EMPIR 18NRM02 (2019-2022)

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

(„PRISM-eBT“)

Thorsten Schneider, PTB, project coordinator

Valentin Blideanu, CEA-LNHB, presenter on behalf of the consortium

PRISM-eBT Outline

Context

The project and its objectives

Main achievements

Discussions

PRISM-eBT Context

Benefits of electronic BrachyTherapy (eBT)

- Electronic brachytherapy (eBT) is a **promising radiotherapeutic treatment modality** for several treatment applications: Head & Neck Tumours, Brain Tumours, Breast Cancer, Gastrointestinal Tumours, Spinal Metastases and Skin Cancer.
- Operating at **only 50 kilovolts**, **low** capital expenditure on **shielding is required** and treatments can be performed **in normal operating rooms**. Treatment directly after surgery is attributed with better therapeutic outcome. **Steep dose gradients enable higher dose delivery** and reduce the number of treatment fractions.

Status before the project

- **Calibration** tools and **procedures** are **separate** and documented **dose values** are **only valid within a specific system**.
- Direct **traceability to** a National Metrology Institute **(NMI)** in terms of D_w is **currently non-existent**
- Independent and traceable **verification of dosimetry is not given** in the clinics and high uncertainties (10–15%, k=1) are reported.
- This **hampers the progress in radiotherapy** and **clinicians refuse** to uptake this modality.

PRISM-eBT Context

EMPIR Work Programme

Call Scope – Metrology for Pre- and Co-normative Research (2018)

Document: P-PRG-GUI-052 Version: 1.0
Approved: EMPIR Committee 2017-11-21

The overall strategic aim of the Targeted Programme (TP) "Pre- and co-normative research" is to develop metrological methods and techniques required for standardisation, regulation and conformity assessment.

PRISM-eBT Consortium

6 Internal

2 External

1 Unfunded

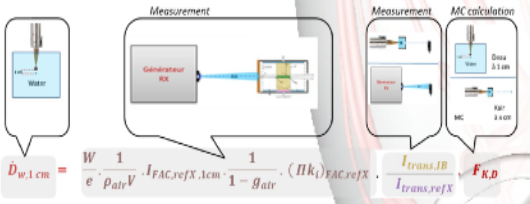
+ 10 external collaborators and stakeholders
+ 5 scientific advisory committee members

PRISM-eBT Objectives

Primary and transfer standards — WP1

Establishment of:

- Primary standards for D_w.
- Transfer standards for D_w.
- Traceability chains for D_w.



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

Traceability for superficial treatment — WP2

Establishment of:

- Surface dose ($D_{70\,\mu m}$) via air kerma standards.

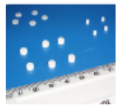
- Conversion between surface dose ($D_{70\,\mu m}$) and depth-dose (D_w, WP1).
- Traceability chains for the absorbed dose rate to water.

Characterisation and calibration of detectors for 3D dose distribution measurements — WP3

Characterisation and traceable (D_w, WP1) calibration of:

- Small volume online detectors.

- Fricke gel dosimeters.



- Characterisation and calibration of alanine dosimeters.

3D dose distribution measurements — WP4

- Measurement of the 3D dose distributions close to the eBT devices with or without applicators.
- Comparison of measurements with vendor supplied dose maps.

Creating impact & Coordination

- Dissemination of the project outputs given by close cooperation with National (DIN), European (BraphyQS) and International (IAEA) Organisations.
- IAEA substantially support this project and agreed to be the Chief Stakeholder.
- Update of IAEA Tecdoc 1274 (2 members of the JRP will be members of the Working Group).
- Medical Physics organisations are represented in the advisory board.
- All known device manufacturers and PTW want to be collaborators and attend the meetings.
- A Good Practice Guide will be provided to SDOs for uptake in their standards.
- Catalogue of validated spectra of eBT sources.
- Close collaboration of European NMIs.
- Increased competitiveness with NMIs outside Europe.
- Dissemination Workshop.

