

DETECTOR TECHNOLOGIES

- **Goal of this course**
- **Gaseous detectors principles**
- **Semi-conductors principles**

Goal for a detector :

Observation and identification of final states
(whatever the processus)

A particle is defined by its : Mass
Electrical Charge
Momentum
Energy
Lifetime
(~~spin, flavour, color....~~)

A Detector : does not give any measurement.

Gives an information coming after an **interaction**
between the **particle** and a **medium**, through
energy deposition

Energy deposition

- **Limited** (the particle goes almost undisturbed)

Momentum

Electrical charge (if magnet)

→ Trajectory

- **Total** (the particle stops)

Energy

→ Identification

Various processes :

Ionization (Bethe-Bloch)

Radiation (Bremsstrahlung or Transition Radiation)

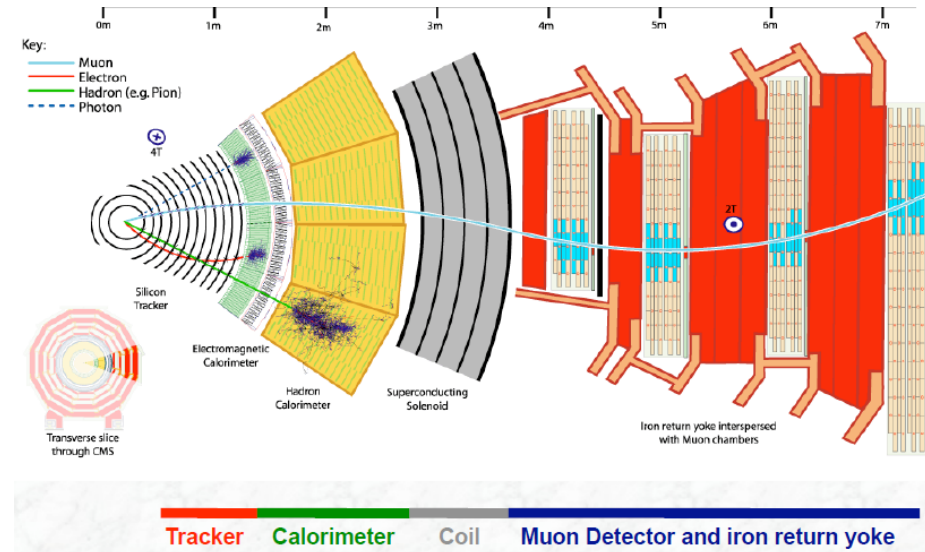
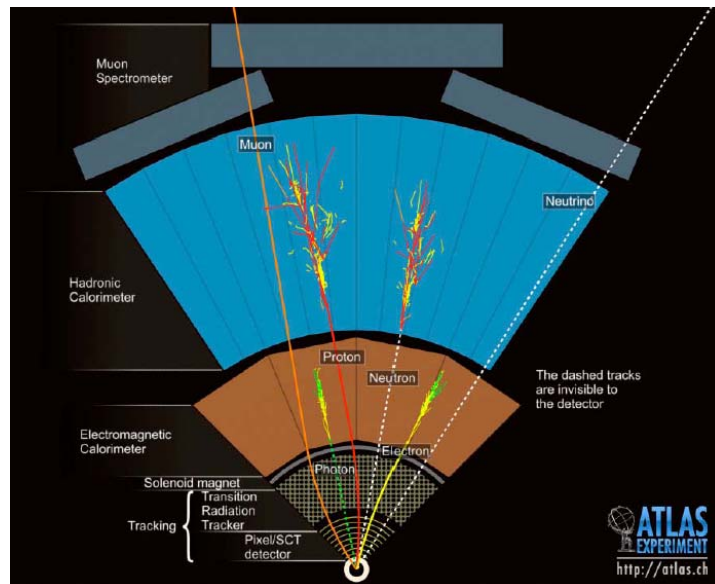
Scattering (Coulomb or direct)

Particle production (photon)

Cerenkov emission

Types of detectors :

- Trackers (position and momentum measurement)
- Calorimeters (energy measurement)
- Identifiers (identification of various types of particles)
- Trigger counters (decision)



Gaseous Detectors :

Using the interaction between a
CHARGED PARTICLE and a medium,
through **ENERGY DEPOSITION**
it will be possible to know the
POSITION of a particle
Without **disturbing** its trajectory

Gaseous detectors : Principle of operation

E. Rutherford and H. Geiger (1908) "An electrical method of counting the number of α particles from radioactive substances," Proceedings of the Royal Society (London)

1. A charged particle is passing through a gaseous medium : loss of energy

$$-\frac{dE}{dx} = K z^2 \frac{Z}{A} \frac{1}{\beta^2} \left[\frac{1}{2} \ln \frac{2m_e c^2 \beta^2 \gamma^2 T_{\max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2} \right]$$

$$T_{\max} = \frac{2 m \beta^2}{1 - \beta^2} \quad \text{Ex : proton 1 GeV/c}^2$$

$$T_{\max} = 1.2 \text{ MeV}$$

$$K = 4 \pi N_A r_e^2 m_e = 0.3071$$

A, Z : atomic mass and number relative to the medium

N_A : Avogadro's number

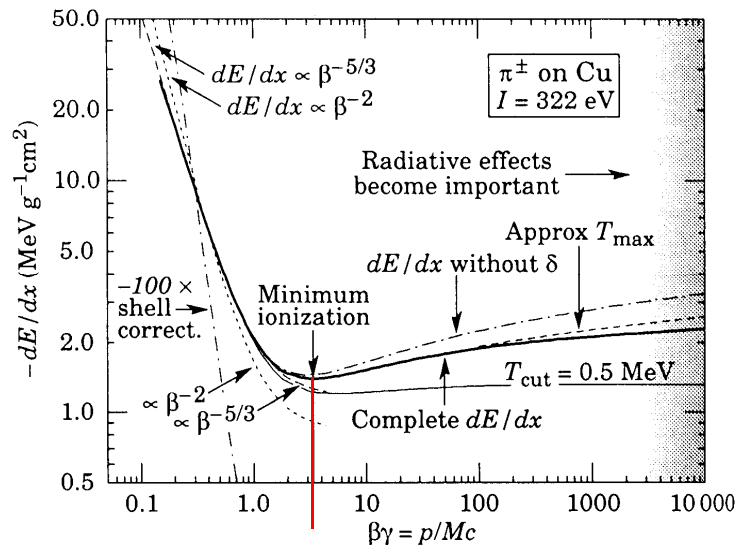
T_{\max} : maximum possible energy transferred to an electron in the medium

z : charge of the incoming particle

β, γ : relatives to the particle

Loss of energy independent of the mass of the particle.

$$\beta = \frac{v}{c} \quad \gamma = \frac{1}{\sqrt{1 - \beta^2}}$$



**In High Energy Physics,
we have to deal with MIPs
Minimum Ionizing Particles ($\beta\gamma \approx 3-4$)**

Gaseous detectors : Principle of operation

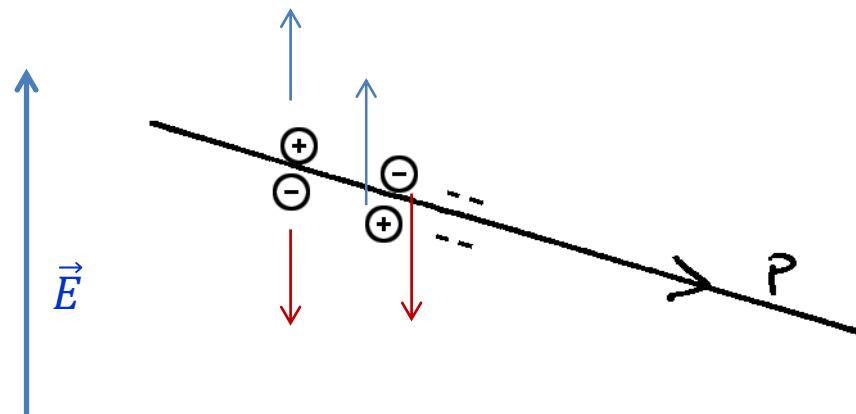
2. **E_i** : Ionization Energy corresponds to the energy required to remove a single electron from a single atom (or molecule).

Approximation : $E_i \approx 16 Z^{0.9}$

3. If $T_{max} > E_i$ One or more pairs electron – ion is (are) created

Gas	E_i (eV)	$\frac{dE}{dx}$ (MeV)	N pairs /cm for 1 MIP
H2	15.4	4.03	5.2
O2	15.2	1.69	22
Ne	21.6	1.68	12
Ar	15.8	1.47	29.4
Xe	12.1	1.23	44
CO2	13.7	1.62	34
CH4	13.1	2.21	16
DME	10.0	1.85	55

4. If exists an **electrical field** (exterior)
Electrons (and ions) are drifting ...



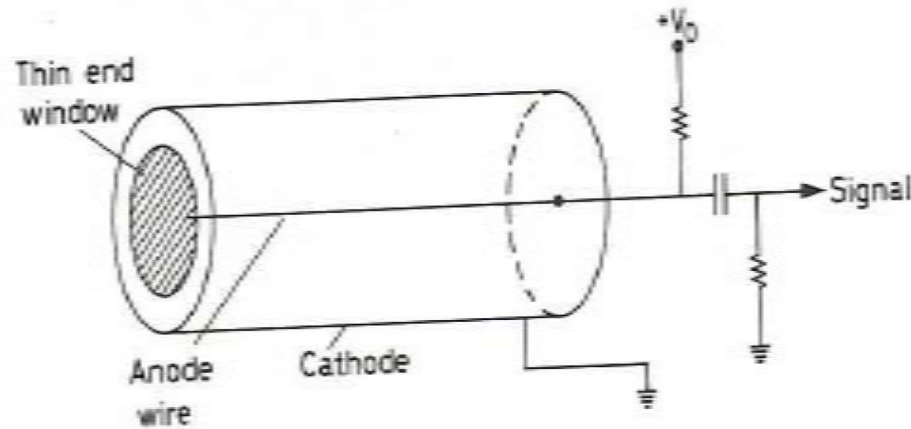
(and if one is able to collect the
Electrons...

→ Signal...)

Gaseous detectors : Principle of operation

First example : Geiger-Muller counter

Idea from Hans Geiger in 1913 – Development with Walther Muller in 1928



$$\text{Radial Electrical field : } E(r) = \frac{V_0}{r \ln \frac{r_a}{r}}$$

r_a = anode radius
 r = counter radius

$$\text{Signal collected } V = \frac{N_e}{C}$$

$$\text{Where } C = \frac{2\pi\epsilon}{\ln \frac{r_a}{r}}$$

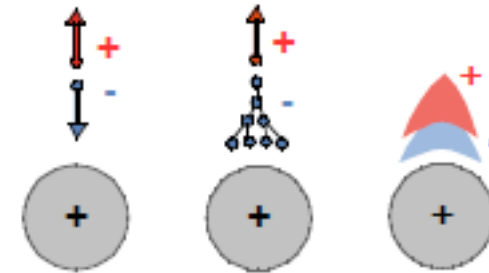
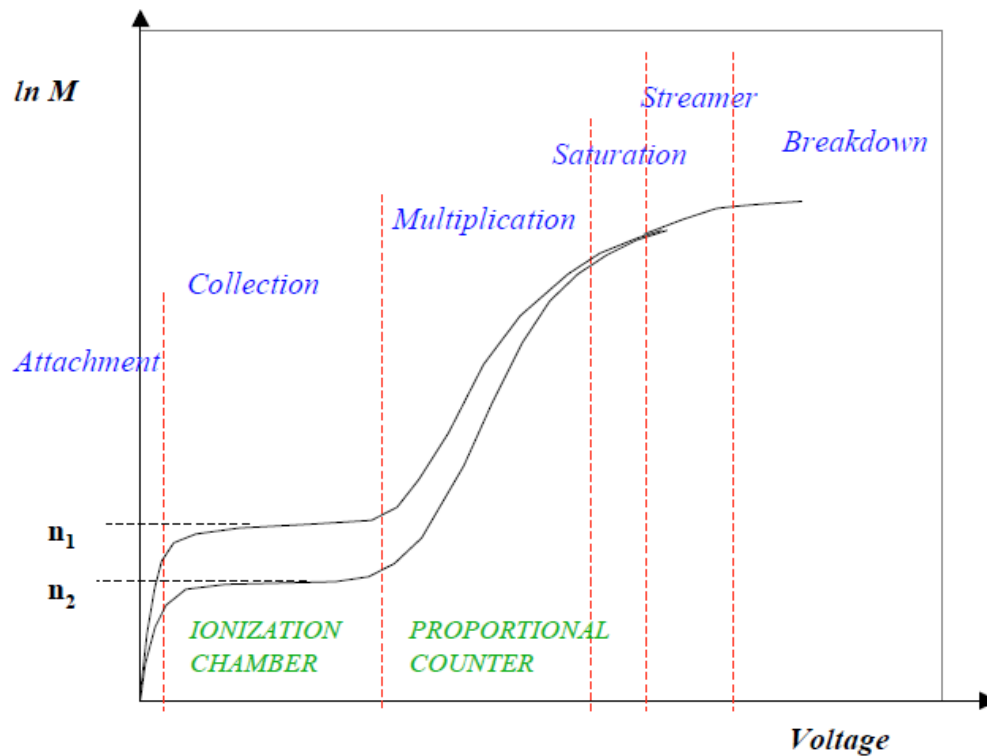
Example :
 $r = 1 \text{ cm}$
Gas : Argon
particle = MIP \rightarrow 120 pairs
 $C = 10 \text{ pF}$
Signal : $2 \mu\text{V}$

Extremely weak signal... (One electron = 10^{-9} Coulomb...)

But : what can happen to the electrons (and ions) during the drift before collection ?

It depends on the Electrical Field (applied voltage)

Gaseous detectors : Principle of operation

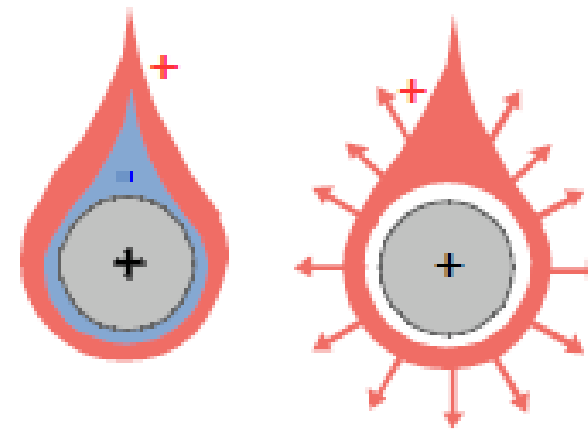
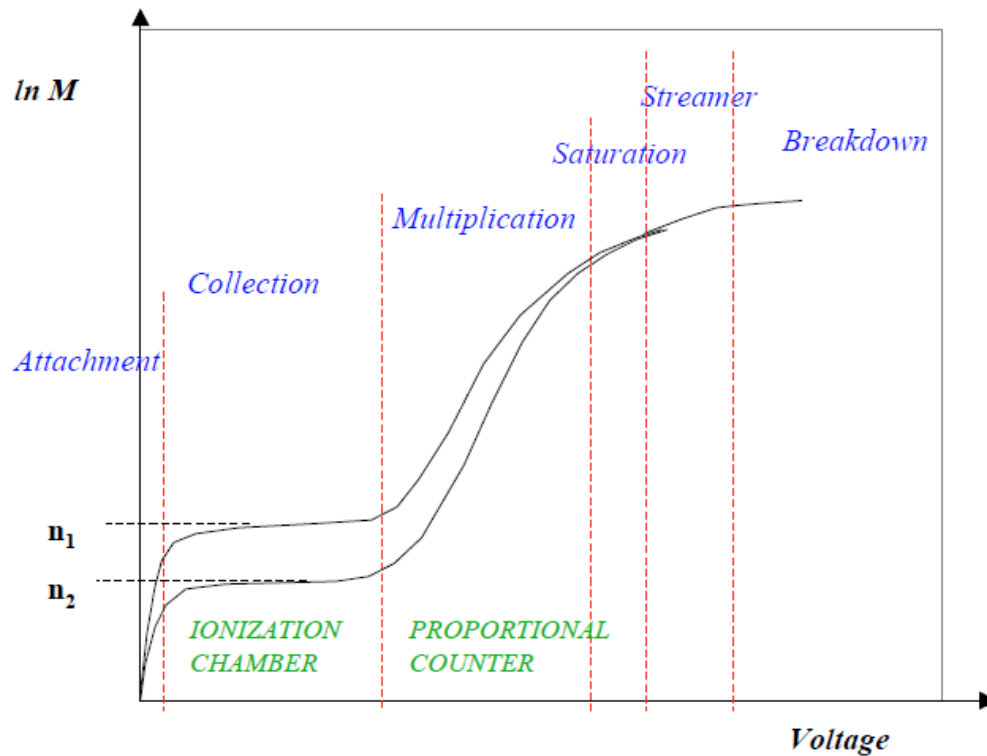


Attachement : E is weaker than the ion proper field
 e^- - ion recombination - almost no signal

Collection - Ionization chamber : All e^- are drifting towards the anode.
 Weak signal (typically 1 e^- for 30 eV)

Multiplication - proportional regime : E big enough for accelerating e^- above E_i
 Production of secondary e^- ... Avalanche
 Multiplication factor (Gain) can reach $10^5 - 10^6$

Gaseous detectors : Principle of operation



Saturation and Streamer mode - Geiger-Muller regime :

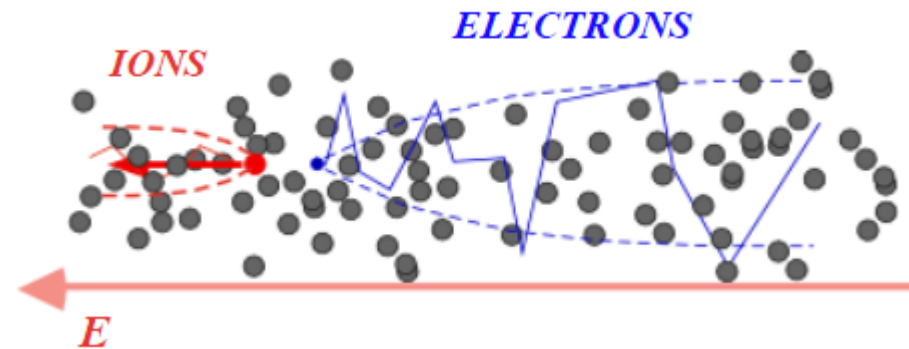
Electronic avalanche amplified by desexcitation of ions thru γ (pair creation)
 Saturation of the signal.
 Loss of proportionality

Breakdown : Continuous discharges between anode and cathode... Ultimate destruction...

