OPTICAL PROPERTIES OF PLASTIC SCINTILATORS FOR HIGH-RESOLUTION DOSIMETRY USING FLUKA AND DATA

LIP Summer Internship 2020

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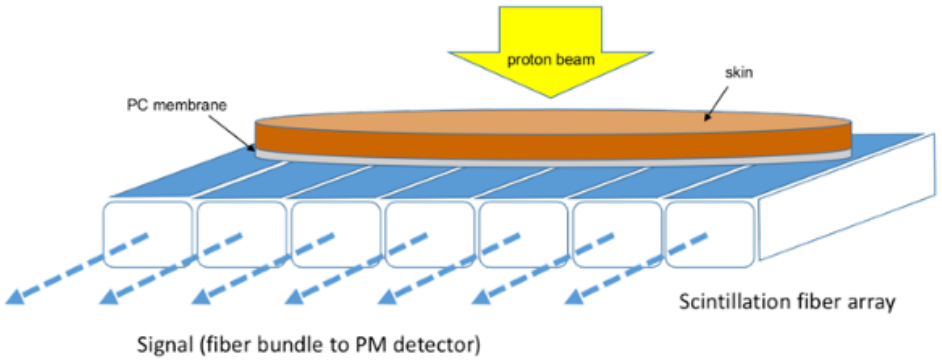
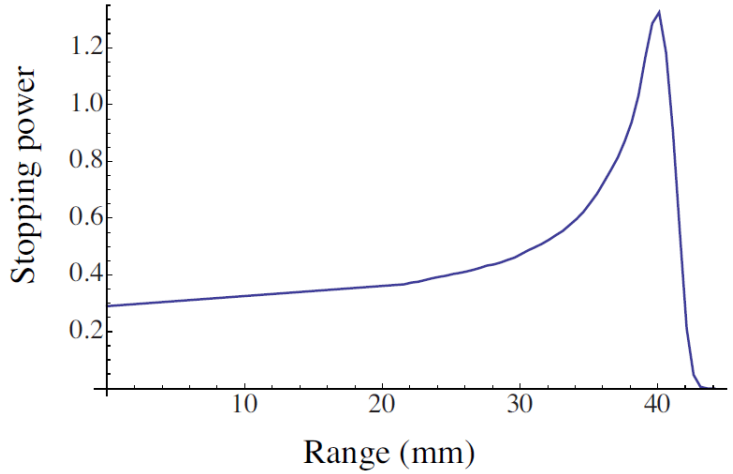
MOTIVATION

Dosimeter capable of measuring the energy deposition at the sub-millimeter scale:

1. More accurate cell surviving fraction vs. dose curves.

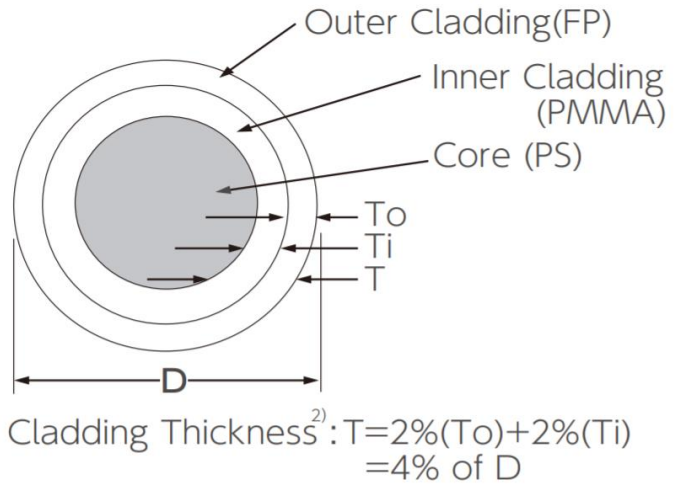
2. Beeing able to determine the position of the Bargg´s peak.





GOALS

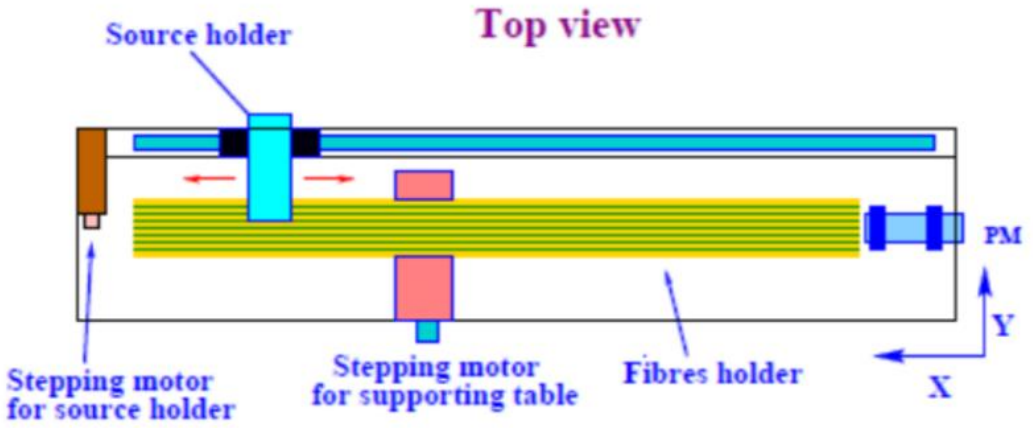
- Characterize the optical properties;
- **Quantify the crosstalk effect.**



