Annual Meeting 2024

JR14 Micropattern Gaseous Detectors for Hadron Physics

Bernhard Ketzer and Fulvio Tessarotto

Plan of presentation

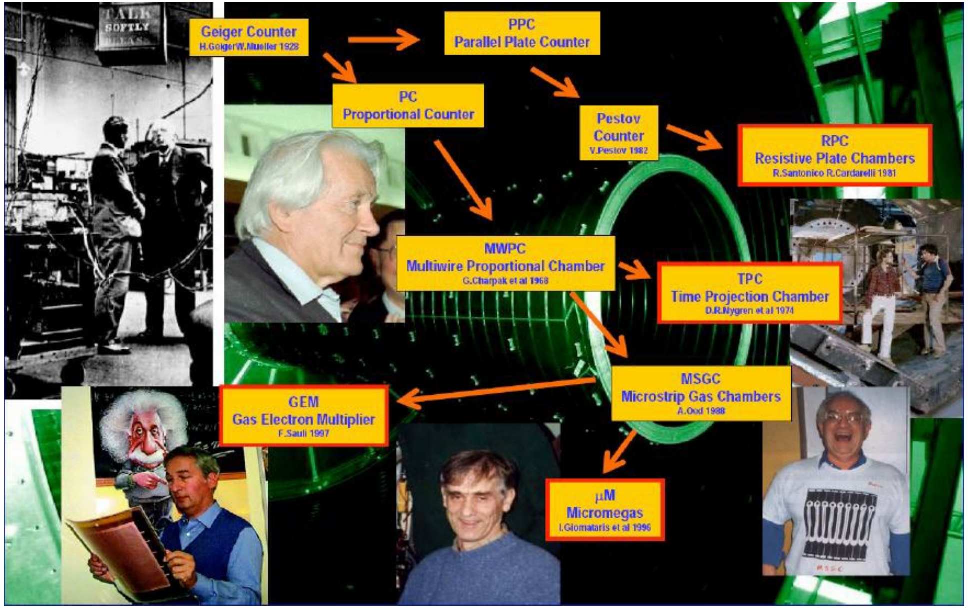
01 JR14: MPGD for Hadron Physics a joint effort to improve gaseous detectors

02 Highlights of the achievements of the four tasks

03 Achievements beyond the Work Program

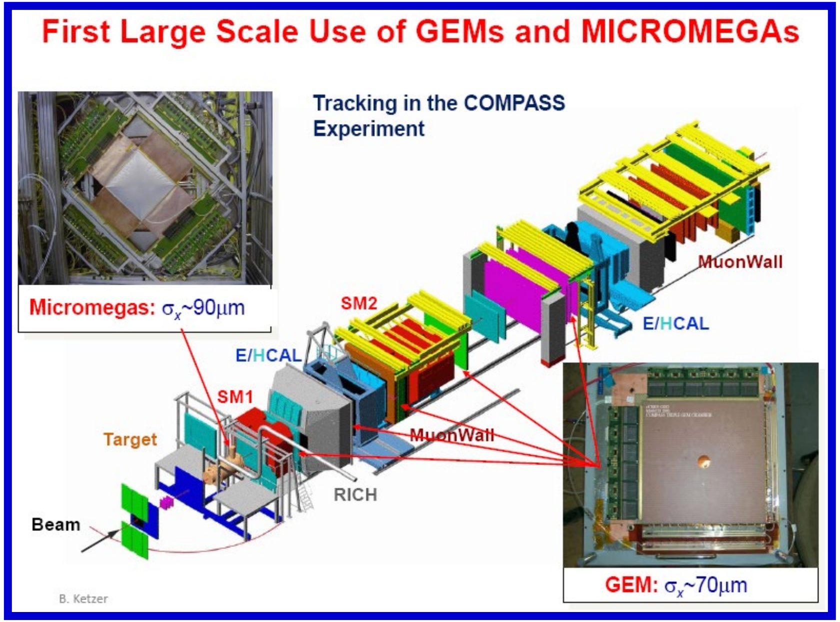
Micropattern Gaseous Detectors for Hadron Physics

