PARTICLE GAS DETECTORS

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V UNIANDES PARTICLE DETECTOR SCHOOL

TALK OUTLINE

1. Principle of operation
    - Gas amplification – Townsend coefficients
    - Operation modes
    - Penning effect
    - Gas choice
    - Gas quenchers
    - Electronegative gases
    - signal formation
    - Drift and diffusion
2. Types of detectors
    - MWPC
    - Cathode Strip chambers
    - Drift chambers
    - Time projection chambers
    - Resistive plate chambers
    - MPGDs: MSG, Micromegas, GEM
3. Conclusions

TALK BASED ON THE FOLLOWING MATERIAL:

1. PDG : Review of particle detectors of 2020:

2. Gaseous Radiation Detectors, Fundamentals and Applications, Fabio Sauli, Cambridge Univ, 2014

3. Particle Detectors, 2nd edition, Claus Grupen & Boris Scwartz, Cambridge Monographs, 2008

4. Talks Given by : Manfred Kramer, Mar Capeans, Christian Joram, CERN

FEATURES OF GAS DETECTORS

- Good spatial resolution
- Good dE/dx
- Good Rate capability
- Fast & Large Signals
- Low radiation length
- Large area coverage
- Multiple configurations/flexible geometry

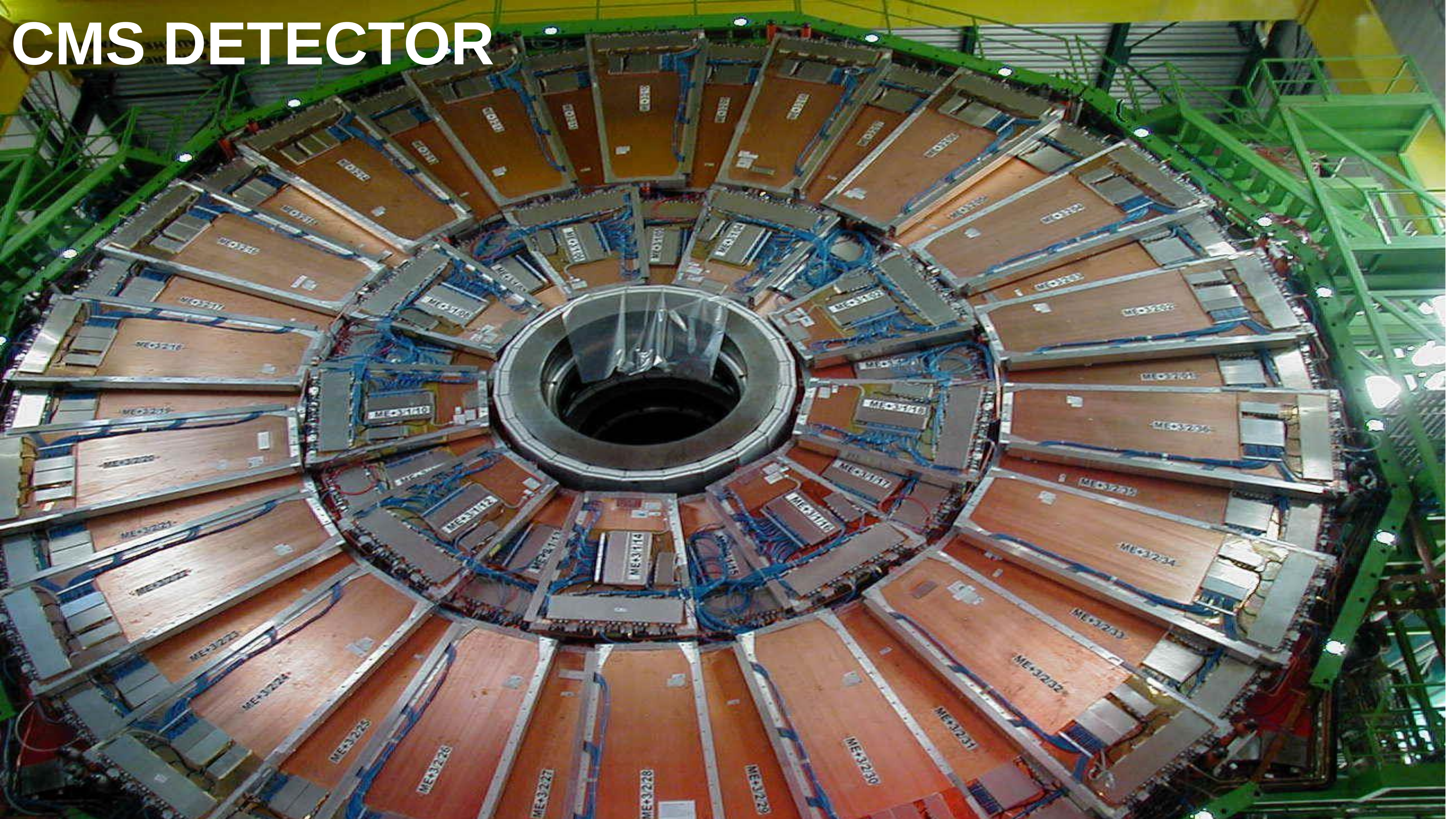
GAS DETECTORS AT THE LHC

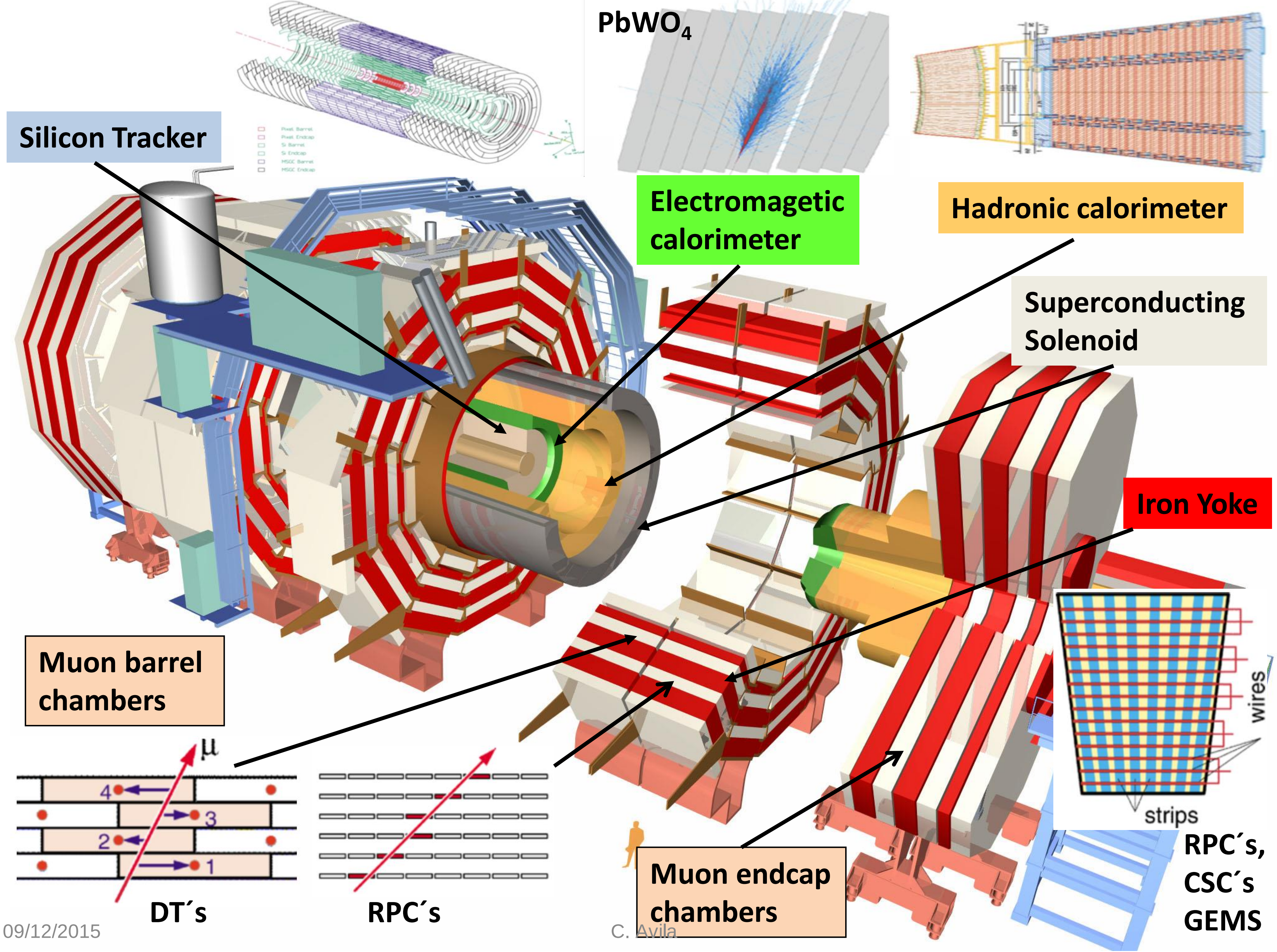
	High Accurate Trackers		Large Area muon Systems	
	Tracking	**Particle Identification**	**Tracking**	**Triggering**
ALICE	**TPC** **Straw tubes**	**RPC** **Straw tubes** **RICH Pad Chamber**	**Pad Chamber**	**RPC**
ATLAS	**Straw tubes**		**Drift tubes**	**RPC** **TGC**
CMS			**Drift tubes** **CSC, GEM**	**RPC**
LHCb	**Straw tubes**	**RICH**	**MWPC** **GEM**	
TOTEM	**CSC** **GEM**			

• Gas in LHC detectors •

Experiment	Sub- Detector	Gas Mixture
ALICE	TPC, TRD, PMD	Noble Gas + CO_2
ATLAS	CSC, MDT, TRT	
CMS	DT	
LHCb	OT straws	
TOTEM	GEM, CSC	
LHCb	MWPC, GEM	Ar – CO_2 - CF_4
CMS	CSC	
ATLAS, CMS, ALICE	RPC	$C_2H_2F_4$ - iC_4H_{10} - SF_6
ATLAS	TGC	CO_2 – n-pentane
LHCb	RICH	CF_4 or C_4F_{10}

CMS DETECTOR





$PbWO_4$

Silicon Tracker

Electromagetic calorimeter

Hadronic calorimeter

Superconducting Solenoid

Iron Yoke

Muon barrel chambers

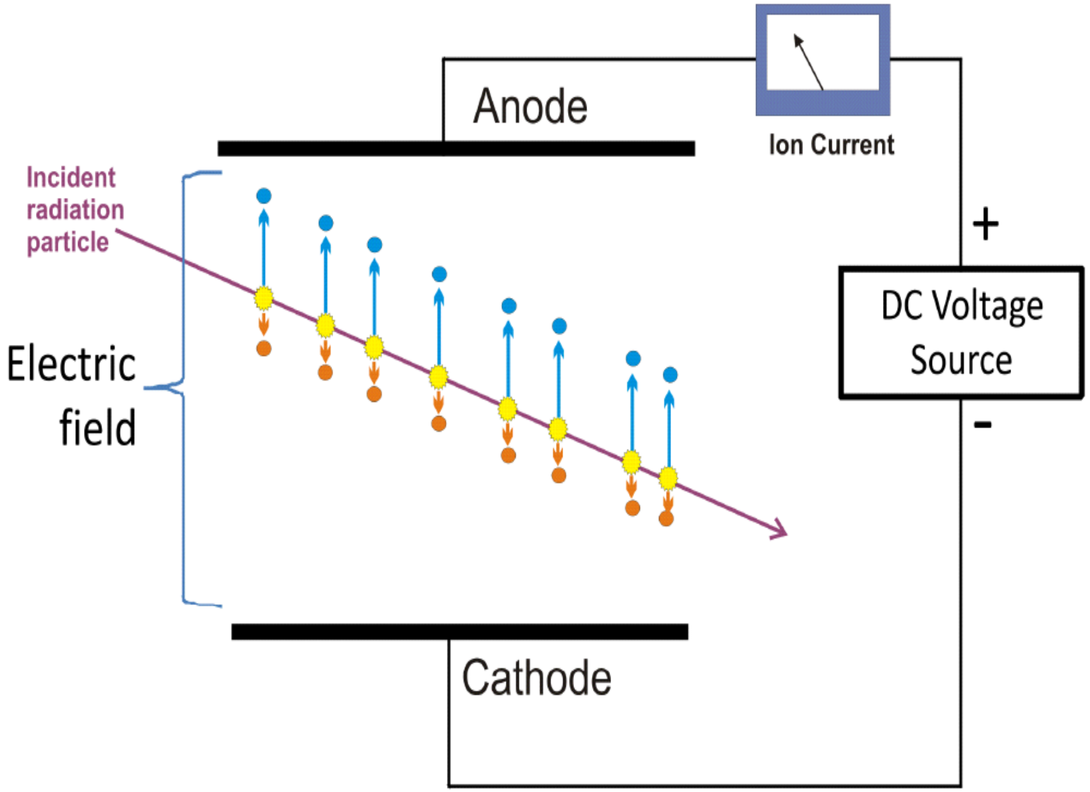
DT´s

RPC´s

Muon endcap chambers

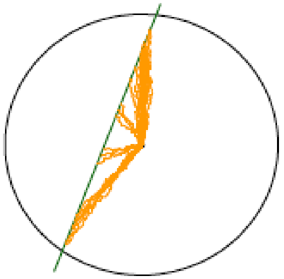
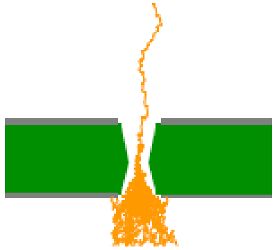
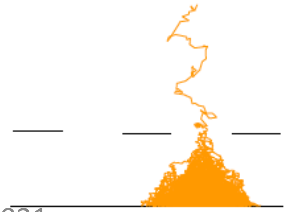
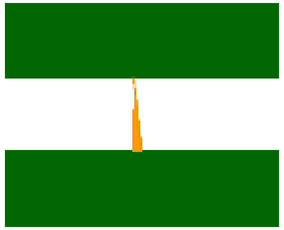
RPC´s, CSC´s GEMS

PRINCIPLE OF OPERATION



- Charged particles ionize atoms of the gas along its track.
- An electric field transports electrons and ions towards electrodes.
- Electrons are multiplied in a strong electric field: The resulting primary electrons get enough kinetic energy to ionize other atoms
- The motion of electrons and ions induces a current on the readout electrodes
- The coordinates of the incident particle are deduced from the measurement of drift time, or of the center of gravity of the collected charge.

Different Geometries posible:

Many questions to answer:

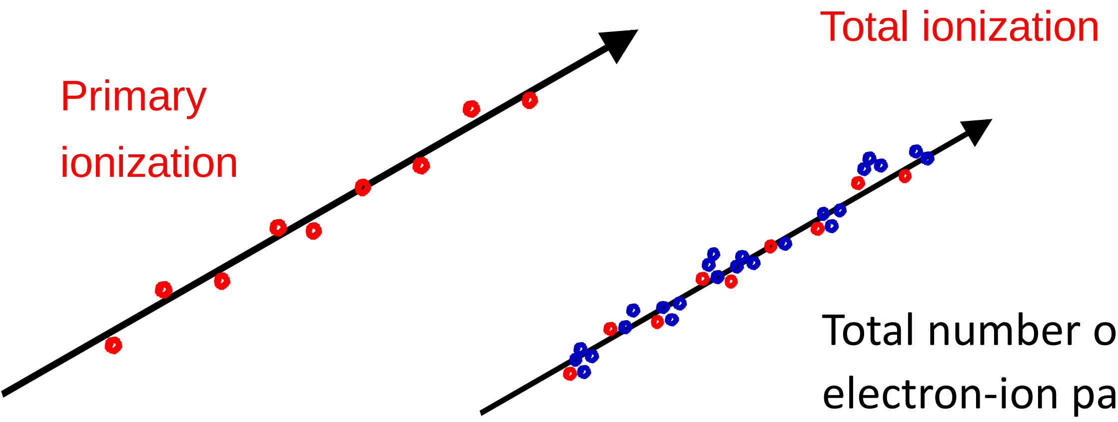
- How many electrons are produced ?
- Which energy do the electrons have?
- How far are they from the track?
- How fast are the electrons?
- Will electrons move in a straight line?
- Are they absorbed?
- Do they produce showers?
- How the electric field affects operation?
- ….

INTERACTION OF CHARGED PARTICLES WITH THE GAS

Any charged particle traversing a gas will loose energy due to interactions with the atoms of the gas. This results in:

- **Excitation**, the particle passes a specific amount of energy to a gas atom
- **Ionization**, the particle knocks an electron off the gas atom, and leaves a positively charged ion

Resulting primary e- will have enough kinetic energy to ionize other atoms of gas. The sum is called Total Ionization



Primary ionization

Total ionization

$$X + part. \rightarrow X^{+} + \text{part.} + e^{-}$$

$$X + e^{-} \rightarrow X^{+} + e^{-} + e^{-}$$

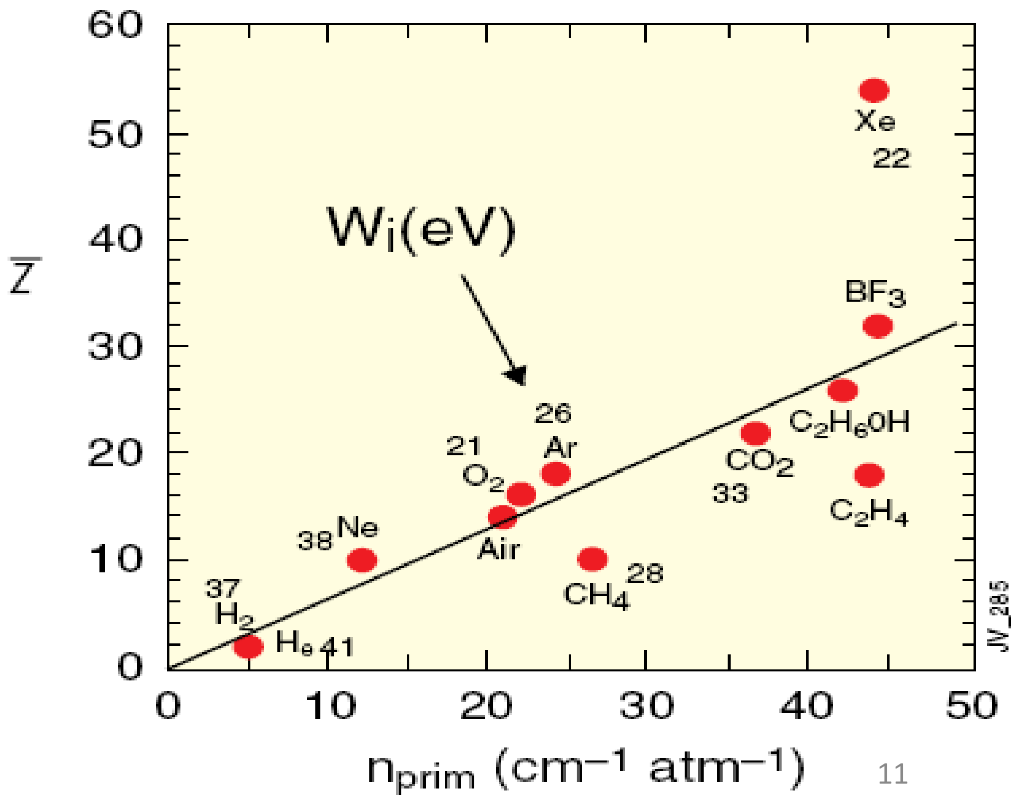
Total number of created electron-ion pairs:

$$n_{total} = \frac{\Delta E}{W_i} = \frac{\frac{dE}{dx}\Delta x}{W_i}$$

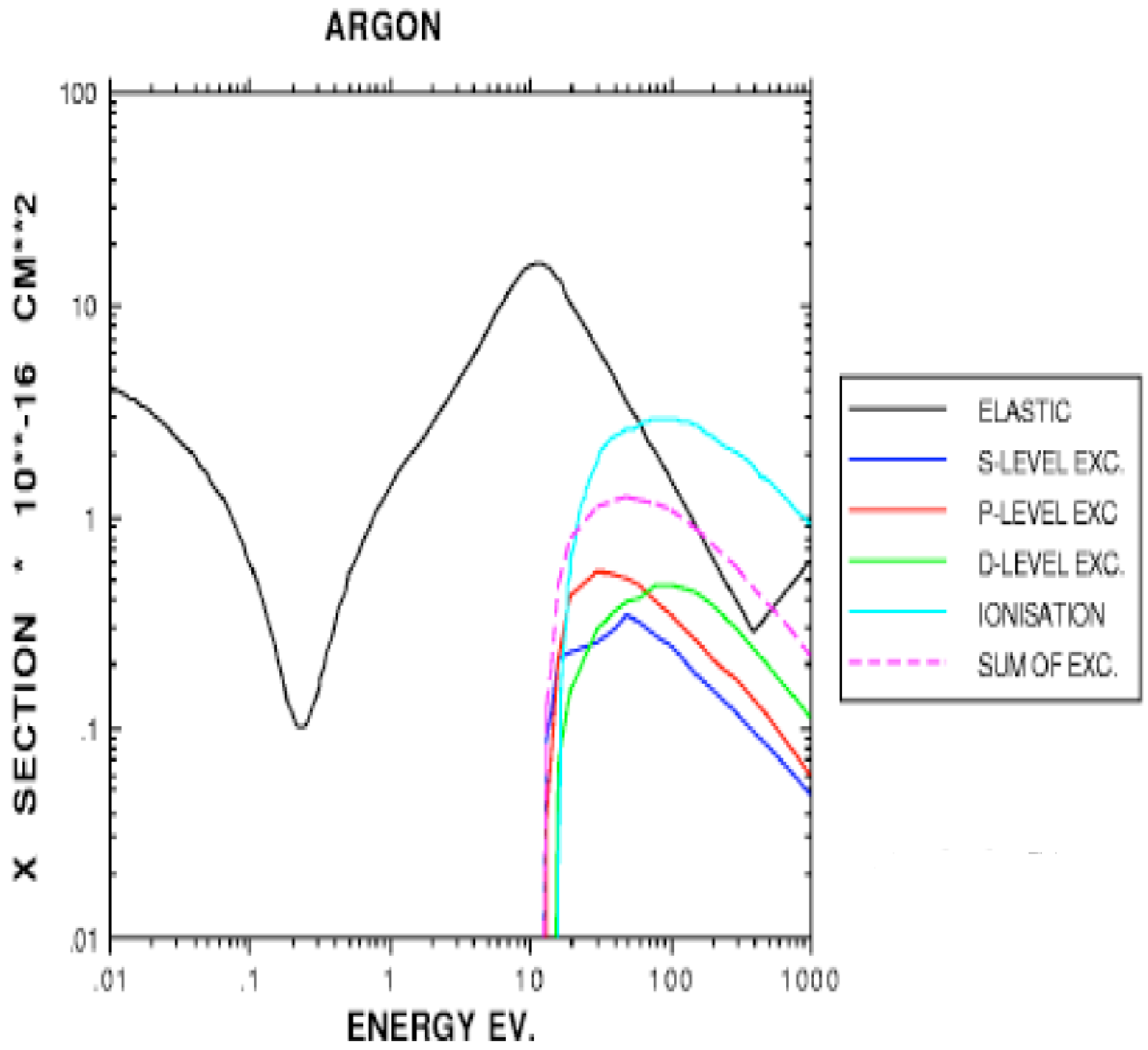
$$n_{total} \approx 3 \ldots 4 \cdot n_{primary}$$

