ProtoDUNE-DP (6x6x6 m^3) Light Calibration System: Specifications and Requirements

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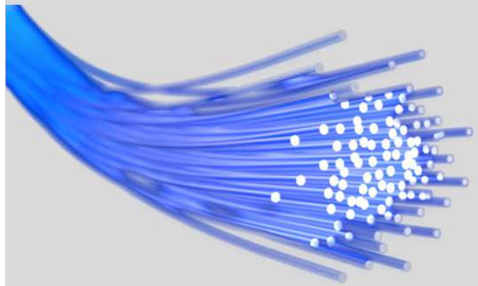
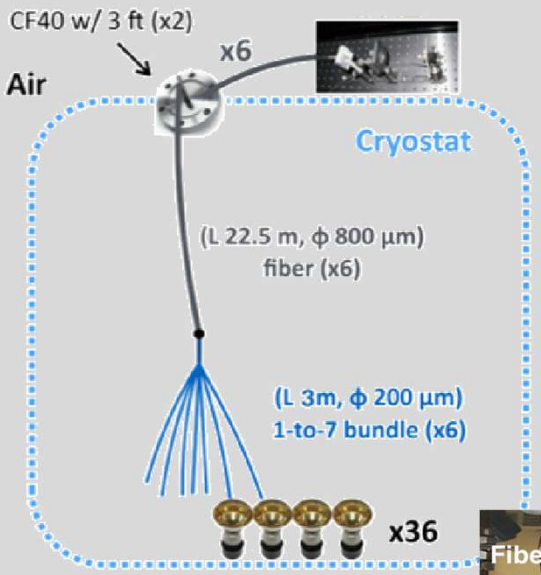
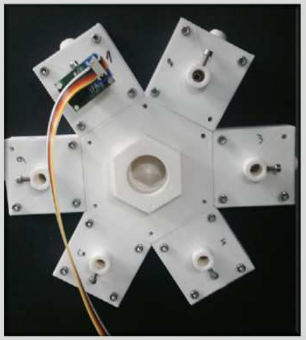


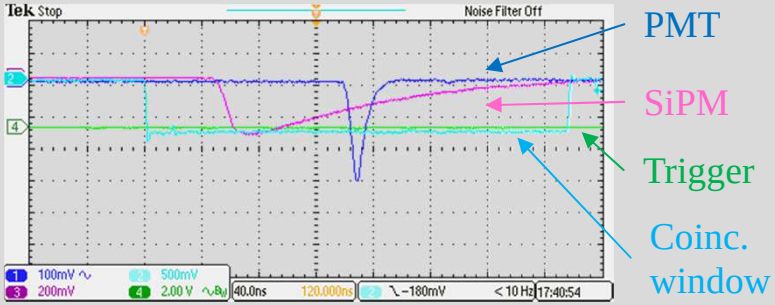
Light Calibration System Description



Six 22.5 m length stainless-steel jacket fibers are used inside the cryostat, each one attached to a 1 to 7-fiber bundle so one fiber is finally installed pointing at each PMT



The calibration light is provided by six blue LEDs. Each LED is connected to one fiber that goes to an optical feedthrough. The six LEDs are placed in a hexagonal geometry. The direct light goes to the fiber and the reflected stray light to the reference sensor (SiPM) used as a single reference sensor in the center.



The full system has been tested successfully at Ciemat in LN_2

Calibration Measurements

Gain stability: Single photo-electron (SPE) spectrum at the PMT operating high-voltage (HV) in order to measure the gain. This measurement will be taken every time the PMTs are biased up, and regularly.

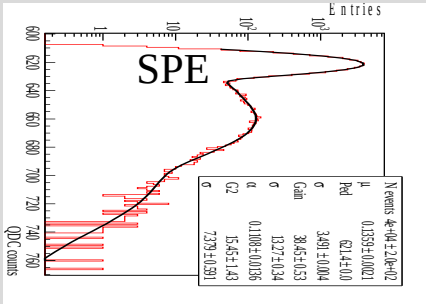
Measurement	Periodicity	# Events/PMT	Size*	Time
Gain stability	Daily	20000	XX	~5 min
G vs HV	Weekly	20000 * 8 PMT HV	XX	~1 hour
Light response	Weekly	20000 * 3 LED HV	XX	~15 min

