

ECAL LED Monitoring System

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Light monitoring system

Motivations for a light monitoring system in the HPS Ecal:

- The system provide a fast pre-calibration during in-lab commissioning, both for energy and timing, before real calibration with physics is performed.
- 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.

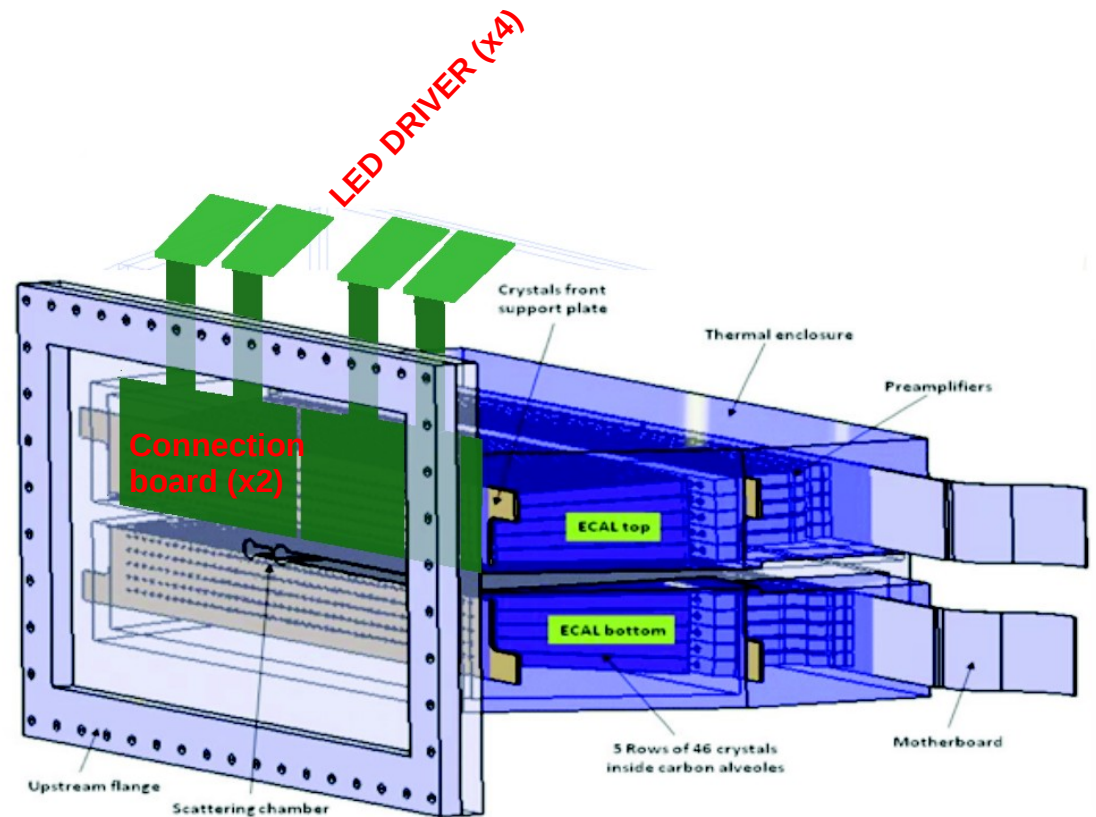
Light monitoring system design

Foreseen design: couple LEDs directly to PbWO_4 crystals.

Use wires to connect LEDs to CONNECTION BOARD, mounted in ECAL FRONT

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

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



Light monitoring system

Design of the system for HPS ECal

The HPS-ECal light monitoring system is made of 3 separate sub-components:

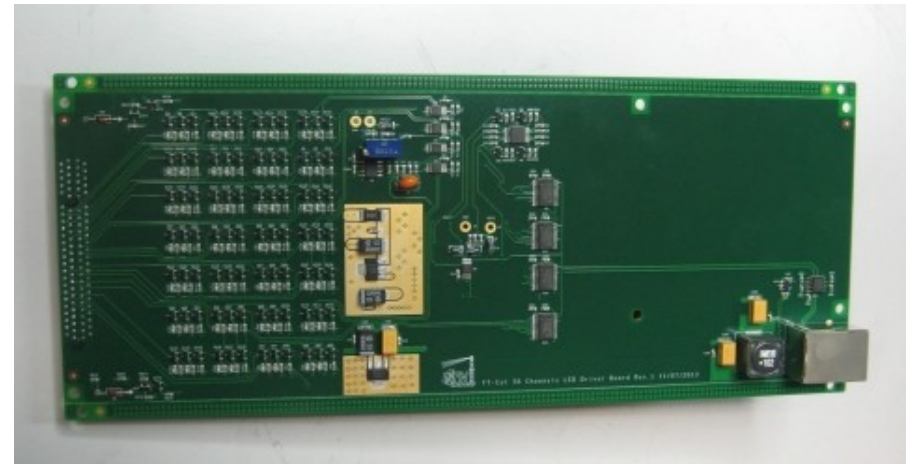
The main controller

- Provides communication with the system through Ethernet/USB interfaces.
- EPICS compliant.
- Mounted in a crate, ~10 m from the calorimeter.
- Handles up to 6 driver boards.
- **READY.**



The driver board

- Hosts 56 independent LED pulser circuits.
- Communicates via I²C with the main controller, through Ethernet-like cable
- Mounted out of the calorimeter enclosure, it is connected to the LED board.
- **READY.**



Light monitoring system

Design of the system for HPS Ecal

The connection board

- Is mounted in front of the calorimeter, inside the thermal enclosure.
- Is connected to the driver boards trough board-to-board connectors.
- **Needs to be designed from scratch.**

Required boards:

