

ECAL LED Monitoring System

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Light monitoring system

Motivations for a light monitoring system in the HPS Ecal:

During commissioning, it is **critical** to switch on/off channels independently for fast debugging.

- Test the correct functionality of all APDs / amplifiers.
- Verify correct cabling.
- Check all the electronic channels.
- Perform a fast **pre-equalization** during in-lab commissioning.

During operations, the system can measure fluctuations in the ECAL components response.

- 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.

During operations, the system can be ALSO used to recover the EM-induced radiation damage.

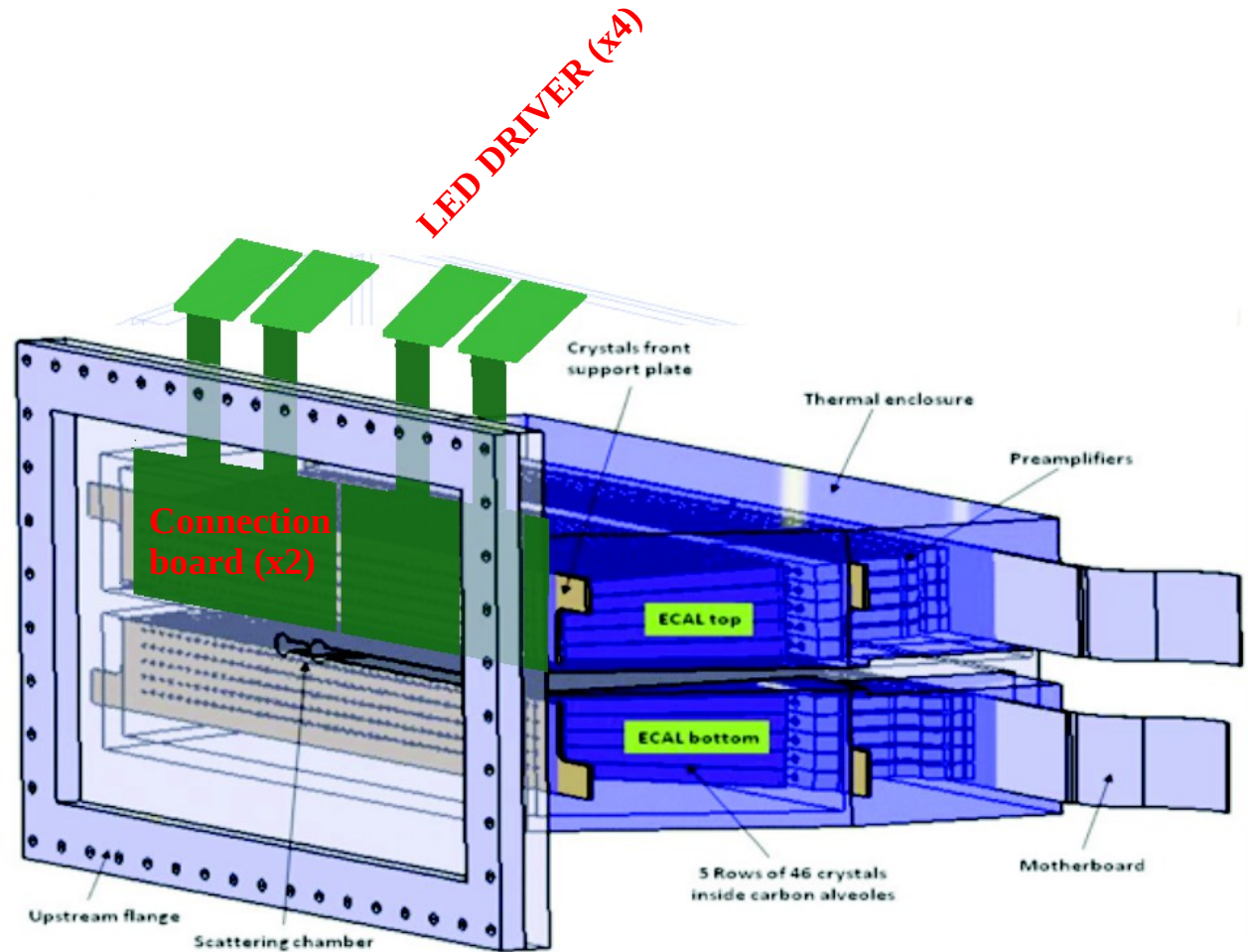
LED monitoring system design

Design: LEDs mounted in front of PbWO_4 crystals.

Use wires to connect LEDs to a connection board, mounted in front of ECal

Components:

- Main controller (2x)
- Driver Boards (8x)
- Connection boards (4x)
- LEDs (442x)



Main controller

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.
- **1 Ready and tested, 2 in production.**



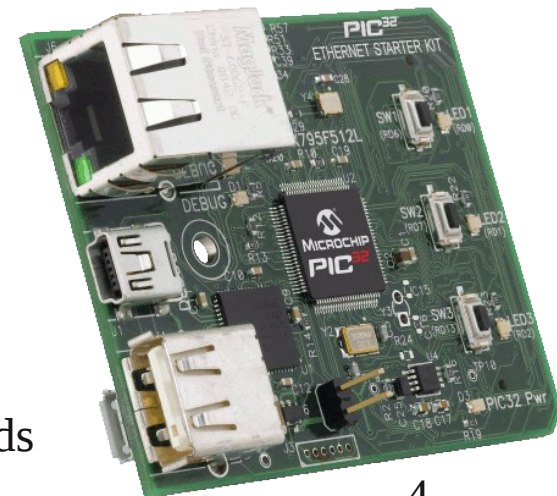
2 independent controllers, one for ECAL TOP, one for ECAL BOTTOM.
Clock is propagated from the first to the second for synchronization.

The controller communicates with the driver boards through I²C bus.

- **USB port:** gives direct connection with I²C bus: **debug only.**
- **Ethernet:** communication handled through PIC32 Ethernet starter kit (32-bit MCU), connected to the I2C bus as master.

