Unity Physics Training

Absolute Dosimetry

第2版：2021/7/28

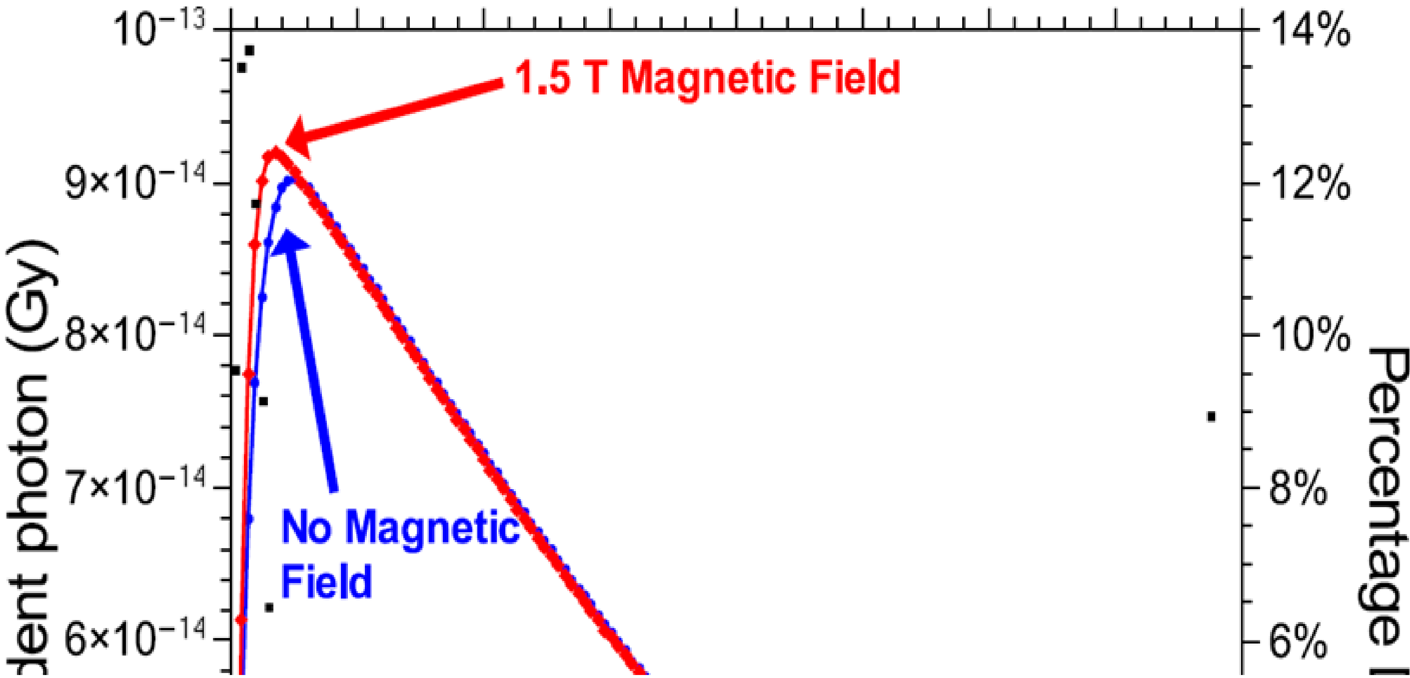
E006489/1.0

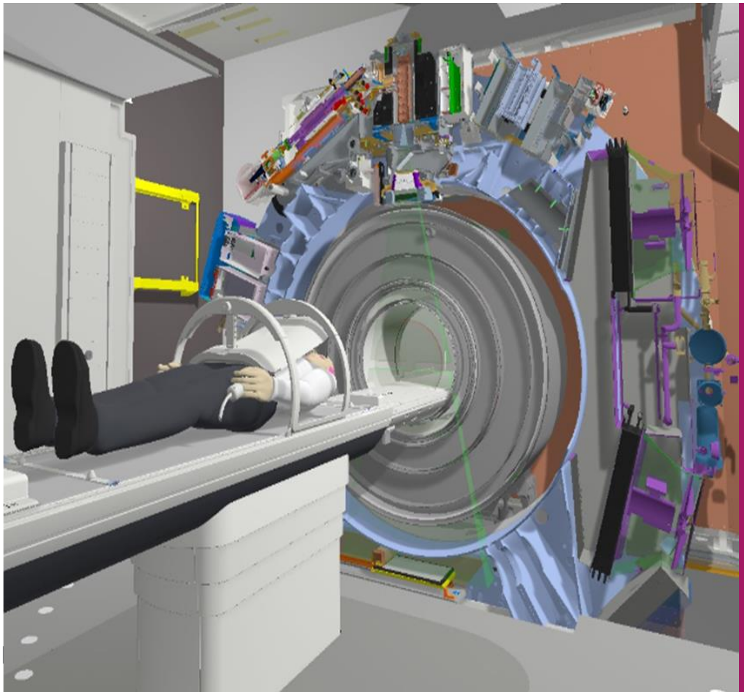
Elekta

Absolute Dosimetry

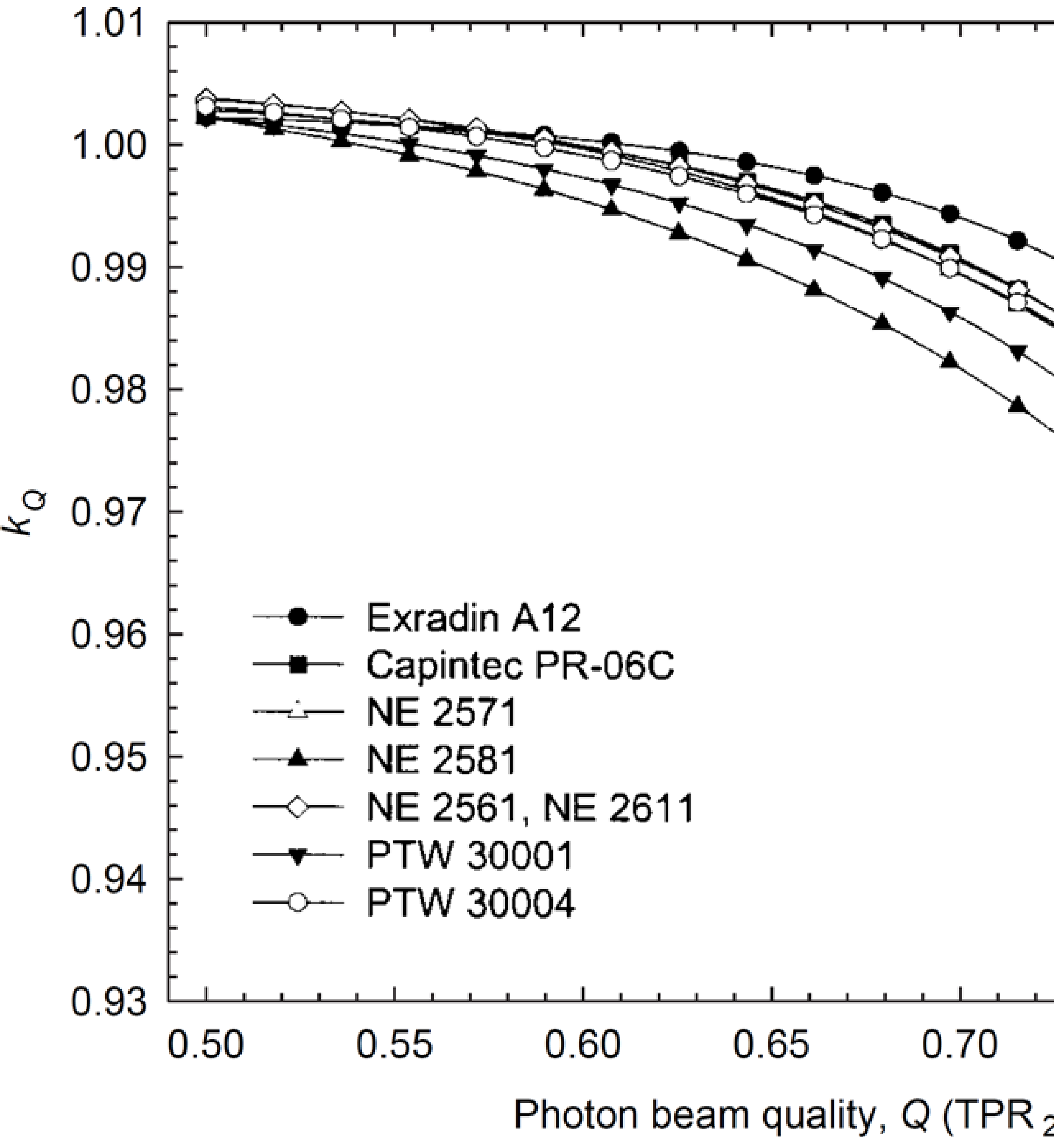
目的

リファレンス線量測定における磁場による影響の理解





Lesson Objectives



Standard Reference Dosimetry Protocols

Formalism

Standard Reference Dosimetry Protocols

線量測定プロトコルは、以下の形式を使用

$$D_w^Q = M \cdot N_{D,w}^{Q_0} \cdot k_Q$$

(e.g. AAPM, IAEA)

