

More details/material in the KM3 Wiki
<http://wiki.infn.it/cn/csn2/km3/calibration/ledbeacontest>



LED Beacon Test

- Description of the system.
- Description of the measurement procedure.
- Preliminary results (October 2014).
- Status and future plans.

Giulia De Bonis

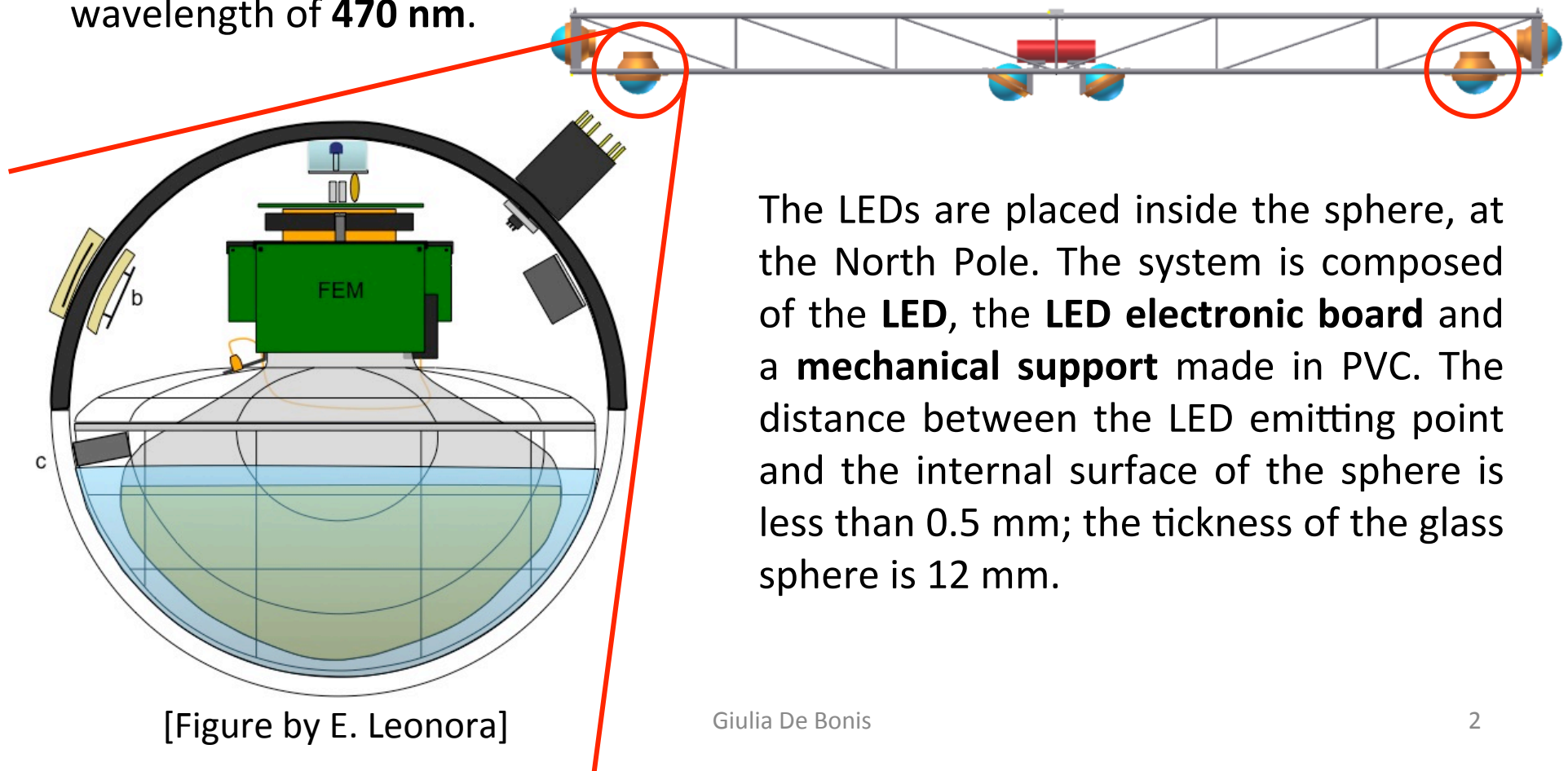
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KM3NeT_IT Collaboration Meeting, Catania, November 27-28, 2014

Special thanks for help, suggestions and fruitful discussions to: F. Ameli, A. Capone, R. Cereseto, M. Circella, E. Leonora, E. Maccioni, M. Musumeci, C. Nicolau, A. Orlando, G. Riccobene, F. Simeone.

LED Beacons in the Optical Modules

2 LED sources per floor are mounted in the Tower in the 2 Optical Modules that are downward-looking, for a total of 28 LEDs per Tower. The LEDs emit at a wavelength of **470 nm**.

