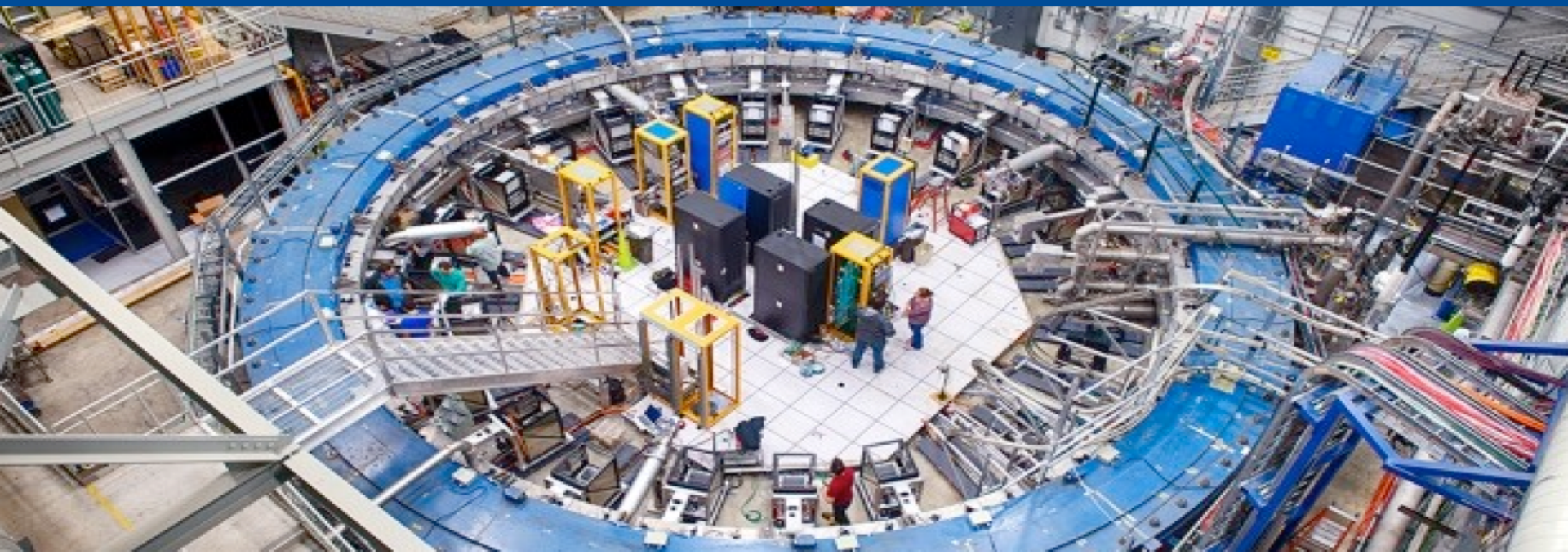


Stato dell'esperimento e attivita' gruppo Italiano

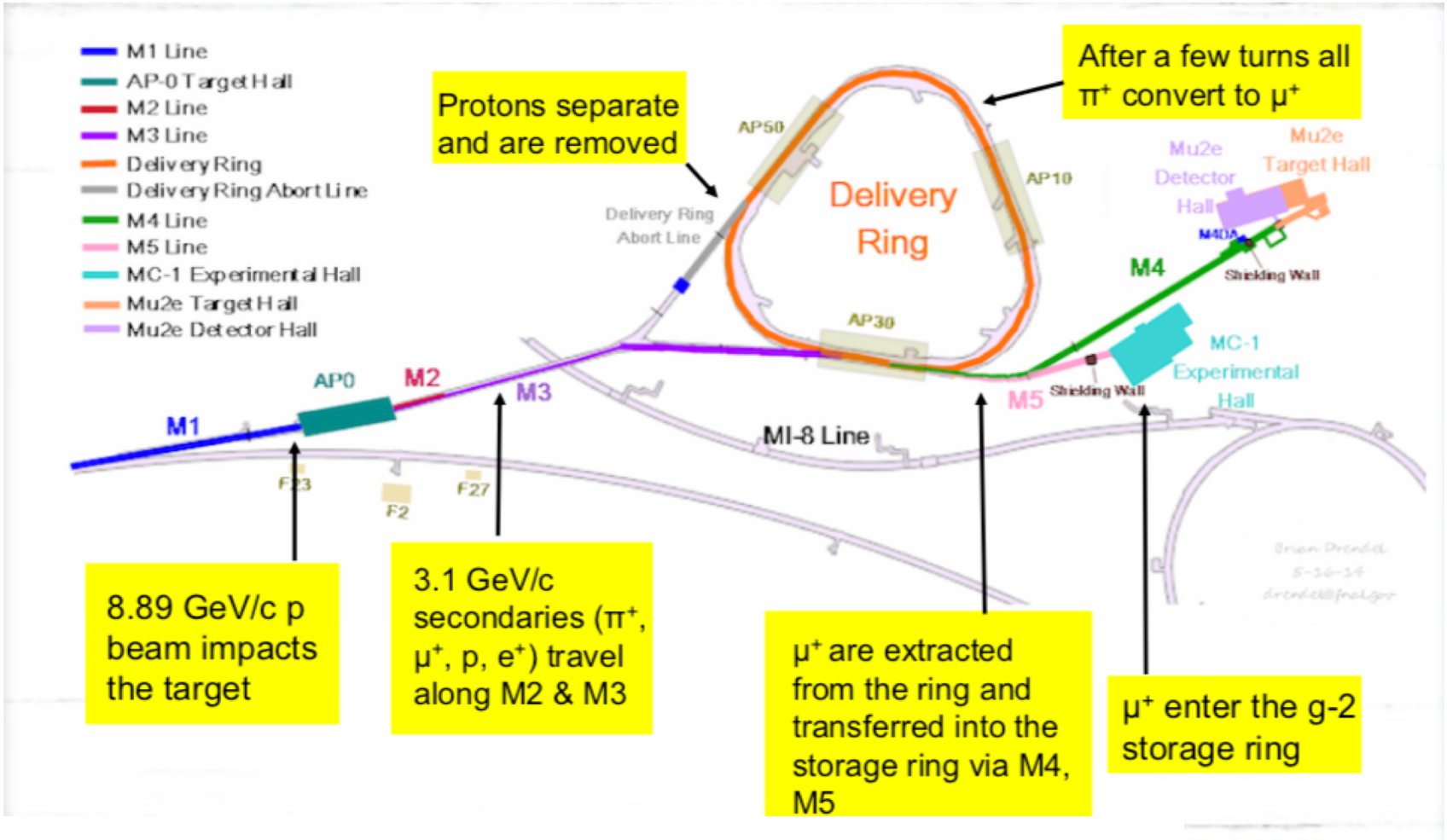
Graziano Venanzoni– INFN Pisa

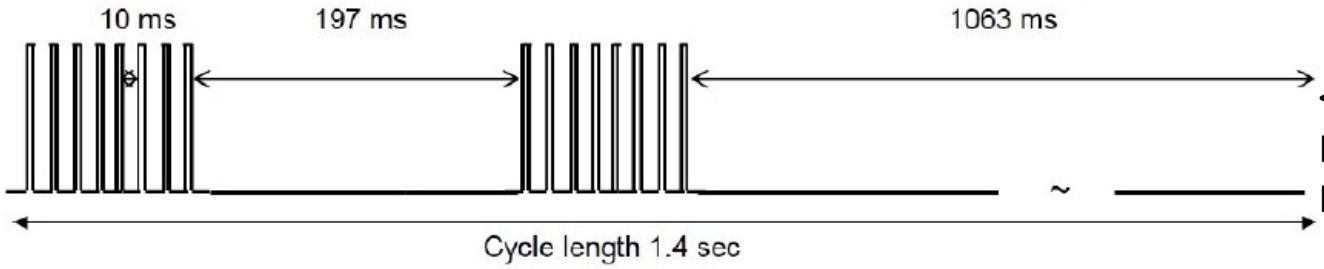
2/lug/2019

Outline

- Status of the experiment
- Italian activity
- Richiesta SJ 2019
- Conclusioni

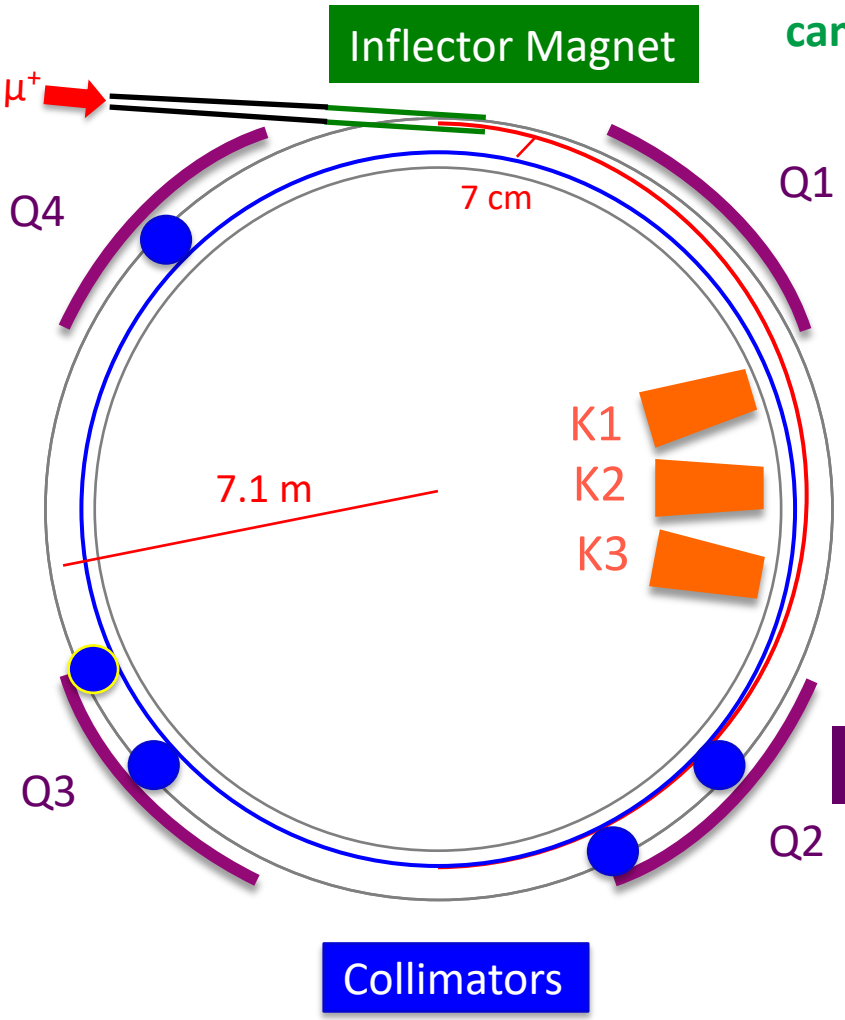
Accelerator Performance





$<R_{fill}>$~13Hz (R_{max}~100Hz)
N_μ/fill (TDR)~ 10^4
N_μ/sec(TDR)~ 1.3×10^5

Injection / storage



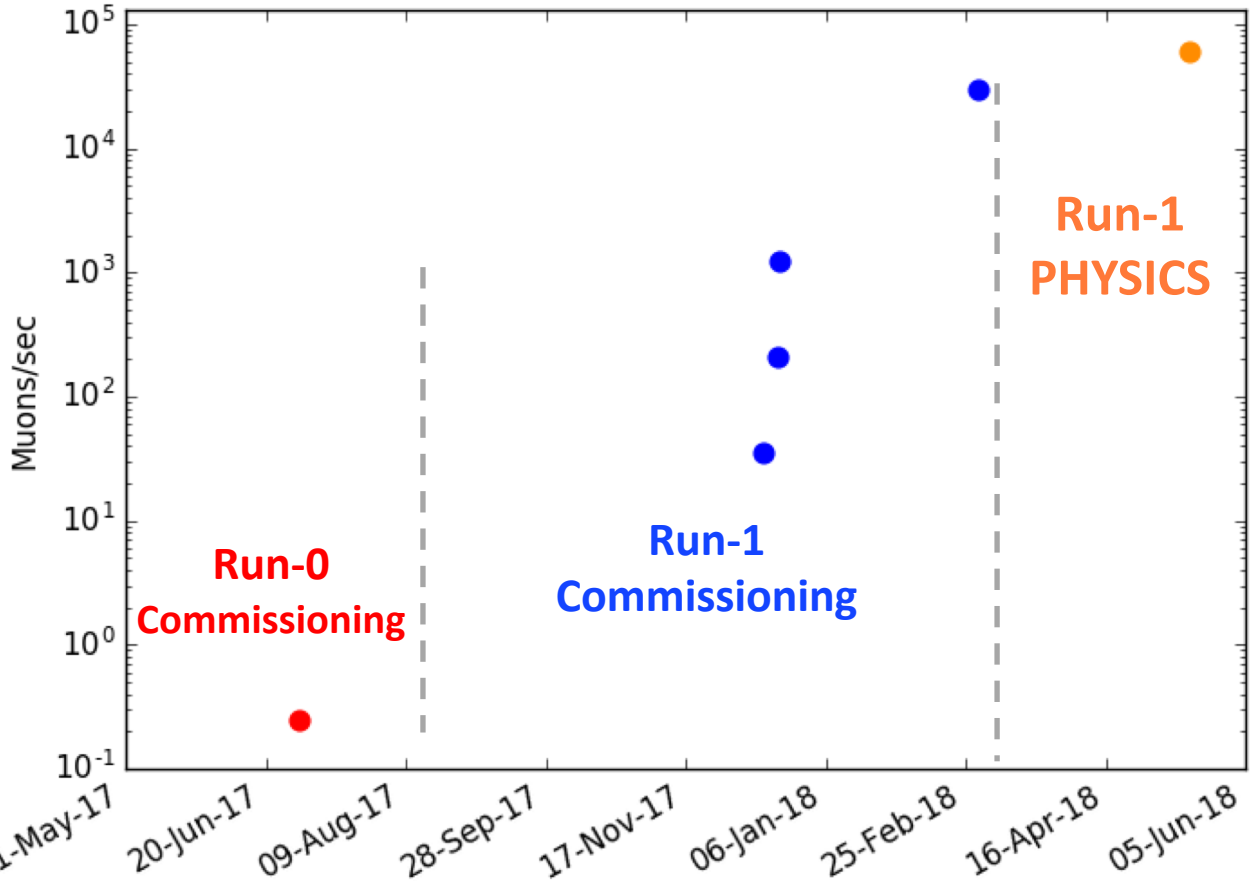
R_{fill}~13Hz

N_μ/fill (TDR)~ 10^4

N_μ/sec(TDR)~ 1.3×10^5

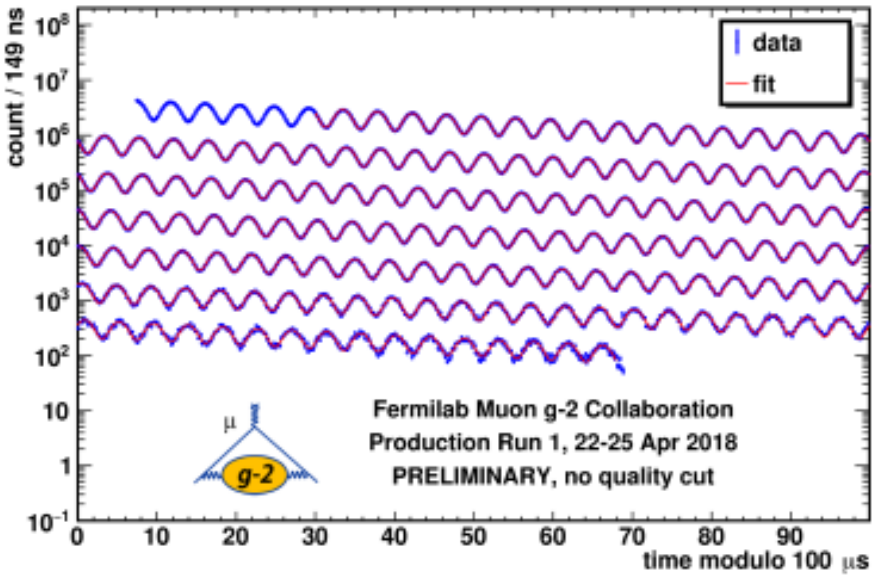
$N_{e+\ E>1.8\ GeV}$/fill (TDR)~ 10^3

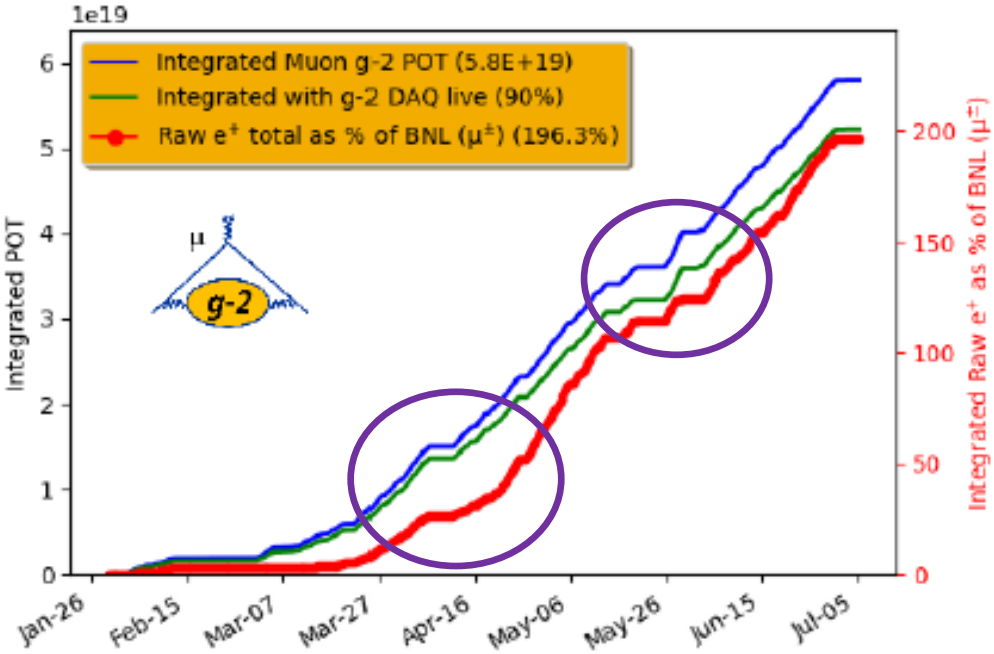
Commissioning : Jun 2017 – Mar 2018



5 orders of magnitude improvement in muon flux
TDR envisaged 200 days of commissioning (June-17, Nov-17 → Mar-18)
Still a factor 2 less than TDR

Run-1 (Apr-Jul 2018)



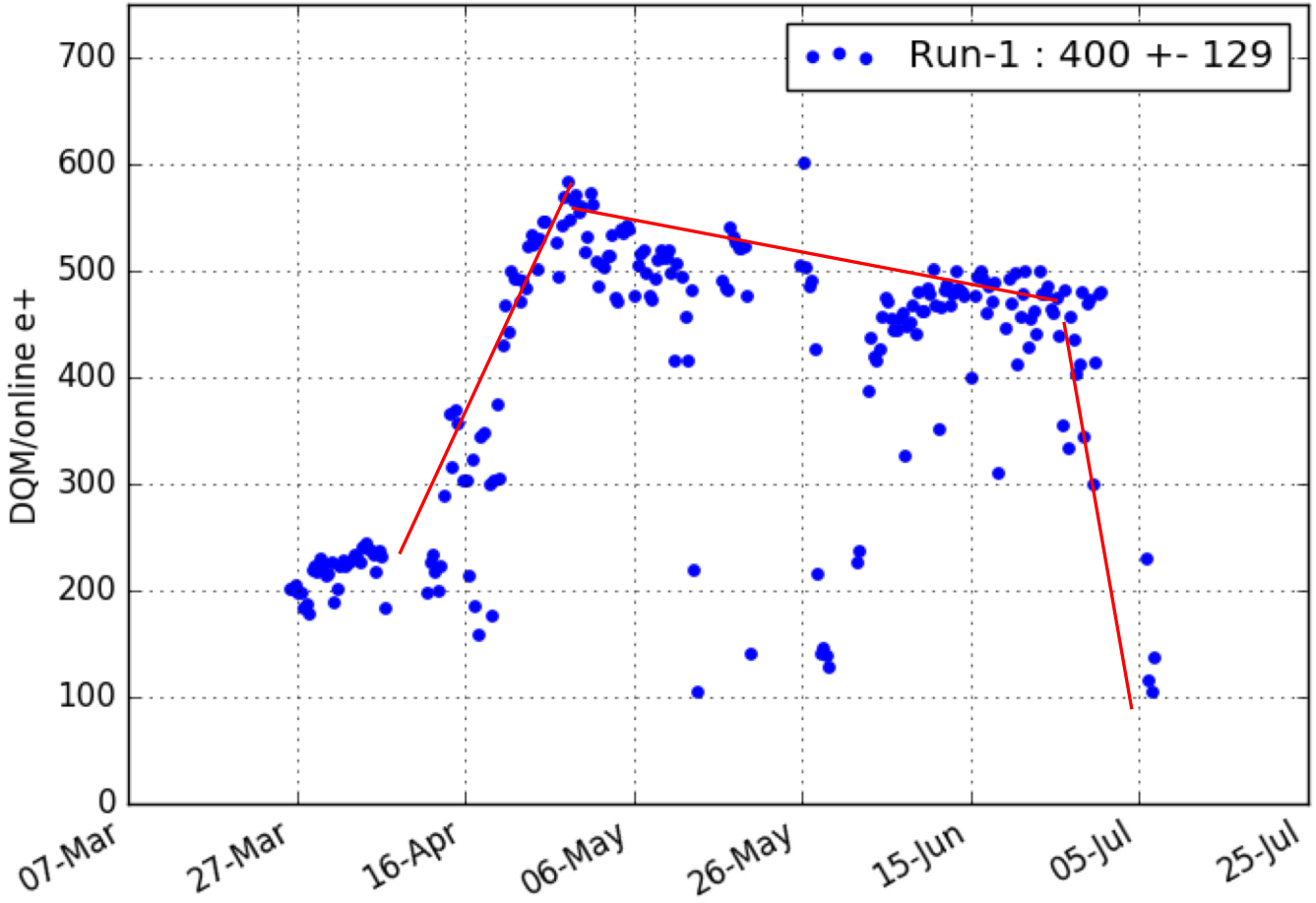


Name	Date acquired	n	Kicker [kV]	CTAG
9 day	05/04–05/12	0.120	128-132	2.4B
60 hour	04/22–04/25	0.108	128-132	1.0B
End Game	06/06–06/29	0.108	122-127	4.0B
High Kick	04/26–05/02	0.120	136-138	1.2B
Low Kick	05/17–05/19	0.120	123-127	0.7B
Superlow Kick	06/02–06/06	0.108	117–119	1.0B
Spin Resonance	03/22–04/06	0.119	104-105	1.6B

Raw data: x2 BNL **but** several different quad/kicker settings.
