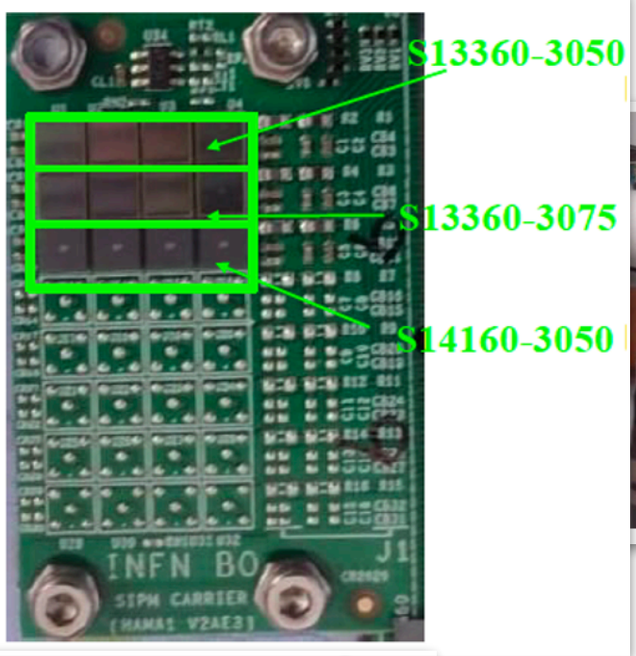

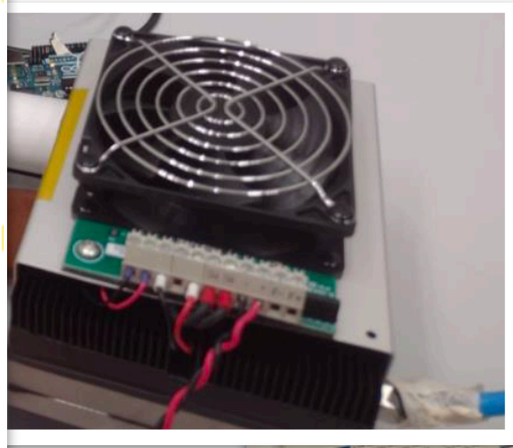

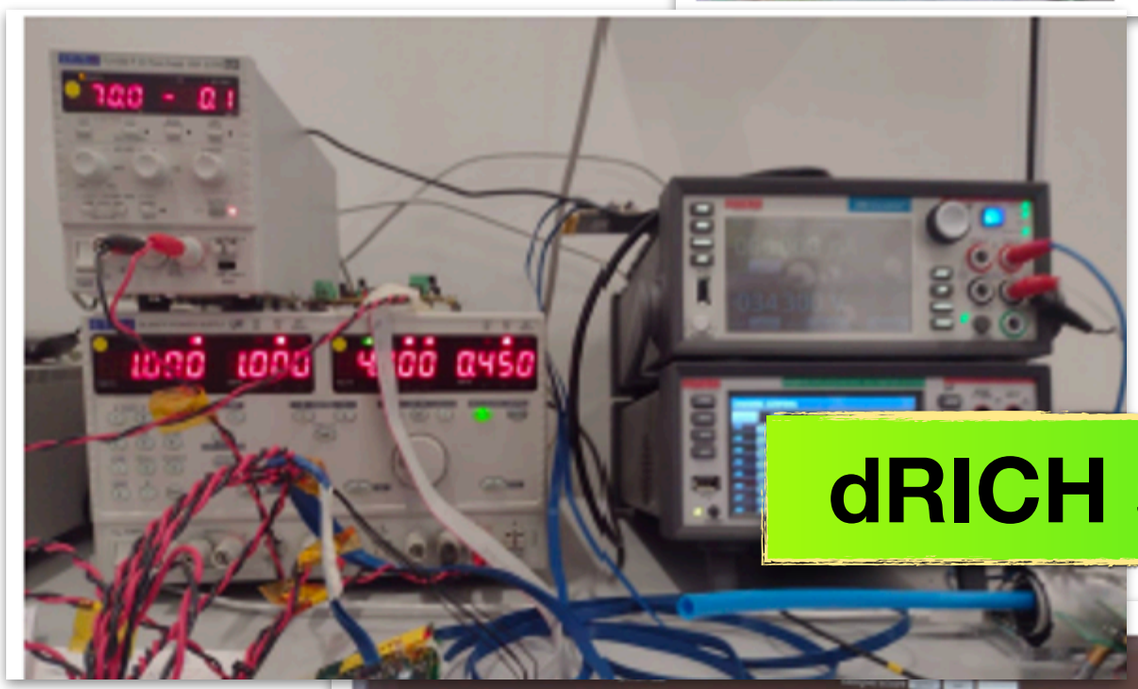

dRICH sensors

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dRICH SiPMs

- These slides are a starting point for the content to be shown at the next *Giornate Nazionali in Padova*
- Recent activities and *plans* will be discussed
- Summary of activities in Bologna not shown in these slides (see timetable)
- *INFN Sections involved* in sensors activity
  - Bologna
  - Catania
  - Cosenza
  - Salerno
  - Trieste

dRICH SiPMs

- *Extensive studies done* in Bologna lab and @CERN (beam tests)
- Irradiation campaigns done @ TIFPA, LNL and GIF++ and annealing procedures
- *Catania, Cosenza and Salerno* participated to *irradiation* and *beam tests*
- Catania, Cosenza, Salerno are creating a *"South Italy" hub*
- Part of the measurements have been done in Cosenza and Salerno with the aim to prepare a *robust setup for QA* during SiPM carriers mass production
