Detector R&D Effort in Belgium

for HEP and Beyond-HEP Applications

This talk covers:

- Selected (still) ongoing R&D for CMS
- R&D for Future Colliders
  - Calorimetry with T-SDHCAL
  - Vertex Detector with MAPS
- Beyond-HEP Applications
  - Muon Radiography
  - Flash Dosimetry
- Concluding remarks
- (Belgium in DRD collaborations)

The following topics are covered in detail in other contributions today:

- CMS Phase-2 Upgrade
  - Silicon Strip Tracker
  - Muon System (RPC/GEM)
- NA62/Ship
- MilliQan/Formosa
- IceCube/RNO-G/AUGER/JUNO
- …

Many thanks to all colleagues for providing input

Michael Tytgat

RECFA Visit to Belgium

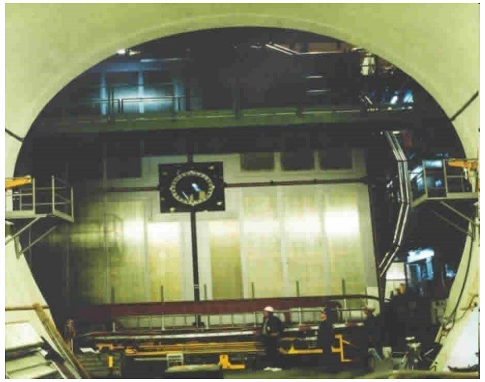
September 12, 2025

iihe BRUXELLES BRUSSEL

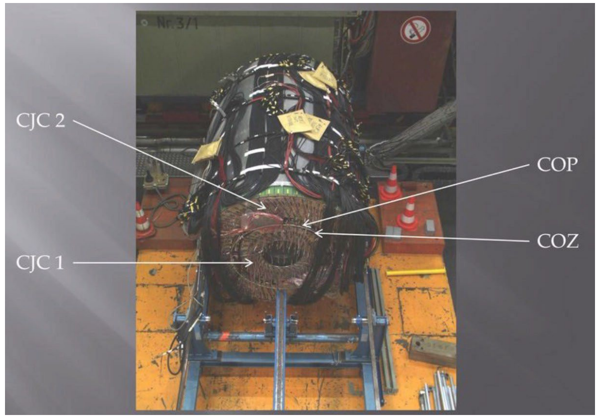
VUB VRIJE UNIVERSITEIT BRUSSEL

(Examples of) Past R&D in Belgium

a)



b)



Belgium has a long tradition in R&D of gaseous detectors

a) mid-80's: Drift chambers for the Muon system of Delphi

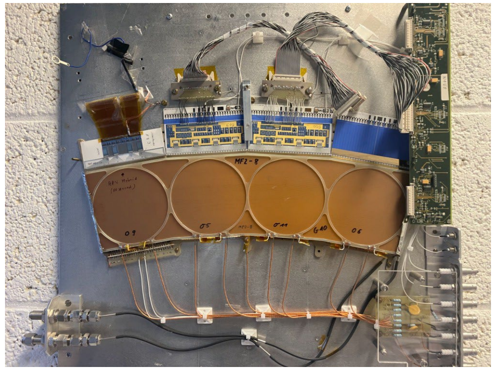
b) mid-90's: COP (Central Outer Proportional chamber) of H1

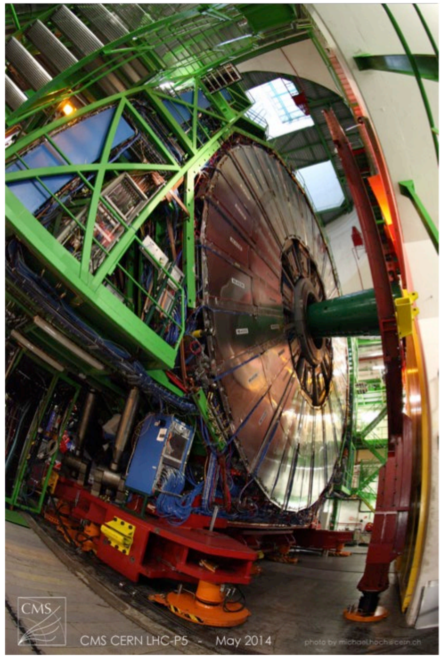
c) end of 90's: MSGC (Micro-Strip Gas Chambers) and their variants as option for CMS Tracker

d) 2000's-now: Resistive Plate Chambers (RPC) for CMS Muon

e) 2009-now: Gas Electron Multipliers (GEMs) for CMS Muon

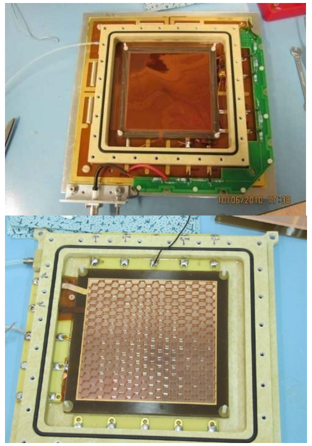
c)





d)

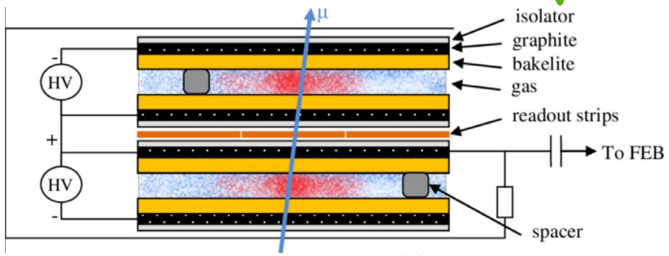
e)



GE1/1-I (2010) GE1/1-II (2011) GE1/1-III (2012) GE1/1-IV (2013) GE1/1-V-S (2014) GE1/1-VI-L (2015)

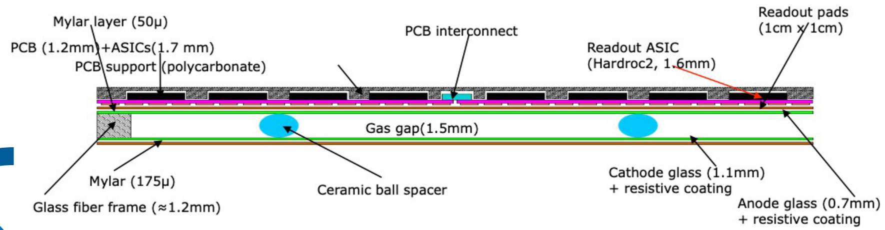
From CMS to the future …

CMS standard Bakelite RPC



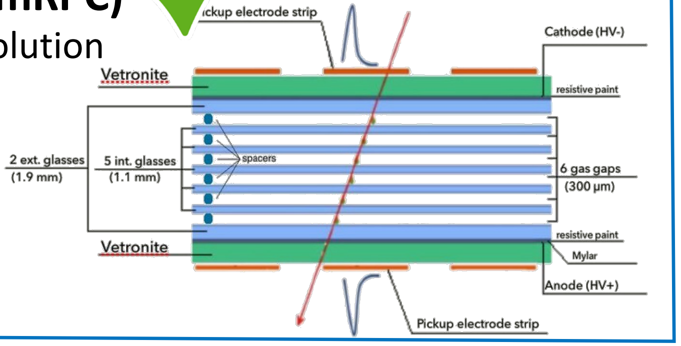
glass RPC (gRPC)

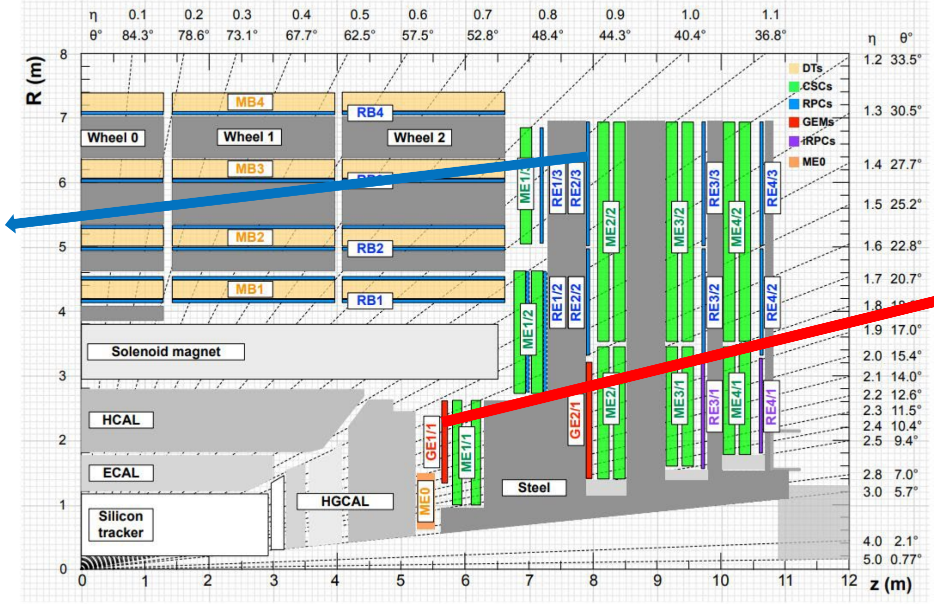
- Excellent surface quality, i.e. no electrode oiling or humidified gas needed
- Simplified gap assembly procedure
- Higher rate capability (with e.g. doped glass)



Multi-gap RPC (mRPC)

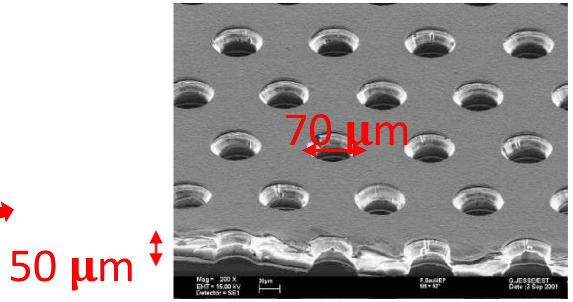
- Better time resolution ~50 ps





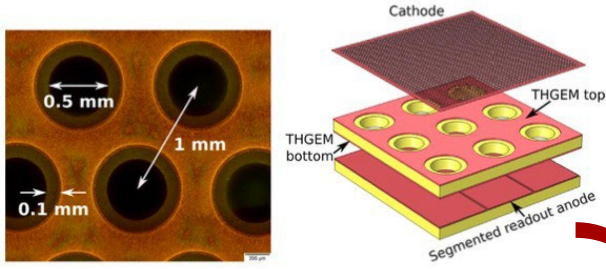
CMS Standard GEM

- Thin (50 μm) Kapton foil
- Chemical etching to create the holes



Thick GEM (TGEM)

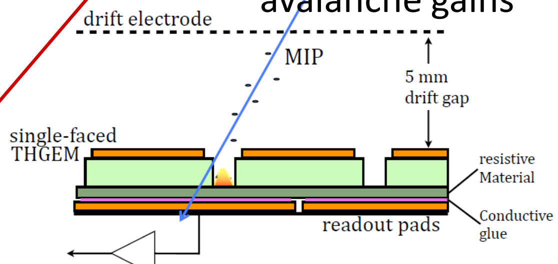
- Printed Circuit Board (PCB) with mechanically drilled holes



R&D for Future Colliders and Beyond-HEP applications

Resistive MPGD, e.g. RPWELL ?

