H2020-MSCA-RISE-2015 — Grant Agreement N° 690835

Highlights of the g-2 Laser Calibration System

G. Venanzoni (INFN) Pisa

MUSE Mid Term Meeting

Frascati - 11-May-2017

Talk Layout

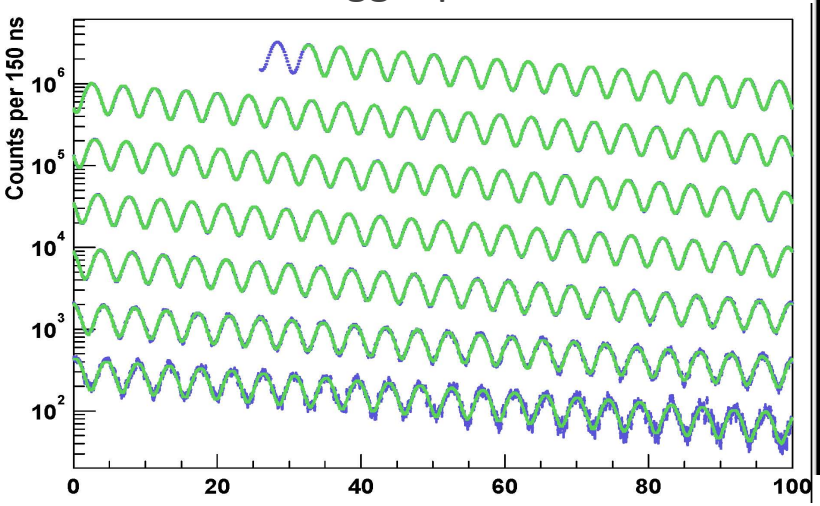
- Overview of the g-2 experiment
- Overview of the g-2 laser calibration system
- g-2 laser calibration system inside MUSE project
- Status of the installation

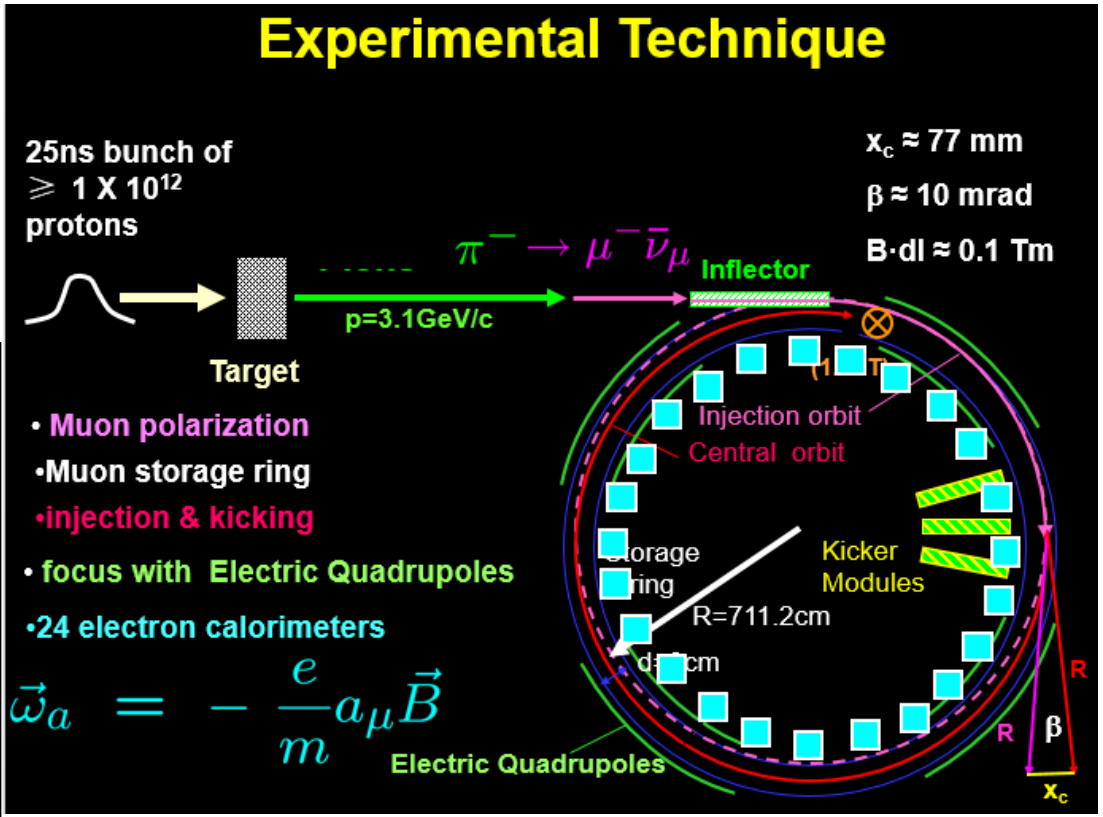
The New Muon g-2 experiment at Fermilab (E989)

The $(g-2)_\mu$ as Standard Model precision test

- Systematic uncertainty expected to be reduced by a factor 3 (compared to E821) thanks to reduced pion contamination, the segmented detectors, an improved storage ring kick of the muons onto orbit, better shimming (uniformity of B), and relocations of critical NMR probes
- Statistical accuracy reduced by a factor 4 (x20 muons)
- Error goal: 0.14 ppm (0.54ppm at E821)

Wiggle plot





Second challenge – ω_a systematics

Category	E821 [ppb]	E989 Improvement Plans	Goal [ppb]
Gain changes	120	Better laser calibration	
		low-energy threshold	20
Pileup	80	Low-energy samples recorded	
		calorimeter segmentation	40
Lost muons	90	Better collimation in ring	20
CBO	70	Higher n value (frequency)	
		Better match of beamline to ring	< 30
E and pitch	50	Improved tracker	
		Precise storage ring simulations	30
Total	180	Quadrature sum	70

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The g-2 experiment: laser system goals

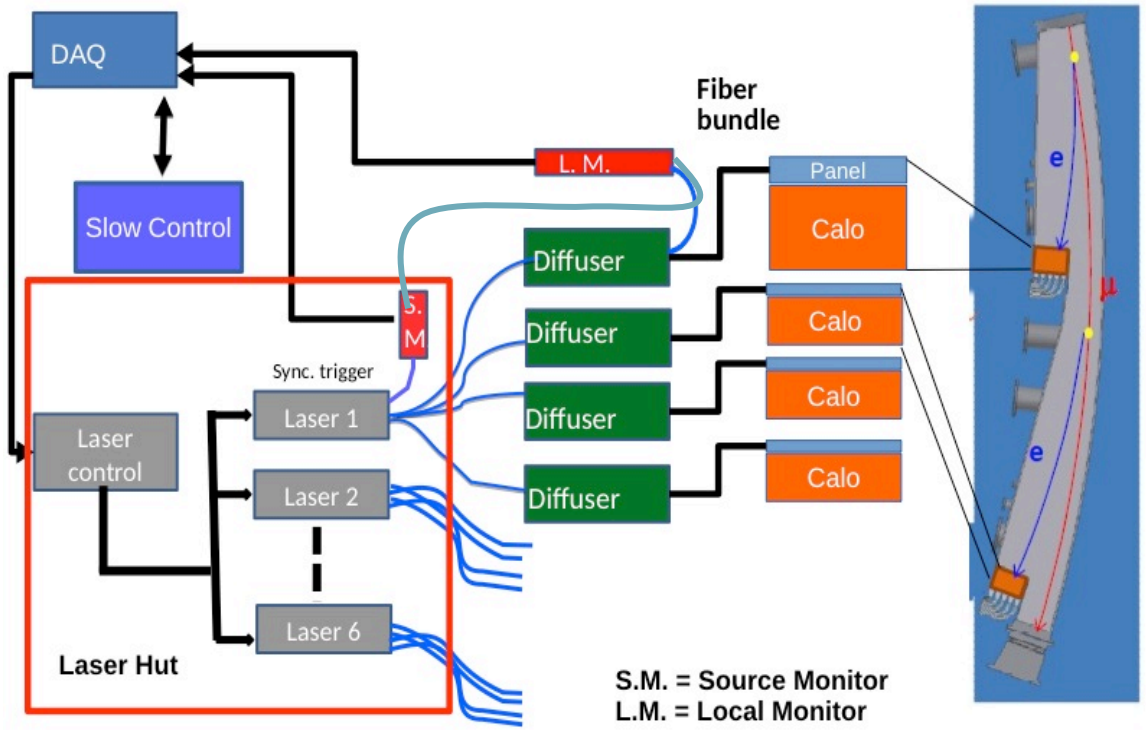
- SiPM Gain calibration
- SiPM Energy calibration
- Time alignment and synchronization
- Gain calibration for T0 detector

