Satus on Front-End Readout Electronics
→ The FATALIC Project ←

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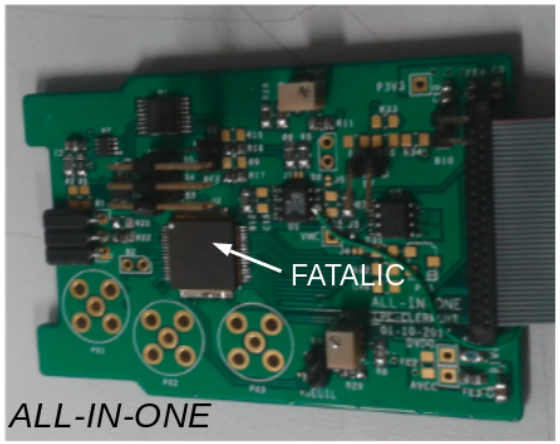
Tile Upgrade Week

– Wednesday 10th of June 2015 –

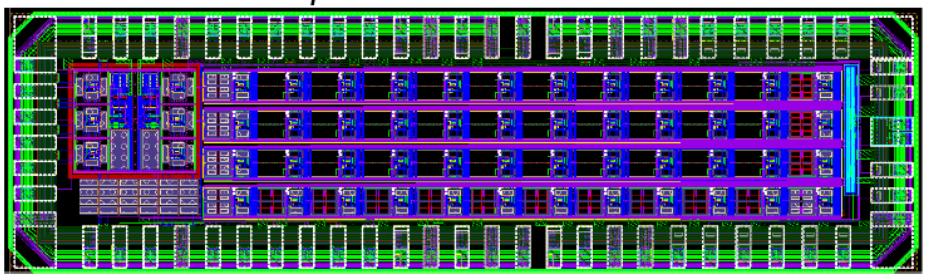
Overview

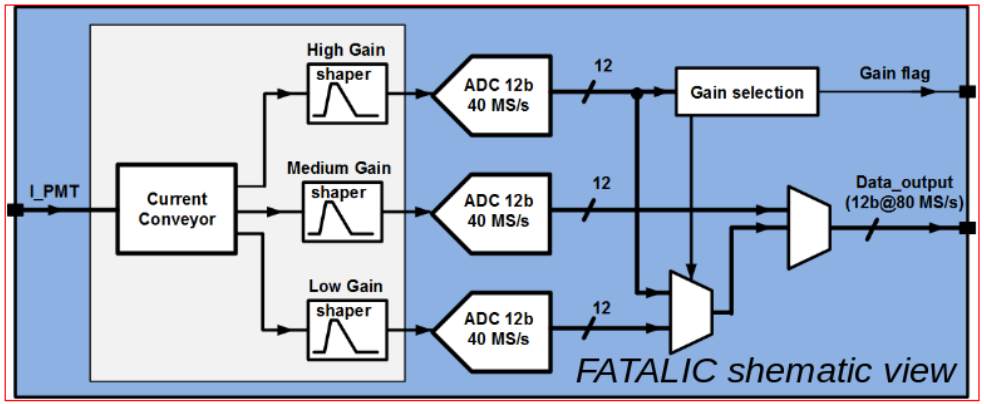
Front-end ATlAs tiLe Integrated Circuit

FATALIC chip embedded in the "All-in-One" FE board



FATALIC microscop view



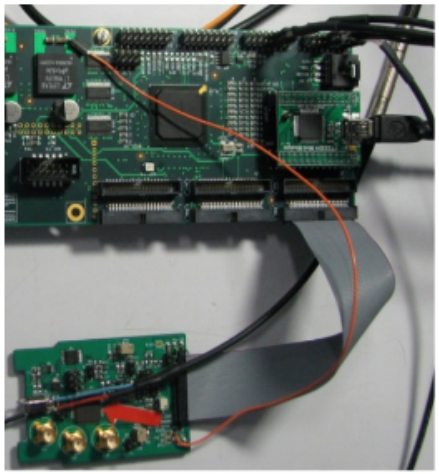


Main characteristics of FATALIC:

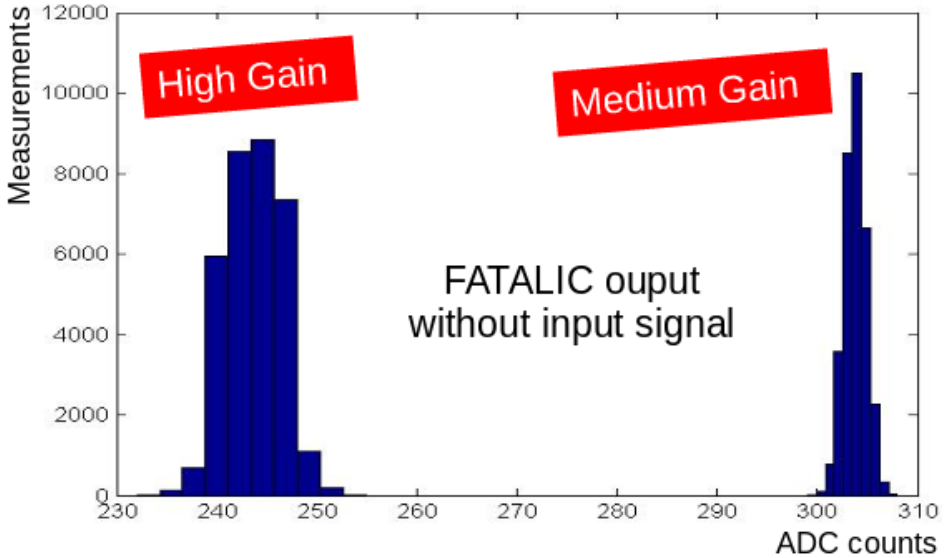
- A 3-gain PM-signal **analog processing** (current conveyor + 3 shapers)
- 3 embedded **12-bit ADCs** (one per gain)
- An **auto gain-selection** (MEDIUM and {HIGH or LOW})
- A **12-bit data output bus** with the data of the 2-selected gain multiplexed

FATALIC strengh: low noise

Noise Requirement :
"the smallest signal of interest from the detector, expressed in terms of **equivalent input charge** delivered to the front end electronics, is **24 fC**. The intrinsic noise of the electronics, as measured through the digitization path, expressed in terms of equivalent input charge, shall not be greater than **12 fC rms** at pedestal."



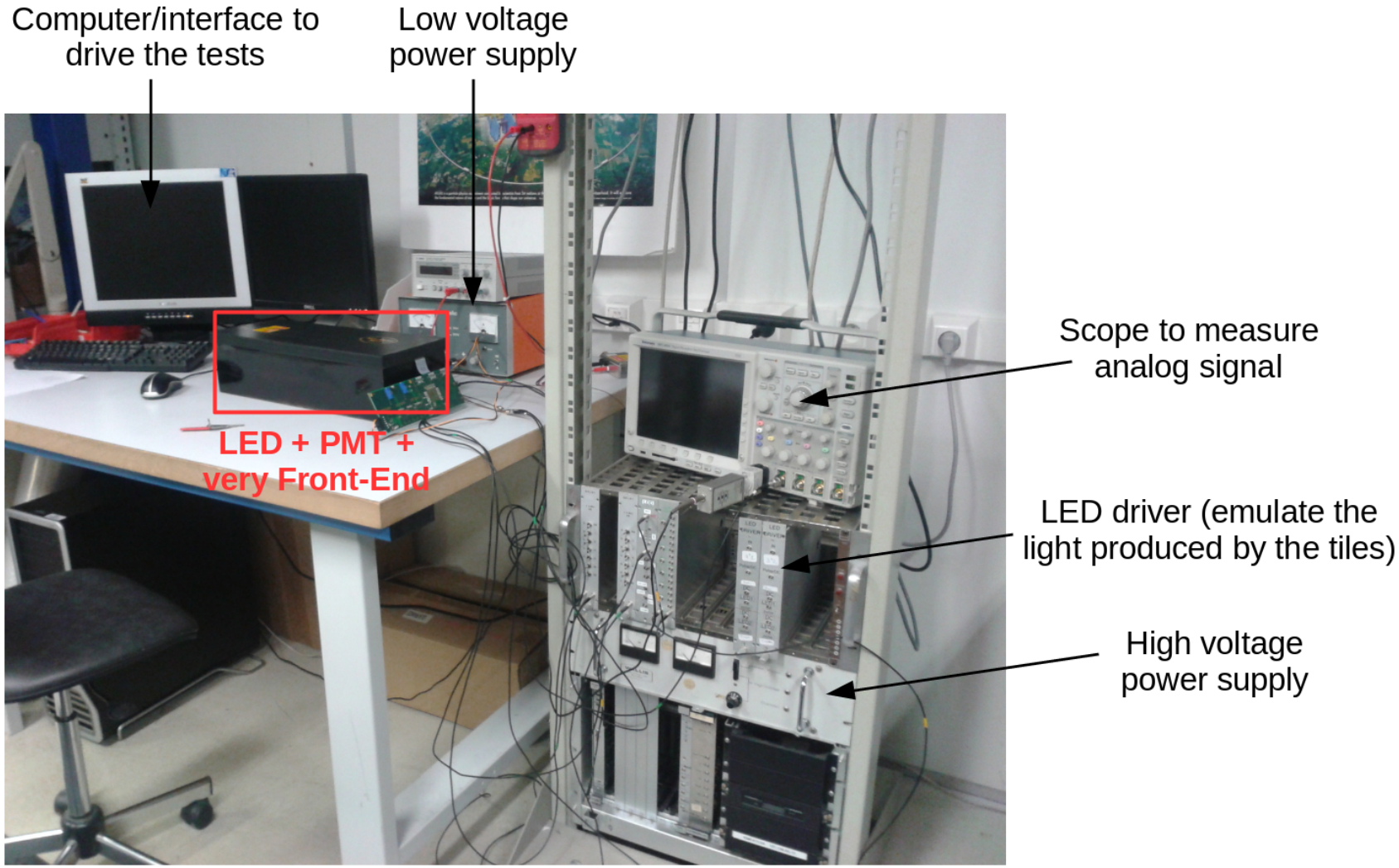
FATALIC noise measurement	
Medium Gain :	Std Deviation = 1.23 LSB → 42 fC rms
High Gain :	Std Deviation = 2.74 LSB → **9.4fC rms**



