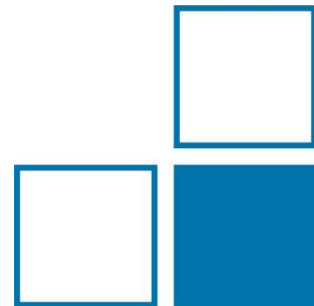
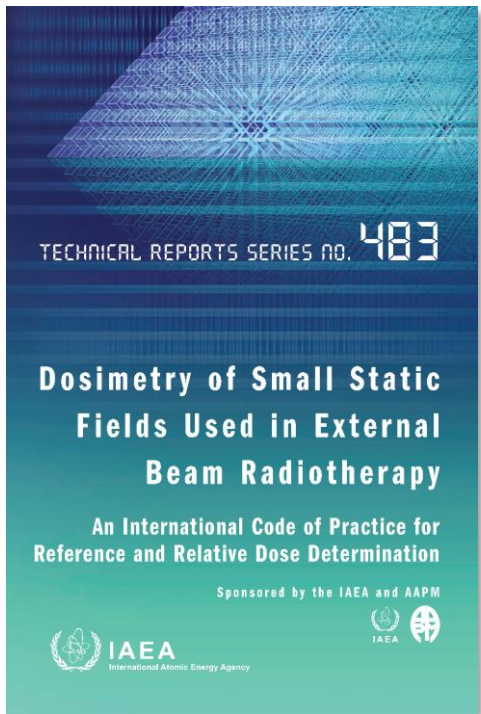


Extending TRS-483 to small fields in MRgRT

Ralf-Peter Kapsch



Extending TRS-483 to small fields in MRgRT



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 MRgRT 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

