Functioning Principle of Gaseous Detectors

Outline:

- Generalities
- Ionization
- Electrons and ions mouvement
- Amplification
- Ageing and breakdown
- Generation of the signal
- Simulation tools
- Examples of detectors: MWPC, MPGD…

J. Pancin, GANIL/STP

Generalities

Measure of: E, $p_{x,y,z}$, x, y, z, dE/dx, charge, time → type, Z, M

Large spectrum of particles : μ, γ, X, π, K, proton, n, jets, (ν), $^{Z}A^{Q}$, β+/– …

Main final interaction: Electromagnetic interaction with electrons of the medium

Charged particles (light or heavy)
- Collision with electrons
- Collision with the nuclei
- Radiation: bremsstrahlung…

Neutral Particules: n
- Nuclear reaction

Photon
- photoelectric, compton, pair creation

Ionization or free electrons creation

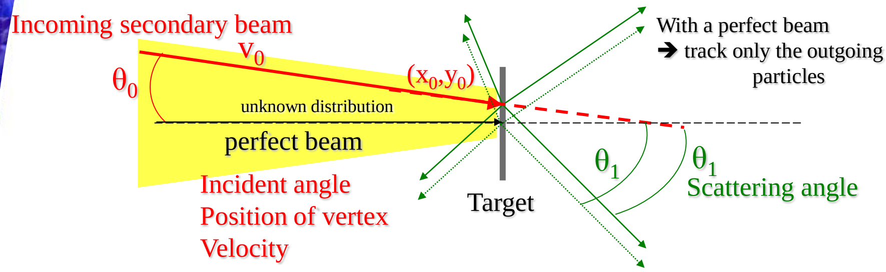
↓

Electrical signal

not considered: bubble chamber, bolometer, strong interaction…

Example of Nuclear Physics

Information about the reaction process and the nuclei
→ angular distributions, velocity, energy
(curvature radius in a magnetic field for momentum, dE/dx vs E for Z…)



What for ?

Determine the trajectories of ions before the interaction point
→ positions + time of flight

Need for a transmission detector (low interaction rate, weak influence of beam characteristics), with position and time measurement on an event by event basis

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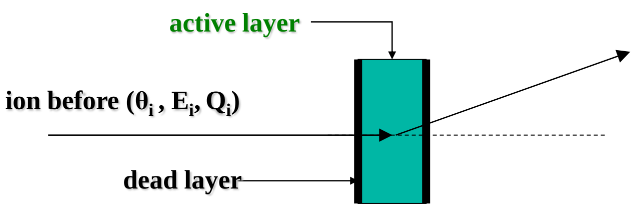
Transmission detector:

enough (electron) signal to detect the ion

Wihtout changing too much its characteristics (important in case of beam profilers)…



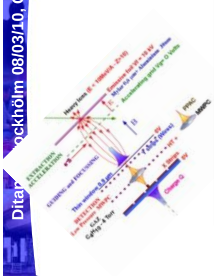
ion after
$\theta_f = \theta_i + \delta\theta$
$E_i = E_i - \Delta E + \delta E$
$Q_f = Q_i + \delta Q$

Energy losses ΔE
Energy straggling δE
Angular straggling $\delta\theta$
Charge exchange

Losses & Straggling mainly estimations
- Bethe-Bloch formula
- Empirical formula for straggling
-Very empirical for charge exchange

Losses, Straggling and Detection Set-up

^{40}Ca



Material	500MeV/u	50MeV/u	5MeV/u
2mm BC400 (scintillating plastic)	ΔE = 227MeV δE = 0.08MeV/u δθ = 0.4mrad	1385 0.11 3.5	Stopped ! Rg=70µm
0.2mm Silicon (solid state detector)	42 0.04 0.27	185 0.03 2.4	Stopped ! Rg=46µm
1cm Ar at 1bar (gas detector+windows)	13 0.023 0.17	57.8 0.01 1.5	Stopped ! Rg=7mm
10cm C_4H_{10} at 10mbar (low pressure detector+thin windows)	0.29 0.003 0.014	1.28 0.002 0.11	6.02 0.002 1.14
1µm Mylar© foil (window) with detector off beam (gas detectors or…)	0.14 0.002 0.01	0.64 .001 0.10	2.9 0.001 0.93
0.2µm carbon foil (emissive foil) with detector off beam (gas detectors…)	0.02 0.0008 0.004	0.087 0.0006 0.035	0.39 0.0005 0.34

Tool : LISE++ code by O. Tarasov and D. Bazin

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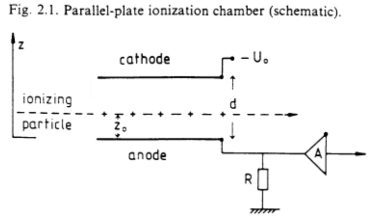
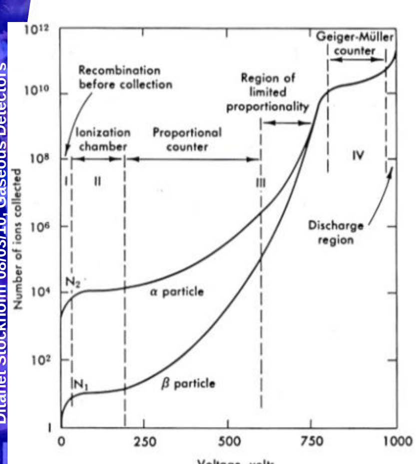
The different regimes of gaseous detectors

The simplest detector

Fig. 2.1. Parallel-plate ionization chamber (schematic).





I: too small voltage→ recombination of pairs.

II: <u>ionisation</u> chamber. Charge collection without amplification.

IIIa: <u>proportional</u> mode. Signal is amplified and proportional to deposit ionisation.

IIIb: *<u>streamer</u>* mode. Secondary avalanches induced by photons from the first avalanche. → *quenching* gas needed.

IV: *<u>Geiger-Müller</u>* mode (or *breakdown* mode). Avalanche in the whole detector. Output current saturated.

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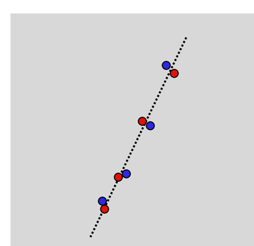
Ionization in gas: primary ionization

Electron-ion air production:



- Coulomb interaction between the electric field of the particle and of the molecules of the medium produce electron-ion pairs
  $\Rightarrow$ **X + p → X^+ + p + e^-**
- Excitation: **Ne+p → Ne^*+ p**
  Ne^* + Ar → Ne + Ar^+ + e^- (*Penning* effect)

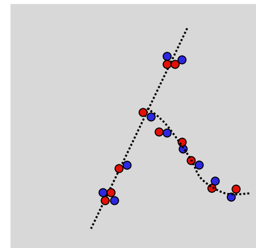
- Multiple ionizing collisions follow Poisson's statistics:

$$P_k^n = \frac{n^k}{k!} e^{-n}$$

n : average
k : actual number

Ionization in gas: secondary ionization

A second ionization process can occur with δ **ray electrons**: primary electrons with enough energy to ionize the gas: effects on the total number of ionization electrons !! (and spatial resolution as well)

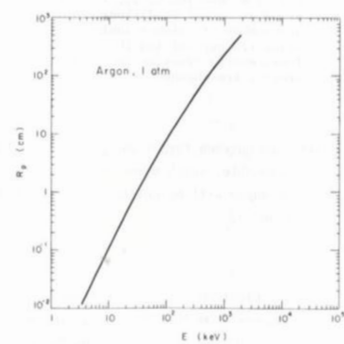


Total ionization:

$$n_T = \Delta E/Wi = dE/dx \times \Delta x/Wi$$

Wi: energy for 1 pair creation, gas dependent

$$n_T/n_p \approx 3$$



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Ionization

GAS	Density g cm^{-2}	E_X eV	E_I eV	W_I eV	dE/dx keV cm^{-1}	N_P cm^{-1}	N_T cm^{-1}
Ne	0.839 10^{-3}	16.7	21.6	30	1.45	13	50
Ar	1.66 10^{-3}	11.6	15.7	25	2.65	25	106
Xe	5.495 10^{-3}	8.4	12.1	22	6.87	41	312
CH_4	0.667 10^{-3}	8.8	12.6	30	1.61	37	54
C_2H_6	1.26	8.2	11.5	26	2.91	48	112
i-C_4H_{10}	2.49 10^{-3}		10.6	26	5.67	90	220
CO_2	1.84 10^{-3}	7	13.8	34	3.35	35	100
CF_4	3.78 10^{-3}	10	16	54	6.38	63	120

