REAL-TIME 3D DOSE IMAGING AND SOURCE LOCALIZATION IN BRACHYTHERAPY

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The ORIGIN project is an initiative of the Photonics Public Private Partnership (www.photonics21.org), and has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement n° 871324

ORIGIN

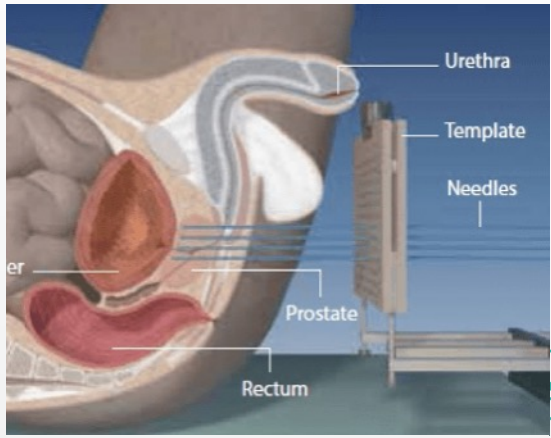
optical fibre dose imaging for adaptive brachytherapy

ONCOLOGICAL BRACHYTHERAPY

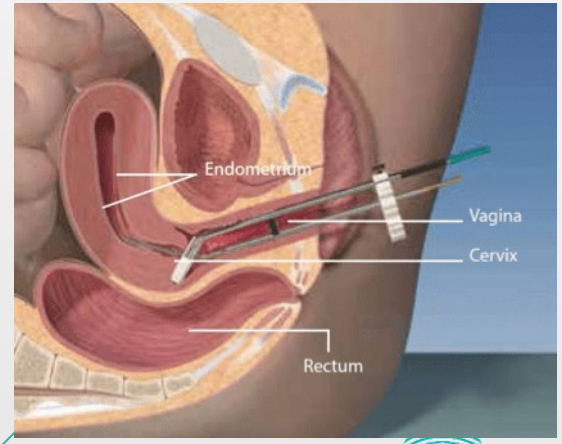
- **Radiotherapy** is the use of ionizing radiation for treatment. It is delivered into external beam radiotherapy using accelerators, or internal, using sources, known as brachytherapy (BT).
- **Brachytherapy** is a form of radiation therapy where a sealed radiation **source is placed inside or next to the cancer area**. The source placement is vital to ensure radiation to the tumor, while ensuring **minimum exposure to nearby critical organs**.
- Brachytherapy is divided into **Low Dose Rate** (LDR) and **High Dose Rate** (HDR).

	Source	Activity	Implantation	<Eγ>	Abs. Length
LDR	^{125}I	15 MBq	Permanent	35 keV	3 cm
HDR	^{192}Ir	~100 GBq	Temporary	380 keV	10 cm

prostate cancer



gynecological cancer



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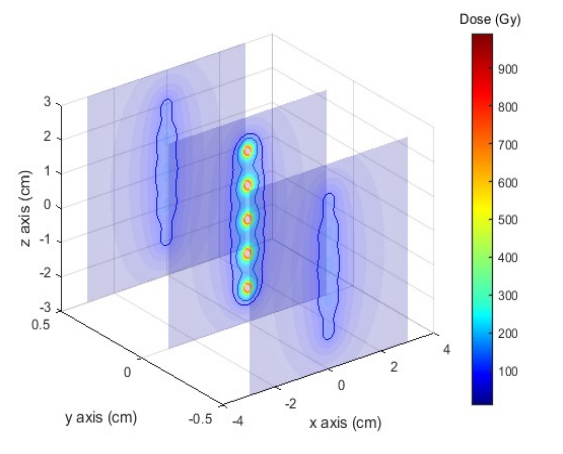
THE ORIGIN PROJECT

Optical Fibre Dose Imaging for Adaptive Brachytherapy

ORIGIN aims to deliver more effective, photonics-enabled, brachytherapy for cancer treatment through advanced **real-time radiation dose imaging** and source localisation. This will be achieved by the development of a new **optical fibre-based sensor** system to support diagnostics-driven therapy through enhanced adaptive brachytherapy.



ORIGIN CONSORTIUM

PI from Limerick University

UNIVERSITY OF LIMERICK OLLSCOIL LUIMNIGH

VUB VRIJE UNIVERSITEIT BRUSSEL

UNIVERSITÀ DEGLI STUDI DELL'INSUBRIA

QUEEN'S UNIVERSITY BELFAST

GALWAY CLINIC

BEBIG

DOSEVUE

FINBA
Fundación para la Investigación y la Innovación Biosanitaria del Principado de Asturias

SERVICIO DE SALUD DEL PRINCIPADO DE ASTURIAS
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Servicio Radiofísica y P.R.

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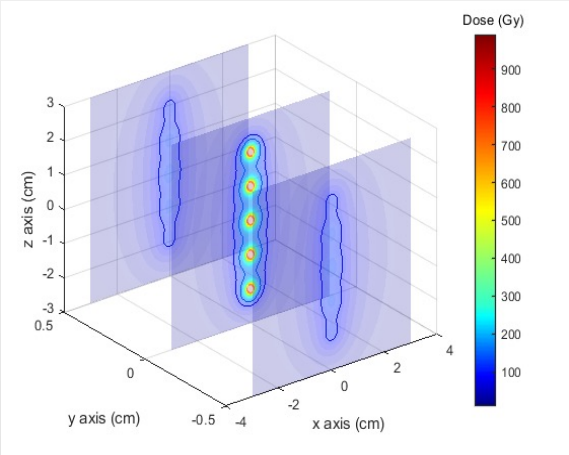

	LDR - BT	HDR - BT
Sensitivity to Dose	up to 3 cm	up to 10 cm
Spatial Resolution	3 mm @ 3 cm	1 mm @ 5 cm
Dose Rate Range	1 mGy/s up to 15 Gy/s	
Statistical Precision	5% in 0.5 s	5% in 0.1 s

At least 16 dosimeters are need to localize the source.

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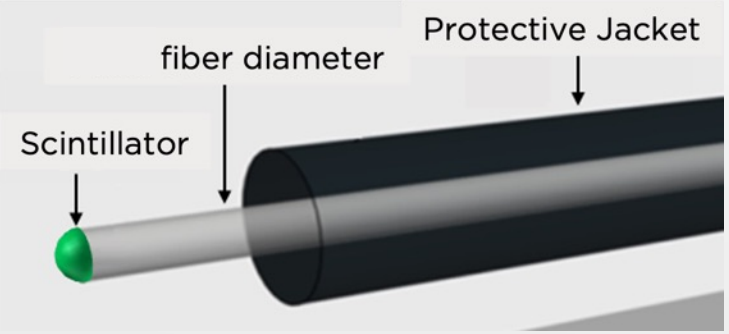
THE ORIGIN PROJECT: DOSIMETER SYSTEM

The project's goal will be achieved by developing a **16 optical fiber**-based system with **scintillating light detected by SiPM** to reconstruct the dose map.



