EMPIR project 18NRM02 PRISM-eBT: WP3 progress report – December 2021

Thorsten Sander

Web meeting on 14 December 2021

Activities 3.1.x for PTB and AU

(pptx-slides prepared by Rolf Behrens, Thorsten Schneider, Jaroslav Šolc and Peter Georgi)

A1.2.1 (Dec 20) – Compile list of suitable transfer instruments for $D_{w,1cm}$ measurements, select at least 2 small volume ionisation chambers

A3.1.1 (Dec 20) – Characterisation & calibration of at least 3 detectors (1 scintillator fully characterised by AU), 2 ionisation chambers and 1 diamond detector

A3.1.2 (Mar 21) – Development of a standardised traceable calibration process for commercially available small volume ionisation chambers at distances > 3 cm; results to be included in DIN 6803-3; *Monte Carlo simulations and measurements in water in progress for determination of correction factors*

A3.1.3 (Aug 21) – Determination of system specific quality correction factors for at least 3 different detectors (1 scintillator fully characterised by AU)

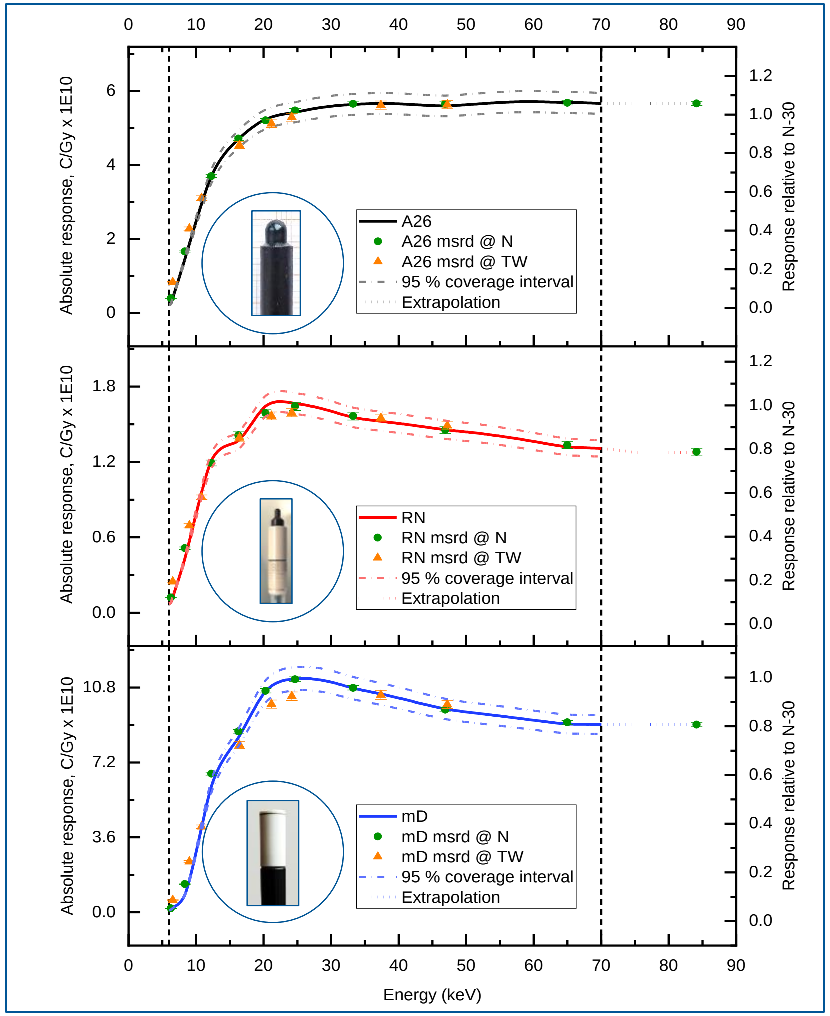
A3.1.4 (Feb 22) – Developm. of a stand. traceable calibr. process for scintillation and diamond detectors; results to be included in DIN 6803-3; *see MC information above*

A3.1.5 (Aug 22) – Summary report on A3.1.1 to A3.1.4.

A3.3.6 (Dec 22) – Good Practice Guide (based on summary reports A3.x.5)

WP3 progress (PTB)
A3.1.1 (Dec 20) continued…

- The air kerma response of 3 small detectors was measured at low energy photon beams
- For the overall response all the calibration qualities (narrow and wide) are considered simultaneously using a Bayesian approach
- A paper on their suitability for eBT dosimetry has been submitted to PMB



Submitted for publication

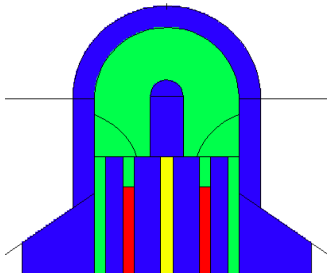
WP3 progress (PTB, CMI)

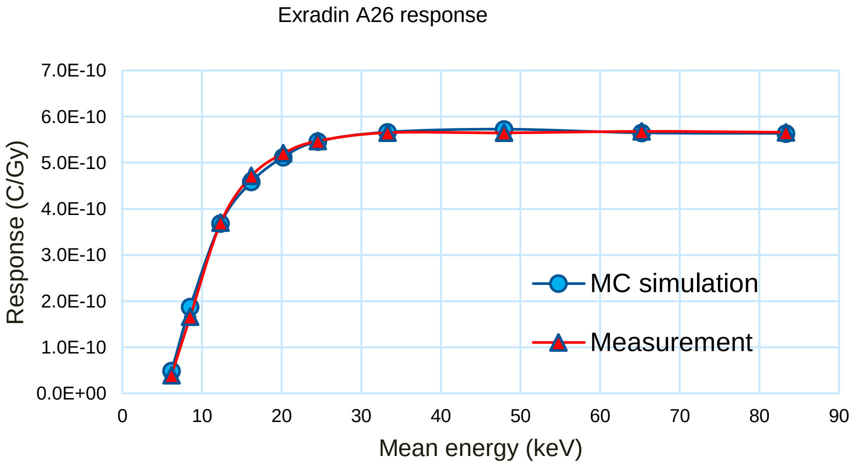
A3.1.3 (Aug 21) - Determination of system specific quality correction factors

- Monte Carlo simulations (by Jaroslav Šolc, CMI) of the detectors in order to determine correction factors to convert the detector responses measured in terms of air kerma to absorbed dose to water

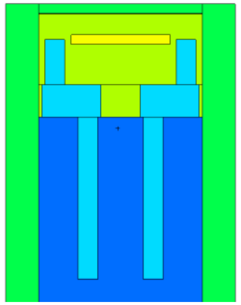
- The MCNP models of 2 detectors were validated with the response measured in air at PTB

