

Semiconductor sensors development and applications WG-5.2

Status Report

FAPESP Thematic 2020/04867-2

May. 27th 2026



WG-5.2.1 & WG-5.2.2 : Recap

- WG-5.2.1 : ATLAS High Granularity Timing Detector (HGTD)
- WG-5.2.2 : Low Gain Avalanche Detectors (LGADs) for low energy applications

More details on [kick-off meeting](#)

WG 5.2.1: People and Action Items (Recap)

1. Current Team - HGTD

1. M. Leite (Physicist)
2. G. Saito (DD FAPESP)
3. R. Estevam (DD FAPESP)
4. R. Menegasso (TS)
5. M. Kuriyama (TS)
6. G. Gonçalves (IC FAPESP)

1. Action items

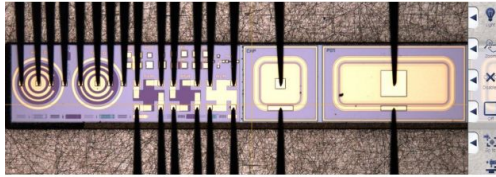
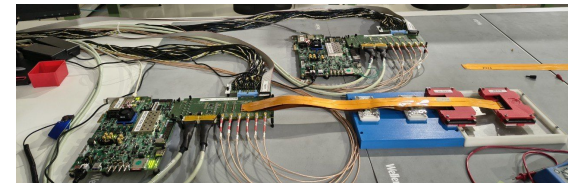
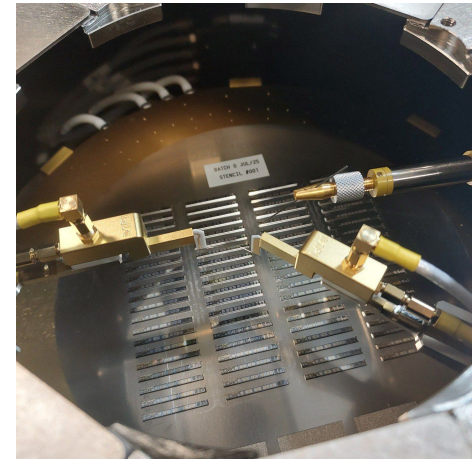
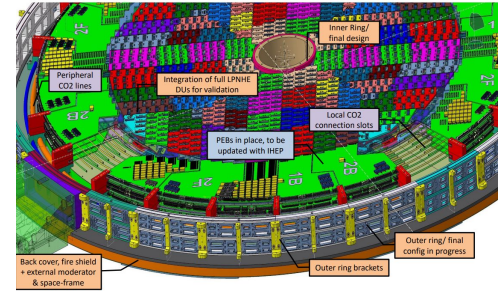
1. Equipment availability (importation) **(DONE!)**
2. Preparing civil infrastructure for Lab **(DONE!)**
3. Lab installation **(DONE!, but will keep updating)**
4. DD, TT hiring (Still on-going ...)
5. Start testing sensors **(DONE!)**
6. **Significant work to commission local infrastructure (EMU FAPESP)**
7. **Significant commitment of people on @CERN activities**

1. Deliverables

1. **LGAD Characterization Lab.**
2. **Characterization of LGAD sensors (on-going)**
3. **Performance studies on irradiated arrays (on-going)**
4. **PEB test stand system**
5. **Participation in HGTD assembly facility construction @ CERN (on-going)**
6. **Demonstrator construction @ CERN (on-going)**
7. **HGTD installation**
8. **HGTD commissioning**

UFSD Sensor Characterization and HGTD integration

- Completed the pre-production and pilot batch sensor characterization
- CERN and USP sites fully cross validated (milestone for the project)
 - More than 2000 test structures (TS) and few arrays will be tested
 - Automatic measurement and new instrumentation in place, DAQ send data directly to a database
- Collaborate on HGTD demonstrator tests at CERN
- Installation is ready for other users (see next slides)
- New upgrade for probe station installed
- We are able to do very precise measurements (aF resolution)