Scintillator	Gadox (LDR)	YVO (HDR)
τ [μs] *	500	500
λ_{max} [nm]	545	600 - 650
LY [ph/MeV]*	$7.1 \cdot 10^4$	$4.8 \cdot 10^4$
Transmittance*	10.2 %	4.2 %

*S. Cometti et al. "Characterization of scintillating materials in use for brachytherapy fiber based dosimeters", accepted for publication to NIMA

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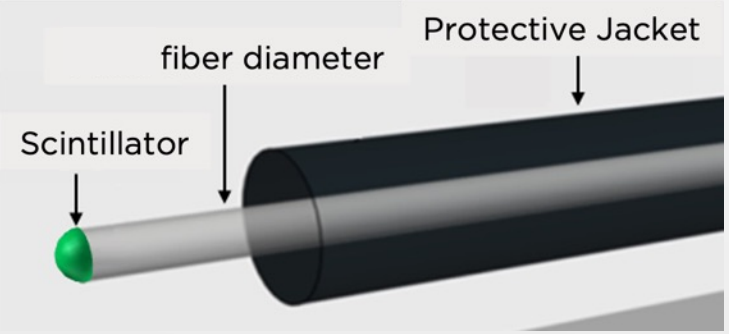

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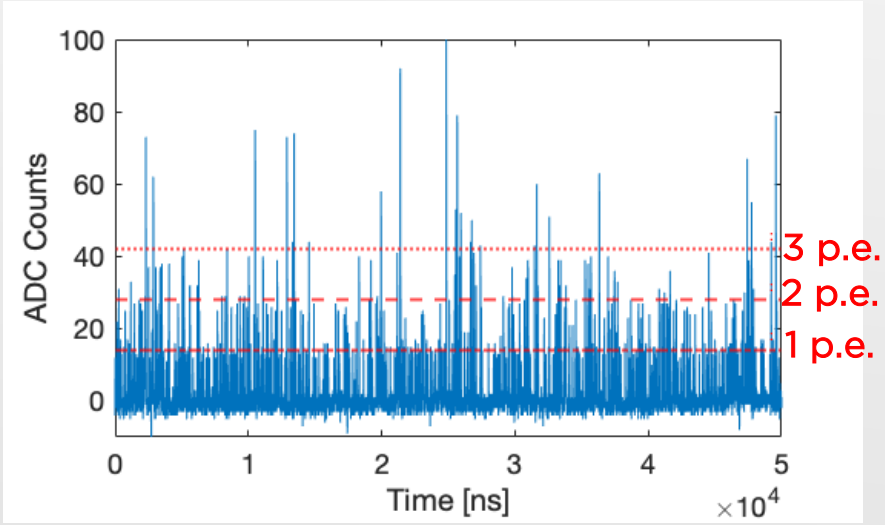

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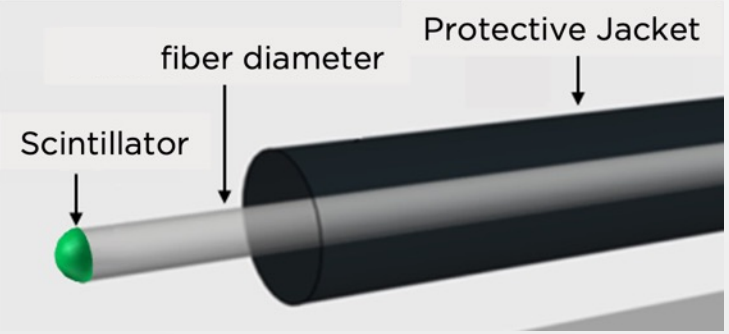

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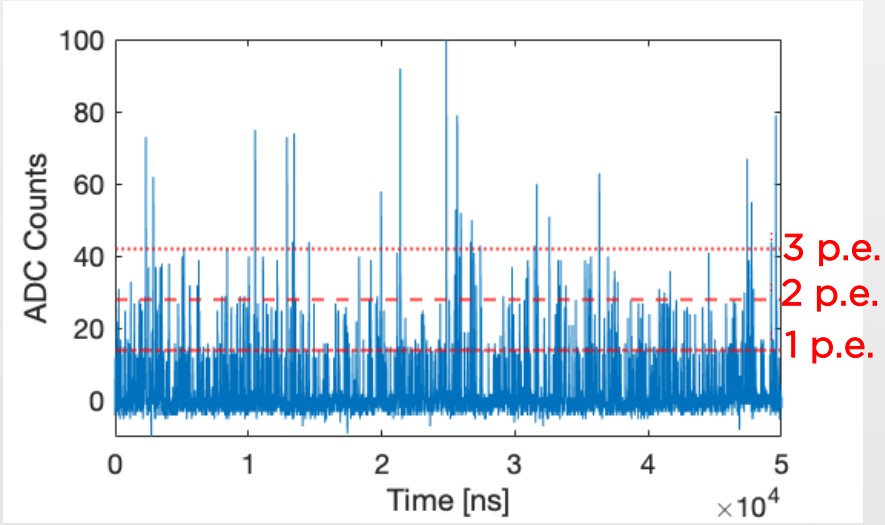

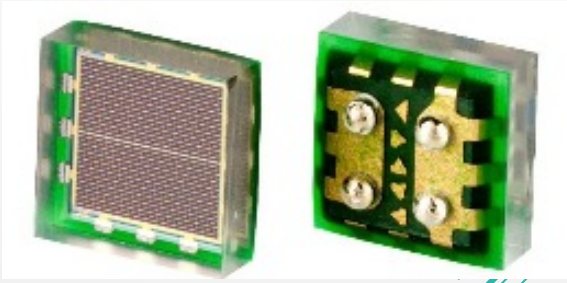

Sensor: 1x1 mm² Ketek

PDE @ 600 nm: 14 %
DCR @ 0.5 p.e.: 100 kHZ
OPT: 26%
Op. Voltage: V_{bd} + 7 V

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SINGLE CHANNEL MEASUREMENTS

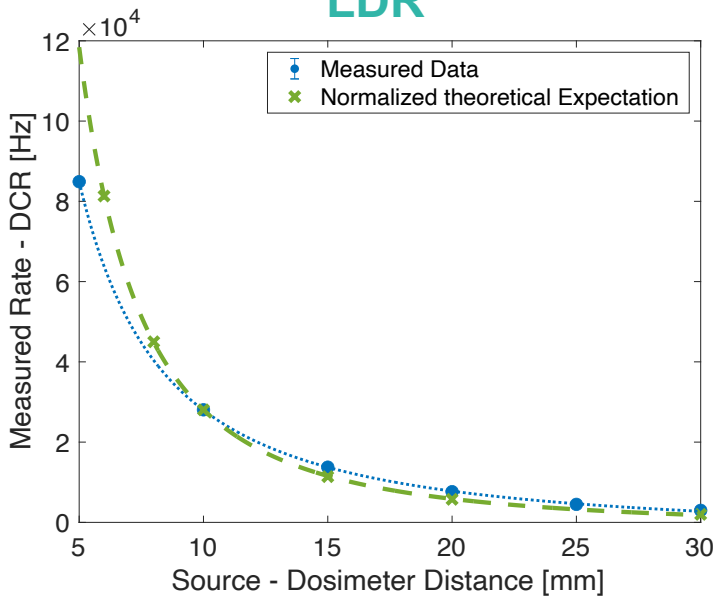
- From single channel measurement was possible to extract all the specification of the project.
- The results prove that the single fibre dosimeter system complies with the specifications for both the **HDR-BT** and **LDR-BT**.
- The data follow the Treatment Planning System (TPS)

