# PhotoSensors

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on behalf of the PhotoSensors WG

# The Test Labs network for FD-1

In order to test the custom SiPM from vendors a network of test labs was setup:

- Milano Bicocca, Bologna, Ferrara, Madrid, Valencia, Prague, NIU
- Each lab setup a small test system capable to fully characterise the prototypes from vendors (Vbr, Rq, DCR, xtalk, afterpulse, gain)
- The same front end electronics based on MiB cryoamplifier was distributed
- Some difference in the setup was anyway usefull as crosscheck
- Same test procedure was used by all test centers

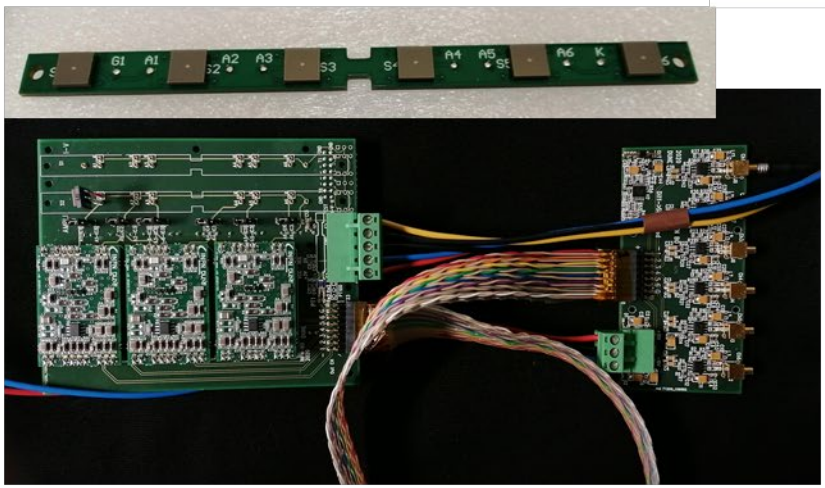
In parallel:

- Ganging (48 x) tests were performed in MilanoB, Madrid.

