AUTOMATIZED DARK CURRENT MEASUREMENT SYSTEM FOR IRRADIATED SIPM DETECTORS IN COSY

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Mitglied der Helmholtz-Gemeinschaft

JÜLICH
Forschungszentrum

OUTLINE

I) Introduction

II) SiPM Dark Current

III) Healthy vs Irradiated

IV) Experimental Setup

- Basic (Manual)
- Semi-automatic
- Completely automatized

V) Results

VI) Current Issues and Future Plans

INTRODUCTION

- SiPMs are used in the polarimeter in CoSy at Forschungszentrum Jülich along with the LYSO crystal.

- A photon, as a result of the recombination in the crystal, triggers the APD (Avalanche Photo-Diode) recording the event and the energy of the photon.

- SiPM array is a matrix of 16 (8x8) of such APD which are set to geiger mode

- For this presentation, all the SiPM array modules used and the results obtained are from

SensL ArrayJ 30020 8x8

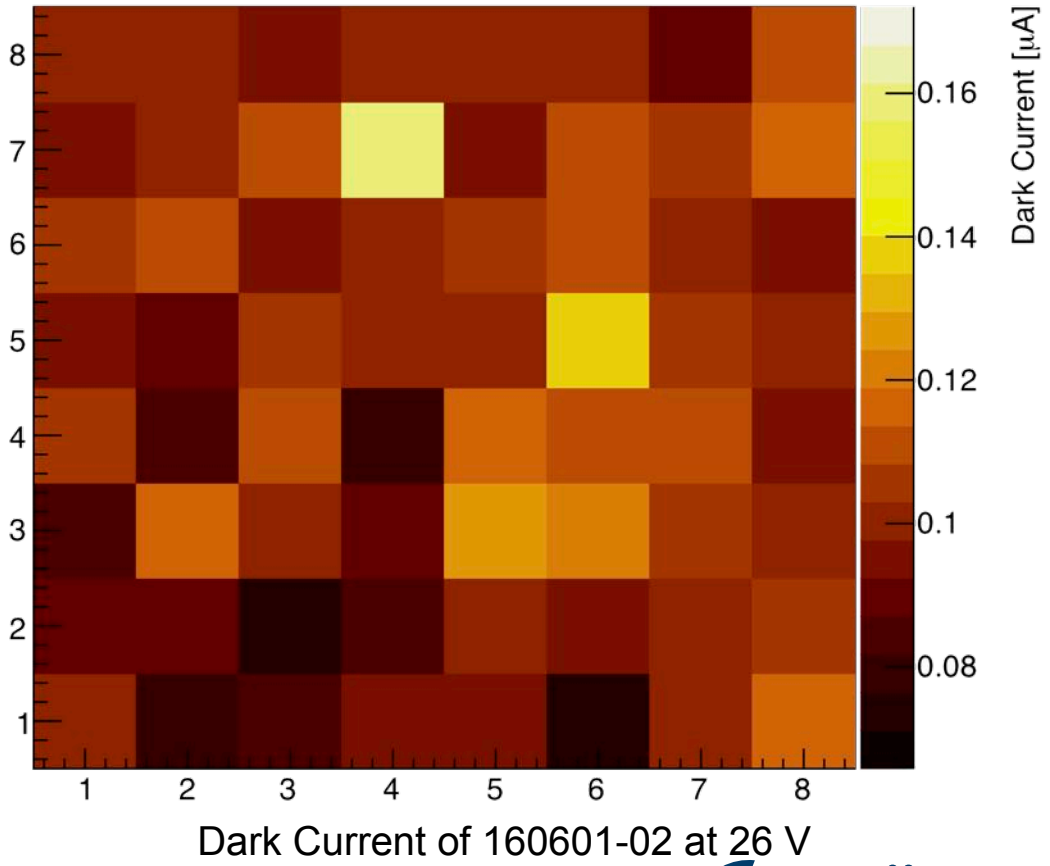
SIPM DARK CURRENT

- Dark Current is current generated in the absence of photon
  - Phenomena such as thermal excitation, defects in crystal lattice etc.

- Dark current is the noise in the signal.

- Range of dark current in our lab conditions:
  - 1 to 10 µA @ 26 V

✴ Dark current of 160601-02 @ 26 V is 6.471 µA



Dark Current of 160601-02 at 26 V

HEALTHY VS IRRADIATED

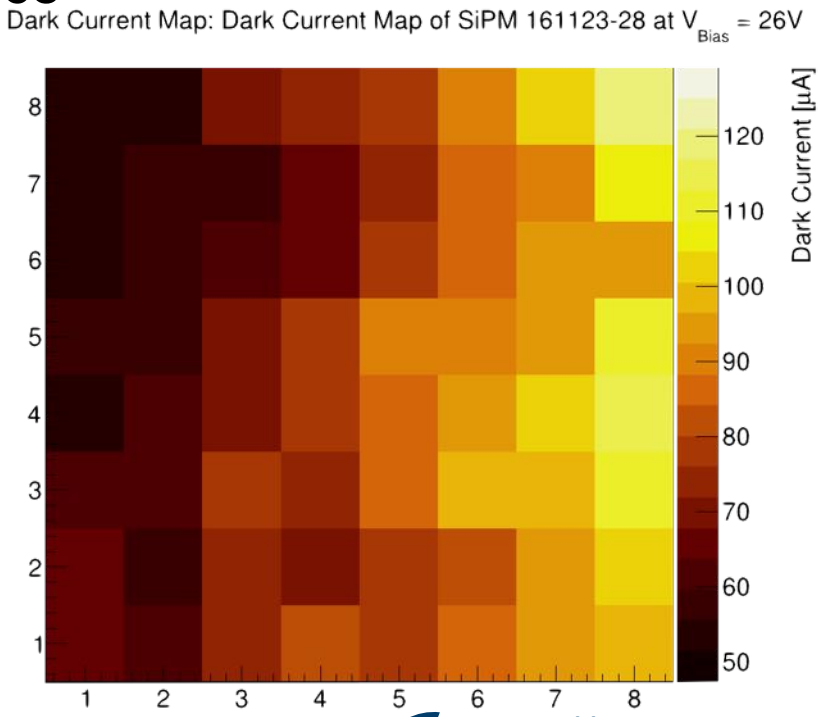
Healthy SiPM	Irradiated SiPM
Low dark current ⇒ low noise	High dark current ⇒ high noise
Very good resolution	Very low resolution
Reading are consistent over time	Reading varies because of annealing over time
In lab conditions: 1 - 10 µA at 26 V	After irradiation: 500 - 7000 µA at 26 V

Note: Values are for 8x8 SiPM matrix

INSPIRATION

- SiPMs in CoSy are exposed to radiation
- SiPMs are not completely radiation hard

- To understand the effects and to know the limitations of the device
- Need instrumentation to study irradiated SiPM?
  - Dark current of the SiPM matrix
  - Dark current of individual SiPM
  - Ability to control voltage
  - Observe the change in dark current
  - Observe the radiation effects (patterns)
  - Observe annealing effects



