Electronics linearity studies

JUNO Italia meeting @ Politecnico di Milano - Bovisa
06/05/2022

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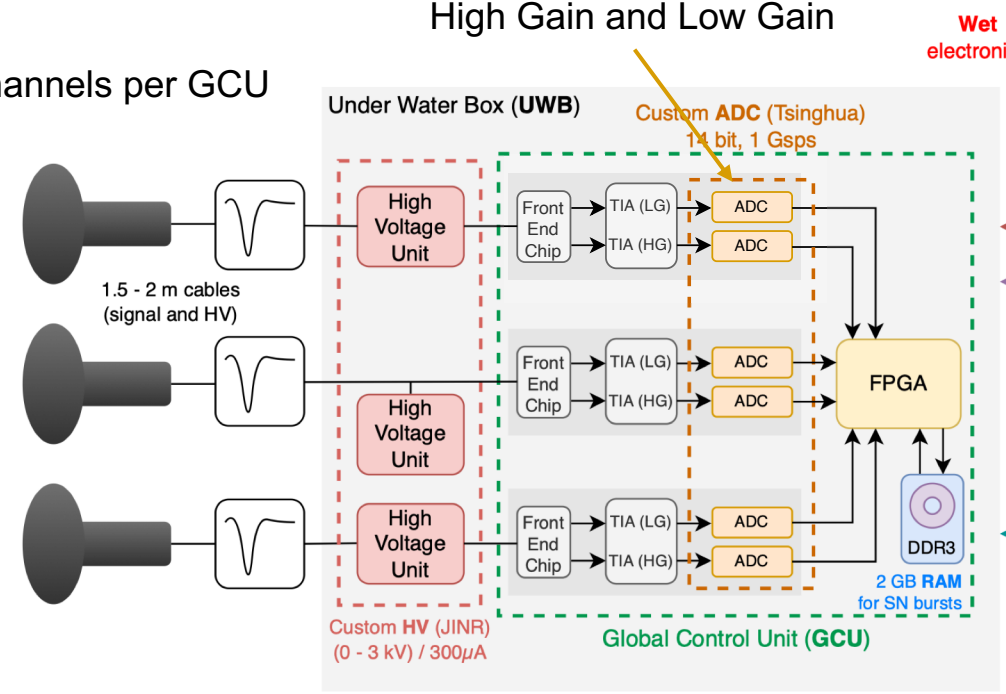
LPMT readout electronics - recap

2 ADCs per channel:
High Gain and Low Gain

3 channels per GCU



Flash ADCs:
- 14 bit
- 1 GSps
- ~10 ENOB
- 75 μV/ADC count

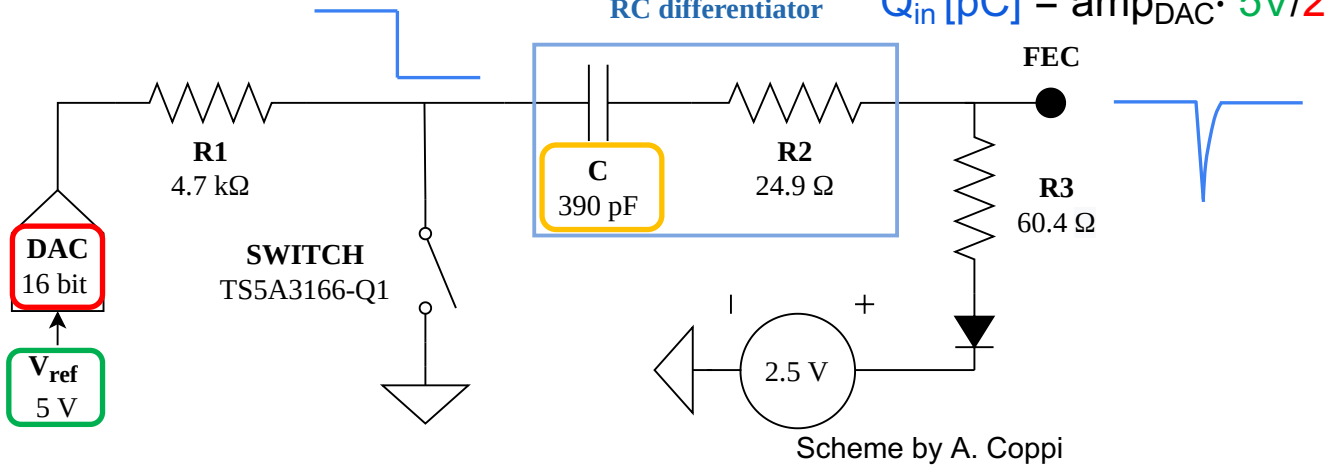
- IPbus protocol
- slow control parameters

LPMT readout electronics - calibration circuit

Each channel is equipped with an internal test pulse generator, or **calibration circuit**

