A SCINTILLATING FIBER DOSIMETER FOR RADIOTHERAPY

G. Bartesaghi

INFN - Milano, Università degli Studi dell'Insubria - Como

in collaboration with Azienda Ospedaliera Sant'Anna - Como

Outline

- Radiotherapy in the cancer care
- Why a multichannel scintillator detector?
- Single scintillating fiber prototype
- Multifiber monodimensional detector
- 2D prototype
- Conclusions and outlooks

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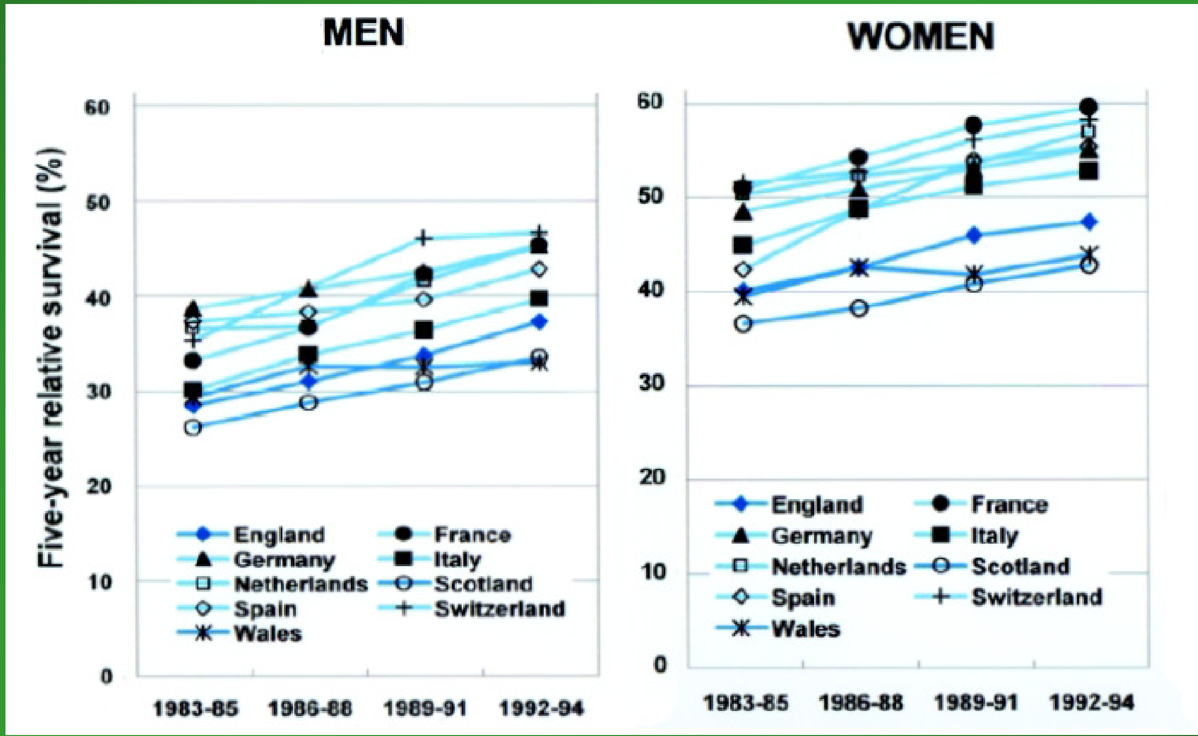
Radiotherapy in the cancer care

In the last decades, a constant progress has been made in the fight against cancer



Data from EUROCARE 3 (European cancer registries study on cancer patients' survival and care)

Three factors have a crucial role:

- primary prevention
- earlier diagnosis
- better treatment

General treatment methods

- chemotherapy
- immunotherapy

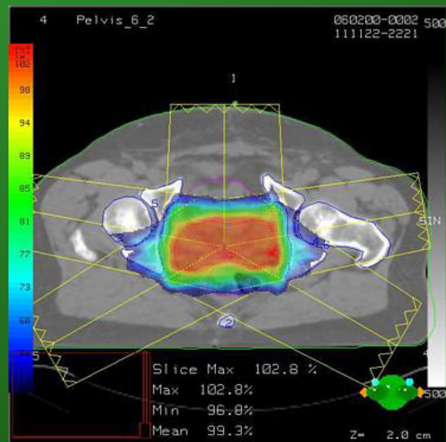
} *systemic treatments*

- radiotherapy
- surgical removal

} *loco-regional treatments*

Radiotherapy exploits the effect of ionizing radiation on human tissues to eliminate tumour cells or to control their development.
The radiation beam typically consists in electrons or photons (energy up to 20 MeV) emitted by a linear accelerator.

Radiotherapy is one of the most popular method in cancer treatment.
Every year, more than 5 millions patients worldwide receive almost a radiotherapic treatment, exploiting more than 7500 linacs.



Quality assurance in Radiotherapy

For the future, the goal for radiotherapy is the same of the past

→ delivering a high dose in the target volume preserving the surrounding volume

All the procedures that ensure consistency of medical prescription and safe fulfilment of that prescription are part of the quality assurance.

The goal of this work is to develop of a dosimeter that, performing real time 2D measurement in the radiation beam, may simplify and accelerate the quality assurance controls.

Why a scintillator dosimeter?

Most popular dosimeters:

Ionization chambers and diodes	real time, accurate single channel not tissue equivalent
Radiographic films	excellent 2D resolution long processing time not tissue equivalent
TLD	small size time consuming requiring great care

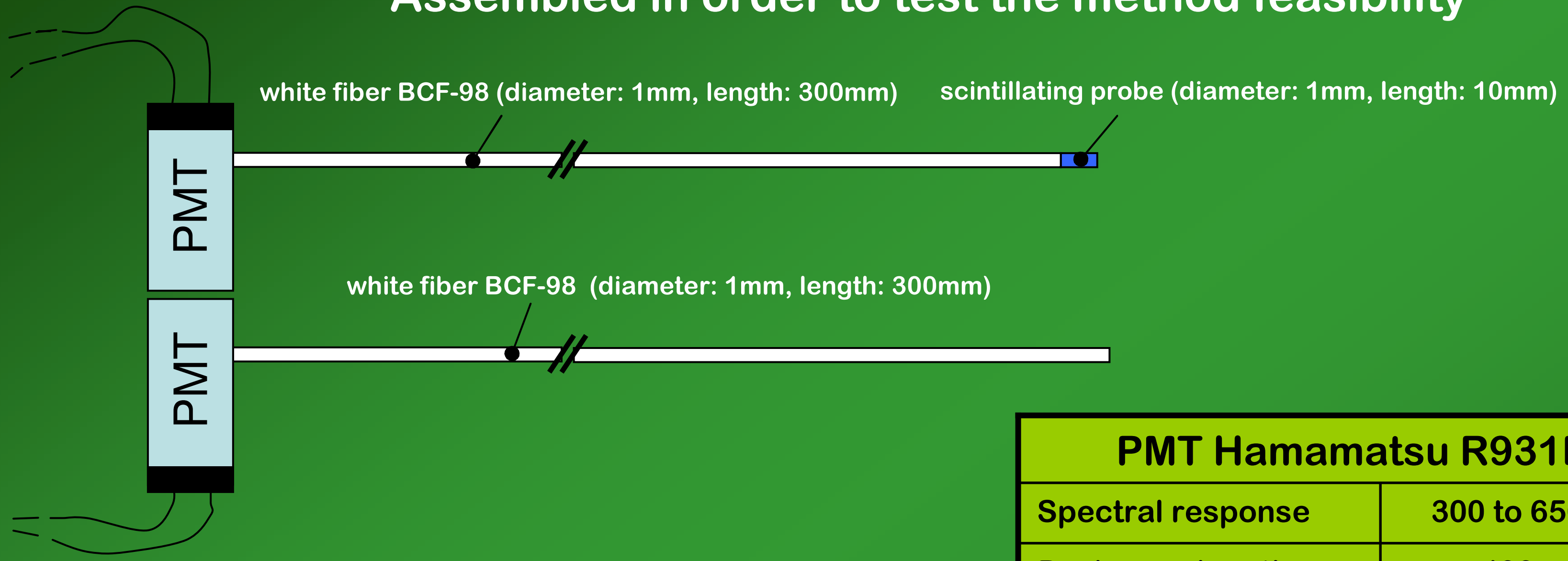
Why a scintillator dosimeter?

A plastic multifiber scintillator dosimeter assures important advantages:

- real time measurement of 2D dose distribution
- high tissue equivalence
- a large dynamic range (100 keV – more than 20 MeV)
- excellent radiation hardness
- no pressure and temperature dependence
- no high voltage near the probe

Single channel dosimeter

Assembled in order to test the method feasibility



PMT Hamamatsu R931B	
Spectral response	300 to 650 nm
Peak wavelength	400 nm
Num. of mult. stages	9

High energy electrons crossing a transparent medium produce Cherenkov light, which is not proportional to absorbed dose.

It is therefore necessary a twin detector, without the scintillating probe, in order to evaluate the Cherenkov contribution.