Sensitivity to Dose: 3 cm

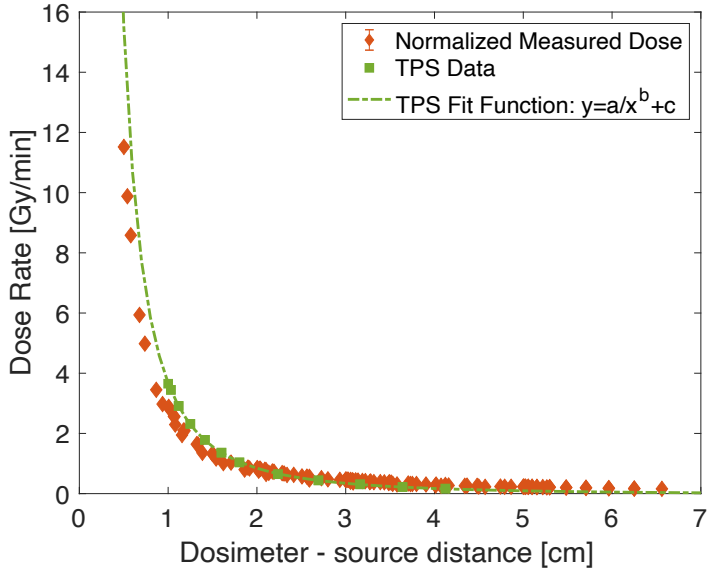
Spatial Resolution: 1.4 mm

Statistical Precision: 2.6 % in 0.5 s

LDR



HDR



Sensitivity to Dose: 10 cm

Spatial Resolution: 0.8 mm

Statistical Precision: 3 % in 0.1 s

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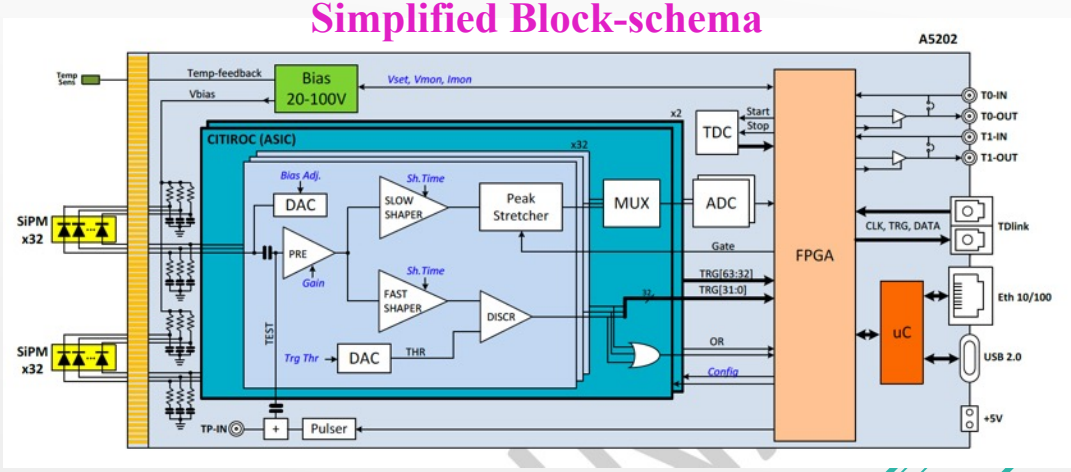
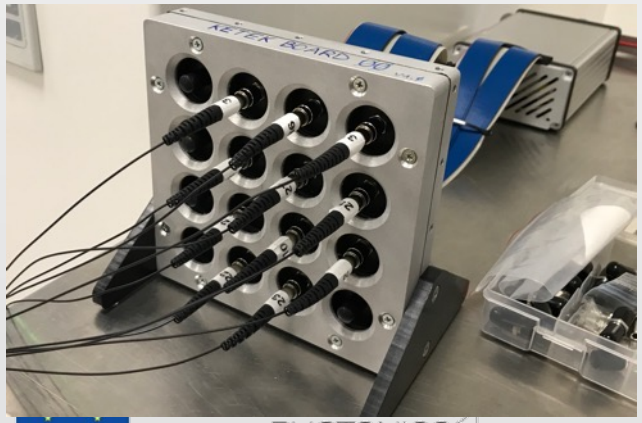
THE 16 CHANNEL READOUT SYSTEM

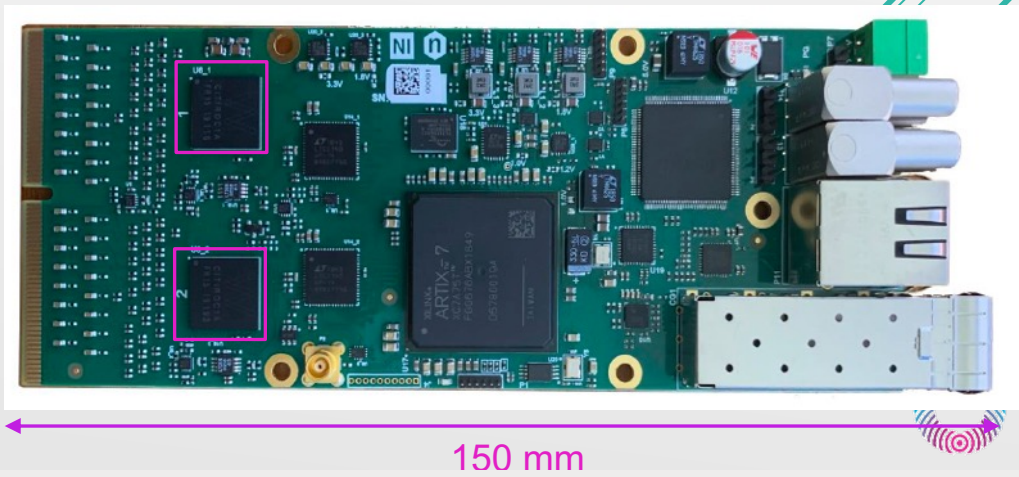
64-channel SiPM readout board (CAEN* FERS) equipped with 2 WEEROC CITIROC1A ASICs**

- ✓ Single p.e. counting capability
- ✓ Maximum counting rate: 20 MHz
- ✓ 1 HV power supply (20 – 100V) with temperature compensation
- ✓ Ethernet, usb2 and optical link interface for readout (up to 6.25 Gbit/s)

