RICAP-13

Roma International Conference on

AstroParticle Physics

SiPM application for a detector for UHE neutrinos tested at Sphinx Station

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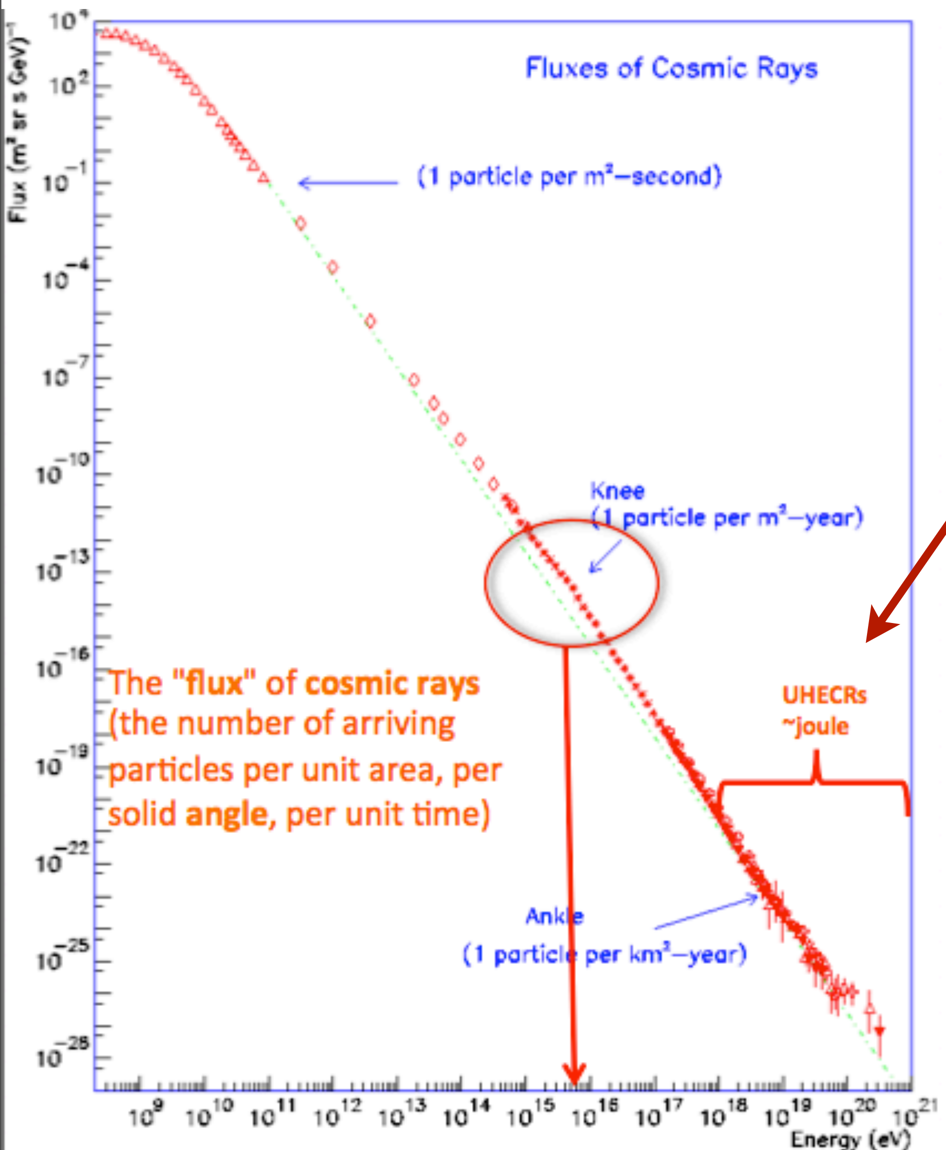
OUTLINE :

- TAUWER project

- Silicon Photomultipliers (SiPMs) tests
  - Laboratory tests in Roma
  - Outdoor tests at Sphinx Station

- Mini Array Tests at KIT
  - shower detection capability & results

TAUWER (TAU-neutrino multitoWER) Project :

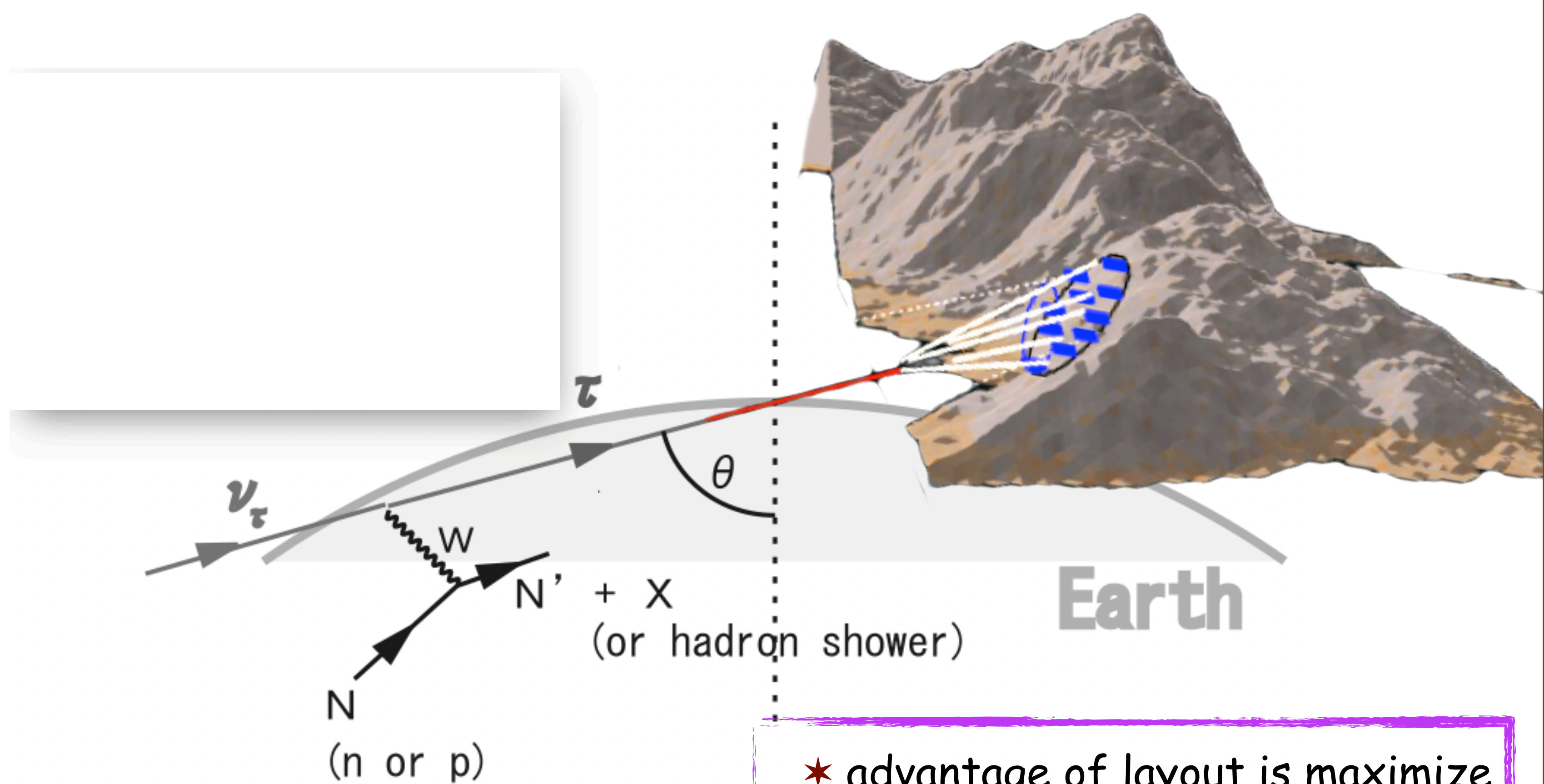


✶ is a ground based surface array designed to measure UHE (0.01-100 EeV) neutrinos using the Earth-skimming technique.

Goals:

✶ is to establish high-energy τ neutrino spectrum for energies in the AGN range and above.

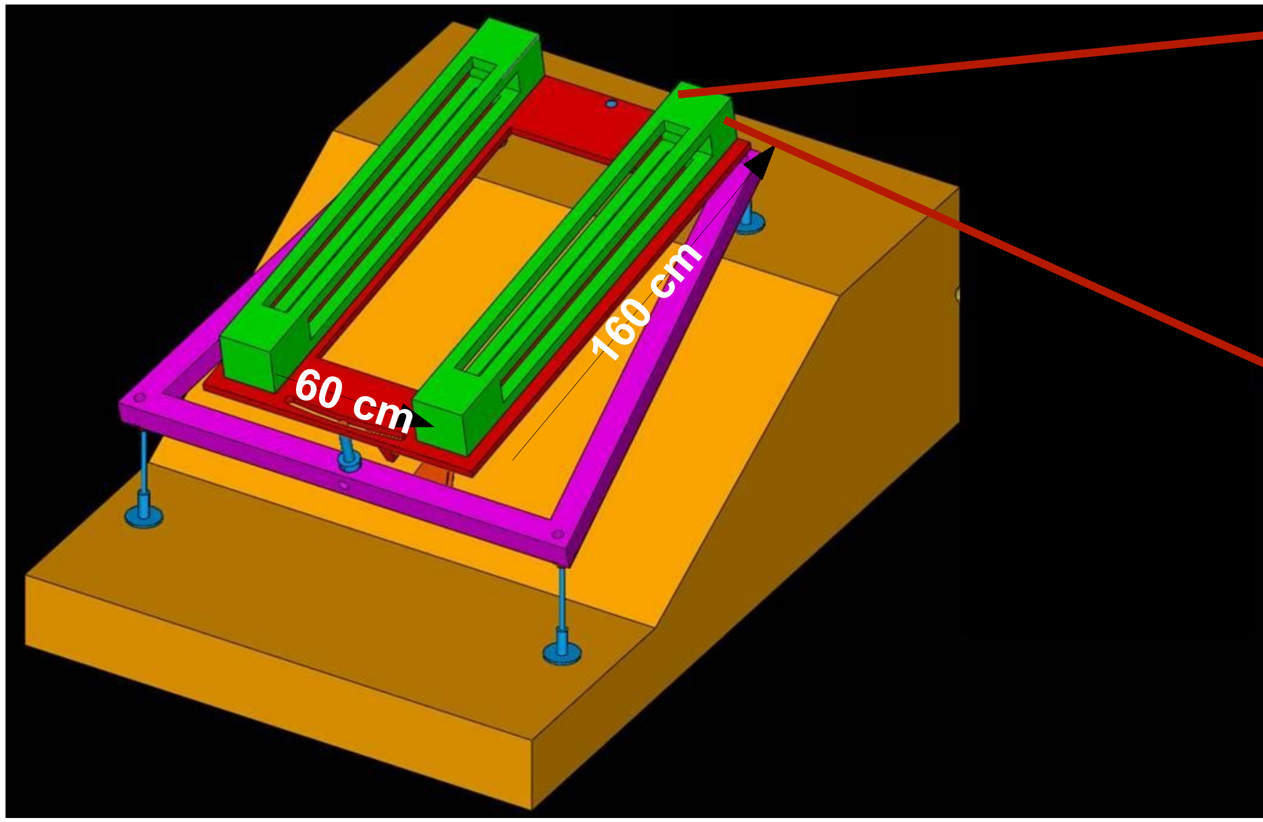
✶ measure τ neutrino spectrum above the 'ankle' to look for evidence of GZK effects on neutrinos.



