

# Semiconductor sensors development and applications WG-5.2.1 & WG-5.2.2

Status report

FAPESP Thematic 2020/04867-2

December 14th 2022



# 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

*Details on August [kick-off meeting](#)*

Perspectives for the next months highlighted in blue

# WG 5.2.1: People and Action Items (Recap)

## 1. Current Team

- 1.1. M. Leite (Physicist)
- 1.2. G. Saito (MS,PhD)
- 1.3. R. Menegasso (TS)
- 1.4. M. Kuriyama (TS)
- 1.5. DD (Dedicated)
- 1.6. DD (Sharing with PA)
- 1.7. PD (Sharing with PA)
- 1.8. IC (TT-2 ?)
- 1.9. TT-4

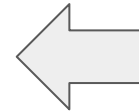
DD-4: *Ultra-fast semiconductor sensors and associated instrumentation for radiation detection*

## 1. Action items

- 1.1. Equipment availability (importation)
- 1.2. Preparing civil infrastructure for Lab
- 1.3. Lab installation
- 1.4. PD, DD, TT hiring
- 1.5. Start testing sensors
- 1.6. **Significant work to commission local infrastructure (EMU FAPESP)**
- 1.7. **Significant commitment of people on @CERN activities**

## 1. Deliverables

- 1.1. **LGAD Characterization Lab.**
- 1.2. **Characterization of LGAD sensors (on-going)**
- 1.3. **Performance studies on irradiated arrays (on-going)**
- 1.4. **PEB test stand system**
- 1.5. **Participation in HGTD assembly facility construction @ CERN (on-going)**
- 1.6. **Demonstrator construction @ CERN (on-going)**
- 1.7. **HGTD installation**
- 1.8. **HGTD commissioning**

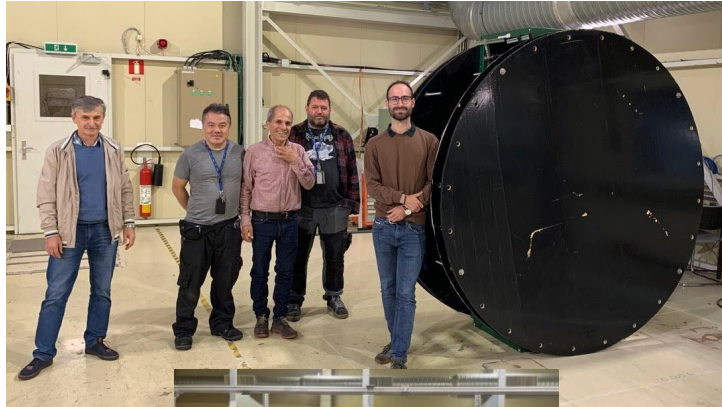


Almost zero float on these items !

# WG 5.2.1 : ATLAS HGTD - Infrastructure @CERN

Done (2022)

- **R. Menegasso & M. Kuriyama @ CERN (3 Months)**
  - Clean room and metrology setup for HGTD assembly @ B180
  - Demonstrator construction and thermal test system support
- **Effort will intensify during construction and integration years !**



# WG 5.2.1 : ATLAS HGTD - Sensor test and Database

On Track

- M. Leite, G. Saito - collaboration in HGTD DB group
  - [Documentation \(Sphinx, gitlab pages\)](#)
  - Sensor database (MySQL)
  - Plot (Grafana)
- Concludes in 2023, updates after that

HGTD Sensors Prototype DB Proposal

Introduction

This document describes a possible scheme to store the prototype LGAD sensors measurements for the ATLAS High Granularity Timing Detector (HGTD[1]), for the Phase-II upgrade program. Several measurement are being performed by several sites, using many different designs and conditions. Hence it is important to keep track not only of the measurements, but also provide a link to the setup used, the methodology used in the measurement and methods for parameter extraction. The following sections will provide a description of the proposed database schema, the reasons why this schema was chosen and the visualization tools used to display the stored information.