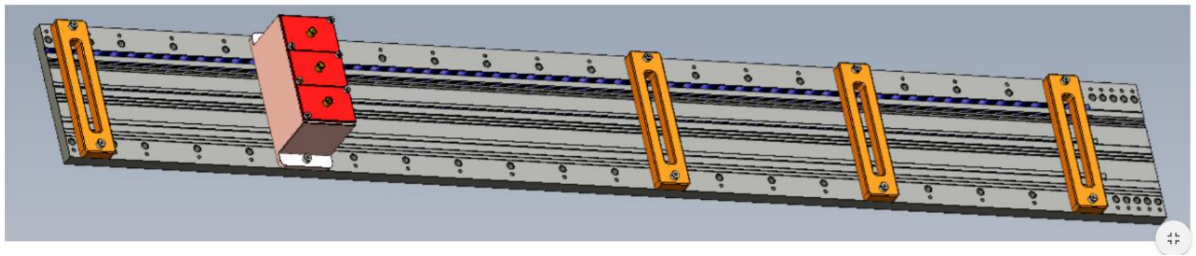
- Experimental work with a fibrometer;
- Simulations with FLUKA/FLAIR.

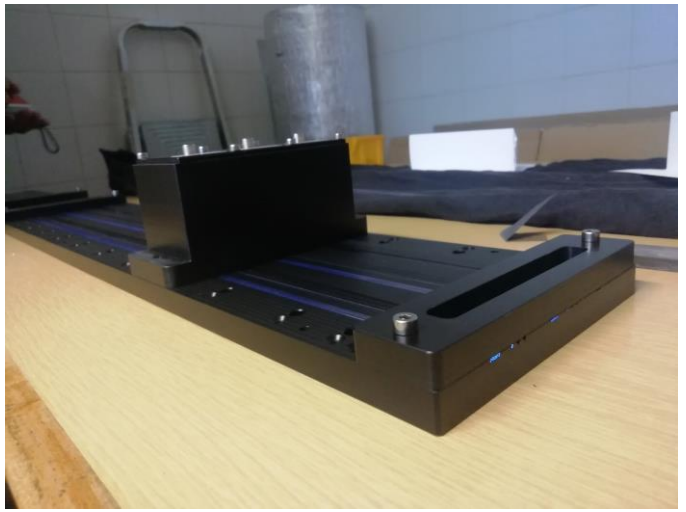
Core refractive index	1.59
PMMA refractive index	1.49
FP refractive index	1.42
Attenuation length	4 m
Decay time	2.8 ns
Wavelength	450 nm

