The LED Beacons prototype system for the time calibration of the KM3NeT-IT Towers

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on behalf of KM3NeT-IT

Outline

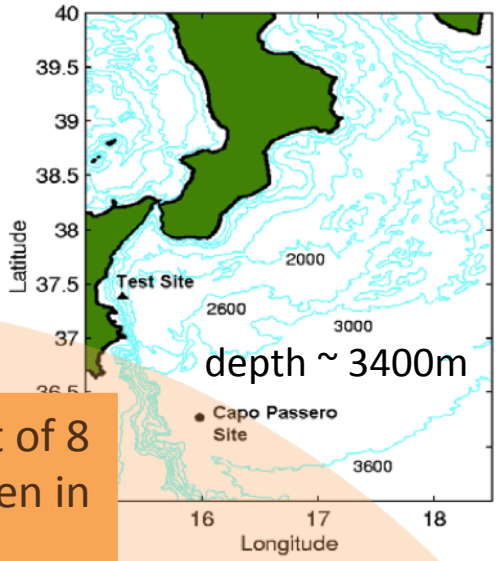
- The Towers detector in KM3NeT-IT
- The LED sources as tool for time calibration of the towers

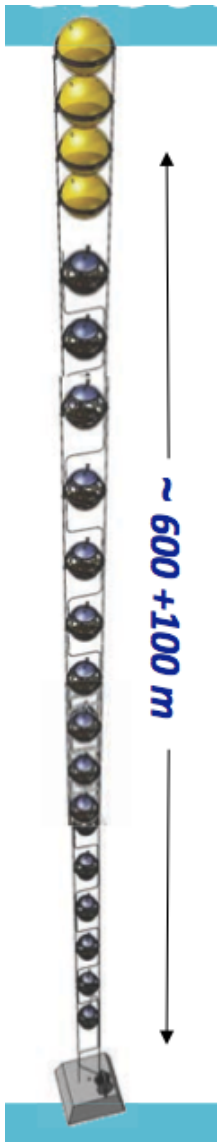
  → **the LED Beacon Test**

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

KM3NeT-IT

KM3NeT @the Capo Passero site





STRINGS + TOWERS

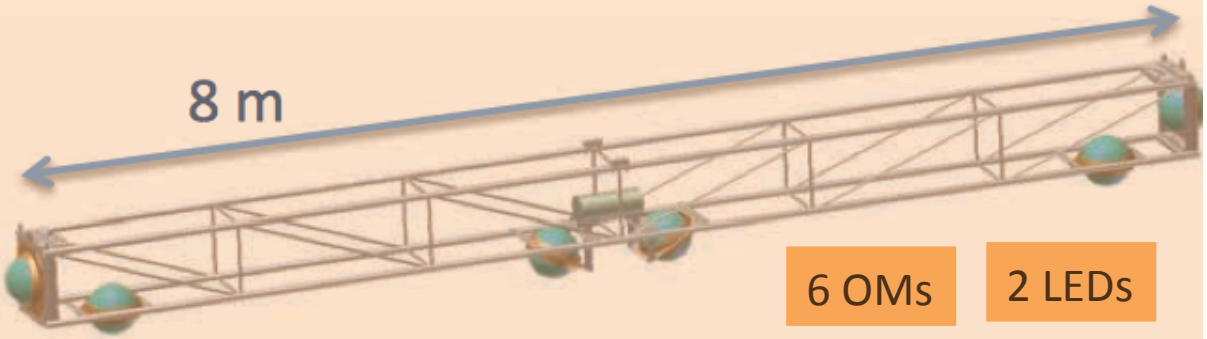
DOM 17"

The deployment of 8 towers is foreseen in Phase-1

Buoy

14 floors

Tower base



6 OMs

2 LEDs

The Tower

Power Supply
Clock Distribution: all the systems off-shore are syncronous with the on-shore generated clock
eFCM: on-shore counterpart of the FCM
→ receive data from the floor (OMs, hydrophones, slow-control instruments)
→ send clock and commands to the floors

FCM = Floor Control Module

for each OM,
FEM = Front End Module
→ collect data from the PMT
→ control the LED emission

