CCRI webinar (September 12, 2023)

Small field dosimetry for MRgRT:
Performance of scintillators in presence of magnetic fields

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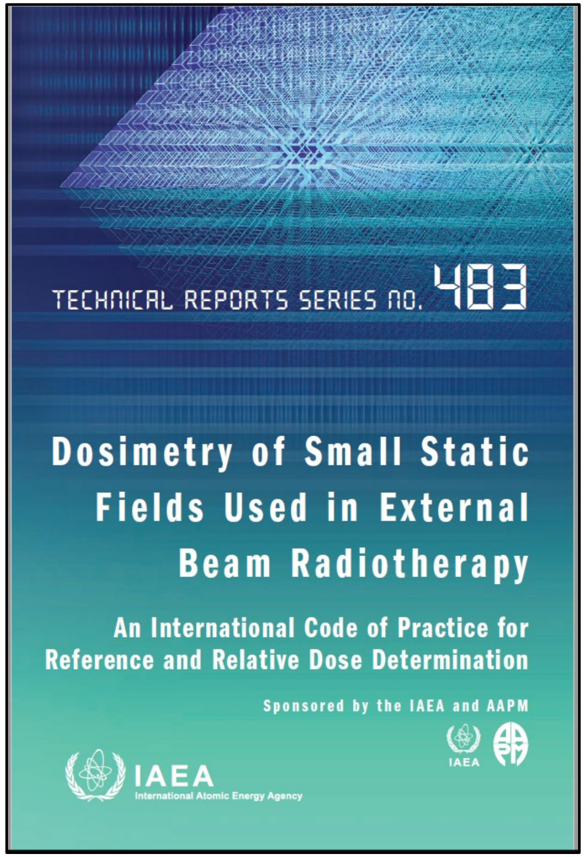
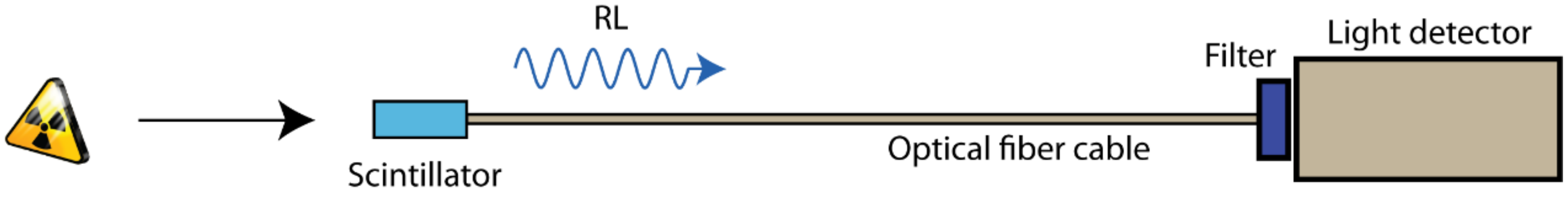
TRS-483





Main driver for scintillators:

Essentially perturbation-free

Time-resolved

Main application:

Short-term, relative dosimetry

TABLE 24. FIELD OUTPUT CORRECTION FACTORS $k^{f_{clin},f_{msr}}_{Q_{clin},Q_{msr}}$ FOR TOMOTHERAPY MACHINES, AS A FUNCTION OF THE EQUIVALENT SQUARE FIELD SIZE (cont.)

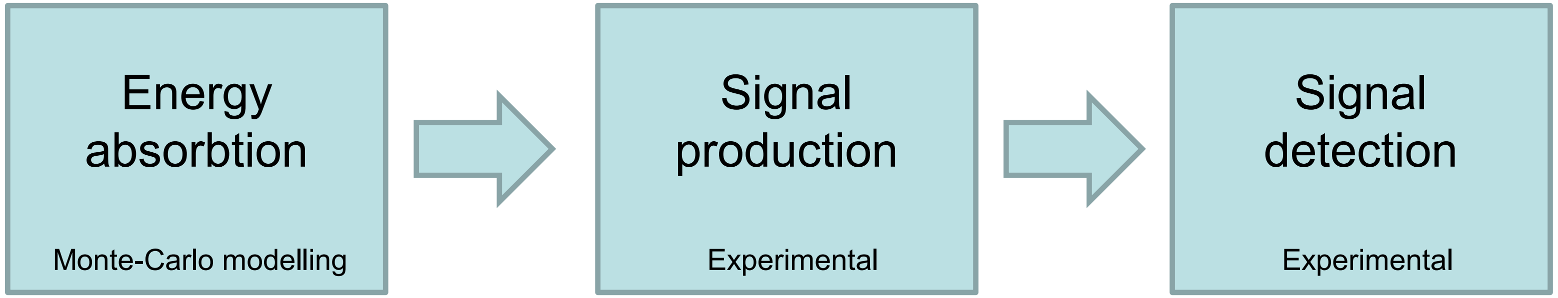
Detector	Equivalent square field size, S_{clin} (cm)												
	5.0	4.0	3.5	3.0	2.5	2.0	1.5	1.2	1.0	0.8	0.6	0.5	0.4
PTW 31018 liquid ion chamber	0.997	0.995	0.994	0.994	0.993	0.992	0.991	0.991	0.992	0.994	1.003	1.015	1.038
Sun Nuclear EDGE Detector	1.000	1.000	1.000	0.999	0.998	0.994	0.986	0.976	0.966	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

Note: The msr field is 5 cm × 10 cm and the reference depth is 10 cm.

Multiply by 1.000 !

