LOMAC / LIP

Laboratório de óptica e materiais cintilantes

Caracterização de materiais óticos para os upgrades do calorímetro hadrónico TileCal

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Brief introduction to TileCal

- ATLAS Barrel Hadronic calorimeter
- Uses steel plates as absorber and plastic scintillating tiles as the active material
- Tiles parallel to the incoming particles at η=0, allow the WLS fibers to run straight to the outer radius, allowing for a good calorimeter hermeticity and easy tiles-fibers coupling.
- Together with the em calorimeter, TileCal provides precise measurement of hadrons, jets, taus and missing transverse energy
- Interaction length λ = 20.7cm

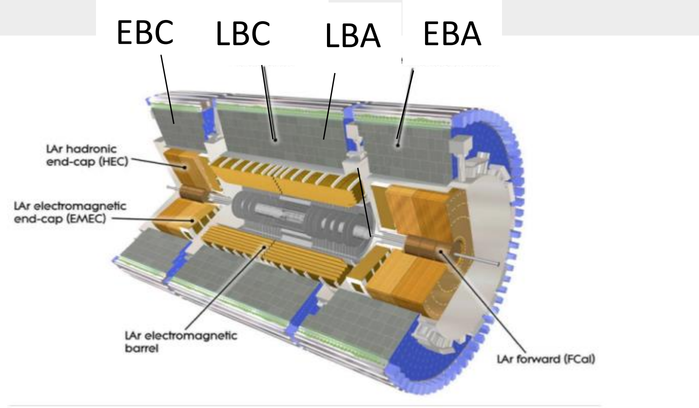
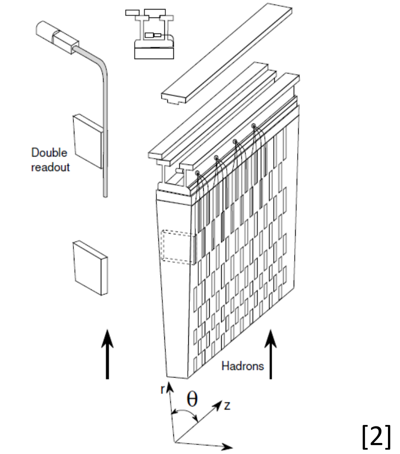


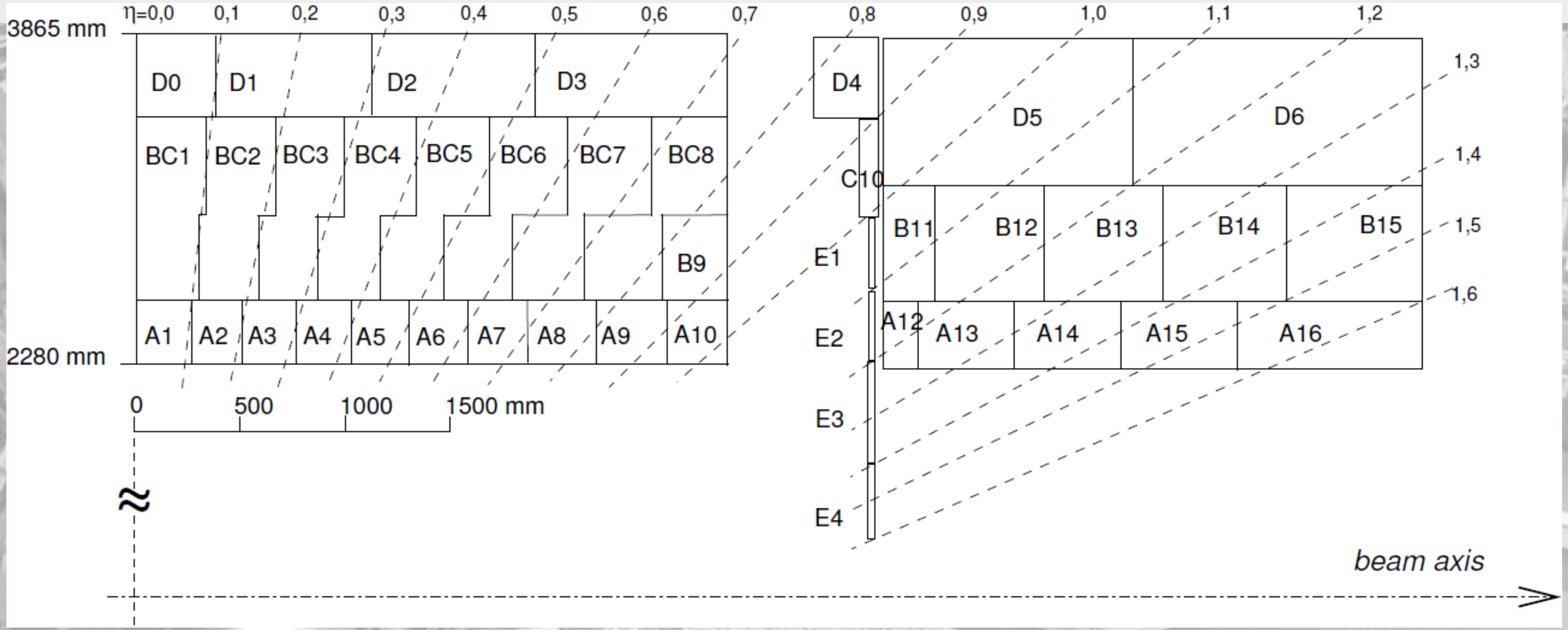
Fig. 1. A cut-away view of the ATLAS calorimeters. The Tile Calorimeter consists of one central barrel and two extended barrels. [2]



[2]

Pseudo-rapidity (η) is defined as η = − ln tan(θ/2), where θ is the polar angle measured from the beam axis.
#Nuclear interaction length (λ) is the mean path length required to reduce the numbers of relativistic charged particles by the factor 1/*e*

- 64 modules per barrel, total of 256 modules, each covering the azimuthal ϕ angle of $2\pi/64 = 0.1$
- Total calorimeter depth of 7.4 λ at η = 0
- Calorimeter modules are segmented into three longitudinal layers (A, BC, D) of 1.5, 4.1 and 1.8 λ in the barrel and 1.5, 2.6, 3.3 λ in the extended barrels
- Covers the central region of the ATLAS detector up to a pseudorapidity of |η| < 1.7
- Tiles segmentation $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$
- E cells cover the gap-crack region

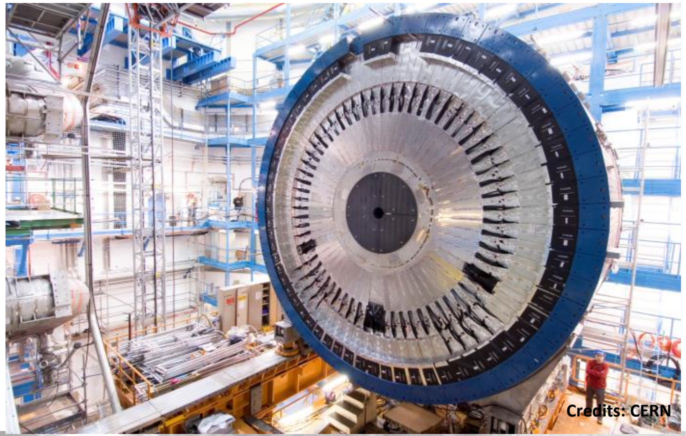


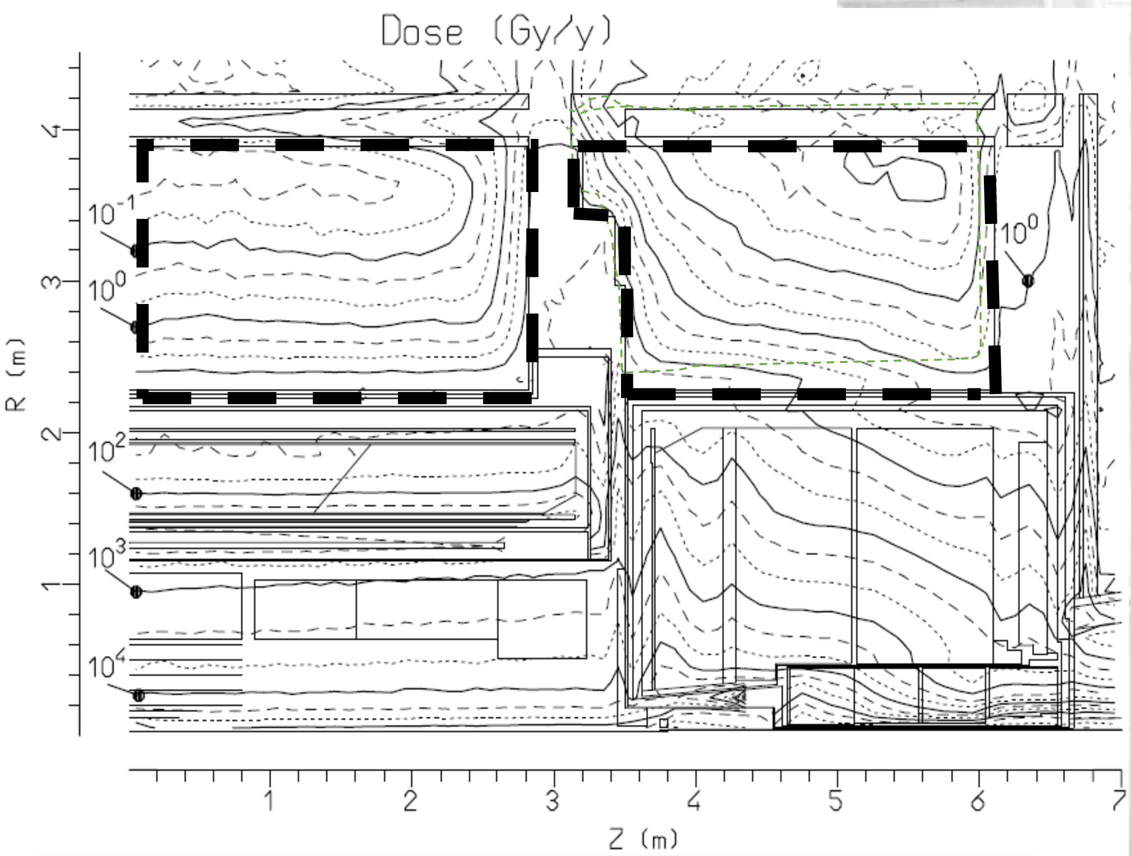
Pseudo-rapidity η is defined as $\eta = -\ln\tan(\theta/2)$, where θ is the polar angle measured from the beam axis.

