Gas-based Detector R&D in DT

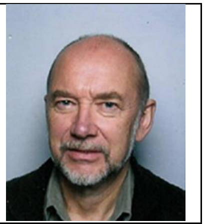
Antonija Utrobicic on behalf EP-DT-DD GDD group

EP-DT group meeting

December 9, 2021

GDD Team 2021/2022

People

							
Leszek Ropelewski	Miranda van Stenis	Eraldo Oliveri	Florian Brunbauer	Dorothea Pfeiffer	Jerome Samarati	Fabio Sauli	Hans Muller
							
Lucian Scharenberg	Antonija Utrobicic	Rob Veenhof	Djunes Janssens	**Karl Jonathan Floethner**	**Marta Lisowska**	**Giorgio Orlandini**	

New people

GDD lab

154-R-007

GDD research topics

Amplification
- GEM
- Micromegas
- µRWELL
- …

Solid converters
- PICOSEC
- NMX
- Graphene research

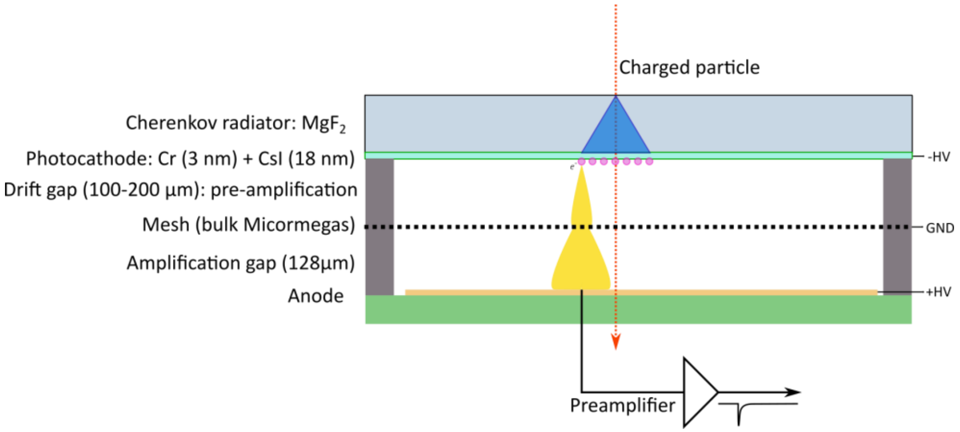
Readout
- Electrical
- Optical
- Hybrid

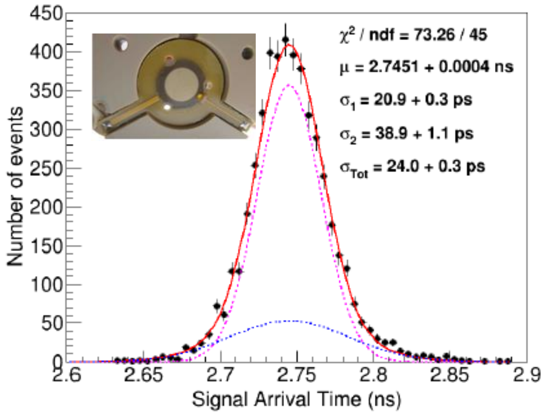
Electronics
- VMM3a & SRS
- Custom precise timing electronics

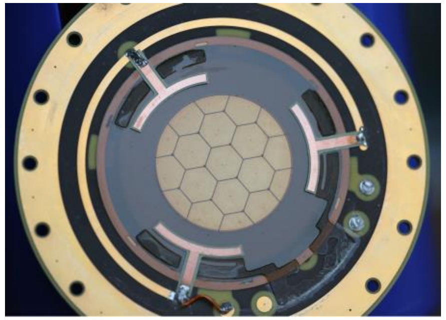
Simulations and modeling
- GARFIELD++
- COMSOL
- Magboltz

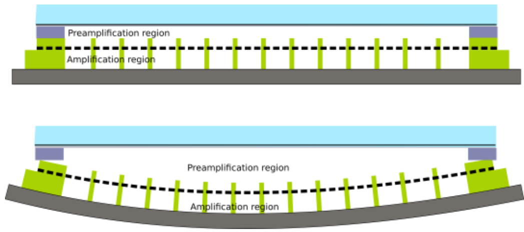
CERN EP R&D RD51 Collaboration GDD Gas Detectors Development Group

PICOSEC Micromegas detector









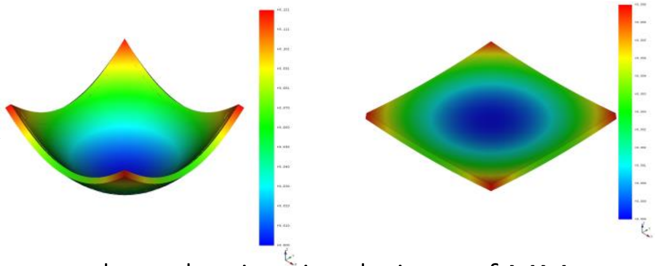
First (19 ch. Prototype of active area of Φ3.6 cm)

- Very good results (25 / 30 ps at the pad center/edges)
  - but only after correction using hit position from tracker to account for PCB bending
- Measured deformations in the range of 30 µm in the active area -> time error in SAT 100/200 ps

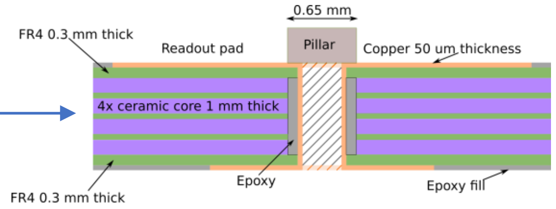
Purpose: give **precise timing** information of the passage of the particle.

Successful proof of concept with single channel (Φ1 cm) prototype- **PICOSEC can achieve timing ~25 ps for MIPs.**

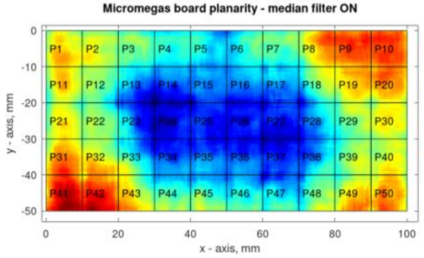
New 100 channel prototype



Structural mechanics simulations of MM board deformation under mesh tension



Design choice: 4mm thick embedded ceramic



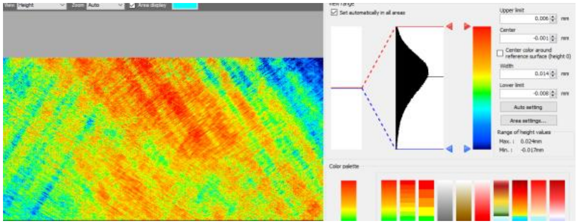
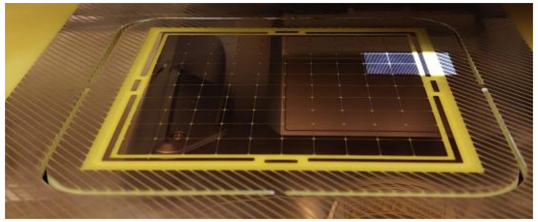
Production follow up with planarity measurements and analysis

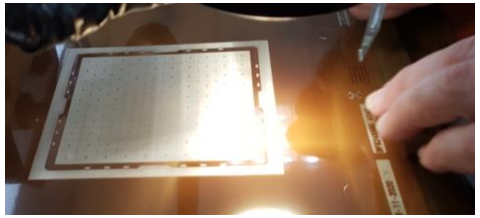
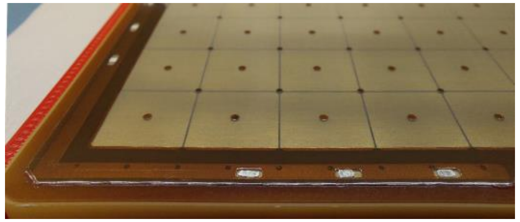
Antonija Utrobicic, RD51 CM June2020: https://indico.cern.ch/event/911950/sessions/348123/#20200626

Antonija Utrobicic, Djunes Janssens, Marta Lisowska, Florian M. Brunbauer and Hans Muller