Scintillating fiber Bicron BCF-10	
Material	polystyrene
Diameter	1mm
Emission color	blue
Emission peak	432 nm
Decay time	3.2ns
No. of photons per MeV	~ 8000

Linear Accelerator

Clinac Varian 2100

Radiotherapy Unit
Ospedale S. Anna
Como (Italy)

Electron beam:

- Energy: 6, 9, 12, 16, 20 MeV
- Dose rate: from 100 to 600 MU/min
- Field: up to 25x25 cm^2

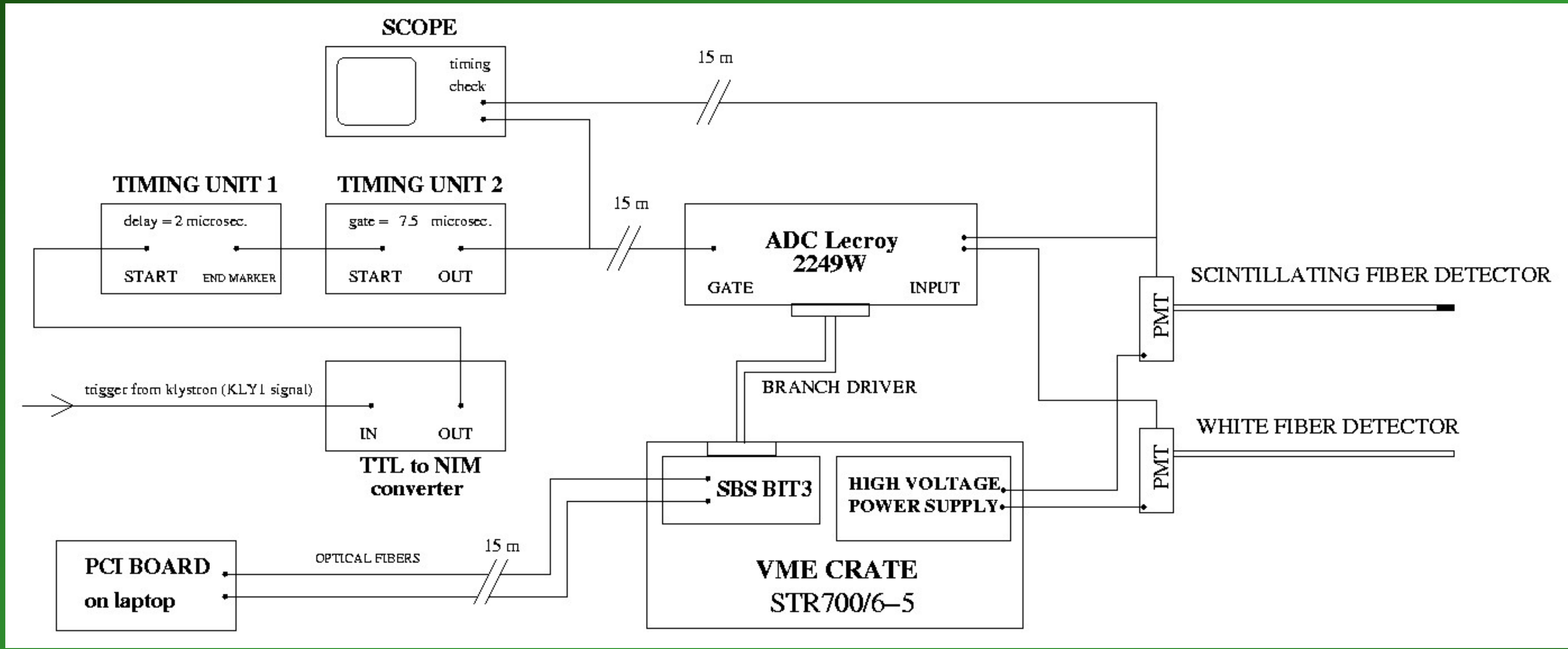
Photon beam:

- Energy: 6, 18 MV
- Dose rate: from 100 to 600 MU/min
- Field: up to 40x40 cm^2

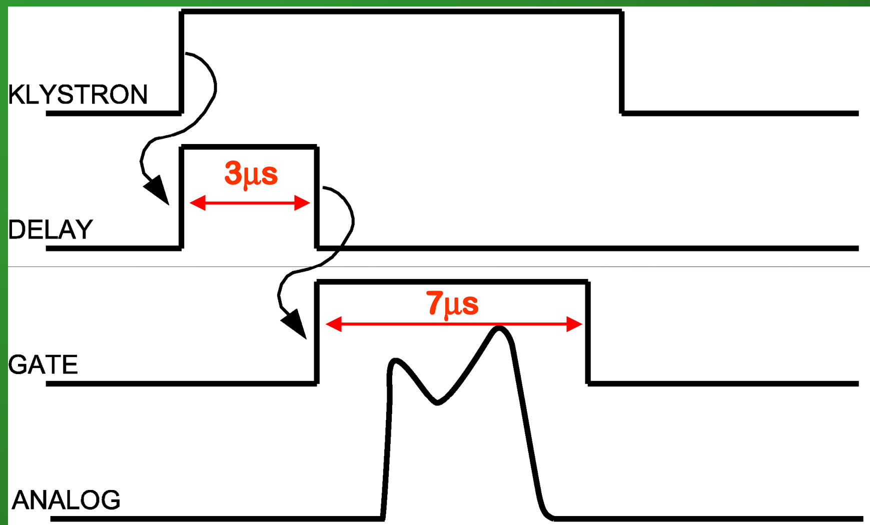
1 Monitor Unit = 1 Gy at the build up (maximum dose region)

Particles are emitted in bunches (100-300 Hz, depending on the dose rate)

Read out electronics

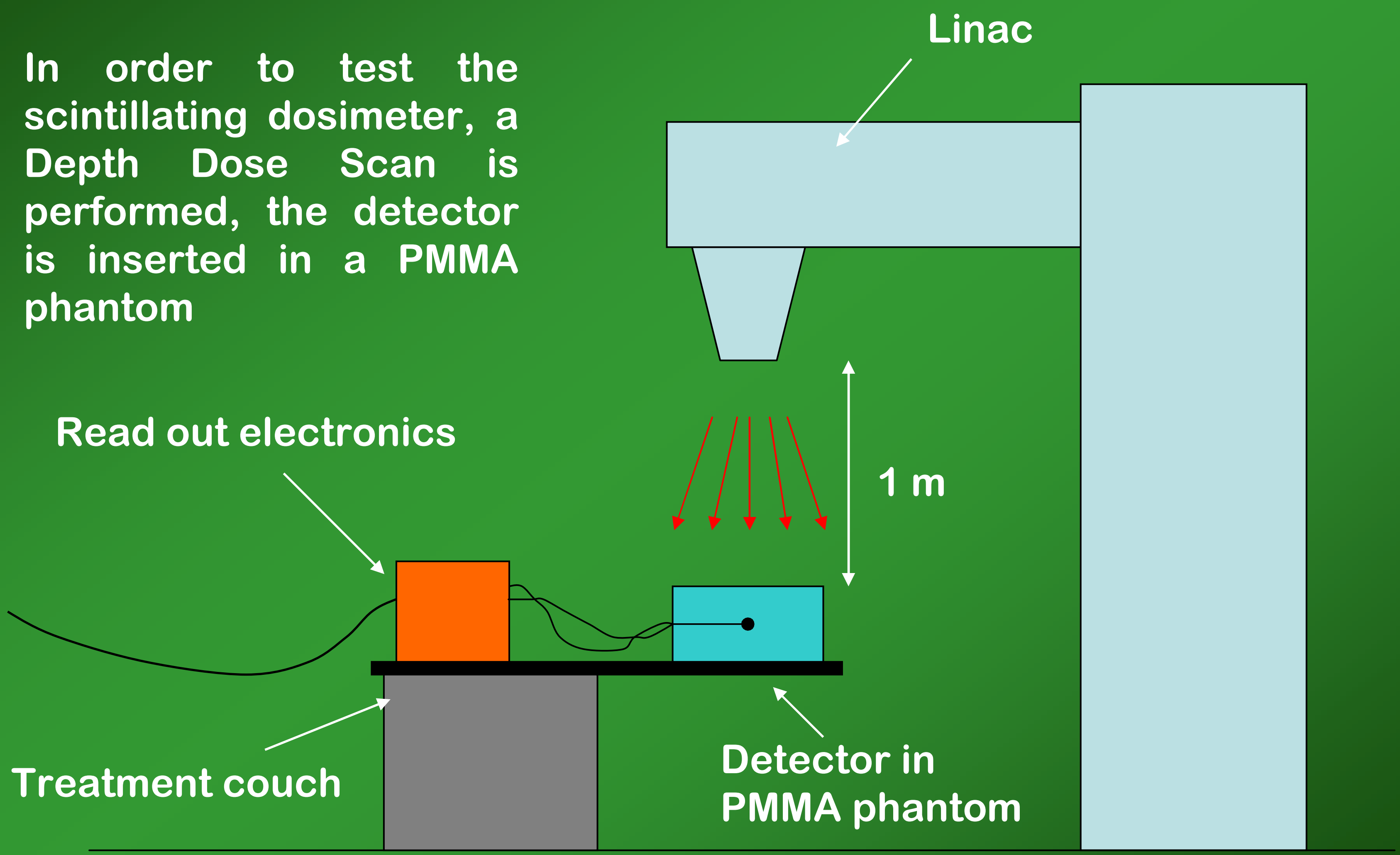


The read out electronics is based on a charge integrating ADC (12 channels), with the trigger taken from the linac itself