The three-step dosimetry model **for organic plastic scintillator detectors**

Beam → Gy | Gy → Signal | Signal → Detection



Beam → Gy: x 1 for MV beams

Gy → Signal:

Quenching for low energy electrons

Temperature

Signal → Detection:

Stem signal

Fiber degradation

Fiber attenuation

The three-step dosimetry model for organic plastic scintillator detectors

Beam → Gy | Gy → Signal | Signal → Detection

Energy absorbtion — Monte-Carlo modelling → **Signal production** — Experimental → **Signal detection** — Experimental

x 1 for MV beams

Quenching for
low energy electrons

Temperature
S. Buranurak et al. (2013)
Wootton & Bedar (2013)

Stem signal

Fiber degradation

Fiber attenuation

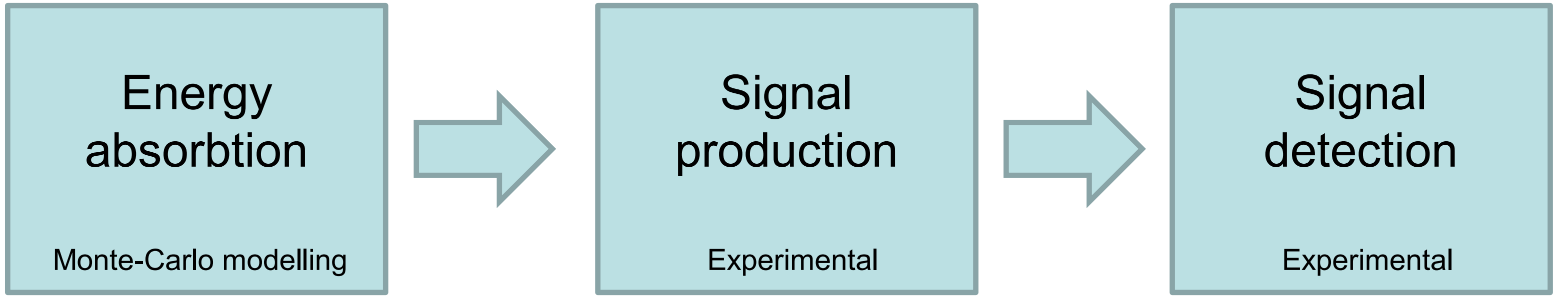
Grichar V. Santurio & C.E. Andersen: *Quantifying the ionization quenching effect in organic plastic scintillators used in MV photon dosimetry*. Rad. Meas. 2019.

Effect on field output factor meas.: (0.6 +/- 0.2)% k =1

Effect on k_Q measurements: (2.0 +/- 0.4)%

The three-step dosimetry model **for organic plastic scintillator detectors**

Beam → Gy | Gy → Signal | Signal → Detection



x 1 for MV beams

Quenching for
low energy electrons

Temperature

Light yield changes with magnetic field ?