Q_{in} [pC] = amp_{DAC} · 5V/2^{16} · 390pF

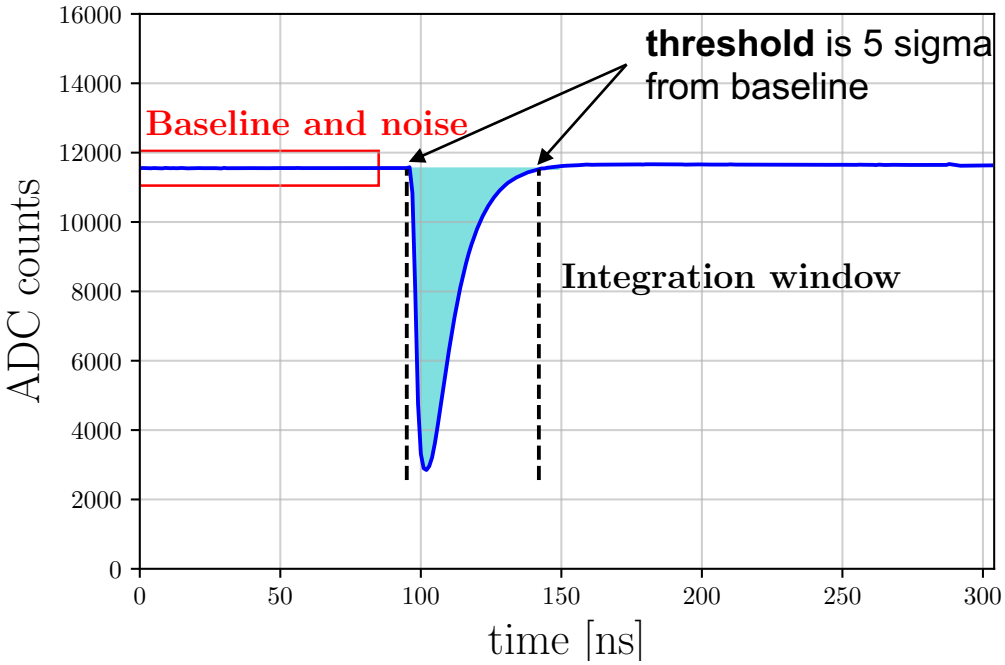
The amplitude of the test pulse is set with a **DAC**, controlled through IPbus protocol



The **switch** is controlled through IPbus protocol

Pulse generator is used in **self-trigger mode** - no trigger confirmation from BEC/CTU

LPMT readout electronics - waveform



Baseline B evaluated on the first ~90 waveform samples

$Q_{out} = \sum_i^{N_s} |N_i - B| \cdot \Delta t_i$

[ADC counts · ns]

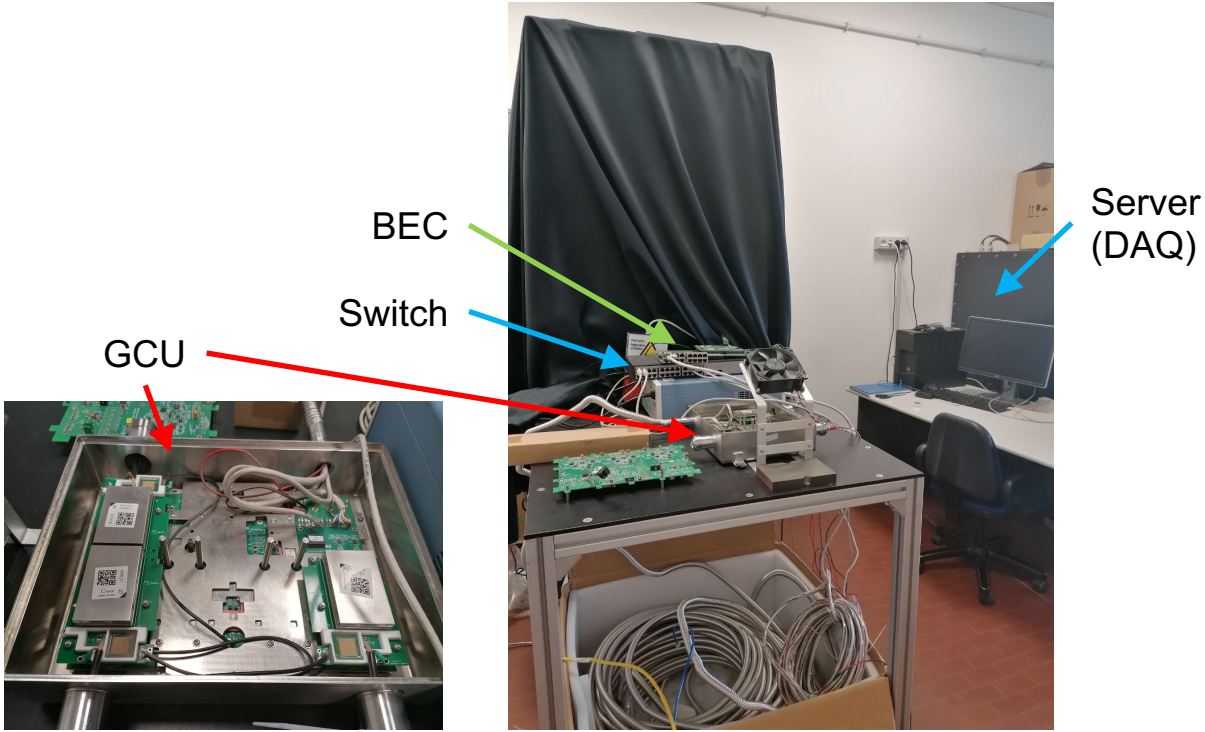
Δt_i is 1 ns (sampling frequency is 1 GHz)