ΔE = total energy loss

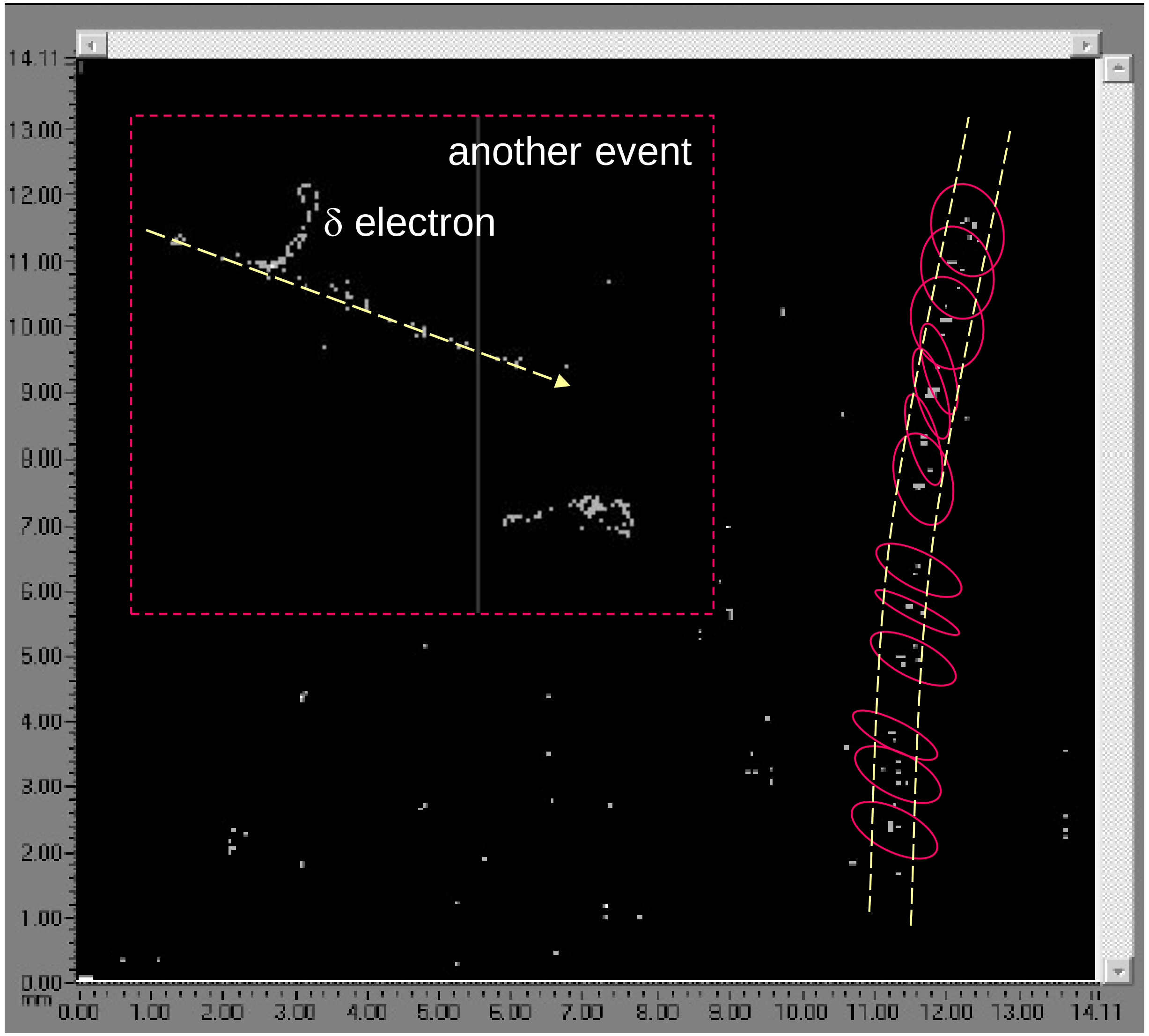
W_i = effective <energy loss>/pair



Energy dissipation mainly due to ionization

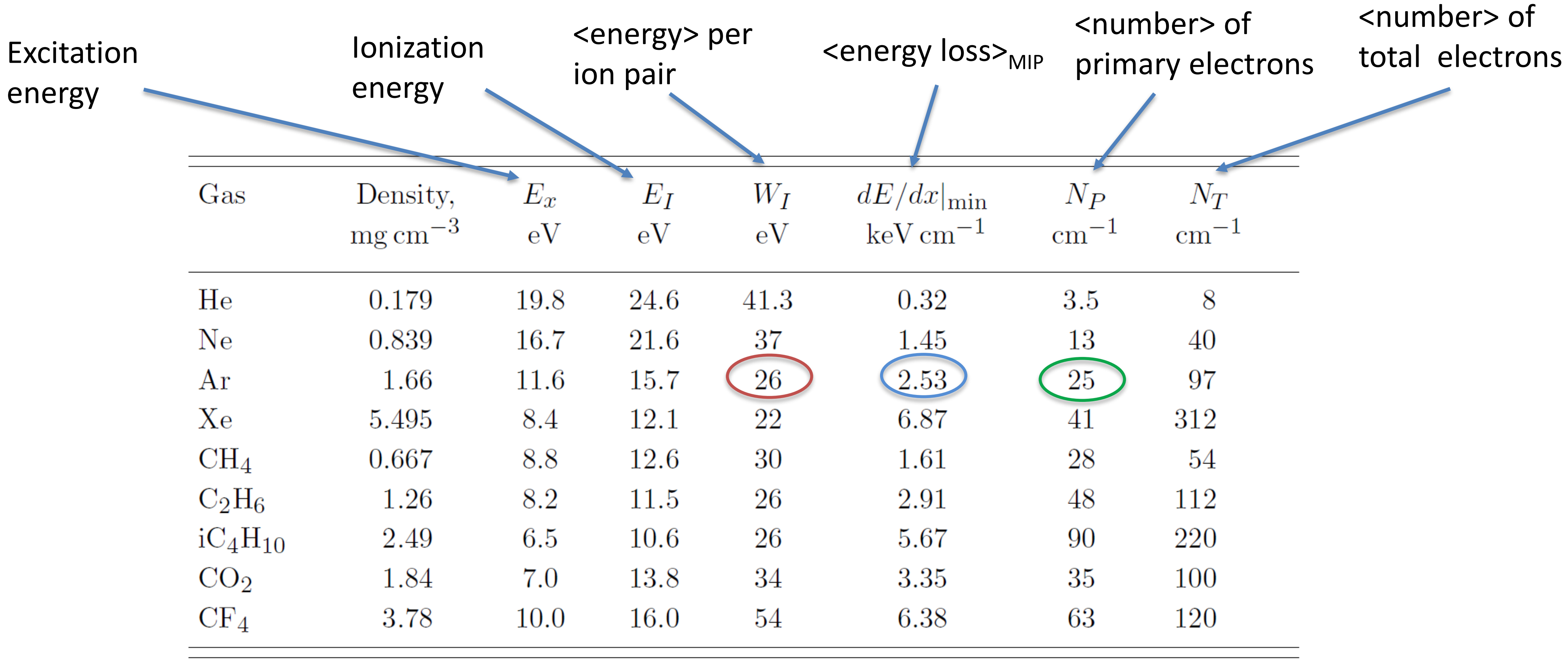


Delta rays



track by cosmic particle (mip): 0.52 clusters / mm, ~3 e$^-$/cluster

Energy Loss of Charged Particles in Gases



Excitation energy

Ionization energy

<energy> per ion pair

<energy loss>$_{MIP}$

<number> of primary electrons

<number> of total electrons

Gas	Density, mg cm^{-3}	E_x eV	E_I eV	W_I eV	$dE/dx\|_{min}$ keV cm^{-1}	N_P cm^{-1}	N_T cm^{-1}
He	0.179	19.8	24.6	41.3	0.32	3.5	8
Ne	0.839	16.7	21.6	37	1.45	13	40
Ar	1.66	11.6	15.7	26	2.53	25	97
Xe	5.495	8.4	12.1	22	6.87	41	312
CH_4	0.667	8.8	12.6	30	1.61	28	54
C_2H_6	1.26	8.2	11.5	26	2.91	48	112
iC_4H_{10}	2.49	6.5	10.6	26	5.67	90	220
CO_2	1.84	7.0	13.8	34	3.35	35	100
CF_4	3.78	10.0	16.0	54	6.38	63	120

N_P = 25 electron-ion pairs/cm

$n_T = \Delta E/W_i$ = 2.5 keV/cm / 26 eV ~ 100 ion pairs/cm

$n_T / n_P \sim 4$

PRIMARY ELECTRONS

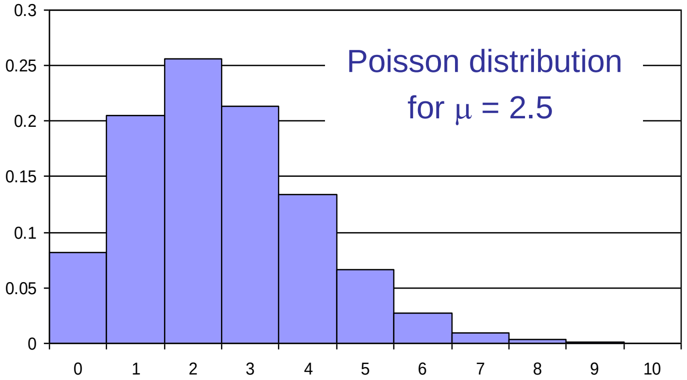
- The actual number of primary electron/ion pairs is Poisson distributed.

$$P(n) = \frac{\mu^n e^{-\mu}}{n!} \qquad \mu=\langle n\rangle=L/\lambda \qquad \lambda = \frac{1}{n_e \sigma_I}$$

n = # primary electrons
L = thickness
λ = mean free path
n_e =electron density
σ_I =Ionization x-section

The detection efficiency is therefore limited to :

$$\varepsilon_{\det} = 1 - P(0) = 1 - e^{-\mu}$$



For thin layers ε_{det} can be significantly lower than 1.

For example for 1 mm layer of Ar $n_{primary} = 2.5 \rightarrow \varepsilon_{det} = 0.92$.

Consider a 10 mm thick Ar layer

→ $n_{primary} = 25 \rightarrow \varepsilon_{det} = 1$

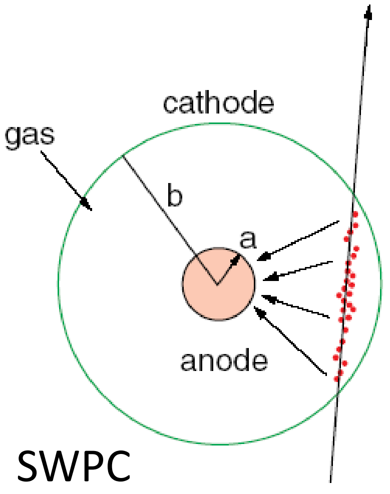
→ n_{total}= 80-100

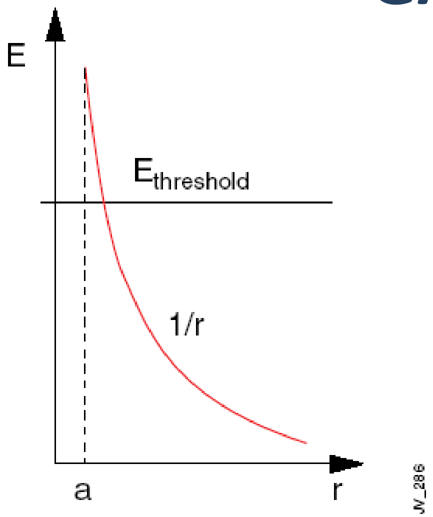
100 electron/ion pairs created during ionization process are not easy to detect.

Typical noise of the amplifier ≈ 1000 e^-

→ The number of charge carriers have to be increased by gas amplification .

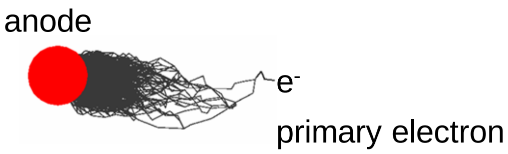
GAS AMPLIFICATION





Electrons liberated by ionization drift towards the anode wire.

Electrical field close to the wire (typical wire Ø~few tens of μm) is sufficiently high for electrons (above 10 kV/cm) to gain enough energy to ionize further → avalanche – exponential increase of number of electron ion pairs.

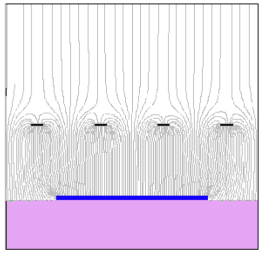


$$E(r) = \frac{CV_0}{2\pi\varepsilon_0} \cdot \frac{1}{r}$$

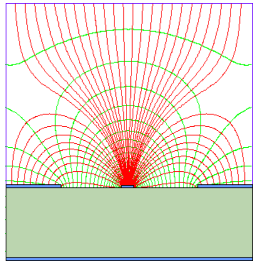
$$V(r) = \frac{CV_0}{2\pi\varepsilon_0} \cdot \ln\frac{r}{a}$$

C – capacitance/unit length

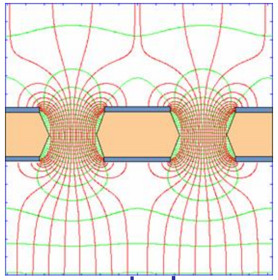
Cylindrical geometry is not the only one able to generate strong electric field:



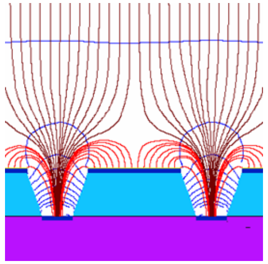
parallel plate



strip



hole



groove

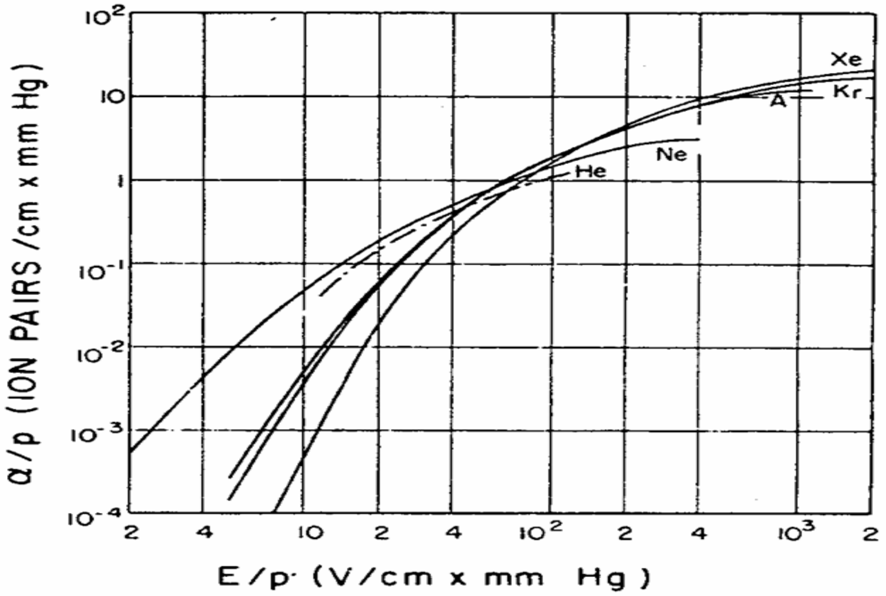
GAS AMPLIFICATION

Multiplication of ionization is described by the first Townsend coefficient $\alpha(E)$

$$dn = n \cdot \alpha \, dx$$

$$\alpha = \frac{1}{\lambda}$$ λ – mean free path

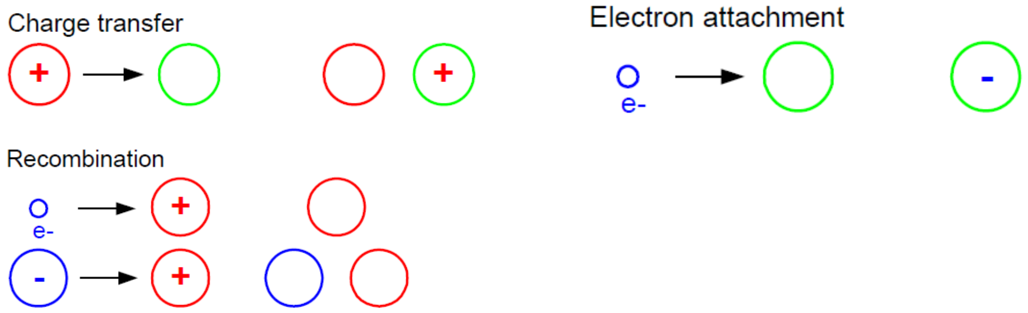
$$n = n_0 e^{\alpha(E)x} \quad \text{or} \quad n = n_0 e^{\alpha(r)x}$$



S.C. Brown, Basic data of plasma physics (MIT Press, 1959)

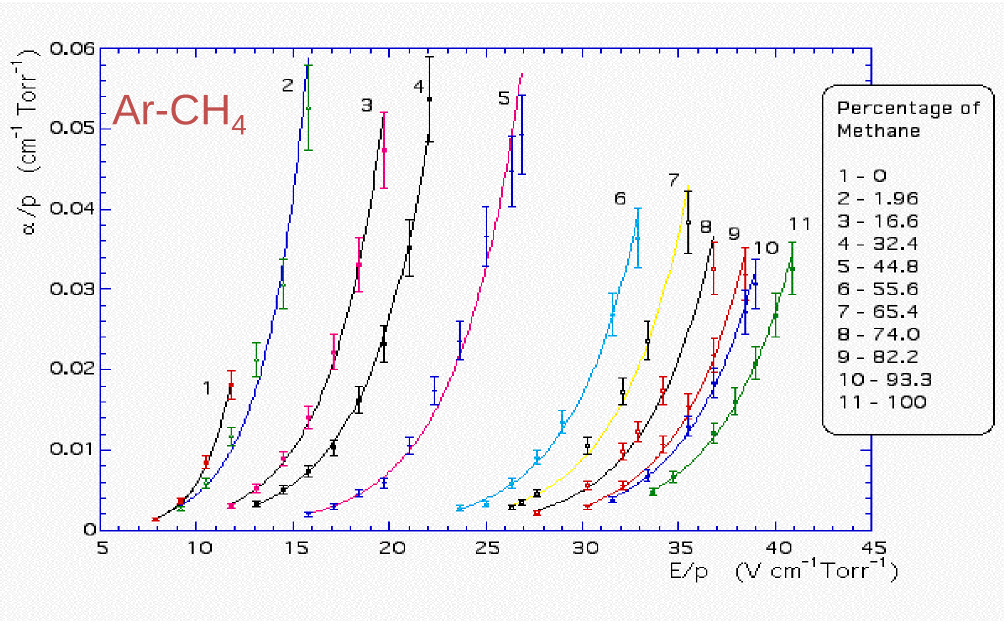
$\alpha(E)$ is determined by the excitation and ionization cross sections of the electrons in the gas.

It depends also on various and complex energy transfer mechanisms between gas molecules:



There is no fundamental expression for $\alpha(E)$ → it has to be measured for every gas mixture.

$$M = \frac{n}{n_0} = \exp\left[\int_a^{r_C} \alpha(r)\,dr\right]$$ Amplification factor or Gain



A. Sharma and F. Sauli, NIM A334(1993)420

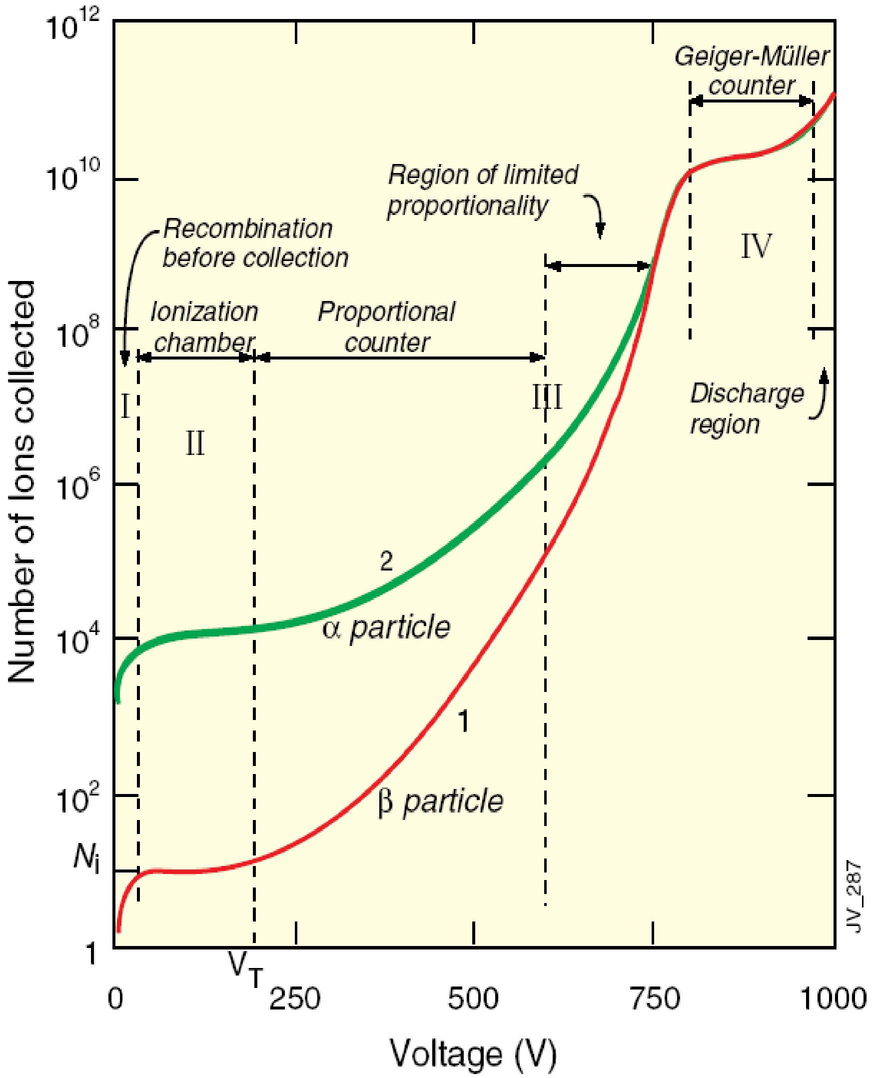
SECOND TOWSEND COEFFICIENT

- Following ionization, atoms may be in an excited state and subsequently emit photons, via the photoelectric effect additional electrons are produced.
- Probability of an electron to produce a photoelectron is called the second Townsend coefficient γ .
- In the first generation the primary e^- are amplified to N_0M and produce γN_0M photoelectrons, these are amplified in the second generation to $(\gamma N_0 M)\cdot M = \gamma N_0 M^2$ e^- and create $\gamma \cdot (\gamma N_0 M^2)$ photoelectrons, etc.

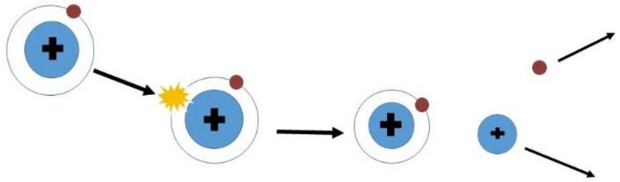
$$N(x) = N_0 M + N_0 M^2 \gamma + N_0 M^3 \gamma^2 + \ldots = N_0 A \sum_{k=0}^{\infty} (M\gamma)^k = \frac{N_0 M}{1 - \gamma M}$$

OPERATION MODES

- ionization mode – full charge collection, but no charge multiplication; gain ~ 1
- proportional mode – multiplication of ionization starts; detected signal proportional to original ionization → possible energy measurement (dE/dx); secondary avalanches have to be quenched; gain ~ $10^4 – 10^5$
- limited proportional mode (saturated, streamer) – strong photoemission; secondary avalanches merging with original avalanche; requires pulsed HV; large signals → simple electronics; gain ~ 10^{10}
- Geiger mode – massive photoemission; full length of the anode wire affected; discharge stopped by HV cut;



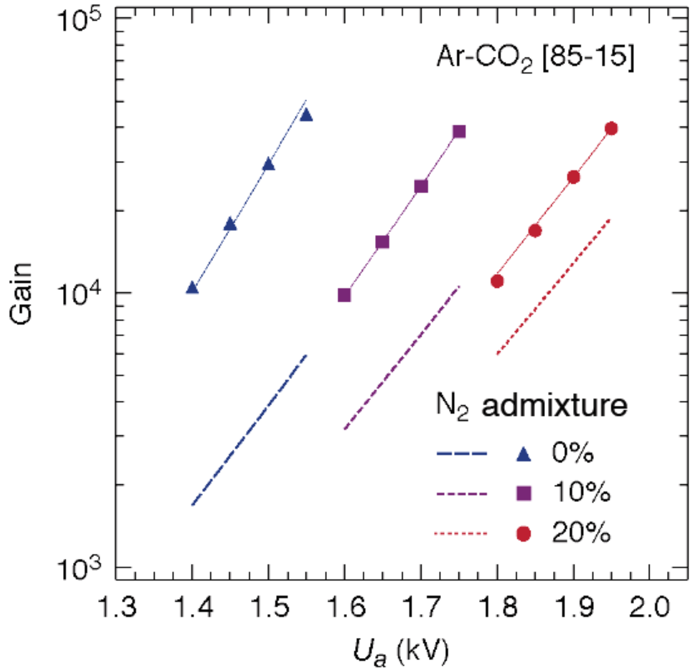
PENNING EFFECT



- The Penning effect occurs in gas mixtures, in which a metastable excited state of one gas component is energetically higher than the ionization energy of the second gas component. The excited gas atoms/molecules ionize the second gas through collisions. → increase of the number of electron ion pairs.

- Penning gas mixtures consist typically of a noble gas (in most cases Ar) and a low concentration admixture of a molecular gas.

