SCINTILLATING ARRAY FOR REAL TIME HIGH-RESOLUTION ION THERAPY RESOLUTION ION THERAPY DOSIMETRY: INITIAL DESIGN AND SIMULATIONS

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The need for a good microdosimeter

RADIOBIOLOGY

- Radiobiology is used to study how cells and organs react to being irradiated.
- This information is important to plan radiotherapy sessions.

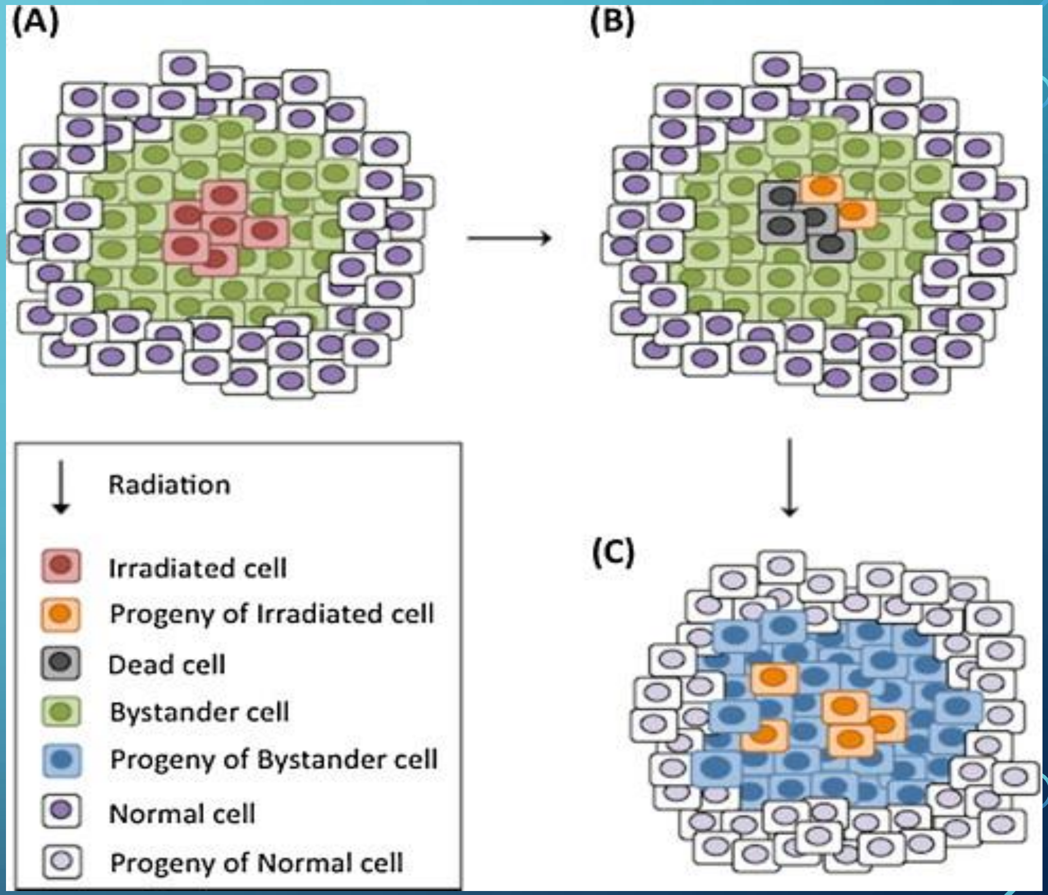


Figure1. Radiobiology study scheme.

RADIOBIOLOGY – CELL SURVIVAL CURVES

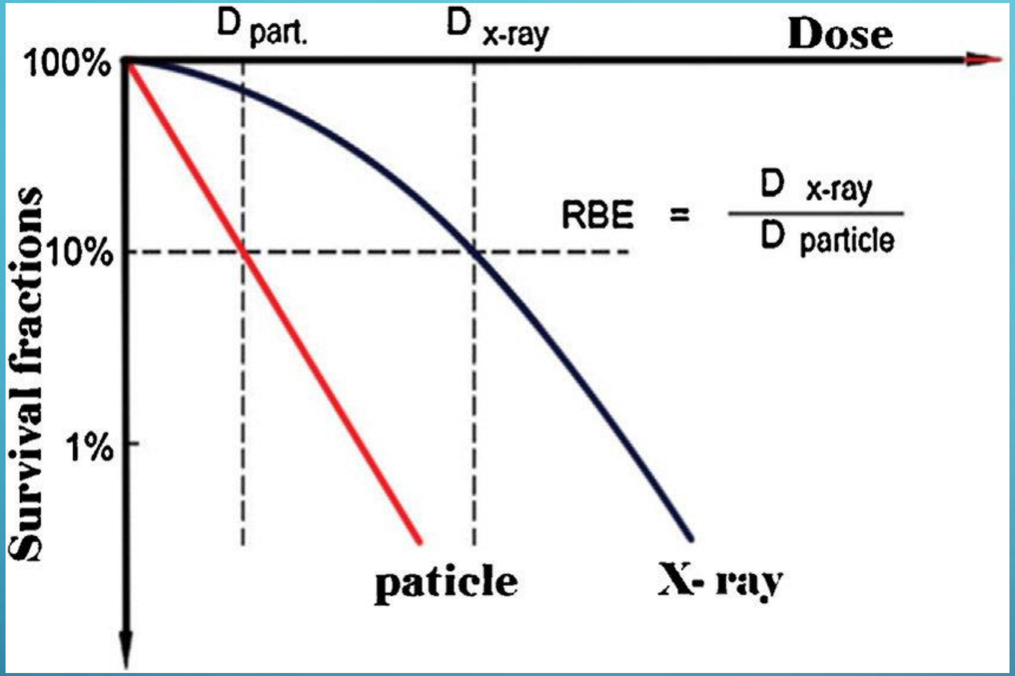


Figure4. Cell survival rate for each dose.
Comparisson between High-LET and Low-LET.

- The cell survival against dose is graphically represented by plotting the surviving dose S(D) on a log scale against the dose D.

RADIOBIOLOGY – RBE

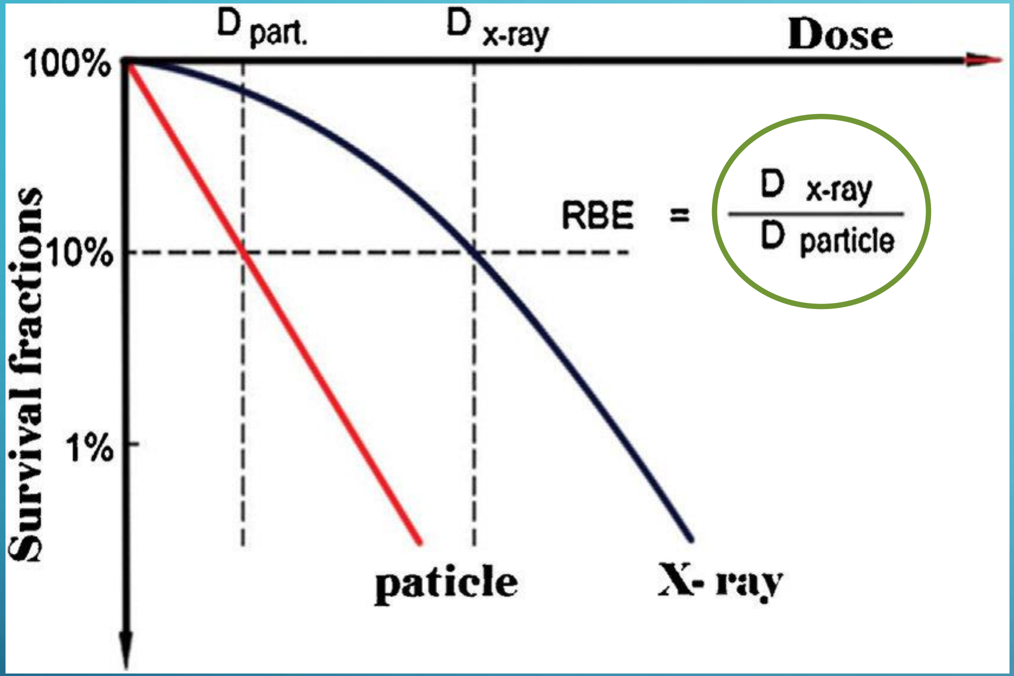


Figure4. Cell survival rate for each dose. Comparisson between High-LET and Low-LET.

- Relative biological effectiveness (RBE) compares the dose of test radiation to the dose of standard radiation to produce the same biological effect.