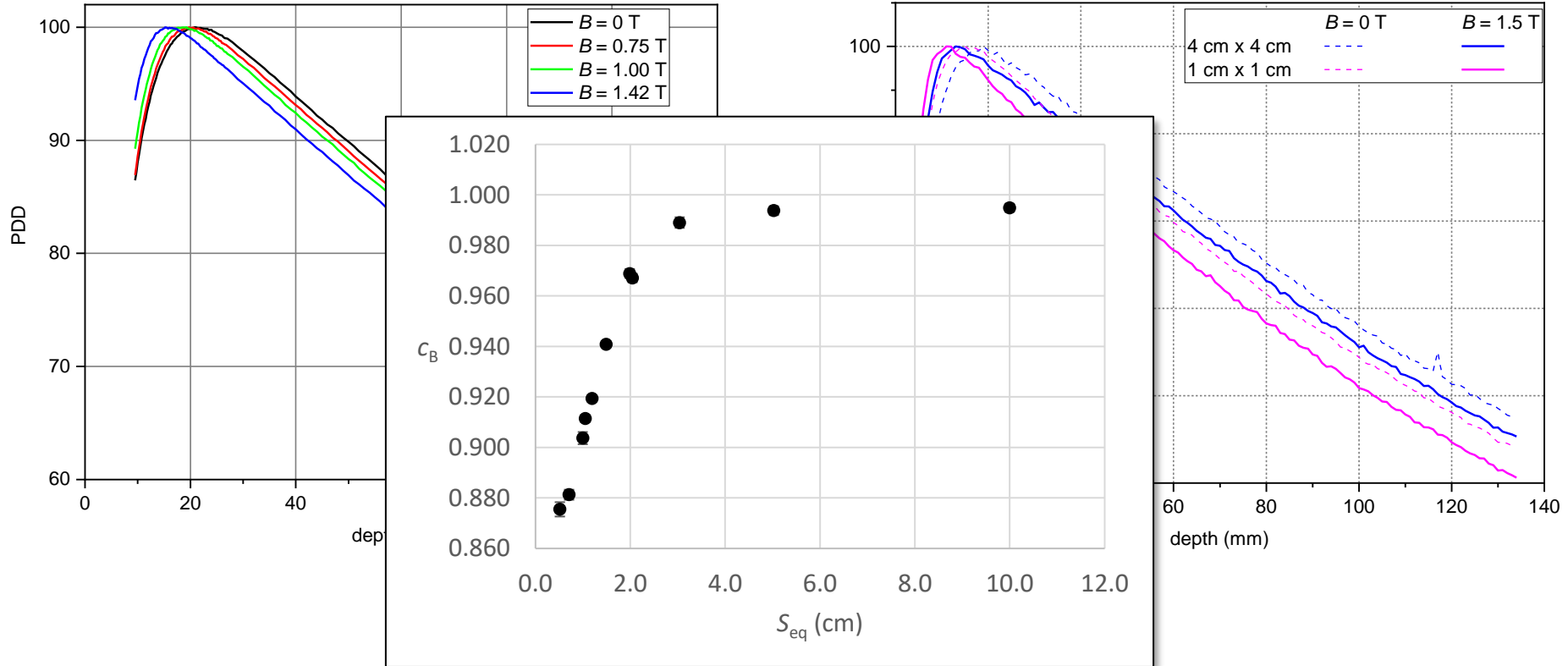


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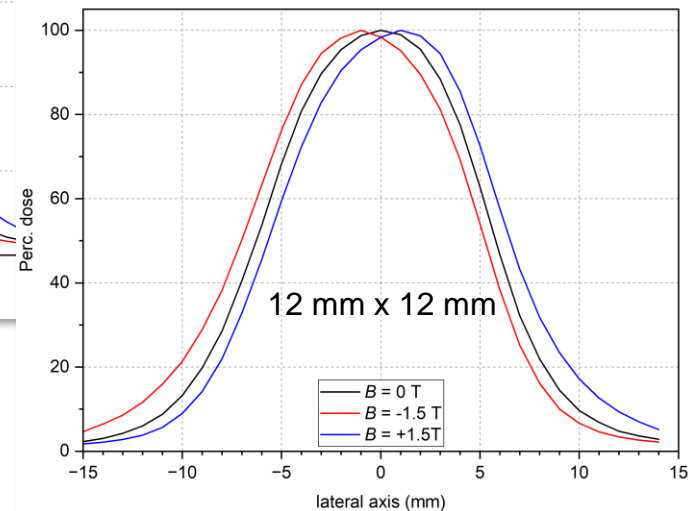
