ECAL LED Monitoring System

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Light monitoring system

Motivations for a light monitoring system in the HPS Ecal:

- $PbWO_4$ crystals are radiation-sensitive, light transmission lowers resulting in effective LY loss.
- Such a process is non-uniform in the Ecal, due to the different irradiation in each crystal (geometrical effect).
- Crystals response needs to be monitored continuously and, if necessary, re-calibrated
- Possible APDs gain variation during time needs to be under control.

From the CLAS12 FT-Cal experience, we learned that, during commissioning, it is critical to switch on/off channels independently for fast debugging.

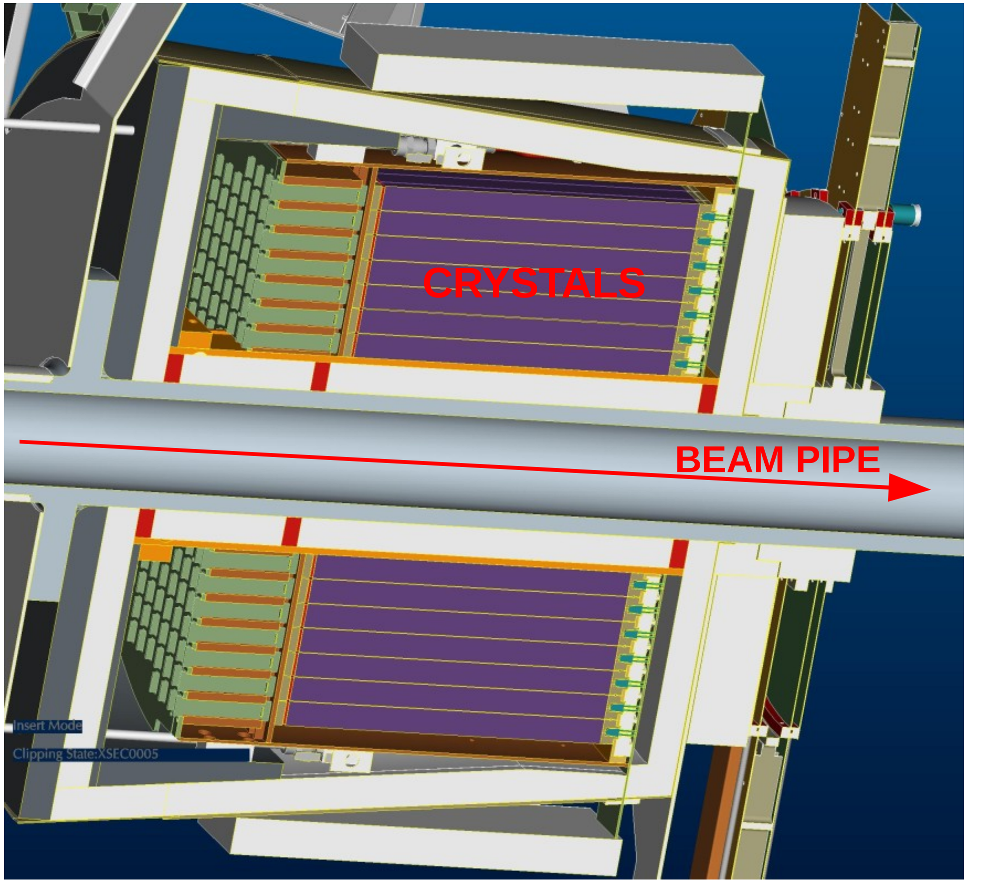
- Test the correct functionality of all APDs / amplifiers.
- Check all the electronic channels.
- Verify correct cabling.

