g-2: getting ready for beam

Marco Incagli – INFN Pisa

6 Settembre 2017

Outline

- The overall schedule
- Status of the muon line
- The g-2 detector
- The laser system

The overall schedule

- Expected beam : Nov 15
- Expected production beam : Jan 15
- Expect to run until July, 15 2018
- BNL “statistics” achieved ~3 months later? (depends on luminosity and storage capability)

- Next Collaboration Meeting Nov 30 – Dec 2 (FNAL)
- Next-to-Next Collaboration Meeting March 22 – 24 (FNAL)
- Physics meeting 2018 Late July (Denver)
- Physics meeting 2019 Late May (Pisa)

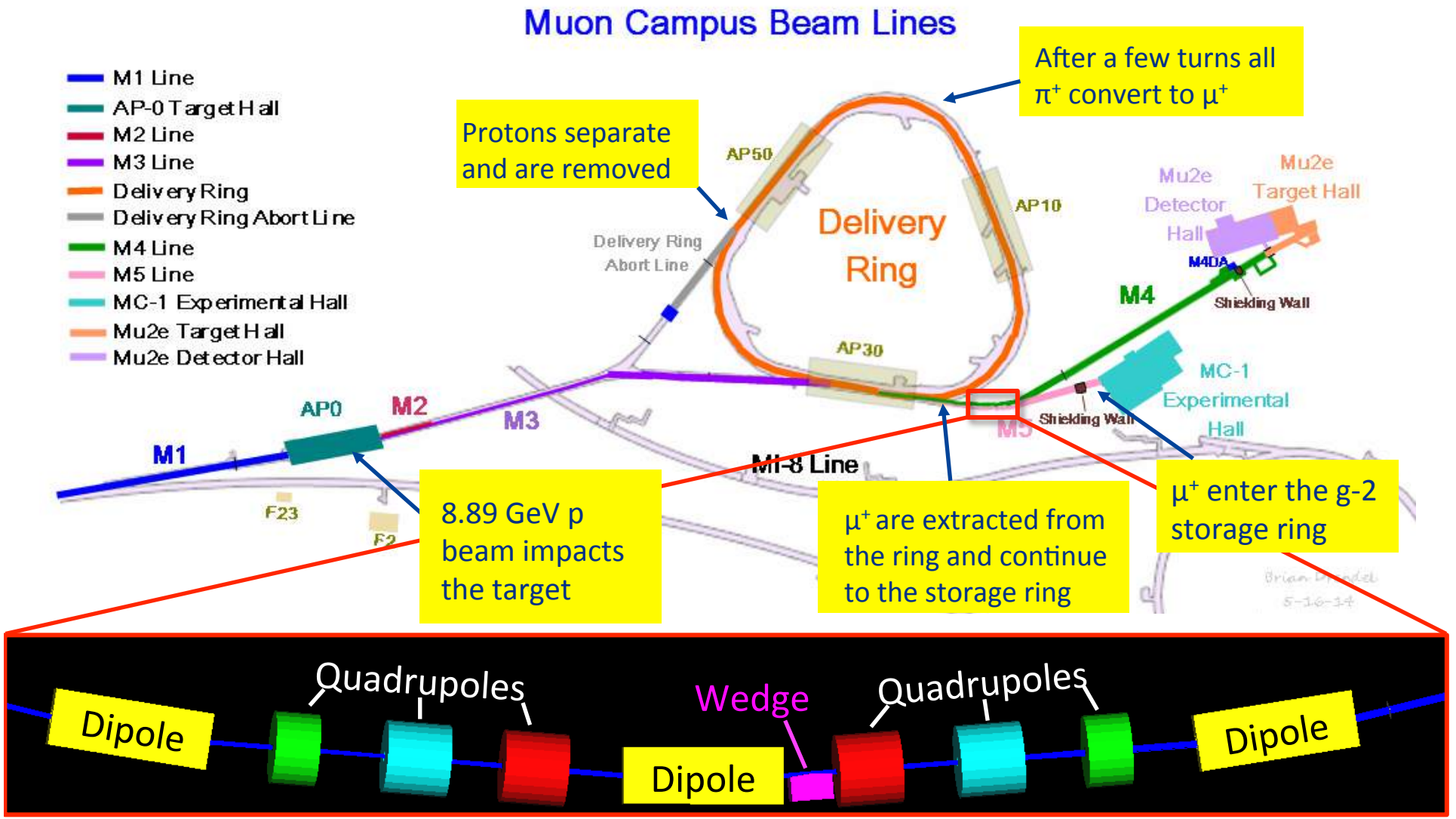
Shutdown schedule

- 8/21: Kicker week
  - K1, K2, K3 feedthrough work. All three rebuilt. Testing pending better vacuum.
  - Inflector shorted bus work. Quench detection main culprit identified
  - Trolley drive, shimming, plunging probe work parasitic to kicker work
  - Full rate DAQ tests paused due to operating system upgrades
  - Kickers now requesting operating vacuum of 1e-6 Torr.
- 8/28: RF and SRV week
  - Installation of 2 more turbo pumps completed
  - RF installed on Q3, expect low power tests this week
  - Optics being installed for electro-optical measurements of kicker pulse. Expect low power tests this week.
  - Inflector tested, failed test
  - Full trolley run finally taken with inflector on
  - Full rate DAQ tests still on hold
  - Site wide power outage Friday morning
- 9/4: ~~collimator week~~ Inflector week
  - Inflector testing has highest priority
  - Collimators come out (at least 3) but expect most of the week will be planning work
  - Trolley/plunging probe cross calibration, then trolley goes to Argonne
  - Full rate DAQ tests continue
- 9/11-10/15: quad/kicker month, ¾ SRV always closed and best vacuum possible.
- 10/16-10/29: Installation
  - Tracker, collimators, trolley, plunging probe, cryo pump gate valves
  - Last collimators come out and go back in
- 10/30: stable configuration
  - Expect breaks in SRV for trolley
- Mid November: first cryo pump installed. Schedule driven by procurements.