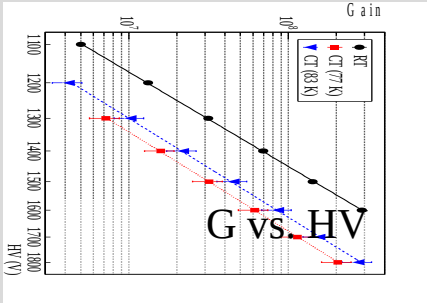
***Data size depends on the event size at the front-end output**

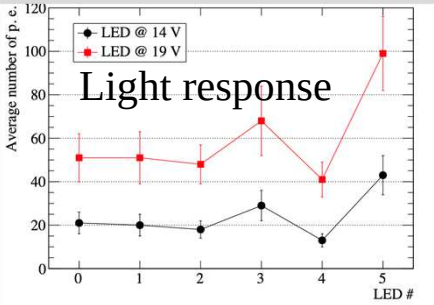
G vs. HV: SPE spectrum at different PMT voltages (1200 – 1900 V, 100 V steps) to obtain the gain calibration curve. This measurement requires more time for the data taking and can be performed approximately once a week.

Light response: the LED voltage can be increased to study the PMT performance for different light levels: from the SPE several hundreds of photo-electrons.

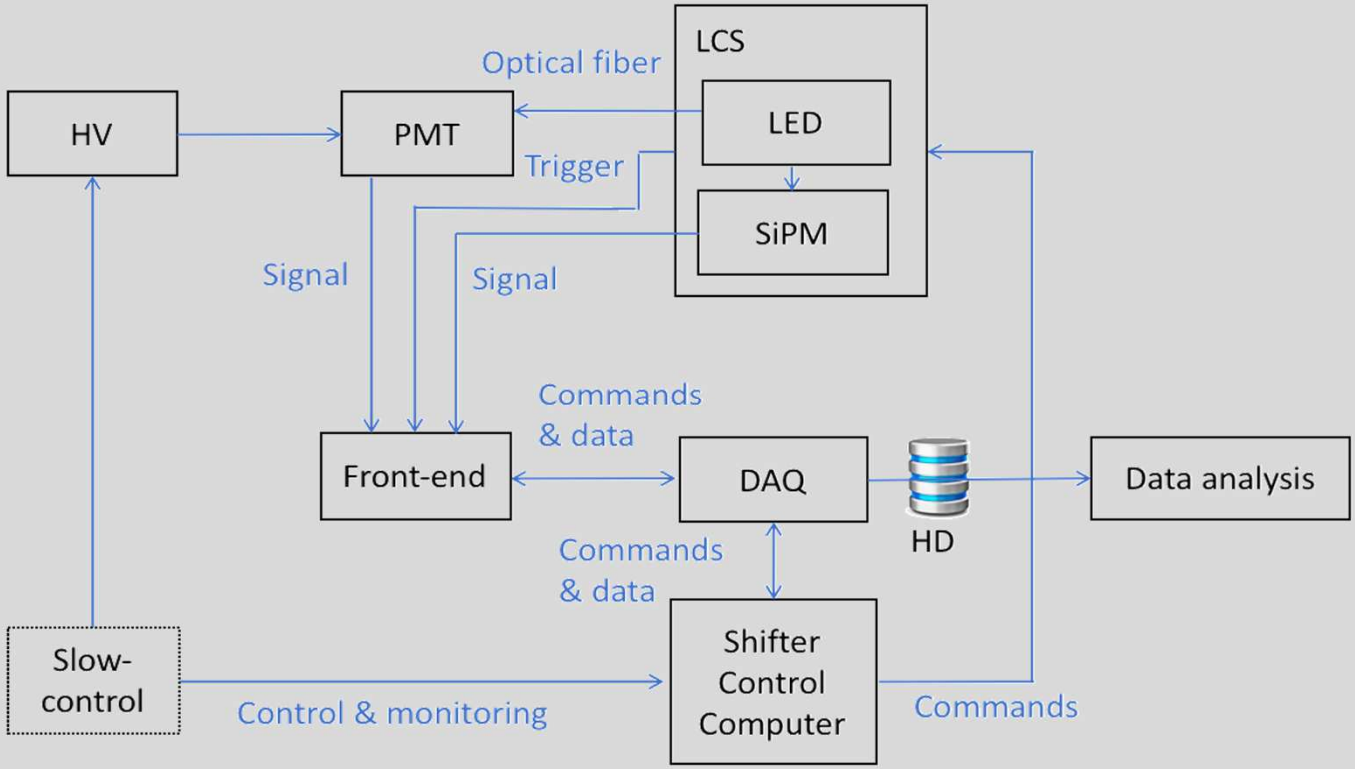
All measurements are taken with one LED providing light pulses to 6 PMTs simultaneously at a time.



