Semiconductor sensors development and applications WG-5.2

Status Report

FAPESP Thematic 2020/04867-2

Feb. 22nd 2024

FAPESP
FUNDAÇÃO DE AMPARO À PESQUISA DO ESTADO DE SÃO PAULO

ATLAS EXPERIMENT

HEPIC IFUSP

LSI

centro universitário FEI

ipen

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
and More details on October 2023 WG 5.2 Workshop

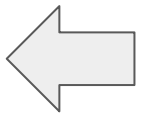
WG 5.2.1: People and Action Items (Recap)

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. 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

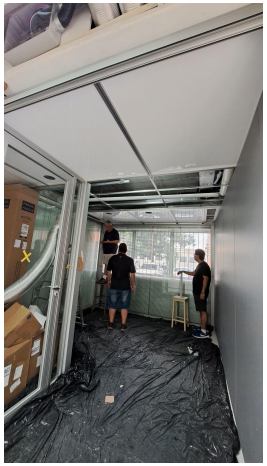
1. Action items
   - 1.1. Equipment availability (importation)
   - 1.2. Preparing civil infrastructure for Lab
   - 1.3. Lab installation
   - 1.4. PD, DD, TT hiring
   - 1.5. Start testing sensors
   - **1.6. Significant work to commission local infrastructure (EMU FAPESP)**
   - 1.7. **Significant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

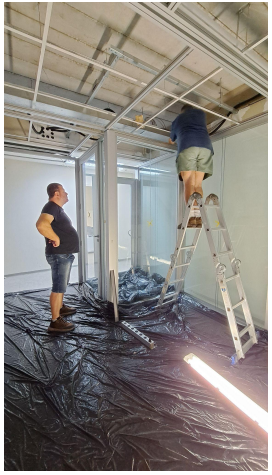


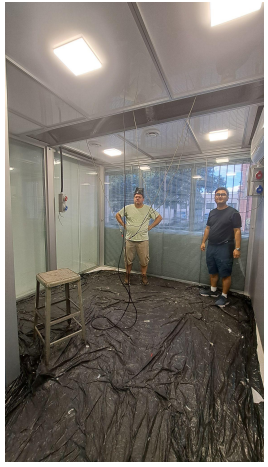
Almost zero float on these items !

WG 5.2.1 : ATLAS HGTD - Infrastructure @USP

WG 5.2.1 : ATLAS HGTD - Infrastructure @USP







WG 5.2.1 : ATLAS HGTD - Infrastructure @USP

- After more than one and half year we finally got the area to install the probe station
- Area is far from ideal
  - Nonetheless we made it work

WG 5.2.1 : ATLAS HGTD - Infrastructure @USP

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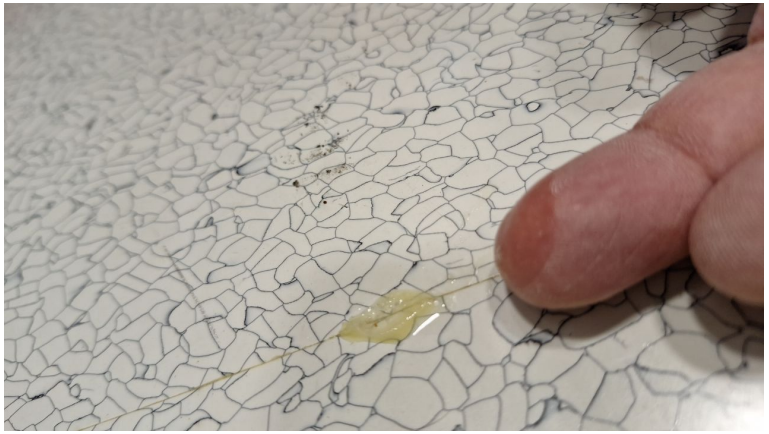
WG 5.2.1 : ATLAS HGTD - Infrastructure @USP

Water leaking from tile joints ….



WG 5.2.1 : ATLAS HGTD - Infrastructure @USP

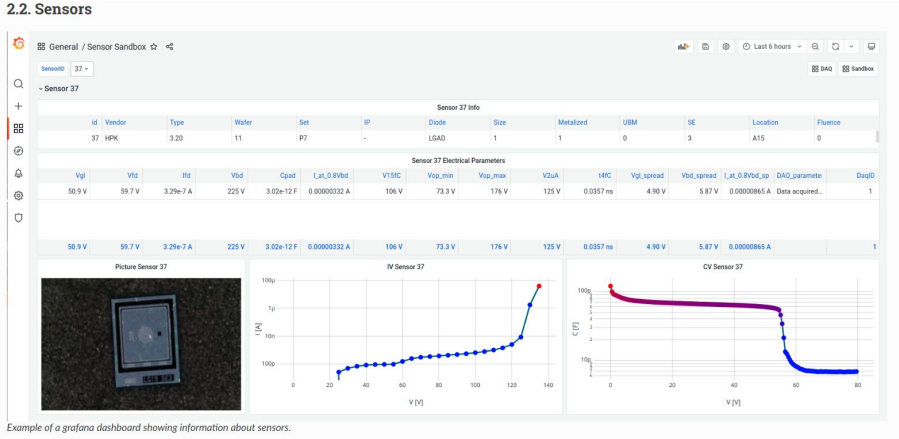
February 13th 2024 - The machine is installed by MPI USA engineers