New probe card setup and 100 structures stencil holder

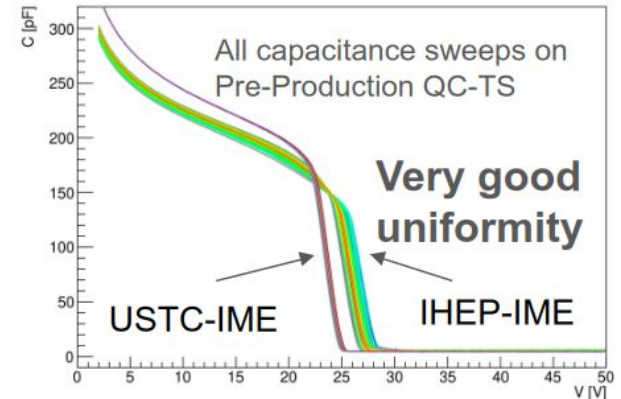
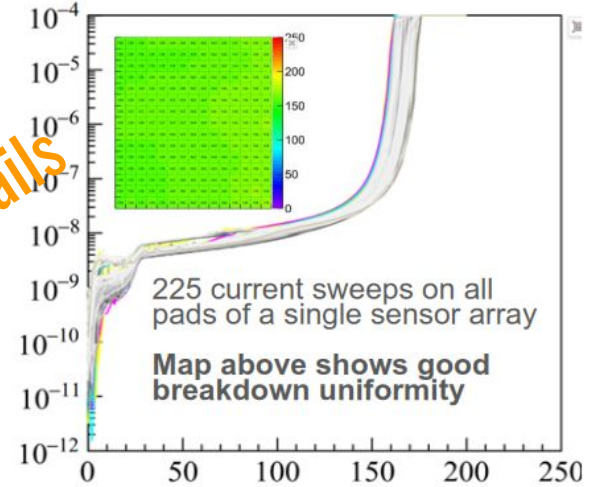
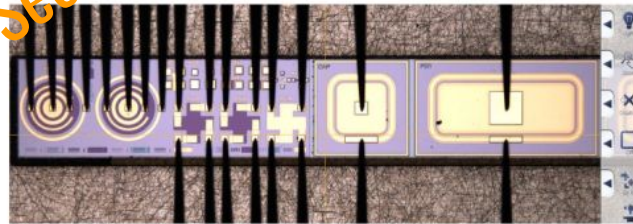
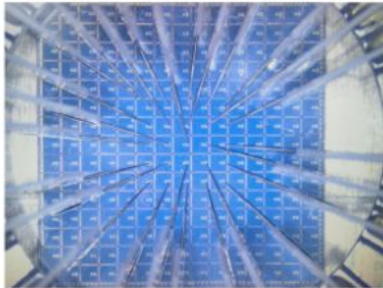
Sensor and Wafer Quality Control

Quality control on **sensor level**:

- Only measure Breakdown Voltage and Leakage Current
 - Before company delivery: **on all sensors** with probe card
 - On selected sensors: **pad by pad** (at IHEP and USTC)

Quality control on **wafer level**:

- Dedicated Quality Control Test Structures (QC-TS)
 - **Monitor all available electrical parameters** across the wafer (USP and CERN - 50% each)
 - **Ensures LGAD performance** after irradiation (at JSI)



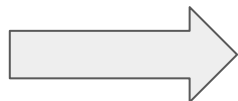
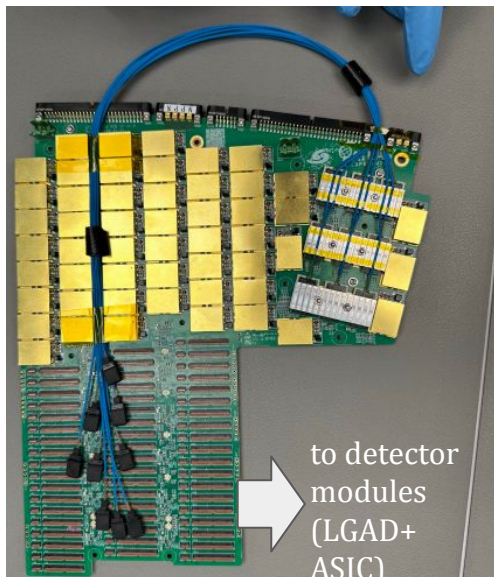
Probe-card measurement on **main sensor**