Note

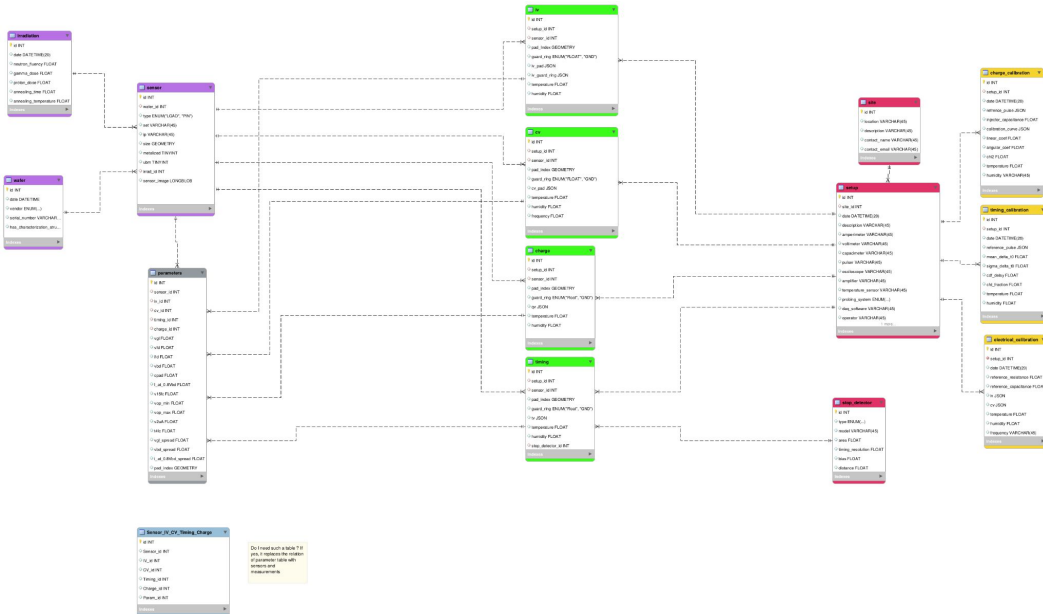
This document is [and will always be...] a work in progress. A PDF copy is available here .

Indices and tables

- Index

[1] - ATLAS HGTD Technical Design Report

## DB Schema



## DB Query and plot in Grafana

### 2.2. Sensors

General / Sensor Sandbox

Sensor 37

Sensor 37 Info												
Id	Vendor	Type	Wafer	Set	IP	Diods	Size	Metalized	UBM	SE	Location	Fluence
37	HPK	3.20	11	P7	-	LGAD	1	1	0	3	AT5	0

Sensor 37 Parameters															
Vgl	Vfg	IIS	Vfd	Cpad	Ldi, S1Vd	V13C	Vop_min	Vop_max	V2uA	tRC	Vgl_spread	Vfd_spread	Ldi_0, P10d_cst	DAQ_parameters	DspD
98.9 V	99.7 V	3.27e-7 A	225 V	3.02e-12 F	0.0000032 A	106 V	73.3 V	176 V	125 V	0.037 ns	4.90 V	5.87 V	0.0000860 A	Data acquired...	1

Picture Sensor 37

TV Sensor 37

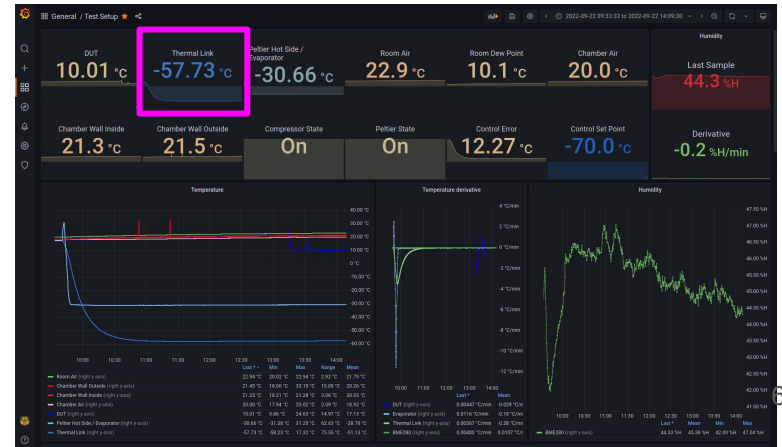
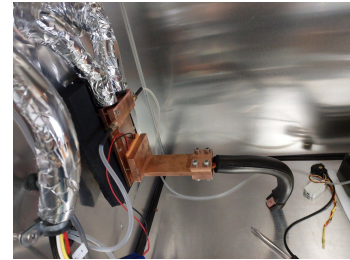
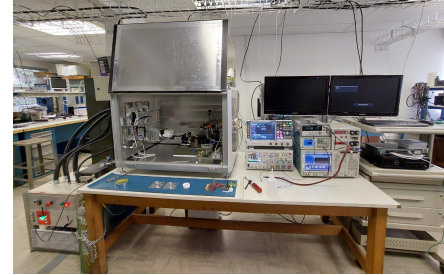
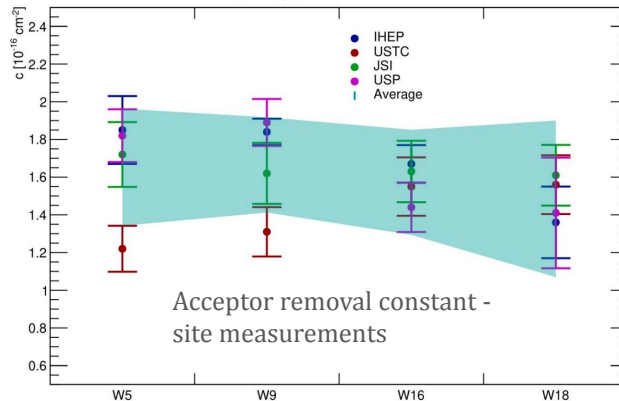
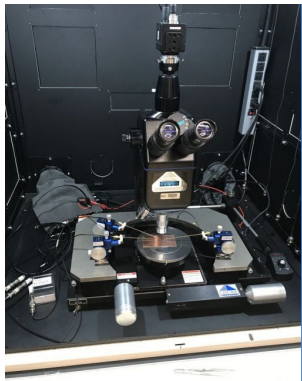
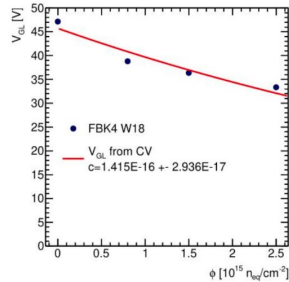
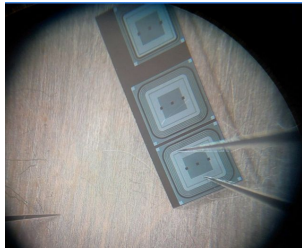
CV Sensor 37