PIC32 firmware written and tested (v1.3)

- Uses Microchip TCP-IP stack (supports DHCP/static IP address)
- Implements a TCP server listening for incoming connections
- A connected client can interact with the system sending string commands



Main controller: commands

List of commands currently implemented in the firmware:

Basic:

- | | |
|----------------------|---|
| • TURN ON-OFF | Turn ON/OFF the system. Init I2C bus. |
| • SWITCH ON-OFF xyz | Turn ON/OFF a LED (xyz), with the proper AMPL and WIDTH |
| • SET AMPL xyz abcd | Set the amplitude (abcd) for LED xyz |
| • SET WIDTH xyz abcd | Set the width (abcd) for LED xyz |
| • SET CLK | Set the clock source (internal - external) |
| • SET FREQ | For internal clock, select frequency |
| • SET COLOR | Select LED color to turn on |
| | |
| • GET STATUS | Get the system status (ON-OFF) |
| • GET AMPL xyz | Get amplitude of LED xyz |
| • GET WIDTH xyz | Get width of LED xyz |
| • GET CLOCK | Get clock source |
| • GET FREQ | Get internal clock frequency |

Evolved:

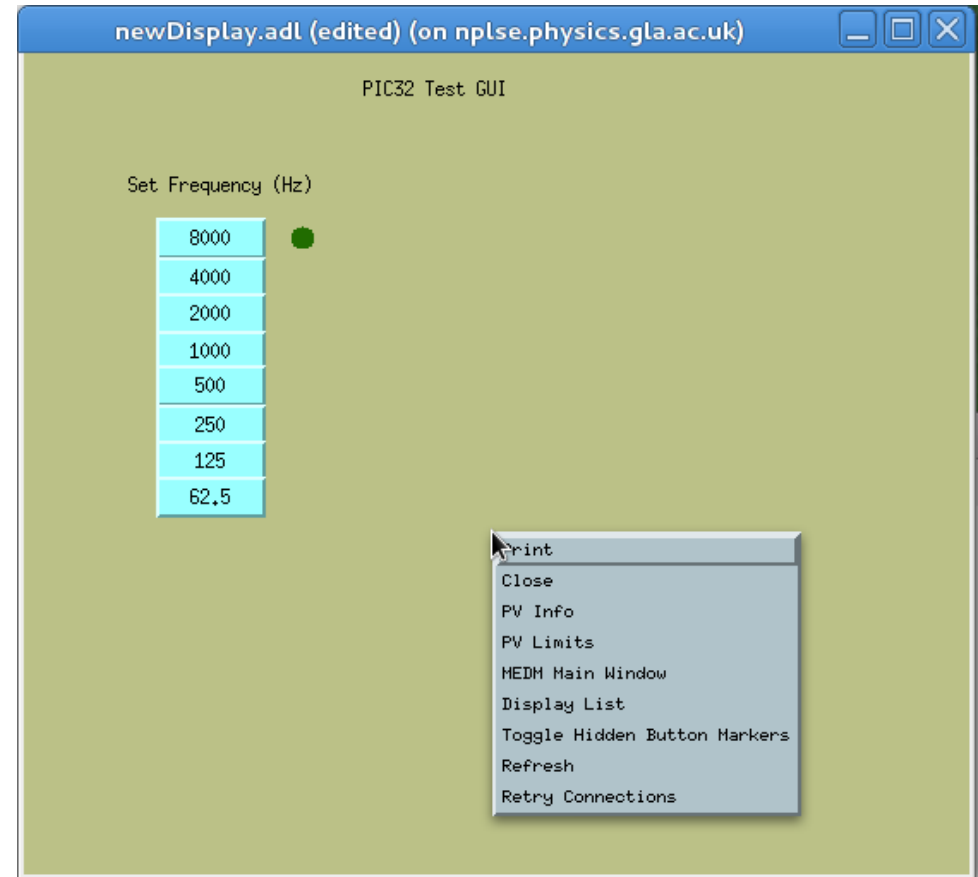
- | | |
|-----------------|--|
| • LOAD DATA | Load LEDs data from a remote file on a TFTP server |
| • LOAD SEQUENCE | Load a sequence data from a remote file on a TFTP server |
| • ... | |

Main controller: EPICS integration

Ken Livingstone is developing the EPICS-side software to interact with the Led Monitoring System

- SoftIOC running on a PC, communicating with the controller through the StreamModule module
- GUI for users interaction

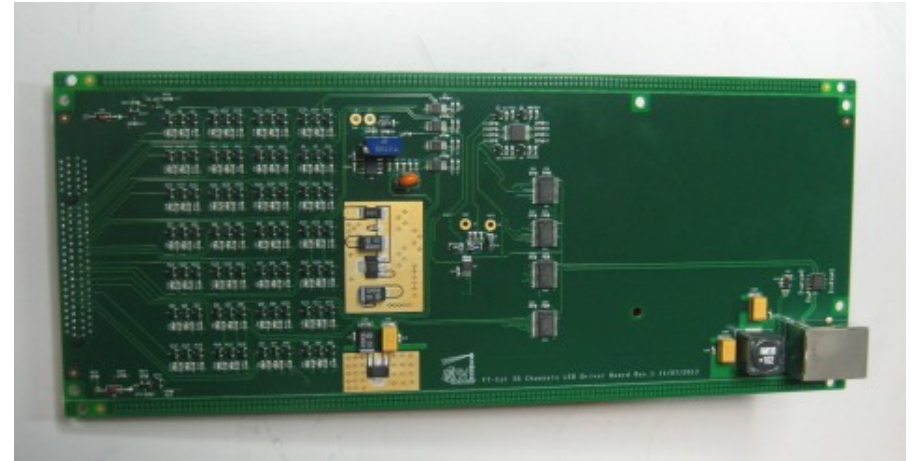
DRAWING OF THE GUI HERE
TBD



Driver board

The driver board

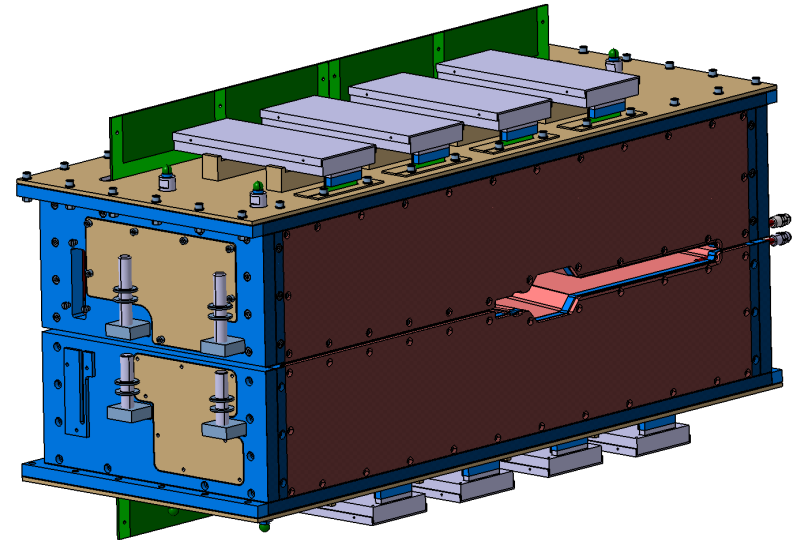
- Hosts **56** independent LED pulser circuits.
- Communicates via I²C with the main controller, through Ethernet-like cable
- Mounted out of the calorimeter enclosure, it is connected to the LED board.
- **During tests, one minor project error found and corrected (bad LVPECL twisted pair termination).**
- **7 boards ready and tested.**