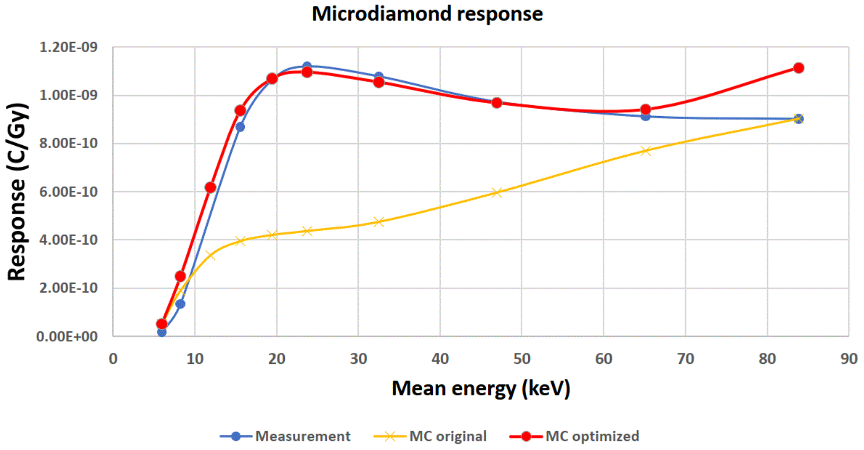
A26





microDiamond





(Images from Jaroslav Šolc, CMI)

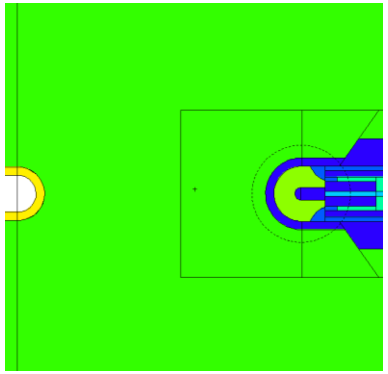
WP3 progress (PTB, CMI)

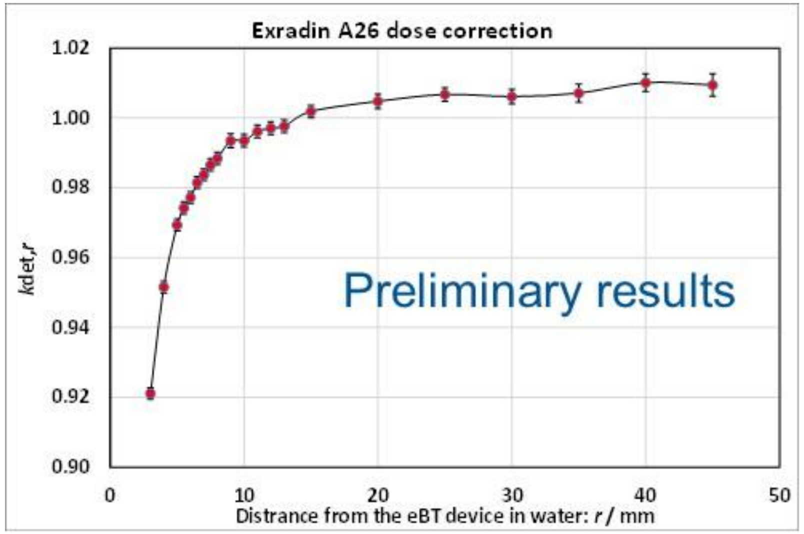
A3.1.3 (Aug 21) - Determination of system specific quality correction factors

- Monte Carlo simulations (by Jaroslav Šolc, CMI) of the detectors in order to determine correction factors to convert the detector responses measured in terms of air kerma to absorbed dose to water

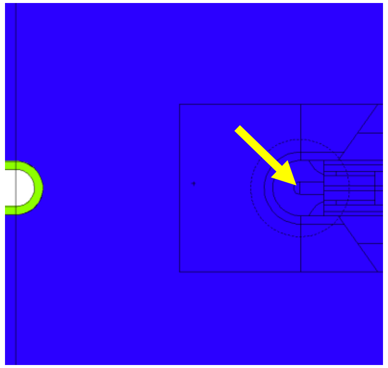
- Simulations in water using eBT spectra are ongoing to determine detector specific correction factors

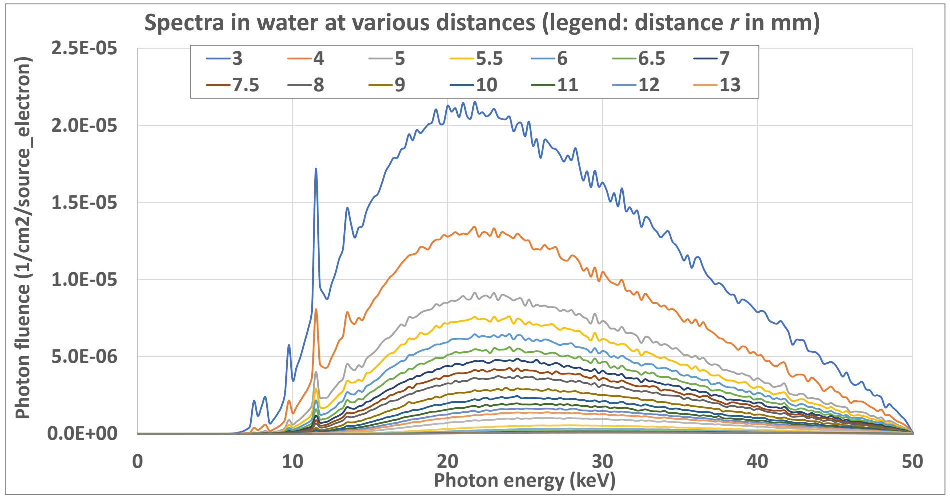
A26 in air





A26 in/as water





(Images from Jaroslav Šolc, CMI)

WP3 progress (AU)

A3.1.1 (Dec 20)