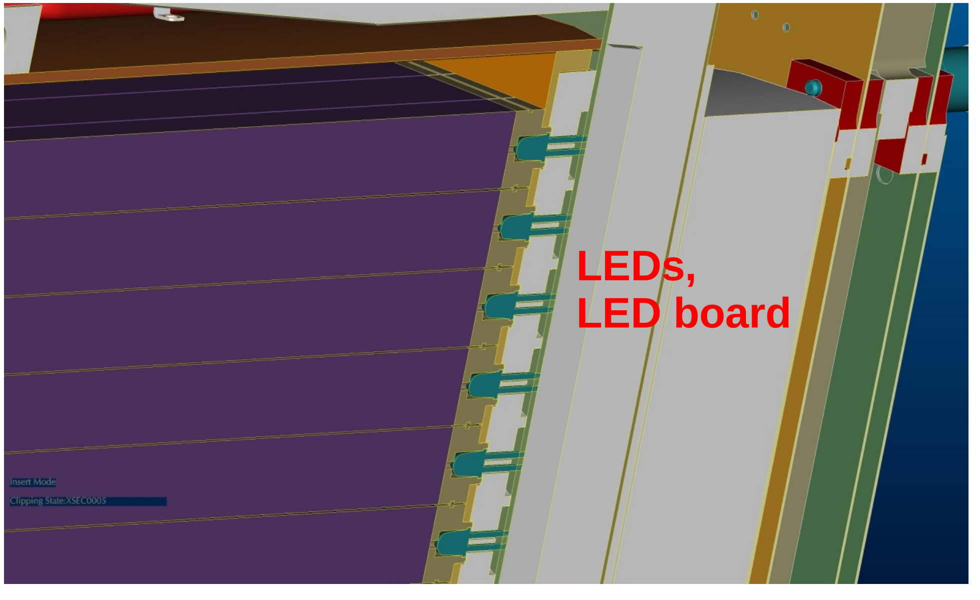
Light monitoring system

We propose to design the HPS Ecal monitoring system starting from the existing FT-Cal LED monitoring system.

FT-Cal monitoring system:

- **Blue** LEDs coupled directly to the front of the crystals trough a proper PEEK support.
- Each LED is pulsed by a dedicated, fast driver.
- The whole system is managed trough a dedicated controller, EPICS compliant.





Light monitoring system

Design of the system for HPS ECal

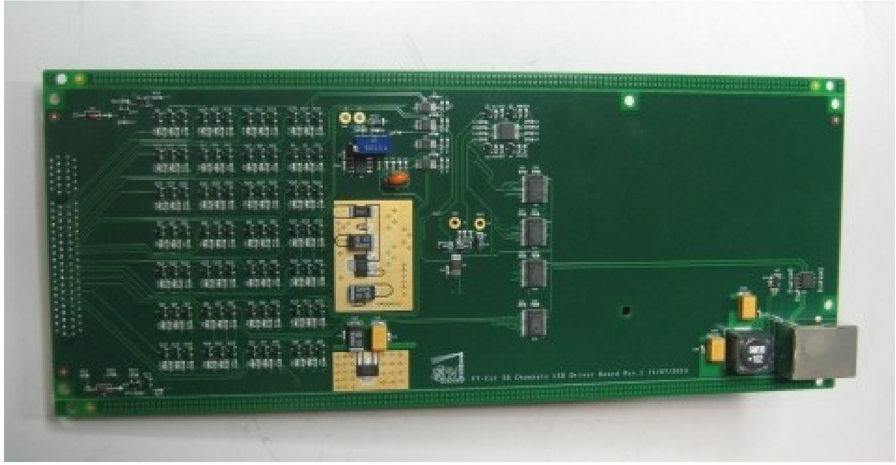
The FT-Cal light monitoring system is currently made of 3 separate sub-components:

The main controller

- Provides communication with the system trough Ethernet/USB interfaces.
- EPICS compliant.
- Mounted in a crate, ~10 m from the calorimeter.
- Handles up to 6 driver boards.
- **No further modifications are needed.**

The driver board

- Hosts the independent LED pulser circuits.
- Communicates via I^2C with the main controller.
- Mounted out of the calorimeter enclosure, it is connected to the LED board.



Light monitoring system

Design of the system for HPS Ecal

The LED board

- It is mounted in front of the calorimeter, inside the thermal enclosure.
- It is connected to the driver board trough a board-to-board connector.
- It needs to be re-designed according to HPS mechanics.

