A light collection upgrade proposal for the FDD

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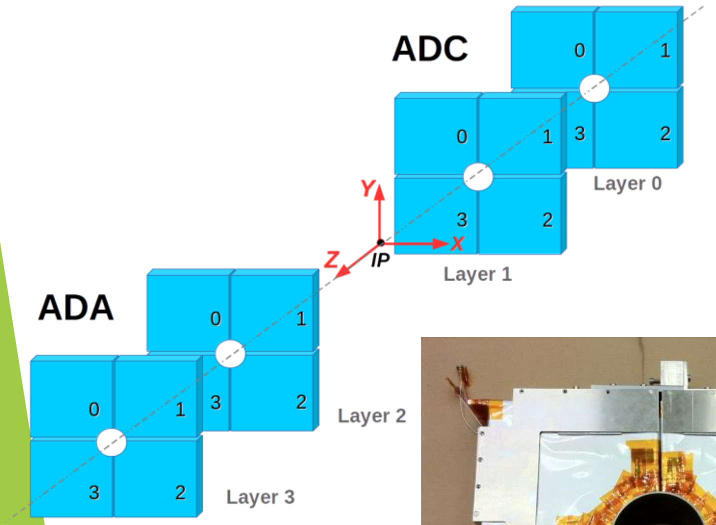
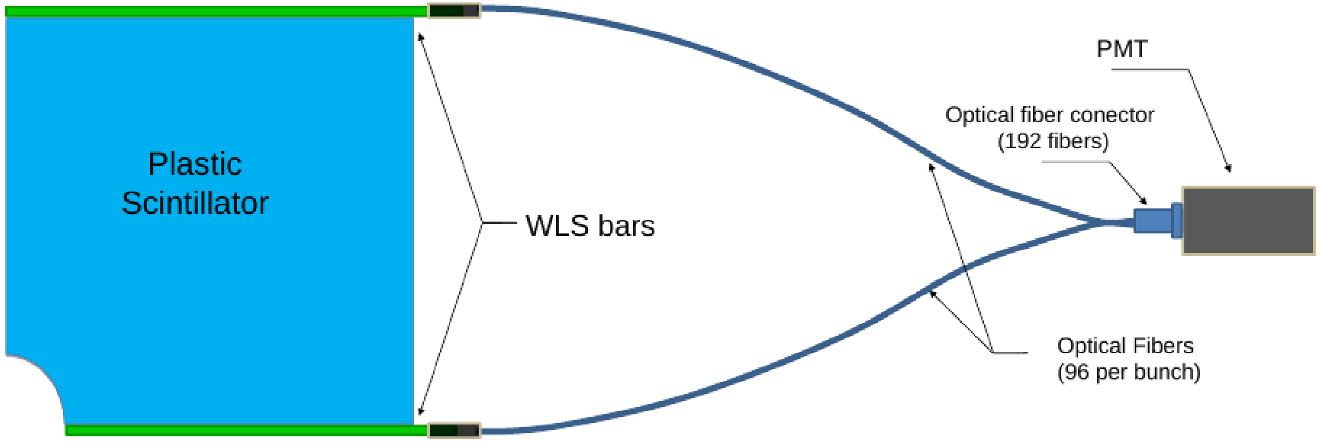
XXXIII Annual Meeting of the Division of Particles and Fields of the Mexican Society of Physics

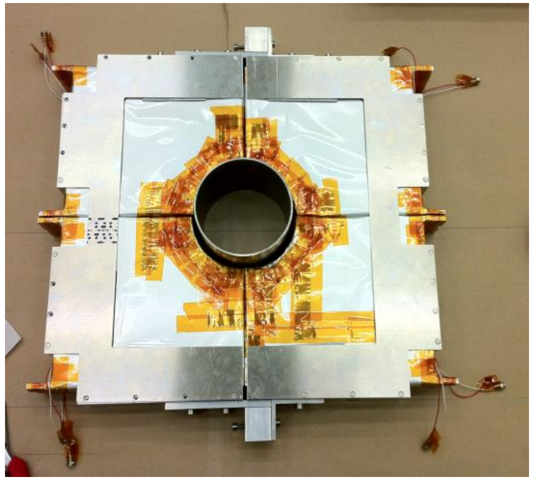
AD DETECTOR

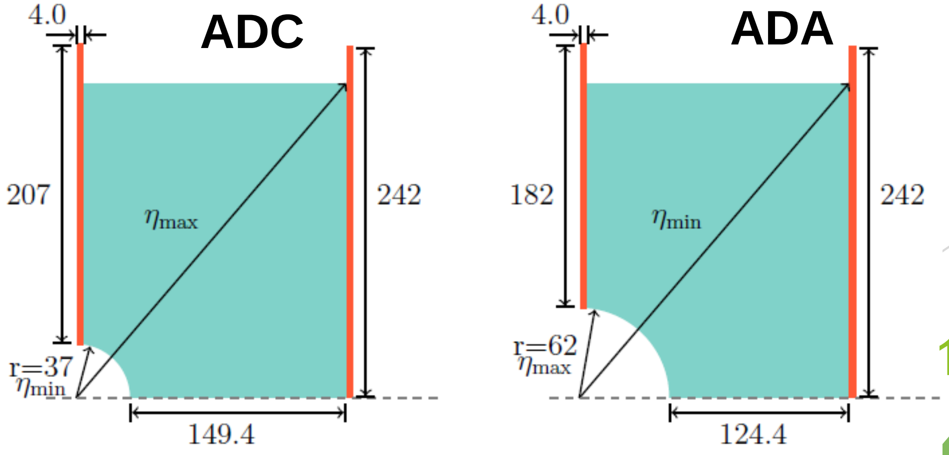
Consist of:

- Two stations, ADA and ADC, positioned 17 m and 19.5 m away from the interaction point, respectively.
- Two layers per station.
- Four pads per layer.
- One assambly per pad.