- Iso-6 cleanness (filtered air)
- Thermal isolation provides +/- 0.5C stability
- 30% humidity
- 2 Ethernet connected PLC systems controls and monitors everything in the the room (developed by us)
- Many other nice improvements on the way…

WG 5.2.1 : ATLAS HGTD - Infrastructure @USP

WG 5.2.1 : ATLAS HGTD - QA/QC

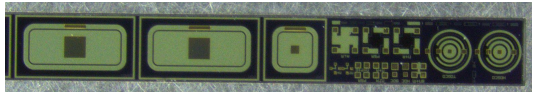
- **USP is one of the main sites for sensor PQC**
  - Development of DAQ system (hDAQ) from ground up
  - G. Saito ATLAS qualification work
  - System at use at USP-CERN-IHEP-USTC-IJS
  - Data uploaded automatically to CERN DB on-demand
  - Grafana is used to query DB and plot data

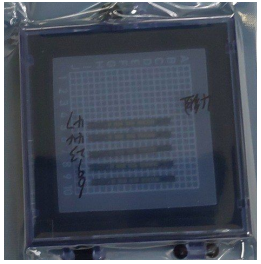


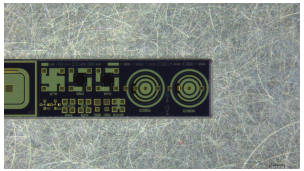
Example of a grafana dashboard showing information about sensors.

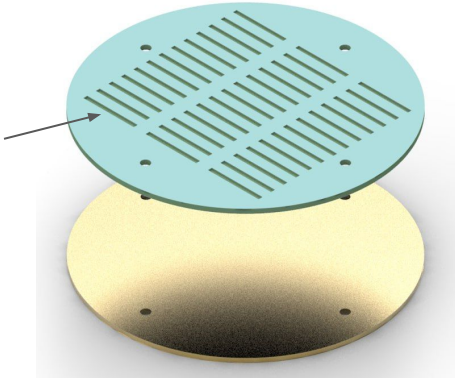
WG 5.2.1 : ATLAS HGTD - QA/QC

- There is a lot of work ahead
- Structures from pre-productions are already being sent to USP for testing
- HGTD sensor PRR mid March
- Need to evaluate
  - systematics on parameter extraction
  - calibration impact on repeatability and accuracy
  - automation achieved by structure holder
- Probe card holder just arrived yesterday
- Cabling will be done in the next days





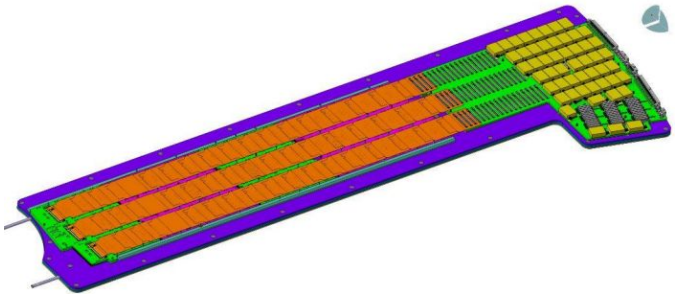




WG 5.2.1 : ATLAS HGTD - Integration @ CERN

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

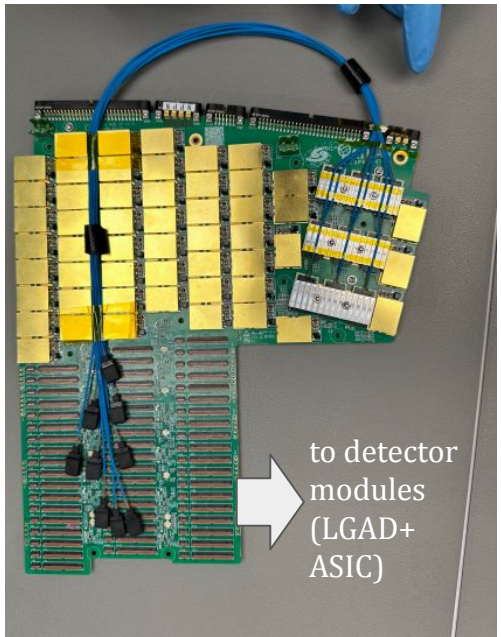
- Demonstrator cooling plate construction at CERN



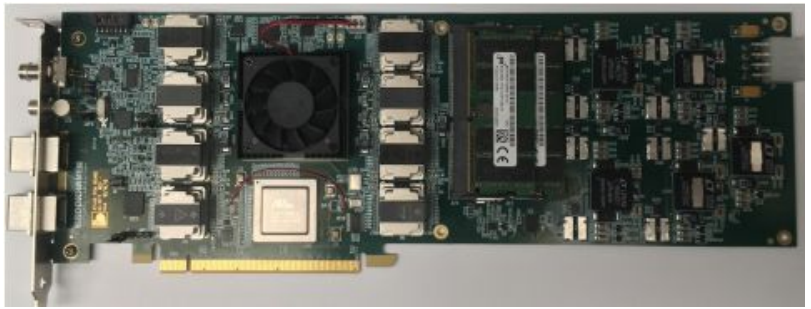
WG 5.2.1 : ATLAS HGTD - Integration @ CERN