#Nuclear interaction (λ) length is the mean path length required to reduce the numbers of relativistic charged particles by the factor 1/*e*

Motivation for the work

- Need to upgrade the detectors
- Natural ageing and radiation degradation of tiles
- A, BC and D areas are not accessible
- Process of materials´s characterization
- How to prepare the fibers for testing





Scintillating Tiles Optical fibers

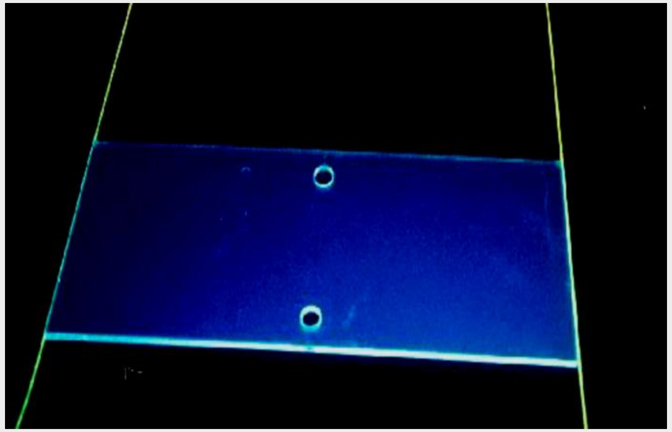
- 3 mm tick scintillating tiles
- Polystyrene dopped with PTP (para-terphenyl) and POPOP (1,4-di(5-phenyloxazolyl-2) benzene)
- Spectral peak – 400 nm
- PTP absorbs ultra-violet light and reemit it in a longer wavelength, and POPOP acts in an equivalent way with the PTP light
- $\frac{dL}{dr} = S\frac{dE}{dr}$
- The light produced in the tile is collected at two of the tile edges by WLS fibers 1mm diameter

Size of tiles

- in the azimuthal direction 200 - 400 mm
- in the radial direction 97 - 187 mm

No. of tiles per module

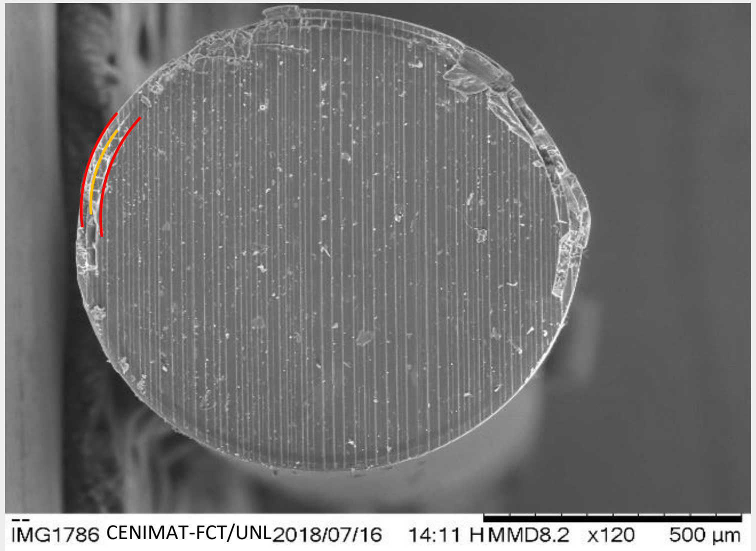
- Barrel 3355
- ext. barrel 1529
- ITC 323



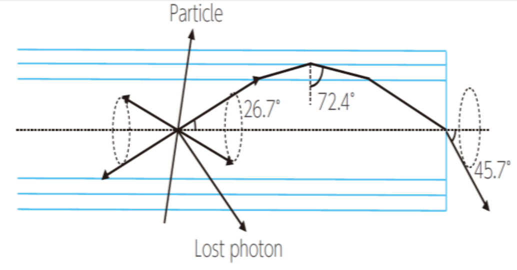
- Total number of tiles ~463000

WLS Optical fibers

- Wave lenght shifting (WLS) optical fibers Kuraray Y11-MS, Double Cladding, 1mm diameter
- 896 µm Polystyrene refraction index 1.59 plus a die (K27)
- 30 µm thick PMMA cladding
- 22 µm outer cladding fluorinated polymer
- No. of fibers per PMT min: 26, max: 92
- Total no. of PMTs- Barrel 4030, Barrel 5980



120 x Amplification of a fiber's edge, the vertical scratches and cladding defects are related to the cutting and polishing processes

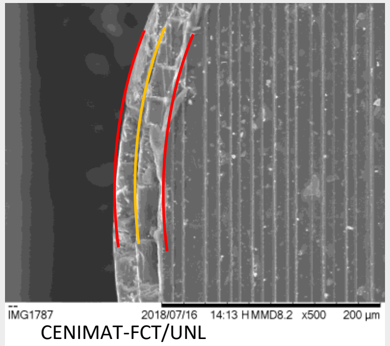


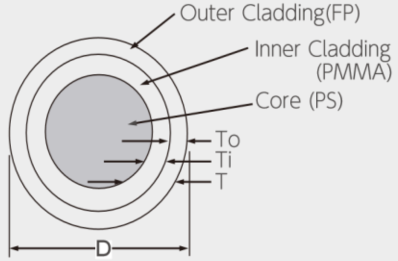
Materials

		Materials	Refractive index	Density (g/cm³)	No. of atom per cm³
Core		Polystylene(PS)	n_D=1.59	1.05	C: 4.9×10^{22} H: 4.9×10^{22}
Cladding	for single cladding inner for multi-cladding	Polymethylmethacrylate (PMMA)	n_D=1.49	1.19	C: 3.6×10^{22} H: 5.7×10^{22} O: 1.4×10^{22}
	outer for multi-cladding	Fluorinated polymer (FP)	n_D=1.42	1.43	

Cross-section and Cladding Thickness

Round Fiber (D)



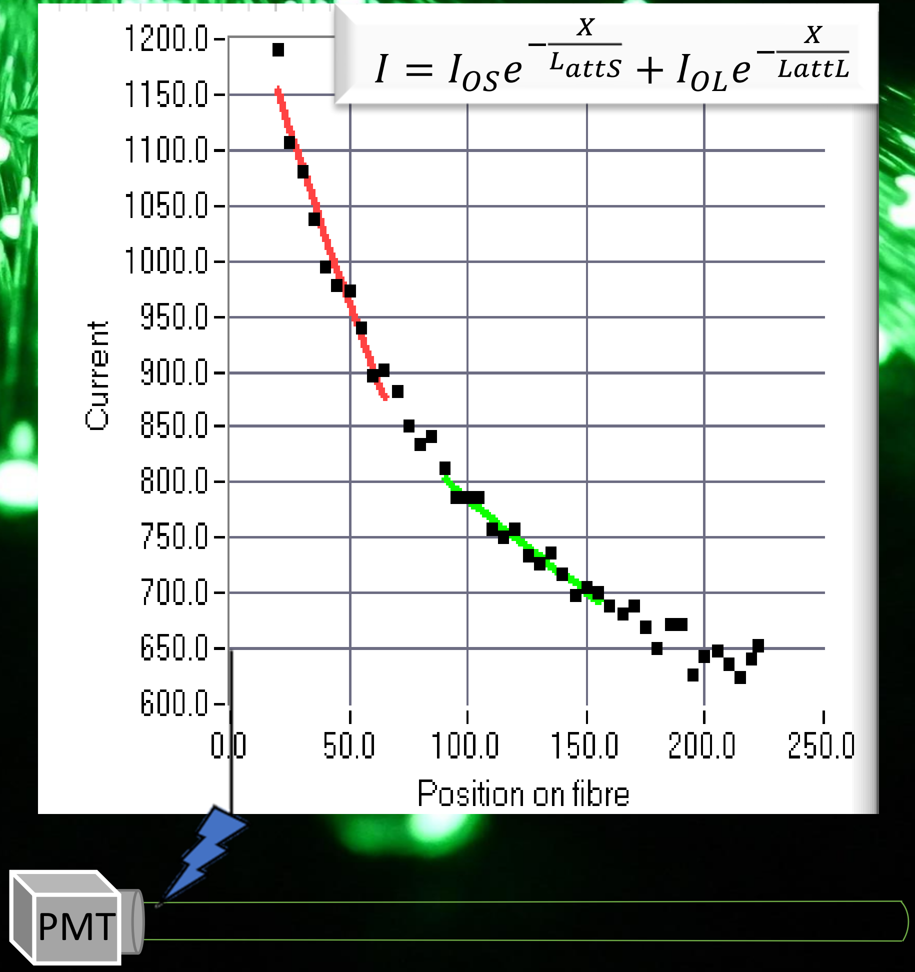


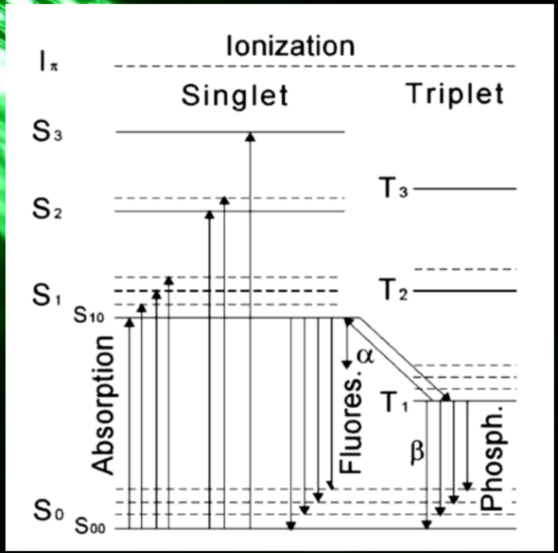
Cladding Thickness[2)]: T=2%(To)+2%(Ti) =4% of D
Numerical Aperture : NA=0.72
Trapping Efficiency : 5.4%

Light Production and Propagation in the fiber

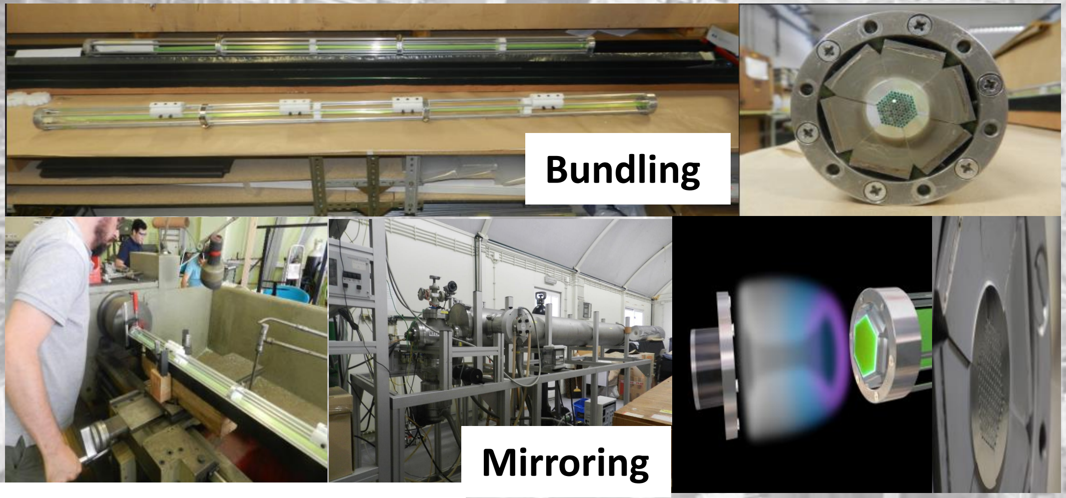
- Luminescence phenomena
  - Absorption of blue and emission of green
- Absorption, Fluorescence, Phosphorescence
- Different responses can be used to differentiate between different particles
- Efficiency depends on:
  - Self-absorption
  - Absorption centers
  - Cladding Imperfections
  - Reflections
- Parameterized by the sum of two exponential functions