- *Trieste* is going to join the effort for long term tests
- Part of the analysis on irradiated sensors done in Cosenza and Catania

*Activity in INFN sections in 2023-24 (in collaboration with Bologna)**

- Beam tests on dRICH prototype (CT,CS,SA)
- Irradiation campaigns with protons @TIFPA, LNL and GIF++ (CT,CS,SA)
- Irradiation campaigns with neutrons @LNL (CT,CS,SA)
- Irradiation campaigns with gamma @GIF++ (CT,CS,SA)
- Energy scan study after irradiation with p,n (CT,CS)
- Study of IV curves after irradiation with γ (CT,CS,SA)

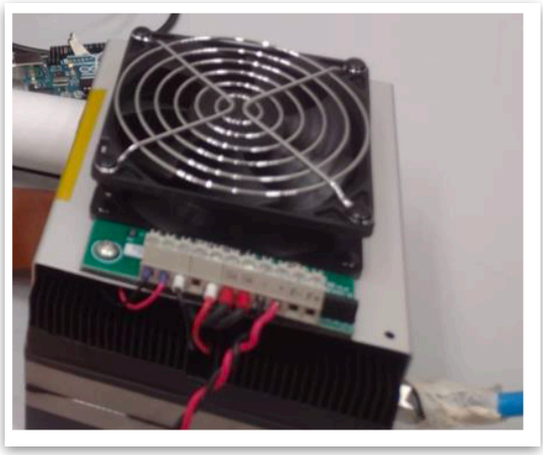
Activity in INFN sections in 2025

- IV measurements (SA) in order to reproduce the CS setup (adding multiplexer)
- Study of a new air box (SA) with temperature and humidity sensors and setup to stabilize T
- Define the strategy for QA during mass production (CT,CS,SA,TS)

