ATLAS HGTD status and studies of UFSD for X-ray Synchrotron applications

IV Reunião Geral

Projeto Temático FAPESP

WG 5-2

Guilherme Saito

4 Oct 2023

HEPIC

IFUSP

In this Presentation

- ATLAS HGTD Status
  - Activities at CERN
  - São Paulo setup
- Studies of UFSD for X-ray Synchrotron applications
  - Recent results
  - Future prospects

ATLAS HGTD Status

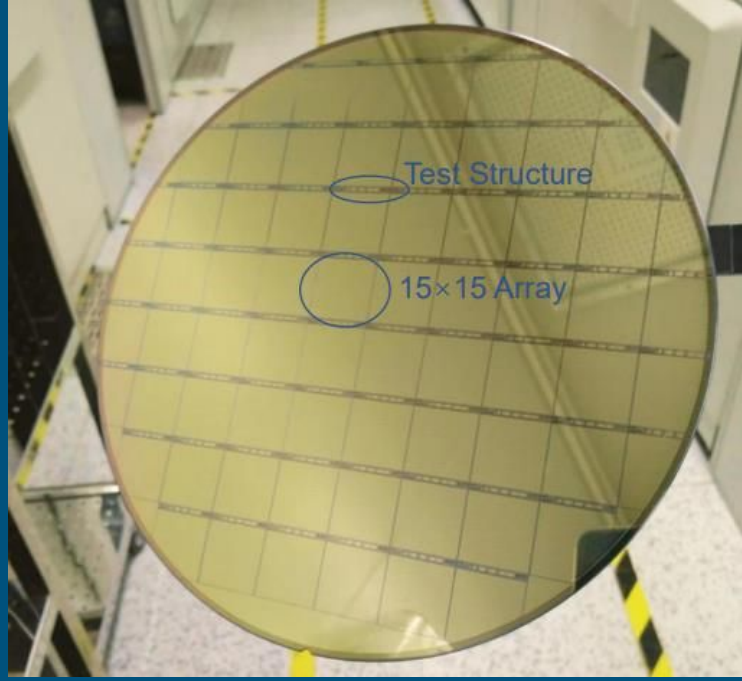
HGTD LGAD Quality Control

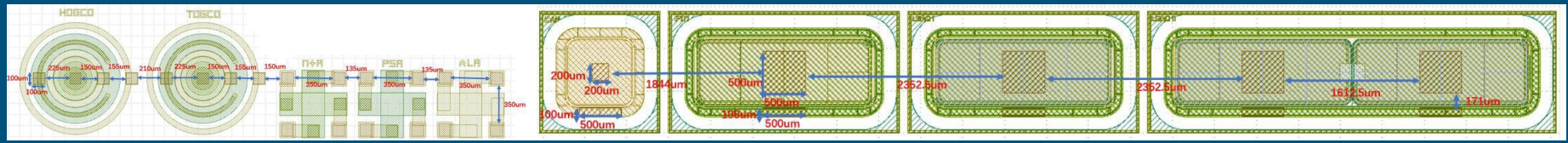
HGTD is buying ~**16000** LGAD
- 15x15 arrays

Various acceptance criteria:
- # of good pads / sensor
- # of good sensors / wafer
- Performance of individual sensors
- Quality of wafer fabrication process

How to qualify the wafer?