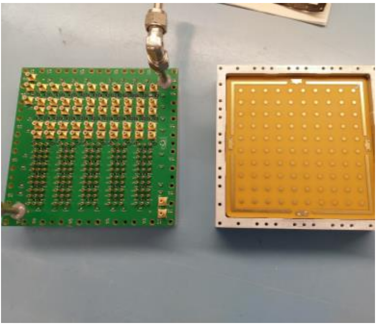
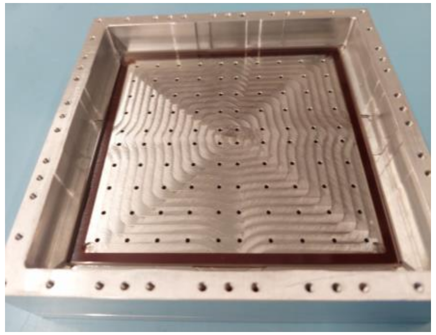
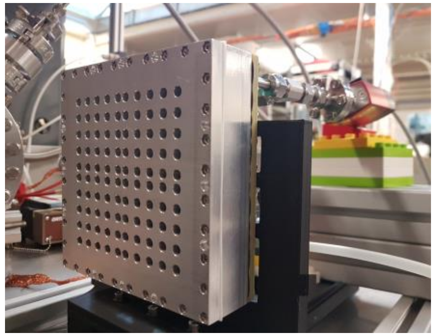
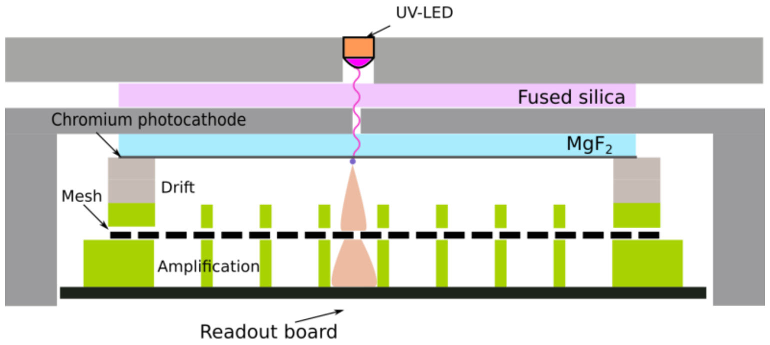
Picosec Micromegas 100 channel detector

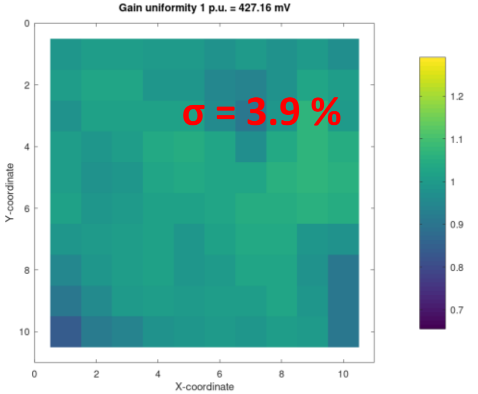
Improvements in MM production: ensure planarity below 10 µm: machine fattening, residual stress reduction methods, thermal profiling during the production, fine polishing, supervision of the production using Keyence 3D Macroscope, tight cooperation with **MPT (Rui De Oliveira, Antonio Teixeira, Olivier Pizzirusso and Bertrand Mehl).**

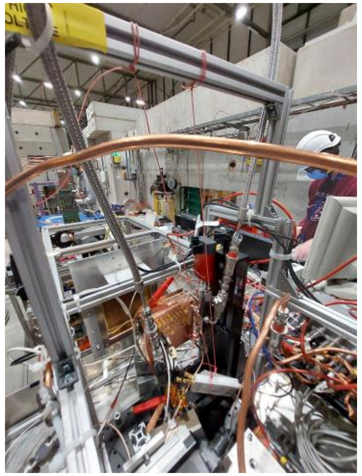



New chamber design: mechanical decoupling of the crystal and MM board from housing, usage of spring-loaded contacts, collimation holes for UV light calibration, additional fused silica window (sealing), laboratory gain uniformity measurements. Achieved gain uniformity of 3.9 % over the 10x10 cm^2.



Test beam measurements @ H4 beam line of the SPS: two prototypes (CsI and DLC photocathode) tested. Preliminary results show time resolution below 25 ps at all tested pads for CsI photocathode prototype and 45 ps for one with the DLC.



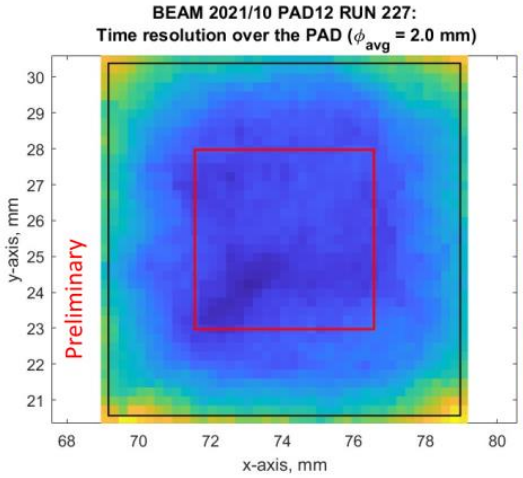
Time resolution, CsI photochatode, V_{CAT} 500 V **Preliminary**

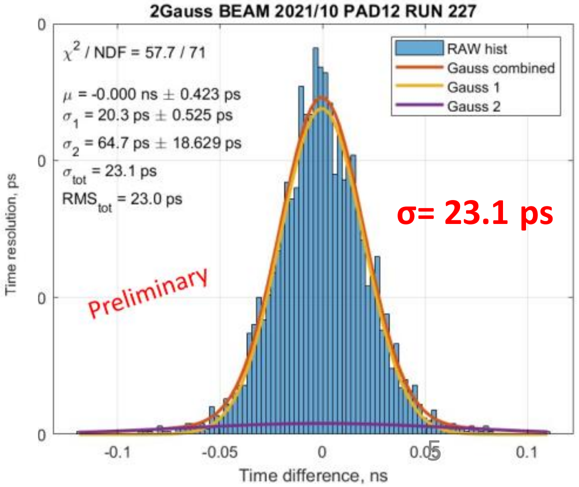
PAD	03	06	12	13	15	16	17	18	20	26	36	41
σ, ps	24.6	24.1	24.6	23.9	22.1	22.9	24.7	23.0	23.0	23.9	23.9	24.0

Time resolution, DLC photochatode, V_{CAT} 550 V (570 V) **Preliminary**

PAD	12	14	21	23	27	29	31
σ, ps	44.8 (41.3)	46.3 (45.4)	40.3 (41.4)	46.1	46.7	45.3	42.9 (40.0)

Antonija Utrobicic, RD51 mini week:
February 2021: https://indico.cern.ch/event/989298/sessions/378403/#20210216
Antonija Utrobicic, RD51 collaboration meeting:
June 2021: https://indico.cern.ch/event/1040996/timetable/
October 2021: https://indico.cern.ch/event/1071632/sessions/408827/#20211116
More info on PICOSEC test beam: Marta Lisowska: https://indico.cern.ch/event/1071632/sessions/408824/#20211119





Working plans for next months :GEM-based tracking system for future experiments

Upgrade of existing triple GEM tracking detectors for COMPASS++/AMBER.

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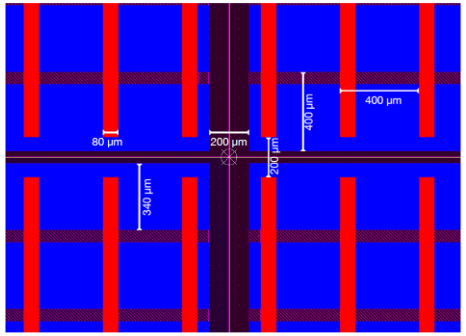
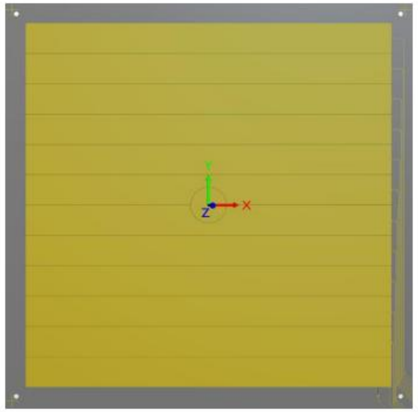
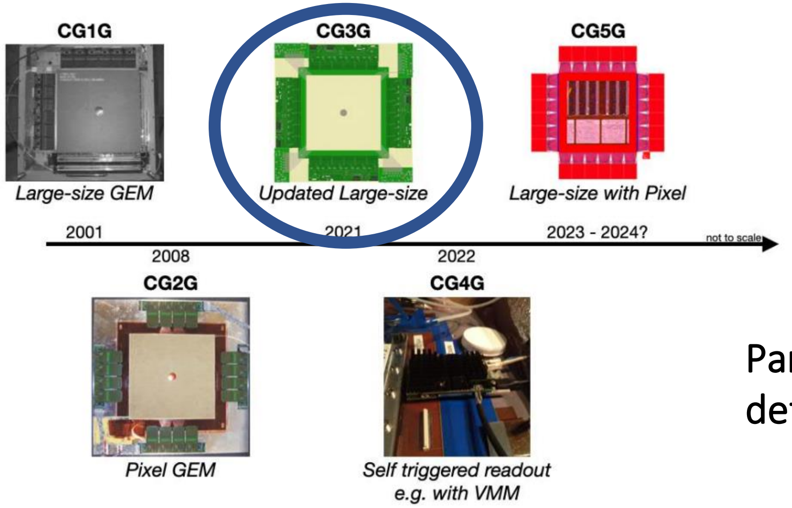
Currently ongoing production of large-size GEM (CG3G). Improvements in detector design:

- 30.7 cm x 30.7 cm
- **Reducing occupancy: strips divided in the readout plane center**.
- 13 times top-sectored GEM
- **Reducing dead area: spacers without grids**.
- **Modular design** (APV & VMM exchangeable)
- **Reducing material budget:** Additional copper etching
- **Improved gas distribution**.

