Monitoring electronics and DAQ in g-2

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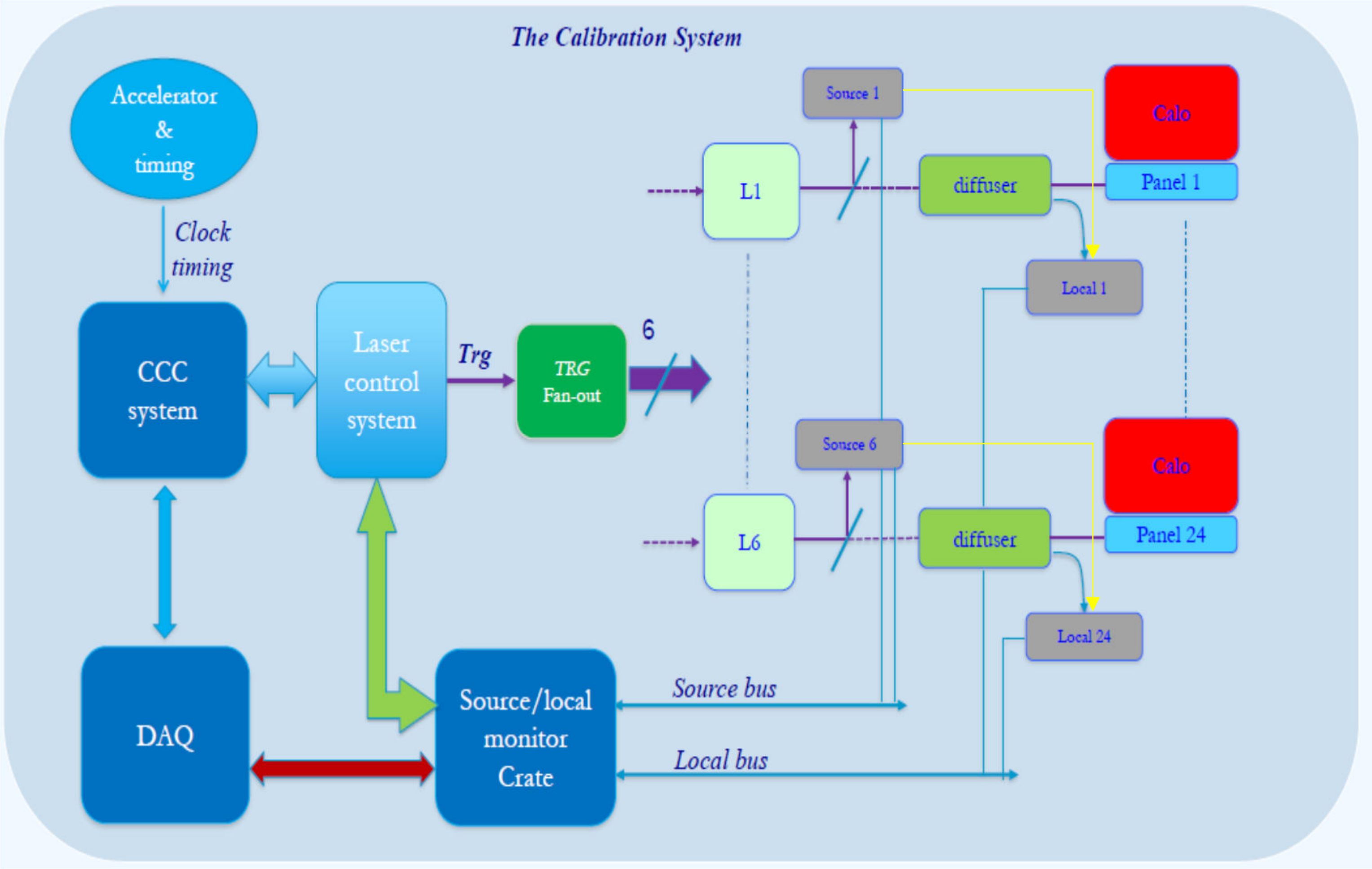
Laser Calibration System

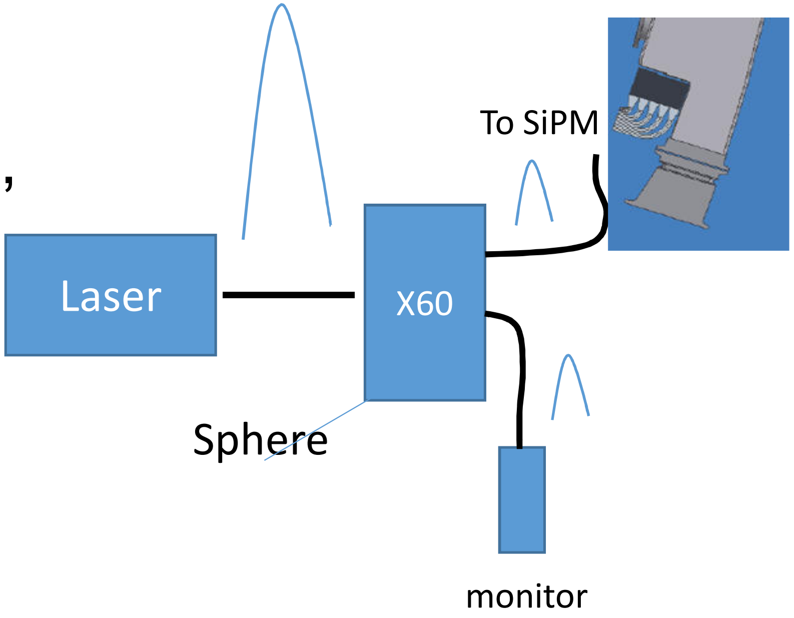


The system consists of a laser control card (Laser control , which is able to drive 6 lasers (L1, ... L6) which, via a distribution system (diffuser, 4 calorimeter / diffuser), provide light signals of calibration to calorimeters (Calo). The light arriving at the calorimeters simulates the signal produced by the decay electrons of muons. The light produced by the laser is monitored at source (Source 1, ... Source 6) then downstream of the distribution (Local1, ... Local 24). These light signals are translated into electrical pulses by suitable detectors, then measured by dedicated electronics (Monitoring electronic).

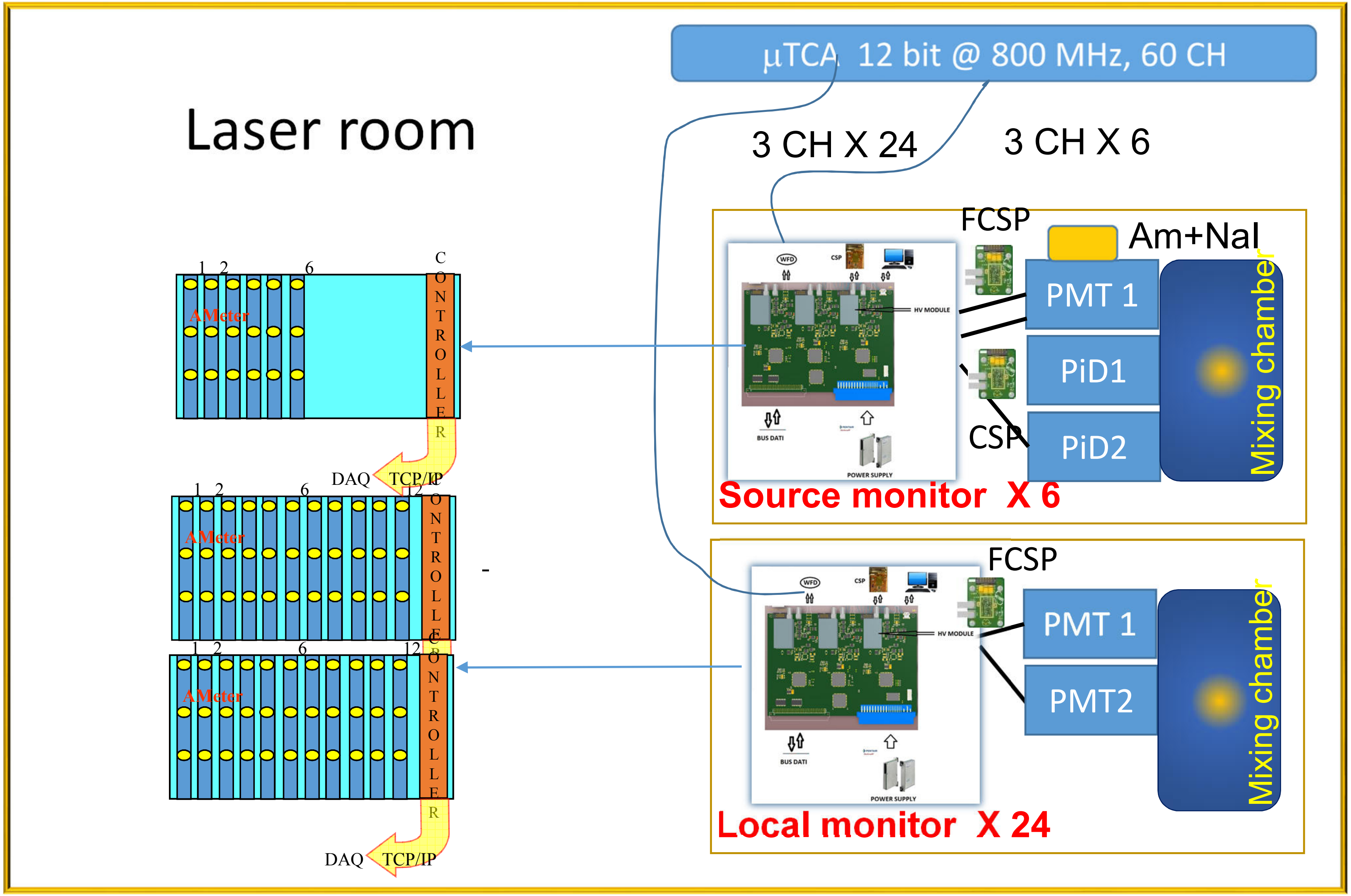
What matters is **the absolute value of the monitoring signal** (Source Monitor)

