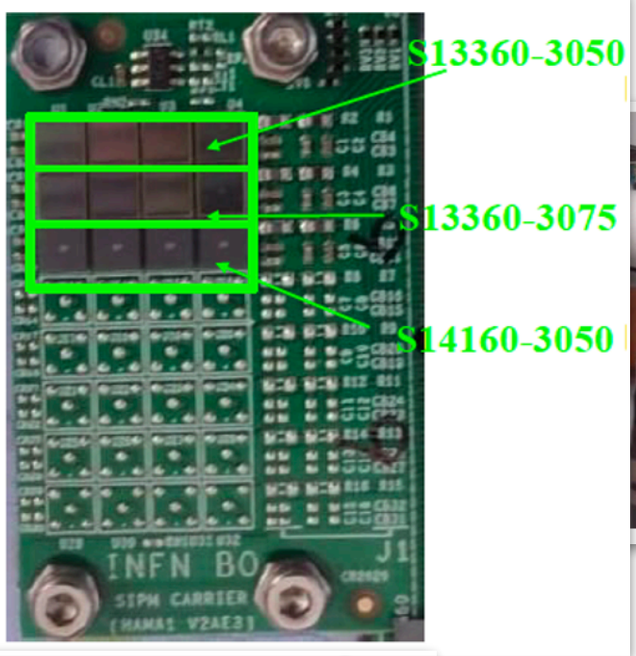
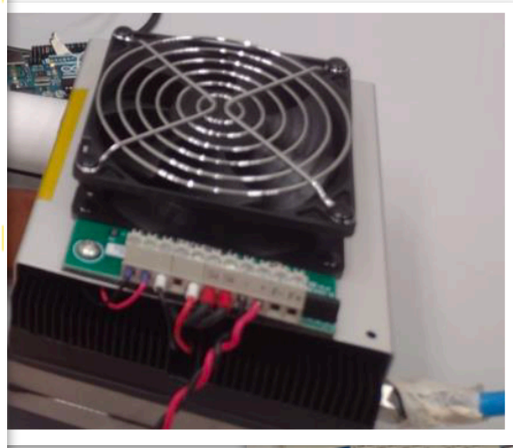
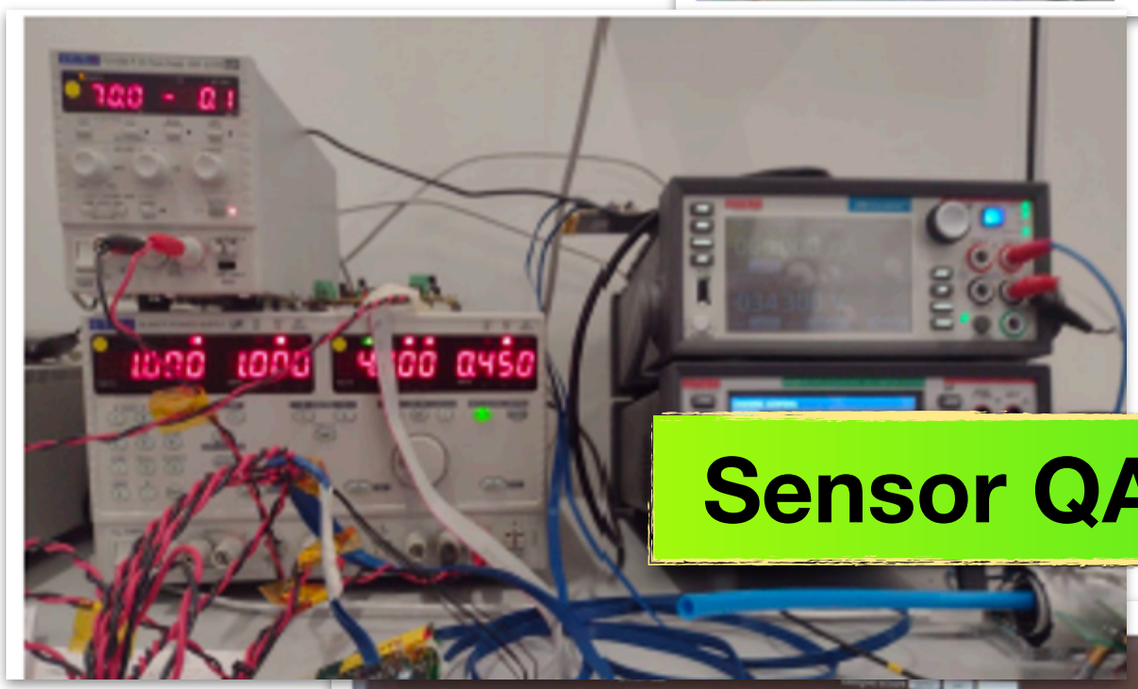






