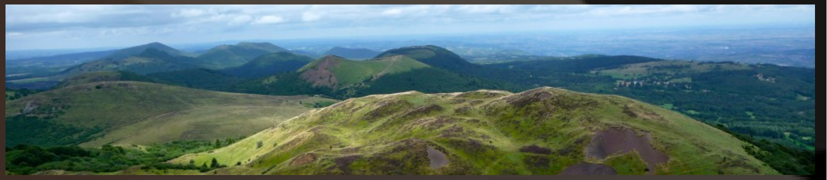
# *Perspectives for the MuRay experiment electronics*

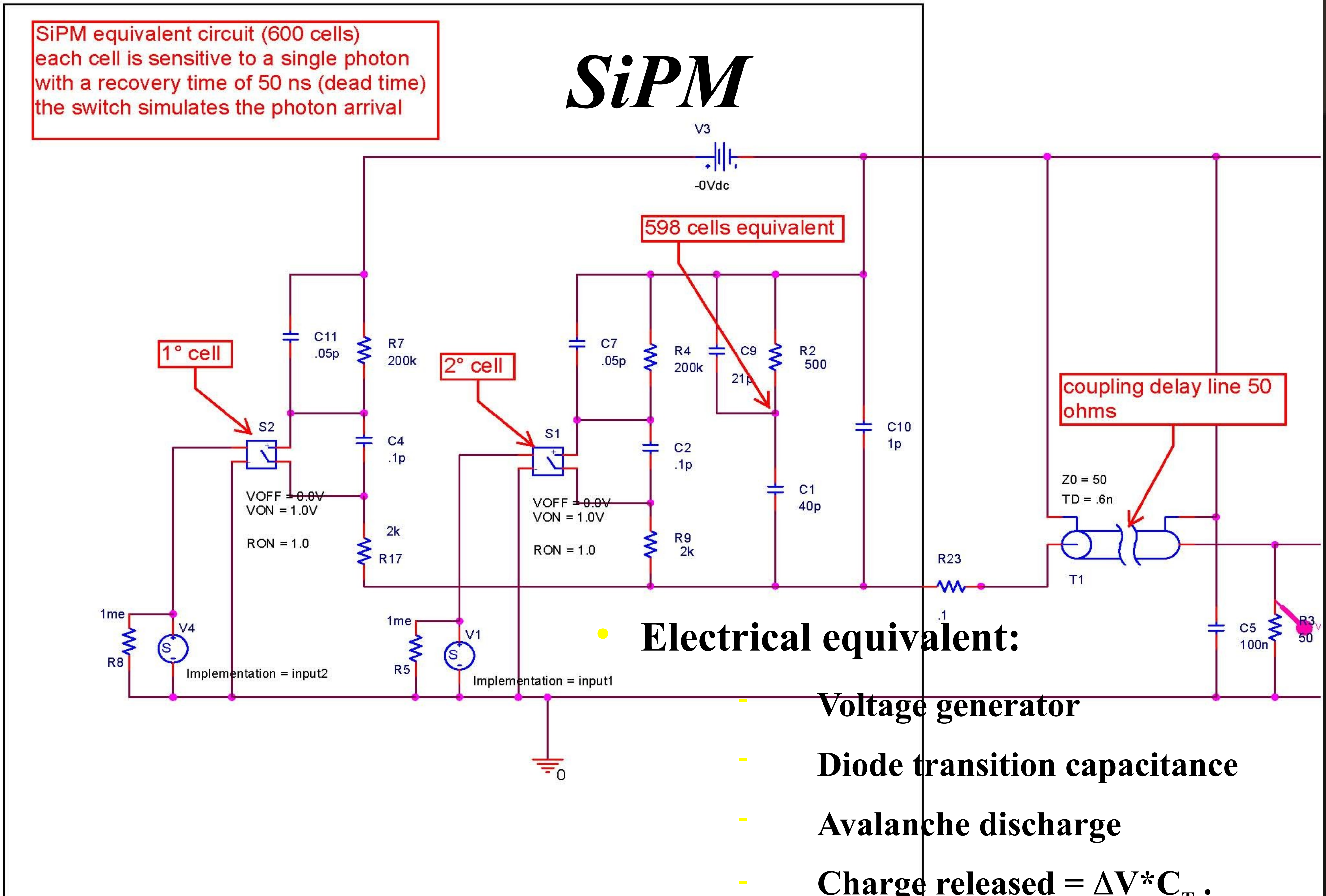
- Scintillator bars detect muon passage
- SiPM used coupled with WLS (Wavelength Shifters)
- SPIROC based Read Out
- Hybrid with SiPM
- Next: EASIROC chip
  - Better adapted to asynchronous operation
  - Greater granularity for a more versatile triggering
  - Less components integrated on a die
    - Lower power consumption
    - More flexibility in deployment





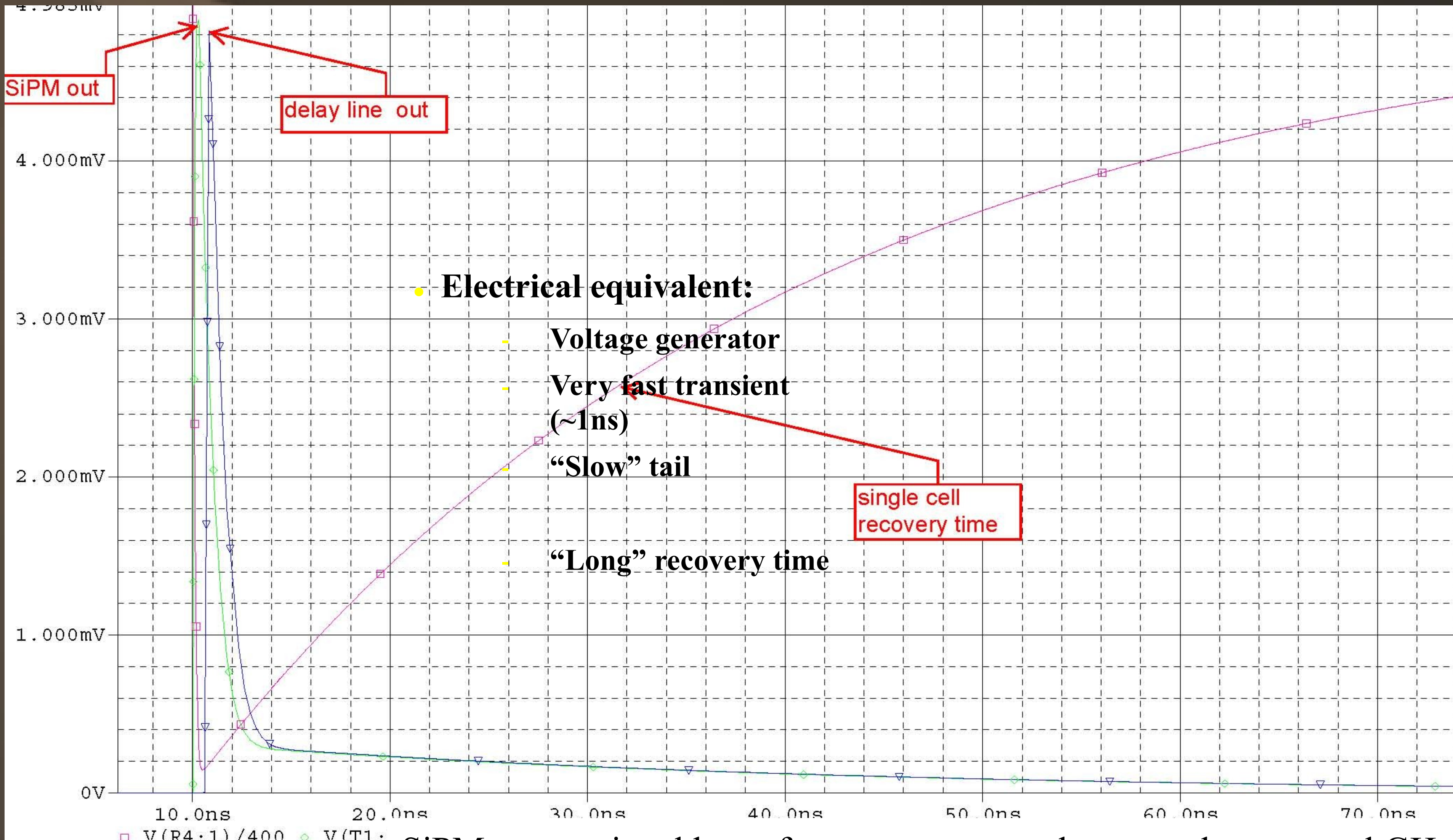
R.D'Alessandro
**(Università di Firenze e INFN-Firenze)**

# SiPM




- **Electrical equivalent:**
  - **Voltage generator**
  - **Diode transition capacitance**
  - **Avalanche discharge**
  - **Charge released = $\Delta V * C_T$ .**

# *SiPM signal characteristics*




- **Electrical equivalent:**
  - **Voltage generator**
  - **Very fast transient (~1ns)**
  - **“Slow” tail**
  - **“Long” recovery time**

SiPM output signal has a frequency content that extends to several GHz

In order to qualify SiPM timing characteristics a very high speed set-up is needed (WORK IN PROGRESS IN FLORENCE, now well advanced)

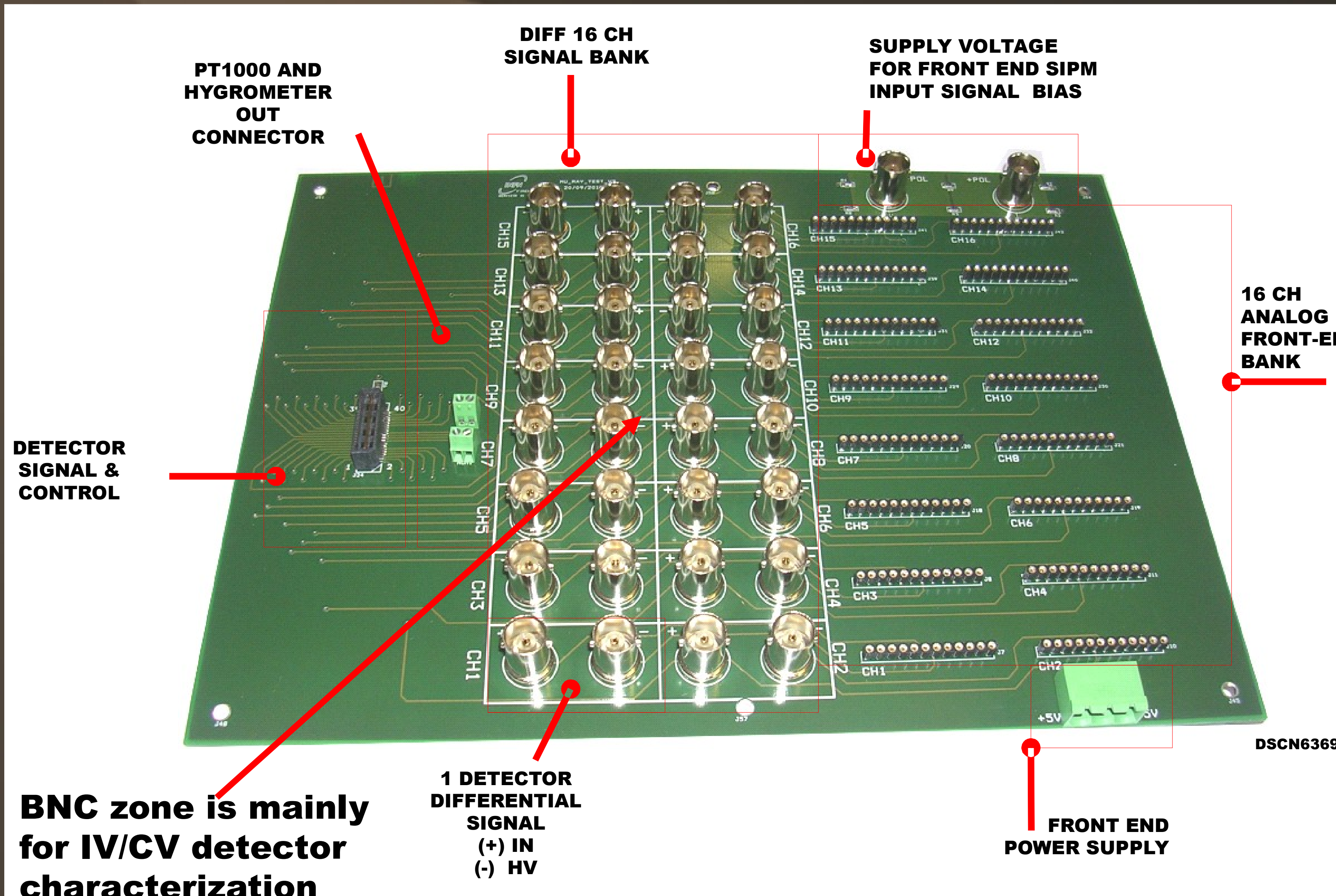
R.D'Alessandro
(Università di Firenze e INFN-Firenze)

