_{\text{clin}}} = M_{Q_{\text{clin}}}^{f_{\text{clin}}} N_{D,w,Q_0}^{f_{\text{ref}}} k_{Q_{\text{msr}},Q_0}^{f_{\text{msr}},f_{\text{ref}}} k_{Q_{\text{clin}},Q_{\text{msr}}}^{f_{\text{clin}},f_{\text{ref}}}$$

Extended Formalism (with $\vec{B}$)

1. Reference dosimetry of machine specific reference (msr) fields

$$D_{w,B,Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}} = M_{B,Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}} N_{D,w,Q_0}^{f_{\mathrm{ref}}} k_{Q_{\mathrm{msr}},Q_0}^{f_{\mathrm{msr}},f_{\mathrm{ref}}} k_{B,Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}}$$

2. Relative dosimetry of small fields (clin)

$$\Omega_{B,Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{msr}}} = \frac{D_{w,B,Q_{\mathrm{clin}}}^{f_{\mathrm{clin}}}}{D_{w,B,Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}}} = \frac{M_{B,Q_{\mathrm{clin}}}^{f_{\mathrm{clin}}}}{M_{B,Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}}} \underbrace{k_{Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{msr}}} \frac{k_{B,Q_{\mathrm{clin}}}^{f_{\mathrm{clin}}}}{k_{B,Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}}}}_{k_{B,Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{msr}}}}$$

$$\Omega_{B,Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{msr}}} = \frac{D_{w,B,Q_{\mathrm{clin}}}^{f_{\mathrm{clin}}}}{D_{w,B,Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}}} = \frac{M_{B,Q_{\mathrm{clin}}}^{f_{\mathrm{clin}}}}{M_{B,Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}}} k_{B,Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{msr}}}$$

Formalism

with $\vec{B}$

$$\Omega^{f_{\text{clin}},f_{\text{msr}}}_{B,Q_{\text{clin}},Q_{\text{msr}}} = \frac{M^{f_{\text{clin}}}_{B,Q_{\text{clin}}}}{M^{f_{\text{msr}}}_{B,Q_{\text{msr}}}} k^{f_{\text{clin}},f_{\text{msr}}}_{B,Q_{\text{clin}},Q_{\text{msr}}}$$

$$k^{f_{\text{clin}},f_{\text{msr}}}_{B,Q_{\text{clin}},Q_{\text{msr}}} = k^{f_{\text{clin}},f_{\text{msr}}}_{Q_{\text{clin}},Q_{\text{msr}}} \frac{k^{f_{\text{clin}}}_{B,Q_{\text{clin}}}}{k^{f_{\text{msr}}}_{B,Q_{\text{msr}}}}$$

tabulated

- de Pooter et al., Phys. Med. Biol. 66
- …

without $\vec{B}$

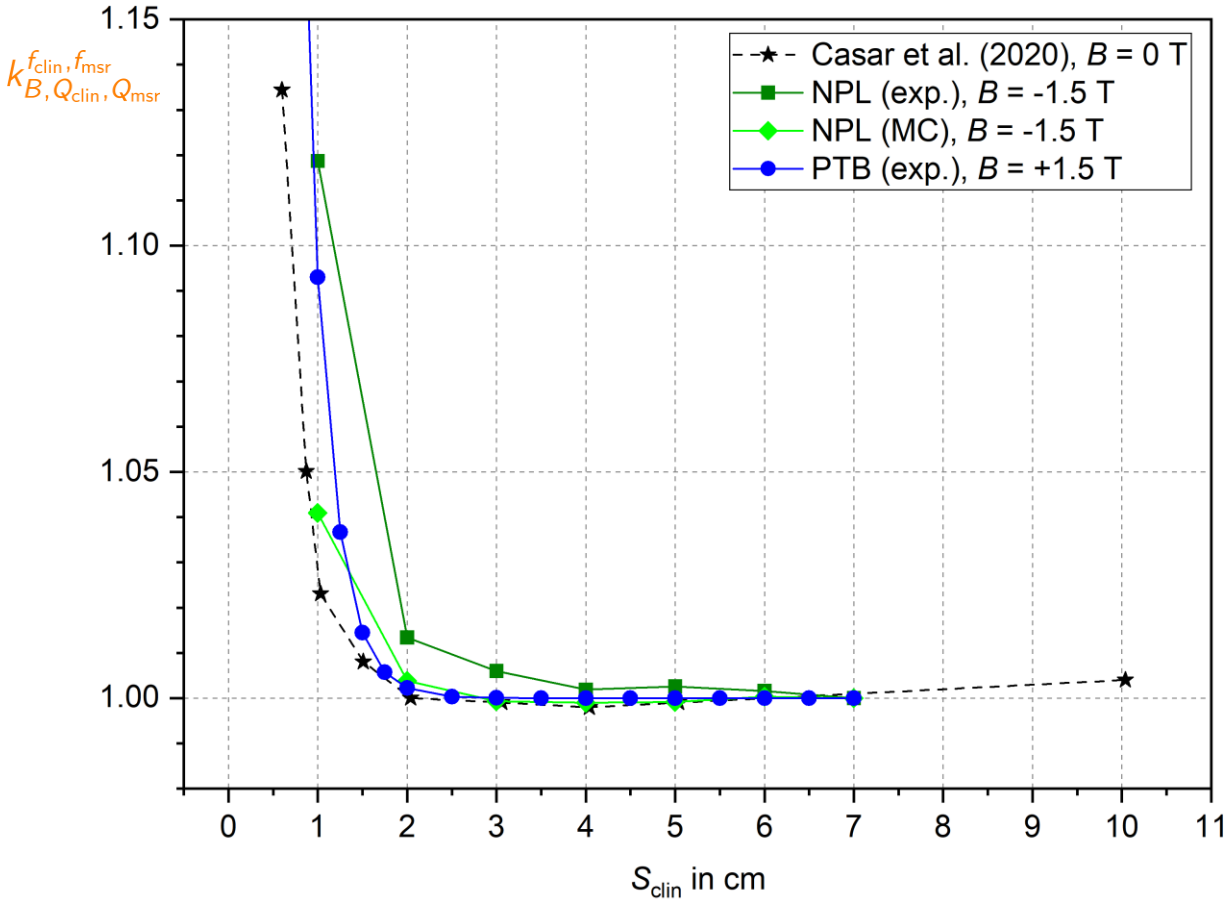
$$\Omega^{f_{\text{clin}},f_{\text{msr}}}_{Q_{\text{clin}},Q_{\text{msr}}} = \frac{M^{f_{\text{clin}}}_{Q_{\text{clin}}}}{M^{f_{\text{msr}}}_{Q_{\text{msr}}}} k^{f_{\text{clin}},f_{\text{msr}}}_{Q_{\text{clin}},Q_{\text{msr}}}$$

$$k^{f_{\text{clin}}}_{B,Q_{\text{clin}}} = \frac{D^{f_{\text{clin}}}_{w,B,Q_{\text{clin}}}}{D^{f_{\text{clin}}}_{w,Q_{\text{clin}}}} \cdot \frac{M^{f_{\text{clin}}}_{Q_{\text{clin}}}}{M^{f_{\text{clin}}}_{B,Q_{\text{clin}}}}$$

tabulated

- IAEA TRS-483
- Casar et al., Med. Phys. 46
- Casar et al., Med. Phys. 47
- …

Output correction factors (example)



PTW 31022
PinPoint 3D

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