Beam Quality

Standard Reference Dosimetry Protocols

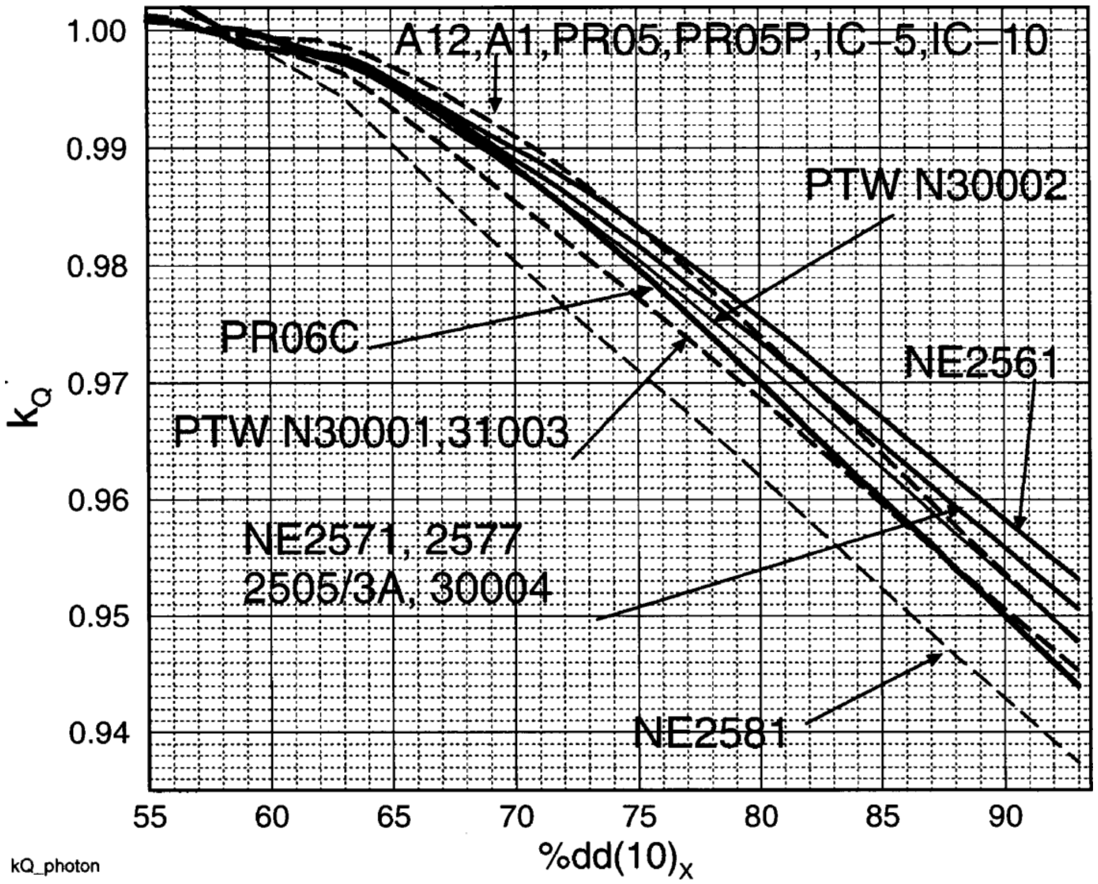
- ビーム線質を決定する必要がある。

- 一般的な2つの線質指標は次の通り
  - $\%dd(10)_x$ Used by AAPM TG-51 protocol
    純粋な光子ビーム（電子汚染なし）の深さ10㎝での深さ線量のパーセンテージ。
    SSD100㎝で測定する必要がある。
  - TPR_{10}^{20} Used by IAEA TRS-398 protocol
    深さ20㎝と10㎝のアイソセンターでの線量比。SSDに依存しない。