Resulted in 7 datasets with approx. x1.4 BNL.
Run 1 analysis underway. Total error (stat+syst) expected ~ 0.4 ppm

Run-1

On average 35% of e+/fill postulated in the TDR (1,100 e+/fill)



Run-1 to Run-2

Run-1 issues affecting integrated stats (& systematics/ease of analysis)

- kick was too low
- kicker had significant downtime
- quad sparks
- magnet downtime due to cryo issues

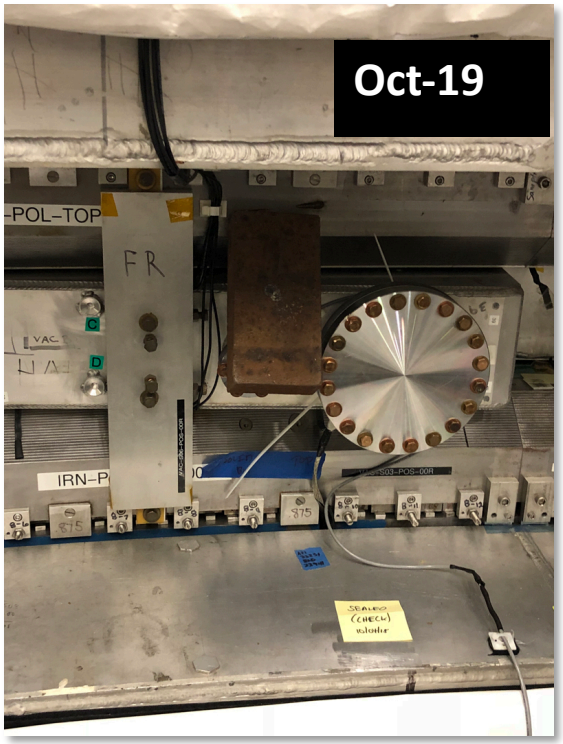
Such that fraction of days with > 100M e+ (TDR: 800M) was 57%.

CTAG=#e+ con E>1.8 GeV ~10^8 ~1% BNL (10^{10} e+)
Stat E989=2x10^{11} e+ (con E>1.8 GeV)

The run-1/2 shutdown work aimed to address these issues

RUN2

- Oct-19: Magnet field incident: an iron brick was pulled into the magnet gap
- Oct-20 : Work Pause
- Nov-13 : HPI Report
- Nov-14 : MC1 Access resumed
- Nov-27 : MC1 High Bay Access resumed
- Dec-28 : Resumed kicker/quad work
- Jan-28 : Magnet turned on
- Feb/March: Commissioning/Beam tuning
- March: start of production run
- July 7: end of production run



Resumption of shutdown work delayed by ~4 months

Improved role articulation

g-2 Operational Roles and Responsibilities

In this document we describe the roles and responsibilities pertaining to the safe and optimized maintenance, operation (and upgrades) of the g-2 experiment.