Measure test structures and sensors

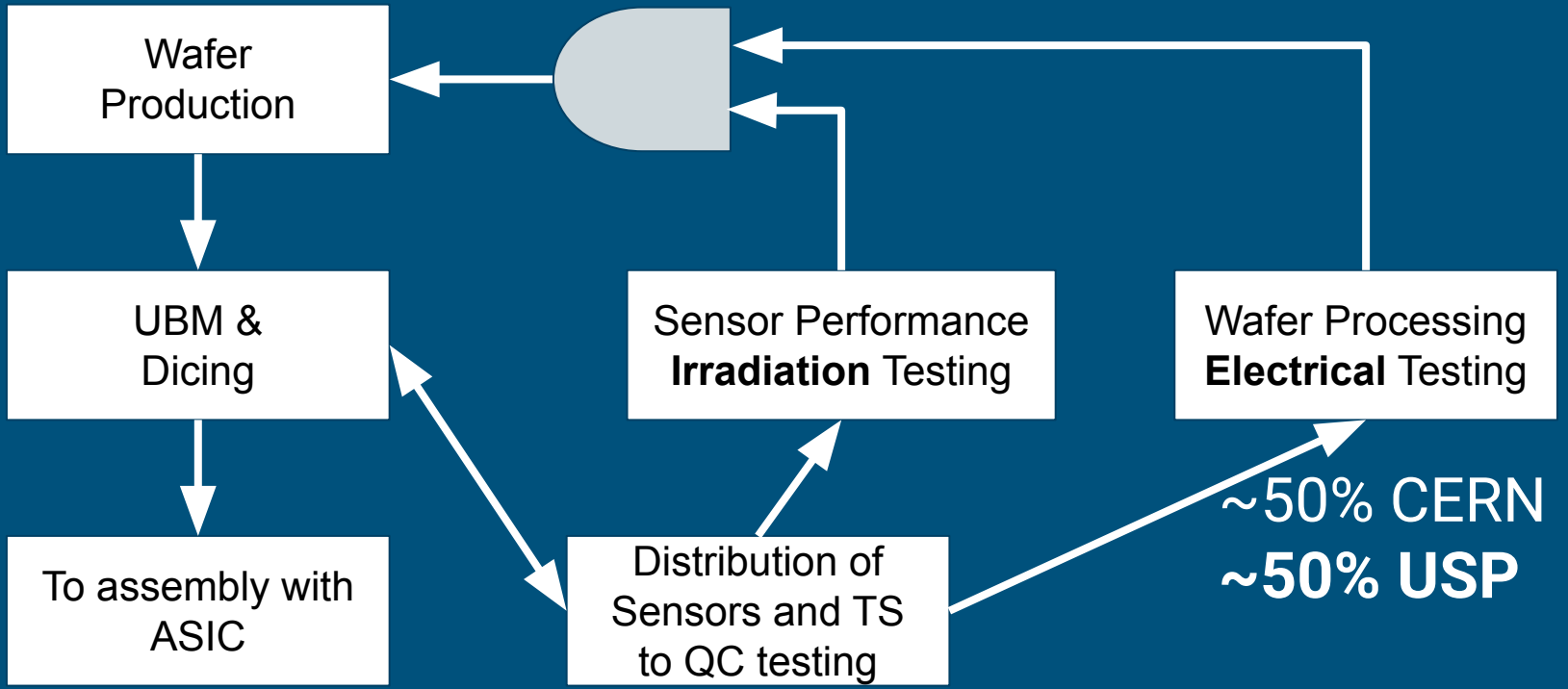




Gated Diodes | Van der Pauw | MOS Capacitor | PIN Diode | LGAD | 1x2 LGAD

16mm

Qualification Procedure



Setup at CERN

On ATLAS Clean Room - ISO7:

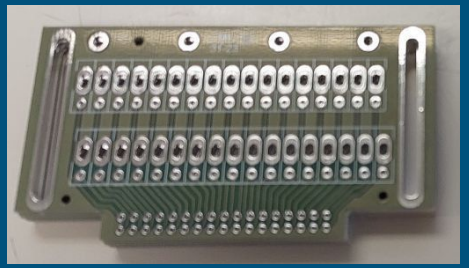
- MPI TS2000 Probe Station
- Keithley 2470 Electrometer
- Keithley 6487 Picoammeter/VSource
- Agilent 4263B LCR

