

Detectores para hadronterapia

Consuelo Guardiola¹, Jose Manuel Udías², Faustino Gómez³, Gabriela Llosa⁴

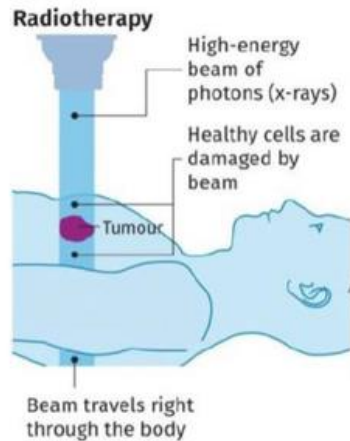
¹*Centro Nacional de Microelectrónica (CNM), Grupo Detectores de Radiación*

²*Univ. Complutense de Madrid (UCM), Grupo de Física Nuclear*

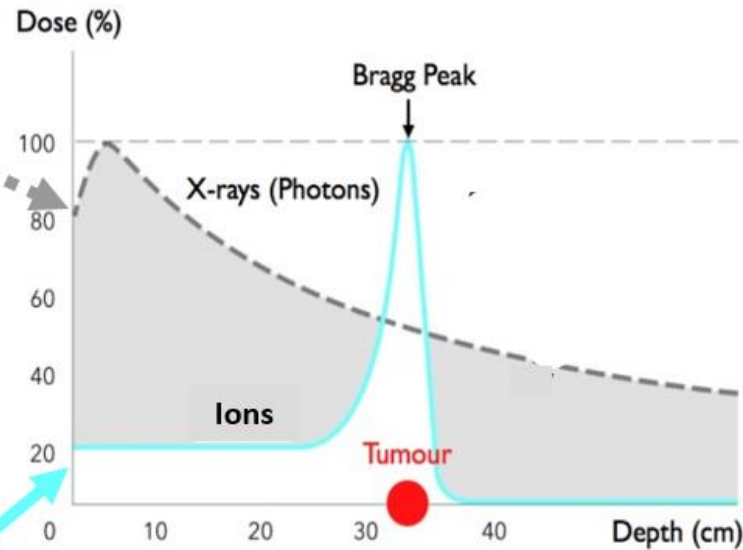
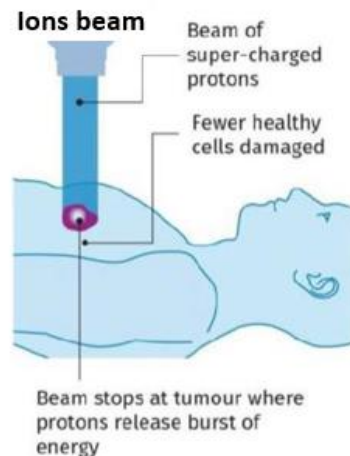
³*Univ. Santiago de Compostela (USC), Laboratorio de Radiofísica*

⁴*Instituto de Física Corpuscular (IFIC), Grupo de Imagen Médica*

Hadrontherapy: radiotherapy using protons and heavy ions



Source: Cancer Research UK



Physical advantages:

- Finite range → Bragg peak:
 - Better conformity of dose in tumor
 - Sparing healthy tissue
- Reduced dose by a factor of 2 to 5 outside of the target

10 new proton therapy centers in Spain in the next 3 years!

FICHA TÉCNICA

Fecha de inicio

2021

Fecha prevista de fin

2025

Tipo de equipamiento

10 aceleradores de protones para el tratamiento del cáncer, situados en las provincias de A Coruña, Barcelona (2), Bizkaia, Madrid (2), Málaga, Sevilla, Valencia y la isla de Gran Canaria.

