

Progress on PD read-out of CALO

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Outline

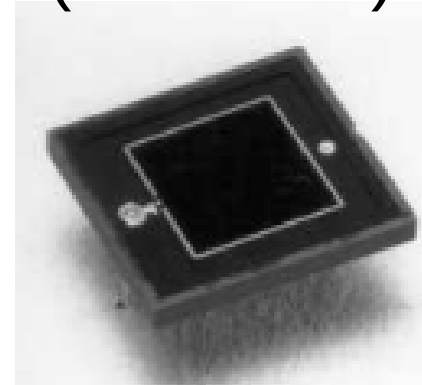
- Test of PD candidates
- Test of PD kapton cables
- Study of the front-end electronics self trigger circuit
- Study of PD integration on the beam test prototype
- Realization of a small prototype
- Characterization of the small prototype

Photodiodes situation

Each instrumented channel is readout by **two PDs by Excelitas**.
VTH2090 is out of production and we plan to substitute it with VTH2110.

Respect to VTH2090, the VTH2110 has an active area smaller by a factor of about 3.5.

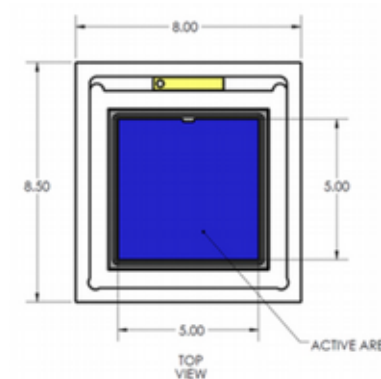
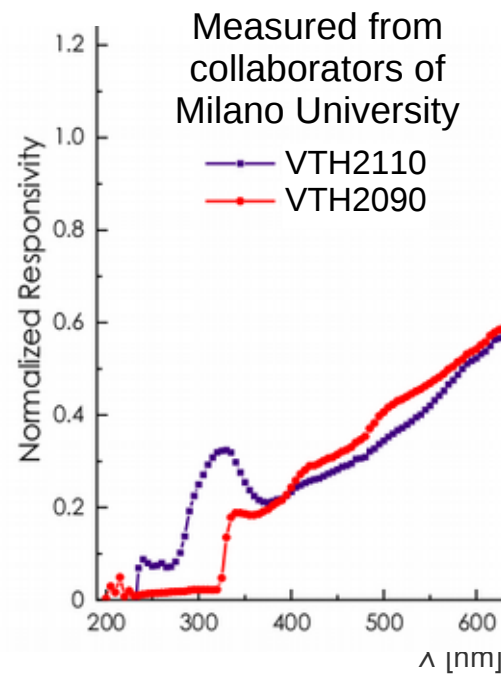
VTH2090
(84.6 mm²)



VTP9412
(1.6 mm²)



↓
VTH2110
(25 mm²)



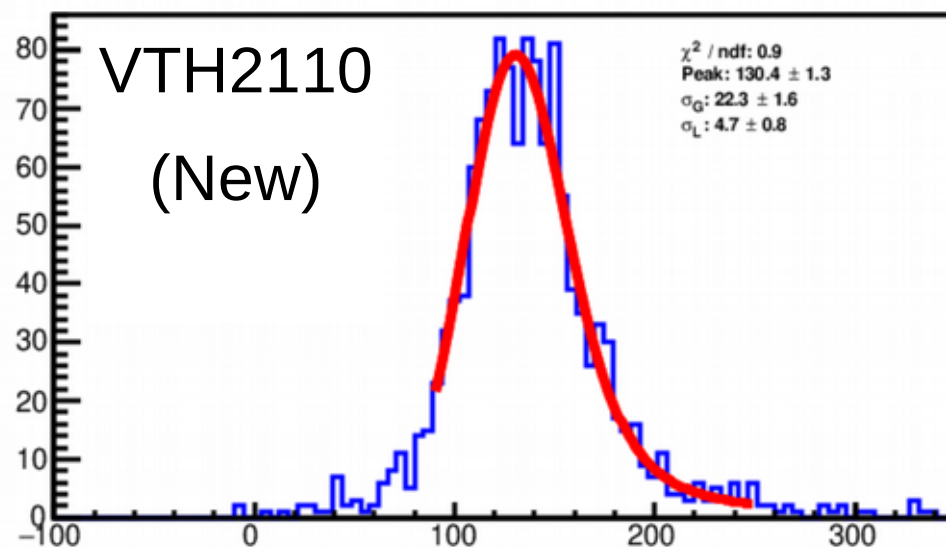
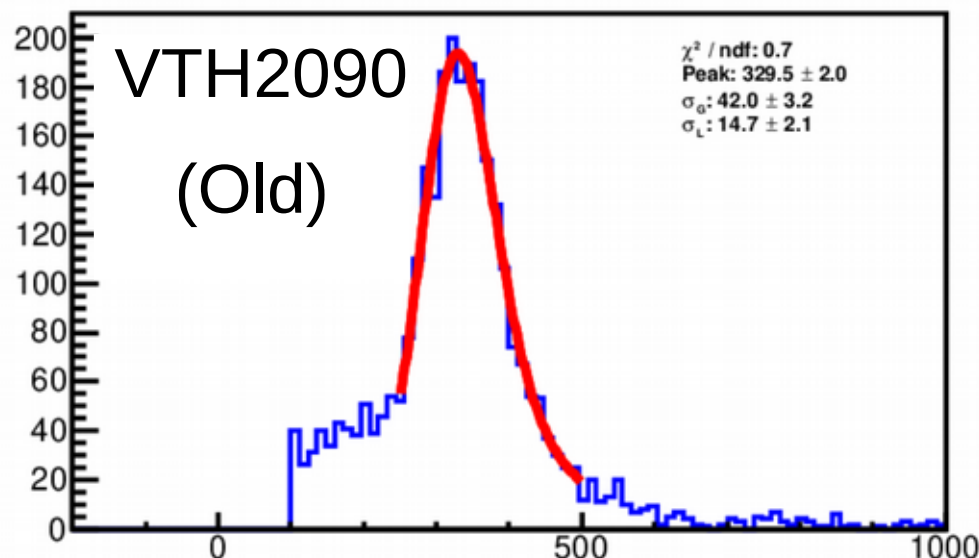
Old and new Large PD

The gain ratio between VTH2090 and VTH2110 PDs was measured using cosmic muons on a LYSO cube instrumented with PD+WLS

Several measurements were made in different configurations: the uncertainty on the estimated gain is about 10-20%.

