Projeto Temático 2020/04867-2
Kick-off Meeting

Marco Bregant / Tiago Fiorini da Silva

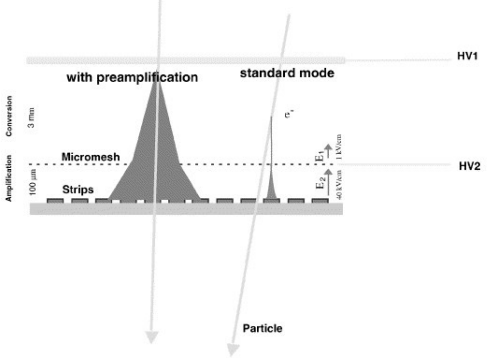
WG 5.1: MPGD sensors development and applications

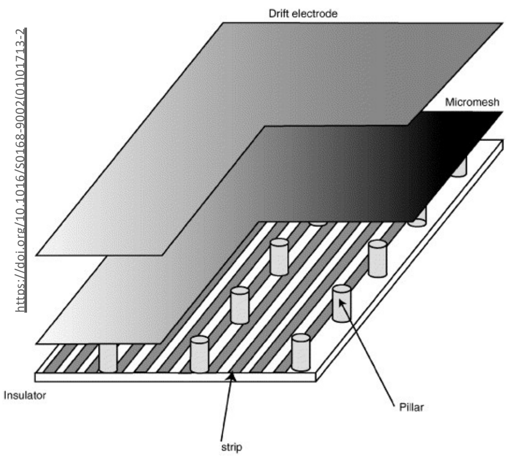
Que são MPGD, que é um GEM

Micro **P**attern **G**as **D**etector

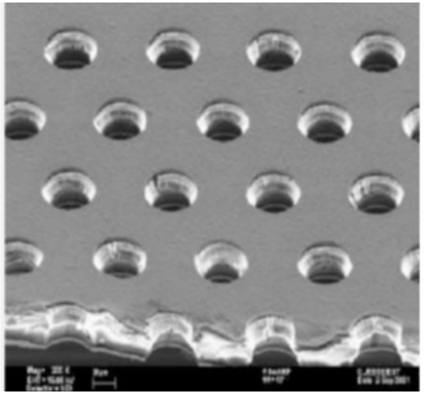
os mais conhecidos:

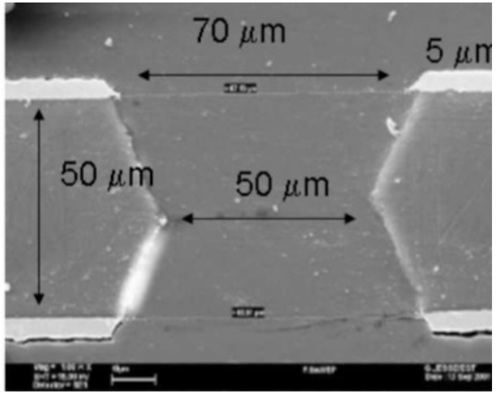
MicroMega



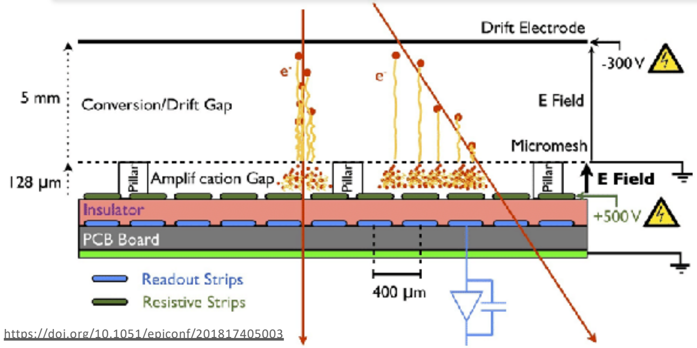


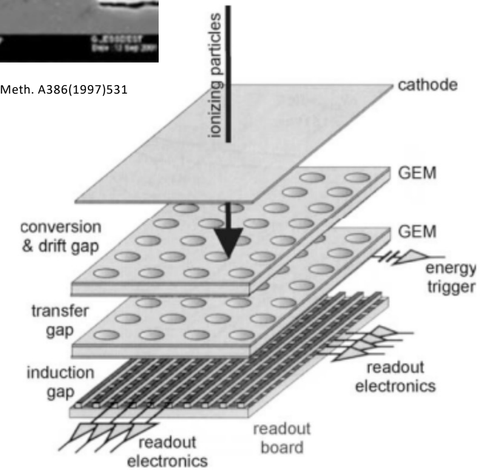
Gas **E**lectron **M**ultiplier





F. Sauli, Nucl. Instr. Meth. A386(1997)531





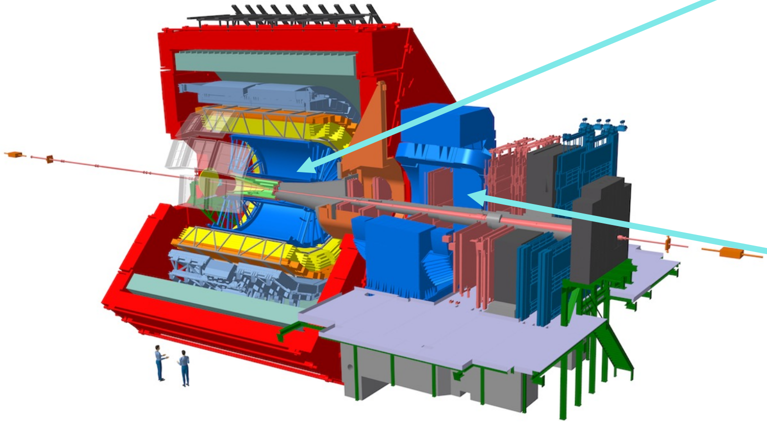
MPGD, como tudo começou: o upgrade de ALICE para o run3

HEPIC
IFUSP

Since right after the detector entered in data taking (2010), it was clear that starting from Run3 (the LHC period started now) ALICE should plan to operate at higher rate, recording all MB events

Goal set: 50kHz in Pb-Pb (~10nb^{-1} in Run3 and Run4)

Detectors and electronics would require an upgraded during Long Shutdown 2 (“2020”)



- Time Projection Chamber (TPC)
  - **GEM** readout plane, high rate capability, continuous readout.

TPC electronics used till run2 was not made to amplify negative charge input (as GEMs provides) and cannot cope with the higher rate and with the continuous readout operation planned

- Muon Chamber (Forward muon spectrometer)
  - Higher rate capability, new acquisition electronics chain in ALICE

new electronics was needed

TPC required a new readout, MCH too.

A common project to design a new ASIC: SAMPA

Partnership IFUSP - LSI (EP-USP)

MPGD, como tudo começou:
Hugo Natal da Luz se juntando ao grupo

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Convergence of paths

The group is developing an ASIC for GEM-based TPC, prototype of the basic block are coming…

would be nice to have a GEM-based detector to try them (especially CSA) with a real detector.

A young, nevertheless expert, researcher is moving from Europe to São Paulo for familiar reasons, he is looking for a local group to continue his research:

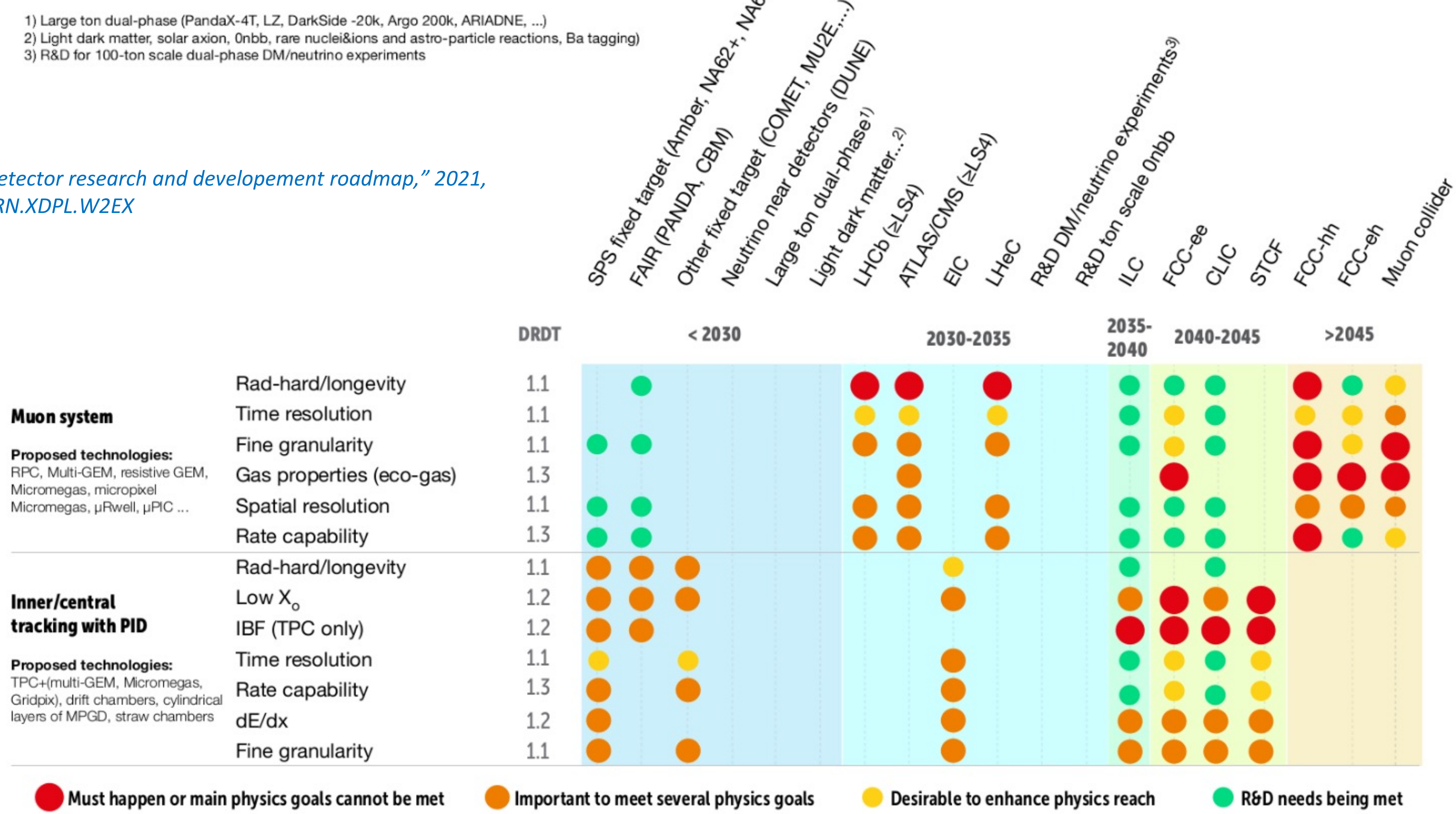
gaseous detectors, namely MPGD, GEMs

A PERFECT MATCH!

Official start of HEPIC activity with MPGD/GEM
A dedicated Lab is prepared and equipped.