Example of a grafana dashboard showing information about sensors.

# WG 5.2.1 : ATLAS HGTD - Sensor tests and Database

On Track

- M. Leite, G. Saito - ongoing sensor testing
  - Sensor tests at USP and FEI (M. Pavanello)
  - New laser system in 2023 ...
- Part of the commitments for HGTD (forever ...)



# WG 5.2.1 : ATLAS HGTD - Infrastructure @USP

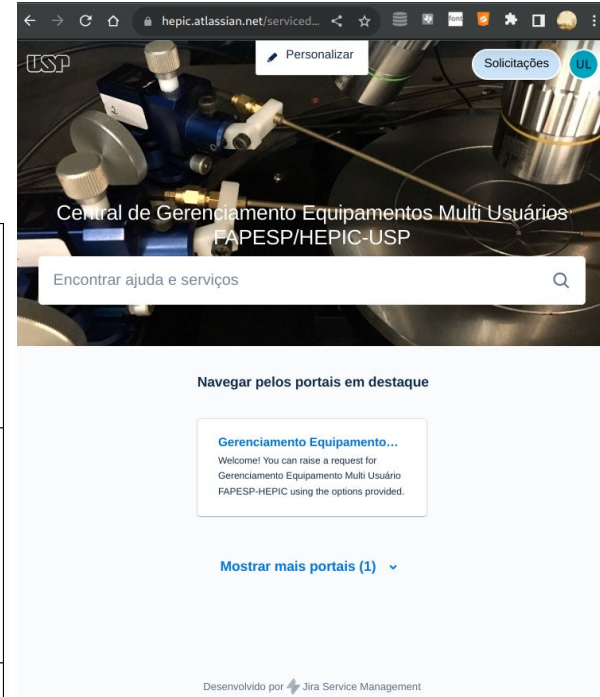
- Semiconductor lab will be a FAPESP E.M.U
  - Most of heavy work already done ....
  - [EMU Site documentation](#)
  - [EMU user registration and request portal \(JIRA\)](#)
  - Workflow implemented as Jira services (needs test...)
  - Starting the process formalities

● ~~Must complete soon (2022)~~ (Done, approved by USP & FAPESP)

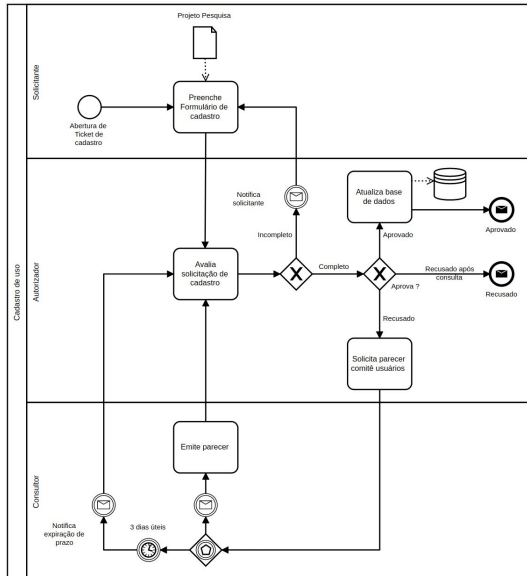
Watch



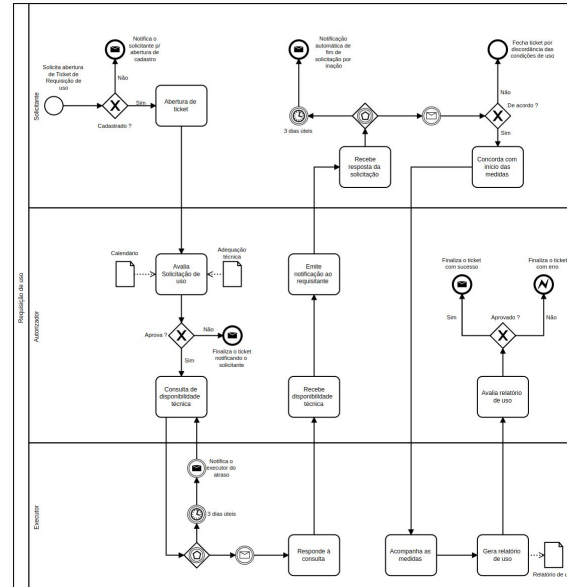
Done !



