

# Muon g-2

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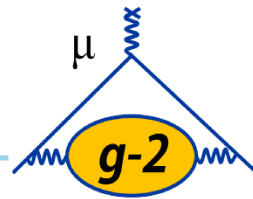
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## **g-2 “fast daq” commissioning, testing and operations.**

Tim Gorringer  
University of Kentucky  
8 November, 2016

# Background remarks

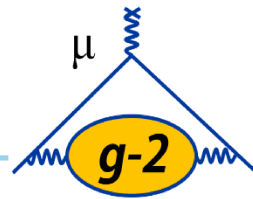
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- during the past year we've carried out
  - the staged installation of daq hardware, i.e., increasing calorimeter frontends, ...
  - the staged implementation of daq software, i.e., increasing processing functionality, ...
- in parallel we've also carried out
  - various unit and integration testing and soak and stress testing of the daq system.
  - utilized system components for calorimeter beam tests @ SLAC, tracker cosmic / source tests @FNAL, Q-method development @FNAL, ...

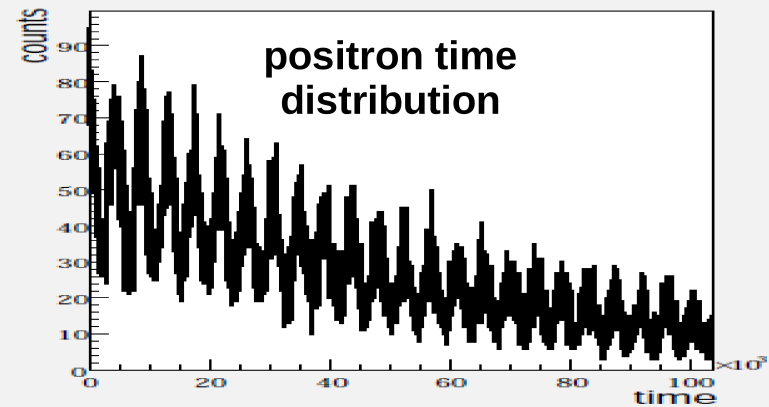
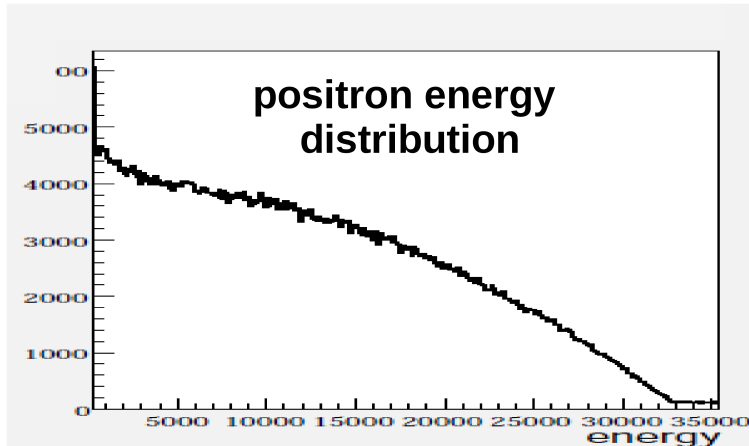
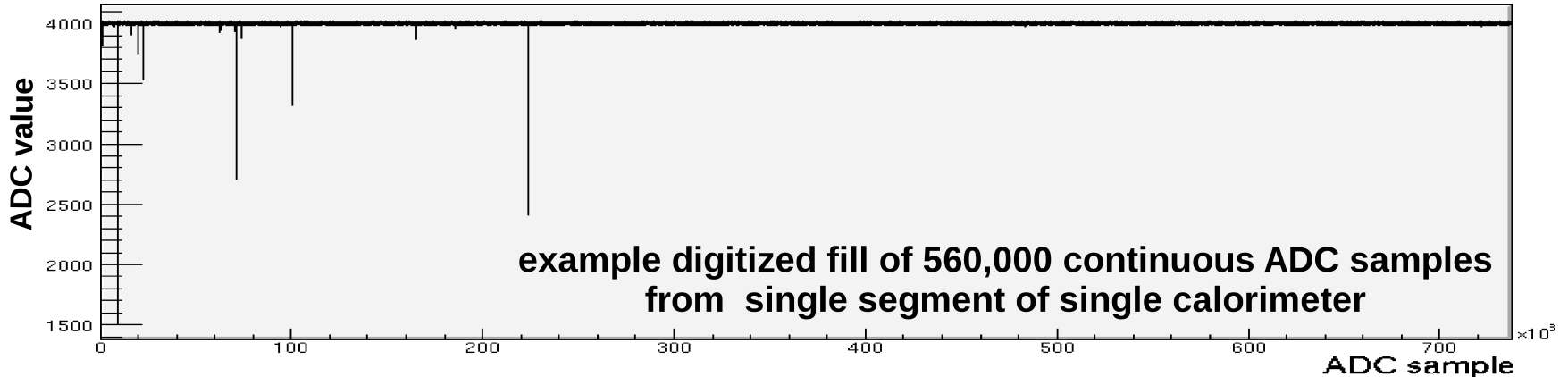
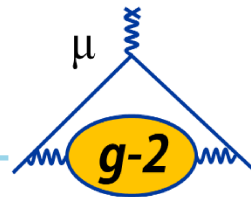
# Talk outline

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- here describe some examples of testing and use of the daq system:
  - emulator-based soak, stress testing of 24 calorimeter readout, processing, event building and data storage
  - hardware-based soak, stress testing with multiple mTCA crates, clock-control system, and fill time-stamping
  - use of daq platform for “physics” in beam test of calorimeter and development of Q-method
- also describe the transition to data taking and operations

# Emulator-based testing



- generates fills of continuously-digitized samples
- empirical positron energy-time and x-y distributions
- options for pedestal noise and laser pulses
- stores truth data as Midas databank for integrity check

- Rider module / channel headers / trailers
- AMC13 aggregation, headers / trailers
- 10GbE / localhost TCPIP data transfer

# Emulator-based testing

does test

- ✓ transfer over 10GbE network hardware.
- ✓ tcp readout performance.
- ✓ gpu processing performance.
- ✓ event building capability.
- ✓ data storage capability.

doesn't test

- AMC13 / Rider configuration via ipbus
- daq interaction with clock-control center
- “unknowns” of AMC13 data transfer, ...
- “unknowns” of Rider digitized samples, ...
- bunched fill-structure

emulator has proved an invaluable tool for daq development without readout / control hardware.