Shutdown schedule very busy from now to mid-November, when first "real" muons are supposed to arrive

Machine starts Oct, 23 and first bunches expected to arrive in g-2 ring end October, in particular to test the M4-M5 transfer line (see next transparency)

Muon Campus Map



Muon Campus overview

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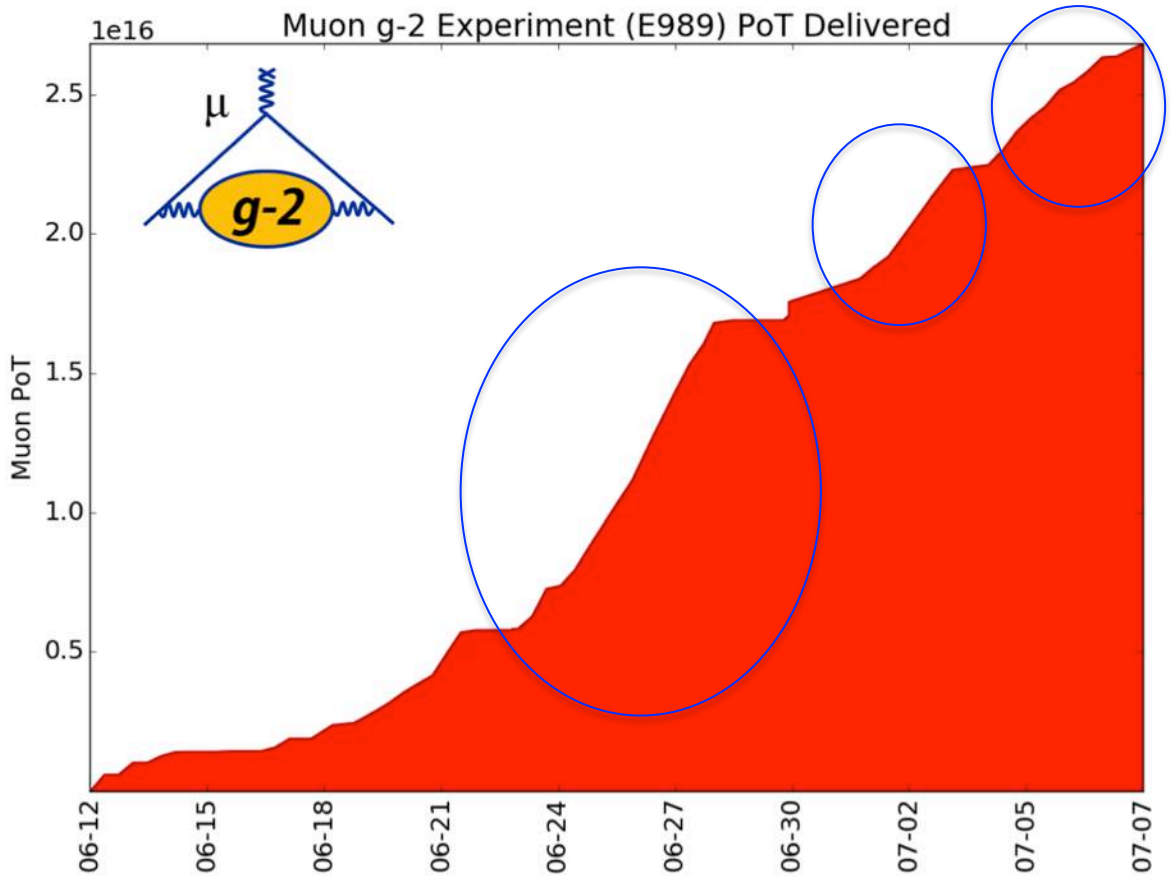
Test Run : 1 June – 7 July

- 3M muons and 2.5x10^{16} pot collected in 38 days of test run
  → see talk of Anna D.
- need 10^{20} for real measurement



Only 3 periods of "real run"

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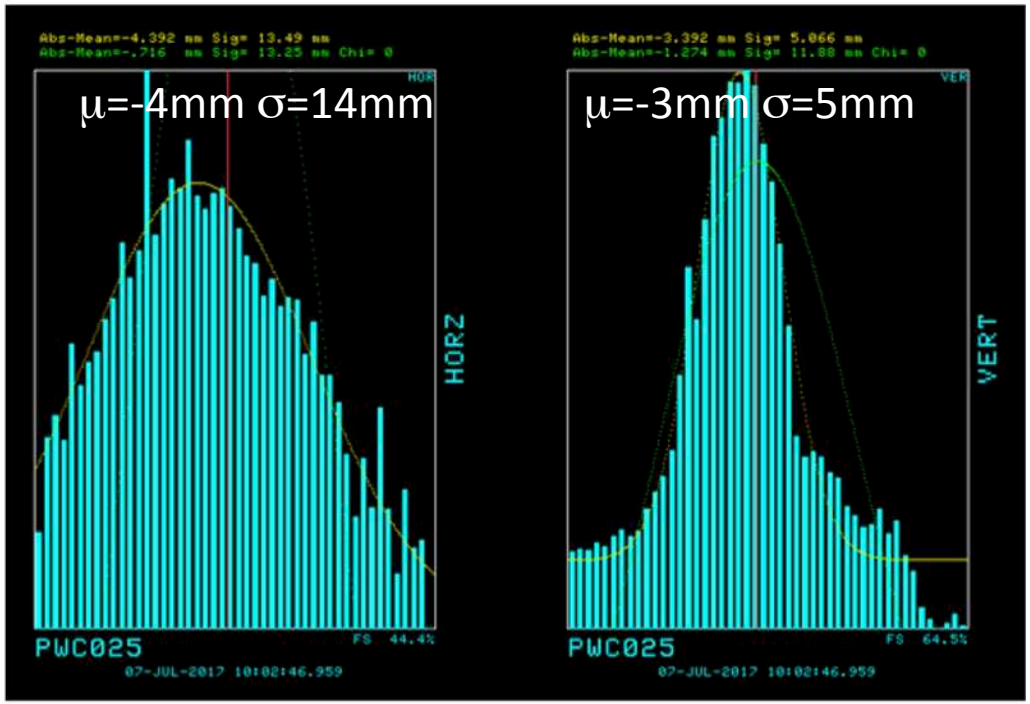
Beam profile before GM2 ring



