UNIVERSITÀ DEGLI STUDI DI PADOVA

INFN CAGLIARI

High spatial and temporal resolution pixelated radiation sensors characterization for next generation experiments in fundamental physics

TFPA

Detectors, lasers and optics

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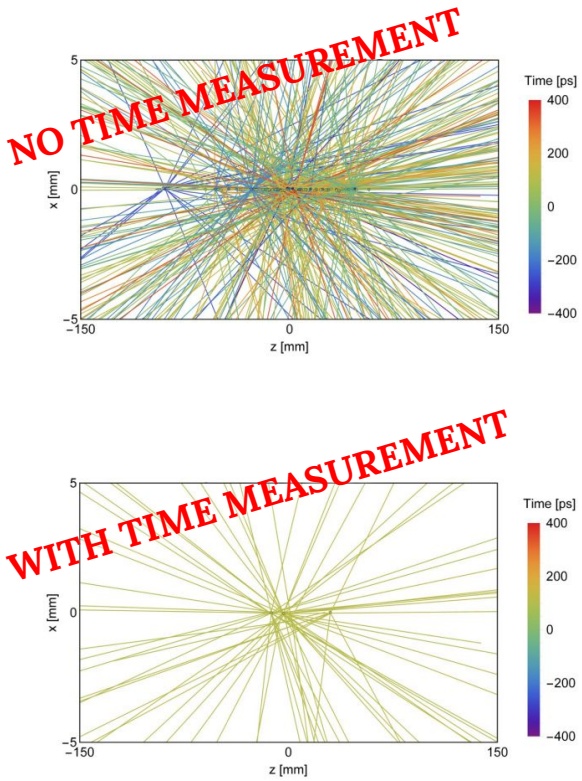
Overview

1) Research topic of my PhD program;
2) Objectives of my PhD program;
3) Overall planning;
4) Courses, the exams and other training activities;
5) Research activities carried out so far and those planned for the 2nd year;
6) Other academic achievements;
7) Test Beam campaign results

Research topic of my PhD program

The research topic falls within the field of research and development of inner tracker detectors for *future colliders*. The challenges are given by the increase in luminosity (HL-LHC > $5x10^{34}$ cm^{-2} s^{-1}) this requires detectors capable of:

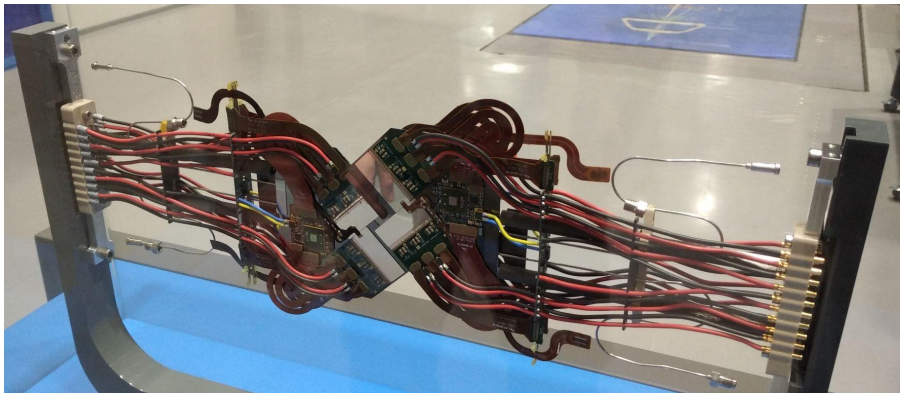
- Time measurements (σ_t~ 50 ps or better)
- Radiation hardness ($\Phi > 10^{16}$ 1 MeV n_{eq} cm^{-2})



Research topic of my PhD program

The case study of the PhD project is the upgrade of the LHCb Vertex Locator (VeLo) detector (planned for 2032).

Specifically, my PhD project consists in the characterization and optimization of sensors and ASICs (up to high irradiation levels, $\Phi > 10^{16}$ 1 MeV n_{eq} cm^{-2}).

