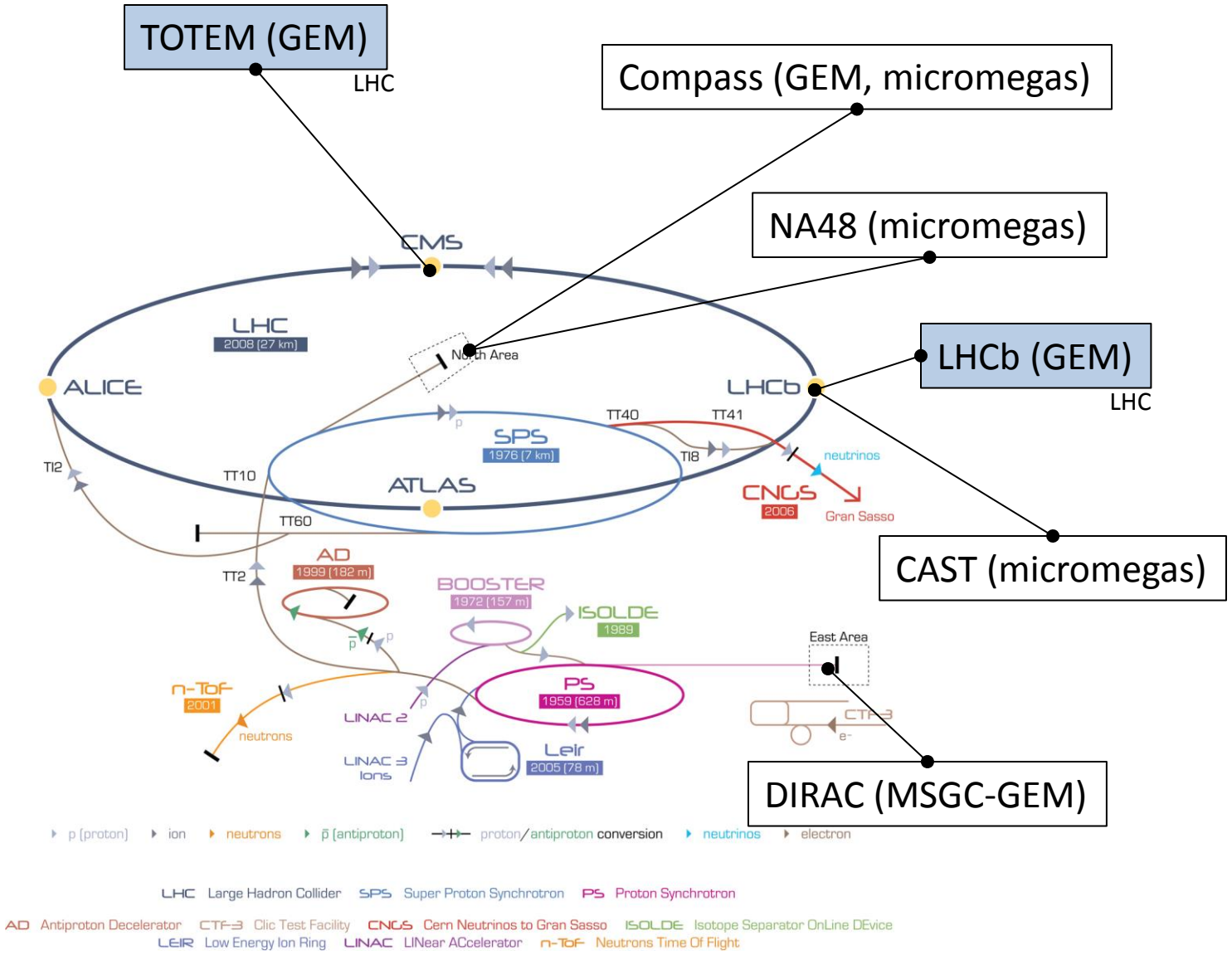
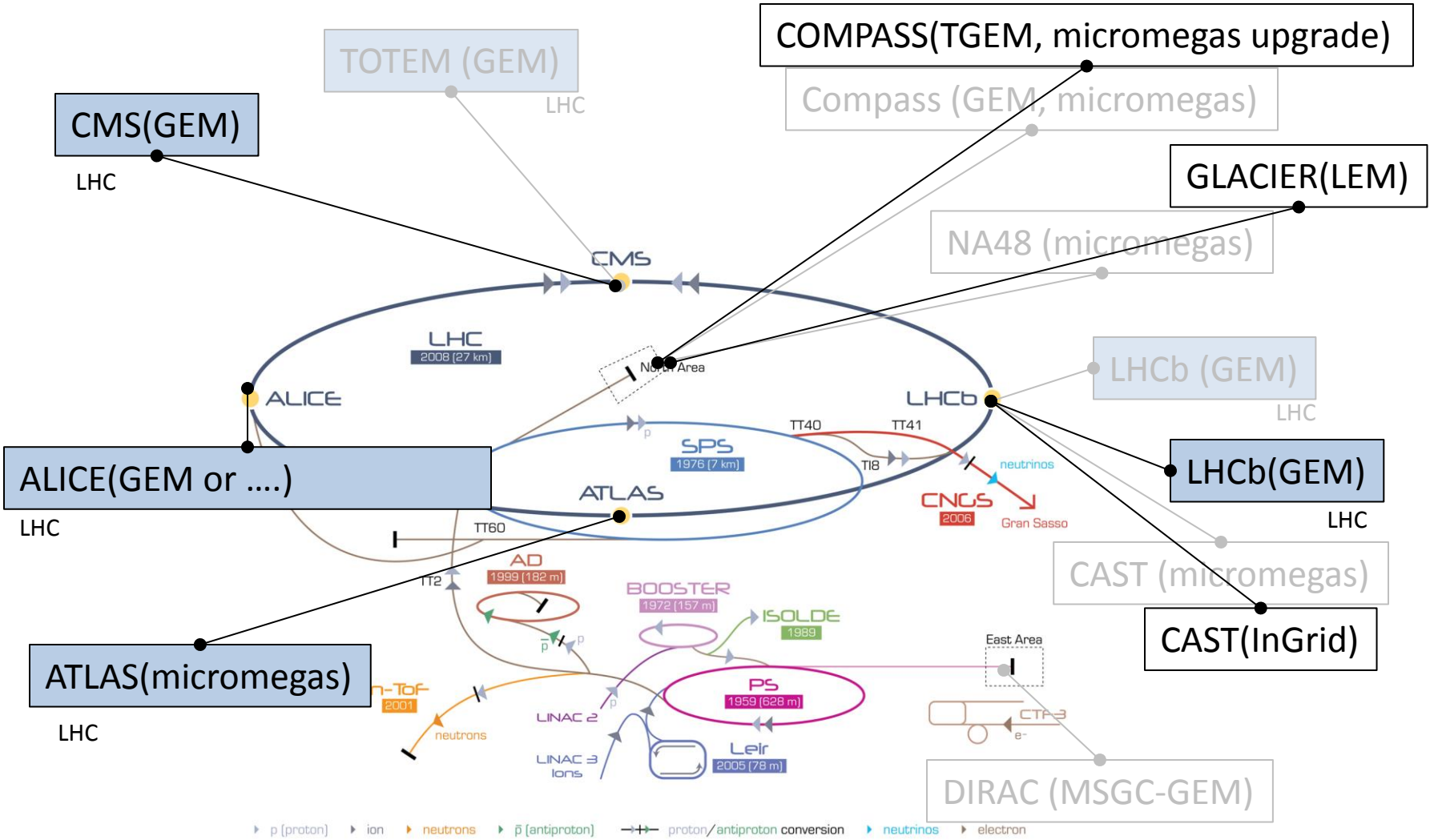
Micro Pattern Gas Detector

Oliveri Eraldo (PH-DT-DD)

MPGD detectors already running at CERN….



…. and possible upgrades



… but I will not talk directly about them

- Mostly focused on the detector...

- You will not find therefore a list of current, future solutions and fields of application... (actually they are too many and someone would be for sure unhappy if forgotten…)

- We will mostly discuss about problems to better understand the mechanisms and maybe trigger some new ideas…

- Because of this we will discuss also about maybe out-dated detectors… (all the critical point are fixed in the current MPGDs and therefore no reason to talk about them!?? …)

Cathode

Gas volume

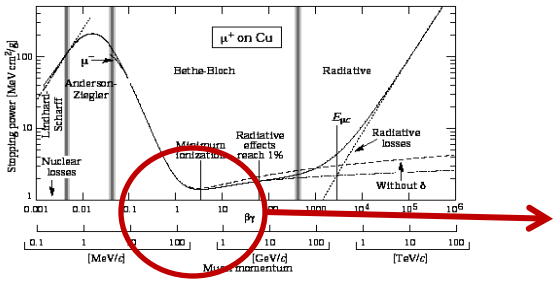
Edrift

Edrift

Egain

Charged Particles

Anode



You have to learn how to play with fields

MIP≈ 2 Mev cm² /g

Energy loss due to electromagnetic interaction

Multi Wire Proportional Chamber (G. Charpak, 1968): a pattern detector

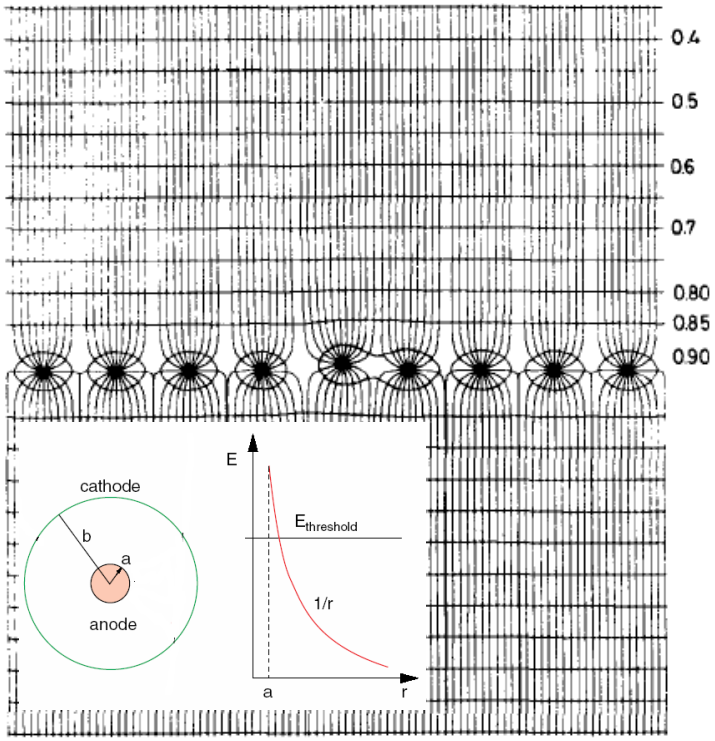


Fig. 56 Electric field equipotentials and field lines in a multiwire proportional chamber. The effect on the field of a small displacement of one wire is also shown[37].

G. Charpak, D. Rahm, H. Steiner, Some developments in the operation of multiwire proportional chambers, Nuclear Instruments and Methods, Volume 80, Issue 1, 1970, 13-34

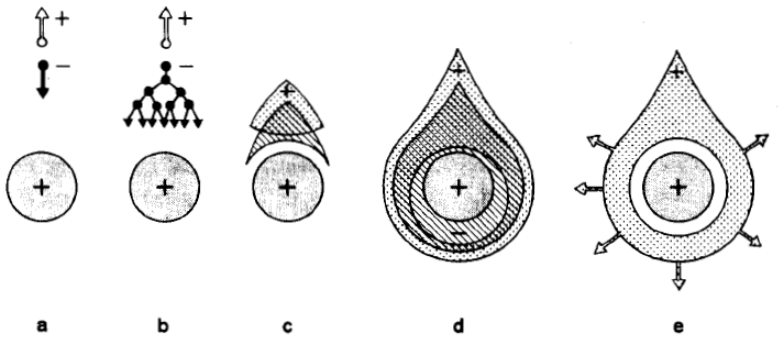


Fig. 49 Time development of an avalanche in a proportional counter[30]. A single primary electron proceeds towards the anode, in regions of increasingly high fields, experiencing ionizing collisions; due to the lateral diffusion, a drop-like avalanche, surrounding the wire, develops. Electrons are collected in a very short time (1 nsec or so) and a cloud of positive ions is left, slowly migrating towards the cathode.

F. Sauli, Principles of operation of multiwire proportional and drift chambers, CERN-77-09, [G. Charpak, Filet a particules, Découverte (février 1972)]

- **Limited space resolution multi-track separation**

  mechanical instabilities due to electrostatic repulsion - less than 10cm length for 1mm spacing

- **Fast gain drop at high fluxes**

  field-distorting space charge accumulation due to the long time taken by the ions produced in the avalanches to clear the region of multiplication

- **Aging**

  permanent damage of the structures after long-term exposure to radiation due to the formation of solid deposits on electrodes.

The basic idea: move down in size & add cathodes very close to anodes to evacuate ions produced during the avalanche process

Higher Spatial resolution and multi-track separation (granularity)
Higher Rate (Faster Ions Evacuation)

the first Micro Pattern Gaseous Detector:
MSGC (OED, 1988 – 20 years after MWPC)

Semiconductor industry technology
Photolithography, Etching, Lift-off, Coating, Doping, …

Micro Strip Gas Chamber Oed A. Nucl. Instrum. Methods A263:351 (1988)

Position-sensitive detector with microstrip anode for electron multiplication with gases, Oed A. Nucl. Instrum. Methods A263:351 (1988)

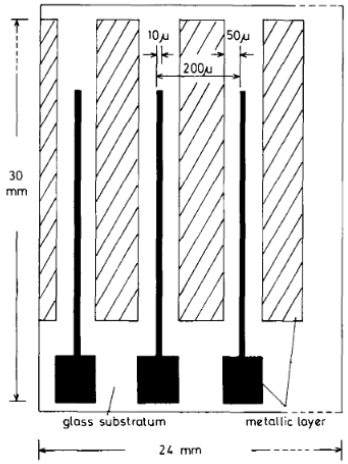


Fig. 1. Dimensions of the microstrip plate (MS-plate) used for the measurements. The chromium layer on the glass substrate is 300 nm in thickness.

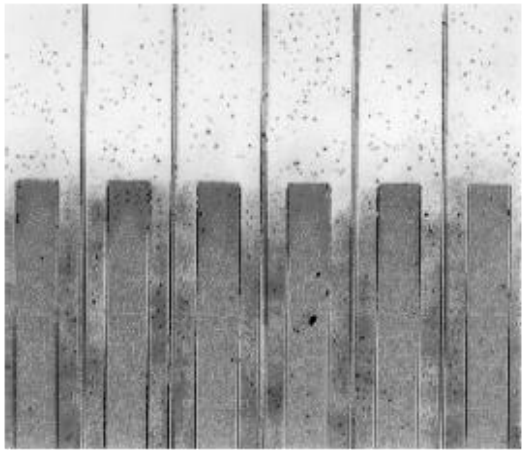


Figure 1 Close view of one of the first microstrip plates developed by Oed at the Institut Laue-Langevin. On an insulating substrate, thin metallic anode strips alternate with wider cathodes; the pitch is 200 μm.

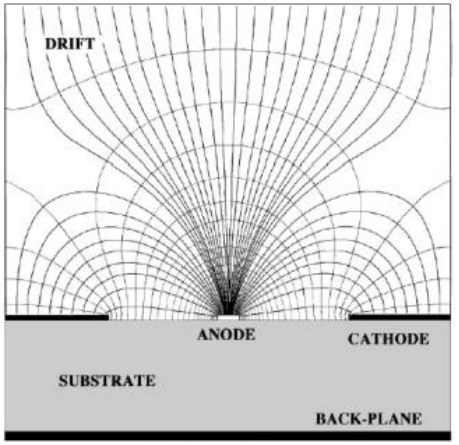


Figure 2 Equipotentials and field lines in the microstrip chamber, computed close to the substrate. The back-plane potential has been selected to prevent field lines entering the dielectric.

F,Sauli, A. Sharma, Micropattern Gaseous Detectors , Annu. Rev. Nucl. Part. Sci. 1999. 49:341–88

- Insulating material in between amplifying anode and cathode
- High electric field in most of the region in between the amplification stage electrodes
- Micro-Anode (wire style) structures

- Insulating material in between amplifying anode and cathode

  It will affect almost everything… let's say stability issue

- High electric field in most of the region in between the amplification-stage-electrodes

  Avalanche → Streamer → Spark

- Micro-Anode (wire style) structures

  Permanent deterioration (Aging) & Lethal damages (Sparks)

Space resolution and multi-track separation

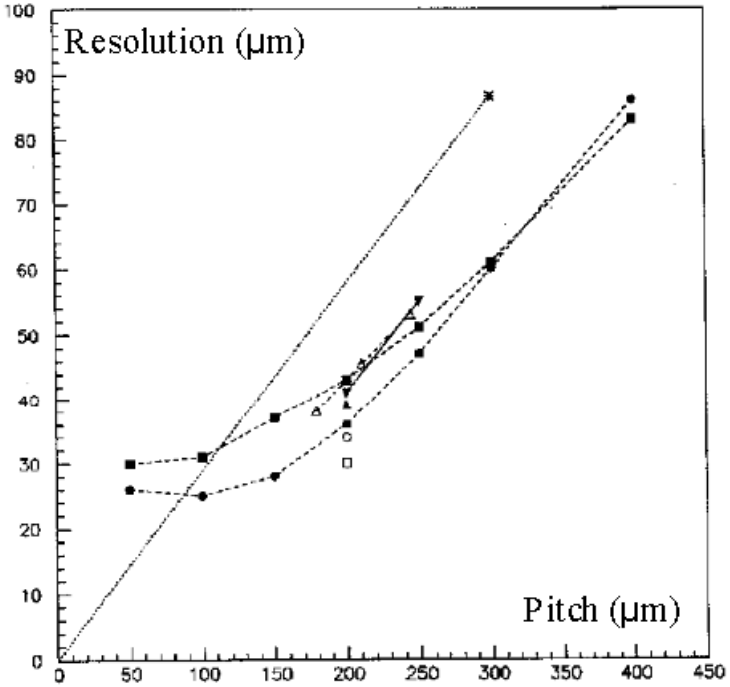


Fig. 17: Space resolution as a function of pitch.

Development of high rate MSGCs: Overview of results from RD-28, F. Sauli, CERN [S. Snow et al., Proc. Int. Workshop on Micro-Strip Gas Chambers (Lyon, 1995), 127.

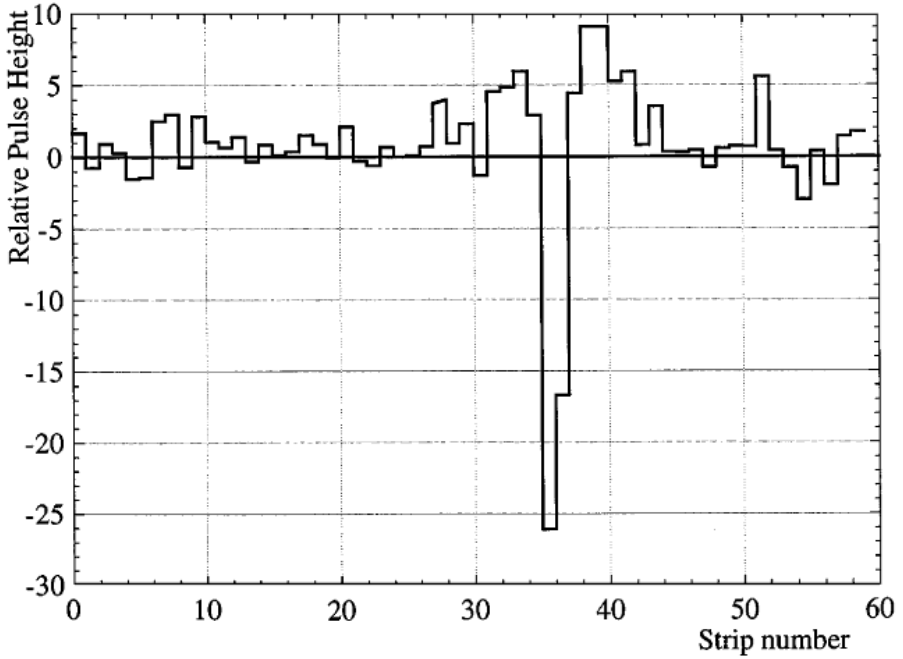


Figure 3 Typical pulse height profile recorded, for a localized avalanche, on adjacent anodes 200 μm apart in a microstrip chamber. The positive overshoot is caused by a signal reinjection from the grouped cathode strips. The width of the distribution, about two strips fwhm (400 μm), determines the multitrack resolution.