Inversión estimada

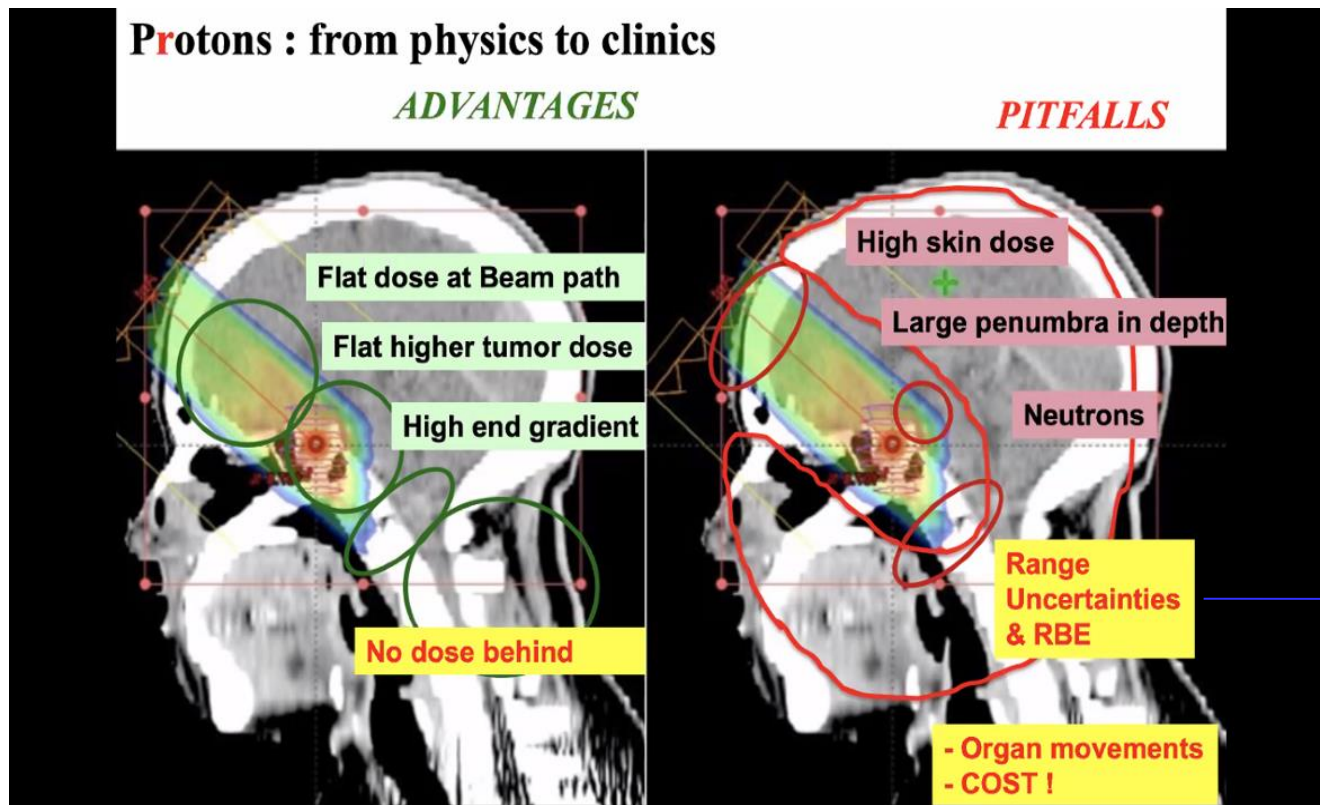
280 millones de €

Programa para la implantación de la protonterapia en el sistema público de salud de España

Área salud

En octubre de 2021, la Fundación Amancio Ortega acordó con el Gobierno de España y varias comunidades autónomas una donación de 280 millones de euros para instalar diez aceleradores de protones en el sistema público de salud.

Source: Amancio Ortega foundation web page

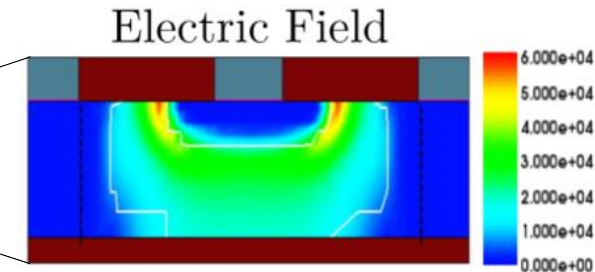
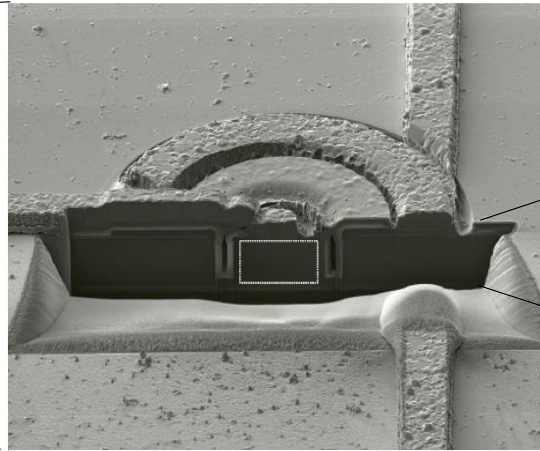
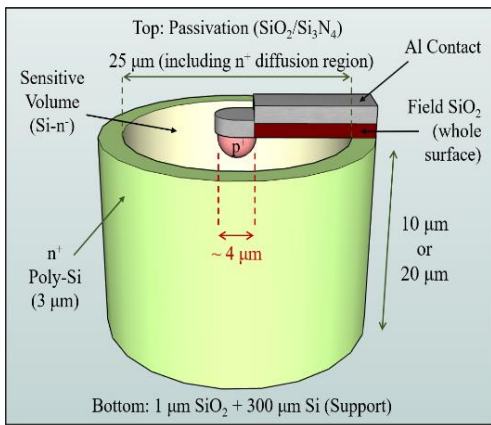


Source: A. Mazal (QuirónSalud Proton therapy center)

- CNM & USC → microdosimetry (RBE)
- UCM & IFIC → Range verification, dose monitoring

+ advanced modalities (**FLASH**): detectors (US), beam structure (UCM)

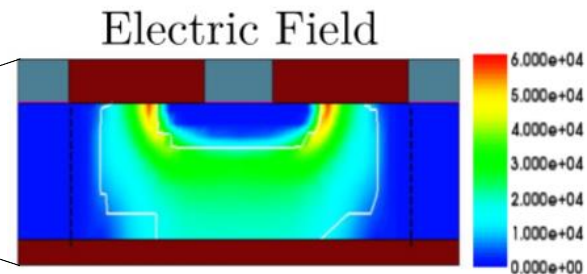
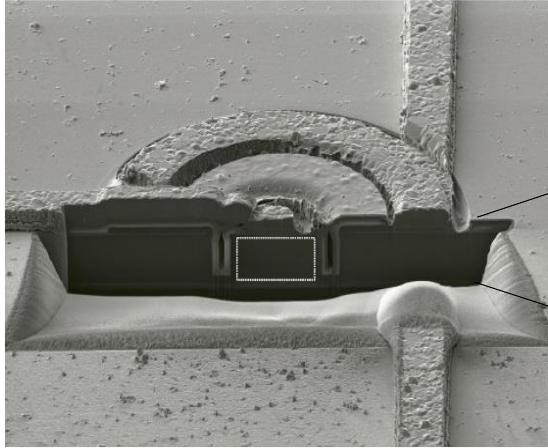
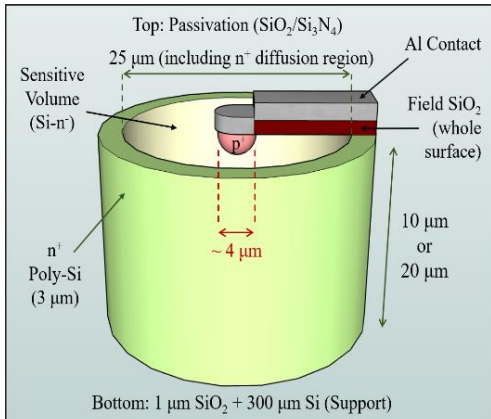
Novel 3D-cylindrical silicon microdetectors



