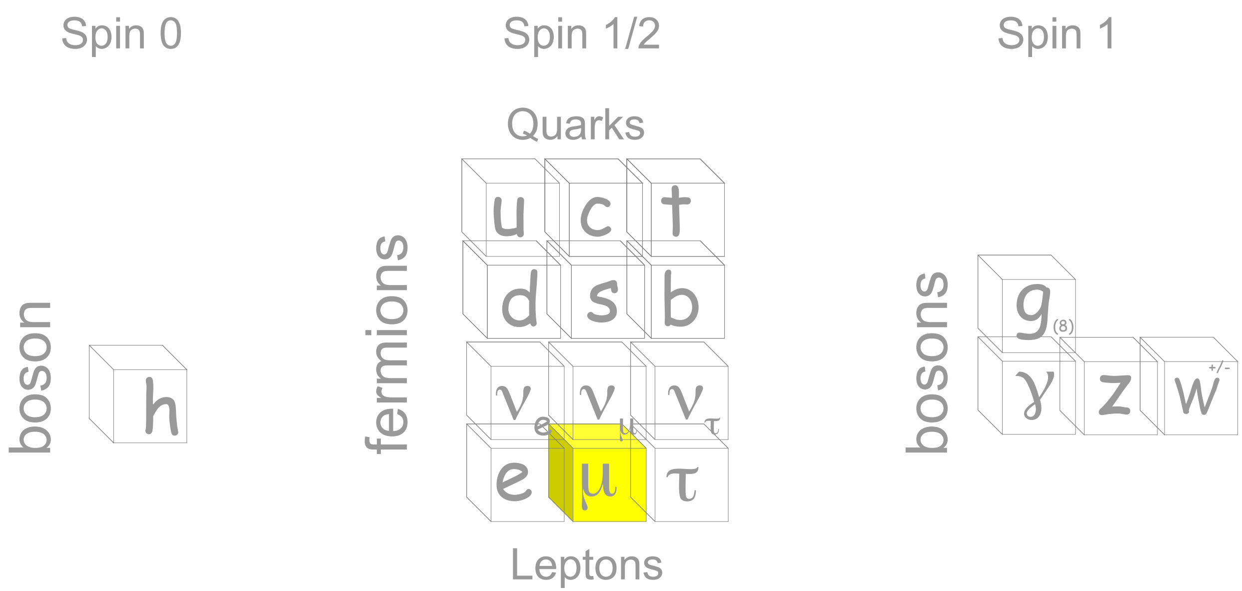


Carl David Anderson
(1905-1991)

Phys. Rev. 51 (1937) 884

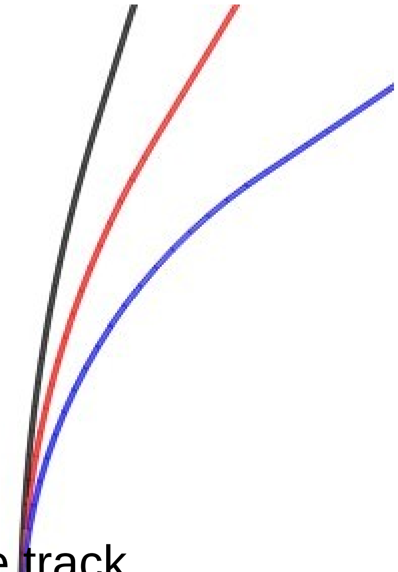
The experimental fact that penetrating particles occur both with positive and negative charges suggests that they might be created in pairs by photons, and that they might be represented as higher mass states of ordinary electrons.

Independent evidence indicating the existence of particles of a new type has already been found, based on range, curvature and ionization relations; for example, Figs. 12 and 13 of our previous publication.[1] In particular the strongly ionizing particle of Fig. 13 cannot readily be explained except in terms of a particle of e/m greater than that of a proton. The large value of e/m apparently is not due to an e greater than the electronic charge since above the plate the particle ionizes imperceptibly differently from a fast electron, whereas below the plate its ionization definitely exceeds that of an electron of the same curvature in the magnetic field; the effects, however, are understandable on the assumption that the particle's mass is greater than that of a free electron. We should like to suggest, merely as a possibility, that the strongly ionizing particles of the type of Fig. 13, although they occur predominantly with positive charge, may be related with the penetrating group above.

Observation

Muon discovery

B ⊗



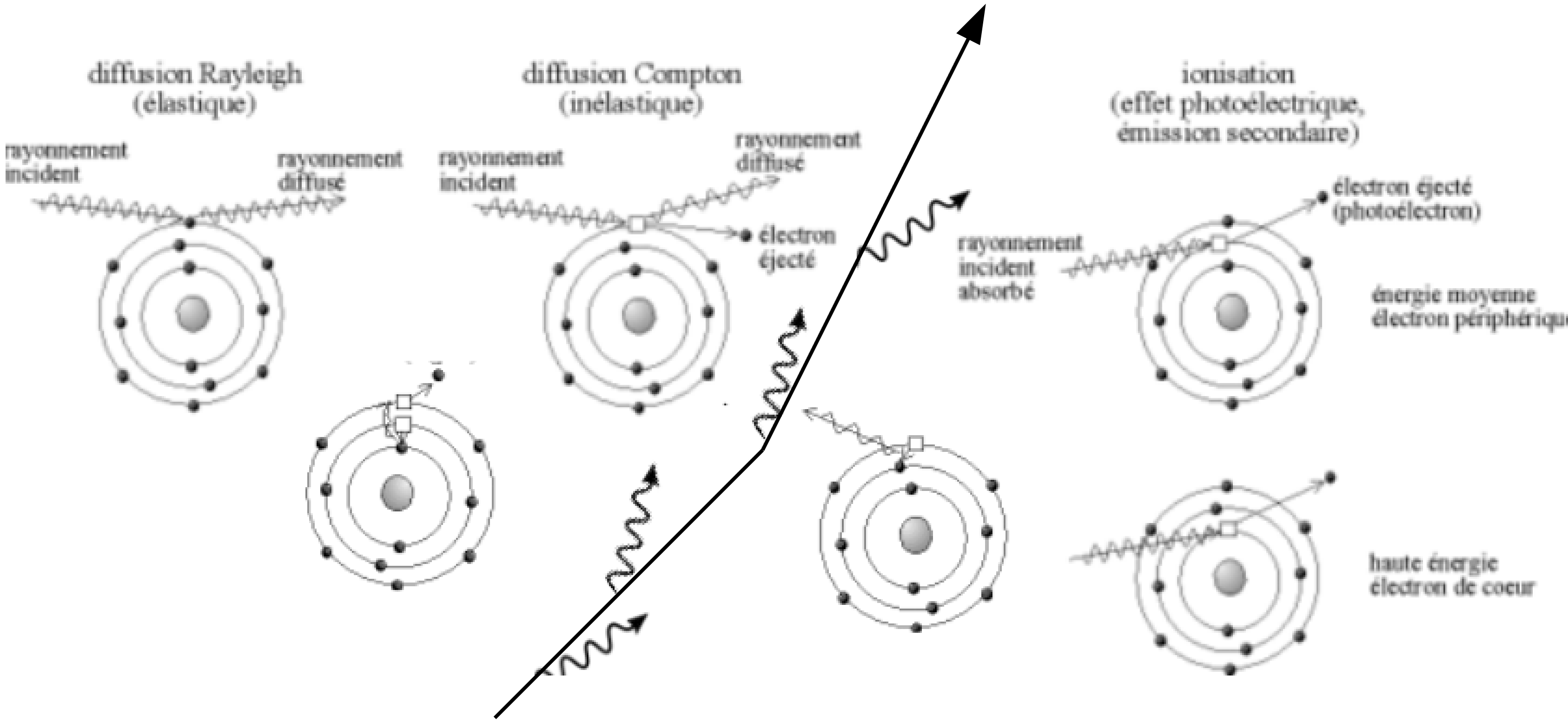
For a given B and P
the black track corresponds
to a heavier object than blue track.
So the red track correspond to an intermediate
mass object