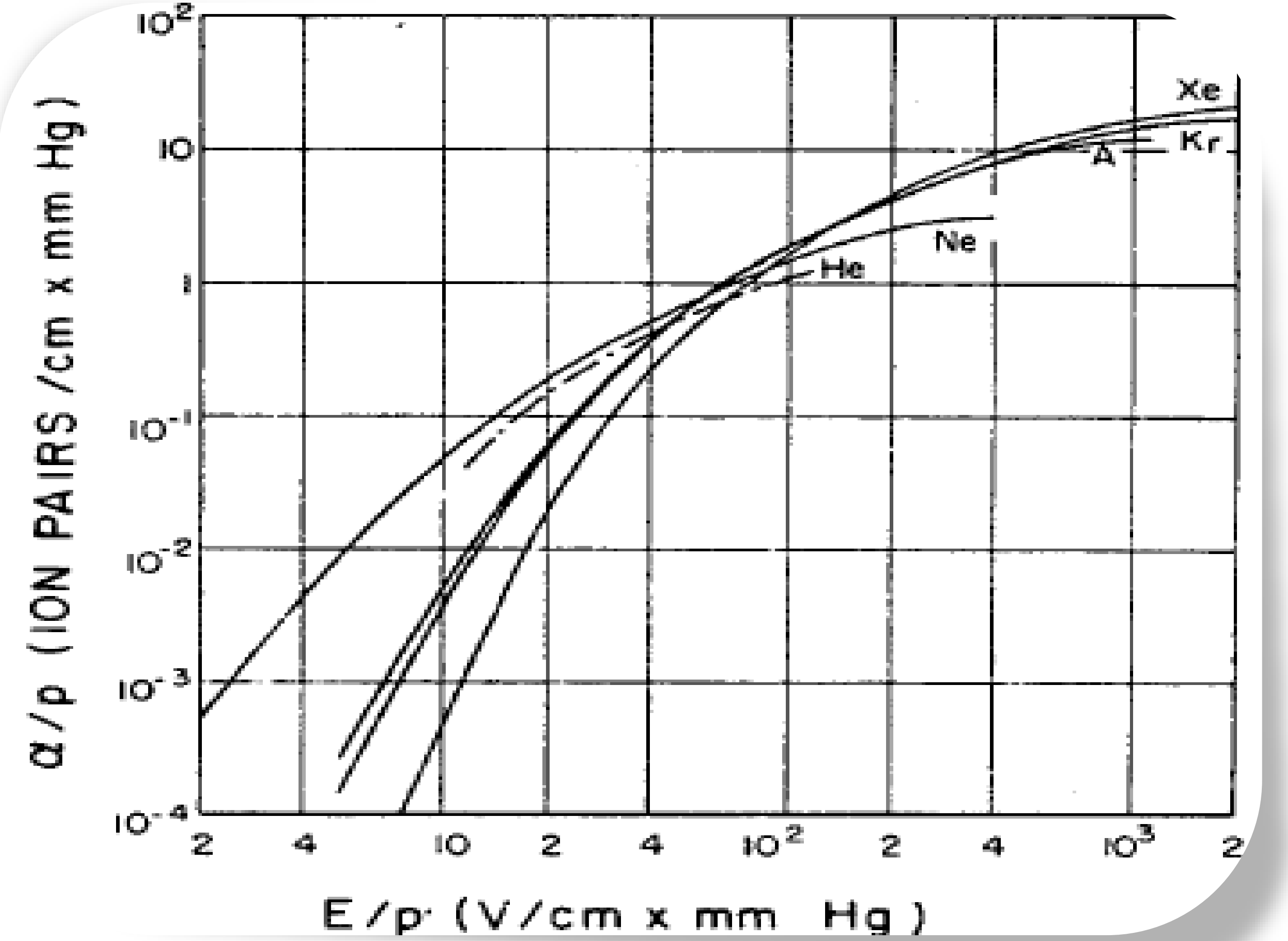
Amplification in a mixture of Ar (85%) and CO2 (15%) with different admixtures of N2:

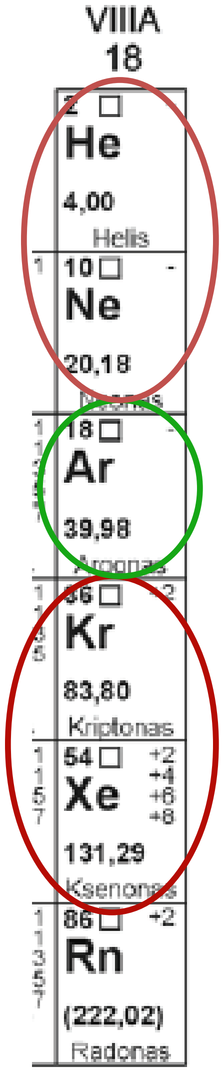


Penning effect:
$Ar^* + CO_2 \rightarrow Ar + CO_2 + e^-$

Points: measurements
Dashed lines: simulation without Penning effect
Continuous lines: simulation with Penning effect

GAS CHOICE – NOBLE GASES





Light

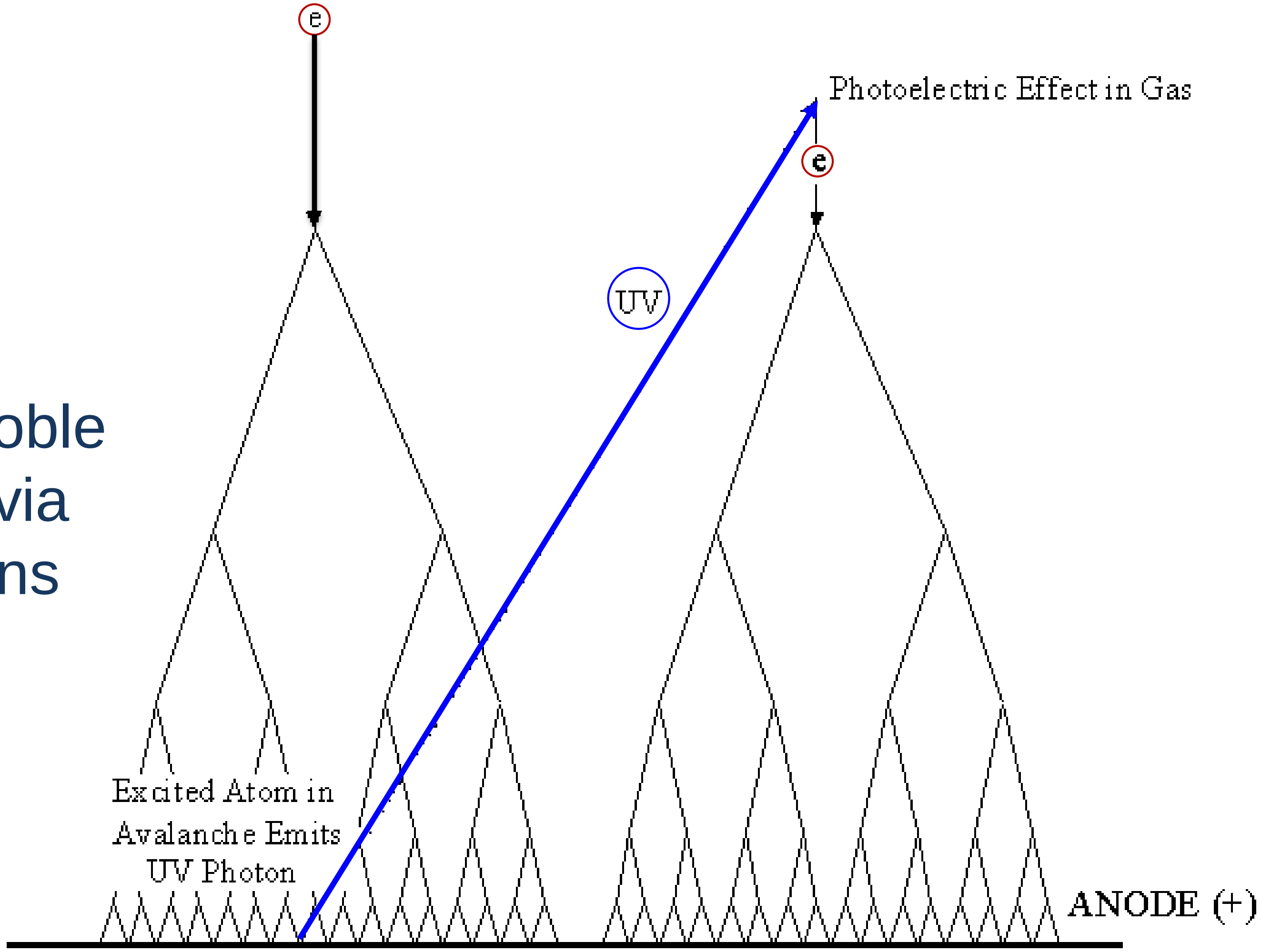
Abundant
Inert
Cheap

Expensive

Noble gases require the lowest electric field for formation of avalanche

DE-EXCITATION IN NOBLE GASES

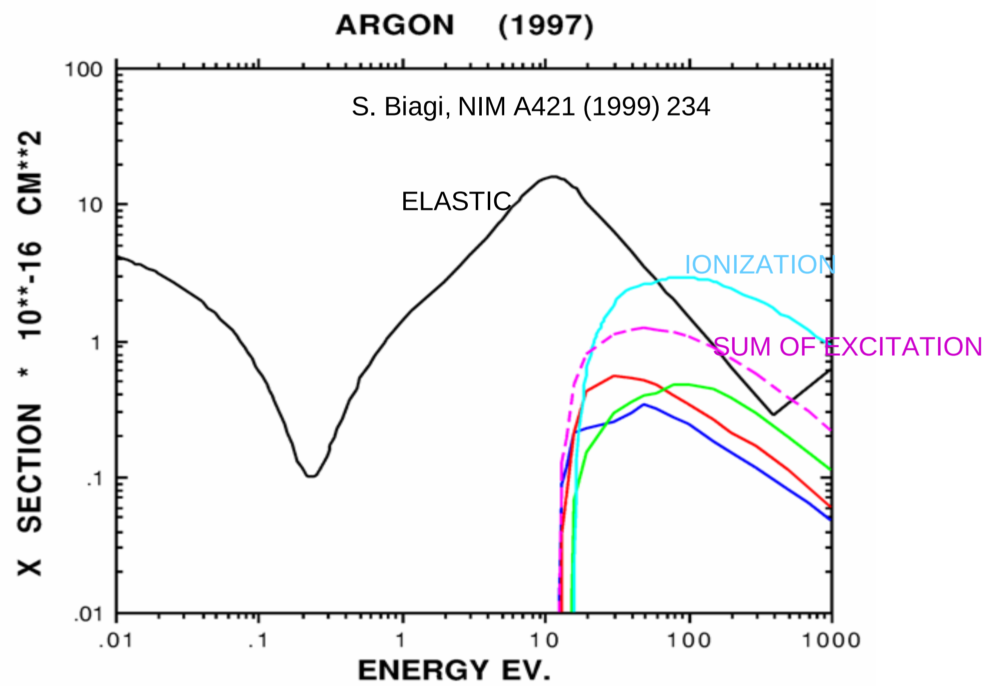
De-excitation of noble gases occur only via emission of photons



Primary avalanche **Secondary avalanche**

GAS CHOICE

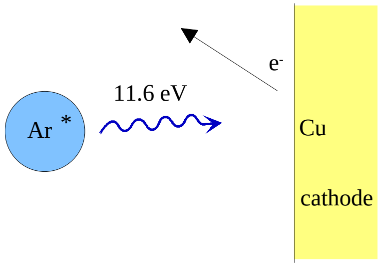
In noble gases, ionization is the dominant process, but there are also excited states.



De-excitation of noble gases only via emission of photons; e.g. 11.6 eV for Ar.

This is above ionization threshold of metals, e.g. Cu 7.7 eV.

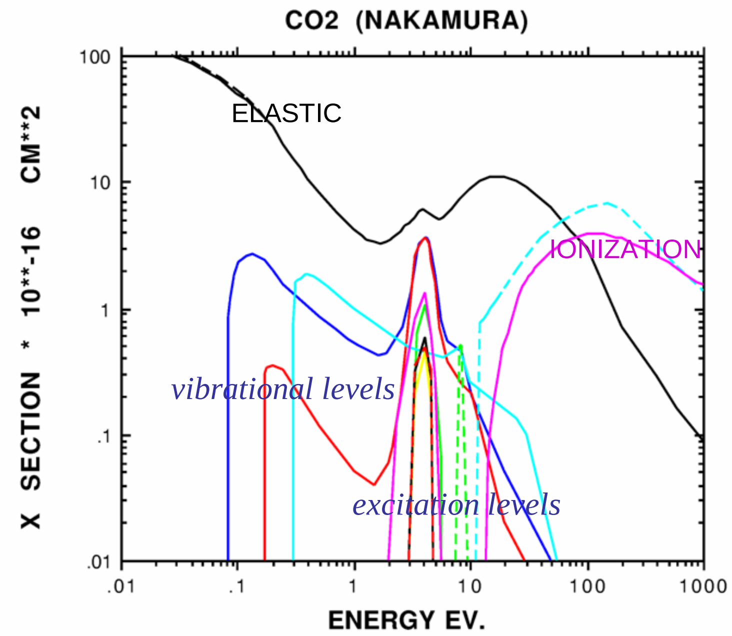
→ new avalanches → permanent discharges !



Solution: addition of polyatomic gas as a quencher

Absorption of photons in a large energy range (many vibrational and rotational energy levels).

Energy dissipation by collisions with gas molecules or dissociation into smaller molecules.

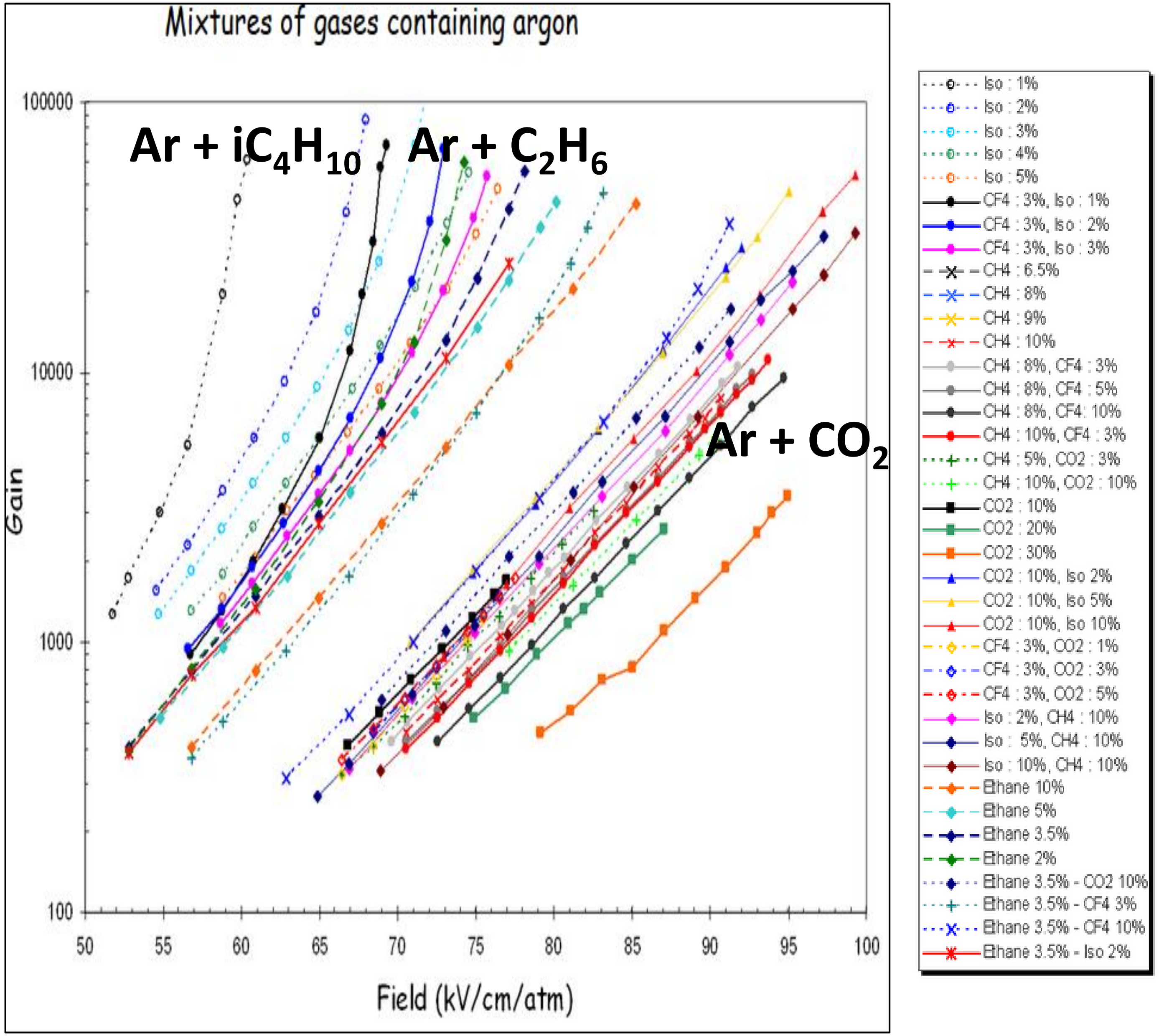


QUENCHER GASES

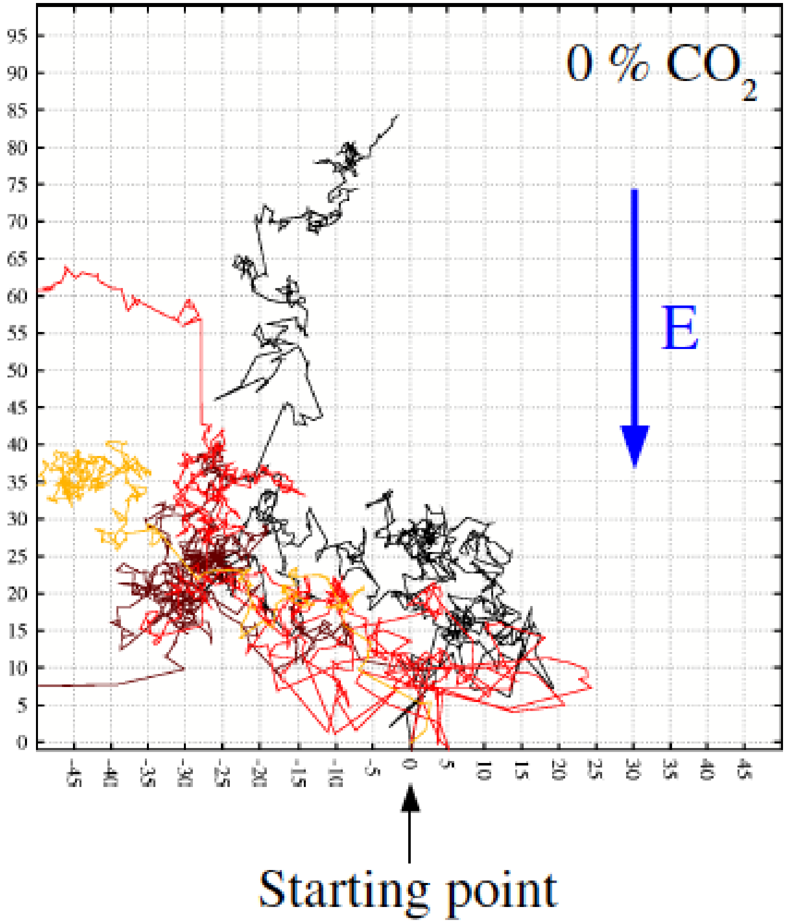
A polyatomic gas acts as a QUENCHER, i.e., absorbs photons in a large energy range due to the large amount of non-radiative excited states (rotational and vibrational)

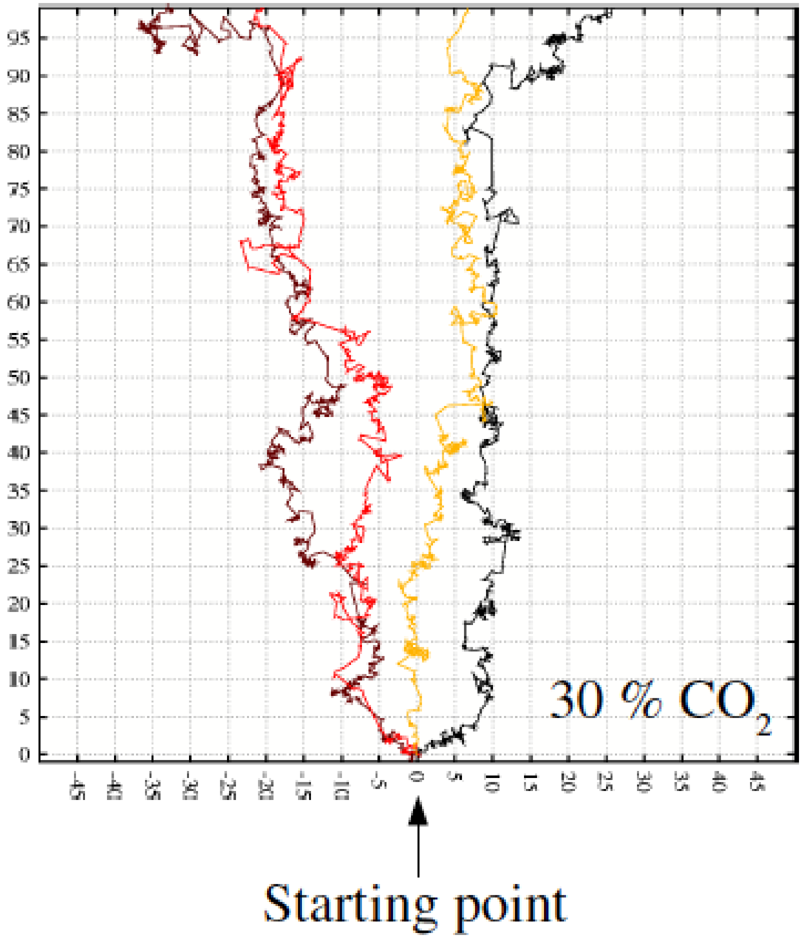
- Most organic compounds in the HC and -OH families. The quenching efficiency increases with the # of atoms in the molecule
- Freons, BF_3
- CO_2: non flammable, non polymerizing, easily available

QUENCHING = Process that decreases the probability of secondary discharges



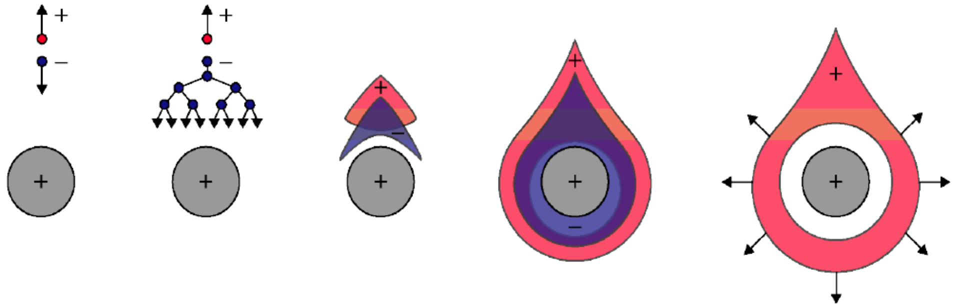
ELECTRONS IN ARGON at 1 kV/cm

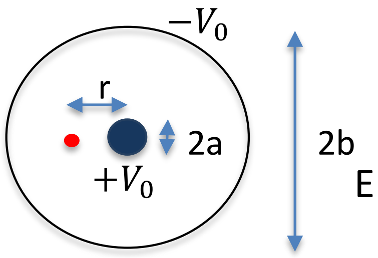




SIGNAL FORMATION

- Electron avalanche occurs very close to the wire, with first multiplication occurring ~2x the wire radius.
- Electrons move to the wire surface very quickly (<<1ns), but the ions drift to the tube wall more slowly (~100 μs).
- Total charge induced by the electrons amount to only ~1-2 % of the total charge.





Cylinder of lenth ℓ

Electric field: $E(r) = \frac{CV_0}{2\pi\varepsilon_0 r}$

Electric potencial: $\phi(r) = -\frac{CV_0}{2\pi\varepsilon_0} ln\left(\frac{r}{a}\right)$

Capacitance/length: $C = \frac{2\pi\varepsilon_0}{\ln\left(\frac{b}{a}\right)}$

Change in kinetic energy for a charge q: $dW = \vec{F}\cdot d\vec{r} = -q\frac{d\phi}{dr}dr$

Electrostatic energy: U= $\frac{1}{2}\ell C V^2$ ⇨ $dW = -dU = -\ell C V_0 \mathrm{dV}$

⇨ $q\frac{d\phi}{dr}dr = \ell C V_0 \mathrm{dV}$ ⇨ $dV = \frac{q}{\ell C V_0}\frac{d\phi}{dr}dr$

Total induced voltage for electrons (r' = position where avalanche starts):

$$V^- = -\frac{q}{\ell C V_0}\int_{a+r'}^{a}\frac{d\phi}{dr}dr = -\frac{q}{\ell C V_0}\left\{\frac{CV_0}{2\pi\varepsilon_0} ln\left(\frac{a+r'}{a}\right)\right\}$$

Total induced voltage for ions:

$$V^+ = \frac{q}{\ell C V_0}\int_{a+r'}^{b}\frac{d\phi}{dr}dr = -\frac{q}{\ell C V_0}\left\{\frac{CV_0}{2\pi\varepsilon_0} ln\left(\frac{b}{a+r'}\right)\right\}$$

$$\frac{V^-}{V^+} = \frac{ln\left(\frac{a+r'}{a}\right)}{ln\left(\frac{b}{a+r'}\right)}$$

If we use typical values:
a =10 μm, b = 10 mm, r' = 1 μm

⇨ $\frac{V^-}{V^+} \approx 1.4\%$

Signal is mainly due to ions

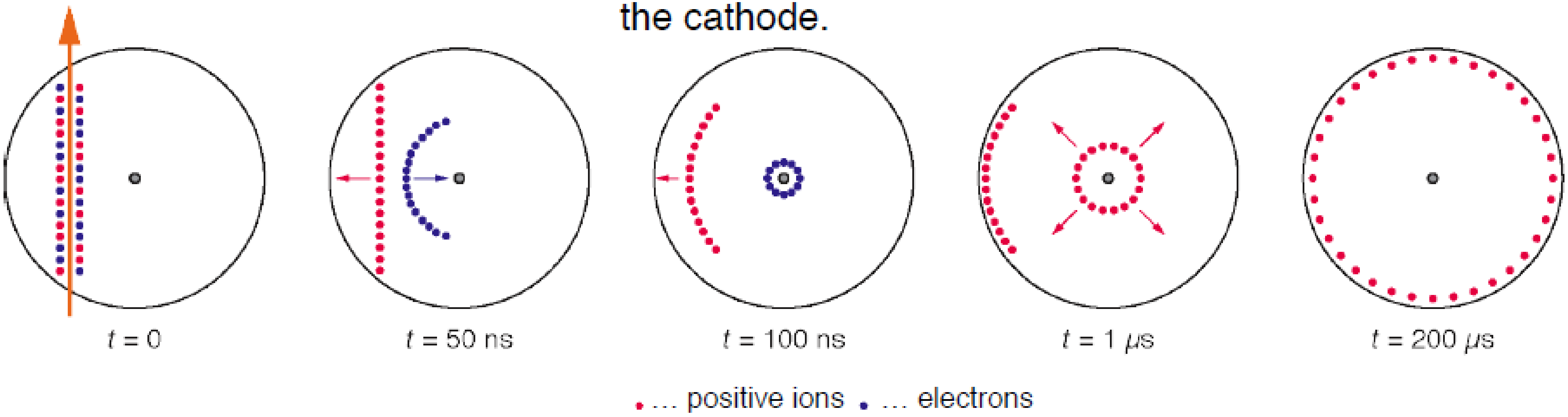
Charged particle produces primary ionization along the track.

Primary e^- drift quickly to the anode wire. Ions drift much slower to the cathode cylinder.

The primary e^- reach the region of high field and produce secondary ionization → charge carrier avalanche around the wire. The primary ions continue to drift to the cathode.

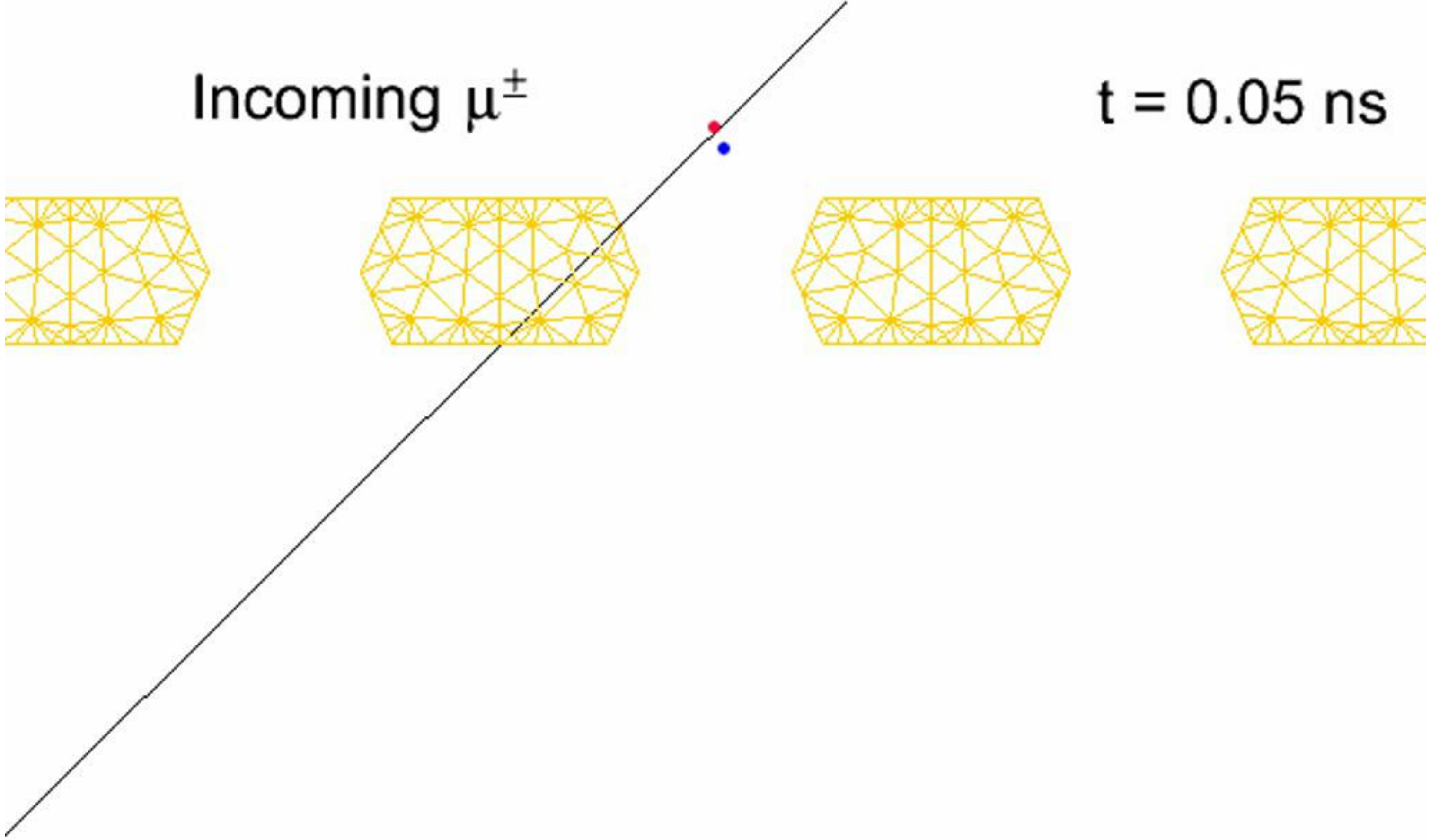
The ions produced in the secondary ionization drift also to the cathode. The secondary e^- are generated close to the anode.