EXPERIMENTAL SETUP

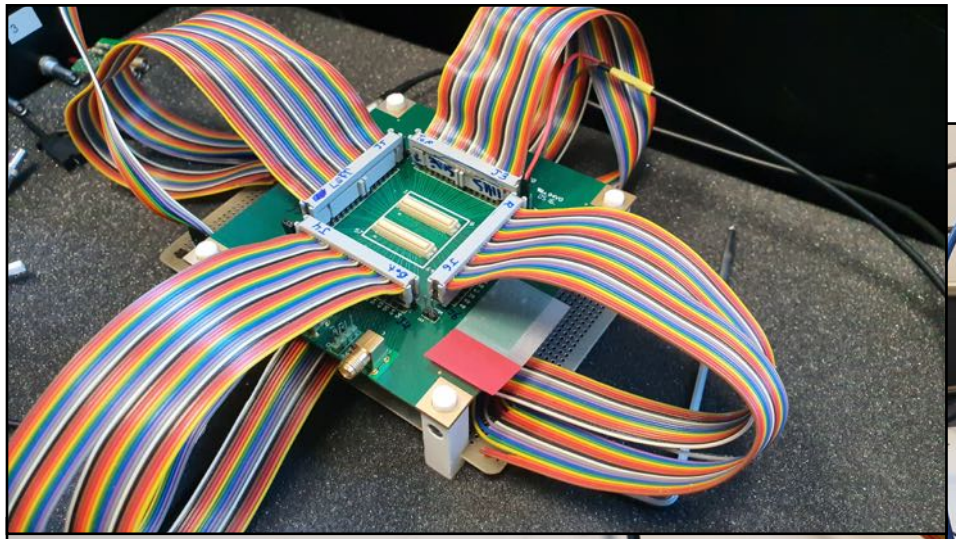
Ideas and goals to achieve

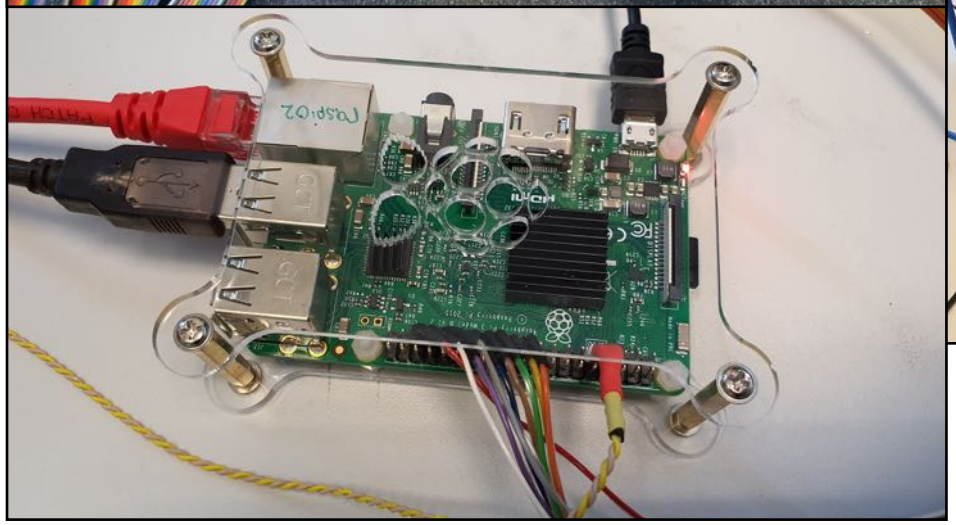
- Measure the dark current of each SiPM in the matrix
- Compare the analysis data to the old datasets (also in batch)
- Generate reports of one or several SiPMs along with their comparisons
- Change the supply voltage to the SiPMs
- Monitor recorded data live on web browser during the measurements
- Workaround for the heating issues during measurements
- Timely measurements without human intervention

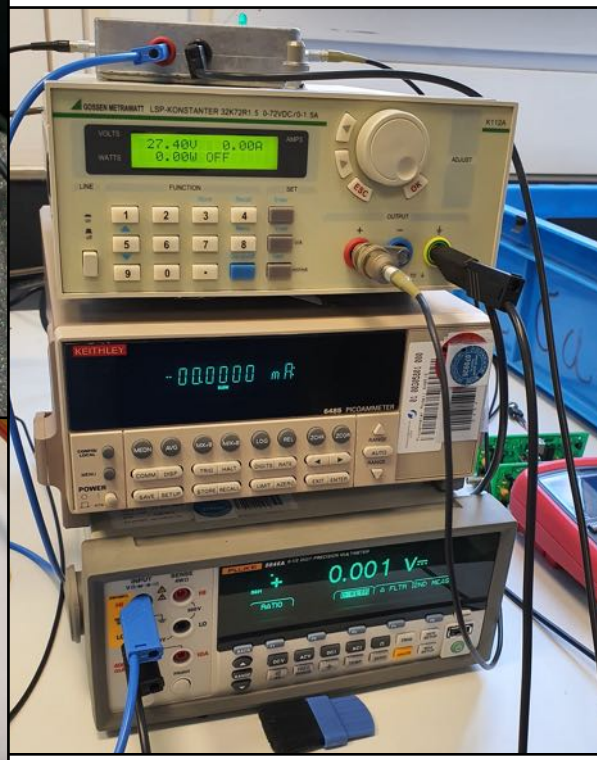
EXPERIMENTAL SETUP

Basic setup

- SiPM matrix has 64 SiPMs.
- Channeling of each SiPM from SensL SiPM development board with 5 multiplexer was designed by Dr. Fabian Müller
- Controlled by Raspberry Pi
- Measurement script on python
- Instruments:
  - Pico-ammeter - Keithley
  - Voltmeter - Fluke
  - Power supply - GW



