The g-2 laser calibration system: testing the light distribution chain

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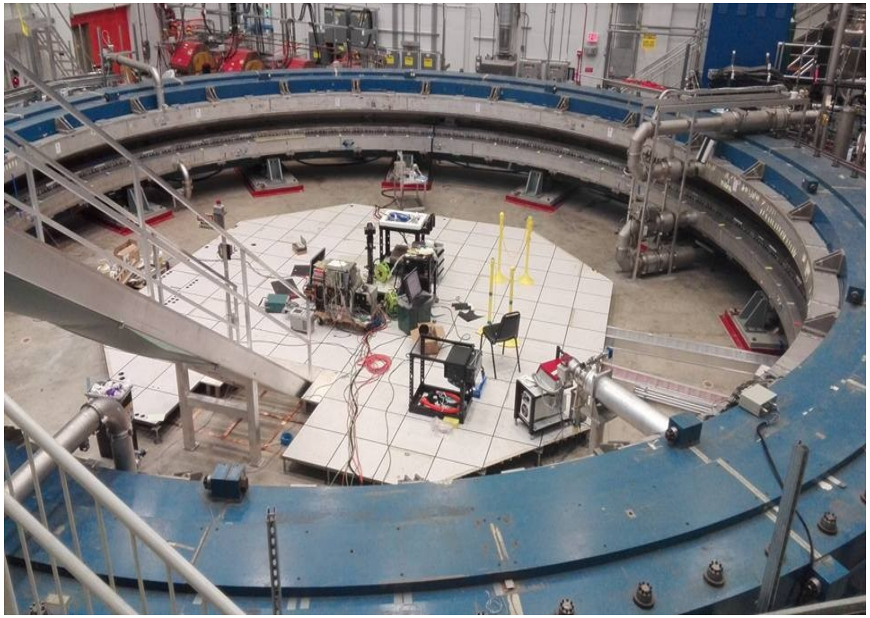
IN SUPREMÆ DIGNITATIS 1343
UNIVERSITÀ DI PISA

μ g-2

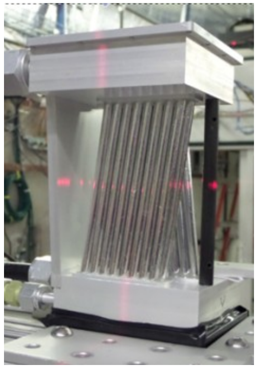
The g-2 experiment

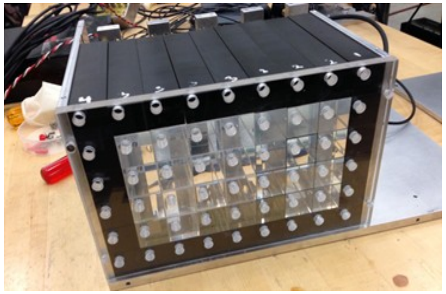
The Muon g-2 experiment will examine the precession of muons that are subjected to a magnetic field.



- **Goal of the experiment**: test the Standard Model's predictions of the muon anomalous magnetic moment to a precision of 0.14 parts per million.
- **Focusing on the calorimeter**

The g-2 calorimeter



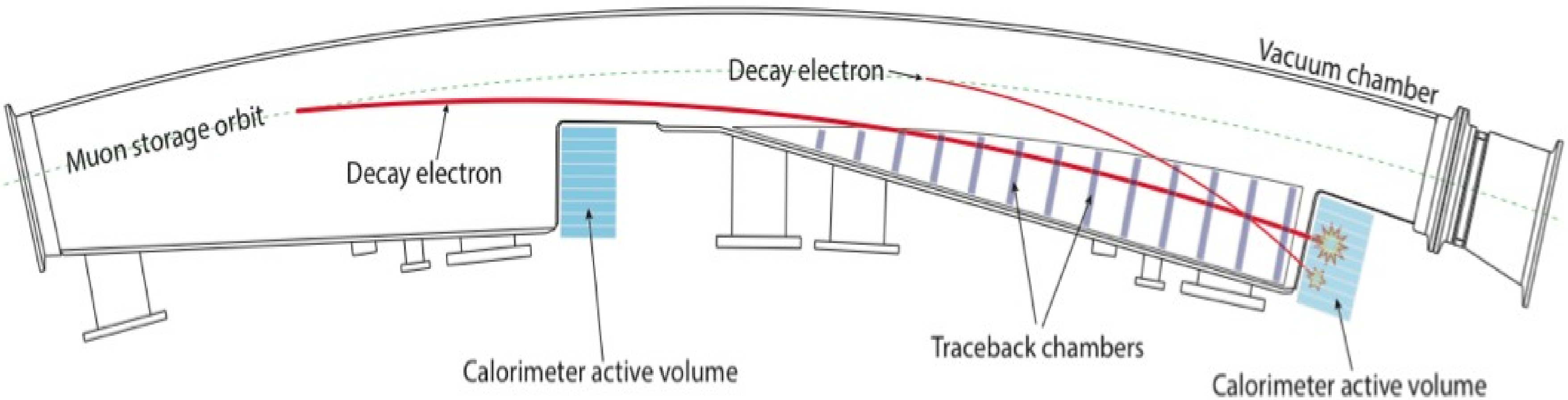


The main features of the calorimeter:

1. Measure positron hit time accurately (100 psec above 100 MeV);

2. Measure deposited energy with resolution better than 5% at 2 GeV

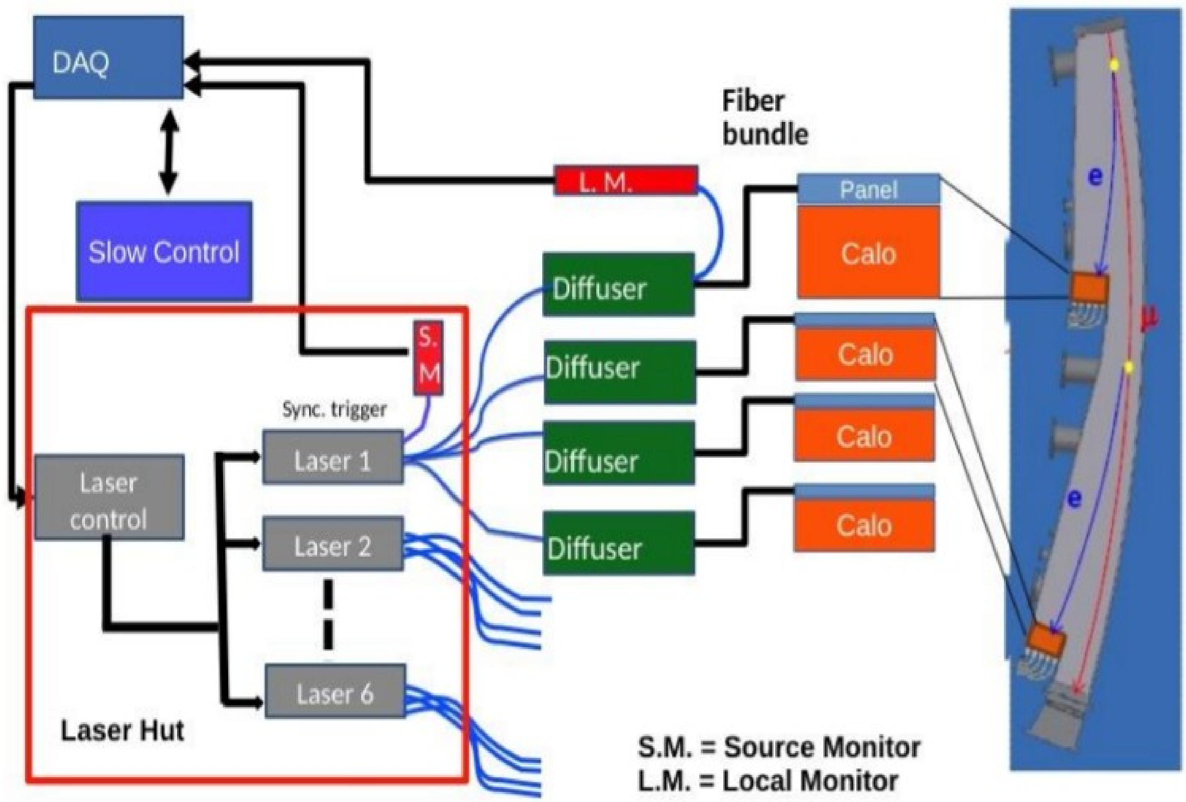
A calorimeter station will consist of 54 lead fluoride (PbF2) crystals in a 6 high by 9 wide array, with each crystal read out on the rear face using a SiPM coupled directly to the crystal surface.



Why a laser calibration?