The observed gain ratio is 2.5
(active area ratio is 3.5), likely
because light collection does not linearly scale with PD area.

This result was confirmed by optical photon simulation in a simplified channel geometry (simulation work is ongoing).



Expected saturation

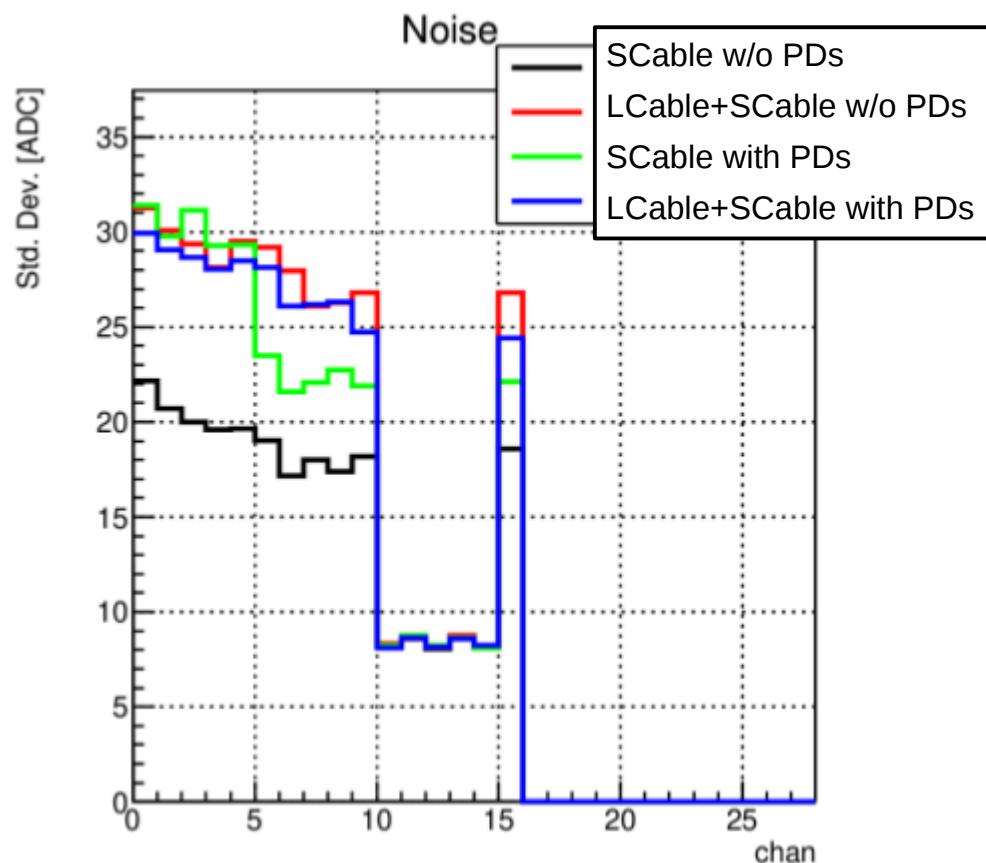
- HiDRA front-end electronics
 - **GR** = Gain Ratio = High Gain / Low Gain = 20
 - **SV** = Saturation Value = 37000 ADC
 - **EN** = Electric Noise = 25 ADC
 - **DR** = Dynamic Range = $GR \cdot SV / EN = 30000$
- Saturation with Current Configuration:
 - Old Large PD (VTH2090): $GR \cdot SV / 300 \text{ ADC/MIP} \sim 2500 \text{ MIP} \sim 75 \text{ GeV}$
 - Small PD (VTP9412): $GR \cdot SV / 4 \text{ ADC/MIP} \sim 185000 \text{ MIP} \sim 5 \text{ TeV}$
- Saturation with Future Configuration:
 - New Large PD (VTH2110): $GR \cdot SV / 120 \text{ ADC/MIP} \sim 6200 \text{ MIP} \sim \mathbf{185 \text{ GeV}}$
 - Small PD must be attenuated to increase dynamic range without losing overlap:
 - a reasonable criteria is to request Small PD signal $> 10 \cdot EN$ when Large PD signal saturates
 - the required attenuation factor is **50-100**, corresponding to a saturation of **250-500 TeV**
 - signal reduction can be obtained by a light filter application or an active area reduction

PD kapton cables

Short Cable (SCable) with PDs

Short Cable (SCable) w/o PDs

Long Cable (LCable)



PDs are connected to the front-end electronics by kapton cables: in the final design, kapton cables are very long and their capacitance could degrade the electric noise on the channels far from the electronics.

We tested the expected noise change by using the Short Cable from the current prototype and a Long Cable+Short Cable that mimics the capacitance of the final experimental configuration.

From our measurements, it seems that switching from Short Cable to Long Cable+Short Cable, the electric noise changes only from 20 to 30 ADC, still ensuring a **S/N ~ 4 for the new Large PD (VTH2110)**.

