UNIVERSITÀ DEGLI STUDI DI PADOVA

First year annual report

Camilla Forza

Supervisors: Gianmaria Collazuol (Unipd), Alberto Gola (FBK)

TechTFPA PhD, University of Padova XL cycle

Overview on the first year

Thesis title: *'Study and Characterization of Silicon Photomultipliers with Applications to Large Area Radiation Detectors.'*

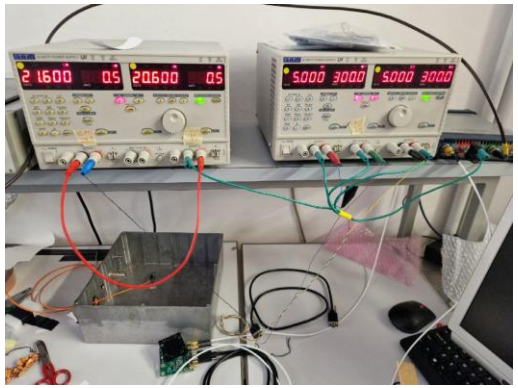
Neutrino Physics

Detector Physics and R&D

Where I am involved:

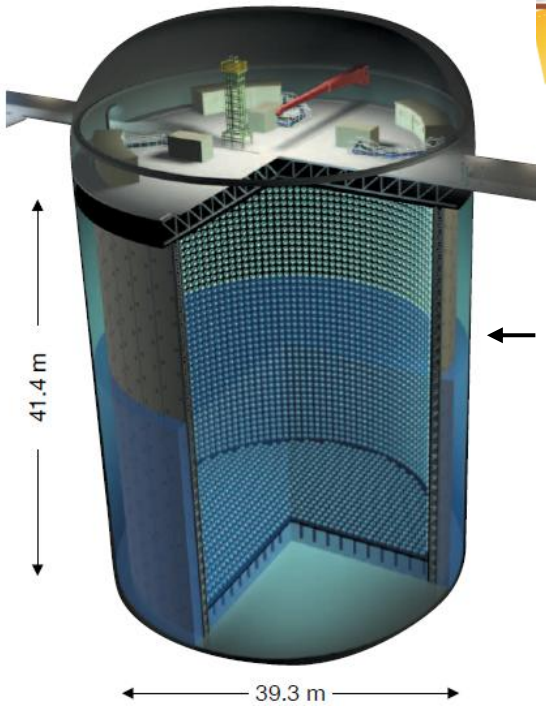
- Still part of T2K collaboration, TPCs group (only for shifts and detector maintenance)
- I joined the Hyper-K collaboration, PMTs electronics working group.
- In parallel I also at Fondazione Bruno Kessler on NUV-BSI SiPM R&D

\+ Small contribution within the LHCb group in Padova to build a Single Photon Time Resolution (SPTR) setup to test Hamamatsu SiPMs for the RICH upgrade.