$$I = I_{OS} e^{-\frac{x}{L_{attS}}} + I_{OL} e^{-\frac{x}{L_{attL}}}$$



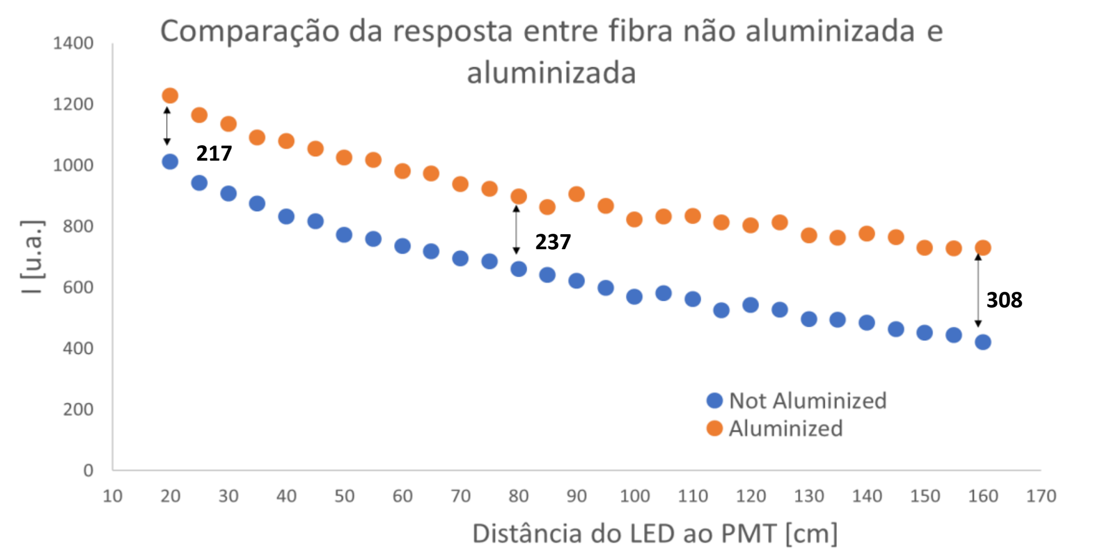


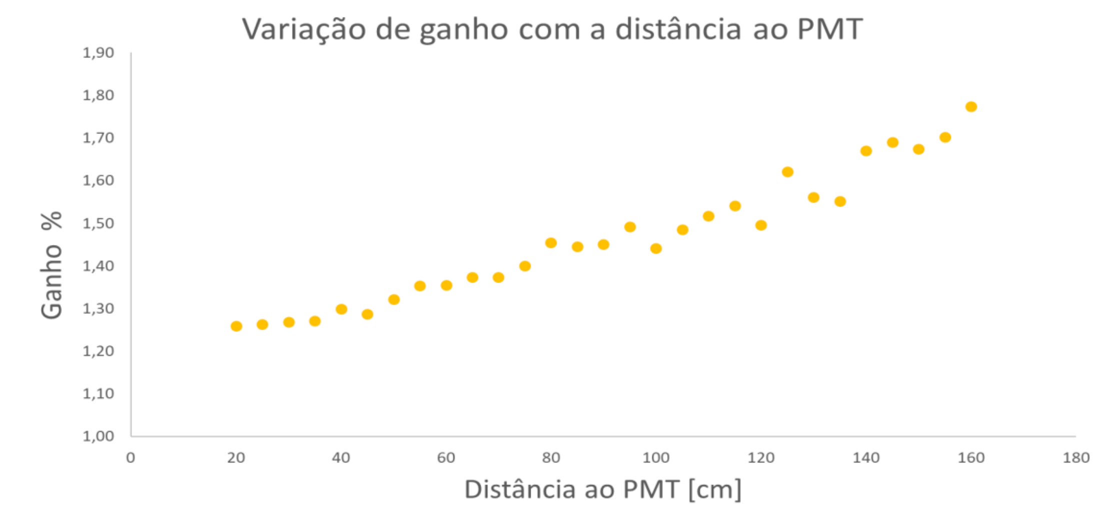
Aluminization of the top of the fibers



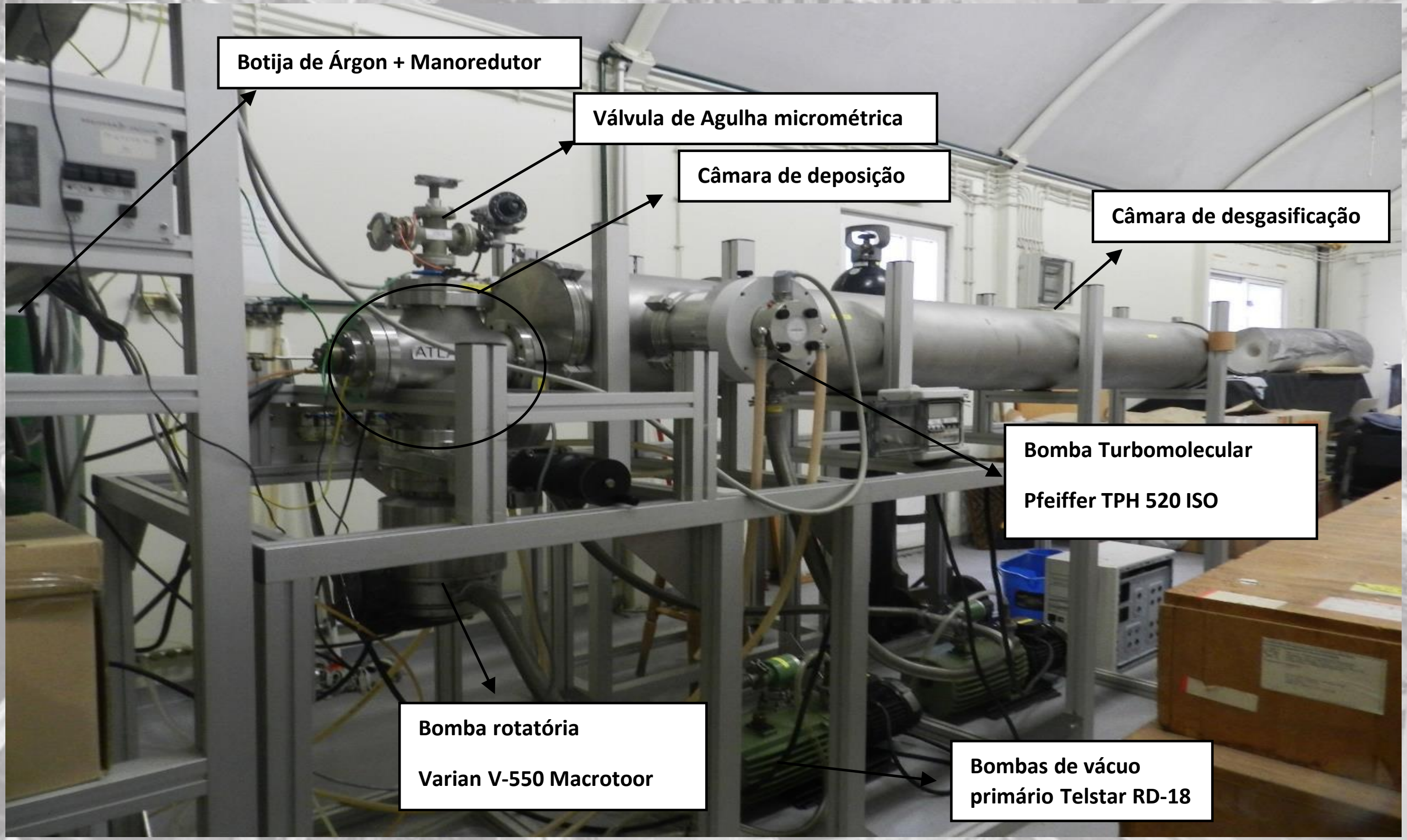
Cut and pollishing

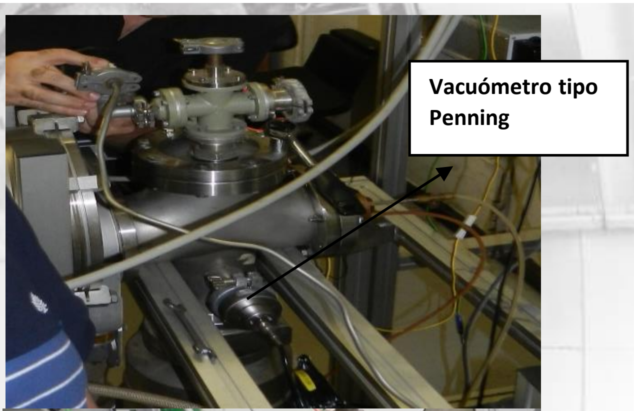
- Diamond blade tool with 2 blades mounted on a Lathe (DEGE/FCUL)
- Table: 140 μm/s perpendicular to the cutting tool
- 1500 rotations/minute

