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Istituto Nazionale di Fisica Nucleare
SEZIONE DI FIRENZE

Status of the dual read-out for the Calorimeter prototype.

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Introduction

- The basic idea is the design of a dual read-out system for the HERD Calorimeter:
  - The Chinese system $\rightarrow$ wavelength shifter (WLS) fibers read-out with Imaging Intensifier + IsCMOS
    - 3 fibers per crystals, one is used for the trigger, 2 are connected to the Imaging Intensifier with 2 different gains.
  - The CaloCube system $\rightarrow$ photo-diodes (PD) (so far: read-out with HIDRA1 chips).
    - 2 PDs with different active areas are glued to the cube (ratio between areas $\sim$ 100).
    - HIDRA is a double gain Carge Sensitive Amplifier (CSA) with automatic gain selection.
- Pro: the same scintillation light is read-out with 2 independent system.
- Cons: power consumption, difficult mechanical arrangement (not discussed in this presentation).
- **Important check: is the fiber signal strongly affected by the presence of the PD?**
- **Are we able to build a prototype of the dual-readout?**

Content of this presentation

- Attenuation of the fiber signal due to the light absorbed by the large PD.
  - Using SiPM to read-out the WLS

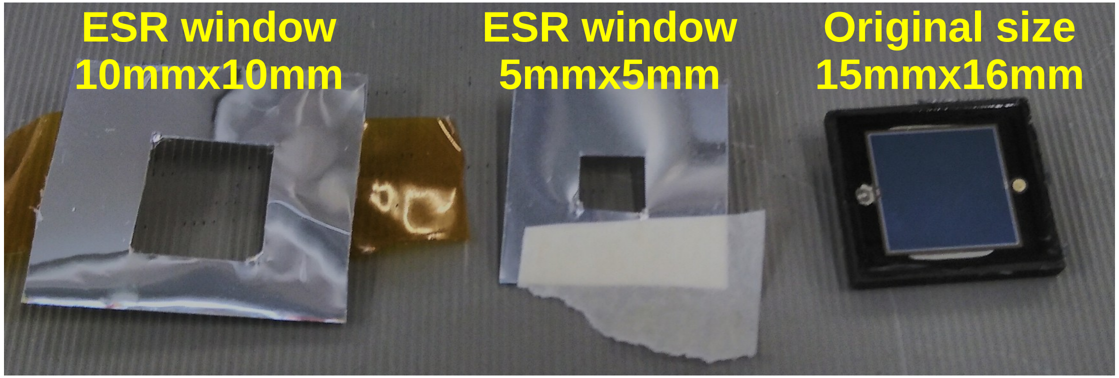
- Expected S/N ratio for MIP signal with LYSO, using the same configuration which will be employed in the prototype.

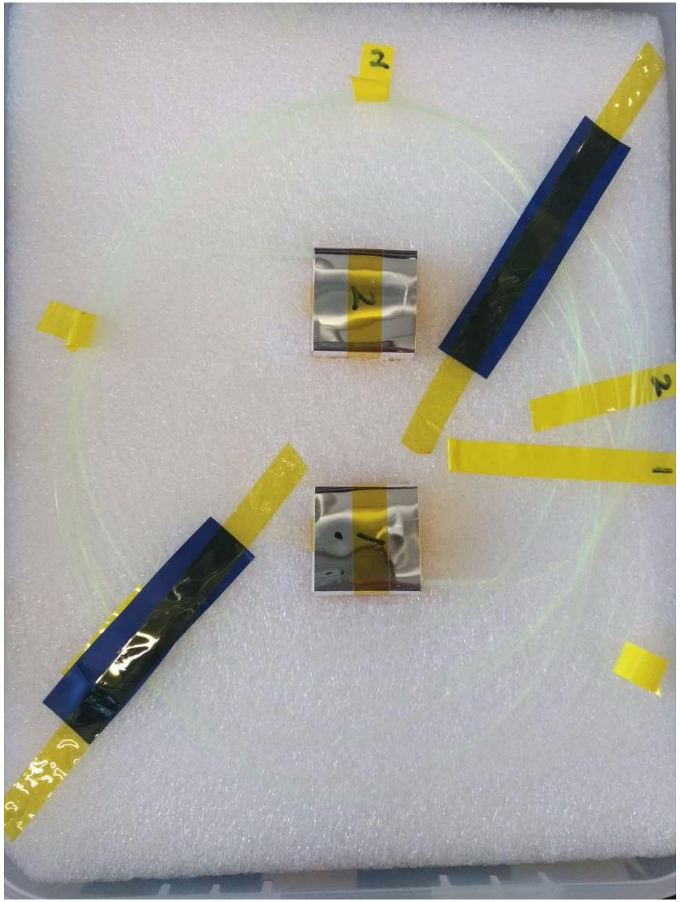
- Prototype design and status of the assembling.

- !!! New HIDRA2 board with auto trigger, digital logic developed by CIEMAT (Madrid). !!!
  - First test in Firenze started one week ago!