$Q_{out} = \frac{\sum_i^{N_s} |N_i - B| \cdot \Delta t_i}{50\Omega} \cdot 75\mu V/ADC$

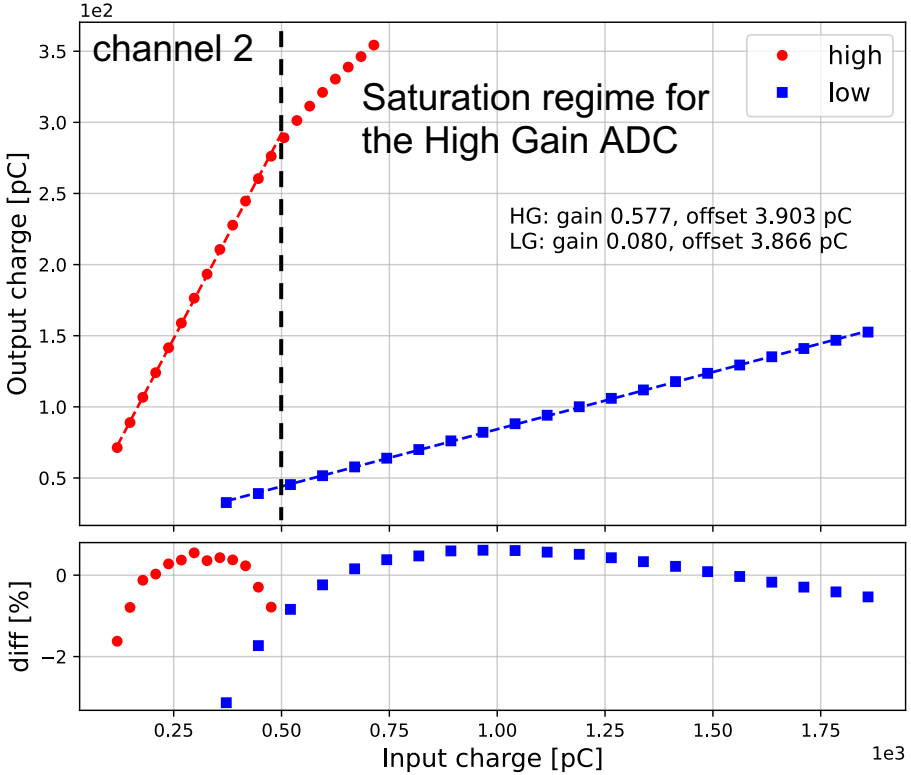
[pC]

