Status of Laser System

Marco Incagli – INFN Pisa

Meeting with referees – 16 mar 2018

Main activities sep/2017 – mar/2018

Short summary: the system is ready for data taking!

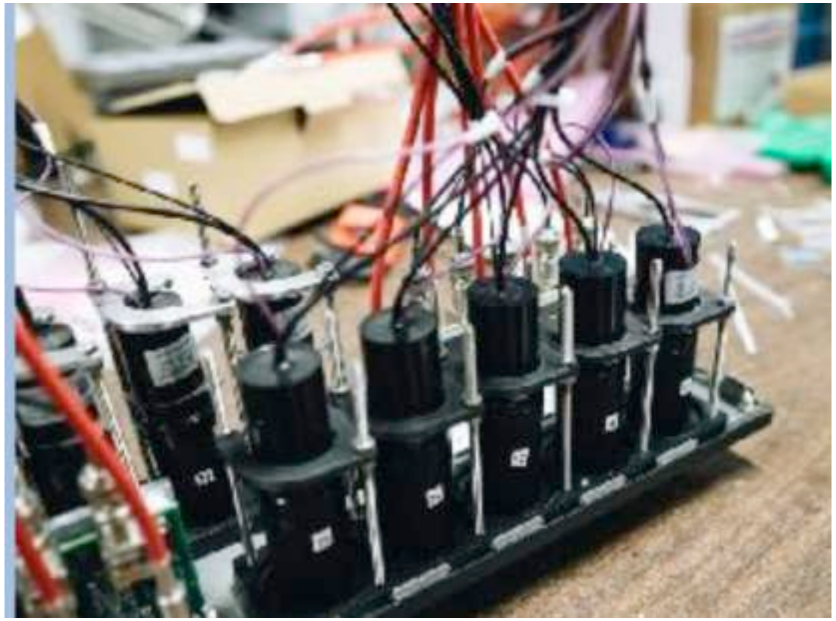
- Hardware
  1. Local Monitor installation
  2. Source MoniTor optimization
  3. Laser Heads relative timing
  4. Filter Wheel transmission
  5. Laser Control Board
  6. Double Pulse
- Software
  1. Reconstruction software
  2. Data Quality Control
  3. Slow Control
- Varie
  1. shifts/experts oncall
  2. wiki page
  3. web page

Hardware

1. Local Monitor installation
2. Source Monitor optimization
3. Laser Heads relative timing
4. Filter Wheel transmission
5. Laser Control Board
6. Double Pulse

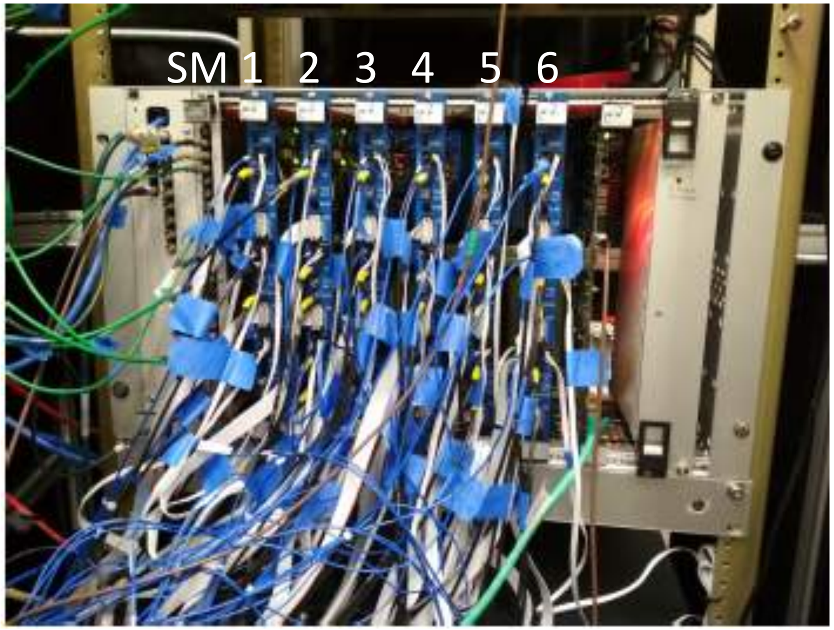
1 - New PMTs for Local Monitors (LM) installed

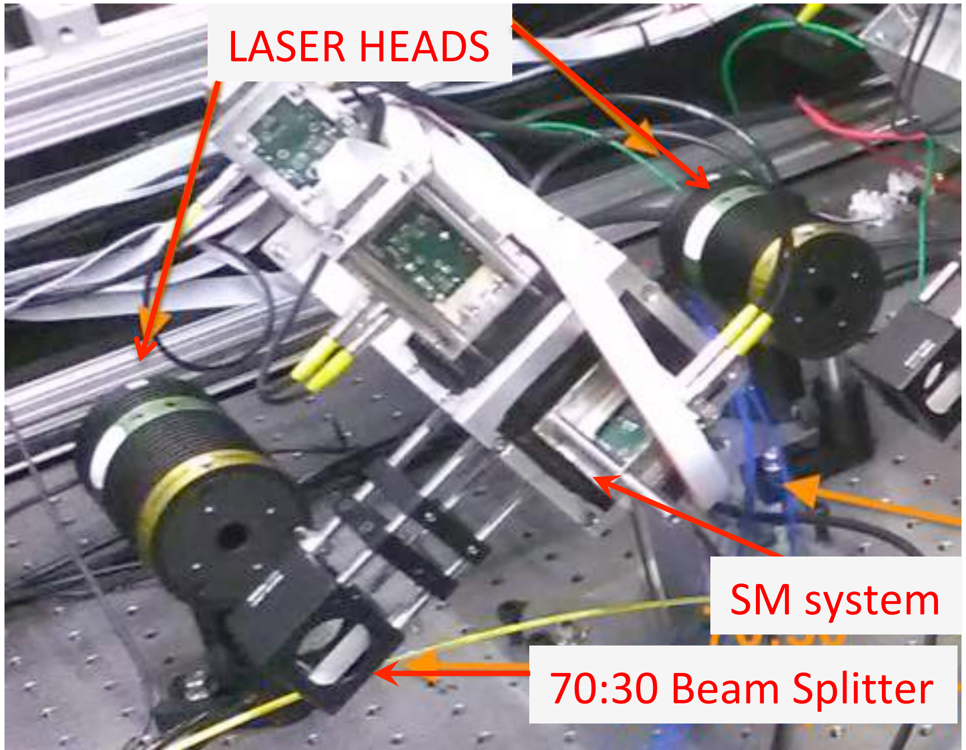
- All 24 LM PMTs installed and working
- New PMTs (Hamamatsu R1924A-100)
- New HV system (CAEN)
- 5 old PMTs connected to spare channels to study the effect of LM redundancy