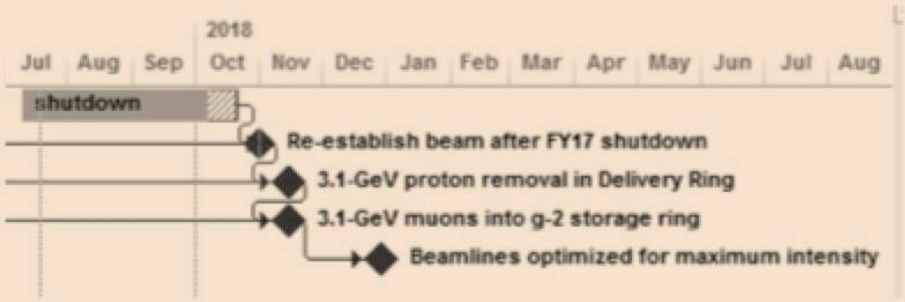
- 3 billion muons sent to storage ring
- p = 3.1 GeV ± 0.5%
- ring acceptance ± 0.1%
- wide beam, in particular x
- not perfectly centered
- proton contamination 70:1

- beam dynamics:
  - use delivery ring → proton contamination/momentum spread
  - beam transport M3-M4 and M4-M5 (~25% loss)
  - beam profile

Schedule from Accelerator Division

Summary

- Had good success with FY17 commissioning run
  - Accomplished all pre-shutdown goals
  - Delivered ~3 billion muons to storage ring
- Have a plan for repairs and improvements during shutdown
- Have a plan for continued commissioning
  - Commission proton removal (several weeks)
  - Commission full repetition rate
  - Optimization for maximum intensity



Fermilab

18 Accelerator Status and Plans I M Convery 7/24/17

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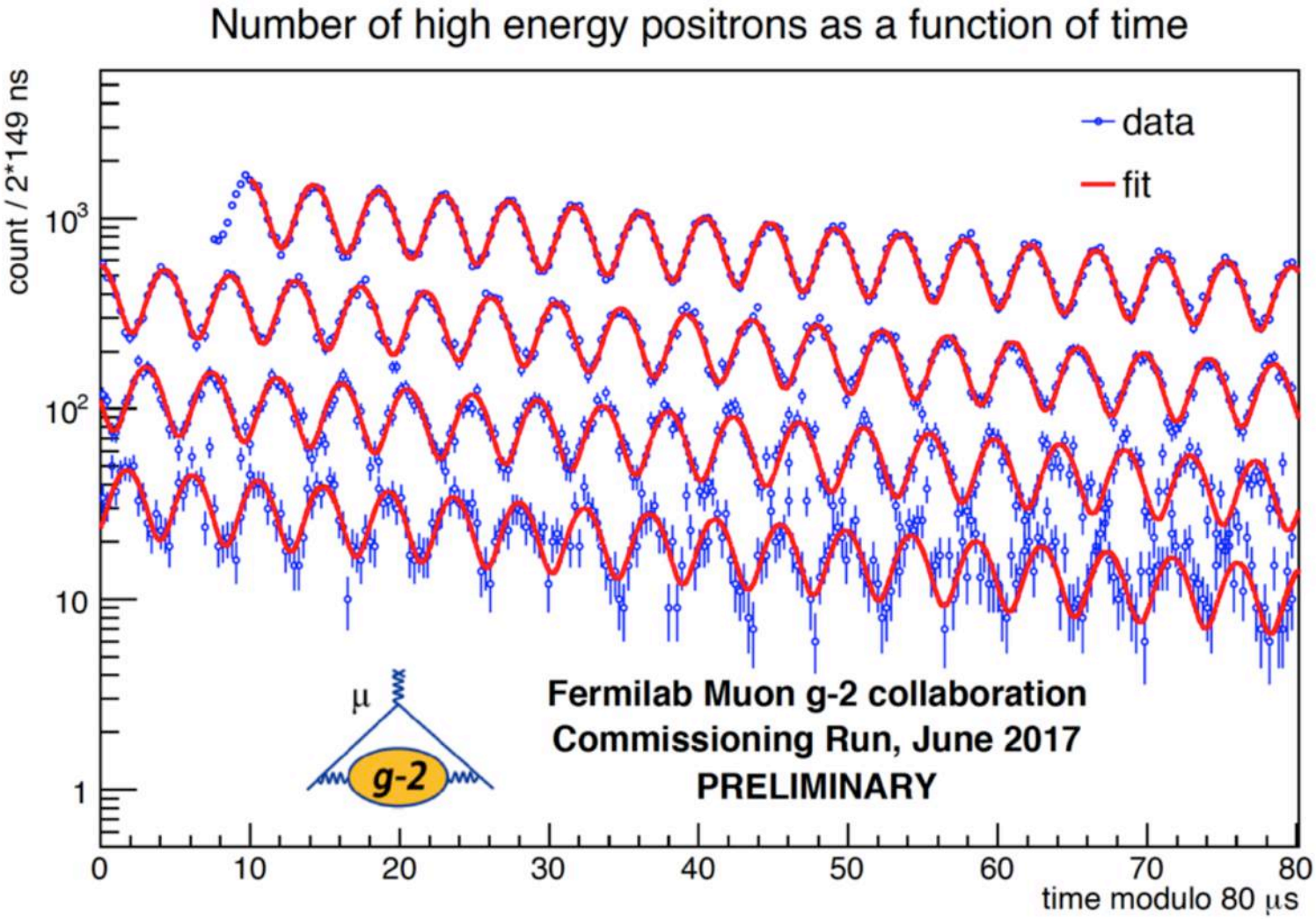
Main goal achieved: the first Wiggle Plot