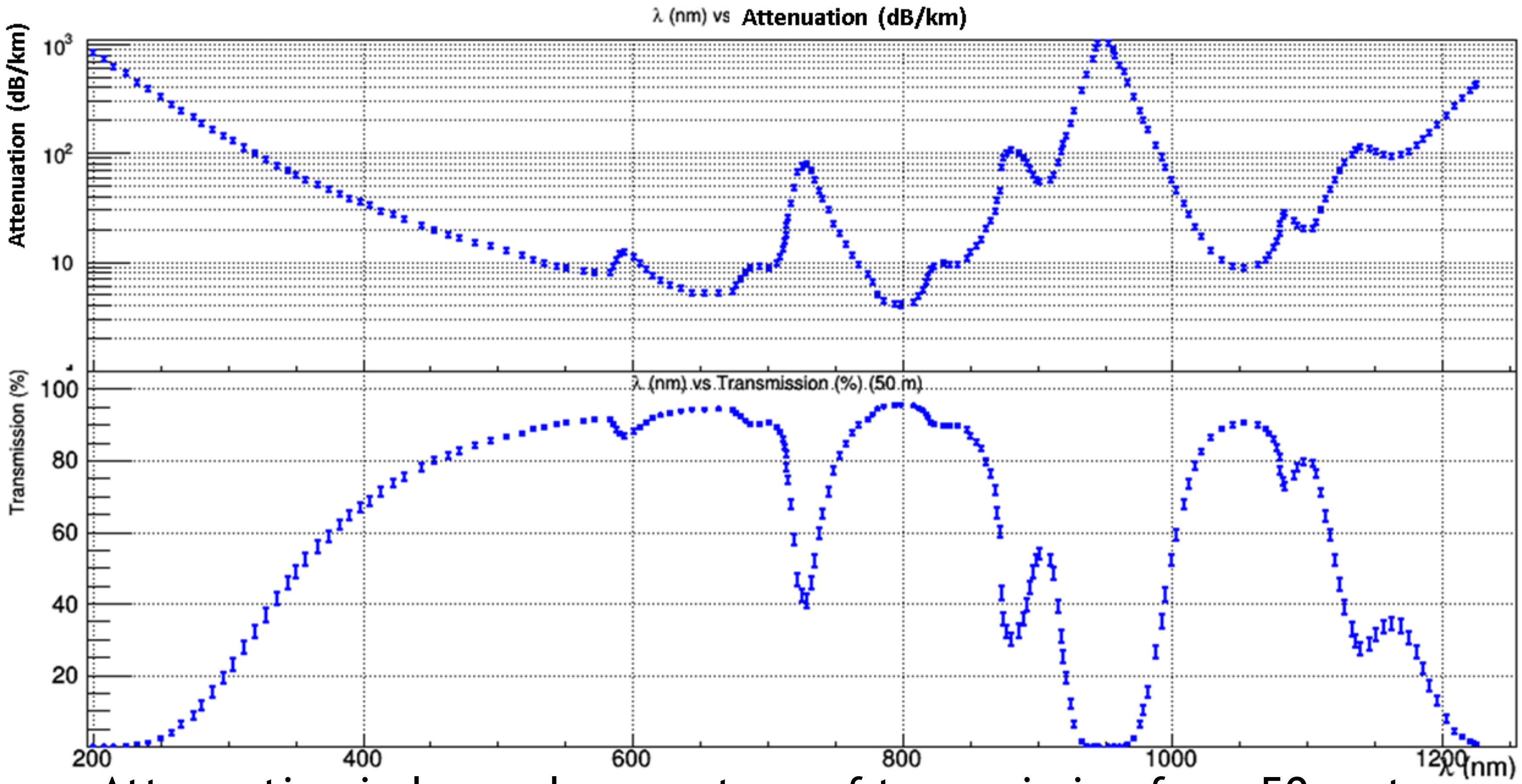


INTRODUCTION AND PROBLEMATIC

In the new stage of the LHC (run 3) there will be an important high luminosity update in the ALICE experiment. This implies that the new systems should be updated to meet these new requirements:

1. Improved radiation hardness.
2. Better time response, which implies a better time resolution.
3. A better efficiency on its performance.

OPTICAL FIBERS



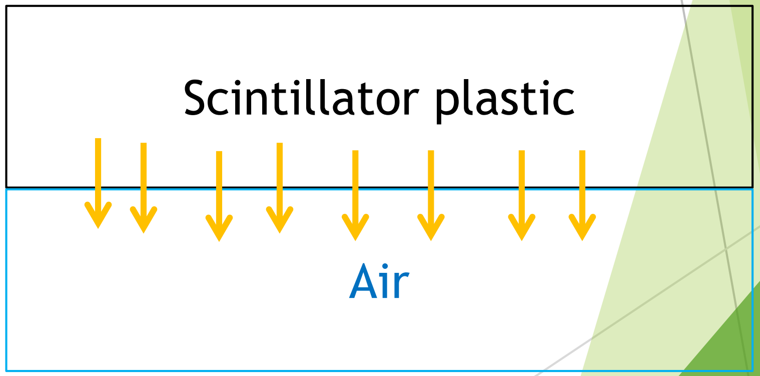
Attenuation index and percentage of transmission for a 50 meters long CERAMOPTEC Optran UV NSS optical fiber. The detectors will be placed further away from the interaction point.

Using data recovered from:
https://www.ceramoptec.com/products/fibers/optran-uv-nss.html

DESING OF A CPC-TYPE OPTICAL CONCENTRATOR

- Using Snell's law, the critical angle for the photons to move from the scintillator plastic into the air was computed.
- CPC (Compound Parabolical Concentrators) are light collecting devices that focus light into an absorber area.

# de material	Material	n
1	BC-420 (Scintillator plastic)	1.58
2	Air	1.0



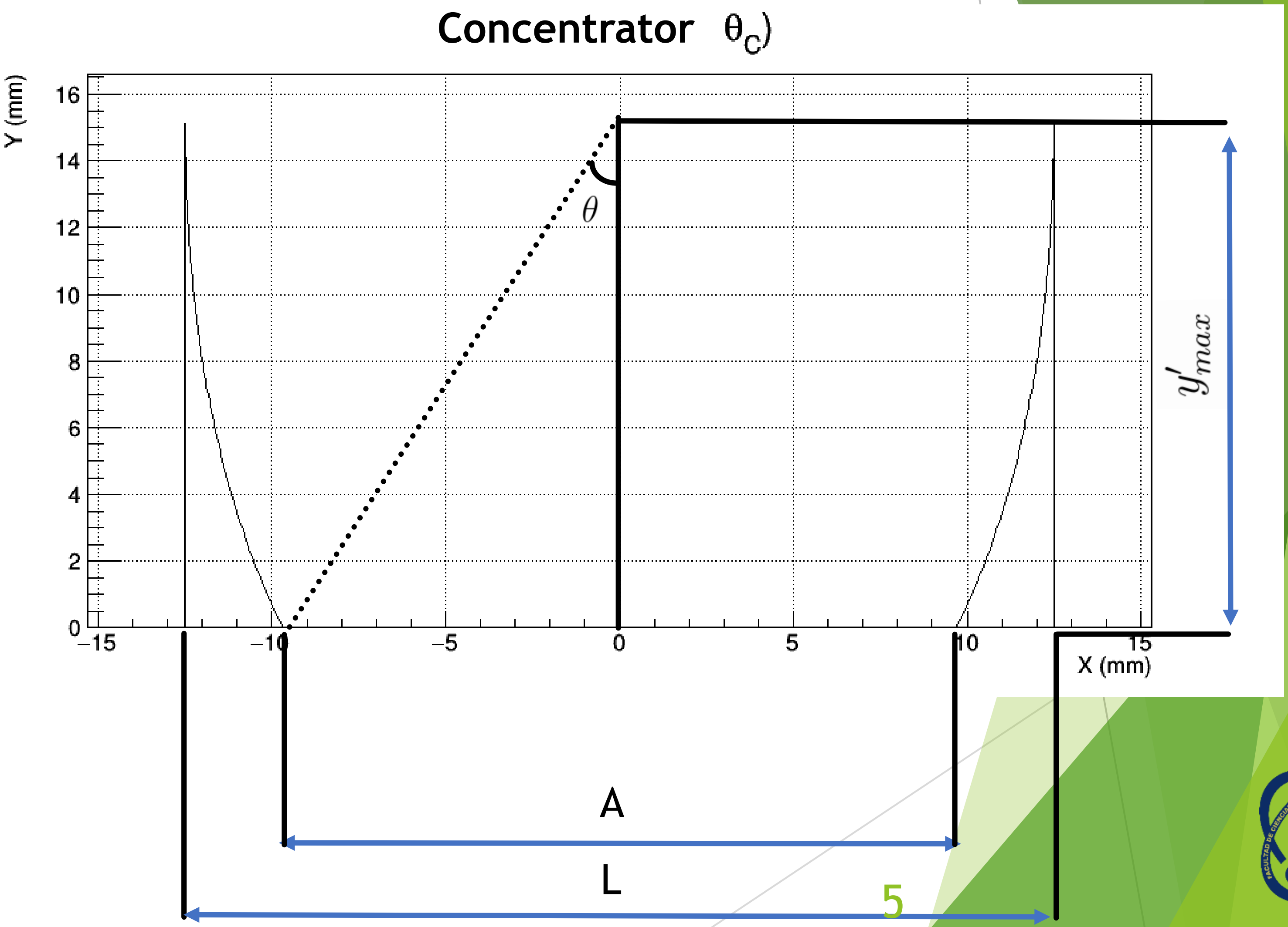
$$\theta_C = sin^{-1}(n_2/n_1) = 39.26^\circ = 0.6853rad$$