Sensor QA stations

Daniele De Gruttola
University & INFN of Salerno
ddegruttola@unisa.it

QA strategy for dRICH SiPMs

color code = defined

- ***Kick-off to define QA protocol(s)***
  - Define pipeline for QA on SiPMs
  - Tests to be performed at different stages and with different scopes
  - **Possibility to perform “basic” tests in parallel (2/3 sites)**
  - **Possibility to perform specific tests in one site**
- ***SiPM matrices for the dRICH***
  - ~5000 SiPM matrices will be built and delivered by Hamamatsu
  - Each matrix has 64 sensors
  - 4 matrices will be installed a carrier
  - 1248 carriers
  - **Assembling matrices into carriers will be done by a company**

QA strategy for dRICH SiPMs

- ***QA tests - when, where***

  - QA tests on sensor matrices ?

  - Maybe not useful - to be decided according to needs and costs

  - Maybe test on a sub-sample?

  - Test on matrix before assembling could be useful to be sure that matrices with similar parameters go into one carrier?

  - Investigate possibility to perform these tests in Hamamatsu? Costs?

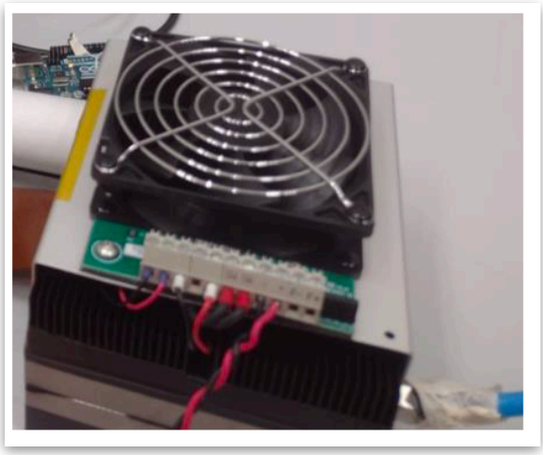
  - **Tests in our QA hub after assembling on carriers**

QA strategy for dRICH SiPMs

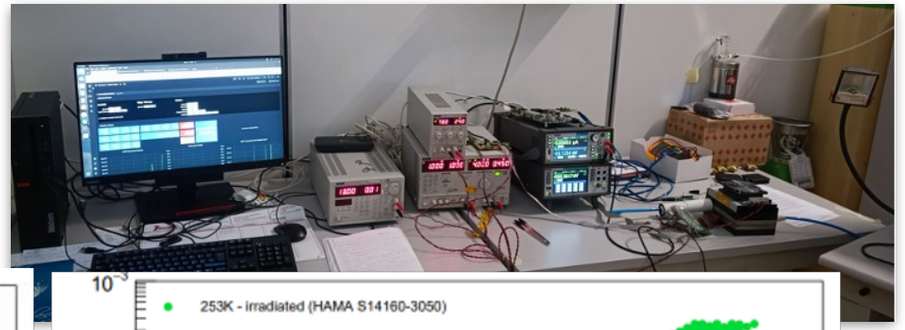
- ***QA tests - what***
  - Electrical inspection (on nude matrix? on assembled carrier?)
  - IV curves, breakdown
  - Tests vs temperature
  - <u>Ensure to be stable in temperature</u> (**work done and in progress in Salerno and Cosenza**)
  - Define three T values to perform IV characterization (*-20°C,0°C,20°C* or *0°C,10°C,20°C*)
  - Tests at -40°C on a subsample (1-2%?)
  - Check V bias trending vs T
  - **Optical inspection** (before and after assembling?)
    - Microscopes are available in Catania
    - Procedure to remove scratches well known (tested in Bologna)