Beam Quality Correction

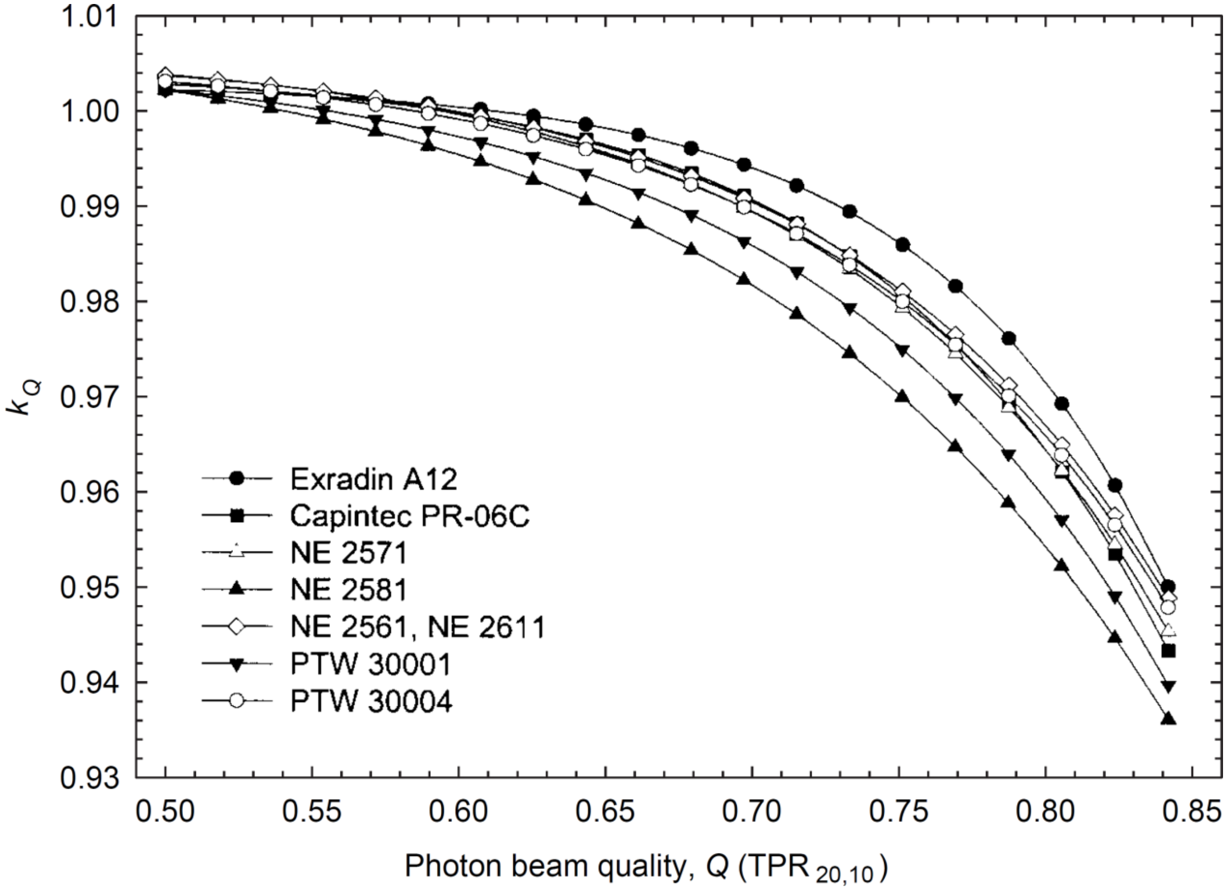
Standard Reference Dosimetry Protocols

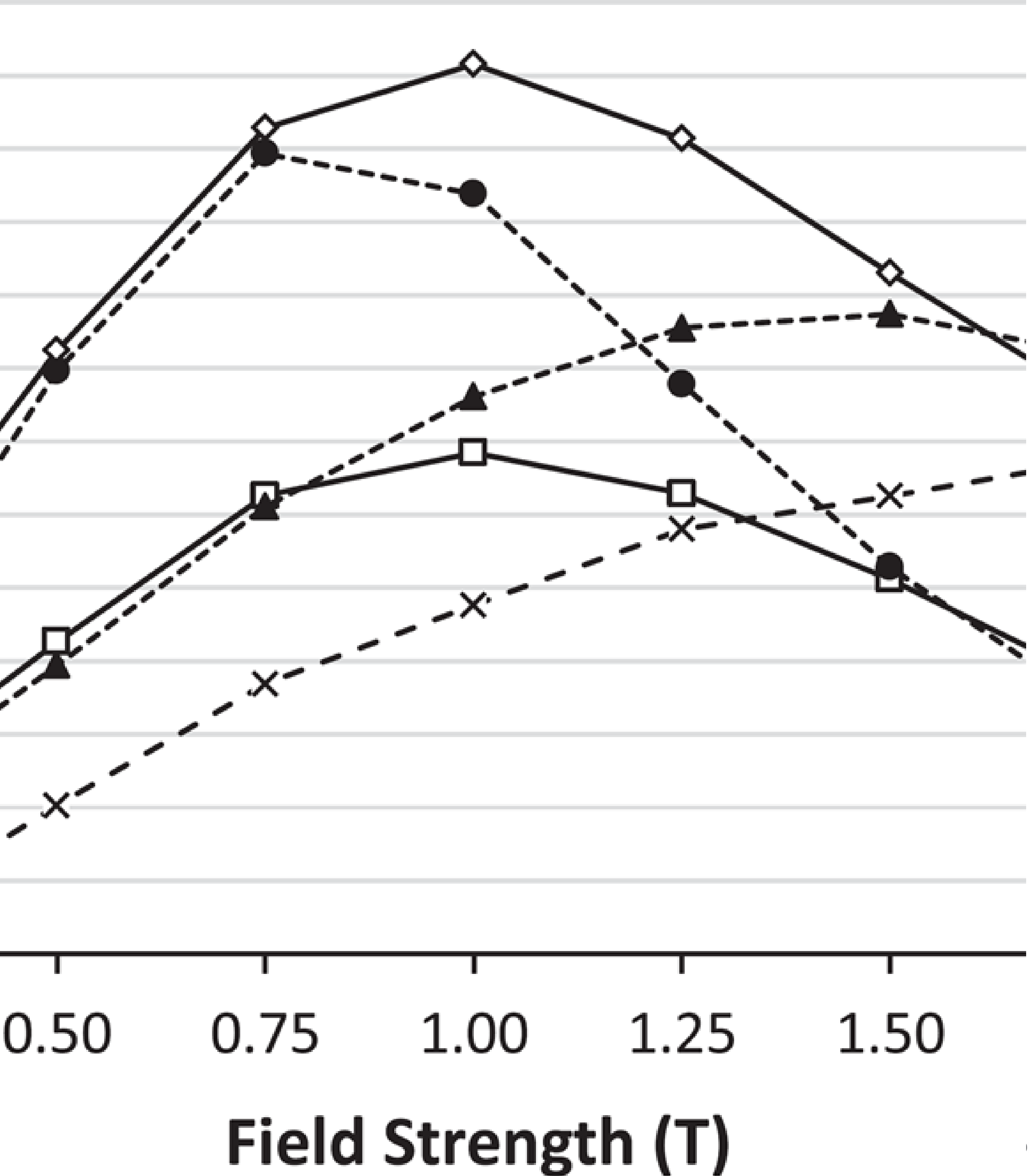
AAPM TG-51



kQ_photon

IAEA TRS-398





Complications in Magnetic Fields

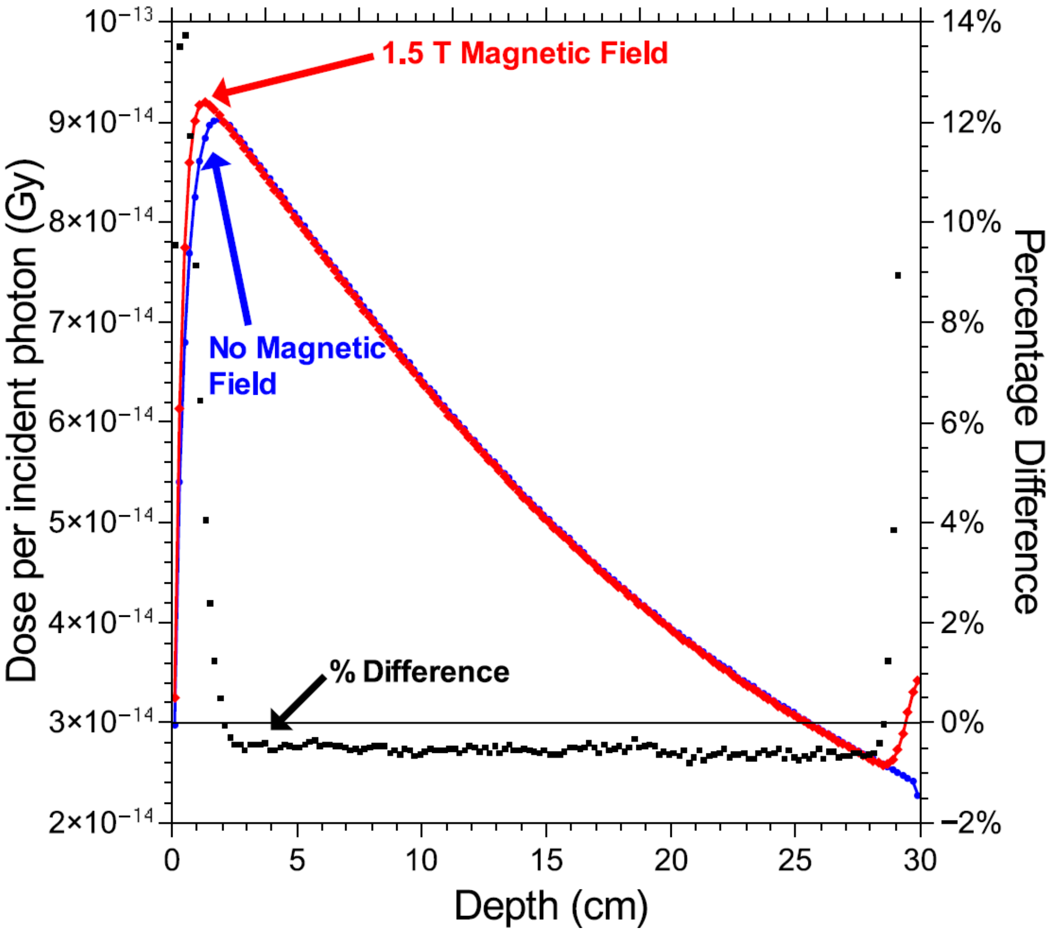
Beam Quality Determination

Complications in Magnetic Fields

磁場はPDDを変化させる。

Pure Photon Beam	d_{max}	$\%dd(10)_x$	TPR^{20}_{10}
No magnetic field	1.85	71.4	0.697
1.5 T magnetic field	1.30	69.7	0.695

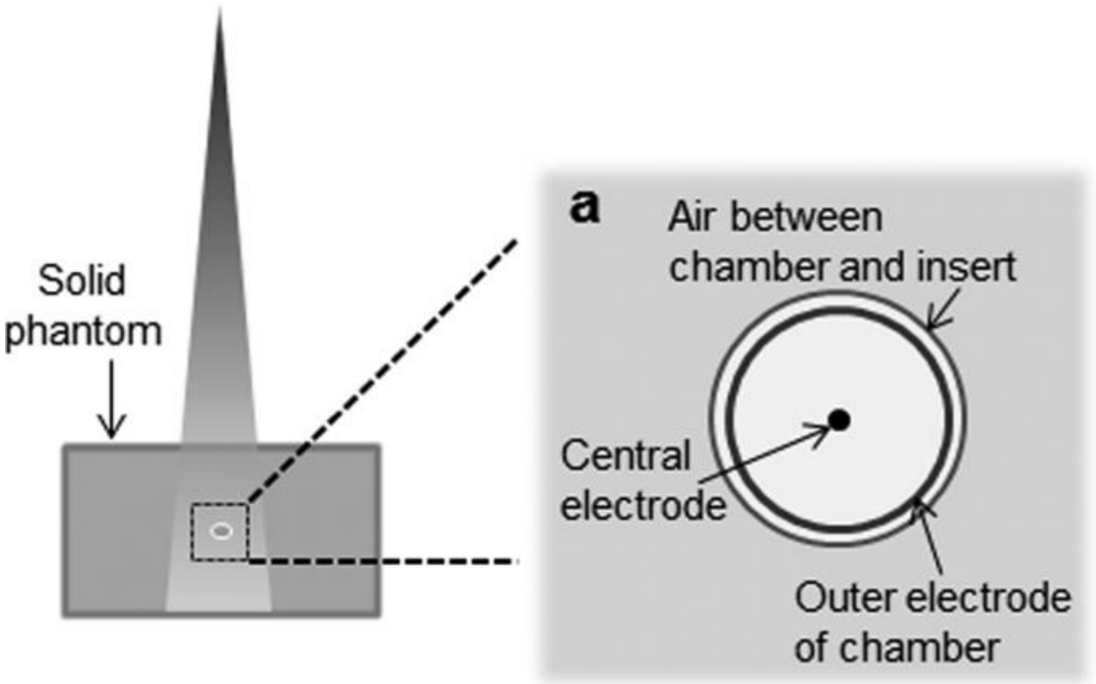
- **$\%dd(10)_x$ は変化する。**
- **TPR^{20}_{10} は磁場の強さに依存しない。**



