PRISM-eBT: A European Metrology project on electronic Brachytherapy

Thorsten Schneider, Coordinator

On behalf of the PRISM-eBT consortium

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

PRISM-eBT: Primary standards and traceable measurement methods for X-ray emitting electronic brachytherapy devices

PRISM-eBT

Core Members:

AARHUS UNIVERSITY

CZECH METROLOGY INSTITUTE

ENEA
Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

Maastro
in de beste handen

NPL
National Physical Laboratory

PTB

UHASSELT

VSL

Industrial partners (collaborators)

Ariane™ MEDICAL SYSTEMS

Elekta

PTW

WOmed
An Eckert & Ziegler BEBIG Company

Xoft®
a subsidiary of iCAD®

ZEISS

Stakeholders:

Chief Stakeholder:
International Atomic Energy Agency
Zakithin Msimang

BraphyQS (Asa Carlson Tedgren, Frank-Andre Siebert)

AAPM (Brachytherapy)
Mark J. Rivard

DIN 6803-3 (Frank Hensley)

DGMP-IORT (Frank Schneider)

UK - NHS (David Eaton)

Structure

technical Workpackages

- WP1: Primary and transfer standards
- WP2: Traceability for superficial treatment
- WP3: Characterisation and calibration of detectors for 3D dose distribution measurements
- WP4: 3D dose distribution measurements

Two Management Workpackages: Creating impact and Coordination

PRISM-eBT

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http://www.ebt-empir.eu/

Introduction

Highlights

The list of project meetings till the end of the project is available here.

Two workshops for stakeholders are planned in 2022: The dissemination workshop on 22 November 2022 and the final scientific workshop for stakeholders on 13-14 December 2022. Details will be periodically updated.

Catalogues of X-ray photon fluence spectra generated by electronic brachytherapy devices and their eBT-equivalent spectra realizable in laboratories with common X-ray tubes were published in section Impact.

Acknowledgement

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EMPIR EURAMET

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

EURAMET website of the Project is here.

About this project

WP1: Primary and transfer standards:

Due to national request, the NMIs of the

- Czech Republic (CMI)
- France (LNE-LNHB)
- Italy (ENEA)

Are realizing Dw for the 4 cm (diam.) spherical applicator of the Intrabeam system (TARGIT-study).

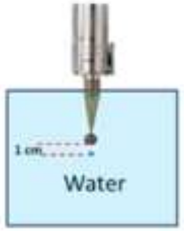
PTB (Germany) has different aims.

LNE-LNHB D_W standard for the INTRABEAM source

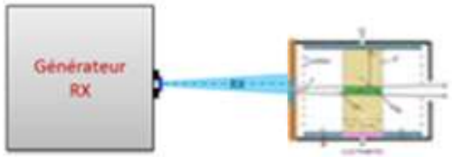
General methodology used to develop a D_W standard for the INTRABEAM source

Reference conditions : at 1 cm in water from the nude source surface or from the applicator surface

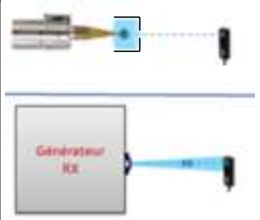
1. Reproduction, using a LNE-LNHB x-ray generator, of a beam presenting the same photon energy distribution as the photons emitted by the INTRABEAM after crossing 1 cm of water
2. Establishment of a standard in terms of $\dot{K}_{air}$ for the considered beam using a LNE-LNHB standard free-air ionization chamber (FAC), including the assessment of the correction factors
3. Calibration in terms of $\dot{K}_{air}$ of a secondary ionization chamber in the considered beam
4. Measurement of the $\dot{K}_{air}$ delivered by the INTRABEAM photons after crossing 1 cm of water
5. MC calculation of a conversion factor to go from $\dot{K}_{air}$ to $\dot{D}_{eau}$ in the reference conditions



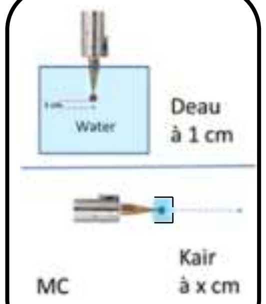
Measurement



Measurement



MC calculation



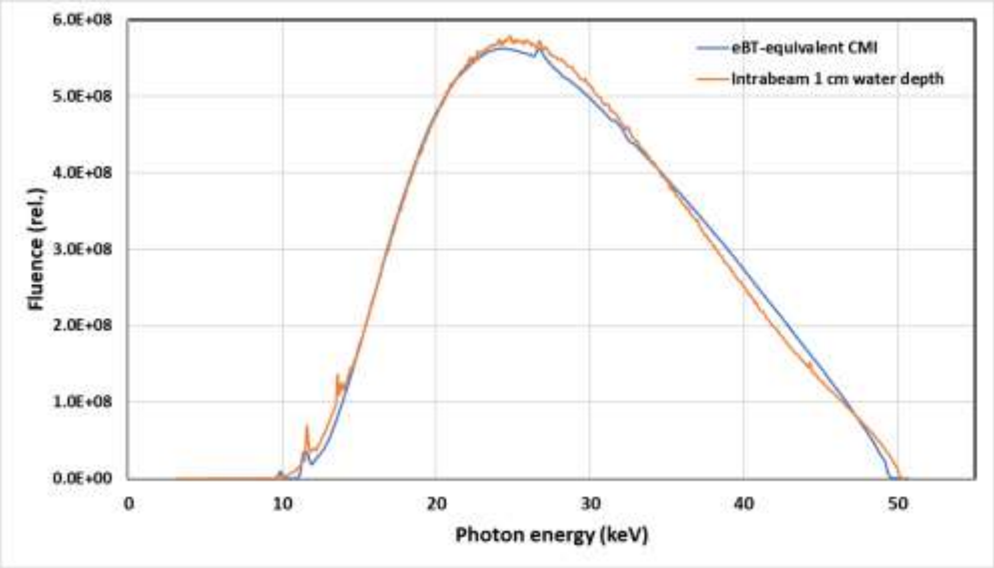
$$\dot{D}_{w,1\,cm} = \frac{W}{e}\cdot\frac{1}{\rho_{air}V}\cdot I_{FAC,refX,1cm}\cdot\frac{1}{1-g_{air}}\cdot(\Pi k_i)_{FAC,refX}\cdot\frac{I_{trans,IB}}{I_{trans,refX}}\cdot F_{K,D}$$

