SiPMs proton energy scan

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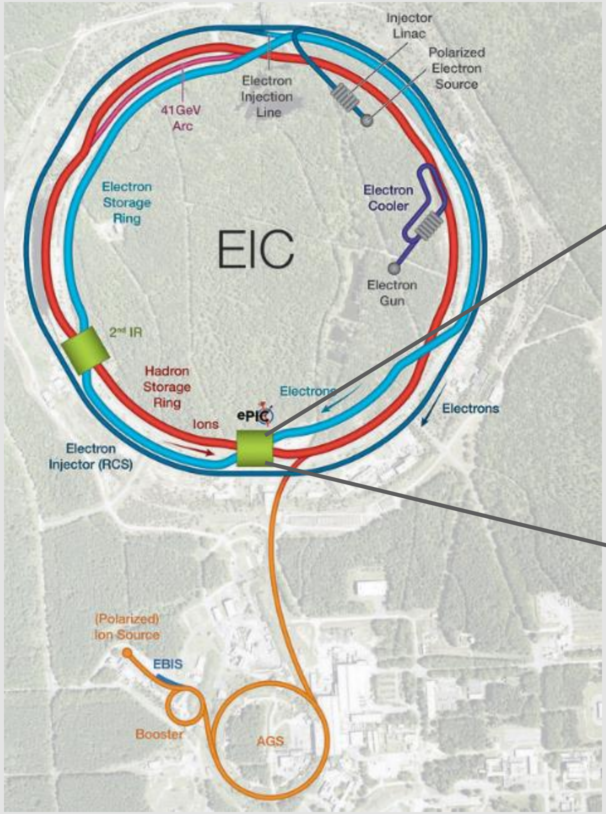
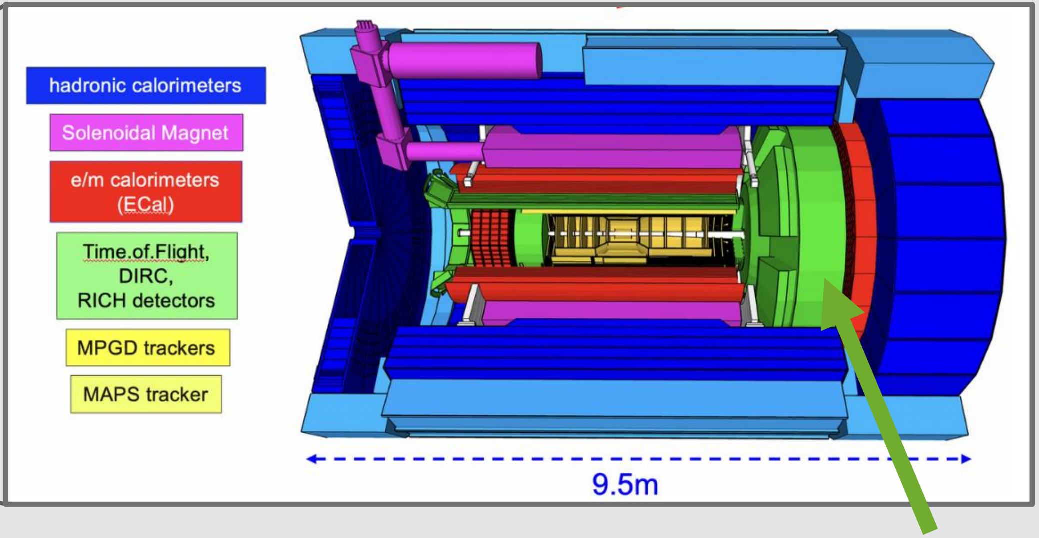
01

INTRODUCTION

THE ELECTRON-ION COLLIDER AND THE ePIC EXPERIMENT



Key capability: particle tracking and identification (**PID**), aiming to separate electrons from pions, kaons and protons.