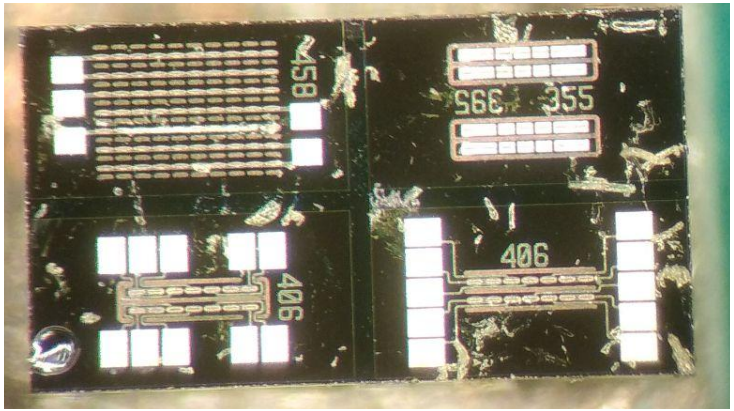


Current VeLo module (Image taken by M. Verdoglia in the LHCb museum room)

Objectives of my PhD program

The objectives are to evaluate the proposed technology for the VeLo upgrade, to study the performance and the operability range in terms of irradiation level.

As a conclusion my project aims to provide all the information needed to confirm this technology as the most suitable to be used for the VeLo detector.



High irradiated TimeSPOT test structure, $\Phi = 10^{17}$ 1 MeV n_{eq} cm^{-2} (microscope image)

Overall planning

To complete the three-year doctoral program with the timely submission of the final thesis in September 2026, the plan is as follows:

1 Year: Characterization and testing of highly irradiated test structures, studying the time resolution, efficiency and charge collection efficiency;

2 Year: Study 28nm CMOS ASICs performances, study of 64x64 pixels matrices bump-bonded to the ASICs, design build and successfully test a 4D (tracking and timing) telescope at the test beam;

3 Year: Assess high irradiated 64x64 pixel detectors

Courses, the exams and other training activities

1 Year:

1) Advanced Scientific programming in MATLAB (**passed**)
2) Simulation of optical photon propagation for generic scintillator-based detectors (**attended**)
3) Laser Physics and Applications (**to attend**)
4) Electronic systems in high energy physics (**to attend**)

2 Year:

1) Attending a summer school, yet to be decided
2) Pass all remaining exams

Research activities carried out so far and those planned for the 2nd year

1st Year:

1) Characterization of highly irradiated (up to $\Phi = 10^{17}$ 1 MeV n_{eq} cm^{-2}) TimeSPOT (3D trench silicon pixel sensors) test structures, development of a laser setup and laboratory characterization, with particular attention to the study of time resolution, at low temperature (-20°C).

2) Study of highly irradiated test structures at H8 SPS (CERN) using minimum ionizing particles. The test beam campaign results show a time resolution of 11 ps, efficiency of 97% and charge collection efficiency fully recoverable by acting on the reverse voltage. I participate in all the activities of the test beam: preparation of the setup, characterization of the test structure, data acquisition and analysis.

2nd Year:

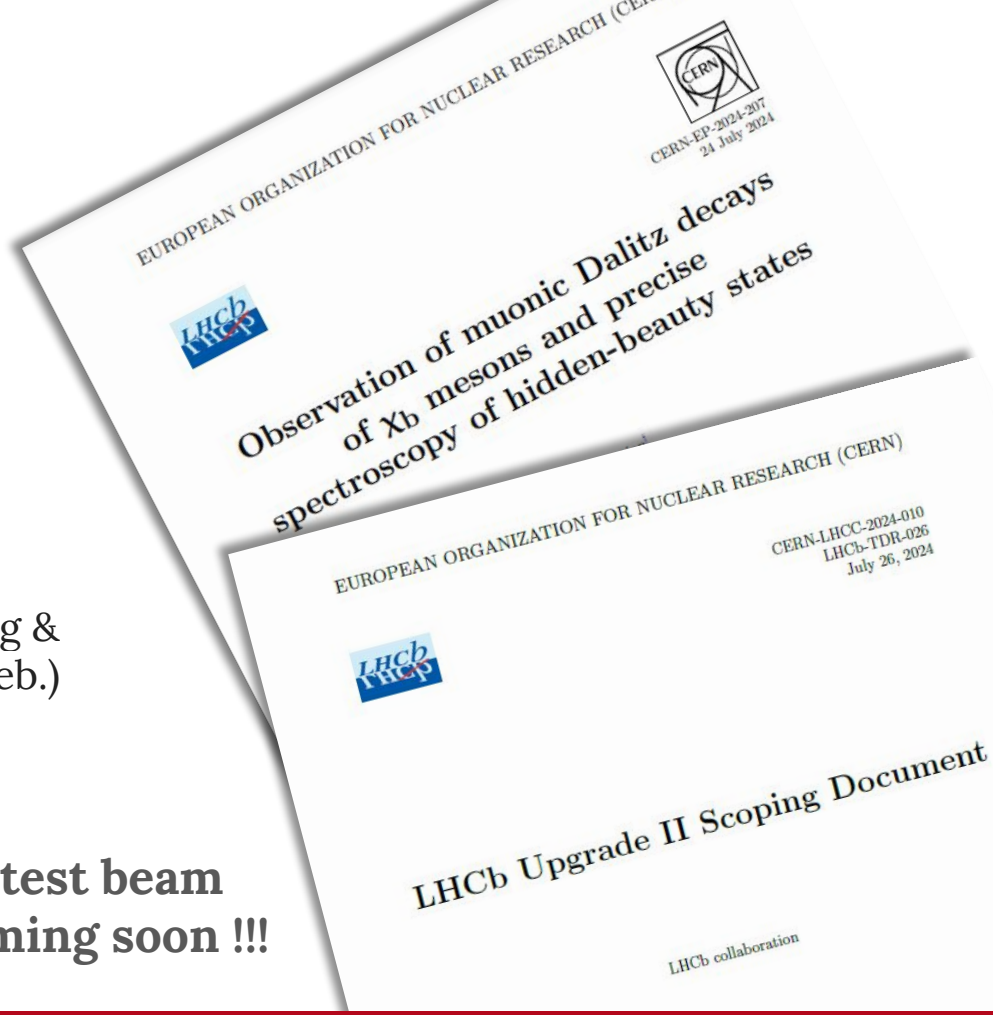
1) I will focus on the characterization of 64x64 matrix detectors and test structures irradiated up to $\Phi = 10^{18}$ 1 MeV n_{eq} cm^{-2} (FCC-hh fluences!!!)

Other academic achievements

Talk at TREDI24 (Feb.)

LHCb VeLo Recabling & Recommissioning (Feb.)

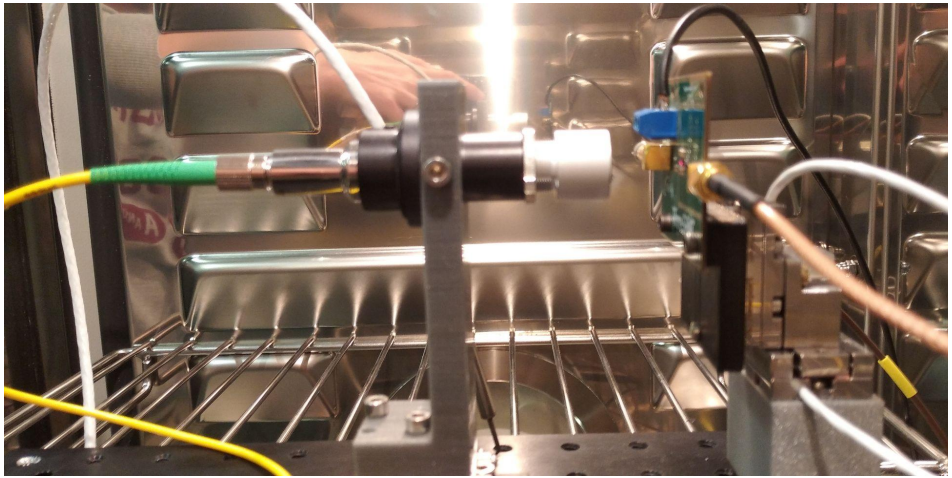
Talk at SIF 2024 (Sept.)