*C. Guardiola et al.,
Brevet ref: PCT/ES2015/070056*

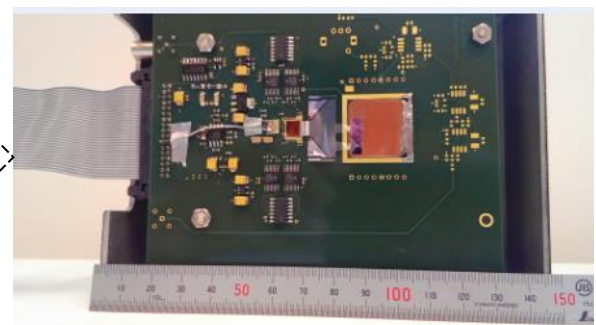
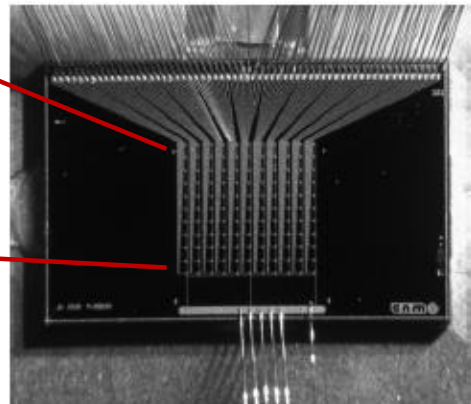
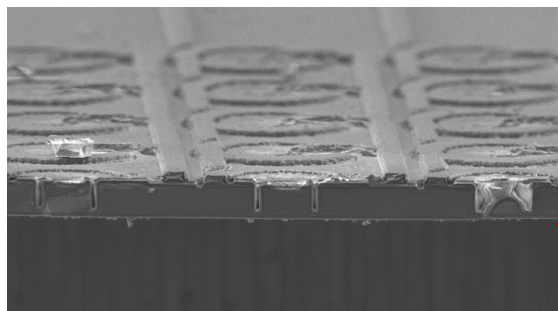
Diameters: 9, 10, 15, 20, 25 μm
Thickness: 5, 10, 20 μm

Novel 3D-cylindrical silicon microdetectors



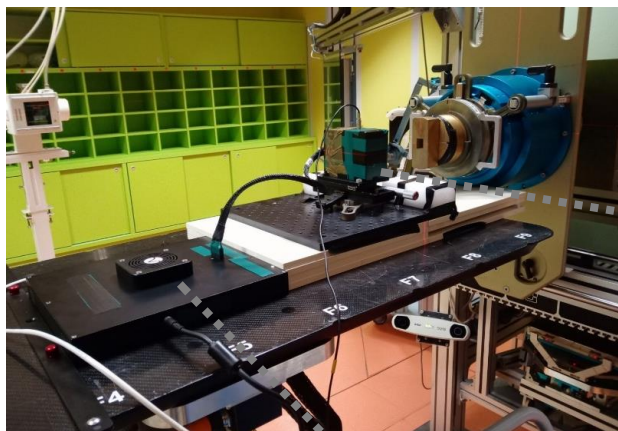
C. Guardiola et al.,
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Diameters: 9, 10, 15, 20, 25 μm
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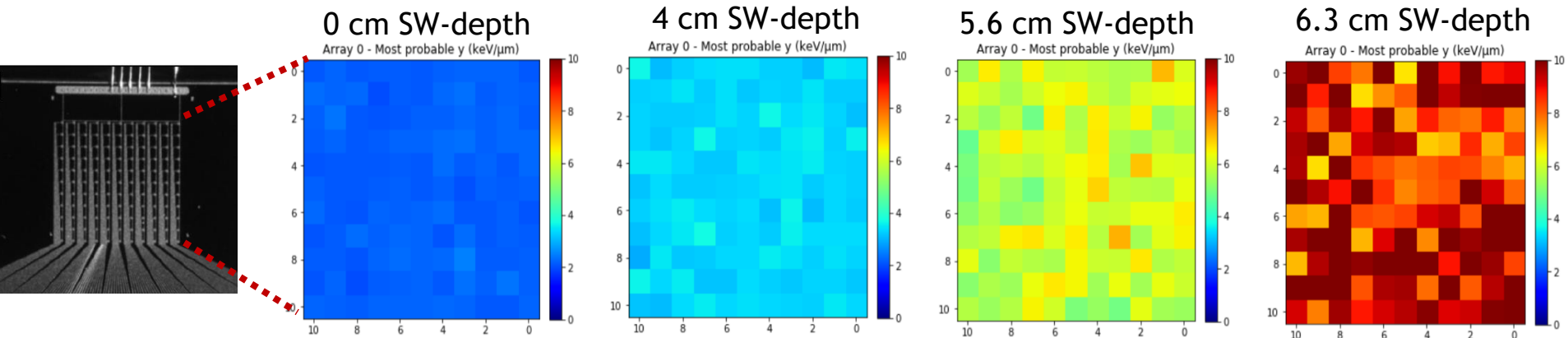
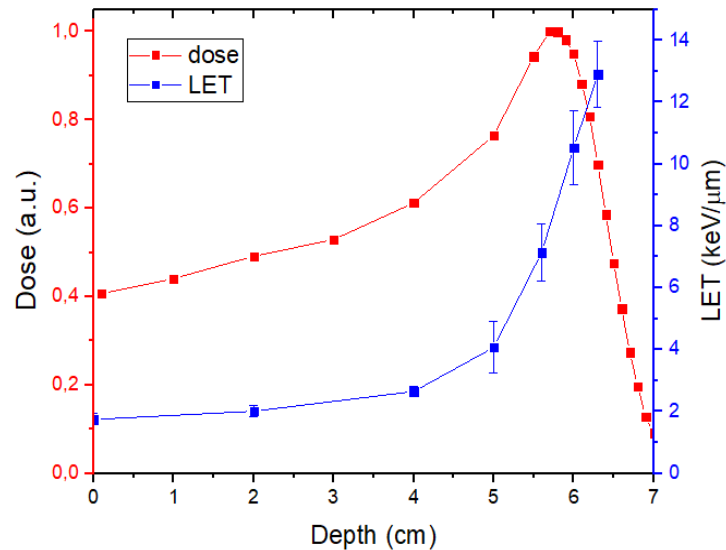
Pitch: 25, 50, 100, 200 μm