Simplified Block-schema





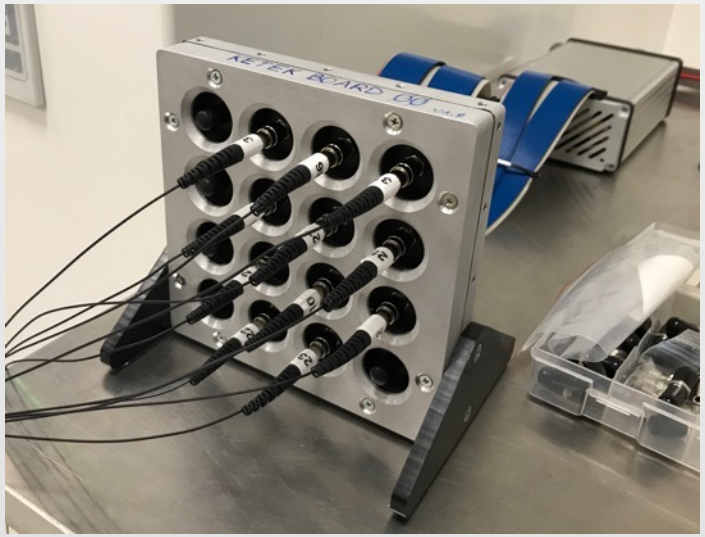


*https://www.caen.it/products/a5202/

**https://www.weeroc.com/products/sipm-read-out/citiroc-1a

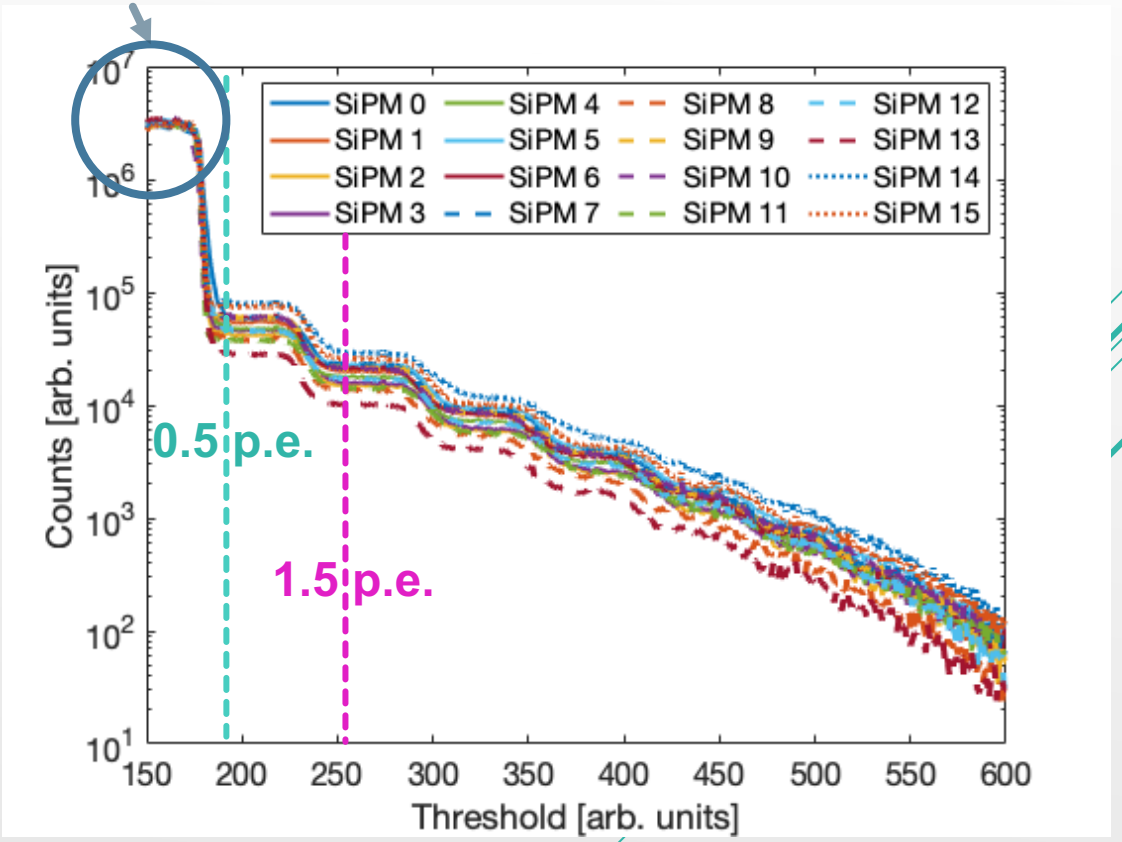
LABORATORY-QUALIFICATION

- An automatic procedure is used to estimate the $V_{BreakDown}$ (V_{BD}) for all SiPMs.
- **V_{BIAS}** adjustment allows to equalize the Δpp and to operate all SiPMs at the same PDE (**$V_{BIAS} = V_{BD} + 7$ V**).
- Staircases acquired at **V_{BIAS}** to select **0.5 p.e.** and **1.5 p.e.** threshold.



Baseline crossing

Typical Staircase



Same Threshold on all channels

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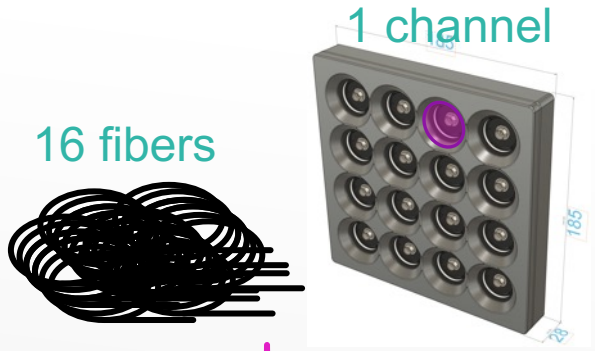
LABORATORY-QUALIFICATION

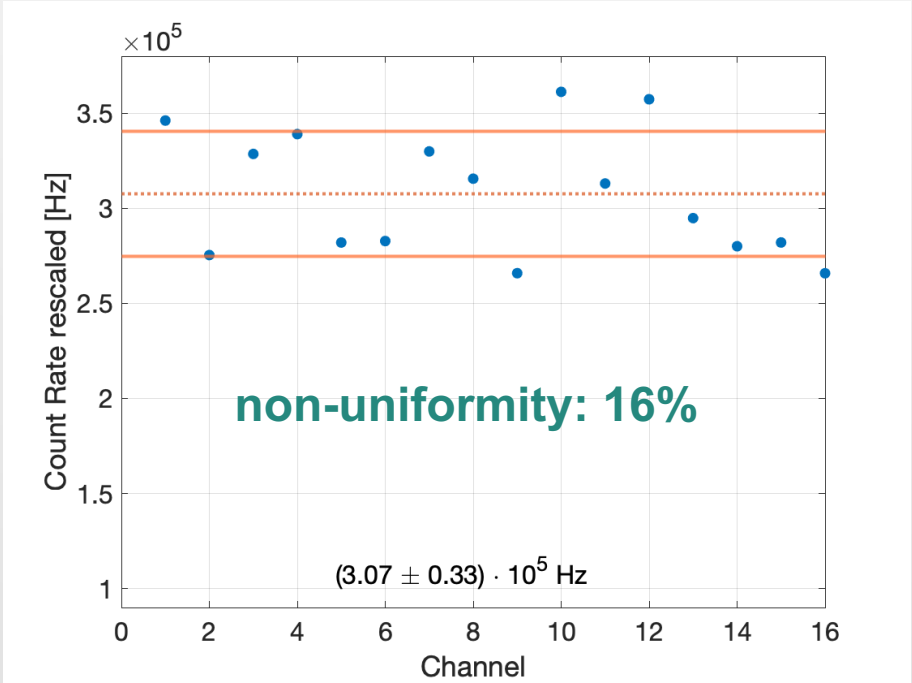
Measurements with X-ray cabinet to evaluated the uncertainties:

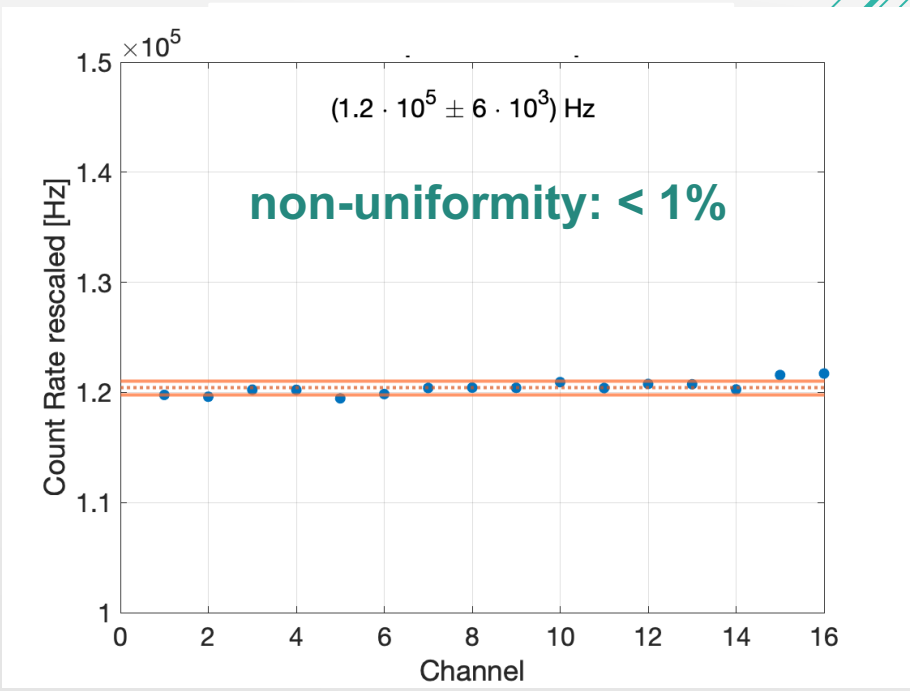
- Fiber positioning: 0.8%
- Fiber connection: 0.1%
- Geometrical acceptance: 10 %



- Fiber Non-Uniformity:
  16 % (pre-production)
  1.2 % (new production)