F,Sauli, A. Sharma, Micropattern Gaseous Detectors , Annu. Rev. Nucl. Part. Sci. 1999. 49:341–88

Insulating material in between amplifying anode and cathode

"… a substantial increase of resistivity with time after the application of voltage, accompanied by a decrease of gain (Figure 7) and a rate-dependent gain shift (Figure 8), has been observed….

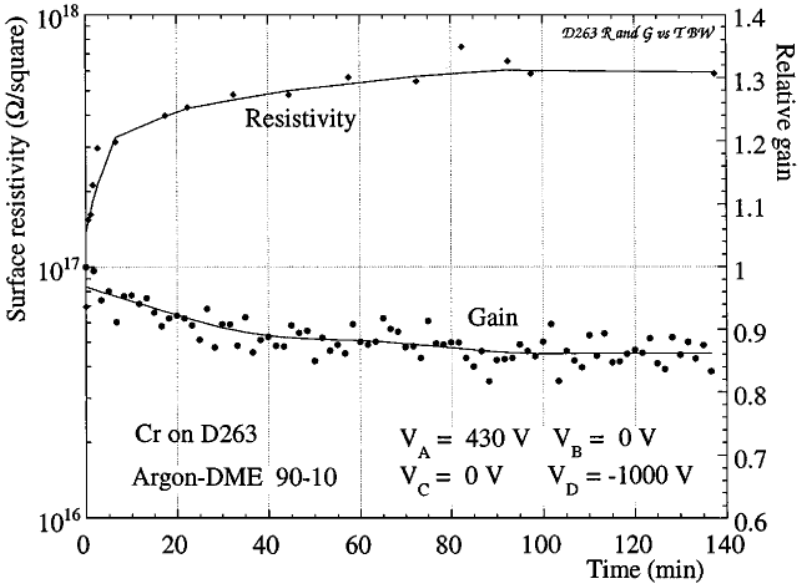


Figure 7 Initial gain variation of gain and resistivity as a function of time from the application of voltage for a plate made on insulating borosilicate glass substrate. V_A, V_B, V_C, and V_D are the anode, back-plane, cathode, and drift potentials, respectively.

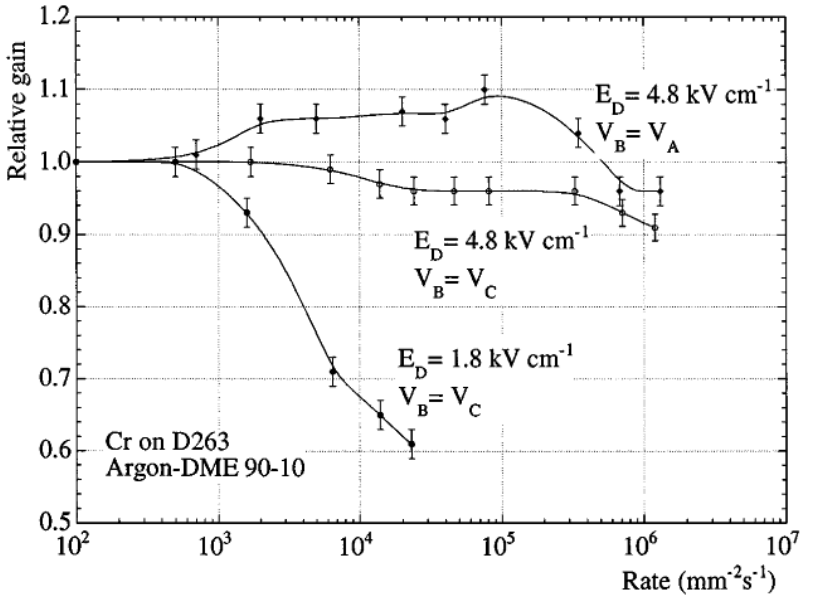
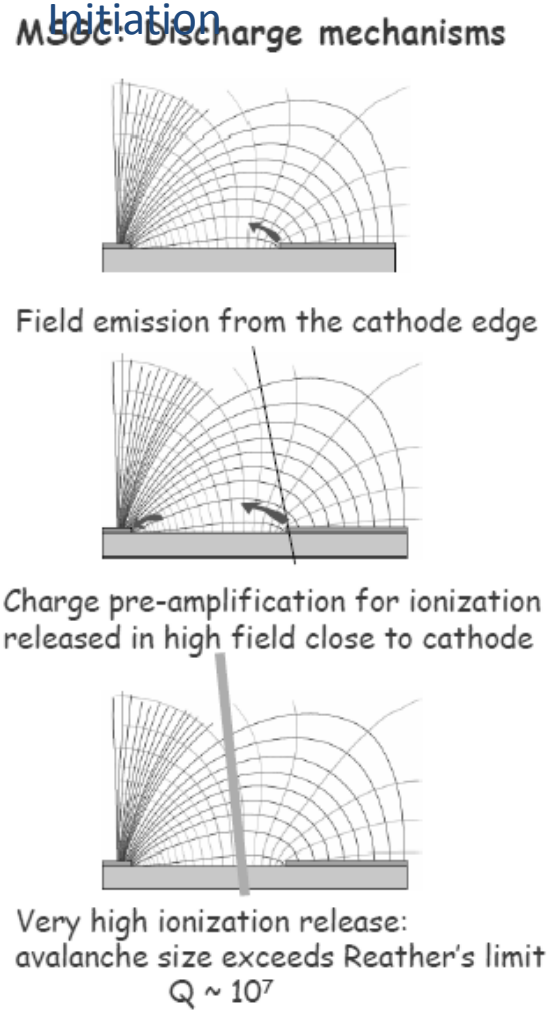


Figure 8 Relative gain as a function of irradiation rate, measured on a microstrip made on borosilicate glass. The performance depends strongly on the applied voltages. E_D is the drift field; V_B and V_C are the back-plane and cathode potentials.

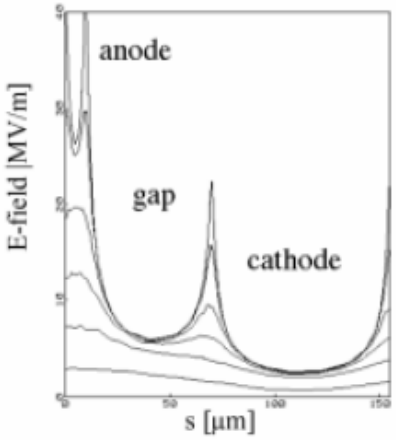
The effects are attributed to a dynamic modification of the electric field following the application of voltage and to substrate polarization, internal rearrangements of the charge carriers, and surface charge accumulation…" *F,Sauli, A. Sharma, Micropattern Gaseous Detectors , Annu. Rev. Nucl. Part. Sci. 1999. 49:341–88*

High electric field in most of the region in between the amplification-stage-electrodes (from avalanche to discharge)

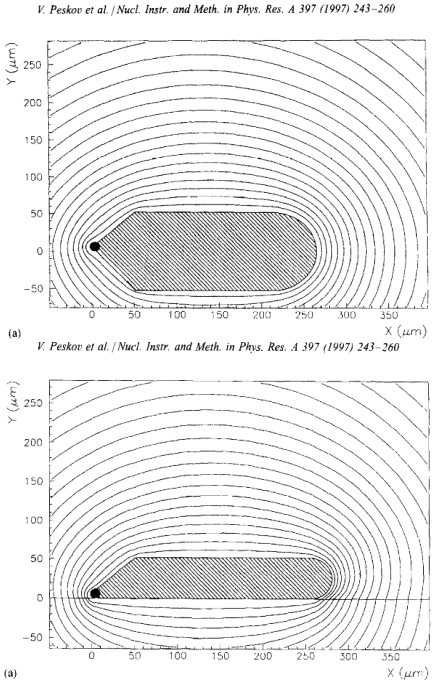
Initiation



Fields



Plus…possible enhancement of the transition to spark because of the substrate



Field map calculations for a streamer in the MSGC without/with substrate

Peskov , NIM A397 (1997) 243.-260

HIGH RATE BEHAVIOR AND DISCHARGE LIMITS IN MICRO-PATTERN DETECTORS

A. Bressan et al. CERN-EP/98-139, 18 September 1998

Triggered by the invention, ten years ago, of the micro-strip gas chamber (MSGC) [1], during the last decade a new generation of fast, performing gas detectors has emerged, relying for manufacturing on more or less sophisticated photo-lithographic patterning technologies. A non-exhaustive list of such innovative devices includes the micro-gap [2], micro-dot [3], "compteur à trous" (CAT) [4], small gap [5], micromegas [6], gas electron multiplier (GEM) [7], micro-CAT [8], micro-groove and WELL detectors [9, 10]. For a recent review see for example [11, 12]. All these devices, here collectively named micro-pattern detectors, share a common characteristics setting them aside in behavior from multiwire counters: a high electric field extends over a large fraction or all of the gap between anodes and cathodes, generally very narrow (few tens to few hundred μm), and in most cases high field singularities also exist close to the cathode surface.

It should be recalled that in multiwire proportional chambers and derivatives, having a high electric field around the thin wires but well below the critical values for multiplication in most of the remaining volume, a transition from proportional to streamer regime is also observed at high voltages, but in most cases the streamer propagation stops in the decreasing field well before reaching the cathode. The limited streamer regime has been widely exploited for obtaining conveniently large signals in wire counters [30] and has as sole shortcoming a modest rate capability.

Micro-Anode (wire style) structures & Aging

Micro-Anodes:
Smaller amplification volume, higher energy density in the avalanche plasma.
Large effects on the field (deposit) as for wires.

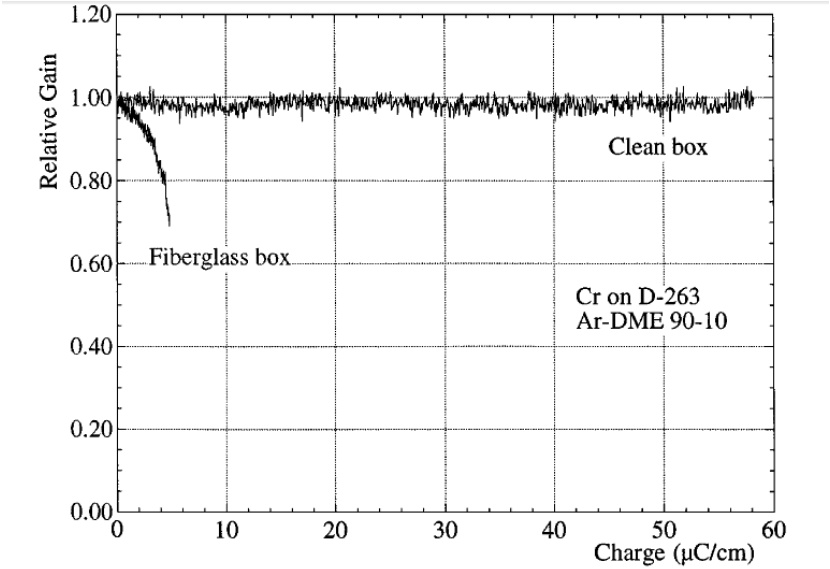
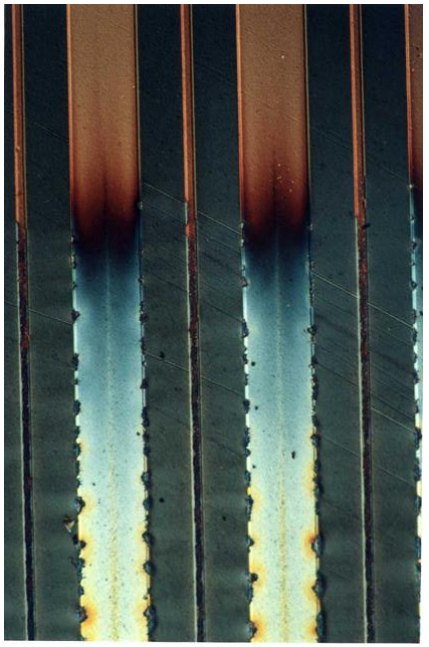


Figure 21 Comparison of aging rate under irradiation for identical plates, mounted either in a conventional fiberglass assembly or in a clean container.



Bouclier R, et al. In Proc. MSGC Workshop, Legnaro, p. 48 (1994)

medium- and long-term stability determined by physical parameters used to manufacture and operate the detectors as : substrate material, metal of the strips, type and purity of the gas mixture

DEVELOPMENT OF HIGH RATE MSGCS: OVERVIEW OF RESULTS FROM RD-28
Fabio Sauli, CERN, CH-1211 Geneva, Switzerland

Some stability problems have however been met:
-gain modifications due to substrate polarization and charging up
-permanent deterioration (ageing) during sustained irradiation
…
the situation is complicated by the interdependence of the various parameters.
…
These effects are attributed to
-modification of the electric field by substrate polarization following the application of the potentials
-charging up of the insulator by electrons and ions produced in the avalanches
-ions migration within the substrate.
…
Use of a substrate with lower resistivity and electronic conductivity eliminates the polarization and surface charging processes up to very high rates; it results also in more stable operation and reduced ageing rates.

Substrate/Coatings: Effects on rate

ELSEVIER

Nuclear Instruments and Methods in Physics Research A 374 (1996) 144–148

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

MSGCs with Pestov-glass coatings

W.G. Gong [a,*], R. Bellazzini [b], A. Brez [b], R. Raffo [b], G. Spandre [b]

[a] *Max-Planck-Institut für Physik, Föhringer Ring 6, D-80805 München, Germany*

[b] *INFN-Pisa and University of Pisa, Via Livornese 582, S. Piero a Grado, I-56010 Pisa, Italy*

Received 8 March 1996

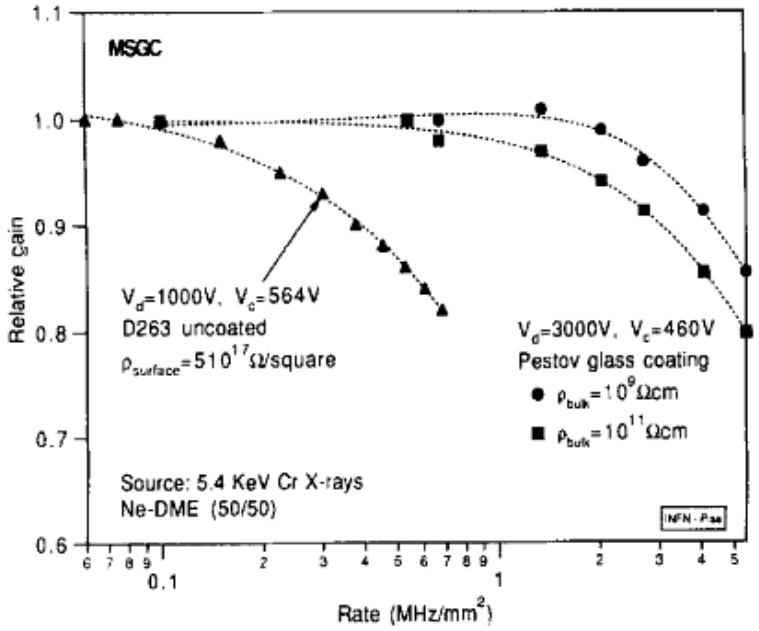
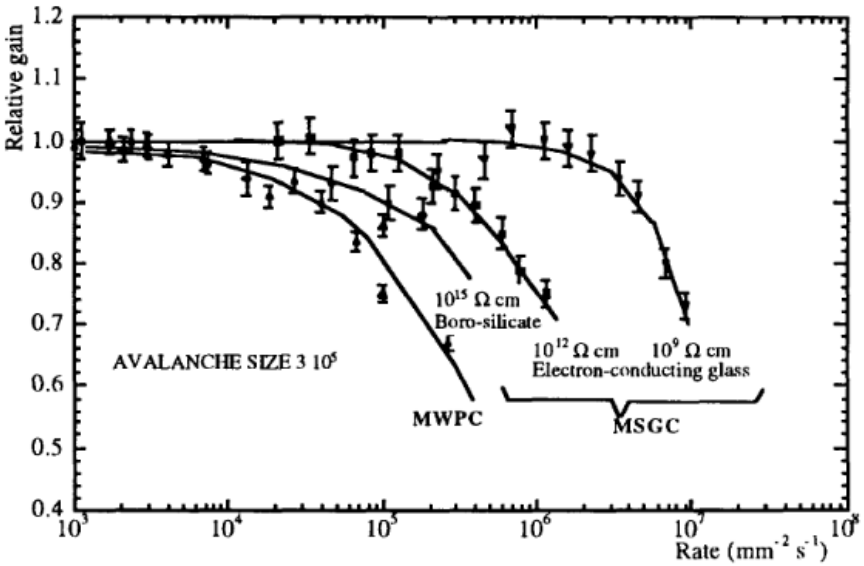


Fig. 9. Rate capabilities of various MSGCs with and without Pestov-glass coatings.

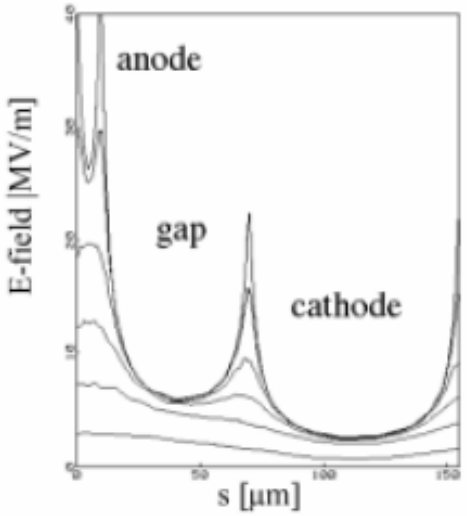


GURE 12: Rate capability of the MWPC and of MSGCs manufactured on substrates with several values of bulk or surface resistivity.

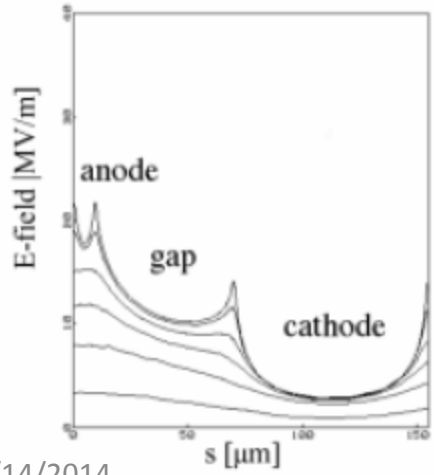
Applications of gaseous particle detectors in physics and medicine, F. Sauli, CERN-PPE-94-196

Substrate/Coatings: Sparks

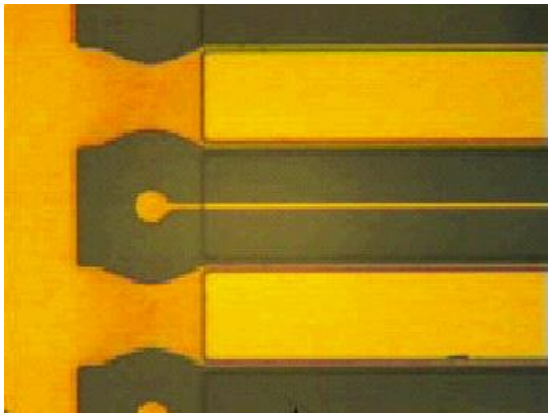
Standard MSGC

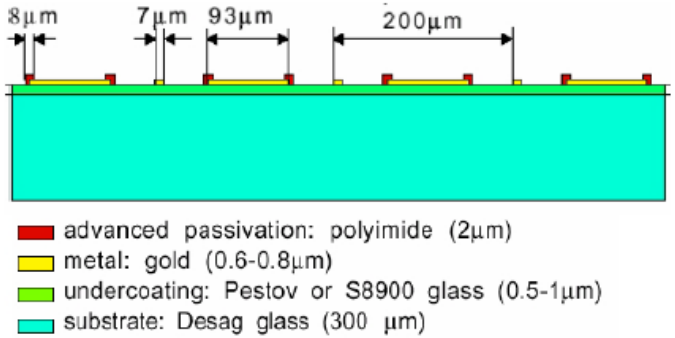


CVD Diamond Coated MSGC



Cathode Edge Passivation
[Bellazzini et al]





Substrate: Aging

All other conditions being equal, use of low-resistivity substrates permits higher levels of exposure without loss of gain (40, 49, 132), possibly by reducing the effect of thin deposits on the field. The choice of metal for the strips also appears to play an important role (71), gold being the best (Figure 22) (133).