Finally also the secondary ions reach the cathode.



$t = 0$ $t = 50$ ns $t = 100$ ns $t = 1$ μs $t = 200$ μs

The induced signal is by far dominated by the movement of the ions!

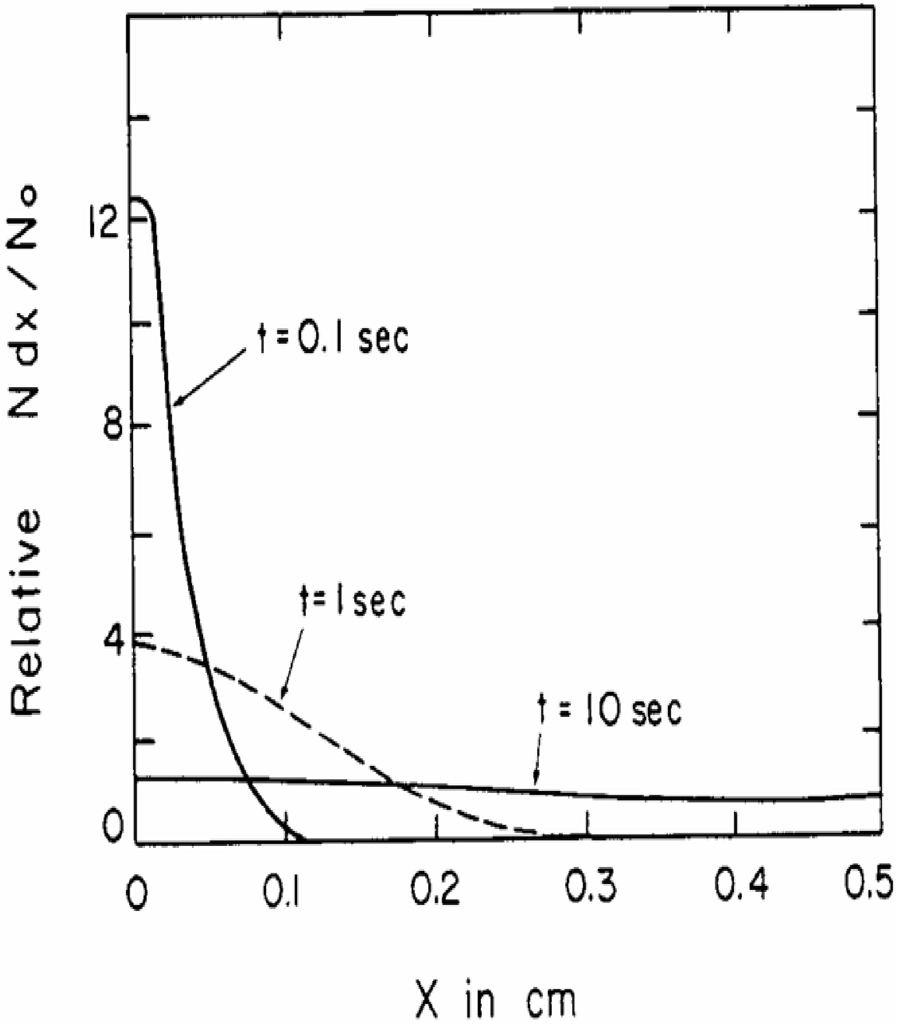

Incoming μ±
t = 0.05 ns

CHARGE CARRIER DISTRIBUTION

The charge carrier distribution follows a Gaussian distribution:

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

N= number of free charged carrier
x = distance from point of creatio
t= time after creation;
D = Diffusion coefficient



The width (rms) of the distribution (linear diffusion):

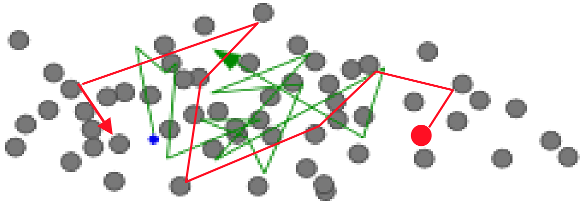
$$\sigma_x = \sqrt{2Dt}$$

For volume diffusion (spherical dispersion):

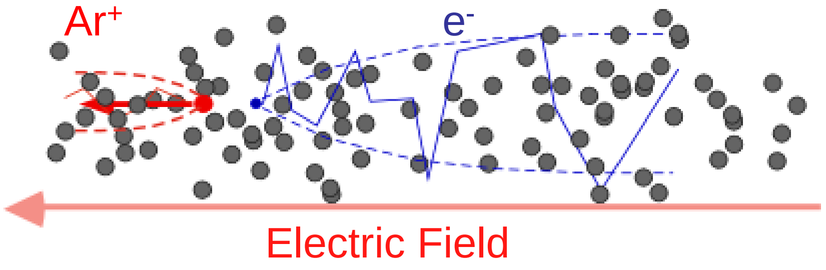
$$\sigma_{\mathrm{vol}} = \sqrt{3}\sigma_x = \sqrt{6Dt}$$

DRIFT AND DIFUSSION IN THE PRESENCE OF E FIELD

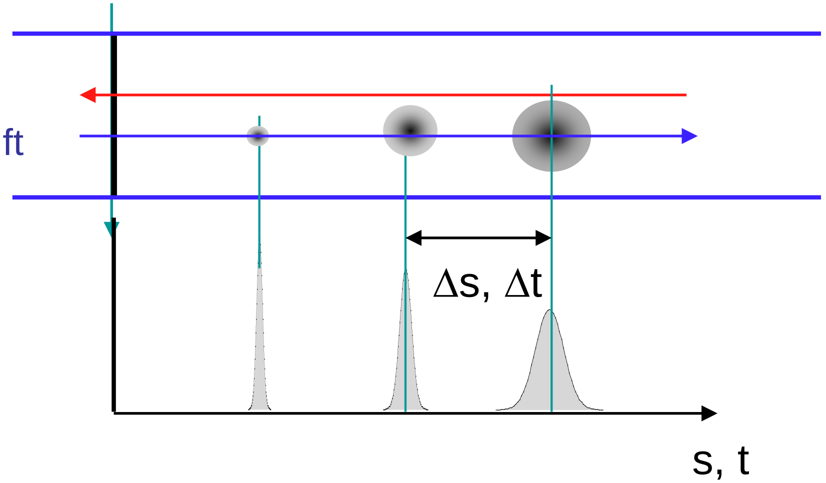
E=0 thermal diffusion $\langle v \rangle_t = 0$



E>0 charge transport and diffusion $\langle v \rangle_t = v_D$



Electron cloud drift

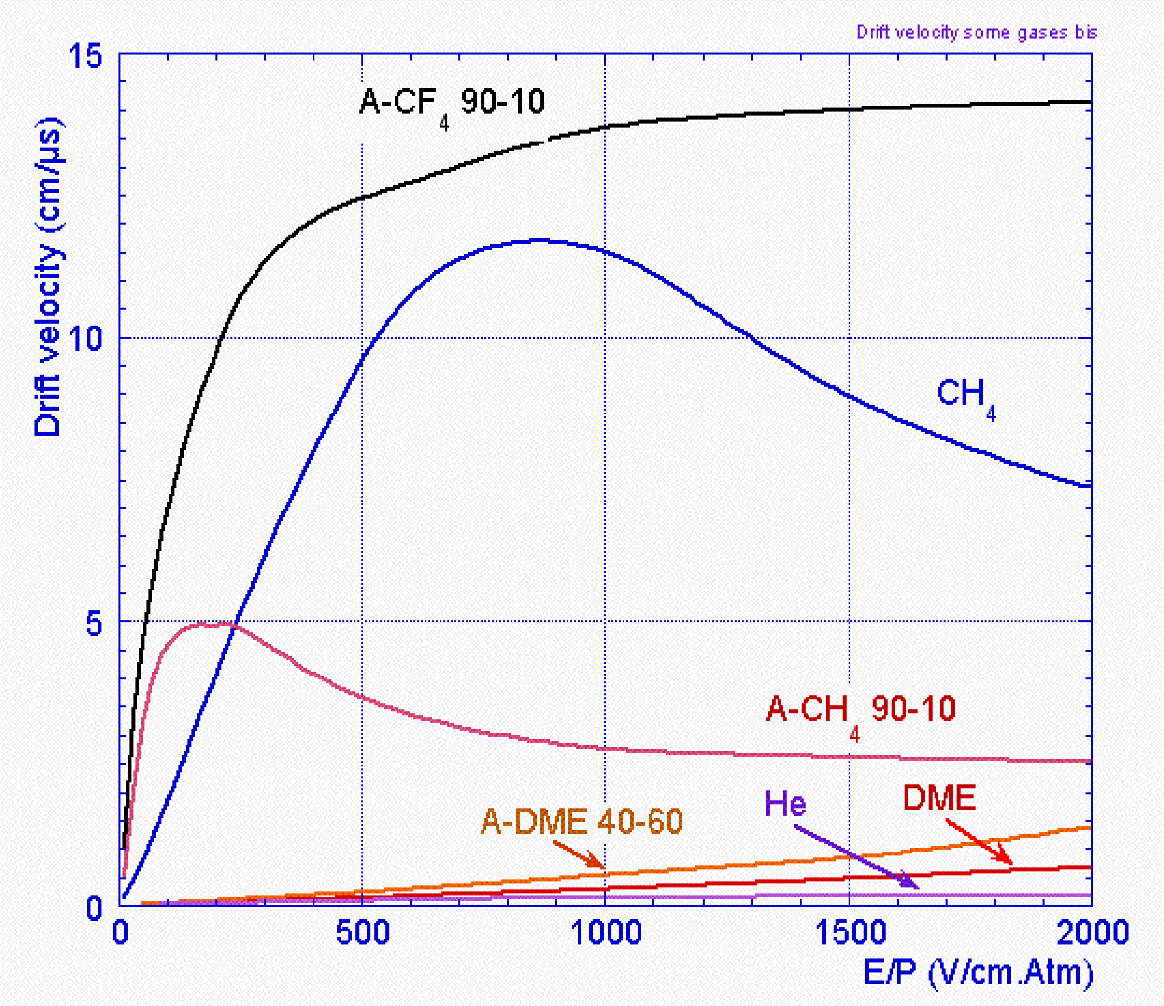


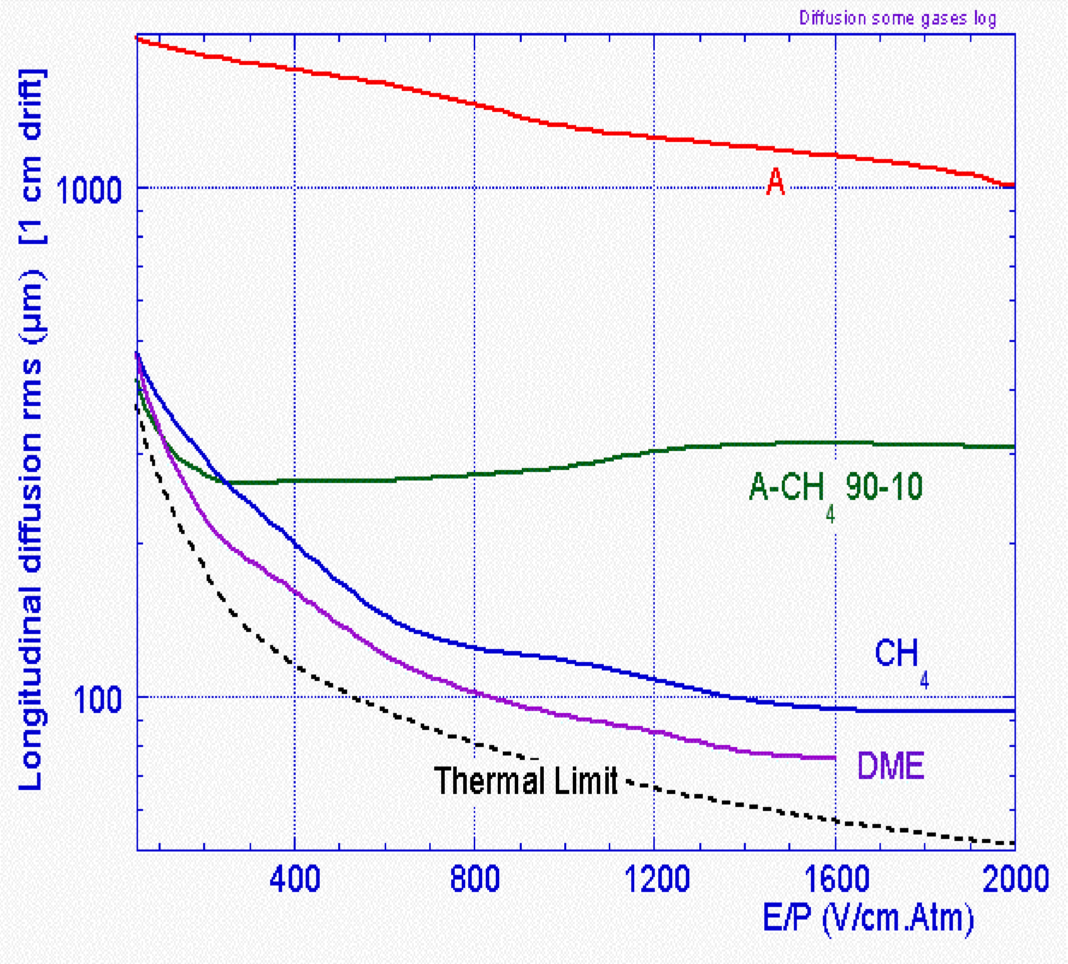
$$v_D = \frac{\Delta s}{\Delta t}$$ Drift velocity

$$\sigma_x = \sqrt{2Dt} = \sqrt{2D\frac{s}{v_D}}$$ Diffusion

- If an external electric field is applied the electrons and ions are accelerated and move along the field lines drift
- The drift is superimposed onto the diffusion movement
- Acceleration is interrupted by collision with gas atoms, this limits the drift velocity mean drift velocity v_D

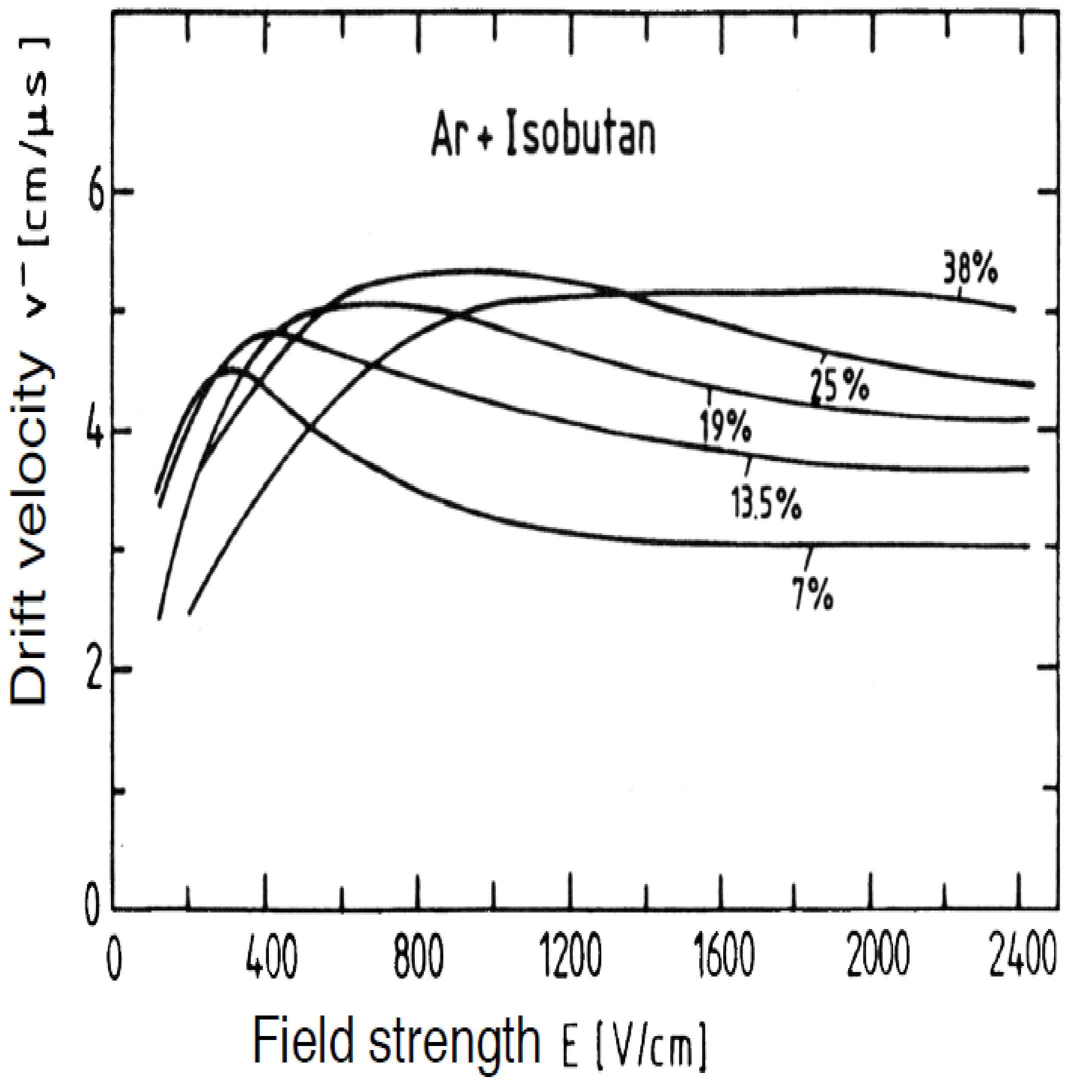
DRIFT VELOCITY AND DIFUSSION

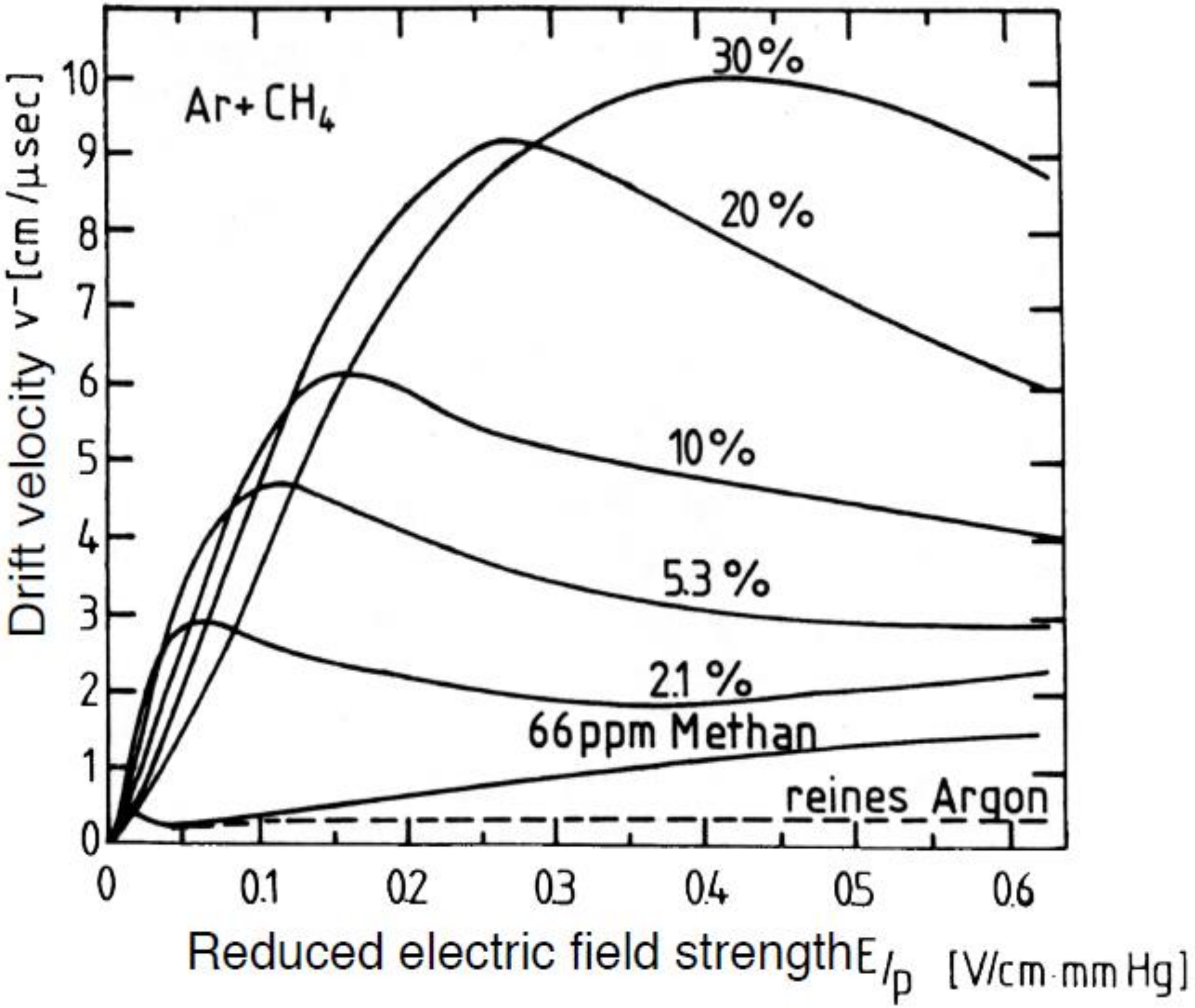




Rule of thumb: v_D (electrons) ~ 5 cm/µs = 50 µm / ns. Ions drift ~1000 times slower.