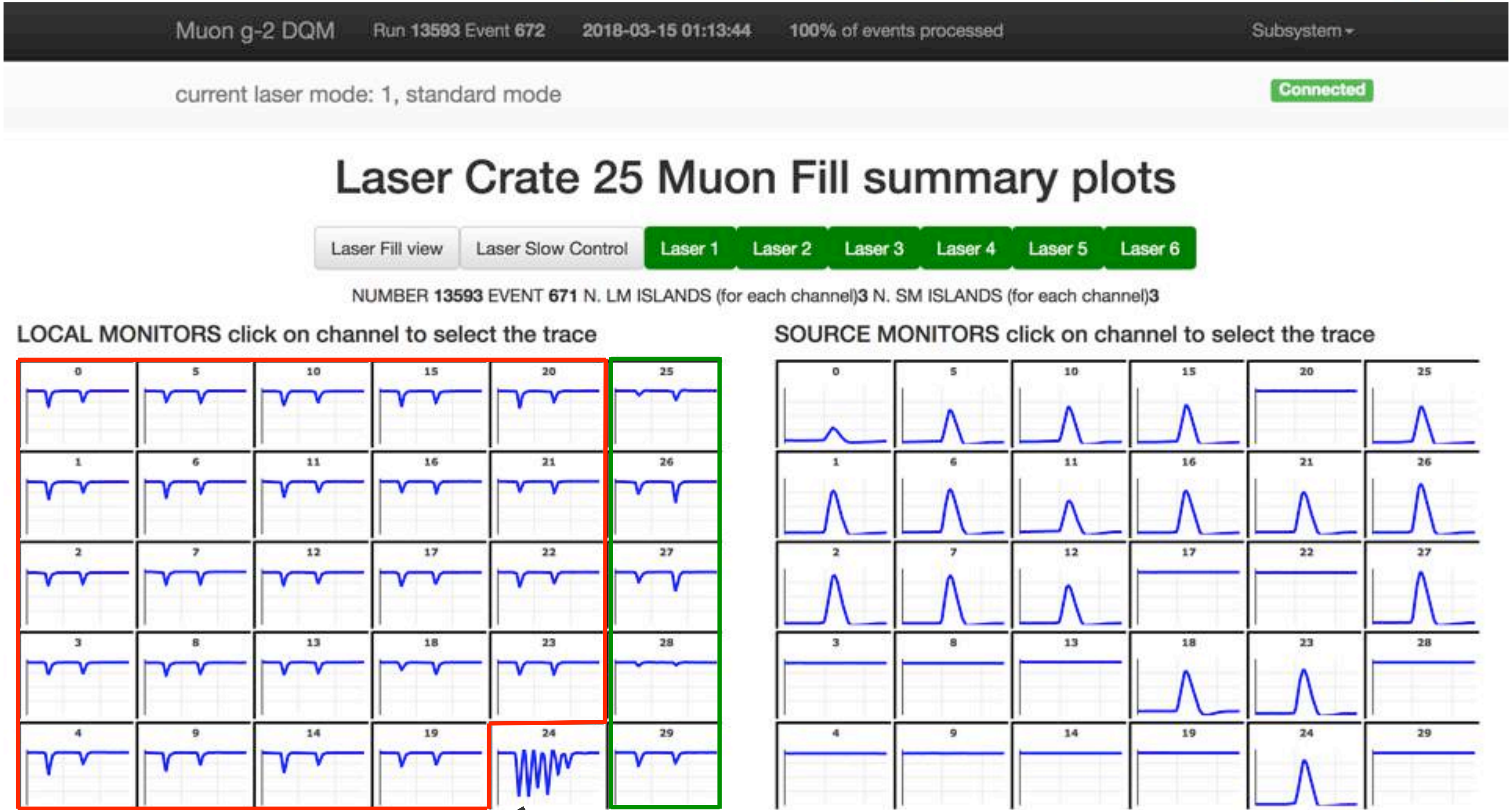
2 - Source Monitor (SM) system

- Each laser is monitored by 1 PMT and 2 PiN diodes
- SM system powered by Naples electronics providing Voltage Bias for PiNs and Voltage reference for PMT
- Readout both with Wave Form Digitizers (WFD) and with custom (Naples) electronics





DQM = Data Quality (online) Monitor



24 LOCAL MONITORS

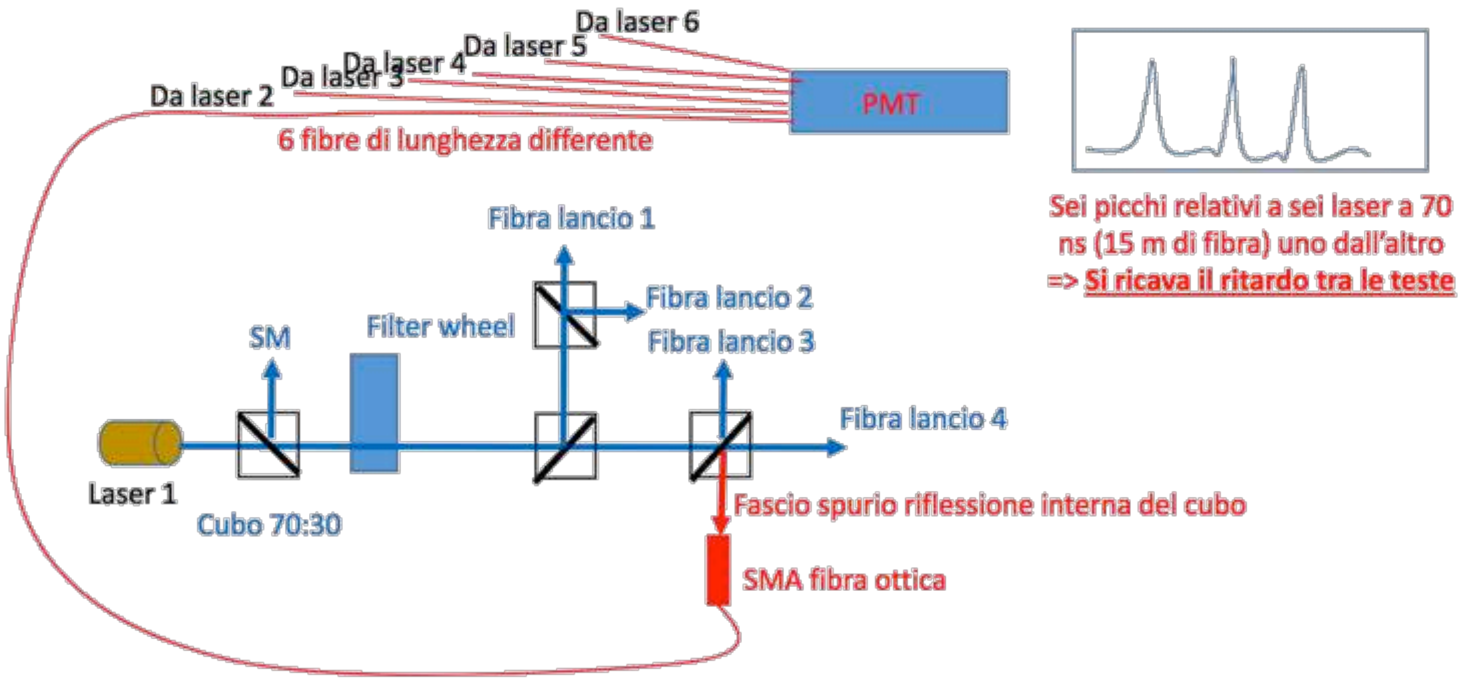
5 REDUNDANT OLD MONITORS

6(X3) SOURCE MONITORS

SPECIAL PMT (see later)

3 - The special PMT: Laser Heads relative delay

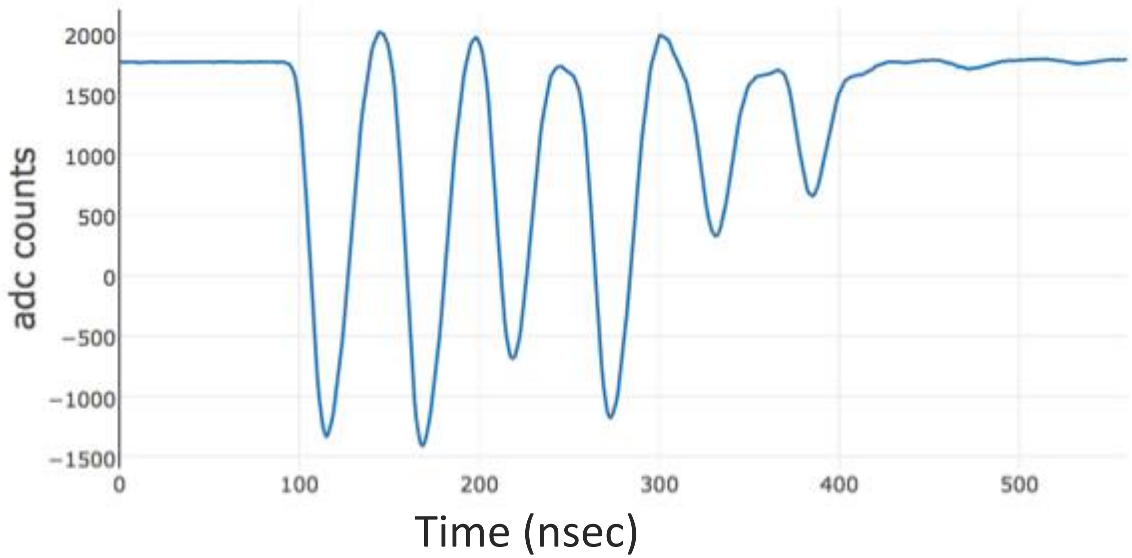
- Problem: *lost muons** distort the wiggle function (2[nd] largest systematic error on ω_a in BNL)
- Often they cross 2 or even 3 calorimeters → tight (~1ns) coincidence between calorimeters to select them
- Time sync set by laser → must know relative laser time shift



** lost muon = high or low momentum muon which hit a collimator and spiralize*

Relative timing

- Fiber lengths: 2, 15, 27, 39, 51, 65 m
- The delay due to different fiber length can be measured indipendently and subtracted

