Design and test of the calibration system of the MEGII Pixelated Timing Counter

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Abstract

The MEG II experiment is designed to improve the sensitivity to the $\mu^+ \to e^+\gamma$ decay. A crucial component is the Pixelated Timing Counter (pTC), dedicated to the measurement of the positron time to reduce the combinatorial background. The detector consists of 512 scintillation counters, each performing a precise measurement of the positron crossing time.

This approach requires that the time offsets of the counters are calibrated and regularly monitored over the lifetime of the experiment with adequate precision. The pTC time calibration and monitor system will make use of a laser diode to deliver pulses to each pixel. The system components have been thoroughly tested in laboratory, the results demonstrate that a calibration and monitoring resolution satisfying the requirements is within reach.

Introduction

The MEG experiment, at the Paul Scherrer Institute (Switzerland), has searched for the μ^+->$e^+\gamma$ decay down to a Branching Ratio (BR) 5×10^{-13}, exploiting the most intense continuous muon beam in the world. After the conclusion in 2013 of the data taking with the first version of the detector, an upgrade (MEG-II) has been designed to improve by an order of magnitude the sensitivity, to be operational in the next years. A crucial component is the new pixelated Timing Counter (pTC) (Fig.1).

It consists of 512 pixels (Fig. 2) of 3 different sizes. Each of them consists of a plastic scintillator tile and of two arrays of 6 SiPMs connected in series, attached at both sides, measuring the positron crossing time with an accuracy of ~90 ps. Combining those measurements together the positron time accuracy reaches ~30 ps.