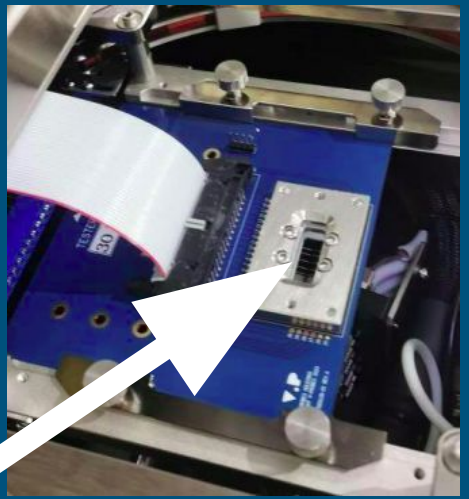
Similar to our setup

Software developed by USP, deployed in person

Setup commissioning by CERN, USP and USTC

COAX



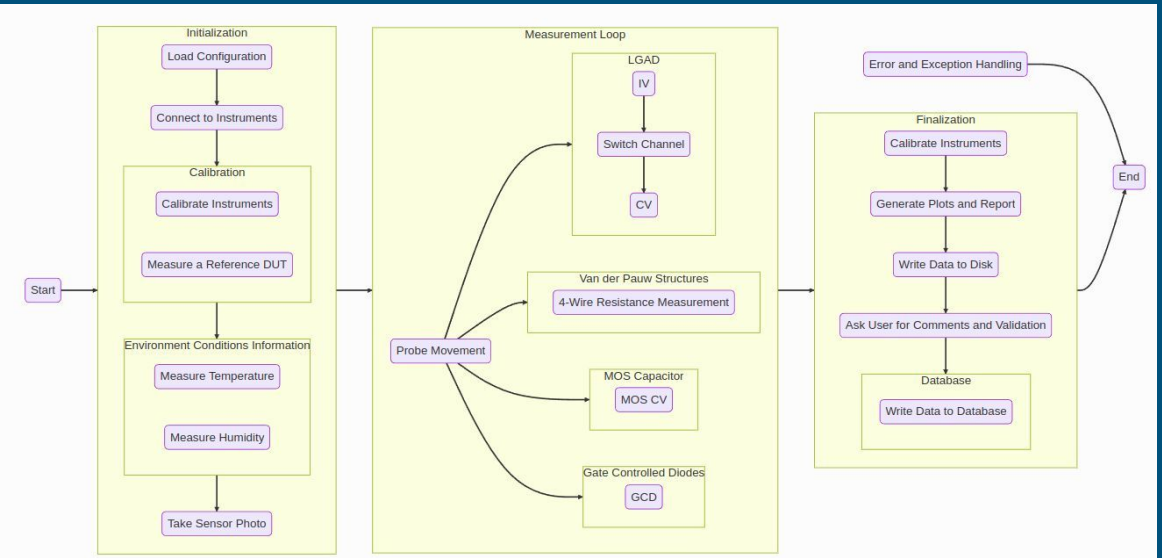


Test Structure needles contact

HGTD Sensors QC Data Acquisition system

Python-based scripting control of all test structures measurements and data keeping

Already deployed and used at CERN, JSI (Slovenia), IHEP (China), USTC (China) and USP



Drivers implemented

- Agilent 4263B LCR
- Keithley 2410, 2470 Sourcemeter
- Keithley 6482 Dual Picoammeter / VSource
- Keithley 6487 Picoammeter / V Source
- Keithley 6514, 6517 Electrometer
- Keysight 34461 DMM
- Keysight E4980 LCR
- R&S HM8118 LCR

Next :

- Keysight B2985B Electrometer/Vsource
- R&S LCX-200 LCR

Qualification Task

Write a data acquisition software for **assessing wafer quality**:

- Automatic procedure to measure the different devices
- Drivers for all instruments across the 5 sites
- Real-time plotting and parameter extraction
- Datakeeping on HGTD Production DB
- **Tracking and report of wafer quality**

ATLAS EXPERIMENT

3 October 2023

HGTD Sensors Quality Control Data Acquisition System

ATLAS collaboration

Summary

Data acquisition software for ATLAS-HGTD sensor QC during preproduction and production will be developed. It will include different configurations of available equipment at the HGTD groups. The DAQ software should be written by use of standardized drivers, which would then be easily modified/added to include any possible new the equipment of the groups doing QC. The software should produce online plots, checks and reports. The software package must include the interface for sending measured data to the production database. A large part of the QT would be development of tools for visualisation, analysis and tracking of production quality from the data stored in the database using Grafana interface. The QT will include the complete QC report from preproduction using the developed tools. The tools should be well documented in the ATLAS note and regularly presented at the meetings.