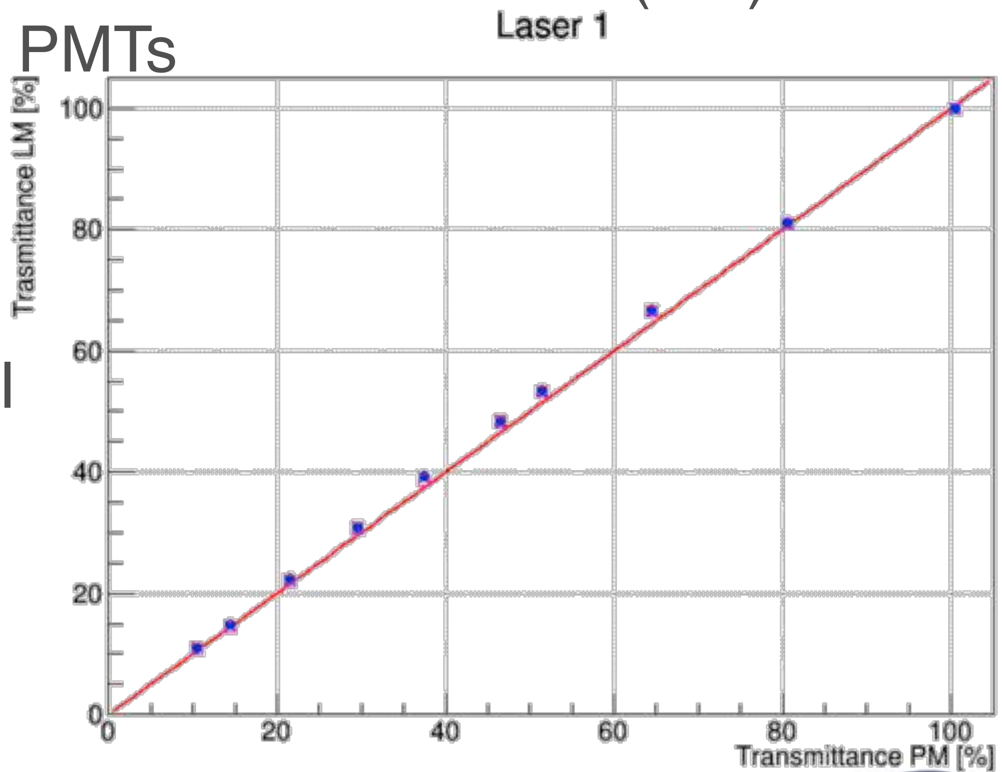


- Residual delay ranges from 0.2 to 2 nsec
- Must correct for this effect

Laser	$(\Delta t_{x-(x-1)})_{STD}$	$(\Delta t_{x-(x-1)})_{DP}$	$(\Delta t_{STD} - \Delta t_{DP})/2$ (1.2 ns)	Delay laser (ns)	Delay laser DRS4 (ns)
2 – 1	54.534	57.833	-1.65	-1.98	-1.4
4 – 3	55.459	55.816	-0.18	-0.21	-0.25
6 – 5	95.113	96.240	-0.56	-0.68	-0.15

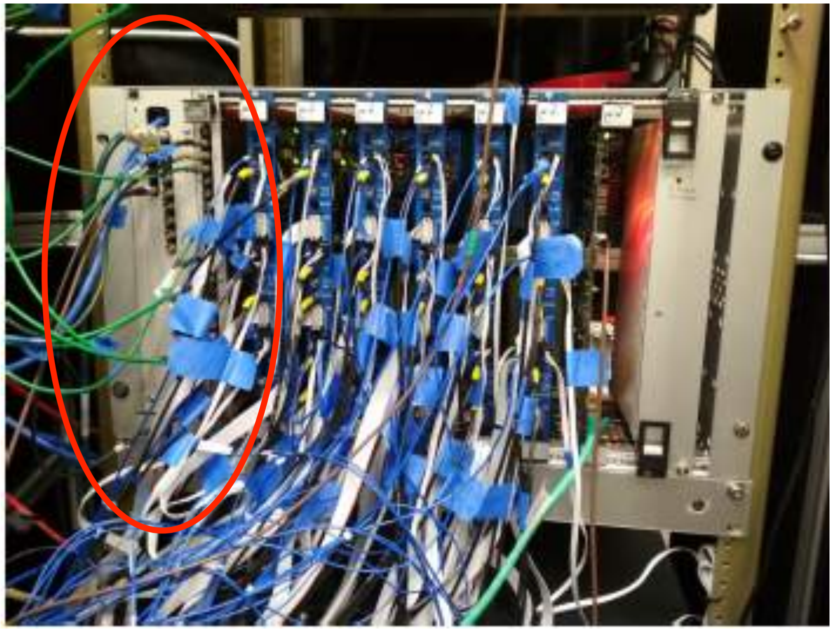
4 - Filter Wheel transmission

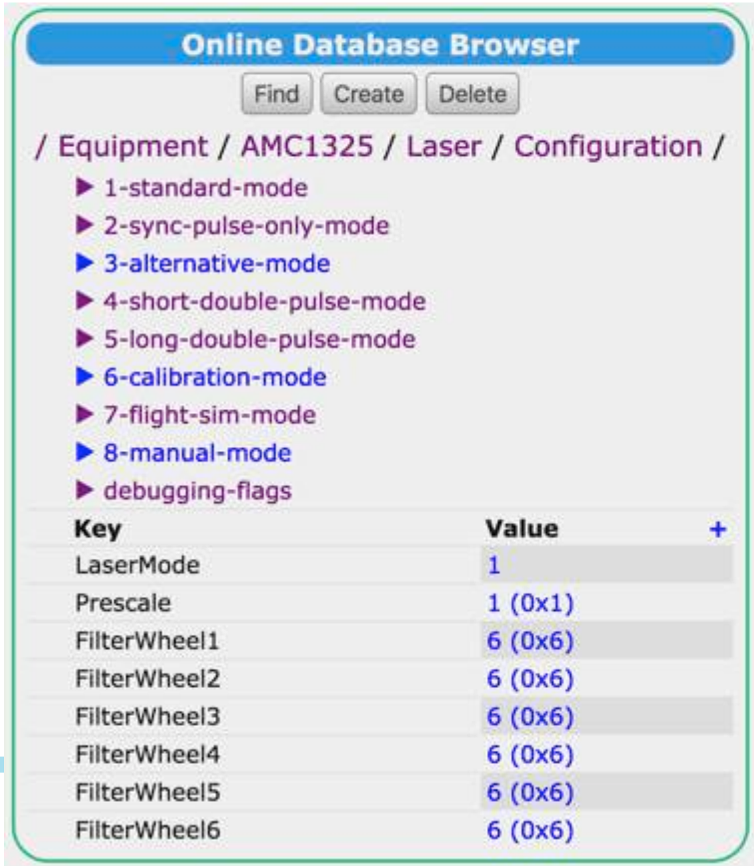
- The Filter Wheel system allows to vary the transmitted light from 100% to 0% in 12 steps → default position = 6
- It is used for calorimeter calibration
- Light transmission measured with a Power Meter (PM) and with the Local Monitor (LM) PMTs
- After some optimization, a good linearity is observed for all 6 lasers (note that when measuring with LM all optical transmission elements are included!)



5 - Laser Control Board

- Located in the same crate where the SM boards are
- Output: Several Trigger Patterns, sent to the Laser Driver, selected and configured through standard Online Database (ODB) interface
- New features included in firmware: Double Pulse, Prescale, Beam Splash Simulator





Article published on JINST 13(2018)

The laser control of the muon $g-2$ experiment at Fermilab

Muon g-2 Collaboration (A. Anastasi (Frascati & Messina U.) , A. Anastasio (INFN, Naples), S. Avino (INFN, Naples & INFN, Messina), A. Basti, F. Bedeschi (INFN, Pisa), A. Bolano (INFN, Naples), G. Cantatore (INFN, Udine & Triste U.), D. Cauz (INFN, Udine & Udine U.), S. Ceravolo, G. Corradi (Frascati), S. Dabagov (Frascato & Moscow Phys. Eng. Inst.), P. Di Meo (INFN, Naples), A. Driutti (INFN, Trieste & Udine U.), G. Di Sciascio (INFN, Rome2), R. Di Stefano (INFN, Naples & Cassino U.), O. Escalante (INFN, Naples & Naples U.), C. Ferrari (Frascati), A.T. Fienberg (Washington U., Seattle), A. Fioretti, C. Gabbanini (INFN, Pisa), A. Gioiosa (INFN, Lecce), D. Hampai (Frascati), D.W. Hertzog (Washington U., Seattle), M. Iacovacci (INFN, Naples & Naples U.), M. Incagli (INFN, Pisa), M. Karuza (INFN, INFN & Rijeka U. & Udine U.), J. Kaspar (Washington U., Seattle), A. Lusiani (INFN, Pisa & Pisa, Scuola Normale Superiore), F. Marignetti (INFN, Naples & Cassino U.), S. Mastroianni (INFN, Naples), D. Moricciani (INFN, Rome2), A. Nath (INFN, Naples), G. Pauletta (INFN, Trieste & Udine U.), G.M. Piacentino (INFN, Lecce), N. Raha (INFN, Rome2), L. Santi (INFN, Trieste & Udine U.), M.W. Smith (INFN, Pisa & Washingotn U., Seattle), G. Venanzoni (INFN, Pisa), D. Cauz) *Hide*

Nov 9, 2017 - 15 pages

JINST 13 (2018) no.02, T02009
(2018-02-21)
DOI: 10.1088/1748-0221/13/02/T02009
FERMILAB-PUB-17-502-E
Experiment: FNAL-E-0989