Muon g-2 Safety Improvement Plan

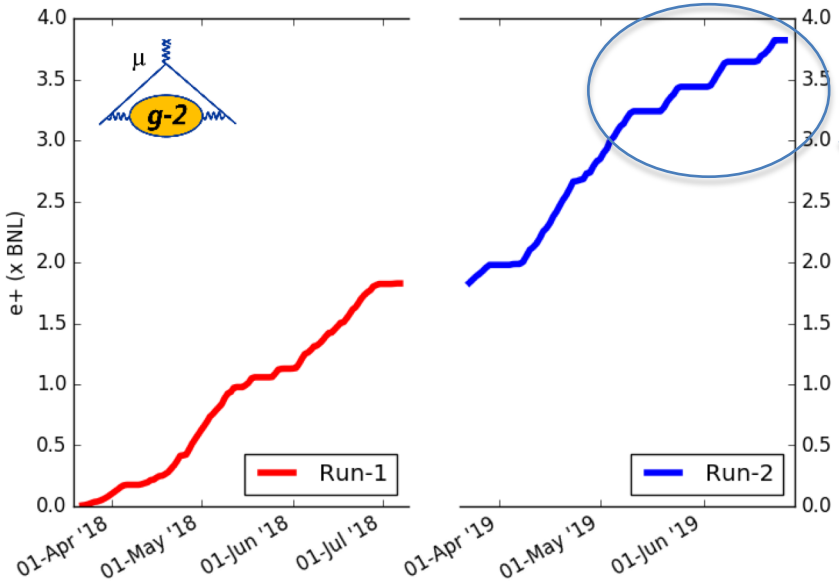
Introduction

This document outlines a plan from the g-2 experiment in response to a safety incident where a piece of ferromagnetic material, an iron brick, was inadvertently brought to an unsafe distance from the magnetic field generated by the g-2 storage ring. Due to the large gradients in the magnetic field and the mass of the brick, a significant force developed that led to the brick accelerating rapidly into the storage ring gap as it was in the hands of a postdoctoral researcher. Fortunately, there was no injury or serious damage to equipment, but the potential to maim an individual or cause very serious damage to the experiment was narrowly avoided.

Run 2 Plan - V1.2
Muon g-2 Collaboration

Run-2 aim:
Double Run-1 dataset
→ x 3.3 BNL (raw)

RUN-2 (April-July 2019)



Almost doubled the statistics at 1 working point

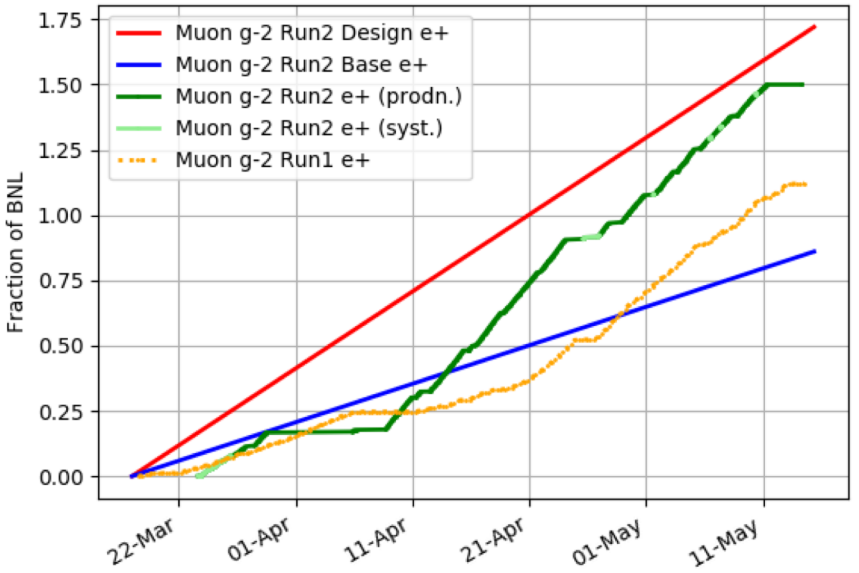
5/14 Cycle (5 days beam on; 9d beam off) due to Laboratory budget saving

– Magnetic field uniformity about 2x better

• Run 2 in progress

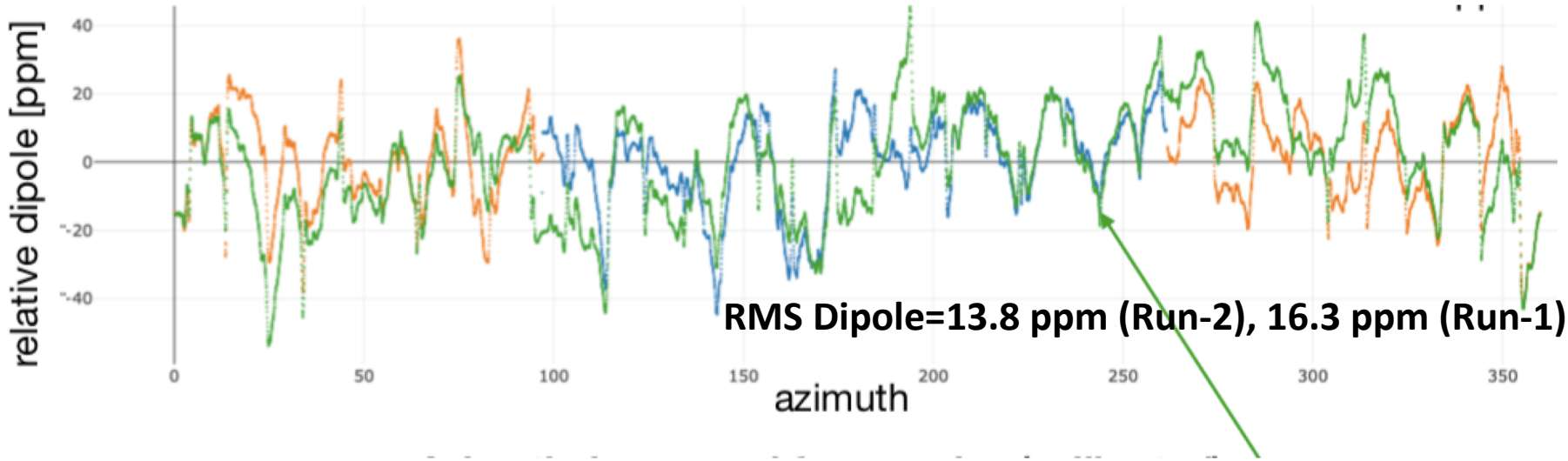
– Currently collected ~2x the statistics of E821

– Improved stability of run conditions (1 working point)

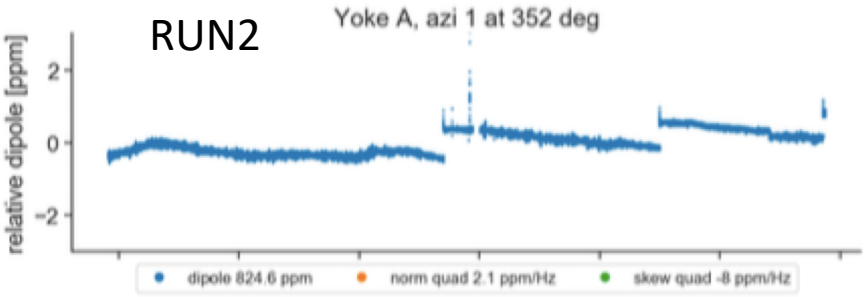


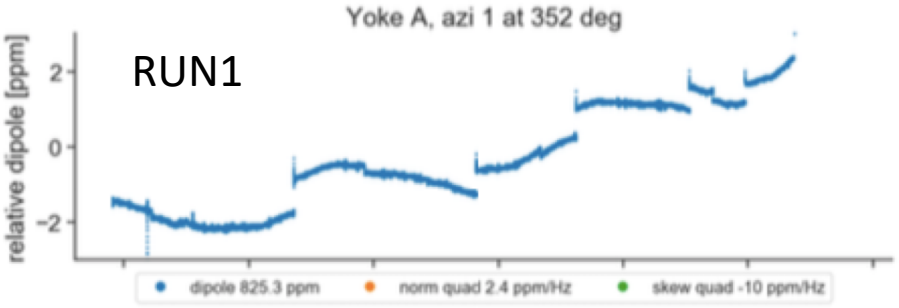
Field Performance

More uniform and stable than Run-1

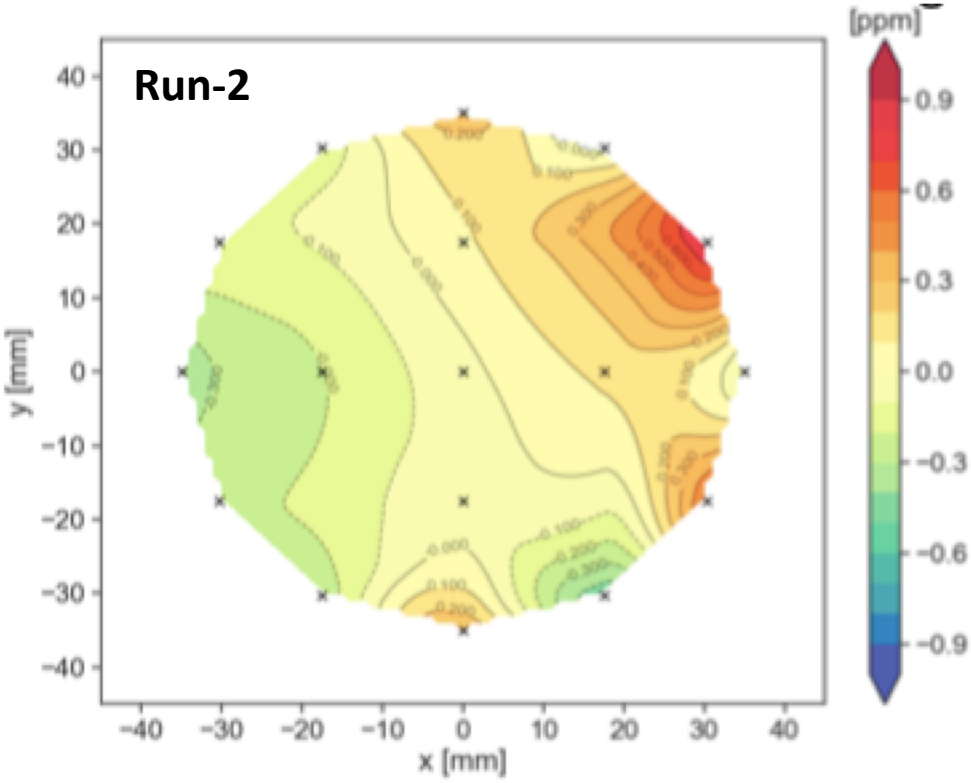


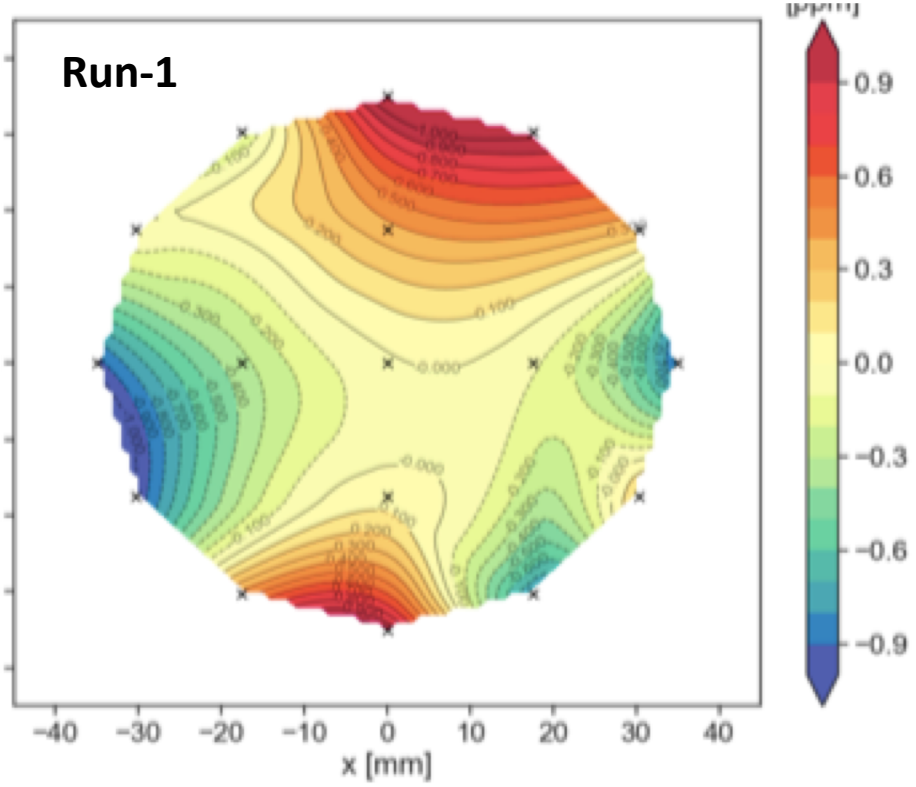
Insulation added has reduced temperature dependence