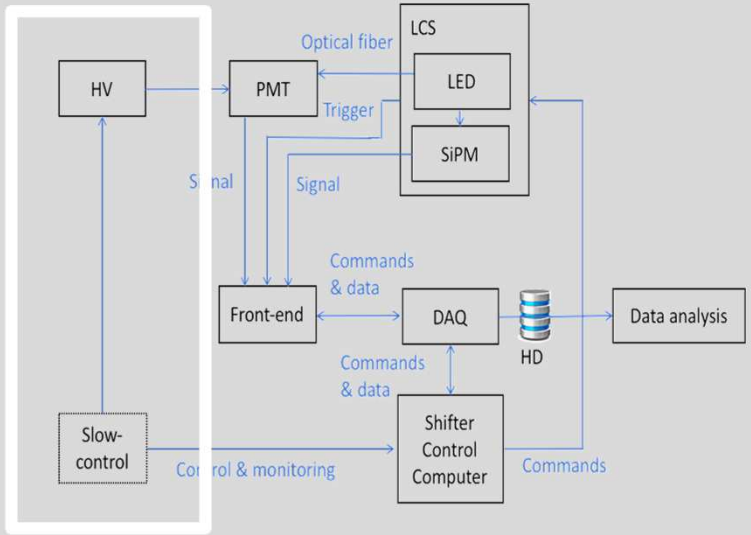




Interfaces with other Systems



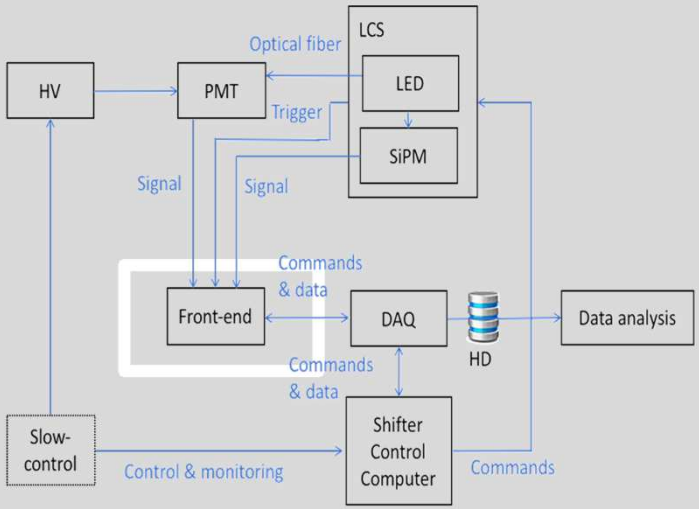
PMT HV SYSTEM – SLOW CONTROL (CERN and slow-control team)



The PMT biasing high voltage needs to be controlled and shifted during the calibration tests. A script to automatically bias all the PMTs at the target HV is needed.

Interfaces: The HV system needs to be connected to the shifter control computer (directly or through the slow-control) to control and monitor the status of the different HV channels.

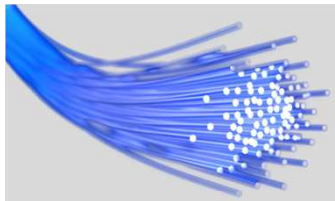
FRONT-END
(Front-end team – IN2P3)