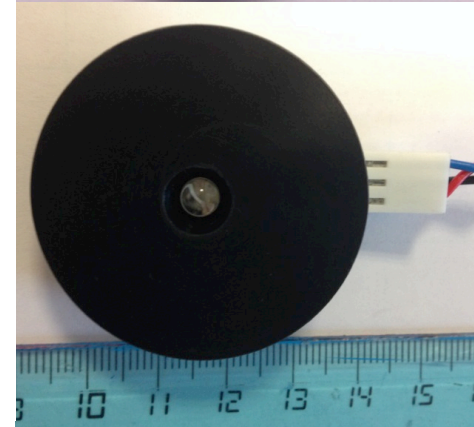
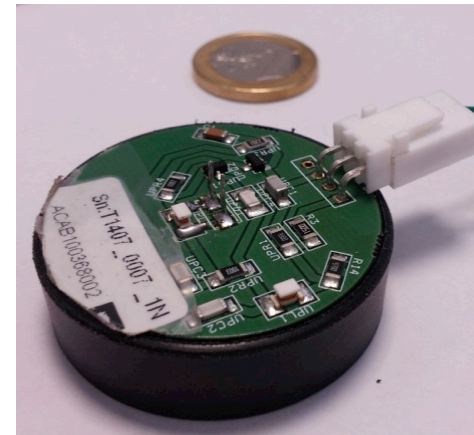
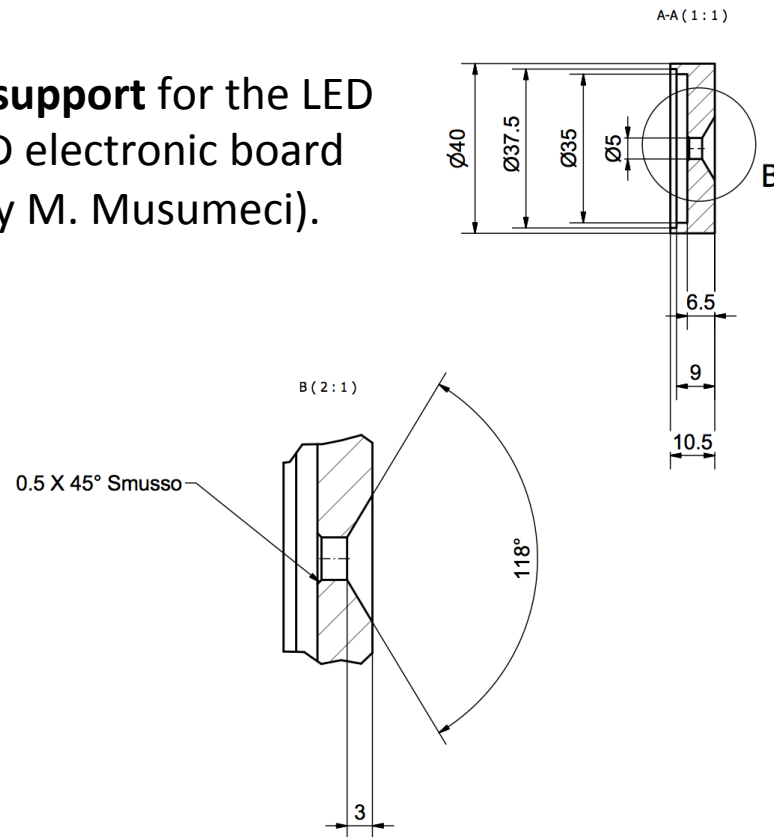


The LEDs are placed inside the sphere, at the North Pole. The system is composed of the **LED**, the **LED electronic board** and a **mechanical support** made in PVC. The distance between the LED emitting point and the internal surface of the sphere is less than 0.5 mm; the thickness of the glass sphere is 12 mm.

[Figure by E. Leonora]

The LED Beacon System

Mechanical support for the LED and the LED electronic board (project by M. Musumeci).



Front and rear view
(pictures by E. Leonora)

Hamamatsu C11208-350 MPPC Starter Kit

MPPC = Multi-Pixel Photon Counter

- semiconductor device;
- each pixel is an APD (Avalanche Photo Diode) operating in Geiger mode.

Advantages

- excellent photon counting capability;
- low voltage operation;
- insensitivity to magnetic fields.



Photo sensor

- effective photosensitive area: $3 \times 3 \text{ mm}^2$;
- 3600 pixels;
- pixel pitch: $50 \mu\text{m}$.

