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WP3: Muon g-2 Calibration System Update

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Outline

- SM
- LM2
- Asynchronous trigger
- Laser hut temperature
- Laser studies: STDP, LTDP
- Gain corrections: OoF, IF
- Paper

SM: gain sag problem

- PINs and PMT signals from SMs show a gain sag for times less than 100 μs
- It is due to proximity of the first In-Fill pulses with the Sync pulse...
- and ensuing overlap of the shaped signals in the SM electronics chain
- This prevents us from correcting the In-Fill gain functions with the SM for the Run1 data
- Using LM first peak, instead

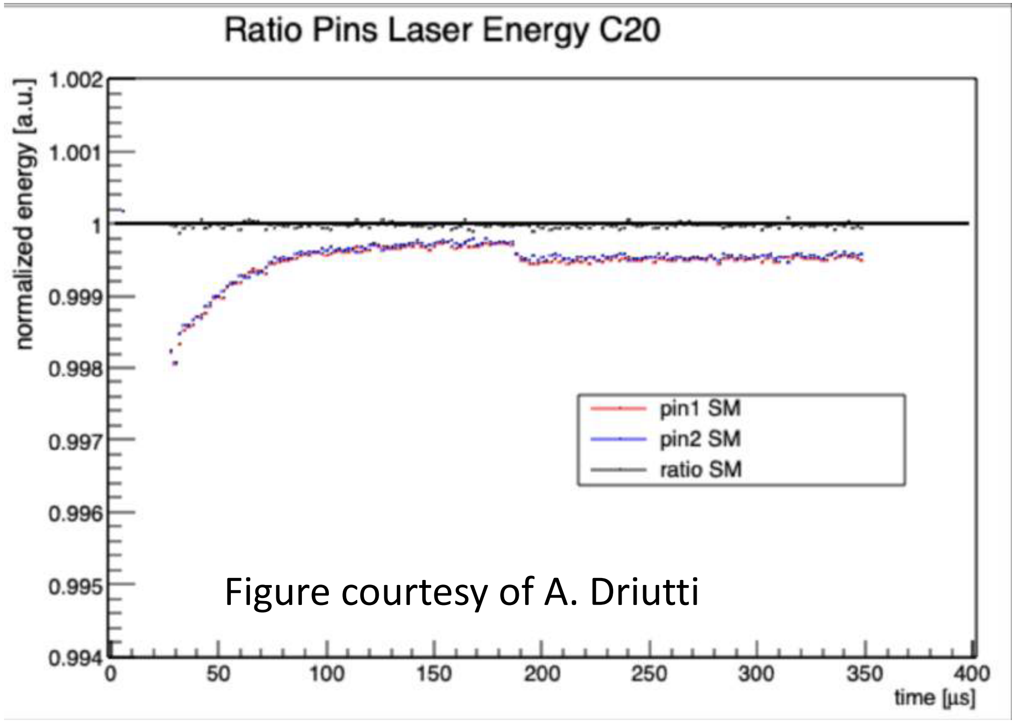
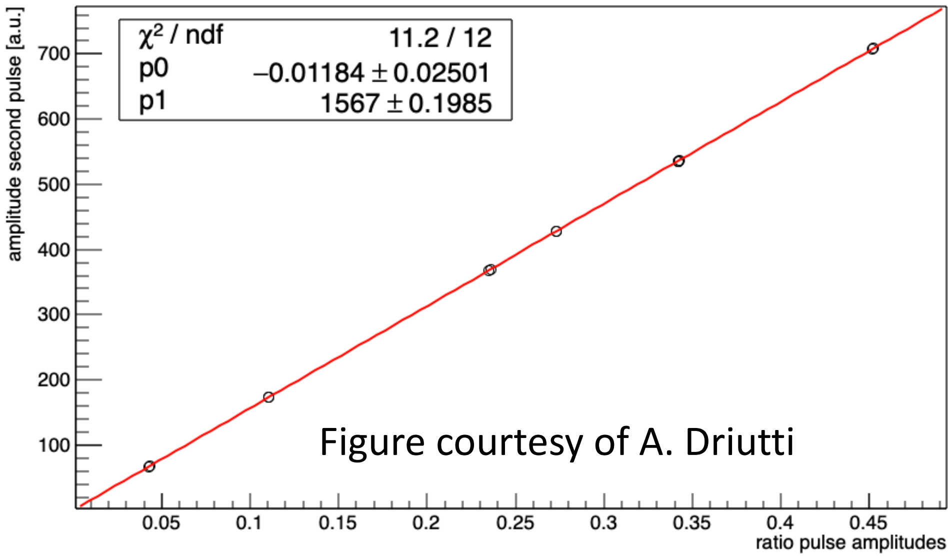