Probe-card measurement on **QC-TS**

WG 5.2.1 : ATLAS HGTD - Integration @ CERN

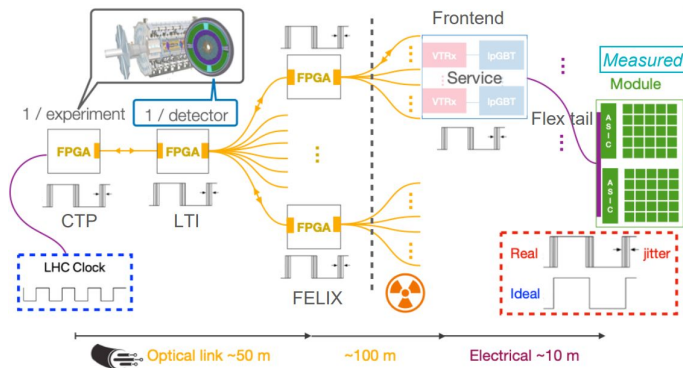
- Moving towards a test stand for HGTD using full readout (FELIX)
 - Important to develop some knowledge on high speed DAQ
 - Quite some work when integration time comes
 - Test stand at USP for studying timing distribution, calibration etc.
 - Knowledge will also be useful for ALICE and LHCb (FELIX based DAQ for future upgrades)

PEB @ CERN



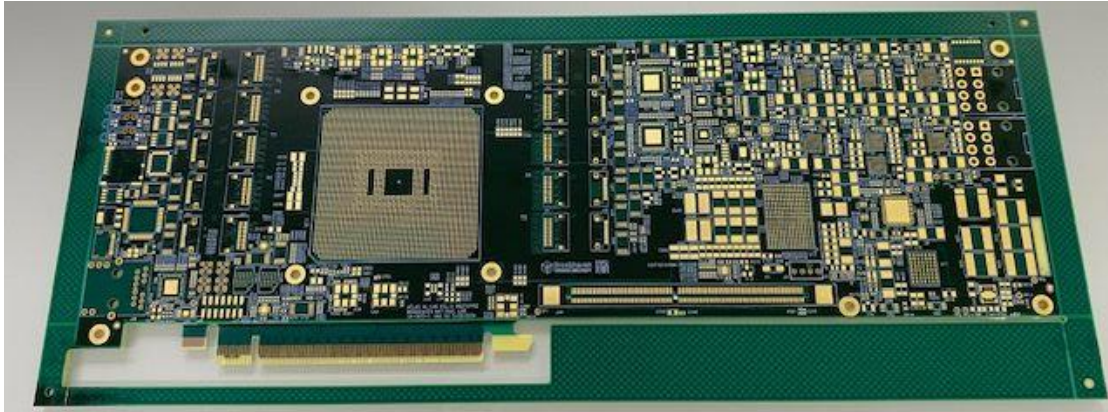
FLX155

Clock distribution chain in HL-LHC



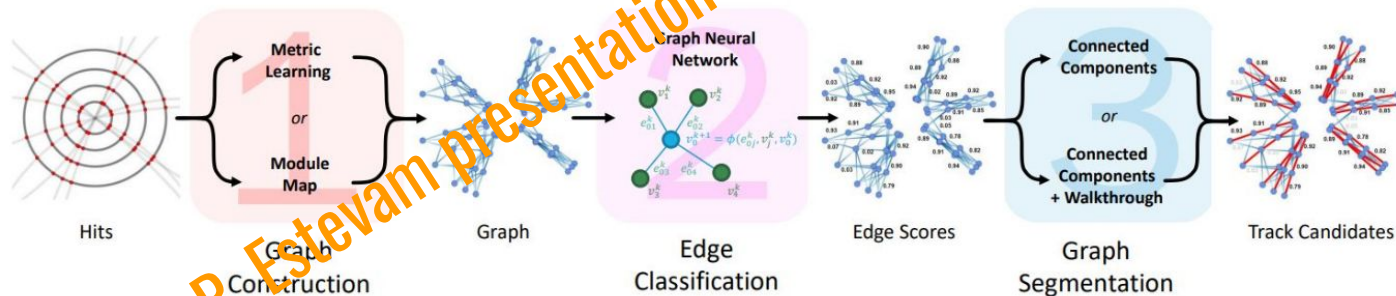
WG 5.2.2 : FELIX 155(A,B)