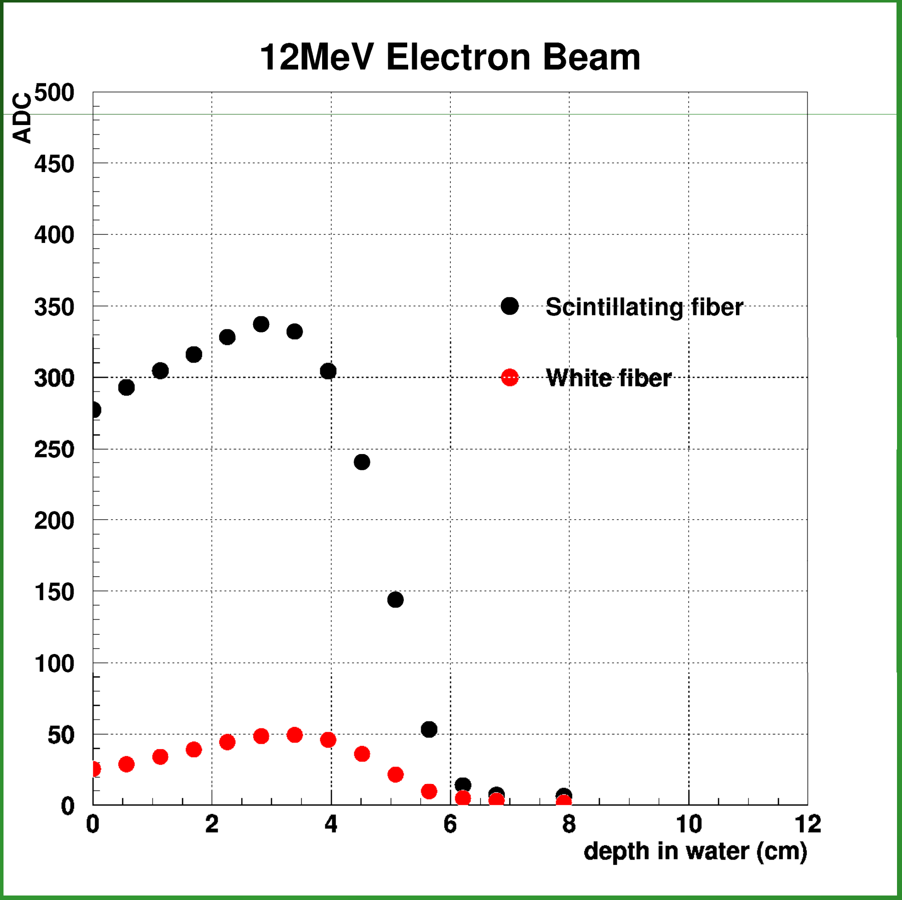


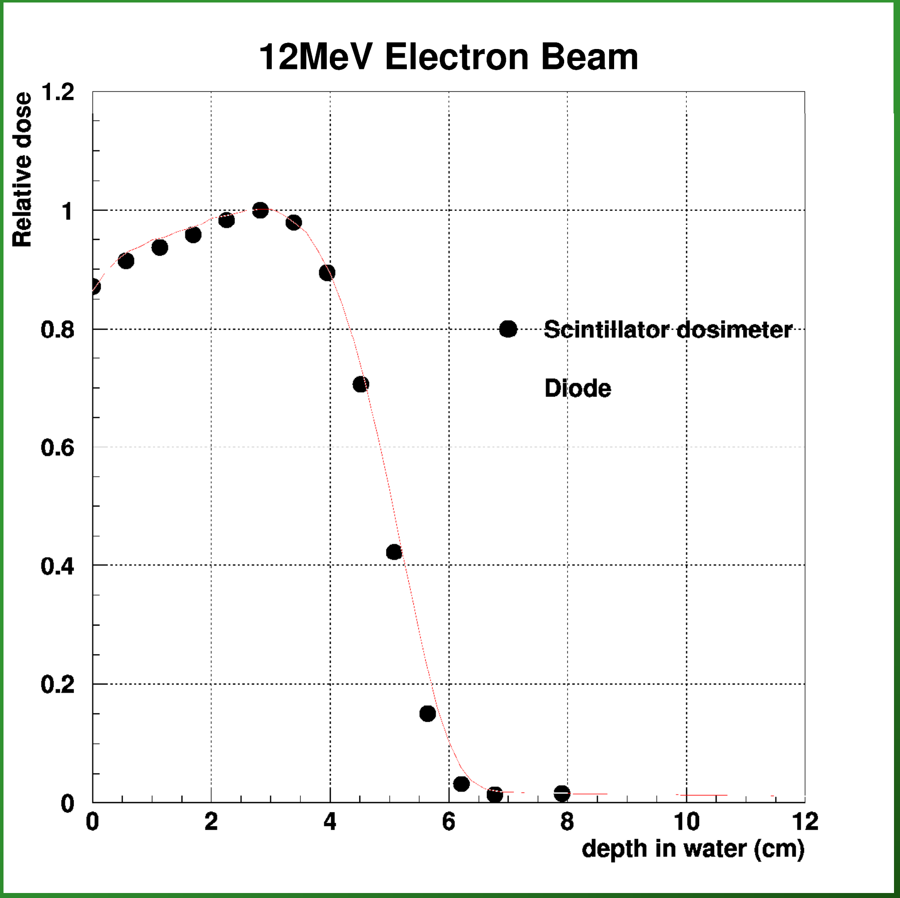
Measurement set up

In order to test the scintillating dosimeter, a Depth Dose Scan is performed, the detector is inserted in a PMMA phantom



Depth Dose Curves in Electron Beams

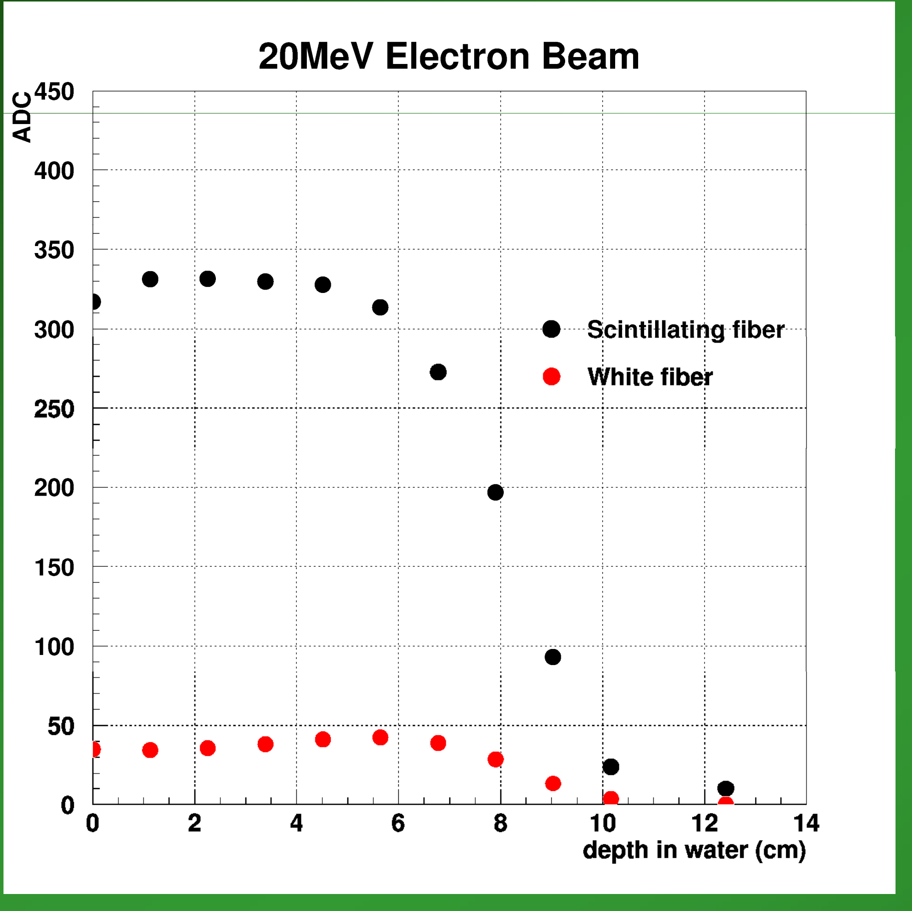


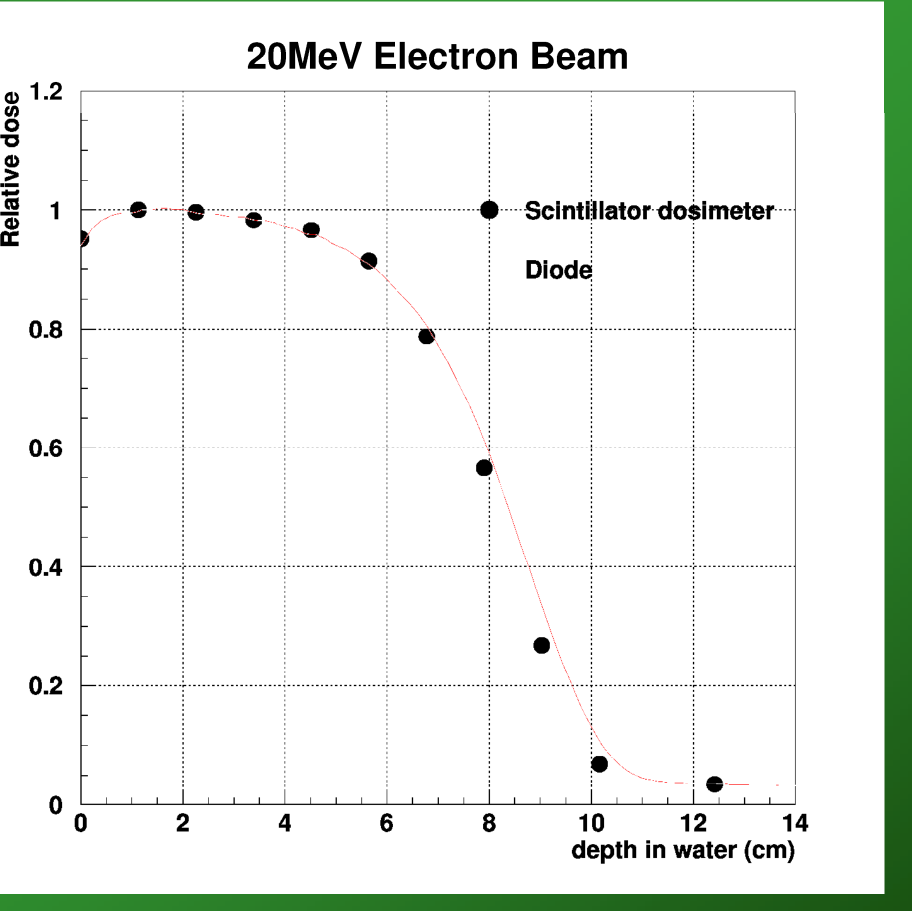


Field size: 10x10cm^2

Our measurements are compared with data taken by a diode Scanditronix DEB101 (1.25 mm^3)