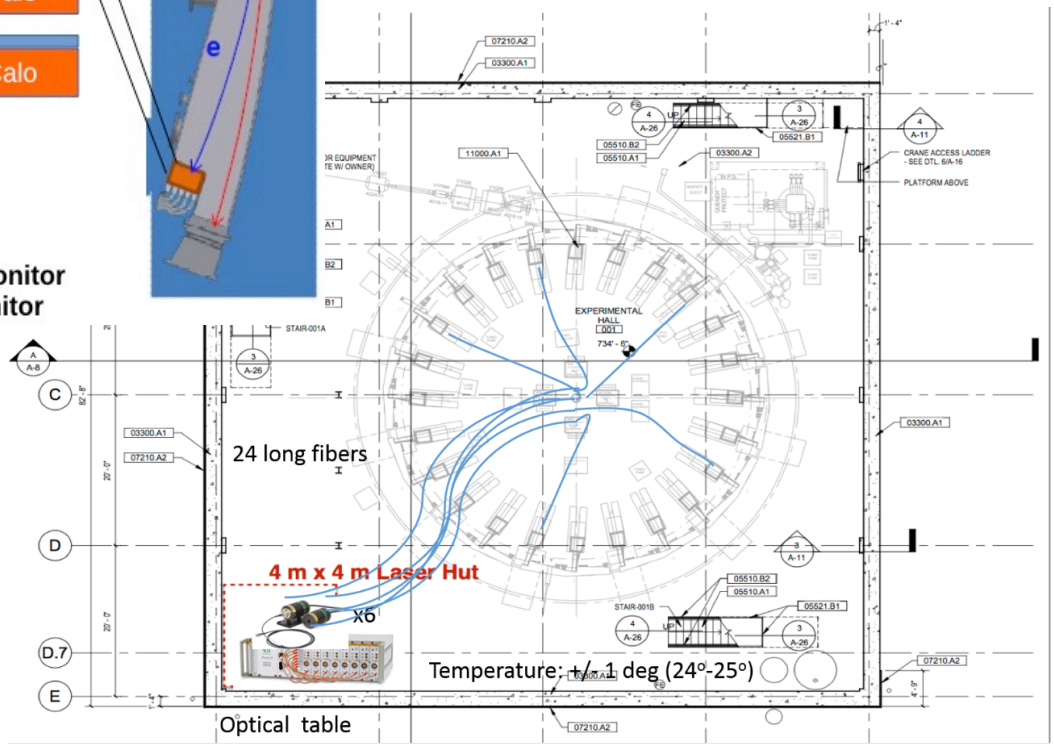
The g-2 laser system requirements

The g-2 laser system should:

- Laser pulse of: λ = 400 nm, short duration (< 1 ns), 3 GeV energy/pulse
- Provide laser synchronization pulses to 1296 SiPMs (24 calorimeters), before and after each muon fill, and to the T0 detector
- Provide laser calibration pulses to 1296 SiPMs, in fill and out of fill
- Monitor the laser calibration pulses amplitude in order to calibrate the SiPMs gain to the 10^{-4} level
- Remote control of the pulses amplitude, for energy calibration purpose
- Allow the study of the SiPMs gain curve (sagging) through a two pulse technique

The g-2 laser system design





Multilaser with 6 heads;
24 launching fibers;
4 diffusers per laser,
6 Source monitors;
24 local monitors.

g-2@INFN

6 INFN Sections:

- LNF (Frascati)
- Napoli
- PISA
- Roma2
- Trieste
- Lecce

6 Universities:

- Udine
- Naples
- Trieste
- Rjeka
- Molise (Campobasso)
- Scuola Normale Superiore (Pisa)

CNR INO:

- Pisa

28 People, 16 FTE

Rijeka

Laser team: 21 staff; 4postdoc; 3PhD students

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First PhD Thesis in g-2!

A. Anastasi,
University of Messina

Università degli Studi di Messina

DIPARTIMENTO DI SCIENZE MATEMATICHE E INFORMATICHE,
SCIENZE FISICHE E SCIENZE DELLA TERRA

DOTTORATO DI RICERCA IN FISICA *XXIX* CICLO

The Calibration System of the E989 Experiment at Fermilab
PhD Thesis
Antonio ANASTASI

SSD:FIS04

PhD Coordinator:
Prof. Lorenzo TORRISI

Tutor:
Dr. Giuseppe MANDAGLIO
Co-Tutor:
Dr. Graziano VENANZONI
Co-Tutor:
Prof. David HERTZOG

Triennio 2014/2016

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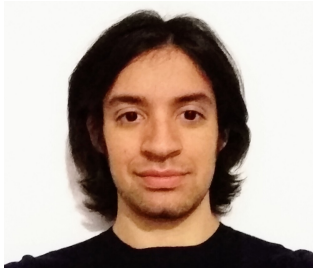
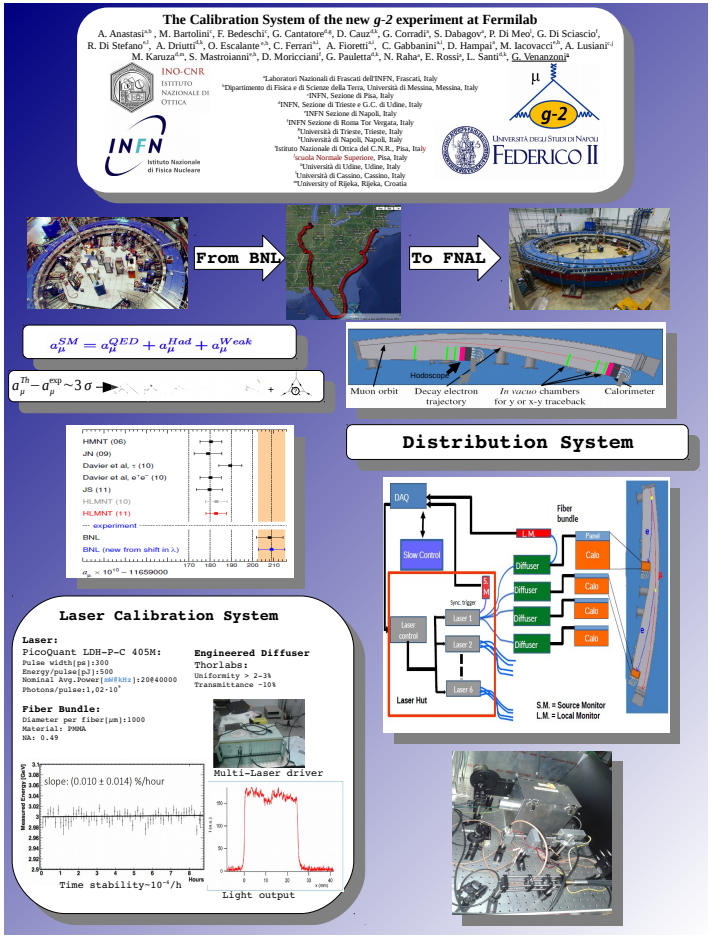
Another highlight



Best poster at the **conference IFAE 2016!**

O. Escalante **(PhD Student at Unviversity of Naples)**



The g-2 laser system in MUSE

The g-2 laser calibration system appear in 2 WPs in MUSE:

→ Task 1.1: Development, construction and commissioning of Laser-DAQ boards

→ Task 3.1: Development and assembly of the g-2 laser system

→ Task 3.3: Commissioning of calibration systems in g-2

Deliverable:

D1.1: Report on assembly and integration of Laser-DAQ boards in DAQ

Due date: Month 24

D3.1: Final design of the g-2 calorimeter Laser calibration system.

Due date: Month 10

Milestone:

MS5: g-2 calibration commissioned

Due date: Month 36

Deliverable 1.1: Report on assembly and integration of Laser-DAQ boards in DAQ

- A laser control board has been constructed:
  - Interface with TRG system
  - Provides the calibration pulses in different modes
  - Interface with the monitor system electronics
  - Time reference signal for reset, synchronization and initialization of DAQ and electronics (BOF/

The Laser Control
in the Laser Calibration System
of the muon g-2 experiment at Fermilab

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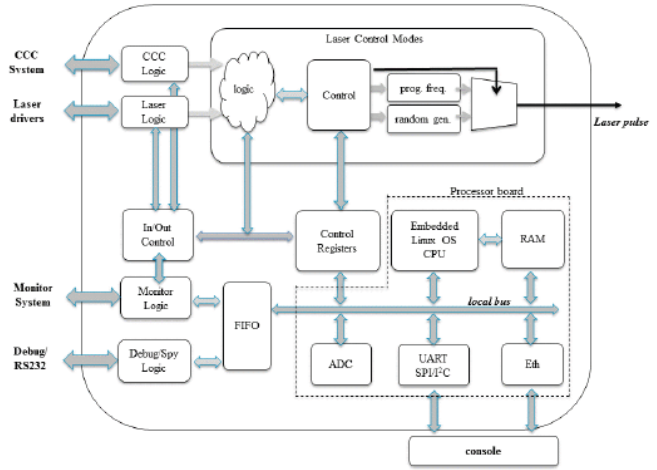
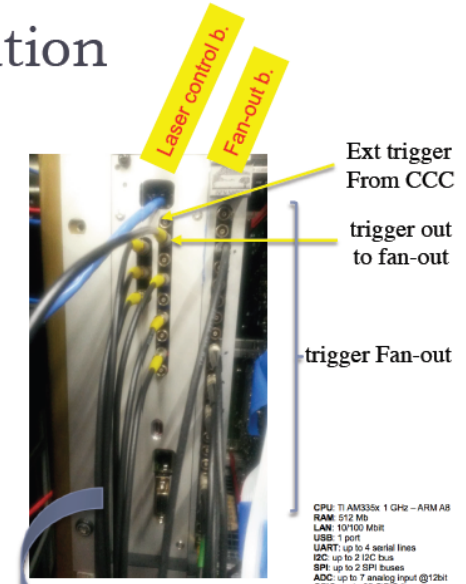
Abstract