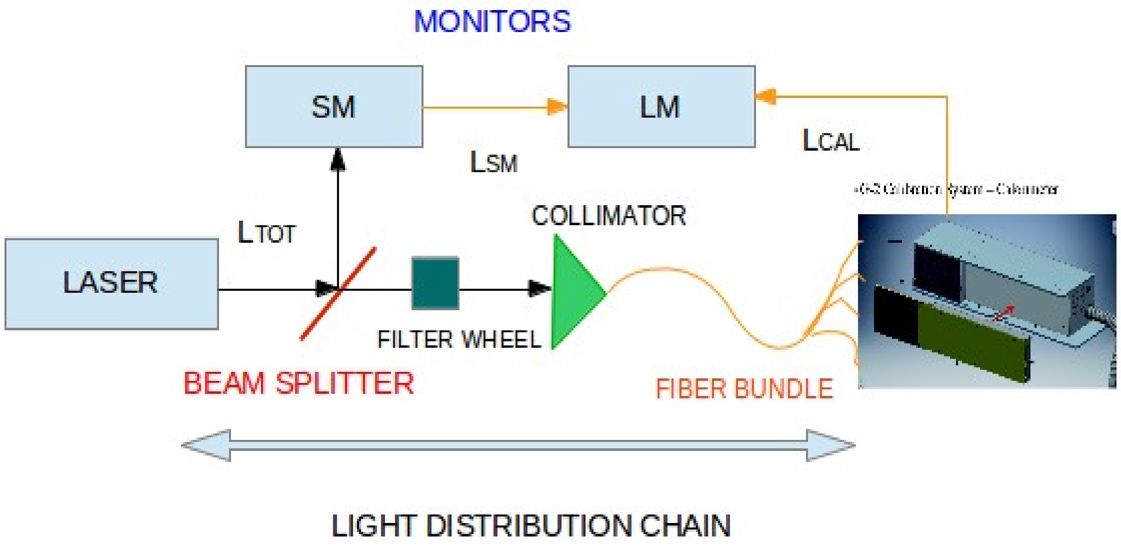
- To synchronize the 24 calorimeters.
- To calibrate the photon detection efficiency of the SiPM sending simultaneous light calibration pulses into the SiPM through the active crystals (PbF_2) that make up the calorimeters and then couple into bundles of optical fibers.
- Light pulses should be stable in intensity and timing in order to correct systematic effects due to drifts in the response of the crystal readout devices.
- Light wavelength must be in the spectral range accepted by the detector and determined by the convolution of the spectral density of the Cherenkov signal produced by electrons in PbF_2 with the spectral transmission of the crystals
- Pulsed diode lasers in the blue seem to best address all the criteria.

Laser calibration scheme



Multilaser with 6 heads; 24 launching fibers; 24 diffuser, 6 Source monitoring; 24 local monitoring

MONITORS

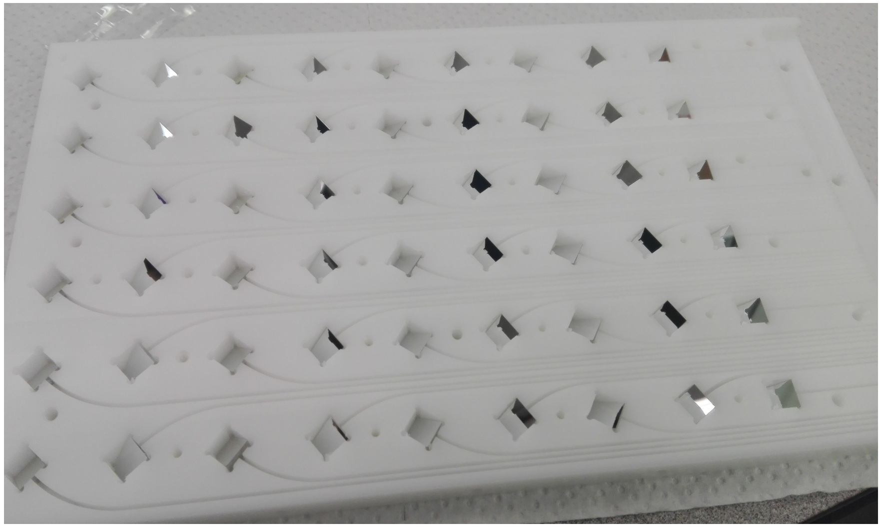


Most important feature of the calibration system : LIGHT STABILITY

- To be sure that this level of stability is maintained during data taking a monitoring procedure has to be included in this calibration system → a Source Monitor (SM) and a Local Monitor (LM) are used.
- SM: PMT that reads out LCAL and LSM pulse-to-pulse;
- LM: measures the laser stability;
- The ratio LCAL/LSM is a measurement of the (possible) fluctuations on the light due to the distribution chain.

STATUS OF THE MECHANICS

- All Front Panels are ready and filled with the crystals
- All Beam Splitters are ready
- All Collimators are assembled