EXPERIMENTAL SETUP: THE FIBROMETER

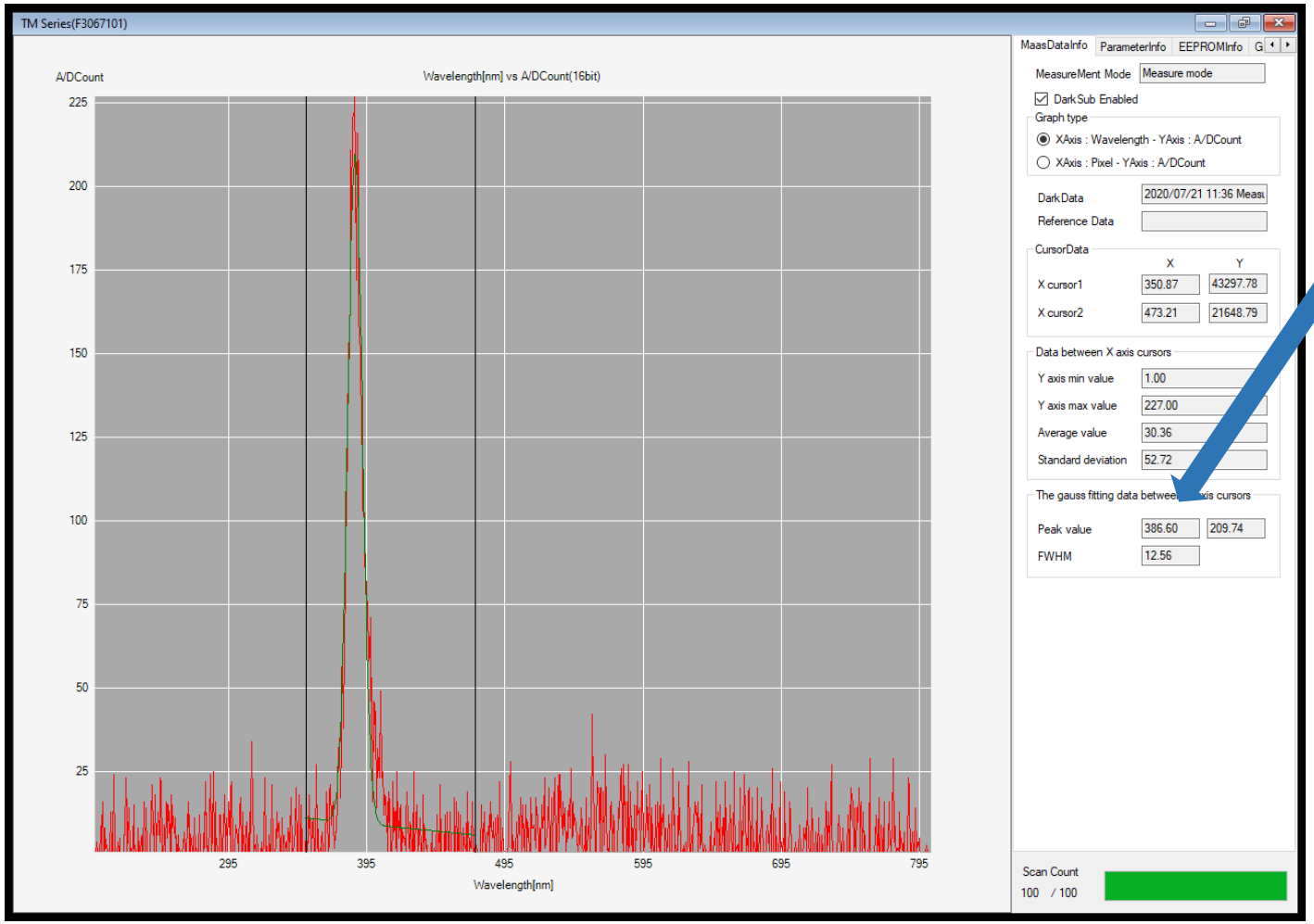


- The fiber board has grooves to place the fibers;
- Each red box has two UV LEDs – one that irradiates the separate fiber and the other irradiates the ribbon;
- The orange parts secure the fibers in place.





EXPERIMENTAL DATA: LEDS



386 nm

- The LEDs have different intensities.

LEDs	Maximum Ratios
LED1.1/LED1.2	1.24
LED2.1/LED2.2	1.06
LED3.1/LED3.2	1.60

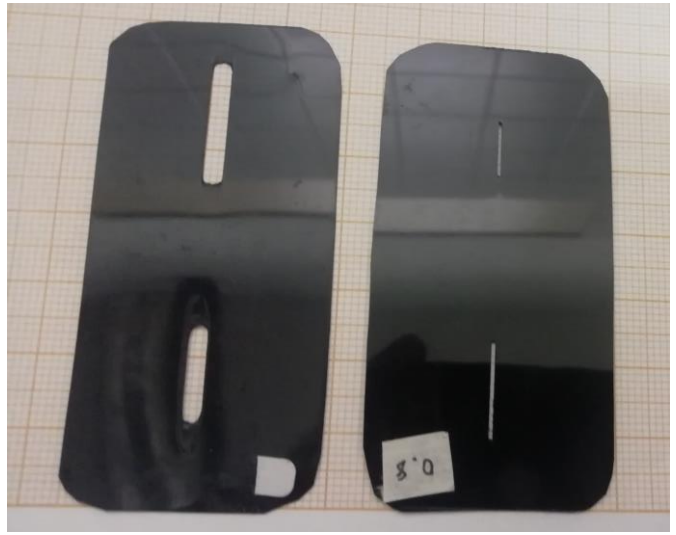
EXPERIMENTAL DATA: LEDS

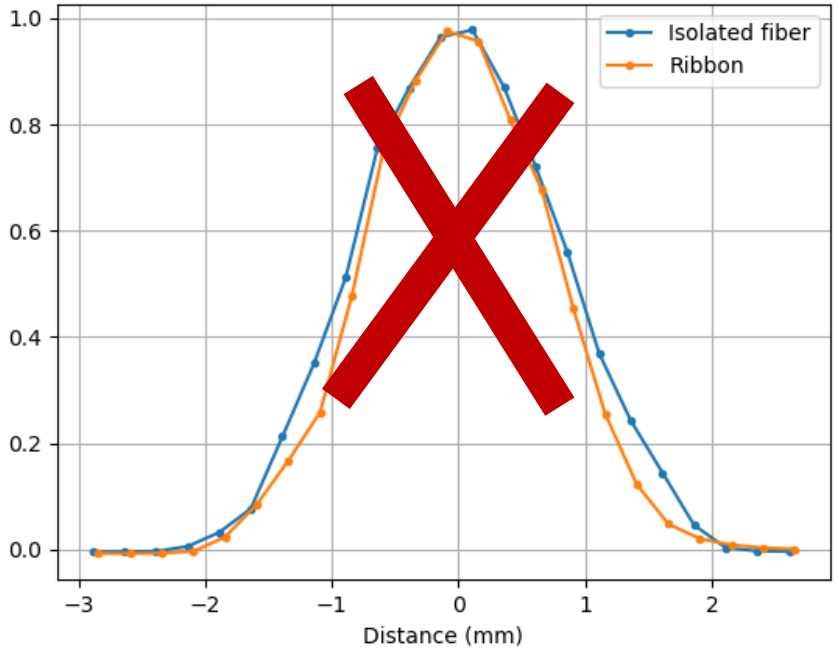
- Measurements using the 1 mm fibers;
- The LEDs intensity ratios don’t match the fibers response ratios.