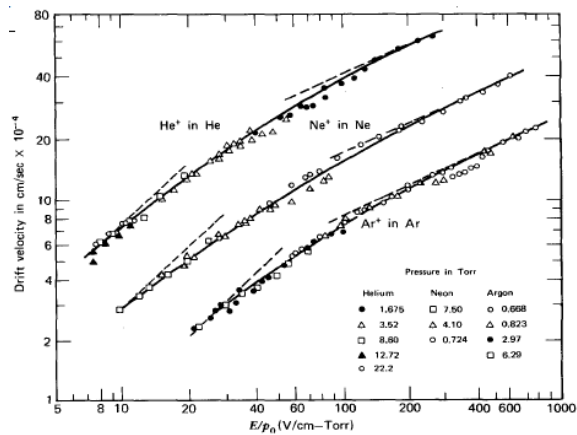
Gaseous detectors : Principle of operation

Transport of electrons and ions in the gas :

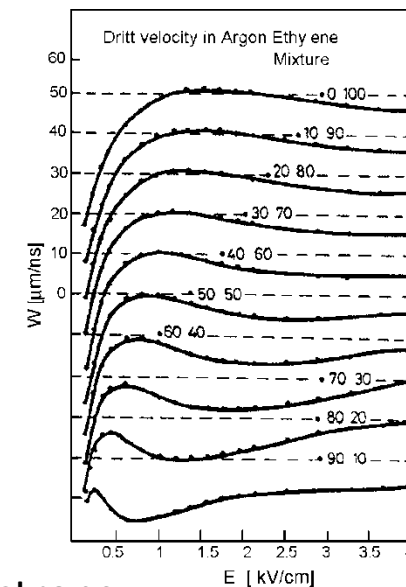
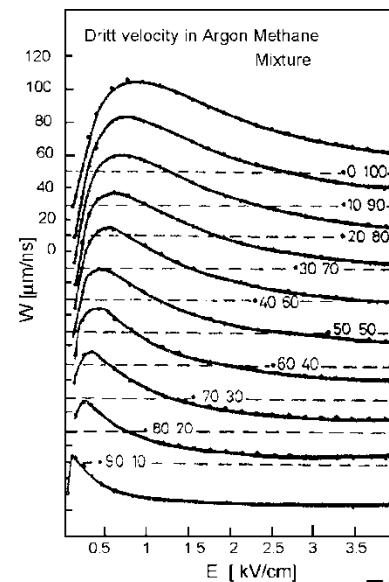
With an electric field, electrons and ions are accelerated along the field lines. Their movement is interrupted by collisions (mean free path...) which limit the maximum average velocity.



This drift velocity is **low** compare to the thermal velocity.



Ions



Electrons

The ion collection time is determinant !
The detector may be blind during the travel of the ions

Gaseous detectors : Principle of operation

Choice of gas : Of course, ionization exists in any possible gas.

- Maximum gain (primary electrons)
- Applied voltage as low as possible
- Avalanche with a good proportionality
- Drift velocity as high as possible

A good compromise : Noble gas (Ar, Xe, Ne...) :

Example : Argon : 30 primary electrons

Possible gain $10^3 - 10^4$

e – drift velocity : 100 $\mu\text{m}/\text{nsec.}$ at $E = 1\text{kV}/\text{cm}$

Limitation : Noble gas have an high excitation energy (typically 10-12 eV). Excited atoms formed in the avalanche desexcite giving photons which can ionize, causing further avalanche... .. Possible discharges.

Solution : **the quencher**

Gas	E_i (eV)	$\frac{dE}{dx}$ (MeV)	N pairs /cm
H2	15.4	4.03	5.2
O2	15.2	1.69	22
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Ar	15.8	1.47	29.4
Xe	12.1	1.23	44
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DME	10.0	1.85	55

Gaseous detectors : Principle of operation

Quencher : one has to add a polyatomic gas in order to absorb the photons created either by multiple collisions or molecule dissociation
Usually CH₄, CO₂, CF₃, C₂H₄

With a mixture of Noble gas – Quencher, one can achieve gains up to 10⁶ - 10⁷

Magic Gas : 70% Ar, isobutane 29.6%, Fréon 0.4% .

Problem : after dissociation, the organic molecules will polymerize on the anode.

- Loss of efficiency
- Need gas circulation

One has to add another agent....
(alcohol...)

One of the BEST possible choice :

DME : Dymethylether CH₃OCH₃

No polymerization

Good gain (10⁶)

But it is a solvent !

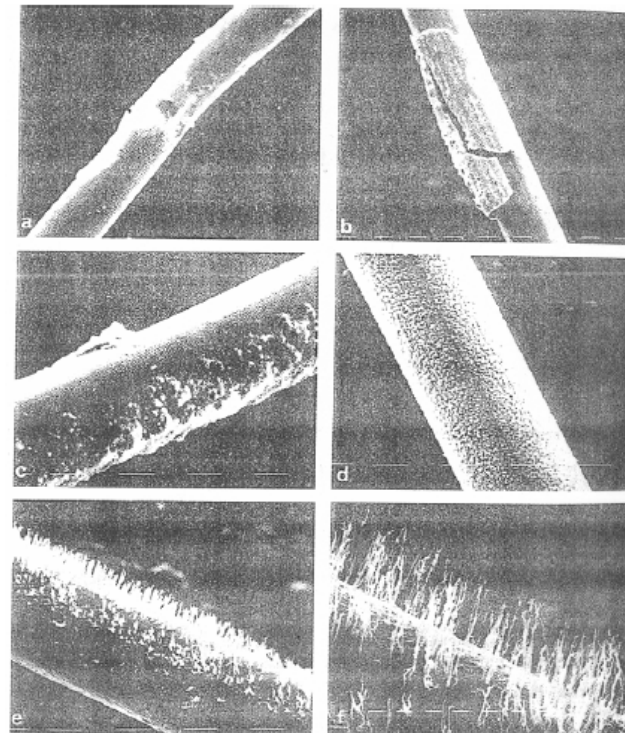


Fig. 4.31. Deposits on anode wires: (a) – Ar+C₂H₆; (b) – Ar+ C₂H₆+ methylal; (c) – Ar+CO₂; (d) – perspex chamber; (e, f) – chambers with G10 fiber-glass and a cold trap (Adam 1983)

Gaseous detectors : Principle of operation

Basic requirement for a gas detector : determination of particle trajectories

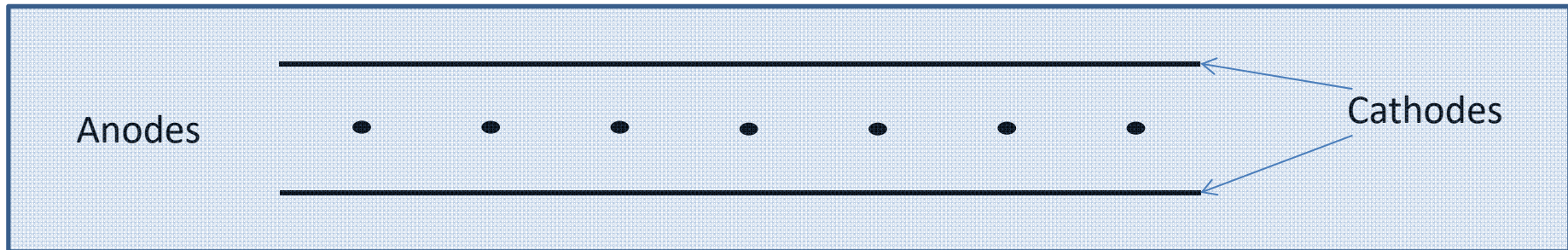
Recipe for a Gas detector

- **Thin** (minimization of dE/dx , does not perturb the particle trajectory)
- **Maximum gain** (choice of gas)
- **Stability** (High Voltage, choice of quencher)
- **Choice of material** (to avoid polymerization)
- **Precision** (by construction, placement...)

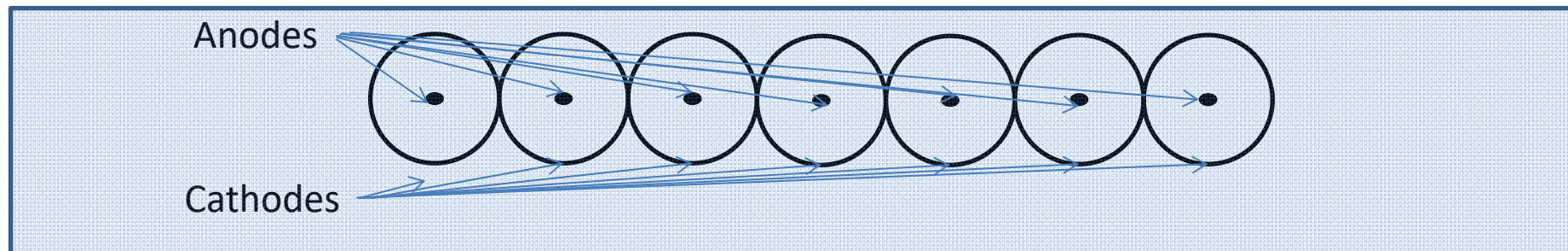
And... **Evolution** from **GM counter** to **Multiwire Proportional Chamber (MWPC)**
G. Charpak and all., 1968

Gaseous detectors : MWPC . The idea

An array of closely spaced anode wires in the same volume

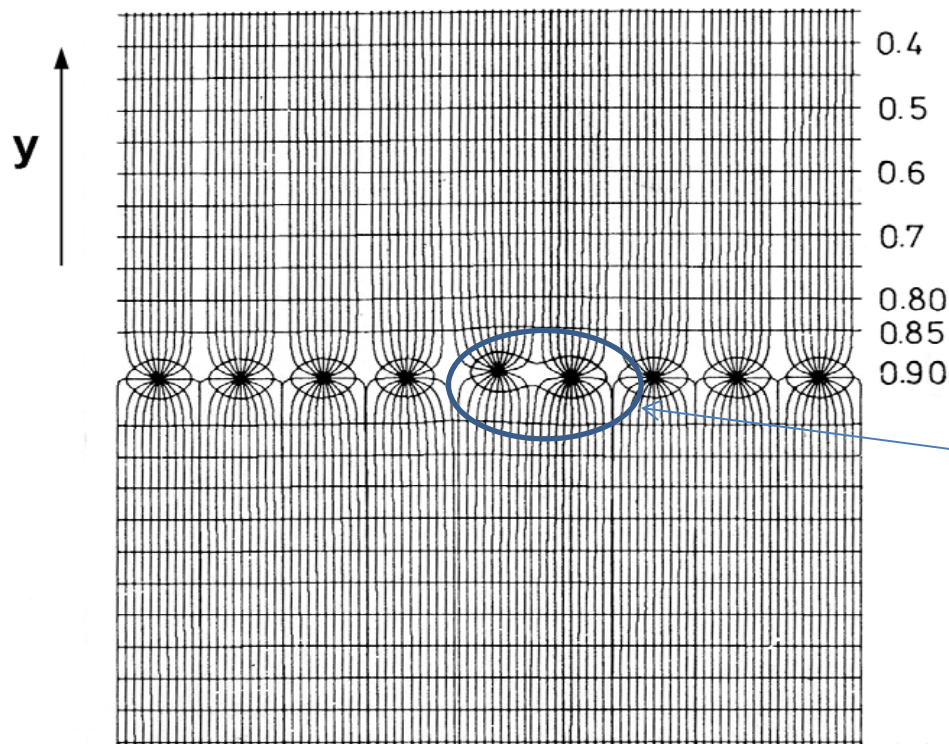
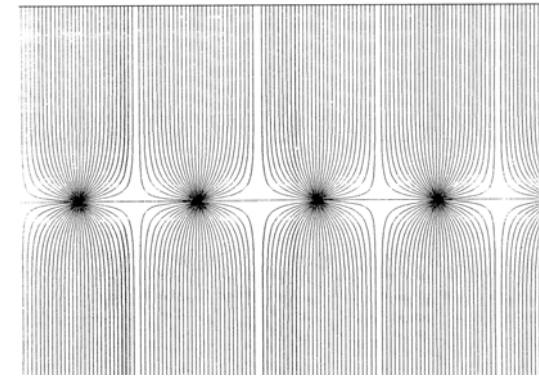
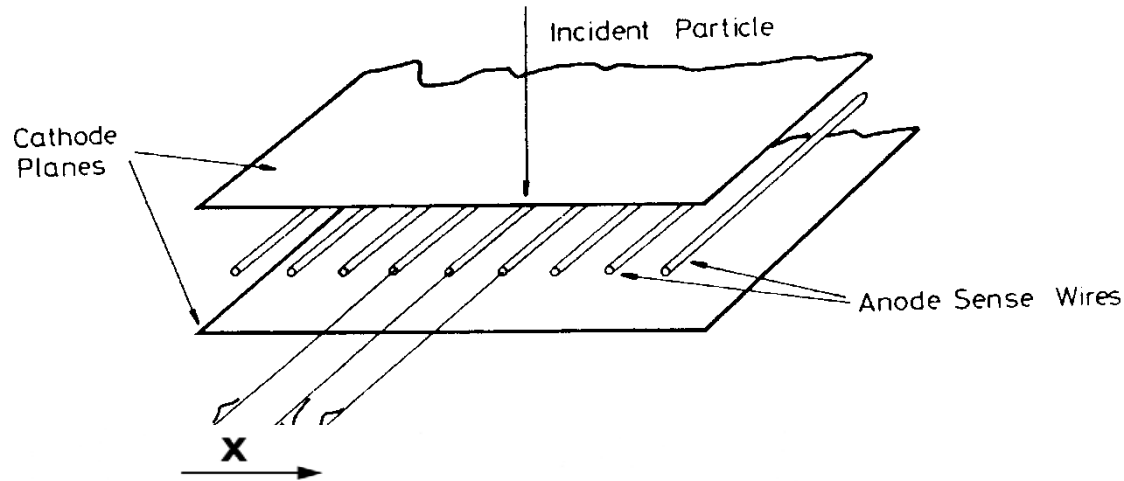


Is equivalent to



An array of proportional counter tubes (classical during the fifties)

Gaseous detectors : MWPC



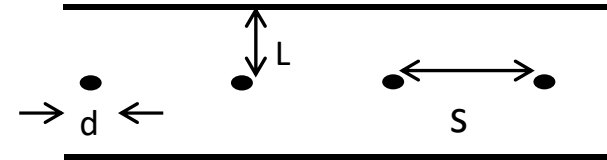
Classical figure of electrical field disturbed by a misplaced anode wire

Gaseous detectors : MWPC

Signal : as seen for the GM proportional counter : $\text{Signal } V = \frac{N_e}{C}$ $C = \frac{2\pi\epsilon}{\ln \frac{r_a}{r}}$

For an MWPC chamber
($L \gg s \gg d$)

$$C = \frac{2\pi\epsilon}{\frac{\pi L}{s} - \ln \frac{\pi d}{s}}$$



$$C = \frac{2\pi\epsilon}{\ln \frac{r_a}{r}} \text{ For GM counter}$$

Spatial resolution :

The charges due to the particle passing in the gas are distributed over more than one anode. The spatial resolution of a MWPC is the variance of this distribution .

$$\sigma = \frac{a}{\sqrt{12}} \quad \text{Typically } \approx 200 \mu\text{m}$$

Signal formation time : depends on the drift time for electrons (typically 50 nsec)

Dead time : depends on the drift time for the ions (typically 200 nsec)

Gaseous detectors : MWPC limitations

Limitation 1 : Typically : anode spacing of the order of 1-1.5 mm
(Résolution $\approx 200 - 500 \mu\text{m}$)

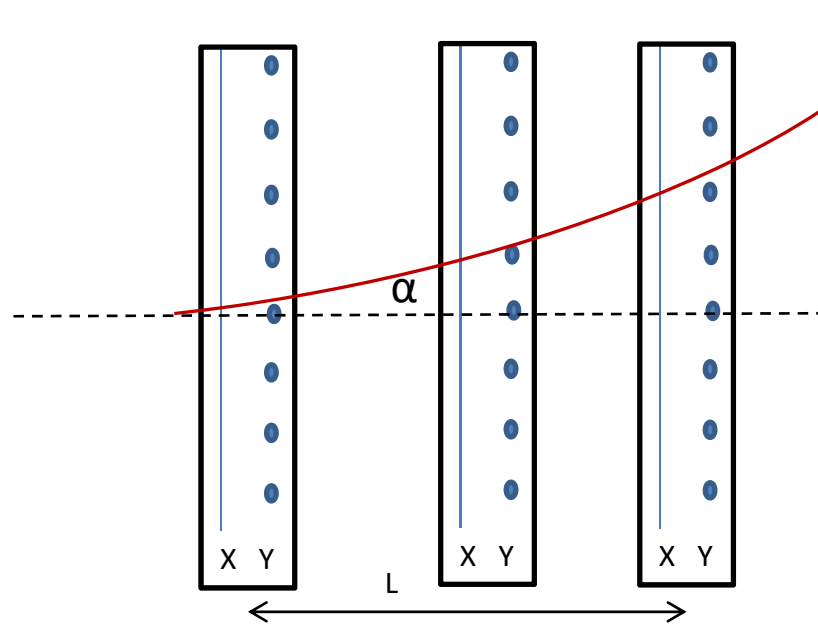
In order to improve the spatial résolution : closer anodes ?

Does not work. Instabilities due to electrostatic forces anode-anode.

Limitation 2 : MWPC can measure only one coordinate.

