Laser Calibration System: outcome of the commissioning run

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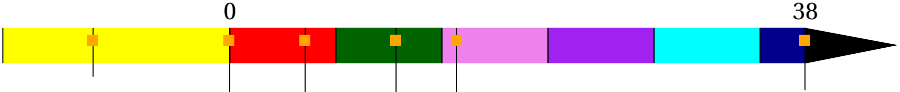
g − 2 **referee meeting** – September 6^{th}, 2017

Summer 2017 muon g–2 run highlights



23/05/2017:
first particles delivered to ring (particle splash observed in calos)

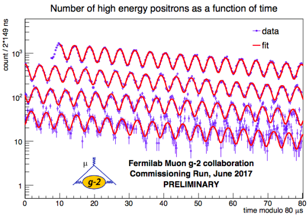
31/05/2017:
first particle injection + revolution

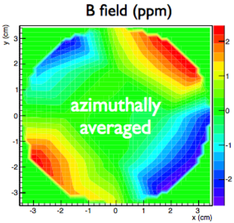
5/06/2017:
first particle stored for 100's of turns

11/06/2017: first wiggle plot

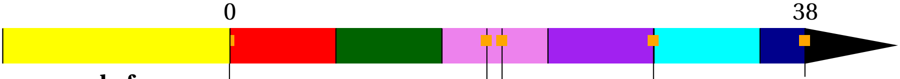
15/06/2017: first filed map

7/07/2017: end of run





Laser Calibration System highlights



end of may:
all calorimeters connected. Hardware for the laser calibration system completed.

31/05/2017:
beginning of run

17/06/2017:
first test of in-fill and out-of-fill modes

18/06/2017: replaced fiber calo 18

28/06/2017:
adjusted all HV, equalized LM light, system frozen

7/07/2017:
end of run

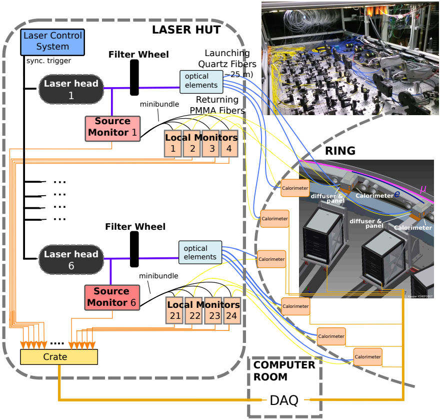
Reminder: Purpose and Overview of the system

Purpose:

- calorimeter gain stability monitoring;
- calibration of the calorimeters;
- timing.

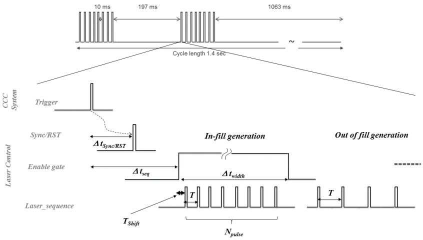
The system is composed of:

- Laser control system (LCS): a control board interfaced with the Sepia II driver;
- 6 source monitors (SMs) one for each laser;
- optical distribution system from laser head to calorimeters;
- 24 local monitors (LMs) one for each light distribution system to each calorimeter.



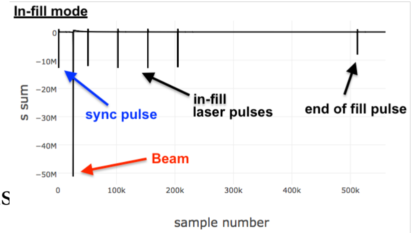
Laser Control System (LCS)

- synchronized with the clock, control and command system (CCC);
- generation of the laser pulse trains at programmable frequencies both in-fill and out-of-fill;
- physics event simulation (“flight simulator”).



What worked and what didn’t work:

- ✓ laser heads fired 24/7 for the entire commissioning run;
- ✓ different laser trigger path configurations used: sync. pulse only, both out-of-fill and in-fill and flight simulator.



Plans:

- incorporate the LCS configurations in the ODB.

Offline reconstruction of the in-fill and out-of-fill mode

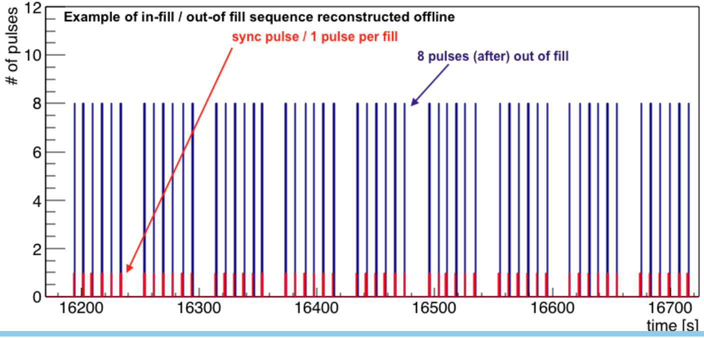
- two different unpackers to extract the data from the MIDAS file;
- time correlation using the time saved in the bank header.