Normalization with a **scaling factor** including all the contributions





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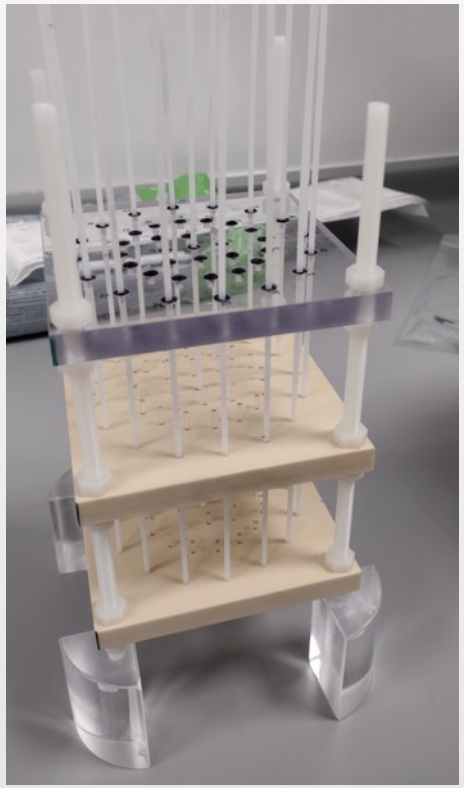
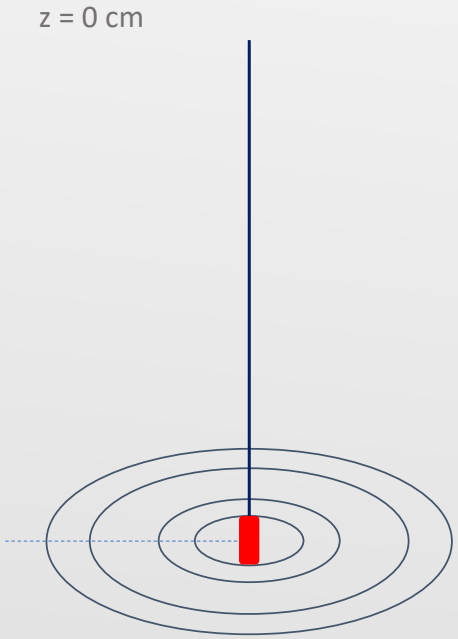
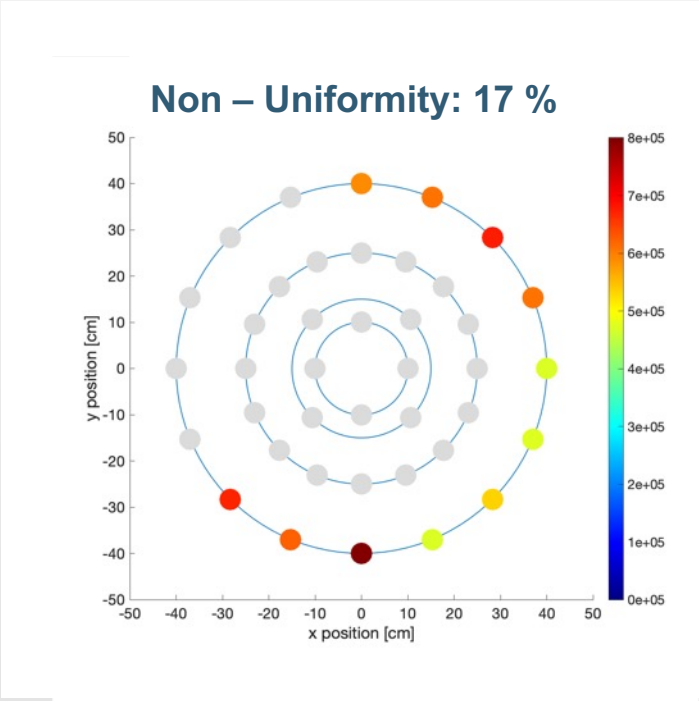
EQUALIZATION MEASUREMENT

- Water-phantom with circular geometry
- All fibres at the same distance from the source
- Measured counting rate normalised at mean value
- Run to check equalization procedure; systematics variation less than 1%







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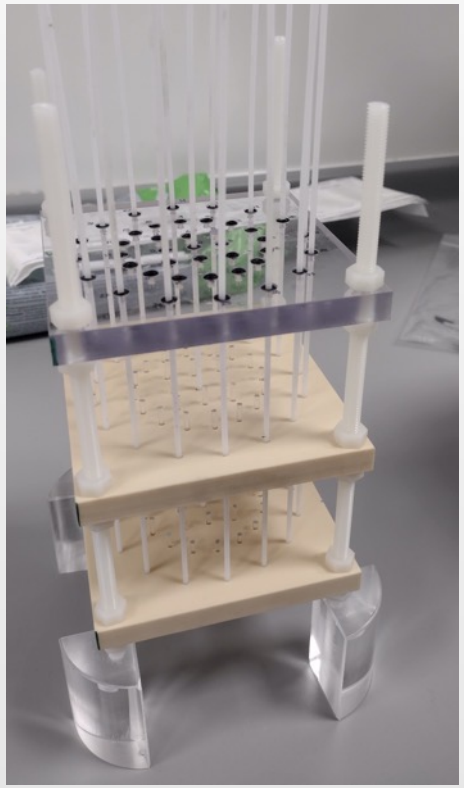
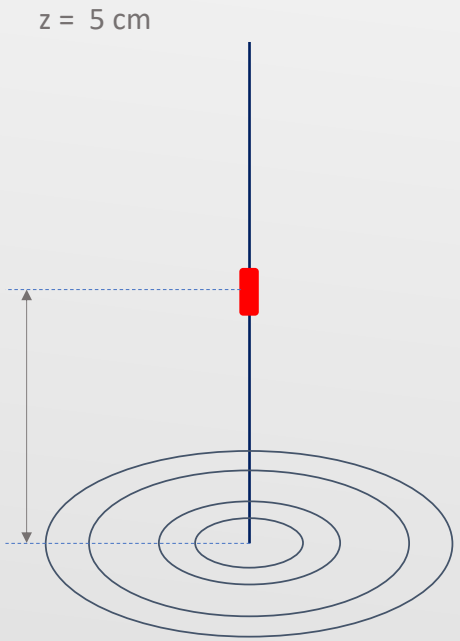
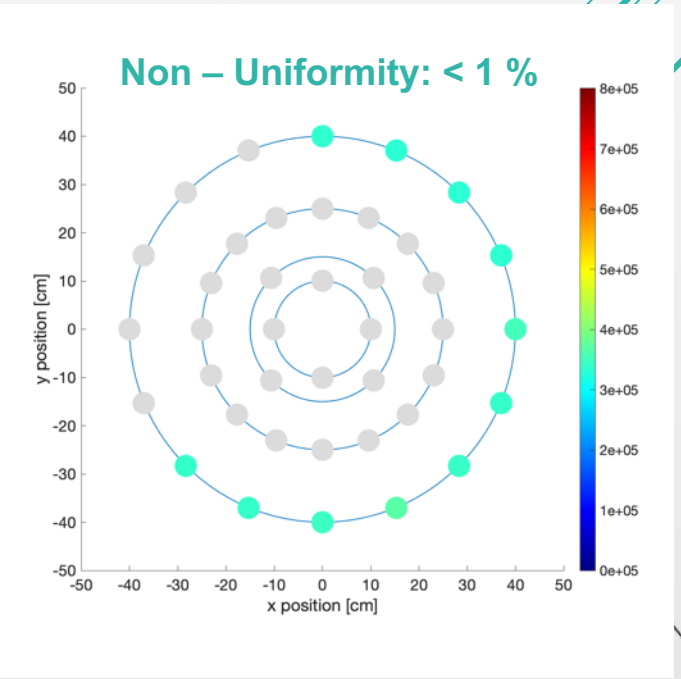




