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DUNE ND-LAr 2x2 Demonstrator Tests

Vanessa Cerrone

Supervisors: **Antonio Ereditato, Ting Miao**

Co-supervisor: **Geoff Savage**

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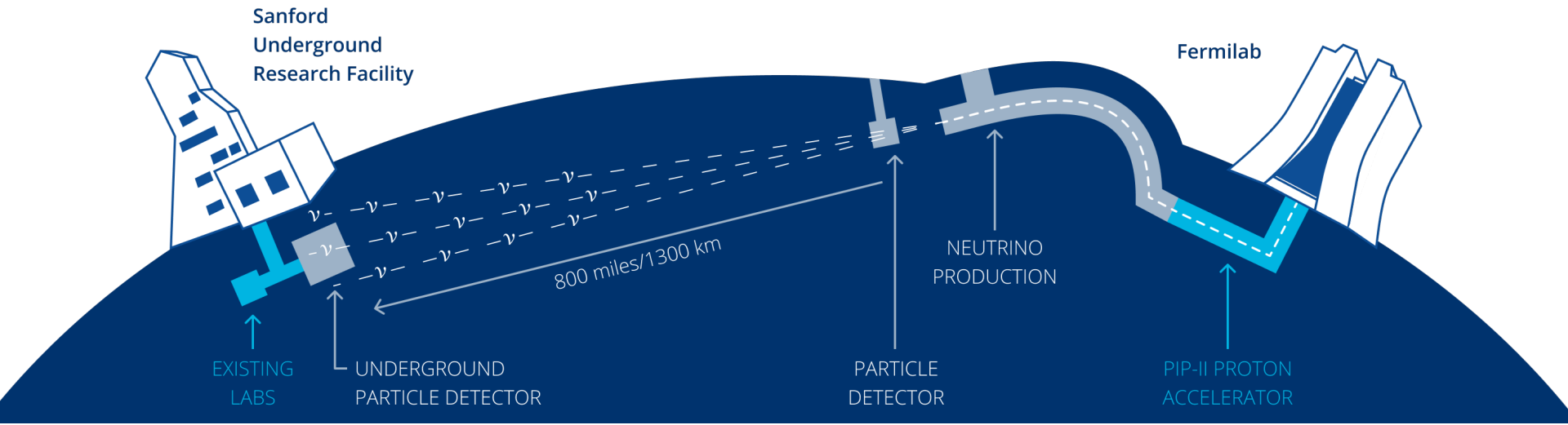
In partnership with:

ArgonCube

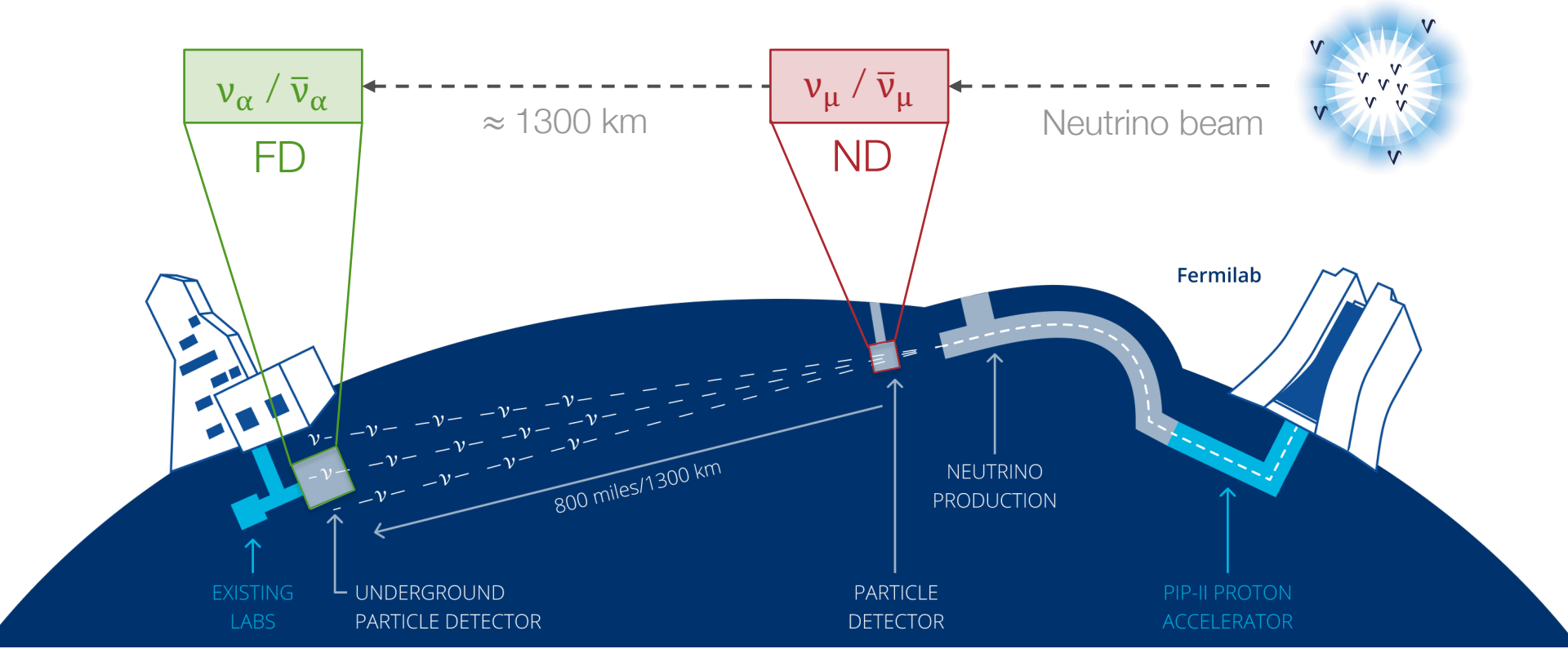
DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT

The DUNE experiment

- Leading-edge, international neutrino experiment
- **Far Detector** (FD): ≈ 1.5 km underground at the Sanford Underground Research Facility (SURF) in South Dakota, 1300 km from Fermilab
- **Near Detector** (ND): 574 m from the target, at Fermilab



The DUNE experiment



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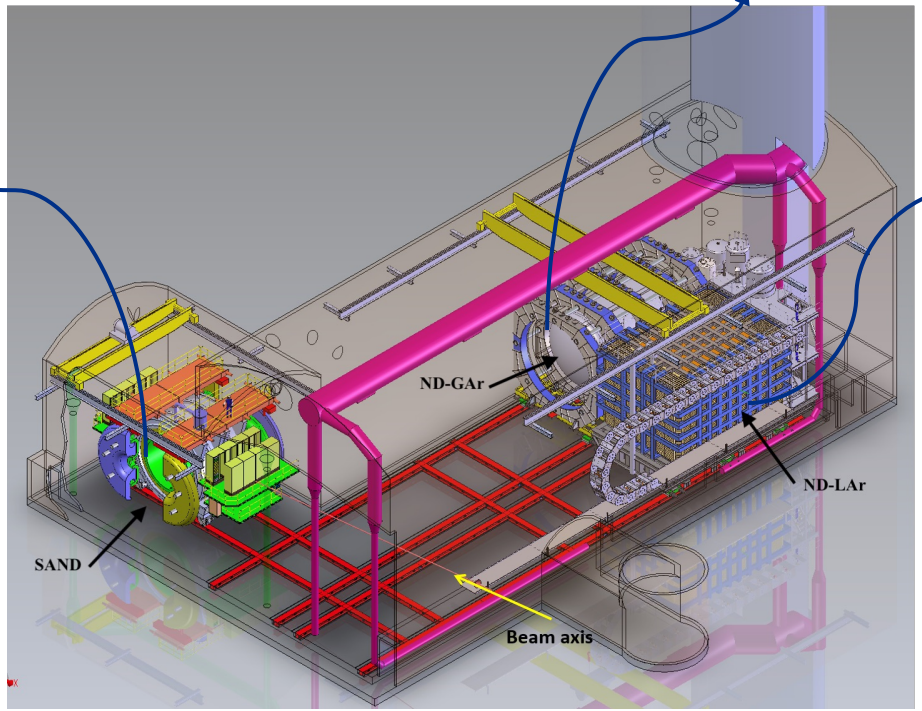
The Near Detector (ND)