Desenvolvimento em MPGD para experimentos futuros

“The 2021 ECFA detector research and developement roadmap,” 2021, doi: 10.17181/CERN.XDPL.W2EX



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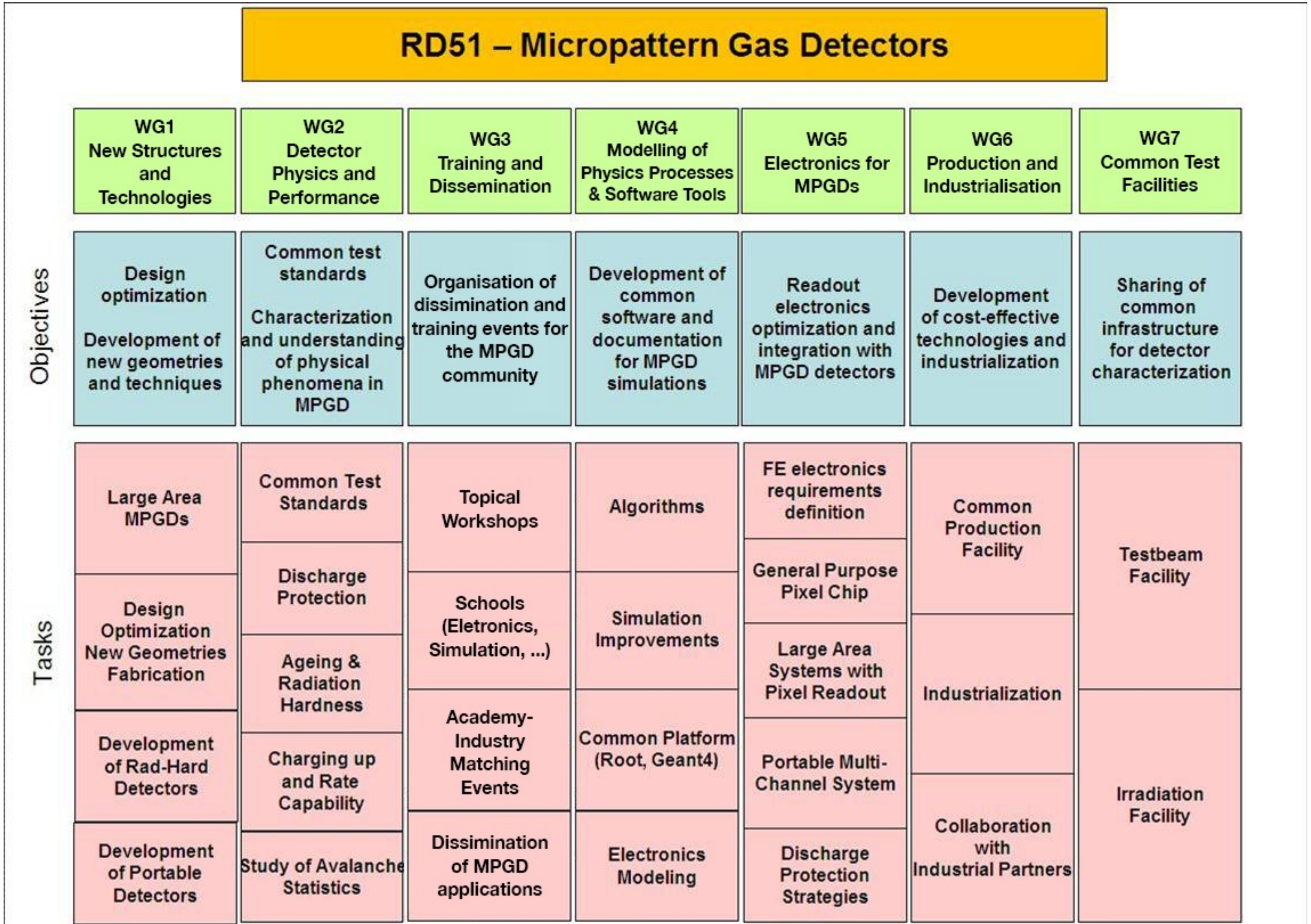
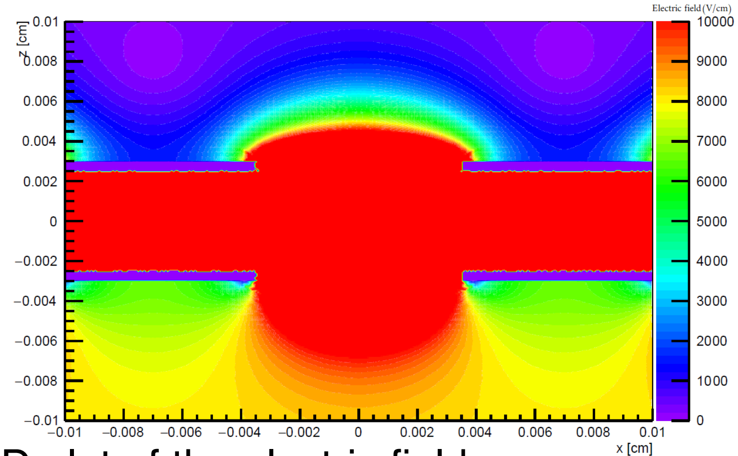

RD51 – Micropattern Gas Detectors
WG1 New Structures and Technologies
WG2 Detector Physics and Performance
WG3 Training and Dissemination
WG4 Modelling of Physics Processes & Software Tools
WG5 Electronics for MPGDs
WG6 Production and Industrialisation
WG7 Common Test Facilities
Objectives
Design optimization
Development of new geometries and techniques
Common test standards
Characterization and understanding of physical phenomena in MPGD
Organisation of dissimination and training events for the MPGD community
Development of common software and documentation for MPGD simulations
Readout electronics optimization and integration with MPGD detectors
Development of cost-effective technologies and industrialization
Sharing of common infrastructure for detector characterization
Tasks
Large Area MPGDs
Design Optimization New Geometries Fabrication
Development of Rad-Hard Detectors
Development of Portable Detectors
Common Test Standards
Discharge Protection
Ageing & Radiation Hardness
Charging up and Rate Capability
Study of Avalanche Statistics
Topical Workshops
Schools (Eletronics, Simulation, ...)
Academy-Industry Matching Events
Dissimination of MPGD applications
Algorithms
Simulation Improvements
Common Platform (Root, Geant4)
Electronics Modeling
FE electronics requirements definition
General Purpose Pixel Chip
Large Area Systems with Pixel Readout
Portable Multi-Channel System
Discharge Protection Strategies
Common Production Facility
Industrialization
Collaboration with Industrial Partners
Testbeam Facility
Irradiation Facility

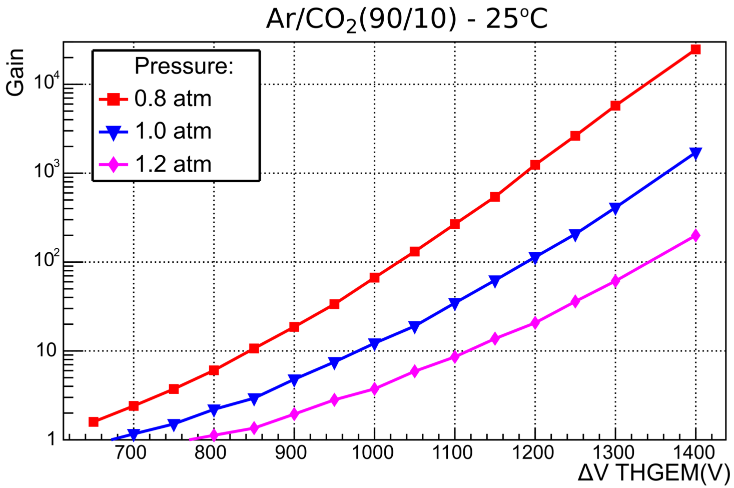
GEM-based detectors

SIMULAÇÕES

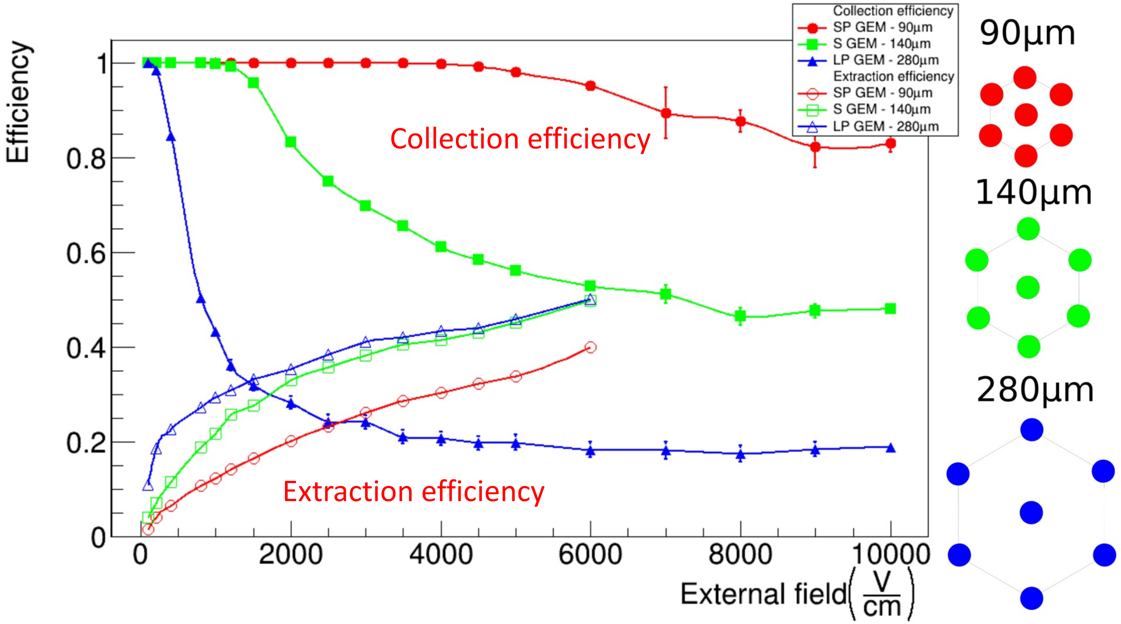
Simulations



2D plot of the electric field



Simulated gain curves for Thick-GEMs

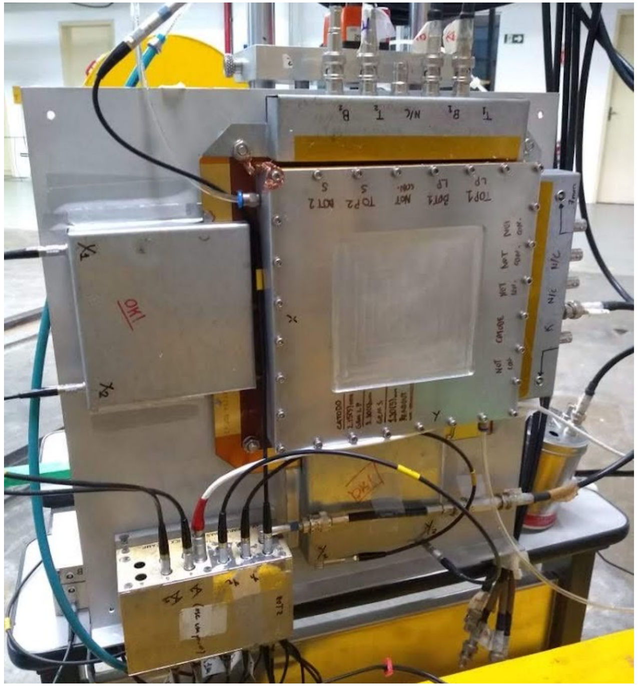


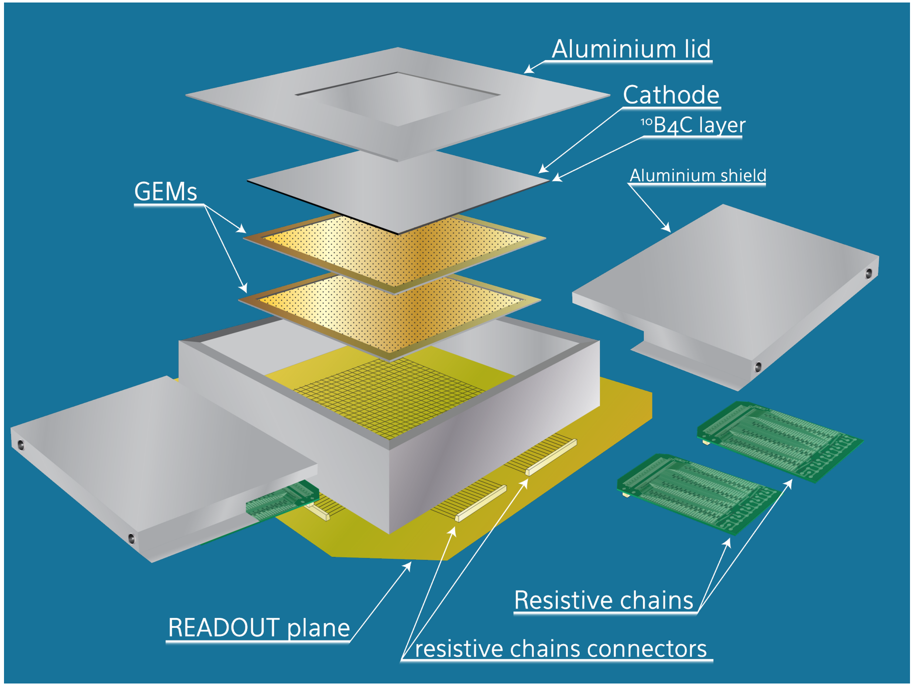
Efficiencies obtained through simulations