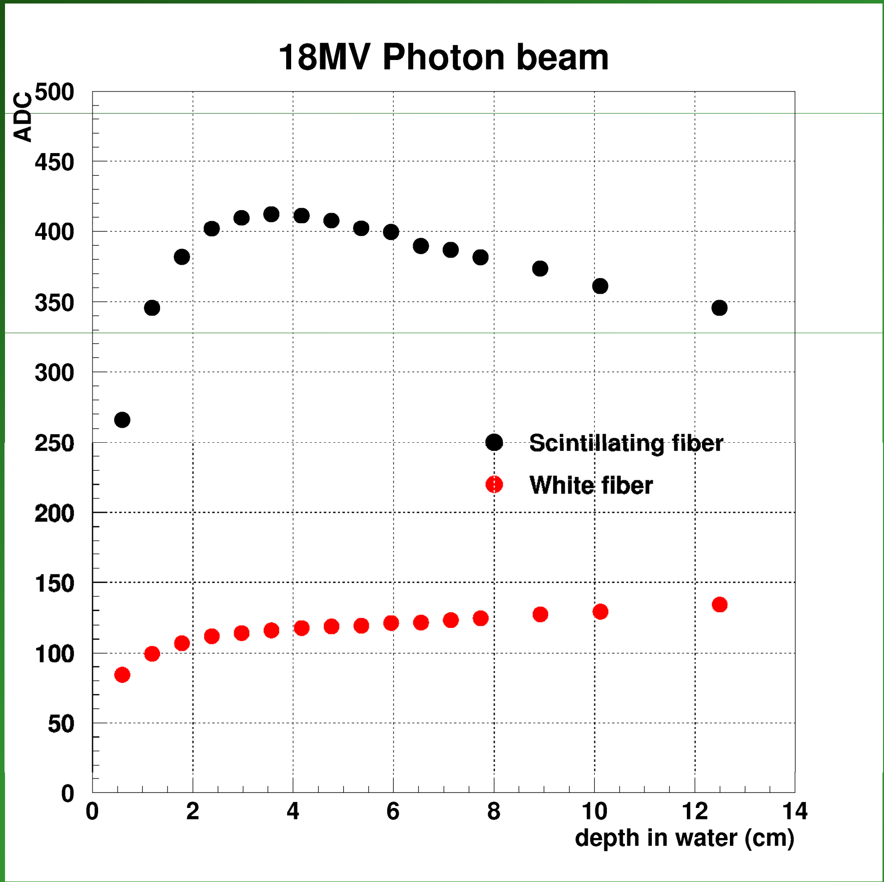
Depth Dose Curves in Electron Beams

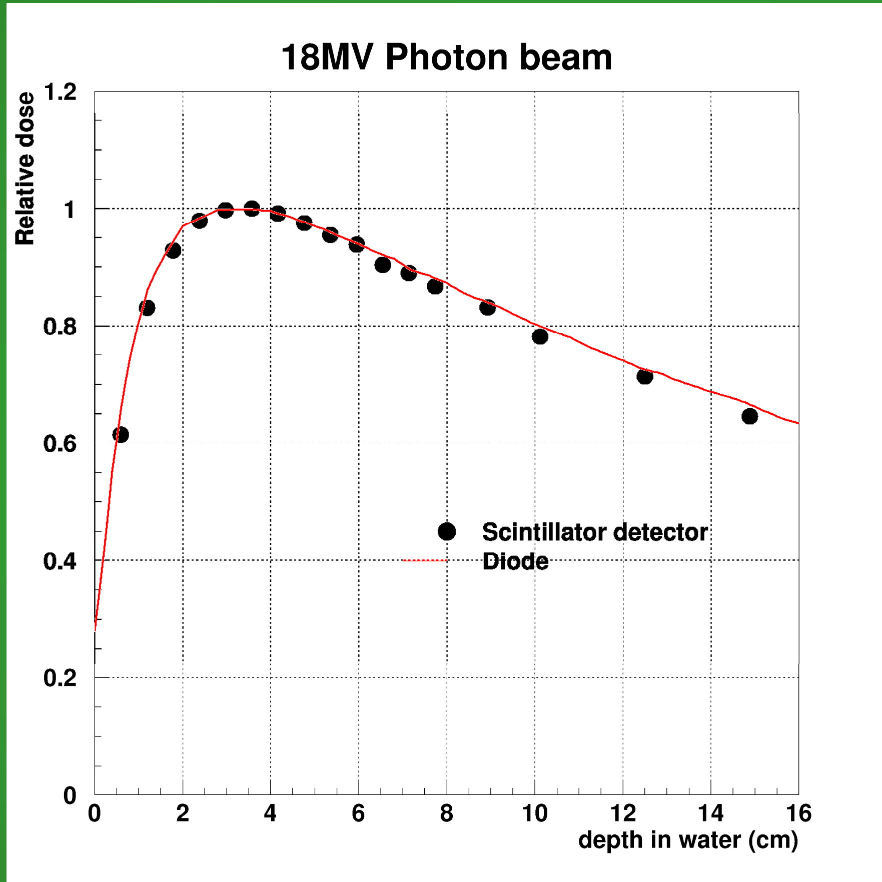




Field size: 10x10cm^2

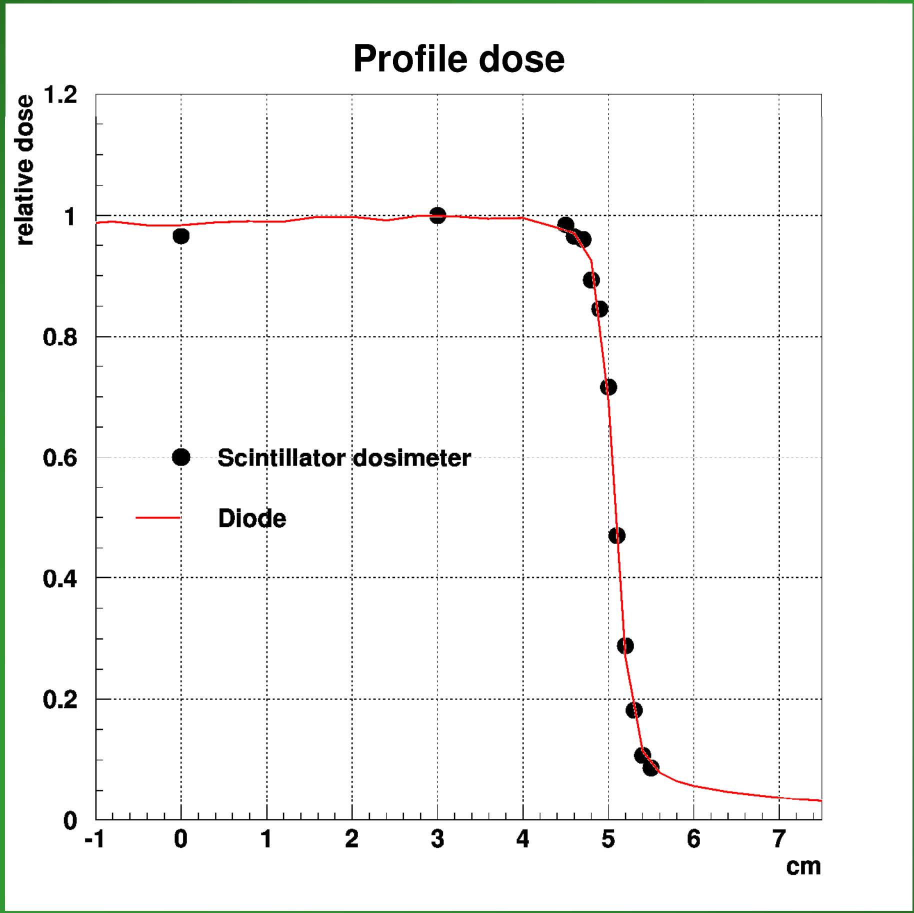
Depth Dose Curve in Photon Beams





Field size: $10x10cm^2$

Crossline scan



In a 6 MV photon beam, the detector is moved across the 10x10cm^2 field.