ATLAS Doc:	xxx-yyy-zzzz	
EDMS Id:	123456	
Version:	0.1	
Last modified:	14:50 on 3 October 2023	
Prepared by:	**Checked by:**	**Approved by:**
G. T. Saito		

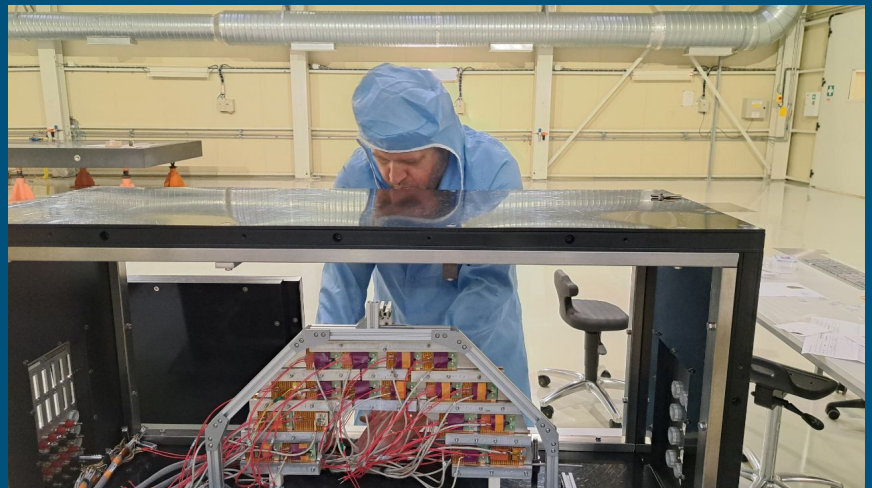
1

Technical Work at CERN

Ricardo and Marcel currently at CERN - 3 months during 2023

Infrastructure on ATLAS clean room

- Probe station commissioning and area for die manipulation
  - Needed to start sensor quality control
- HGTD Demonstrator bench
  - Needed for next phase production modules testing



USP Setup Commissioning

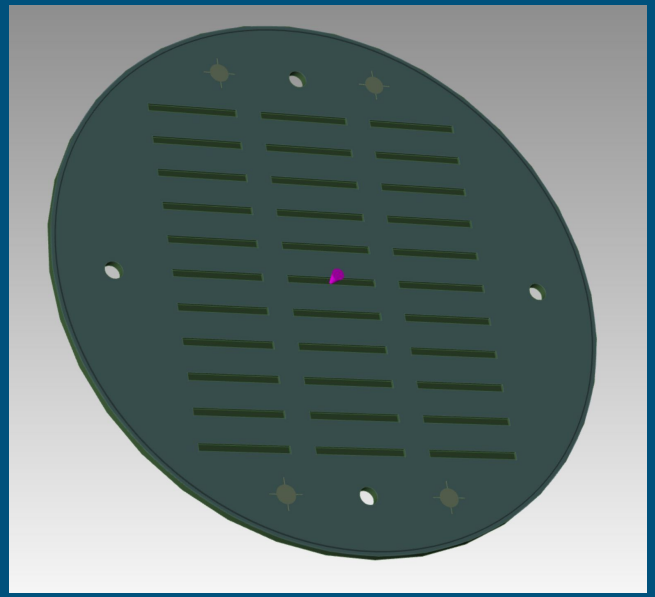
- Probe station, TM equipment, dry cabinet, microscope already arrived
  - Probe station installation by MPI (from USA)
- Probe card holder still to arrive
- Anti-static floor and area closing finished
- Infrastructure finished after Ricardo & Marcel return from CERN
  - Complete services (power, dry air, access control) and ceiling
- Air filtering system (ISO-7), bench with anti-static blower