GEM-based detectors

APPLICATIONS

Thermal neutron GEM detector





Cross sections at 25.2 meV:

- ^{113}Cd → 20600 b
- ^{157}Gd → 254000 b
- ^{3}He → 5327 b
- ^{10}B → 3837 b
- ^{6}Li → 940 b

$n + {}^{157}Gd \longrightarrow {}^{158}Gd + \gamma + 7.938$ MeV

$n + {}^{113}Cd \longrightarrow {}^{114}Cd + \gamma$ (várias energias)

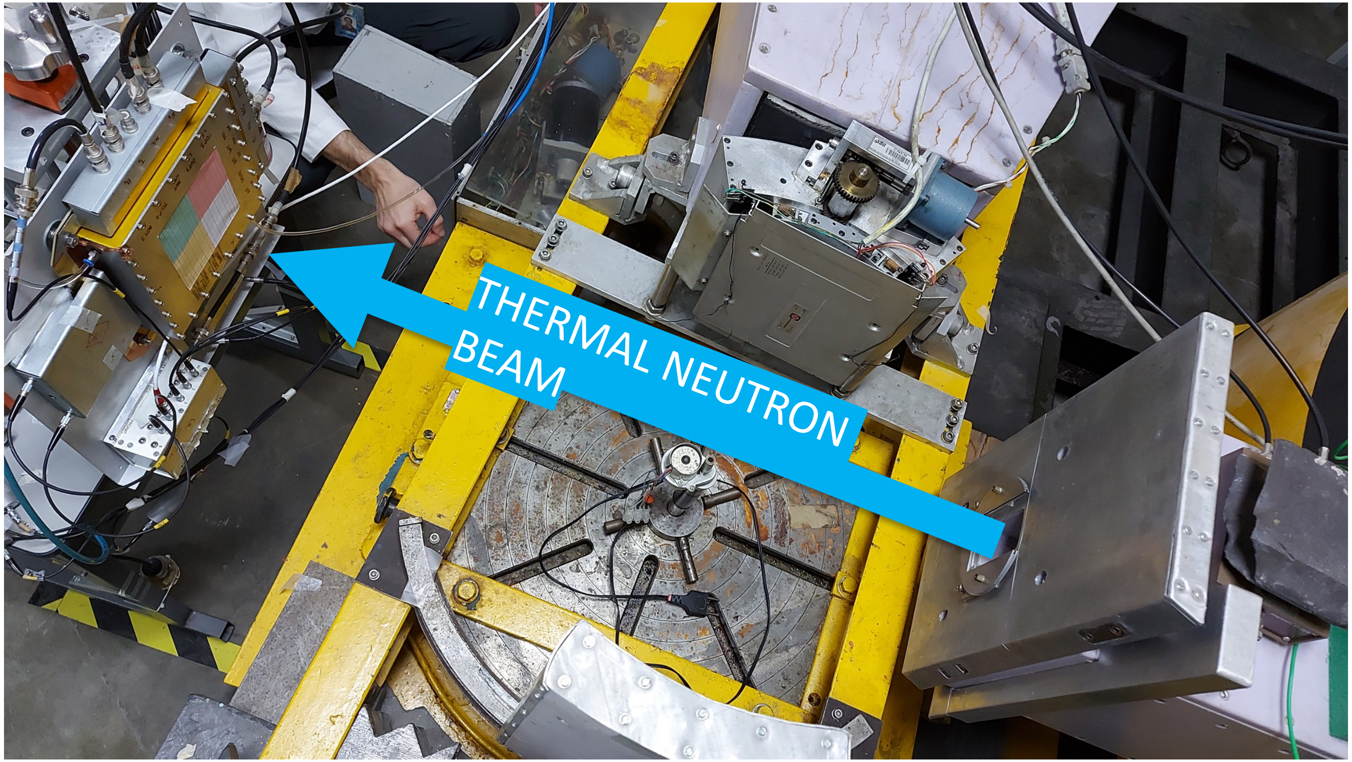
$n + {}^{3}He \longrightarrow {}^{3}H + {}^{1}H + 0.764$ MeV

$n + {}^{6}Li \longrightarrow 4\ {}^{3}He + 3\ H + 4.79$ MeV

$n + {}^{10}B \longrightarrow {}^{7}Li + {}^{4}He + 0.48$ MeV (γ) + 2.3 MeV (93%)

$\longrightarrow {}^{7}Li + {}^{4}He +$ 2.8 MeV (93%)

Thermal neutron GEM detector



- 1.399 Å (41.80 meV) neutrons from diffractometer beam line.
- 6,22(19)x10^4 n/$cm^2 s^{-1}$ neutron flux, measured using $^{197}Au(n, \gamma)^{198}Au$ reaction.

Neutron images (Lucas' dissertation)

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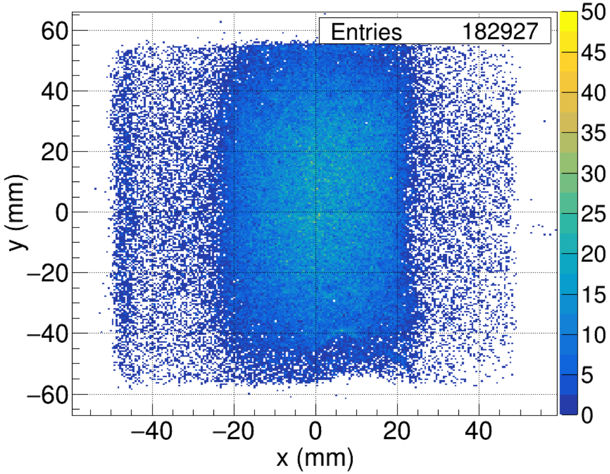

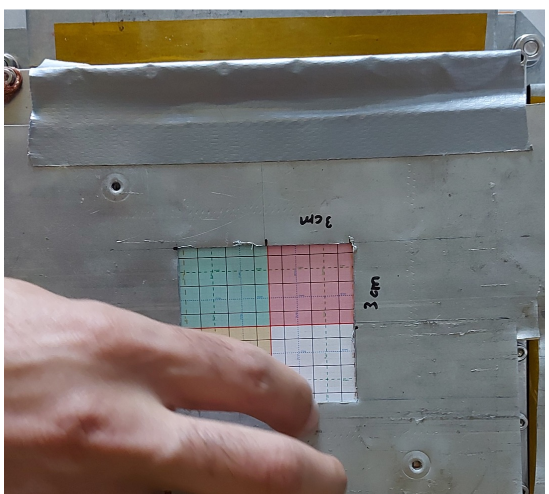

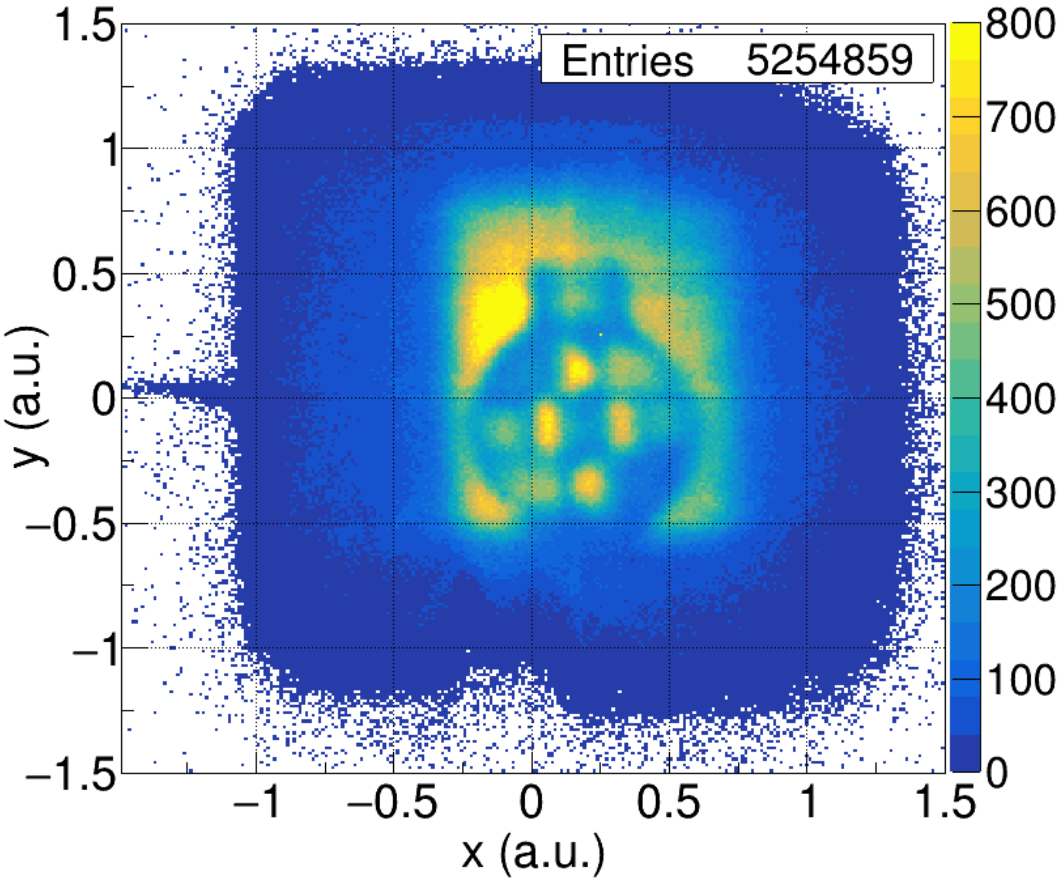

One of the fist thermal neutron image produced with our prototype

https://doi.org/h6st

X-ray Detector

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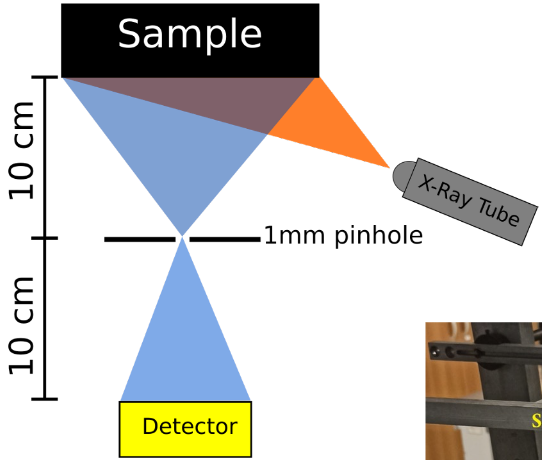
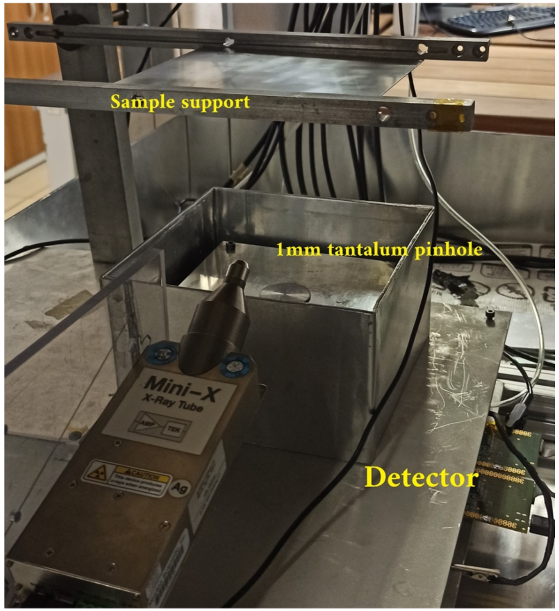
First round
Geovane's Master project