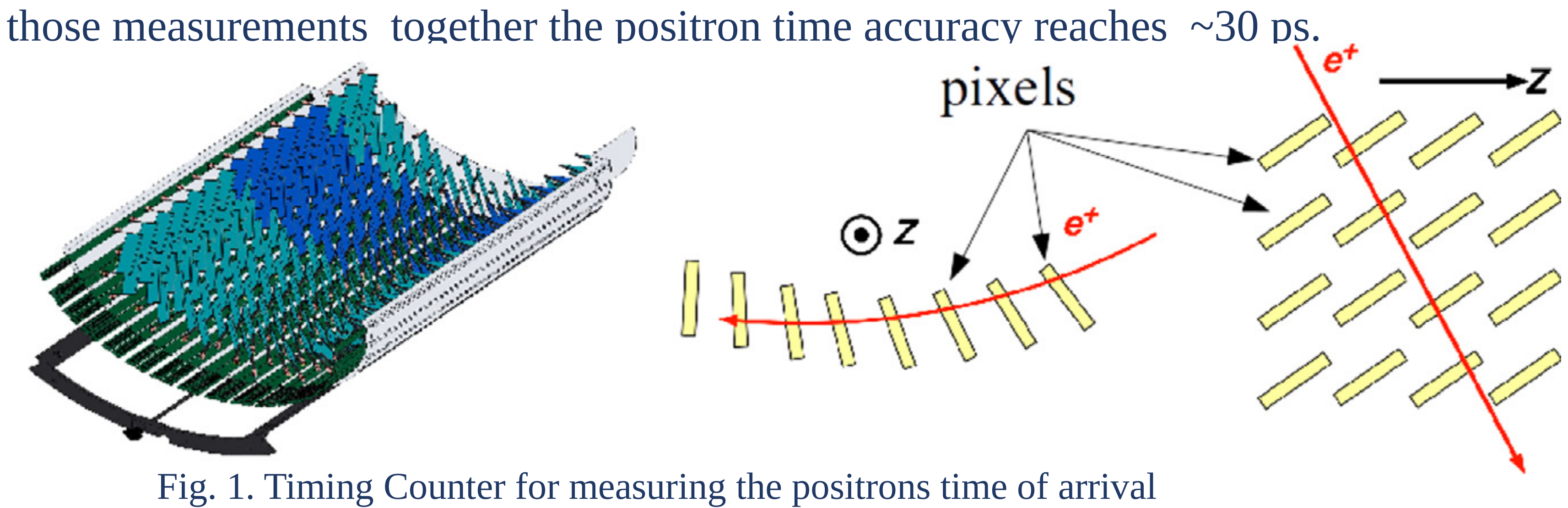

Fig. 1. Timing Counter for measuring the positrons time of arrival

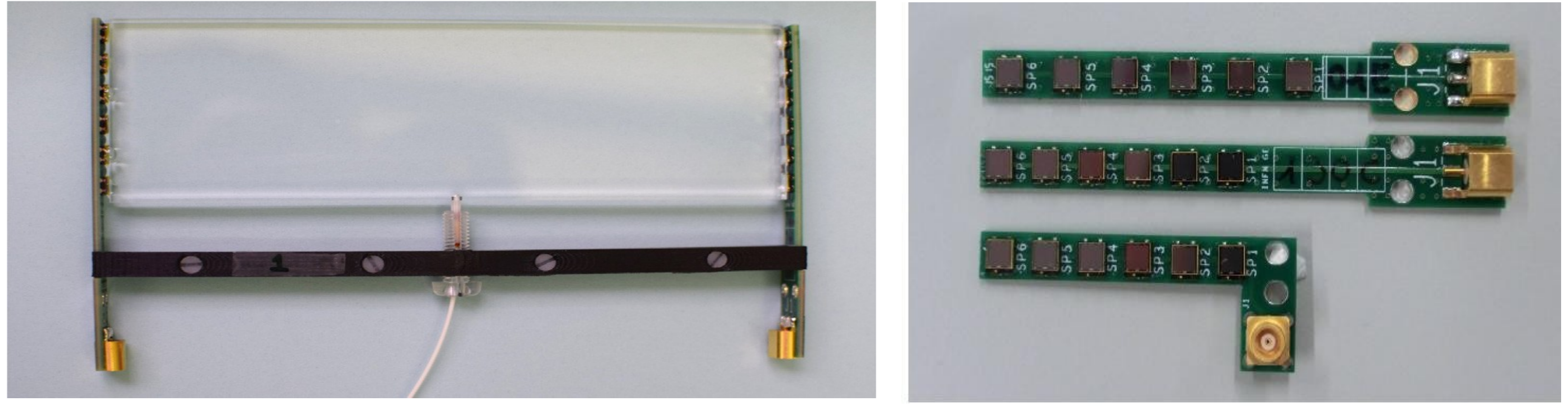

Fig. 2. A pixel with calibration optical fiber and the SiPM boards for different sizes.

The Calibration System of the pTC

In the pTC it is important to precisely synchronize all the counters. The counters are time-aligned by distributing synchronous light pulses to all the counters through optical fibres. To this goal, we have developed a laser calibration system shown schematically in Fig. 3.

The fast light pulse is first split into two outputs: one to a photodiode to gauge the signal amplitude, the other as input to an active optical multiplexer remotely controlled with several output channels, such that the signal is output alternatively to each of them. Each output (except one used as a monitor) is then input to two cascaded stages of 1x8 optical splitters. each of which splits the input signal into eight signals of approximately equal output amplitudes. As a result, 64 channels become available in parallel with an amplitude 1/64 of the original (actually smaller due to losses in the various stages). Finally, each output signal from the last stage of the splitters is fed into a pixel through an optical fiber, fixed with a screw (see Fig. 4).