Glorious tradition of Gaseous detectors



MPGDs developed in the '90s

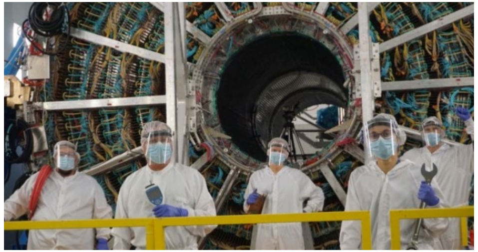
First use: Hadron Physics

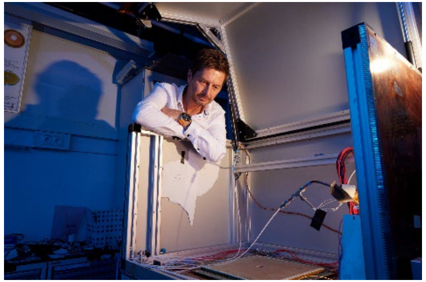


STRONG-2020

Micropattern Gaseous Detectors for Hadron Physics

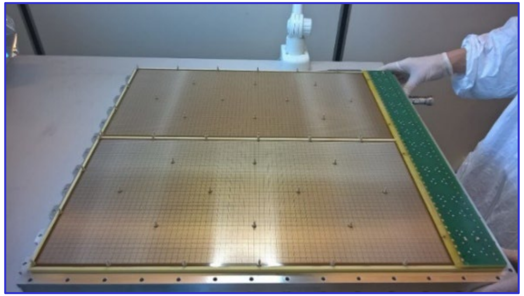
First use of pixelised GEMs ,
ALICE TPC with GEMs B. Ketzer

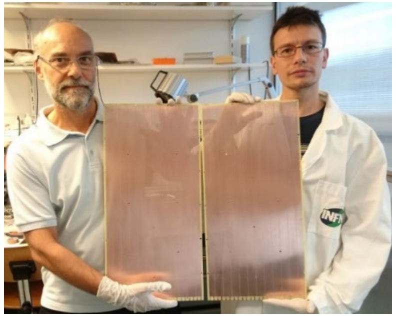




First use of pixelised and resistive Micromegas,
Combined GEM + Micromegas D. Neyret

First MPGD-based Photon Detectors
Hybrid THGEM + Micromegas F. Tessarotto





More abitious goals → STRONG-2020

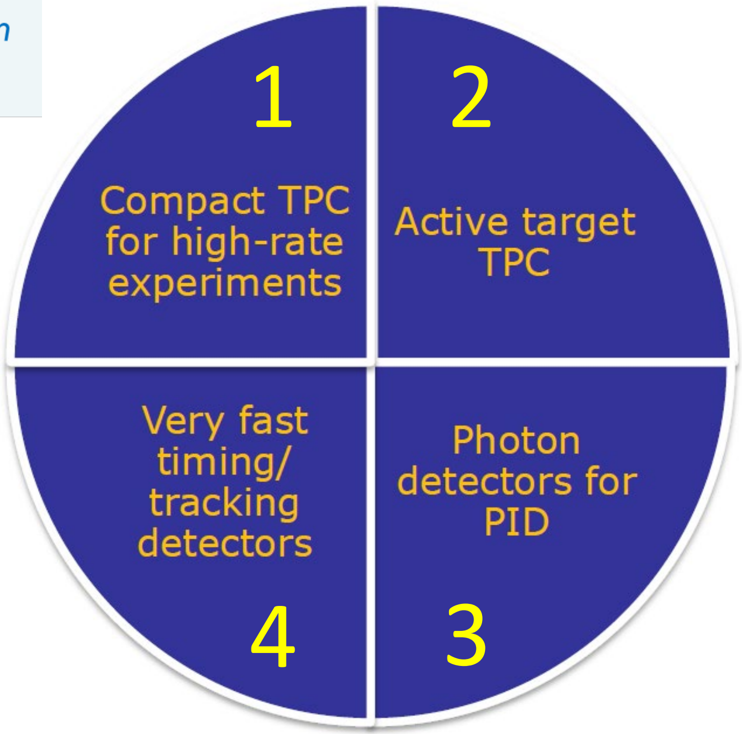
Objective:

improve gaseous detector capabilities for:

Tracking *Particle identification*

Photon detection *Timing*

4 Tasks:

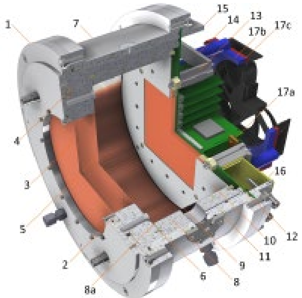


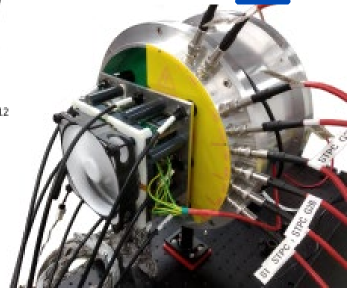
University of Aveiro
University of Bonn
Stefan-Meyer-Institut
GSI
University of Glasgow
INFN Bari
INFN Trieste
TU München
CEA Saclay

Joao Veloso
Bernhard Ketzer
Hannes Zmeskal
Bernd Voss
Rachel Montgomery
Antonio Valentini
Fulvio Tessarotto
Laura Fabbietti
Damien Neyret

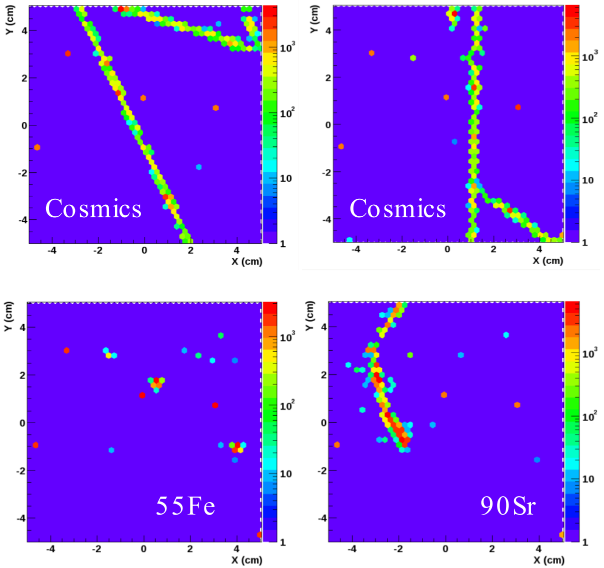
Task 1 : High-rate TPC

University of Bonn – Modular compact TPC





- GEM-TPC with continuous readout established: FOPI, ALICE, sPHENIX
- Advanced calibration methods are a prerequisite to achieve performance
  - static distortions: pad-by-pad gain map, electrostatic field distortions
  - dynamical distortions: charging-up, T/p, space-charge
- Compact TPC designed and built to study these distortions:
  - UV light injected from anode side
  - cathode with specially designed pattern
  - modular: 3- or 4-GEM stack, other MPGD
  - precision field cage
  - hexagonal pads
- Construction of chamber finished (D32.3)
- Commissioning successful



STRONG-2020

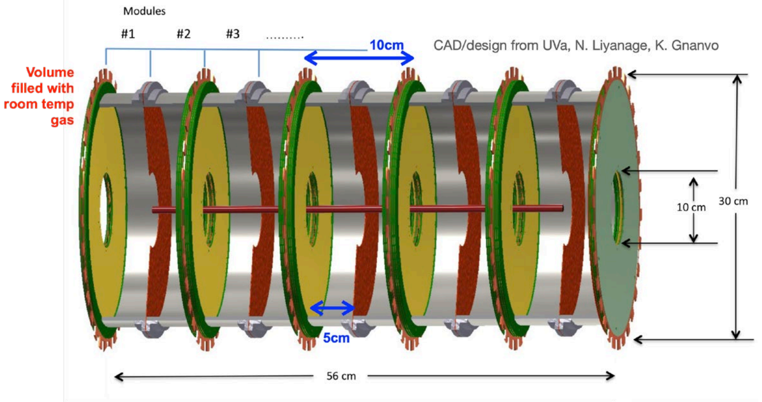
Task 1 : High-rate TPC

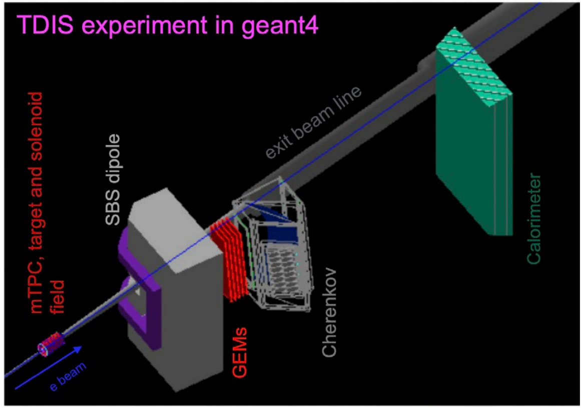
University of Glasgow – High Rate TPC for Jlab Hall A