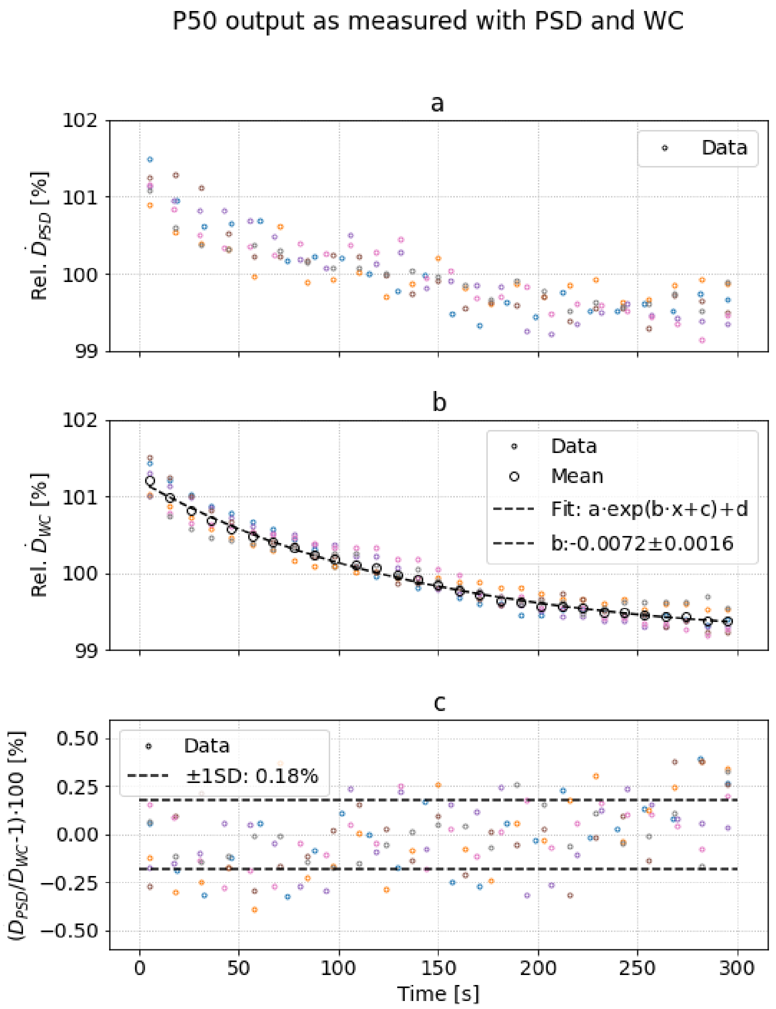
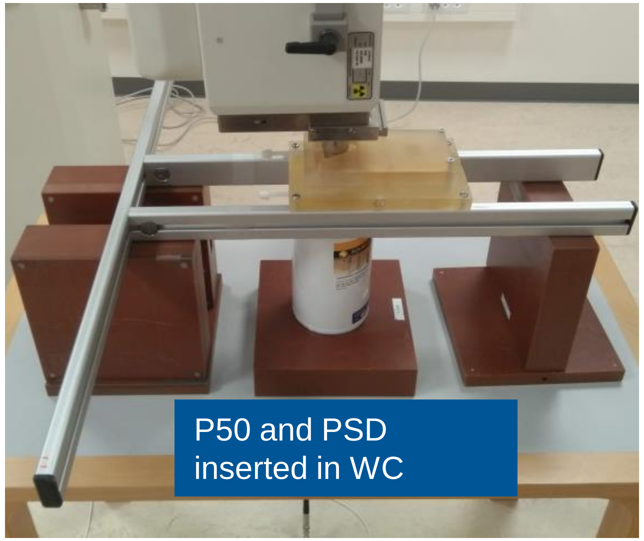


Fig.1: P50 output temporal stability measured with PSD and WC

- **Detector characterisation:**
  1. Irradiate PSD and WC simultaneously for 300 s at P50 current 2.7 mA (clinical current). Gives temporal variation of P50 and stability of PSD, fig. 1.
  2. Vary current between 0.3 mA and 3 mA and thereby vary dose-rate. Irradiate for 60 s. Compare PSD to WC to gain PSD stability and efficiency at varying dose-rates. Response drops linearly with increased dose-rate (fig. 3)!



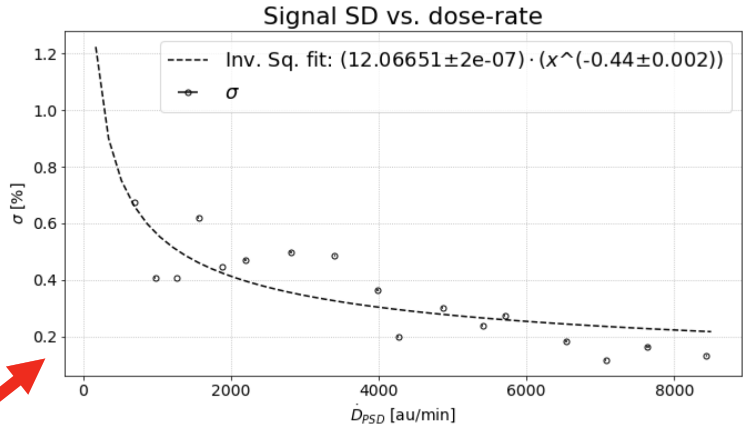


Fig. 2: Uncertainty of PSD signal vs. measured dose-rate

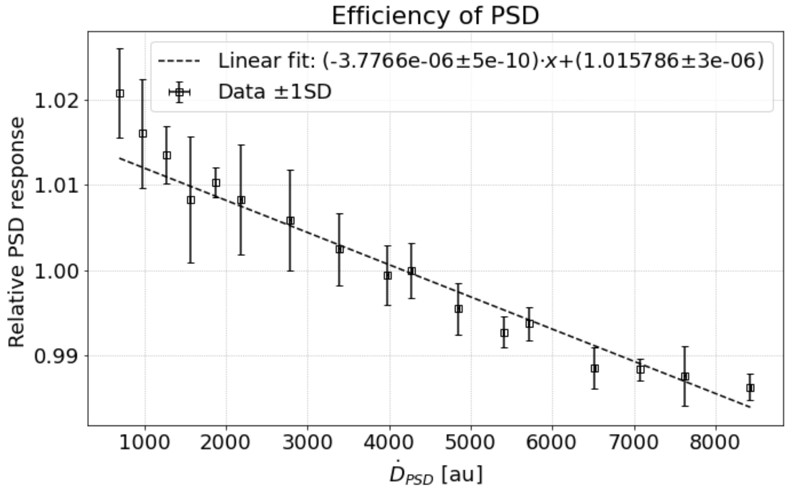


Fig. 3: Relative efficiency of PSD vs. dose-rate, $\dot{D}_{PSD}/\dot{D}_{WC}$

PRISM-eBT

WP3 progress (AU)

A3.1.1 (Dec 20)

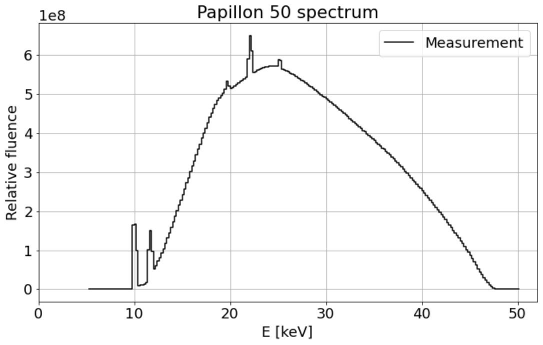


Fig. 4: P50 spectrum.