What worked and what didn't work:

✓ we collect 3 days of data with sync pulse in-fill + 2 sequence of 4 pulses out of fill;

Plans:

- module to extract the gain correction factors and save them into the database.



6 Source Monitors (SMs)

- 30% of the laser light distributed to 3 photo-detectors: 2 fast PIN diodes and 1 PMT;
- pin diodes monitor stability at sub-0.1% level;
- PMT also views an Am/NaI light pulse for long term absolute stability.

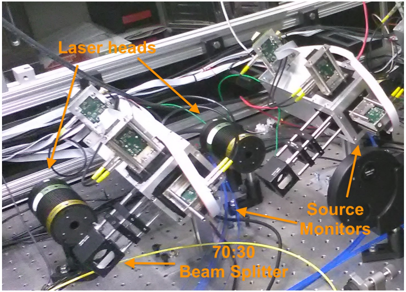
What worked and what didn't work:

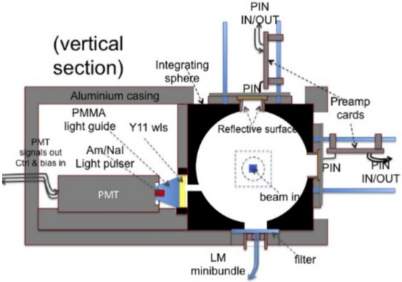
✓ all photo-detectors were observed to function correctly;

✗ asynchronous acquisition from Am/NaI pulses wasn't tested;

Plans:

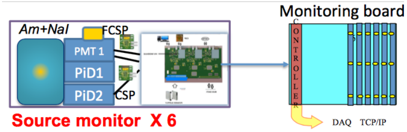
- 4 older PMTs will be replaced with newer versions [july-aug];
- test asynchronous DAQ of absolute calibration events from Am/NaI source [started aug].

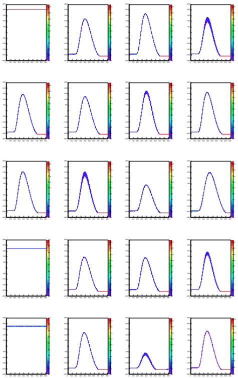




SMs Front End Electronics and Readout

- SMs read out by custom (Naples) front end electronics;
- signals shaped for input to Micro-TCA crate 25 (Laser crate);
- independent digitization of all signals and monitoring of ambient and electronics temperature by custom electronics (Naples DAQ);



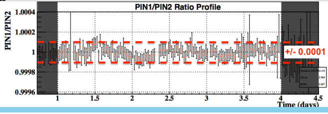


What worked and what didn't work:

- ✓ all signals but one were acquired and digitized by laser crate. Some anomalous (noise?) effects observed.
- ✓ independent digitization by custom Naples DAQ partially tested;
- ✓ temperature dependences at the 0.4%-level observed.

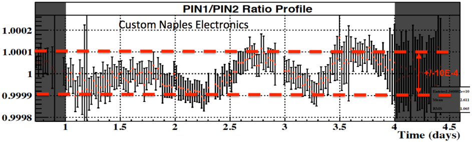
Plans:

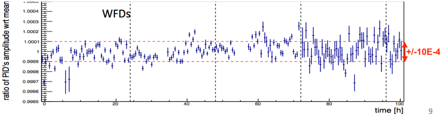
- investigate all observed anomalies and optimize signal amplitudes;
- workout temperature correction procedures;
- incorporate data from Na-DAQ in datastream.



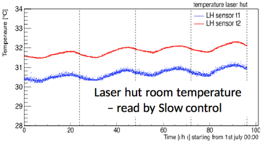
Offline analysis of the SMs signals

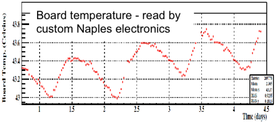
- ✓ the comparison of the SMs' stability (*i.e.*, ratio of the PiN diodes) between data acquired by the WFDs and by the custom electronics showed good agreement.

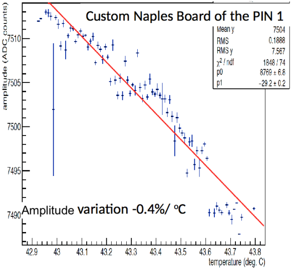




- ✓ temperature dependences studies showed correlation between amplitude and temperature.
- ✓ Monitored both ambient and board temperature. The board temperature is higher ($\overline{T}_{\text{board}} = 43.4°\text{C}$) than the room temperature ($\overline{T}_{\text{room}} = 31°\text{C}$), but the two temperatures have same trend (day/night cycle).