E_x, E_i : first excitation and ionization potentials
w_i: average energy per ion pair
n_P , n_T : primary and total ion pairs per cm for 1 proton at MI

- Q=CV, if C=10 pF we have 1 μV of signal only for 10 keV energy deposit in Ar
- In SC, Wi around 4 eV and density factor of 10^3 which gives 10 mV signal in same conditions

$\Rightarrow$ **Avalanche process needed!!**

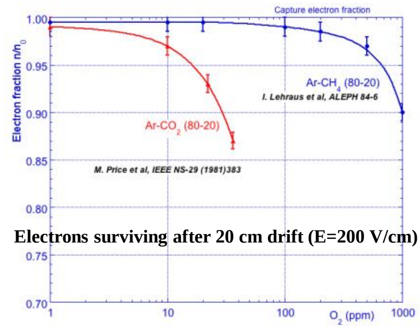
Electron attachment

n_T: number of total electrons but free or not?

$e^- + A \rightarrow A^-$ (+hν) : influence of electronegative atoms (O, F…)

Coefficient, number of collisions, and average time for electron attachment in several gases under normal conditions[12,18,21]

Gas	h	N (sec^{-1})	t (sec)
CO_2	6.2×10^{-9}	2.2×10^{11}	0.71×10^{-3}
O_2	2.5×10^{-5}	2.1×10^{11}	1.9×10^{-7}
H_2O	2.5×10^{-5}	2.8×10^{11}	1.4×10^{-7}
Cℓ	4.8×10^{-4}	4.5×10^{11}	4.7×10^{-9}



Electrons surviving after 20 cm drift (E=200 V/cm)

The attachment cross section: strong influence of the gas mixture (quasi no attachment in pure noble gas) and the applied electric field

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Electron and ion mouvement

With no E field

- Dissipation of the energy gained in the ionization till reach thermal energies (Maxwell distribution), and recombinate

$$v = \sqrt{\frac{8kT}{\pi m}}$$

k Boltzmann's constant,
T the temperature
m the mass

$v_e = 10^7$ cm/s
$v_{He} = 10^5$ cm/s

- A charges distribution diffuses by multiple collisions (Gaussian law):

$$\frac{dN}{dx} = \frac{N_0}{\sqrt{4\pi Dt}} \exp\left(-\frac{x^2}{4Dt}\right)$$

N_0 total number of charges
x distance
D diffusion coefficient

Then the linear and volume r.m.s. of the spread are:

$$\sigma_x = \sqrt{2Dt}$$
$$\sigma_V = \sqrt{6Dt}$$

radial spread of ions in air in normal conditions: about 1 mm after 1 second

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Electron and ion mouvement

With E field

- Electrons and ions drift in the gas, the drift velocity of electrons (much smaller size) factor of 10^2 to 10^3 higher than for ions

μ = v/E : mobility with v the drift velocity and E the electric field

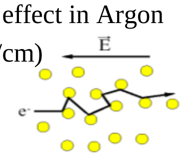
Gas	Ion	Mobility μ^+ (cm^2/V s)
He	He^+	10.2
Ar	Ar^+	1.7
H_2O	H_2O^+	0.7
Ar	$(OCH_3)_2CH_2^+$	1.51
Iso-C_4H_{10}	$(OCH_3)_2CH_2^+$	0.55
$(OCH_3)_2CH_2$	$(OCH_3)_2CH_2^+$	0.26
Ar	Iso$C_4H_{10}^+$	1.56
Iso-C_4H_{10}	Iso$C_4H_{10}^+$	0.61
Ar	CH_4^+	1.87
CH_4	CH_4^+	2.26
Ar	CO_2^+	1.72
CO_2	CO_2^+	1.09

- **Ions:** constant mobility up to high electric field
  ⇒ V_+ only proportional to E×Po/P

  V_{He+}=0.01 cm/μs at 1 kV/cm

- **Electrons:**

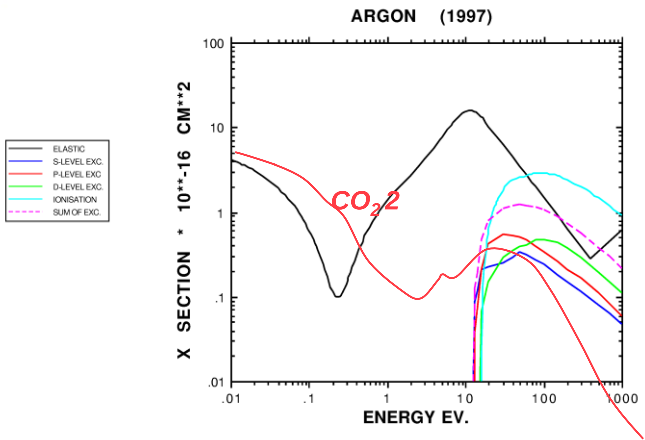
  Drift velocity $V_- = (e/2m).E.\tau$ with τ mean time between 2 collisions
  σ and hence τ depends on electron energy
  $\lambda_e \sim \lambda_{\text{e-atomique}}$ ⇒ quantum coupling effects like Ramsauer effect in Argon
  Typical value ≈cm/μs (1.5 cm/ μs in He+iC4H10 at 1 kV/cm)



Electron mouvement

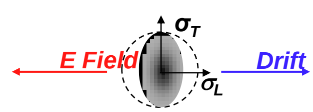
With E field

- Important variation of the cross section versus energy
- Strong influence of the mixture (noble gas+polyatomic molecule)

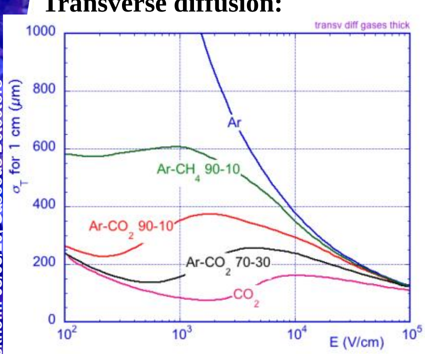


Longitudinal and transverse diffusion

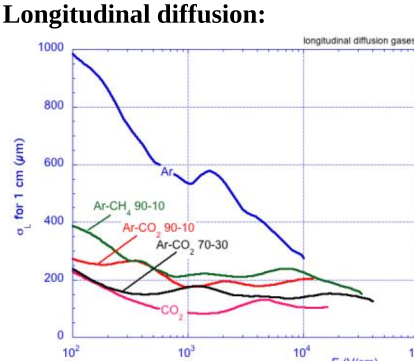
At low electric fields, the diffusion is symmetric. At moderate to high fields, the longitudinal diffusion (in the direction of drift) is reduced



Transverse diffusion:



Longitudinal diffusion:



In drift chambers, the dispersive factor ≈ longitudinal diffusion

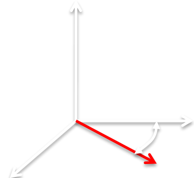
In Time Projection Chambers (TPC), the dispersive factor ≈ transverse diffusion (center of gravity of charge induced on pad rows)

Electrons mouvement

With E and B field

The drifting electrons cloud is rotated by an angle θ_B in the plane perpendicular to E and B.