Run Status

Start: Mon Jul 18 16:26:49 2016 Running time: 0h00m56s

Alarms: On Restart: Yes

Data dir: /data/wes

Experiment Name: WES

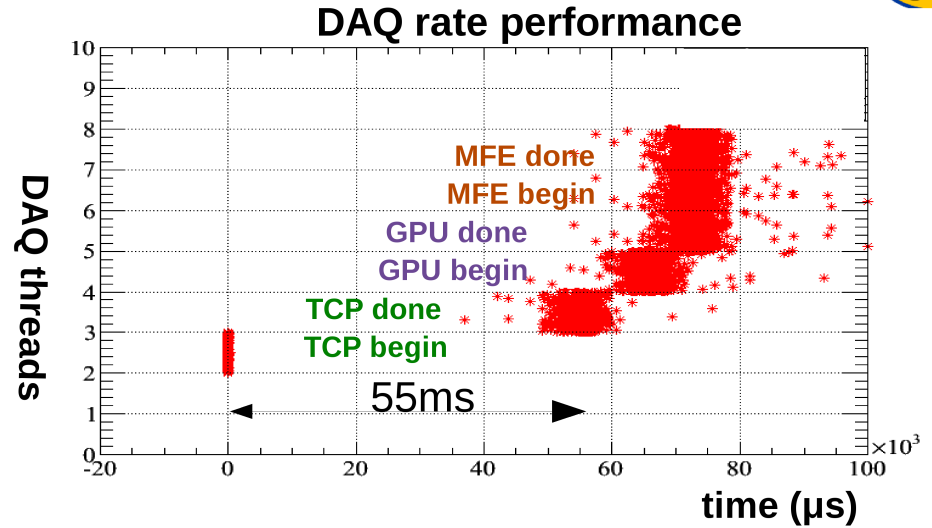
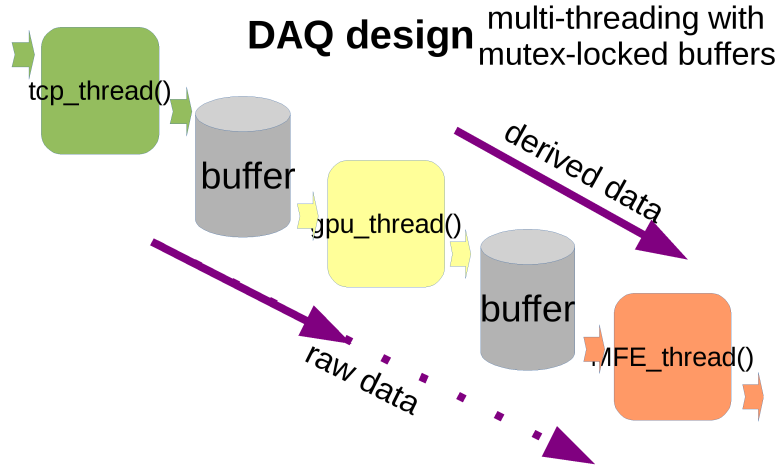
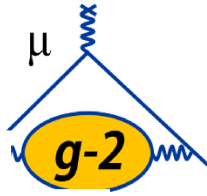
16:26:50 [mhttpd,INFO] Run #5132 started

Equipment +	Status	Event	Events/s	Data[MB/s]
EB	Ebuilder@g2be1.fnal.gov	634	13.0	70.611
AMC1301	AMC1301@g2calo0102.fnal.gov	652	12.0	2.478
MasterGM2	MasterGM2@g2be1.fnal.gov	640	12.0	0.001
AMC1305	AMC1305@g2calo0506.fnal.gov	635	12.0	2.923
AMC1306	AMC1306@g2calo0506.fnal.gov	654	12.0	2.530
AMC1302	AMC1302@g2calo0102.fnal.gov	628	12.0	2.590
AMC1307	AMC1307@g2calo0708.fnal.gov	637	12.0	2.537
AMC1308	AMC1308@g2calo0708.fnal.gov	635	12.0	2.431
AMC1303	AMC1303@g2calo0304.fnal.gov	652	12.0	2.844
AMC1304	AMC1304@g2calo0304.fnal.gov	627	12.0	2.594
AMC1309	AMC1309@g2calo0910.fnal.gov	635	12.0	2.768
AMC1310	AMC1310@g2calo0910.fnal.gov	644	12.0	2.430
AMC1311	AMC1311@g2calo1112.fnal.gov	637	12.0	2.948
AMC1312	AMC1312@g2calo1112.fnal.gov	636	12.3	2.864
AMC1313	AMC1313@g2calo1314.fnal.gov	635	12.0	2.596
AMC1314	AMC1314@g2calo1314.fnal.gov	620	12.0	2.396
AMC1315	AMC1315@g2calo1516.fnal.gov	652	12.0	2.858
AMC1316	AMC1316@g2calo1516.fnal.gov	630	12.3	2.937
AMC1317	AMC1317@g2calo1718.fnal.gov	620	12.0	2.915
AMC1318	AMC1318@g2calo1718.fnal.gov	653	12.3	2.590
AMC1319	AMC1319@g2calo1920.fnal.gov	625	12.0	2.727
AMC1320	AMC1320@g2calo1920.fnal.gov	632	12.0	2.928
AMC1321	AMC1321@g2calo2122.fnal.gov	620	12.0	2.693
AMC1322	AMC1322@g2calo2122.fnal.gov	653	12.0	3.046
AMC1323	AMC1323@g2calo2324.fnal.gov	621	12.0	2.694
AMC1324	AMC1324@g2calo2324.fnal.gov	643	12.0	2.850

Channel	Events	MB written	Compr.	Disk level
#0: run05132.mid	634	3449.517	N/A	2.6 %