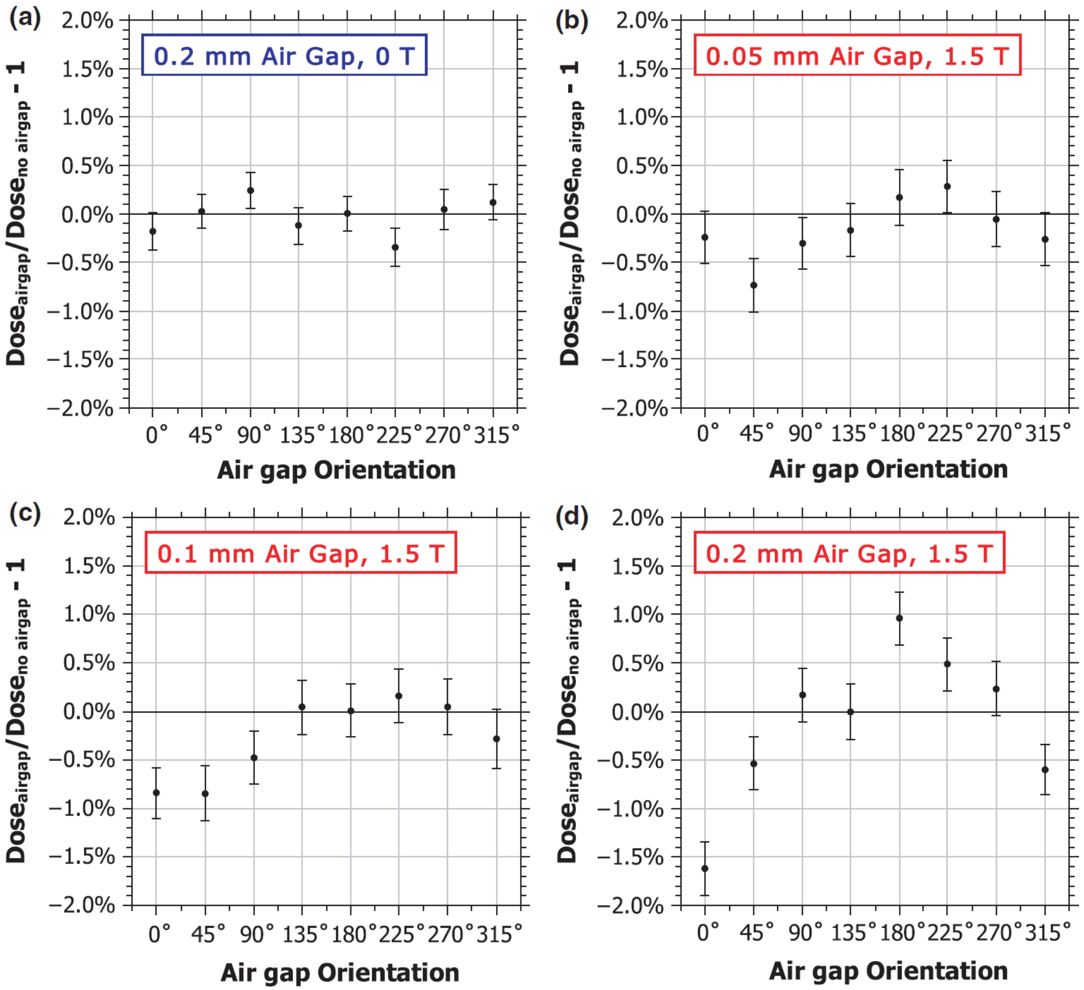
* O’Brien et al. (2016). "Reference dosimetry in magnetic fields: formalism and ionization chamber correction factors." Med. Phys. 43(8), 4915–4927

Air Gap Effect

Complications in Magnetic Fields



* (Adapted) Hackett et al. (2016). "Consequences of air around an ionization chamber : Are existing solid phantoms suitable for reference dosimetry on an MR-linac?" Med. Phys. 43(7), 3961–3968

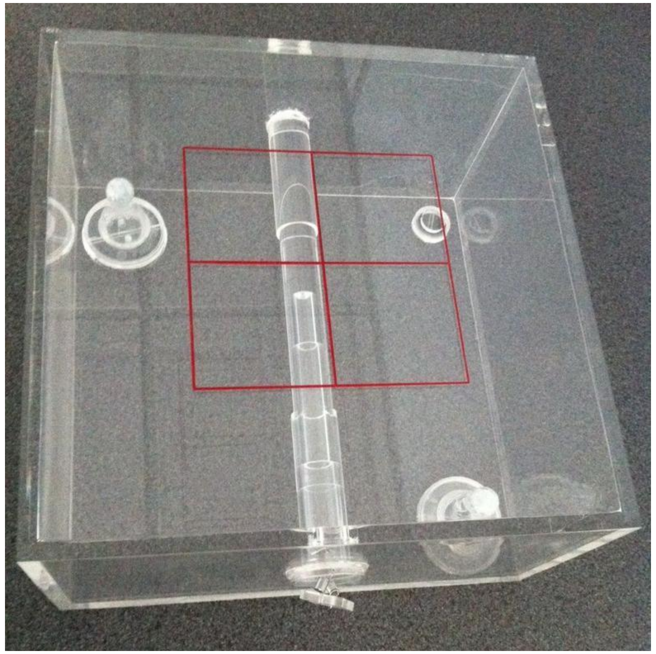


* O’Brien et al. (2017). "Monte Carlo study of the chamber-phantom air gap effect in a magnetic field." Med. Phys. 44(7), 3830–3838

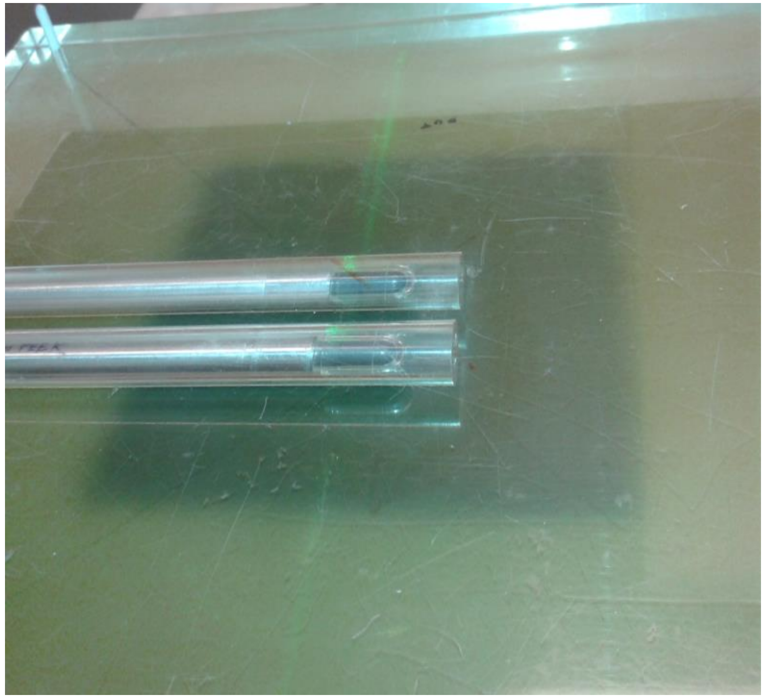
Calibration Phantoms

Complications in Magnetic Fields

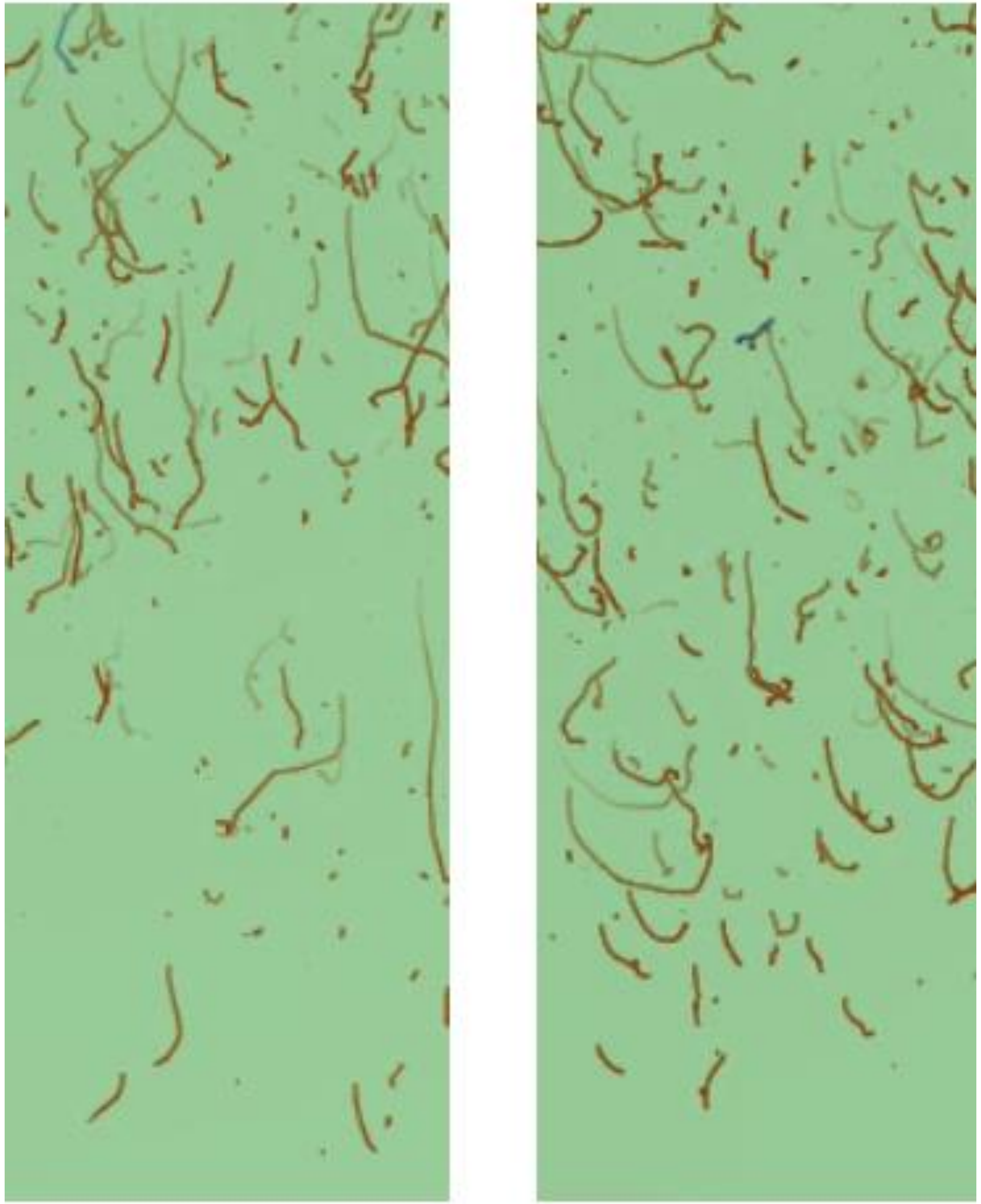
例えば エアギャップの影響を受けやすいファントム



非防水性ファーマーチャンバー用の水ファントム



クロスキャリブレーションファントム



Adaptation Strategies

Code of Practices?

