Micro-scintillating array for real-time sensitive dosimetry for proton therapy using 3D human skin model

D.R Guerreiro[1,2,6], M.Santos[1,2], L.Peralta[1,2], , J.M.Sampaio[1,2], J.G.Saraiva[1], P.Assis[1,5], M.Ferreira[1] L.Gurriana[1], F.Herrera[4], A.Oliva[3], J.Nogueira[1], Pamela Teubig[1,2], S.Ventura[3]

[1]Laboratório de Instrumentação e Física Experimental de Partículas | [2]Faculdade de Ciências da Universidade de Lisboa | [3]Instituto de Tecnologia Química e Biológica António Xavier | [4]Instituto de Biossistemas e Ciências Integrativas | [5]Instituto Superior Técnico | [6]IDPASC PHD programme

Abstract

This project intends to demonstrate the feasibility of a new detector for proton radiology studies, capable of measuring real-time doses with sub-millimeter resolution and simultaneously supporting the growth of the 3D skin model to be irradiated. The detector will be constructed of juxtaposed thin plastic scintillating fibers coupled with a system for reading and converting the optical signal into deposited energy. The fiber's surfaces directly exposed to ionizing irradiation will be functionalized to allow cell adhesion and tissue growth. X-ray and proton irradiation tests will be done to confirm the detector's multi-channel response.

Objectives

To make a Proof-of-Concept (PoC) for a detector prototype that enables to:

- Tissue-equivalence;
- The unique capability to support cell and tissue growth;
- Real-time dose measurements;
- High spatial resolution;
- Cost-effectiveness;

Investigate the relationship between the biological effects of irradiation of a skin model and the signal read by the detector.