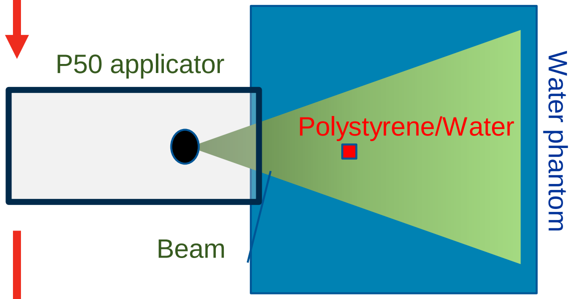


Fig. 5: Monte Carlo set-up sketch.

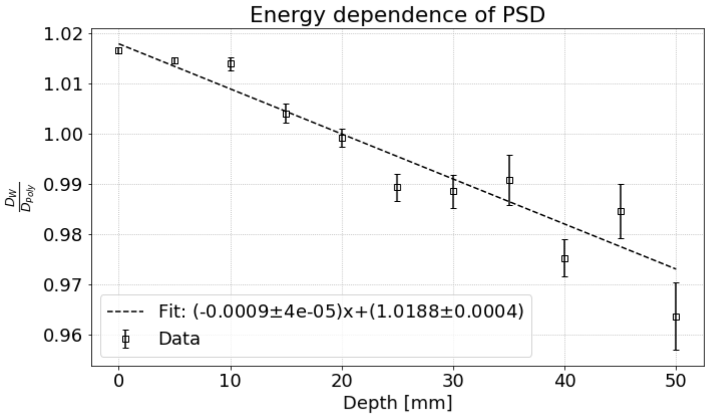


Fig. 6: Ratio of scored dose to water and polystyrene normalised at 20 mm depth.

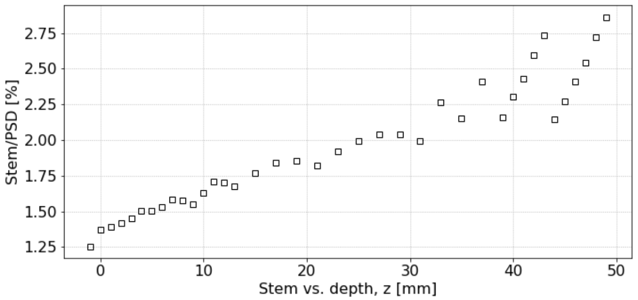
System specific characterisation:

1. Energy-dependence:

Obtained with TOPAS(Geant4) Monte Carlo simulation using P50 spectrum from PRISM-eBT catalogue measured by Jaroslav Šolc and Gustavo Kertzscher.

2. Stem-effect:

Obtained (and removed) with dummy probe without scintillating fibre. 1-3 % inside profile edges, 5-17% around edges and undetectable outside edges.



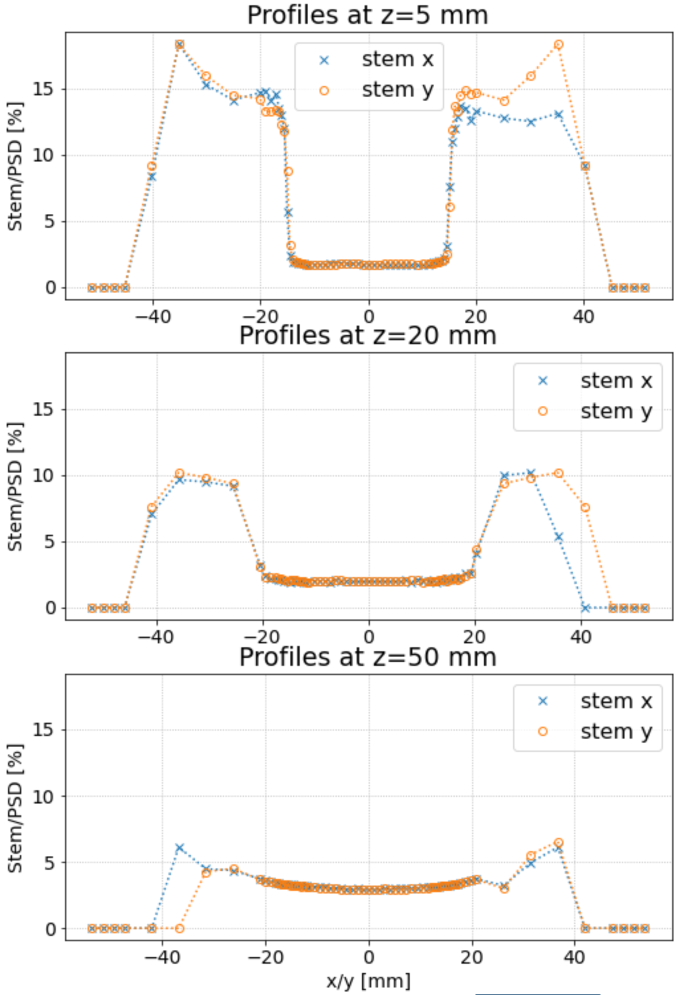


Fig. 7: Stem-effect contribution to measured signal along applicator central axis (top) and along profiles (rest).