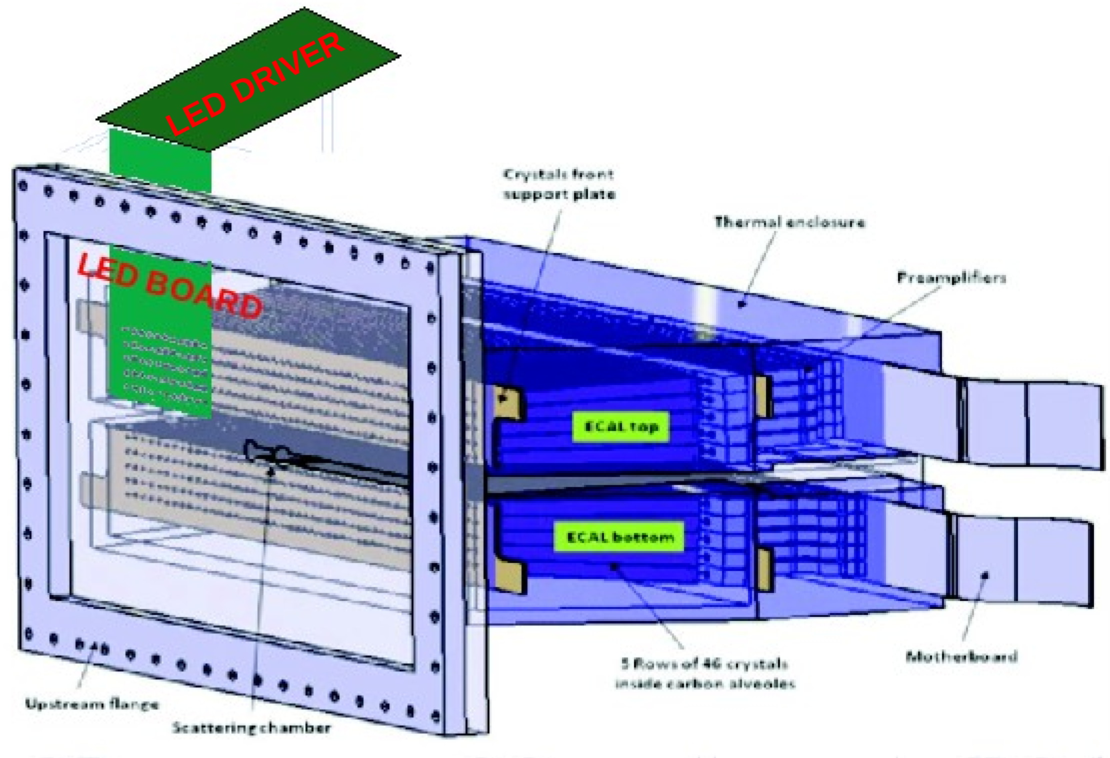
All LEDs must be tested independently before mounting on the LED board, to check if they are compliant with the required dynamic range and timing response.

- We use a single-channel LED driver coupled to a $PbWO_4$ crystal + APD.
- The full test procedure requires ~ 5 minutes / LED.

Light monitoring system design

Foreseen design: couple LEDs directly to crystals.

New PCB boards hosting LEDs mounted in the ECAL front, with connectors out of the vacuum-tight box to the LED drivers.



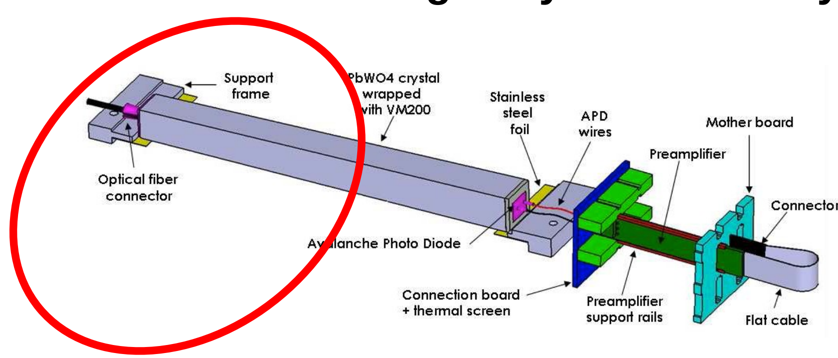
PRO:

- Tested solution, already validated with a 16-channels prototype.
- Only a re-arrangement of the driver components is required for the electronic design.

CON:

- Need to re-design single-crystal assembly, changing the upstream PEEK support.
- Need to modify ECAL enclosure to accommodate the new PCBs.
  (The enclosure has to be modified anyhow for the new motherboards).