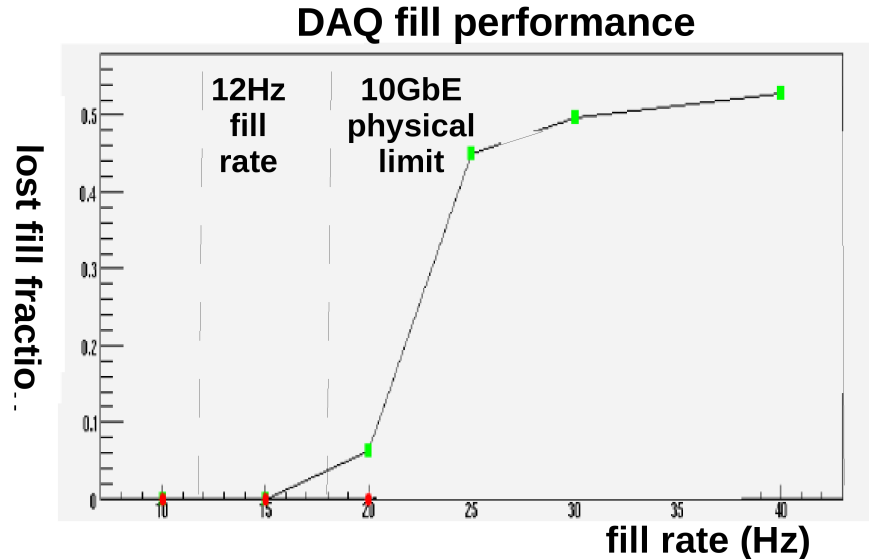
# Emulator-based testing

120 ms max allowable time per thread

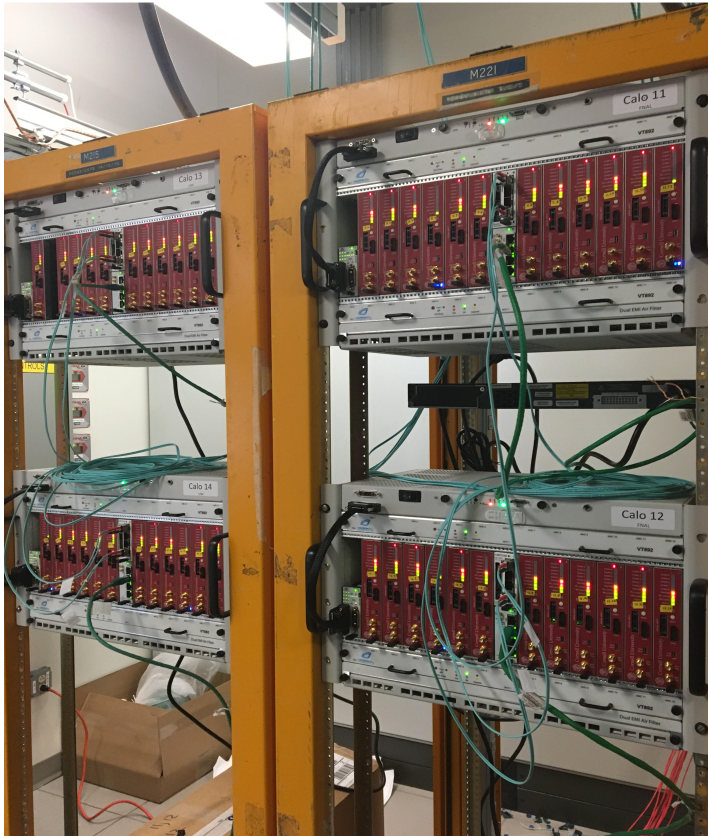
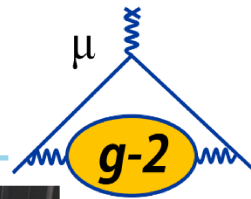


## GPU tasks

GPU function call	threads	time (ms)
Compute pedestals	54	0.1
Check threshold	560k	1.7
Add pre / post samples	560k	0.1
Merge overlapping islands	560k	0.2
Save T-method data	560k	0.2
Make calo sum (diagnostic)	560k	1.2
Decimate calo sum (diagnostic)	17.5k	0.3
Make Q-method hists	30M	2.4



# hardware-based testing



- 10 GbE readout, 1GbE control of up to 7 full uTCA crates of 12 Rider modules / 60 Rider channel
- 10 Rider channels with pulser readout, 410 Rider channels with pedestal readout

- readout, configuration of clock-control crate
- hardware trigger of bunched, 12Hz fills
- time-stamping of bunched, 12Hz fills

# hardware-based testing

does test

- ✓
- ✓ AMC13, Rider, FC7 configuration by ipbus
- ✓ bunched, 12 Hz fill structure.
- ✓ “unknowns” of AMC13 data transfer, ...
- ✓ “unknowns” of Rider digitized samples, ...
- ✓ clock-control system.
- ✓ fill time-stamping.
- ✓ rate limit of AMC13 → FE data transfer
- ✓ rate limit of FE → BE data transfer
- ✓ storage on local RAID to FNAL dCache.

doesn't yet test

- full twenty four calorimeter readout
- integration of tracker, auxiliary, laser, IBMS sub-systems (many elements individually tested)
- rate limit of event building and data storage (is > 600 MB/sec)

hardware setup is invaluable test stand for daq development, hardware testing, physics studies

### Run Status

Run 1422 Running

Start: Fri Sep 23 13:58:43 2016      Running time: 0h00m45s

Alarms: On      Restart: Sequencer

Data dir: /data2/CRTTest

Experiment Name: CR

13:58:43 Logger:starting new run

13:59:24 [Logger,INFO] channel /data2/CRTTest/run01422\_03.mid writer chain: CRC32C | CRC32C | >

### Equipment

Equipment	Status	Events	Events[/s]	Data[MB/s]
MasterGMZ	MasterGM2@g2be1.fnal.gov	437	12.2	0.001
EB	Ebuilder@g2be1.fnal.gov	465	12.0	216.282
AMC1303	AMC1303@g2calo0304-data	461	12.3	31.519
AMC1304	AMC1304@g2calo0304-data	452	12.0	30.767
AMC1302	AMC1302@g2calo0102-data	459	12.3	31.224
AMC1305	AMC1305@g2calo0506-data	464	12.3	31.839
AMC1311	AMC1311@g2calo1112-data	464	12.2	31.754
AMC1312	AMC1312@g2calo1112-data	462	12.0	31.019
AMC1314	AMC1314@g2calo1314-data	465	12.0	31.009

### Logging Channels

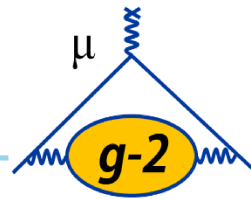
Channel	Events	MiB written	Compr.	Disk level
#0: run01422_04.mid	469	8393.151	N/A	14.9 %

### Clients

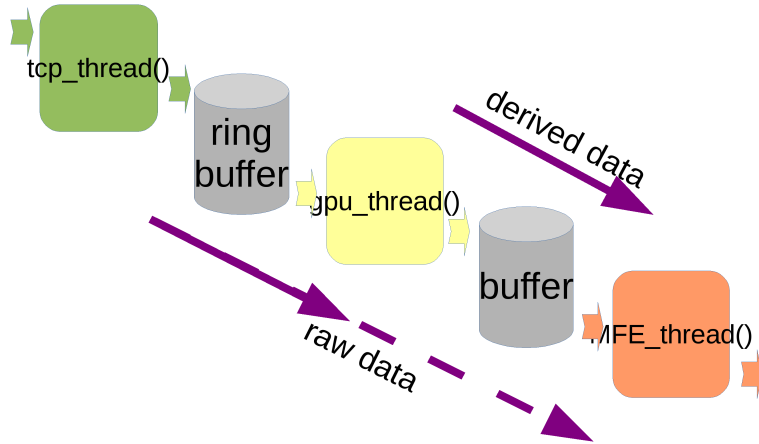
mserver [g2be1.fnal.gov]	Ebuilder [g2be1.fnal.gov]	AMC1302 [g2calo0102-data]
AMC1303 [g2calo0304-data]	AMC1304 [g2calo0304-data]	AMC1305 [g2calo0506-data]
AMC1311 [g2calo1112-data]	AMC1312 [g2calo1112-data]	AMC1314 [g2calo1314-data]
ODBEEdit [g2be1.fnal.gov]	mhttpd [g2be1.fnal.gov]	Logger [g2be1.fnal.gov]
DOM [102.168.50.21]	MasterGM2 [g2be1.fnal.gov]	



