Ciências ULisboa

LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

New radiobiology detector using s cintillating arrays

Speaker: Duarte Guerreiro

Laboratório de Instrumentação e Física Experimental de Partículas (LIP)

RAdiation **D**osimetry to **A**dvance **R**adio**T**herapy (RADART)

Fundação para a Ciência e a Tecnologia

IDPASC

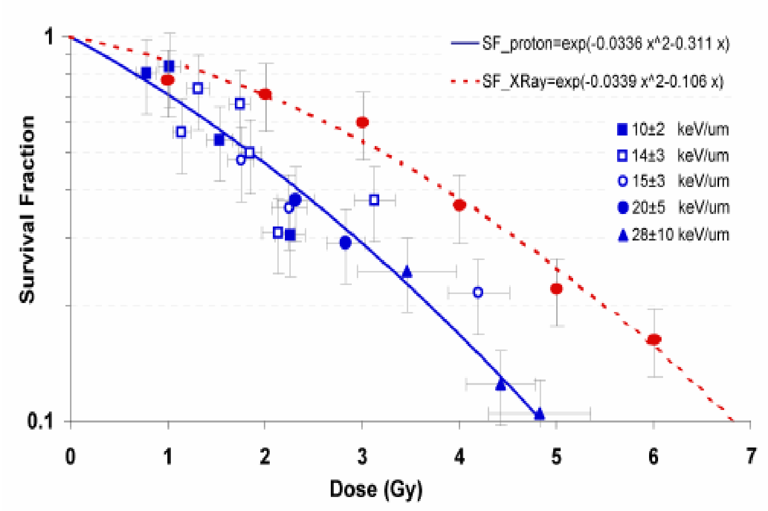
IGFAE Instituto Galego de Física de Altas Enerxías

USC UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

XUNTA DE GALICIA

IGFAE workshop on technologies and applied research at the future Galician proton-therapy facility

Project overview – the need for a high-resolution dose map



Cell-survival curves are used to describe the relationship between radiation dose and the proportion of cells that survive [1].

Harvard Natural Sciences Lecture Demonstrations. (2014, March 6). *Cloud Chamber* [Video]. YouTube. https://www.youtube.com/watch?v=e3fi6uyyrEs

It is important to have a high-resolution dose map to correlate the biological effect to the dosimetric measurements.

[1] Doria, Domenico & Kakolee, K. & Kar, Satya & Litt, Sandeep & Fiorini, Francesca & Ahmed, Hamad & Green, Stuart & Jeynes, Jonathan & Kavanagh, Joy & Kirby, Dar Kirkby, Karen & Lewis, Cls & Merchant, Michael & Nersisyan, G. & Prasad, Rajendra & Prise, Kevin & Schettino, Giuseppe & Zepf, Matt & Borghesi, Marco. (2012). Biological effectiveness on live cells of laser driven protons at dose rates exceeding 10(9) Gy/s. Aip Advances. 2. 10.1063/1.3699063.

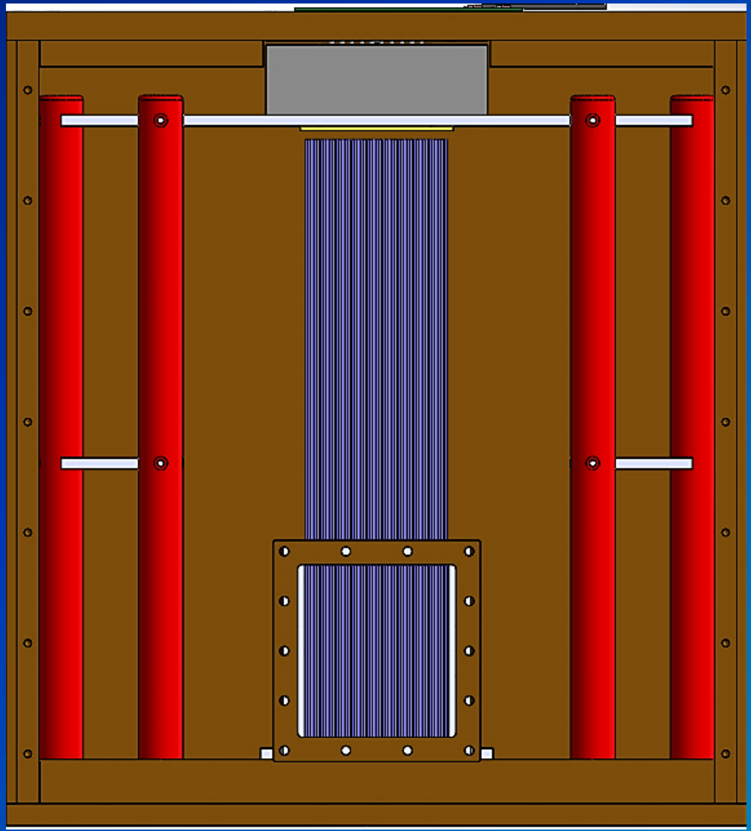
Project overview – scintillating array

The aim is to develop a detector with:

- real time dose measurements;
- good spatial resolution;
- tissue equivalence.

Possibility of placing the cell culture directly on top of the optical fibres is being explored:

- Reducing the errors introduced by the cell culture plates.