- Triple-GEM with strip read-out

(256 strips for each dimension)

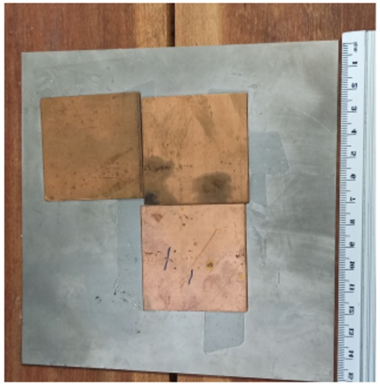
- 100 cm^2 active area
- Ar/CO2 (70/30) at atmospheric pressure
- Gain of the order of 10^4
- Detector field of view limited by the 1 mm tantalum pinhole for near field images
- Acquisition rate ≈ 250 Hz (APV25 readout)



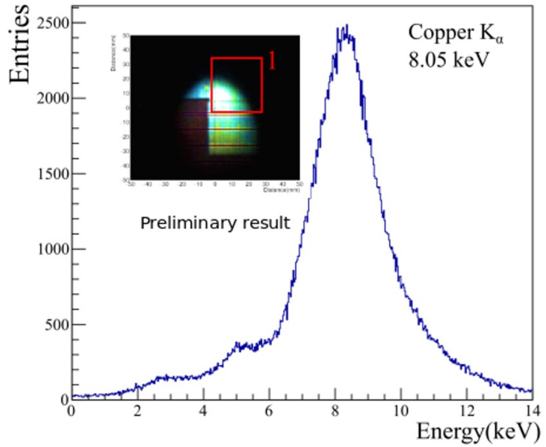


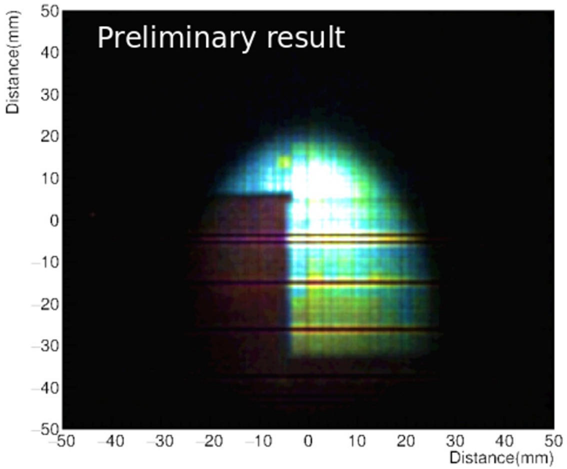
X-ray Detector

Test sample of a titanium plate with cooper sectors

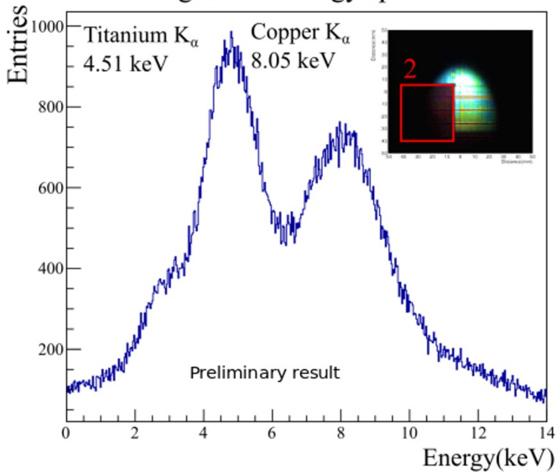


Region 1 - Energy spectrum



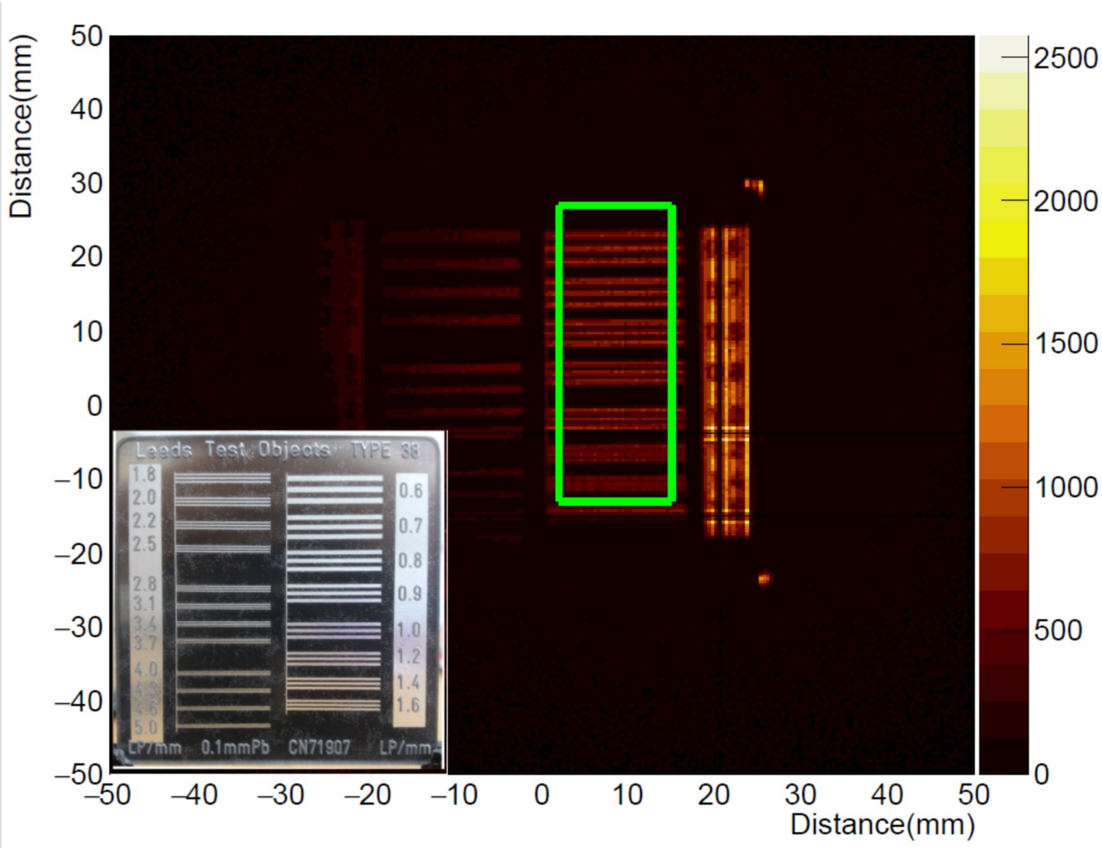


Region 2 - Energy spectrum

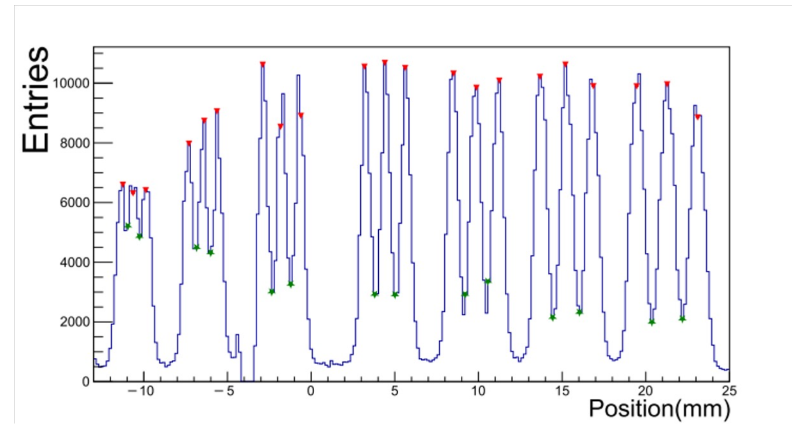


Capability to measure energy: Different chemical elements may be identify in the image! (”colour photo” in the X-ray range)

X-ray (Geovane dissertation)



And the picture can have good level of details!



Longevity and materials

GEM AGING AND DEGRADATION STUDIES

What happens to the detector when irradiated?

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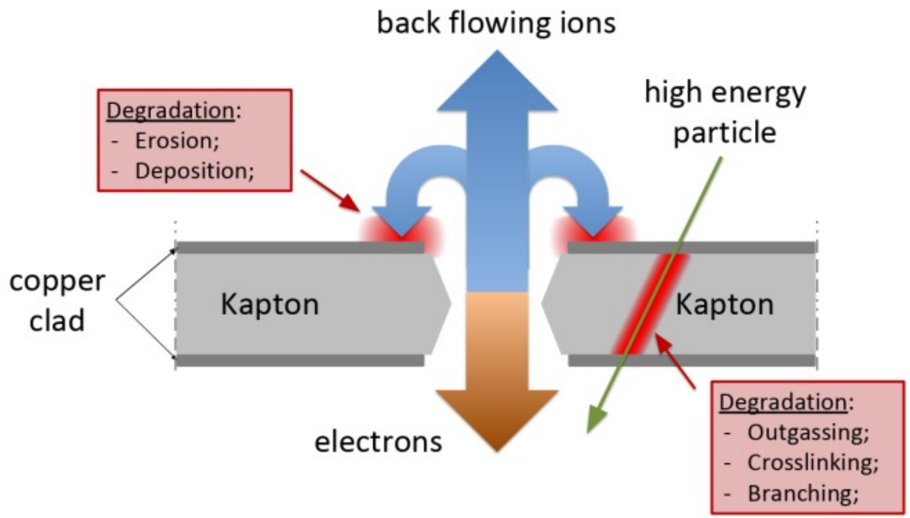
Goal: Develop a deeper understanding on aging and degradation processes of Gas Electron Multipliers (GEMs).