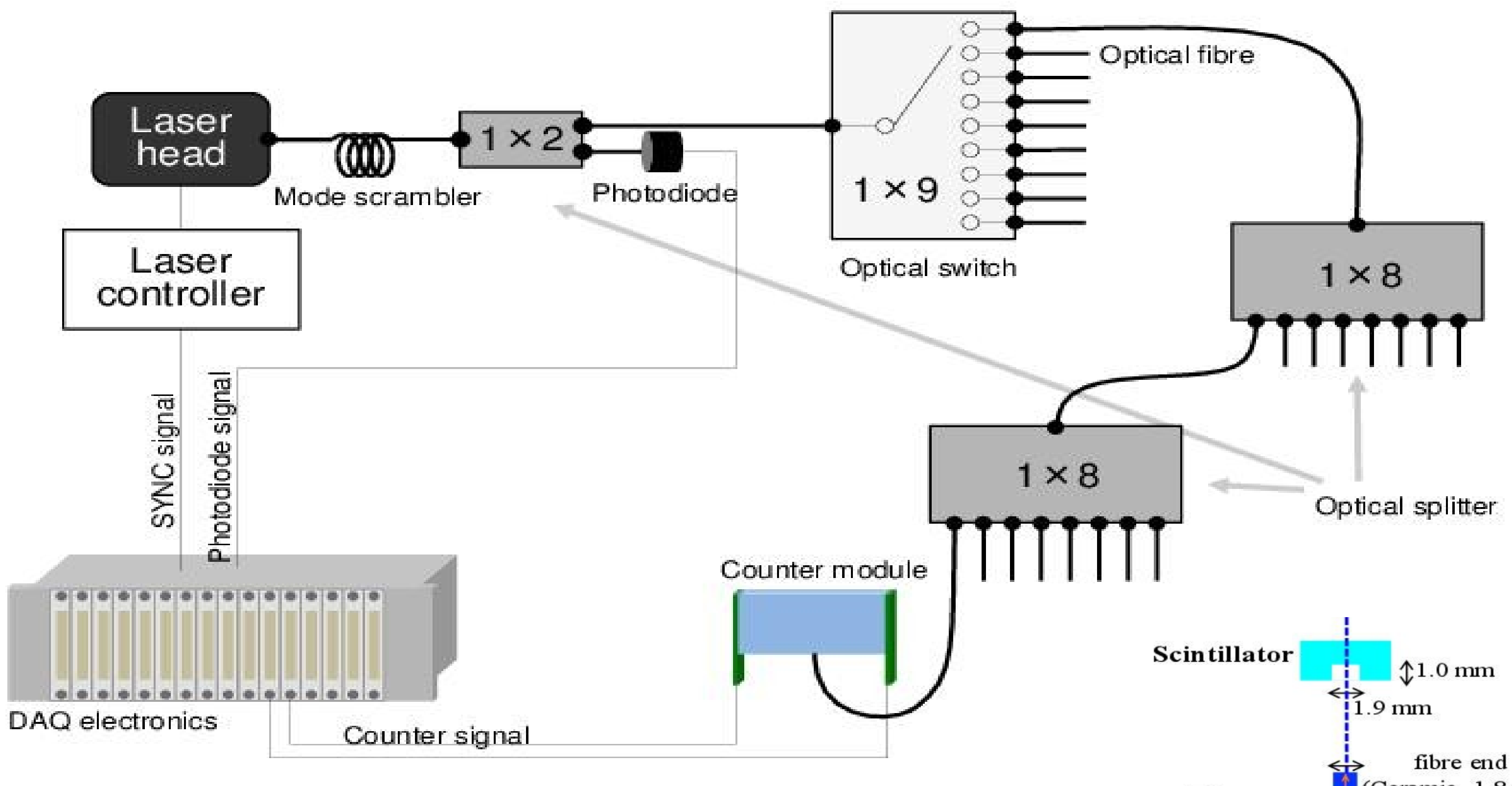

Fig. 3: The laser calibration system.

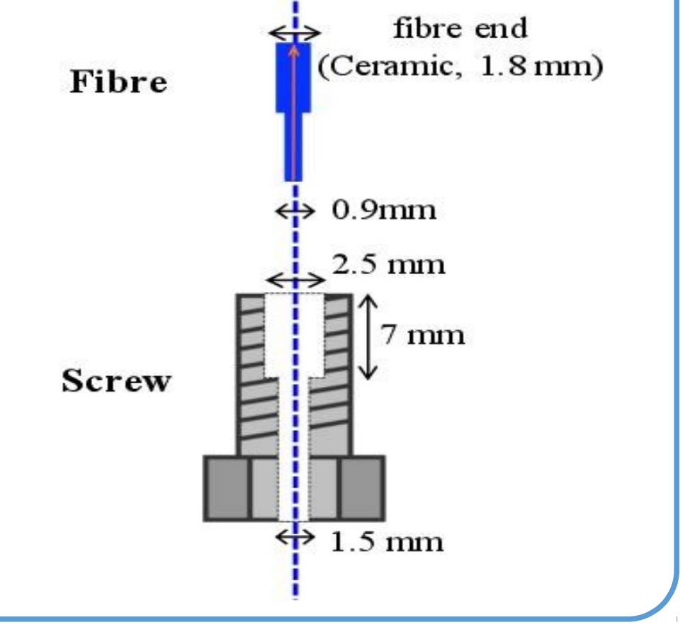

Fig. 4: Schematic of the fiber fixing method.