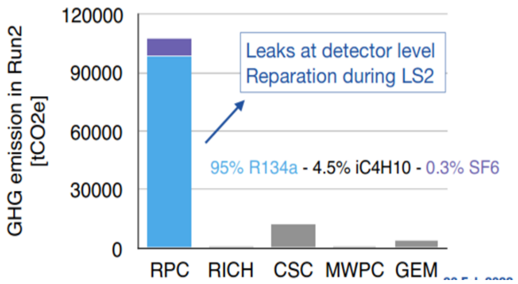
- Discharge-free operation at high gas-avalanche gains



Selected ongoing R&D for CMS

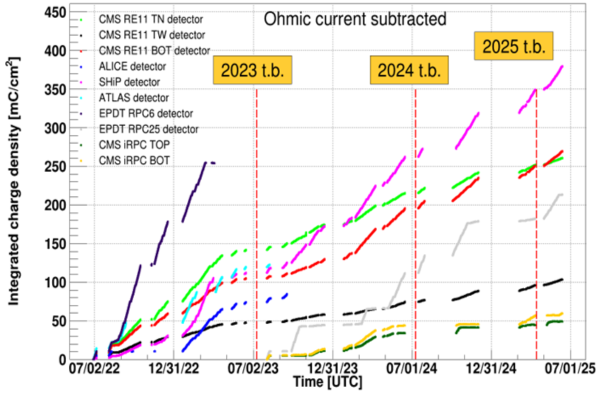
(CMS Muon-)RPC: ecogas studies

- Standard RPC gas $C_2H_2F_4$ (~95%)/ C_4H_{10} / SF_6 → F-gases, high Green Warming Potential (GWP)
- 2013: global phase-down in EU of F-gases → huge cost increase & reduced availability in Europe
- ➢ Search for alternative, low GWP, low toxicity, non-flammable gases, yielding RPC performance similar to standard RPC mixture (and compatible with current RPC electronics and HV @ LHC)
- ➢ Study ageing effects to ensure long-term stable operation

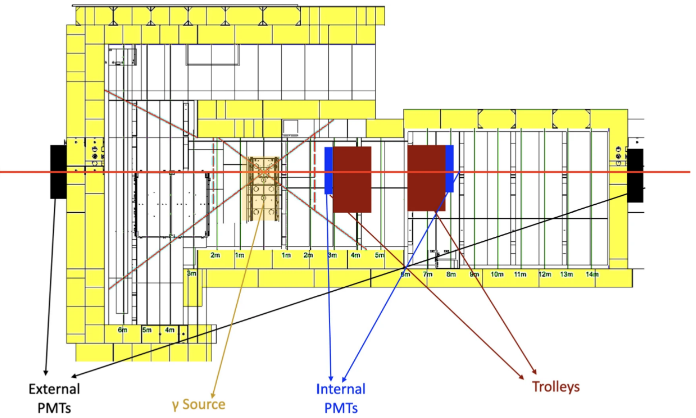


RPC Ecogas@GIF++ Collaboration (2019-…)

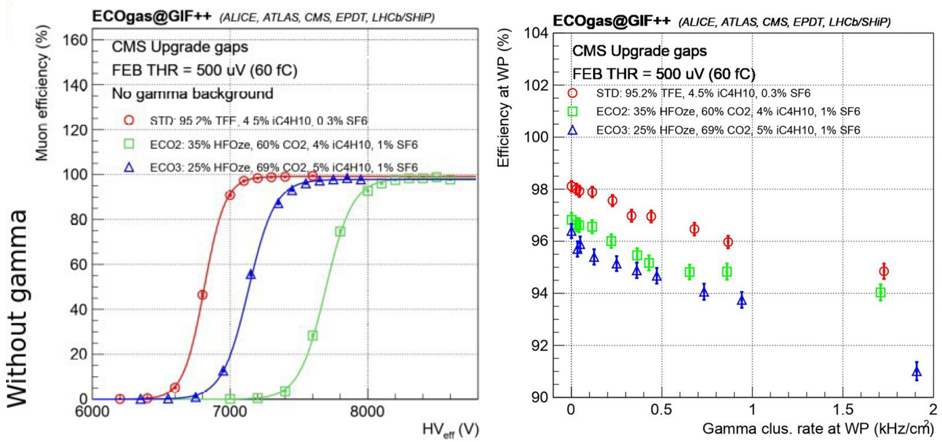
- Long-term RPC ageing tests with alternative eco-friendly gas mixtures under LHC irradiation conditions @ CERN GIF++ (12.5 TBq ^{137}Cs source + 150 GeV/c muon test beam facility)
- RPCs with different technical layouts (CMS, ATLAS, ALICE, LHCb/Ship, CERN EDPT)
- ➢ **Currently testing:** replacing $C_2H_2F_4$ by $C_3H_2F_4$ze + CO_2



VUB (past:UGent); activity supported by AIDAinnova (WP7) H2020 project (2021-2025); embedded in DRD1



	R134-a (%)	HFO-1234ze (%)	CO_2 (%)	i-C_4H_{10} (%)	SF_6 (%)	GWP_{MIX}
GWP	1430	7	1	3	22800	
Density (g/L)	4.68	5.26	1.98	2.69	6.61	
STD	95.2			4.5	0.3	1486
ECO2		35	60	4	1	476
ECO3		25	69	5	1	527

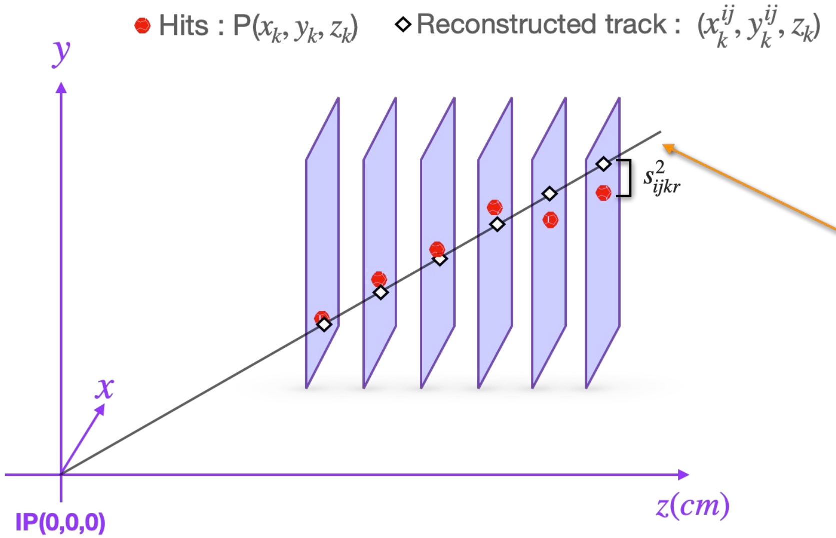


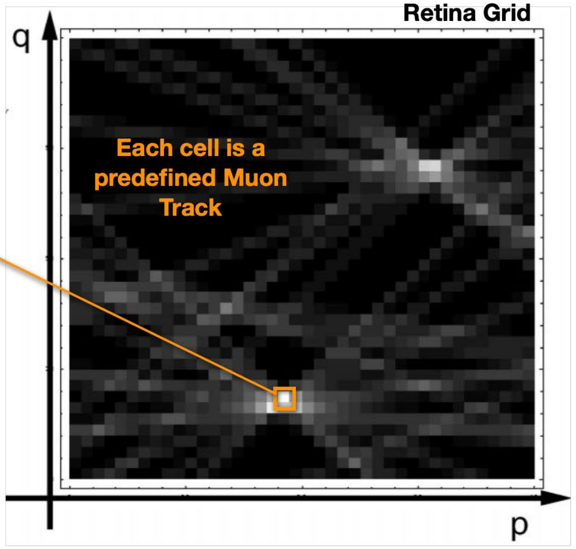
[M. Abresscia et al., *Performance and long-term aging studies on Eco-Friendly Resistive Plate Chamber detectors*, NIM-A 1080 (2025) 170624]

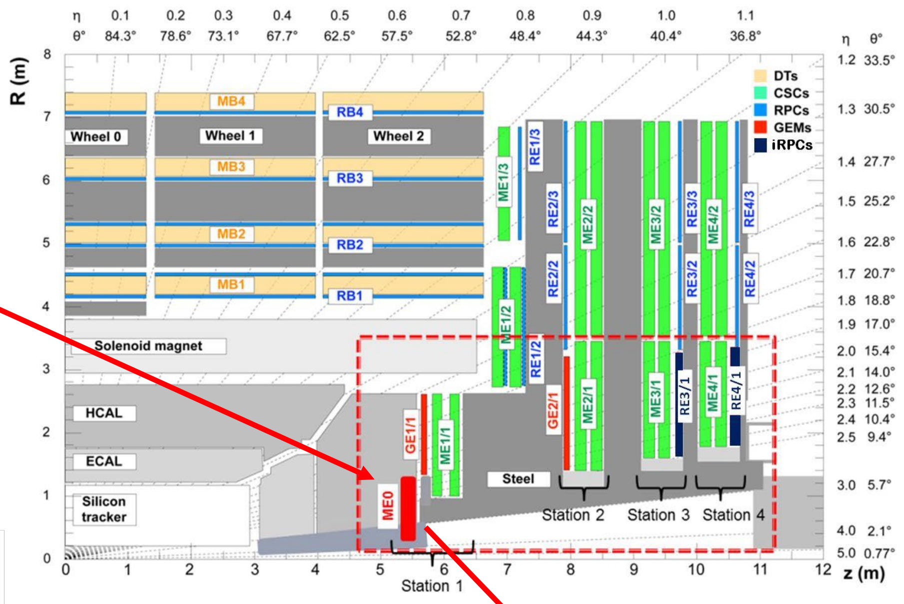
CMS Muon-GEM: ME0 retina algorithm

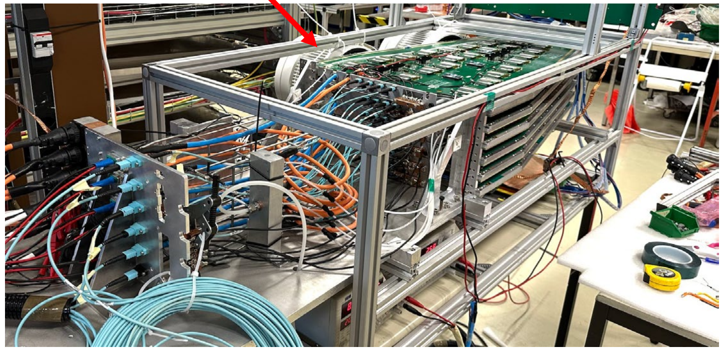
ULB

ME0:
- 6 layers of triple-GEM chambers at 2.0<|η|<2.8
- **Retina algorithm for track reconstruction**
  - inspired by visual mechanism in mammals
  - highly parallelized → suitable for FPGA
  - robust to background hits
  - ME0 geometry is perfectly suitable









