WP 2 - Gaseous Detectors

Florian Brunbauer, Marta Lisowska, Eraldo Oliveri, Gianluca Rigoletti, Lucian Scharenberg

on behalf of EP R&D WP2

EP R&D Day - 22 May 2024

Content

Introduction and synergies with DRD1

- New structures and large-area gaseous detector systems
- R&D framework and tools
- Novel technologies

References

WP2 - Gaseous Detectors - Research lines for 2024-2028

New structures and large-area gaseous detector systems

Precise timing detectors
Optimisation of scalable prototypes (modules of 100 cm^2 active area, <20ps) towards applications in future experiments including usage of robust photocathodes on larger areas.

Detectors with resistive elements
Optimise resistive detector technologies driven by detailed simulations of signal induction in dedicated resistive MPGD prototypes.
Explore potential of sputtering machine in EP-DT MPT workshop for resistive detectors and photocathodes.

Low material budget
Lightweight support structures, potential of resistive materials as low-material budget electrodes.

R&D framework and tools

Gas studies
Mixtures for RPC and timing applications, scintillation gases and alternatives will be explored. Gas property measurements and simulations will assist evaluation and irradiation campaigns. Performances of new mixtures will be tested for stability and aging.

Detector modelling
Extension of modelling framework for gaseous detectors, application of signal induction simulation for resistive elements in other technologies (gaseous, silicon, SiPM).

Electronics
Support and continued integration of VMM3A ASIC, dedicated FE electronics for precise timing applications, input protection and auxiliary instrumentation.

Novel technologies

Primary ionisation
Solid converters and photocathodes for precise timing applications.

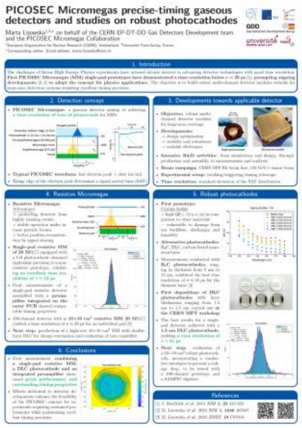
Pixelated readout
High-resolution readout with novel pixel sensors (optical & electronic). Hybrid detectors combining MPGDs with pixel readout chips such as Timepix.
Evaluation of optimal coupling between detector geometries and readout.

Manufacturing
In synergy with EP-DT MPT workshop, Thin Film & Glass (TFG) laboratory and external partners and facilities advances in novel materials for gaseous detectors will be explored. This may include coatings, additive manufacturing and nano materials such as graphene.

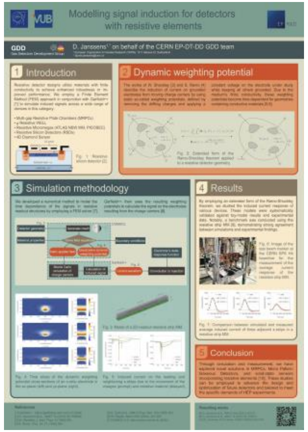
EP R&D seminar and posters from WP2

EP R&D Seminar (6 May 2024)
Karl Jonathan Floethner, The RD51/DRD1 Beam-Telescope - A versatile trigger-less tracking system for MPGDs
https://indico.cern.ch/event/1411526/

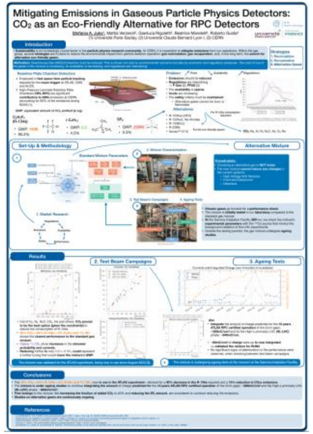
PICOSEC Micromegas precise-timing gaseous detectors and studies on robust photocathodes
M. Lisowska



Modelling signal induction for detectors with resistive elements
D. Janssens



Mitigating Emissions in Gaseous Particle Physics Detectors: CO2 as an Eco-Friendly Alternative for RPC Detectors
S. A. Juks



DRD1: Gaseous Detectors

Newly established DRD1 collaboration as result of ECFA Detector Roadmap Implementation

- Strong involvement in DRD1 management, organisation and activities in various roles:
  - Co-spokesperson (E. Oliveri)
  - WG coordinator (B. Mandelli)
  - WG convenors and WP leader (F. Brunbauer, B. Mandelli, H. Muller, E. Oliveri, R. Guida, R. Veenhof, R. de Oliveira)

- Exchange with collaborating groups in WGs and WPs and exploiting synergies for R&D activities

Events organised at CERN in 2024:
- Three DRD1 test beam periods in 2024 (H4 beamline)
- Three collaboration meetings (Jan / Jun / Dec)
- Topical workshop on Electronics for Gaseous Detectors
- DRD1 Gaseous Detector School (Nov 27 - Dec 6)

https://drd1.web.cern.ch/

Participation in multiple WPs with activities of EP R&D program:

- WP1: Genuine trackers/hodoscopes
- WP4: Tracking TPCs
- WP6: Photon detectors
- WP7: Timing detectors
- WP8: Reaction/Decay TPCs

New structures and large-area gaseous detector systems

Precise timing detectors

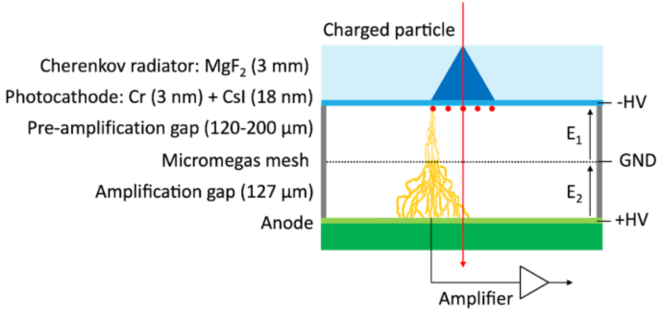
Marta Lisowska

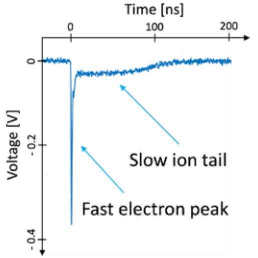
on behalf of EP R&D WP 2 Gaseous Detectors

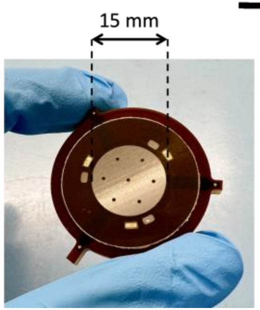
Precise timing with PICOSEC Micromegas

Detector concept

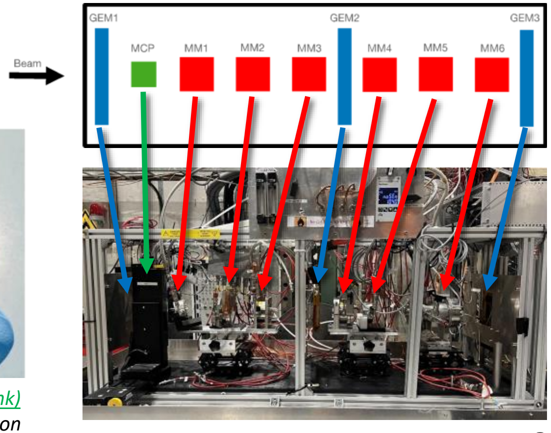
- **PICOSEC Micromegas collaboration:** gaseous detector aiming at achieving **a time resolution of tens of picoseconds** for MIPs
- **Objective:** robust tilable multi-channel detector modules suitable for large-area coverage with excellent timing precision
- **Developments:**
  → <u>optimisation</u>: new detector designs, large-area prototypes, gas studies
  → <u>stability and robustness</u>: resistive Micromegas, robust photocathodes
  → <u>scalable electronics</u>: integrated preamplifiers, FastIC ASICs, SAMPIC
- **Intensive R&D activities**: from simulations and design, through production and assembly, to measurements and analysis
- **Beam campaign**: CERN SPS H4 beam line, 150 GeV/c muon beam
- **Experimental setup**: tracking/triggering/timing telescope







New single-pad prototype (link) A.Utrobicic, RD51 Collaboration meeting, December 2023



Clean (wireless) setup (after disconnecting the cables ☺)