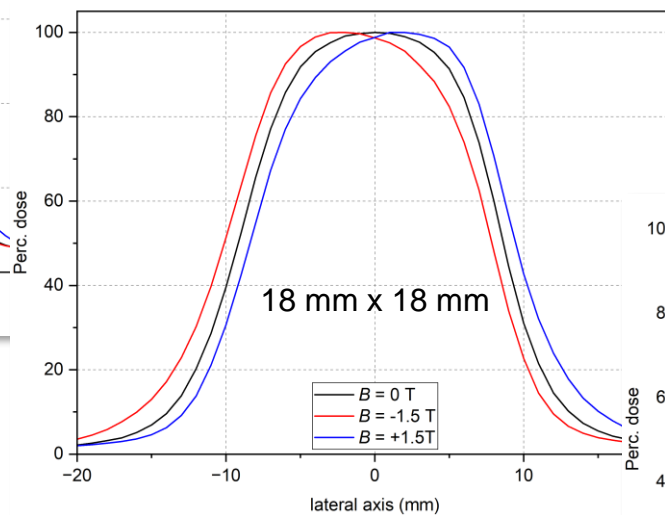
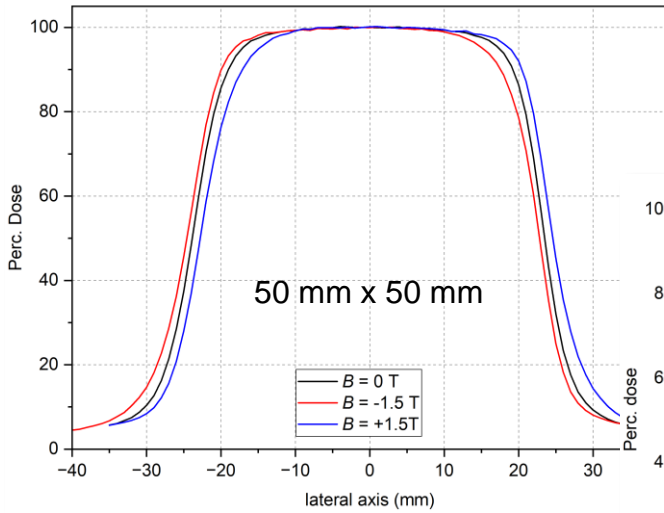
Effects of magnetic fields