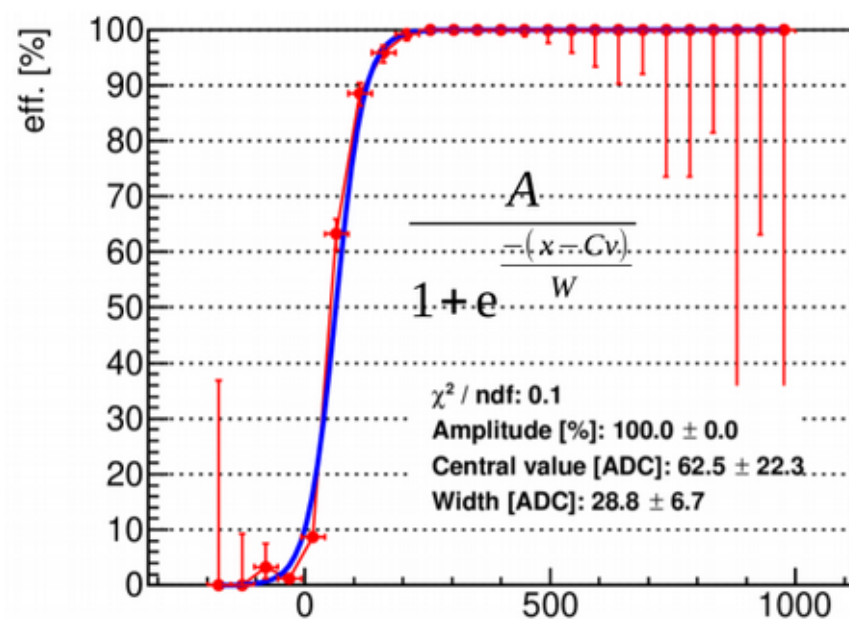
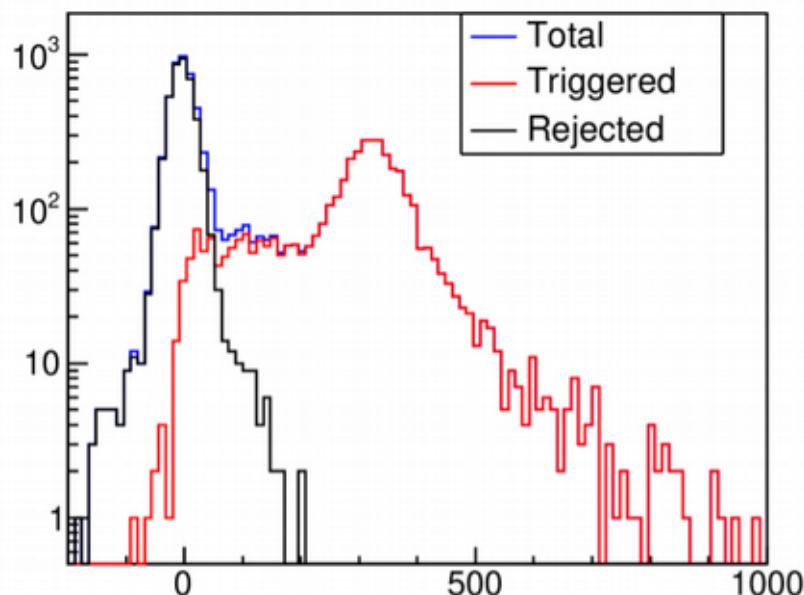
Self trigger Circuit

Starting from the current version of the front-end electronics (HIDRA2), chip has **self trigger capability**.

Currently, two adjacent channels (now: 2 Large PDs or 2 Small PDs) are connected to an internal discriminator with a fixed threshold.

Self-trigger system was tested using cosmic muons.

Average trigger threshold corresponds to about 0.5 MIP with new Large PD (VTH2110) and 0.2 MIP with old Large PD (VTH2090).



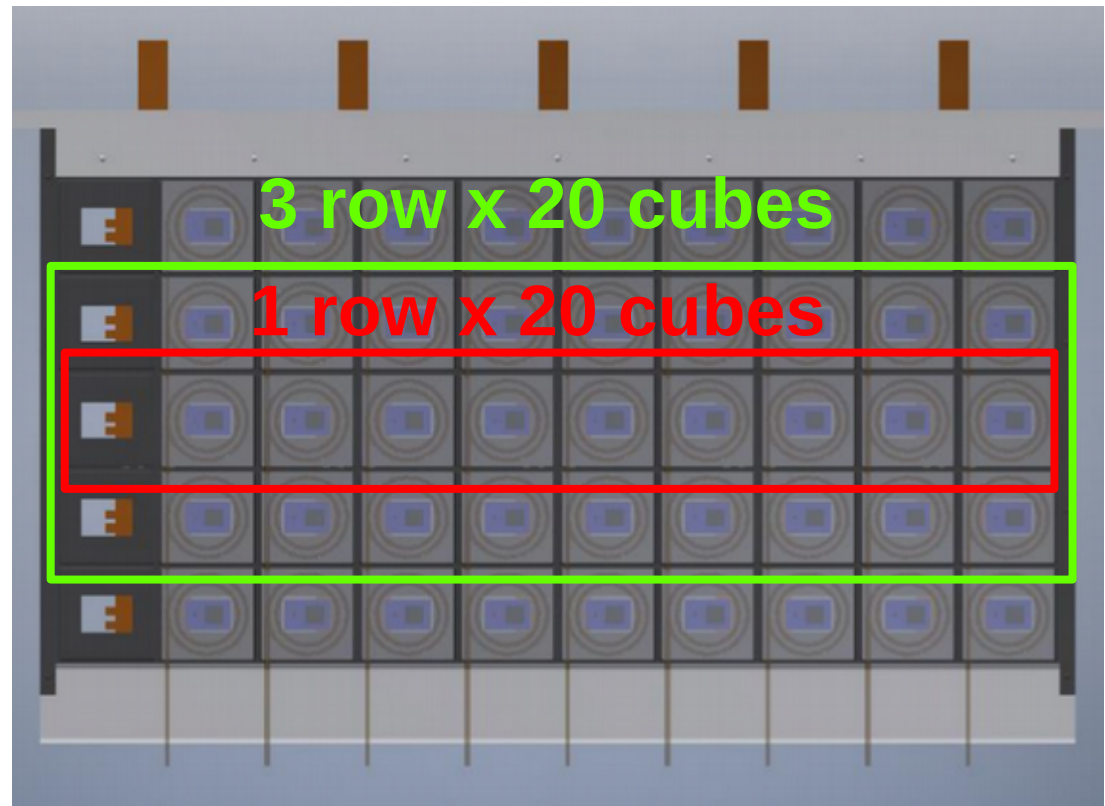
Beam Test Mechanics

Mechanical
study by O.
Starodubtsev

For the beam test we plan to equip **20-60 cubes** (1 row x 20 cubes or 3 row x 20 cubes) with new Large PD and small PD mounted on a homemade monolithic package (not the final package version).