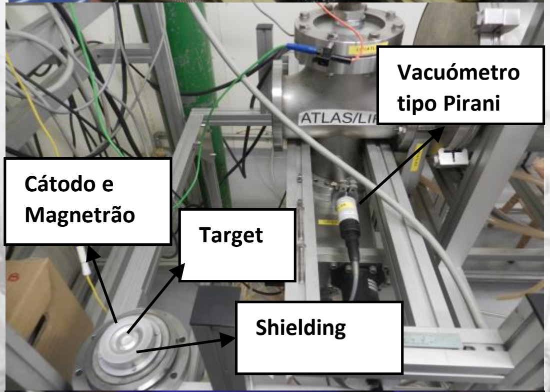


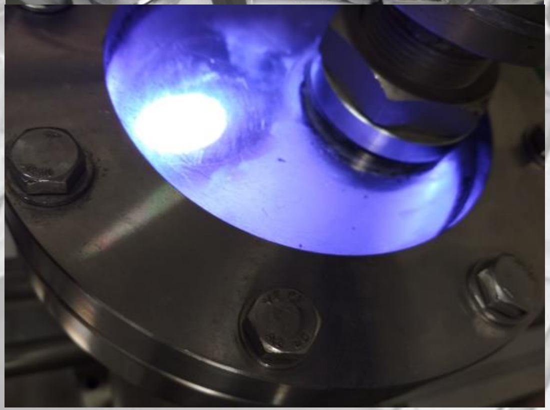


SIDELO II

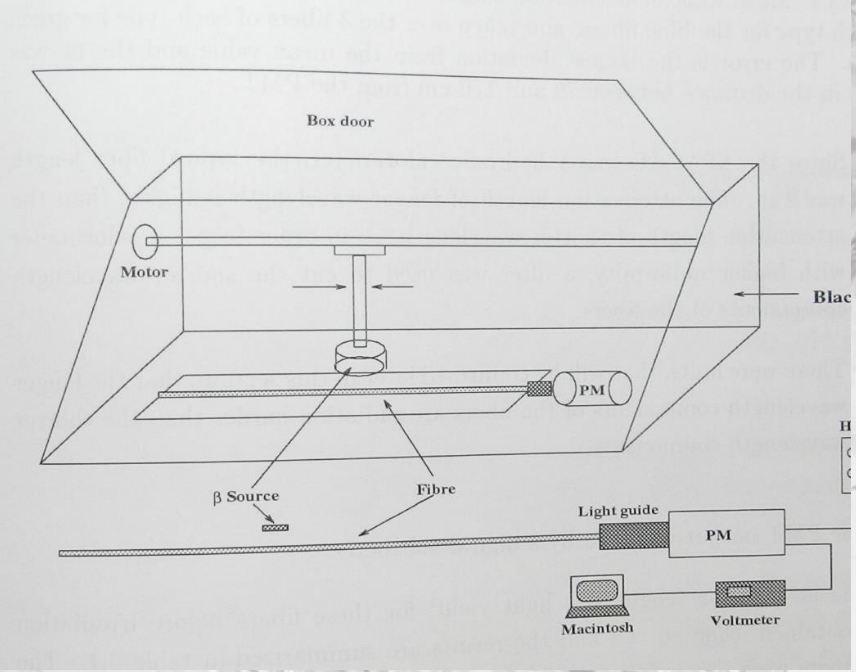


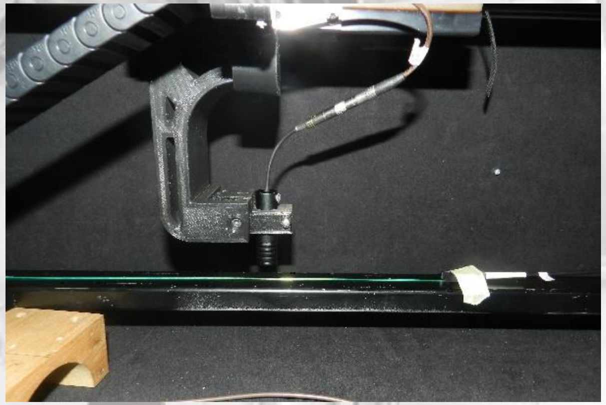






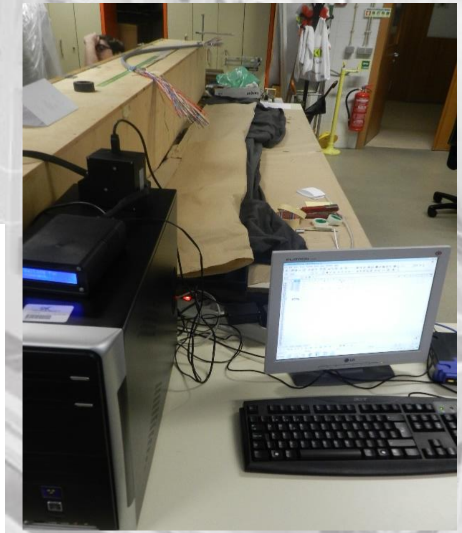
Cleaning pressure →1.6x10^-3 mbar
Discharge pressure→3x10^-3 mbar (Argon atmosphere)
Operating power→1kW (~2 min discharge)
Argon plasma + 99,9999 % 'Good Fellow' target Aluminum disc





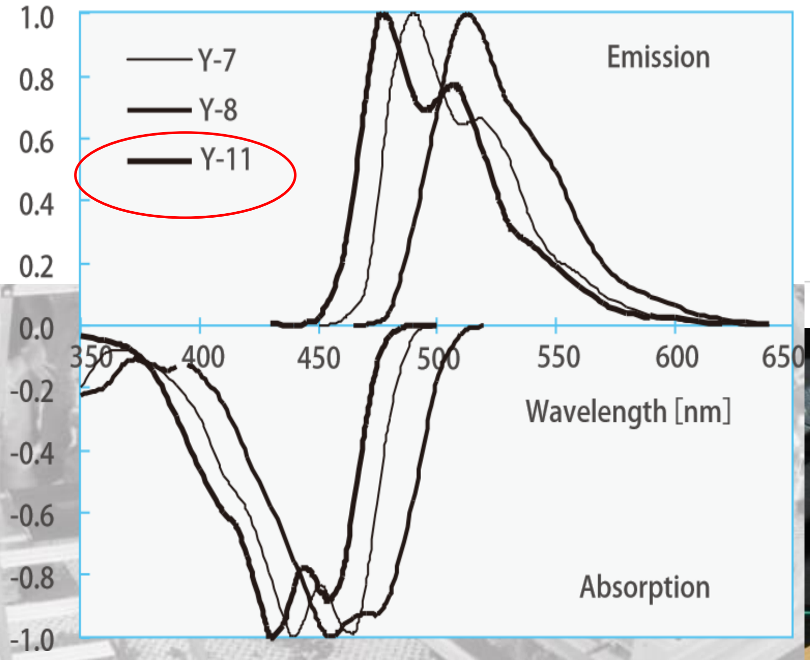
Mono-Fibrometer

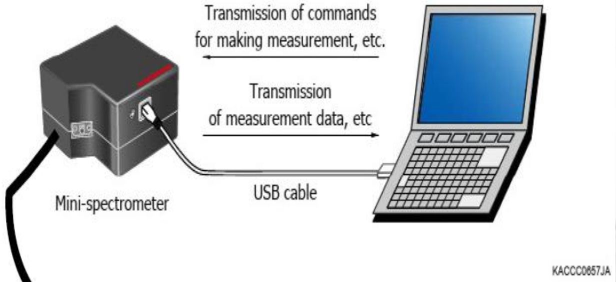
- One fiber is scanned longitudinally by a radioactive source, or simply a LED
- Remote step motor with GPIB interface (General Purpose Interface Bus)
- The fiber is connected to a XP2081B (green extended photocathode) PMT trough a light guide



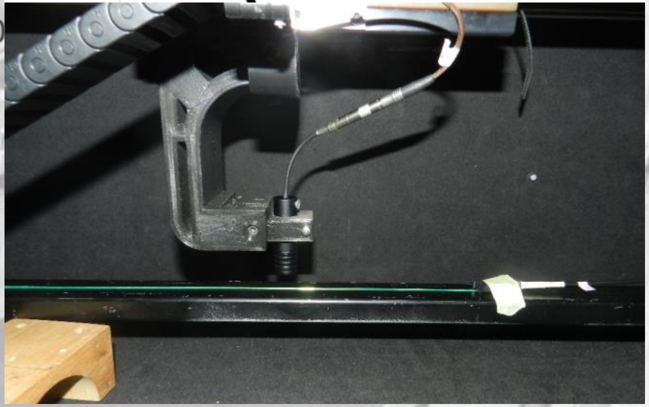
Fiber´s emission spectrum

- Determination the variation on the emission spectrum of the fiber
    - Variation of spectral peaks with distance
    - Tree different LEDS were used
    - Spectral peaks 465, 470 and 400 [nm]
- Fiber´s emission spectrum
    - ~450 nm to ~600 [nm]
- Fiber´s absorption spectrum
    - 350 to 500 [nm]



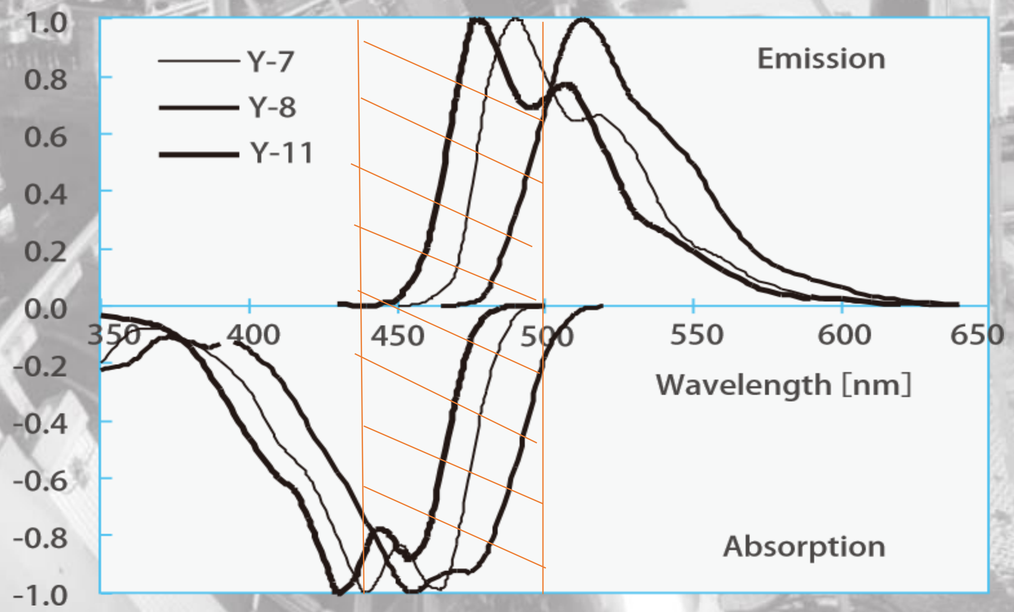


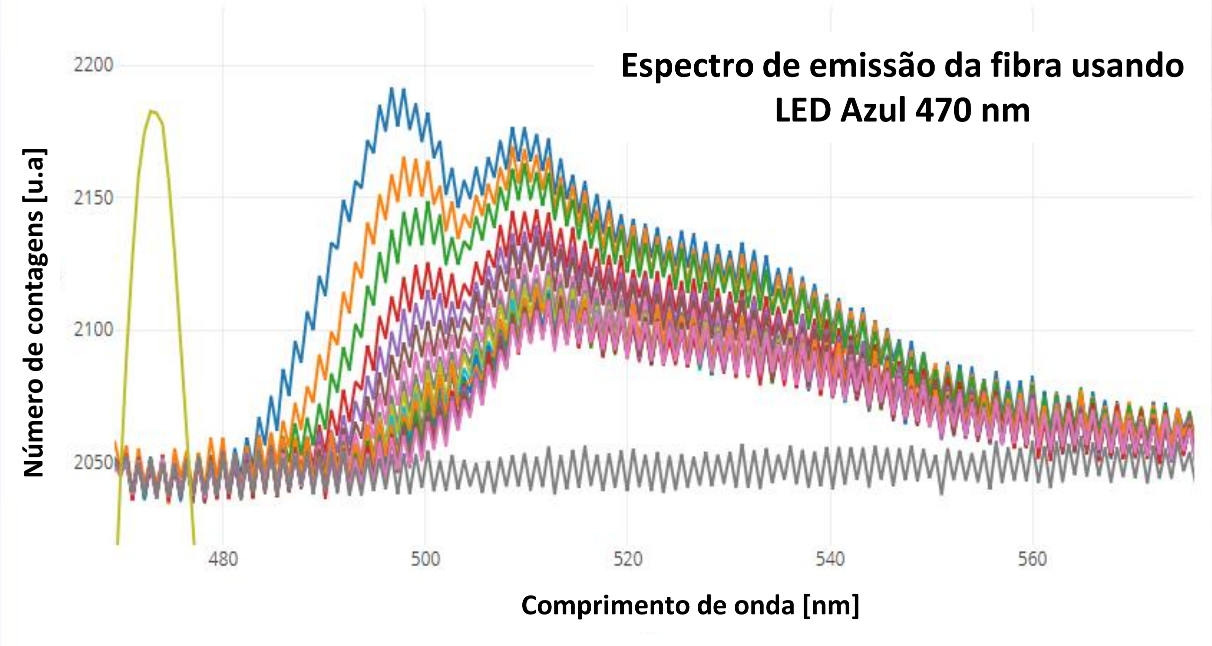
Mini-spectrometer
TM-UV/VIS C10082 MD
Hamamatsu