1. Development of multiple time projection chamber (mTPC) for upcoming meson structure studies in tagged deep inelastic scattering at Jefferson Lab (Jlab)

2. Simulation and design of final mTPC design in Geant4, Garfield++ and Magboltz completed ✔

3. Prototype for mTPC concept was built by colleagues at University of Virginia (N. Liyanage, H. Nguyen et al) and device is under test at Jlab (E. Christy) to be compared with simulation in future and to feed into future prototypes





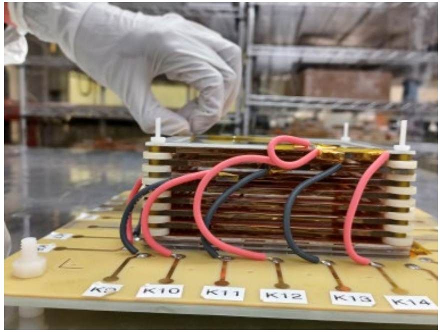
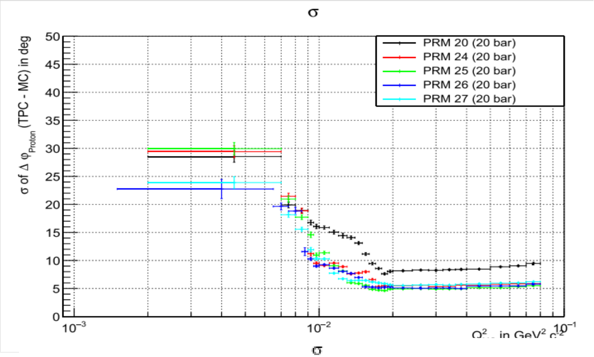


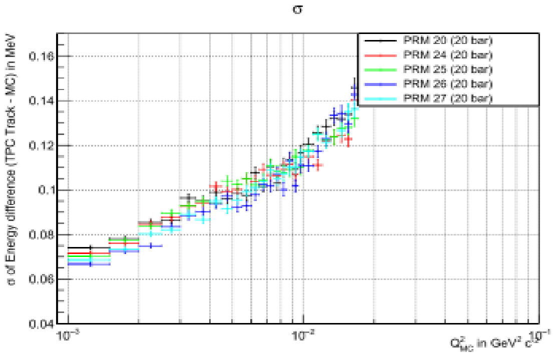
Photo: H. Nguyen (Uva)/A. Nadeeshani (MSU)

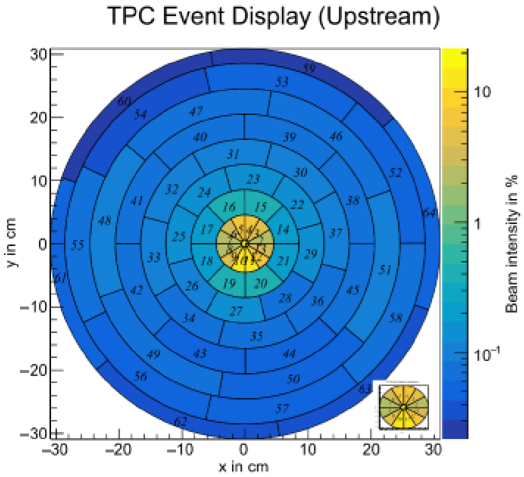
Task 2 : Active-target TPC

Pad Plane geometry optimization

- Increased number of pads to 64
- Expected lower electronic noise, especially on outer rings
- Higher segmentation in the centre leads to improved azimuthal angle resolution at lower Q^2

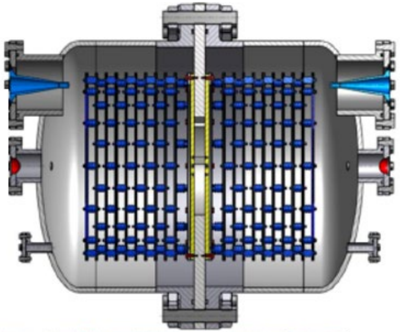






- Simulation studies for AMBER Proton-Radius Measurement finished (D32.4)