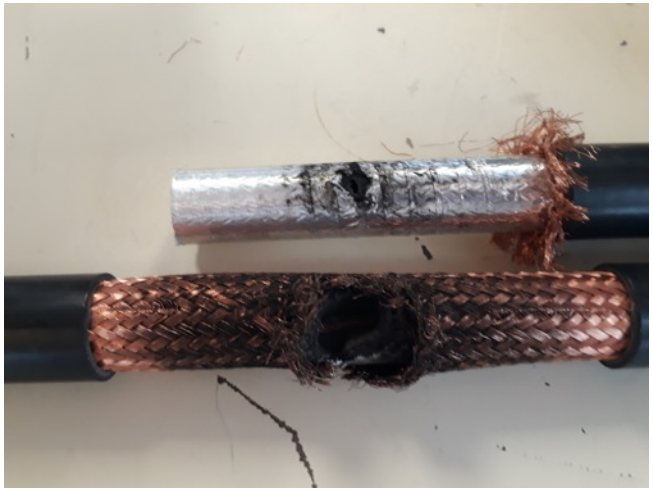
Field Performance

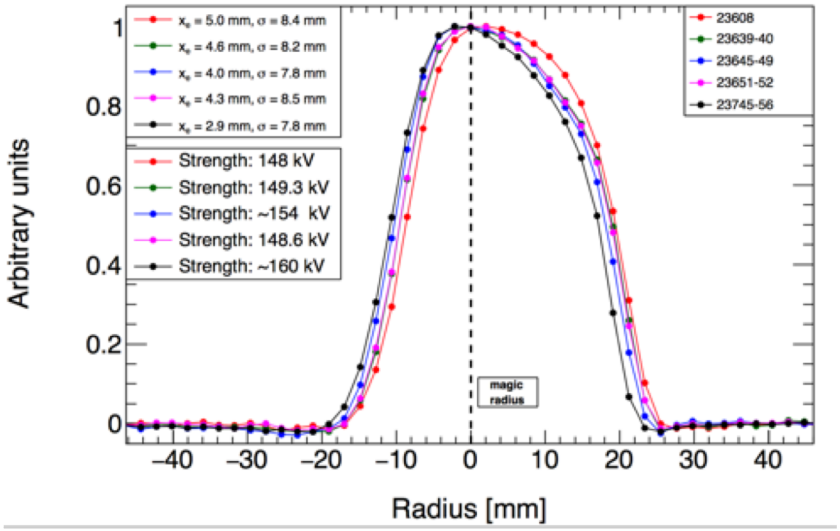




Run-1 to Run-2

Cryo : expected downtime now 2.5 days/month on average.

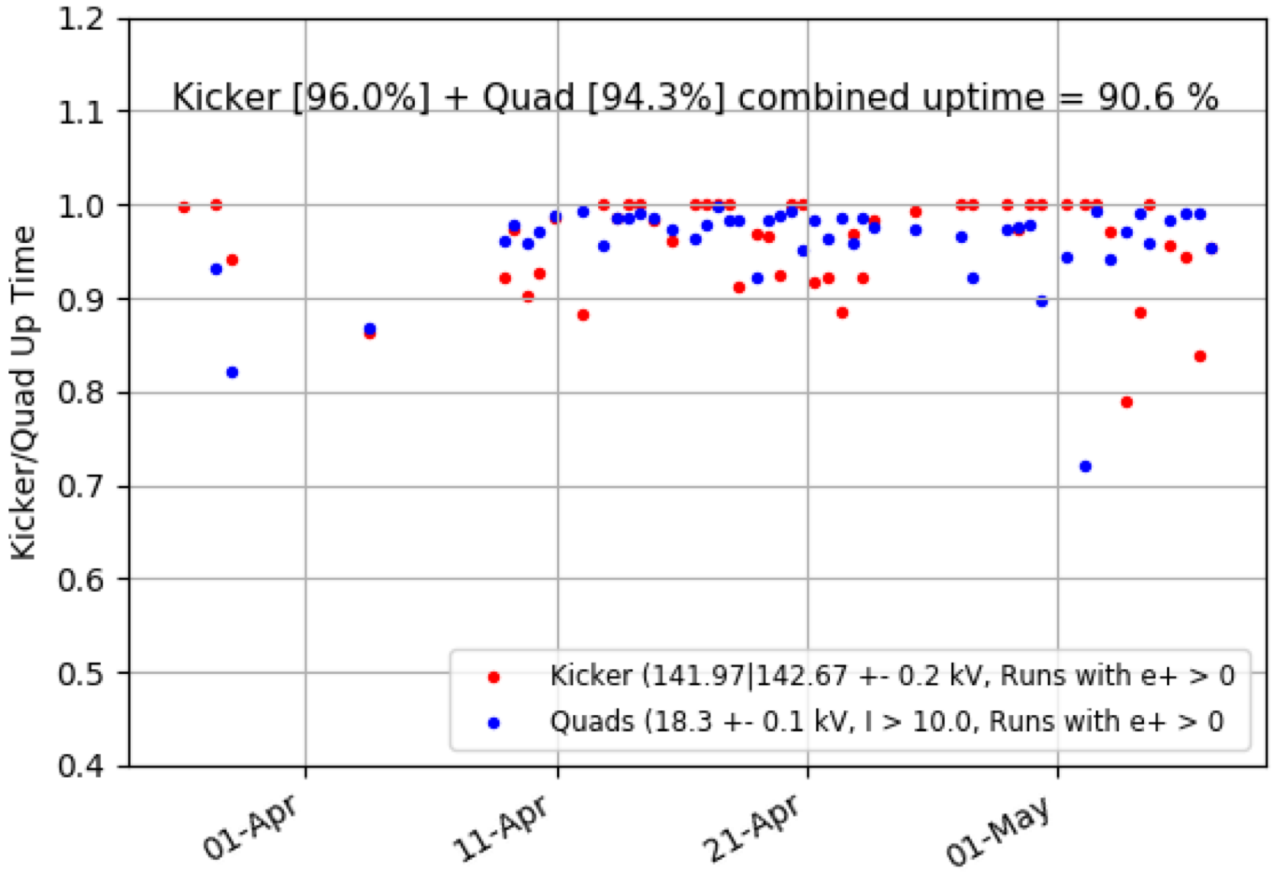




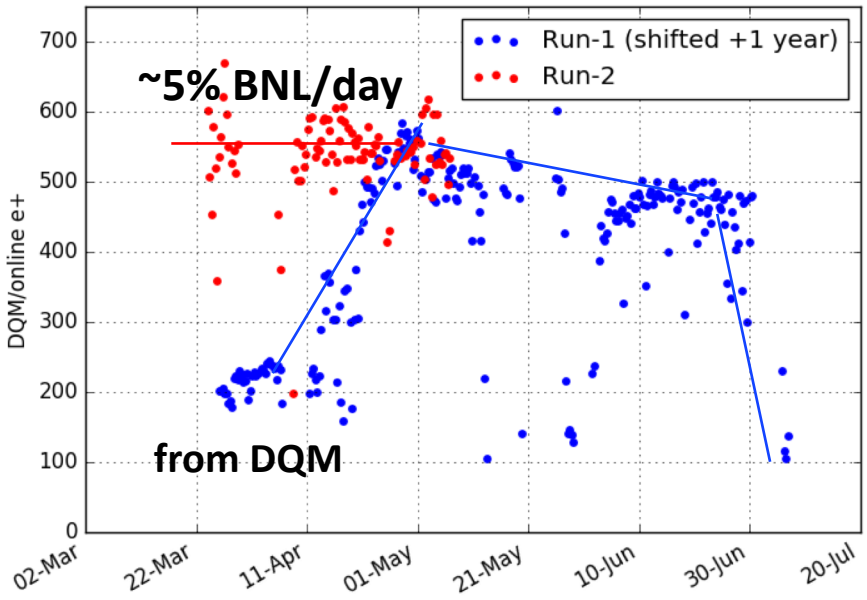
Kicker running at 142 kV. Run-1 average was 125 kV. Aim : 165 kV.
Ran briefly at 160 kV.

Run-1 to Run-2

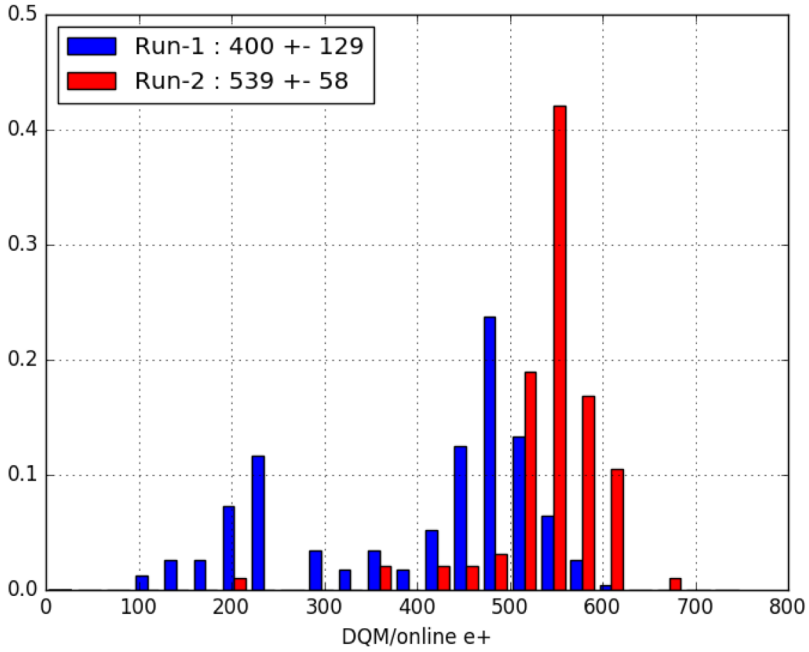
Combined uptime of kicker/quads is now 91%.



e+ / fill



Run-2: 1.35 x Run-1



This despite a 19% reduction in intensity due to running the Li lens with 10% lower current

Expectations vs Reality

	TDR	Run-2
g-2 systems	0.9	0.77 *0.92 (DAQ), 0.91 (kicker/quad), 0.92 (cryo)*
MI Cycles 1.4 vs 1.33 sec		0.95
Trolley Runs	0.94	0.94
Testbeam Users		0.91
Accelerator uptime	0.85	0.80
TOTAL	0.72	0.5

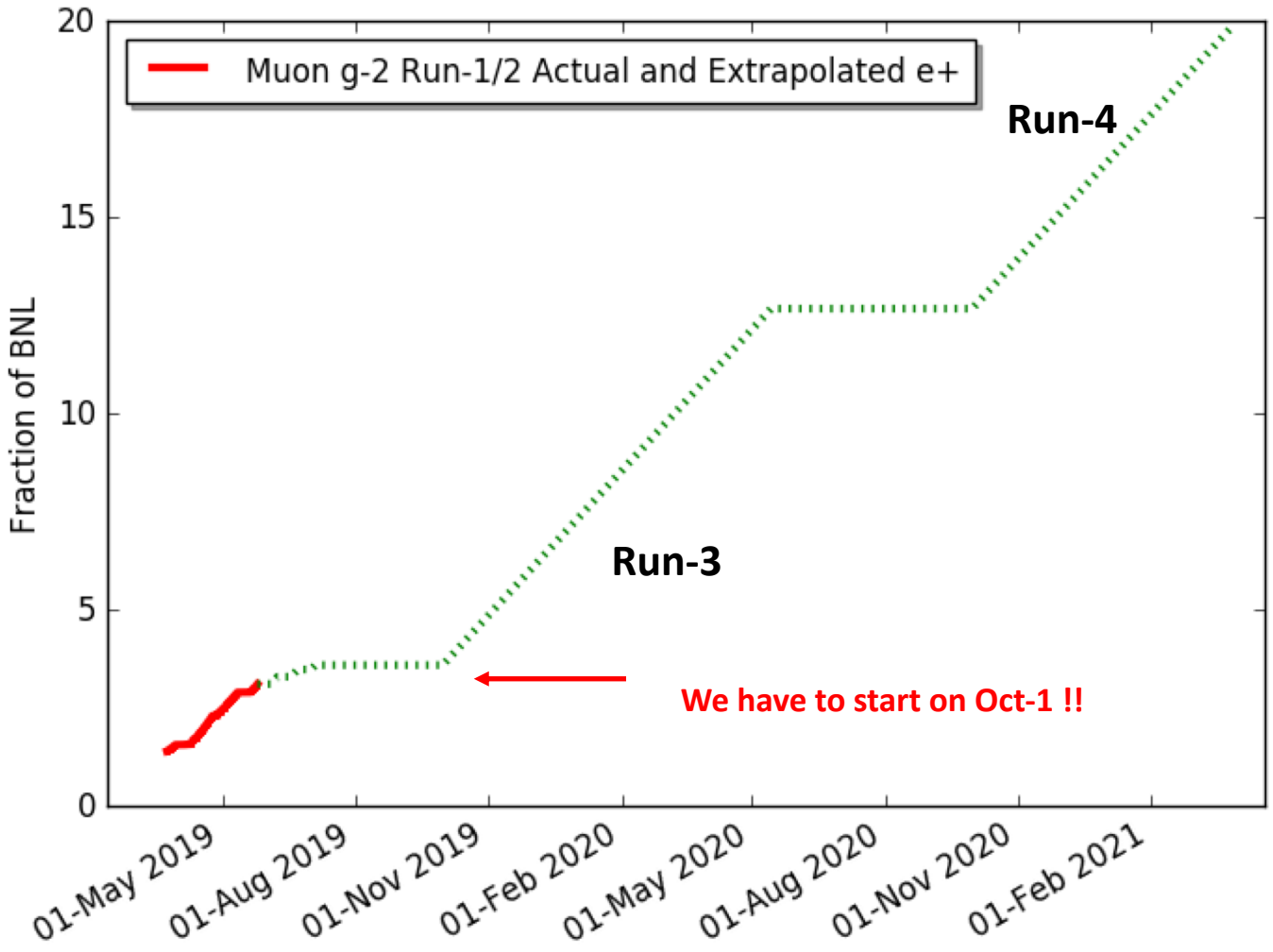
TDR expectation: 1,100 e+/fill and 72% uptime → 800M/day