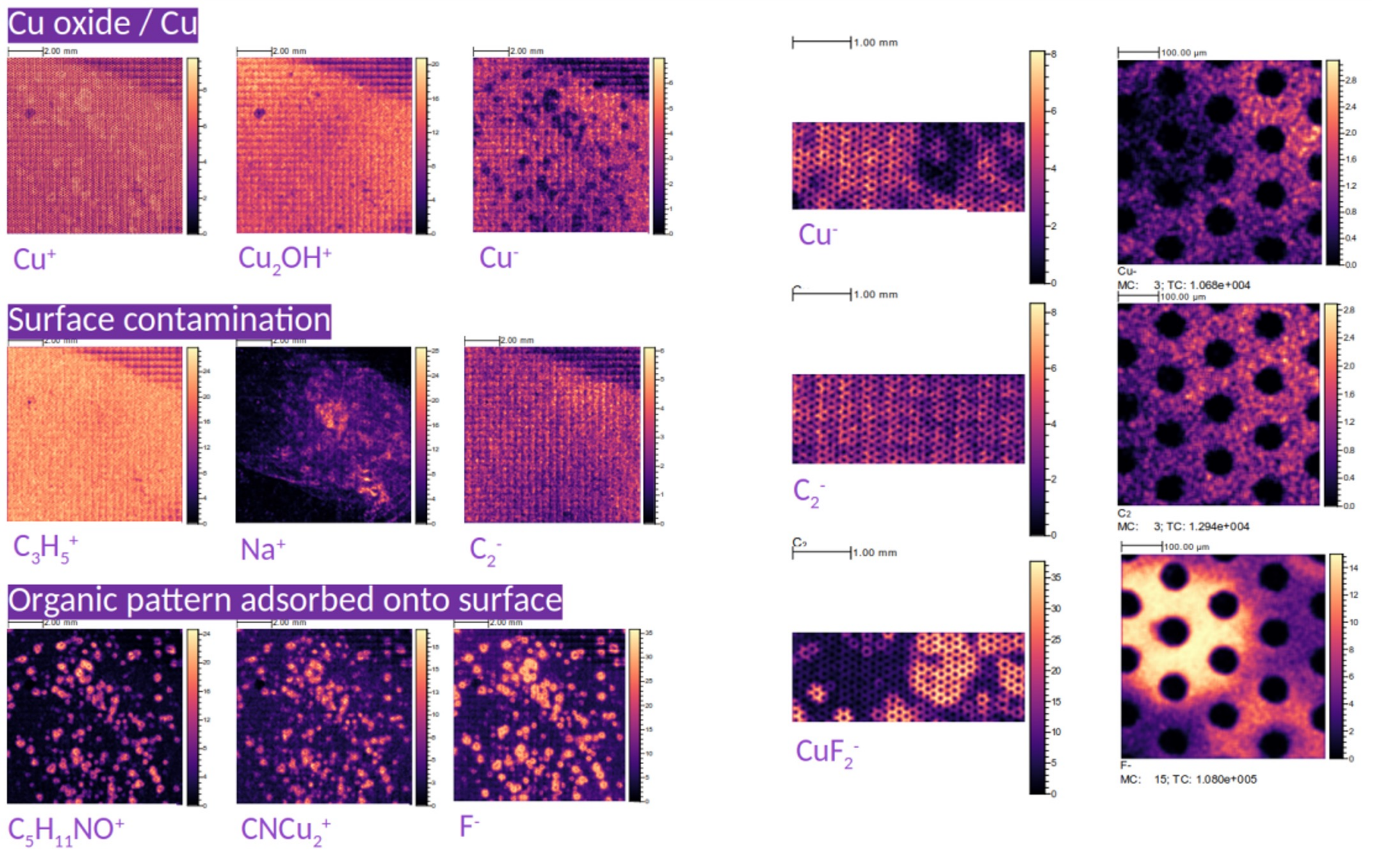


Challenges: Definition of controlled environment
Partners: Univ. of Nottingham and NPL.
Motivation: Enable longer lifetime and stability.
The new idea: Use of advanced surface analysis.
Who: Research line of Tiago + Thiago (doctorate student)

Analysing GEM foil modification

e.g. ToF-SIMS surface analysis

made at Nottingham University, our collaborators in this activity



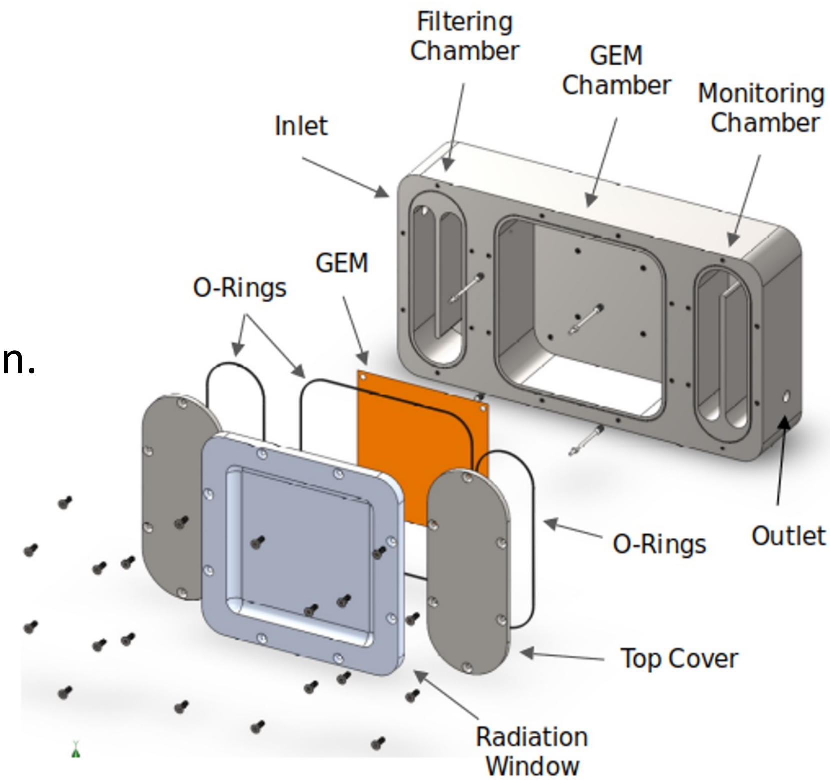
There is evidence of kapton redeposition!

Analysing contaminants in the gas

Controlled aging

An ad hoc designed degradation chamber

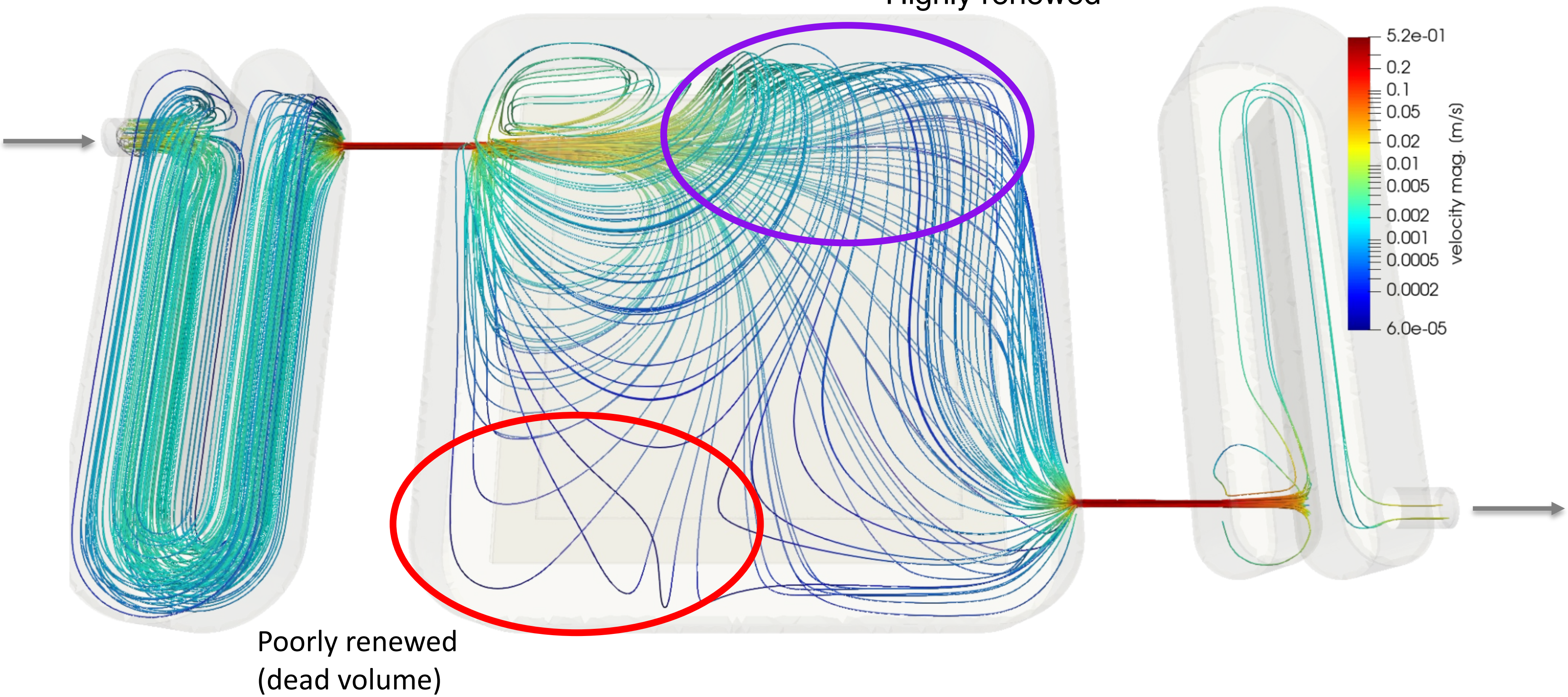
- **Stainless steal chamber**
  - Clean ambient and avoid degassing.
- **Inlet/Filtering Chamber**
  - Filed with purifying materials.
  - Removal of eventual H2O and O2 contamination.
- **Outlet/Monitoring chamber**
  - Environmental sensors:
  - Temperature and pressure.
  - Gas quality monitoring:
  - H2O, O2 and **H2**.
- **Both attached to the GEM chamber**
  - To avoid tubes.



Analysing contaminants in the gas

Controlled aging

The flow is not homogeneous in the GEM chamber, effect will be position-dependent?

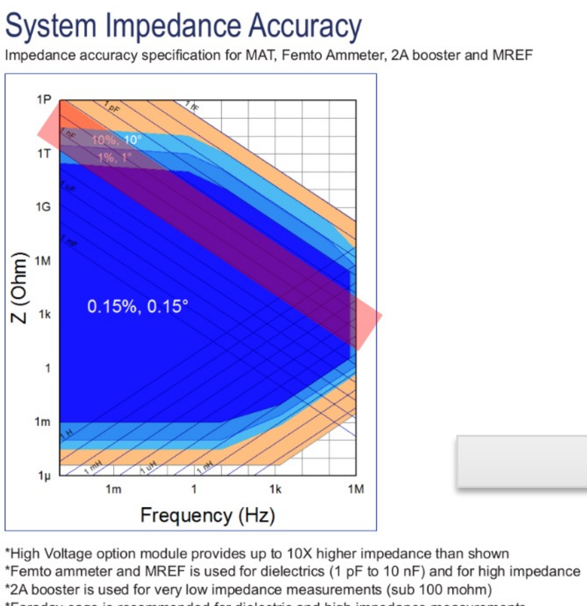


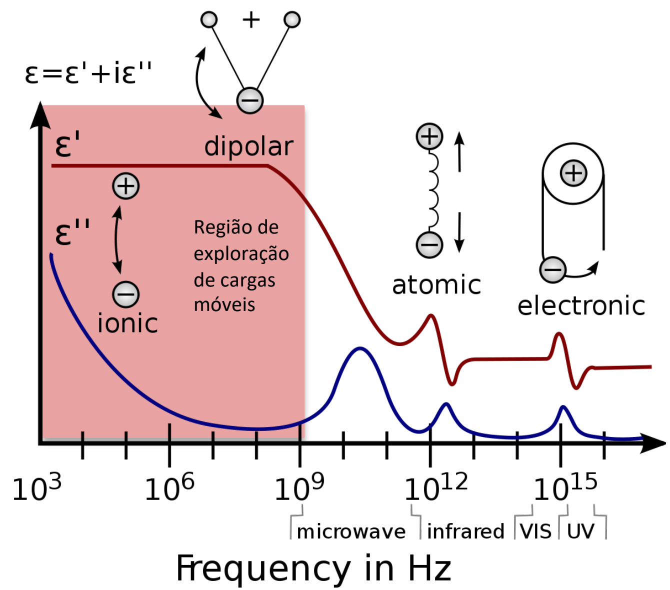
Diagnóstico não invasivo

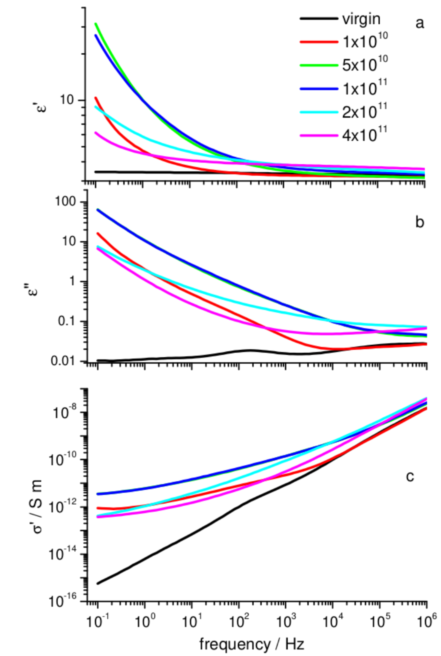
Goal: Develop a non-invasive diagnostic tool for GEM based detectors to enable periodic check.
Challenges: Definition of protocols and standards
Motivation: Enable sanity check of the ALICE TPC.
The new idea: Exploit dielectric relaxation spectroscopy
Who: Research line of Tiago + Thiago (doctorate student)