RADIOBIOLOGY – RBE

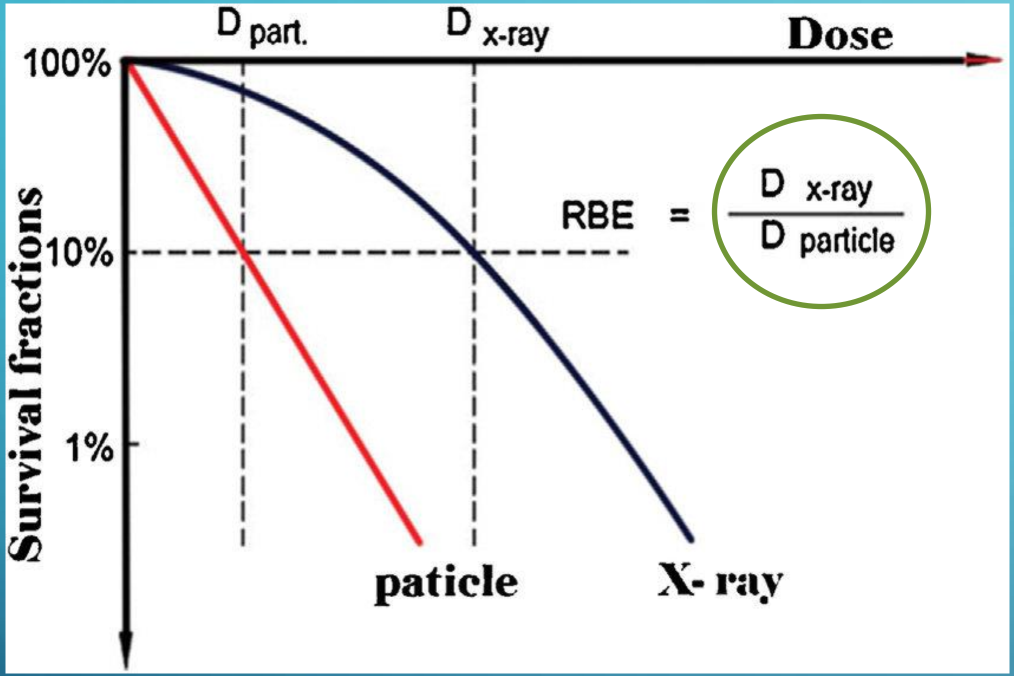


Figure4. Cell survival rate for each dose. Comparisson between High-LET and Low-LET.

- RBE is complex. It depends on: LET, dose, dose rate.
- It is known that it is possible to have different RBE for particles witht the same LET depending on the track structure.
- To study the biological effects it is importan to have a dose distribution map at a micrometric scale

The Project

THE PROJECT

- The aim is to develop a detector with real time dose measurement, good spatial resolution and tissue equivalence.
- The possibility of placing a cell culture directly on top of the optical fibres is being explored.
- This seeks to reduce the errors introduced by the cell culture plates.

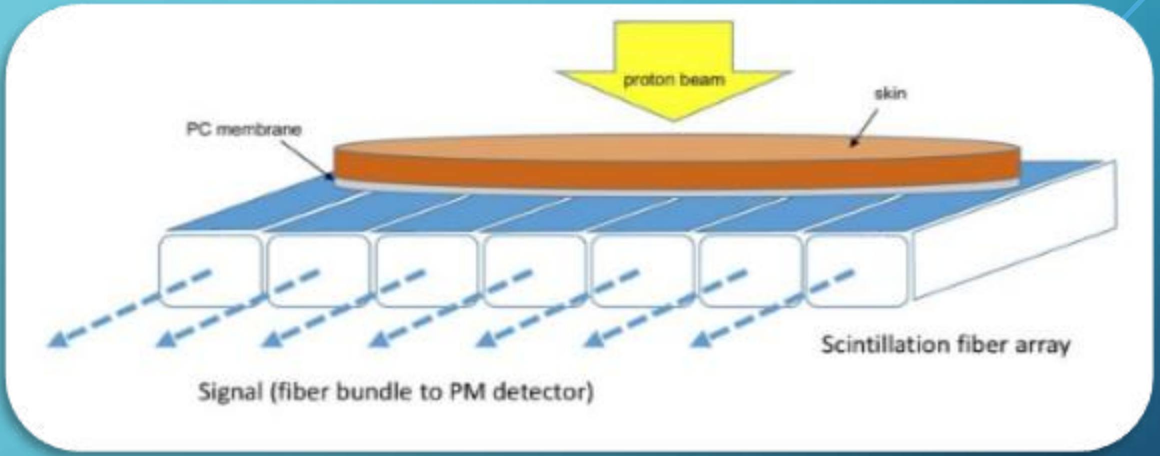


Figure5. Scheme describing the project. The skin cell model is placed directly on top of the optical fibres.

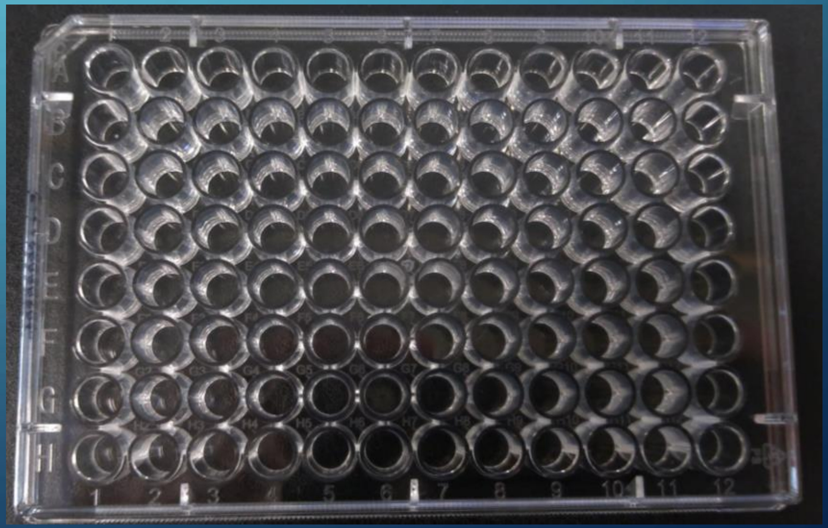


Figure6. Cell culture plates.

THE PROJECT

- It became necessary to design the detector as an irradiation box.
- This irradiation box includes the sensitive area and the PMT. Includes enough space to receive the cell cultures.

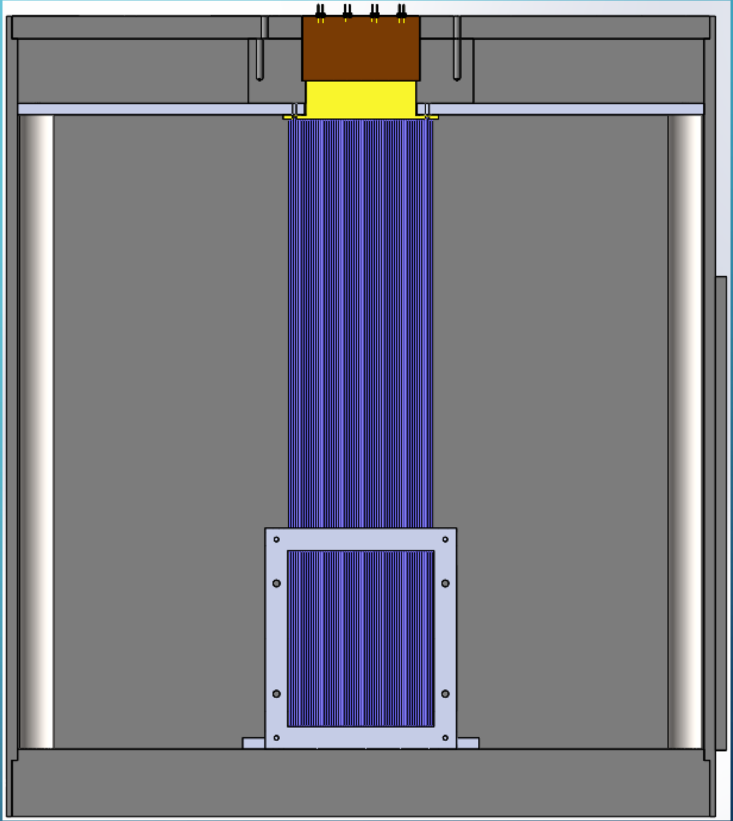


Figure7. Inside of the detector. The volume that receives the optical fibres is shown (the figure shows a cross-section of the detector).

WORK DONE

1. Photodetector and DAQ board testing.
2. Optical Fibre Crosstalk Measurements & Simulations.
3. Optical Fibre Array Assemble and Quality Control.
4. Detector Design.
5. Shielding and Optical Photons Transport Simulations.

1.Photodetector and DAQ board testing

PHOTODETECTOR AND DAQ BOARD TESTING

- Performed measurements to test the MAPMT and the DAQ board:
  - SNR;
  - Time stabilization;
  - Optical crosstalk;
  - DAQ response in frequency and energy.

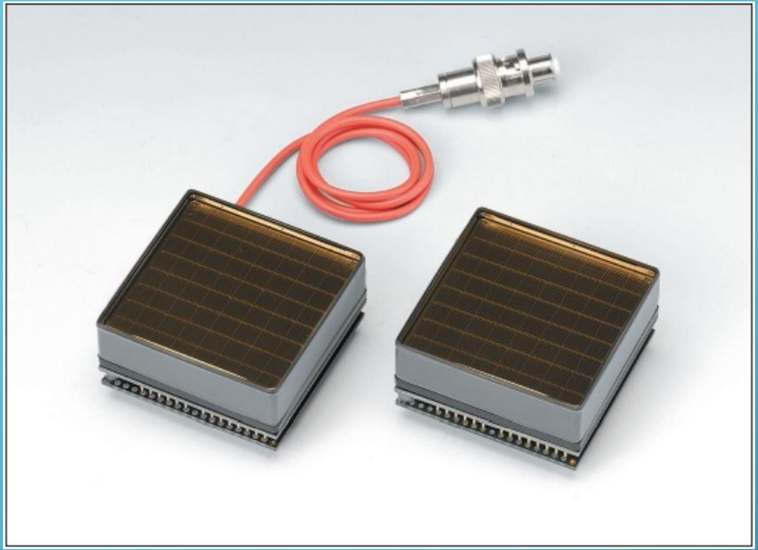


Figure8. Hamamatsu Multianode PMT (MAPMT) used in the detector.