Set-up to test SiPMs @UNICAL

- ***Bench for SiPMs characterization in Cosenza radiation lab***
  - Setup specifically designed to measure DCR
  - dark current versus reverse bias voltage
  - more details in backup

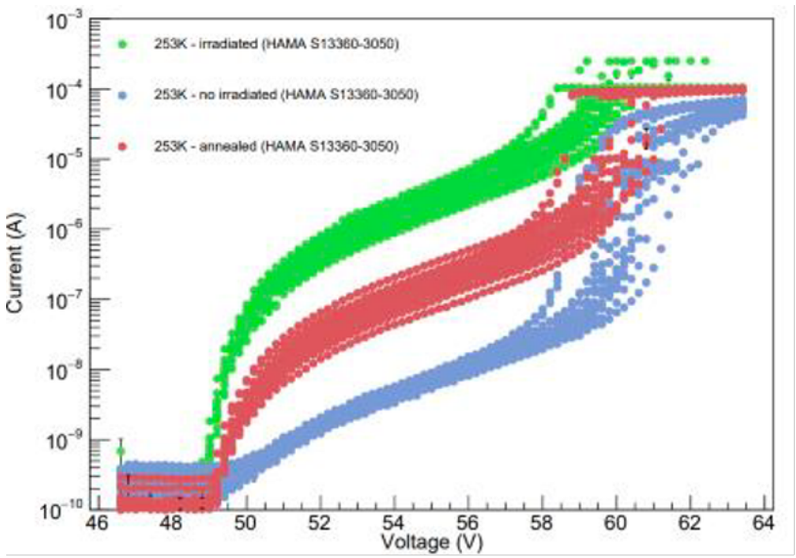


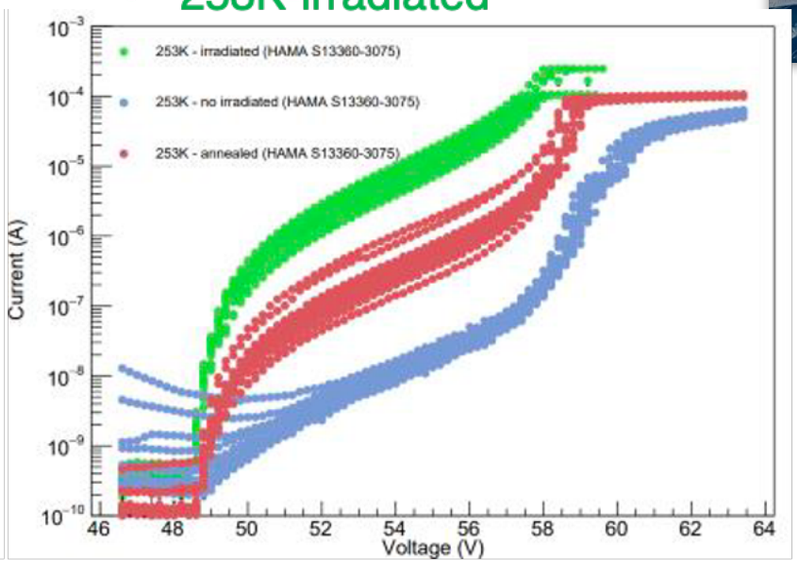
- **Example of studies performed in 2023-2024**
  - **Three types of Hamamatsu sensors tested**
  - **Irradiation tests:** protons (TIFPA-Trento); neutrons (CN-Legnaro); gamma (GIF-CERN)
  - **SiPMs characterization:** study of damage by protons and gammas