# *Full SiPM characterization*

- Full characterization of the SiPM can be divided in three ‘stages’:
- Static:
  - Includes forward and reverse IV and CV measurements
- Dynamic:
  - Includes  dark count, gain, afterpusle probability, optical crosstalk measurements and temporal characterization
- Optical:
  - Includes spectral sensitivity and photon detection efficiency measurements

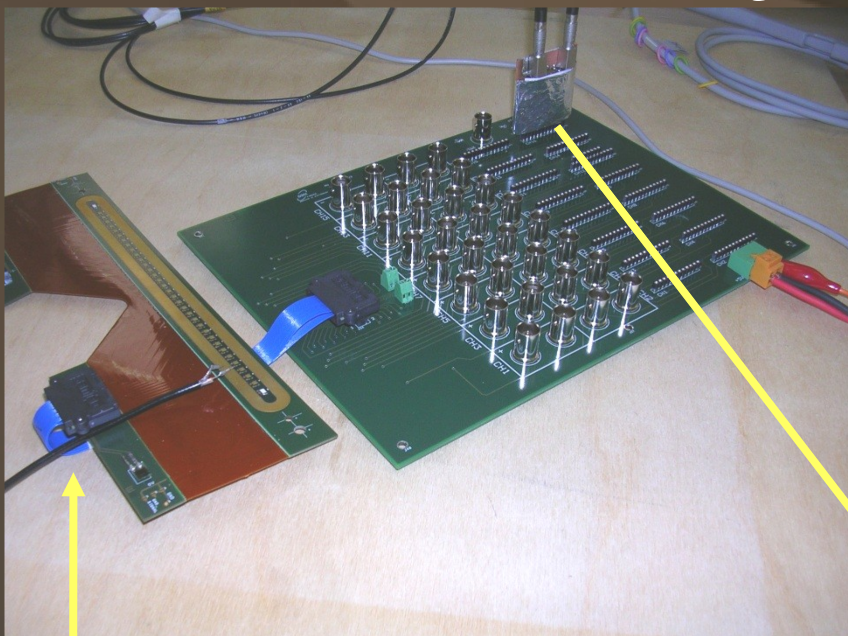
*Two setups developed (and mixed .....):*
*One dedicated to single SiPM characterizations, with custom electronics and temperature control,*
*and one using MuRay hybrids and EASIROC chip and MuRay developed test boards.*
*Results presented have been obtained from both setups and/or a mixture of the two.*

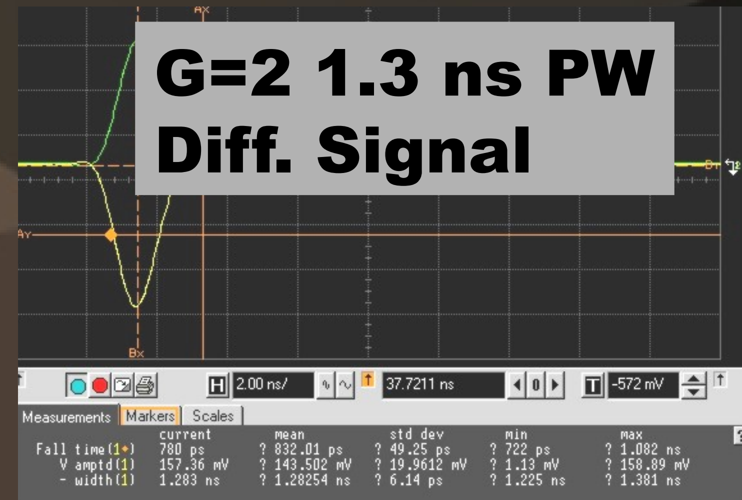
# *I-V, C-V and signal TEST PCB*



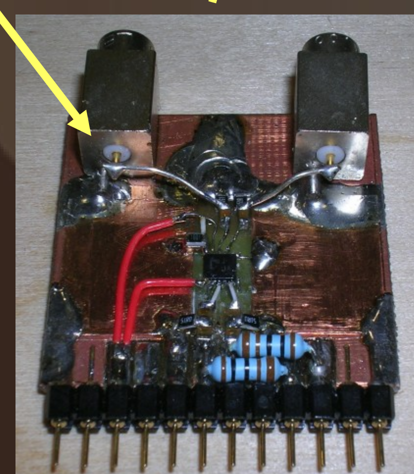

R.D'Alessandro
(Università di Firenze e INFN-Firenze)

# *Experimental Set-Up (MuRay hybrid for SiPM)*









Relatively “slow” electronics
Setup used also for IV and CV

R.D'Alessandro
(Università di Firenze e INFN-Firenze)

# *SiPM characterization*

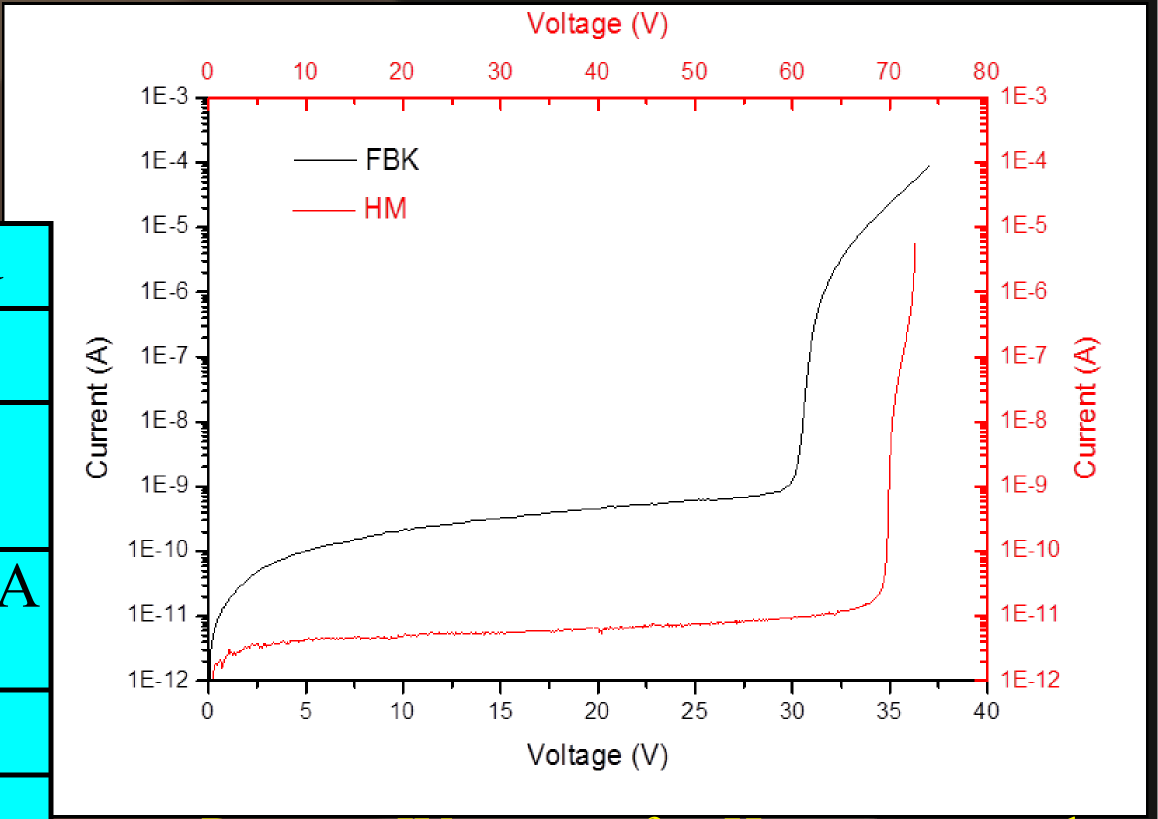
For some of these tests we have used also a modified hybrid. This modification allows connecting to hybrid  single encapsulated SiPM

Two devices have been used for this test:

1. FBK IRST described above, packed up in TO case
2. Hamamatsu S10362-11-050U series in metal package. It has 400 cells with dimension 50x50 micron$^2$ and its total active area is 1 mm$^2$.

Both devices have been electrically characterized. This characterization includes forward and reverse IV and CV measurements.

| | FBK | Hamamatsu |
|---|---|---|
| $V_{BD}$ | 29.25 V | 69.7 V |
| Working region | > 6 V | ~ 2V |
| Current | Up to 10e$^{-4}$ A | Up to 10e$^{-6}$ A |
| $R_q$ | 650 kOhm | 129 kOhm |
| C | 51 pF | 36 pF |




Reverse IV curves for Hamamatsu and FBK at 20 $^{o}$C.


R.D'Alessandro
(Università di Firenze e INFN-Firenze)

# *SiPM characterization*

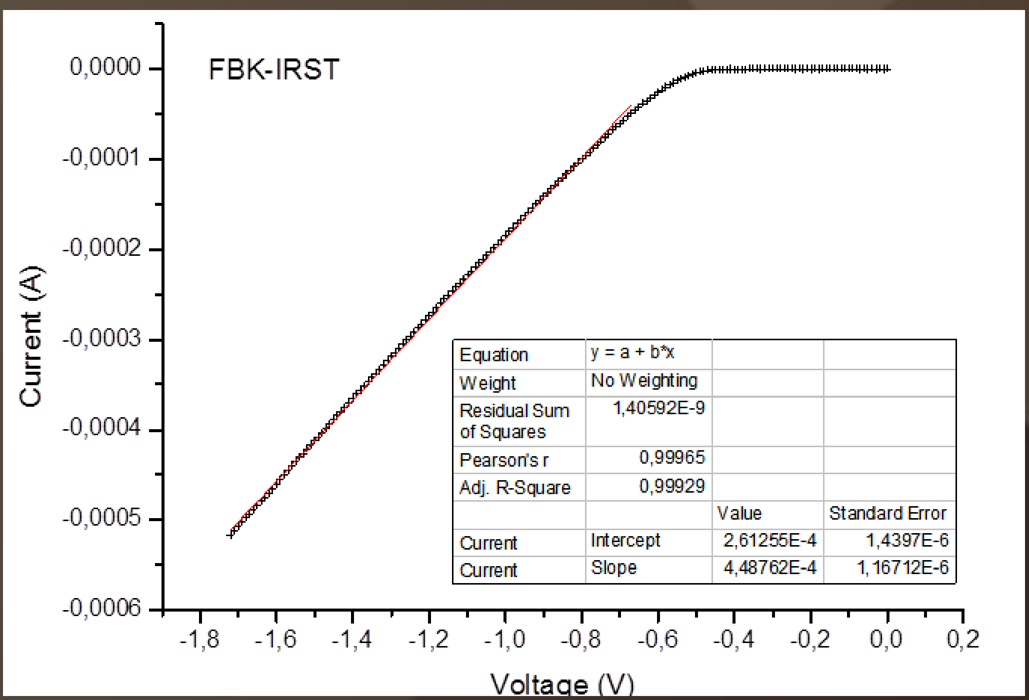
## Forward IV

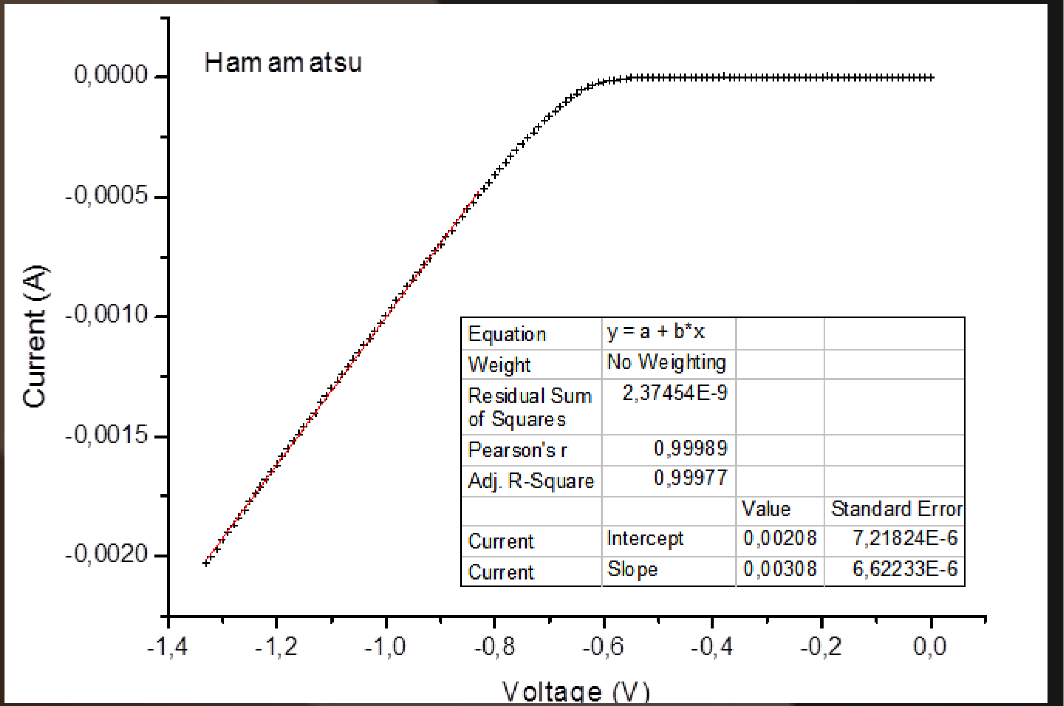
Total resistance is 2228 Ohm. Quenching resistor is