Daniel Severin. "Study of the degradation process of polyimide induced by high energetic ion irradiation". https://d-nb.info/990901416/34

Equipamento aprovado como EMU







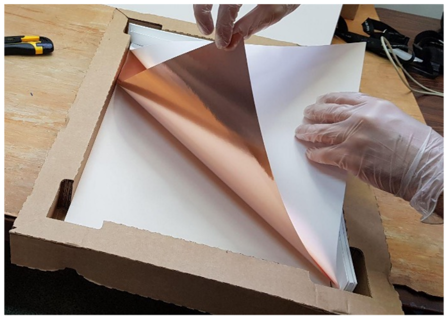
Experimenting new shapes

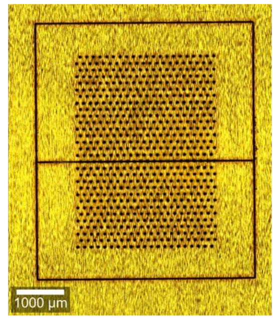
ALTERNATIVE FABRICATION METHODS

Locally: using Laser Ablation

In collaboration with USP Engineering Faculty

Goal: Develop a self-sufficient production of Gas Electron Multipliers (GEMs).



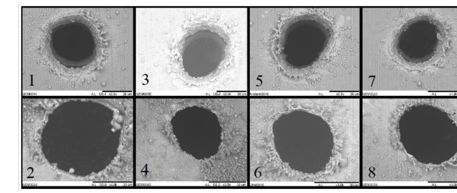


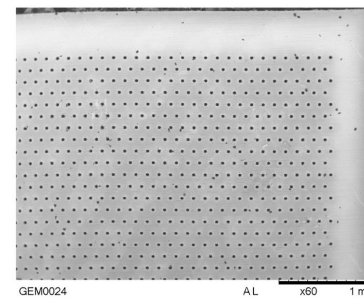
Challenges: Microfabrication with homogeneous quality
Motivation: Enable the GEM production in different shapes, quicker turn-around, reducing the costs of prototyping.
The new idea : Use of laser ablation for fast production.

Who: Research line of Tiago + Eduardo (Master Student)

Method: Laser milling
Why? - New, clean (free of KOH) and fast

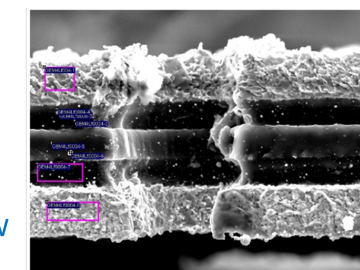
Laser parameter optimization





Homogeneity check

Cross-section view



Tecnology transfer: laserTOOLS Soluções a laser

3D printing of MPGDs

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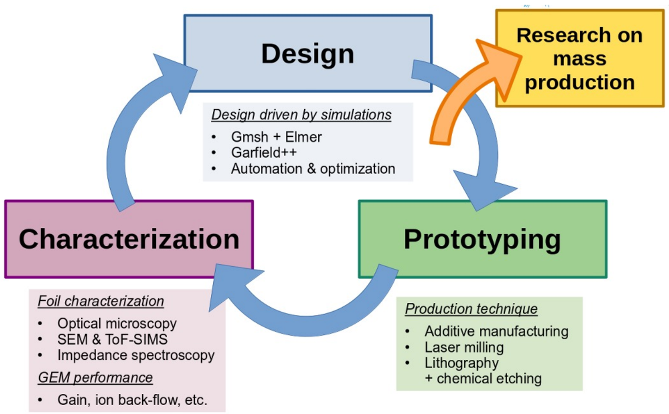
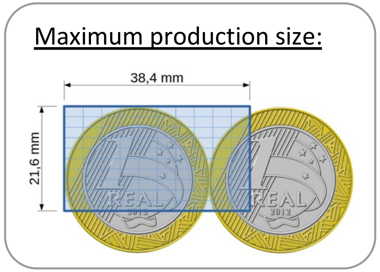
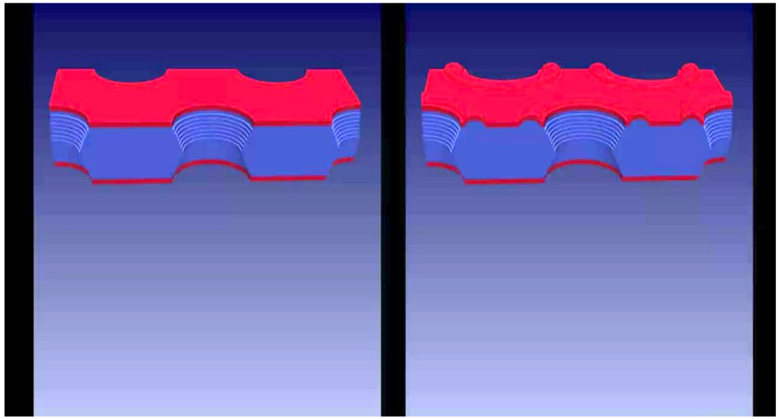
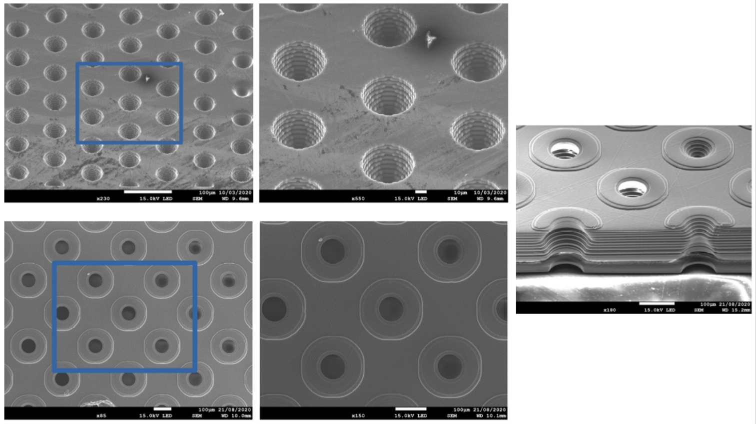
In collaboration with Univ. of Nottingham and NPL.

<u>Goal:</u> Enable fast prototyping for tests of new geometries. Smooth integration between modelling and tests.









<u>Challenges:</u> Multi-material printing in high-resolution.
<u>Motivation:</u> Suppression of charging up, ion backflow and mitigation of degradation.

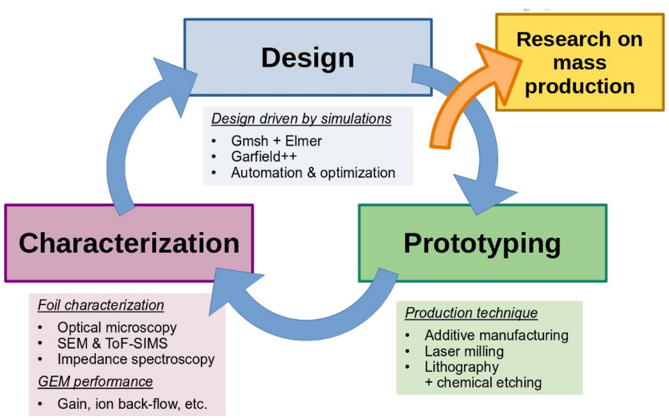
<u>Who:</u> Tiago + UoN collaborators

3D printing of MPGDs

HEPIC IFUSP

In collaboration with Univ. of Nottingham and NPL.

Goal: Enable fast prototyping for tests of new geometries. Smooth integration between modelling and tests.



Maximum production size:

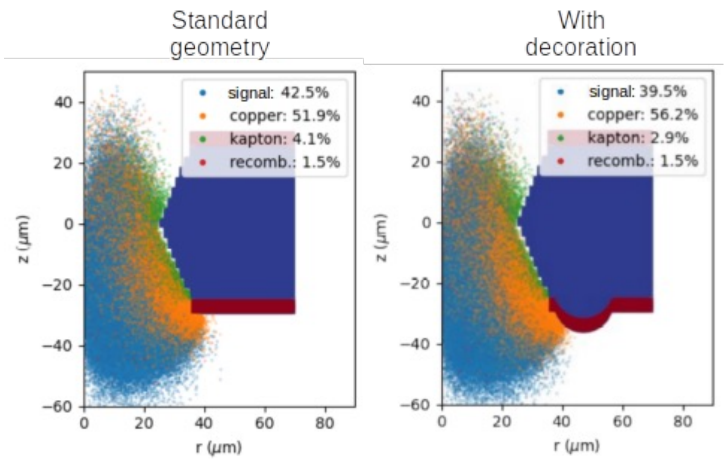
Challenges: Multi-material printing in high-resolution.
Motivation: Suppression of charging up, ion backflow and mitigation of degradation.

Who: Tiago + UoN collaborators

What are possible benefits achievable with micro-sized decorations:

- 7% reduction in the signal intensity ☹
- 29% of reduction of electron hit in the kapton (charging up) 😎

Electron destination:



Testing detectors in stress conditions

RADIATION HARDNESS

Proton beam line for tests of radiation hardness

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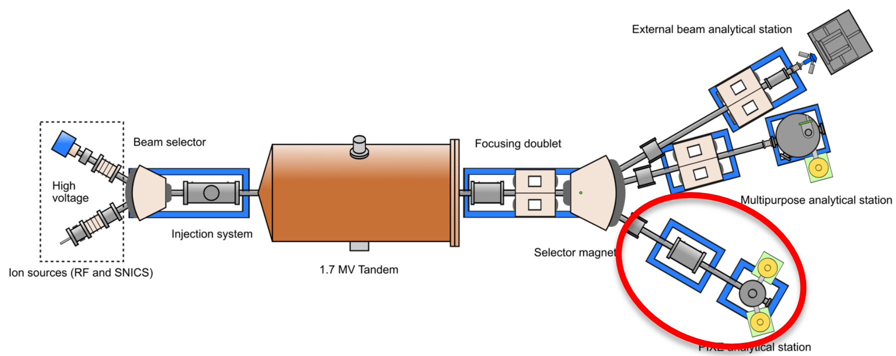
- **Goal:** Explore the radiation hardness of detectors (GEMs and LGADs)
- **Challenge:** Implementation of a microbeam line at the LAMFI facility (collaboration with CNPEM engineering team)



LAMFI
Laboratório de Análises de Materiais por Feixes Iônicos

CNPEM
Centro Nacional de Pesquisa em Energia e Materiais

- **Motivation:** High induced charge by protons well localized in space. Proton beam line with energy between 800 keV and 3.4 MeV (from 12 µm up to 120 µm in silicon)
- **Who:** Tiago + LAMFI team

