Silicon Photomultipliers for scintillating trackers

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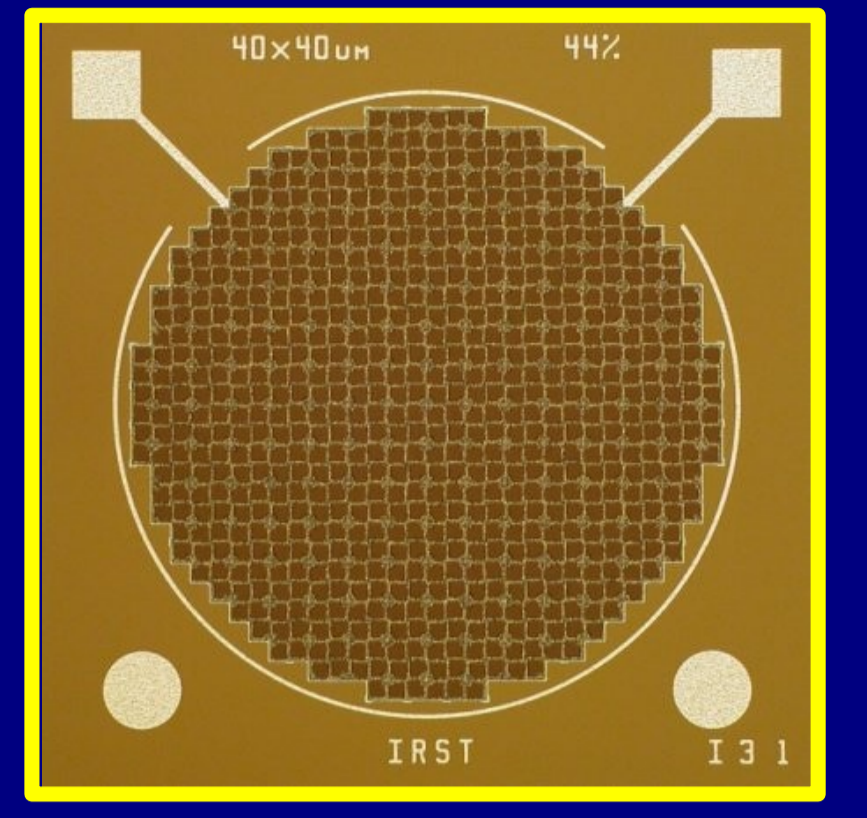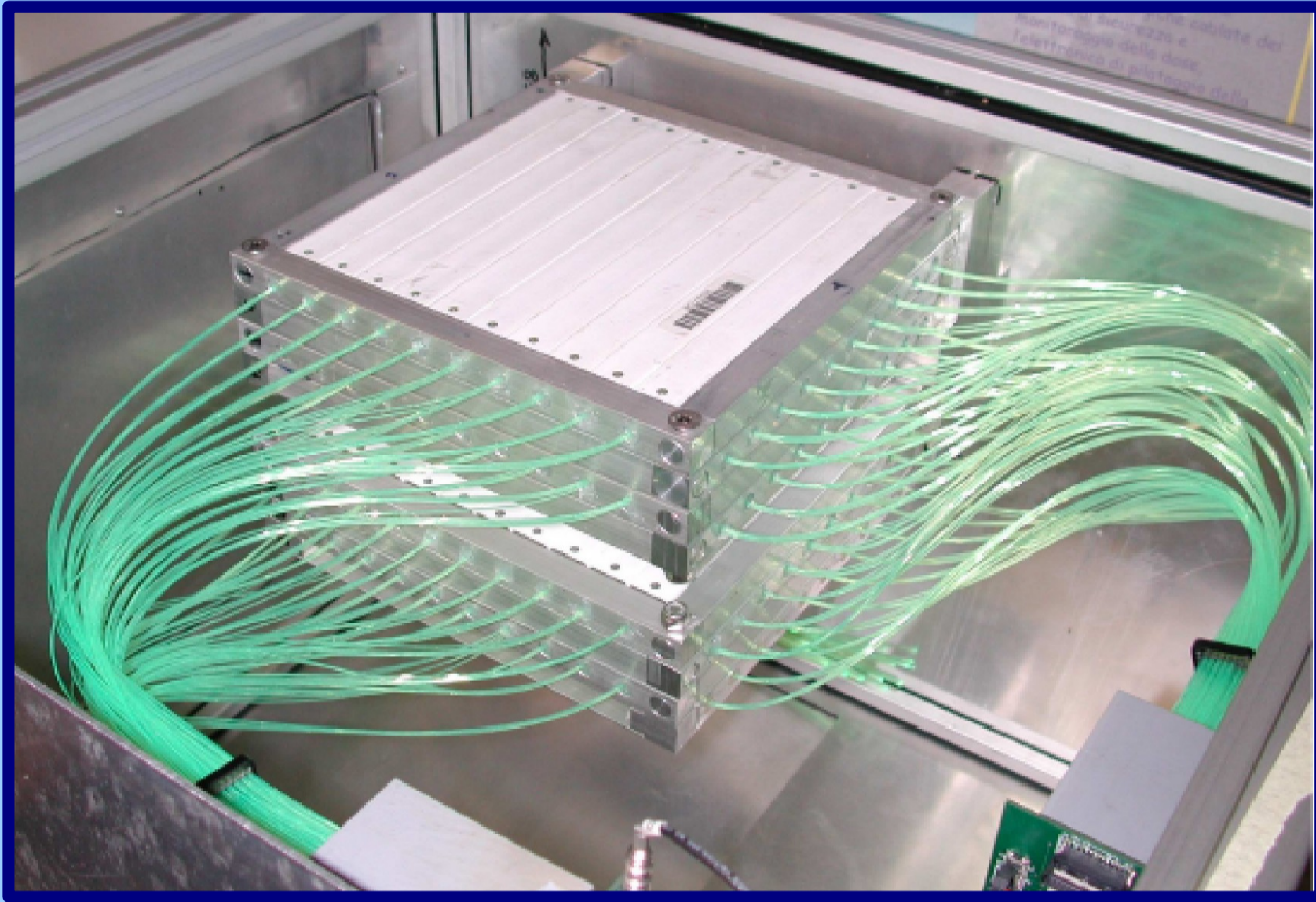
Silicon PhotoMultipliers (SiPMs) are semiconductor photodiodes consisting of a matrix of parallel-connected pixels operating in Geiger mode