WP3 progress (AU)
Continued…

- Uncertainty of reported dose (relative): $D_{PSD}=((S_{PSD}*L(\dot{S}_{PSD})- S_{BG1})-R_{PSD/BF}*(S_{BF}-S_{BG2}))*E.$

Term	Description	Relative uncertainty contribution [%]
S_{PSD}	The raw signal from the PSD.	1.3
L	Dose-rate response correction factor.	1.7
$R_{PSD/BF}$	Normalisation factor for stem-effect in PSD and BF probe.	0.4
S_{BF}	The signal from the BF probe.	0.4
S_{BG1}	The background signal when measuring with PSD. Undetectable in current setup, and therefore set to the minimally detectable value.	0.5
S_{BG2}	The background signal when measuring with the BF probe. Undetectable in current setup, and therefore set to the minimally detectable value.	0.5
E	The energy-correction factor.	0.8
D_{PSD}	Conservative estimate of total uncertainty ($\sqrt{\Sigma\sigma^2}$)	2.5

Submitted to Medical Physics

3D Dose verification of an electronic brachytherapy source with a plastic scintillation detector

Dosimetry for electronic brachytherapy

Peter Georgi[a*)], Gustavo Kertzscher[b)], Lars Nyvang[b)], Jaroslav Šolc[c)], Thorsten Schneider[d)], Kari Tanderup[a, b)], Jacob Graversen Johansen[a, b)]

a) *Department of Clinical Medicine, Aarhus University, Aarhus, Denmark*
b) *Department of Oncology, Aarhus University Hospital, Aarhus, Denmark*
c) *Czech Metrology Institute, Brno, Czech Republic*
d) *WG 6.34 "Dosimetry for Brachytherapy and Beta Radiation Protection", Physicalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany.*

Activities 3.2.x for CEA

(pptx-slides prepared by Valentin Blideanu)

NPL National Physical Laboratory
EURAMET

A1.1.4 (Feb 22) – Development of $D_{w,1cm}$ primary standards for eBT

A3.2.1 (Jun 20) – Determination of the effect of ageing of the Fricke gel on the dose sensitivity

A3.2.2 (Dec 20) – Monte Carlo calculations of absorbed dose and mean energy profiles in gel phantoms when irradiated in eBT-equivalent X-ray beams

A3.2.3 (Dec 20) – Experimental determination of correction factors for distortions in the MRI signal when reading out the Fricke gel dosimeter

A3.2.4 (Dec 21) – Calibration of the Fricke gel dosimeter in reference beam equivalent to INTRABEAM system with 40 mm diameter applicator (scheduled for end 2021)

A3.2.5 (Jan 22) – Summary report on A3.2.1 to A3.2.4.

A3.3.6 (Dec 22) – Good Practice Guide (based on summary reports A3.x.5)

A4.1.6 (Dec 21) – Measurement of 3D D_{gel} dose distributions close to INTRABEAM system with 40 mm diameter applicator and conversion to absorbed dose to water

PRISM-eBT

WP3 progress (CEA)

A3.2.2 (Dec 20)

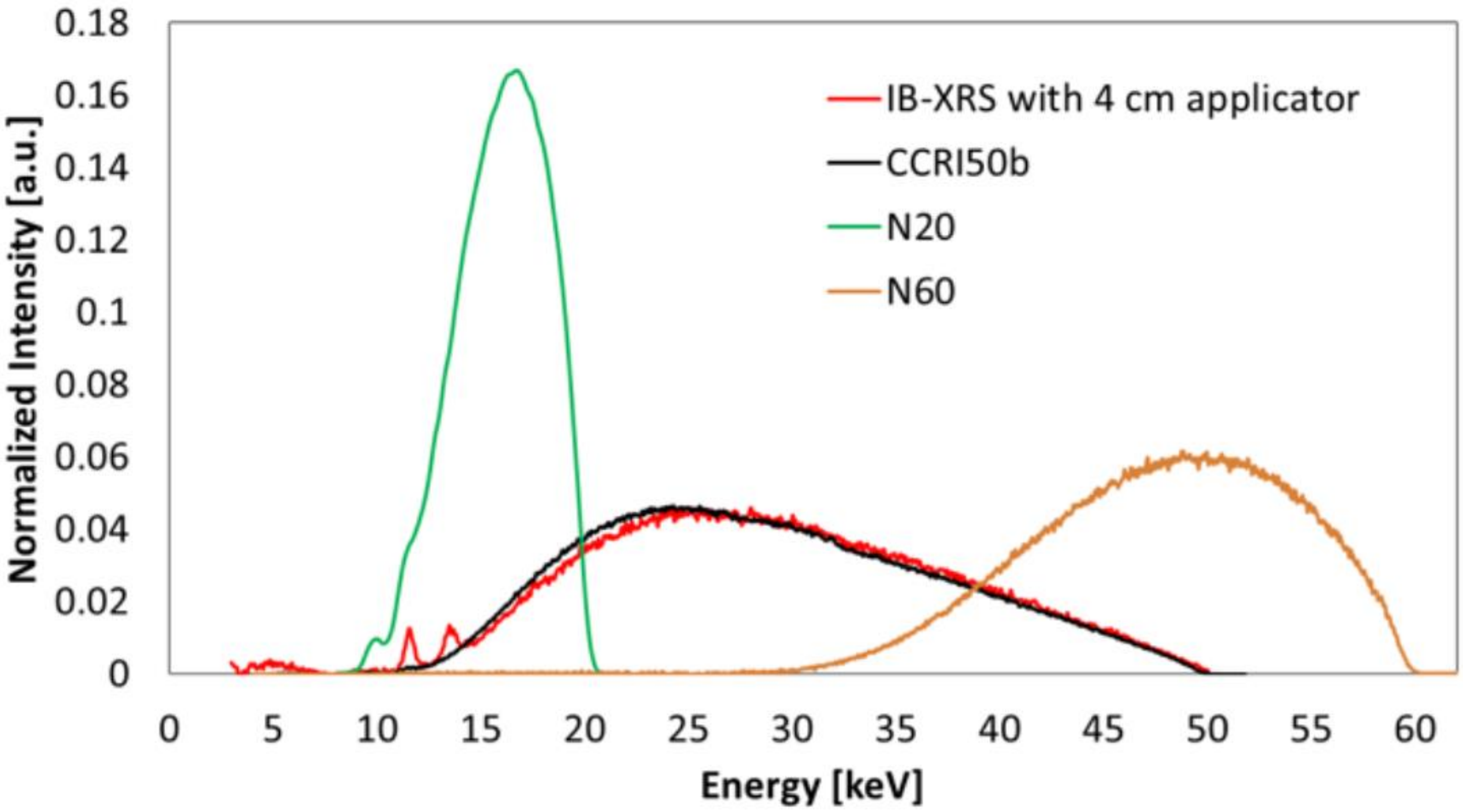


Fig. 8: INTRABEAM equivalent beam (IB-XRS) compared to existing normalized beam qualities