NEW AMBER TPC



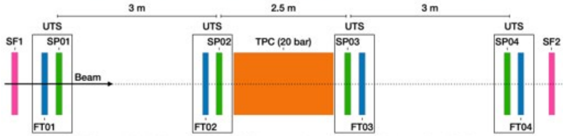
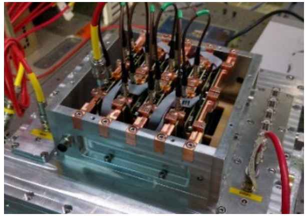


Fig. 23: Sketch of the foreseen 2024/2025 setup with the final TPC and all four UTS equipped.

Task 3 : Photon Detectors for PID

INFN-TS, Bari, TUM



Modular Minipad Photon Detector Demonstrator

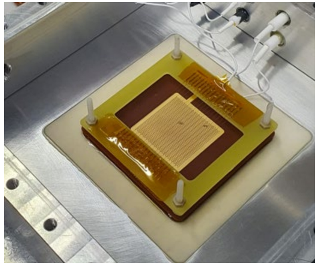
- THGEM + Micromegas +CsI, 3 mm x 3 mm pads
- Built and fully tested

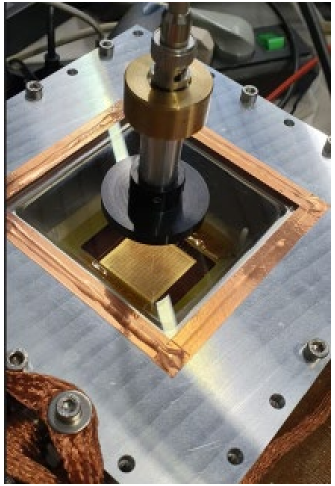
Hydrogenated nanodiamond photocathodes

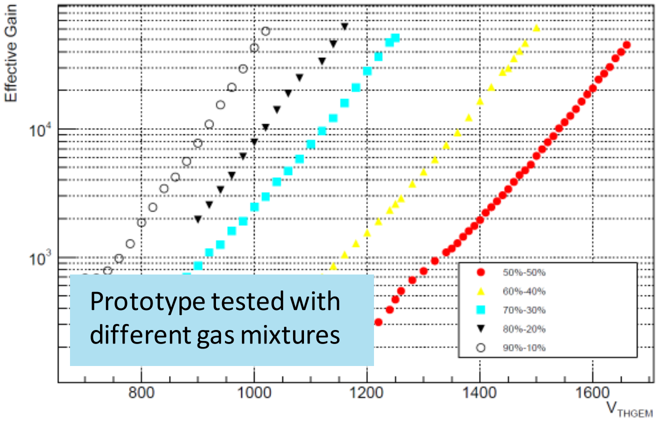
- Systematic tests of H-ND response in different gas mixtures
- Aging studies: H-ND 10 times more robust than CsI