Stem signal

Fiber degradation

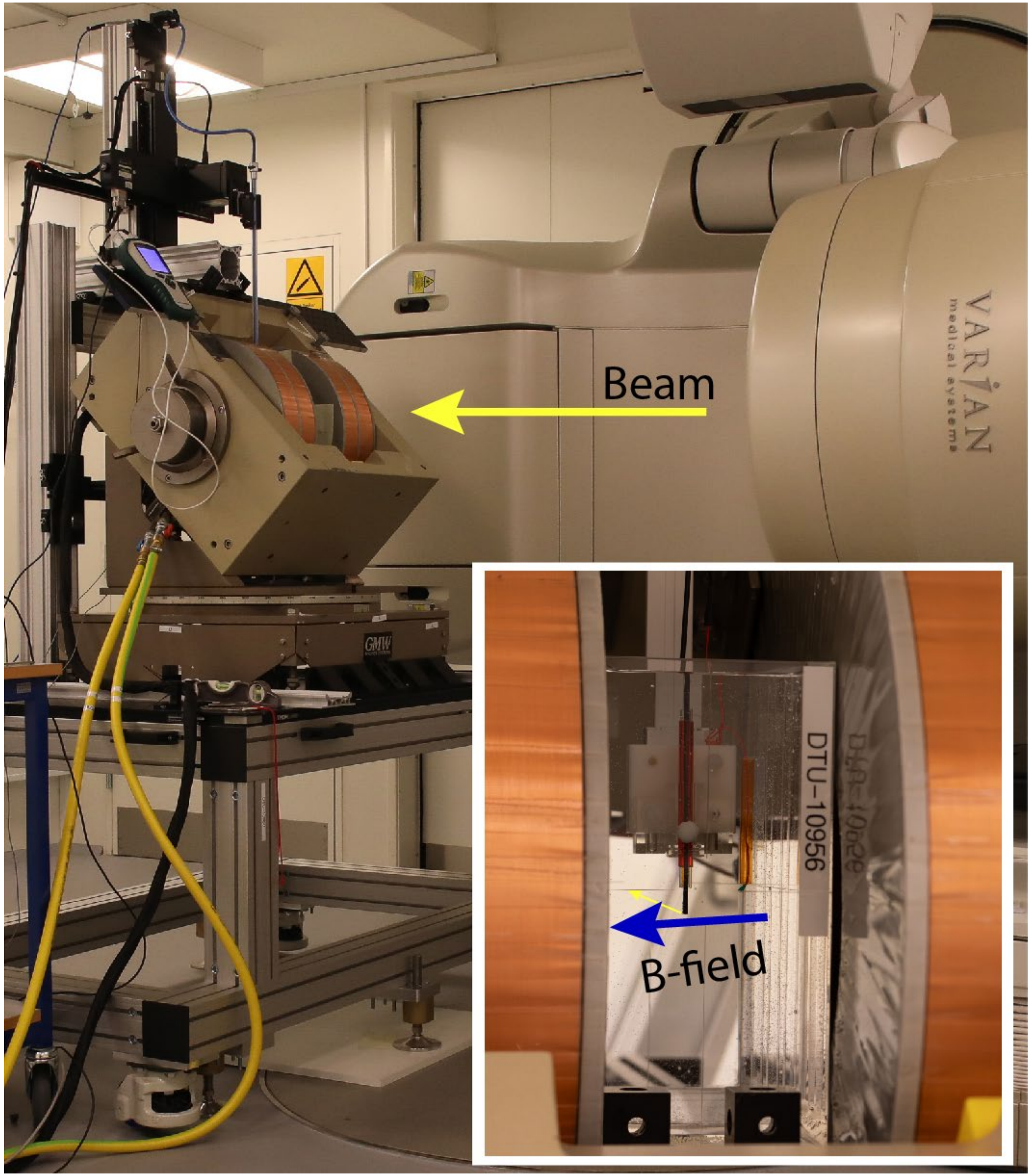
Fiber attenuation

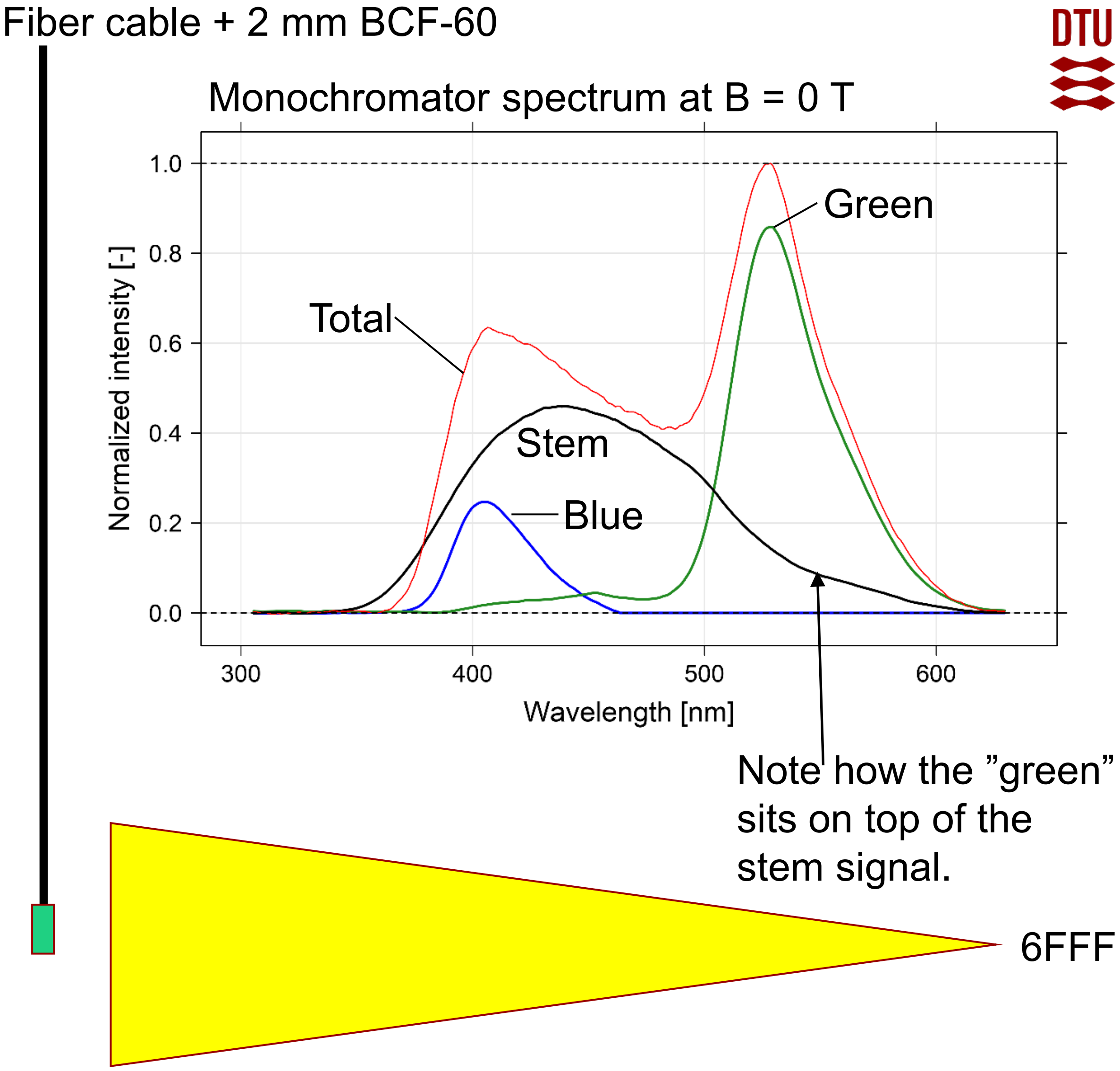
S. Stefanowicz et al.: *Dosimetry in clinical static magnetic fields using plastic scintillation detectors.* Rad. Meas. (2013).

E. Simiele et al.: *Spectral characterization of plastic scintillation detector response as a function of magnetic field strength.* Phys. Med. Biol. (2018).

F. Therriault-Proulx et al.: *Effect of magnetic field strength on plastic scintillation detector response.* Rad. Meas. (2018).