HPS ECAL single crystal assembly

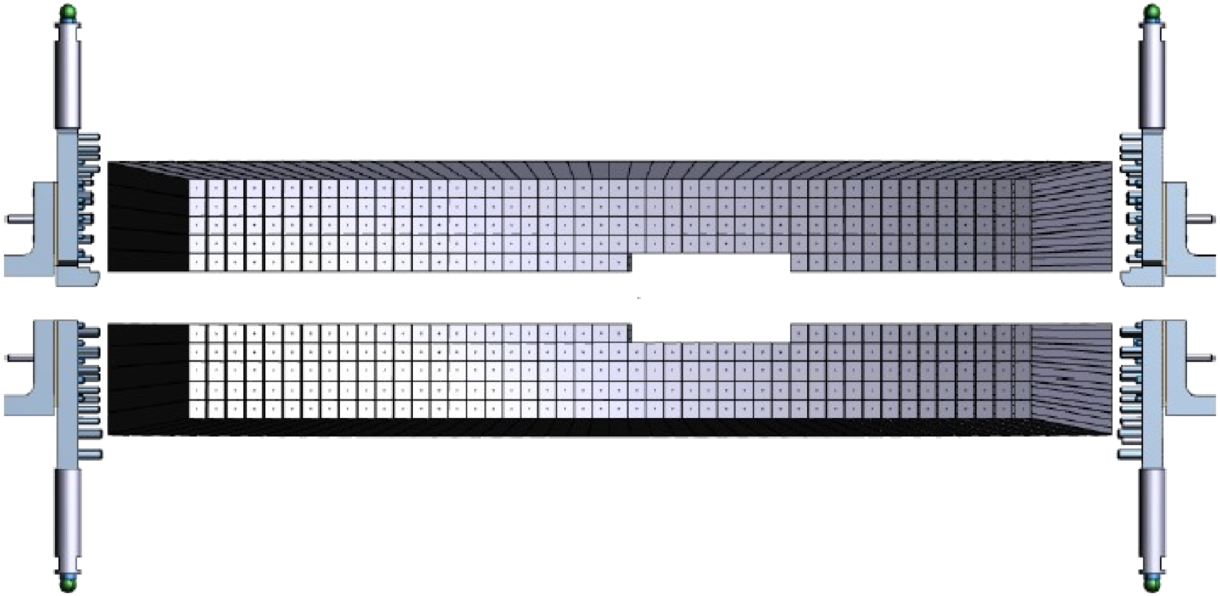


Light monitoring system design

ECAL crystals are tapered: the ECAL front face is not planar.
The mechanics of the LED boards needs to be adapted.

- Mount the board-to-board connectors following the curvature of the ECAL front face.
- Use a rigid-flex PCB for the LED board. It can be adapted to the ECAL curved front face. Mechanical stability is guaranteed by PEEK supports LED are inserted in.

R&D is in progress.



HPS ECAL:

- 2 symmetric modules.
- 221 crystals per module.
- 46 columns with 5 crystals in each module.

By-color LEDs

We explored the possibility to use by-color LEDs (blu/red), model RAPID 56-0352.

- Different colors permit to check different ECAL parameters:
  - Blue LED: optical transmission / radiation damage.
  - Red LED: APD gain.

- RED component is less sensitive to radiation damage: we exposed by-color LEDs to a ^{60}Co source (~3 krad) and measured their emission before and after irradiation.
  - Red: no appreciable variation
  - Blue: variation ~ 10%
  - For comparison: single-blue LED, FT-Cal: variation ~ 20-30%

The design modifications needed to use by-color LEDs have been tested and validated trough a single-LED driver.

These single-LED pulsers will be employed during the foreseen tests of all the ECAL crystals+APDs.

- 5 pulsers have been produces and tested.
- The performances of the by-color LED have been measured to see if they match ECAL requirements.

Conclusions

We are designing the ECAL light monitoring system starting from the already-existing Forward Tagger system.

- Single LEDs coupled to the front face of the crystals, trough properly-modified PEEK front support.
- Each LED is pulsed independently by a dedicate circuit.

- The option to use by-color red/blue LED is being explored. It has been validated with single-channel pulsers, regarding both the LED model that can be used and the modifications needed to the “standard” single-color circuit.

- The project design is in progress.
  - Need to adapt the PCBs to the curved ECAL front face.
  - Different solutions are available.
  - Need to coordinate with the mechanical experts.