Example:proton,muon,electron

Interaction Particle-Matter

Charged particle trajectory through matter

- Many different mechanisms occur
- Marco Delmastro
  - Particle interactions in particle detectors



Interaction Particle-Matter

Particles are detected by their interactions with the traversed medium

- Electromagnetic, strong & weak interactions (and gravity...must be forgotten)

Mainly Electromagnetic mechanism is used in our detectors

- Ionisation (dE/dx)
- Bremsstrahlung radiation
- Cherenkov radiation
- Transition radiation

Perturbations

- Landau fluctuations
- Multiple scattering
- Pairs creation (e+/e-)

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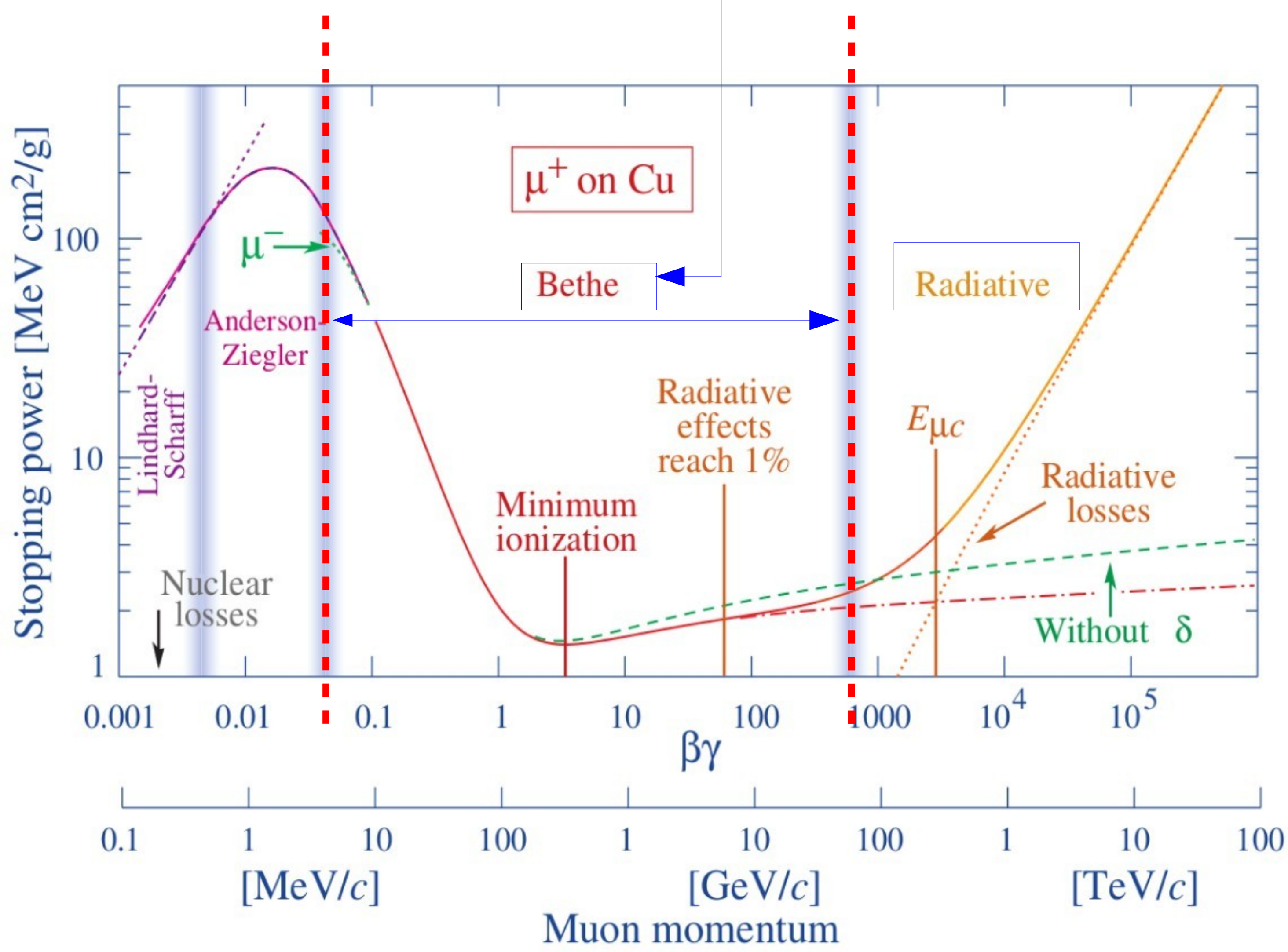
Interaction Particle-Matter

Marco Delmastro
(in particular for T_{max},I,K)