Precise timing with PICOSEC Micromegas

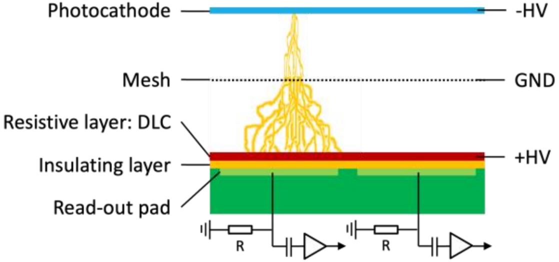
Resistive Micromegas

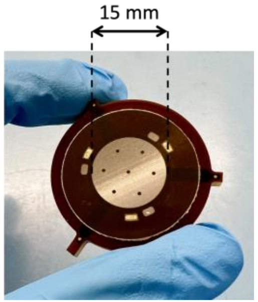
- **Advantages:**

  + protecting detector from highly ionizing events

  + ensuring stable operation under intense particle beams

  + achieving better position reconstruction by signal sharing

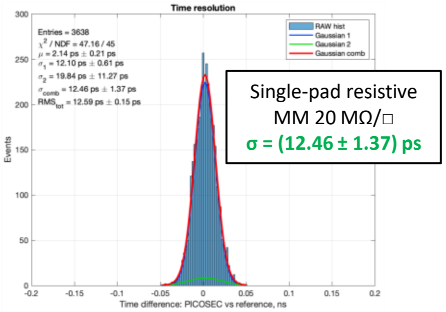


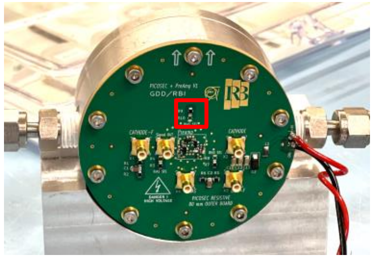


Resistive single-pad prototype

In collaboration with A. Utrobicic (now RBI, previously EP R&D Fell)

- **Single-pad resistive MM of 20 MΩ/□** equipped with a CsI photocathode obtained equivalent precision to a non-resistive prototype, exhibiting **an excellent time resolution of σ ≈ 12 ps**

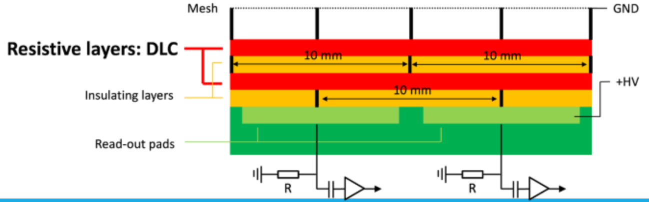




Amplifier integrated on the outer PCB

- Single-pad resistive MM assembled with **a preamplifier integrated on the outer PCB** showed comparable timing properties

- **Next step:** production of a high-rate 10×10 cm^2 MM with double-layer DLC for vertical charge evacuation and evaluation of rate capability



Precise timing with PICOSEC Micromegas

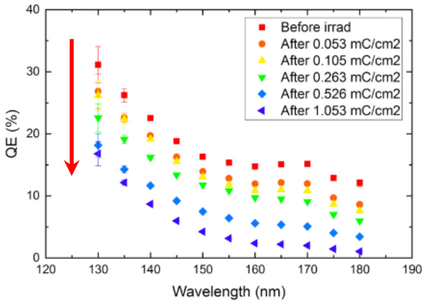
Robust photocathodes

- First single-pad prototype: Cesium Iodide

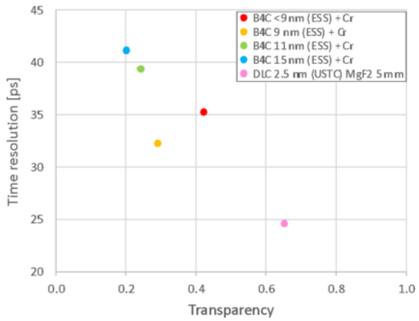
  + high QE (~12 p.e./μ) in comparison to other materials

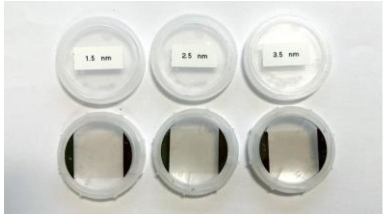
  − vulnerable to damage from ion backflow, discharges and humidity
- **Alternative photocathodes:** B_4C, DLC, carbon-based nanostructures
- Measurements conducted with B_4C photocathodes exhibited the best time resolution of σ ≈ 33 ps for the 9 nm layer
- **First depositions of DLC photocathodes carried out at the CERN MPT workshop** using a pulsed DC magnetron vacuum deposition machine
- The best results for a single-pad detector achieved with a **1.5 nm DLC photocathode**, yielding **a time resolution of σ ≈ 31 ps**
- **Next step:** evaluation of a 10×10 cm^2 robust photocathode

Ageing studies - CsI



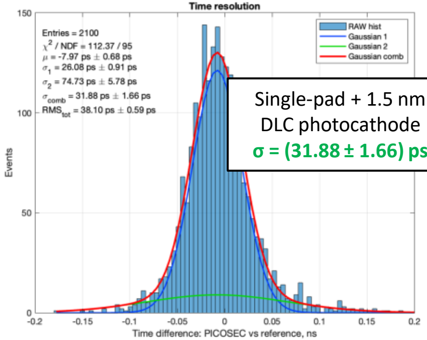
B_4C and DLC photocathodes





DLC photocathodes of different thicknesses

Pulsed DC magnetron vacuum deposition machine

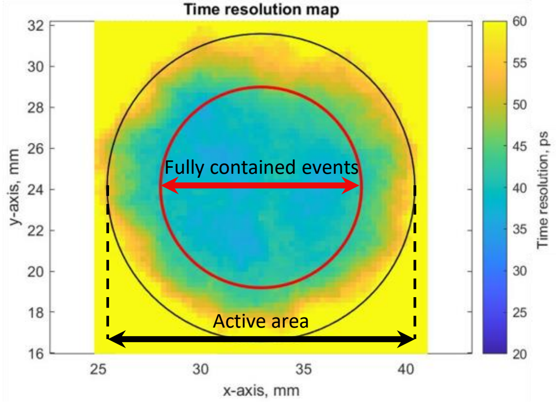


Single-pad + 1.5 nm DLC photocathode
σ = (31.88 ± 1.66) ps

Precise timing with PICOSEC MM

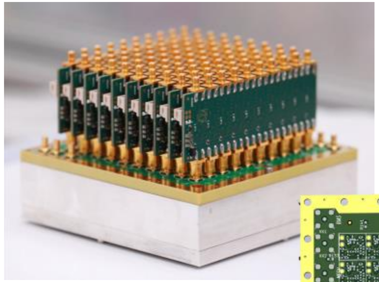
Stability and robustness

- First measurement **combining a single-pad resistive MM, a DLC photocathode and an integrated preamplifier** showcased **great performance and outstanding timing properties**



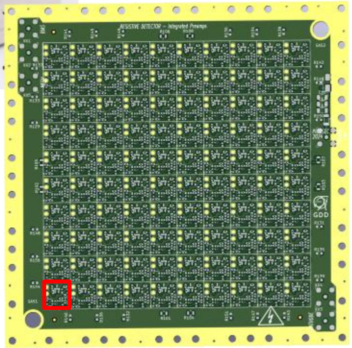
Multipad: 100-channel module with scalable electronics

- **Multipad**: a 100-channel module with a uniform thickness (< 10 μm) of the drift gap
- Excellent timing performance of the single-pad proof-of-concept transferred to **a 100-channel detector**, exhibiting **a time resolution of σ ≈ 18 ps** for individual pads
- **Scalable electronics:** successful readout of multiple channels using a complete readout chain consisting of dedicated preamplifier cards and a SAMPIC digitiser
- **Next step:** combining a of a high-rate 100-channel MM with double-layer DLC, a 10×10 cm^2 DLC photocathode and preamplifiers integrated on the outer PCB



Multipad with 100 preamplifier cards

Antonija Utrobicic (EP R&D Fellow, now RBI)