Solicitação de cadastro



Solicitação de uso



# WG 5.2.1 : ATLAS HGTD - Infraestructure @USP

Critical



Watch

- We need to be ready by March 2023
- Difficult and long tendering with probe station suppliers
  - Got amendment to FAPESP EMU budget 👍
  - ~~First choice (MPI) does not accept LC, CAD, Net30~~ 🙅
  - ~~Second choice (FormFactor) on going~~
  - MPI finally accepted FAPESP terms
  - ML visited MPI office in San Jose (CA) in November to discuss technical details about system installation and operation).
  - Starting importation now
  - Need start importation of the rest of equipment (LCR, Electrometers, Microscope)





# WG 5.2.1 : ATLAS HGTD - Infrastructre @USP

- Participate in DAQ development for QA/QC sites
  - USP- CERN-IHEP-USTC-JSI
  - Very long lead time for T&M (over 1 year in some cases)
  - Already got some T&M equipment from local distrib. in 2022
  - Must plan carefully !
  - Measurement of sensors and test structures
- Lab space still an issue
  - Need to setup temporary area NOW
  - Negotiation on-going
- Needs to settle in 2022; finalize in 2023

**Critical**

**Critical**



**Very Critical**

# WG 5.2.2 : WBS and Deliverables

## WBS

1. Simulation
  - 1.1. Geant4 Simulation (LGAD, AC-LGAD) (**M. Morales - IPEN**)
  - 1.2. TCAD Simulation (LGAD, AC-LGAD) (**R. Buehler, R. Giacomini**)
  - 1.3. Multiplication Mechanism Simulation (Weightfield2, KDetSim)
  - 1.4. Radiation damage processes
  - 1.5. Charge Sharing and position determination (Custom Code)
  - 1.6. Circuit and Layout simulation (ELDO, Spice, Hyperlinx) (**G. Saito**)
  - 1.7. Integration framework
2. Characterization of *available* LGAD, AC-LGAD
  - 2.1. Sensors electrical characterization
  - 2.2. Aux. structures electrical characterization
  - 2.3. Laser testing (new item 🟡...)
3. Readout electronics for *available* LGAD, AC-LGAD
  - 3.1. Fast amplifier and calibration board
  - 3.2. Prototype readout system (ATLAS-FELIX based)
4. Radiation testing of *available* LGAD, AC-LGAD
  - 4.1. X-Ray testing
  - 4.2. Charged particle testing (electrons, protons, ions)
  - 4.3. Time Resolved X-Ray testing (**M. Leite & UCSC**)
5. Irradiation of *available* LGAD, AC-LGAD
  - 5.1. Photons
  - 5.2. Neutrons

## Deliverables

1. Analysis and interpretation of simulation results (G4)
2. Analysis and interpretation of simulation results (TCAD)
3. Readout board simulation, design, assembly and test
4. Analysis of *available* LGAD and AC-LGAD X-Ray testing
5. Analysis of *available* LGAD and AC-LGAD picosecond X-Ray testing
6. Analysis of LGAD charged particle testing
7. Validation of framework integration for simulation/beam test
8. Electrical testing of irradiated/non-irradiated sensors

# WG 5.2.2 : WBS and Deliverables

On Track

## 1. Simulation

- 1.1. Geant4 Simulation (LGAD, AC-LGAD) (M. Morales - IPEN)
- 1.2. TCAD Simulation (LGAD, AC-LGAD) (R.Buehler, R. Giacomini, M. Guazelli)

## Starting with AC-LGADs (see next slide)

WG 5.2.2 - Simulation and tests of existing LGAD structures for XRays applications

December 2022	
01 Dec	Simulation I - Geant-4 and TCAD
November 2022	
10 Nov	Simulation I - Geant-4 and TCAD
03 Nov	Simulation I - Geant-4 and TCAD
October 2022	
27 Oct	Simulation I - Geant-4 and TCAD
20 Oct	Simulation I - Geant-4 and TCAD
13 Oct	Simulation I - Geant-4 and TCAD
06 Oct	Simulation I - Geant-4 and TCAD
September 2022	
29 Sept	Simulation I - Geant-4 and TCAD
22 Sept	Simulation I - Geant-4 and TCAD
13 Sept	Simulation I - Geant-4 and TCAD
August 2022	
25 Aug	Simulation I - Geant-4 and TCAD
June 2022	
24 Jun	Pré-reunião RENAFAE-CNPEM

There are 9 events in the past. Hide

## Project evolution follow-up on gitlab

The screenshot shows a GitLab issues page for the project 'usp9/UFSD/simulation/geant4-simulations'. The page is filtered to show 'All' 17 issues. The issues are listed with their titles, creation dates, and various tags indicating their status and priority. The issues are:

- Persist primary particle information** (CLOSED, 1 issue, 4 effort, Low effort, New feature, Geant4, Priority High) - created 1 month ago by Marco Leite
- Transfer the build directory examples to documentation** (1 issue, 2 effort, Medium effort, Feature Fix, Geant4, Priority Medium) - updated 1 week ago
- Threshold for photons in physics processes** (1 issue, 1 effort, Low effort, Geant4, Priority Low) - updated 1 month ago
- Understand the input files needed to simulate a LGAD** (1 issue, 1 effort, Medium effort, Kdetsim, Priority High) - updated 1 month ago
- Commit working example of UFSD** (1 issue, 2 effort, Low effort, Feature New, Garfield++, Priority Medium) - updated 1 month ago
- New sources for GDML scheme** (1 issue, 1 effort, High priority, Geant4, Priority High) - closed 1 month ago
- Push current version to gitlab** (1 issue, 3 effort, Low effort, Geant4, Priority High) - closed 1 month ago
- Edit README.md** (1 issue, 7 effort, Low effort, Geant4, Priority High) - closed 1 month ago
- Fix compilation errors** (1 issue, 5 effort, High priority, Kdetsim, Priority Medium) - closed 1 month ago
- Generate electrical field for the AC-LGAD structures from Taylor's example** (1 issue, 7 effort, Medium effort, Priority Blocking, TCAD) - updated 1 month ago

Long range and continuous effort forever ...

# WG 5.2.2 : WBS and Deliverables

On Track

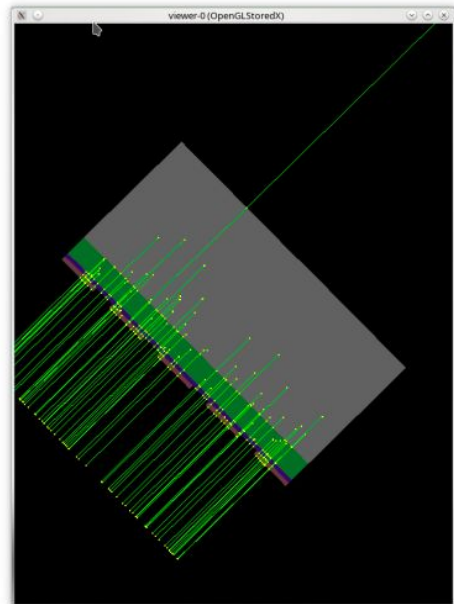
## 1. Simulation

- 1.1. Geant4 Simulation (LGAD, AC-LGAD) (M. Morales - IPEN) V. 1.0.0 Ready (AC LGAD Geometry on GDML)

## São Paulo Status

Detector - top view with X-rays (8 keV)

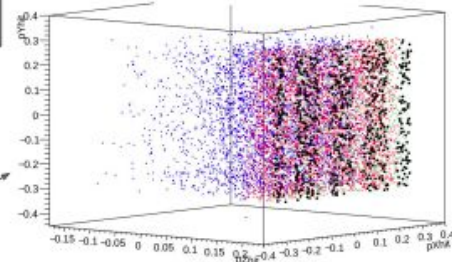
M. Morales : Geant hits persisted in a ROOT Tree (a new version with more information is being finalized)



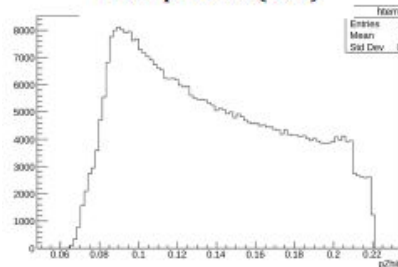
Row	Instance	NHits.NHit	VolHit	pXhit	pYhit	pZhit
0	*	1	1	-0.298738	0.0362952	0.1247924
1	*	1	4	-0.184261	0.2582879	0.2151612
2	*	1	2	0.0108717	0.2288132	0.1812709
3	*	1	1	0.0770458	-0.258765	0.1217693
4	*	1	2	-0.073189	0.1496997	0.1886541
5	*	2	2	0.2841557	0.2855948	0.1740219
5	*	1	2	0.2841538	0.2855997	0.1740467
6	*	1	1	-0.112592	-0.156638	0.1299960
7	*	2	2	-0.250619	-0.026739	0.1535057
7	*	1	2	-0.250564	-0.026645	0.1535206
8	*	1	4	-0.189973	-0.210352	0.2139893
9	*	1	4	-0.014172	0.1597958	0.2187885
10	*	1	2	-0.251207	0.2347846	0.1757388

+ Process ; (Energy, p)

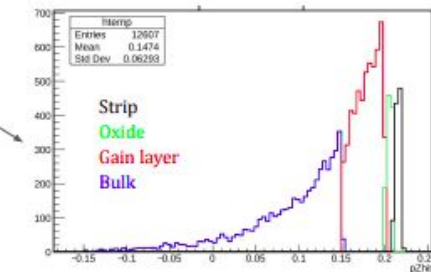
8 keV  $\gamma$  (10k)