E ⊥ B



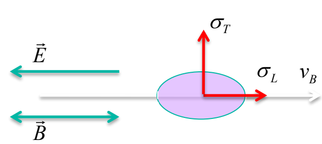
$$\tan\theta_B = \omega\tau$$

τ : mean collision time

$$v_B = \frac{E}{B}\frac{\omega\tau}{\sqrt{1+\omega^2\tau^2}}$$

ω=eB/m **→ Larmor frequency**

E // B



$$v_B = v_0$$

$$\sigma_L = \sigma_0$$

Drift velocity unchanged

$$\sigma_T = \frac{\sigma_0}{\sqrt{1+\omega^2\tau^2}}$$

Transverse diffusion is reduced

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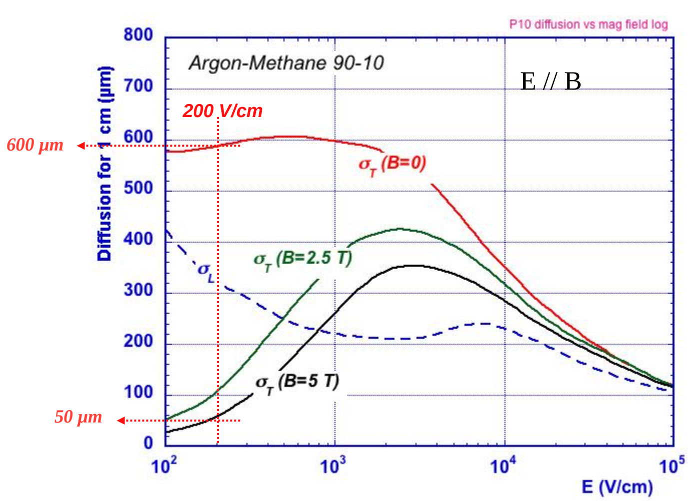
Transverse diffusion in magnetic field

In some gases transverse diffusion strongly reduced by B field

⇒ improves the precision of the projected coordinate measurement in Time Projection Chambers



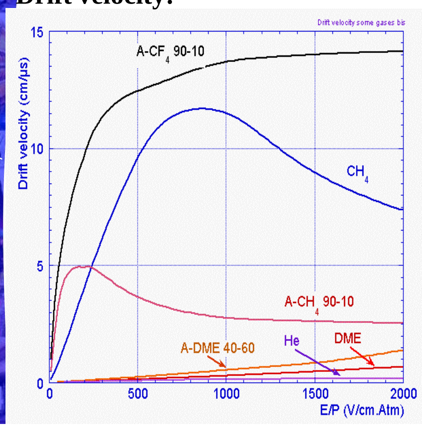
Electrons mouvement

Drift velocity and diffusion of electrons vary in a wide range, depending on gas mixture.

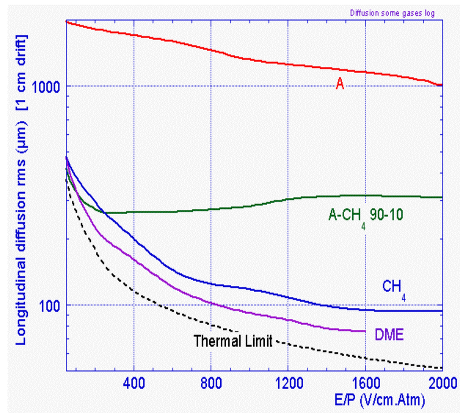
Relation between mobility and diffusion: $\frac{D}{\mu} = \frac{kT}{e} \approx 0.026 \text{ eV}$

The minimum diffusion at a given field is given by the thermal value: $\sigma_x = \sqrt{\frac{2kT}{e}\frac{x}{E}}$

Drift velocity:



Diffusion:



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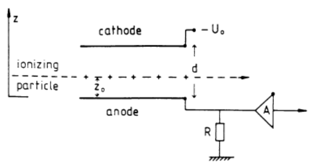
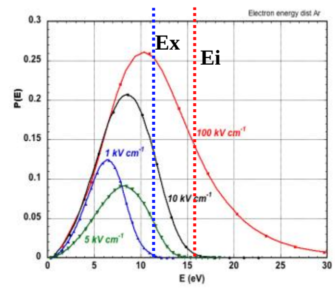
Amplification by avalanche

Minimum field E_c for avalanche multiplication ≈ **40 V/cm/torr**

Decrease pressure or gaps or increase V.

Fig. 2.1. Parallel-plate ionization chamber (schematic).





d= 3 mm⇒V_c≈10 kV at 1bar

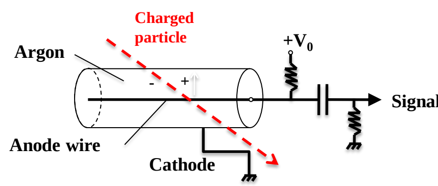
Adapt geometry to increase the field locally: **use of thin wires**

$$E = \frac{1}{r}\frac{V_0}{\ln(b/a)}$$

r **: radial distance from axis**

b **:inside radius of cylinder**

a **: radius of central wire**



Or use of thin gaps like in MPGD: micromegas, GEMs, MSGC

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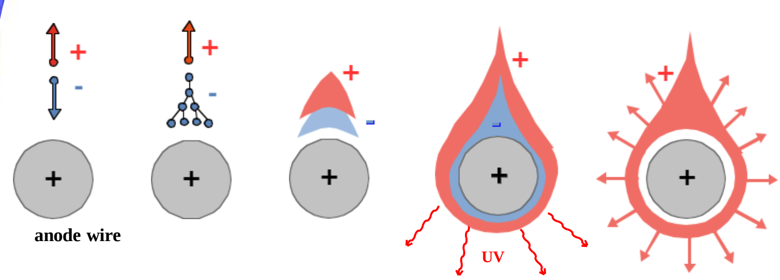
Amplification by avalanche



- One electron drifts towards the anode wire:
  - Electric field is increasing
  - Ionizing collisions → pair multiplication
- Due to lateral diffusion and difference of velocity of electrons-ions, a drop-like avalanche develops near the wire
- UV photons can be emitted → risk of uncontrolled amplification (spark)
- Electrons are collected in a very short time (few ns) and ions drift slowly towards the cathode

Avalanche calculation

- $\alpha = 1/\lambda = 1/(N\sigma)$ is the probability of ionization per unit length with λ the mean free path of the electron for a secondary ionizing collision
- For n electrons, there will be $dn = n\alpha dx$ new electrons created in a path dx

$\Rightarrow$ $n = n_0 e^{\alpha x}$ with α: first Townsend coefficient

Multiplication factor M:

$$M = \frac{n}{n_0} = \exp\left[\int_{r_1}^{r_2} \alpha(x)dx\right]$$

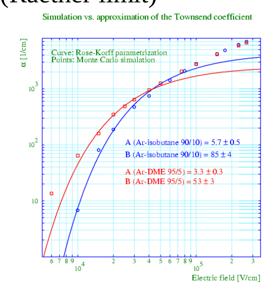
α usually function of x (non uniform electric fields)

- Limitation of M: above 10^7, sparks occur (Raether limit)
- Different empirical formula for α :

Rose and Korff: $\frac{\alpha}{p} = A\exp\left(\frac{-Bp}{E}\right)$

A and B gas dependent

Diethorn…



- Usually it is M which is measured *(typical max. value around 10^4)*

Avalanches

2 to 3 radius at 1 bar

Fig. 5 Two dimensional display of a simulated drift process of one electron from starting point to anode wire surface.

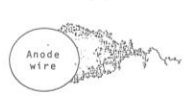


Fig. 6 Two dimensional display of a simulated electron avalanche.

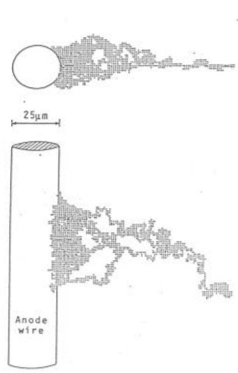
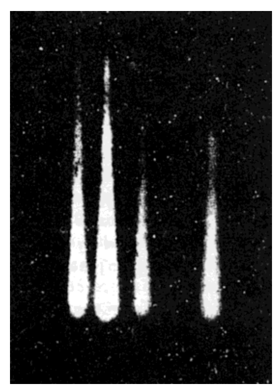
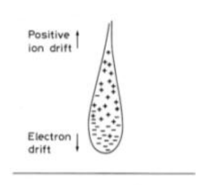


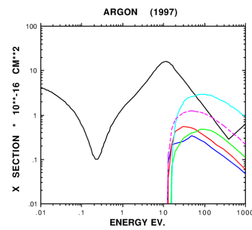
Fig. 7 Two dimensional displays of a simulated electron avalanche. Shading shows the density of electrons in the avalanche.