CPC-TYPE CONCENTRATOR FOR A PLANAR ABSORBER

Parameter	Value
A (mm)	19.37
L (mm)	25
Ymax (mm)	15.29
Θ (°)	39.26

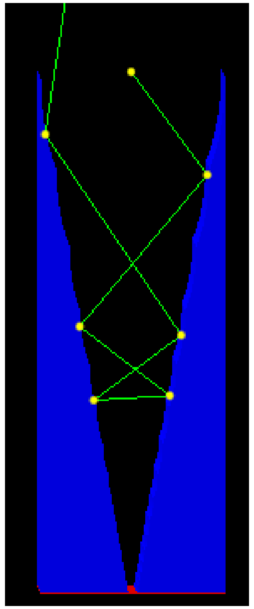
Scintillator plastic

Concentrator



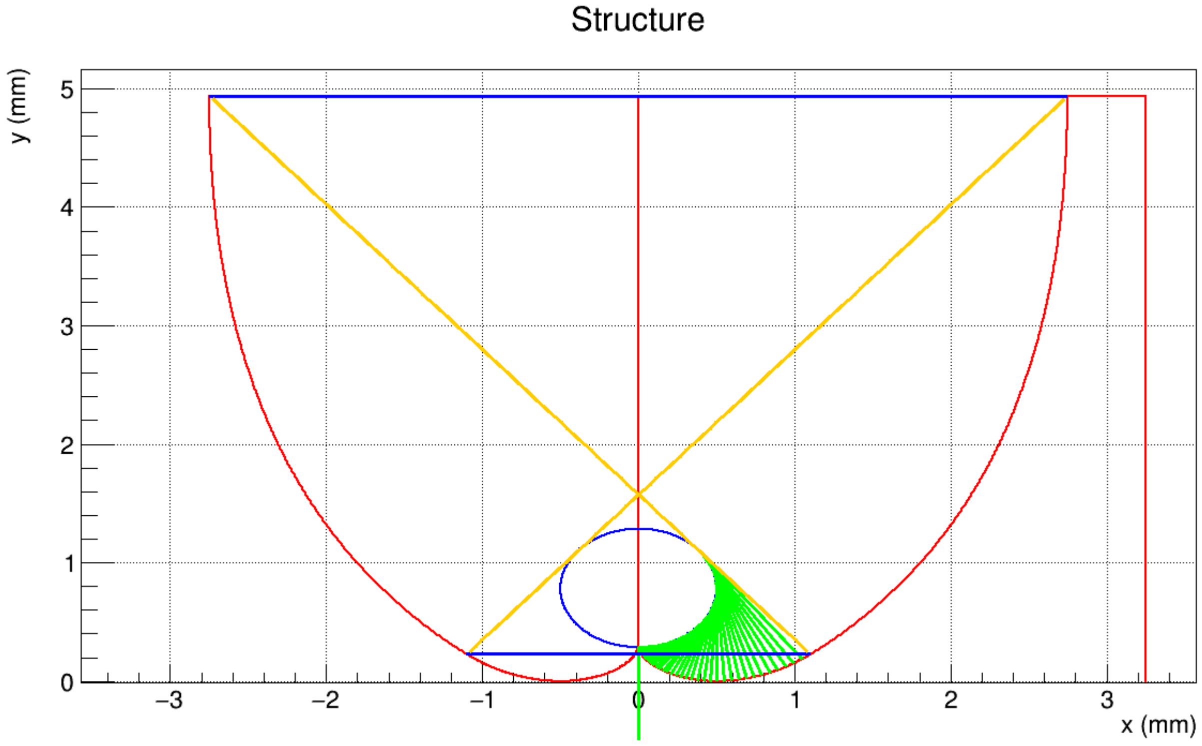
THE PROBLEM OF USING A MULTI-STAGE CPC FOR A PLAIN ABSORBER SURFACE

- Liouville's theorem <u>imposes</u> some constraints on the transportation of light from a given input to a given output, forbiding the efficency of this process from being 100%.
- This can be seen in the multi-stage CPC for a planar absorber surface.