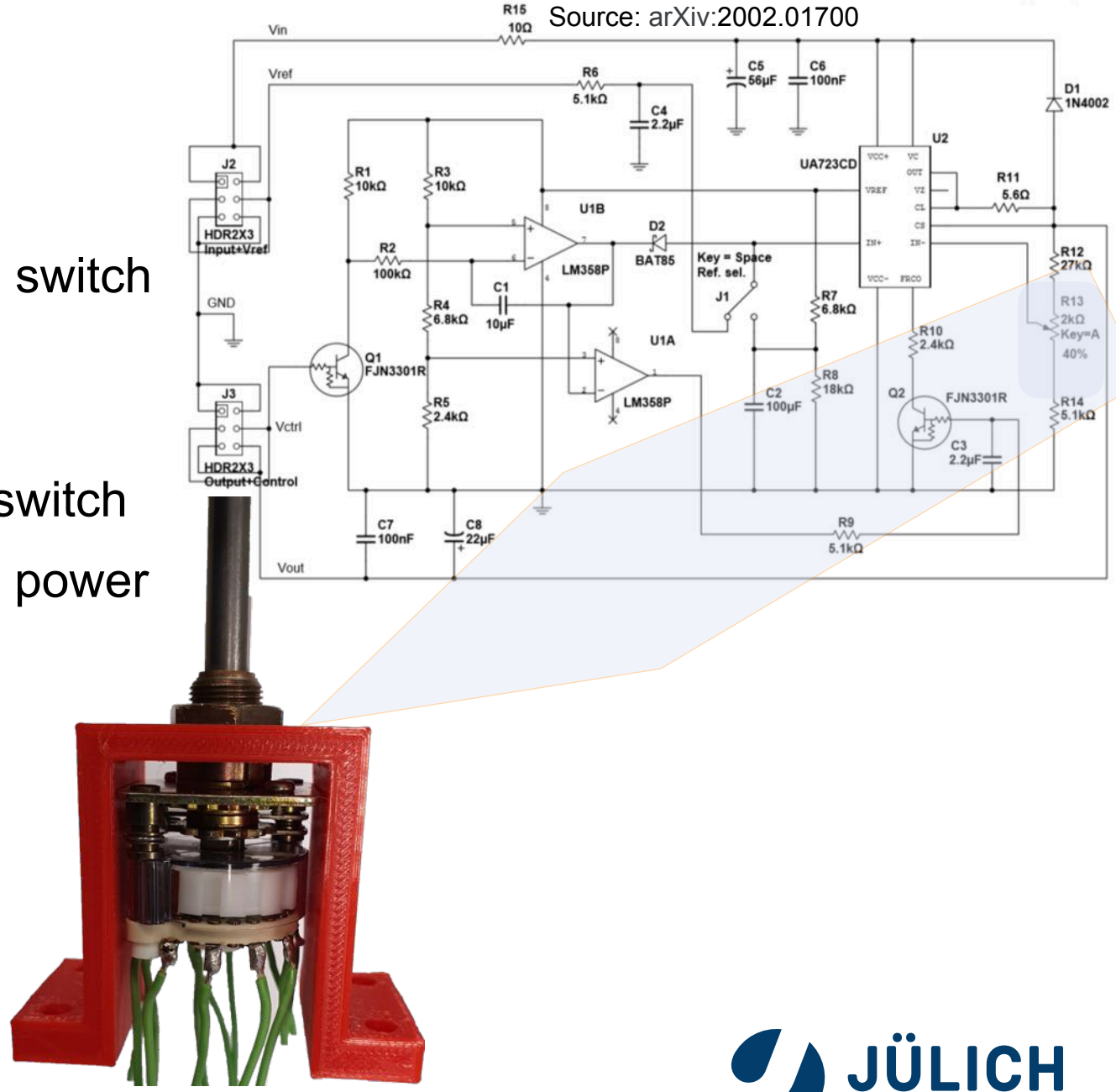




EXPERIMENTAL SETUP

Manual device

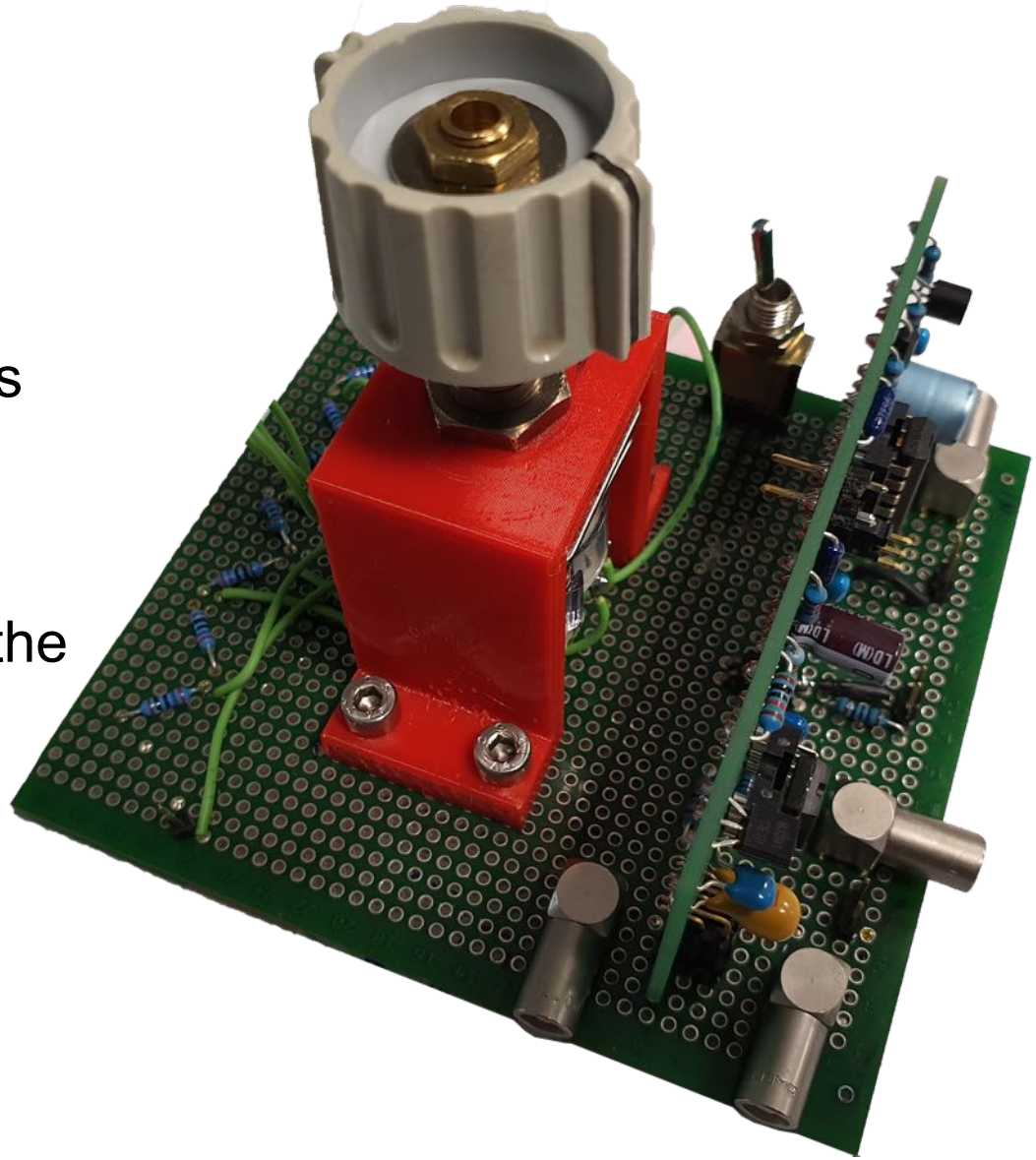
- Onboard potentiometer was replaced by a switch connecting a series of resistors
- Housing for the switch was printed
- Voltage could be changed by rotating the switch
- Separate switch to turn on and turn off the power supply



EXPERIMENTAL SETUP

Manual device

- Issues with this setup
  - Manually switching for several measurements would be tedious
  - Connector in the switch had bad contact
  - Switch added an extra varying resistance to the circuit

