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

Core Members:
Industrial partners (collaborators)

Ariane Medical Systems
Elekta
PTW
Womed
Xoft
ZEISS

An Eckert & Ziegler BEBIG Company
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
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

This project has received funding from the EMPIR programme co-financed by the Participating States and from the European Union’s Horizon 2020 research and innovation programme.

EURAMET website of the Project is here.

About this project
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.
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 $K_{air}$ 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 $K_{air}$ of a secondary ionization chamber in the considered beam
4. Measurement of the $K_{air}$ delivered by the INTRABEAM photons after crossing 1 cm of water
5. MC calculation of a conversion factor to go from $K_{air}$ to $D_{eau}$ in the reference conditions

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

Dw(1cm)

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

\[ N_{K,Q_{eBT}} = N_{K,Q_0} \cdot k_{Q_{eBT}} \]

\[ K_{air,eBT} = M \cdot N_{K,Q_0} \cdot k_{Q_{eBT}} \]

\[ D_{w,surf} = K_{air,eBT} \cdot B_{w,eBT} \cdot \left( \frac{\mu_{en}}{\rho} \right)^{w} \]

\[ D_{w,z} = D_{w,sur} \cdot k_{z,eBT} \]
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
Work package 4, task 4.1
Measurement of 3D dose distributions close to eBT devices

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
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.
A4.1.3: Phantom for measurement using Fricke gels of 3D distributions of $D_W$ has been manufactured and 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 $D = f(R_2)$
Authors

Kari Tanderup, Gustavo Kertzscher, Jacob Johanson, Peter Georgi
Aarhus University Hospital, Palle Juul-Jensens Blvd. 99, 8200 Aarhus, Denmark

Valentin Blideanu, Christel Stien, Johann Plagnard
Commissariat à l’Énergie Atomique et aux Énergies alternatives (CEA), 25 rue Leblanc, Immeuble ‘Le Ponant D’, 75015, Paris, France

Jaroslav Solc, Vladimir Sochor
Cesky Metrologicky Institut (CMI), Okruzni 31, CZ-638 00 Brno, Czech Republic

Massimo Pinto
Agenzia Nazionale per le Nuove Tecnologie, l’Energia e lo Sviluppo Economico Sostenibile (ENEA), Istituto Nazionale di Metrologia delle Radiazioni Ionizzanti, CR Casaccia, Via Anguillarese 301, Santa Maria di Galeria (RM) IT-00123, Italy

Thorsten Sander, Anna Subiel, Clare Gouldstone
NPL Management Limited (NPL), Hampton Road, Teddington, Middlesex, TW11 0LW, United Kingdom

Leon de Prez
VSL B.V. (VSL), Thijsseweg 11, NL-2629 JA Delft, Netherlands

Frank Verhaegen
Stichting Maastricht Radiation Oncology Maastro Clinic (MAASTRO clinic), Dr Tanslaan 12, 6229 ET, Maastricht, Netherlands

Brigitte Reniers
Hasselt University, Universiteit Hasselt - Campus Diepenbeek, Agoralaan Gebouw H - B-3590 Diepenbeek

Paz Avilés Lucas, PhD LMRI-CIEMAT, National Metrology Institute of Spain Avda Complutense 40, Madrid 28040, Spain

Zakithin Msimang, International Atomic Energy Agency, Vienna International Centre, PO Box 100, 1400 Vienna, Austria

David J Eaton, Department of Medical Physics, Guy’s and St Thomas' Hospitals, London, United Kingdom & School of Biomedical Engineering & Imaging Sciences, King’s College London, London, United Kingdom

Frank Weigand, Carl Zeiss Meditec AG, Rudolf-Eber-Straße 11, 73447 Oberkochen, Germany

Mark J. Rivard
Dept. Radiation Oncology, Brown University, Providence, RI, United States of America

Rolf Behrens, Fernando Garcia-Yip, Thorsten Schneider,
Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, DE-38116 Braunschweig, Germany