$$R_{ij} = \sum_{k,r} \exp\left(-\frac{s^2_{ijkr}}{2\sigma^2}\right)$$

→ $s_{ijkr} = x_r^{(k)} - y_k(p_i, q_j)$

→ Width of response function

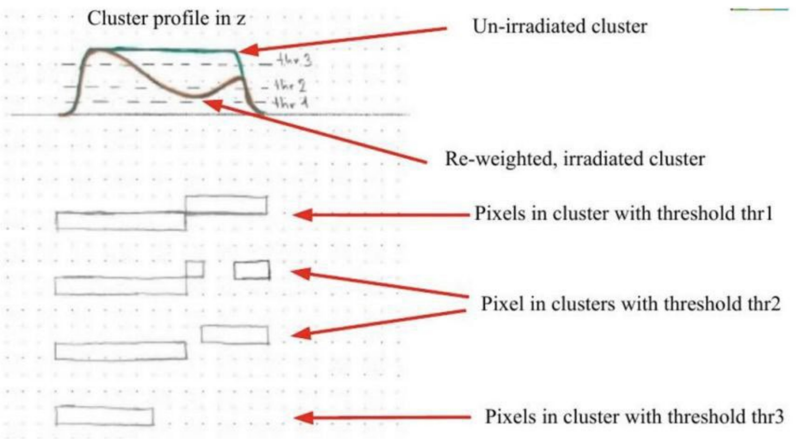
CMS Tracker: Digi-morphing for HLT

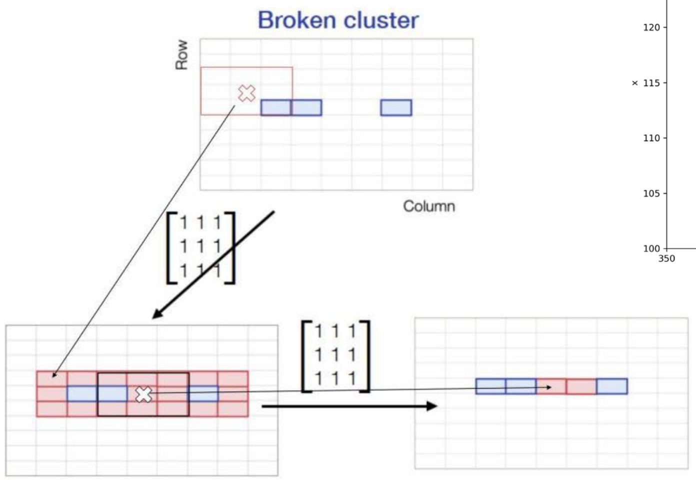
VUB

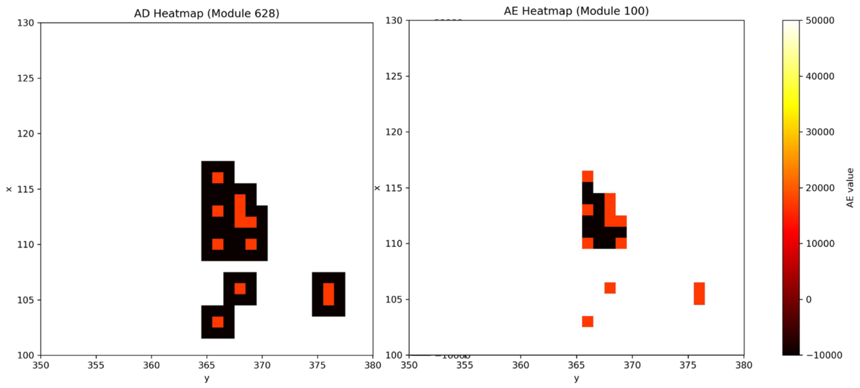
Significant radiation damage is expected in the remainder of Run 3 for silicon sensors in the CMS pixel detector

- Decrease of charge collection efficiency → loss of pixels
  - Pixels missing inside clusters → split or broken clusters
  - Pixels missing at end of clusters → shorter clusters
- ➢ Consequence of cluster splitting: more off-track clusters, fake/duplicate tracks, reduced resolution, and large hit position bias

- ➢ **Solution**: An **image morphing-based "closing" technique to reconnect fragmented clusters**
- ➢ Algorithm operates directly at pixel (Digi) level; offline and High-Level Trigger (HLT) versions (GPU)
- ➢ Employ convolution operations using **dilate + erode** kernels to insert "**extra pixels**" into broken pixel clusters

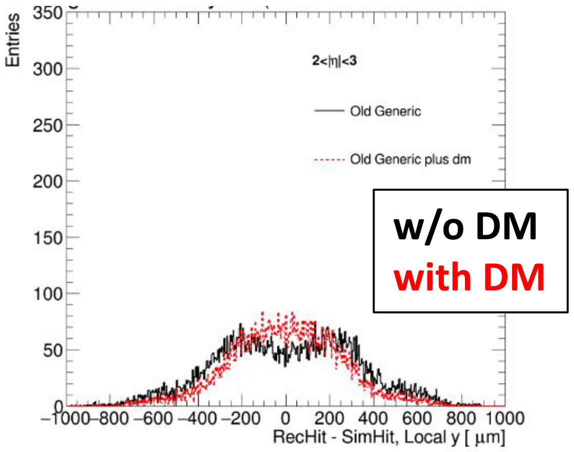






- **dilate**: X(i,j) → Y(i,j):
  Y(i, j) = max X(i+k, j+l) for all (k, l) where M(k,l)!=0 in a kernel M

→ **erode**: same, but "min" instead of "max"

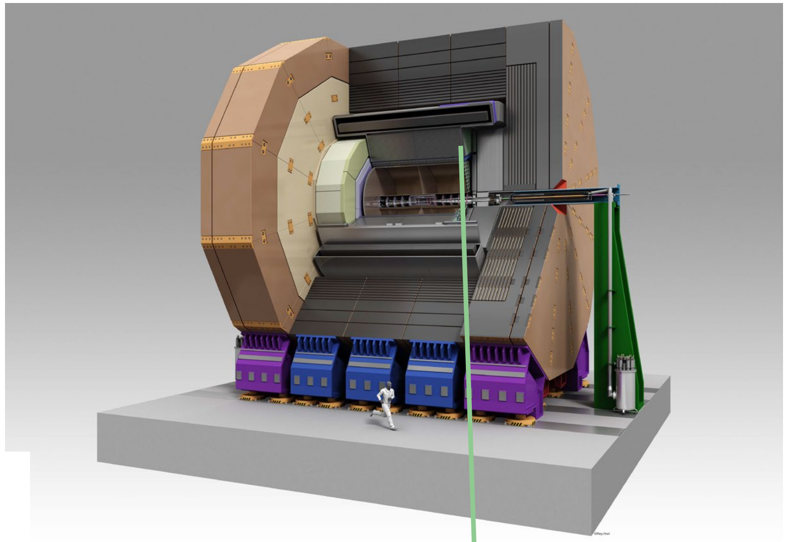


Future Colliders

I. RPC-based calorimeter

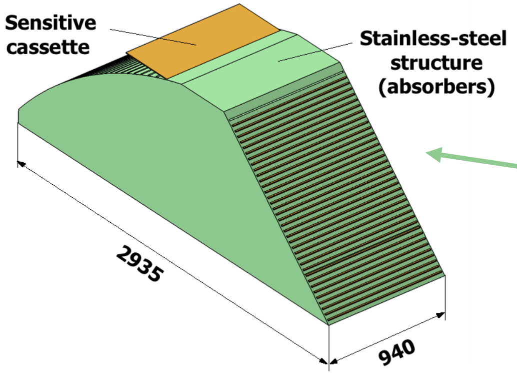
The **Semi-Digital HCAL (SDHCAL)** is

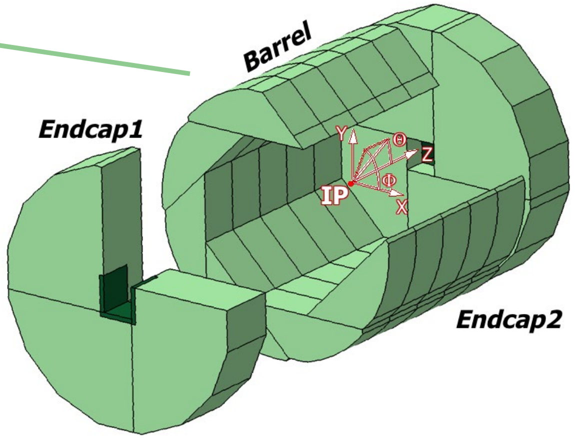
- **a gaseous detector-based, highly-granular option for an HCAL based on PFA**
- part of the **International Large Detector (ILD)** baseline detector option, originally proposed for ILC/CEPC, and now also submitted to **FCCee**



SDHCAL structure:

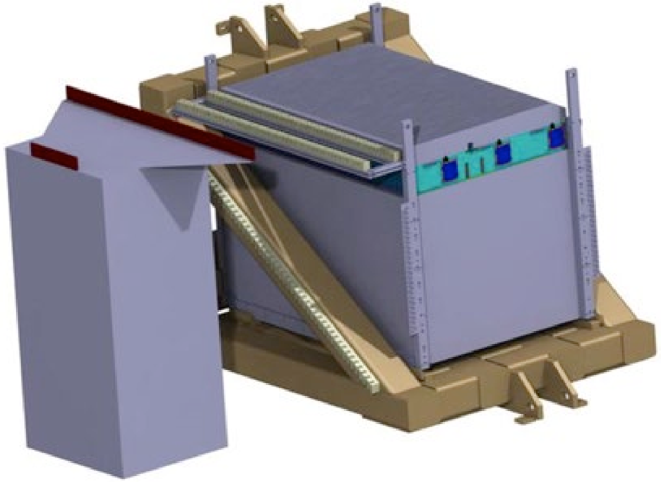
- very **compact** with negligible dead zones
- eliminates projective cracks
- minimizes barrel / endcap separation (services leaving from the outer radius)





SDHCAL technological prototype aimed to be as close as possible to ILD modules, with ability to study **hadronic showers; challenges include:**

- Homogeneity for large surfaces (up to 3m length)
- Thickness of a few mms only
- Lateral segmentation of 1 cm x 1 cm
- Services from one side
- Embedded (power-cycled) electronics
- Self-supporting mechanical structure



VUB in ILD

SDHCAL prototype

UGent in CALICE (2009-2023); supported by FWO project

SDHCAL was developed inside CALICE Collaboration:

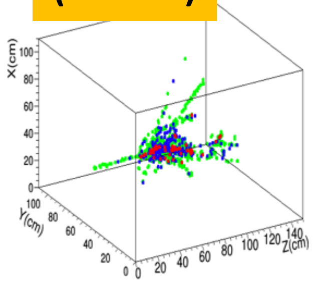
- **sampling calorimeter, i.e. stainless steel absorber alternated with single-gap glass resistive plate chambers**
- 48-50 layers (-6λ_I); ~1.3m^3 prototype
- 1 cm x 1 cm readout granularity with pads; ~450k channels (more than full CMS calorimeter system already …)
- 3-threshold readout with 64-ch HARDROC ASICs (144 ASICs or 9k ch/m^2)
- Triggerless DAQ system using power-pulsing scheme tailored to ILC (to be modified for FCCee)
- Self-supporting mechanical structure made with stainless steel plates
- Collaborators mainly from France, Spain, Belgium, Korea, China

[G. Baulieu et al., *Construction and commissioning of a technological prototype of a high-granularity semi-digital hadronic calorimeter*, JINST 10 (2015) 10, P10039]

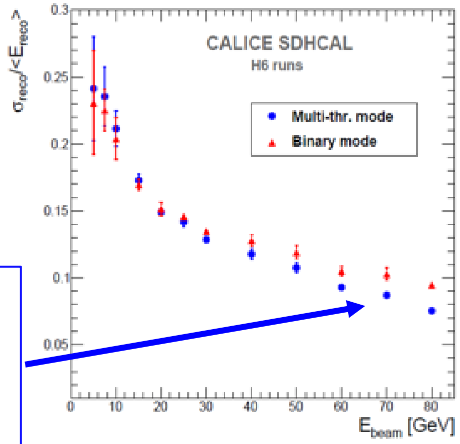
Initial beam tests with small gRPCs in 2009

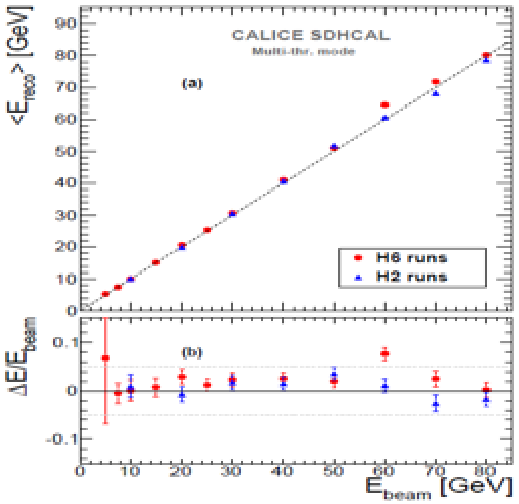
SDHCAL prototype was exposed to beam particles at CERN PS, SPS in 2012, 2015, 2017,2018 and 2022

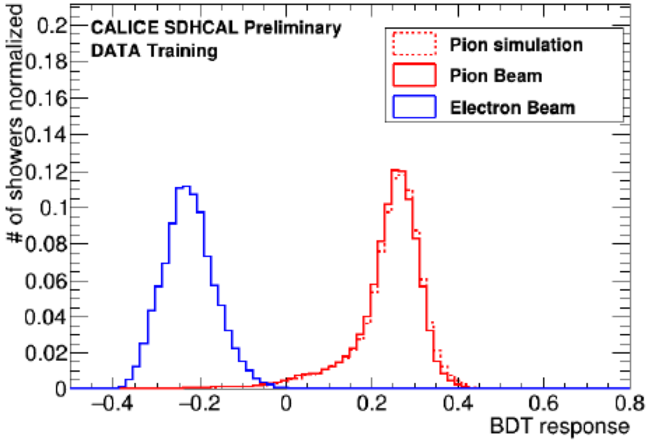
Pion (50 GeV)



multi-threshold mode (semi-digital) does help at high energy !