CPC-TYPE DESIGN FOR TUBULAR ABSORBER

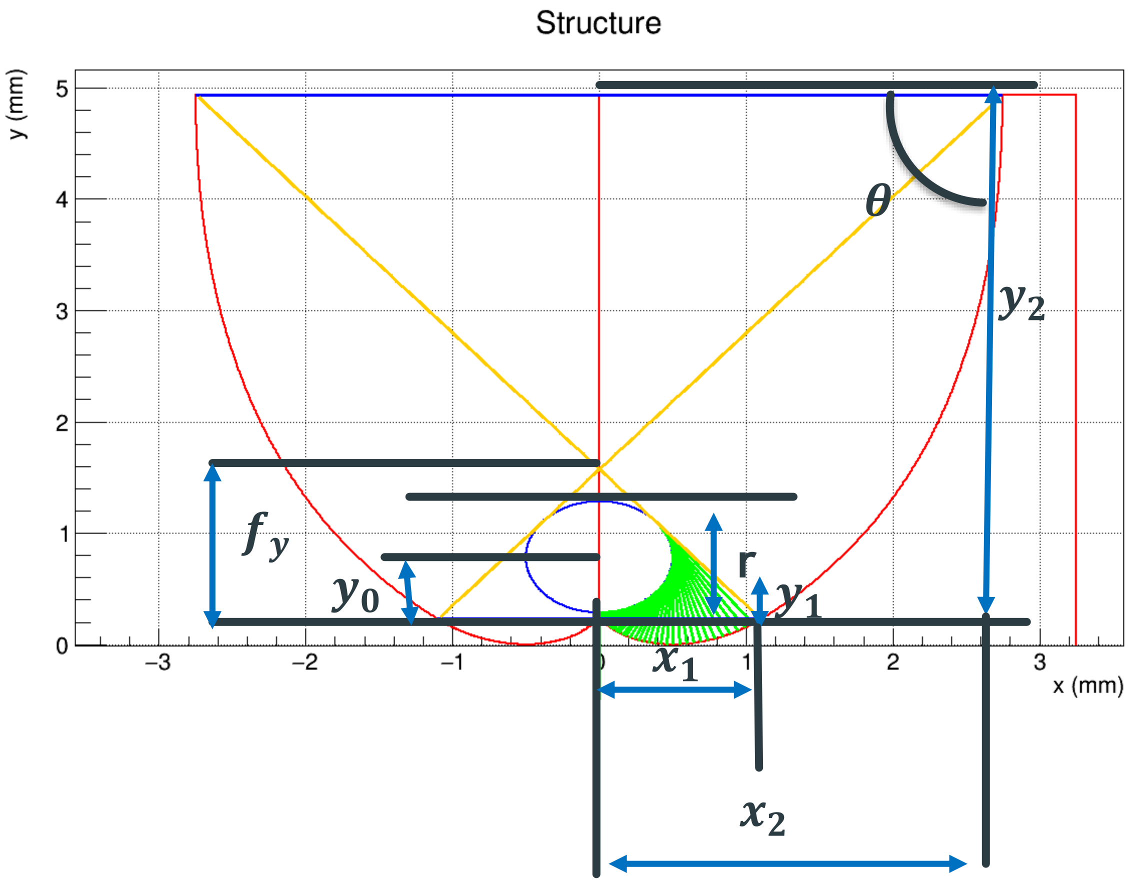
After having concluded that it is not feasible to use a multi – stage CPC for a planar surface absorber, we proceeded to design and simulate a CPC concentrator for a tubular absorber in search to improve light collection, concentrating light from a given input area into a 1 mm radius circular cross-sectional area.



Scintillator plastic

Concentrator array

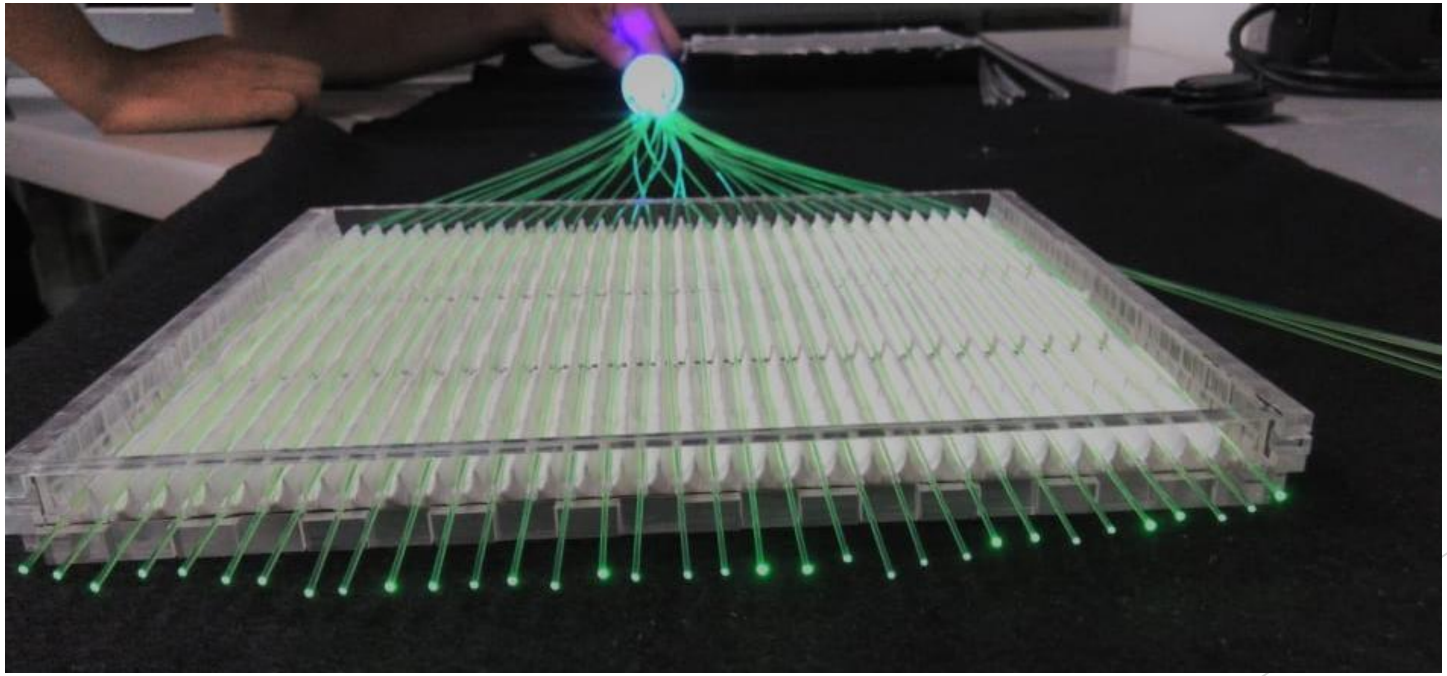
CPC DESIGN FOR A TUBULAR ABSORBER



Parameter	Value
x_1 (mm)	1.101
y_1 (mm)	0.23
x_2 (mm)	2.75
y_2 (mm)	4.94
r (mm)	0.5
Θ ($^\circ$)	39.26