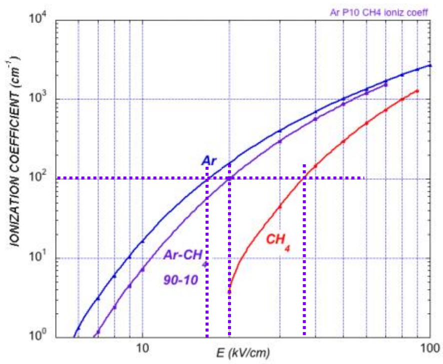


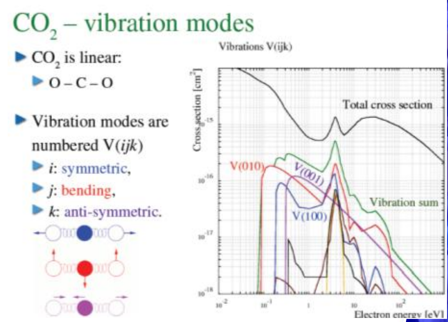


Avalanche: Quencher gas

- Polyatomic gases (several vibration and rotation modes: **non radiative mode**)
- Absorbe the radiated photons
- Limit the breakdown
- Typical quenchers: CH_4, i-C_4H_{10}, CO_2, CF_4...
- Problem of ageing







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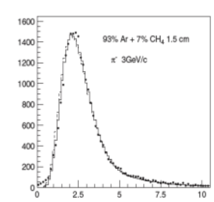
Energy resolution



Several statistical processes:

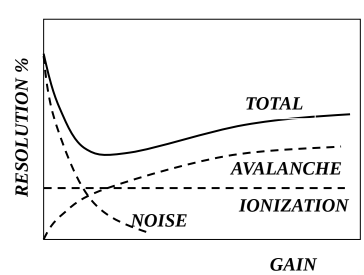
• Energy loss: landau distribution

• and Ionization: $R = 2.35\sqrt{\frac{F.w_i}{\Delta E}}$ F: Fano factor (00.5 to 0.4)

• Gain fluctuation: for high gain variance of a polya dist. given by factor b (0.5)

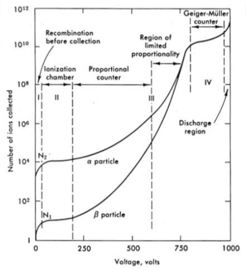
• Electronical noise

$$\left(\frac{\sigma_E}{E}\right)^2 = \underbrace{\left(\frac{\sigma_N}{N}\right)^2 + \left(\frac{\sigma_M}{M}\right)^2}_{(\sigma_Q/Q)^2 = W(F+b)/E} + \left(\frac{\sigma_{el}}{M}\right)^2$$

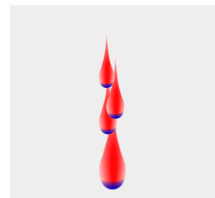


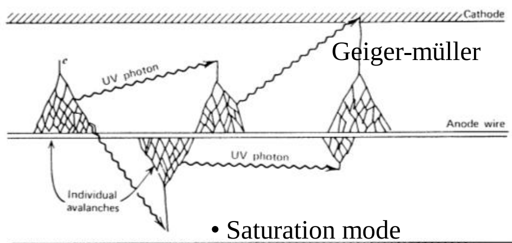
Ionization chamber : no b…

Beyond proportional avalanche



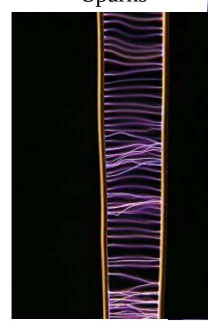
STREAMER





Geiger-müller

Sparks



- Saturation mode
- no particule discrimination
- High dead time (1 ms)
- Very sensitive

- Generalities: *what for and how?*
- Ionization
- Electrons and ions mouvement
- Amplification
- Ageing and breakdown
- Generation of the signal
- Simulation tools
- Examples of detectors: MWPC, MPGD…

Ageing and polymer formation

- Polymer formation by the dissociated quencher gas
- Complex chemistery
- Insulated layer degrading the detector performances

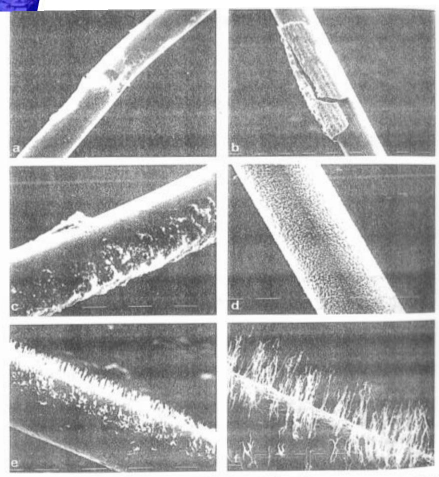
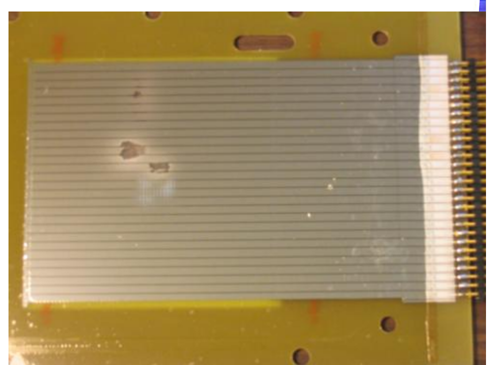


Fig. 4.31. Deposits on anode wires: (a) – $Ar + C_2H_6$; (b) – $Ar + C_2H_6$ + methylal; (c) – $Ar + CO_2$; (d) – perspex chamber; (e, f) – chambers with G10 fiber-glass and a cold trap (Adam 1983)



- Generalities: *what for and how?*
- Ionization
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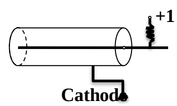
- Ageing and breakdown
- Generation of the signal
- Simulation tools
- Examples of detectors: MWPC, MPGD…

Generation of the signal

- Shockley-Ramo theorem and weighting field concept: Instantaneous current given by

$$i = q\,\vec{v}.\vec{E}_0 \Leftrightarrow Q = q\Delta\varphi_0$$

q charge (electrons or ions)
v velocity
E_0 weighting field (1V on the electrode of interest)
Q Induced charge
φ_0 weighting potentiel



Cylindrical detector

$$E = \frac{1}{r}\frac{V_0}{\ln(b/a)} \qquad \varphi(r) = -\frac{CV_0}{2\pi\varepsilon}\ln\left(\frac{r}{a}\right) \qquad C = \frac{2\pi\varepsilon}{\ln(b/a)}$$

Considering an avalanche starting at a small distance λ from the anode wire

$$Q^- = \frac{q}{V_0}\int_a^{a+\lambda}\frac{dV}{dr}dr = -\frac{QC}{2\pi\varepsilon_0}\ln\frac{a+\lambda}{a}$$

$$Q^+ = \frac{q}{V_0}\int_{a+\lambda}^{b}\frac{dV}{dr}dr = -\frac{QC}{2\pi\varepsilon_0}\ln\frac{b}{a+\lambda}$$

$Q^- + Q^+ = q$

$Q^-/Q^+ < 10\%$ for typical geometries:
Ion signal mainly

Generation of the signal

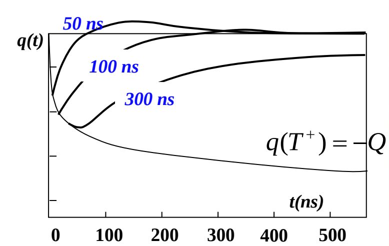
Time development of the signal on anode:

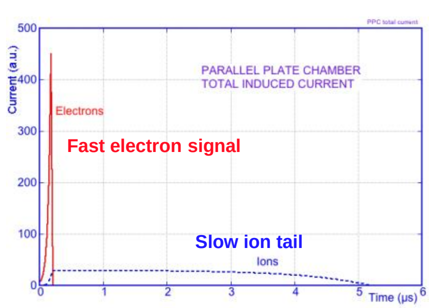
$$q(t) = -\frac{QC}{2\pi\varepsilon_0}\ln\left(1 + \frac{\mu^+ CV_0}{2\pi\varepsilon_0 a^2}t\right) = -\frac{QC}{2\pi\varepsilon_0}\ln\left(1 + \frac{t}{t_0}\right)$$

Total ions drift time: $T^+ = \frac{\pi\varepsilon_0(b^2 - a^2)}{\mu^+ CV_0}$

About 10 µs
Limiting the counting rate up to pile-up

FAST SIGNAL DIFFERENTIATION:





Adapt the electronics to the information wanted:
- Fast amplifier (voltage or current) for timing
- Charge amplifier for energy and position

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- Generalities: *what for and how?*
- Ionization
- Electrons and ions mouvement
- Amplification
- Ageing and breakdown
- Generation of the signal
- Simulation tools
- Examples of detectors: MWPC, MPGD…

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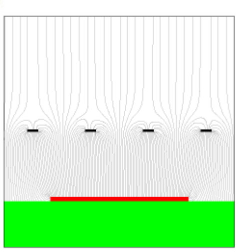
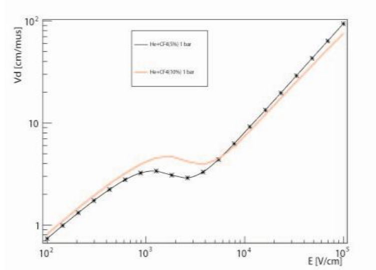
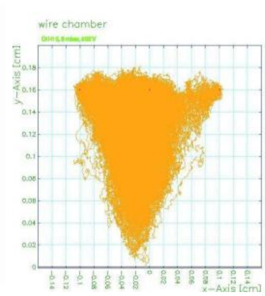
Simulation tools

- Field map calculation using 3D FEM (Maxwell 3D, COMSOL or GARFIELD (neBEM))
- Ionization models in gas with Heed program
- Electron transport properties in gas with Monte Carlo simulation (magboltz) based on electron cross sections (velocity, diffusion, attachment, townsend…),
- GARFIELD contains all this modules permits full simulations of gaseous detectors from ionization and field mapping to final signals







- Generalities: *what for and how?*
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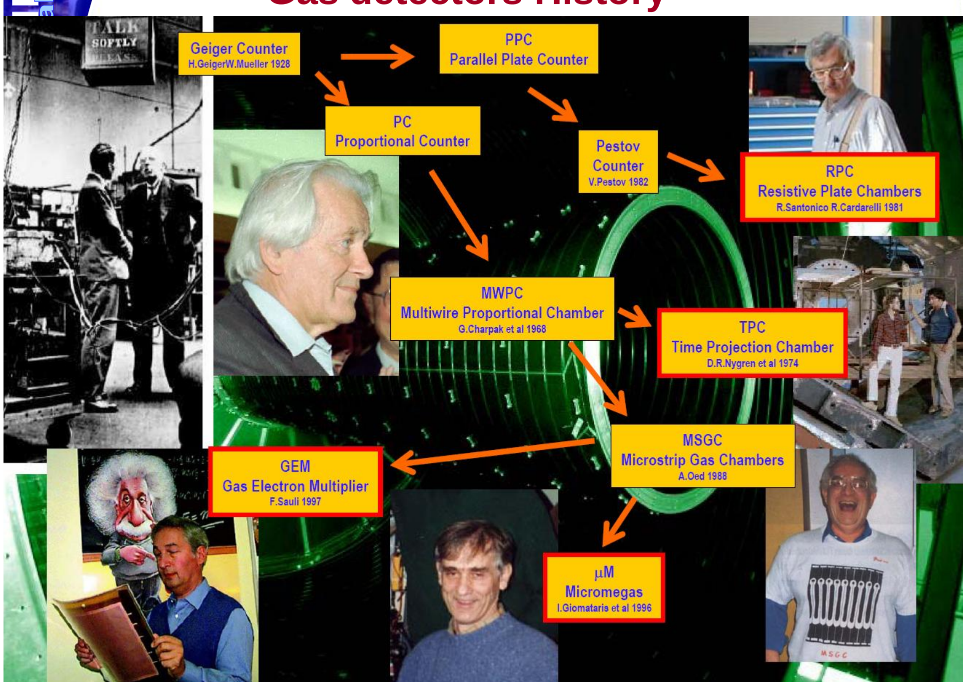
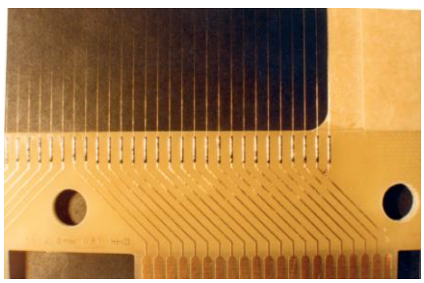
- Examples of detectors: MWPC, MPGD…

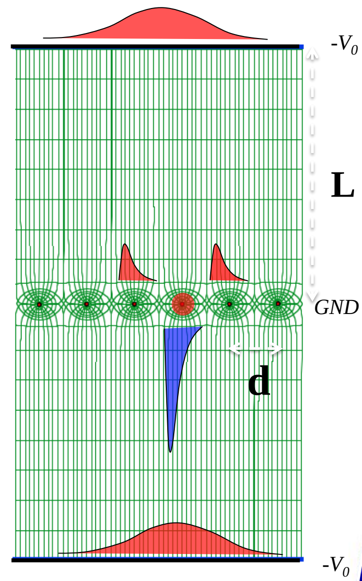
Gas detectors History



MWPC (MultiWire Proportional Chamber)

- Parallel thin anode wires between two cathode planes.
- Typical values:
  - L=8 mm, d=2mm (L/d ~ 3-4)
  - Wire diameters: 20-30 µm
- Spatial resolution:
  - $\sigma = d/\sqrt{12} \sim 600\ \mu m$
- Large area (>m^2)





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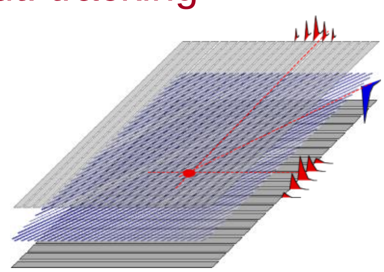
Cathode signal readout: tracking

The center of gravity of the induced charge distribution on cathode strips provides the X and Y projections of the avalanche position:

$$X = \sum \frac{X_i A_i(X)}{A(X)} \qquad Y = \sum \frac{Y_i A_i(Y)}{A(Y)}$$

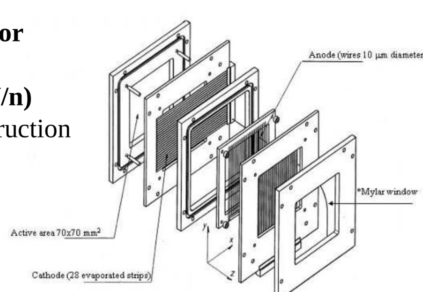


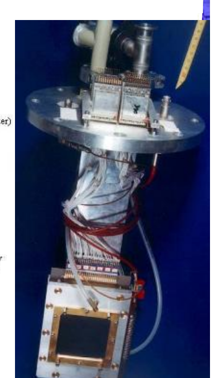
Still widely used nowdays…

Gas profilers for accelerator

CATs detectors (> 10MeV/n)