- ✓ **Two radiators**: aerogel ($n \sim 1.02$), C2F6($n \sim 1.008$)
- ✓ **Mirrors:** 6 large open sectors with radius 220 cm
- ✓ **SiPM sensors**

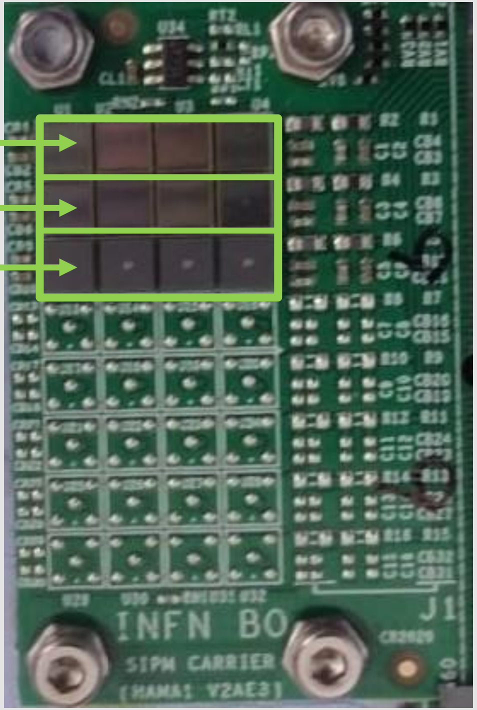
Silicon Photomultiplier Sensors (SiPM)

Sensors: 3x3 mm^2 pixel

PRO
- ✓ Single photon detection;
- ✓ High Photon Detection Efficiency;
- ✓ Good time resolution;
- ✓ Insensitive to magnetic field.
- ✓ Cheap

CONS:
- ✓ Large Dark Count Rate (DCR)
- ✓ Prone to radiation damage

HAMA S13360-3050
HAMA S13360-3075
HAMA S14160-3050



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- ❖ The Dark Dount Rate (signal per unit of time observed in absence of a photon beam) can be reduced by operating at low temperatures ($\sim[-20,\ -30]\ °C$).

- ❖ Effect of radiation on SiPMs depends of various factor:

1. Type of radiation
2. Energy of the particles
3. Radiation dose
4. Duration of exposure

- ❖ Radiation damage by Non-Ionizing Energy Loss (**NIEL**) leads to displacement damages and build up of crystal defects that results basically in increased DCR http://rd50.web.cern.ch/NIEL/default.html.
- ❖ Different particles → different interaction → different damage.

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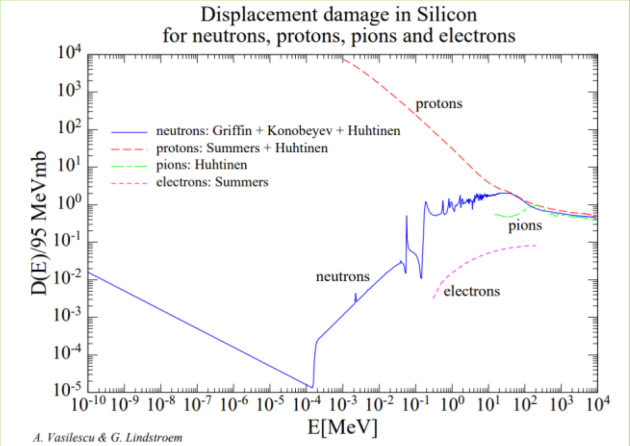
❖ The hardness factor k is used to normalize the damage caused by different incident particles relative to a reference particle, in this case a 1 MeV neutron.

❖ This allows us to compare the damage caused by particles with different energies on a common scale.

$$k = \frac{D_{particle}}{D_n(1\ \mathrm{MeV\ n_{eq}})} = \frac{D_{particle}}{95\ \mathrm{MeV\ mb}}$$



❖ Where D is the displacement damage cross section.

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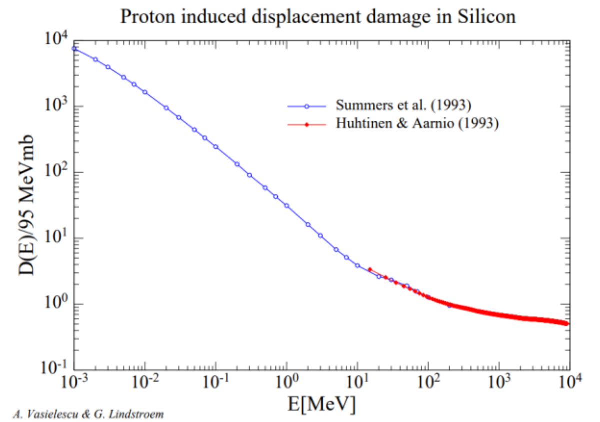