LNHB
Laboratoire National Henri Becquerel

Catalogue of eBT X-ray spectra

Catalogue of eBT and eBT-equivalent spectra developed for eBT sstems Axxent (Xoft), Esteya (Elekta), INTRABEAM (ZEISS), ioRT-50 (WOmed), and Papillon50 (Ariane Medical Systems).

Available on the project website (http://www.ebt-empir.eu/).



Example of eBT spectra at 1 cm water depth (Intrabeam) compared to eBT-equivalent spectra realized at laboratory with a standard X-ray tube with tungsten anode.

Task 1.1 A1.1.3 Formalism for „equivalent eBT" spectra

ENEA

Situation in Germany

Brachytherapy medical physicist community wants to measure dose distribution in addition to TG-43

-> DIN 6803-3 (HDR (radioactive) and will include eBT as an outcome of this project)

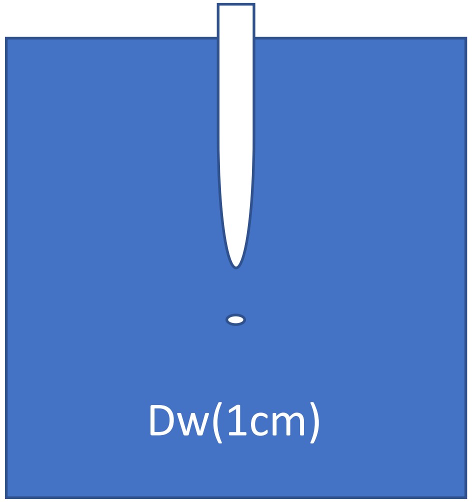
e.g. Zeiss “End-user phantom” was designed according to the request of the MPE.

Applicator-transfer-function (ATF):

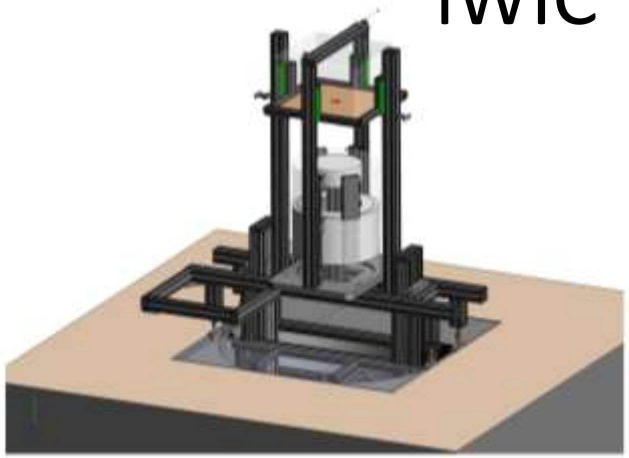
Concept to derive dose when using an applicator from “reference conditions” -> reduce calibrations

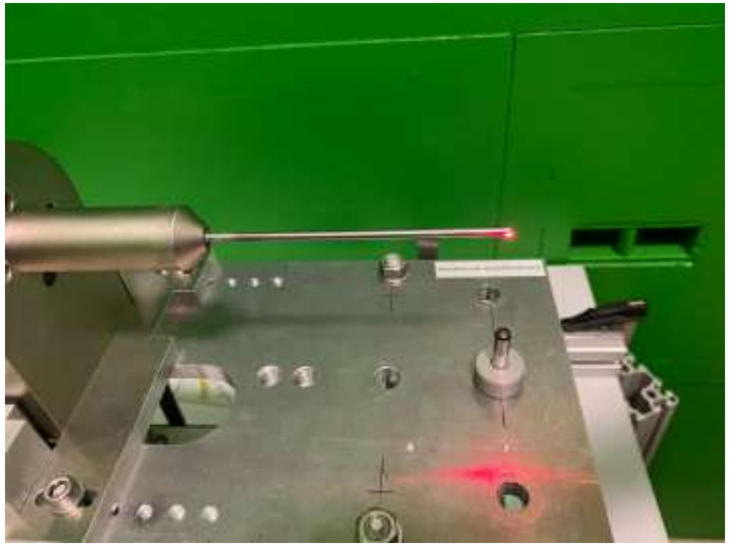
(Zeiss-System: bare needle)