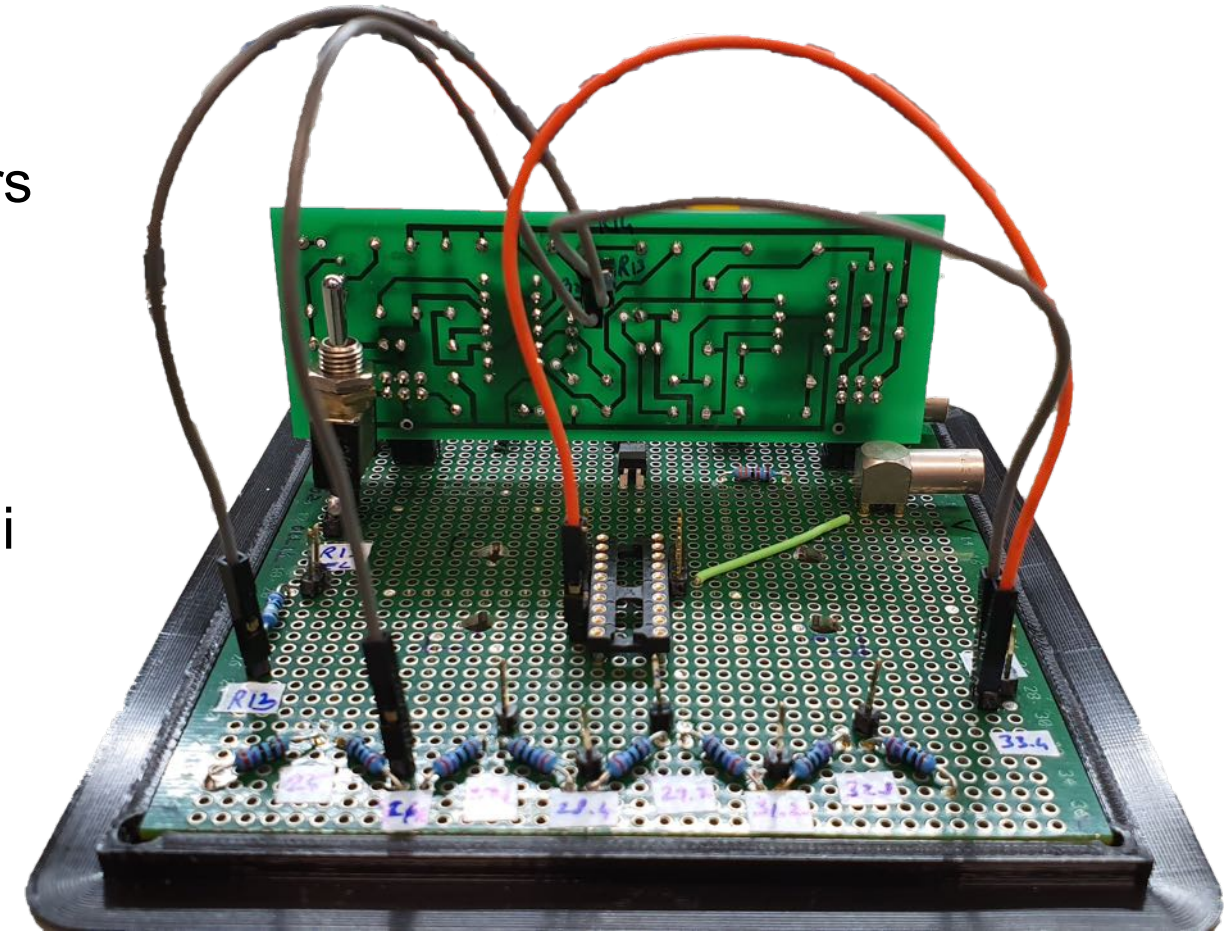


EXPERIMENTAL SETUP

Semi-automatic device

- Switch was replaced by a series of connectors around the resistors
- The connection was made manually by wires with option to add a multiplexer
- Power on / off was controlled by Raspberry Pi

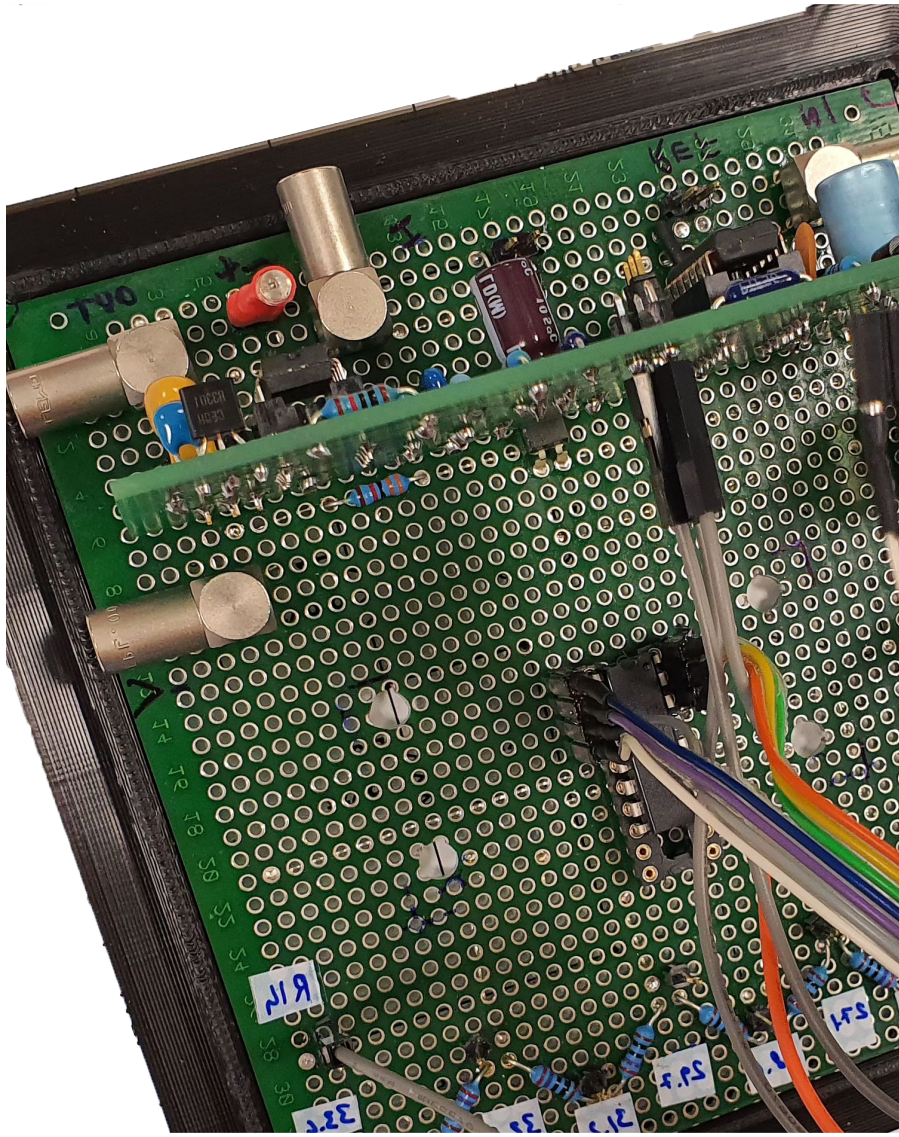
- Issues:
  - Still manual to change voltage



EXPERIMENTAL SETUP

Automatic device

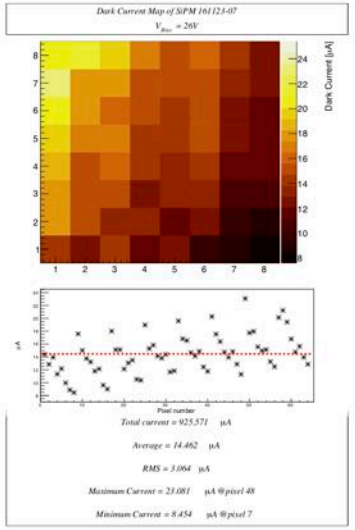
- Multiplexer was added and circuit was adjusted to choose the required resistance
- Voltage could be changed to pre-determined values through Raspberry Pi
- Scanning dark current through different voltages is possible
- An algorithm was devised to avoid heating issue - reads SiPM which are always the farthest from the previous SiPM