Overview

ND-GAr
gaseous argon TPC + electromagnetic calorimeter (ECAL)

ND complex

SAND
(System for on-Axis Neutrino Detection) magnetized beam spectrum monitor



Liquid Argon TPC (ND-LAr)

[1] arXiv 2103:13910 DUNE ND CDR

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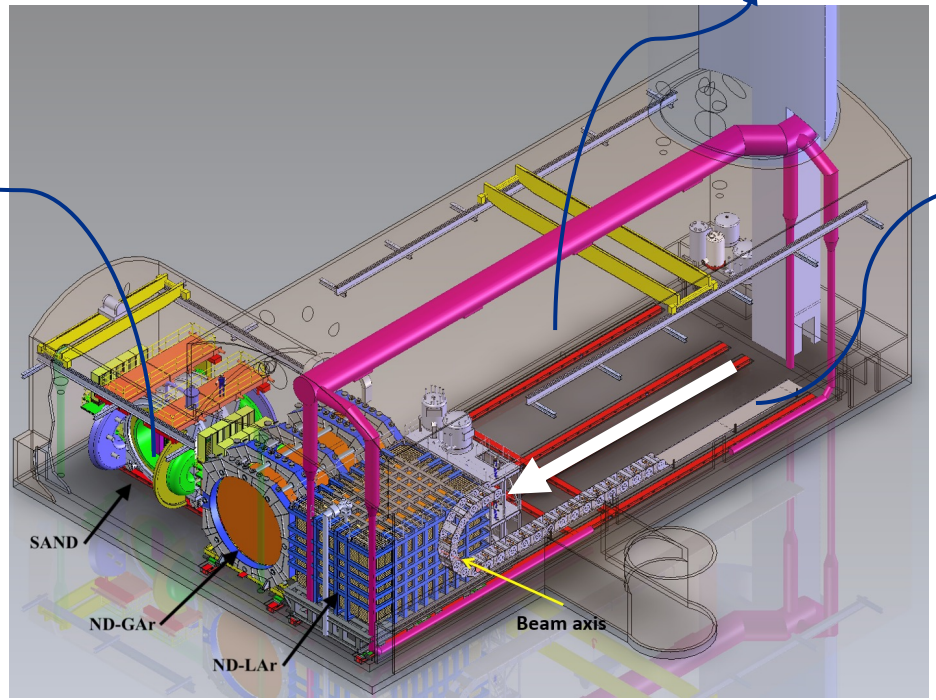

Liquid Argon TPC (ND-LAr)

PRISM
System to move the ND-LAr and ND-GAr off-axis

[1] arXiv 2103:13910 DUNE ND CDR

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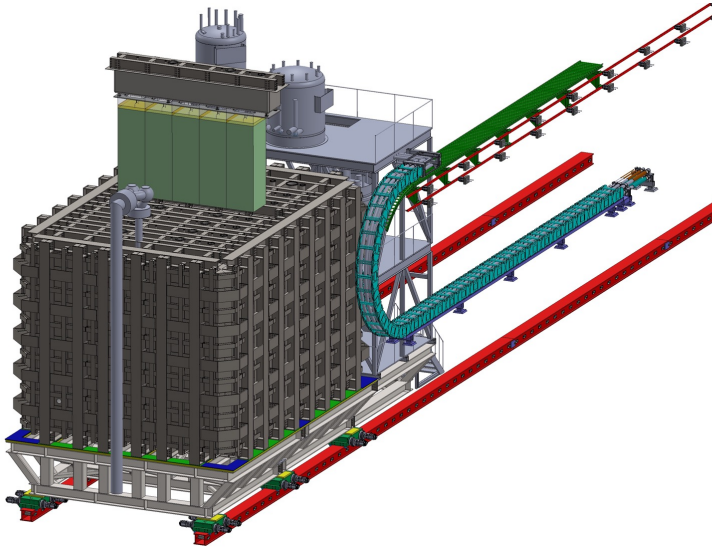
Liquid Argon TPC - ND-LAr

- **ArgonCube** technology [2]
- 35 LAr TPC modules in a common bath of liquid argon
- Active mass ≈ 150 t, 50 t fiducial
- Detector **modularization**:
  - Improved drift field stability
  - Reduced high voltage and LAr purity requirements
- **Pixelated charge readout**:
  - 3D imaging of particles interactions
- **Large area dielectric photon detection system:**
  - Fast timing information from scintillation light



ND-LAr detector

[2] Tech. Rep. CERN-SPSC-2015-009

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ArgonCube 2x2 Demonstrator

[3] DUNE-doc-12571

- Ton-scale LAr TPC detector → verify technical readiness of the ND-LAr TPC module design
- Four LAr TPC modules in a 2 x 2 grid and a shared high-purity LAr bath
- To be operated in the NuMI beamline → **First DUNE detector to take neutrino events**

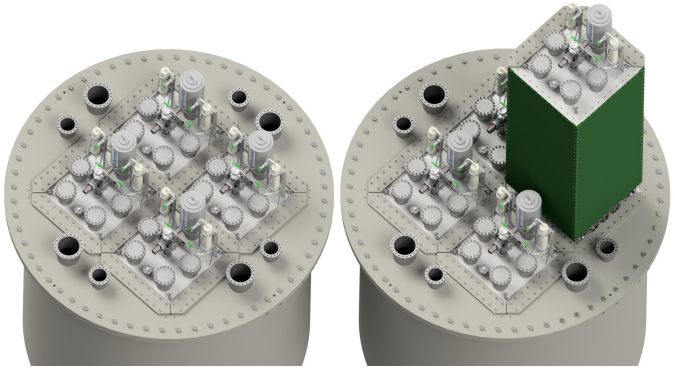
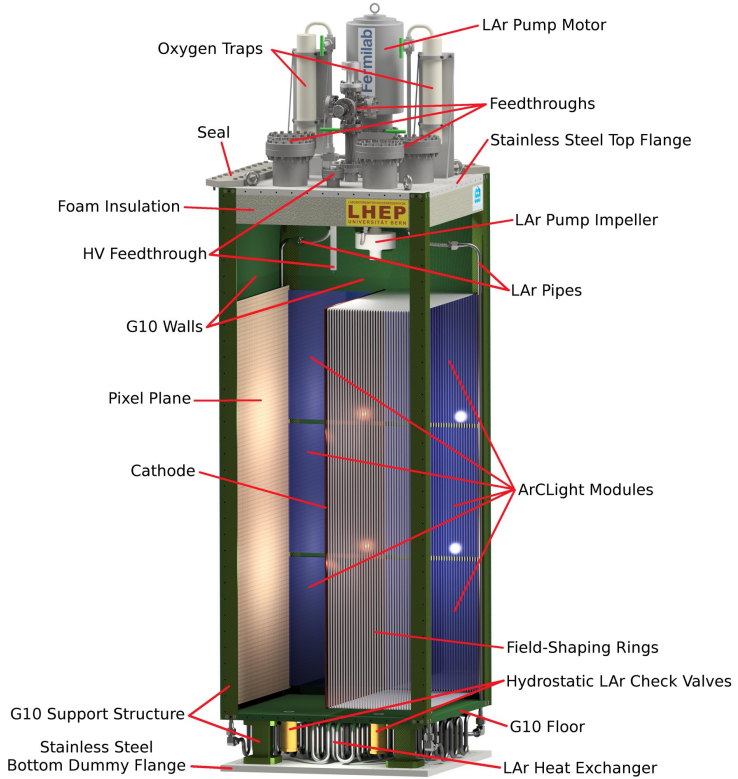