Fiber attenuation due to PD

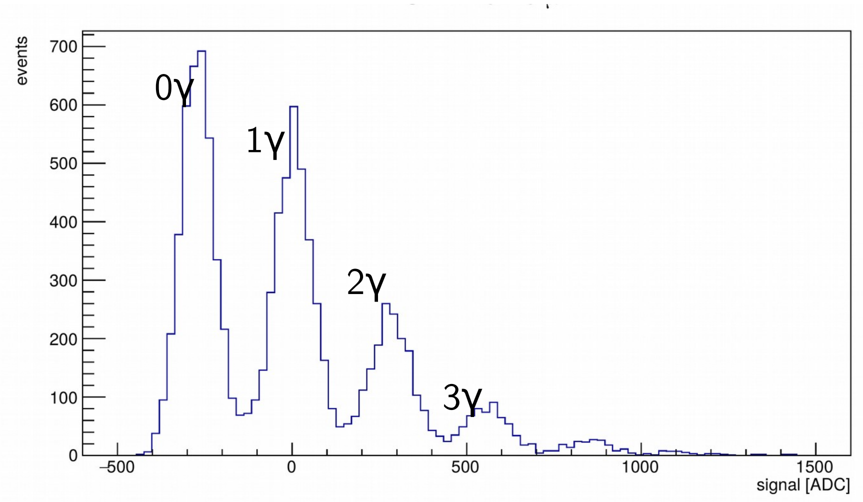
- Thanks to the Chinese colleagues, we have 3 cubes wrapped with ESR film and with 3 WLSs glued to the top surface.
- We connected the 3 WLSs to 3 SiPMs (AdvanSid ASD-RGB1C-P):
  - 673 cells 40 µm x 40 µm cell size, 1.13 mm^2 effective (circular) area.
- We use the HIDRA to read-out SiPM (see next slide).
- We compare WLS signal without and with the Large PD (VTH2090), we also used some ESR to simulate different active area for the LPD.





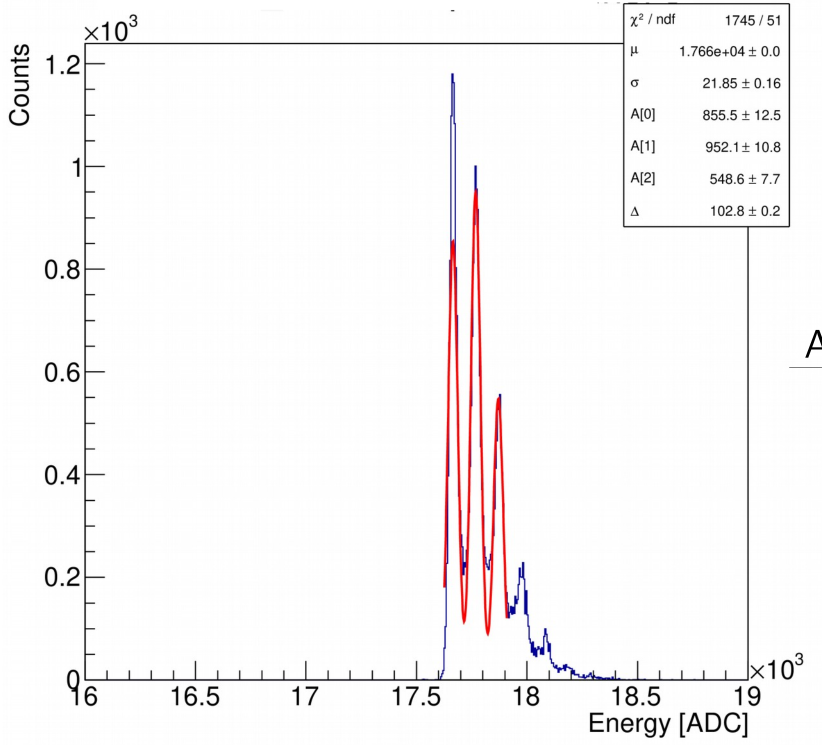
SiPM + HIDRA read-out

- HIDRA is a CSA which integrates for a selected amount of time.
  - This chip is not studied for SiPMs, thus the performance is not optimized so far.
  - Minimum integration window width (used for SiPM): 10 µs.
- Pedestal acquisition with random trigger: a large number of events contains at least one photo-peak due to the SiPM dark counts. ($\sim$ 100KHz).
- The photo-peaks acquired during the random trigger can be used to check the SiPM gain during the data-taking