✶ advantage of layout is maximize the τ shower acceptance

✶ is supported by National Science Foundation (NSF) - USA

SiPM Tests in Rome Lab : The Prototype Detector and its components

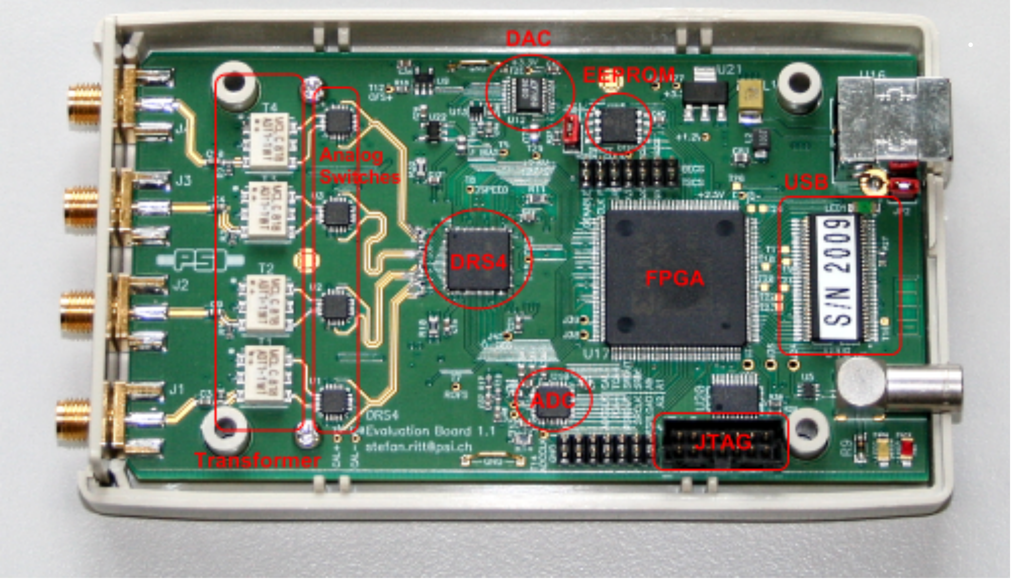


Counter box :

- Kuraray Organic Scintillator (20 x 20 x 1.4 cm^3)
- SiPM SensL 30035FM series ; gain ~$2.4*10^6$
- read out by mini circuits low-noise amplifier

S454+ - dissipation power ~ 300mW

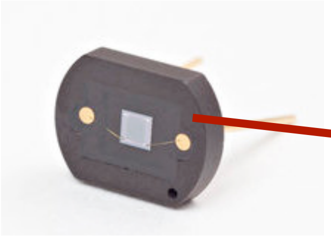
DRS4 Board

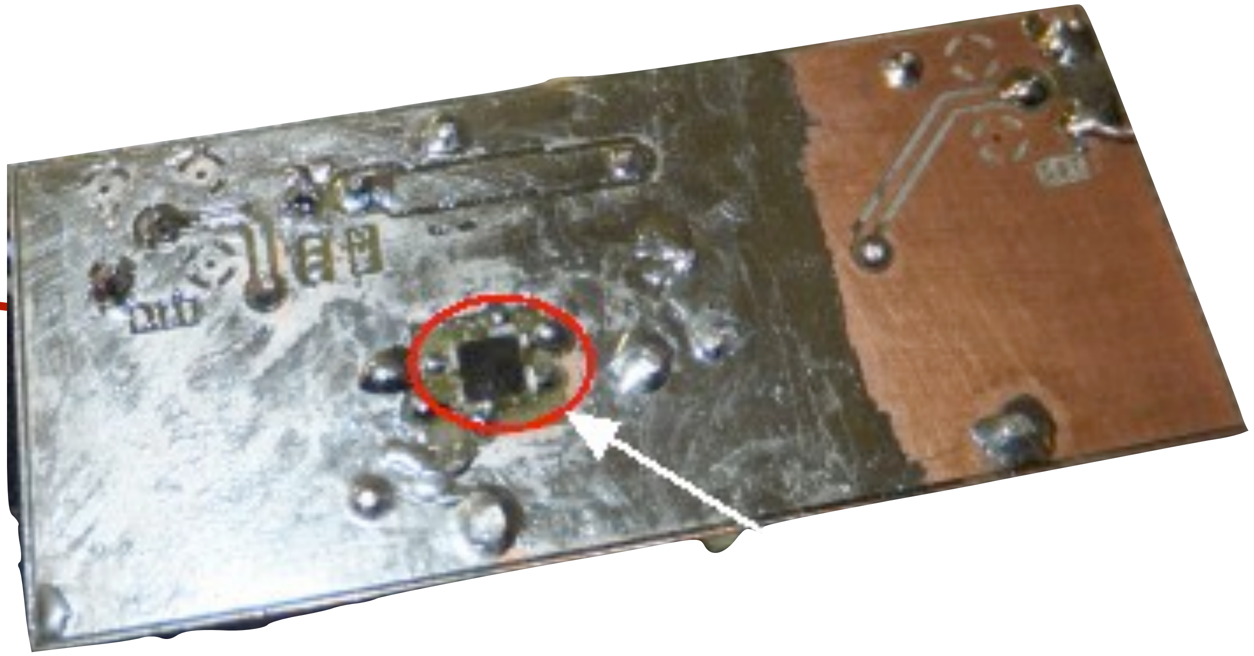


- have 4 input channels
- each having 1024 sampling capacitor
- Domino wave circuit generates a write pulse which opens analog switches at the sampling cells of each channel.

SiPM Tests in Rome Lab : Readout Board

done in lab, Rome

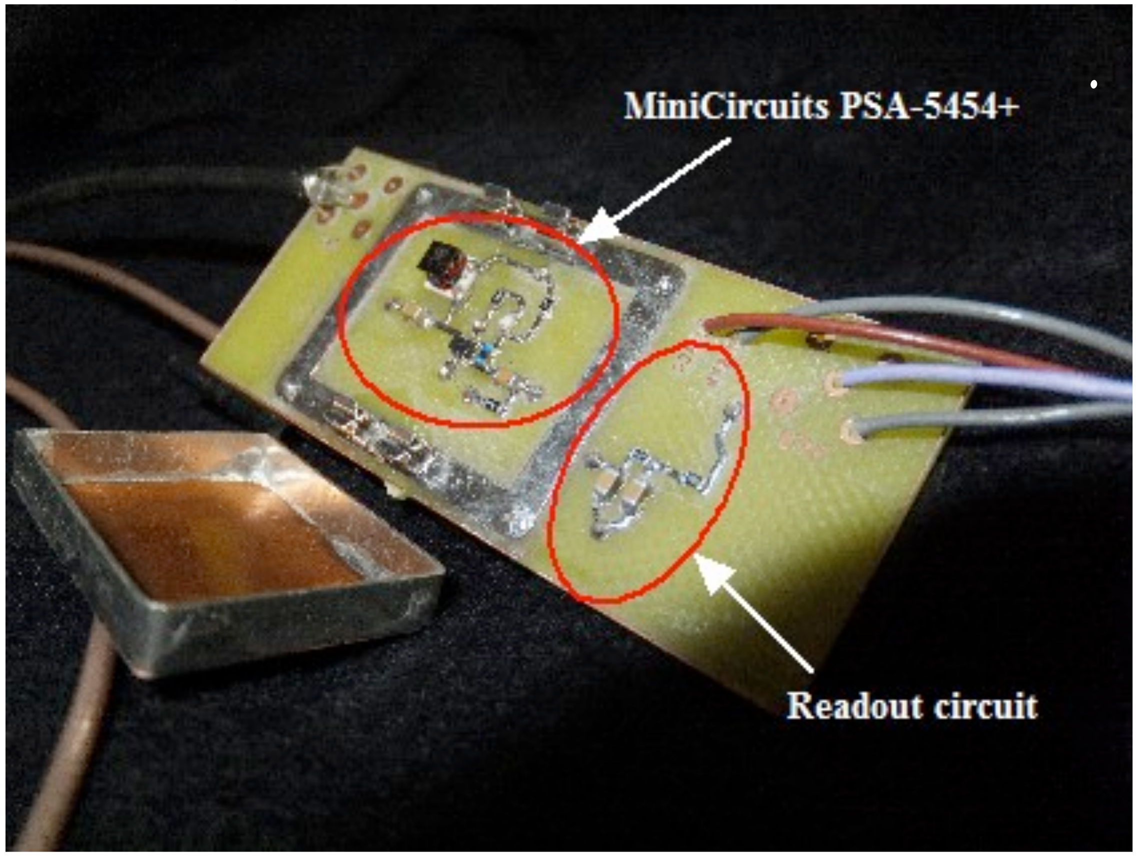




SensL 30035FM :