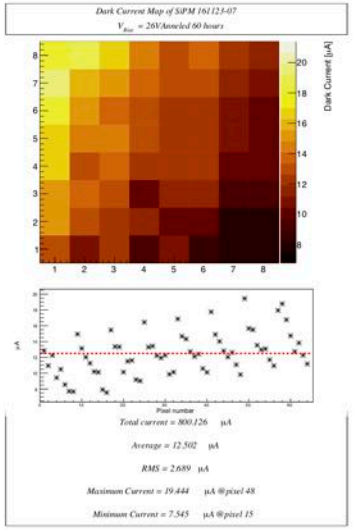


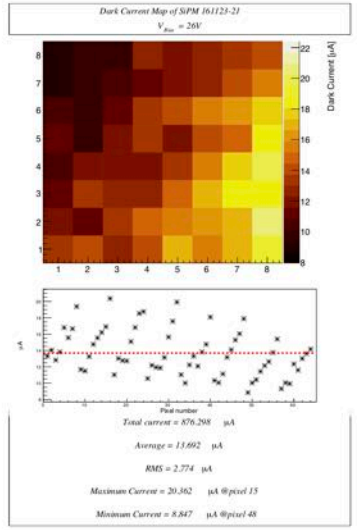
RESULTS

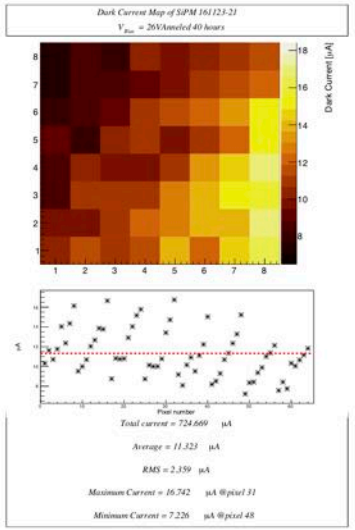
Accidental damage in CoSy

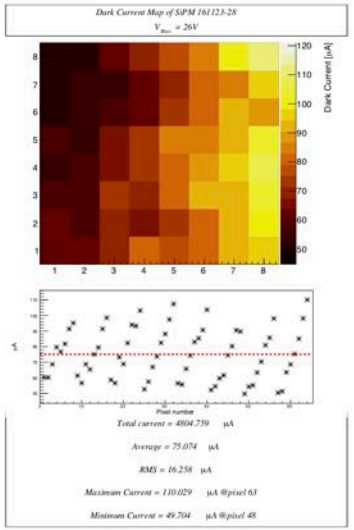
- Examples of the reports generated after the measurement
- By observing the patterns ⇨ location of the beam
- Identify defective or broken SiPM
- Observe the change in dark current after annealing in the oven

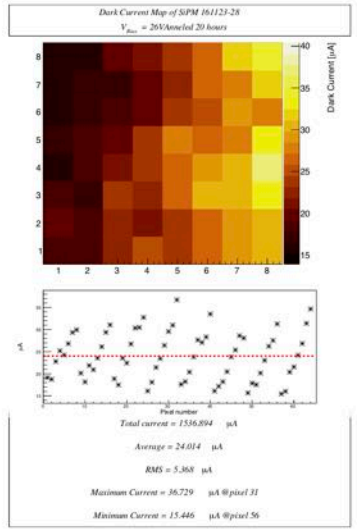












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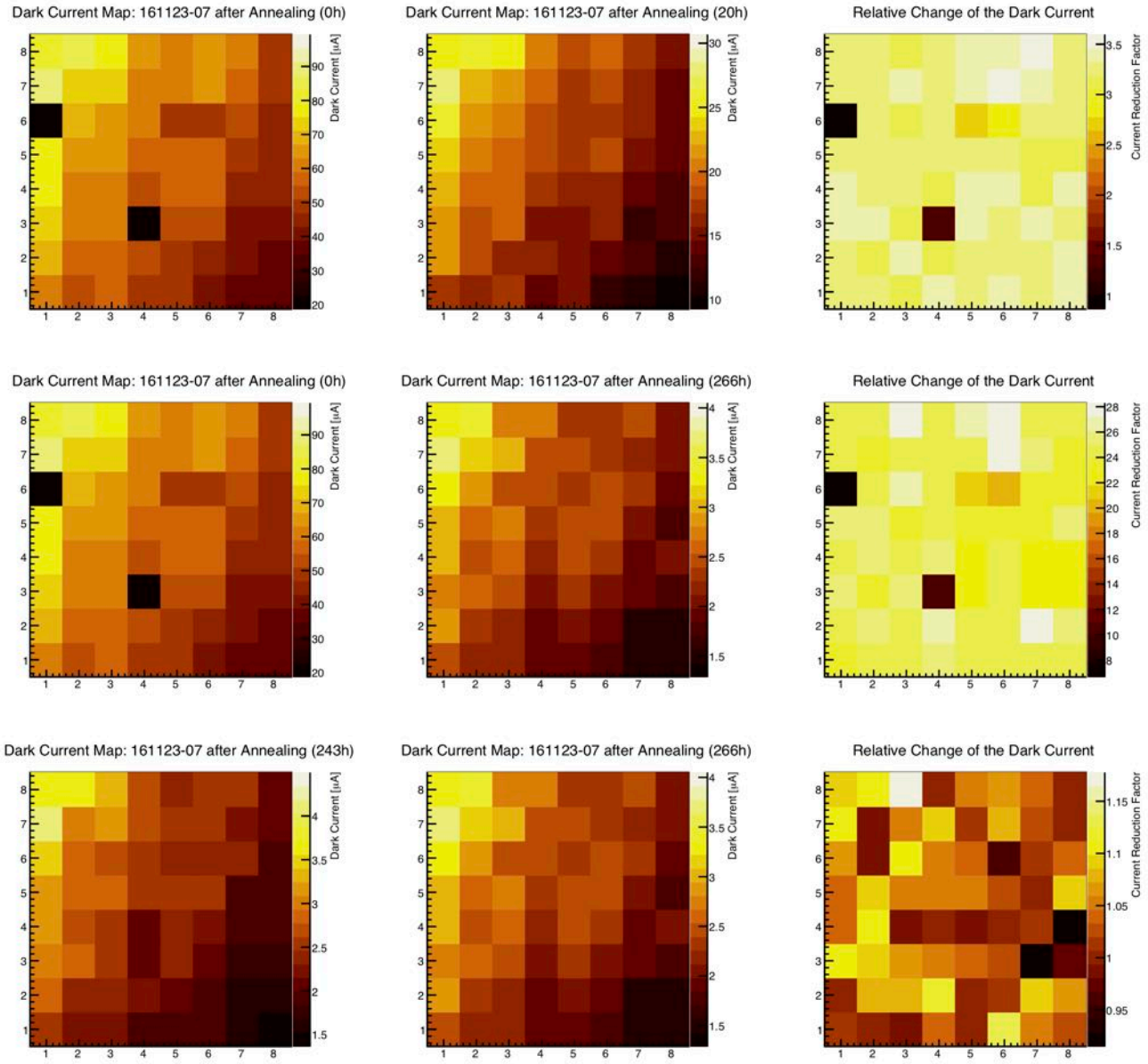
RESULTS

Accidental damage in CoSy

- Examples of comparison reports generated
- Change in dark current can be visualised
- Examples:
  - 0 - 20 hours annealing
  - 0 - 266 hours annealing
  - 243 - 266 hours annealing