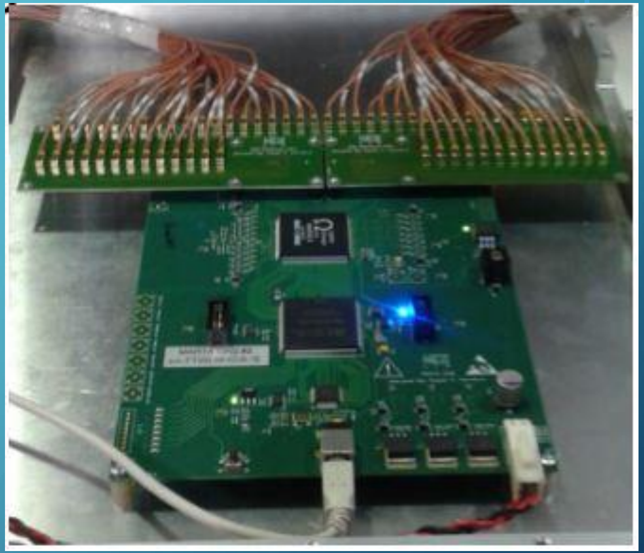


Figure9. MARTA DAQ with 64 channels.

More information at M.Santo's poster "Characterization and functional test of a micro dosimeter of scintillated optical fibers"

2. Optical Fibre Crosstalk Simulations.

CROSSTALK SIMULATIONS

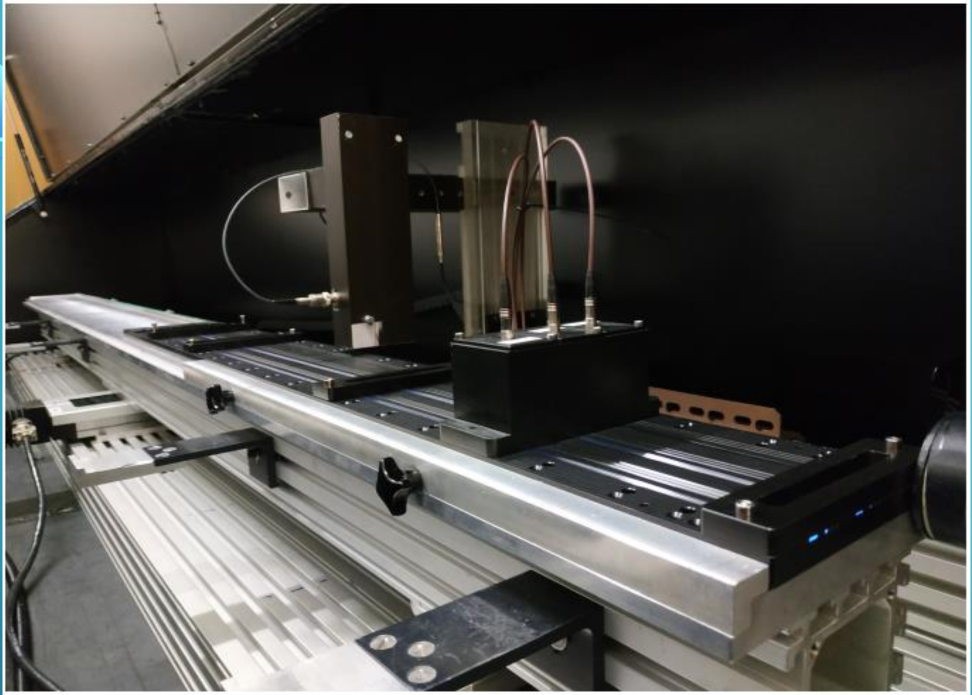


Figure10. Fiber test bench used in LOMAC laboratory. In the image it is possible to see the system used to place the optical fibres side by side.

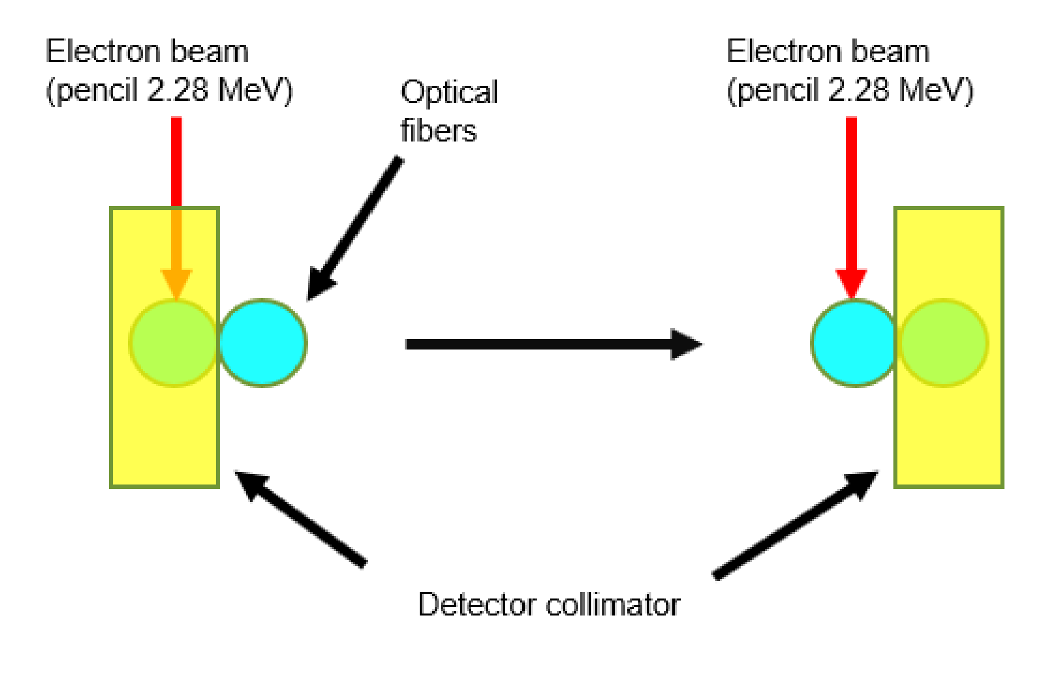


Figure11. Scheme illustrating the experimental protocol.