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The g-2 detector

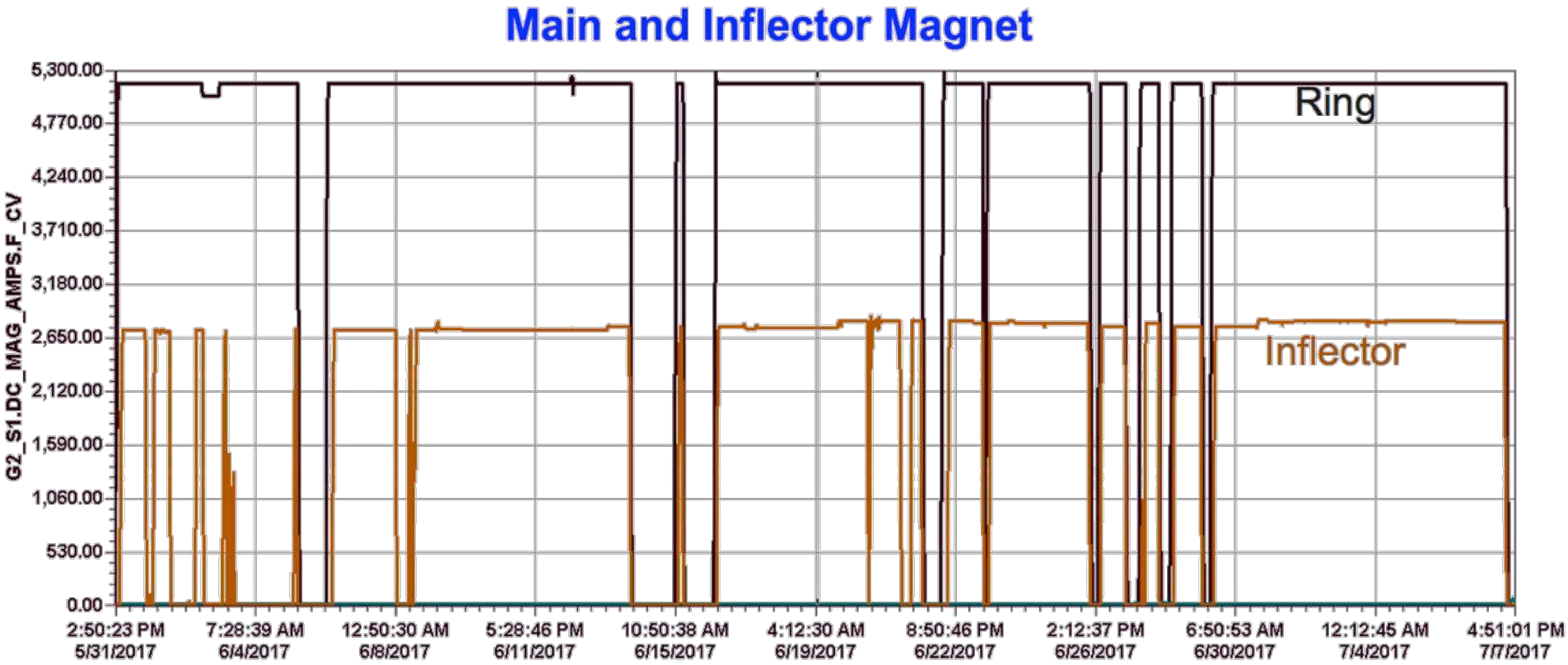
- Tracker
- Calorimeter
- Laser calibration system

- Main Magnet
- Inflector
- Kicker
- Quadrupoles
- Trolley

$$a_\mu = \frac{m\omega_a}{eB}$$

(red = subsystems descibed in the following)

Magnet up time



Main Magnet: SuperConducting magnet at ~5280A – up most of the time with no problems

Inflector: at the intersection point between beam line and Main Magnet

- **several trips in first part of data taking limited the efficiency**
- **new inflector being built with 50% increased efficiency → summer 2018**

Inflector and Quadrupoles

- inflector instabilities due to cooling problems
  - more valves and fans added
  - starting from 27 June no more trips
- Sparking problems in Quad4 (4 quads all together) at ~20 kV − supposed to reach 25 kV
- sparking due to
  - inflector instabilities (trips)
  - vacuum not as good as expected (10^{-6} torr, expected $2x10^{-7}$ torr)
- vacuum:
  - suspected chamber leakage: tested, no evident leaks found
  - add 2 more cryo pumps to the system