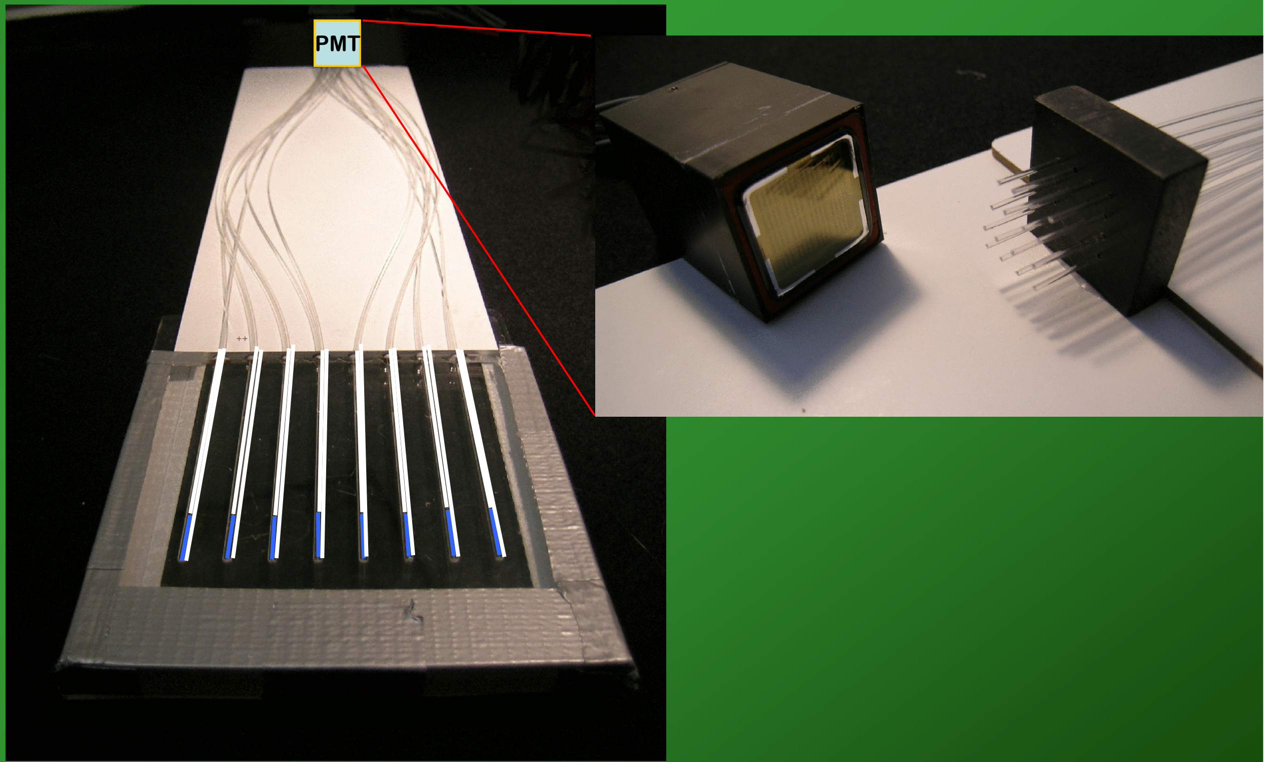
The single channel detector demonstrates the feasibility of a scintillating fiber dosimeter easy to handle and accurate.

Next step is to develop a …

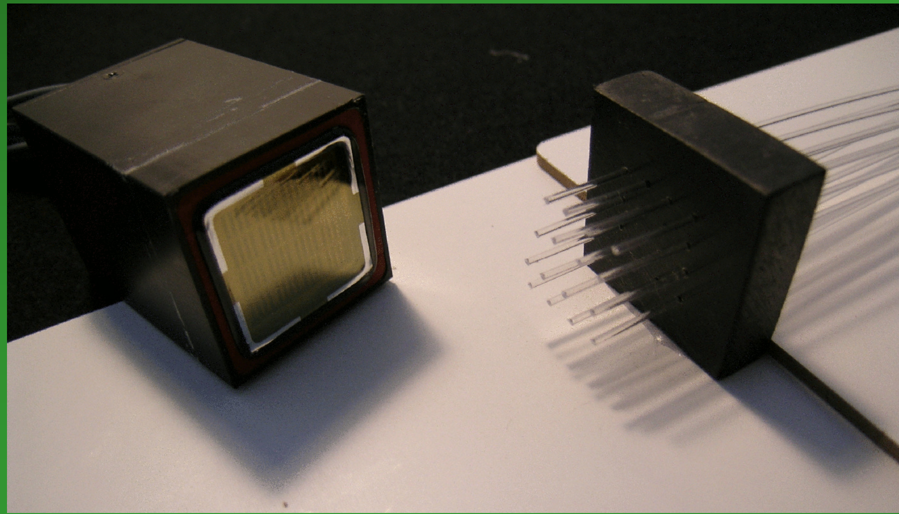
Multifiber 1D prototype

8 scintillating fibers (Bicron BCF-10, 1 cm long) inserted in a PMMA phantom are readout by a multichannel PMT.

Each fiber is coupled with a twin white one for Cherenkov subtraction.



PMT Hamamatsu H8711	
Spectral response	300 to 650 nm
Peak wavelength	420 nm
Electron transit time	10.9 ns



Scintillating fiber Bicron BCF-10	
Material	polystyrene
Diameter	1mm
Emission color	blue
Emission peak	432 nm
Decay time	3.2ns
No. of photons per MeV	~ 8000

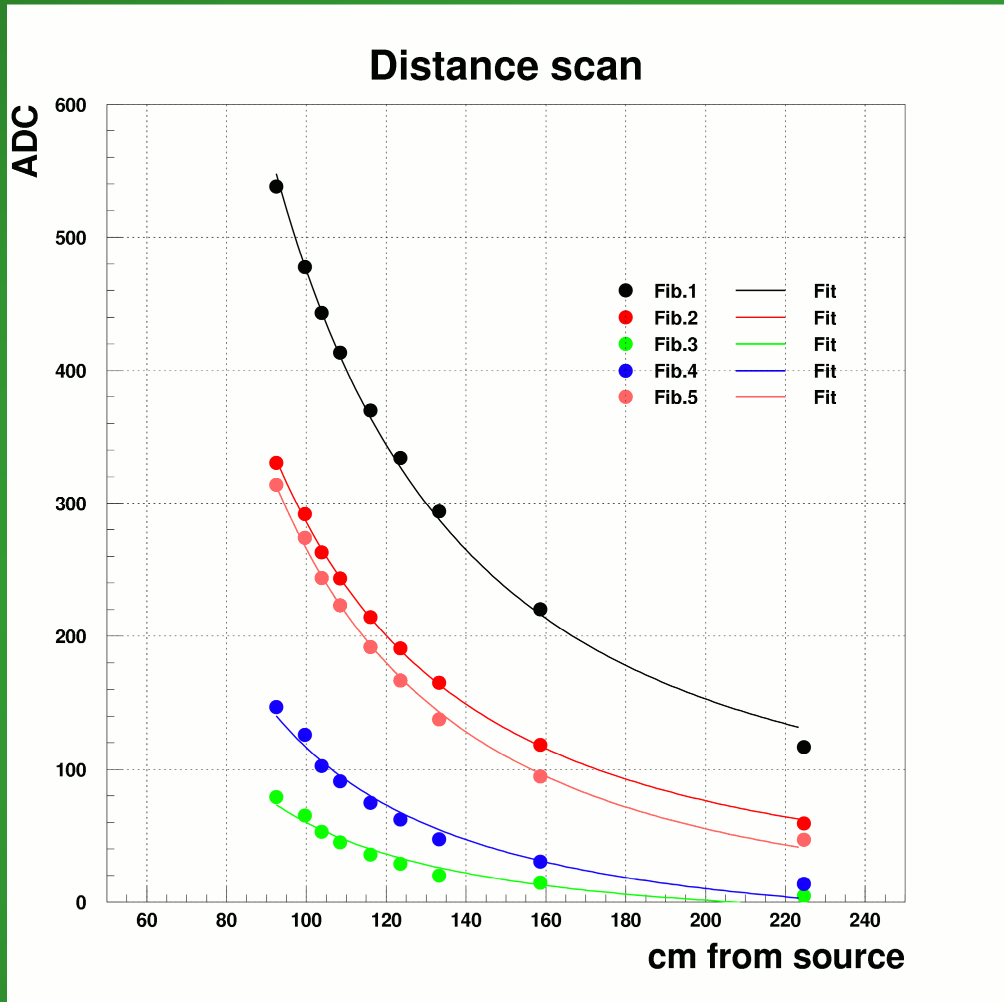
The PMT is a 16 channel, fast and low cross talk device.