Backbone: point-to-point e.o. connection to the BT

The LED Beacon Test

- use the LED sources mounted in the OMs to develop a complementary system for the **determination** (on shore and before the Tower deployment) **of time delays**, aiming at the characterizations of the time response **of the different elements of the detector**. In particular, two sets of measurements can be planned:

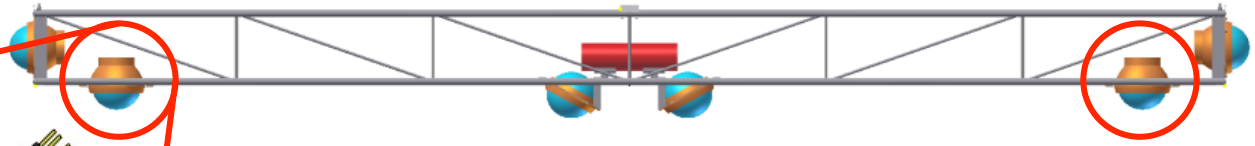
- the FLOOR Test → estimate the **floor latency** (system FCM + cable + FEM)
- the TOWER Test → estimate the **backbone latency** for each floor (using the result of the floor latencies)

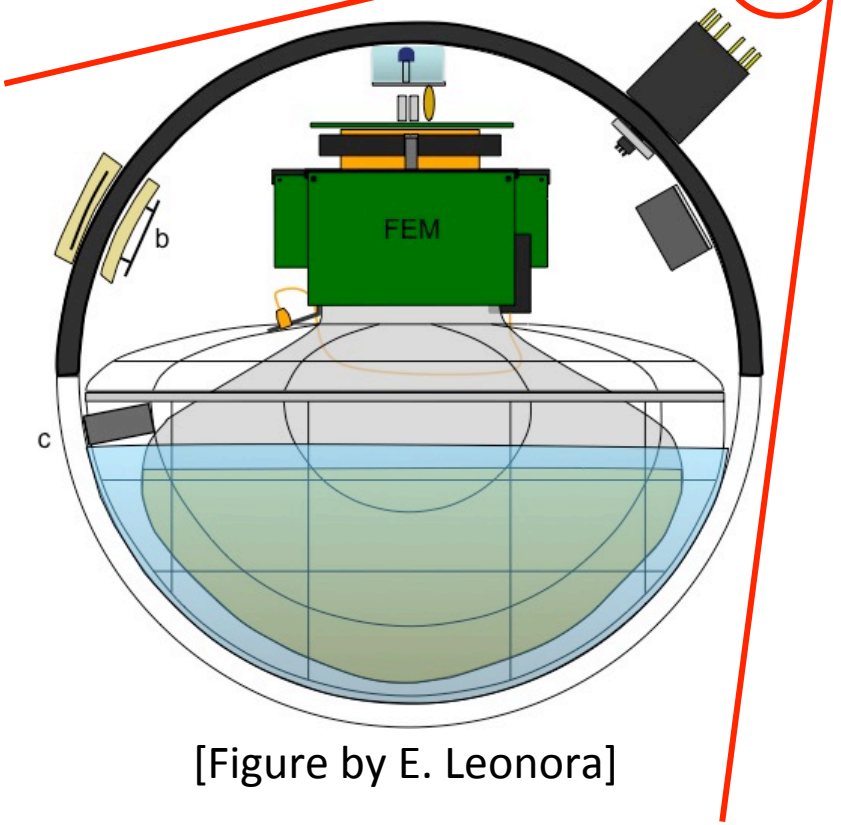
Desiderata for the time calibration system

- Easy&quick…
  - to implement
  - to carry on the measurements
  - to analyze the data
- Due to the large number of detection units to be tested (and the severe time-restrictions imposed during the integration phase)…
  - require a short amount of time for a complete set of measurement
  - allow the possibility to perform the test in parallel with other activities carried on in the intregration site

LED Beacons
in the Optical Modules

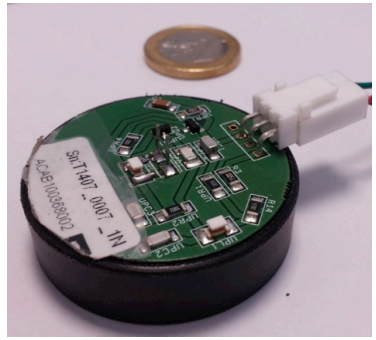
2 LED sources per floor are mounted in the Tower in the 2 Optical Modules that are downward-looking, for a total of 28 LEDs per Tower. The LEDs emit at a wavelength of **470 nm**.