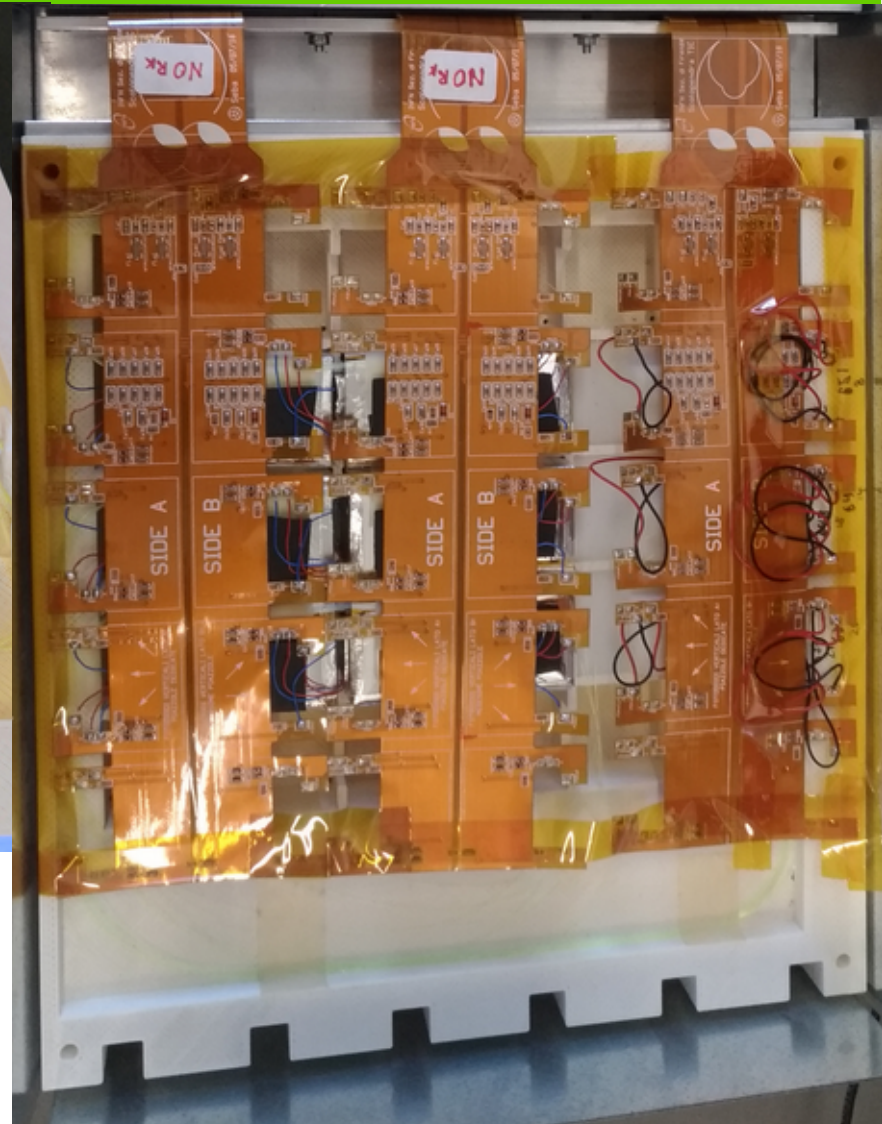
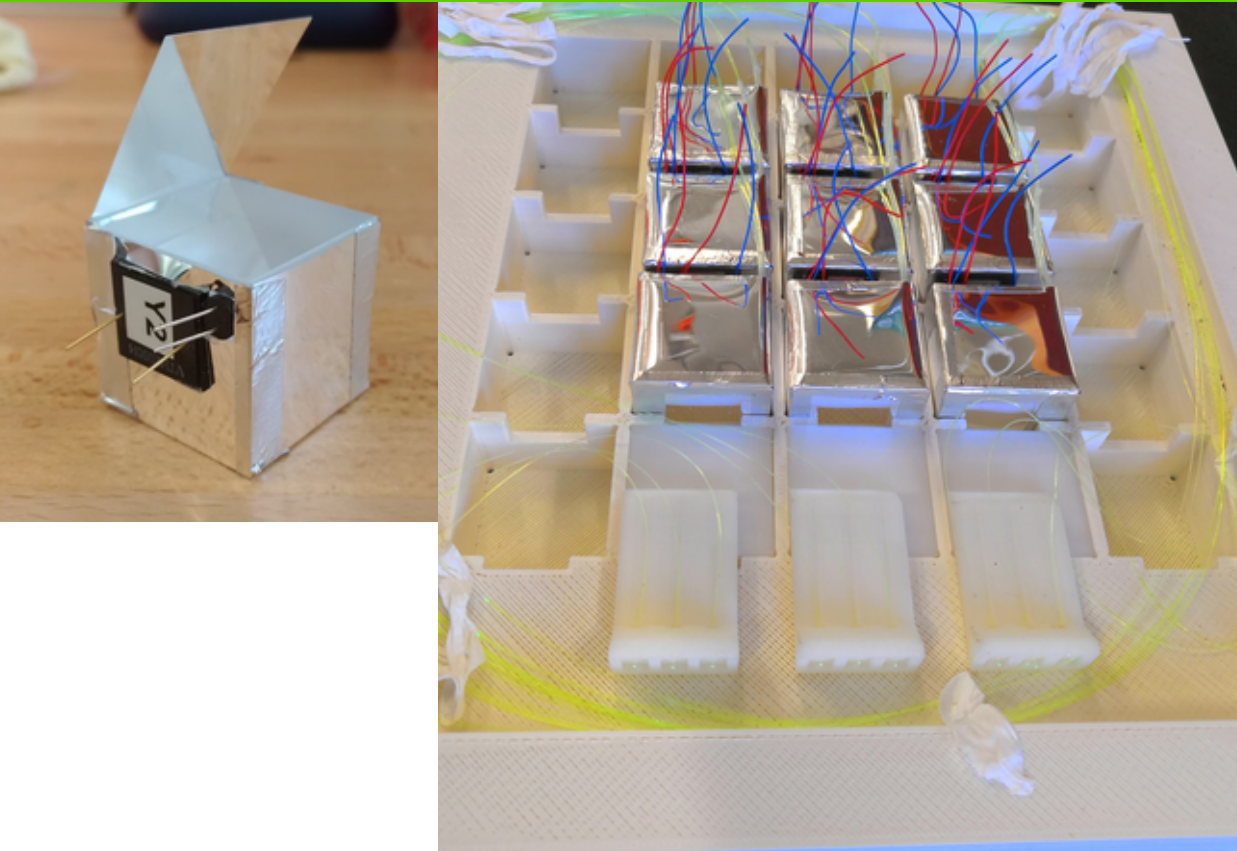
PDs and fibers will be mounted on the opposite side of the cubes.

Depending on whether the layers are arranged vertically or horizontally, PD kapton cables can exit from the top or the lateral face, with 2-3 HIDRA boards locates just outside the calorimeter box.