DRIFT VELOCITY FOR DIFFERENT GAS MIXTURES

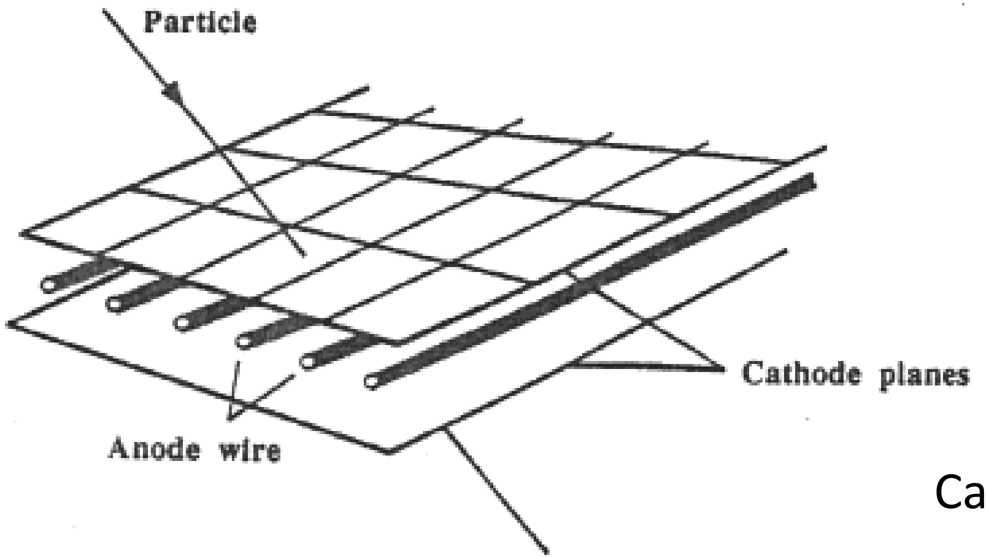




CONSIDERATIONS FOR GAS CHOICE

- With an appropriate field, avalanche multiplication occurs in all gases
- But, there are many requirements:
  - Low working voltage
  - High Gas Gain
  - Good proportionality
  - High Rate capability
  - Long lifetime
  - Fast response/recovery
  - Safety (flammability, corrosive, irritants, toxics, etc.)
  - Stable (rad-hard)
  - Cost

MULTIWIRE PROPORTIONAL CHAMBER (MWPC)

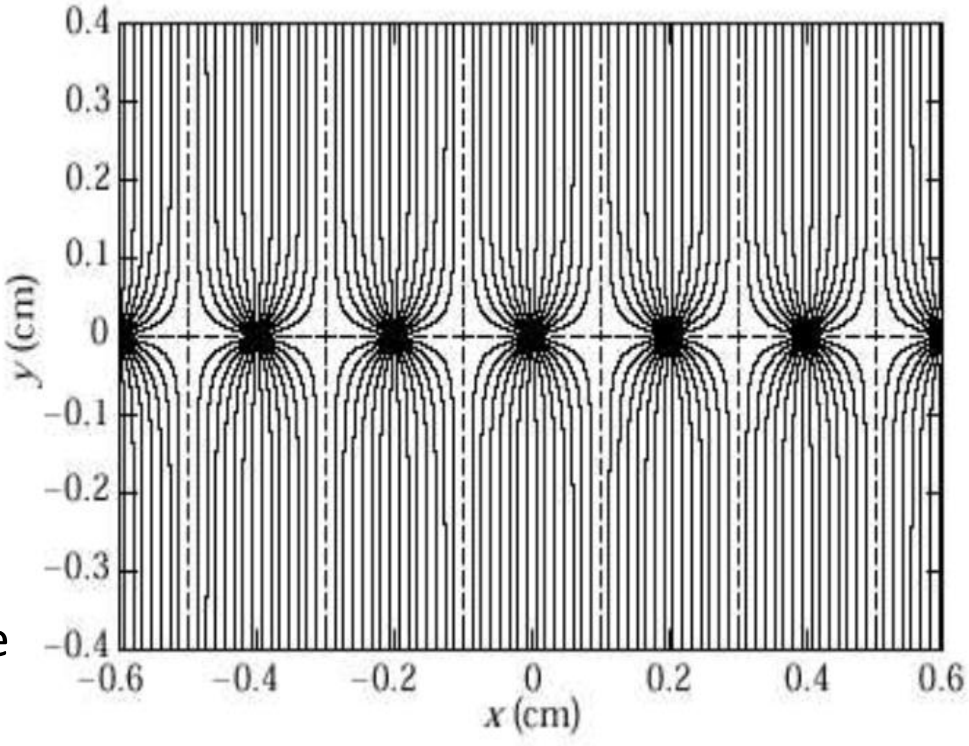


- Diameter of anode wires 10 – 50 μm
- Distances between wires 1 – 5 mm
- Each wire connected to an amplifier
- Typical gas amplification in MWPC is 10^5
- Max. particle rate ~10 kHz/mm^2

Position resolution:

Depends on wire distance
e.g. for d = 1 mm
By simply using the wire position

$$\sigma_X = \frac{d}{\sqrt{12}} = 300\ \mu m$$

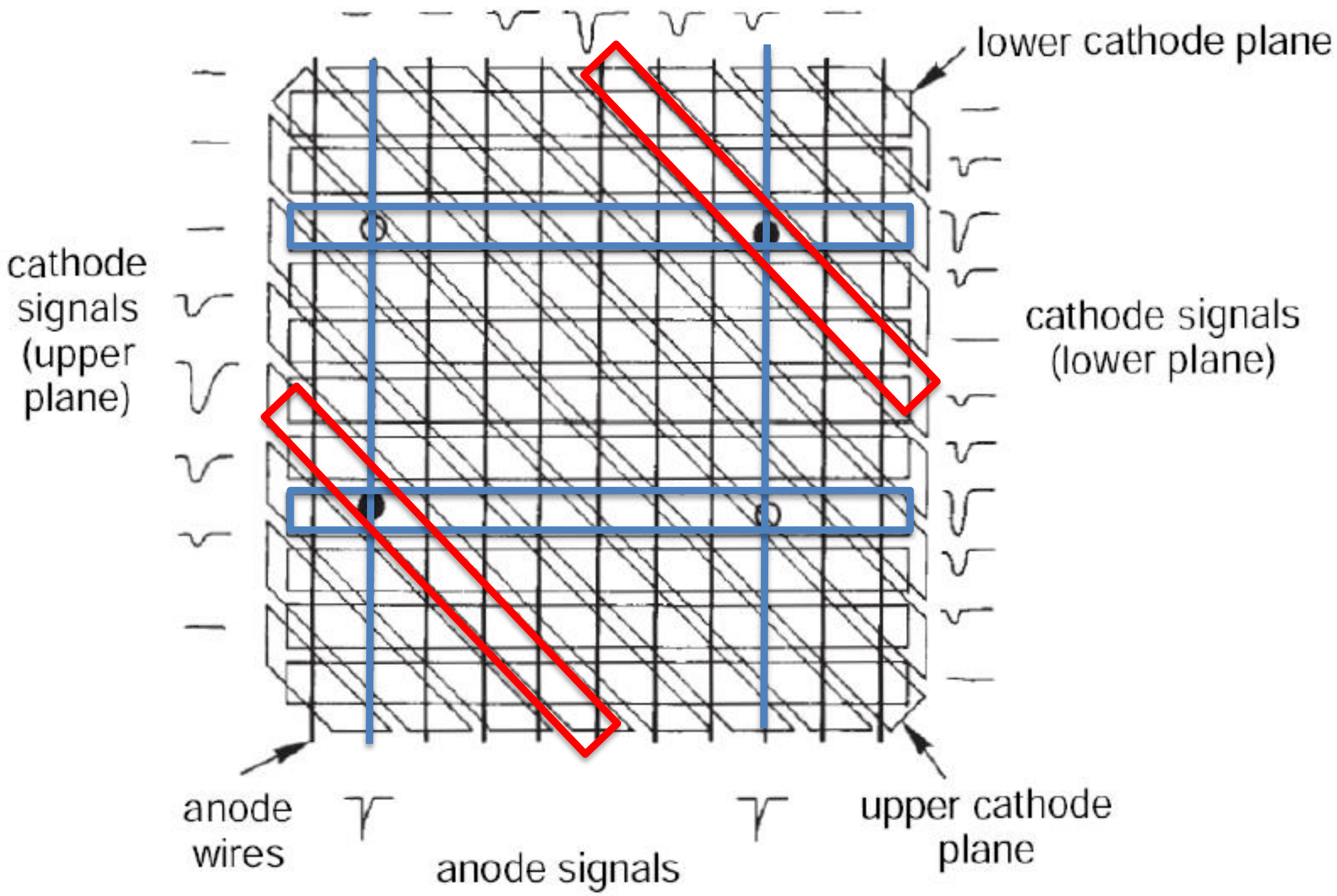


Catode plane

Anode wires

Catode plane

CATHODE STRIP CHAMBERS



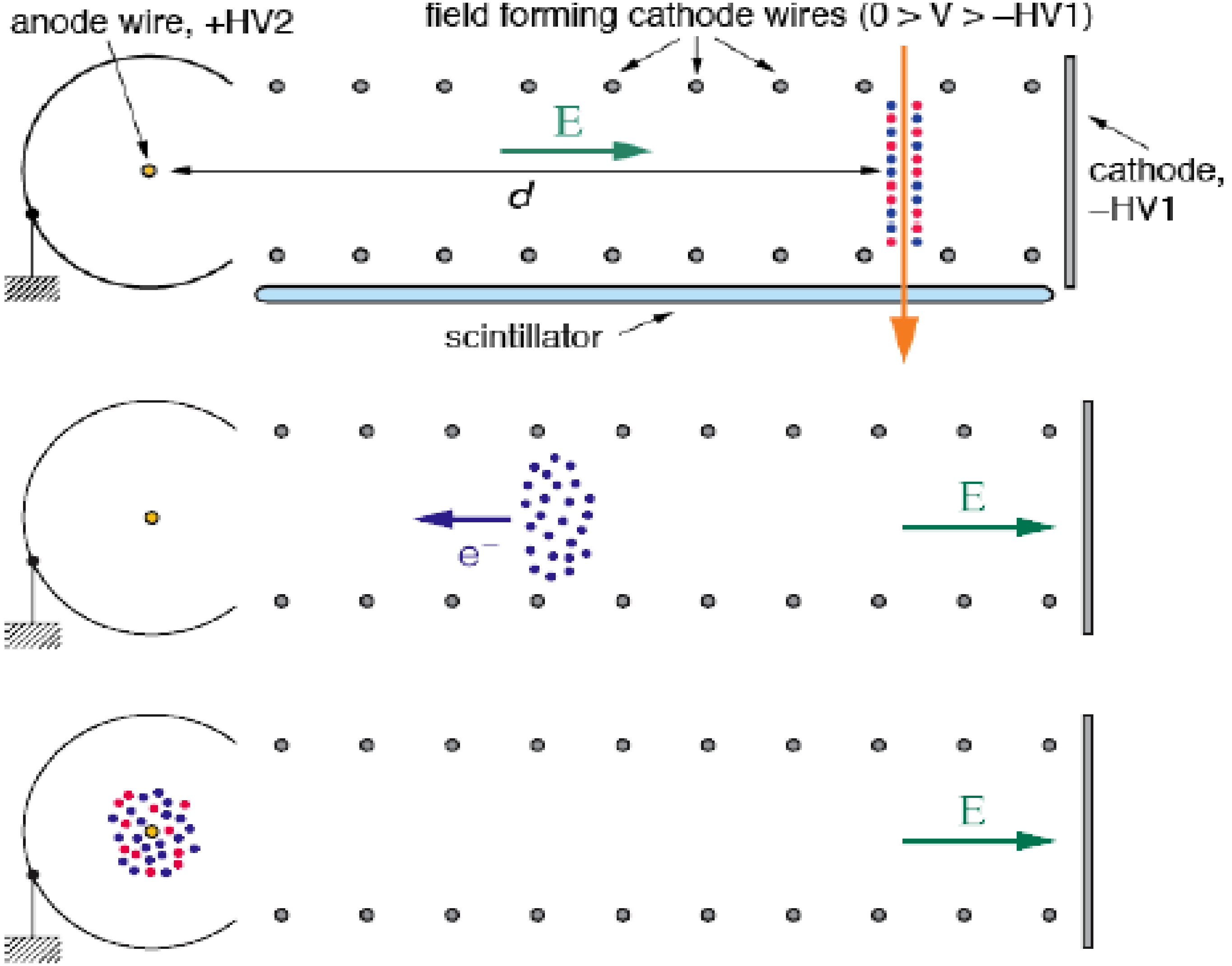
- A MWPC can only measure the coordinate perpendicular to the wires. No position measurement along the wires.
- If the cathode is segmented, perpendicular to the wires, the signal induced can be used to determine the second coordinate.
- Employing a center of charge calculation a position resolution of 50 µm is achievable.
- Substantial functionality improvement due to cathode strips/pads.

DRIFT CHAMBERS

1. Charged particle traversing the chamber produce ionisation. The scintillator signal starts a timer ($t = t_0$).
2. Electrons drift to the anode wire.
3. Electrons reaching the wire create secondary ionisation (avalanche) and trigger a signal ($t = t_1$).

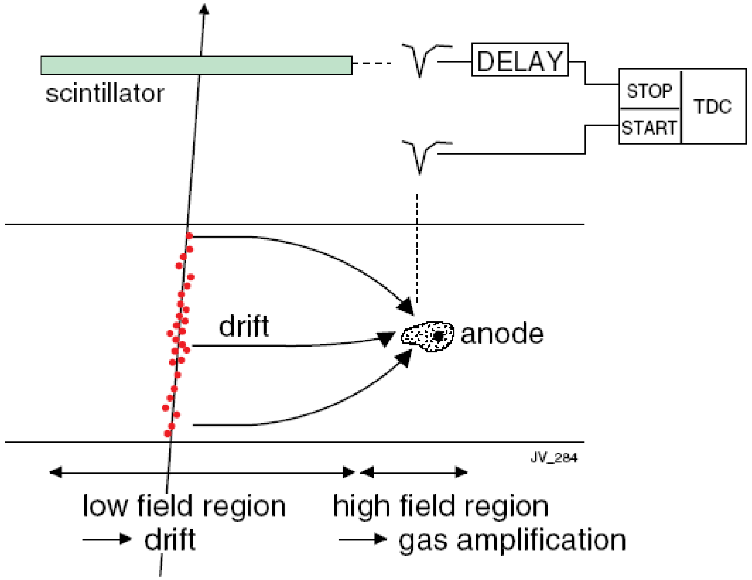
From the time difference the distance of the traversing particle to the wire is deduced.

$\Delta t = t_1 - t_0, \quad x = v \cdot \Delta t$

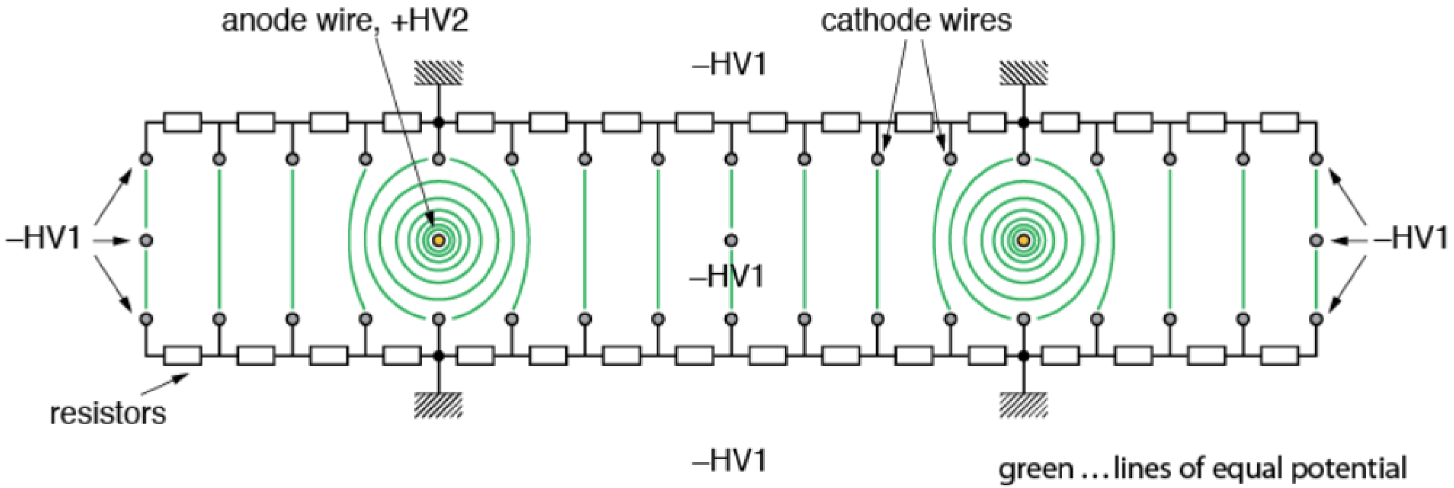


DRIFT CHAMBERS

The electric field has to be homogeneous and the drift velocity constant and known.
Additional field wires can improve the homogeneity.

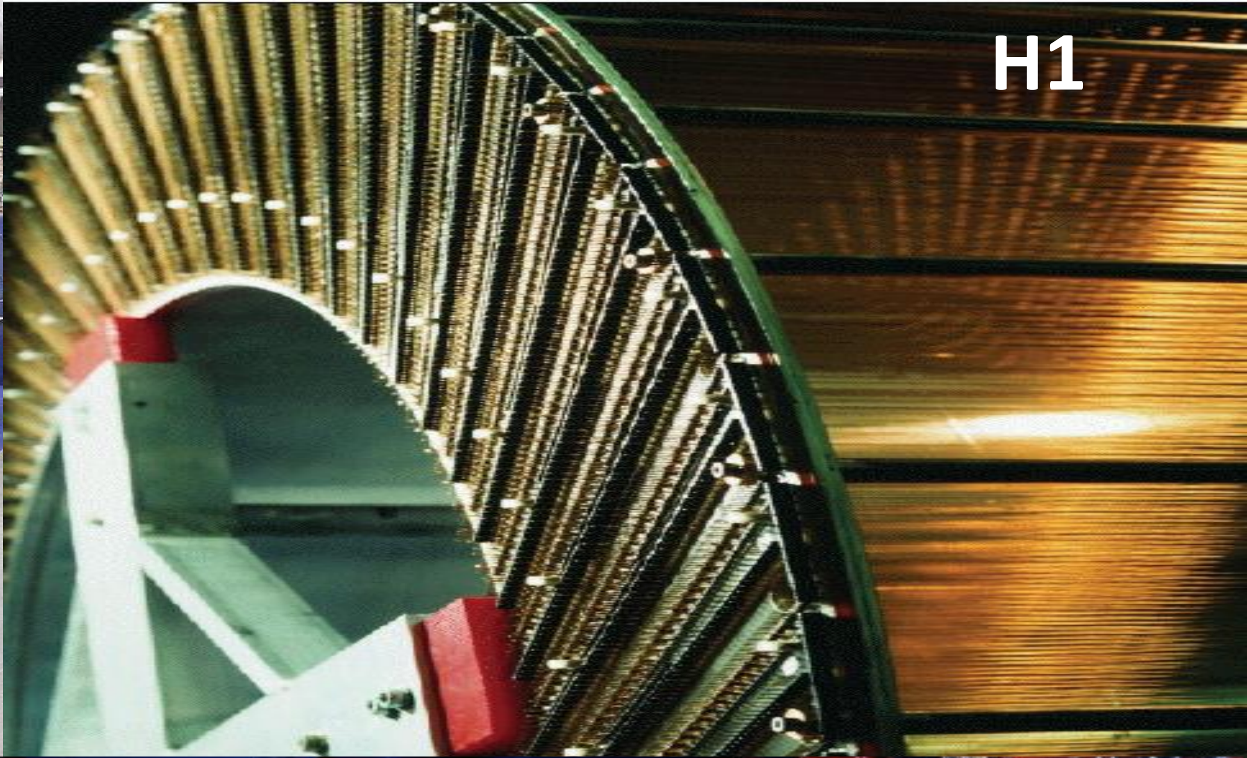


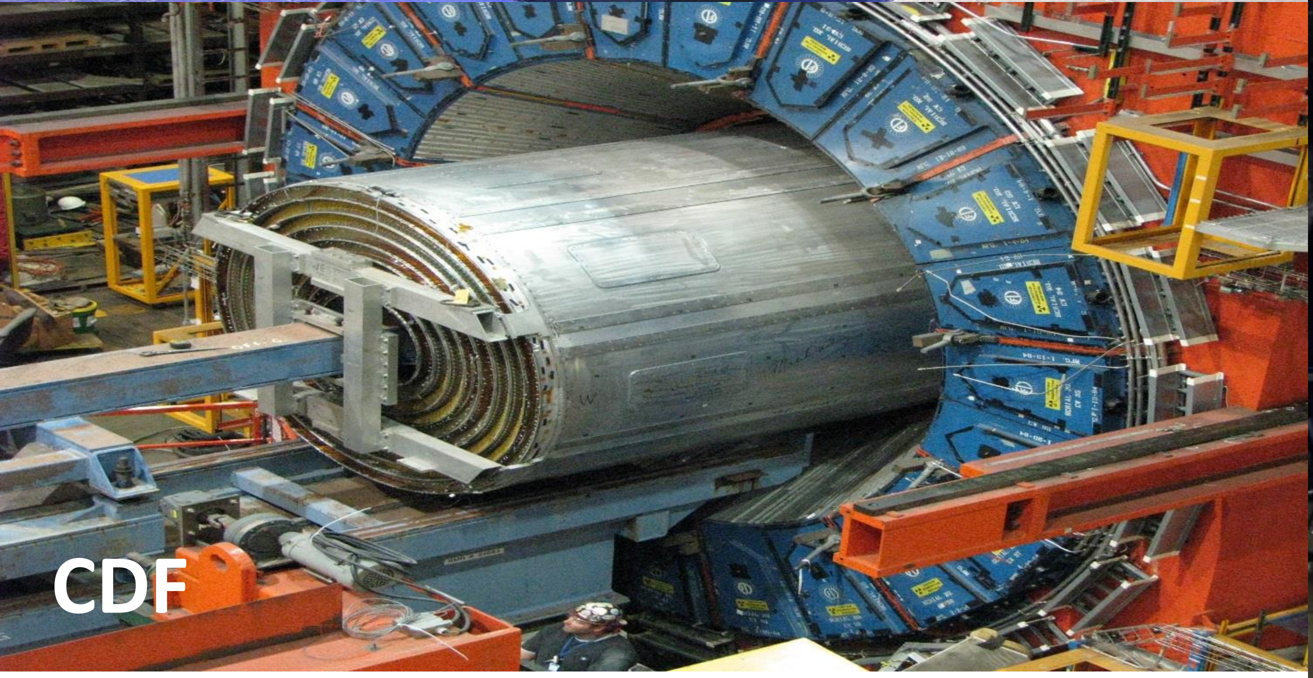
Typical geometry of a drift cell:

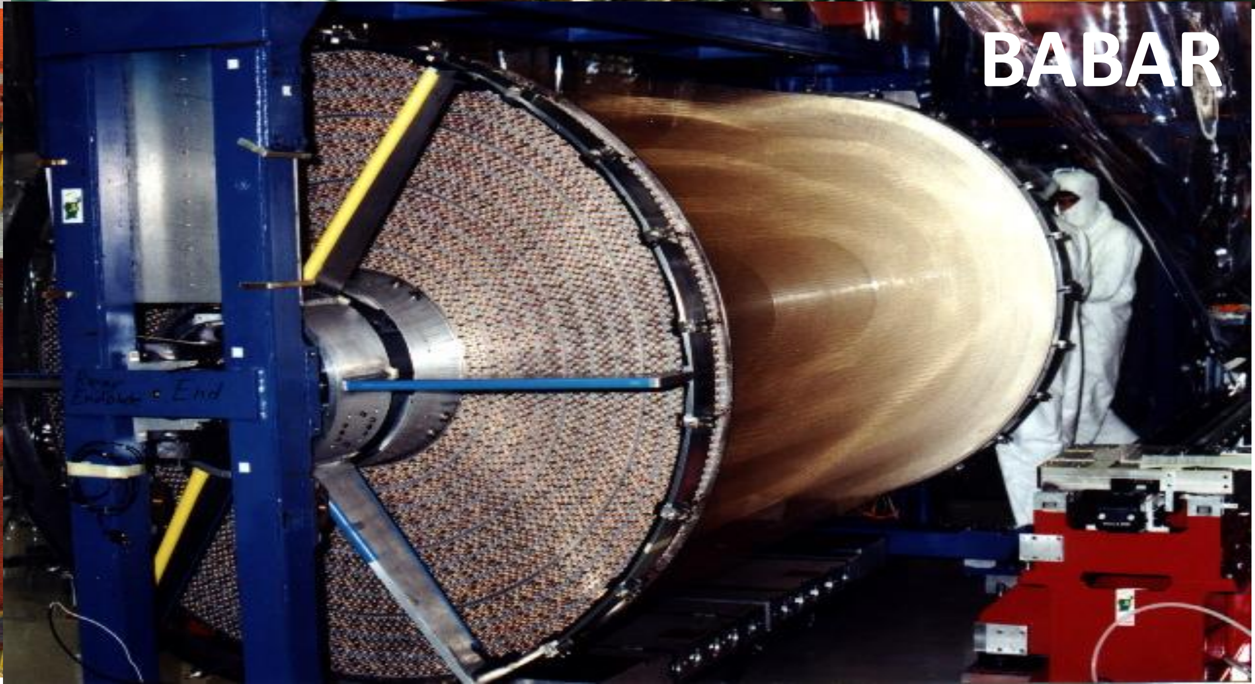


- Position resolution for large area chambers 200 µm (small chambers as good as 20 µm)
- Various gases used. Distinguish between fast gases (high v_D for high particle rates) and slow gases (low v_D for high spatial precision).
- Compared to MWPC: fewer wires and electronic channels, higher precision, but lower rate capability
- Typical drift distances 10 – 20 cm