Institut Curie-Center of Proton therapy d'Orsay (ICPO)



microdosimeters

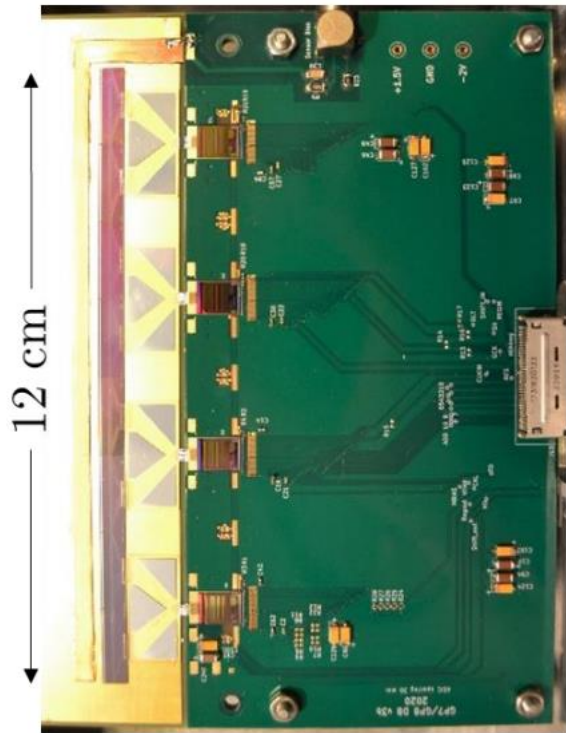
DAQ



First LET 2D-maps in clinical conditions!

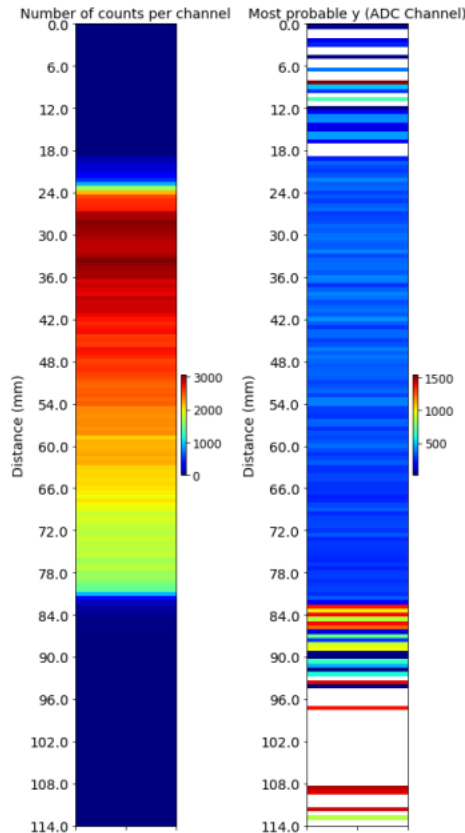
Guardiola C. et al, Medical Physics, 2022

Covering larger sensitive surfaces (cms)

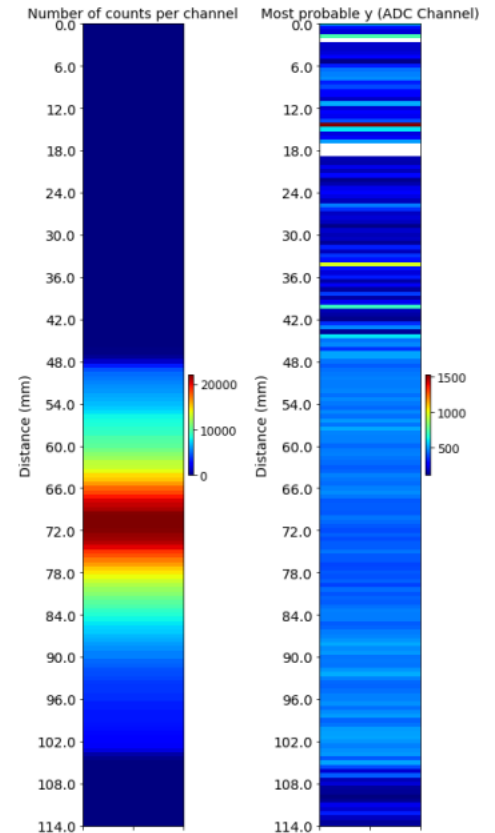


~ 12 cm

16 MeV Protons



10 MeV Protons



Bachiller-Perea D. et al, Scientific Reports (Nature), 2022

Detector +DAQ for nanosecond proton beam structure measurements and real time dose measurements

Problem: high dose rate in new centers → conventional prompt-gammas (e.g. IBA) saturates

Beam /bunch Sub- μ s structure fully resolved with sub-nanosecond time resolution