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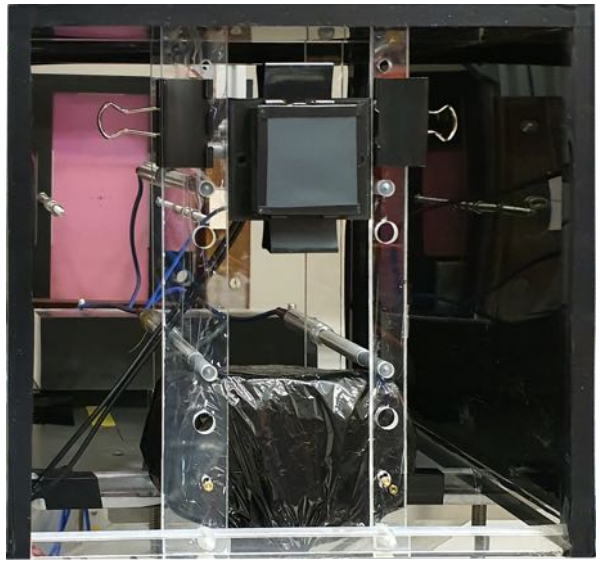
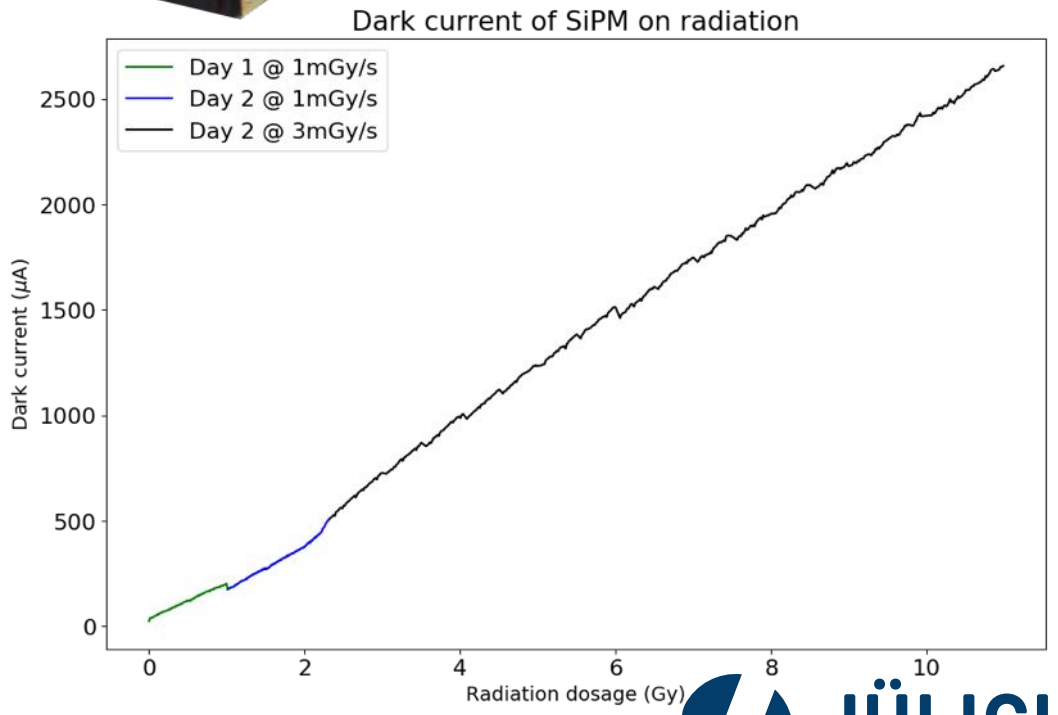
RESULTS

Investigating the radiation hardness of the SiPM arrays

- Healthy SiPM was exposed to totally of 11 Gy from Cyclotron
- Dark current was measured during irradiation and also when radiation was switched off
- Radiation film was placed on the SiPM to observe the radiation pattern and uniformity
- Live feed of the dark current was set up to observe the changes instantly
- Radiation damage with Cyclotron was similar to the damaged caused in the accident for the SiPMs in the second ring





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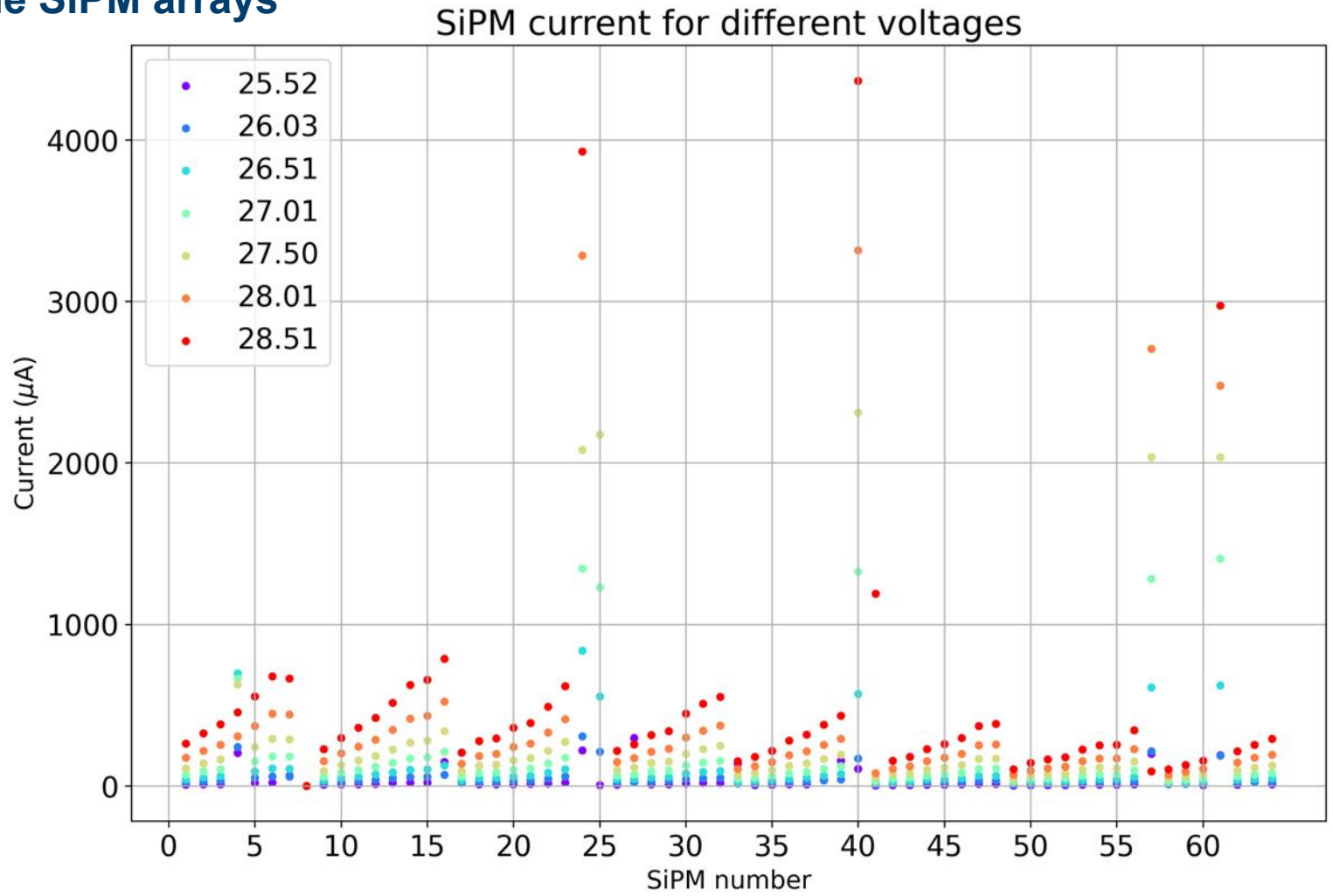
RESULTS