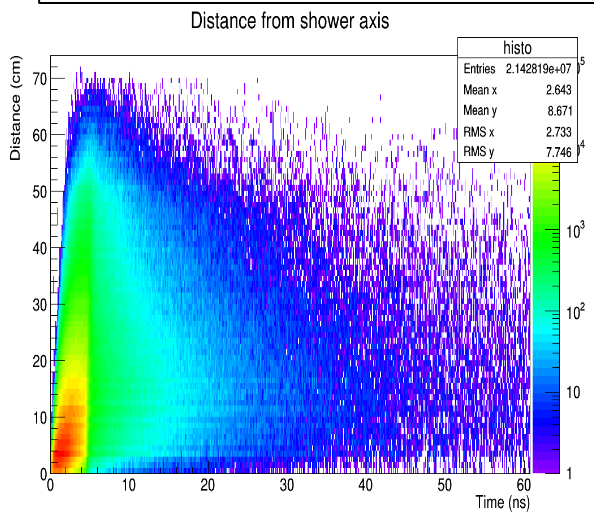


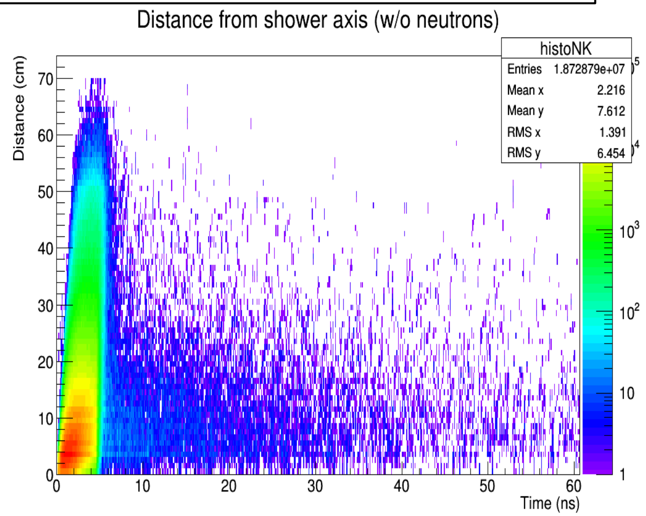


[D. Boumediene et al., *Energy reconstruction of hadronic showers at the CERN PS and SPS using the Semi-Digital Hadronic Calorimeter*, JINST 17 (2022) 07, P07017]

Timing-SDHCAL

Separate delayed neutrons for better energy reconstruction



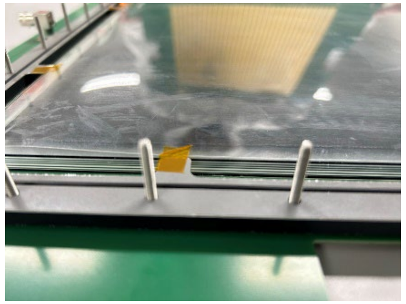


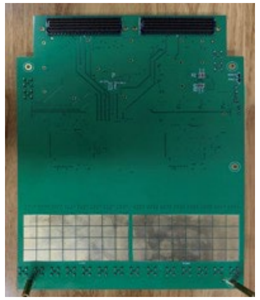
Next step: **Timing-SDHCAL (5D calorimetry)**, i.e. timing capabilities of calorimeter systems open up new possibilities for TOF, LLP, shower reconstruction …; hadronic showers show a complex time structure, with late components connected to neutron-induced processes; e.g. 100ps timing precision could aid in shower energy reconstruction and shower separation

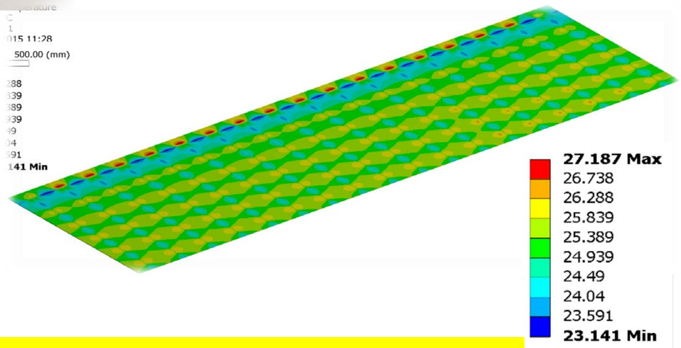
→ replace single-gap RPCs in SDHCAL with **advanced 100ps multi-gap RPCs**; R&D on:

- **large-area detectors** for ILD-like concept
- **optimization of timing precision**, rate capability (new materials ?)
- **new front-end electronics**, i.e. high time precision + continuous readout for circular colliders
  → baseline: **Petiroc ASIC**
  future: **LIROC ASIC + PicoTDC**
- **new detector cooling system**

[M. Tytgat et al., *Towards the T-SDHCAL hadronic calorimeter for a future Higgs factory*, NIM-A 1077 (2025) 170520]







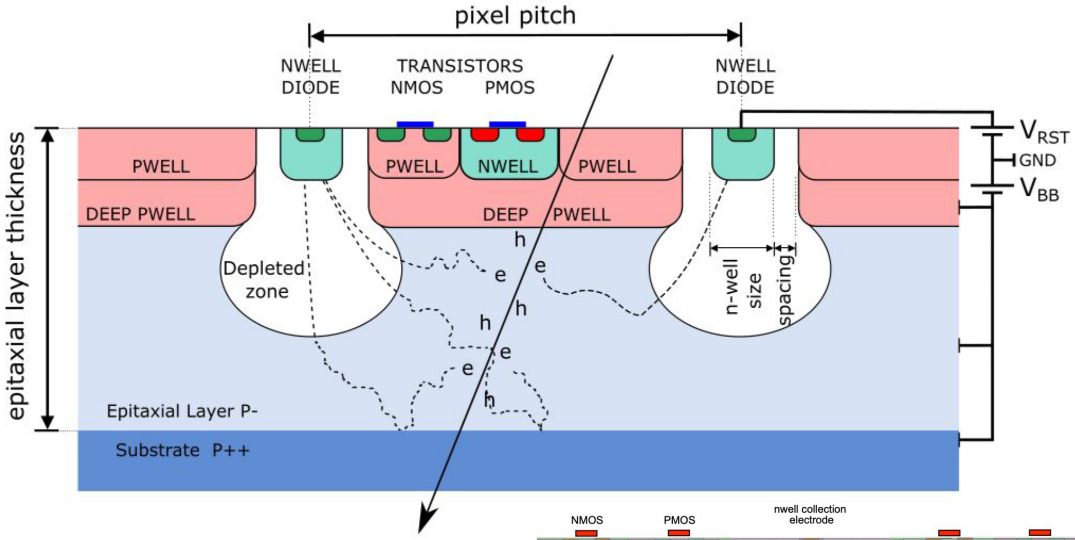
VUB; embedded in DRD6/DRD1

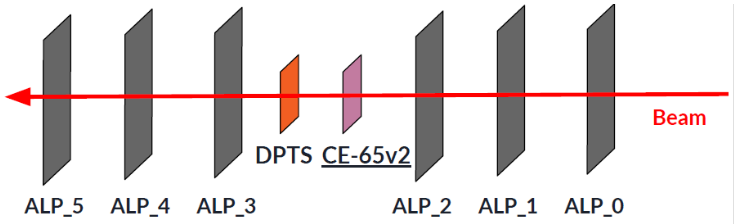
II. MAPS-based vertex detector

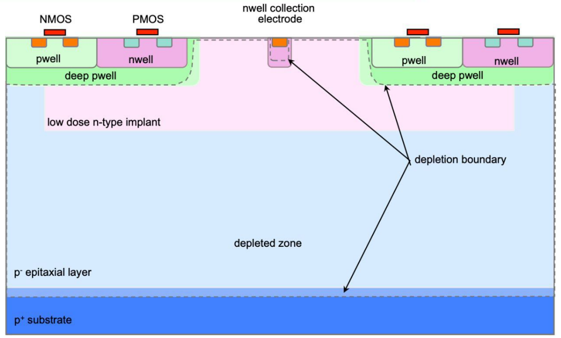
VUB;
supported by SNSF-FWO Weave project (UZH-VUB)

Higgs and heavy flavor physics @ FCC-ee imposes stringent performance requirements for vertex detectors:

- 3 µm point resolution and 20 ns timing resolution
- sensor thickness smaller than 50 µm and material budget of ≲ 0.3 % of X_0
- Power consumption ≲ 50 mW cm^{-2} to allow for air-cooling
- few $10^{13} cm^{-2} n_{eq}$ /year fluence per year
- 100 kGy/year total ionizing dose
- O(100MHz cm^{-2}) highest particle hit rate for the innermost layer at a radius of 1.37 cm
- Acceptance up to |cos θ| < 0.99 for all layers





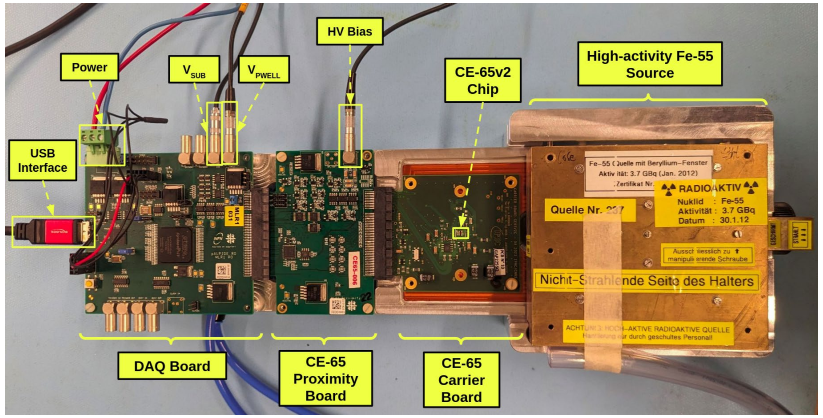


CMOS Monolithic Active Pixel Sensors (MAPS) are ideal candidates for FCC-ee vertex detectors thanks to

- possibility of thinning them to small thicknesses
- feasibility of achieving a small pitch and low-power dissipation

→ R&D is needed to fulfill all requirements at the same time:

- 65nm TPSCo CMOS technology
- Lab tests with ^{55}Fe radioactive source (UZH)
- Beam tests with 120 GeV hadrons at CERN SPS