Connection board

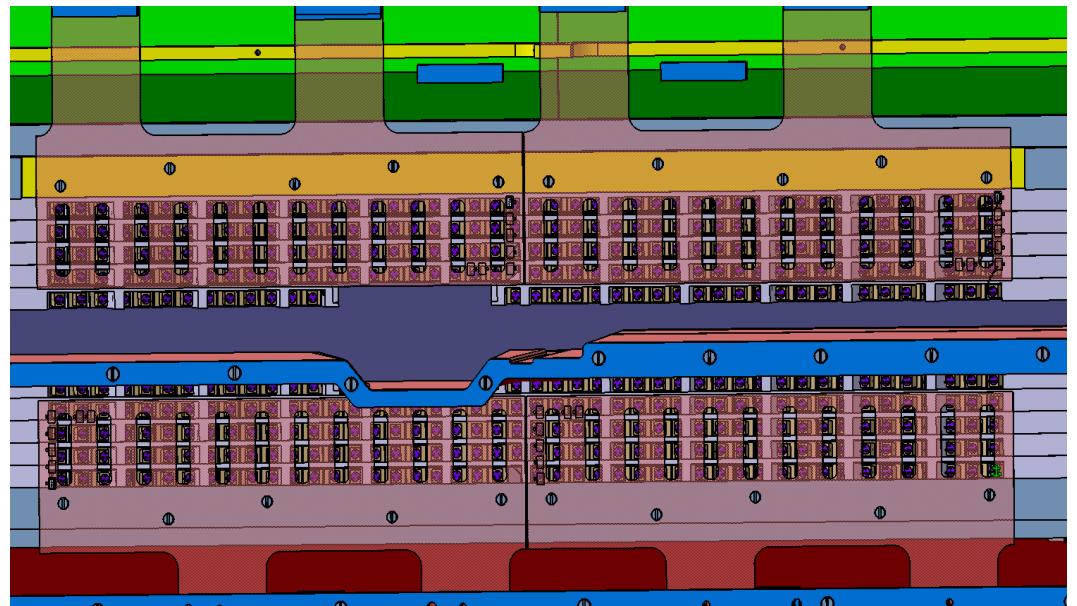
Mechanics

- ECAL enclosure has to be modified to support drivers and let the connection boards exit.
- Iterative process to match mechanical and electronic requirements, now completed.
 - All details were discussed between Orsay (mechanics), INFN-TO (connection board design), INFN-GE.