100 preamplifiers integrated on 1x1 cm^2 areas of the outer PCB

Precise timing with PICOSEC Micromegas

Other ongoing activities within the PICOSEC Collaboration

- **Stable resistive detectors:** double-layer DLC MM; prototypes with different resistivities; µRWELL
- **Improving the spatial resolution:** signal sharing with resistive PICOSEC MM
- **Robust photocathodes:** studies on B_4C, DLC, Nanodiamonds
- **Alternative electronics:** integrated preamplifiers; FastIC ASICs; SAMPIC TDC
- **Operating gas**: exploring alternative gas mixtures
- **Material budget:** alternative ways to preserve detector's planarity; sealed detectors
- **Scaling up to larger area:** tiling 10x10 cm^2 modules, development of larger prototypes

Conclusions

- Efforts dedicated to detector developments enhance the feasibility of the PICOSEC concept for experiments requiring precise timing
- **Detectors with sub-ns time resolution: Tileable multi-channel detector modules for large area coverage fulfilling the requirement of the robustness with "relaxed" timing properties**

R&D framework and tools

Gas studies

Gianluca Rigoletti

on behalf of EP R&D WP 2 Gaseous Detectors

Greenhouse gases and particle detectors

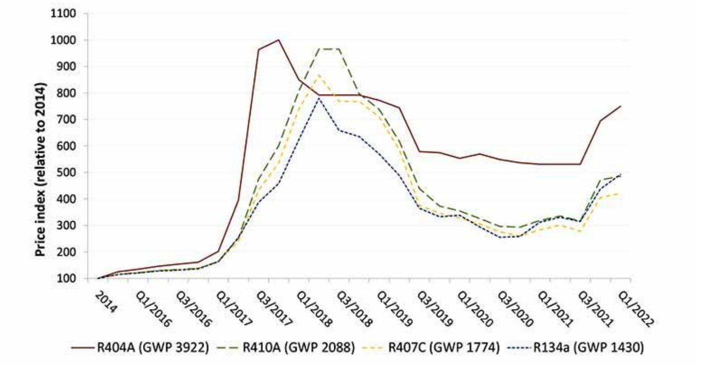
Greenhouse gases are often required in gaseous detector

- Mostly for performance reasons
- Mostly Fluorine-based

GHG are subjected to EU F- regulation

- Usage restriction and market availability affected
- Price increase

Average HFCs price variation in EU (from 2014)



<u>Goal</u>

Reduce GHG emissions from particle detectors

Gas recirculation

- Large installations (e.g. LHC experiments)
- Facility and Laboratory size systems development

Gas recuperation

- Suitable for large installations
- Complex systems

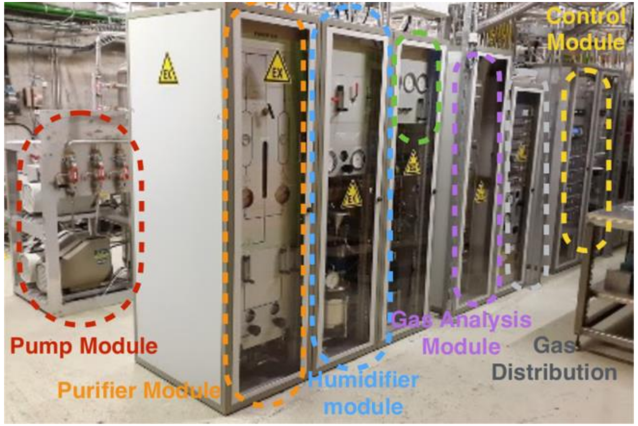
Alternative gases

- **Eco-friendly** gas research
- Short term and long term performance on detectors

Gas Recirculating Systems

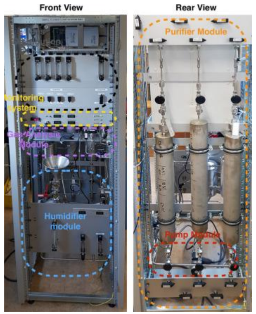
Large LHC gas systems

- ~100-1000s chamber volumes ~ m^3
- Reduce GHG emissions about 90%
- **Complex operation** and maintenance
- Price ~ $O(10^5)$ CHF



Small size gas systems

- ~10s detector volumes ~ 10-100 liters
- **Compact** ⇒ different modules in one rack
- Simpler control/monitoring system
- Price ~ $O(10^4)$ CHF



"Micro" gas systems

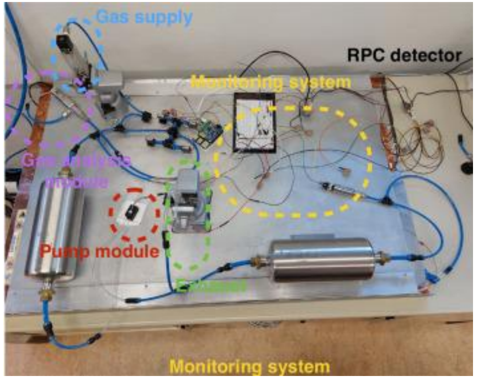
- Few detectors volume ~ few **liters**
- Should be **portable**
- Should be **easy** to build and use
- Price ~ $O(10^3)$ CHF

μ loop gas system development

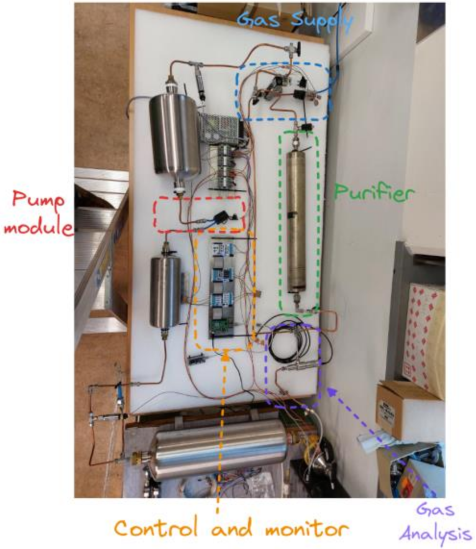
Main Features

- Desk size system
- **Optional modules**: purifier, backup, analysers, flow reading
- Flow and pressure **monitoring**
- **Control** injection and recirculating fraction
- **Raspberry PI** based monitoring and control system

Prototype 0 - HPL RPC

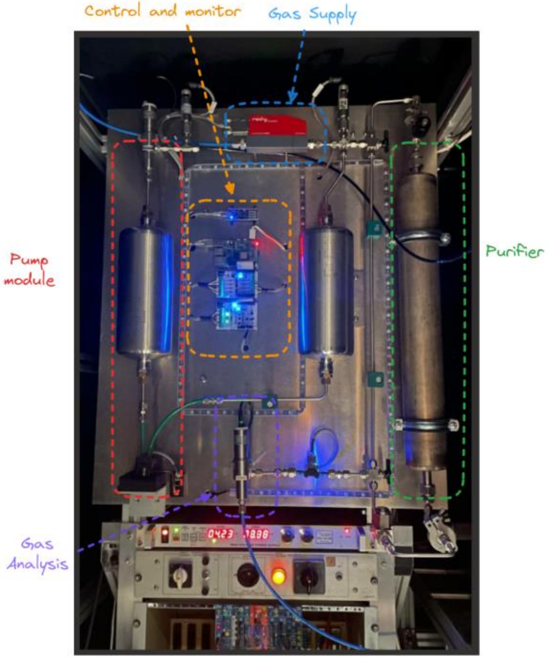


Prototype for EEE MRPC station at CERN



Science Gateway

Spark Chamber μ-loop



Setup for gas mixture studies

HPL RPC Setup upgrade

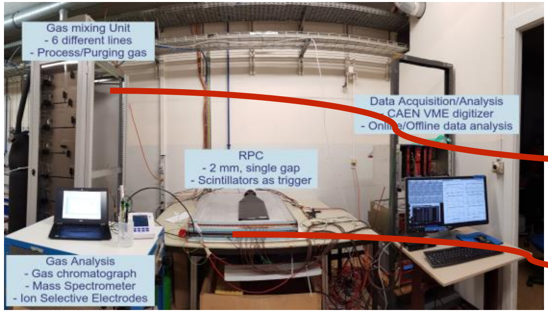
- New distribution **EX** compliant built
- Distribution and humidifier modules added to allow parallel tests of several RPCs
- New multi-layer tray support