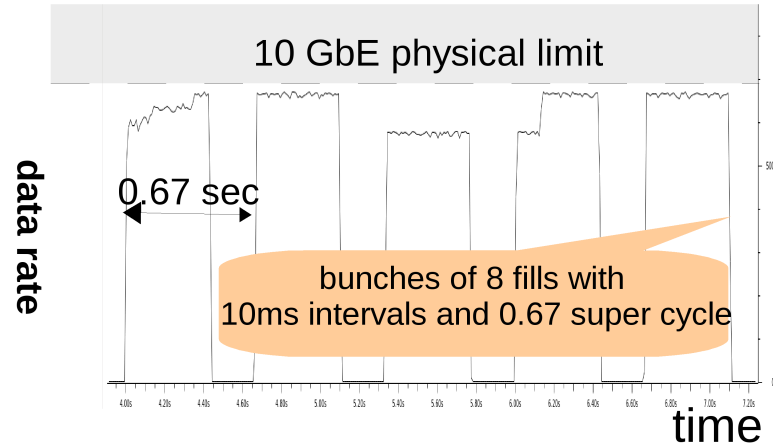
# hardware-based testing



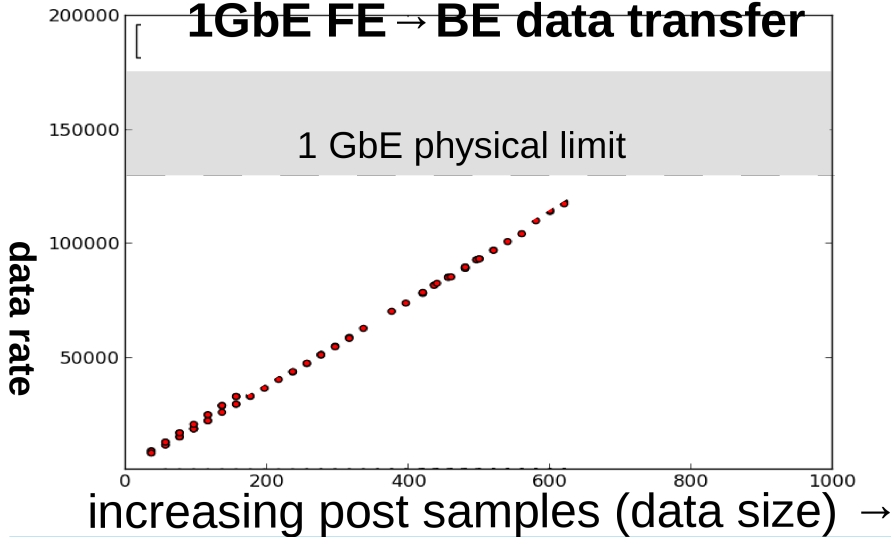
**DAQ design** multi-threading with mutex-locked buffers



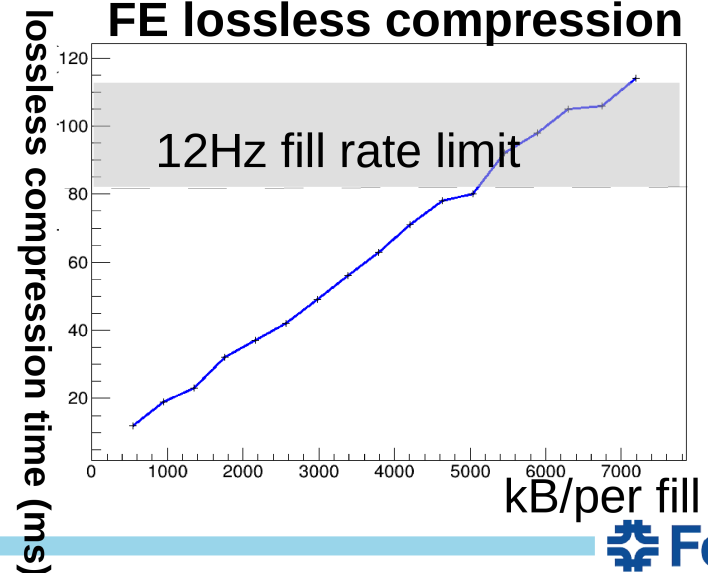
## 10GbE AMC13 → FE data transfer



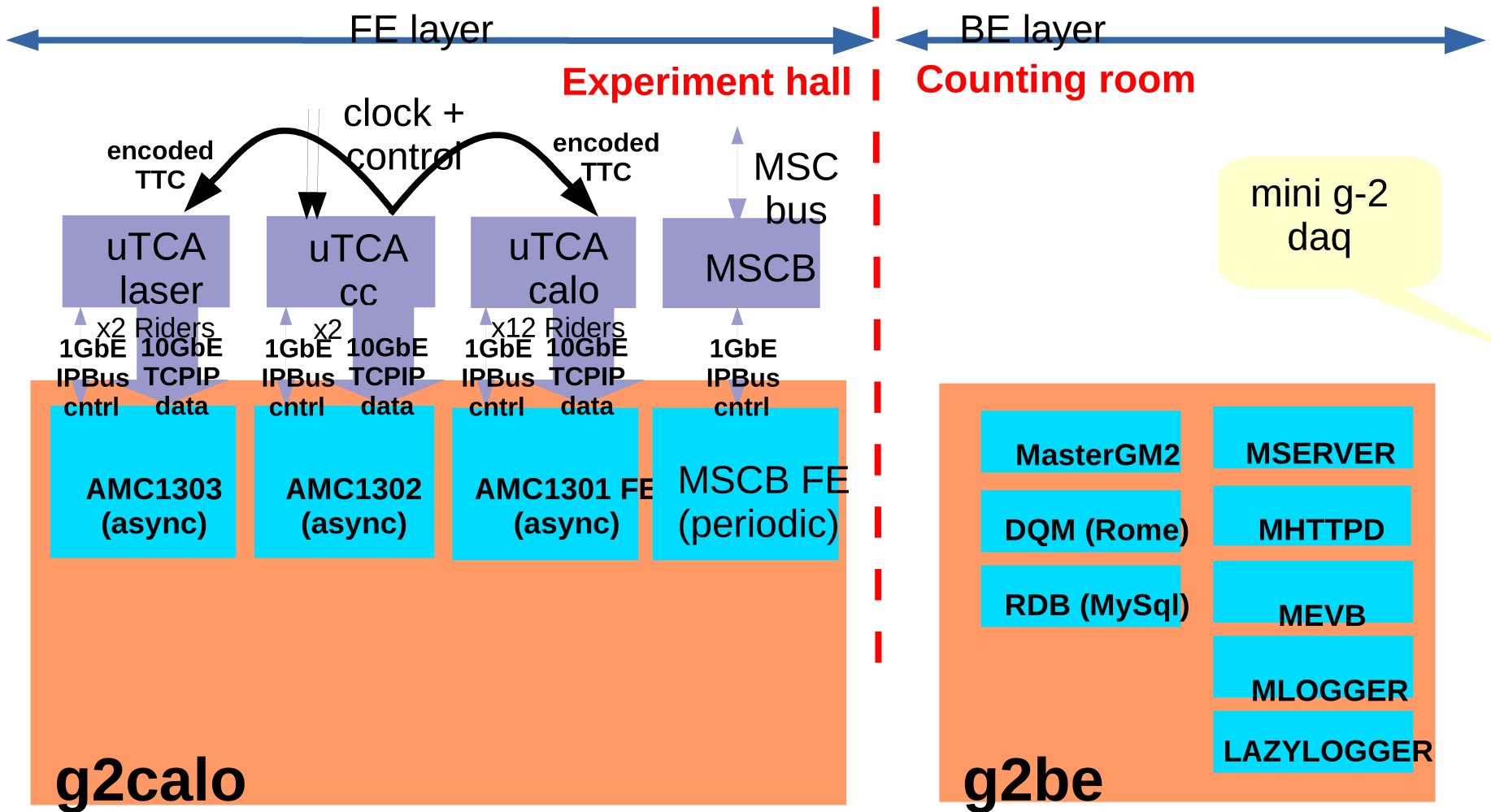
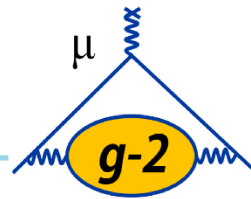
## 1GbE FE → BE data transfer