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



Interaction Particle-Matter

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Remarks:

$$\frac{dE}{dx}\ \alpha\ \frac{1}{\beta^2}\ln(\beta^2\gamma^2)$$

Interaction Particle-Matter

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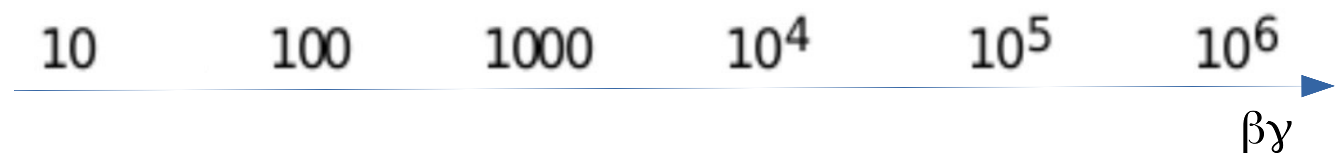
Remarks:

$$\frac{dE}{dx} \; \alpha \; \frac{1}{\beta^2} \ln(\beta^2 \gamma^2)$$

$$\beta\gamma = \frac{P}{m}$$



Interaction Particle-Matter

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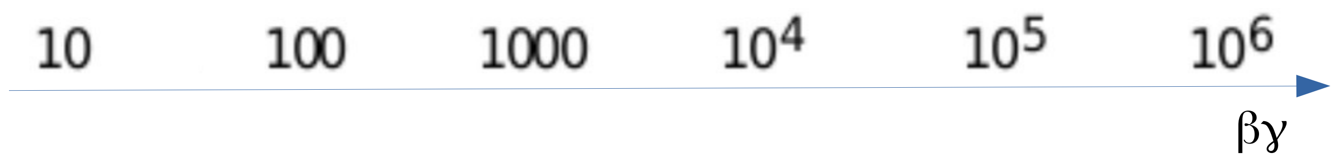
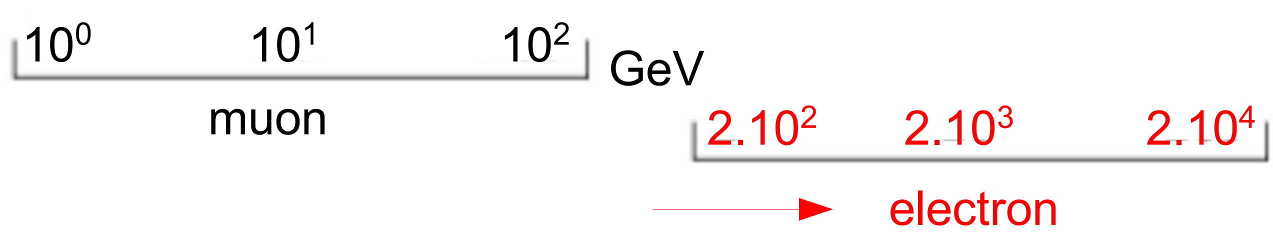