WP3 progress (CEA)
A3.2.2 (Dec 20) continued…

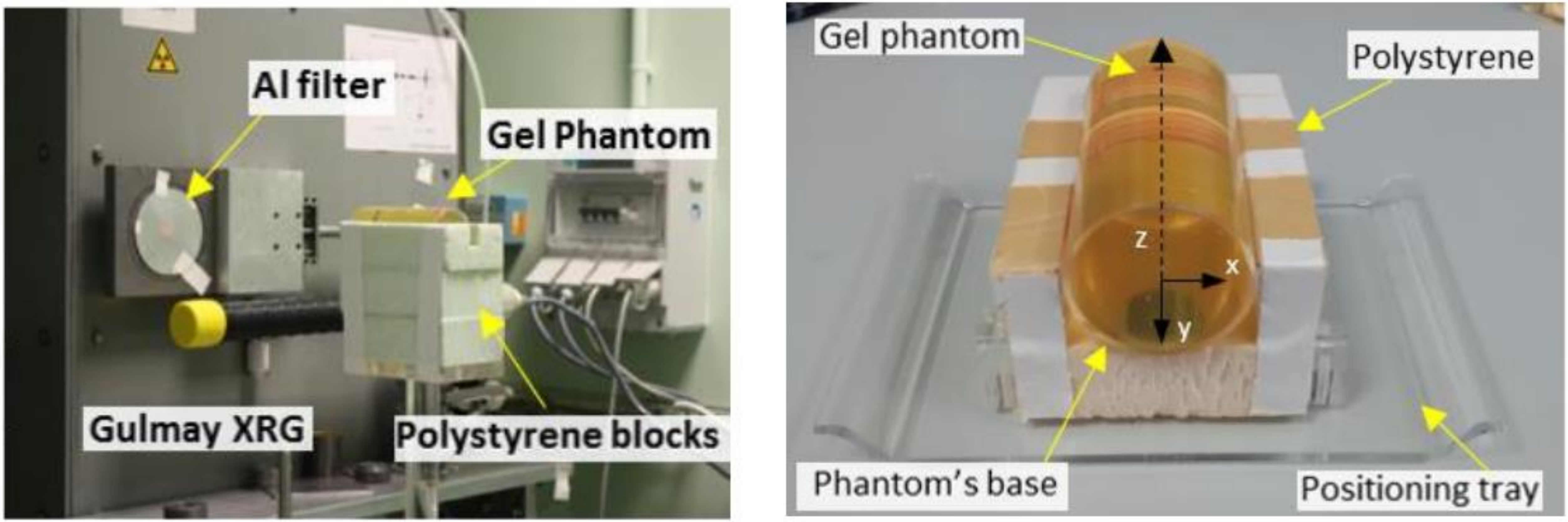
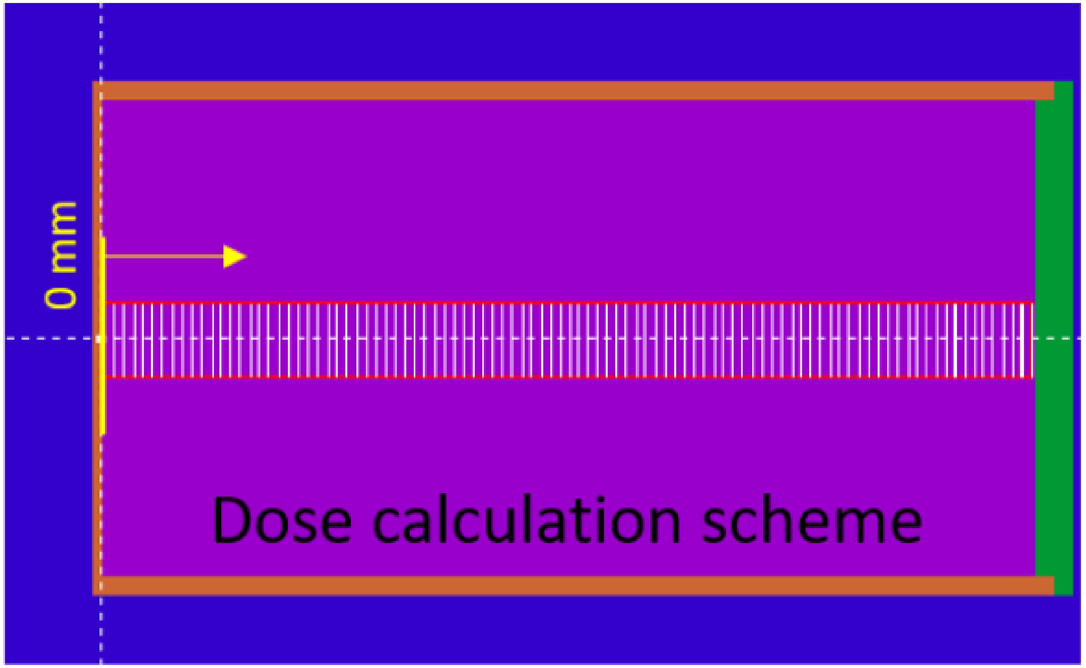


Fig. 9: Experimental set-up for gel irradiation

WP3 progress (CEA)