First Gaseous Photon Detector using H-ND

- Built and tested in laboratory (gain up to 50 k)
- New technology validation







Prototype tested with different gas mixtures

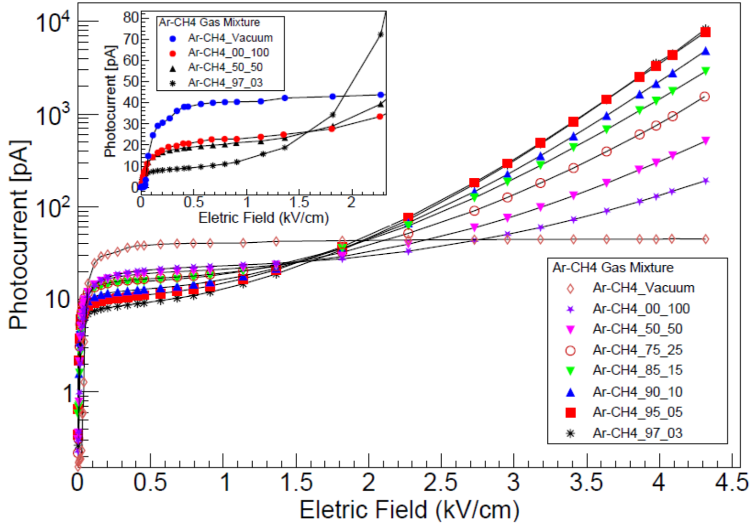
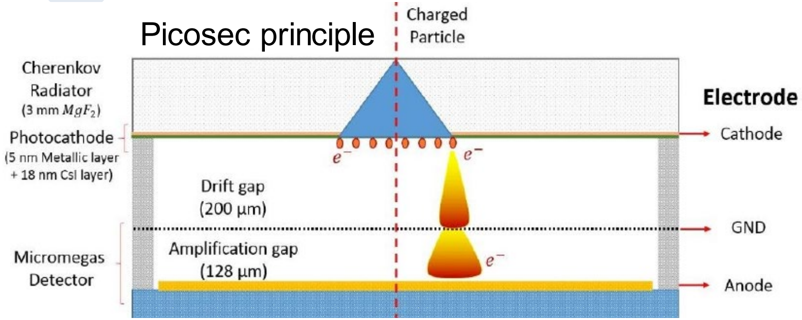


Figure 3: Photoemission current as a function of the applied electric field for HND-based photocathode at the fixed wavelength of 162 nm, and measured at indicated $Ar : CH_4$ gas mixture compositions. The inset image shows a magnification of the lower electric field region.

Task 4: The Picosec detectors



Detection from Cerenkov light though photocathode emitter and Micromegas detector

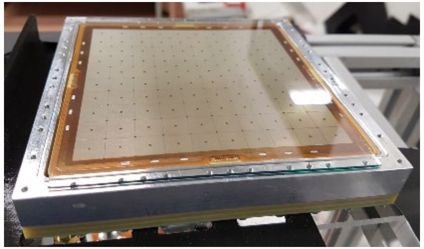
- Time resolution of a few 10ps from electron peak
- Require flatness < 10 µm to equalize drift lengths and thus signal times

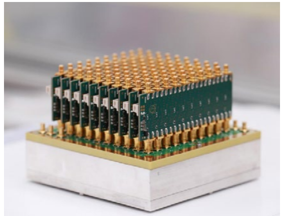
Goals : to develop modular scalable pixelated detectors with low material budget

- 10x10cm active area
- Could be tiled in the future
- Ensure uniform gaps over the active area
- Robust enough to be used on large surface

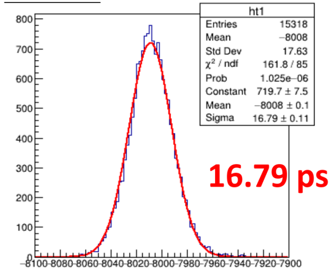
Large 10x10 cm² prototype built at CERN tested in 2022

- Ceramic board with 100 pads, CsI photocathode
- Saclay front-end electronics (Strong 2020) + SAMPIC TDC
- Time resolution 17-25 ps depending on drift gap
- But not adapted for hadronic physics → FR4 board

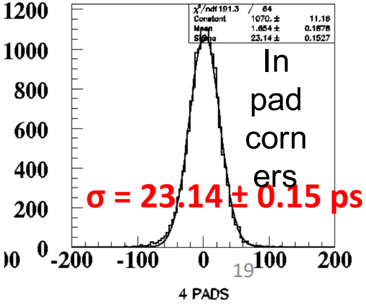




Analytical way of signal Processing



A. Kallitsopoulou



The 10x10 cm² Picosec FR4 prototype

Characteristics

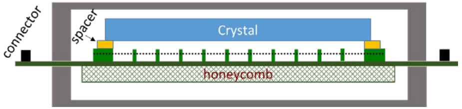
- FR4 board instead of ceramic → lower material budget
- Two kinds of boards, 0.8 and 1.6mm thick
- Resistive DLC layer to protect against discharges, 10MOhm/□
- Planarity with stiffener or gas pressure
- Photocathodes: Cr/CsI, DLC, B_4C