Readout Plane Centre



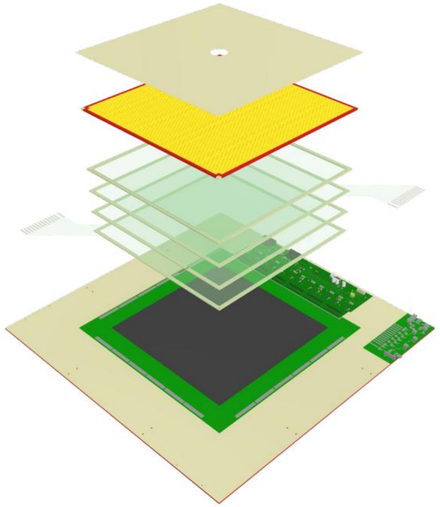




Schedule for the COMPASS GEM generations

Future upgrades:

- Large area coverage (40 cm x 40 cm)
- High-rate capabilities.
  - Self triggered readout electronics.
  - Different readout design (with pixel region).



Parallel research in the lab on improving GEM detector:

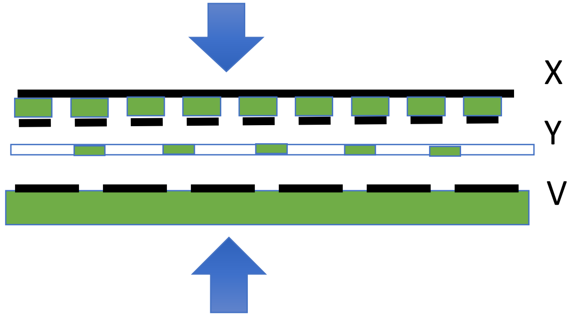
- Better spatial resolution, usage of small pitch GEMs, sectorization, HV distribution..

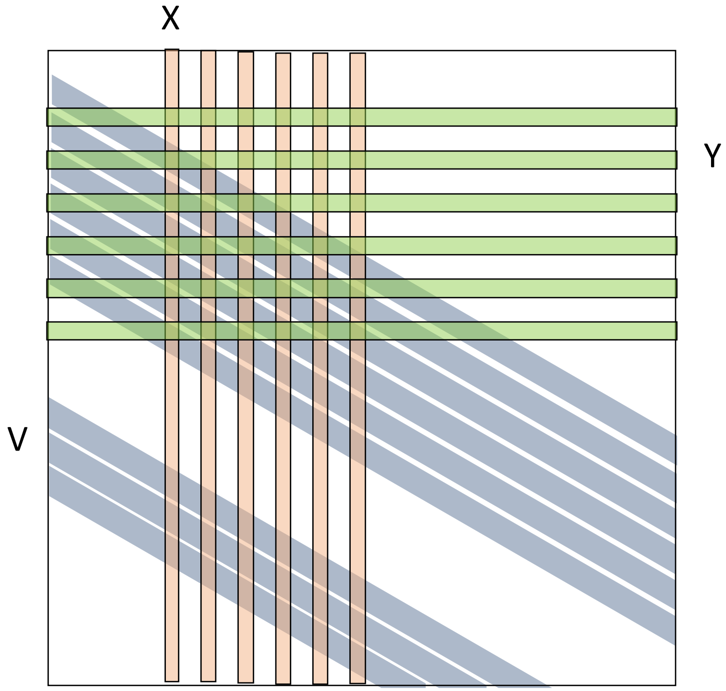
Karl Jonathan Floethner

Ongoing work: 3-dimensional X-Y-V GEM readout

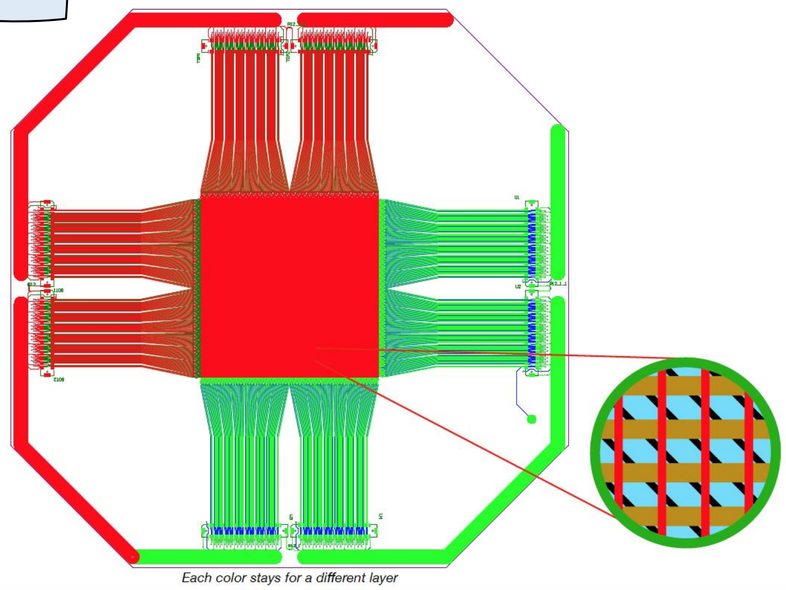
To improve particle detection in high rate environment a third coordinate can be introduced for the charge collection.