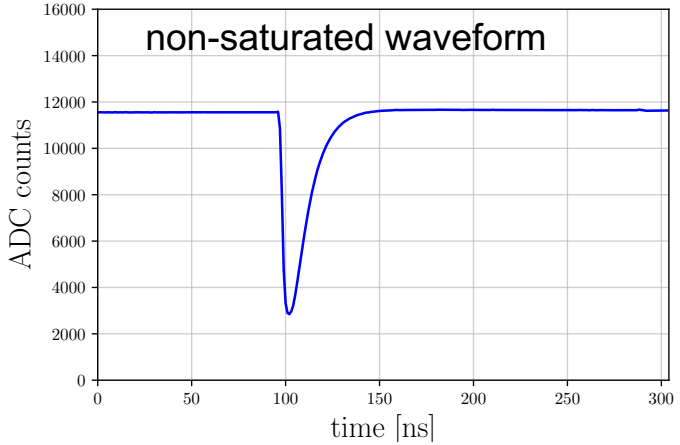
specific for JUNO ADCs

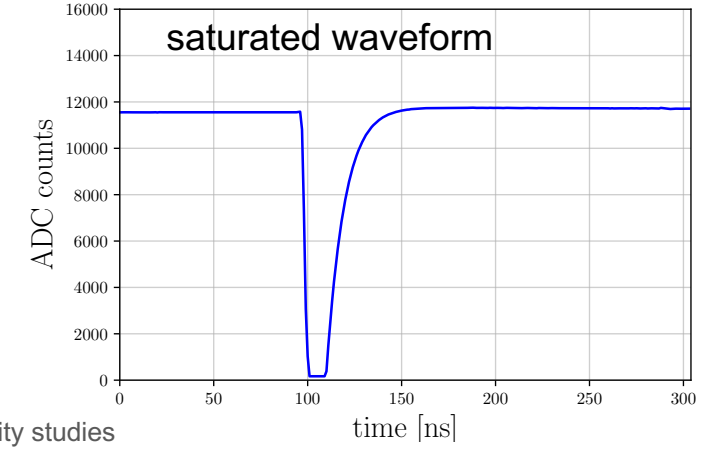
Setup @ Padova



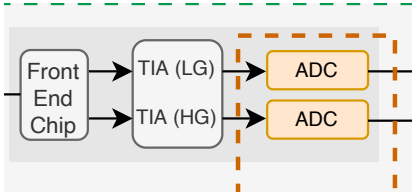
Results with the calibration circuit

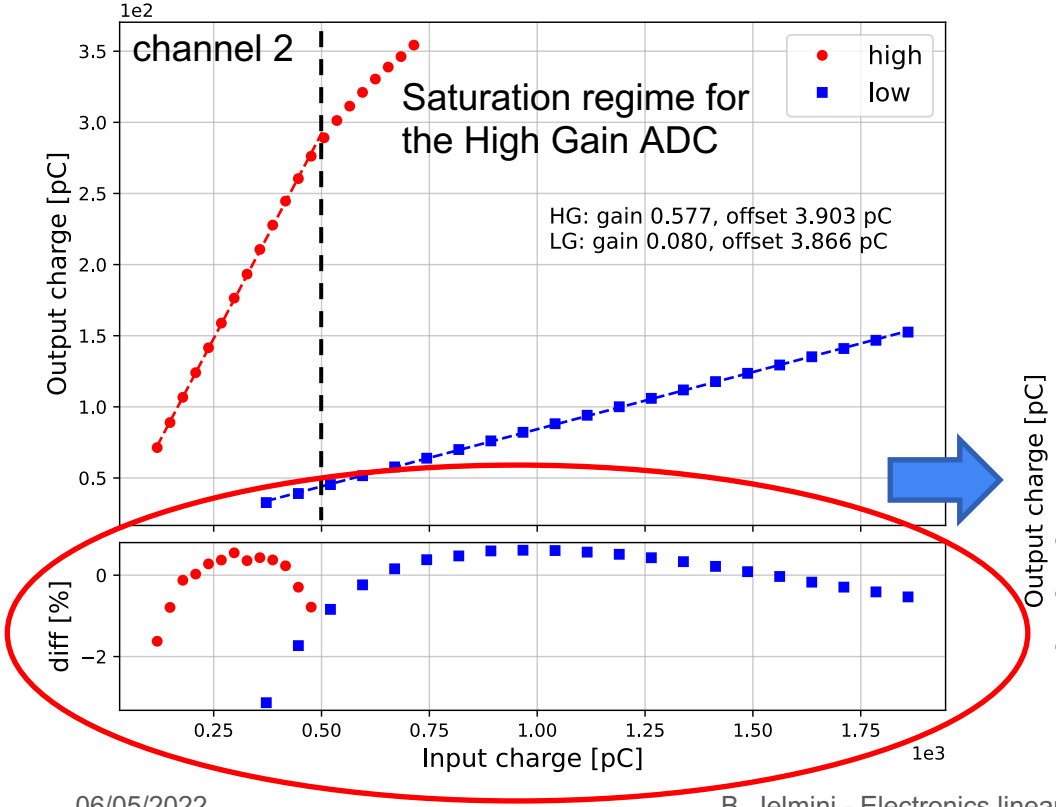






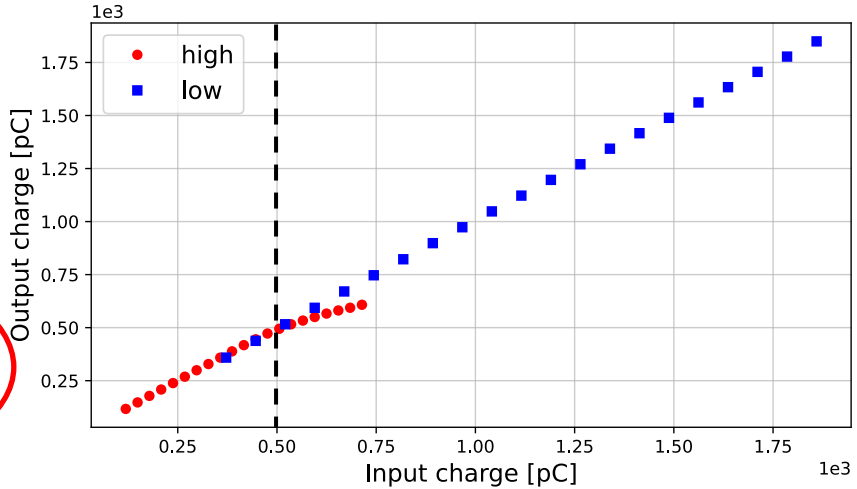
Results with the calibration circuit





Linear regression is done on both ADCs.