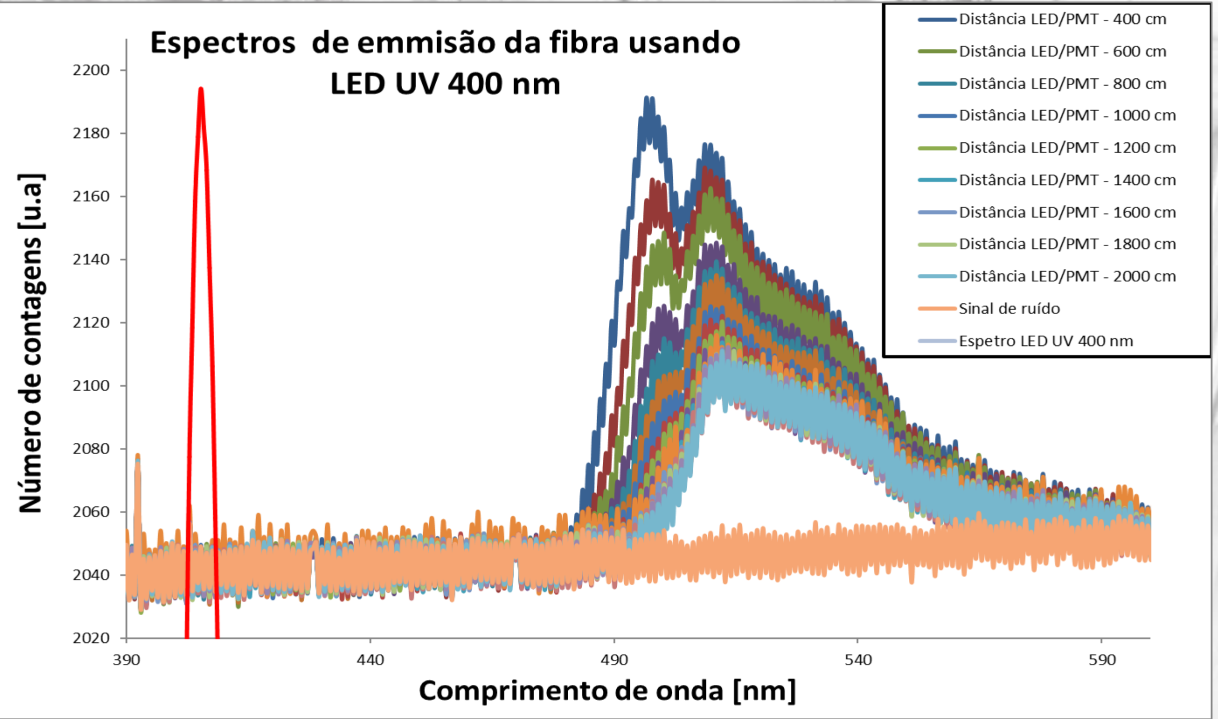


Fiber´s emission spectrum

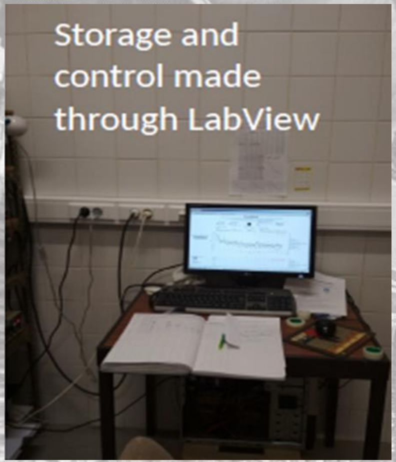
- Spectral Peaks modifications
- Effect of different LEDs
- Area Integral relations to the measurement of the attenuation leght
  - Calculated attenuation length using numerical integration of emission spectrums – 2.5 metres

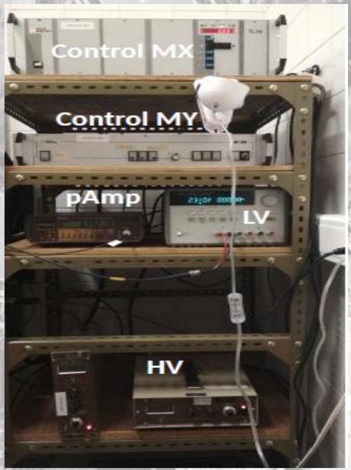


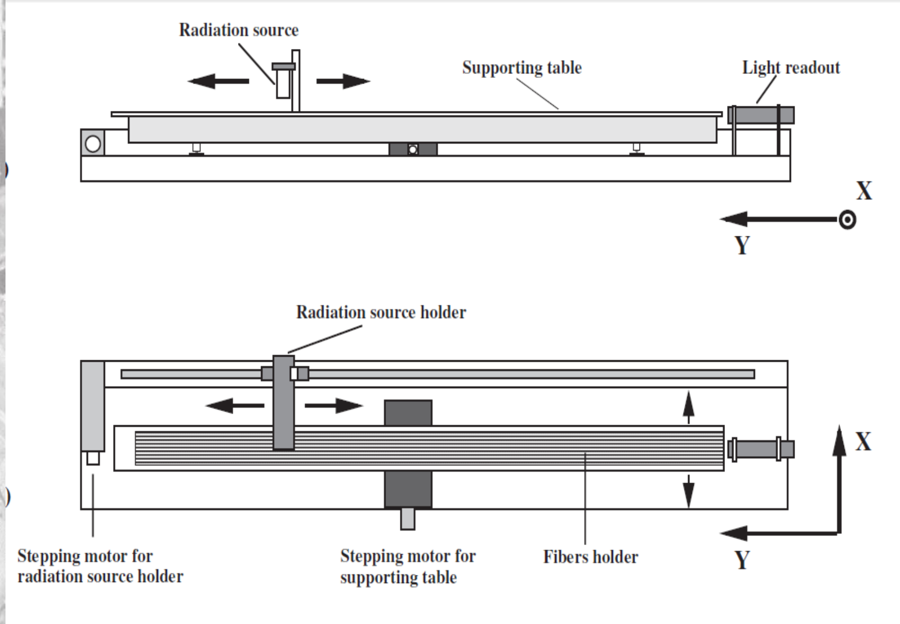




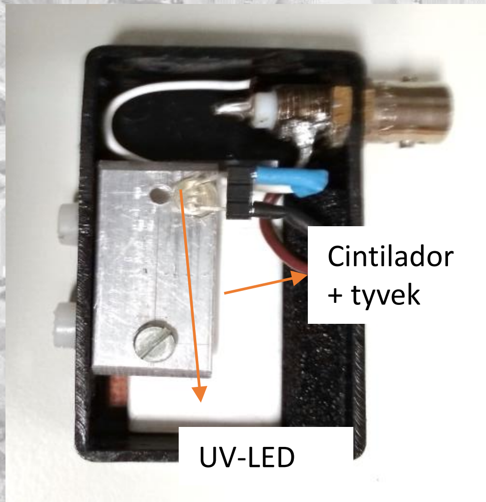
Fibrometer

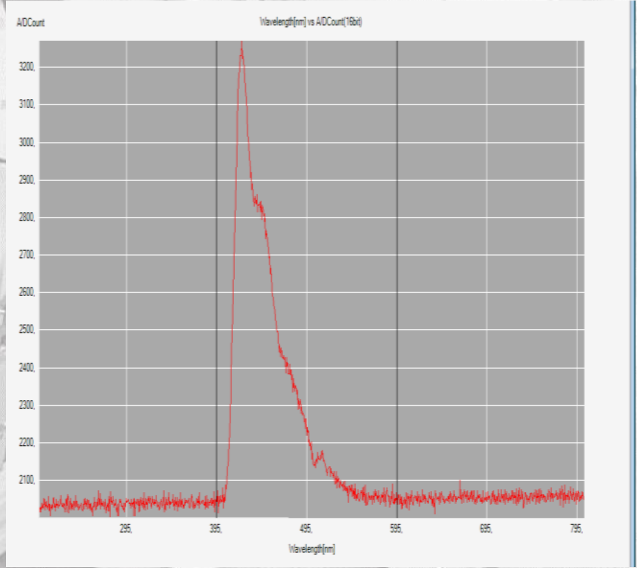






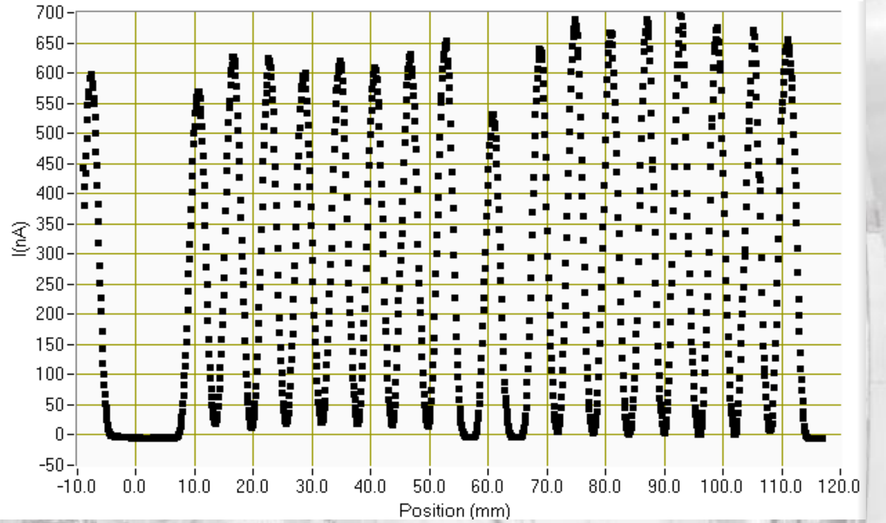
- X-Y MicroControl optical table 10x100 um motor resolution
- 3 meter long table - removable holder
- The test bench controlled by a PC through GPIB interface
- Software - LabView.
- EMI 9813KB photomultiplier
- UV-LED + scintillator
- PicoAmp Keithley 485
- 2 Reference fibers: Fixed and holder