4MeV protons (10k)



Number of hits  
NHits (electrons)  
produced

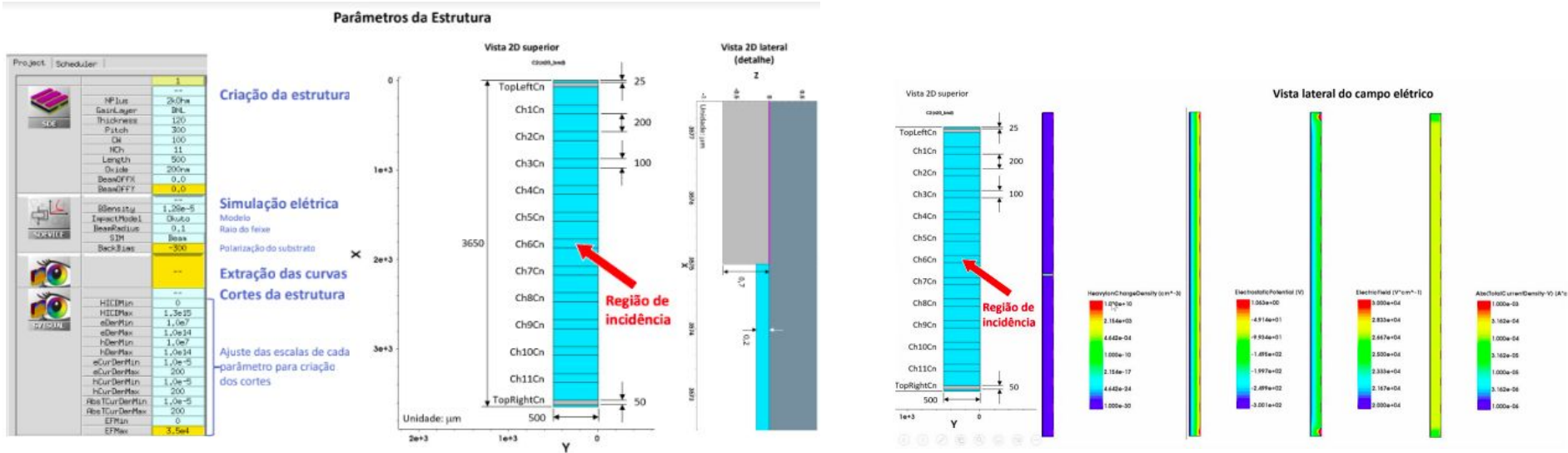


# WG 5.2.2 : WBS and Deliverables

On Track

## 1. Simulation

TCAD Simulation (LGAD, AC-LGAD) (R.Buehler, R. Giacomini) On going



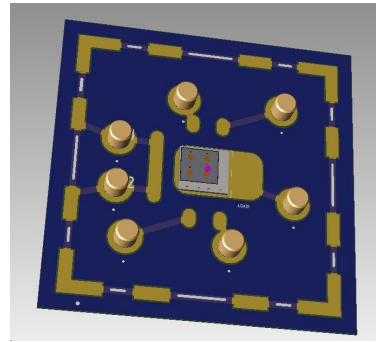
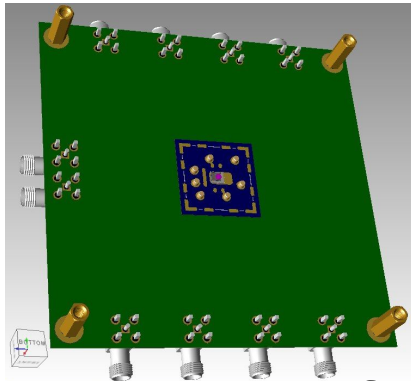
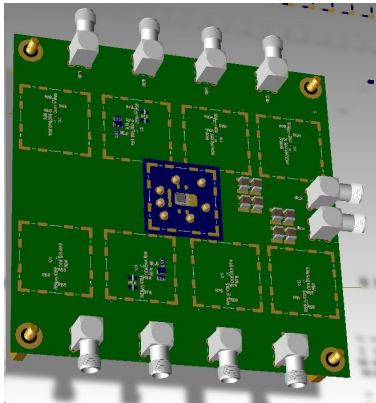
# WG 5.2.2 : WBS and Deliverables