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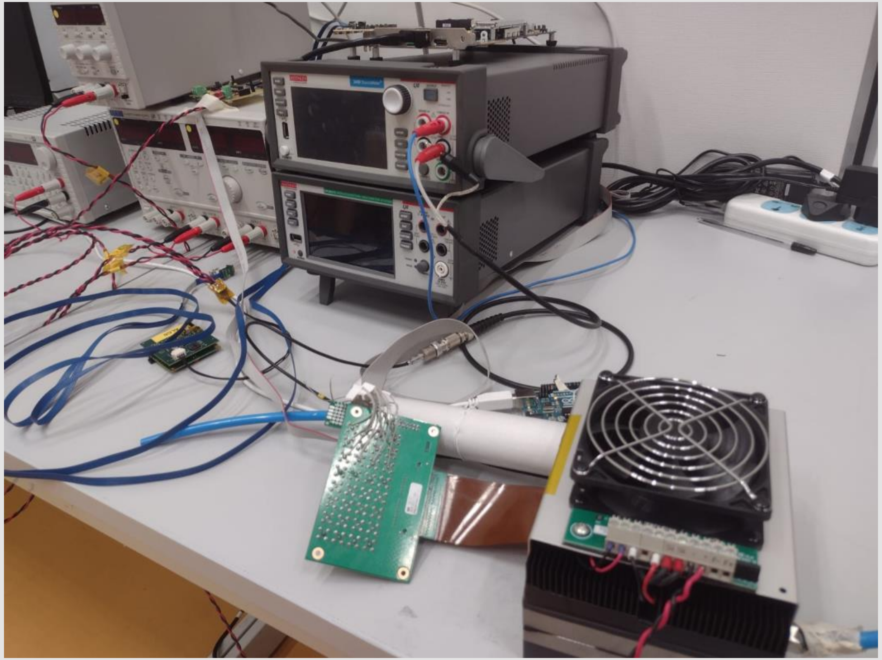
02

I-V CHARACTERIZATION

I-V CHARACTERIZATION

Characterization setup for I-V characteristic installed in Cosenza, University of Calabria.



- Custom made portable Peltier box
- Ultra pure air tanks
- Multiplexer
- Source Meter
- Power supplies
- Adapter board
- SiPM boards

1° step of measurements

- ✓ 5 boards analyzed.
- ✓ Data acquisition of I-V characteristic @ 253 K.

- Irradiation with different energies @ fixed fluence, 10^9 p/cm^2.
- To lower energy: IBA Solid Plate Phantom (**RW3**).

#Board	Energy scan (MeV)	RW3 thickness (mm)
1	138	0
2	73	88
3	41	116
4	20	127
5	13	131

- Custom made portable Peltier box
- Ultra pure air tanks
- Multiplexer
- Source Meter
- Power supplies
- Adapter board
- SiPM boards

2° step of measurements

- ✓ 5 boards analyzed.
- ✓ Data acquisition of I-V characteristic @ 253 K.

- Irradiation with different energies @ fixed fluence, 10^9 p/cm^2.
- To lower energy: IBA Solid Plate Phantom (RW3)

#Board		
1		
2	73	88
3	41	116
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- made portable Peltier box
- re air tanks
- exer
- Meter
- upplies
- board
- boards

Oven annealing: 150 h @ 150 °C

<u>3° step of measurements</u>

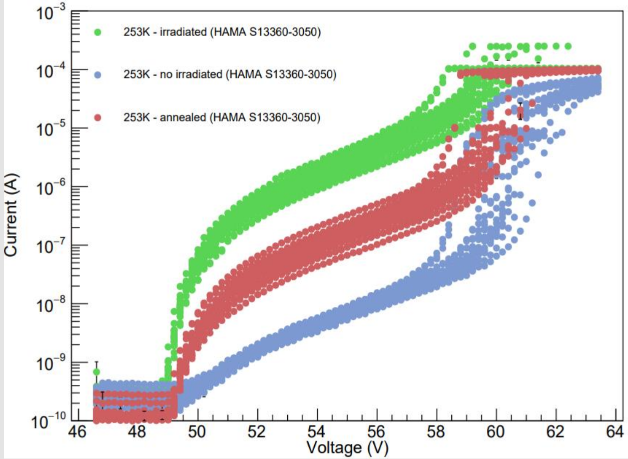
- ✓ 5 boards analyzed.
- ✓ Data acquisition of I-V characteristic @ 253 K.