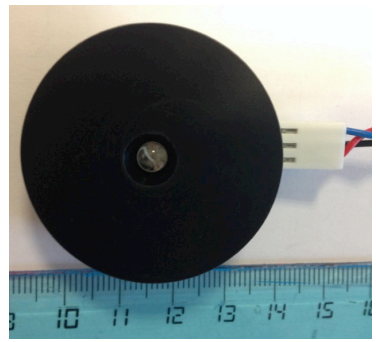
[Figure by E. Leonora]

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.



Front and rear view

The distance between the LED emitting point and the internal surface of the sphere is less than 0.5 mm; the tickness of the glass sphere is 12 mm.



The light sensor

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.

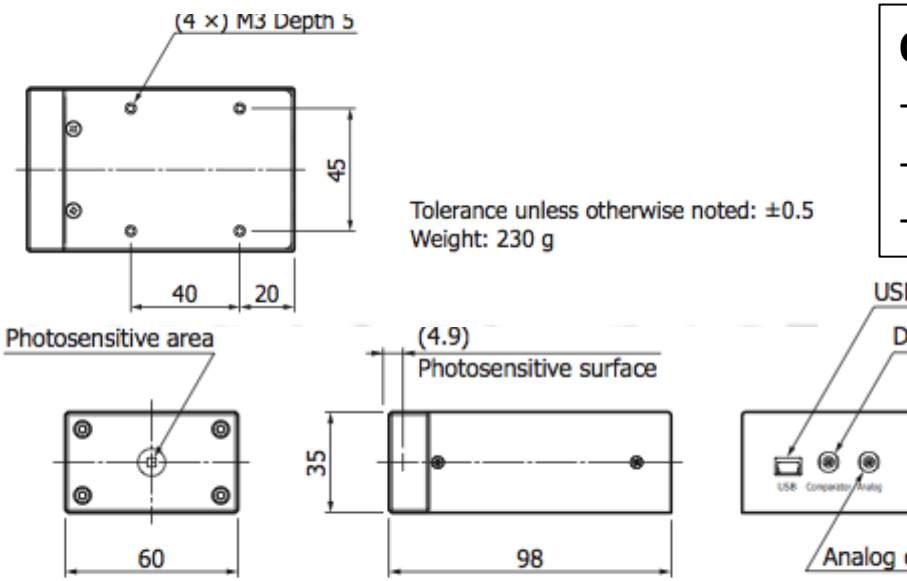
Advantages
- excellent photon counting capability;
- insensitivity to magnetic fields;
- low voltage operation (USB connection);
- pocket-size.

Photo sensor
- effective photosensitive area: 3 x 3 mm^2;
- 3600 pixels;
- pixel pitch: 50 μm.

Hamamatsu C11208-350 MPPC Starter Kit

Electrical and optical characteristics (Typ. Ta=25 °C, λ=λp, 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	λp		-	450	-	-	450	-	nm
Element temperature (setting temperature)	Td		-	-10	-	-	0	-	°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) → Photon counting
- Comparator (digital output)
- Analog (analog output)