Why a low noise chip ?
→ Thanks to the digitalization of the analog signal inside Fatalic

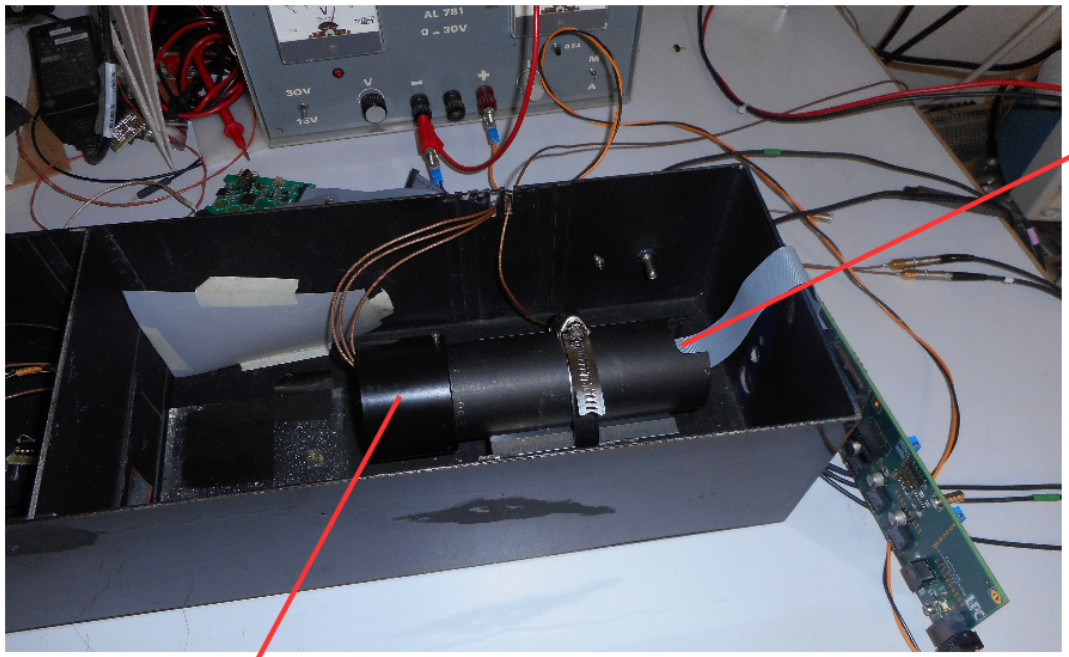
(a) no sensitivity to the noise induced by the main board
(b) no sensitivity to EMC properties of the interface-flat cable

The CF Test Bench

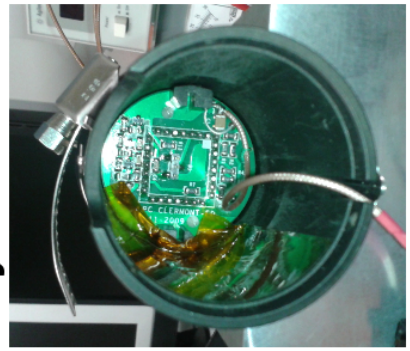


The CF Test Bench

LED + PM + very Front-End

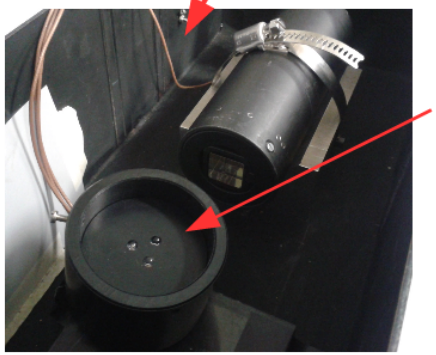


very Front-End



Possibility to follow the signal through the whole chain (see next slide)

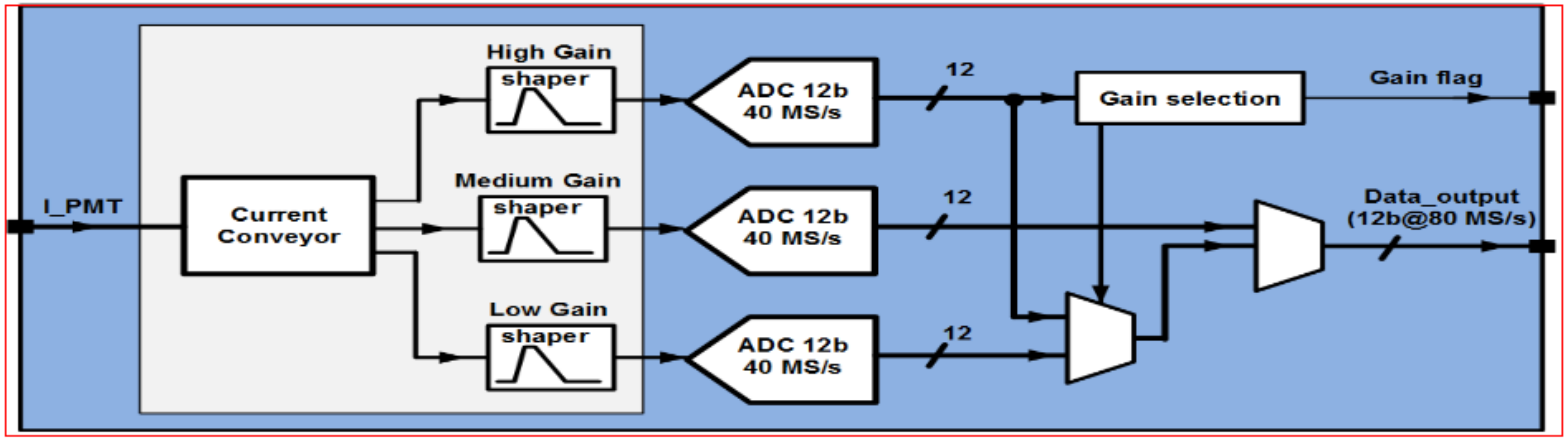
LED + PM



3 LEDs to simulate a realistic physics conditions:
- → incoming particle = pulse
- → out-of-tim pile-up = second pusle time-delayed
- → in-time pile-up = constant light

For the discussed studies : only one pusle

How to follow the signal ?

