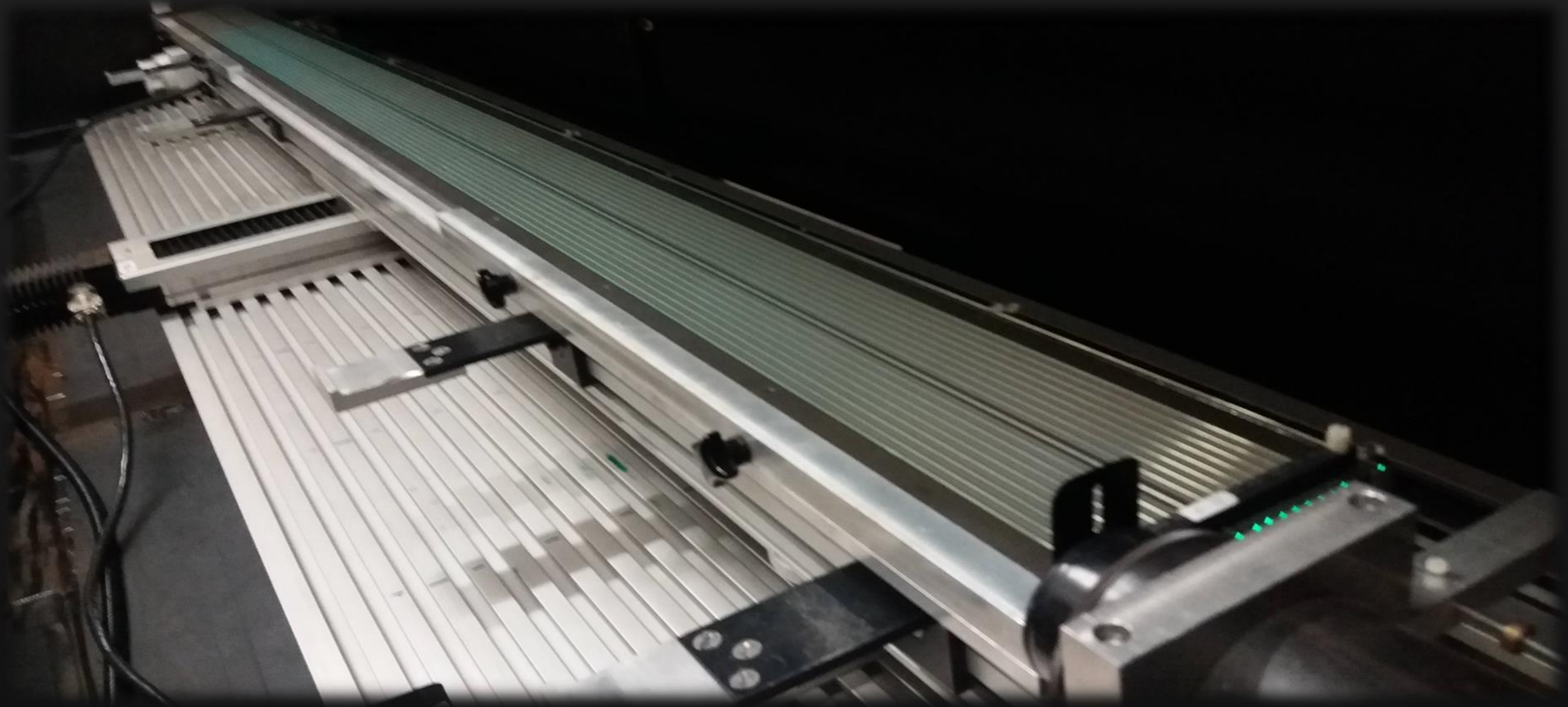
Optical Materials Applications



LOMaC – Laboratório de Ótica e Materiais Cintilantes

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Optical Materials

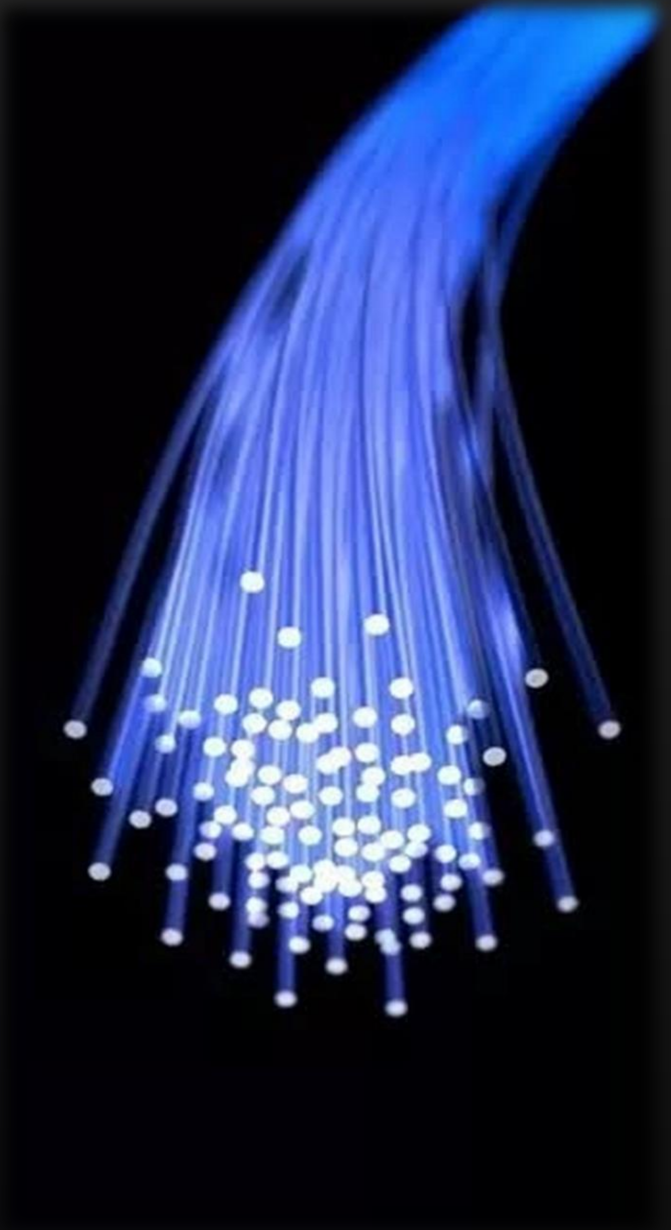
For physics and applied technologies, the interest of optical materials is to use as signal transducers, signal measurement and signal transport.

(1) A scintillator is used to measure the enery from ionizing particles and they can be produced in several shapes. In particular the 3 mm thickness scintillating tiles used in the ATLAS detector.

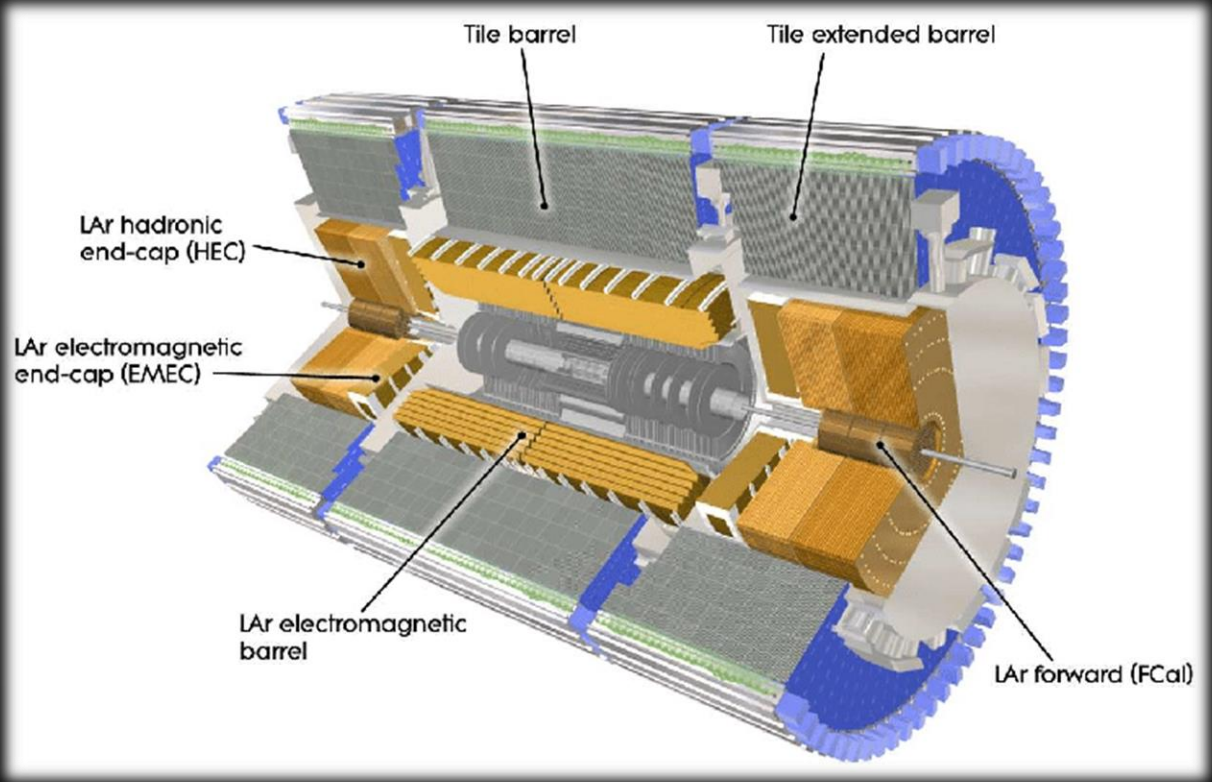
(2) An optical fiber is a cable that is used to guide light from a source to a chosen location.

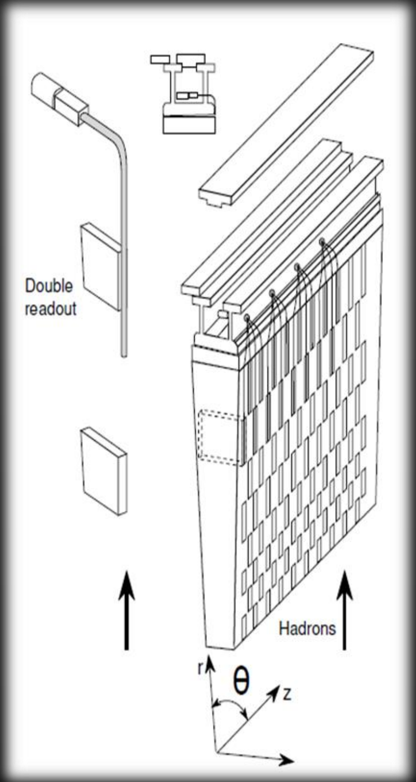
Applications
- Telecommunications
- Medical Sciences
- Physics → High Energy Physics

In the ATLAS detector, there are different types of plastic optical fibers:
- Clear Fibers
- Fluorescent Fibers (Wavelength Shifting)