HEPIC 10/2023

USP Setup Commissioning

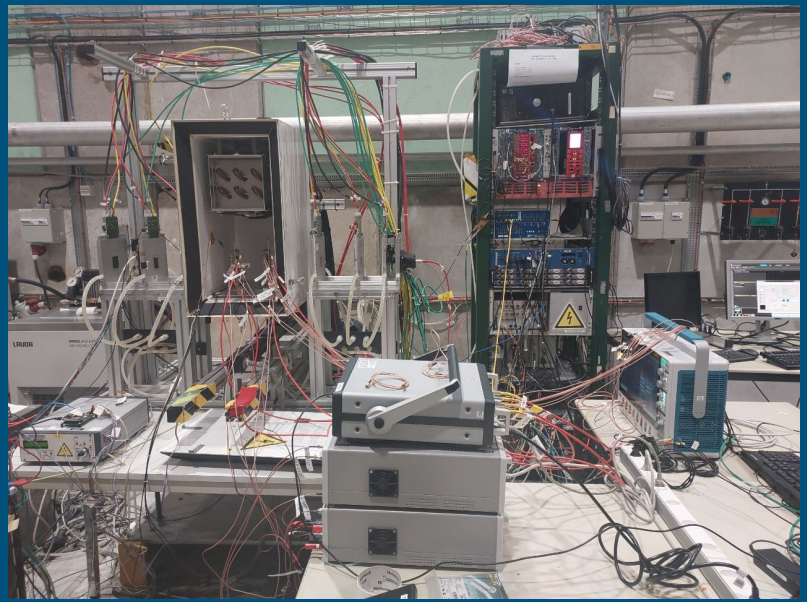
To perform a truly full automatic measurement and measure dozens of dies at the same time:

- Take advantage of semi-automatic probe station movement
- Fabricate a die holder to position them inside the probe station
- Assembly a switching matrix to allow multiple instruments at the same time - no recabling



Testbeam at CERN

- Guilherme - July 2023
  - Last CNM prototype production for HGTD
- Marco - September 2023
  - First test with (pre-)production for HGTD



2 papers on previous testbeams just published:

Jinst

Published by IOP Publishing for Sissa Medialab

Received: June 22, 2023
Accepted: June 26, 2023
Published: July 14, 2023

Destructive breakdown studies of irradiated LGADs at beam tests for the ATLAS HGTD

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DOI 10.1088/1748-0221/18/07/P07030

Jinst

Published by IOP Publishing for Sissa Medialab

Received: June 16, 2023
Accepted: July 27, 2023
Published: August 21, 2023

Performance of a front-end prototype ASIC for the ATLAS High Granularity timing detector

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DOI 10.1088/1748-0221/18/08/P08019

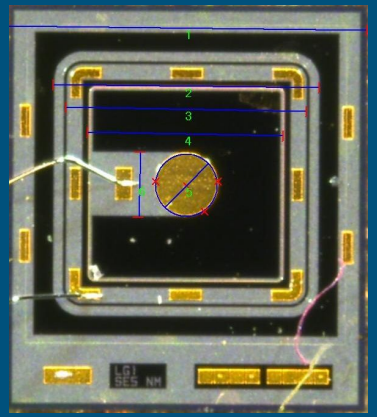
UFSD on X-Ray Synchrotrons

Inception

LGAD originally developed for 4D tracking of MIPs on LHC:

- Very good time resolution for charged particles:
  - Can we maintain this for X-ray detection?
- Intrinsic gain -> Improves S/N
  - Can we use this to probe even lower energy X-rays?
- Future collider trackers will need thinner segmentation:
  - Can we use these new LGAD geometries in very fast “X-ray cameras”?