A3.2.2 (Dec 20) continued…



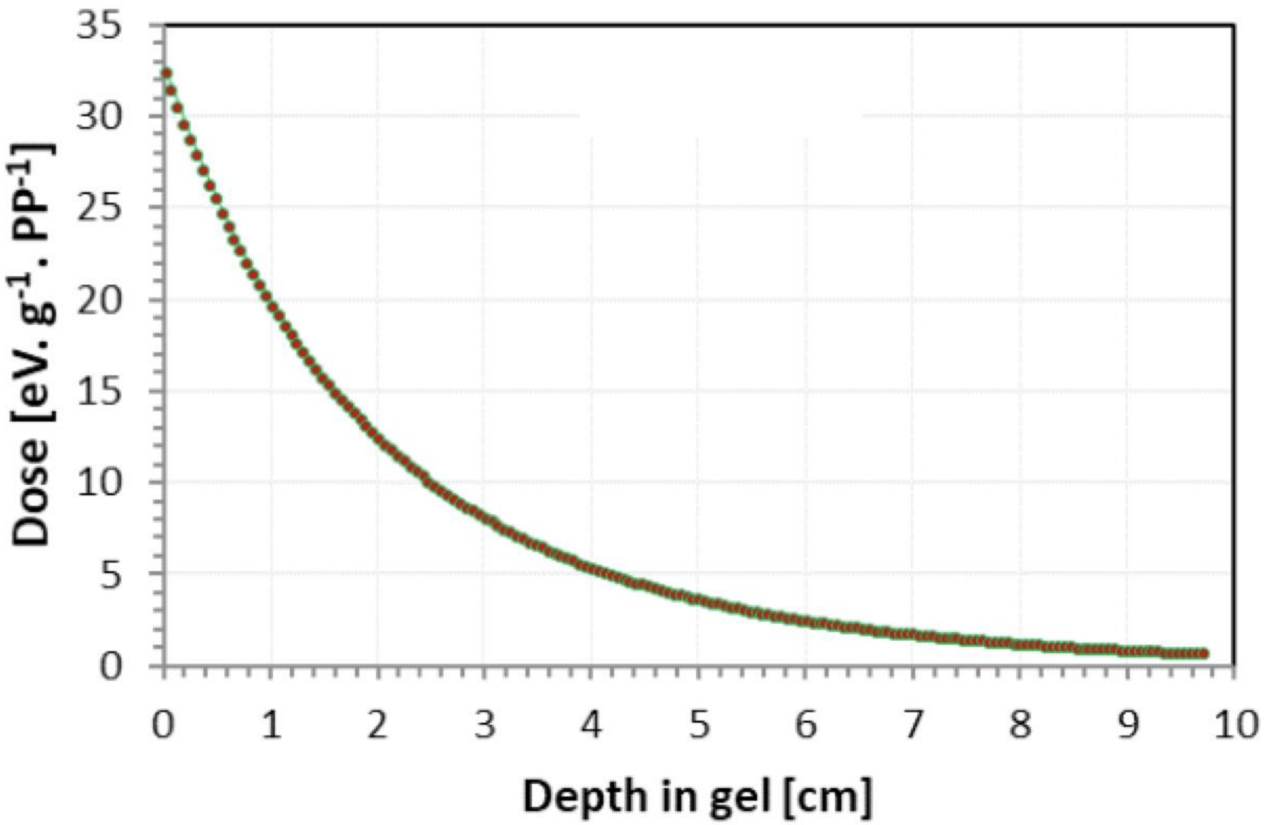


Fig. 10: Monte-Carlo model and calculation of absorbed dose distribution in gel phantom

Activities 3.3.x for NPL

(pptx-slides prepared by Anna Subiel and Thorsten Sander)

NPL National Physical Laboratory

EURAMET

A1.1.4 (Feb 22) – Development of $D_{w,1cm}$ primary standards for eBT

A3.1.5 (Aug 22) – Summary report on A3.1.1 to A3.1.4.

A3.2.5 (Jan 22) – Summary report on A3.2.1 to A3.2.4.

A3.3.1 (Nov 21) – Measurement of k_Q factors for eBT X-rays (using mono-E synchrotron radiation)

A3.3.2 (Nov 21) – Monte Carlo calculated k_Q factors for alanine for eBT X-rays

A3.3.3 (Dec 21) – Determine system specific quality correction factors for alanine (specific eBT source spectra from **CMI**, **MAASTRO clinic**, **PTB**)

A3.3.4 (Jul 22) – Write a paper on A3.3.1 to A3.3.3 and submit to peer-reviewed journal

A3.3.5 (Aug 22) – Summary report on A3.3.1 to A3.3.4.

A3.3.6 (Dec 22) – Good Practice Guide (based on summary reports A3.x.5)

A4.1.2 (Jun 22) – D_w dose distribution measurements close to INTRABEAM (with & without applicator) and Papillon 50

A5.1.7 (Dec 22) – Submission of paper (A3.3.4)

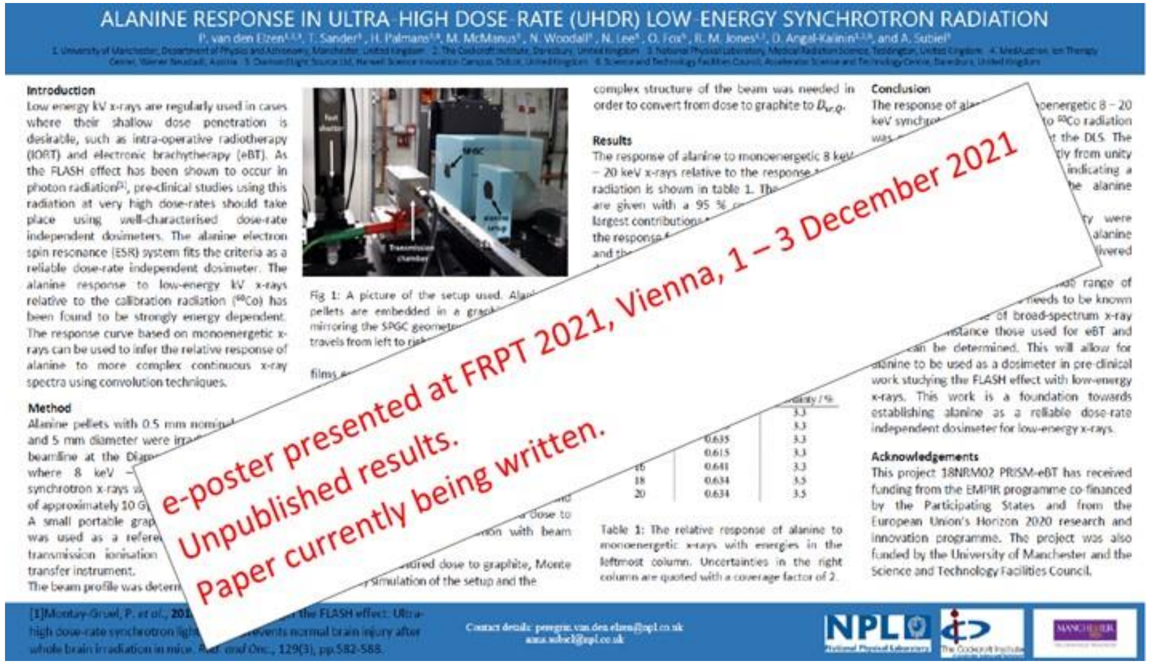
WP3 progress (NPL)

A3.3.1 (Nov 21)

- Alanine characterisation at the DLS synchrotron using 8 - 20 keV monoenergetic X-rays in December 2019

Fig. 11: Diamond Light Source (synchrotron), Didcot, UK

- e-poster was presented at the International FLASH Radiotherapy & Particle Therapy conference, FRPT, Vienna, 1-3 December 2021



WP3 progress (NPL)

