The calibration system of the muon *g-2* experiment at Fermilab

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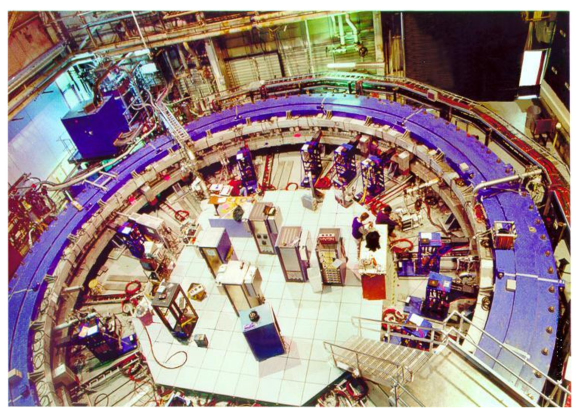
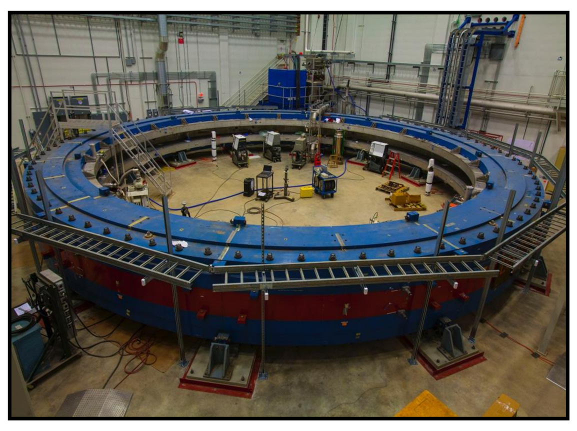
The **muon anomaly, $a_\mu=(g_\mu-2)/2$** , is a low-energy observable, which can be both measured and computed to high precision [1], therefore it provides an important test of the Standard Model (SM) and it is a sensitive probe for new physics [2].
The muon anomaly has been measured to 0.54 parts per million by the E821 experiment at the Brookhaven National Laboratory. This result shows a 3 to 4 standard-deviation difference with respect to the SM prediction [3]. A new muon g-2 experiment, E989, is under construction at Fermilab, aiming to improve the experimental uncertainty by a factor of four to clarify the origin of this difference [4]. A central component to reach this fourfold improvement in accuracy is **the high-precision laser calibration system**, which is designed to monitor the gain fluctuations of the calorimeter photodetectors at 0.04% accuracy during the time muons are kept inside the storage ring (700 μsec). Over longer data collection periods the goal is to keep systematics contributions due to gain fluctuations at the sub-percent level. Another important scope of our system is that the laser calibration pulses will be used, prior to data taking, to simulate physics runs and test all calorimeters.

Introduction

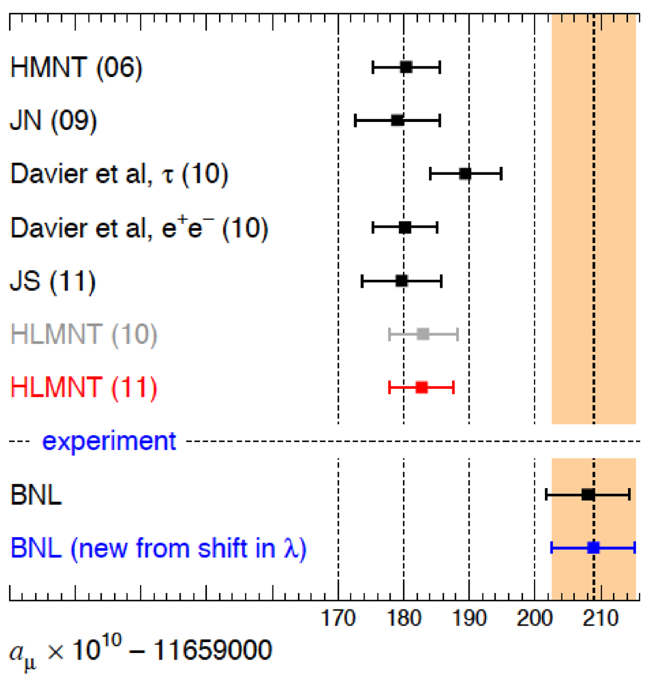


E821 *E989*

from BNL to FNAL



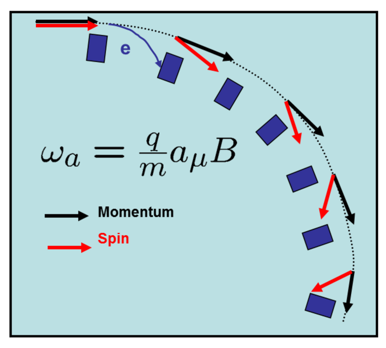
The E821 collaboration al BNL measured a 3.2 σ discrepancy between data and SM theory. $\delta a_\mu^{(Exp)}$ **= 6.3 10^{-10} (0.54 ppm)**