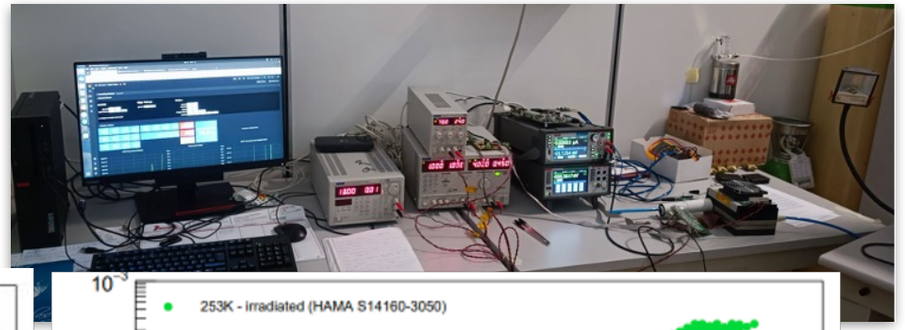
** This is not an exhaustive list; it only includes the activities related to the sensors*

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

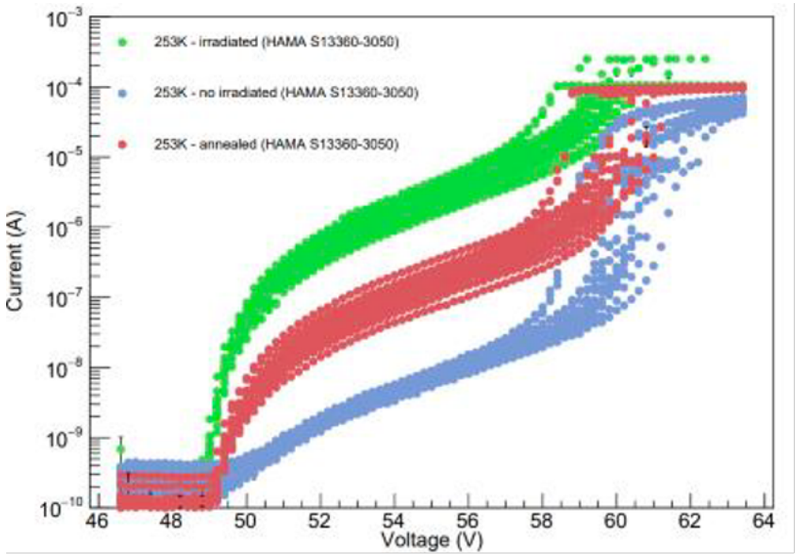


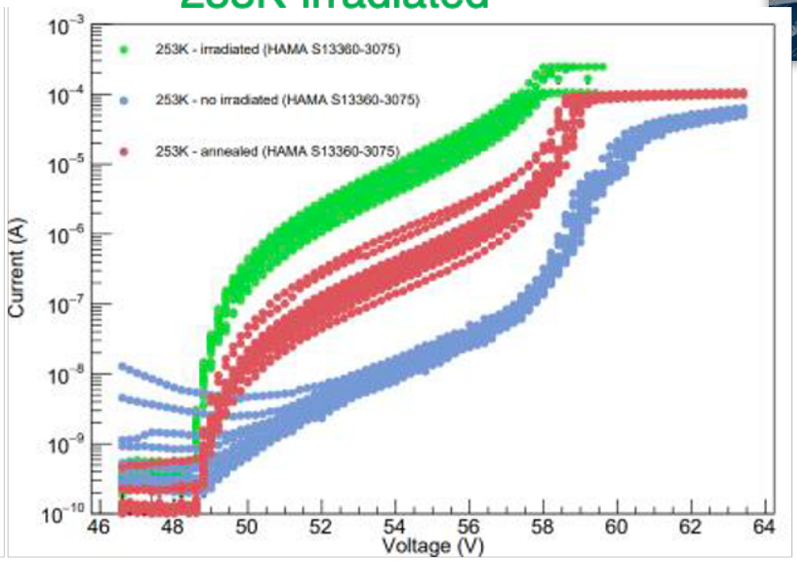
- **Example of studies performed in 2023-2024**
  - **Three types of Hamamatsu sensors tested**
  - **Irradiation tests:** protons (TIFPA-Trento); neutrons (CN-Legnaro); gamma (GIF-CERN)
  - **SiPMs characterization:** study of damage by protons and gammas