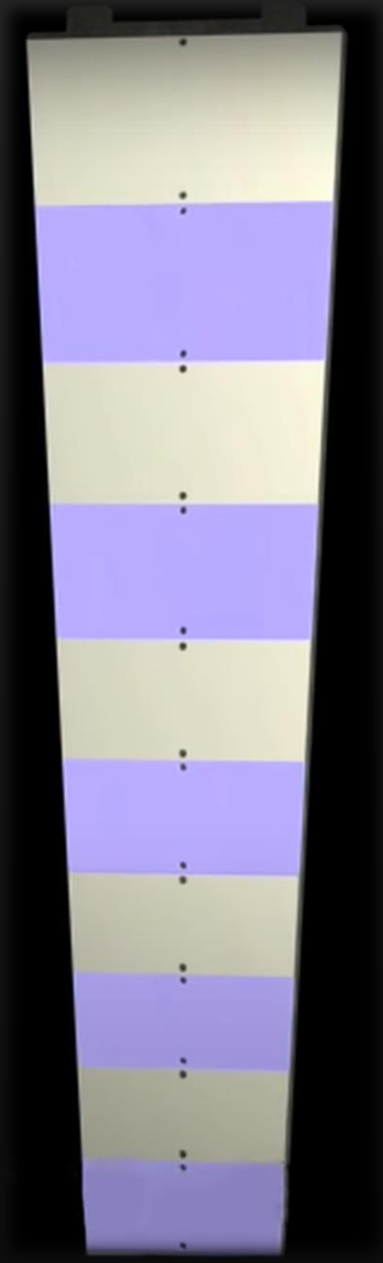
The ATLAS Tile Calorimeter





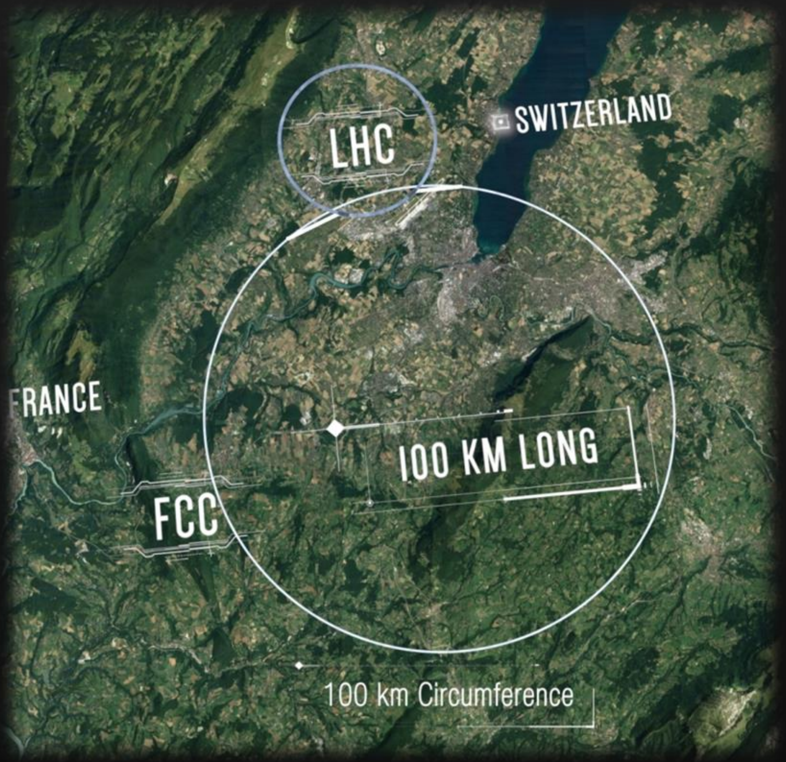
- Barrel Hadronic Calorimeter
- 3 sections
  - Central Barrel (5,56 m)
  - 2 Extended Barrels (2,91 m)
- 64 modules each

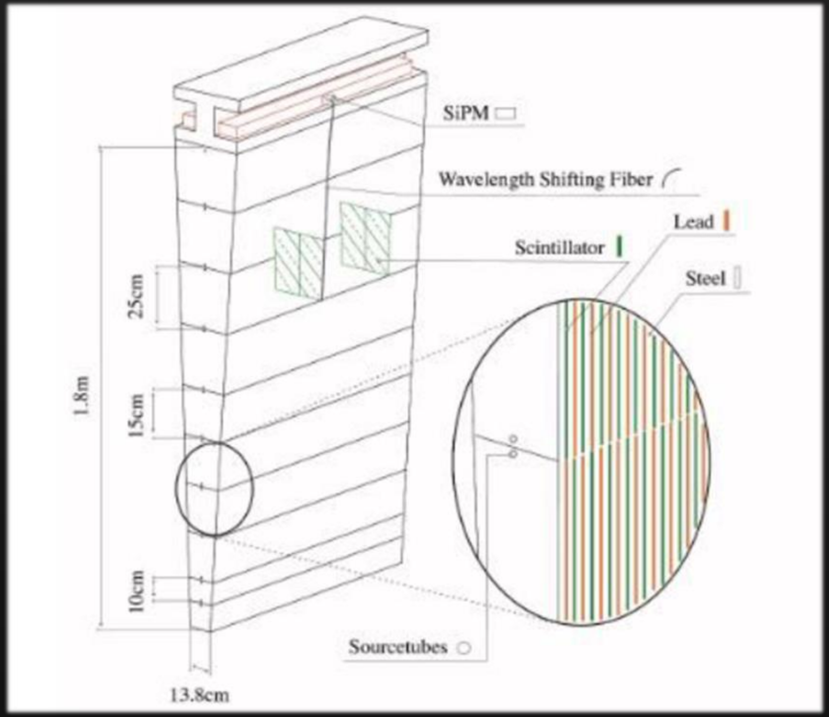
The Tile Modules



Proposal for the Future Circular Collider’s (FCC’s) Hadronic Calorimeter

The Future Circular Collider is a particle accelerator that is expected to start operating at around 2040.

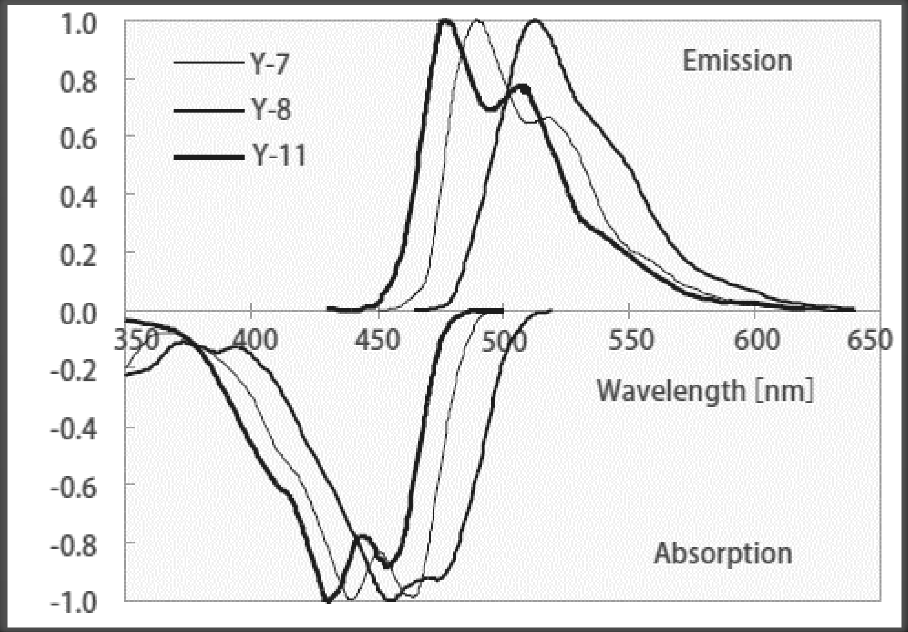




According to its Conceptual Design Report, it is supposed for each FCC tile module to have two optical fibers, one on each side, increasing 4 times its granularity in comparison with the ATLAS TileCal.

Optical materials properties and their evolution throughout time

$$I(x) = I_0 \, e^{-\frac{x}{Latt}}$$



Properties

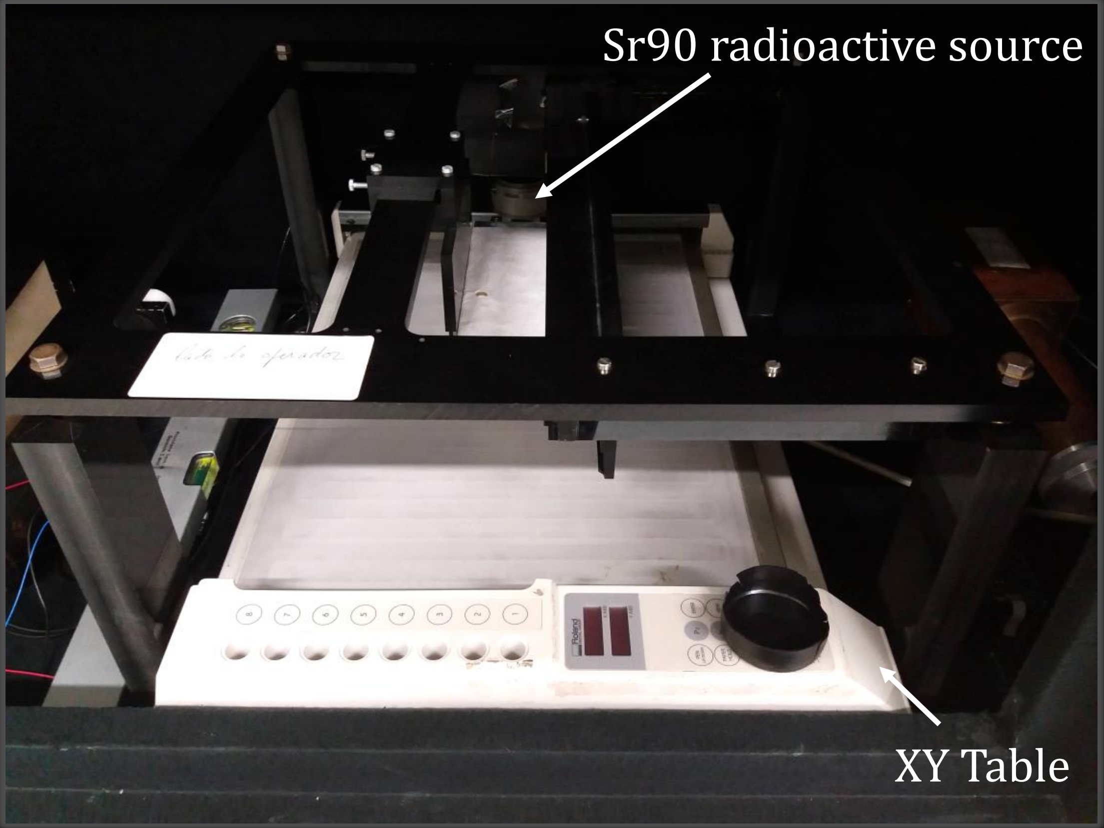
- Initial Intensity (I_0)
- Attenuation length ($Latt$)
- Absorption and emission spectra
- Geometric design
- …