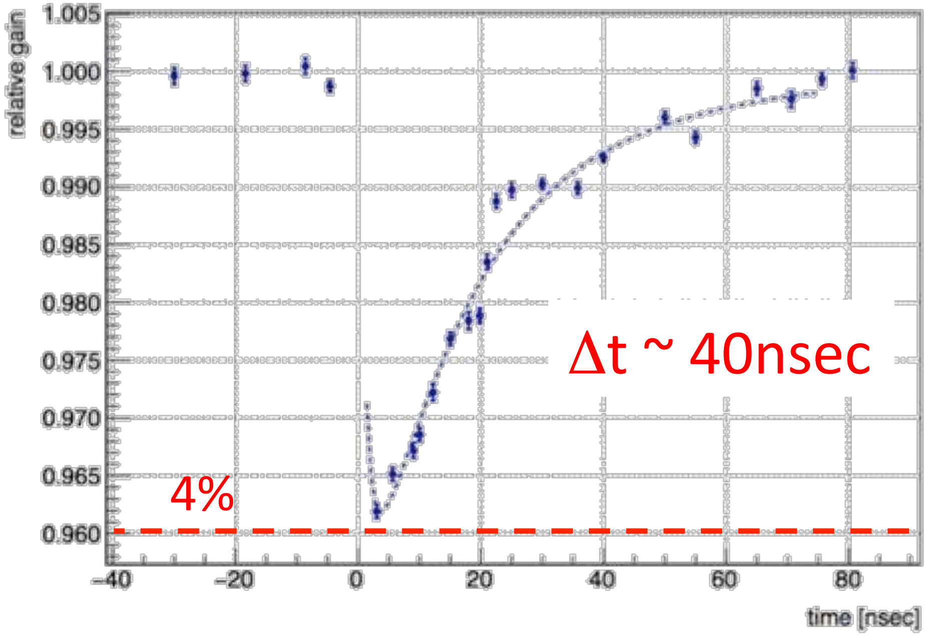
Abstract
The Muon g-2 Experiment at Fermilab is expected to start data taking in 2017. It will measure the muon anomalous magnetic moment, a = ¹g 2º2 to an unprecedented precision: the goal is 0.14 parts per million (ppm). The new experiment will require upgrades of detectors, electronics and data acquisition 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.

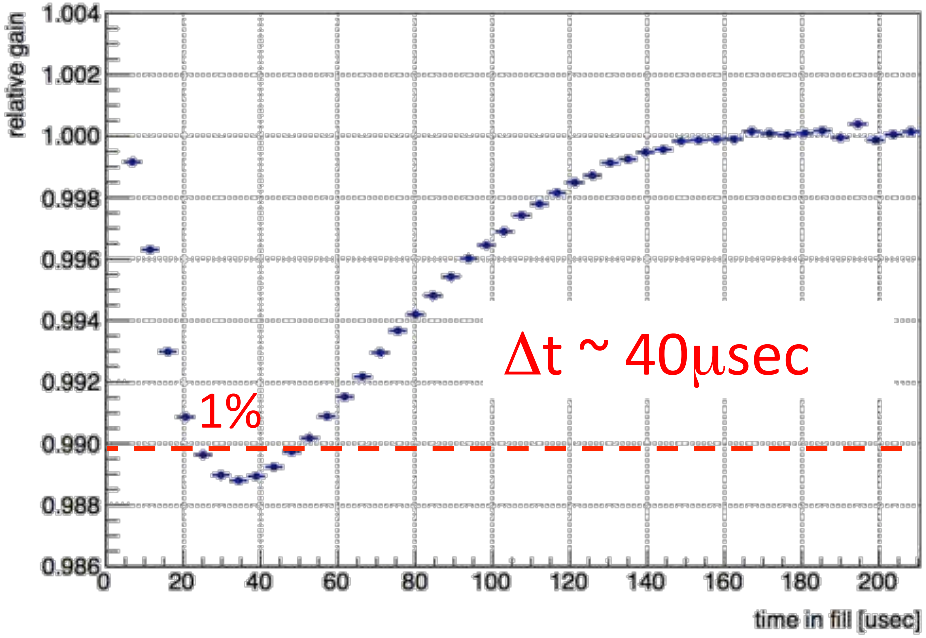
6 - The Double Pulse System

- The calorimeter response is not constant within fill:

  ~4% drop for consecutive pulses ~40nsec (SiPM response)

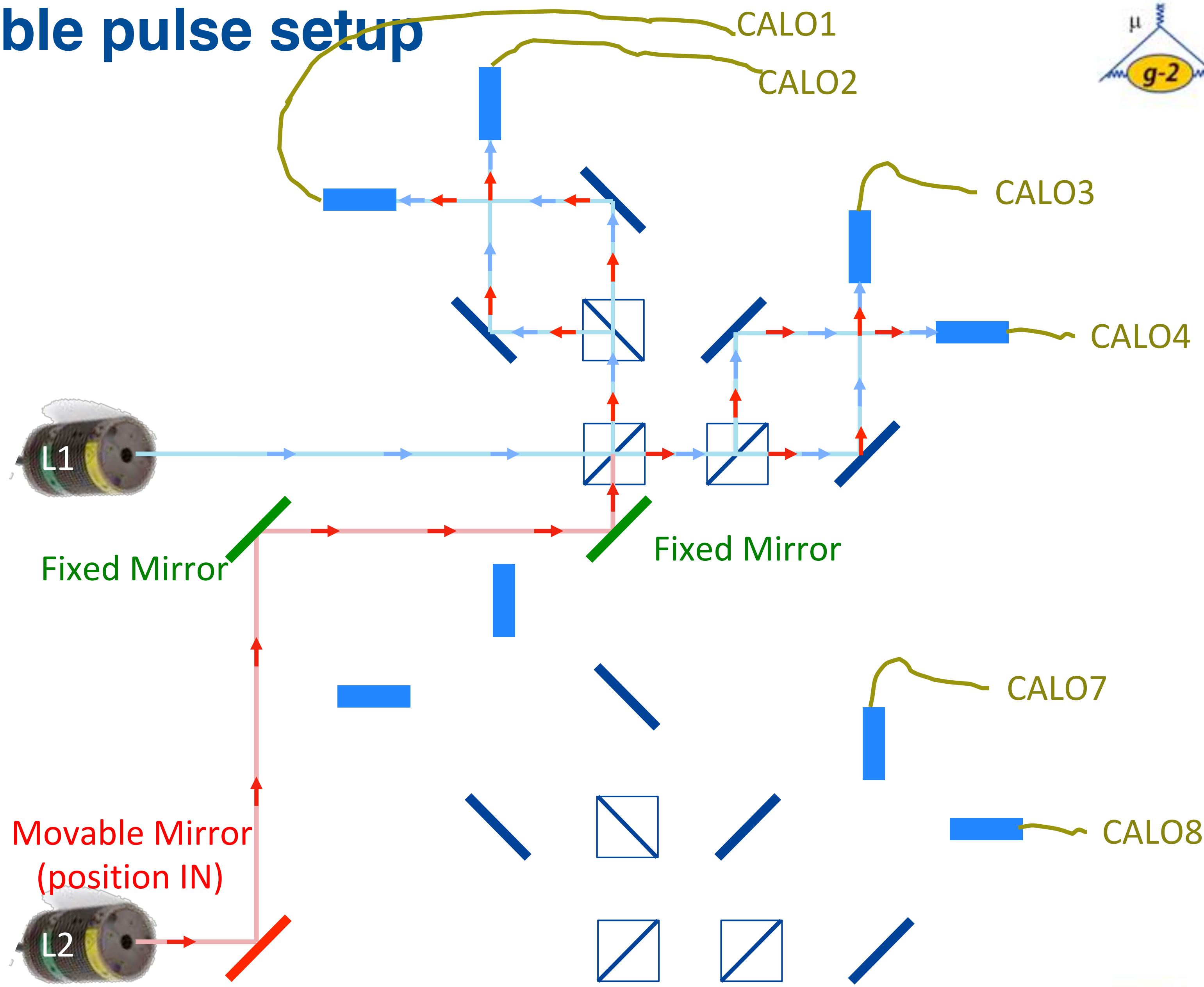
  <1% drop in first 40μsec (load on Voltage power supply due to *beam splash*)