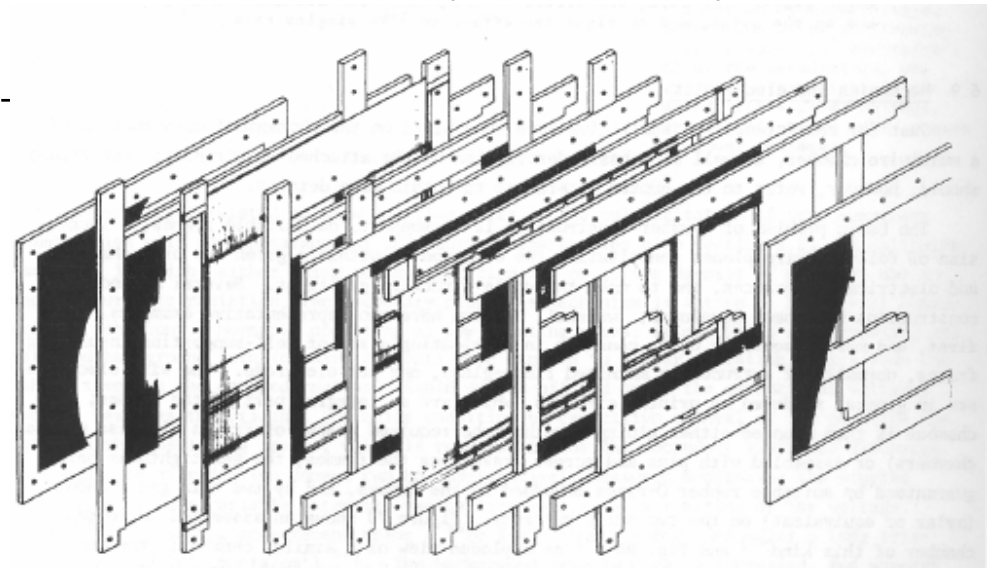
A second MWPC ?

X-Y coordinate with a second anode row



Precision : $\Delta \alpha \approx \frac{1}{L} \sigma$

One can reduce the wire spacing...
Or increase L (dimensions...)



Gaseous detectors : MWPC limitations

Can the resolution be improved by mounting the wires closer to each other?

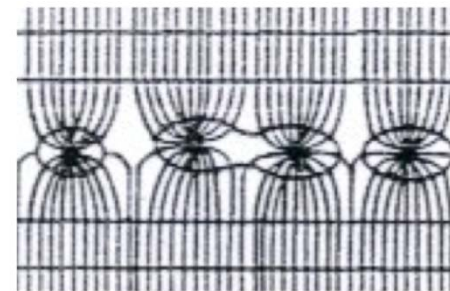
Practical difficulty in stretching wires precisely, closer than 1 mm:

- Electrostatic repulsion between anode wires (particularly for long wires)
→ can lead to “staggering”
To avoid this, the wire tension T has to be larger than a critical value T_0 (order of 0.5 N for wires of 1 m and typical chamber geometry)
- For horizontal wires problem of gravity → sag



$$f = \frac{\pi r_i^2}{8} \rho g \frac{l^2}{T} = \frac{m l g}{8 T}$$

gold-plated W-wire $r_i = 15 \mu\text{m}$, T as above → $f = 34 \mu\text{m}$ → visible difference in gain

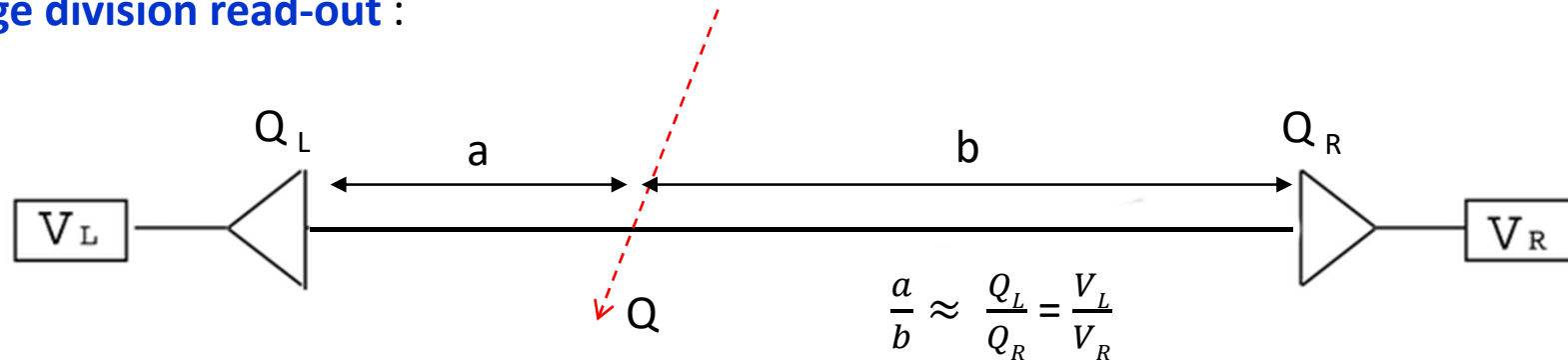


!

Gaseous detectors : MWPC limitations

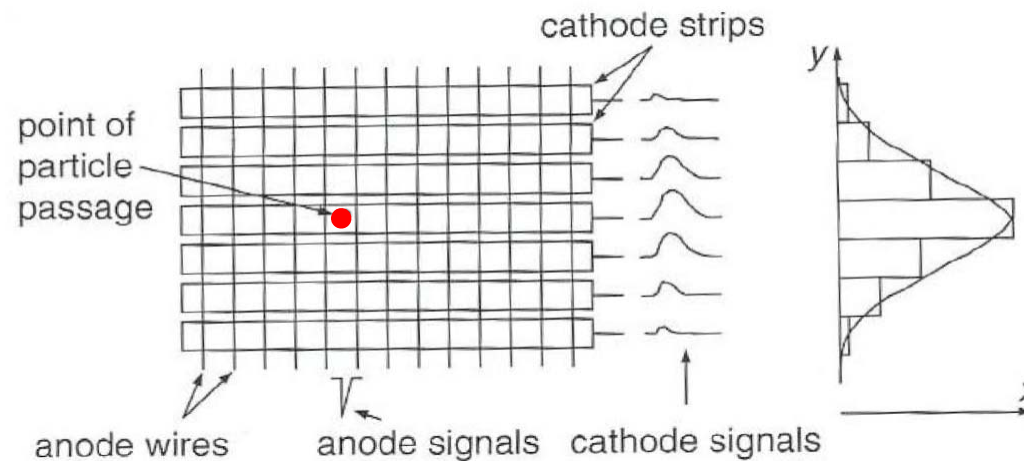
Solutions for 2-coordinates ?

Charge division read-out :



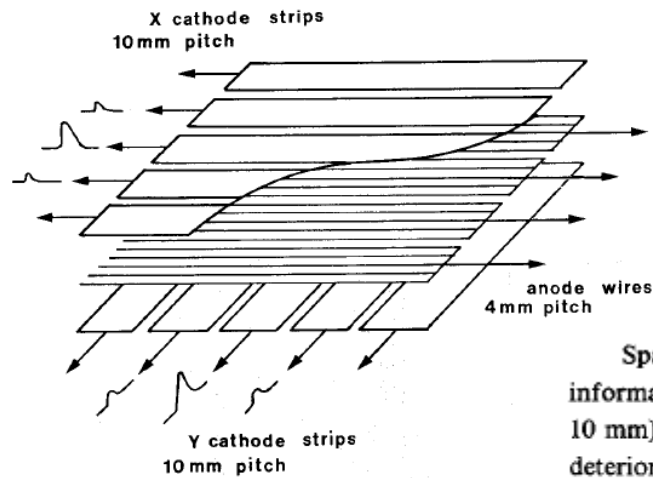
OK, but limited to low fluxes of particles

Anode – Cathode read-out:



Gaseous detectors : MWPC evolution

Cathode read-out chamber : One anode plan
Segmented cathode plan
Analog read-out

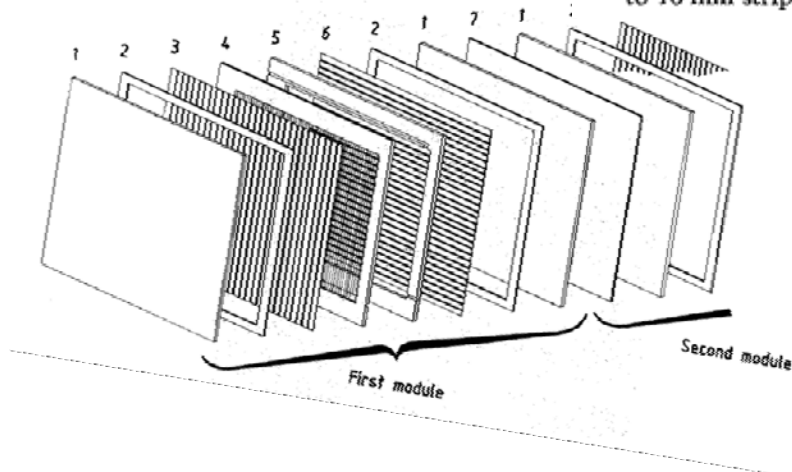


The features of one chamber module of the final stack were the following:

- half gap: 5 ± 0.02 mm
- anode pitch: 4 mm
- anode wire diameter: $20 \mu\text{m}$
- cathode strip pitch: 10 mm
- cathode strip width: 9 mm
- sensitive area: $1100 \times 970 \text{ mm}^2$
- gas composition: Ar 80% + CO₂ 20% (vol).

The total stack thickness was 1 radiation length.

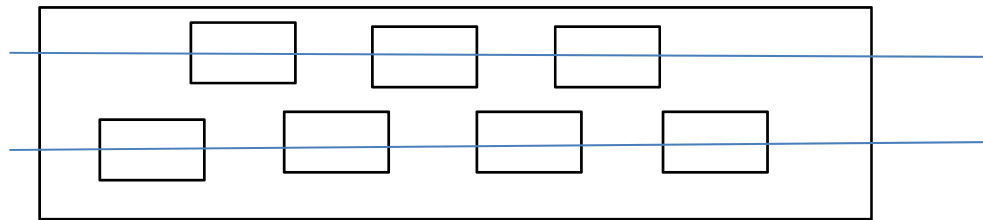
Spatial localization was investigated by comparing the analog chamber results with the information given by the set of digital MWPCs. A value of $\sigma = 2.4$ mm (98% of events inside 10 mm) was obtained for 4 GeV shower electrons after 4 radiation lengths (fig. 8). The resolution deteriorated quickly for lower energies ($\sigma = 5.9$ mm, 91% of events inside 10 mm at 2 GeV) and for wider strips ($\sigma = 5.3$ mm, 86% of events inside 10 mm for 4 GeV electrons, when going from 8 mm to 16 mm strip width).



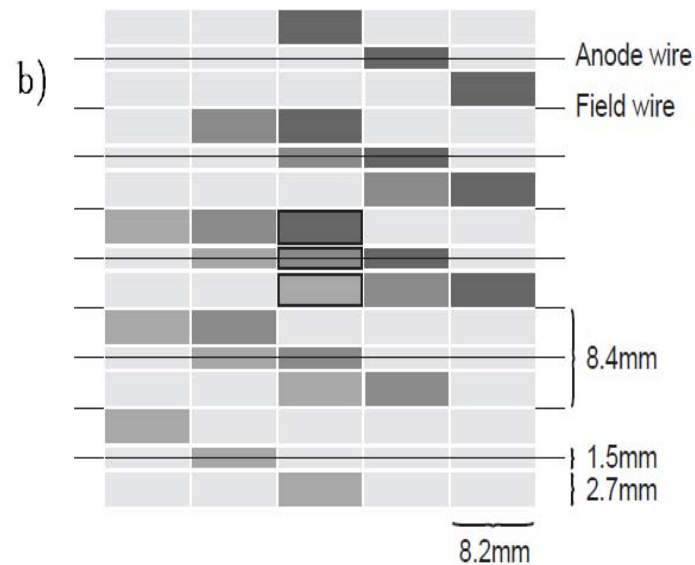
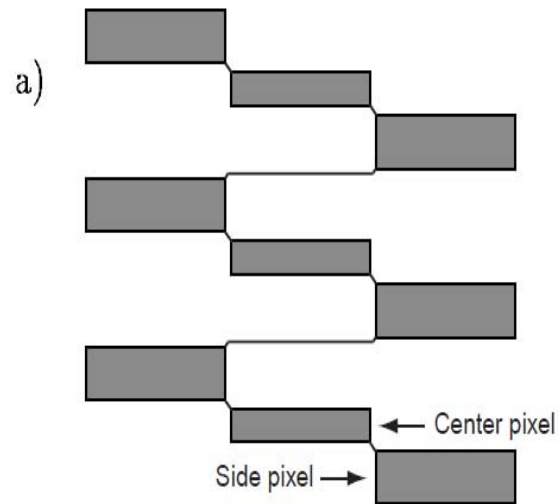
Experiment R704 (CERN) 1981 - 1985

Gaseous detectors : Pad chambers

Direct 2-D detector : Pad chambers cathode segmented in pads



Needs a lot of electronics

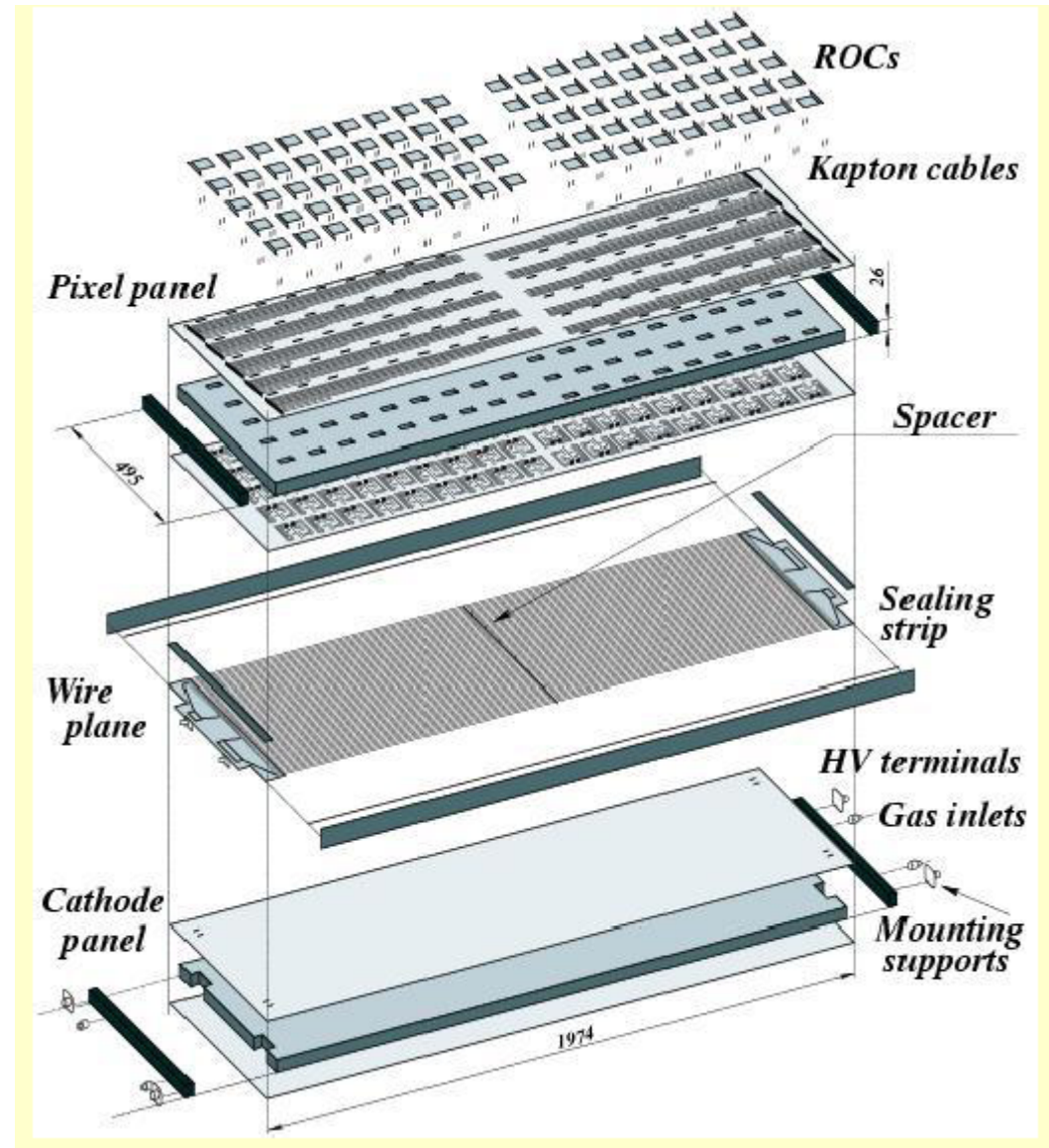


Pads regrouped in cells

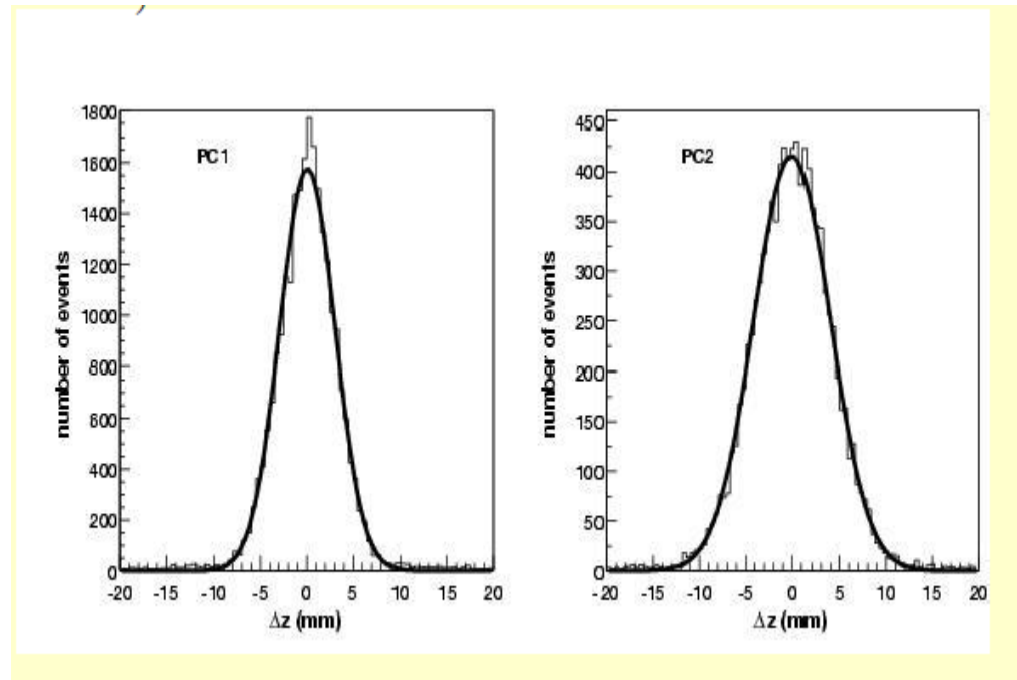
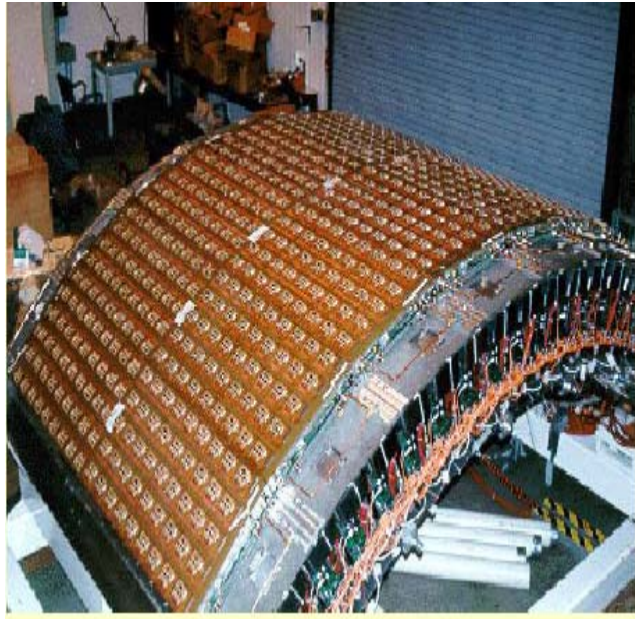
PHENIX experiment