Laser, mode scramble, long connection fiber

The laser is a Hamamatsu PLP10-040, with a wavelength at 401 nm, pulse width of 60 ps (FWHM) and peak power of 200 mW. The mode scramble is put just after the laser source to homogenize propagation modes injected by the laser into the fibers to make the output insensitive to the position and the curvature of the optical fibers (model "MODCON" by Arden Photonics LTD). It is constructed with 8 multimode 50/125 μm optical fibers (Thorlabs) after the optical switch that are 10 m long. Due to their positions and lengths, the temperature dependance of the their time delay must be taken into account. For this reason, the delay versus the temperature has been measured (see Fig. 5).

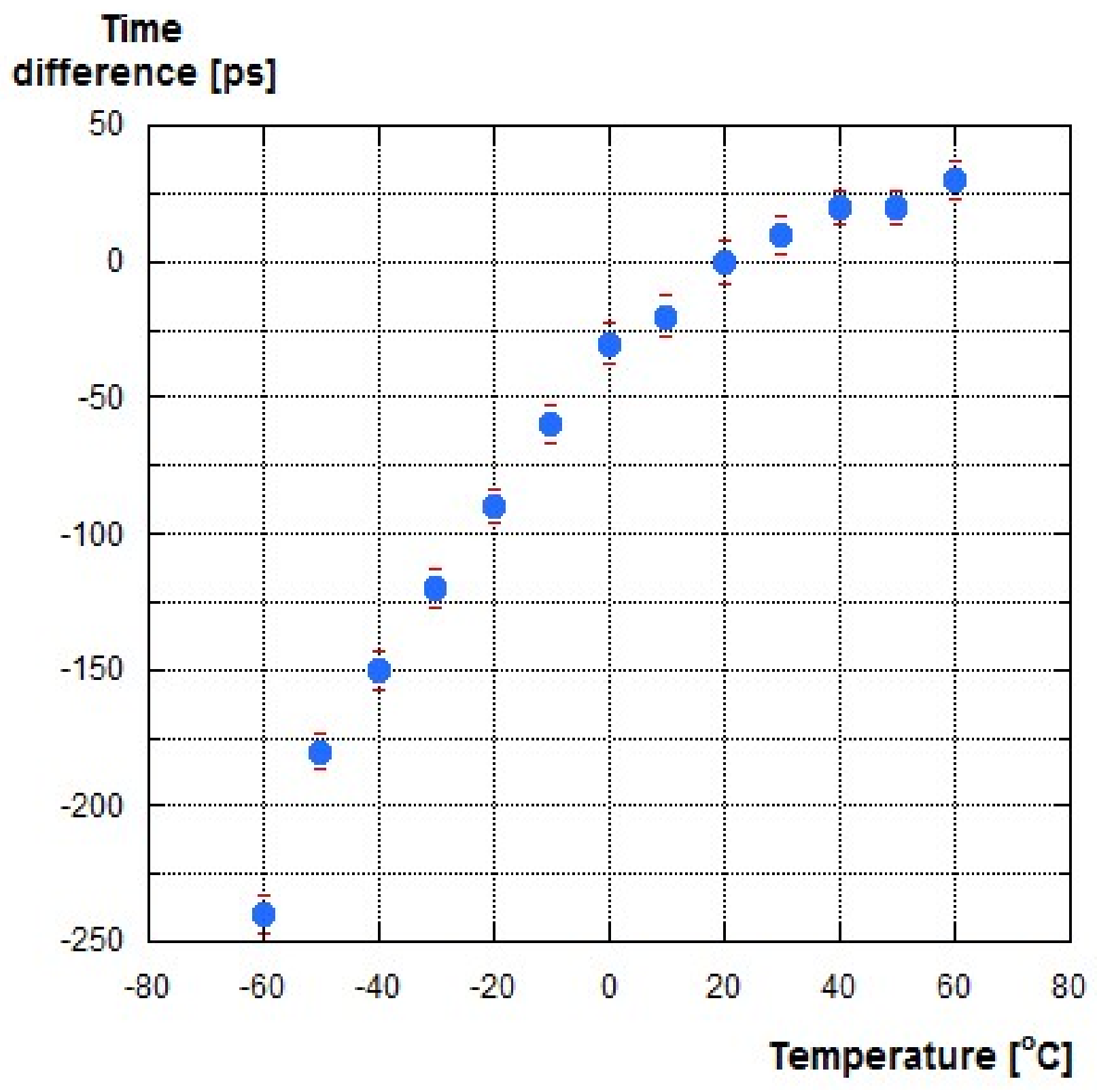

Fig.5: delay variation due to temperature

The optical switch and the optical splitter

An optical switch is an active device that can direct the signal injected in the input optical fiber to one of the outputs sequentially. The output channel can be selected remotely; in principle no reduction of the output is expected.