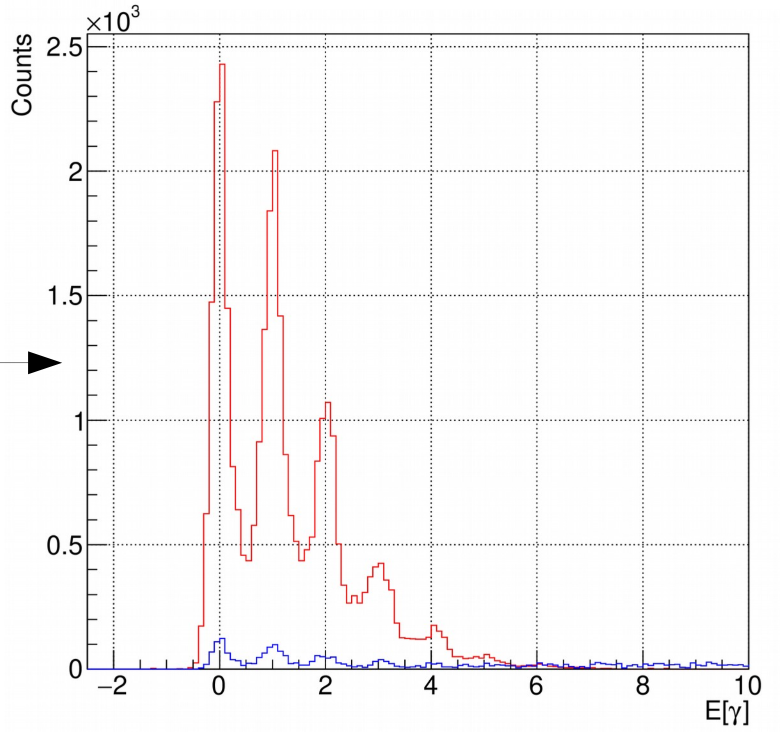


SiPM + HIDRA calibration

- SiPM+HIDRA gain is defined as the distance between two photo-peak.
- Can be found using Gaussian fit of 3 peaks, then we can calibrate the scale in N. of photons.



After calib.

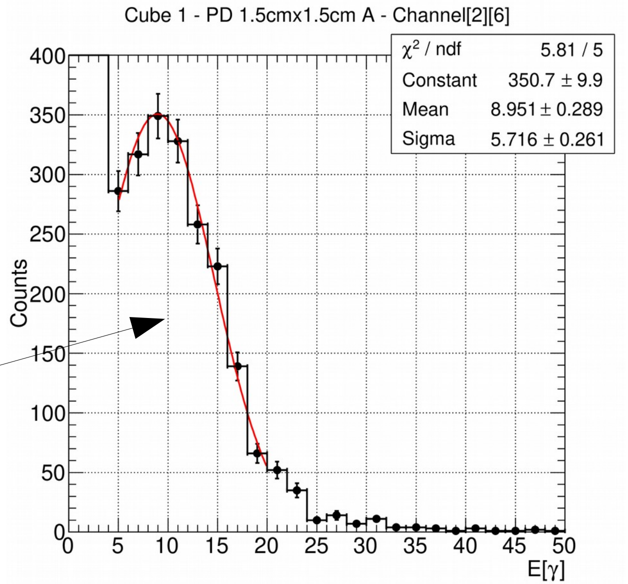


Tested configurations

Thanks to Eugenio Berti

- The configuration are named:
  - ESR**X** - Cube 1 is wrapped with ESR (WLS only)
  - PD**X** - VTH2090 is attached to Cube 1 (WLS+LPD), so that the equivalent dark *area* is 15x16mm^2
  - PD5x5/PD10x10 - as before, but we cut a ESR square in order to reduce the dark *area* to 5x5 and 10x10 mm^2
  - Sequence of tests:
    - ESRA -> PDA -> ESRB1 -> ESRB2 -> PDB -> PD5x5 ->
    - - > ESRC -> PD10x10A -> PD10x10B -> ESRD

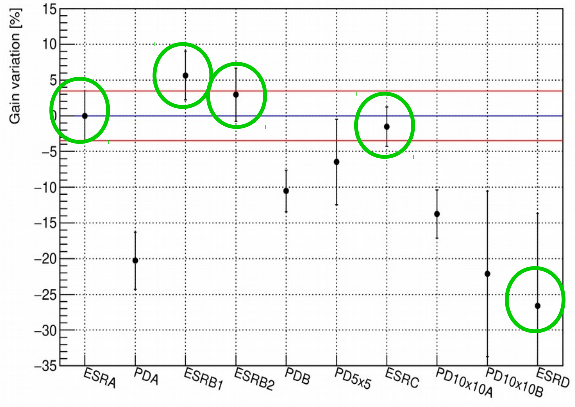
Example of MIP signal with one configuration.
The peak is estimated with a gaussain fit.