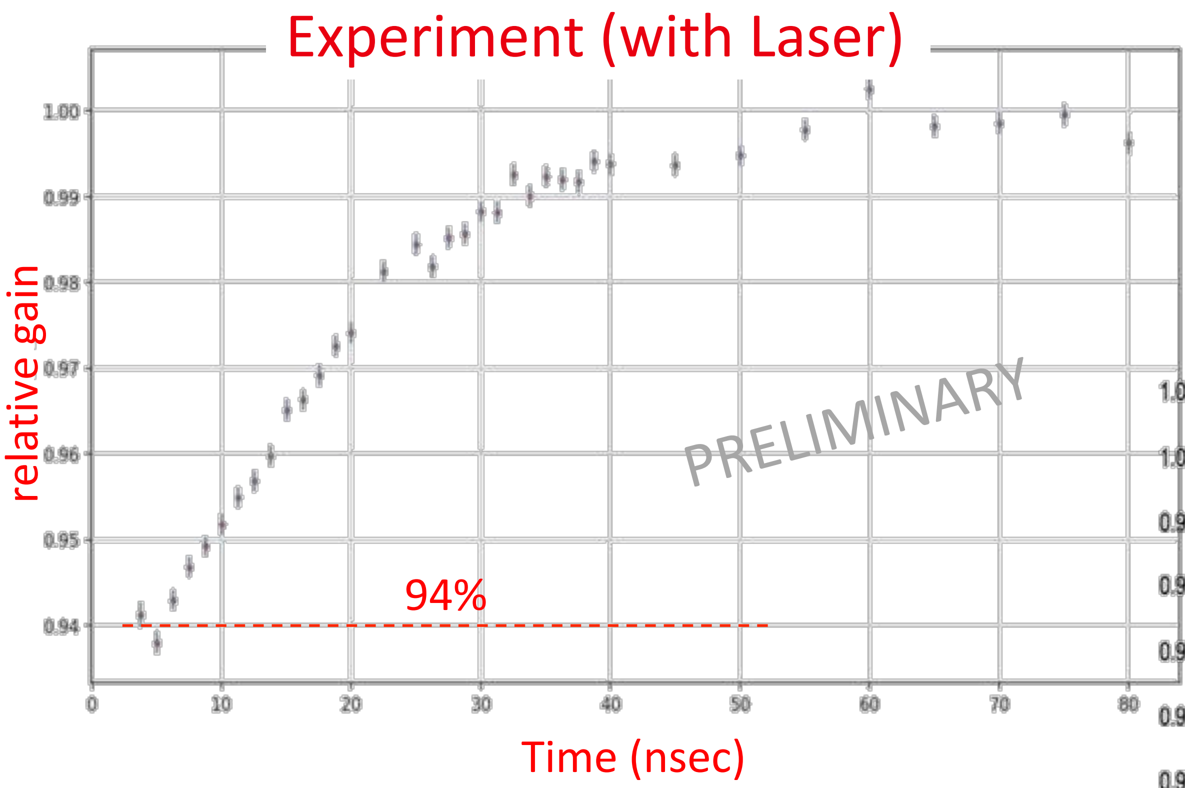


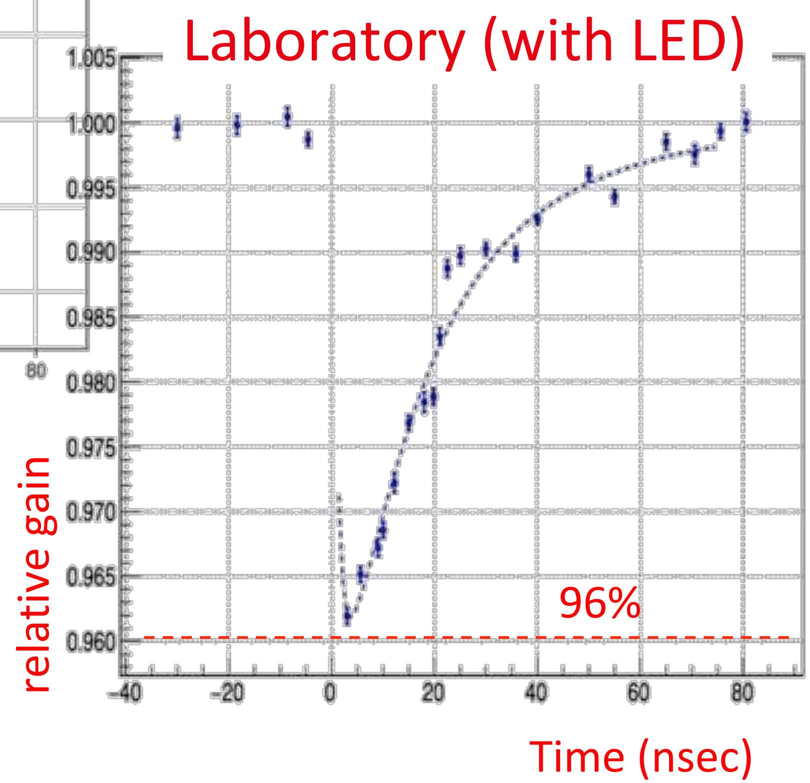
- <u>Gain changes have been the largest systematic in BNL exp</u>

The double pulse setup



Preliminary gain function determination: crystal 23 of calo 17

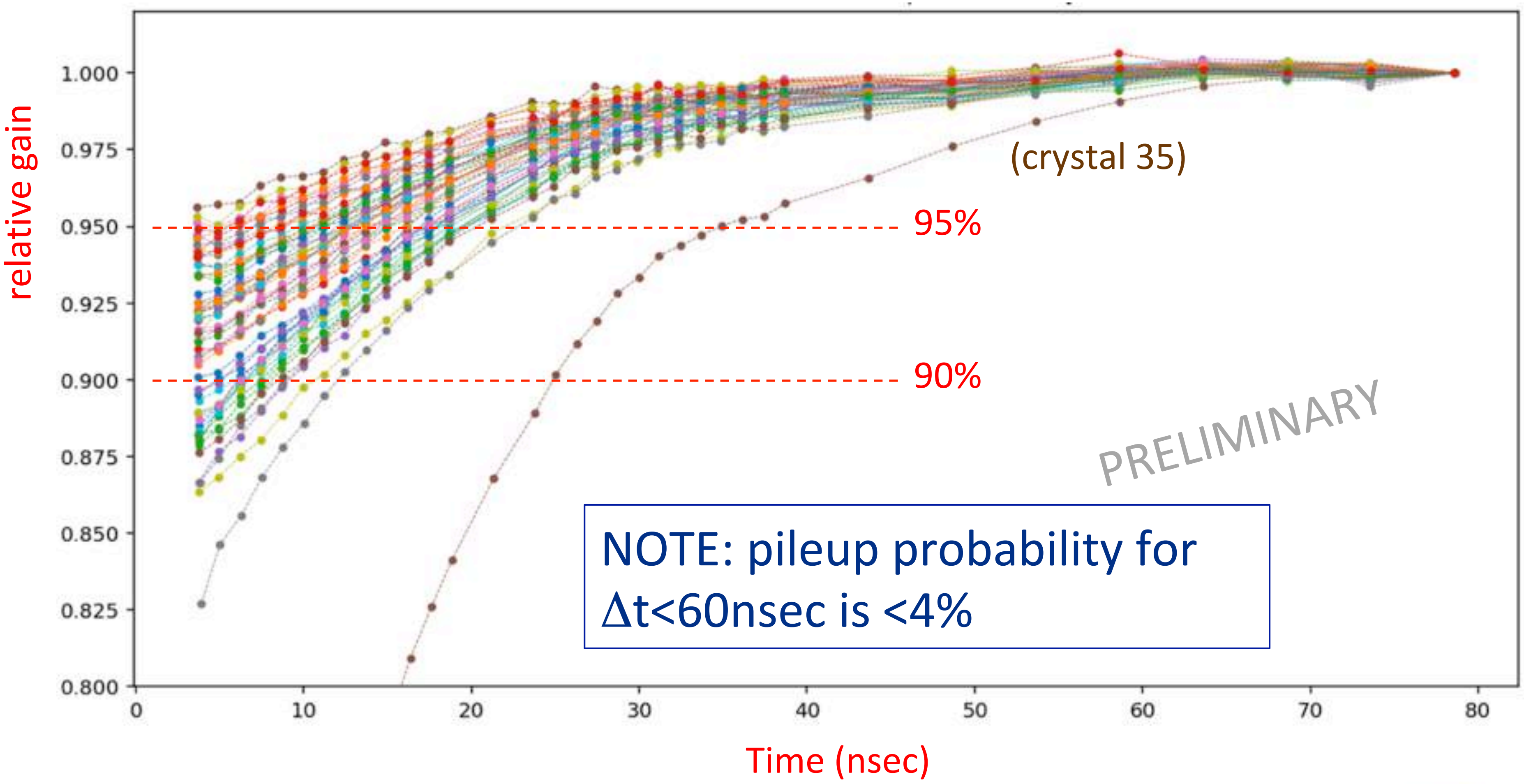




- The behavior is well reproduced
- The gain losses seem slightly larger than expected (preliminary result)
- Large fluctuation among crystals (next slide)