Intensity response

The detector was positioned at different distances from the source in order to test the intensity response

Data fitted with

$y = A/x^2 + B$

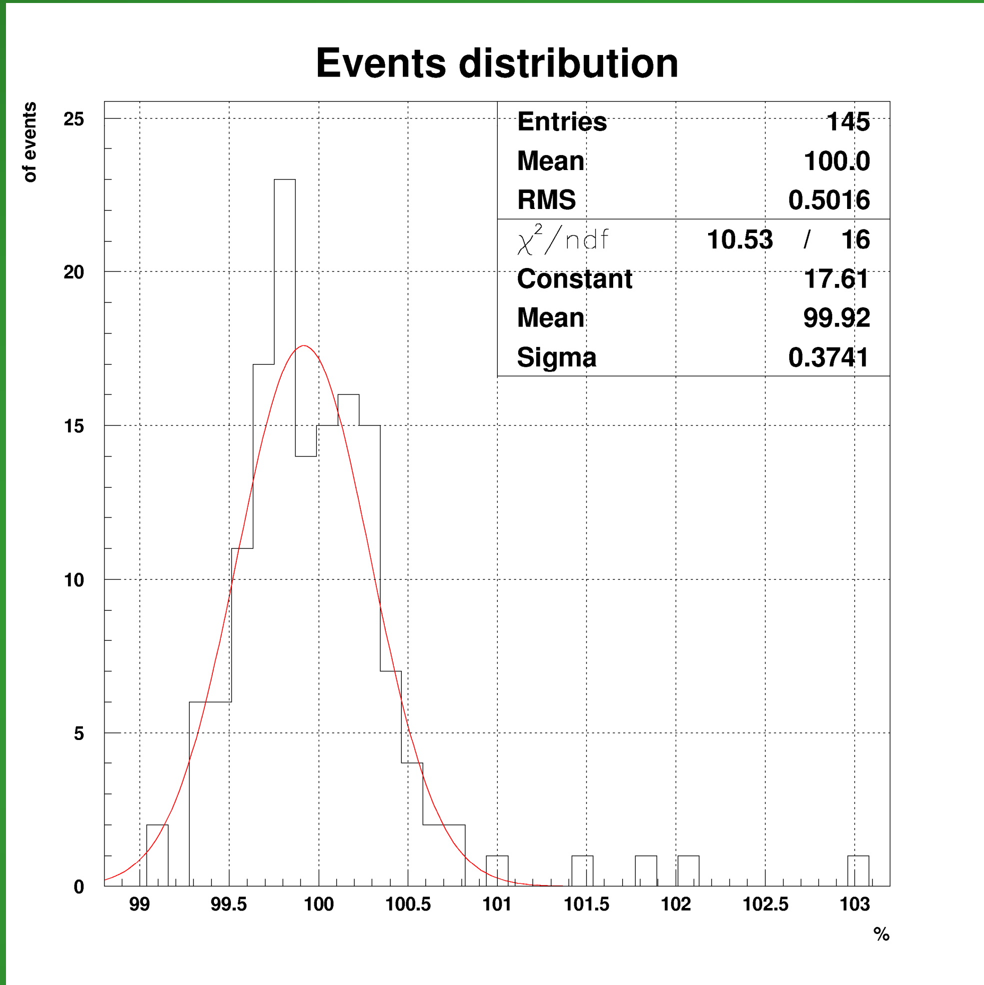


Reproducibility test

5 Gy are given 20 times

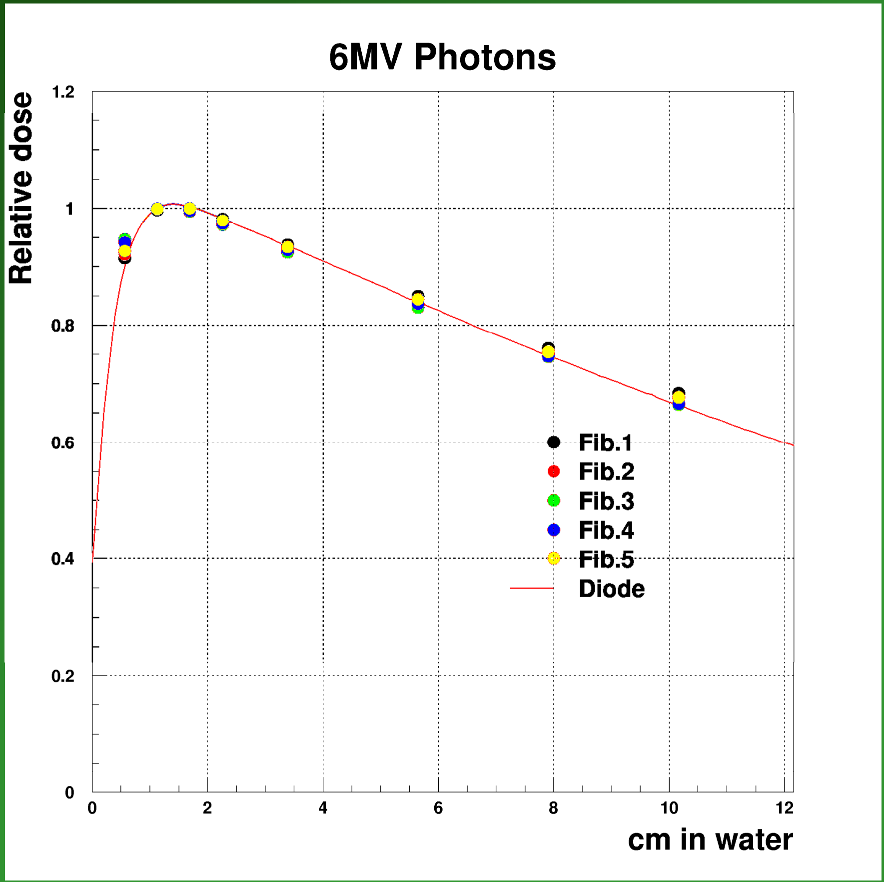
Distribution of the charge read by the 5 scintillating fibers

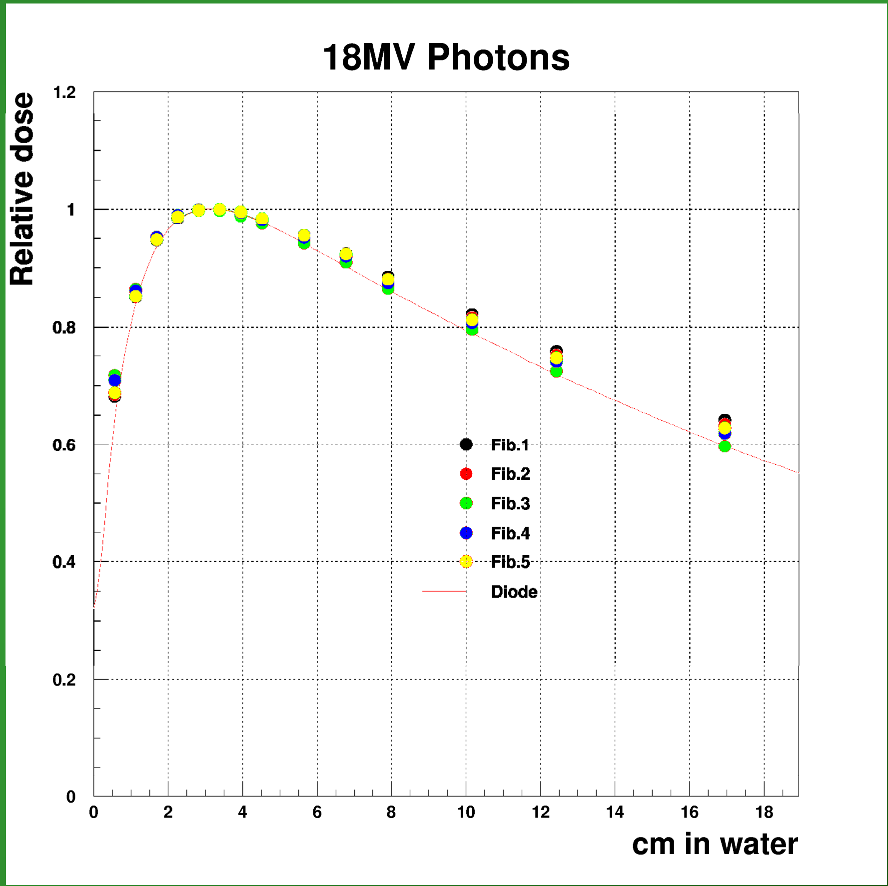
(each channel normalized to 100)