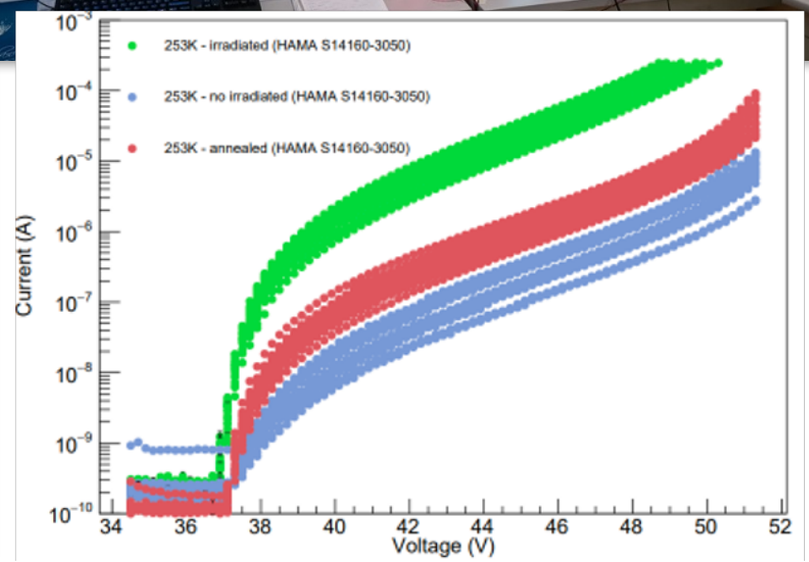


- 253K-no irradiated
- 253K-annealed
- 253K-irradiated

IV-curves







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

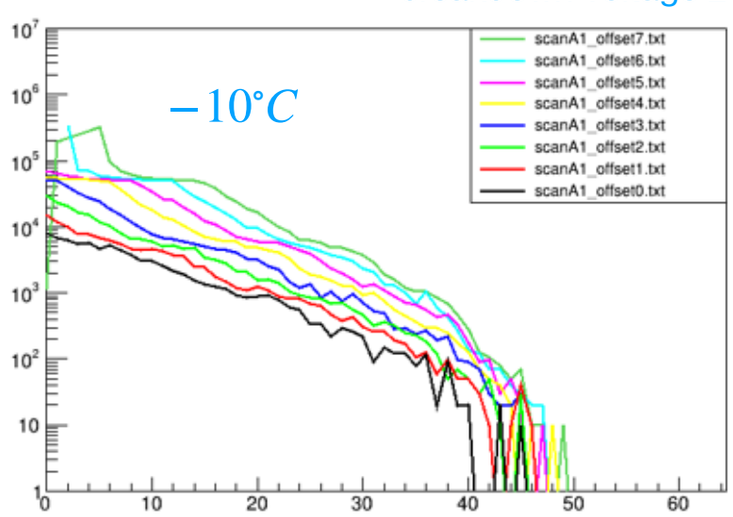
Set-up to test SiPM @UNISA

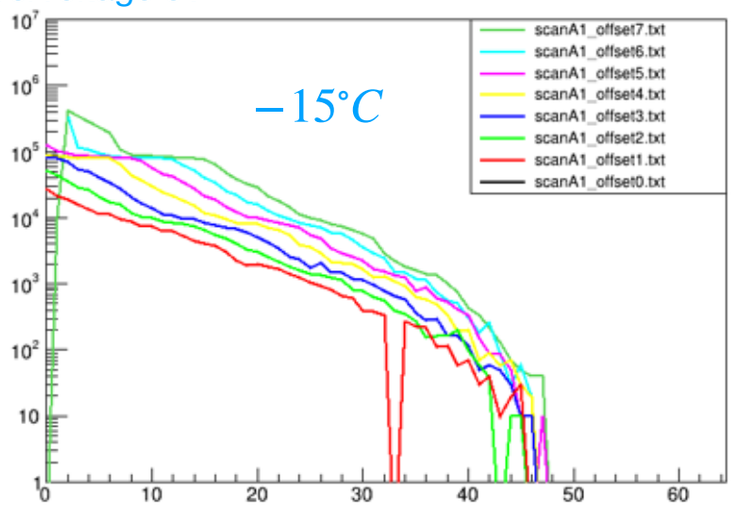
- Idea to build a larger AirBox and use a dewar to go down in temperature
- AirBox + Peltier + dewar (SiPM HV on)
  Low temperature far away from dew point