- FDR for ATLAS FELIX was in April -> hardware frozen
- CNPEM will produce several FELIX cards for Orion/USP/ATLAS and other experiments
- No more show stoppers (licencing, etc.)
- Bidding for manufacturers are starting
- FPGA & Fireflies starting
- Lauquen is able to produce a pilot test PCB with perfect alignment between stackups
- Assembly / Qualification / Testing / Integration -> done in BR
- Possibility for long term commitment from companies (e.g. firmware support)

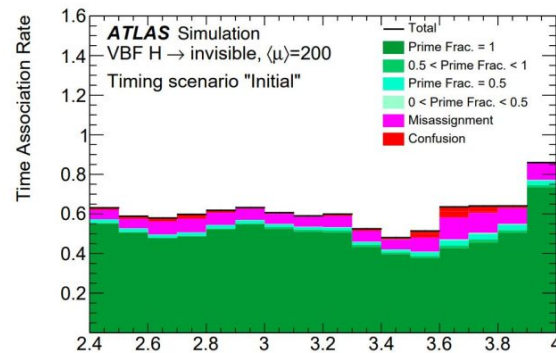


WG 5.2 - 4D Tracking

- Promising pipelines utilize **Graph Neural Networks (GNNs)** as a high-throughput alternative
 - Input graph represent hits as nodes and track segments as edges
 - The GNN then estimates the likelihood of the edge being part of a particle track
 - Selected track segments are then grouped into particle tracks
 - **Highly parallelizable! Significantly decreasing runtime when processing high number of events**



- Large amount of work implementing ACTS into ATLAS ATHENA
- Working in close collaboration with ITk project

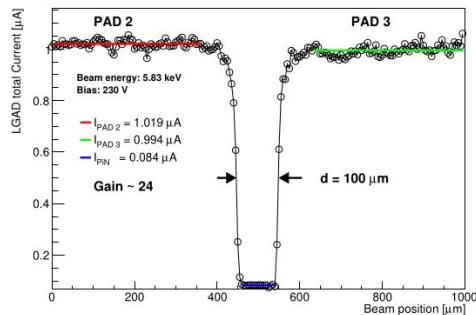
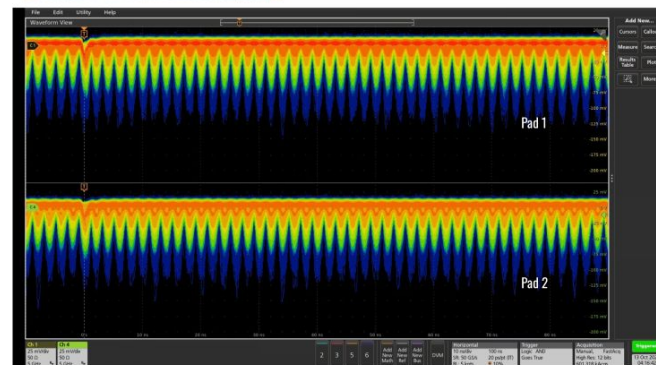
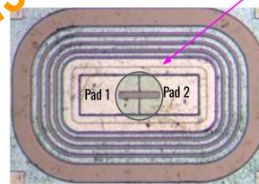
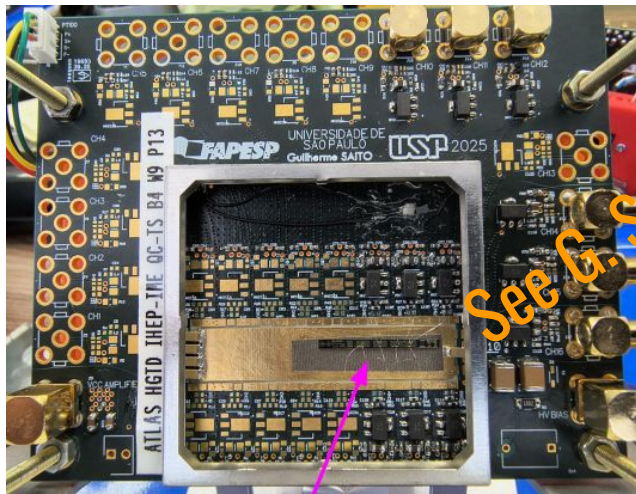


