Characterization of SiPMs for the LHCb RICH Detectors Upgrade-II

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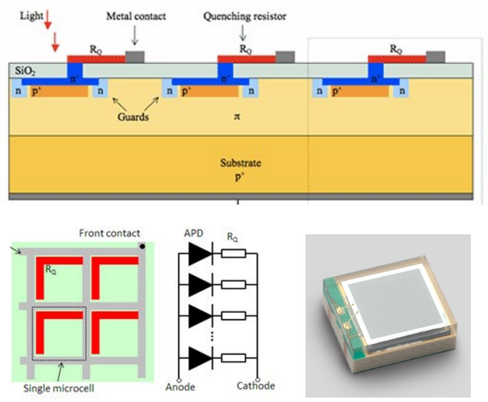
LHCb upgrade-II

Major detector Upgrade for LHC run5 (2035).

Instanteneous peak luminosity of 10^34 cm-2s-1 (increase of 5 with respect to actual value)

For the upgraded RICH detectors **new photosensors are needed**. The main driving requirements are:

- **Single photoelectron sensitivity** and large Quantum Efficiency
- **Fast time response**, ideally <100ps r.m.s. for single photon
- **Fine granularity** to keep occupancy below 30% in an harsh environment
- **Radiation hardness** (up to 3 10^13 1MeV neq/cm^2)



SiPM structure and picture

Silicon Photomultiplies

SiPMs are:

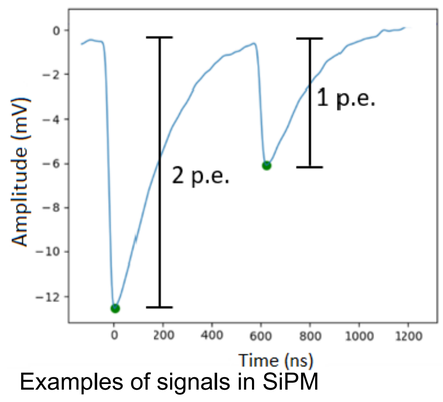
- Solid state photodetecors based on pn junctions;
- Matrices of **avalanche photodiodes**;
- Operated in **reversed bias** regime above breakdown voltage.

Important parameters:

- Breakdown voltage (Vbd) to set the working voltage;
- Quenching resistor (Rq) to stop avalanche and restoree operation;
- Dark count rate (DCR) that accounts for dark signals;
- Time resolution (Tr) that defines the temporal response of the sensor.

Their main features are:

- **single photoelectron sensitivity**;
- **fast devices**;
- simple and compact devices;
- **low voltage operation**;
- **good robustness**;
- low cost;
- **scalability and granularity**;
- large area coverage;
- good dynamic range.



Examples of signals in SiPM

Characterization procedure

Test procedure:

- IV curves (**Rq and Vbd**);
- **DCR**, **Gain**, **Time resolution**;

As a function of **irradiation fluences**;

As a function of **temperature**.

After irradiation, room temperature annealing for 48h during transportation

Goals:

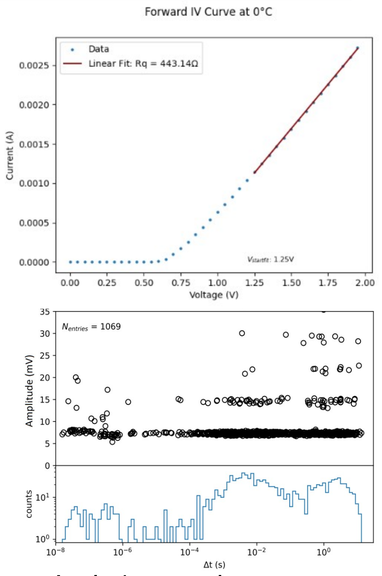
- Identify most promising technology;
- Find a good SiPM candidate to start customization;
- Find the best working point:

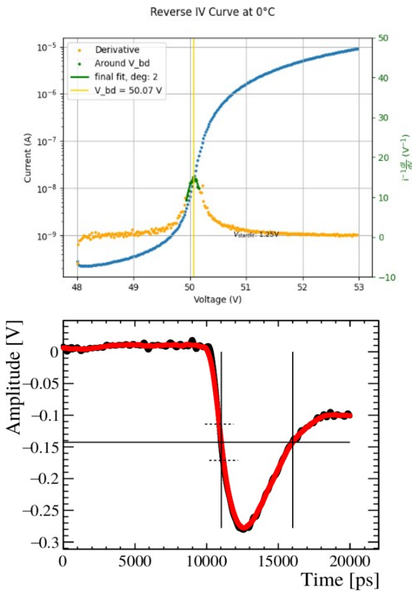
Commercial SiPM produced by Hamamatsu Photonics

SiPM model	Pitch (um)	Area (mm^2)	Packaging	Window	V_{bd} room (V)	Fill factor %
S13360-1325PE	25	1.3x1.3	SMD	epoxy	53	47
S13360-1350PE	50	1.3x1.3	SMD	epoxy	53	74
S13360-1375PE	75	1.3x1.3	SMD	epoxy	53	82
S13360-2050VE	50	2x2	SMD	epoxy	53	74
S14160-3050HS	50	3x3	SMD	epoxy	38	74