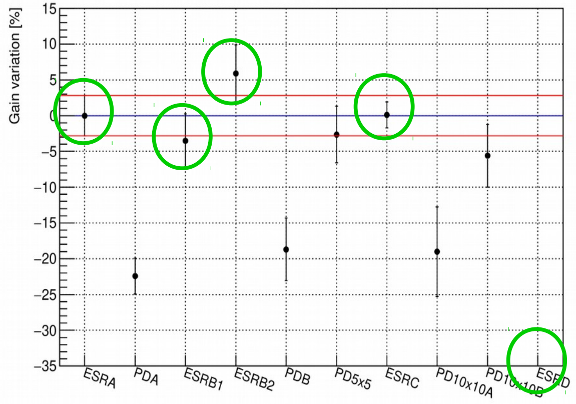
Attenuation results

Thanks to Eugenio Berti

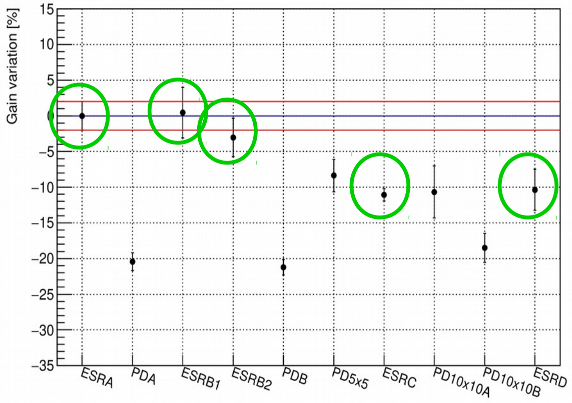
Fiber 1



Fiber 2



Fiber 3

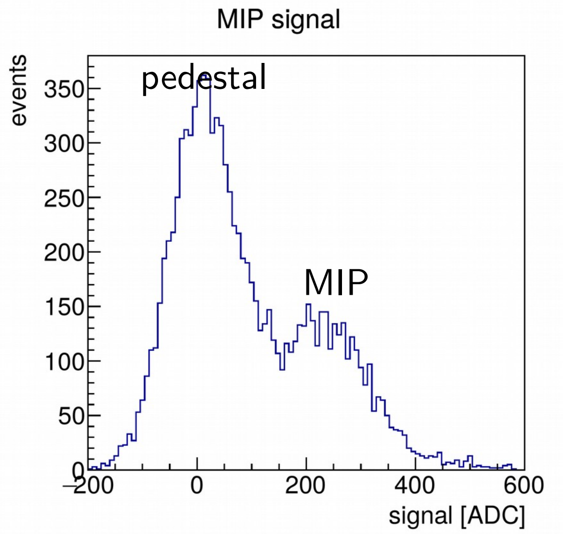


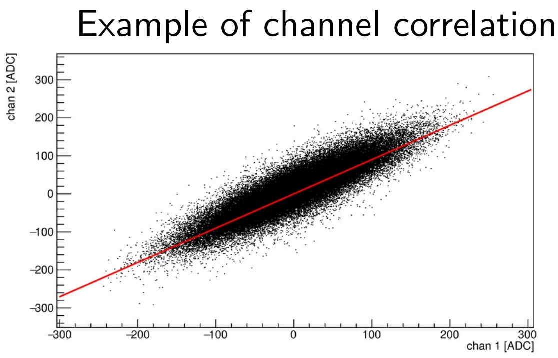
- Relative variations with respect to the first configuration.
- Green circles are acquisition with ESR used to check the stability of the system

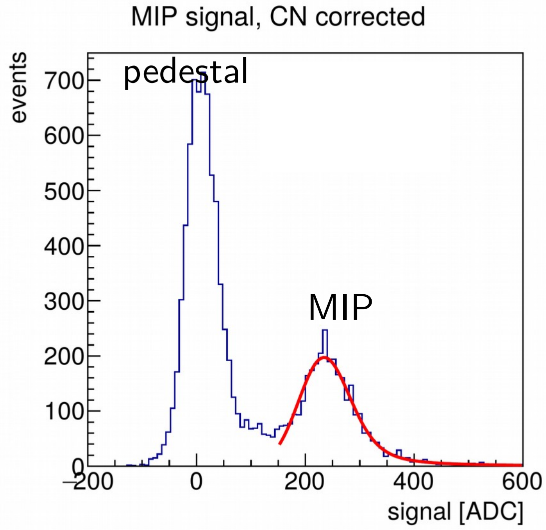
- The last acquisitions are not well stable due to big variation in temperature.
- Attenuation results:
  - **Standard PD: 20.0 $\pm$ 2.5%**
  - 5mm x 5mm PD: 5 $\pm$ 2.5%
  - 10mm x 10mm PD: the system it was not stable but the attenuation is ~ 15-10 %
- Chinese colleagues have confirmed that a 20% attenuation is acceptable but it is better to reduce it, if it is possible….