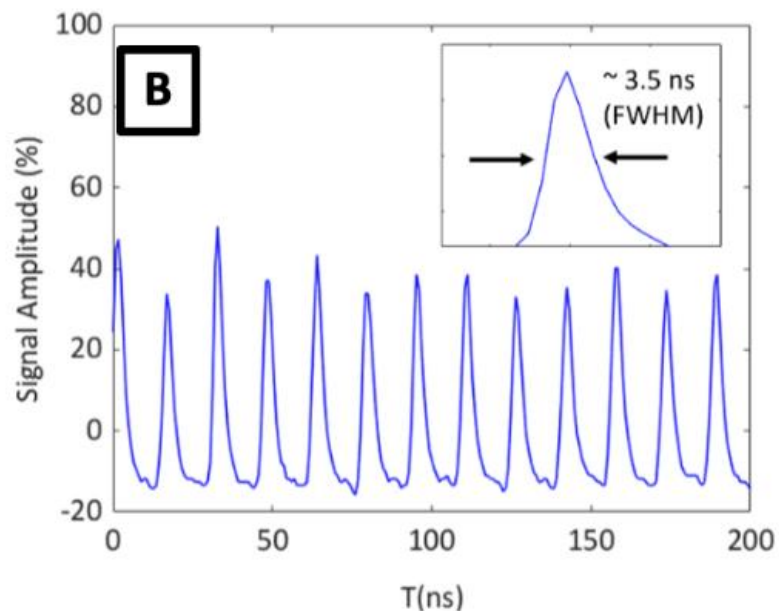
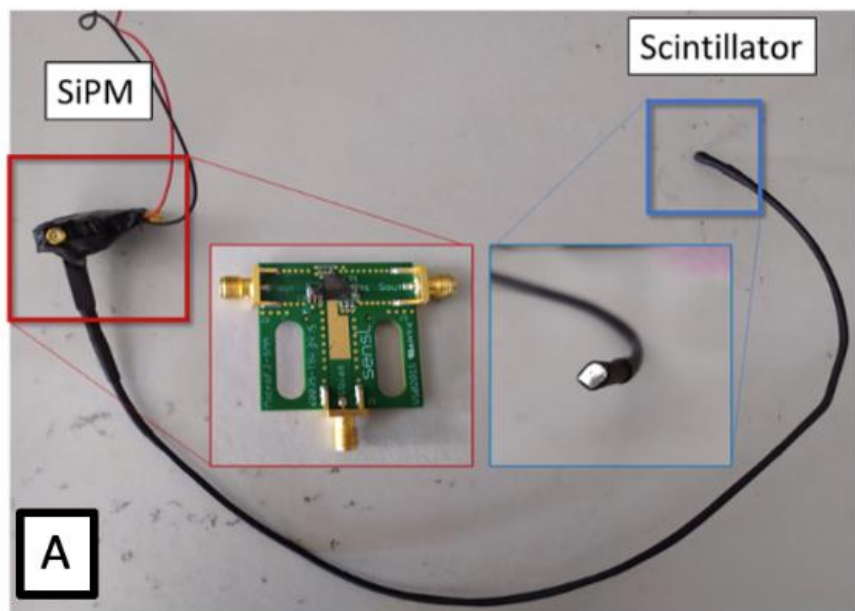
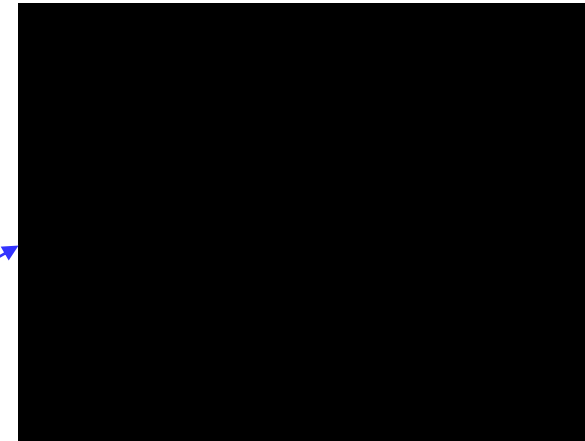
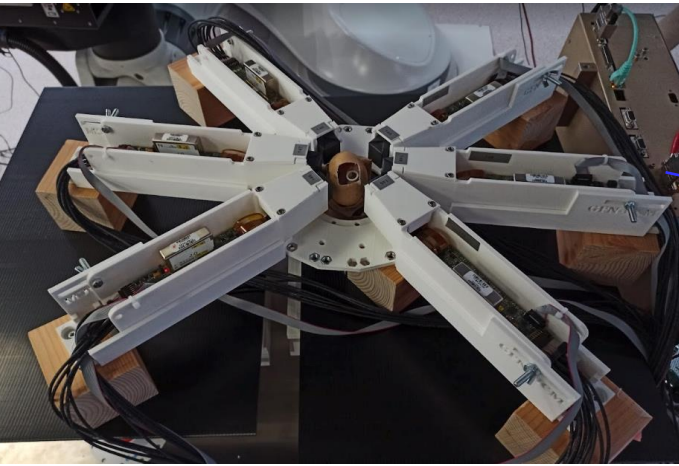


Fig. Detector: $3 \times 3 \times 3 \text{ mm}^3$ plastic scintillator (right)+coupled to a $3 \times 3 \text{ mm}^2$ SiPM (left) from SensL, through an optical fiber. A fully digital DAQ at 5 Gs/s processes the signals in real time. The detector has been tested at FLASH and conventional rates at CMAM and Quiron (ProteusOne IBA) protontherapy facility.

Mini-PET for proton range verification (collaboration with SEDECAL)

Working in real-time, close to patient, without saturation and high-spatial resolution



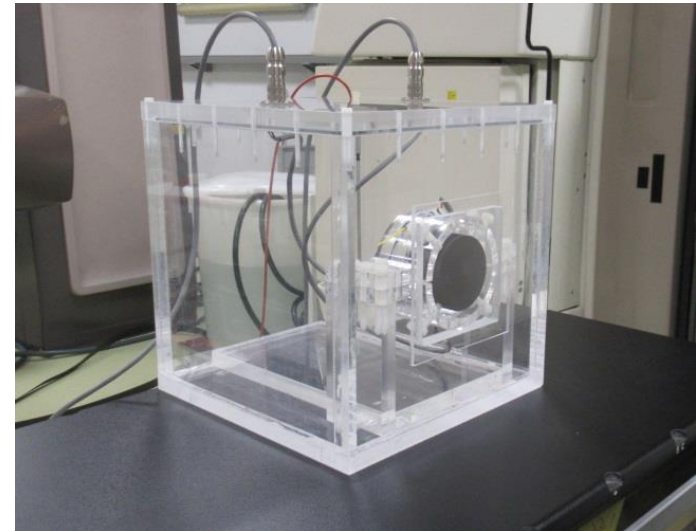
Resolution (mm³)

12 PET detectors (318 crystals
each one of 1.55x1.55 mm²)

¿Se puede construir un patrón de dosis de la máxima calidad que garantice la trazabilidad directa de la dosimetría de los centros de radioterapia de España?