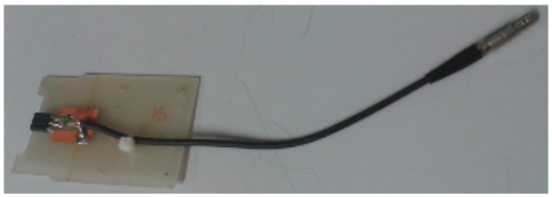


PM

Shaper

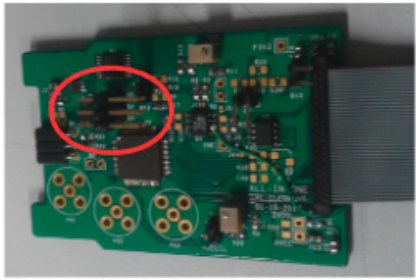
ADC

1. FATALIC input



direct readout getting the PM ouput through the Active Divider

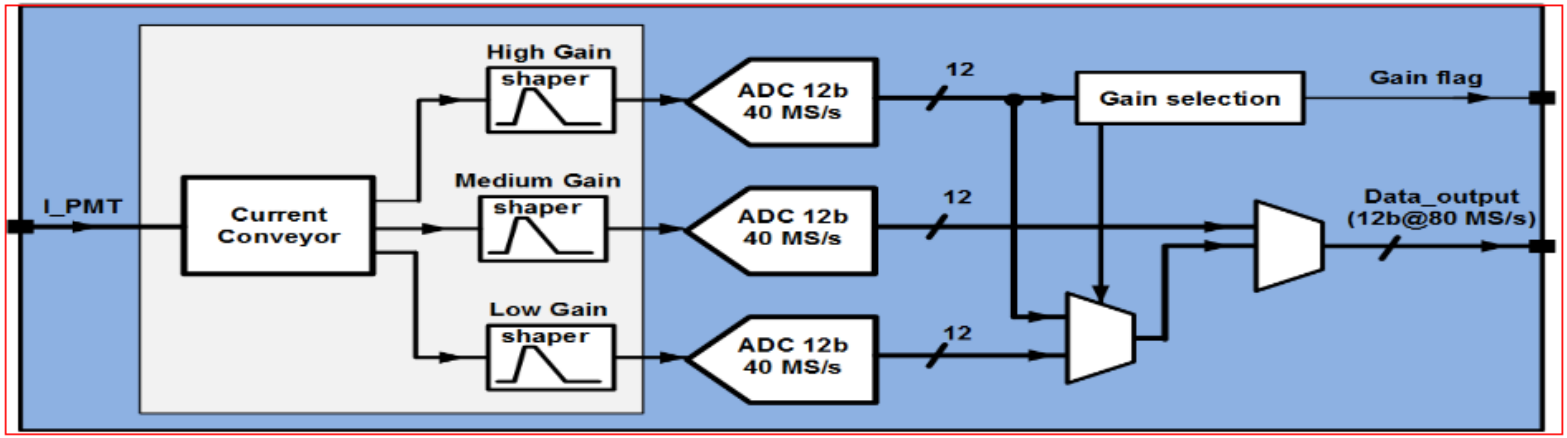
2. Analog signal (shaper output)



All-In-One with additional access for the shaper

3. Digitized signal (ADC output)

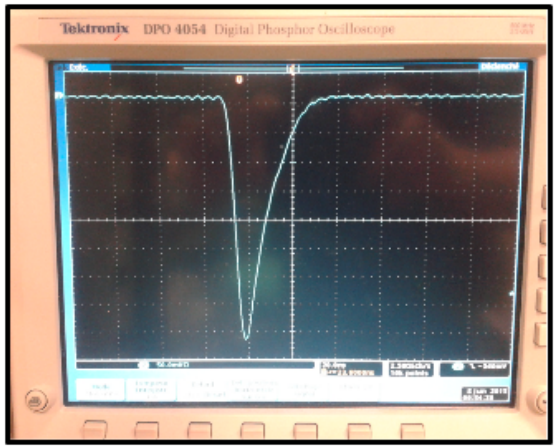
How to follow the signal ?

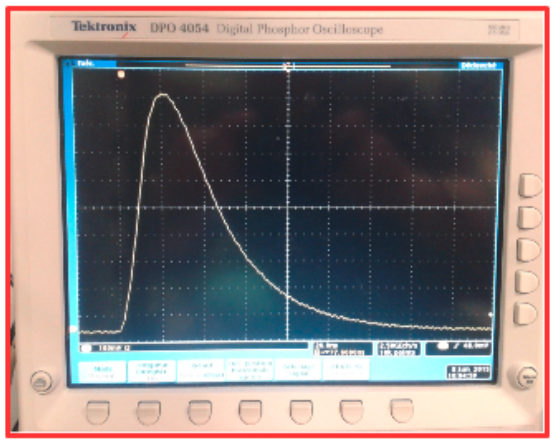


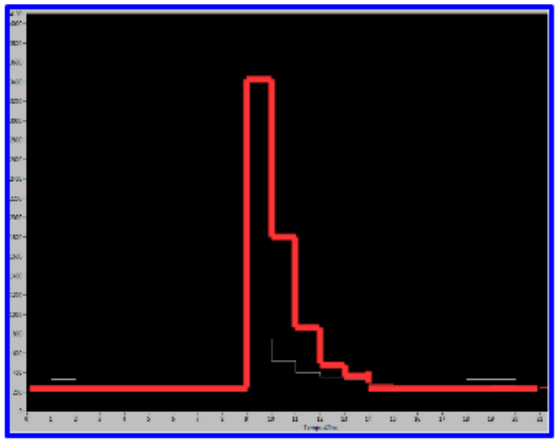
PM signal

Shaper signal

ADC signal



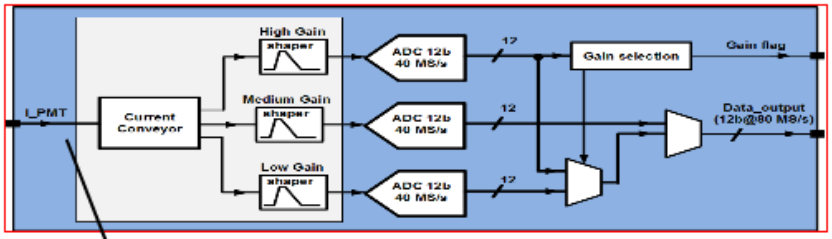




Overview

PM signal quick look

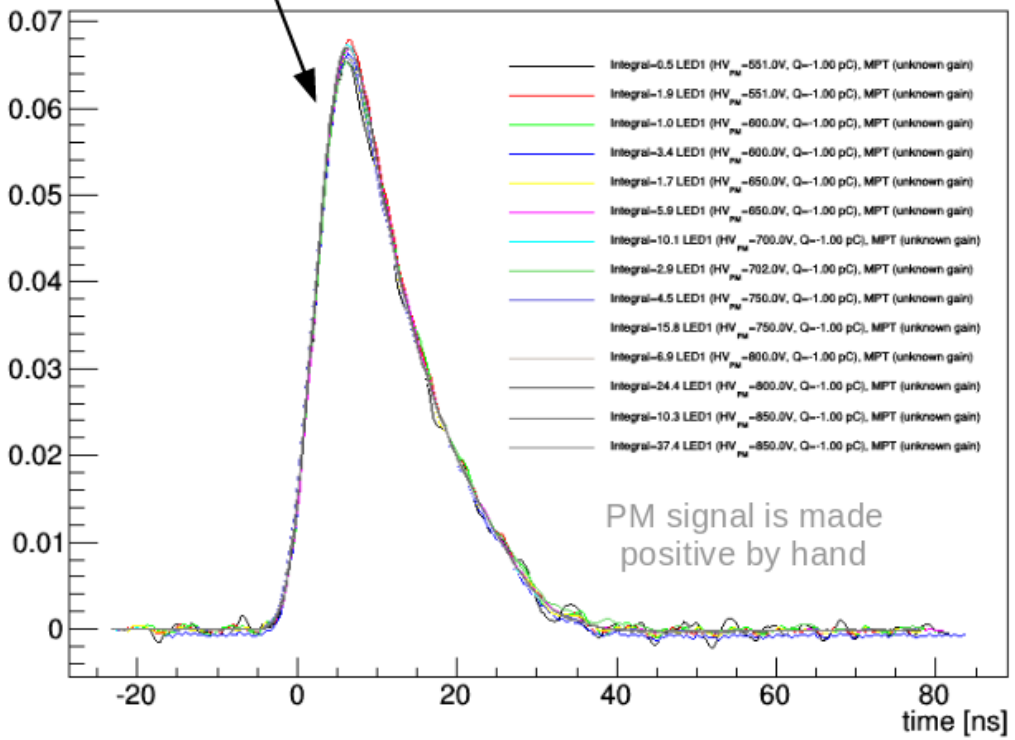
1. Analysing the shape of the PM response for different HV