Issues: dose, stem, temperature



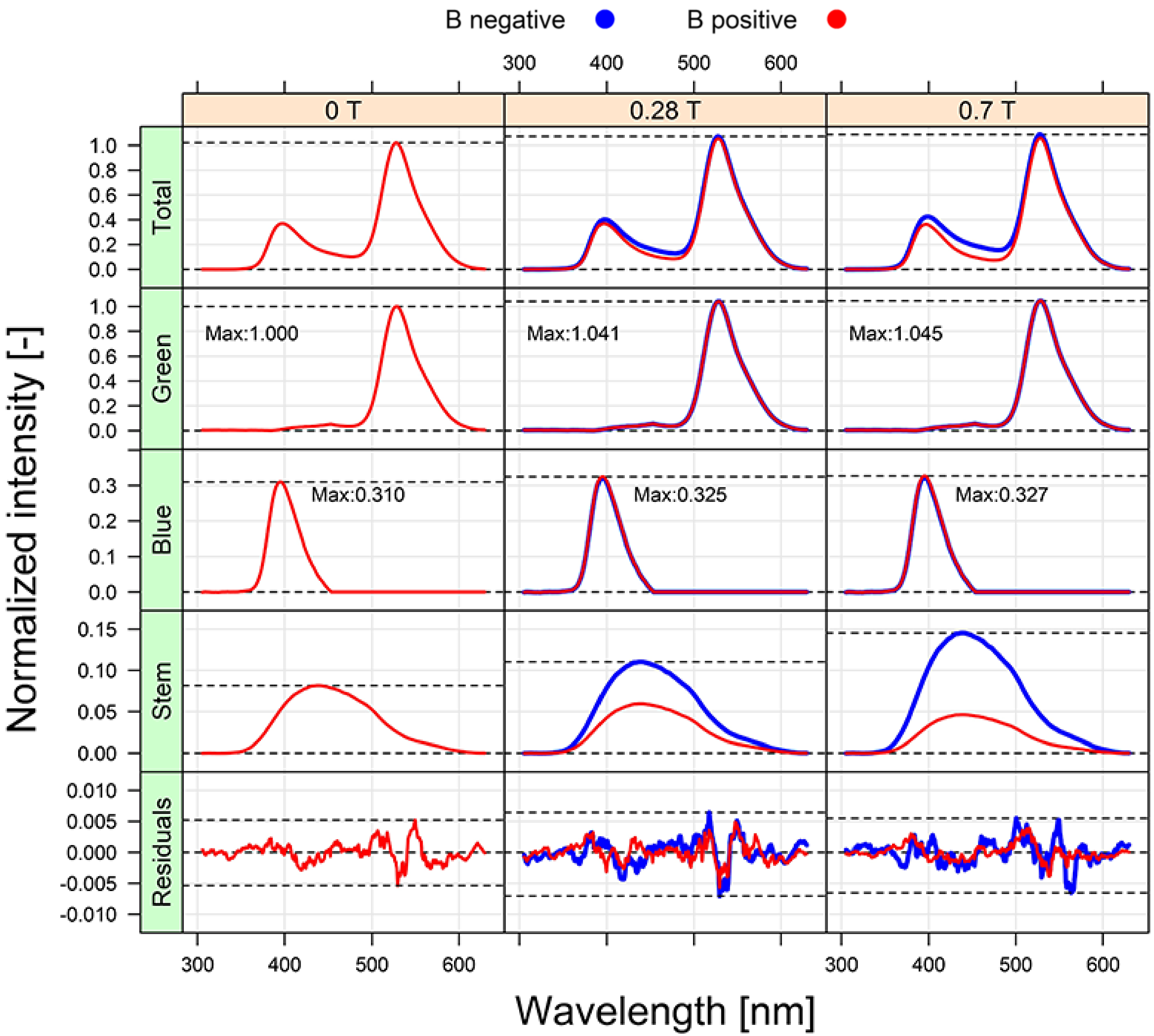


Extended distance to linac source: 180 cm

Transverse magnetic field

Lorentz force on electrons mainly down (B pos.) or up (B neg.)

Measurements in electromagnet



Field size :
Nominal 50 mm x 50 mm

Beam:
10FFF

Scintillator:
10 mm BCF-60

Orientation:
Perpendicular to beam

Full separation of green and stem.

Clear effect of magnetic field on scintillator light yield.