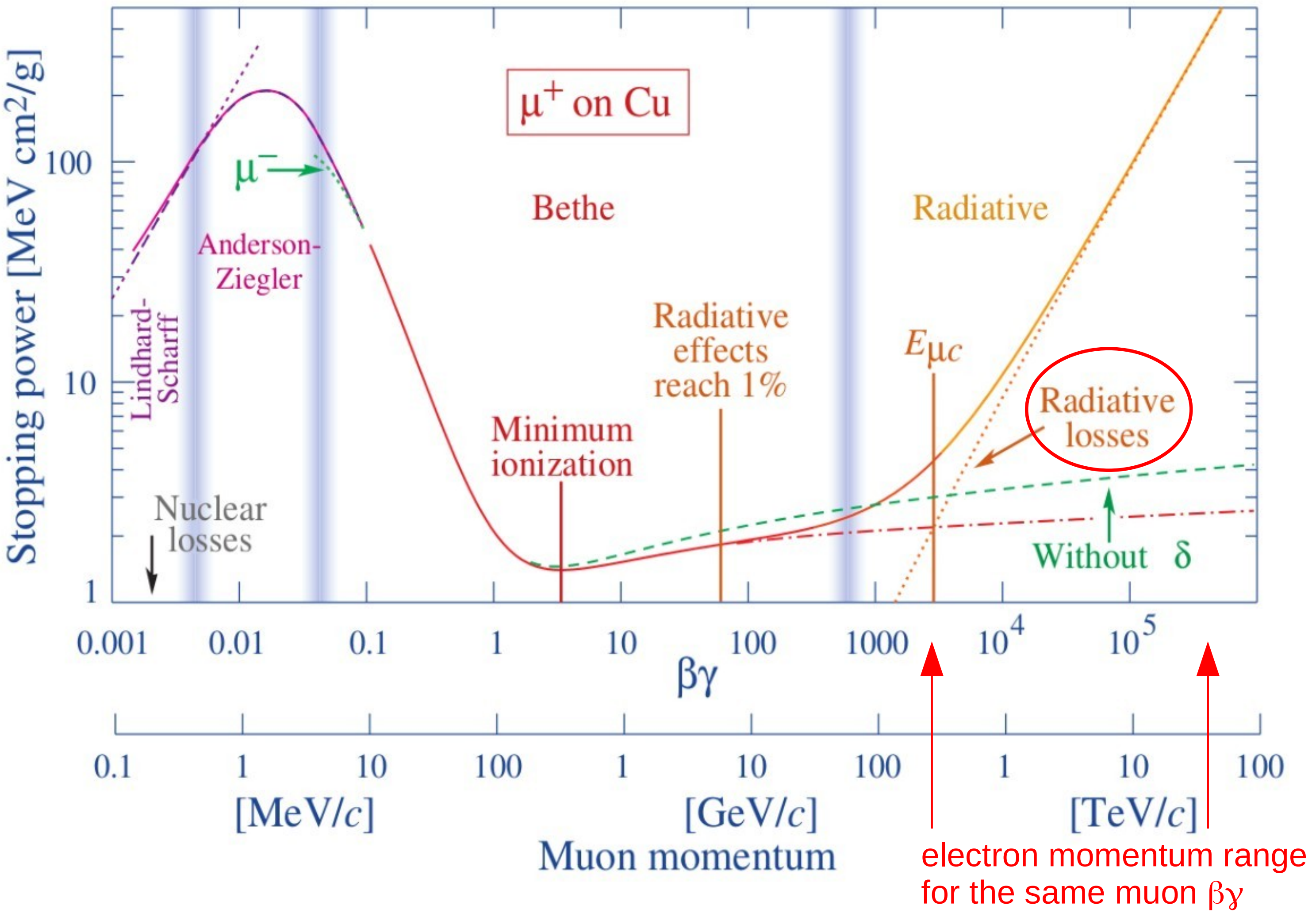
$\beta\gamma \longrightarrow$ muon



$$\frac{P}{m_\mu} * 207 = \frac{P}{m_e}$$

Interaction Particle-Matter

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



Interaction Particle-Matter

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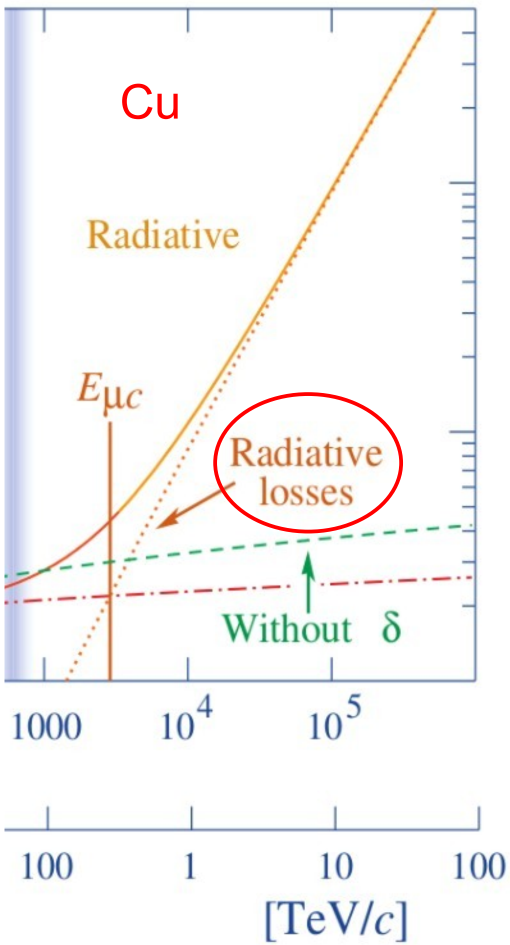
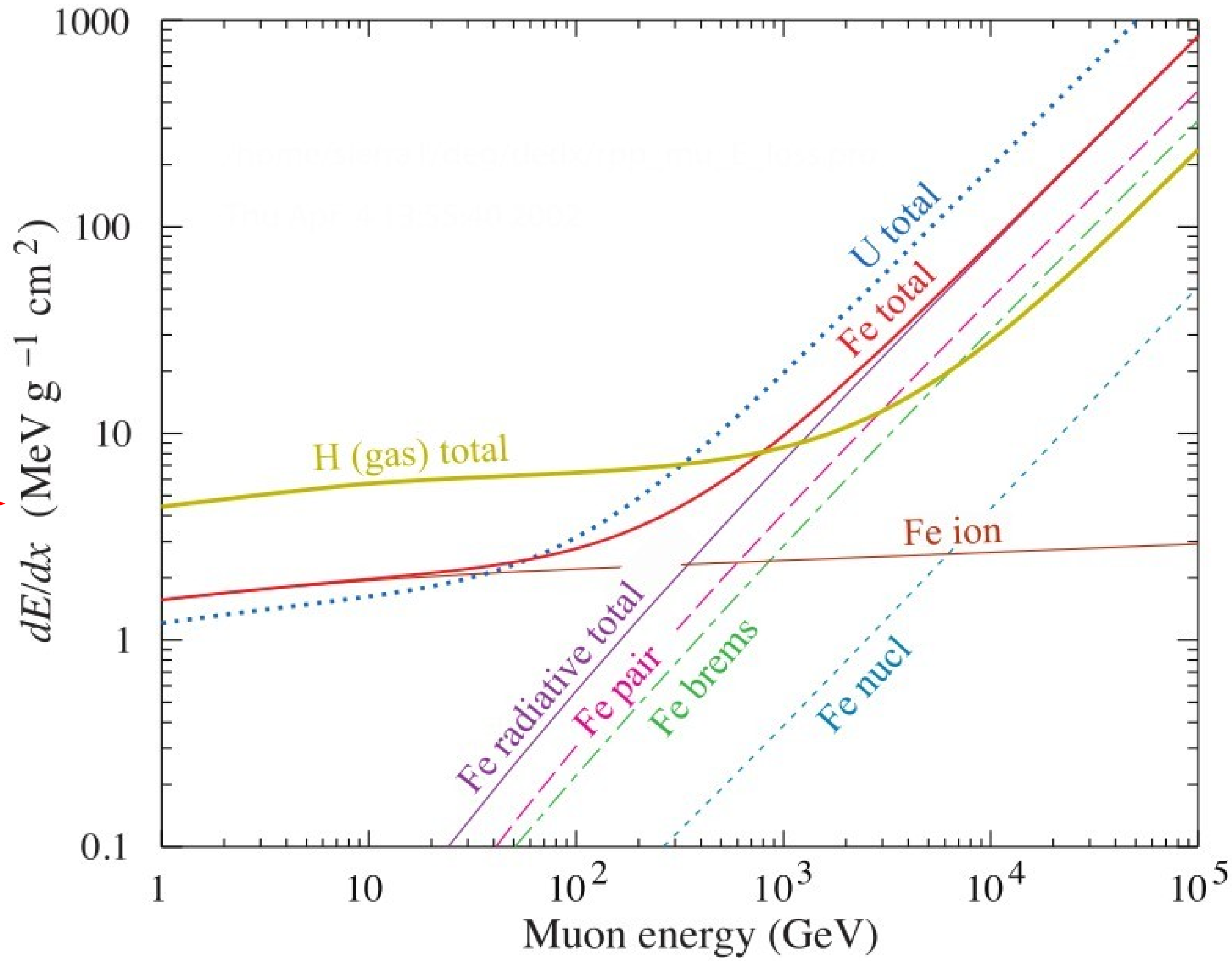