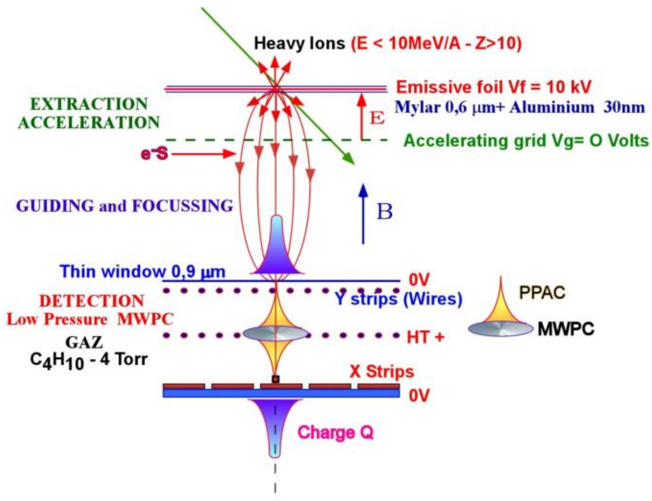
- In beam trajectory reconstruction
- Low pressure isobutane
- 1 mm spatial resolution
- 400 ps time resolution
- 10^5 pps/cm^2





Ottini & al., NIM A, 431(1999) p. 476-484.

SED using MWPC at low pressure



A. Drouart & a.l, NIM A579, (2007) p1090

Time Projection Chamber (David Nygren, 1975)

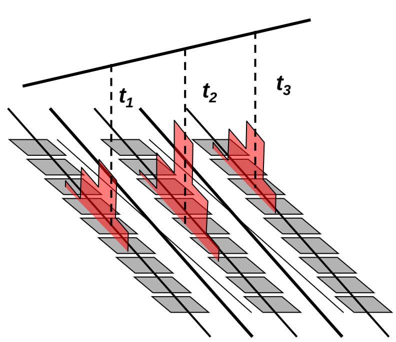
◆ Uniform electric field over a large volume

◆ Electrons of tracks drift to an end-cap position-sensitive detector (MWPC, …)

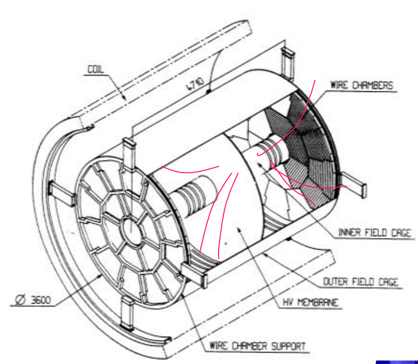
◆ A magnetic field B//E deflects the tracks to measure their momentum

◆ The drift time of each track segment is measured on the anode wires, giving the vertical coordinate Z

◆ The position in the XY projection is obtained by recording the induced charge profiles on cathode pad rows. The recorded charge provides dE/dx for particle identification.



ALEPH TPC (CERN 1990):



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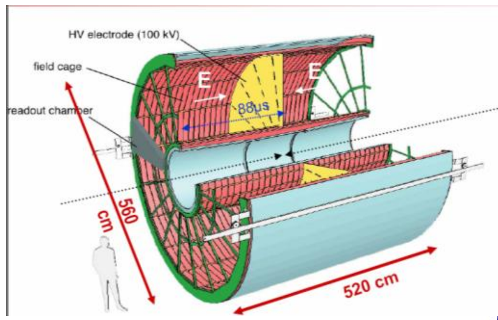
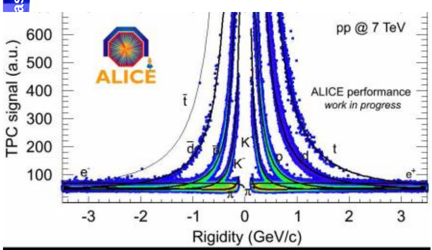
ALICE TPC @ CERN-LHC

Largest Time Projection Chamber ever made

- Inner radius: 845 mm
- Outer radius: 2466 mm
- Drift length: 2 x 2500 mm
- Drift gas: Ne-CO2-N2 (90-10-5)
- Gas volume: 95 m3
- 557568 readout pads





Expected Performances:

- Space point resolution ~500µm
- Two-track separation 0.5 cm
- dp/p <2% @ 1GeV, 10% @10GeV
- dE/dx <7%
- Rapidity coverage $-0.9 < \eta < 0.9$

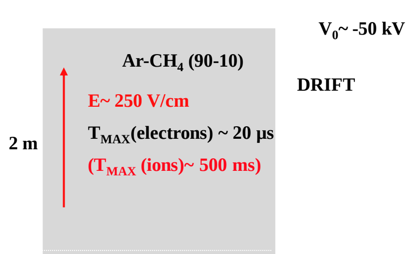
Gaseous Detectors

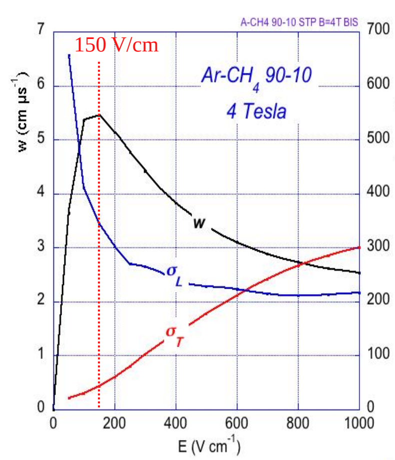
GANIL Spiral 2

TPC: gas mixture

A common choice for the gas filling is a mixture of Ar-CH_4 90-10 (flamable!!!):

- Saturated drift velocity at low fields (~ 150 V/cm)
- Strong reduction of the transverse diffusion with magnetic field (σ_T~40 µm√cm at 4 T)
- Moderate longitudinal diffusion (σ_L~350 µm√cm)





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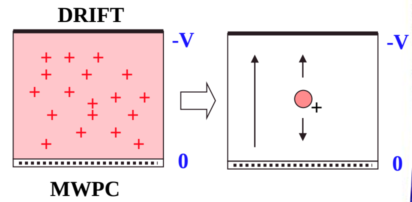
Ion feedback

A fraction of the positive ions produced in the avalanches slowly drift in the sensitive volume and modify the electric field:



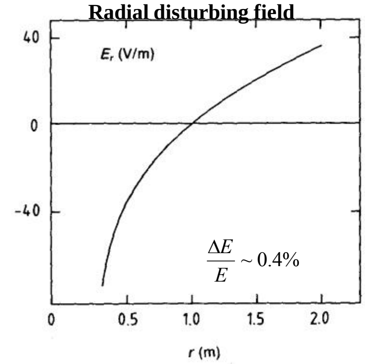
Ar-CH_4 (80-20) E=200 V/cm w^+ ~ 320 cm/s
For 1 m drift → T^+ = 300 ms

For uniform irradiation releasing R electrons per second per cubic meter, the positive ion charge density is given by:

$$\rho^+ = \frac{eRLM\varepsilon}{w^+}$$

***L*: drift length**
***M*: gain**
ε: fractional ion feedback

Radial disturbing field



EXAMPLE: ALEPH TPC
$R=2.10^6\ s^{-1}.m^{-3}$ $w^+=1.5\ m.s^{-1}$
$M=10^4$ $\varepsilon=10^{-1}$
$M.\varepsilon=10^3$: ion feedback per primary electron
$E=10^4\ V.m^{-1}$

Use of ion gate possible

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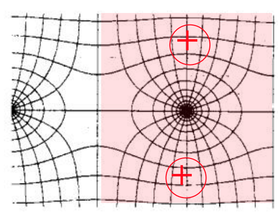
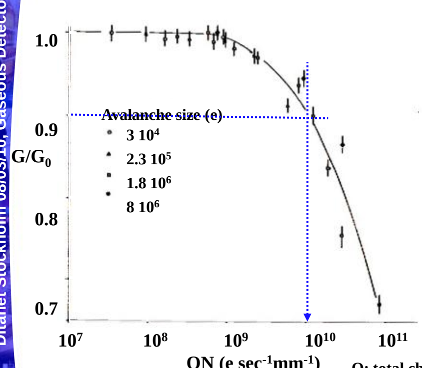
Space charge effect: gain reduction