with a gain of the order of 10^6. The pixels are joined together on the same silicon substrate: the single pixel operates as a binary device, while the analog response of the whole SiPM is the result of the pixels being connected to the same output. The main advantages of SiPMs with respect to PhotoMultiplier Tubes (PMTs) are the small dimensions, a low bias voltage and the insensitivity to magnetic fields. This poster presents the use of an array of eight SiPMs for the readout of a scintillating bar tracker.
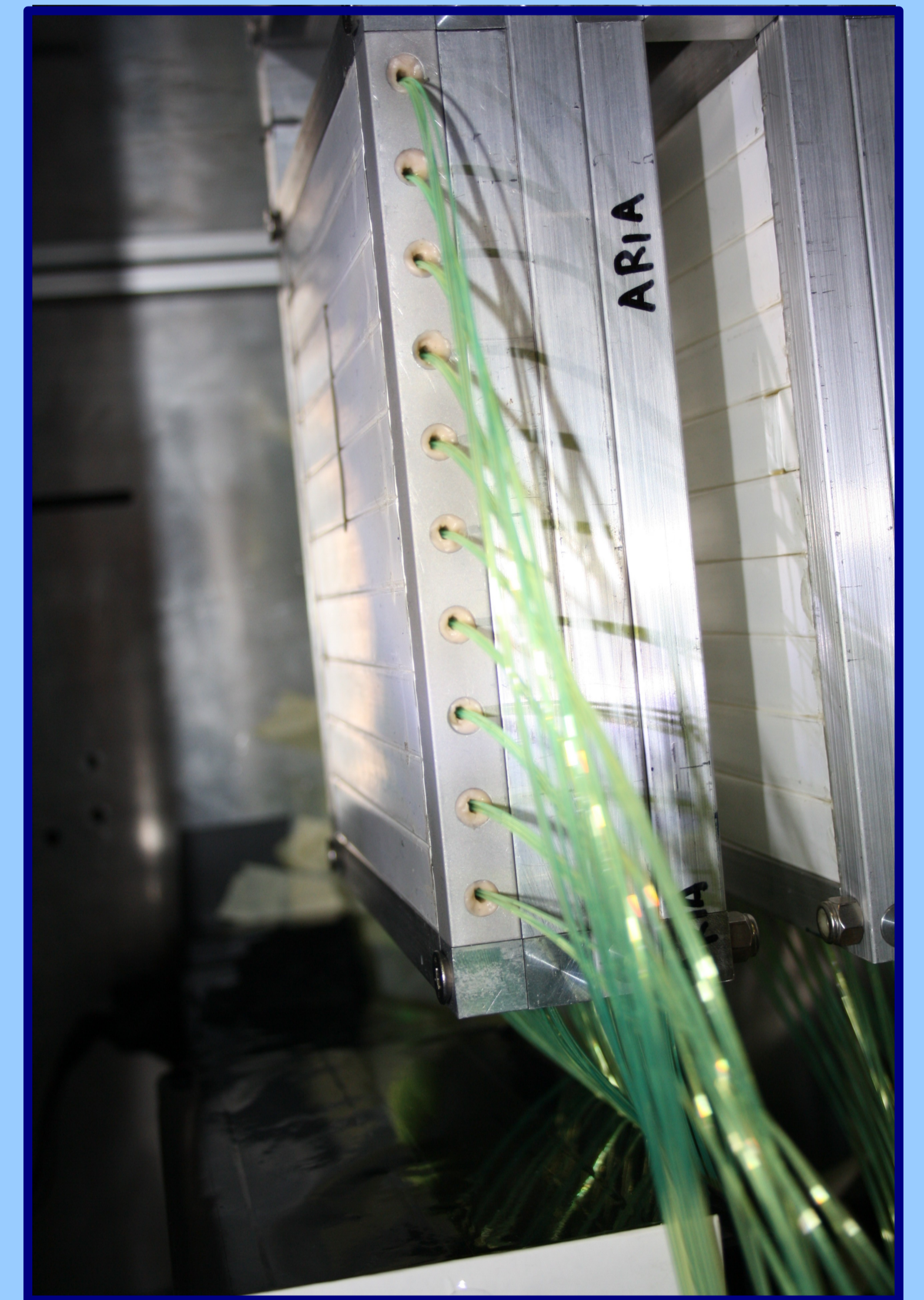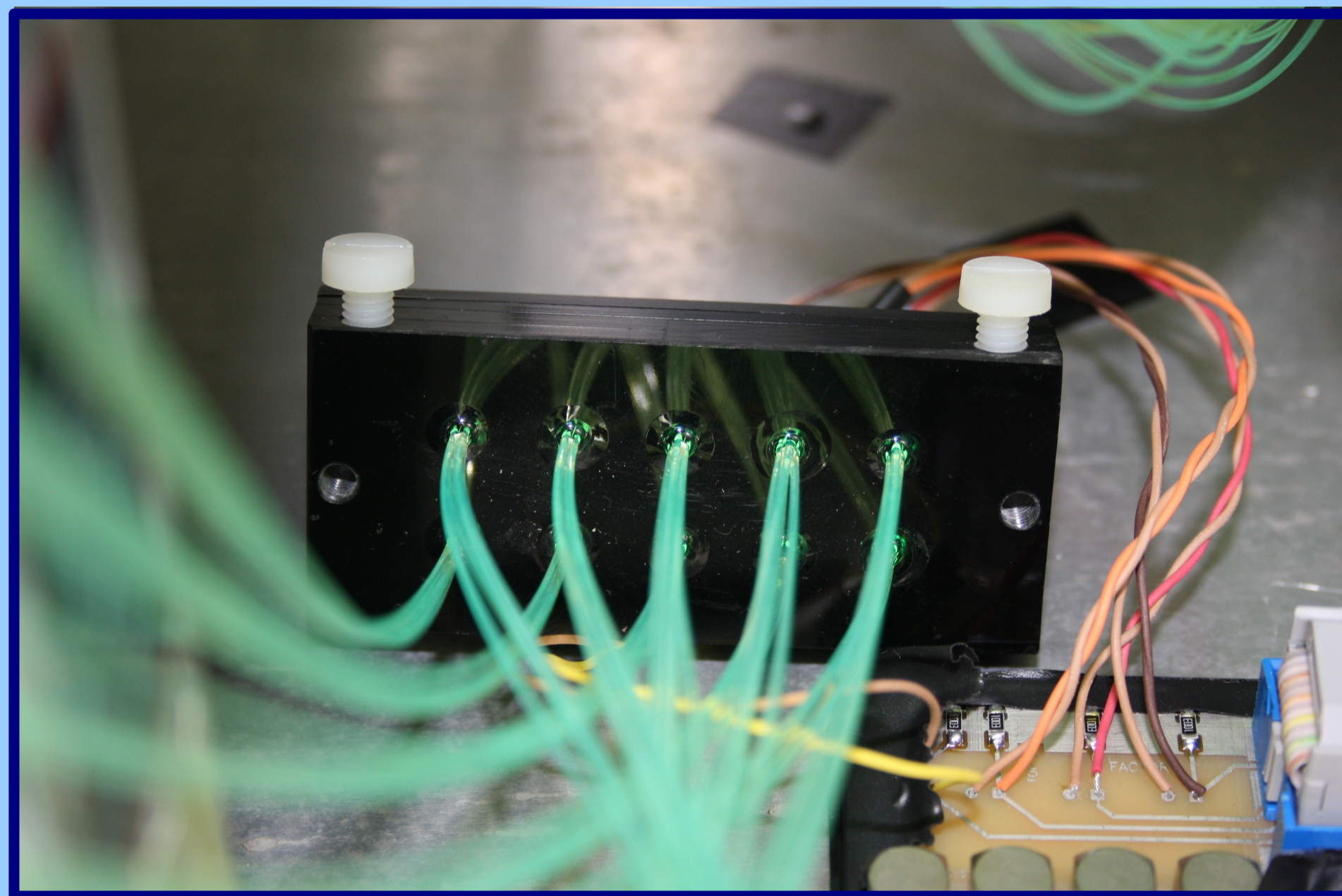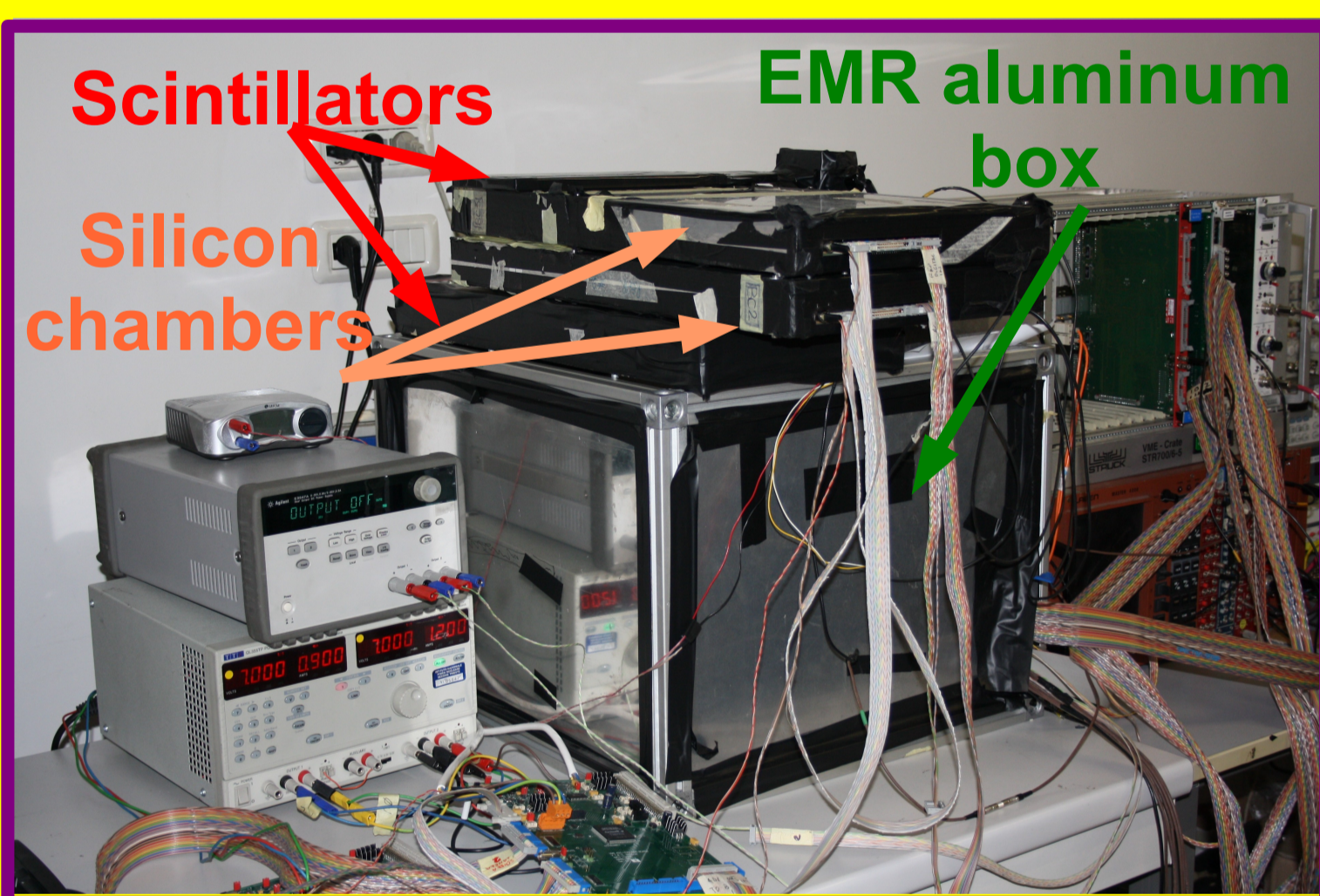
The tracker

