GMINUS2

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1 The $g-2$ experiment at Fermilab

The new $g-2$ experiment at Fermilab (E989) plans to measure the muon anomaly $a_\mu = (g-2)/2$ to an uncertainty of 16×10^{-11} (0.14 ppm), derived from a 0.10 ppm statistical error and roughly equal 0.07 ppm systematic uncertainties on ω_a and ω_p. The proposal efficiently uses the unique properties of the Fermilab beam complex to produce the necessary flux of muons, which will be injected and stored in the (relocated) muon storage ring. To achieve a statistical uncertainty of 0.1 ppm, the total data set must contain more than 1.8×10^{11} detected positrons with energy greater than 1.8 GeV, and arrival time greater than 30 μs after injection into the storage ring.

With a higher expected beam rate, more rapid filling of the ring, and even more demanding goals in systematic uncertainties, the collaboration has had to devise improved instrumentation. The ring kicker-system will be entirely new, optimized to give a precise kick on the first turn only, to increase the storage fraction. The magnetic field will be even more carefully prepared and monitored. The detectors and electronics are entirely new, and a state-of-the-art calibration system will ensure critical performance stability throughout the long data taking periods. New in situ trackers will provide unprecedented information on the stored beam. The first physics data-taking is expected in early 2017.

2 The Laser Calibration system

The $g-2$ experiment will require a continuous monitoring and re-calibration of the detectors, whose response may vary on both a short timescale of a single beam fill, and a long one of accumulated data over a period of more than one year. It is estimated that the detector response must be calibrated with relative accuracy at sub-per mil level to achieve the goal of the E989 experiment to keep systematics contributions due to gain fluctuations at the sub-per mil level on the beam fill scale (0-700s) and at the sub per cent level over the longer data collection period. This is a challenge for the design of the calibration system because the desired accuracy is at least one order of magnitude higher than that of all other existing, or adopted in the past, calibration systems for calorimetry in particle physics.

As almost 1300 channels must be kept calibrated during data taking, the proposed solution is based on the method of sending simultaneous light calibration pulses onto the readout photo-detector through the crystals of the calorimeter. Light pulses should be stable in intensity and timing in order to correct for systematic effects due to drifts in the response of the crystal readout devices. A suitable photo-detector system must be included in the calibration architecture to monitor any fluctuation of the light. The guidelines given by the experiment to define in the correct way the architecture of the entire system could be found in [1]. A sketch of the actual design of the calibration system is shown in Fig. 1. The crucial point for the realization of this system are: the light source, the distribution system that shares the light to the calorimeters with

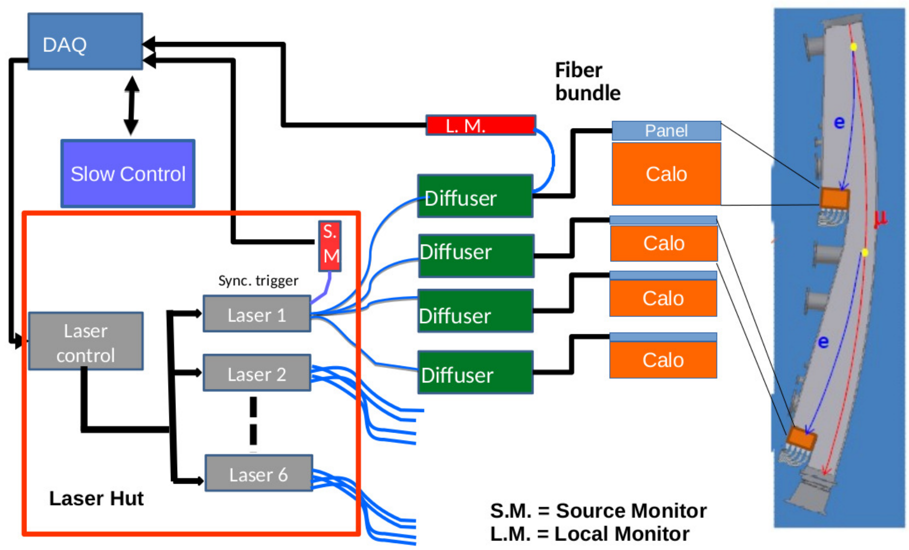

Figure 1: Schematic view of the Laser Calibration System design.

sufficient intensity and sufficient homogeneity among them. The light source should be in the same spectral range accepted by the photodetectors and has to be powerful enough to ensure a sufficient amount of light for each calorimeter station considering losses due to the distribution chain.

3 GMINUS2 Activity in 2015

The LNF activity in 2015 has been focused on:

- Choice of the number of the laser heads. In the final configuration the laser source is composed by 6 lasers LDH-P-C-405M from PicoQuant driven by a single PDL 828 Sepia II 8 channel multi-laser driver, with a measured light output: 1000 pJ/pulse @ 10 kHz (Fig. 2).

  Each laser gives light to four calorimeter stations and it is very important to share its light between the calorimeters in a uniform way.