Adaptation Strategies

New facility supp
MRI-guided radic

A new electromagnet at the National Physic
enable research supporting MRI-guided rad

Radiotherapy treats cancer by focusing beams radiation on a tumour, killing cancerous cells by damaging their DNA. Radiation delivery must be tightly controlled to minimise damage to the surrounding healthy tissue. Typically, X-ray based techniques are used to image a patient immediately before treatment to direct the radiation. But tumours move and deform inside a patient's body with bodily functions such as breathing, and can shift and change in size over the course of treatment.

MRI-guided radiotherapy provides real-time images during a patient's treatment, and offers more detailed and higher contrast images for the identification of tumours and soft tissues. This boosts tumour targeting accuracy, reducing side-effects and increasing survival rates. Currently untreatable cancers, such as kidney and pancreatic tumours, which can't be accurately tracked during treatment, may become treatable.

リファレンス線量測定は
ご施設様判断となります

FIRST WATER CALORIMETER MEASUREMENTS IN AN MRI-LINAC

A leap towards traceable dosimetry for MR-guided radiotherapy

A team of researchers from VSL Dutch Metrology Institute and the University Medical Centre Utrecht have, for the first time ever, carried out calorimetric absorbed dose to water measurements in a 1.5 T magnetic field of an Elekta Atlantic MRI-linac. The measurements that

Formalism

Adaptation Strategies

現在の公式は、磁場による電離箱の影響を説明していない。

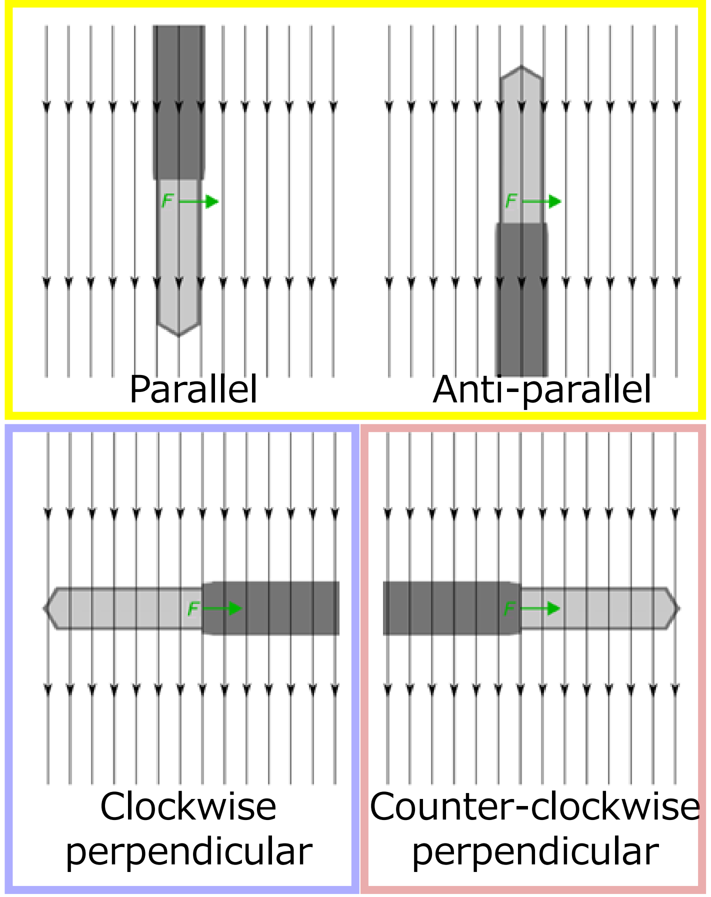
Original Formalism $$D_w^Q = M \cdot N_{D,w}^{^{60}Co} \cdot k_Q$$

Adapted Formalism $$D_w^Q = M \cdot N_{D,w}^{^{60}Co} \cdot k_Q \boxed{\cdot k_B}$$

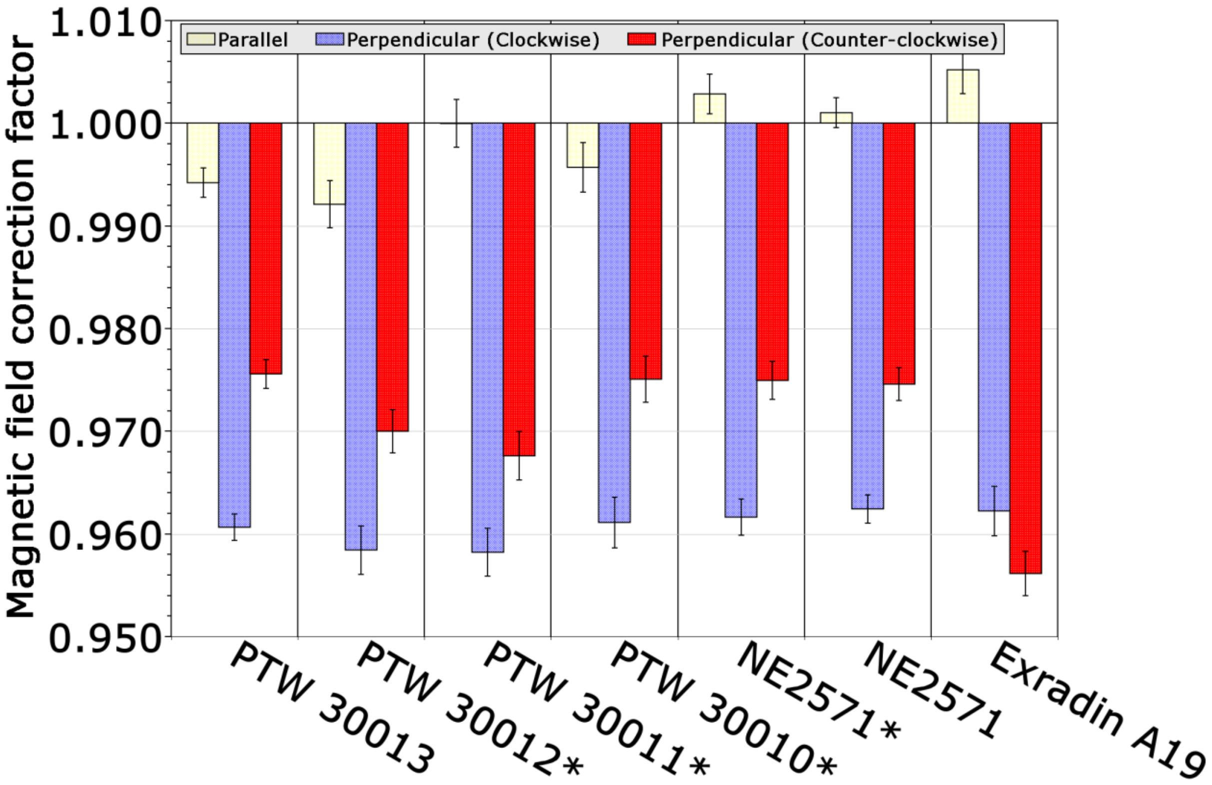
補正係数k_Bを使用して、磁場による電離箱の影響を考慮する必要がある。

Ion Chamber Orientation

Adaptation Strategies



* O’Brien et al. (2016) Med. Phys. 43(8), 4915–4927



* *modeled with waterproof sleeve*

Published values of k_B

Adaptation Strategies

- $\mathrm{k_B}$が検討された3つの論文のご紹介

#1	O'Brien, D J et al. “Reference dosimetry in magnetic fields: formalism and ionization chamber correction factors.” Medical physics vol. 43,8 (2016): 4915. doi:10.1118/1.4959785
#2	Van Asselen, Bram, et al. "A formalism for reference dosimetry in photon beams in the presence of a magnetic field." Physics in Medicine & Biology 63.12 (2018): 125008.
#3	Malkov, Victor N, and D W O Rogers. “Monte Carlo study of ionization chamber magnetic field correction factors as a function of angle and beam quality.” Medical physics vol. 45,2 (2018): 908-925. doi:10.1002/mp.12716