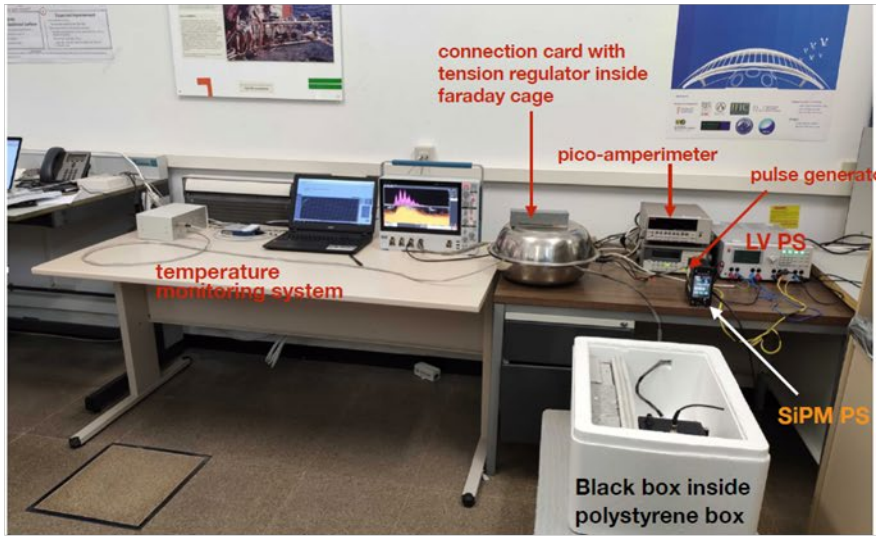
# Some piece of hardware

Single SiPM amplifier


Small dewar

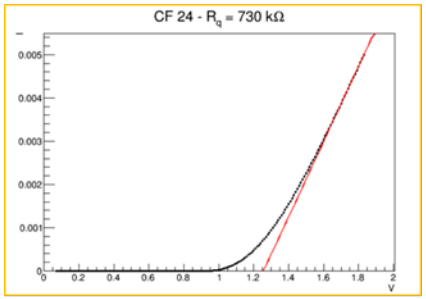


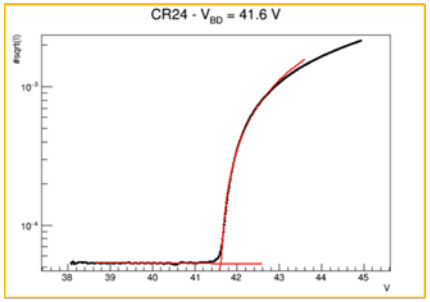
Test board with 6 amplifiers

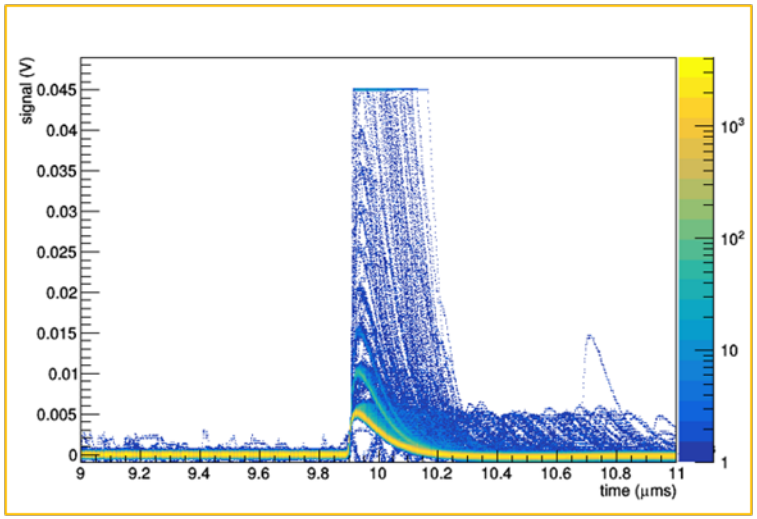


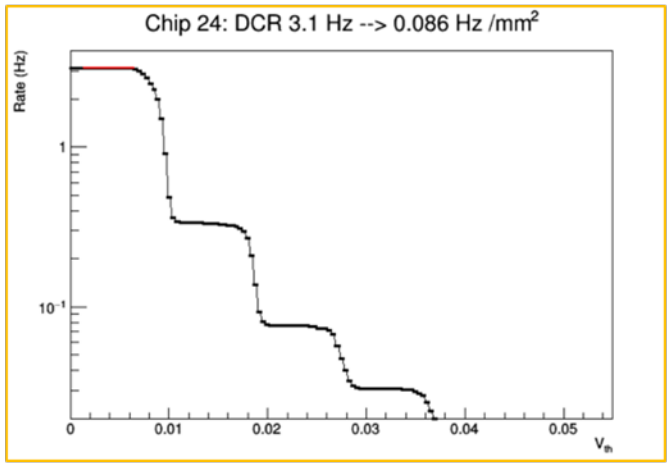

A typical test setup

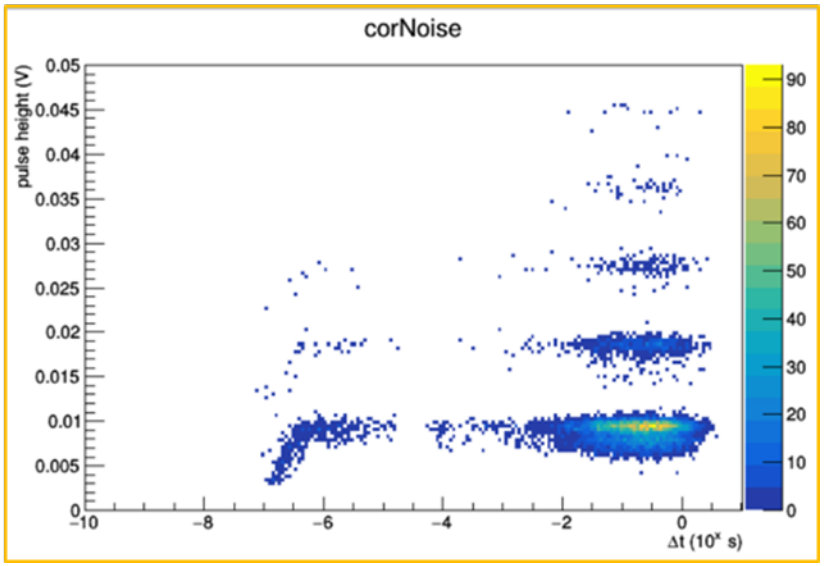
# Some example of data processed



# Anomalous DCR: burst events

First observed in Ferrara's test center:

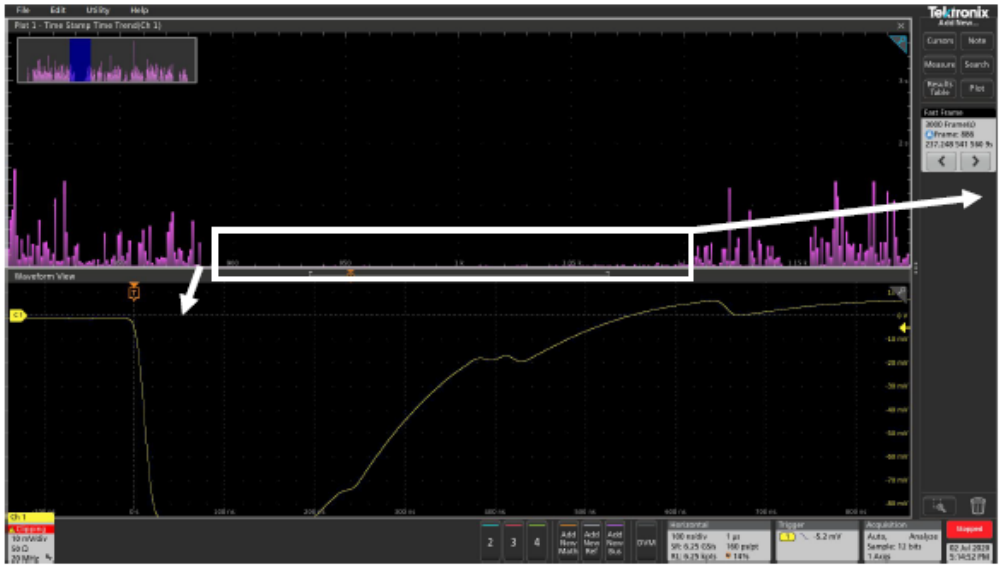
- origin still under investigation together with vendors

**Burst of consecutive events with 1ms to >10 ms time delay between each other in the DUNE split sensors**

- Bursts usually following a high-amplitude event (higher than several p. e., eventually saturating the OSC)
- Time span between two consecutive bursts of the order of minutes
- Total time duration of each burst of the order of seconds
- All events in the burst have 1 p.e. amplitude (except for the first high-amplitude one)