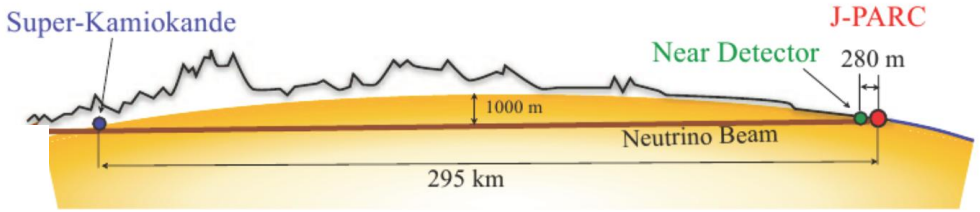
T2K activities

Far Detector



Super-Kamiokande

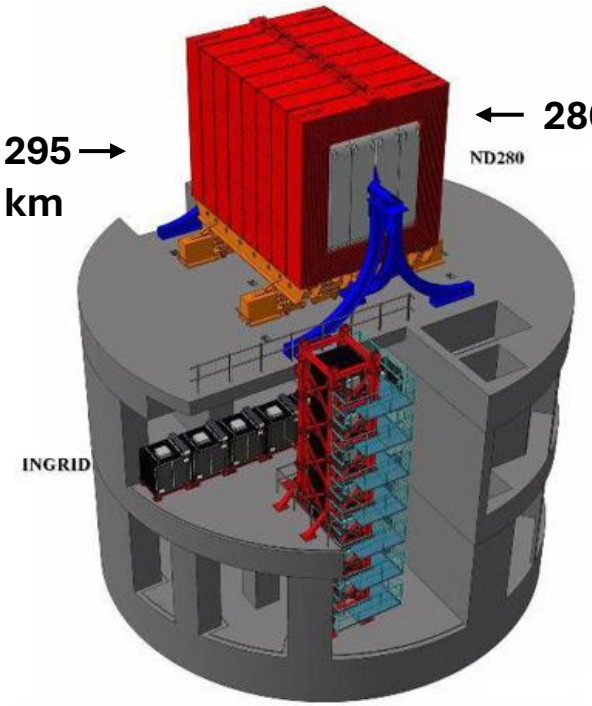
Water Cherenkov detector



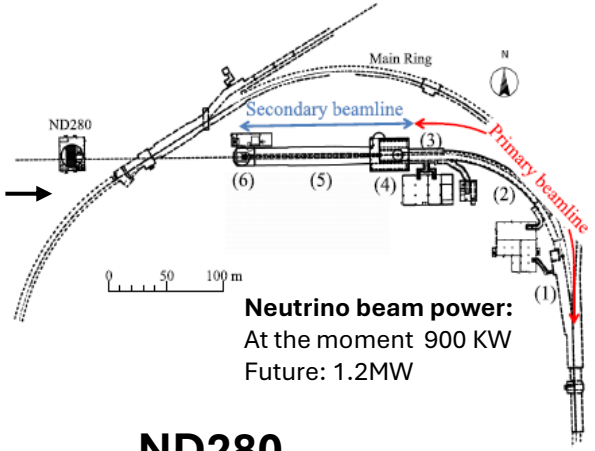
295 km

280 m

Near Detector Complex

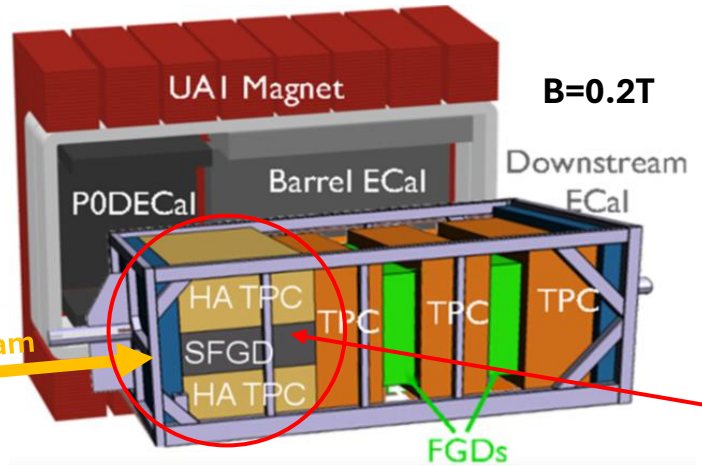


Neutrino Beam



Neutrino beam power:
At the moment 900 KW
Future: 1.2MW

ND280



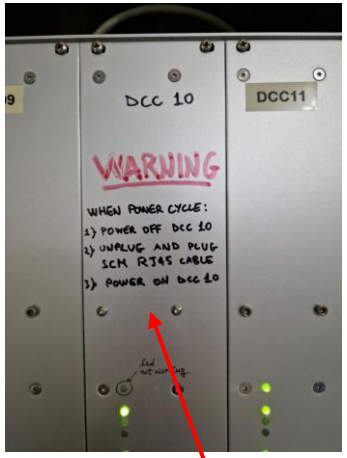
My tasks in the T2K collaboration:

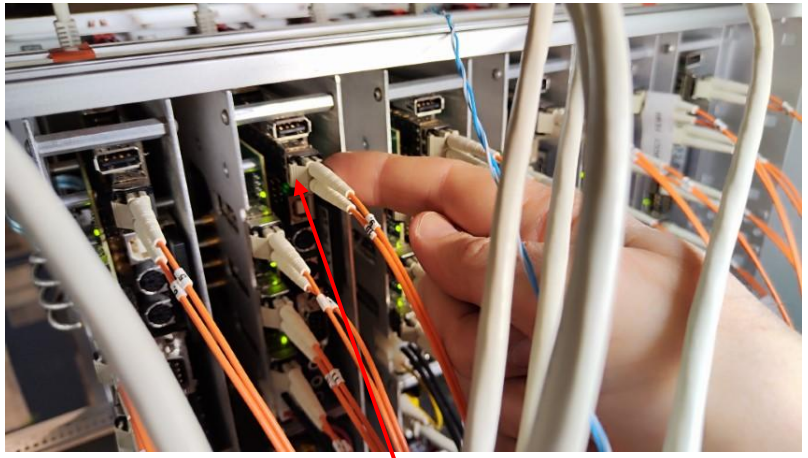
- TPC data quality (together with David Henaff, CEA, Saclay)
- **TPC expert shifts**