[power supply] → connection with PC (Windows XP/Vista/7) is required

Optical Fibres

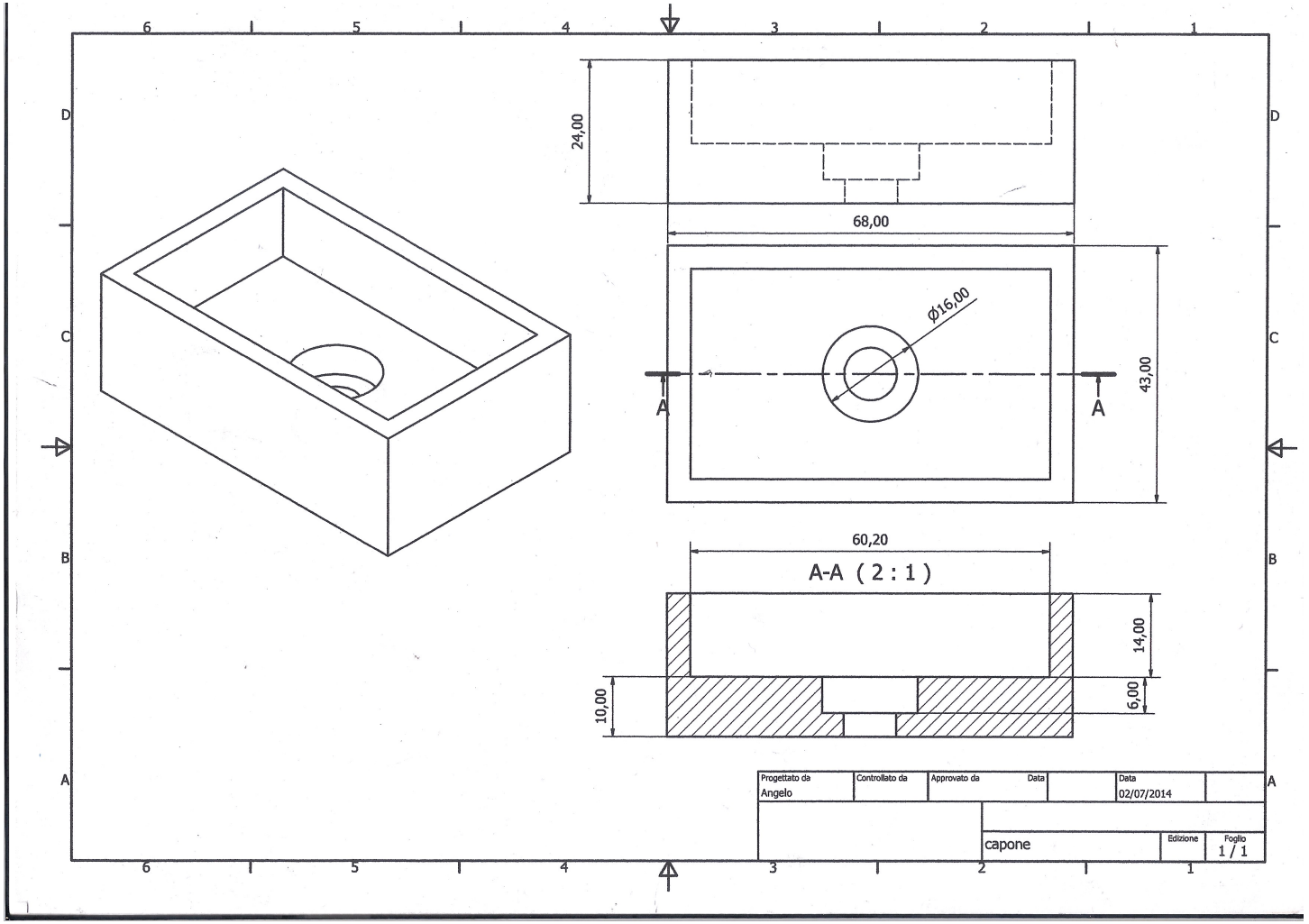
An optical fibre collects the light emitted by the LED and transmits it to the sensor. **FC/PC connectors** are mounted at each end of the fibre. The coupling of the fibre with the light source and the light sensor is an important **mechanical issue** to be faced for the accomplishment of the LED Beacon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

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

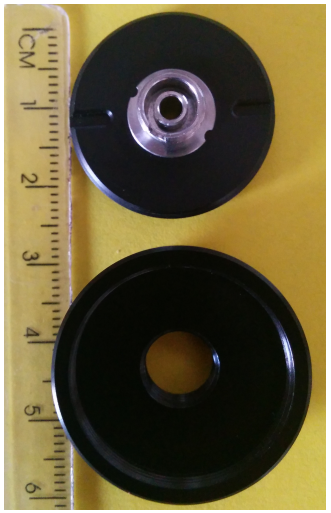
The cap allows a perfect match of the photo-sensitive area with the optical fibre and prevents the detection of back-ground light.