The Muon g-2 Experiment at Fermilab is expected to start data taking in 2017. It will measure the muon anomalous magnetic moment, $a_\mu = (g_\mu - 2)/2$ to an unprecedented precision: the goal is 0.14 parts per million (ppm). The new experiment will require upgrades of detectors, electronics and data acquisition equipment to handle the much higher data volumes and slightly higher instantaneous rates. In particular, it will require a continuous monitoring and state-of-art calibration of the detectors, whose response may vary on both the millisecond and hour long timescale.
The calibration system is composed of six laser sources and a light distribution system will provide short light pulses directly into each crystal (54) of the 24 calorimeters which measure energy and arrival time of the decay positrons.
A Laser Control board will manage the interface between the experiment and the laser source, allowing the generation of light pulses according to specific needs including detector calibration, study of detector performance in running conditions, evaluation of DAQ performance.
Here we present and discuss the main features of the Laser Control board.

Keywords: Calibration, FPGA

Architecture & implementation

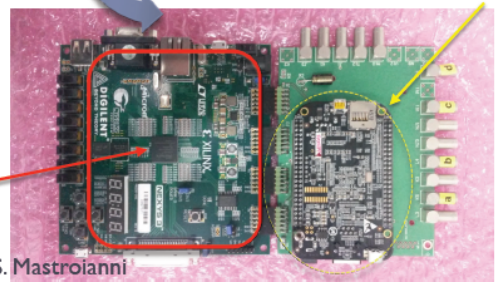




Platform for embedded applications:

- *Complete managing of the laser pulse generations*
- *Fully managed remotely*
- *Based on ARM8 board*
- *Running Linux OS*

Xilinx Spartan-6 XC6LX16-CS324
16Mbyte Micron Cellular RAM
16Mbyte Micron Parallel PCM
16Mbyte Micron Quad-mode SPI PCM
100 MHz fixed-frequency oscillator
10/100 SMSC LAN8710 PHY
USB-UART



g-2it Meeting, April 2017 S. Mastroianni

- The board is currently working at FNAL

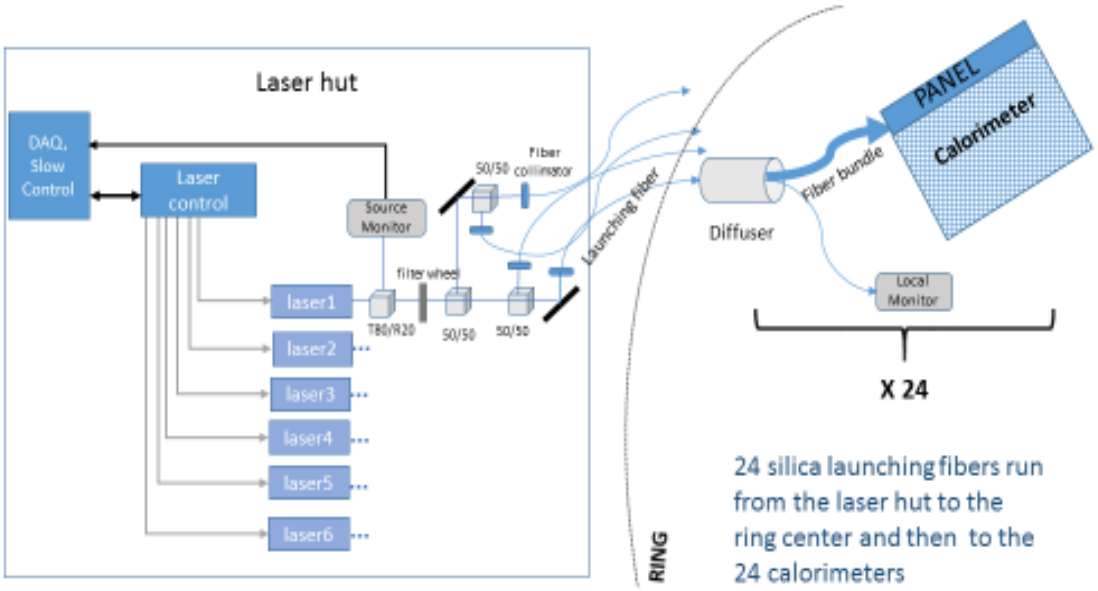
The integration with the DAQ has started. We are on time on the schedule

Deliverable 3.1: Final design

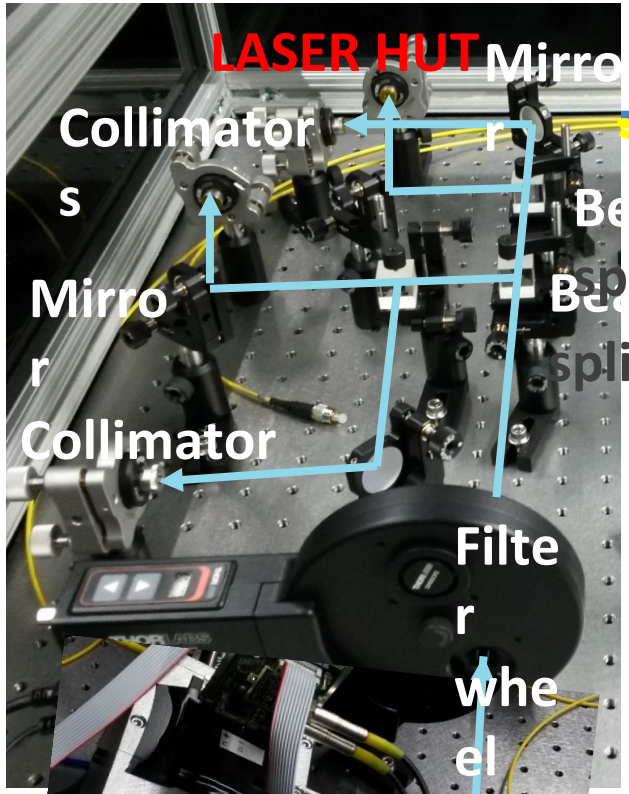
✓ Deliverable of WP-3 done in time at the end of October.

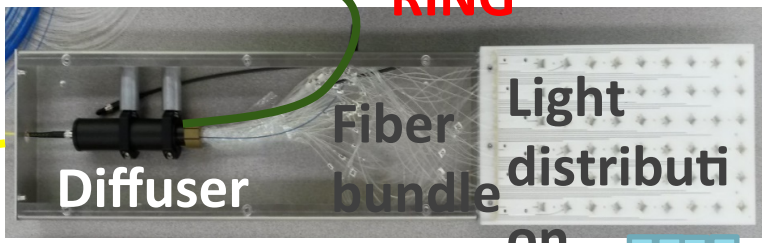
It is a complete Technical Design Report describing all final design features of the laser system.

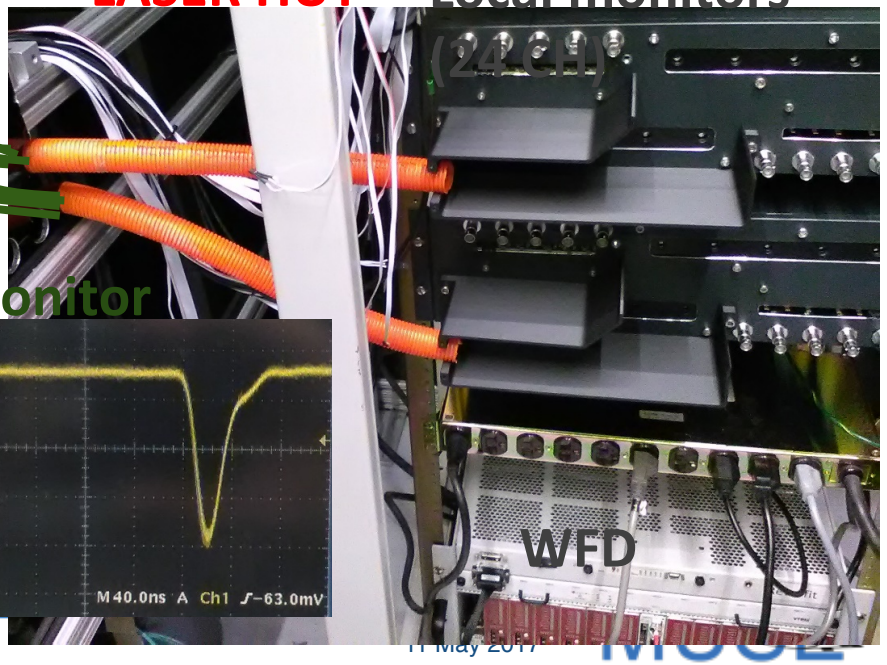
It is both a public g-2 Document (E989 Note 98) and a public MUSE document.