The first layer of the tracker has a dual WLS fibers readout system: the fibers are connected to both a multianode PMT and to a coupling mask holding an array of SiPMs (manufactured by FBK – irst) with a ~1 mm diameter composed by 688 40x40 μm^2 cells; 8 out of 10 SiPMs are connected.

EMR (Electron Muon Ranger) Prototype
Prototype of a traker for the MICE experiment composed of 8 x-y planes of plastic scintillator bars with a 1.5x1.9 cm^2 cross section and 19 cm long, read out by 4 0.8 mm WLS fibers. The readout of the scintillation light is performed with both SiPMs and a 64 channel multianode PMT (MAPMT, R7600-00-M64, H7546B assembly - Hamamatsu).

Experimental setup & Readout

Scintillators
Silicon chambers
EMR aluminum box

Above the EMR aluminum box (containing the scintillator bars, the detectors and the electronics), there are two scintillators for the trigger and two silicon chambers for the particle track reconstruction. The readout for both the SiPMs and the MAPMT is performed by two 64 – channel Maroc (Multi Anode ReadOut Chip) v3 boards. Each channel features a preamplifier, a slow and a fast shaper, a discriminator and a sample & hold circuit. The Maroc3 board can be operated in an analog and a digital way.
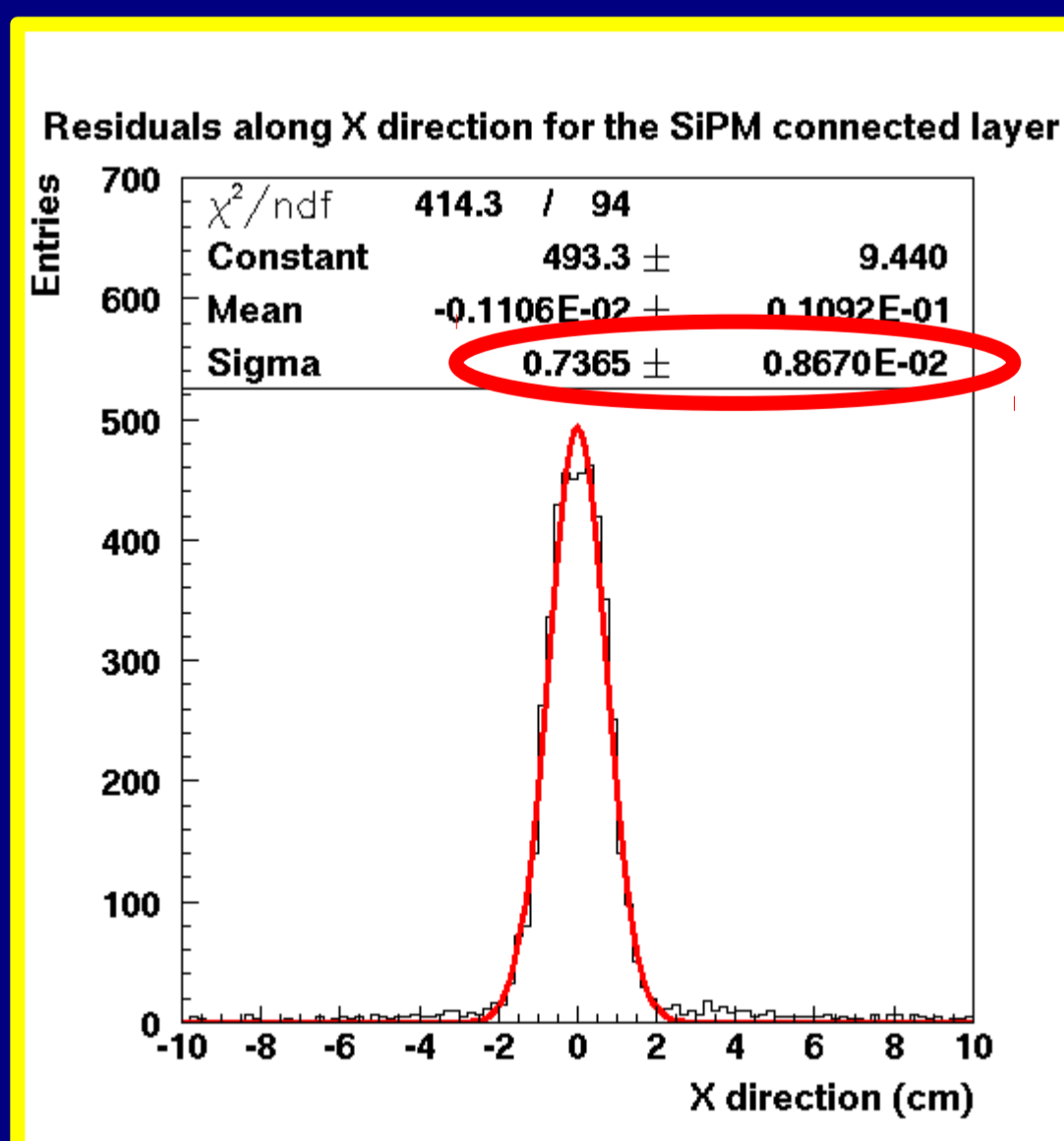
Efficiency