Description of the system

Test Setup

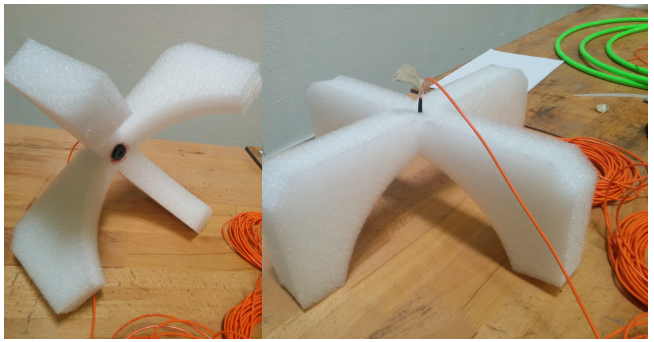
implemented for Tower 8 (October 2014)

Because of the shortage of time, only few measurements have been carried on in the "Dark Box"[1] (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 perform the test using only one **fibre** (**multi-mode, 50/125, FC/PC**, ~**40 m long**[2]) that was manually shifted from LED to LED.



During the preliminary test (Oct 2014) a **temporary solution** was adopted for **positioning the termination of the fibre in front of the LED**: 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.



[1] The "Dark Box" is a container designed to encapsulate the floor during the tests, preventing ambient light to invest the structures (project by INFN-Genova).

[2] A dedicated measurement, done by G. Riccobene using the LeCroy optical probe OE425, has produced the result of 39,90 m for the fibre length.

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

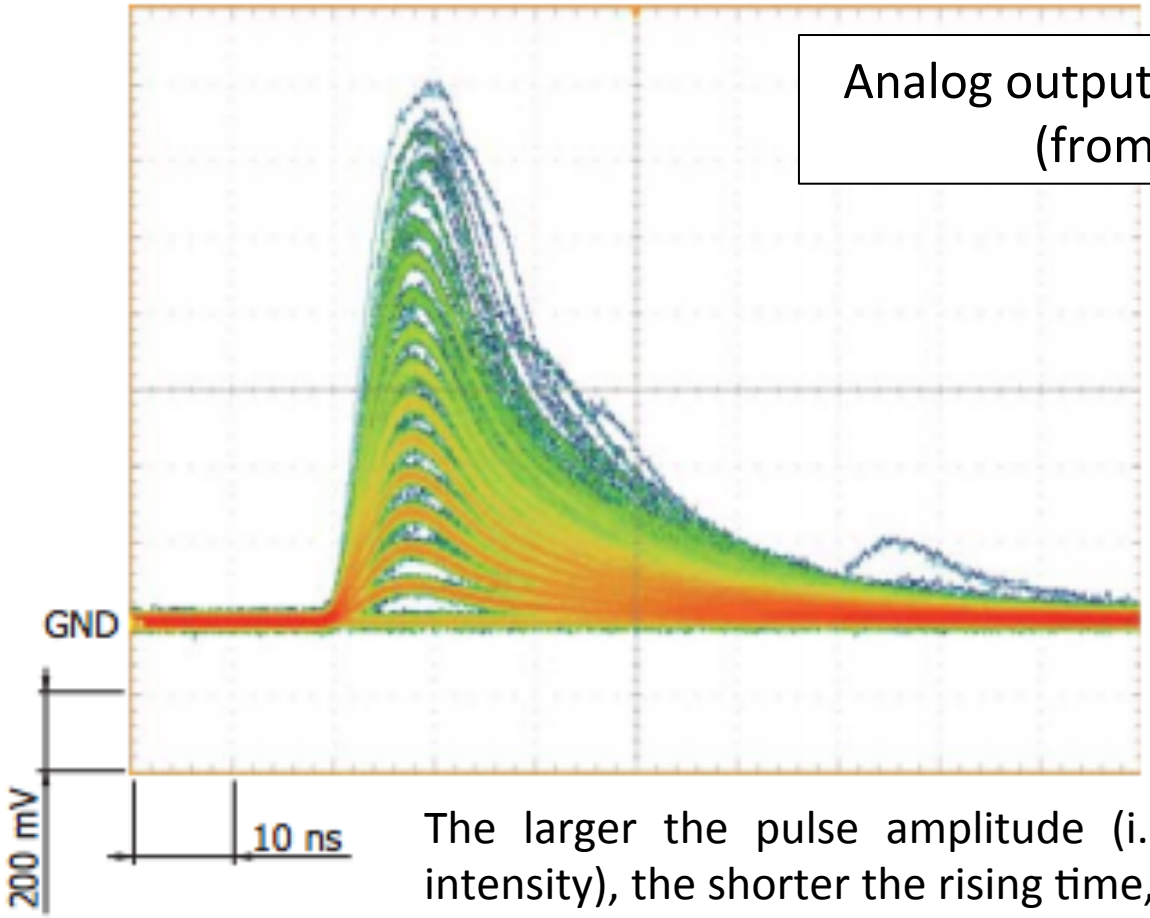
The other end of the fibre was connected at the MPPC cap through the fiber adaptor; the MPPC sensor received the light from the LED. The MPPC was powered via USB using the PC in the rack located in the test hall.