64 SCSF-78 optical fibres
H8500 Hamamatsu MAPMT

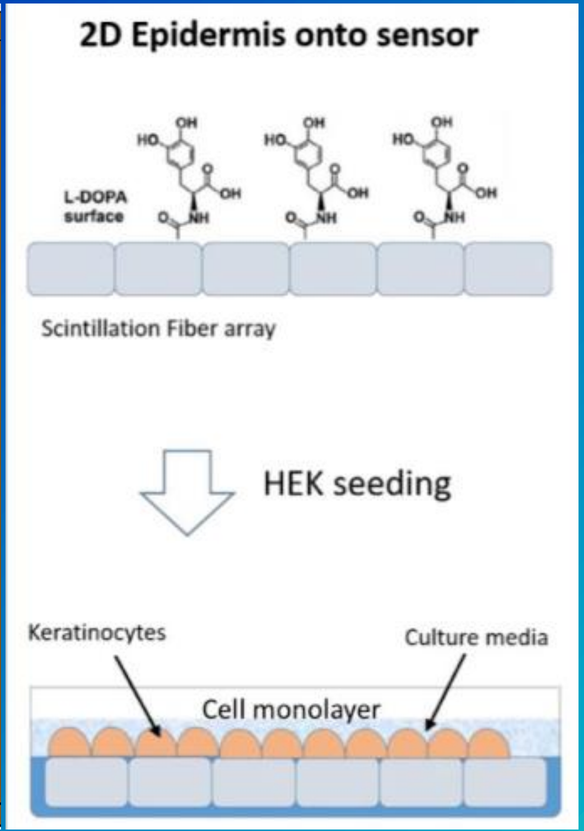
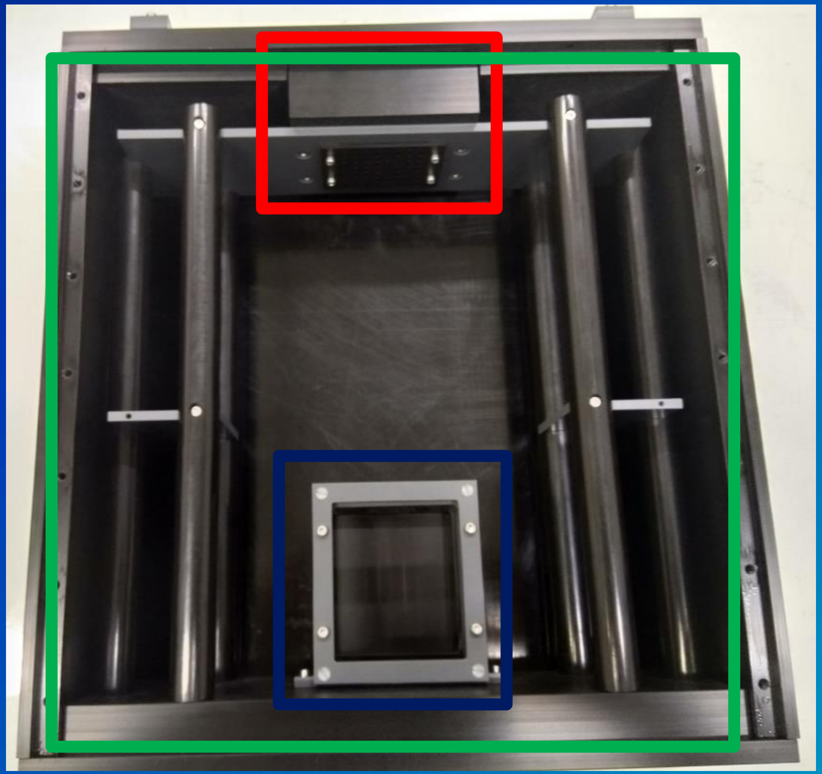


Image by A. Oliva. Internal communications

Irradiation Box

Irradiation box features:
Keep the fibres in a light-tight environment.
Make the interface between the fibres and the MAPMT mechanically stable.

Design constraints:
It should not get activated by irradiation -> POM plastic.