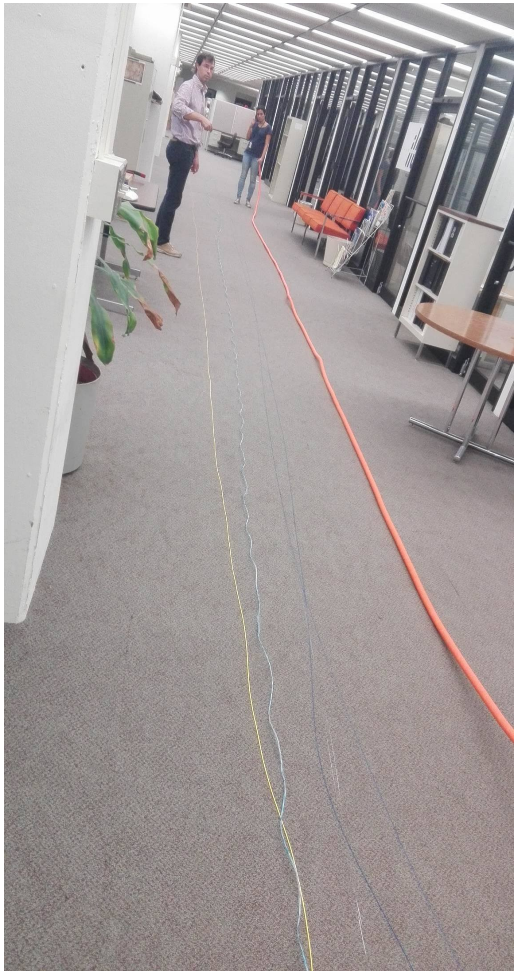
FRONT PANEL WITH 54 CRYSTALS PRISMS

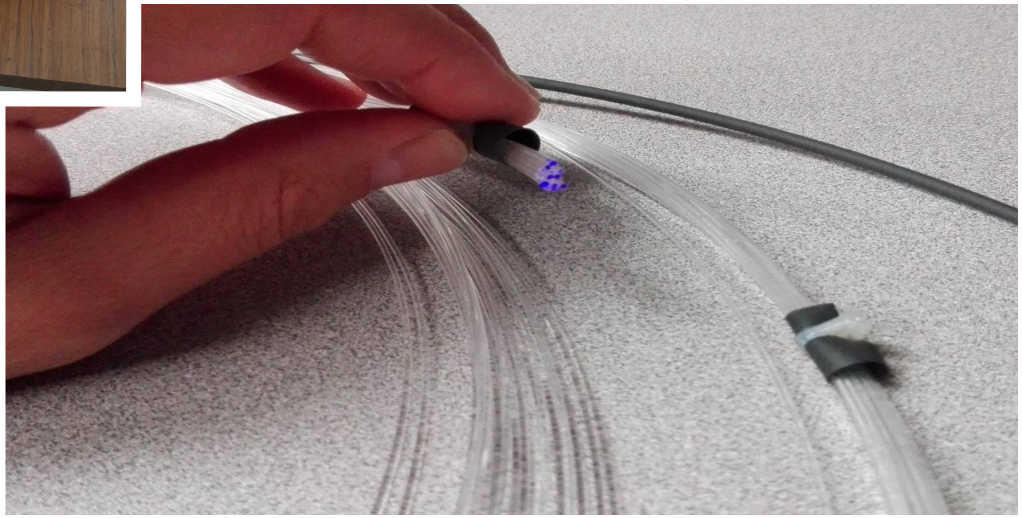
BEAM SPLITTER

COLLIMATORS

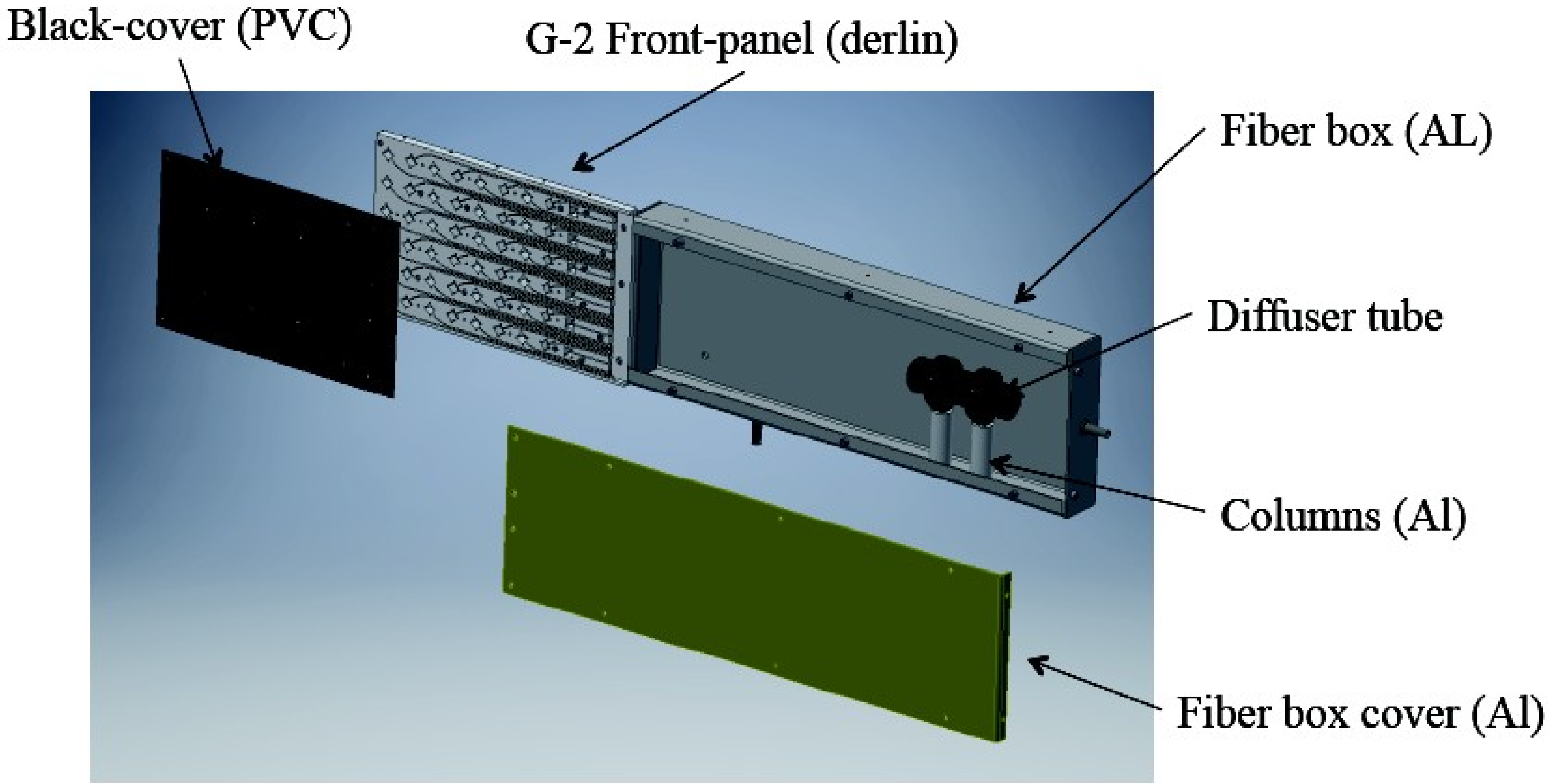
Fibers assemblance

- We cut and spliced the fibers and prepared the bundles
- We test the power of every fiber of the bundle (we want an average power ~4μW) and we cleaned and fixed the ones which