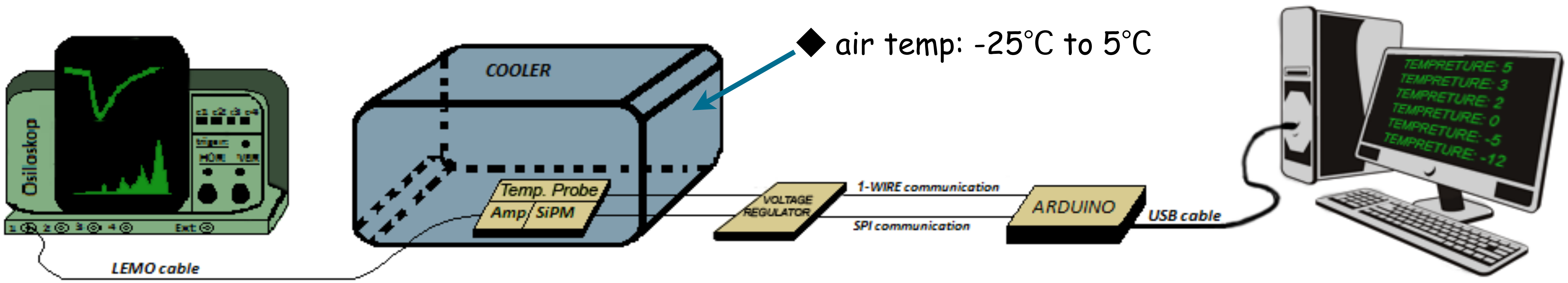
- dimensions : 3x3 mm2
- microcell size : 35 μm
- gain ~2.4*10^6
- cross talk < 10%
- recovery time 130 ns
- 14% PDE@450 nm

  25% PDE@500 nm

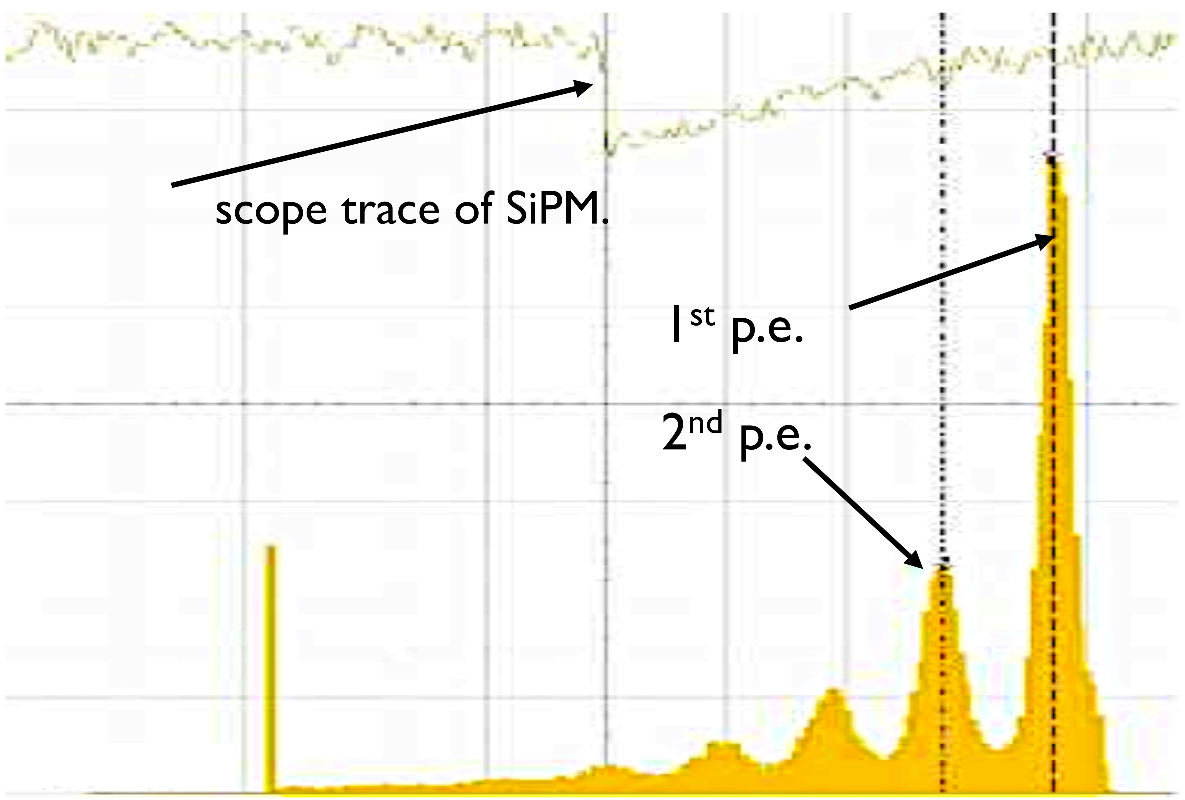


- readout via Minicircuit low-noise amplifier S454+
- amplification factor ~ 10

SiPM Tests in Rome Lab : Temperature Test Setup



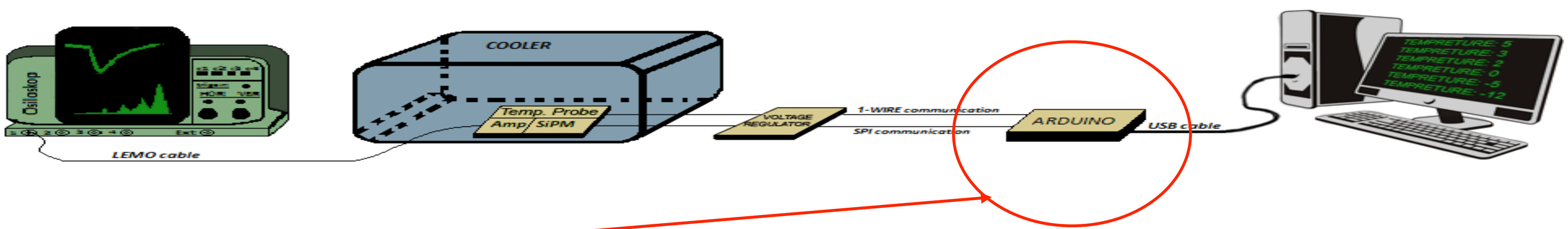
gain vs temp.



* sample the thermal signal of the amplified SiPM with a Lecroy WaveRunner HRO 64Zi (12 bit - 2 GS/s) integrating the full signal charge.

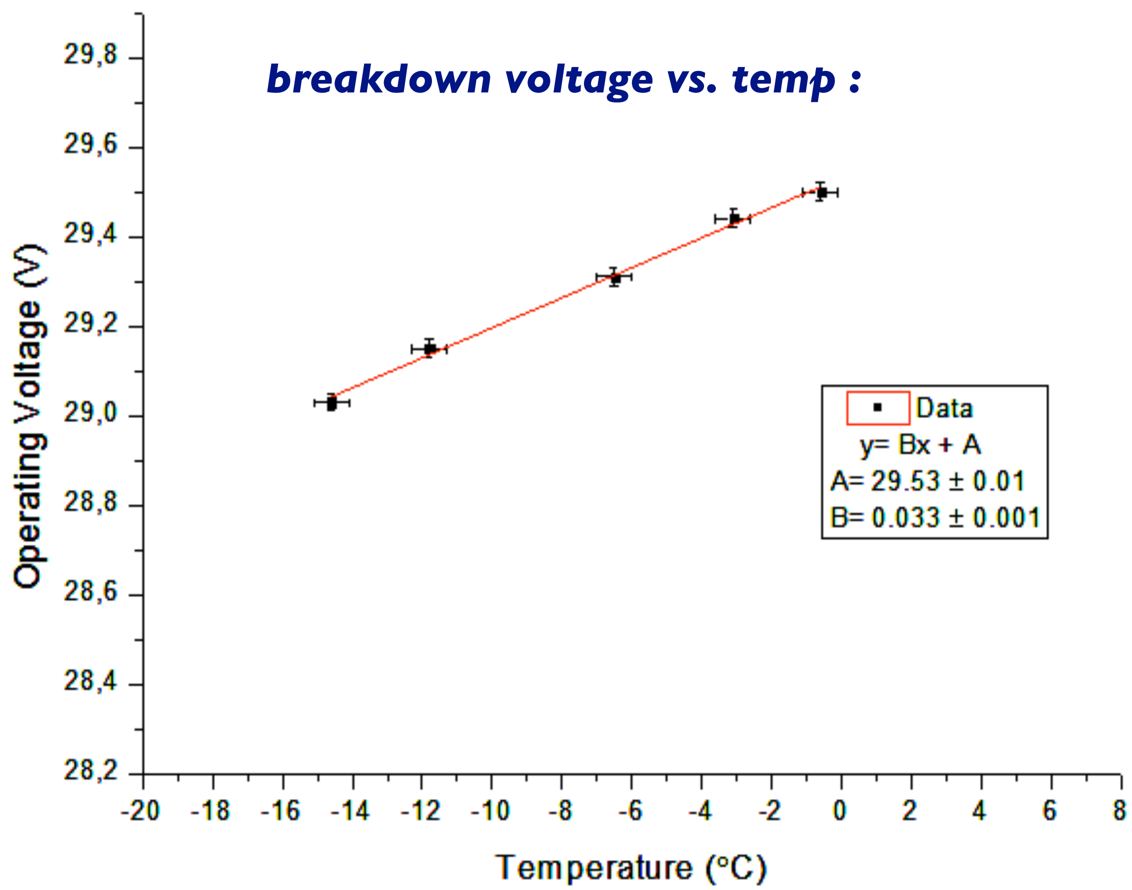
* the (relative) gain is being calculated at each temperature from the ratio of the 2 p.e. peak vs the 1 p.e. peak