How to read our detectors

READOUT ELECTRONICS

An ASIC is not (yet) a Readout Electronics

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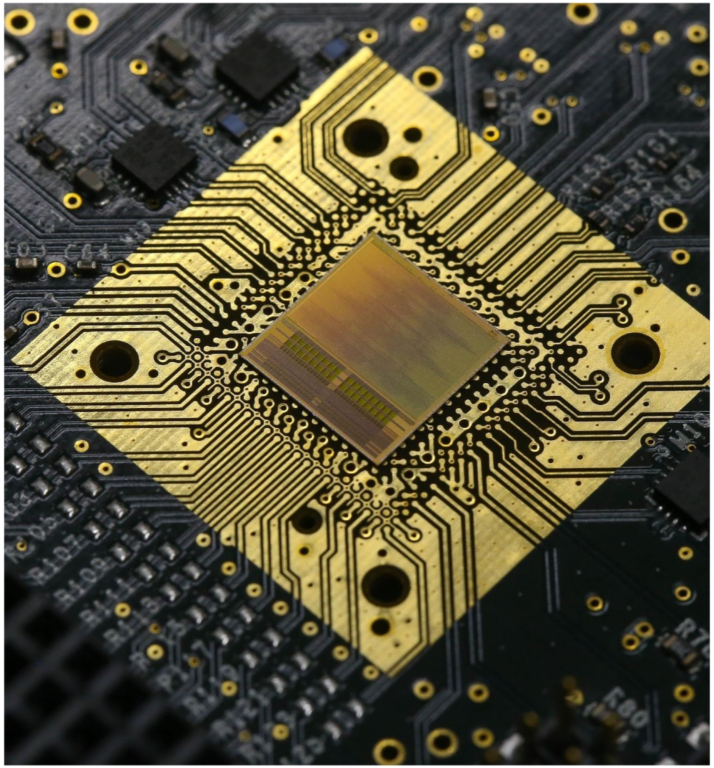


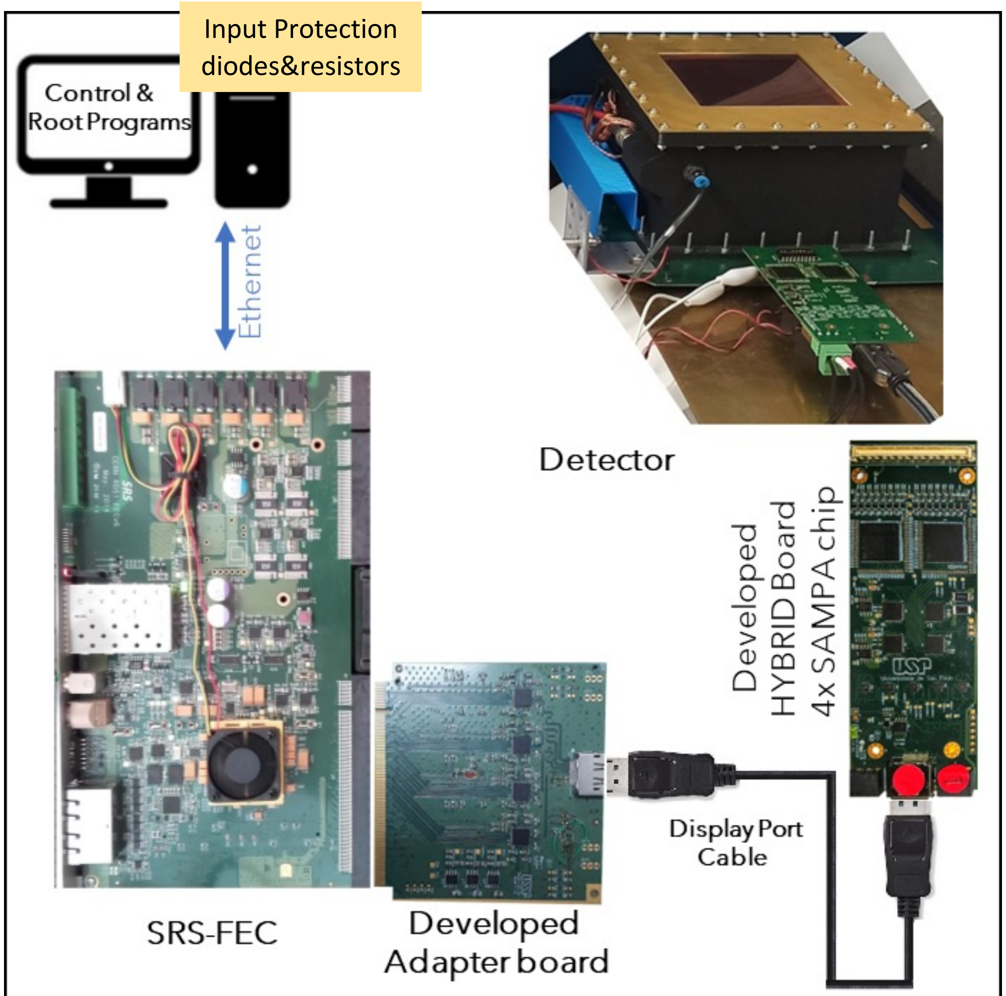
It's a nice ASIC! We are proud of!

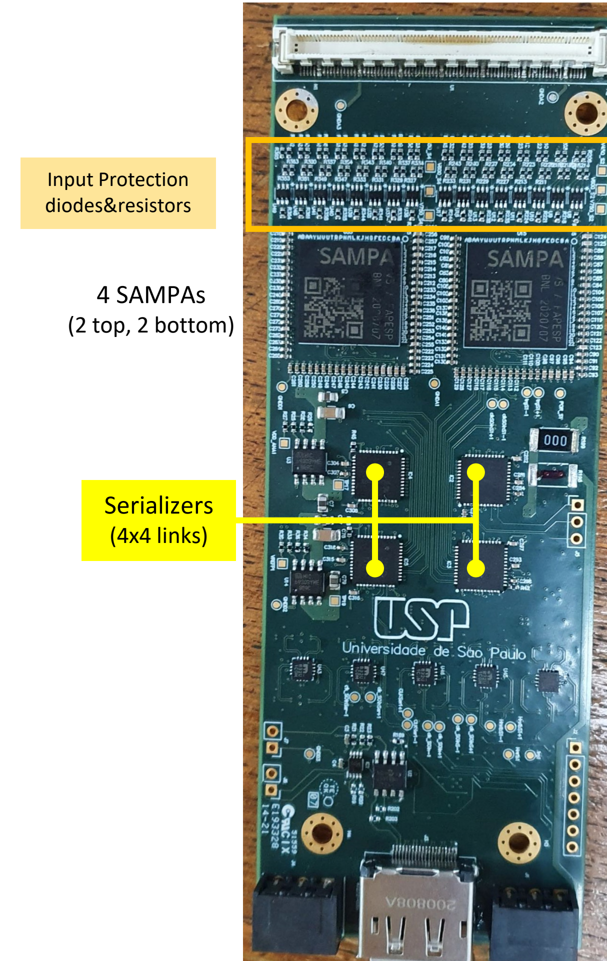
<u>Nevertheless 'useless' on its own!</u>

It needs to be host in a card that allows to plug its inputs to the detector, and the communication lines to an acquisition system (not mentioning providing power)

As shown, there are several activities in our lab, some of them will profit from, NEED!, a readout system with several tens of channels to add high position resolution to the detector

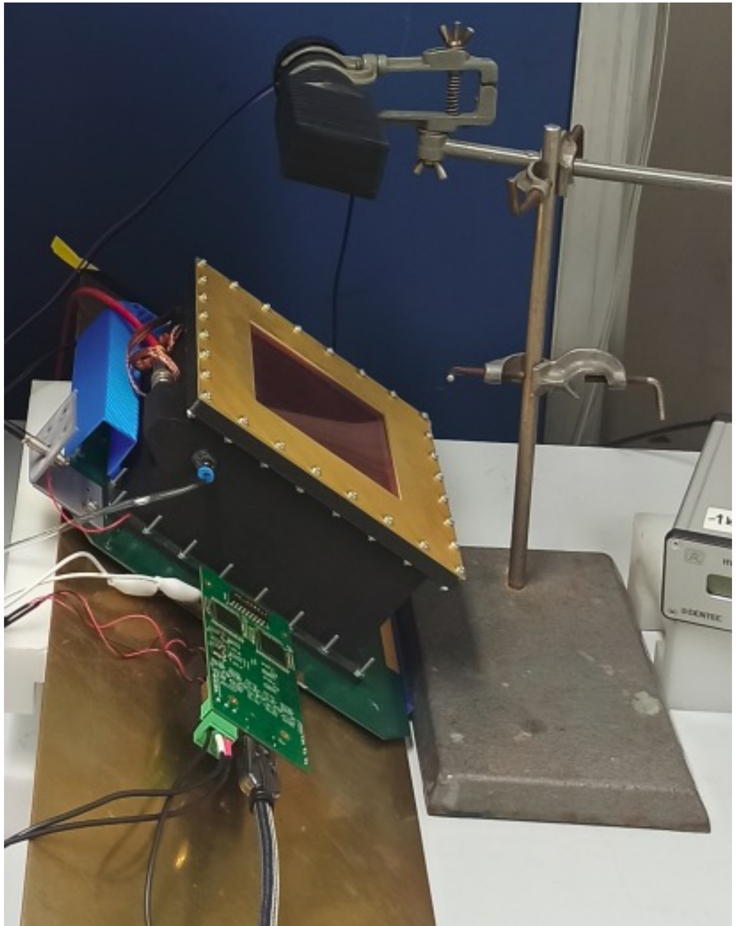
Integrating SAMPA into the RD51-SRS



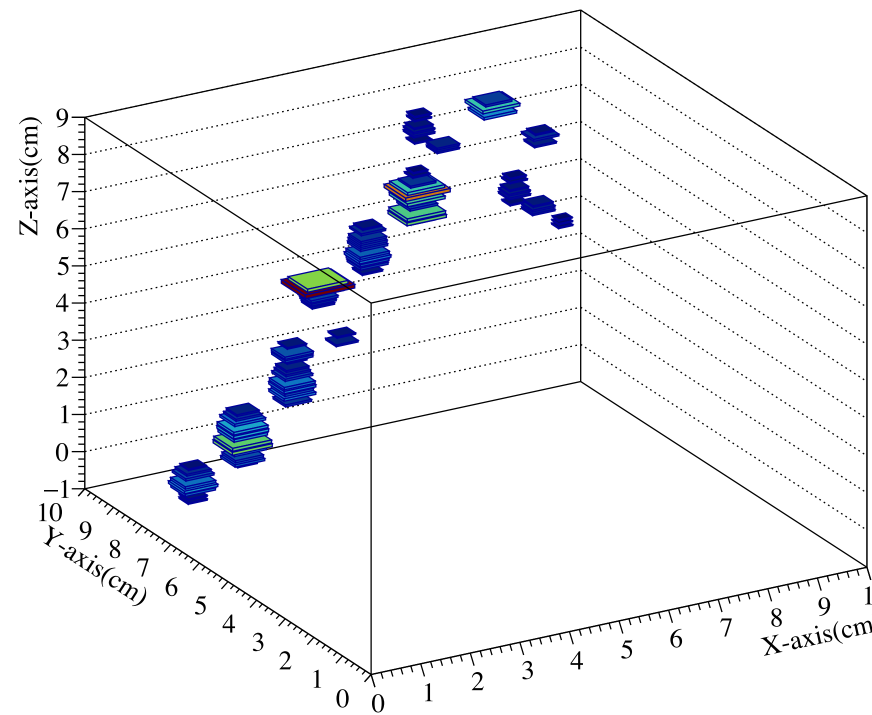


Integrating SAMPA into the RD51-SRS

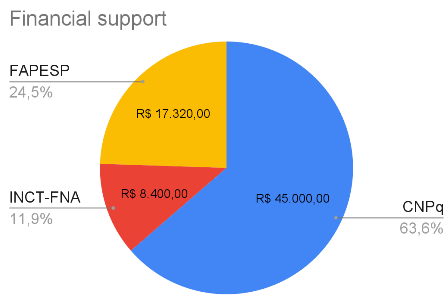
Tested in real life ☺ (colaboration with CVUT Prague)