Illustration of the ArgonCube 2x2 Demonstrator module



Cutaway drawing of ArgonCube module for the 2x2 Demonstrator

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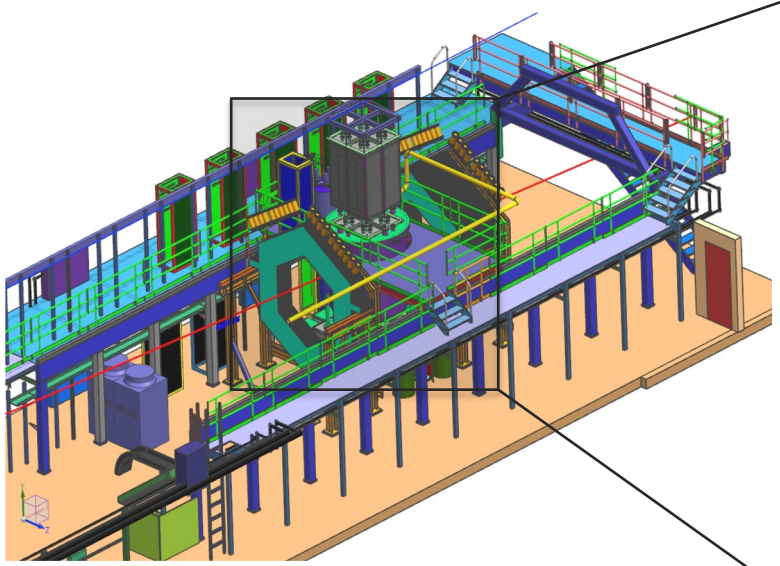
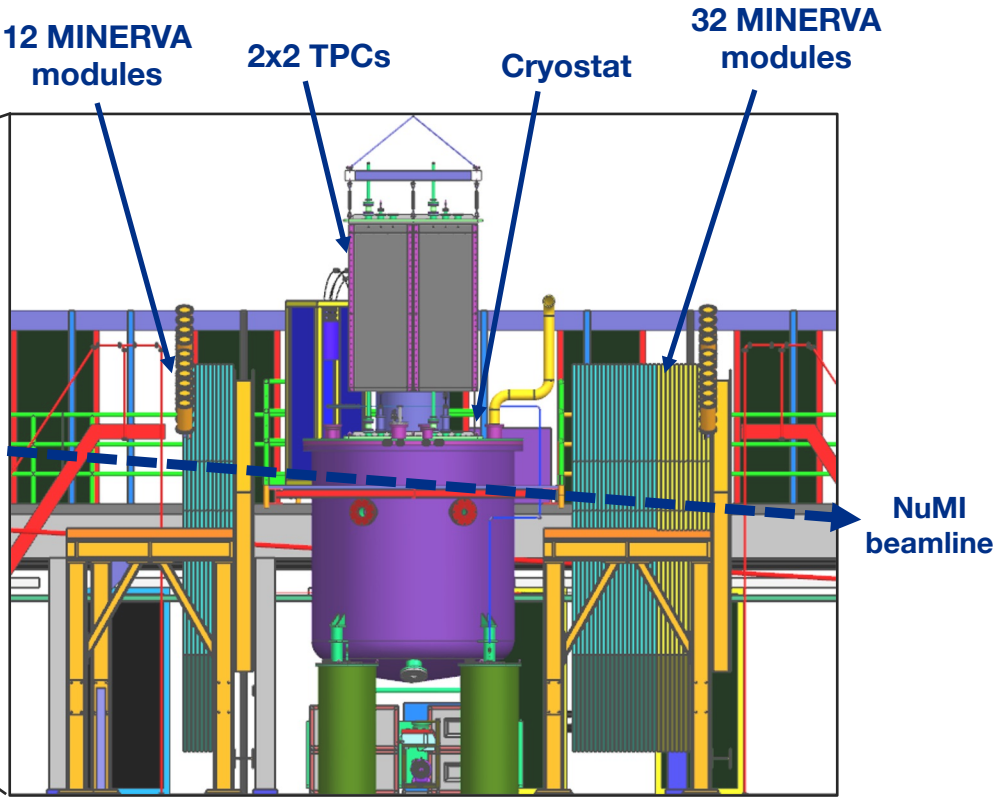
ArgonCube 2x2 Demonstrator in MINOS hall



ArgonCube 2x2 and NuMI beam in MINOS hall



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LArTF ‘Low Noise’ AC Power Distribution

Motivations

- ArgonCube 2x2 modules tested in the Liquid Argon Test Facility (LArTF)
- Neutrino interactions: low electrical signals → easily affected by noise
- Dedicated **ground system**: minimize noise transmission from the building ground to the detector electronics and instrumentation
  - Single-point grounding configuration
- **Low Noise AC Power Distribution** system upgrade at LArTF:
  - Latest design of the Impedance Monitor system included

Ground Current Impedance Monitor (GIZMO)

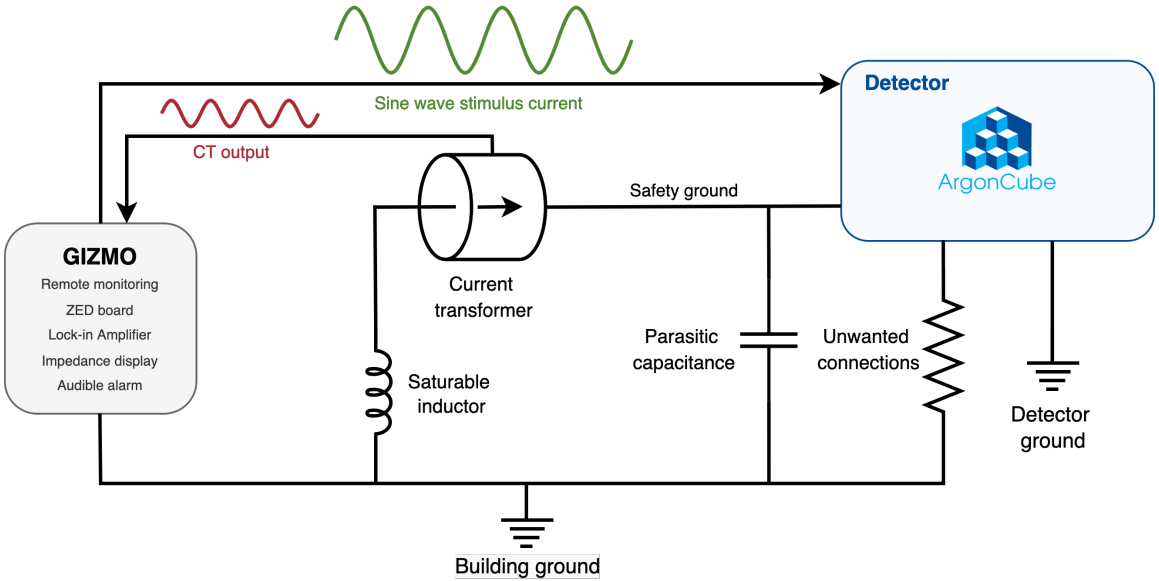
- GIZMO monitors the integrity of the single-point grounding configuration
- Audible and visual alarm in case of a rogue short
- Numerical value on front panel: **resistance between the detector ground and the building ground**