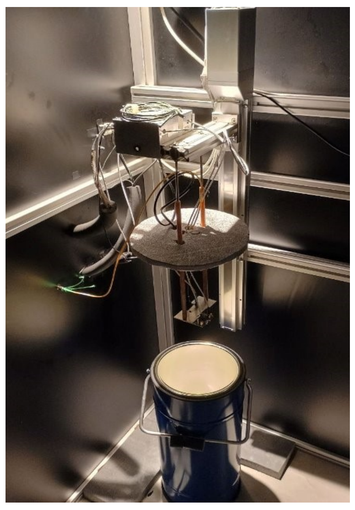
Fluence of the irradiation campaign in Ljubljana JSI reactor:

Fluence 1MeV n_{eq}/cm^2	$3x10^{11}$	$3x10^{12}$	$6x10^{12}$	$3x10^{13}$	$6x10^{13}$
# SiPM	3	3	3	3	3





Analysis examples



example of Ferrara setup

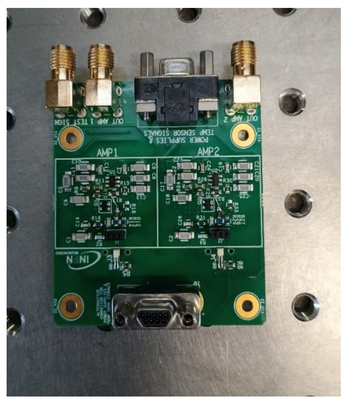
Setup

The groups involved in the project arranged different setup with **commmon features** to perform characterization tests in parallel:

- Different temperatures availability (down to liquid nitrogen);
- Source meter unit (resolution <1pA);
- Stabilized power supply;
- Oscilloscope with 12bit res., 2.5GHz bandwidth;
- Common cold amplifier designed by Milano Bicocca;
- Led system;
- Pulsed UV laser (Hamamatsu PLP10 @405nm, 50ps pulse width).

The setup can perform:

- **IV curves**:
  - Quenching resistor Rq;
  - Breakdown voltage Vbd;
- **DCR analysis**:
  - Primary DCR;
  - Afterpulses;
  - Cross-talk;
  - Burst effect;
- **Temporal study**:
  - Time resolution.

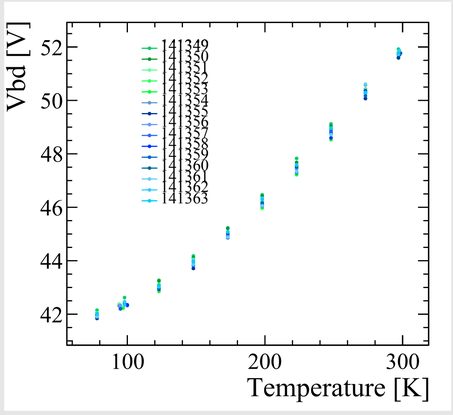


Cold amplifier board

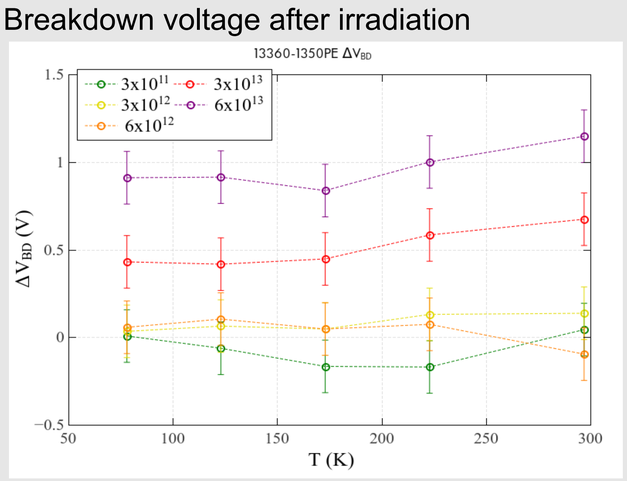
Results

Initial results of Hamamatsu **13360-1350P**E model completely tested before and after irradiation at different temperatures.