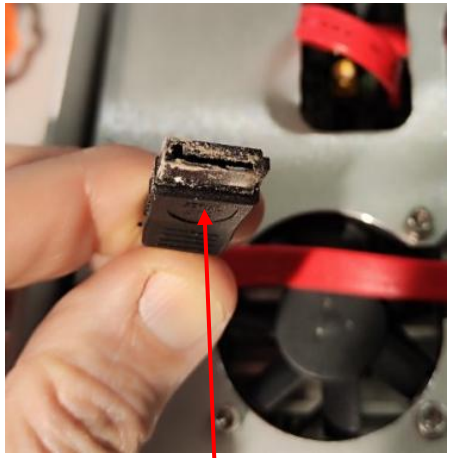
Means taking care of:

- Two HA-TPCs from the Upgrade
- Three TPCs (legacy)
- Gas system

T2K (adventurous) activities





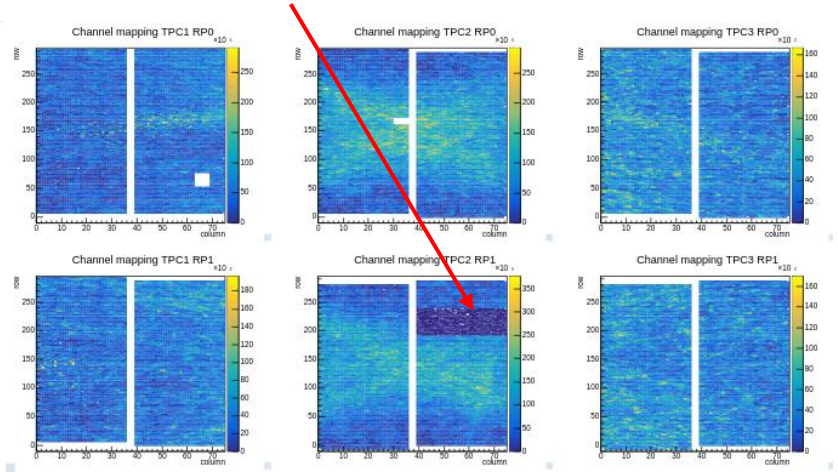


Power cycle failure

Broken connector

Salt!

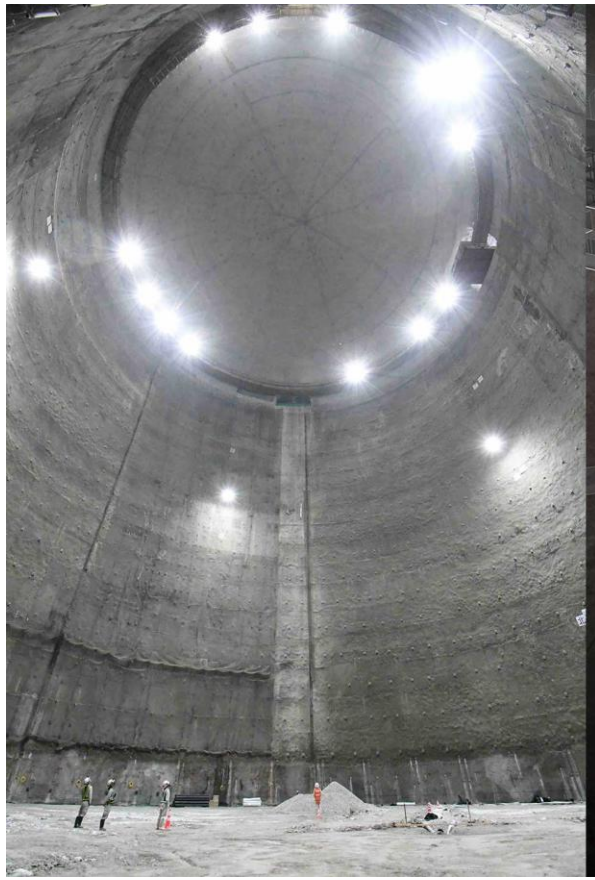
DCC failure connection with one Micromegas