Investigating the radiation hardness of the SiPM arrays

- Dark current of each SiPM in the matrix for different voltages is measured

- Increase in the dark current with increasing voltage can be observed



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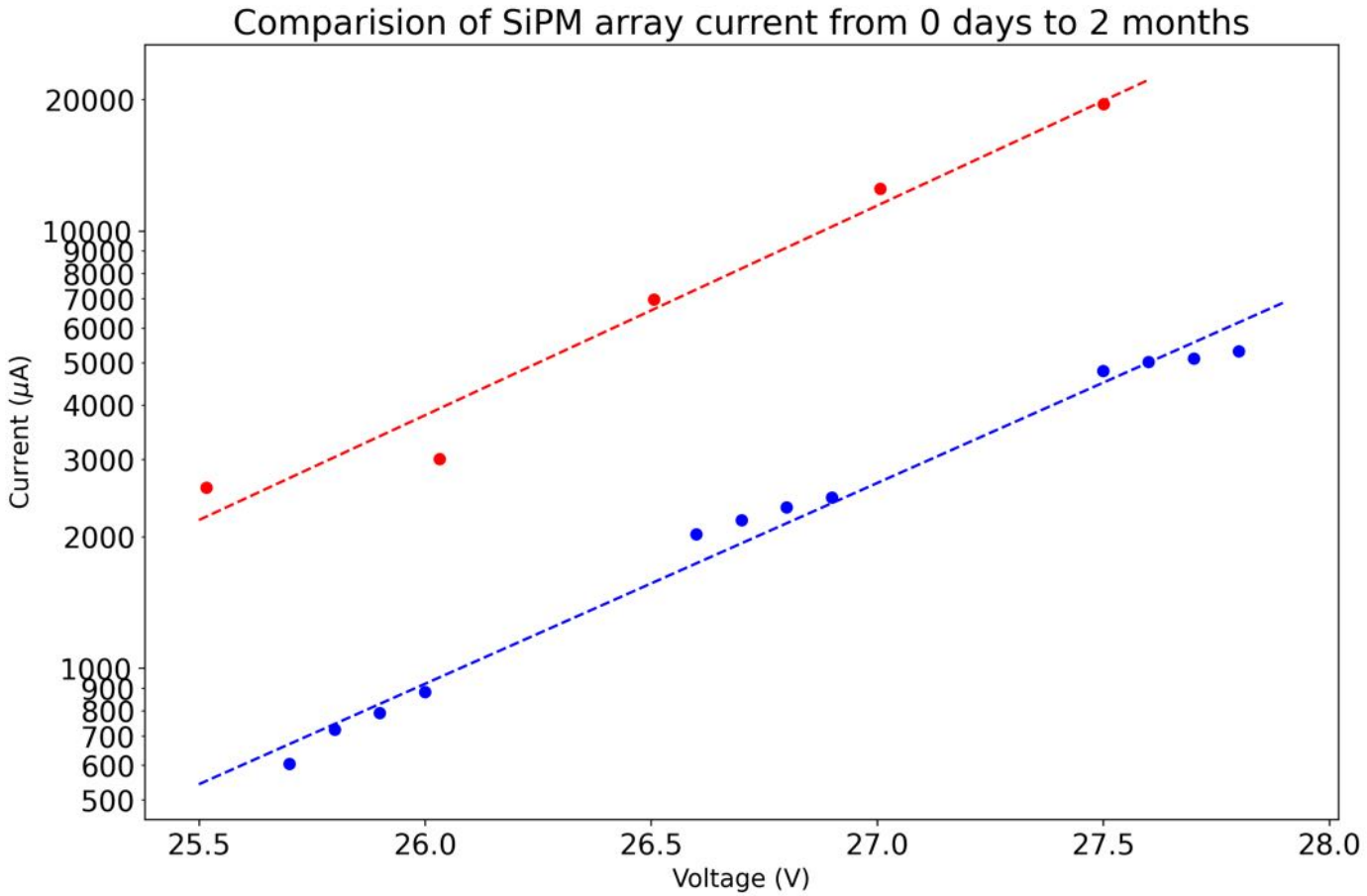
RESULTS

Investigating the radiation hardness of the SiPM arrays

- Dark current of the SiPM matrix for different voltages
- Change in dark current over the period of 2 months of annealing
- Data was recorded every 12 hours for a period of 7 days



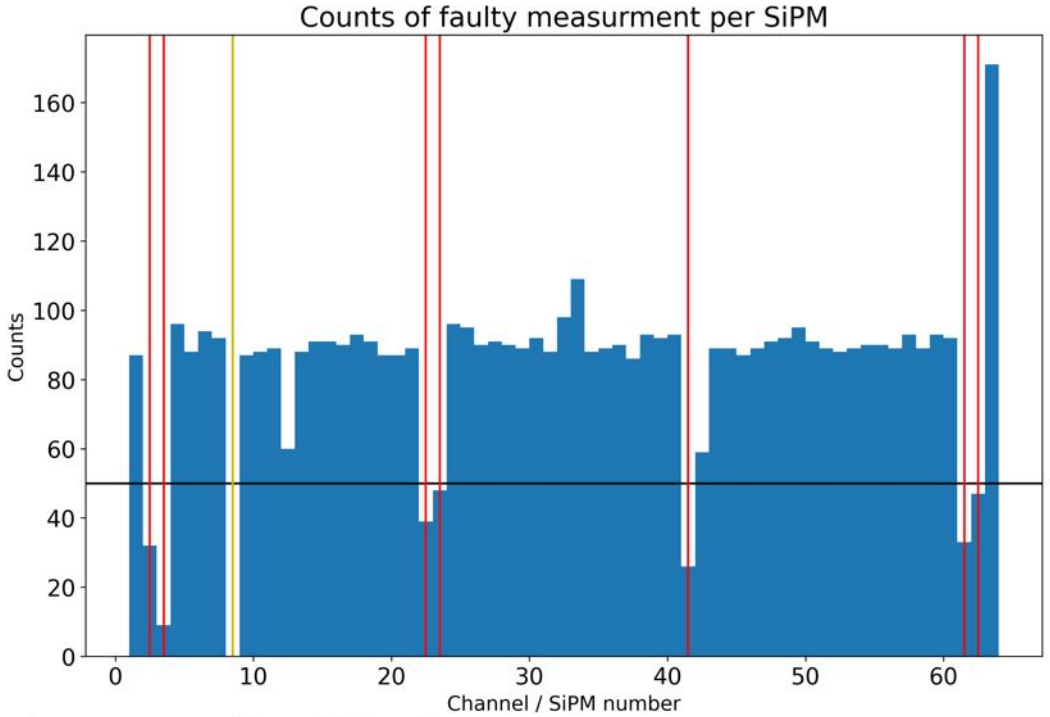
CURRENT ISSUES

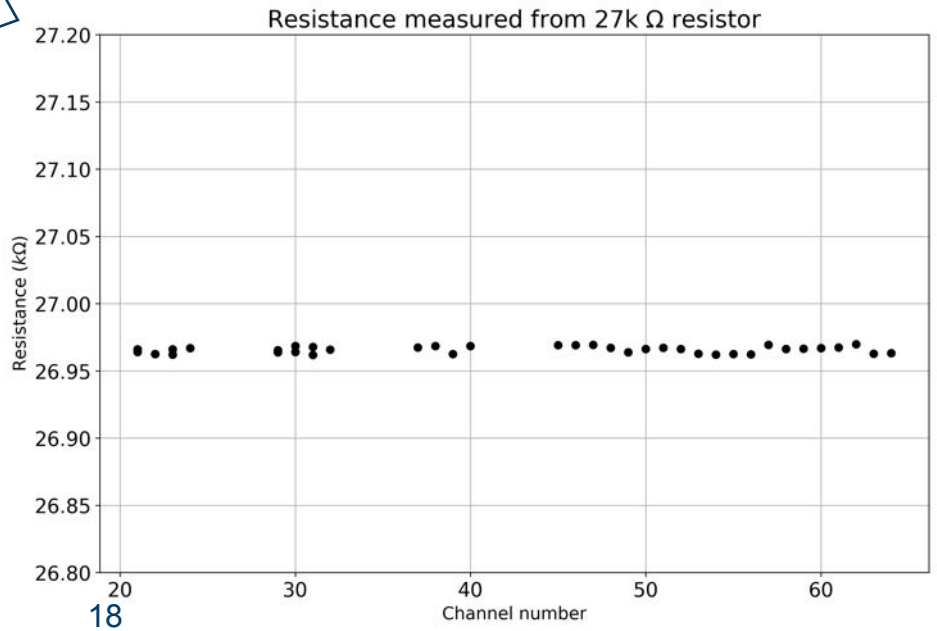
- Random jumps in the current recorded
- No pattern has been found yet

✳Calibration of the setup was performed by replacing SiPM board with 27kΩ resistor

Voltage and current were measured at all times.
Resistance of the resistor was calculated using

$$R = \frac{V}{I}$$





- Measuring dark current of the whole matrix gives comparable results but not individual SiPM results