Impedance Monitor Front Panel

[4] DUNE-doc-25365

Impedance Monitor
Design

- AC current injected into the detector
- Safety ground wire through a current transformer (CT)
- CT measures the current flowing through the saturable inductor
- Saturable inductor: tackle safety issues



Impedance Monitor Circuit

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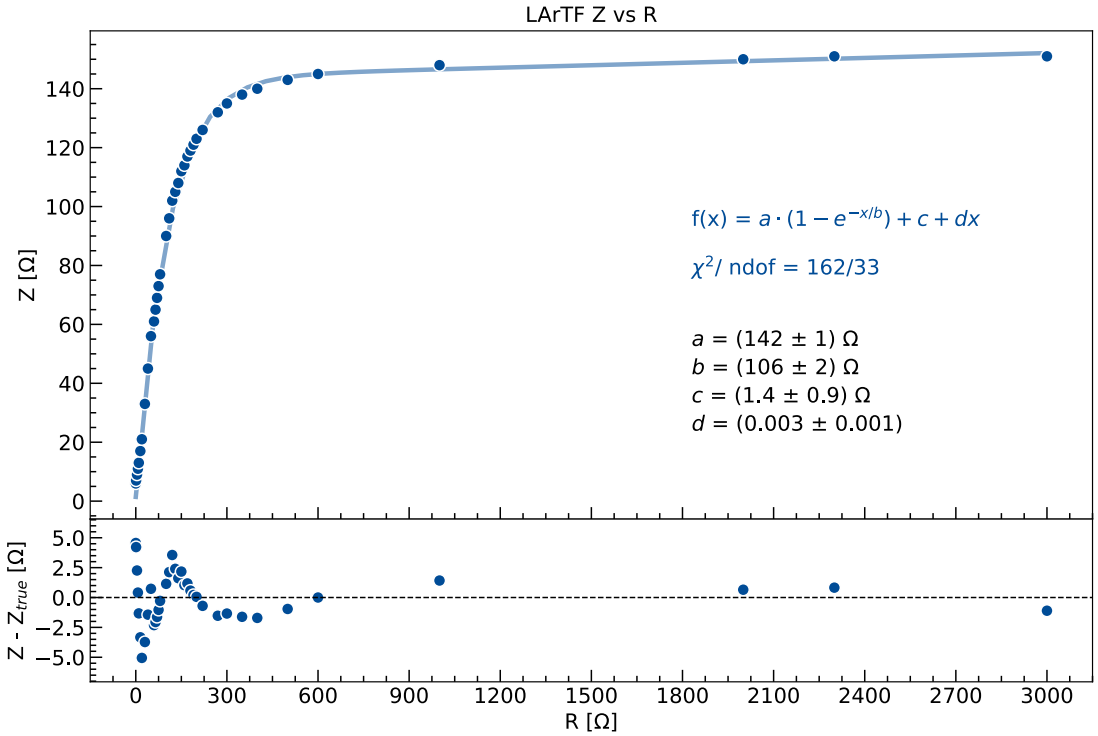
Impedance Monitor characterization measurement

Front panel reading Impedance (Z) vs Resistance data

- Resistive decade box connection: between detector ground wire/building ground reference
- Resistance increased until initial condition value*

*Baseline without capacitive or resistive loads: ≈ **152 ohms**



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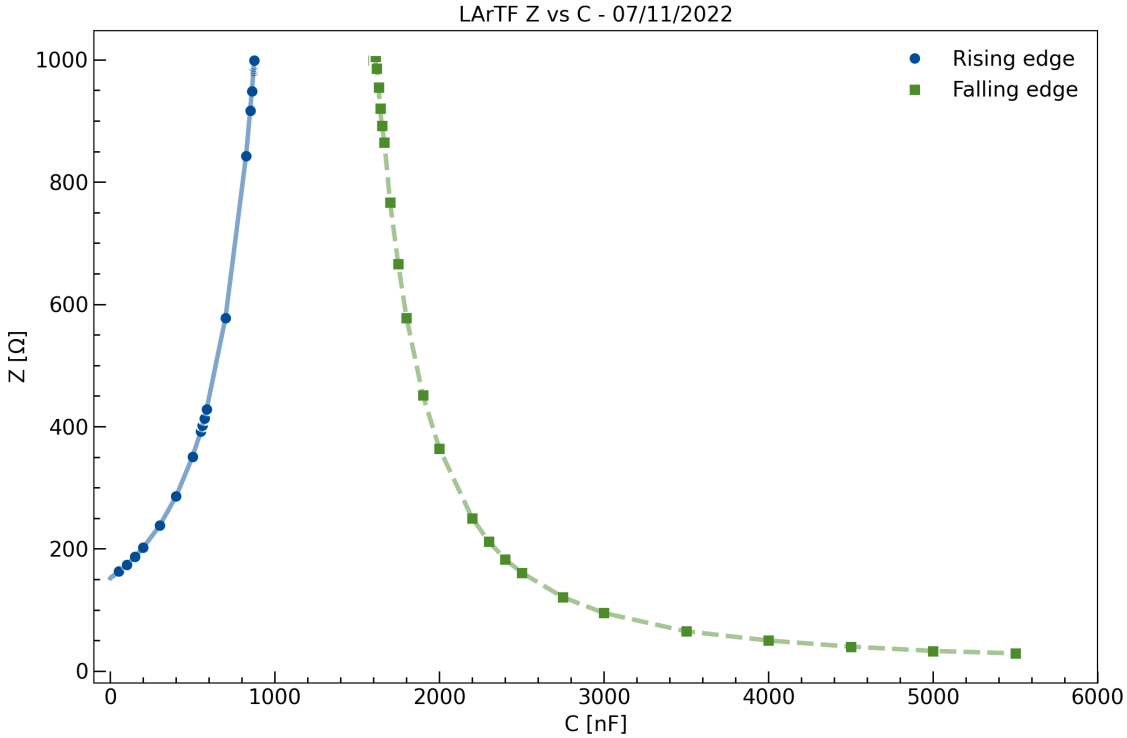
Impedance Monitor characterization measurement

Front panel reading Impedance (Z) vs Capacitance data

- Detector ground cable/2x2 module-1 connection
- Capacitive decade box connection: between cryostat/building ground
- Data interpolation → capacitive coupling