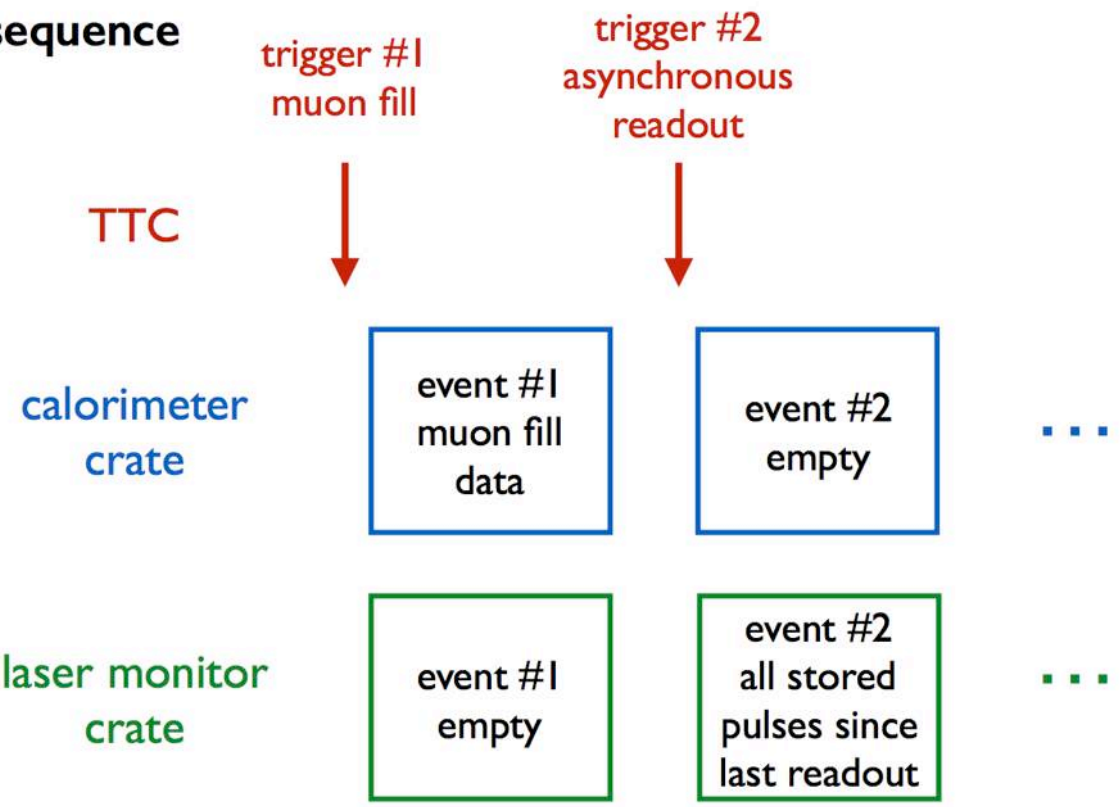
Laser System

- The Laser System is getting ready for beam
- Main activities going on:
  - Analysis of data collected in test run → talk of Anna D.
  - Local Monitoring Electronics and DAQ → talk of Michele I.
  - Async trigger for Americium
  - New PMTs for Local Monitors
  - Double Pulse

Async trigger for Americium

- 2 types of trigger produced by the Master Clock:
  - MUON trigger: synchronized to the machine muon fill
  - LASER trigger: for "out of fill" pulses, based on laser board
- The Source Monitor PMTs have an Am source (5 MeV α particles) built in for absolute calibration and stability control
- Of course the source emits in an asyncronous way, therefore a third trigger type has been setup and tested
- ASYNC trigger: when a readout board is set in *async mode* and a trigger arrive, the event segment is recorded in the board buffer. After a programmed delay from the MUON trigger (e.g. 5msec) a global ASYNC trigger is issued and *all the buffers of the boards set in async mode are readout*

Async trigger example sequence



- tests have been performed using NIM logic to build the trigger
- in the future, the Naples boards will send the trigger to the readout boards

- clearly the data structure is different from the standard one
  - DAQ has been made compatible with new structure (DAQ group)
  - new *data unpackers* had to be written for reconstruction (A. Driutti)

New Local Monitor PMTs

- 24 PMTs arrived in Italy → shipment to Fermilab
- HV system arrive at Naples Sep 15 → shipment to Fermilab
- Mounted in the period 25 Sep – 13 Oct
  - Activities:
    - prepare the divider of the new PMTs : BNC and SHV connector to be mounted
    - install the boxes holding the PMTs
    - mount new PMTs
    - install new HV system → remote programming
    - prepare the fibers to be inserted in new PMTs
    - connect to readout boards (rider boards in μTCA crate)
- If all steps are not accomplished, start with 1PMT and switch on second one summer 2018

Double Pulse system

- Why? To measure the calorimeter response to 2 consecutive particles (positrons)
- 2 time structures: one at short times (~20nsec) due to SiPM, one at longer times (~20μsec) due to power supply

Design and performance of SiPM-based readout of PbF_2 crystals for high-rate, precision timing applications

J. Kaspar[a,*], A. T. Fienberg[a], D. W. Hertzog[a], M. A. Huehn[a], P. Kammel[a], K. S. Khaw[a], D. A. Peterson[a], M. W. Smith[a], T. D. Van Wechel[a], A. Chapelain[b], L. K. Gibbons[b], D. A. Sweigart[b], C. Ferrari[c,d], A. Fioretti[c,d], C. Gabbanini[c,d], G. Venanzoni[c], M. Iacovacci[e,f], S. Mastroianni[e], K. Giovanetti[g], W. Gohn[f], T. Gorringe[h], D. Pocanic[i]

[a] *University of Washington, Department of Physics, Box 351560, Seattle, WA 98195, USA*
[b] *Cornell University, Department of Physics, 511 Clark Hall, Ithaca, NY 14853, USA*
[c] *Laboratori Nazionali Frascati dell' INFN, Via E. Fermi 40, 00044 Frascati, Italy*
[d] *Istituto Nazionale di Ottica del C.N.R., UOS Pisa, Via Moruzzi 1, 56124 Pisa, Italy*
[e] *INFN, Sezione di Napoli, Ed. 6 Via Cintia, 80126 Napoli, Italy*
[f] *Università di Napoli, Corso Umberto I 40, 80138 Napoli, Italy*
[g] *James Madison University, Department of Physics and Astronomy, 901 Carrier Dr, Harrisonburg, VA 22807, USA*
[h] *University of Kentucky, Department of Physics and Astronomy, 505 Rose Street, Lexington, KY 40506, USA*
[i] *University of Virginia, Department of Physics, 382 McCormick Rd, Charlottesville, VA 22904, USA*

E-mail: kaspar@uw.edu

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Short time constant

- SiPM gain after a positron signal can decrease as much as 4% (measured with LED in lab)