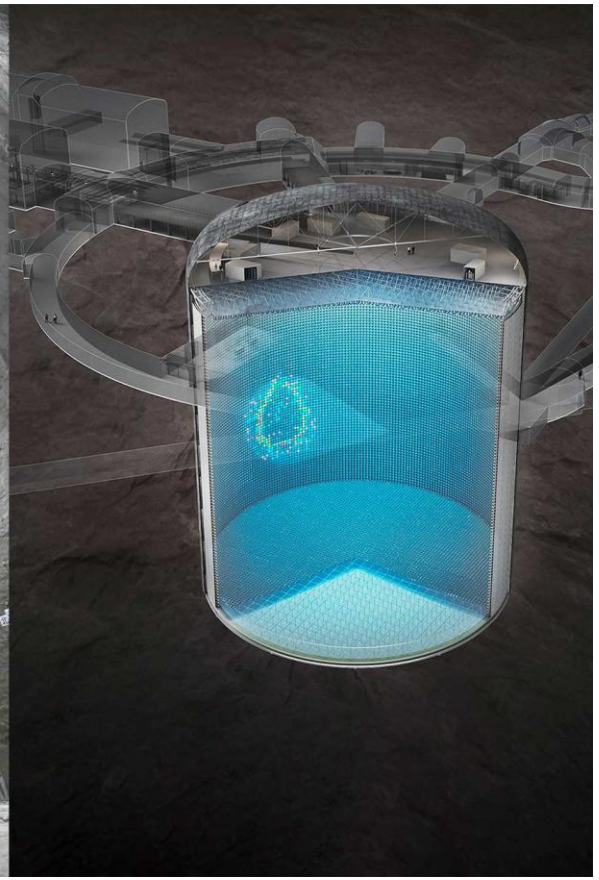
Occupancy map of old TPCs

- Data quality is now renovated both for old and new TPCs.
- New TPCs worked very well.
- Old TPCs face ageing problems, in particular the Data Concentrator Cards (DCCs).
- Battle against DCC failures: substitution with spares, open the bad ones, unmount several connection to check, cleaning, try to recover some of them, test, write documentation, do reports for collaboration, ecc…
- Neutrino beam run stopped after 2 weeks: major problem of He leak at the neutrino beamline.
- Long shut-down procedures required.

Hyper-Kamiokande



Now



Future

A water Cherenkov neutrino detector:

- Large astrophysics program (neutrinos from supernova, indirect dark matter searches, solar neutrinos etc.)
- Aims to answer the CP violation question in the lepton sector (hint by T2K experiment)
- Test GUT theories through proton decay measurement
- Fiducial volume 8.4 x SK, improved neutrino beam

Technical details:

- Diameter: 69 m
- Height: 73 m + 21 m dome
- 20,000 20-inch high-sensitivity photomultiplier tubes (PMTs)
- 800 multi-PMTs, composed of nineteen 3-inch PMTs
- Divided in Outer Detector (OD) and Inner Detector (ID)
- Will be filled with 258.000 metric tons of ultrapure water.

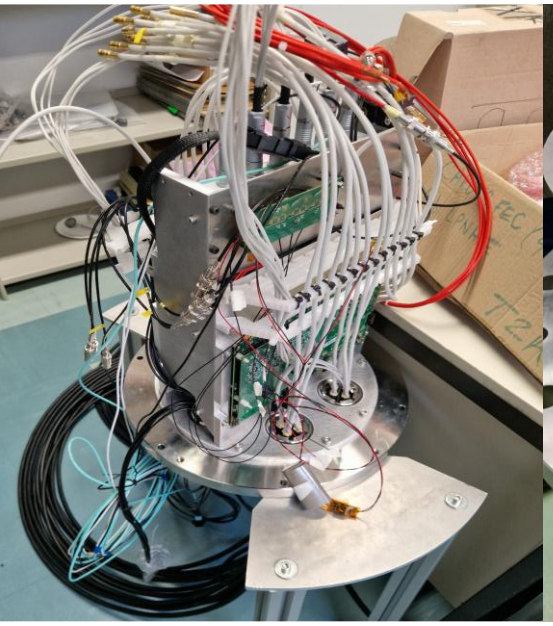
- The excavation of the cavern is completed (July 31, 2025).
- From 2028, Hyper-Kamiokande will start the data taking.