and **the SiPM/monitoring** signal ratio (Local Monitor) :

- With a performing monitoring all the effects of beam pointing, source fluctuation, etc…, cancel in the ratio;
- loss of uniformity (in time) and local effects (temperature gradients, mechanical stress) could modify the ratio



Monitoring electronics and DAQ



µTCA 12 bit @ 800 MHz, 60 CH

Laser room

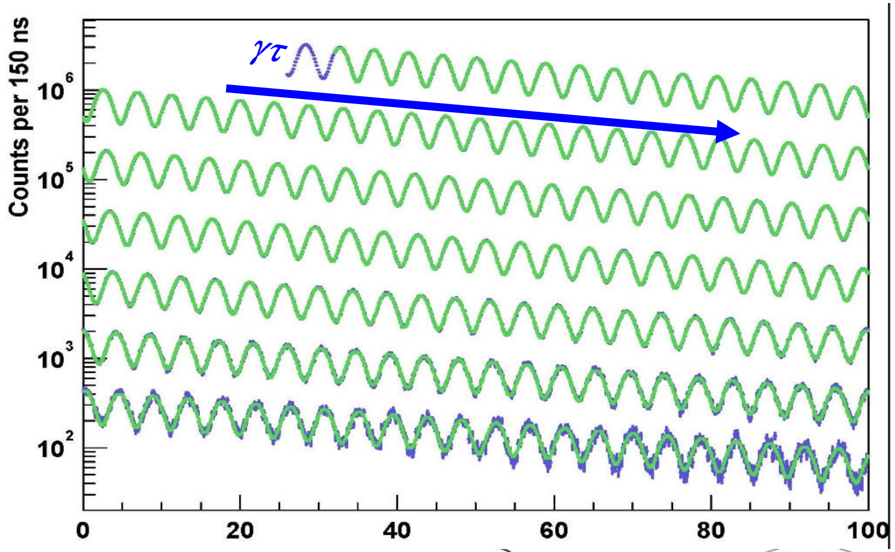
3 CH X 24

3 CH X 6

Source monitor X 6

Local monitor X 24

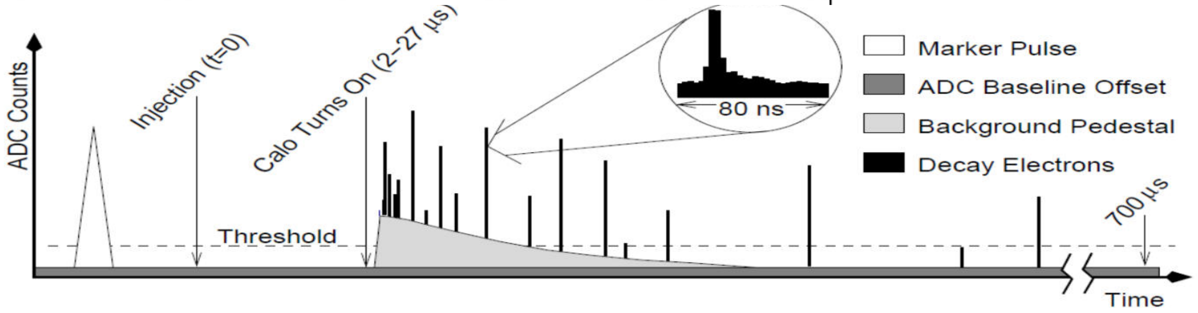
Measuring ω_a



The arrival time spectrum of high-energy e^- ($E_\mu \geq$ **1.8 GeV**

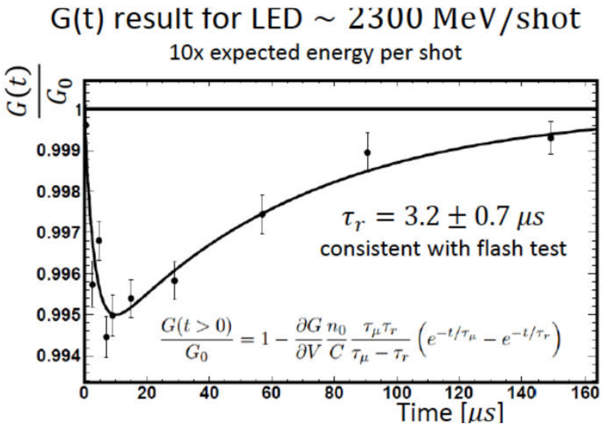
$$f(t) \simeq N_0 e^{-\lambda t}[1 + A\cos\omega_a t + \phi)]$$

$\gamma\tau_\mu$ = 64.4 μs;
(g-2): τ_a = 4.37 μs;
Cyclotron: τ_C = 149 ns



4000 pe per laser pulse corrisponds to an electron of 2 GeV. The error (%) in the energy is 1/sqrt(4000) = 1.6% per single laser pulse. For 1600 events --> 1.6%/sqrt(1600) = 0.04%

30'/1h calibration runs with ~10 kHz laser frequency → sampling of G(t) in 140 points between 0 and 700μs



We are interested in "short term" stability, i.e. the gain variation within [0-700 μs] at 0.04%
The expected rate changes by many orders of magnitude O(MHz)→O(100 Hz)

Goal

- Monitoring electronics stable at 10^{-4}/h (time derivative)
- Laser pulse measured at ~10^{-3} (single pulse resolution)

→ Stable, redundant and self-calibrating monitoring system

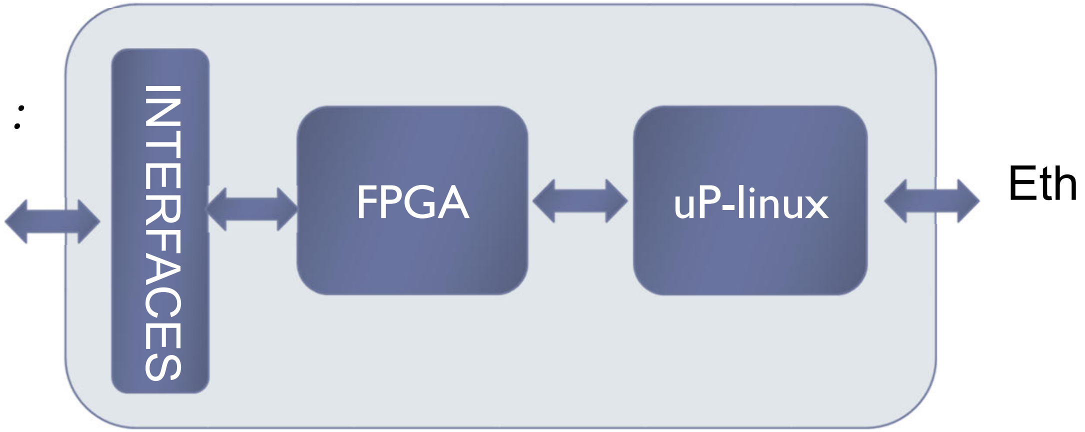
- Measuring accuracy of the order of ‰
- Sampling ADC 14-bit resolution
- Long-term stability, better than ‰
- LASER rate of 10kHz
- Charge Preamplifier, sensitivity> = 100 mV/pC
- Preamplifier bandwidth 200MHz