- 8 driver boards, 4 for TOP, 4 for BOTTOM
- **448** available LED channels
- Each connection boards serves 112 LED
- The 3 LEDs in excess on LEFT side are handled trough the 6 free connectors on the RIGHT side. RIGHT side PCB is properly designed for this.
- 2 controllers, 1 for TOP, 1 for BOTTOM



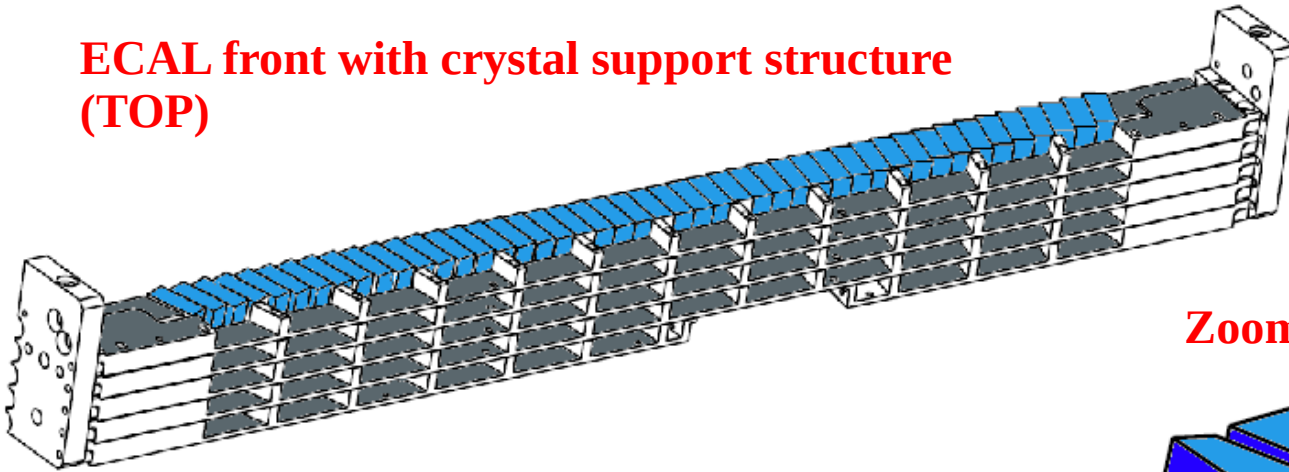
Crystal counts (442 total):

TOP-LEFT	TOP-RIGHT
115	106
115	106
BOTTOM-LEFT	BOTTOM-RIGHT

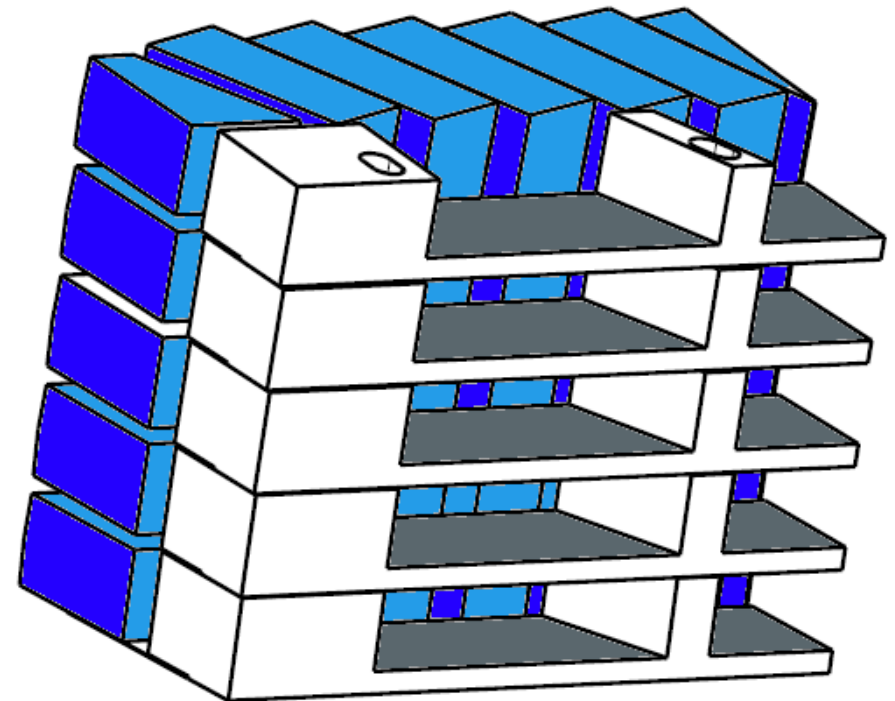
Light monitoring system: connection board

LED connection to LED board trough wires is the easiest solution, given the mechanical constraints on ECAL front.

**ECAL front with crystal support structure
(TOP)**



Zoom, left corner (TOP)