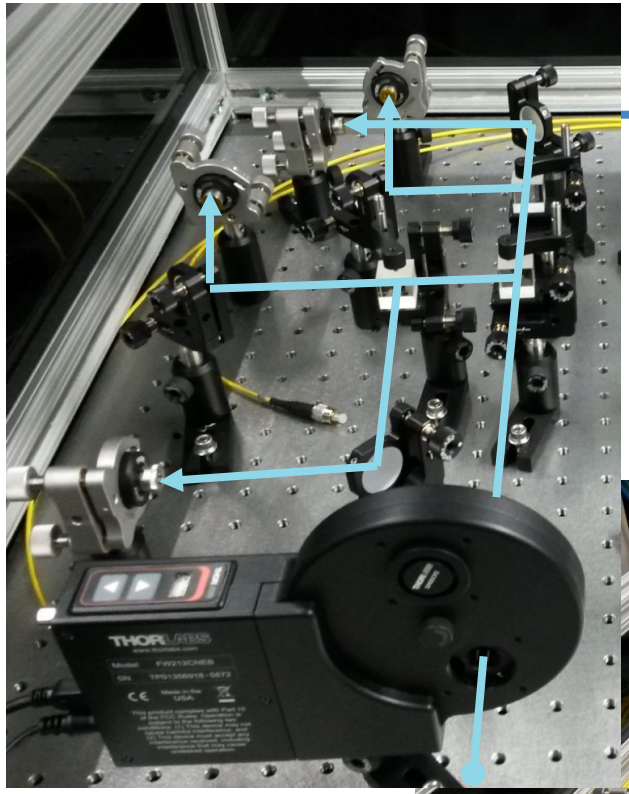


The g-2 laser system installed





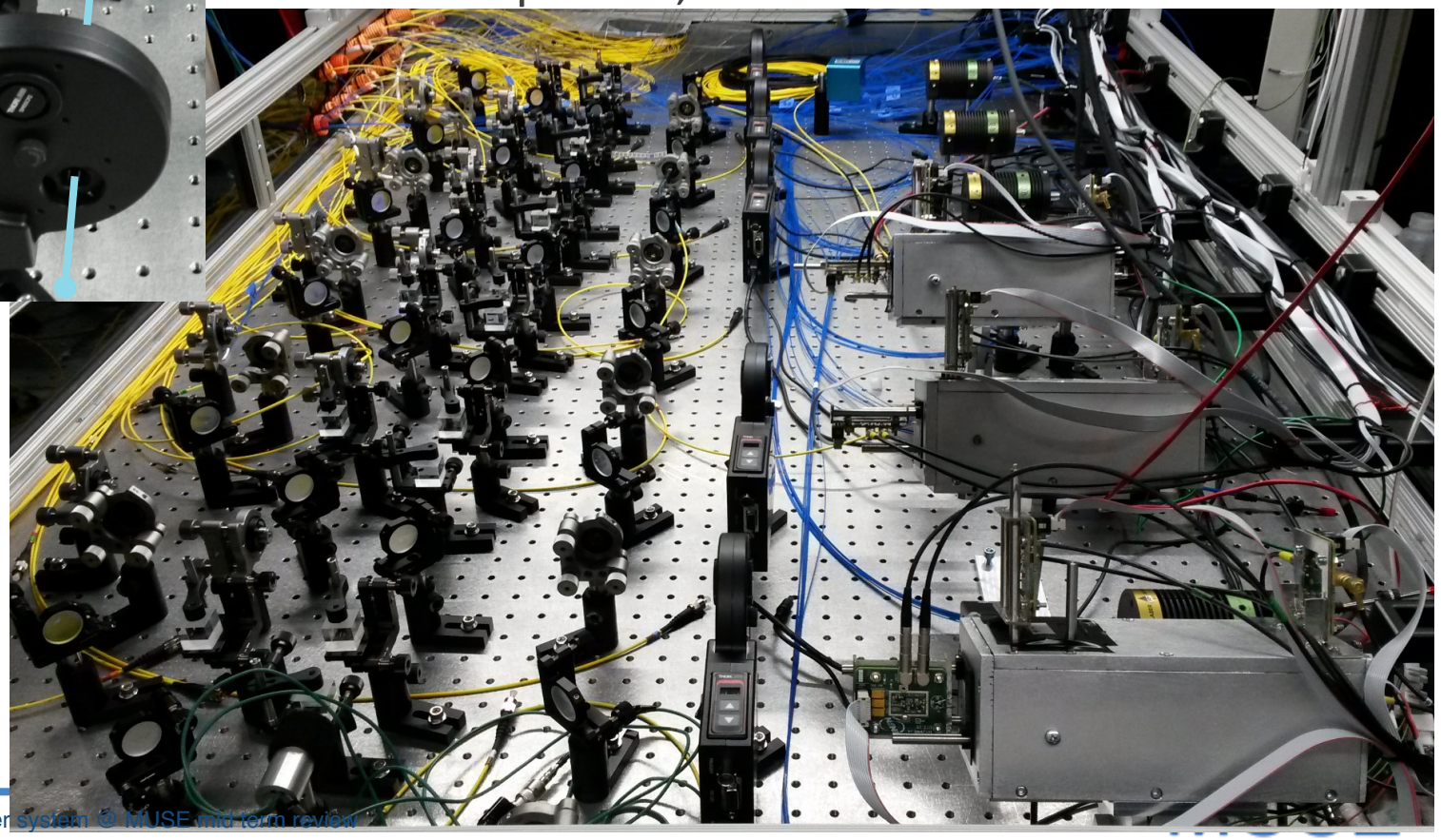




The laser hut

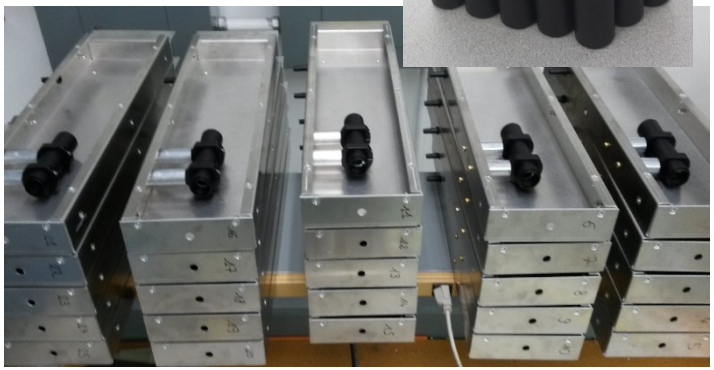
Installation complete:

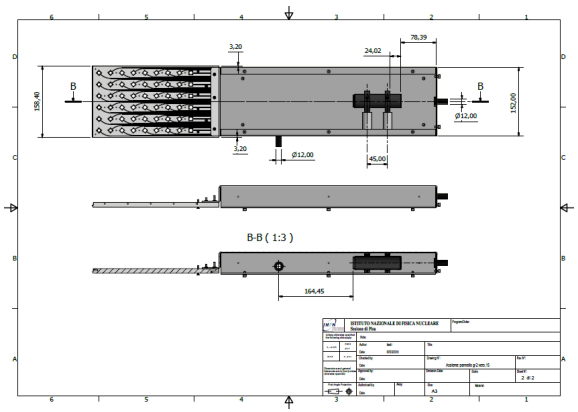
- 6 laser heads
- 6 filter wheels (controlled remotely through beaglebone)
- Beam splitters, mirrors and collimators