We need to study the best arrangement using the updated CAD geometry for the beam test prototype

Double read-out of LYSO cubes

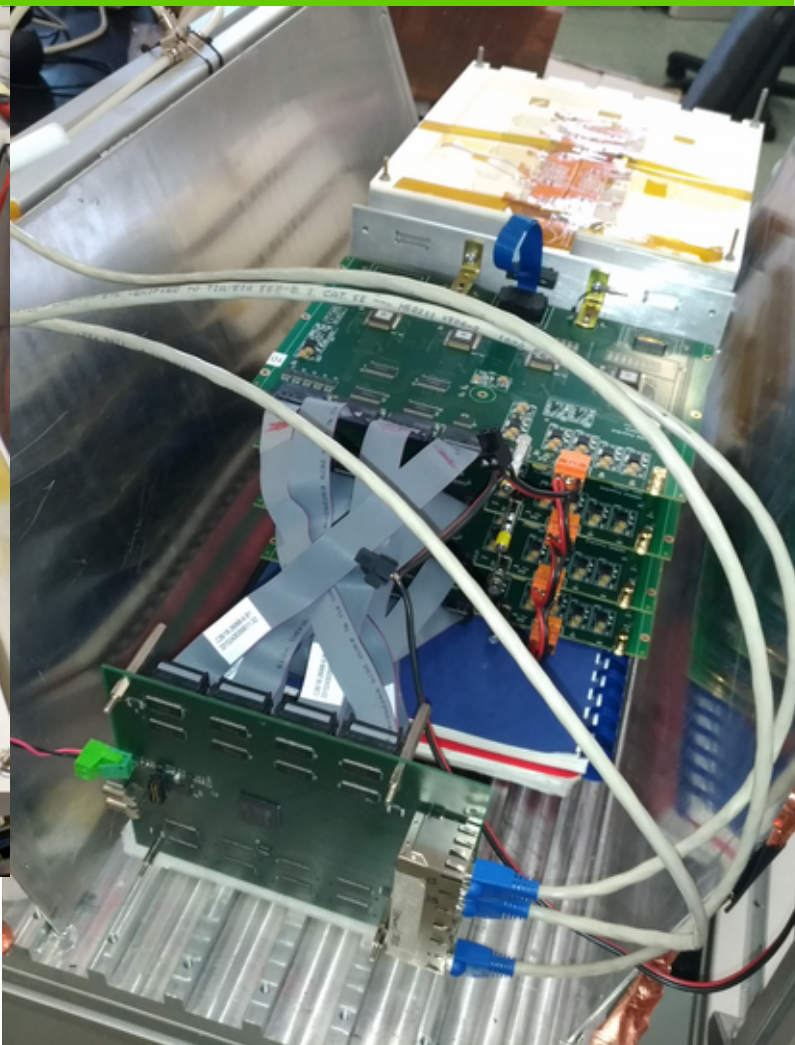
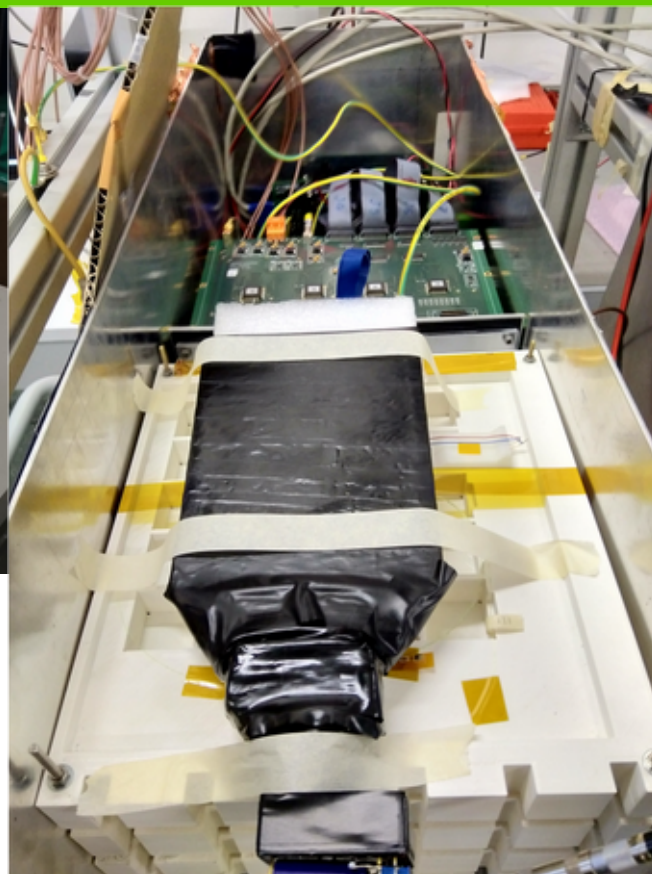


Thanks to the help of Chinese colleagues, we equipped 28 crystals with VTH2090 (old Large PD), VTP9412 (small PD) and WLS+SiPM (Hamamatsu S12571-010P).

Small Prototype



We assembled these 28 crystals in a small prototype made of 4 layers.



The idea is to test this small prototype at BTF in Frascati (Italy) if we will have beam time.

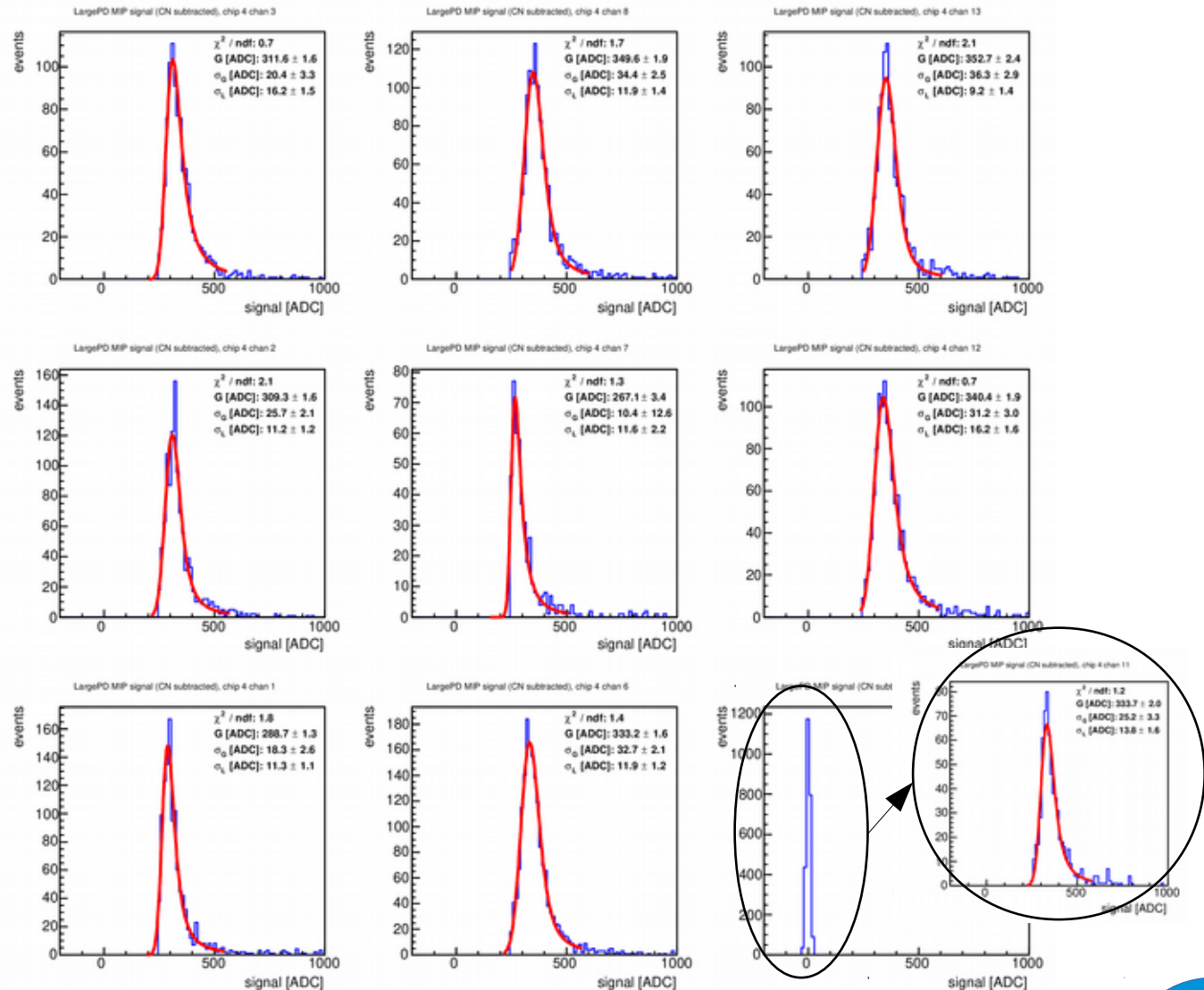
For the moment we used cosmic muons to check that everything is OK.