The Laser control board

The Laser Control provides calibration pulses according the following modes:

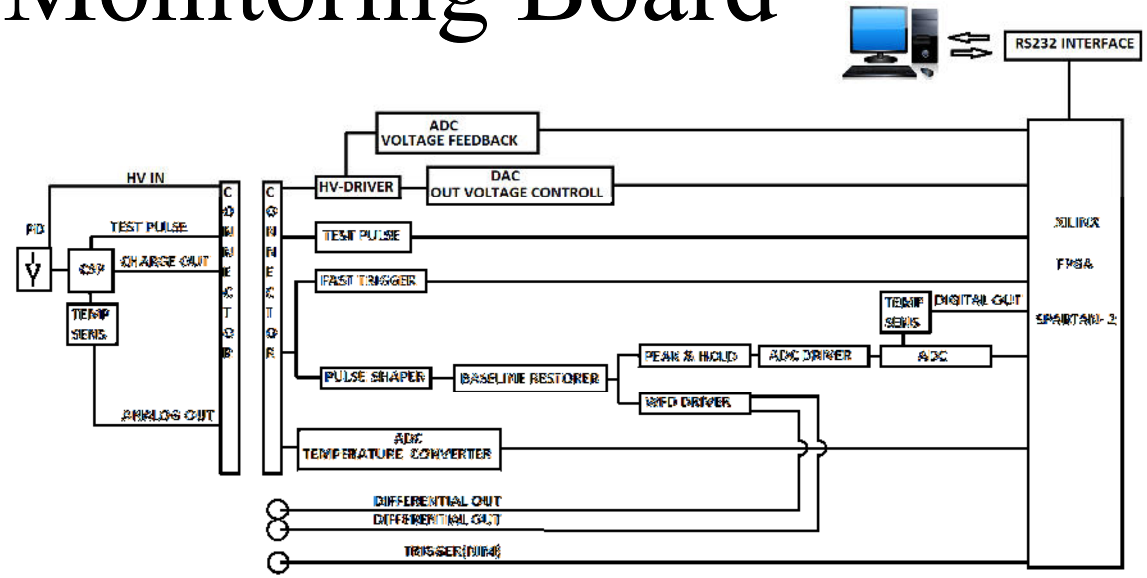
1. Fixed frequency at ~10 kHz during the FILL
    - The train pulses are shifted of 5μs at each FILL cycle
2. Physics simulation “Flight simulator”
3. Single pulse for a specific request (before FILL to synchronize WFD etc..)
4. SiPM calibration with a dynamic range ~ 5
5. Pulses between FILL cycle?

The hybrid platform guarantees :
- *complete managing and monitoring by remote:*
- *total reconfiguration of the FPGA firmware*



CSP & Monitoring Board

- CSP sensitivity = 800mV/pC
- CSP Bandwidth: 200MHz



Monitoring board sends signal to WFD, according to Common mode +/- 0.5 V at 1.9 V.
Provides the LASER / Monitoring trigger to the WFD / DAQ
Triggers the asynchronous transfers (Am) to µTCA / WFD
Opens a time window for digitization to the WFD.

Digitizes the Monitoring signals with a14-bit ADC and sends the values to the CONTROLLER which in turns provides the data to the DAQ via TCP / IP protocol.

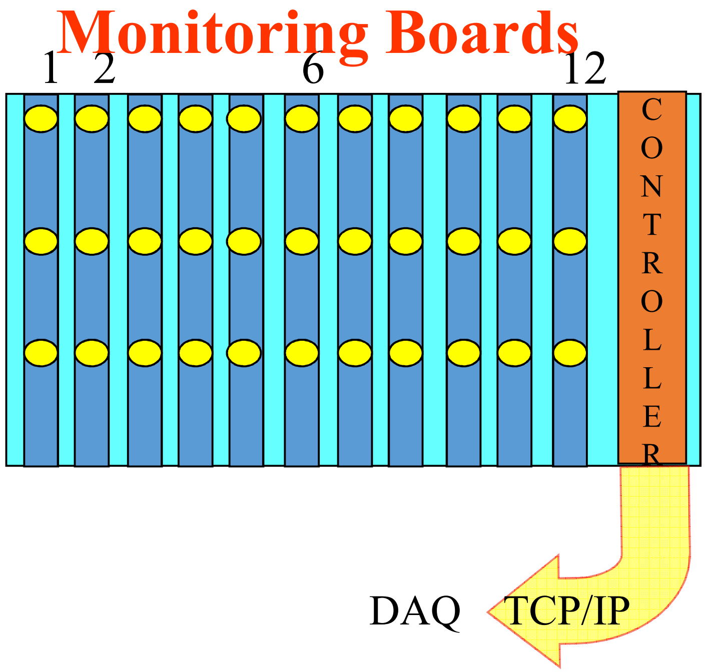
Digitization is started by the signal of the Laser Control (Start) appropriately timed (programmable delay)

Provides BiasV/HV to the detectors (PiD/PMT) and monitor it
Reads the detector currents
Reads 3 Temp/channel (Tpream, Tboard, Tenvir) - 0.1^0C resolution

Self-calibration of the electronic channel (known pulse to the input)

DAQ of the Monitoring Signals

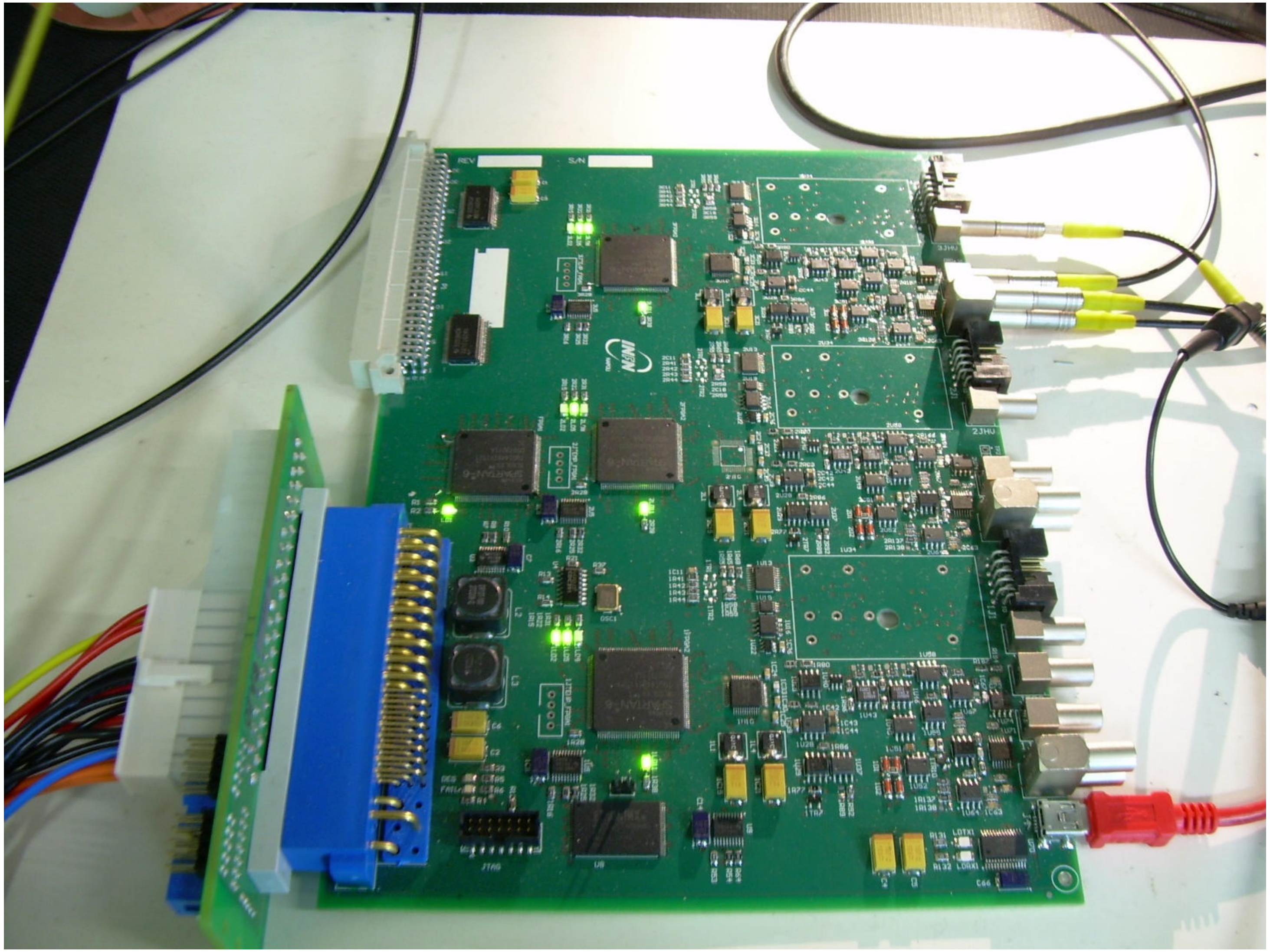
The elemental unit of DAQ is the *MonCRATE*