2228*292 = 650.6 kOhm

Total resistance is 324 Ohm. Quenching resistor is

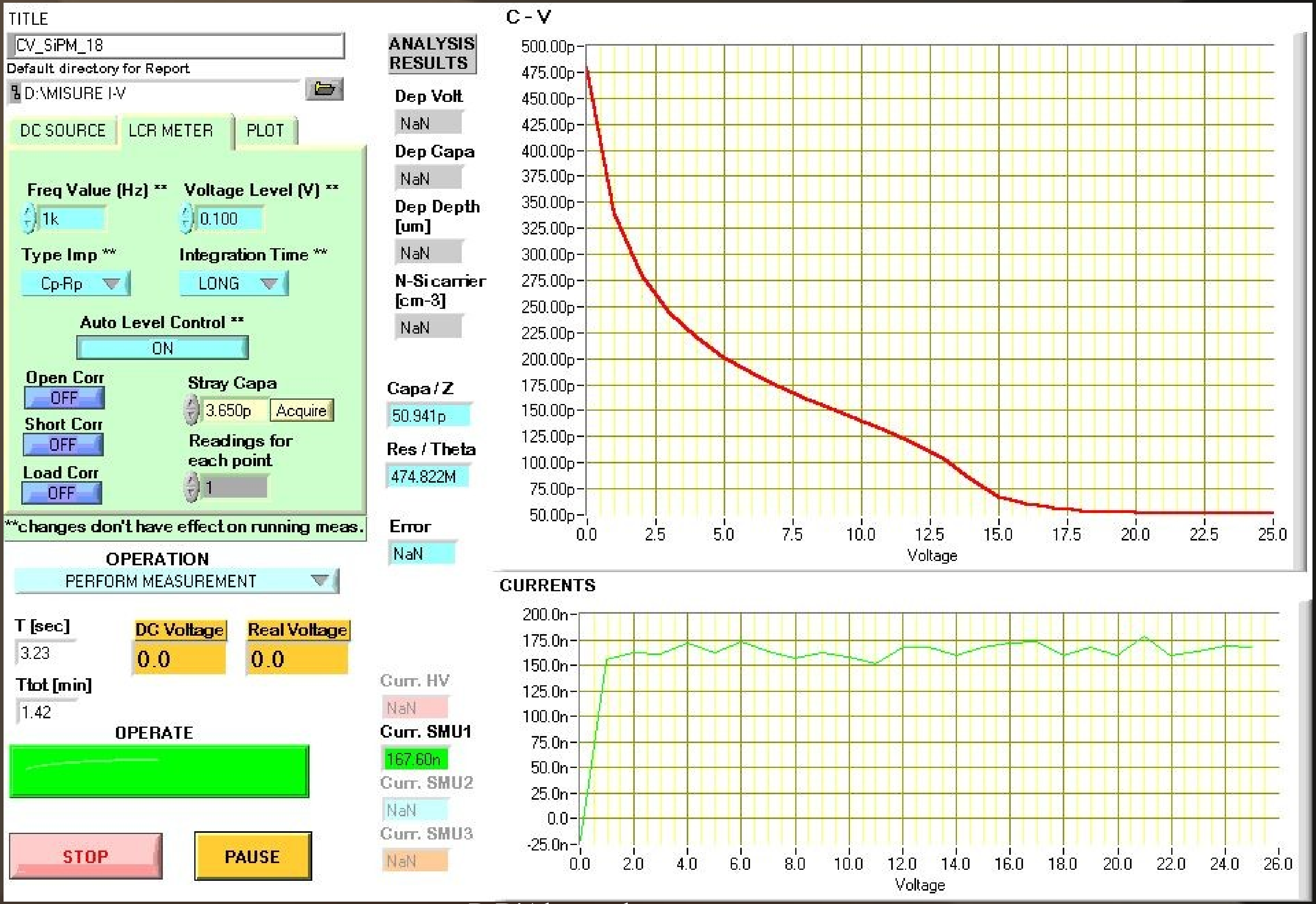
324*400 = 129.6 kOhm



# *SiPM characterization*

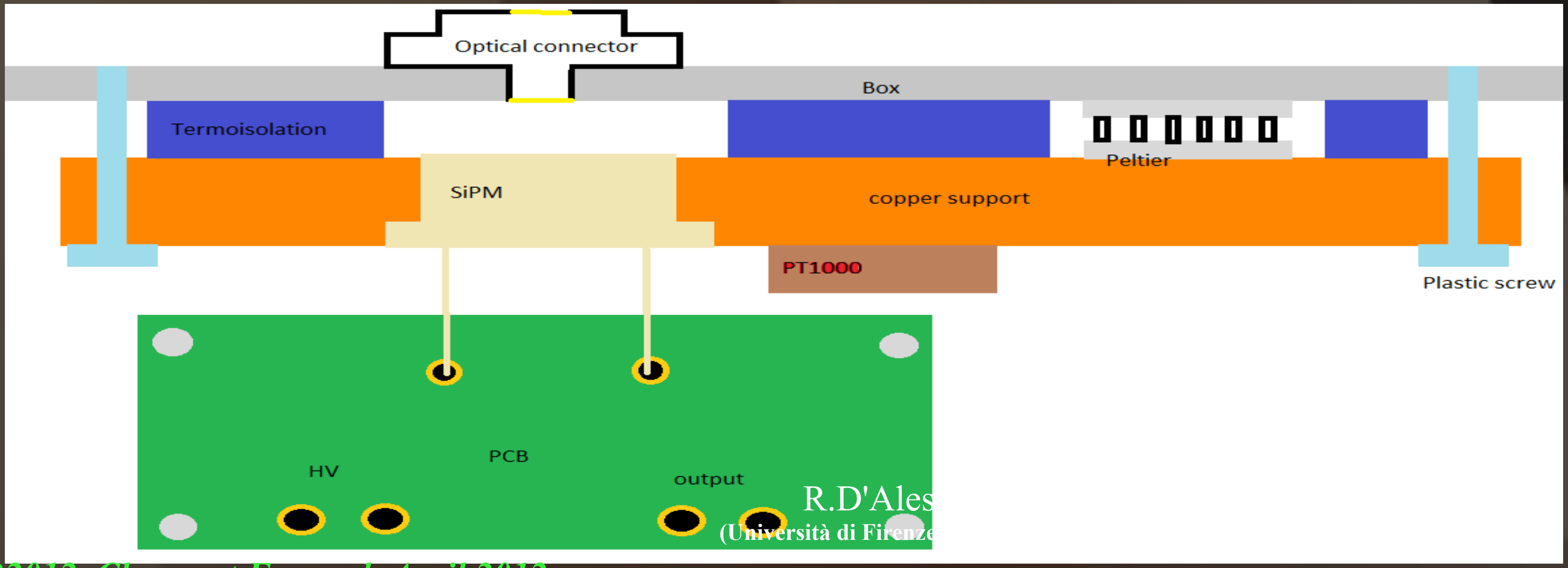
CV (FBK)




R.D'Alessandro
(Università di Firenze e INFN-Firenze)

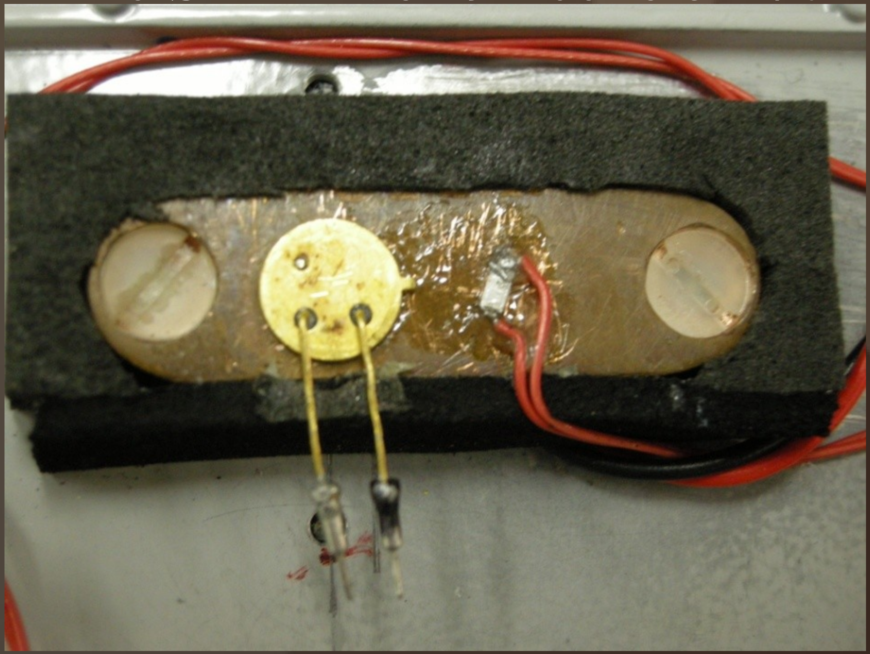
# *Experimental Set-Up (Single SiPM)*

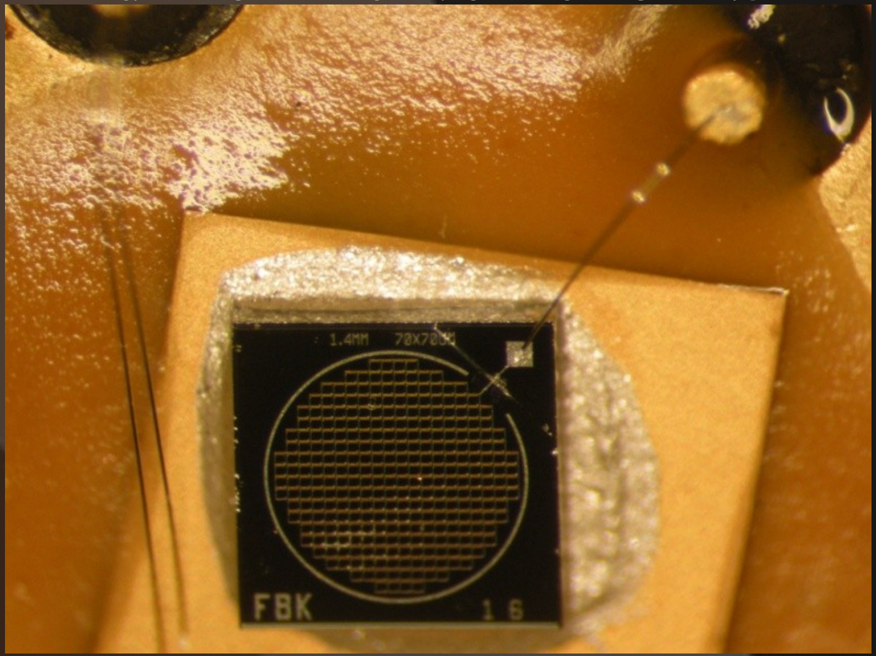
- Set of instruments for IV and CV measurements;
  - HP 4142B , HP 4284 (Precision Voltage Source, Precision LCR meter (20Hz-1MHz)
- Fast preamlifier and oscilloscope;
  - Tektronix, various models Max 1GHz BW.
  - LeCroy SDA 760Zi: 6 GHz, 40 GS/s (Only arrived now!) Most of the results presented were obtained with less performant scopes.
  - Custom preamplifiers: G = 1-10, bandwidth from 0.3 to 3 GHz
- Fast laser;
  - pulse laser 76 MHz, 4 ps, 600 nm
  - Laser support equipment
- Mechanical support for temperature control, electrical and optical connections