The distribution RMS is about 0.5%

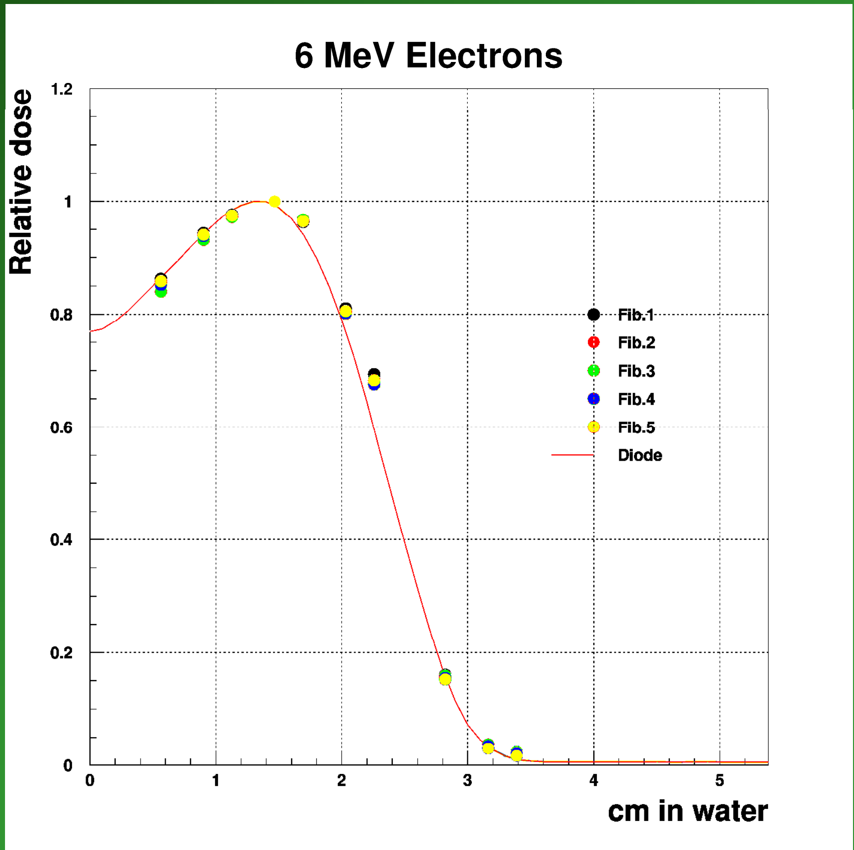
Depth Dose Curve in Photon Beams

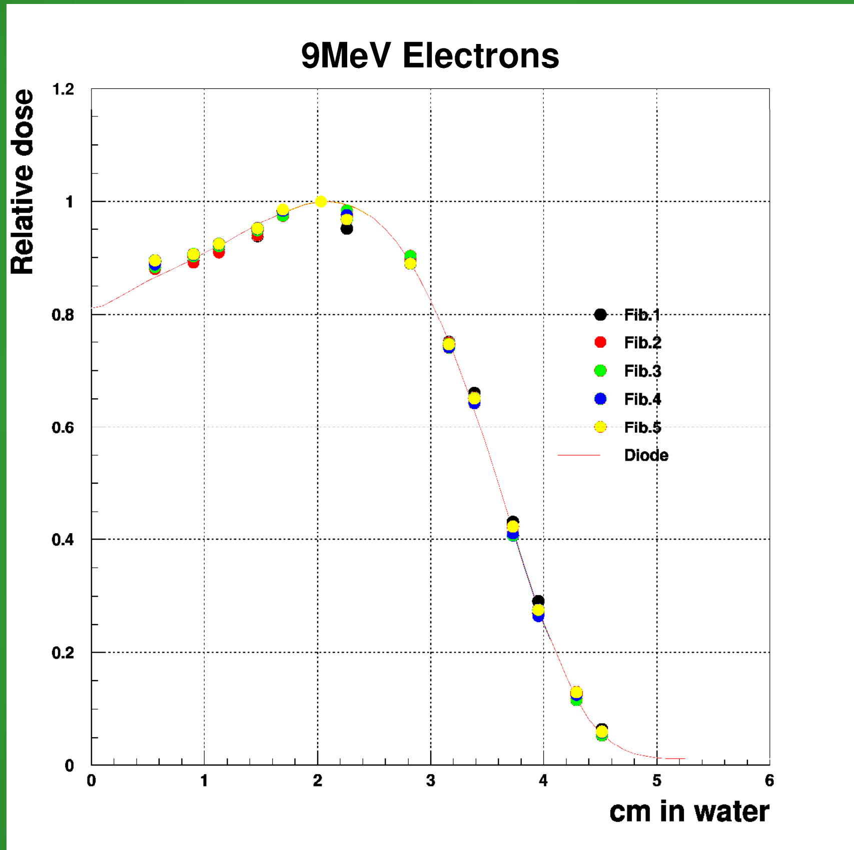




Field size: $10x10cm^2$

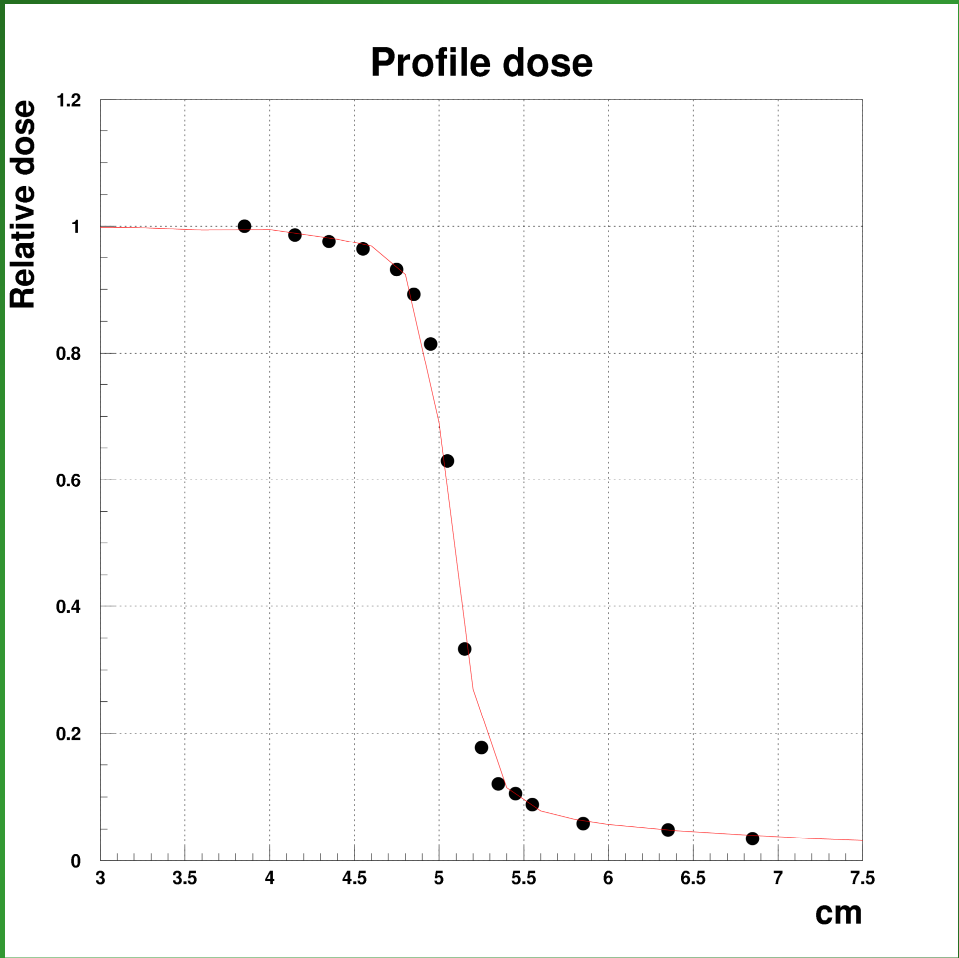
Depth Dose Curve in Electron Beams





Field size: 10x10cm^2

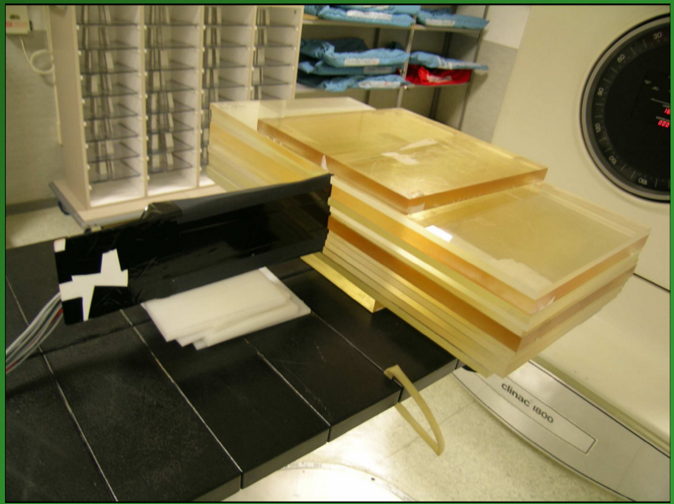
Crossline scan

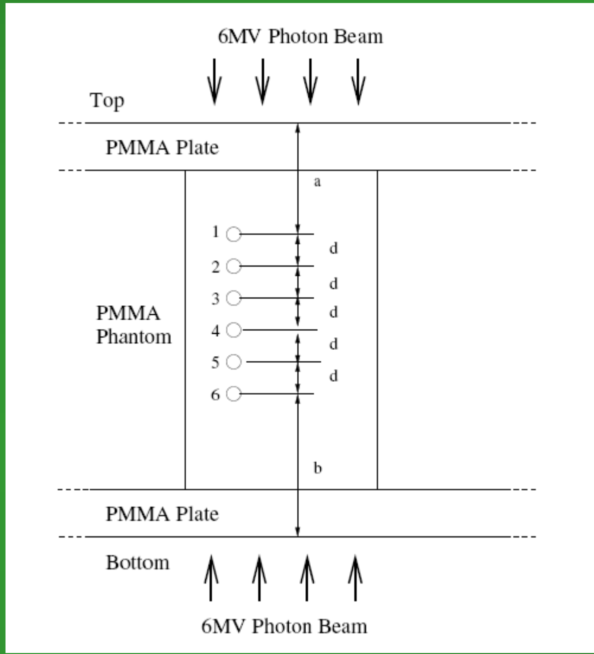


In a 6 MV photon beam, at 1.5 cm depth, the detector is moved across the 10x10cm^2 field.