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

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)

In a few moths Salerno a new lab (founded by PNRR) will be available → clean site with more space to install the setup

QA strategy

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**

dRICH meeting 12/02/2025

QA meetings started in April (more or less bi-weekly each Thursday)

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**

dRICH meeting 12/02/2025

to be discussed

Tests after assembling in Cosenza-Salerno labs

QA strategy for dRICH SiPMs

- ***QA tests - what***
  - Electrical inspection (on nude matrix? on assembled carrier?)
  - IV curves, breakdown
  - Tests vs temperature
  - Ensure to be stable in temperature (**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)

dRICH meeting 12/02/2025

basic - SiPM functionality - IV at fixed T (measure breakdown)
IV vs T to be discussed - maybe tests on subsamples

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

dRICH meeting 12/02/2025

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?

basic - SiPM functionality - IV at fixed T (measure breakdown)
IV vs T to be discussed - maybe tests on subsamples

Basic tests

- 1500 carriers to be tested over two years (starting in 2027?)
- IV at a fixed T $\rightarrow \sim 2.5h$ (30s per SiPM)
- 3 carriers per day in one lab
- Possibility to perform IV in 2 labs (CS, SA) in 250 days $\rightarrow 1500$ carriers in one year

Enough time to add more tests

- IV vs T → to be discussed
- Dark/light tests → to be discussed

On carriers subsample?

On small percentage of sensors on all carriers?

Activity in 2025

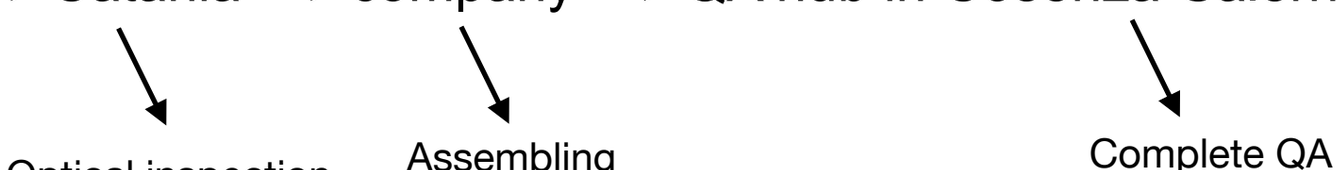
- Focus on QA strategy
- Focus on optimizing the setup (software+hardware) to speed up basic tests wrt R&D phase

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 (*back-up needed*)

Option 1) preferred to avoid too many transfers

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 being defined
- Sites can perform ***QA tests in parallel***
- ***Redundancy*** is also crucial as backup (TS) in case of issues

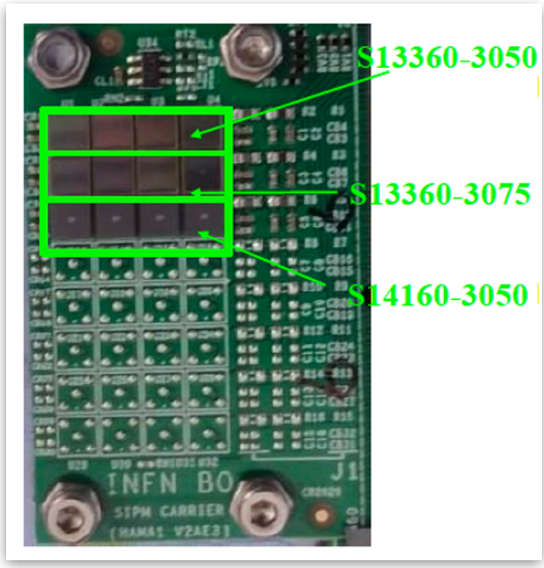
- Ongoing brain-storming in Bologna-Catania-Cosenza-Salerno-Trieste groups
- Test pipeline being defined to be ready in ~1 year
- ***Detailed pipeline, database and checklist*** will be crucial