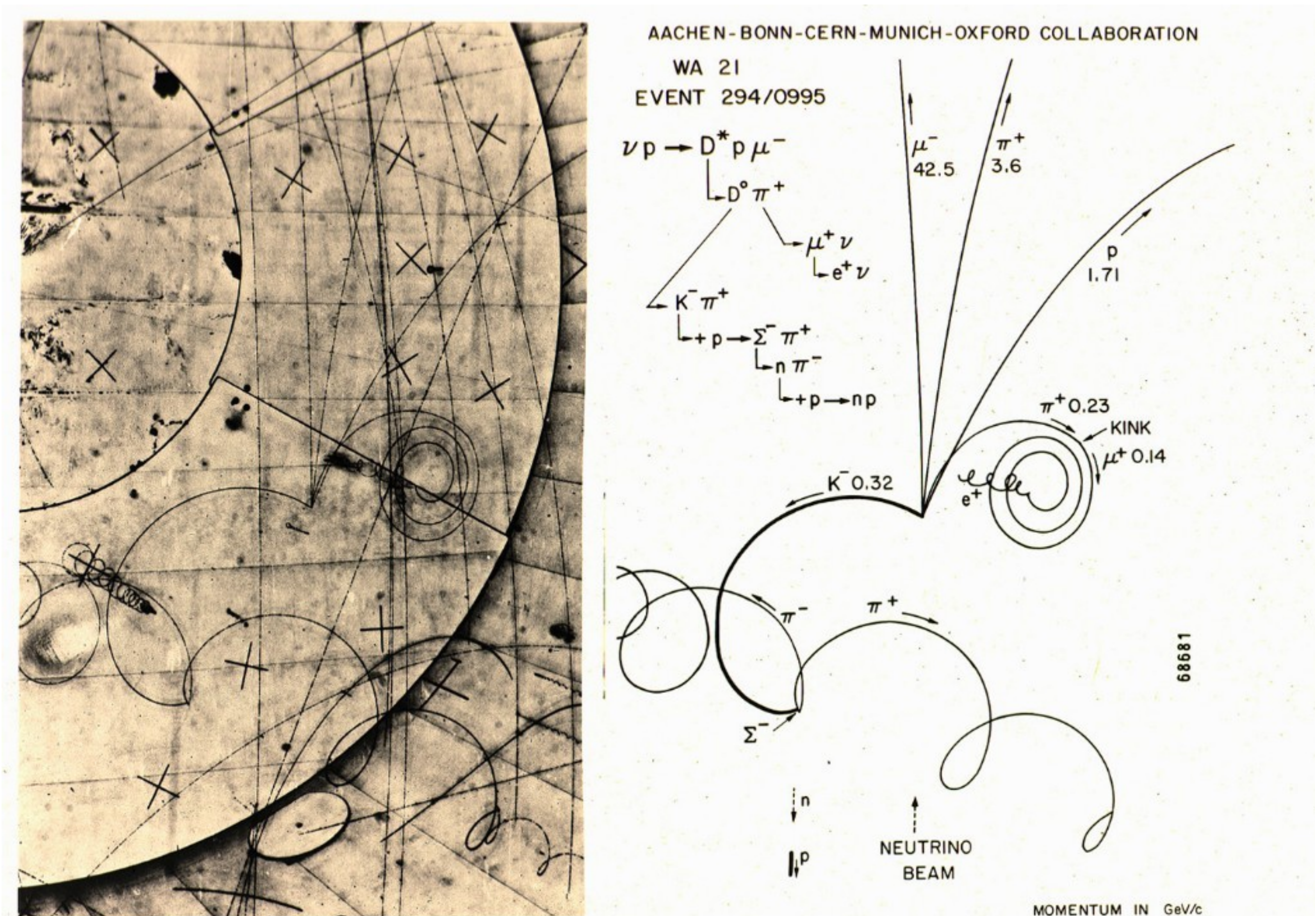
Detectors

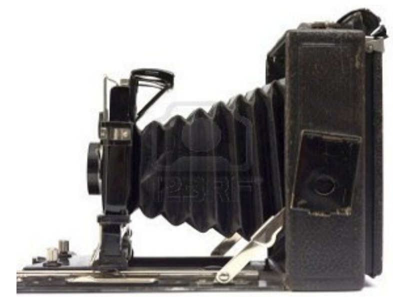
Detectors

Definition:
a detector is an instrument which is used to keep a track of a phenomenon
- -trace in the sand
  - (sand is the detector)
- -visible light
  - (eyes are the detectors)

L'œil était dans la tombe

et regardait Caïn





analogical

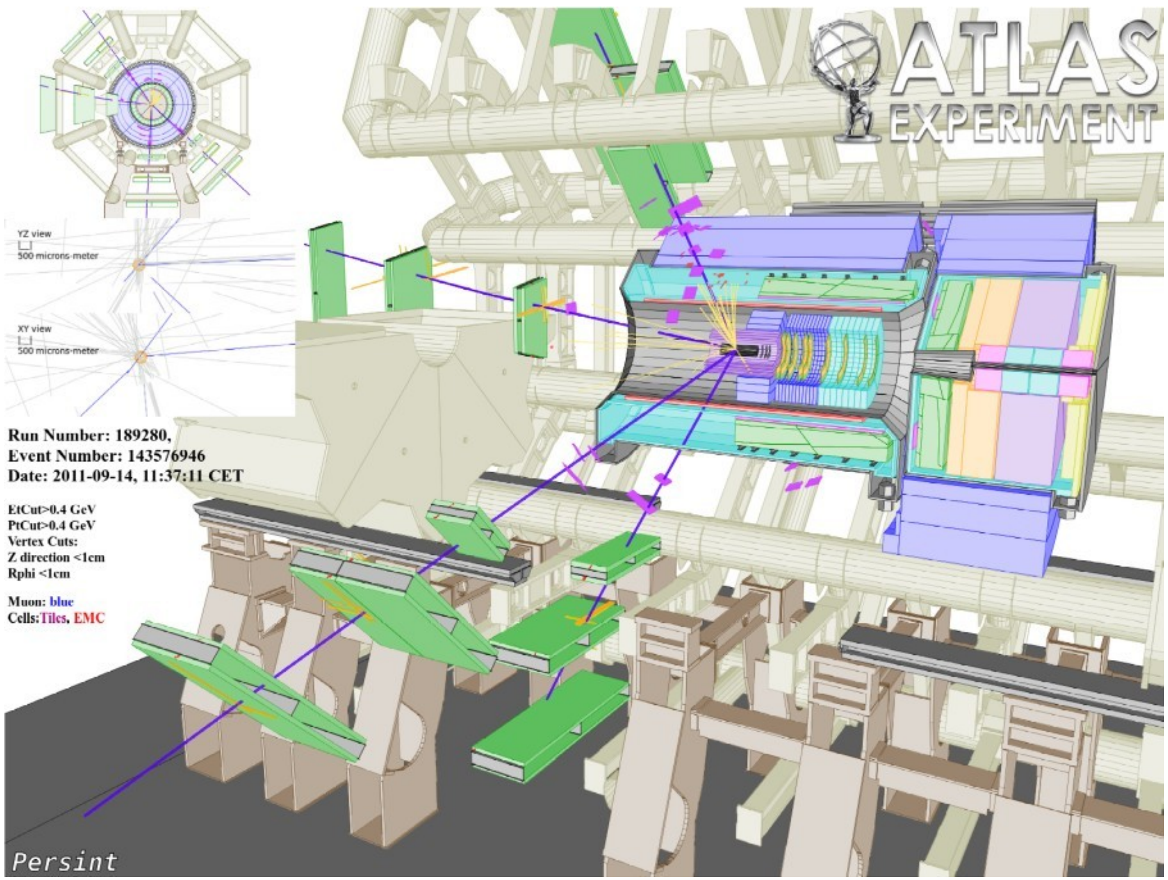
Bubble chambers

Detectors

Different types of detectors must be used
to understand and to keep the track of a phenomenon:

- -different types of particles,
- -different way to interact with matter,
- -fast detectors,
- -precise detectors (spatially)
- -...