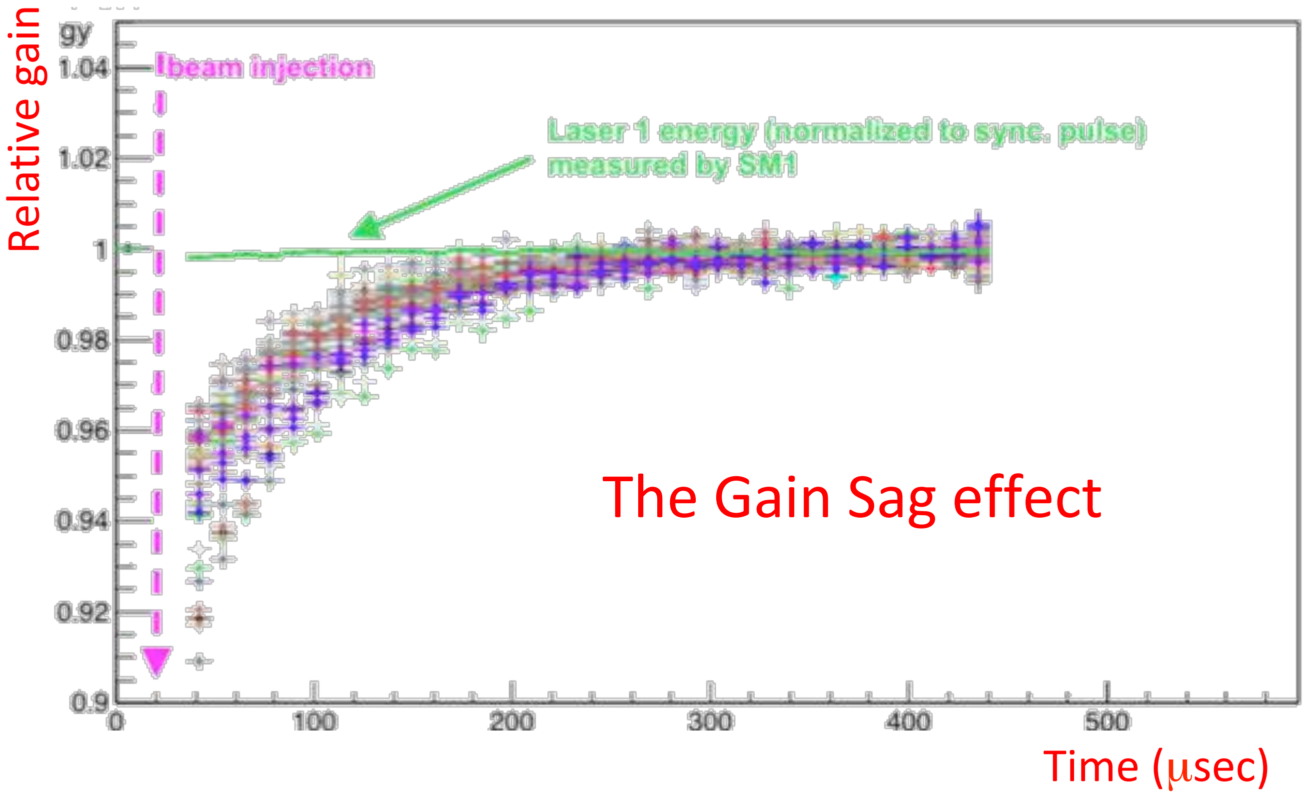
Preliminary gain function determination:calo 17

- Large spread among different crystals



The long time (~40usec) term

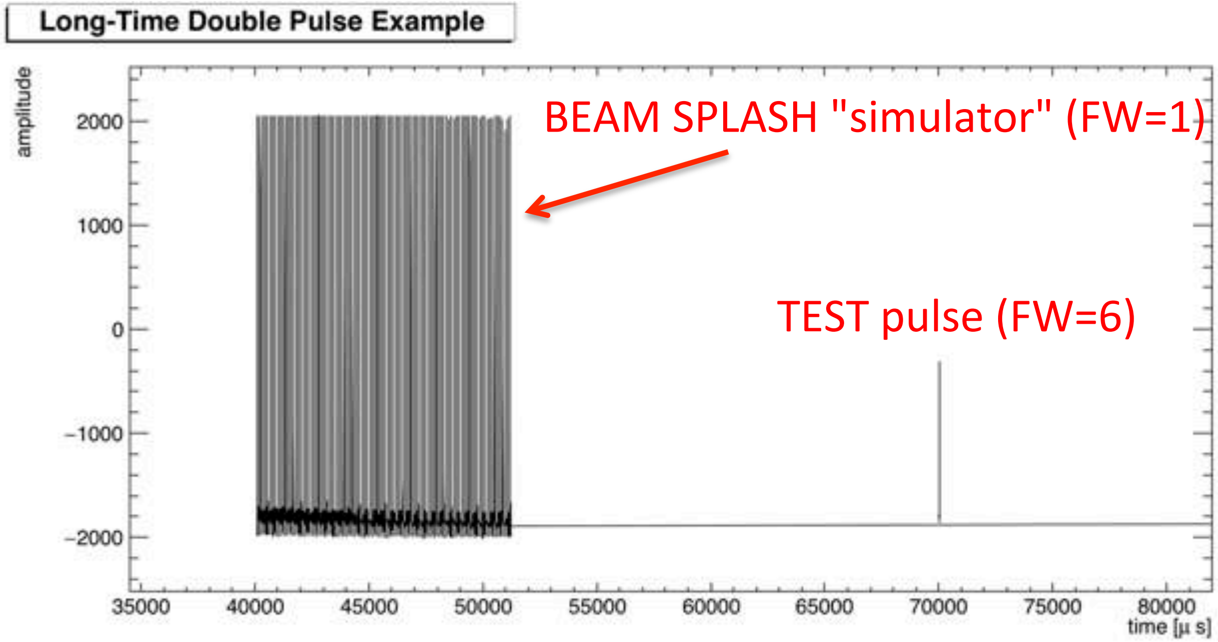
- This term is potentially much more dangerous
- Expected to be <1%, but ....



- 54 crystals of CALO1
- The Source Monitor shows that laser light is stable
- The Gain Sag is induced by *Beam Splash*

- Systematic studies performed with Double Pulse

Long Time Double Pulse (LTDP)

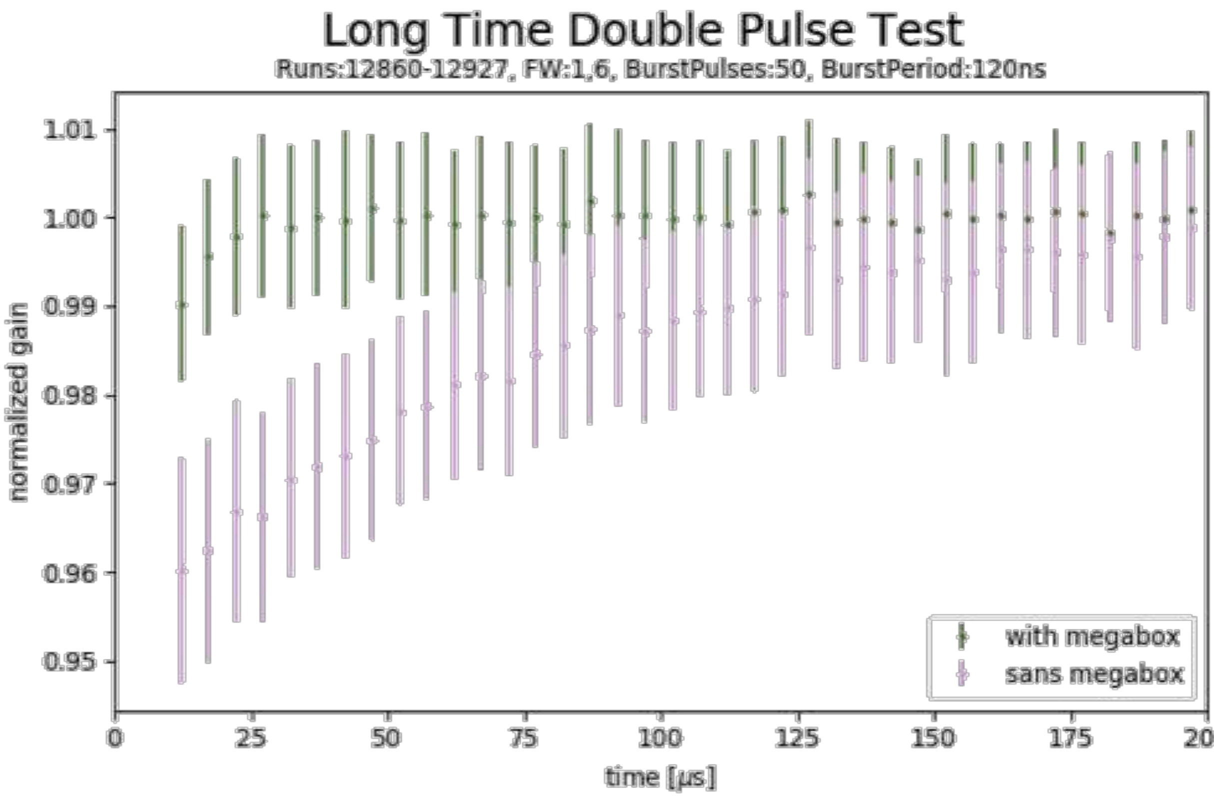


- FW = Filter Wheel
- Default position = 6

- Burst of ***N = 50*** pulses with ***δt = 120ns*** and ***FW=1***
- Programmable values: **N**, **δt, FW**
- Test pulse sent after ***Δt = [0,200] μsec***
- Scan on **Δt**
- Several input values have been tested to parametrize calorimeter response under different beam conditions