An optical splitter is a passive device that redistribute the signal injected in the input fiber on all the N output channel: the signal output is reduced at least by a factor of N.

We used one switch with 8 outputs followed by the cascade of two splitters 1x8, in order to get a total of 1/64 level of splitting. First we investigated the performances of the switch in order to evaluate the intrinsic losses: the results are in Fig. 6. The 1x8 optical splitter are made by Lightel Tech. Inc. model MMC-18-A-EVEN-1-A-30CM-R-1 from Corning 50/125 μm multimode optical fiber. Each splitter is characterized in term of delay and in term of % of output power, as in Fig. 7. The measured delays are corrected offline.

The Transmission is lower than 1/8=12.5% because of losses in the fibers and in the splitters but the light output is sufficent for the required precision.

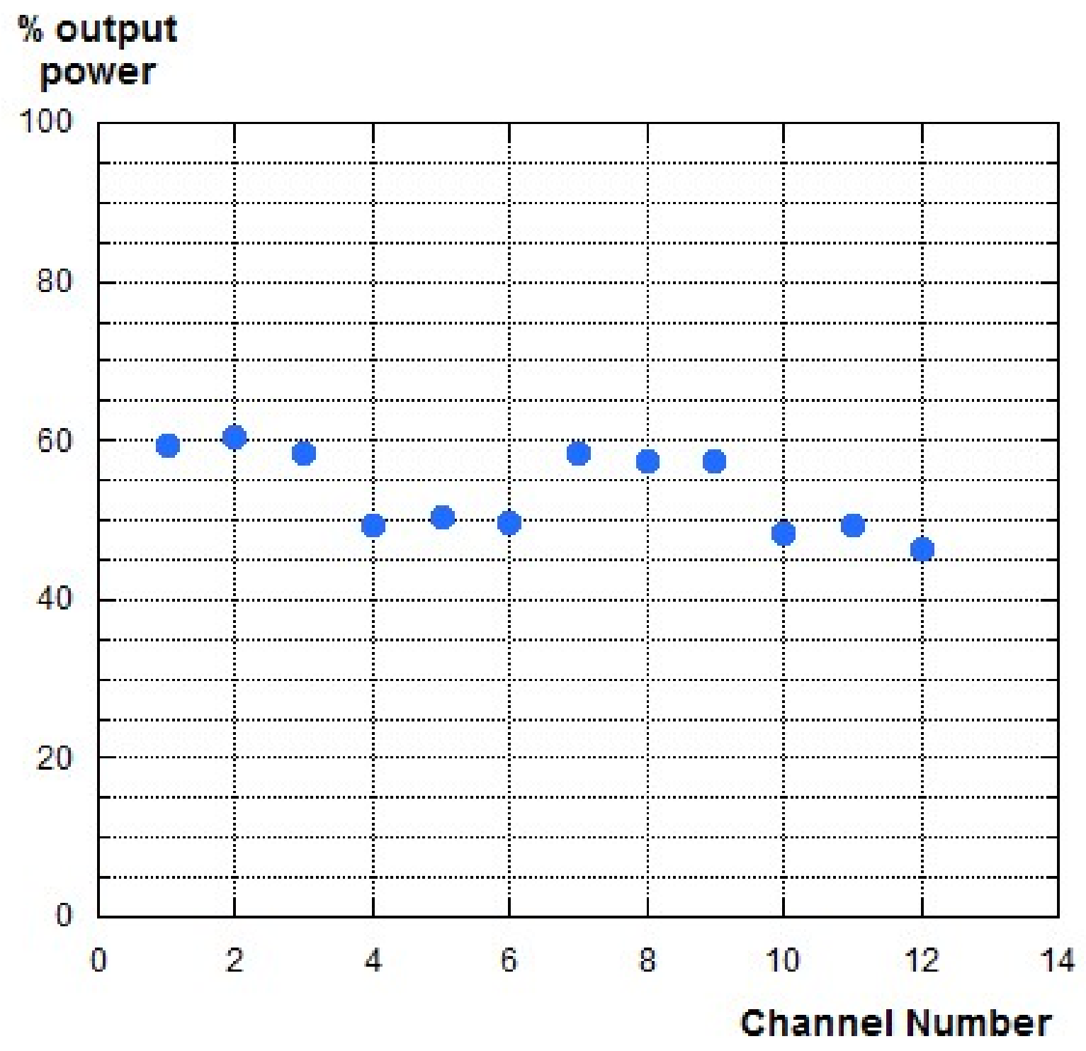

Fig. 6: Percentatge of output power from the switch vs the channel number.

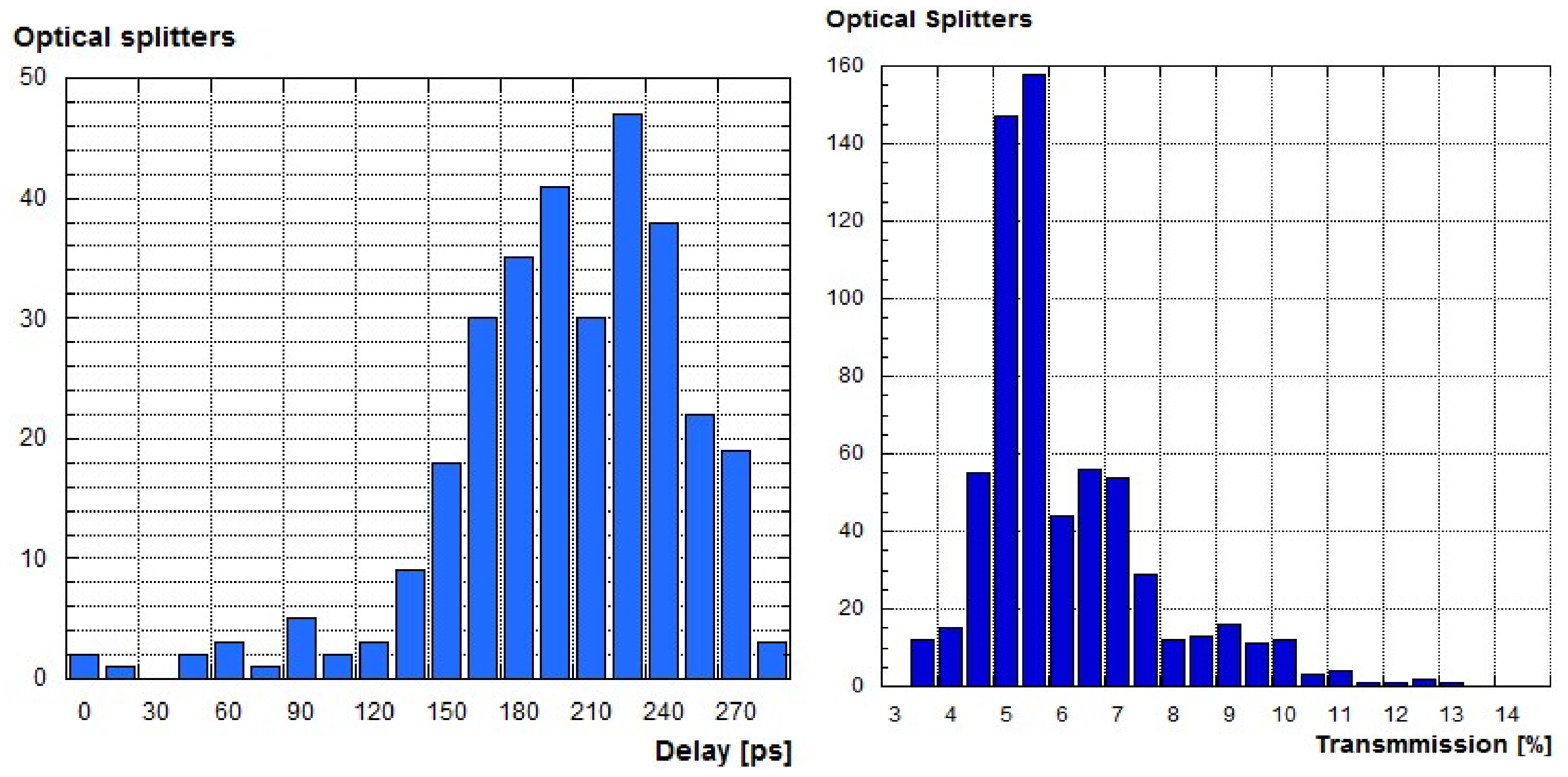

Fig. 7: Left: Optical delay distribution. Right: Optical Transmission distribution