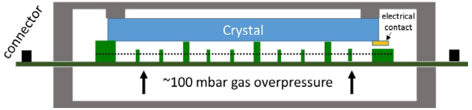
Present status

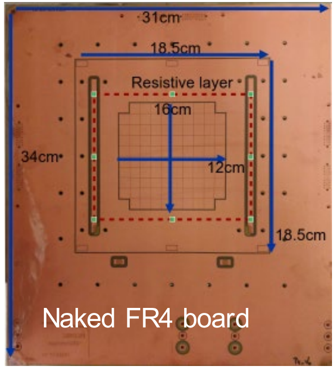
- 10 FR4 boards produced
- Delivery of boards from CERN foreseen this week after resistive layer gluing, few of them bulked (others will be bulked at Saclay)
- Mechanics just received, DLC-coated radiator crystals this week, Cr/CsI-coated from CERN beginning of July
- Assembly and preliminary tests of prototype expected next week, beam tests foreseen beginning of July

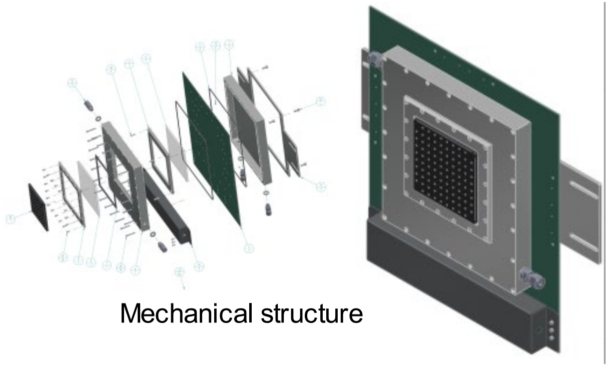
Planarity tests

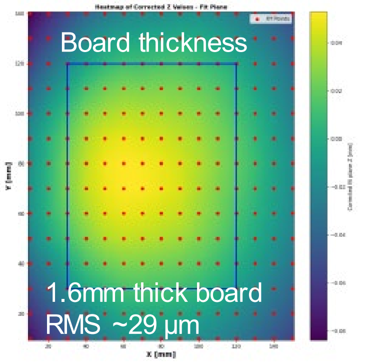
- Board thickness: RMS 10 to 50µm for 1.6mm boards, 10 to 25µm for 0.8mm
- Stiffener planarity: RMS 5 to 20µm

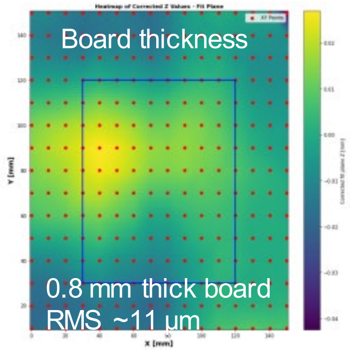












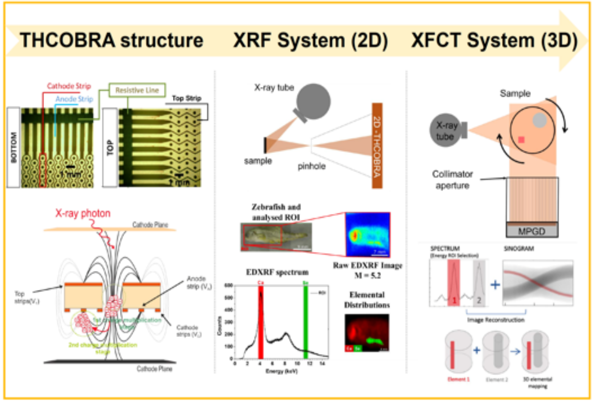
JR14 Milestones and deliverables

Work package number	32
Work package acronym	MPGD_HP
Work package title	JRA14-Micropattern Gaseous Detectors for Hadron Physics

TASKS/Subtasks	Year 1				Year 2				Year 3				Year 4			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Compact micro-pattern TPC for high-rate experiments																
1.1 Numerical simulations for MPGDs																
1.2 Development of prototype TPC for high rates																
2. Active target TPC																
2.1 Active target TPC																
3. Photon detectors for PID																
3.1 Construction of a Minipad Modular PD																
3.2 Test of diamond-based photoconverters																
3.3 Test of windowless RICH PD prototype																
4. Very fast timing by Micromegas-based Cherenkov PDs																
4.1 Fast Cherenkov MM																