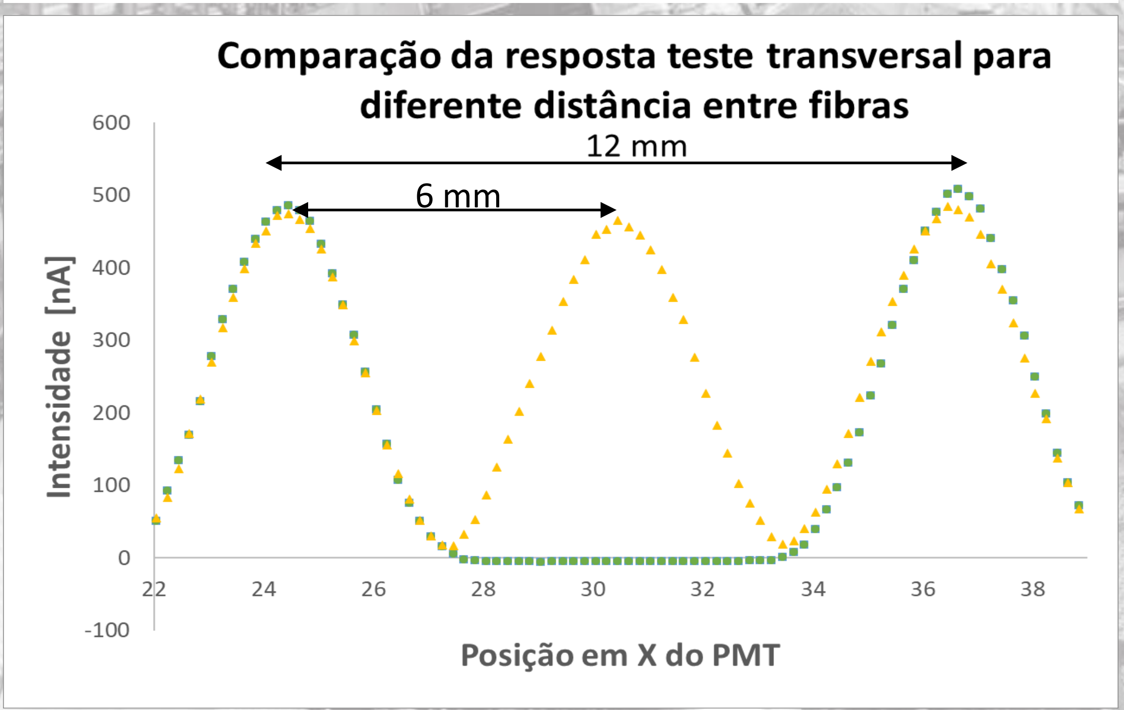




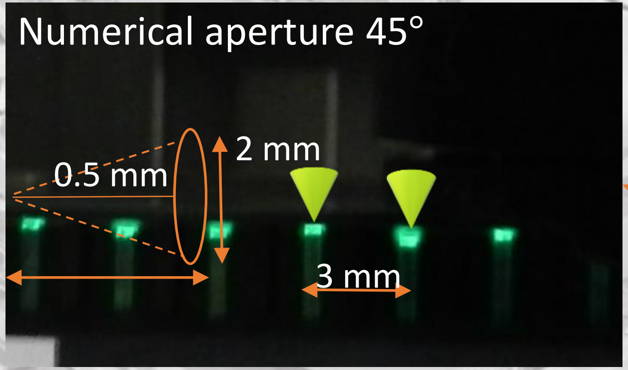
Transversal Scan

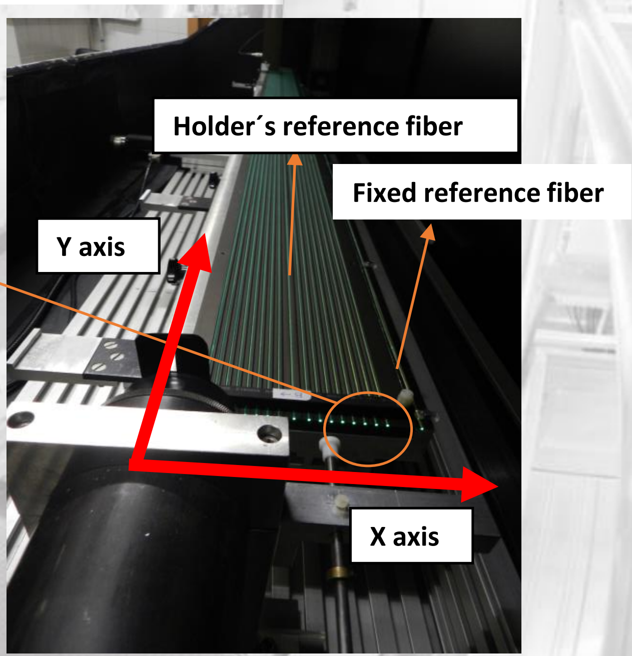
- Measurement of the same set of fibers placed separated by different distances
- The contribution from from the neighbor fibers
  - cross talk.
- PMT ´s collimator
  - 2 mm wide a 1 cm in height
  - 0,5 mm away from the fibers





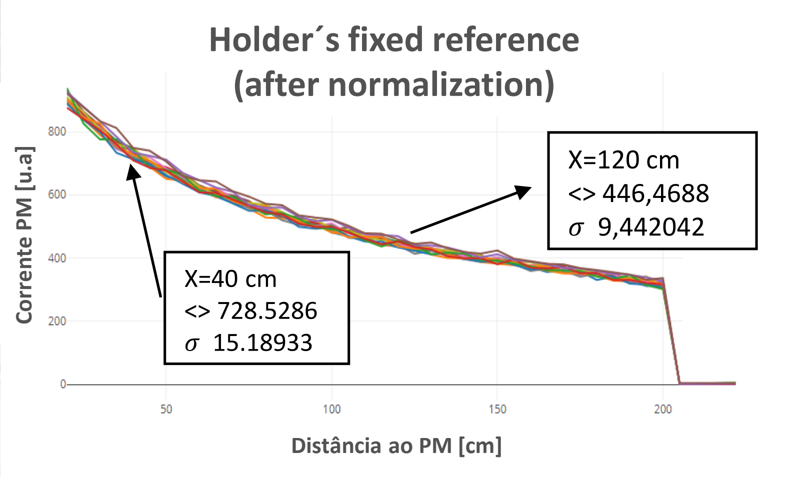
Realizado com uma calha de dimensões diferentes da representada ao lado

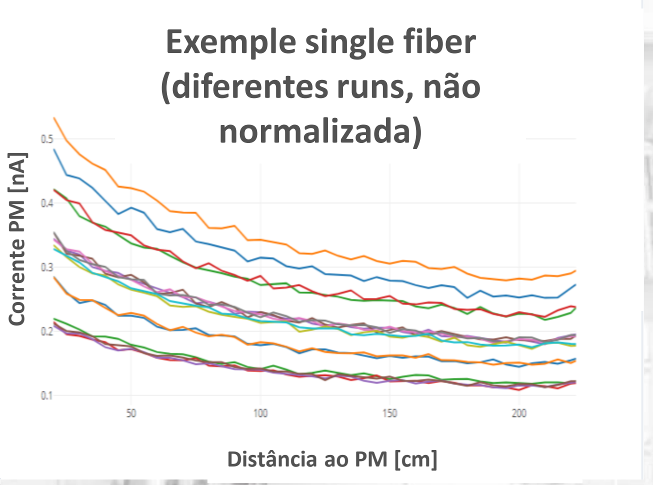


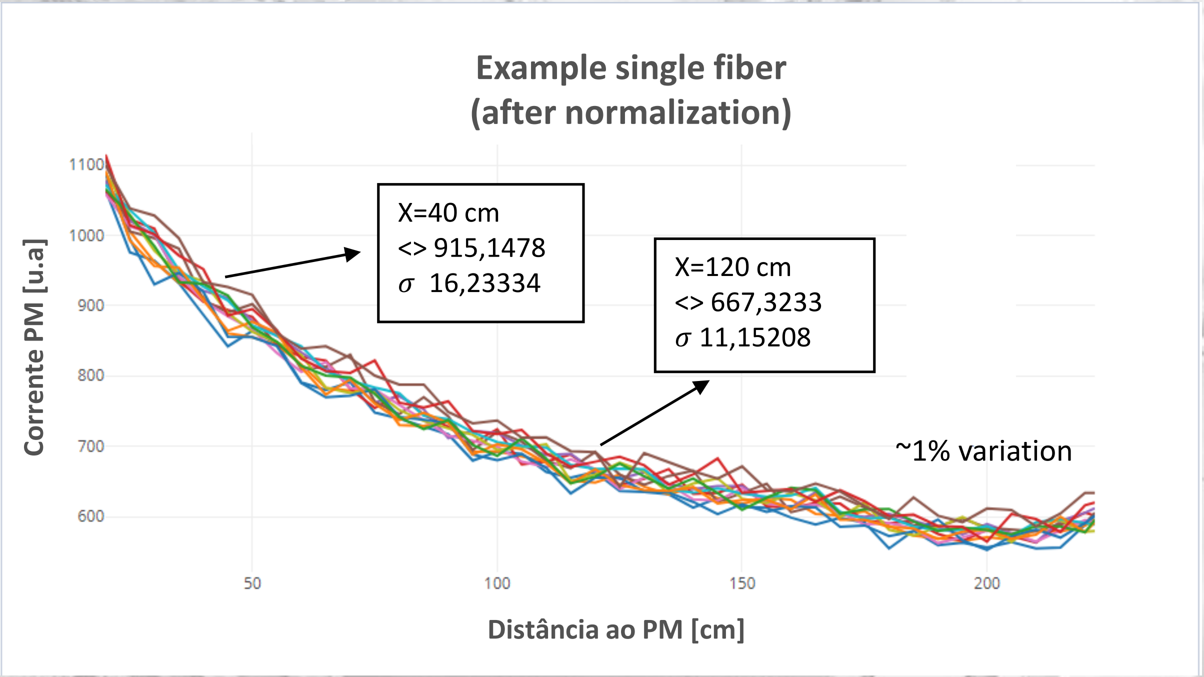


Longitudinal Test –Reference´s roles

- Normalization
  (X*1000)/I_{30} (Fixed reference)
- Fiber Holder Reference fiber (nº9)
  - Attenuation length 184,9002 $\pm$0.88 % [m]
- 20 runs
  - Different LEDs were being applied
  - Different LED applied tension
- Set of 16 fibers + 1 fiber as holder reference
  - 223 cm test fibers
  - 200 cm reference fibers
- 16 Tested fibers with an aluminized top
  - For the same distance <=6% RMS
  - Attenuation length <=10% RMS

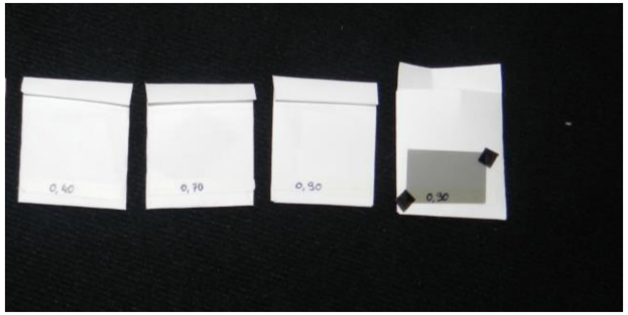




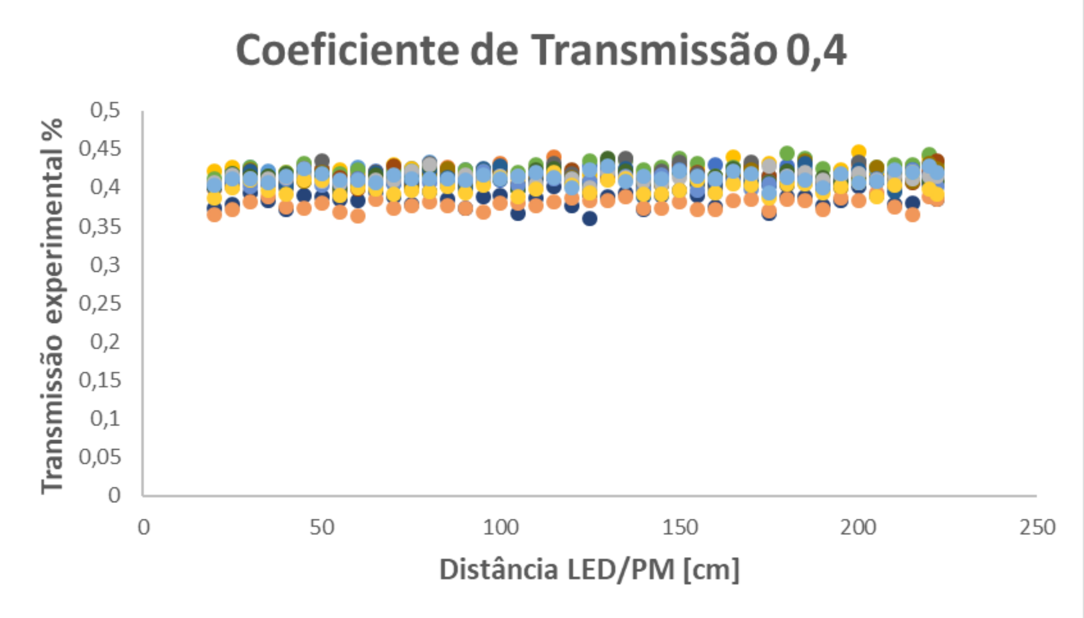


Test to determine PMT´s Linearity

- ND filter Kodak Wratten 2 Neutral Density Filters- 0.4±10% ,0.5±10% ,0.63±10% ,0.8±10%
- The same set of 16 test fibers was used in these measurements
- Measurements with filter are normalized to measurements with no filter
- Longitudinal scans (along the length of the fibers) to increase the achieved linearity range characterization