The optical fibers

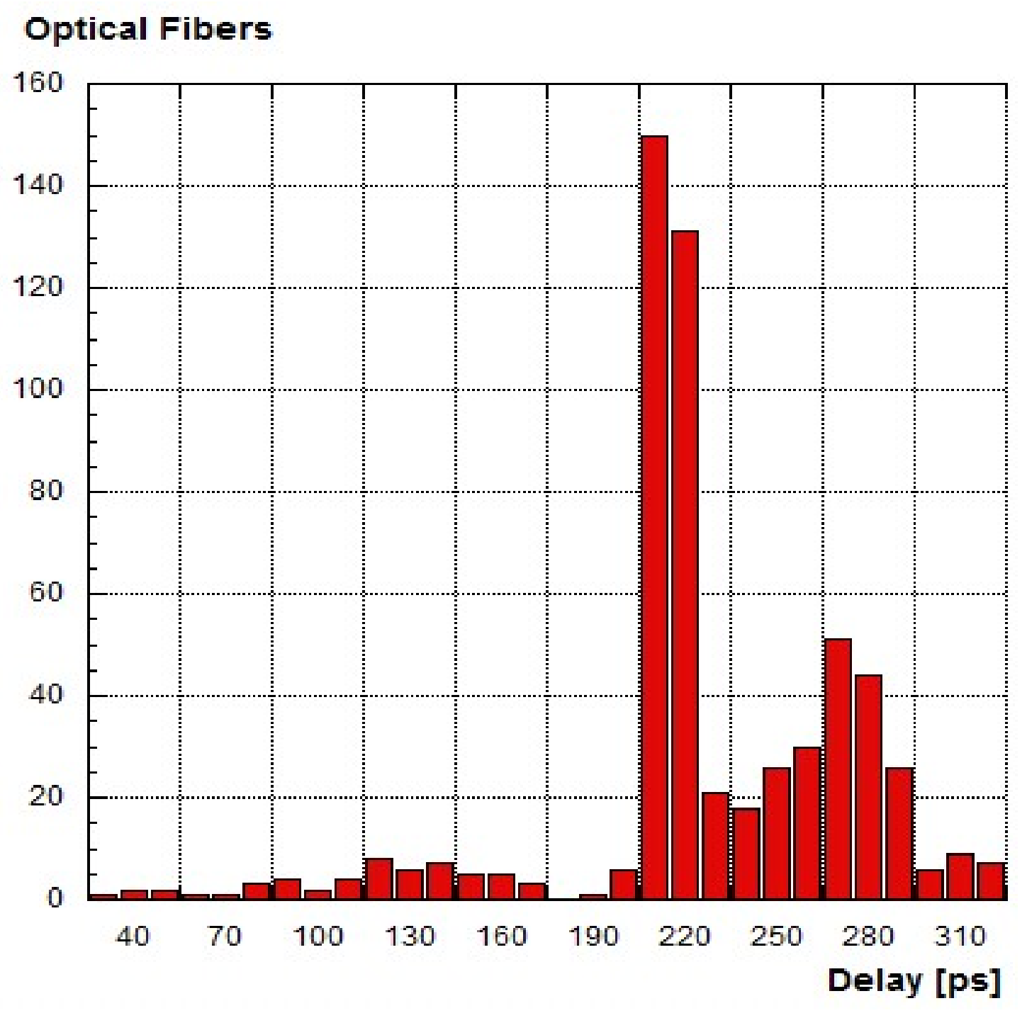

Fig. 8: Distribution of the fiber delays.

After the splitters, an optical fiber injects the light into each pTC pixel. For each fiber the delay introduced has been measured. The distribution of the delays is shown in Fig.8. The measured delays are corrected offline.

Conclusion

We describe an approach to time calibration and monitoring of the pTC of the MEG II experiment based on a laser system.

The sketch of the system is presented and results of the laboratory test of some subcomponents are shown to be compatible with the resolution requirement.