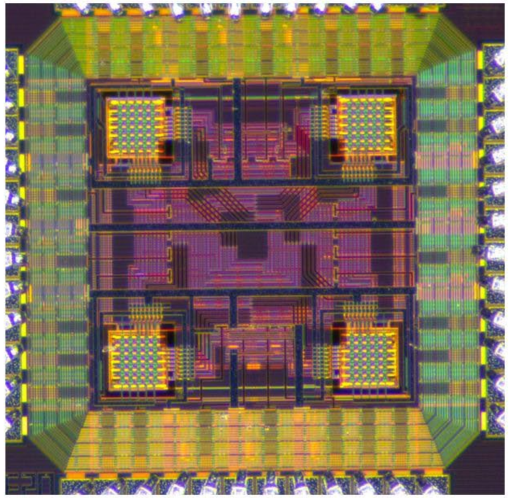
MAPS R&D

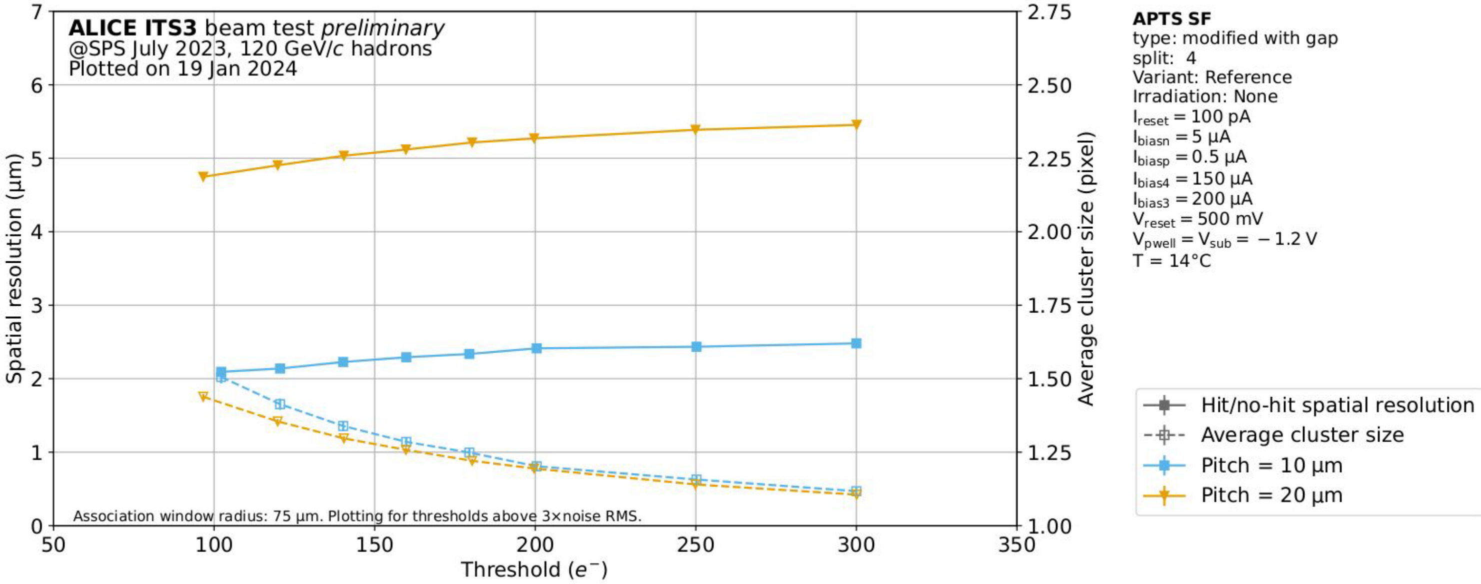
ALICE ITS3-like Analogue Pixel Test Structure multiplexer for performance characterization of MAPS in 65nm CMOS

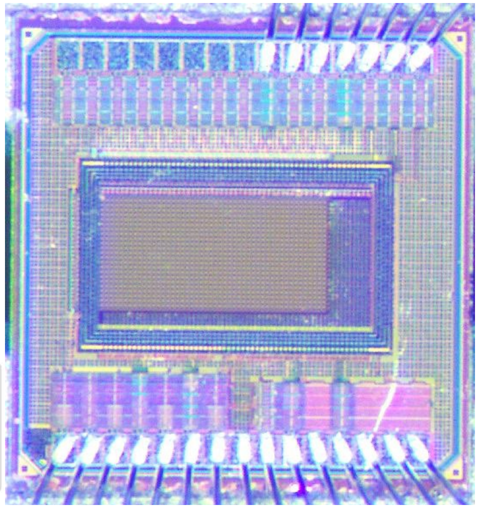
- 6x6 pixel matrix
- Direct analog readout of central 4x4 pixels
- Pitch: 10, 15, 20, 25 µm
- Readout: source-follower, in-pixel amplifier + source-follower
- Coupling: DC, AC
- Process: Standard, Modified, Modified with Gap
- Pixel Geometry: four variants

CE-65 "Circuit Exploratoire"

- Developed by IPHC Strasbourg in **65nm TPSCo CMOS**
- Two generations: CE-65v1 (MLR1), CE-65v2 (ER1)
- Four exploration axes:
  - Amplification scheme: AC-amp., DC-amp., SF
  - Process: Standard, Modified, Modified w/Gap
  - Pitch variation: 15 µm, 18 µm, 22.5 µm
  - Matrix geometry: square vs staggered







[K. Gautam et al., *Characterisation of analogue MAPS fabricated in 65 nm technology for the ALICE ITS3, NIM-A* 1068 (2024) 169787]

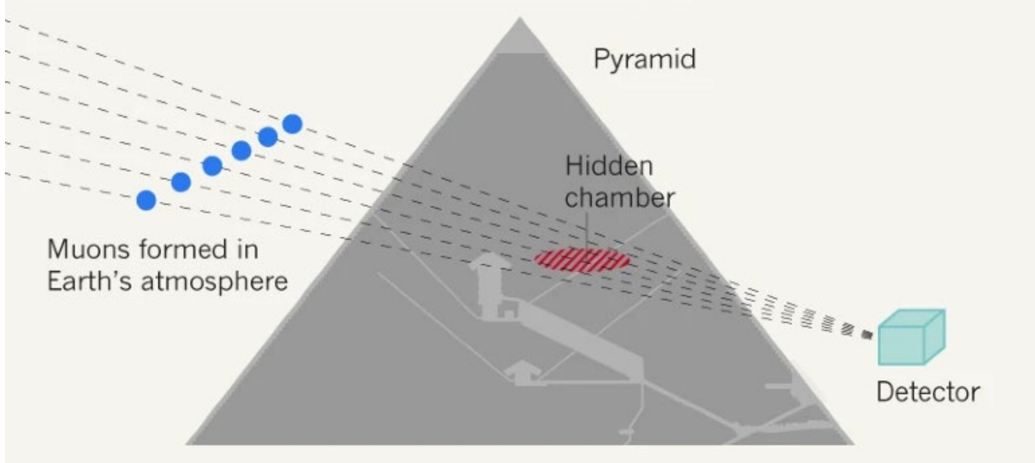
[E. Ploerer et al., *Characterisation of analogue MAPS produced in the 65 nm TPSCo process, JINST* 20 (2025) 01, C01019]

Beyond-HEP Applications

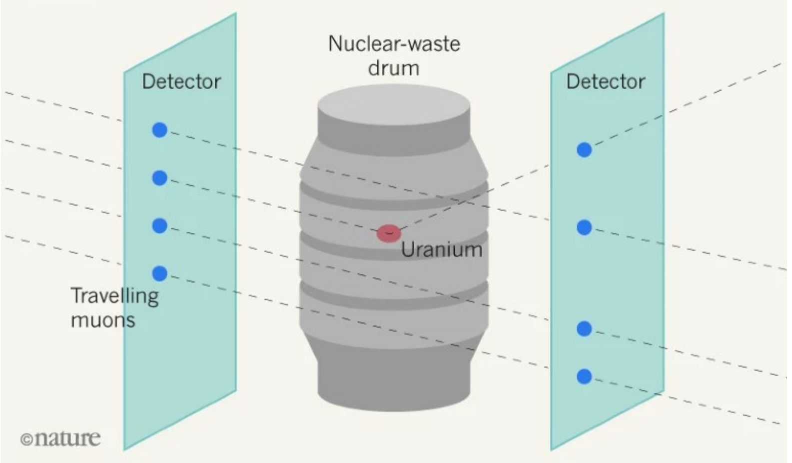
I. Muon Radiography

An imaging technique that utilizes naturally occurring cosmic-ray muons to probe the internal structure of large-scale objects

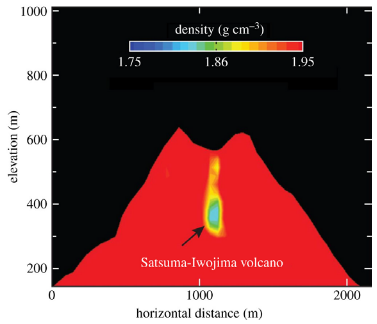
Absorption/transmission muography vs. **scattering muography**

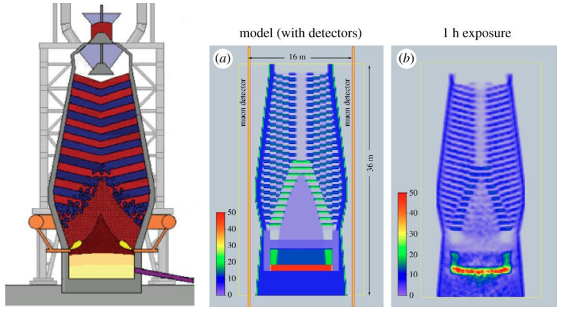


- sensitive to density
- 2D image, also 3D with multiple viewpoints
- applicable to very large targets
- relies on knowledge of incident muon flux



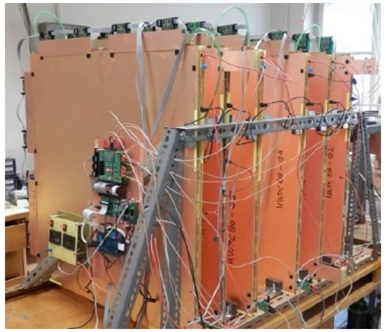
- sensitive to atomic number
- 3D image
- small to medium size targets
- high position resolution, large area detectors





<u>Common detector technologies for muography</u>:

- Plastic scintillators
- Nuclear emulsions
- Gaseous detectors (MWPC, Micromegas, RPC …)

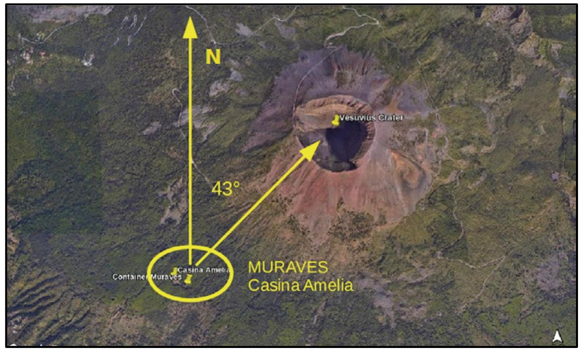


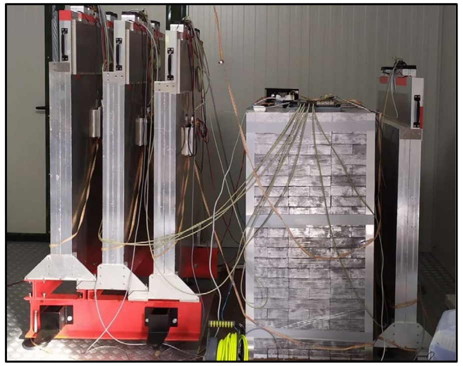
➢ **HEP technology for interdisciplinary scientific research (geoscience, archaeology …), industrial applications, nuclear safety …**