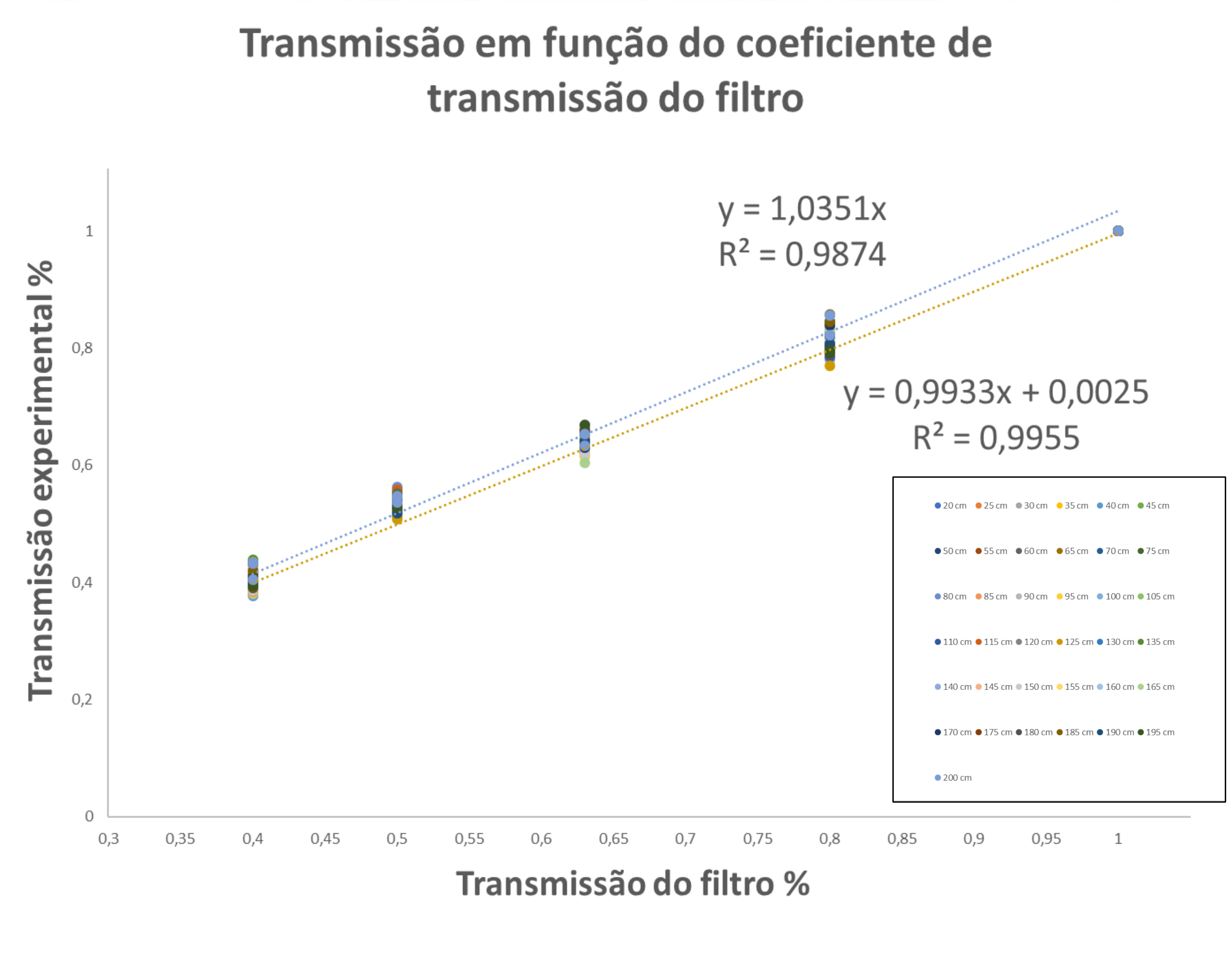


The numbers that are written do not correspond to a transmission coefficient but rather to a manufacture's code



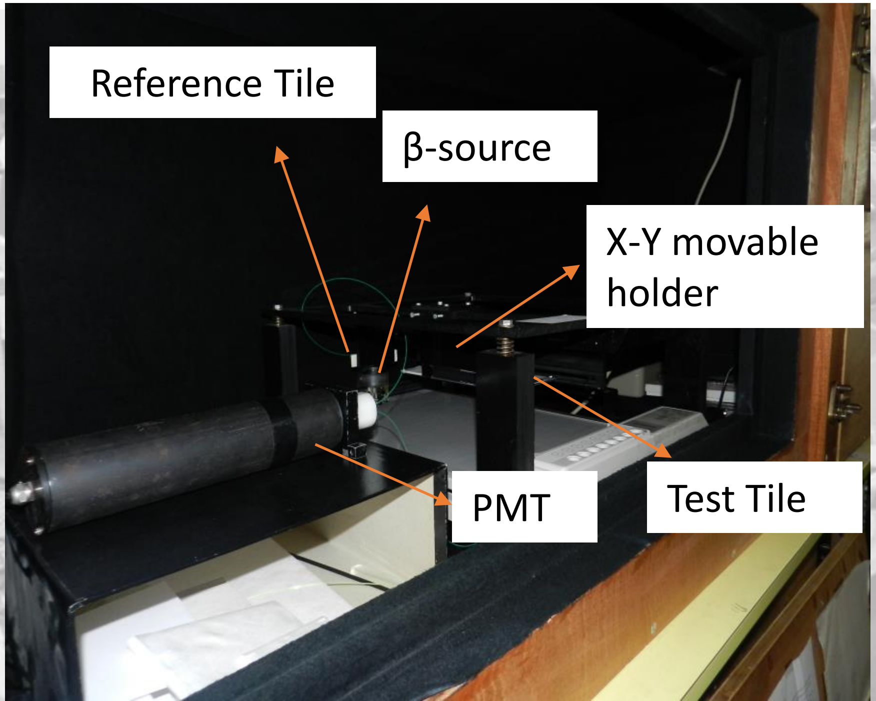
c.transmissão do filtro	0.4±10%	0.5±10%	0.63±10%	0.8±10%
<> Average	0.4101	0.5257	0.6322	0.8067
δ RMS	0.0085	0.0106	0.0114	0.01466

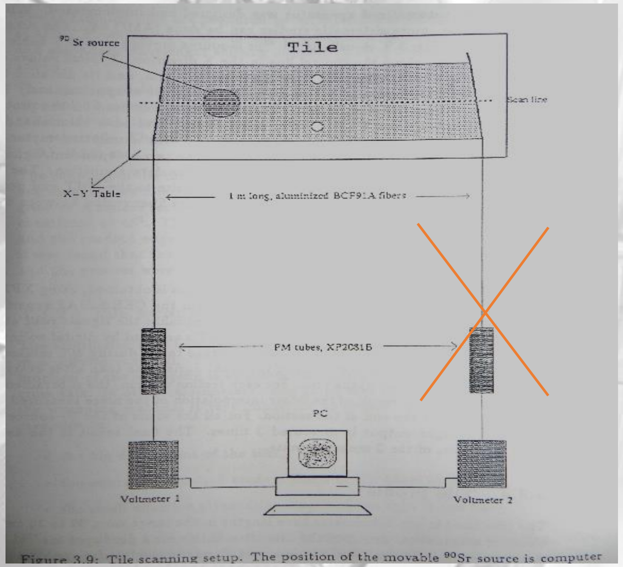
- 5 runs
  - No filter + ND Filters
- Points representing 36 distances (due to overlapping not all are visible)
  - 20→200 (cm) steps 5 cm
  - Average for that run and that particular distance
- Linear fitting represented to extremal cases (biggest and smallest linear slope)



Tile scanning Setup

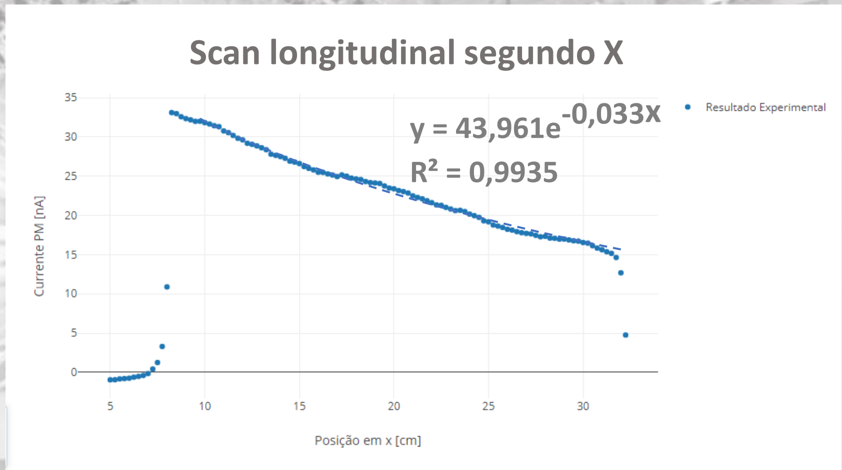
- ^{90}Sr collimated β-source
- Small scintillator used as reference
- Tested a typical TileCal scintillator
- WLS Optical fibers read out each scintillator
  - Top aluminized at the side opposite the PMT and polished in the other side
- PMT XP2081B + Digital Multimeter Schlumberger 7150 plus (Integrates PMT signal in a 400 ms)

