PROCEEDINGS OF SCIENCE

PoS(PANIC2021)039

Characterization and functional test of a micro dosimeter of scintillating optical fibers

M. M. Sobreiro Santos,[a,b,*] **D. R. Guerreiro,**[a,b] **J. G. Saraiva,**[b] **J. M. Sampaio,**[a,b] **L. Peralta,**[a,b] **G. Evans,**[a,b] **P. Assis,**[a,c] **M. Ferreira**[b] **and J.C. Nogueira**[b]

[a] *Faculty of Sciences of the University of Lisbon*

[b] *Laboratory for Instrumentation and Experimental Particle Physics*

[c] *Technical Superior Institute of the University of Lisbon*

E-mail: mmssantos@lip.pt

As demand increases for better and improved techniques for cancer treatment in Portugal, there is an ongoing discussion on the need to build a proton therapy center, as well as to train skilled workers in this field. As a result, there is the need for high precision measurement instruments that provide real-time absorbed dose measurements on the patients at tissue or DNA level.

The goal of the present work is to develop a new detector capable of measuring real-time absorbed dose with sub-millimeter resolution. The device is constructed using juxtaposed thin scintillating plastic optical fibers (SPOF) readout by a multi-anode photomultiplier (MAPMT, 64 channels) and a suitable data acquisition (DAQ) system. In this article, we discuss the characterization of the full detection chain: SPOFs, MAPMT and DAQ.

**** Particles and Nuclei International Conference - PANIC2021 ****
**** 5 - 10 September, 2021 ****
**** Online ****

[*] Speaker

1. Introduction

With the ongoing discussion to build a hadrontherapy center at Campus Tecnológico e Nuclear (CTN) for proton therapy (PT) treatments, it is important to improve the understanding of radiobiology to provide the necessary parameters for the planning of radiation treatments. The extraction of the parameters with a high precision and resolution requires a dose map at micro and nano scales. Thus the development of detectors capable of obtaining real-time data of absorbed dose are necessary. The concept of one those detectors is illustrated in figure 1.

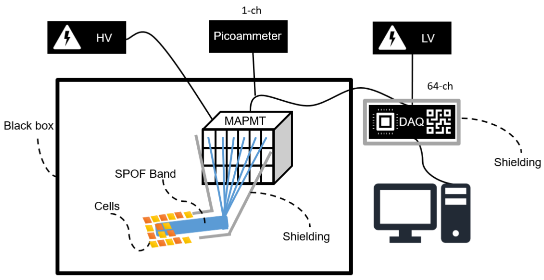

Figure 1: Concept of the microdosimeter: Thin juxtaposed scintillating plastic optical fibers (SPOF) coupled to a multi-anode photomultiplier (MAPMT, 64 channels) readout by a costumed data acquisition (DAQ) board.

2. Scintillating plastic optical fiber's Characterization

2.1 Characterization of Isolated Optical Fibers

The used scintillating plastic optical fibers (SPOFs), Kuraray SCSF-78 [1], are characterized using a LED as excitation source with a fibrometer [2]. In charts 2, there are typical scans to measure attenuation lengths, L_{at}, (160 cm for 1 mm SPOFs) and light yield ratios (ranging from $31 - 51\%$ for 0.5 mm relative to 1 mm SPOFs).

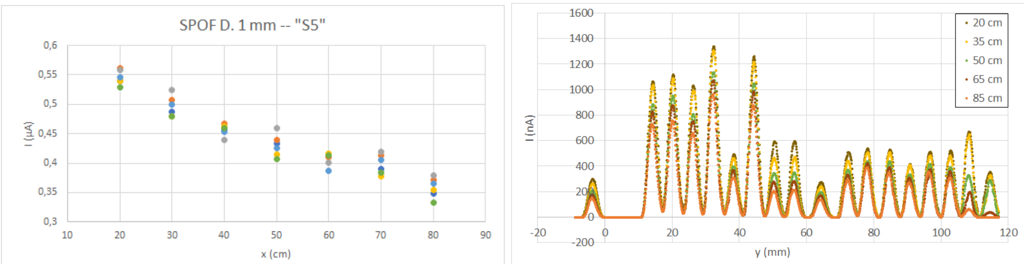

Figure 2: Set of measurements of 1 mm SPOF measured with the fibrometer's system: (left) the excitation source moves away from the PMT using a x=10 cm step with a L_{at} =160 cm; (right) excitation source is fixed for different y and the 18 fibers positions and relative intensities are shown.