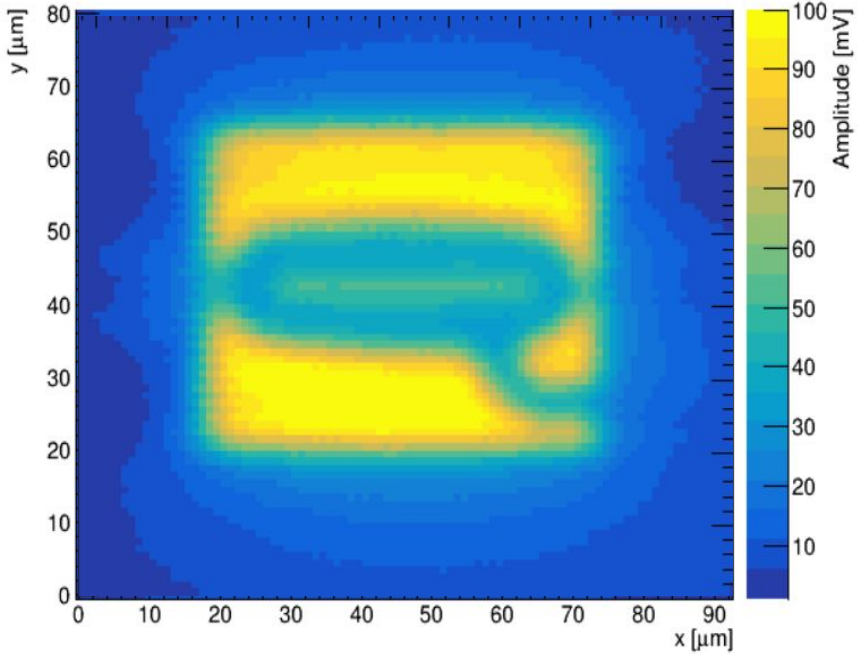
+ Paper on test beam results, coming soon !!!

Laboratory measurements

In-pixel studies using microfocused laser in a climate chamber:



SETUP IN THE CLIMATIC CHAMBER

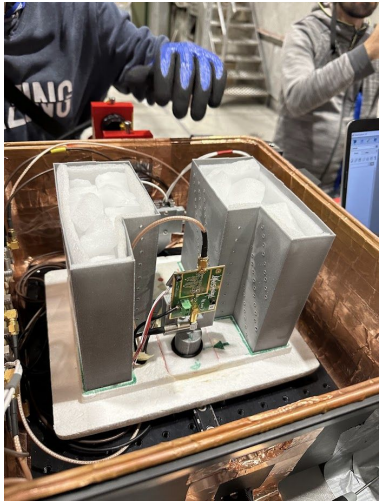


IN-PIXEL SIGNAL AMPLITUDE MAP

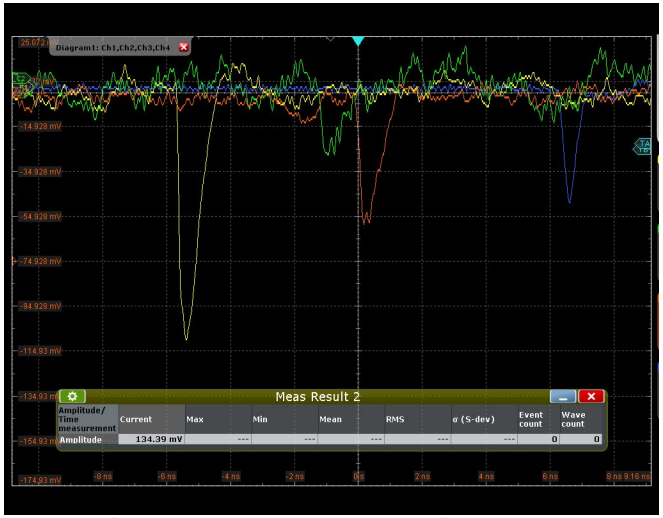
Test Beam campaign: setup overview

Test Beam campaign at H8 SPS:

SETUP IN THE EXPERIMENTAL AREA



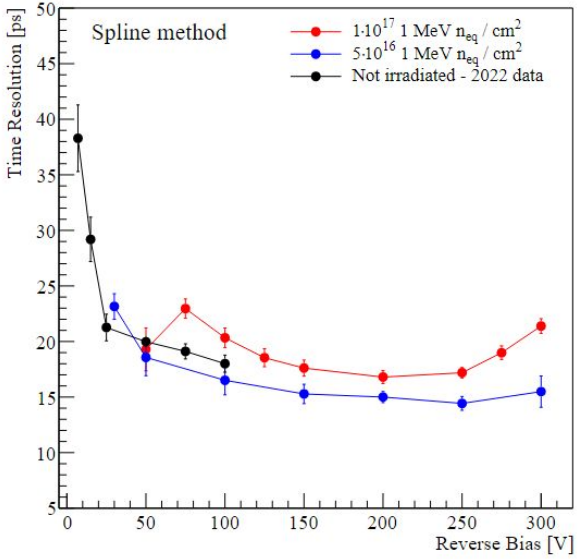
COOLING SYSTEM (DRY-ICE) & DUT



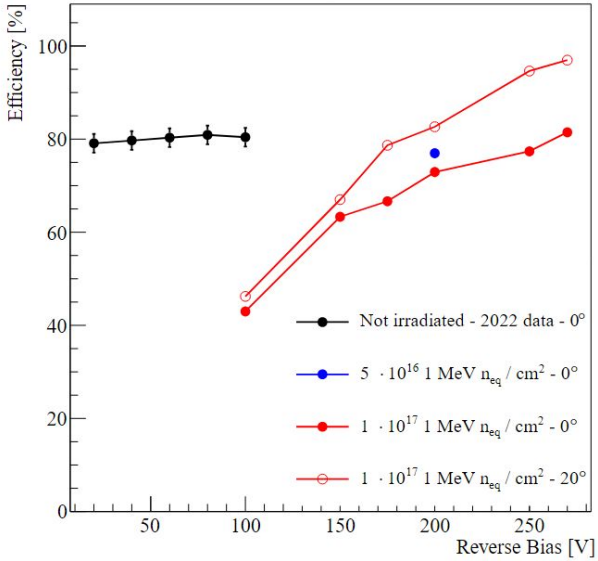
EXAMPLE OF TYPICAL EVENT

Test Beam campaign results:

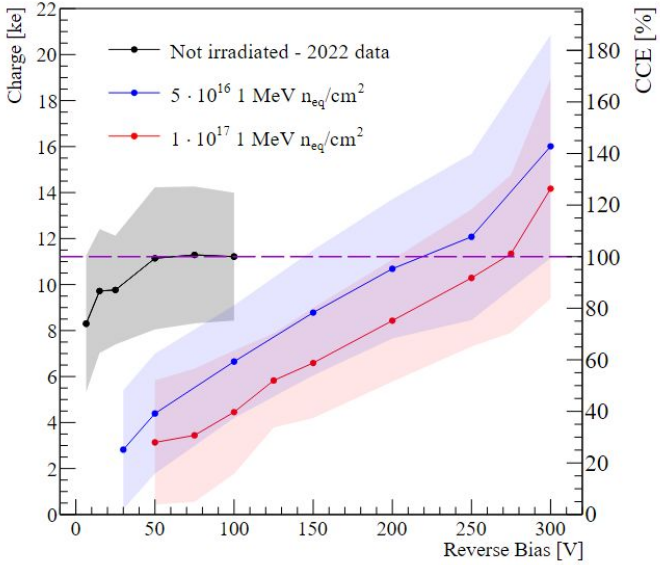
Some results: time resolution, efficiency and charge collection efficiency:



Time resolution (calculated with spline method) less than 20 ps



Efficiency, calculated as the number of DUT signals over Triggers signals can rise up to 97%



Charge collection can be restored by acting on the reverse voltage. We also discover “multiplication” effects on this type of technology.