- Measurement of the light transmission efficiency of the distribution chain. The task of the distribution chain is to divide and carry the light from the laser source to the different calorimeter stations placed around the ring. The first step consists in collecting the light of the laser using optical fibers. The attenuation loss of the fibers should be minimized because the distance from the laser to a single calorimeter station could be $\sim$25 m. For this reason the fibers used are quartz fibers with an attenuation of 20 dB/km @ 400 nm. Each laser is splitted in four and coupled to quartz fibers; each output is coupled with an engineered diffuser ED1-S20 by RPC Photonics. The diffuser is needed to to make a uniform light pattern for a fiber bundle that distributes light to each crystal of the calorimeter. The efficiency of each step of the distribution system has been measured in laboratory.

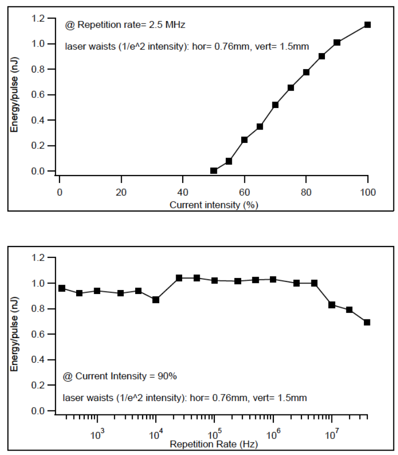

Figure 2: Laser energy/pulse with respect to the current (upper figure) and with respect to the repetition rate (lower figure).

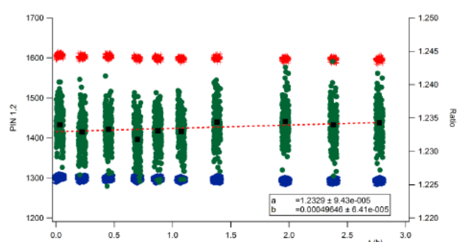

Figure 3: Stability measurement of the calibration system vs time. The red and the blue points are the signals read by Pin2 and Pin1 respectively and must be red on the left axis. The green points represent the ratio between the two signals and refers to the right axis.

- Design of the front panel. Each fiber will be routed to each crystal through a front panel done in Delrin, which contains 54 optical prisms in N-BK7. Various prototypes have been made at the LNF Mechanical Workshop ("Officina Meccanica").

- Measurement of the time stability. The most important feature of this calibration system is the time stability. In fact is requested a stability of the order of 10^{-4} over 2 hours.

  In Fig. 3 are shown the results obtained. To ensure that this level of stability is maintained during data taking a monitoring procedure has to be included in this calibration system. The monitoring system is composed by two parts. The source monitor (made of two pin diodes, a PMT, and an ^{241}Am pulser for absolute calibration), checks all the possible fluctuations of the laser sources. The number of source monitors is the same number of the laser sources. The local monitor (which has to be different from the source monitor because of different position and light characteristics) checks the stability just before the light injection to the calorimeters.

4 List of Conference Talks, Posters by LNF Authors in Year 2015

1. G. Venanzoni "The New Muon g-2 experiment at Fermilab (E989)", European Physical Society Conference on High Energy Physics (HEP-EPS 2015), Vienna, Austria, 24 July 2015.
2. G. Venanzoni "The calibration system of the new g-2 experiment at Fermilab", Poster at the 13th Pisa meeting on Advanced Detectors, 24-30 May 2015, La Biodola, Isola d'Elba (Italy).
3. G. Venanzoni "The calorimeter system of the new g-2 experiment at Fermilab", Poster at the 13th Pisa meeting on Advanced Detectors, 24-30 May 2015, La Biodola, Isola d'Elba (Italy).
4. A. Anastasi, "Simulation of the PbF2 crystal for the new g-2 experiment at Fermilab", Seminar at MEPhI, Moscow, Russia, 14 December 2015.
5. G. Venanzoni "The Muon g-2 Laser Calibration system", Seminar at MEPhI, Moscow, Russia, 14 December 2015.

5 List of Papers/Proceeding

1. G. Venanzoni, "The Fermilab Muon g-2 Experiment," PoS EPS **-HEP2015** (2015) 568.
2. A. Anastasi *et al.*, "Test of candidate light distributors for the muon (g-2) laser calibration system," Nucl. Instrum. Meth. A **788** (2015) 43.
3. I. Logashenko *et al.*, "The Measurement of the Anomalous Magnetic Moment of the Muon at Fermilab," J. Phys. Chem. Ref. Data **44** (2015) no.3, 031211.
4. A. T. Fienberg *et al.*, "Studies of an array of PbF_2 Cherenkov crystals with large-area SiPM readout," Nucl. Instrum. Meth. A **783** (2015) 12.
5. A. Anastasi, "The Muon g-2 experiment at Fermilab," EPJ Web Conf. **96** (2015) 01002.

References

1. A. Anastasi *et al.*, "Test of candidate light distributors for the muon (g-2) laser calibration system", Nucl. Instum. Meth. A**788** (2015) 43-48.