Figure courtesy of A. Driutti

- For Run2 the effect is mitigated by anticipating the Sync pulse by additional 70 μs

LM2: readout electronics fix

- Doubling LM (LM2) installed: 24 new PMTs
- The trailing edge of the signals negatively affects the linearity of the reconstructed energy
- An HV fix to readout electronics has been designed and implemented on one channel...



- tests on the channel have been performed
- Preliminary results indicate that the fix is successful

Asynchronous trigger

- Used to record the signals from the Am/NaI source, needed for the absolute calibration with SM PMTs
- Two raiders (11 and 12) were successfully read out in async mode after MIDAS upgrade
- Integration problem: DAQ running with the async trigger is unstable and acquisition keeps crashing
- The problem is under investigation, action to be taken:
  - In HW: implementation of the trigger logic with VME modules
  - In SW: choice of optimal running parameters

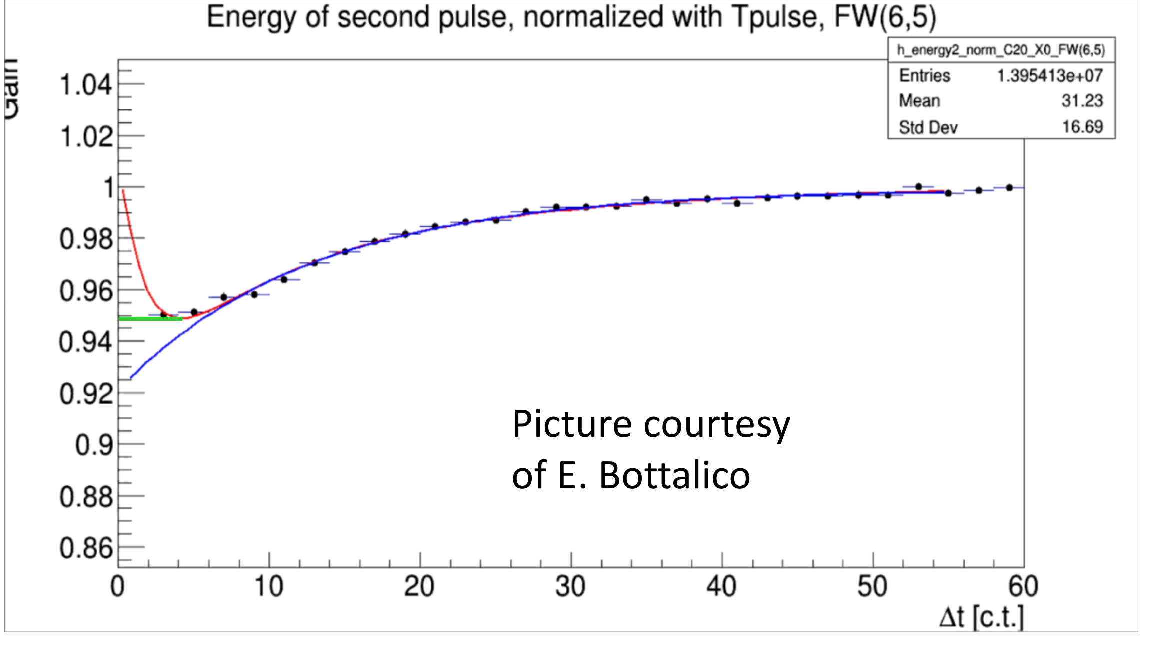
Laser hut temperature

- Due to limited space inside the laser hut and the presence of equipment that produces heat...
- the temperature this summer raised above 35°C (30°C is the rating limit)
- This caused the failure of a laser head
- The head was substituted and the optical alignment restored
- During the summer shutdown a cooling system will be installed
- An interlock to inhibit laser operation if the temperature exceeds 30°C will be implemented