Depth dose curves



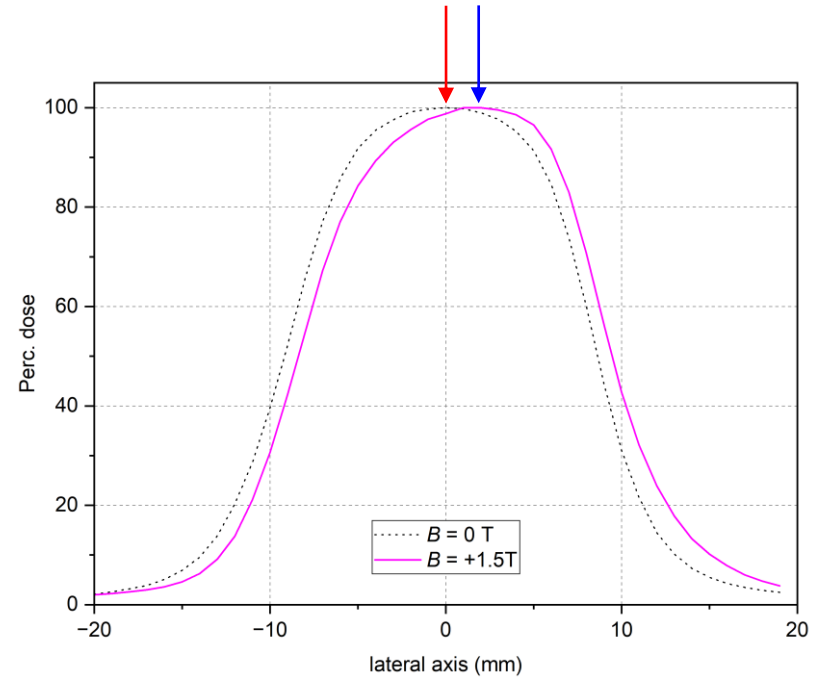
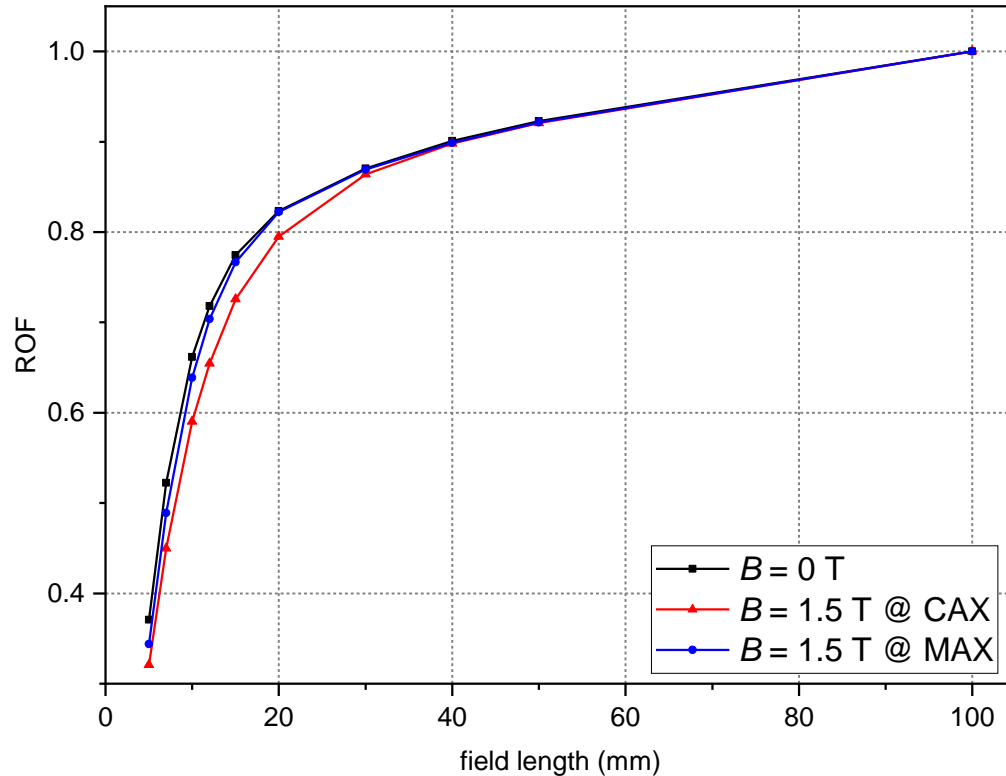
Effects of magnetic fields