Gaseous detectors : Pad chambers

PHENIX at RHIC



Gaseous detectors : Pad chambers



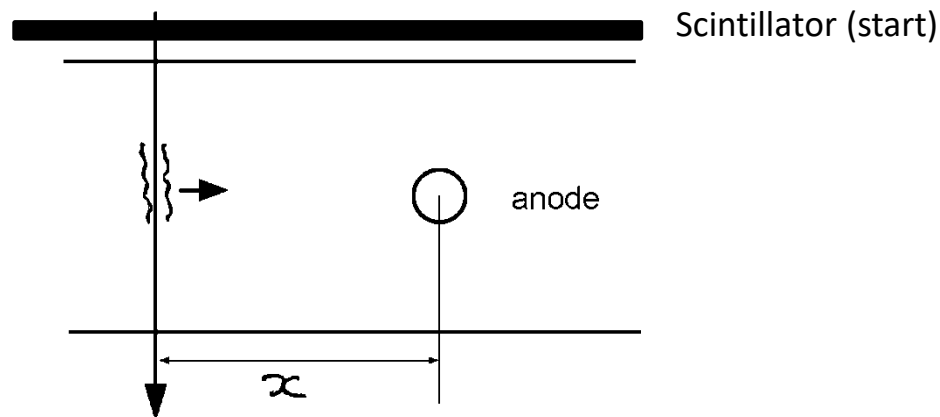
chamber	Wire dist (mm)	Z-resol. (mm)	Perp res (mm)	Rad. Thickn.
PC1	8.4	1.7	2.5	1.2%
PC2	13.6	3.1	3.9	2.4%
PC3	16.0	3.6	4.6	2.4%

Gaseous detectors : Drift Chambers

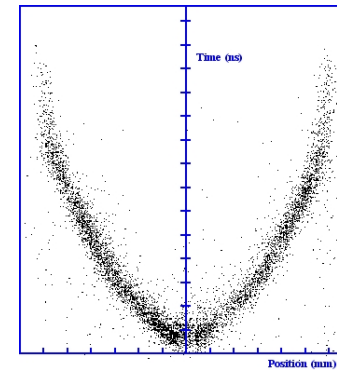
A drift chamber is a particle tracking detector that measure the drift time of ionization electrons in a gas to calculate the spatial position of ionizing (charged) particle. Similar to MWPC, but with a better accuracy.

Measure of the position of the particle by mesuring the drift time of the electrons

Need : Precise knoweledge of drift velocities
Precise timing (trigger)



$$X = Vd \Delta t$$



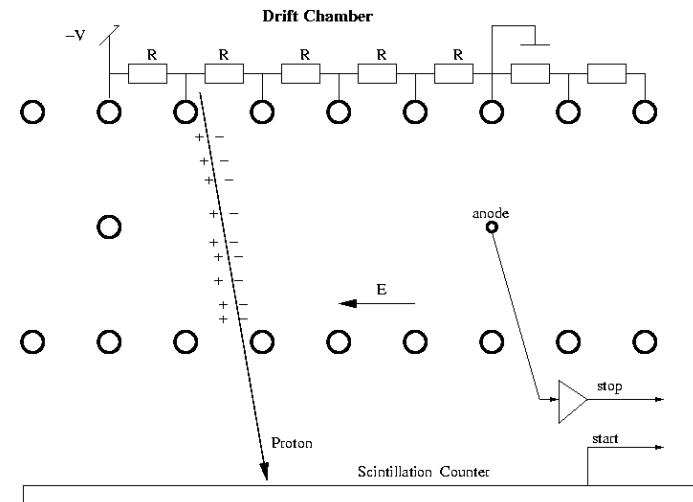
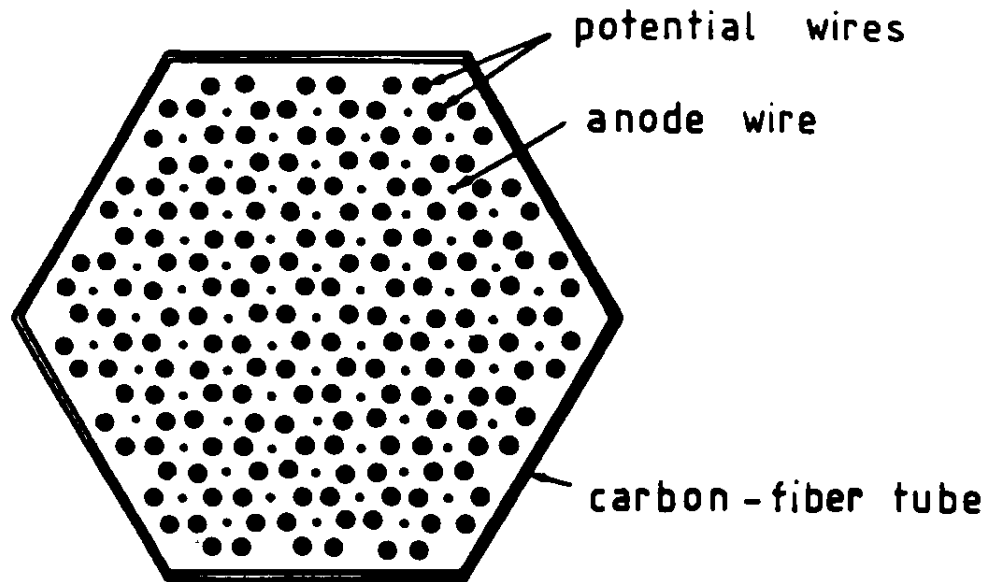
SPACE-TIME CORRELATION
(RIGHT-LEFT AMBIGUITY)

Possible resolution down to 50 μm

Gaseous detectors : Drift Chambers

Main limitation : non-uniformity of the field (non uniformity of the drift time)

Solution : defining a cell (basic unit of field)



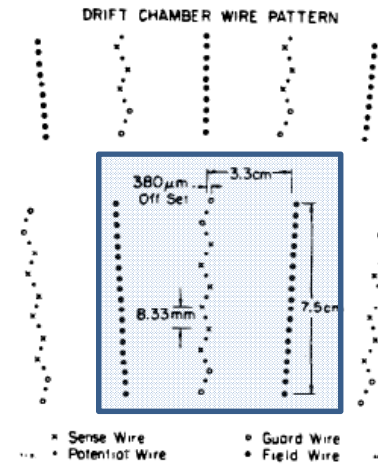
$$\text{Drift Distance} = \text{Drift Velocity} * \text{Time}$$

PHENIX (RHIC) Drift Chamber

Gaseous detectors : Drift Chambers



MarkII (1985 – 1990) big Drift Chamber



1 cell = 7.5 cm x 6.6 cm

12 layers

Length : 2.3 m

Radius : 1.6 m

5732 sense wires (anodes)

31104 potential wires

Gas mixture : 89% Ar, 10% CO₂, 1% methane

Gain : $2 \cdot 10^4$

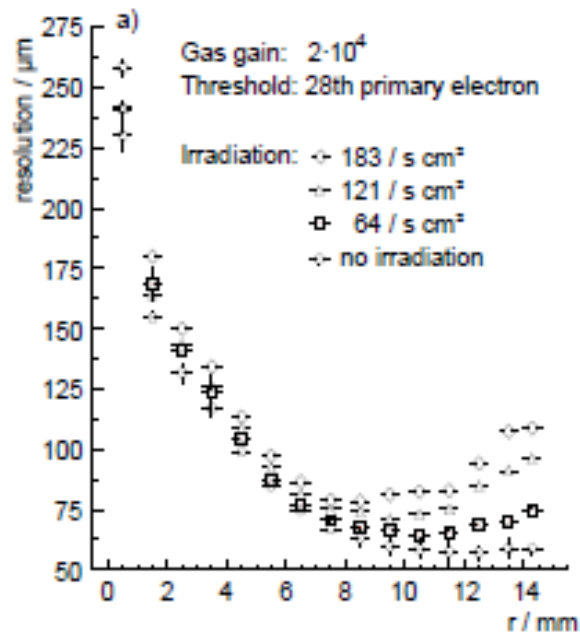
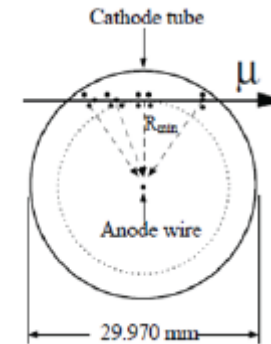
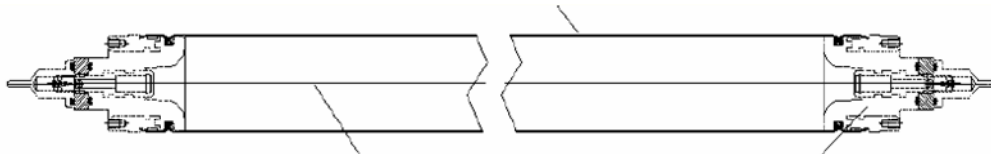
Drift field : 900 V/m

Spatial resolution : $\approx 150 \mu\text{m}$

Gaseous detectors : Drift Chambers

ATLAS DRIFTS TUBES (MUON SPECTROMETER)

370 000 tubes
Surface 5500 m²



Parameter	Design value
Tube material	Al
Outer tube diameter	29.970 mm
Tube wall thickness	0.4 mm
Wire material	gold-plated W/Re (97/3)
Wire diameter	50 μm
Gas mixture	Ar/CO ₂ /H ₂ O (93/7/ \leq 1000 ppm)
Gas pressure	3 bar (absolute)
Gas gain	2×10^4
Wire potential	3080 V
Maximum drift time	\sim 700 ns
Average resolution per tube	\sim 80 μm

Max counting rate : 20 Hz / m

Gas leak < 10^{-8} Bar.l / sec.

Wire tension tolerance 17g

Wire position tolerance : 25 μm

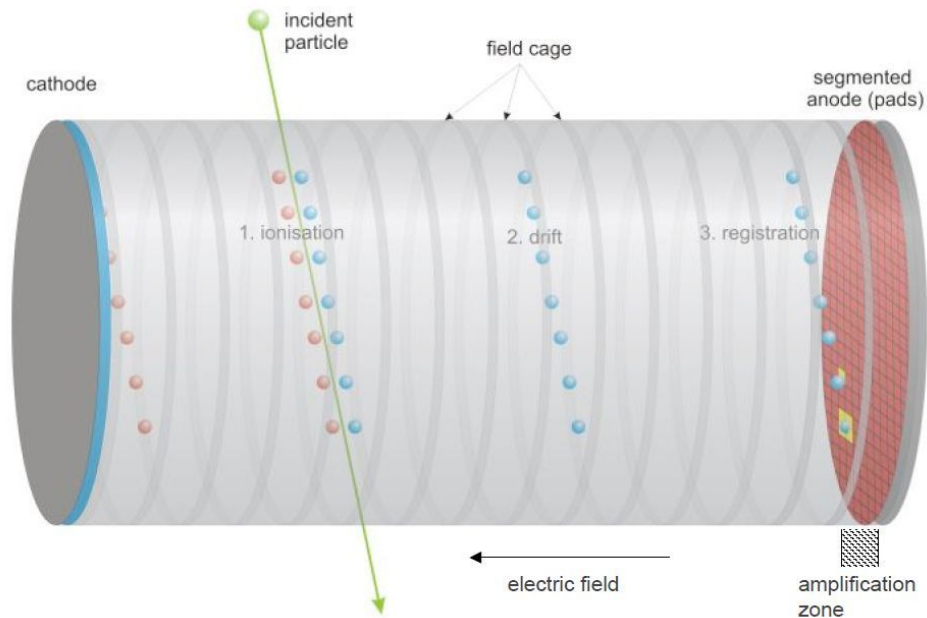
Gaseous detectors : Drift Chambers



Gaseous detectors : Time Projection Chambers

TPC : « The best of the best evolution »

Combination of a Drift Chamber and a MWPC (Pad chamber)



Position (X and Y measurements)

Drift time (Z measurement)

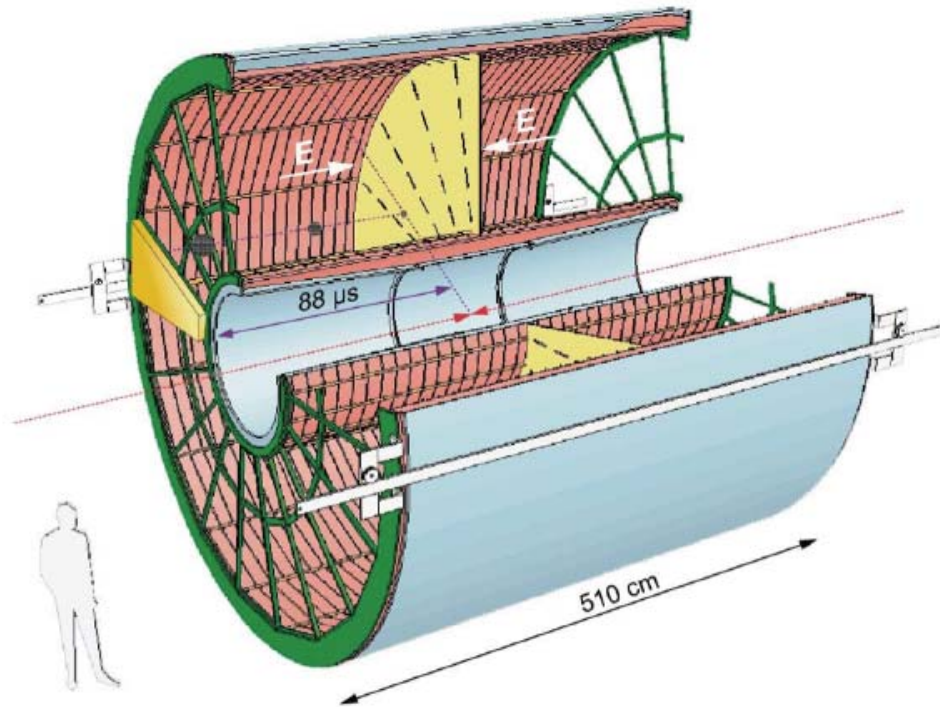
Huge (and empty) drift volume

Multi channels (read out pads)

Drift volume full of ions

→ séparation for the avalanche region

Gaseous detectors : Time Projection Chambers – The ALICE TPC at LHC



Length: 5 meter
 Radius: 2.5 meter
 Gas volume: 88 m³

Total drift time: 92 μs
 High voltage: 100 kV

End-cap detectors: 32 m²
 Readout pads: 557568

159 samples radially
 1000 samples in time

Gas: Ne/CO₂/N₂ (90-10-5)
 Low diffusion (cold gas)

Gain: > 10⁴

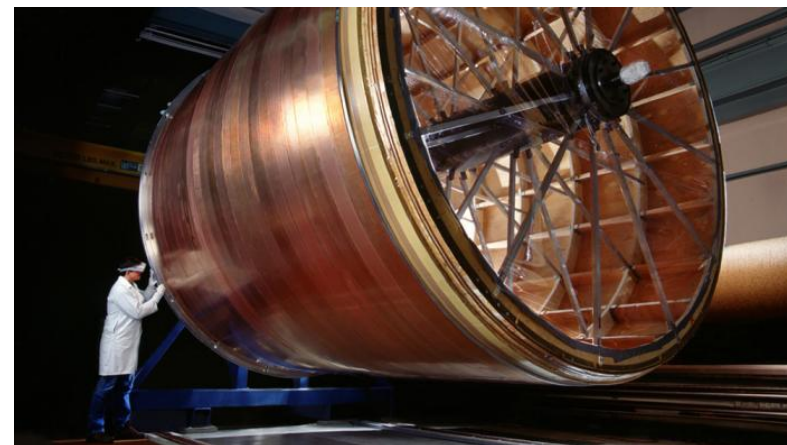
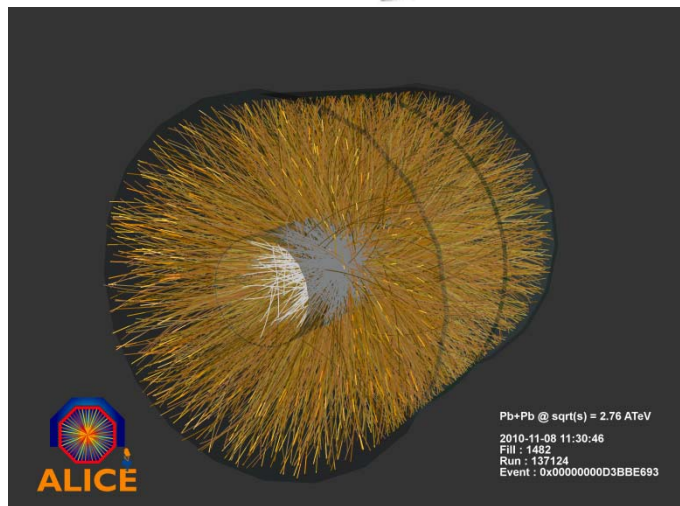
Diffusion: $\sigma_t = 250 \mu\text{m}$
 Resolution: $\sigma \approx 0.2 \text{ mm}$

$\sigma_p/p \sim 1\% p$; $\epsilon \sim 97\%$
 $\sigma_{dE/dx}/(dE/dx) \sim 6\%$

Magnetic field: 0.5 T

Pad size: 5x7.5 mm² (inner)
 6x15 mm² (outer)

Temperature control: 0.1 K



Gaseous detectors : Time Projection Chambers – The ALICE TPC at LHC

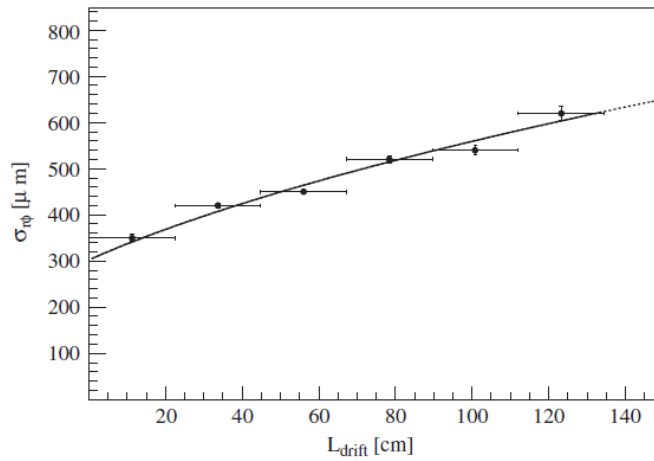


Fig. 6. Space point resolution in pad direction (momentum plane) as a function of drift length. Solid line shows the fit and dashed line the extrapolation.