A3.3.1 and 3.3.2 (Nov 21) continued …

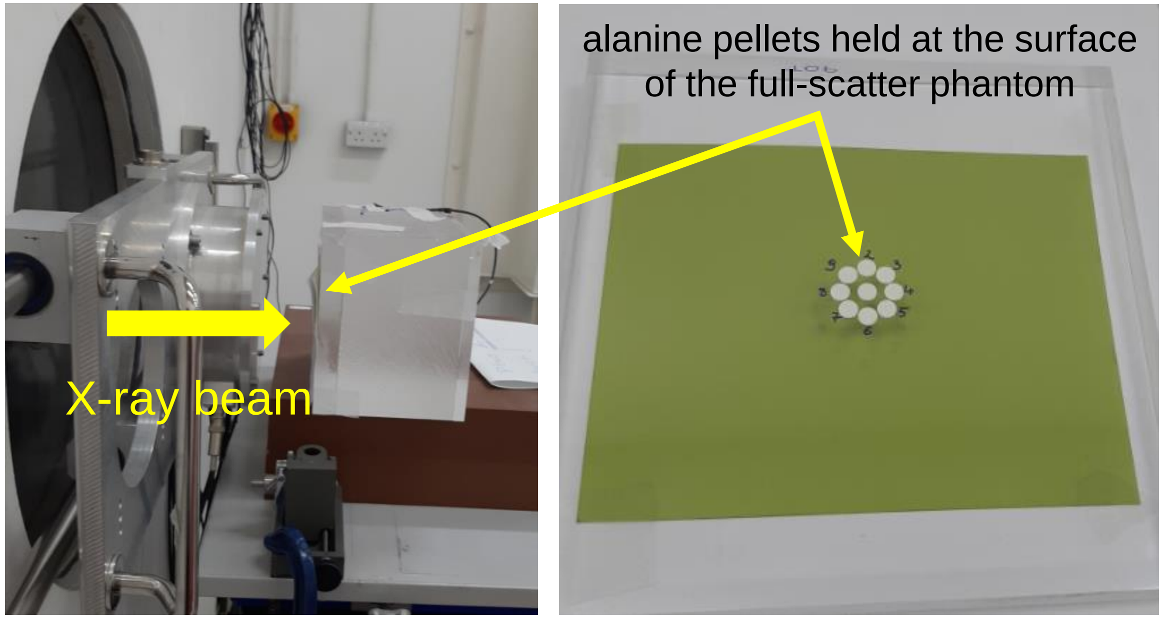


Fig. 12: Experimental setup of alanine calibration at NPL

- Due to lack of further access to DLS (due to Covid-19 pandemic) full energy characterisation (10 – 60 kV X-rays) has been carried out using NPL kV X-ray facilities employing ISO 4037 qualities (**N-10,N-15,N-20,N-25,N-40 and N-60 kV**) → for setup see **Fig. 12**
- Alanine pellets were cross-calibrated against a secondary standard 2611 ion chamber calibrated against primary standard FAC in terms of N_K
- Conversion to D_w was carried out according to IPEM kV CoP
- Measurements completed
- Alanine pellets read out by NPL's Chemical Dosimetry Group using EPR system
- Now working on uncertainty budget

WP3 progress (NPL)

A3.3.1 and 3.3.2 (Nov 21) continued …

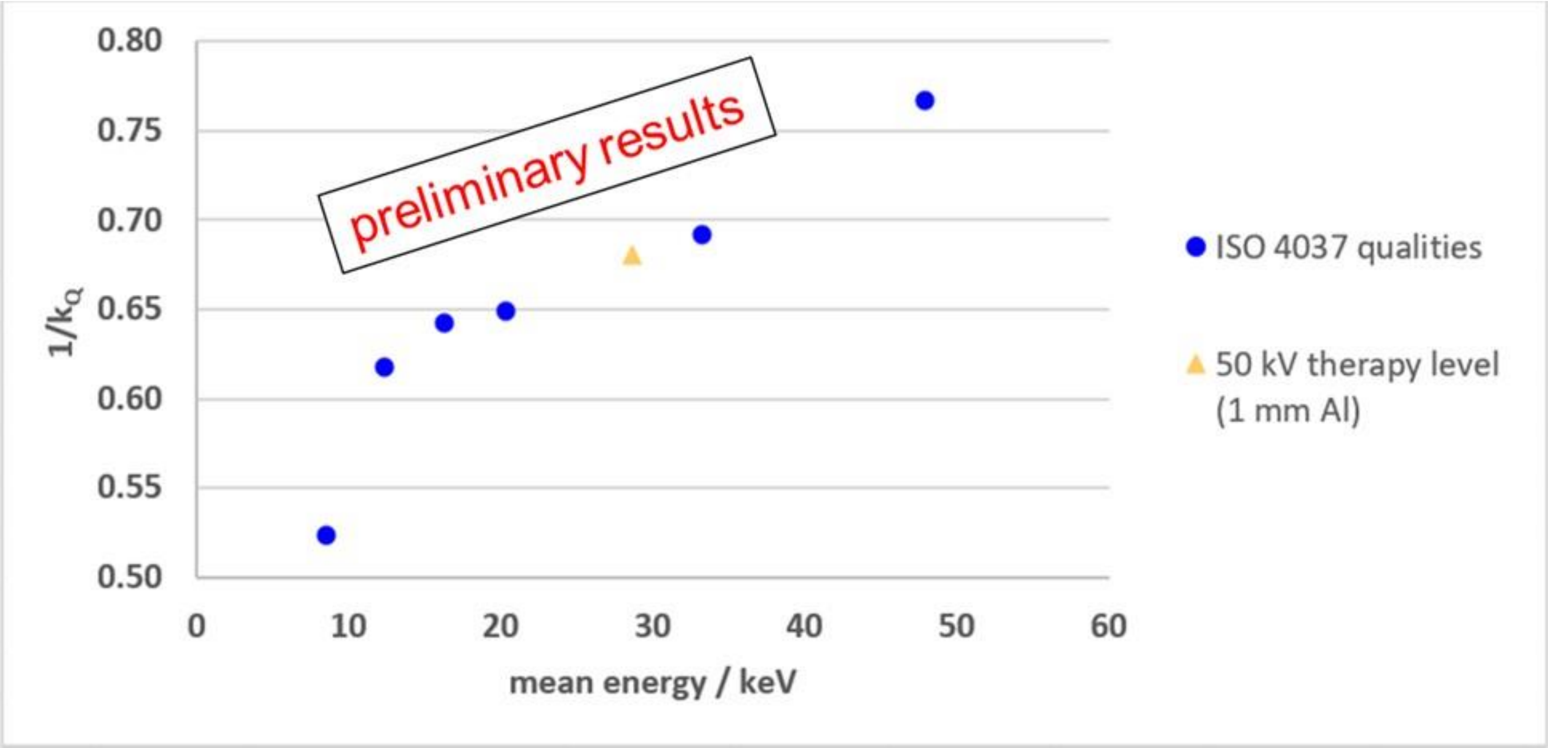


Fig. 13: Alanine calibration at NPL based on ISO 4037 qualities: N-10,N-15,N-20,N-25,N-40 and N-60 kV