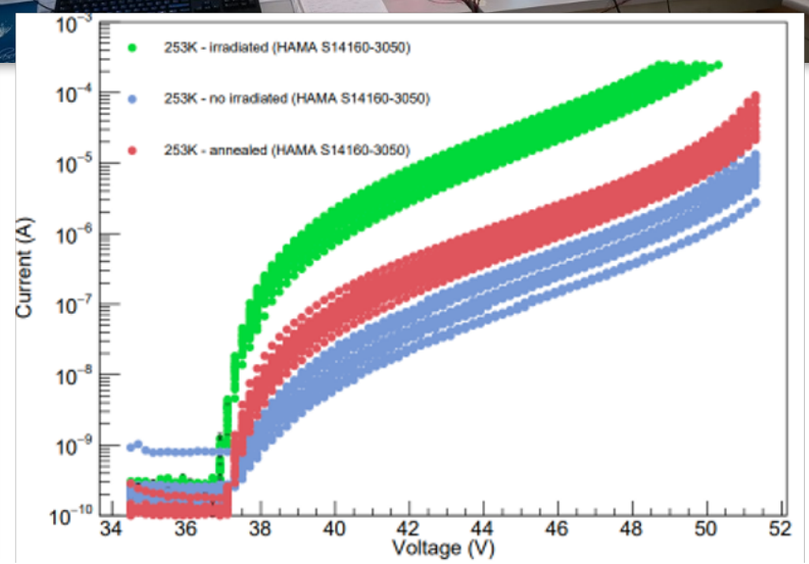


IV-curves

- 253K-no irradiated
- 253K-annealed
- 253K-irradiated







- **Studies on energy scan (backup)**

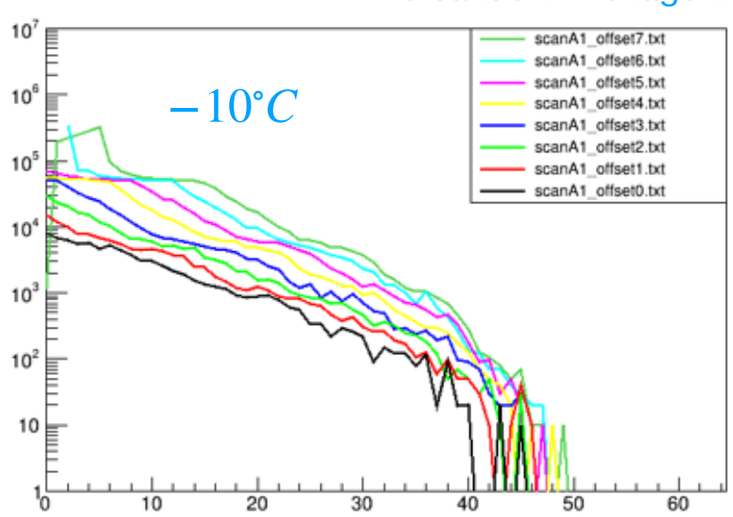
Set-up to test SiPM @UNISA

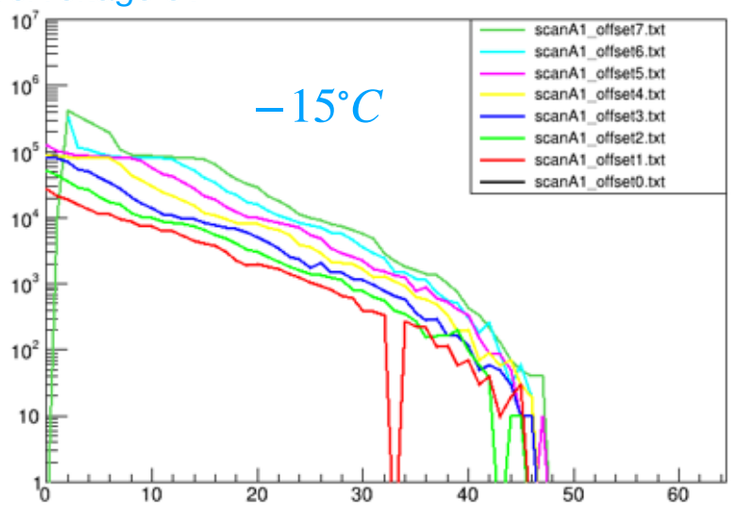
- Idea to build a larger AirBox and use a dewar to go down in temperature
- AirBox + Peltier + dewar (SiPM HV on)
  Low temperature far away from dew point