LEDs	Isolated Fiber	Band	LEDs	Isolated Fiber/LEDs	Band/LEDs
LED1.1/LED1.2	1.28	1.52	1.24	+3.2%	+22.6%
LED2.1/LED2.2	1.17	1.16	1.06	+10.4%	+9.4%
LED3.1/LED3.2	0.36	0.39	1.60	-77.5%	-75.6%

EXPERIMENTAL MEASUREMENTS

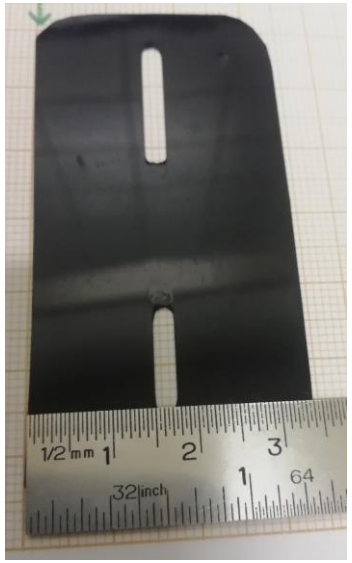
- Sets of measurements:
  - Using the 1 mm and 0.5 mm fibers;
  - Placing the light source 25 cm and 15 cm from the tip of the fibers;
  - Using the slit with length 2.8 mm and 0.8 mm;
- Analysis procedure:
  - Normalizing the curves with the maximum and the integral;
  - Alignment of the isolated fiber and ribbon curves.

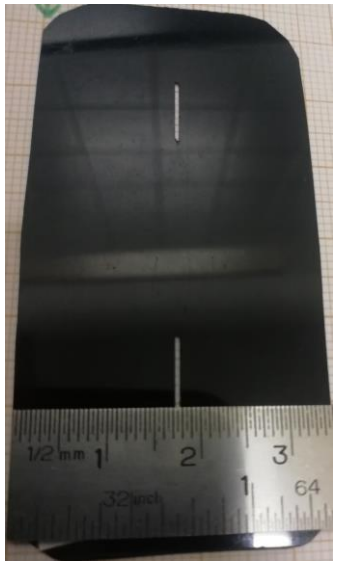


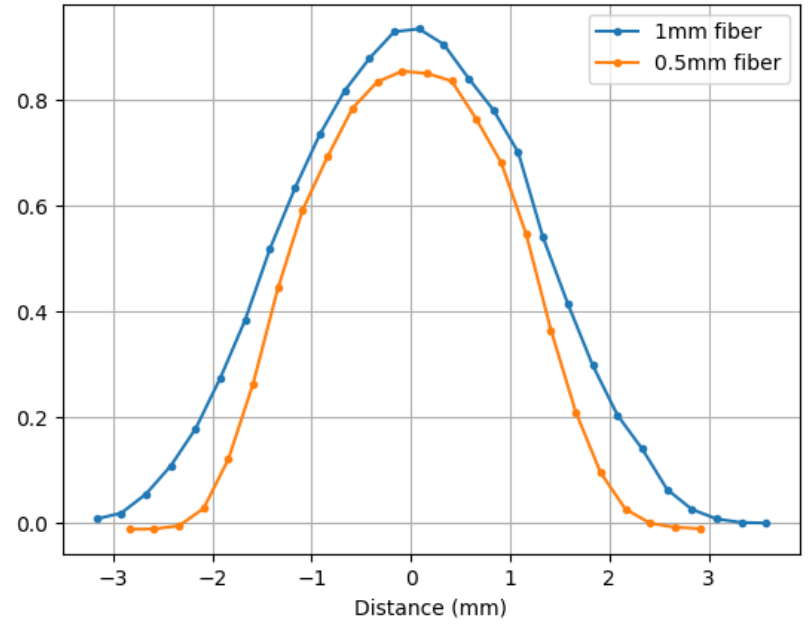


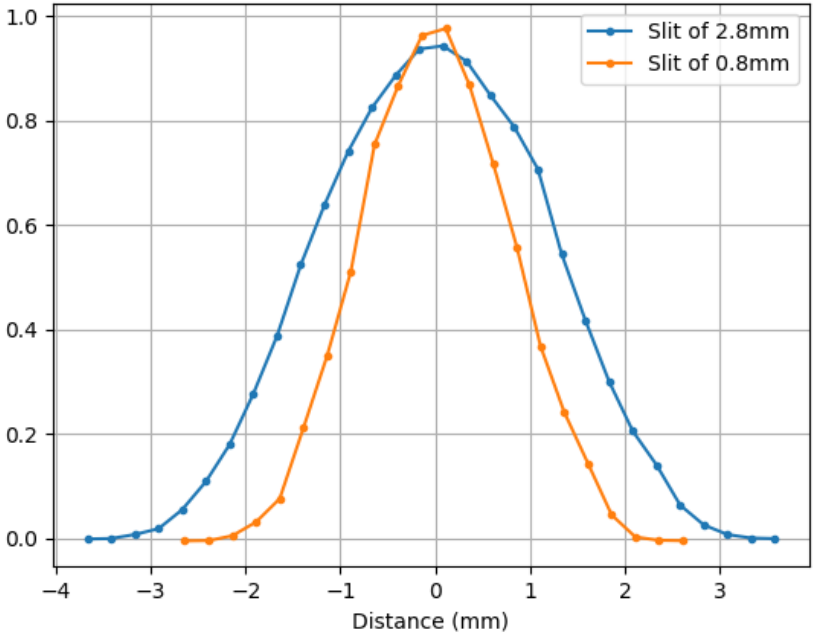
COMPARING DIFFERENT FIBERS AND SLITS

- The 0.5 mm fiber curve has a smaller width;
- When using the 0.8 mm slit the width of the curves decreases;
- The two slits are not aligned with each other;