RPC activities in laboratory

- Characterization and conditioning of ~20 RPCs + 20 more expected
- Study on **new** and **old** alternative gases: low-GWP HFCs, HFOs, Cl-HFO, PFCs

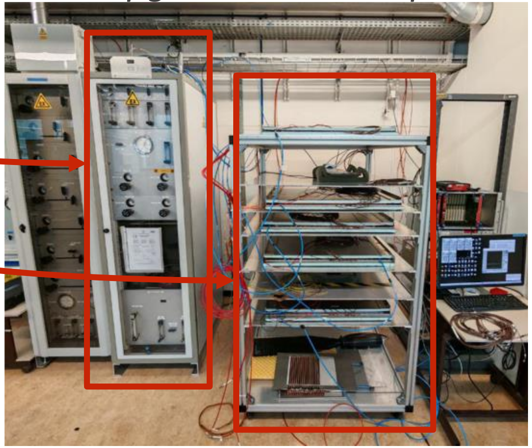
RPC activities @ GIF++

- Irradiation chambers + reference chamber (outside irradiation)
- LHC-like gas components
- Muon beam tests
- Long term tests ⇒ aging studies

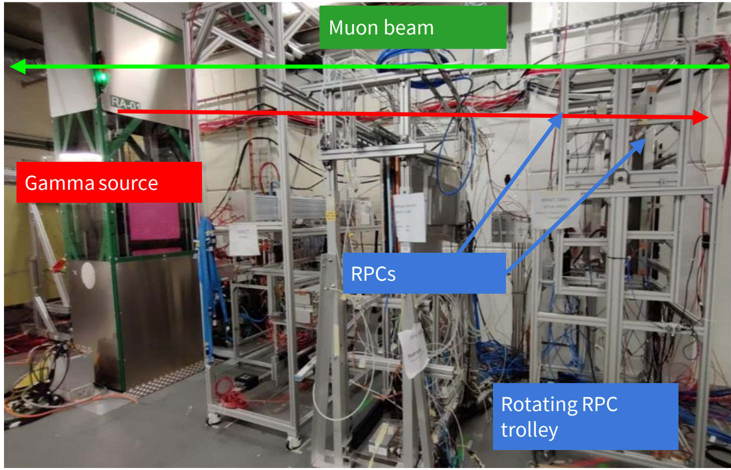


Old lab. setup

Upgraded lab. setup



GIF++ setup



Alternative gas mixtures - studies with CO2

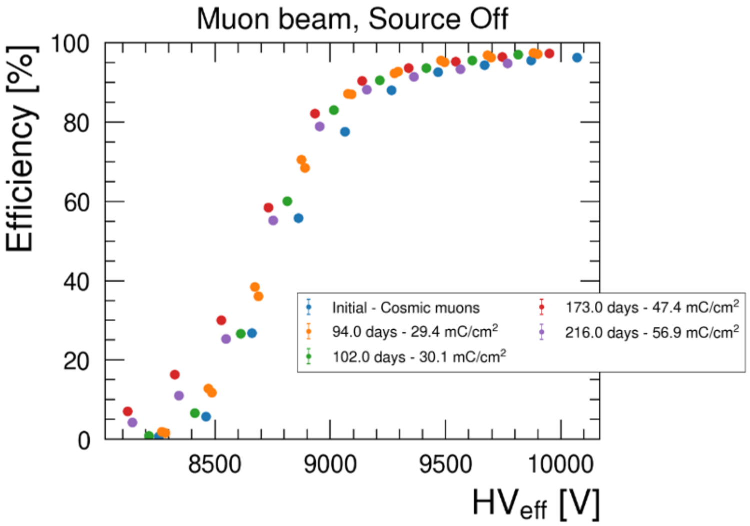
HPL-RPC gas mixture LHC ⇒ ~95% R-134a, 5% iso, 0.3% SF6

2022 - Studies on replacing 95% R-134a with 64% R-134a + 30% CO2

- **SF6 increased** to 1% added to suppress streamers
- R-134a reduction of **30%**
- GHG reduction of ~15%

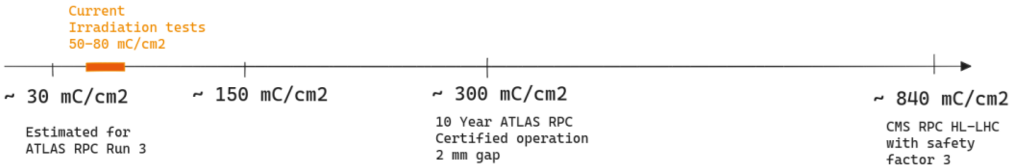
Nucl.Instrum.Meth.A 1049

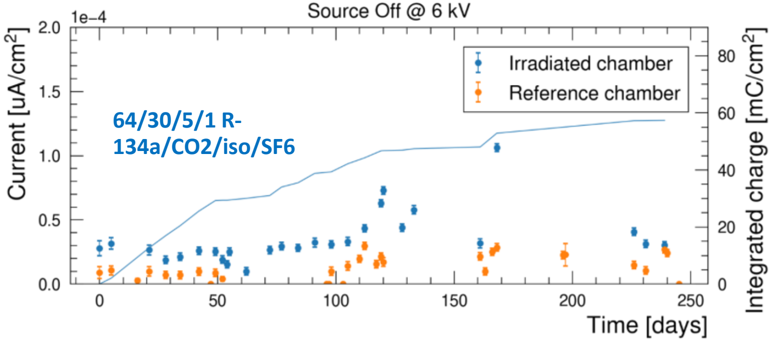
Gas mixture is now used in ATLAS RPC!



2023- Muon beam tests and long term tests at GIF++

- ~60 mC/cm2 integrated ⇒ validated for **ATLAS Run 3**
- Detector performance **not significantly affected**
- Further tests needed:
  - Integrate expected HL-LHC charge
  - Longer tests with lower SF6 or higher CO2





Novel technologies

Pixelated readout

- Charge
- Optical

Lucian Scharenberg

on behalf of EP R&D WP 2 Gaseous Detectors

High-granularity readout of gaseous detectors

Possibilities offered by HG readout of gaseous detectors

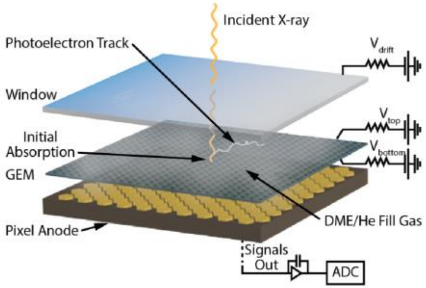
- Event-selection based on geometrical signature
- Low-material budget tracking with high spatial accuracy
- Sensitivity to low-energetic photon interactions (E_{gamma} < 2 keV)

Example applications:

- X-ray polarimetry (e.g. IXPE @ NASA)
- Nuclear recoil events (e.g. MIGDAL)
- Material science (e.g. MIXE @ PSI)
- Axion helioscopes (e.g. IAXO)

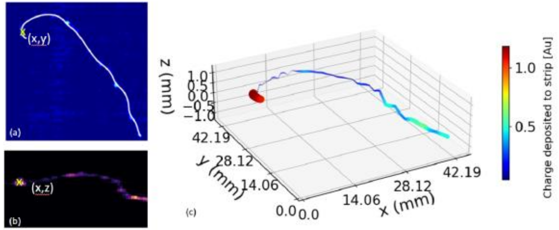
Charge and optical readout

Charge readout example:
X-ray polarimetry



https://ixpe.msfc.nasa.gov/for_scientists/papers/2017spie_0829_sgro.pdf

Optical readout example:
Nuclear recoil



https://doi.org/10.1088/1748-0221/18/07/C07013

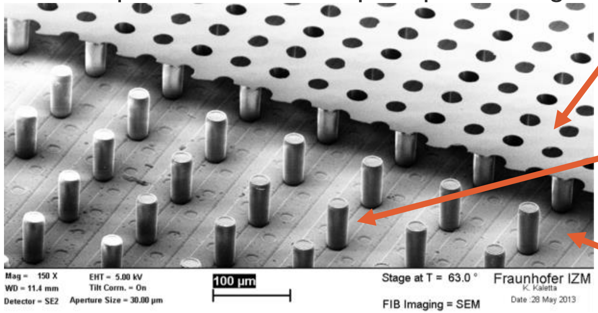
High-granularity readout of gaseous detectors
Charge readout