Lateral beam profiles



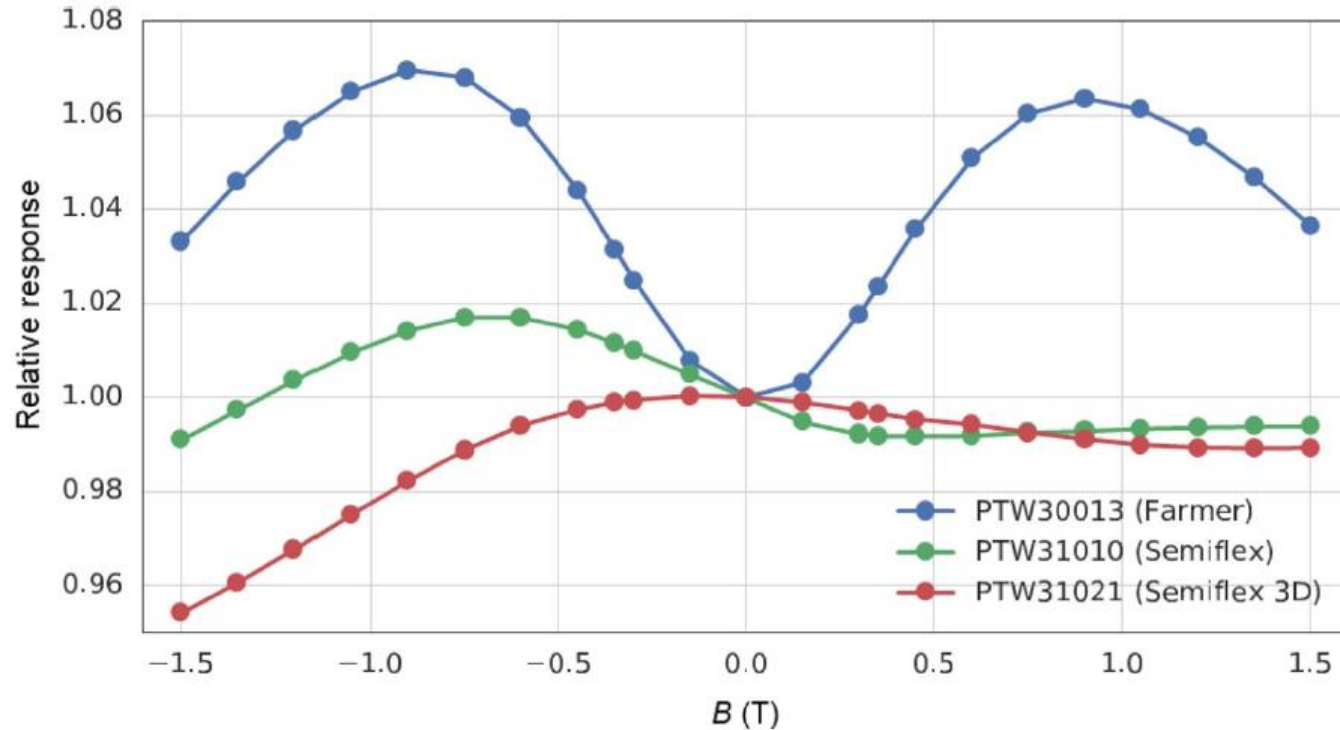
Effects of magnetic fields

Relative Output Factors



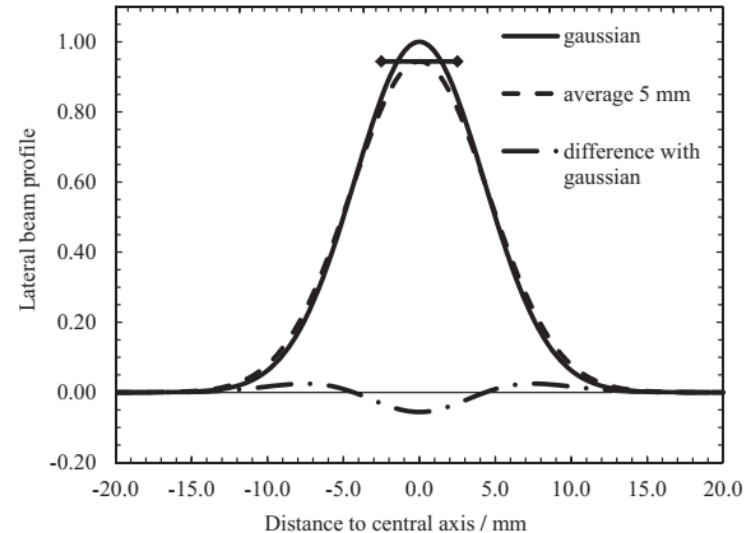
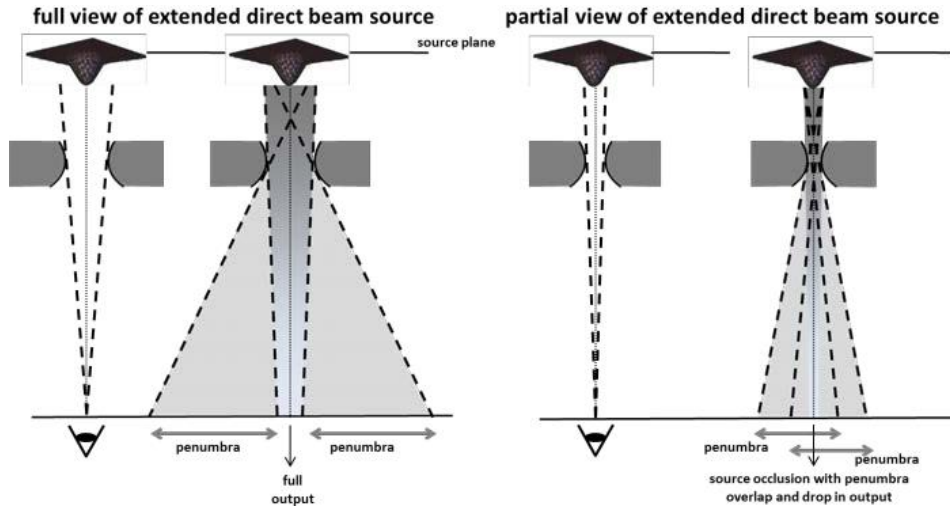
Effects of magnetic fields