$\sim 4min$ $\sim 4min$ $\sim 6min$ $\sim 6min$ $\sim 6min$ $\sim 10min$

Laboratory temperature ~28°C

Measuring DCR on SENSL sensors
breakdown voltage 24C, overvoltage 6V





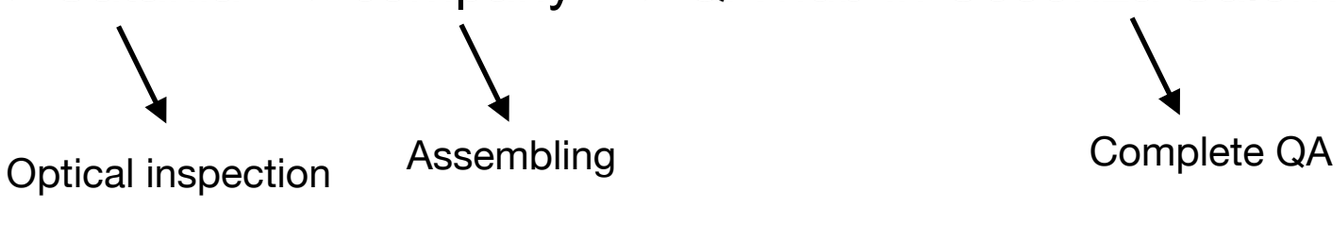
Salerno lab is currently being equipped with the same setup built in Cosenza (installing DAQ + multiplexer)

Test, action and delivery flow

- ***Possible test flow***

1) Hamamatsu → company → QA hub in Cosenza-Salerno-Trieste

2) Hamamatsu → Catania → company → QA hub in Cosenza-Salerno-Trieste



3) Other possible options

- *Trieste* is equipping a lab to make studies on microscopic behavior of sensors
- Available to be part of the QA hub

Timeline for QA

- ***Estimate total time needed for tests***
- ***Experience from JUNO in Catania***

Step	Action	Time/Action [min/Action]	Number of Actions	Total time [min]	Notes
0	Optical inspection	1/tile	16	16	
1	Assembling 16 matrices on PCB	1/tile	16	16	
2	Cooling at -50°C	30+15	1	45	4.5°C - 5°C/min + 15 min stability
3	IV-curve Dark	0.5/curve - 1/curve	16x16(=32/2)	128 - 256	Ammeter w/ 2 channels
4	IV-curve Light	0.5/curve - 1/curve 0.3/DS	16x16	128 - 256 + 11	
5	Charge spectrum Dark	1.5/16 spectra/ Vpoint	32x5 Vpoint	240	1kHz event rate
6	Charge spectrum Light	1.5/16 spectra/ Vpoint	32x5 Vpoint	240 + 11	
7	Going up to environment T	20+10	1	30	
8	Removing 16 matrices	1/tile	16	16	
9	Logbook + DB	5+5	2	10	Writing notes + data sharing
CASE 1	Only IV-curve no charge spectra 359 (6h)			359 (6h)	1538 h (193 shifts)
CASE 2	No IV, only charge spectra 582 (9.7h)			582 (9.7h)	2486 h (311 shifts)
CASE 3	IV and charge spectra850 (14.2h)			850 (14.2h)	3639 h (459 shifts)
CASE 4	I-V and 10% charge spectra 420 (7h)			420 (7h)	1794 h (225 shifts)

Timeline for QA

Consider Catania-Cosenza-Salerno-Trieste + Hamamatsu delivery + assembling in company