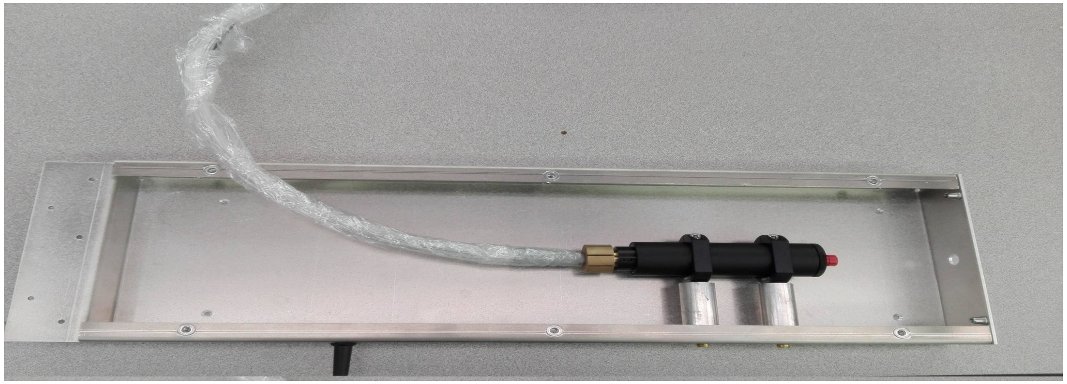


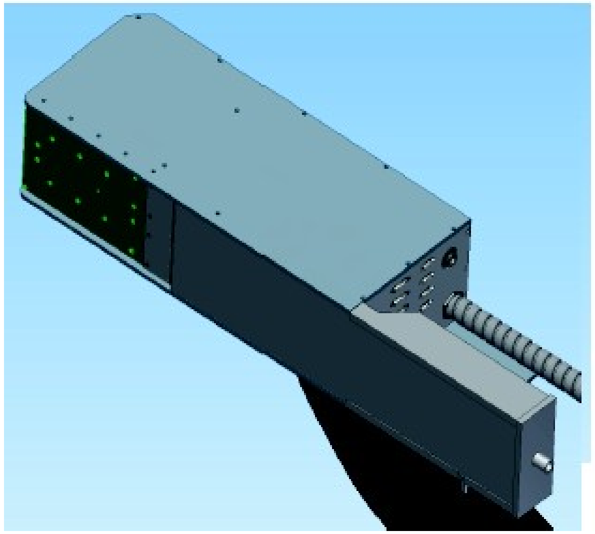


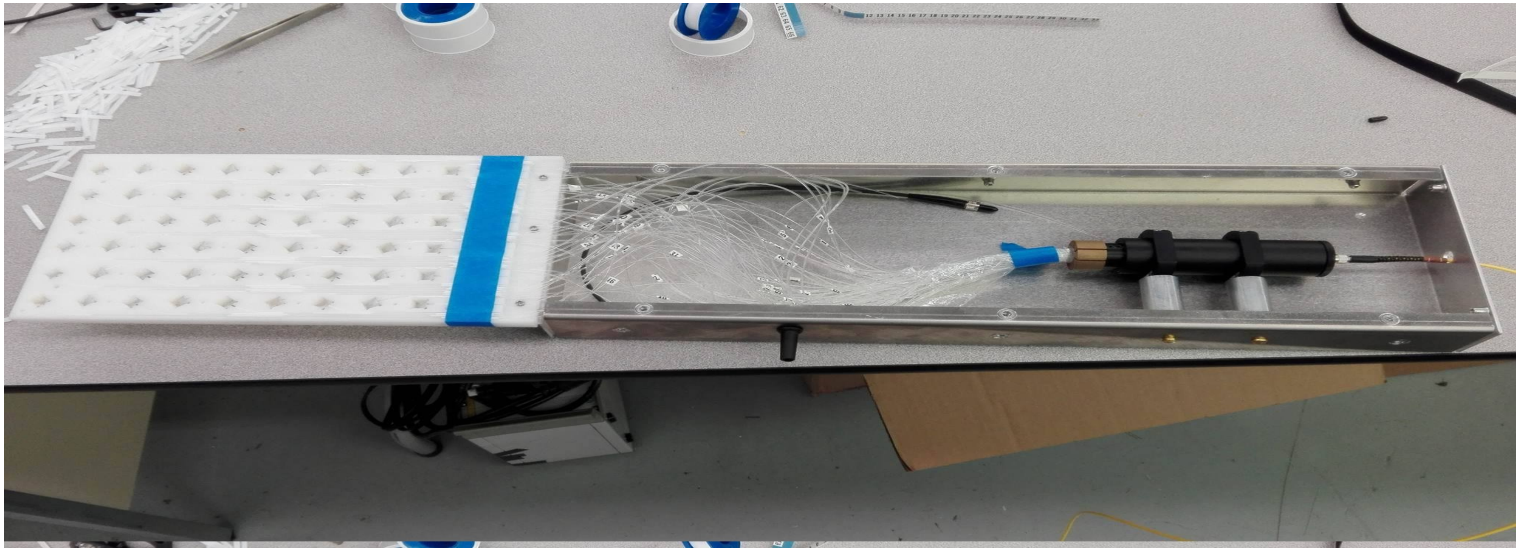
G-2 Calibration System



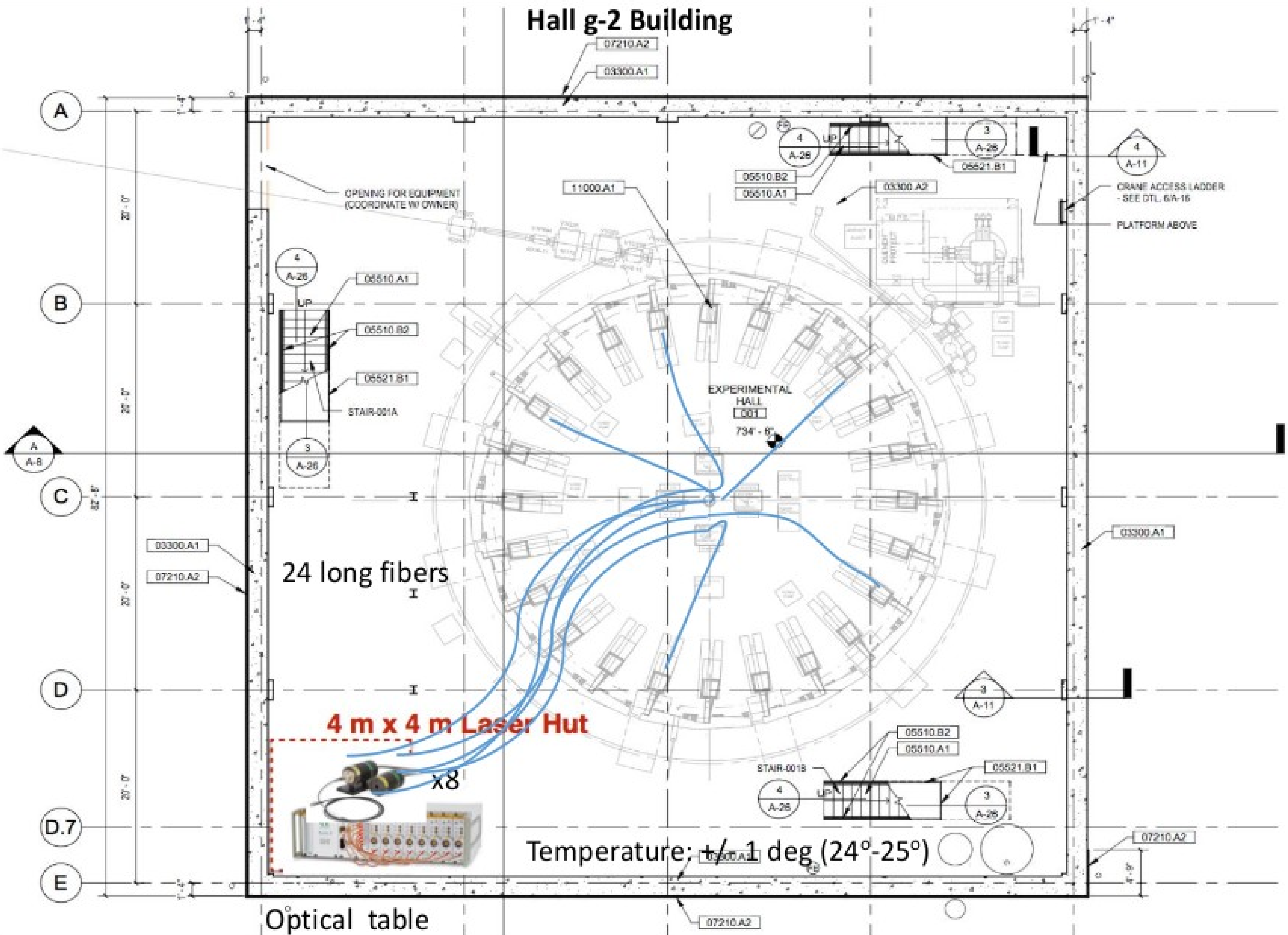
G-2 Calibration System







Hall g-2 Building

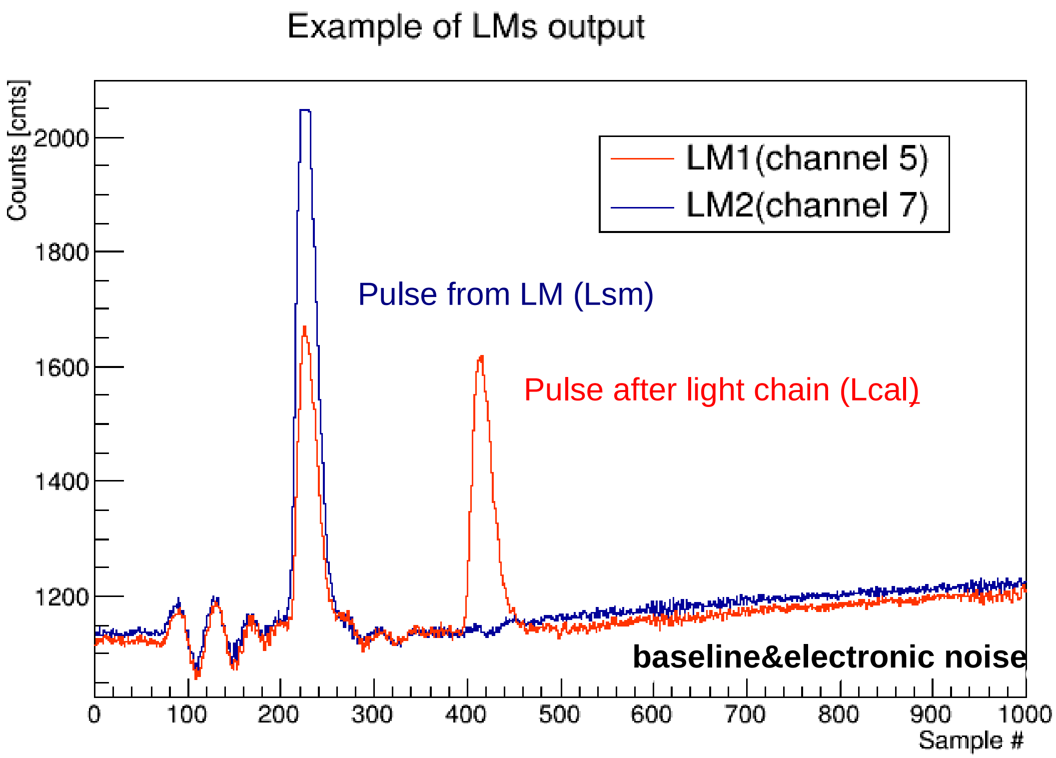


Data Analysis

Two LMs avalaible:

- LM1(channel 5) both pulses;
- LM2(channel7) only first pulse;
- Pulses separated in time approximately 250ns;