At high rates, positive ions accumulate in the gaps and create a positive space charge with a density that depends on rates, gain and geometry.
⇒ Field and hence gain reduction
No improvement in 30 years…



DRIFT CHAMBERS (1980):



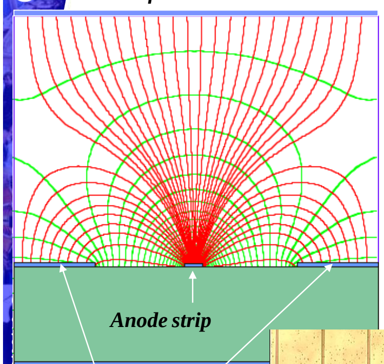
Q: total charge in single avalanche
N: particle rate / wire length

Solutions:
- Reduce the collection time of Ions
- Reduce the gaps
- Use of micropattern detectors with sub mm gaps (MPGD): MSGC, GEMs, Micromegas…

MicroStrip Gas Chambers (MSGC)

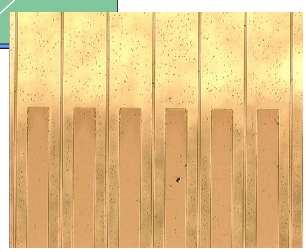
A.Oed, Nucl. Instr. and Meth. A263(1988)351

Drift Electrode



Cathode strips

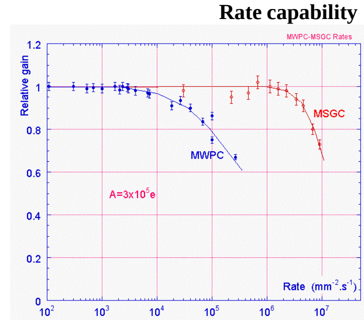
Considered by CMS experiment, but sparks and aging problem (replace by Si)



Typical MSGC:
- 10 µm anode strips
- 50 µm cathode strips
- Pitch: 200 µm
- Alminium or gold 1 µm thick on 200 µm glass

Performances:
- Very good spatial resolution (~50 µm)
- Two-tracks resolution (~500 µm)

Rate capability



MSGCs drawbacks

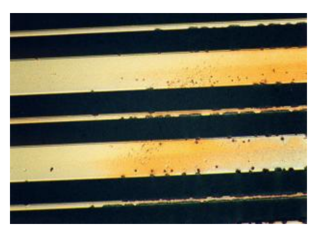
suffer from discharge problems due to:
- Imperfections (spikes, metal bridges, …)
- Field emission from the cathode strips edges
- Heavily ionizing event (neutrons conversions, nuclear fragments, …)

Neutron → ~ MeV protons → few 10^4 electrons

Gain of 10^4 (needed to detect M.I.P.)→ exceed the Raether limit

Irreversible damages

Microdischarges

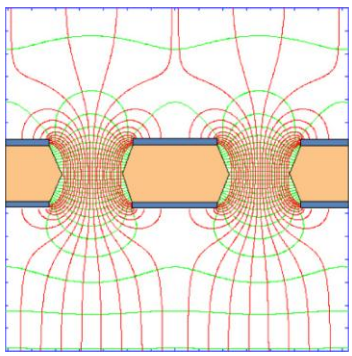


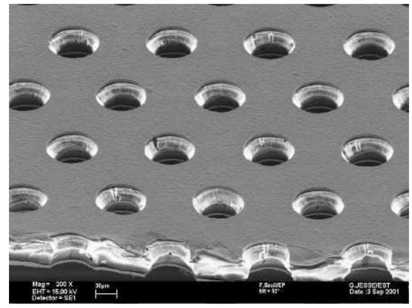
Full breakdown

Other MPGDs have been considered (Microgap or micropiwel ch., Micro Pin array…) but only **GEMs and Micromegas** have really shown great adavantages

GEM: Gas Electron Multiplier

Thin, metal-coated polymer foil with high density of holes. On application of a voltage difference, each hole acts as an individual proportional counter, multiplying the electrons entering from the drift region. The amplified electrons leave the hole; most of the ions are collected by the upper electrode:





Typical geometry:
5 μm Cu on 50 μm Kapton
70 μm holes at 140 μm pitch

5-10,000 INDEPENDENT PROPORTIONAL COUNTERS per cm^2

F. Sauli, Nucl. Instrum. Methods A386(1997)531

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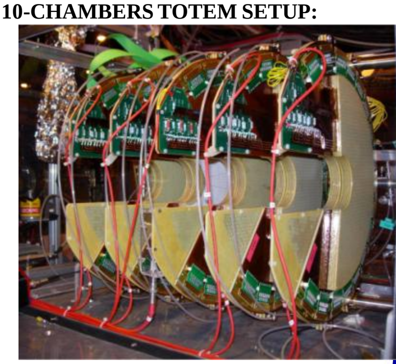
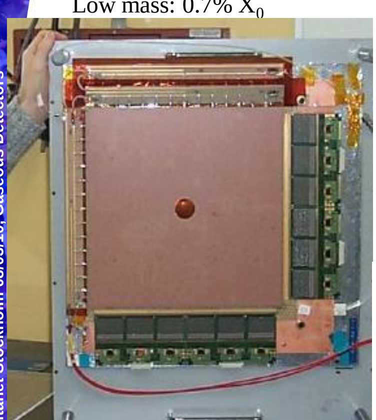
GEM size and shape

Active Area 30.7 x 30.7 cm^2
2-Dimensional Read-out with remotely controlled Beam Killer 5 cm Ø
Total Thickness: 15 mm
Honeycomb support plates
Low mass: 0.7% X_0

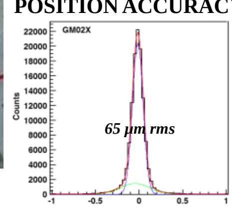
FORWARD TRACKER IN CMS
10-CHAMBERS TOTEM SETUP:

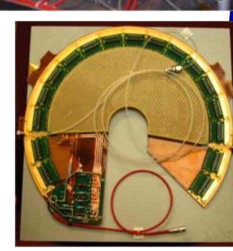




COMPASS GEM

POSITION ACCURACY

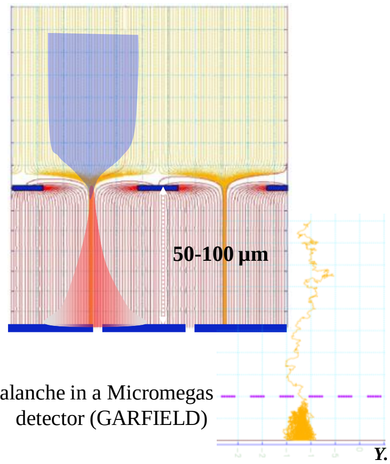




Micromegas: MICRO MEsh GAseous Structure

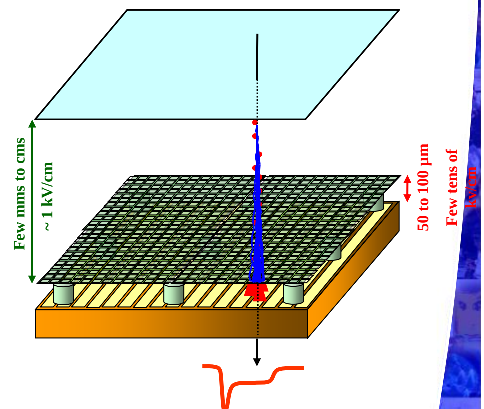
THIN GAP PARALLEL PLATE AVALANCHE CHAMBER

Use of a thin gap allows to reach large gains, overcoming the discharge problems of classic parallel plate avalanche chambers:



avalanche in a Micromegas detector (GARFIELD)