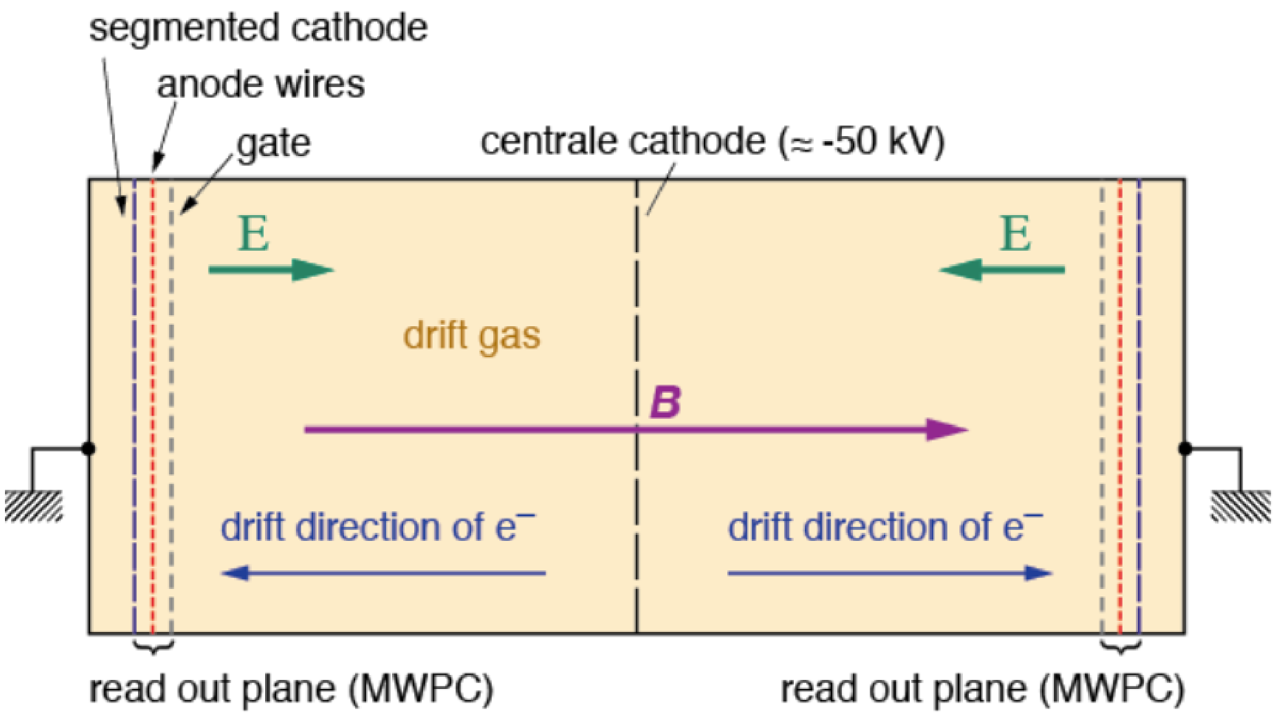

BELLE


H1

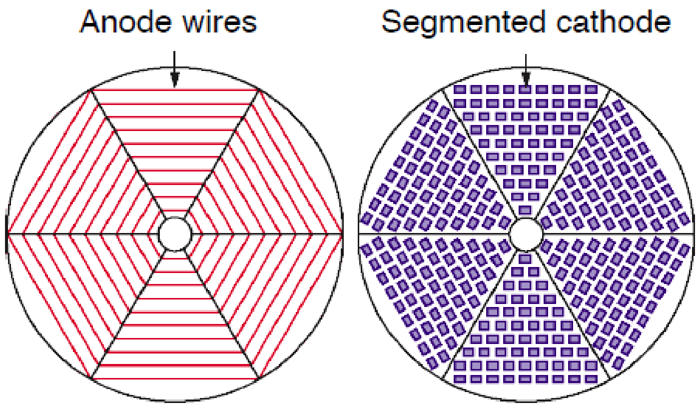

CDF


BABAR

TIME PROJECTION CHAMBERS

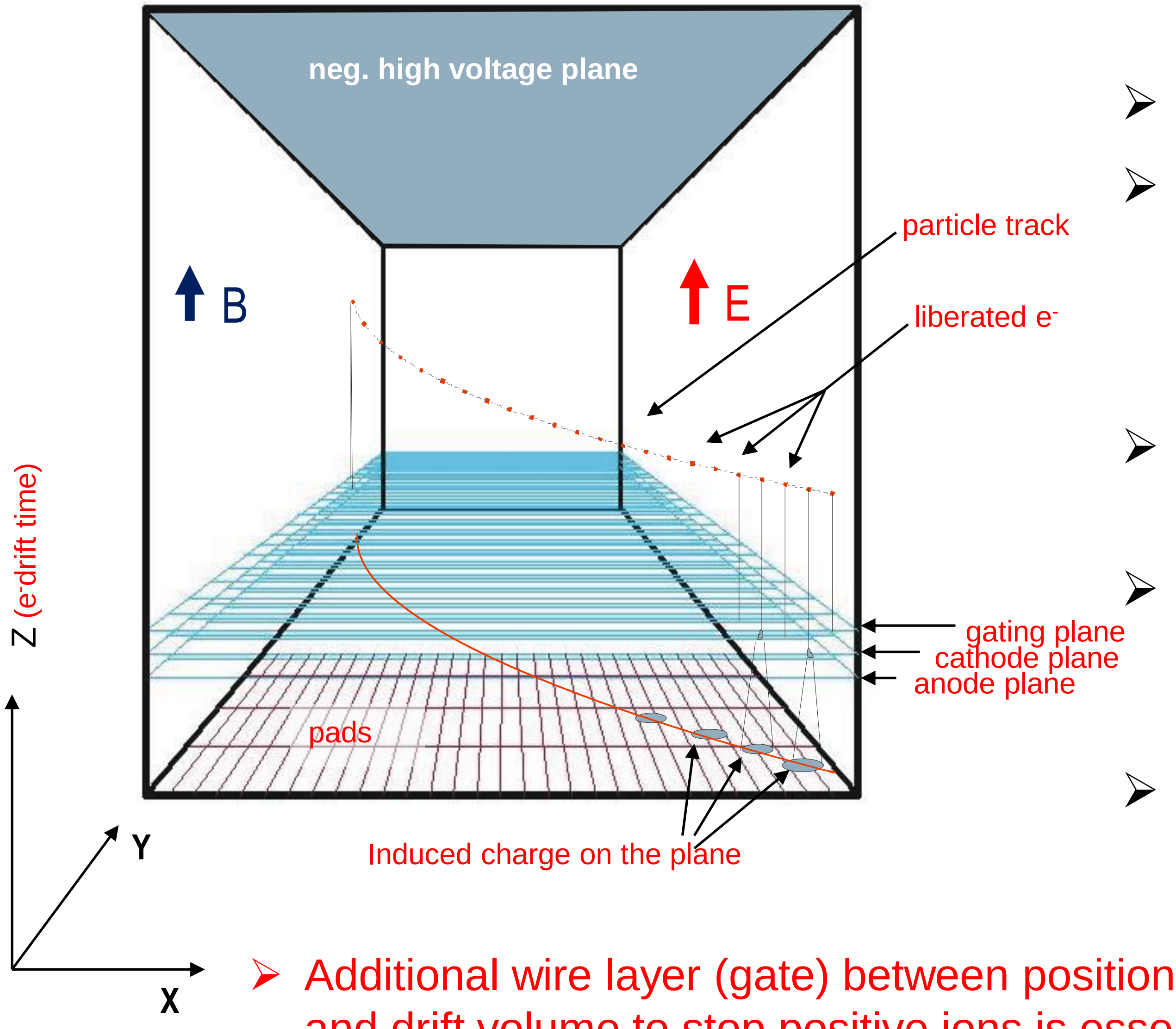


End plate detector (e.g. with segmented MWPC):



- Big gas filled volume
- Usually a central cathode at very high (negative) voltage in the middle
- On both sides position detectors for 2 dimensions (end plates)
- Electric field created by anode plane and central cathode plane parallel to the magnetic field of the experiment.

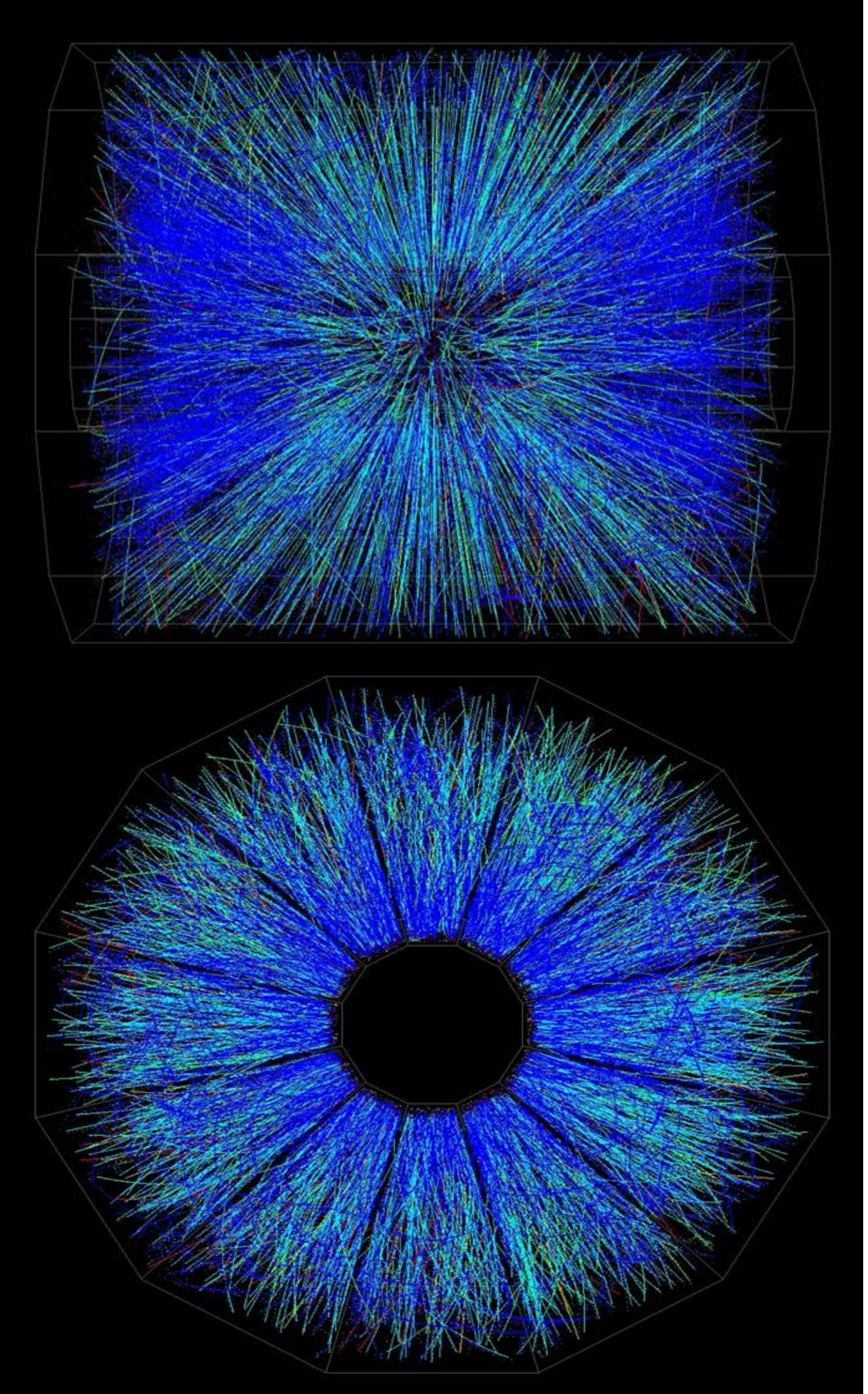
TIME PROJECTION CHAMBERS

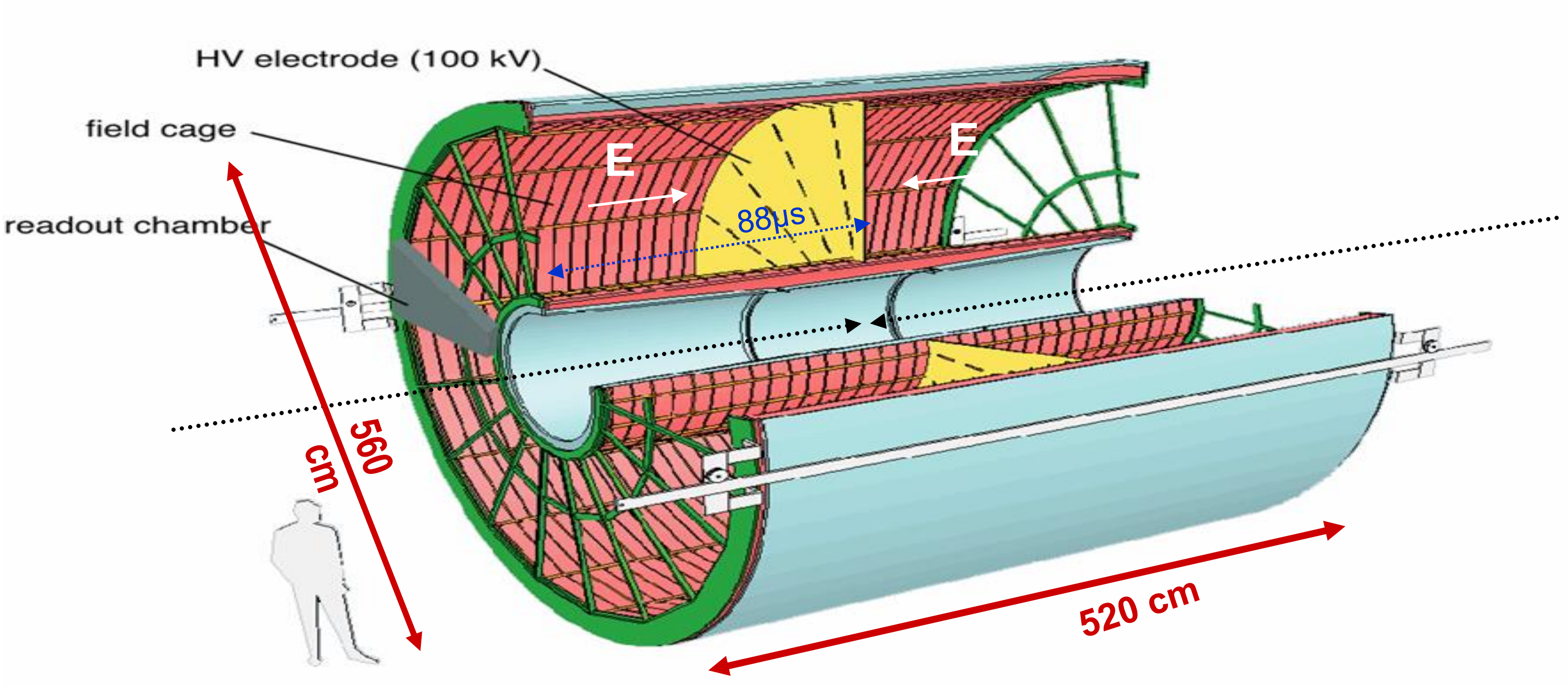


- TPC covers a large volume and delivers three dimensional images of the particle track.
- Very little material involved (no wires in central volume)
- Typical gas mixture argon methane (90%-10%)
- Up to a few hundreds of measurement points per particle track measured in large TPCs → excellent determination of the particle tracks (measurements also used for multiple dE/dx measurements).
- Position resolution of typically $\sigma_{r,\phi} = 150\text{–}250\ \mu\text{m}$ and $\sigma_z \approx 1$ mm
- Due to long drift times (e.g. 90 μs for 2,5 m drift length ALICE TPC), TPCs are not suitable for high particle rates.
- Ions from end plate detector drift back into gas volume → long drift times and distortion of field due to space charge

- Additional wire layer (gate) between position detector and drift volume to stop positive ions is essential

TIME PROJECTION CHAMBERS





Alice TPC

HV central electrode at –100 kV

Drift length 250 cm at E = 400 V/cm

Gas Ne-CO_2 90-10

Space point resolution ~500 mm

dp/p = 2%@1GeV/c; 10%@10 GeV/c

Events from STAR TPC at RHIC Au-Au collisions at CM energy of 130 GeV/n

Typically ~2000 tracks/event

ALICE TPC

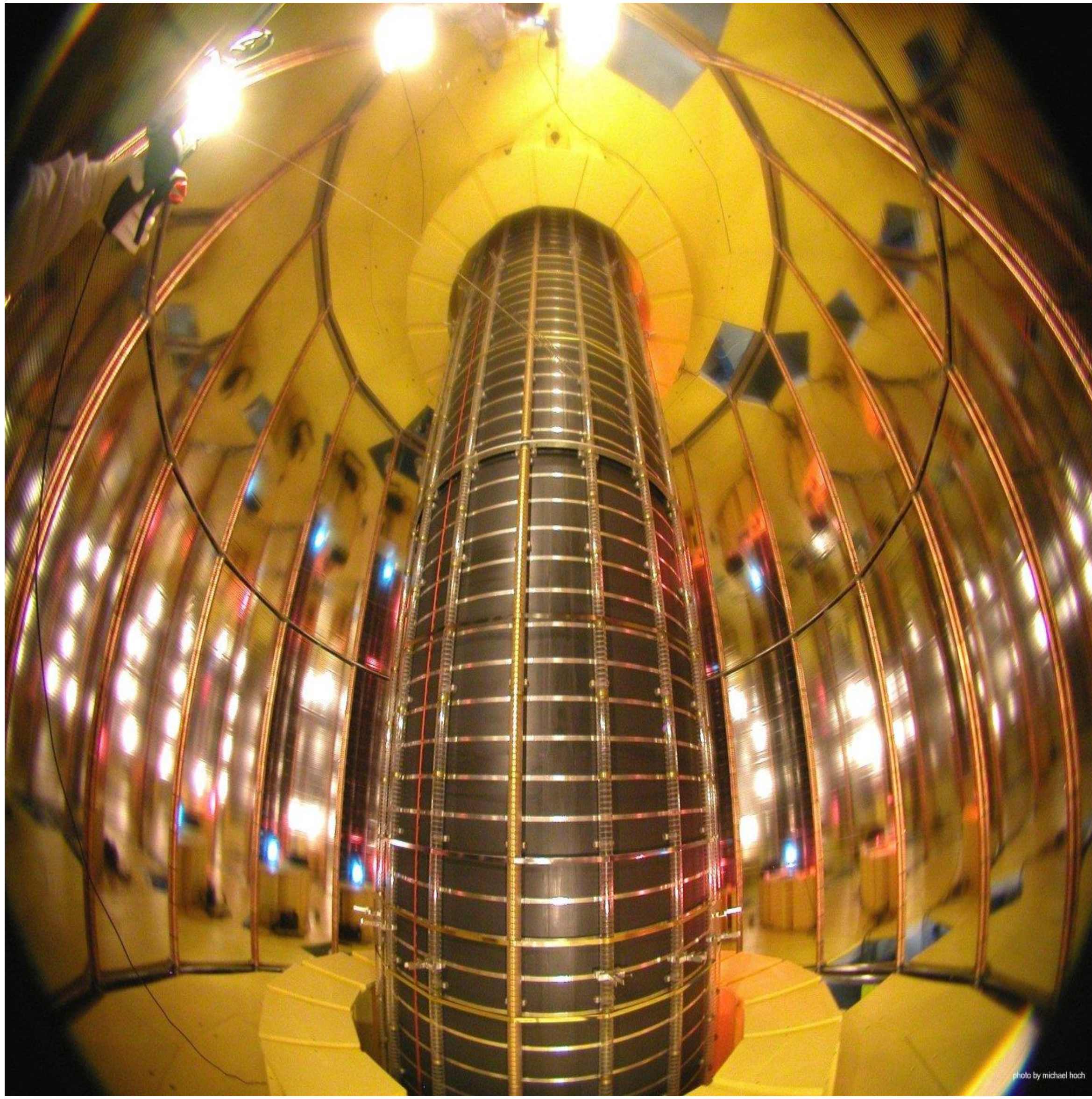
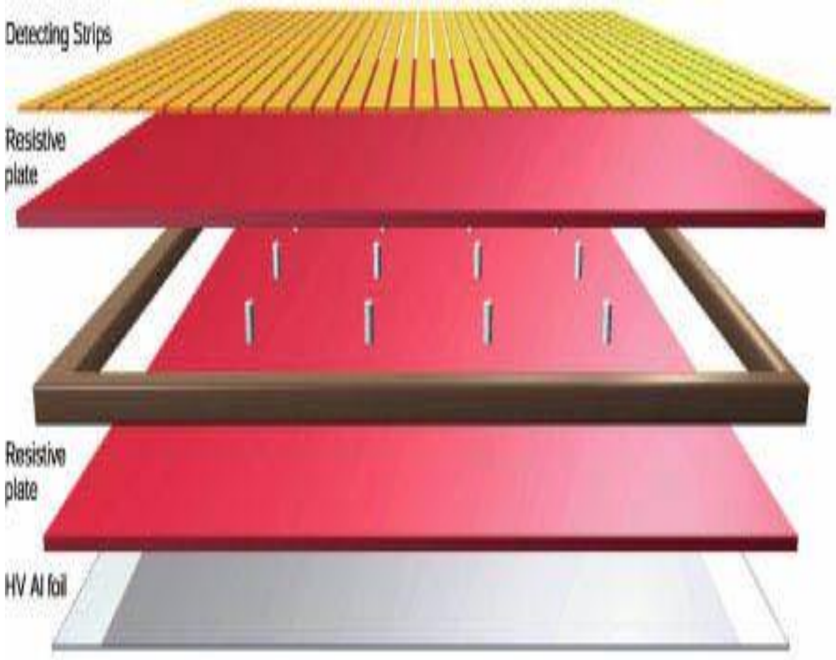
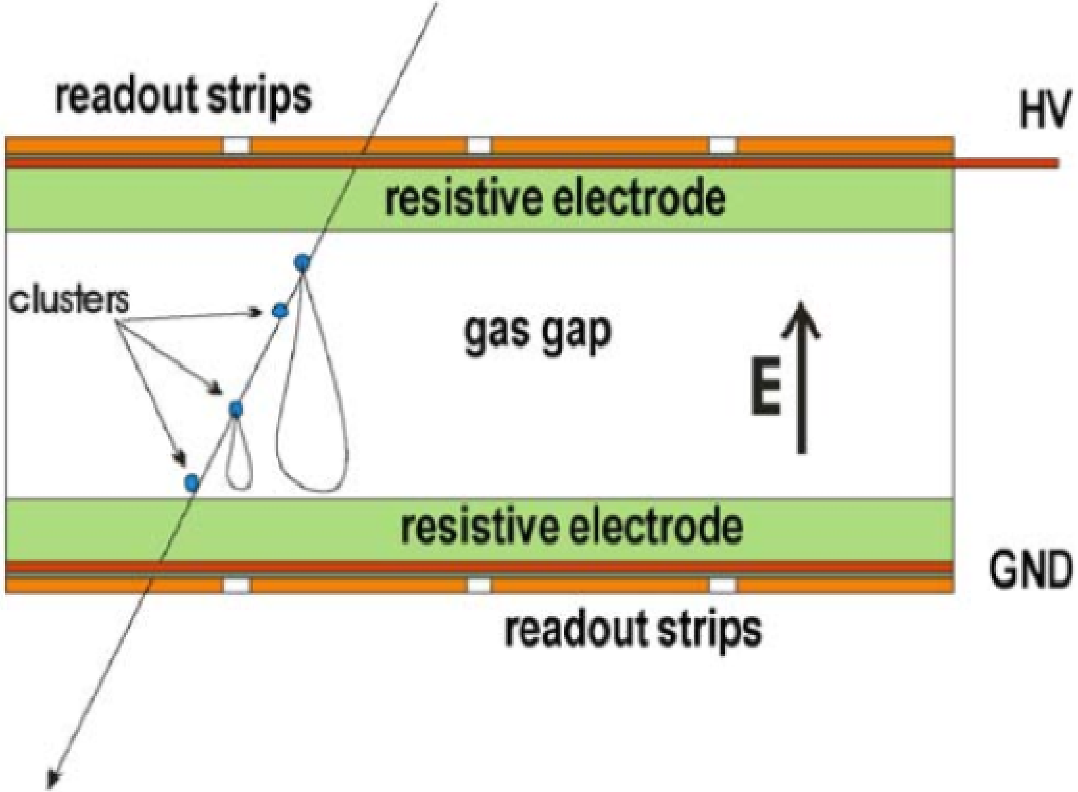


photo by michael hoch

RESISTIVE PLATE CHAMBERS (RPCs)



- ★ Gas gap typically 2 mm
- ★ resistive electrodes made of phenolic-melaminic (Bakelite),
- ★ electrodes to apply high voltage and insulated pick up electrodes
- ★ Gas chambers operated in avalanche or streamer mode.

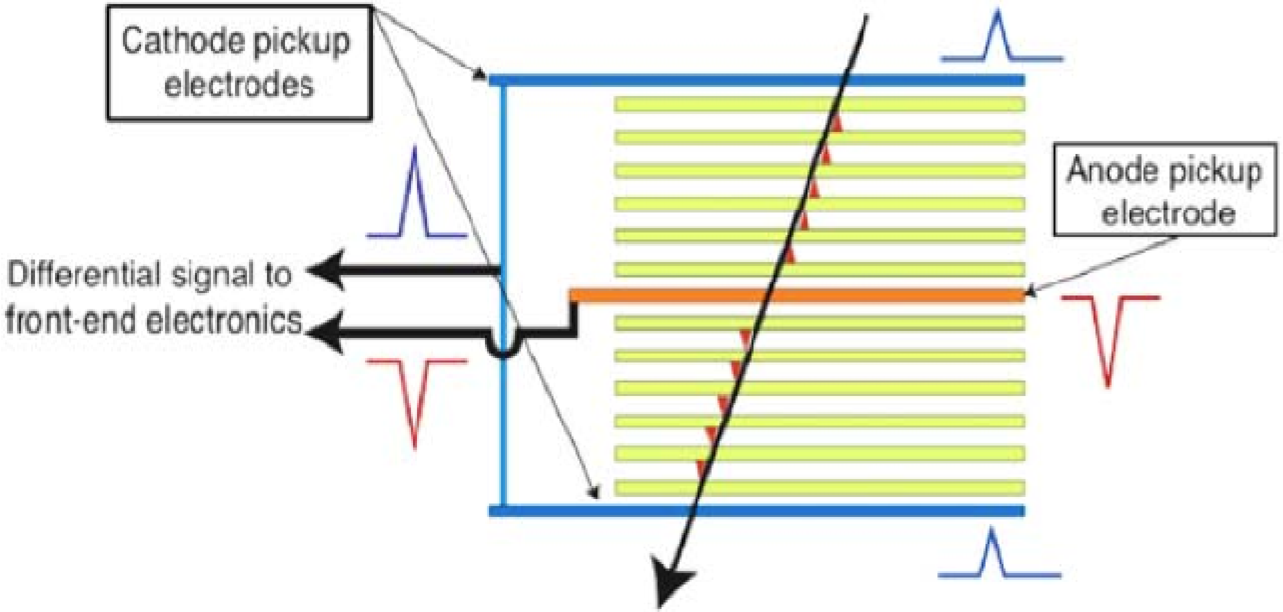


M. Hoch, Nucl. Instr. Meth. A **535**, 1 (2004)

Large area detectors
Space resolution ~ mm
Very fast timing (~ 1 ns) and
sufficient high rate
capability (~ 100 Hz/cm^2)
➔ ideal devices for trigger detectors

MULTIGAP RPCs

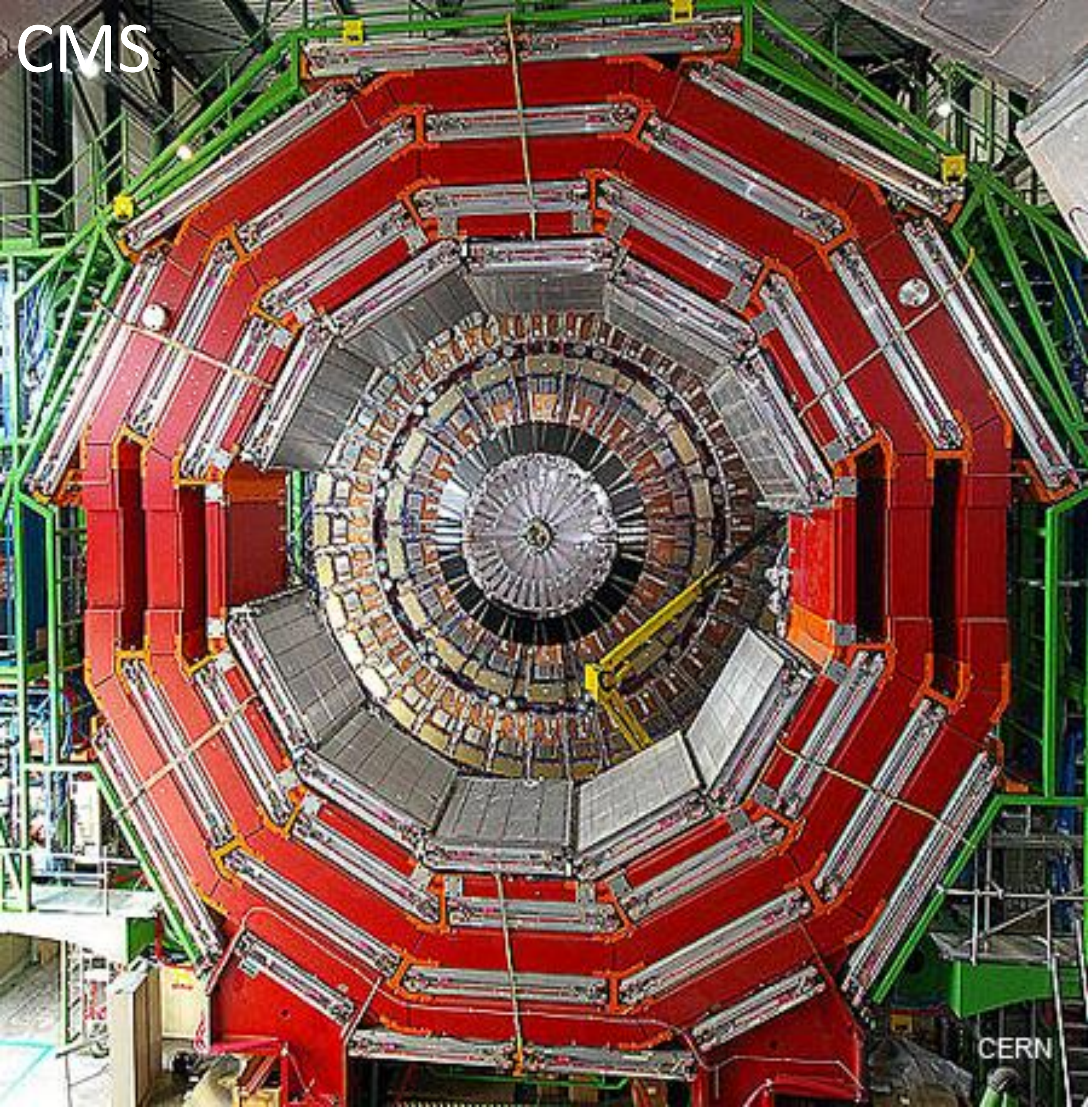
- ★ Pile of resistive gas plates separated by thins spacers (~250 μm, e.g. nylon fishing lines)
- ★ High voltage is applied to the outer electrodes, internal plates are floating and get correct potential by electrostatic equilibrium