Vertical scans in electromagnet

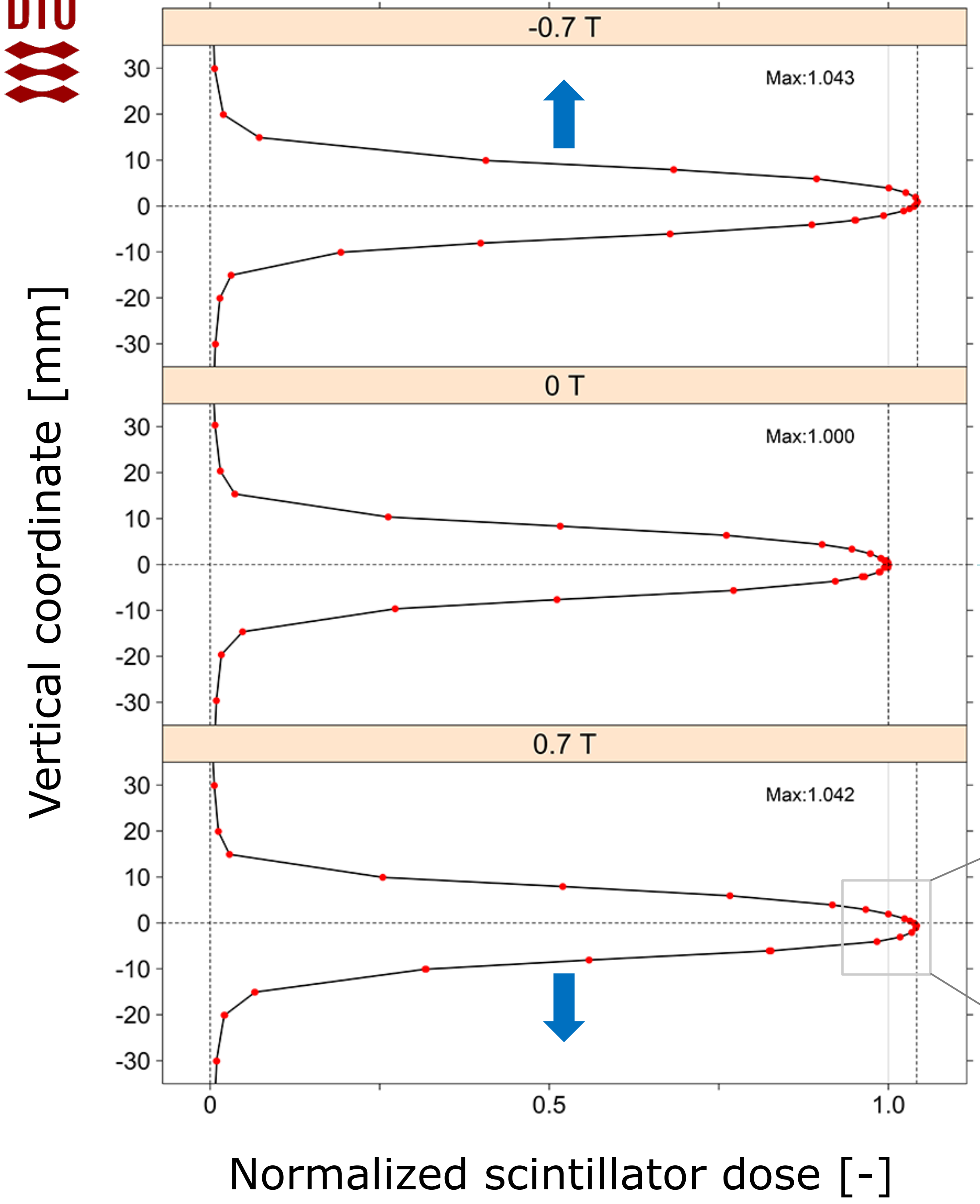
Field size : Nominal 10 mm x 10 mm

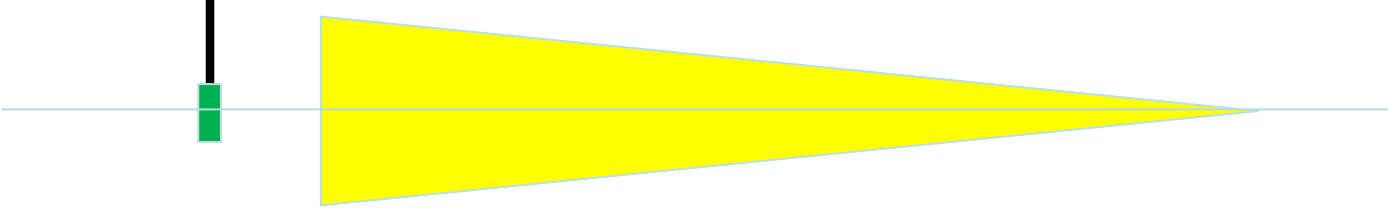
Beam: 6FFF

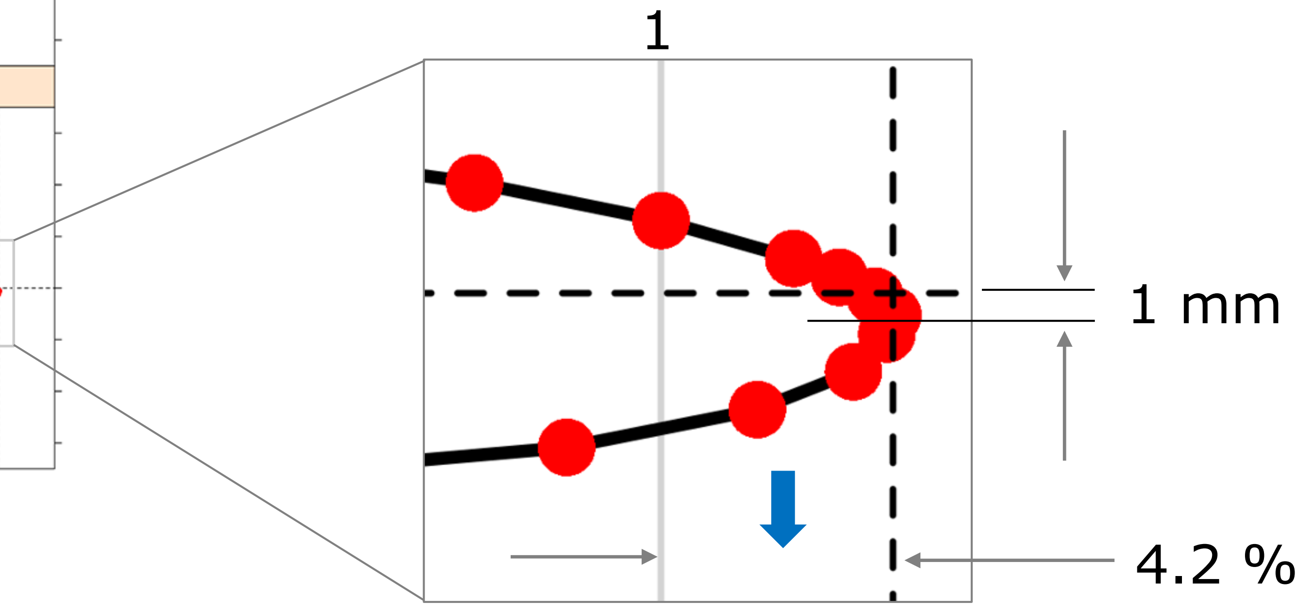
Scintillator: 2 mm BCF-60

Orientation: Perpendicular to beam

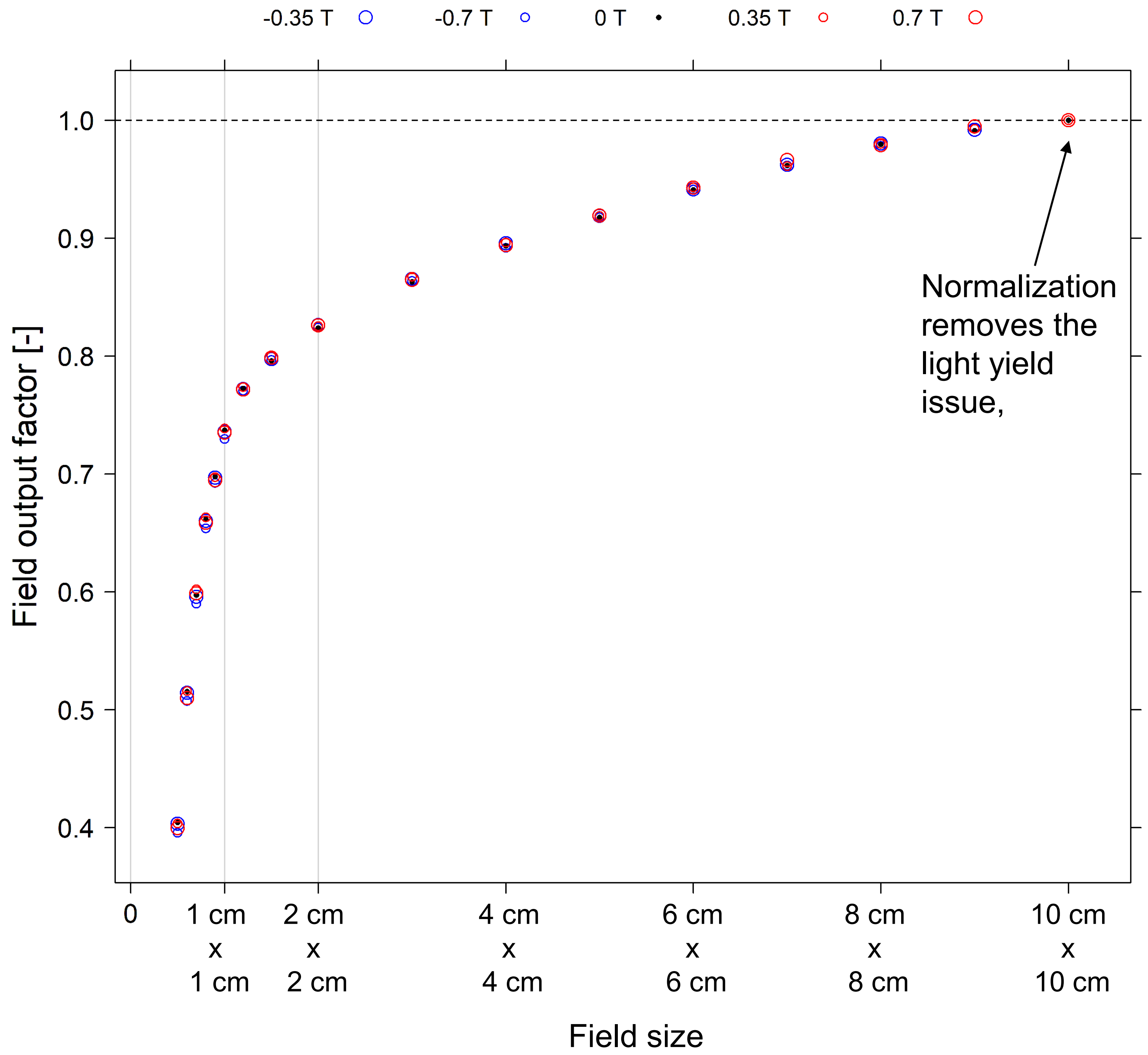
Stem removal: Two-channel chromatic (ME40)