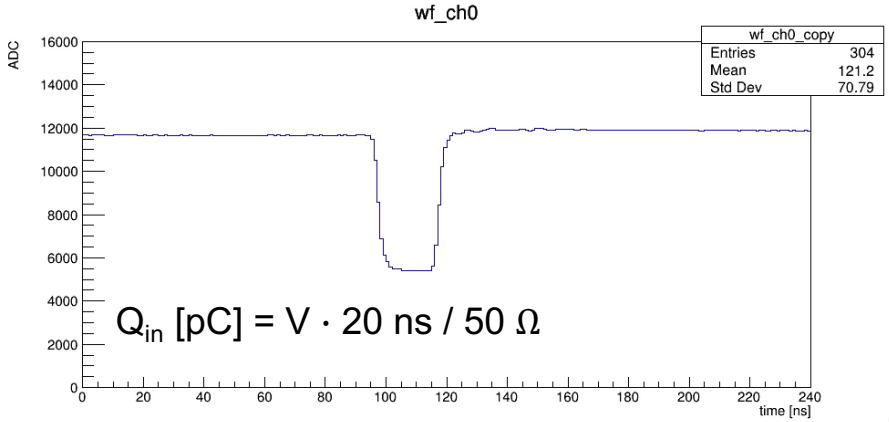
Gain is used to calibrate the output of the two ADCs.



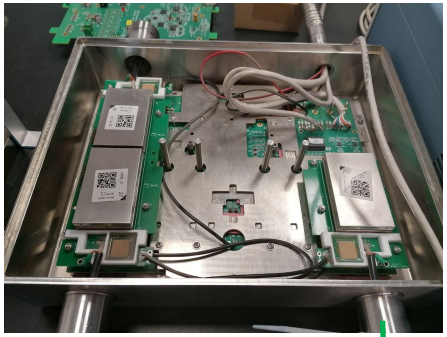
Results with external source

Validation of the calibration circuit results with an **external** source:
a square pulse from an external pulser