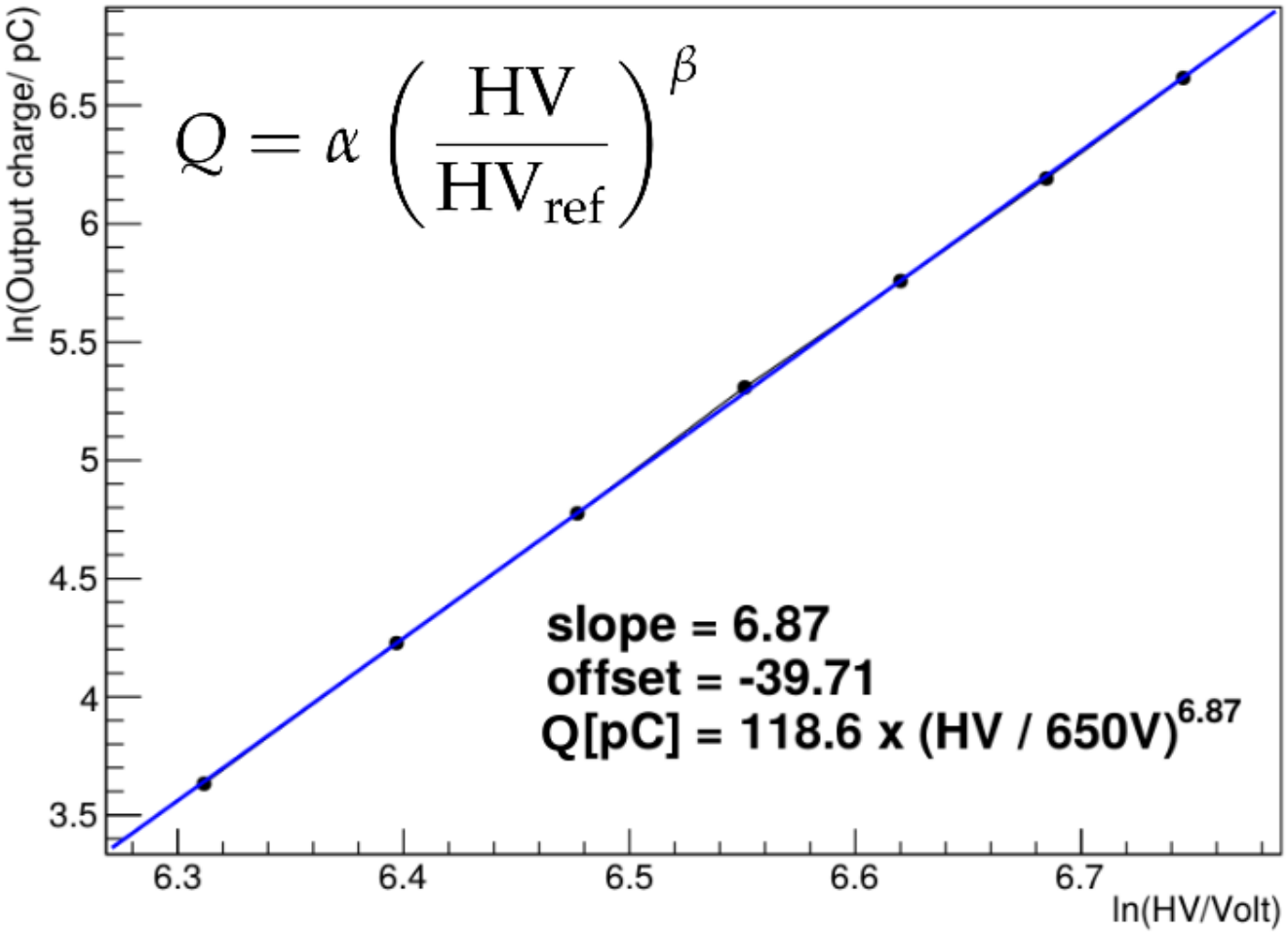
2. The PM : absolute charge source (Scope impedance = 50 Ω)

$$Q = \int \frac{V_{\text{scope}}(t)}{R_{\text{scope}}} \mathrm{dt}$$

→ useful for calibration test (complete charge injector tool)



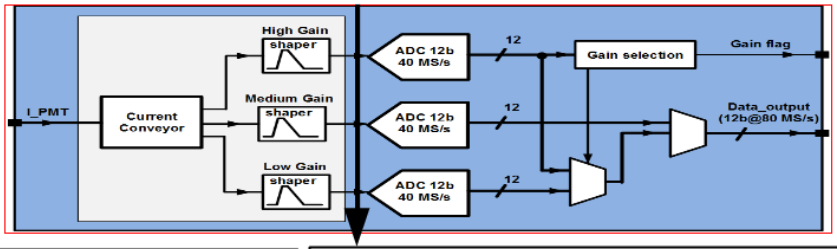
PM as absolute charge source

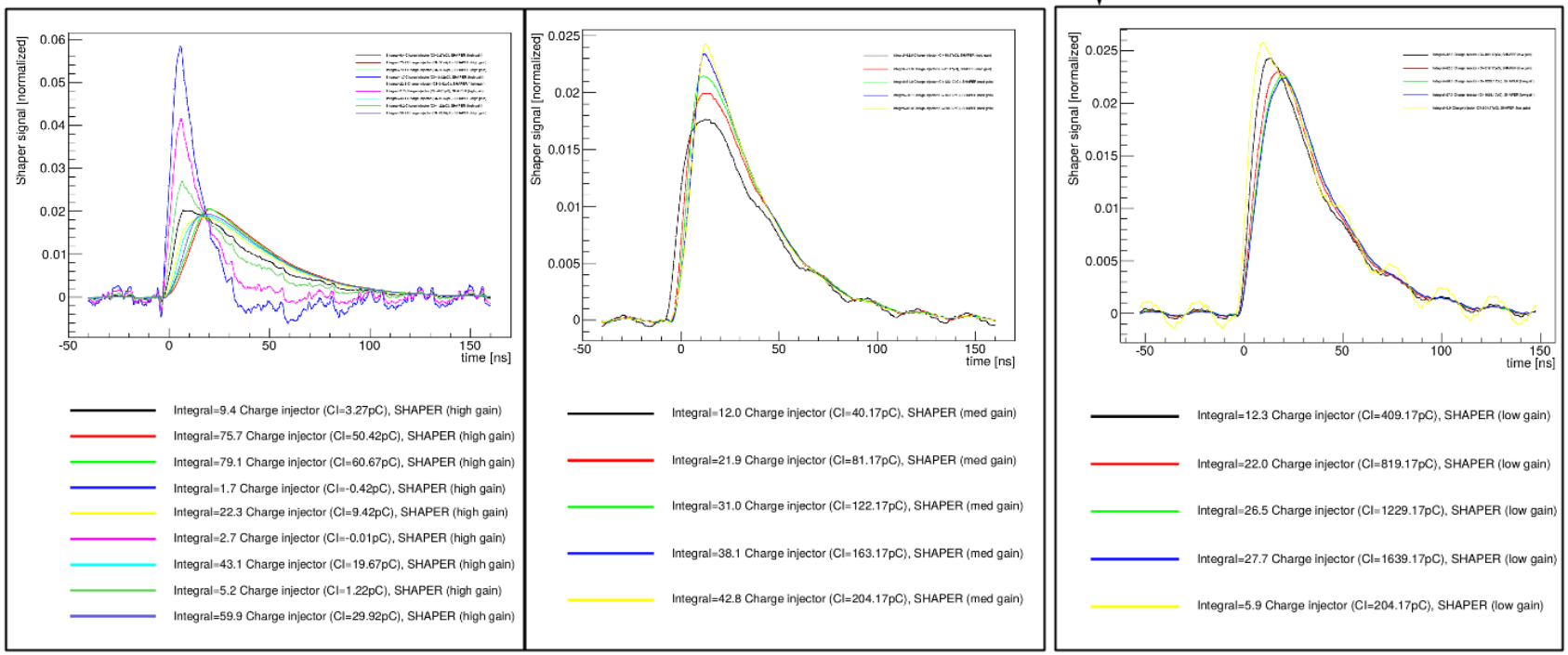


Overview

Signal shape comparison

Comparing the shape of the analog signals for different injected charge. Essential for the optimal filtering (using the charge injector)