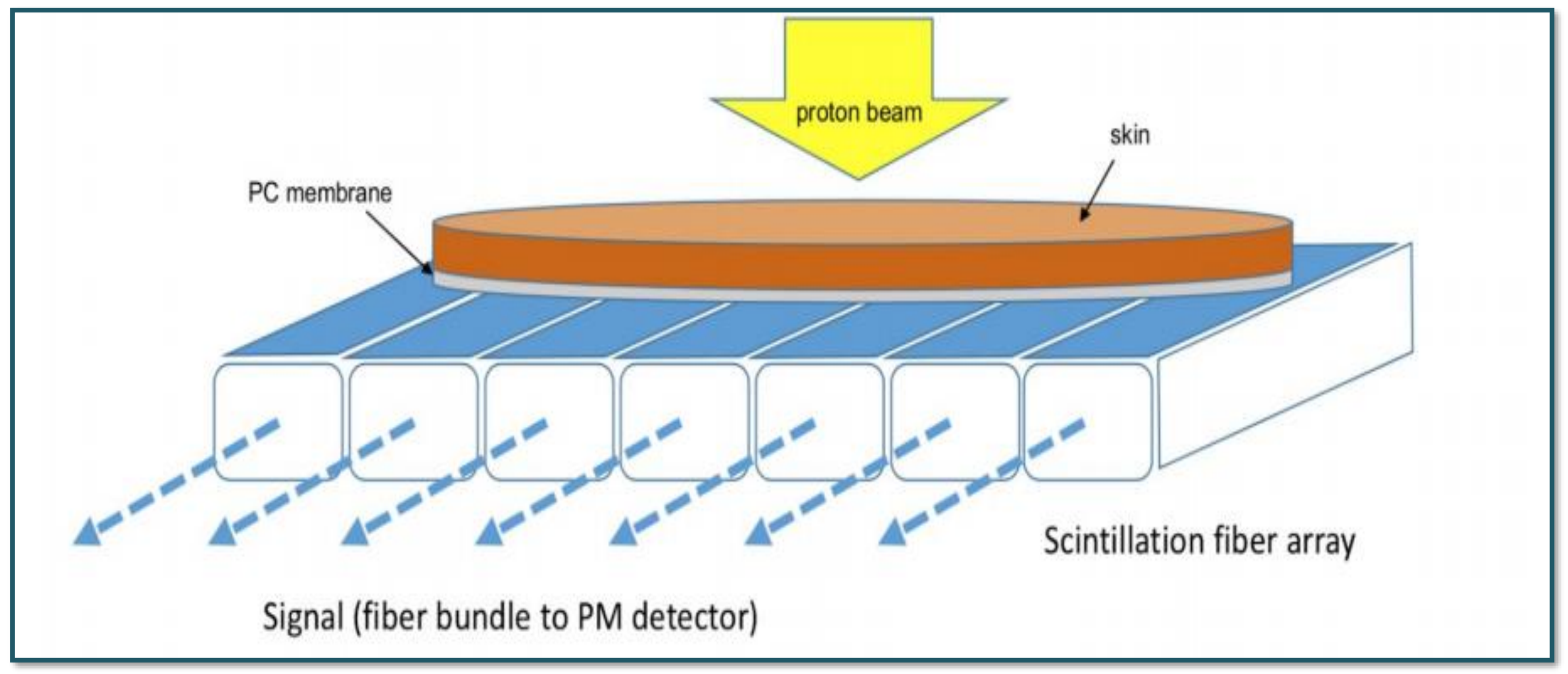

Fig.1: Model of the detector. This simplified model shows the display of the detector's parts. The proton beam passes through the skin model before interacting with the optical fibres (sketch by Abel Oliva, ITQB)

Methods

1. Construct and test a small prototype for the detector coupled to a multichannel reading readout;
2. Directly growing skin cells (human keratinocytes) over the treated fibers to develop a confluent monolayer;
3. Grow 3D full skin (dermis and epidermis) onto scaffolds and place over the detector;
4. Perform irradiation tests of the micro-scintillating prototype detector dressed with cells and 3D skin models to assess its real-time response in x-ray and proton beams.

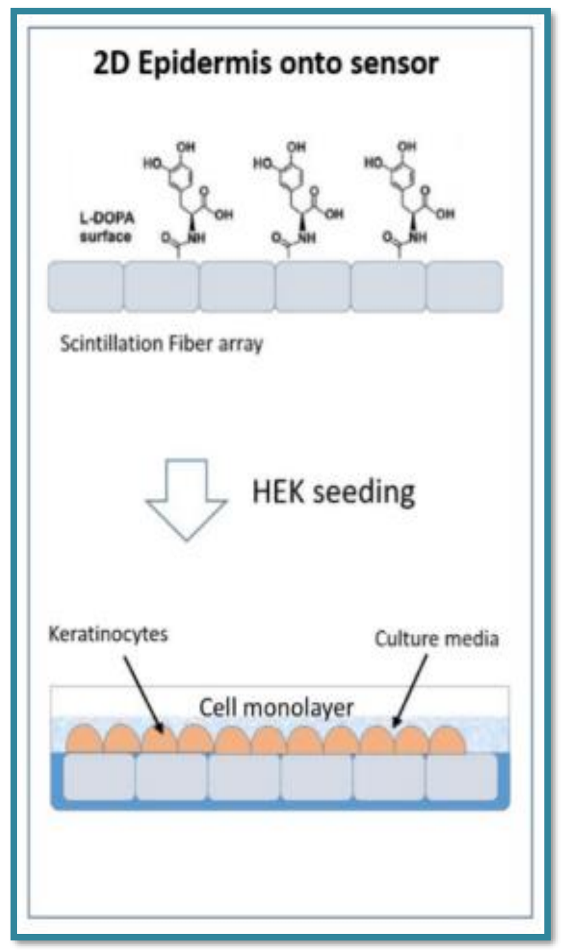

Fig.2: The fibre bundle has to be prepared to receive the skin model. The skin model will the attached to the pmma fibres with the help of a surface treatment (sketch by Abel Oliva, ITQB).