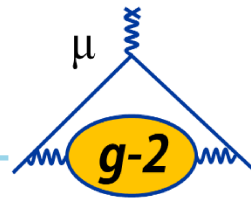
## FE lossless compression



# Calorimeter beam test at SLAC



# Calorimeter beam test at SLAC



### Run Status

**Run 3413**  
Running

Start: Tue Jun 14 00:34:23 2016      Running time: 0h07m50s  
            Data dir: /data/slac/  
Experiment Name: SLAC  
Rider status: 0

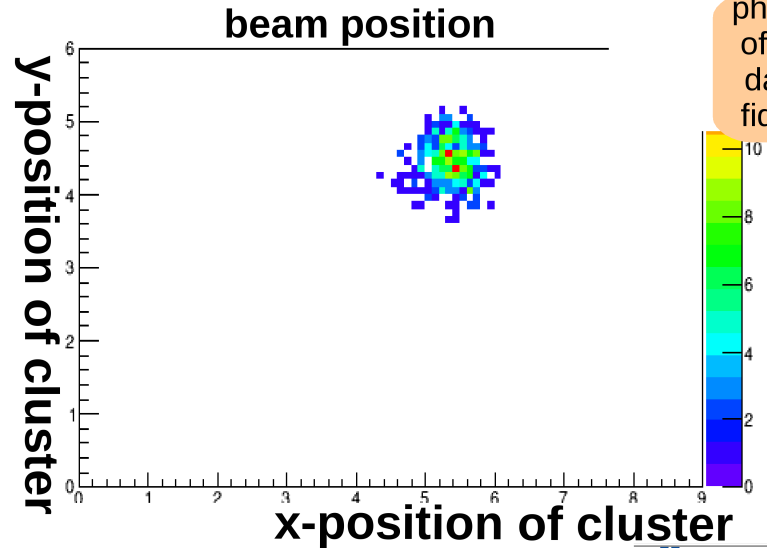
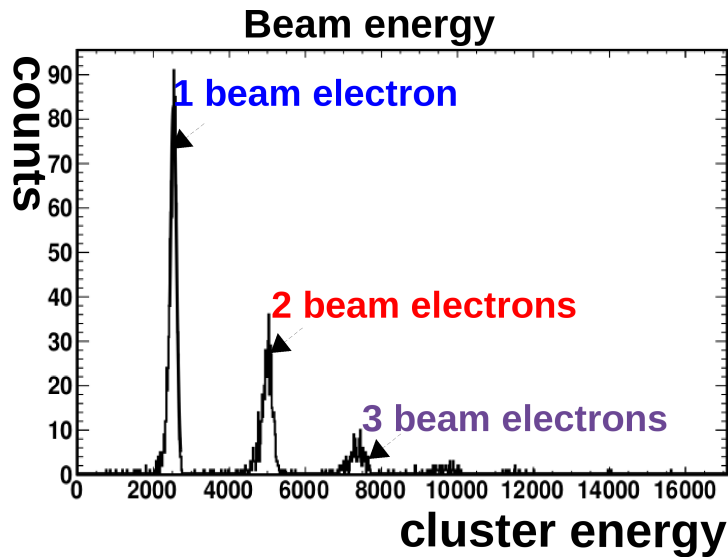
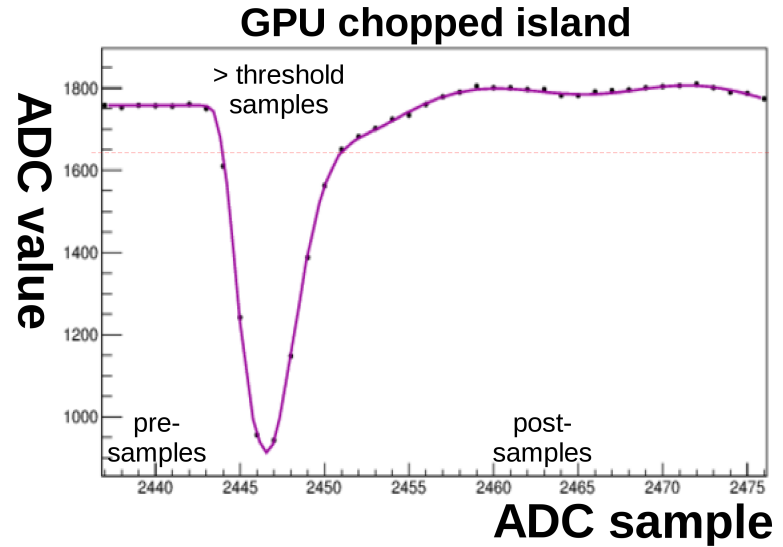
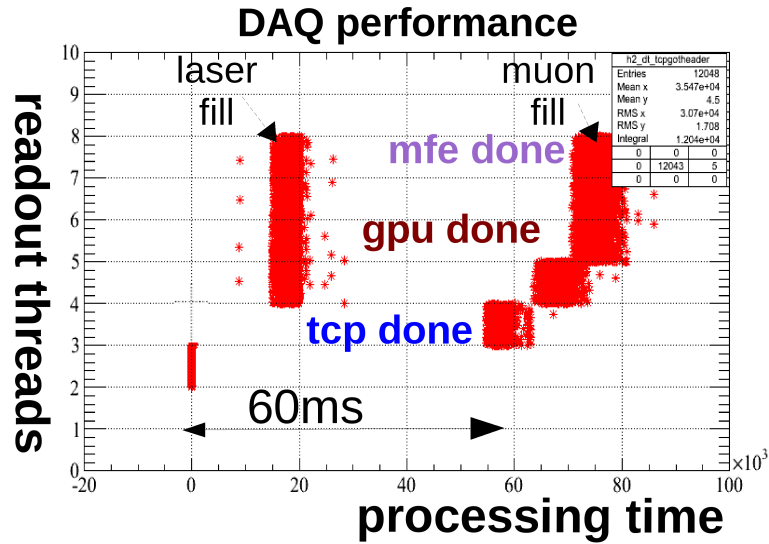
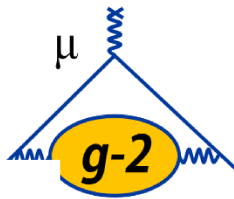
00:34:28 [mhttpd,INFO] Run #3413 started

fill-by-fill events

### Equipment

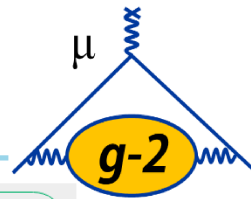
Equipment	Status	Events	Events[/s]	Data[MB/s]
EB	Ebuilder@g2be	4610	12.0	8.339
calo	MasterGM2	0	0.0	0.000
cc	AMC1301	4588	10.0	3.686
laser	AMC1302	4586	10.0	0.197
slow	AMC1303	4604	10.0	3.051
control	Temperature	47	0.0	0.000

# Calorimeter beam test at SLAC



physics studies offer essential daq integrity / fidelity checks

# Q-method development at FNAL



Online Database Browser

Find Create Delete Create Elog from this page

/ Equipment / AMC1301 / Settings /

- ▶ Link01
- ▶ AMC13
- ▶ Rider01
- ▶ Rider02
- ▶ Rider03
- ▶ Rider04
- ▶ Rider05
- ▶ Rider06
- ▶ Rider07
- ▶ Rider08
- ▶ Rider09
- ▶ Rider10
- ▶ Rider11
- ▶ Rider12
- ▶ Calorimet Settings
- ▶ Global
- ▶ TQ01
- ▶ TQ02
- ▶ TQ03

multiple q-method histogram

q-method histogram range, decimation, flush-rate.