2 MPPCs acquired by
INFN – Sezione di Roma

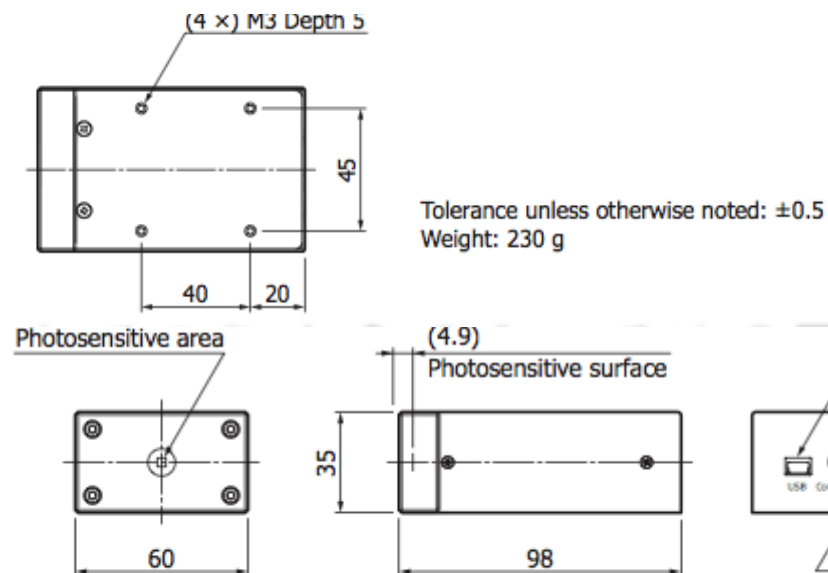


Hamamatsu C11208-350

MPPC Starter Kit

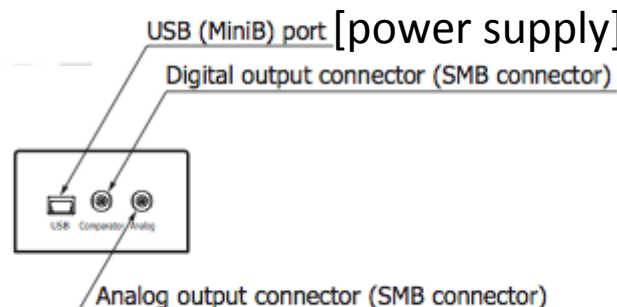
Electrical and optical characteristics (Typ. $T_a = 25^\circ\text{C}$, $\lambda = \lambda_p$, unless otherwise noted)

Parameter	Symbol	Condition	C11208-150			C11208-350			Unit
			Min.	Typ.	Max.	Min.	Typ.	Max.	
Spectral response range	λ		320 to 900			320 to 900			nm
Peak sensitivity wavelength	λ_p		-	450	-	-	450	-	nm
Element temperature (setting temperature)	T_d		-	-10	-	-	0	-	$^\circ\text{C}$
Photon detection efficiency	PDE	Threshold: 0.5 p.e.	-	35	-	-	35	-	%
Dark count	CD	Threshold: 0.5 p.e.	-	5	50	-	120	1200	kcps
Comparator output	-		TTL compatible						-
Comparator threshold level	-		9 adjustable levels: 0.5 to 7.5 and disable						p.e.



OUTPUT

- USB (miniB) \rightarrow Photon counting
- Comparator (digital output)
- Analog (analog output)



Optical Fibres

An optical fibre collects the light emitted by the LED and transmits it to the sensor. **FC/PC connectors** are mounted at each end of the fibre. The coupling of the fibre with the light source and the light sensor is an important **mechanical issue** to be faced for the accomplishment of the LED Beacon Test.

Task 1) **coupling of the fibre with the light sensor** → **DONE** 😊

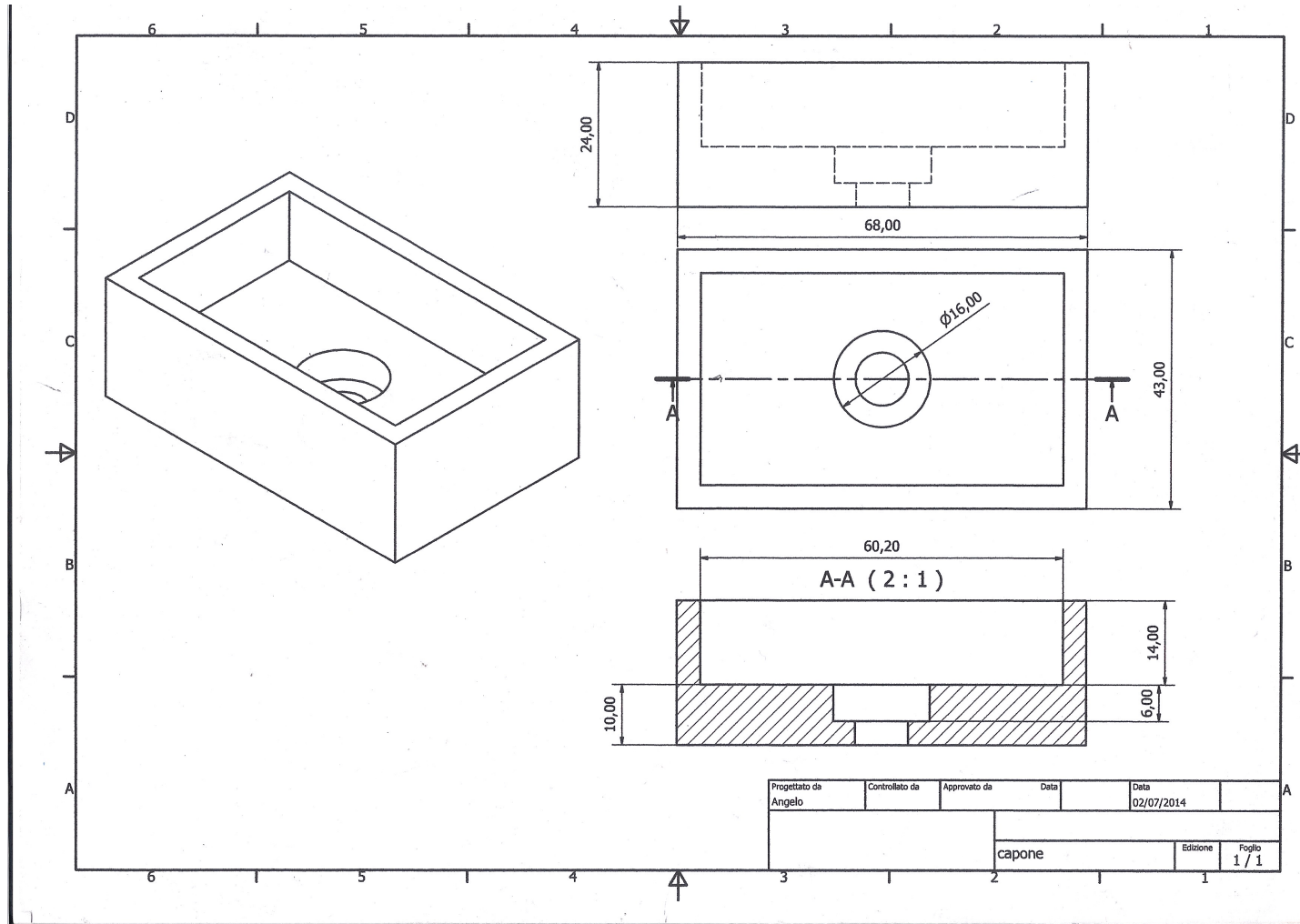
Designed a "cap" to be placed on the side of the sensor with the detection window; an adaptor for a FC/PC connector is inserted to face the photo-sensor. The task has been completed with the support of the Officina Meccanica – Sezione di Roma.