Realisation of Dw in 1cm in water

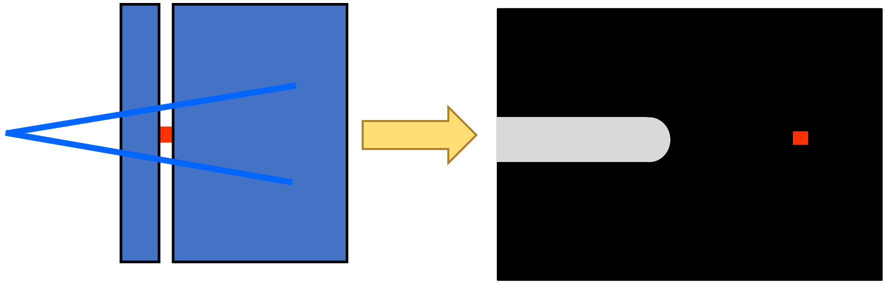


iWIC





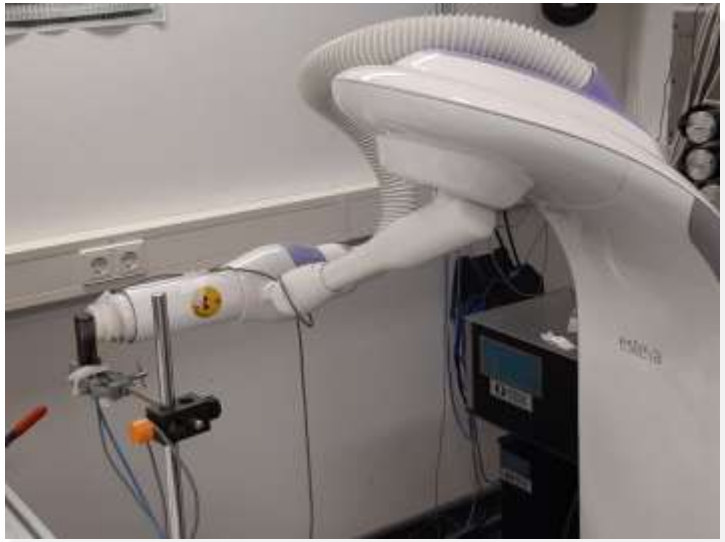
ipFAC

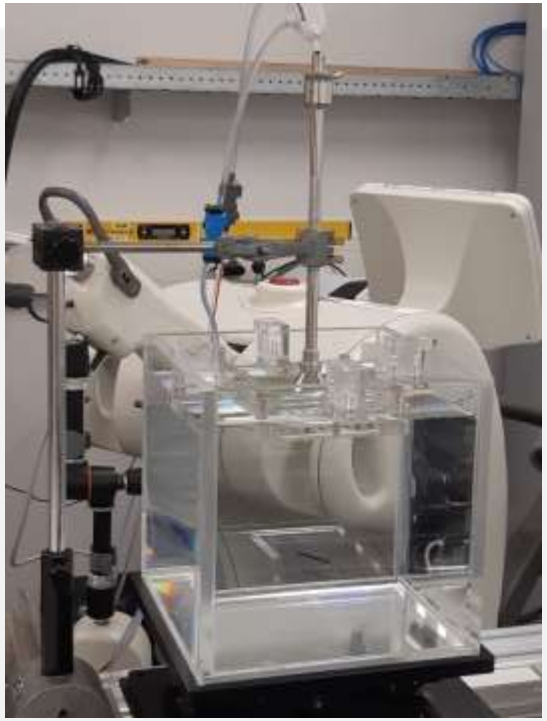


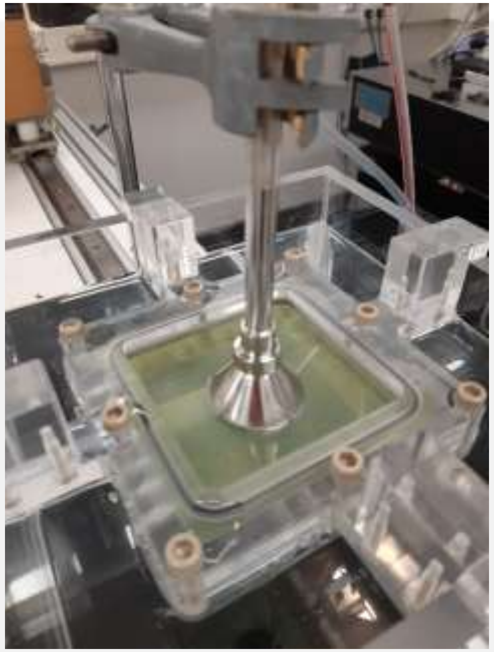
30 cm

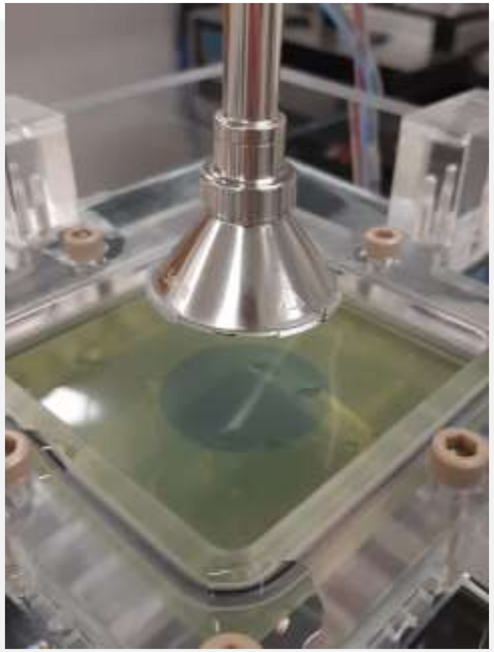
1 cm

WP2 PRISM-eBT: Traceability for superficial treatment



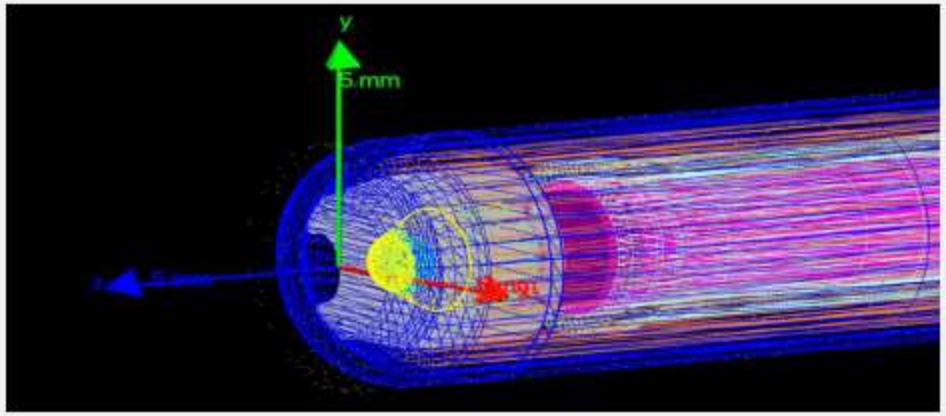


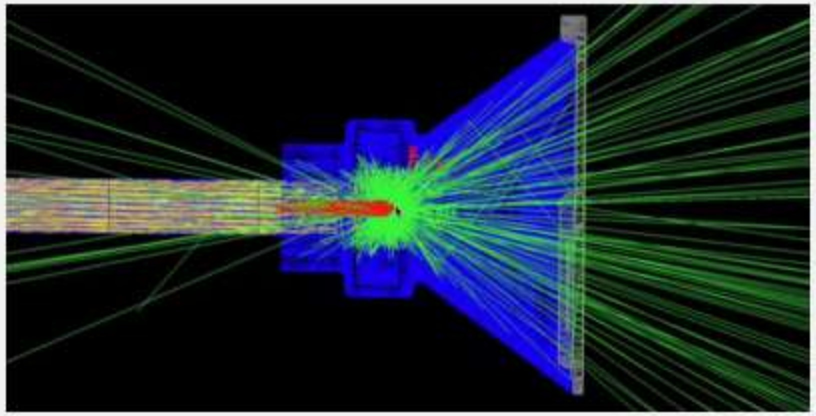




model for xoft

MC code: Topas (Geant4)
Based on stl files from Xoft
Validated using spectra and pdds

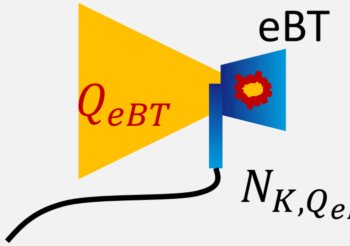




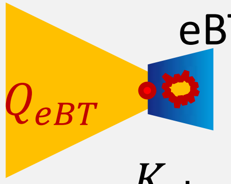
Master students: Simon Arits, Morgane Wieme, Rafael Federighi