Online Database Browser

Find Create Delete Create Elog from this page

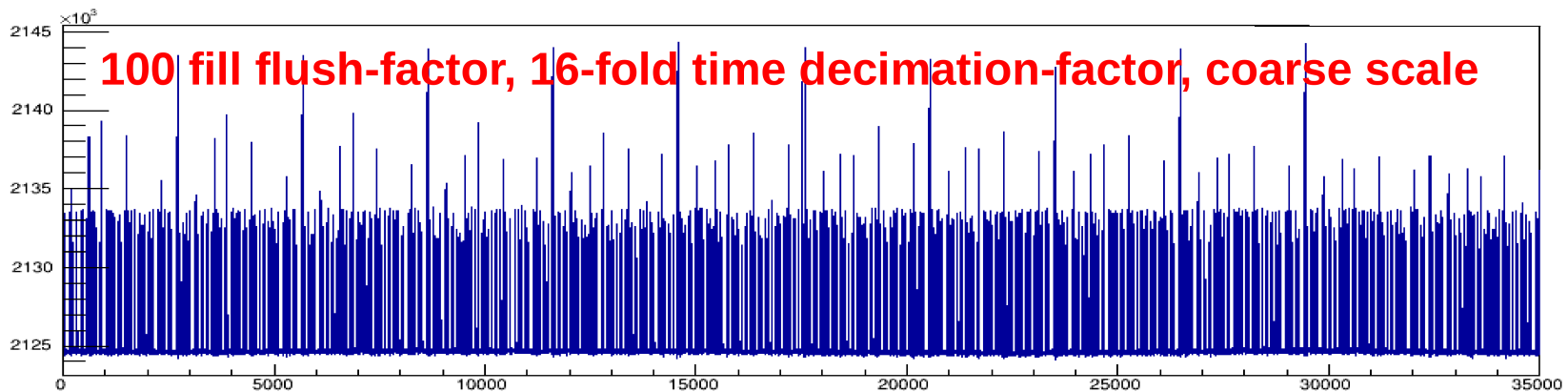
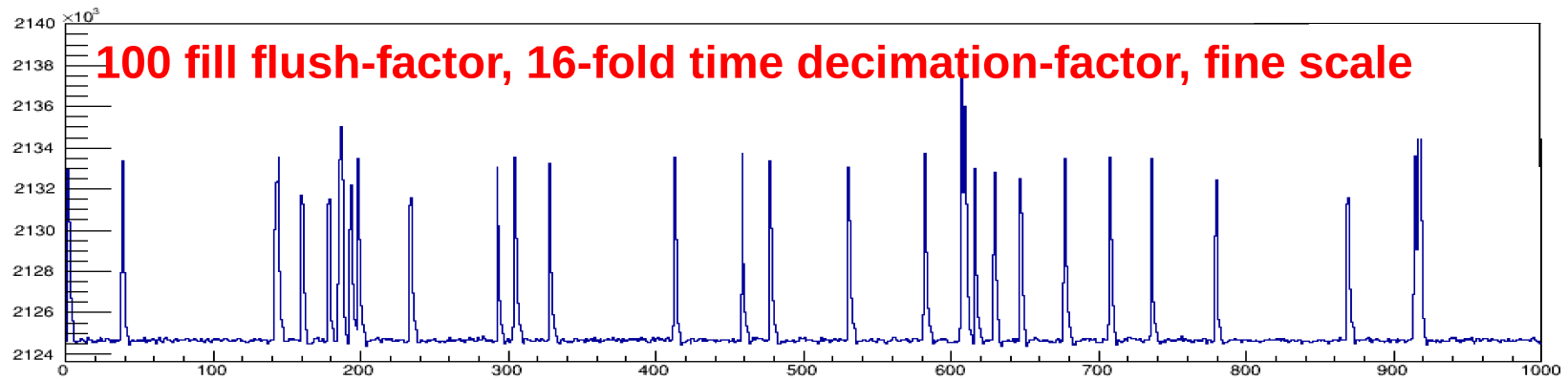
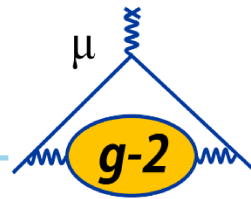
/ Equipment / AMC1302 / Settings / TQ01 / GlobalParameters /

Key	Value	+
TQ Midas Bank prefix	C	
TQ map type (0-array,1-enabled)	0 (0x0)	
GPU T,Q,P bank processing	Y	
waveform length	560000 (0x88B80)	
array x-segments	9 (0x9)	
array y-segments	6 (0x6)	
island presamples	8 (0x8)	
island postsamples	16 (0x10)	
thres type 0-dt,1-sm,2-eg,3-wgt	0 (0x0)	
global threshold value	200 (0xC8)	
+ve(-ve) global thres xing Y(N)	Y	
use individual thresholds Y(N)	n	
pedestal type 0-glbl,1-fbyf	1 (0x1)	
global pedestal value	0 (0x0)	
consum time decimation	128 (0x80)	
GPU bank processing	n	
histo data time decimation	8 (0x8)	
histo data first sample index	1 (0x1)	
histo data last sample index	140000 (0x222E0)	
histo data flush period	10 (0xA)	
histo data flush offset	0 (0x0)	
whether to run gpu fitter	0 (0x0)	
minimum fit time	9 (0x9)	
fit threshold	1280 (0x6A4)	

- “Q-method” is an alternative approach to data analysis.
- involves building a “wobble-plot” of the recorded energy (not hits) versus fill time.
- individual pulses are not fitted and clusters are not identified.
- offers much reduced pile-up, gain-change sensitivity

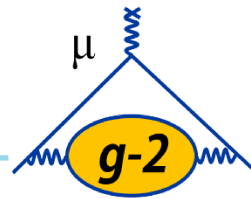
- at 20 GB/s its impossible to save all the individual data from each crystal of each calorimeter for each fill.
- in practice fill-summed, time-decimated Q-method histograms are accumulated and flushed by the GPUs
- what is the optimal strategy for decimating and flushing these histograms?