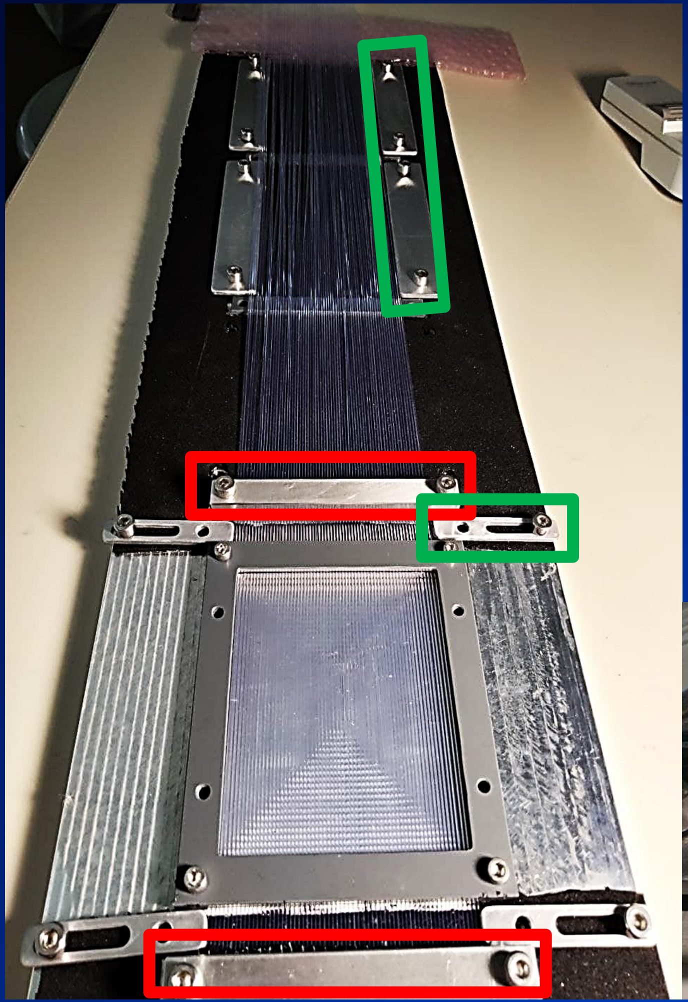


MAPMT casing

Removable inside structure

Optical fibre holding frame

Detector assembly



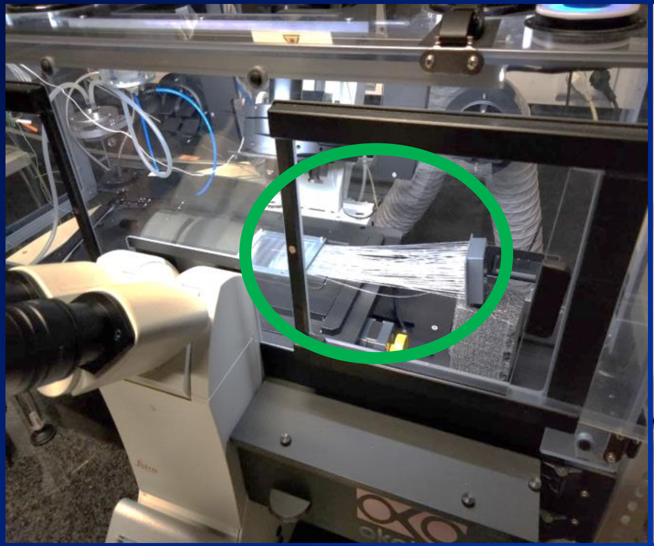
- The design of a table that helps to keep the optical fibres aligned was necessary.
- This table allows for a much faster and superior quality assembly.

Feature used to keep the fibres juxtaposed

Feature used to keep the fibres flat and parallel

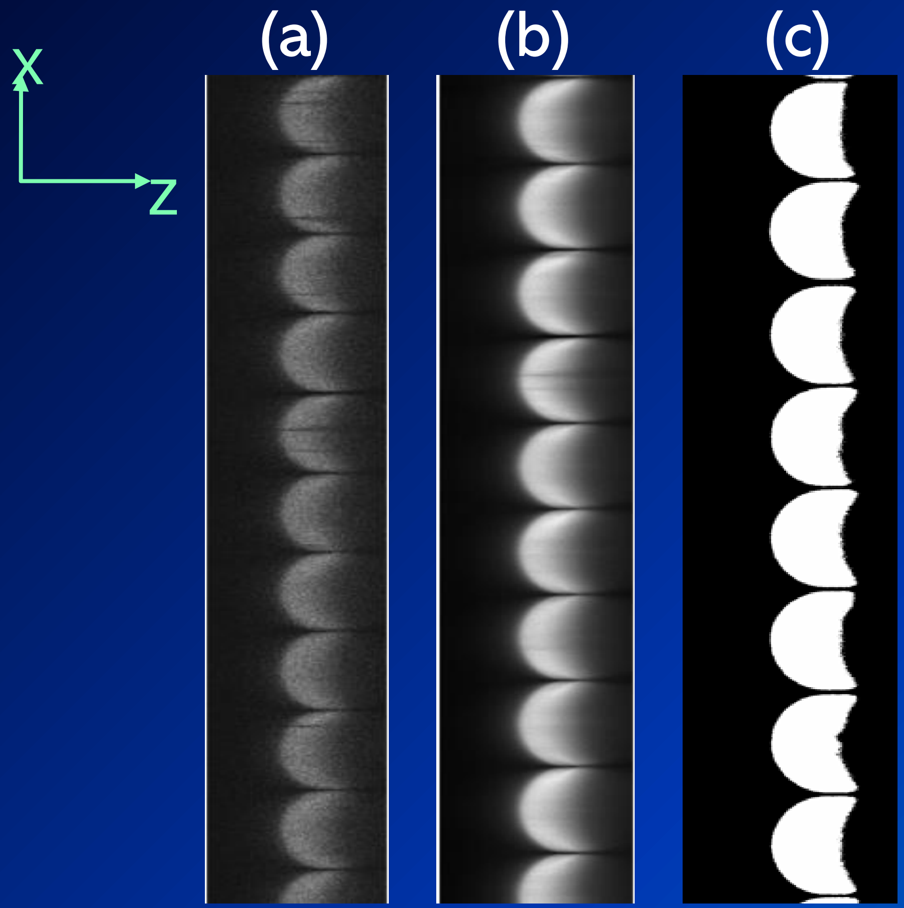
Detector Quality Control

Confocal microscopy with fluorescence used to get a 3D image of the optical fibres