Predicted Run-2 : x0.49 (e+/fill) and x0.69 (uptime) → 270M/day

Run-2 actual : 274M/day (3.2% BNL/day). Run-2 peak: 5.6% BNL/day

Downtime sources: g-2 systems, accelerator, cryo, g-2 trolley runs

Run-3/4 extrapolation with 3.7% BNL

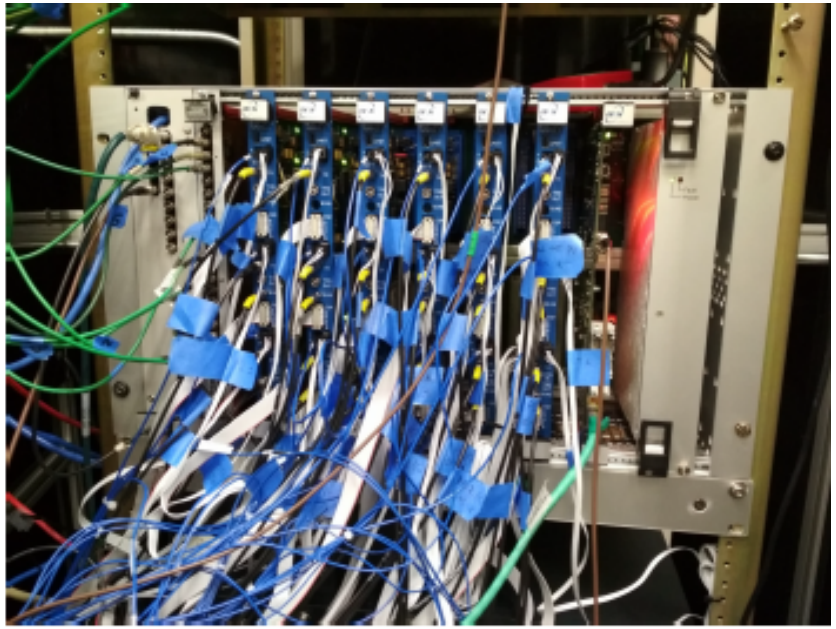


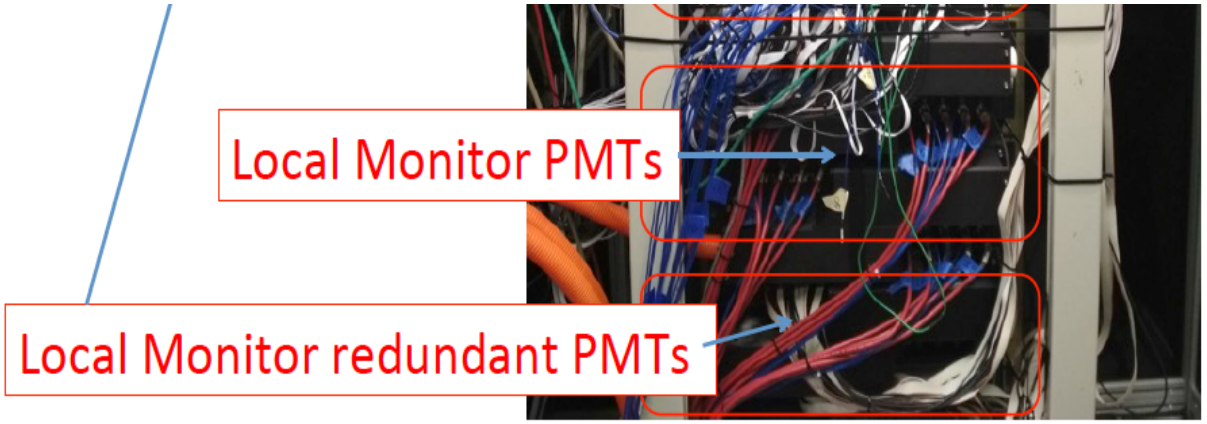
Attivita' gruppo Italiano (da Ottobre 2018)

- Hardware:
  - Riparazione/Messa a punto del Sistema laser (SM, LM, DQM, etc…) per RUN2
  - Mantenimento Sistema RUN2
- Software:
  - Correzioni di Guadagno (ST, IFG)
  - Problema Sagging SM
- Analisi dati:
  - Analisi omega_a RUN1
- Physics Week Elba (Maggio 2019)
- Sottomissione articolo sul Sistema di calibrazione laser a JINST

Lavoro Hardware

- Cambiata una scheda SM che dava un problema con un PD
- Installati 24 PMT e il Crate di Napoli del secondo LM
- Rimpiazzata la connessione CCC-scheda laser con cavo ottico
- Moltissimi Run ST/LT Doppio impulso
- Aggiornato il Monitoring/Slow Control
- Test asincroni





Laser Slow Control

Muon g-2 DQM | Run **27311** Event **39353** | **2019-06-25 10:12:53** | **26%** of events processed | Subsystem

current laser mode: 1, standard mode — Connected

Laser Slow Control

Laser traces - Muon Fill view

Last update Tue Jun 25 2019 17:12:50 GMT+0200 (Central European Summer Time)

Source Monitor Bias Voltage

Last time Mon Jun 24 2019 21:59:42 GMT+0200 (Central European Summer Time)

SM DEV	PMT SET	PMT MON	PID 1 SET	PID 1 MON	PID 2 SET	PID 2 MON
SM 1	0.67	0.61	49.14	49.20	49.14	49.52
SM 2	0.63	0.59	49.14	49.35	49.14	49.17
SM 3	0.68	0.64	49.14	49.06	49.14	49.37
SM 4	0.79	0.74	49.14	49.27	49.14	49.01
SM 5	0.68	0.64	49.14	49.39	49.14	49.20
SM	0.67	0.63	49.14	49.50	49.14	49.32

Local Monitor High Voltage Power Supply

Last time Tue Jun 25 2019 17:12:27 GMT+0200 (Central European Summer Time)

HV CH	HV SET	HV MONITOR	I MON	STATUS	POW
0	635	635.39	148.69	1	ON
1	585	585.45	137.55	1	ON
2	585	585.44	135.83	1	ON
3	555	555.40	130.38	1	ON
4	635	635.53	149.41	1	ON
5	550	550.54	128.91	1	ON
6	545	545.38	127.41	1	ON
7	510	510.48	119.28	1	ON
8	585	585.36	136.85	1	ON
9	590	590.53	137.99	1	ON

Delay Generator Trigger Status

Last timeTue Jun 25 2019 17:11:58 GMT+0200 (Central European Summer Time)

SINGLE SHOT

Filter wheels actual position

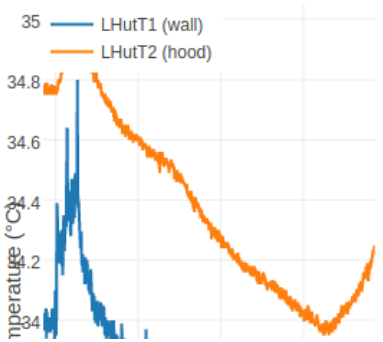
Last time Tue Jun 25 2019 17:11:55 GMT+0200 (Central European Summer Time)

NUMBER	1	2	3	4	5	
POSITION	7	7	7	7	7	7

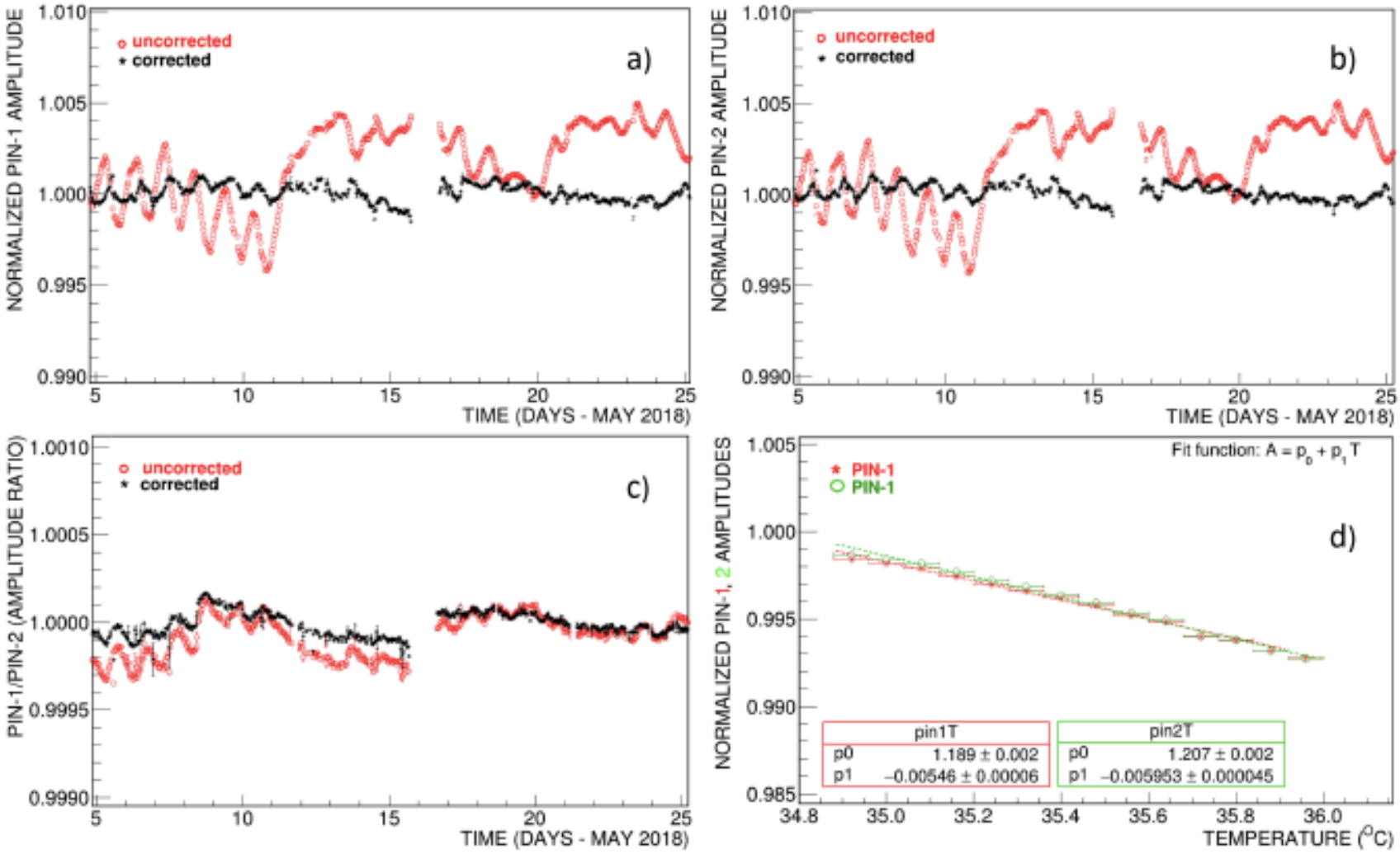
24h Temperature Monitor

Last time Tue Jun 25 2019 17:12:25 GMT+0200 (Central European Summer Time)

Last 24 hours



Stability of SM



Software fluttuazioni di guadagno

Why calibrating for the gain

Error	E821 [ppb]	E989 goal [ppb]
Gain changes	120	20
Lost muons	90	20
Pileup	80	40
CBO	70	40
E and pitch	50	30
Total	180	70

Change of gain in a fill → Different energy acceptance → Shift in ω_a phase → Effect on ω_a

How to calibrate?

The calibration is performed with the **Laser Calibration System**.

Three time regimes:

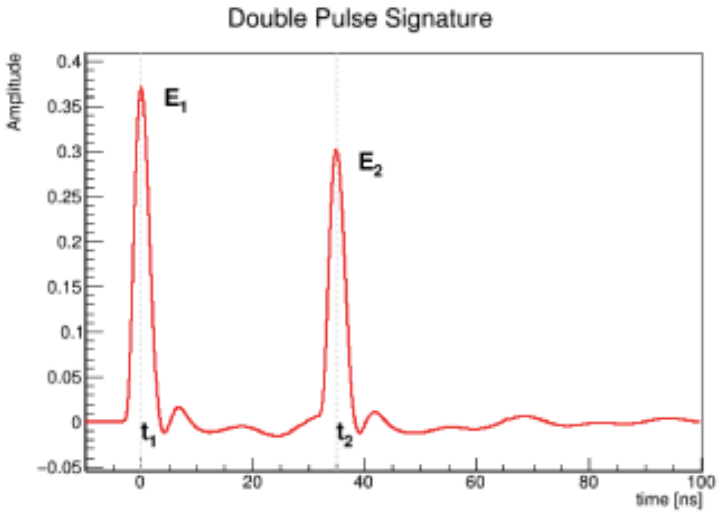
- 0-100 ns: Short Time Double Pulse
- 0-600 us: In-Fill Gain Correction
- 0-1000 days: Long Term Calibration

Short Time Double Pulse (STDP)

What it is:

Two near-timed signals don't allow the SiPM electronics to recover in time.