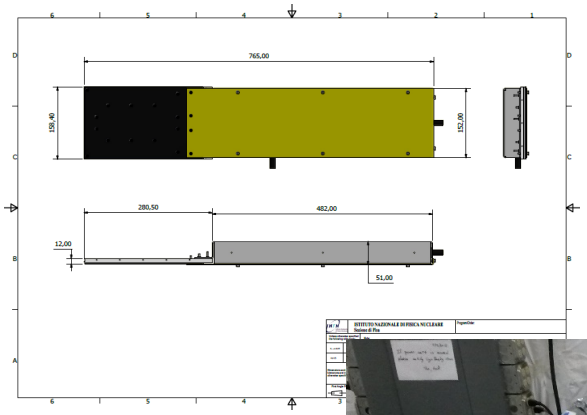


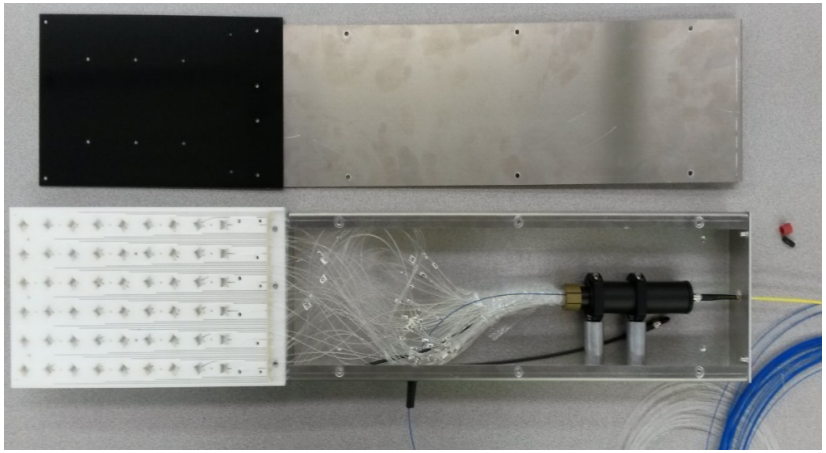
Secondary distribution boxes

The 25 boxes have been completed,
24 already embedded in
calorimeters, 1 spare





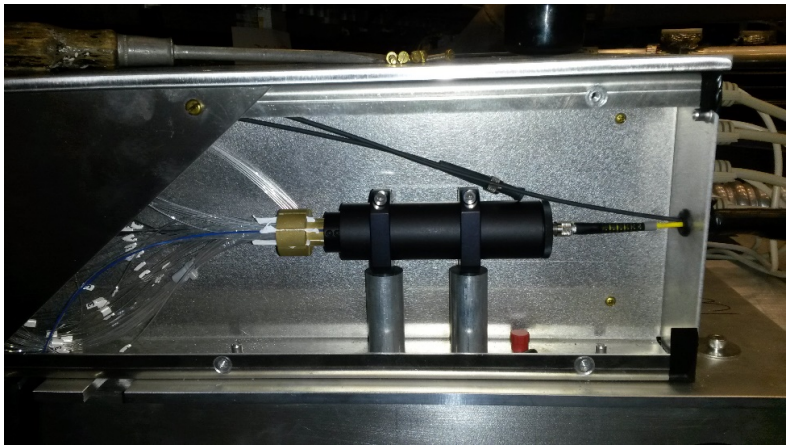


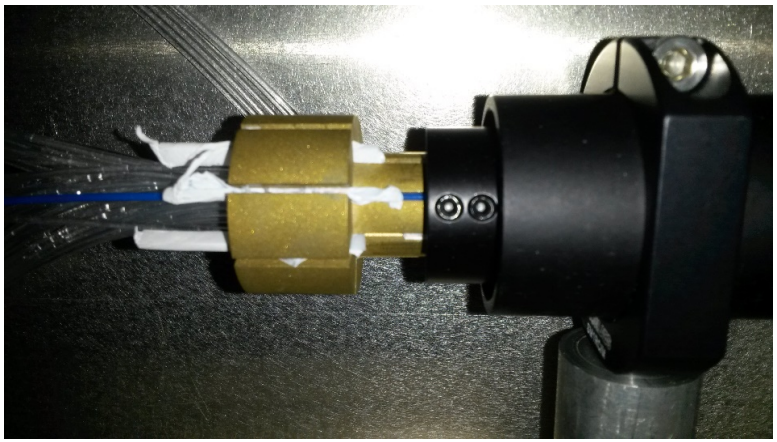


Calorimeters connection

Installed **13** boxes at the bottom of the trolley. Magnetic field test: perturbation within errors

Connected **13** calorimeters. Local monitor fibers held in position





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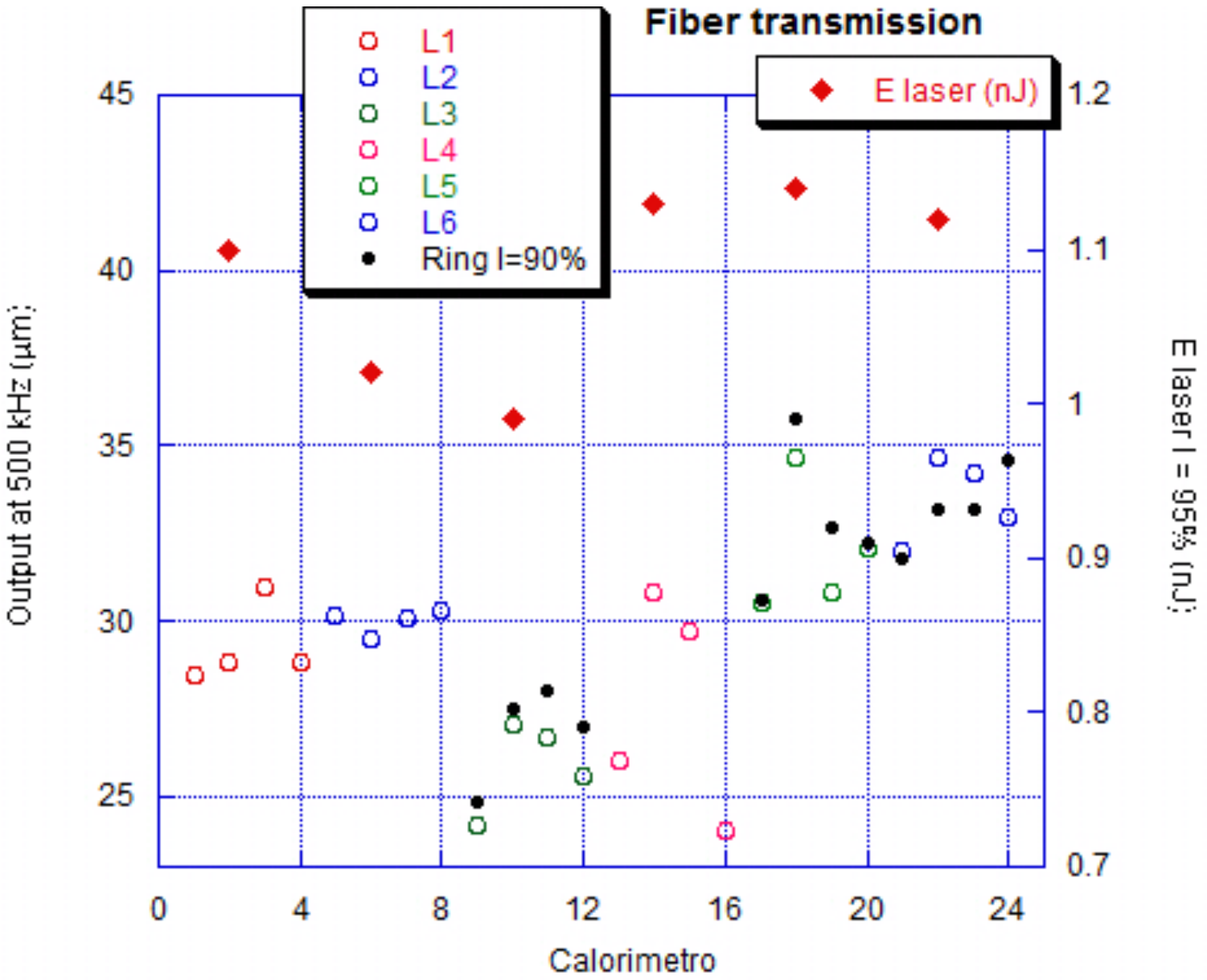
Output test

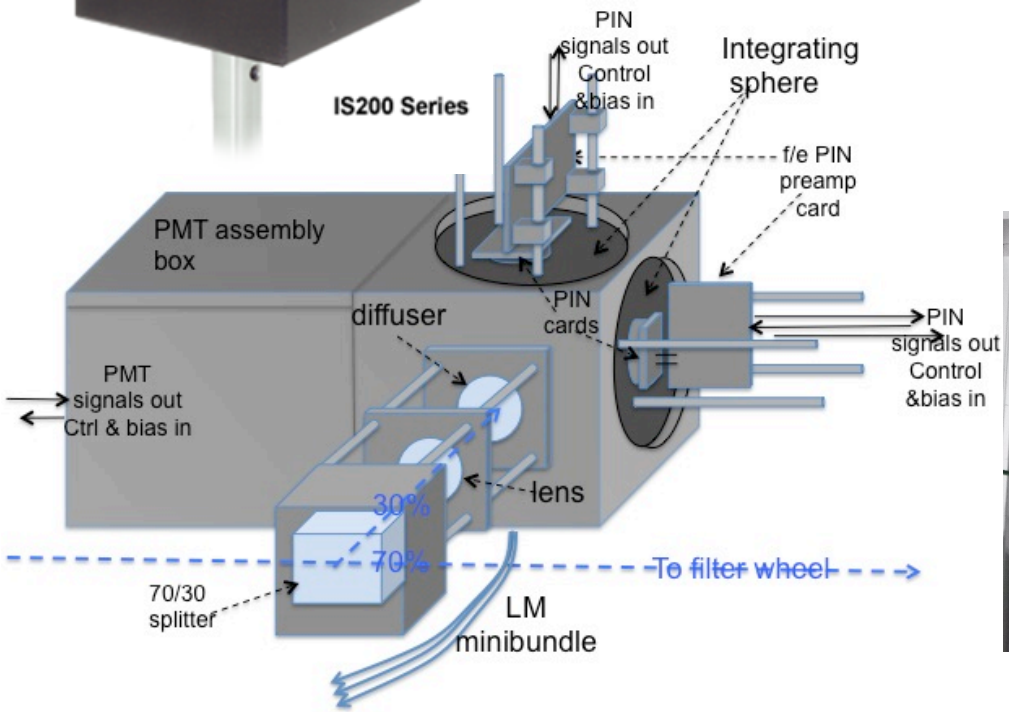
Alignment made with the power meter in the ring.