Modified calorimeter electronics

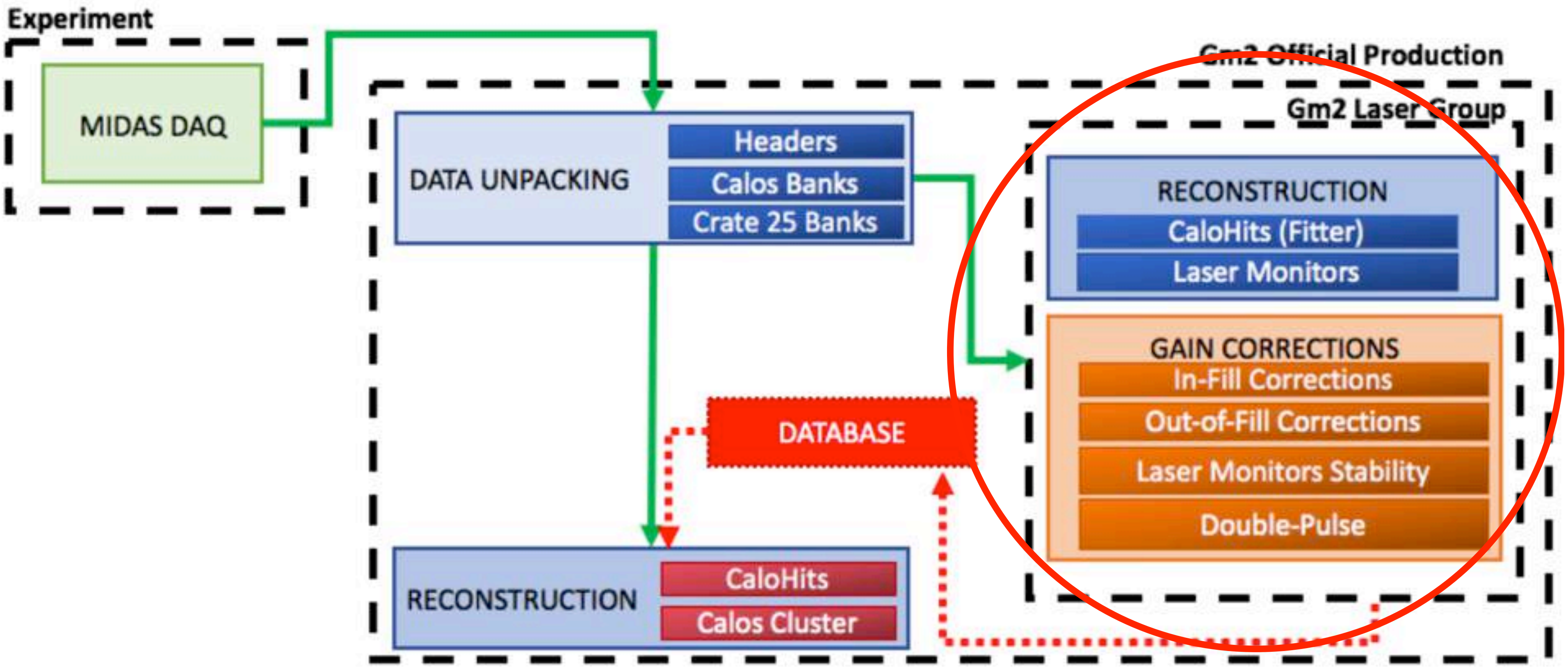
- Following our measurement, the calorimeter UW group added a set of capacitors (so-called *megaboxes*) between power supplies and SiPMs
- Residual effect below 1% level
- Now we must precisely measure it !!



Software

1. Reconstruction software
2. Data Quality Control
3. Slow Control

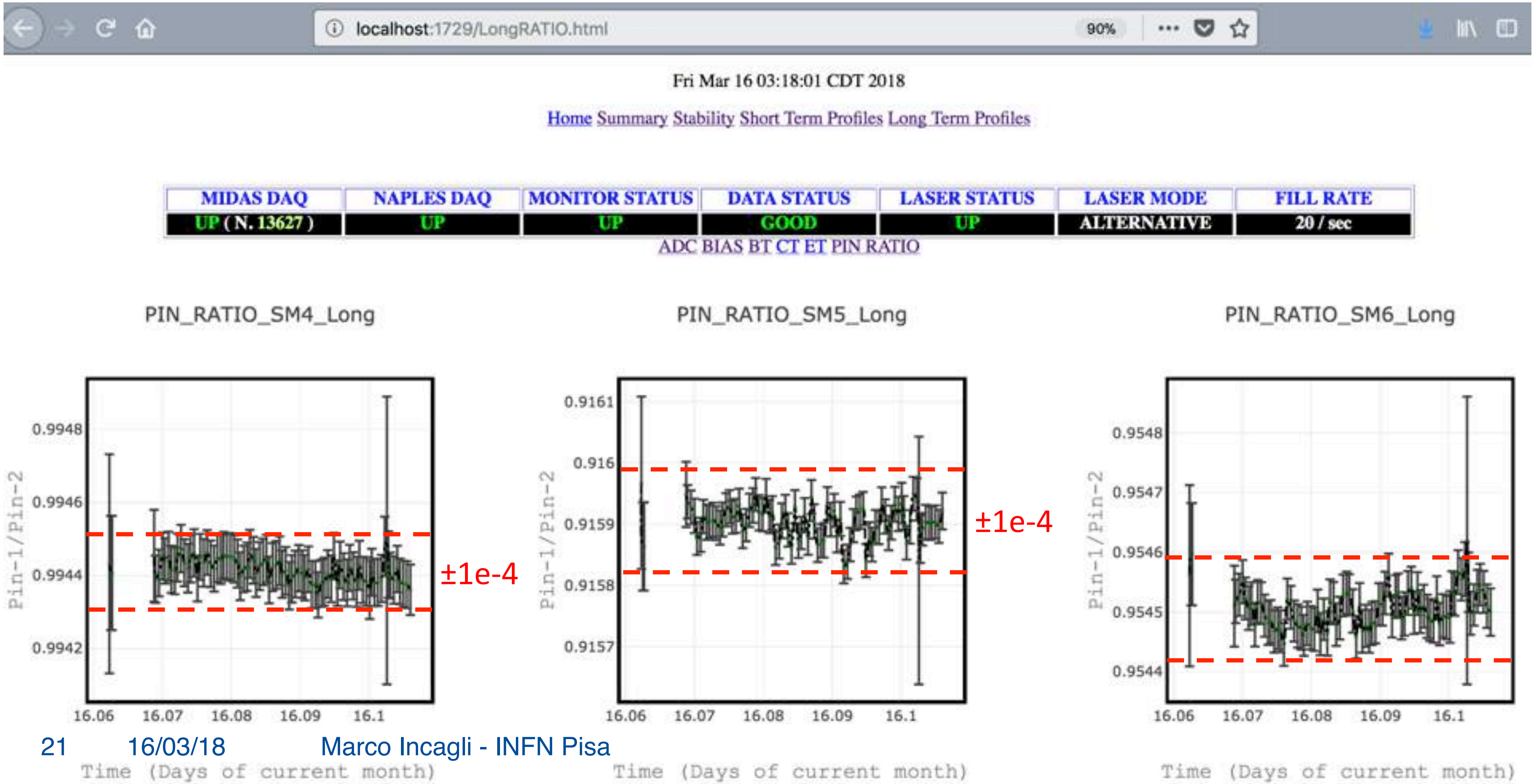
1 – Software infrastructure



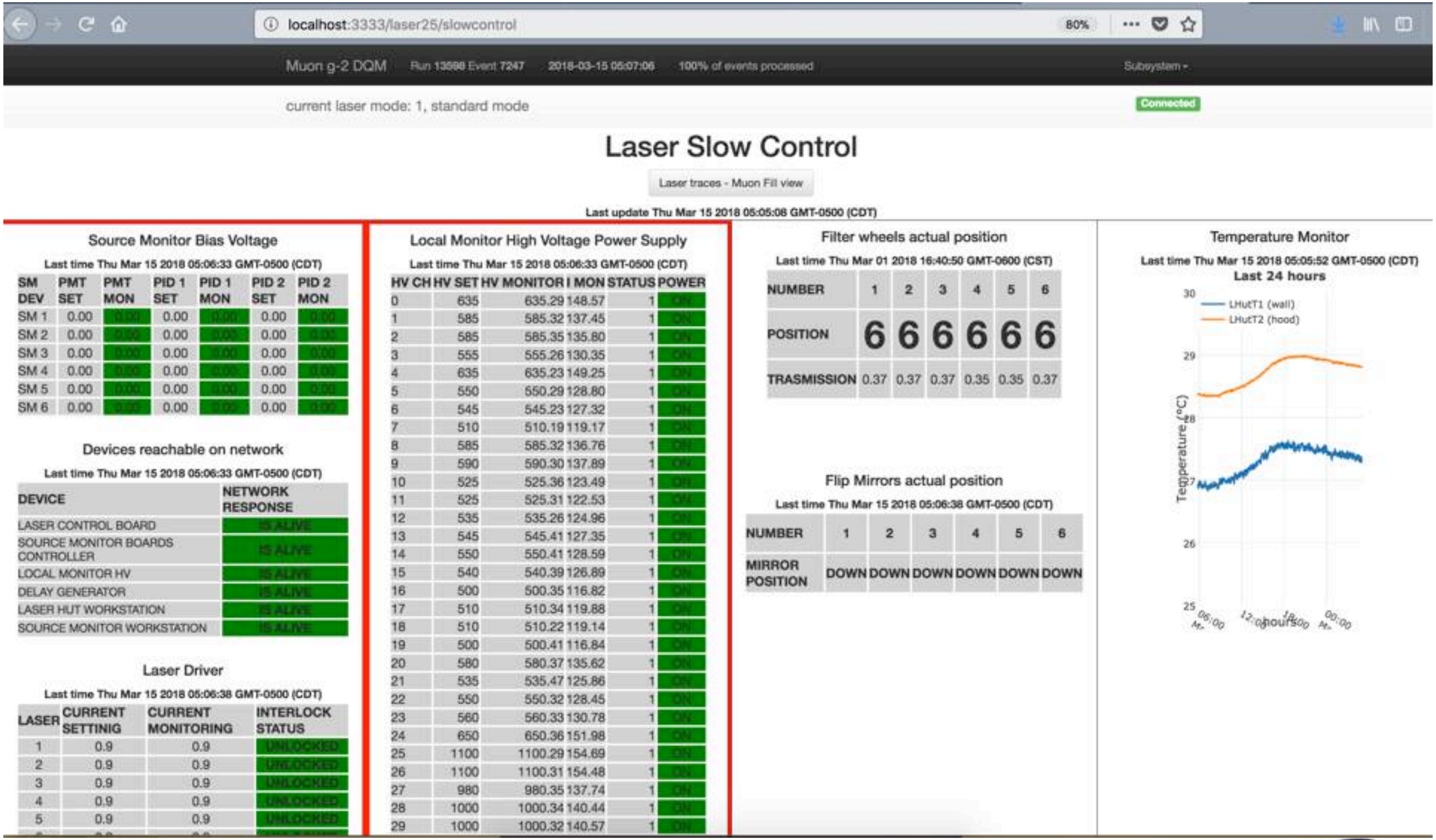
- Gain correction modules are under development
- See next talk by Anna Driutti