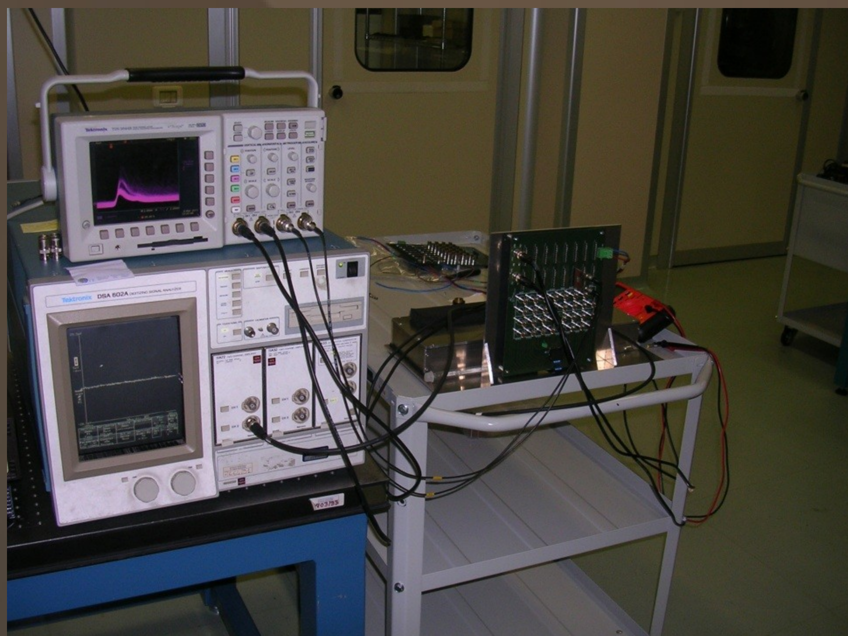
# *Experimental Set-Up for FBK*

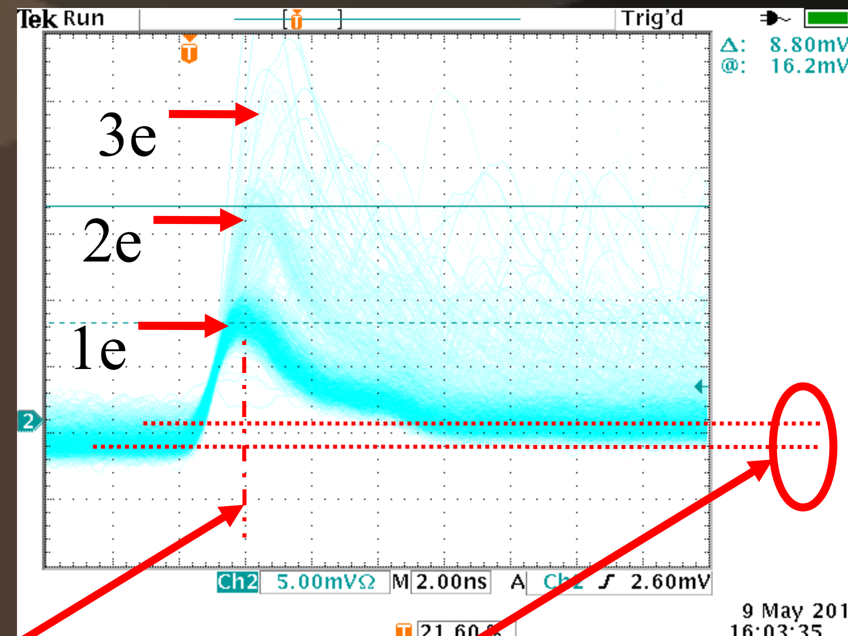
- The present data refers to the Silicon Photomultiplier by FBK-IRST for the MuRay project.
- This device has been packaged and bonded in our laboratory.
- We have used an opened TO case as package.
- The SIPM has 292 cells of 70x70 $\mu^2$ and a total active area of 1.54 $mm^2$





# *LAB Test with Thermal Electron*





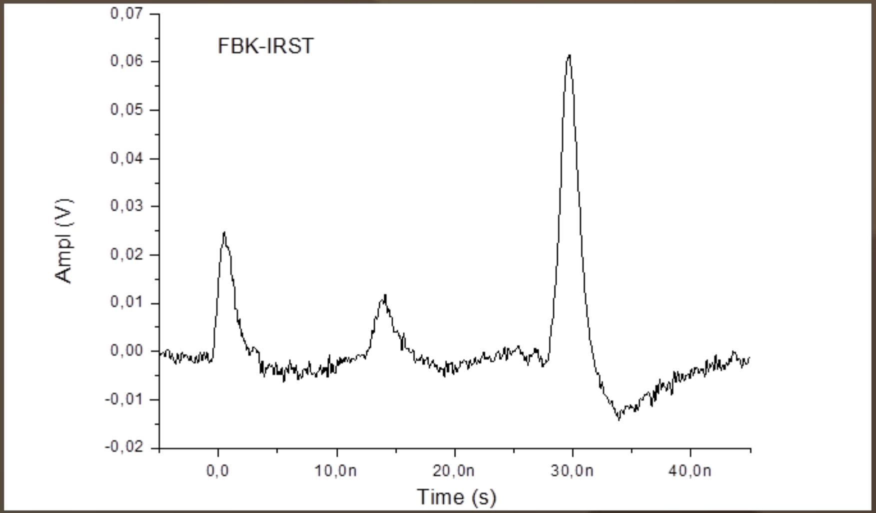

Peak amplidue and peak time degradation caused by insufficient bandwidth scope

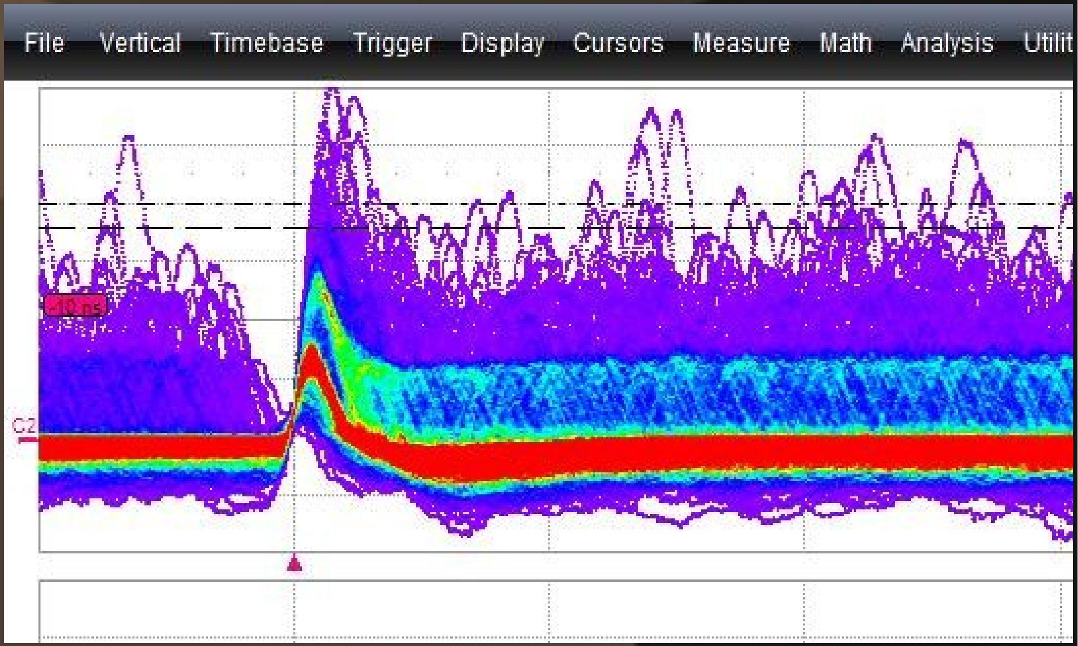
Baseline difference due to SLOW TAIL SiPM response

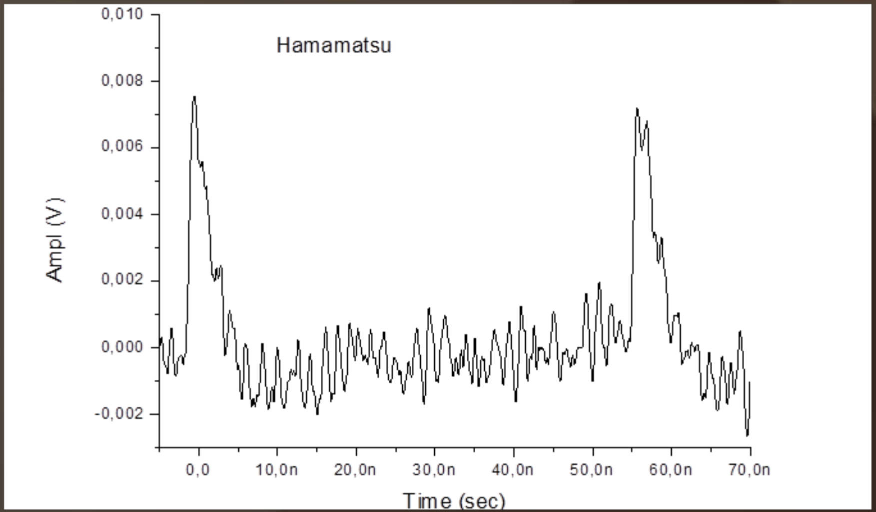
R.D'Alessandro
(Università di Firenze e INFN-Firenze)

# SiPM characterization

***Signal characterization with single –channel custom preamplifier ("slow")***



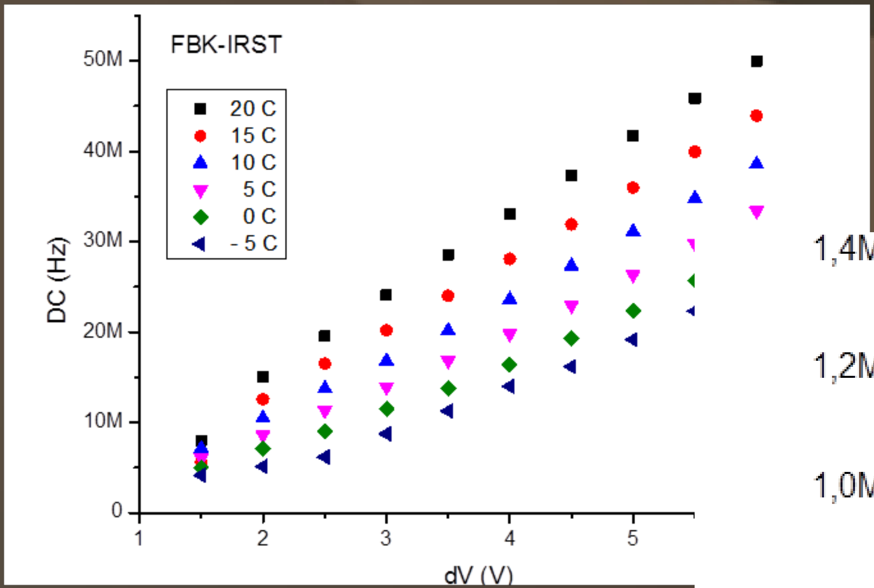

Rise time for both sensors is about of 550 ps

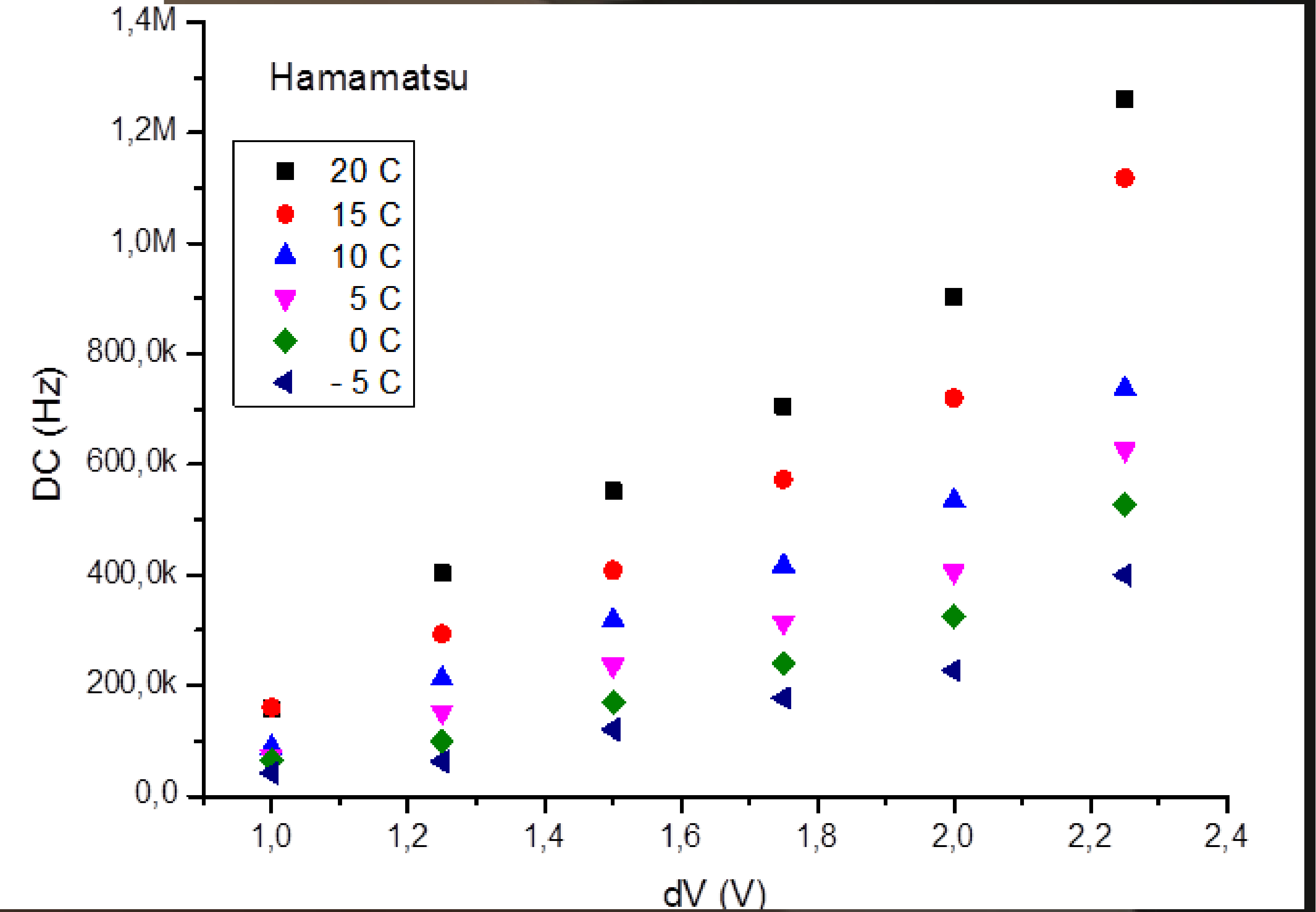
Preamplifier makes some signal distortion (negative overshoot on the trailing edge of the pulse)