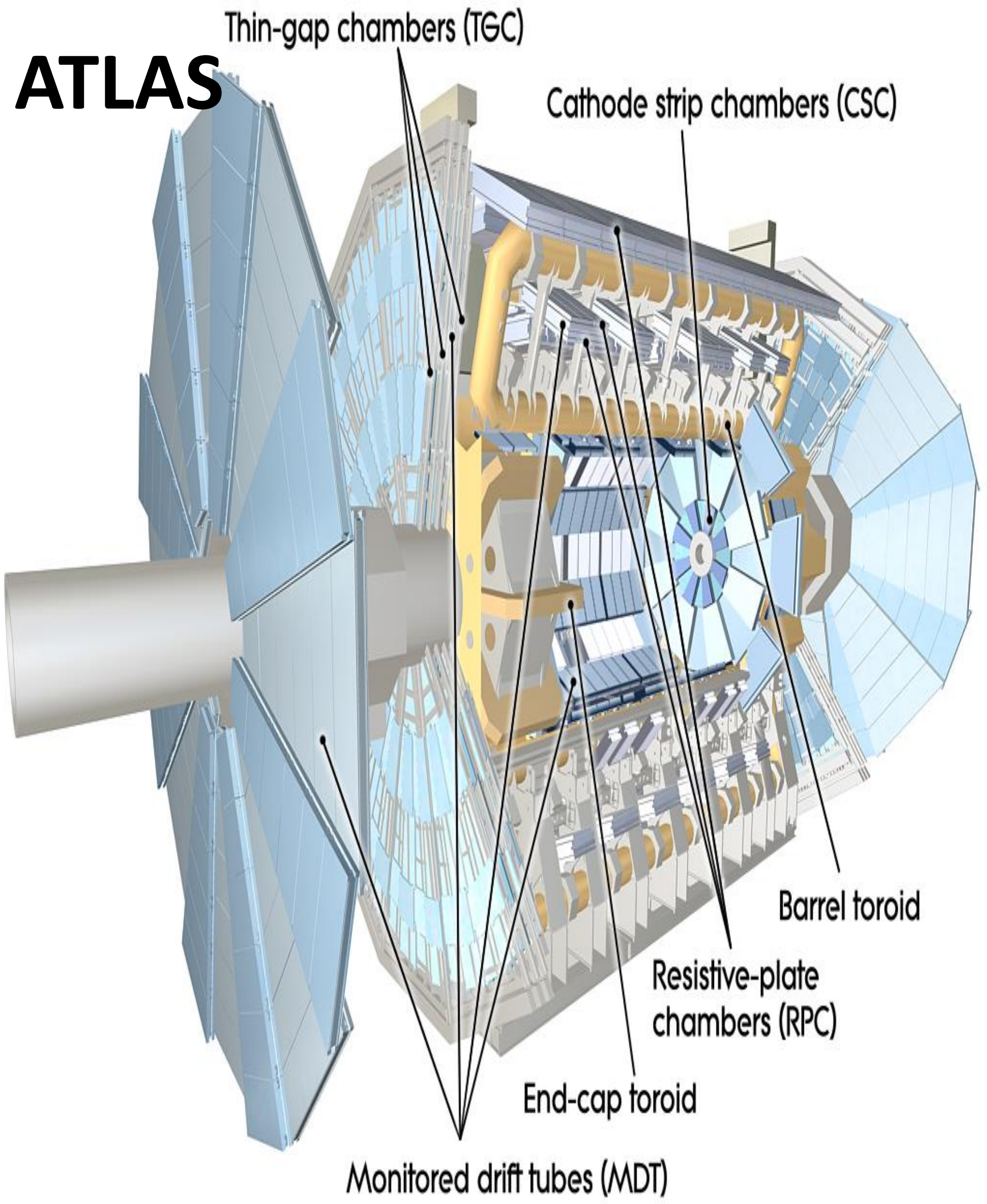
Very high efficiencies
Time resolution as low as 50 ps

Used for example in the ALICE TOF chambers.

CMS


CERN

ATLAS


Thin-gap chambers (TGC)
Cathode strip chambers (CSC)
Barrel toroid
Resistive-plate chambers (RPC)
End-cap toroid
Monitored drift tubes (MDT)

MICRO PATTERN GAS DETECTORS (MPGDs)

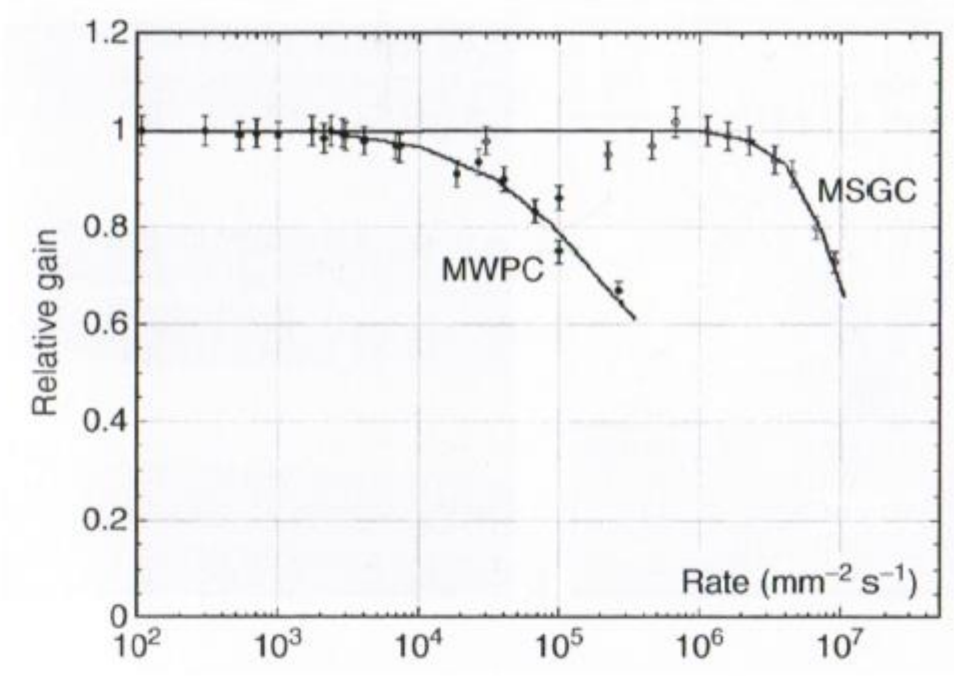
Large group of different detector geometries

★ No wires – electrodes are deposited materials or printed structures. Photolithography of these processes allow for very fine structures.

★ Smaller cell sizes → improved position resolution ~ 30 μm
→ high rate capability ~ MHz/mm^2

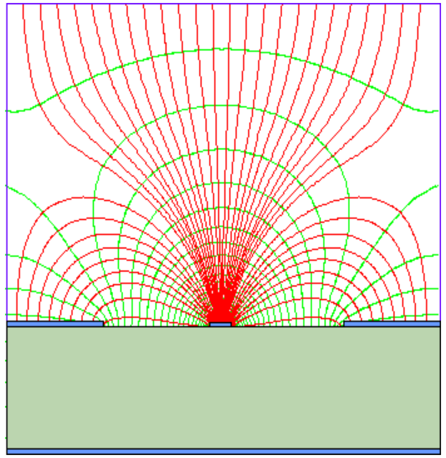
Examples :

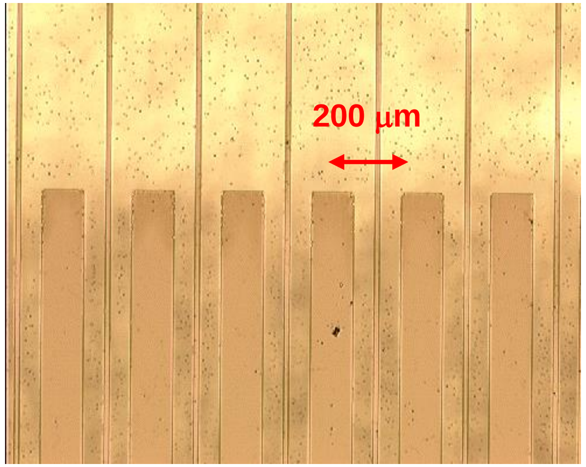
- ★ Micro Strip Gas Counter
- ★ GEM
- ★ Micromegas



(MWPC) A. Breskin et al., Nucl. Instr. Meth. A **124** (1975)
(MSGC) A. Barr et al., Nucl. Phys. B **61B** (1998)

MICRO STRIP GAS COUNTERS (MSGs)





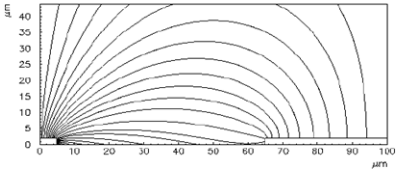
Thin metal anodes and cathodes on insulating support (glass, flexible polyimide ..)

Problems:

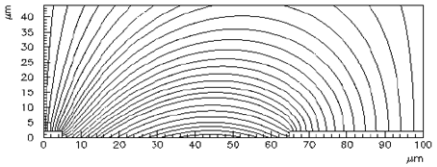
High discharge probability under exposure to highly ionizing particles caused by the regions of very high E field on the border between conductor and insulator.

Charging up of the insulator and modification of the E field → time evolution of the gain.

insulating support



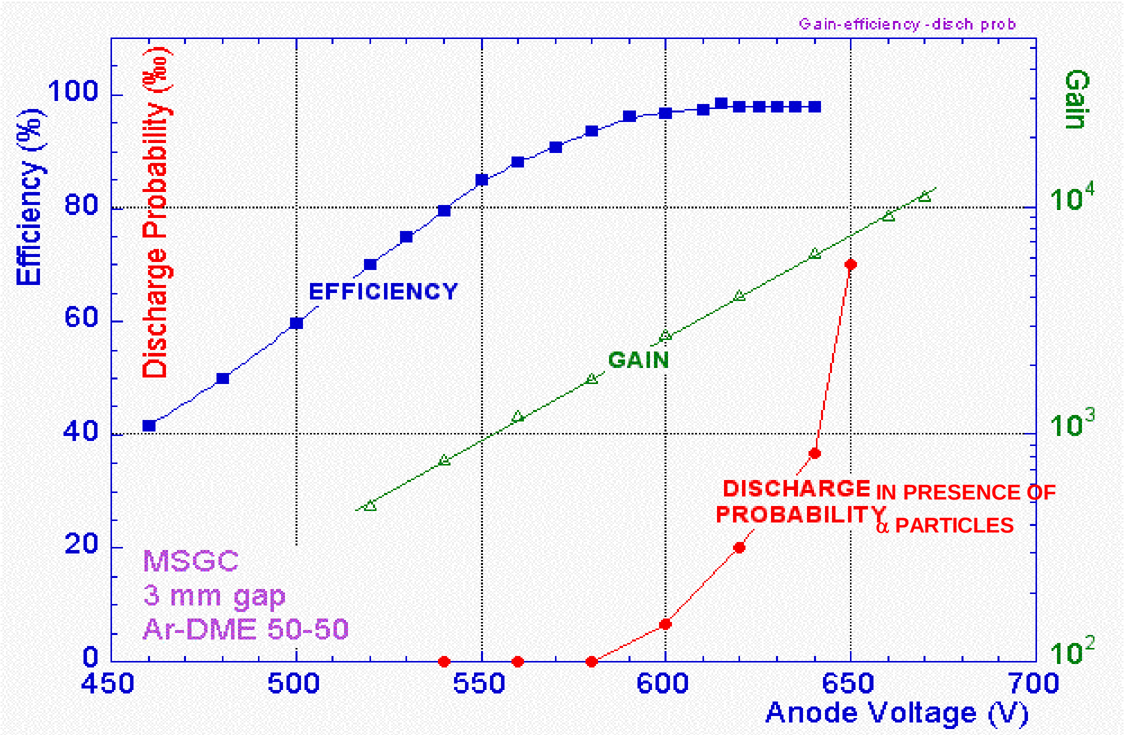
slightly conductive support



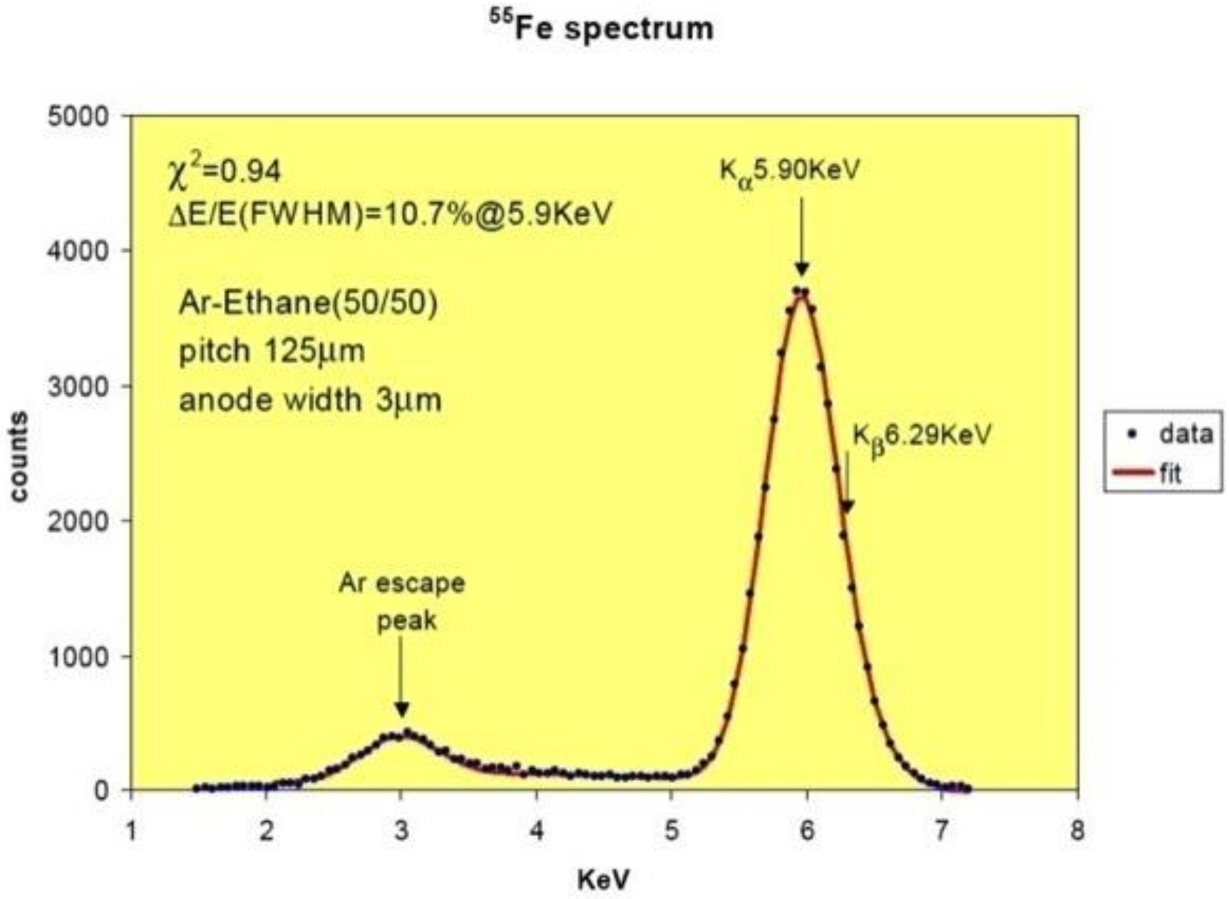
R. Bellazzini et al.

Solutions:

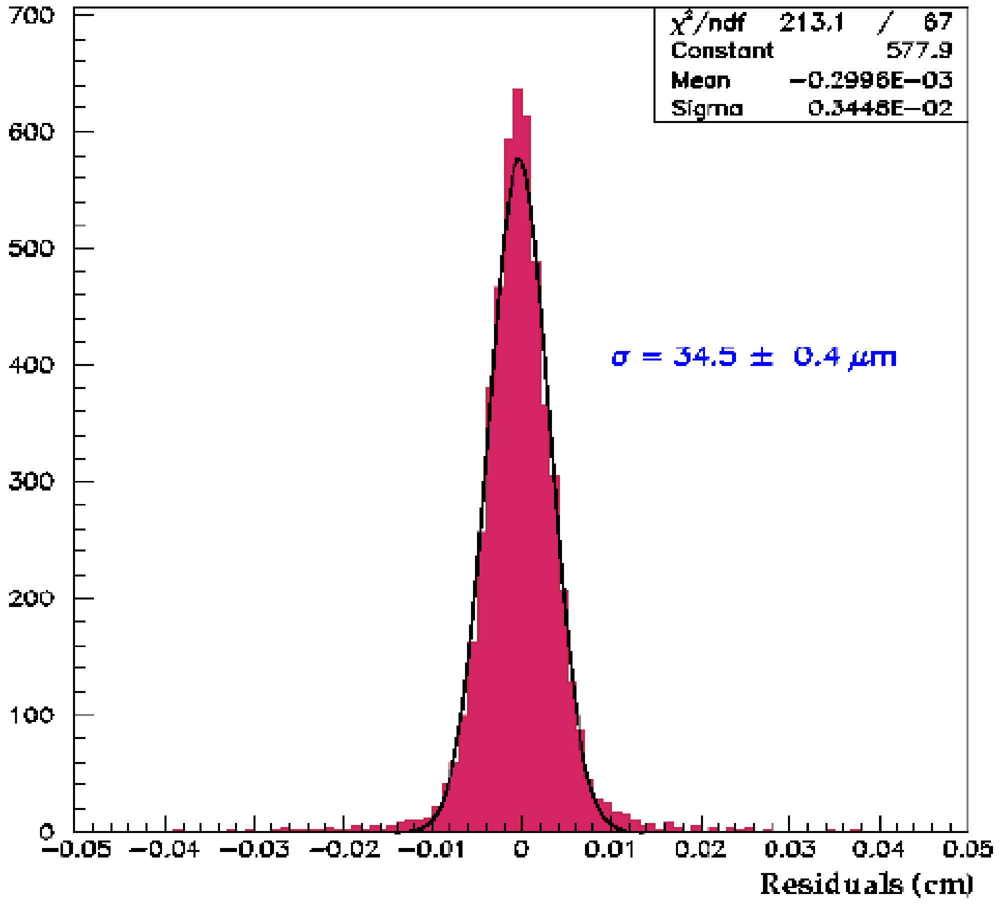
- slightly conductive support
- multistage amplification



MICRO STRIP GAS COUNTERS (MSGs)

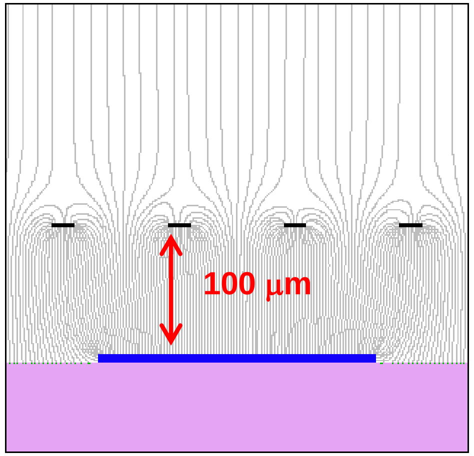


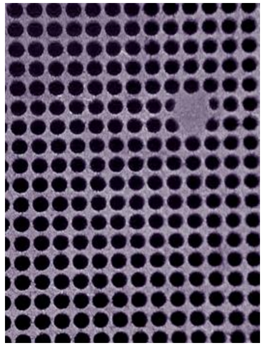
Energy resolution ~11% for 5.9 keV



Spatial resolution = 34.5 ± 0.4 μm
2-track resolution ~400 μm

Micromegas – Micromesh Gaseous Structure



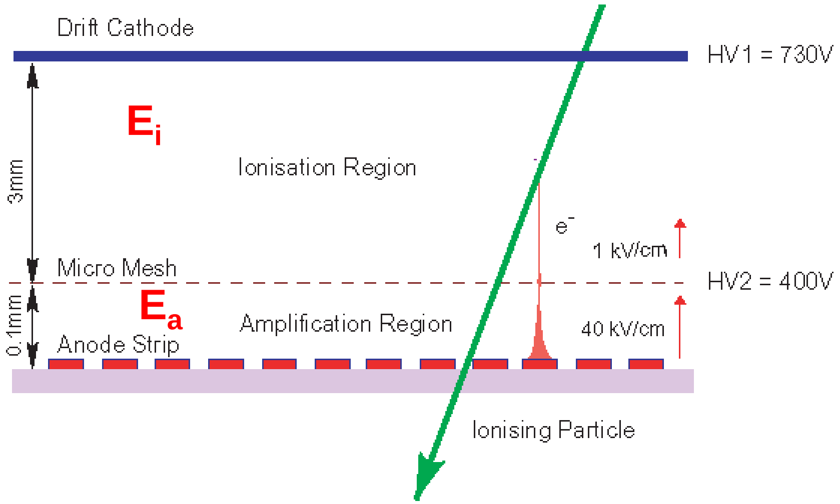


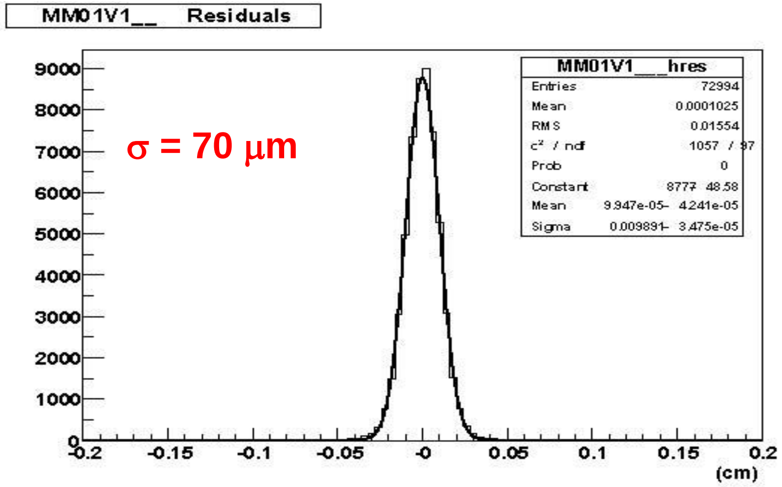
micromesh

Metal micromesh mounted above readout structure (typically strips).

E field similar to parallel plate detector.

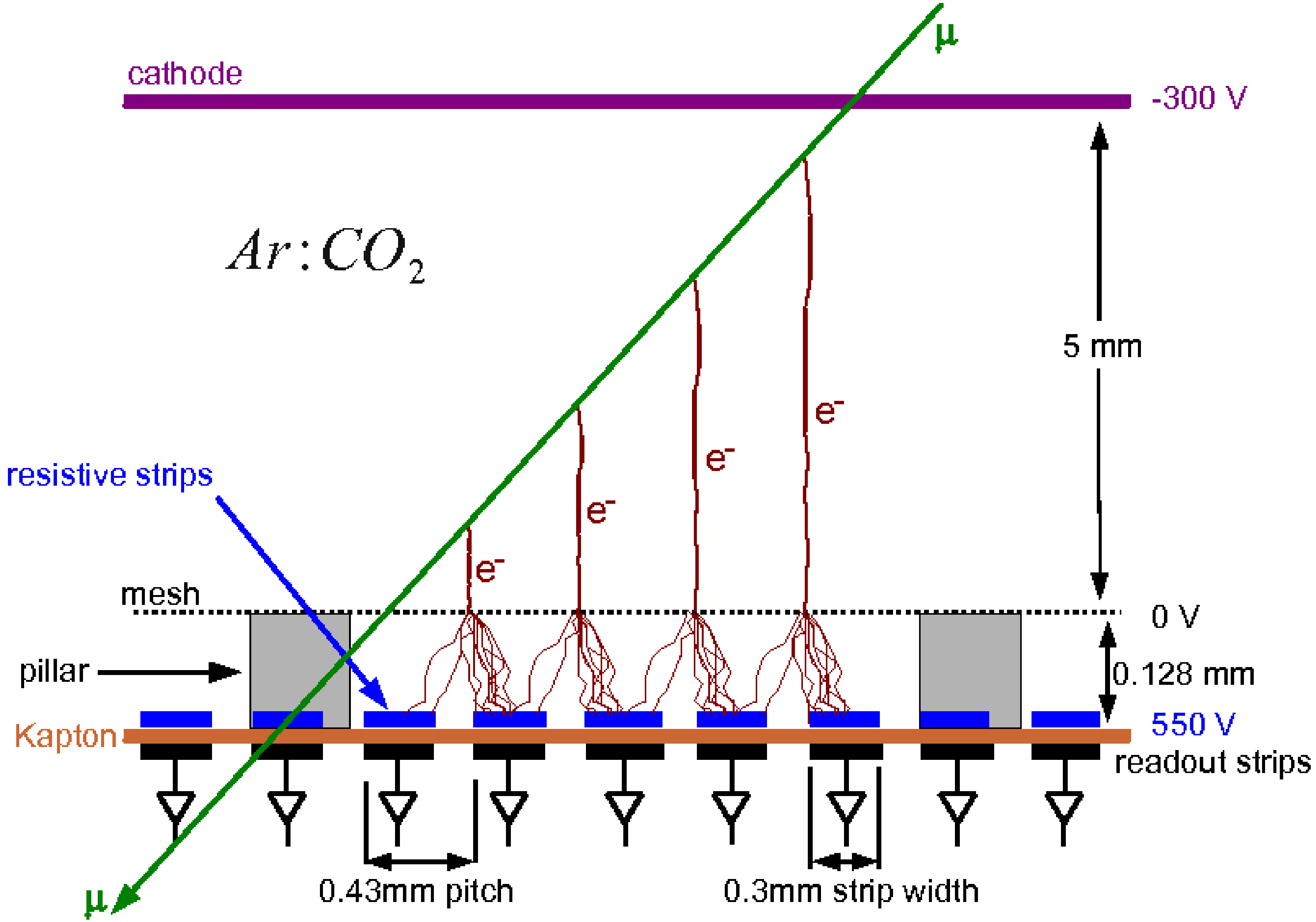
E_a/E_i ~ 50 to ensure electron transparency and positive ion flowback supression.