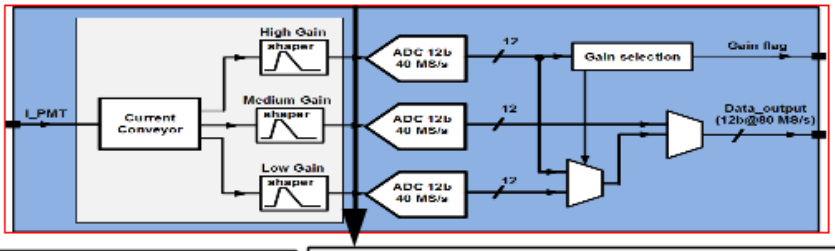


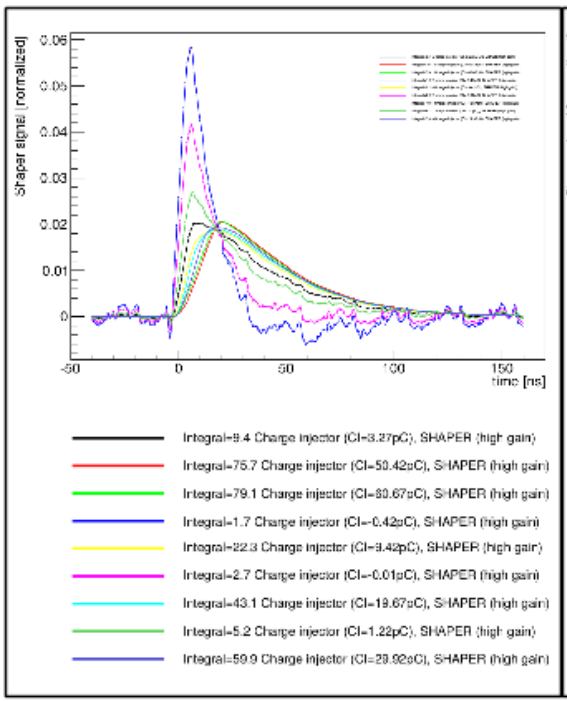


high gain **medium gain** **low gain**

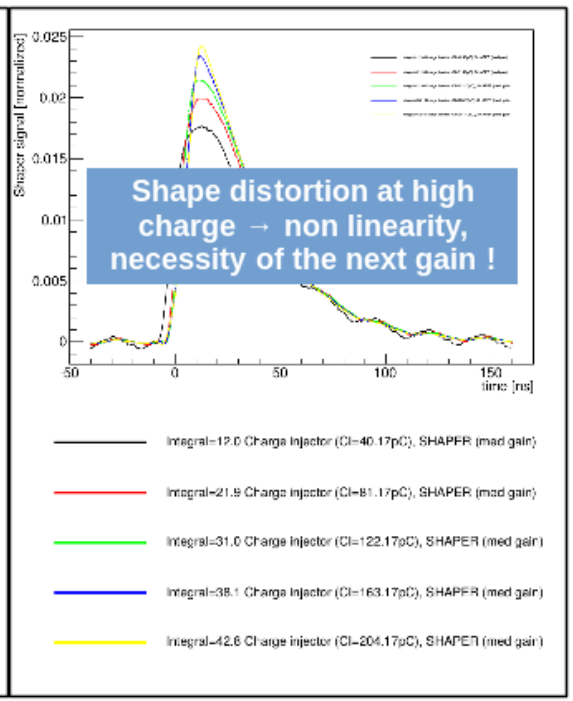
Signal shape comparison

Comparing the shape of the analog signals for different injected charge. Essential for the optimal filtering (using the charge injector)

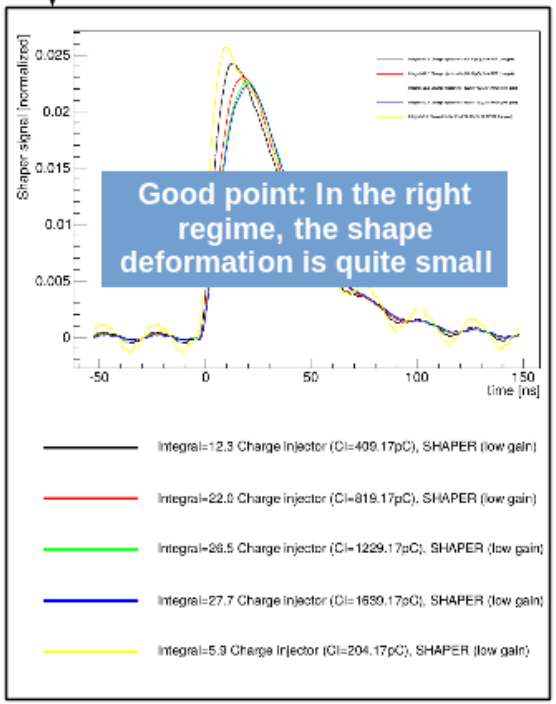




high gain



medium gain

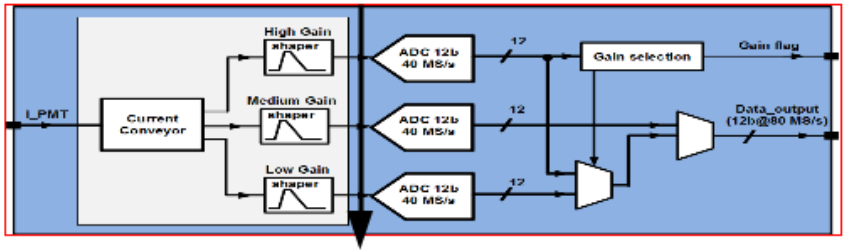


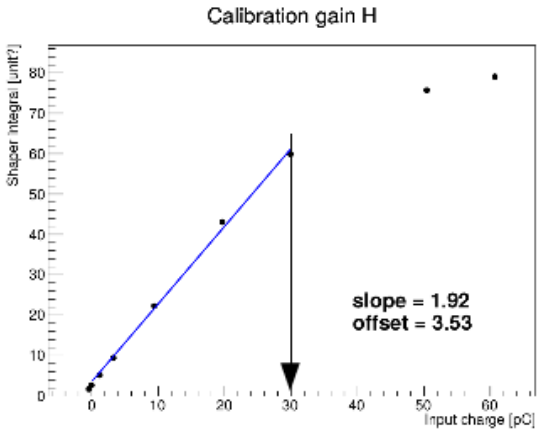
low gain

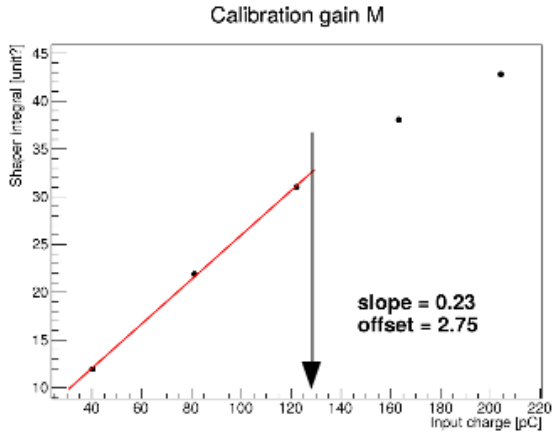
Calibration with the Charge Injector

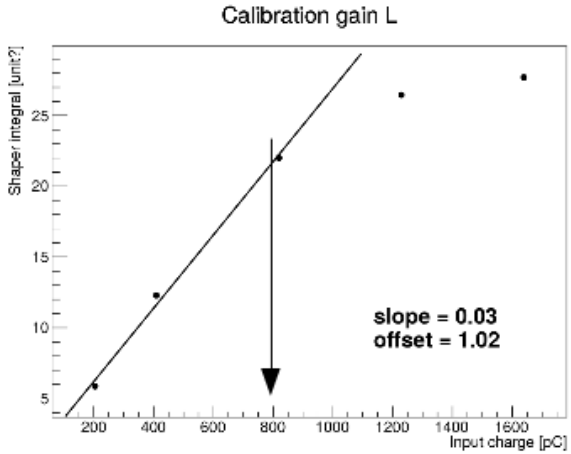
Calibrating each gain and estimating when the linearity breaks (using the charge injector)

→ **working quite well in each validity domaine**









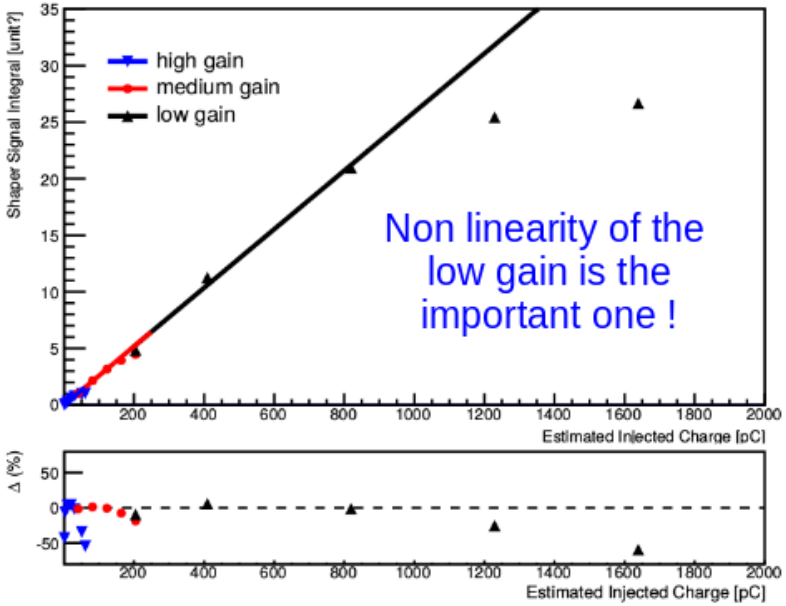
Gain ratio:
- **H/M = 8.3**
- **M/L = 7.6**