The efficiency plot has been obtained as the ratio of the beam profile reconstructed by the bars and the one measured by the silicon detectors.
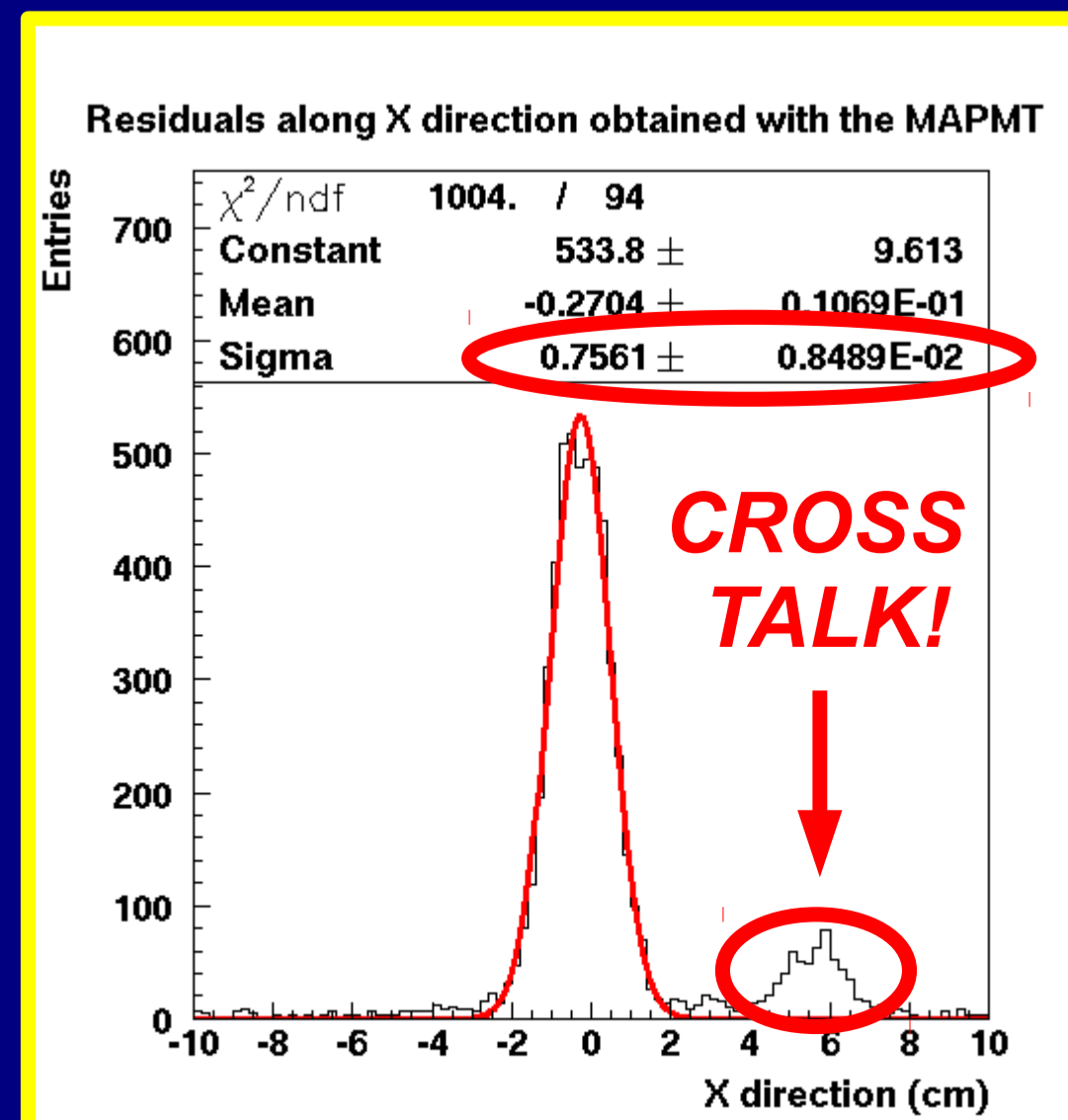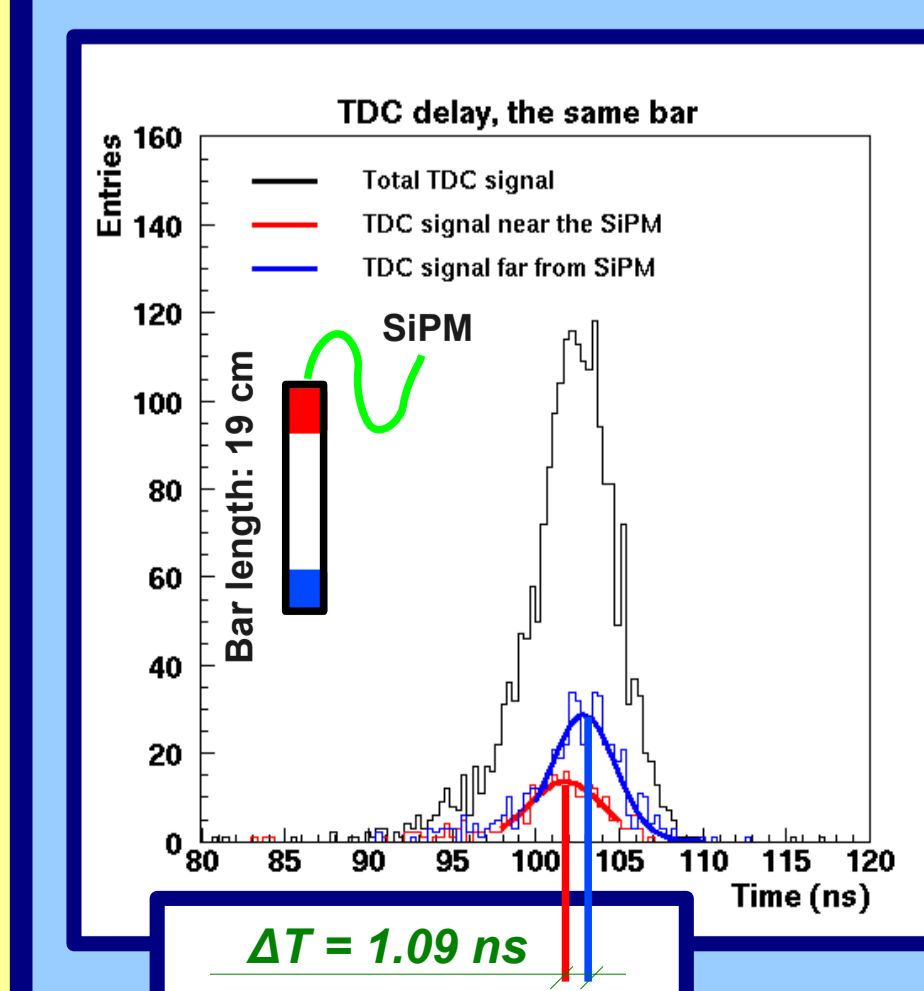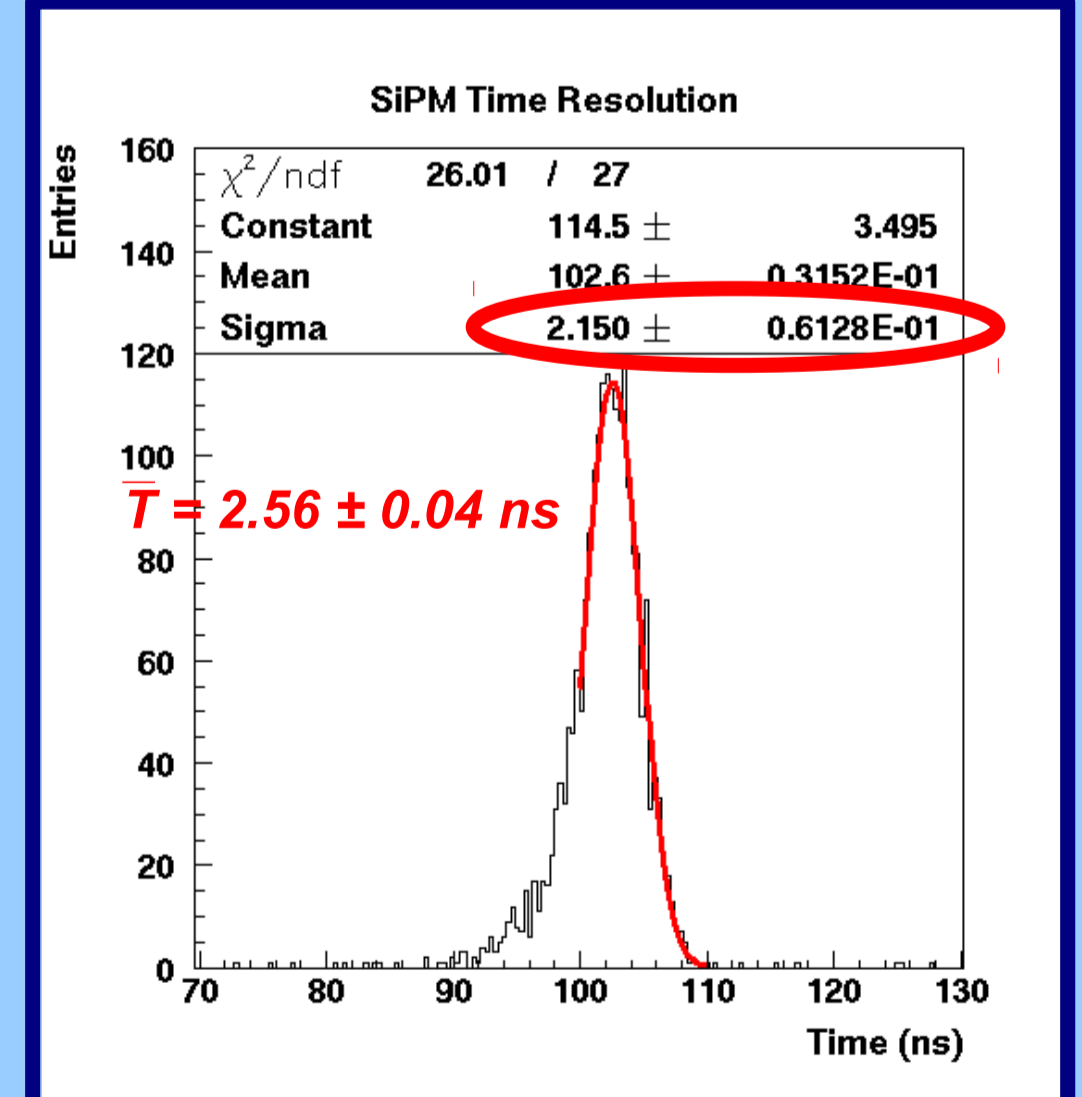
EFFICIENCY ~ 95%