Optical fibre's diameter	Tolerance
1 mm	0,7 mm
0,5 mm	0,4 mm
0,25 mm	0,3 mm

Detector Quality Control

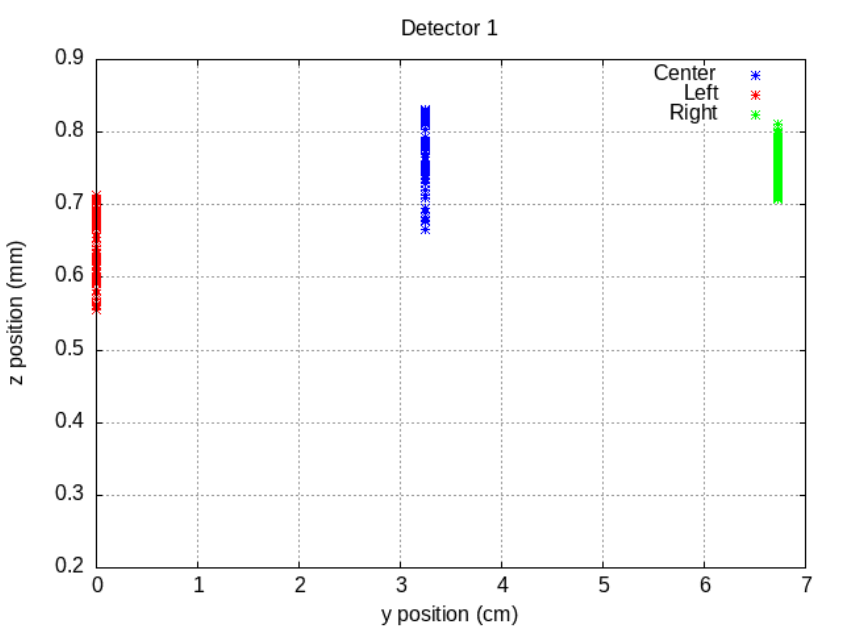


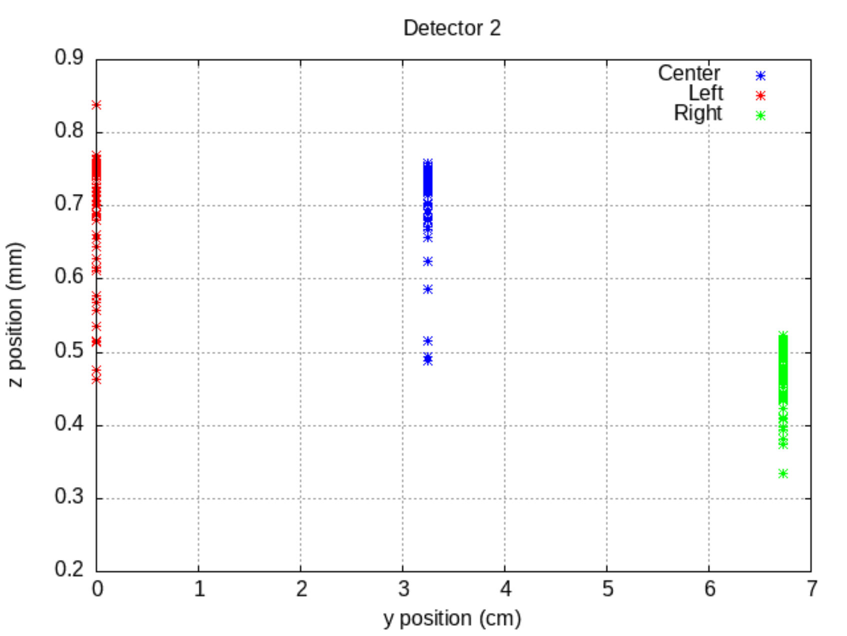
a) Raw image taken from confocal microscope;
b) All pixels are summed along Y axis to reduce noise
c) Otsu's threshold method is applied.

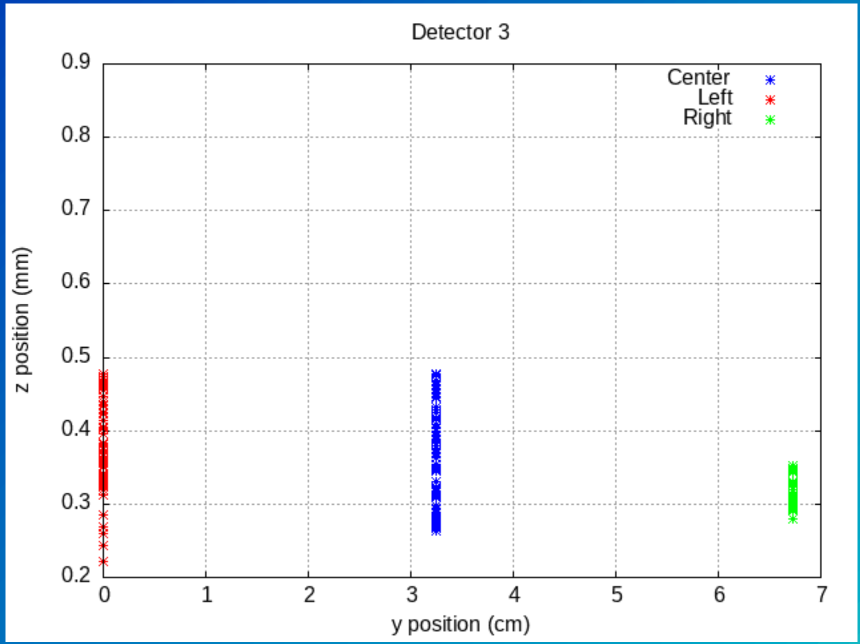
Image (c) goes through a clustering algorithm that calculates the position of each optical fibre:

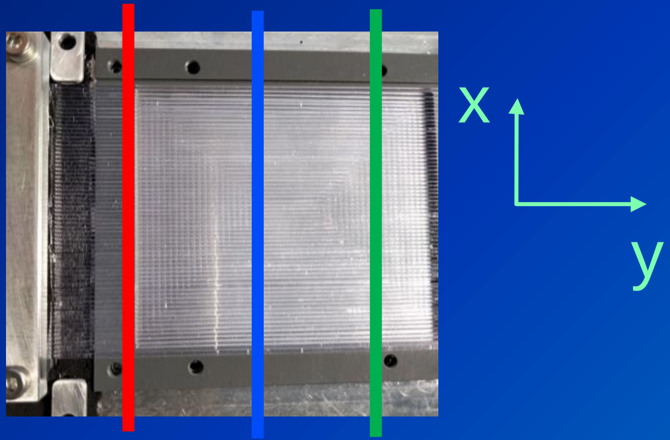
$$z_{position} = \frac{\Sigma z_i}{n}; \; x_{position} = \frac{\Sigma x_i}{n}$$