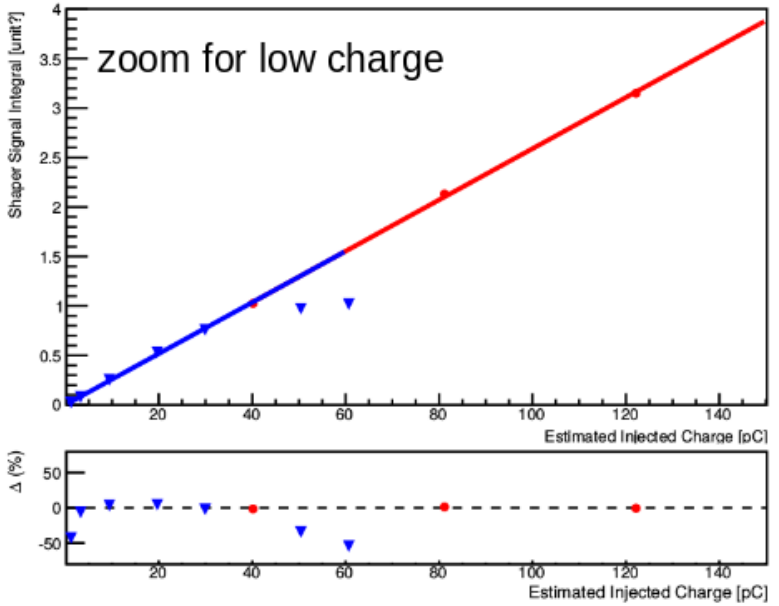
Important caution : the input charge is simply an estimation since the Charge Injector not precisely calibrated (non linearity).

Calibration with the Charge Injector

To **overlay** the response of the 3 gain on the same plot:
- remove the offset for each data point
- scale the slope by the gain ratio

This is an illustrative plot more than a physics one !

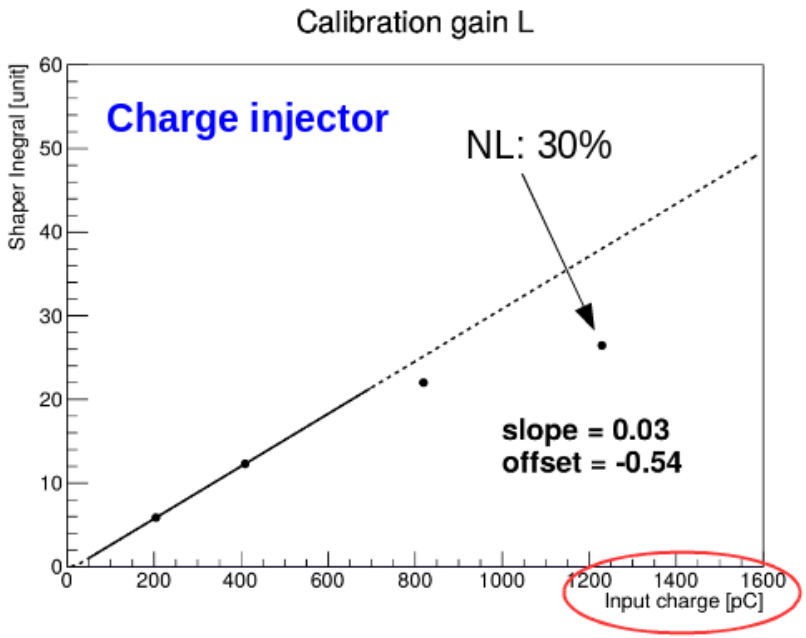


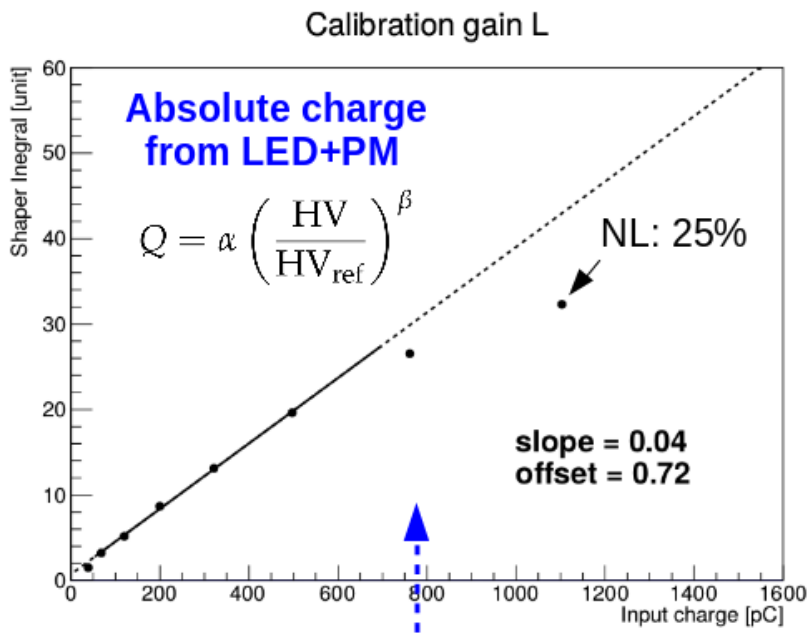


Important caution : the input charge is simply an estimation since the Charge Injector not precisely calibrated (non linearity).

Calibration: Charge Injector VS LED+PM

Important caution : the input charge is simply an estimation since the Charge Injector not precisely calibrated (non linearity).



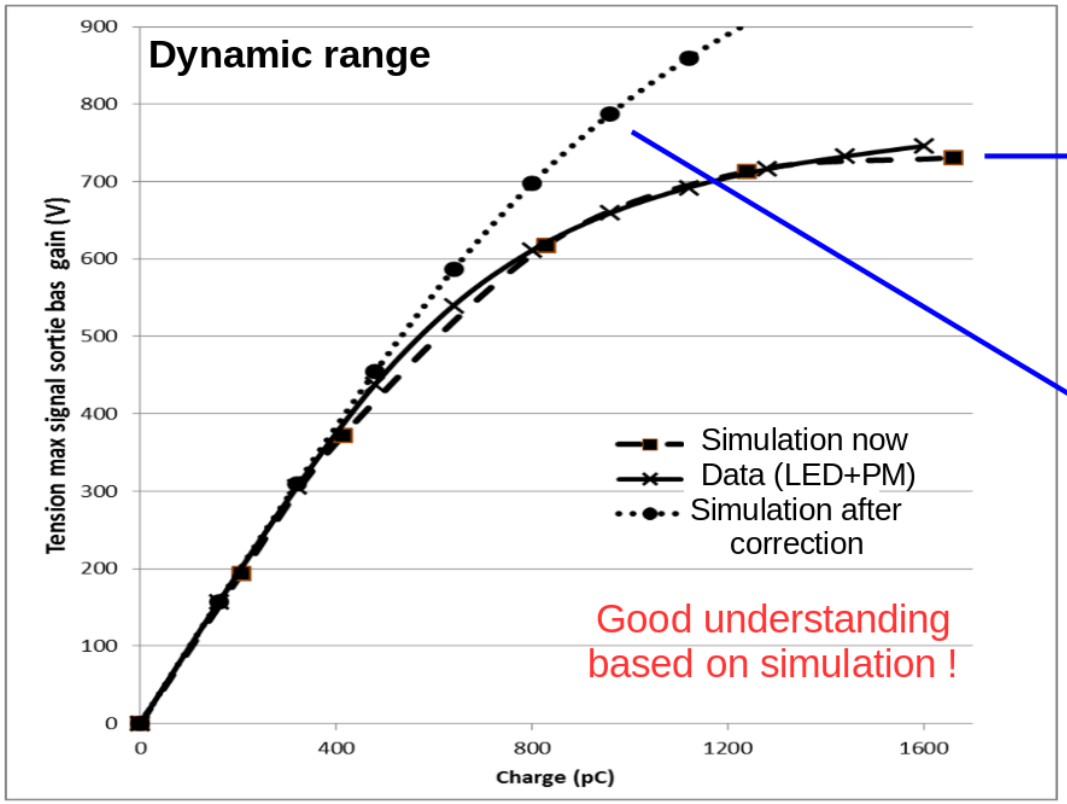


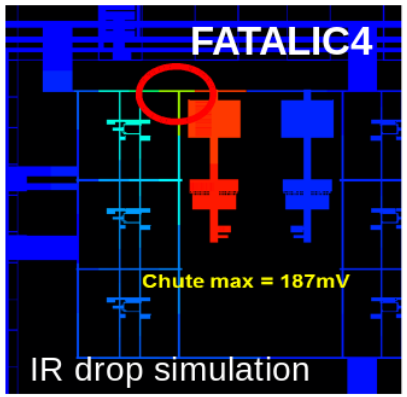
If the charge injector has some non linearity, this measurement is biased ! Use a well calibrated charge source, like **LED+PM**)