40. Bouclier R, et al. *Nucl. Instrum. Methods* A332:100 (1993)

49. Bouclier R, et al. In *Proc. MSGC Workshop, Legnaro*, p. 39 (1994)

132. Duerdoth IP, et al. *Nucl. Instrum. Methods* A392:127 (1997)

71. Bateman JE, Connolly JF. RAL-94–114 (1994)

133. van den Berg FD, et al. *Nucl. Instrum. Methods* A392:94 (1997)

van den Berg FD, et al. *Nucl. Instrum. Methods A392:94 (1997)*

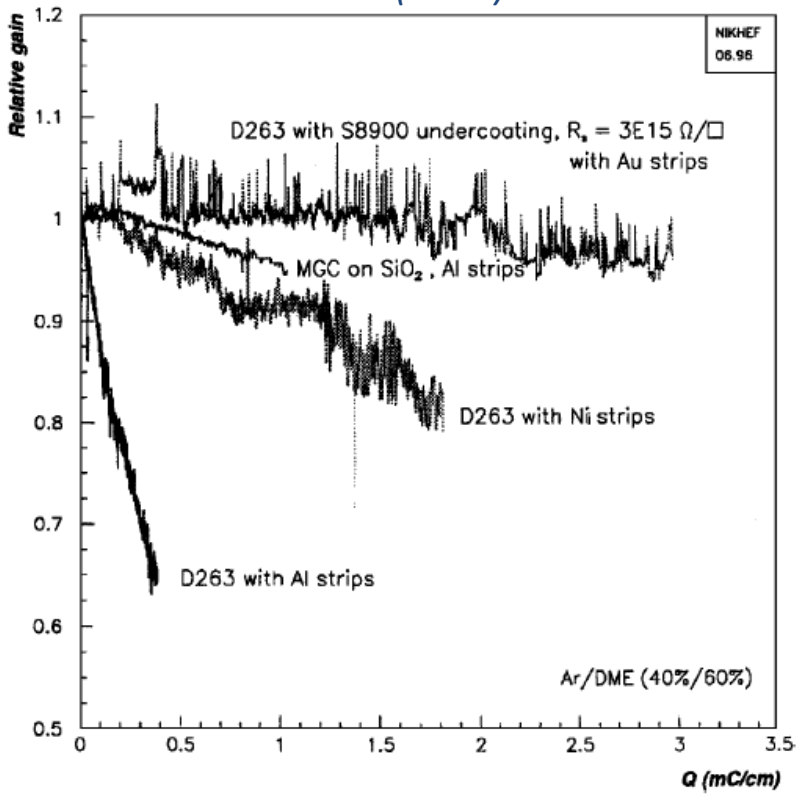


Figure 22 Gain drop, or aging, under sustained irradiation of microstrip plates manufactured on insulating and semiconducting substrates, for different strip metals.

F,Sauli, A. Sharma, Micropattern Gaseous Detectors , Annu. Rev. Nucl. Part. Sci. 1999. 49:341–88

Rapid Development of many different structures to improve the performances and solve the problems of MSGC

Micro Gap Chambers

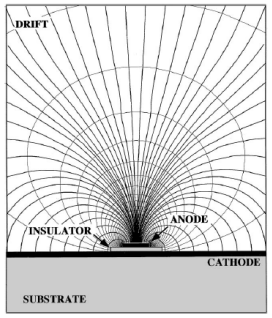


Figure 24 Equipotential and electric field lines for the microgap chamber.

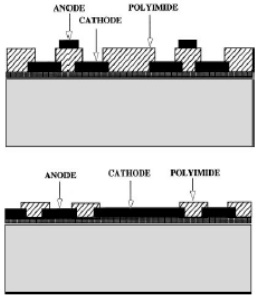


Figure 25 Two variants of small-gap chambers, using thick polyimide ridges to prevent the onset of discharges.

Angelini F, et al. Nucl. Instrum. Methods A335:69 (1993)

Micro Gap Wire Chamber

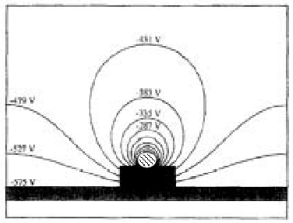
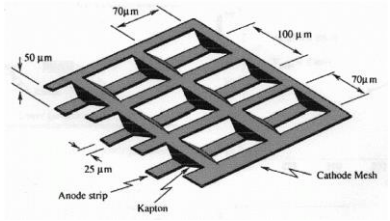


Figure 2.27 Scheme of a MGWC with equipotential and field lines. The circle filled with lines is the section of an anode wire [CHRISTOPHEL1997].

E. Christophel et al, Nucl. Instr. and Meth, vol 398 (1997) 195

Micro Wire Chamber



B. Adeva et al., Nucl. Instr. And Meth. A435 (1999) 402

MicroDot

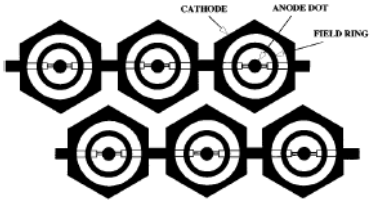
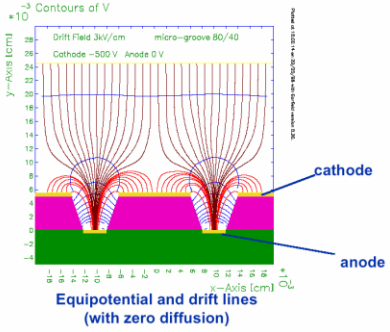


Figure 26 Schematics of the microdot chamber. A pattern of metallic anode dots surrounded by field and cathode electrodes is implemented on an insulating substrate, using microelectronics technology. Anodes are interconnected for readout.

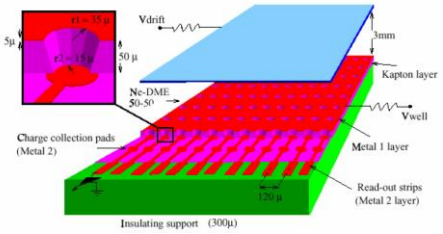
Biagi SF, Jones TJ. Nucl. Instrum. Methods A361:72 (1995)

MicroGroove



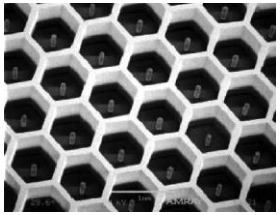
R. Bellazzini et al
Nucl. Instr. and Meth. A424(1999)444

MicroWELL



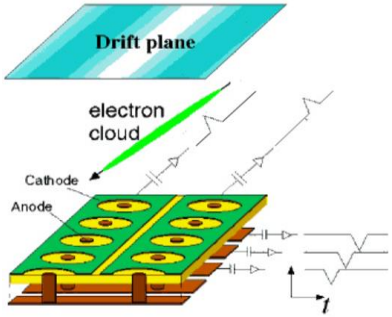
R. Bellazziniet al
Nucl. Instr. and Meth. A423(1999)125

MicroPin



P. Rehak et al., IEEE Nucl. Sci. Symposium seattle 1999

µPIC



Ochi et al NIMA471(2001)264

… and many others

… just a comment on MicroDot & sparks before moving on

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Nuclear Instruments and Methods in Physics Research A 424 (1999) 321–342
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

High rate behavior and discharge limits in micro-pattern detectors

A. Bressan[a], M. Hoch[a], P. Pagano[a], L. Ropelewski[a], F. Sauli[a,*], S. Biagi[b], A. Buzulutskov[c], M. Gruwé[d], G. De Lentdecker[e], D. Moermann[f], A. Sharma[g]

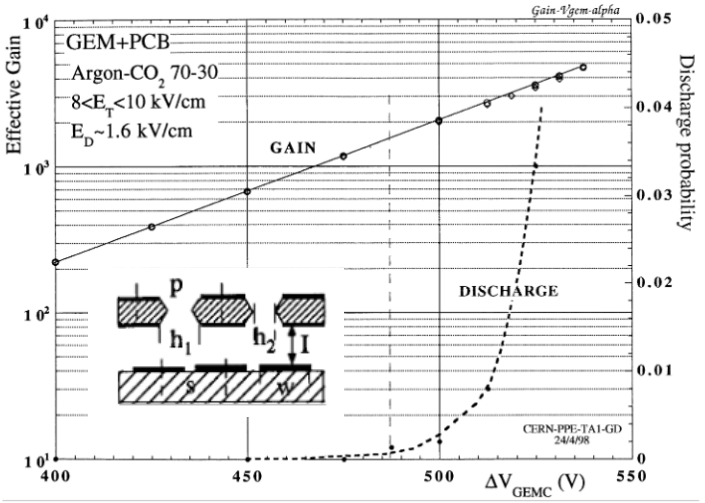


Fig. 9. Effective gain and discharge probability on the internal α source obtained with the GEM detector with an argon–CO_2 gas filling.

GEM + PCB: GEM: 5 μm Cu on 50 μm kapton
$p = 140$ μm, $h_1 = 80$ μm, $h_2 = 55$ μm
PCB: 5 μm Cu on 50 μm kapton
$s = 100$ μm, $w = 150$ μm
Induction gap $I = 1$ mm. Active area: $10 \times 10\ \mathrm{cm}^2$

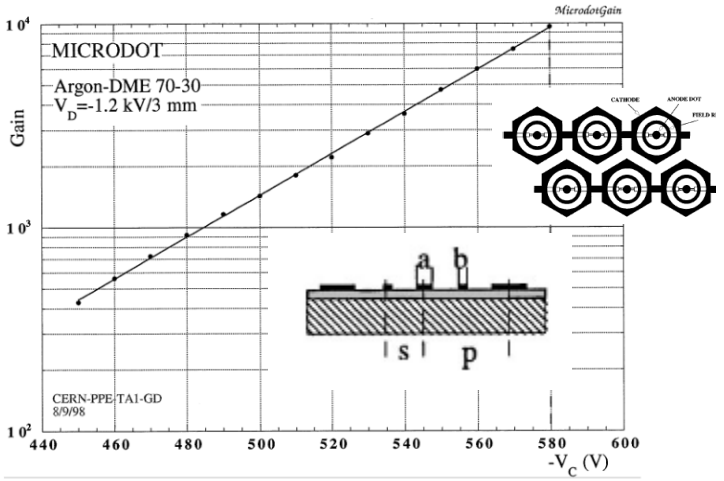


Fig. 15. Gain as a function of voltage in the micro-dot detector. No effect of the internal α source has been observed up to a gain of 10^4.

Micro-dot: Anode diameter $a = 24$ μm Guard ring
$b = 5$ μm $s = 55$ μm
Pitch $p = 100$ μm
Active area: $6 \times 0.6\ \mathrm{cm}^2$

Remarkably, and in opposition to all other devices tested, introduction of the α emitter did not result in any sign of discharge, up to gains of 10^4; at this point, and short of reaching 2×10^4, a fatal breakdown resulted in the destruction of the detector.[6]

This suggests that the low field at the cathode surface and the intermediate field ring act as an effective stop against the formation and propagation of streamers;

Uniform Field Amplification & MPGD

"…The successful development of multiwire and microstrip structures has somewhat sidestepped the research on gas detectors that exploit the multiplication in uniform fields. Parallel-plate multipliers not only are mechanically sturdier but also have better energy resolution and higher rate capability. "

From: F,Sauli, A. Sharma, MICROPATTERN GASEOUS DETECTORS , Annu. Rev. Nucl. Part. Sci. 1999. 49:341–88

1. Uniform Field Amplification stage
(single stage devices… micromegas family)

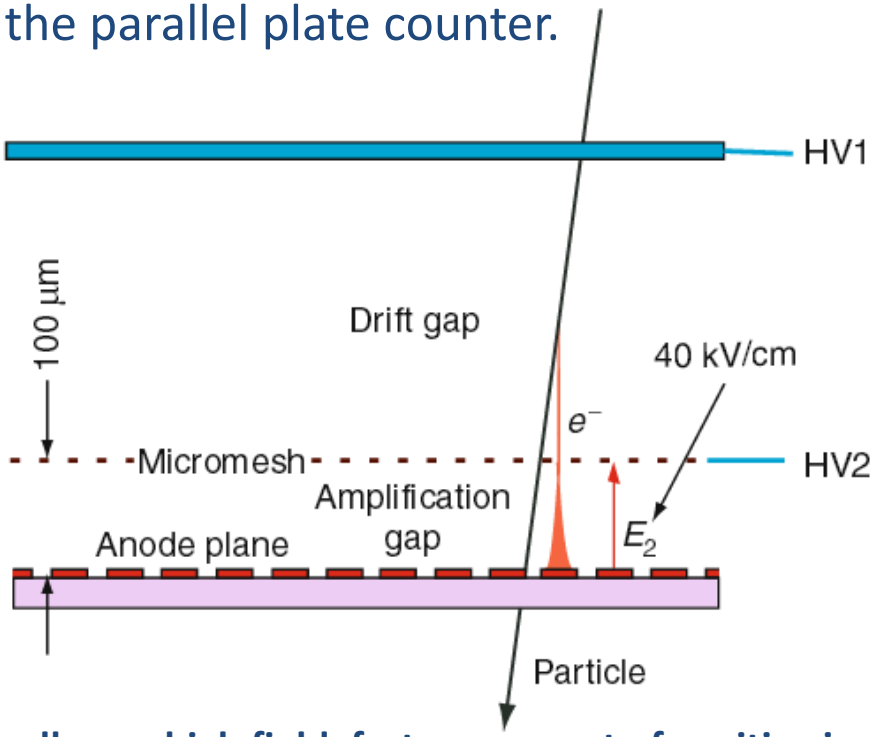
2. Uniform Field Amplification and Transfer stage
(multi stage devices… GEMs Family)

MicroMEGAS: Parallel Plate with Small GAP

MICRO Mesh Gaseous Structure

MICROMEGAS: a high-granularity position-sensitive gaseous detector for high particle-flux environments Y. Giomataris et al, Nucl. Instr. and Meth. A376(1996)29

Rate capability and energy resolution of the parallel plate counter.



Two-stage parallel-plate avalanche chamber of small amplification gap

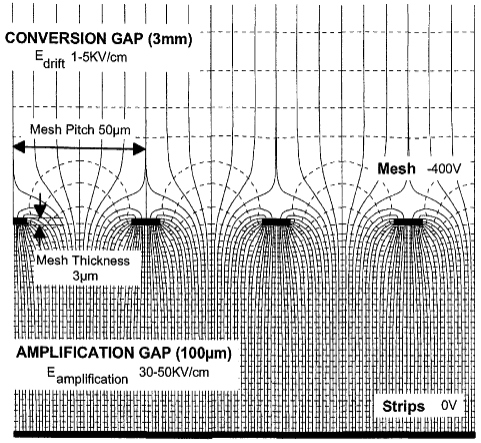
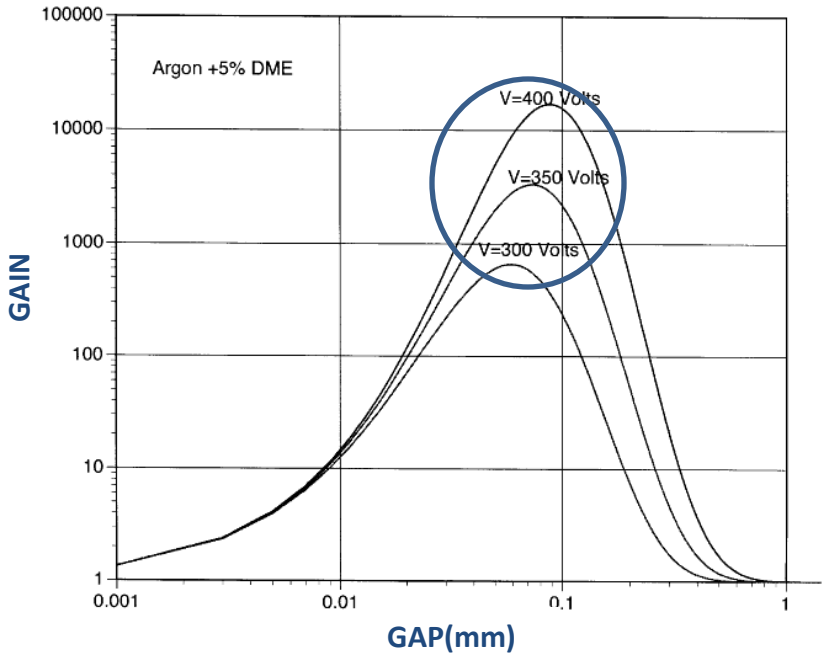


Fig. 1. Micromegas electric field map.

Y. Giomataris, Nucl.Instr. and Meth. in Physi.Res. A 419 (1998) 239

Small gap , high field: fast movement of positive ions that are mostly collected on the mesh (small space-charge accumulation) and very fast signals

An interesting property of narrow gaps



" Optimum gap provides stable operation and minimizes gain variation from pressure-temperature variations and fluctuations due to gap variations" Introduction to MPGD Y. Giomataris, CEA-Irfu-France

small variations of the amplification gap compensated by an inverse variation of the amplification factor

Reduced dependence of gain on the gap thickness because of the saturating characteristics of the multiplication factor at very high field

Y. Giomataris, Nucl.Instr. and Meth. in Physi.Res. A 419 (1998) 239

i.e. good uniformity and stability of response over a large area.

$$M = e^{\alpha d} \qquad \alpha = pAe^{-Bp/E} \qquad M = e^{Apde^{-Bpd/V}} \qquad \frac{\delta M}{M} = \alpha d\left(1 - \frac{Bd}{V}\right)\frac{\delta d}{d}$$

maximum value is for $d = V/B$ at $p = 1$ bar.

MicroCAT

The C.A.T. Pixel Proportional Gas Counter Detector

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(Received 9 June 1995, accepted 20 December 1995)

PACS.29.40.Cs – Gas-filled counters: ionization chambers, proportionnal and avalanche counters
PACS.29.40.Gx – Tracking and position-sensitive detectors

Abstract. — A simple geometry of real pixel gas detectors has been evaluated that c
the limitations of a microstrips, namely aging, gain drift and flux limitation due to th
charging. A good resolution has been obtained while preserving a large active size
gain and counting rate capabilities.

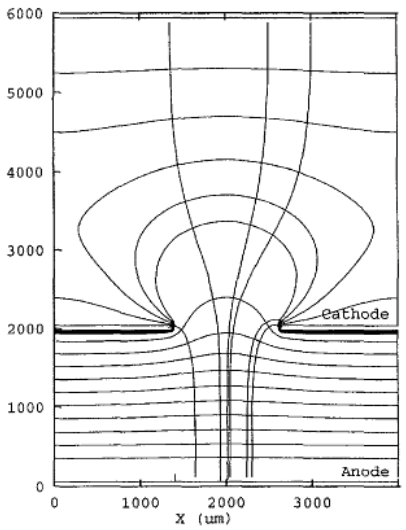


Fig. 1. — Cross-section view and equipotential contours. The field lines appear as arbitrary ion or electron paths. Potentials are: Drift = −25 V, Cathode = 0, Anode = +3 kV.