CROSSTALK SIMULATIONS

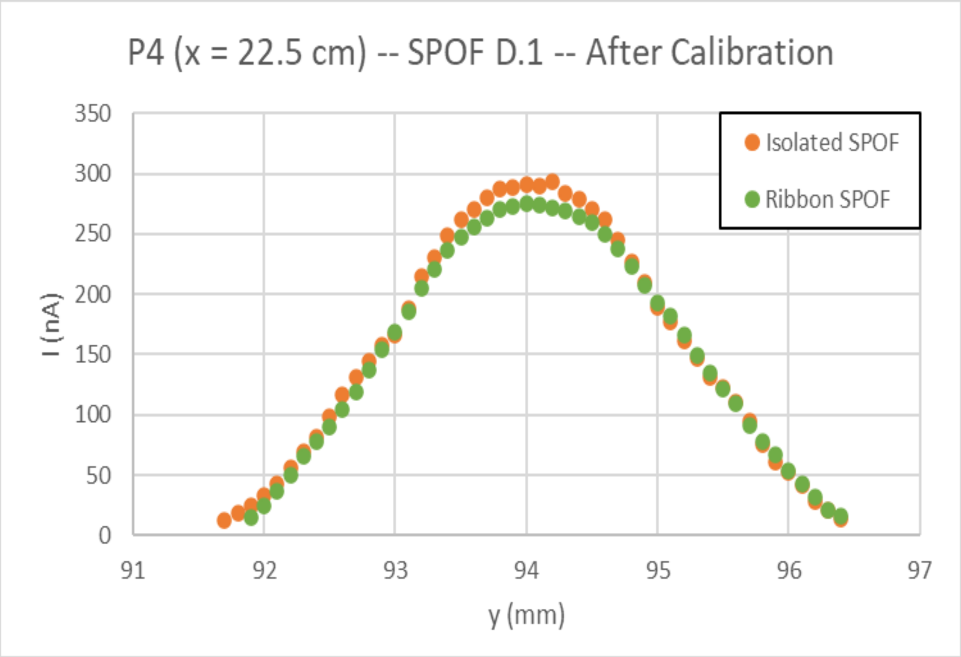


Figure12. Signal captured in the detector. Experimental measurements

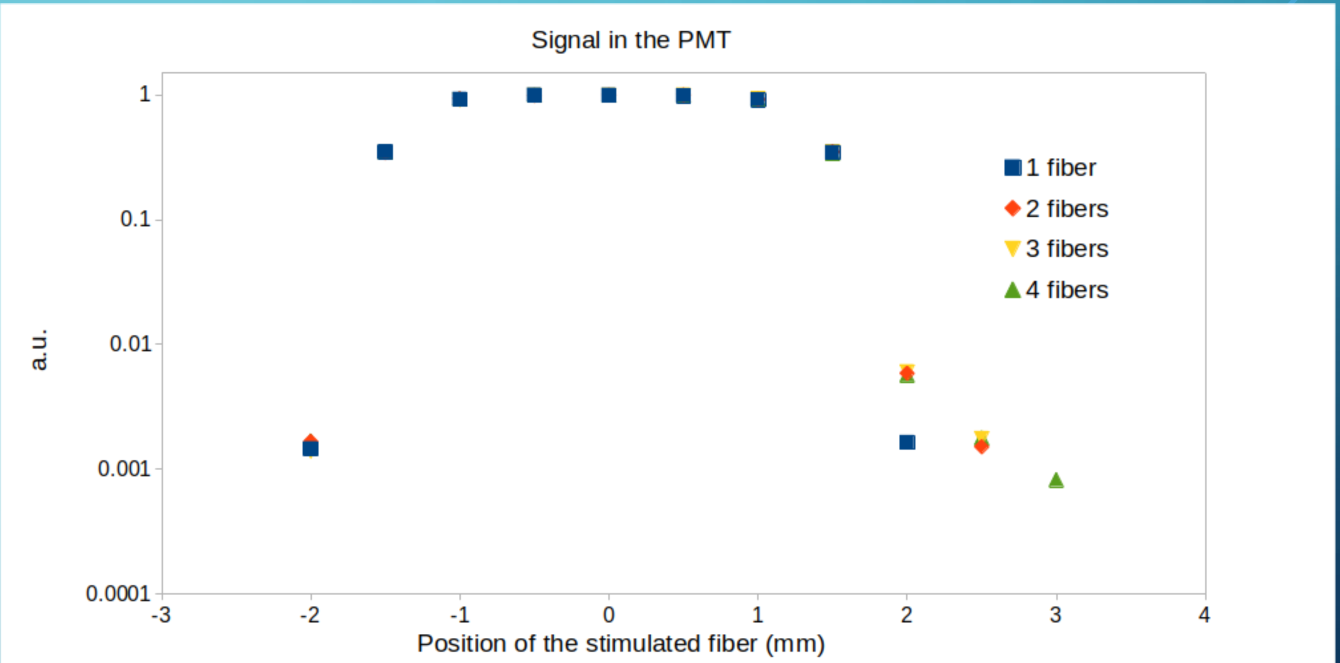


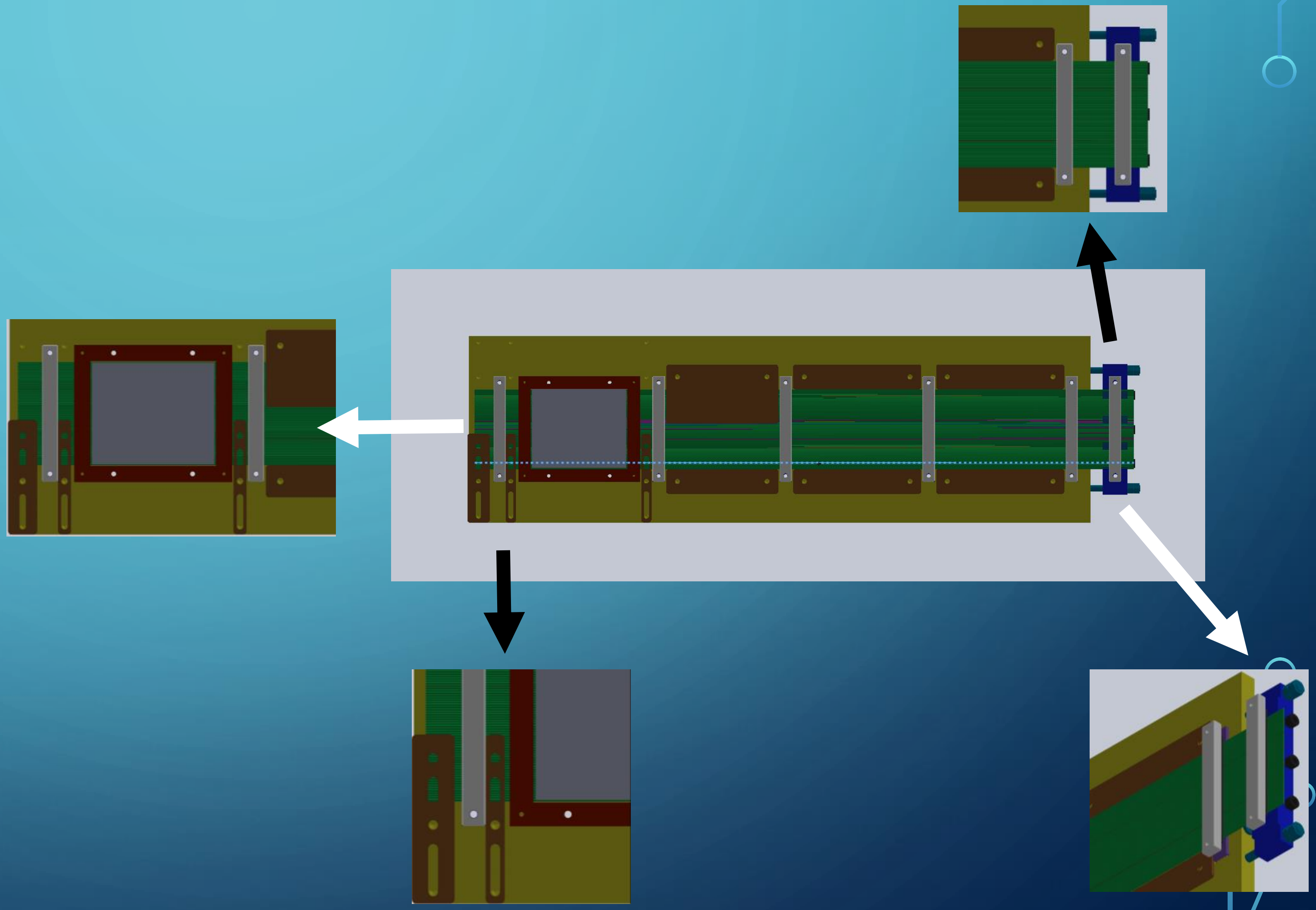
Figure13. Signal captured in the detector. Not considering Cherenkov radiation. In the graph the x axis corresponds to the position of the stimulated optical fibre.

More information at M.Santo's poster "Characterization and functional test of a micro dosimeter of scintillated optical fibers"

3. Optical Fibre Array Assemble and Quality Control.

OPTICAL FIBRE ARRAY ASSEMBLY AND QUALITY CONTROL

- With this tool the optical fibres are assembled in the following way (may be changed, in the future):
  1. The optical fibres are placed on top of the tool
  2. The moving parts are place in such a way as to ensure that the optical fibres are juxtaposed
  3. Tension is applied longitudinally to the optical fibres, this is made in such a way as to guarantee that the optical fibres are all in the same plane.
  4. The optical fibres are glued to the bottom half of the frame.
  5. The glue is then left to dry.



OPTICAL FIBRE ARRAY ASSEMBLY AND QUALITY CONTROL

- The most important aspect of the optical fibre assembly is that the optical fibres present are juxtaposed and all in the same plane.
- The error that can be accepted in the construction of the optical fibre arrays has been calculated using Monte Carlo simulations.

Simulations

- In these simulations an optical fibre array of 64 fibres was placed in air and the irradiated with a proton beam (13 MeV). Fibers are place in the beam's Bragg Peak.
- The central fibre was picked and moved.

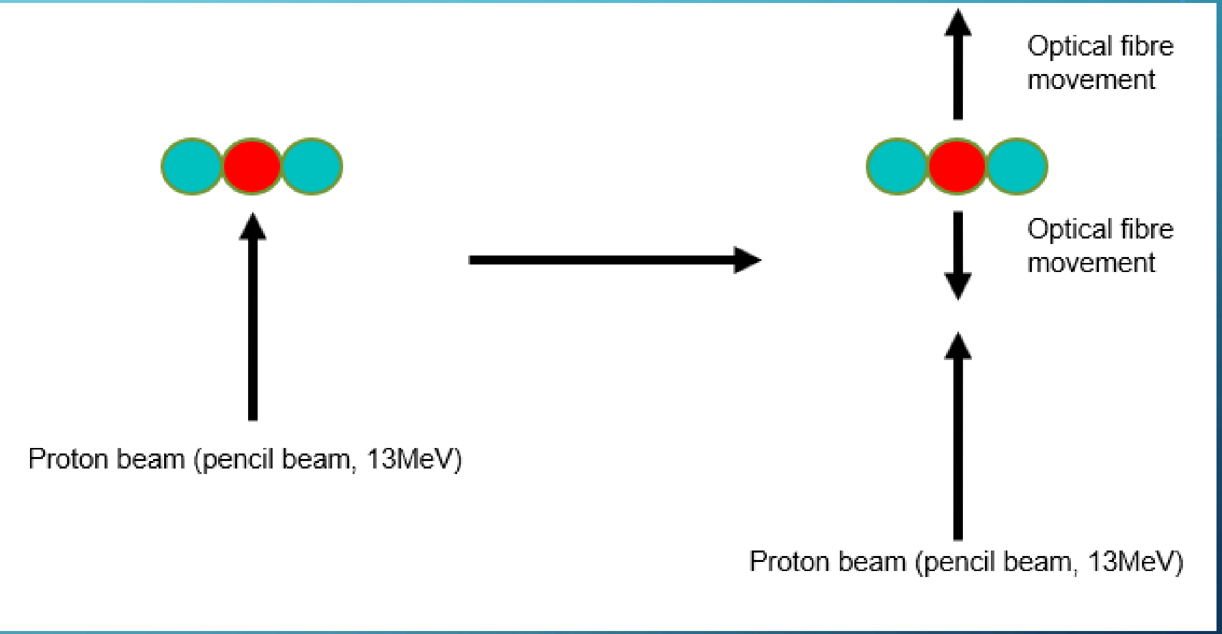


Figure14. Scheme illustrating the experimental protocol.