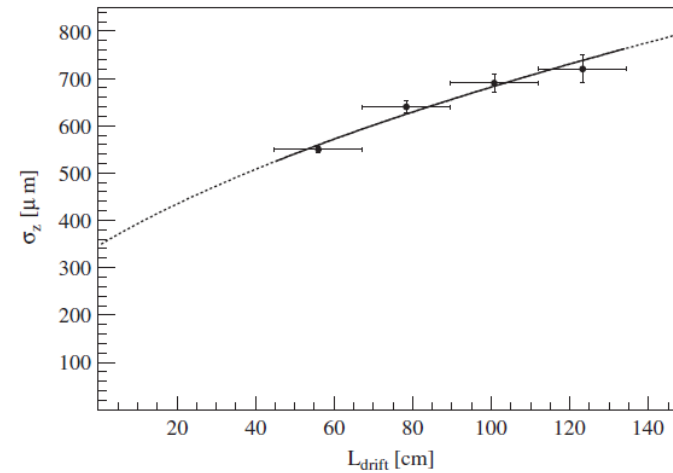
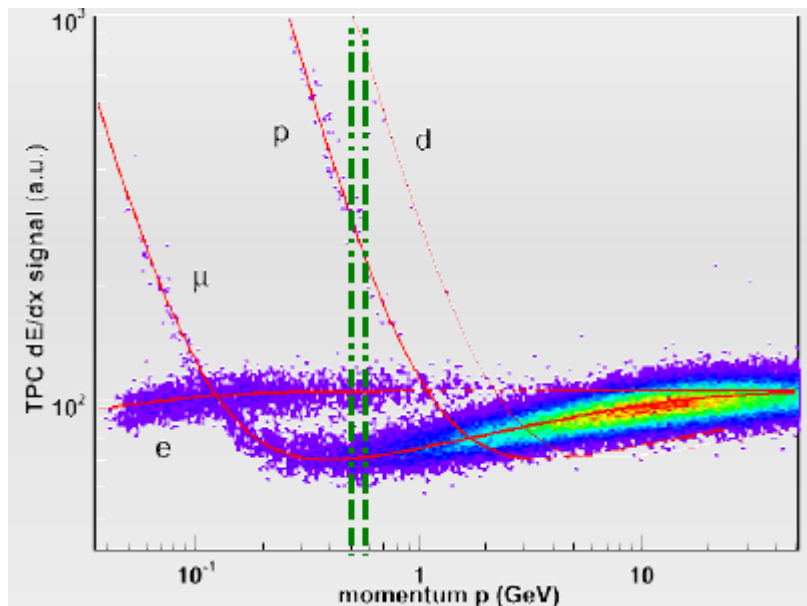


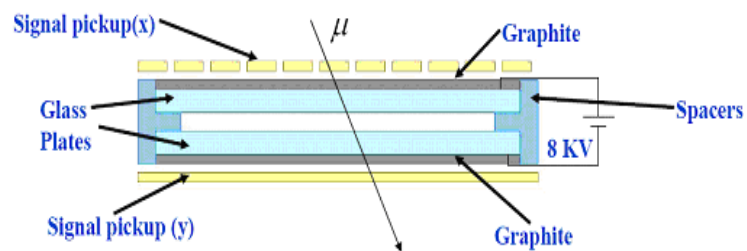
Fig. 7. Space point resolution in drift direction as a function of drift length. Solid line shows the fit and dashed line the extrapolation.



	Experiment	Monte Carlo
σ_{rp} (μm)	800 ± 80	900
σ_z (μm)	900 ± 100	900

Gaseous detectors : Resistive Plate Chamber

RPC : Thin (2 mm) drift volume sandwiched between
Two highly resistive ($2.5 \cdot 10^{10} \Omega \cdot \text{cm}$) plates
Simple – inexpensive – fast (used as trigger)

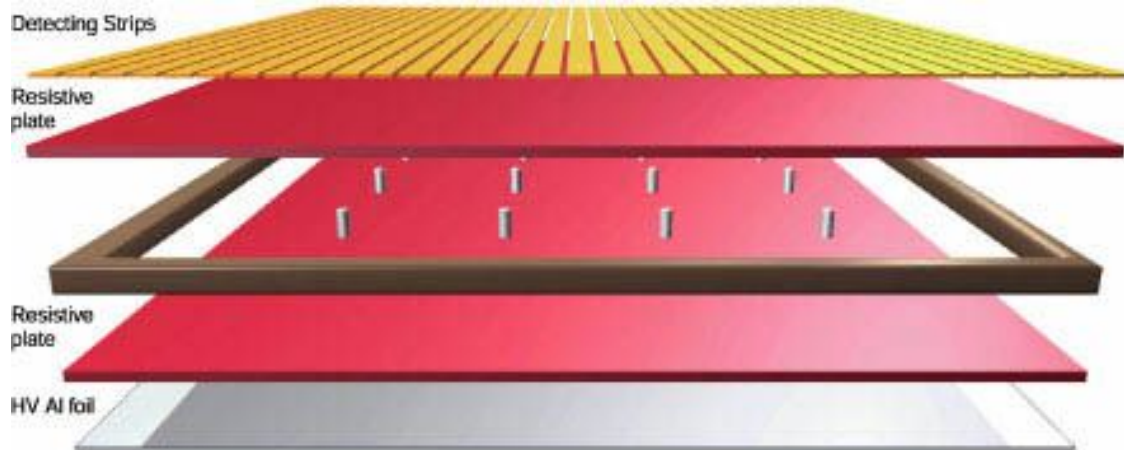


Thin drift volume and High field

Works usually in streamer mode
Large signal, but slow (100 nsec)

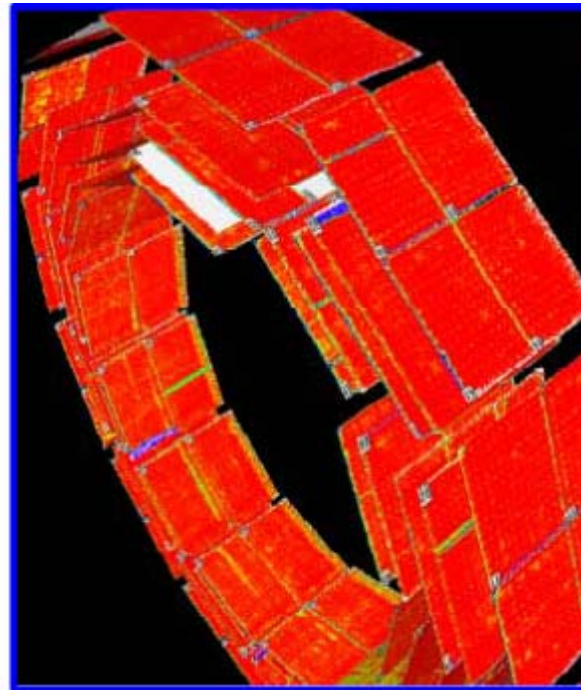
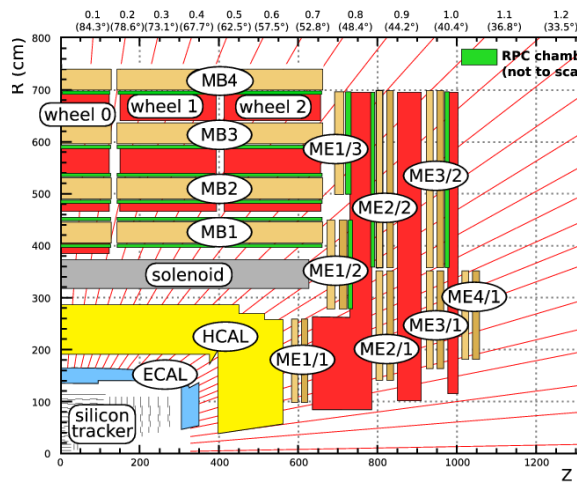
At LHC : in avalanche mode
Lower signal, but fast (1-10 nsec)

Gaseous detectors : Resistive Plate Chamber for CMS - LHC



Resistive plates : $1 \cdot 10^{12} \Omega \cdot \text{cm}$
 Gas mixture :
 $\text{C}_2\text{H}_2\text{F}_4$ (92.5 %) – C_4H_{10} (4.5%) – SF_6 (0.3%)
 HV : 8.5 – 9.7 kV

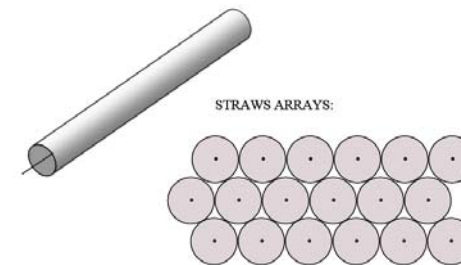
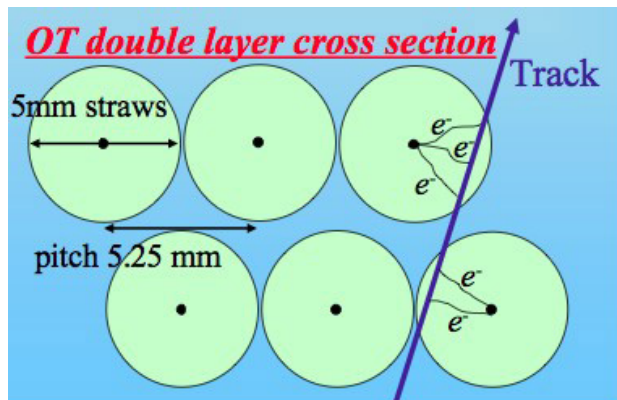
RPC efficiency > 97%
 Rate capability > 1 KHz/cm²
 Operation efficiency plateau > 400V
 Time resolution < 3ns
 Cluster size < 3
 Dead time should be few nano seconds



Gaseous detectors : Straw Chambers

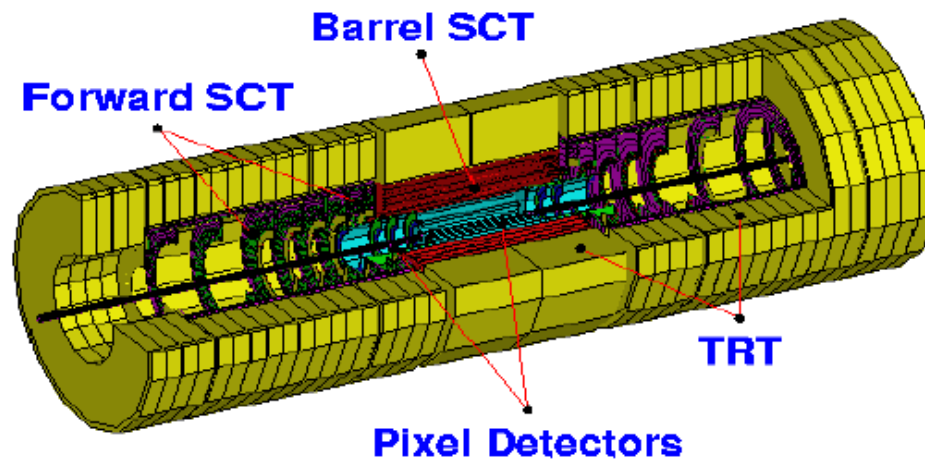
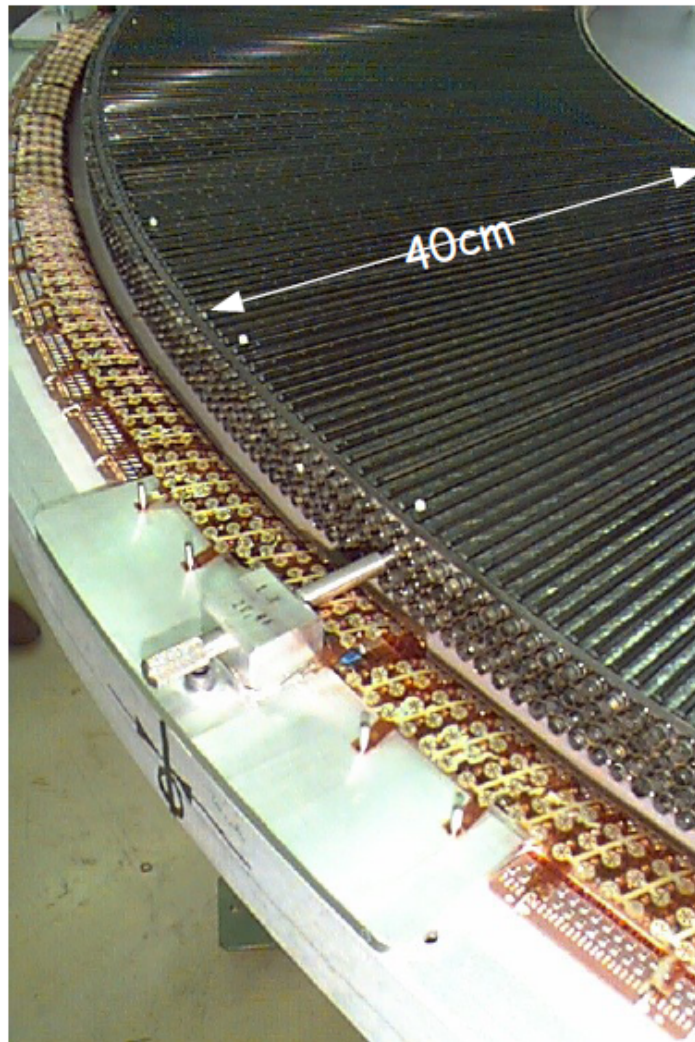
SWPC : Single Wire Proportional Chamber
Single proportional counter in an array

- Cheap and simple to build
- Capable of withstanding very high fluxes



Gaseous detectors : Straw Chambers

Straw Chambers : the ATLAS read-out system for the Transition Radiation Tracker



- 372000 straw proportional tubes
- $|\eta| < 2.5$
- Xe-CO₂-O₂, 70%, 27%, 3%
- Gain $\sim 2.5-4 \cdot 10^4$
- 4ns e- collection time in B=2T

Beam test result:

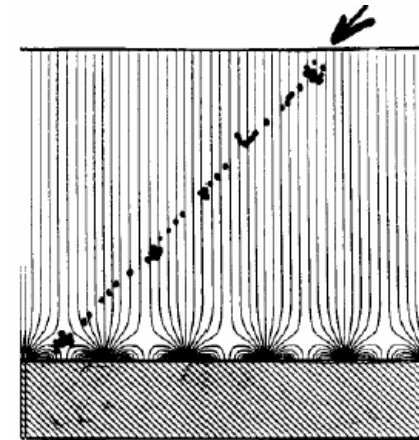
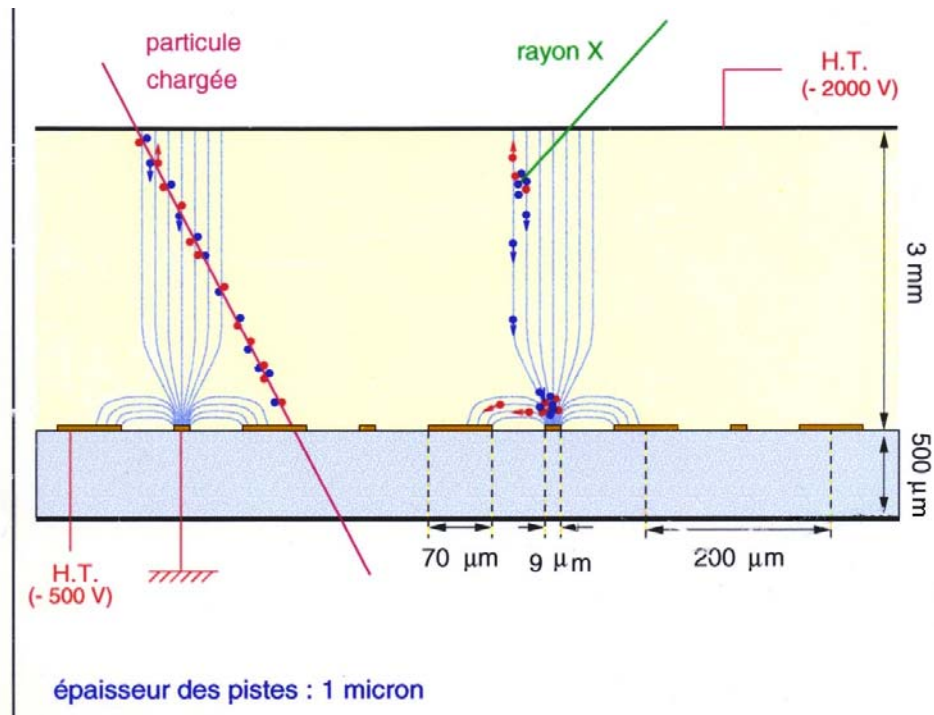
Hit efficiency: $96.7 \pm 0.8\%$

Drift-time accuracy: $133 \pm 4 \mu\text{m}$

Gaseous detectors : MicroStrips Gas Detector

MSGC : following an idea of Oed (1989) :

A MWPC where the wires are replaced by strips deposited on an insulating substrate (glass)



High field : gain $\approx 10^4$

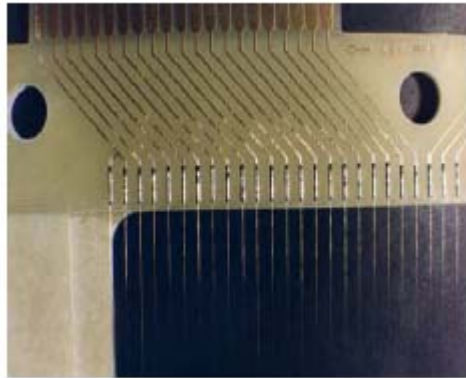
Spatial resolution : $\sigma \approx 20 \mu\text{m}$

Dead time $\approx 10^{-5}$ sec.