PhD student: Dries Colson

Formalism CIEMAT-VSL PRISM-eBT WP2

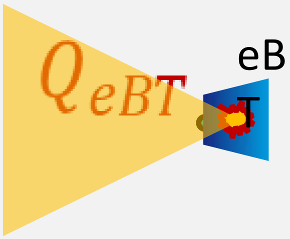
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas



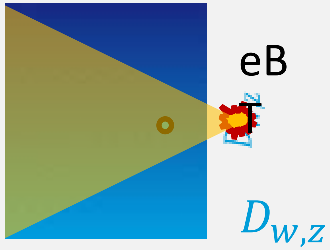
$$N_{K,Q_{eBT}} = N_{K,Q_0} \cdot k_{Q_{\mathrm{eBT}}}$$



$$K_{\mathrm{air,eBT}} = M \cdot N_{K,Q_0} \cdot k_{Q_{\mathrm{eBT}}}$$



$$D_{\mathrm{w,surf}} = \underbrace{K_{\mathrm{air,eBT}} \cdot B_{\mathrm{w,eBT}}}_{\mathrm{MC}} \cdot \underbrace{\left(\frac{\bar{\mu}_{\mathrm{en}}}{\rho}\right)^{\mathrm{w}}_{\mathrm{air}}}_{\mathrm{spc}}$$



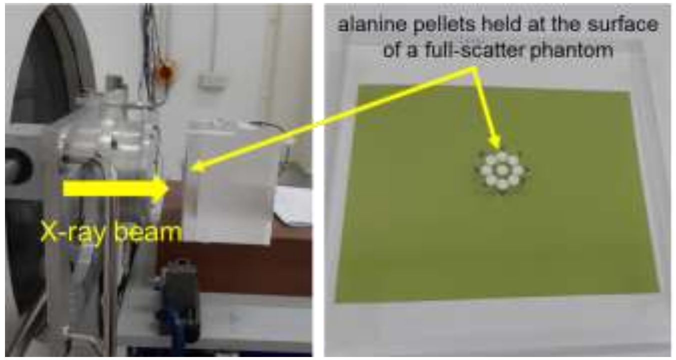
$$D_{\mathrm{w,z}} = D_{\mathrm{w,sur}} \cdot \underbrace{k_{z,eBT}}_{\mathrm{measured}}$$