The second signal is systematically measured lower than reality.



How to correct:

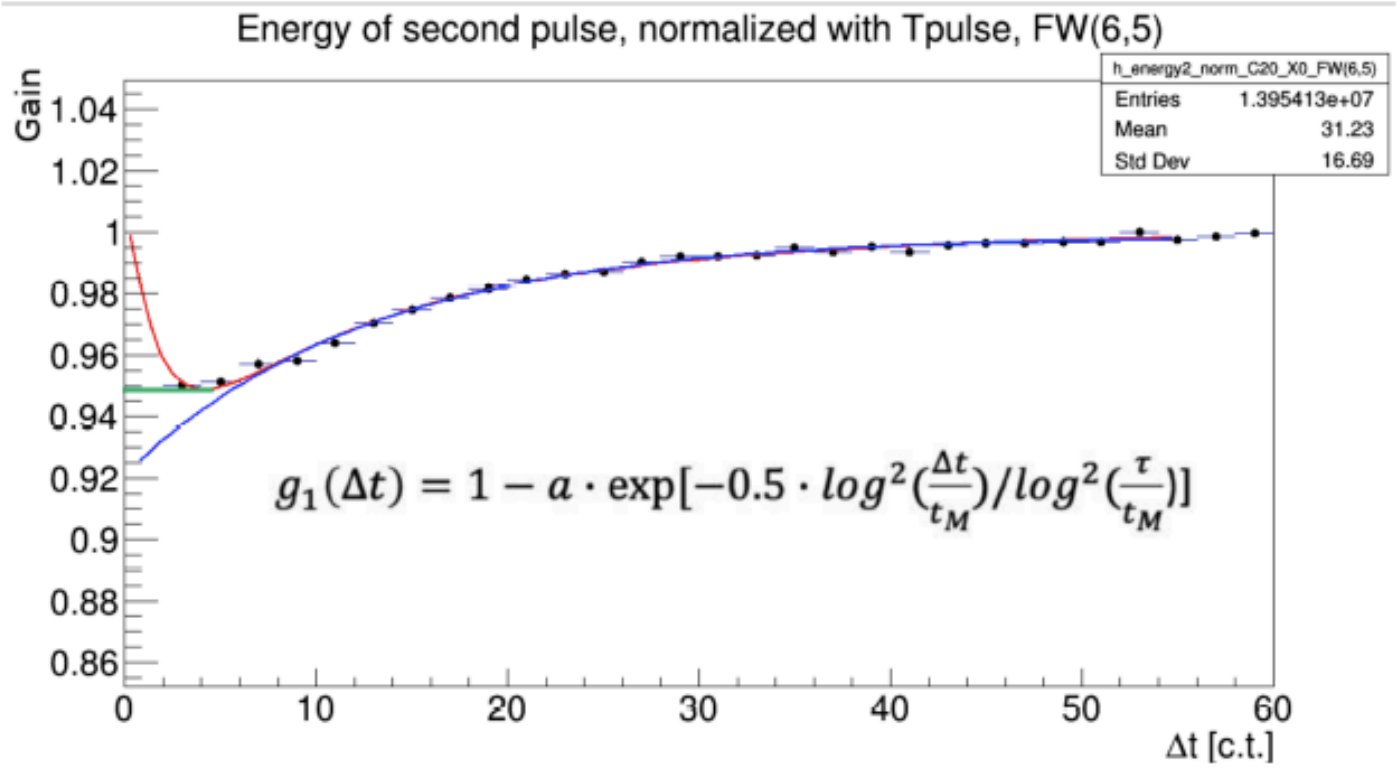
- Dedicated laser studies that scan time separation and energies.
- Extract 1296 energy-dependent gain shapes of the form:

$$G(t, E_1) = 1 - p_0 E_1 \cdot e^{-\frac{\Delta t}{\tau}}$$

- Correct the raw positron pulses before anything else.

STDP

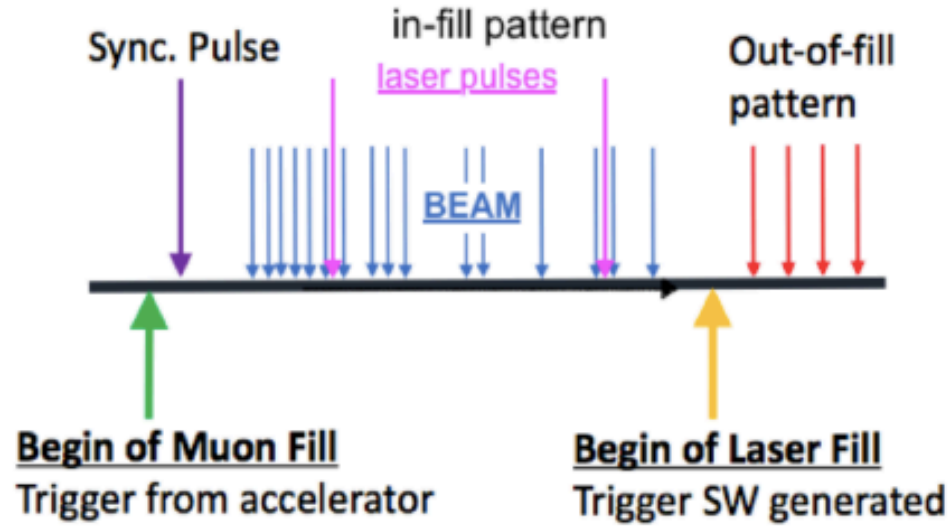
- The gain function is fitted as either exponential (blue) or lognormal (red).
- We decided after some discussion to cut the function at the lognormal minimum (green).



In-Fill Gain Correction

What it is:

A gain sag due to the splash of particles at the muon injection that saturates the calorimeters.

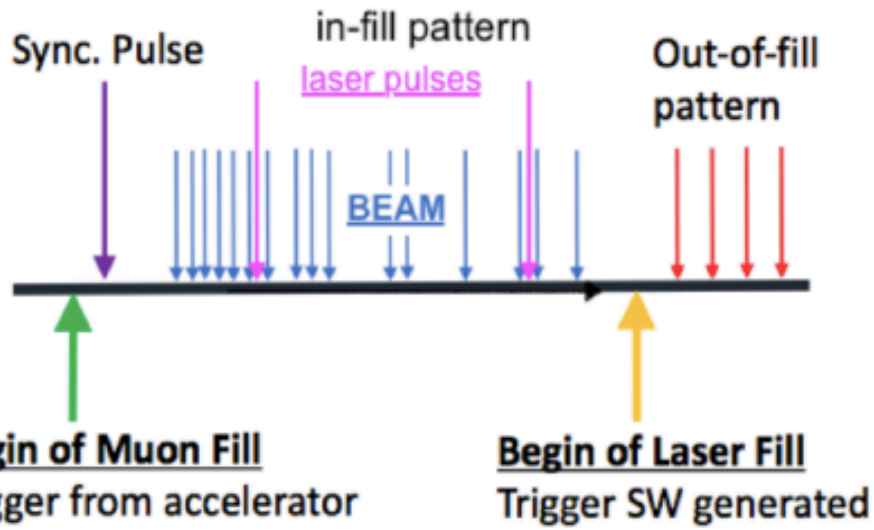


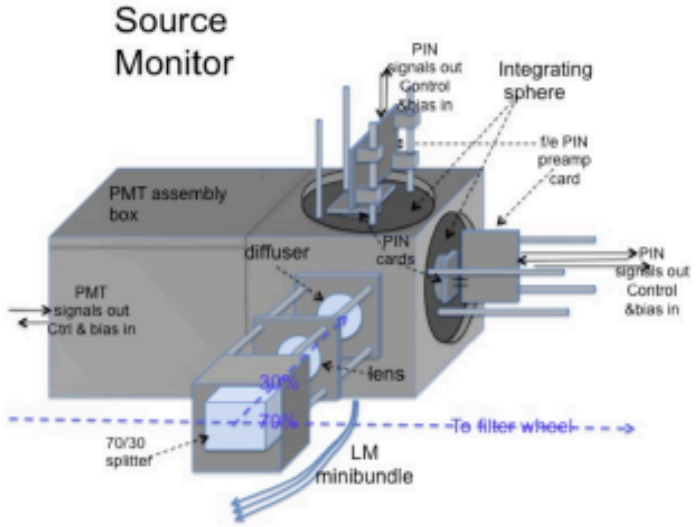
How to correct:

During a prescaled subset of muon fills, the laser fires a fixed number of pulses.

These pulses move in time during different fills, allowing for a complete scan of the 700 us of acquisition.

IFG correction





$$G_{ifg}(t_i) = \left\langle \frac{SiPM_{if}}{SM_{if}} \right\rangle_{t_i} \left\langle \frac{SM_{oof}}{SiPM_{oof}} \right\rangle_{subrun}$$

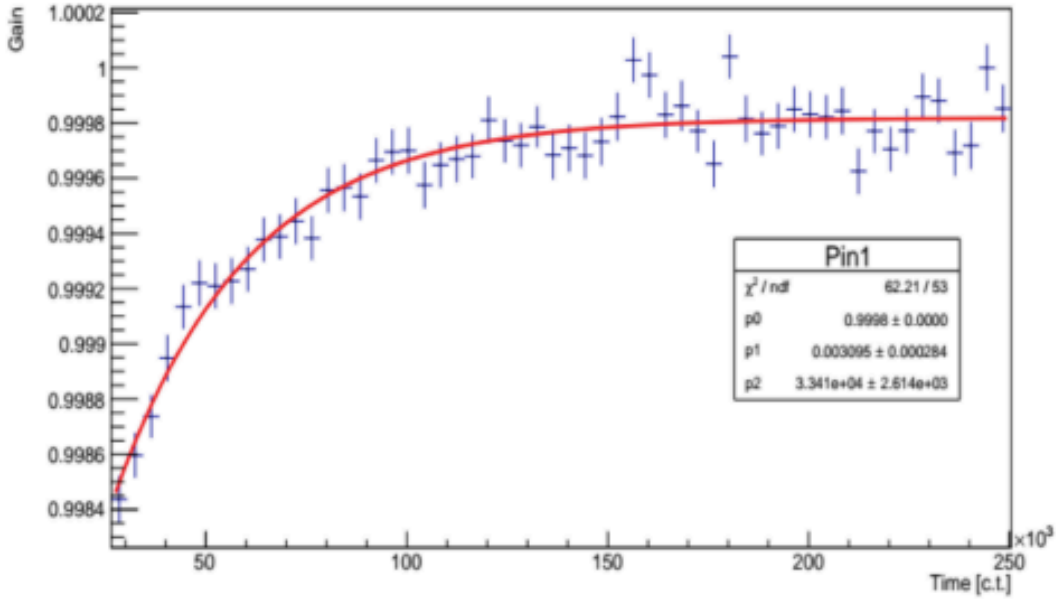
These gain functions rely on the Source Monitor:

the laser light intensity is monitored near the laser heads by two stable PIN-diodes.

Fermilab

Source Monitor gain sag

On December, it was discovered that the Source Monitor presents a gain sag at the 0.2% level due to the preceding SYNC pulse.

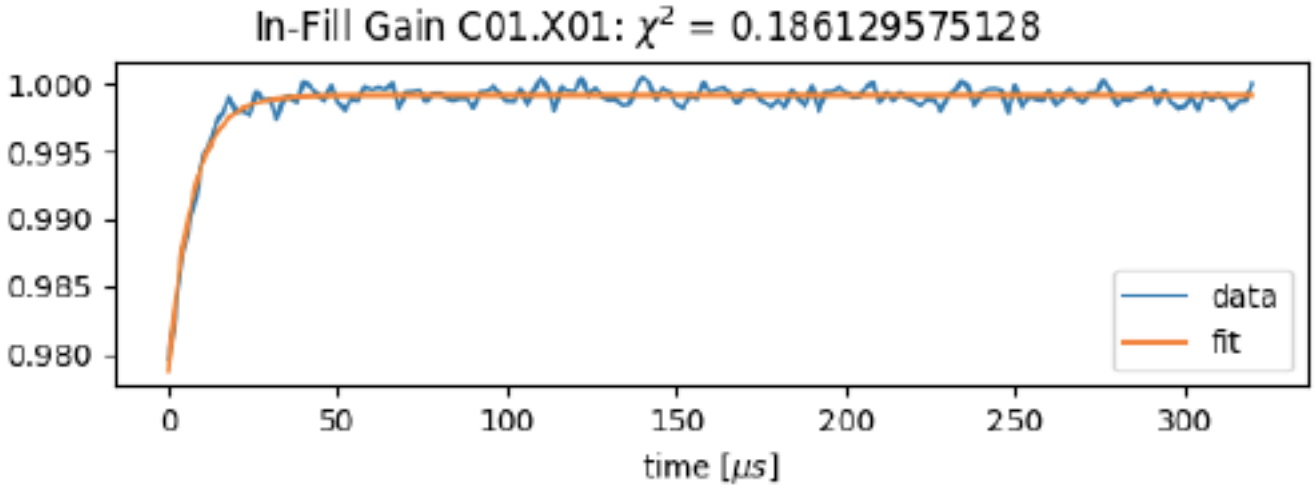


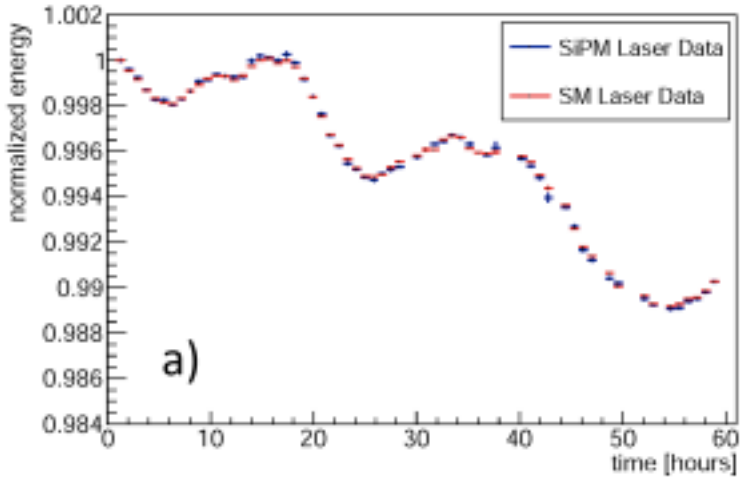
The solution (for Run1) is to use the first pulse observed by the Local Monitor. The first (of two pulses) is a replica of the source monitor light.