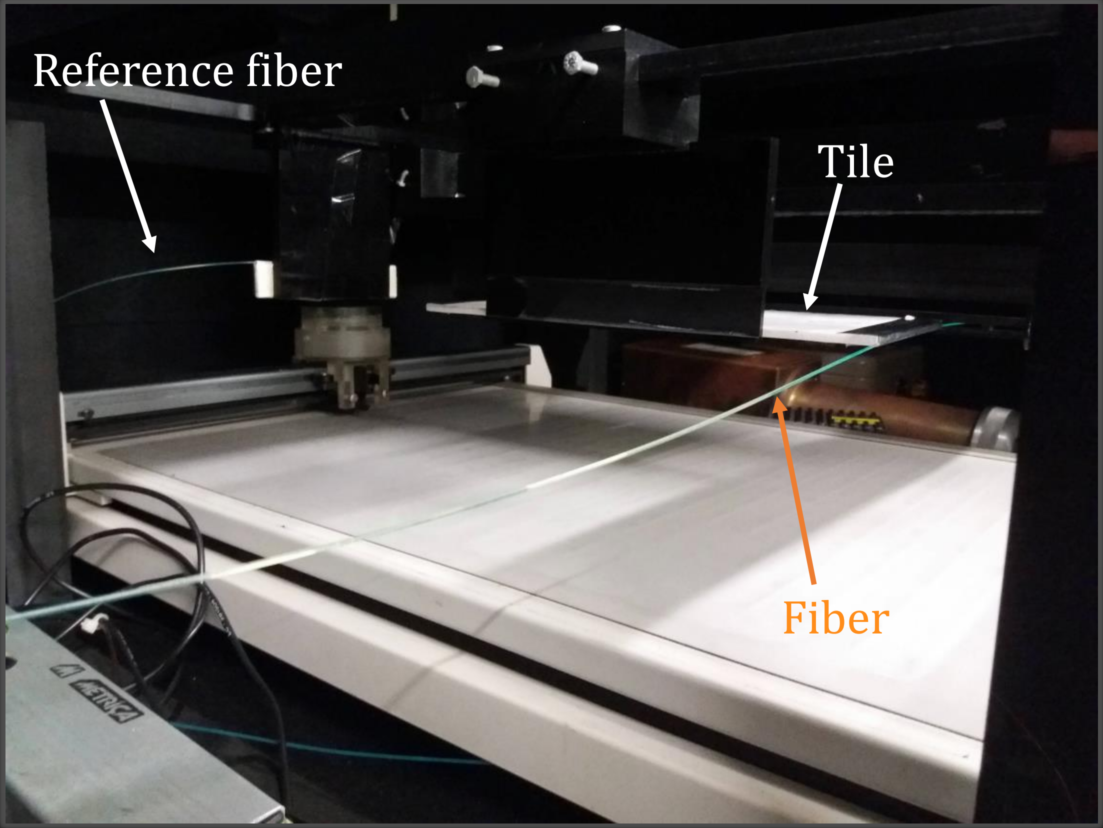
Optical Fibers Aging

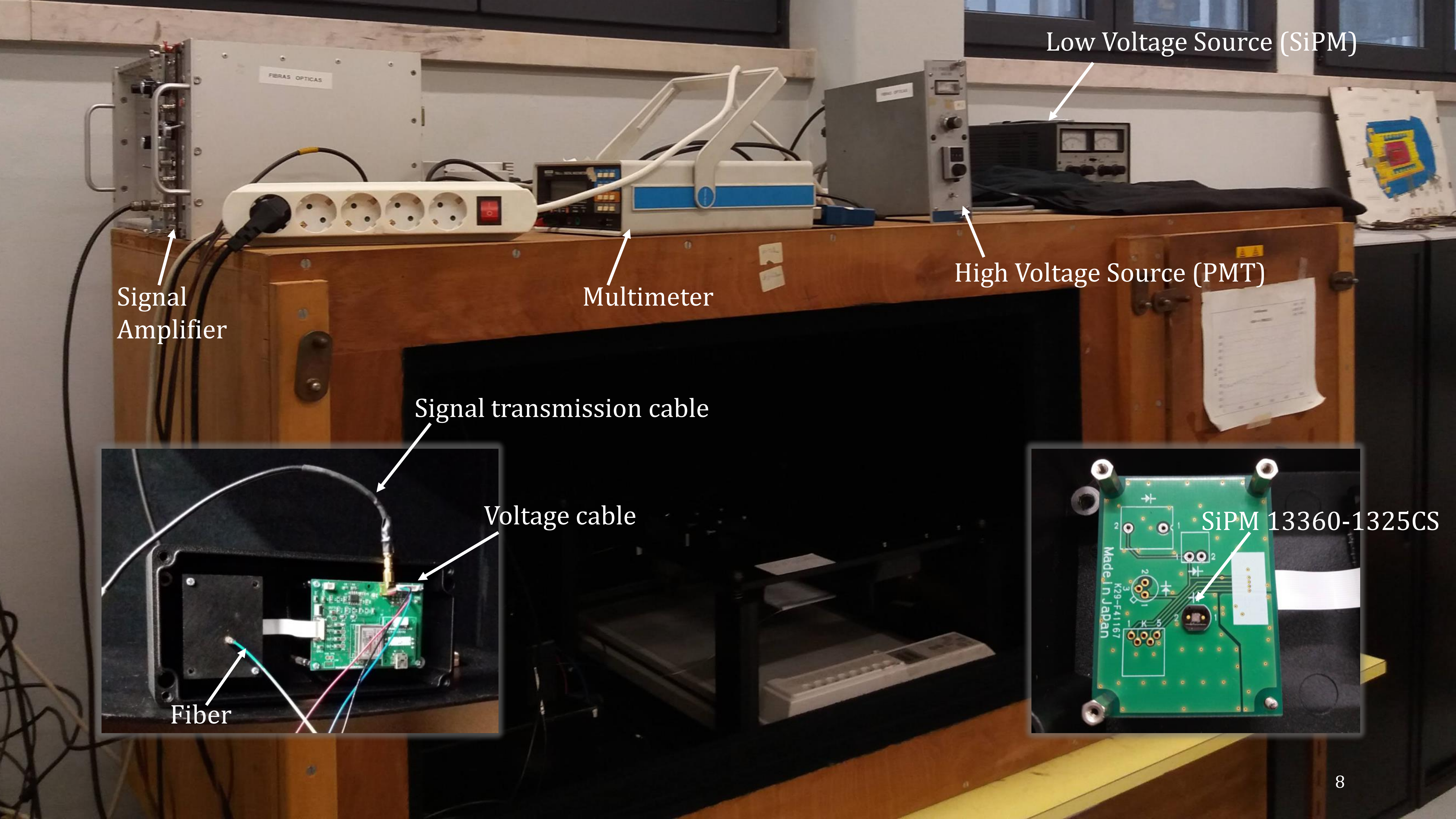
- Natural aging (in this internship)
- Induced aging
  - Caused by ionizing radiation
  - Caused by mechanical stress

Scintillator properties

Experimental Setup







Low Voltage Source (SiPM)
Signal
Amplifier
Multimeter
High Voltage Source (PMT)
Signal transmission cable
Voltage cable
Fiber
SiPM 13360-1325CS
Made in Japan
K29-F41167

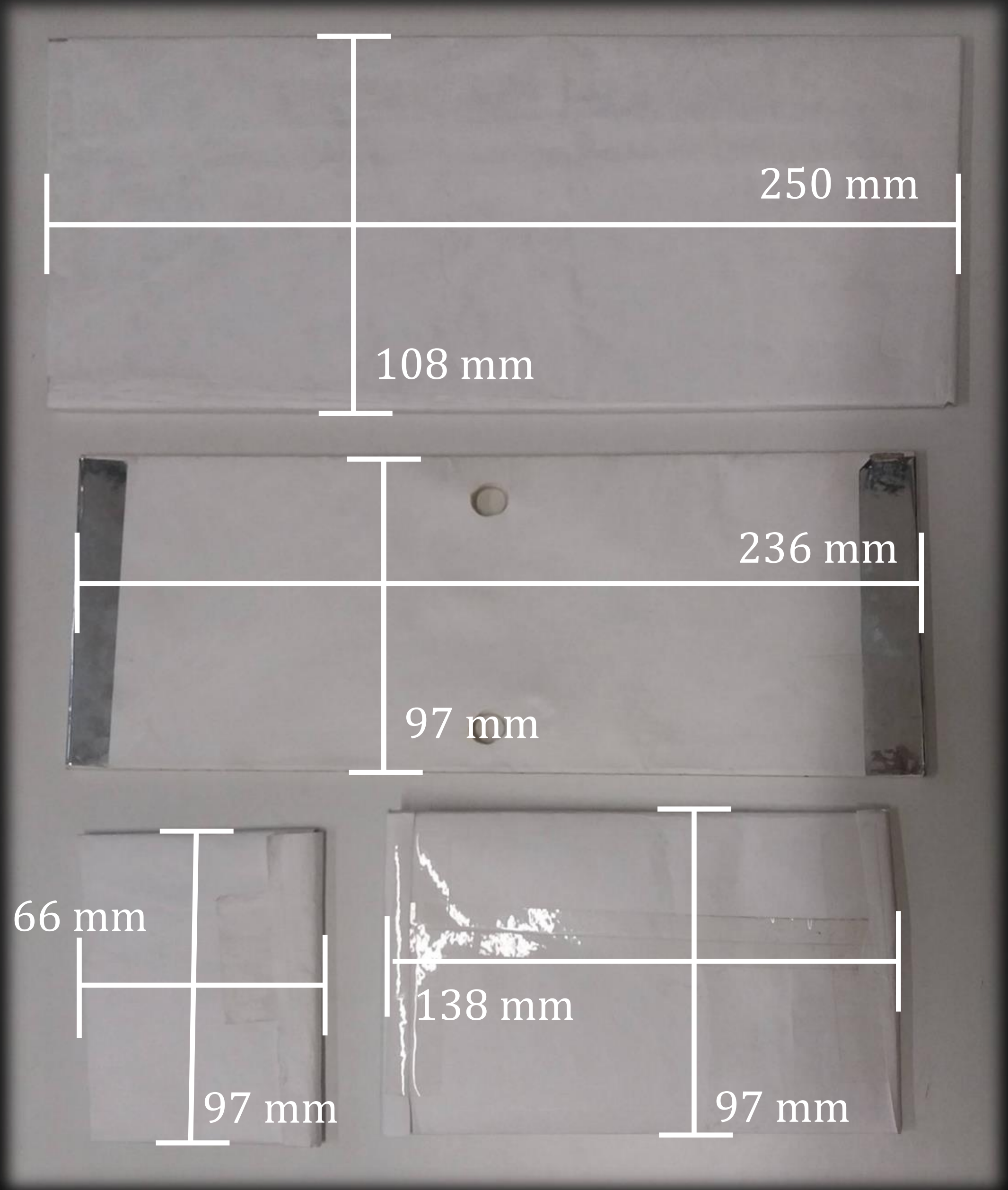
Tiles

Sizes

- Big
- Medium
- Small

Covering

- Fully covered in tyvek
- Mylar covering on the edges
- Black border inside the tyvek covering