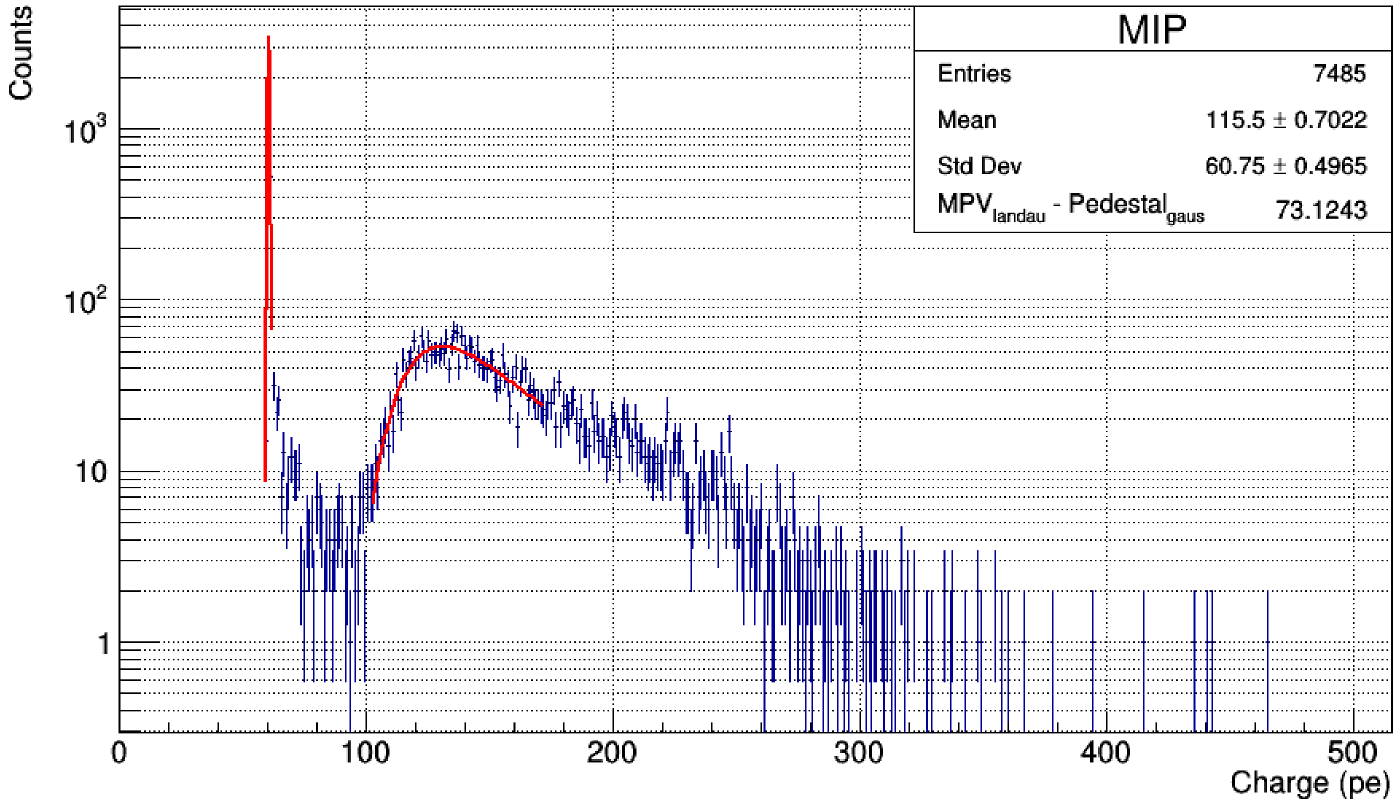
MANUFACTURING AND TESTING

- A prototype with a CPC design for tubular absorbers was manufacured and tested to characterized the proposed system using PMTs.
- This prototype was designed considering an acceptance angle equal to the critical angle obtained.
- A prototype was designed and manufactured to test the proposed system using different PMT models.



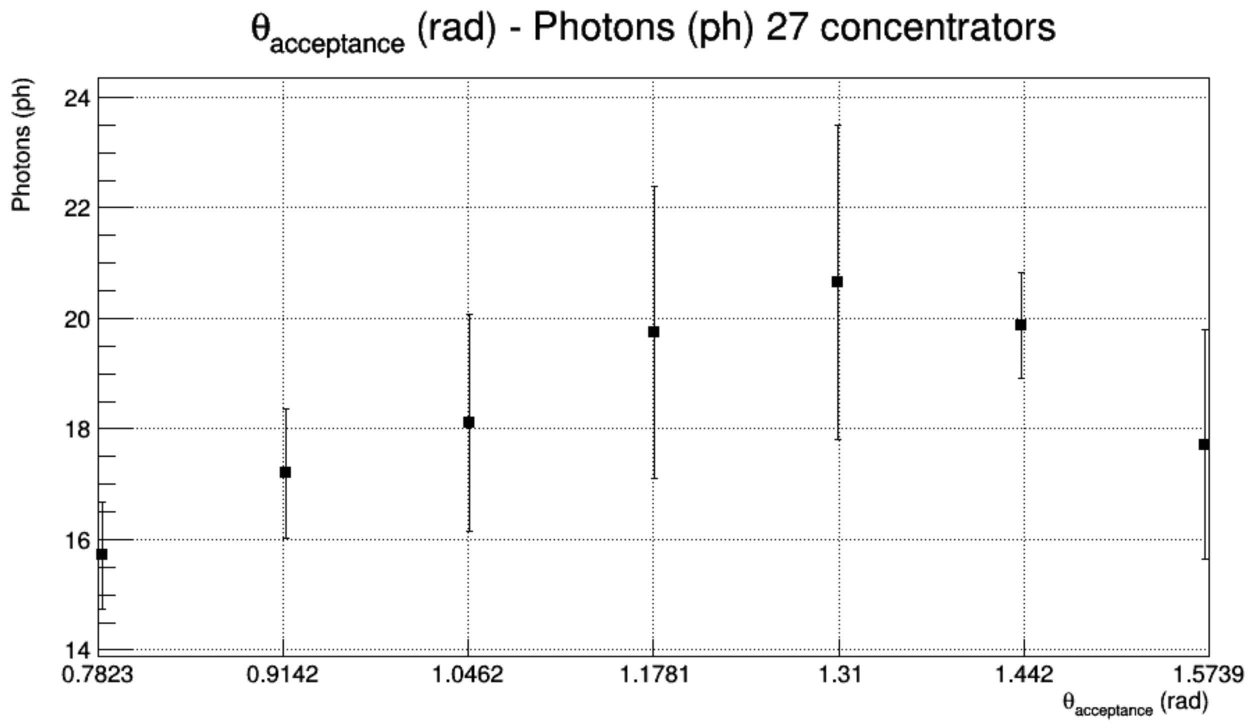
SYSTEM CHARACTERIZATION

- Single photon detection test have been made using different PMT models in order to calibrate them for the system characterization.
- Using the proposed system, 73 photoelectrons per MIP are being obtained, which is a similar quantity than the obtained than for the current system.