Gain equalization

In order to evaluate the gain factor of the different channels the detector is positioned vertically and irradiated in a 6MV photon beam twice: from the top and from the bottom side

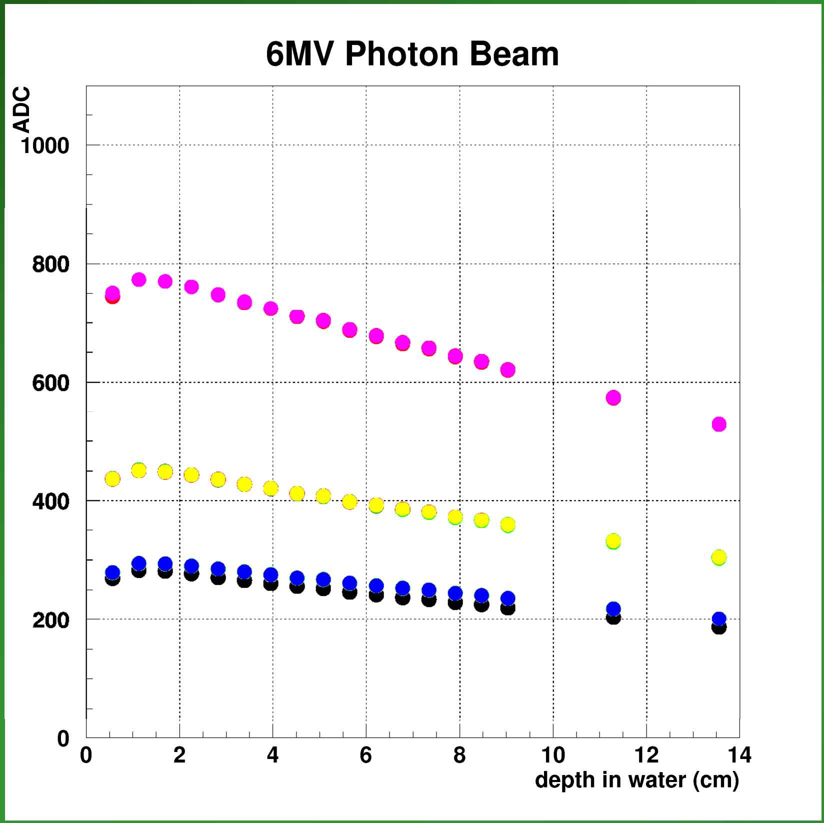


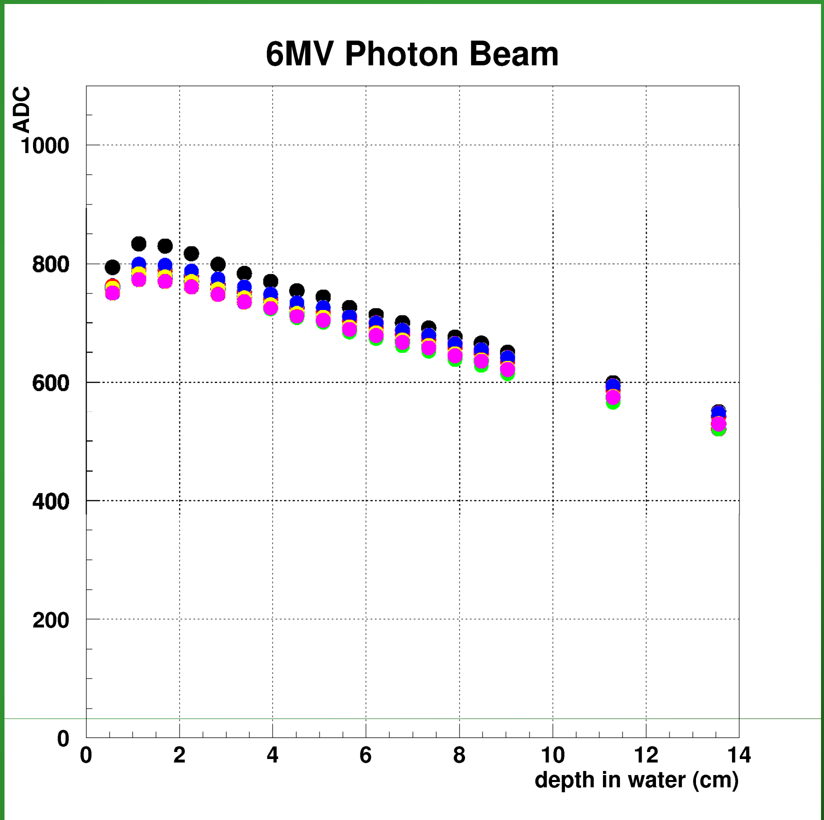


Fiber	Relative gain factors
1	1.000
2	0.576
3	0.368
4	0.581
5	0.976
6	0.339

The photon exponential attenuation is exploited to get the gain factors

Gain equalization



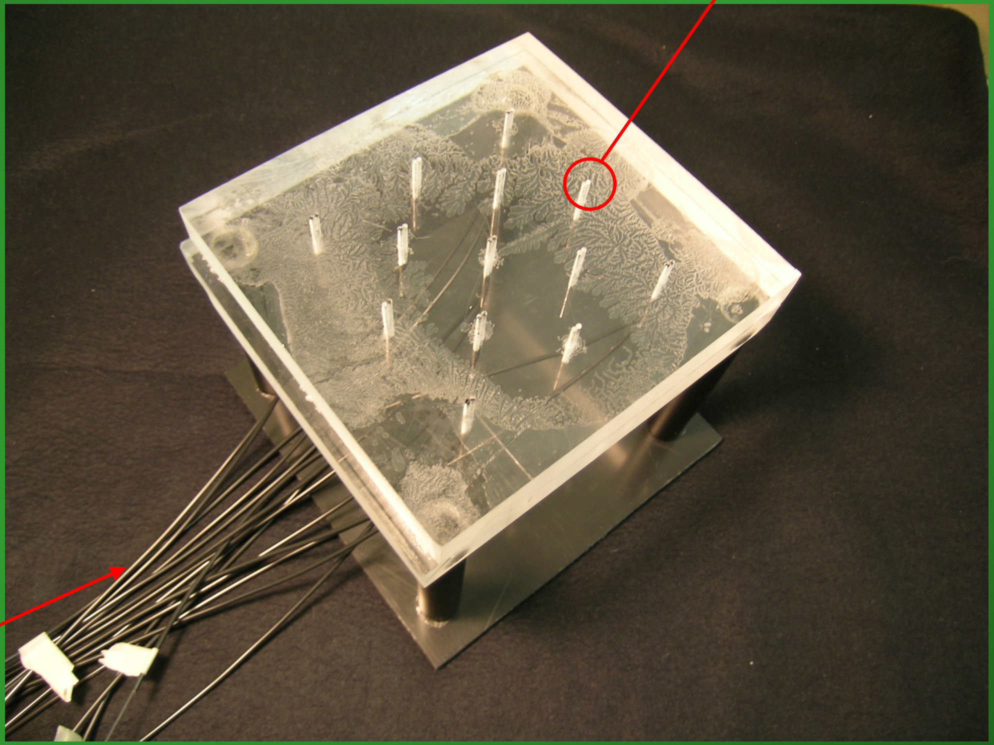


Before and … … after the equalization

Multifiber 2D prototype

1 cm scintillating fiber + 1 cm white fiber in every pit

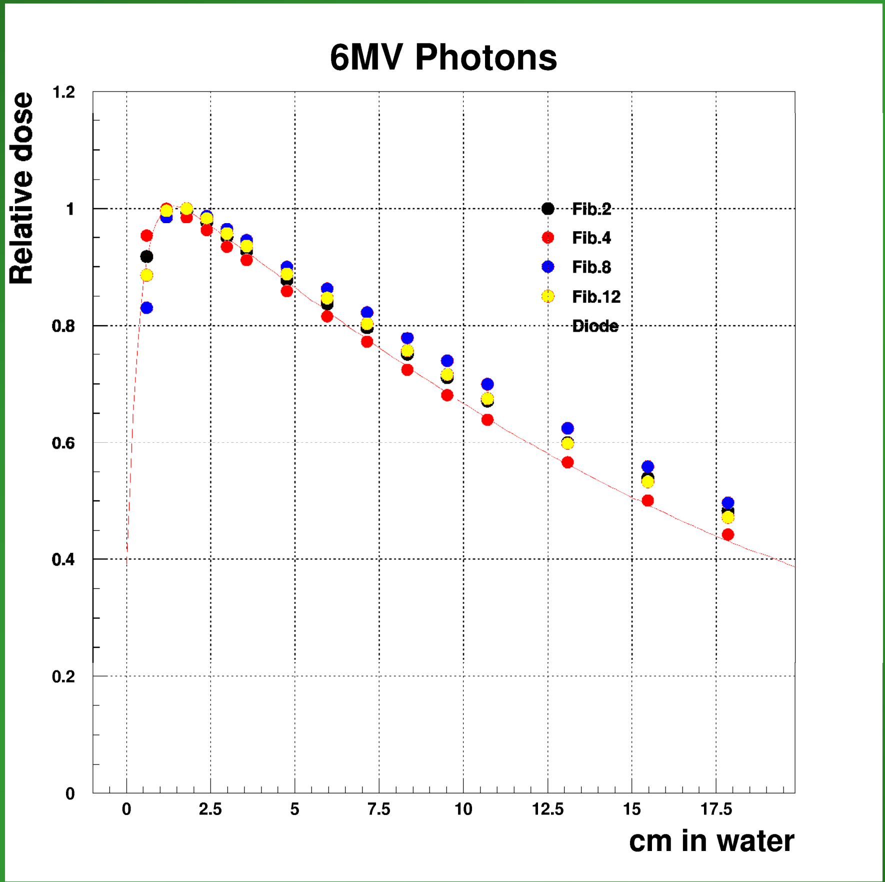
8 scintillating fibers are inserted vertically in a PMMA phantom (20x20x4 cm^3)



16 white fibers (35 cm long) exiting from the bottom side of the phantom carry the light to the PMT

Multifiber 2D prototype

Depth Dose Scan



Field size: $10x10cm^2$

Conclusions …

- a scintillating fiber dosimeter can perform accurate real time measurement
- good spatial resolution
- good response at different radiation intensities
- excellent reproducibility

… and Outlooks

- development of the 2D dosimeter increasing the number of channels (up to 256 or more)
- some equalization methods are under evaluation
- development of an integrated electronics (connection to PC with a USB/parallel port)