Task 2) **coupling of the fibre with the LED source** → in progress/pending

This is a critical point to for the collection of the LED light.

A **temporary solution** (*adopted in Catania, Oct 2014, during the preliminary tests done on Tower 8*) will be shown in the next slides. Solution for the next towers will be discussed in the "Future Plans".

The MPPC cap



(project by Officina Meccanica, Roma)

The MPPC cap



The cap allows a perfect match of the photo-sensitive area with the optical fibre and prevents the detection of background light.



**2 MPPC caps realized by
INFN – Sezione di Roma**

Test Setup

The initial project

The LED Beacon Test consists of 2 phases: the “**Floor Test**” and the “**Tower Test**”.

Several changes have occurred in the last few months concerning the test setup, in particular the number of LEDs to be mounted (and thus monitored) per floor: was 6, then 4, then 2. The Floor Test was intended to be carried out with the floor inside the dark box, the dark box closed and only few connections going out the box through the connection panel. With 6 (or 4) LED per floor, the initial project for the Floor Test, aiming at monitoring all the LEDs of the floor, was to use a splitter inside the dark box, with 6(4) fan-in and 1 fan-out, for collecting the fibres coming from the Optical Modules and for carrying outside the dark box the light signal of the LEDs. Initially, the optical fibres to be used in this system were single-mode fibres, with Numerical Aperture (NA) of 0,13. This element appeared immediately as a complication, since the reduced dimension of the fibre core would have practically prevented the light of the LED (overfilled launch) to enter the light guide and reach the sensor. The case was verified with preliminary measurements with the single-mode fibre. To solve the issue, (sub-millimetric) precision optics would have been required, but the realization of such a system was not compatible with the other mechanical constraints of the Tower.

Test Setup

implemented for Tower 8 (October 2014)

Unfortunately a large delay was produced in the delivery of the splitter and the fibres, such that the system was not yet available on mid-October, i.e. the time when the Tower was ready to be integrated and tested at LNS before the deployment. However, the change in the project, i.e. the reduced number of LEDs mounted per floor, made unnecessary the splitter itself. In addition, because of the shortage of time, only few measurements have been carried on in the dark box (the operation of which requires time and care) and **the Floor Test of the LED Beacon was done with the floors outside the dark box**. This configuration allowed to manually move the fibres. As a consequence, it was possible to carry on the test with only one fibre, that was manually shifted to monitor several LEDs (in analogy to what was planned for the Tower Test).

The fibre that was available and ready to be used in October 2014 was lent by M. Circella. It was a **multi-mode fibre, 50/125, FC/PC**, about **40 m long** (a dedicated measurement, done by G. Riccobene using a LeCroy optical probe - OE425, has produced the result of 39,90 m for the fibre length).