PRISM-eBT Objectives

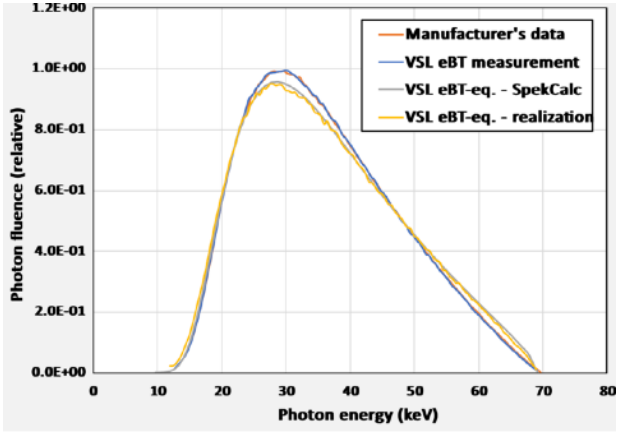
WP5 (leader CMI) Creating impact

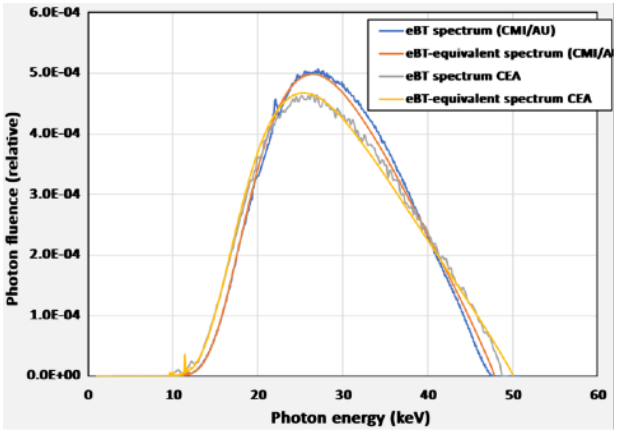
A5.1.10	CEA, with support from the project partners, will organise a conference/workshop that will be held around M35. This will aim to disseminate the results of the project among the clinical, manufacturing and scientific community and to get the feedback from final users in order to allow the best traceability to primary standards.
A5.2.1	One scientific workshop for stakeholders (1-1.5 days duration) will be organised and held during the project. The workshop will be hosted by PTB in 2022.

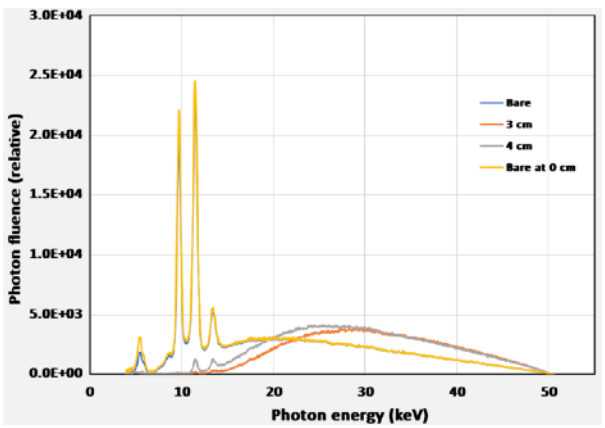
PRISM-eBT Main achievements

WP1 (leader ENEA) Primary and transfer standards for $D_{w,1cm}$

1. Catalogue of photon fluence spectra emitted by eBT devices: measured and/or Monte-Carlo simulated







Total of 21 configurations, 84 spectra compiled:

- Esteya (Elekta), Axxent (Xoft), ioRT50 (Wolf), Papillon50 (Ariane), Intrabeam (Zeiss)
- air, water
- tube filtrations
- applicators
- SDDs

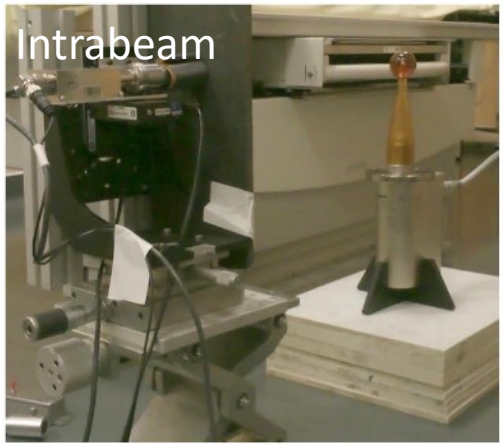
Comprehensive excel files made available to the community:

- project website http://www.ebt-empir.eu/
- ESTRO

PRISM-eBT Main achievements

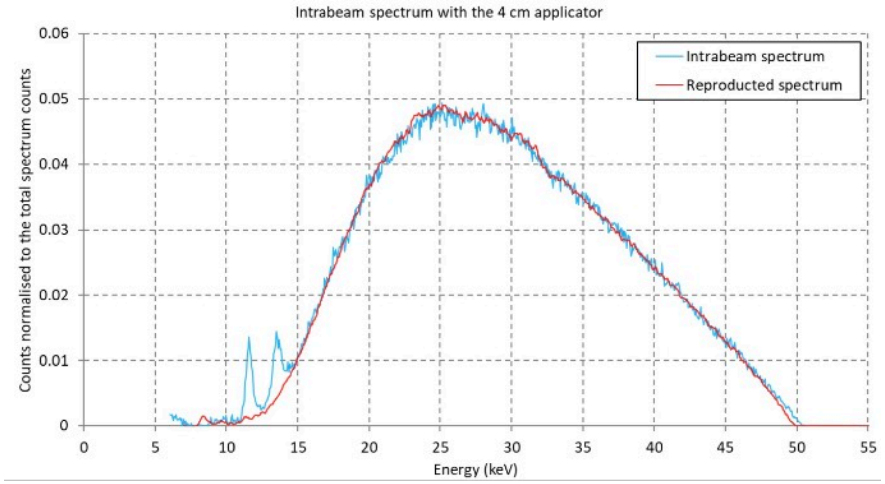
WP1 (leader ENEA) Primary and transfer standards for $D_{w,1cm}$

2. Methodology to reproduce the eBT equivalent beams using a conventional X-ray tube



X-Ray spectrometry of the beam emitted by the eBT system

X-Ray spectrometry of the beam emitted by a conventional X-Ray generator -> appropriate filtration to be added to match the eBT system spectrum



Applied to Intrabeam and Papillon50 but can be done for any eBT system

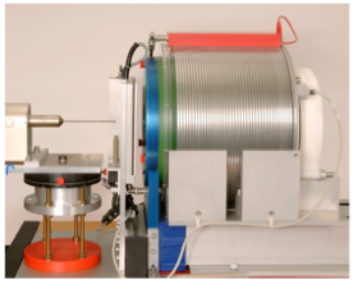
Extend the calibration capabilities: no need to have dedicated eBT systems in lab since the corresponding beam qualities can be reproduced with conventional generators

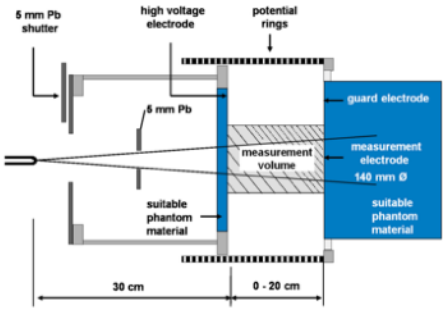
PRISM-eBT Main achievements

WP1 (leader ENEA) Primary and transfer standards for $D_{w,1cm}$

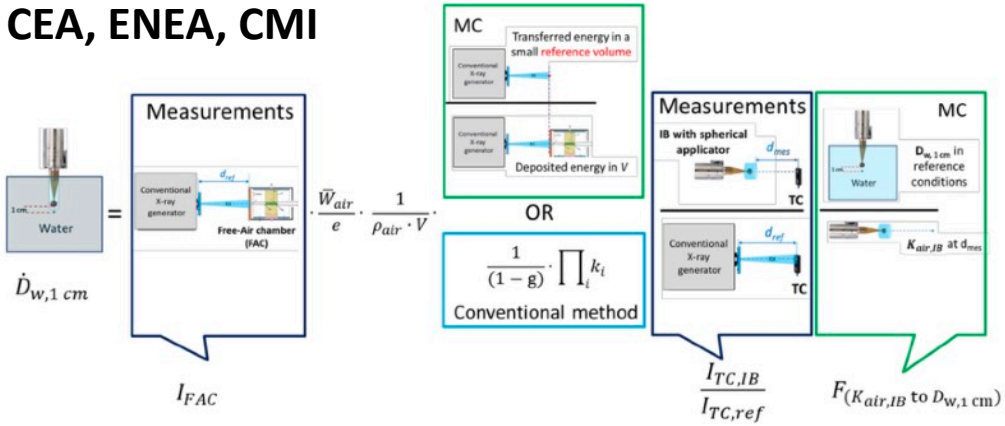
3. Primary standards in $D_{w,1cm}$ for Intrabeam system established by four NMIs/DIs (target uncertainty <2%)

PTB





CEA, ENEA, CMI

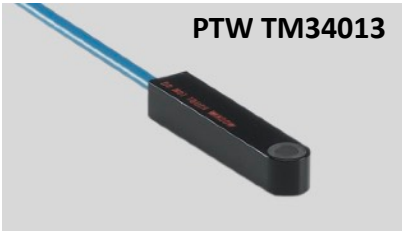


Two different, independent approaches:

- **directly in the Intrabeam beam, based on dedicated extrapolation ipFAC (PTB)**
- **in their own reproduced Intrabeam-equivalent beams, based on K_{air} FAC standards (CEA, ENEA, CMI)**

Standards validation : comparison between the four laboratories, calibration in $D_{w,1cm}$ of two IC types

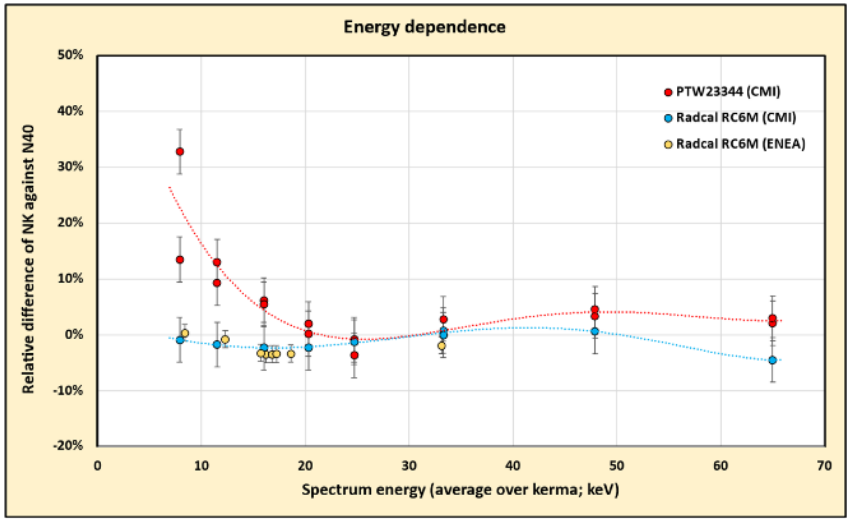
RC6M



PRISM-eBT Main achievements

WP1 (leader ENEA) Primary and transfer standards for $D_{w,1cm}$

4. Calibration procedure in $D_{w,1cm}$ using secondary IC based standards



Characterization of commercially available IC suitable for the purpose

Manufacture of a robust and reliable experimental device for *on-site* calibration of end users' eBT sources

Good practice guide on the establishment of calibration procedure using secondary transfer standards

Contact: massimo.pinto@enea.it

PRISM-eBT Main achievements

WP2 (leader VSL) Traceability for superficial treatment

Low energy air-kerma based formalism

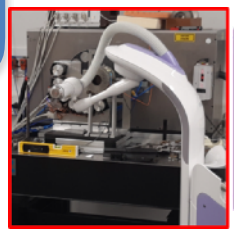
- **NCS-10**
- **AAPM-TG61**

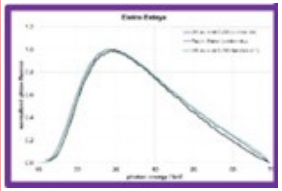
TCPE at 70 µm depth

$$D_{w,surface} = K_{air} \cdot \left(\frac{\bar{\mu}_{en}}{\rho}\right)^{w}_{air} \cdot B_w$$

At the surface of the applicator

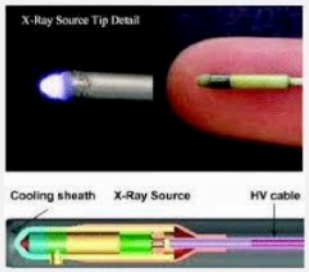
Calculated, require accurate knowledge of the photon spectra