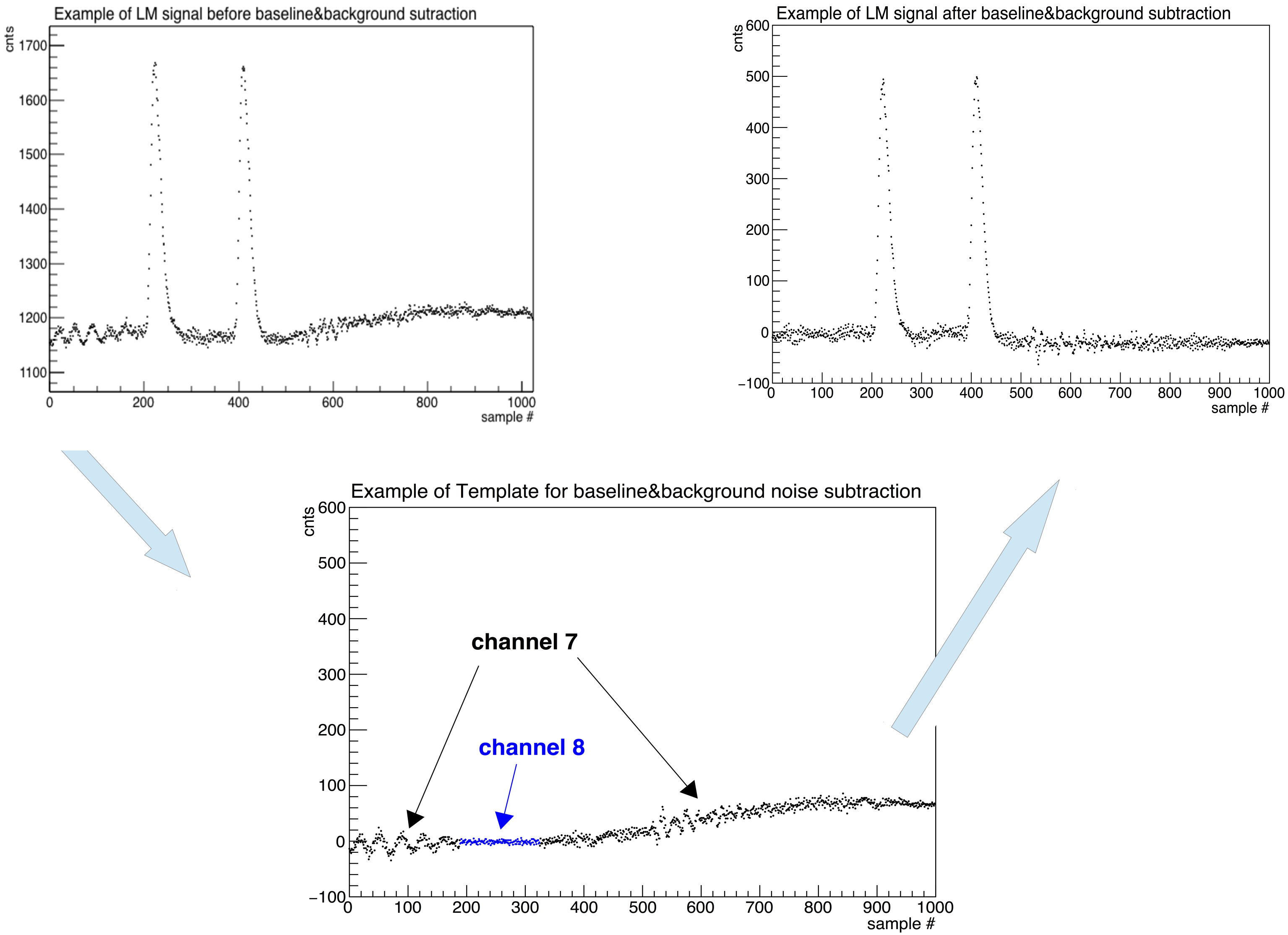
The data are from a recent test beam at SLAC



Main issue: subtracting the baseline and the background noise → we tried many different ways;

Best idea: subtraction using a template event-per event

Details on the baseline subtraction



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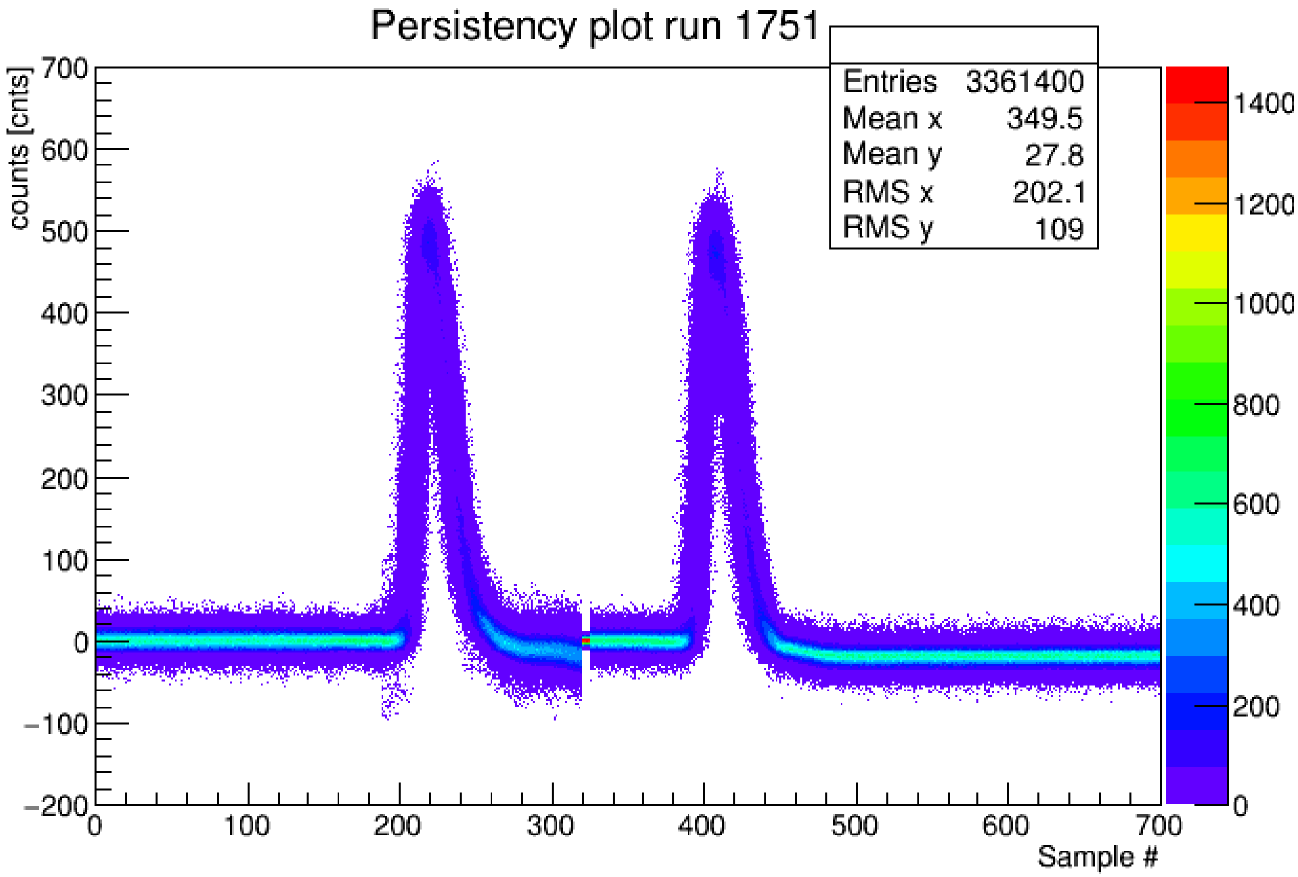
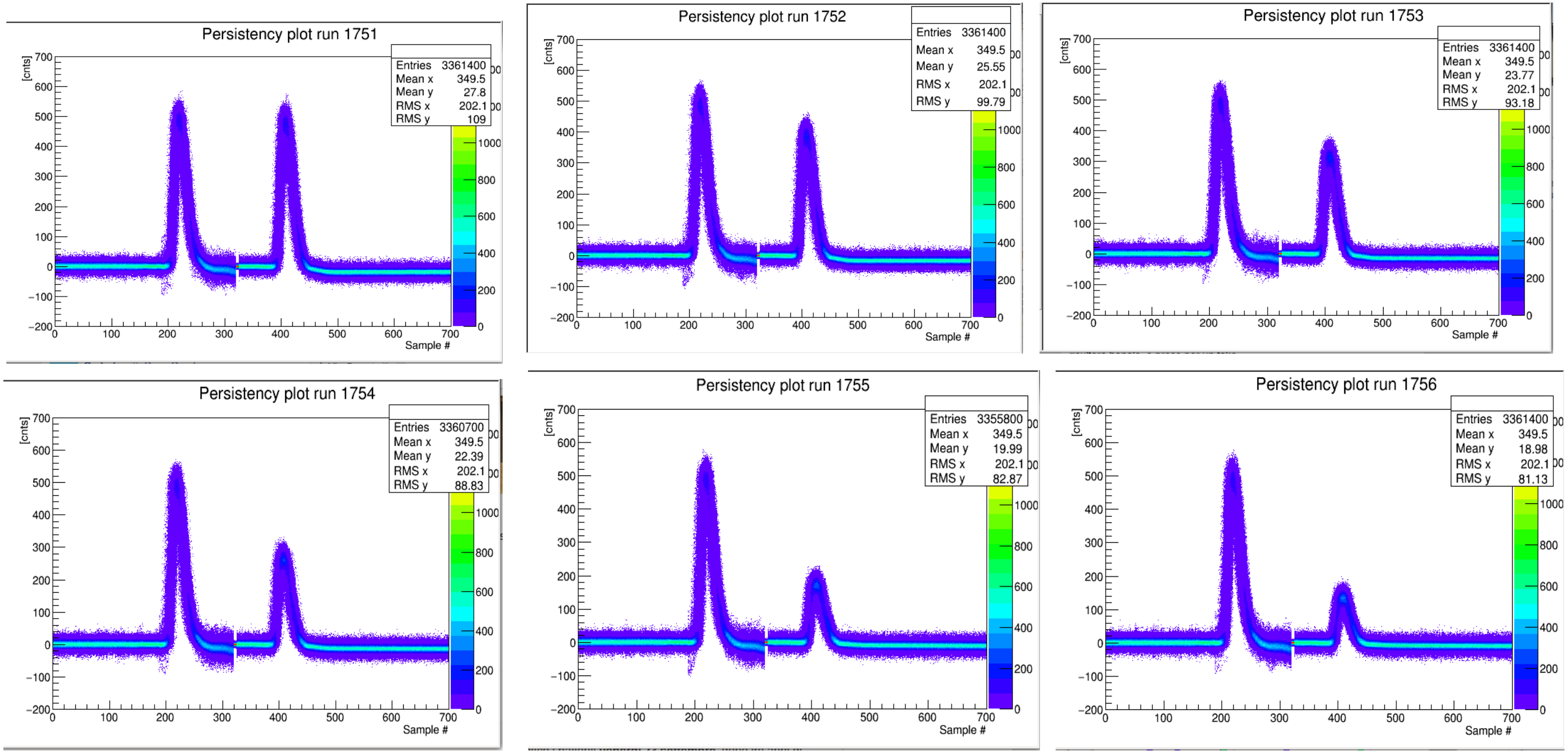
LM PMT Calibration