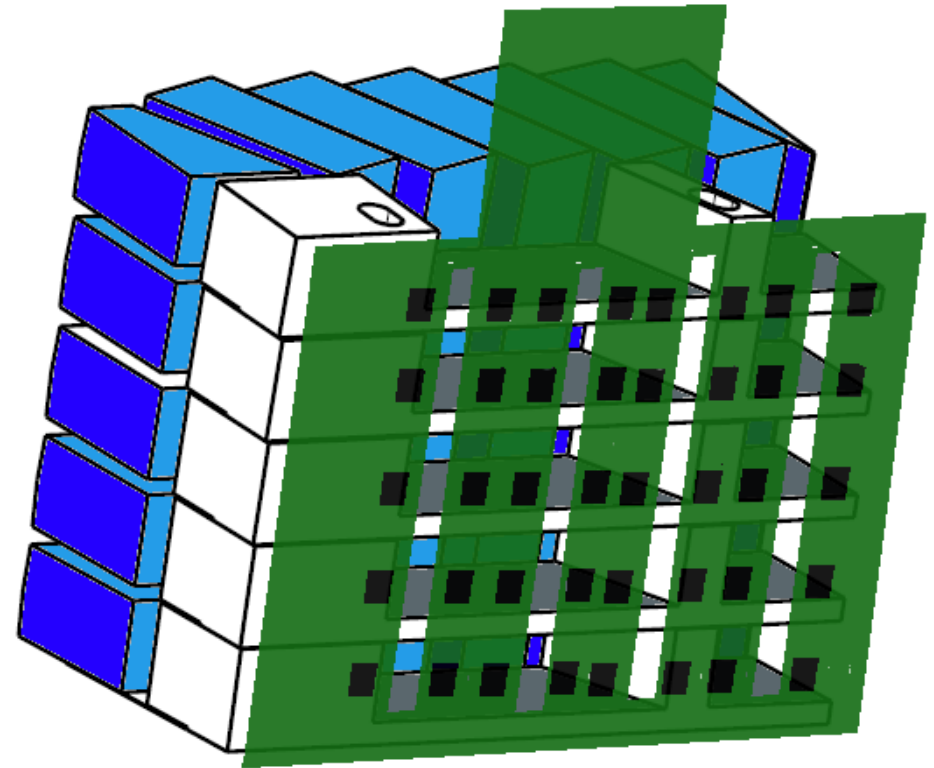
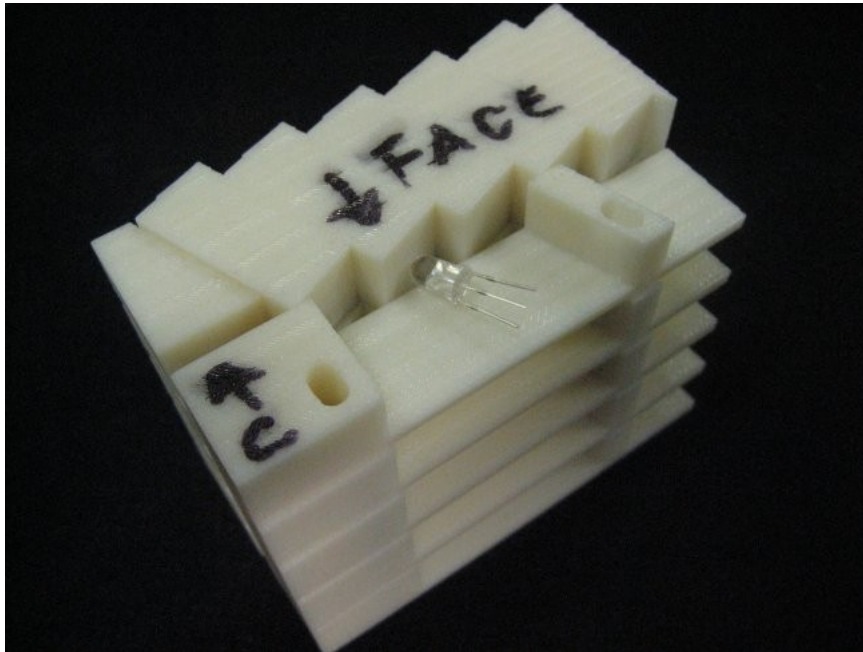


- It is not possible to place a PCB in contact with the crystals, due to the support “cage”
- Pass wires trough “cage” holes.
- Crystal orientation not planar.
- Wires are flexible enough to compensate for this.

Light monitoring system: connection board

- Two connection boards for each calorimeter quadrant: 2 on top TOP – 2 on BOTTOM.
- Each connection boards serve 115 crystals, and is connected to two drivers.
- Left quadrant != right quadrant due to beam hole: need separate design.
- Connectors mounted on the UPSTREAM face, in correspondence of PbWO_4 crystals.
- Vertical holes to pass wires. Each hole serves 10 crystals, two nearby columns.
- Vertical holes positions matched to the metal “cage” to not be in the same position of the vertical rib.