On Track

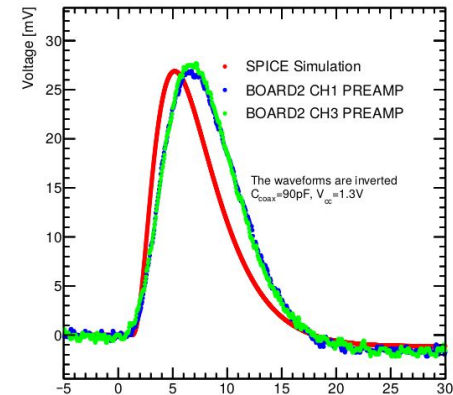
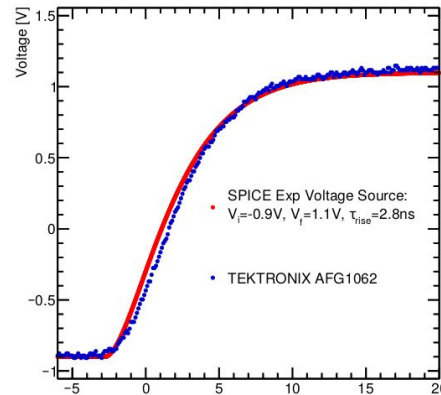
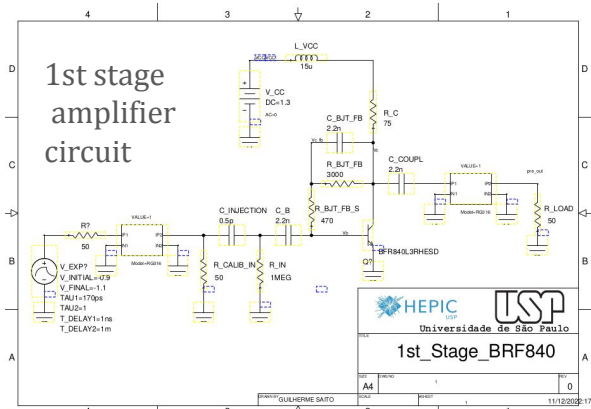
## 1. LGAD carrier board Simulation

Circuit and Layout simulation (ELDO, Spice, Hyperlinx) (G. Saito)

- LGAD + LGAD Carrier board with interposer
- Discussion with Eldorado on fabrication and assembly
- ELDO 1st + 2nd stage simulation on-going
- Hyperlynx signal integrity simulation next



Simulation in Eldo an comparison with measurement



# WG 5.2.2 : WBS and Deliverables

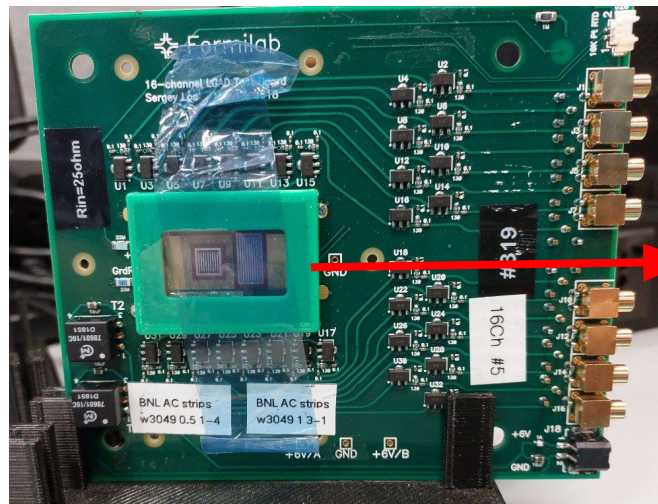
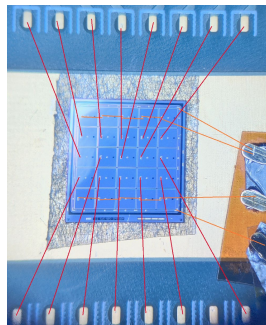
## LGADs/AC-LGADS for picosecond time-resolved X-ray testing

On Track

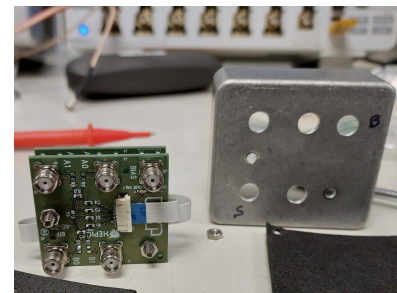
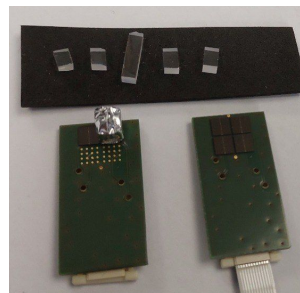
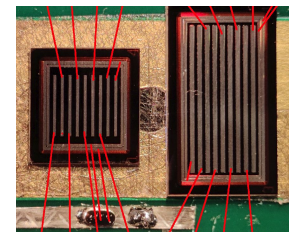
4. Radiation testing of *available* LGAD, AC-LGAD
  - 4.1. X-Ray testing
  - 4.2. Charged particle testing (electrons, protons, ions)
  - 4.3. Time Resolved X-Ray testing (M. Leite & UCSC)

Tested at Stanford SLAC SSRL test beam with UC Santa Cruz in November 2022

- Energies from 5keV to 53 keV (70 keV with harmonics)
- “Flat” beam (BL 11.2) : 12.6mm x 2.14mm
- Several intensities and bias voltages
- LGADs :
  - HPK 3.1 Single (1.3mm)
  - HPK 3.2 single (1.3mm)
  - HPK 3.2 5x5 (1.3mm)
  - BNL 20 $\mu$ m Single (1mm)
- AC-LGADs :
  - BNL strips