Zeiss INTRABEAM

Xoft Axxent



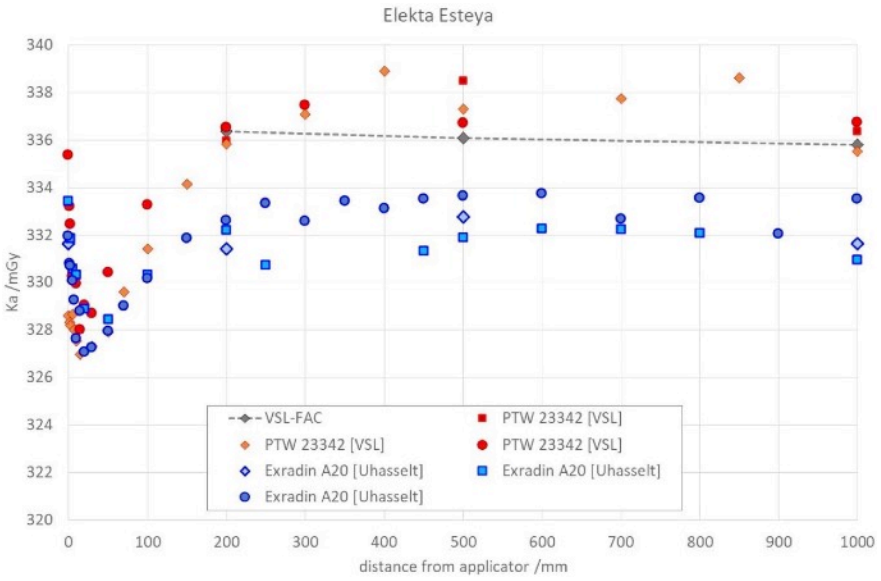
Elekta Esteya

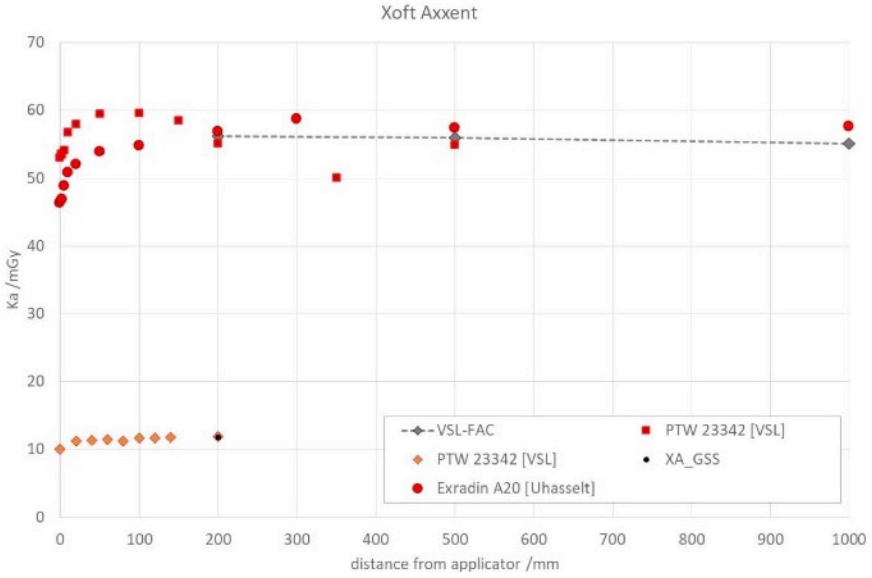
PRISM-eBT Main achievements

WP2 (leader VSL) Traceability for superficial treatment

1. Establishment of $D_{w,70\mu m}$ at the surface of a water phantom

Characterization of eBT systems in terms of K_{air} using two previously calibrated IC against FAC based primary standard



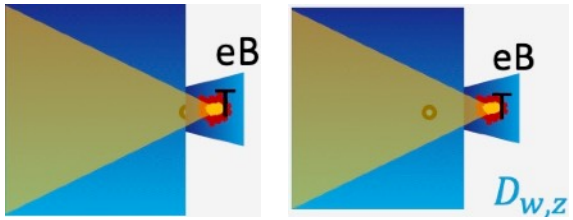


PRISM-eBT Main achievements

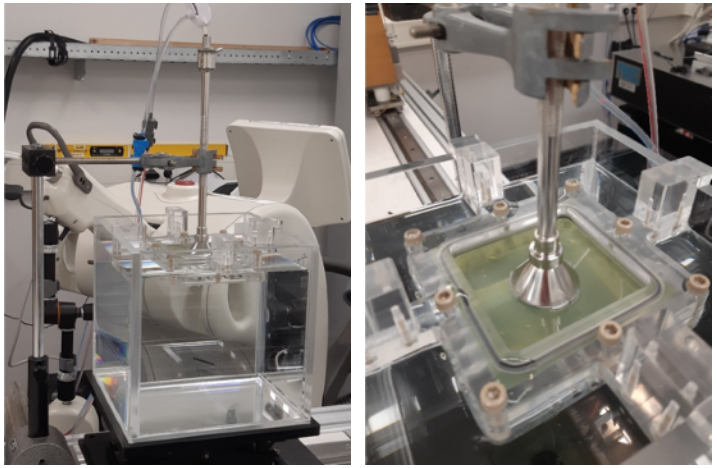
WP2 (leader VSL) Traceability for superficial treatment