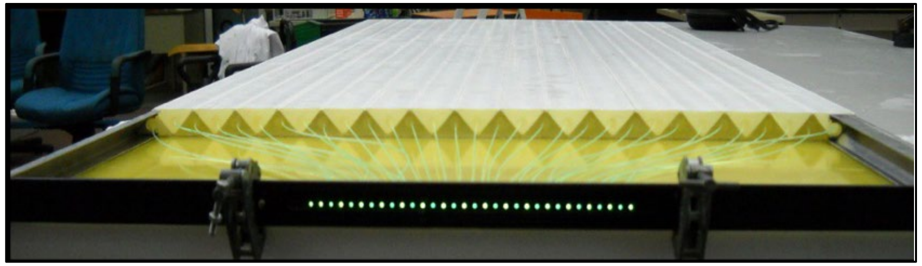
Muraves and ScIDEP projects

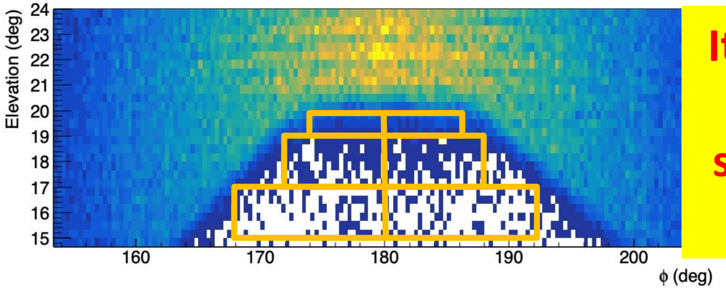
Plastic scintillator based muon telescopes for absorption muography studies of

Mt. Vesuvius, Italy (Muraves)





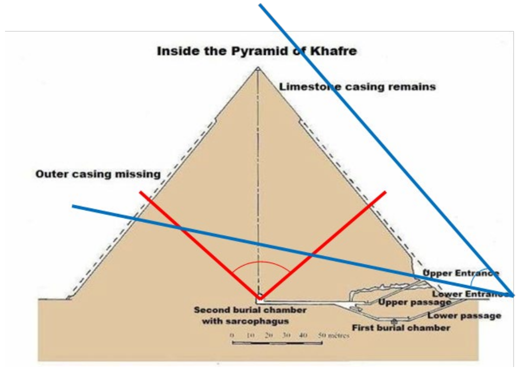


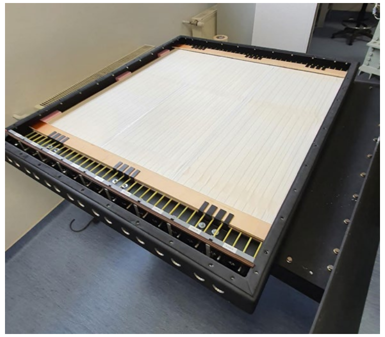


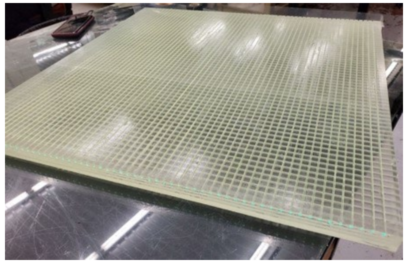
Italy + UCLouvain & VUB; data taking since 2019; supported by FNRS-FWO Weave project

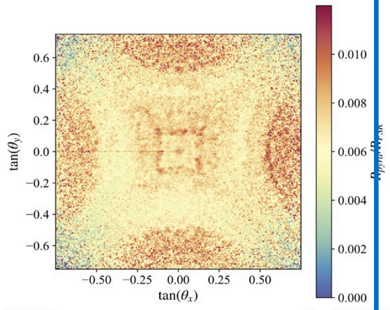
[Y. Hong et al., *Updates on MURAVES Project at Mt. Vesuvius*, J.Appl.Phys. 138 (2025) 6, 064906]

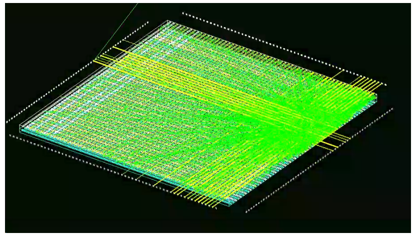
Pyramids at Giza, Egypt (ScIDEP)











Egypt, USA, Romania + VUB detector R&D since 2020

[M. Gamal et al., *The ScIDEP muon radiography project at the Egyptian Pyramid of Khafre*, *J.Appl.Phys.* 138 (2025) 4, 044901]

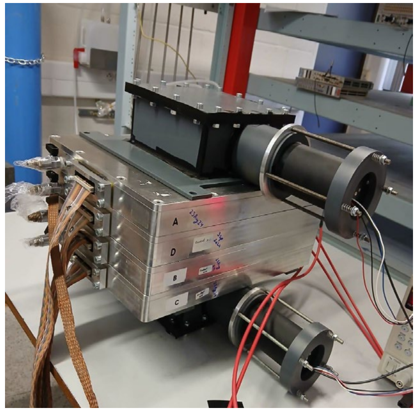
Portable Muoscope Project

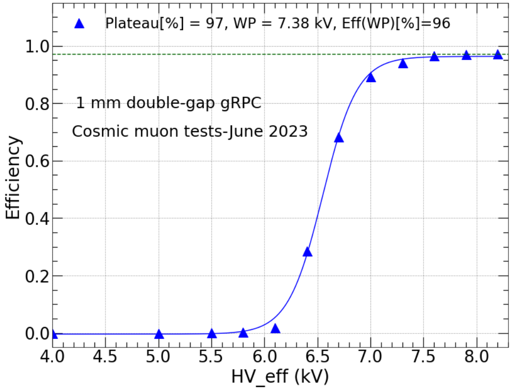
UCLouvain, VUB (past: UGent) + India; embedded in DRD1

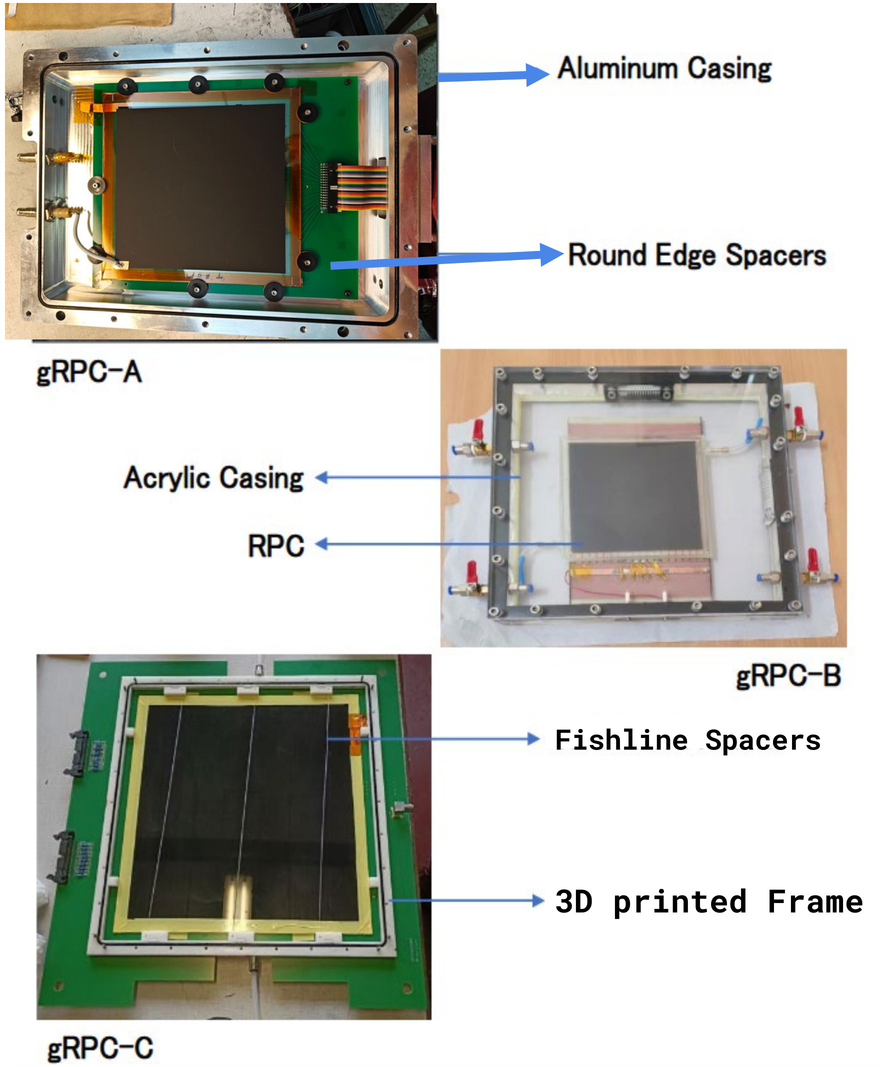
R&D of a **general-purpose, portable gaseous detector based muon telescope for muography applications in confined/remote environments** (geology, archaeology, civil engineering, and industrial safety ...):

- single/double-gap glass-RPC based muon telescope
- design featured by **compactness, portability, robustness, autonomous operation, low power & gas consumption, modular geometry** ...

Detector	A	B	C
Institute	UCLouvain	NISER	UGent/VUB
Size	16 × 16 cm^2	16 × 16 cm^2	28 × 28 cm^2
Outer Casing	Aluminum casing	Standalone RPC housed in acrylic casing	Closed with top and bottom PCBs
Readout Strips	16-1D	16 × 16 - 2D	32 × 32 - 2D
Strip Pitch	1 cm	1 cm	0.8 cm
Gas mixture	95.2% Freon, 0.3% SF6, 4.5% isobutane		
Gas Gap	1 mm Single gap	2 mm Single gap	1 mm Double gap
Thickness of Electrodes	1.1 mm	3.0 mm	1.1 mm
Resistive Coating	Serigraphy (~ 4 MΩ/☐) and Hand-painted (0.5-1.0 MΩ/☐)	Spray gun (~ 1 MΩ/☐)	Spray gun (~ 1.5 MΩ/☐)
DAQ	NIM + CEAN integrated / custom made and ASIC + FPGA		
Portability	Yes	Yes (Currently operating in gas flow mode)	Yes (Currently operating in gas flow mode)



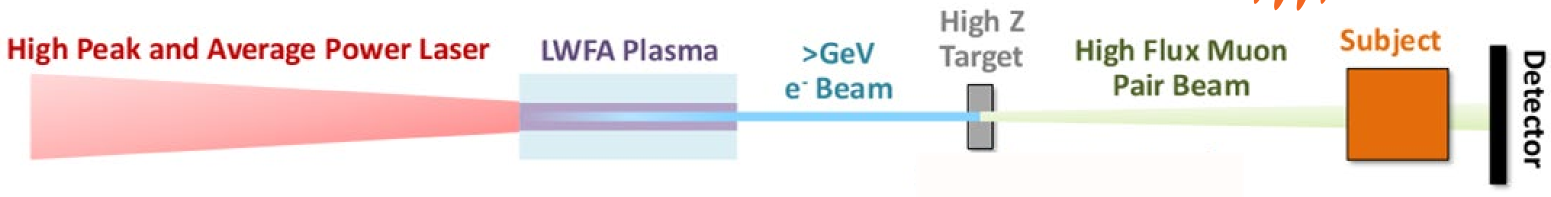


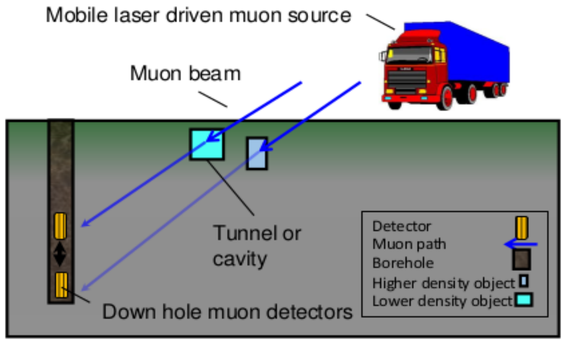


[S. Ikram et al., *Development and Performance Analysis of Glass-Based Gas-Tight RPCs for Muography Applications*, arxiv: 2504.08146 [physics.ins-det]]