Use bump-bond pads as charge-collection pads, with gas as sensor medium

- First introduced ~20 years ago with Gas Pixel Detector (GPD) and Medipix2+MicroMegas
- Advancement in production technology and front-end capabilities

Most prominent examples based on Timepix1 and Timepix3: GEM-TPC with Timepix, GridPix (InGrid) and GEMPix

GridPix, produced in wafer post-processing



Courtesy of Yevgen Bilevych

Integrated Grid (InGrid) MicroMegas-like gas amplification stage

SU-8 support pillars

Timepix1 with Si_xN_y protection layer

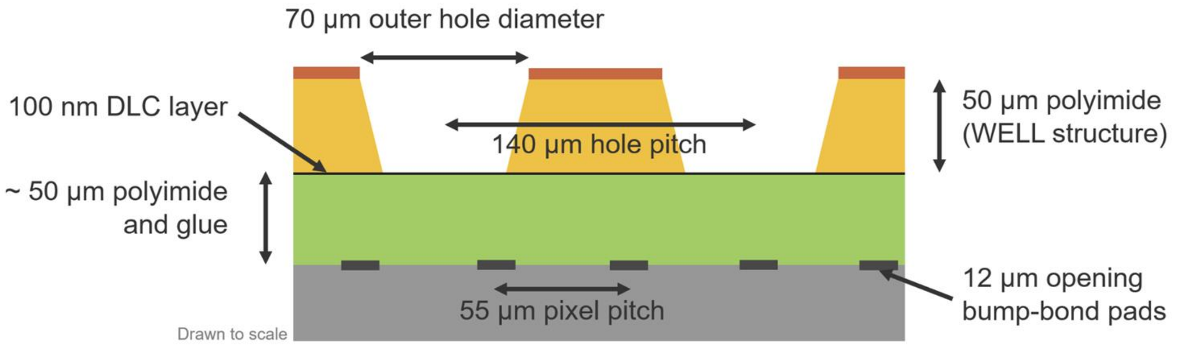
Goal of this R&D line:
Embedding/integration of pixelated front-end ASIC and gas amplification stage into a flexible PCB using standard micro-pattern technologies

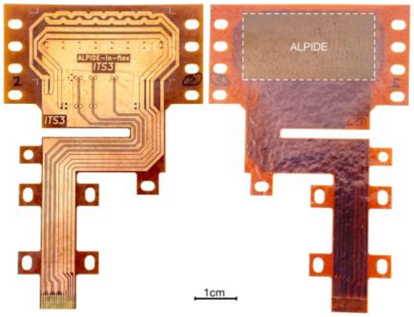
High-granularity readout of gaseous detectors
R&D goal

Embedding of front-end ASIC in flexible PCB, i.e. micro-pattern amplification structure

- Possible with micro-resistive WELL (**µRWELL**) structure, **using standard PCB technologies**
- Presented at the MPGD 2022 (Magnus Mager and Rui de Oliveira)

Evaluate approach, using high-granularity Timepix4





https://doi.org/10.1016/j.nima.2022.167673

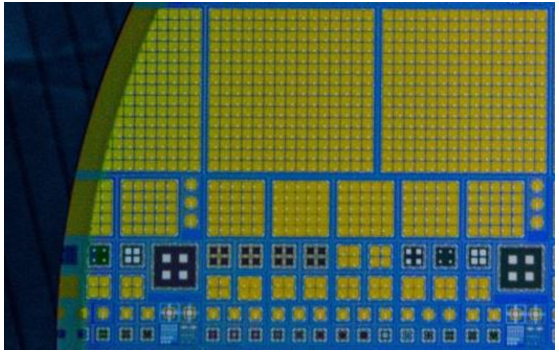
Example of monolithic pixel detectors embedded in polyimide foil

High-granularity readout of gaseous detectors
R&D goal

Long-term goal: establish a manufacturing technique that can be applied to other ASICs

- Most gaseous detector applications do not require 55 µm pixel pitch
- Use ASICs with larger pixel pitch, e.g. **ALTIROC** or **ETROC (both 1.3 mm pitch)**
- Could enable higher-granularity Picosec MicroMegas

1.3 mm pixel pitch ALTIROC



https://indico.cern.ch/event/1323113/contributions/5823798/

On the road of exploring the embedding, test other detector technologies as well

- Triple-GEM
- µRWELL without embedding, using electrostatics

Allows understanding of the signal coupling and optimisation of detector parameters

High-granularity readout of gaseous detectors
Current status: Timepix4

Timepix4

- **Large area ASIC (2.5 x 3.0 cm²)**, ideal for imaging applications
- Excellent performance in spatial resolution **(55 µm pixel pitch)** and time resolution **(200 ps time bins)**
- **TSVs**: can be tiled on four sides (large-area coverage without loss of area possible)
- **Embedding not possible with wire-bonds, requires back-side connection as provided by TSVs**

Read out with the SPIDR4 from Nikhef → two detector geometries

- Small detector on Nikhef carrier board
- Larger detector for R&D purposes (future large-area coverage)

Thanks for the help from the CERN micro-electronics group (EP-ESE-ME), Nikhef, the MPT workshop (EP-DT) and the CERN electronics service (BE-CEM-EPR)

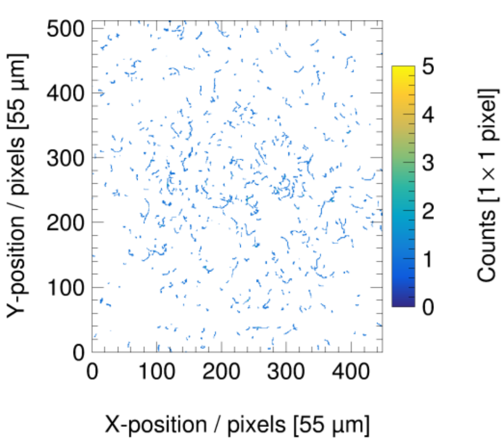
High-granularity readout of gaseous detectors

Current status: readout system

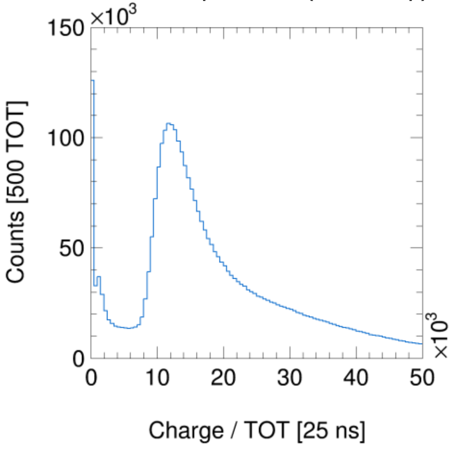
Readout system (SPIDR4) and control software (tpx4tools from Nikhef) ready and operational: tested with Si sensor and wire-bonded Timepix4 using ^{90}Sr source

Thanks to Jerome Alozy, Xavi Llopart and Michael Campbell (CERN) and Kevin Heijhoff and Martin van Beuzekom (Nikhef)

10 ms time slice



Cluster spectrum (60 s acq.)