GEANT4 SIMULATION

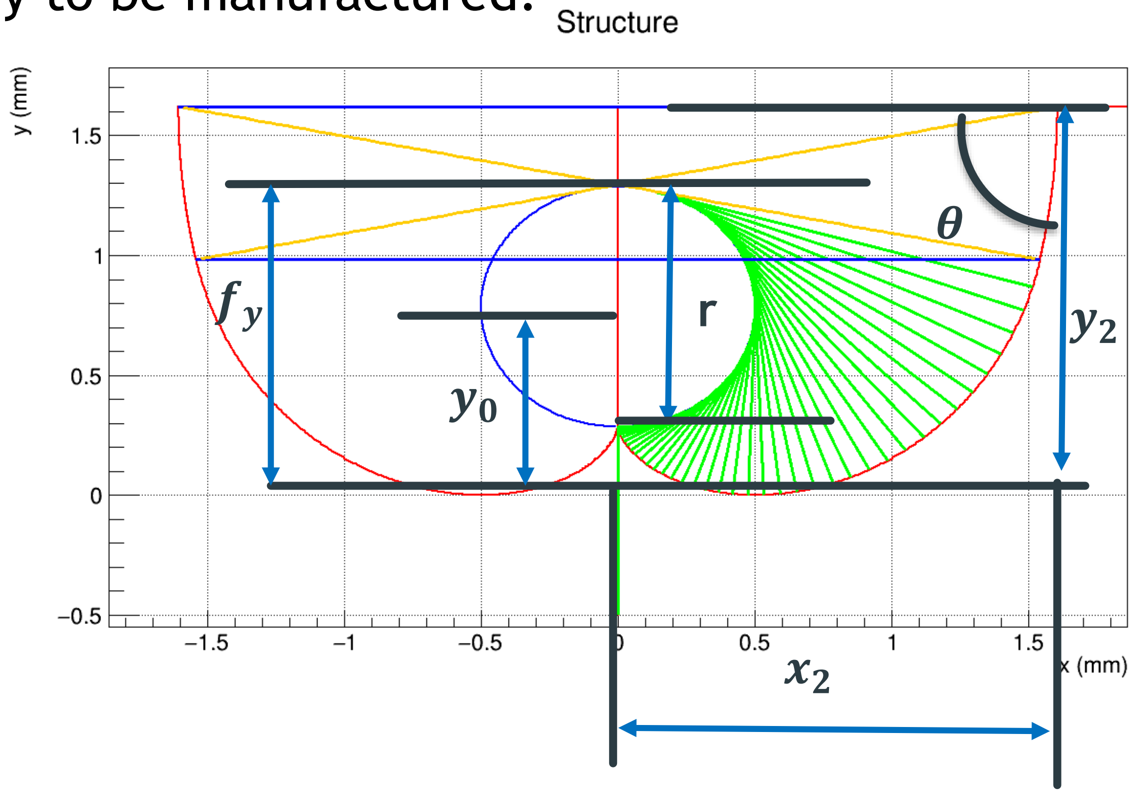
- Several GEANT4 simulations were carried on in order to define the optimal acceptance angle for this design.
- In the simulation, the current characteristics of the AD detector, such as its dimensions, are taken into account.
- The simulation features the scintillator plastic (BC-420), wavelength shifting bars, and clear fibers.



NEXT STAGE: CPC DESIGN FOR A TUBULAR ABSORBER

As it was found that the optimal acceptance angle is aproximately 2 times the critical angle (nearly 1.37 rad), we proceeded to design a prototype using this approach, which is now ready to be manufactured.