Fabio Sauli, Rui de Oliveira, Karl Jonathan Floethner and Djunes Janssens

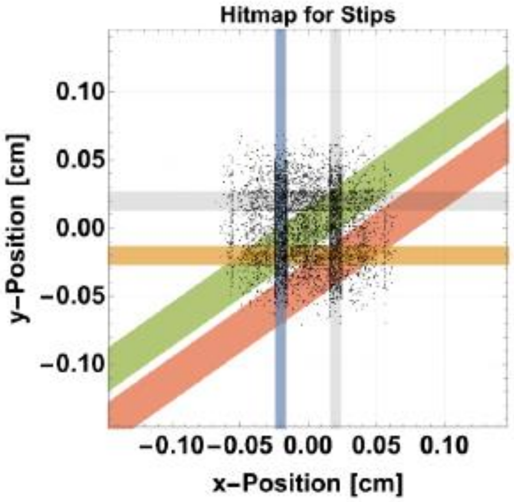


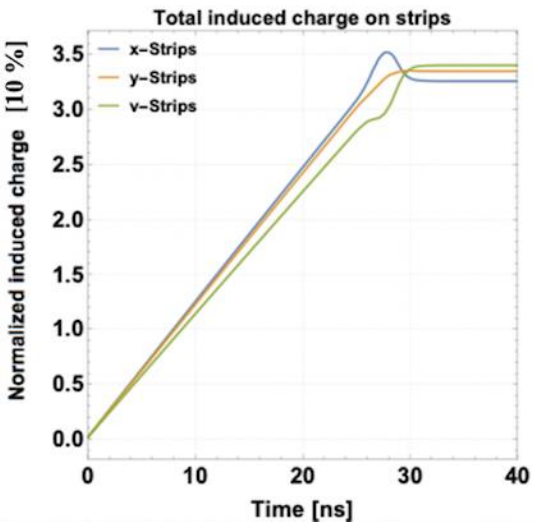


PCB layout



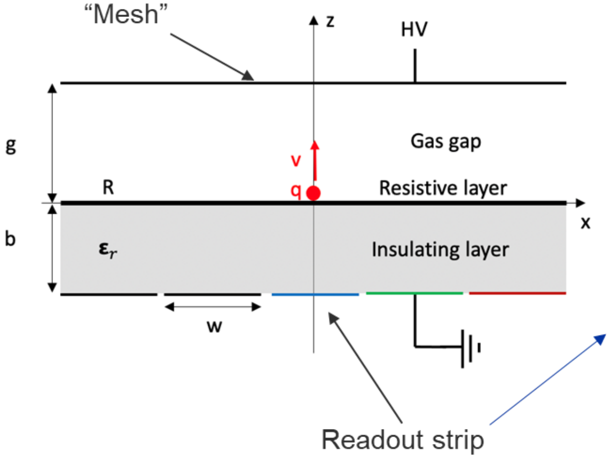
Charge Sharing Simulation

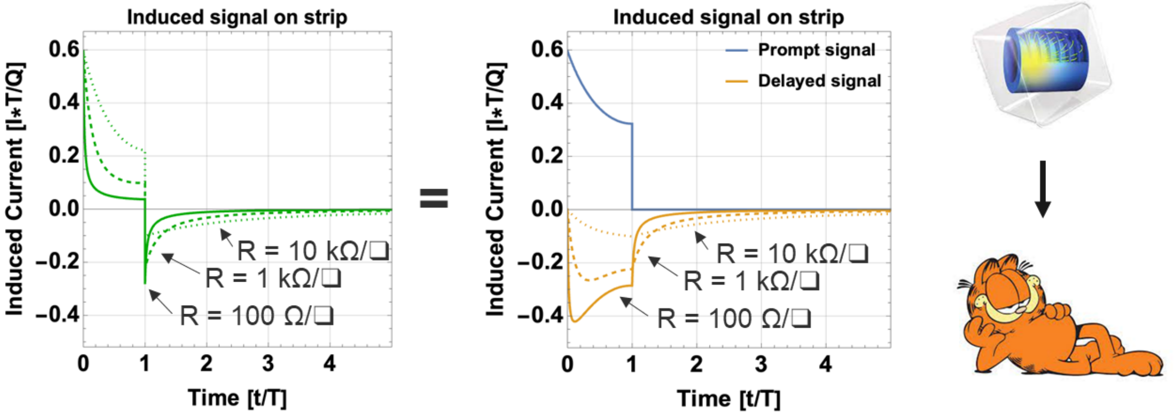




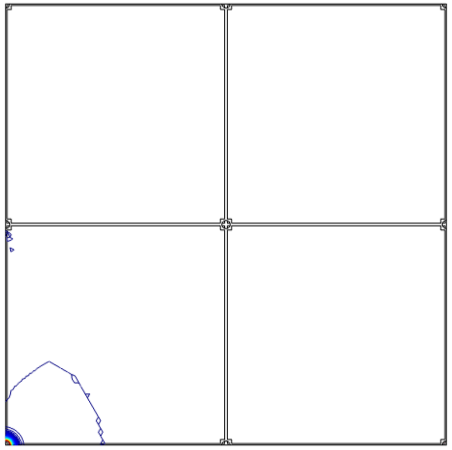
Simulation of induced signals on resistive electrodes

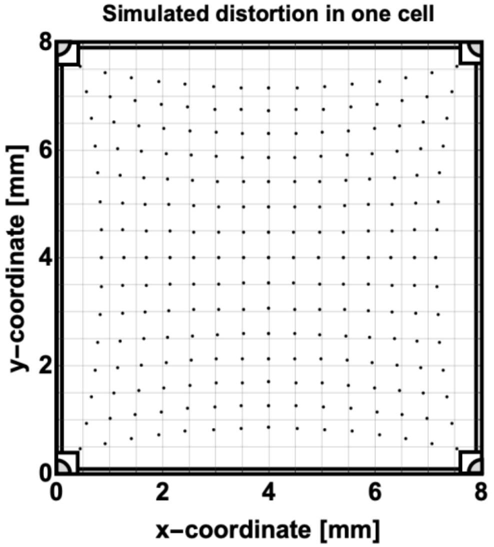
- Re-introduced by the ATLAS New Small Wheel (NSW) community in the Micromegas, resistive electrodes are now applied to different detectors within the MPGD family to improve their performance and robustness.
- Weighting potentials are used to simplify the calculation of the induced current.
- The induced signal is calculated using an extended form of the Ramo-Shockley theorem for several geometries.



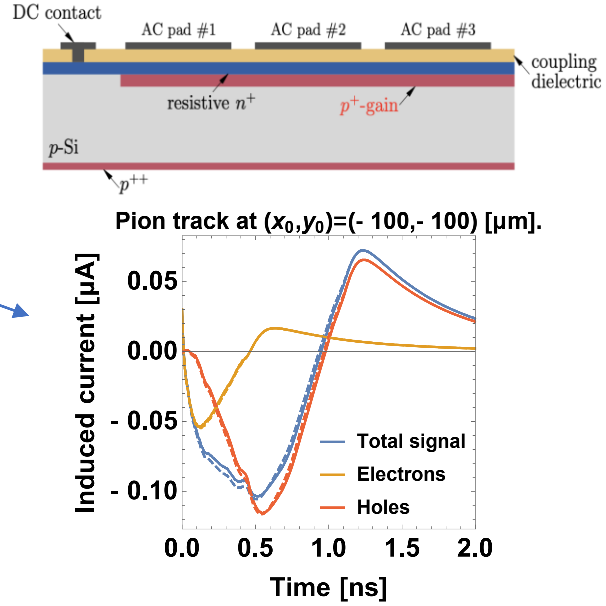


Time-dependent weighting potential map for one readout node





- MicroCAT's two-dimensional interpolating readout
- Multigap Resistive Plate Chambers (MRPC)
- AC-Coupled Low Gain Avalanche Detector
  - Collaborating with INFN Torino group of N. Cartiglia
- Resistive Picosec Micromegas Detector
- µ-Resistive-WELL
- Small-pad resistive Micromegas
- Resistive-strip bulk Micromegas



Djunes Janssens

EP-DT-DD section meeting: https://indico.cern.ch/event/1096954/

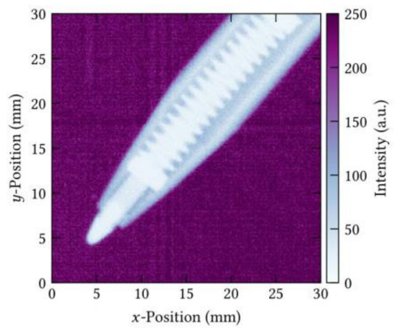
M. Tornago et al., Nucl. Instrum. Meth. A **1003** (2021).
F. Bartol et al. J. Phys. III France, 6 (1996), p. 337
A. Sarvestani et al., Nucl. Instrum. Meth. A 410 (1998) 238–258
A. Sarvestani et al., Nucl. Instrum. Meth. A, 419 (1998) 444
Garfield++: https://garfieldpp.web.cern.ch/garfieldpp/
COMSOL Multiphysics: https://www.comsol.ch
W. Riegler, JINST **11** (2016) no.11, P11002.

MPGDs readout with VMM3a front-end in the RD51 Scalable Readout System

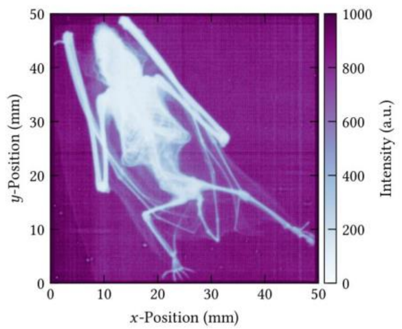
Motivation: to have readout electronic with the high-rate capability suitable for gaseous detector.

- **LAB measurements with single detector (8 VMMs).** Total 512 channels.
  - Measurements with Soft X-ray.
  - Demonstration of rate-capability.
  - Using neighboring logic hardware feature to improve position sensitivity.
- **Beam measurements with telescope and DUT (42 VMMs).** Total 2688 channels.
  - Measurements with MIPs (also using fine-pitch GEMs for spatial resolution studies.)
  - July/October test beam: operation stability, rate performance, position and timing performance.
  - During pion beam, rate limits @10^7 particles per spill.