Hyper-Kamiokande activities

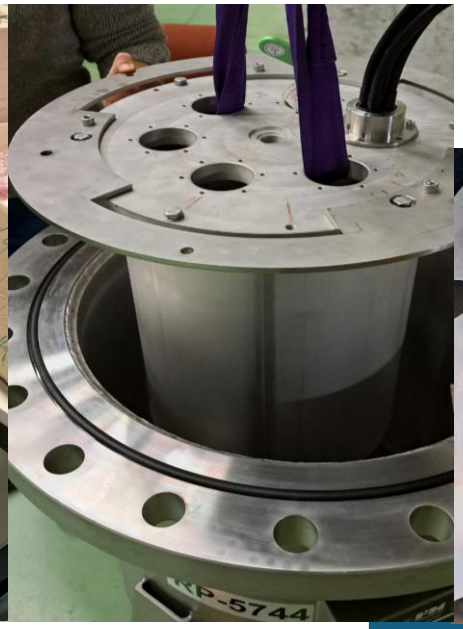
Underwater Unit (UU) description:

- Contains the read-out electronics for 24 PMTs
- The flange has 6 feedthroughs (FTs) for PMT cables + 1 FT for COM cable
- Must remain watertight under a pressure up to about 7 bars in ultra-pure water
- Must be compatible with Gd doping, chosen material: passivated Stainless Steel
- A different flange is used for OD UU.

Inside of a UU



UU vessel



The test vessel project:

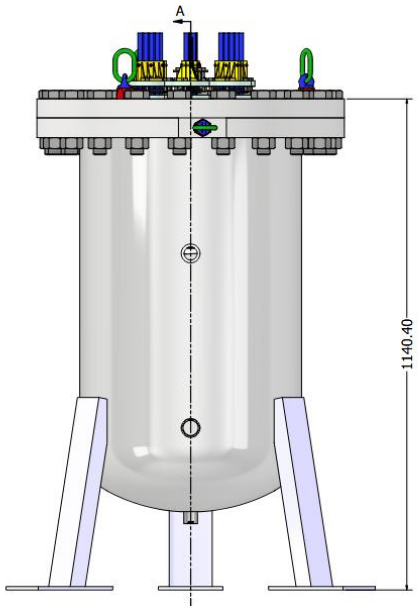
A pressure vessel for testing at 10 bar the Underwater Units (UUs) hosting the electronics for PMTs, for both the Inner Detector (ID) and the Outer Detector (OD).

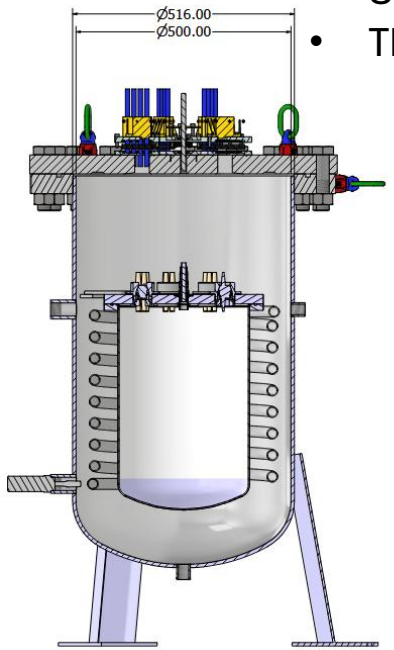
- On the main flange there is the same number of FTs but new design.
- It is ~ 1m high and ~ 50 cm wide
- Chosen material: stainless steel
- Filled with water
- A user interface is available to control the pumps and check the data taking.