Detector Quality Control









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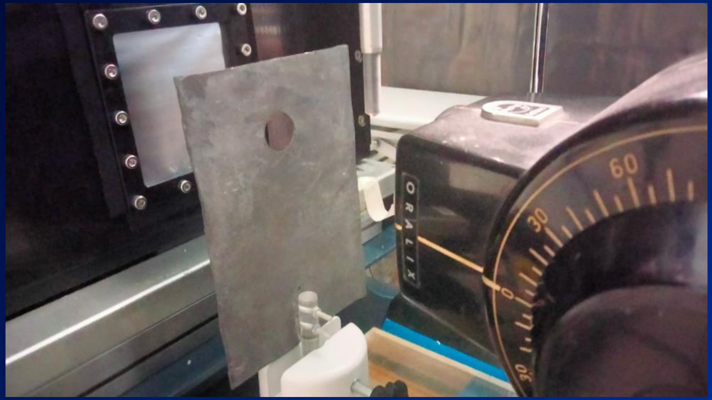
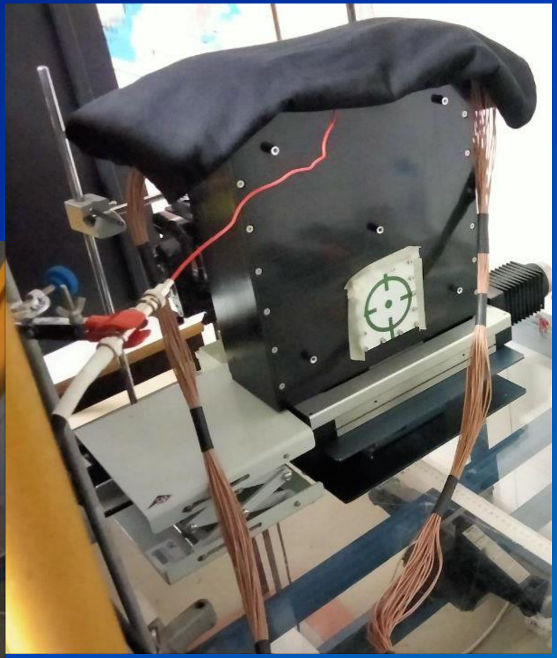
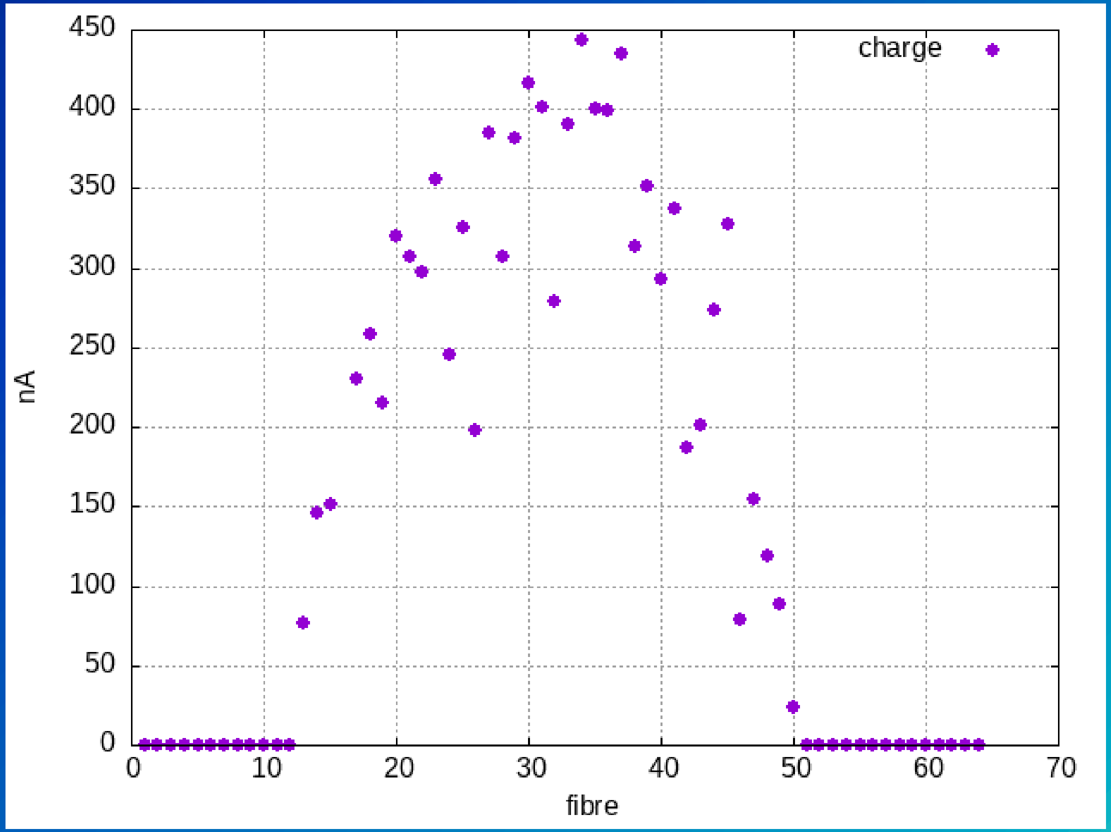
Experimental Measurements – First Results



50 kV X-ray tube.