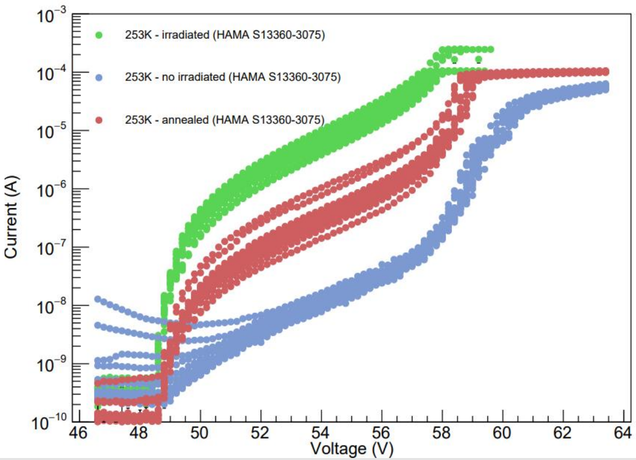
03

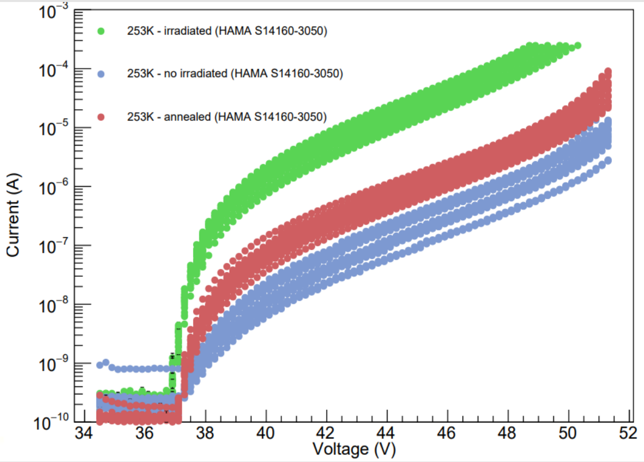
RESULTS

I-V CHARACTERISTIC

- 253K- not irradiated
- 253K- annealed
- 253K- irradiated





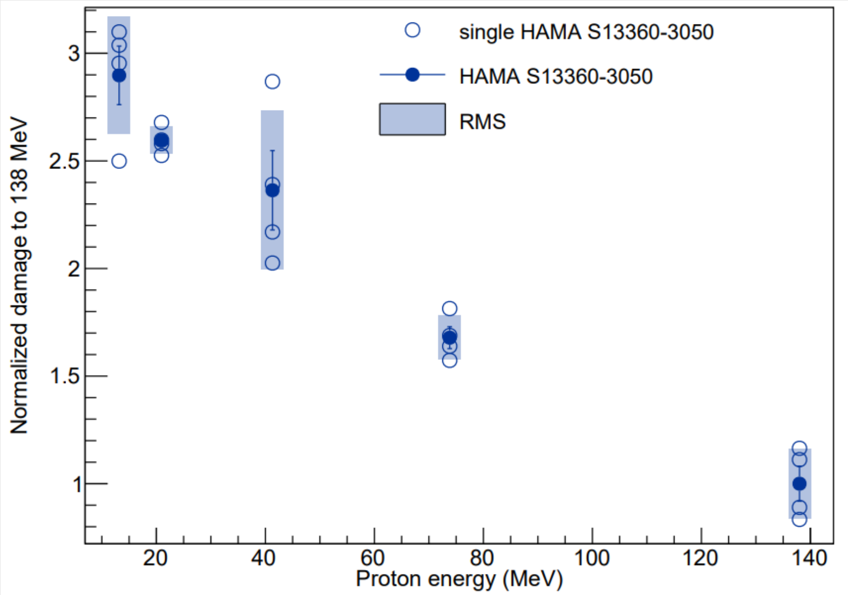


Overvoltage = Dark current - Vbd

ENERGY SCAN

- ✓ Evaluation of breakdown voltage (Vbd).
- ✓ Evaluation of current at 3 Overvoltage.
- ✓ Evaluation of difference between current post and pre irradiation.
- ✓ Normalization at 138 MeV.