Conclusions

The results of the first year of PhD can be summarized as follows:

- I am involved in the R&D of the VeLo upgrade of the LHCb detector;
- I studied in-pixel performances of highly irradiated test structures using a micro-focussed laser in a climatic chamber;
- I took part in a test beam campaign where highly irradiated test structures were characterized, with the following results:
  - Time resolution 11 ps
  - Efficiency 97%
  - Fully recoverable CCE
  - First demonstration of gain regime at high inverse voltage (for 3D trench silicon pixels)

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THANKS !!!

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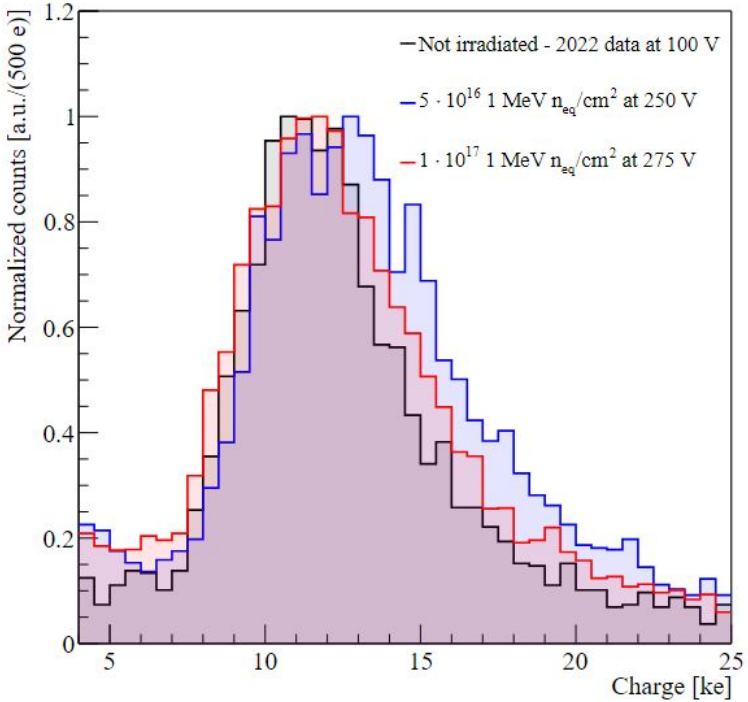
Backup slides

Characterisation of highly irradiated test structures

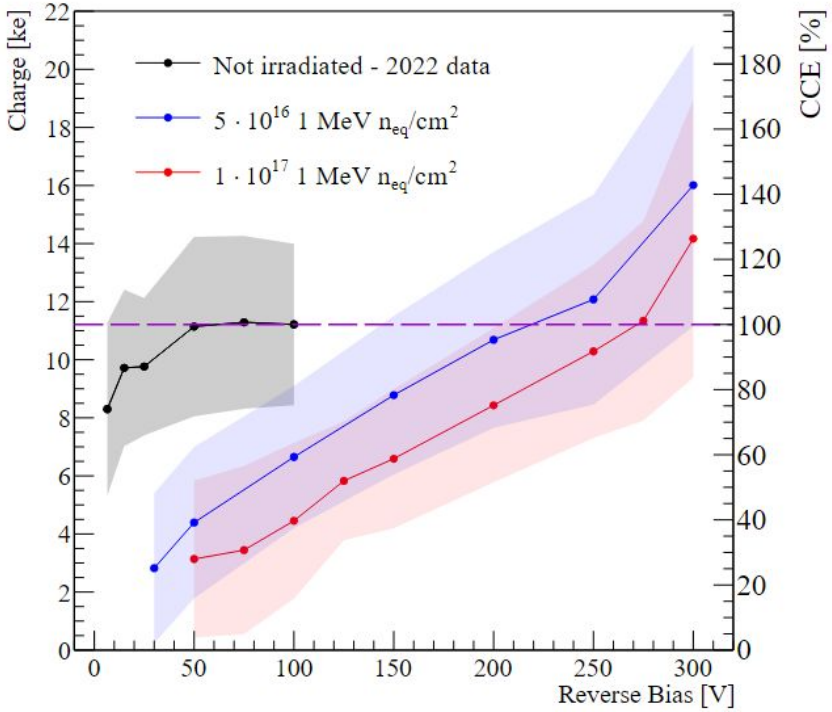
Test Beam campaign at H8 SPS: Charge collection process