Detector response



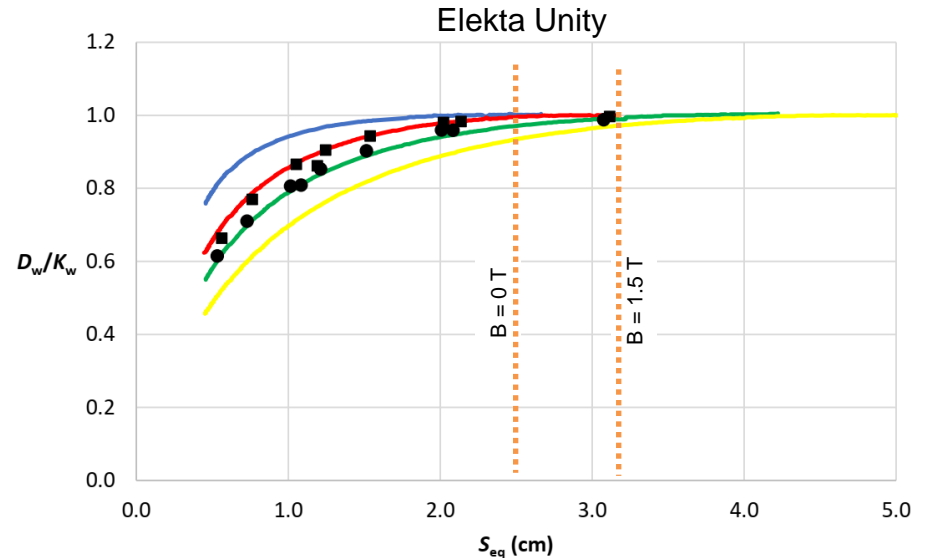
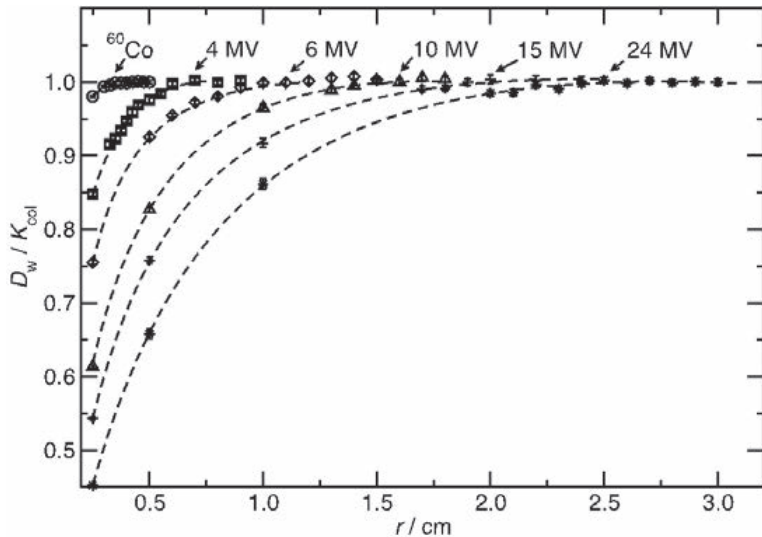
What is a small field?

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



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

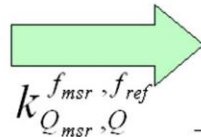
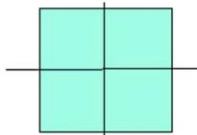


Recap: Formalism of TRS-483 (without \vec{B})

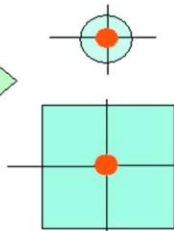
1 REFERENCE DOSIMETRY

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

Broad beam
reference field f_{ref}



Machine specific
reference field f_{msr}

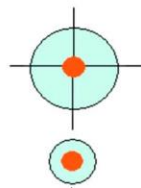
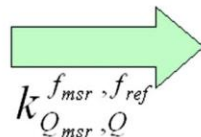