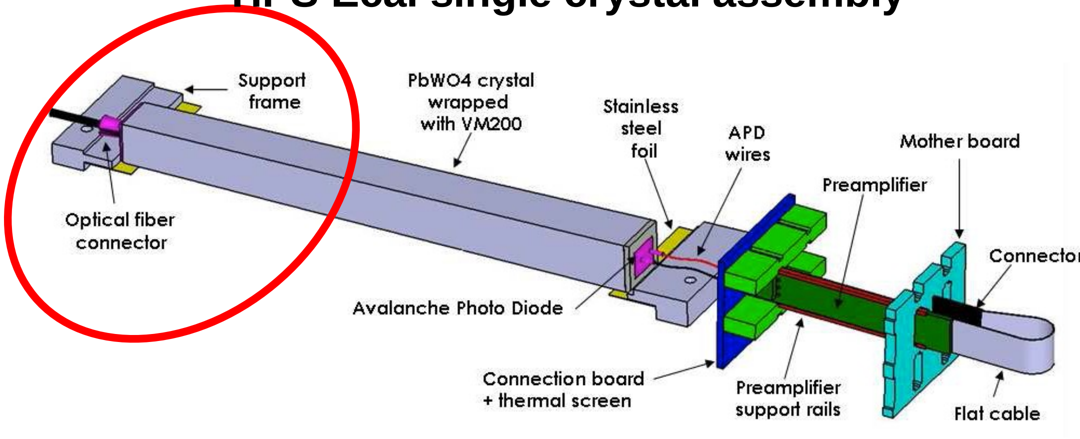
Light monitoring system

Option 1: couple LEDs to crystals with optical fibers (CLAS-IC solution)

PRO:

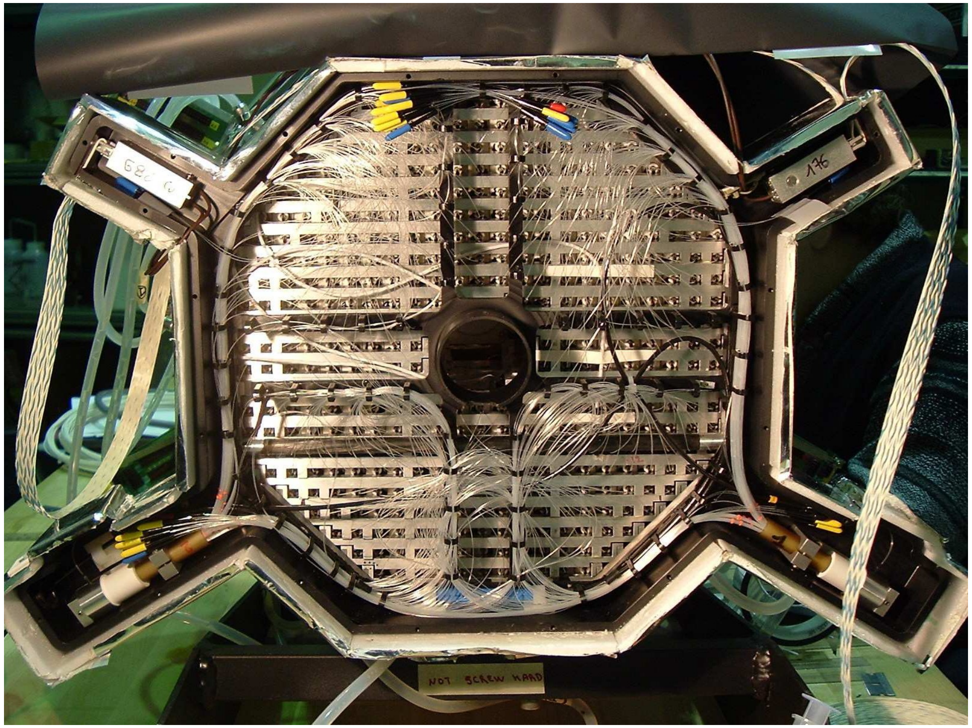
- Crystals already have optical fiber connector.
- No necessity to separate LEDs from the drivers on different PCBs.

HPS Ecal single crystal assembly



CON:

- Need to select optical fibers and study their response.
- Need to route the 442 optical fibers out of the Ecal enclosure.
- Need to study the coupling between LEDs and optical fibers.