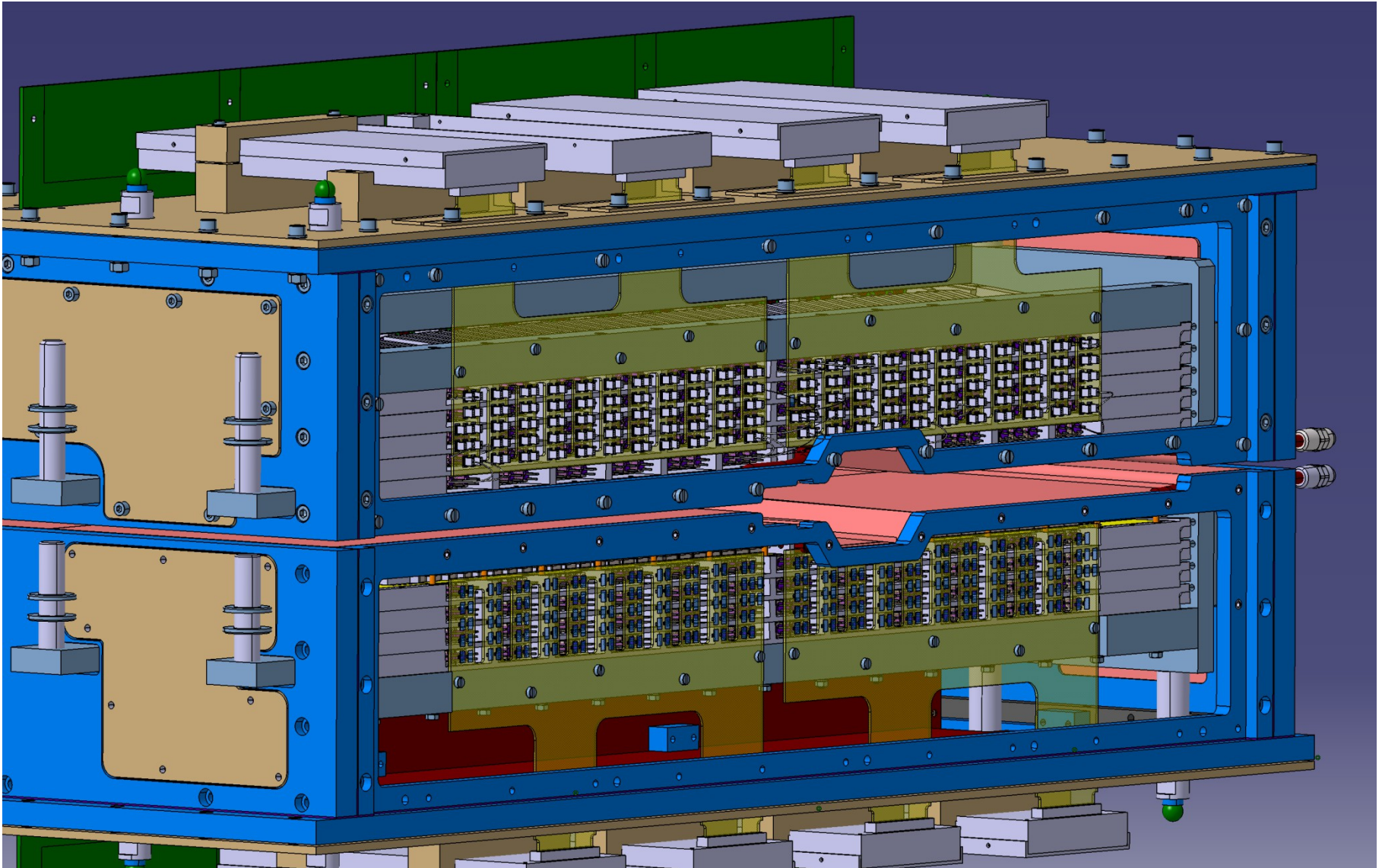


Connection board design

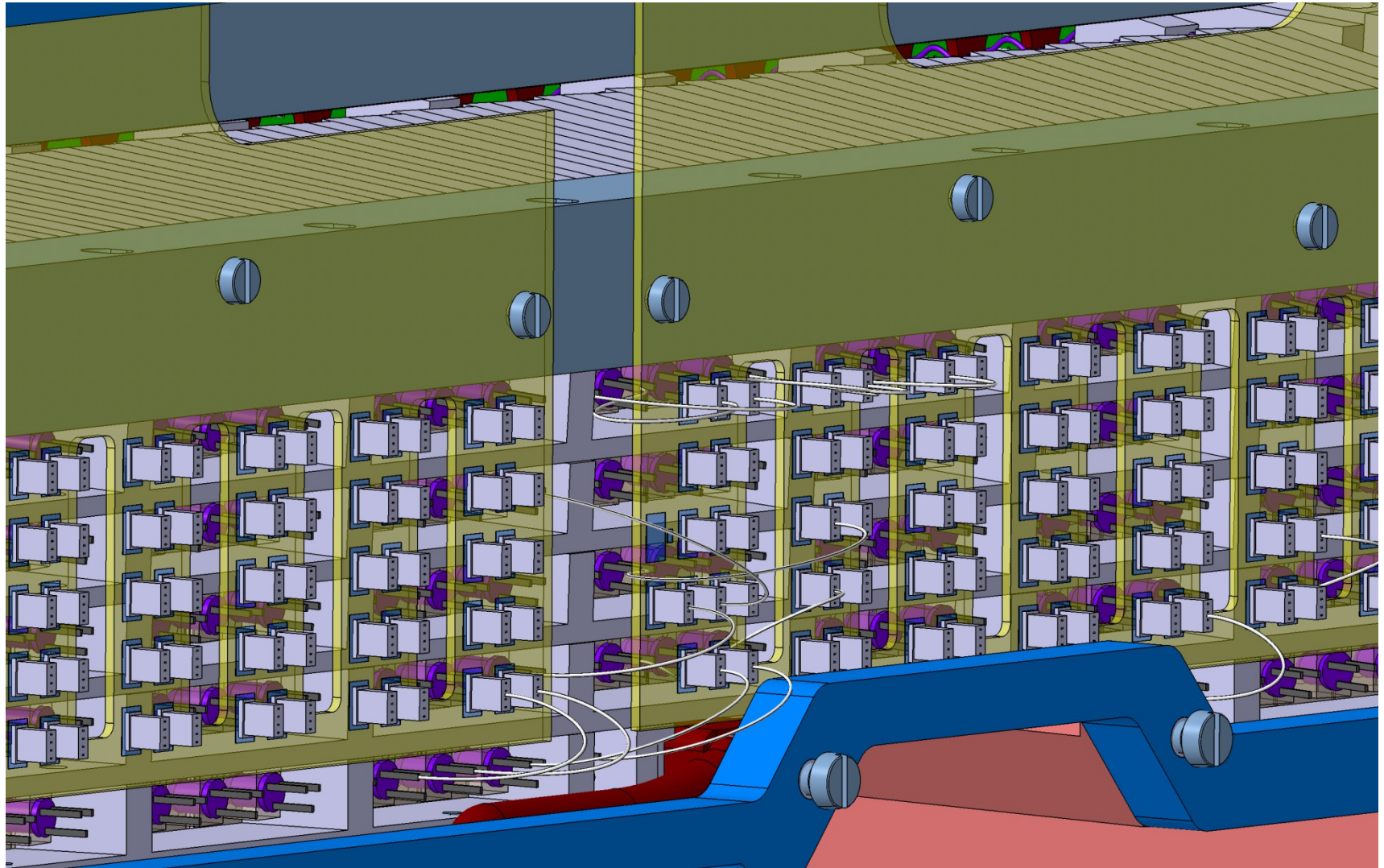
- Connectors mounted on the upstream face.
- Long holes to route wires to crystals.
- Single design for the 4 boards.
- **Mechanical design completed.**
- **Electrical design completed.**
- **Boards currently being produced.**



Connection board



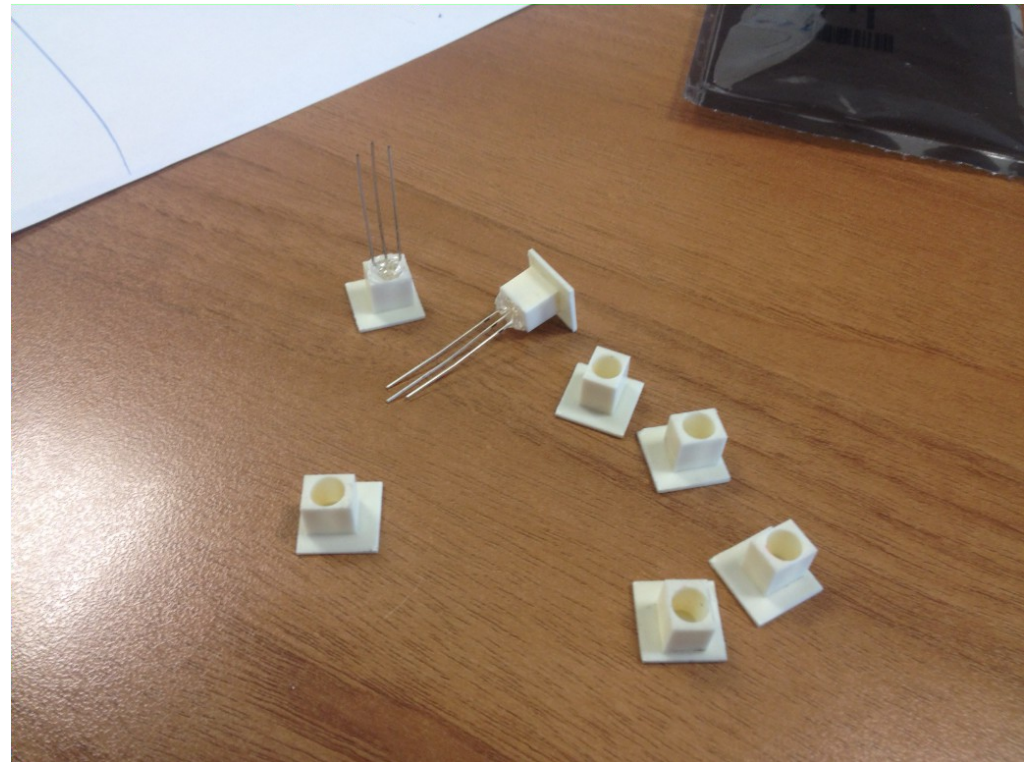
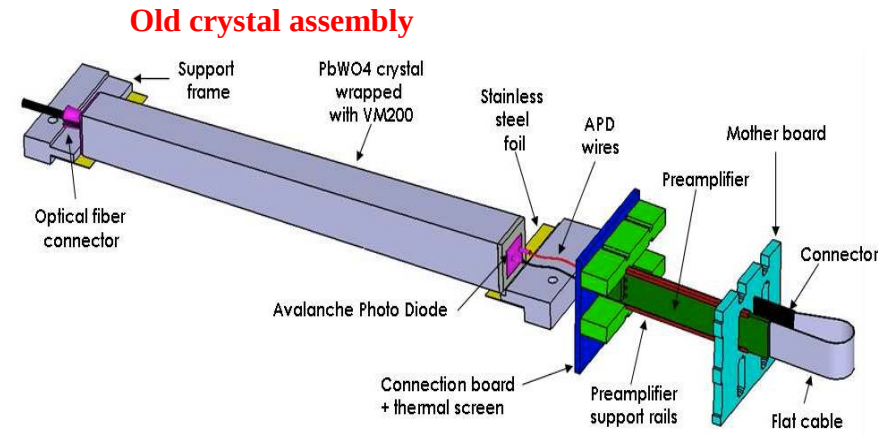
Connection board