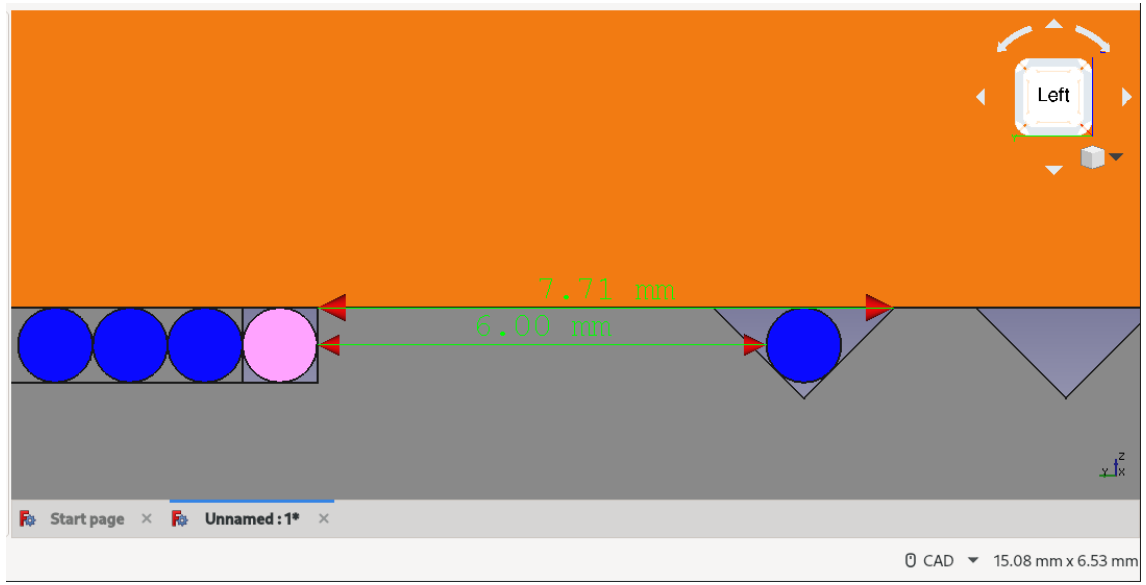


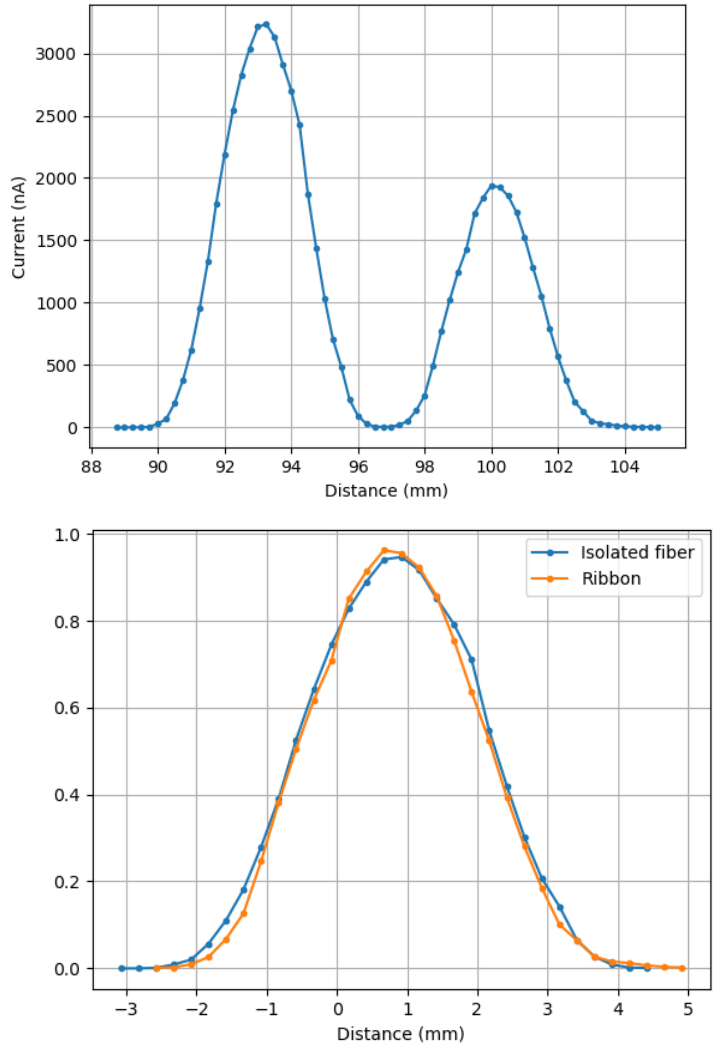




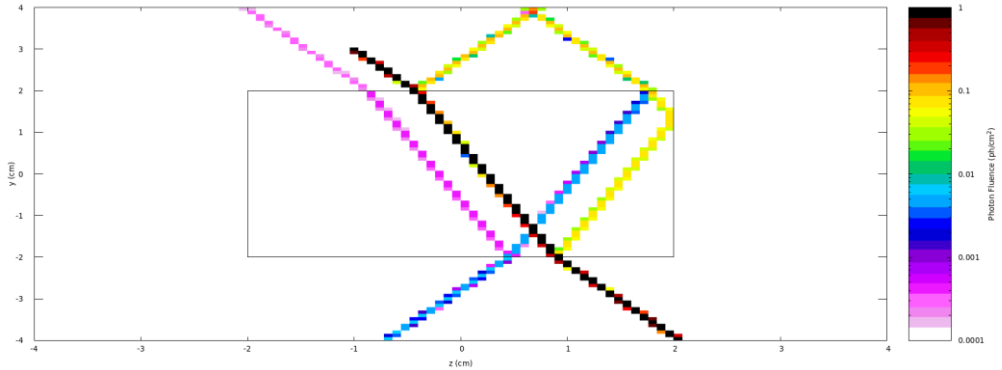
ALIGNING THE ISOLATED AND RIBBON CURVES

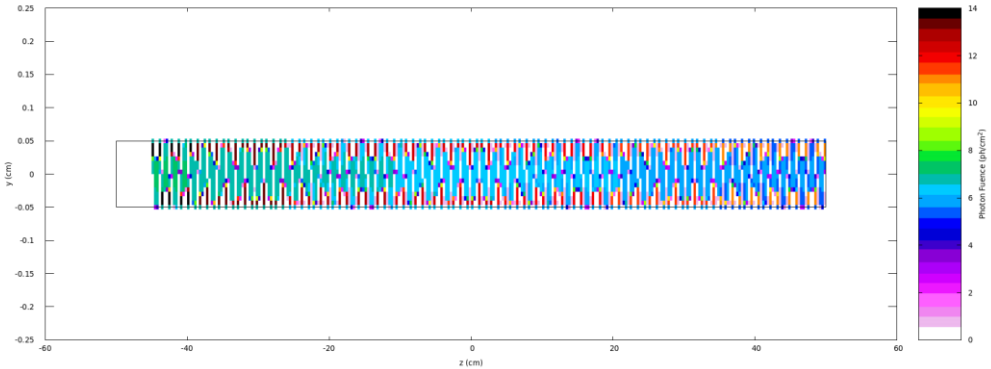
- Comparing the ribbon with the isolated fiber;
- We took a reference point from the board of fibers, using millimetric paper.
- With the CAD design, we can know other points.





FIRST SIMULATIONS