# Q-method development at FNAL

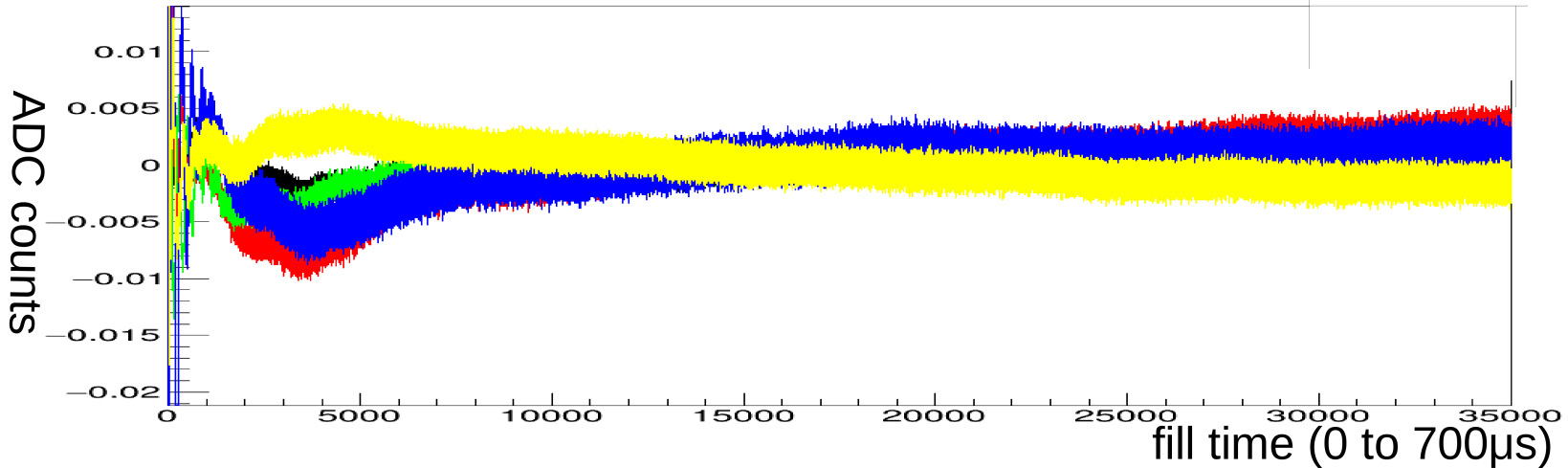


- Sample Q-method histogram with pulser feeding Rider channels and readout by MC-1 daq
- Sample Q-method histogram shows pedestal, noise, single pulses, overlapping pulses.
- Later Q-method analysis involves adding the histograms and accounting for pedestal.

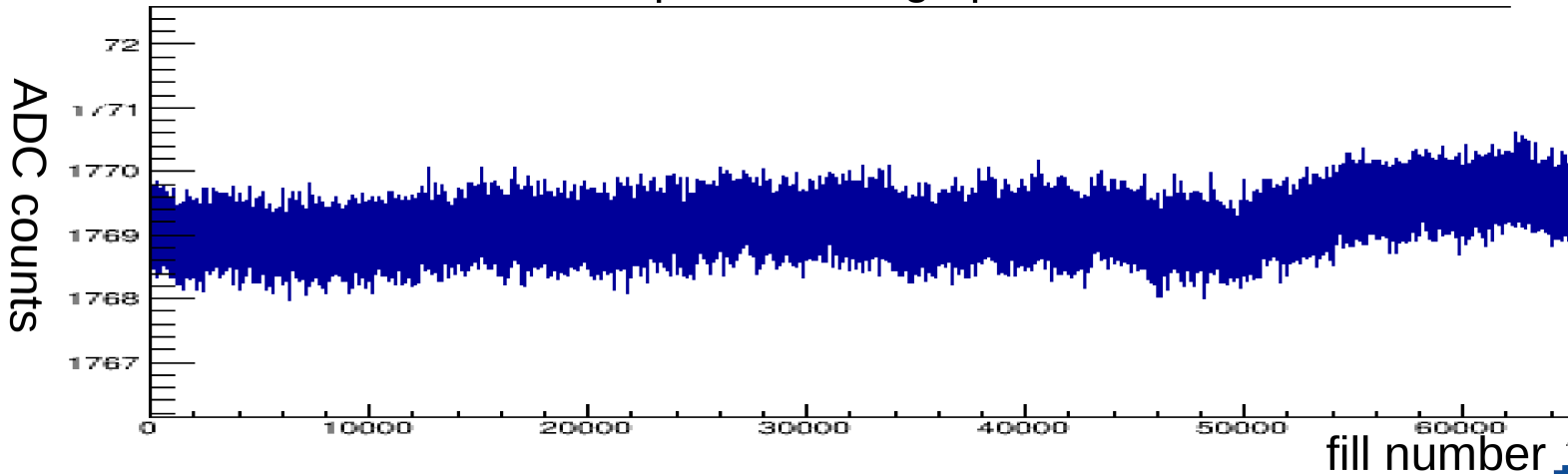
# Q-method development at FNAL



example of fill-time correlated pedestal noise



example of average pedestal drift

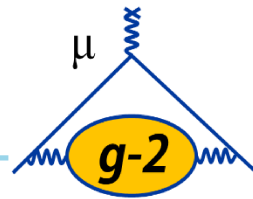


physics studies  
offer essential  
daq integrity /  
fidelity checks

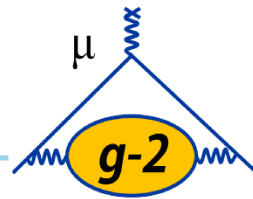




# Comments on schedule and operations



- DAQ networking, o/s, data storage is managed / supported by FNAL computing groups.
- DAQ design based on commodity 10GbE, CPUs, GPUs electronics with FNAL-negotiated vendor contract for replacement / repair, redundant gateway, backend and spare gpus, nics, etc.
- Calorimeter, tracker, auxiliary detectors, laser system use common elec-daq interface and FE code\*.
- Midas is mature, supported system with lots of experience in collaboration thru prior experiments and g-2 test stands
- Remote data taking and DAQ testing with MC-1 daq is straightforward and demonstrated.
- Considerable DAQ-related expertise - students, postdocs, scientists (next slide) – that's broadly distributed over g-2 groups and provides shift-level daq operations expertise as well as daq component experts.

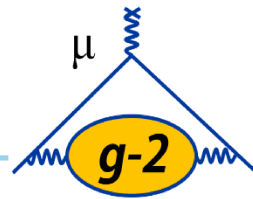


## Computing coordinator + Online Manager: W. Gohn

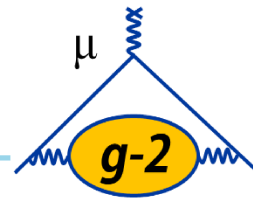
- **fast DAQ organization, Calo/Aux/laser crate readout, GPU processing:**
  - University of Kentucky: T. Gorringer, W. Gohn (PD), F. Han (GS)
- **Tracker DAQ**
  - University College London: M. Lancaster, R. Chislett (PD), G. Lukicov (GS)
- **Field DAQ**
  - Fermilab + University of Washington: B. Kiburg (Wilson Fellow), M. Smith (GS)
- **Laser Monitor**
  - Frascati + Napoli: S. Mastroianni, N. Raha (PD)
- **Data quality monitor**
  - U. Kentucky: R. Fatemi, W. Gohn (PD), L. Kelton (GS), U. Washington: A. Fienberg (GS), M. Smith (GS), UCL: R. Chislett (PD)
- **Paraview event display, Midas database interfacing**
  - Dubna: N. Khomutov, V. Krylov, UCL: W. Turner
- **Slow Controls**
  - Northern Illinois University: M. Eads

# Conclusion

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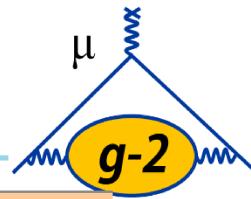


- **DAQ hardware / software are installed in MC-1 computing room / control room.**
- **Various soak, stress, unit and integration tests have demonstrated DAQ capability / functionality.**
- **Various application of DAQ components to detector / physics development have tested the data integrity / fidelity.**
- **Next months will focus on integration and readout of detector hardware and transition to mock data taking and muon data taking.**