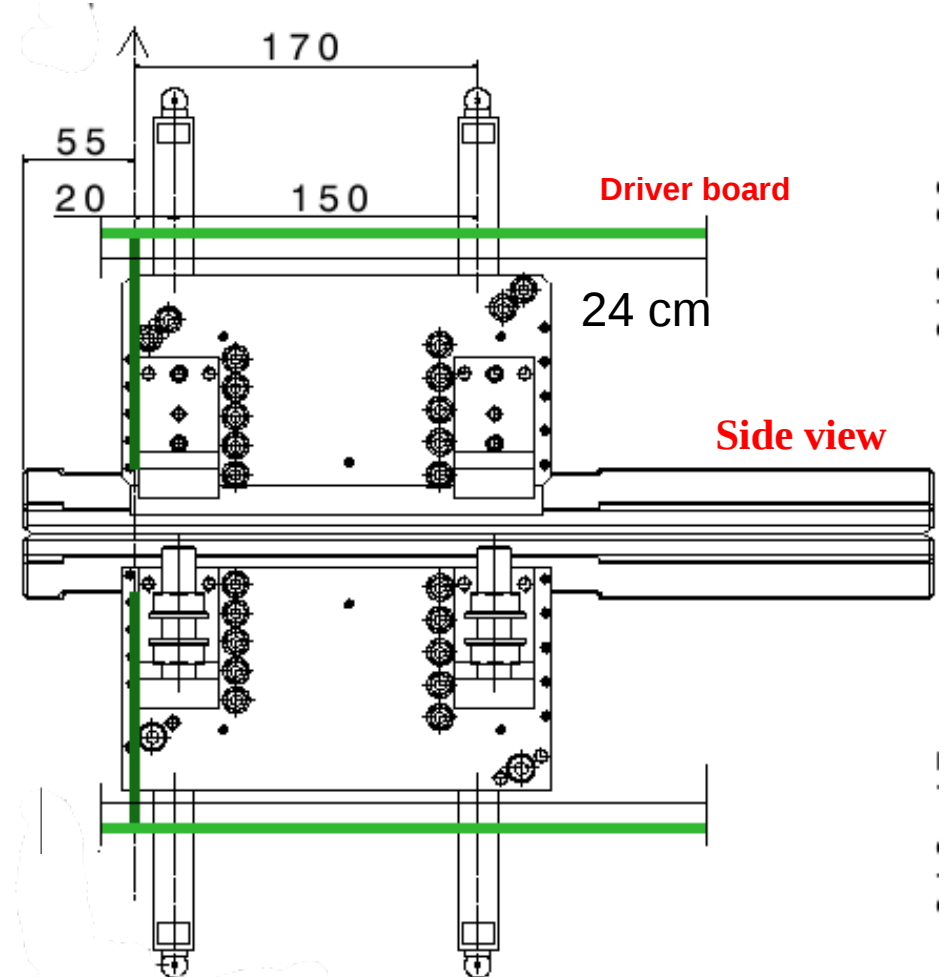
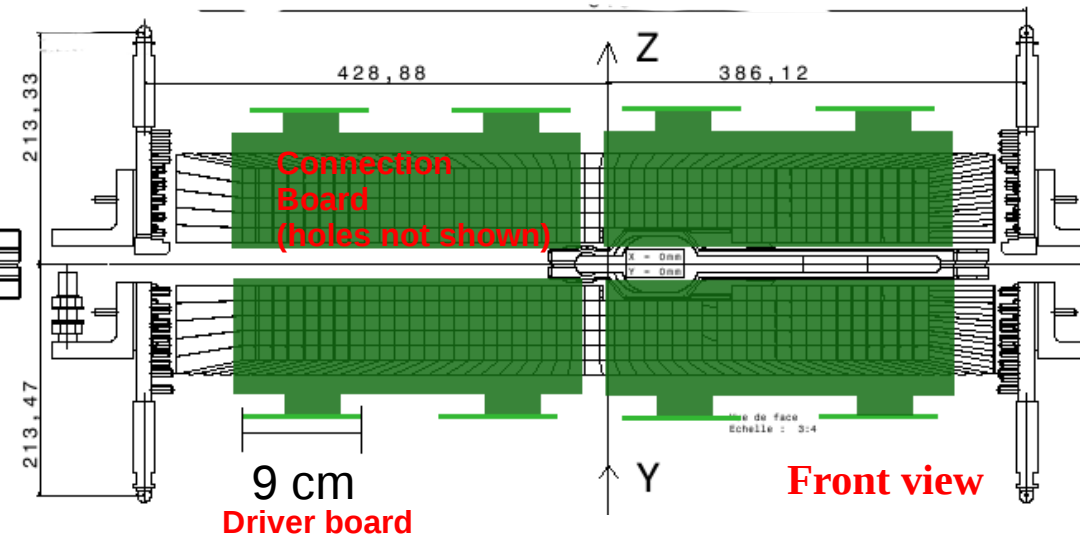
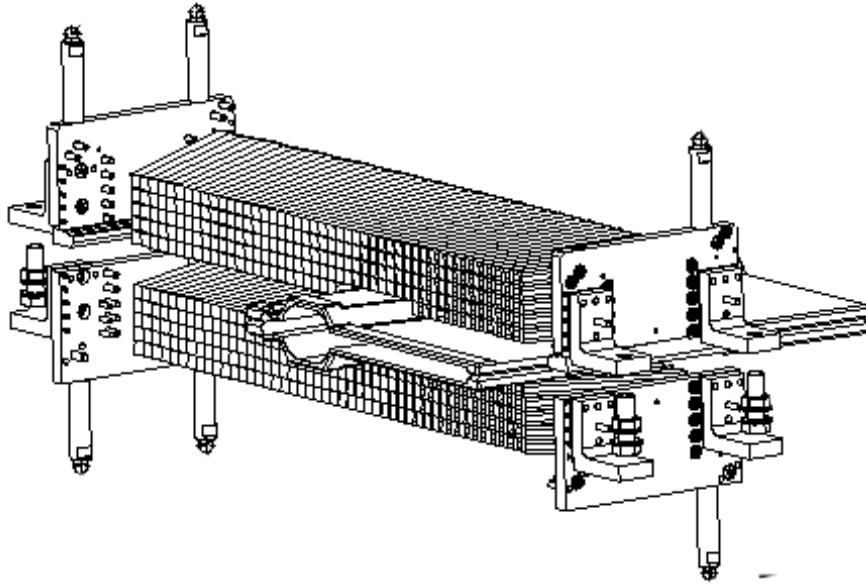
1:1 mock-up of the ECAL front
(TOP LEFT area)



Light monitoring system: LED driver BOARD

- 4 LED drivers mounted on ECAL TOP
- 4 LED drivers mounted on ECAL BOTTOM
- Each board: 24x9 cm²
- Area needed on TOP and BOTTOM: 24x36 cm²

Driver board protrudes ~ 5 cm DOWNSTREAM.



Light monitoring system: LED

LED choice is a critical task.

The system works both with single-color LEDs and bi-color LEDs

The foreseen solution is to use RAPID 56-0352 blue/red LEDs.

- Different colors permit to check different ECAL parameters:
 - **Blue LED: optical transmission / radiation damage.**
 - **Red LED: APD gain.**
- **RED** component is almost not sensitive to radiation damage: we exposed bi-color LEDs to a ^{60}Co source (**~100 krad**) and measured their emission before and after irradiation.
 - **Red: no appreciable variation**
 - **Blue: variation ~ 10%**
 - **Single-blue LED, NICHIA: variation ~ 20-30%**
- Radiation issues:
 - The system is mainly used during Ecal commissioning, to test individual channels and do a pre-calibration.
 - **Blue-red** cross-check can give indications on radiation damage during operations.
 - The system can always be used as ON/OFF check, to quick monitor each channel is operational.