Current Developments

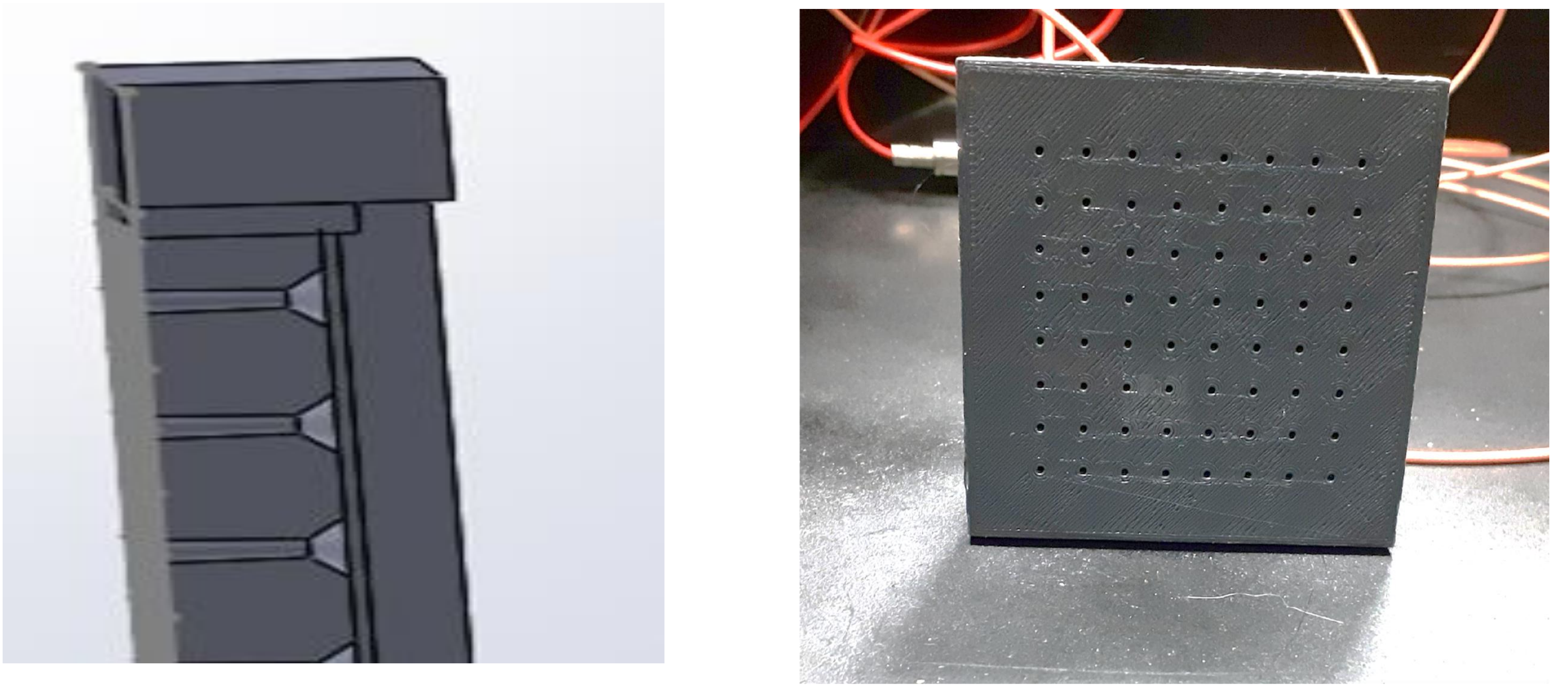

Fig.2: Connector used to simplify the communication between the optical fibres and the PMT. The internal structure of the connector was designed to ensure that the optical fibres are held in place. On the left hand side picture, it is visible the connector's internal structure, the fibre enters the connector from the left hand side where and goes through a hole that is thigher at the end, so to ensure that the fibre stays in place. After that there is a larger hole to ensure that the cone of light doesn't get block by the conector.