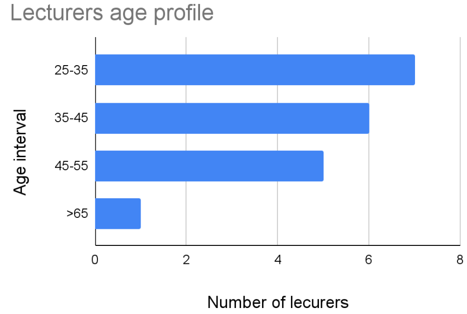


a muon track



Extensão

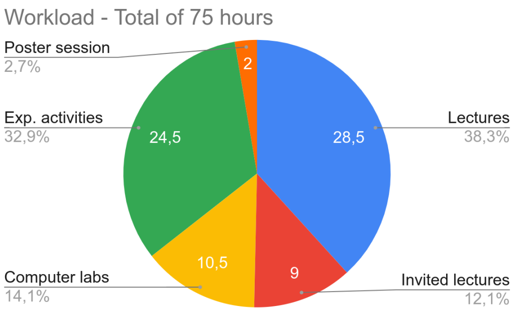


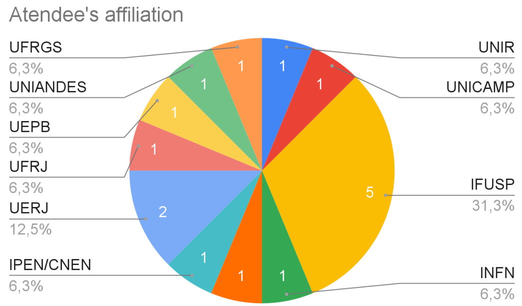


Escola "André Jorge Swieca" de Física Nuclear Experimental da SBF

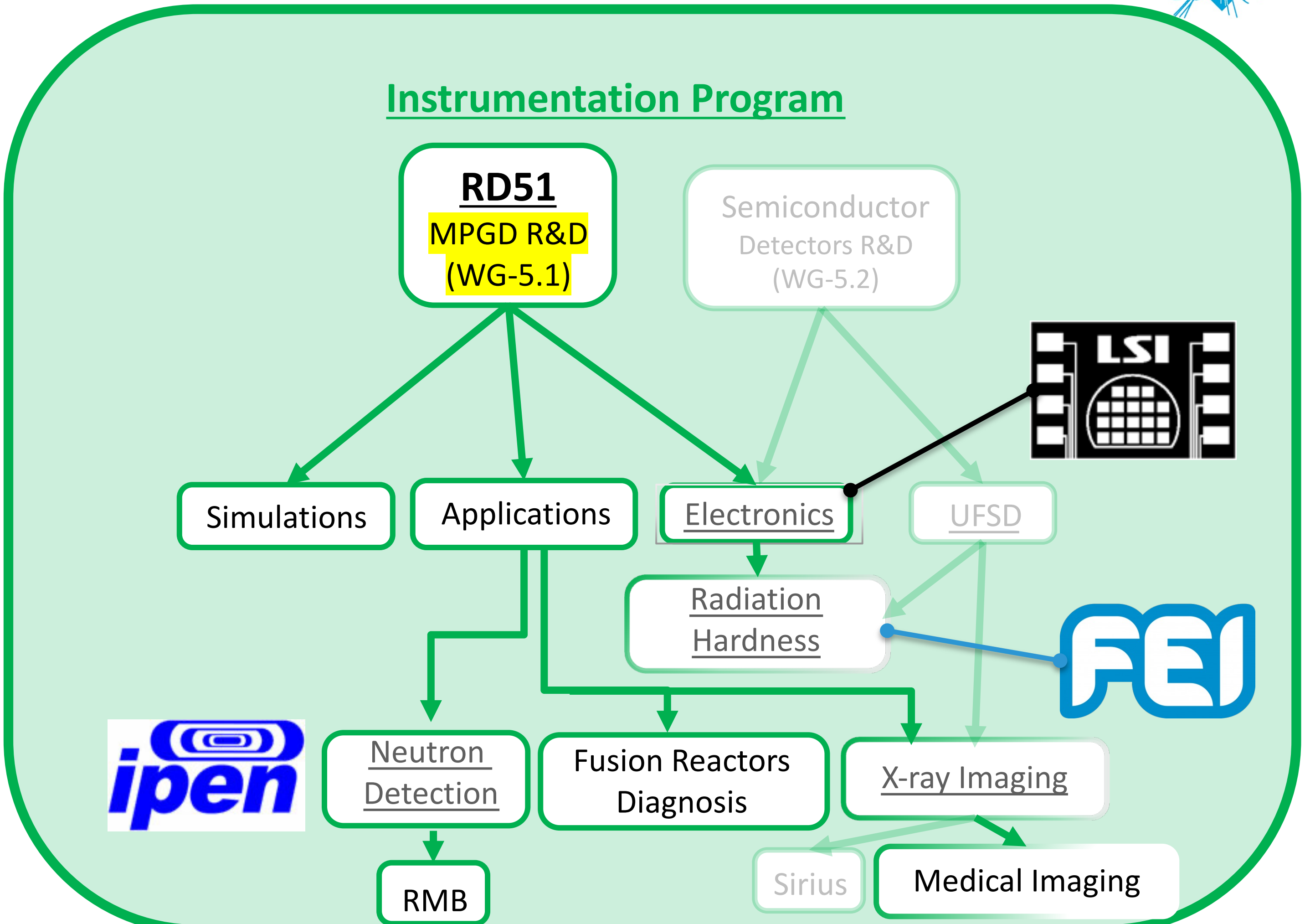
Curso com aulas teóricas e práticas:

- Fabricação
- Leitura de sinal e formação de imagens
- Simulações computacionais
- Aplicações
- Desgaste e degradação

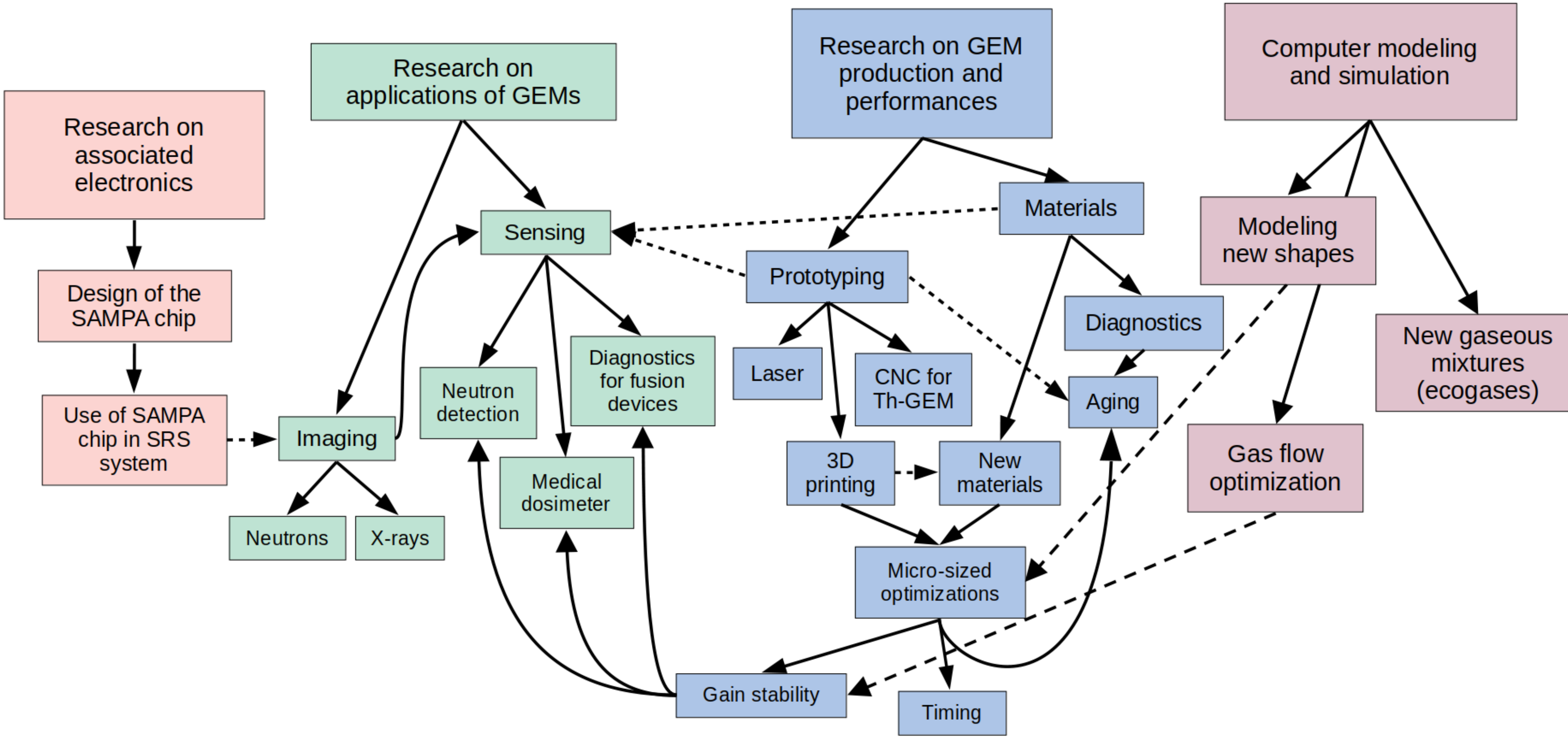




Visão geral


Instrumentation Program
RD51
MPGD R&D
(WG-5.1)
Semiconductor
Detectors R&D
(WG-5.2)
LSI
Simulations
Applications
Electronics
UFSD
Radiation
Hardness
FEI
ipen
Neutron
Detection
Fusion Reactors
Diagnosis
X-ray Imaging
RMB
Sirius
Medical Imaging

Actividades



Linhas principais das atividades

HEPIC IFUSP

- Simulações
  - Otimização do ponto de trabalho (geometria/tensões)
  - Novas configurações
  - Estudo do fluxo do gás no detector
- Electrónica (sistema de aquisição)
  - Otimizações (alta taxa, triggered/continuos readout, daisy chain)
  - Software de aquisição
- Fabricação de GEM/ThickGEM (e avaliação de desempenho/qualidades)
  - Produção local (Laser / Microfabricação)
  - Impressão 3D
- Estudos de envelhecimento e degradação
  - Envelhecimento controlado
  - Investigação e comparação de diferentes técnicas de analise
- Aplicações (desenvolvimento de detectores completos)
  - Imagem de raios-x com resolução em energia.
  - Detectores sensíveis à posição para nêutrons térmicos.
  - Detectores para fins didáticos (um dos objetivos/alvos: curso de Física Medica)
  - ...

Considerações Finais

Dinâmica do WG-5.1

- Plataforma Teams
  - Convites serão enviados a todos
  - Estrutura será apresentada na primeira reunião do WG-5.1

- Reuniões regulares, dia/horário da reunião a ser combinado.

  Proposta: cadência das reuniões em dois níveis
  - Cada dois semanas
    - Atualização das atividades em progresso, e.g.:
      - Simulações
      - Arranjos experimentais (projetos e pedidos nas oficinas, compras, etc)
      - Desenvolvimento de ferramenta de análise
      - Resultados experimentais
  - Mensalmente: “plenárias”
    - “Tour de table” de todas as linhas, com plano para o mês(es) seguinte(s)
    - *(+ os itens acima)*