2.2 SPOF's Crosstalk

The study of crosstalk is done using the XT-plaque [3]. In figure 3, there is an image of the XT-plaque integrated inside the fibrometer system, with major elements carefully labeled and a set of results. The ongoing work is to developed analysis methods to further comprehend these measurements and in particular quantify the crosstalk.

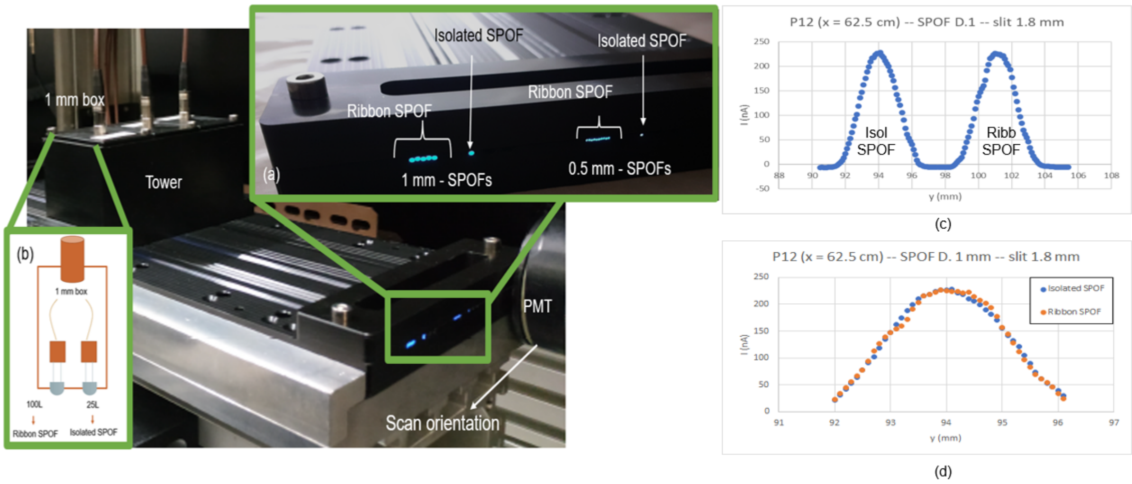

Figure 3: Setup to measure the crosstalk of juxtaposed SPOFs. (a) Top end view showing the juxtaposed fibers and the reference isolated fiber. (b) Inside the support boxes of the LED tower. The LEDs illuminate the fiber through pinholes with half of the SPOF diameter. (c) XT-plaque measurements showing for each figure the scan over the Isolated fiber (left) and the Ribbon (right) for 1 mm SPOFs, placed at x = 62.5 cm on the XT-plaque and using a PMT collimator width of 1.8 mm. (d) Overlapping of the Ribbon and Isolated SPOF response.

3. MAPMT's Characterization

The MAPMT's readout was made with a picoammeter. In order to carry out the characterization, an adequate experimental setup, with LEDs and SPOFs, was assembled to measure the following characteristics:

- **MAPMT Stability:** measured on two different days with a Root Means Square (RMS)= 15.2 pA for day one and RMS=8.6 pA for day two.
- **Dark Current:** HV = -900 V is -143.1 ± 1.75 pA; HV = -1000 V is -681 ± 33 pA.
- **Electrical crosstalk:** Below 3% of the incident light is transferred to neighboring cells but dependent on the channel (figure 4(a)).
- **Linearity:** a good linearity is obtained for typical HV values using neutral density filters (figure 4(b)).
- **MAPMT Current vs High Voltage:** MAPMT high voltage dependance (figure 4(c)).

4. Full Detector Chain Characterization

For the 64 channel readout, a costumed DAQ-board is used. As excitation sources were used: LEDs and (^{37}Cs, ^{60}Co, ^{204}Tl, ^{241}Am). Only two DAQ channels are used but all 64 channels of the MAPMT could be accessed. With the LED the dynamic range shows a saturation that needs further understanding – figure 5 (left). The radioactive source rates are separated in shape and frequency from background – figure 5 (right).