- Monitoring through FELIX
  - We still have sometime, but it would be important to develop some knowledge on high speed DAQ
  - Quite some work when integration time comes

PEB @ CERN



ATLAS Phase-I PCI-E FELIX Card

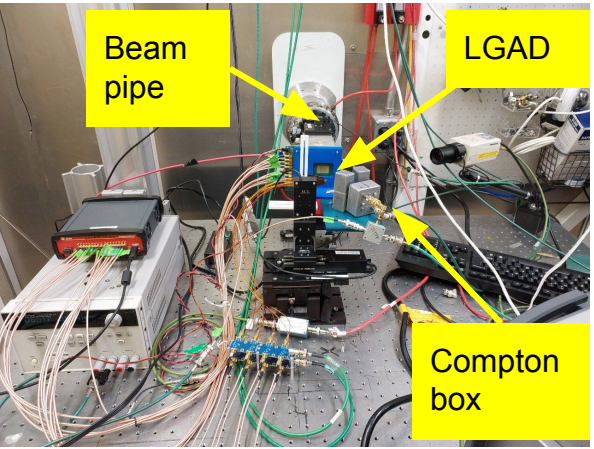


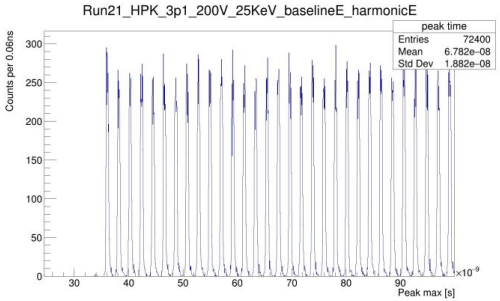
- CNPEM is interested on using these cards for Timepix-4
- We are discussing the possibilities to collaborate on this (both sides winning)

WG 5.2.2 : UFSD for Applied Sciences

Part-I - LGADS for picosecond time resolved X-ray testing

SSRL BL 11-2





Bunch structure

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Synchrotron light source X-ray detection with Low-Gain Avalanche Diodes

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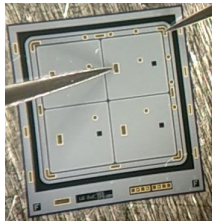
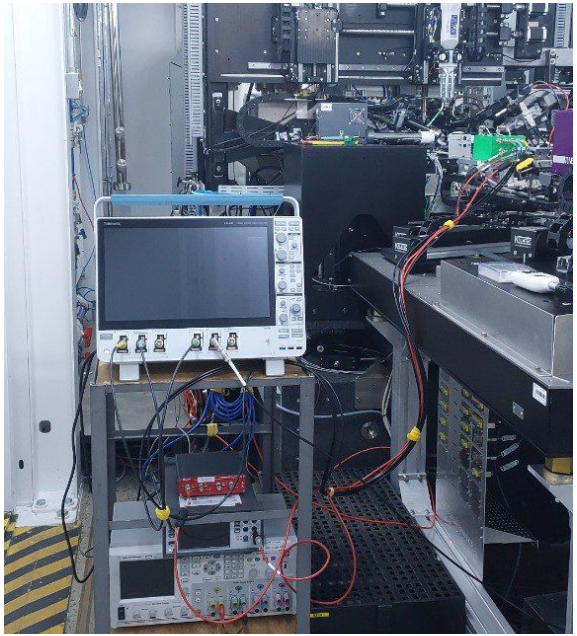
- Paper on SLAC test with UCSC published on JINST Oct. 2023
- Since then, results were also presented at :
  - 13th International Conference on Position Sensitive Detectors
  - 13th International "Hiroshima" Symposium on the Development and Application of Semiconductor Tracking Detectors
  - 43rd RD-50 Workshop
  - 33rd RAU LNLS/CNPEM

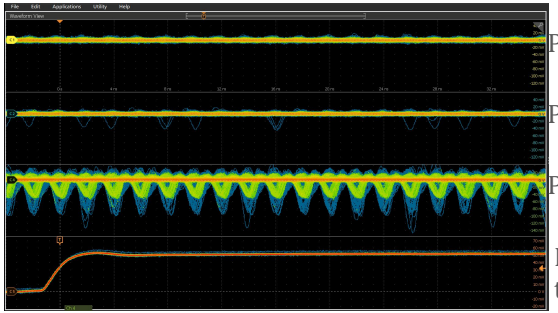
WG 5.2.2 : UFSD for Applied Sciences

LGADS for picosecond time resolved X-ray testing

- **New tests** at Carnaúba beamline at CNPEM
- Excellent support from Sirius people and management-> **very efficient (and very intense)** campaign
- Using HPK 3.1 ATLAS prototype sensor