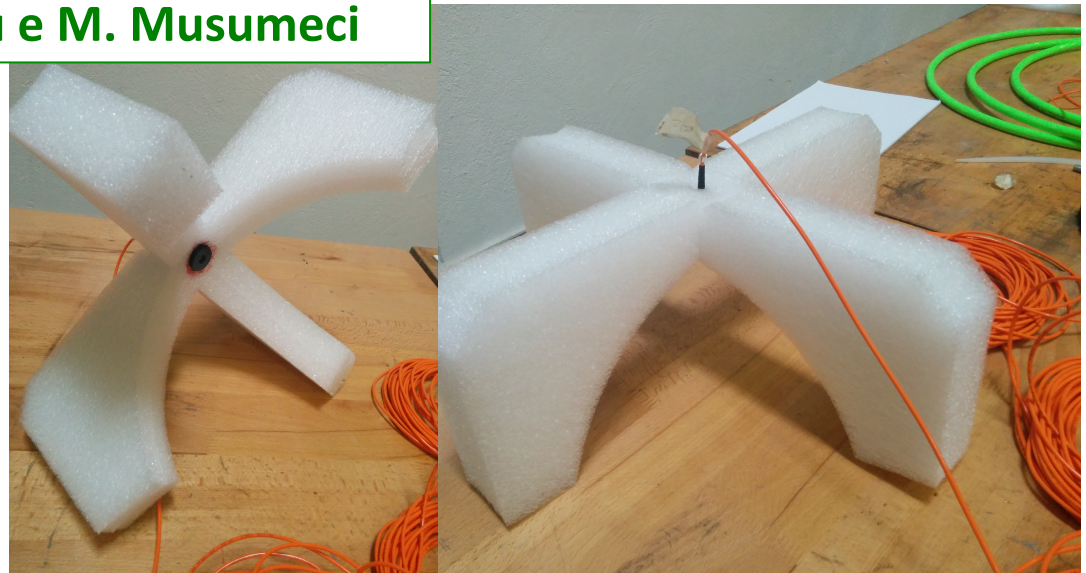
Test Setup

implemented for Tower 8 (October 2014)

The termination of the fibre was positioned on the sphere, in front of the LED. A mechanical solution is under study to sustain the fibre and fix the position. For the mid-October test, a **temporary solution** was adopted: the FC/PC connector at the fibre end was inserted in a fibre adaptor, mounted in a fiber adaptor housing, in order to help maintaining the termination of the fibre in a vertical position above the LED. The styrofoam wrapping of the spheres was also used, as a sort of “hat”, to further help for the fibre positioning.



**Test setup implemented with
C. Nicolau e M. Musumeci**



Description of the system

The instrumentation of measure TDC Agilent 53230A

Time differences are measured with the **TDC Agilent 53230A**, setting: “Time Interval” (CH2-CH1). The TDC receives two signals, S_A and S_B , at times t_A and t_B , and computes the **time difference** $\Delta t = t_B - t_A$. The distribution of the measurements is the observable of the LED Beacon test.

The reference signal (S_A , CH1) is **the synchronization signal produced by the eFCM**; S_B , entering in channel 2 (CH2) is **the digital output produced by the MPPC sensor** when light is detected.

[front and rear view of the TDC, from the datasheet]



The measurement of the time difference

The other end of the fibre was connected at the MPPC cap through the fiber adaptor; the MPPC sensor received the light from the LED. The MPPC was powered via USB using the PC in the rack located in the test hall.

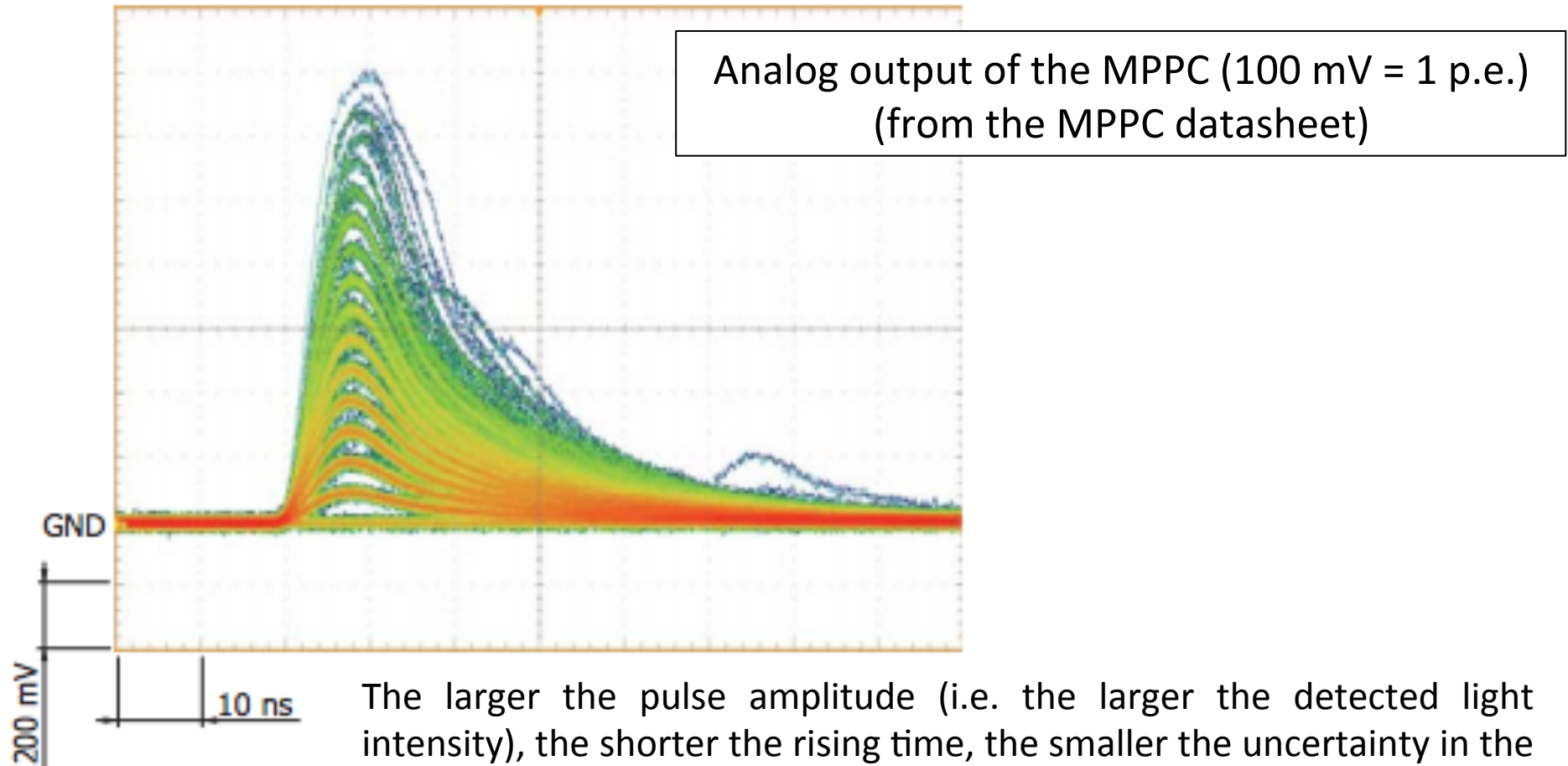
The LED was powered via the FEM, controlled by means of the rack PC through the communication with the eFCM (on the rack) and the floor FCM; the eFCM produced also a **synchronization signal**, that is taken as the time reference for the measurement.