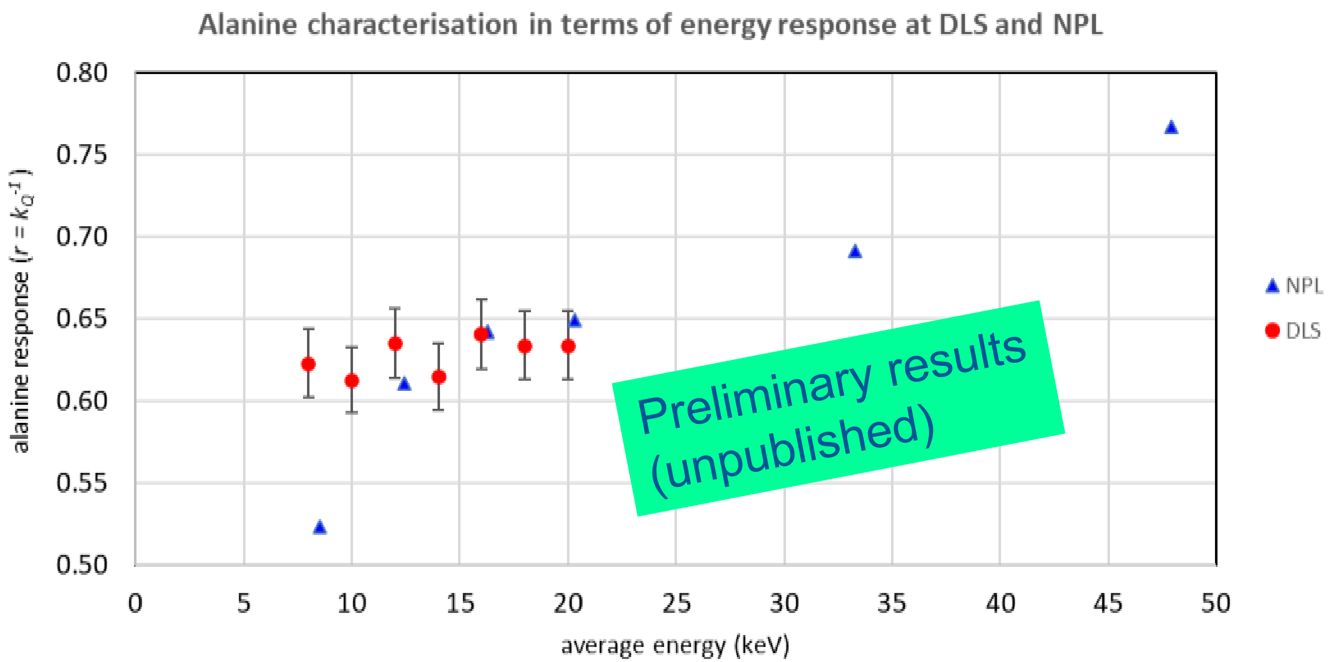
Work package 3

Characterisation and calibration of alanine pellets for eBT

Alanine characterisation at **DLS synchrotron** based on 8, 10, 12, 14, 16, 18 and 20 keV **monoenergetic X-rays**

Alanine characterisation at **NPL** based on low energy kV X-rays, **ISO 4037 qualities** N-10,N-15,N-20,N-25,N-40 and N-60





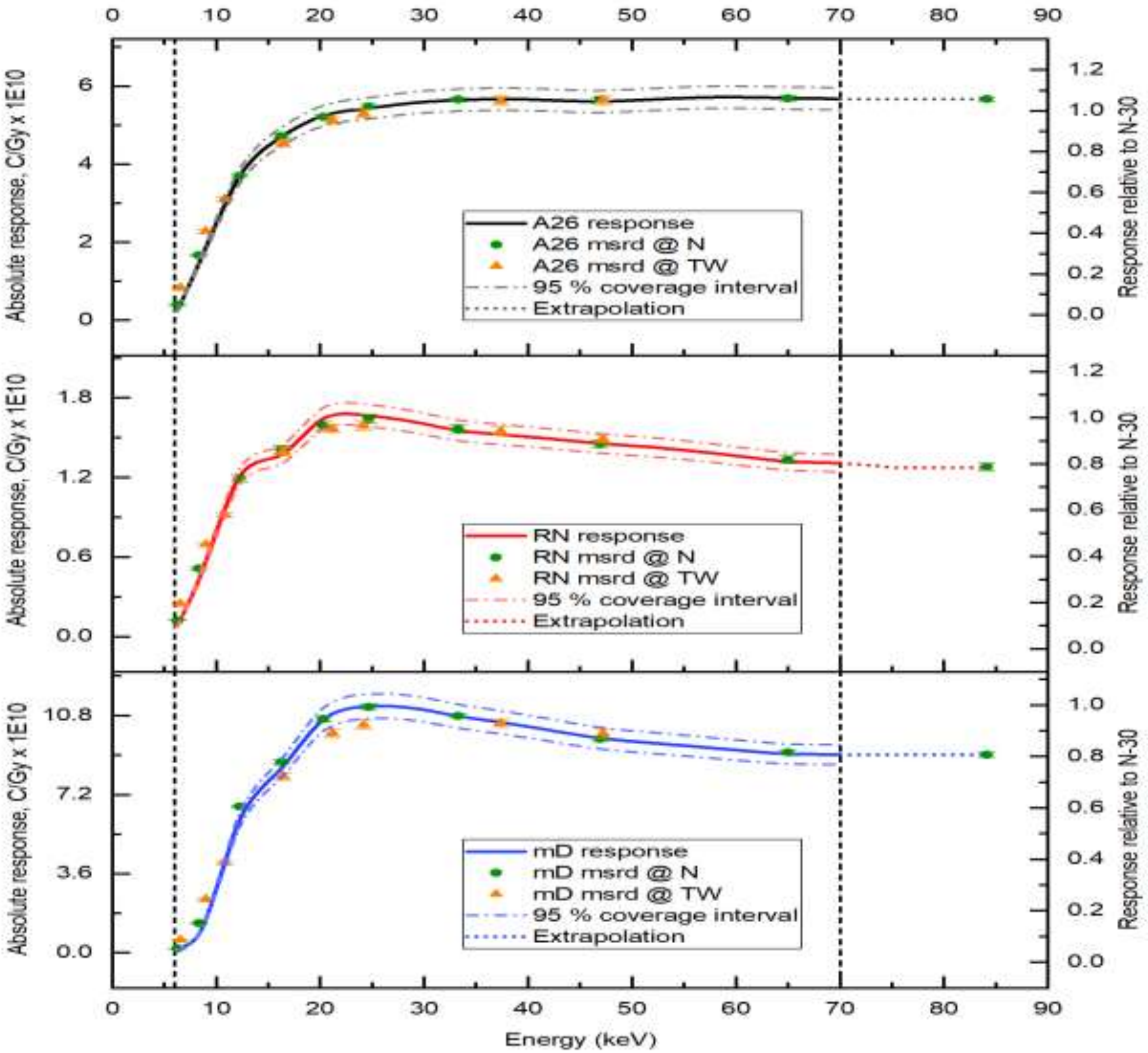
Refined data analysis including uncertainty evaluation is currently underway.