SiPM Tests in Rome Lab : Gain & Breakdown Temperature Tests

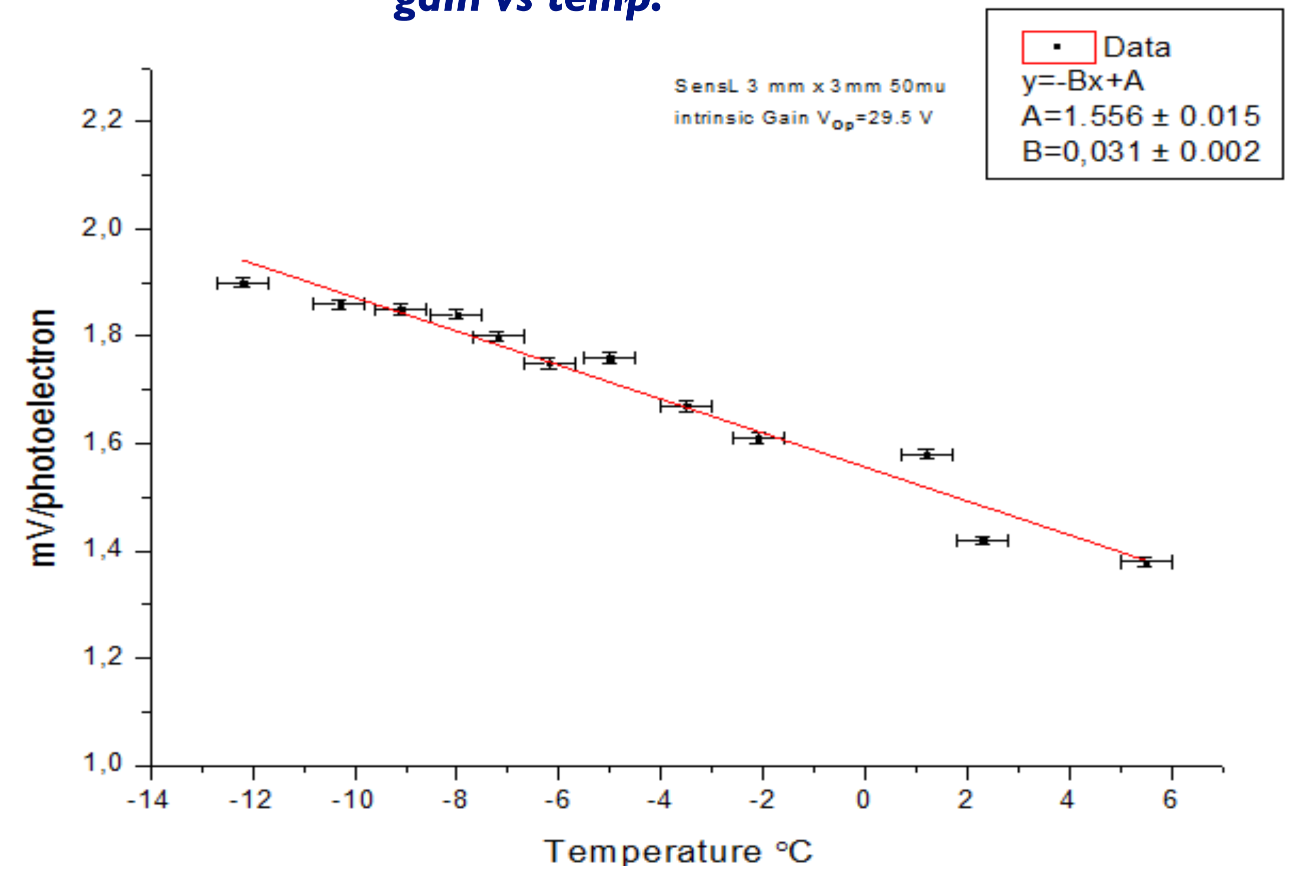


The Arduino will be used to regulate the operating voltage and gain of the SiPM as a function of temperature, once the calibration and gain have been measured and mapped to the Arduino processor.

breakdown voltage vs. temp :



gain vs temp.



Sphinx SiPM Tests :

aim:

- Testing the detector prototype for hard environmental conditions.
- Testing the suitable array location.

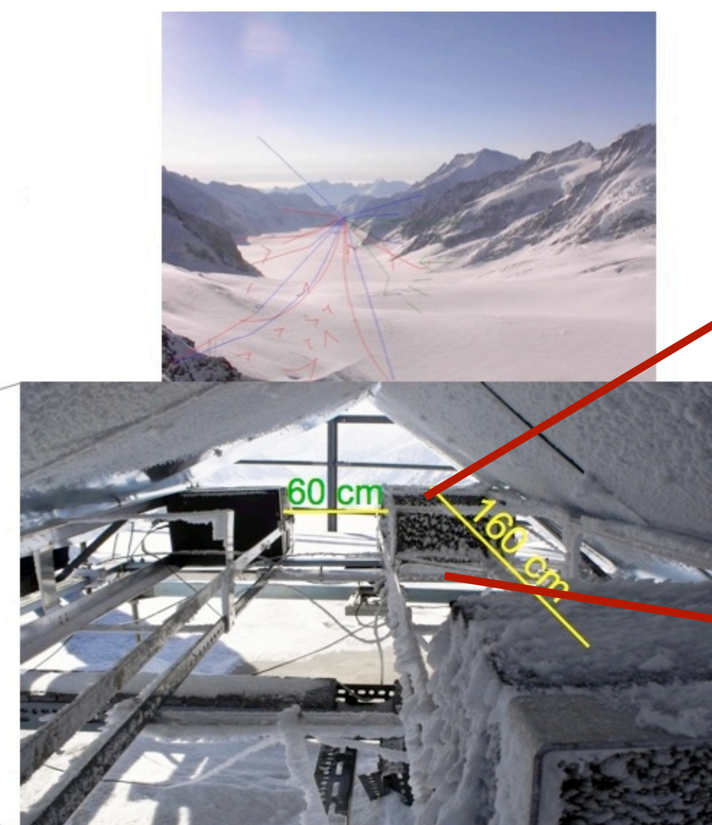
location: Sphinx Observatory Center - Jungfraujoch / Switzerland

The Detector Station :

- 3800 m a.s.l.
- average air pressure : ~ 653 mbar
- air temp: -25 °C and -5 °C

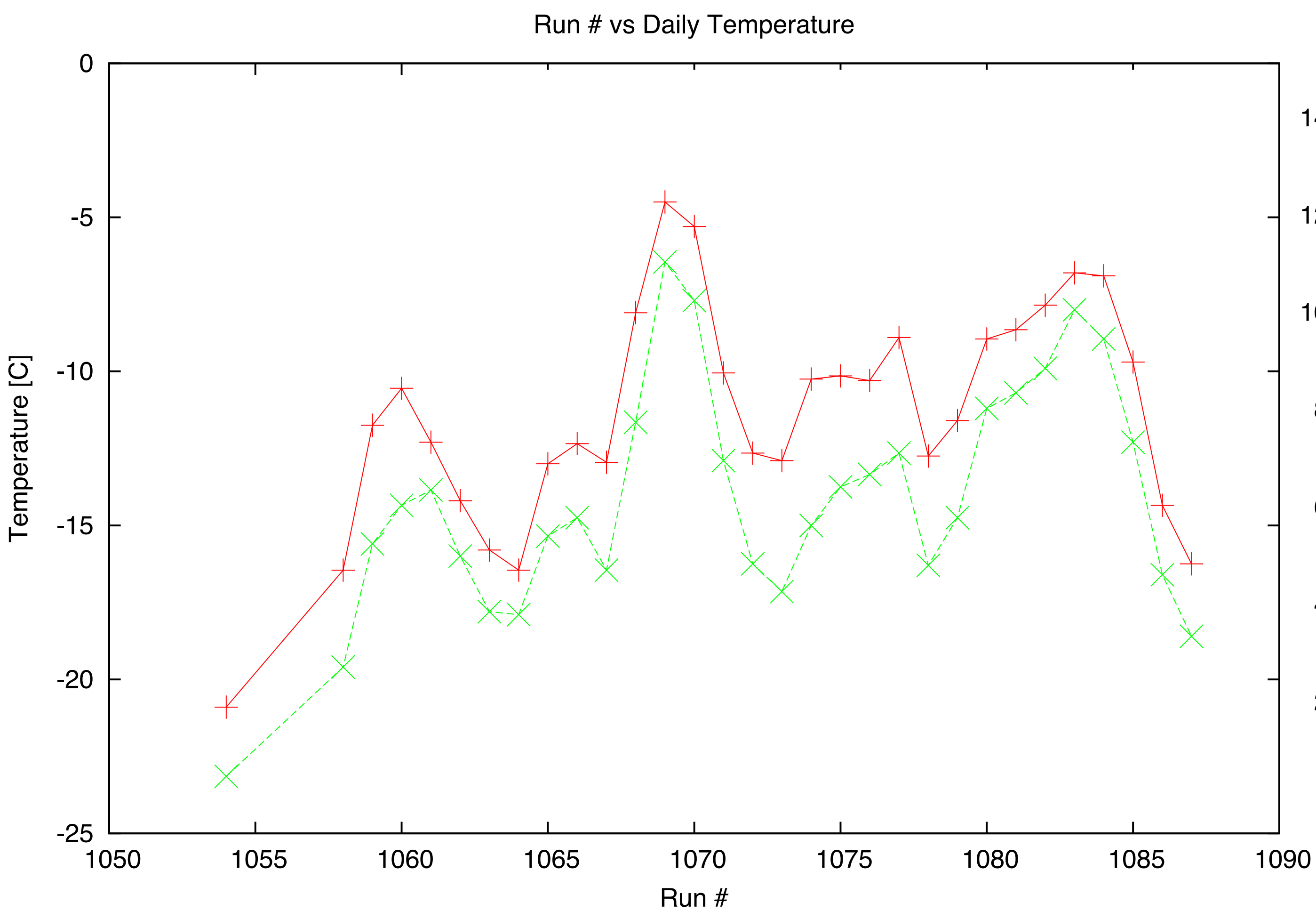
Counter box :