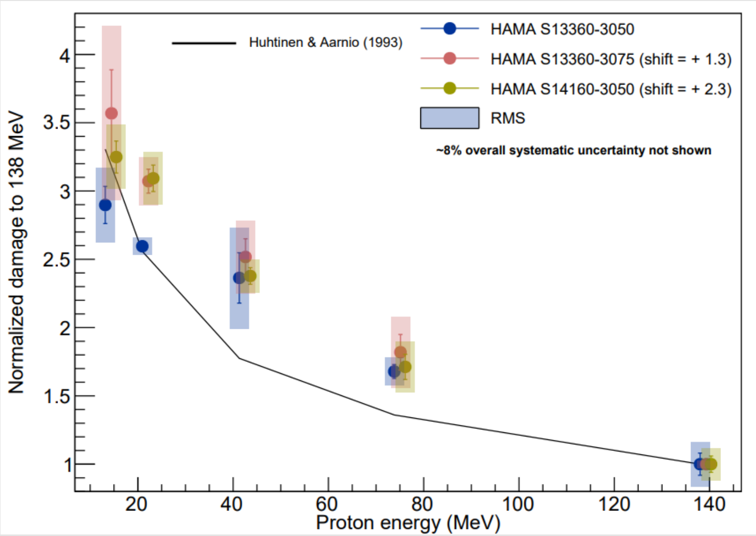
$$\frac{(I_{irr} - I_{noirr})}{(I_{irr} - I_{noirr})(138\ MeV)}\ \frac{1}{\epsilon}$$



ϵ =efficiency of degrader.

ENERGY SCAN

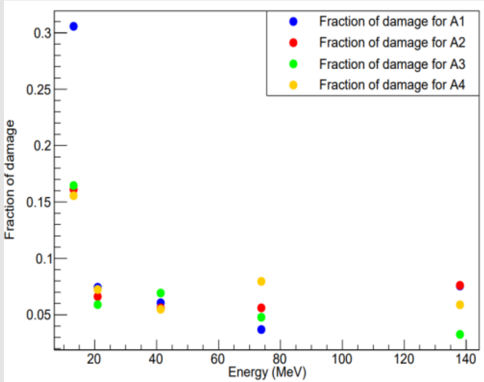
Overvoltage = Dark current - Vbd

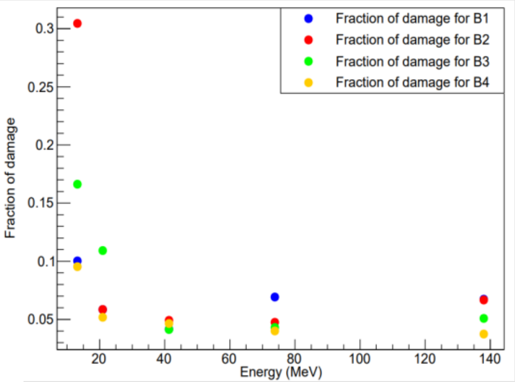


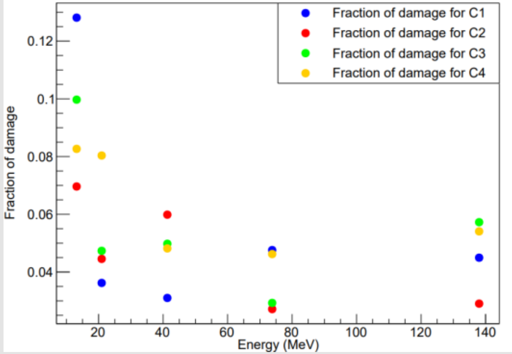
- ✓ Displacement damage for each sensor.
- ✓ A proton at 13 MeV is more harmful than a proton at 138 MeV.

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

ϵ =efficiency of degrader.







- ✓ 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

04

CONCLUSION AND OUTLOOK

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SiPMs

CHARACTERIZATION

- ✓ Radiation damage is in agreement with the NIEL.
- ✓ With annealing there is a recovery of the performance of the sensors independent of the energy used to irradiate them.
- ✓ Next step: paper being written.

OUTLOOK

γ RAYS

- ✓ Irradiation of the sensors with gamma rays in order to study surface damages.

THANKS!