WG 5.2.2 : UFSD for Applied Sciences

LGADS for picosecond time resolved X-ray testing

- **Total of 3 TestBeam campaigns** at Carnaúba beamline at CNPEM
- New low energy (2.1 keV data)
- Measurements for gain and interpad distance with focused beam
- New (up to) 16 channel board tested with success
- Also tested IHEP and FBK TI-LGADS
- Part of DRD3 Work Package and IHEP Sprint project

- 6 keV X-rays (350 μm spot size)

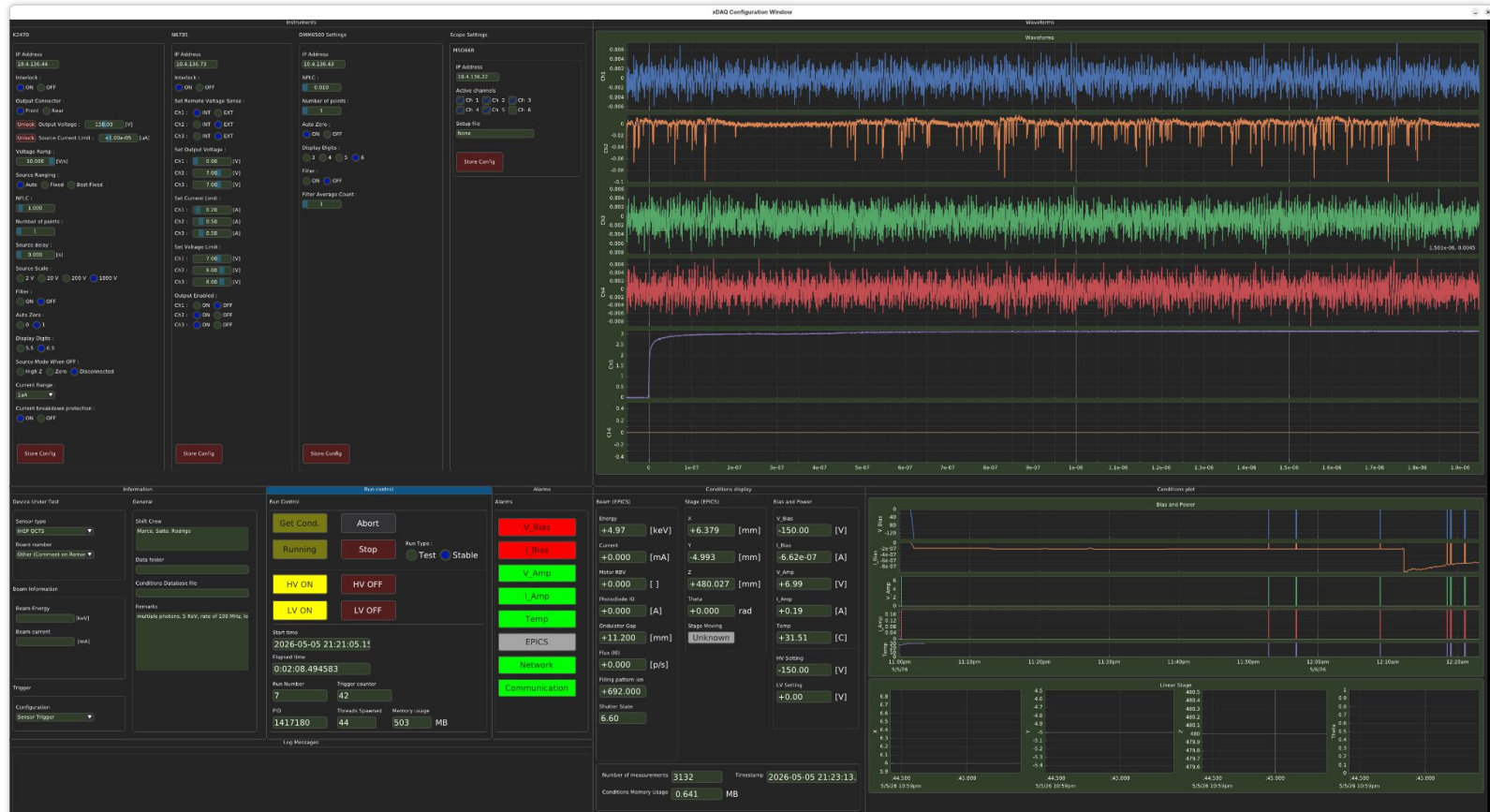


See G. Saito presentation for details



WG 5.2.2 : UFSD for Applied Sciences

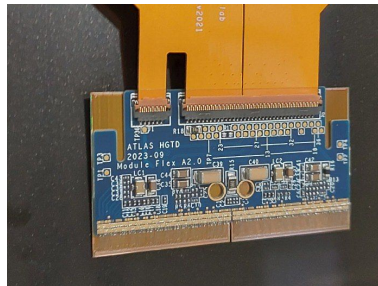
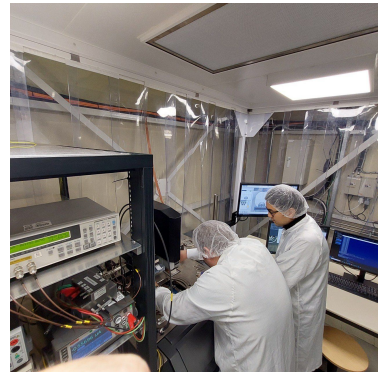
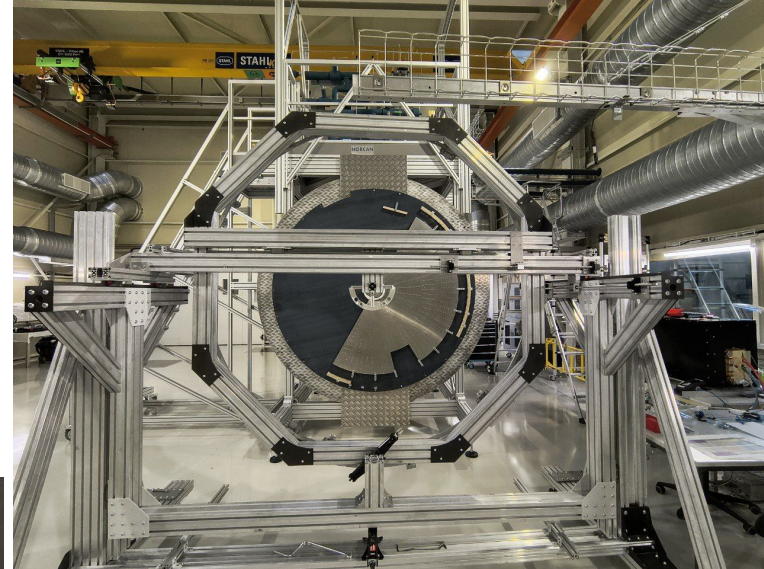
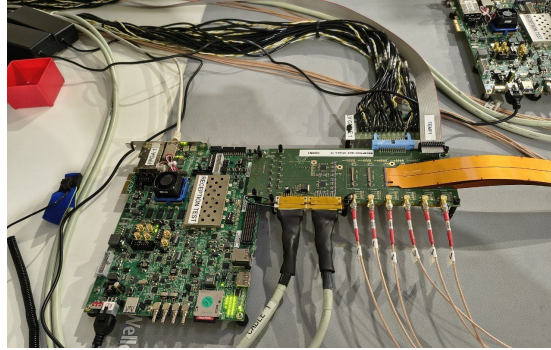
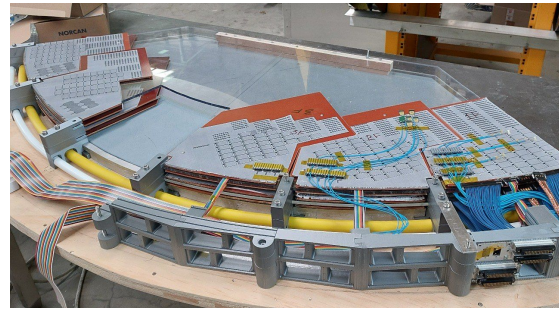
Full DAQ system developed, connected to EPICS LCLS system