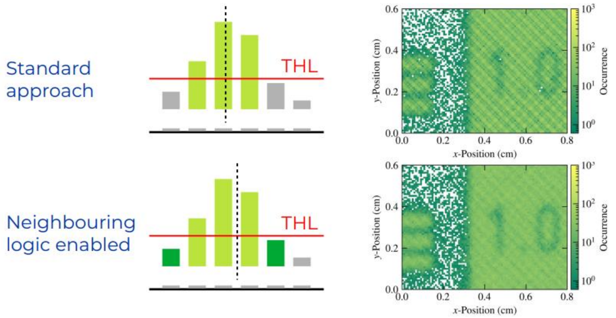
20.8 Mhits/s and **1.7 MHz** cluster rate



50×10^6 clusters in 30 s



277×10^6 clusters in 180 s



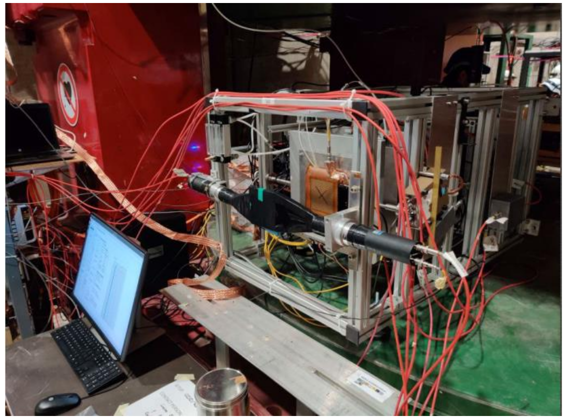
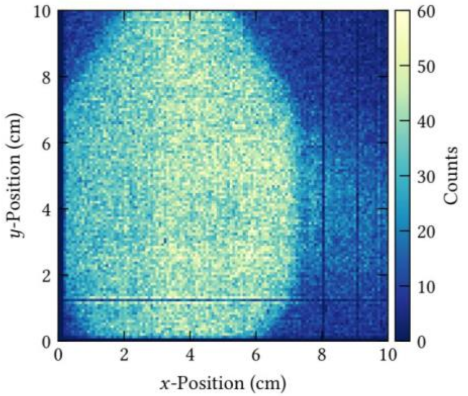
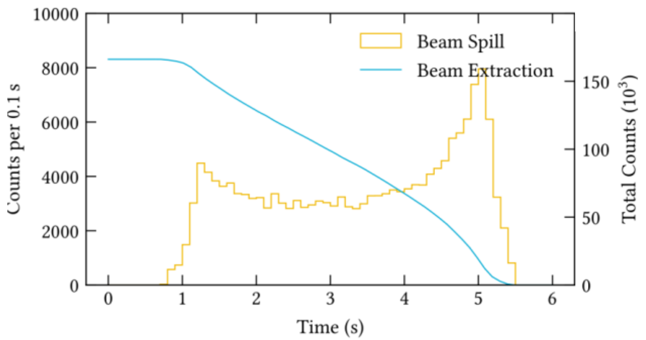


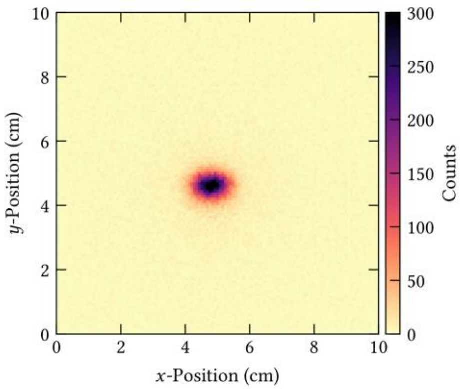
Image of the muon beam



Spill and spill extraction



Reconstruction of the extraction profile of the SPS beam spills to the North Area
→ compatible with SPS Page 1



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Lucian Scharenberg, Hans Muller, Karl Jonathan Floethner, Dorothea Pfeiffer

RD51 VMM3a hybrid for ESS readout

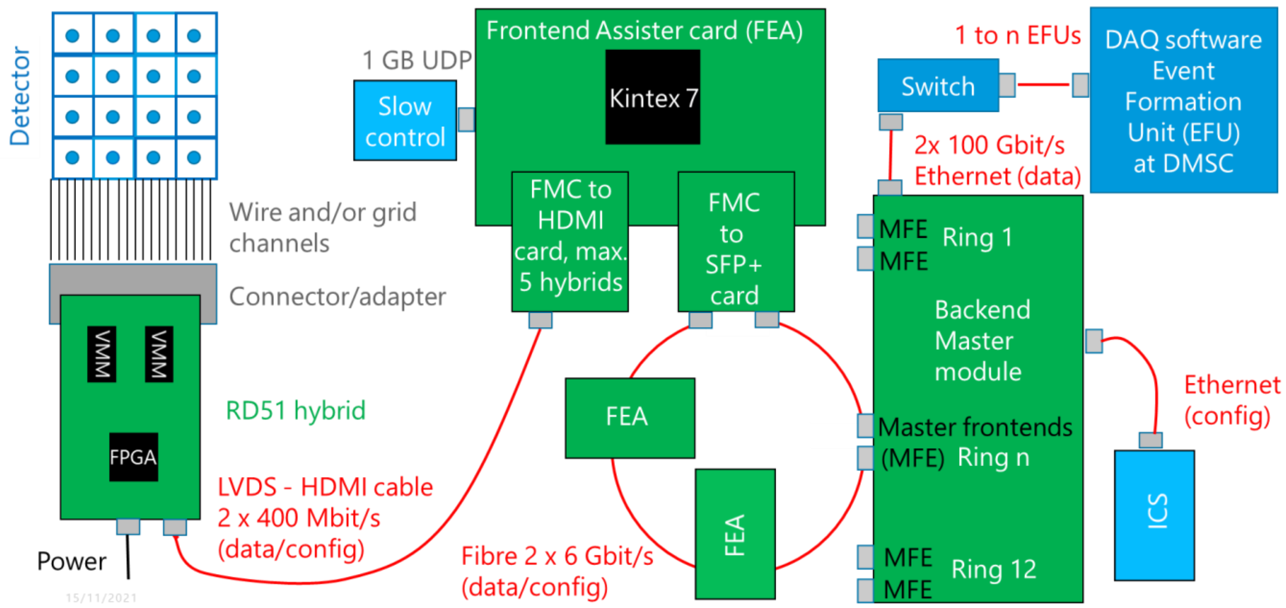
Integration of RD51 VMM3a hybrid into ESS

- SRS FEC Virtex6 firmware substantially rewritten and used in FEA Kintex 7 FPGA.
- FEA data transmission via rings (2 x 6 Gbits/s per ring).
- Slow control via individual 1 GB UDP port on the FEA (debugging).
- Current adapter card connects two RD51 hybrids to the FMC connector of the Kintex evaluation board (Final version - up to 5 RD51 VMM3a hybrids).

Upgrade of RD51 hybrids to Spartan 7 FPGA

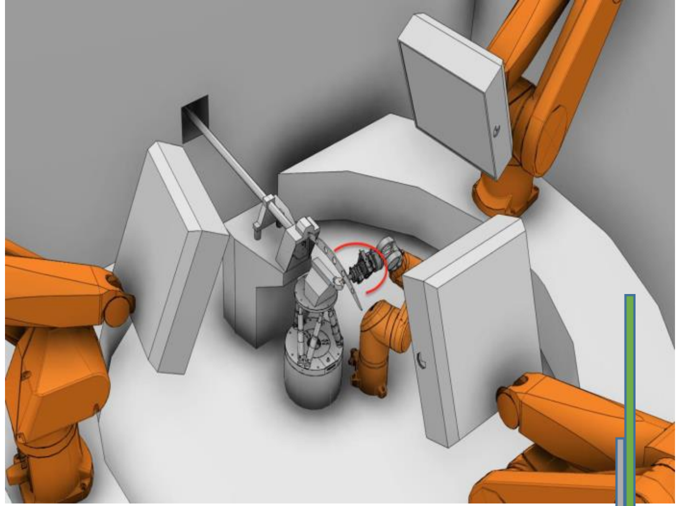
- New firmware written.
- Larger flash 128 MB.
- GEO ID feature added.
- Two prototypes tested; stable operation achieved.