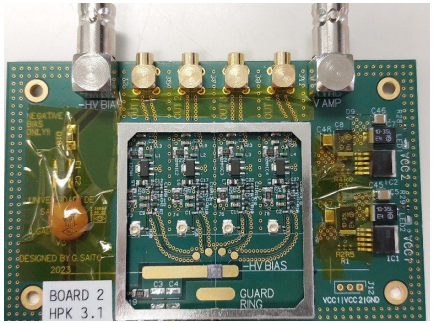


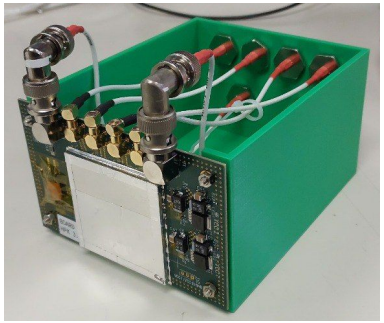
Pad signal

Pad signal

Pad signal

Machine trigger





New board designed for Sirius tests

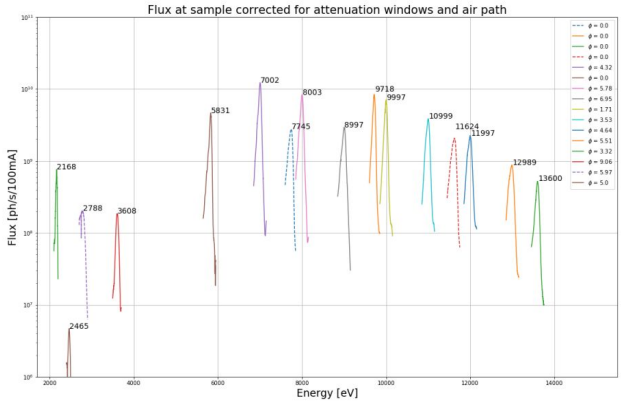
WG 5.2.2 : UFSD for Applied Sciences

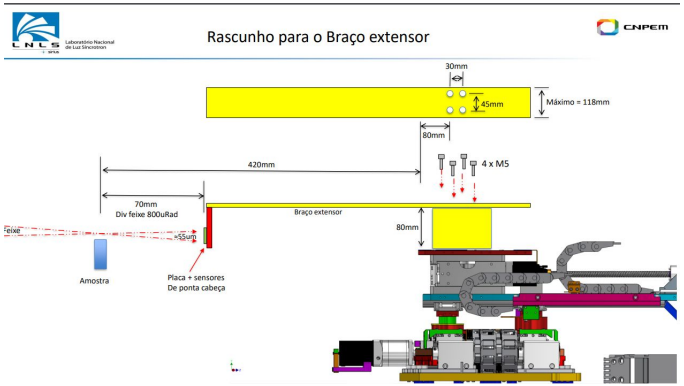
- Tests performed at Carnauba beam line at Sirius Light source in São Paulo
- Beam time from Lab. directorate strategic program (so we did not compete with other requests)

PARAMETERS

Parameter	Value	Condition
Energy Range	2.05 – 15 keV	Si(111)
Energy Resolution (ΔE/E)	10^{-4} – 10^{-5}	
Harmonic Content	< 10^{-5}	Above 5 keV
Energy Scan	Yes	
Beamsize at sample [μm] @Tarumã	0.15 x 0.15 (0.55 x 0.55)	8 keV (2 keV)
Beam Divergence at sample [mrad] @Tarumã	(1 x 1)	All energy range
Estimated flux [ph/s/100 mA] @Tarumã	10^{11}	–
Beamsize at sample [μm] @Sapoti	0.03 x 0.03 (0.12 x 0.12)	8 keV (2 keV)
Beam Divergence at sample [mrad] @Sapoti	5×5 (4 x 4)	< 10 keV (12keV)
Estimated flux [ph/s/100 mA] @Sapoti	10^{12}	–
Imaging Mode	Scanning	–
Coherence Modes	~1	–

Flux at sample corrected for attenuation (log plot)

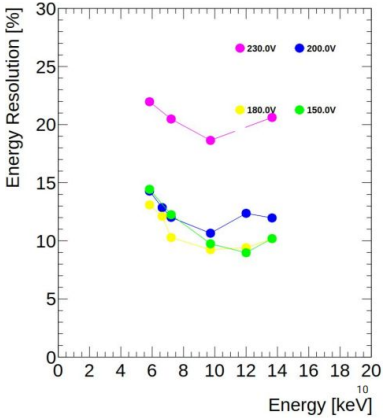


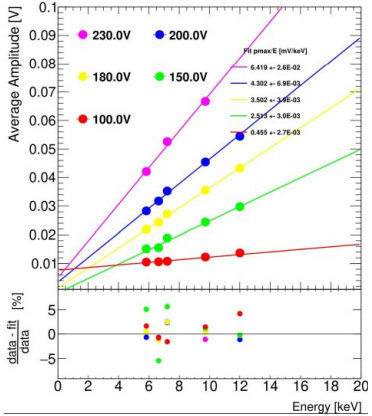


WG 5.2.2 : UFSD for Applied Sciences

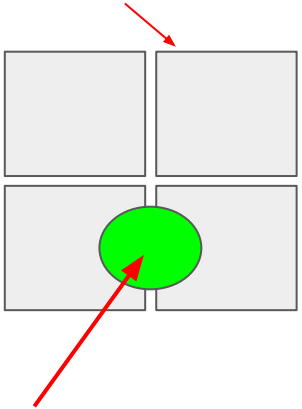
LGADS for picosecond time resolved X-ray testing