Small Prototype (Old) Large PDs - Layer 1

Event selection is obtained selecting **vertical tracks** by requiring that Large PDs of all cubes in the same position on different layers have **$dE > 250$ ADC**.

Fit using convolution of Landau and Gaussian.

Of 28 (Old) Large PDs, only 1 was disconnected, but it was repaired before the following acquisitions.



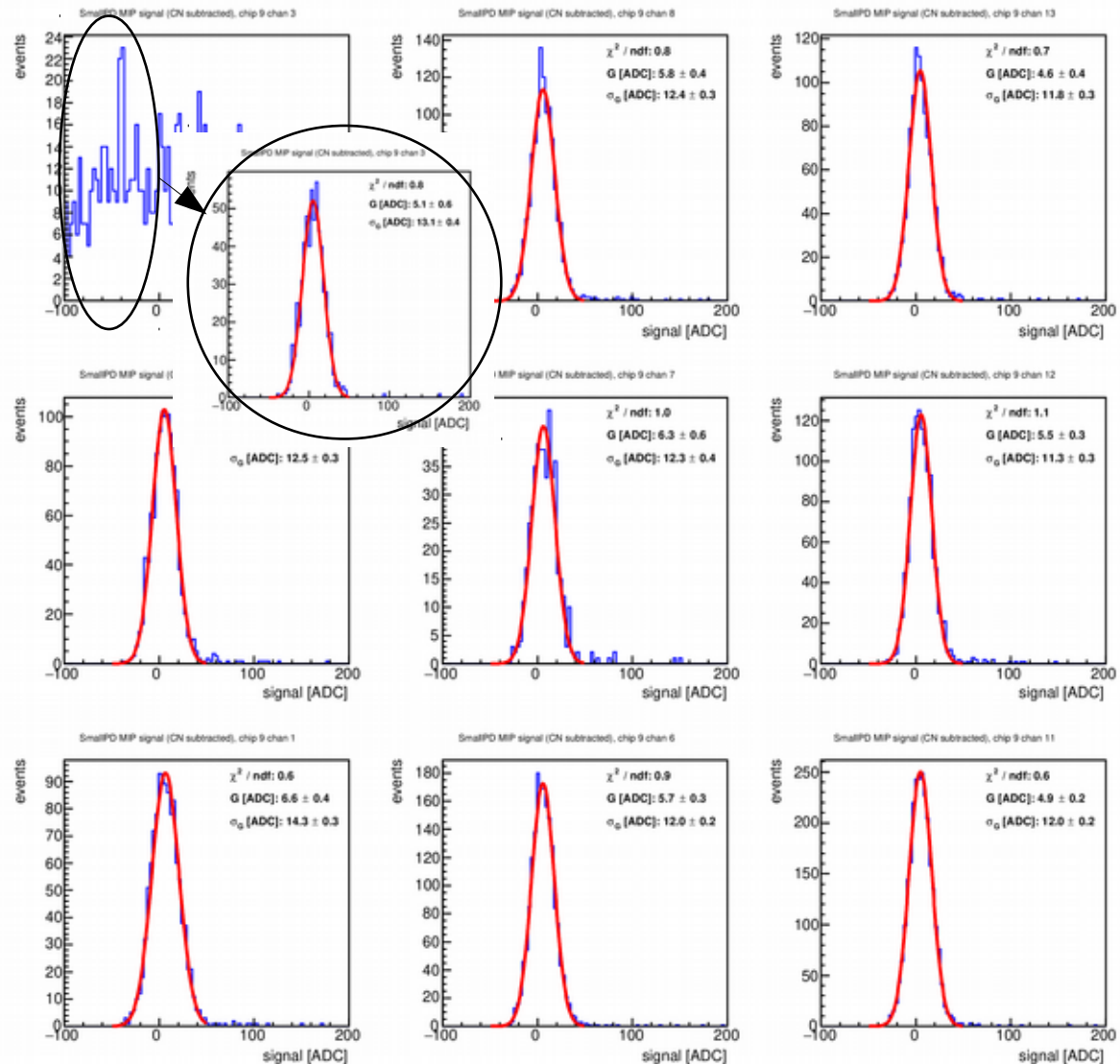
Small Prototype

Small PDs - Layer 2

Event selection is obtained selecting **vertical tracks** by requiring that Large PDs of all cubes in the same position on different layers have **$dE > 250$ ADC**.

Fit using a Gaussian.

Of 28 Small PDs, only 1 had bias problem, but it was repaired before the following acquisitions.