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Published values of k_B

Adaptation Strategies

1

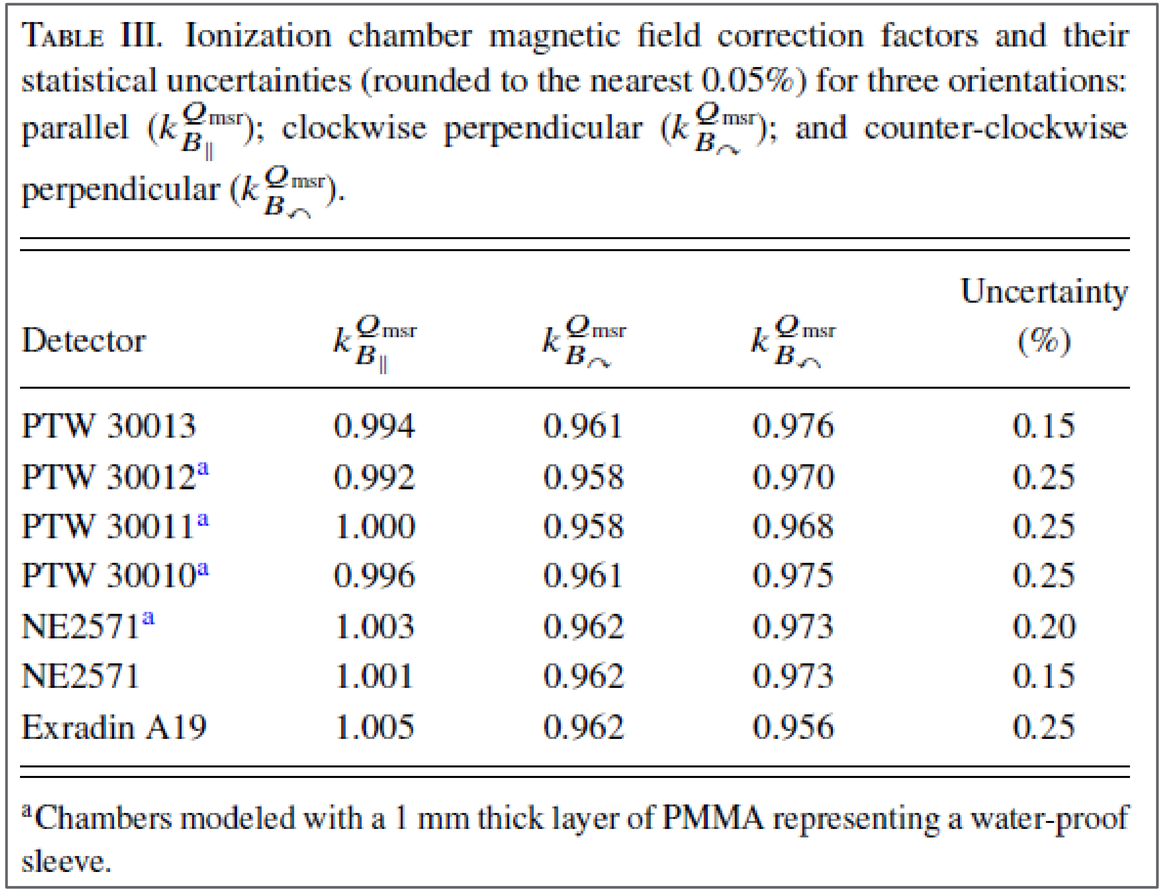


TABLE III. Ionization chamber magnetic field correction factors and their statistical uncertainties (rounded to the nearest 0.05%) for three orientations: parallel ($k_{B_\parallel}^{Q_\text{msr}}$); clockwise perpendicular ($k_{B_\curvearrowright}^{Q_\text{msr}}$); and counter-clockwise perpendicular ($k_{B_\curvearrowleft}^{Q_\text{msr}}$).

Detector	$k_{B_\parallel}^{Q_\text{msr}}$	$k_{B_\curvearrowright}^{Q_\text{msr}}$	$k_{B_\curvearrowleft}^{Q_\text{msr}}$	Uncertainty (%)
PTW 30013	0.994	0.961	0.976	0.15
PTW 30012[a]	0.992	0.958	0.970	0.25
PTW 30011[a]	1.000	0.958	0.968	0.25
PTW 30010[a]	0.996	0.961	0.975	0.25
NE2571[a]	1.003	0.962	0.973	0.20
NE2571	1.001	0.962	0.973	0.15
Exradin A19	1.005	0.962	0.956	0.25

[a] Chambers modeled with a 1 mm thick layer of PMMA representing a water-proof sleeve.

O'Brien, D J et al. "Reference dosimetry in magnetic fields: formalism and ionization chamber correction factors." Medical physics vol. 43,8 (2016): 4915. doi:10.1118/1.4959785

Published values of k_B

Adaptation Strategies

2

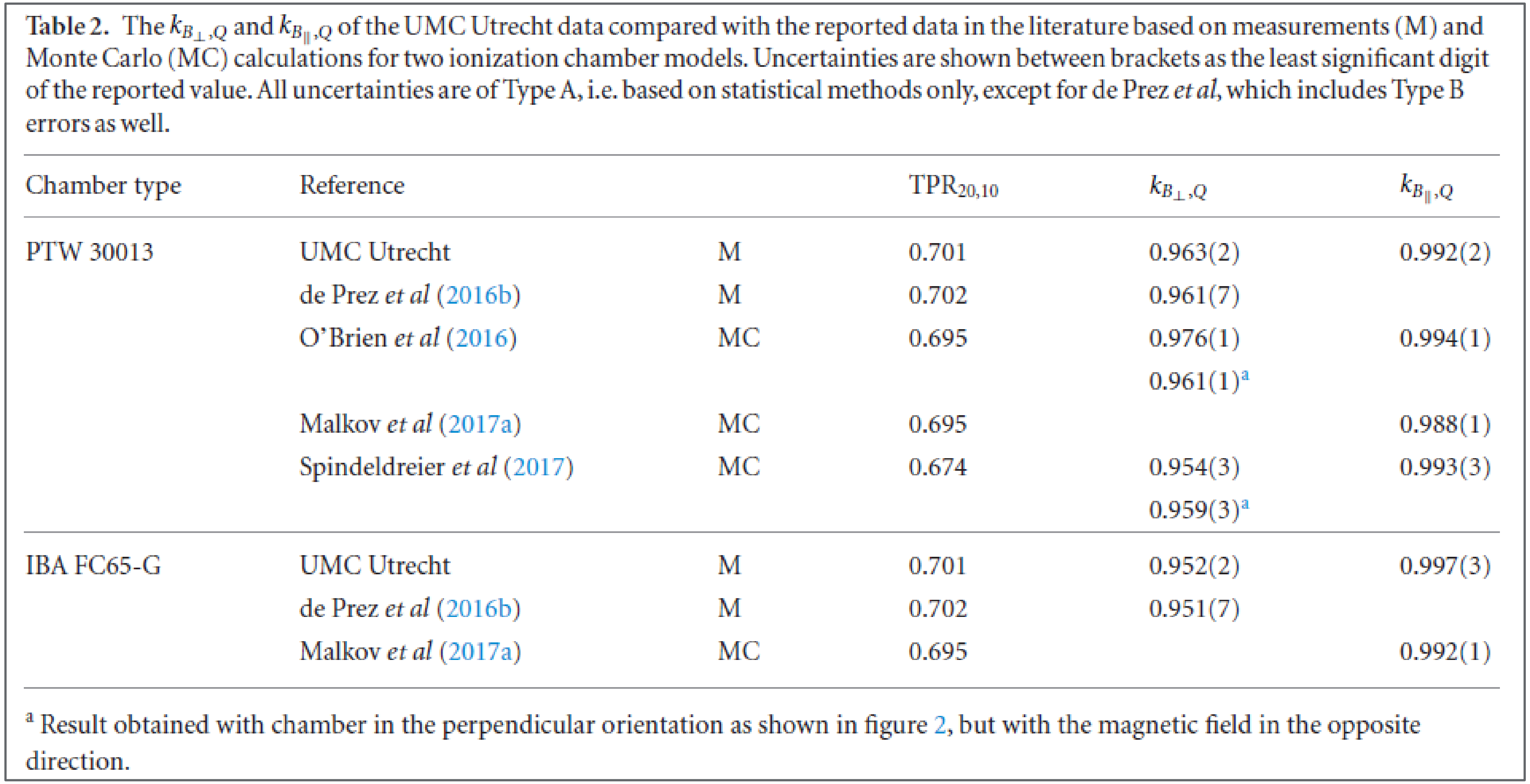


Table 2. The $k_{B_\perp,Q}$ and $k_{B_\parallel,Q}$ of the UMC Utrecht data compared with the reported data in the literature based on measurements (M) and Monte Carlo (MC) calculations for two ionization chamber models. Uncertainties are shown between brackets as the least significant digit of the reported value. All uncertainties are of Type A, i.e. based on statistical methods only, except for de Prez *et al*, which includes Type B errors as well.

Chamber type	Reference		$TPR_{20,10}$	$k_{B_\perp,Q}$	$k_{B_\parallel,Q}$
PTW 30013	UMC Utrecht	M	0.701	0.963(2)	0.992(2)
	de Prez *et al* (2016b)	M	0.702	0.961(7)	
	O'Brien *et al* (2016)	MC	0.695	0.976(1) 0.961(1)[a]	0.994(1)
	Malkov *et al* (2017a)	MC	0.695		0.988(1)
	Spindeldreier *et al* (2017)	MC	0.674	0.954(3) 0.959(3)[a]	0.993(3)
IBA FC65-G	UMC Utrecht	M	0.701	0.952(2)	0.997(3)
	de Prez *et al* (2016b)	M	0.702	0.951(7)	
	Malkov *et al* (2017a)	MC	0.695		0.992(1)

[a] Result obtained with chamber in the perpendicular orientation as shown in figure 2, but with the magnetic field in the opposite direction.