[ask C. Nicolau for details]

The reference signal and the digital output of the MPPC were sent to the **TDC** to get the measurement of the time difference; **20×10^3 readings** are acquired for each LED.

The analog and the digital output of the MPPC were also visualized on the **oscilloscope** (LeCroy Wave Runner 610 Zi), together with the reference signal from the eFCM. This allowed to check the test setup: in particular, the **visualization of the MPPC response** confirmed that **the optical fibre was correctly positioned on the LED** (the emitted light was collected by the fibre and received by the sensor), and that the amount of light received by **the sensor was** enough to put it **in saturation** (condition required to **reduce the uncertainty in the time response of the MPPC**).

Why put the MPPC in saturation?



The larger the pulse amplitude (i.e. the larger the detected light intensity), the shorter the rising time, the smaller the uncertainty in the measurement of the time at a fixed threshold.

Details on the DAQ and on the connections

eFcm → [lemo cable: 8 m] → oscilloscope → [lemo cable: 6 m] → TDC CH1

MPPC_digital → [lemo cable: 1 m] → oscilloscope → [lemo cable: 2 m] → TDC CH2

floor cables: ~ 6 m

(cables connecting the FCM and the FEM for the optical modules hosting the LEDs)

multi-mode optical fibre: ~40 m

(used to transmit the light from the LED to the sensor)

Floor Test (FLOOR 01 ONLY) [shortage of time]

test backbone: ~40 m

Floor outside the dark box (in the “packed tower” configuration); optical modules not covered/obscured; large amount of ambient light.

In addition, the measurement on the LEDs of Floor 01 was done during mechanical operations on the other floors → change of the geometry of the test → **fluctuations in the amount of collected light.**

N.B. not all the readings produced by the TDC are a measurement of the time of interest, because of the presence of **spurious light pulse (background light) collected by the fibre and detected by the light sensor.**

NO Tower Test DONE [shortage of time; unavailability of the test operator]

(Tower Test is the measurement performed with floors and backbone integrated)