A. Sarvestani et al., Nucl. Instr. And Meth. A410 (1998) 238

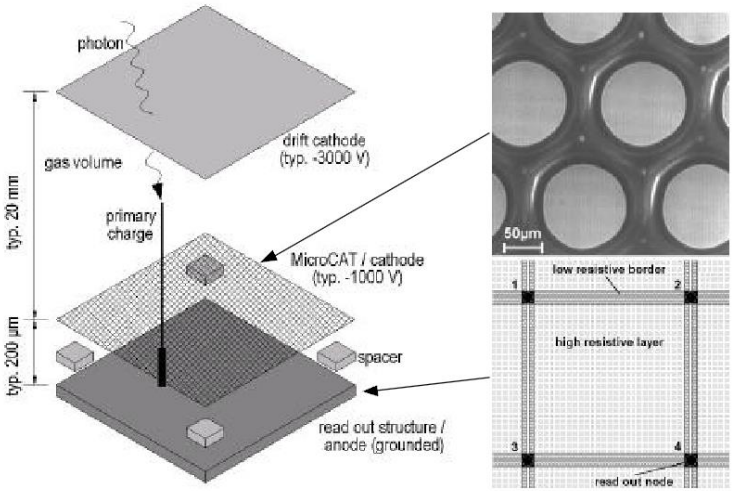


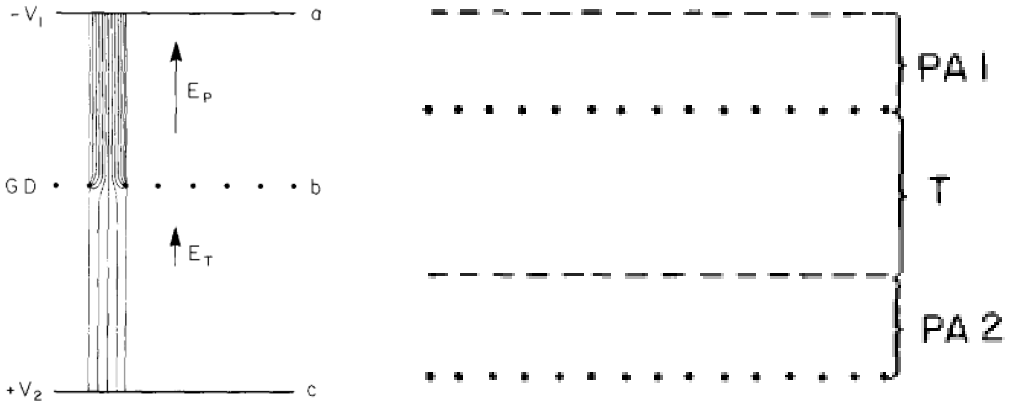
Fig. 4: Exposed view of the prototype detector plus details of the gas gain structure (MicroCAT) and the resistive position encoding structure (one single interpolation cell). The full active area of 28 x 28 mm² is composed of 7 x 7 interpolation cells, each one 4 x 4 mm² in size.

Cellular resistive readout using a resistive anode foil that is padded with conducting lines and forms a regular matrix of nodes, each connected to a charge-sensitive amplifier.

Resistive layer (to improve spatial resolution)

Multistep Avalanche Chamber (Charpak G, Sauli F. Phys. Lett. B78:523 (1978))

Made with a succession of metal meshes, the detector multiplied ionization electrons injected from a drift region into a high field. A fraction of the avalanche was then transferred through a lower field region into a second element of multiplication, a parallel plate or a wire chamber. Despite the loss of charge in the transfer from high to moderate fields, effective preamplification factors of several hundred were possible. Followed by a standard MWPC, the device permitted the high gains necessary to detect single photoelectrons.



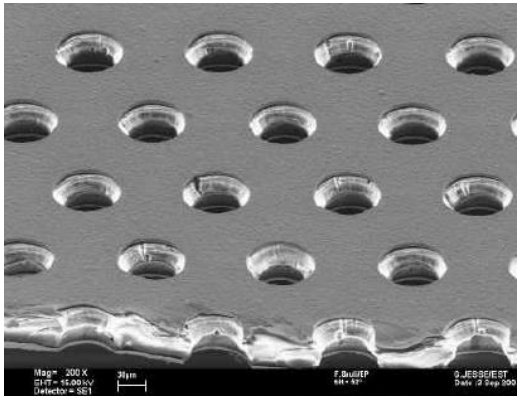
PAT
[PreAmplification and Transfer]

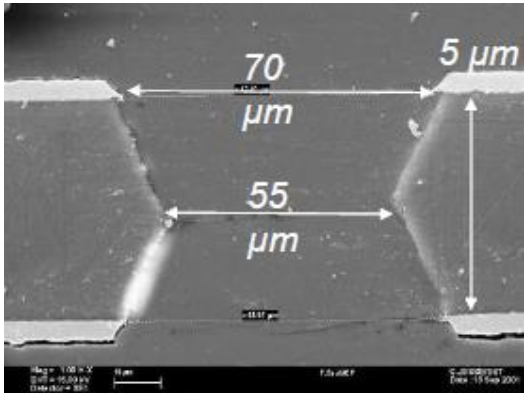
To obtain larger gains with parallel-plate structures

"The multistep chamber was mechanically complex to implement and had only limited success, but demonstrated the great potential of subdividing the gain among several cascaded elements separated by low-field gaps"

GEM (gas electron multiplier) introduced by Sauli in 1997, consists of a thin, metal-clad polymer foil chemically perforated by a high density of holes, typically 100/mm2

GEM: A new concept for electron amplification in gas detectors
F. Sauli, Nucl. Instr. and Meth. A386(1997)531





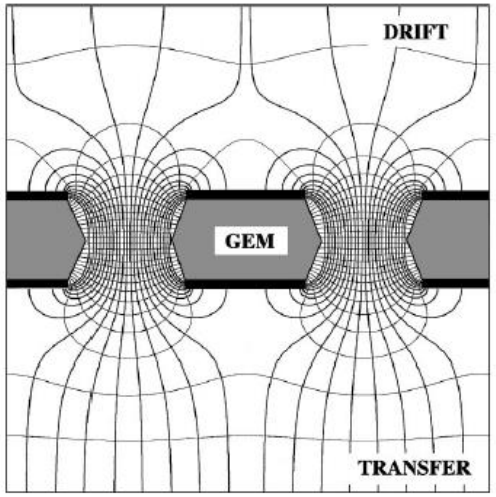


Figure 34 Electric field and equipotentials lines in the gas electron multiplier.

UNIQUE FEATURE
PREAMPLIFICATION AND TRANSFER OF CHARGE PRESERVING THE IONIZATION PATTERN

Sharing of the gain between two or more cascaded amplifiers, each operated at a voltage well below the discharge limit, appears to be a good solution to the problems common to all single-stage micro pattern detectors.

Thick GEM

(R. Chechik, A. Breskin and C. Shalem,Thick GEM-like multipliers—a simple solution for large area UV-RICH detectors, to be published in NIMA - Similar approach to Peskov's "optimized GEM")

THGEM Peculiarity

Geometrical parameters scale respect with standard GEM

while

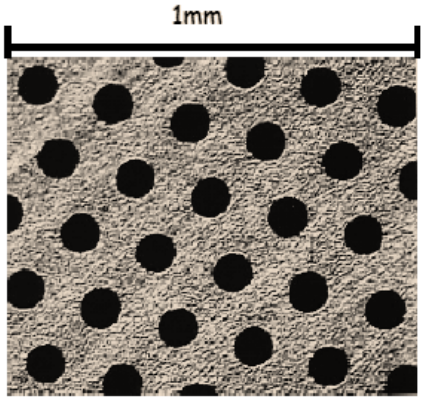
microscopic behavior of the electrons does not (in particular diffusion in the gas)

therefore

More effective electron collection and transport between cascaded elements

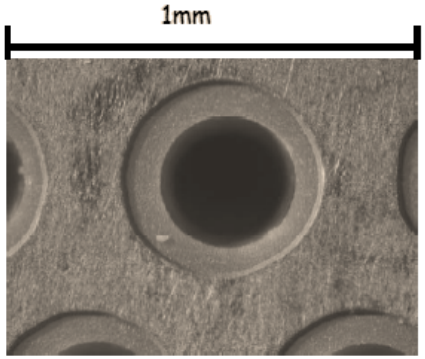
(hole diameter is larger than the electron's diffusion range when approaching the hole)

Standard GEM



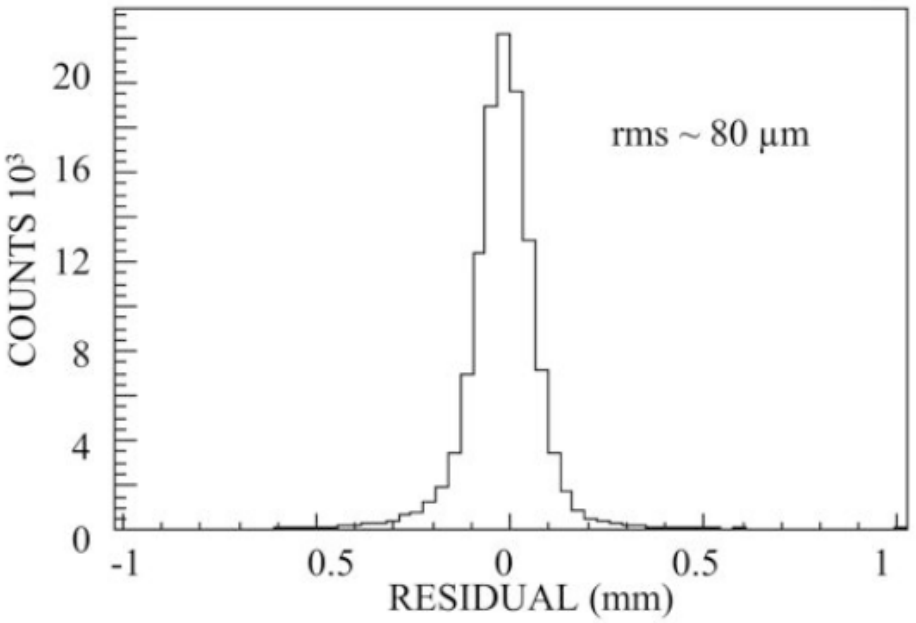
- Microlithography + etching
- High Spatial resolution (tens of microns): V_{GEM}~400V
- >10^3 gain in single GEM
- 10^6 gain in cascaded GEMs
- Fast (ns)
- Low pressure – gain~30

TGEM*

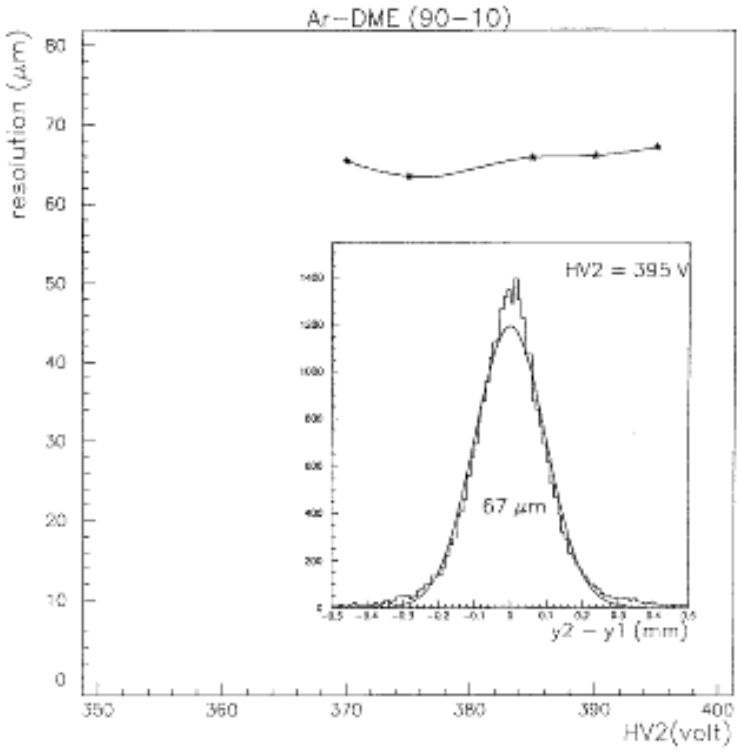


- PCB tech - etching + drilling
- Simple and robust
- V_{TGEM}~2KV (at atmospheric pressure)
- 10^5 gain in single- & 10^7 double-TGEM
- Sub-mm to mm special resolution
- Fast (ns)
- Low pressure (<1Torr) gain 10^4

Space Resolution



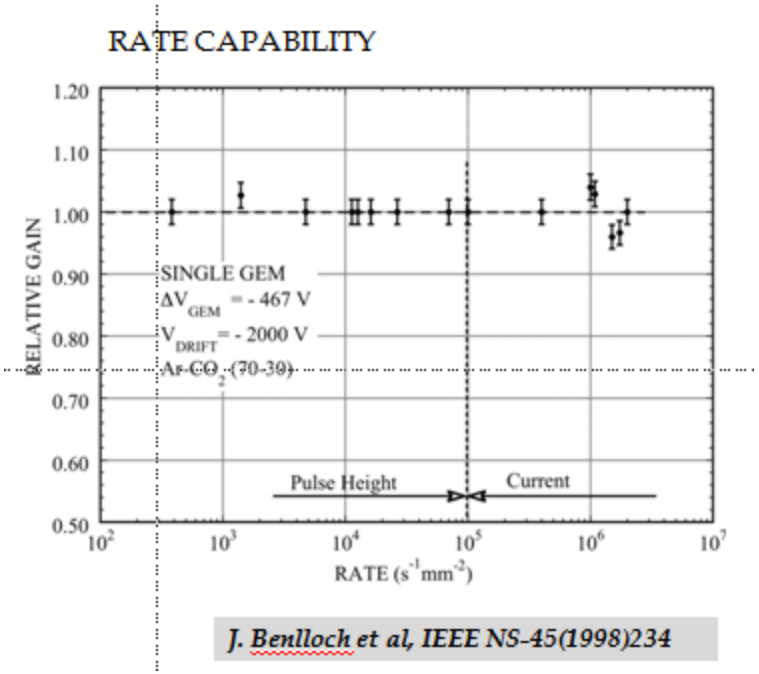
Ketzer, B. et al. (2004) Nucl. Instr. and Meth. A535, 314.



Y. Giomataris, Nucl.Instr. and Meth. in Physi.Res. A 419 (1998) 239

nb: not the best results obtained, just two example…

Rate Capabilities



J. Benlloch et al, IEEE NS-45(1998)234

MIPs

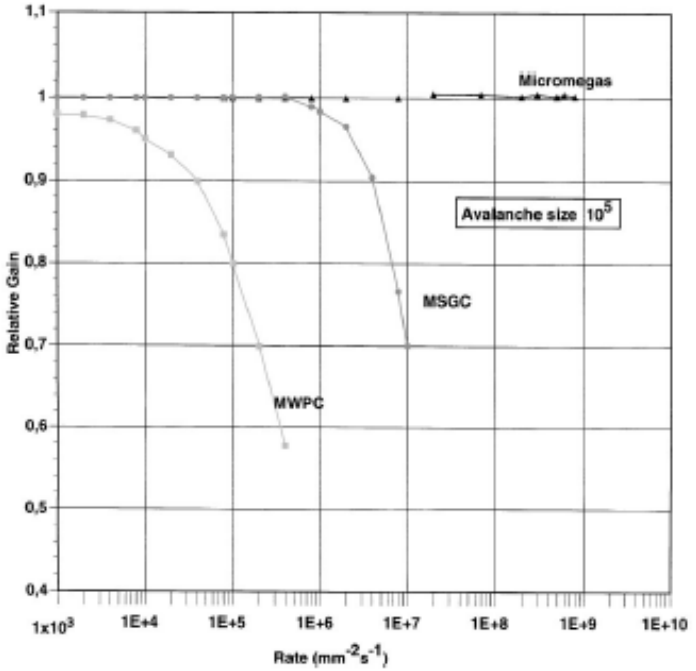


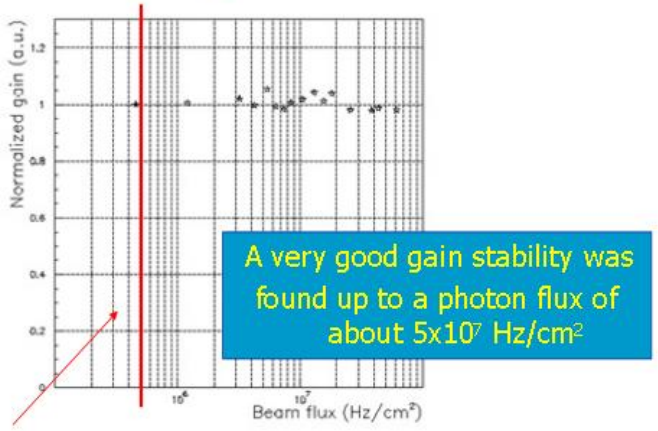
Fig. 12. Comparaison of the rate capability of MWPC and Micromegas. The avalanche size was fixed at 100 000 electrons.