Studies to define the read-out of the prototype

- Thanks to the Chinese colleagues, we have received 29 “nude” LYSO crystals, without ESR and WLSs.
- We used one cube to measure the S/N ratio with the large PD (VTH2090) and 2 different SiPMs:
  - SiPMs: Hamamatsu S12571-010, pitch 10 or 15 µm.
  - For the prototype we will not use the AdvanSid SiPM: we want a higher dynamic range and smaller dark count.
- First test: verify the S/N with the PD only: common noise subtraction is needed:







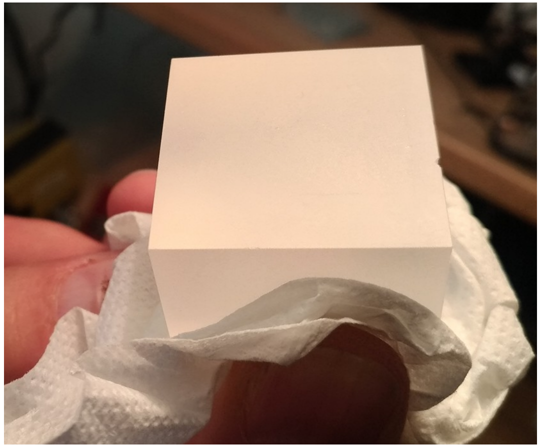
Summary of LPD+LYSO tests

- We tested few configurations, the summery is below.

Test number	Face	Opt. coupling	MIP [ADC]	MIP (% test 1)
1	Polished	Optical greases	222	100
2	Course	Optical greases	240	108
3	Course	Air	165	74
4	Course	Silicone sealant	246	111

- Configuration for the prototype: PD on the coarse face with silicone sealant (Dow Corning – 3145), the S/N ratio is >6. (with CsI(Tl) it is ~ 10)

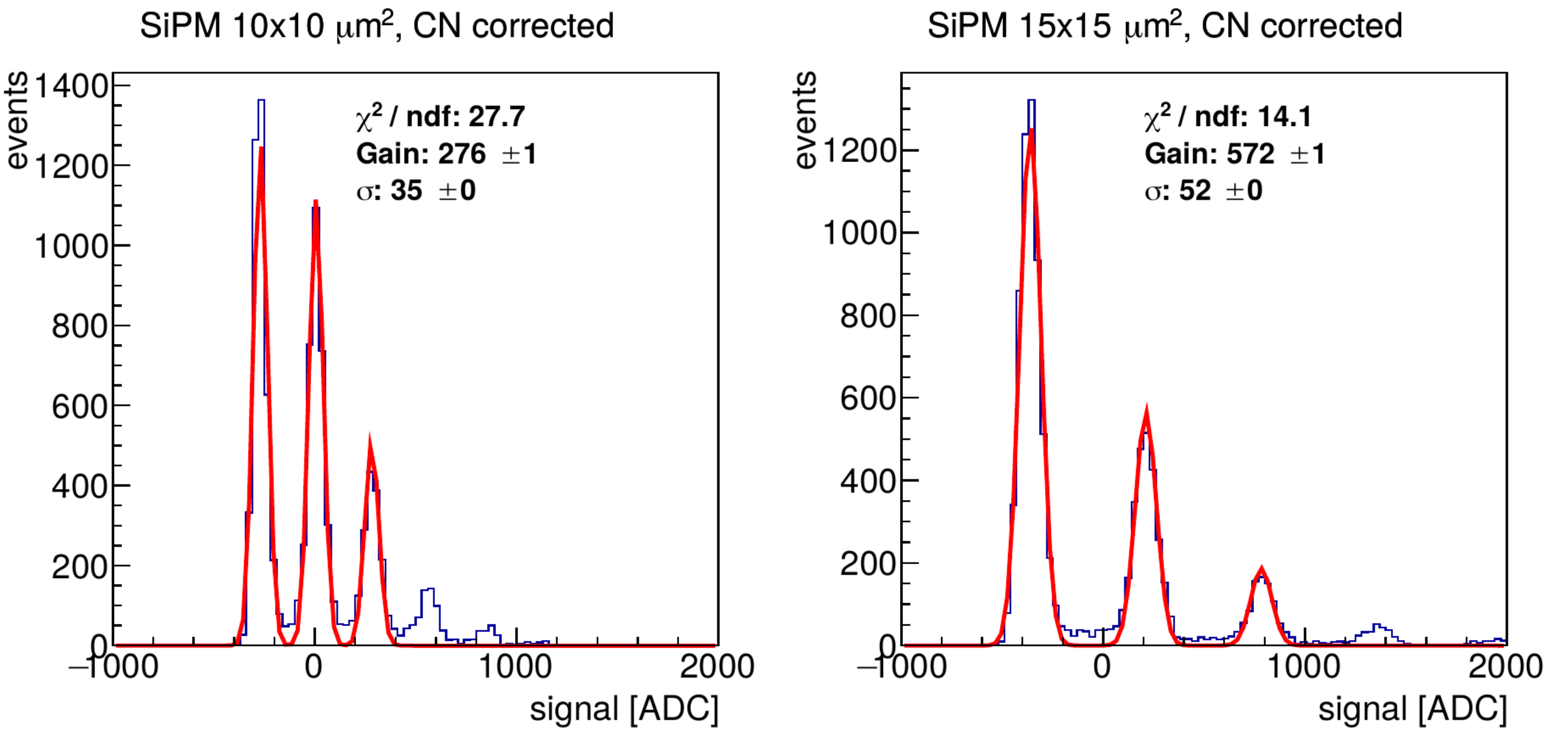
- Silicone sealant seems a good solution since it can be removed using different products, e.g. Saratoga VIA.SIL