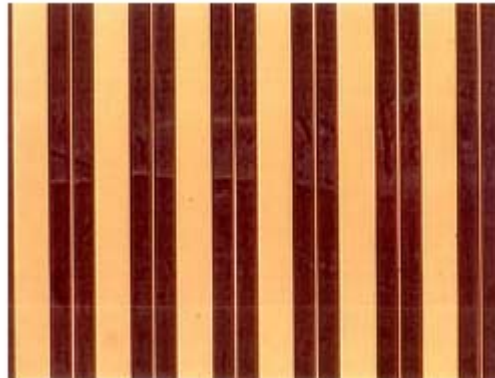
(Short distance for the ions)

Gas : Ar – DME / Ne - DME

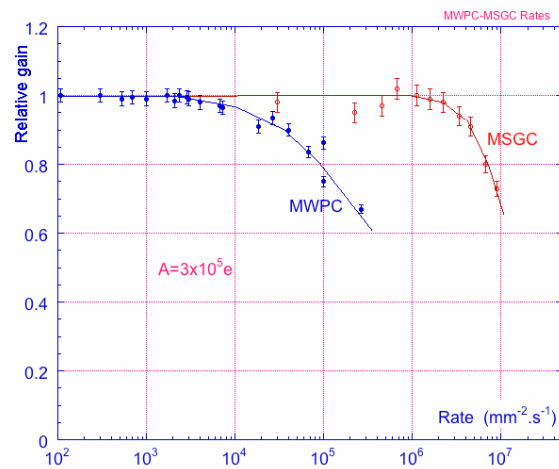
Gaseous detectors : MicroStrips Gas Detector



MWPC
anode spacing : 1-3 mm

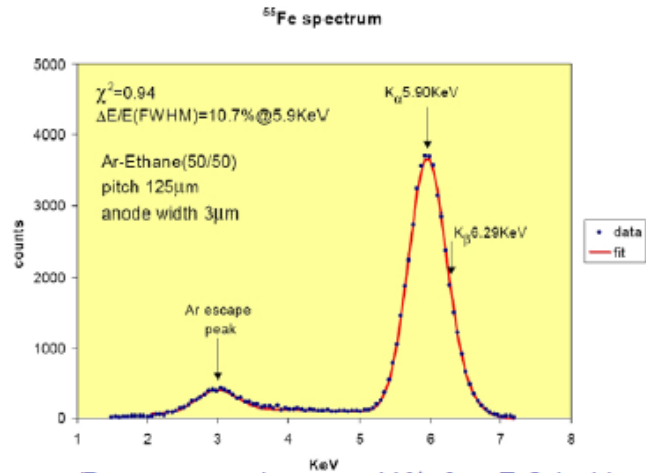


MSGC
anode spacing 200 μm

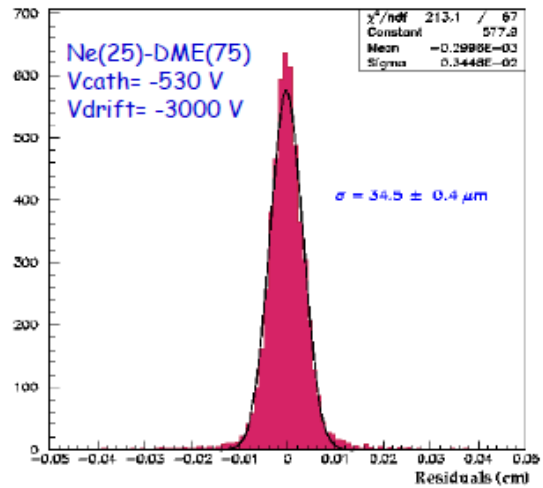


Rate capability comparison
MSGC seems to be well adapted
to high fluxes of particles (LHC)

Gaseous detectors : MicroStrips Gas Detector



Energy resolution ~11% for 5.9 keV



Spatial resolution = $34.5 \pm 0.4 \mu\text{m}$
 2-track resolution ~400 μm

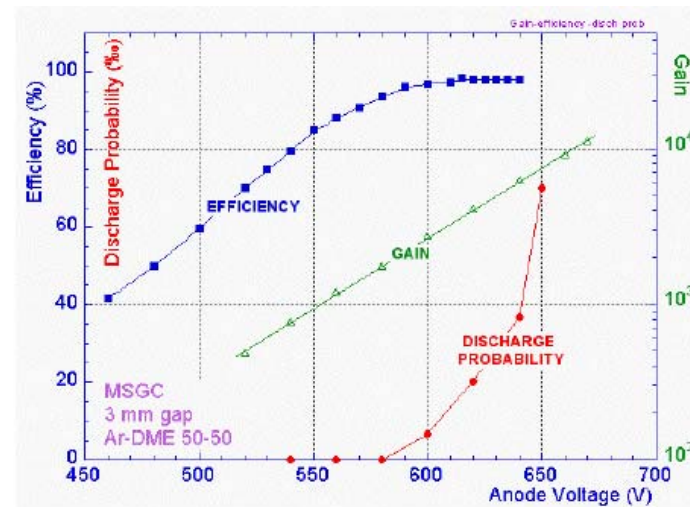
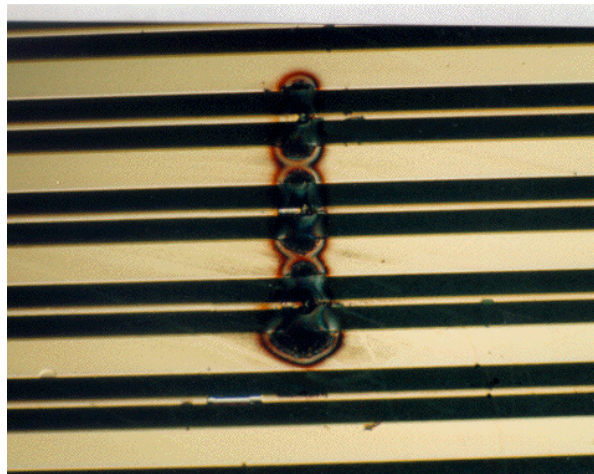
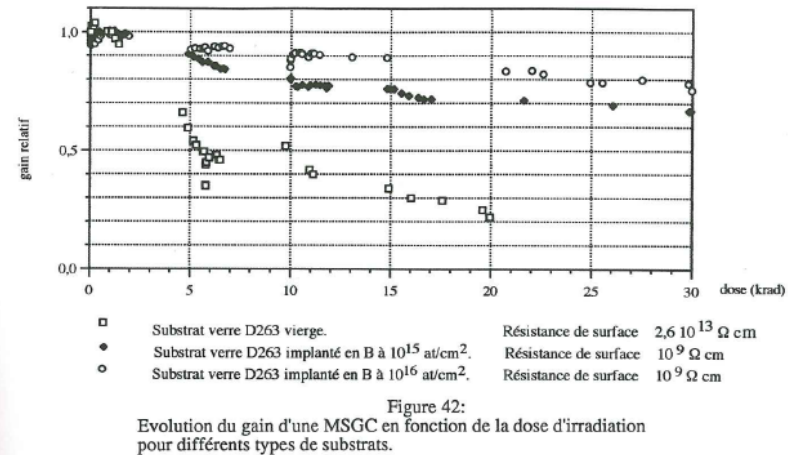


Gaseous detectors : MicroStrips Gas Detector

Surface charging : Bulk or surface resistivity of the support material is modified by irradiation (flux)
Choice of support (special glass or doping)

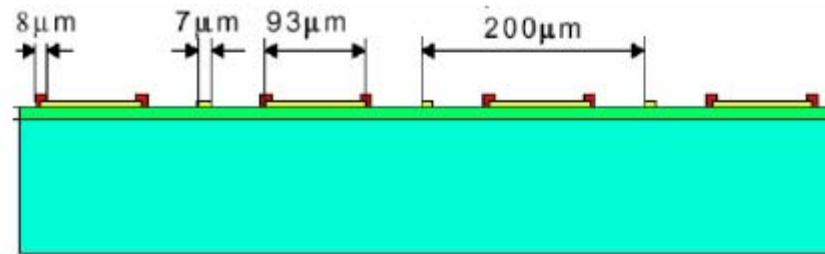
Ageing : Polymerization due to construction material
(DME is a solvent)
Choice of non-solvable material in DME

Discharges: Possible with higher flux or low energetic particles
Certain with dust (short between anode and cathode (50 μm))

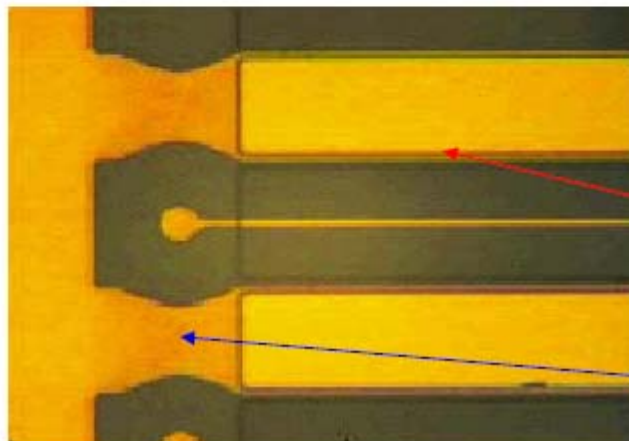


Gaseous detectors : MicroStrips Gas Detector

Cathode edge passivation



- advanced passivation: polyimide (2 μm)
- metal: gold (0.6-0.8 μm)
- undercoating: Pestov or S8900 glass (0.5-1 μm)
- substrate: Desag glass (300 μm)

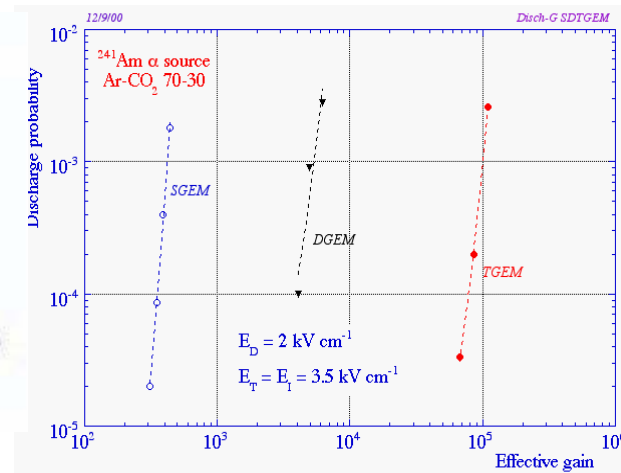
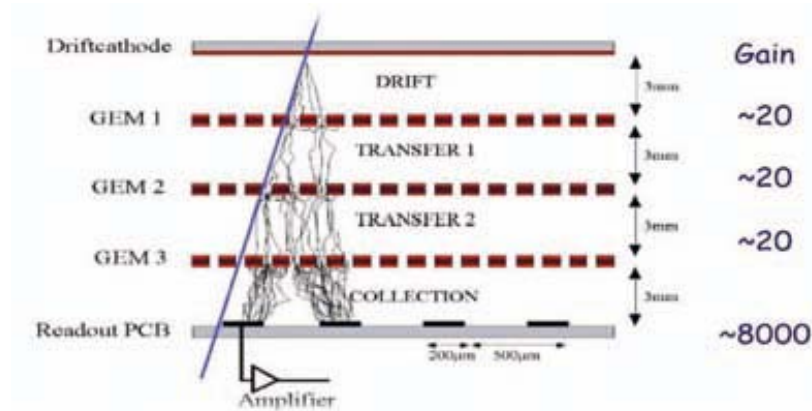
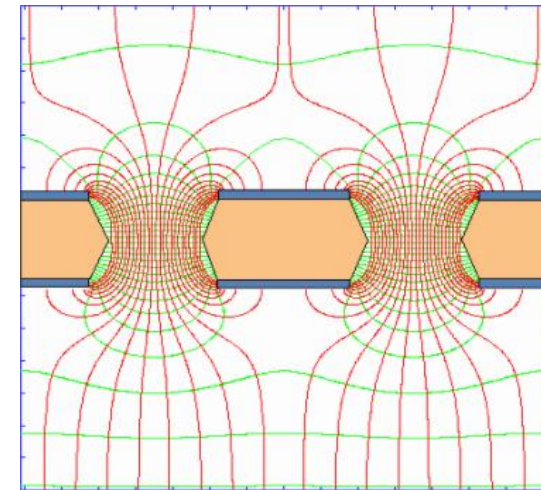
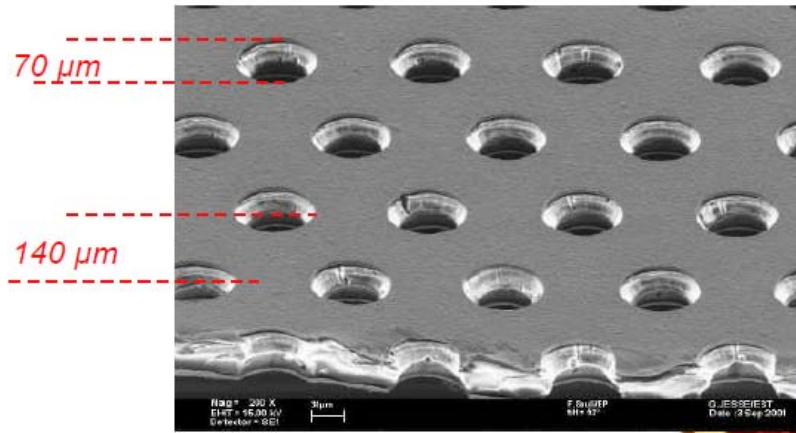


Advanced passivation

Standard passivation

Gaseous detectors : Gas Electron Multiplier

GEM (on a MSCG) : préamplification at $\approx 100 \mu\text{m}$ above the substrate kapton foil (copper coated) with amplification holes

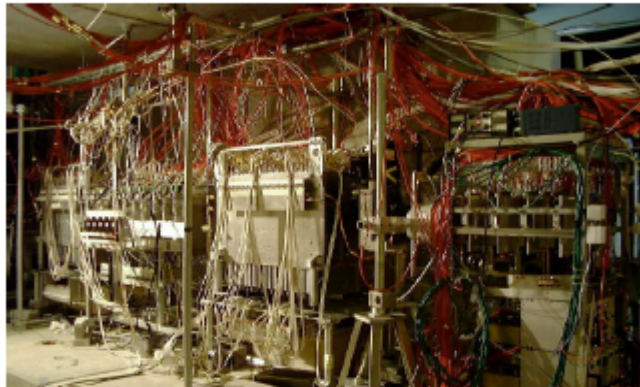
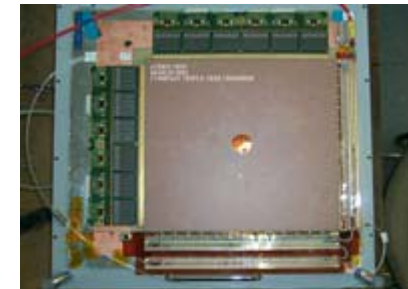


Discharge probability using single, double and triple GEMs

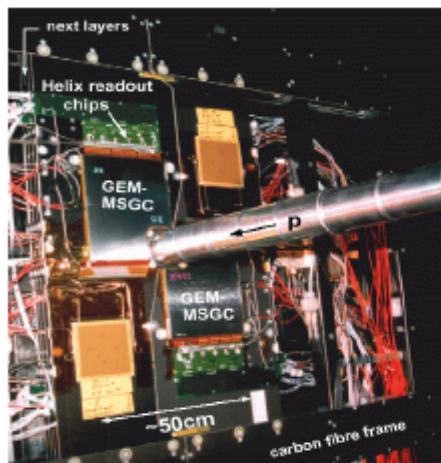
Gaseous detectors : MSGC + GEMs

Compass

MicroStrip Gas Chamber

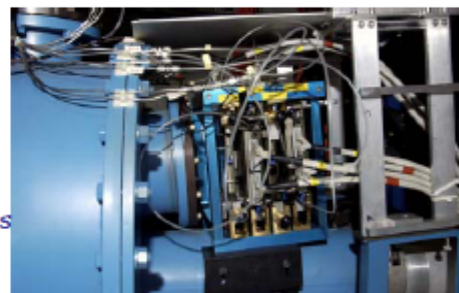


CMS (rejected)
 Advanced passivated MSGC
 Telescope of 32 MSGCs tested at
 PSI in Nov99 (CMS Milestone)



HERA-B Inner Tracker
 MSGC-GEM detectors
 $R_{min} \sim 6$ cm
 10^6 particles/cm²·s
 300 μm pitch
 184 chambers: max 25x25 cm²
 ~ 10 m²; 140.000 channels