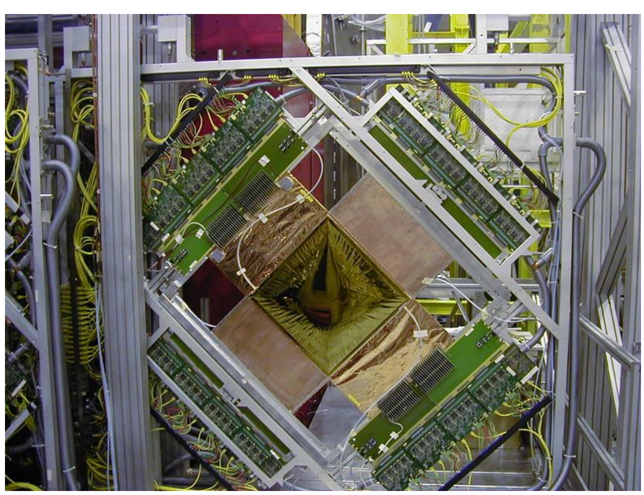
Thin cathode mesh 10-50 µm pitch, 3-10 µm thickness
Thin gap (50-100 µm)
Insulating gap-restoring wires or pillars



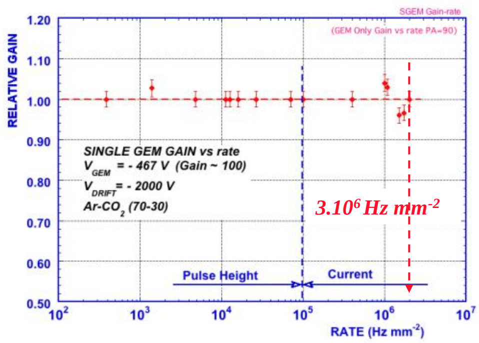
Y. Giomataris et al, Nucl. Instr. and Meth. A376(1996)29

Micromegas@compass

- **3 stations of 4 planes XYUV**
- **Active area 40×40 cm²**
- **Strips: pitch 360 µm /420 µm**
- **total 30 MHz; 450 kHz/strip**
- **0.2% X_0 rad. length/plane**
- **Spatial resolution of 65 µm**

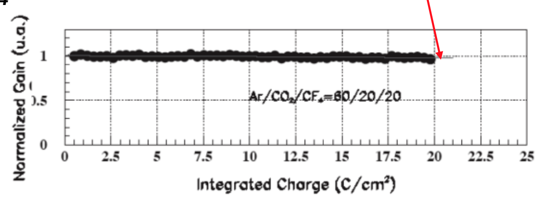


MPGD performances



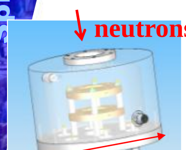
J. Benlloch et al, IEEE NS-45(1998)234

High rate capability and long-term radiation hardness



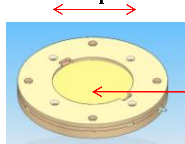
n-TOF detector: neutron beam profiler

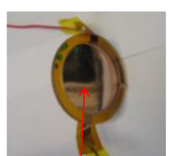
neutrons



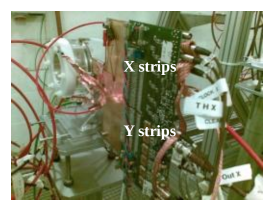
15 cm

3.5 cm beam interception



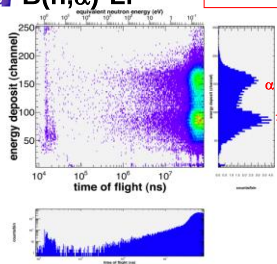


MicroBulk

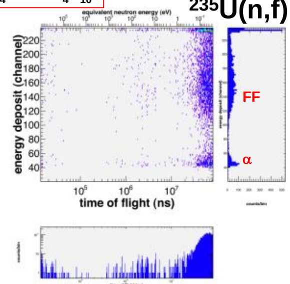


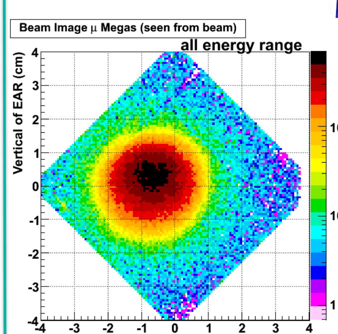
gas:
Ar + 10%CF_4 + 2%iC_4H_{10}

^{10}B(n,α)^{7}Li



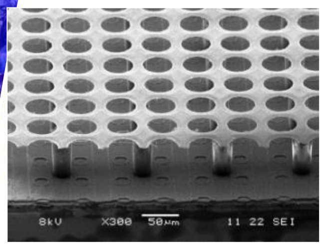
^{235}U(n,f)



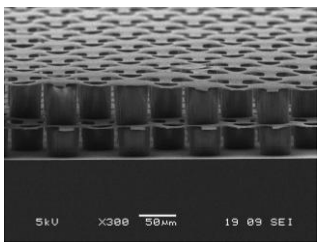


Integration of detector and electronics

SINGLE LAYER MICROMEGAS:

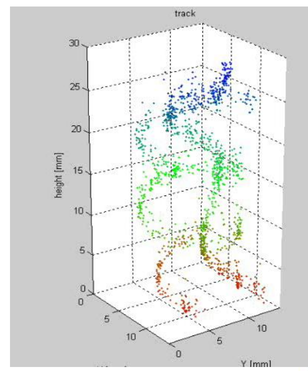


DUAL LAYER:



Using silicon foundry technology, the MPGD is built directly over the silicon pixel readout chip. The high gain-small pixel size allows single electron detection.
A high-resistivity silicon oxide layer over the chip protects against discharges.

ELECTRON TRACKS IN MAGNETIC FIELD:

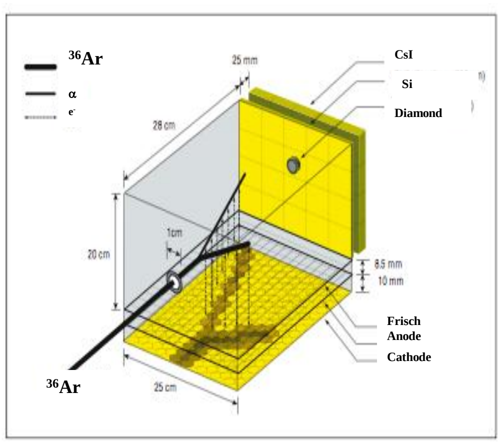


– surface: 1.4 x 1.6 cm^2
– Matrix of 256 x 256
– pixel size: 55 x 55 μm^2

H. Van der Graaf ,
IEEE Nucl. Sci. Symp. Conf. Rec. (Dresden, October 2008)

Active targets like MAYA

TPC with MWPC



To conclude…

- Gaseous detectors are widely used in particle and nuclear physics
- Great versatility: choice of gases, geometry, pressure (mbar to bars)
- Wide subject, no universal detector, need for simulations, advices from specialists and technicians
- Physics with its own R&D (international collaboration RD51 in the framework of SLHC)
- New detectors under investigation like: Th-GEM, microbulk or ingrid…

GANIL Spiral 2

Bibliography

F. Sauli: *Principles of Operation of Multiwire Proportional and Drift Chambers* (CERN 77-09, 1977)

W.R. Leo: *Techniques for Nuclear and Particle Physics Experiments* (Springer, 1987)

C. Fabjan and J. Pilcher, ed.: *Instrumentation in Elementary Particle Physics* (World Scientific, 1988)

R. Gilmore: *Single Particle Detection and Measurement* (Taylor and Francis, 1992)

F. Sauli, ed.: *Instrumentation in High Energy Physics* (World Scientific, 1992)

K. Kleinknecht: *Detectors for Particle Radiation* (Cambridge Univ. Press 1998)

G.F. Knoll: *Radiation Detection and Measurements, 3d Ed.* (Wiley, 2000)

W. Blum, W. Riegler and L. Rolandi: *Particle Detection with Drift Chambers, 2d Ed.* (Springer 2008)az

www.garfield.cern.ch (Rob Veenhof)

adapted from presentation of **F. Sauli - Gas Detectors - KEK March, 2009**

Ditanet Stockhölm 08/03/10, Gaseous Detectors