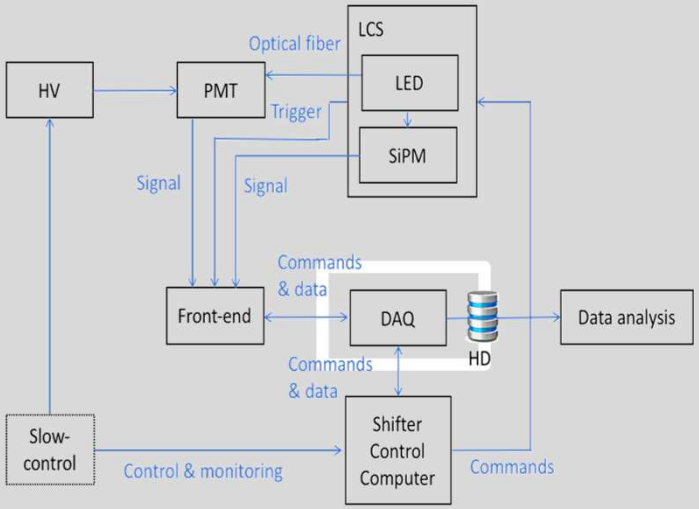
Requirements for inputs and acquisition

- The LCS will provide a 5 V TTL trigger (3V3 compatible) with rising edge.
- The reference sensor (SiPM) signal will be connected to one of the spare analogue inputs. The dynamic range is +1, but can be adapted to match the dynamic range of the PMT signals.
- The PMT signal will differ among the measurements, from mV to few V.
- The SPE width is ~10 ns. For the right acquisition, the maximum sampling rate must be used.
- The time between the trigger and the acquisition start should be programable to ensure the acquisition in the proper time window.

Interfaces: The DAQ will send to the front-end the commands to start the acquisition in LCS mode. The front-end will send the LCS data with a special header to be identified in the DAQ.



DAQ
(DAQ team - Lyon)



Interfaces

➔ The DAQ receives an LCS command from the shift control with the necessary information to perform the calibration run.

←The DAQ sends an answer to the shift control saying that the LCS command has been (un)successfully completed, the n. of acquired events and in case of fail, the cause.

It is needed that the DAQ enters in a LCS mode under request of the shifter controlled by an LCS command. This command will include a character string indicating the type of calibration. When the LCS mode command is received, the DAQ needs to perform the following actions:

- Send to the front-end the configuration command to enter in LCS mode indicating thePMTs to be acquired.

- Start a timer with the time-out value received in the LCS command.

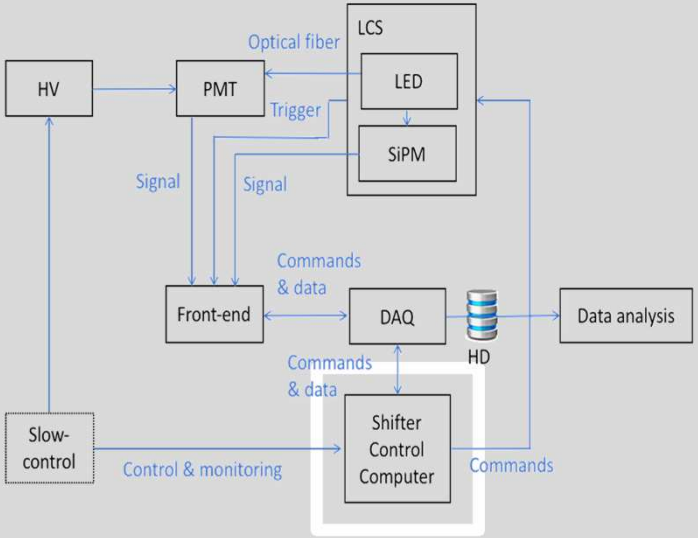
- Save LCS data in a fixed directory for LCS. Include in the file name the character string received in the LCS mode command.

- Only the PMTs and reference sensor channels are acquired.

- The run should stop after the number of triggers indicated in the LCS command, manually, or if after the time-out, no trigger is received.

- Send a command to the shift control saying that the LCS command has been successfully/unsuccessfully completed.

SHIFTER CONTROL COMPUTER (CERN, Lyon, IFAE)



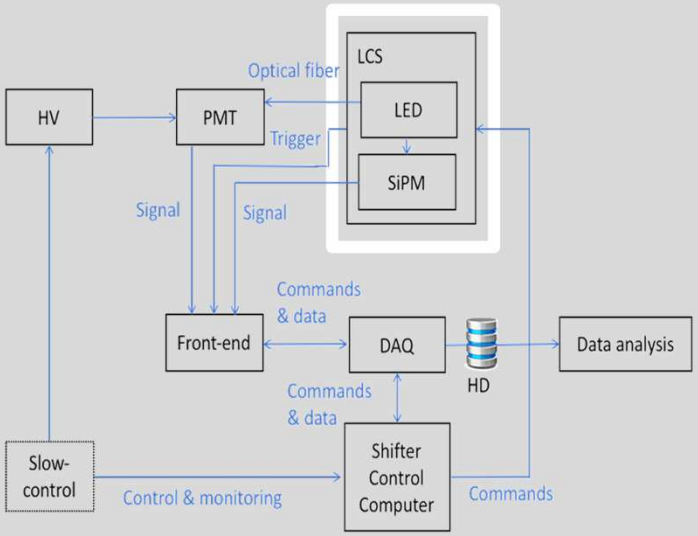
This module is in charge of coordinating all the systems involved in the LCS operation. Three different sets of commands are sent from the shifter control: to the HV (or slow-control), to the LCS, and to the DAQ. The format of these commands has to be the defined by the receptor subsystem.