- Voltage drift in the power supply

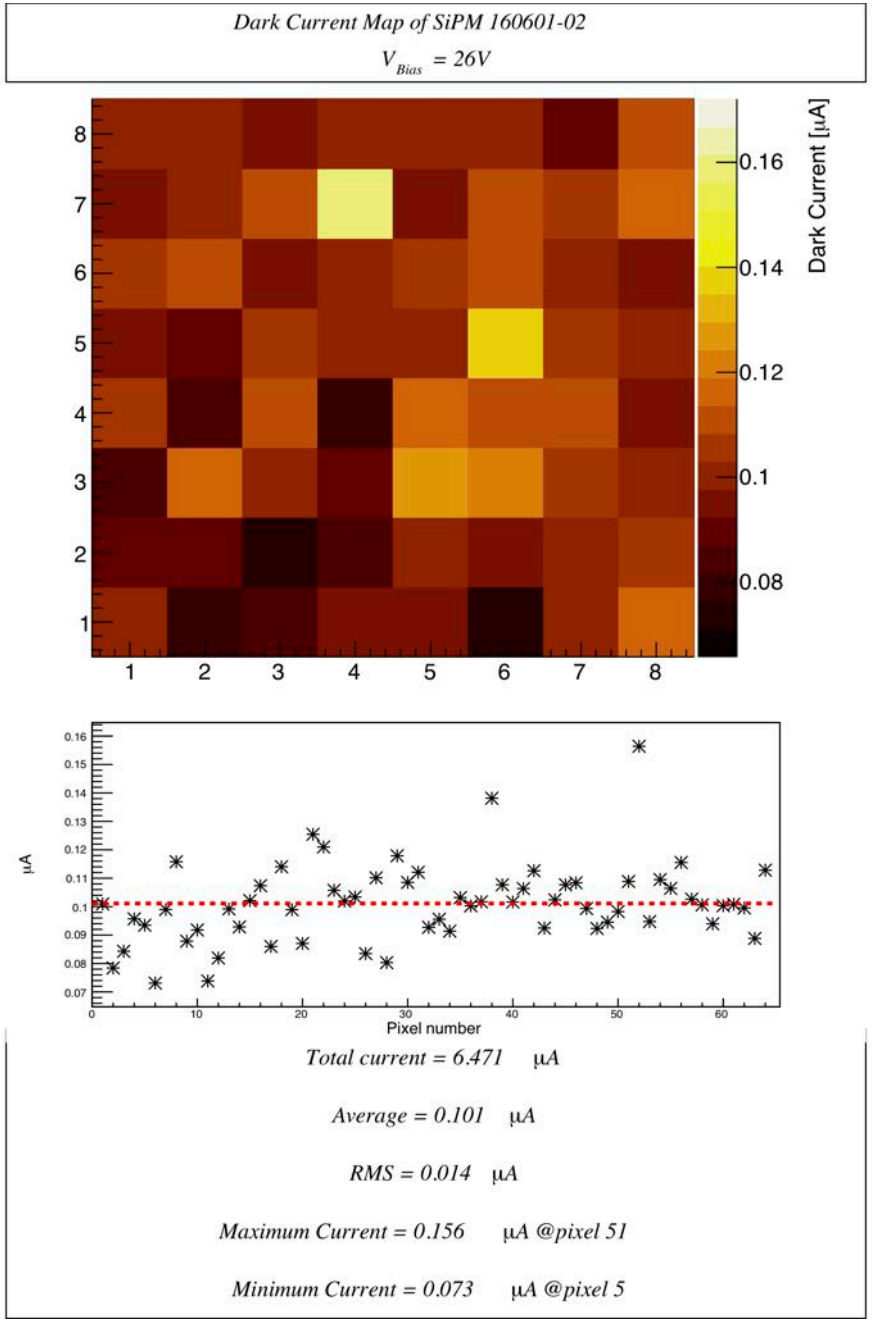
FUTURE PLANS

- Identifying the root cause for jumps
- Adding an external reference to have much higher stability in supply voltage

Thank you

BACK-UP

Full report of 160601-02



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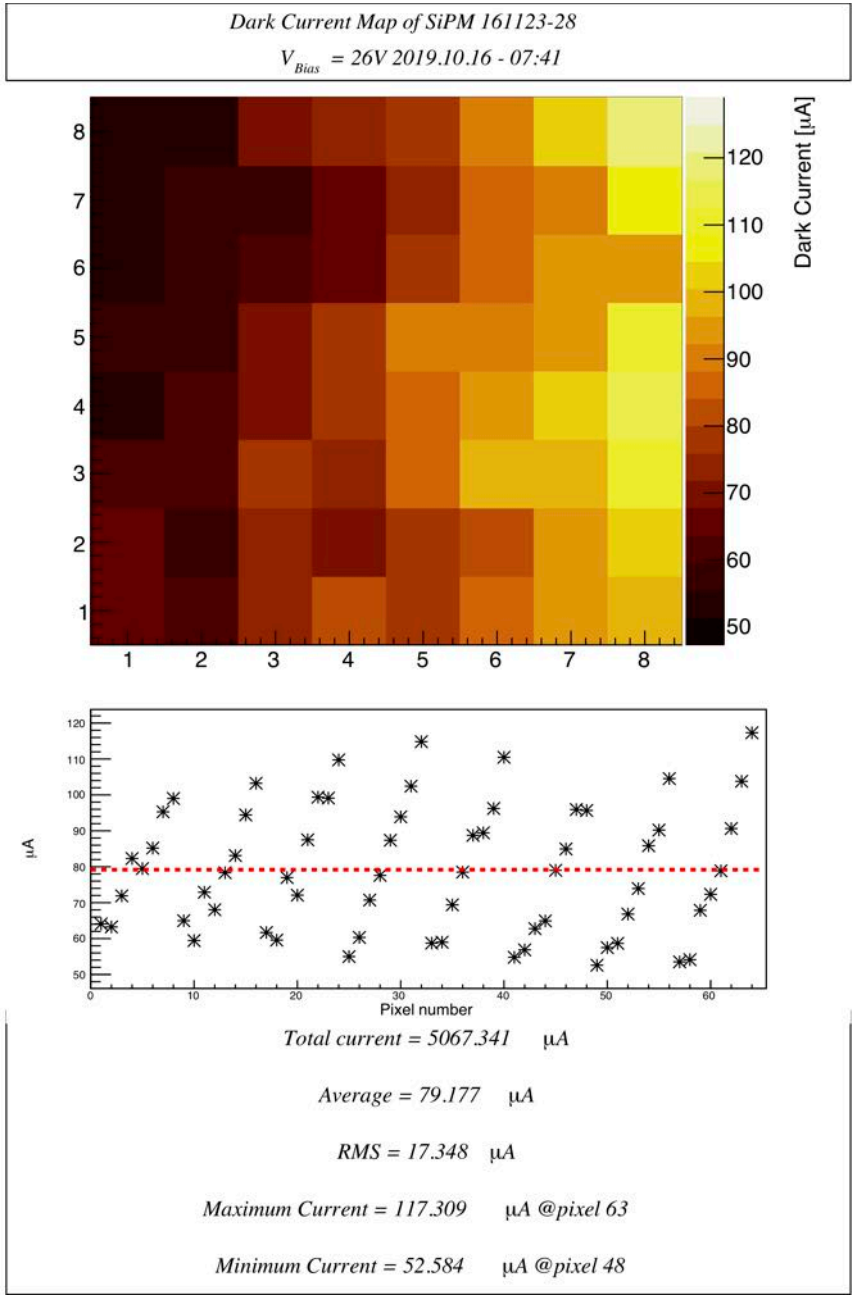
BACK-UP

Full report of pattern plot



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