Energy response characterization (in terms of Air Kerma Free in Air)

Exradin A26

IBA RAZOR Nano

PTW 60019 micro Diamond



PRISM-eBT

Work package 4, task 4.1

Measurement of 3D dose distributions close to eBT devices

NPL National Physical Laboratory

EURAMET

Three water equivalent plastic phantoms designed and built at NPL for 3D dose measurements close to eBT X-ray sources using alanine dosimeters. Measurements at Aarhus University Hospital (Papillon 50) and PTB (Intrabeam) planned for summer 2022.

Papillon 50 phantom with alanine pellets at 0, 5, 10, 15, 20 and 25 mm distance from end of 25 mm diameter applicator tube

Intrabeam phantom 1 with alanine pellets at 5, 10, 20, 30 and 40 mm distance from end of bare needle

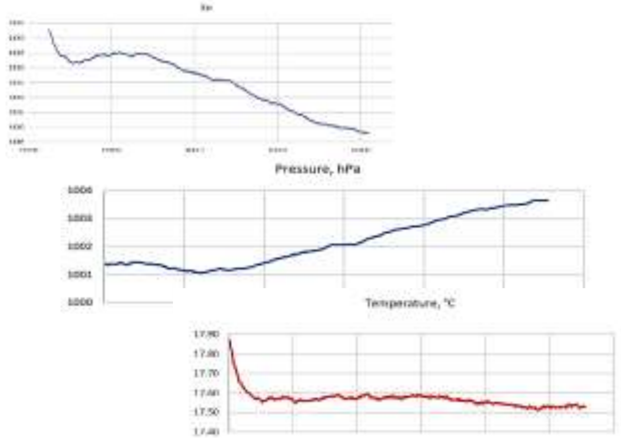
Intrabeam phantom 2 with alanine pellets at 5, 10 and 15 mm distance from surface of 40 mm spherical applicator

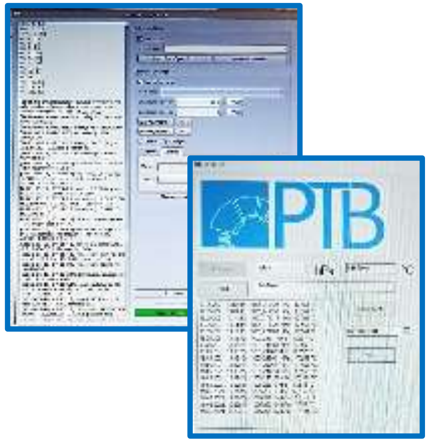
Points of measurements

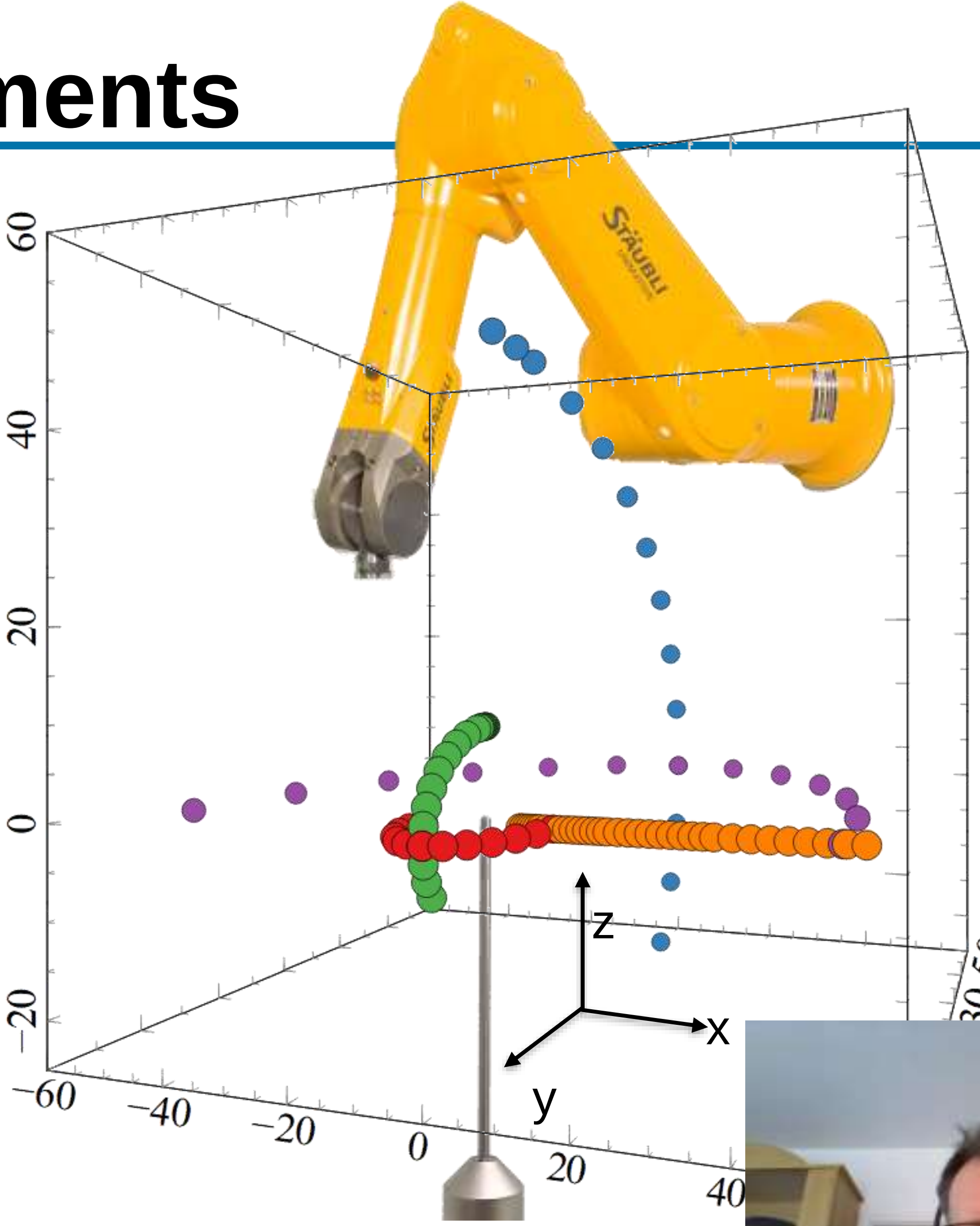
The measuring points:

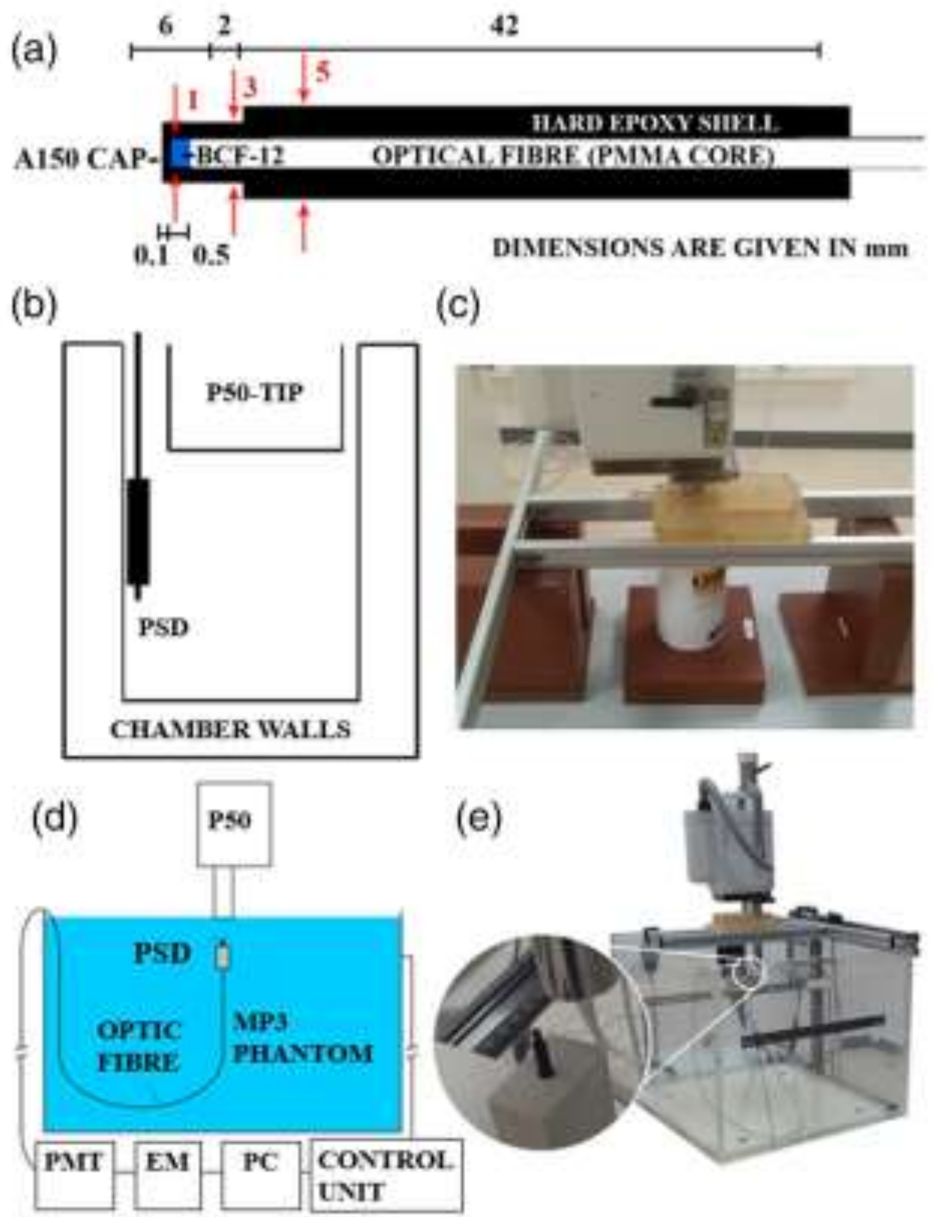
- For dose with distance
- For radial distribution at 10 mm and 50 mm
- For polar distribution at 10 mm and 50 mm