Y. Giomataris, Nucl.Instr. and Meth. in Physi.Res. A 419 (1998) 239

Rate Capabilities

Triple GEM

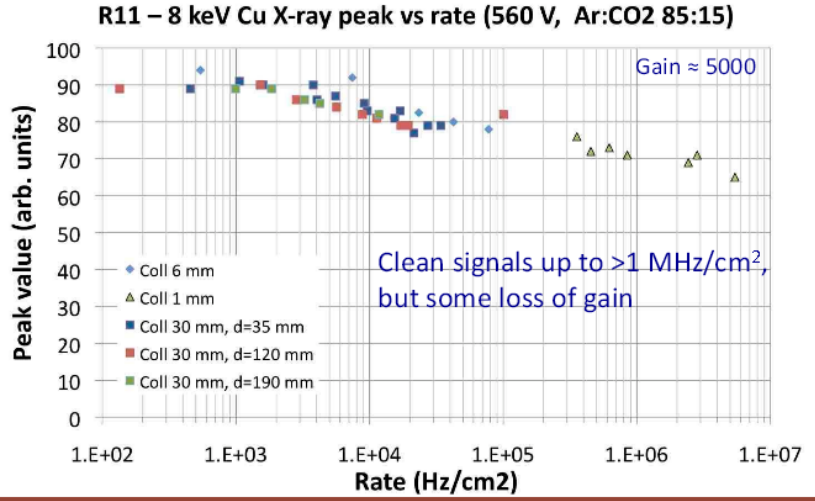
- ✓ The rate capability was measured with an X-ray (5.9 keV) tube;
- ✓ The detector was supplied with an $Ar/CO_2/CF_4$ (60/20/20) mixture resulting in a gain of about $2x10^4$;



LHCb R1M1 maximum rate

Resistive Micromegas

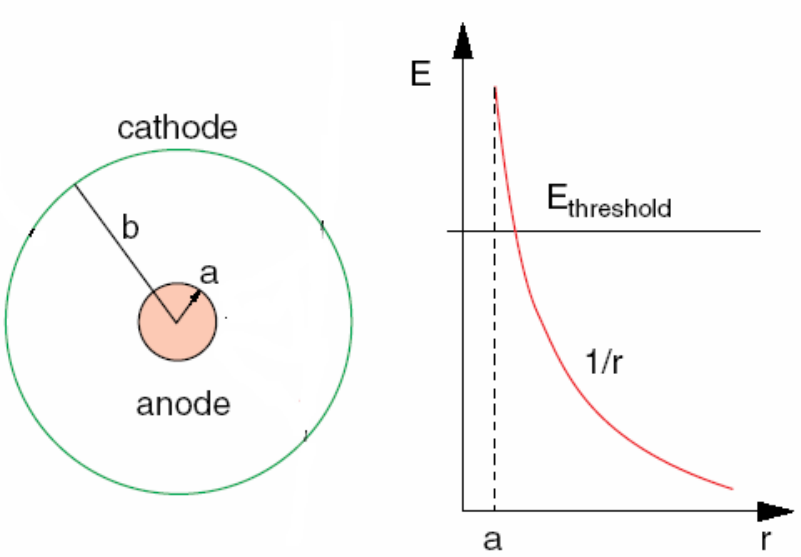
R11 rate studies

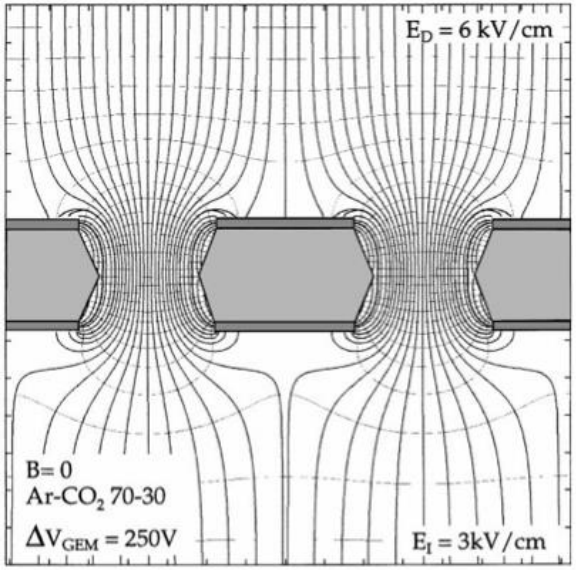


M. Bianco, https://indico.cern.ch/event/323839/session/4/contribution/48/material/slides/1.pdf

Chamber	R_{GND} (MΩ)	R_{strip} (MΩ/cm)
R11	15	2

New MPGDs & Discharges





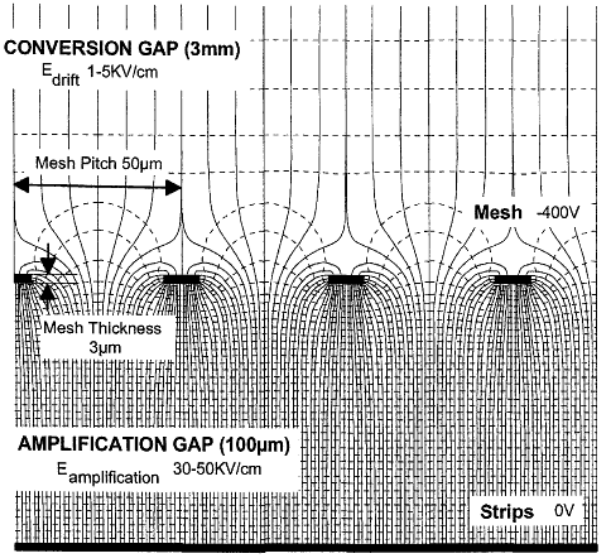


Fig. 1. Micromegas electric field map.

Discharges in new MPGDs

MPGD faster because of smaller gaps between anode and cathode but:
streamer -> fast discharges

- **Spontaneous breakdown, in absence of radiation, above a critical voltage**
- **Rate-induced breakdown (presence of long-lived excited states produced in the gas or, according to recent evidence, more likely on the electrode surface)**
- **Heavily ionizing tracks**

High rate behavior and discharge limits in micro-pattern detectors. A. Bressan et al, Nuclear Instruments and Methods in Physics Research A 424 (1999) 321

Let's have a look to mesh and hole based MPGD, micromegas and GEM. Two different approach followed against discharges:

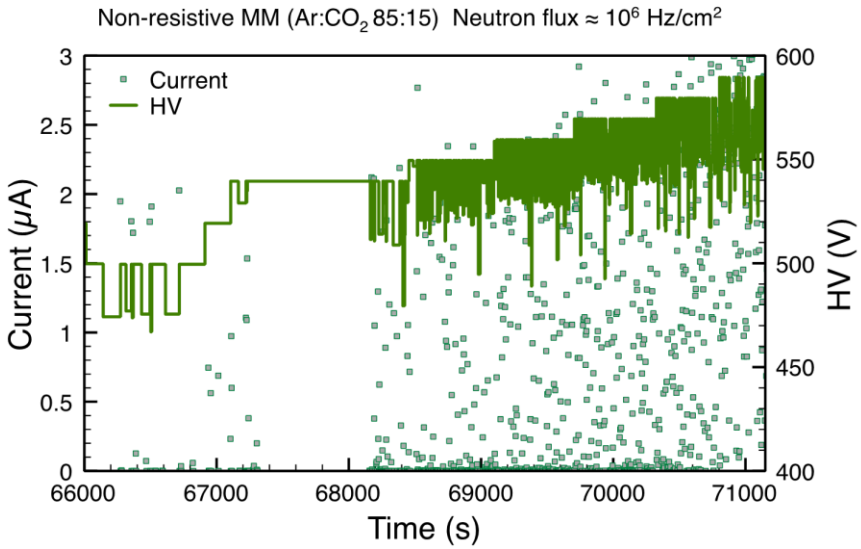
1. *Single Stage Detectors → Resistive Material*
2. *Multi stage detectors → Gain sharing*

Micromegas

Something good:
Amplifying structure not destroyed by discharges
(studier structure)

Something to fix:
Inacceptable high spark rate at LHC operating conditions with standard micromegas

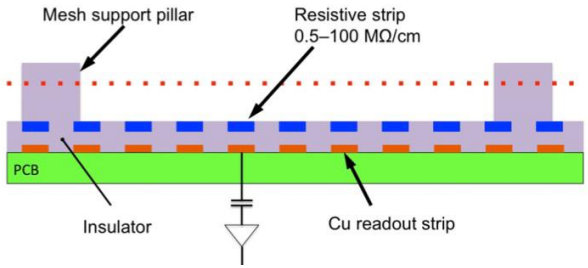
High Voltage and Current in the mesh under neutron irradiation

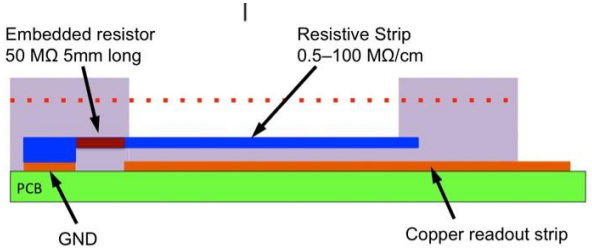


Large-area micromegas detectors for the ATLAS muon system upgrade On Atlas Micromegas, Joerg Wotschack , IWAD and 14th RD51 Collaboration Meeting, Kolkata, India

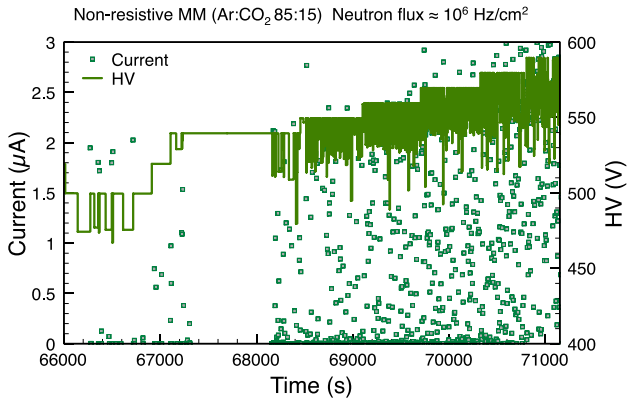
Resistive Electrodes (learned from RPC)

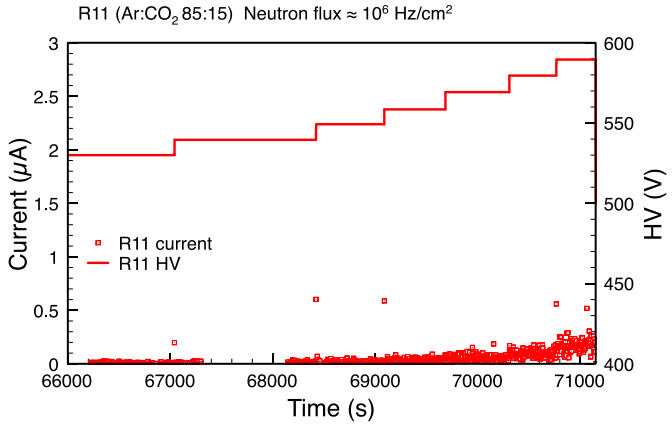
Micromegas Project for the ATLAS Small Wheel Upgrade (J. Wotschack et al.)





G. Iakovidis, arXiv:1310.0734v1 [physics.ins-det] 2 Oct 2013



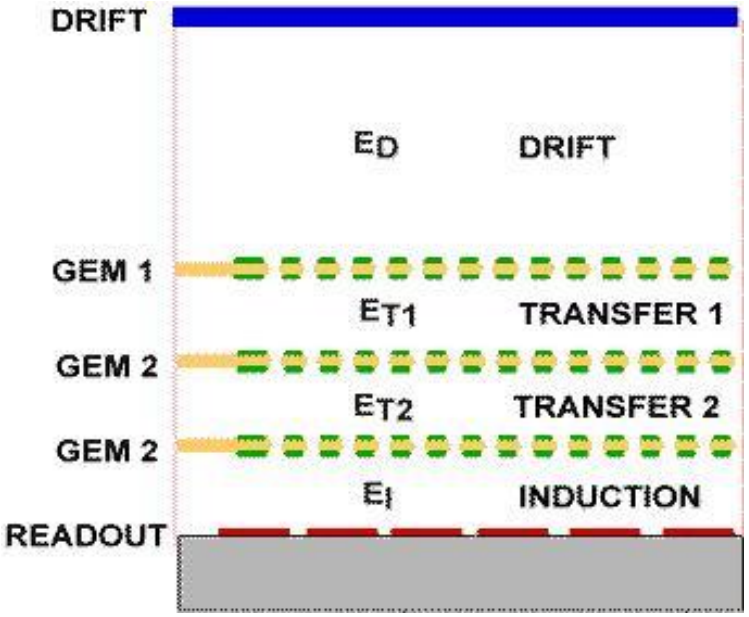


Nuclear Instruments and Methods in Physics Research A 640 (2011) 110–118

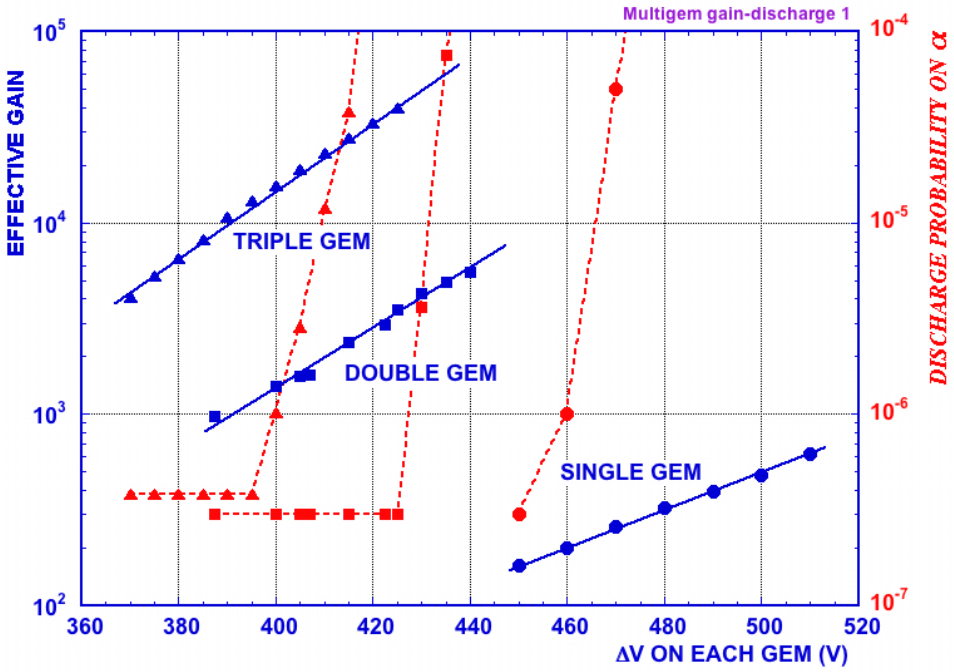
A spark-resistant bulk-micromegas chamber for high-rate applications

T. Alexopoulos [a], J. Burnens [b], R. de Oliveira [b], G. Glonti [b], O. Pizzirusso [b], V. Polychronakos [c], G. Sekhniaidze [d], G. Tsipolitis [a], J. Wotschack [b,*]

GEM: Multi Stage Devices



DISCHARGE PROBABILITY ON EXPOSURE TO 5 MeV α (from internal 220Rn gas)



S. Bachmann et al, NIMA 479(2002)294

The low-field separation between multipliers is crucial, probably because it suppresses photon- and ion-mediated feedback mechanisms; its fundamental role has been confirmed by observed failures of detectors that directly combine two elements in contact. [***F,Sauli, A. Sharma, MICROPATTERN GASEOUS DETECTORS , Annu. Rev. Nucl. Part. Sci. 1999. 49:341–88***

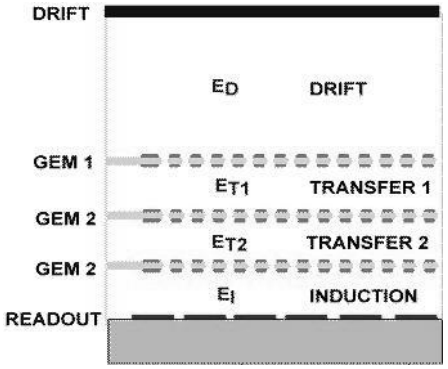
]

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-EP/ 2000-151
11 December 2000

DISCHARGE STUDIES AND PREVENTION IN THE GAS ELECTRON MULTIPLIER (GEM)

S. Bachmann[1], A. Bressan[1], M. Capeáns[3], M. Deutel[1], S. Kappler[2], B. Ketzer[1], A. Polouektov[4], L. Ropelewski[1], F. Sauli[1], E. Schulte[5], L. Shekhtman[4], A. Sokolov[4]



Discharge Probability in between amplifying electrodes

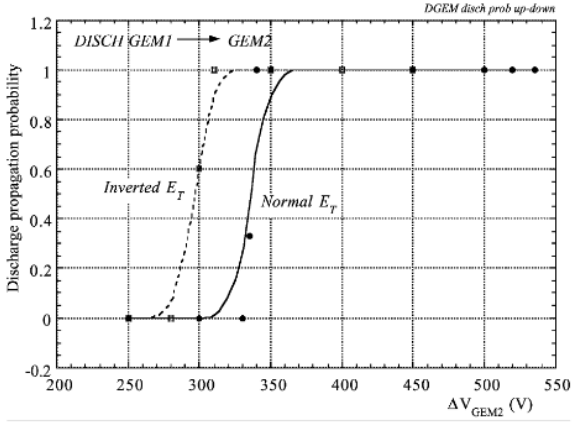


Fig. 13. Discharge propagation probability between first and second GEM in a cascade, as a function of voltage on the second, for normal and inverted transfer fields.

Discharge Probability as a function of the gain sharing between the GEMs

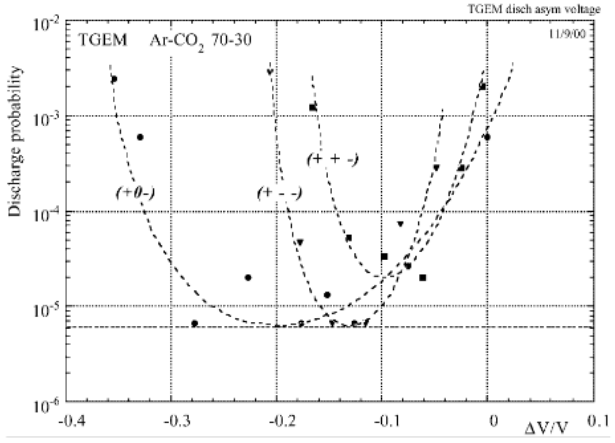


Fig. 12. Discharge probability for the triple GEM as a function of the asymmetry in applied voltages (for the meaning of symbols, see text).

Discharge Probability to the anode readout

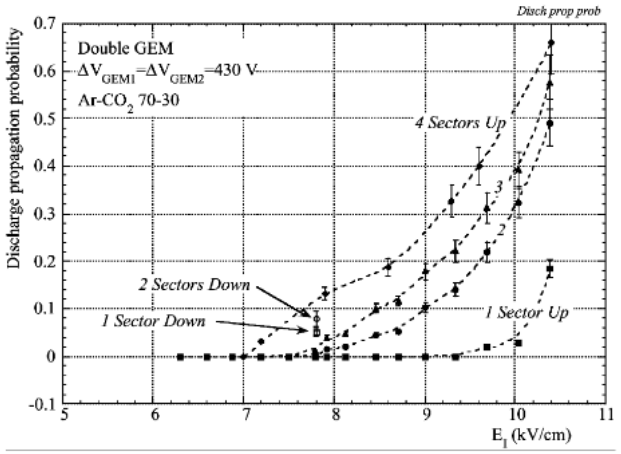


Fig. 17. Discharge propagation probability as a function of induction field for a sectored GEM.