R.D'Alessandro
**(Università di Firenze e INFN-Firenze)**

# SiPM characterization

*Signal characterization with single –channel custom preamplifier*



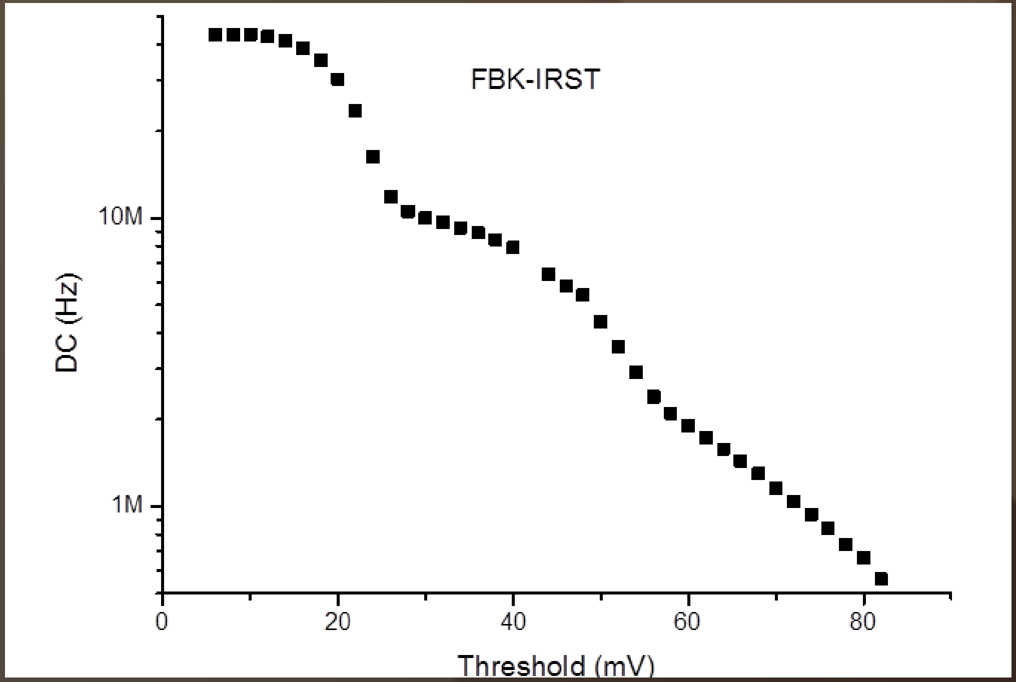




R.D'Alessandro
(Università di Firenze e INFN-Firenze)

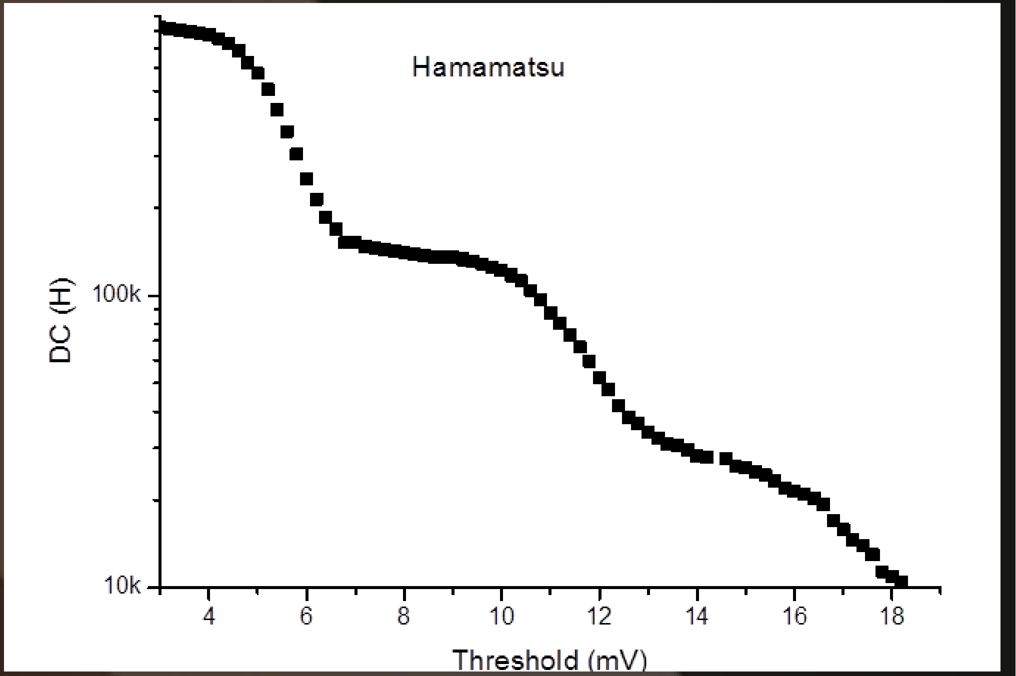
# *SiPM characterization*

Dark count rate vs threshold **(obtained with LeCroy SDA 760Zi: 6 GHz)**

DC at 20 $^{o}$C and 5,5 V overvoltage



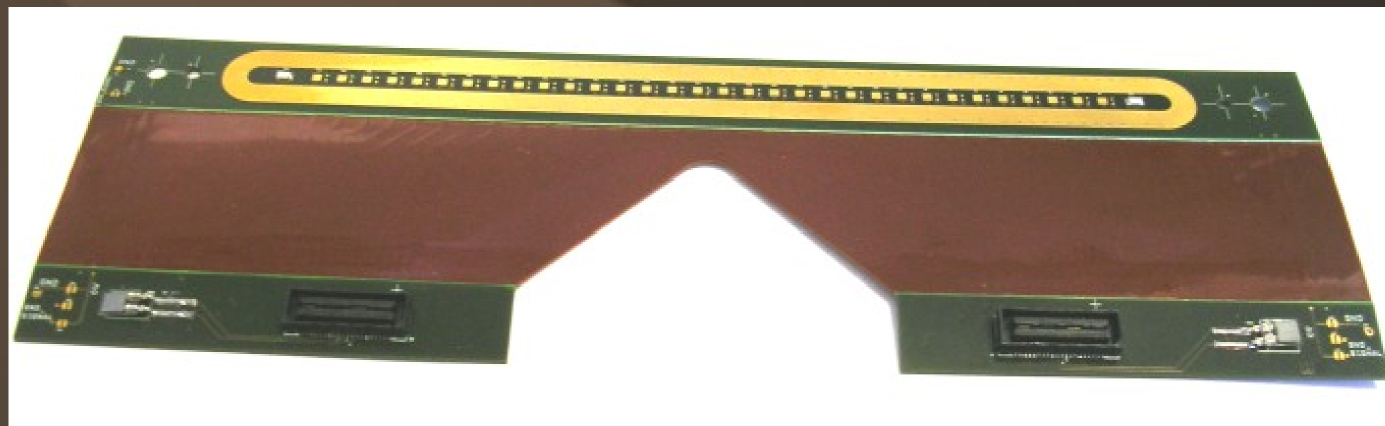

DC at 20 $^{o}$C and 2 V overvoltage




R.D'Alessandro
(Università di Firenze e INFN-Firenze)

# *New hybrid support for SiPM*

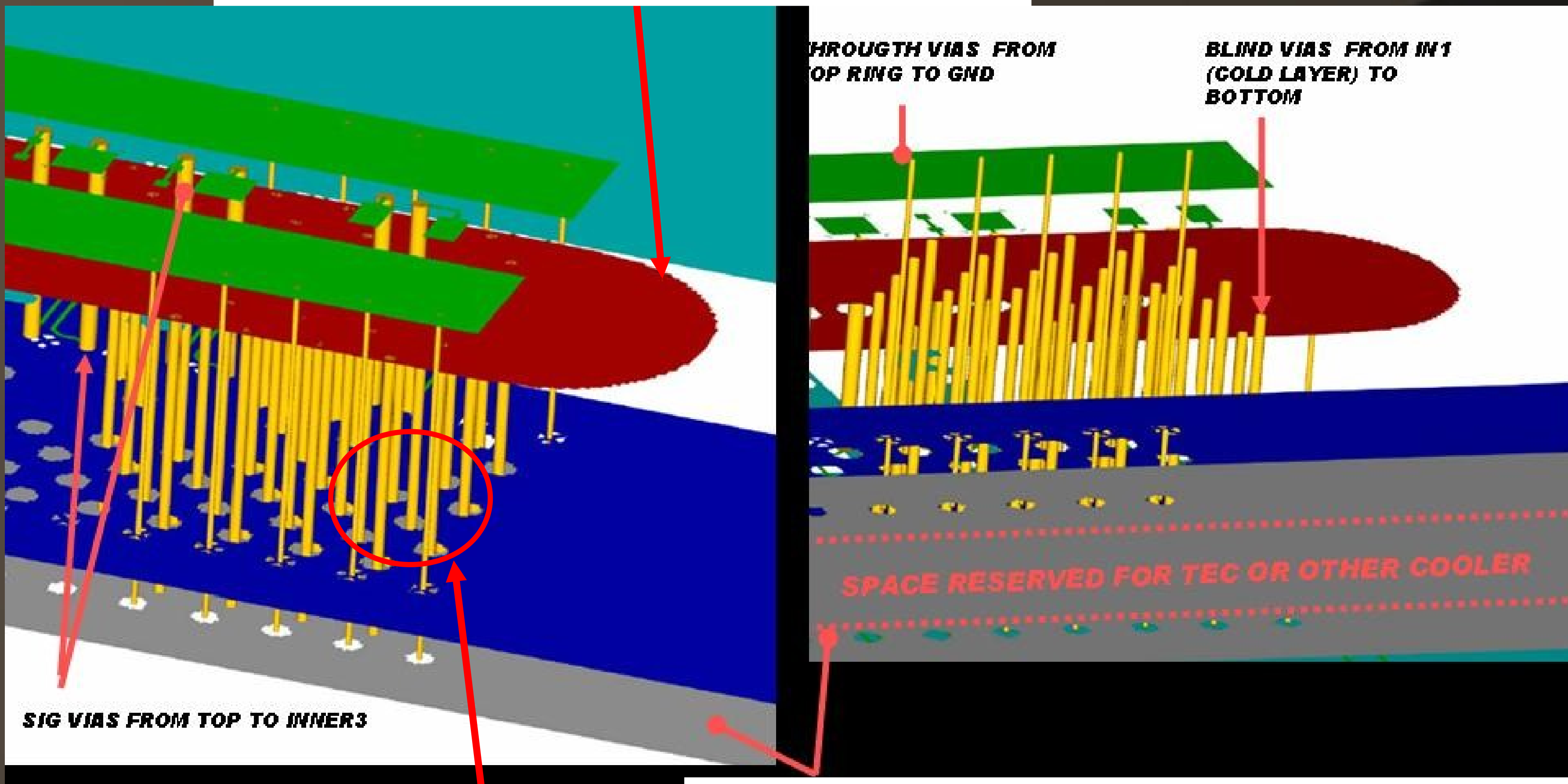
- Improved flexibility for front-end acquisition board.



- Thermal connection between the TE cooler (Peltier) and the inner cold metal has been improved with a lot of vias.