The used surface (top) seems clean after the treatment

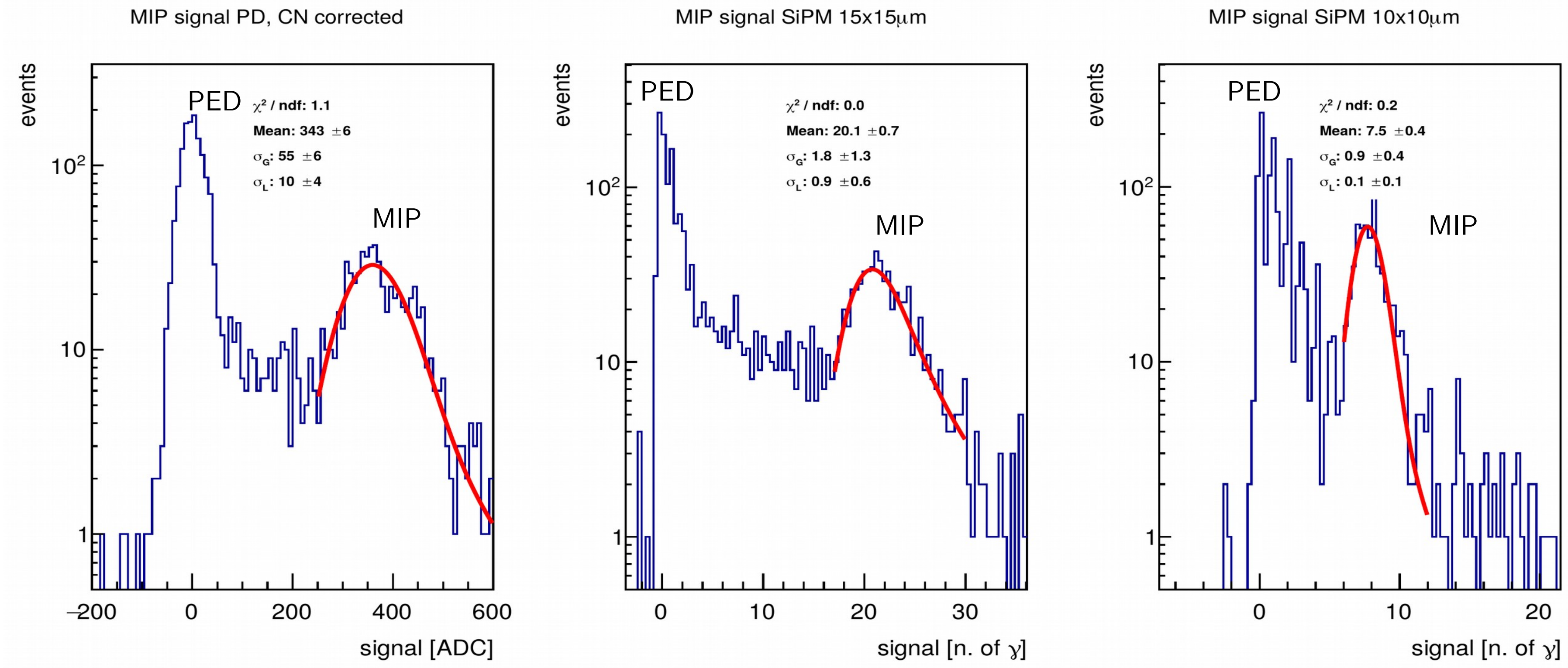
SiPM Hamamatus + HIDRA gain

- Can be found using Gaussin fit of 3 peaks.



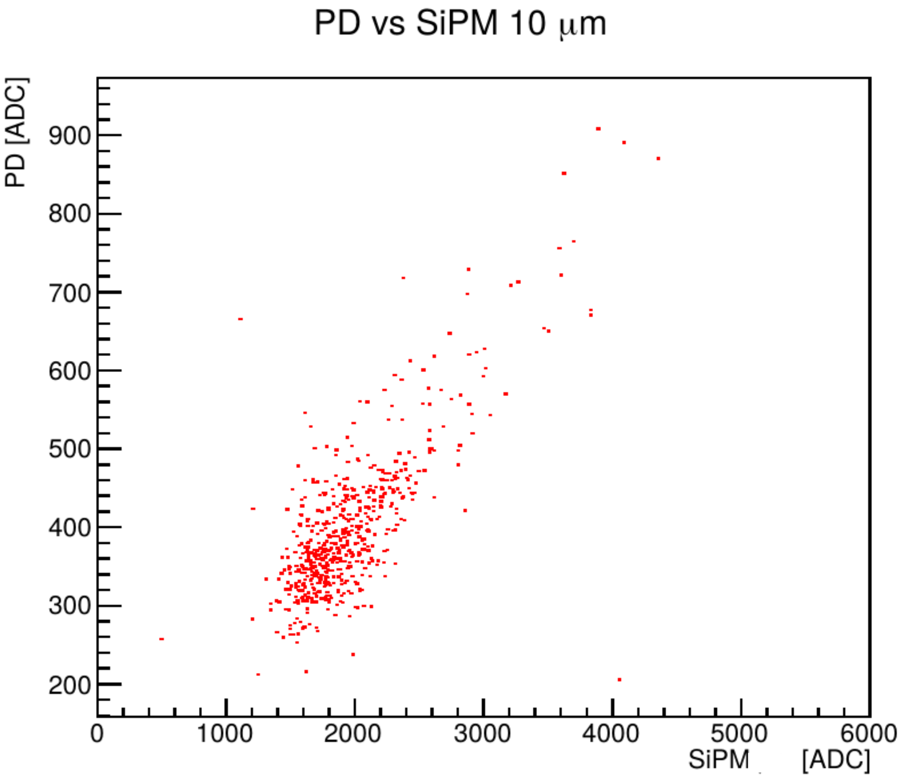
- The gain of 10 μm SiPM is smaller with respect to the 15 μm SiPM, as expected.