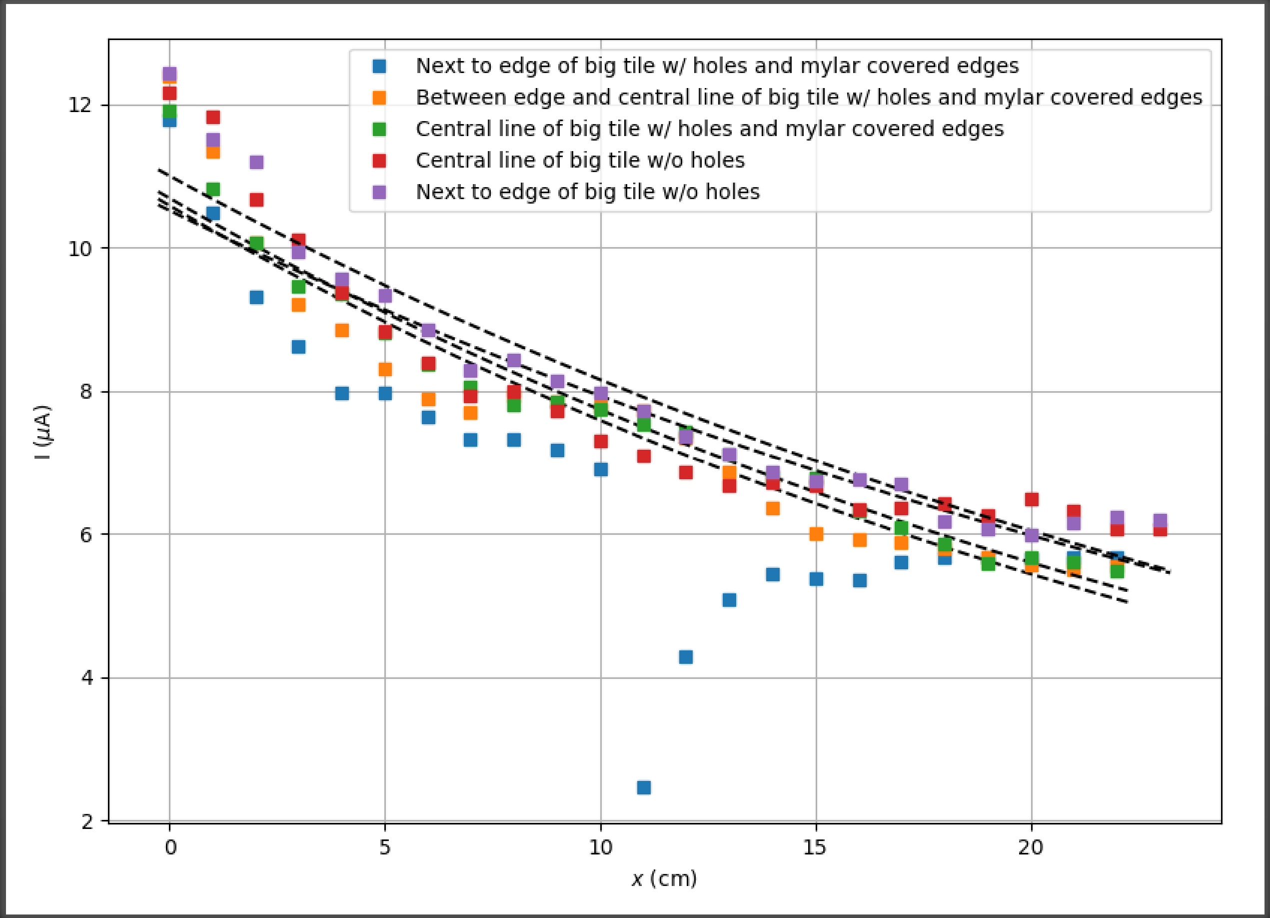


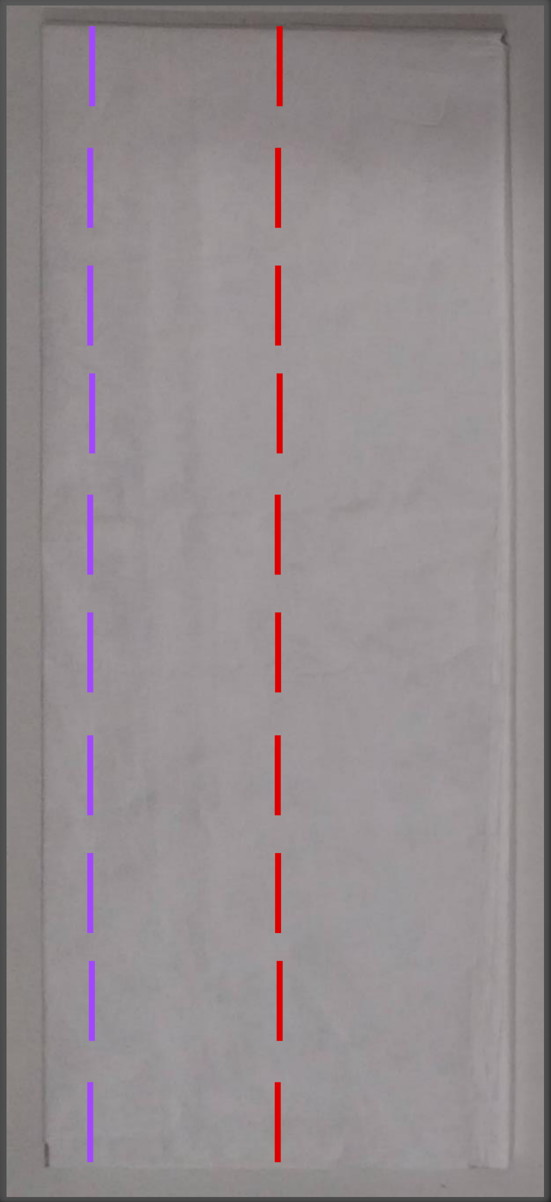
TileCal type results

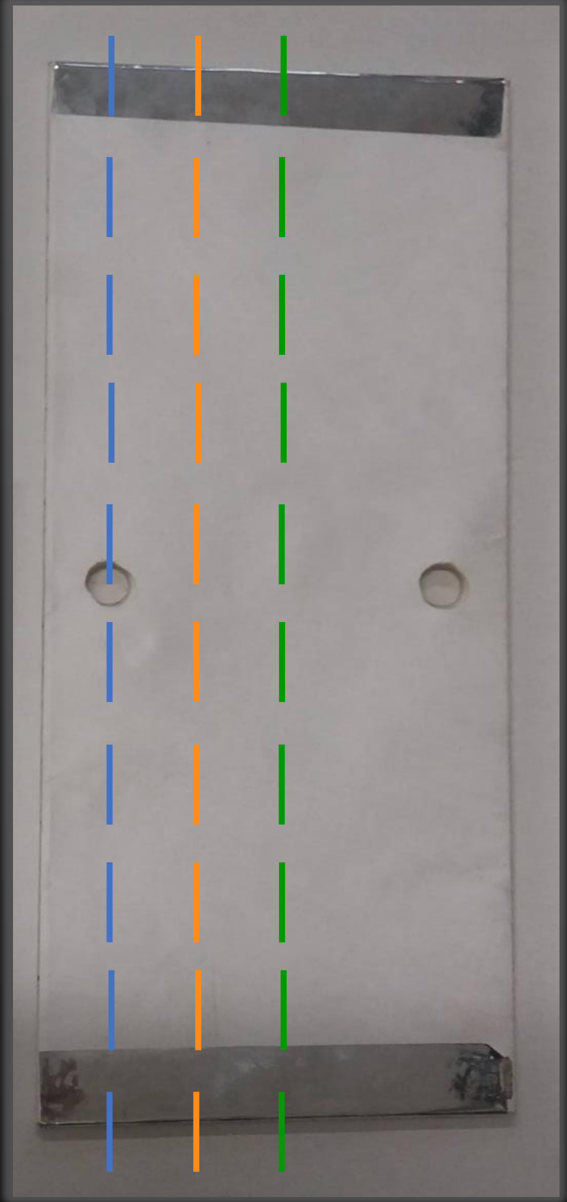
- Big Tile w/ Holes
- Big Tile w/o Holes