Throughput: 50 kB/s

- **each MonCRATE deserves 12 Calorimetri**
- **The information of one Diffuser (2 PiD / 1 PMT) including 1 with Am, is read by a Monitoring Board (3 channels /card) which receives the power from the backplane where is also a transfer bus for digitized signals.**
- **The digitized information (14 bit) of each board is collected by a CONTROLLER board which takes care of the all information collection from the MonCRATE and provide data to the external by TCP/IP protocol.**

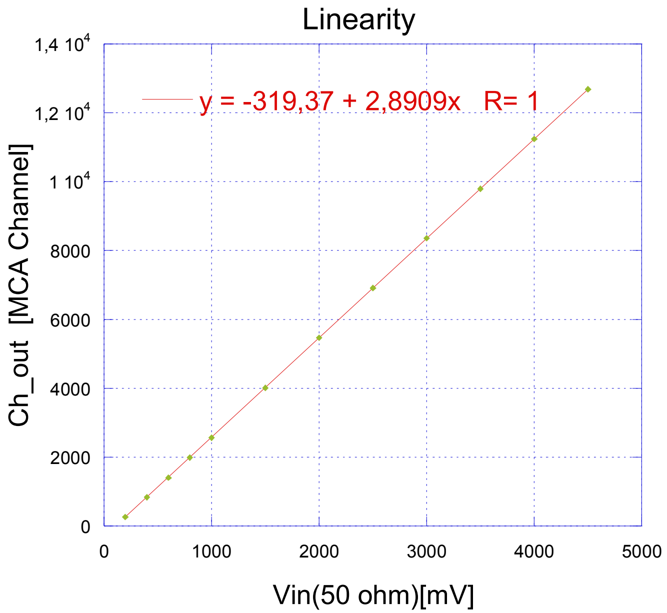
Test results on
CSP & Monitoring Board

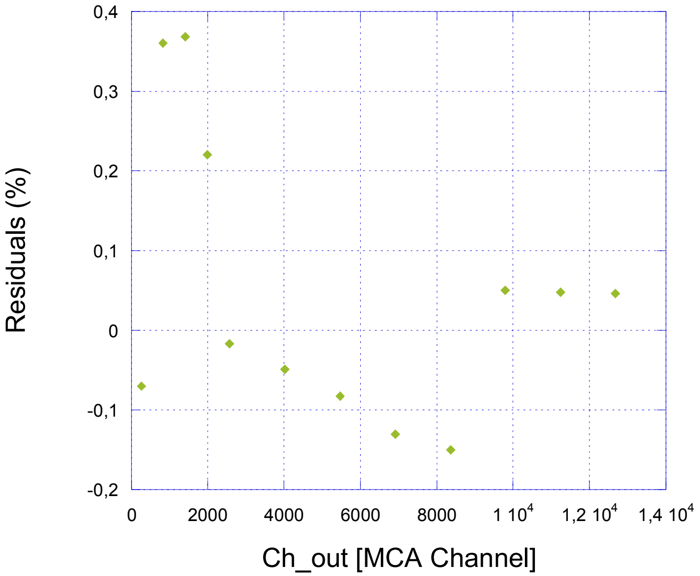


CSP Linearity

Measured linearity (left) and estimated differential linearity (right) from a linear fit. The setup to check the CSP card consisted of:

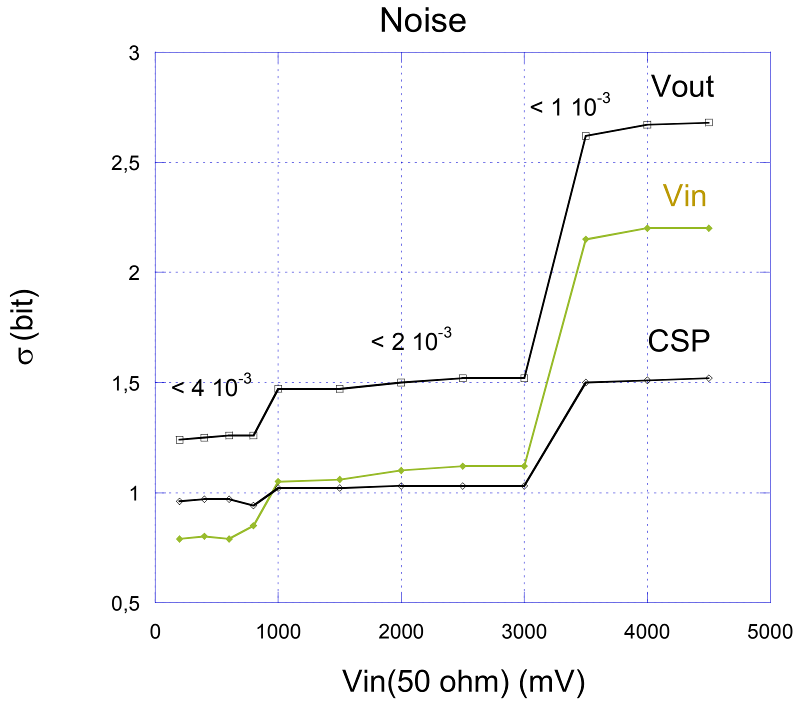
Pulser Agilent 33250
MCA Canberra multiportII (14-bit)
Oscilloscope Tek 3054.





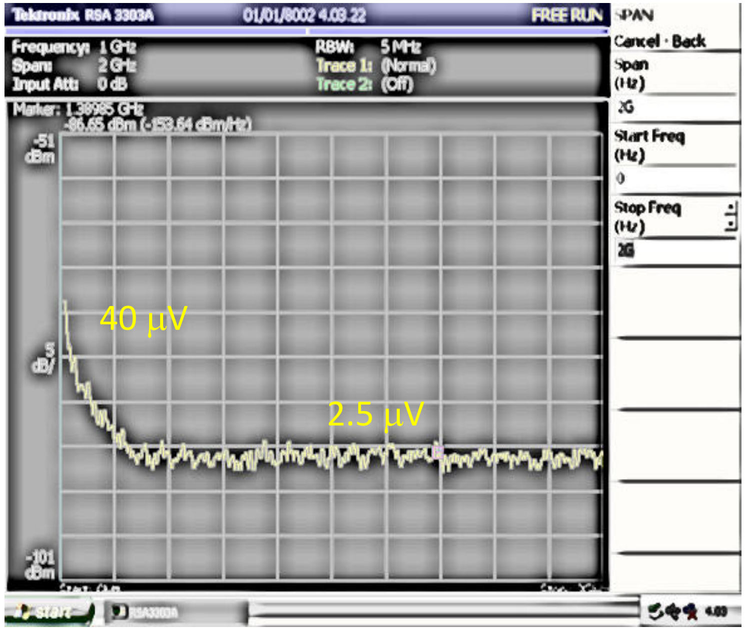
The signal (mV) was provided via a capacity of 1pF at the input of the preamplifier (CSP). From Figure dx, it emerges that for output values higher than 15% of the f.s. the deviation is contained within 0.2%.