OPTICAL FIBRE ARRAY ASSEMBLY AND QUALITY CONTROL

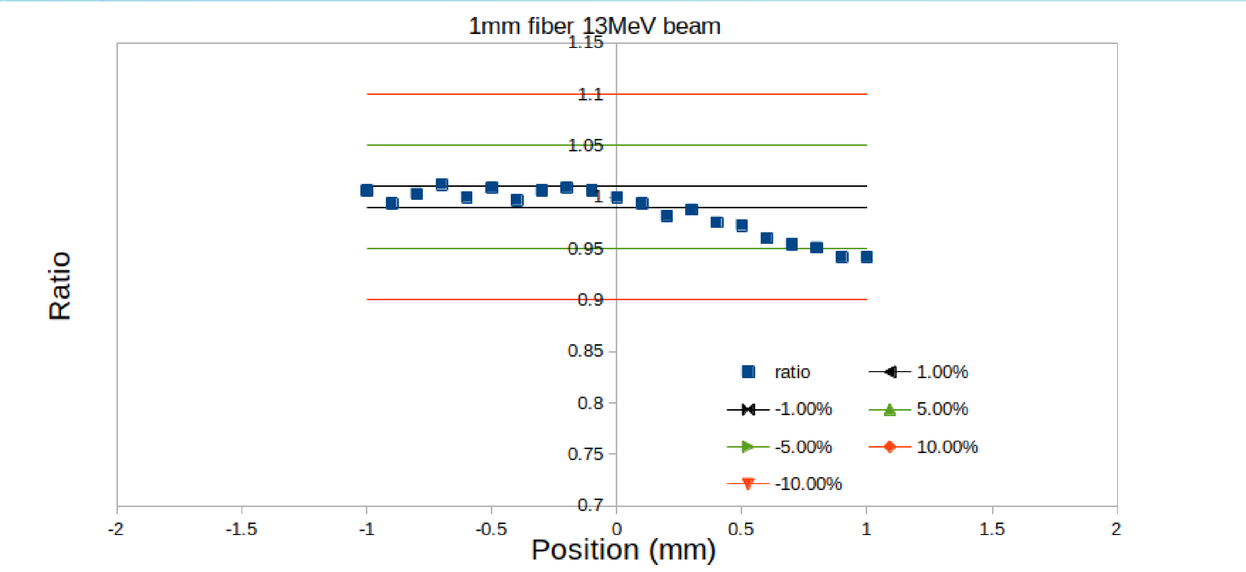


Figure15. Ratio between the energy absorbed by the optical fibre in the central position and the other positions. Simulations for 1 mm optical fibers.

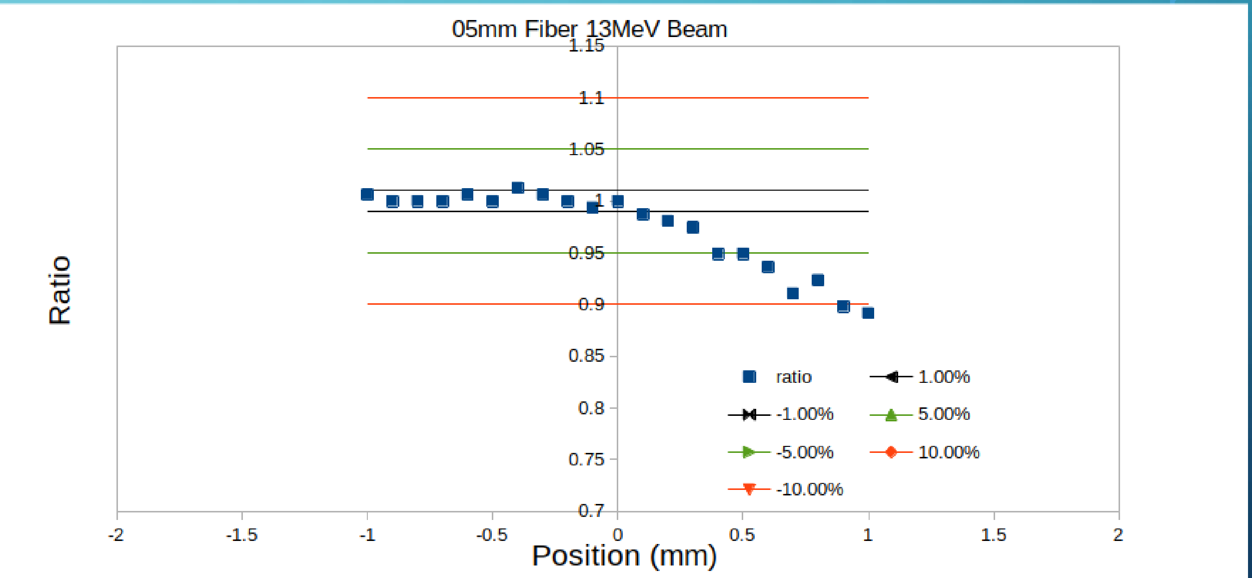


Figure16. Ratio between the energy absorbed by the optical fibre in the central position and the other positions. Simulations for 0.5 mm optical fibers.

OPTICAL FIBRE ARRAY ASSEMBLY AND QUALITY CONTROL

- The technique chosen to be used in the quality control protocol is confocal microscopy with fluorescence.

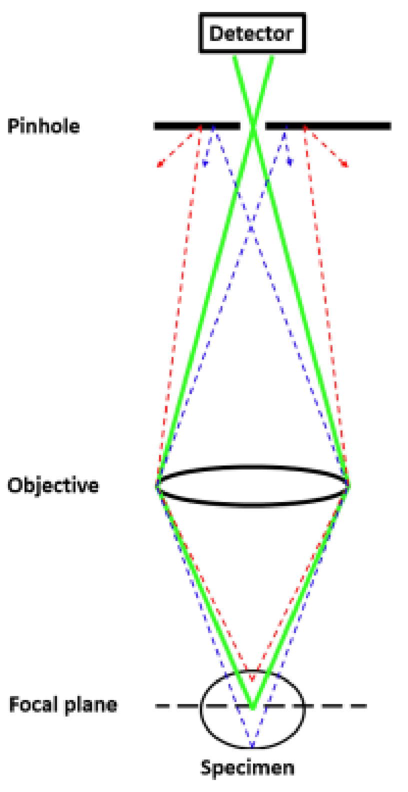


Figure17. Confocal microscopy scheme.

Figure18. Dummy optical fibre array. Produced to perform the tests.

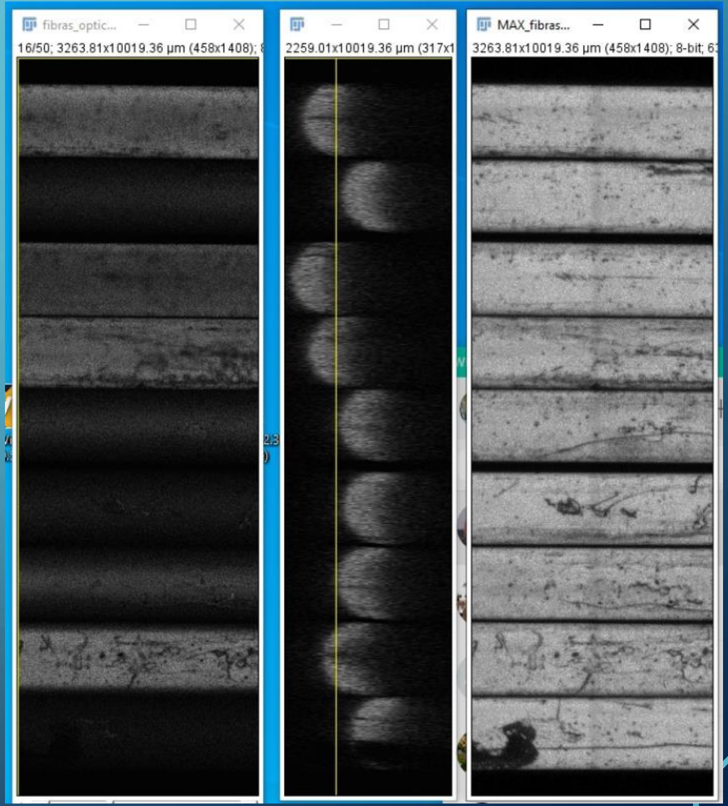


Figure19. Result of the measurements made with confocal microscopy. The middle image shows that the optical fibres are not all in the same plane.