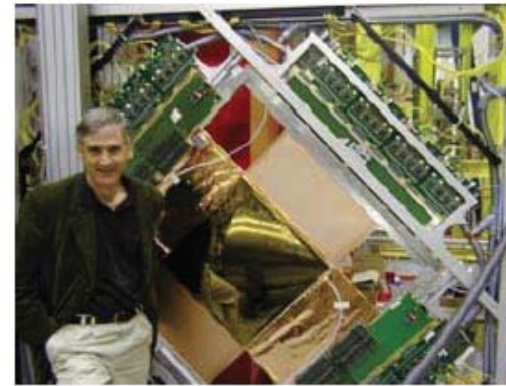
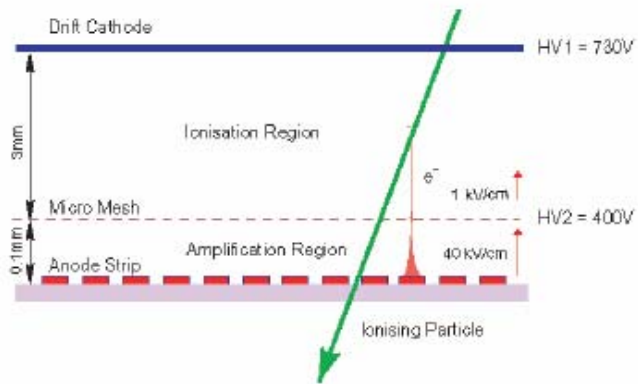
D20 diffractometer at ILL
 for neutron detection
 1D localisation
 48 MSGC plates (8 cm x 15 cm)
 Substrate: Schott 58900
 Angular coverage : 160° x 5,8°
 Position resolution : 2.57 mm (0,1°)
 5 cm gap; 1.2 bar CF4 + 2.8 bars 3He
 Efficiency 60% @ 0.8 Å



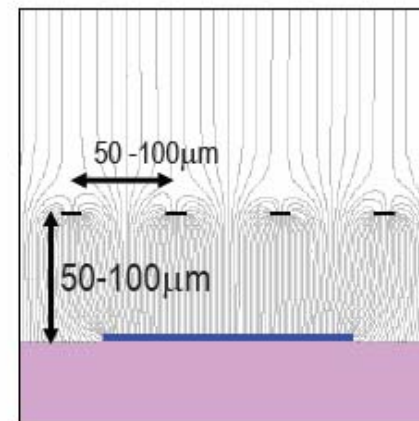
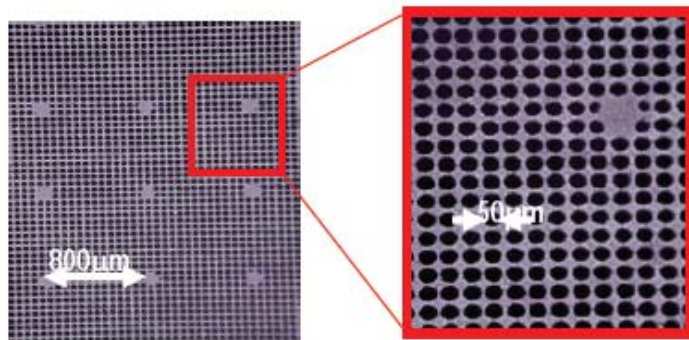
DIRAC
 MSGC-GEM detectors
 Hadron beam
 $3 \cdot 10^5$ particles/cm²·s
 4 planes; 10x10 cm²

Gaseous detectors : Micromegas

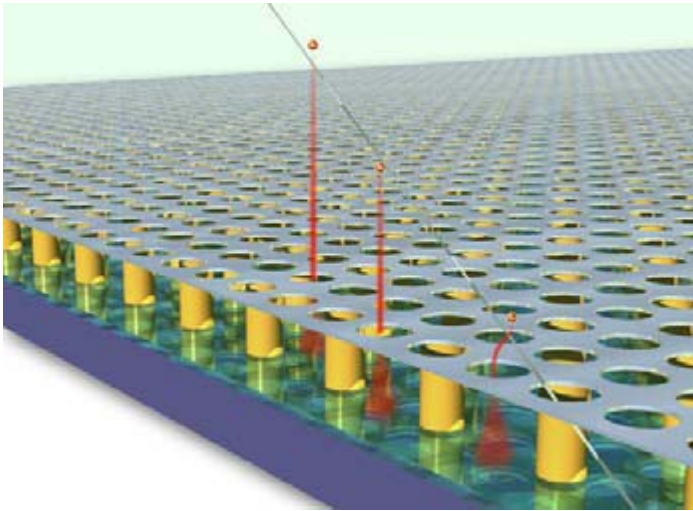
Micromegas : (G. Charpak and Y.Giomataris – 1992) is similar to a MSGC+GEM and a drift chamber. The cathode is a mesh at 100mm from the anodes (strip deposited on a substrate)



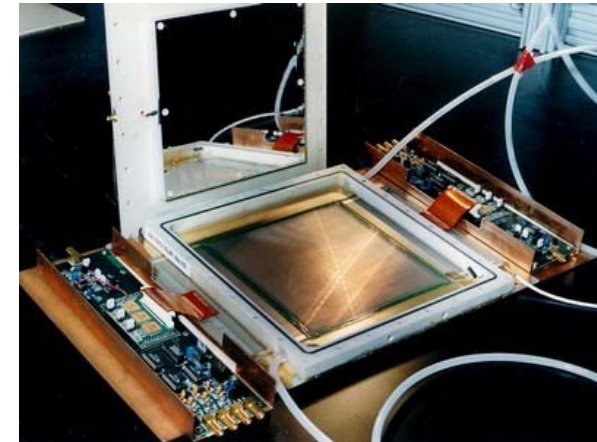
Y.Giomataris et al, NIM A 376 (1996) 29



Gaseous detectors : Micromegas

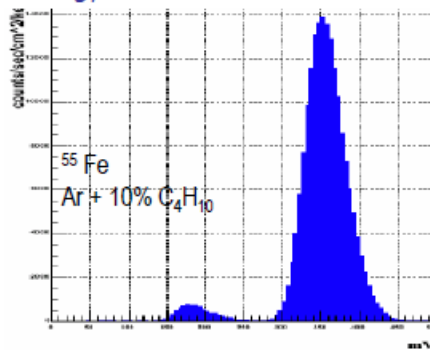


Limitation : Mesh spacers (loss of acceptance)

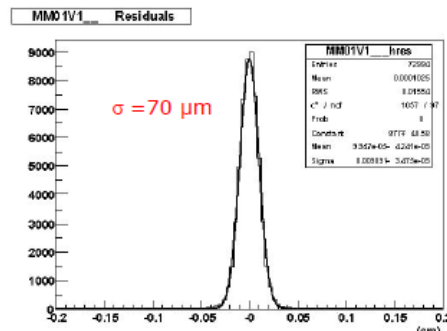


Prototype (1997)

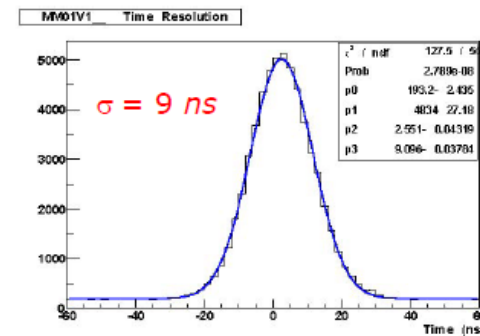
energy resolution ~ 10%



D.Thers et al NIM A 469 (2001) 133



Spatial resolution < 70 μm

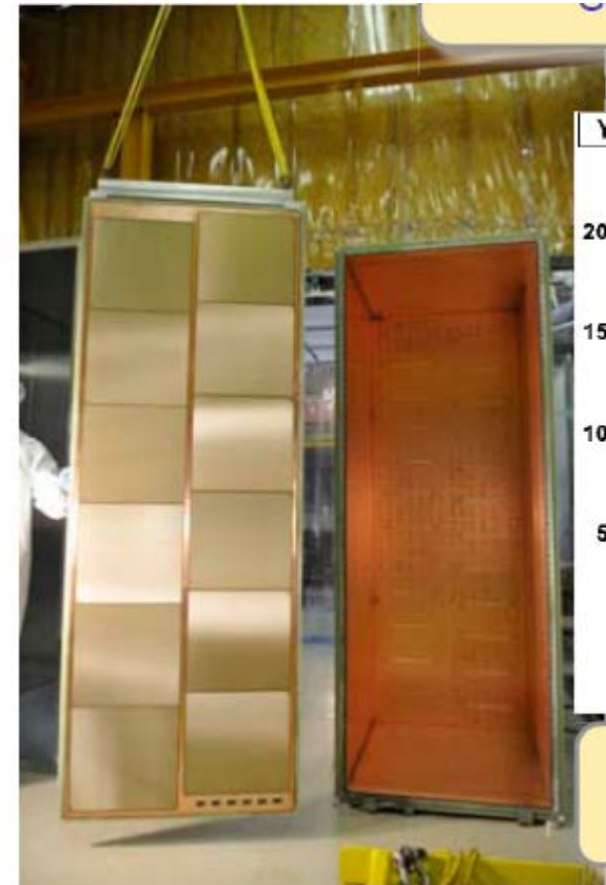


Time resolution : 9 ns

Gaseous detectors : Micromegas



Compass
Set of 12 plates 40x40 cm²



T2K / TPC
Set of 12 plates 40x40 cm²

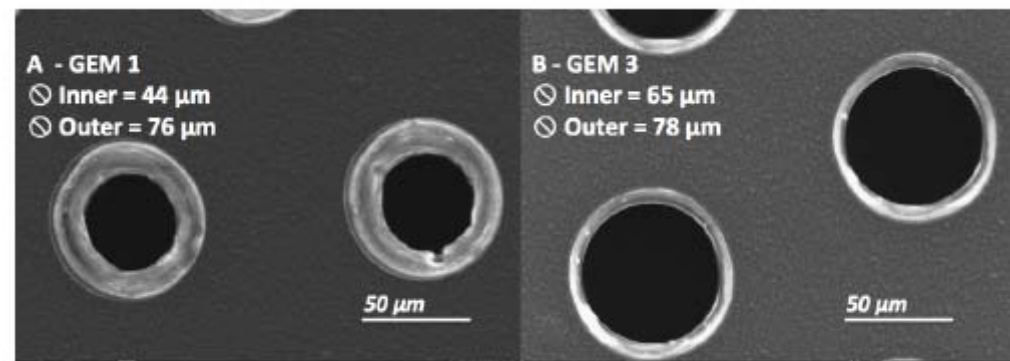
Gaseous detectors : Aging problems

Example : The GE1/1 project for CMS :

Adding CF_4 to the « classic Ar/CO_2 mixture to increase the time response (5 nsec)

Effect : dissociation of CF_4 leads to HF (hydrofluoric acid) which etch the copper...

Example :
Etching of the GEM
Holes (GE1/1 project)

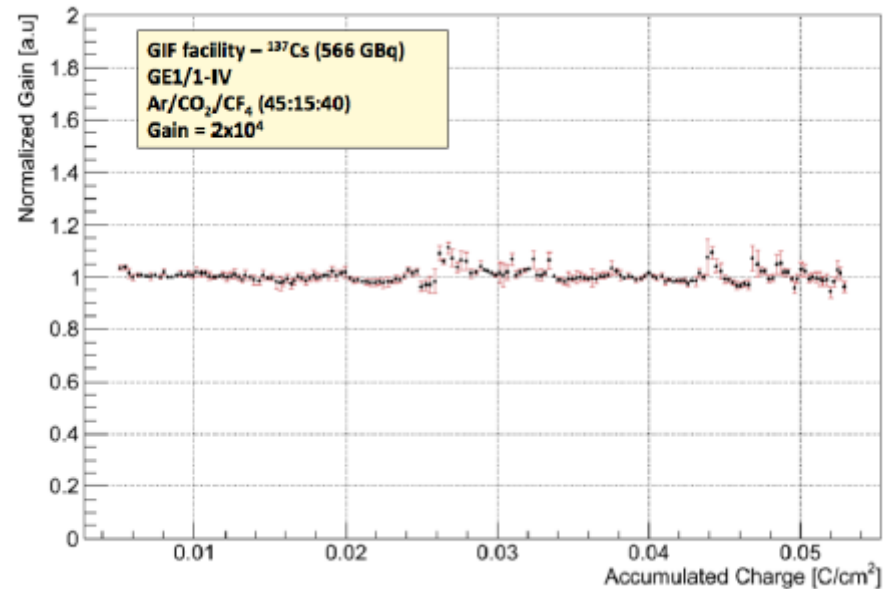


Gaseous detectors : « New » Aging problems

In future machine (HL-LHC, FCC...) at very high Luminosity, the particle flux will degrade the performances of the detectors.

One has to test the irradiation effects !
But simulation is « impossible »....

Example :
Gain versus irradiation
(corresponds to 10 years of
Operation at CMS)



Gaseous detectors : Conclusions

Conclusion :

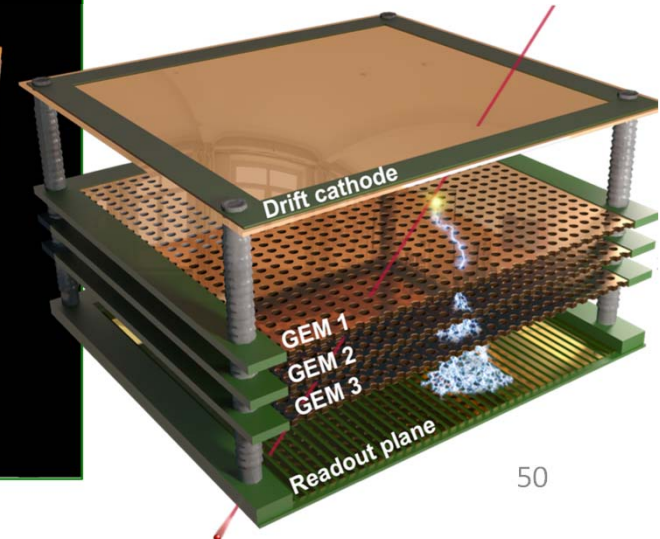
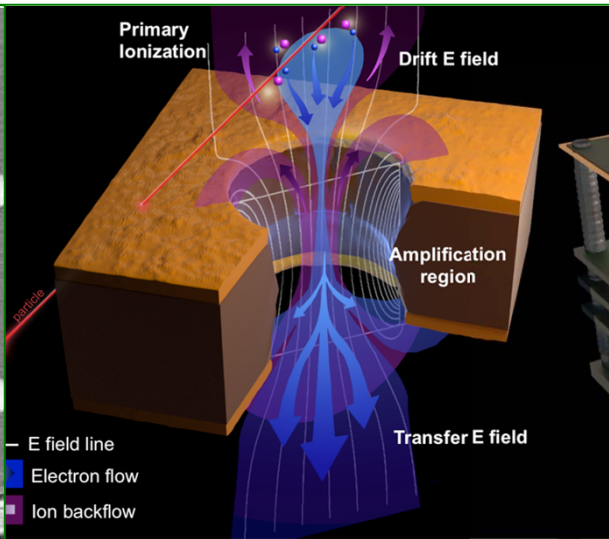
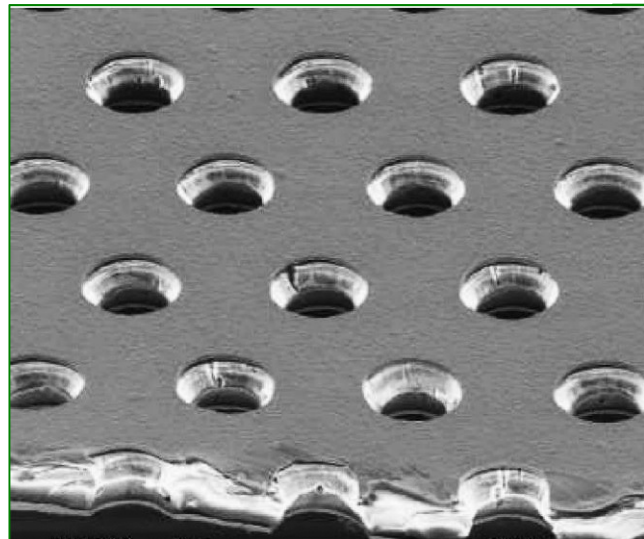
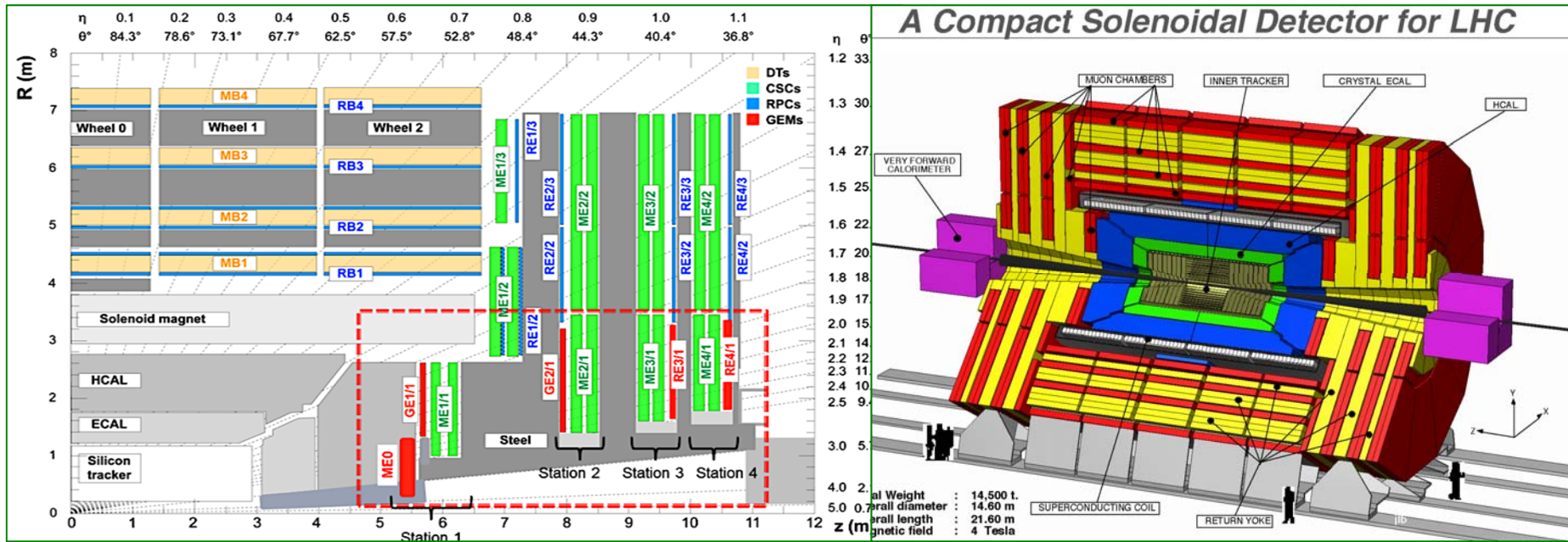
- Evolution of gaseous detectors : MGD (Micro Gap Detectors)
 - GEM
 - Micromégas
- Main problem for these detectors :
 - Cleaningness
 - Long term operation