- Persistency plot of 6000 events;
- noise in the first pulse not completely removed.

LM PMT Calibration



Filter wheel allows to take measurements with different light intensities. Only the light in the second pulse is affected.

Using the second pulse we can test the linearity and the photo-statistics of the PMT.

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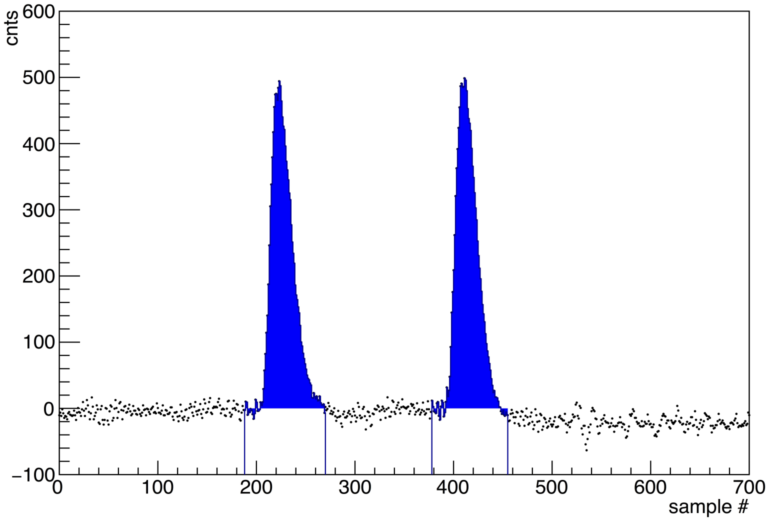
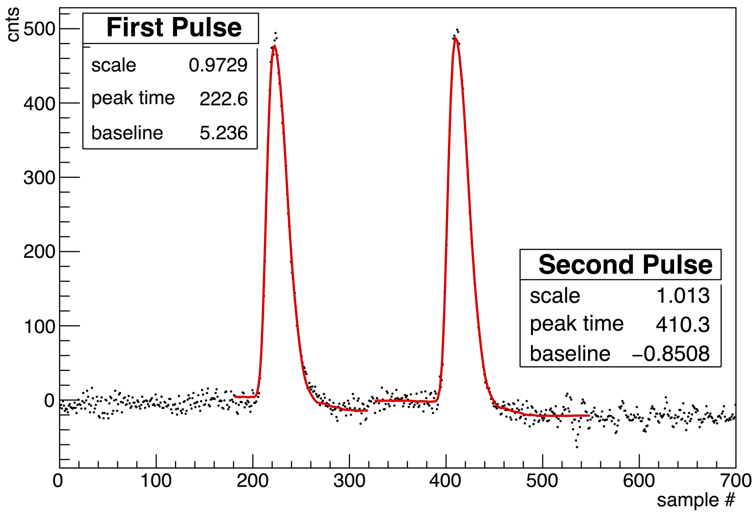
From pulse to charge

Two methods to evaluate the charged of the signal:

by performing an integration around the peaks (with a fixed ranged);

- spurious noise might be included;
- pulses outside the range are not properly integrated.



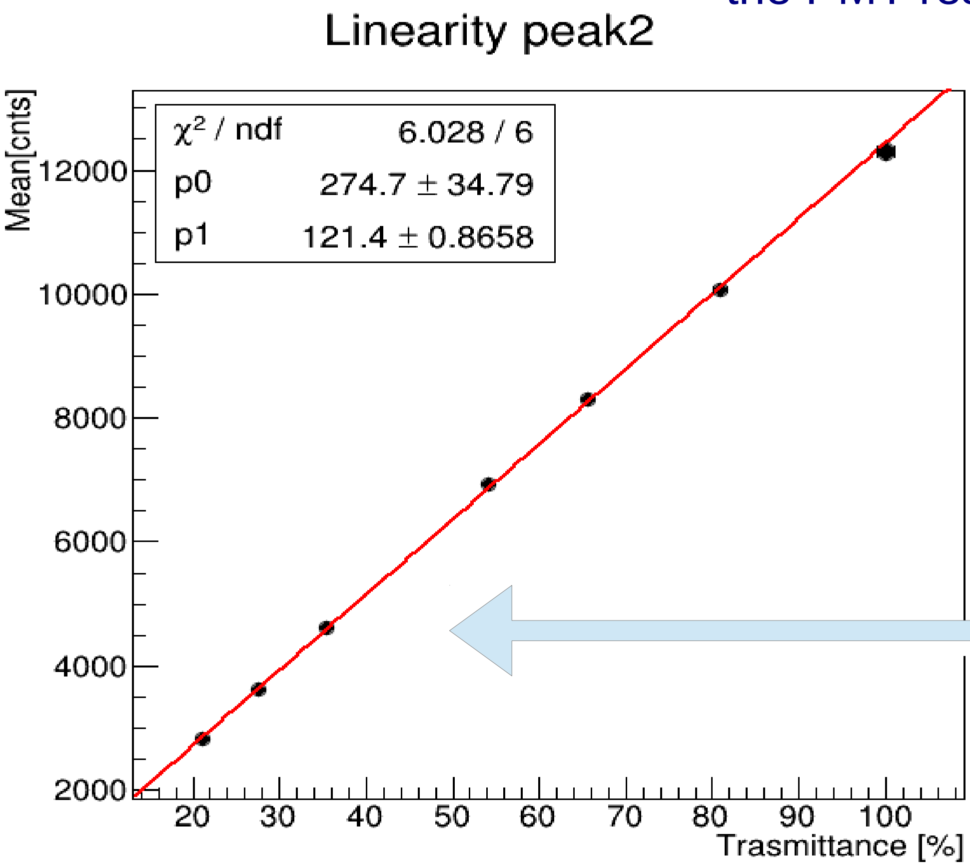


by performing a fit with the template;

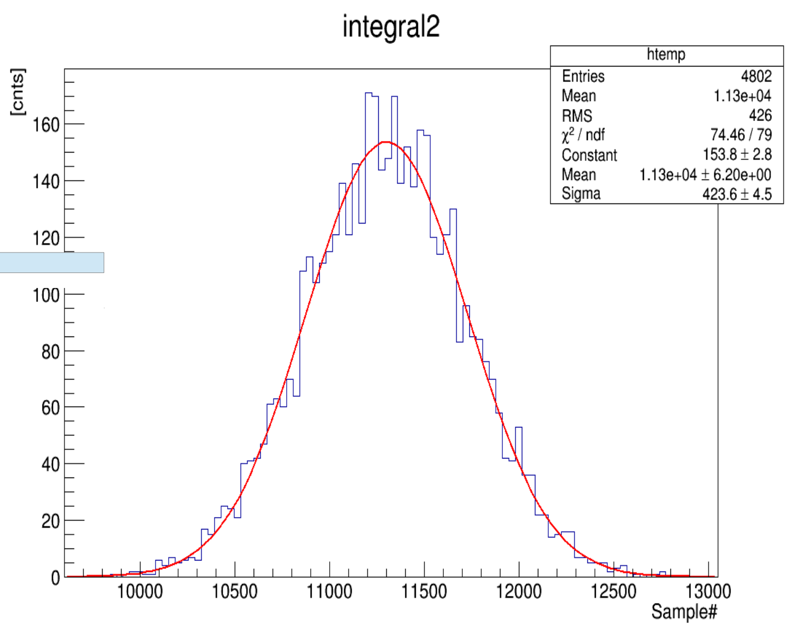
- Template from data: spline of the average of the 2nd pulse of indipendent run.
- residual baseline and noise excluded.