Same GCU and same channel



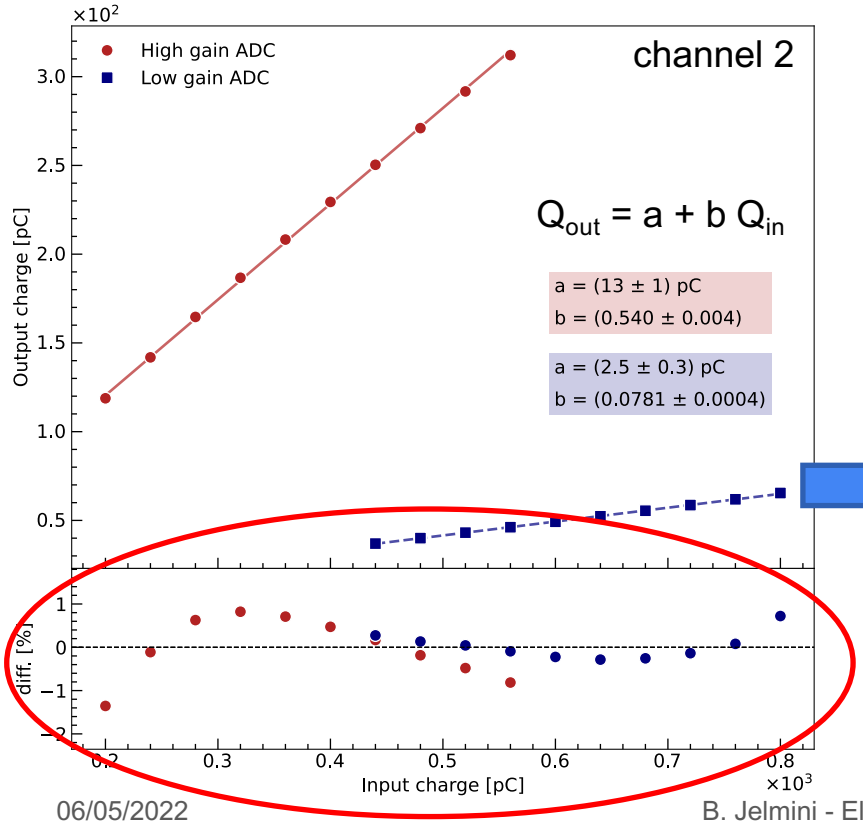
GCU

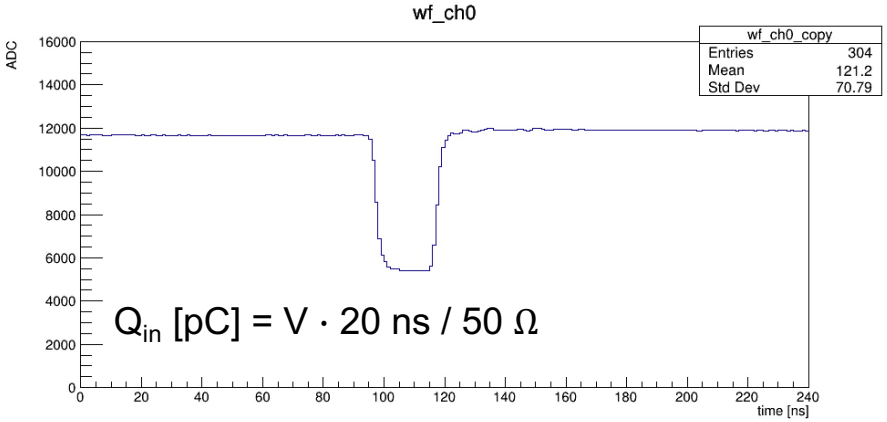


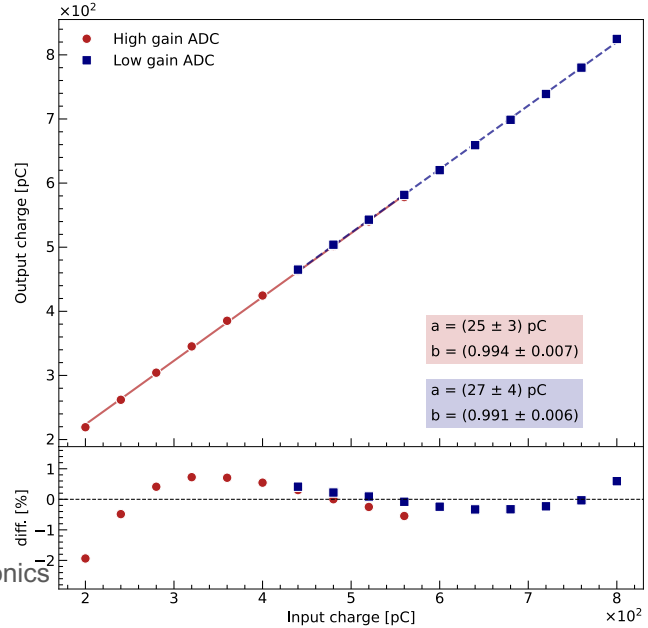
external pulser

cable

Results with external source

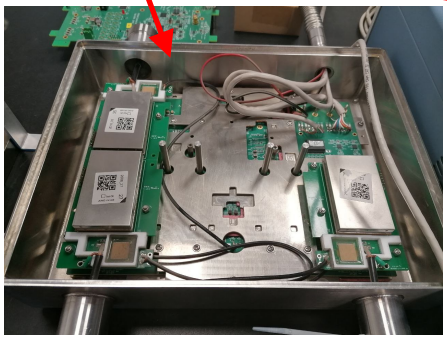


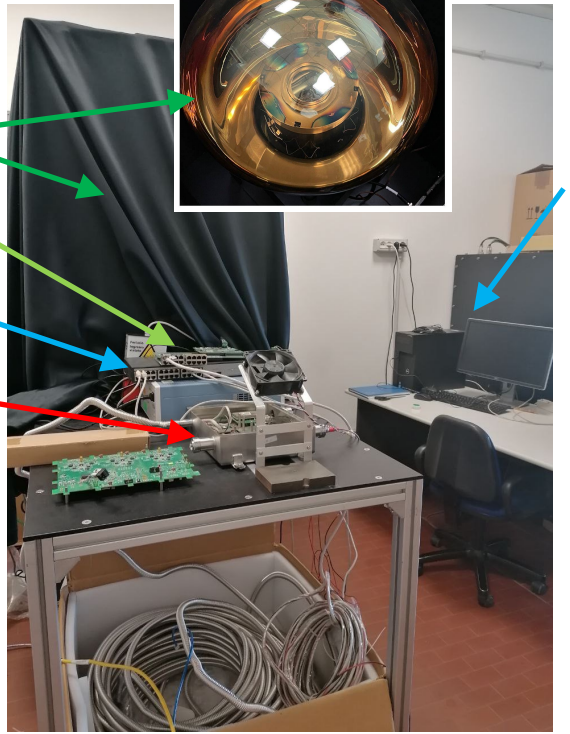


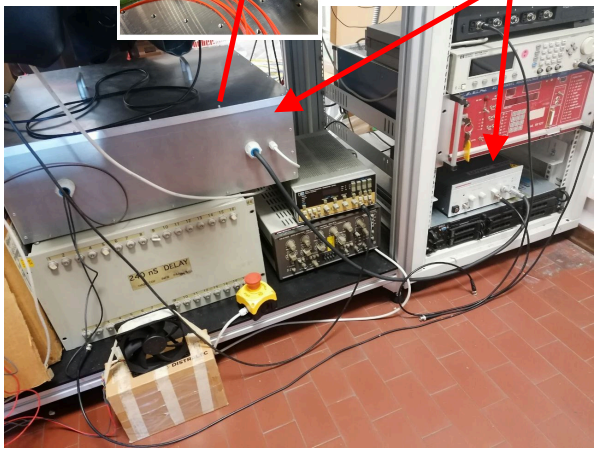


plots by V. Cerrone

Setup @ Padova with the LPMT







Large-PMT

BEC

Switch

GCU

Server (DAQ)

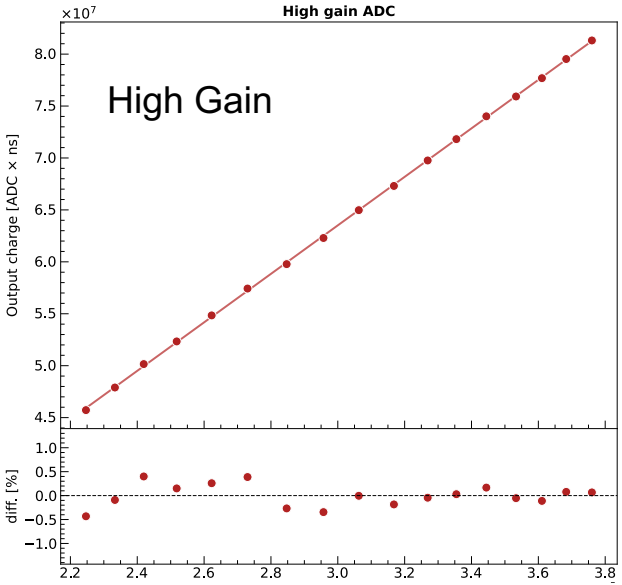