**Time-trend plot**
y is time-delay between two consecutive events
x is event number

**Waveform** of the high-amplitude event (saturating the OSC) that starts the burst (1$\mu$s time scale)




**Burst of 1 p. e. events**
(barely visible due to the vertical scale)

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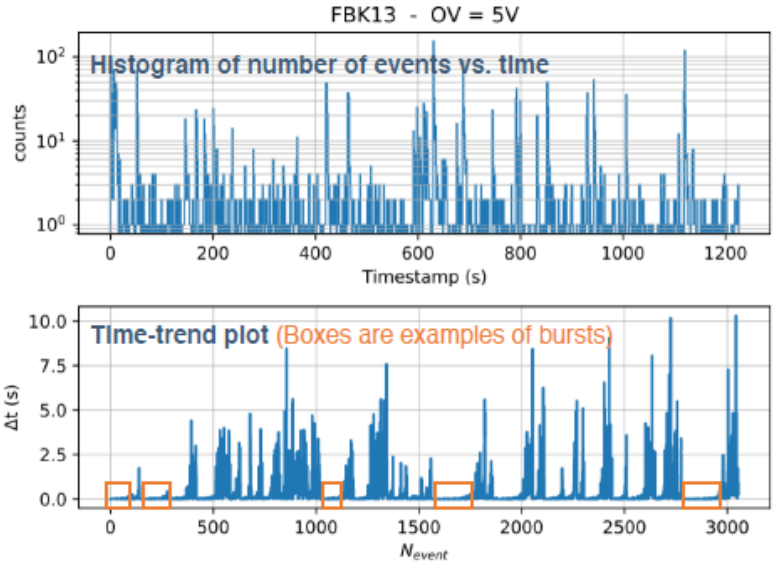
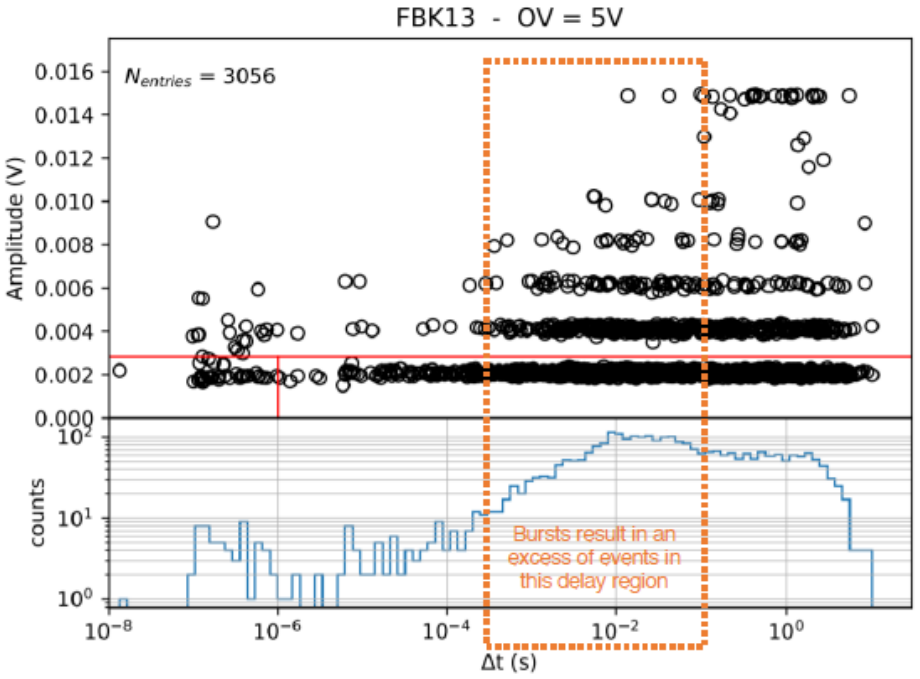
# DCR with and without burst

- 37300 cells, 6x6 mm$^2$, 30 µm pitch
- Measurement taken after 20$^{th}$ thermal cycle
- ~3000 frames in 1225 s
- DCR = (68.0 ± 1.2) mHz/mm$^2$




DCR becomes (40 ± 1) mHz/mm$^2$
when burst events are excluded by offline software analysis



# SiPM requirements for FD-1

The requirements for SiPM to operated in FD-1 are rather tight and usually non fullfilled by commercial devices

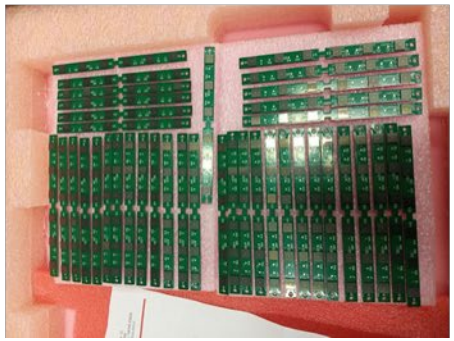
Two vendors produced custom devices complying the low level requirements:

- Cryo reliability (tested with 20 cycles in Liquid Nitrogen)
- High gain (big microcells) and high dynamic range
- Dark Count Rate (DCR) < 100 mHz/mm2
- Low terminal capacitance (for ganging)
- PDE at 430 nm >35% at nominal OverVoltage
- xtalk and afterpulse < 15-20 % at nominal OV

# SiPM downselection

Two models from FBK and Four models from Hamamatsu were under evaluation

- 250 samples mounted on final pcb were delivered
- Samples were distributed to the test centers (same model tested at least by two different labs
- Each SiPM experienced 20 thermal cycle
- The results from different labs were combined
- The two candidates were finally tested for ganging

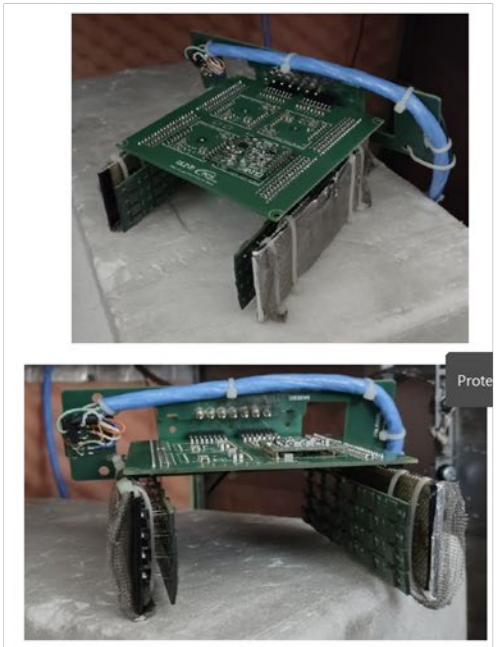


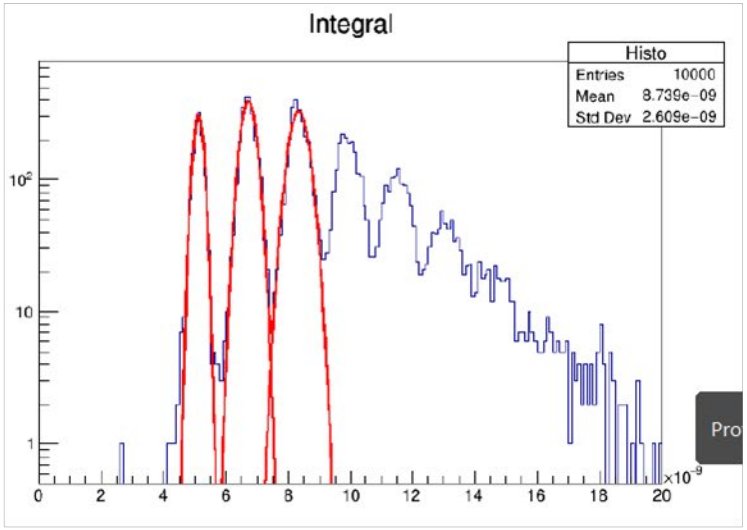
# Ganging of first module

A lot of work was done to optimize MiB cold amplifier and tune it with downselected SiPM:

- dynamic range-> single p.e. peaks at 400 uV (differential) and saturates at 800 mV (2000 p.e.)

- S/N = 6.8 at 1 p.e. (thanks to SiPM high gain – big ucell size)





# Improvements for FD-2 ??

Main handles for improvements:

- lower breakdown voltages _> lower power consumption
- metal trench -> lower correlated noise (xtalk, afterpulse)
- extend depletion region -> lower cell capacitance
- eliminate burst event -> lower DCR
- different topology for ganging (see Totani's talk)

# Conclusions

Thanks to the work done in PhotoSensor WG for SiPM tests and selection of best sensors for Horizontal Drift:

- Network of labs established and able to fully characterise sensors at Liquid Nitrogen temperature
- Test electronics can be eventually tuned and optimized for VD sensors
- Good connections established with some vendors
- Some ideas of how to improve performances for VD are already under discussion