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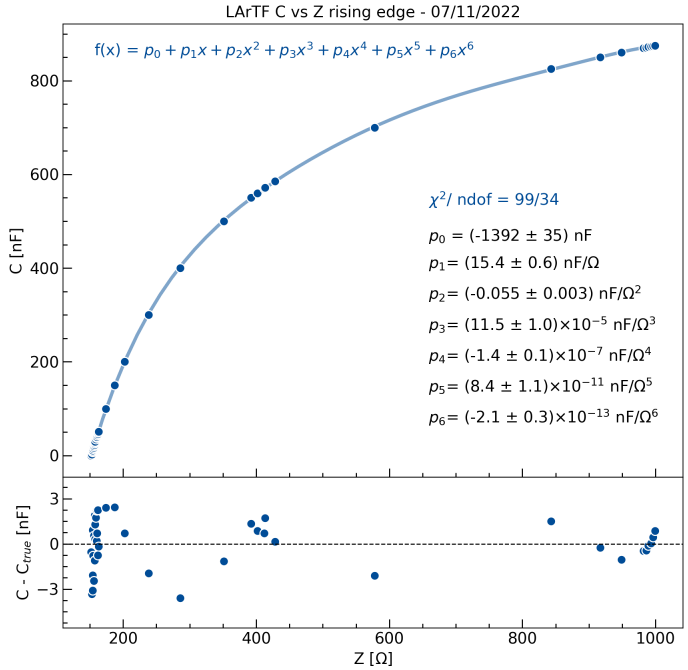
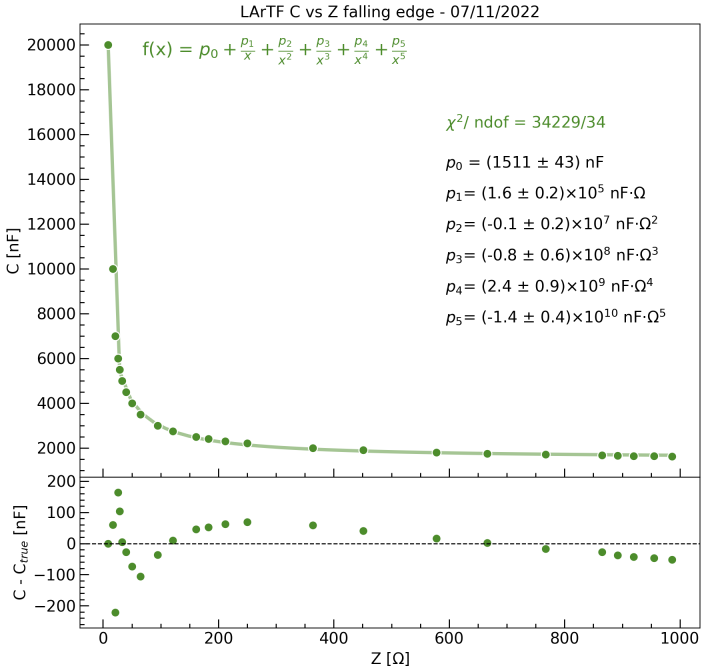
Impedance Monitor characterization measurement

Rising and falling edge fit





Impedance **increase:** system on the **rising edge** of the Z vs C curve.

Impedance **decrease:** system on the **falling edge** of the Z vs C curve.

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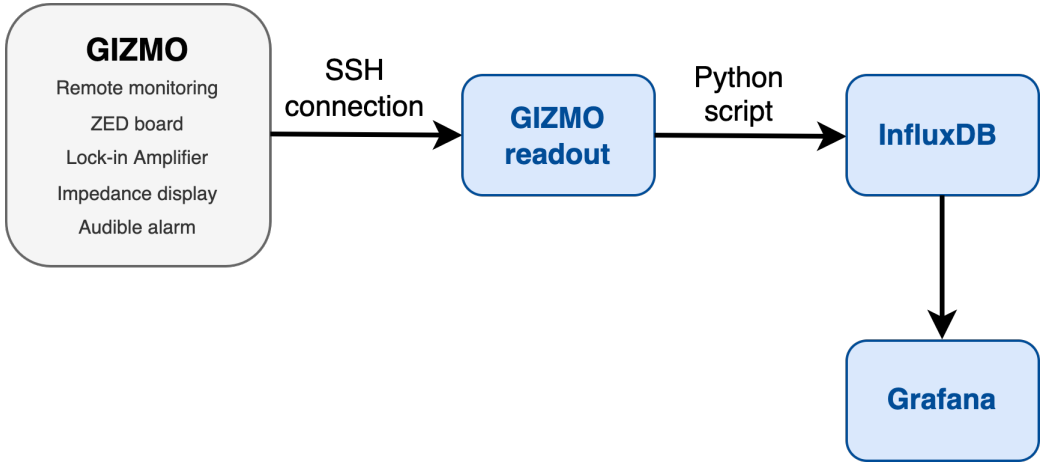
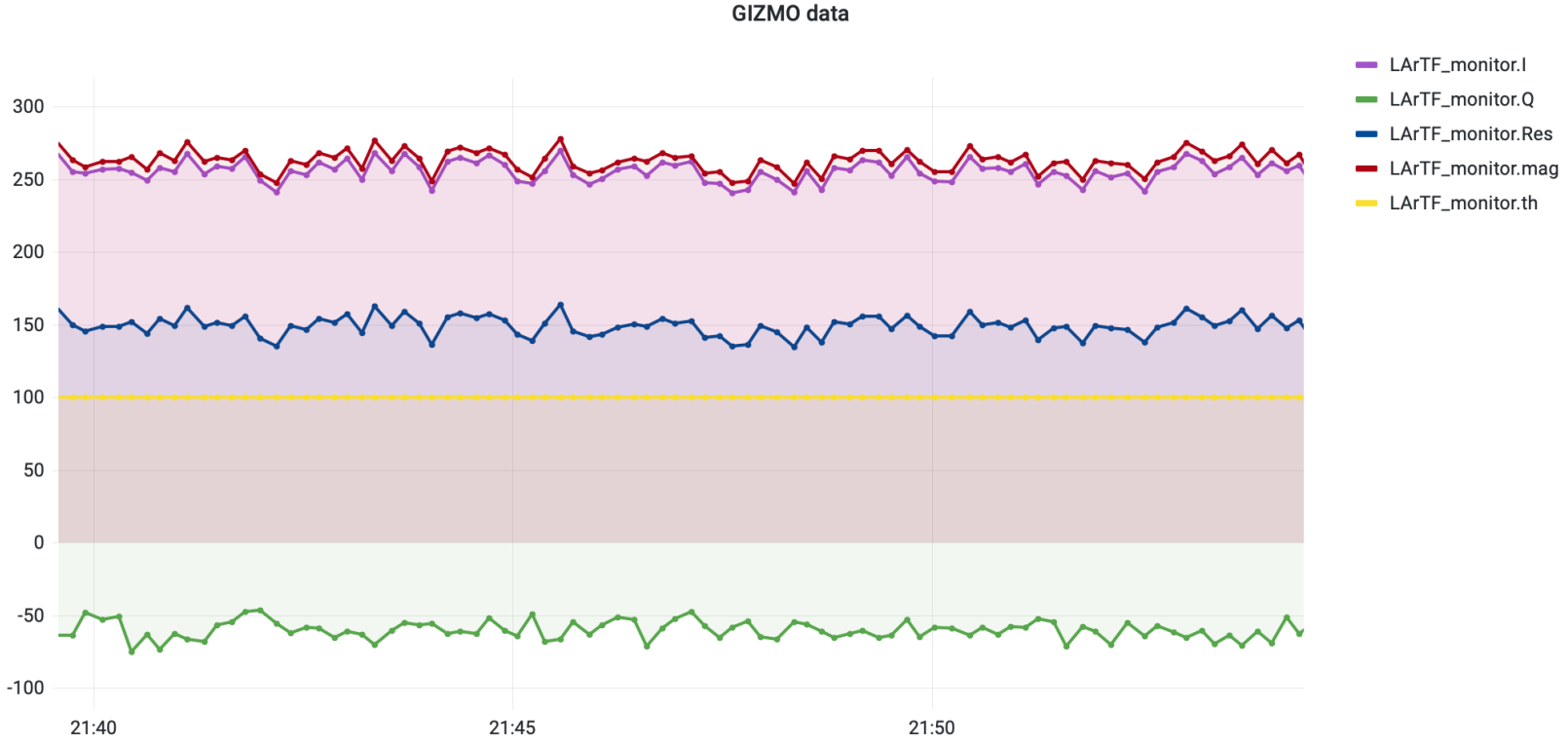
Impedance Monitor Control