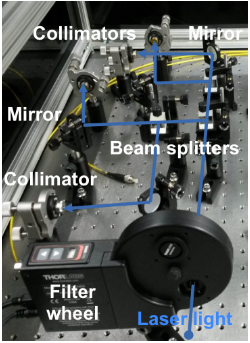






Light Distribution System

- light from each laser is equally distributed between 4 calorimeters by means of optical elements;
- remotely controlled filter wheels varies light intensity during calibration;
- light transported to each calorimeter by single quartz fiber and distributed by diffuser and PMMA fiber bundle to crystals via coupling prisms.



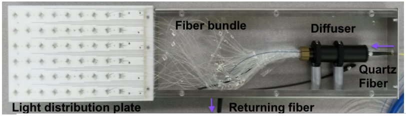
What worked and what didn't work:

✓ alignment of optical elements appears adequate;

✓ light intensity per crystal ~ 1 GeV (max. 4 GeV);

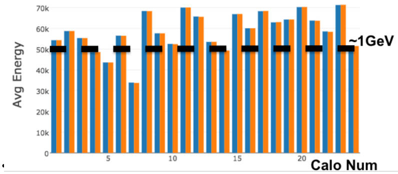
✓ FW calibrations carried out successfully;

✓ one quartz transport fiber needed replacement;



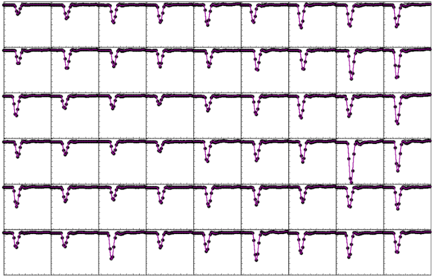
Plans:

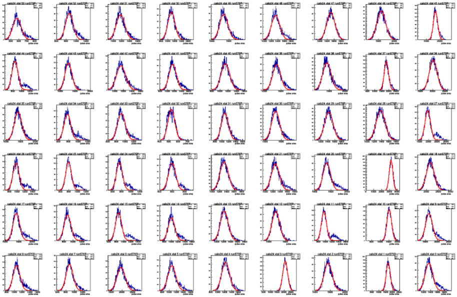
- optimize and equilize light intensity for all crystals (bring the intensity to ~ 2 GeV).

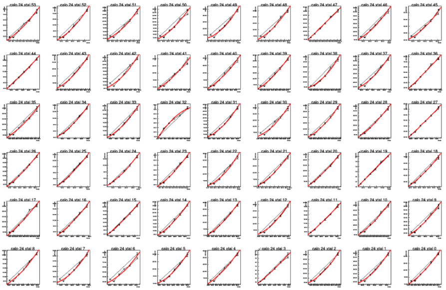


Example of FW calibration

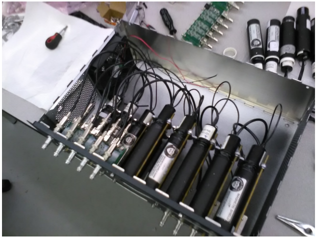
- ✓ Laser pulses seen by the 54 SiPM in a calorimeter are fitted with a template.
- ✓ ~ 5000 pulses collected for each FW setting and charge distribution fitted with a gaussian.
- ✓ Calibration curve for each crystal permits to measure the pulse-to-n.p.e conversion factor.



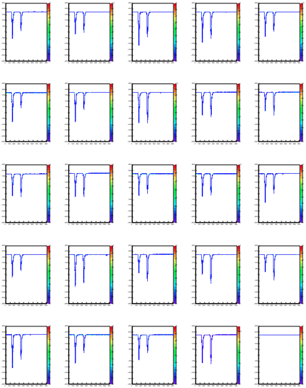




24 Local Monitors (LMs)



- each LM consists of a Photonics XP2982 PMT which views light pulses from the SM (P_1, before distribution) and from the diffuser (P_2, after distribution).
- stability of the light distribution to each calorimeter is monitored by the ratio P_2/P_1.



What worked and what didn't work:

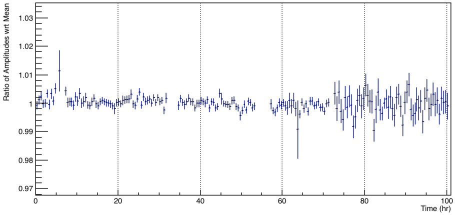
- ✓ all signals were visible;
- ✓ PMT front end electronics appeared to operate adequately;
- ✓ PMT signals spread larger than expected (4% *vs.* 3%).