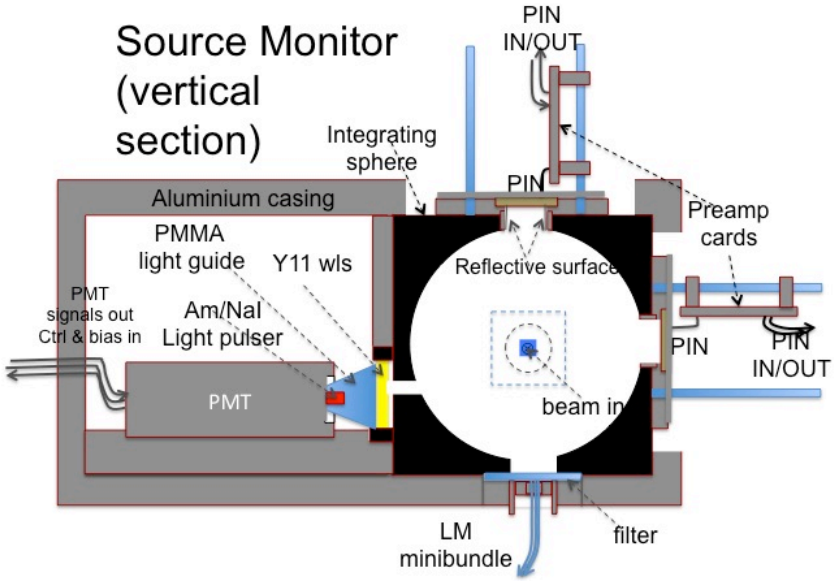
- Laser threshold current always lower than 60%
- Trasmission collimator + fiber about 40%

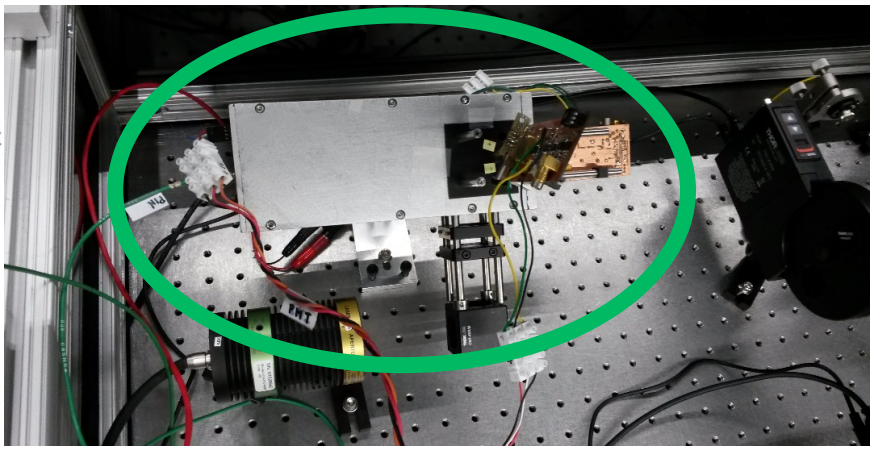


The source monitor

Fully tested in two test beams. **Six installed at FNAL**







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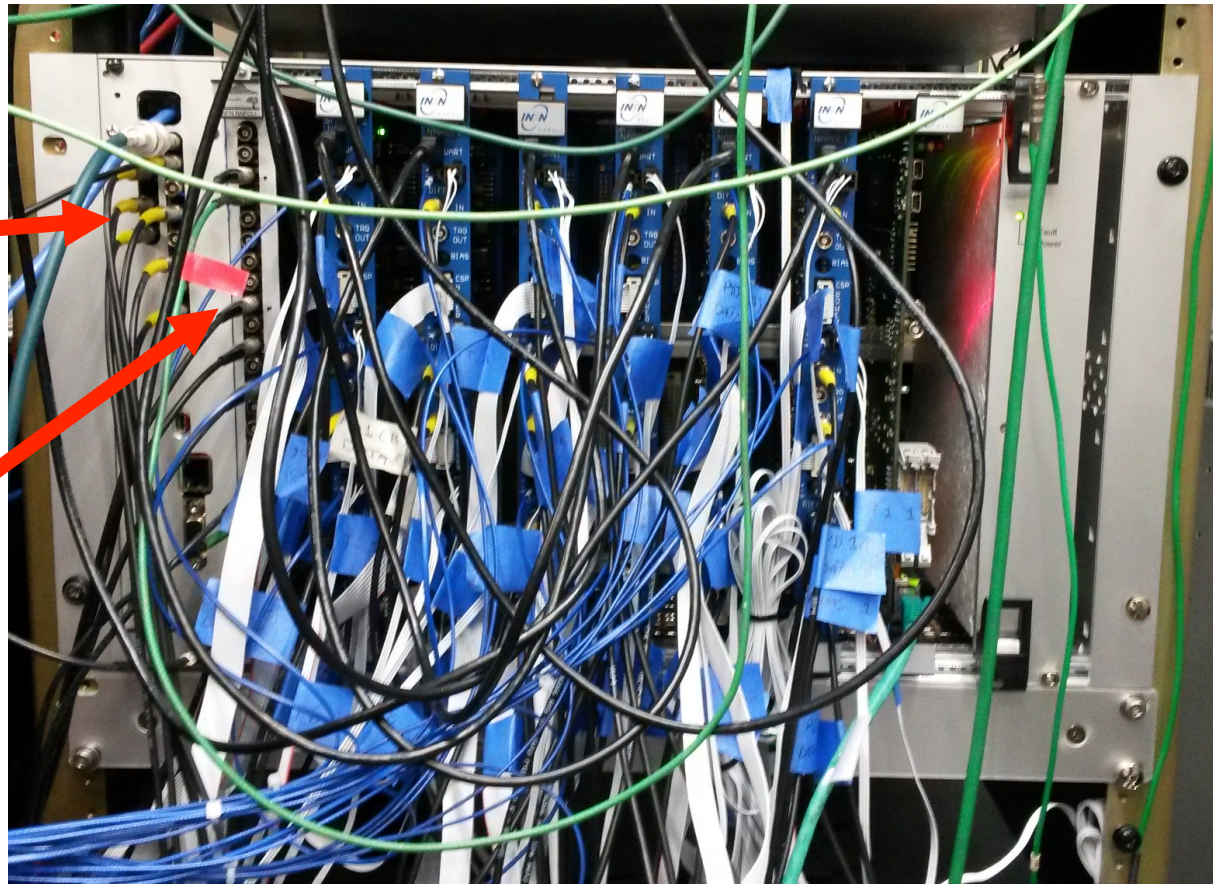
The source monitor electronics

All the SM are equipped with front-end electronics and interfaced with the WFD, data have been read with the DAQ system: **installation complete**

Lase control board

Constant pattern & flight simulator tested

NIM fan-out

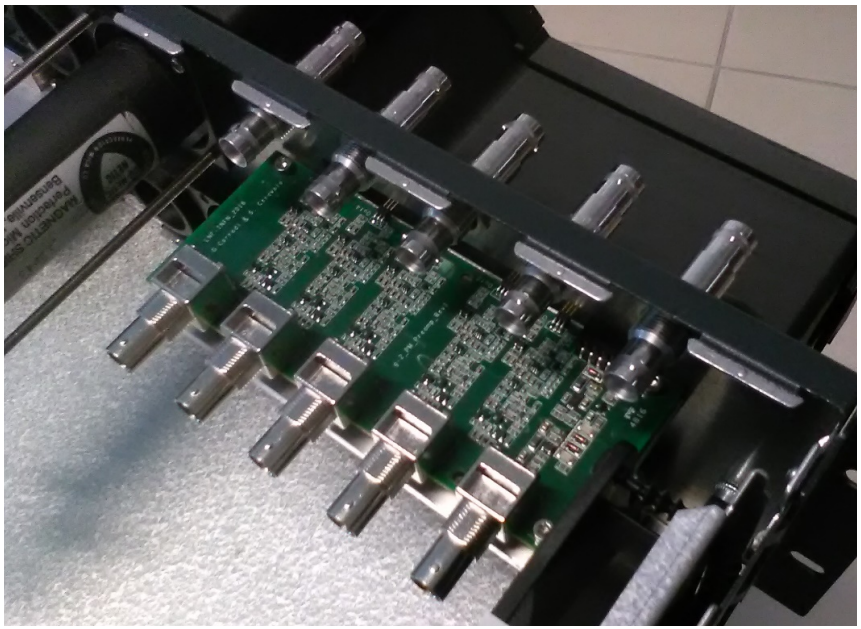


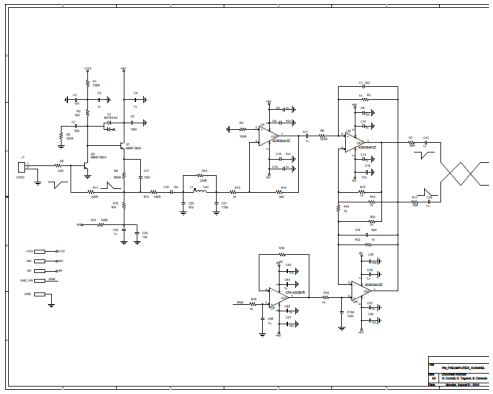
Last task left: firmware for the event building