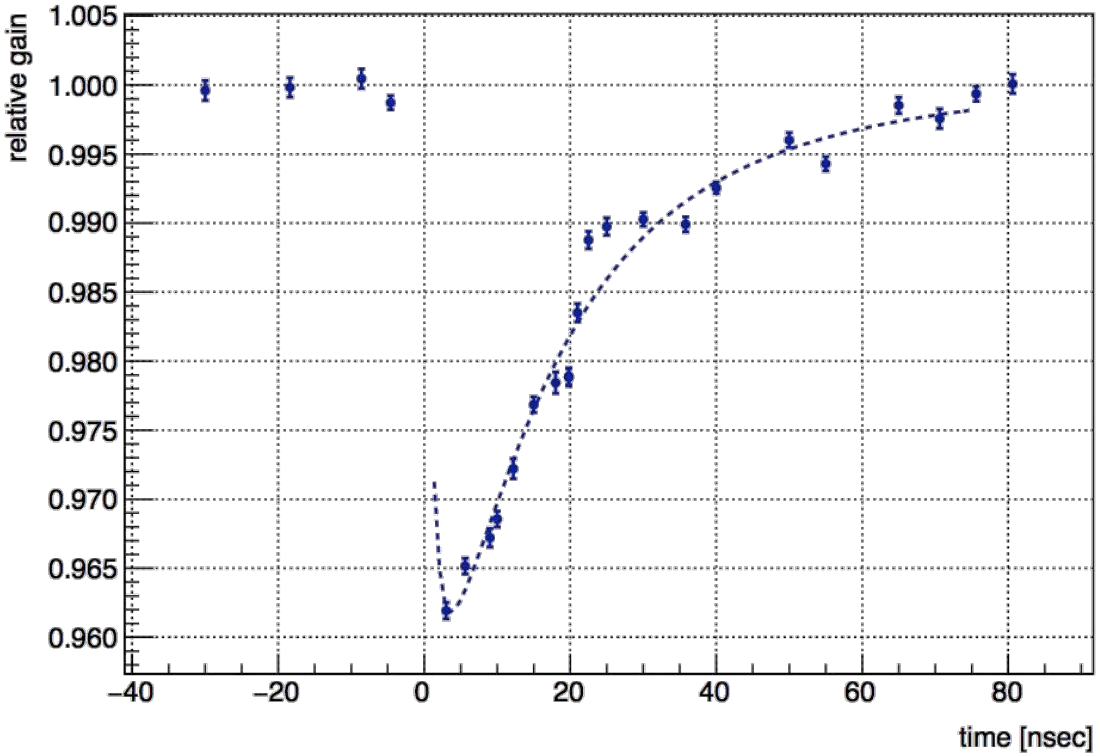


Figure 11. Relative gain of the laser pulse with respect to the reference LED pulse versus a fixed time interval between the two pulses.

Long time constant

- The overlap of ~100 signals due to muon decay within a fill (700μsec) in a crystal, convoluted with the power supply recovery time, can provide a gain drop of <1% (simulation)