Van Asselen, Bram, et al. "A formalism for reference dosimetry in photon beams in the presence of a magnetic field." Physics in Medicine & Biology 63.12 (2018): 125008.

Published values of k_B

Adaptation Strategies

#3

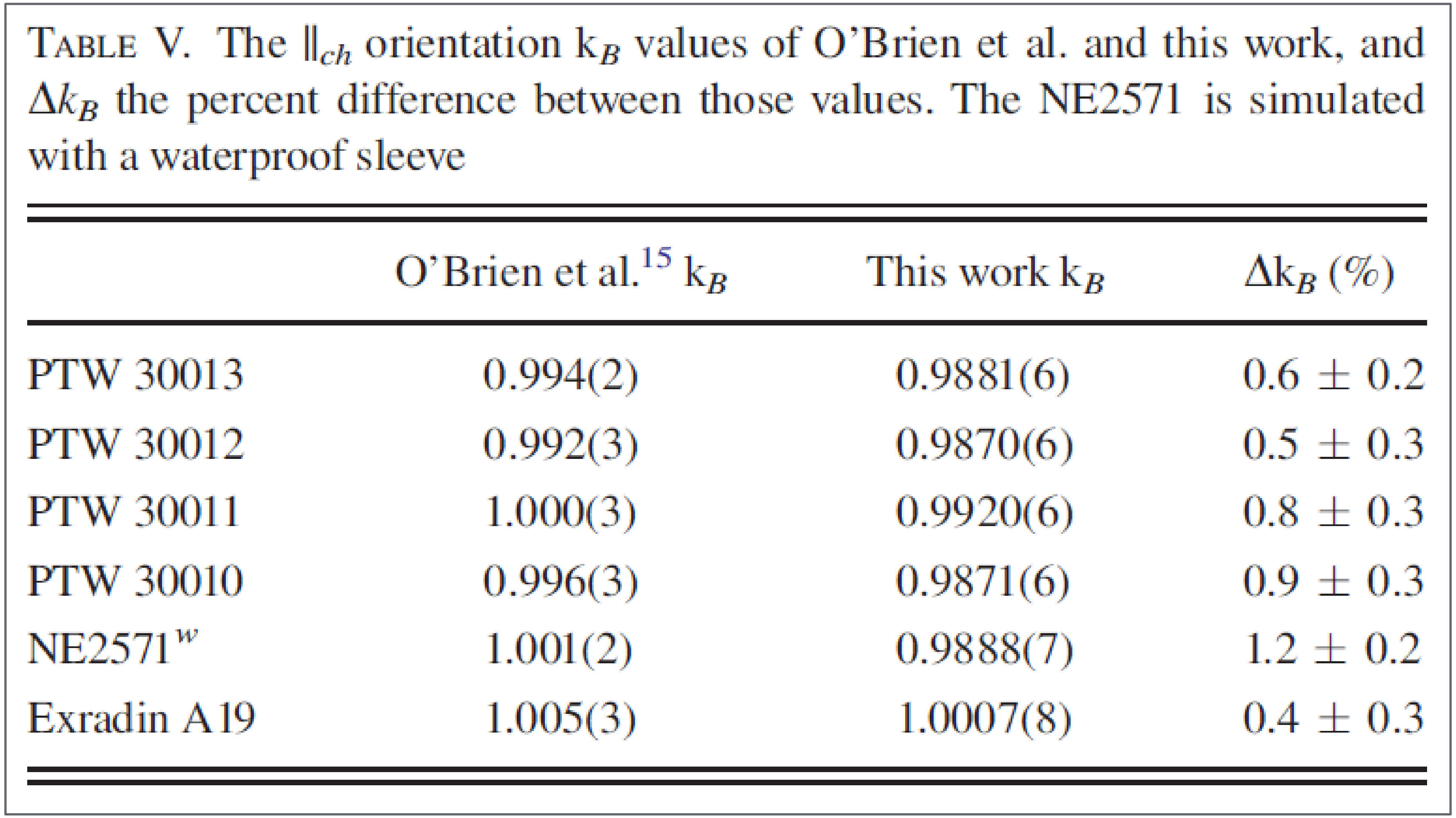
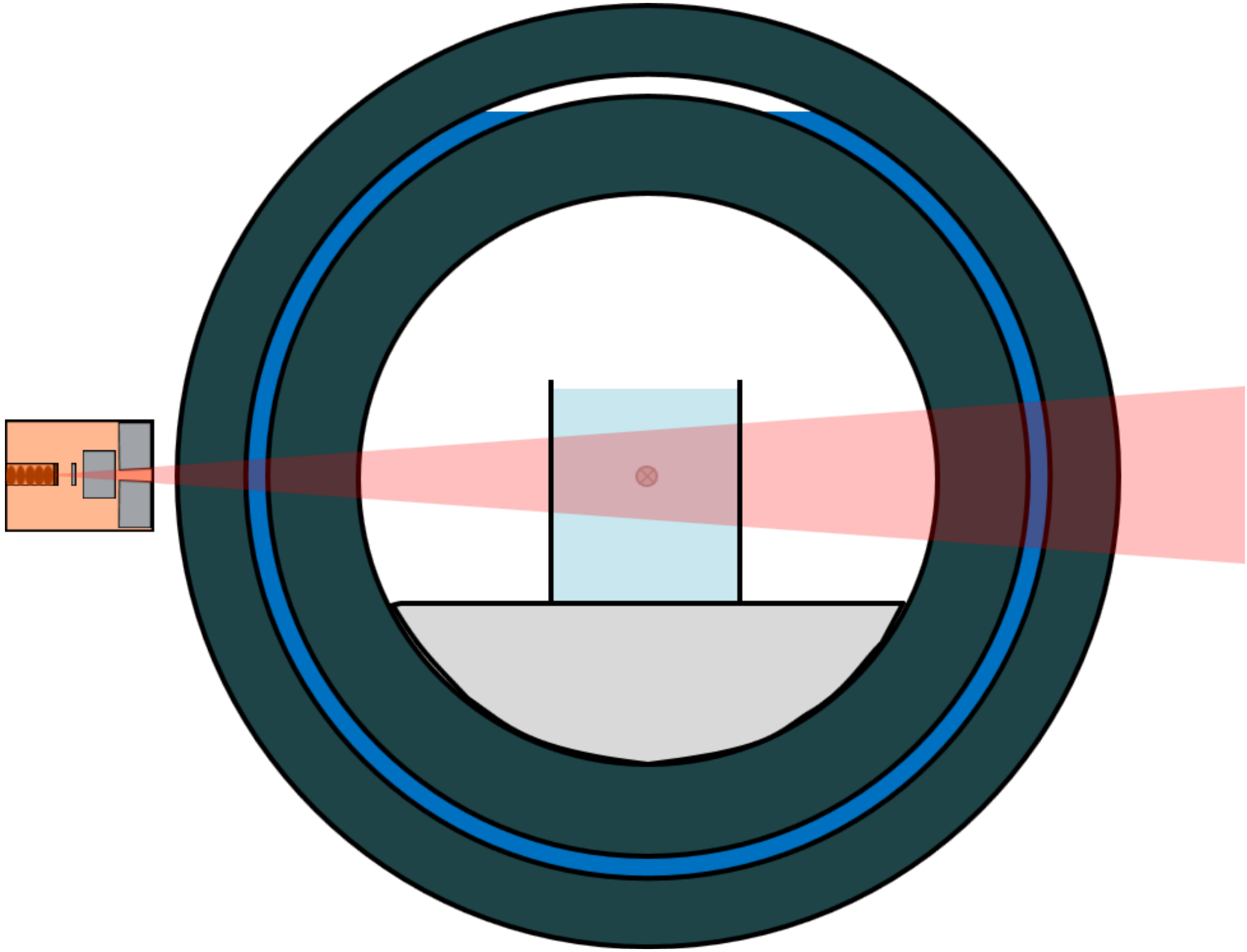


TABLE V. The $\|_{ch}$ orientation k_B values of O'Brien et al. and this work, and Δk_B the percent difference between those values. The NE2571 is simulated with a waterproof sleeve

	O'Brien et al.[15] k_B	This work k_B	Δk_B (%)
PTW 30013	0.994(2)	0.9881(6)	0.6 ± 0.2
PTW 30012	0.992(3)	0.9870(6)	0.5 ± 0.3
PTW 30011	1.000(3)	0.9920(6)	0.8 ± 0.3
PTW 30010	0.996(3)	0.9871(6)	0.9 ± 0.3
NE2571^w	1.001(2)	0.9888(7)	1.2 ± 0.2
Exradin A19	1.005(3)	1.0007(8)	0.4 ± 0.3

Malkov, Victor N, and D W O Rogers. "Monte Carlo study of ionization chamber magnetic field correction factors as a function of angle and beam quality." Medical physics vol. 45,2 (2018): 908-925. doi:10.1002/mp.12716