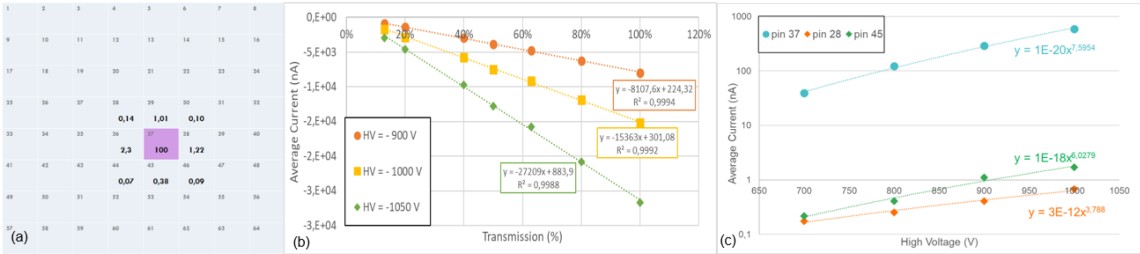

Figure 4: (a) MAPMT crosstalk: the purple square is the MAPMT channel stimulated by a SPOF; (b) Average current measured on a MAPMT channel 25 versus the transmission of neutral filters for HV = [-900 (orange), - 1000 (yellow), -1050 (green)] V. (c) Average current measured on the picoammeter and RMS for a cell with fiber (channel 37) and two channels without receiving light from a fiber (channel 28 and 45).

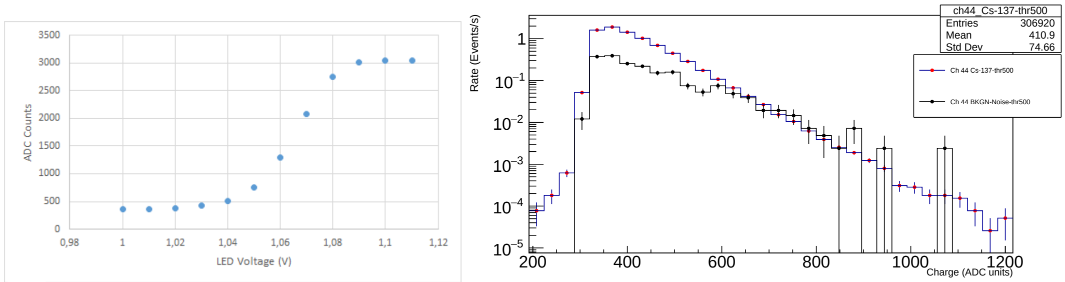

Figure 5: (left) Charge (ADC Counts) as function of LED voltage using a LED as light source for the DAQ-board channel 44. (right) Events rate as function of charge for a radioactive source ^{137}Cs (blue line) and the background noise (black line).

5. Future Work

The detector construction is at its final stage, having the detector assembly and volume going through final drawing revisions. Also, the 64 channel interface board design is being concluded. The next step is testing the prototype performance in beam facilities with x-ray and proton beams.

References

[1] Kuraray, "Plastic Scintillating Fibers (PSF)", 2017; https://www.kuraray.com/products/psf.

[2] J G Saraiva et al "The aluminization of 600-k WLS fibers for the TileCal/ATLAS/LHC" 10.1109/TNS.2004.829387; IEEE Trans.Nucl.Sci. 51 (2004) 1235-1241.

[3] Carvalho, Filipa. "Conception of a Tissue Equivalent Plastic Dosimeter Using Scintillating Fibres for Hadronic Therapy and Space Radiation Effects Studies", 2019, http://hdl.handle.net/10362/89188.

[4] Hamamatsu, "Flat Panel Type Multianode PMT Assembly: H8500 series/H10966 series", 2011.

[5] P. Assis, A. Blanco, P. Brogueira, M. Ferreira and R. Luz, "The MARTA (Muon Array With RPCs for Tagging Air Showers) Front-End Acquisition System," 10.1109/TNS.2018.2879089; IEEE Trans.Nucl.Sci. 65 (2018) 2920-2928.