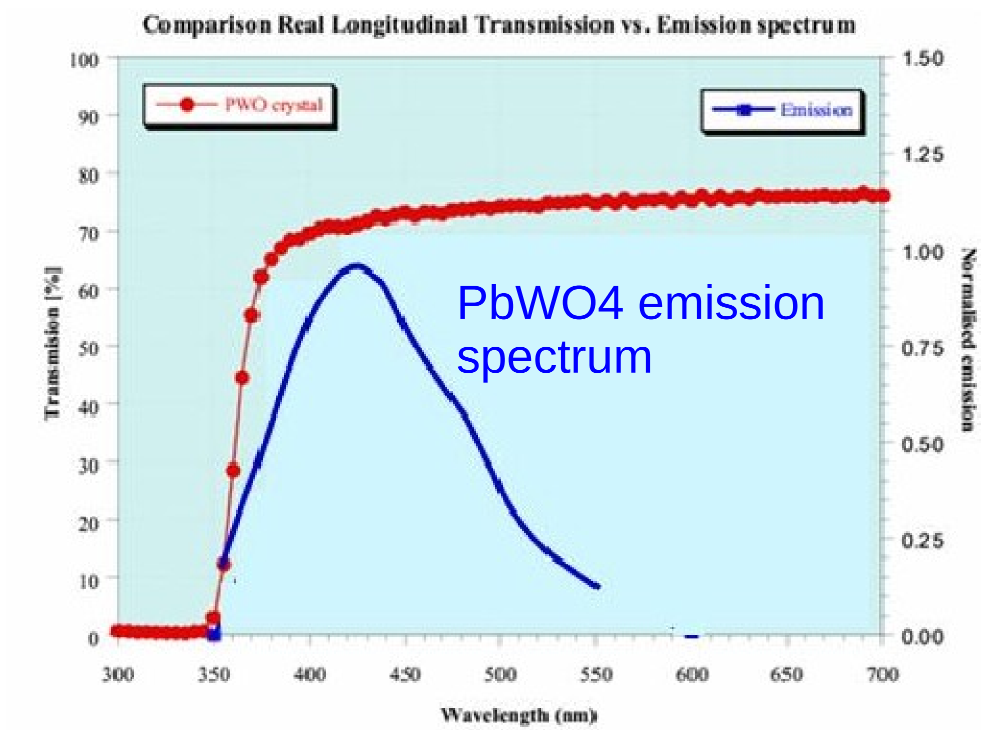


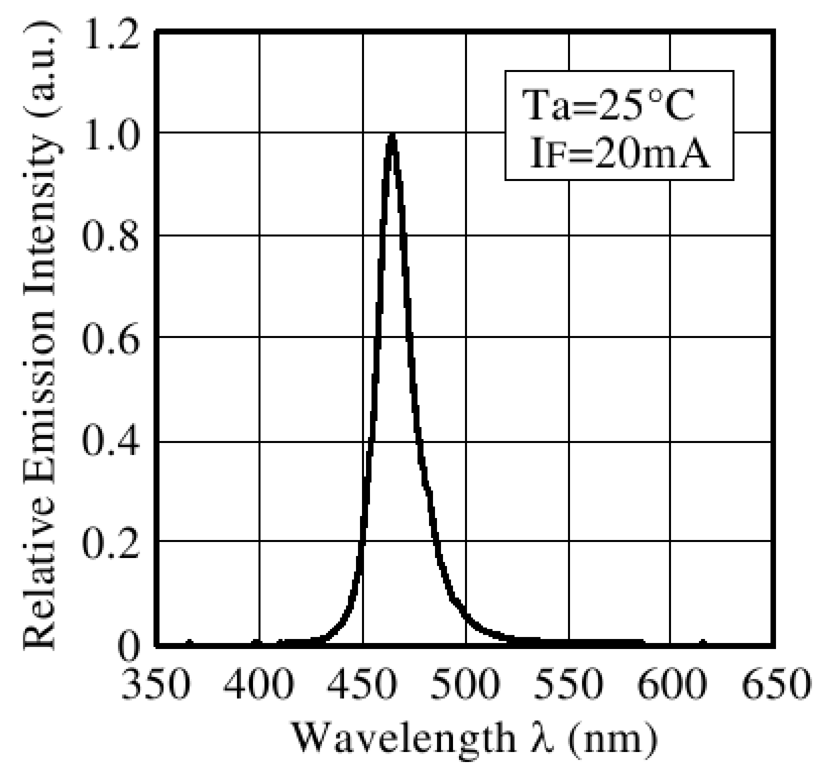
Light monitoring system

LED choice was a critical task.