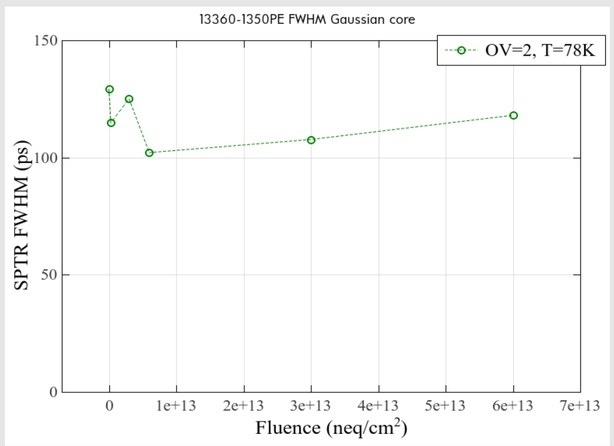
Breakdown voltage



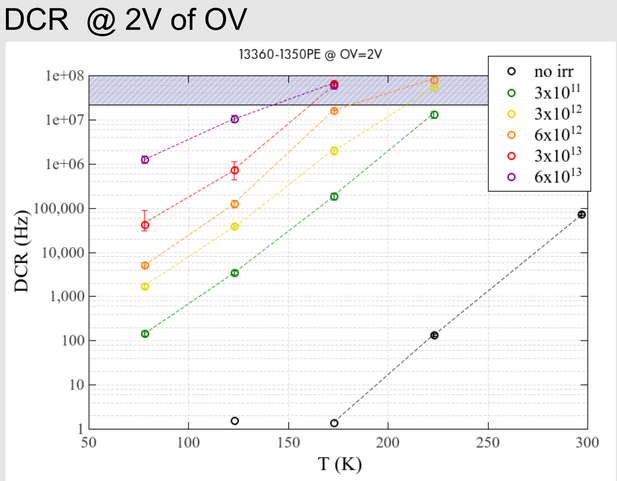
Breakdown voltage after irradiation



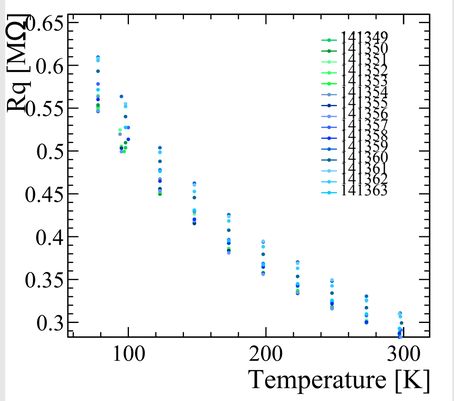
Time resolution after irradiation



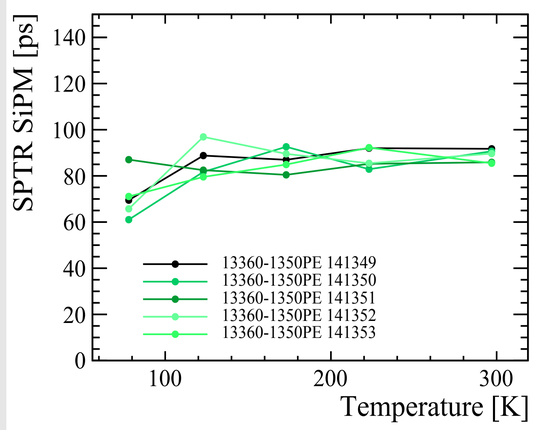
DCR @ 2V of OV



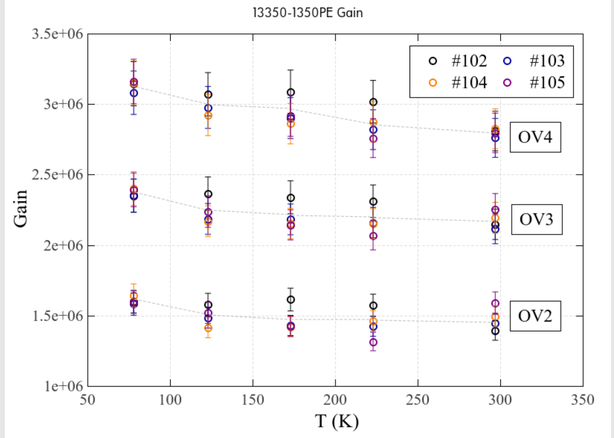
Quenching resistor



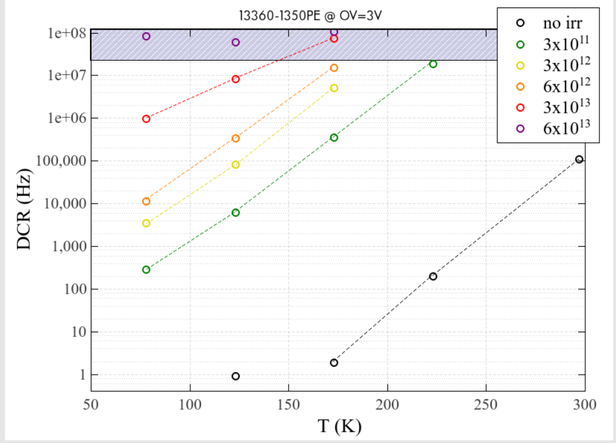
Non-irradiated time resolution



Gain



DCR @ 3V of OV



Conclusions

- **SiPMs are a possible candidate** for the LHCb RICH Upgrade-II photodetectors;
- The main **drawback is the radiation damage** that cause a large increase of DCR;
- Possible **mitigation strategies** under study;
- Started a **test campaing** on commercial HPK SiPMs;
- Many groups involved to parallelize tests;
- **Promising results** and ready to start customization with vendors.