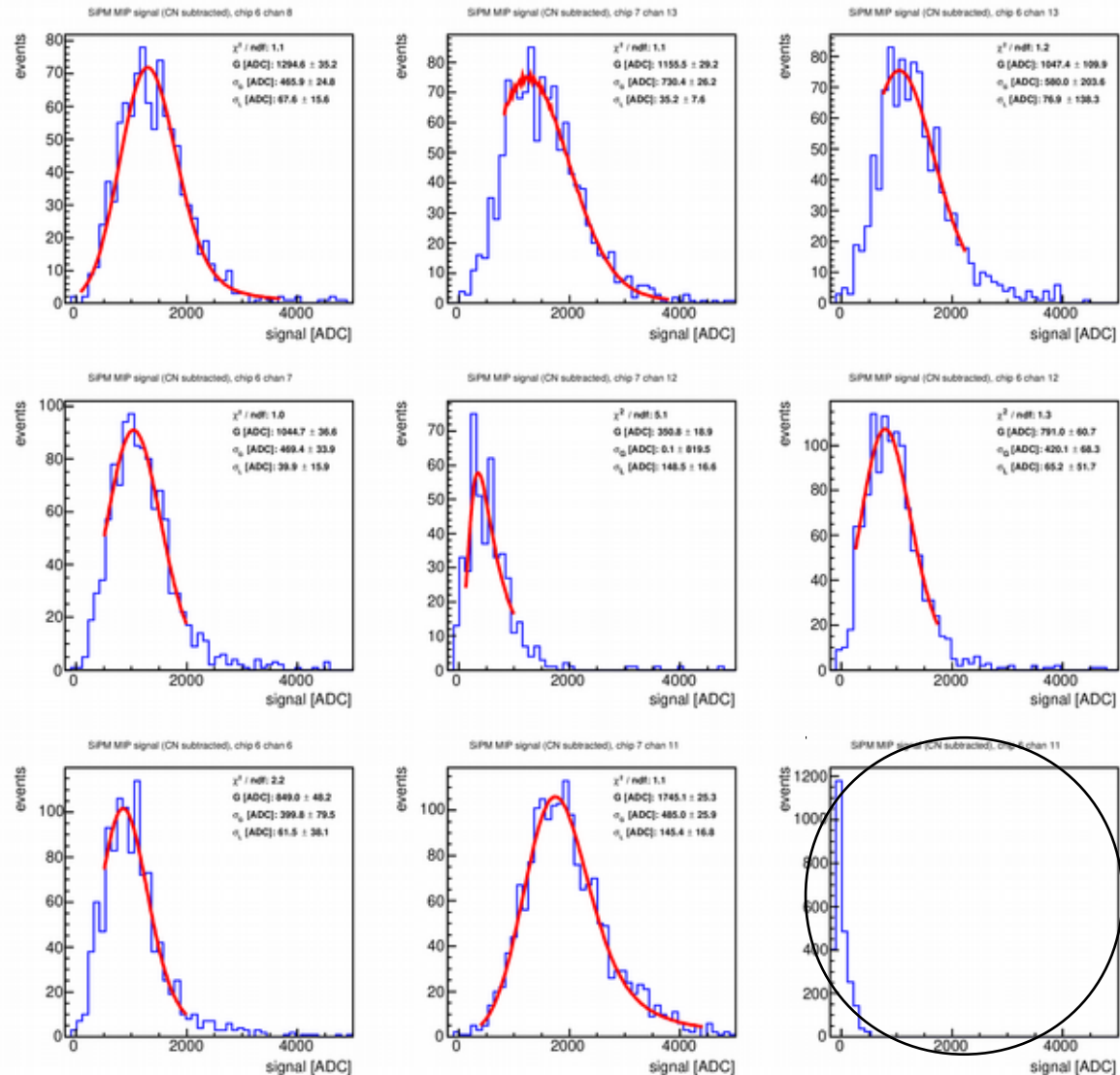


Small Prototype SiPM - Layer 1

Event selection is obtained selecting **vertical tracks** by requiring that Large PDs of all cubes in the same position on different layers have **$dE > 250$ ADC**.

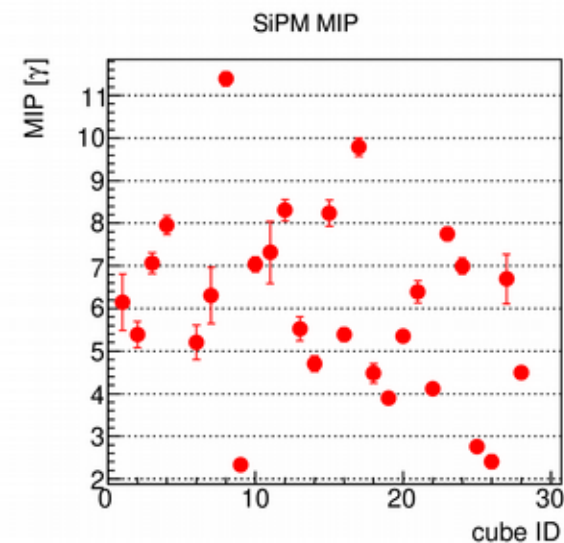
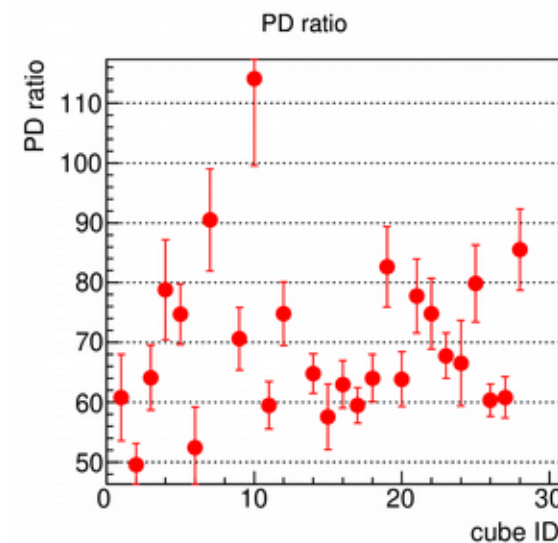
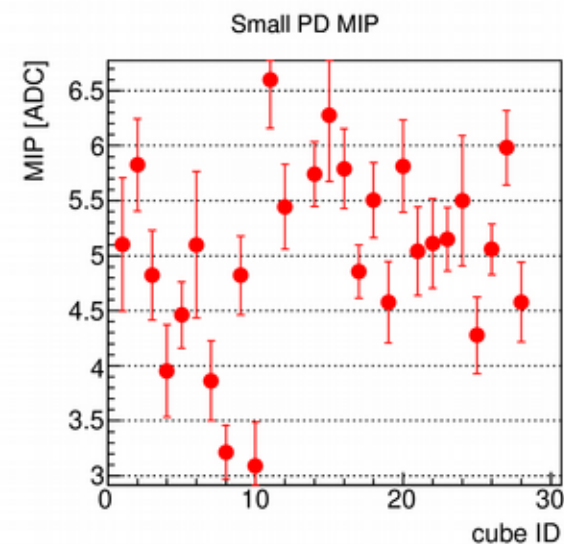
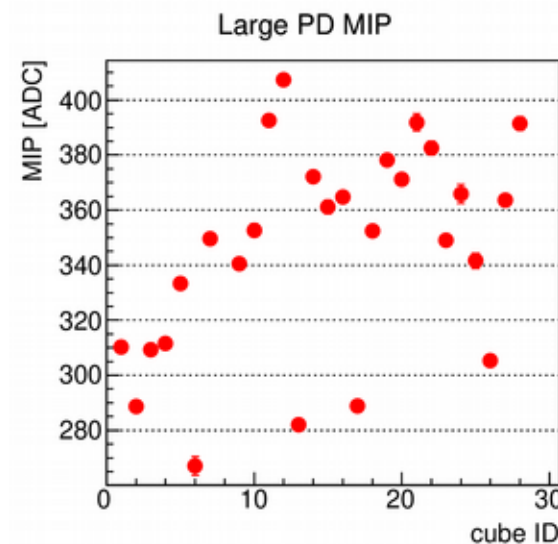
Fit using convolution of Landau and Gaussian.