2. Traceability to $D_{w,1cm}$ primary standard (target uncertainty 5%)

Conversion $D_{w,70\mu m}$ to $D_{w,1cm}$:



- **Monte-Carlo**
- **Measurements (radiochromic film, alanine)**



Comparison with calibrations of eBT systems using $D_{w,1cm}$ primary standard established by PTB in WP1 (modified for eBT systems with applicators for surface therapy treatments)

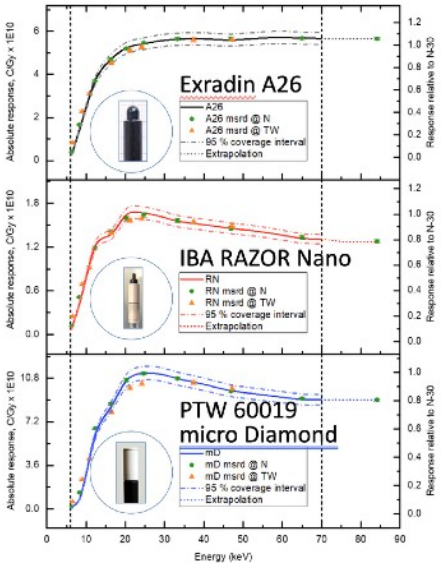
Publication of a protocol for calibration of superficial (skin) eBT systems with recommendations and conversion factors for the selected ion chambers

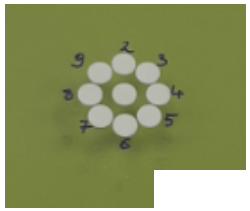
Publication of recommendations of best practice for dosimetric methodologies of superficial (skin) eBT systems using the new primary D_w-route

Contact: ldprez@vsl.nl

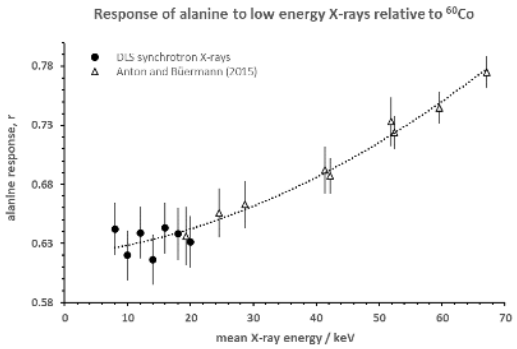
PRISM-eBT Main achievements

WP3 (leader NPL) Characterization and calibration of detectors for 3D dose distribution measurements

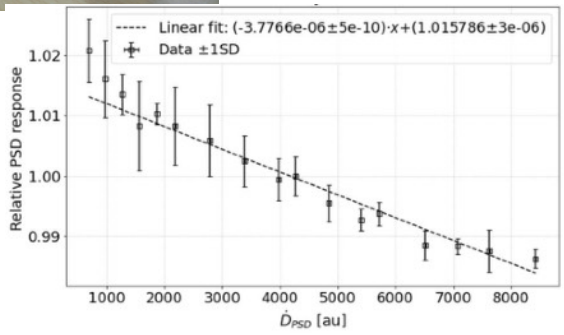




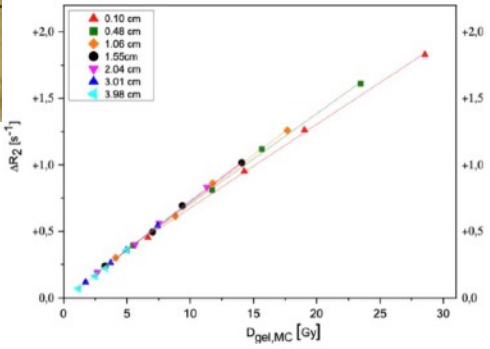
Alanine



Plastic scintillator



Fricke gel



Complete characterization (response in energy and dose) and calibration using established $D_{w,1cm}$ primary standards of 6 different detector types:

- **4 commercially available (2 IC, 1 diamond, alanine pellets)**
- **2 custom-made (plastic scintillator, Fricke gel)**

Good Practice Guide on the characterization and calibration of detectors for 3D dose distribution measurements close to eBT devices