Single channel electrometer used as charge integrator

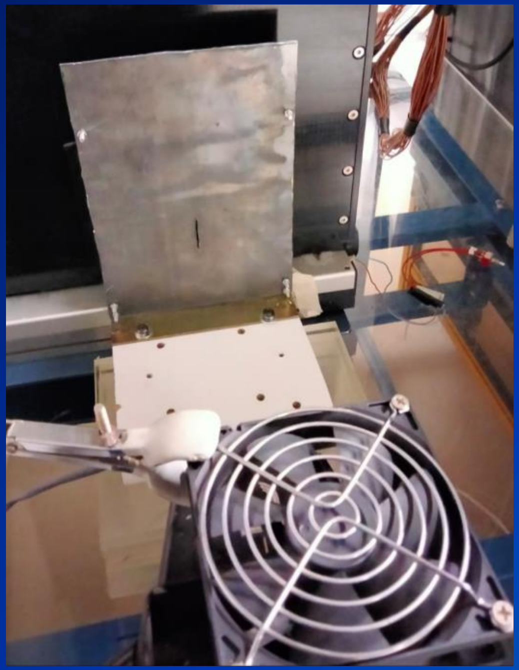


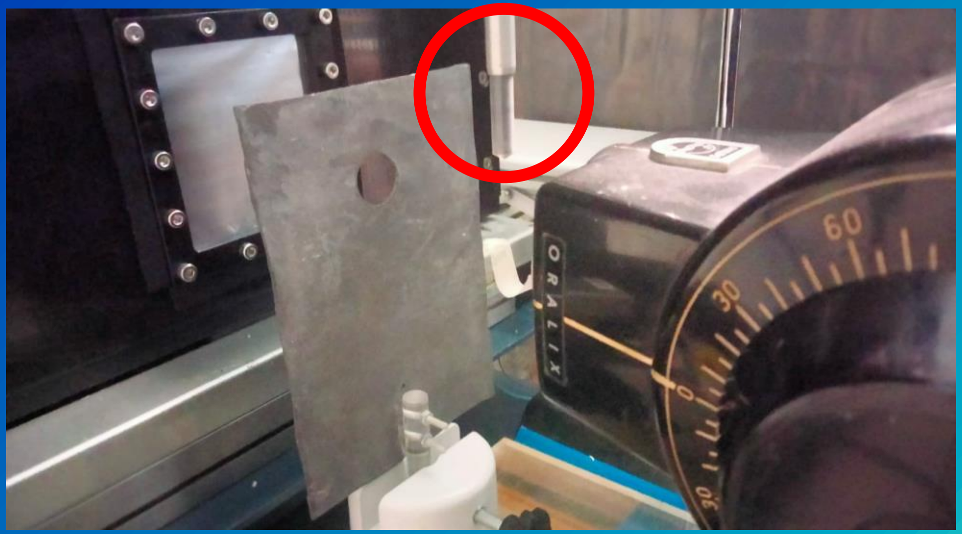


Experimental Measurements - Equalization

Equaliziation performed through:

- the exposure of each optical fibre to the same radiation dose (collimating the radiation field)
- using an ionization chamber (red in the image) to control the fluctuations of the X-ray tube