NICHIA NSPB500AS single blue LEDs is a backup choice.

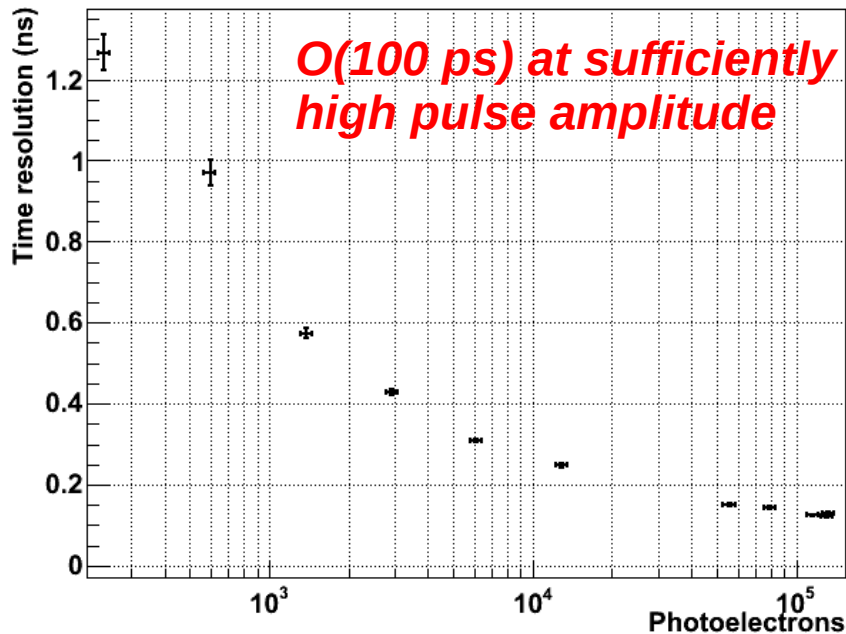
- Already tested and validated model, used in FT-Cal: **NICHIA NSPB500AS blue led**
- ~ 350 LEDs, out of a sample of ~ 700, have been tested and found to be compliant with the requirements.

Light monitoring system: dynamic range

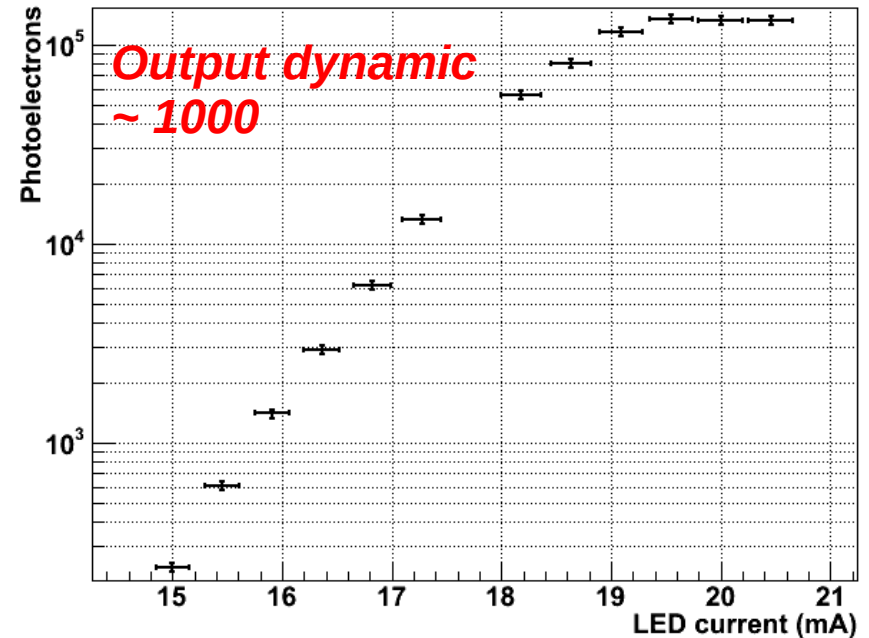
Measure with BLUE LED @ Room Temperature:

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

Time resolution



Photoelectrons



Measure with RED-BLUE LED + PbWO4 + LAAPD @ G=150 @ Room Temperature:

- **Dynamic range accessible:** 0.1 – 4 V red, 0.1 – 2 V blue
- **Timing @ 2 V:** ~200 ps, both colors