Of 28 SiPM, only 1 is disconnected.



Small Prototype Overview

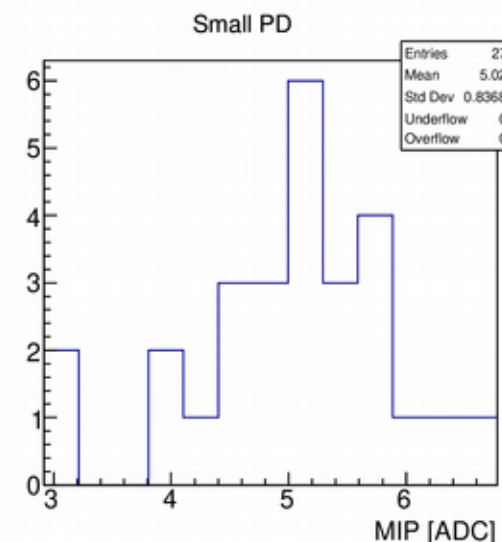
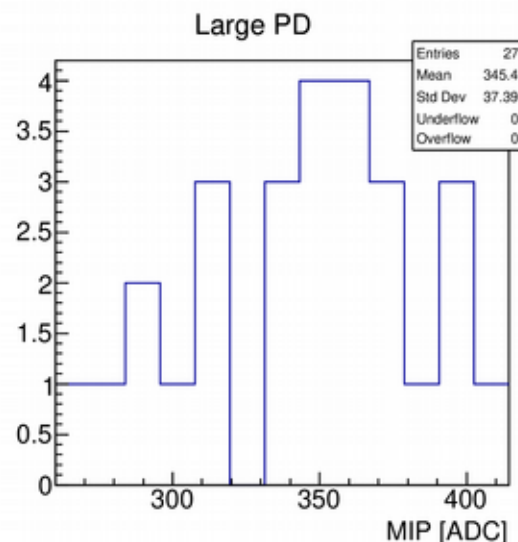
The final SiPM gain is expressed in terms of detected photons by the use of an independent calibration procedure.



Small Prototype Overview

Average gain

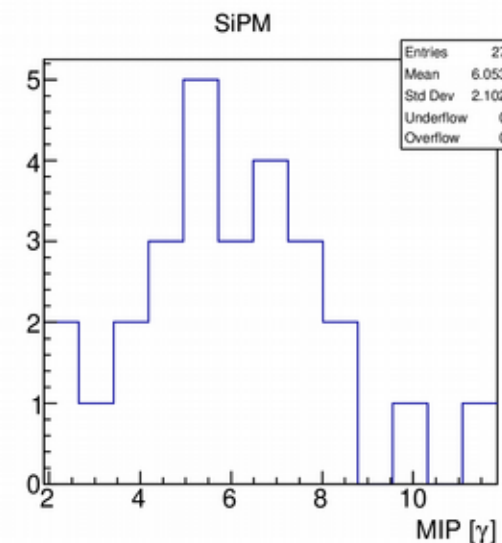
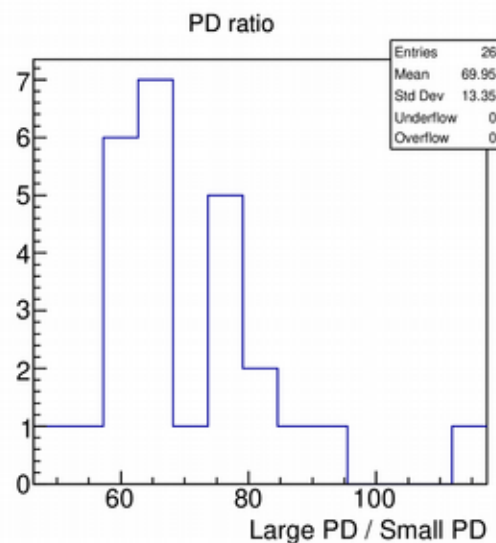
- Large PD : 345 ADC
- Small PD : 5 ADC
- SiPM : 6 photons



Gain dispersion

- Large PD : 11%
- Small PD : 17%
- SiPM : 35%

Average Large PD /Small PD
70



Summary

- We characterized the new Large PD (Excelitas VTH2110) that will replace the old one (Excelitas VTH2090) in the final configuration:
 - MIP signal is around 130 ADC channels
 - Saturation should happen for an energy deposit of 185 GeV
 - Small PD gain must be decreased by a factor 50-100 (study is ongoing)
- We have characterized the new HIDRA2 front-end electronics:
 - Self trigger works well and it has a threshold of about 0.5 MIP
 - S/N ratio is about 6.5 with for the current kapton cables
 - Even with long kapton cables S/N ratio is better than 4.0
- We realized a small prototype made of 28 LYSO crystals equipped with the Old Large PDs, Small PDs and WLSs connected to SiPMs
 - Only a SiPM is not connected
 - All Old Large PDs and Small PDs channels are now correctly working
 - The test of the prototype confirmed the characteristics and performances that were obtained from the previous measurements on a single crystal.