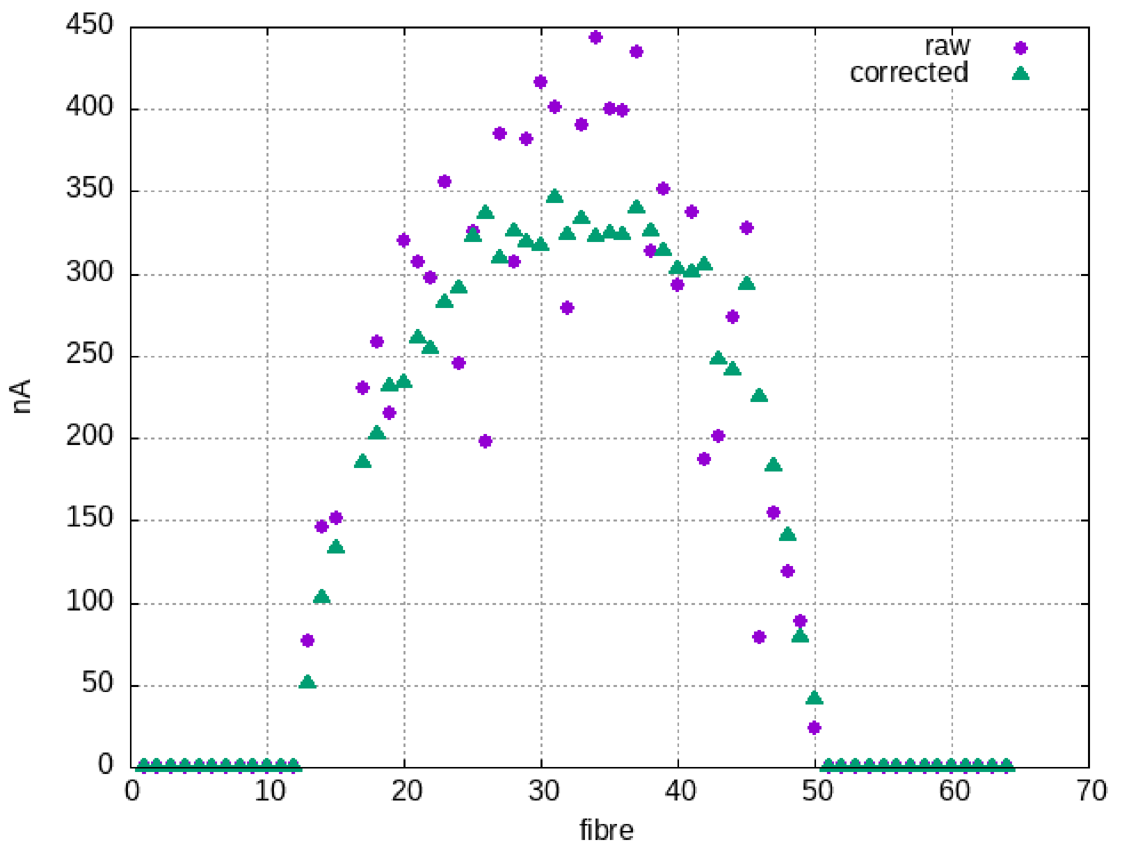




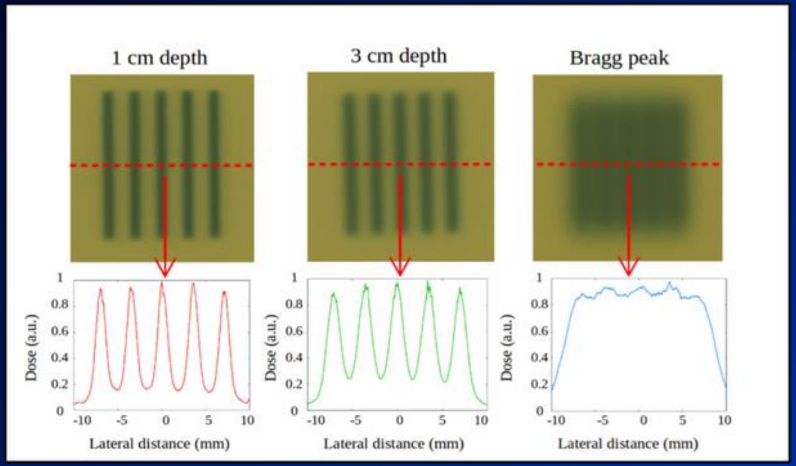
Experimental Measurements – After correction

After correction it is possible to observe:

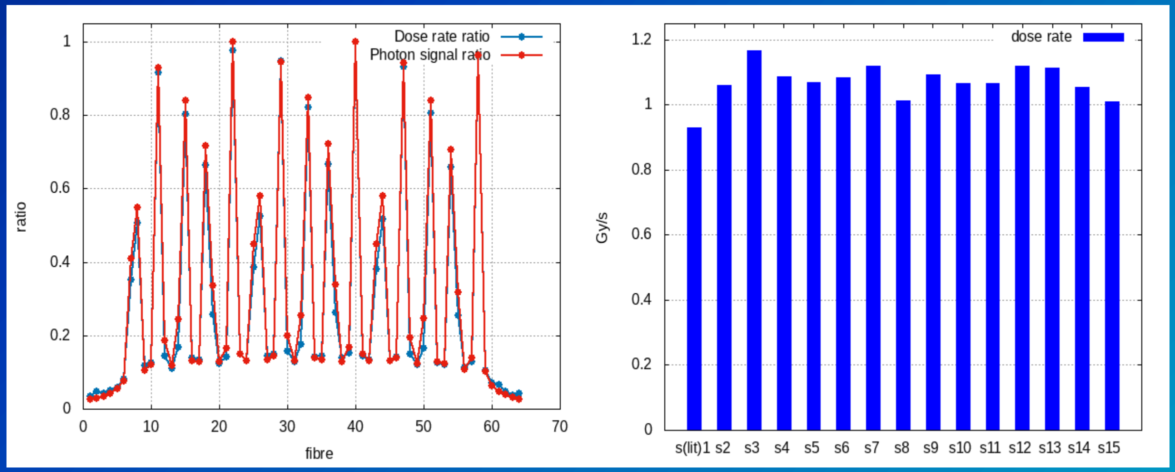
- The plateau create by the usage of a large collimator.
- The tilt to the right that we know is present in our system.



Other Applications – Minibeam Dosimetry

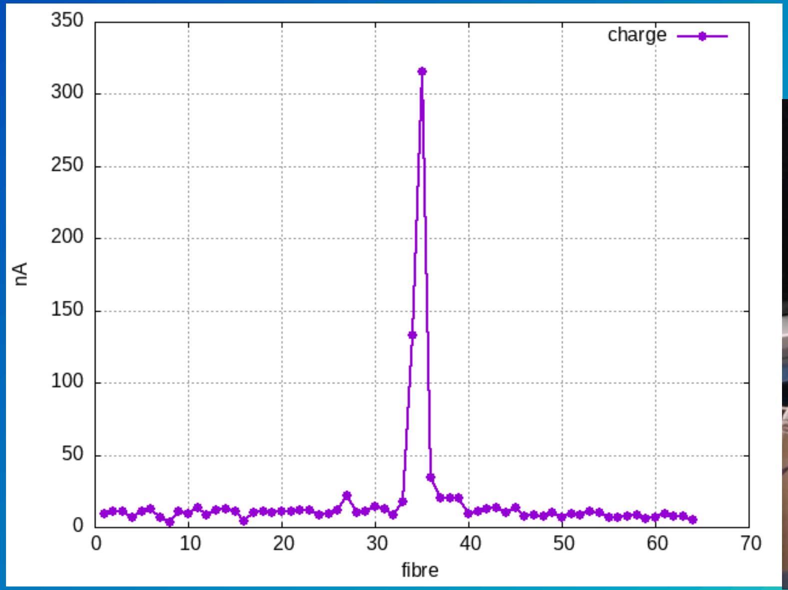


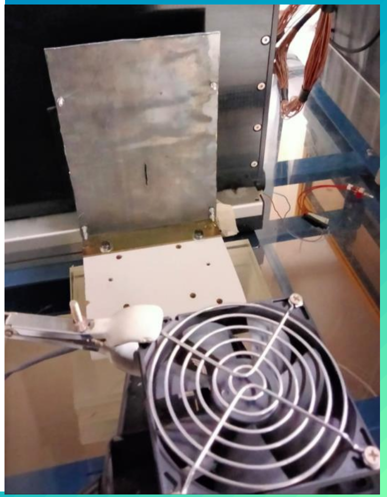
Minibeam dose distribution [2].