# *Thermal configuration - SiPM side*

**INNER copper PLATE 75um from SiPM Bottom**




**Copper vias to improve thermal conducibility between bottom cold plate and inner plate below SiPM**

**BOTTOM PLANE (COLD LAYER)**

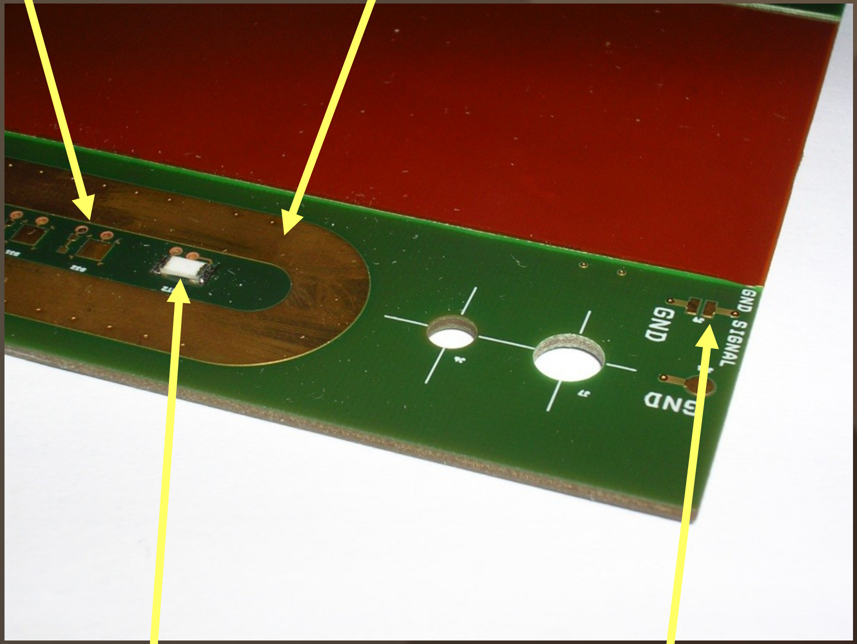

R.D'Alessandro
(Università di Firenze e INFN-Firenze)

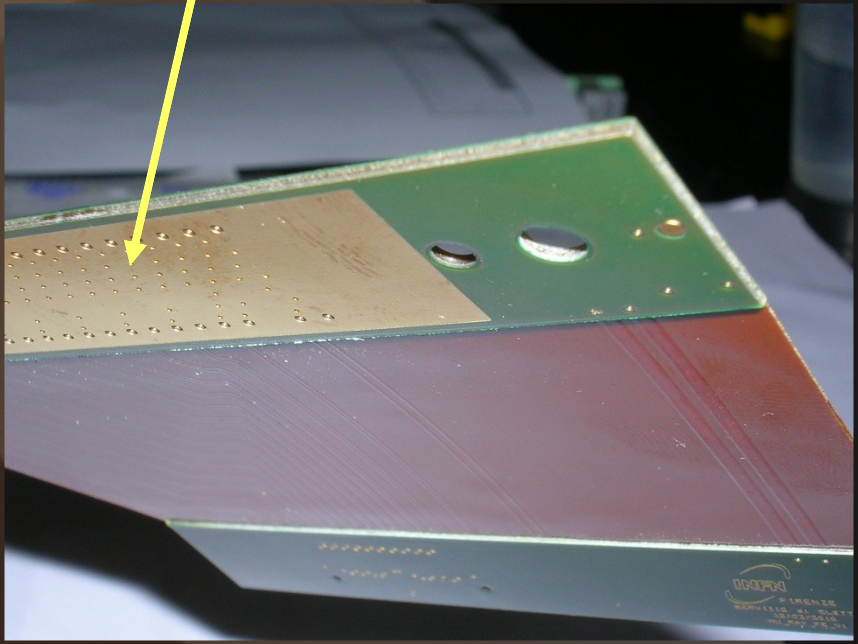
# *Detailed view of SiPM side*

SiPM bonding PAD

Anular ring to create an isolated volume from outside

Copper plate for cooling SiPM bottom side



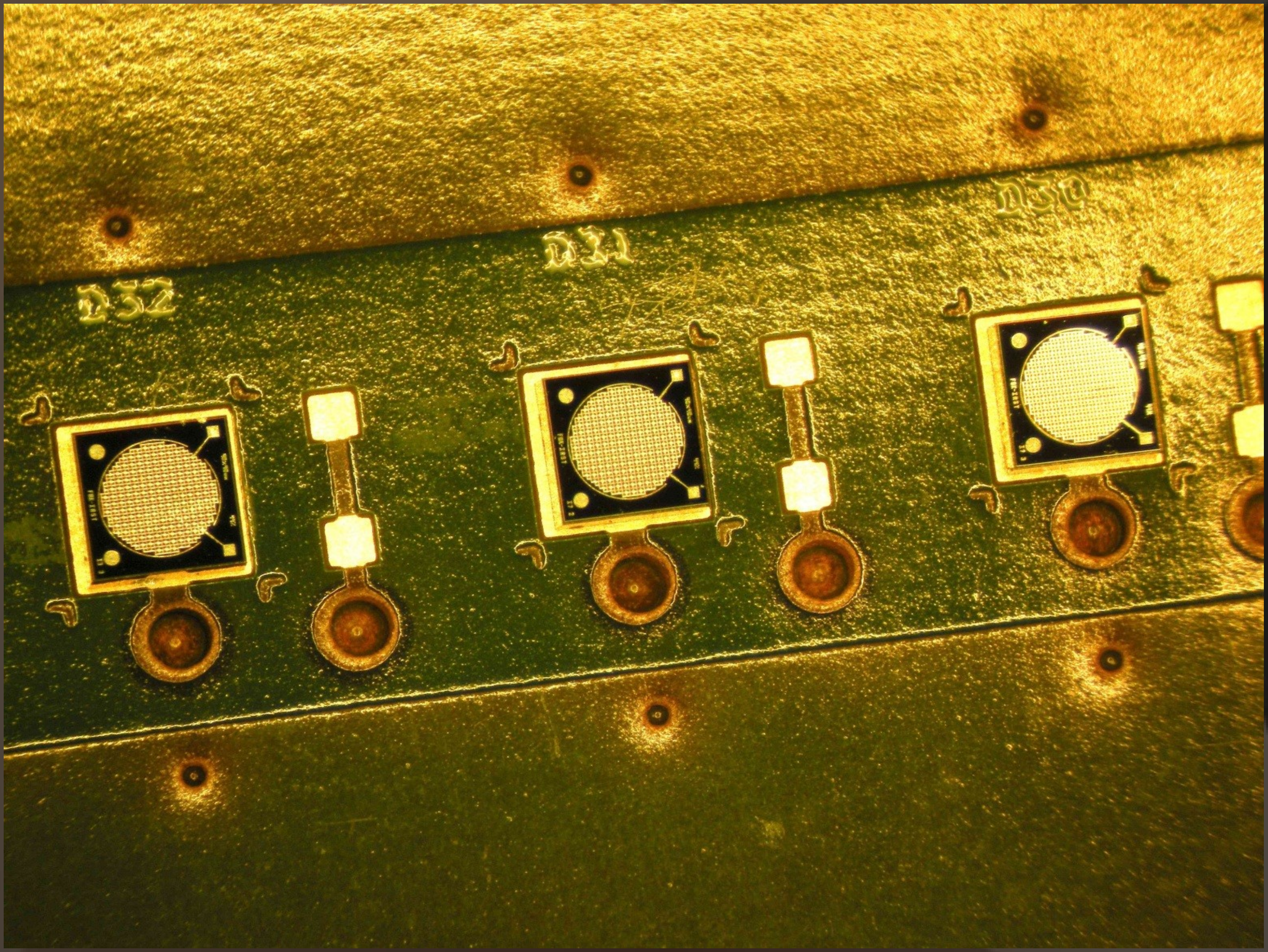



PT1000 temperature sensor

GND jumper

R.D'Alessandro
(Università di Firenze e INFN-Firenze)

# *Hybrid SiPM side complete*




R.D'Alessandro
**(Università di Firenze e INFN-Firenze)**

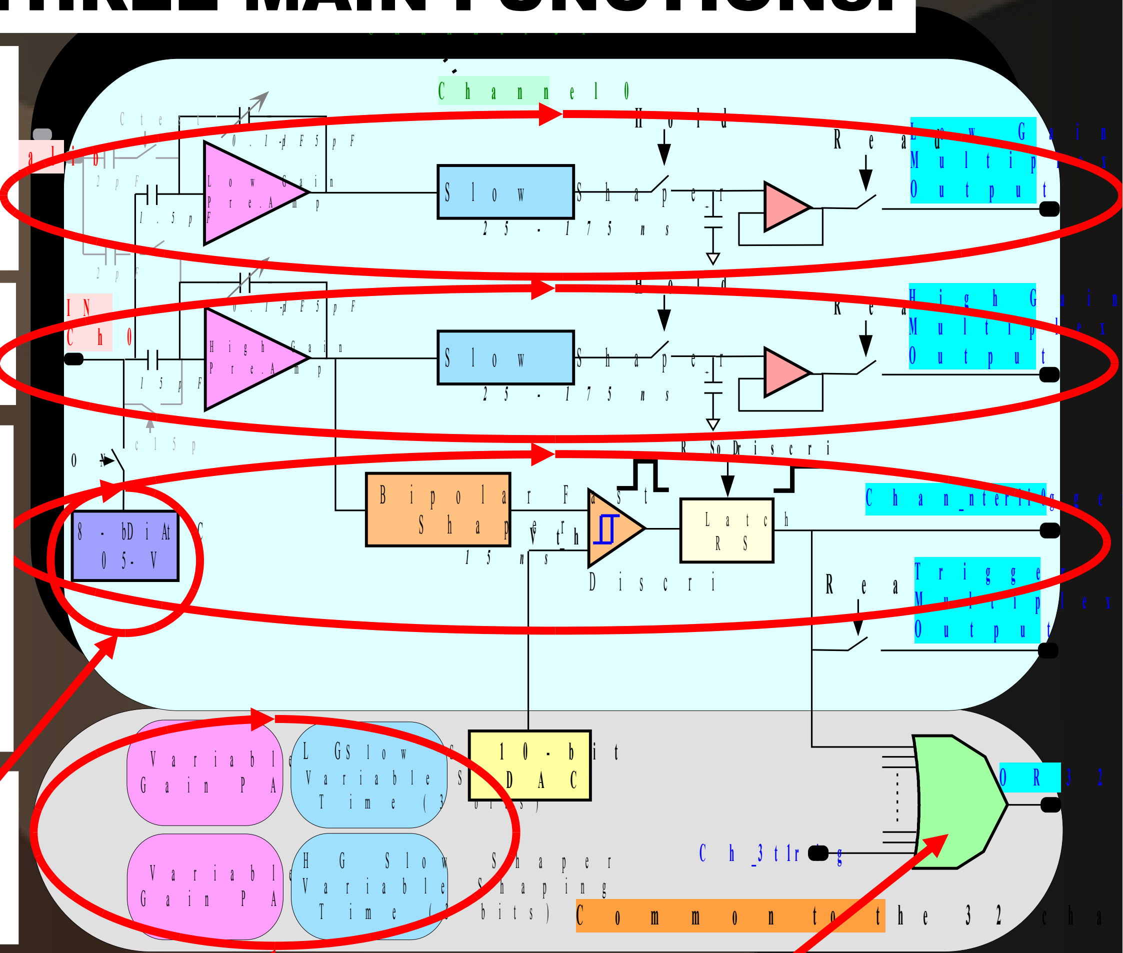
# «EASIROC»

## EASIROC 32 CH ASIC HAS THREE MAIN FUNCTIONS:

**1) 32 CH LOW GAIN, PROGRAMMABLE SHAPING, VOLTAGE MEASUREMENT PATH THAT HAS SAMPLE AND HOLD CAPABILITY**

**2) 32 CH HIGH GAIN , PROGRAMMABLE SHAPING, LIKE PREVIOUS ONE**

**3) 32 CH FAST TIMING PATH, WITH COMMON THRESHOLD PROGRAMMABLE COMPARATOR WITH 32 OUTPUTS. MAIN DATA IN TIMING APPLICATION AND ARE FED TO THE FPGA CHIP TO BE PROCESSED AS REQUESTED.**




**SiPM BIAS VOLTAGE CAN BE PRECISELY ADJUSTED FOR EACH CHANNEL BY A PROGRAMMABLE 5V DAC**

**IN ORDER TO PROPERLY CONFIGURE AND PROGRAMM THE CHIP, 3 REGISTERS CAN BE SERIALLY ACCESSED : «SLOW CONTROL» REG, »READ» REG. , «PROBE» REG.**

**«OR32» FAST SIGNAL USED TO TRIGGER ACQUISITION SEQUENCE**

R.D'Alessandro
(Università di Firenze e INFN-Firenze)