Resolution & Noise



The intrinsic noise or the electronics contribution to the signal spread, calculated assuming a quadrature combination between the input signal Vin and the output signal from the preamplifier Vout , it is found to be less than 1.5 bits. Percentage values are shown for different Vout.

The plot at right shows the electronics noise in absence of signal, the corresponding voltage values are reported for the flat region and at the maximum is at low frequencies. The measurements were made with a spectrum analyzer Tektronix RSA 3303A.

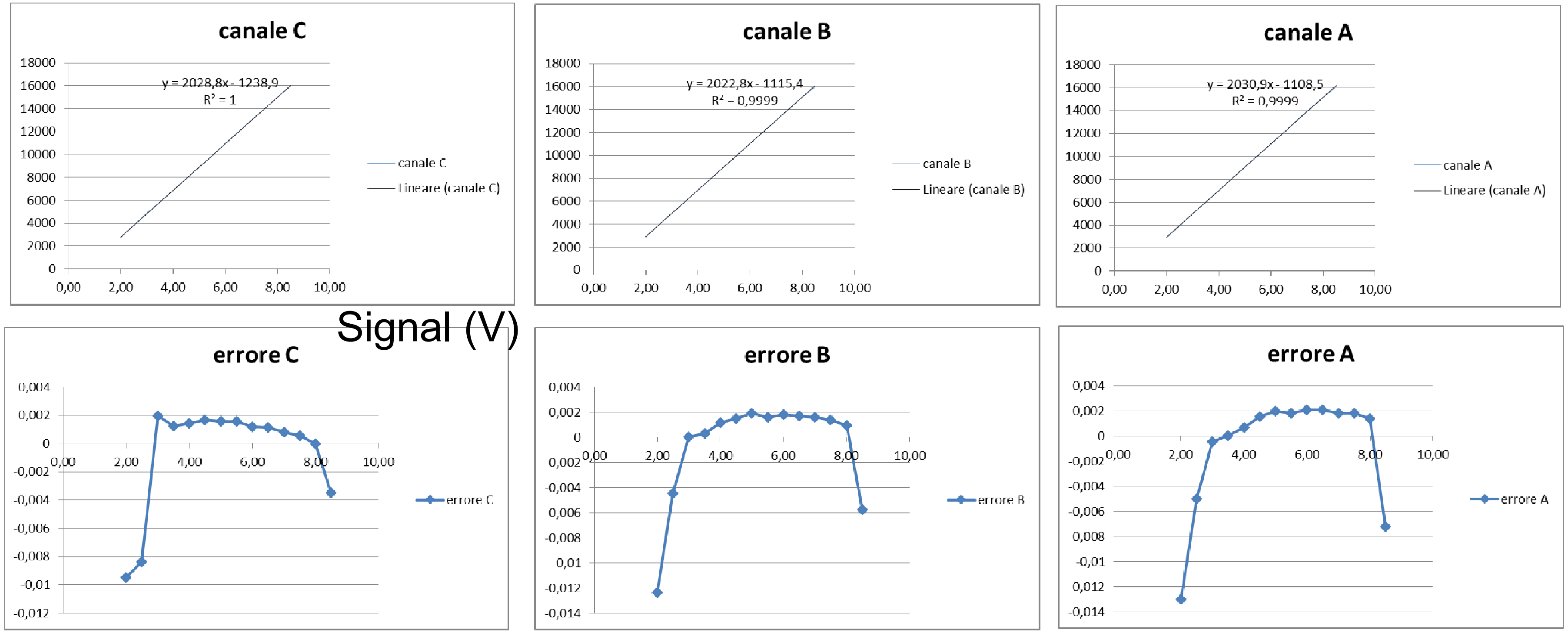

Tektronix RSA 3303A 01/01/8002 4.03.22 FREE RUN

Frequency: 1 GHz
Span: 2 GHz
Input Att: 0 dB
RBW: 5 MHz
Trace 1: (Normal)
Trace 2: (Off)
Marker: 1.38985 GHz
-86.65 dBm (-153.64 dBm/Hz)

Span (Hz) 2G
Start Freq (Hz) 0
Stop Freq (Hz) 2G

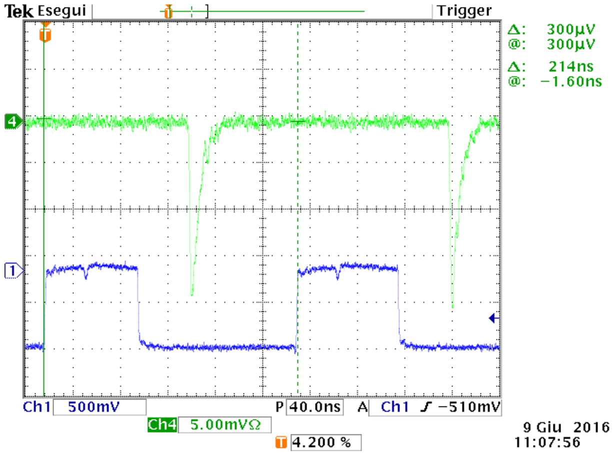
Flicker noise (inversely proportional to frequency - pink-noise, due to the resistance fluctuations that generate current or voltage fluctuations) + White Gaussian Noise (uniform with frequency with Gaussian distribution)

MB Linearity and resolution



- For Vin> 2 V, the difference from linearity is < 0.2%
- Working in the central zone (4-5 V), the difference is <0.1%
- Each channel has 3-4 counts of Std Dev at each sampling.
- The 3 channels show same behavior
- We can rely on resolution as 3-4/10000

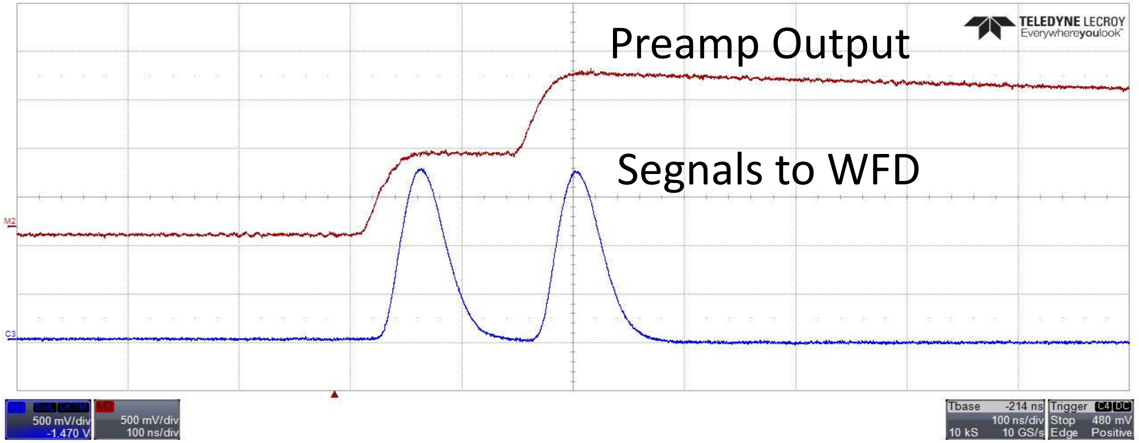
Local MB (1)



Local Monitor: need to separate two PMT pulses separated by approximately 200 ns.

Fixed parameters: a) integration time of preamp signal : 40-50 ns; b) separation of pulses: 200 ns; c) discharge time of FCSP: 10 kHz;

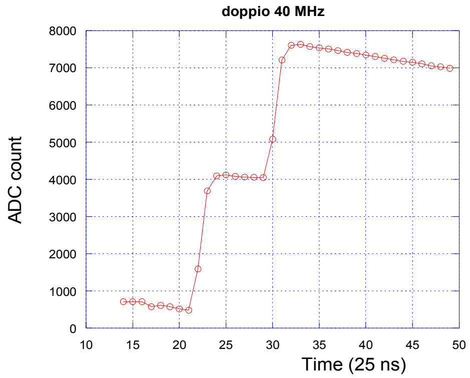
Blue trace is the trigger signal; green trace is signal of the PMT measured on resistance.