It was difficult to find a device emitting short-enough light pulses: data-sheets do not report LED performances at ns scale.

Final choice: **NICHIA NSPB500AS blue led**, well matched to the $PbWO_4$ spectrum and capable to emit fast (~10 ns) pulses.





Light monitoring system

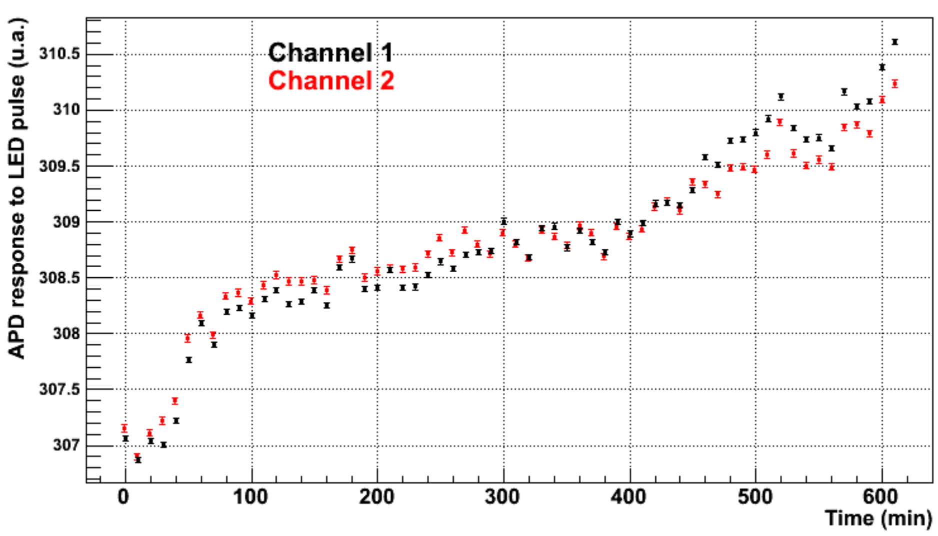
System stability

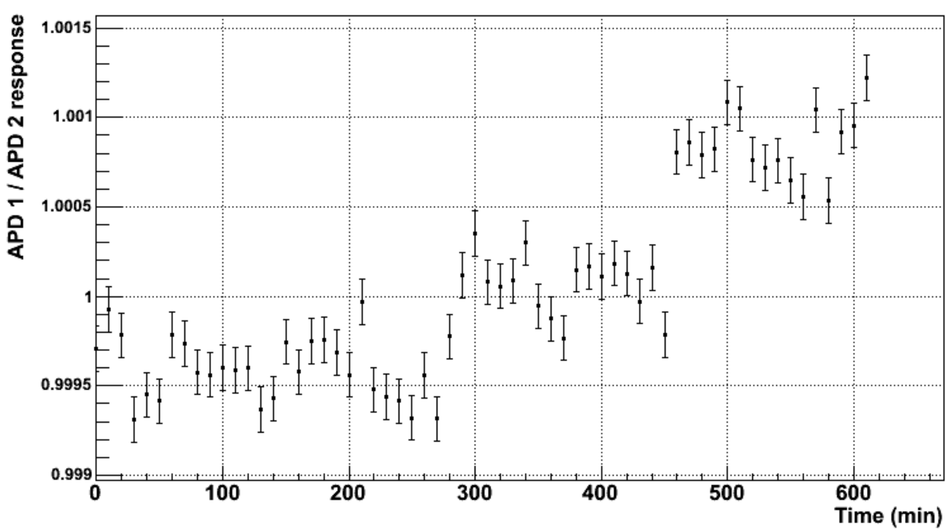
Time stability of the light monitoring system is a mandatory requirement.

We measured the stability of a 16-channel prototype of the FT-Cal light monitoring system, during a **100h** time period.