Efficiency of the SiPMs

SNR = 12.4
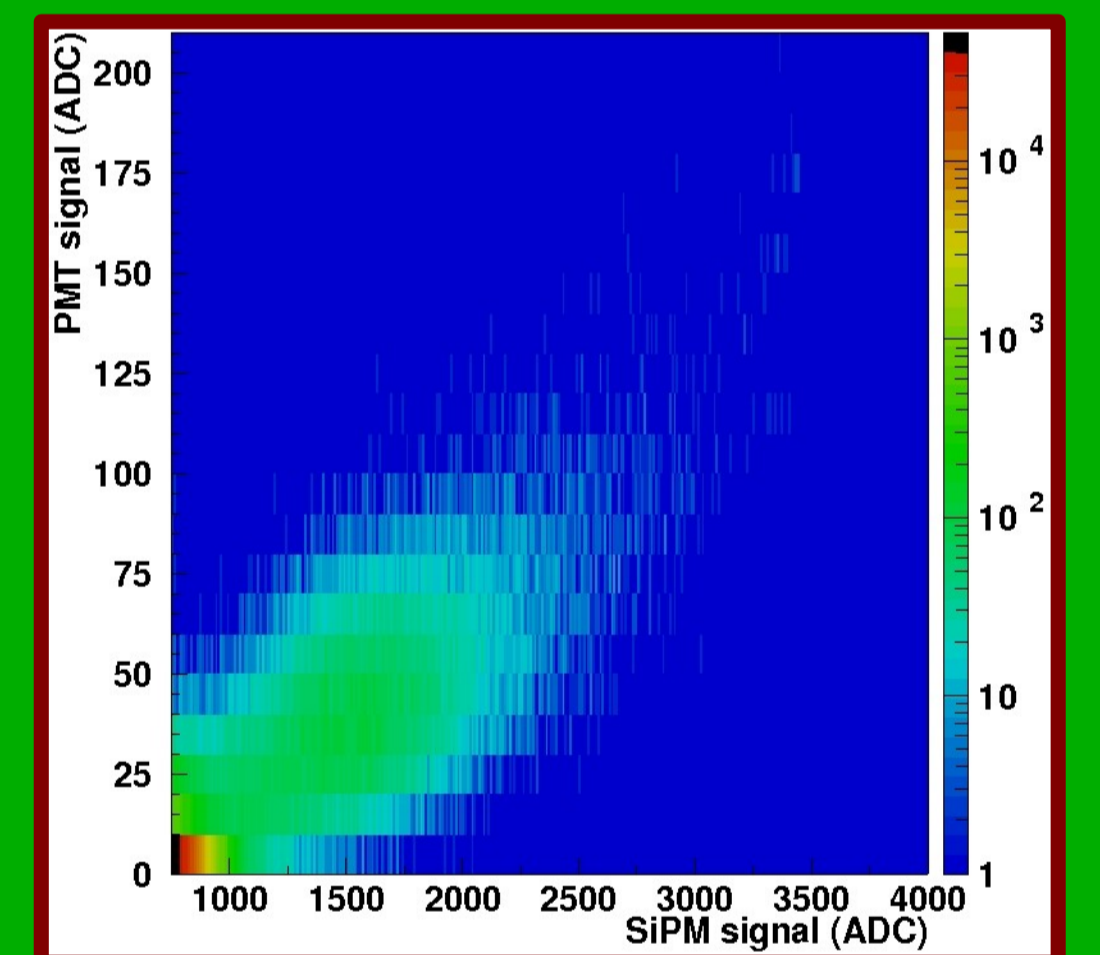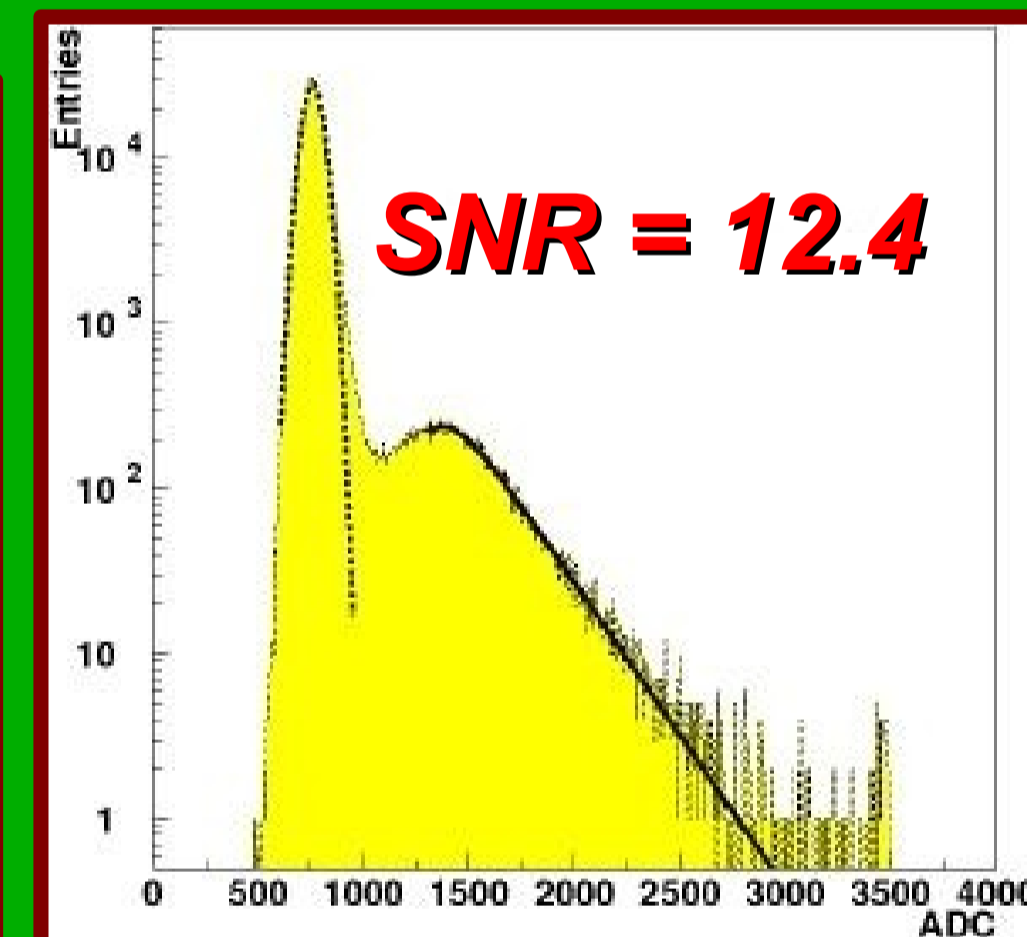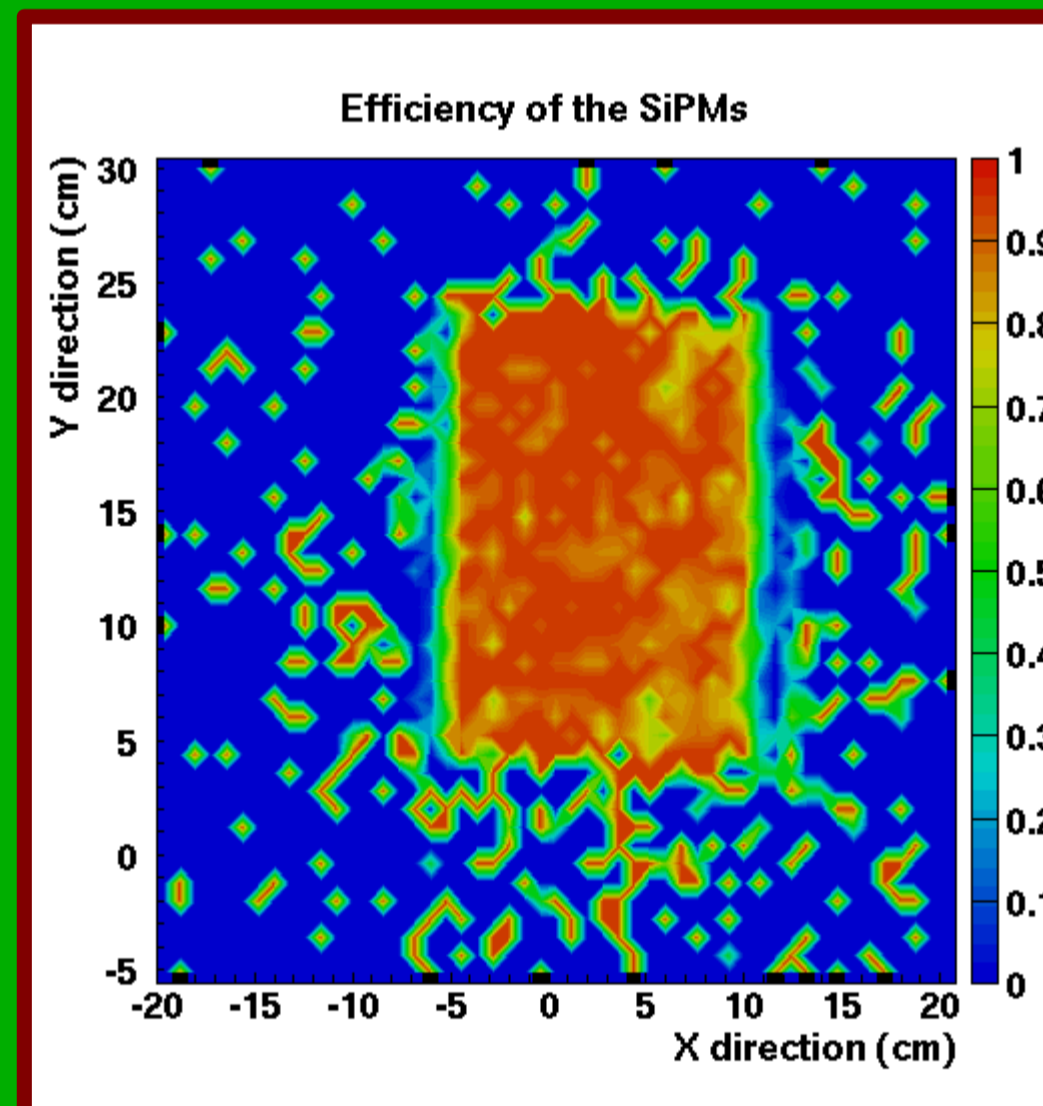
Spatial Resolution