Portable Muoscope @ ELI Laser-Driven Muon Source

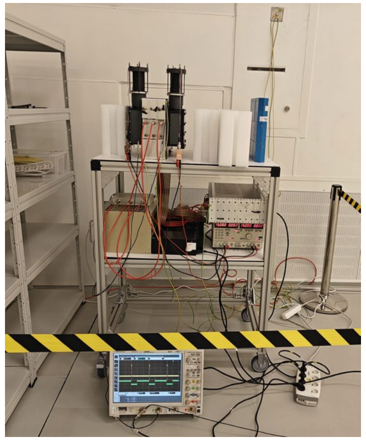
Compact (<100m^2) GeV muon production driven by laser electron acceleration at ELI (Extreme Light Infrastructure) Beamlines laser centre (near Prague, Czech Republic)

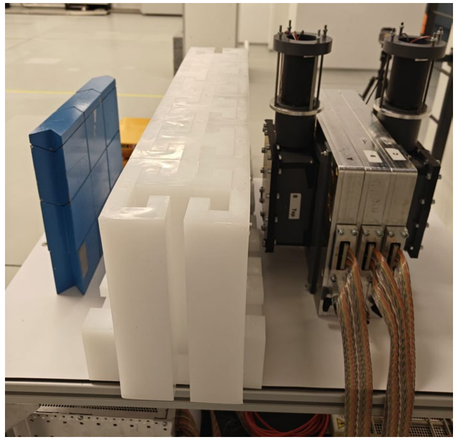




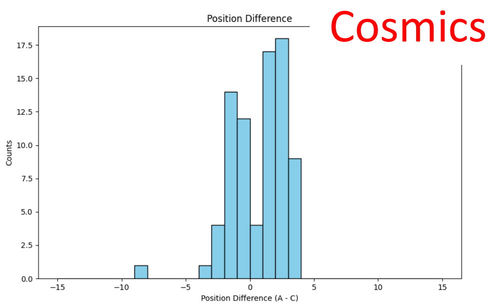
Multi-PW lasers can produce >GeV e- beams, yielding $10^{3\text{-}4}$ μ/shot

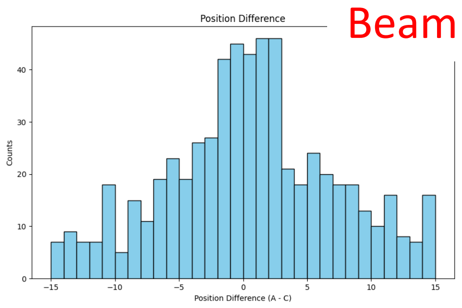
- **High Particle Flux:** high particle rates ↔ low cosmic muon rates
- **Controllable Energy**: control over the energy of the beam ↔ wide energy cosmic muon spectrum
- **Known Directionality**: well-defined beam direction ↔ random directions of cosmic muons





First muon source users at ELI, now in 2025!
Data taking with portable RPC muoscope in April-May and August 2025; data analysis ongoing





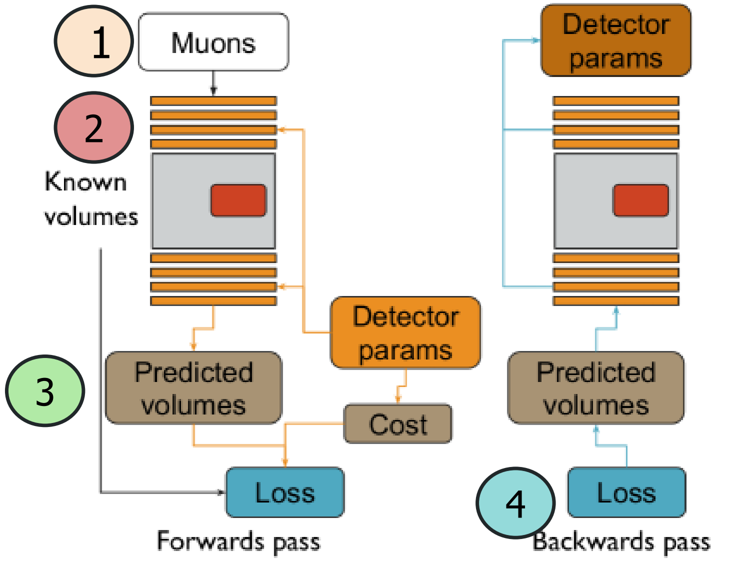
UCLouvain & VUB

TomOpt & Silentborder

Muon scattering **Tom**ography

Optimisation

- **Optimisation of scattering muography detector design with differentiable programming**
- End-to-end, differentiable wrt. detector design parameters



1 Muon generation

2 Hit recording and propagation

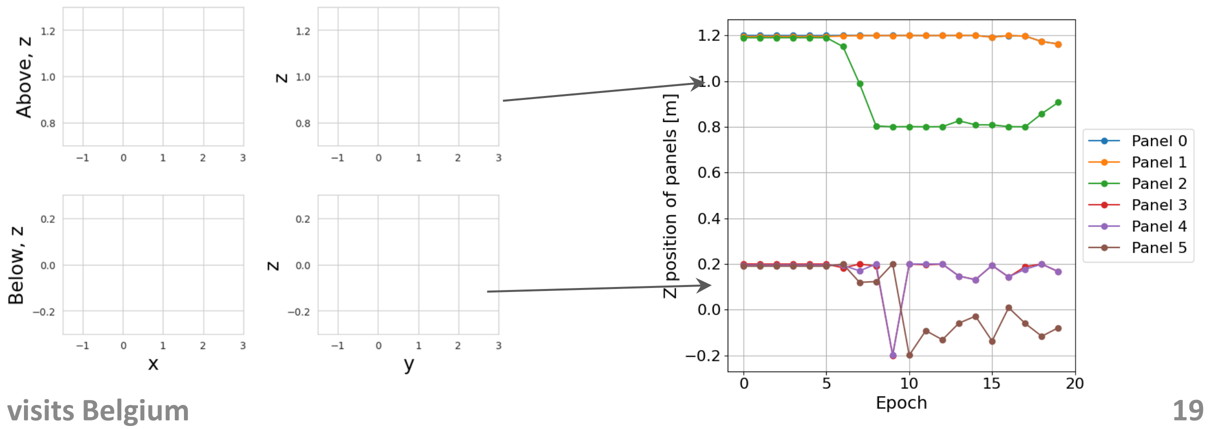
3 Inference

4 Loss calc. & backpropagation

Various universities/companies /customs + UCLouvain; supported by H2020

SilentBorder: identification of hidden hazardous and illegal goods in trucks and sea containers using scattering muography

- Optimize detector design with TomOpt, i.e. minimal gap (electronics, PMT channels, protecting case) between detector modules; separation of inner sensitive panels in each detector module
- Inference-agnostic approach: optimizing tracking angular resolution

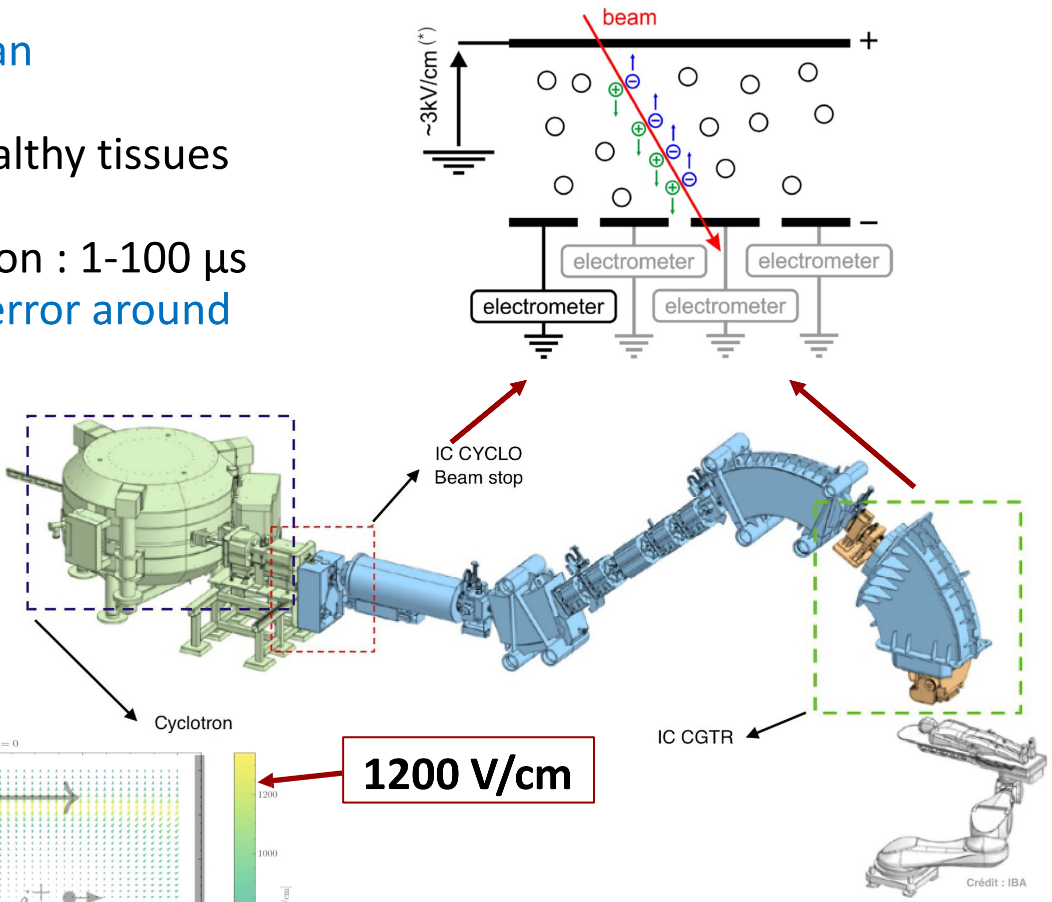


II. Dosimetry for Proton Flash Therapy

ULB; collaboration with IBA; supported by ProtherWal project

Flash proton radiotherapy

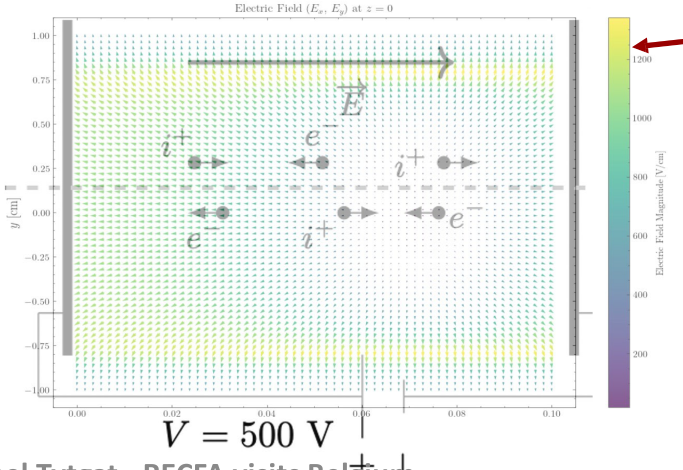
- Deliver high doses (>40 Gy/s) within a few milliseconds (10X higher than conventional proton therapy …)
- Biological effect - Studies have shown that FLASH has less effect on healthy tissues around the tumor
- Specifications for pulsed beams: dose/pulse ~ 1Gy/pulse, pulse duration : 1-100 μs
- Requires accurate real-time measurement of the delivered dose with error around <0.5% and around <10% for dose rates



Dose monitoring of Proteus One

- 230 MeV proton beam intercepted by air-filled Ionization Chambers (IC) measuring current (charge)
- In Flash proton-therapy, up to 100 pC/pulse, ie. released charge is so high that there are issues with recombinations & space charge screening effects, distorting linearity
- Corrections for ion recombination via Boag models, but no good agreement was found between data for flash doses

➢ **Detailed simulations needed, i.e. Garfield++ and dynamic electric field computations**



PSQUAD - Patient Specific QUality Assurance Dosimetry

A semiconductor-based flat panel detector for radiotherapy and proton FLASH therapy

Geant4 Simulation

- Geant4 Simulation via proton pencil beam scanning (PBS)
- Simulating IBA Razor diode
- Performing Irradiation measurements at the Proton Therapy Center in Prague.