I_0 (µA)	$Latt$ (cm)
10,59	30,01
10,69	30,91
10,52	35,38
11,00	33,39

$$I(x) = I_0\, e^{-\frac{x}{Latt}}$$





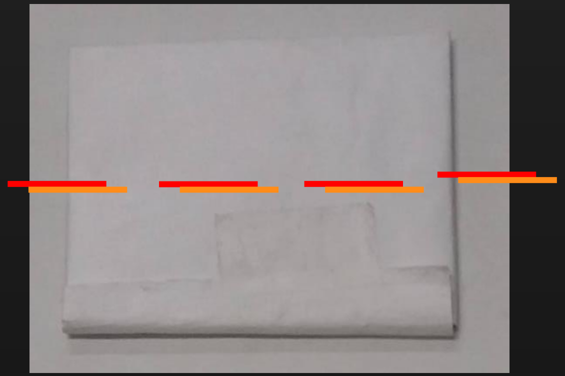


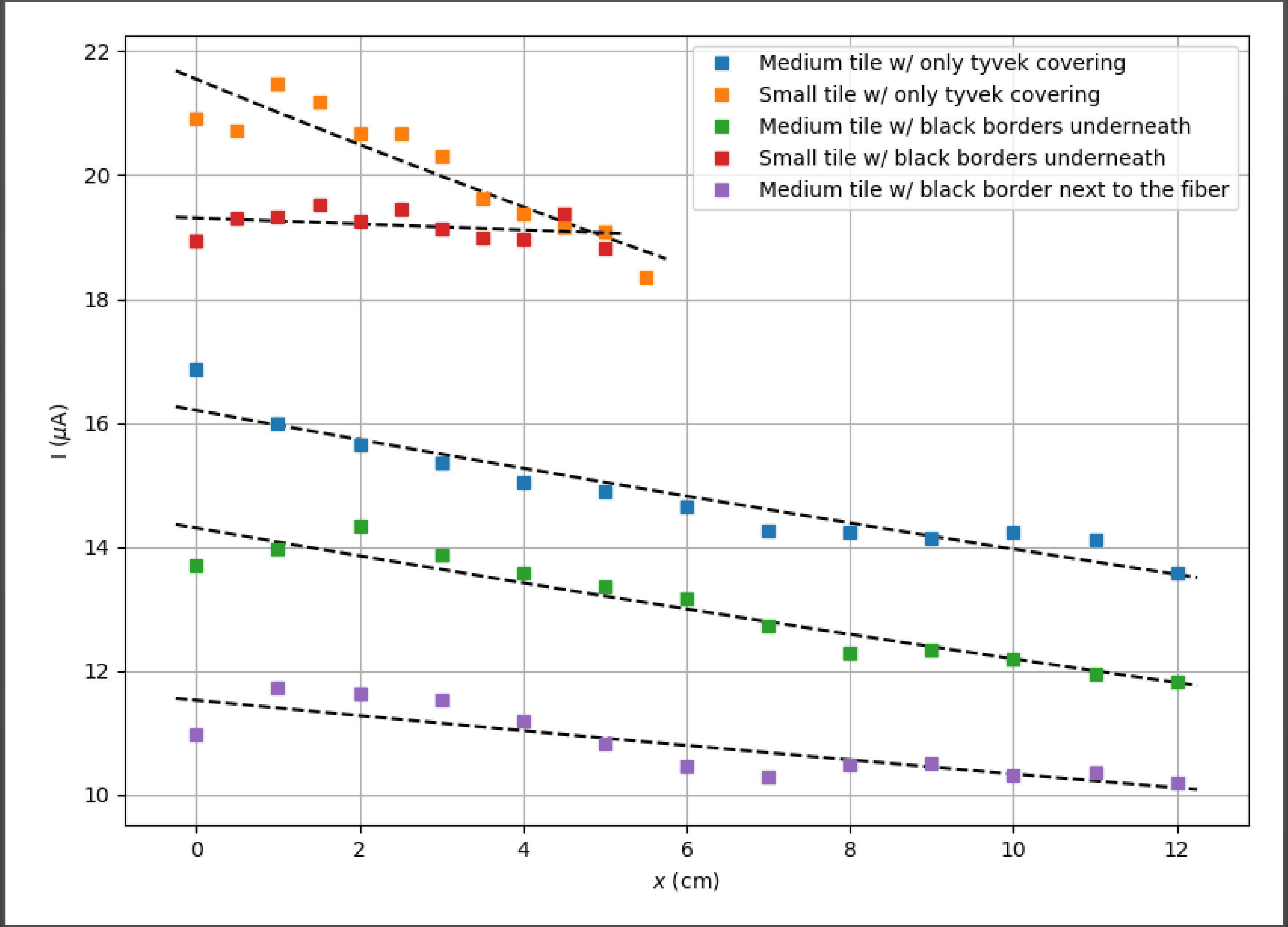
FCC type results

$$I(x) = I_0 \, e^{-\frac{x}{Latt}}$$

– Medium Tile
– Small Tile

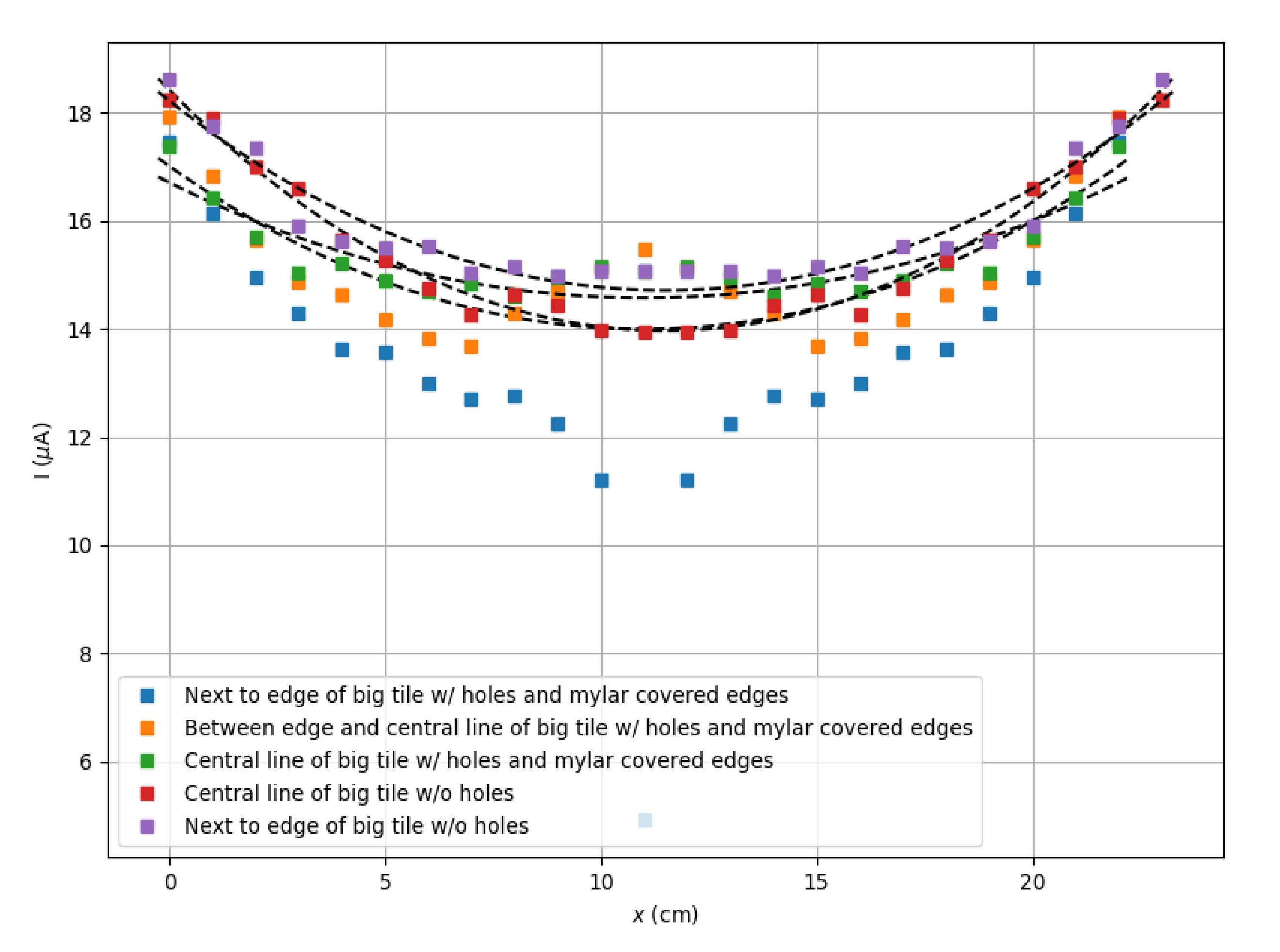
I_0 (µA)	$Latt$ (cm)
21,55	39,79
19,31	396,5
16,20	67,18
14,30	62,54
11,52	91,70





Dual readout in the ATLAS TileCal

In the TileCal, there is an optical fiber on each side of the tiles.



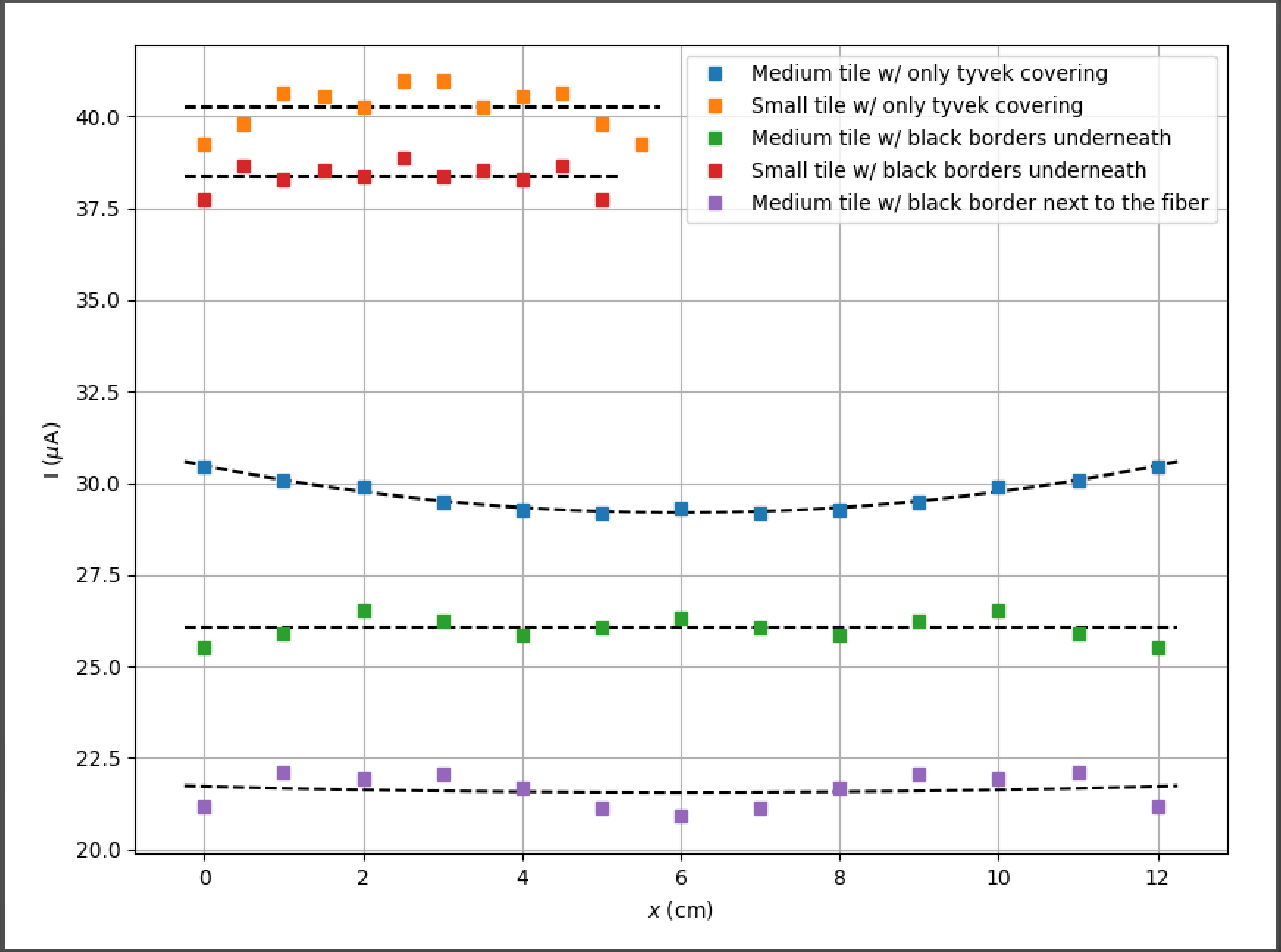
$$I(x) = a \times e^{-\frac{x}{Latt}} + a \times e^{-\frac{L-x}{Latt}}$$

a (µA)	$Latt$ (cm)
13,35	17,04
12,44	20,56
15,22	14,76
14,49	16,97

Dual readout in the FCC TileCal ?

In the FCC, the proposal is to have a single fiber reading a single tile.
Below, it's the case where there's na optical fiber on each side of a tile.

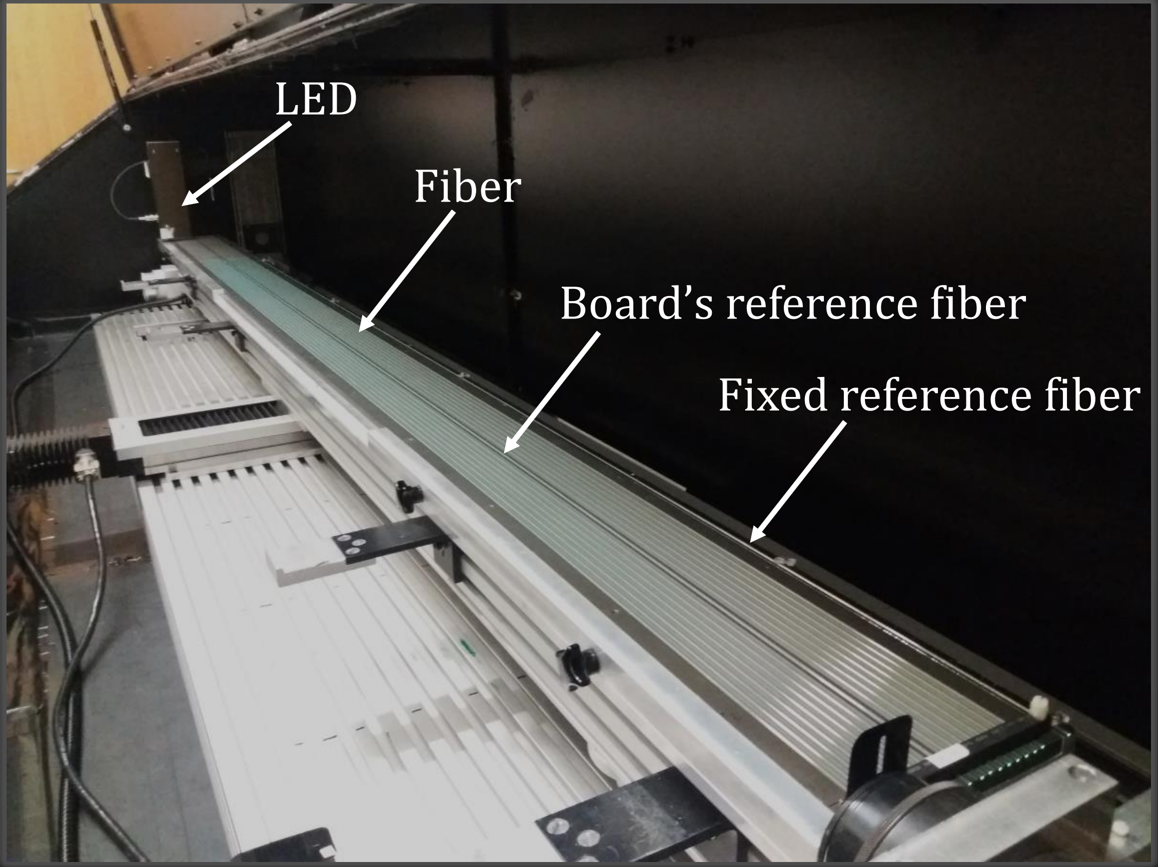
$$I(x) = a \times e^{-\frac{x}{Latt}} + a \times e^{-\frac{L-x}{Latt}}$$

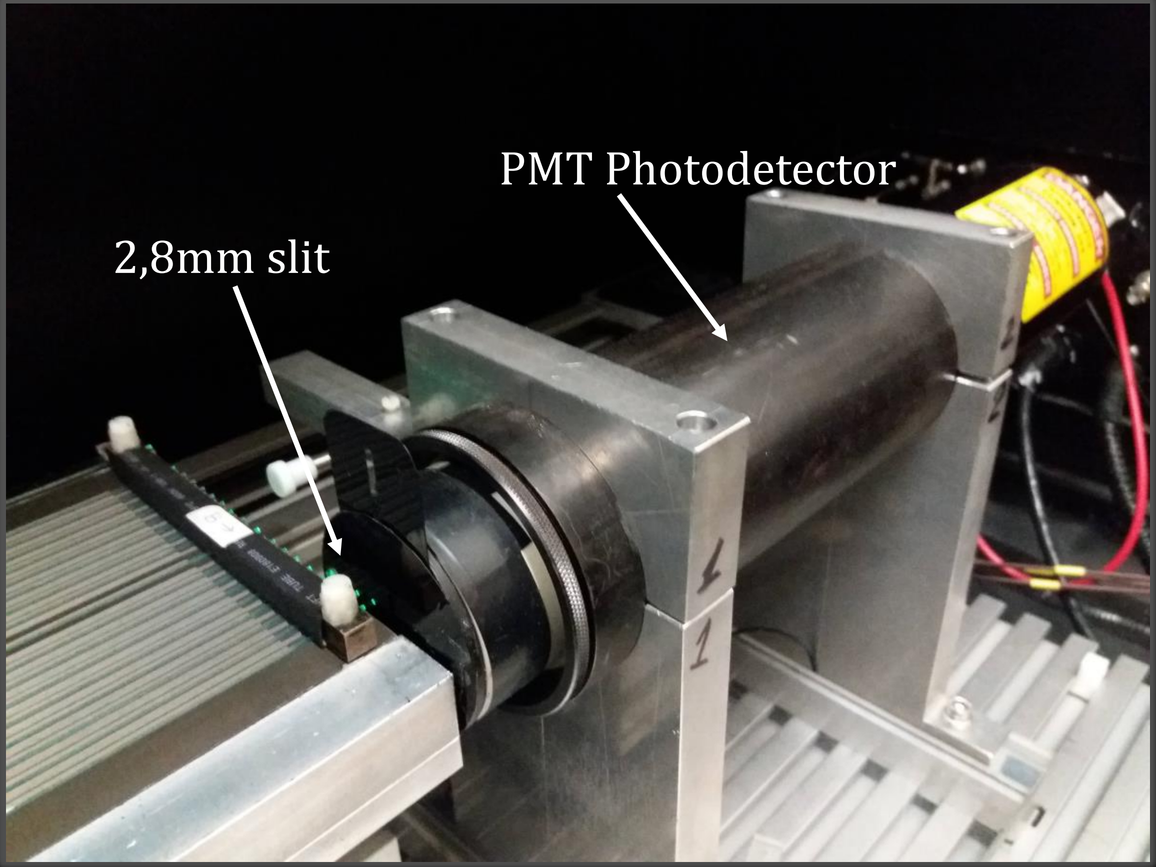


a (μA)	*Latt* (cm)
20,13	151785 ?
19,19	264051 ?
19,63	20,23 ?
13,02	132834 ?
12,22	47,36 ?