EASY TO DESIGN

COMPLICATED TO BUILD

DIFFICULT TO OPERATE ON A LONG TERM BASIS

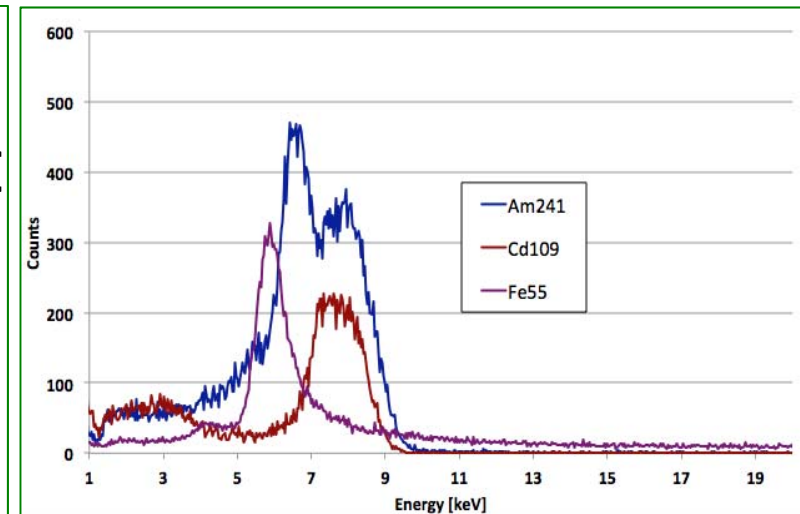
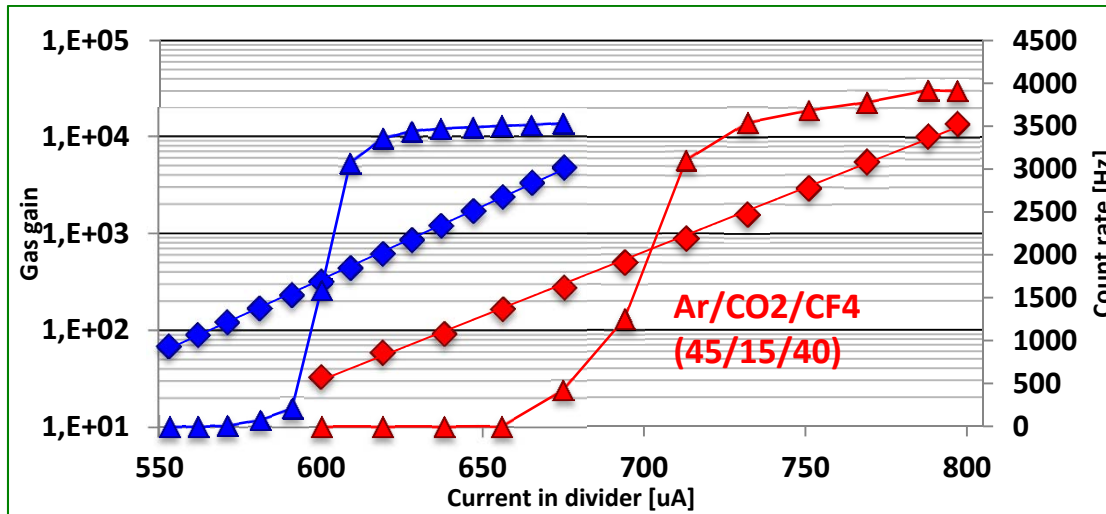
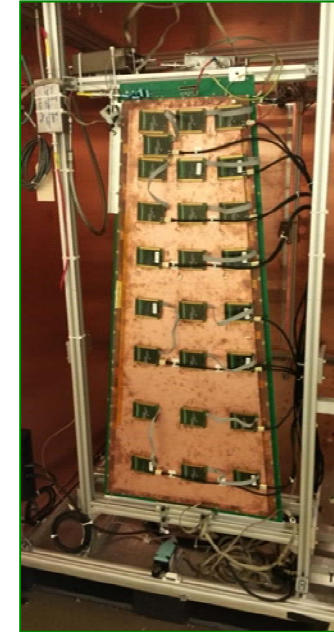
R&D on Big GEM Chambers : a nice nightmare !



R&D on Big GEM Chambers : 1. DEFINING THE PARAMETERS

Extensive study on GEM detectors :

- Basic operation with Xray sources
- Calibration tests with different :
 - gas mixtures
 - GEM geometries
 - HV power systems
 - sizes of detectors
- Defining the best configuration



R&D on Big GEM Chambers : 2. VERIFYING THE PARAMETERS

Advanced measurements and characterization:

- General understanding on GEM technology
- Comparison with past measurements
- Charging up effects (short-term stability)

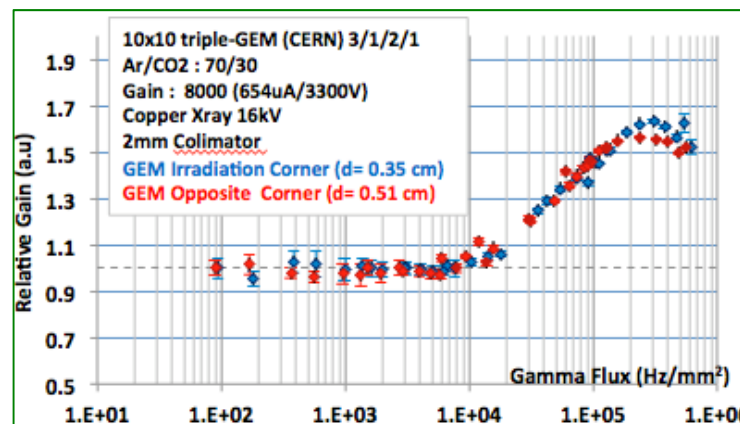
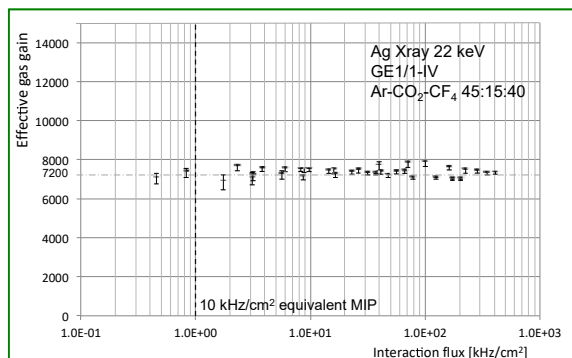
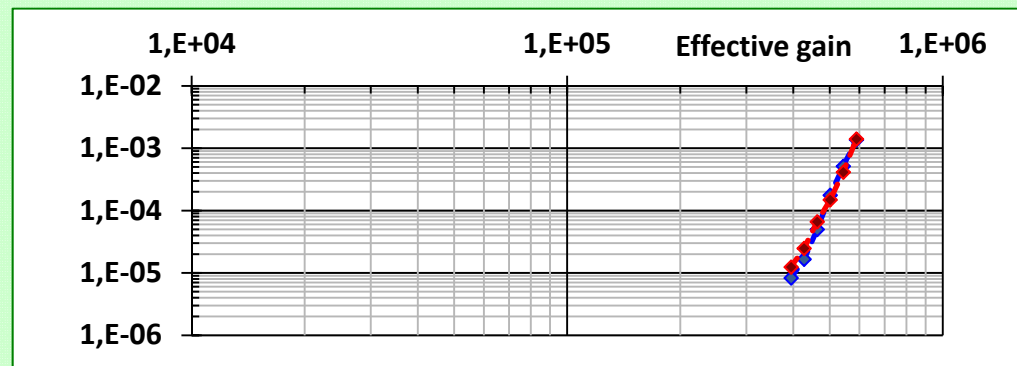
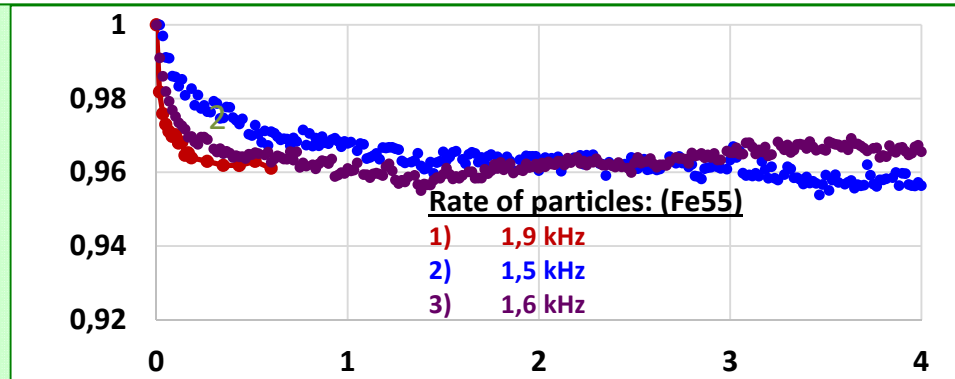
5-10 % after 1 hour

- Discharge probability

$< 10^{-12}$ at a gain of 10^4

- Rate capability

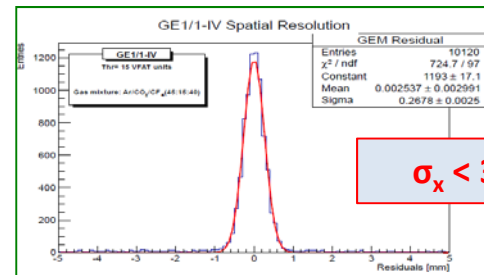
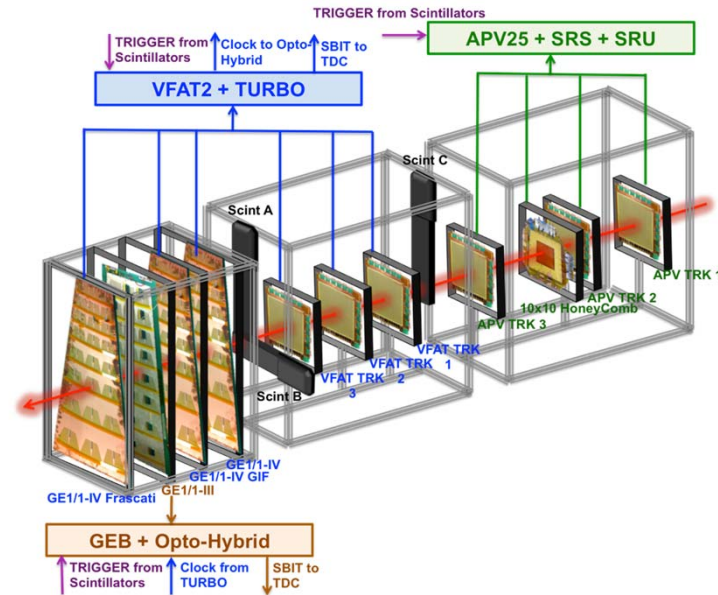
No gain loss up to 1 MHz/mm^2



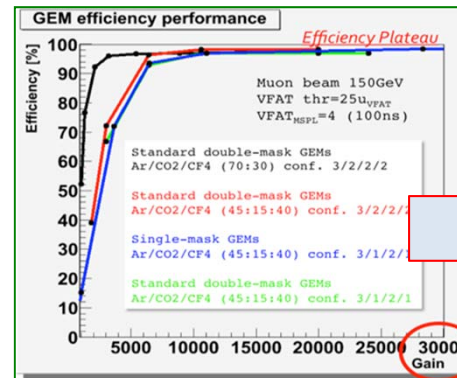
R&D on Big GEM Chambers : 3. BEAM TESTS

Detectors performances :

- Intense beam of **charged particles**
- All generations tested in different config. And B field.
- **Characterization** of the beam and comparison with the detector response
- Information about :
 - **Efficiency**
 - **Space resolution**
 - **Time resolution**
- Characterization of new electronics and DAQ systems

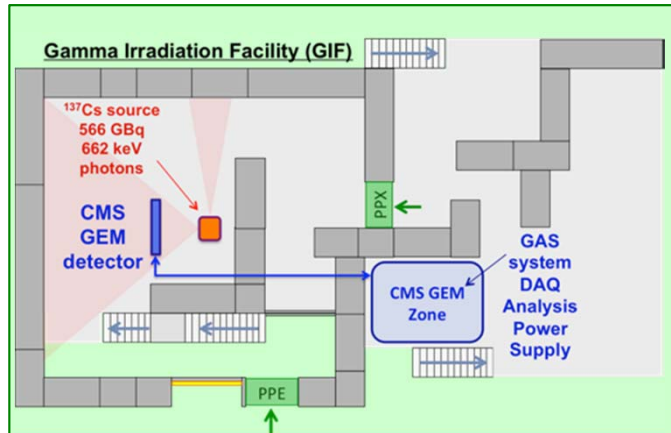


$\sigma_x < 300 \mu\text{m}$ (digital readout)



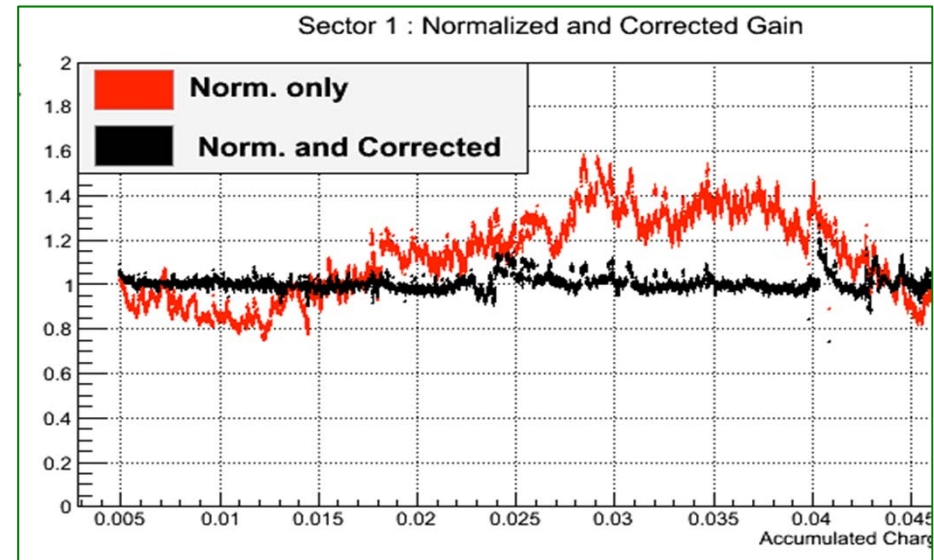
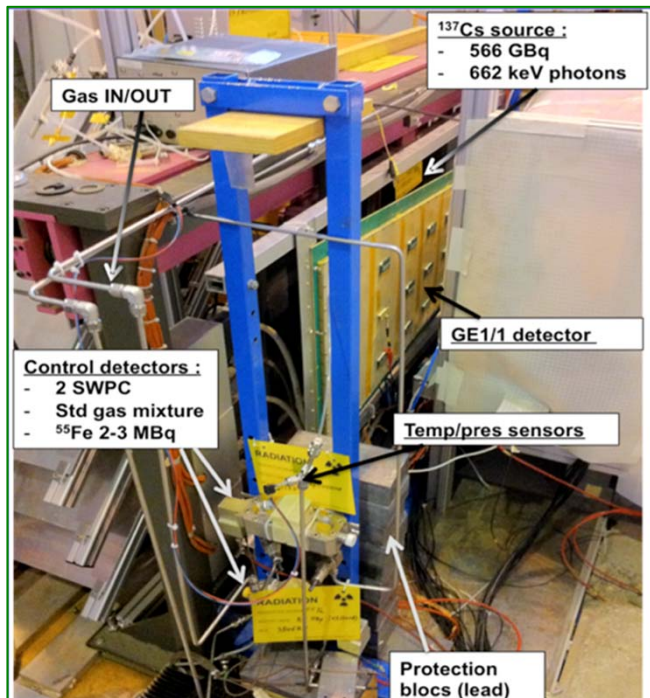
Detector efficiencies above 98%

R&D on Big GEM Chambers : 4. LONG TERM TESTS...

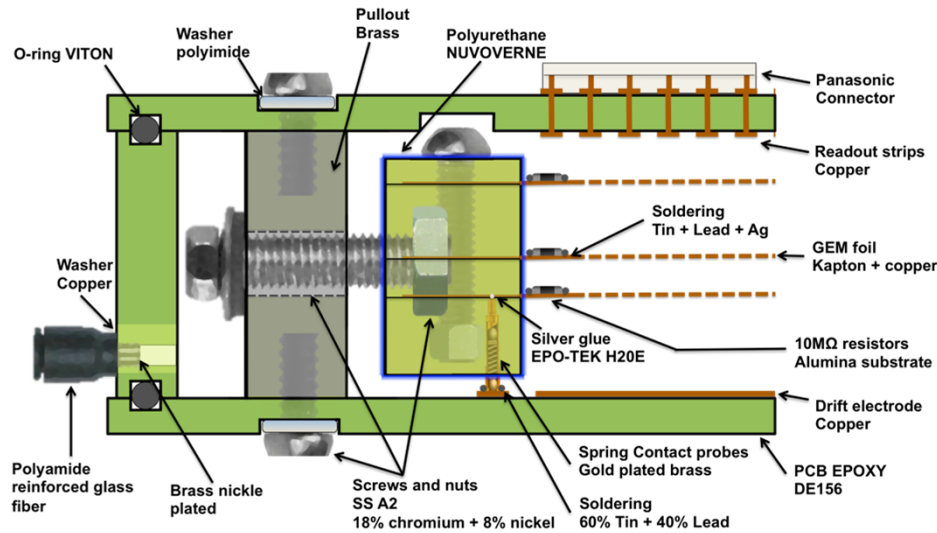


Aging Test at CERN GIF

- ^{137}Cs source 566 GBq
- Gamma emission 662 keV



R&D on Big GEM Chambers : 5. AGING TESTS



Outgassing Study :

- select “clean” materials to prevent self-contamination and increase longevity
- 9 materials already tested / 8 approved