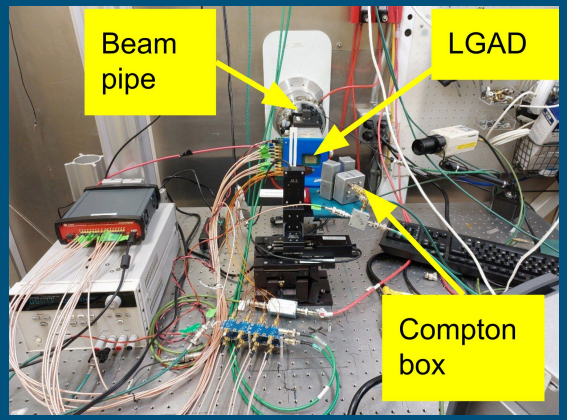
SLAC SSRL Beam Test

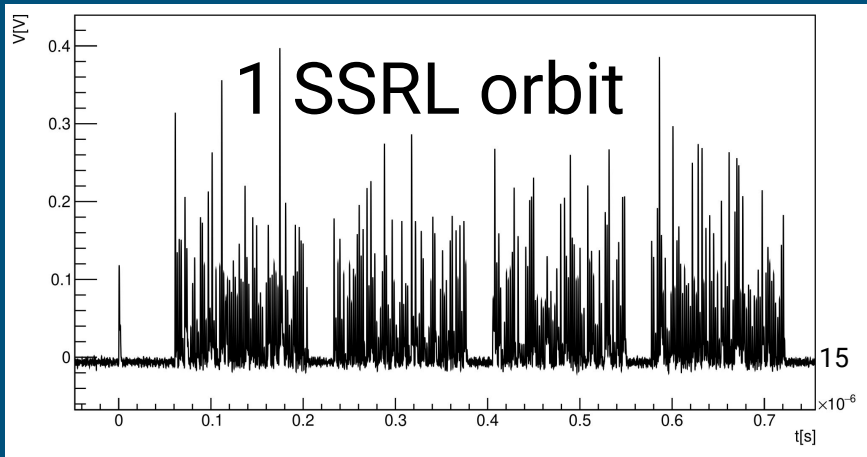


Testbeam at Stanford SLAC SSRL together with UC Santa Cruz in November 2022

- Monochromatic beam from 5 to 35 keV (70 w/ harmonics)
- Broad 12.6mm x 2.14mm spot
- Multiple sensors w/ different geometries

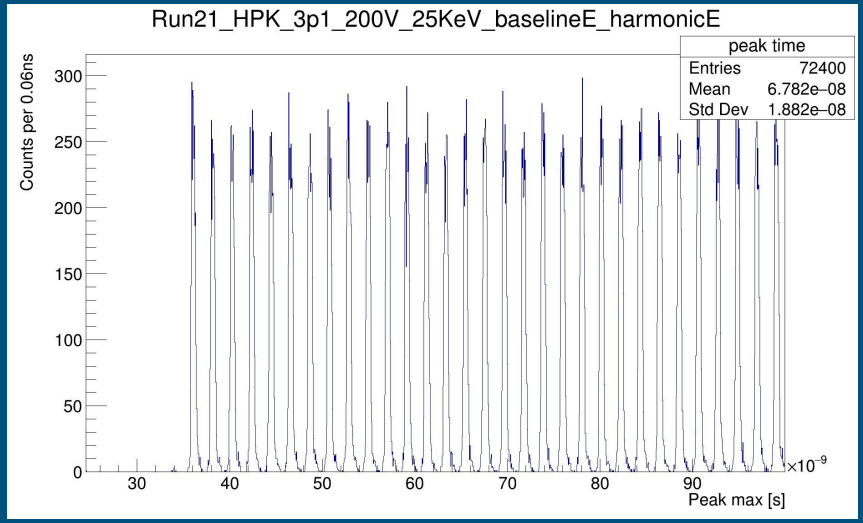
First comprehensive testing of LGAD in X-Ray synchrotrons