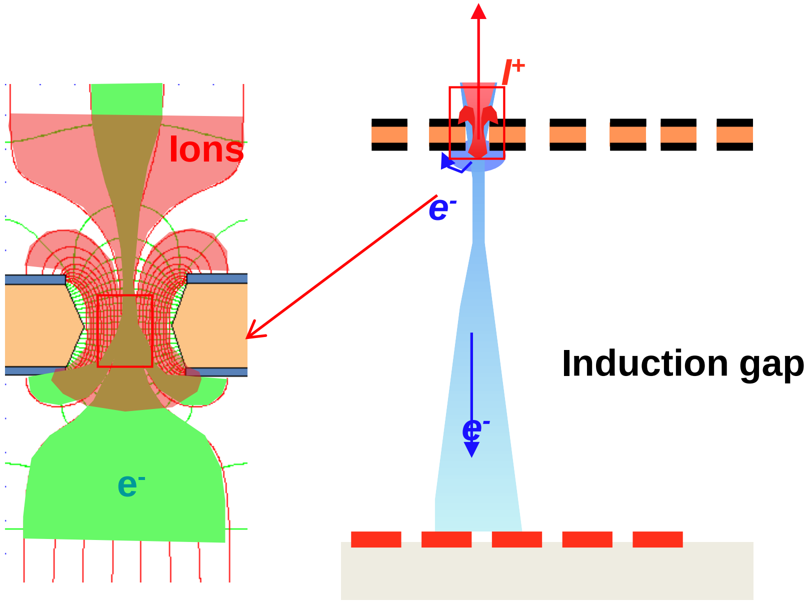


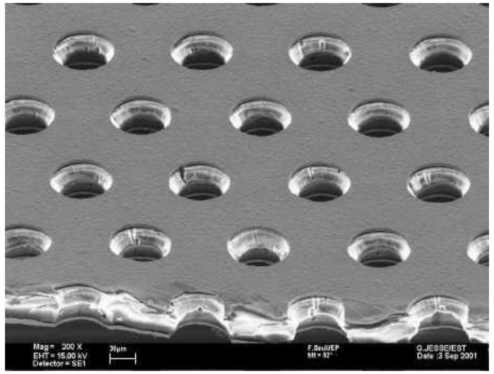
Space resolution

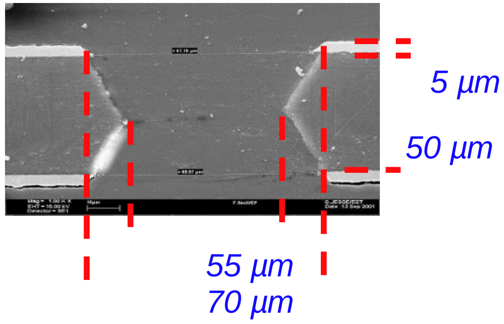
Micromegas – Micromesh Gaseous Structure



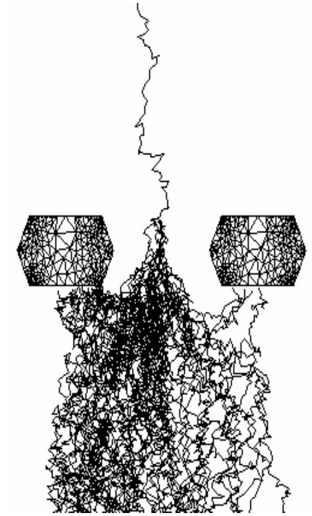
GEM – Gas Electron Multiplier





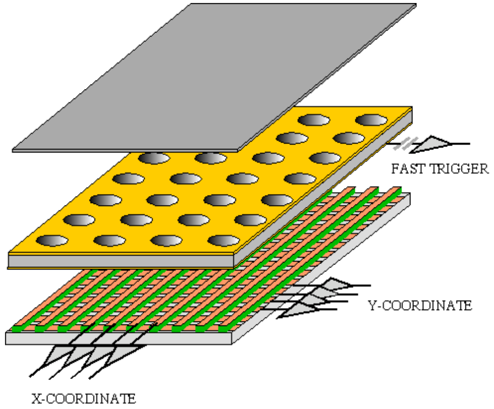


Thin, metal coated polyimide foil perforated with high density holes.



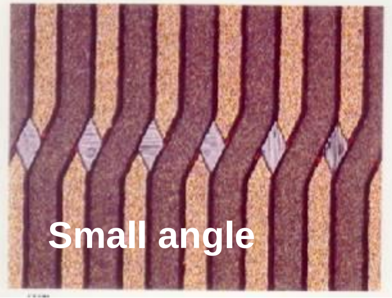
Electrons are collected on patterned readout board.
A fast signal can be detected on the lower GEM electrode for triggering or energy discrimination.
All readout electrodes are at ground potential.
Positive ions partially collected on the GEM electrodes.

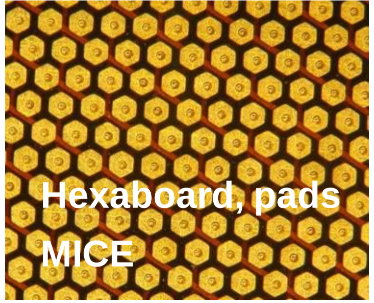
GEM – Gas Electron Multiplier

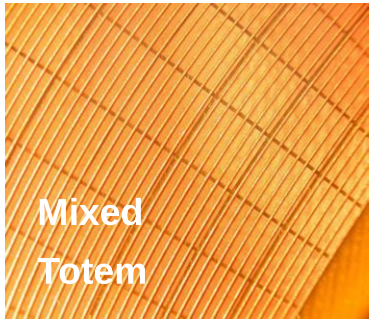


Full decupling of the charge ampification structure from the charge collection and readout structure.

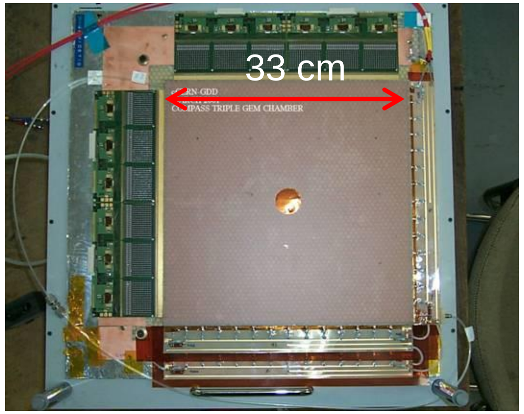
Both structures can be optimized independently !



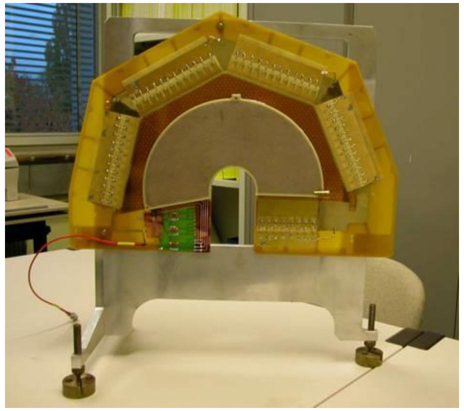




A. Bressan et al, Nucl. Instr. and Meth. A425(1999)254



Compass

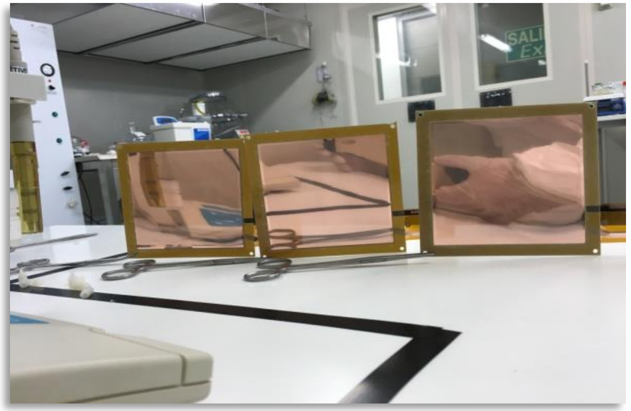


Totem

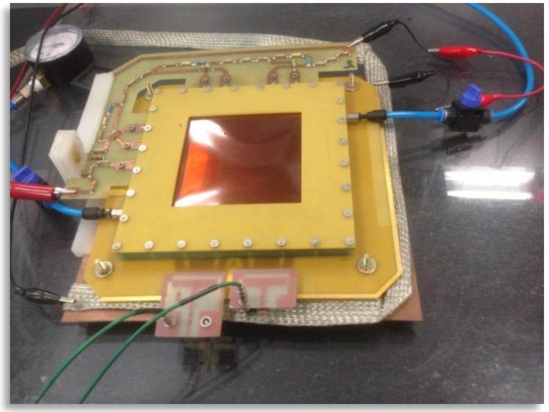
Both detectors use three GEM foils in cascade for amplification to reduce discharge probability by reducing field strenght.

ACTIVITIES CARRIED OUT WITH 10cmx10 cm GEMS AT OUR UNIVERSITY

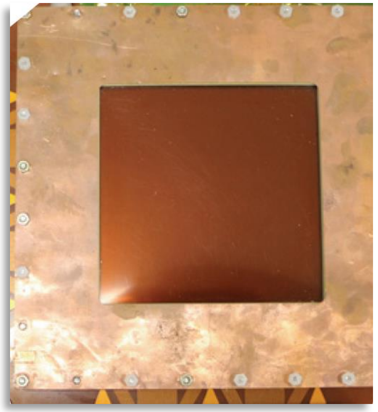
- Firts 2 GEM Kits, Assembled @ Uniandes Clean Room



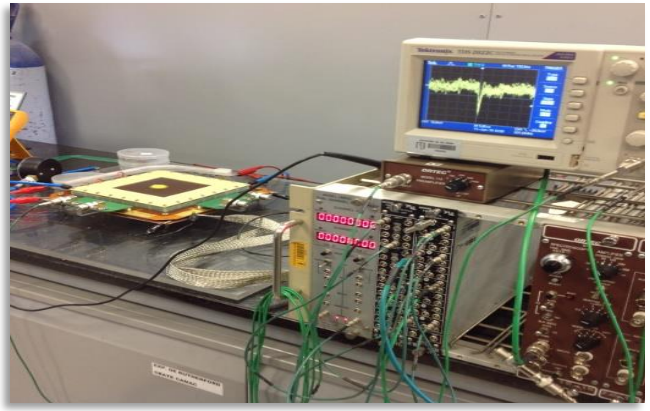
- We use Ar 75 % CO_2 25% as main gas mixture. We have access to other mixtures



- Grounding improvements

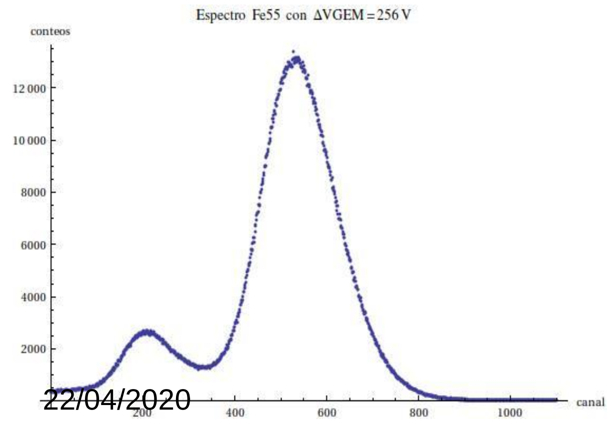


Tested GEMs with ^{55}Fe source

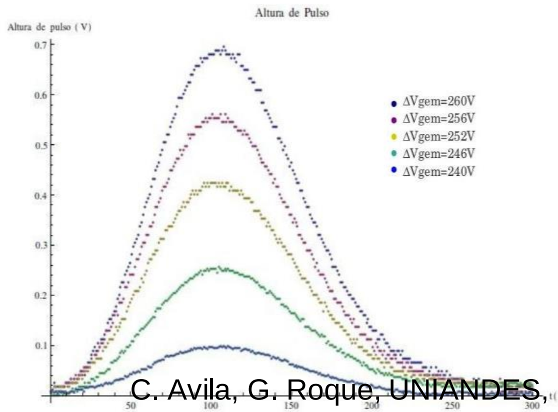


GEM performance tests performed with all channels short circuited.

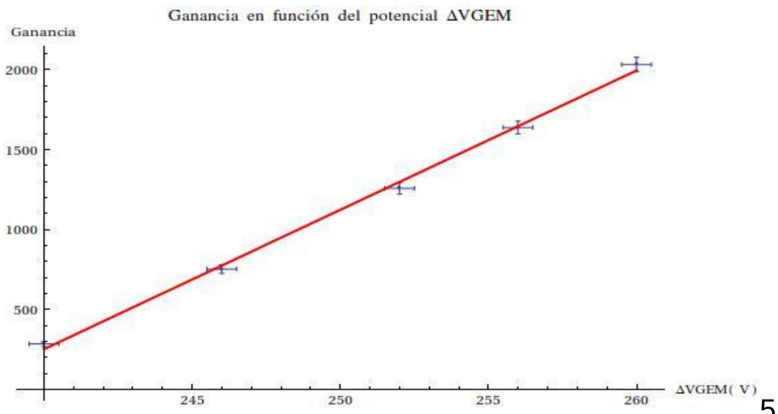
Measured ^{55}Fe Spectrum



Gain as function of ΔV_{GEM}



Gain Linearity as function of ΔV_{GEM}



MUON TELESCOPE TO MEASURE MUON FLUX THROUGH MONSERRATE HILL

Monserrate Hill at 1.1 km for University Campus

Scan muon flux through cells near top of the Hill and normalize to open sky flux.

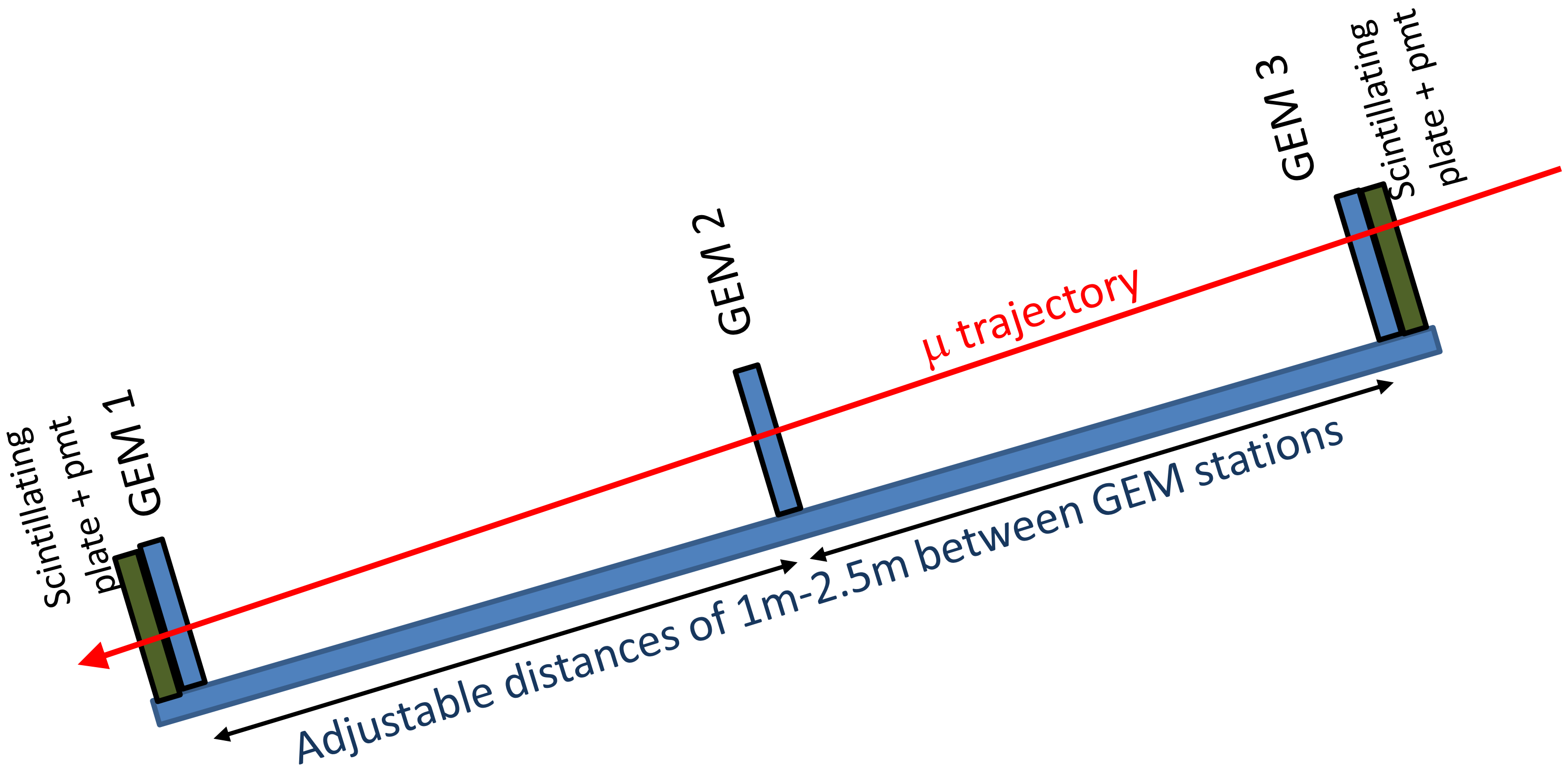
Four 25cmx25 cmX 1cm scintillator blocks readout with standrad pmts

Aim:

- To understand detector setup details, sources of noise and logistics: effect of temperature gradient between day and night, vibrations due to wind, protection against rain, etc.
- Measure muon flux at open sky at ecuador level 2640 m asl.
- Make estimates of average material density of Monserrate hill near its top.
- Compare measurements to CORSIKA Simulation.

OUR PLAN WITH GEM DETECTORS

PHASE 1 (within a year): Assemble a Muon Telescope with 3 GEM stations



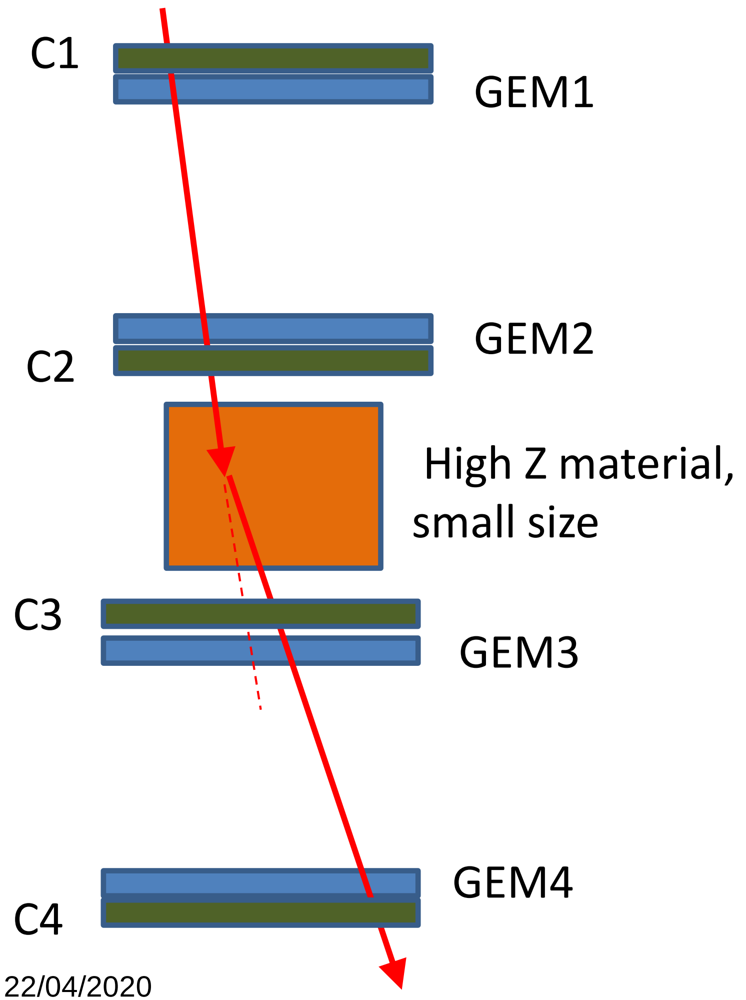
It might need at least 6 months of data taking for scanning the top part of Monserrate Hill.

DAQ REQUIREMENTS:

- Trigger + timing with scintillation plates
- Readout of the (x,y) coordinates of each of the 3 GEM stations. Each GEM having 256 channels in x and 256 channels in y. Total of 1536 channels.
- DAQ rate < 200 HZ
- Integrate with other external devices: Temperature, humidity, HV, current.. Measurements.
- DAQ software for monitoring and data storage.
- Provisions for gas feeding and recirculation between all the GEM stations.

OUR PLAN WITH GEM DETECTORS

PHASE 1 (within 1-2 years): Assemble a Muon Telescope with 4 GEM stations for muon scattering

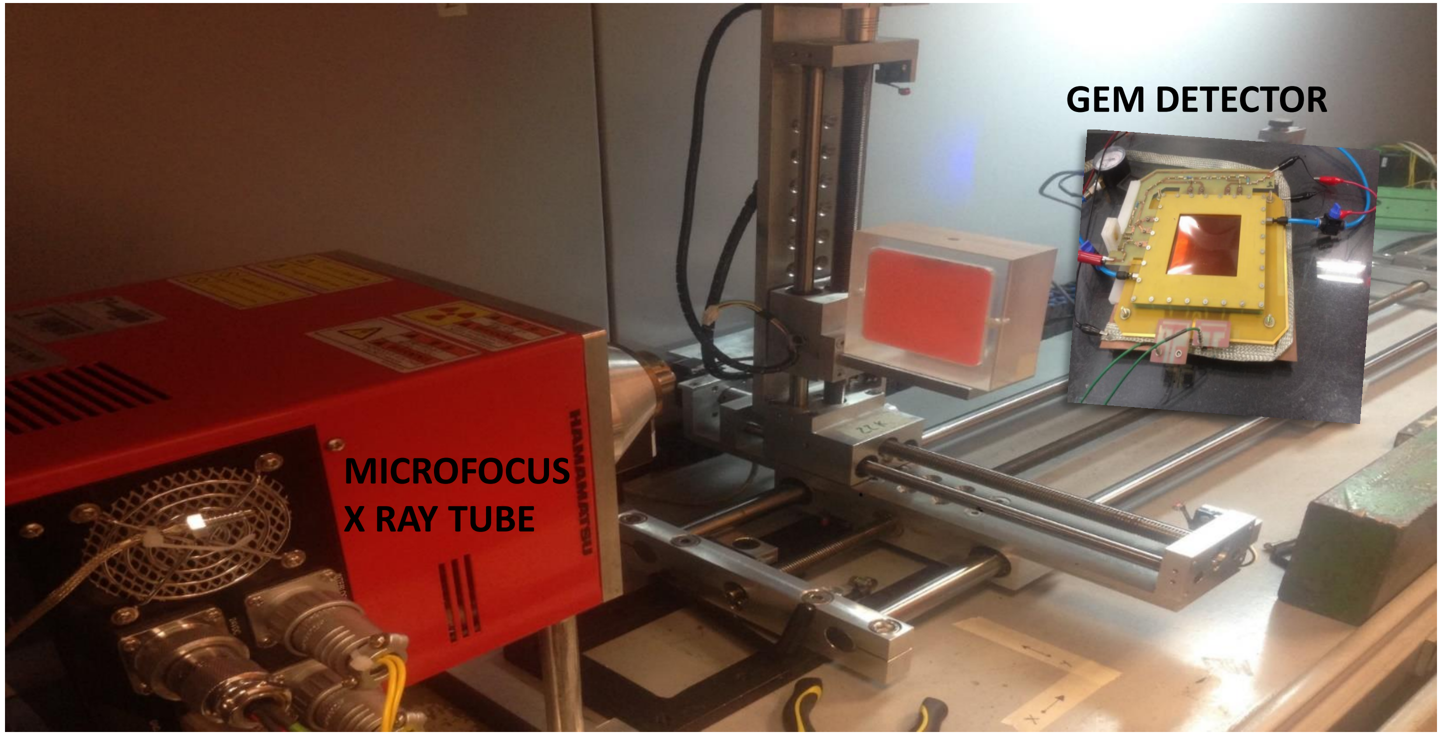


DAQ REQUIREMENTS:

- Trigger + timing with scintillation counters
- Readout of the (x,y) coordinates of each of the 4 GEM stations. Each GEM having 256 channels in x and 256 channels in y. Total of 2048 channels.
- DAQ rate < 200 HZ
- Integrate with other external devices: HV, current.. Measurements.
- DAQ software for monitoring and data storage.
- Provisions for gas feeding and recirculation between all the GEM stations.

OUR PLAN WITH GEM DETECTORS

PHASE 2 (within 1-2 years): Assemble a GEM detector for X-ray imaging



DAQ REQUIREMENTS:

- Need only one GEM detector
- **DAQ rate ~ MHZ**
- Integrate with other external devices: HV, current.. Measurements.
- DAQ software for monitoring and data storage and integrate to CT software.

CONCLUDING REMARKS

- Gaseous radiation detectors play important role in triggering and track reconstruction of muons in LHC experiments
- Large areas and different geometries
- High efficcient and high rate capabilities.
- Useful for many interdisciplinary applications

Thank you for your Attention