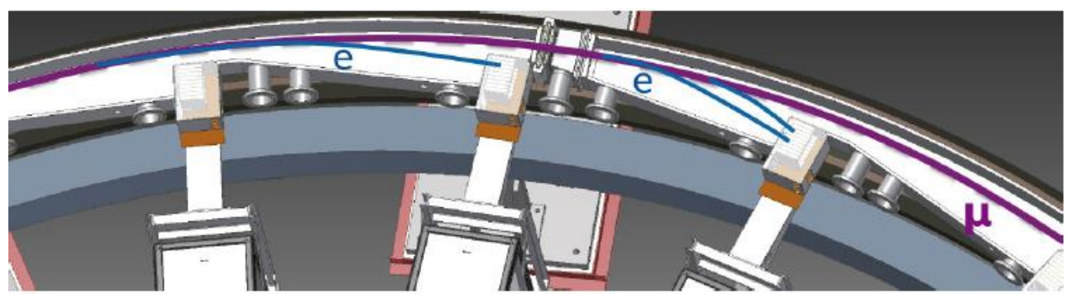


The new experiment E989 under construction at Fermilab is intended to measure the muon anomaly to a precision of **1.6 10^{-10}** (0.14 ppm). The total dataset must contain more than 1.8 10^{11} detected positrons with energy greater than 1.8 GeV

The experiment

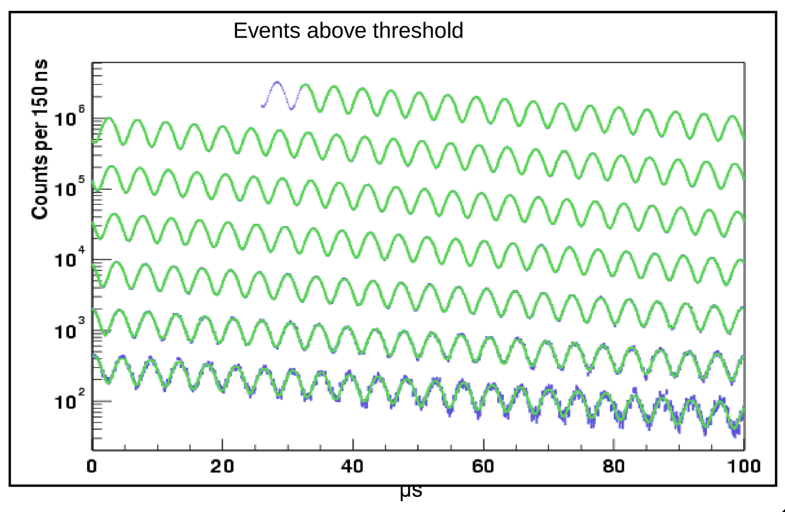
The E989 experiment will measure the difference between the spin precession and cyclotron motion for a muon moving in a magnetic field. The anomalous precision frequency ω_a is measured by detecting positrons, emitted in muon decay, with 24 electromagnetic calorimeters stationed symmetrically around the storage ring.





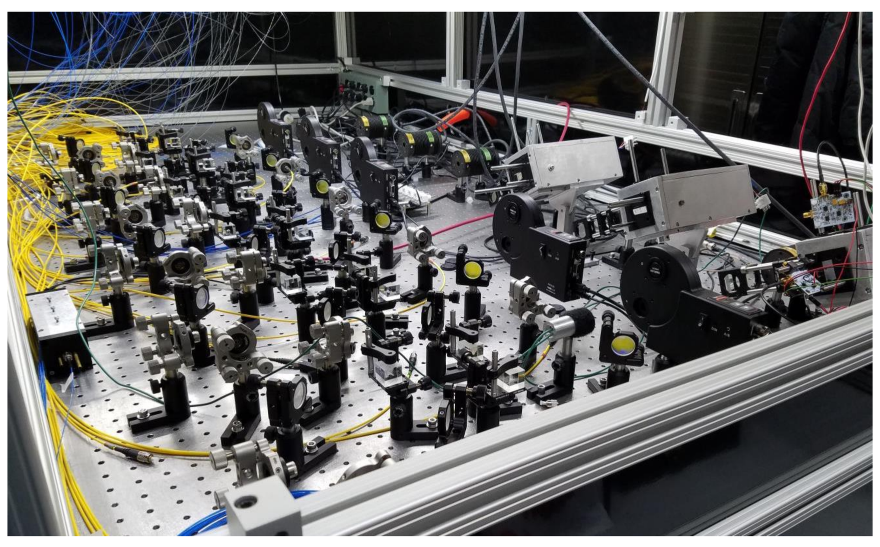
Each of the 24 calorimeters is composed of a 9 x 6 array of PbF_2 crystals with silicon photomultiplier readout, giving 1296 total channels.