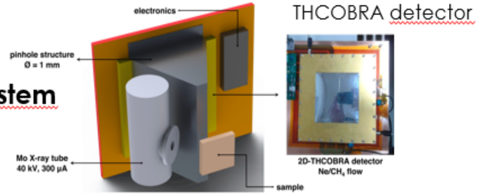
D32.1	Minipad Modular PD	WP32	30 - INFN	Demonstrator	Public	36
D32.2	Fast Cherenkov Micromegas Detector	WP32	24 - CEA	Demonstrator	Public	42
D32.3	A small-scale prototype of the high-rate TPC	WP32	13 - TUM	Demonstrator	Public	48
D32.4	Simulation results on energy ranges and resolutions in active target TPC	WP32	10 - UBO	Report	Public	48
D32.5	Publication of the diamond-based photoconverter performance in gaseous PDs	WP32	30 - INFN	Report	Public	48

Bonus: applications of THCOBRA

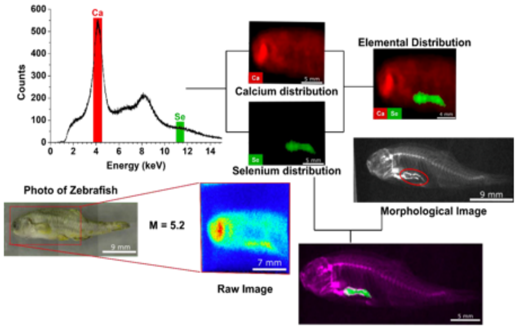


University of Aveiro

EDXRF System



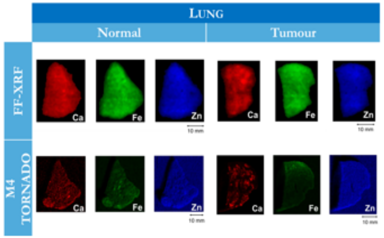
Analysis of Zebrafish contamination by Selenium



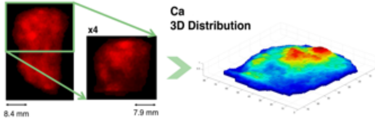
protection of health, environment and cultural heritage

EDXRF imaging System based on MPGDs

Biomedical Application

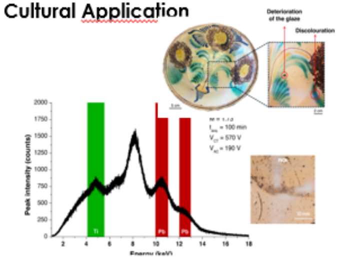


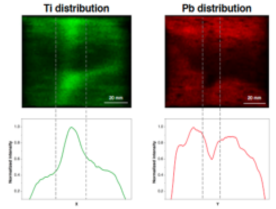
- **Elemental distributions** mapped with the **FF-XRF** scanner and confirmed with the M4 TORNADO.
- **Homogeneous distribution** through the tissues' surfaces.
- **Ca deposits in lung tumour tissues,** indicating possible **malignancy**.



Poster communication: "New insights into the study of normal and tumour tissues using EDXRF analysis"
P. M. S. Carvalho, F. Leite, M. C. Lopes, M. L. Carvalho, S. Pessanha, J. P. Santos, J. F. C. A. Veloso, A. L. M. Silva. European Conference on X-Ray Spectrometry 2022, 26 june - 01 july, 2022 .Bruges, Belgium.

Cultural Application





Poster Comunication - "A new approach to evaluate large area samples of Portuguese ceramics" P. M. S. Carvalho, F. Leite, L. Carramate, S. Pessanha, M. L. Carvalho, J.P. Santos, J. F. C. A. Veloso, A. L. M. Silva. European Conference on X-Ray Spectrometry 2022, 26 june - 01 july, 2022 .Bruges, Belgium.

Summary

JRA14: MPGD R&D experts developing gaseous detectors technologies for hadron physics experiments

Task 1: advanced calibration methodes for high-rate TPC Simulations performed Prototypes successfully operated

Task 2: active target TPC. Pilot run data analysed. AMBER TPC design finalized; TPC vessel produced

Task 3: gaseous photon detectors R&D. Photocathode materials alternative to CsI. Possibility to use H-ND validated.

Task 4: very fast timing. PICOSEC detector resolution < 30 ps.

Beyond JR project: THCOBRA for protection of health, environment and cultural heritage.

JR14: successful and productive activities.

MPGD Community ready for new challenges to meet future experiments needs