Linearity of PMT

Using the calibration runs we check the linearity of the PMT response:

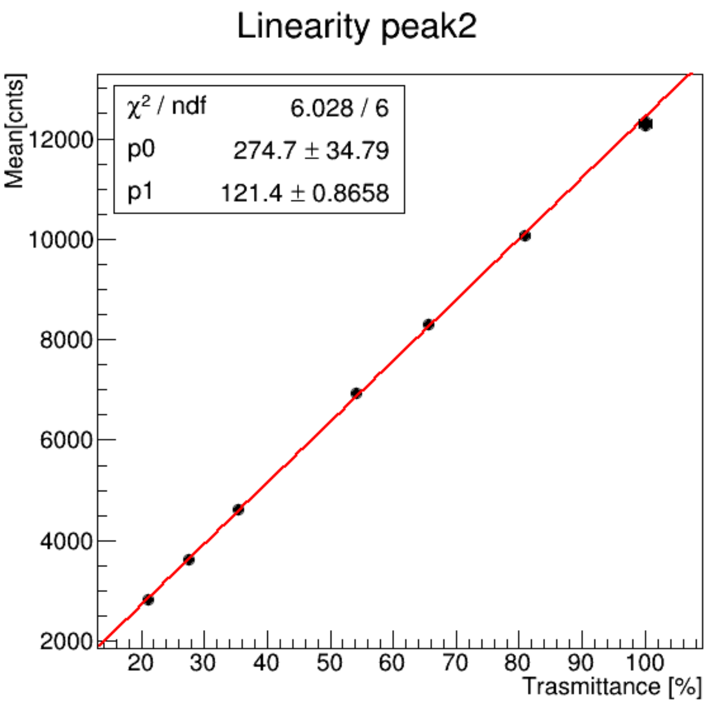


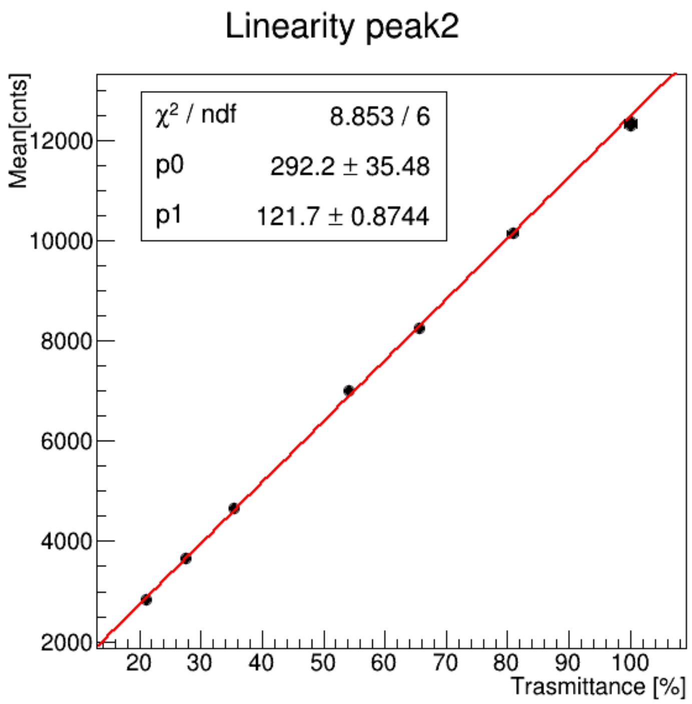
- For each run we fit with a Gaussian function the distributions of the two integrals



Transmittance: fraction of radiant energy that having entered a layer of absorbing matter reaches its farther boundary.

Comparison: similar results from the two methods



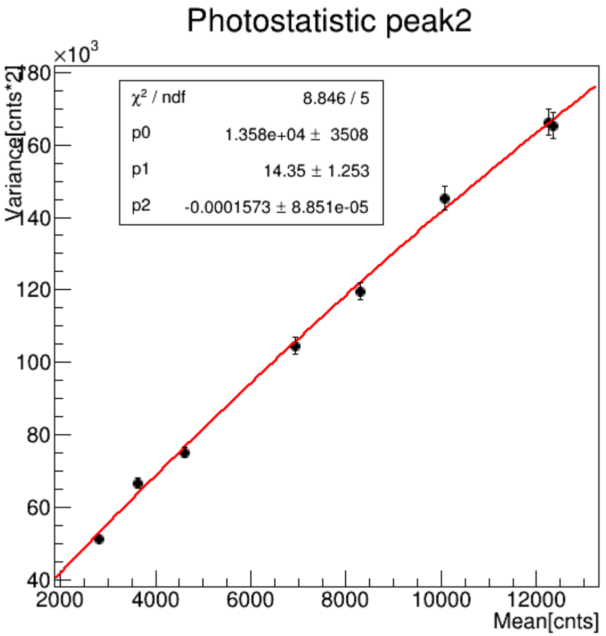


- Linearity obtained with the template fit
- Linearity obtained with the integral calculation of the two peaks

Photoelectron calibration

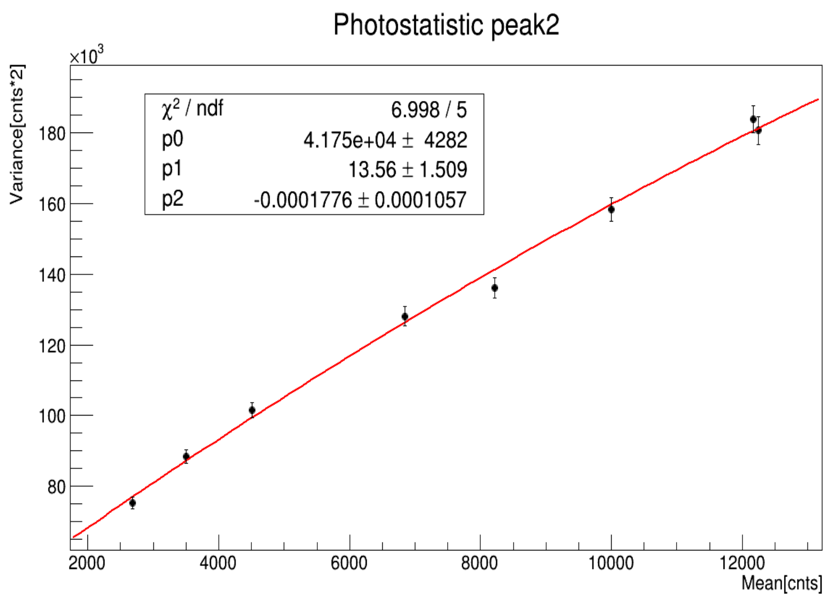
And we performed the calibration through the p.e. statistics:

- p0= electronic noise;
- p1= mean/pe (pe are the photoelectrons)
- p2=contribution proportional to the signal.

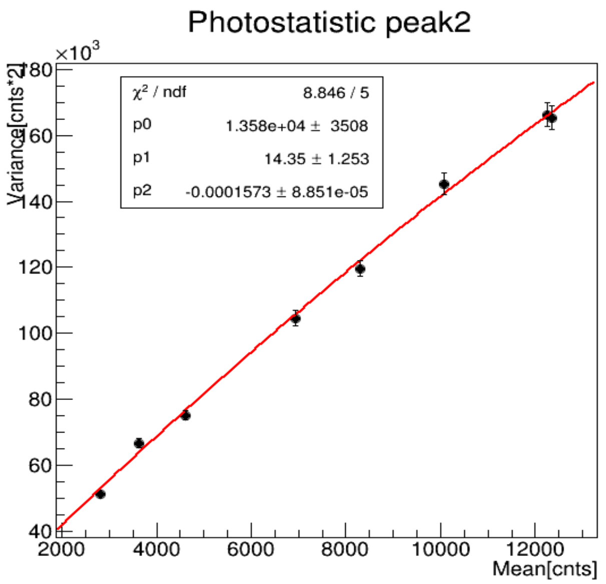


The relationship between the mean and the variance allows us to determine the amount of light that arrives to the detector in function of the number of photoelectrons produced.

Comparison



- Photostatics calculated by the integration of the peaks



- Photostatics calculated by the template fit

Similar results from the two methods: at max (no filters) measured 910 p.e. And 870 p.e. respectively.