- **Goal**: monitor the impedance value throughout time
  - Front panel impedance: remote monitoring via SSH/GIZMO connection

- Readout program: hardware reading + values printed on the shell
- Python script: parameters read and stored in **InfluxDB**
- Live monitoring: **Grafana**



Impedance Monitor Control



Grafana dashboard

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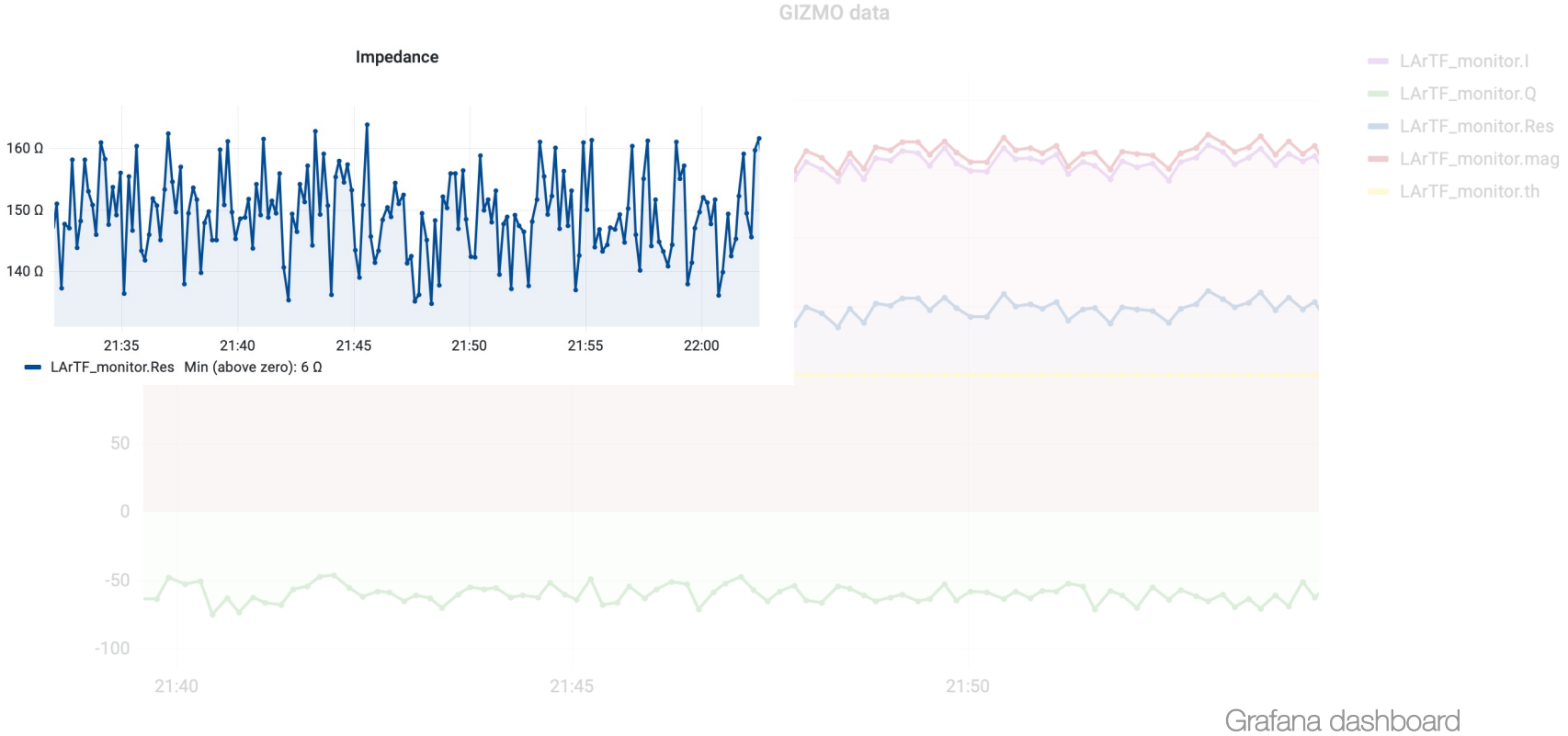
Impedance Monitor Control



Grafana dashboard

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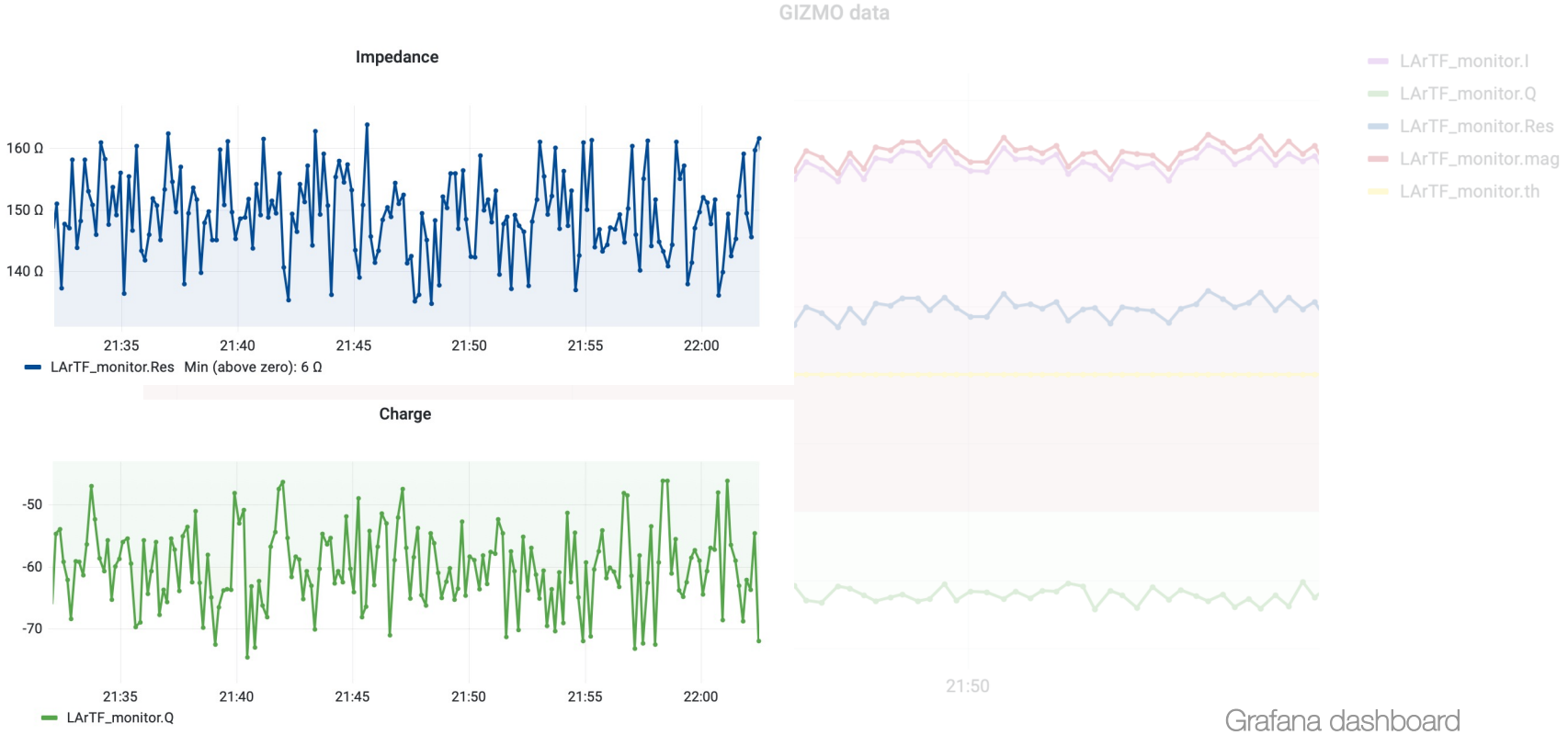
Impedance Monitor Control