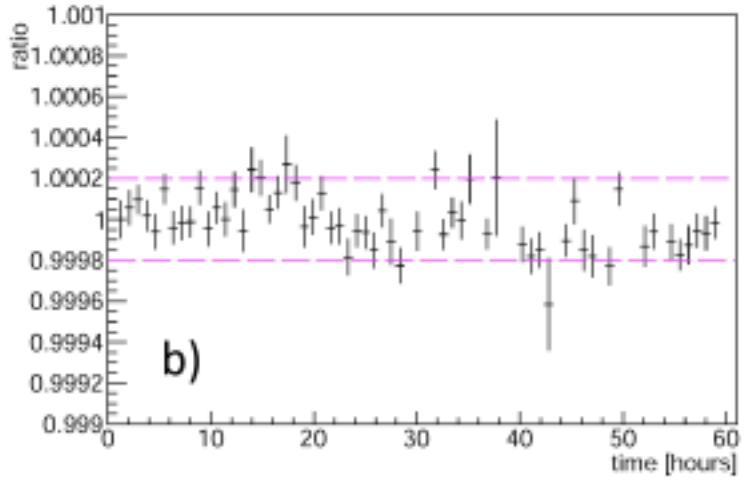
SYNC pulse shifted to 100 us before injection for Run2.

Fermilab

IN-FILL and OUT-OF-Fill Gain corrections

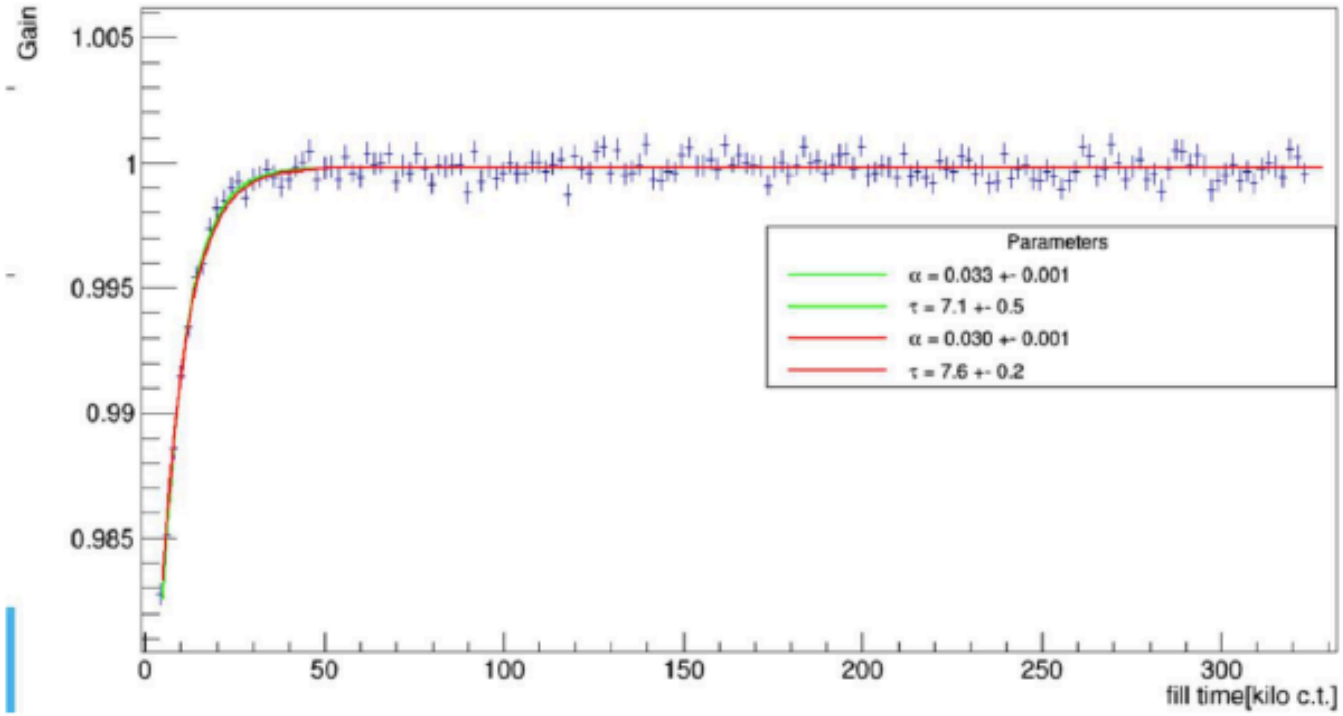






LTDP

- The burst length has been proven to be able to simulate the splash energy (Elia, Graziano)
- Good agreement with data



- IFGF with superimposed two curves derived from LTDP sequences (not a fit!)

Review paper (33p) on Laser Calibration system submitted in June !

PREPARED FOR SUBMISSION TO JINST

The laser calibration system of the Muon $g-2$ experiment at Fermilab

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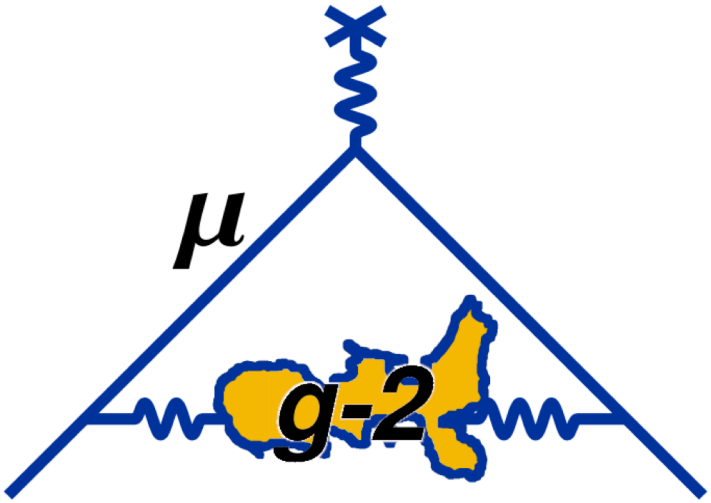
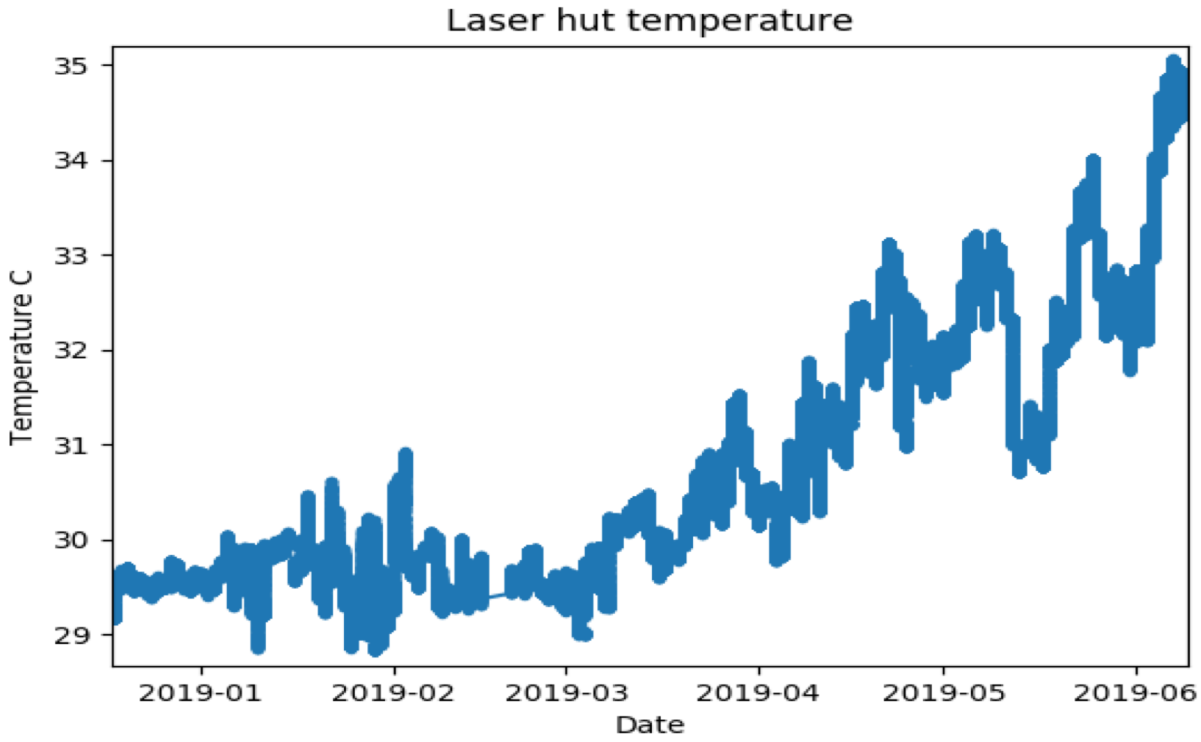
Physics Week a L'Elba



Raffreddamento Laser Hut



- A giugno: Temperatura nella LH ~35^{o}C
- Temperatura consigliata ~ 25^{o}C → Problema con l'allineamento e performance del Sistema laser. Particolarmente importante per il Run 3
- Il raffreddamento della LH deve essere visto all'interno del raffreddamento della sala
- Attivita' prevista per lo shutdown estivo. Costo ~ 15k$ (da finalizzare con gli ingegneri di Fermilab)
- Richiesta sblocco SJ apparati 2019

Breaking news (2/7/19)

laser head 6 in trouble

Messaggio 2 di 96

Mittente jarek kaspar
Destinatario Marco Incagli
Cc Graziano Venanzoni, Carlo Ferrari, Anna Driutti, Becky Chislett, Jason Hempstead
Data Oggi 00:21

Hi Guys,

Earlier today, laser head #6 developed a problem. It seems the head stops outputting any light for a couple minutes, and then the problem goes away for another couple minutes. The "uptime" of the laser head is about 50 %. We checked that the light is missing completely in calorimeters 21 – 24, and also in the source and local monitors. Hogan and I went down to the laser hut, and checked that the LED on Sepia driver for head #6 flashes consistently even if there's no light generated.

Is there a laser expert onsite that could further investigate? If not, would it be possible to turn the laser head off?