Parameter	Value
x_2 (mm)	2.75
y_2 (mm)	4.94
r (mm)	0.5
Θ ($^\circ$)	78.53



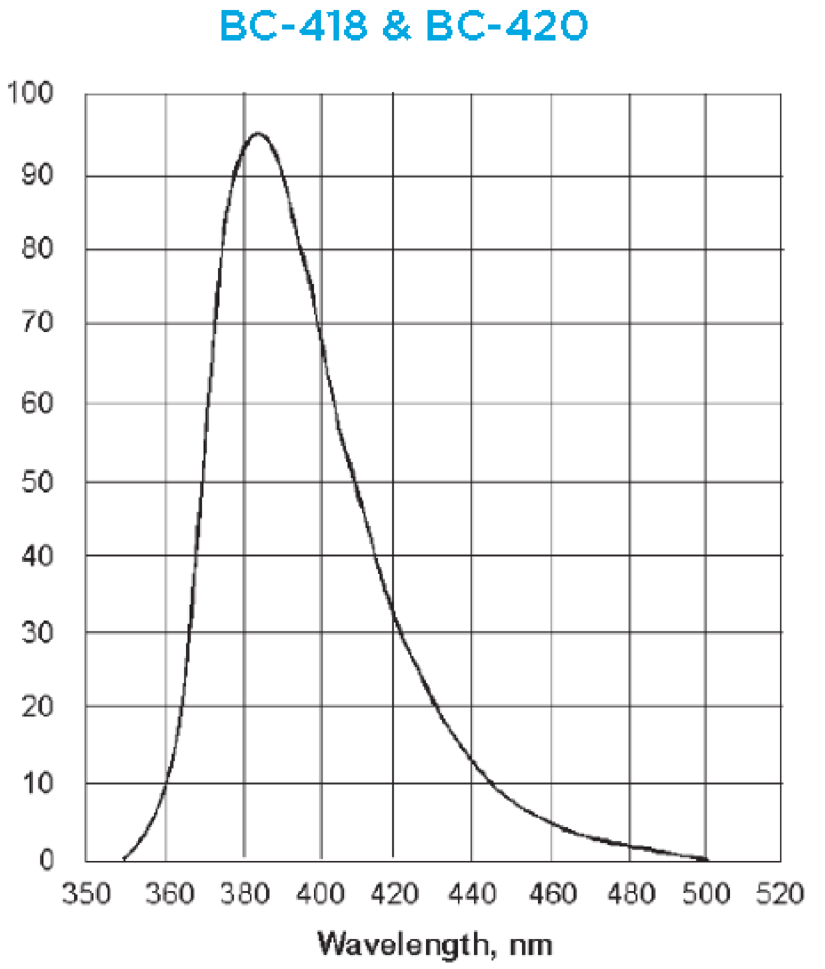
Scintillator plastic

Concentrator array

BACK UP SLIDES

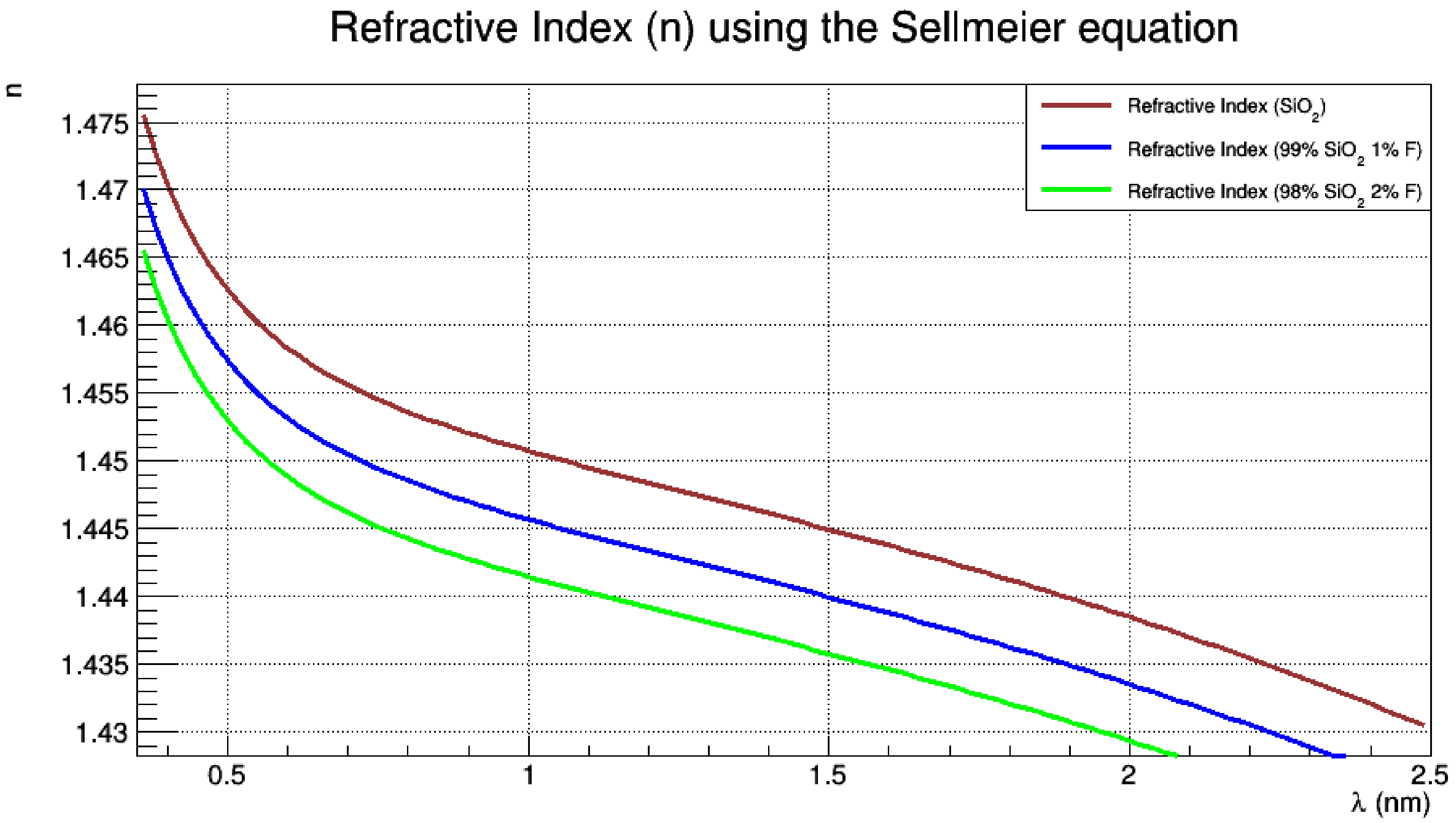
SCINTILLATOR PLASTIC BC-420

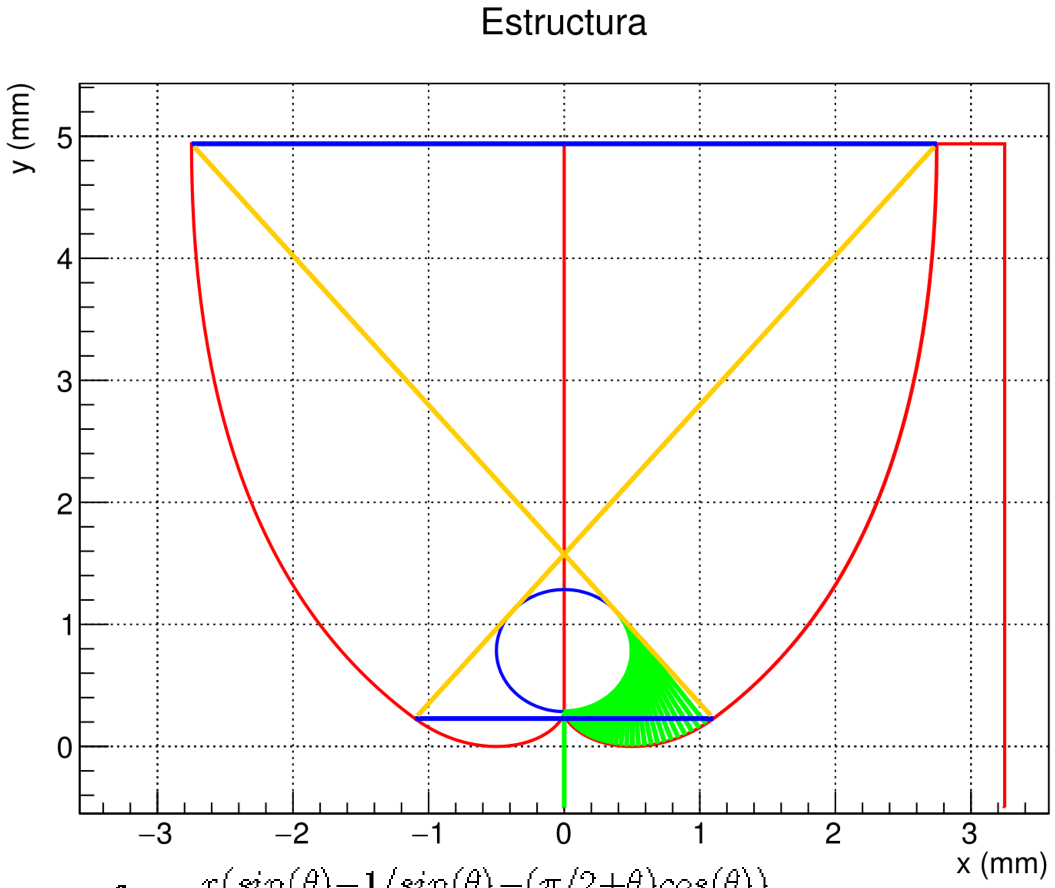
Propiedad	Value
Rise time(ns)	0.5
Fall time(ns)	1.5
Maximum emisión wavelength (nm)	391



Data recovered from:
https://www.crystals.saint-gobain.com/sites/imdf.crystals.com/files/documents/bc418-420-422-data-sheet.pdf

Reffractive index





$$L = 2(a_1 + a_2) = 2a_2(1 + sin(\theta))$$

$$a_2 = \frac{L}{2(1+sin(\theta))}$$

$$a_1 = a_2 sin(\theta) = \frac{L sin(\theta)}{2(1+sin(\theta))}$$

$$f = a_1(1 + sin(\theta)) = \frac{L sin(\theta)}{2}$$

$$y = \frac{x^2}{4f}$$

$$x'_{par} = x cos(\theta) - (\frac{x^2}{4f} - f) sin(\theta)$$

$$y'_{par} = x sin(\theta) + (\frac{x^2}{4f} - f) cos(\theta) + f_y$$

$$x'_{par}(x = 0) = f sin(\theta)$$

$$y'_{par}(x = 0) = -f cos(\theta)$$

$$f = \frac{r(sin(\theta) - 1/sin(\theta) - (\pi/2 + \theta) cos(\theta))}{cos(\theta)}$$

$$f_y = \frac{r\pi}{2} + \frac{r}{sin(\theta)}$$

$$x_{inv}(\phi = \frac{\pi}{2} + \theta) = x'_{par}(x = 0) \quad x_{max} = \frac{2f}{tan(\theta)} = 2L cos(\theta)$$

$$y_{inv}(\phi = \frac{\pi}{2} + \theta) = y'_{par}(x = 0) \quad y_{max} = \frac{f}{tan^2(\theta)}$$