Minibeam dose distribution (proton beam) on the detector simulation on FLUKA

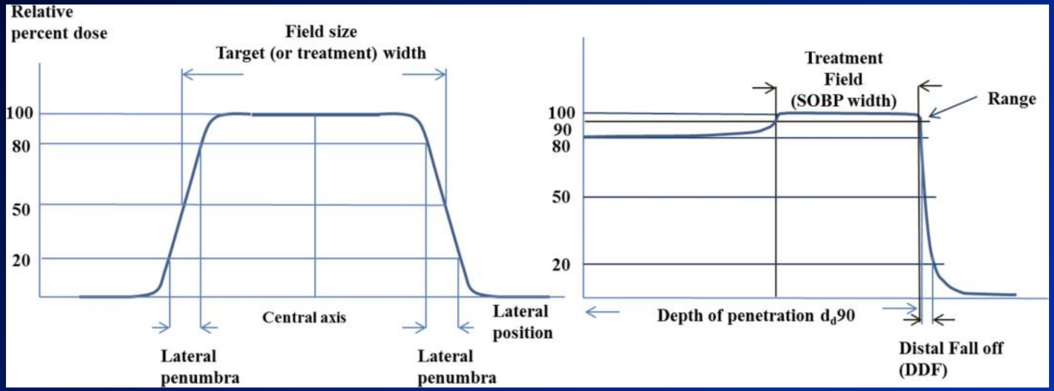
Experimental result showing the detection of a dose peak (X-Ray). FWHM ≈ 1.4 mm





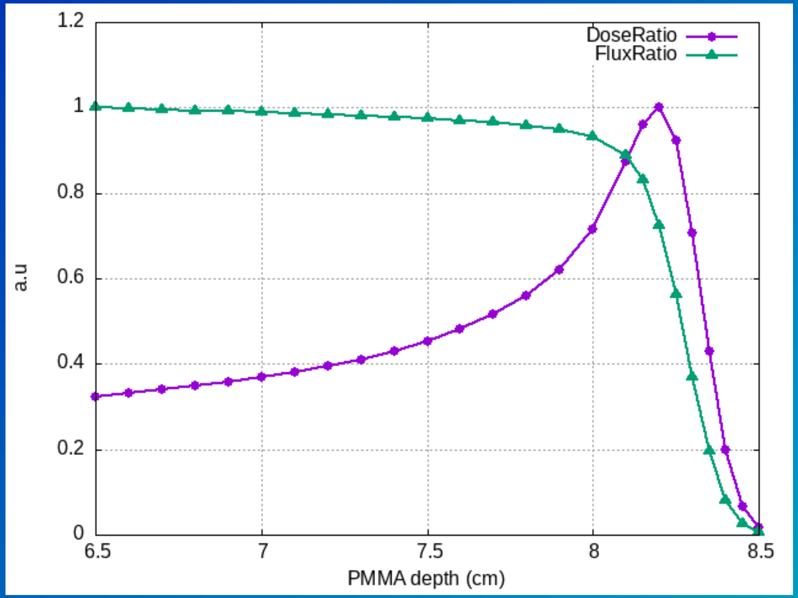
[2] A M M Leite, M G Ronga, M Giorgi, Y Ristic, Y Perrot, F Trompier, Y Prezado, G Cŕ ehange, and L De Marzi. Secondary neutron dose contribution from pencil beam scanning, scattered and spatially fractionated proton therapy. Physics in Medicine &amp Biology, 66(22):225010, nov 2021

Other Applications – Machine Quality Assurance



AAPM defined the geometric characteristics of a proton therapeutic beam [3].

Opportunity to test the quality assurance capabilities at HollandPTC/Delft



Fluka simulation of irradiation of array inside PMMA phantom

[3] Arjomandy B, Taylor P, Ainsley C, Safai S, Sahoo N, Pankuch M, Farr JB, Yong Park S, Klein E, Flanz J, Yorke ED, Followill D, Kase Y. AAPM task group 224: Comprehensive proton therapy machine quality assurance. Med Phys. 2019 Aug;46(8):e678-e705. doi: 10.1002/mp.13622. Epub 2019 Jun 14. PMID: 31125441.

Future Work

1. Development of a dedicated DAQ board (impulse processing and charge integration).
2. Radiobiology studies.
3. Integration of optical fibres with a few microns (under development at the group) to the detector.

Team & Contacts

Duarte Guerreiro, LIP FCUL
Jorge Sampaio, LIP FCUL
Luis Peralta, LIP FCUL
João Gentil, LIP
Maria João Borges, LIP ISEL
Cristiana Rodrigues, LIP FCUL
Matilde Santos, LIP FCUL
Daniel Salgueiro, LIP FCUL
Luis Lopes, LIP FCTUC
Pamela Teubig, LIP FCUL
Pedro Assis, LIP IST
Miguel Ferreira, LIP
José Carlos Nogueira, LIP
Luis Gurriana, LIP
Guiomar Evans, LIP FCUL
Daniel Galaviz, LIP FCUL

Abel Oliva, ITQB

Federico Herrera, BioISI

Francisco Alves, ICNAS
Sérgio do Carmo, ICNAS

Principal Investigator: Jorge Sampaio (jmsampaio@fc.ul.pt)
Speaker: Duarte Guerreiro dguerreiro@lip.pt