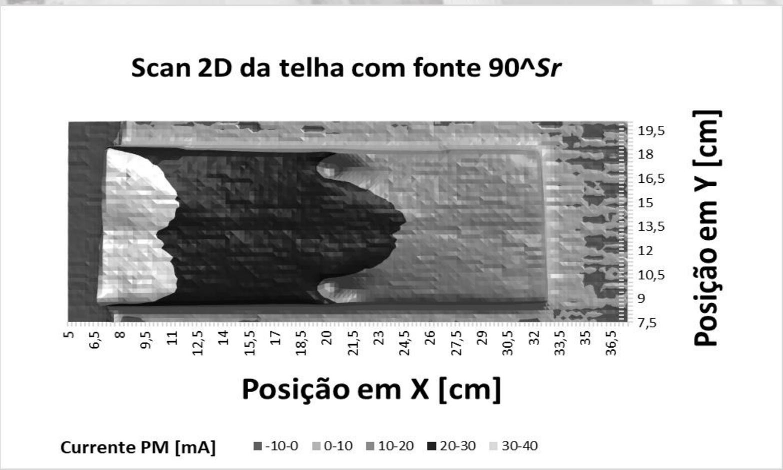


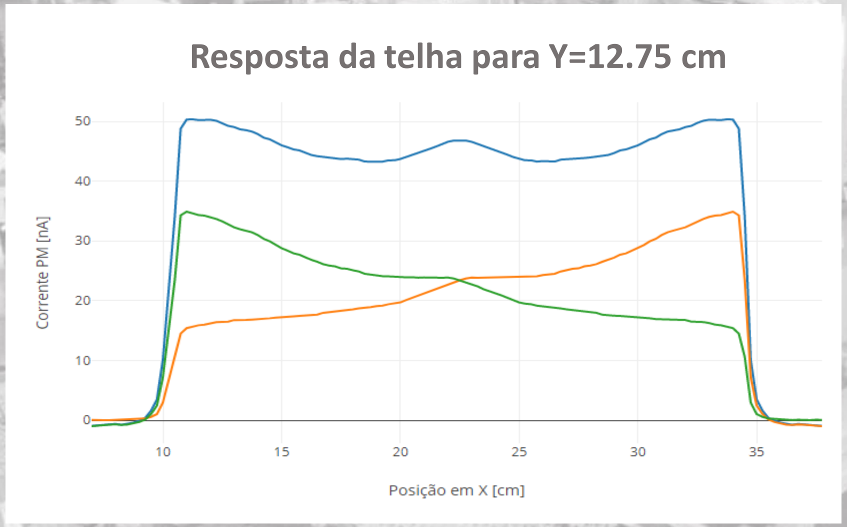


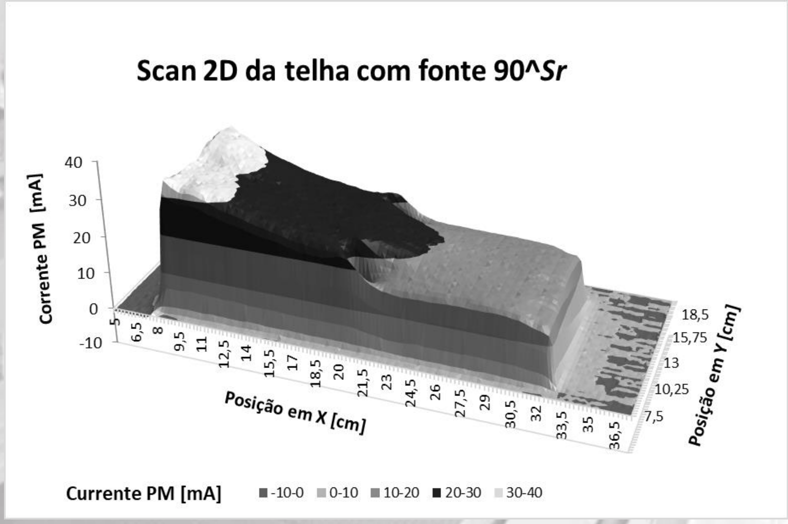
Tile´s Behaviour and Light Distribution

- LED steps
  - 2 mm (X-Y plane)
- Tile Scan along the XY plane
  - Attenuation length: 30 cm (obtained from single exponential fit)
  - Uniformity using two fibers









Summary

- There is a gain in the light output signal of the fibers with an aluminized edge
  - That gain is not constant or linear, do to the exponential behaviour of the light absorption throughout the fiber
- LEDs with spectral peaks within the absorption range of the fiber only influence the light output efficiency
- The peak in the emission spectrum of the fiber, corresponding to the fluorescence process tend to disappear with increasing distance from the PMT
- The effect of the cross talk in the current fibrometer configuration is residual
- The effect of different LEDs and small variations on the applied tension have little effect on the fibers´s longitudinal parametrized scans
- The PMT as a linear behaviour to the different light input intensities
- By adding a symmetric curve to the one obtained in a longitudinal tile scan we can observe a uniform output.

References

[1] J. G. Saraiva *et al.,* The Aluminization of 600 k WLS fibers for the TileCal/ATLAS/LHC, IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 51, NO. 3, JUNE 2004

[2] Tile Calorimeter Technical Design Report, CERN/LHCC/96-42

[3] A. Henriques, The ATLAS Tile Calorimeter,ATL-TILECAL-PROC-2015-002

[4] M.David, Efeitos de pequenas taxas de dose produzidas por radiações ionizantes em fibras ópticas cintilantes e WLS, Tese de Mestrado, Lisboa 1996

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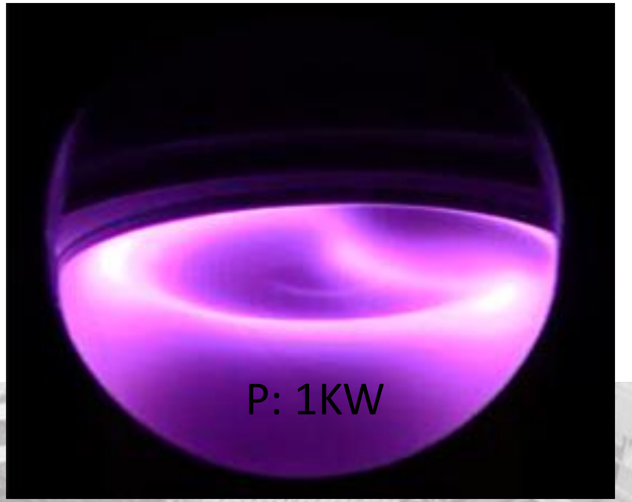
[6] A.Gomes, Resistência à radiação e uniformidade do calorímetro TILECAL, Tese de Mestrado, Lisboa 1995

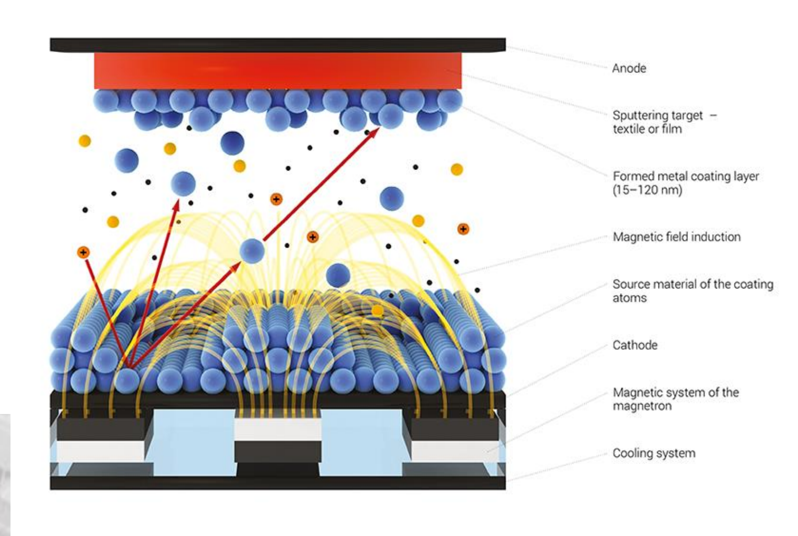
Extra Slides

Magnetron Sputtering

- Argon + 99,9999 % Aluminum disc
- Cathodic polarization
- Four stages of a luminescent discharge

Townsend, Normal Stage, Abnormal Stage, Arch Stage





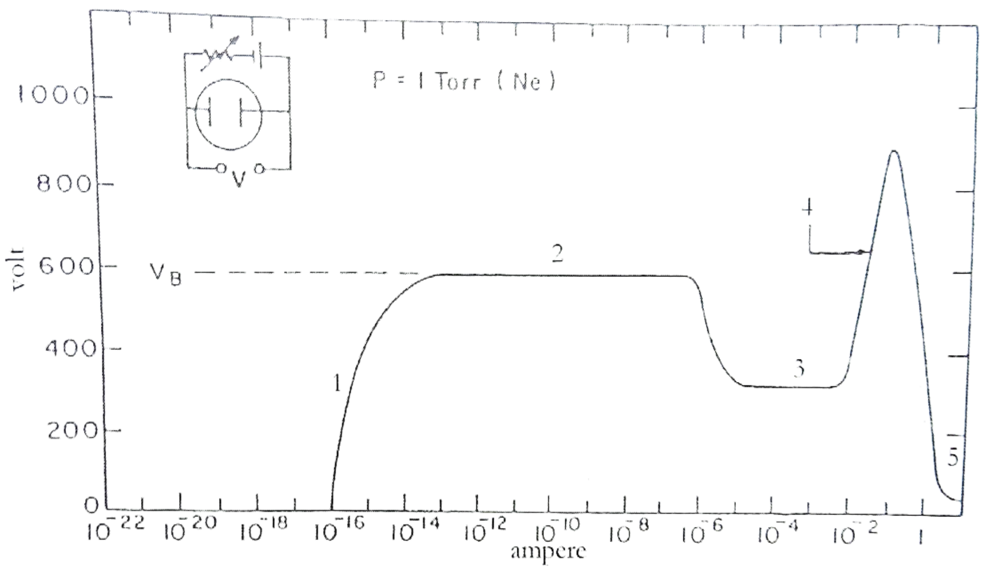
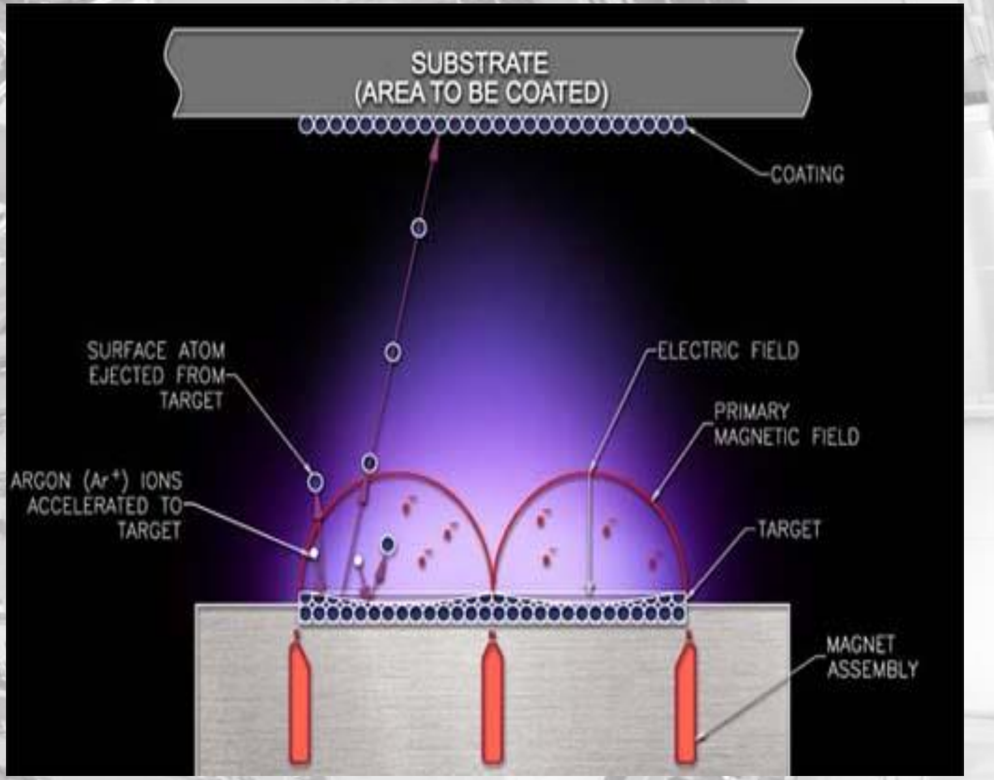


Fig.2.1. Formação de uma descarga luminescente

1- Ionização do gás 2-Townsend 3- Normal 4- Anómala 5- Regime de arco



Process with control over the power

1. Presence of free electrons on the gas
2. Formation of secondary electrons
3. Gain in the area of discharge
4. Cathode is all immersed by discharges
5. Thermionic emission