Fully equipped UU flange

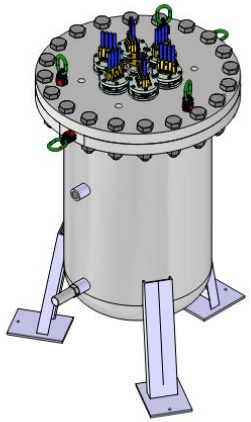
Hyper-Kamiokande activities

Final design



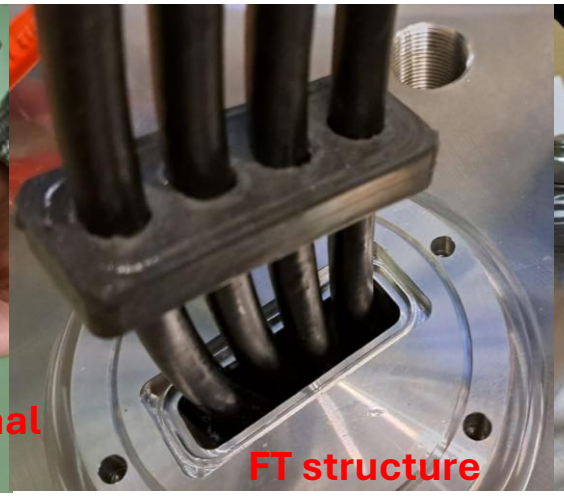


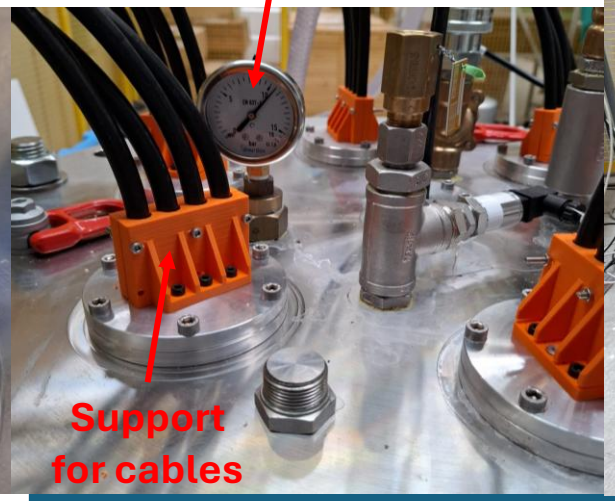
- Slightly higher and wider than the prototype
- Thermal coil around the UU

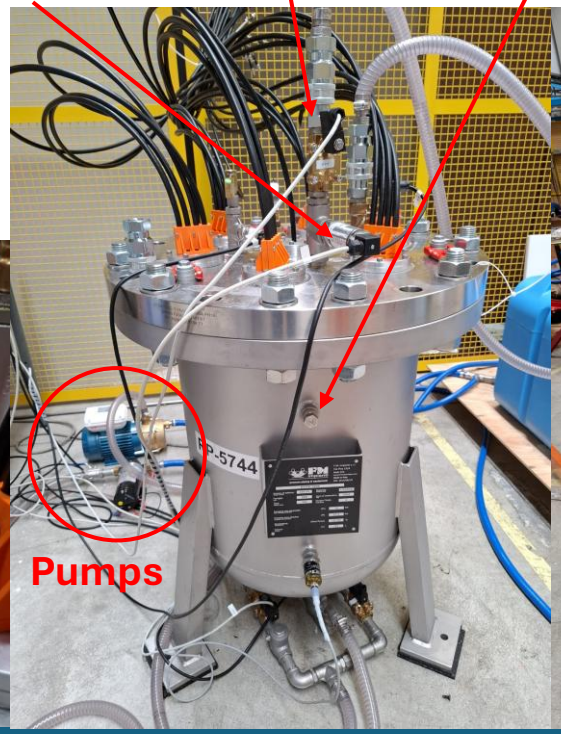


Prototype achievements:

- Pressure stability over time.
- Water pumps electronic control system is working.
- Sensors read-out electronics is working, PCB to be made.
- Ready to produce the 6 new and final vessels.





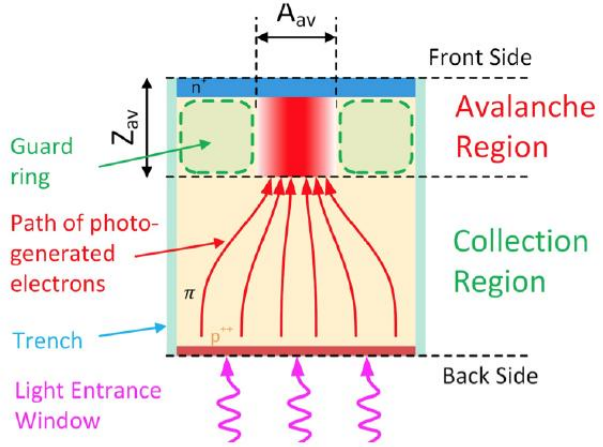


FBK activities

I spent 5 months (ending the 25 of September) at FBK working on NUV-BSI SiPM project. During the full period I was supervised by Alberto Gola.