Crystal Assembly

The single crystal assembly was re-designed

- Front PEEK nose changed to accommodate LED.
- LED “embedded” in the PEEK nose, becomes part of the crystal assembly.
- Non-central geometry due to ECal mechanical structure (vertical pillars).
- **LED holders design done (Orsay).**
- **LED holders production completed (Catania).**
- **LED holders currently at Jlab, being mounted in the crystals.**

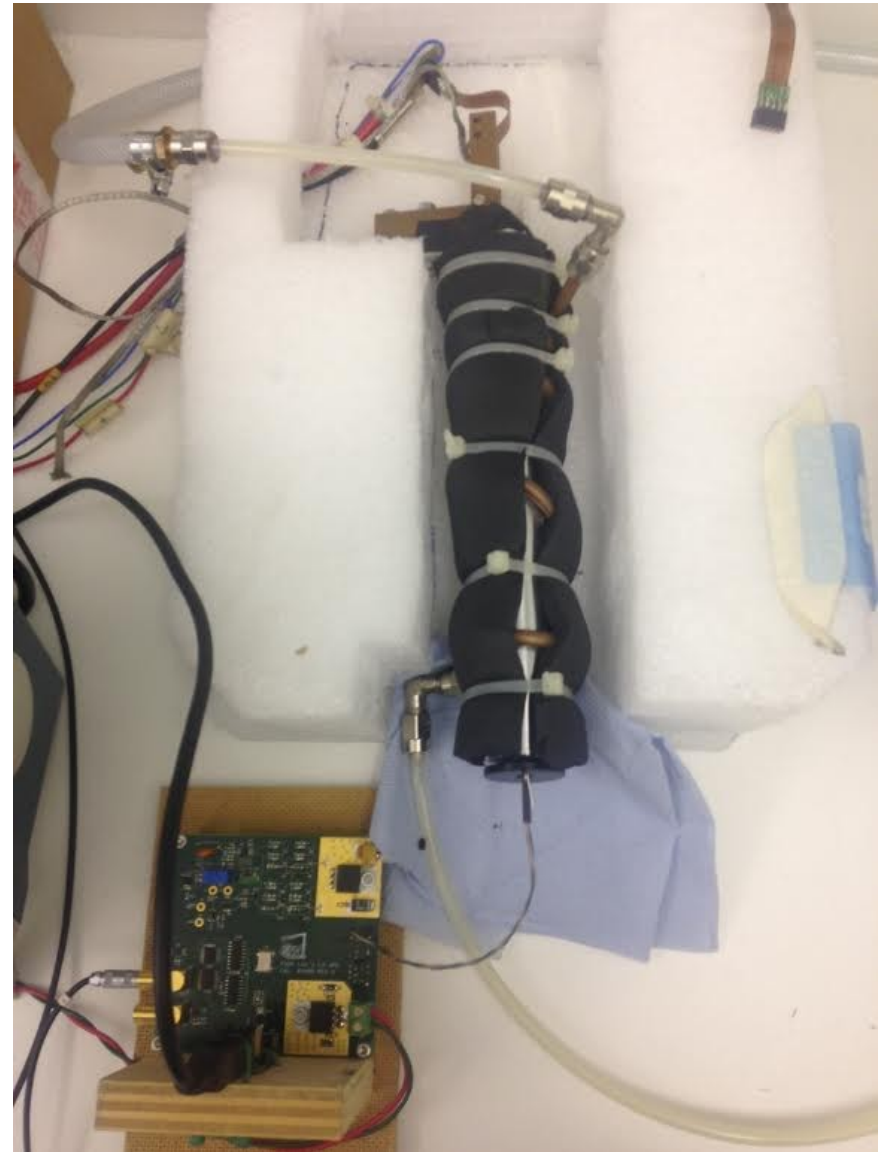
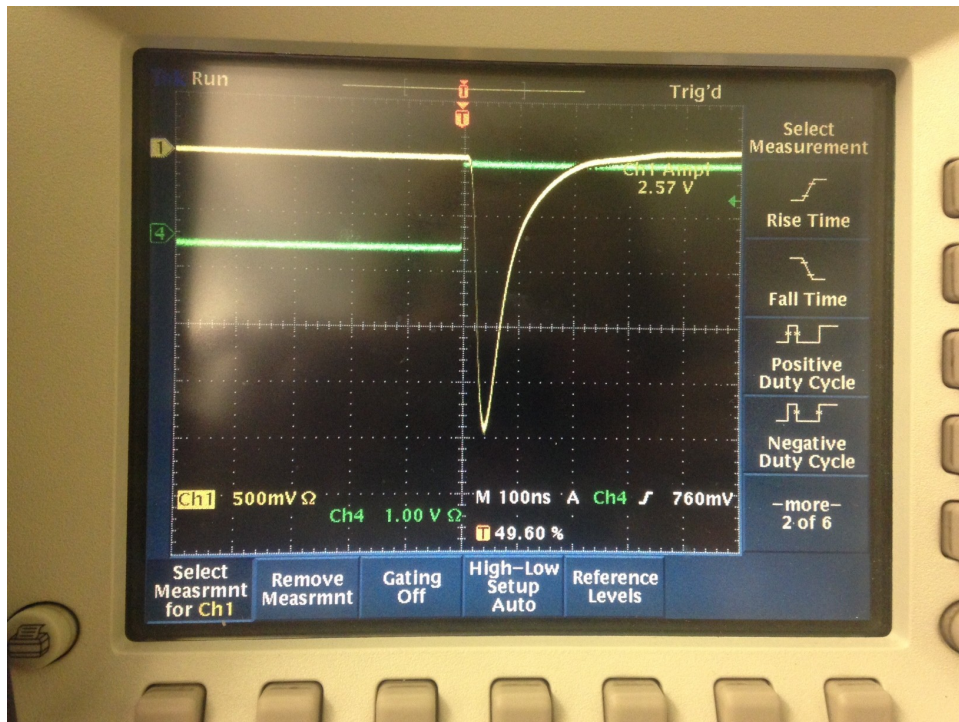