Dorothea Pfeiffer

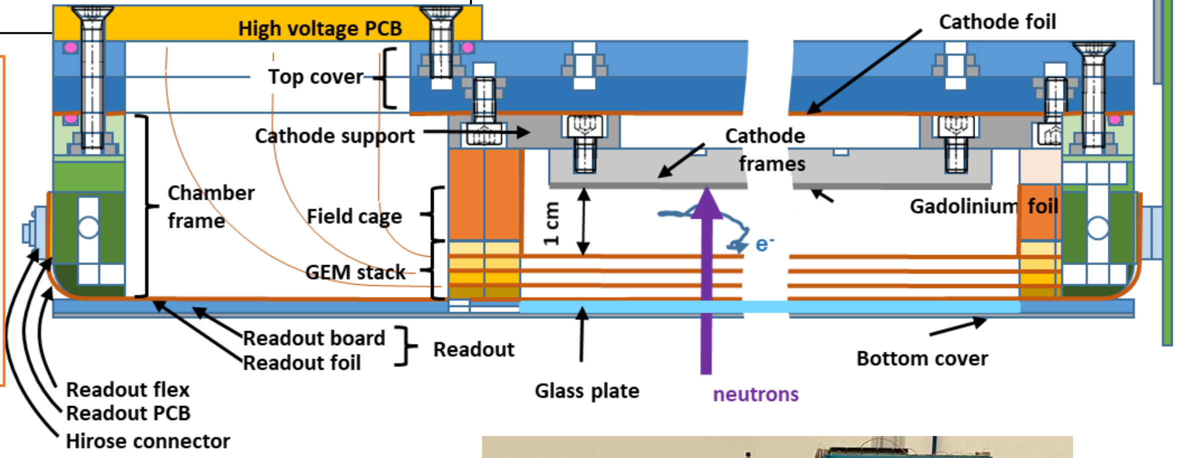


High resolution neutron detector for NMX

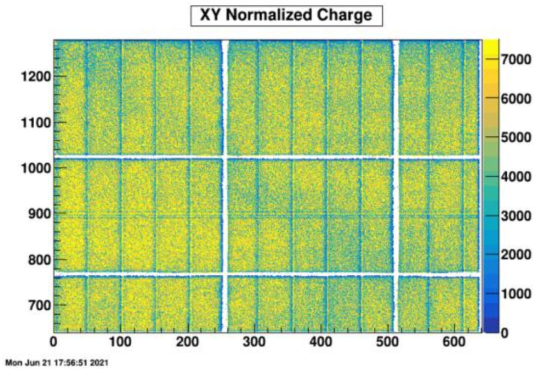
- ESS is multi-disciplinary research facility (currently under construction) based on the most powerful neutron source.
- 1 of the 22 planned instruments is designed to perform Neutron Macromolecular Crystallography.
- Purpose of the NMX instrument is to determine structures of complex proteins, in particular location of hydrogen atoms in the structure.
- Requirements: **position resolution** of ***O*****(200µm) and time resolution *O*(ns).**

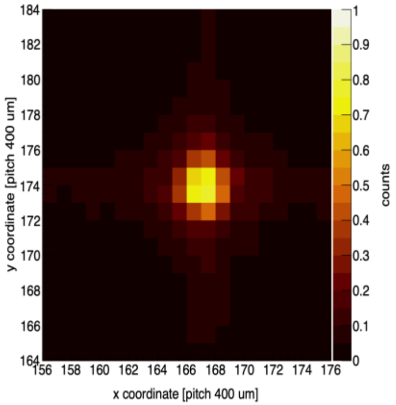


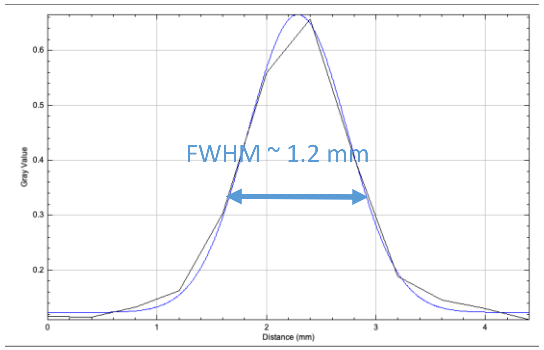
- Triple-GEM detector with natural gadolinium as neutron converter
- Active detector area 50 x 50 cm².
- Readout anode: thin stretched foil, x/y strip readout with 400 um pitch
- Improving readout plane flatness with glass plate.
- Using the RP facility's neutron sources, the response of the system is tested.

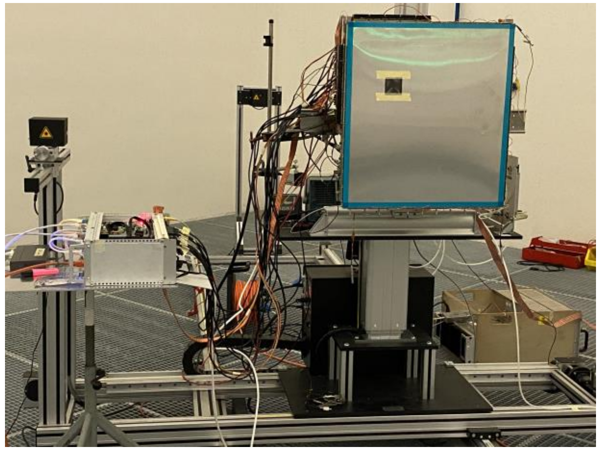


Response of the detector full active area







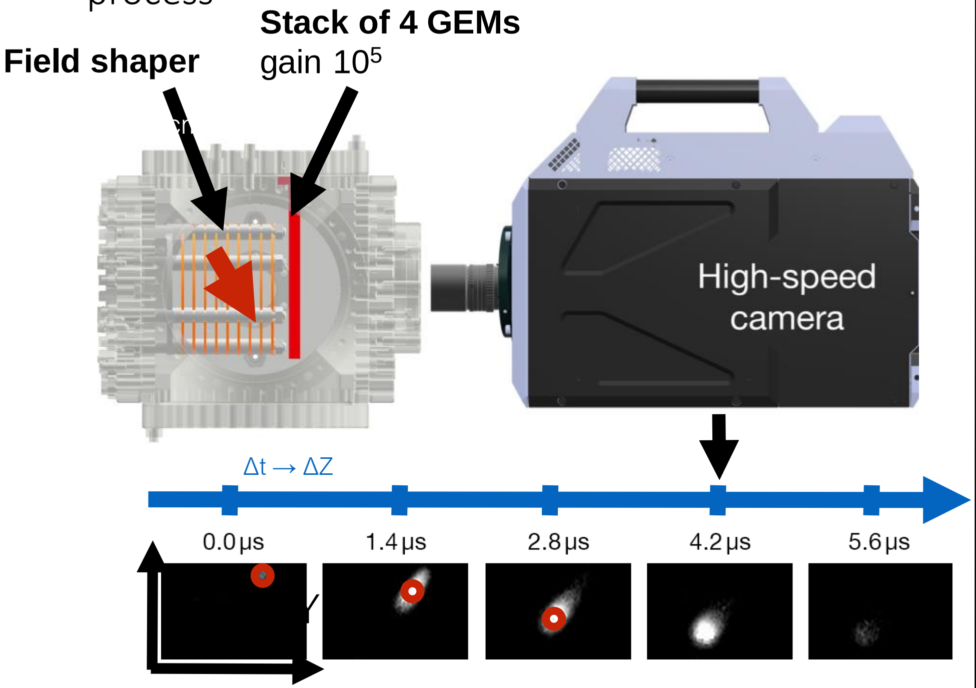


Dorothea Pfeiffer, Jerome Samarati

Optical readout

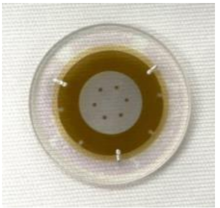
Ultra-fast CMOS optical readout

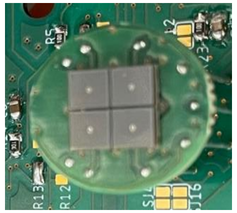
- Record sequences resolving drift time differences with ultra-fast CMOS sensors (10k-1M frames per second) for direct 3D track reconstruction in TPCs.
- Use negative ion drift (SF6) to slow down drift process



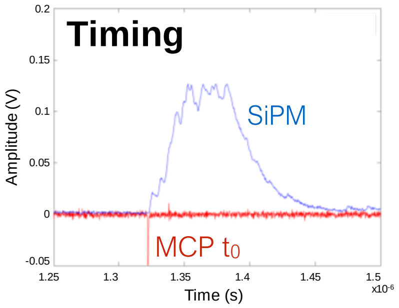
SiPM readout

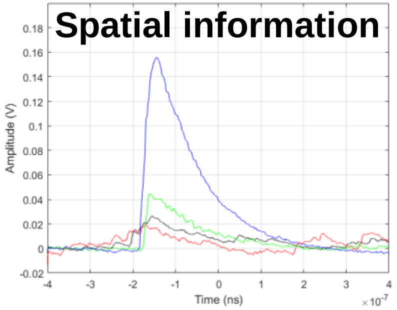
- Explore possibility to use SiPMs for optical readout of MPGDs
- Timing performance and position reconstruction with SiPM arrays





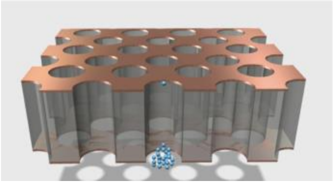
- Glass Micromegas with Cr or ITO (with TFG & MPT workshops / CEA Saclay)
- 2x2 SiPM array reading out scintillation light



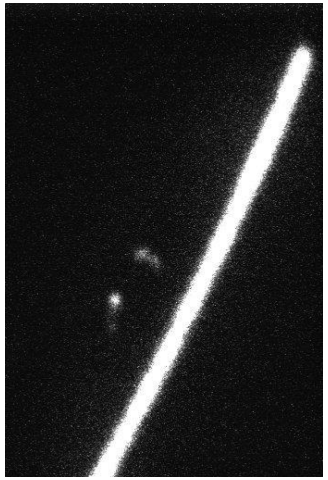


Dynamic range in low pressure TPC

- High resolution imaging with optical readout of low energy events
- Glass GEM in low pressure TPC
- Explore stability limits in presence of highly ionising events