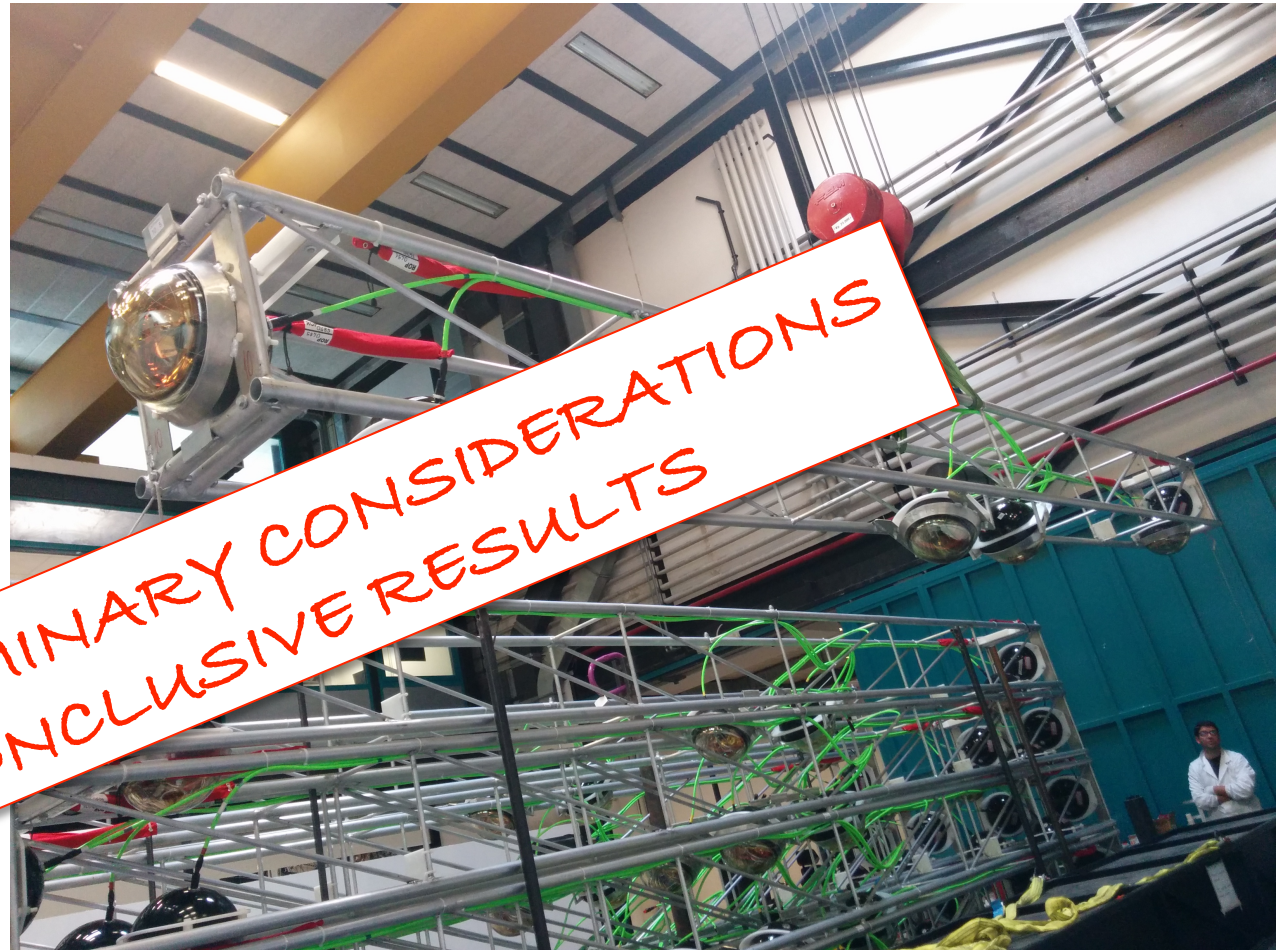
Description of the measurement procedure (October 24th, 2014)

Details on the DAQ and on the connections

Floor Test (FLOOR 01 ONLY)