Performance of LGAD on X-ray Synchrotron

- Easily discriminate 5 keV X-ray:
  - SNR > 7
- Easily resolves 2ns:
  - 70ps resolution
- Energy resolution as good as Si allows:
  - ~6%



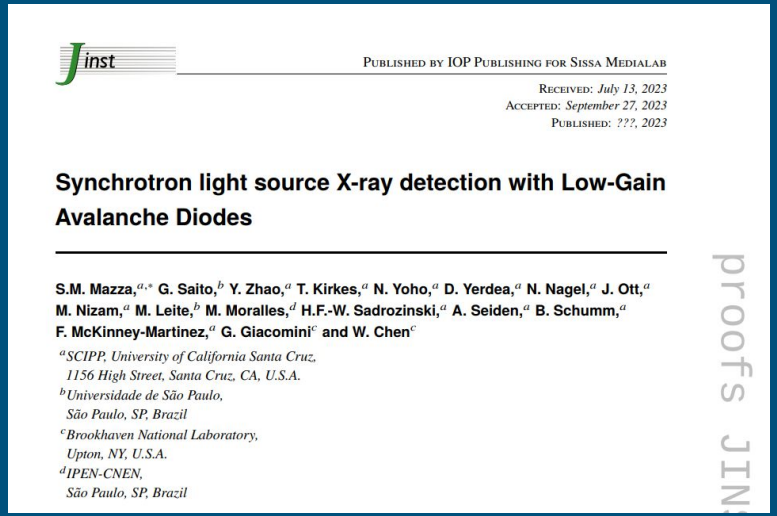
For 35 keV X-ray:

	HPK PIN	HPK3.1		HPK3.2		BNL 20um	
Bias V	200 V	150 V	230 V	80 V	130 V	50 V	100 V
Energy Resolution	14 %	6 %	17 %	10 %	20 %	6 %	16 %
Energy Response	19 mV	75 mV	185 mV	68 mV	211 mV	66 mV	147 mV
σ_t CFD	78 ps	141 ps	123 ps	371 ps	171 ps	69 ps	65 ps

Work published

1st paper accepted by JINST:

Work in collaboration with University of California Santa Cruz



Published by IOP Publishing for Sissa Medialab

Received: *July 13, 2023*
Accepted: *September 27, 2023*
Published: *???, 2023*

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

S.M. Mazza,[a,*] G. Saito,[b] Y. Zhao,[a] T. Kirkes,[a] N. Yoho,[a] D. Yerdea,[a] N. Nagel,[a] J. Ott,[a] M. Nizam,[a] M. Leite,[b] M. Moralles,[d] H.F.-W. Sadrozinski,[a] A. Seiden,[a] B. Schumm,[a] F. McKinney-Martinez,[a] G. Giacomini[c] and W. Chen[c]

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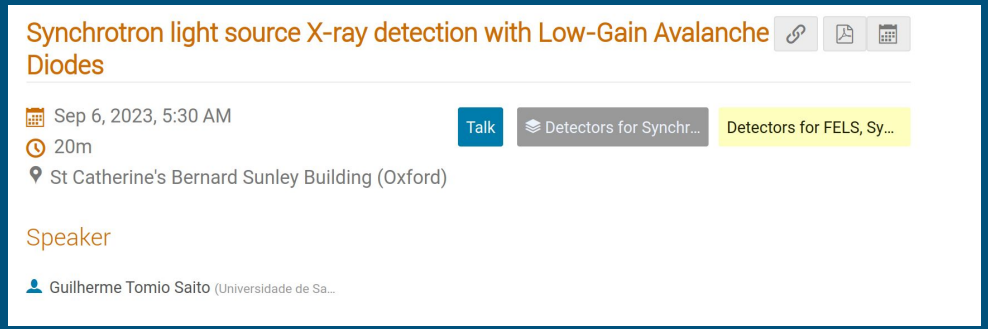
[d]*IPEN-CNEN, São Paulo, SP, Brazil*

https://arxiv.org/abs/2306.15798

At least 1 more to come

Talk presented on the
13th International Conference on Position Sensitive Detectors

Oxford University, Sep 6 2023



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

Sep 6, 2023, 5:30 AM
20m
St Catherine's Bernard Sunley Building (Oxford)

Talk | Detectors for Synchr... | Detectors for FELS, Sy...