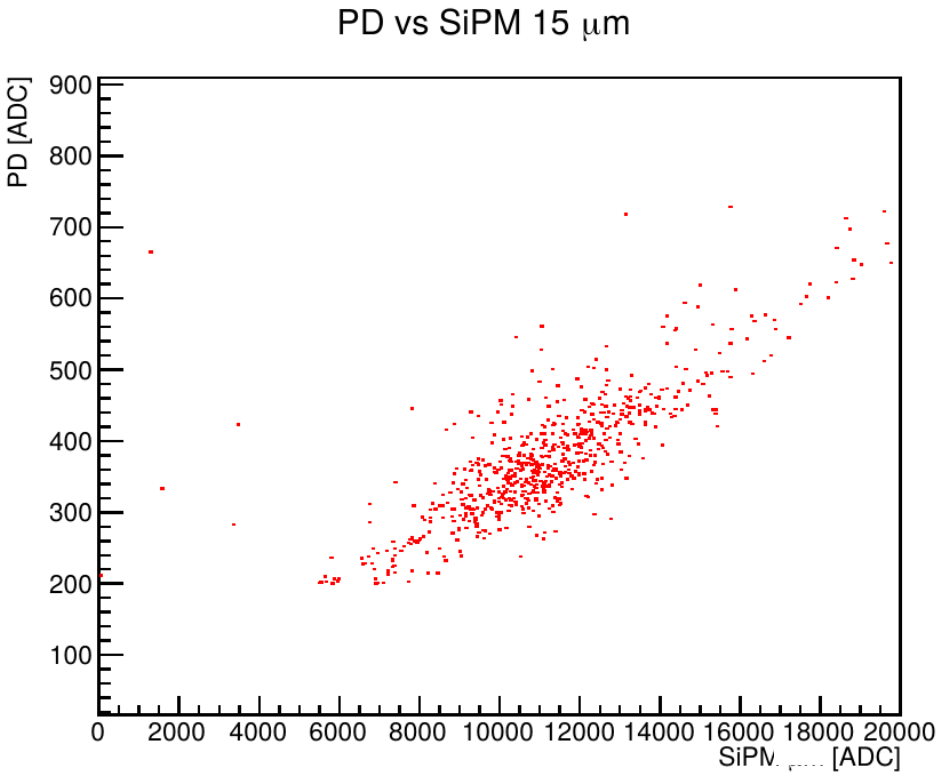
SiPM-fiber + LPD: MIP values



- MIP signal is well separated with respect to the pedestal with both PD and SiPMs
- PD signal 40% bigger than the one obtained in previous tests: it can be due to the different wrapping procedure or to the presence of the wave length-sifter (TBD).

SiPM-fiber vs LPD: correlation





- Event selected with PD: PD signal > 200 ADC.
- Strong correlation between SiPMs and PD as expected.

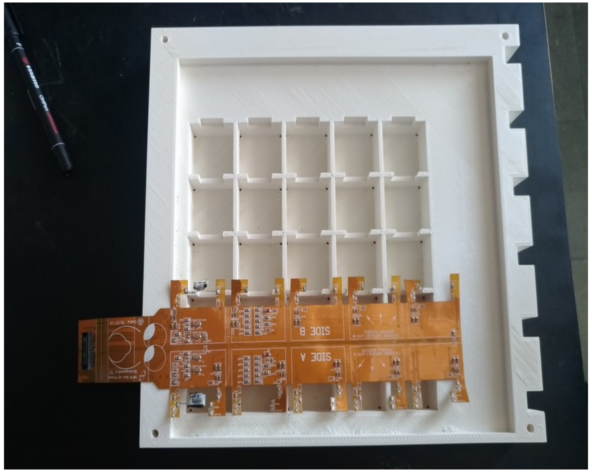
Summary and expected saturation values

- It is possible to read-out both the PDs and the SiPM using the HIDRA front-end electronics
- We decided to use the SiPM 10 μm to increase the expected range, which is calculated here:
  - the MIP value obtained in previous test,
  - the saturation of HIDRA chip (which is $>=$ 30000 ADC * 20).
  - **Large PD saturation $\sim$ 1800 MIP $\sim$ 54 GeV,** [S/N(MIP) $\sim$ 7]
  - **Small PD saturation $\sim$ 100 * LPD $\sim$ 5 TeV**
  - SiPM 15 μm $\sim$ 50 MIP $\sim$ 1.5 GeV, [S/N(MIP) $\sim$ 8]
  - **SiPM 10 μm $\sim$ 340 MIP $\sim$ 10 GeV.** **[S/N(MIP) $\sim$ 6.5]**