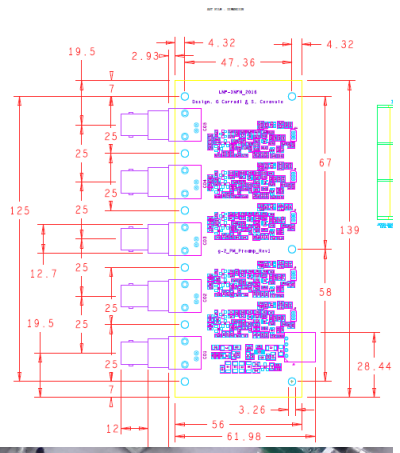
The local monitor electronics

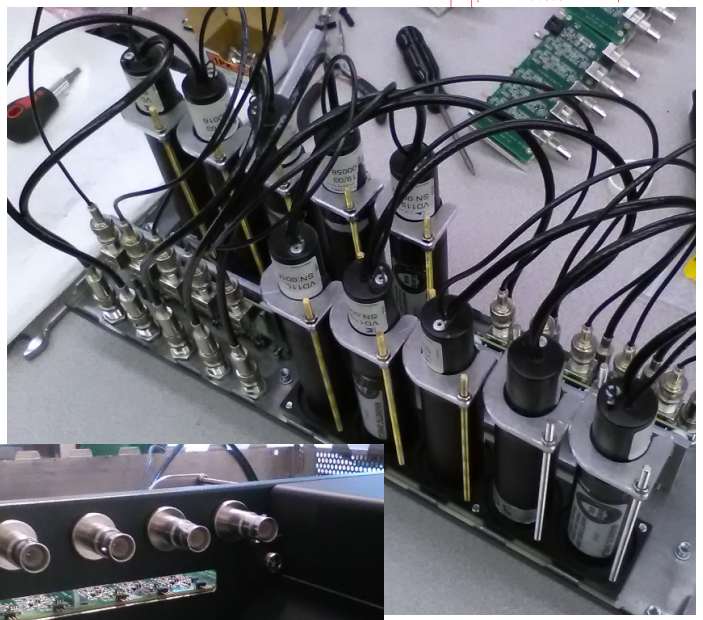
It consists of 24 PMT, and its associated electronics boards for signal conditioning and make it differential.

2 optical fibers reach each PMT, bandpass filters reduce the ambient light.







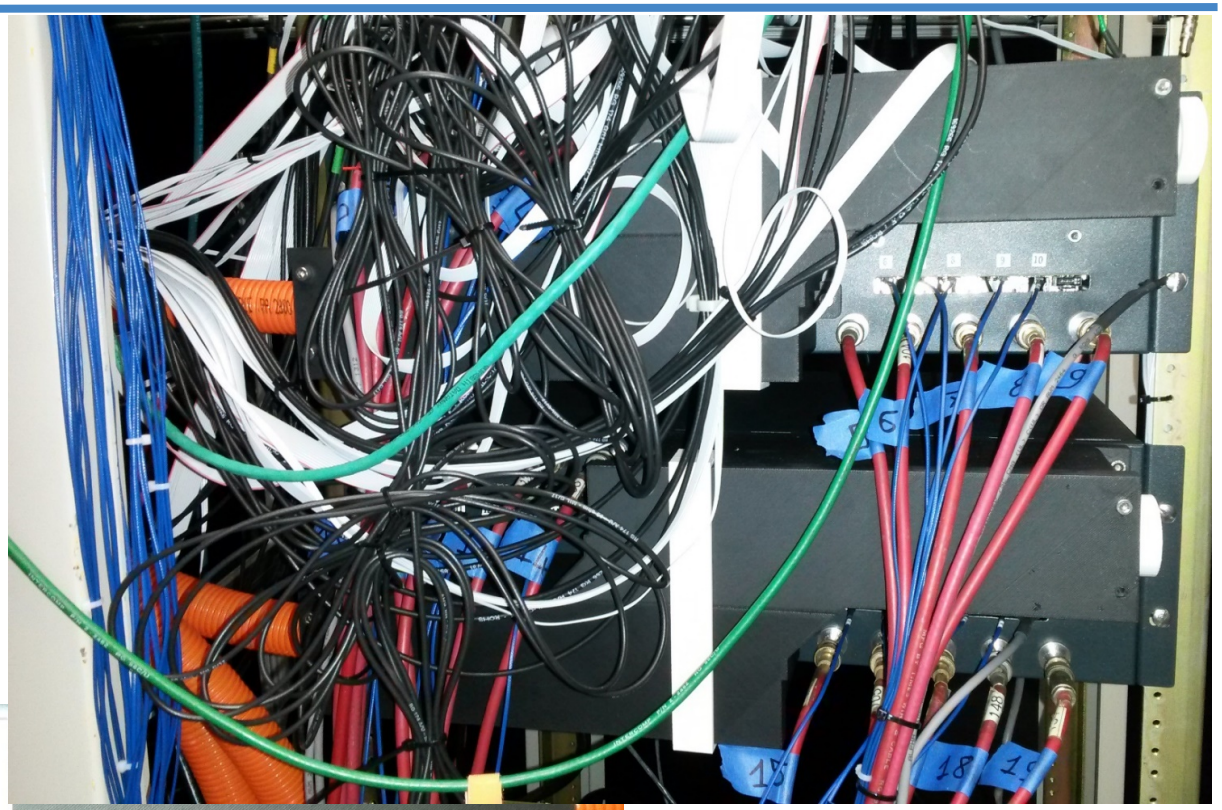


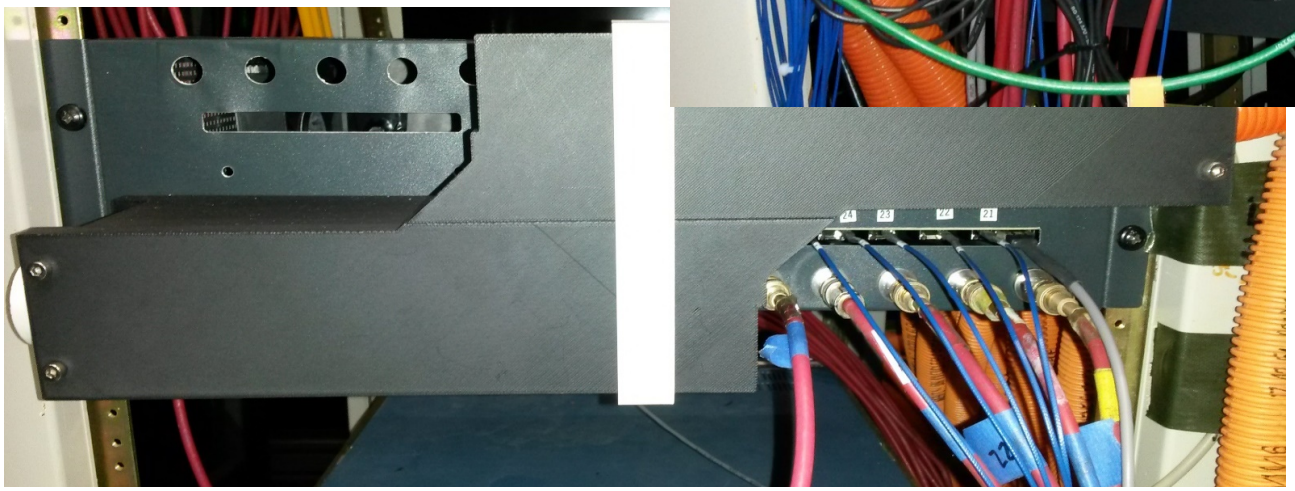
The local monitor have been installed in March
The installation includes the electronic boards to interface with the WFD.

The source monitor electronics

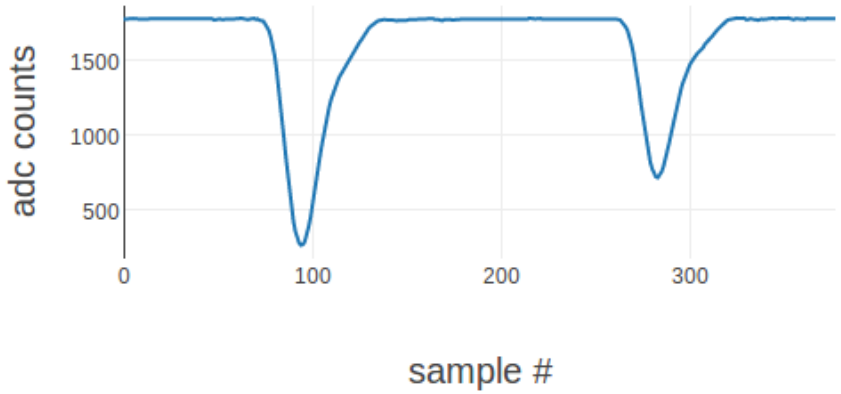
Installation and cabling (HV, LV, WFD) complete.