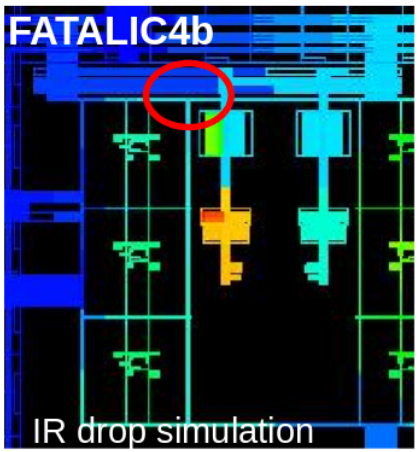
Linearity improvement: FATALIC4b

For high energy events, the input peak current reaches tens of mA. In FATALIC4, this current induces a 200mV-voltage drop of the power supply, limiting the input dynamic range.

This problem has been fixed in FATALIC4b with larger power rails.



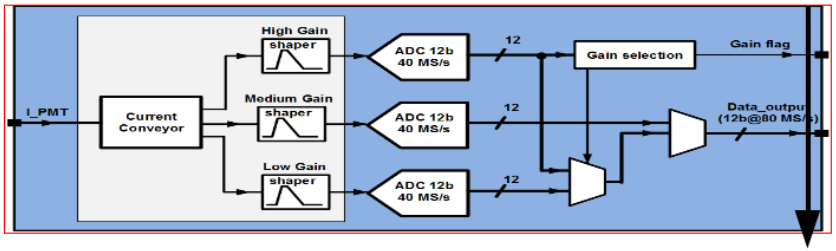


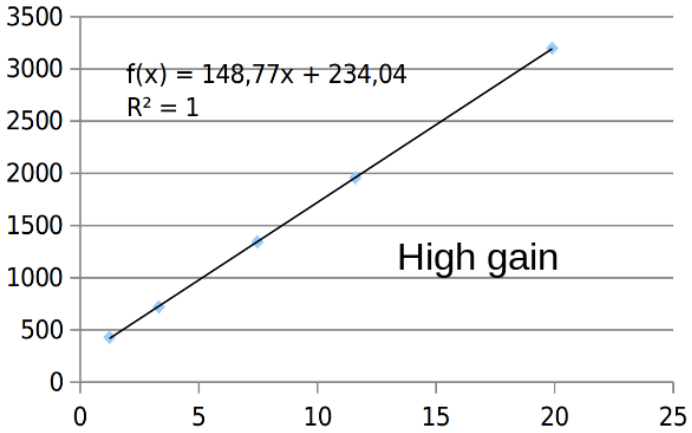


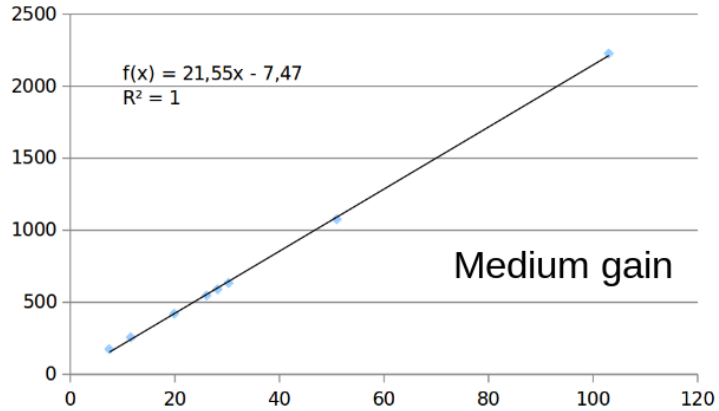
Comment : this problem was not presented in Valencia because it was only seen in a dynamic regime (**pusle**), tested later.

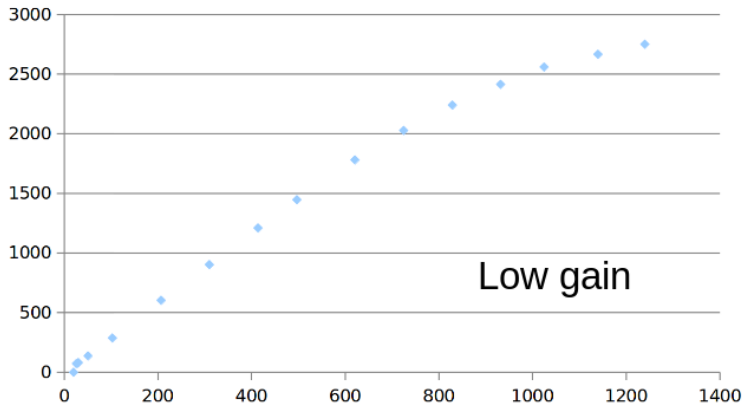
Overview

Calibration with the Charge Injector

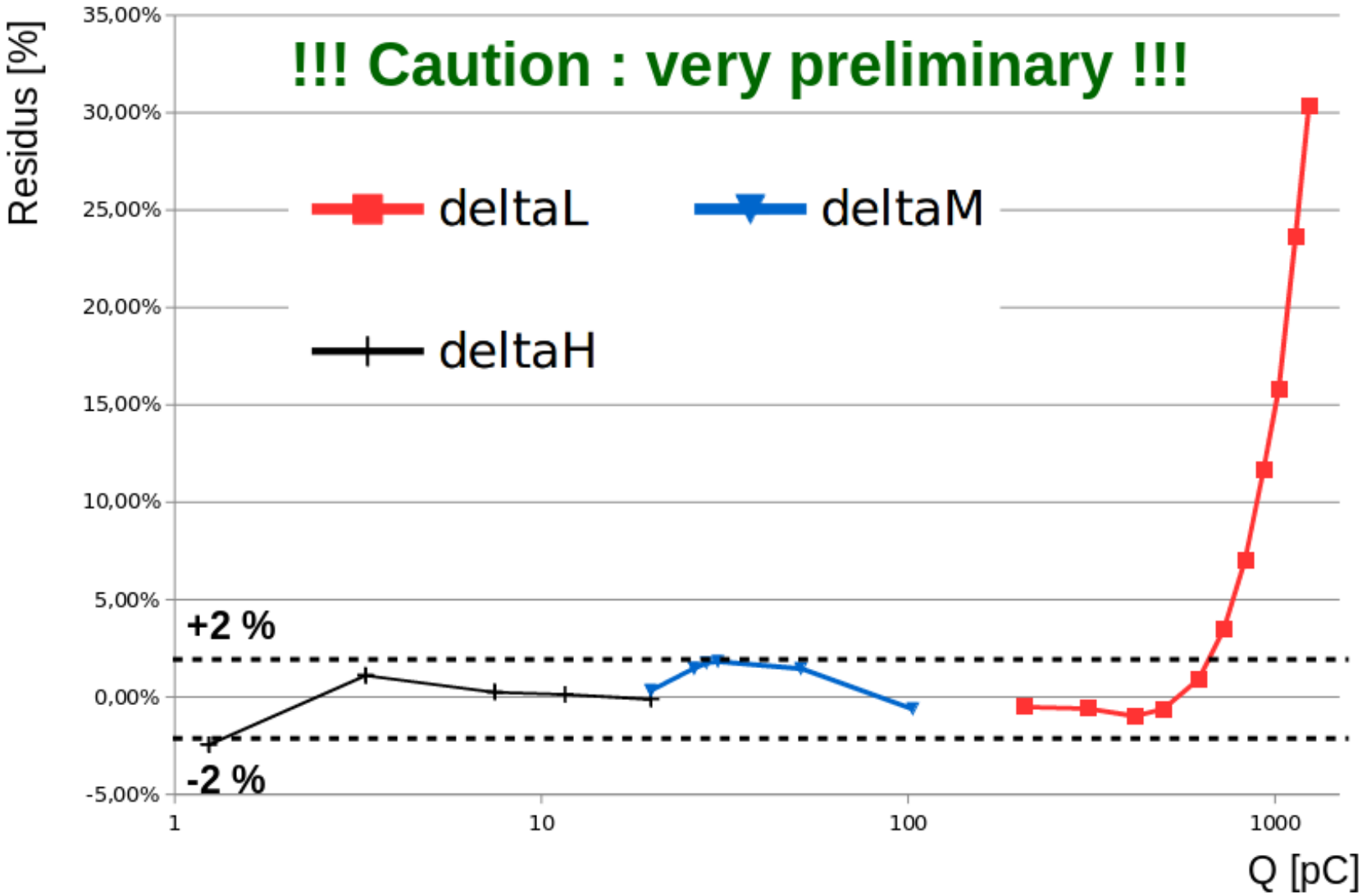








Non linearity: residus



Overview

Summary And Outlooks

Summary

- Performed deep tests to characterize FATLIC4 in a **dynamic regime**
- Scrutinize the signal at each step: PM, shaper, ADC
- Very good signal-to-noise results
- FATALIC4 has an overall good response (linearity) over the three gains