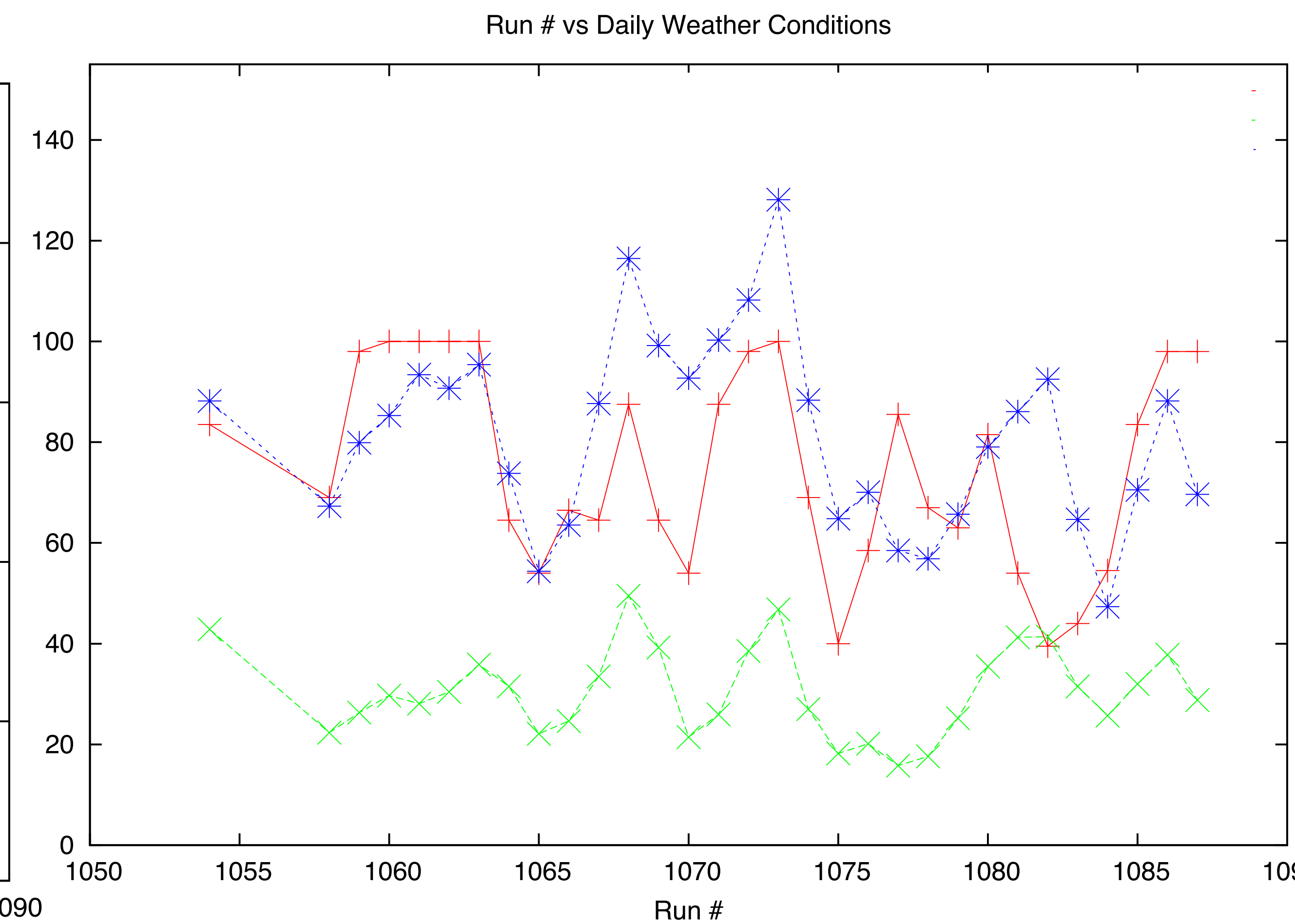
- Kuraray Organic Scintillator (20 x 20 x 1.4 cm^3)
- SiPM SensL 30035FM series ; gain ~$2.4*10^6$
- read out by mini circuits low-noise amplifier S454+ - dissipation power ~ 300mW



Sphinx SiPM Tests: Weather conditions of the Station

data taking period : November 2012, (474 hours) ; taken from Sphinx Station





+ :: measured daily average temp: ~ -25 to -5 °C

X :: measured daily minimum temp: -24 °C

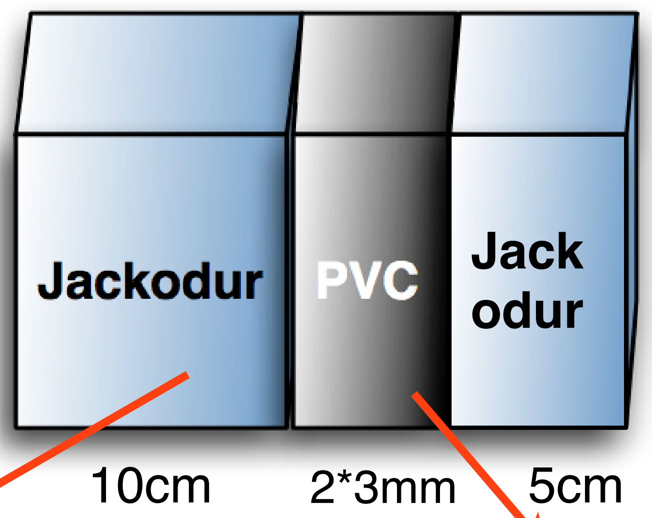
+ :: observed daily average cloud coverage above ~ 40 %

X :: measured average wind: 20 - 50 km/h

* :: measured sudden wind : 60 - 120 km/h : reach to 120 km/h

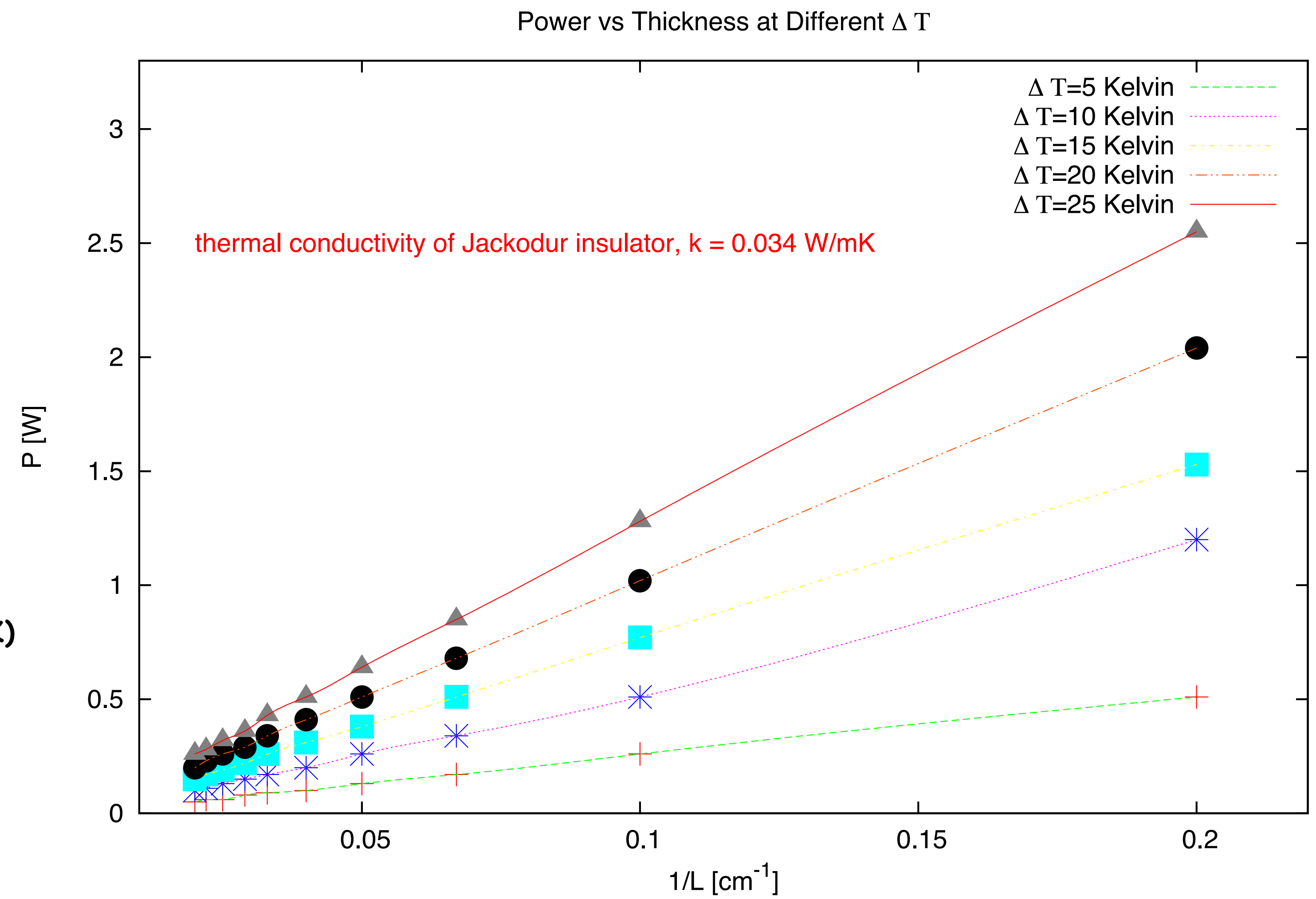
Sphinx SiPM Tests: We Protected the Box for air temperature differences

we protected each counter by jackodur xps



$$\Phi = A \times U \times [T_{in} - T_{out}]$$

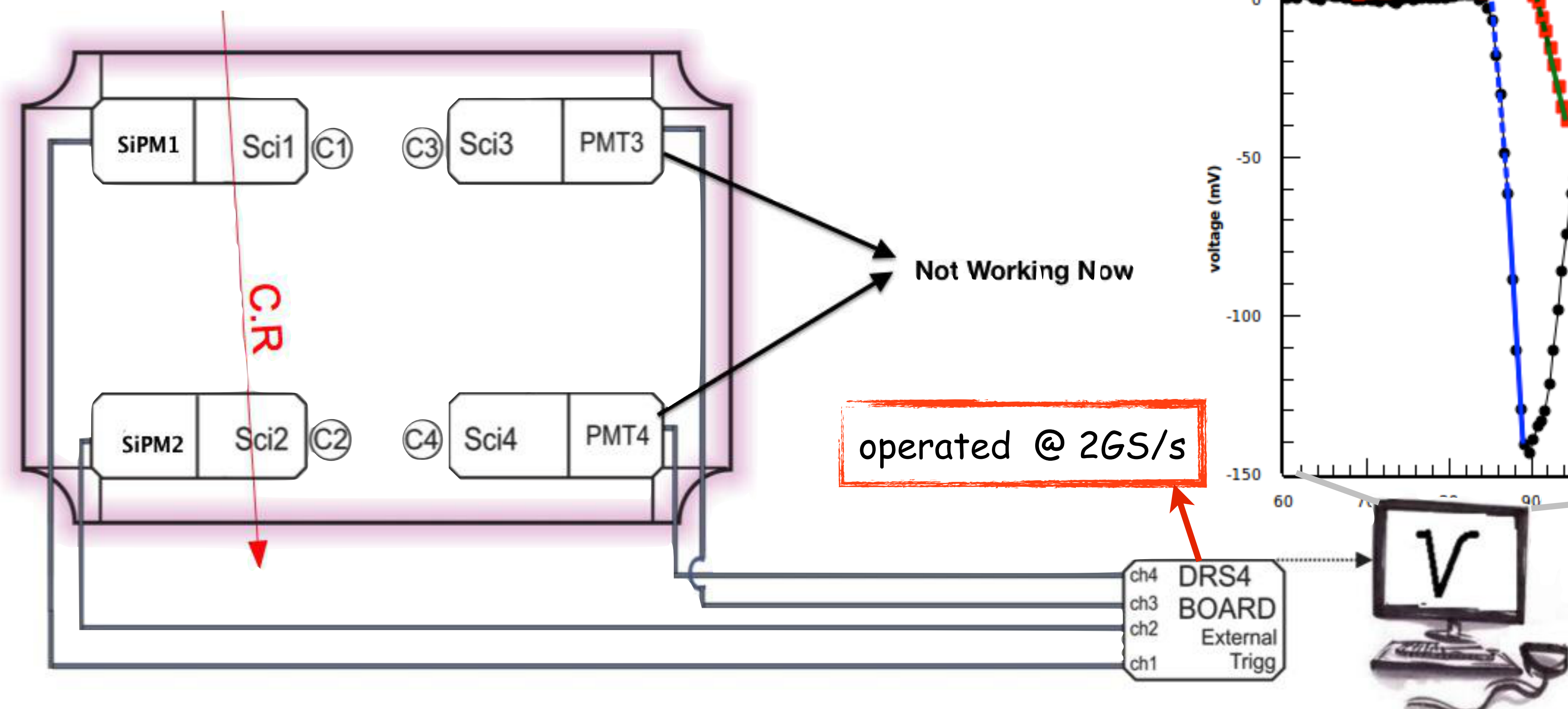
$$T_{in} - T_{out} = \frac{300 \times 10^{-3} W}{0.15 m^2 \times 0.23 \frac{W}{m^2 \times K}} = 8.4K$$