LEDs

RAPID 56-0352 blue/red LEDs are used in the ECal LED monitoring system



- All LEDs were individually tested in Glasgow (E. Buchanan)
 - Dynamic range 2.5 V
 - Pulse width < 150 ns
- LEDs were soldered to wires in Orsay.
 - All LEDs ready to be mounted in the connection board.



LEDs radiation damage

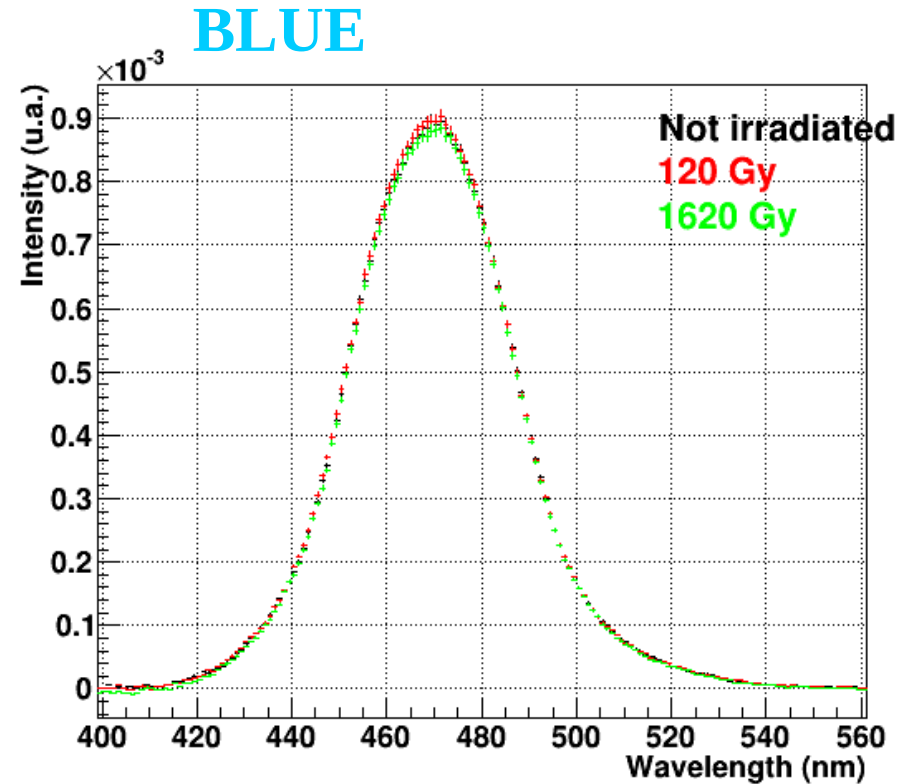
EM radiation:

- LED radiation hardness was evaluated by exposing LEDs to a known EM dose (^{60}Co source).
- Emission spectrum measured before and after irradiation.
- Control LEDs (not-irradiated) showed no variation during different measurements.

Expected radiation dose in Ecal: \sim rad/hour

- 120 Gy:
- 1620 Gy:

No damage was seen at 1% (system accuracy)