WG 5.2.1 : ATLAS HGTD - Integration @ CERN

- CERN will be construction site for HGTD
- Need to build infrastructure and tooling
- Agreed as M&O contribution

- Module 0 @ CERN early 2027
- Sensor+ASIC+PEB+FELIX readout



WG 5.2.1 : Irradiation studies

- Conducted by FEI team using 10 keV X-rays

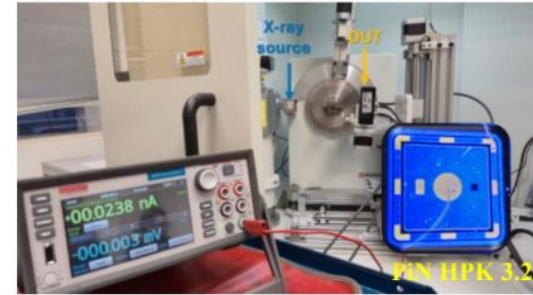


Fig. 2- Experimental setup used during the irradiation campaign.

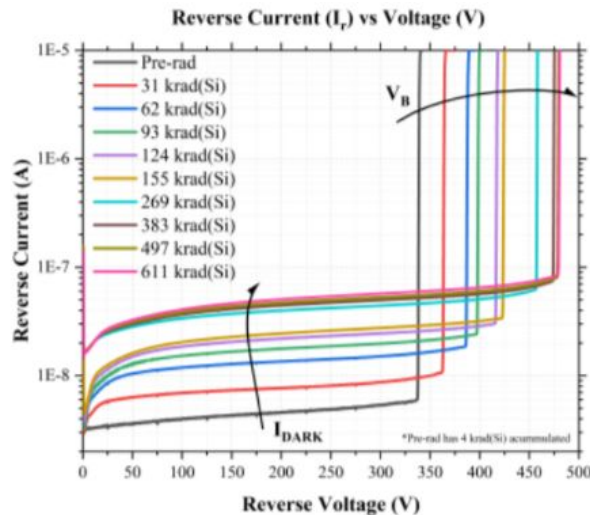


Fig. 4-Reverse Current (I_r) vs Voltage (V) TID up to 611 krad. V_B was obtained through a linear fitting of the experimental curves.

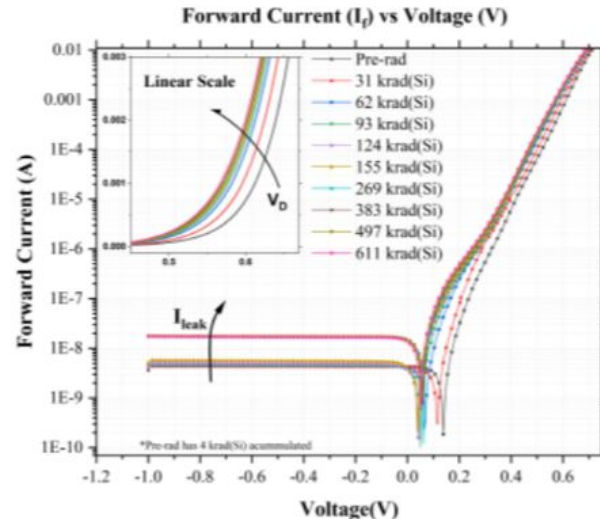


Fig. 5- Forward Current (I_f) vs Voltage (V) TID up to 611 krad.