- **First test** in November 2023
- ~500um 2ns, 10ps X-Ray bunches
- 1 TB of data being analyzed
- ATLAS HPK 3.1 2x2 array
- **Energy and timing resolution as function of Bias Voltage and Energy**

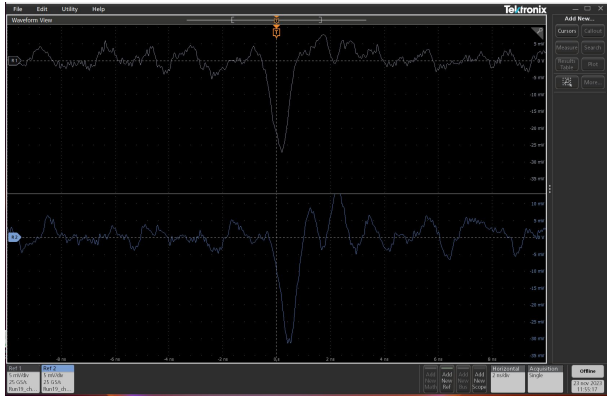




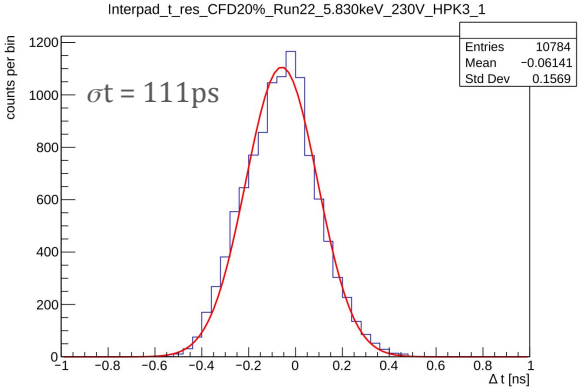
2x2 LGAD arrray



500um X-ray beam



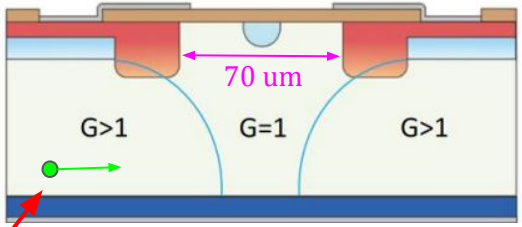
First time ever !!



WG 5.2.2 : UFSD for Applied Sciences

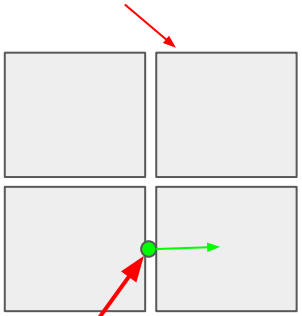
LGADS for picosecond time resolved X-ray testing

- **Second tes**t beam in Jan 2024
- ATLAS HPK 3.1 2x2 array
- ~150nm 2ns, 10ps X-Ray bunches
- **Position scan to measure/model the gain**
- Scripting using EPIC by Sirius team
- We are advancing on the TCAD simulation with UC Santa Cruz