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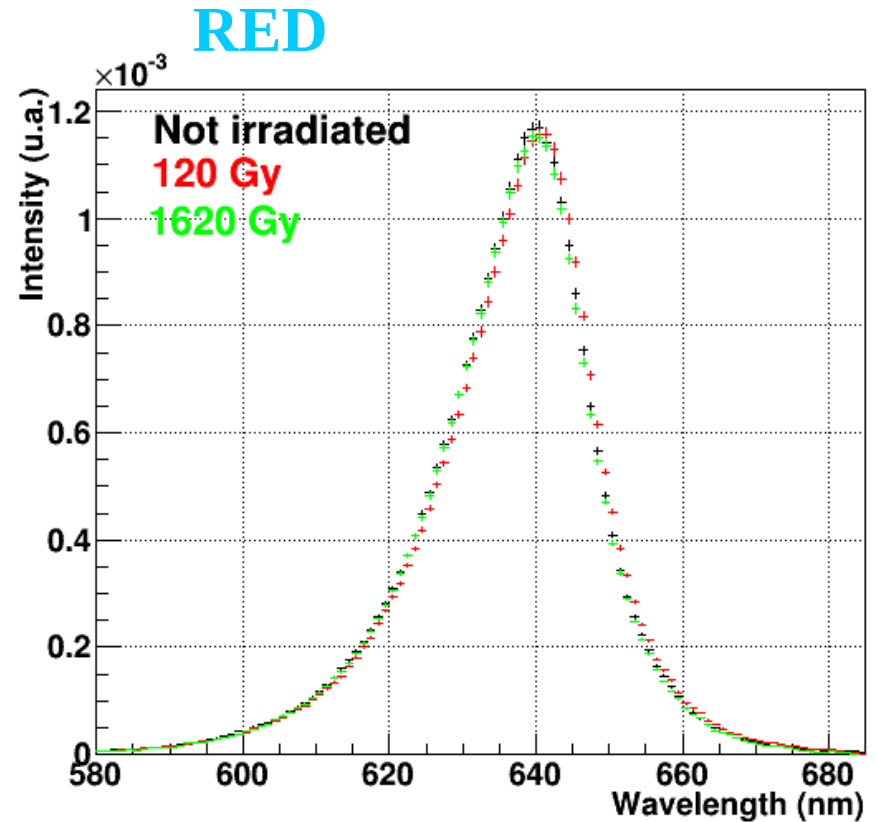
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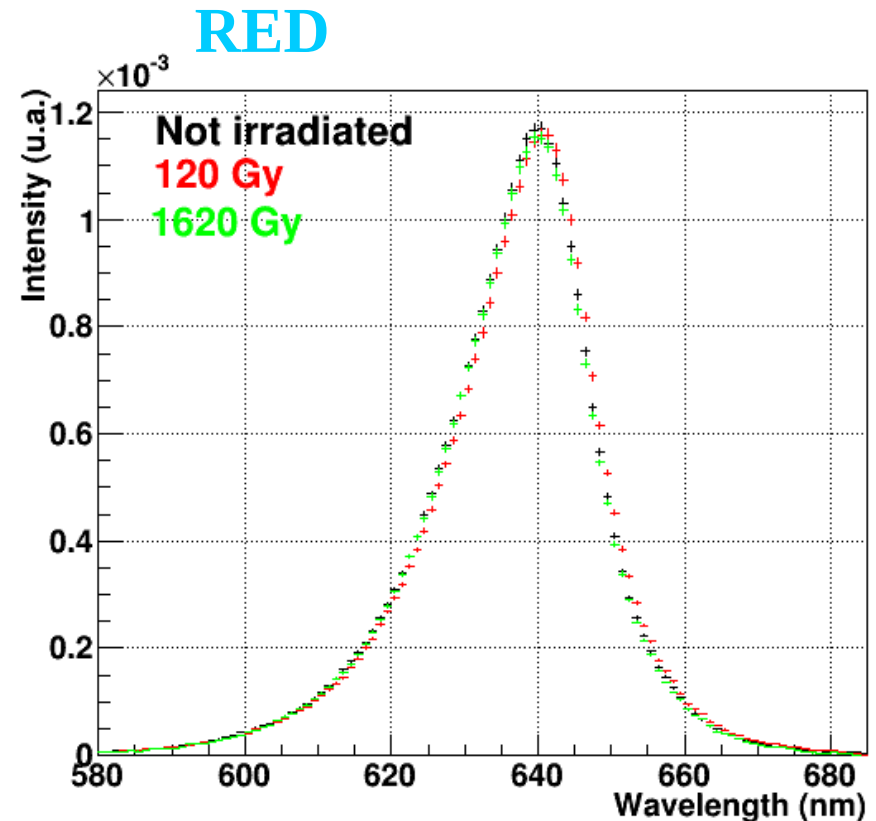
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Neutrons:

- LEDs exposed to neutron flux $\sim 4 \cdot 10^{11} \text{ n/cm}^2$ @ 14 MeV
- Expected neutron flux in ECal:

No damage was seen. System accuracy not better than 15% (normalization)

—► **Further studies are required.**



System performances

CAVEAT: test performed with FT LEDs and LED connection board. Same drivers, same controller.

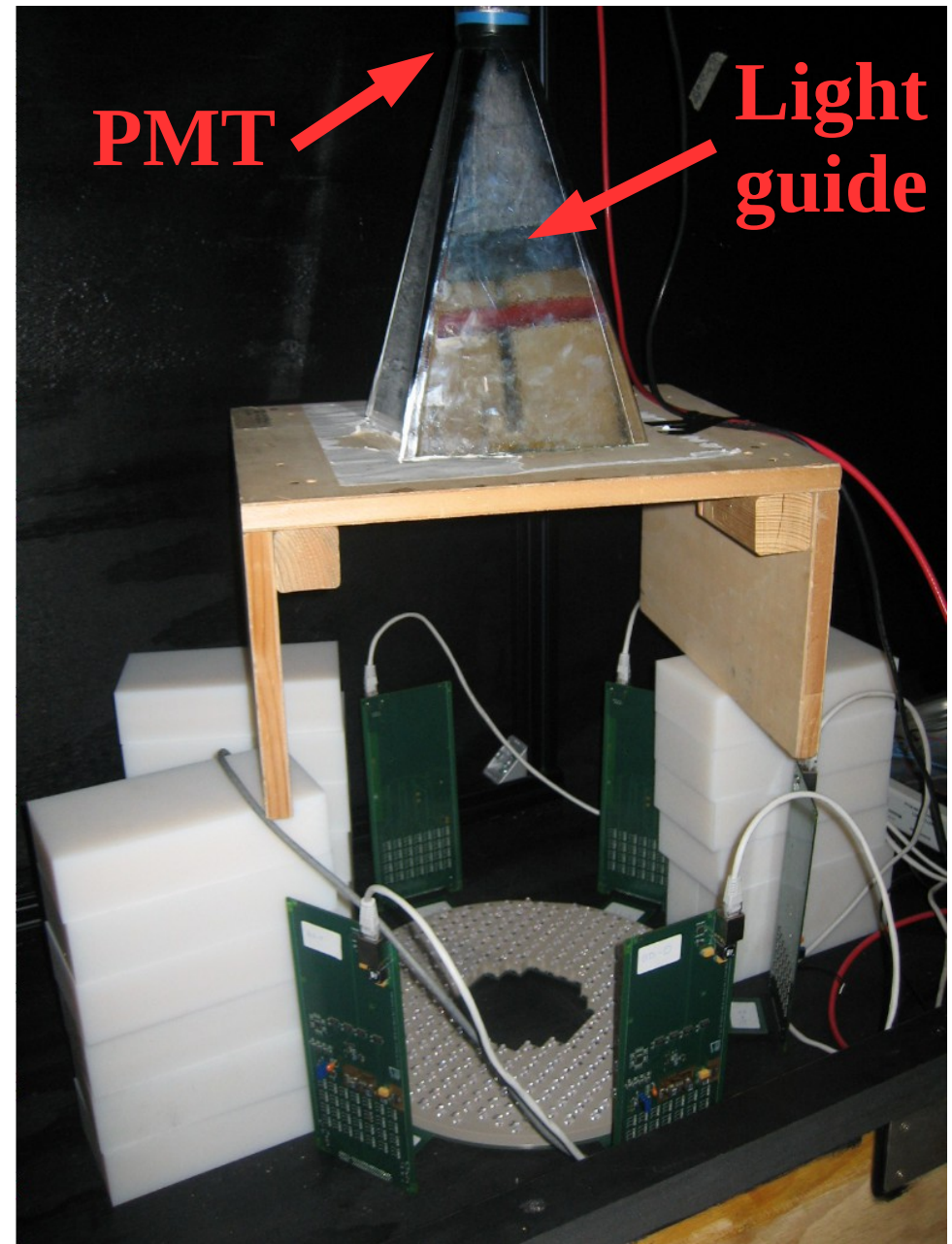
LMS performances tested with a fast PMT.