Grafana dashboard

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Impedance Monitor Control

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Impedance Monitor Control

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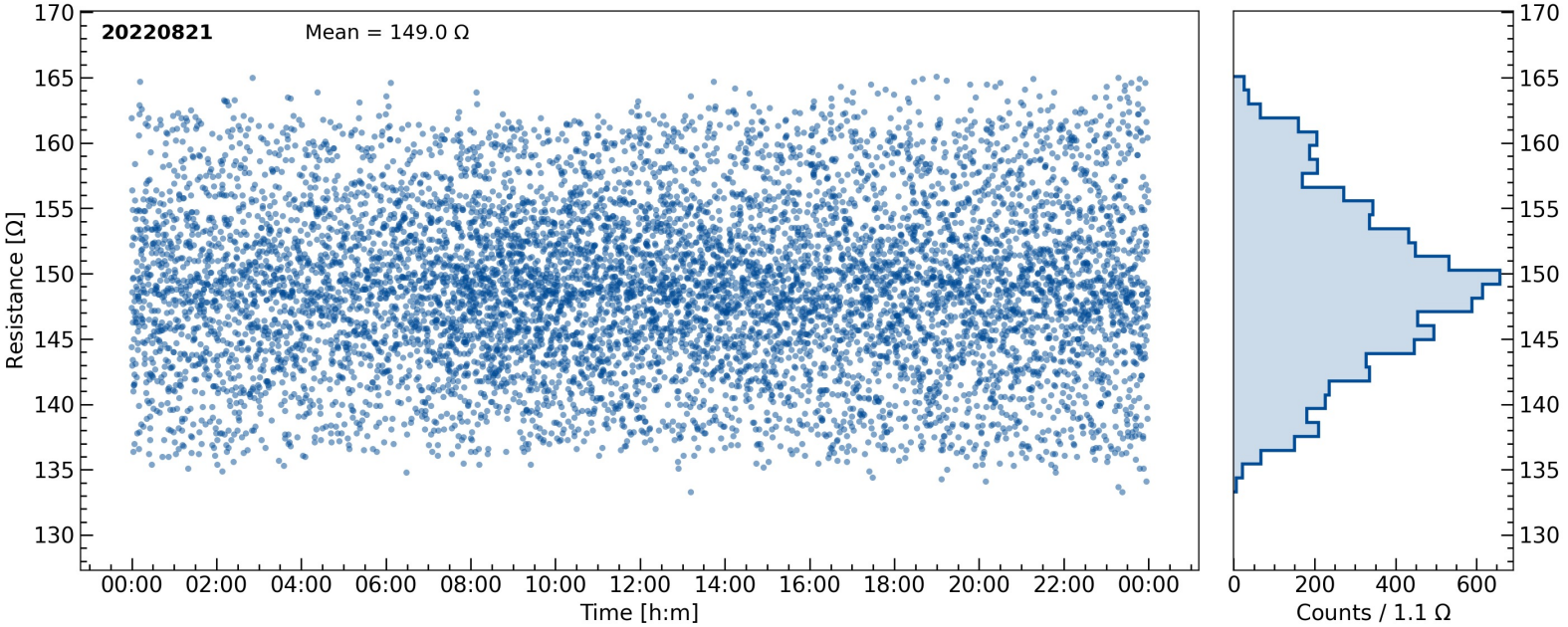
Impedance Monitor Control

Python script reading data from InfluxDB: 24 hours summary plot of the measured impedance.



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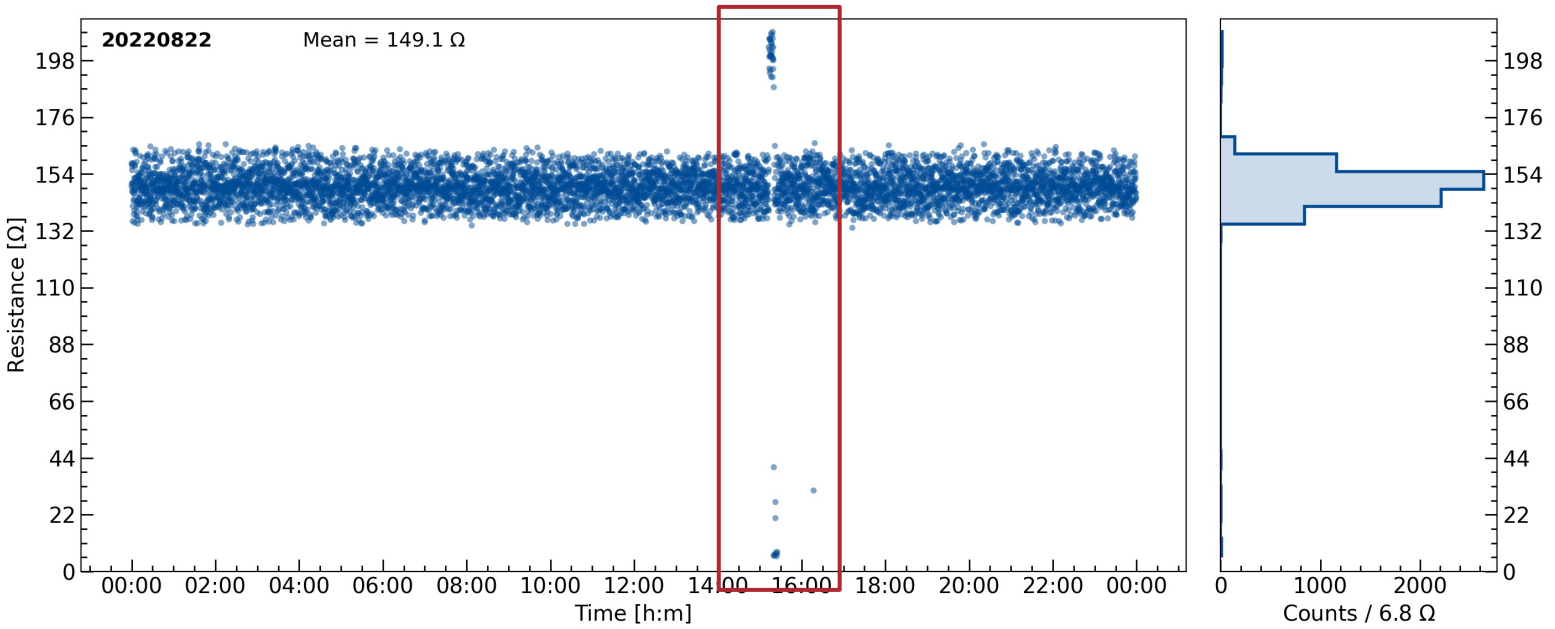
Impedance Monitor Control

24 hours summary plot of the measured impedance → **identify potential ground shorts.**



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Summary

- Ground Impedance Monitor to record the integrity of the single-point grounding configuration required for low noise operations and power distributions of ArgonCube 2x2
- Python script: front panel impedance read and saved in a time series database
- Real-time monitoring of the impedance Detector/Building grounds with Grafana

- **Future work**:
  - Analyse charge readout QA/QC tests data
  - Light readout electronics setup and QA/QC tests

THANK YOU!