The spatial resolution has been calculated using the residuals method.

Residuals along X direction for the SiPM connected layer

χ^2/ndf	414.3	/ 94
Constant	493.3 ±	9.440
Mean	-0.1106E-02 ±	0.1092E-01
Sigma	0.7365 ±	0.8670E-02

The residuals are defined as the difference between the position reconstructed with the prototype and the expected one computed with the silicon chambers.

Residuals along X direction obtained with the MAPMT

χ^2/ndf	1004.	/ 94
Constant	533.8 ±	9.613
Mean	-0.2704 ±	0.1069E-01
Sigma	0.7561 ±	0.8489E-02

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Time Resolution

The time resolution has been obtained connecting the digital output of the Maroc3 board to a 12 bit CAEN V775 TDC. The 8 SiPMs and 8 MAPMT channels have been connected. The time resolution has been calculated as the weighted mean of the 8 digital outputs.

SiPM Time Resolution

χ^2/ndf	26.01	/ 27
Constant	114.5 ±	3.495
Mean	102.6 ±	0.3152E-01
Sigma	2.150 ±	0.6128E-01

T = 2.56 ± 0.04 ns

MAPMT Time Resolution

χ^2/ndf	23.51	/ 21
Constant	83.71 ±	3.009
Mean	104.3 ±	0.3809E-01
Sigma	2.101 ±	0.7276E-01

T = 2.54 ± 0.03 ns

TDC delay, the same bar
Total TDC signal
TDC signal near the SiPM
TDC signal far from SiPM
SiPM
Bar length: 19 cm
ΔT = 1.09 ns

The delay is in perfect agreement with the theory since the speed of light in the fiber is ~ 20 cm/ns.