Scintillator based field-output factor measurements in electromagnet at dose maximum



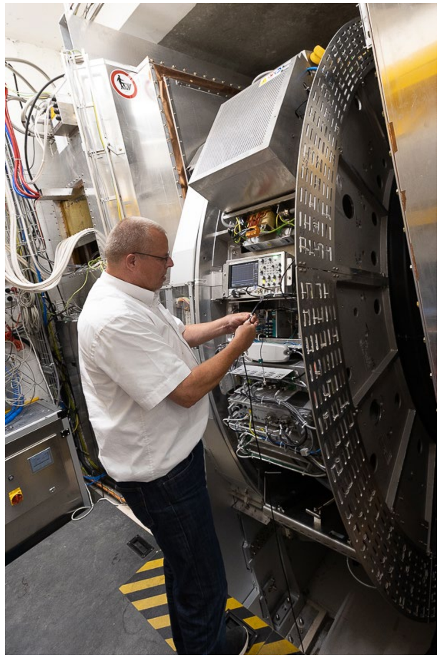
6FFF beam

There is no significant change in field-output factors when measured at the maximum dose point.

The scintillator measurements show that the main effect of the magnetic field is that the maximum dose point is moved.

Scintillator-based field output factor measurements in MR linacs at five hospitals

University Hospitals: Heidelberg, Herlev, Odense, Rigshospitalet, and Zürich.

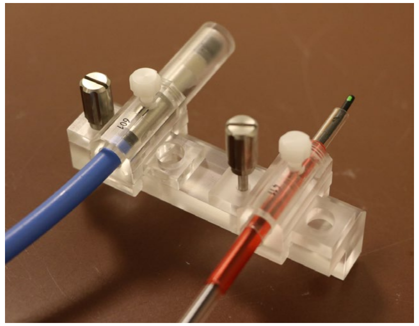


Uncertainty budget for field-output factor measurement in MR linac
at 0.5 cm x 0.5 cm relative to 10 cm x 10 cm.

	Type A	Type B
Reproducibility*	0.1 %	
Stem signal correction		0.48 %
Attenuation correction		0.10 %
Position		0.91 %
Calibration		0.07 %
Ionization quenching		0.61 %
Combined uncertainty (k=1)	1.2 %	

*MR-linac dependent

Dose-per-pulse measurements ME40 scintillator system (DTU)

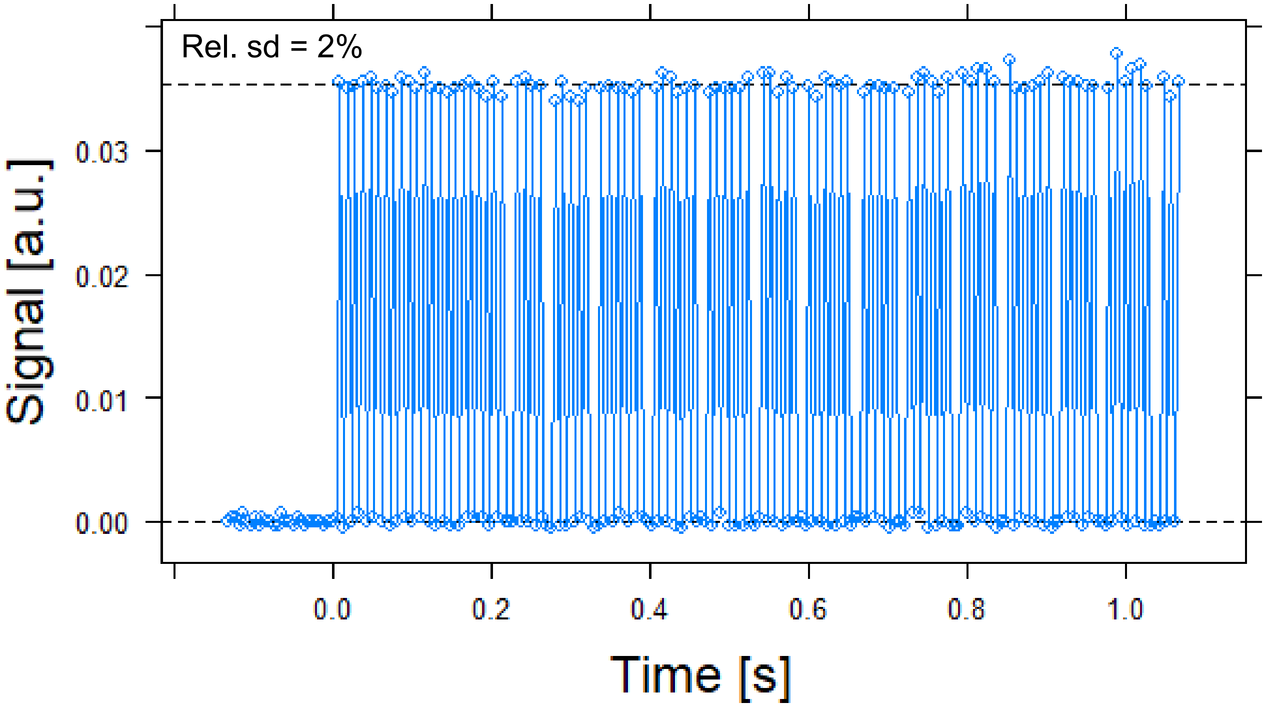


Scintillator ø1 mm

Sync

Gun pulse

DPP green & blue ch.