4. Detector Design.

DETECTOR DESIGN

34 x 31.5 x 16 cm

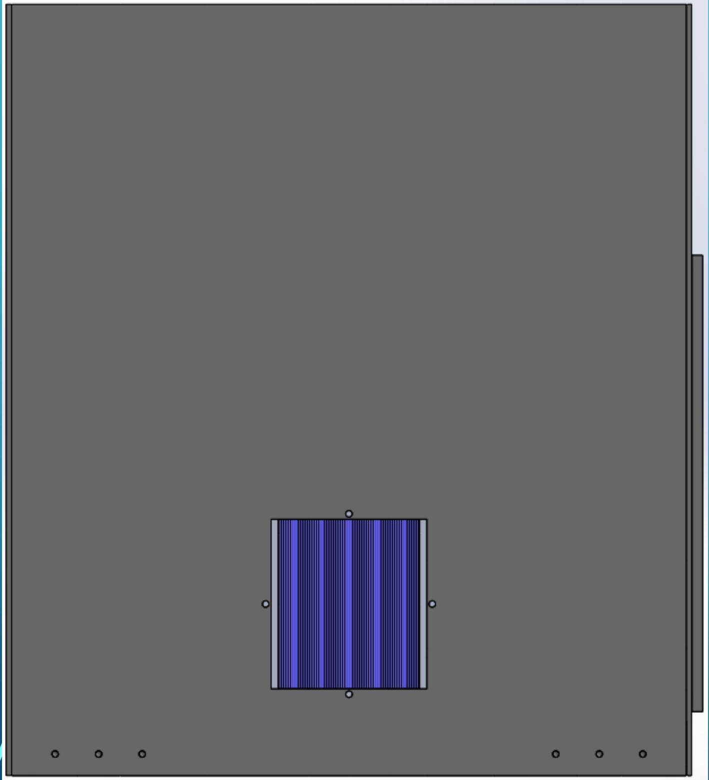


Figure20. Front view of the detector.

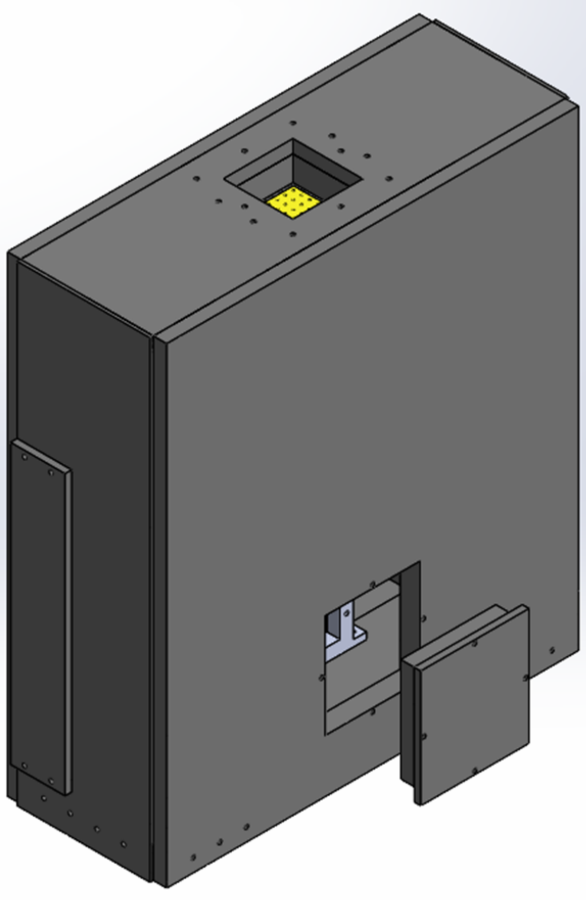


Figure21. Back view of the detector. The beam entrance is shown.

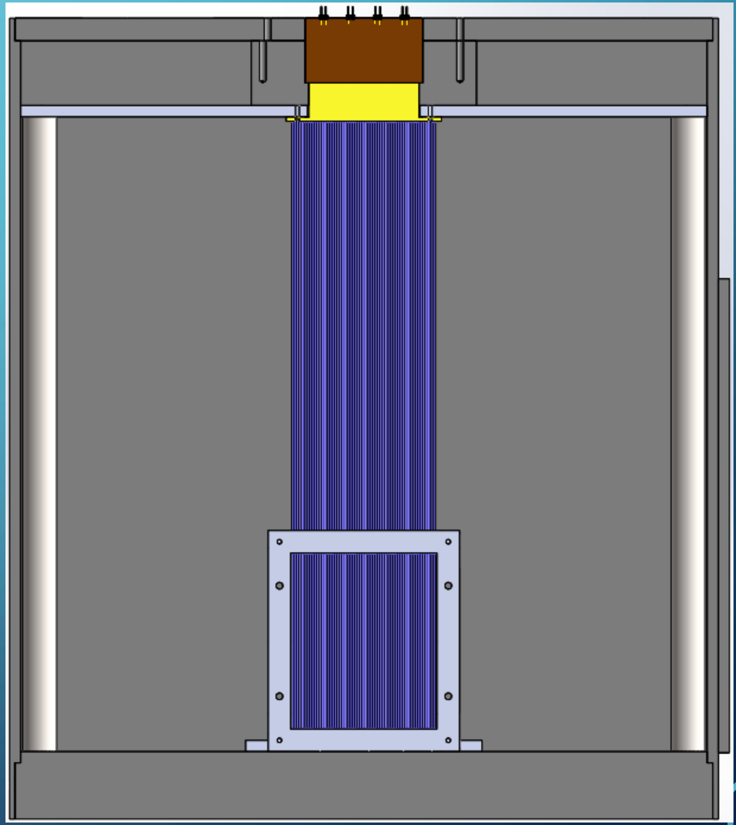


Figure22. Inside view of the detector. The volume that receives the optical fibres is shown.

DETECTOR DESIGN

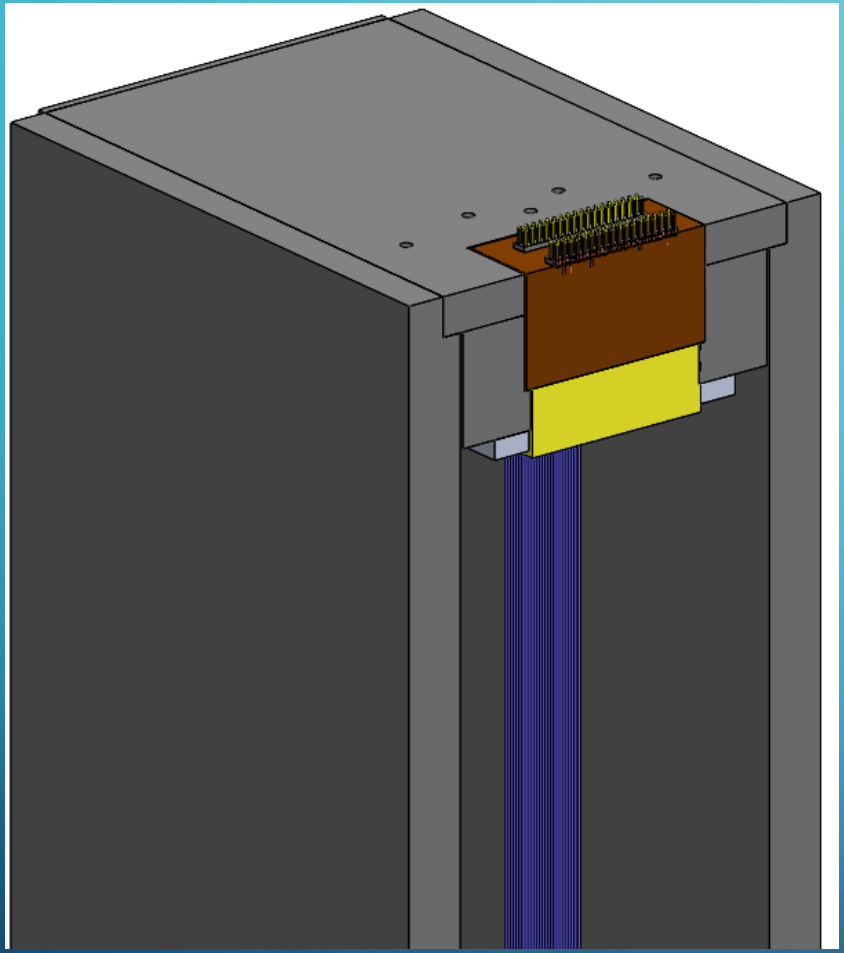


Figure23. Inside view of the detector. The PMT (in brown) and the connector (in yellow) is shown.