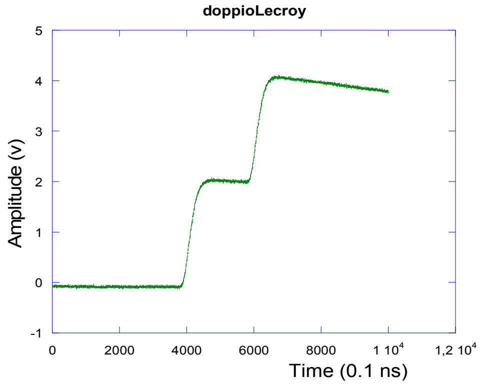


Signal from FCSP (green) and signal to WFD (blue)

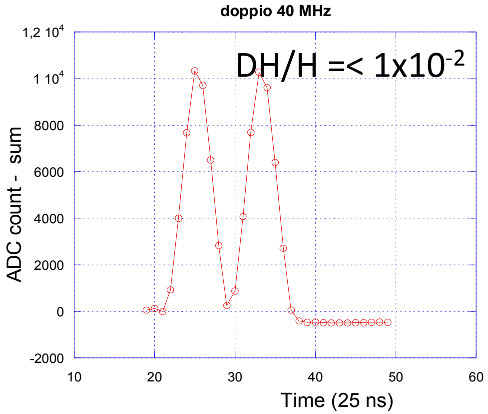
Local MB (2)

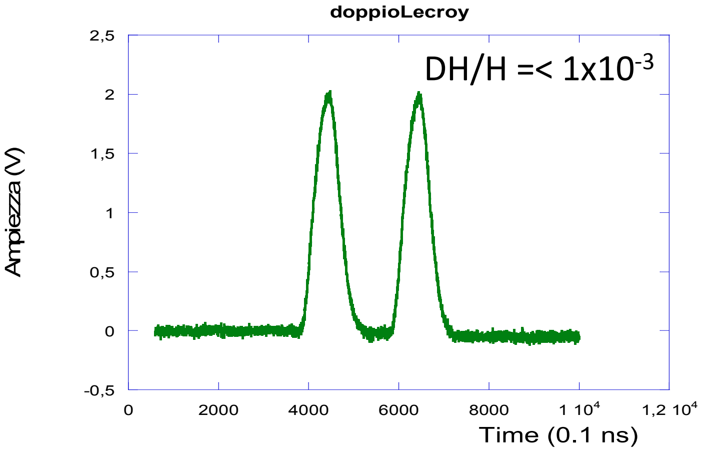
Adopted strategy for measuring the LMB amplitudes is direct sampling of the Preamplifier output (FCSP) with the ADC 40 MHz (14 bit), the one currently resident on the card, and with the oscilloscope Lecroy -wave Runner 610 Zi- to 10 GHz (8-bit). Then compare the two digitizations





Output of FCSP as sampled by ADC at 40 MHz / 14 bits (left) and by the Lecroy 10 GHz / 8-bit (right)



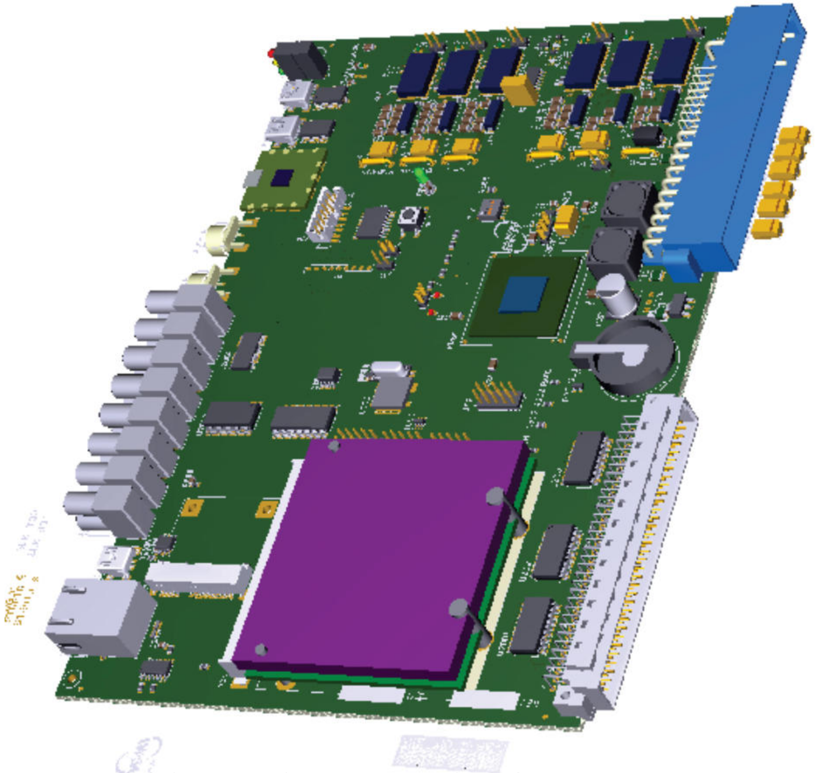


Extracted signals respectively with 40 MHz /18 bits (left) and 10 GHz / 8-bit (right).

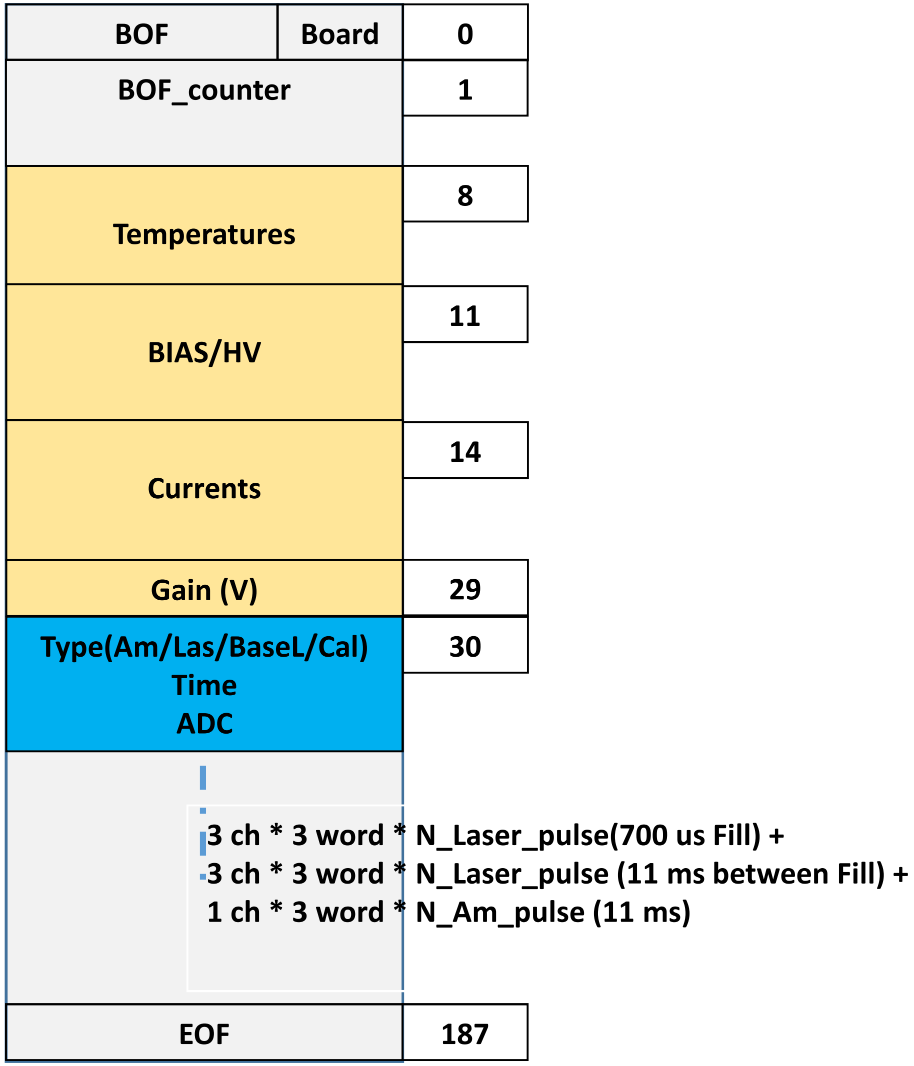
Tests provided positive indication for sampling the output of the FCSP with an ADC at frequency> 100 MHz and direct extraction of the signal.