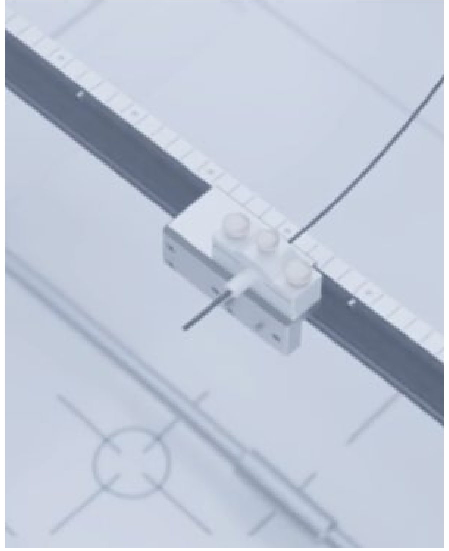


Where we use the high time resolution:

Klavsen et al.: *Time-resolved plastic scintillator dosimetry in MR linear accelerators without image distortion. Rad. Meas. (2022).*

Klavsen et al.: *Accumulated dose implications from systematic dose-rate transients in gated treatments with Viewray MRIdian accelerators. Biomed. Phys. Eng. Express (2023).*

STANDARD IMAGING

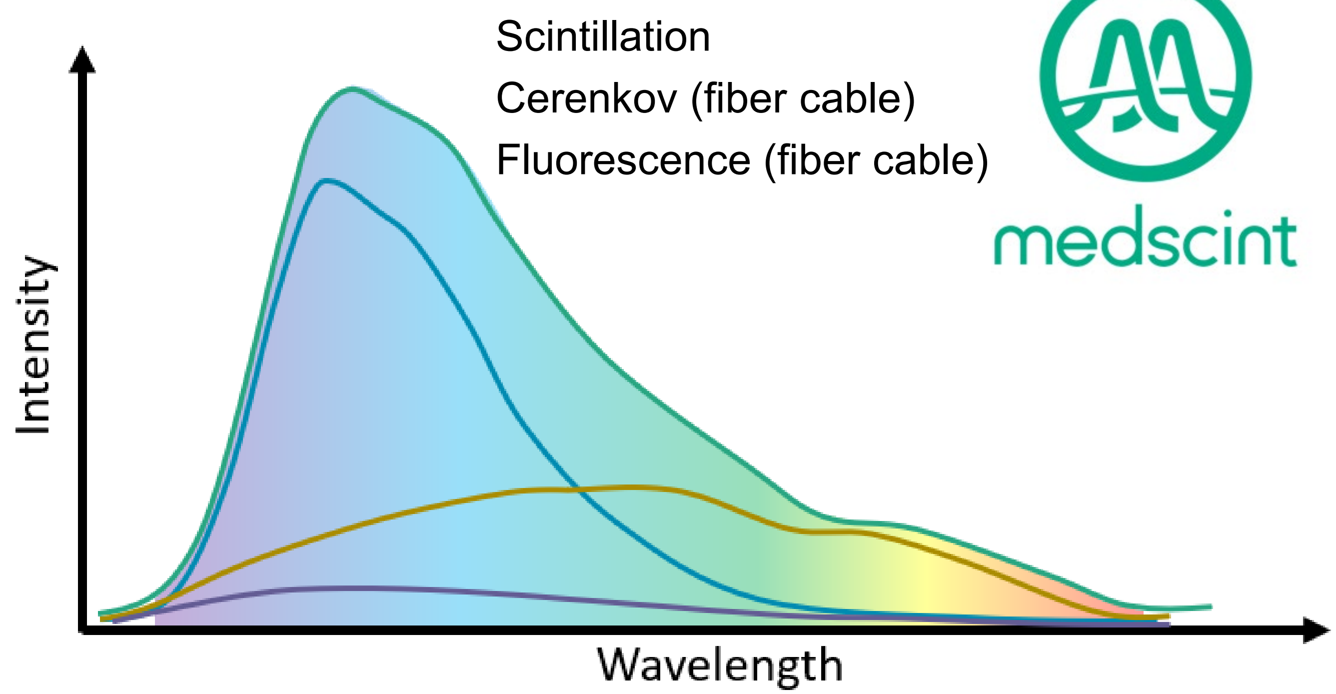


Exradin® W2 Scintillator

Measurement without perturbation

Yoon et al:
Characteristics of the Exradin W1 scintillator in the magnetic field.
Rad. meas. (2019).