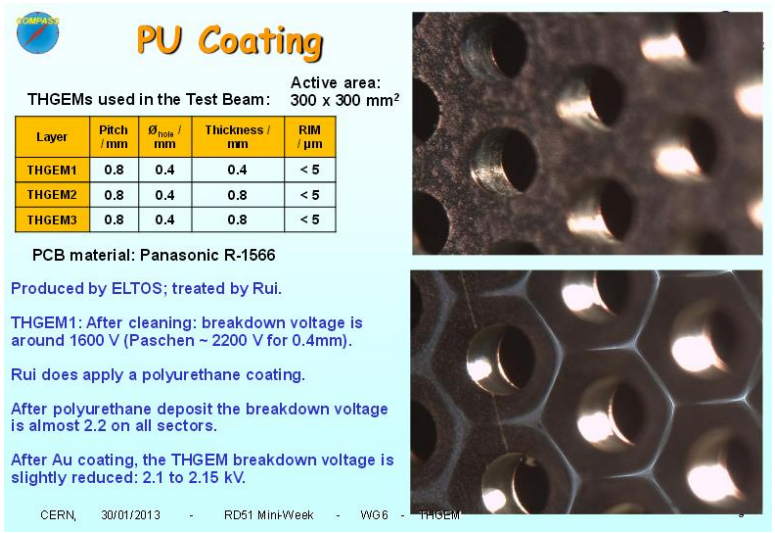
Thick GEM

THGEM: looking for the Pashen limit

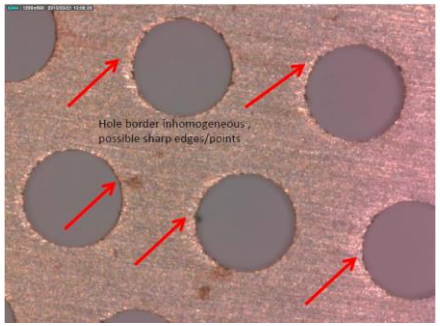
300 X 300 Single Sector #1 (before treatment)	300 X 300 Single Sector #1 (After treatment)
1390	2180

Paschen limit expected = 2190.76V

Polyurethane Coating (CERN workshop)

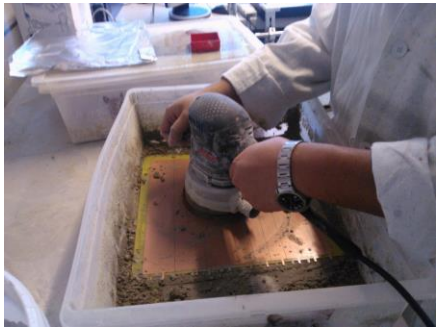


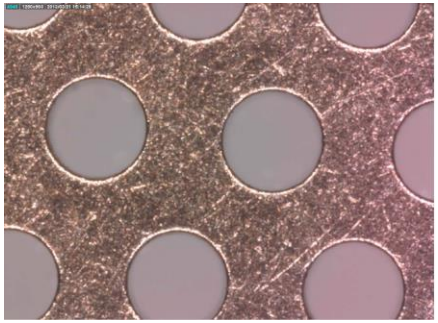
Mechanical cleaning (Trieste Group)



First step mechanical brushing using pumice stone plus water 3 types are used I 0-40 µm II 90-300 µm III (coarse) Hinrichs Pumice Powder, Coarse

Ultrasonic bath @ 50-60 C in Sonica pcb solution, long bath ~1h or more (check every 20 min) extremely mild chemical attack
Sonica PCB is alkaline pH11 ultrasonic cleaning solution

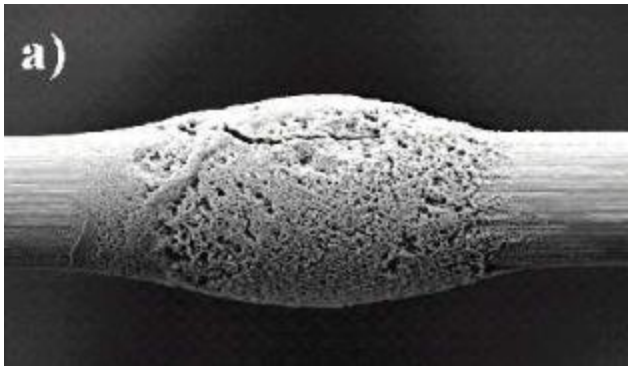


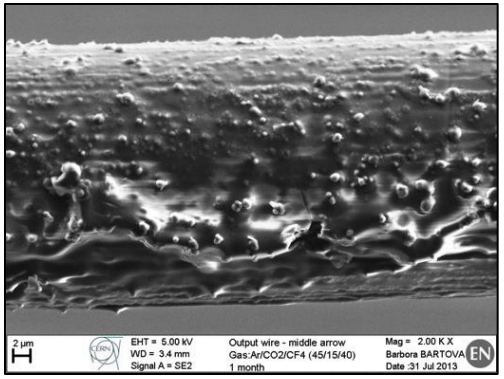


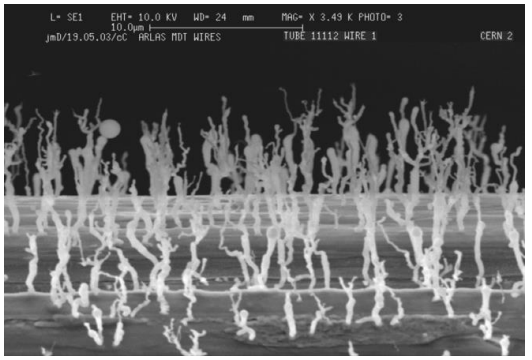
Cleaning with high pressure water to remove all pumice residuals a/o other materials,
Result after first polishing, reduced irregularities, smoothened borders, still scratches

After washing with demineralized water plus oven at 180 C for 24 h

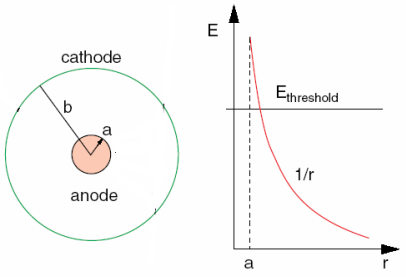
S. Levorato 22-24 April 2013 CERN, RD51 mini week



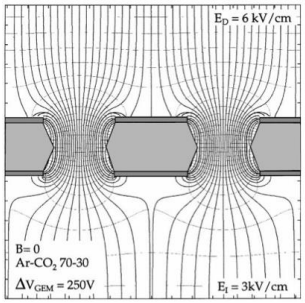




The wire experience



Uniform field MPGDs & Aging (Classical or not)



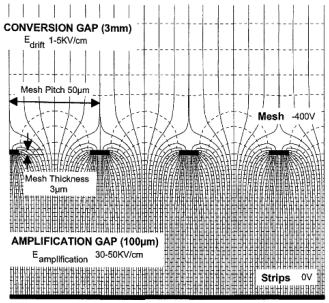


Fig. 1. Micromegas electric field map.

Aging…

F. Sauli, RD51-NOTE-2012-007

GEM are less affected by the presence of deposits on electrodes. In accelerated aging tests, realized with continuous exposure to high rate soft X-rays, no degradation of performances has been observed up to an accumulated charge of several tens of mC/mm2 with argon-CO2 gas fillings (Guirl, L. et al. (2002)) (Altunbas, C. et al. (2003)).

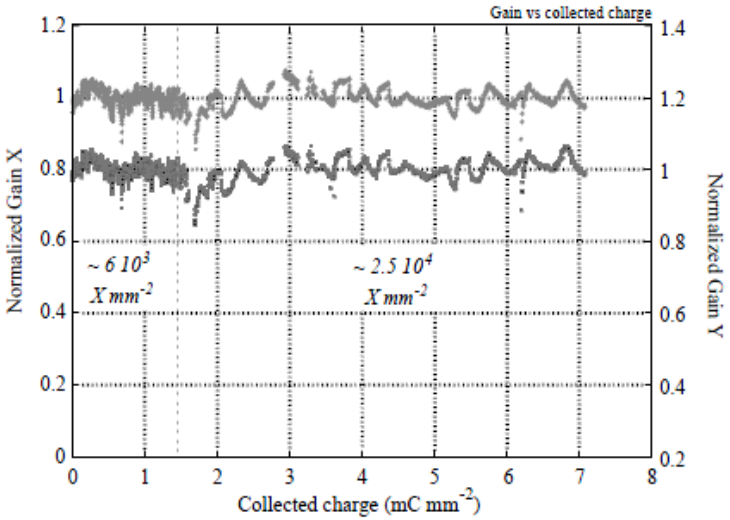
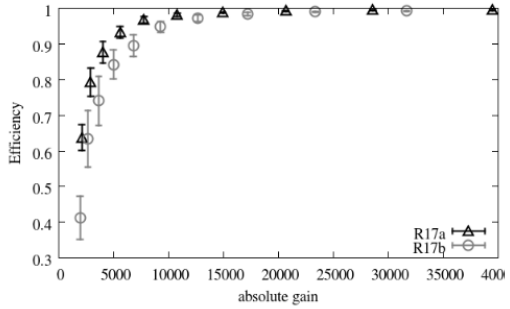
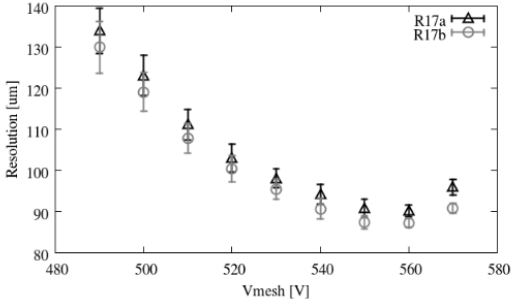


Fig. 38. Long-term gain stability under irradiation.

Altunbas, C *et al. (2002) Nucl. Instr. and Meth.* ***A490, 177 (COMPASS)***

J. Galán et al., An ageing study of resistive micromegas for the HL–LHC environment, 2013 JINST 8 P04028.





Comparison of efficiency and spatial resolution of irradiated (R17a) and not irradiated (R17b) resistive micromegas as a function of the absolute gain.

Table 1. Radiation test with micromegas detectors.

Irradiation with	Charge Deposit (mC/cm^2)	HL-LHC Equivalent
X-Ray	225	5 HL–LHC years equivalent
X-Neutron	0.5	10 HL–LHC years equivalent
Gamma	14.84	10 HL–LHC years equivalent
Alpha	2.4	5×10^8 sparks equivalent

G *Iakovidis* 2013 JINST 8 C12007

Aging…

Less sensitive ≠ Insensitive

Usual control of the quality of the gas system is strongly suggested as the selection and test of all the material in contact with the gas volume and all the precaution used to be protected against aging (ref to single wire experience)

Aging (non classical)

LHCb

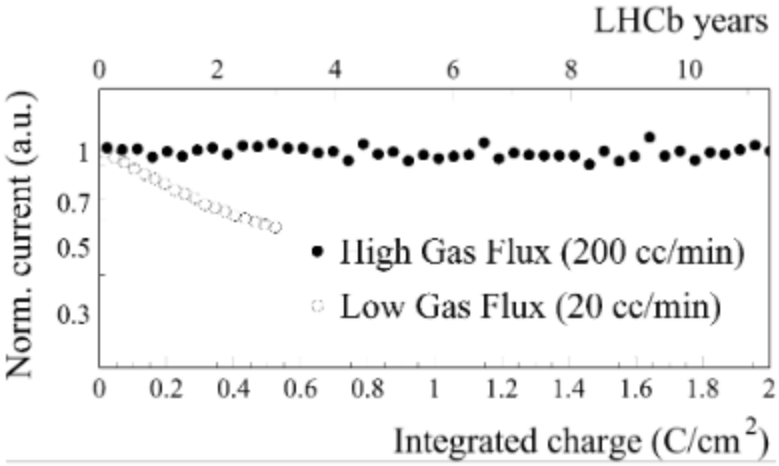


Fig. 14. Comparison between the aging measured on a small prototype with low gas flow (~20 cm ^{3}/min) and high gas flow (~200 cm ^{3}/min).

Ar/CO2/CF4
(45/15/40)

We have demonstrated that the etching observed during this test is clearly correlated with bad gas flow rate conditions. No aging occur if the gas flow is properly set.

Studies of Etching Effects on Triple-GEM Detectors Operated With CF_4-Based Gas Mixtures

M. Alfonsi, S. Baccaro, G. Bencivenni, W. Bonivento, A. Cardini, P. de Simone, F. Murtas, D. Pinci, M. Poli Lener, D. Raspino, and B. Saitta

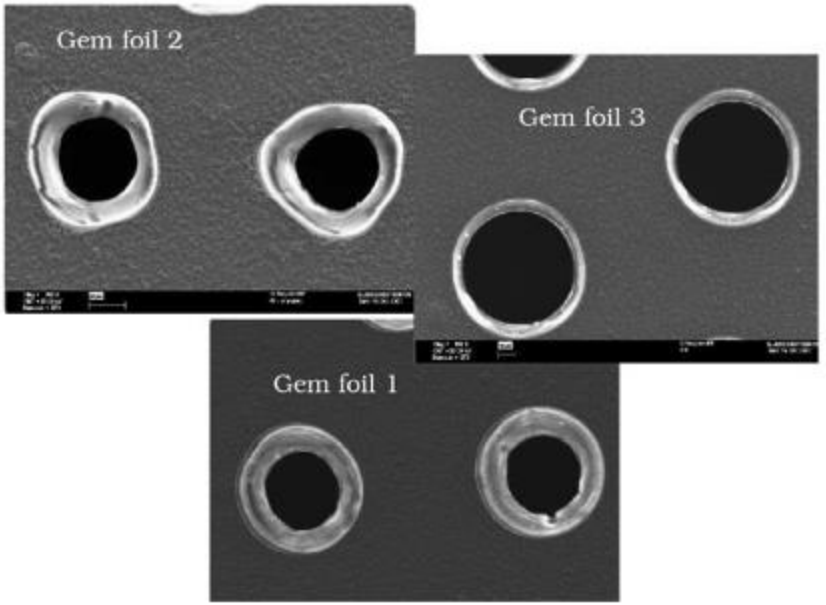


Fig. 7. Picture of the three gem foils. The widening of the holes from the first to the third foil is visible.

Something to keep in mind… not easy to handle because of the LHC, HL-LHC integrated charge

NIKHEF

MPGD ageing

Fred Hartjes
NIKHEF

Magic or science?

Intensity dependence of ageing

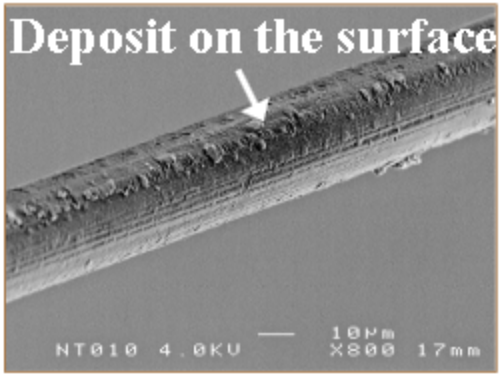
2nd RD51 collaboration meeting
Paris, October 13 - 15, 2008

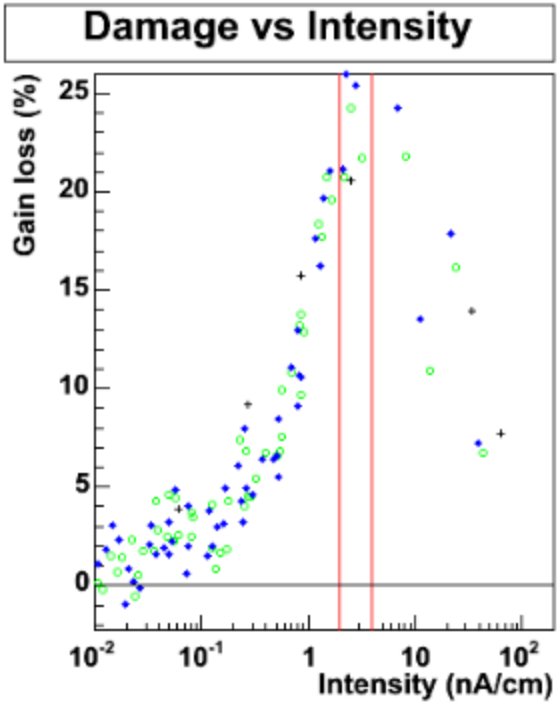
Fred Hartjes

1

2nd RD51 collaboration meeting, Paris, October 13 - 15, 2008

- Strongest ageing at moderate intensity
  - Not much ageing at the highest intensity
    - => not proportional to accumulated charge
  - Highest ageing at ~ 0.2 mC/cm
- Deposit on wire surface visible



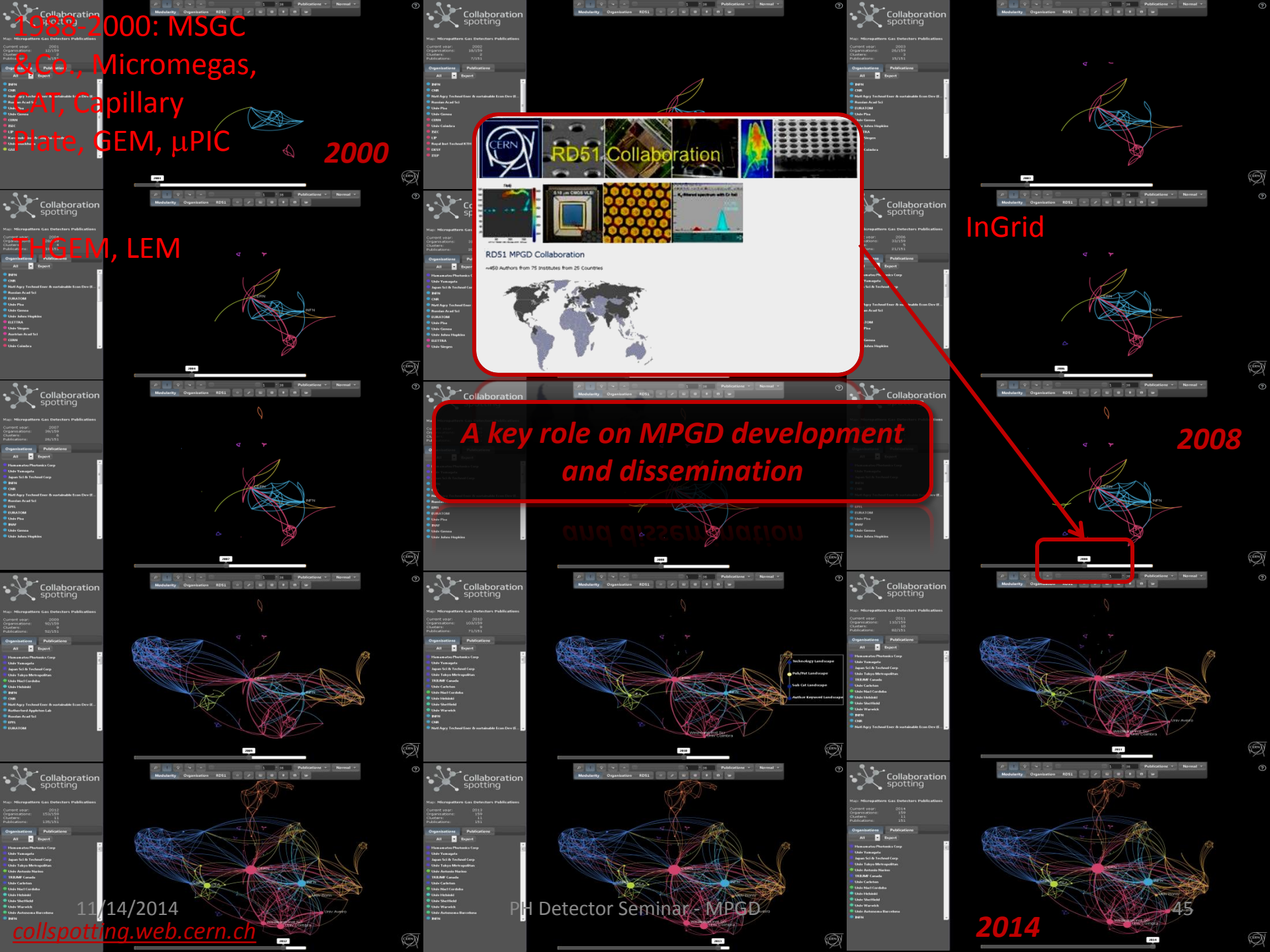


Fred Hartjes

23

2nd RD51 collaboration meeting, Paris, October 13 - 15, 2008

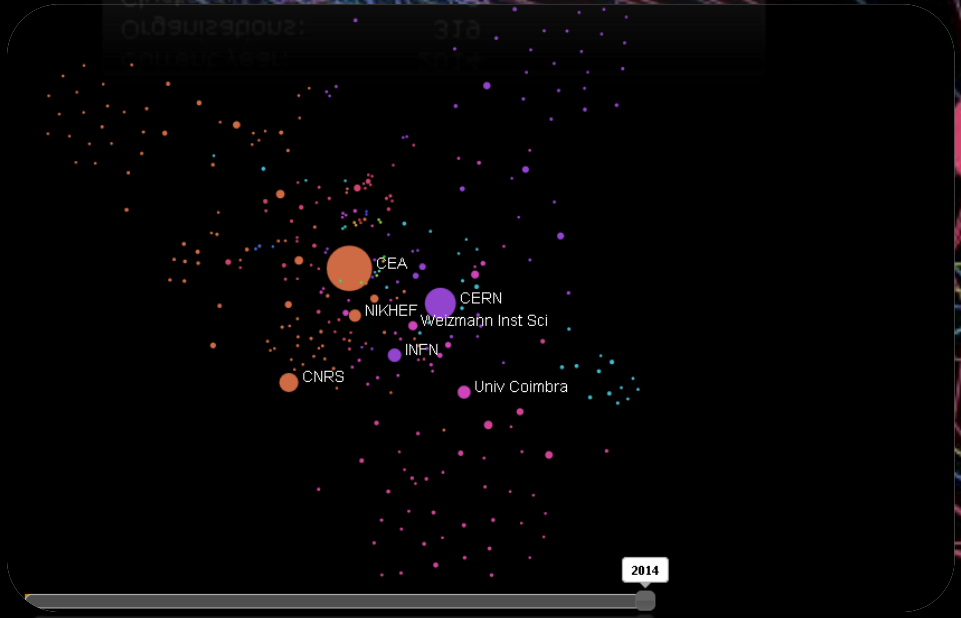
MPGD.. A large community


1988-2000: MSGC
RCo., Micromegas,
CAT, Capillary
Plate, GEM, μPIC
2000
HGEM, LEM
RD51 Collaboration
RD51 MPGD Collaboration
InGrid
A key role on MPGD development
and dissemination
2008
2014
collspotting.web.cern.ch