Optical fiber

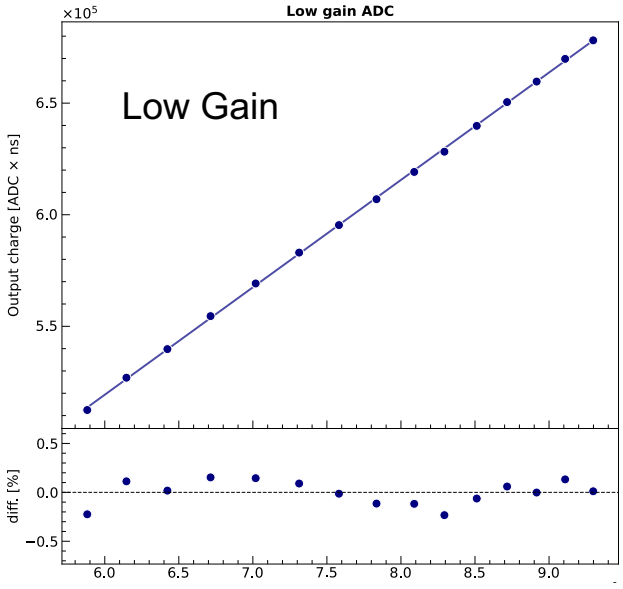
Laser, 403 nm

Results with the Large-PMT and the laser

Q_{out} [ADC counts · ns]

System of electronics + LPMT presents non-linearity below 1%





plots by V. Cerrone

@ Kunshan site

Linearity test with the **calibration circuit** is part of the test protocol during mass production and testing in Kunshan

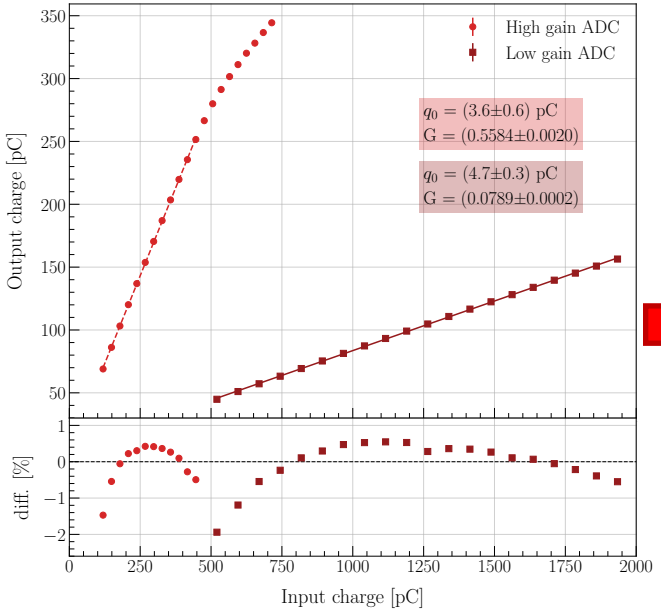
Linearity test has been **automated** and is performed on 1032 channels in parallel