Speaker

Guilherme Tomio Saito (Universidade de Sa...

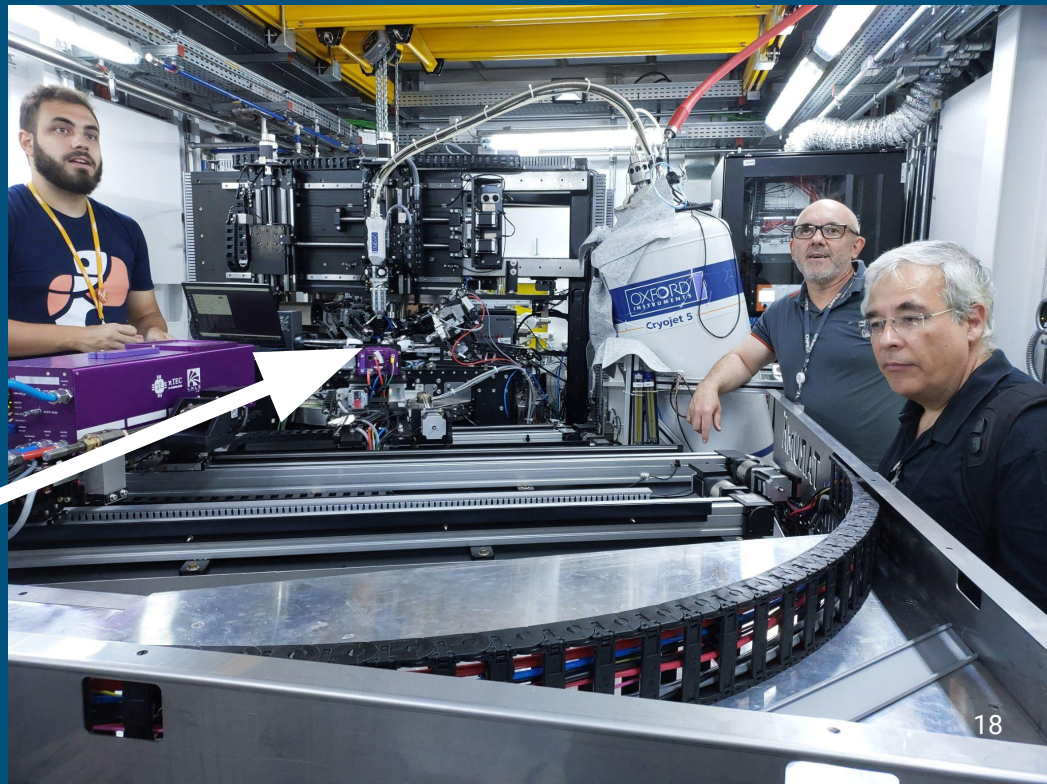
Proceedings to be published on NIM A

https://indico.cern.ch/event/1230837/contributions/5518011/

SIRIUS Testbeam

- End of the November
  - Tarumã beam line (2keV - 17 keV, .1um to few mm beam size, max intensity ~10^{12} photons/s, 10ps timing signal for trigger)
- Will test a HPK device from HGTD LGAD prototype run
  - Try to confirm results from SSRL
  - Add some measurements to understand X-ray gain and signal formation
- Developing a new amplification chain readout
  - Optimized to probe low energies
  - Very fast electronics

Tarumã beamline:



Beam pipe

Remarks

- HGTD
  - Ramp up of activities
    - O(100) devices to be tested at USP on next months
  - Continue supporting Sensor QC software for the foreseeable future
  - Next year:
    - Full demonstrator activities
    - Start HGTD assembly
- Synchrotron applications
  - Testbeam at Sirius
  - Start research on sensor readout