Light monitoring system: stability

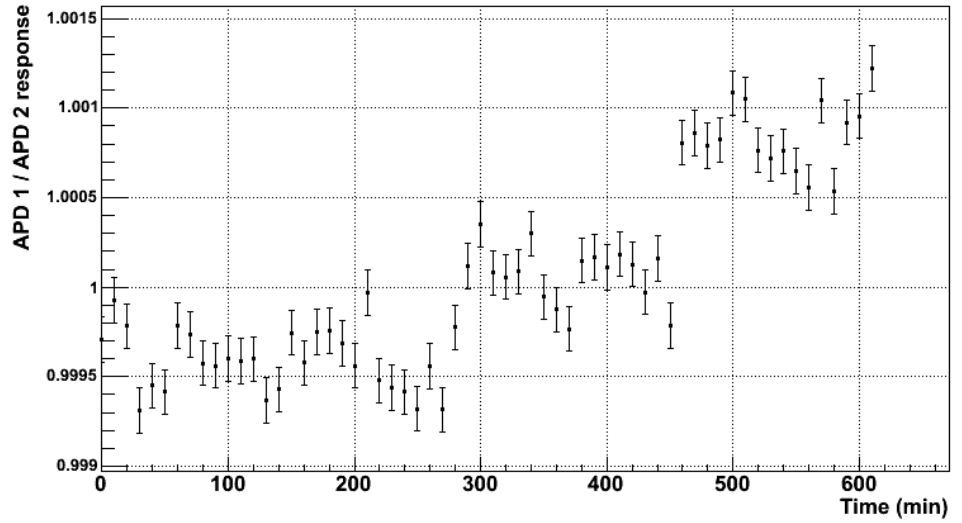
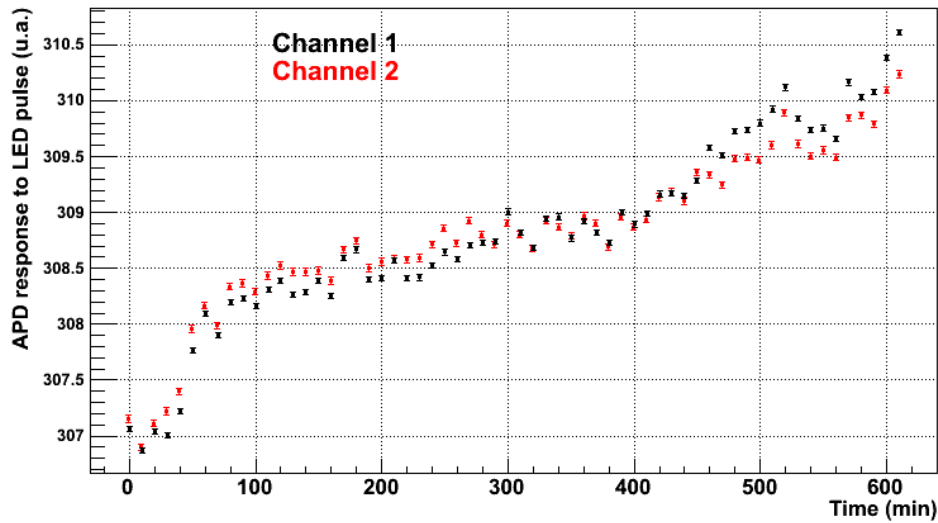
System stability:

measured with BLUE LED+PbWO₄ crystal + LAAPD @ G=150 @ Room Temperature

We measured the stability of a 16-channel prototype of the light monitoring system, equipped with BLUE LEDs, during a **100h** time period.

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

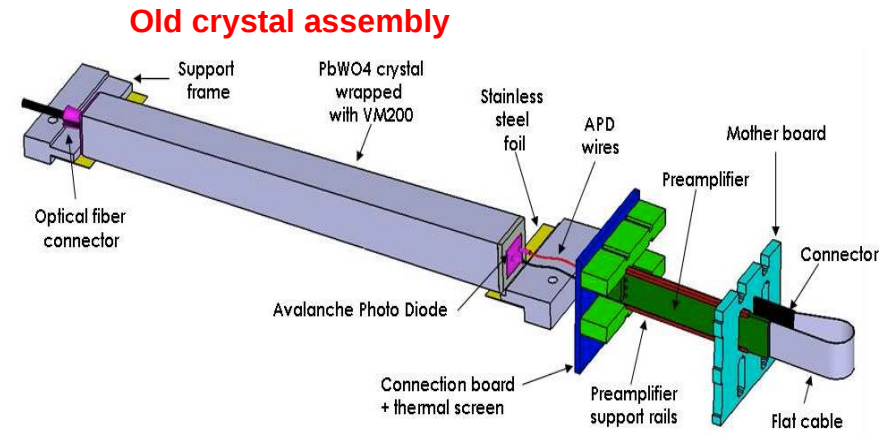
10 hours strip-charts



Light monitoring system: Crystal Assembly

The single crystal assembly has to be re-designed

- Front PEEK nose changed to accommodate LED.
- Noses are different depending on crystal location, due to the interference with metal cage. More models required.
- LED “embedded” in the PEEK nose, becomes part of the crystal assembly, through a bayonet design.
- PEEK replacement is done during crystal re-assembly, after APD replacement (see Marco's talk).



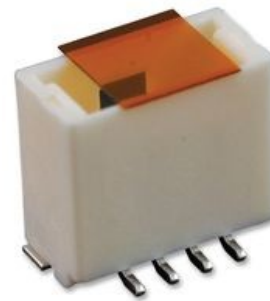
New crystal assembly:

Crystal + VM2000 + APD + Front PEEK + LED + wires + connector to connection board.

Wires are WELDED to LED, on the crystal side

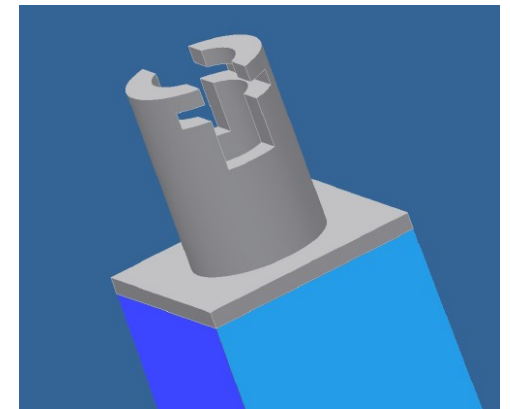
Connector on connection board:

MOLEX 501331-0407 board-to-wire connector



PEEK Nose:

Preliminary design. Need to define the different models, according to crystals position in ECAL



Light monitoring system: time-line

		We eks	Oct - Nov	Dec	Jan	Feb	March	A pr	M ay	Jun	Jul
Connection board	Design	6									
	Electric test	2									
PEEK Nose	Design	4									
	Production	8									
LED Wires and connectors	Prop. definition	4									
	Procurement	4									
	Welding	8									
LED Tests	LED procurement	8									
	Design	6									
	Construction	6									
	Tests	6									
LED Assembly	LED welding	6									
	PEEK install	4									
LMS mounting	LMS mounting	1									
	LMS tests	4									

Light monitoring system: resources

WHAT?	HOW MUCH?	WHO?
LED System controller (2x)	2k € / each	INFN
LED System driver (8x)	1k € / each	INFN
LED System connection board (4x)	1k € / each	INFN
LEDs (1000x)	1k € total	INFN
LED Connectors (500x)	1k € total	INFN
LED Wires	1k€ total	INFN
LED test system	3 k€	INFN
LED noses	10 k€	INFN

N.B.