- ***Estimate total time needed for tests***
- ***Our table to be defined (study of protocols and time estimate)***

next: remove "?" and establish detailed needs

Step	Action	Where	Number of Actions	Total time	Notes
0	Optical inspection	Catania? Company?	?	?	Microscope
1	Assembling 4 matrices	Company	?	?	
2	IV-curve Dark at T_1	dRICH QA hub	?	2h?	Testing in CS-SA labs
3	IV-curve Light at T_1	dRICH QA hub	?	2h?	Testing in CS-SA labs
4	IV-curve Dark at T_2	dRICH QA hub	?	2h?	Testing in CS-SA labs
5	IV-curve Light at T_2	dRICH QA hub	?	2h?	Testing in CS-SA labs
6	IV-curve Dark at T_3	dRICH QA hub	?	2h?	Testing in CS-SA labs
7	IV-curve Light at T_3	dRICH QA hub	?	2h?	Testing in CS-SA labs
8	IV-curve Light at -40°C	dRICH QA hub	?	2h?	Sub-sample
9	Logbook + DB	dRICH QA hub	?	0.5h?	Writing notes + data sharing
Define cases	according to previous considerations			?	shifts?

Manpower

- ***Current manpower in Catania***
  - 1 tenured faculty: *Cristina Tuvé*
  - 1 undergrad student
- ***Current manpower in Cosenza***
  - 3 tenured faculties: *Enrico Tassi, Marcella Capua, Salvatore Fazio*
  - 1 PhD student: *Luisa Occhiuto*
  - 1 undergrad student: *Cristian Romeo*
  - 1 technician: *Vittorio Romano*
  - Hiring manpower dedicated to QA tests: 1 postdoc + undergraduates and a master student
- ***Current manpower in Salerno***
  - 3 tenured faculties: *Daniele De Gruttola, Annalisa De Caro, Alberto Calivà*
  - 1 postdoc: *Cristina Ripoli*
  - 1 technician: *Nicola Funicello*
  - Possibly hiring manpower dedicated to QA tests in the future (students+tenured faculties)
- ***+ Trieste***

- Continuous activity in our sites foreseen during QA phases
- Shifts to be performed by dedicated people

Conclusions

- ***Available manpower*** from Catania-Cosenza-Salerno-Trieste
- ***Laboratories*** equipped and operational in Cosenza and Salerno (and Trieste)
- Characterization studies performed and QA protocol to be defined
- Sites can perform ***QA tests in parallel***
- ***Redundancy*** is also crucial as backup in case of issues

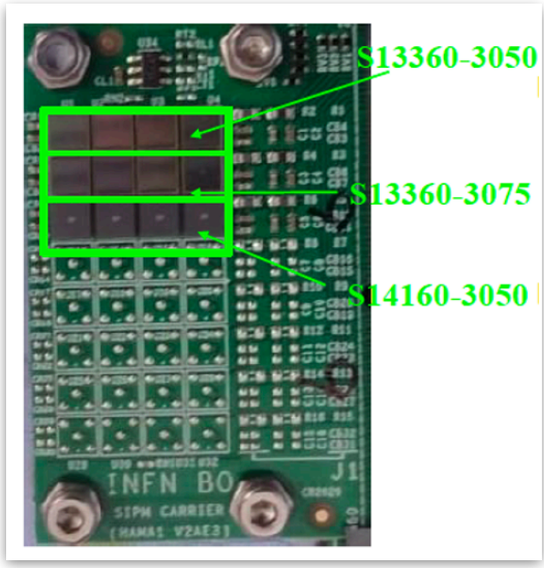
- Ongoing brain-storming in Bologna-Catania-Cosenza-Salerno-Trieste groups
- Test pipeline being defined to be ready in ~1 year
- ***Detailed pipeline, database and checklist*** will be crucial