- Single channel response variation ~ 2.2 %
- Variation in the ratio between two different channels response ~ 0.1 %

10 hours strip-charts

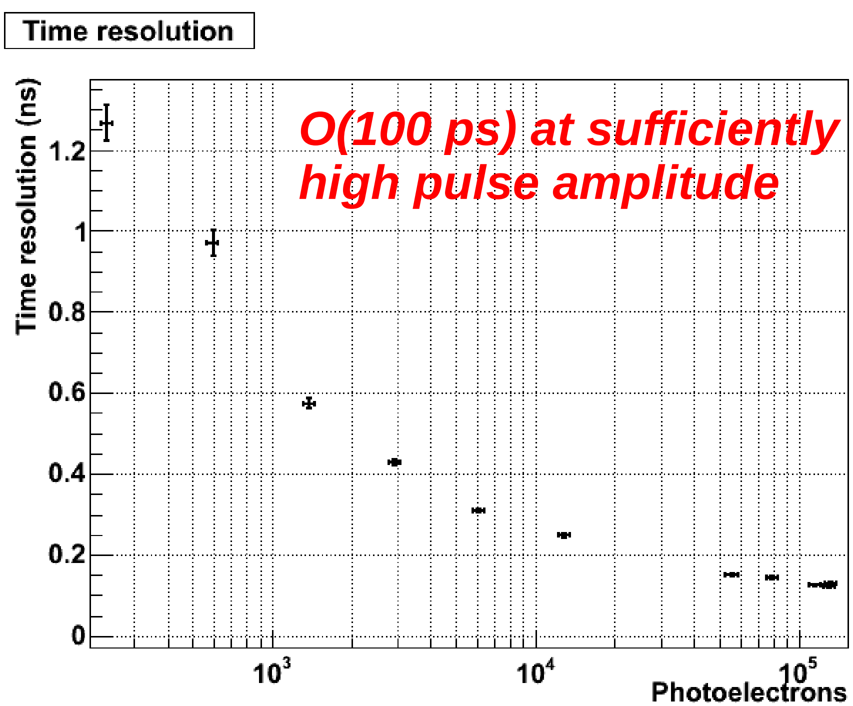


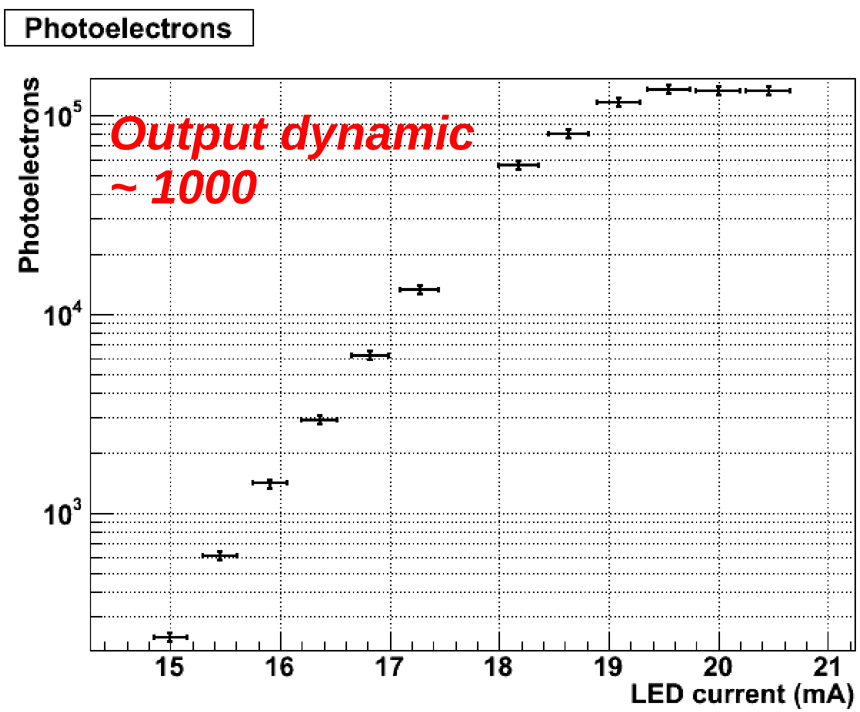


Light monitoring system

Driver Performances

Both the dynamic range and the timing of a prototype of the LED driver were measured using a fast PMT (XP2262B).





Current resolution:
0 – 50 mA, 12 bits ⟶ 0.012 mA