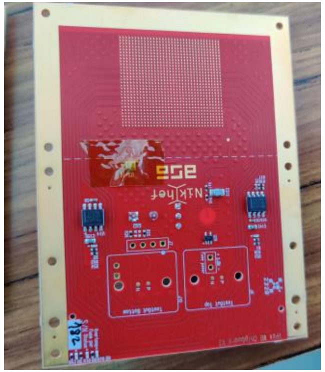


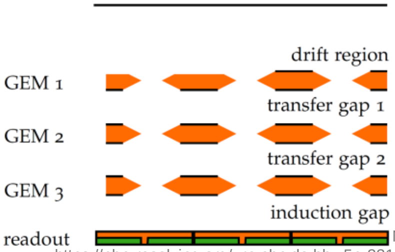
High-granularity readout of gaseous detectors
Timepix4 and triple-GEM detector (Nikhef board)

First, set up expertise in our group with well-known technology (triple-GEM detector)

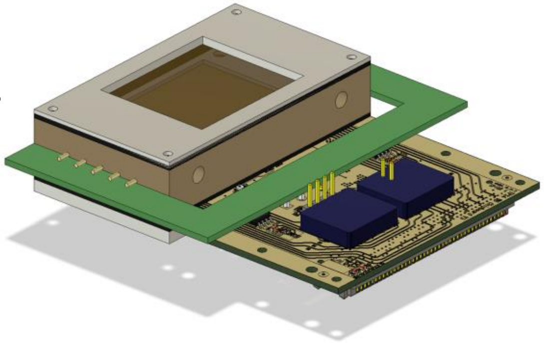
Dedicated detector-module to fit existing readout hardware

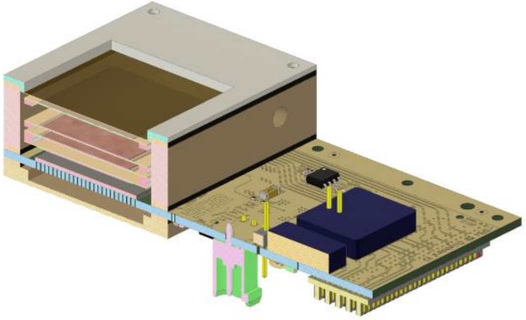
- COMPASS-like triple-GEM detector that can be screwed to PCB (fixed field configuration)
- Requires TSV/BGA-bonded chips, no wire-bonding
- Special, smaller-area GEMs (2.5 x 3.0 cm² area) to fit geometry of Timepix4
- 3 mm drift region





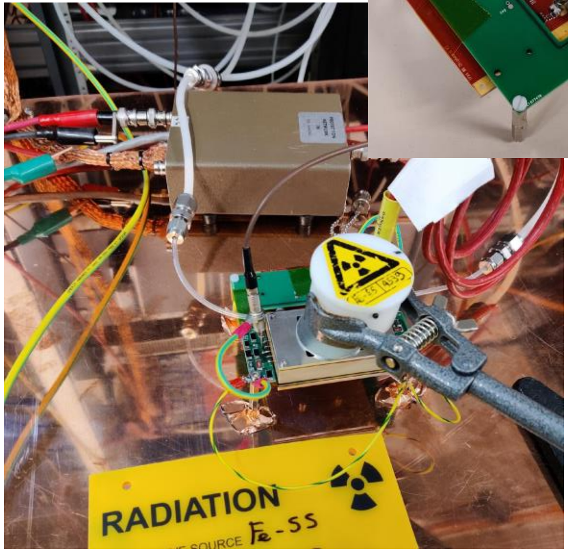
https://nbn-resolving.org/urn:nbn:de:hbz:5n-33163

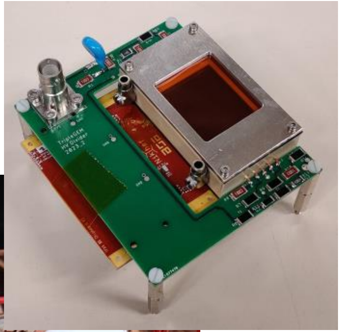




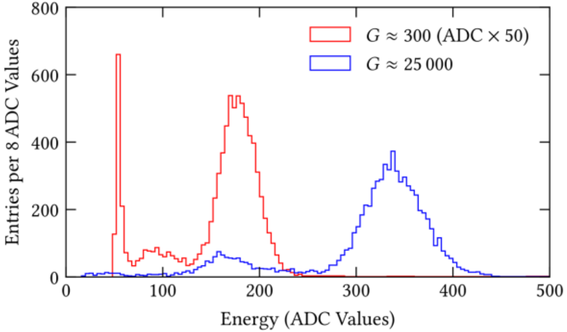
High-granularity readout of gaseous detectors
Triple-GEM detector

Set-up for gain measurements with ^{55}Fe source

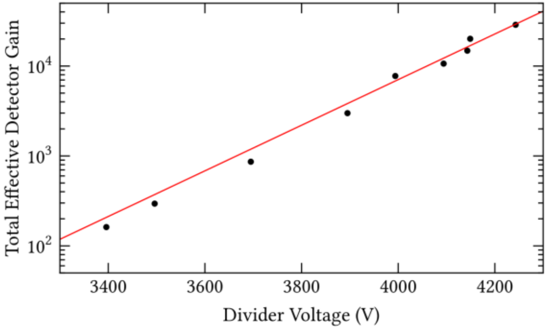




Test dynamic range of the detector operation.
Results obtained **WITHOUT Timepix4**, but **single-channel anode.**



Good energy resolution, even at very low gains



Good dynamic range and no discharges observed at G = 25 000

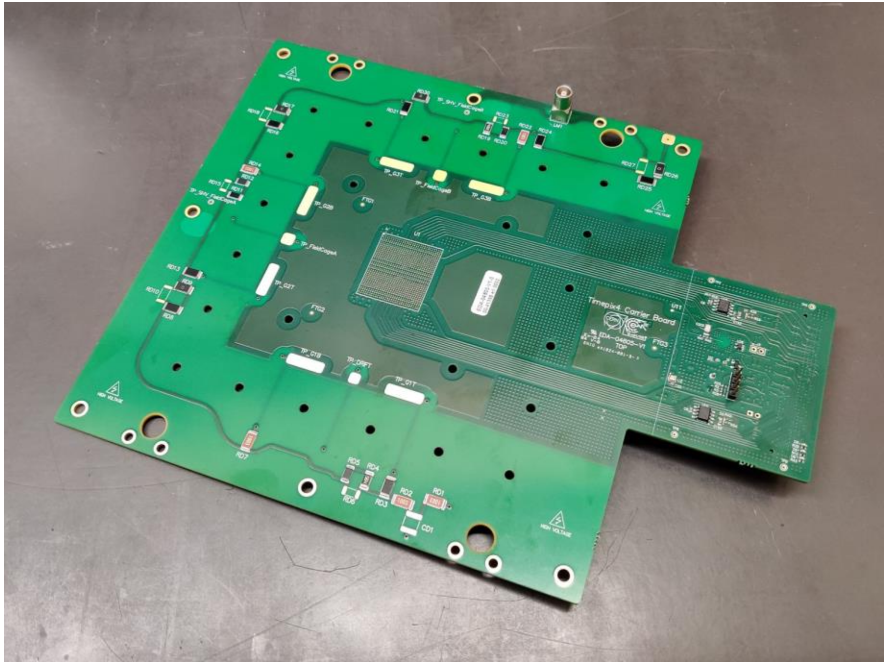
Waiting to repeat the measurements with TSV-Timepix4v2

High-granularity readout of gaseous detectors
Timepix4 and triple-GEM detector (custom board)

Single-chip prototype of what can be “easily” modified to house 2 x 2 or 3 x 3 Timepix4

Enables tests with 5 x 5 cm² GEM foils and more flexibility in terms of detector configuration

- Triple-GEM with adjustable fields
- µRWELL single-stage
- µRWELL with GEM preamplification
- Adjustable drift region, up to 15 mm



Thanks to William Billereau

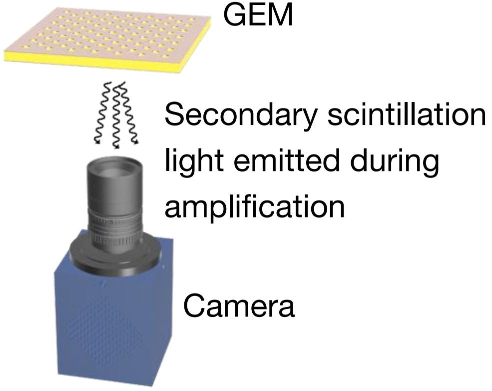
Optical readout of MPGDs

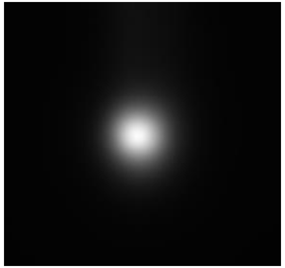
High **spatial resolution**

Integrated pixelated imaging approach with **megapixel imaging sensors**

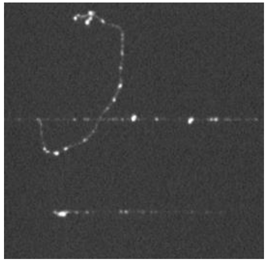
Adjustable magnification with lenses

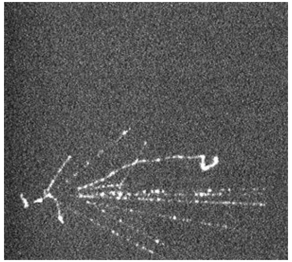
Need of **CF_4**-based gas mixtures or wavelength shifters