2 – Data Quality

- Data quality is checked routinely
- An automatic program checks for deviation from pre-defined stability bands and flag the periods with large fluctuations



3 - Slow Control



SM DEV	PMT SET	PMT MON	PID 1 SET	PID 1 MON	PID 2 SET	PID 2 MON
SM 1	0.00	0.00	0.00	0.00	0.00	0.00
SM 2	0.00	0.00	0.00	0.00	0.00	0.00
SM 3	0.00	0.00	0.00	0.00	0.00	0.00
SM 4	0.00	0.00	0.00	0.00	0.00	0.00
SM 5	0.00	0.00	0.00	0.00	0.00	0.00
SM 6	0.00	0.00	0.00	0.00	0.00	0.00

DEVICE	NETWORK RESPONSE
LASER CONTROL BOARD	IS ALIVE
SOURCE MONITOR BOARDS CONTROLLER	IS ALIVE
LOCAL MONITOR HV	IS ALIVE
DELAY GENERATOR	IS ALIVE
LASER HUT WORKSTATION	IS ALIVE
SOURCE MONITOR WORKSTATION	IS ALIVE

LASER	CURRENT SETTINIG	CURRENT MONITORING	INTERLOCK STATUS
1	0.9	0.9	UNLOCKED
2	0.9	0.9	UNLOCKED
3	0.9	0.9	UNLOCKED
4	0.9	0.9	UNLOCKED
5	0.9	0.9	UNLOCKED

HV CH	HV SET	HV MONITOR	I MON	STATUS	POWER
0	635	635.29	148.57	1	ON
1	585	585.32	137.45	1	ON
2	585	585.35	135.80	1	ON
3	555	555.26	130.35	1	ON
4	635	635.23	149.25	1	ON
5	550	550.29	128.80	1	ON
6	545	545.23	127.32	1	ON
7	510	510.19	119.17	1	ON
8	585	585.32	136.76	1	ON
9	590	590.30	137.89	1	ON
10	525	525.36	123.49	1	ON
11	525	525.31	122.53	1	ON
12	535	535.26	124.96	1	ON
13	545	545.41	127.35	1	ON
14	550	550.41	128.59	1	ON
15	540	540.39	126.89	1	ON
16	500	500.35	116.82	1	ON
17	510	510.34	119.88	1	ON
18	510	510.22	119.14	1	ON
19	500	500.41	116.84	1	ON
20	580	580.37	135.62	1	ON
21	535	535.47	125.86	1	ON
22	550	550.32	128.45	1	ON
23	560	560.33	130.78	1	ON
24	650	650.36	151.98	1	ON
25	1100	1100.29	154.69	1	ON
26	1100	1100.31	154.48	1	ON
27	980	980.35	137.74	1	ON
28	1000	1000.34	140.44	1	ON
29	1000	1000.32	140.57	1	ON

NUMBER	1	2	3	4	5	6
POSITION	6	6	6	6	6	6
TRASMISSION	0.37	0.37	0.37	0.35	0.35	0.37

NUMBER	1	2	3	4	5	6
MIRROR POSITION	DOWN	DOWN	DOWN	DOWN	DOWN	DOWN

Varie

1. shifts/experts oncall
2. wiki page
3. web page

1 – At FNAL: shifts / experts on call

- Shifts taken as of March, 15 : 380/1857 = 20.4%
- Shifts in Run 1 (Mar-Jul 2018): 615/3128 = 19.8%
- An expert-on-call always present on weekly base
- Spreadsheet with list of experts available for shifter

Laser experts on call - 2018

File Edit View Insert Format Data Tools Add-ons Help Last edit was made on February 27 by anonymous

A	B	C	D	E	F	G	H	I	J	K	L
	January	January	January	February	February	February	February	March	March	March	March
Starting day	11	18	25	1	8	15	22	1	8	15	22
Expert on call:	Marco Incagli	Diego Cauz	Octavio Escalante	Atanu Nath	Marin Karuza	Carlo Ferrari	Carlo Ferrari	Anna Driutti	Matthias Smith	Graziano Venanzoni	Andrea Fiorel
pager :	4305122192	4305122192	4305122192	4305122192	4305122192	4305122192	4305122192	4305122192	4305122192	4305122192	4305122192
(optional) personal phone :						393493235938	393493235938		1-618-691-8870	393338493409	

NOTE: the expert on call shift starts and finishes on Thursdays. First (last) day is in overlap with previous (following) shifter.

2 – Wiki page

- All Laser related infomation are mantained in a detailed WIKI page

Muon g-2

+ Overview Activity Roadmap Issues Calendar News Documents Wiki Forums

Wiki »

New wiki page Edit Watch Loc

Laser WIKI page

Introduction

This page contains stable and reliable enough information on the Muon g-2 laser calibration system.

For transient on-the-spot information please use the elog sites:

- https://muon.npl.washington.edu/elog/g2/Laser+Calibration+System/ for analysis related logs
  - ask UW people for an account, otherwise use G2Muon...
- http://dbweb5.fnal.gov:8080/ECL/gm2/E/index?category_id=21 for operational & shift logs
  - must use your FNAL services password, it is part of FNAL logbook services

Information

- how to edit and contribute
- General instruction for New Users

Software

- Offline
- Online and ODB
- Calibration
- Database and Slow Control

Hardware

- Hardware maps
- High Voltage System (Local Monitor and Source Monitor)
- Laser related hardware (laser control i.e. Sepia II, ...)

Procedures and Plots

- Laser System for Shifters
- Procedure for Double Pulse
- Procedure for Filter Wheel Calibration
- Procedure for Flight Simulator
- Laser performance plots

3 – Web page!

https://web.infn.it/gminus2/

Gminus2

Muon g-2 experiment at Fermilab, Italian group

Sitemap | Group | Members | Dissemination | Muon g-2 | Opportunities | News | Funding Institutions | House | Internal

The Muon g-2 Fermilab experiment (FNAL E989) plans to measure the muon anomalous magnetic moment with a precision of 0.14 parts per million, about 4 times better than the present world-average (dominated by the result of the BNL E821 experiment). The aim is to compare this measurement with the Standard Model prediction, which has a precision comparable to the present experimental one, and differs from the experimental value by about 3σ.

The E989 collaboration includes several participating Italian research institutions, which have the task to design, construct and operate the **laser calibration system** for the experiment electro-magnetic calorimeter. This system precisely monitors the gain the calorimeter, whose understanding corresponds to a significant systematic

Summary

- System is ready for data taking

Spare

Systematics on ω_a

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

Laser System Role:

Key element

Helps (timing)

Helps (timing)

Beam related effects

- The Laser is the key element in reducing the *overall (including effects on B, not listed here)* largest systematic error and it contributes to the reduction of 2nd and 3rd largest effects on ω_a

Systematics on ω_p

Category	E821 [ppb]	Main E989 Improvement Plans	Goal [ppb]
Absolute field calibration	50	Special 1.45 T calibration magnet with thermal enclosure; additional probes; better electronics	35
Trolley probe calibrations	90	Plunging probes that can cross calibrate off-central probes; better position accuracy by physical stops and/or optical survey; more frequent calibrations	30
Trolley measurements of B_0	50	Reduced position uncertainty by factor of 2; improved rail irregularities; stabilized magnet field during measurements*	30
Fixed probe interpolation	70	Better temperature stability of the magnet; more frequent trolley runs	30
Muon distribution	30	Additional probes at larger radii; improved field uniformity; improved muon tracking	10
Time-dependent external magnetic fields	–	Direct measurement of external fields; simulations of impact; active feedback	5
Others †	100	Improved trolley power supply; trolley probes extended to larger radii; reduced temperature effects on trolley; measure kicker field transients	30
Total systematic error on ω_p	170		70

→ Largest contribution