One big detectors is made by many sub-detectors with precise tasks



Digital

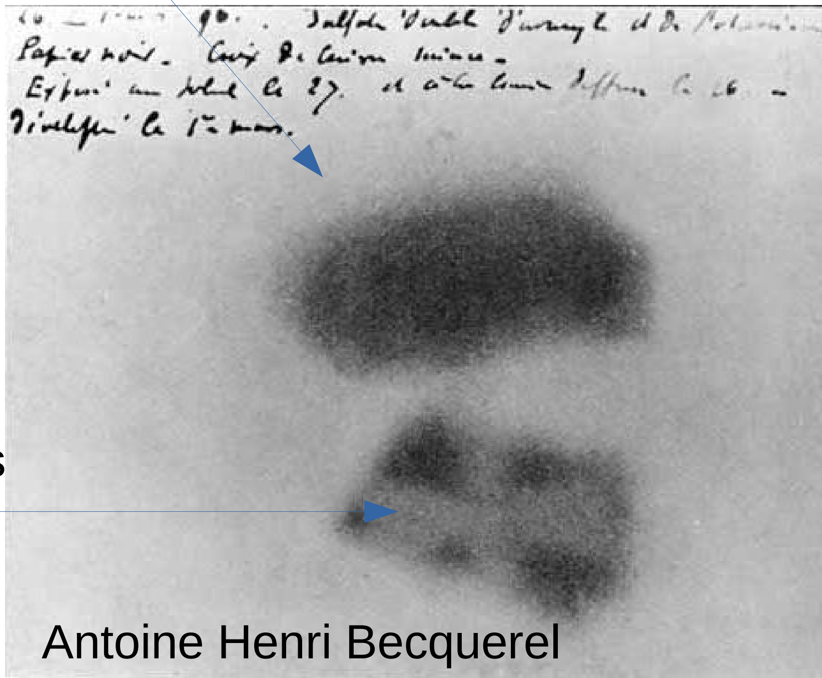
Detectors

Different types

- Gaseous
  - Geiger counter, wires chamber (TPC), Micro-Megas
- Liquid
  - Bubbles chamber
- Solid
  - Scintillator, Silicon, Photographic plates
- Mix

Principle:Ionisation

image of a copper cross

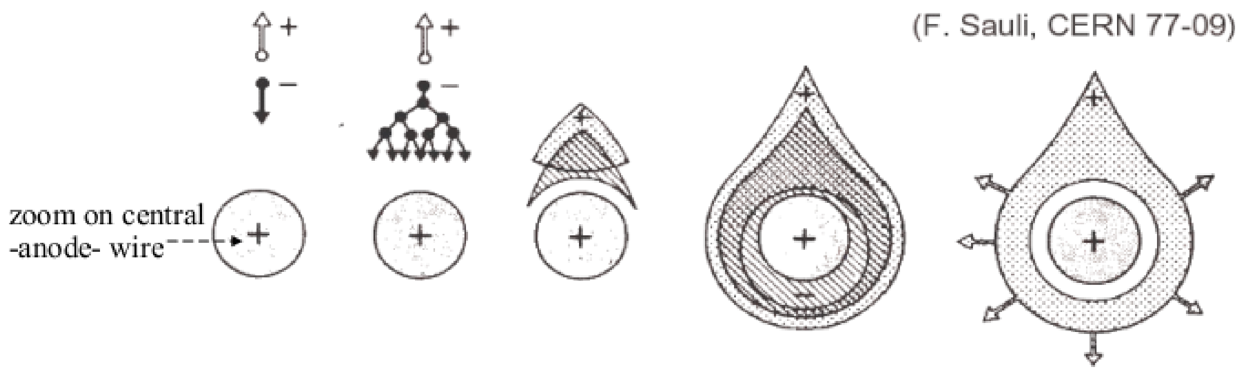


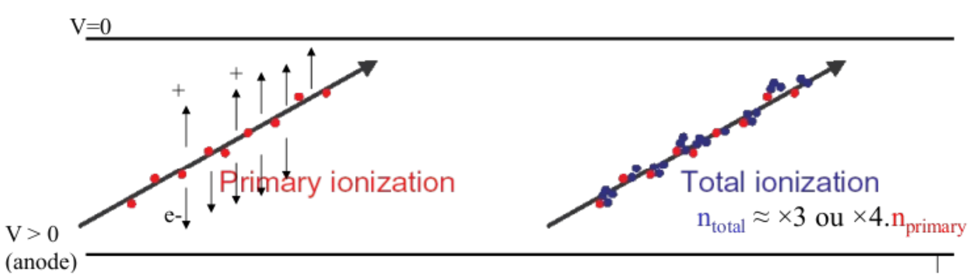
Antoine Henri Becquerel

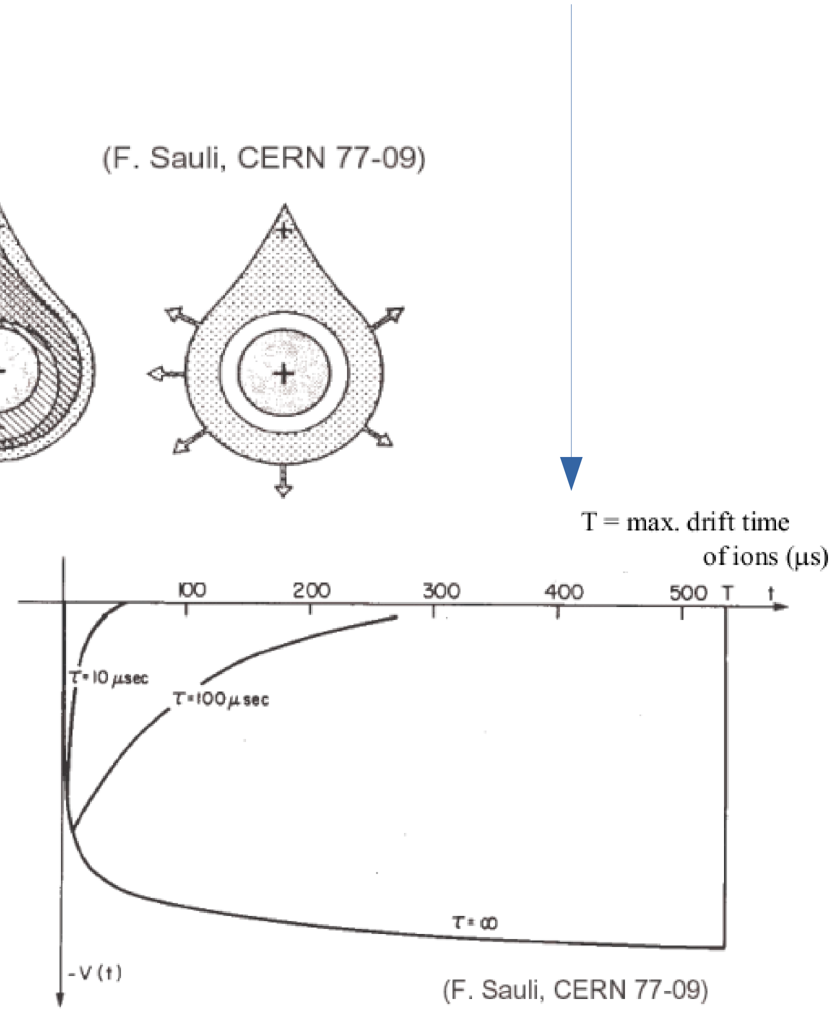
Detectors (Gaseous)