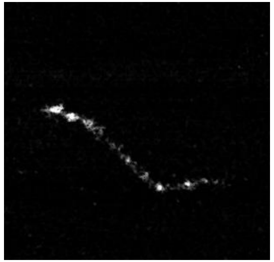


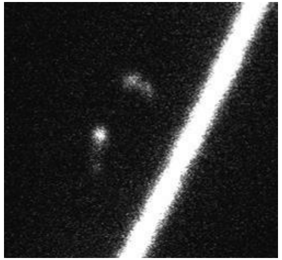

Beam monitoring


X-ray imaging


Muon tracks with δ-ray


Hadronic shower


Track reconstruction

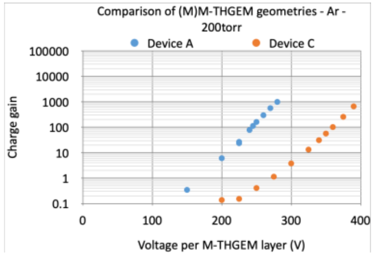

High dynamic range

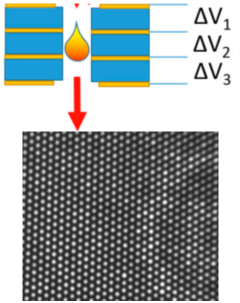
Alternative optical readout approaches

Extend versatility of optical readout for wide range of operating conditions (high/low pressure, pure gases)

Minimise dependence on CF4 as scintillating gas by using solid wavelength shifters

M-THGEMs for pure-noble gas operation

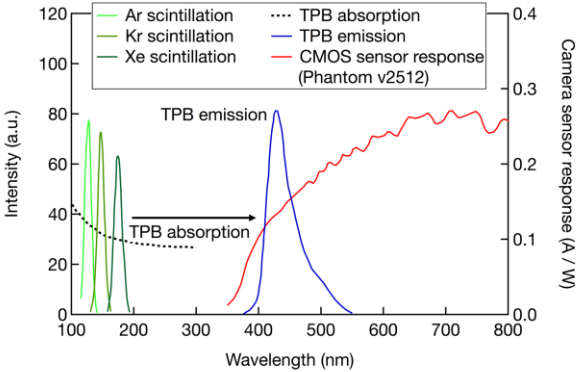


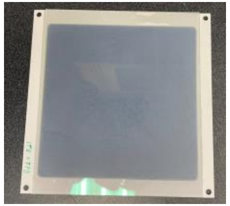


- Achieve high gain in challenging operating conditions (low pressure, pure noble gases)
- Extend dynamic range with multi-layer gain stages minimising transfer losses

Solid wavelength shifters to mitigate CF4

- Conversion of UV light to visible light for imaging
- Quantify spatial resolution effect and efficiency





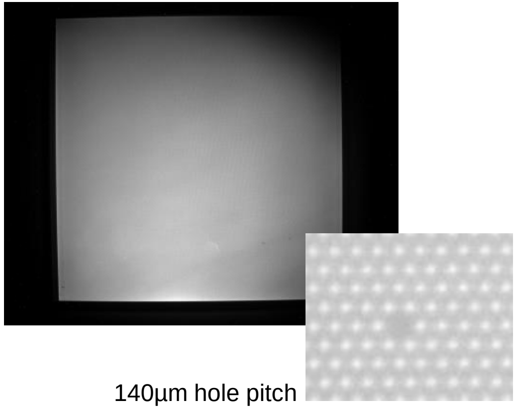
TPB wavelength shifter produced at TFG workshop

High-granularity optical readout of MPGDs

Use scintillation light readout to characterise MPGD detectors: uniformity, gain, spatial resolution

Detailed study of amplification structure response: visualisation of gain profile and locations of instabilities

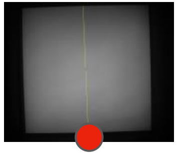
Uniformity map of µRWELL detectors



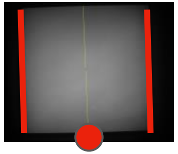
140µm hole pitch

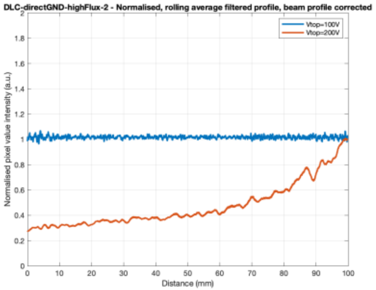
- Visualise non-uniform resistive gain drop in low-rate µRWELL layout
- Inspect hole response and uniformity

Single point GND

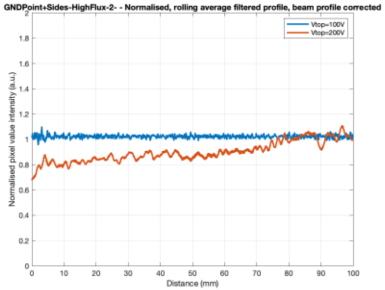


Point+edges GND





Resistive gain drop at high flux



Lower resistive gain drop

WP2 Teams, laboratories and workshops

Gaseous Detector Development (GDD) team (EP-DT-DD), https://gdd.web.cern.ch/

Gas Group team (EP-DT-FS), https://ep-dep-dt.web.cern.ch/gas-systems

Micro Pattern Technology (MPT) Workshop (EP-DT-EF), https://ep-dep-dt.web.cern.ch/micro-pattern-technologies

Thin Film and Glass (TFG) Laboratory (EP-DT-EF), https://ep-dep-dt.web.cern.ch/thin-film-glass-service

References

Synergies

Wolfgang Gentner Scholarships

Lucian Scharenberg, Next Generation Electronics for the Read-Out of Micro-Pattern Gaseous Detectors, FELL

Karl Jonathan Flöthner, R&D on GEM-based tracking system for future experiments, EP-R&D/Large Area, DOCT

AIDAinnova-**WP3-** Test beam and DAQ infrastructure
Task 3.5.2 **SRS/VMM3 common readout** to support gas detector R&D

AIDAinnova-**WP7-** Gaseous detectors
Task 7.2 **Eco-friendly gas mixtures for RPCs**

CERN Environmental Protection Steering board (CEPS)

R&D on **eco-gas, gas recirculating and recovery** (CF4, C4F10 e R134a)

Giorgio Orlandini (DOCT), Graphene-based functional structures and nanostructures for novel gaseous detectors, EP-RD/Novel Technologies

Full overlap with **scientific program** an large synergy in several **activities/topics**: PICOSEC, GEM, MM, µRWELL, photon readout, modelling and simulation, electronics, test beam

WP2 References (EP-RD Internal Seminar)

Seminar 24 (Monday 6 May 2024)
Karl Jonathan Floethner, The RD51/DRD1 Beam-Telescope - A versatile trigger-less tracking system for MPGDs
https://indico.cern.ch/event/1411526/

Seminar 17 (Monday 6 Mar 2023)
Gianluca Rigoletti, Investigating Eco-Friendly Gas Mixtures for RPCs at the LHC (WP2)
https://indico.cern.ch/event/1243563/

Seminar 12 (Monday 13 Jun 2022)
Djunes Janssens, Signal formation in detectors with resistive elements
https://indico.cern.ch/event/1167590/

Seminar 8 (Monday 7 Feb 2022)
Antonija Utrobicic, Precise timing with large area Picosec Micromegas detector
https://indico.cern.ch/event/1110585/

Seminar 2 (Monday 3 May 2021)
Florian Brunbauer, Precise timing with gaseous detectors: towards robust and tileable Picosec Micromegas detectors
https://indico.cern.ch/event/1016656/

WP2 (Recent) References 1

M. Lisowska et al.; Sub-25 ps timing measurements with 10 × 10 cm PICOSEC Micromegas detectors, Nucl. Instrum. Methods Phys. Res. A 1046 (2023), p. 167687.

A.Utrobicic., et al. "A large area 100-channel PICOSEC Micromegas detector with time resolution at the 20 ps level." Journal of Instrumentation 18.07 (2023): C07012.