Laser studies: STDP

- Short-term gain sag, due to previous nearest events, is now parametrized with a truncated *logn* function
- *g* meant to be used to correct SiPM signals for the pileup of two nearby positrons

$$g(\Delta t) = \begin{cases} const \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \Delta t < t_M \\ 1 - a \exp\left(\dfrac{1}{2} \dfrac{\log^2(\Delta t/\tau)}{\log^2(t_M/\tau)} \right) \ldots\ldots \Delta t > t_M \end{cases}$$



Laser studies: LTDP

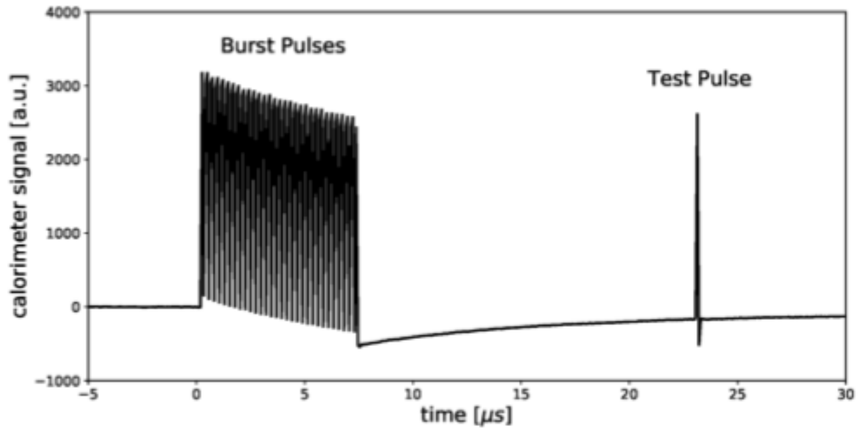
- Studies of the SiPM gain sag over 'long' time intervals (due to muon splash at injection) with a burst of laser flashes

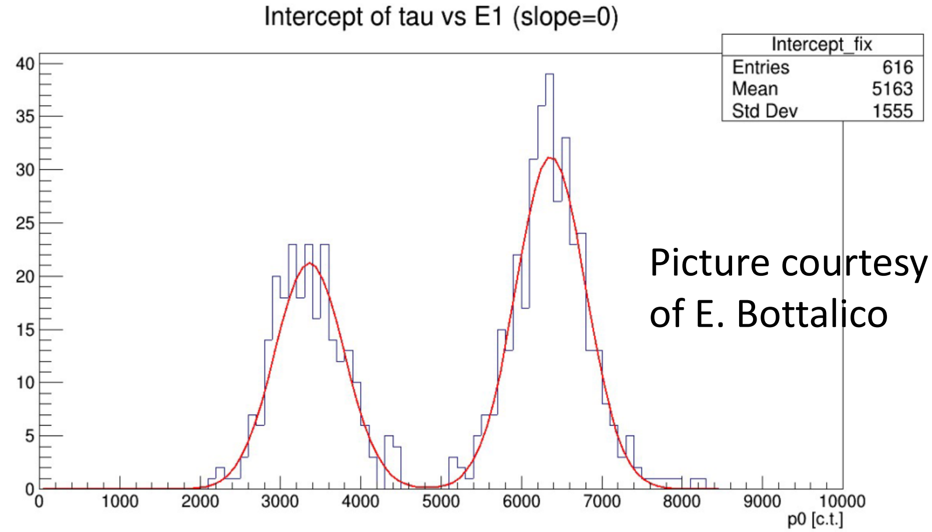
$$g(t) = \frac{G(t)}{G(0)} = 1 - A\exp(-t/\tau)$$

- Fit of *A* (gain drop) and τ (recovery time) for each crystal as a function of the total energy of the burst
- *A* varies linearly: $A = m \cdot E$ with

$$m = (4.9 \pm 0.9) \cdot 10^{-4}\, GeV^{-1}$$

- so for each GeV of deposited energy there is a gain drop of 0.05%
- τ remains constant but has a bimodal distribution over the crystals (due to different wiring to the electronics backplane)