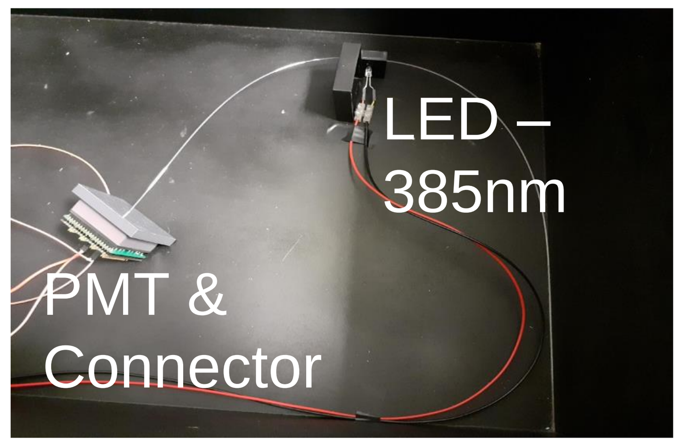

Fig.3: Experimental setup used to test the multi-annode PMT. The 385 nm LED is pointing to a scintillating optical fibre SCSF-78 ,that emits with a wavelength that ensures a maximum response from the PMT.

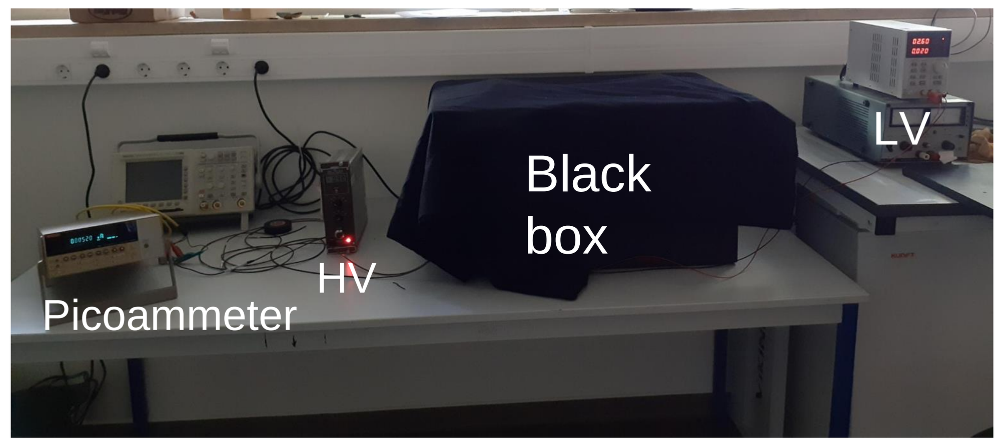

Fig.4: A black box ensures that no light interacts with the setup. The HV ranges from 700V to 1000V to power the PMT and the LED is powered using a LV source (2,6V – 2,82V). The annode current are measured using a picoammeter.