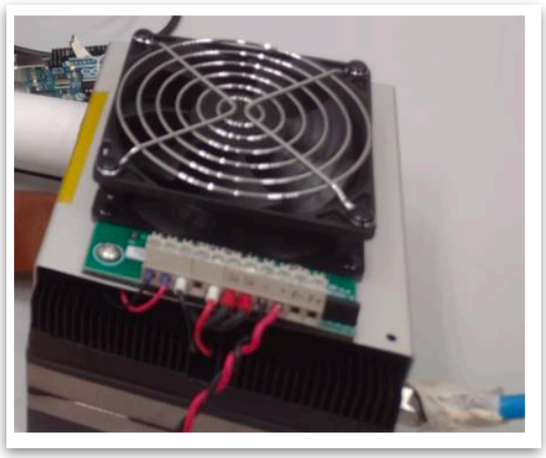
Backup

Set-up to test SiPMs @UNICAL

Experimental setup in Cosenza

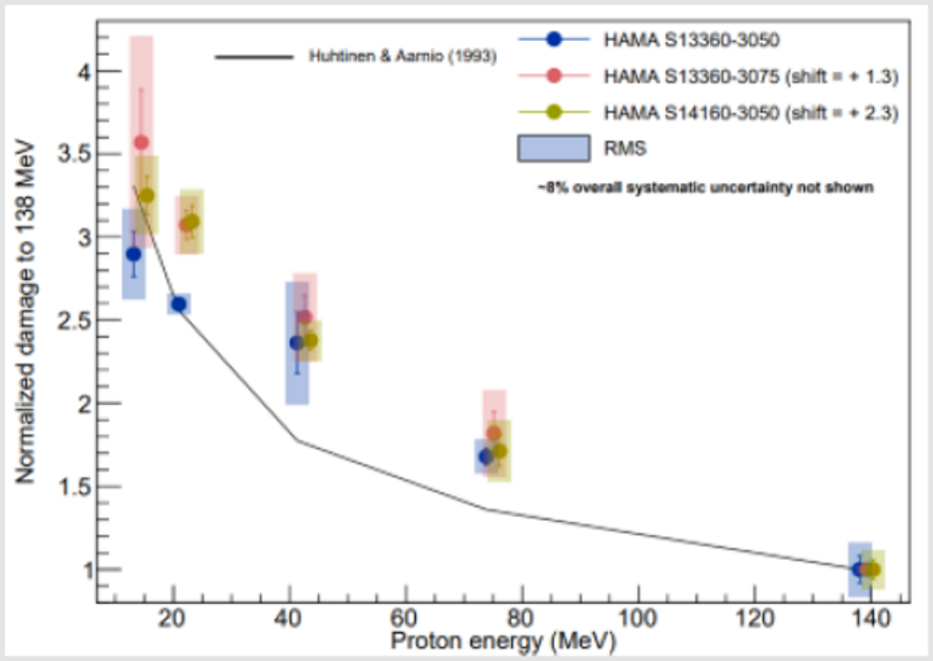
- boards hosting **SiPMs**
- custom made portable **Peltier box**
- ultrapure air tanks to **control humidity** in the inner box
- **Adapter** board to regulate the **voltage** supplied to the SiPMs
- **ALCOR board** for the data acquisition
- A relative **humidity and temperature sensor** (Arduino)
- 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