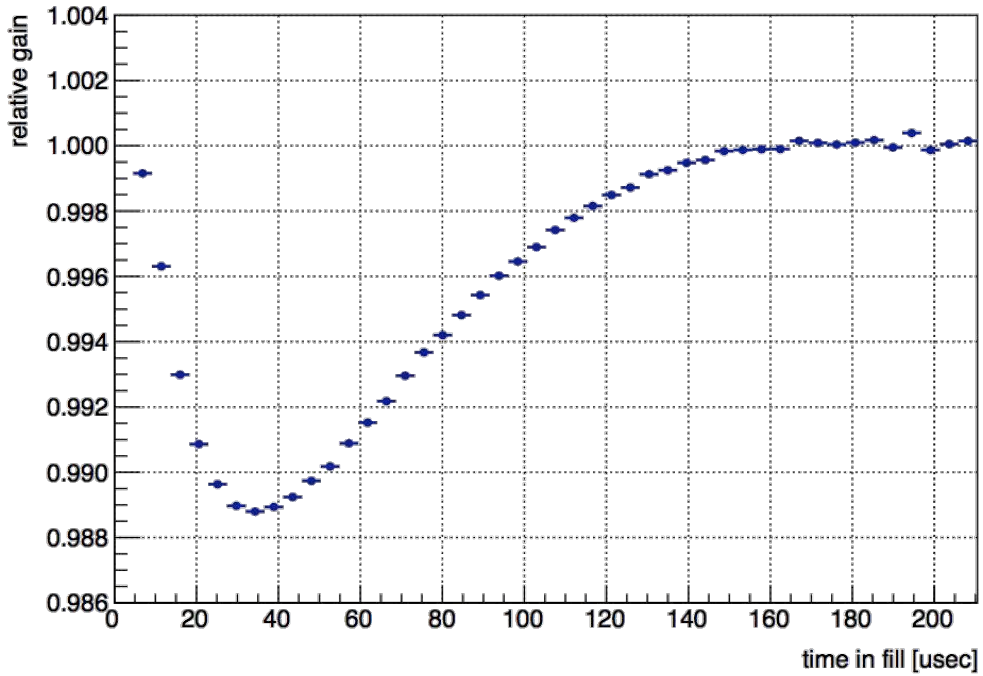
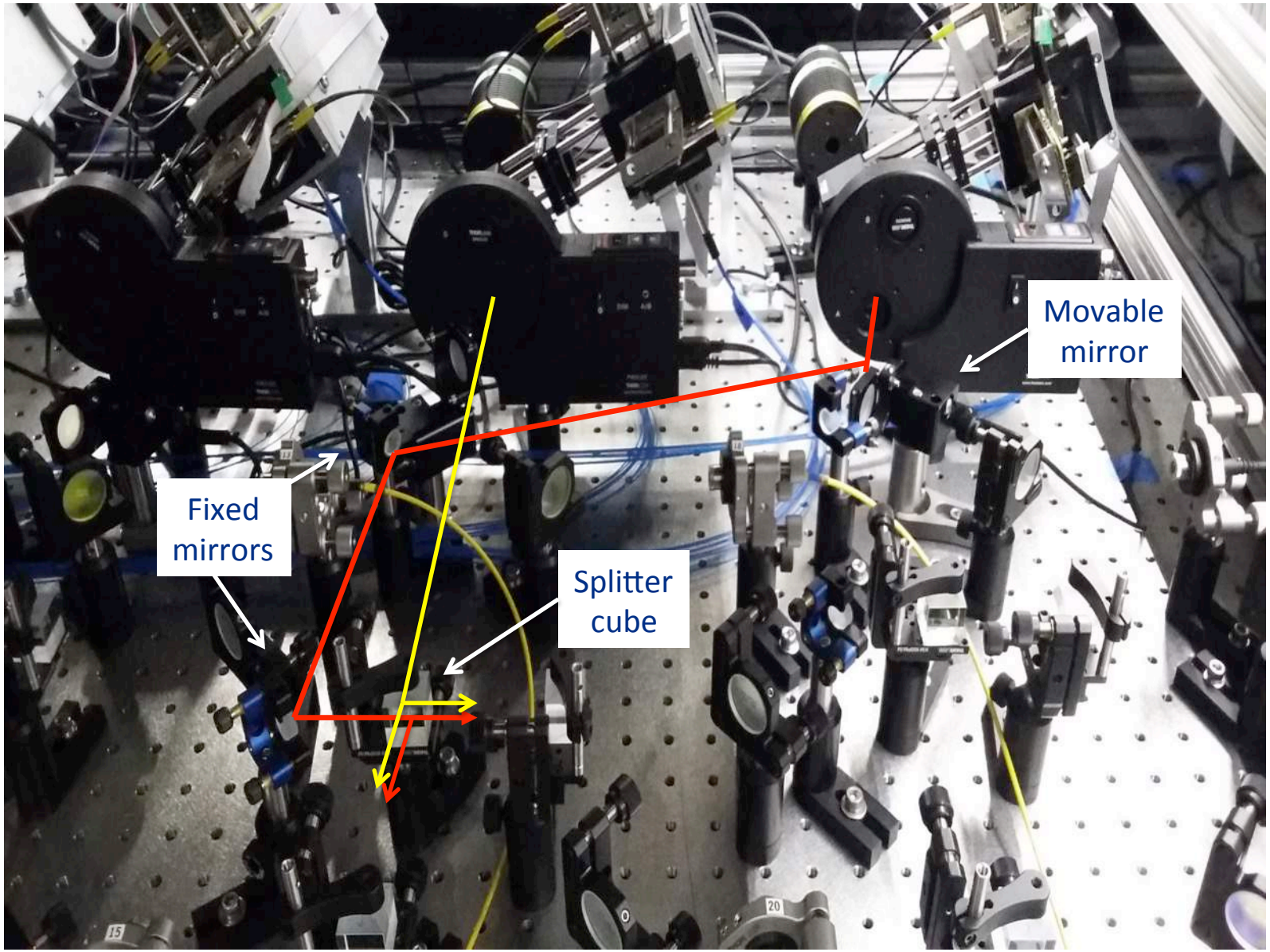


Figure 12. Average gain as a function of time with an initial rate of 2.1 MHz, 1500 PE pulses, and a rate proportional to $exp(-t/\tau)$ with time constant $\tau = 64\,\mu$s. The integrated current drawn is higher than we expect in the Muon $g-2$ experiment for the hottest crystal by a factor of 10. The slight droop and subsequent recovery of the gain is affected by a combination of the bias voltage supply and the buffer capacitance.