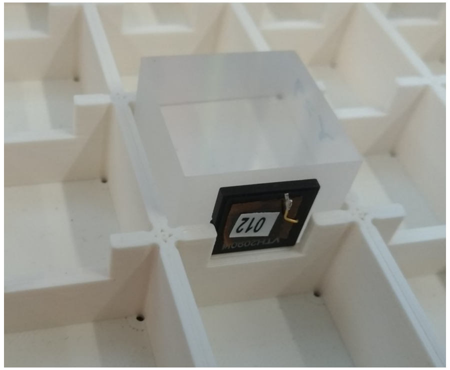
Design of the prototype

- Each crystals will be equipped with LPD, SPD and 3 WLSs
- Only one WLS per cube will be read-out with SiPM
- 4 layer of LYSO will be employed for the beam test.
  - The first has only one cube in the center.
  - The others has 3x3 matrix of cube.
  - Total of 28 cubes.
  - Depth $\sim 13\ X_0$
- Some layers of CsI, with the Calocube configuration, can be added to increase the shower containment

Empty tray with a capton cable



Example of one LYSO on a tray



LYSO + ESR + LPD

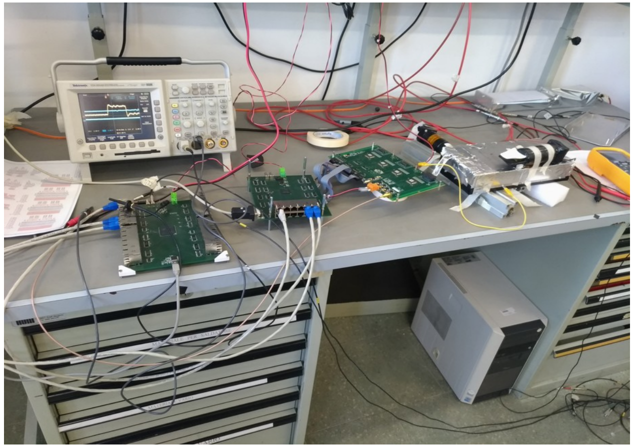
Design of the prototype: HIDRA2 and TROC

- In few weeks we will wrap the 28 “nude” LYSO crystals and we will glue the PDs on the not polished face
- The Chinese colleagues (e.g. Xin Liu) will soon come to Firenze to glue the WLS to those LYSO crystals.
- Front-end electronics:
  - Each layer has one HIDRA board which will be read-out both PDs and SiPMs.
  - All the test discussed in this presentation are done with HIDRA1 boards and ROC digital logic (Calocube configuration)
  - We started the testing of one HIDRA2 board (which includes the auto-trigger) and TROC digital logic (made by CIEMAT)
  - Preliminary test with PD+LYSO show very promising results (S/N better than the previous HIDRA) but some accurate check with SiPM are needed to validate the new electronics.

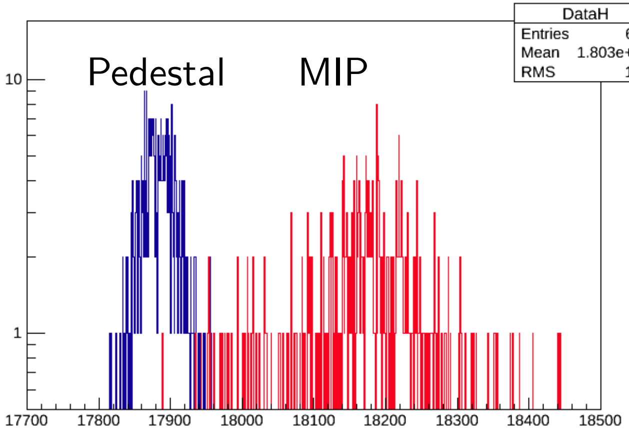
Conclusion

- The attenuation of the WLS signal due to the PD is acceptable and it is possible to read-out the WLS with SiPM obtaining a reasonable dynamic range.
- The assembling of the prototype is starting with the wrapping of the LYSO crystals and the gluing of the PDs, while we are waiting for the Chinese colleagues to glue the WLS.
- The old front-end electronics work well with all the sensors but we need to test the new one: so far we obtained promising results using LPD+LYSO on a single channel.

First test of new electronics



Signal with LPD+LYSO+HIDRA2+TROC



Red: events which hit the trigger

Blue events which do not hit the trigger