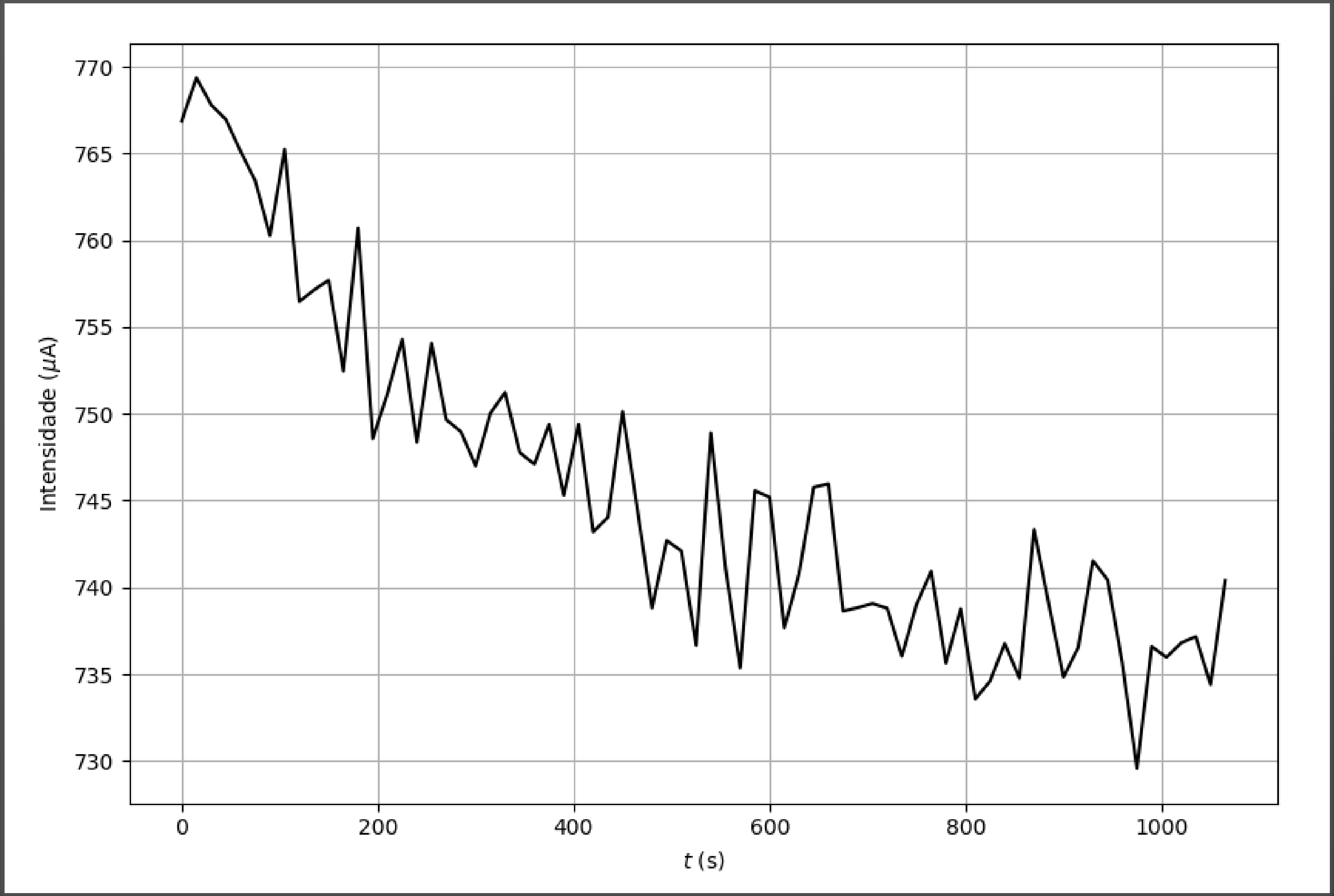
Optical Fibers

Experimental Setup





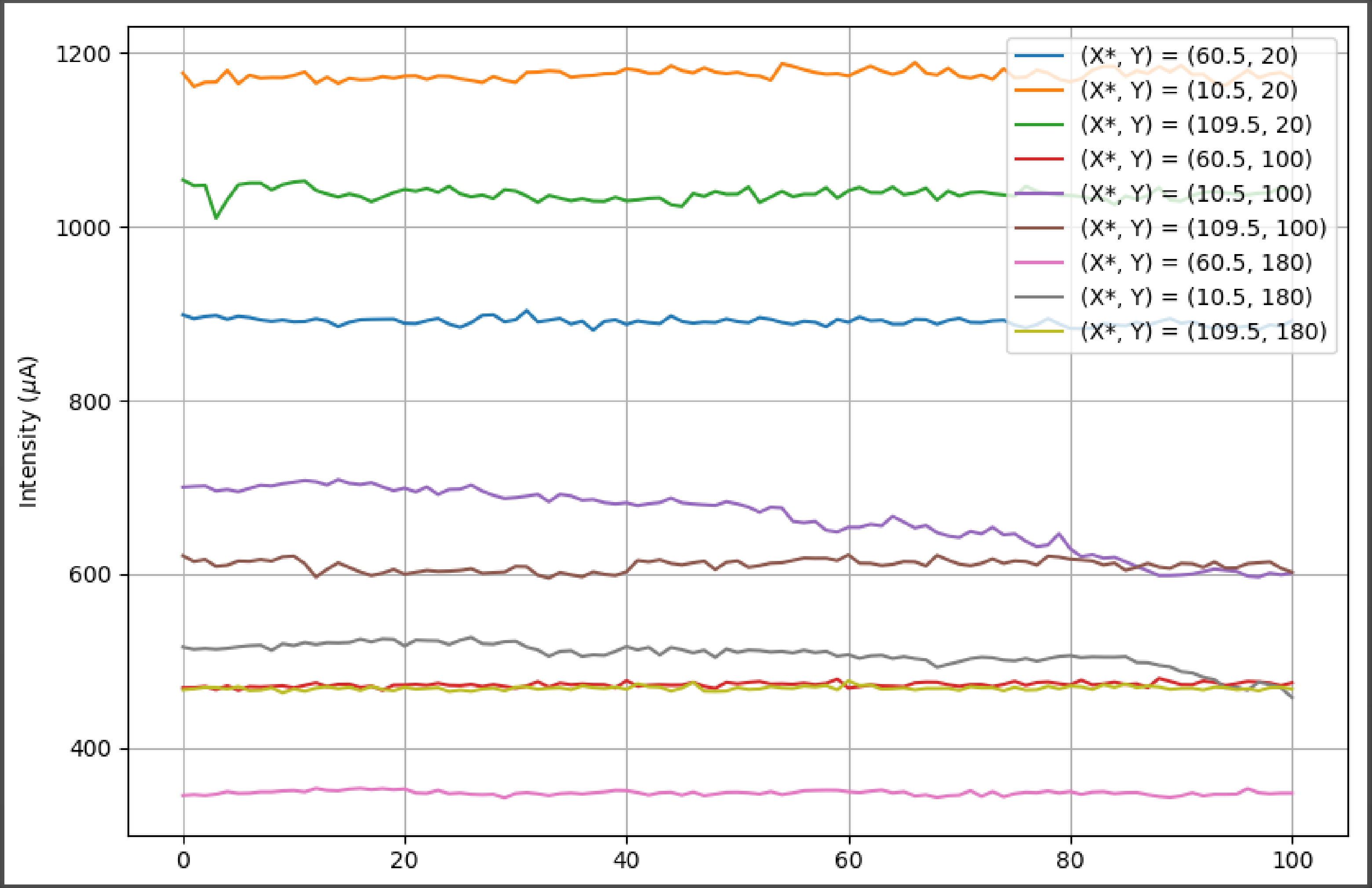
PMT Stabilization



- $\langle I \rangle = 746\ \mu A$
- $\sigma_I = 9{,}7\ \mu A$
- $\frac{\sigma_I}{\langle I \rangle} = 1{,}3\ \%$

Repeatibility

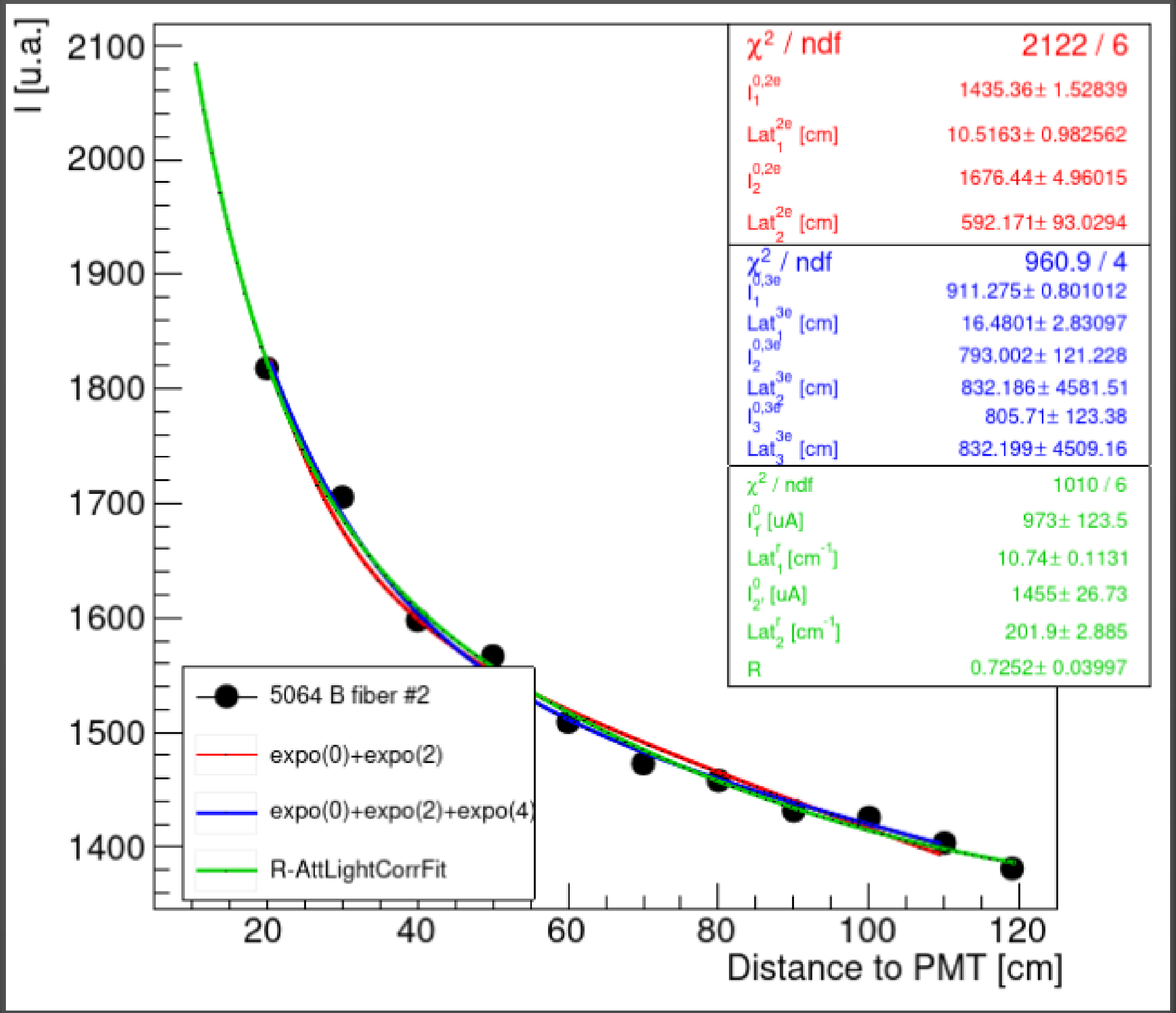
The same point over the fiber is measured with reposition.