# *EASIROC with single SiPM*

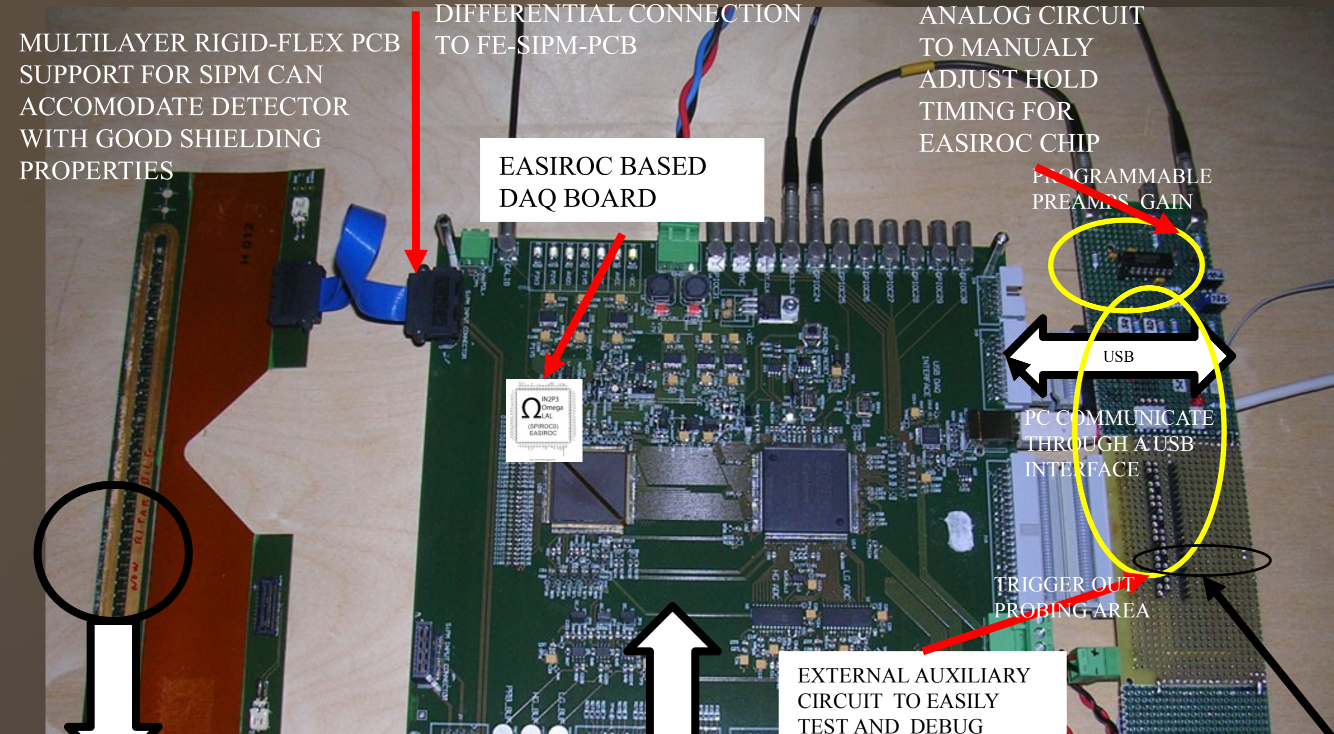
## *SIPM TEST SET-UP using the modified hybrid*

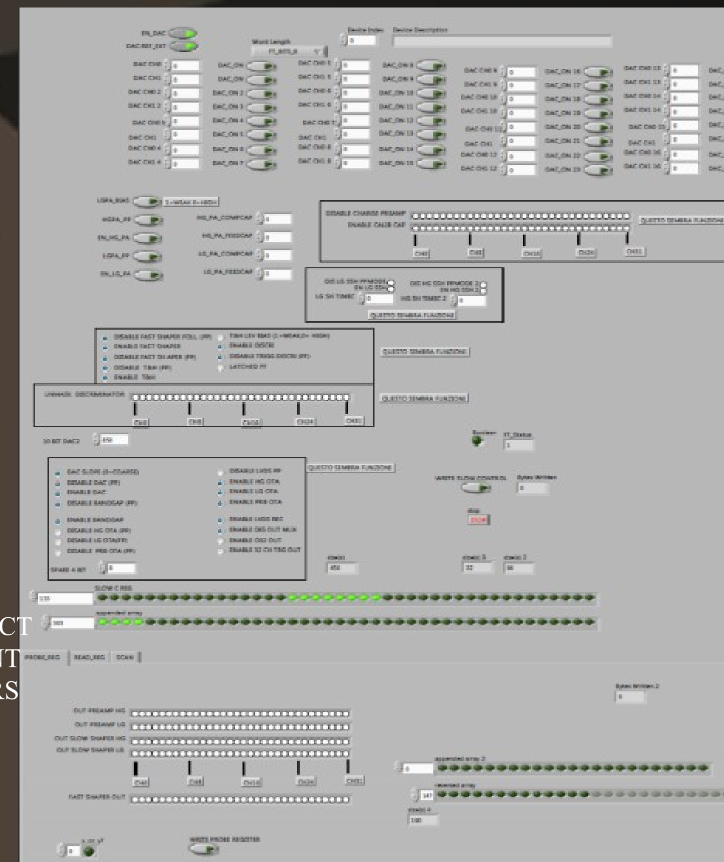
MULTILAYER RIGID-FLEX PCB SUPPORT FOR SIPM CAN ACCOMODATE DETECTOR WITH GOOD SHIELDING PROPERTIES

MICROCOAX 100 OHM DIFFERENTIAL CONNECTION TO FE-SIPM-PCB

DISCRETE ANALOG CIRCUIT TO MANUALY ADJUST HOLD TIMING FOR EASIROC CHIP

-LABVIEW SIMPLE INTERFACE ALLOW TO PROGRAM EASI-ROC CHIP REGISTERS
-SLOW CONTROL,
- READ AND PROBE REGISTERS
- WE CAN ALSO SET OVER-BIAS FOR EACH SINGLE SIPM THROUGH A DAC SETTING



FBK-IRST SIPM BONDED ON PCB. PLACE AVAILABLE ALSO FOR OTHER LEADED DETECTOR (HAMAMATSU)

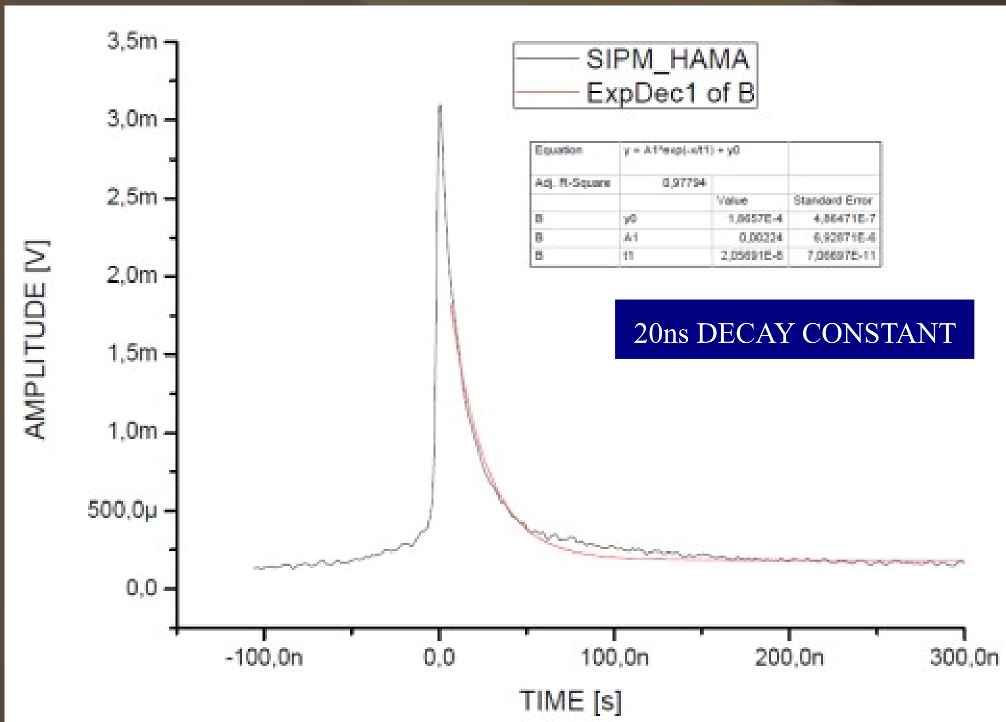
PRELIMINARY MEASURMENTS MADE WITH A FAST SCOPE



R.D'Alessandro
**(Università di Firenze e INFN-Firenze)**

# *EASIROC with single SiPM*

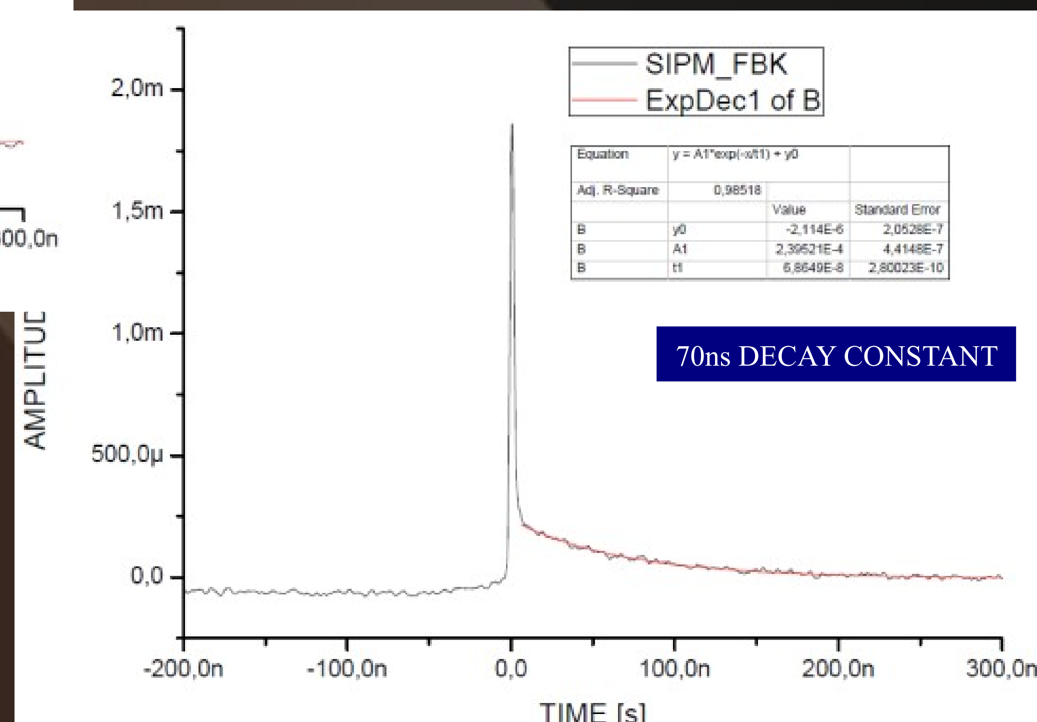
### *SIPM SIGNAL INPUT TO EASIROC*




SIGNAL CAPTURED BY FAST SCOPE (AVERAGE MODE) WITHOUT INTERMEDIATE ELECTRONICS

LeCroy SDA 760Zi: 6 GHz

DIFFERENT SIGNAL SHAPE





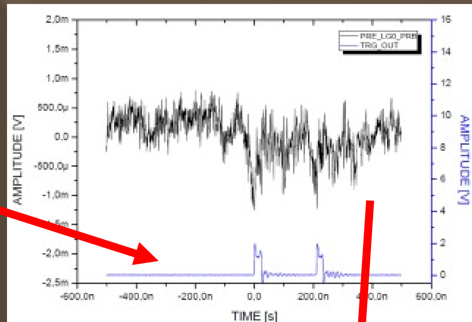
R.D'Alessandro
(Università di Firenze e INFN-Firenze)