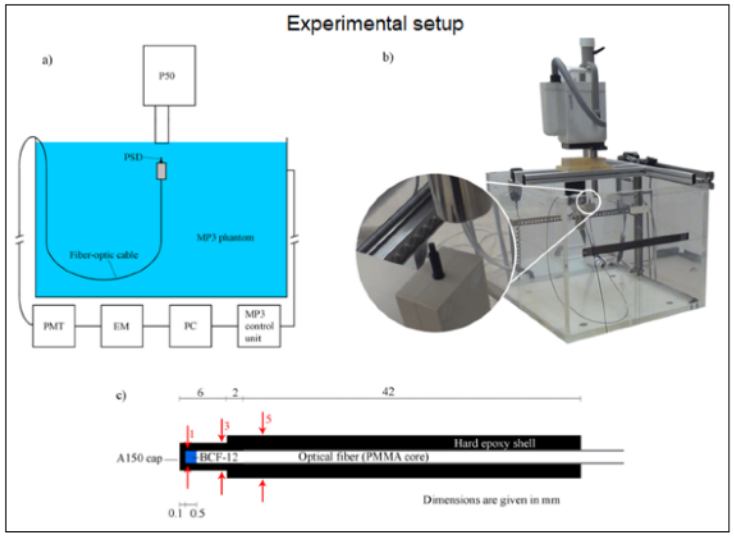
Contact: thorsten.sander@npl.co.uk

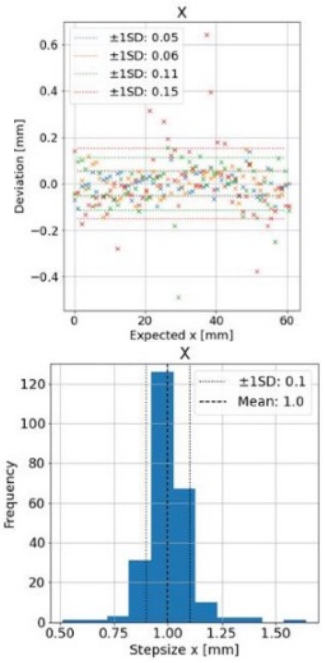
PRISM-eBT Main achievements

WP4 (leader CEA) 3D dose distribution measurements and comparison with manufacturer-supplied dose maps

Exradin A26
Razor Nano
PTW 60019

plastic scintillator





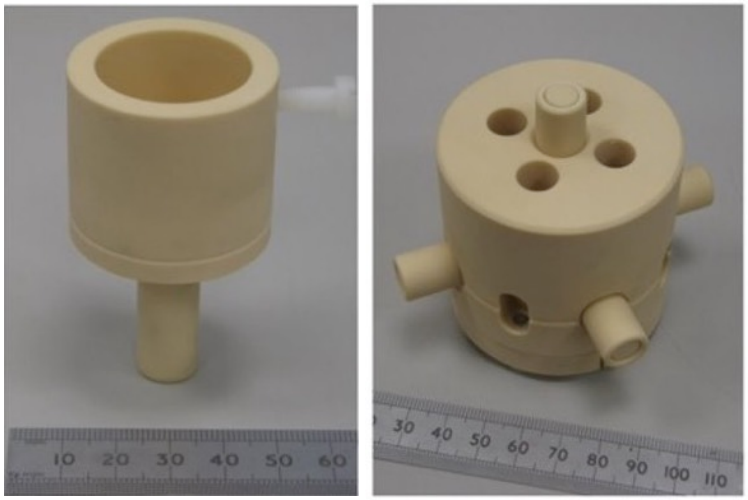
Use of commercially available water phantoms with additional developments:

- **in-house software to control the robot, record collected charge and T,P parameters**
- **positional accuracy of the motorized water phantom used to measure 3D D_w dose distributions**

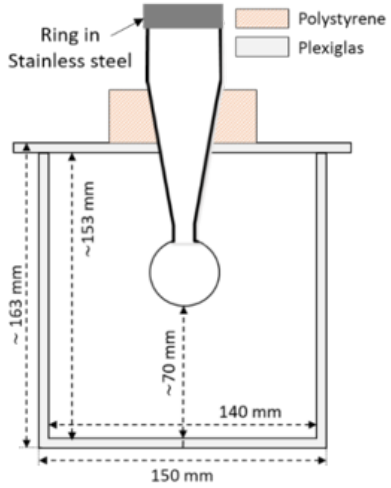
PRISM-eBT Main achievements

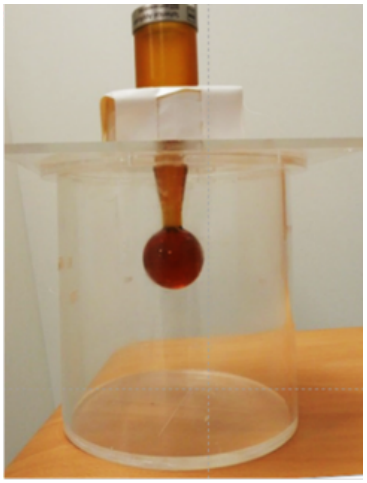
WP4 (leader CEA) 3D dose distribution measurements and comparison with manufacturer-supplied dose maps