The normalization scaling factor was check at different distances: **5 cm**



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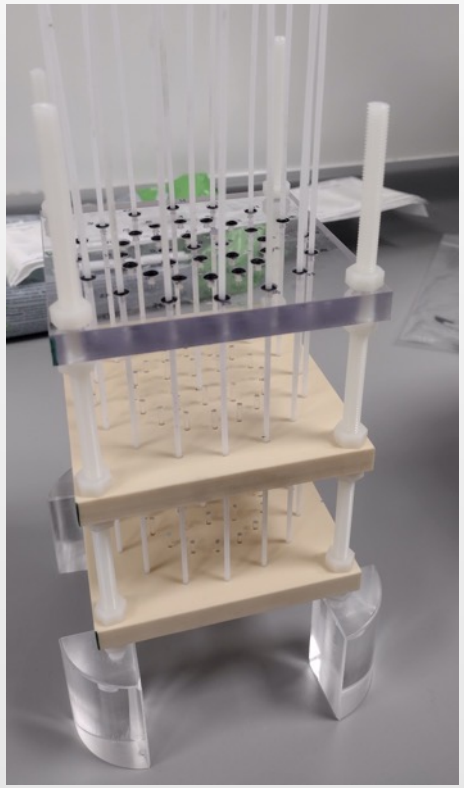
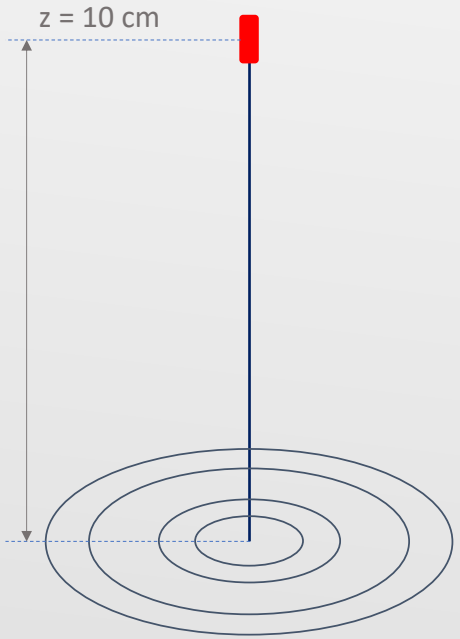
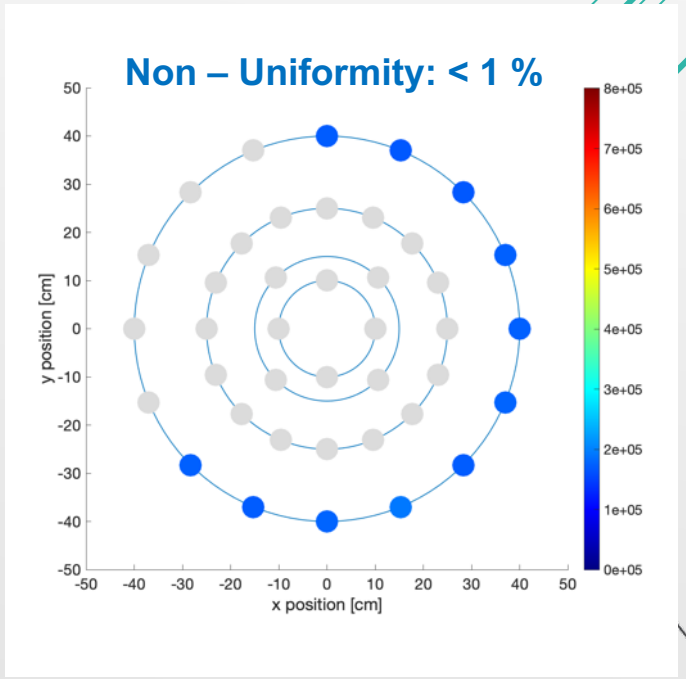




The normalization scaling factor was check at different distances: **10 cm**



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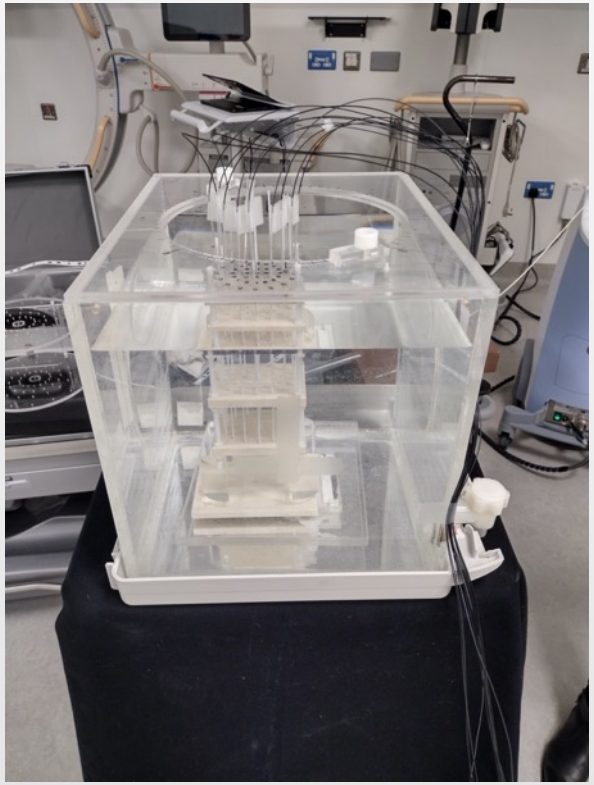
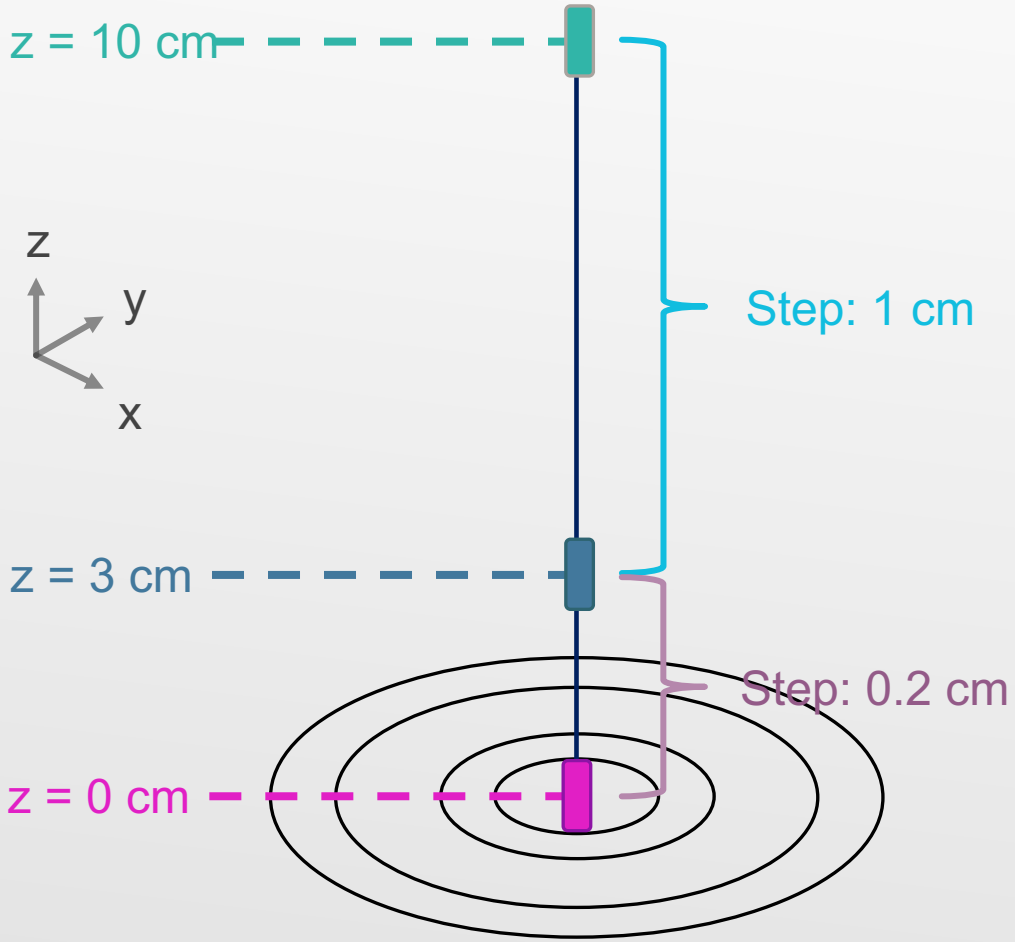
CLINICAL MEASUREMENTS

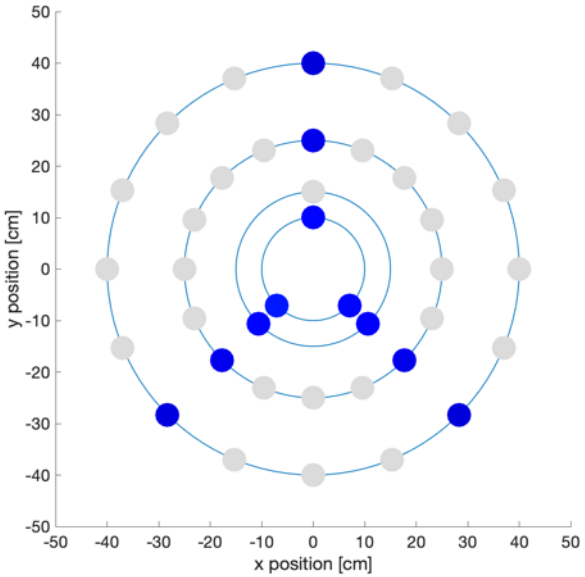
16-channel system, with dosimeters placed around a ^{192}Ir radioactive at the Queen's University Hospital (Belfast, Ireland).