Collaboration spotting

Map: **MicroMegas Publications**

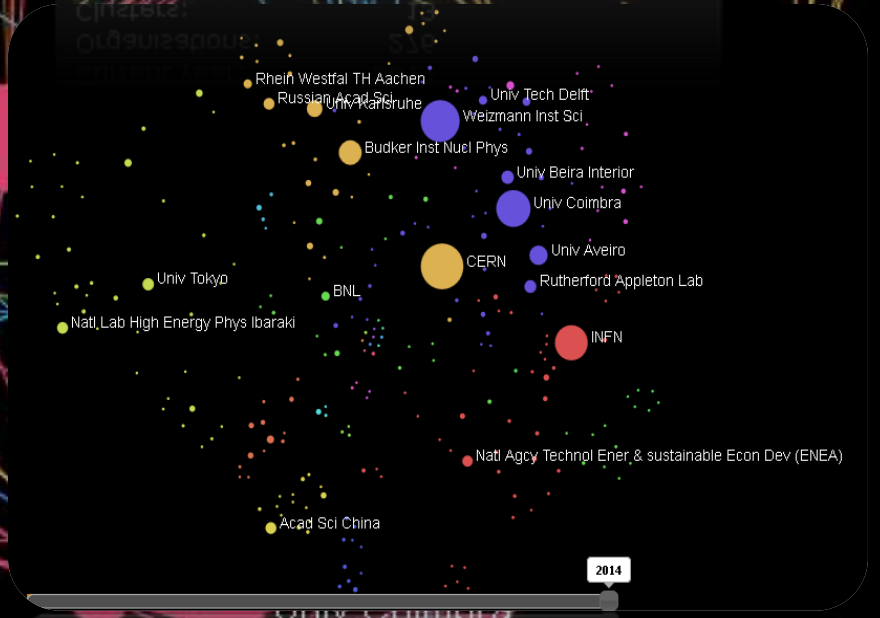
Current year:	2014
Organisations:	319
Clusters:	8
Publications:	450



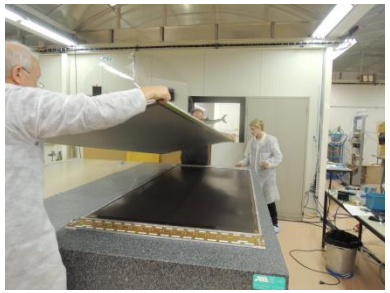
Collaboration spotting

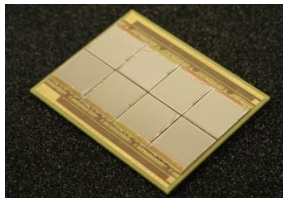
Map: **Gas Electron Multipliers Publications**

Current year:	2014
Organisations:	276
Clusters:	13
Publications:	457

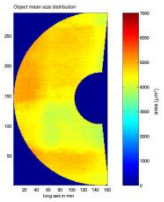


MPGD Technology and new structures (Large Area Detectors, Assembly Optimization)





Characterization and understanding of physical phenomena in MPGD



WG1:

WG2:

WG5:

RD51

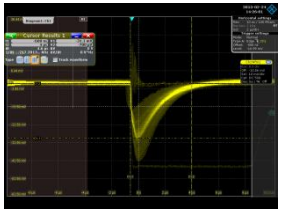
WG4:

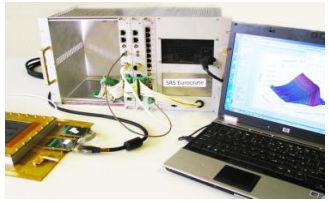
WG3/NEW WG:

WG6:

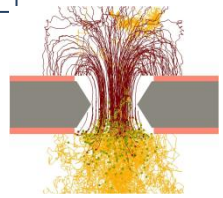
WG7:

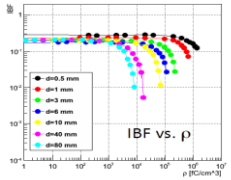
Electronics optimization and integration with MPGD





Development of common software for MPGD Simulation





Conferences / Schools, Academia-Industry Matching Events

CERN MPGD Workshop, Quality Control and Industrialization

Common Test Beam and Lab Facilities

Conclusion

- A deep understanding of the detector physics allows the addressing of some gaseous detector and specifically MPGD issues. Wide and high level expertise developed in many years by many groups.
- Many possibility/structures to fit with the applications. As usual R&D needed to face the specific requirements/environments
- Among the others, uniform field MPGDs (micromesh and hole-type) represent nowadays a robust and mature-enough solution for many challenging applications… but they are not necessarily the only ones (again, case by case…)
- Micro Pattern fit with Large Area (not discussed but extremely important)..
- Wide spectrum of use, not only HEP … not treated in this talk … cryogenics, converter and mpgd (photons, neutron,..), extreme granularity using mpgd and integrated silicon FE...
- Large collaborative community behind these technologies (sharing common tasks and tools for boosting future perspectives – simulation, electronics, facilities).

We conclude as we started… with MWPC

It was the merit of Charpak and collaborators to recognize that the positive induced signals in all electrodes surrounding the anode interested by an avalanche largely compensate the negative signals produced by capacitive coupling; these authors operated in 1967-68 the first effective multiwire proportional chambers[1)], which comprised a set of anode wires closely spaced, all at the same potential, each wire acting as an independent counter.

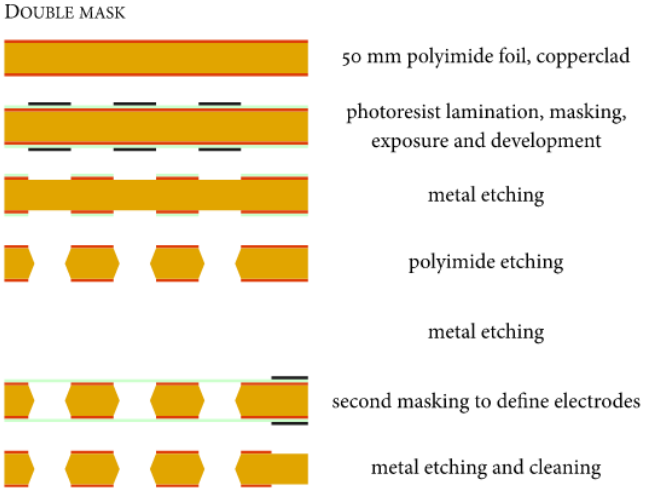
High level of understanding is mandatory and sometime the common sense fails

F. Sauli, Principles of operation of multiwire proportional and drift chambers, CERN-77-09, 3 May 1977

Thanks (I'll upload a list of useful reference in the indico page..)

backup

MICRO Patterns have to be LARGE Area



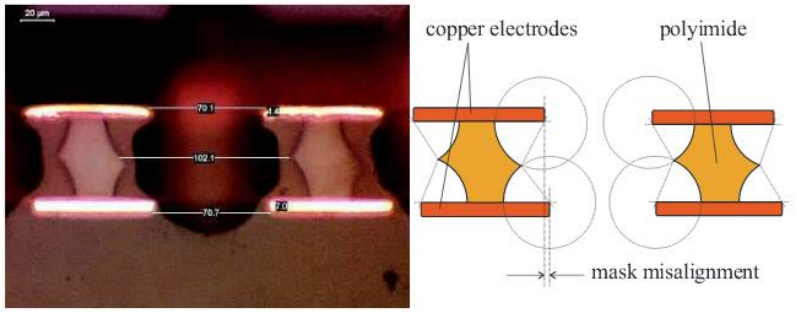
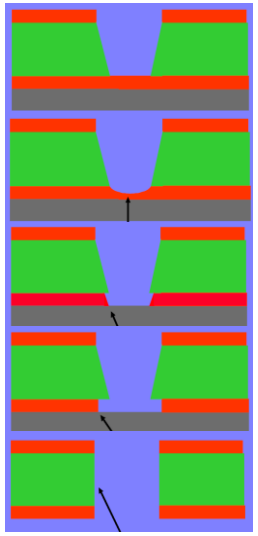


Figure 2. Left: cross-section view of isotropically etched polyimide holes (double-mask technique). The etching extends under the copper electrodes in an expanding circular profile, as shown in the reconstruction drawing on the right. GEM foil made by Tech-Etch (Plymouth, USA).



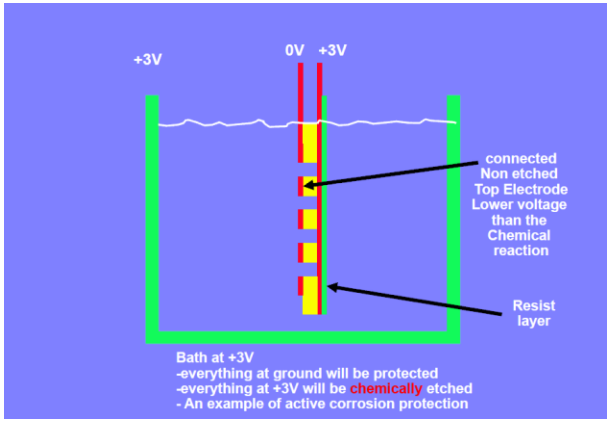
Starting structure

Conventional Isotropic Metal Etching

Hole Created

Over Etching

Back to Polyimide Etching

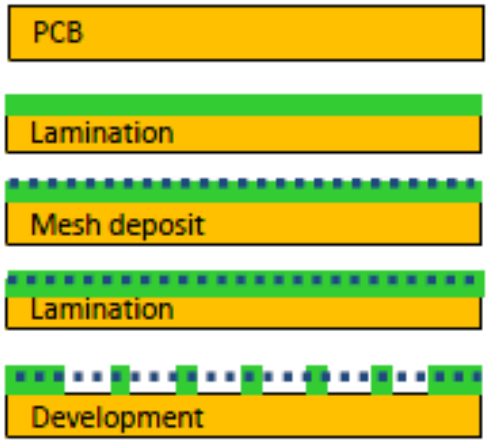


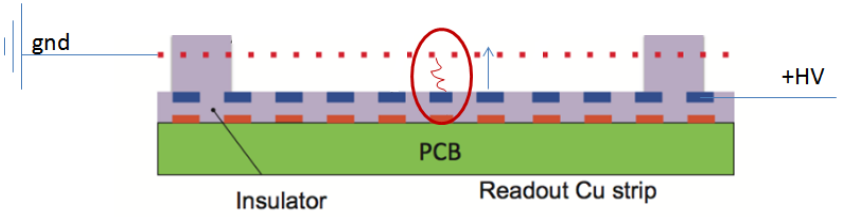
Single Mask GEMs (420cm x 990cm)

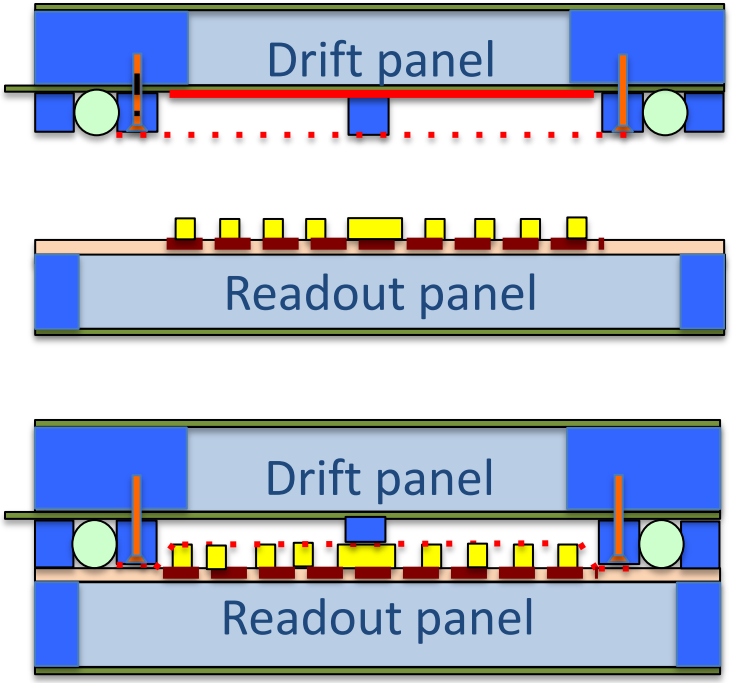
Progress on large area GEMs Serge Duarte Pinto et al., Jinst, November 26, 2009 [http://arxiv.org/pdf/0909.5039v2.pdf]

Rui De Oliveira, Latest MPGD developments and readout board guidelines, Tuesday, 28 April 2009, RD51 Week
https://indico.cern.ch/event/56216/session/1/contribution/5/material/slides/1.pdf

Bulk MicroMegas Process





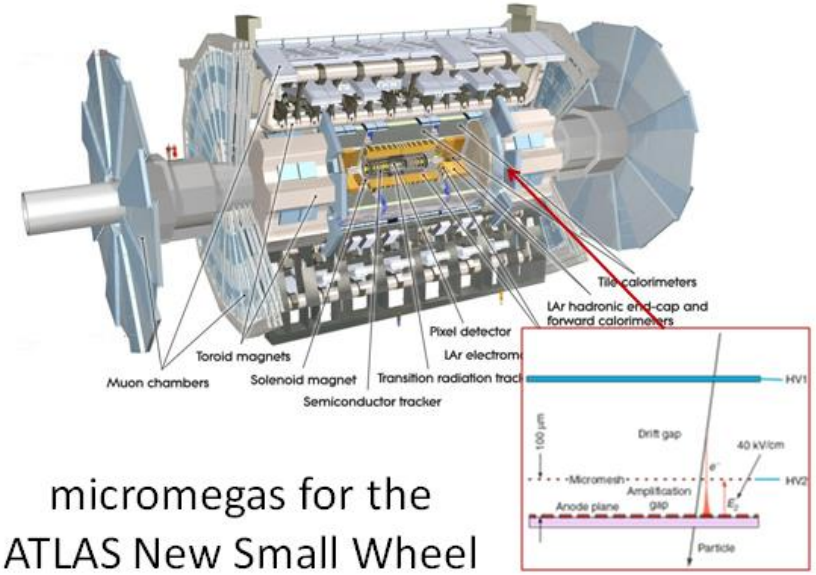


- Interconnections between resistive strips every 10–20 mm
  - Equalize the effective resistance for the charge evacuation
  - Become insensitive to broken strips

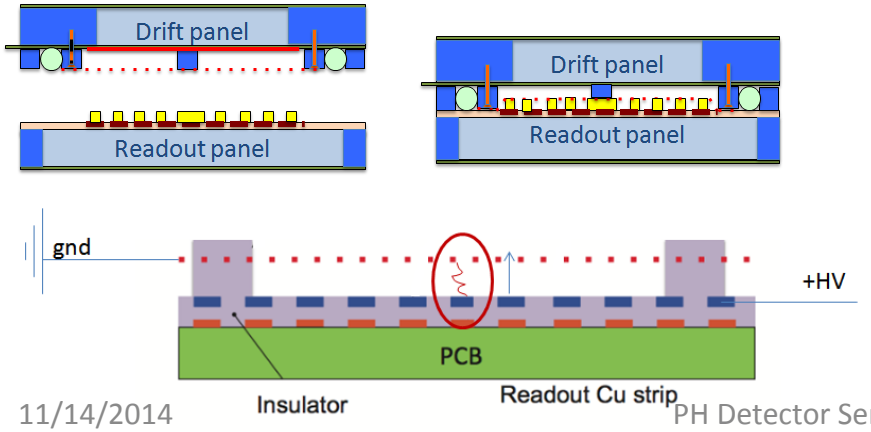
Large-area micromegas detectors for the ATLAS muon system upgrade, J. Wotschack et al, IWAD Kolkata, 28/10/2014

Muons System @ LHC: ATLAS NSW

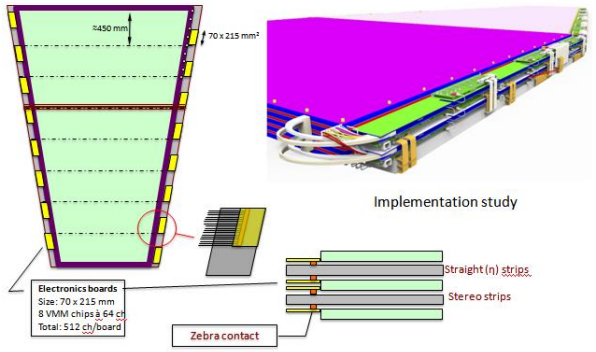
having micromegas spark protected... playing with the induction of the signal in your readout



micromegas for the ATLAS New Small Wheel



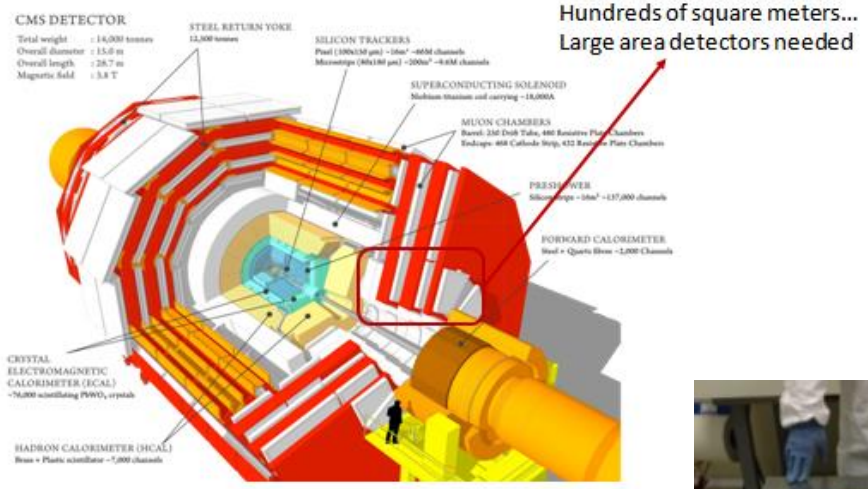
Arrangement of PCBs & electronics on readout panels

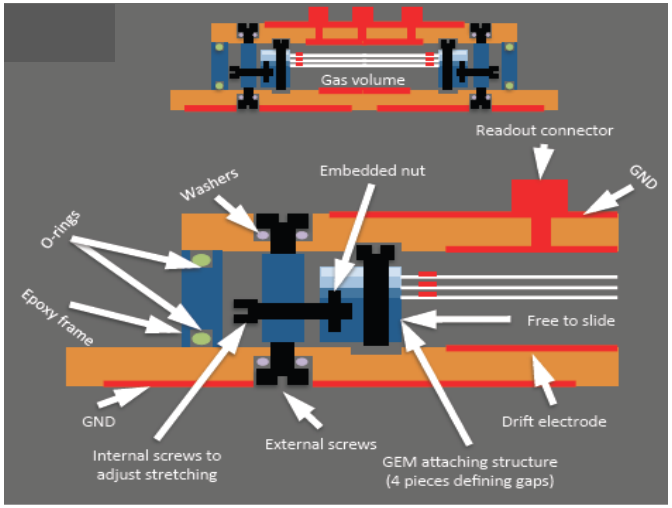


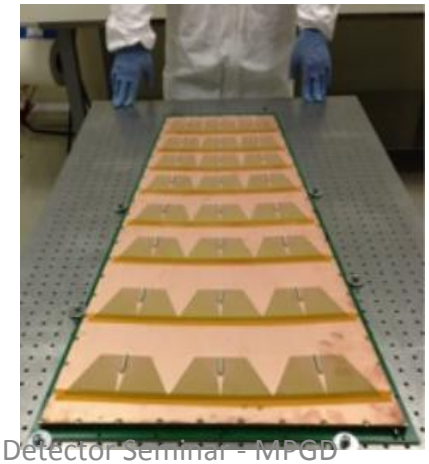
Muons System @ LHC: CMS GEM PROPOSAL

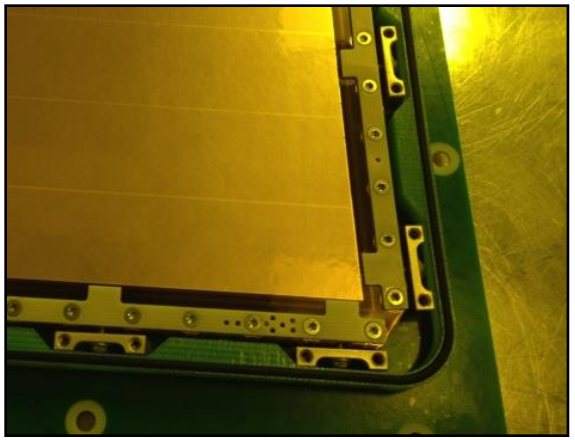
cover large areas with GEM...one example of playing with the production processes