Principle:

- Primary and secondary ionisation not enough for a measurement
- Electric Field (high!) => Avalanche
  - Electric Field increase the number of electrons
  - The drift of Ions induces a variation of the potential, which is measured



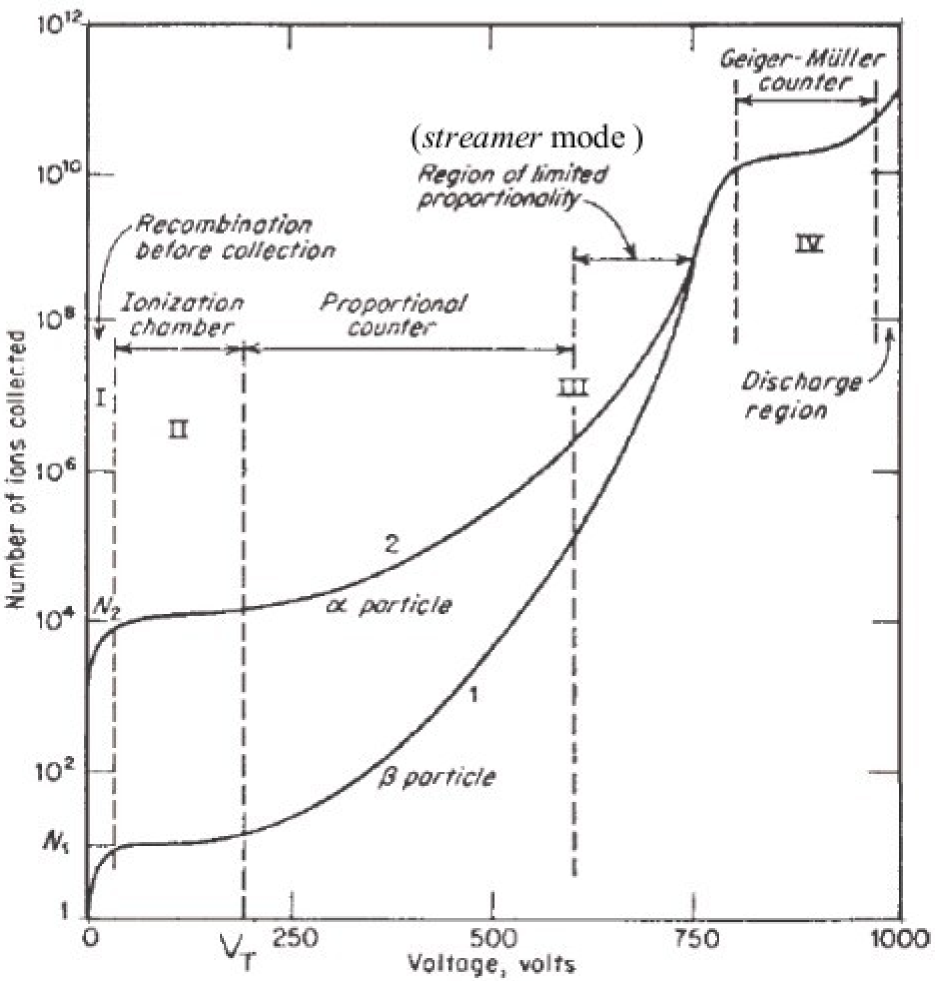




Detectors (Gaseous)

Gain vs Electric field

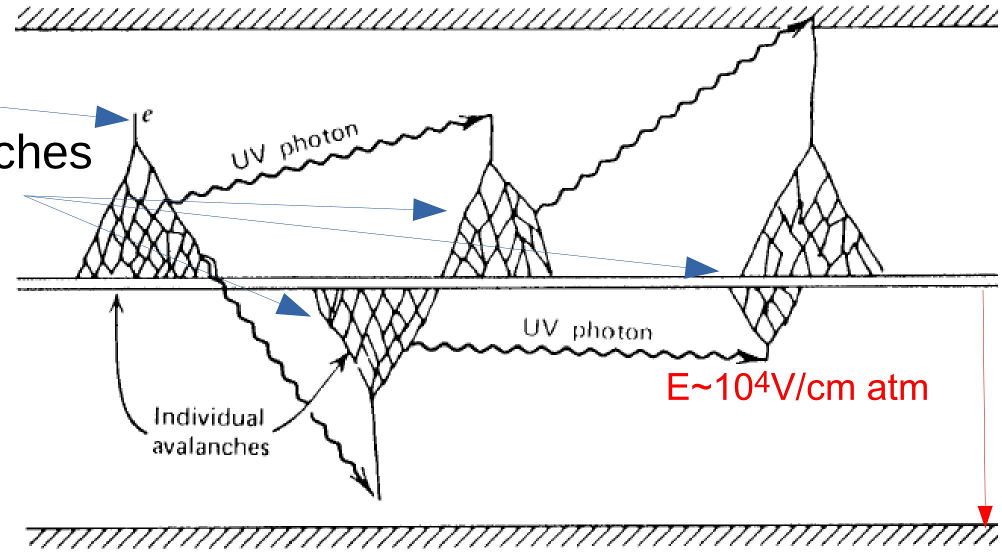
- I Potential too weak, pair recombination
- II Ionisation Chamber: no amplification
- IIIa Proportional mode, signal amplification
  - Proportional to ionisation.
  - Gain: 10^4 to 10^5
- IIIb Streamer mode, secondary avalanches
  - Need "quencher" (CH_4,CO_2,...)
- IV Geiger-Muller mode



Remark: no electric field => no electrons acceleration: recombination

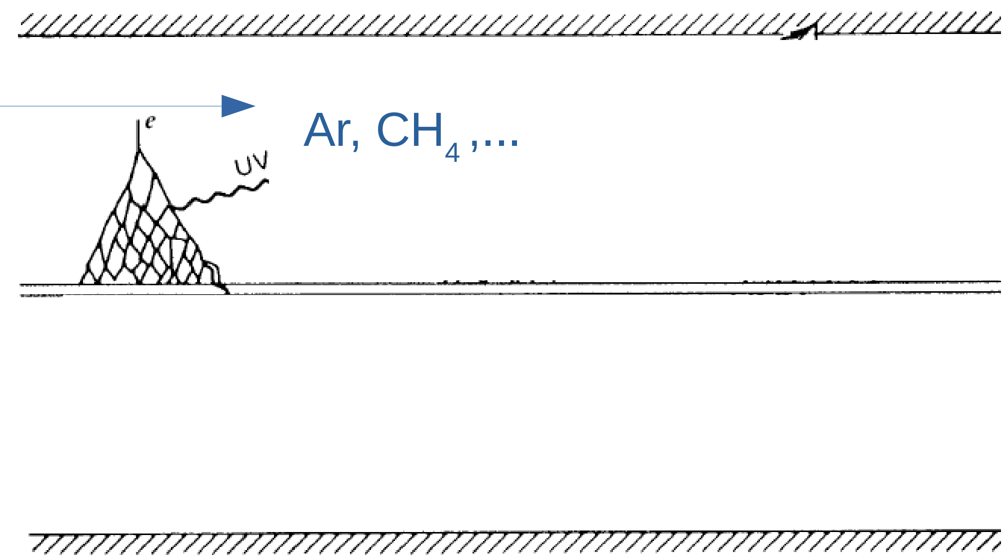
Detectors (Gaseous)