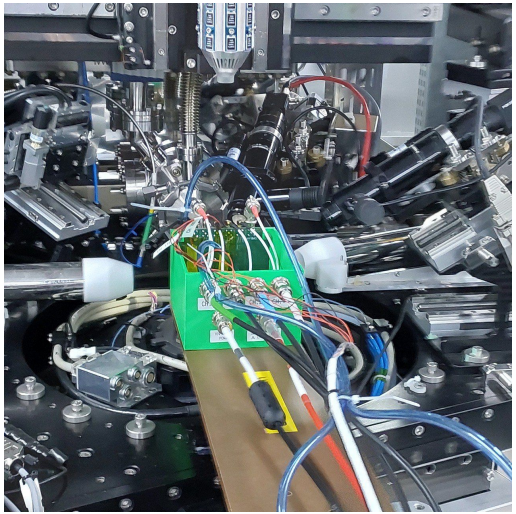


X-ray beam

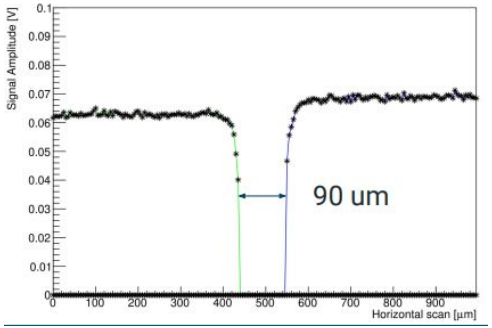
2x2 LGAD arrray



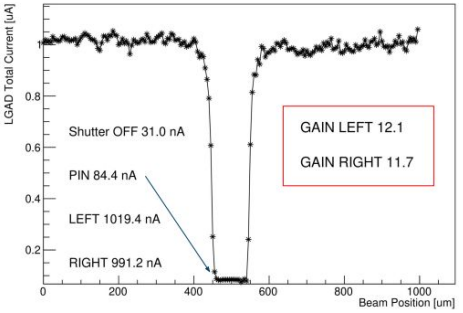
150nm X-ray beam



Waveform scan

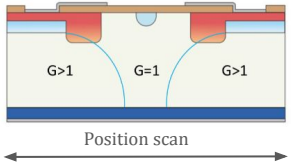


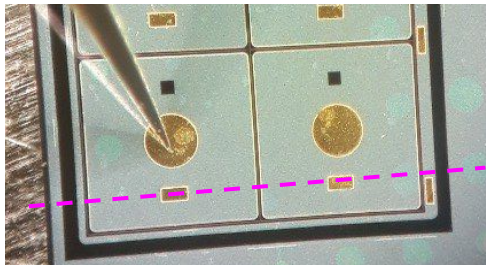
I_bias scan



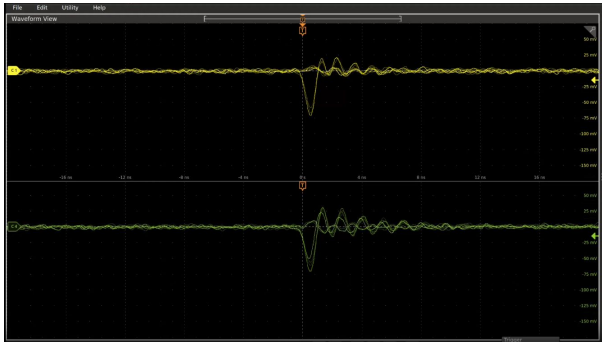
January LGAD TB at Sirius

Interpad position scan

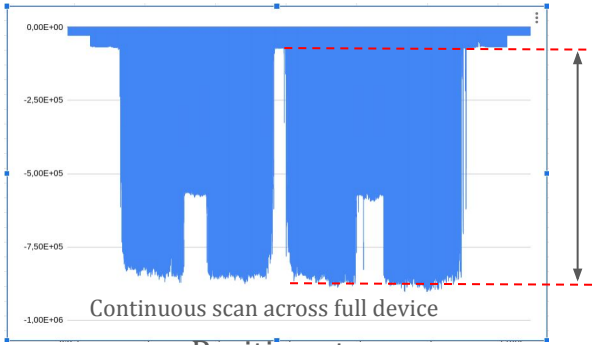




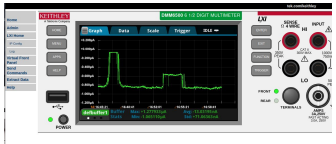
"ORed" scope trigger trigger between 2 ch

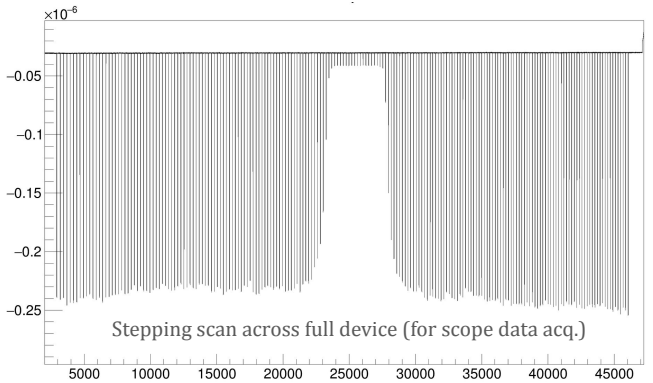


- LGAD **bias current** profile for 50um scan step (230V, 9.75 keV, 150nm beam)



Use for gain estimation (Kramberger)