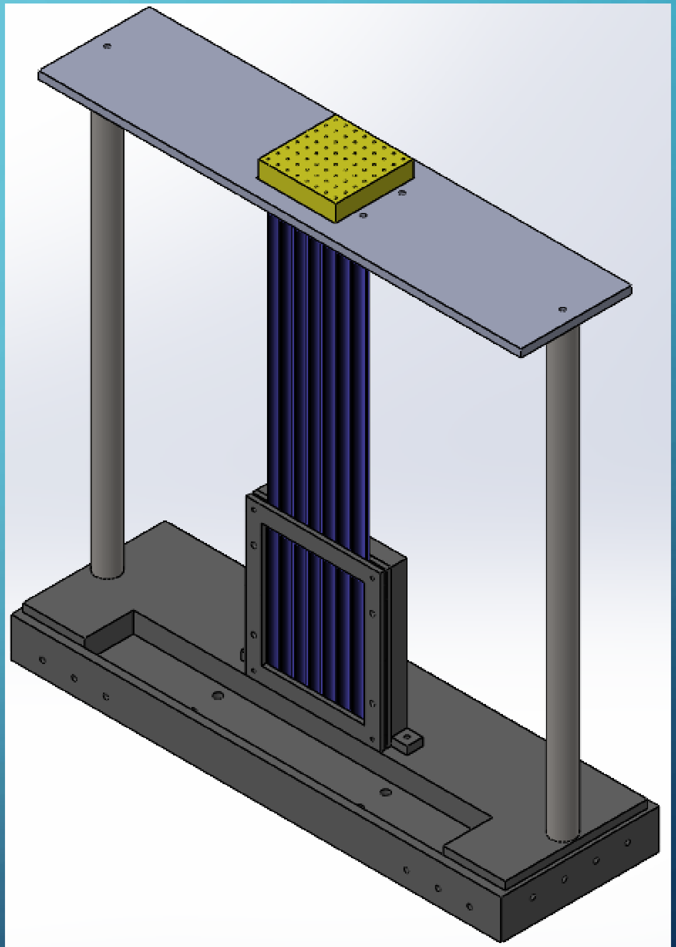
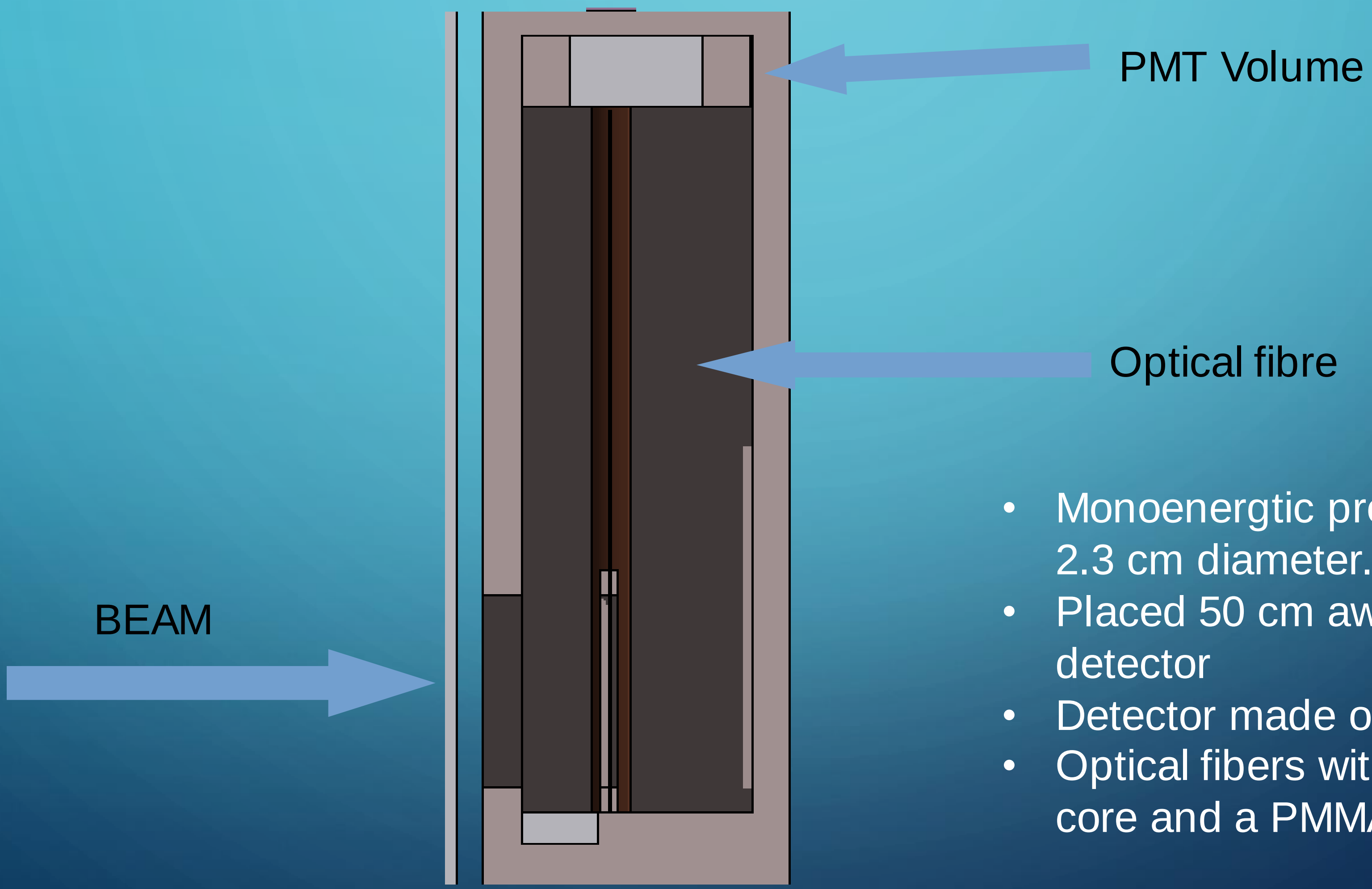


Figure24. System developed to guarantee that the connector is placed with precision in the detector.

5. Shielding and Optical Photons Transport Simulations.

SIMULATIONS



- Monoenergtic proton beam with 2.3 cm diameter.
- Placed 50 cm away from the detector
- Detector made of POM plastic
- Optical fibers with a polystyrene core and a PMMA cladding

SIMULATIONS - SHIELDING

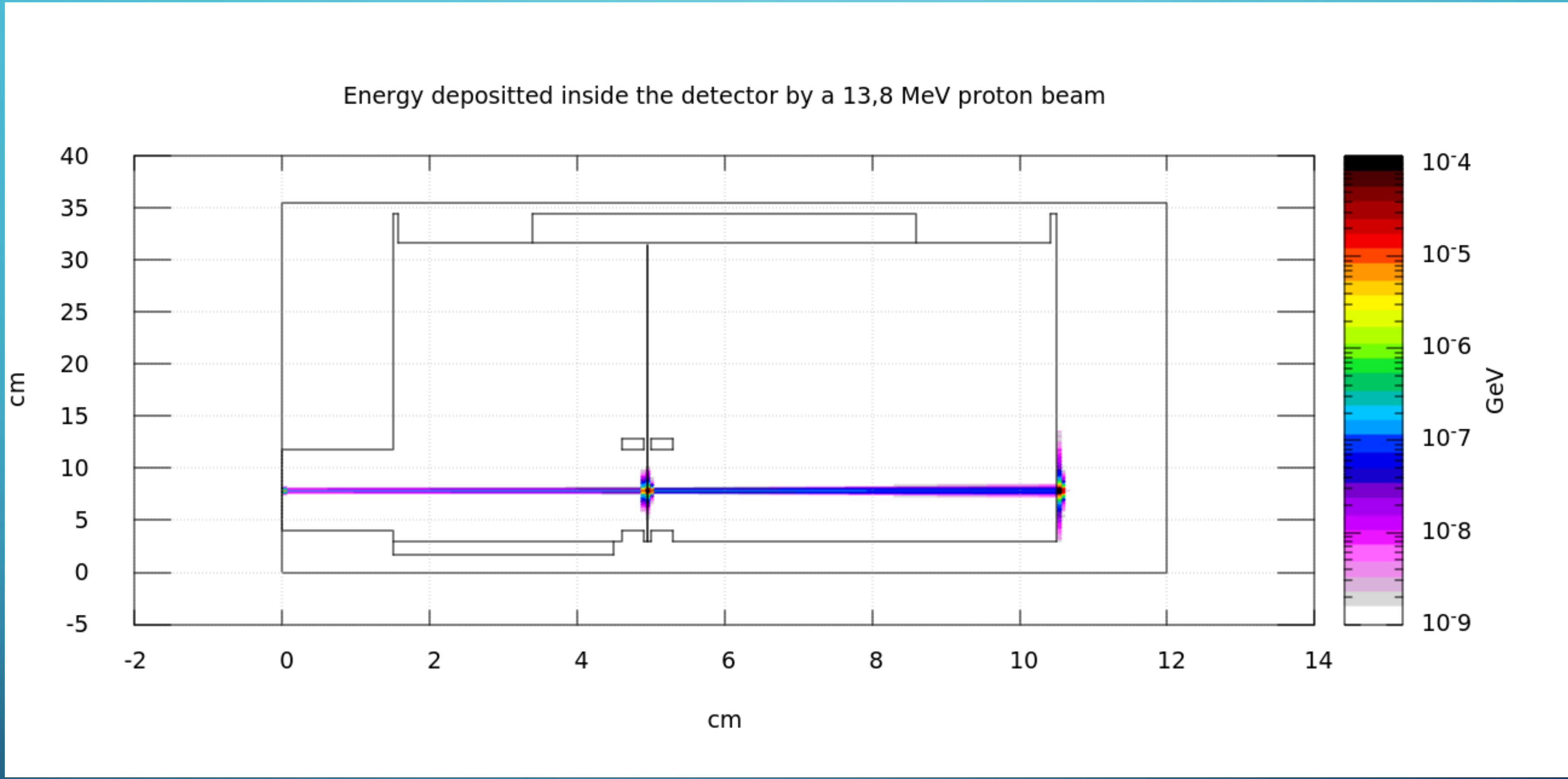


Figure25. Energy deposited inside the detector by a proton beam. The figure shows a cross section of the detector. Simulations performed with FLUKA.