Alanine



Fricke gels

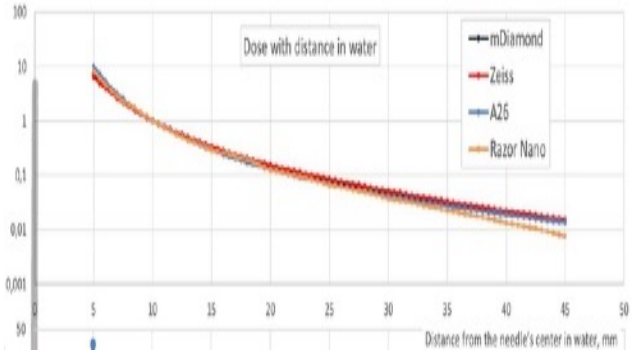


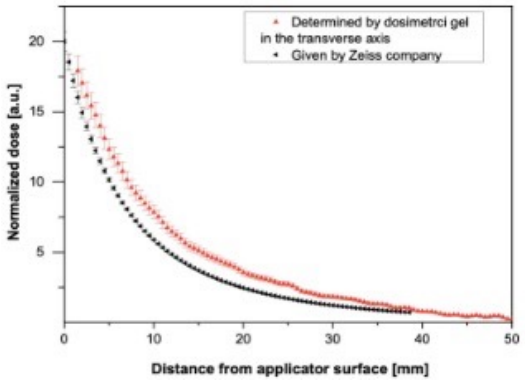


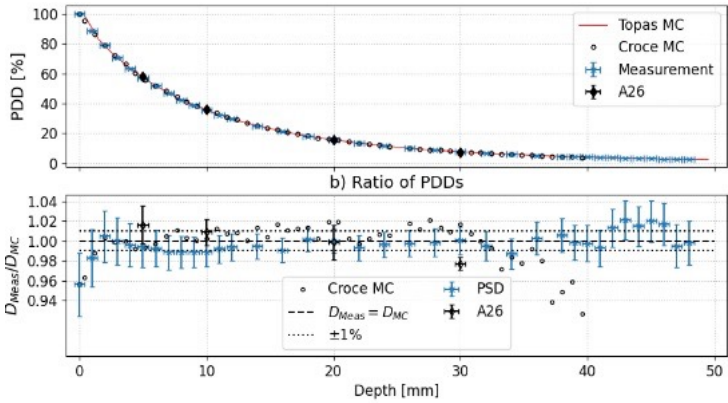
New phantoms specially designed and manufactured

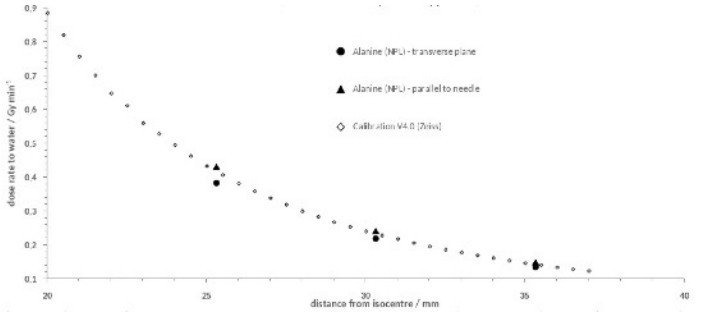
PRISM-eBT Main achievements

WP4 (leader CEA) 3D dose distribution measurements and comparison with manufacturer-supplied dose maps









3D D_w distributions measured:

- **Intrabeam, bare needle (Exradin A26, Razor Nano, PTW 60019, alanine)**
- **Intrabeam, 40 mm applicator (Exradin A26, Razor Nano, PTW 60019, alanine, Fricke gels)**
- **Papillon50, 25 mm applicator (alanine, PSD)**

Comparison with manufacturer data show significant deviations in some cases (up to 20%)

Report on the methodology for providing traceable dosimetry for 3D dose distribution measurements for eBT systems

Contact: valentin.blideanu@cea.fr

Discussions

Best approaches to ensure high benefit for the community: your feedback