Picture courtesy of E. Bottalico

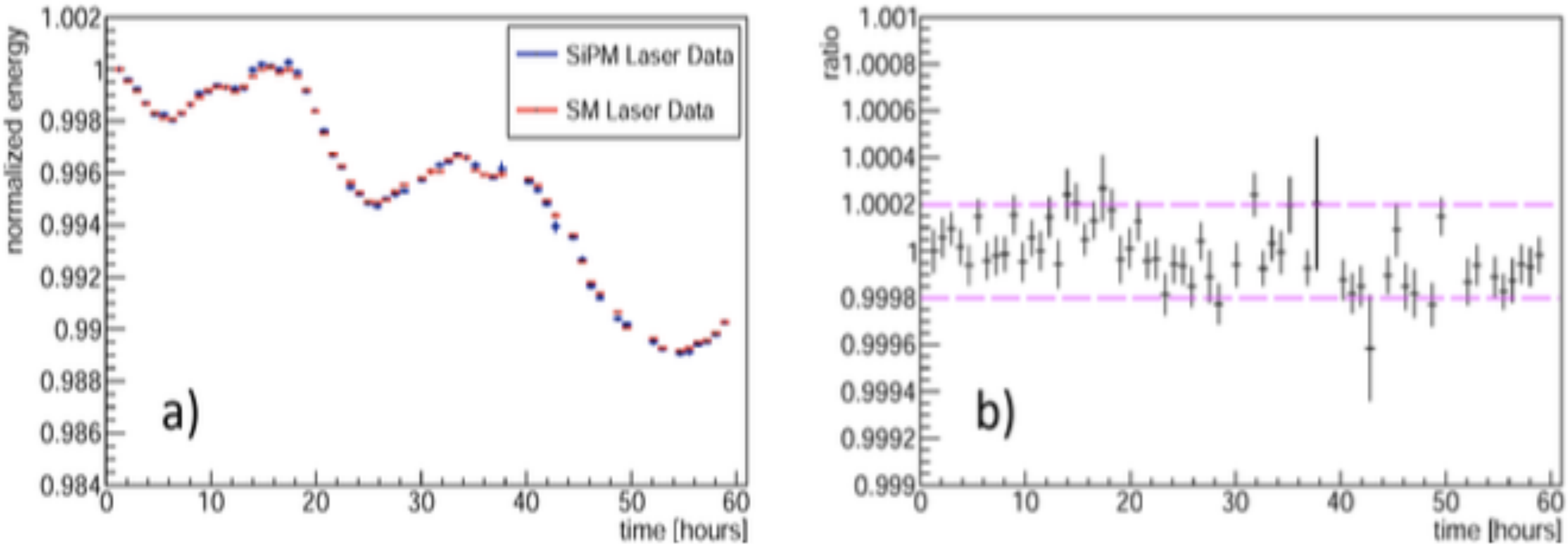
Gain corrections: Out of Fill (OoF)

- First correction applied is OoF, which is relative to the long timescale (seconds) and is not affected by the muons of the fill
- It is due to temperature effects on:
  - Amplification or shaping of the SiPMs, PINs, PMTs
  - Intensity of the laser heads
  - Transmission of the optical fibers
- The global correction is implemented with the equation:

$$G_{SiPM}\left(i\right)=\frac{\left\langle R_{SiPM}\left(i\right)\right\rangle_{subrun}}{R_{SiPM}\left(0\right)}\cdot\frac{R_{SM}\left(0\right)}{\left\langle R_{SM}\left(i\right)\right\rangle_{subrun}}$$

R_{SiPM}(i): amplitude of the *i*-th SiPM response to the laser flash
R_{SM} : amplitude of the corresponding SM signal
The brackets indicate the average of all data in a subrun (about 5 seconds)
The *i*=0 variables are reference amplitudes for normalization

Gain corrections: OoF - cnt'd



a) The raw energy of a SiPM is normalized by the subrun-averaged response to give…
b) the plot of the corrected energy which is flat on the long timescale and exceeds the experimental requirement

Gain corrections: In-Fill (IF)