- 6 driver connected to the LED board.
- LED pulses collected through a single PMT facing the LED board – light guide used to maximize light collection
- Measured quantities:
 - Energy resolution
 - Pulse width
 - Timing
 - Stability during time

Preliminary tests of the system performances.

→ **Acknowledged and fixed an issue in the driver board**

Tests are planned in Genova when the HPS connection boards will be delivered.



Operations during HPS run

(Fast) in-lab commissioning, before ECal moved to the Hall:

- Switch on individually each LED, check proper signal cabling from the detector, even just with an oscilloscope.
- Verify the DAQ chain is working properly for each channel.
- Check the channel mapping.

Time required: one day (conservatively).

(Slow) in-lab commissioning:

- Acquire data with cosmic-rays, for energy calibration.
- Cross-calibrate the LED system, channel-by-channel, to the cosmics reference point.
 - For each channel, record the settings required to reproduce a cosmic-like energy deposition to have an absolute reference.
 - Determine the set-point for ~ 1 GeV energy deposition.

Time required: few days (experience from single-crystal characterization in Genova).

→ The cross-check operation can be repeated any time energy calibration is performed, during major pauses in data-taking.

Operations during HPS run

ECal first installed in HPS:

- Switch on individually each LED, at the work-point found in-lab, and verify again proper equalization.
- Check again cable matching and DAQ chain.

Time required: half-day (conservatively).

At the end of a run, before a long pause (night – weekend runs):

- Switch on individually each LED, at the work-point found in-lab, verify again proper equalization.
- Acknowledge any drift in the channels working points.

Time required: 1 h (1 minute/LED, 8 boards/time, 56 LEDs/board).

At the end of a run, before a long pause (night – weekend runs):

- Switch on LEDs in CONTINUOUS mode, to recover EM-induced radiation damage.

Conclusions

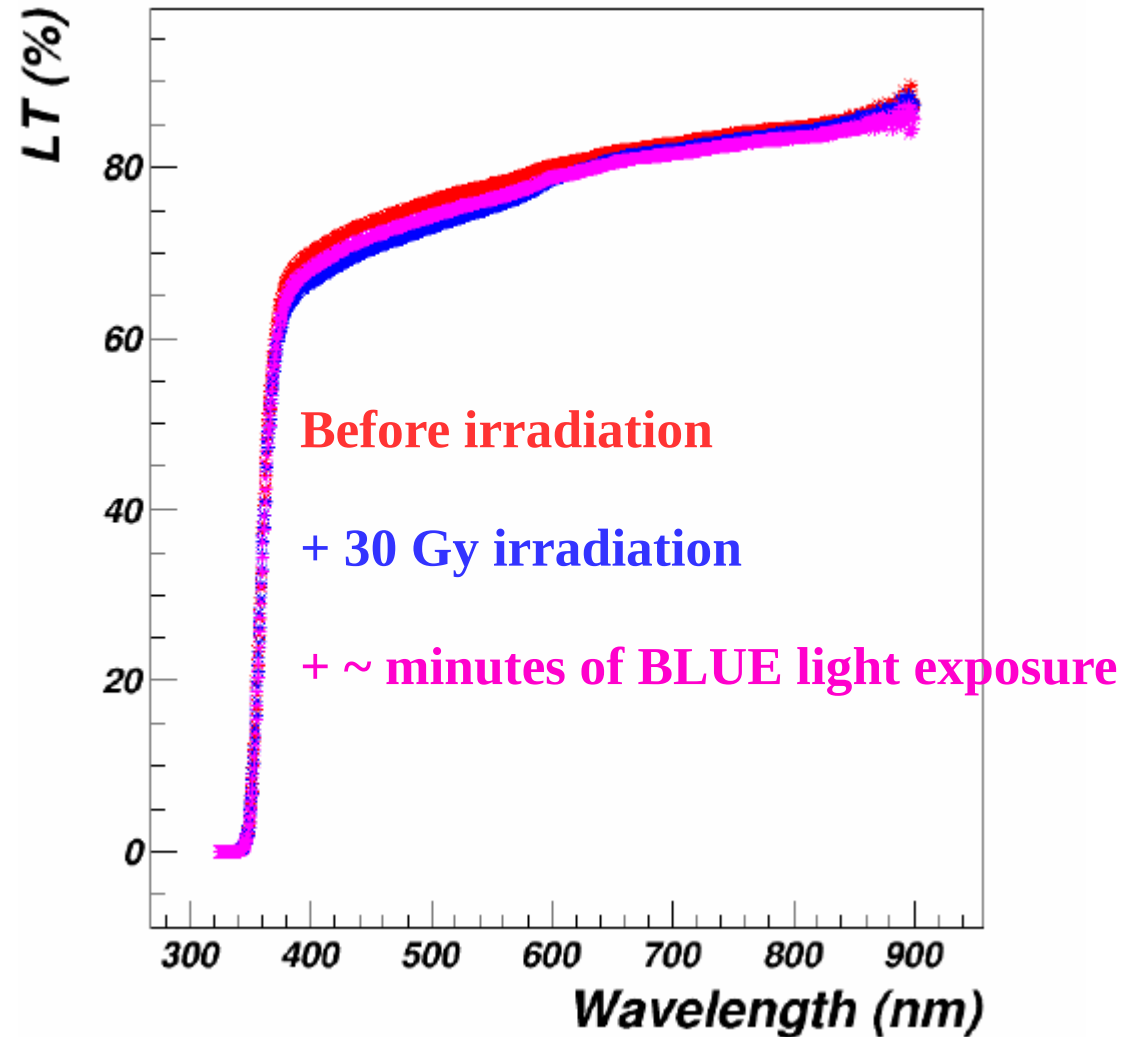
TBD

Backup-slides

PbWO₄ EM-induced radiation damage

PbWO₄ crystals are sensitive to EM radiation.

- EM radiation induces a damage, in terms of decreasing of light transmission, due to color centers creation.
- The damage can be recovered by exposing crystals to an intense light source



Results from a HPS crystal.
N.B. Only one sample was available!