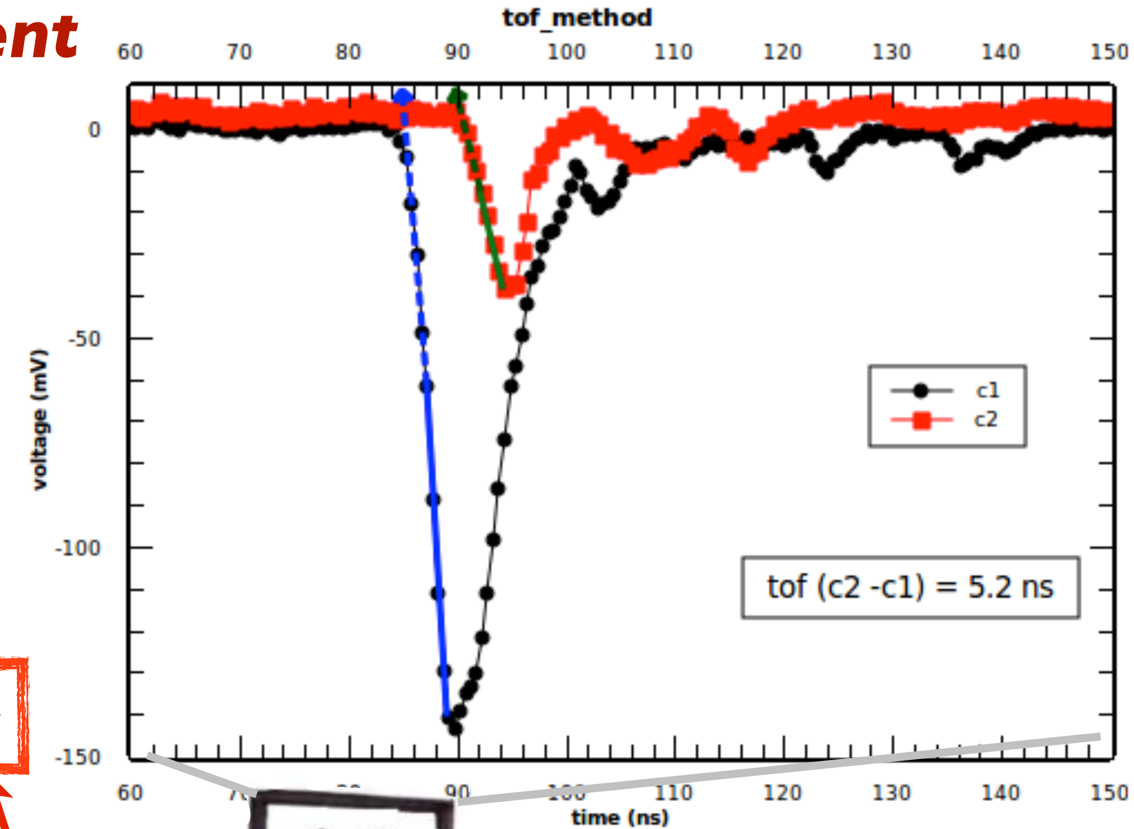


ext. temp : -25 °C to -5 °C

int. temp : -16.6 °C to +3.4 °C

Sphinx SiPM Tests: DAQ and event measurement

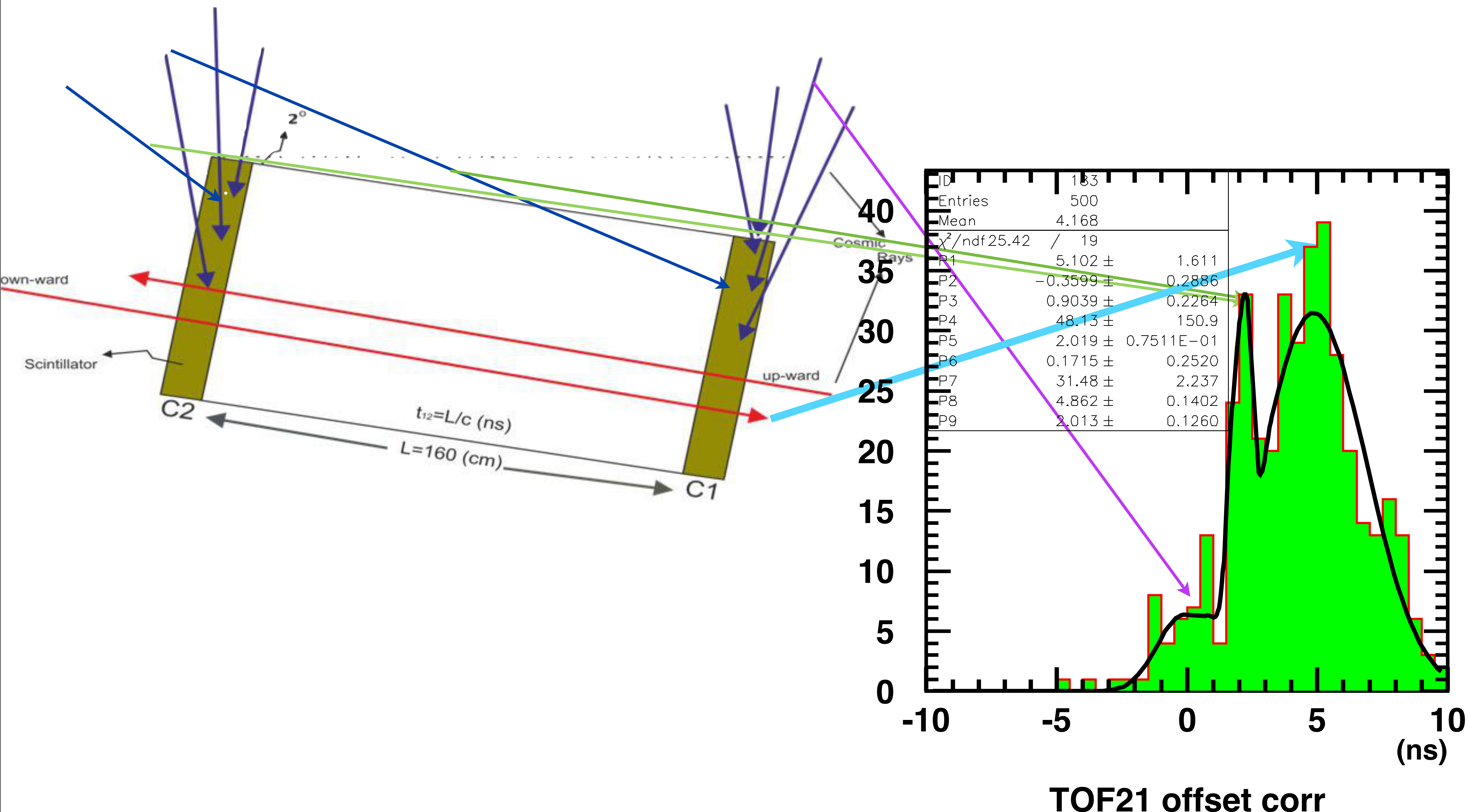




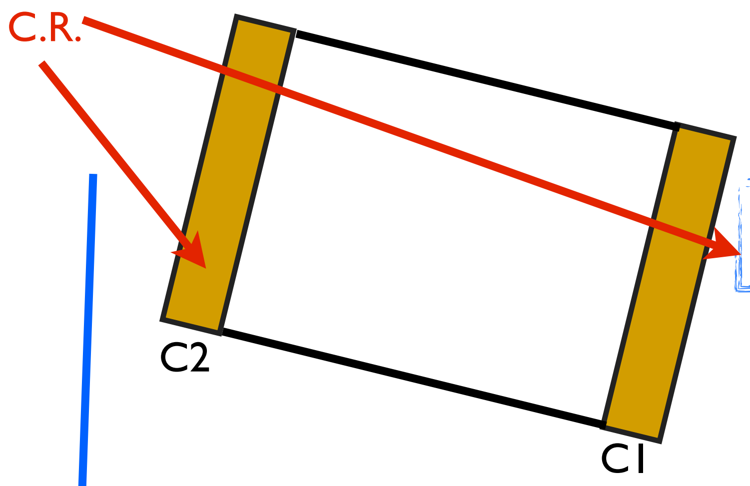
tof method :

- search a signal in a given time window (516 ns)
- find minimum of the signal
- require at least 6 points backwards from minimum
- fit a line to obtain signal time start point for TOF calculation by using the least square method