- Desarrollado en el proyecto de ISCIII con Instituto de Investigaciones Sanitarias de Santiago y Hospital Universitario Lucus Augusti.
- Permite abordar la calibración de nuevos centros y modalidades de tratamiento.
- Garantía de control dosimétrico en los ensayos clínicos de fase III.
- Programa de intercomparación para servicios hospitalarios.

Calorímetro portátil de grafito

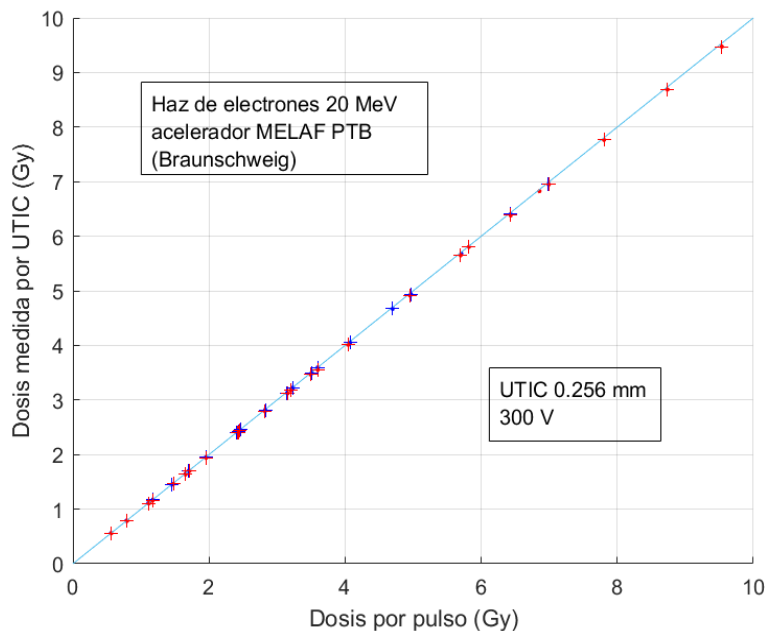


sistema primario de medida de dosis absorbida

Cámara de ionización ultradelgada para FLASH

FLASH (tasas de dosis por pulso superiores a 10^6 Gy/s)

Prototipo construido en USC (2020) con distancia entre electrodos < 0.25 mm y WET 0.85 mm



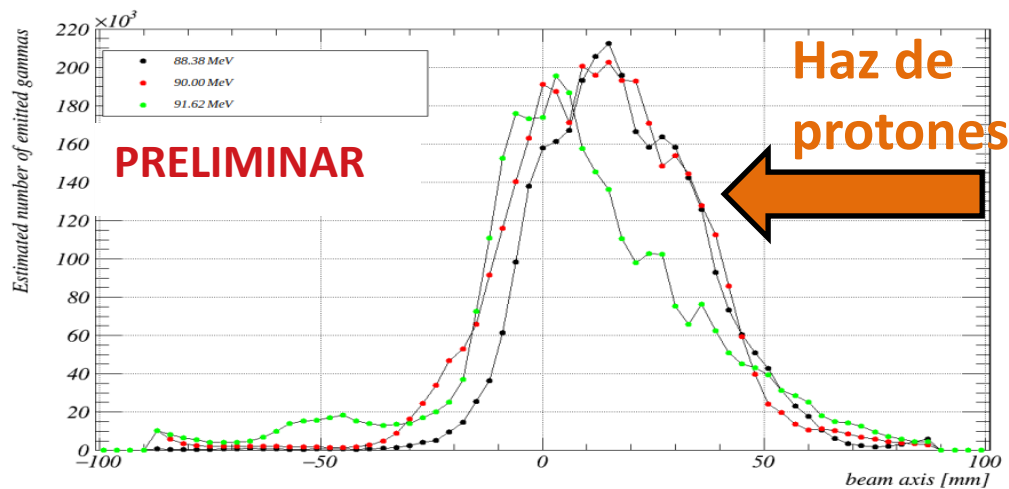
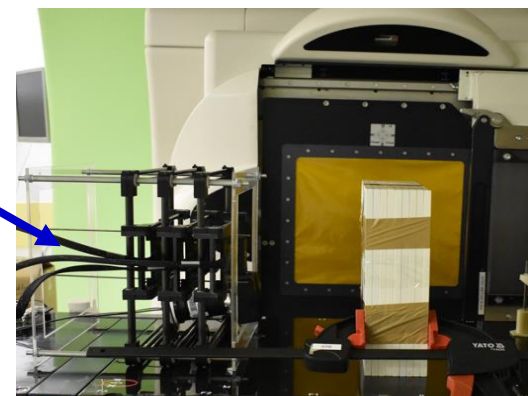
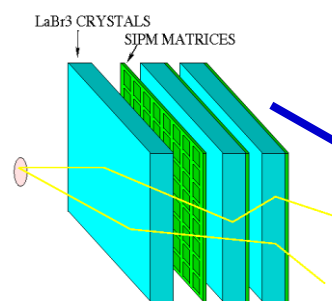
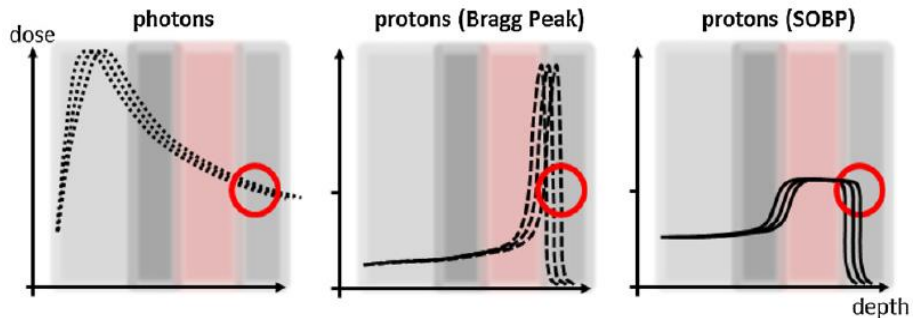
F. Gomez et al, Medical Physics, 2022

Desarrollada en proyecto EMPIR (EURAMET)