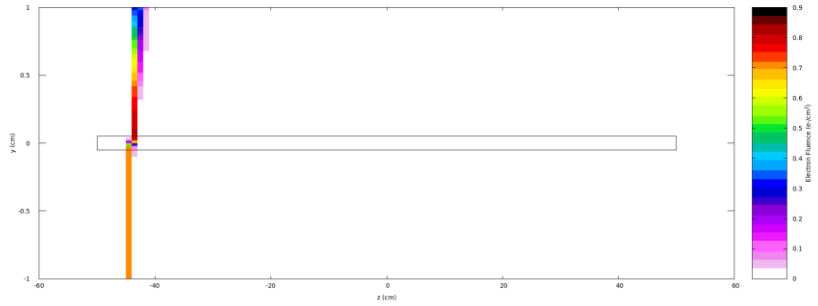




- Optical properties;
- In FLUKA optical photons don’t deposite energy;
- Reflections and refractions;
- Propagation of light in a fiber.

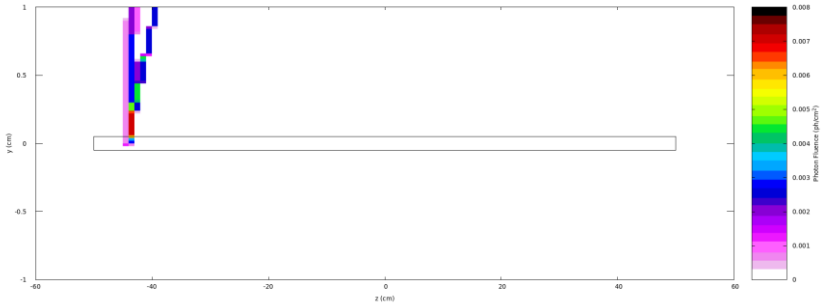
SIMULATIONS: ELECTRON BEAM

Electrons

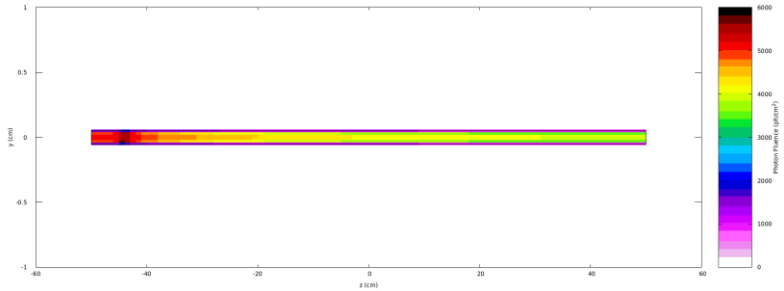


- A 2.2 MeV beam generated outsider the fiber;
- Scintilating properties;
- Production of photons: X-rays;
- Production of optical photons.