Sphinx SiPM Tests: *Time of Flight*

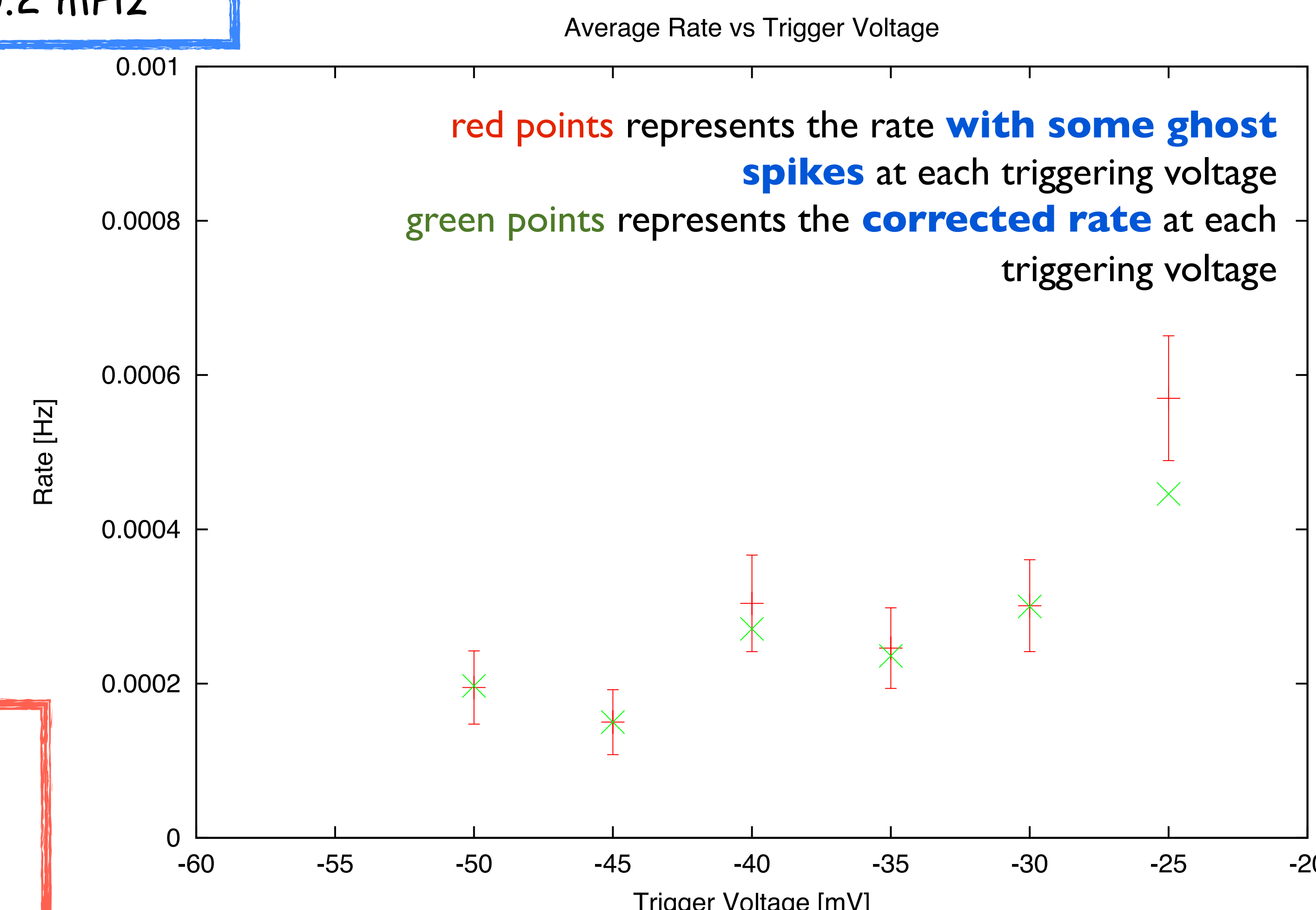


Sphinx SiPM Tests: Testing the Triggering Voltage



coincidence rate : ~ 0.2 mHz

rate of single triggering : ~ 3.0 ± 0.2 mHz



increasing the negative triggering voltage leads to decrease in coinc. rate

useful info to use an electronics board at optimum threshold voltage

Mini Array Tests at KIT :

aims: - test the high energy shower detection capability of mini-array

location: Karlsruhe Institute of Technology - Karslruhe (Germany) near to Kascade experiment huts

- used low voltage R5783 Hamamatsu PM
- DAQ uses one indipendent DRS4 per each

station and gets per each fired counter a unique time stamp obtained via NTP synchronization with Kascade time server to allow the comparison with Kascade reconstructed events

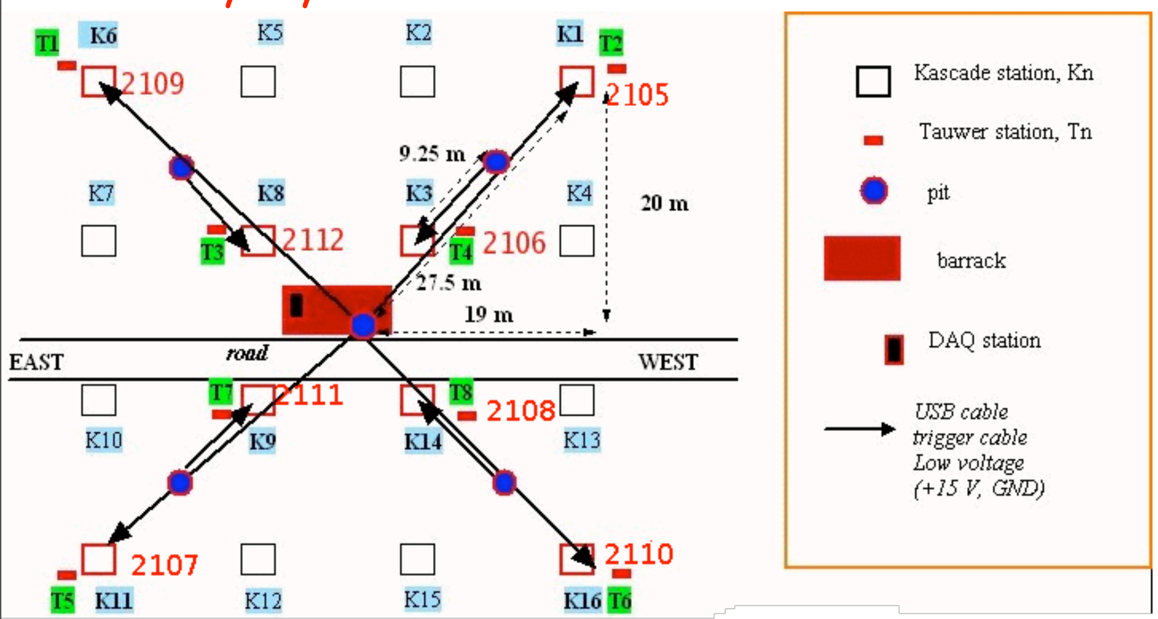
Test has been going on with large (> 90%) array up-time for about 1.5 year:

- Run 0 (vertical setup) 10/6/2011 to 2/8/2011 - Total live DAQ time ~ 1.1*10^6 sec
- Run 1 (horizontal setup) 27/8/2011 to 5/4/2012 - Total live DAQ time ~ 12.9*10^6 sec
- Run 2 (vertical setup) 12/4/2012 to 11/1/2013 - Total live DAQ time ~ 16.4*10^6 sec

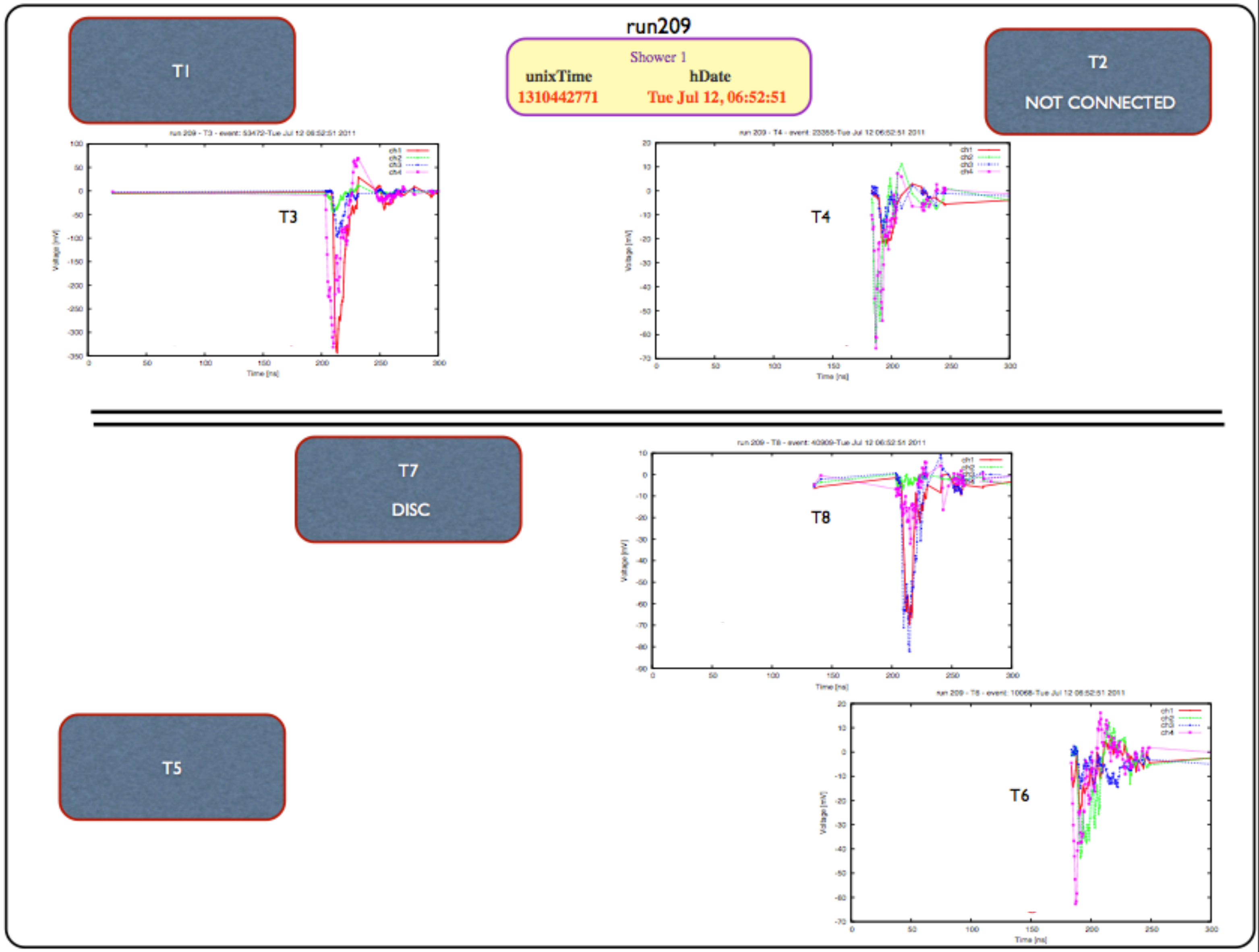
DAQ and data logging have been managed remotely from Roma with few inconvenient for all the test running period.