Visualization: during the calibration, a visualization tool able to show on-line the SPE spectrum of the PMTs and the reference sensor will help to identify failures of the PMTs or CS. At least, a counter showing the acquired events is required to know that the system is working.

Interfaces

- HV/Slow-control: send commands to the HV to program the voltage and monitor the values of the setting.
- LCS: send commands with the settings (SiPM voltage, LED voltage and pulse frequency) and receive SiPM monitoring values
- DAQ: LCS command will be sent from the shifter control to the DAQ and the shifter control will wait for completion information and a message will be displayed with this information.

LIGHT CALIBRATION SYSTEM CONTROL (LCS team - IFAE)



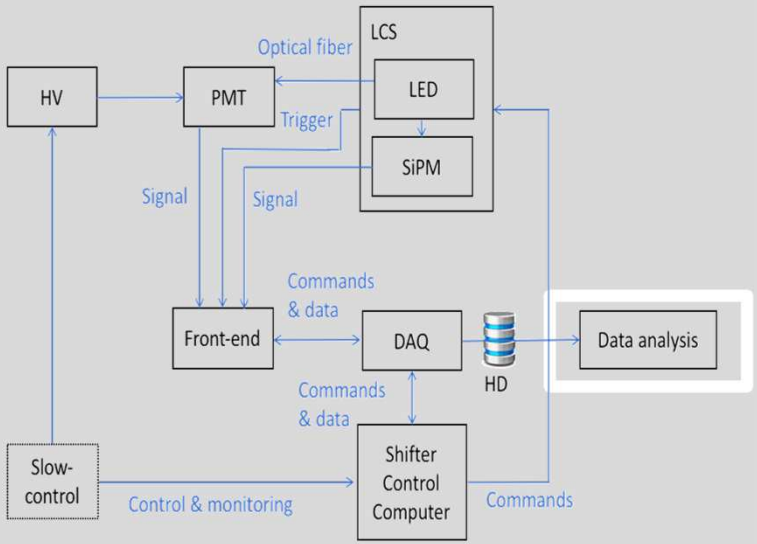
The LCS software will allow operating at different LED bias voltages and select each LED as well as the number of pulses and pulsing frequency. The software will be installed on a BeagleBone board accessed via Ethernet. the SiPM output will be connected to the light readout front-end. For each run, a text file will be generated with the internal measurement of the LED light detected by the SiPM and optionally sent to the shifter control computer.

Interfaces

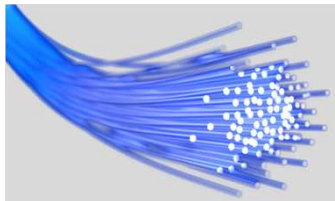
The shifter control computer sends a set of commands to the LCS. The following commands can be sent:

- Settings commands: SiPM voltage, LED voltage, pulse frequency, number of pulses (or continuous).
- Switch on/off an LED.
- Start and stop trigger signal.

Data analysis
(LCS team – Ciemat and IFAE)



No on-line data analysis is foreseen. The PMT gain will be determined with a root macro performing a fit of the SPE spectrum. Fit results will be stored and shifts with previous gain measurements will be quantified.



Summary

- The full LCS has been tested successfully at Ciemat in LN_2
- Calibration measurements: Gain, G vs. HV, and light response defined. Interactions with other systems to be developed to perform the tests.
- Interfaces with other systems:
  - **HV – Slow control:** Commands to change the PMTs Voltage.
  - **Front-end:** Calibration Mode adapted to PMTs timing and dynamic range signals during the tests. Inputs for trigger and internal LCS light monitoring SiPM
  - **DAQ:** Communicate with the Shifter Control Computer to set and monitor the calibration runs.
  - **Shifter control computer:** Communicate with all the interfaces involved and display the performance of an ongoing run.
  - **Light calibration system control:** Provide and measure the desired light level and trigger signal.
  - **Data analysis:** Offline data processing and storage to study the evolution of the PMTs performance.