# *EASIROC with single SiPM*

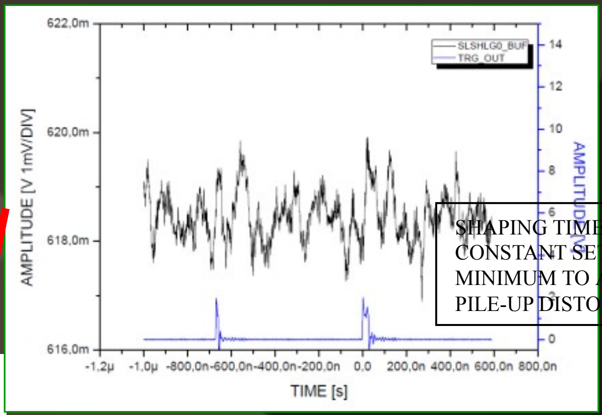
## *SIGNALS AROUND EASIROC*

BLUE SIGNALS ARE TRIGGER OUTPUT CORRELATED WITH INPUT SIGNALS

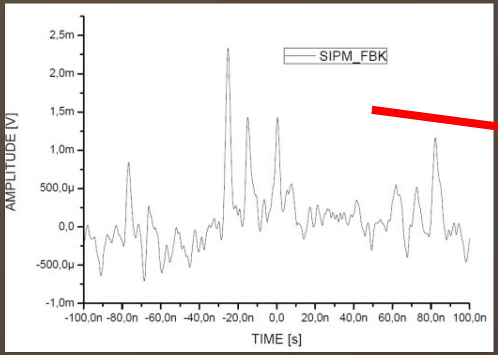
PREAMP LOW GAIN OUTPUT

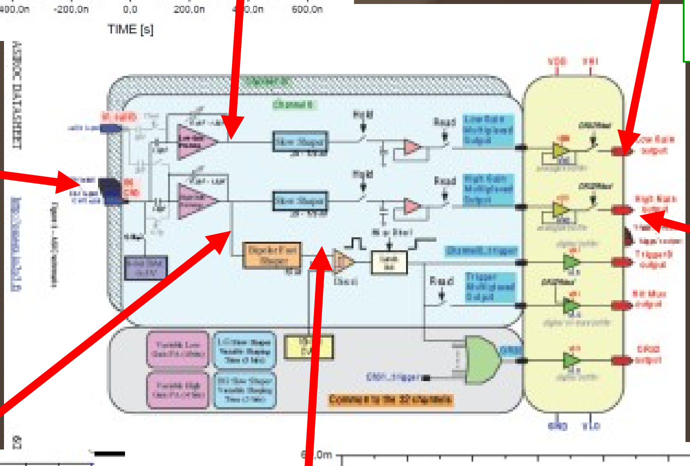


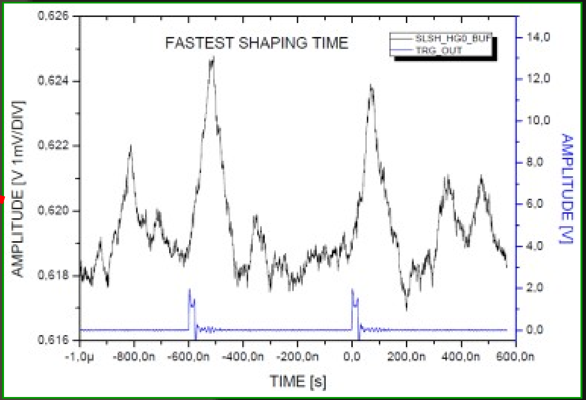

SHAPER LOW GAIN OUT




INPUT SIGNAL FROM FBK SIPM



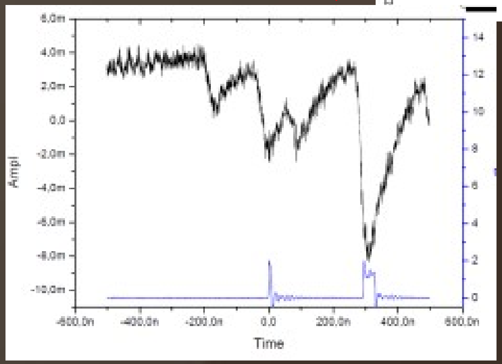





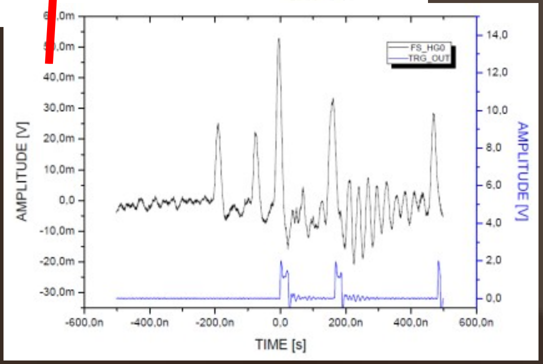

SHAPER HIGH GAIN OUT

HIGH GAIN IS A FACTOR OF TEN GREATER THAN LOW GAIN

BOTH GAINS ARE SET TO MINIMUM (1 AND 10)




PREAMP HIGH GAIN OUTPUT

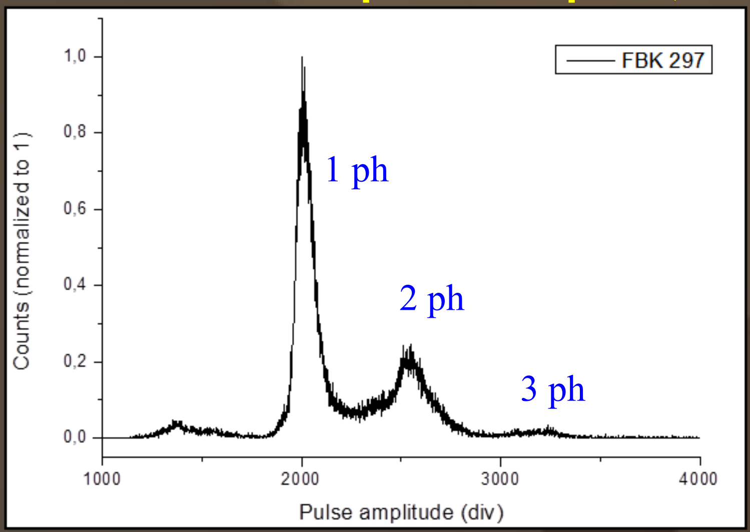


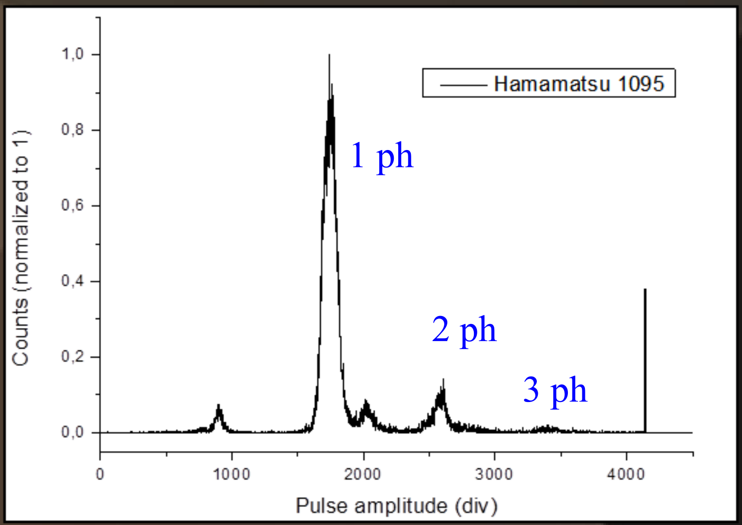

FAST SHAPER INPUT TO TRIGGER COMPARATOR

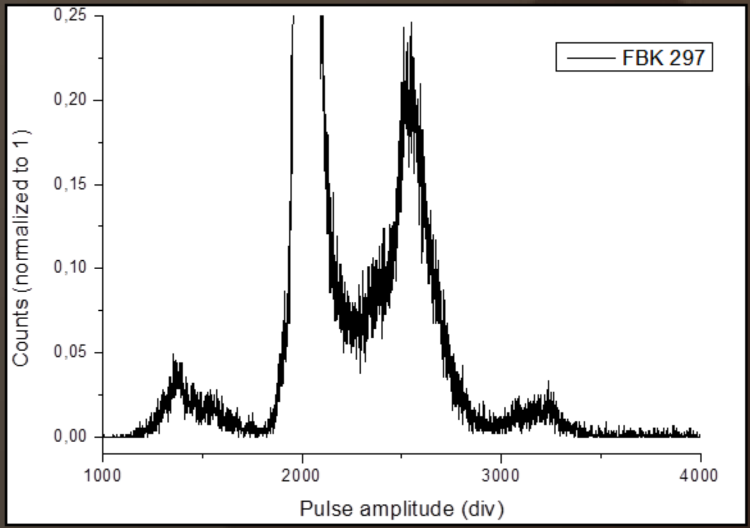
R.D'Alessandro
(Università di Firenze e INFN-Firenze)

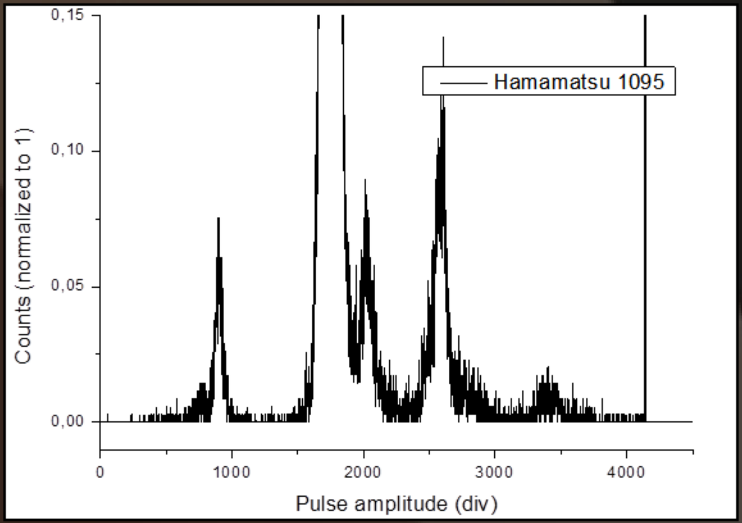
# *EASIROC with single SiPM*

**Pulse amplitude distribution for both devices measured with (EASIROC) probe connected to fast bipolar shaper. (Self trigger, threshold just above noise).**



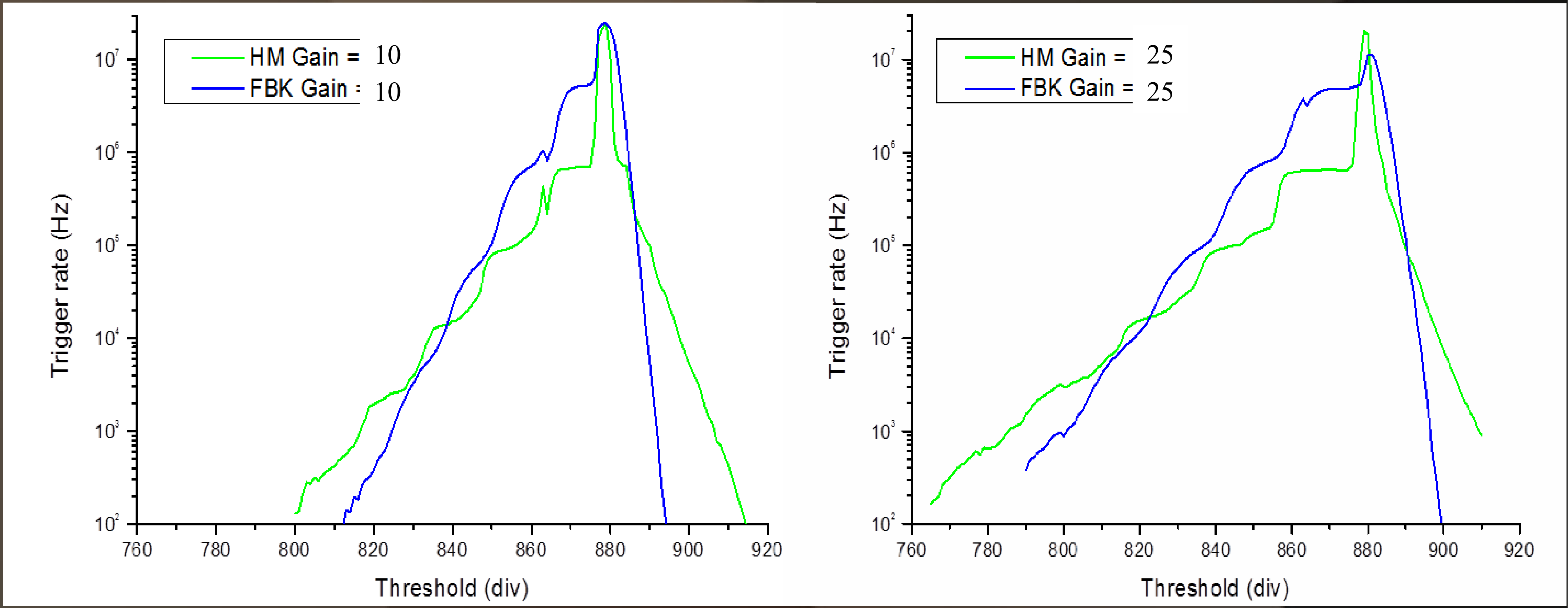




R.D'Alessandro
(Università di Firenze e INFN-Firenze)

# *EASIROC with single SiPM*

**Trigger pulse rate vs threshold for both devices at two values of high gain preamlifier**





R.D'Alessandro
(Università di Firenze e INFN-Firenze)

# *Conclusions*

- Our collaboration is now capable of performing a full characterization of SiPM devices.
- First results with EASIROC chip coupled to SiPM for MuRay are very encouraging.
- Will now finalise and build 16 new DAQ boards for the MuRay 1$m^2$ telescope.