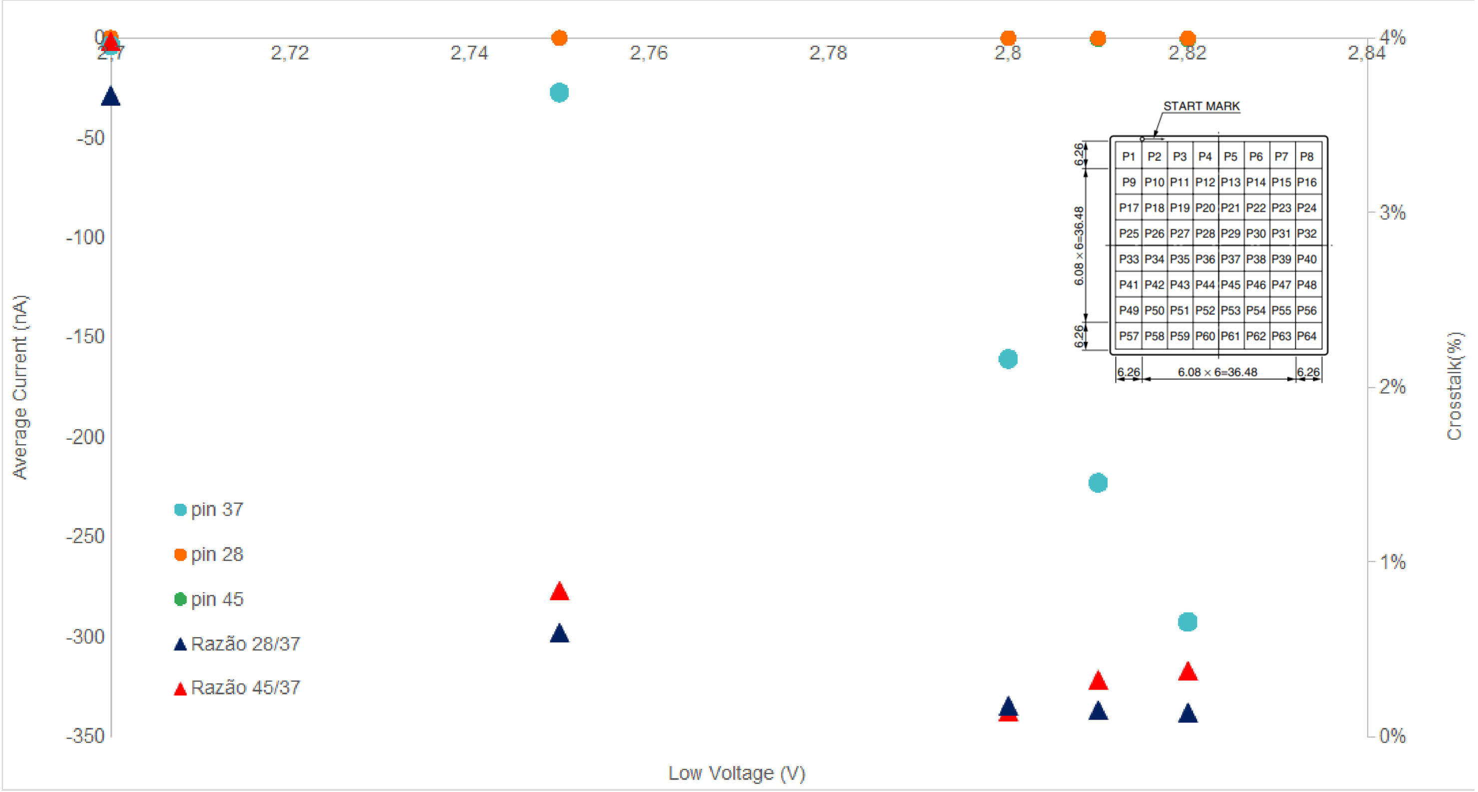

Fig.5. Signal ratios between a illuminated photo-cathode cell and 2 nearest neighbors. These measurements are used to study if the optical and electronic crosstalk are important factors.

Next Steps

PMT Characterization (Hamamatsu H8500C)

- Improvement of the robustness of the experimental setup.
- Conclude crosstalk measurements.
- Measurements with a radiatioactive particle source.

Conception and design of a prototype

- CAD design of the detector.
- Study the assembly procedure of the optical fibre ribbon.

Instrumentation

- Study the integration of the PMT with a custom DAQ board.
- Development of an interface board for the readout of 64 chan.

Simulations using FLUKA/GEANT4

- Experimental setup and prototype.
- Definition of detector shielding and window.
- Response to a proton beam 2 MeV (CTN) – 20 MeV (ICNAS).

Testing in beam facilities

- Performance of prototype tests with x-ray and proton beams.