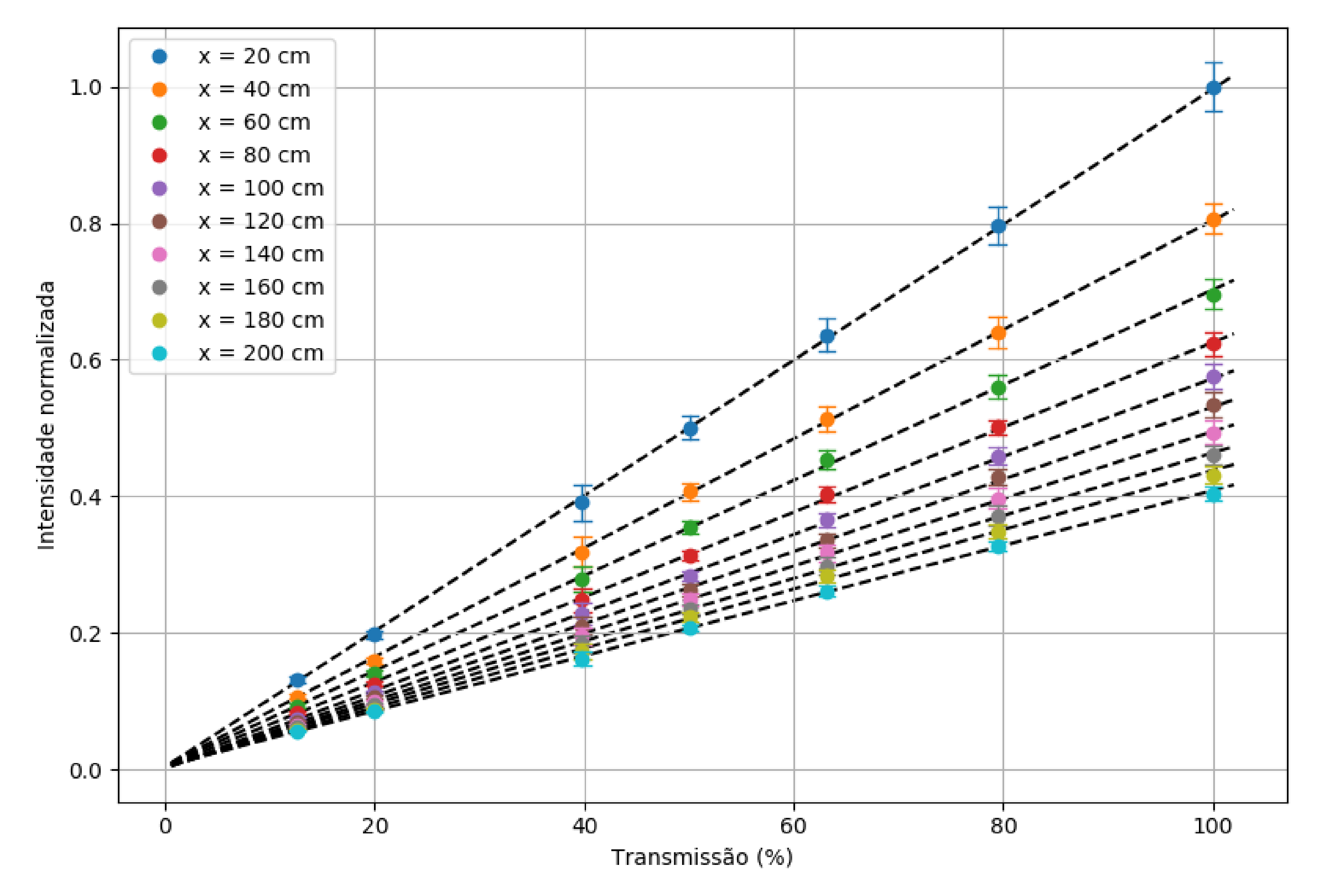
(X*, Y)	$\langle I \rangle$ (μA)	σ_I (μA)	$\frac{\sigma_I}{\langle I \rangle}$ **(%)**
(60.5, 20)	890,3	4,11	0,46
(10.5 , 20)	1175	5,71	0,49
(109.5, 20)	1037	6,76	0,65
(60.5, 100)	472,7	2,61	0,55
(10.5, 100)	664,0	35,2	5,31
(109.5, 100)	610,2	6,39	1,05
(60.5, 180)	348,2	2,46	0,71
(10.5, 180)	507,0	14,2	2,80
(109.5, 180)	468,7	2,28	0,49

Fibre measurement

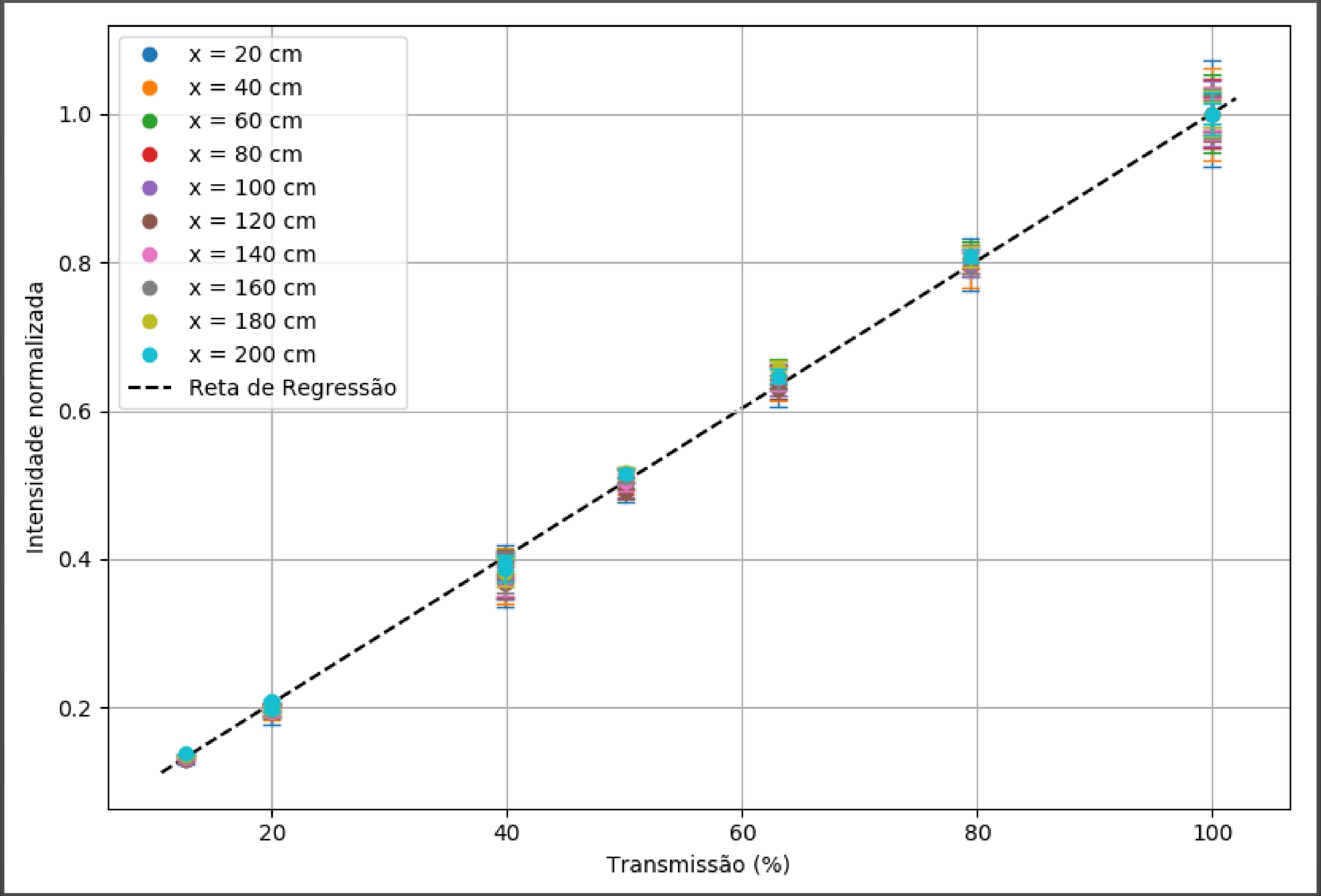
The LED is positioned along the fiber and the intensity is measured.



Measurement of linearity using neutral filters



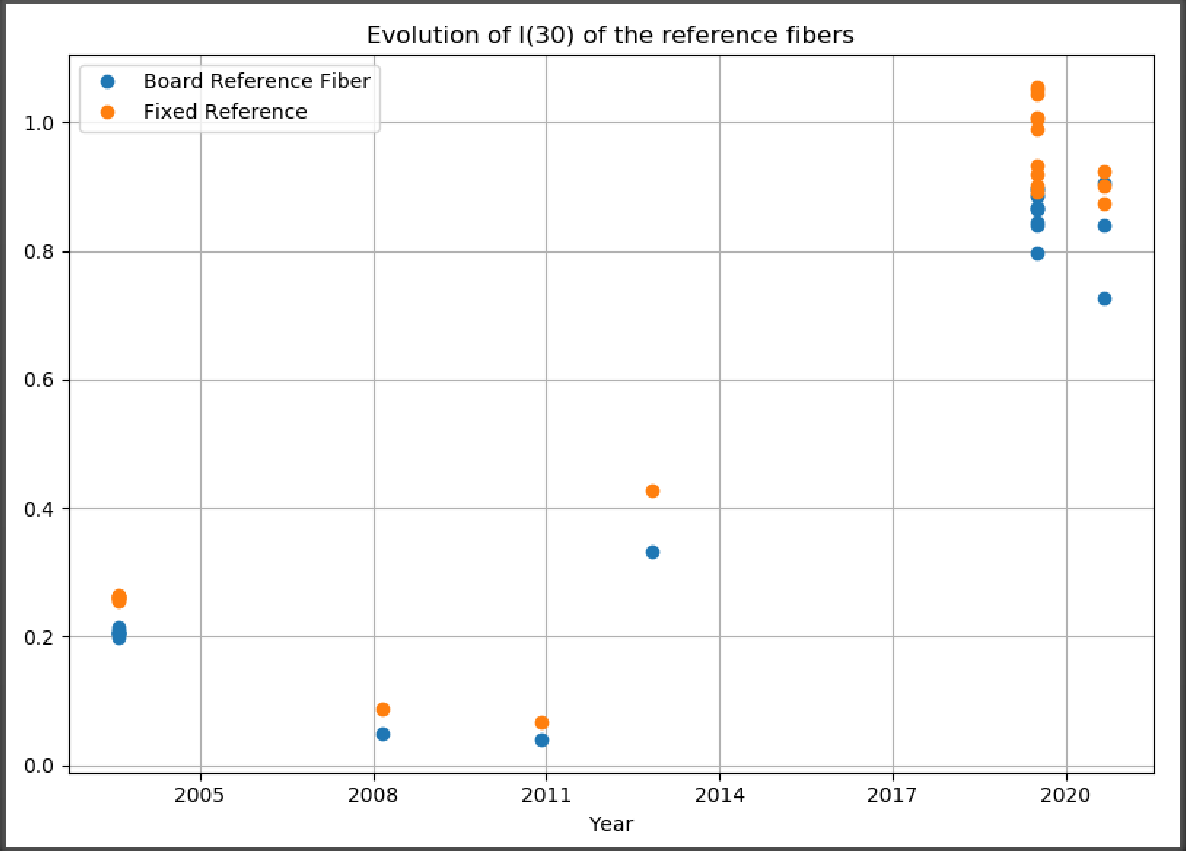
Slopes	
x = 20 cm	0,00993
x = 40 cm	0,00799
x = 60 cm	0,00698
x = 80 cm	0,00622
x = 100 cm	0,00571
x = 120 cm	0,00529
x = 140 cm	0,00493
x = 160 cm	0,00460
x = 180 cm	0,00434
x = 200 cm	0,00404