Mini Array Tests at KIT :

Array layout at KIT



Display of 1 event with 4 fired stations
Run 0 – vertical setup



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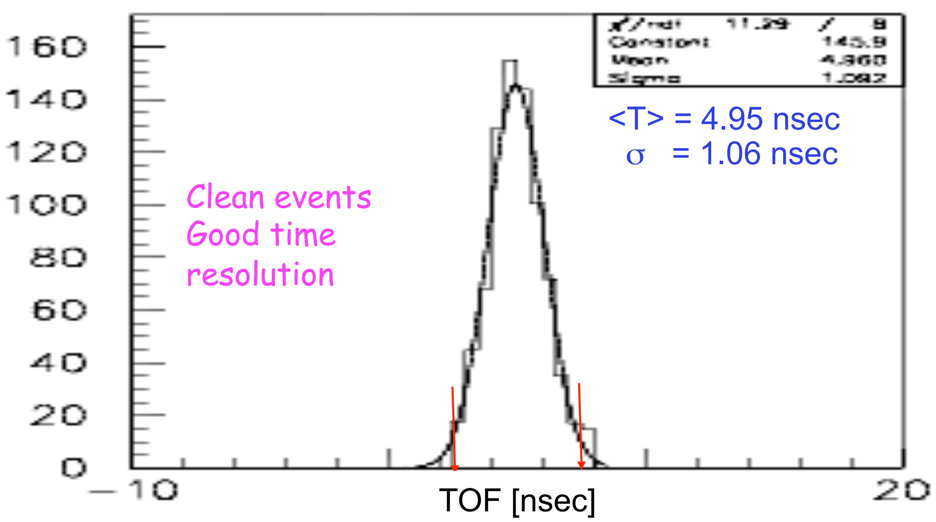
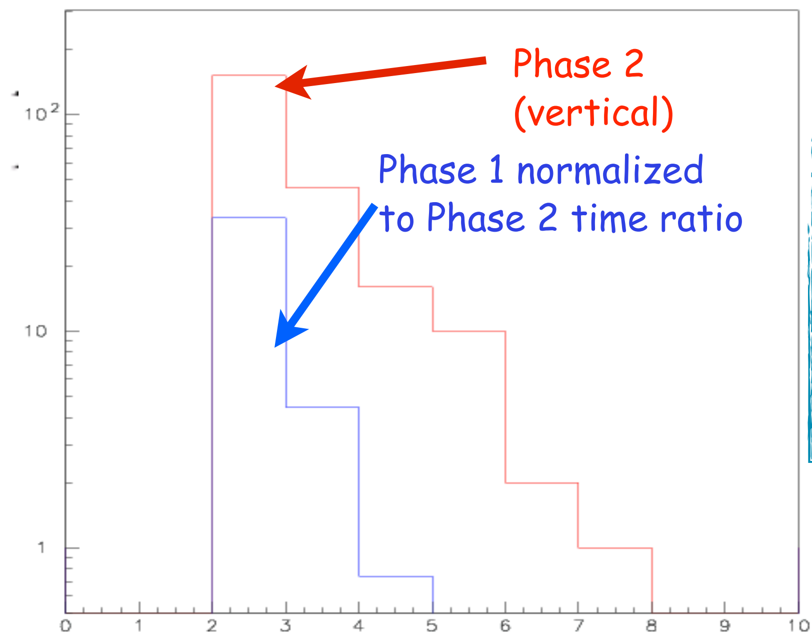
Mini Array Tests at KIT : Phase 2 (vertical) results & background comparison

Phase 2 – verticals only
Cut 2.5 ≤ TOF ≤ 8 nsec





Hit tower/evt multiplicity ≥ 2

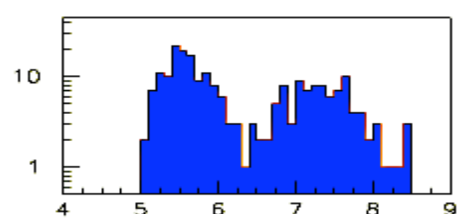
Absolute rates
(≥ 2 tower/evt + Kascade time cut)
Phase 2 (vertical) : 23.6 μHz
Phase 1 (horizontal) : 4.3 μHz

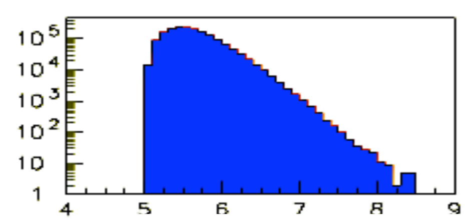
Tower multiplicity of Phase 1 (horizontal) much "steeper" than Phase2 (vertical)

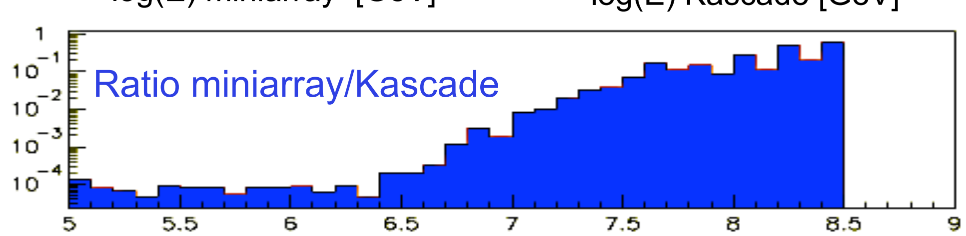
* Cut on higher tower multiplicity improves background rejection

A cut > multiplicity 2 reduces the background rate by 80% → 0.8 μHz in the horz. setup

Phase 2 comparison with Kascade events in miniarray area (on ~ 9.6*10^{6} sec total DAQ time)

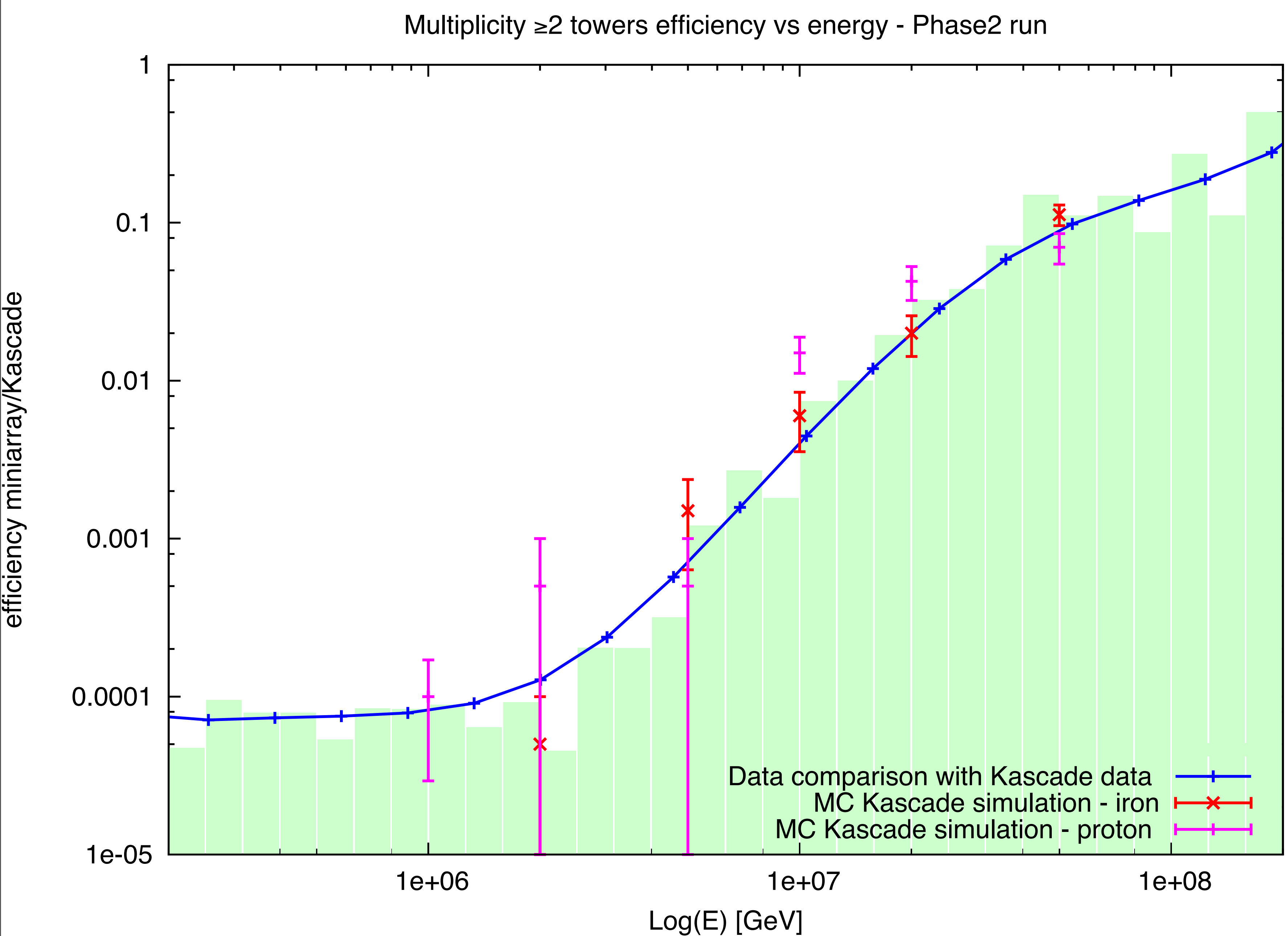






In full detector MC we expect large number of fired detector → larger thresholds cuts are possible (and also "topological" cuts to reduce random background)

Mini Array Tests at KIT : *Run 2 - vertical setup*



-- checked the energy response of the mini-array by analyzing all the reconstructed Kascade events in the running period falling in the active mini-array area and time-correlated by each event recorded time stamp.

- then we used a full Corsika 6.9.90 unthinned simulation of the array with atmospheric showers (primary = proton or iron) in the energy range of interest to check the energy behavior of our apparatus : the efficiency vs energy shape has been reproduced reasonably well.

Summary :

* the new SiPM prototype detector has been working stably without any problem in very harsh experimental conditions.

* the detector prototype is capable to discriminate up-going and down-going particles.

* able to control Operating voltage vs temperature via microprocessor to stabilize the gain value

* next step is to install arduino board to control the gain of SiPMs at sphinx station

* able to manage and control (remotely) the miniarray (synchronization, reconstruction ...)

* miniarray worked reliably, stably at good efficiency and we do understand well its behavior

THANK YOU