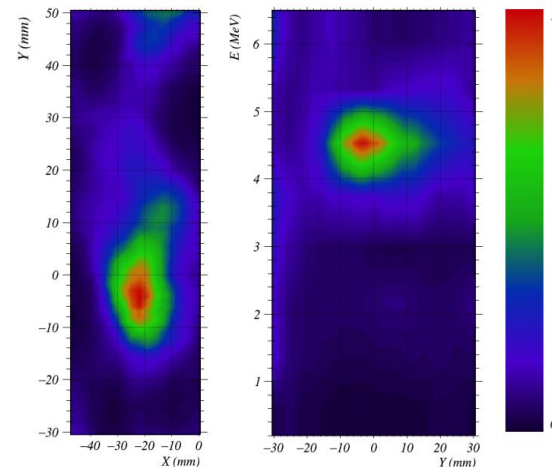
- Capaz de medir dosis por pulso hasta 10 Gy en $4 \mu\text{s}$ a 300 V de polarización (desviación $< 0.5\%$)
- Actualmente en proceso transferencia comercial (PTW)

Sistema de monitorización para terapia hadrónica:

estimación de distribución espacial y energética de los fotones emitidos



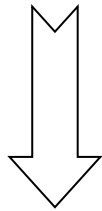
Variaciones de 2 mm en la posición del pico de Bragg observadas



VALMONT- Valorization of a hadron therapy monitoring system (INNVA1/2021/37)
 VALID - Valorization of new detectors for medical imaging (PDC2021-121839-I00)
 MONDO- Monitoring and dosimetry in hadron therapy (PID2019-110657RB-I00)

Conclusions

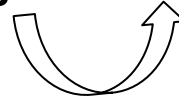
- **Highly competitive technology in hadrontherapy hot-topics**
- **Prototypes** developed ready for being transfer into clinical facilities
- **Strong know-how in radiation detectors**



We are open to collaborate with enterprises!

Needs from industry

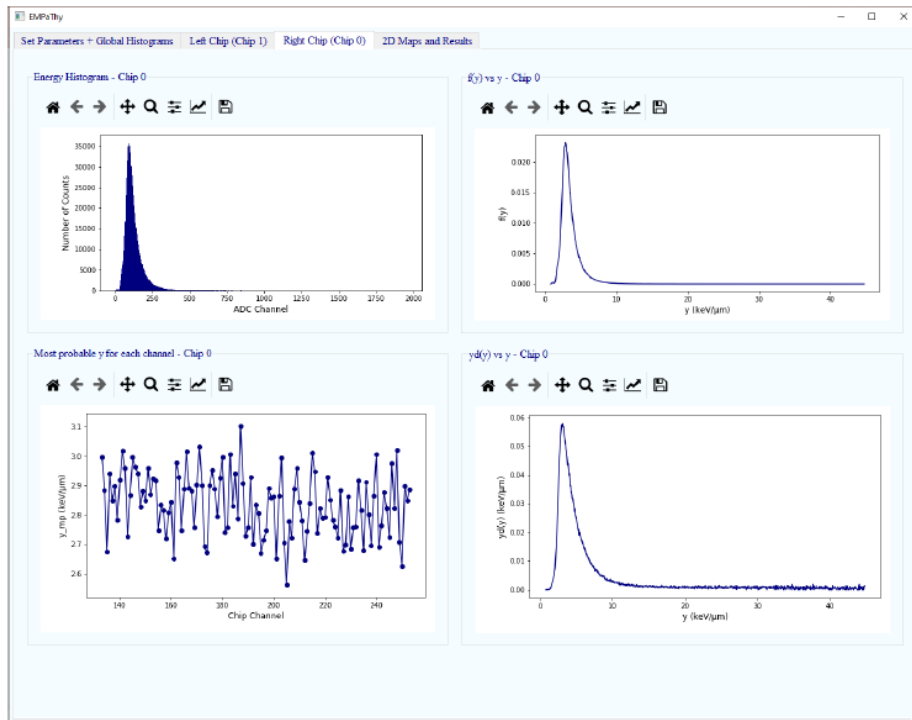
- **Tests in clinical conditions**
- More **electronics** developments
- **Software** developments
- Interest for **transferring techn.**



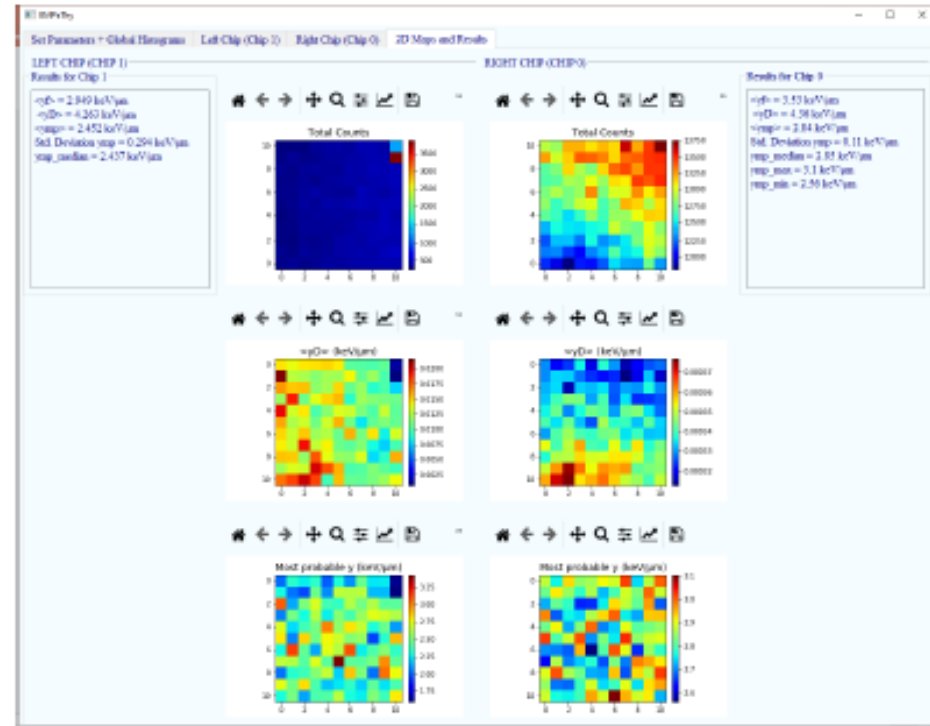
Thanks for your attention!