DISEÑO DE CONCENTRADOR ÓPTICO: Sección involuta

$$x_{inv} = r(sin(\phi) - \phi cos(\phi))$$

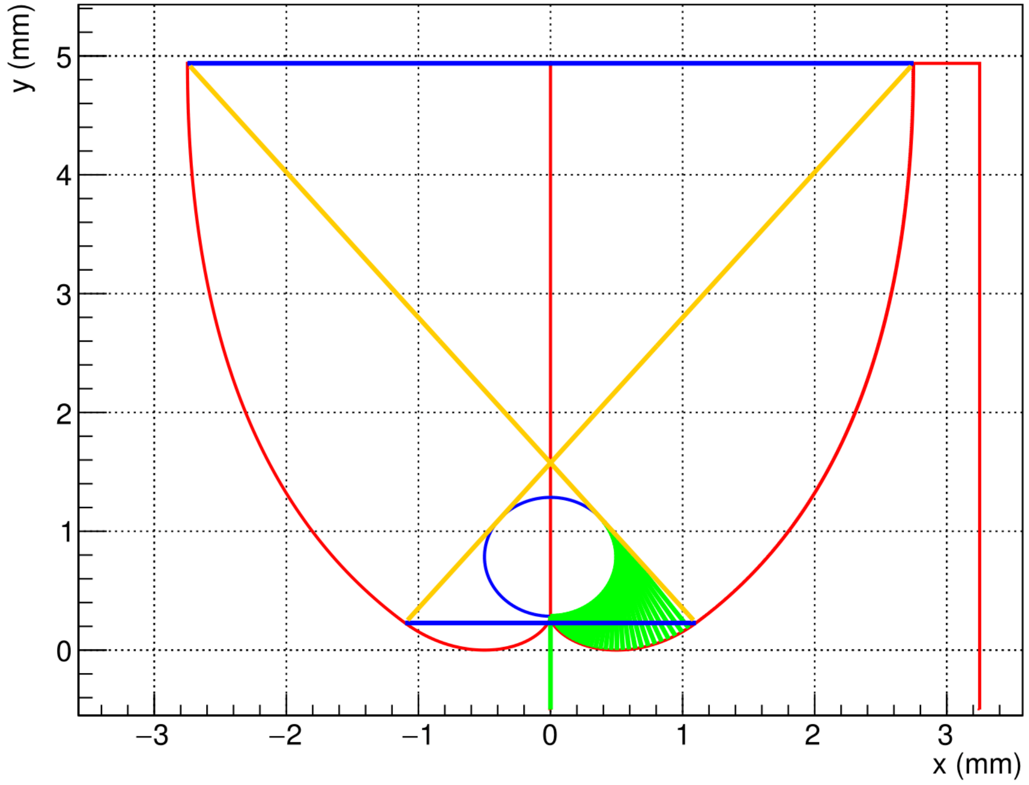
$$y_{inv} = r(\frac{\pi}{2} - cos(\phi) - \phi sin(\phi))$$

$$x_{inv}(\phi = \frac{\pi}{2} + \theta) = r(cos(\theta) + \phi sin(\theta))$$

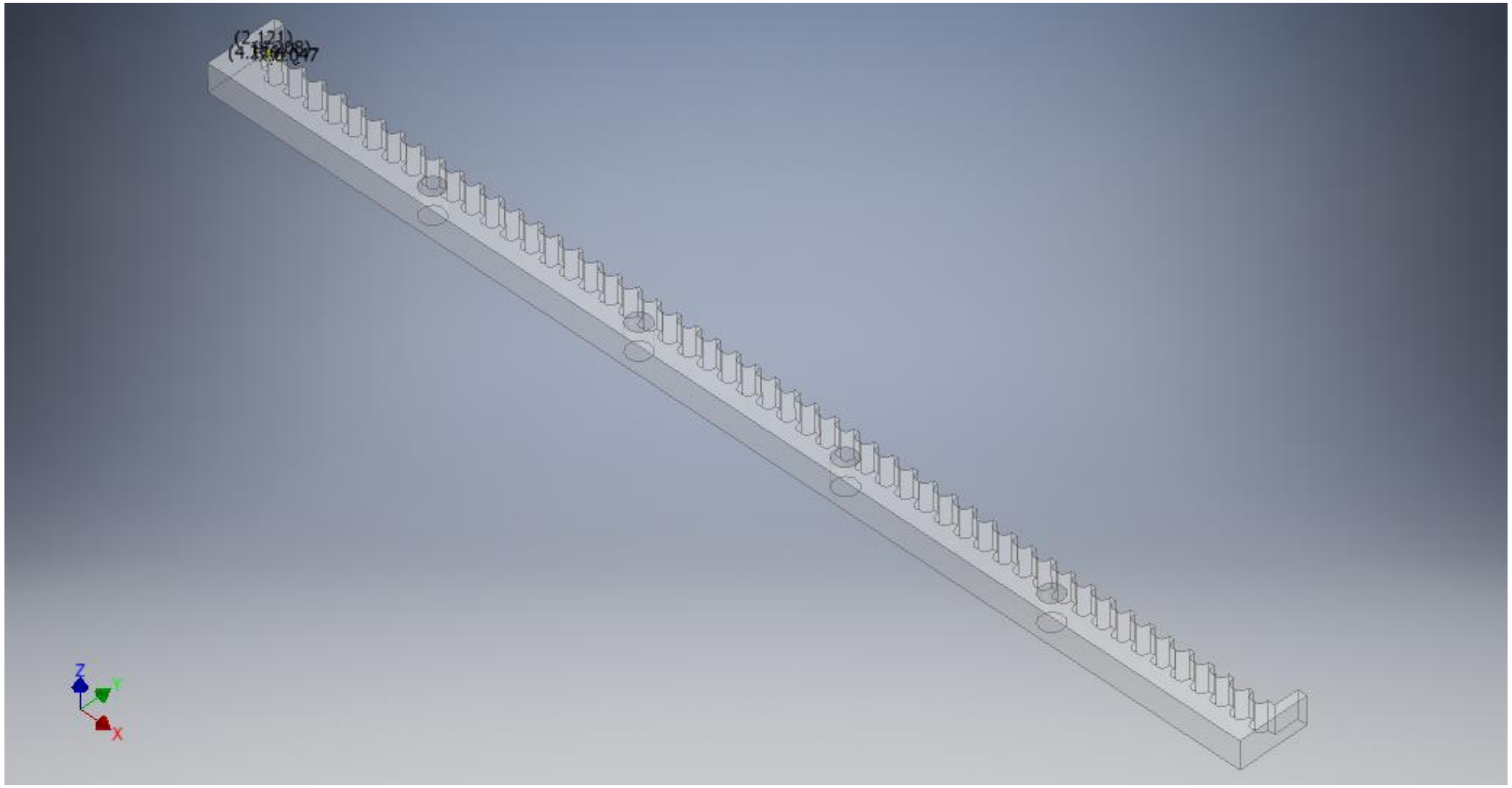
$$y_{inv}(\phi = \frac{\pi}{2} + \theta) = r(\frac{\pi}{2} + sin(\theta) - \phi cos(\theta))$$ ra

$$f = \frac{r(sin(\theta) - 1/sin(\theta) - (\pi/2+\theta)cos(\theta))}{cos(\theta)}$$

$$f_y = \frac{r\pi}{2} + \frac{r}{sin(\theta)}$$



MECHANICAL DESIGN



MECHANICAL DESIGN (ZOOM)