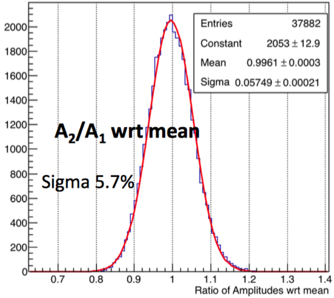
Plans:

- light intensities to be optimized for better statistical accuracy;

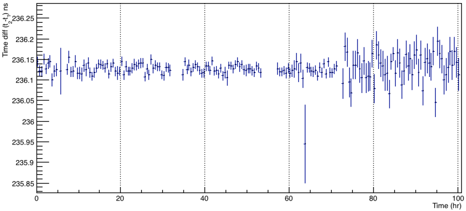
Offline analysis of the LMs signals

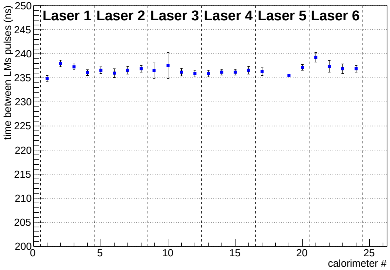
✓ Distribution light stability measured as ratio of the LM's pulse amplitude;





✓ Investigated the time difference $t_2 - t_1$ between the two pulses:

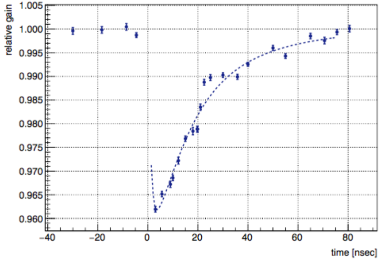


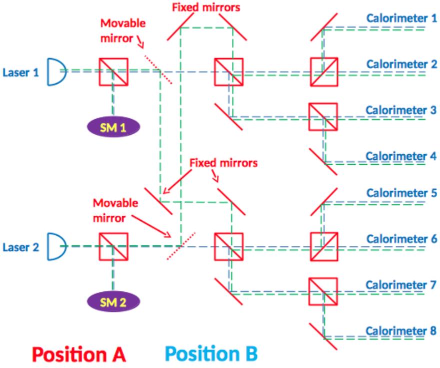


In-fill gain variation measurements

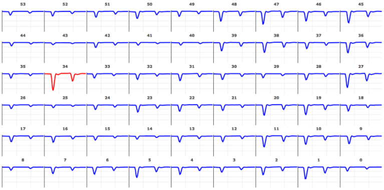
Other Plans:

- schemes for double-pulsing mode are under development for detail study of the in-fill gain variations.
- implemented double pulsing scheme:



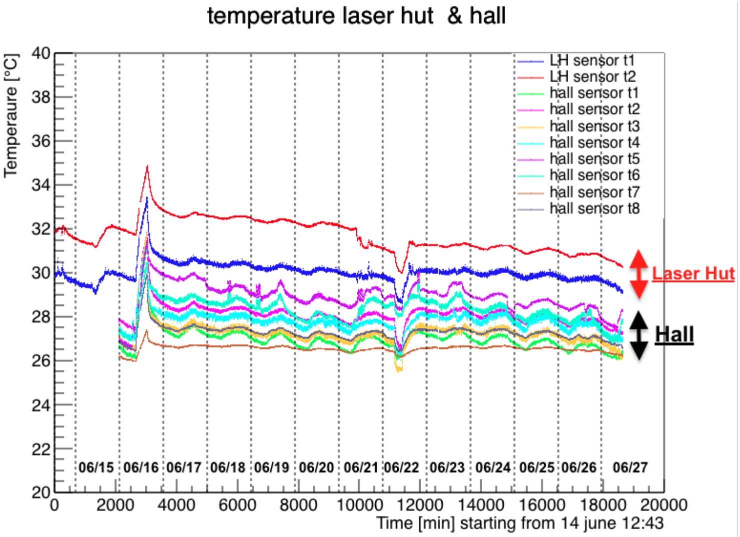


- already started to collect test runs and working on the software.



Temperature in the Laser Hut

- temperatures exceeding (30°C) were recorded in the laser hut (systematically higher by $\sim$ 2°C than those in the hall);



Summary and Conclusions

- The laser calibration system operated adequately in its first implementation;
- temperature dependences (at the 0.1%-level) were revealed and few anomalies (some probably due to noise) were observed;
- temperature in the laser hut was higher than expected (air conditioning?).

Issues already addressed:

- ⇝ Some detectors (*e.g.*, 4 SM photomultipliers) changed.
- ⇝ pulse generator and optics for the double pulsing study in place.

Plans for next few months:

- ⇝ Optimization of the light intensities.
- ⇝ Noise needs to be investigated and eliminated for crate 25 (improved grounding?).
- ⇝ Add a second PMT to each LM and HV power supply.
- ⇝ The asynchronous mode needs additional tests.
- ⇝ Completion of the software modules for gain correction, asynchronous mode and double pulsing study for in-fill gain variations.
- ⇝ Wiki page of the system under completion.