The next-generation of developments, currently being investigated at FBK, is building a ***backside-illuminated, NUV-sensitive SiPM*.**

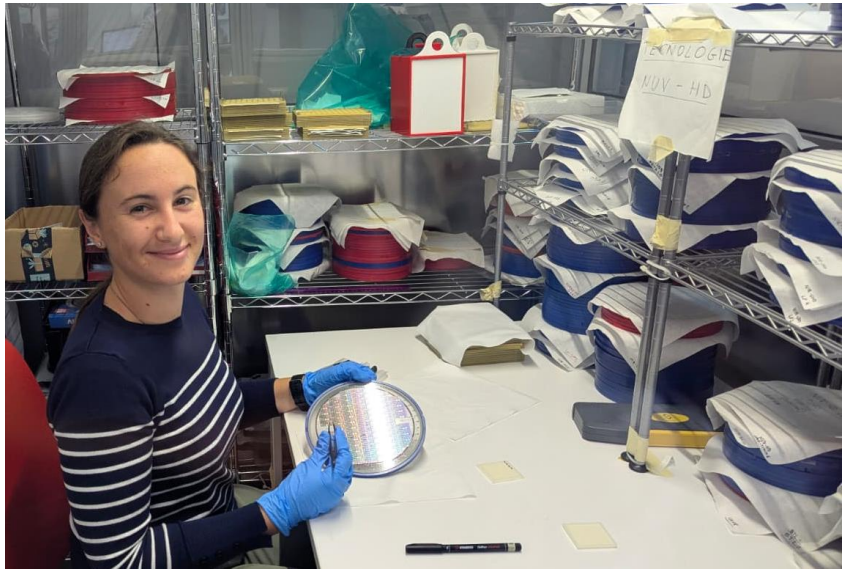
Distinct separation between charge collection and multiplication regions



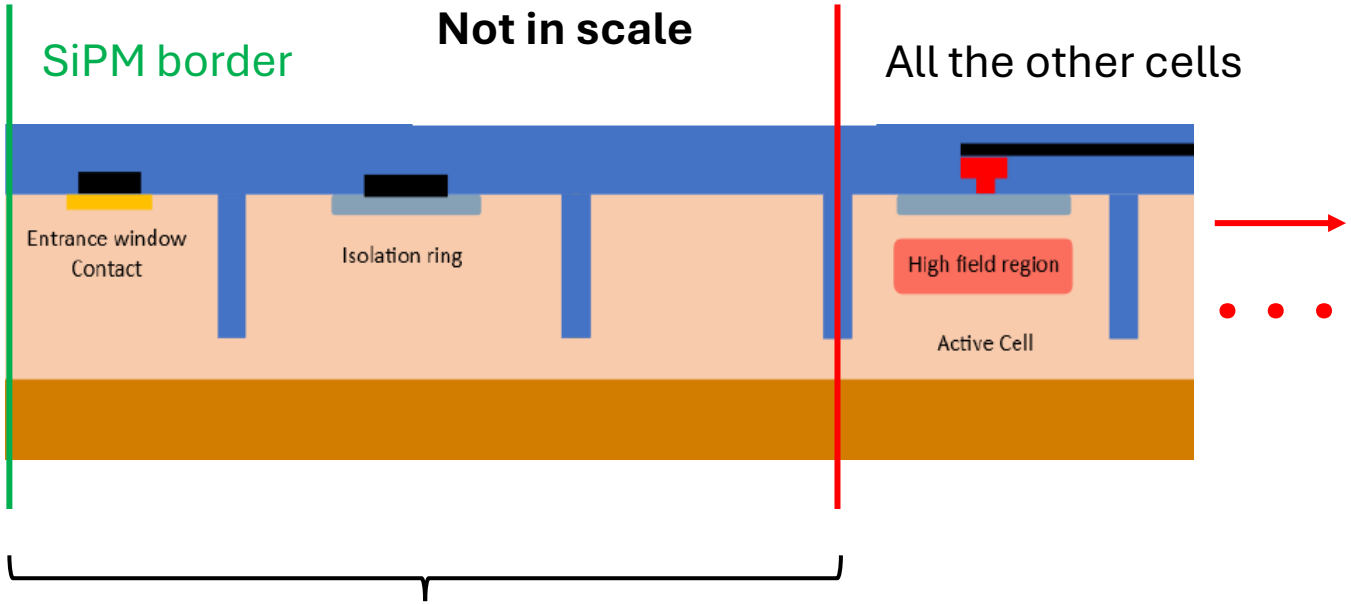
Potential Advantages:

- 100 % FF with maximum focusing factor of small cell sizes
- High speed and dynamic range
- Radiation hardness
- Uniform entrance window on backside: ideal for enhanced optical stack for VUV sensitivity
- Integrated electronics : possibly low power and ultra fast (for timing resolution applications)

Extraction of SiPMs from the silicon wafer



FBK activities



Different splits are produced to understand the impact of each guard ring configuration.