radiosurgical
collimators
Ø as low as 1.8cm

BrainLAB
micro MLC
10cm x 10cm

$N_{D, W, Q_0} k_{Q, Q_0}$

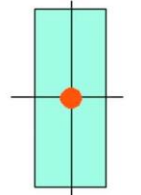
Hypothetical
reference field f_{ref}



CyberKnife
Ø 6.0 cm



GammaKnife
Ø 1.6/1.8 cm



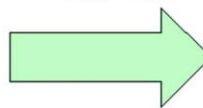
TomoTherapy
5cm x 20cm

● ≡ Ionization chamber

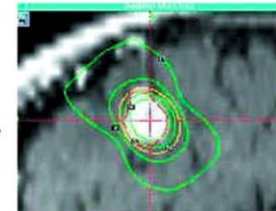
2 RELATIVE DOSIMETRY

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

$\Omega_{Q_{clin}, Q_{msr}}^{f_{clin}, f_{msr}}$



Clinical
 f_{clin}



e.g. a GammaKnife
clinical plan

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



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

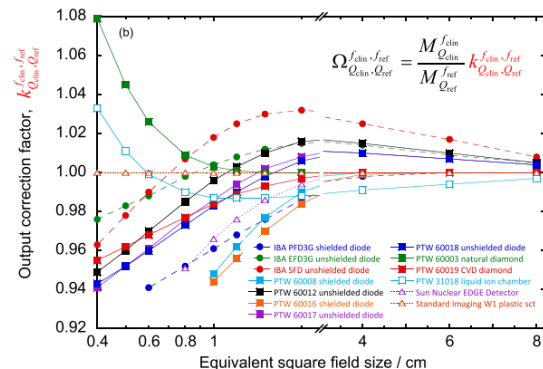
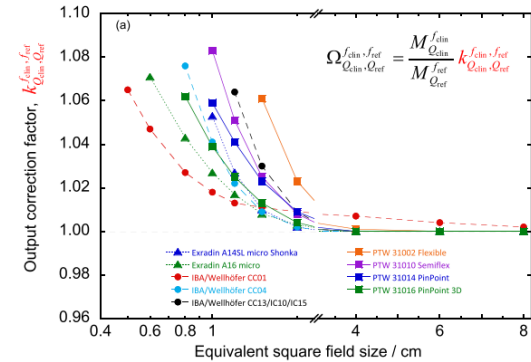
$$D_{W, Q_{msr}}^{f_{msr}} = M_{Q_{msr}}^{f_{msr}} N_{D, W, Q_0}^{f_{ref}} k_{Q_{msr}, Q_0}^{f_{msr}, f_{ref}}$$

2. Relative dosimetry of small fields (clin)

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

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

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



Extended Formalism (with \vec{B})



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

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

$$\begin{aligned} k_{B,Q_{\text{msr}}}^{f_{\text{msr}}} &= \frac{N_{D,w,B,Q_0}^{f_{\text{ref}}}}{N_{D,w,Q_0}^{f_{\text{ref}}}} = \frac{D_{w,B,Q_{\text{msr}}}^{f_{\text{msr}}}}{D_{w,Q_{\text{msr}}}^{f_{\text{msr}}}} \cdot \frac{M_{Q_{\text{msr}}}^{f_{\text{msr}}}}{M_{B,Q_{\text{msr}}}^{f_{\text{msr}}}} \\ &= c_B \cdot k_{B,M,Q} \end{aligned}$$