WG 5.2.2 : Conferences & Presentations & Publications

1. "TCT-based monitoring of LGAD radiation hardness for ATLAS-HGTD production", I. Velkovska *et al.*, Nuclear Instruments and Methods in Physics Research Section A, Nov. 2025, <https://doi.org/10.1016/j.nima.2025.171195>
2. "Thermal Cycling Reliability of Hybrid Pixel Sensor Modules for The ATLAS High Granularity Timing Detector", Y.Li *et al.*, Journal of Instrumentation, Nov. 2025, <https://doi.org/10.1088/1748-0221/20/11/P11003>
3. "Beam-test evaluation of pre-production Low Gain Avalanche Detectors for the ATLAS High Granularity Timing Detector", Aboulhorma, A. *et al.*, Journal of Instrumentation, Mar. 2026, [10.1088/1748-0221/21/03/P03021](https://doi.org/10.1088/1748-0221/21/03/P03021).
4. "Synchrotron light source X-ray detection with Low-Gain Avalanche Diodes", M. Leite, em 1st DRD3 week on Solid State Detectors R&D, 17-21 Jun. 2024, CERN
5. "Evaluation of LGAD Performance Degradation due to TID Aging Under 10 keV X-ray Irradiation", T. A. Silva, em 3rd DRD3 week on Solid State Detectors R&D, 2-6 Jun 2025, Nikhef, Amsterdam
6. "Ultra-Fast Semiconductor Detectors for Radiation Sensing in High-Energy Physics and X-Ray Synchrotron Applications", G.T Saito, em XIX Workshop on Semiconductors and Micro & Nano Technology (SEMINATEC) 2025. São Paulo, Brazil.
7. "4D tracking with semiconductor sensors for particle physics : from signal processing techniques to deep learning approaches", R. S. de Paula, em XIX Workshop on Semiconductors and Micro & Nano Technology (SEMINATEC) 2025. São Paulo, Brazil.
8. "Evaluation of LGAD Performance Degradation due to Aging Under 10 keV X-ray Irradiation", T. A. Silva, em Radiation and its Effects on Components and Systems Conference, 9 Set - 3 Out, 2025, Antuérpia, Bélgica.
9. "Development and Characterization of Sensors and Electronics for the ATLAS High-Granularity Timing Detector", G. T. Saito, 2025 IEEE Nuclear Science Symposium, 1-8 Nov. 2025, Yokohama, Japão.
10. "Hypergraph Neural Network track reconstruction pipeline for HL-LHC experiments", R. S. de Paula, 2025 IEEE Nuclear Science Symposium, , 1-8 Nov. 2025, Yokohama, Japão.
11. "Hypergraph Neural Network 4D track reconstruction pipeline for HL-LHC experiments". R. S. de Paula, Connecting the Dots 2025 Conference, 10-14 Nov. 2025, Tokyo, Japão.
12. "Exploring the response of LGADs for time resolved synchrotron applications", M. Leite, em 14th International Hiroshima Symposium on the Development and Application of Semiconductor Tracking Detectors", 16-21 Nov. 2025, Academia Sínica, Taipei, Taiwan.

13 - ICHEP 2026 : HGTD project status and overview

WG 5.2.2 : ACTION ITEMS FOR NEXT MONTHS

ATLAS
HGTD

- USP infrastructure
 - Most critical item
 - Involves space, import and equipment purchase
 - Needs to prepare lab infrastructure while space discussion is on-going
- DAQ development and DB integration @ USP (in sync with CERN/IHEP/USTC/JSI)
- Infrastructure (baby demo and mockup) @ CERN
- Build the TCT laser system with motorized stages + position measurement
- Studies on 4D tracking integration (ACTS for iTk, HGTD)

on track

critical

new

New
applications

- Validate first functional TCAD and Geant4 simulation
- Add Ad-hoc simulation code for multiplication mechanism
- Sirius Paper
- Understand irradiation needs and prepare infrastructure/tests at local facilities
- Joint project submitted to National Natural Science Foundation of China (IHEP/CAS +USP) as result of ongoing Sprint

New
involvements

- DRD3 R&D on Solid State Detectors (on-going)
 - WP : AC-LGAD for tracking applications (IHEP-USP-IJS)
- TB @ Sirius for new AC-LGADs designs
- FELIX Fase-II
- IHEP and USTC (China) collaboration

Questions ?