The positrons are preferentially emitted in the direction of the muon spin, producing a signal that oscillates at the frequency $\omega_a = \omega_S - \omega_C$ (difference between the Larmor and the Cyclotron frequencies) and steadily decreases over the course of the entire 700 μs.
The number of muons per 700 μs is expected to be 1.0 10^4

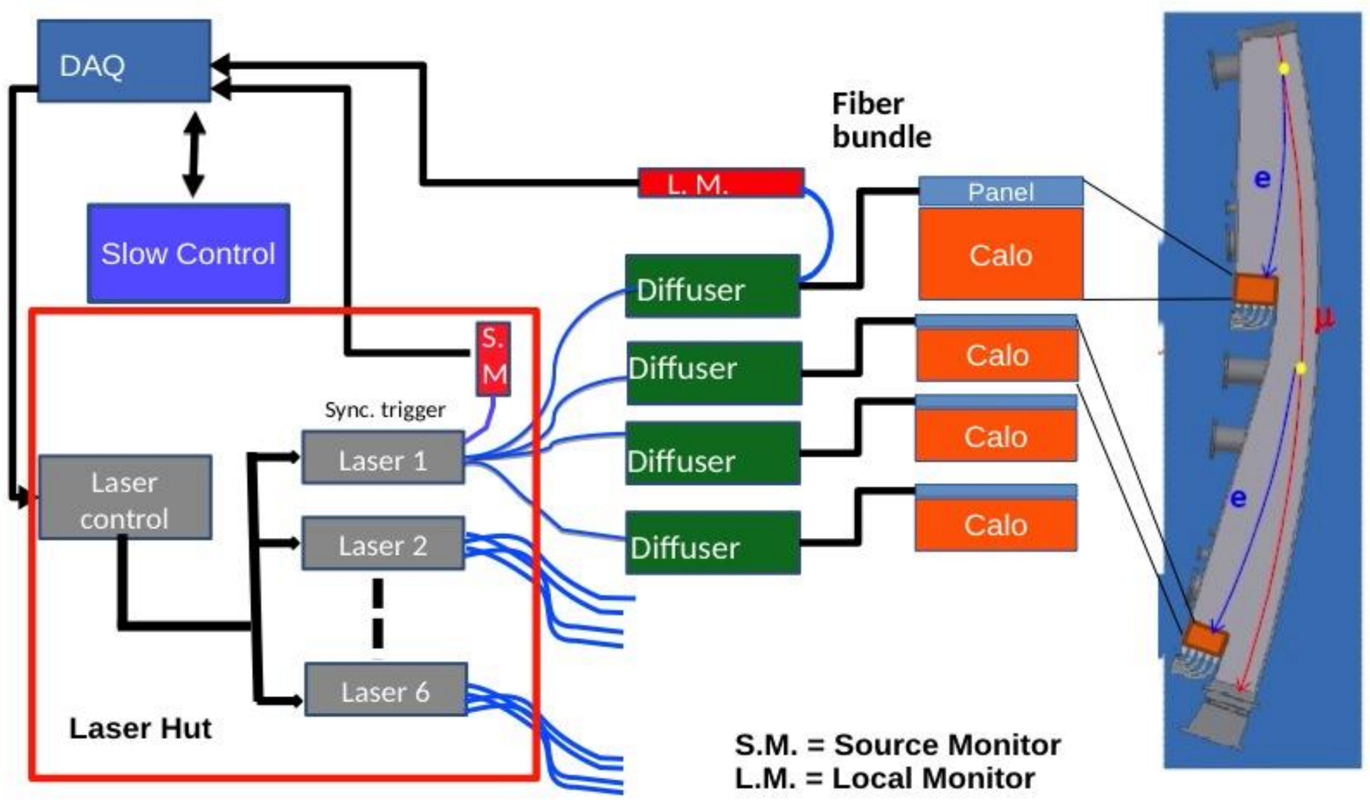


The Calibration system

The optical table in the Laser HUT

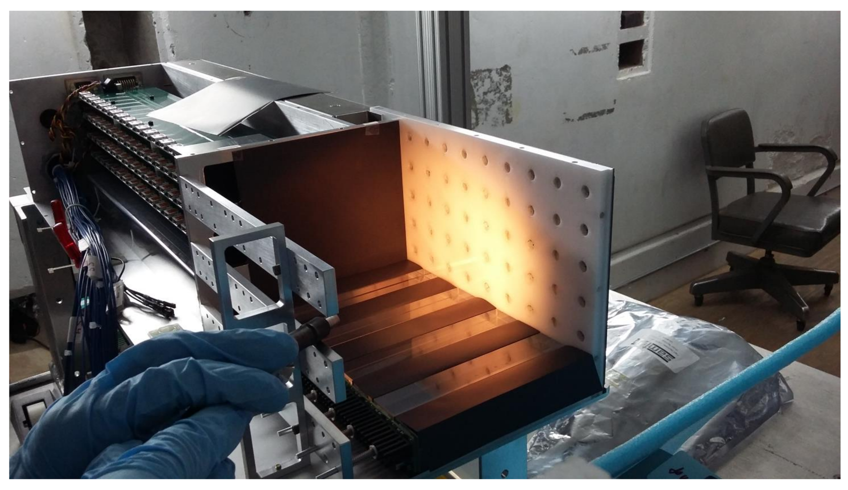


The main aim of the Calibration system is to monitor the gain stability of the silicon photo-multipliers (SiPMs).
The systematic contributions due to gain fluctuations must be contained at sub-per mil level on the beam fill scale (0-700 μs) and at sub-percent level over the longer period. The method is to distribute a series short laser pulses of controlled amplitude directly into each of the 1296 SiPMs via a chain of distribution elements: beam-splitters, optical fibers and other optical elements.

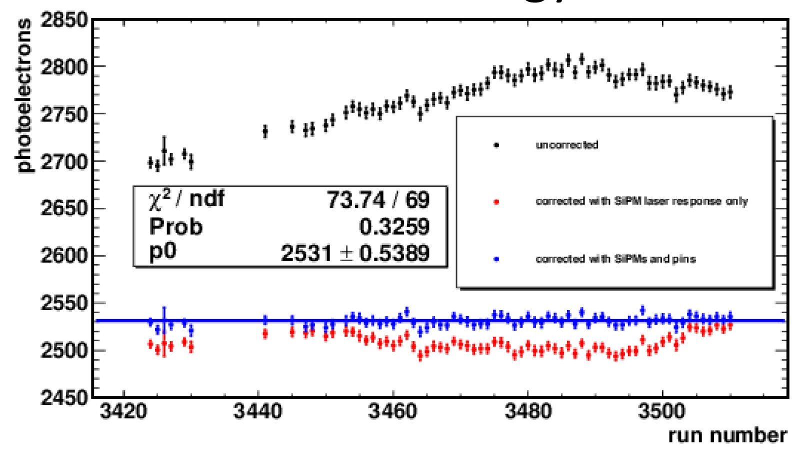


The amplitude of the calibration pulses is continuously monitored by a (redundant) system of **6 "source" and 24 "local" monitors**.
Another important goal of the laser system is to simulate the arrival of the photoelectrons in a so-called "**flight simulator mode**" to test each detector in the calorimeters and the data acquisition system prior to the real experiment.
The laser pulses may also provide a time reference to other detectors in the experiment (tracking chambers and so on).

Calorimeter with the light distribution system



Results of the laser calibration on a test at constant energy at SLAC



Conclusions

The Laser Calibration System of *g-2* experiment has been designed to operate continuously during the data taking of the experiment providing light pulses to measure the stability and the linearity of the SiPMs. It allows the containment of the systematic contributions due to gain fluctuations at sub-per mil level on the beam FILL and at the sub-per cent level on a longer time scale. Moreover, physics simulation can be run to emulate the beam structure by using the "flight simulator" mode. The experimental setup is being completed at Fermilab and the data taking, with muons injected into the ring, is expected by fall 2017. Results of preliminary studies and tests are reported in [5] and in references therein.

References

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