HYPERSCINT™
Research Platform



medscint

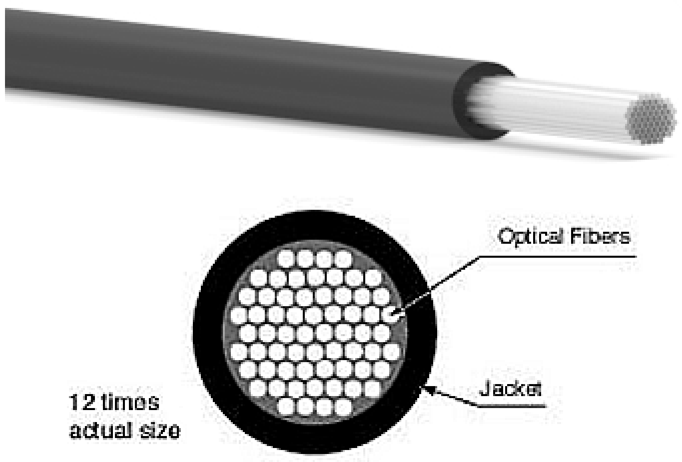
Hyperspectral detection

Complete stem effect removal
Can account for all physical process

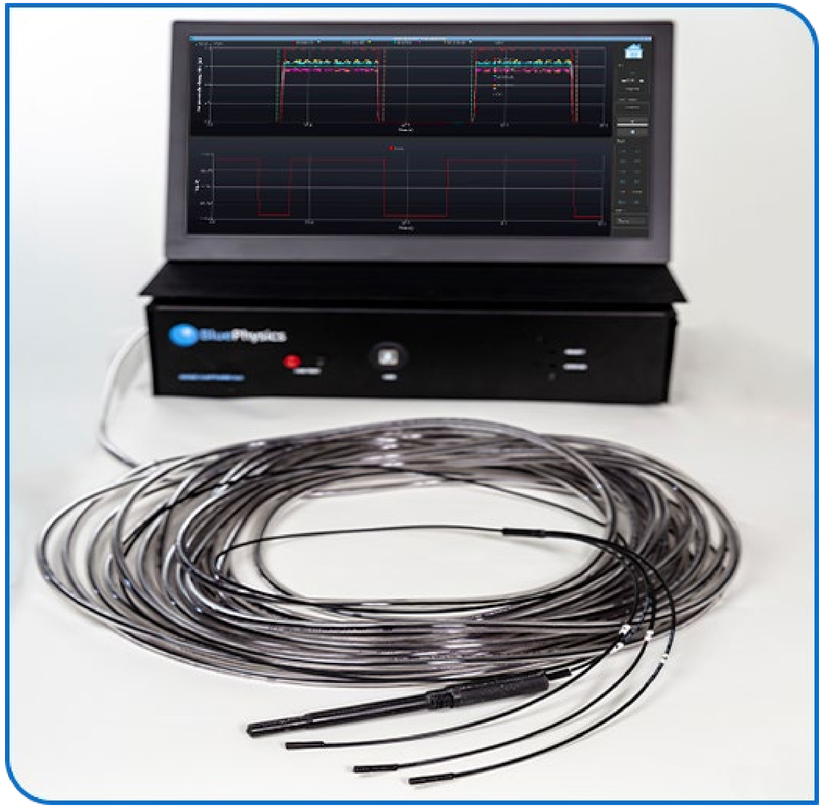
Spectral unmixing of the different sources of light

Prescilla Uijtewaal et al. :
Performance of the HYPERSCINT scintillation dosimetry research platform for the 1.5 T MR-linac.
Phys. Med. Biol. (2023).

BluePhysics

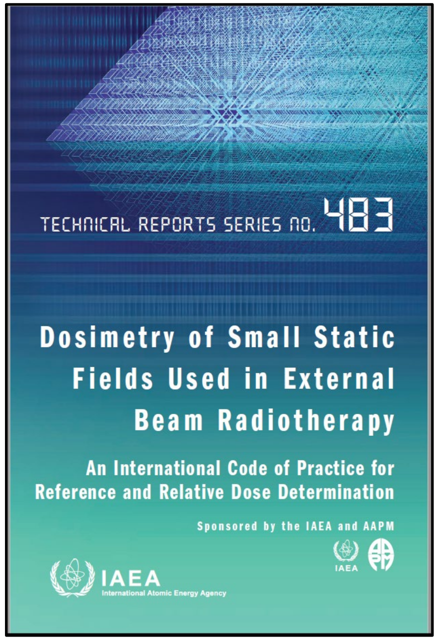


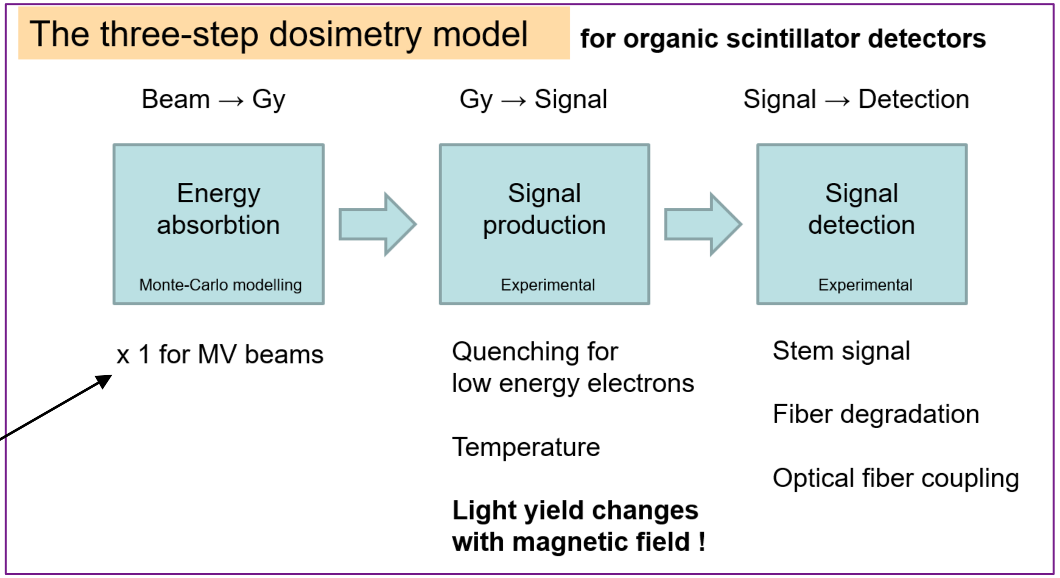
Sectional View



Carlos Ferrer et al.:
Dosimetric characterization of a novel commercial plastic scintillation detector with an MR-Linac.
Medical Phys. (2023).

Performance of scintillators in presence of magnetic fields





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- Magnetic field affects the light yield from BCF-60. Important in non-constant B-field situations.
- No change of stem or scintillator spectra thereby supporting the use for the chromatic stem removal technique (both two-channel and based on full spectra information).
- Scintillator measurements support that the field-output factor at the maximum dose point is not significantly changed by the magnetic field.
- Improved uncertainty budget for scintillator based field-output factor measurements.
- Scintillator based field-output factor measurements at five MR linacs.