- After application of the OoF corrections the calibration system becomes sensitive to the IF gain sag effects
- To monitor and model the IF gain function, the laser system interlaces laser pulses on a pre-scaled subset of the muon fills
- The procedure allows to sample the gain in the 0-700 μs duration of the fill
- The following equation yields the gain changes in a SiPM:

$$G_{IFG}(t) = \left\langle \frac{SiPM_{IF}}{SM_{IF}} \right\rangle_t \cdot \left\langle \frac{SM_{OoF}}{SiPM_{OoF}} \right\rangle_{subrun}$$

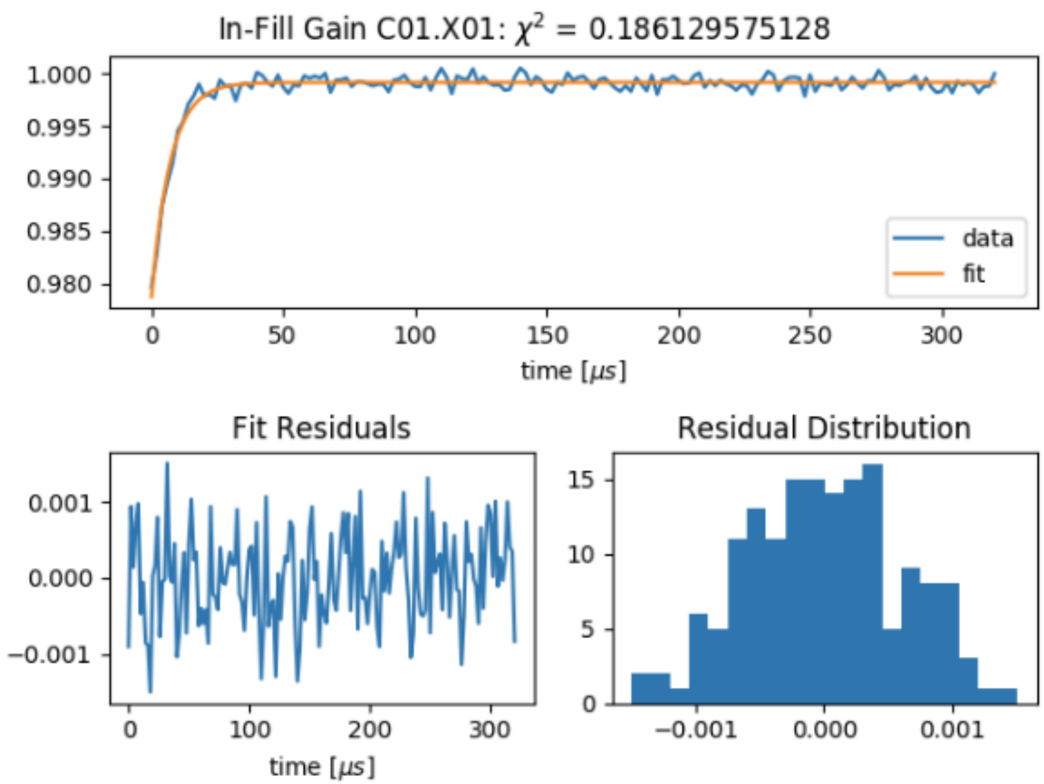
The SiPM IF response is normalized by the OoF laser pulses which are not affected by fluctuations due to beam injection
Fluctuations in the laser amplitude are removed by dividing the SiPM response by the response of the source monitor detectors
The net result is the normalized change in the detector response during muon fills

Gain corrections: IF – cnt'd

- The IFG variation is well modeled with an exponential decay function:

$$f(t) = g_0\left(1 - ae^{-t/\tau}\right)$$

g_0 : asymptotic value of the gain
a : amplitude of the gain drop
τ : recovery time



Example of a measured and modeled IFG function

The function returns to unity at long times (g_0=1)

The residuals show that we can model to a precision of $\pm 4\times10^{-4}$, within the experimental requirements

Gain corrections: IF – cnt'd

- Due to the gain sag problem mentioned in the *Source Monitor* section above, normalization for Run1 data will be done in a different way, by using the first peak of the Local Monitor

Paper

- We submitted a paper to JINST describing the performance of our ”Laser-based gain monitoring system of the calorimeters in the Muon g-2 experiment”
- The referee recommends publication and the editor concurs