- VAT NOT included
- Single LED drivers in the LED test system are the same used to test LAAPD gluing on PbWO_4 crystals. Cost is included there, see Marco's talk.

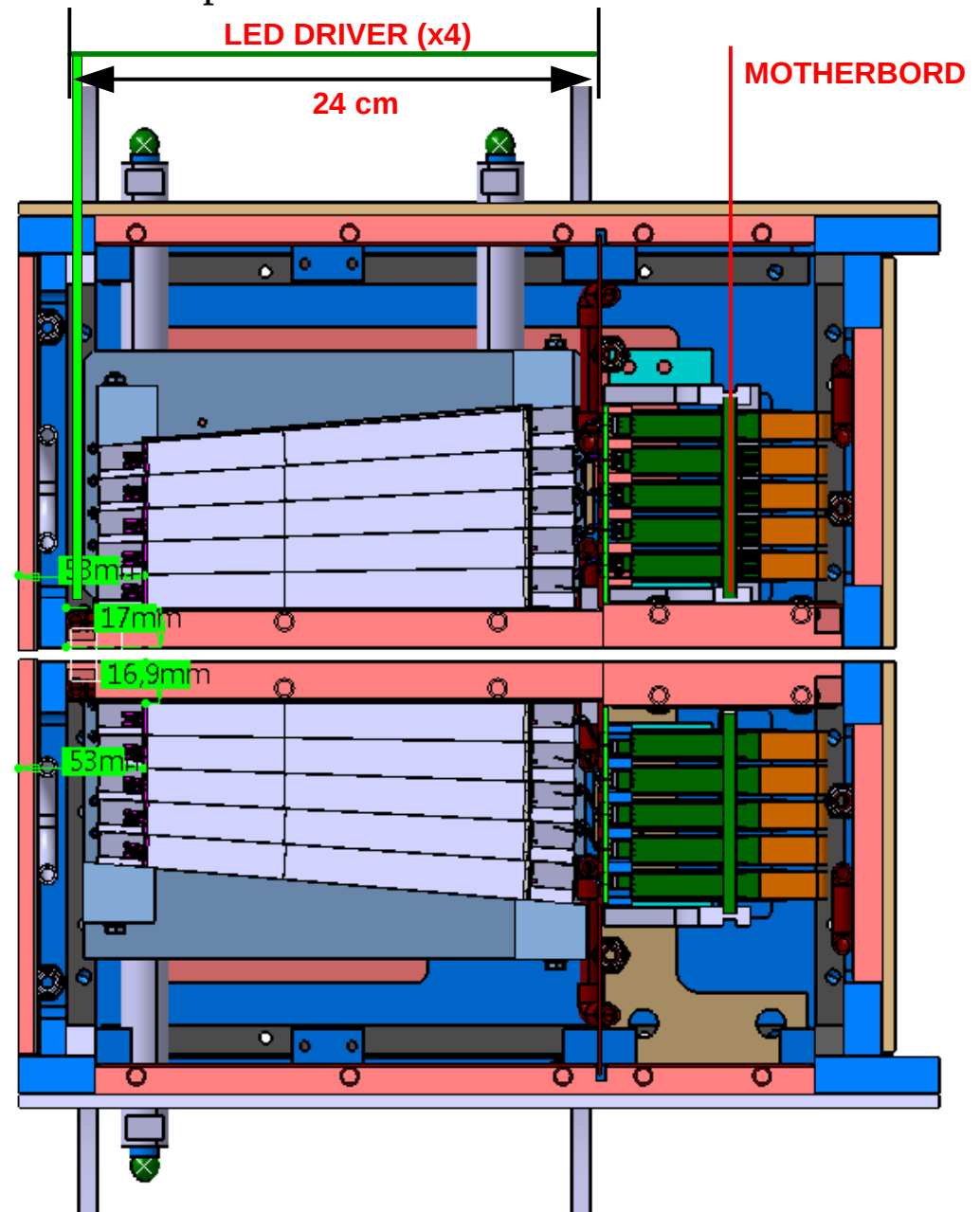
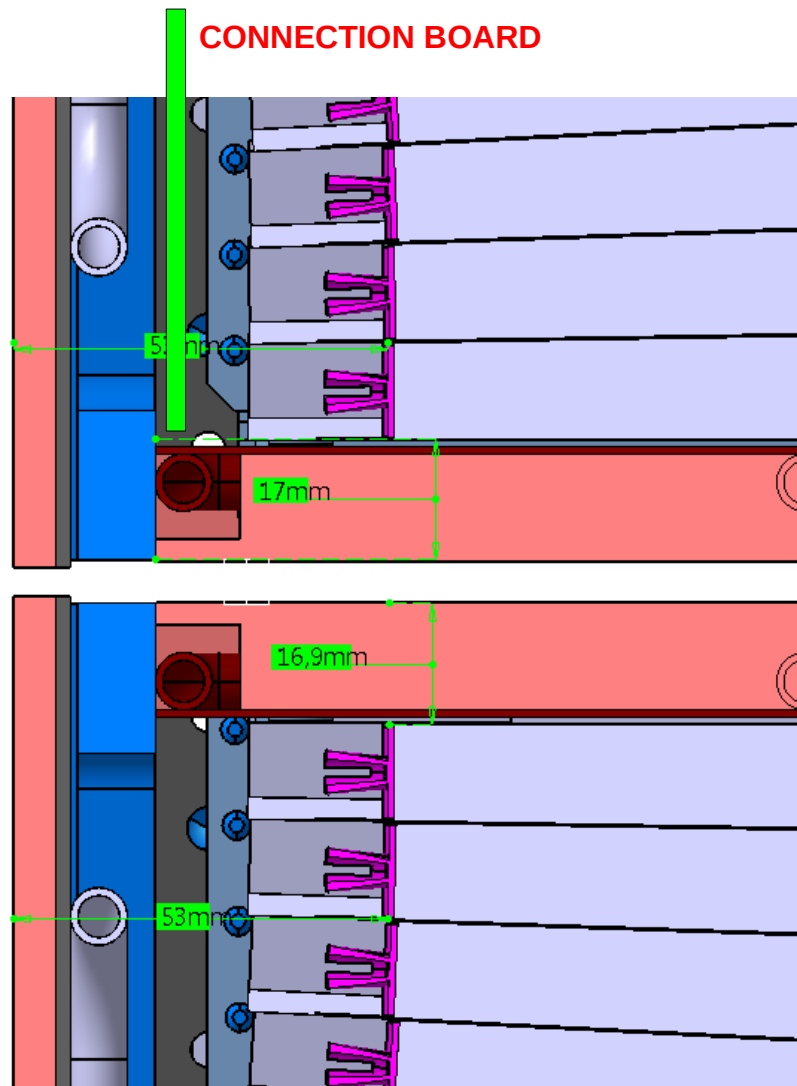
Conclusions