In-house Python code for GUI for in-situ fast data analysis

Energy spectra



LET maps



2D LET maps in Silicon



2D LET maps in CT

CT file

Click to select CT files

Images : 70
Image size (pixels) : 359x362
Volume size (mm) : 210 x 245.410246 x 247.761028
Spacing : [3, 0.683594, 0.683594]
Origin : [97.9039, -79.6, -121.68]

Map

Select npy file

Superposition

Thickness equivalent Depth (Z)

X (pixel) 200 Y (pixel) 250
Water (mm) 50.02 Z (pixel) 39
Energy (J) 0.2

Compute & superpose

Axial

69 mm 23

Frontal

130.6 mm 191

Contrast

1458 -1000

Superposition

23

Contrast

2210 -1000

Sagittal

113.5 mm 166

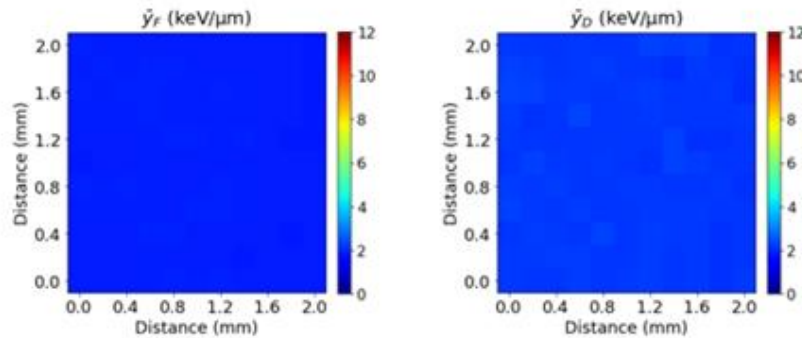
Contrast

1788 -1000

Ongoing: conversion of 2D LET maps in silicon to patient conversion with AI algorithms

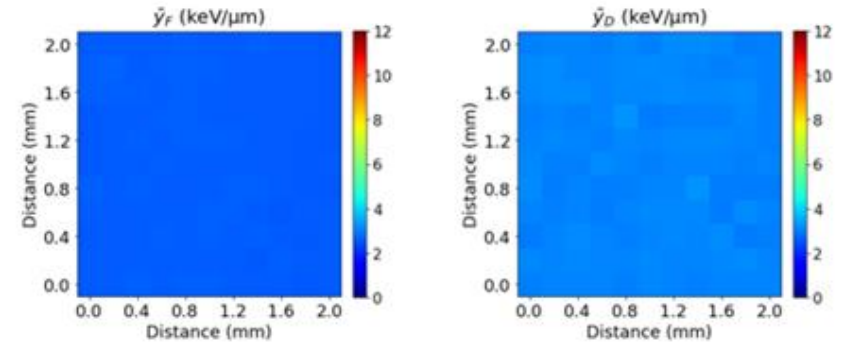
First LET 2D-maps in clinical conditions

0 cm



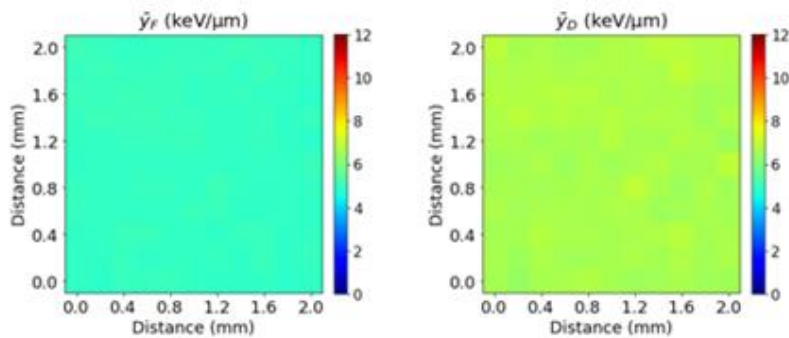
$(1.858 \pm 0.019)\text{keV}\cdot\mu\text{m}^{-1}$ $(2.17 \pm 0.05)\text{keV}\cdot\mu\text{m}^{-1}$

4.0 cm



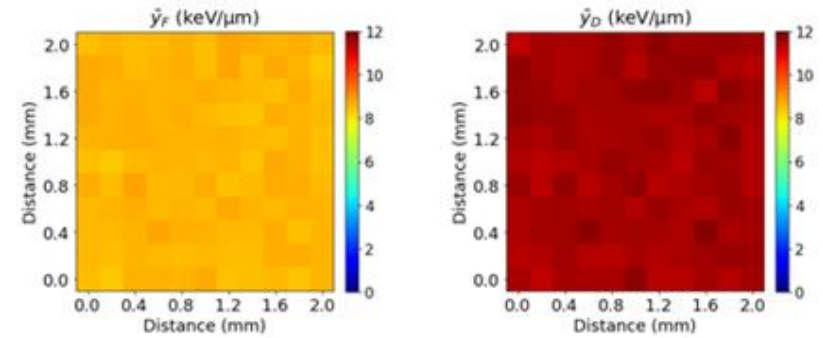
$(2.61 \pm 0.03)\text{keV}\cdot\mu\text{m}^{-1}$ $(3.08 \pm 0.06)\text{keV}\cdot\mu\text{m}^{-1}$

5.6 cm



$(4.97 \pm 0.05)\text{keV}\cdot\mu\text{m}^{-1}$ $(6.69 \pm 0.11)\text{keV}\cdot\mu\text{m}^{-1}$

6.3 cm



$(8.6 \pm 0.1)\text{keV}\cdot\mu\text{m}^{-1}$ $(11.60 \pm 0.13)\text{keV}\cdot\mu\text{m}^{-1}$

Guardiola C. et al, Medical Physics, 2022