X-Rays



Optical photons

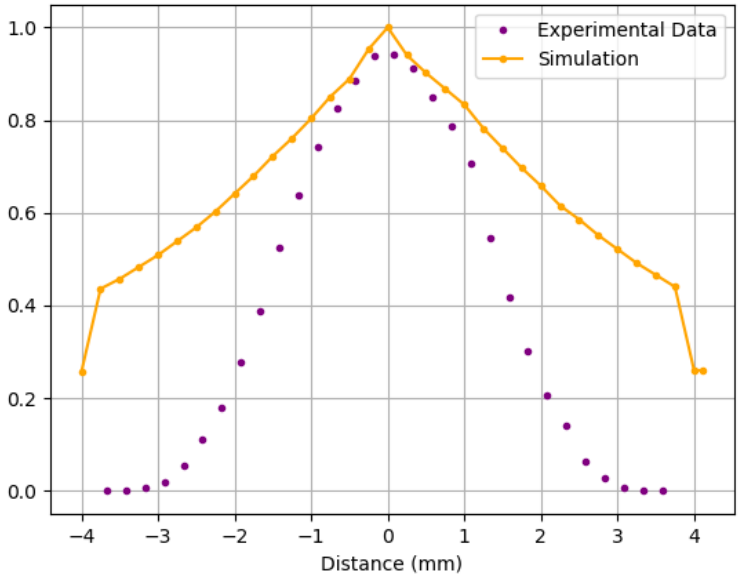


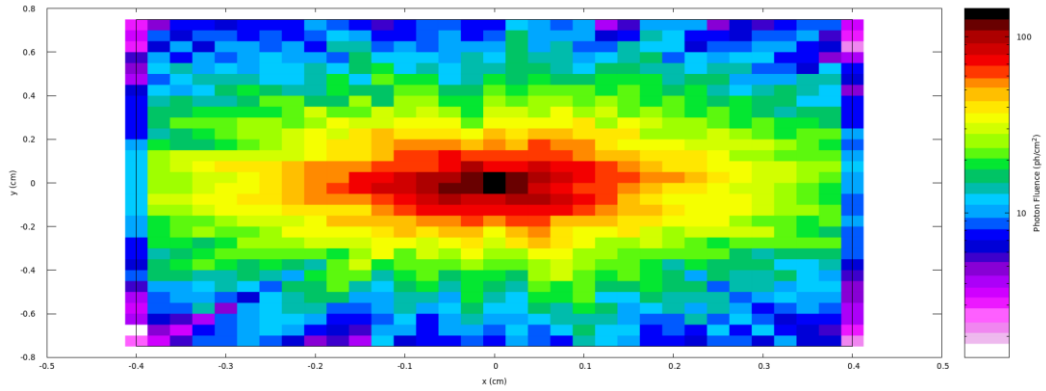
OPT-PROD Type: SCIN-OFF ▾ Mat: AIR ▾ to Mat: AIR ▾ Step:

OPT-PROD Type: SCINT-WV ▾ λi: 4.5E-5 fraction: 0.033

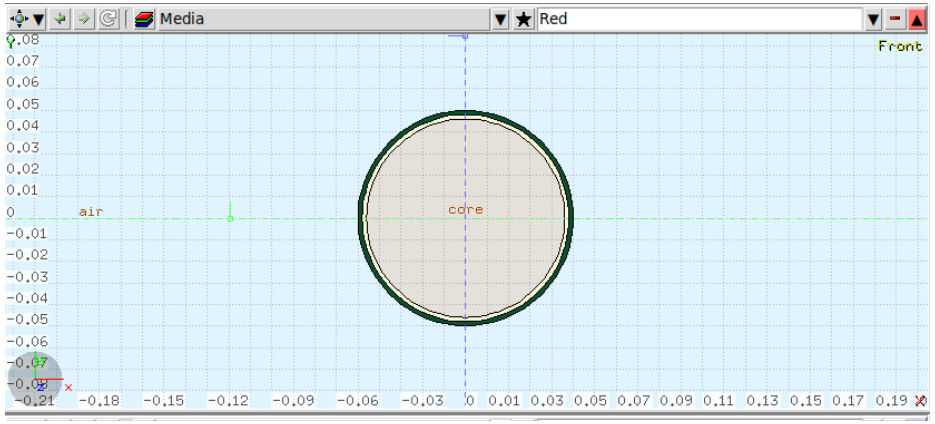
Time: 2.8E-9 Mat: POLYSTYR ▾ to Mat: POLYSTYR ▾ Step:

SIMULATIONS: ELECTRON BEAM

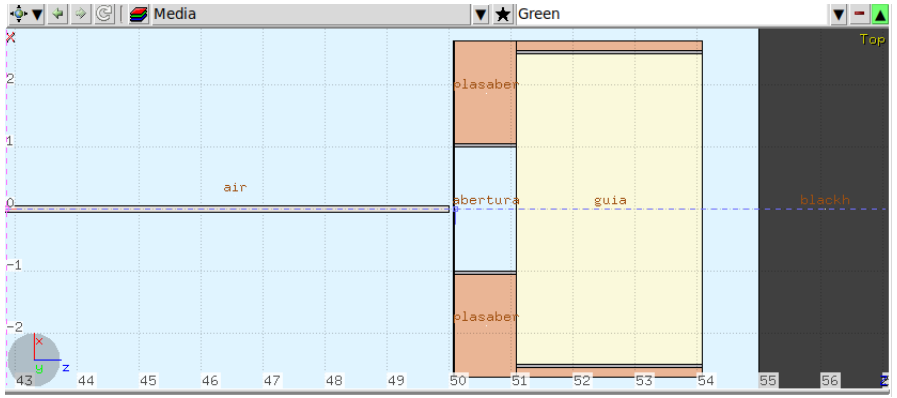


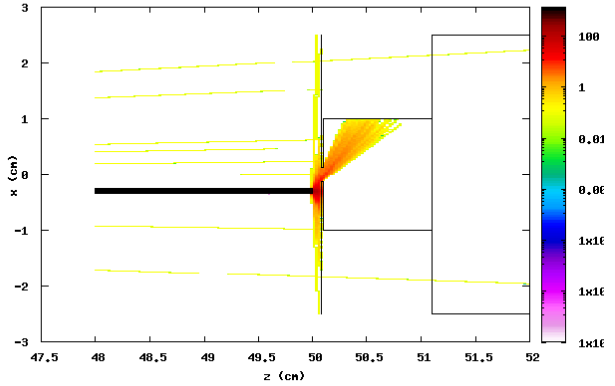


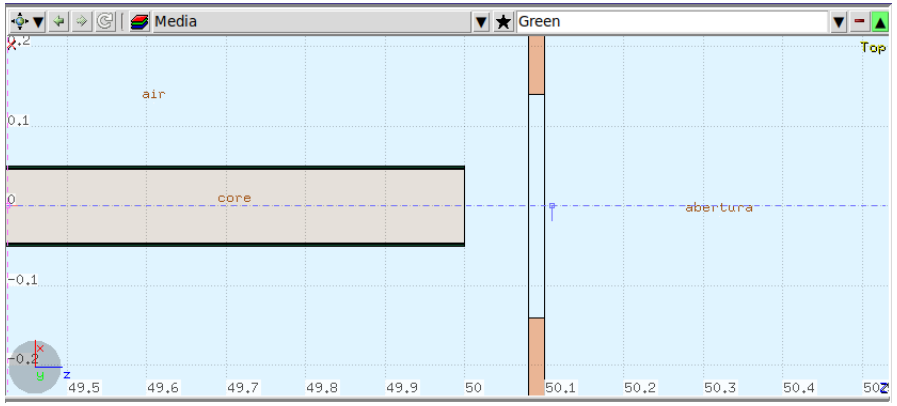
- The beam is 25 cm from the tip of the fiber;
- Two claddings;
- Detector 1 mm away from the fiber;
- The curve of the experimental data is wider.

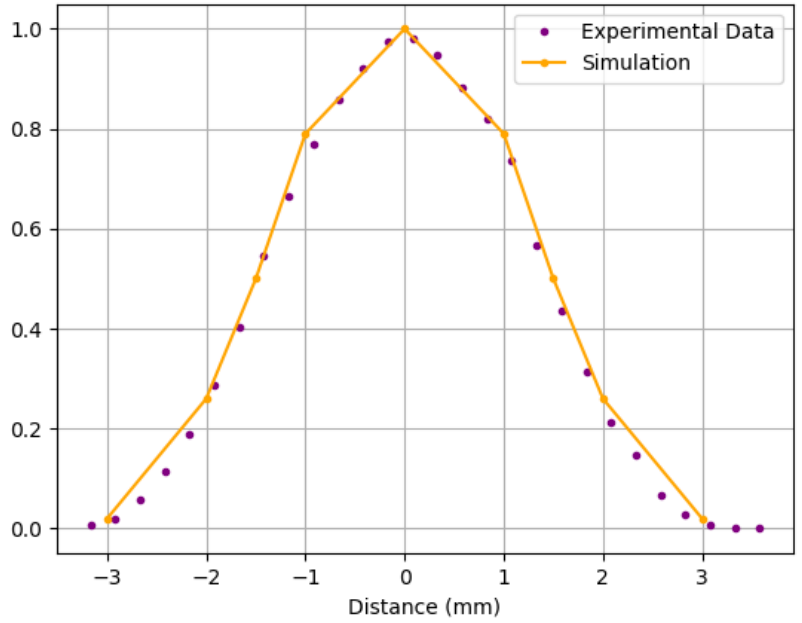


SIMULATIONS: CLOSER TO EXPERIMENTAL DATA









CONCLUSIONS

- The goal was to quantify the crosstalk effect between optical fibers. Two approaches were used:
  - A Monte Carlo simulation of the optical signal propagation and detection was developed;
  - Measurements in the lab, using a dedicated test bench.
- The obtained results were:
  - There was a good agreement between the experimental data and the simulation;
  - We were not able to quantify the crosstalk effect yet.
- We detected several issues in the experimental setup:
  - The fixation of the fibers must be improved;
  - The slits are not centered;
  - The alignment;
  - There is a mismatch between the LEDs intensity and the fibers response which needs to be understood.