11 Fibres:

- 3 fibres at r = 4 cm,
- 3 fibres at r = 2.5 cm,
- 2 fibres at r =1.5 cm,
- 3 fibres at r = 1 cm.



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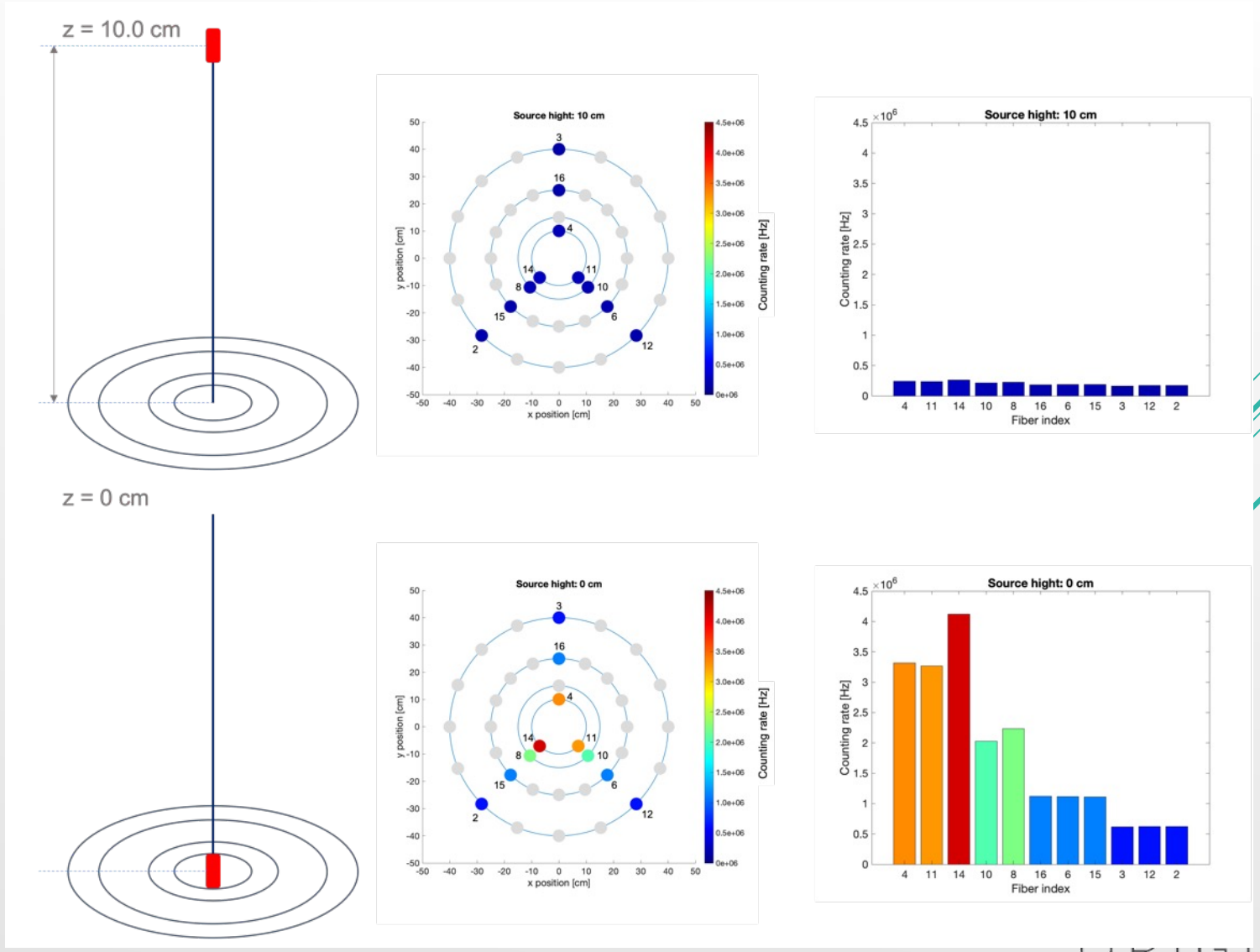
CLINICAL MEASUREMENT RESULTS

- The source is moved from a 10 cm distance on the z axis down to z = 0 cm and the corresponding counting rate as a function of distance was measured.

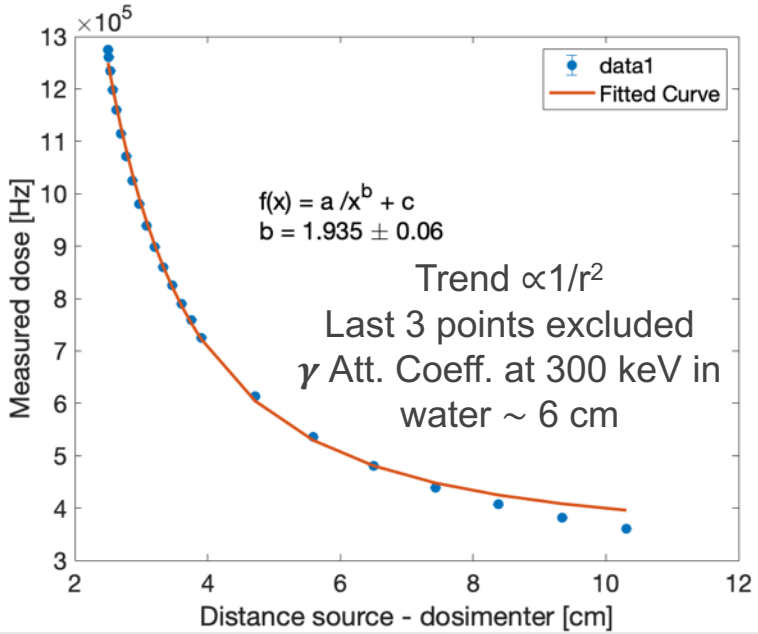


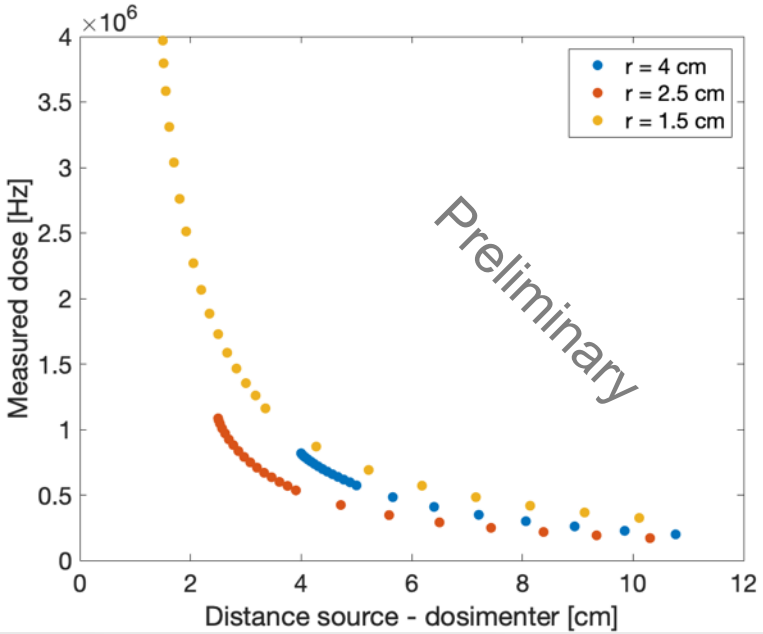
CLINICAL MEASUREMENT RESULTS

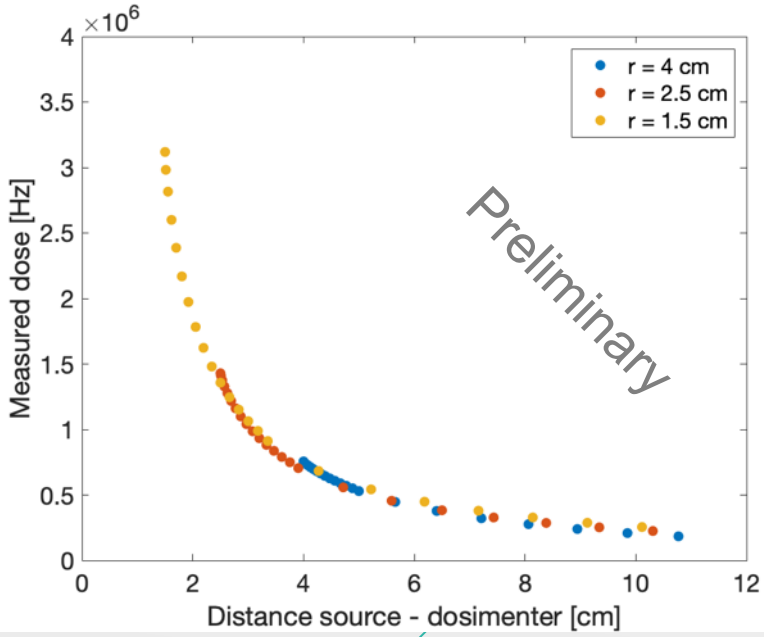
One Fiber (r = 2.5 cm):
pile-up corrected