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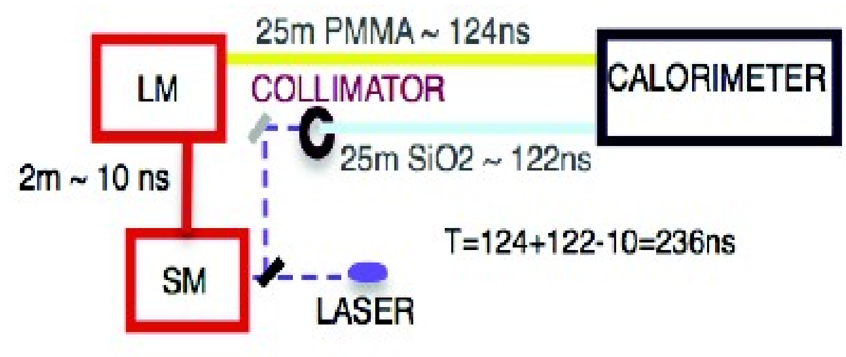
Timing

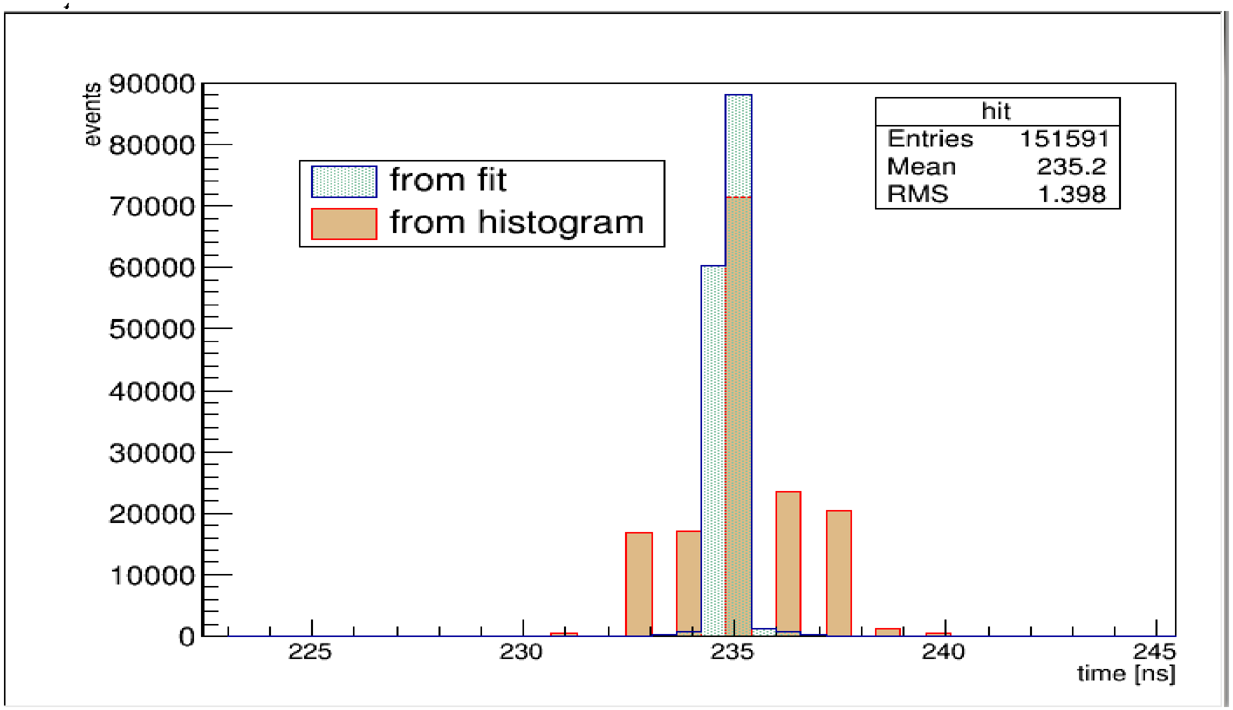
The time between the two pulses is a characteristic of the system.

$$time = \frac{distance}{c/n}$$

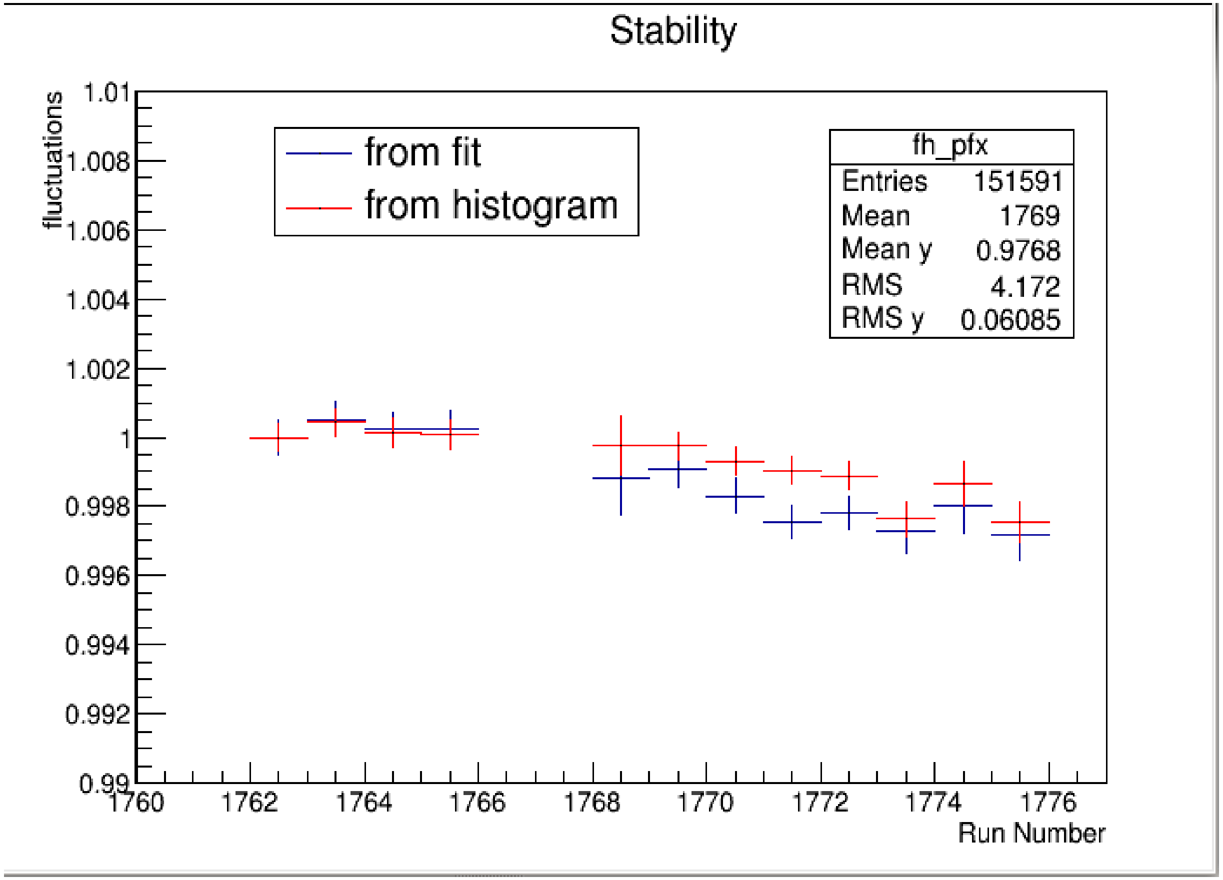
$$D_T(SM-LM) \sim \frac{2}{0.3/1.5} \sim 10\text{ns}$$



$$D_T(collimator-calorimeter-LM) \sim \frac{50}{0.3/1.5} \sim 250\text{ns}$$



Stability



- Analyzed runs from 1762 to1775 (time of the measurement: 1h 30 min)
- During run 1766 and 1767 there were DAQ problems;
- Fluctuations measured with a precision of about ± 0.05% in ~7min.

Conclusions

HARDWARE: I've been involved in the assemblance of the laser calibration system. In D0 building I set the panels and the beam splitters, I arranged the fiber bundles and I linked together all the parts. The majority of the setup is now ready to future uses.

SOFTWARE: I performed a complete analysis of a subset of the LM data. The main challenge was the presence of background noise so that I compared numerous methods to subtract it. Preliminary results show small fluctuations during 1.5h of data-taken. Future prospective of this work is analyzing the entire data available.

A BIG THANKS TO:

- My supervisors Carlo Ferrari and Anna Driutti for the help and the assistance in every single day of this internship. They had the patience and the capability to involve me in their activities within the experiment and to explain me all I needed to know. I really appreciated their care of me.
- The professors Giorgio Bellettini, Simone Donati and Emanuela Barzi to give me the opportunity to partecipate at this summer school and the chance to work in a team of physicists and students in an international environment.
- All the other summer students that lived with me these incredible two months..

THANK YOU!!!