References

[1] “Deep Underground Neutrino Experiment (DUNE) Near Detector Conceptual Design Report”, arXiv 2103:13910

[2] ArgonCube Collaboration, C. Amsler et al., “ArgonCube: a novel, fully-modular approach for the realization of large-mass liquid argon TPC neutrino detectors”, Tech. Rep. CERN-SPSC-2015-009

[3] “ProtoDUNE-ND: proposal to place the ArgonCube 2x2 Demonstrator on-axis in NuMI”, DUNE-doc-12571

[4] “LArTF Impedance Monitor System for 2x2”, DUNE-doc-25365

BACKUP

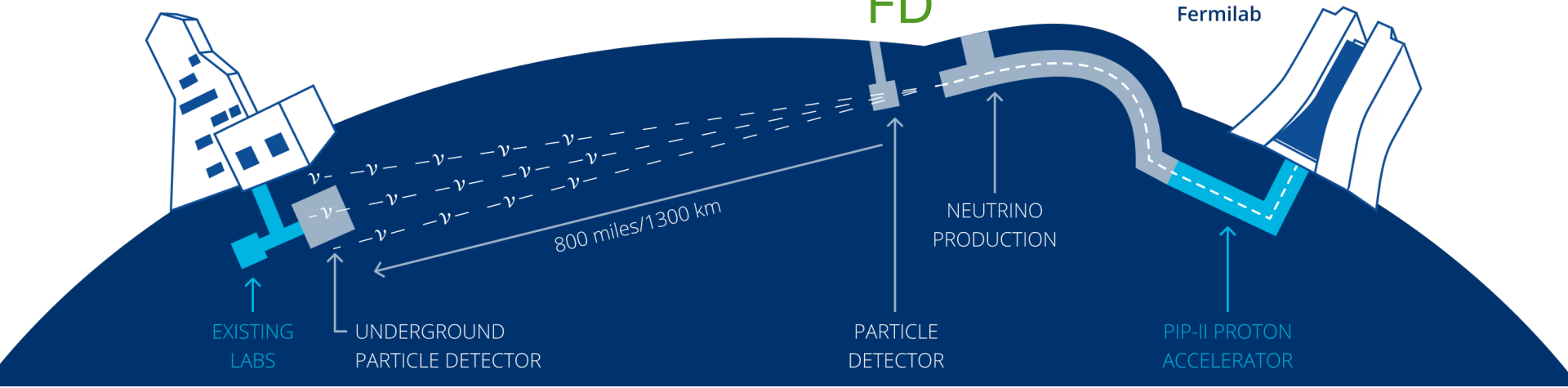
The DUNE experiment

ND

$$R(\vec{x}) = \phi(E_\nu) \times \sigma(E_\nu, \vec{x}) \times \epsilon(\vec{x}) \times P(\nu_A \to \nu_B)$$

Events rate | Neutrino flux | Cross section | Detector efficiency | Oscillation probability

FD



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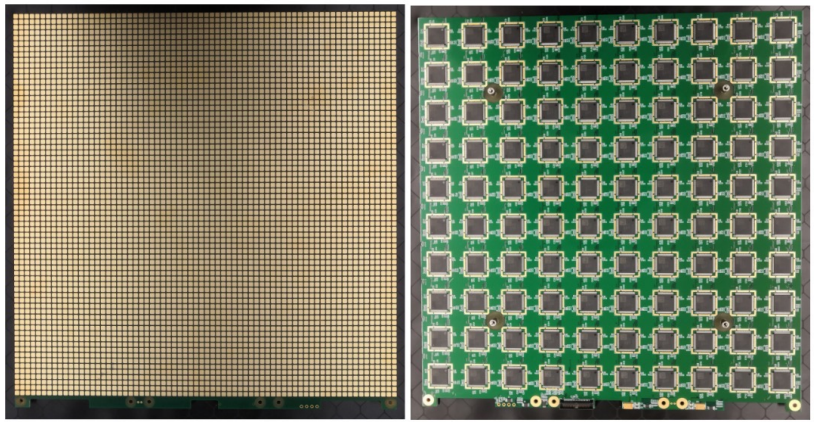
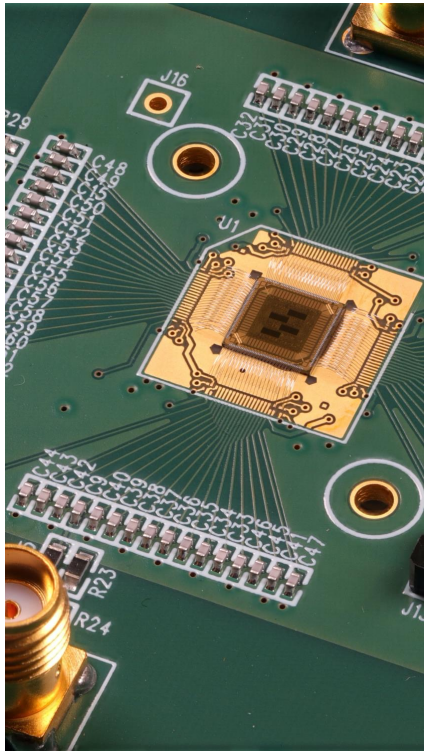
Pixelated charge readout

- Provides unambiguous 3D tracking of charged particles
- Printed circuit boards: Low-power, low-noise integrating amplifier with self-triggered digitization and readout
- Overcomes signal pileup at DUNE Near Site
- Commercial fabrication: fast, scalable production



LArPix pixel node tile



LArPix-v2 ASIC

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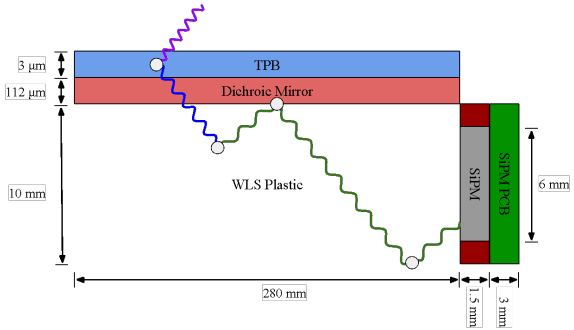
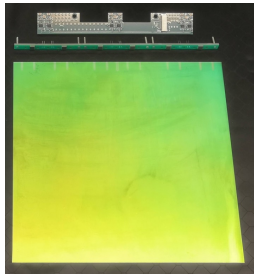
2x2 light readout system

Two comparable SiPM-based systems sharing the same readout electronics:

- **ArgonCube Light detector** (ArCLight)

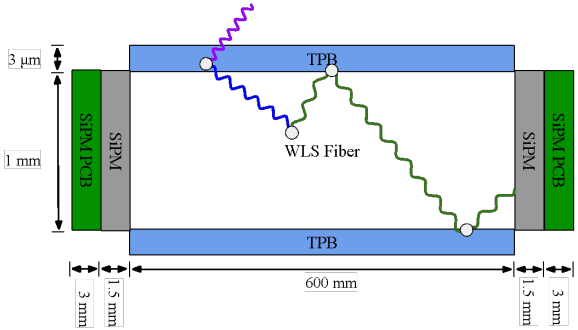




ArCLight

- Dielectric light trap: bar
- Accurate scintillation position reconstruction

- **Light Collection Module** (LCM)



- Dielectric light trap: fibers
- High collection efficiency

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