



1222·2022
800
ANNI



UNIVERSITÀ
DEGLI STUDI
DI PADOVA

**PhD course of National Interest in Technologies for
Fundamental Research in Physics and Astrophysics**

Annual report

Name and surname: Michele Verdoggia

Cycle and a.a.: XXXIX, 2024-2025

Supervisors: Alessandro Cardini, Adriano Lai, Andrea Lampis

- **Research activity carried out during the year** (Describe the aim of the project (very briefly), discuss the research activity carried out during the year mentioning the difficulties encountered until now and the actions taken to face them. 1 page max in total)

My PhD project is dedicated to R&D on innovative silicon detectors for future experiments at colliders, starting from the LHCb inner tracker at HL-LHC, and looking ahead to the next generation of inner trackers at facilities like the FCC, ILC, and the Muon Collider that will require higher performance in particular in terms of radiation tolerance.

My research activity in the *Upgrade II* of the LHCb experiment (at CERN) planned for 2035 focuses on the Vertex Locator (VeLo) detector. The objective is to characterize and optimize the 3D silicon pixel sensors and their front-end electronics for the VeLo detector upgrade, and this technology aims to provide 10 μm of spatial resolution and 50 ps time resolution at high irradiance levels up to $5 \cdot 10^{16} \text{ 1 MeV } n_{\text{eq}}/\text{cm}^2$.

The work carried out during this 2nd year can be summarized as follows:

Hardware and control software development of an innovative Cold-TCT setup in operation at INFN Cagliari, capable of performing sub-pixel characterizations by means of various wavelengths laser sources in a temperature-controlled environment (down to -40°C).

I personally developed the LabVIEW libraries for controlling the climate chamber, coded the algorithms for the automated operation of the instruments required for each type of measurement (laser focusing, voltage scans, real time plots visualization). Of fundamental importance was my collaboration with the 3D-print INFN Cagliari workshop group, with whom I designed and 3D-printed optimized mechanical supports for the setup.

Study and in-lab characterization of highly irradiated sensors with neutrons (up to $\Phi = 10^{18} \text{ 1 MeV } n_{\text{eq}}/\text{cm}^2$) TimeSPOT (3D trench silicon pixel sensors) test structures, with particular attention to the study of IV response curves, time resolution and CCE at low temperature (-20°C and -40°C) using the cold-TCT setup. These studies show good sensor performance in terms of time resolution, below 10 ps, and good capabilities of recover amplitude performances after irradiation.

Preliminary study and characterization in the laboratory of ExFlu1 LGAD sensors, with the aim of comparing different technologies proposed for future experiments at colliders.

Characterization of the HV front-end designed to operate the extreme irradiated sensors up to 1 kV, studies consisted of testing the leakage current and evaluating the intrinsic noise.

Responsible for proton irradiation of 3D-trench TimeSPOT sensors at the IRRAD facility (CERN). I was responsible for bringing the sensors to CERN and preparing them in the appropriate holders before irradiation. I followed every stage of the irradiation process, staying in contact with the IRRAD operators until its completion in July.

The goal of this study is to compare the effects (CCE, temporal resolution) of different types of irradiation damage (neutrons vs. protons) on the same silicon sensors technology at extreme fluences, up to $10^{17} \text{ 1 MeV } n_{\text{eq}}/\text{cm}^2$.



1222 · 2022
800
A N N I



UNIVERSITÀ
DEGLI STUDI
DI PADOVA

**PhD course of National Interest in Technologies for
Fundamental Research in Physics and Astrophysics**

- **List of attended courses and passed exams**

Advanced scientific programming in Matlab (**Passed, 4 CFU**)

Electronic systems in high energy physics (**Passed, 4 CFU**)

XXII Seminar on Software for Nuclear, Subnuclear and Applied Physics (**Passed, 4 CFU**)

Novel detectors for future experiments at collider (**Passed, 2 CFU**)

Solid State Detector (**attended in September 2025**)

- **List of attended conferences, workshops and schools, with mention of the presented talks**

Conferences:

1) TREDI 2024: Characterisation and preliminary results on 3D trench pixel sensors irradiated up to 10^{17} 1 MeV n_{eq} cm^{-2} (<https://agenda.infn.it/event/39042/contributions/221958/>);

2) SIF 2024 (9-13 September 2024): Caratterizzazione e risultati preliminari su sensori 3D a trincea altamente irraggiati a fluenze fino a 10^{17} 1 MeV n_{eq} cm^{-2} (<https://2024.congresso.sif.it/talk/232>);

3) IFD 2025 - INFN Workshop on Future Detectors: 3D-trench silicon pixels irradiated with neutron fluences up to 10^{18} 1 MeV n_{eq}/cm^2 (<https://agenda.infn.it/event/43956/contributions/257747/>);

4) IFAE 2025: Caratterizzazione puntuale mediante laser micrometrico di sensori 3D a trincea irraggiati con neutroni fino a fluenze di 10^{18} 1 MeV n_{eq}/cm^2 (<https://agenda.infn.it/event/44314/contributions/259589/>).

Schools:

1) CHIPP – 2025: CHIPP Winter School of Particle Physics 2025 (<https://indico.cern.ch/event/1463355/overview>);

2) XXII Seminar on Software for Nuclear, Subnuclear and Applied Physics (<https://agenda.infn.it/event/44438/overview>).

- **List of published papers/proceedings**

1) LHCb Upgrade II Scoping Document (<https://cds.cern.ch/record/2903094?ln=en>);

2) Characterisation of 3D trench silicon pixel sensors irradiated at $1 \cdot 10^{17}$ 1 MeV n_{eq} cm^{-2} (<https://www.frontiersin.org/journals/physics/articles/10.3389/fphy.2024.1497267/full>);

3) Performance of 3D trench silicon pixel sensors irradiated up to 10^{17} 1 MeV n_{eq} cm^{-2} (<https://www.sciencedirect.com/science/article/pii/S0168900224009100?via%3Dihub>);



1222·2022
800
A N N I



UNIVERSITÀ
DEGLI STUDI
DI PADOVA

**PhD course of National Interest in Technologies for
Fundamental Research in Physics and Astrophysics**

4) Could we efficiently operate 3D silicon pixel-based tracking detectors irradiated with neutron fluences up to $10^{18} \text{ 1 MeV n}_{\text{eq}} \text{ cm}^{-2}$? (<https://www.sciencedirect.com/science/article/pii/S0168900225005625?via%3Dihub>);

5) More than 40 papers in the LHCb collaboration (<https://inspirehep.net/authors/2768866>).

- **Thesis title (even temporary)**

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

Date, 11/09/2025

Signature

Verdognia Michele

Seen, the supervisors

Andrea Dugo

Alessandro Contri

Adriano Lanza