Monitoring Controller

Designed,
now in production fase



Throughput: 50 kB/s



BOF	Board	0
BOF_counter		1
Temperatures		8
BIAS/HV		11
Currents		14
Gain (V)		29
Type(Am/Las/BaseL/Cal) Time ADC		30
EOF		187

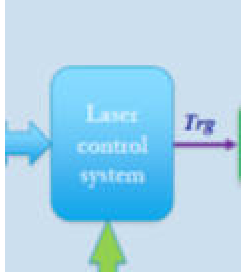
3 ch * 3 word * N_Laser_pulse(700 us Fill) +
3 ch * 3 word * N_Laser_pulse (11 ms between Fill) +
1 ch * 3 word * N_Am_pulse (11 ms)

Frame format of MonitoringBoard. Each word is 16 bit.

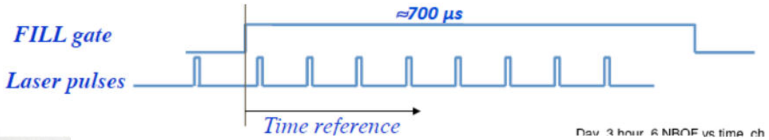
Test beam @ SLAC/ May-June 2016

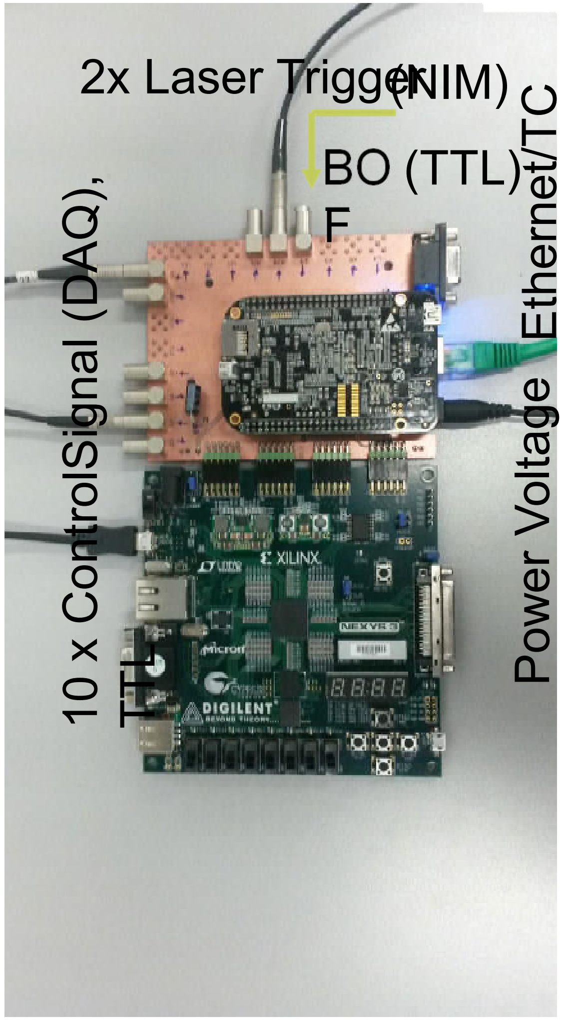
The Laser Control and the Source Monitor have been installed and integrated with the calorimeter DAQ for the first time at SLAC