CMS, Large GEM proposal





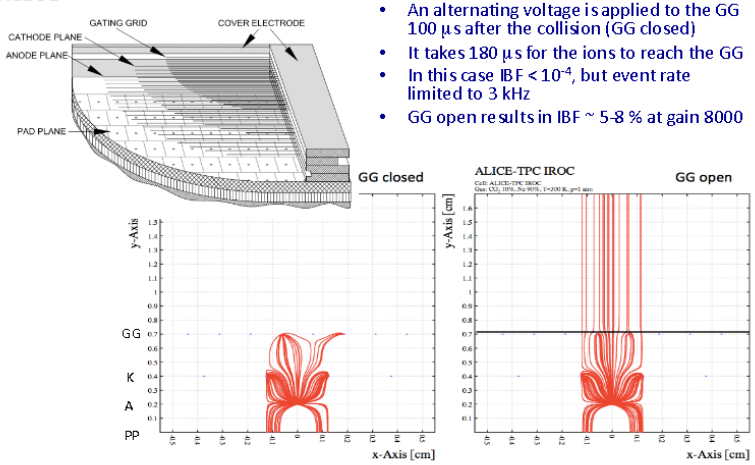




TPC @ LHC: ALICE TPC UPGRADE

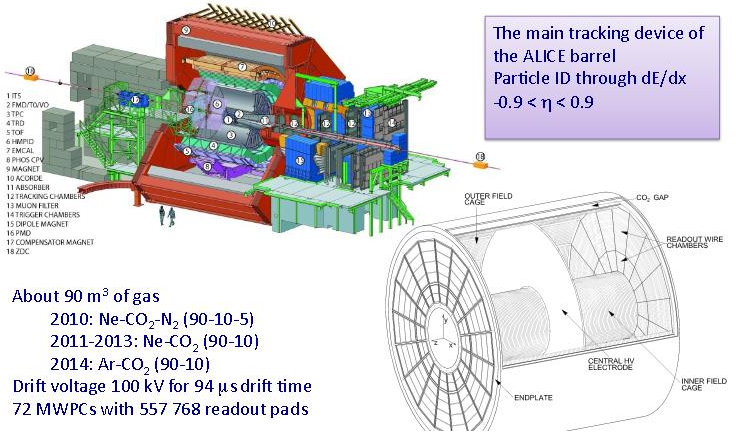
The Gating Grid in MWPC

- An alternating voltage is applied to the GG 100 μs after the collision (GG closed)
- It takes 180 μs for the ions to reach the GG
- In this case IBF < 10^{-4}, but event rate limited to 3 kHz
- GG open results in IBF ~ 5-8 % at gain 8000



The ALICE TPC

The main tracking device of the ALICE barrel
Particle ID through dE/dx
-0.9 < η < 0.9



About 90 m^3 of gas
- 2010: Ne-CO_2-N_2 (90-10-5)
- 2011-2013: Ne-CO_2 (90-10)
- 2014: Ar-CO_2 (90-10)

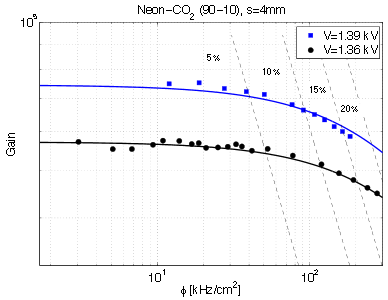
Drift voltage 100 kV for 94 μs drift time
72 MWPCs with 557 768 readout pads

In addition, space-charge in the amplification region

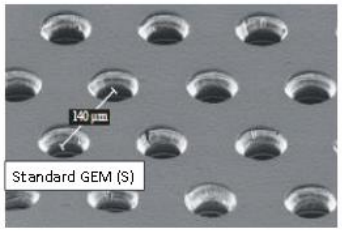
- Maximum particle rate of 40-100 kHz/cm^2 → sizeable gain drop → deterioration of dE/dx

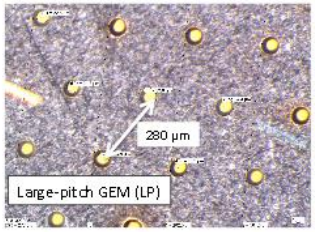
☞ Replace MWPCs with GEMs
- intrinsic ion blocking
- high rate capability
- allows for a factor 3 lower gain
- new FEE needed!

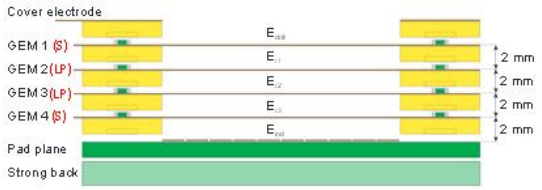
- Keep Field Cage and everything else



TDR baseline solution: 4-GEM stack



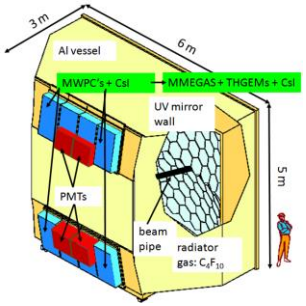




Baseline solution (S-LP-LP-S) employs standard (S) and large-pitch (LP) GEMs

$U_{GEM1}<U_{GEM2}<U_{GEM3}<U_{GEM4}$

Compass Rich: THGEMs



introduced in // by different groups:

L. Periale et al., NIM A478 (2002) 377.

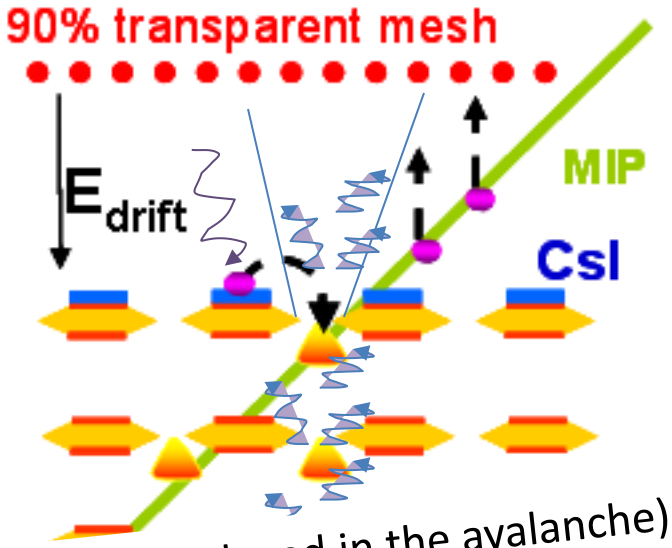
P. Jeanneret, PhD thesis, Neuchatel U., 2001.

P.S. Barbeau et al, IEEE NS50 (2003) 1285

R. Chechik et al, .NIMA 535 (2004) 303

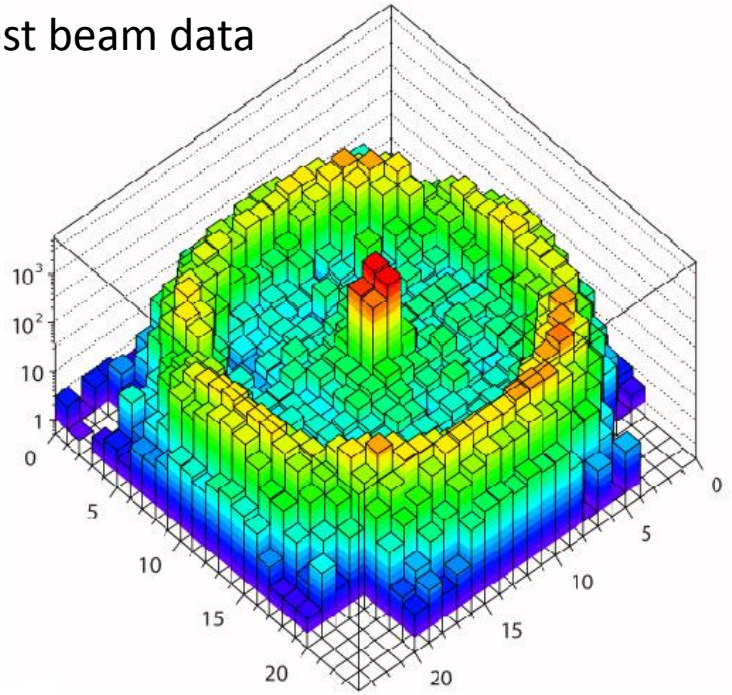
Advances in Gaseous Photomultipliers

Rachel Chechik and Amos Breskin*



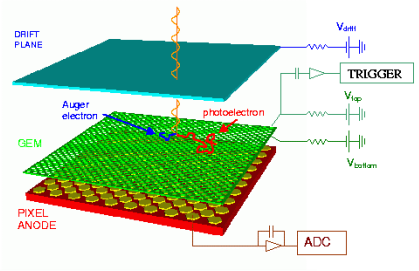
Photon (UV produced in the avalanche) Feedback killed

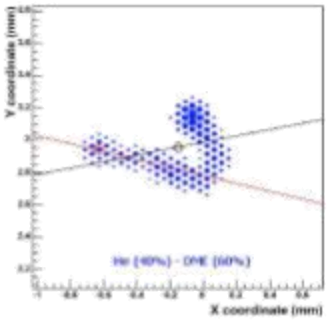
Test beam data



S. Levorato INSTR-2014 International Conference on Instrumentation for Colliding Beam Physics

MPGD and silicon





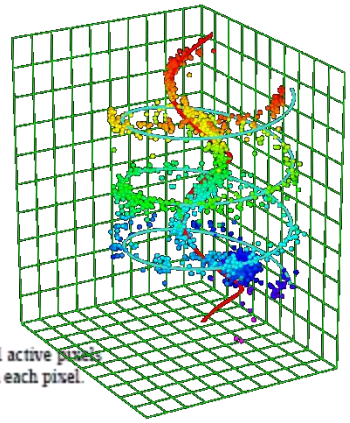


Fig. 82: Photoelectron track emitted by a 5.4 keV X-ray; the hexagonal active pixels have 50 μm pitch, and the content corresponds to the recorded charge on each pixel.

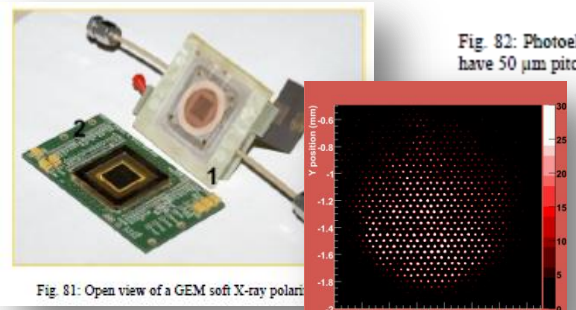
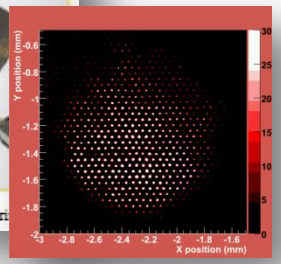
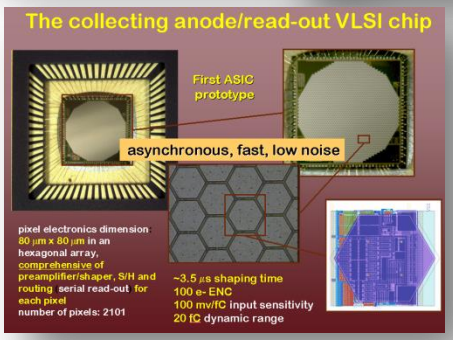
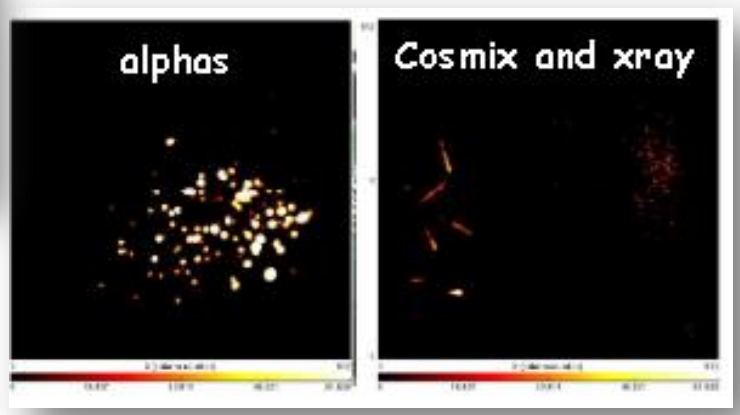


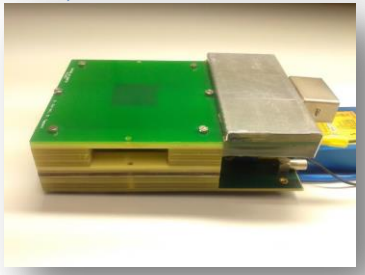
Fig. 81: Open view of a GEM soft X-ray polari





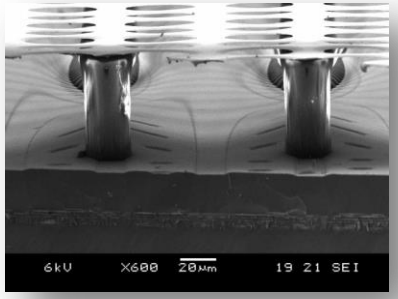


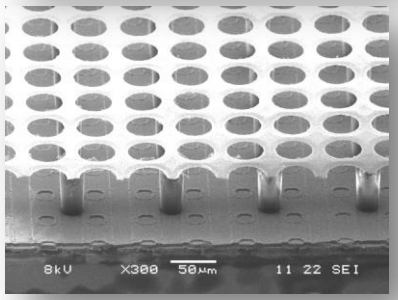
GEMPIx (& TimePix) Murtas et al



Black, J. K. et al . (2003). Nucl. Instr. and Meth. A513, 639.
Bellazzini et al. (2004) Nucl. Instr. and Meth. A 535, 477.
Bellazzini, R et al. (2007a) Nucl. Instr. and Meth. A 572, 160

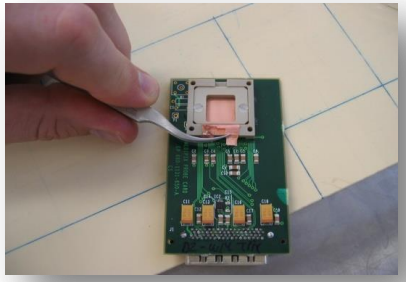
Ingrid (& Timepix chip)





M. Campbell et al, NIMA540(2005)295
M. Chefdeville et al., NIMA556(2006)490

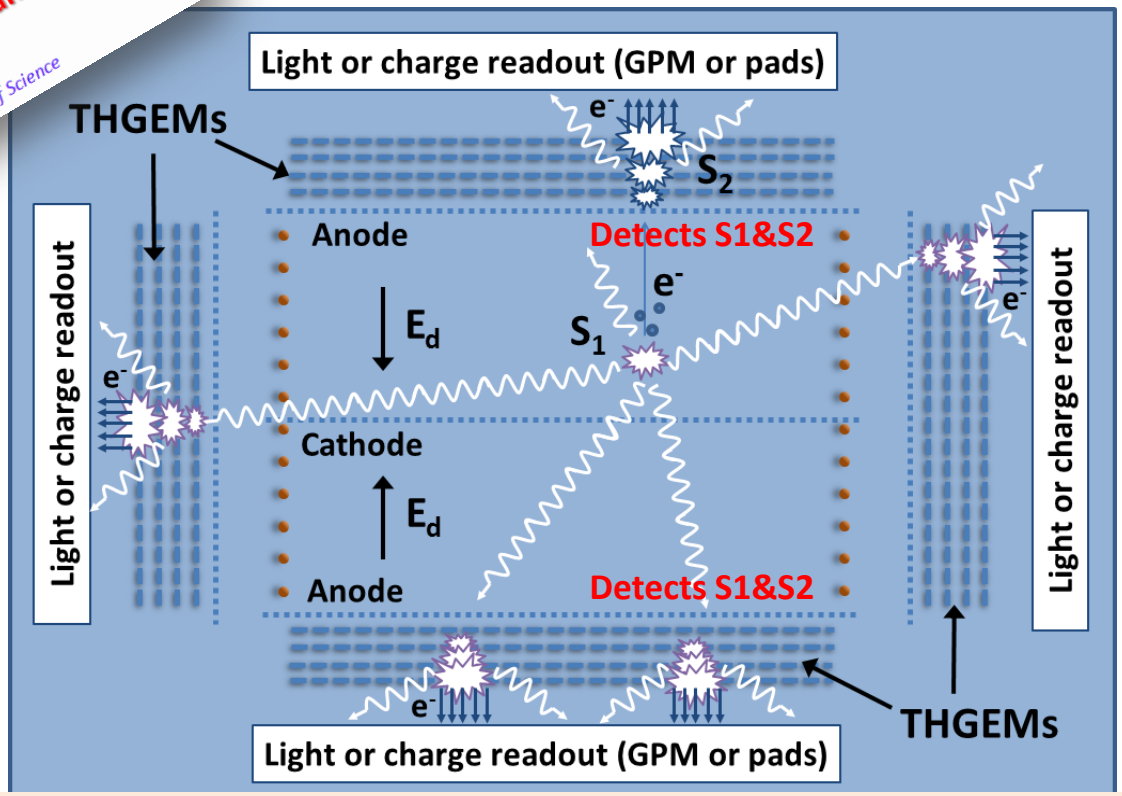
MM(& Medipix chip)



P. Colas et al., NIMA535(2004)506

S1 & S2 with LHM

Noble (liquid) Dreams
Amos Breskin
Weizmann Institute of Science



A dual-sided single-phase TPC DM detector with top, bottom and side THGEM-LHMs.
The prompt S1 scintillation signals are detected with all LHMs. The S2 signals are recorded with bottom and top LHMs.

Highlights:

- **Higher S1 signals ➔ lower expected detection threshold**
- **Shorter drift lengths➔ lower HV applied & lower e- losses**

It was believed that because of the capacitive coupling, the wires next to the amplifying wires would receive a sizeable part of the signal, and for this reason many attempts were made to have each sensitive wire separated by a shielding wire. However, this was costing a factor of two in the spatial resolution, and was limiting the lower distance between wires since a high voltage had to be applied between them.

In fact, if it is true that when you send a negative pulse, with an external generator, on one wire, you receive a sizeable negative pulse on the neighbouring wire, then the situation is different when you detect a particle by proportional amplification on a wire. You have indeed a negative pulse on this wire, but positive pulses on the neighbouring ones. This effect is due to the mechanism generating these pulses, namely the motion of the positive ions in the strong fields around the wires. This effect is responsible for the perfect localization of the pulses on the sensitive wires, irrespective of the distance between the wires. It is sufficient to have amplifiers that are sensitive only to the good polarity, to avoid the spurious effect of capacitive coupling between wires.

Evolution of Some Particle Detectors Based On the Discharge in Gases, Charpak, G., November 19, 1969, CERN--69-29