- ECAL LED monitoring system is designed after the experience of the FT-Cal corresponding system.
- 2/3 of the system are ready: the main controller and the LED driver.
- Connection board needs to be designed. Will stay in front of the ECAL. This requires to modify the external ECAL enclosure. Discussion with Orsay engineers already started, design change is feasible.
- Bi-color LEDs fulfill system requirements, both for resolution and dynamic range:
 - Needs to be tested individually.
 - Assembled with crystals as part of APD replacement.
- Ancillary work must be performed before LED assembly with crystals:
 - Front PEEK nose design and production.
 - Connectors and wires welding.

Backup-slides

Light monitoring system: connection BOARD

Use available space between crystal supporting structure and ECal thermal enclosure to mount connection boards. LED drivers are mounted on the top and on the bottom of the external enclosure.



Light monitoring system: Crystal Assembly

NEW PEEK Nose production: INFN

- PEEK nose design: ready for 1st December
- PEEK nose production: December-January
- PEEK nose delivered in Orsay: ready for 1st February

LED wires and connectors preparation: INFN + ORSAY

- Connectors on connection board: **PROCURED AND READY**
- Wire definition (model / length): before 1st November
- Wire procurements: before 1st December
- Wire welding to connectors:
 - 4 weldings / connector
 - 442 connectors, 1768 weldings
 - 40 weldings / person / day, i.e. 10 connectors / person / day)
 - 2 people: 22 working days
 - 4 working weeks + 1 contingency + 1 extra
 - Welding starts 1th December (to account for holidays)
 - December – January, ready for 1st February

INFN
INFN
ORSAY
ORSAY

Light monitoring system: LED tests

Each LED must be tested independently before mounting it in the system, to ensure it is within design requirements.

The test system is based on a single LED driver circuit, already designed and tested.
(same circuit used to validate LAAPD gluing to PbWO_4 crystals)

- LEDs procurement: **ORSAY**
 - Buy ~ 1000 LEDs: November - December
 - LEDs delivered Orsay: before 1st February
- Test system design and construction: **INFN**
 - System design: November-December
 - System construction: December-January
 - System delivered to Orsay: before 1st February
- LEDs tests and validation: **ORSAY**
 - 1000 LEDs to test
 - 30 LEDs / person / day
 - 2 people: 16 working days
 - 4 working weeks + 1 contingency + 1 extra
 - Tests start 1st February
 - All LEDs tested for 15th March



Light monitoring system: mounting

After being individually characterized, LEDs are welded to wires, to have a single LED assembly: connector + wires + LED.

LED assembly preparation: ORSAY

- 4 weldings / LED
- 442 LEDs, 1768 weldings
- 40 weldings / person / day, i.e. 10 LEDs / person / day
- 2 people, can be who welded wires to connector: 22 working days
- 4 working weeks + 1 contingency + 1 extra
- Welding starts 15st February, when first LEDs have already been tested
- February – March, ready for 1st April

LMS assembly: JLab

- The PEEK nose is attached to the crystal during the crystal re-assembling, after APD replacement (see Marco's talk). The LED assembly is connected to crystals after PEEK support is mounted.
 - 2+1 weeks for final crystal assembly, from 15th June. Already scheduled as part of APD replacement process
- The connection board is put in place after all crystals are back in the ECAL: 1st August
- LMS tests in lab can start immediately after.

Light monitoring system: milestones and man-power

WHAT?	WHERE?	WHEN?	WE EKS	WHO? (INFN)	WHO? (ORSAY)
Connection board design	GE	Jan14-Feb14	6	1xEE	
Connection board test	GE	Feb14	2	1xEE 1xTC	
PEEK nose design	GE	Oct13-Nov13	4	1xME	
PEEK nose production	GE-CT	Dec13-Jan14	8	2xTC	
Wires definition	GE	Oct13	4	0.5xME, 0.5xEE	
Wires procurement	Orsay	Nov13	4		
Wires soldering on LED connectors	Orsay	Dec13-Jan14	8		2xTC
LED procurement	Orsay	Nov13-Jan14	8		
LED test system design	GE	Nov13	6	0.5xME 0.5xEE	
LED test system construction	GE	Dec13-Jan14	6		
LED tests	Orsay	Feb14-March14	6		2xTC
LED welding to wires	Orsay	Feb14-Apr14	6		2xTC

N.B. PEEK installation in crystal assembly not included here, already scheduled for APD replacement (see Marco's talk).