SIMULATIONS – OPTICAL PHOTON PRODUCTION AND TRANSPORT

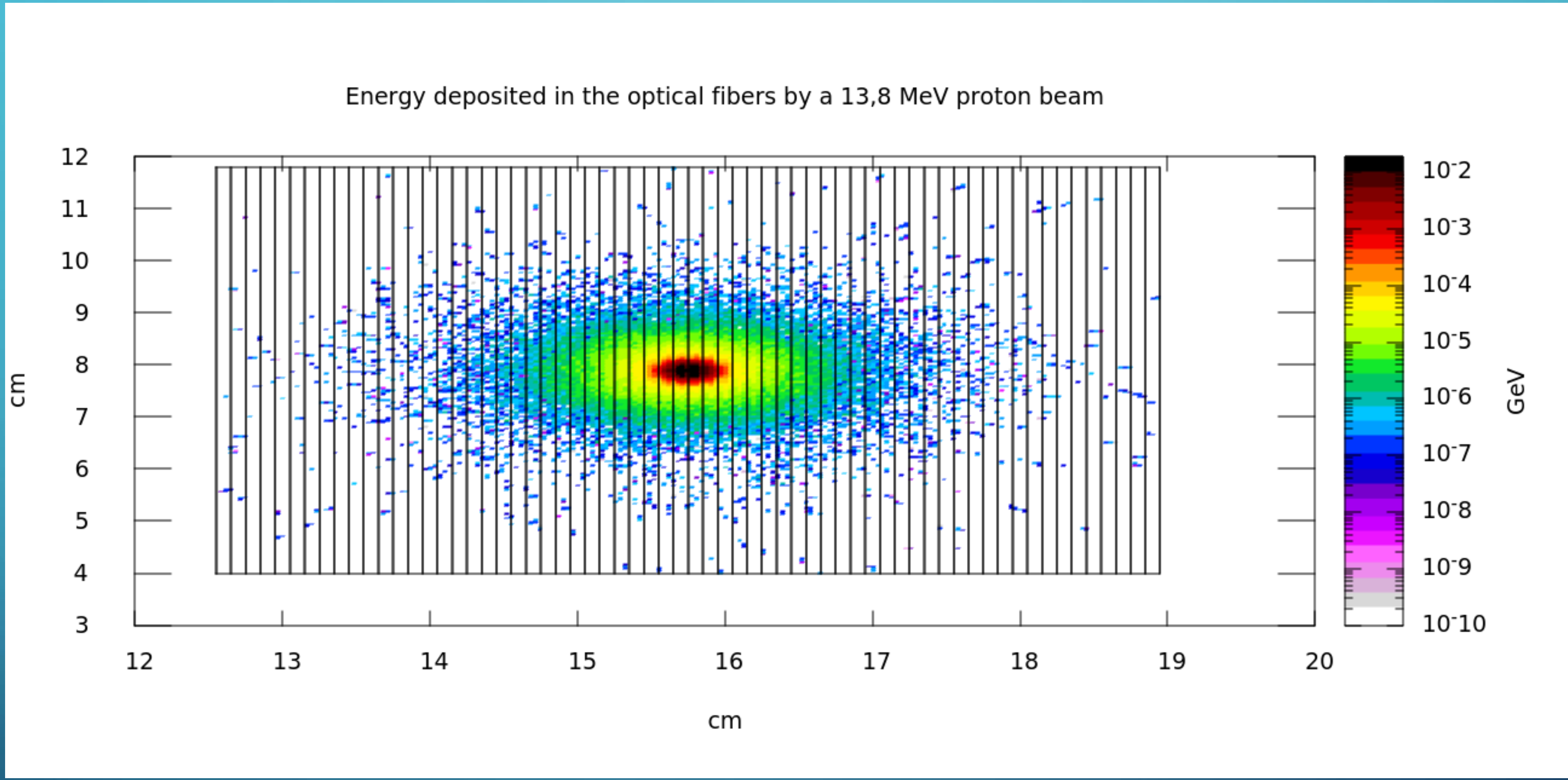


Figure26. Energy deposited by the proton beam in the optical fibres. Simulations performed with FLUKA.

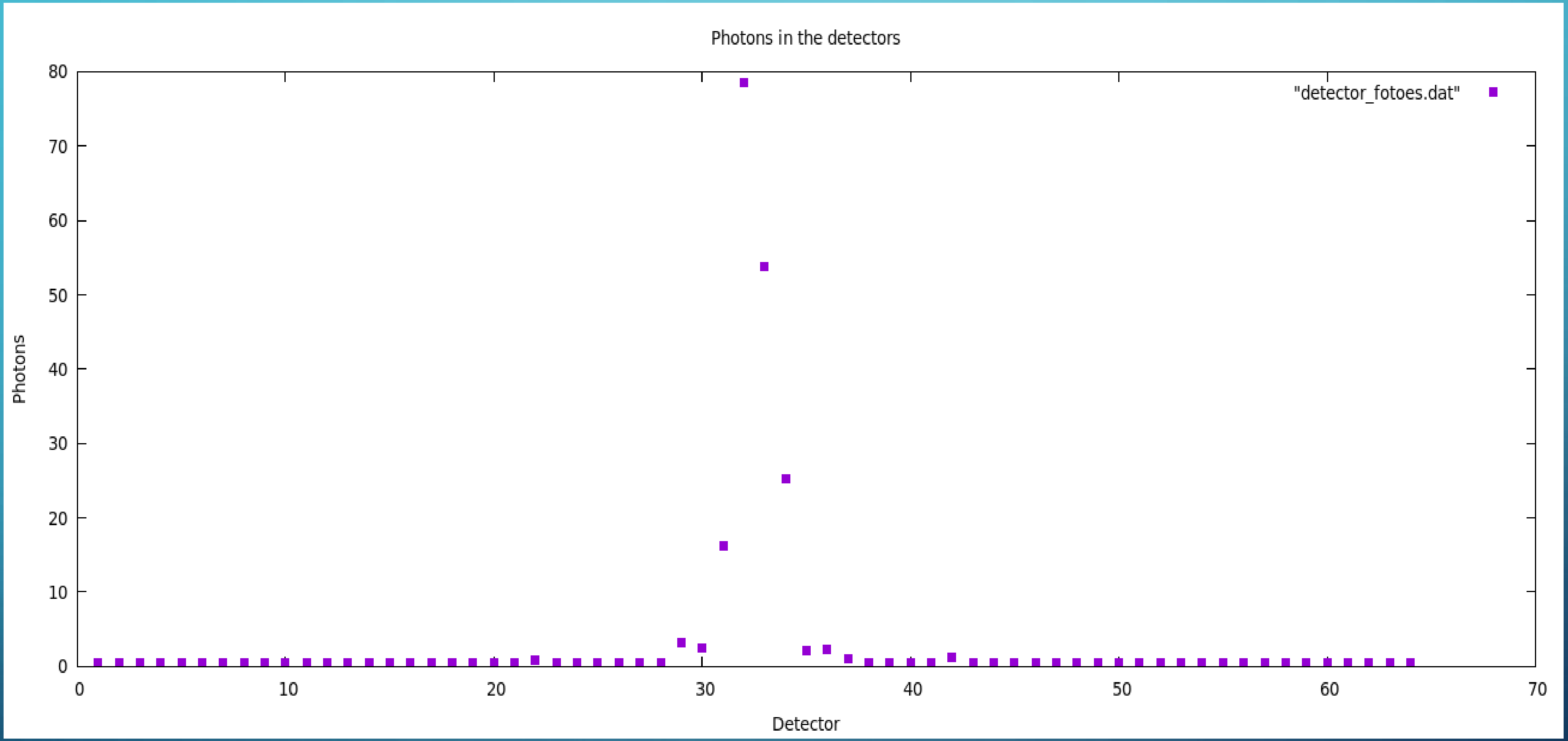


Figure27. Signal for each optical fiber.

FUTURE WORK

- Finish producing the detector. The detector's design is under discussion with the mechanical workshop at LIP- Coimbra.
- Produce the optical fibre arrays using the tool produced at the mechanical workshop at LIP-Coimbra. Theoptical fibre arrays have to be subject of a quality control protocol, using the technique presented previously.
- Test the interface between the the PMT and the DAQ.
- Perform tests with the detector with X-ray photons, electrons and proton beams.
- Perform tests with cell cultures.
- Perform simulation with a two optical fibres planes
- Construct the detector with two optical fibre planes

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