The aim is to reduce as much as possible the diffusion charge carriers coming from the cell border.

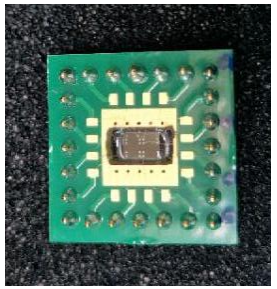
R&D on the cell layout involves:

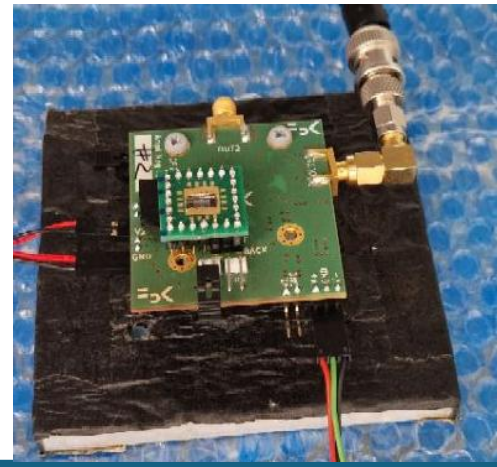
- Shallow Implant (SI)
- Deep Implant (DI)
- Epitaxial layer thickness
- Dopant concentration
- Trench Depth
- Etc…

Layout parameters

My work:

- Characterization of SiPMs:
  - IV curves, IV vs temperature
  - DCR characterization
  - PDE measurements
- Building of SPTR setup with laser





Conferences, schools, passed exams

- T2K collaboration meetings:
  - November 11-16 & March 24-29, Tokai, Japan
- Tech-FPA PhD Retreat 2025, L'Aquila
- Open Symposium on the European Strategy for Particle Physics, 23-27/06/2025, Venice
  - *In this conference I was part of the LOC Staff.*
- XXI International Workshop on Neutrino Telescopes 29/09-03/10/2025, Padova
  - *A contribution has been accepted for the conference.*

LOC Staff Open Symposium

Schools and exams:

- DRD1 School on Gaseous Detectors 27/11-6/12/2024, CERN
  - After the exam 3.5 CFUs have been recognized
- Photodetection: scintillators and silicon photomultipliers
  - 2 CFUs recognized
- Solid state detectors, *still ongoing…*

DRD1 School on Gaseous Detectors

Plans for the next year

Conferences:

- IEEE NSS MIC RTSD, Yokohama, Japan, November 1-8, 2025
  - *Short course on 'Electronics and Signal Processing for Detectors'*
  - *Workshop on 'Scintillator-based photon counting CT detectors'*
  - *Full day tour of Hamamatsu Photonics Central Research Center*
- T2K Collaboration meeting, KEK (Tsukuba), Japan, November 10-15, 2025
- PD2025 (7th international workshop on new Photon-Detectors), Bologna, December 3-5, 2025.
- Neutrino 2026 (XXXII International Conference on Neutrino Physics and Astrophysics), Irvine (Los Angeles), USA, June 22-26, 2026. ⟶ *Abstract for a poster*

Schools:

- EDIT 2026 ? (Excellence in Detector and Instrumentation Technologies), CERN, March 3-13, 2026
  - *If I pass the selection… Application will be sent soon!*

Mandatory period abroad:

- 27/10- 30/11 J-PARC laboratories, Tokai, Japan (T2K experiment)
- At least other 2 months…

Mandatory period at FBK:

- Completion of the 6 months (5 already done, 1 is missing)
- Possibly, I will stay longer than the mandatory period.

Exams:

- One on neutrino physics
- One preferably on detector readout electronics

Plans for the third year

Conferences:

- T2K and Hyper-K collaboration meetings
- NuFact 2027 → Abstract for a talk
- Other conferences on detectors in the first semester

Schools:

- No plans for the moment

Mandatory period abroad:

- Completion of the last 3 months

Mandatory period at FBK:

- Hopefully already completed
- Possibly, another month to finalize the project.

Papers:

- Short paper on pressure vessel construction and testing performance
- SPTR laser setup construction, calibration, performance in PDE measurement
- NUV-BSI paper
- Author of T2K and HK

Write the thesis!!