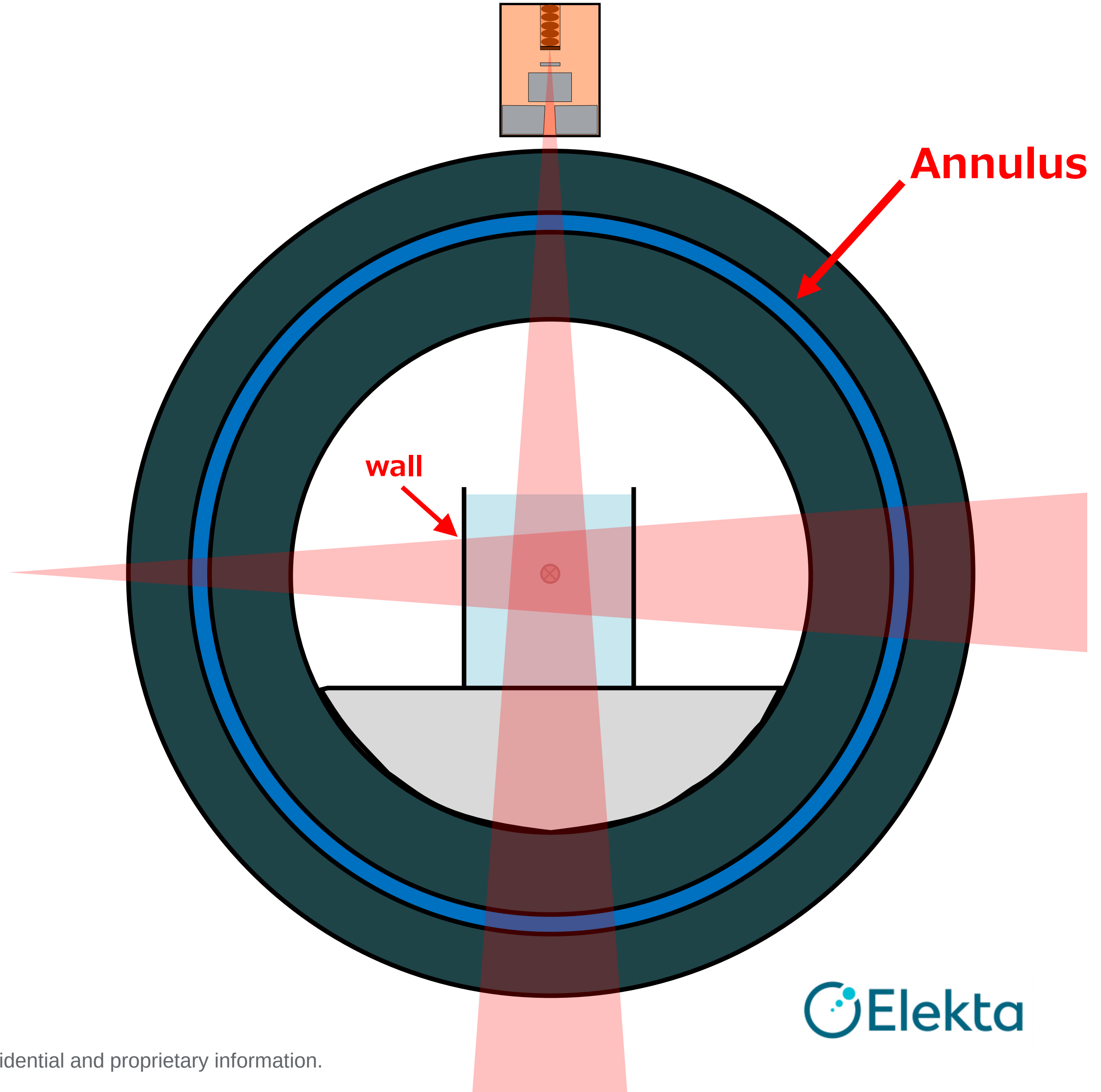


Measurement Conditions

Reference Conditions

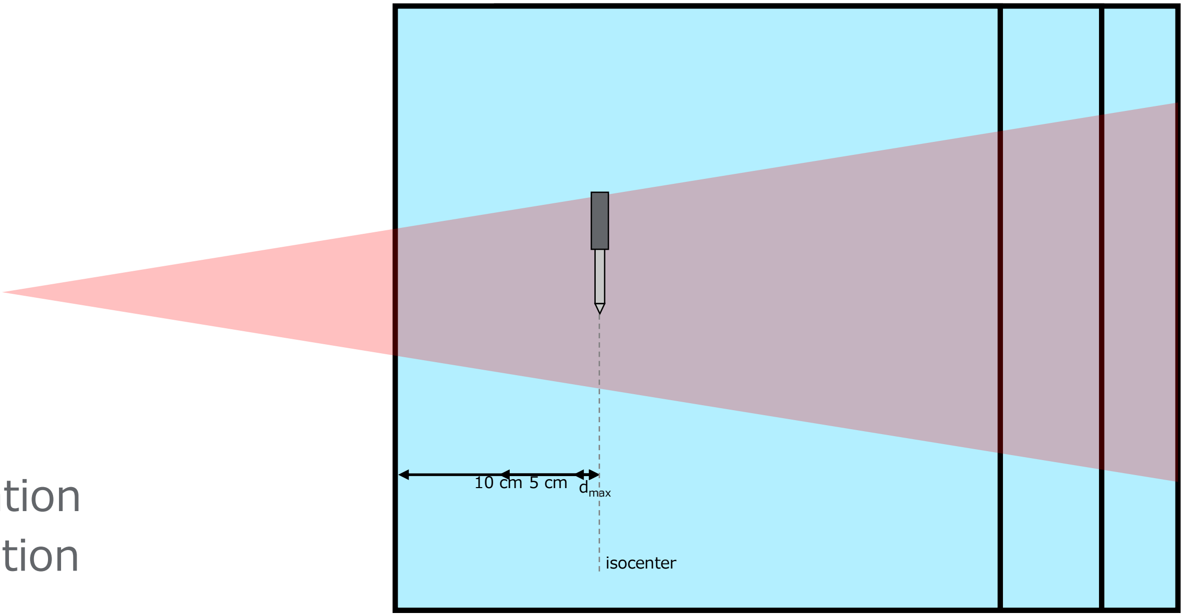
Gantry Angle

- ビームは液体ヘリウムを含む管腔を通過する。
- 管内のヘリウム充填レベルは、ガントリー0°での線量出力に影響を与える可能性がある。
  ※ 最大0.9%
- エレクタ はガントリー90°または270°で線量測定をすることを推奨する。
  - これにより、計画線量全体に対する全体的な影響が最小限に抑えられる。
- これには、水ファントムの側壁を照射する必要がある。
  - 壁の水等価深を考慮する必要がある。



Reference Conditions

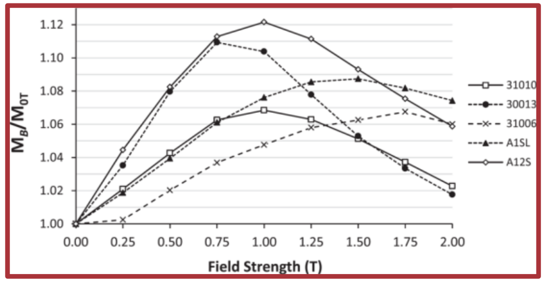
Calibration Depth



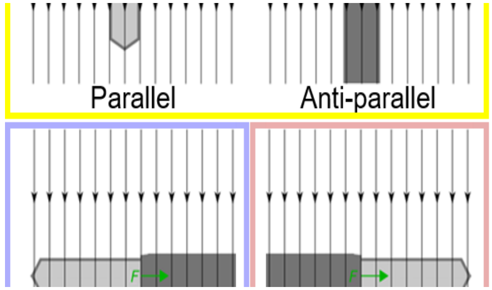
- 校正深度は重要な考慮事項
- 一般的なキャリブレーション条件は1cGy/MU
  - Isocenter @ depth d_{max} (1.3 cm)　※ recommendation
  - Isocenter @ depth 5 cm　※ recommendation
  - Isocenter @ depth 10 cm
- キャリブレーション深度が深いほど、出力が高くなり次のような結果になる。
  - より高いgun duty cycle (~99% for depth 10 cm)。これはマグネトロンに負荷がかかり、寿命を縮める可能性がある。
  - Monaco でのプランニングの際、MU/segの最小制約を満たすために、IMRTプランで生成するセグメントを減らし、プランの品質を制限する場合がある。

Absolute Dosimetry

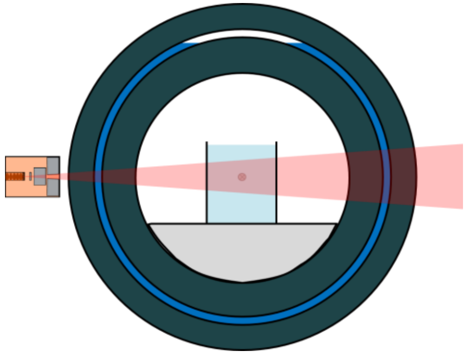
Review



線量測定は、磁場の影響を考慮する必要がある。



公開されている補正係数は存在するが、標準プロトコルは現在存在しない。



エレクタは、深さdmaxもしくは5cm、ガントリー90°(270°)で校正することを推奨する。

Thank you