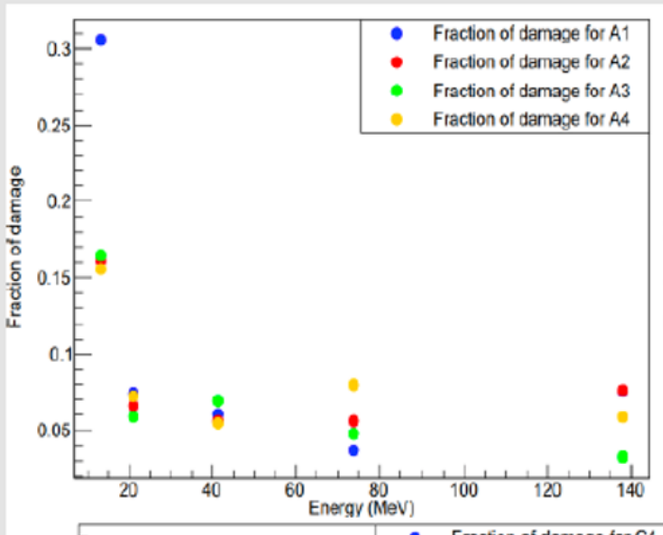
✓ Comparison of radiation damage for each sensor vs radiation damage by NIEL.

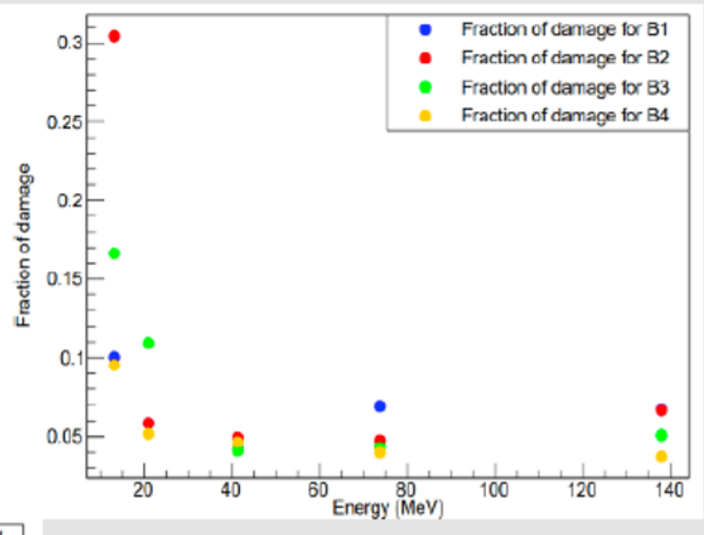
$$\frac{(I_{irr}-I_{noirr})}{(I_{irr}-I_{noirr})(138\,MeV)}\,\frac{1}{\epsilon}$$

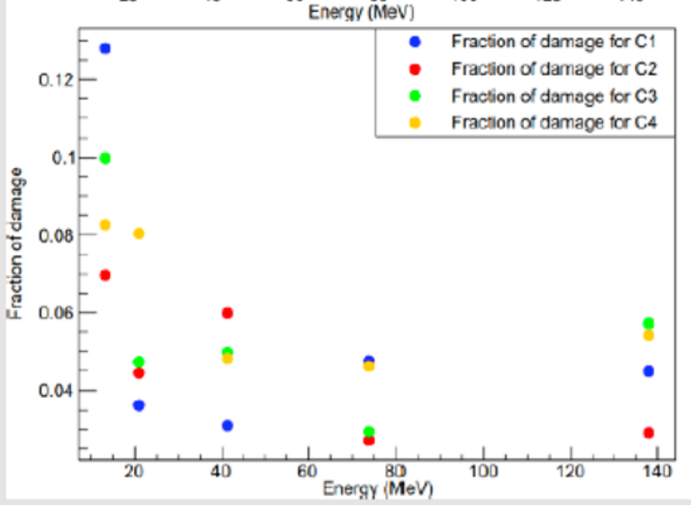
ϵ = efficiency of degrader.

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