Performance recovery



Characterisation of highly irradiated test structures

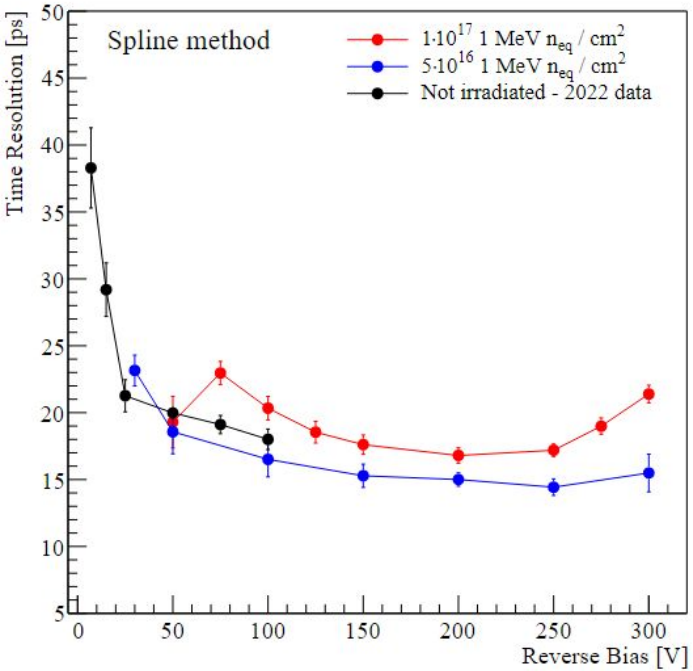
Test Beam campaign at H8 SPS: Charge collection process
Summary plot



Characterisation of highly irradiated test structures

Time resolution comparison

Test-Beam



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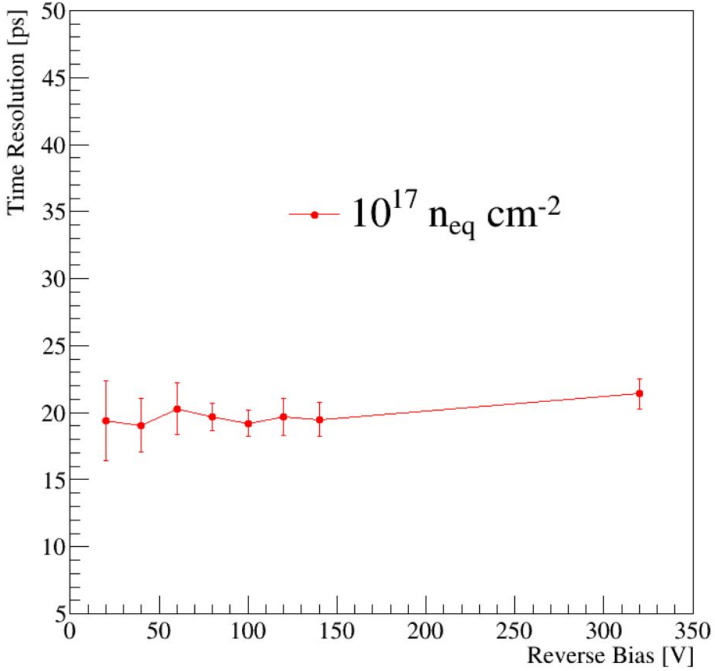

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