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

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

2. Relative dosimetry of small fields (clin)

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

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

with \vec{B}

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

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

tabulated

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

without \vec{B}

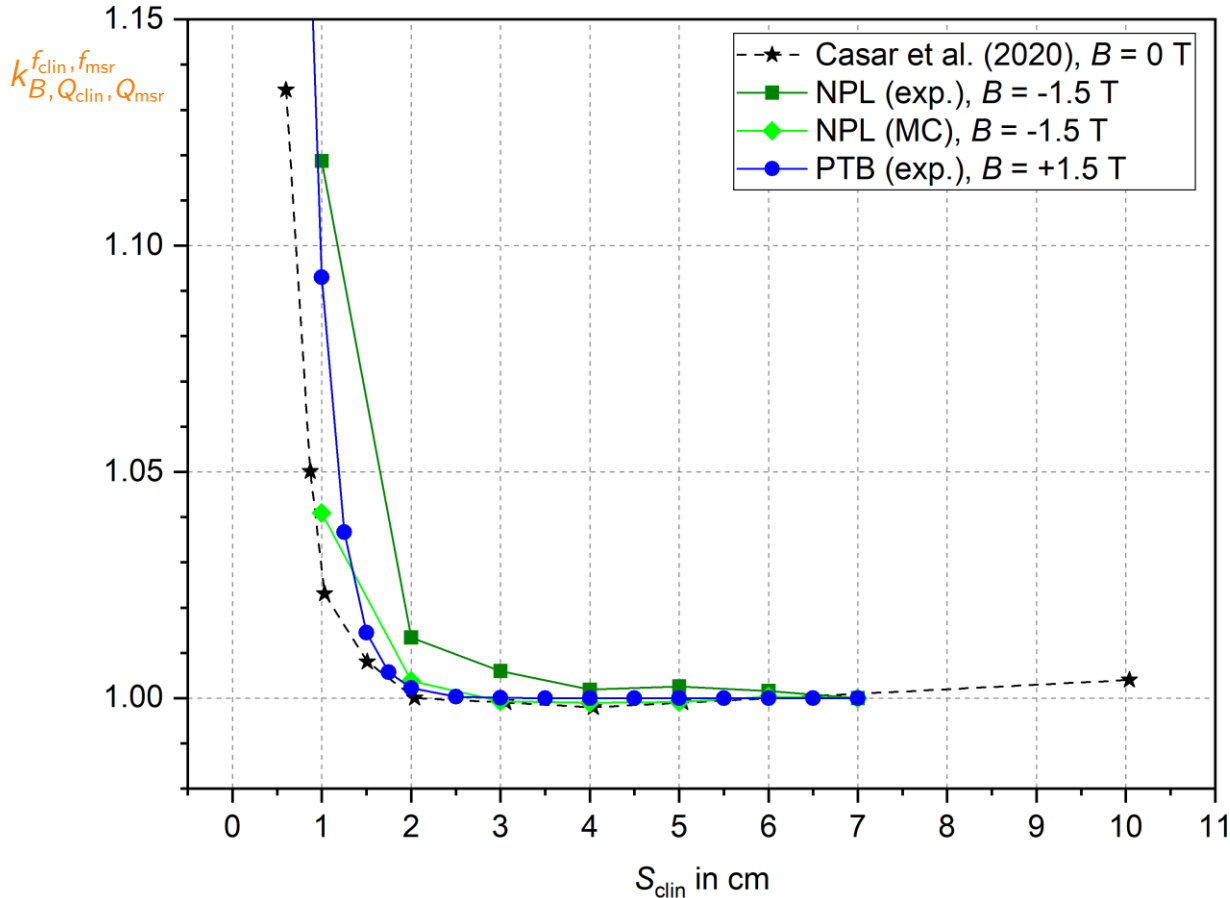
$$\Omega_{Q_{\text{clin}}, Q_{\text{msr}}}^{f_{\text{clin}}, f_{\text{msr}}} = \frac{M_{Q_{\text{clin}}}^{f_{\text{clin}}}}{M_{Q_{\text{msr}}}^{f_{\text{msr}}}} k_{Q_{\text{clin}}, Q_{\text{msr}}}^{f_{\text{clin}}, f_{\text{msr}}}$$

$$k_{B, Q_{\text{clin}}}^{f_{\text{clin}}} = \frac{D_{W, B, Q_{\text{clin}}}^{f_{\text{clin}}}}{D_{W, Q_{\text{clin}}}^{f_{\text{clin}}}} \cdot \frac{M_{Q_{\text{clin}}}^{f_{\text{clin}}}}{M_{B, Q_{\text{clin}}}^{f_{\text{clin}}}}$$

tabulated

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

Output correction factors (example)





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