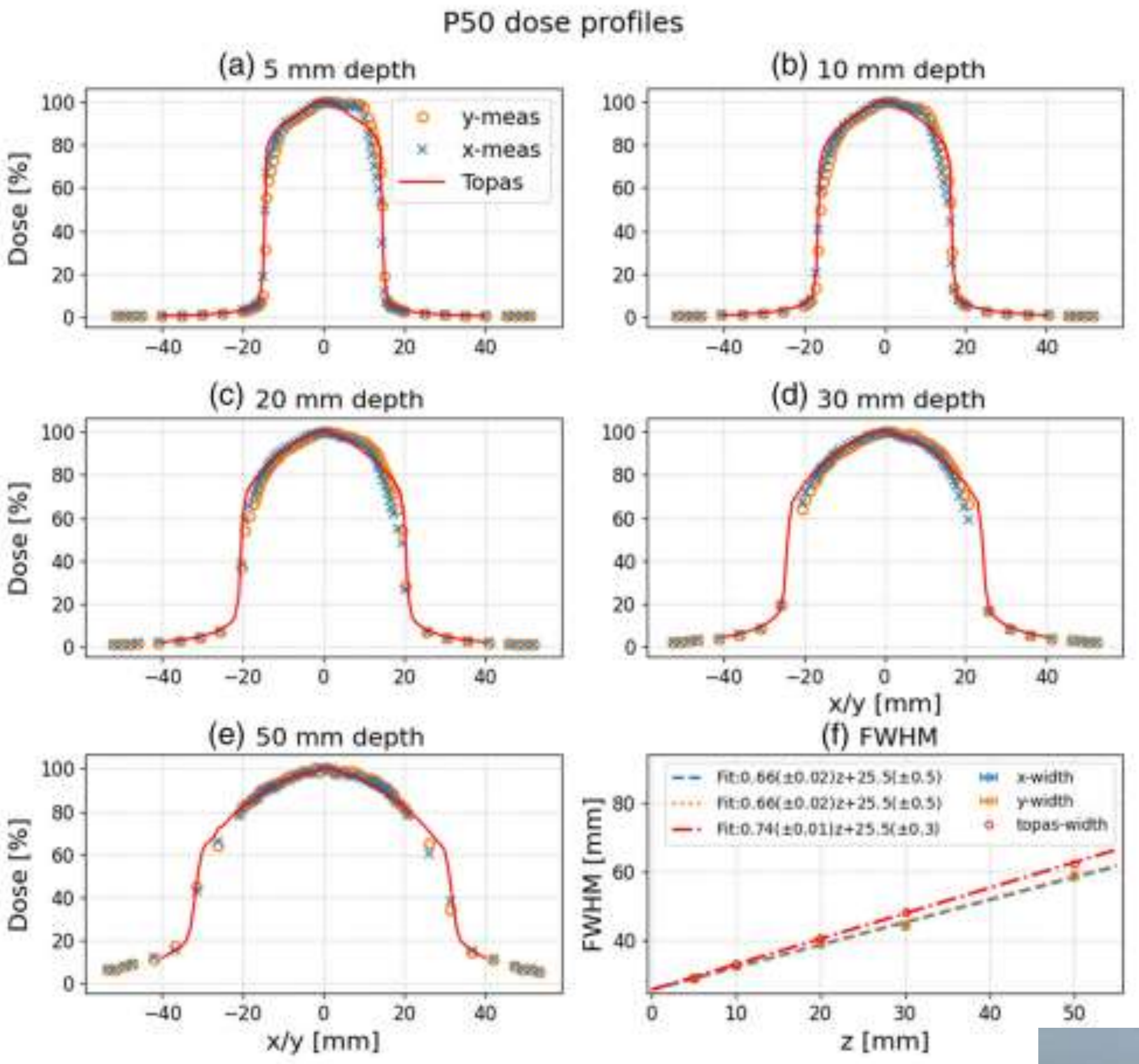
In-house software control the robot, record the collected charge and measure pressure and temperature









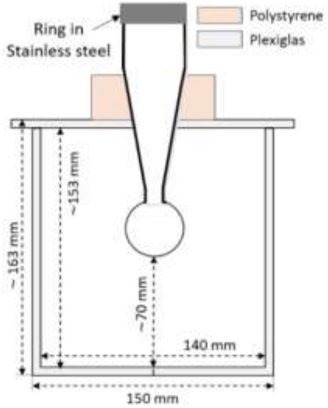


PTB

AARHUS UNIVERSITY

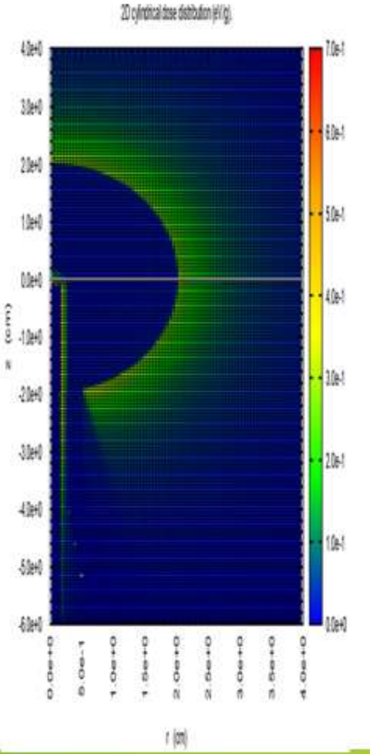
WP4 Progress (CEA)

A4.1.3: Phantom for measurement using Fricke gels of 3D distributions of D_W has been manufactured et tested.



A4.1.4: A numerical model (PENELOPE 2018) of the INTRABEAM system with 4 cm spherical applicator has been developed.

Conversion coefficients $D_{gel} \rightarrow D_W$ to be calculated. Need to agree on the effective source focal point as discussed during the WP4 meeting in June.



A4.1.5: Automatic program for the analysis of the MRI readings

- Python based software has been developed to process the data obtained by imaging irradiated Fricke gel dosimeters with an MRI readout. The MRI sequence used was a T_2-weighted one called 2D Fast-Spin-Echo.
- The intensity values of the pixels in the DICOM images (coming from the MRI readout) are converted into $R_2=1/T_2$ values.
- 3D dose distributions are obtained through a preliminary calibration $D = f(R_2)$

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