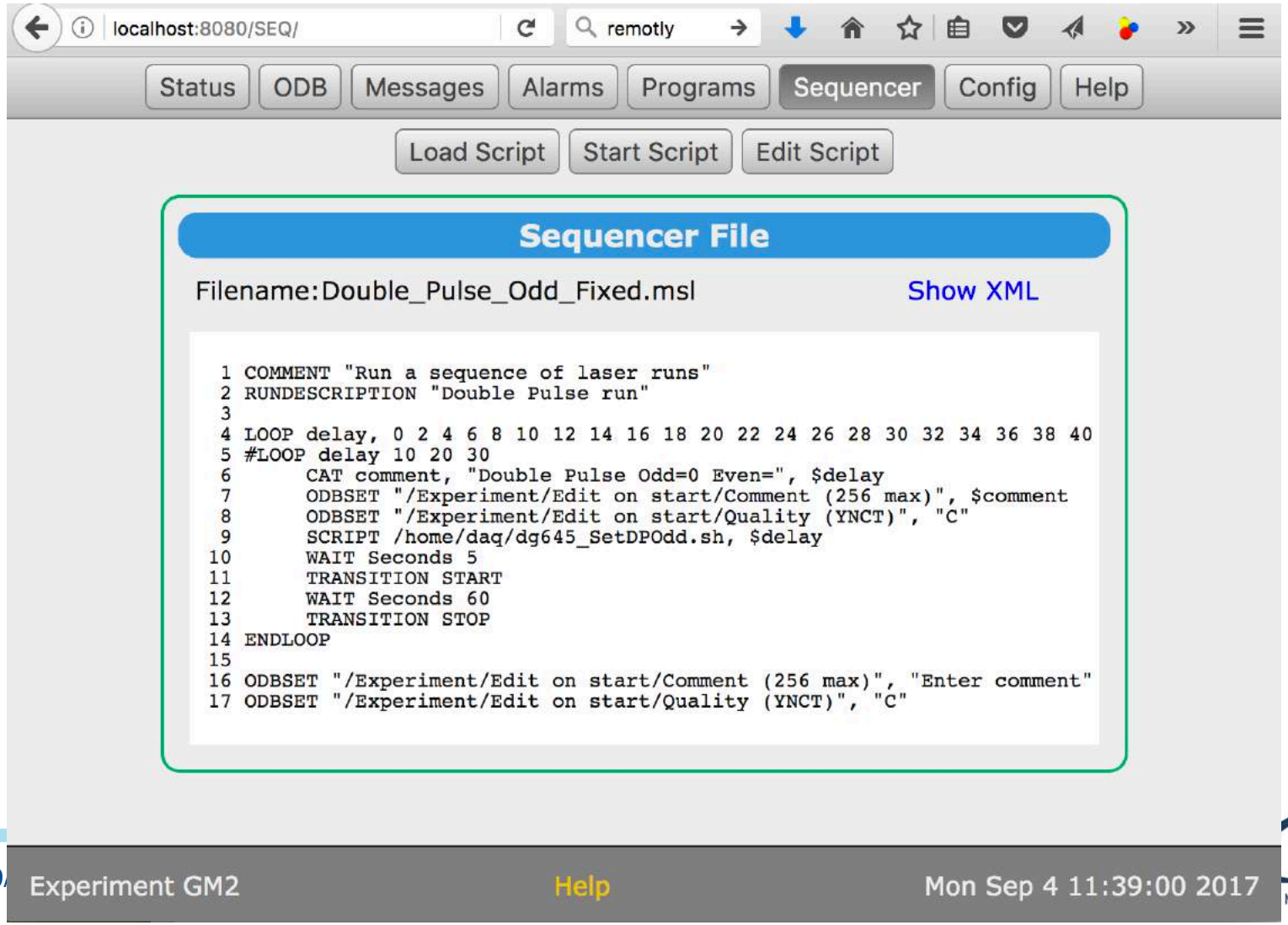
The Double Pulse setup

- system design
  - through a system of movable, remotely controlled mirrors, 2 different lasers are sent on into the same launching fibers
  - a delay generator, triggered by the laser control board, sends 2 pulses to the 2 lasers with a programmable delay ranging from 1 nsec to hundreds of μsec
- already installed
  - table optics to accomodate for movable mirrors
  - 1 complete test line using spare parts (→ picture)
  - delay generator, programmable from remote
  - NIM logic to be able to operate both in standard (single) mode and in double pulse mode
- missing, but ready to order asap
  - movable supports for mirrors



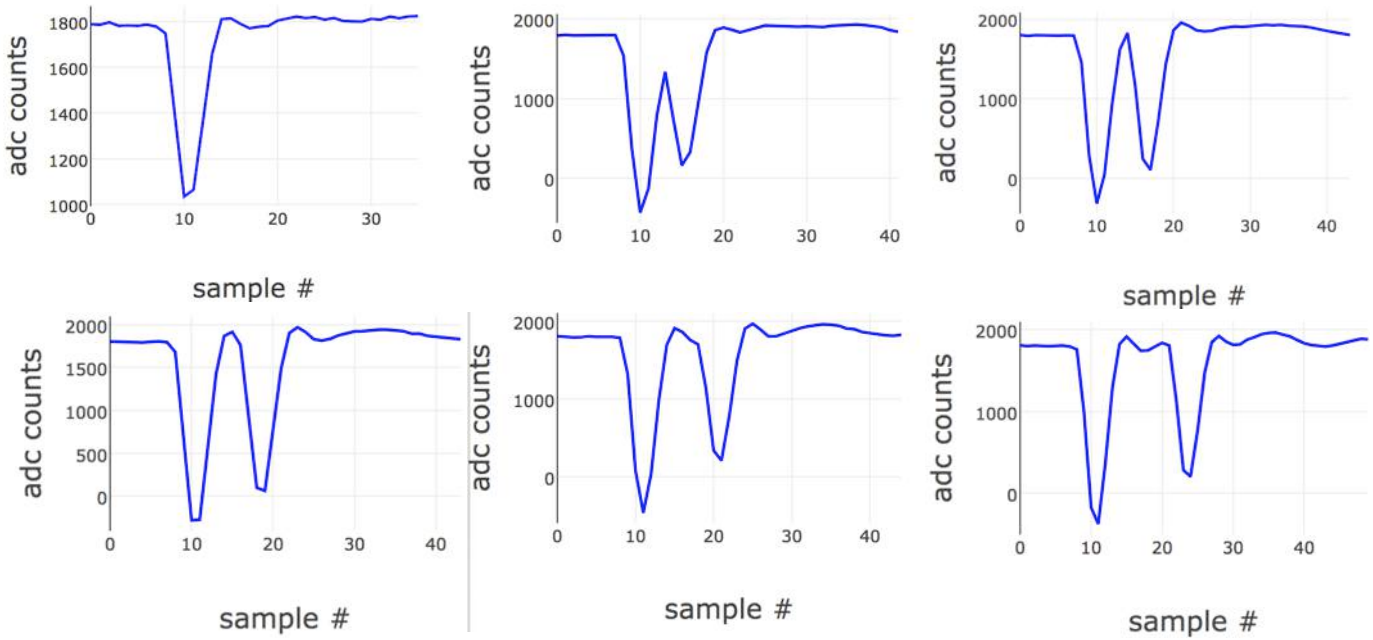
The Sequencer and first test of the system

- All instructions to operate the Double Pulse are coded in a standard Sequencer Script tested on week 25-30 aug



Double Pulse signal on the crystal

- run with second laser delayed in steps of 4 nsec



- x-axis : 1 *sample* = 1.25 nsec
- now we have "simply" to analyze this data and build the gain function!

Conclusions

- The accelator will switch on oct, 23 – shifts start 2 weeks before!
- Except for some tests of the beam line, muons will be delivered to MC1 starting from November 15
- ~2 months of commissioning
- Laser system operating and tested during the run of June-July 2017
- To be done before beam arrives:
  - complete optics for double pulse
  - replace local monitor PMTs with new ones
  - install HV power supply
  - prepare software tools
- Ready for beam!