The system operated in slave mode and was completely controlled by remote

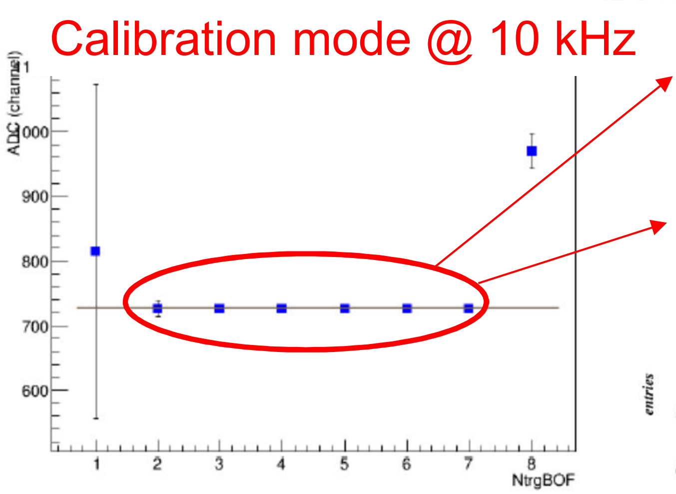


Laser Control Board



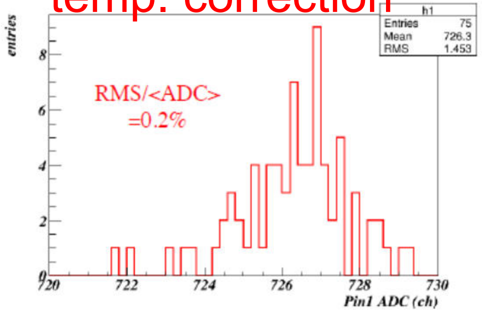


Calibration mode @ 10 kHz

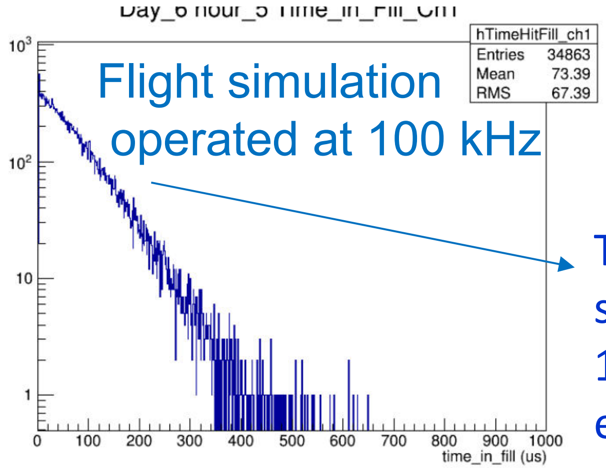


Calibration pulses in fill do not depend on number of pulse

Each pulse within the fill is stable in 0.2% without any temp. correction

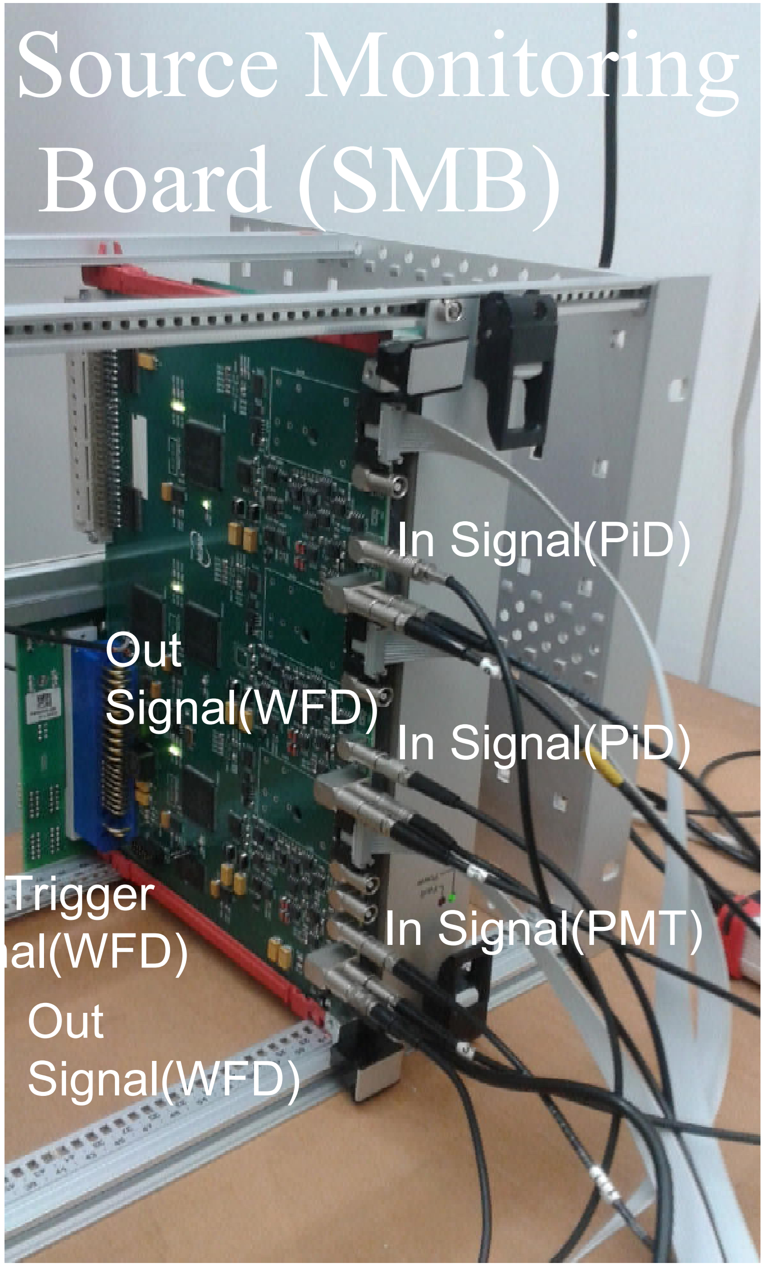


Flight simulation operated at 100 kHz

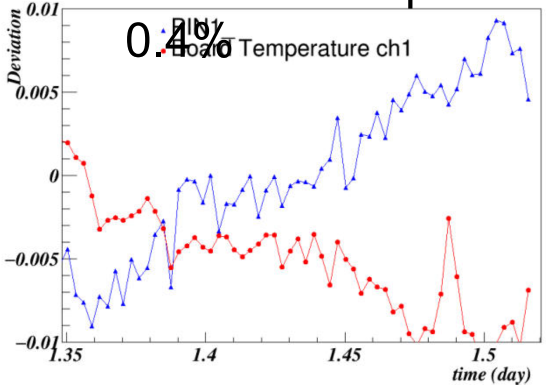


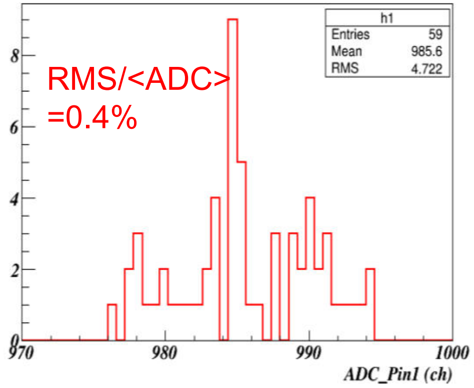
The readout system sustained the data rate > 10 kHz, no deviation from exp. up to 30-40 kHz

Source Monitoring Board (SMB)

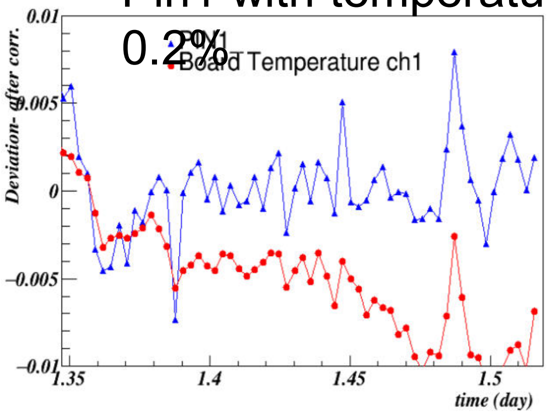


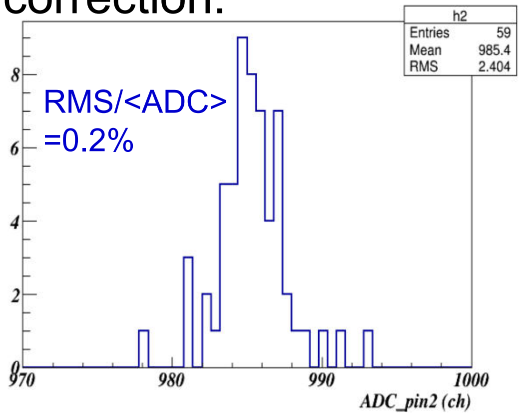
Pin1 -No temperature correction: 0.4%



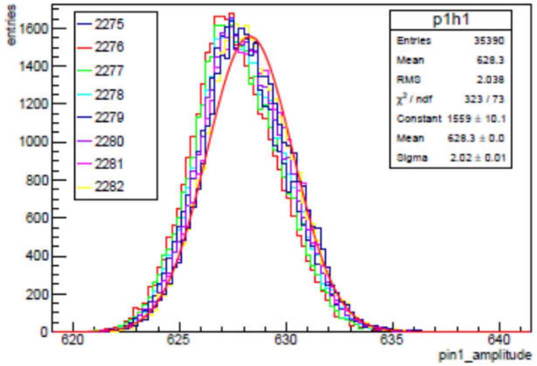


Pin1 with temperature correction: 0.2%





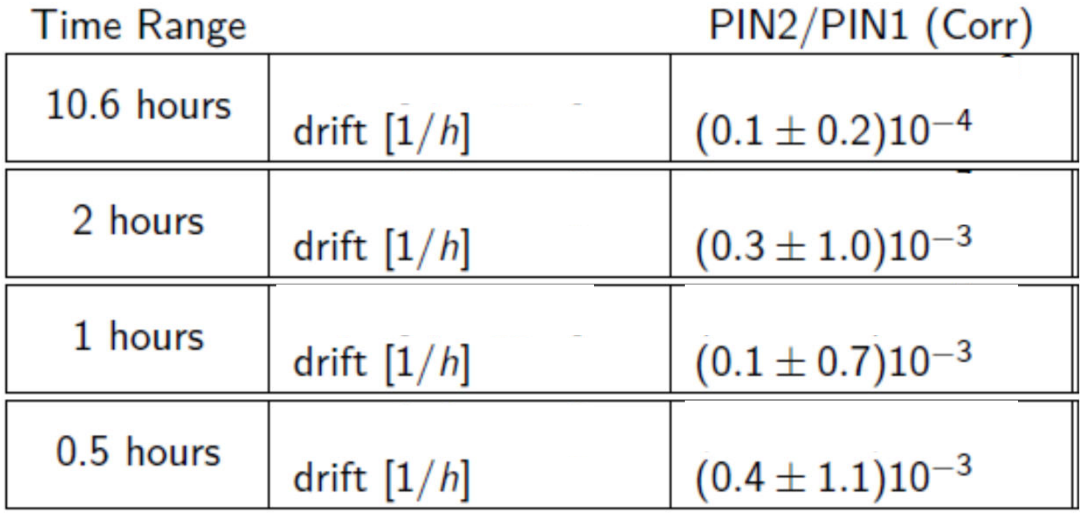
Pin1 from rider: 0.3%
No corrections



Conclusions from SLAC

- The system operated correctly in slave mode.
- Very good consistency between signals digitized by the Source Monitor itself (14 bit ADC) and those digitized by Riders (wafe form, 12 bit) : r.m.s./signal is about 0.3-0.4% , no corrections applied. They are the same signals (splitted).
- Performance have to be optimized and a better understanding of corrections with temperature has to be achieved. We are on the right way.
- System was very stable, well performing even at rate > 10 kHz.
- SLAC data confirmed many results obtained in laboratory tests at Napoli, in particular the system capability to follow time derivative of the signal at level of 0.2%/h.

Conclusions



Time Range		PIN2/PIN1 (Corr)
10.6 hours	drift $[1/h]$	$(0.1 \pm 0.2)10^{-4}$
2 hours	drift $[1/h]$	$(0.3 \pm 1.0)10^{-3}$
1 hours	drift $[1/h]$	$(0.1 \pm 0.7)10^{-3}$
0.5 hours	drift $[1/h]$	$(0.4 \pm 1.1)10^{-3}$

Considering our goal

- Monitoring electronics stable at 10^{-4}/h (time derivative)
- Laser pulse measured at ~10^{-3} (single pulse resolution).

and the above table reporting refined analysis results of the two PIN ratio, Conclusion is that we are on the right track