Main progress: reveal/improve weakness visible in dynamic regime only

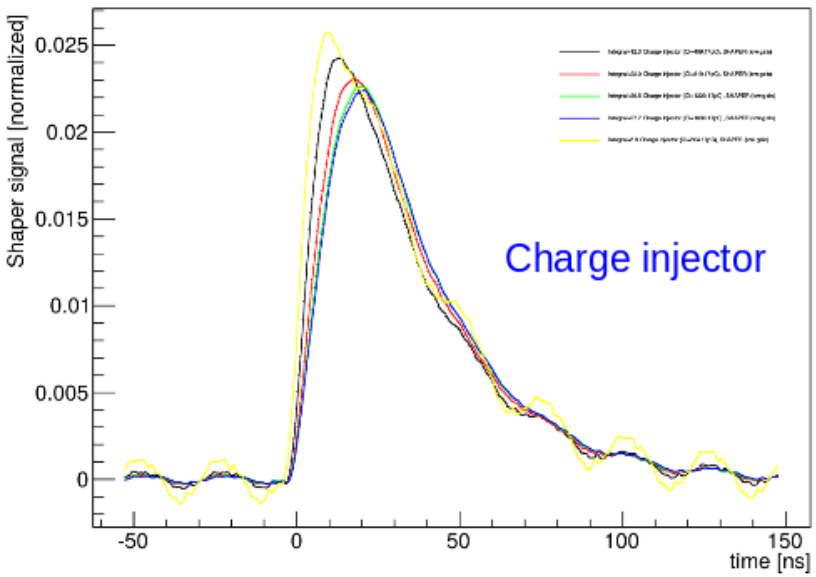
- Identification of a non-linearity at high input charge, only in dynamic
- Very well understood with the simulation and solved $\rightarrow$ **FATALIC4b**

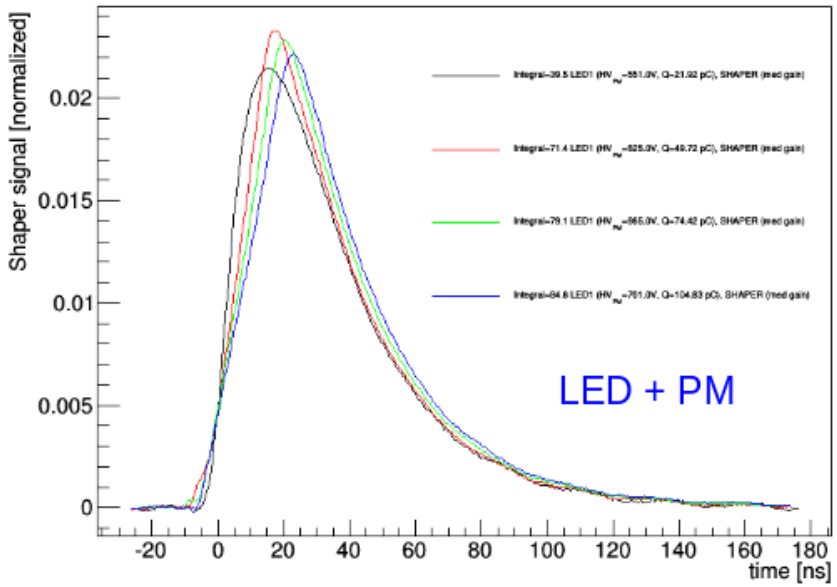
Outlooks

- Currently: linearity precision limited by the source calibration
- A new test board, with an embedded 14-bit precision ADC, has been designed to calibrate input signal of Fatalic with high precision
- Test FATALIC4b (currently under production)

Backup Slides

Low gain shape distortion: CI vs LED+PM





Non linearity precision: discussion

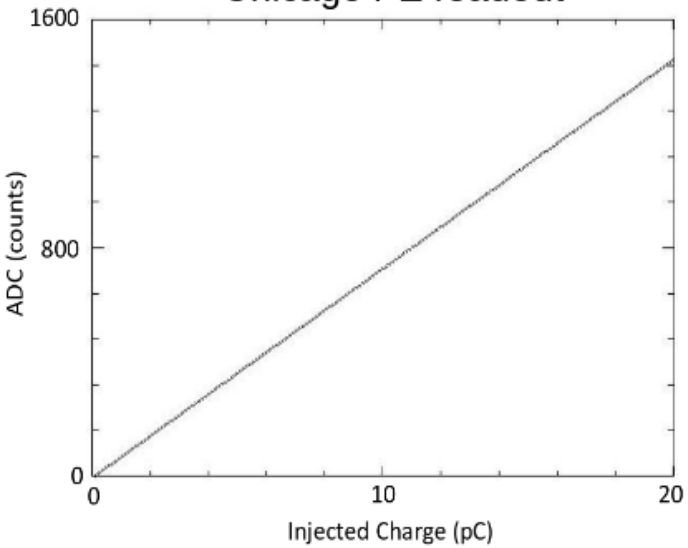
A precise calibration of the charge injector linearity is a key point to properly characterize the chip linearity ...

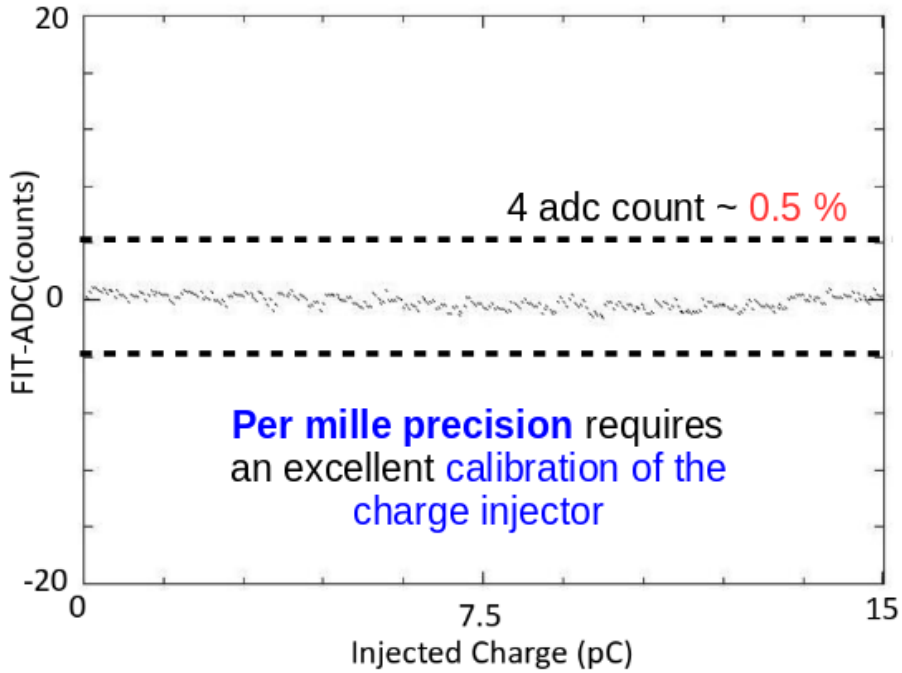
From François Vazeille 13/04/2015 16:19
Subject **Linearity of the CIS**
To tang@edg.uchicago.edu <tang@edg.uchicago.edu>, Kelby J Anderson <kelby@uchep.uchicago.edu>,
Tags TileUpgrade

Dear colleagues,
in the design of our Main Board, we have implemented your charge injection system that works well.
We would like to know its linearity.
Did you perform this study, and if yes, could you give us the results?

With our best regards,
Romeo and francois

From **Valencia presentation** :
Chicago FE readout





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