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 **syncronization signal**, that is taken as the time reference for the measurement.

The reference signal and the digital outoput of the MPPC were sent to the **TDC** to get the measurement of the time difference; **$20x10^3$ readings** were 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?



Analog output of the MPPC (100 mV = 1 p.e.)
(from the MPPC datasheet)

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**.

Details on the DAQ and on the connections

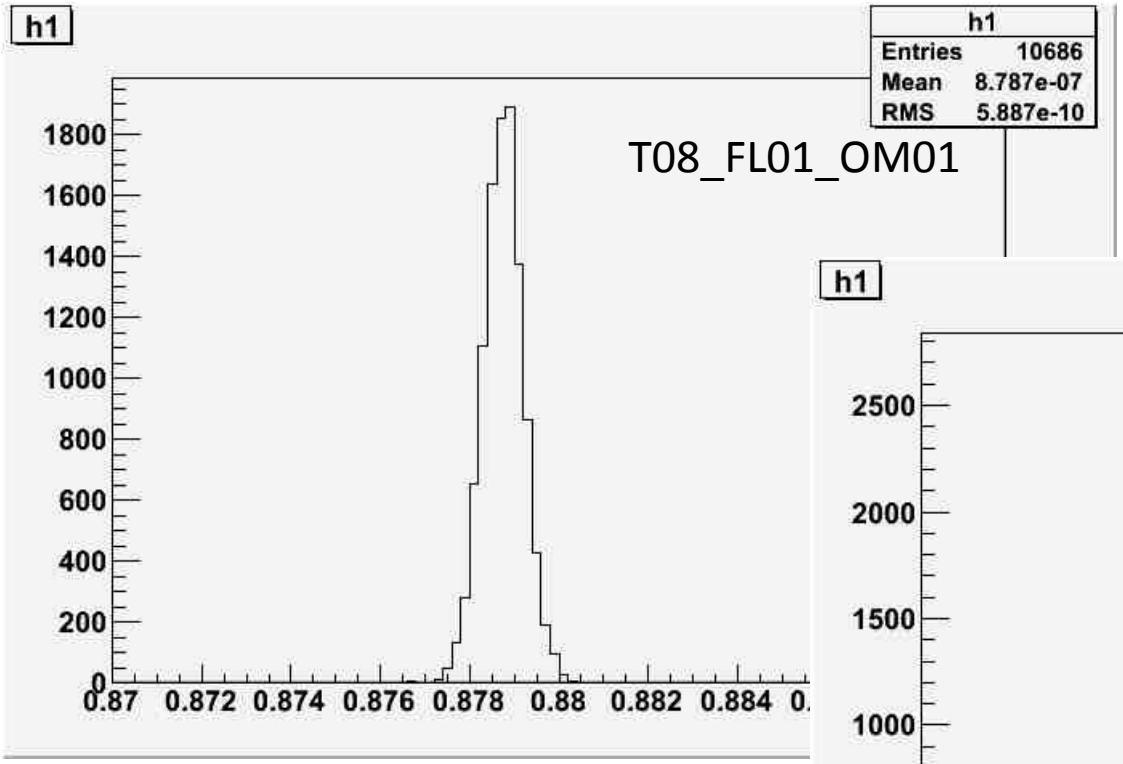
Floor Test (FLOOR 01 ONLY)