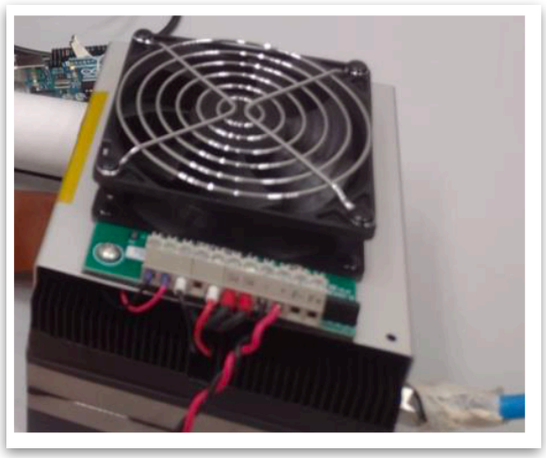
Backup

Set-up to test SiPMs @UNICAL

Experimental setup in Cosenza

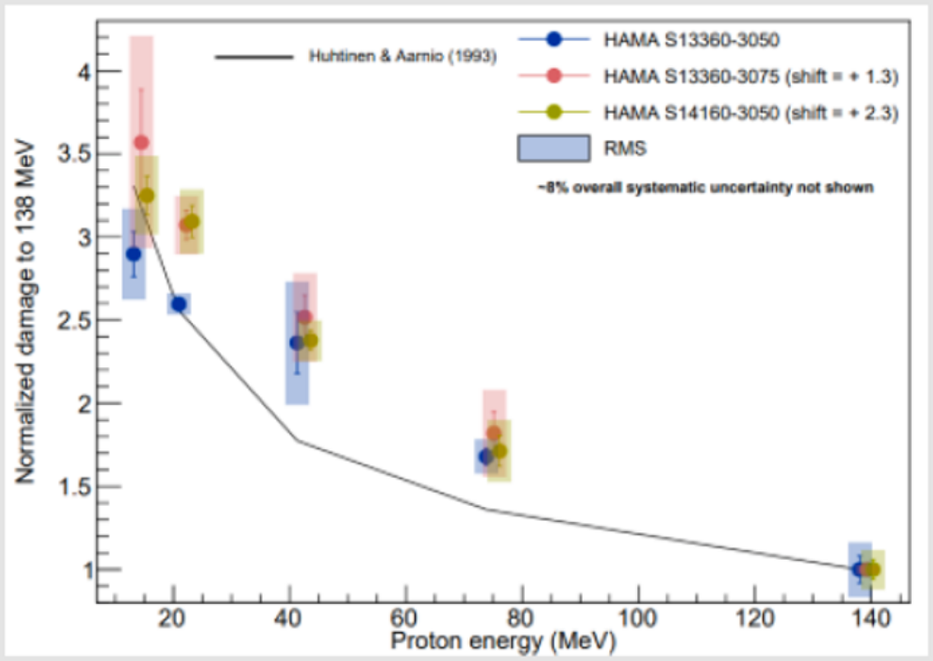
- boards hosting **SiPMs**
- custom made portable **Peltier box**
- ultrapure air tanks to **control humidity** in the inner box
- **Adapter** board to regulate the **voltage** supplied to the SiPMs
- **ALCOR board** for the data acquisition
- A relative **humidity and temperature sensor** (Arduino)
- A **Master Logic board** for communication with the adapter board
- An **FPGA** to program and read the ALCOR data
- *Grafana* web application to monitor operations