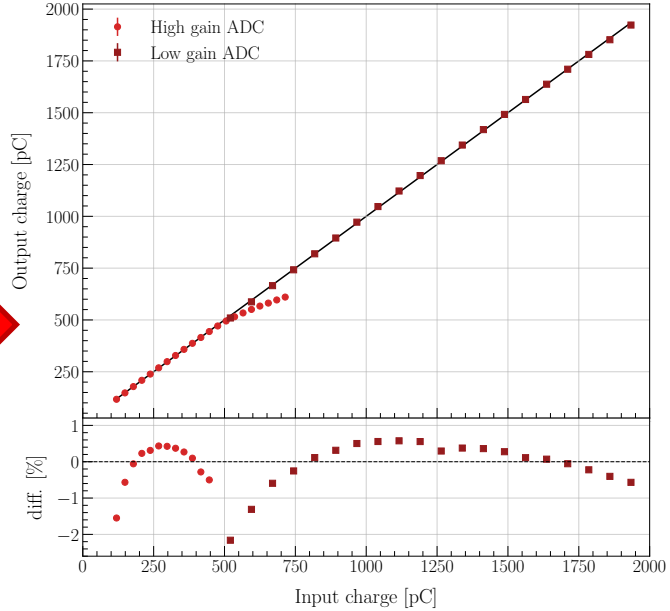
Photo by Fan Lei

Linearity test in Kunshan - one channel

GCU ID 3133
channel 0

At Kunshan we observe the same behavior of the residuals, for all GCUs, all channels, both ADCs



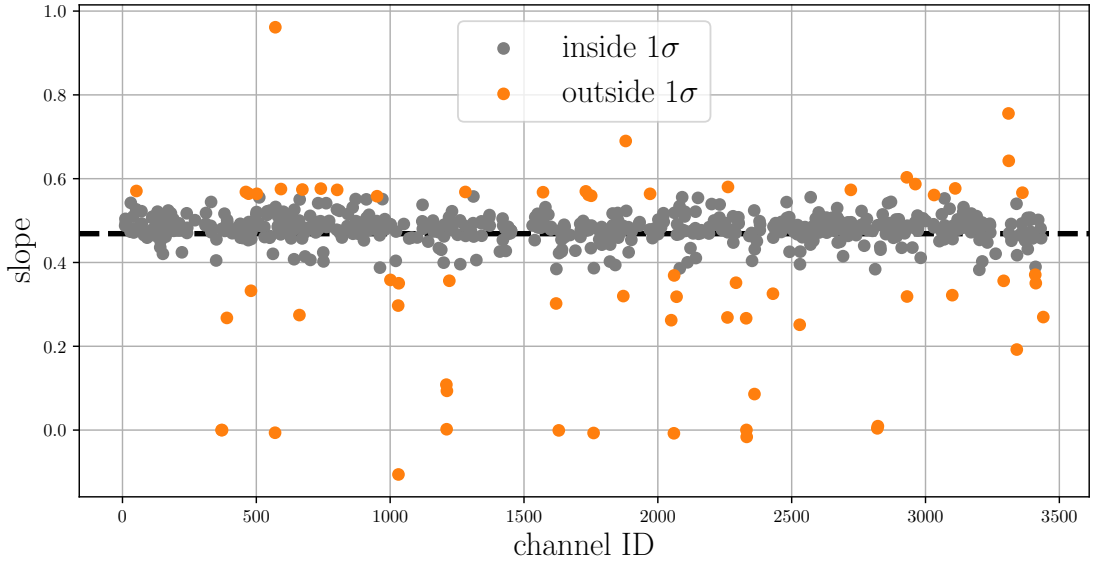


plots by A. Coppi

Linearity test in Kunshan - one run - 344 GCUs

Run with High Gain ADC
26/03/2022

Mean: 0.47
Std dev: 0.09



Note: outliers (even negative gains) are not necessarily due to a malfunctioning of the channel, we have issues with the GCU firmware which compromise waveform acquisition

Summary

- Further tests are ongoing to investigate the trend of the residuals
- Linearity with PMT and laser: within 1%
- 2 papers in preparation:
  - “Mass testing of the 20-inch PMTs readout electronics for the JUNO experiment”
  - “Validation and integration tests of the JUNO large PMTs readout electronics”

Thank you for your attention!