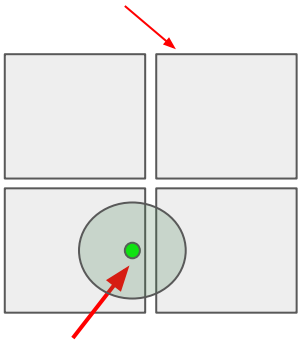


WG 5.2.2 : UFSD for Applied Sciences

LGADS for picosecond time resolved X-ray testing

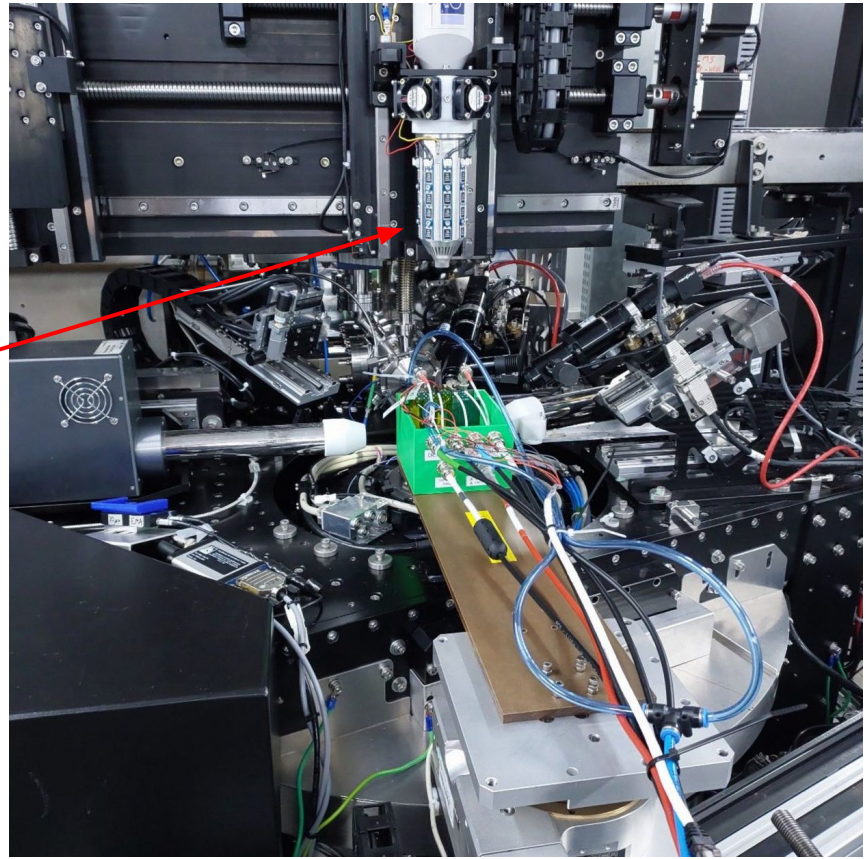
- **Third test** beam in Fev 2024
- ATLAS HPK 3.1 2x2 array
- ~150nm 2ns, 10ps X-Ray bunches
- Scattered by amorphous carbon to provide wider beam
- **Energy/timing resolution wrt temperature**
- Scripting using EPIC by Sirius team

2x2 LGAD arrray



150nm X-ray beam

Temp. Controlled Cryo Jet



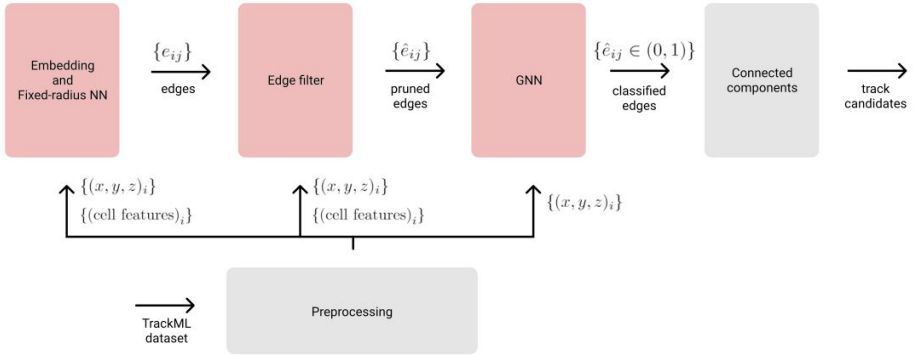
- Paper to be submitted ~ winter
- Much more to come - many interesting ideias being discussed with LNLS team

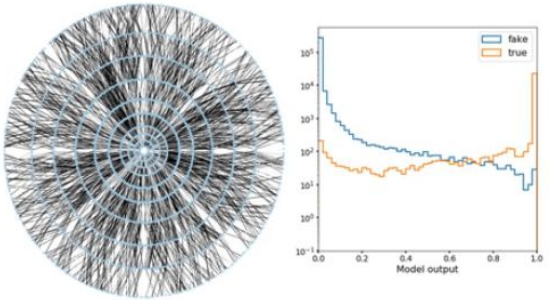
WG 5.2.1 & WG 5.2.2 : ACTION ITEMS FOR NEXT MONTHS

new

Graph based Neural Network approach for ATLAS HL-LHC (iTK+HGTD)

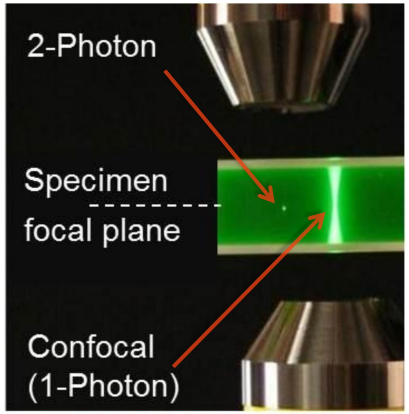
- Exa.trk: HEP advanced tracking algorithms at the Exascale
- See Rodrigo's presentation