M. Lisowska et al., Towards robust PICOSEC Micromegas precise timing detectors, J. Instrum. 18 (2023), p. C07018.

M. Lisowska et al., Current status of PICOSEC Micromegas precise timing detectors and studies on robust photocathodes, Presented at RD51 Collaboration Meeting, 4-8 December 2023.

A. Utrobicic; Design features and timing performance of new single-channel PICOSEC MM detector, Presented at RD51 Collaboration Meeting, 4-8 December 2023.

L. Scharenberg et al.; Performance of the new RD51 VMM3a/SRS beam telescope — studying MPGDs simultaneously in energy, space and time at high rates, J. Instrum. 18 (2023) p. C05017.

L. Scharenberg; Fast-timing and high-granularity readout of MPGDs: FastIC and Timepix4, Presented at the RD51 Collaboration Meeting, 4-8 December 2023. https://indico.cern.ch/event/1327482/contributions/5692915/

L. Scharenberg et al.; Characterisation of resistive MPGDs with 2D readout, J. Instrum. 19 (2024), p. P05053. https://doi.org/10.1088/1748-0221/19/05/P05053

H. Muller, K. J. Flöthner; PBX, a small powerbox for 1kCHF. VMM frontends connected over long HDMI links, Presented at the RD51 Collaboration Meeting, 19–21 June 2023. https://indi.to/JYnyM

K. J. Flöthner, A new Triple-GEM Tracking Detector for COMPASS++/AMBER, Presented at TIPP, 24–28 May 2021. https://indi.to/hH72W

K. J. Flöthner; RD51 VMM3a Tracker and XYU detector, Presented at the RD51 Collaboration Meeting, 19–21 June 2023. https://indi.to/r3tv9

K. J. Flöthner; t0-less GEM-TPC, RD51 Collaboration Meeting, 4–8 December 2023. https://indi.to/SLZNL

D. Janssens; Ion mobility in a MicroMegas detector: a puzzle between measurement and simulation, RD51 Collaboration Meeting, 19-21 June 2023. https://indi.to/MRrGd

D. Janssens et al.; Studying signals in particle detectors with resistive elements such as the 2D resistive strip bulk MicroMegas, JINST 18.08 (2023), p. C08010.

WP2 (Recent) References 2

D. Janssens and W. Riegler; Noise in detectors containing distributed resistive elements, submitted to Nucl. Instrum. Meth. A, NIMA-D-23-01244.

D. Janssens; Resistive electrodes and particle detectors: Modelling and measurements of novel detector structures, Ph.D. thesis at the Vrije Universiteit Brusse, Presented 26 February 2024. https://cds.cern.ch/record/2890572

G. Orlandini et al.; Integration of CVD graphene in gaseous electron multipliers for high energy physics experiments, JINST 18 (2023) C06022.

L. Scharenberg, Evolution & applications of the RD51 VMM3a/SRS beam telescope, 11th Beam Telescopes and Test Beams Workshop, Hamburg 2023, https://indi.to/JrHDN

L. Scharenberg, Latest results and improvements of the RD51 VMM3a/SRS gaseous beam telescope, 12th Beam Telescopes and Test Beams Workshop, Edinburgh 2024, https://indi.to/m7W9q

G. Orlandini, et al.; Large area suspended graphene for low energy electron transparency and gas separation measurements, Tech. rep. Graphene Study 2023.

M. Busato, R. Guida, B. Mandelli, G. Rigoletti, "Optimization strategies for the greenhouse gas consumption of the resistive plate chamber detectors at the CERN LHC experiments", Nucl.Instrum.Meth.A 1055 (2023) 16844, https://doi.org/10.1016/j.nima.2023.168444

R. Guida, B. Mandelli, G. Rigoletti, "Measurements of fluoride production in Resistive Plate Chambers", Nucl.Instrum.Meth.A 1054 (2023) 168393, https://doi.org/10.1016/j.nima.2023.168393

R. Guida, B. Mandelli, G. Rigoletti , "Performance studies of RPC detectors operated with C2H2F4 and CO2 gas mixtures", https://doi.org/10.1016/j.nima.2023.168088

R. Guida, B. Mandelli, G. Rigoletti, "Gas recirculation systems for RPC detectors: From LHC experiments to laboratory set-ups", Nucl.Instrum.Meth.A 1049 (2023) 168095, https://doi.org/10.1016/j.nima.2023.168095

R. Guida, B. Mandelli, G. Rigoletti, "Studies on RPC detectors operated with environmentally friendly gas mixtures in LHC-like conditions", Nuclear Inst. and Methods in Physics Research, A, Volume 1048, 2023, 167961, https://doi.org/10.1016/j.nima.2022.167961

WP2 (Recent) References 3

PICOSEC Micromegas Collaboration

M. Lisowska[1,2,*], Y. Angelis[3], J. Bortfeldt[4], F. Brunbauer[1], E. Chatzianagnostou[3], K. Dehmelt[5], G. Fanourakis[6], K. J. Floethner[1,7], M. Gallinaro[8], F. Garcia[9], P. Garg[5], I. Giomataris[10], K. Gnanvo[11], T. Gustavsson[12], F.J. Iguaz[10], D. Janssens[1,13,14], A. Kallitsopoulou[10], M. Kovacic[15], P. Legou[10], J. Liu[16], M. Lupberger[7,17], S. Malace[11], I. Maniatis[1,3], Y. Meng[16], H. Muller[1,17], E. Oliveri[1], G. Orlandini[1,18], T. Papaevangelou[10], M. Pomorski[19], L. Ropelewski[1], D. Sampsonidis[3,20], L. Scharenberg[1,17], T. Schneider[1], L. Sohl[10], M. van Stenis[1], Y. Tsipolitis[21], S.E. Tzamarias[3,20], A. Utrobicic[22], R. Veenhof[1,23], X. Wang[16], S. White[1,24], Z. Zhang[16], and Y. Zhou[16]

[1]European Organization for Nuclear Research (CERN), CH-1211, Geneve 23, Switzerland
[2]Université Paris-Saclay, F-91191 Gif-sur-Yvette, France
[3]Department of Physics, Aristotle University of Thessaloniki, University Campus, GR-54124, Thessaloniki, Greece
[4]Department for Medical Physics, Ludwig Maximilian University of Munich, Am Coulombwall 1, 85748 Garching, Germany
[5]Stony Brook University, Dept. of Physics and Astronomy, Stony Brook, NY 11794-3800, USA
[6]Institute of Nuclear and Particle Physics, NCSR Demokritos, GR-15341 Agia Paraskevi, Attiki, Greece
[7]Helmholtz-Institut für Strahlen- und Kernphysik, University of Bonn, Nußallee 14–16, 53115 Bonn, Germany
[8]Laboratório de Instrumentacão e Física Experimental de Partículas, Lisbon, Portugal
[9]Helsinki Institute of Physics, University of Helsinki, FI-00014 Helsinki, Finland
[10]IRFU, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France
[11]Jefferson Lab, 12000 Jefferson Avenue, Newport News, VA 23606, USA
[12]LIDYL, CEA, CNRS, Universit Paris-Saclay, F-91191 Gif-sur-Yvette, France
[13]Inter-University Institute for High Energies (IIHE), Belgium
[14]Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, Belgium
[15]Faculty of Electrical Engineering and Computing, University of Zagreb, 10000 Zagreb, Croatia
[16]State Key Laboratory of Particle Detection and Electronics, University of Science and Technology of China, Hefei 230026, China
[17]Physikalisches Institut, University of Bonn, Nußallee 12, 53115 Bonn, Germany
[18]Friedrich-Alexander-Universität Erlangen-Nürnberg, Schloßplatz 4, 91054 Erlangen, Germany
[19]CEA-LIST, Diamond Sensors Laboratory, CEA Saclay, F-91191 Gif-sur-Yvette, France
[20]Center for Interdisciplinary Research and Innovation (CIRI-AUTH), Thessaloniki 57001, Greece
[21]National Technical University of Athens, Athens, Greece
[22]Institute Ruder Bosković Institute, Bijenička cesta 54, 10000, Zagreb, Croatia
[23]Bursa Uludağ University, Görükle Kampusu, 16059 Niufer/Bursa, Turkey
[24]University of Virginia, USA

PICOSEC Micromegas