Strips  
AC-LGAD



Compton Box  
(SiPM + LYSO)

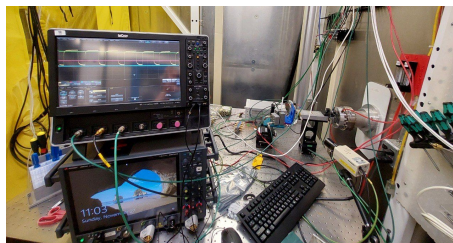
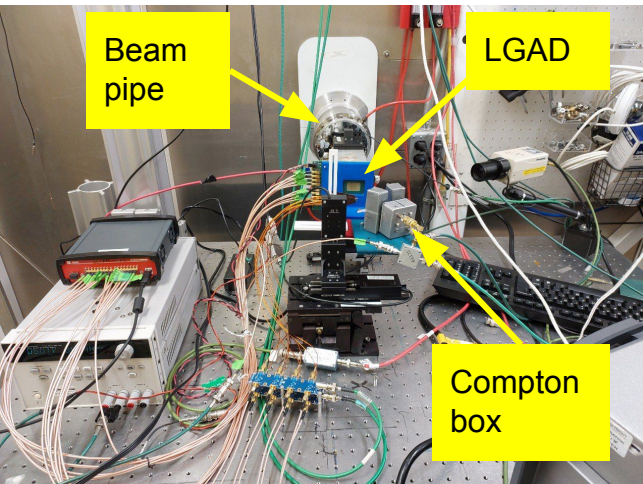
Long range and continuous effort - also discussion with Sirius detector group

# WG 5.2.2 : WBS and Deliverables

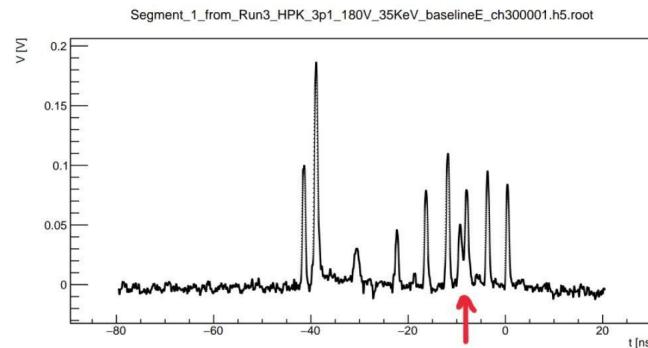
## AC-LGADS for picosecond time resolved X-ray testing

On Track

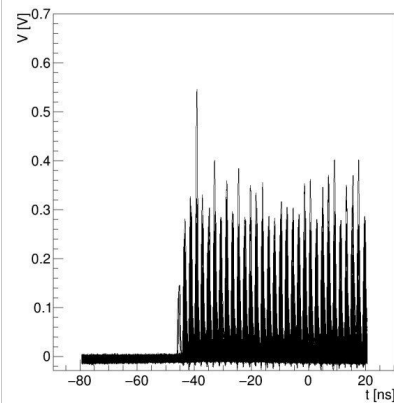
SSRL BL 11-2



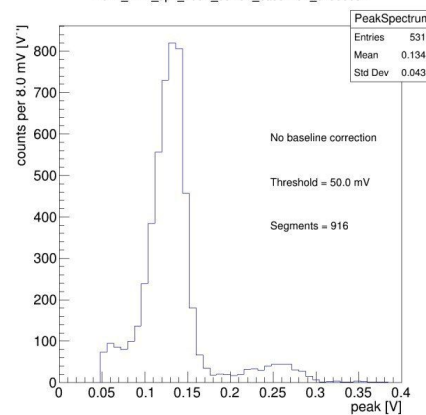
LGAD (HPK3.1) response to 10ps, 2ns apart, 35 keV X-rays pulses from SSRL



Overlaid Segments



Run2\_HPK\_3p1\_200V\_35KeV\_baselineE\_ch300001



$\sigma E / \langle E \rangle \sim 13\%$   
(raw)



# WG 5.2.1 & WG 5.2.2 : ACTION ITEMS FOR NEXT MONTHS

ATLAS  
HGTD

- Move ahead with 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 laser system with motorized stages + position measurement

New  
applications

- Validate first functional TCAD and Geant4 simulation
- Add Ad-hoc simulation code for multiplication mechanism
- Analyze data from TB @SLAC, resume discussion with Sirius (more people involved...)
- Understand irradiation needs and prepare infrastructure/tests at local facilities
- Explore/Converge designs for fabrication (WG 5.2.3 - see next presentation)

on track

critical

new

## WG5.2 Workshop early 2023 (January ?)

- All members with EOI in project will have the opportunity to present their plans/schedule
- follow up through indico working meetings during 1st term of 2023 as preparation for the 1st report to FAPESP