ONLY PRELIMINARY CONSIDERATIONS
NO CONCLUSIVE RESULTS

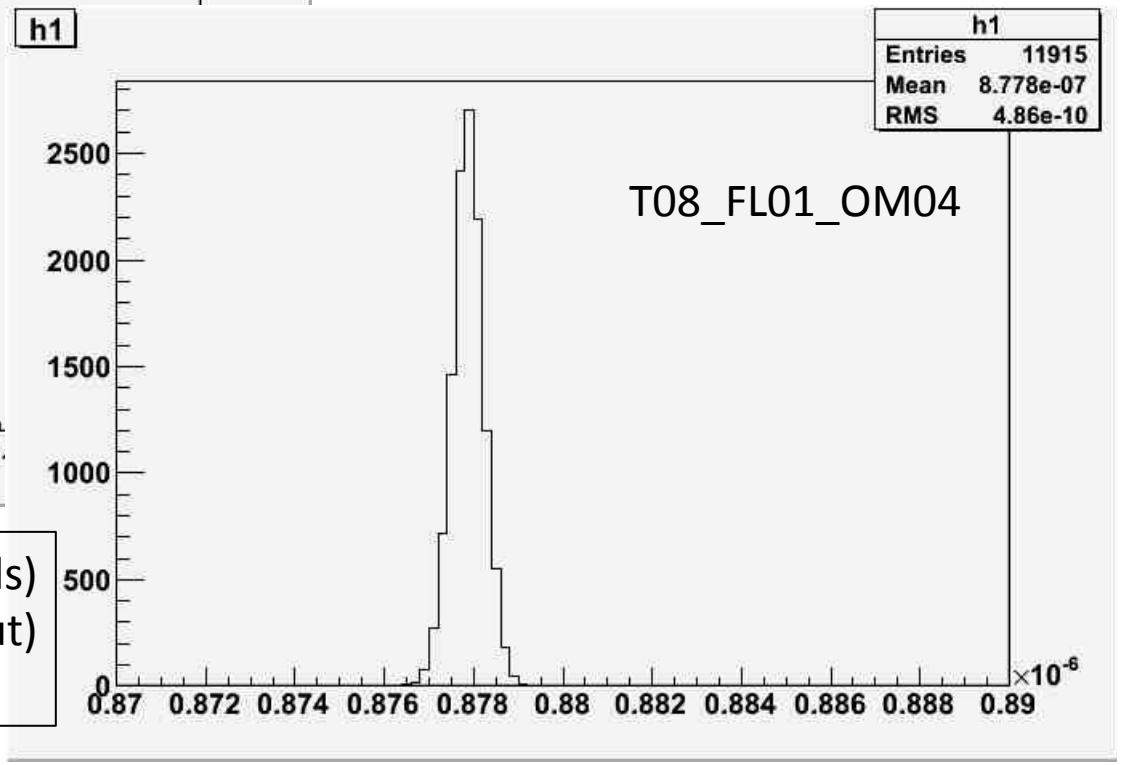
NO Tower Test DONE [shortage of time; unavailability of the test operator]
(Tower Test is the measurement performed with floors and backbone integrated)

Preliminary results (October 2014)

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 $20x10^3$. **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 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** (Δt = 878.7 ns for OM01, Δt = 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 significatly the measurement.
- About **half an hour** is required for completing the acquisition **for a floor** (with the same statistics collected for T08/FL01)
  → 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

ThorLabs F280FC-A; 543 nm, f = 18.07 mm, NA = 0.15 FC/PC

- use multi-mode fibres 62.5/125 (larger core, larger amount of collected light)
- 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! ☺ ☺ ☺