T. Fujiwara, MPGD2017



Gas simulations

Rob Veenhof

Modelling and simulation framework (I)

Search for new and more accurate solutions: IONS PHYSICS, MOBILITY and DIFFUSION

Ion mobility and diffusion calculations - currently not very accurate in Grafield++ (much more complicated than for electrons, where we can safely neglect the thermal energies to get analytical solutions)

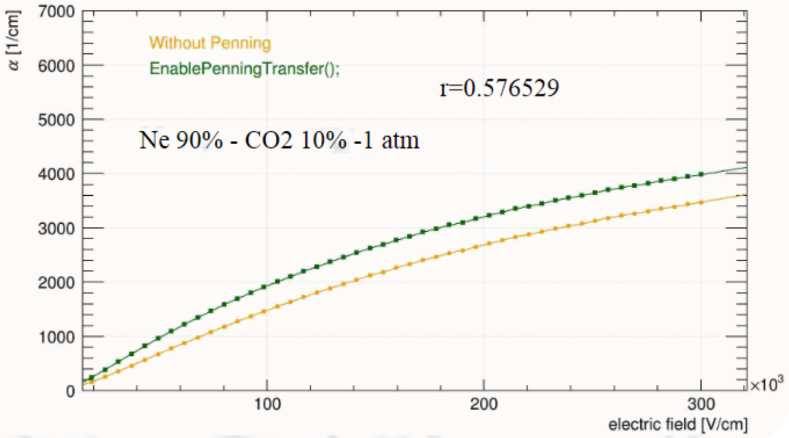
See Field dependence of ion mobility, A.Bal, https://indico.cern.ch/event/1040996/contributions/4404075/

Modelling and simulation framework (II)

Implementation and validation on automated calculations for

PENNING TRANSFER RATE

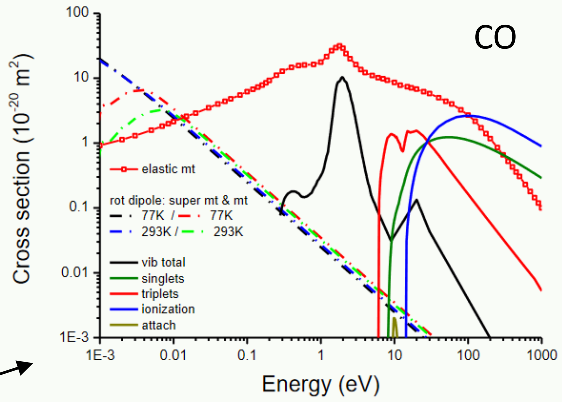
Penning transfer rates fundamental to model correctly the detector response. Data available from literature, **but now implemented in Garfield++ .** See Garfield++ implementation of Penning transfer (Ibrahim A.M. ALASAMAK): https://indico.cern.ch/event/1071632/contributions/4602415/



SEARCH for ECO-GASES

Mini-Workshop on gas transport parameters for present and future generation of experiments

https://indico.cern.ch/event/1022051



Scientific Program

1. Cross sections and simulation techniques - **Rob Veenhof**
2. Experiments at CERN with F gases - Davide Piccolo
3. Measurements of transport parameters of gases & gas mixtures - Piet Verwilligen
4. Status of measurements of alternate gases for large experiments - **Roberto Guida**

Potential collaboration (simulation and measurements) via Swiss National Science Foundation

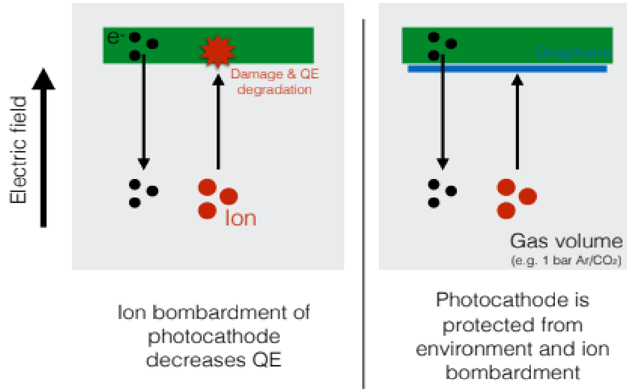
- **Introduction, S. Biagi**
- LXCAT, E.Carbone
- Laser Measurements @ HZDR, L. Naumann
- **HFO1234ze measurements, C. Franck, ETH Power sys. & HV**
- T2K gas transport measurements, P. Hamacher-Baumann
- Proposal for a Setup for microscopic gas properties measurement at Bari, R. Radogna

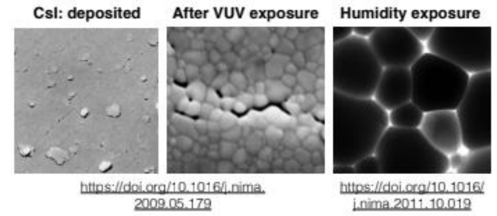
Working plans for next months: Graphene-based functional structures and nanostructures for novel gaseous detectors

Properties of 2D materials such as graphene could offer new perspectives for novel gaseous radiation detectors.

Application 1: Protection layers for photocathodes

- **Encapsulating** photocathodes with **graphene** or **other nanomaterials**, they could be protected from:
  - Degradation
  - Ion's bombardment
- **Work function** modification can be used to increase the photocathodes **QE**





Application 2: Solid converters

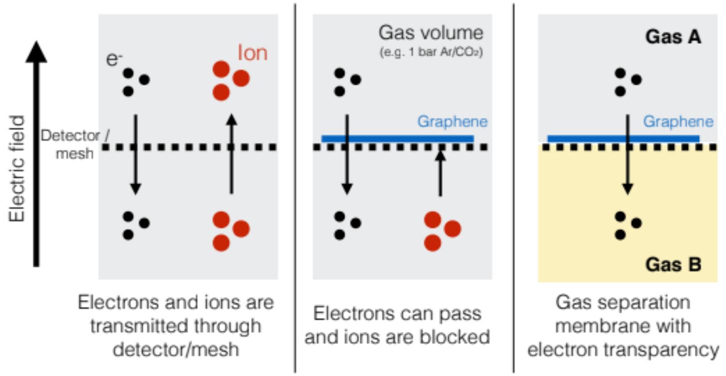
- Multilayer structures as solid converters.

In contact with EN-MME-MM, vacuum surface and coating group (TE-VSC), MPT workshop and EP-DT-TFG.

Application 3: GEM detectors

Mono/few layers of Graphene will be transferred on top of GEMs

- **Ions back flow** suppression → Graphene should be transparent to the electrons but not to ions
- **Gas separation** between drift and amplification regions



EPFL CMi QUANTUM TECHNOLOGY INITIATIVE

Giorgio Orlandini and Florian M. Brunbauer

RD51 collaboration meetings, mini-weeks and topical workshops

- February (2021): "Gaseous detector contributions to PID“ workshop,

  Focus on contributions that gaseous detectors offer to particle identification challenges:
  - Gaseous detectors of single photoelectrons in Cherenkov imaging devices
  - Transition radiation detectors
  - Fine time resolution opportunities with gaseous detectors for TOF measurements.

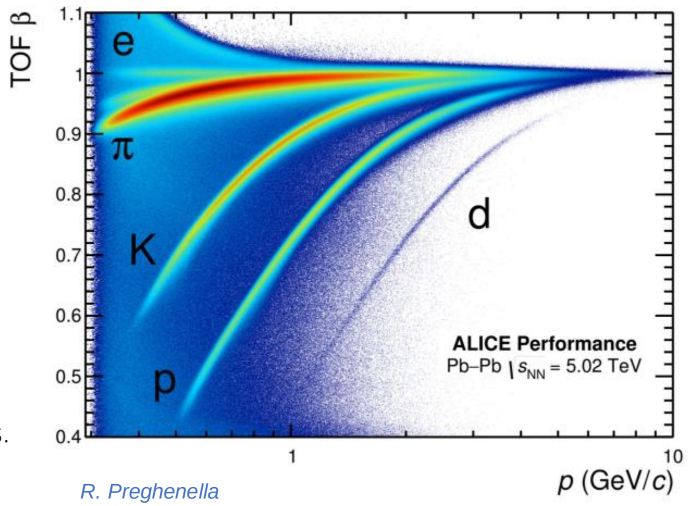
  https://indico.cern.ch/event/989298/

- June (2021): “Front End Electronics for Gas Detectors” workshop
  - Signal detection, coupling, and processing for gaseous detectors.
  - Review requirements, solutions, and future strategies for different applications (tracking and triggering, TPC, calorimetry, timing, photon detection…) and technologies (MPGD, RPC, wires)
  - Overview of existing and new developments (discrete, linear, and pixel chips, digitizer).