# Backup Slides

# Readout sub-system requirements



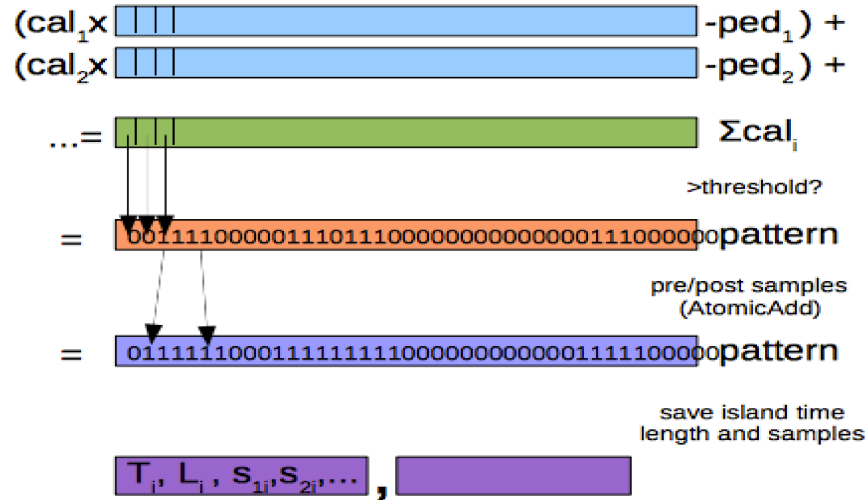
Rider detector type	raw sample rate	waveform length	channels count	uTCA crate count	raw data / crate / sec	data processing	prod data-taking	proc data / crate / sec	DAQ comments
<u>calo</u>	800 MHz	700 us	24 x 54	24 <u>calo</u> crates	725 MB/s	T, Q methods and <u>prescaled-raw</u>	yes	4 MB/s	
t0	800 MHz	700 us? or 1us?	2(hi, lo gain)	in 1 <u>calo</u> crate	27 MB/s	Raw + T method	yes	negligible	needs software development for <u>calo</u> + t0 crate operation *1
laser	800 MHz	700 us	source + 24 local monitors	1 laser crate	564 MB/s	T-method	yes	~2 MB/s	needs software development for aux laser crate operation *2
quad baseline	40 MHz	700 us	4 <u>pulsers</u>	in 1 aux crate	2.7 MB/s	raw (or time-decimated fill-by-fill Q method)	yes	~3 MB/s or decimation factor 2^n less	needs software development for aux (quad+kick+harp) crate operation *3
quad extension	500 MHz	700 us	32	not enough channels in 1 aux crate	269 MB/s	T-method	yes	negligible?	won't fit into aux crate
kicker	200 MHz	2.4 us	from 6 to 9	in 1 aux crate	< 1 MB/s	raw	yes	< 1 MB/s	needs software development for aux (quad+kick+harp) crate operation *3
harps	200 MHz	200 us (or more or less)	4 x 7 = 28	in 1 aux crate	27 MB/s	raw or decimate	no	27 MB/s	needs software development for aux (quad+kick+harp) crate operation *3

\*1 use \*2 or additional T-method for t0 lo, hi

\*2 need flexibility to store specified raw channels on every fill

\*3 need flexibility of different T-method thresholds for each channel

## (i) example T-method

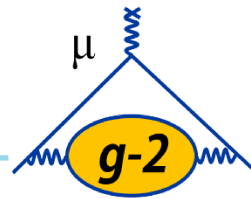


## (ii) example Q-method

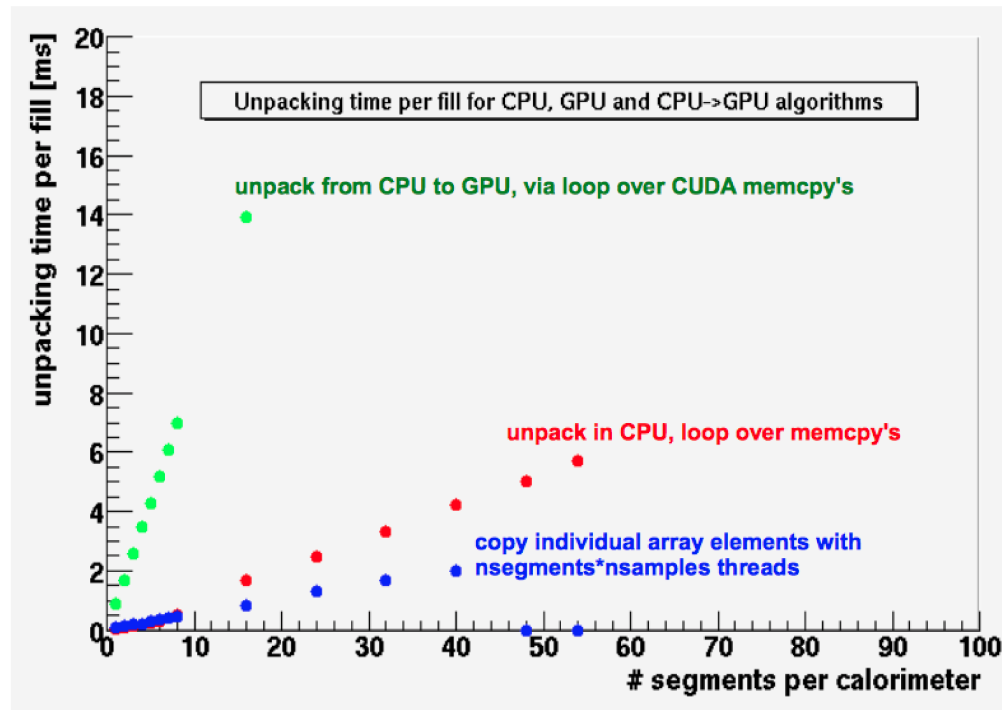


+ prescaled raw data  
 + histogrammed raw data

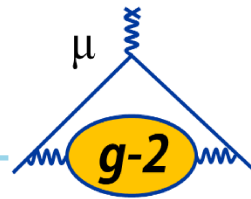
# AMC13 block unpacking



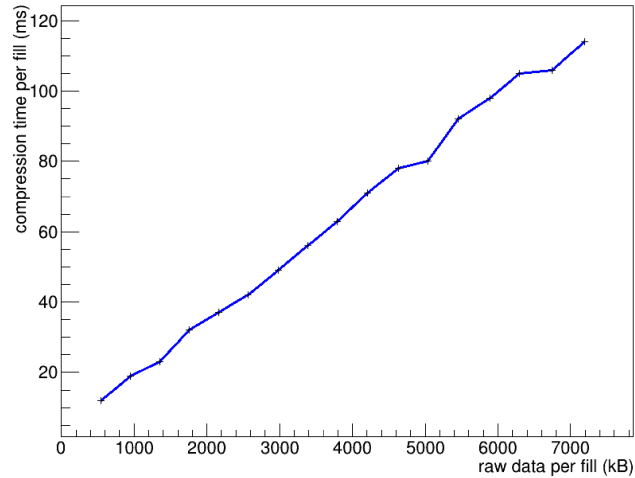
The data from the AMC13 is packed in 32kB blocks



# Lossless, FE data compression



compression time versus raw data



compression factor versus raw data