Characterization

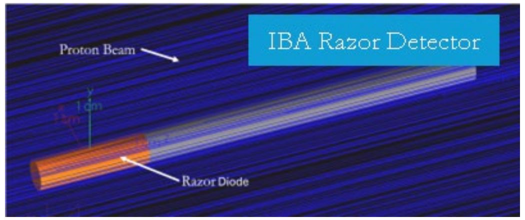
- Acquiring an a-Si TFT pixel array and performing electronic and irradiation characterization.
- Probing results show low leakage current in dark conditions and stable current with light exposure

Laser Measurements

- Using a high-power green laser, the proper functionality of the bonded test board can be tested (Figure 10).
- The detector's charge sensitivity was measured for different reverse-bias voltages, showing slight sensitivity changes.

Proton Irradiation

- Irradiating the IBA Razor diode along with the a-Si Pixels.
- Both Detectors showed pristine charge linearity
- Further plans for irradiating under ultra-high-dose-rate conditions



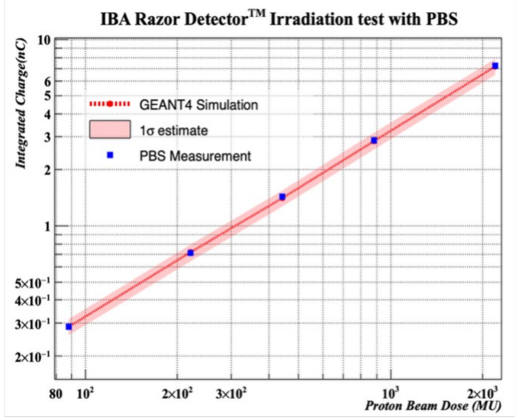


Figure 1: Measurement results showing pristine charge linearity and simulation agreement with <1% offset

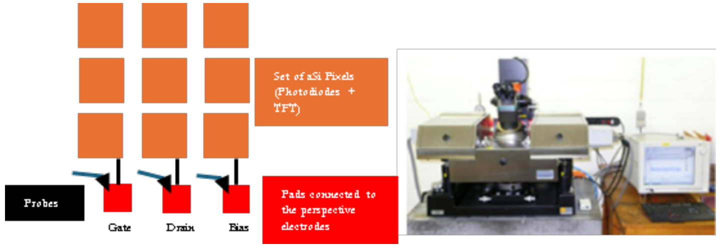


Figure 8: Illustrating how the probing measurements were taken using the PM8PS Semiconductor Probing Device

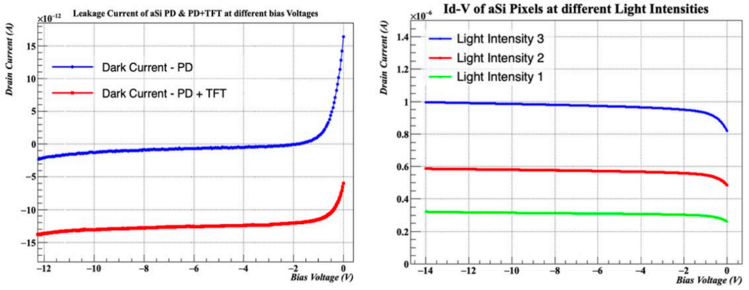
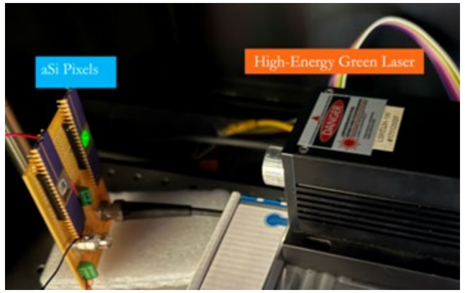
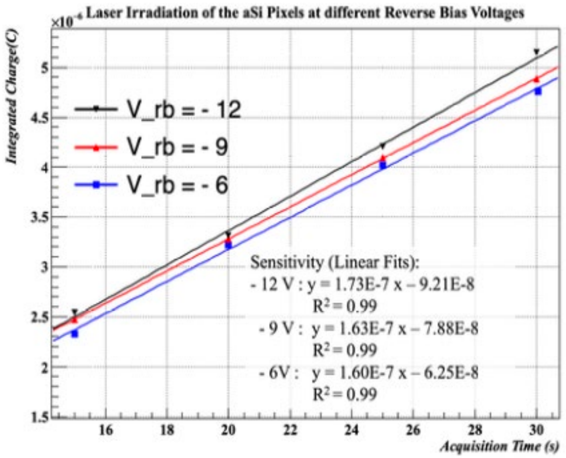
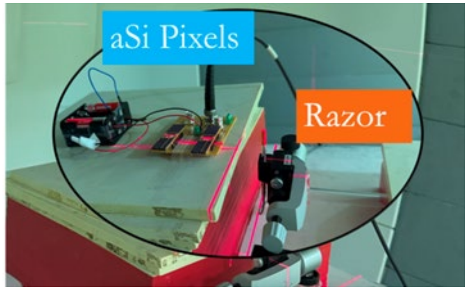


Figure 9: Drain Current measured in dark(a) and light conditions (b) to assess charge stability at different reverse bias voltages.







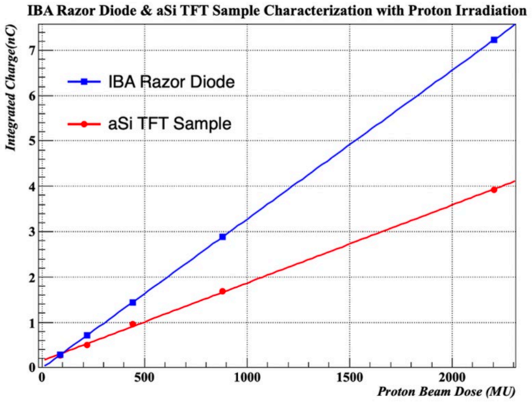


Figure 14: a-Si pixels (red) and RAZOR (blue) Detectors' charge acquisition vs. proton beam dose (MU)

UCLouvain; collaboration with IBA; supported by Wallonne region

Concluding Remarks

Funding for R&D projects

Current funding for detector R&D projects remains relatively limited; the past few years mainly yielded:

- Muography:
  - 3 European H2020 projects: typical large consortia result in minimal budget per partner
  - 1 FNRS-FWO Weave project: scientific personnel plus a small amount of equipment
- Dosimetry: support from ProtherWal and Region Wallonne
- Future Colliders: 1 FWO research project: mainly personnel
- Equipment:
  - Small amounts from FNRS/FWO/university funds

<u>Some issues we experience</u>

- **Funding is mostly "physics" or application-driven**, i.e. generic R&D that pushes technology boundaries (à la DRD collaborations) is difficult to sell

- HEP R&D projects sometimes get **ping-pong**'ed **between fundamental and applied physics/engineering committees**

- **R&D projects are typically long-term, and require dedicated, often custom-made infrastructure at the start**, i.e. long before one gets to the possible construction and application phase

- Securing **technical/engineering staff**, which is essential for these projects, **remains a challenge**

Concluding remarks

The **Belgian HEP community has a rich history in detector R&D**, with contributions to essentially all of our projects in

- Collider physics @ CERN/LHC
- Astroparticle/neutrino physics experiments
- Gravitational waves
- Future Colliders
- Beyond-HEP applications (muography, dosimetry)

Belgium is a major contributor to the CMS Phase-2 upgrade, in particular Outer Strip Tracker and Muon-RPC/GEM systems, where both projects moved from R&D to the construction/installation/commissioning phase

The **LHC post-LS3 phase may open room for increased detector R&D activity towards future colliders**; the global direction of the Belgian collider community is yet to be determined

Belgium has a clear "spin-off" **detector R&D program for Beyond-HEP applications**, i.e. muon radiography and medical applications

Detector R&D forms the basis of any HEP-ex project, and in addition leads to opportunities for knowledge transfer to other science branches, industry, and society, i.e. **long-term support of such projects (with dedicated PD/PhD positions, equipment, engineers, technicians …) will be essential to secure the future of our field, and to keep Belgium being great**

Belgium in the DRD Collaborations

DRD1- Gaseous Detectors

Gaseous

- **DRDT 1.1** Improve time and spatial resolution for gaseous detectors with long-term stability
- **DRDT 1.2** Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out schemes
- **DRDT 1.3** Develop environmentally friendly gaseous detectors for very large areas with high-rate capability
- **DRDT 1.4** Achieve high sensitivity in both low and high-pressure TPCs

Belgian members:
- UCLouvain, UGent, ULB, and VUB

Specific activities:
- WG1: Technological Aspects and Developments of New Detector Structures, Common Characterization and Physics Issues → general interest to all
- WG2: Applications / Work Packages
  → Trackers/hodoscopes/large area systems (VUB: RPC)
  → Calorimetry (VUB: large area systems, timing)
  → Timing detectors (VUB: MRPC)
  → Beyond-HEP in muography, medical applications …
  (VUB, UCLouvain: outdoor detectors, portability …)
- WG3: Gas and Material studies
  → gas properties, gas systems, novel materials …
  (UGent: RPC; VUB: EcoGas@GIF++)
- WG4: Detector physics, simulation and software tools
  → Garfield++ (UGent: running on GPU)
- WG5: Electronics for Gaseous Detectors
  → ULB
- WG7: Collaboration Laboratories and Facilities
  → Test Beam Common Facilities (all)

Management:
- M. Tytgat:
  - member of Management Board and Scientific Coordination Board
  - Co-convenor of WG1

DRDTs

1.1	1.2	1.3	1.4	Work Packages
●		●		Trackers/hodoscopes
●	●	●		Drift chambers
●	●	●		Straw chambers
●	●	●	●	Tracking TPCs
●		●		Calorimetry
●	●	●		Photon detection (PID)
●		●		Timing detectors
●	●	●	●	Reaction/decay TPCs
●		●		Beyond HEP

Forum for discussion on common topics

WG1	WG2	WG3	WG4	WG5	WG6	WG7	WG8
Technologies	Applications	Gas and material studies	Detector physics, simulations and software tools	Electronics for gaseous detectors	Detector production	Common test facilities	Training and dissemination

DRD6 - Calorimetry

Calorimetry		
	DRDT 6.1	Develop radiation-hard calorimeters with enhanced electromagnetic energy and timing resolution
	DRDT 6.2	Develop high-granular calorimeters with multi-dimensional readout for optimised use of particle flow methods
	DRDT 6.3	Develop calorimeters for extreme radiation, rate and pile-up environments

Belgian members: VUB

Specific activities:

- WP1 on Sandwich calorimeters with fully embedded electronics
  - Highly pixelized electromagnetic section
  - Hadronic section with optical tiles
  - **Hadronic section with gaseous readout**
    → T-SDHCAL

Management:

- M. Tytgat: member of WP1 Steering Board (T-SDHCAL representative)