  https://indico.cern.ch/event/1040996/

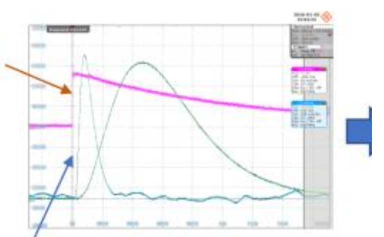
- November (2021): “Wide Dynamic Range Operation of MPGDs” workshop
  - The purpose of this workshop is to discuss upcoming developments and applications of TPCs in the fields of direct **Dark Matter** detection and other Rare Event searches, **Neutrino physics**, **Nuclear** and **Particle** physics, and applied research.

  https://indico.cern.ch/event/1071632/



R. Preghenella
https://indico.cern.ch/event/996326/sessions/381292/#20210216

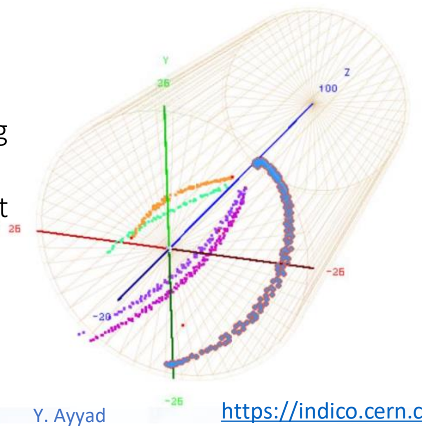
CSA:
t_r O(1ns)



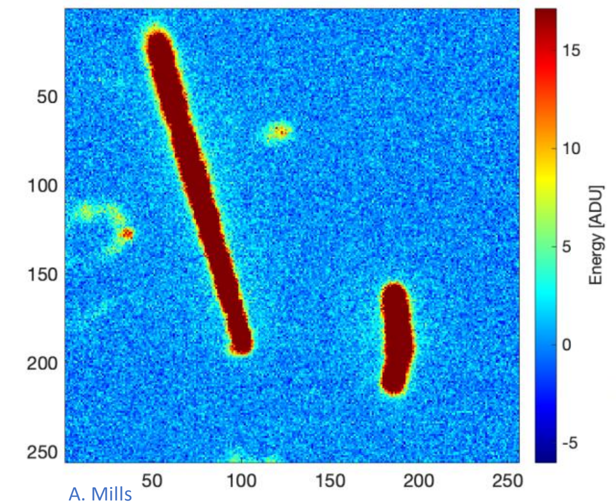
Time resolution via peak-sampling

Γ2(t) shaper peaking time ~ 25 ns
signal envelope ~ 75 ns
~ 25 samples @ 200 MHz

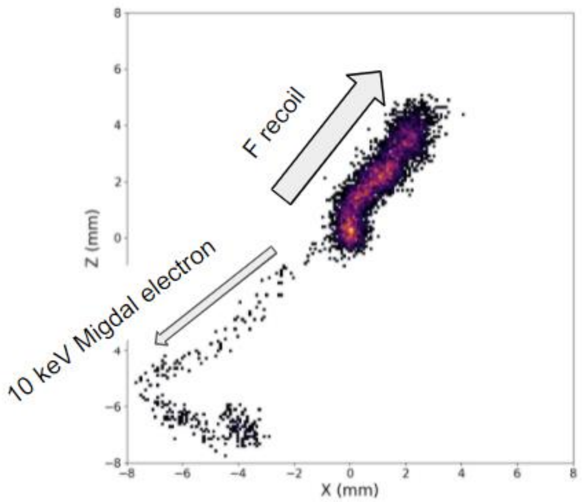
H. Muller
https://indico.cern.ch/event/996326/sessions/381292/#20210216



Y. Ayyad



A. Mills



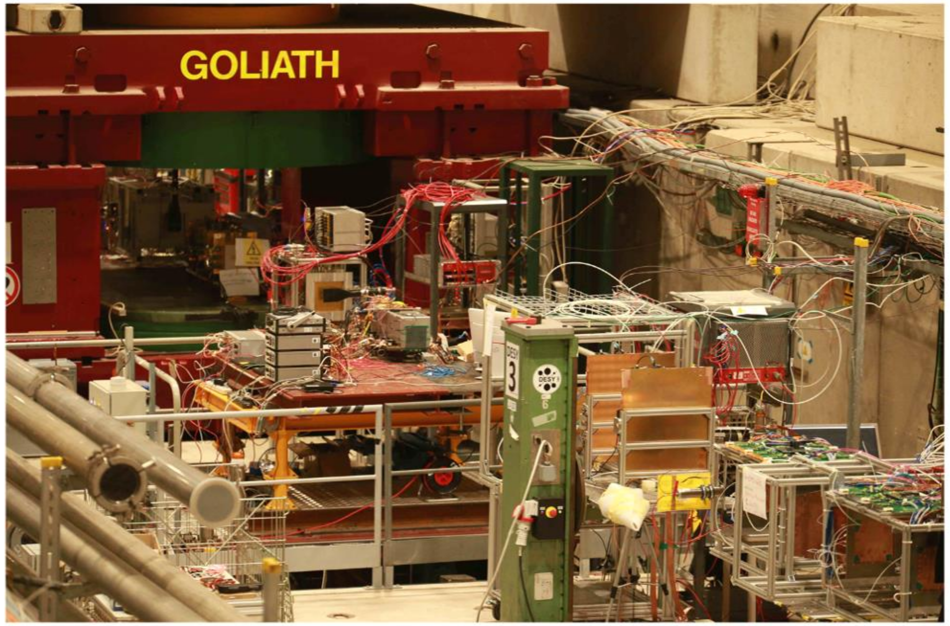
https://indico.cern.ch/event/1071632/sessions/408833/#20211118

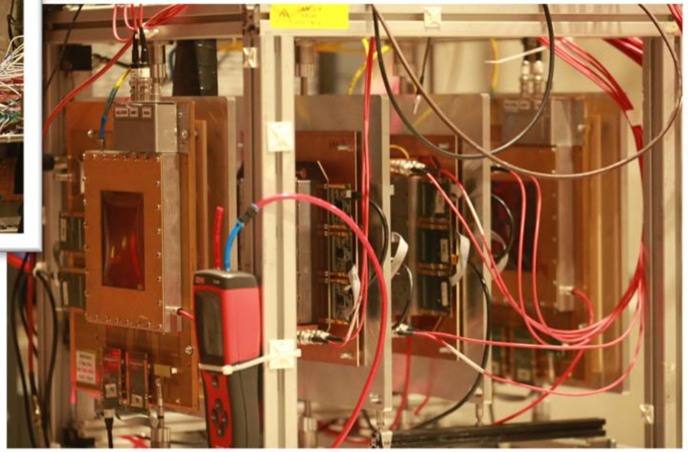
RD51 Test Beam campaign @ H4 beam line of the SPS

II test beam periods: July (12/07 – 21/07) & October (20/10 – 3/11)

October	Amber upgrade (MM & TIGER), INFN Torino	CMS GEM	FTM, High resolution GEM, INFN Bari	GEM-MM hybrid, LMU	Minicactus, CEA	PICOSEC, PICOSEC Collaboration	Proton Computed Tomography, LMU	RD51, RD51 VMM	RPWELL, Weizmann	Small pad resistive MM & embedded RO, INFN Roma 3. Naples, CERN	Straw, JINR/PNPI	UNIANDES/ GSI, UNIANDES/ GSI
July	Amber upgrade (MM & TIGER), INFN Torino	BESIII, INFN Ferrara	PICOSEC, PICOSEC Collaboration	RD51, RD51 VMM								

- **Beam shared with GIF++**
- **Activities:**
  - **Generic and Application driven R&D**
    - Muon/Tracking: GEM, mm and straw
    - Timing: PICOSEC micromegas, FTM, MINICACTUS(MAPS)
    - Calorimetry: RPWELL
  - **Project driven R&D**
    - HL-LHC: CMS GE2/1 ME0
    - PBC: mm and GEM (AMBER/COMPASS++), Straw
    - GSI: PANDA triple GEM
    - Medical Application: Proton Computed Tomography
  - **Detector Commissioning**
    - e+e- collider : CGEM(BESIII)
    - HL-LHC, CMS GEM GE2/1
  - **FE electronics and DAQ**
    - TIGER
    - VMM3a/SRS
    - VFAT3/GEB





Reports on RD51 Collaboration meeting:
February: WG7 session @ https://indico.cern.ch/event/989298
October: WG7 session @ https://indico.cern.ch/event/1071632

Test Beam Campaign
July (**9 days, 4 groups**): Summary@ https://indico.cern.ch/event/1061925/
October (**14 days, 12 groups**): : Summary @ https://indico.cern.ch/event/1094100/contributions/4601502

Thank you for your kind attention
and happy holidays ☺