Set-up to test SiPMs @UNICAL

PRELIMINARY RESULTS



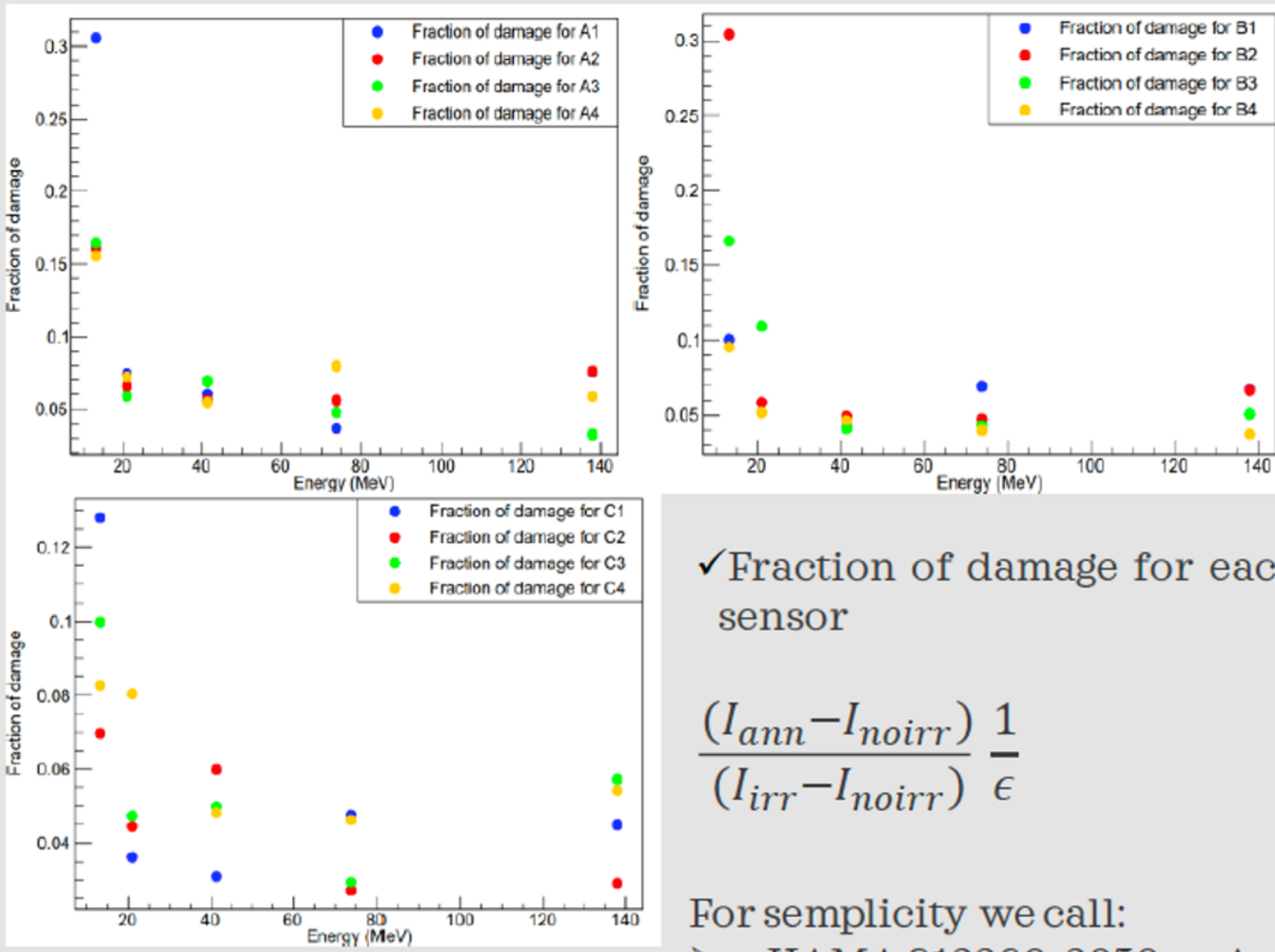
✓ Comparison of radiation damage for each sensor vs radiation damage by NIEL.

$$\frac{(I_{irr}-I_{noirr})}{(I_{irr}-I_{noirr})(138\,MeV)}\,\frac{1}{\epsilon}$$

ϵ = efficiency of degrader.

ENERGY SCAN

Overvoltage = Dark current - Vbd



✓Fraction of damage for each sensor

$$\frac{(I_{ann}-I_{noirr})}{(I_{irr}-I_{noirr})}\,\frac{1}{\epsilon}$$

For semplicity we call:

- HAMA S13360-3050 == A
- HAMA S13360-3075 == B
- HAMA S14160-3050 == C