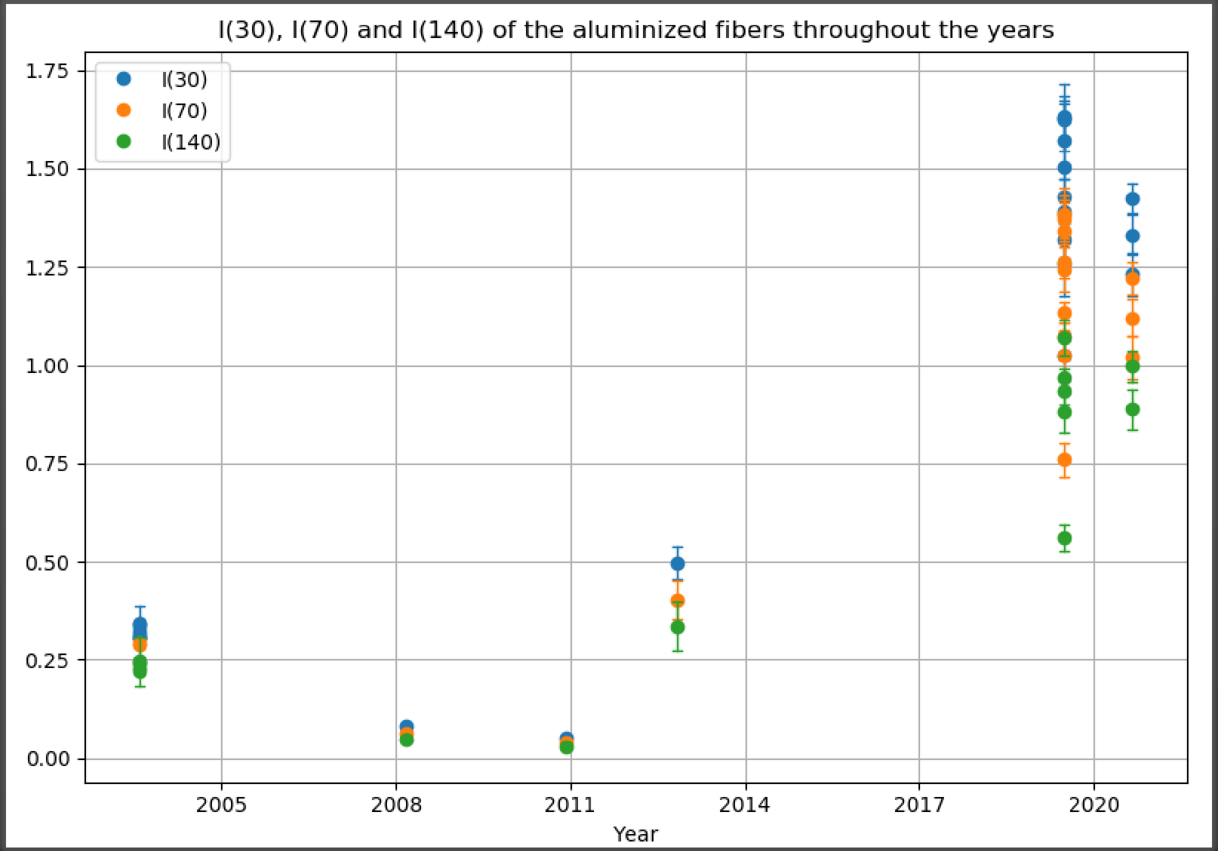


Slope
0,00993

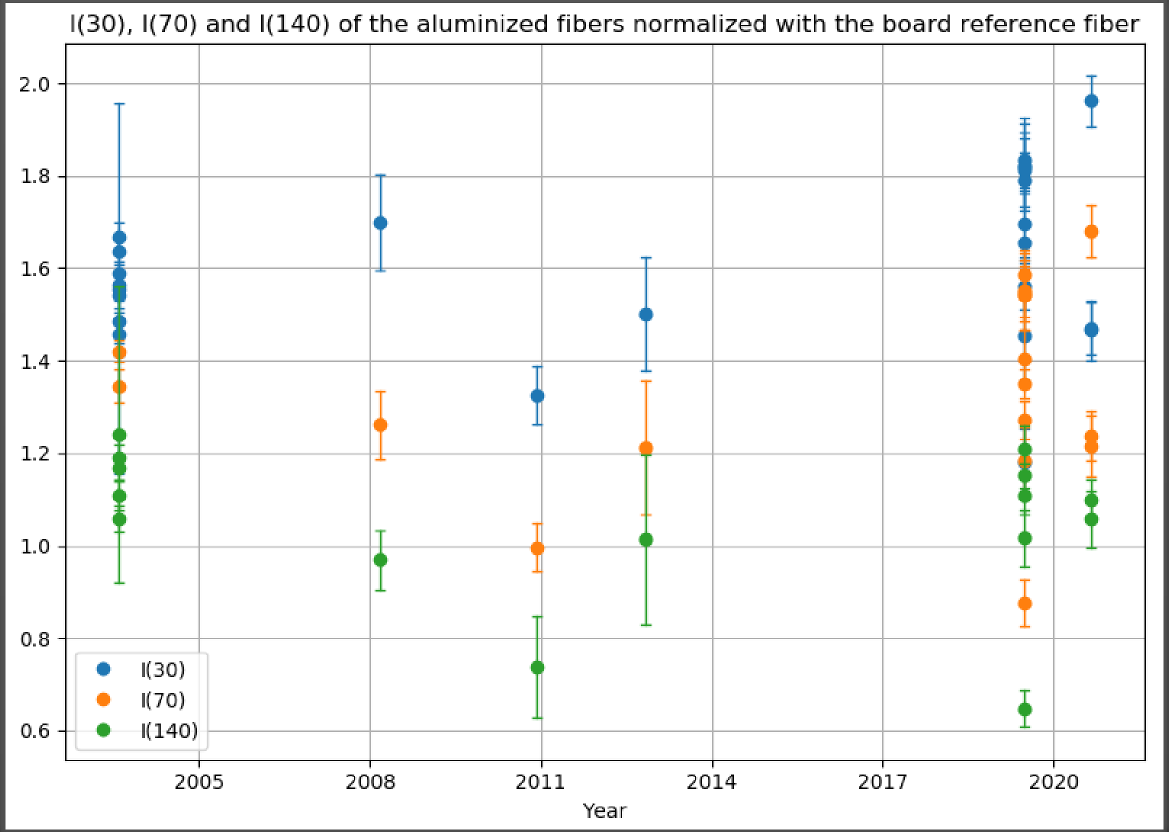
Natural Aging of aluminized fibers

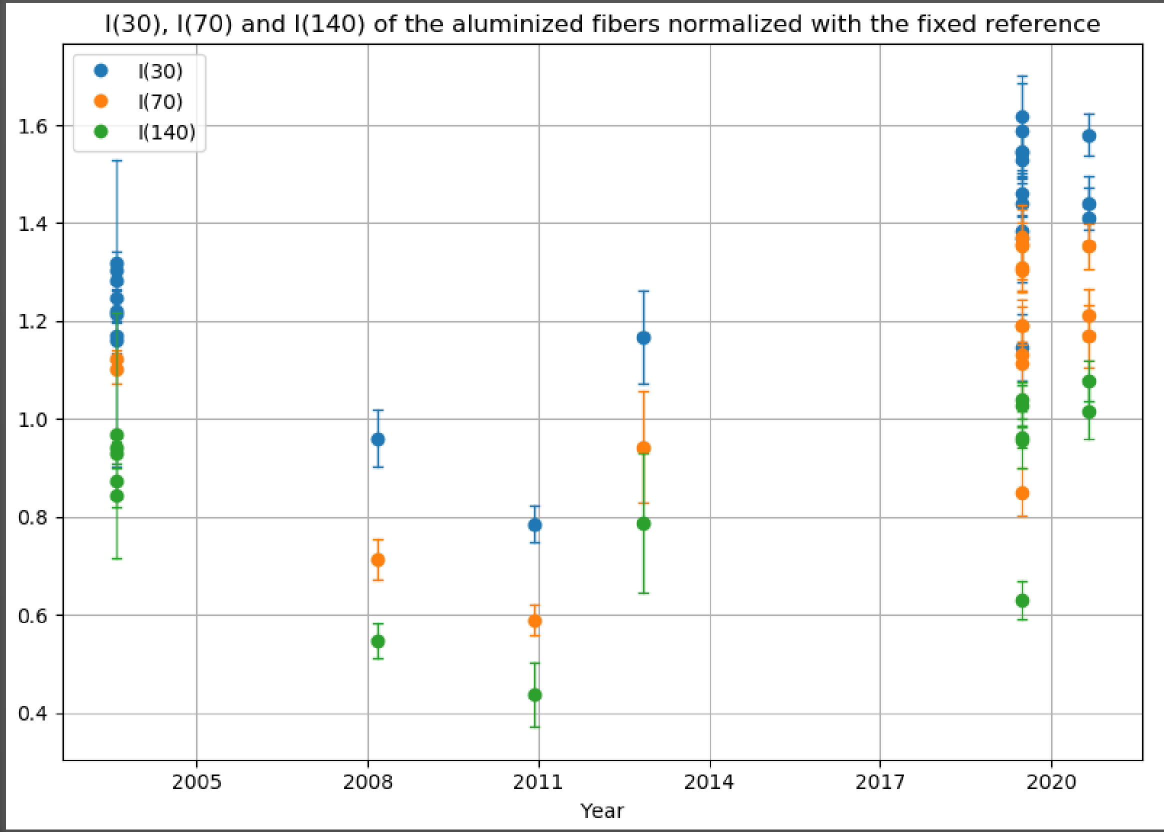
Fibers of different lengths were used.





There's a similar pattern for the reference fibers and the aluminized fibers.


I(30), I(70) and I(140) of the aluminized fibers normalized with the board reference fiber
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
2005
2008
2011
2014
2017
2020
Year
I(30)
I(70)
I(140)


I(30), I(70) and I(140) of the aluminized fibers normalized with the fixed reference
1.6
1.4
1.2
1.0
0.8
0.6
0.4
2005
2008
2011
2014
2017
2020
Year
I(30)
I(70)
I(140)

Results summary

Scintillators

- Tile size and covering play a role in optical characteristics.
- Black borders make a more uniform signal response along the tile.
- Small tiles are subject to a more unform signal response as well.

Fibers

- Most of the repeatibility tests are very stable.
- The slope of the linear fit is 0.00993, quite close to 0.01, which would be the desired value.
- On natural aging, a more in-depth analysis is required, separating the results by fiber length and other parameters.

Discussion

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