Thank you for your help,

Jarek

Abbiamo 2 teste laser riserva…probabilmente necessario comprare una-due teste aggiuntive

Conclusioni

- Dopo un inzio problematico che ha portato a 4 mesi di ritardo Run2 in chiusura. ~ 2BNL presi con un unico punto di lavoro
- Analisi RUN1 in corso. Risultato atteso per la fine dell'anno
- Attivita' Gruppo Italiano molto intensa non solo sull'HW ma anche sul software/analisi dati.
- Lavoro estivo «minimale» (piccole modifiche al setup)
- Run 3 atteso per Ottobre
- Si spera di portare la statistica > x10BNL

THE END

SPARES

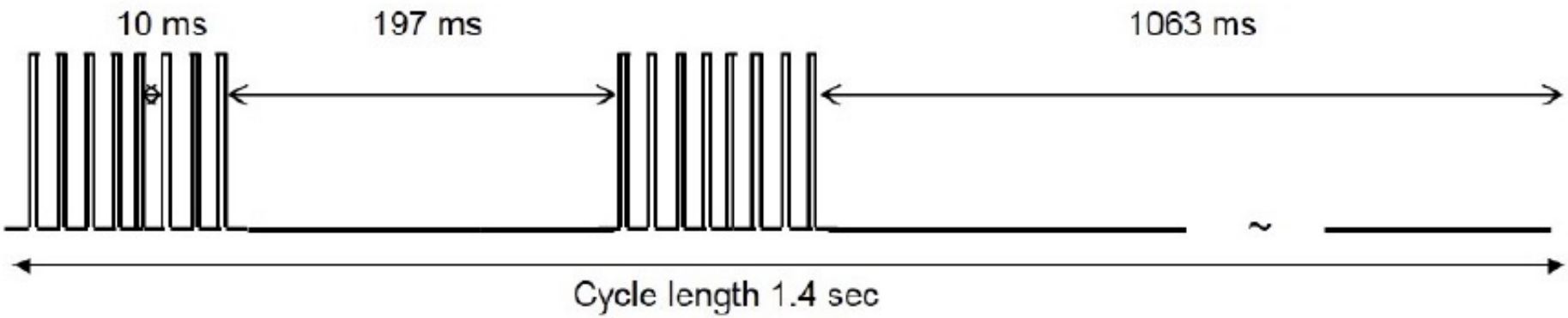
TDR Numbers

- 1.6 x 10^{11} good decay positrons (E>1.8GeV, t>30μs) for 22 BNL statistics (7x10^{9})
- Needs 1.5 x 10^{8} fills (=7 months)

→ **3BNL/month; ~10^{3} e^{+}/fill; 10^{4} μ/fill**

Item	Factor	Value per fill
Protons on target		10^{12} p
Positive pions captured in FODO, $\delta p/p = \pm 0.5\%$	1.2×10^{-4}	1.2×10^{8}
Muons captured and transmitted to SR, $\delta p/p = \pm 2\%$	0.67%	8.1×10^{5}
Transmission efficiency after commissioning	90%	7.3×10^{5}
Transmission and capture in SR	$(2.5 \pm 0.5)\%$	1.8×10^{4}
Stored muons after scraping	87%	1.6×10^{4}
Stored muons after 30 μs	63%	1.0×10^{4}
Accepted positrons above E = 1.86 GeV	10.7%	1.1×10^{3}
Fills to acquire 1.6×10^{11} events (100 ppb)		1.5×10^{8}
Days of good data accumulation	17 h/d	202 d
Beam-on commissioning days		150 d
Dedicated systematic studies days		50 d
Approximate running time		402 ± 80 d
Approximate total proton on target request		$(3.0 \pm 0.6) \times 10^{20}$

Beam structure



ESH

Two new training courses : MC1-HB, MC1-MR
Improved work planning / oversight.

48949	10:03	**Shift log [xml]**	*Run = 26160; quality = T; laser-mode = 1 started ...*
48948	09:52	**Quads [hogann]** Approved Work Request New Work Request	*1 hour of Beam with RF*
48947	09:44	**Quads [hogann]** Approved Work Request New Work Request	*Controlled Access to set RF timing*
48946	09:42	**Beam/Tuning [dflay]** In Review Study Study Request	*M4/M5 beam response matrix*
48945	09:33	**DAQ [lmark]** Approved Completed Work Request New Work Request	*Restart MIDAS to clear zombie processes*
48944	09:32	**Run plan [dflay]** Run Plan	*[REVISED] Run Plan for Monday 5/6/19* We were supposed to get started with beam studi
48943	09:26	**Beam/Tuning [dflay]** Approved Completed Study Study Request	*Wedge improved energy match and trajector*
48942	09:17	**Shift log [jimin]** 30-minute Checklist	*Not able to open localhost:3333/s1 to check laser trigger*
48941	09:07	**Beam [ebarlas]**	*Beam is back at 09.05 AM* MCR called in and said the beam could be back soon. It is back around 09.05

Sign out new HB-Key

Sign out new MR-Key

Check Training

Administer

FNAL ID	Name	Key Type	Key #	Checked out	Return Key
34296V	Barlas, Esra	MR	2	2019/05/07 08:11	click to return key
17706V	Kaspar, Jarek	MR	1	2019/05/07 08:11	click to return key
35203V	Kim, On	MR	3	2019/05/07 08:12	click to return key
10339N	Nguyen, Hogan	MR	4	2019/05/07 08:13	click to return key

Last refreshed at: 2019-05-07 08:27:09.099490

GM2-doc-#	Title	Author(s)	Topic(s)	Last Updated
16339-v4	Trolley Mechanical Motion Checklist JHA	David Flay	JHA Trolley	01 May 2019
17479-v1	Tracker HV Board Reconnection JHA	James Mott	JHA	25 Apr 2019
16937-v1	Listening to K3 spark JHA	Jarek Kaspar	JHA Kicker	21 Mar 2019
16919-v1	Kicker 3 pickup coil cable re-connection JHA	Jarek Kaspar	JHA Kicker	20 Mar 2019
16883-v2	Plugging/Unplugging the RF cables into/from the RF Box	Esra Barlas Yucel *et al.*	ESH&Q JHA	19 Mar 2019
16886-v1	Plunging Probe DAQ Test JHA	David Flay	JHA	19 Mar 2019
16862-v1	IBMS3 Cable Labeling	Rebecca Chislett *et al.*	JHA	15 Mar 2019
16703-v5	Collimator Procedures and JHAs	Brendan Kiburg	ESH&Q JHA	05 Mar 2019
16691-v1	K3 cable replacement JHA's	Del Allspach *et al.*	JHA	01 Mar 2019
16679-v2	Fiber Harp Bracket Removal JHA	Fred Gray *et al.*	JHA	28 Feb 2019

TDR vs Run-1 vs Run-2

	TDR	Run-1	Run-2
Mean e+/fill	1100	400	539
Total # days prodn. running	200	106	38--->60
e+/day/avg	800M	181M	274M
e+/day/max		430M	483M
Uptime	72%	50%	62%

Downtime sources: g-2 systems, accelerator, cryo, g-2 trolley runs

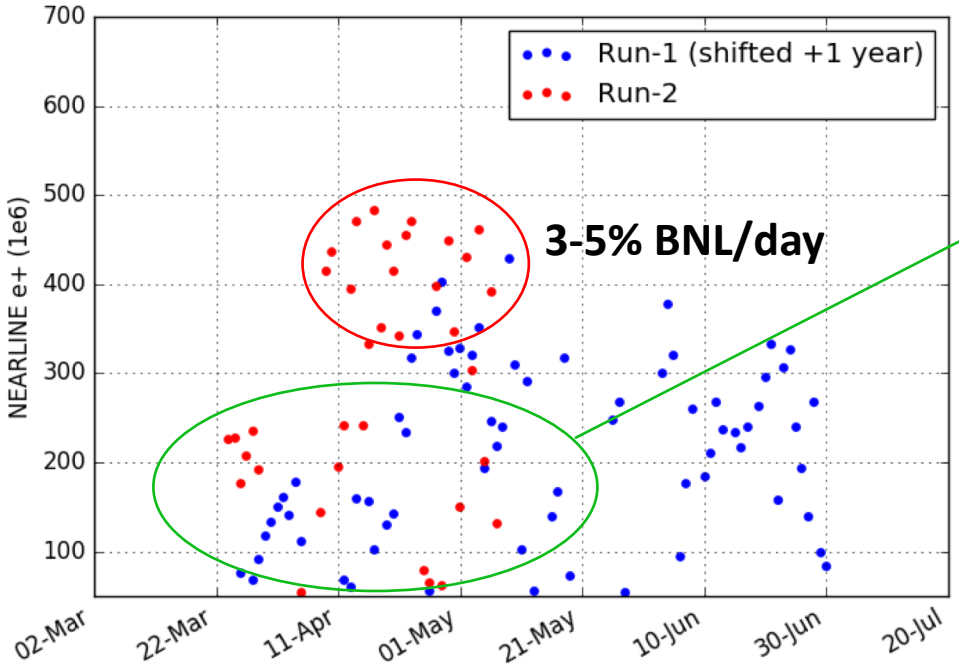
TDR Uptime: x0.9 g-2 systems, x0.85 accelerator, x0.94 trolley

We have a reduced per fill intensity wrt TDR

	e+/fill	Effect	Factor
TDR	**1100**		
		Wedges	1.06
		Li Lens	0.81
		Kick (142 vs 155 kV)	0.84
		Quads (18 vs 28 kV)	0.92
		Actual beamline apertures	0.8
		TOTAL	**0.53**
RUN-2 Predicted			582
RUN-2 Actual			539 +/- 58*

*includes systematic runs where rate was lower.

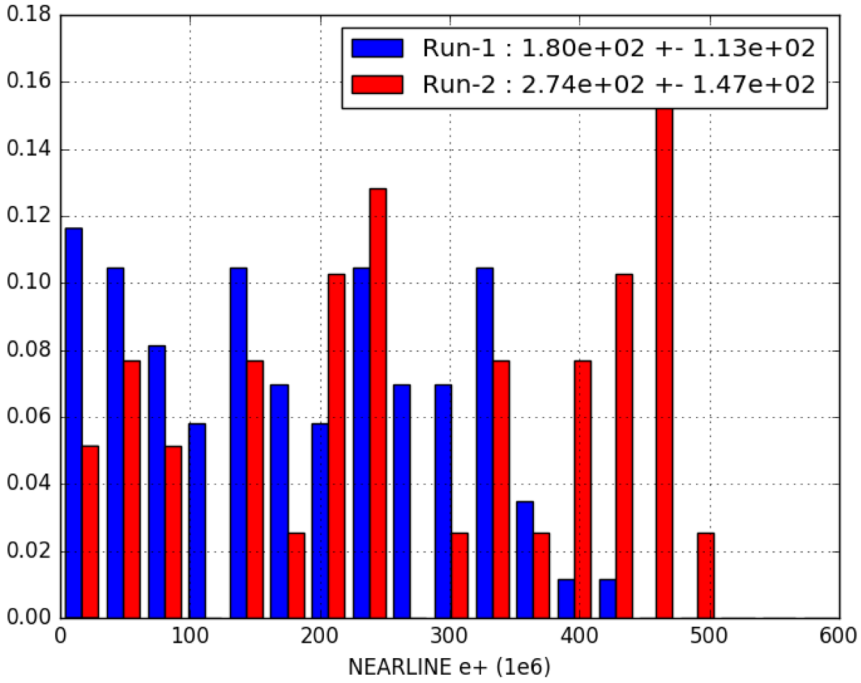
e+ / day



3-5% BNL/day

When accelerator down for more than 8 hours

Run-2: 1.52 x Run-1 per day



4% BNL/day


Muon g-2 Run2 e+ (last 7 days)
Fraction of BNL
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
21-May
22-May
23-May
24-May
25-May

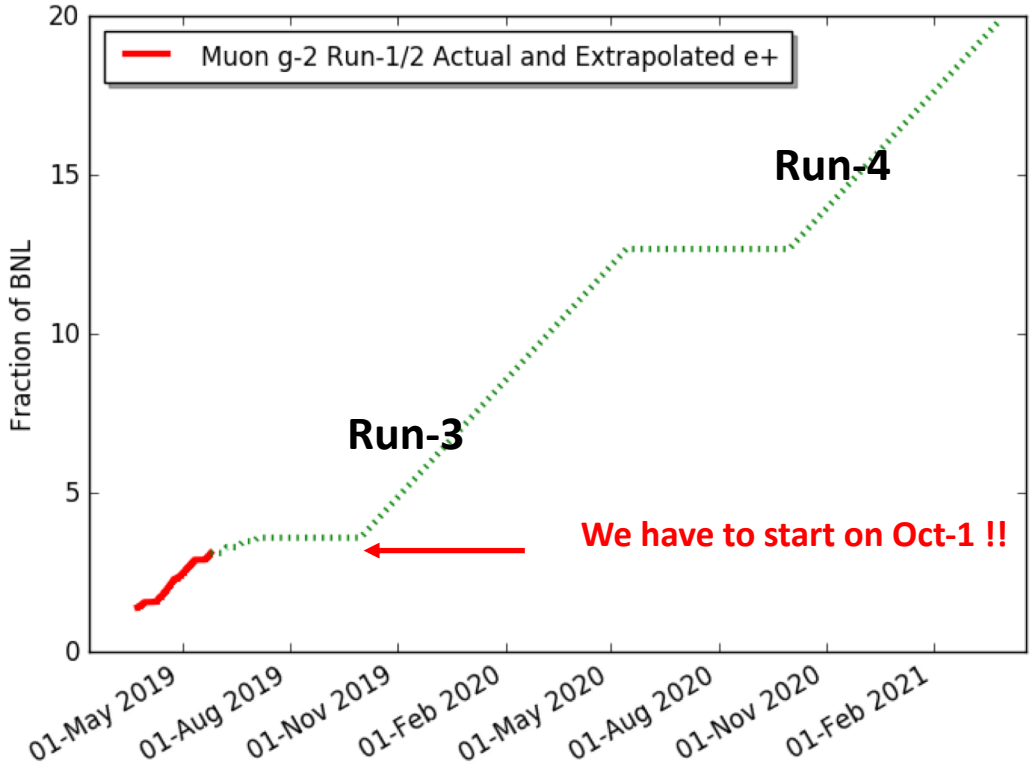
Run-3/4 extrapolation with 3.7% BNL

This is with trolley run every 3 days. Likely needs to be x2 this.

Run-2 average 3.2% per day.

Accelerator uptime: 80% → 85% (TDR)
[90% without O/T…]
Wedges: 1.06 → 1.15
→ 3.7%

Uptime: 0.91 (DAQ) x 0.91 (kicker/quads) x 0.92 (cryo)
-- this may improve …



Not assumed:
- new inflector (x1.4)
- higher kick/quads (x1.1)
- faster switching PS (mitigates testbeam) : (x1.05)