Characterization of Semiconductor sensor using TCT and TPA Laser techniques

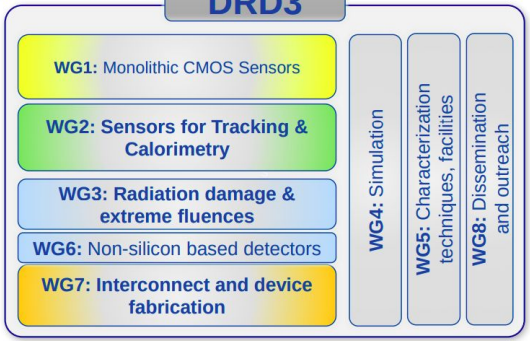
- Conventional TCT:
  - Localized generation of e-h pairs on X-Y
  - We can try to use our MPI to do this
- Two-photon absorption TCT:
  - Localized generation of e-h pairs on X-Y-Z



Photography: Ciceron Yanez, University of Central Florida

DRD-3 R&D on semiconductor sensors

- We are covering all ECFA DRDTs
- Additional WGs were added to cover simulations, facilities and dissemination corresponding to **General Strategic Recommendations (GSRs)** in the ECFA roadmap



WG 5.2.2 : Low Energy Applications - TCAD Simulations

- LGAD TID tests (X-ray) @ FEI (M. Guazelli) bard with HPK 3.1 & 3.2 wire bonded
- More info on March WG 5.2 Workshop (https://indico.cern.ch/event/1251642/contributions/)
- Estudo sobre aplicação de Machine Learning e análise não paramétrica de curvas de dispositivos irradiados

EXEMPLO DE TESTE QUE ACABA DE SER PLANEJADO E PREPARADO NA FEI

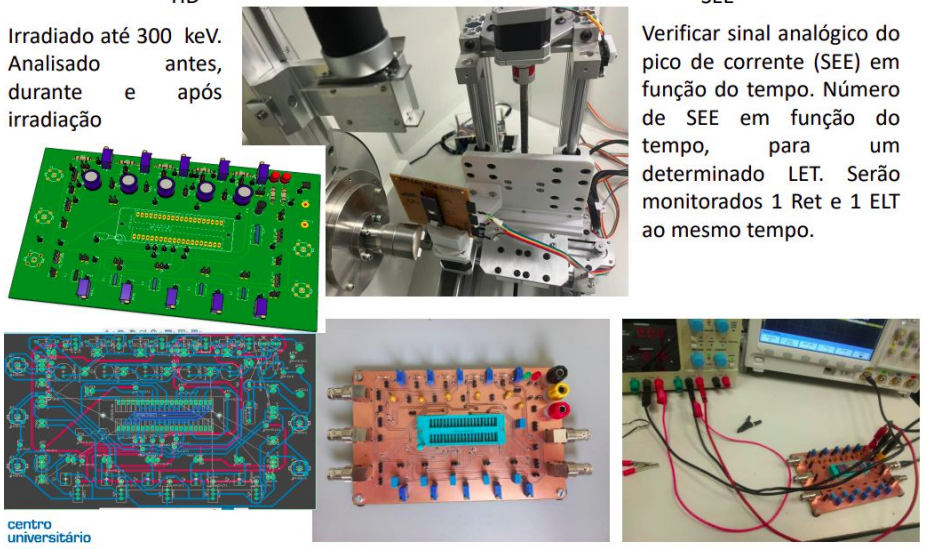
CI com 3 retangulares e 2 ELT

TID

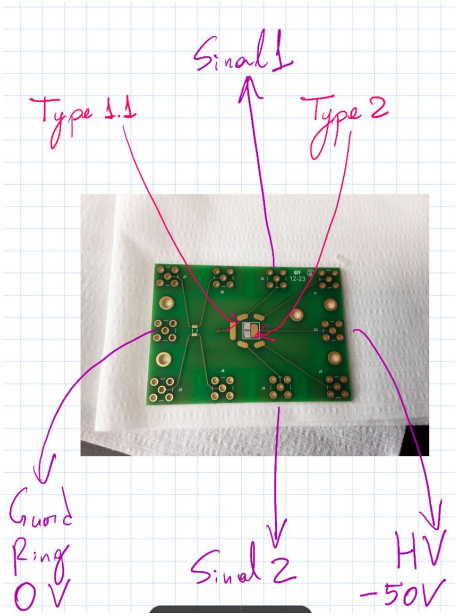
Irradiado até 300 keV. Analisado antes, durante e após irradiação

SEE

Verificar sinal analógico do pico de corrente (SEE) em função do tempo. Número de SEE em função do tempo, para um determinado LET. Serão monitorados 1 Ret e 1 ELT ao mesmo tempo.



centro universitário FEI



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

on track
critical
new

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 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 Ronaldo's presentation)

New involvements

- **G. Saito →DD** (qualification tomorrow, "Ultra-Fast Silicon Detectors for Radiation Sensing") ;
  R. Mansano (Poli) + M. Leite (IFUSP)

- **R. Estevam →DD** (Start next month : "*Métodos de aprendizado profundo e processamento de sinais aplicados à reconstrução de trajetórias em 4 dimensões para o HL-LHC*" ;
  V.H. Nascimento (Poli) + M.Leite (IFUSP)

- ECFA Detector Roadmap : DRD3 R&D on Solid State Detectors (on-going)

Any Questions ?