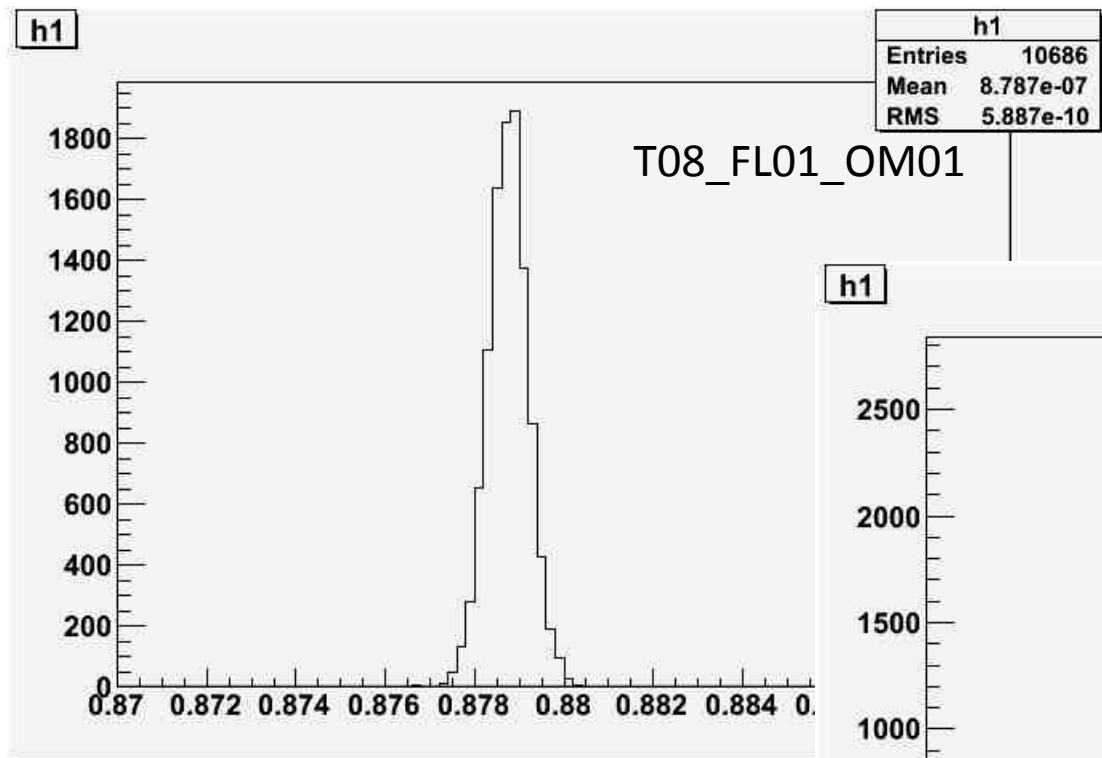


ONLY PRELIMINARY CONSIDERATIONS
NO CONCLUSIVE RESULTS



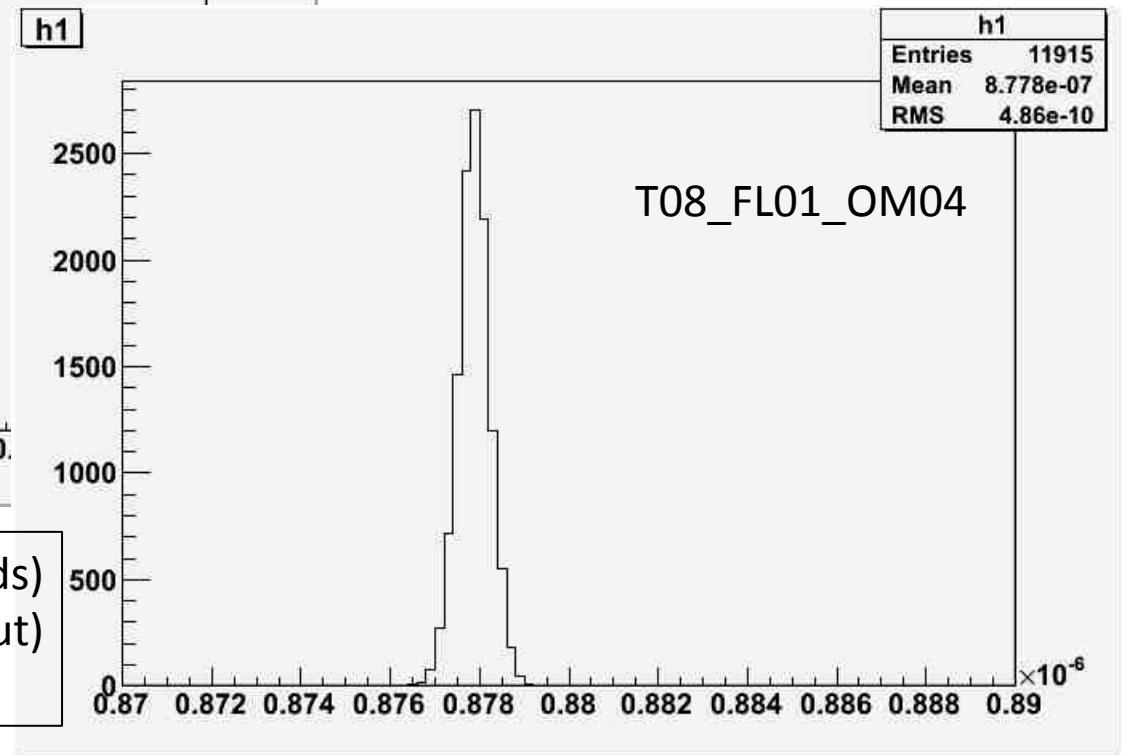
NO Tower Test DONE

Floor Test (T08, FL01)



distribution of the time differences acquired with the TDC

x-axis is the time difference (in seconds) between CH2 (the MPPC digital output) and CH1 (the reference signal)



Floor Test - comments

- Both the measurements have been done setting the number of readings to be acquired with the TDC at the value 20×10^3 . **The statistics is comparable for the 2 Optical Modules** (10686 entries for OM01, 11915 entries for OM04).
- With the LED power such to put the light sensor in saturation the measure of the time difference is quite accurate, with **uncertainty of the order of hundreds of ps** (600 ps for OM01, 500 ps for OM04). It seems that the data we had about the uncertainty on the emission time of the LED (several nanoseconds, by D. Real) were too pessimistic and not correct.
- It is notable that the **mean value** of the distribution is not the same for the 2 Optical Modules of the same floor, with **a difference of about 1 ns** ($\Delta t = 878.7$ ns for OM01, $\Delta t = 877.8$ ns for OM04). The difference is still in the error of the measurement, but it may contain also other effects, for instance: the two LEDs may have a different emission time; the nominal length of the cables connecting the FCM and the FEM for the two modules in symmetric position along the floor is given with an uncertainty of 5 cm.

Lesson Learnt

- The LED Beacon Test is **feasible with the instrumentation already available**; **only few optimizations** may be introduced (already planned, see next slide)
- The test is feasible also with **no cover/obscuration of the optical modules**; the presence of background light does not affect significantly the measurement.
- About **half an hour** is required for completing the acquisition **for a floor** (with the same statistics collected in the preliminary test did on Floor 01)
→ about **1 working day for completing the Floor Test on a Tower**;
< 1 working day for completing the Tower Test on the integrated Tower;
- The **preliminary results are encouraging** about the potential of the measurement **to investigate on the time delay of the system** and to help in **understanding the different components of delay**.
- The Tower Test should produce a valid measurement of **the latency of the backbone** for each floor.

Status & Plans

- Optimize the opto-mechanical interface between the LED and the optical fibre:
 - use collimators
 - ordered by INFN-Roma, in shipment
- ThorLabs F280FC-A; 543 nm, $f = 18.07$ mm, NA = 0.15 FC/PC
[selected with the help of E. Maccioni]
- use multi-mode fibres 62.5/125 (larger core, larger amount of collected light)
 - ordered by INFN-Roma
 - define a simple mechanical support (a precision optics is not compatible with the constraints of the operations) to hold the fibre termination in a fixed position
 - **Collect more data!** 😊 😊 😊