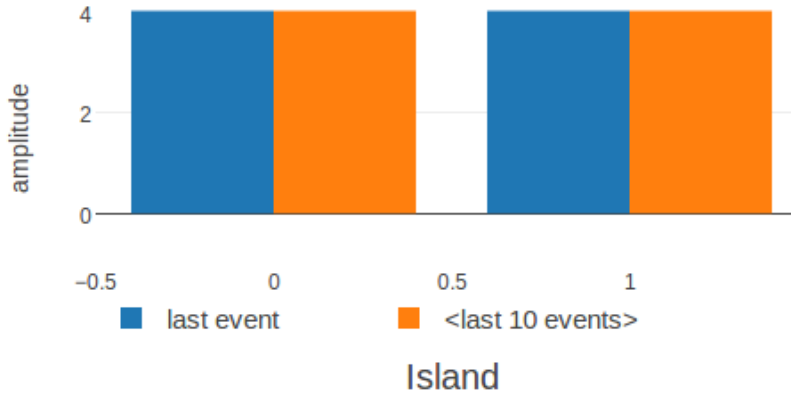
Test in progress.

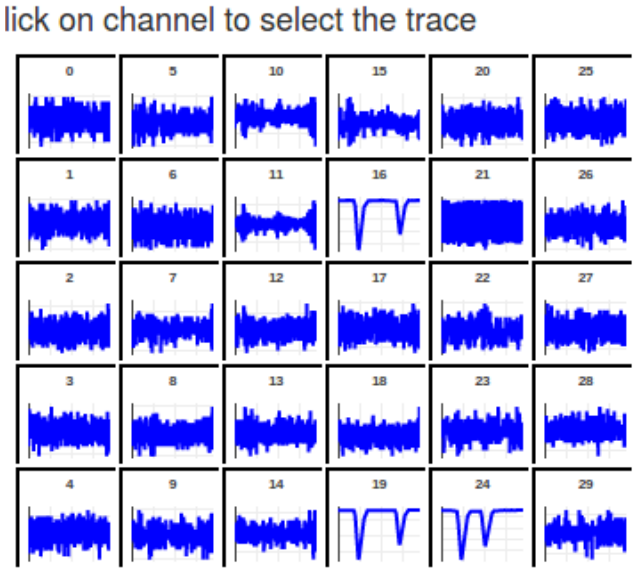


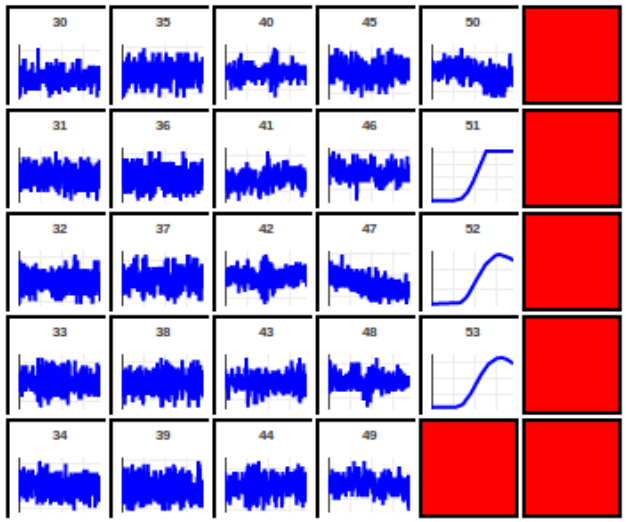


DQM software









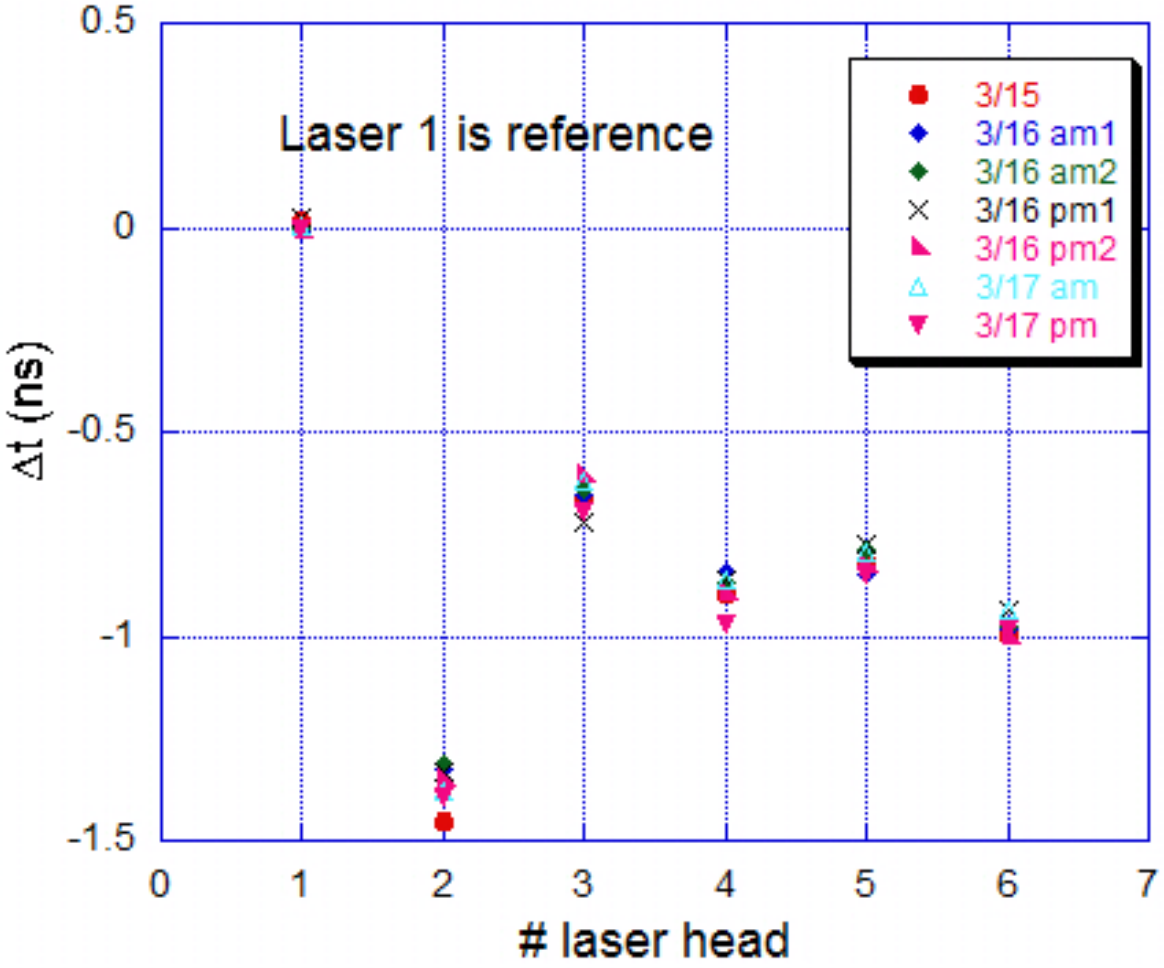
➢ The first version of the on-line software works fine

Timing results

Delay between laser heads has been measured.

The requirement, in order to identify lost muons, is 0.5 ns time synchronizatior between calorimetrs.

Measured jitter is about 200 ps, well below requirement.



Laser calibration system: Status @ May 2017

Calorimeter Subsystem	Design Completion	Remaining Work/Risks
Optical table	**100%**	**Optics and laser heads installed and aligned**, task completed
Optical fibers	**80%**	**Fibers installed, 12 calorimeters connected.** To check the functionality of the remaining fibers
Source monitor	**95%**	**Installed and tested.** Missing just the firmware for the event building
Local monitor	**75%**	**24 installed, 4 tested**. To check the functionality of the remaining 20 monitors.
Laser control board	**100%**	**Installed and tested**
Double pulse setup	**30%**	**Test done**
WFD	**100%**	**Installed, tested and DQM developed**

Engineering run during the summer for commissioning

Preparation for Milestone

- Conclusion of the installation for end of May.
- Commissioning during the summer (flight simulator test, stability test of monitors, pile-up studies)
- **Upgrade of the system (double pulse capabilities) for October**
- **Muon beam expected December 1st**

MS5: g-2 calibration commissioned
→ Due date: Month 36

Conclusions

- **The g-2 laser system is a state of the art calibration system** that will provide a very important contribution to reach the systematic goal in the g-2 experiment

- **The design and installation is almost complete and in schedule.**

- **The EU contribution to this system has been remarkable and has helped to increase the presence at FNAL**

- **We are on schedule and on-budget for MUSE deliverables. One completed. Two in progress**