Tree Fibres:
(**r = 4 cm**, **r = 2.5 cm**, **r =1.5 cm**):
pile-up corrected - DCR subtracted

Tree Fibres:
(**r = 4 cm**, **r = 2.5 cm**, **r =1.5 cm**):
pile-up corrected - DCR subtracted
After Equalization







The sensors are capable of monitoring the radiation dose at distances compatible with brachytherapy.

Data has to be compared with TPS.

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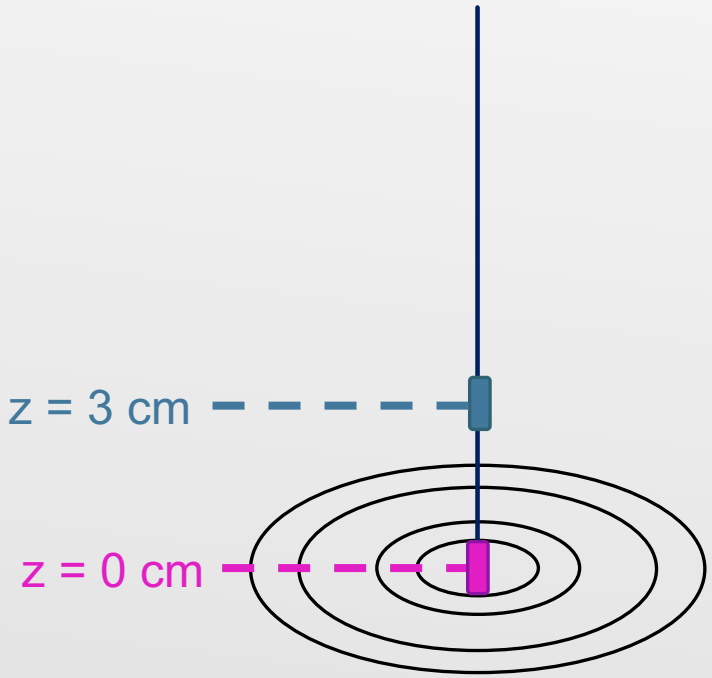
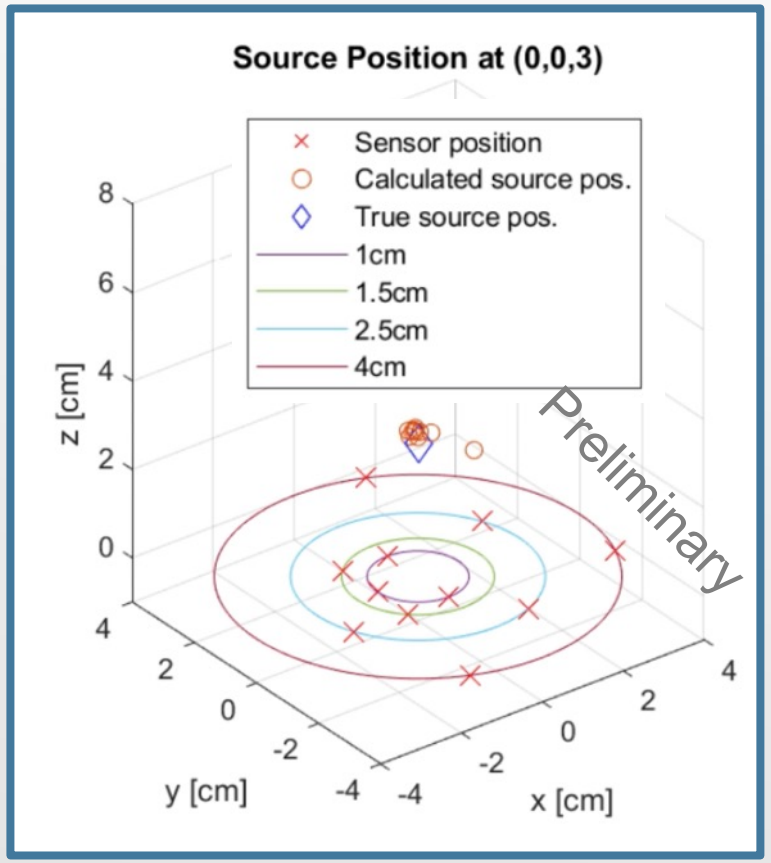
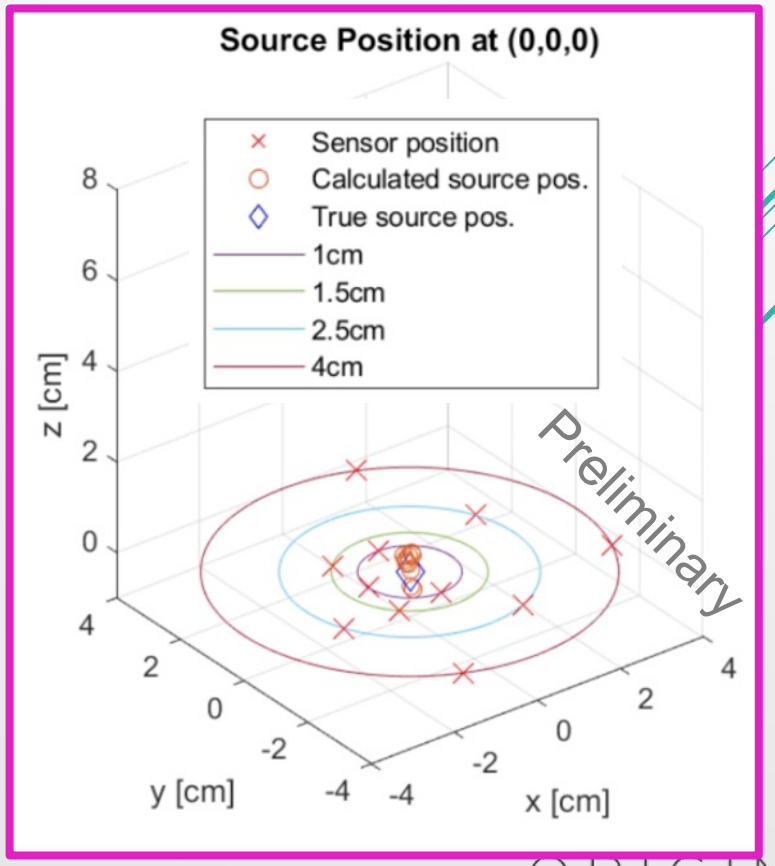
SOURCE LOCALIZATION

- Source localization has been implemented using triangulation algorithm. Initial results looks promising.
- A quantitative assessment was not completed yet.







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OUTLOOK

- The laboratory characterization shows that the uncertainties of the system are less than 1%.
- The clinical HDR characterization of the ORIGIN dosimeter shows the expected trends. The data has to be compared with TPS.
- 3D-printed semi-anatomical phantom prototypes were developed to provide be used in the evaluation of the dosimetry system.
- will be integration of the ORIGIN dosimeter prototype in a clinical systems started.

thank you

Contact Us

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