Primary electron + 10^4V/cm → Avalanche
UV photons (from the avalanche) → many Avalanches

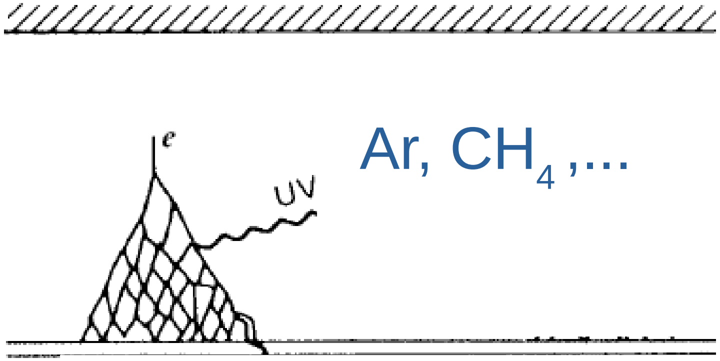


Spatial Resolution

- Avoid secondary avalanches
- Photons absorption (UV production)
- Noble gaseous (He,Ar,...)



Detectors (Gaseous)



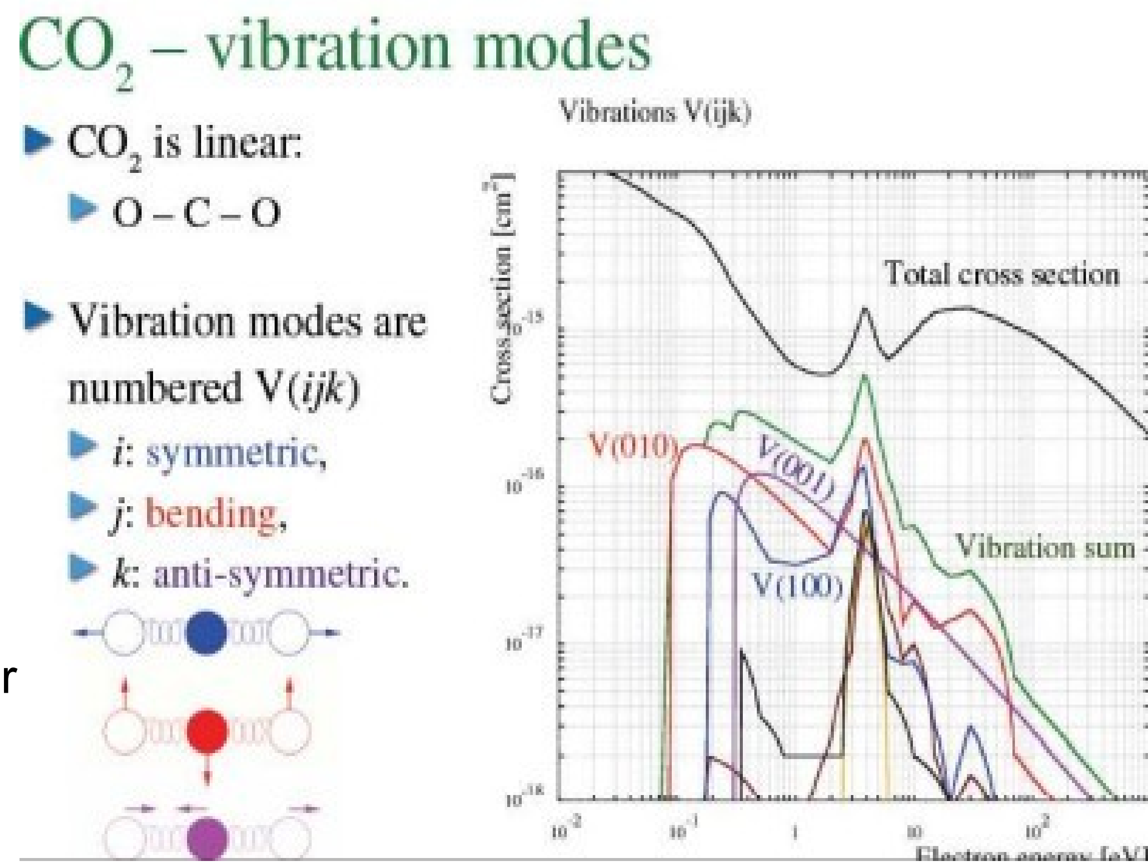
Ar, CH_4,...

Spatial Resolution

- Avoid secondary avalanches
- Photons absorption (UV production)
- Noble gaseous (He,Ar,...)

"Quencher"

- Polyatomic gaseous:
  - ex: CH_4,C_4H_{10},CO_2
- Photons absorption by vibration or molecule rotation
- No easy solution: should be tested
  - Ex: 70%Ar, 29.6%C_4H_{10} , 0.4% Fr



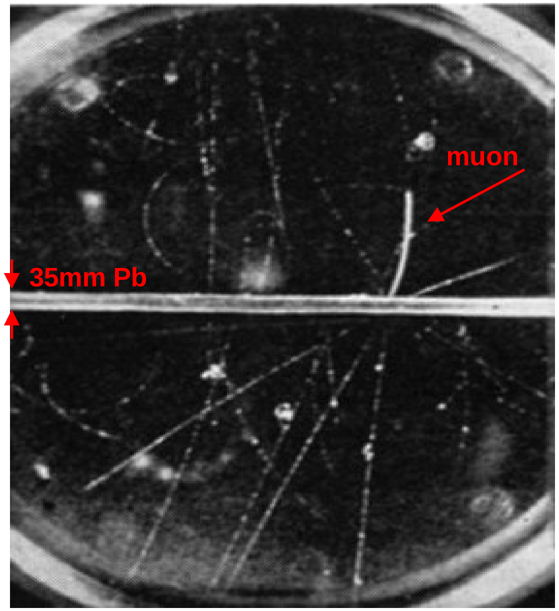
R.Veenhof (Garfield) http://cern.ch/garfieldpp

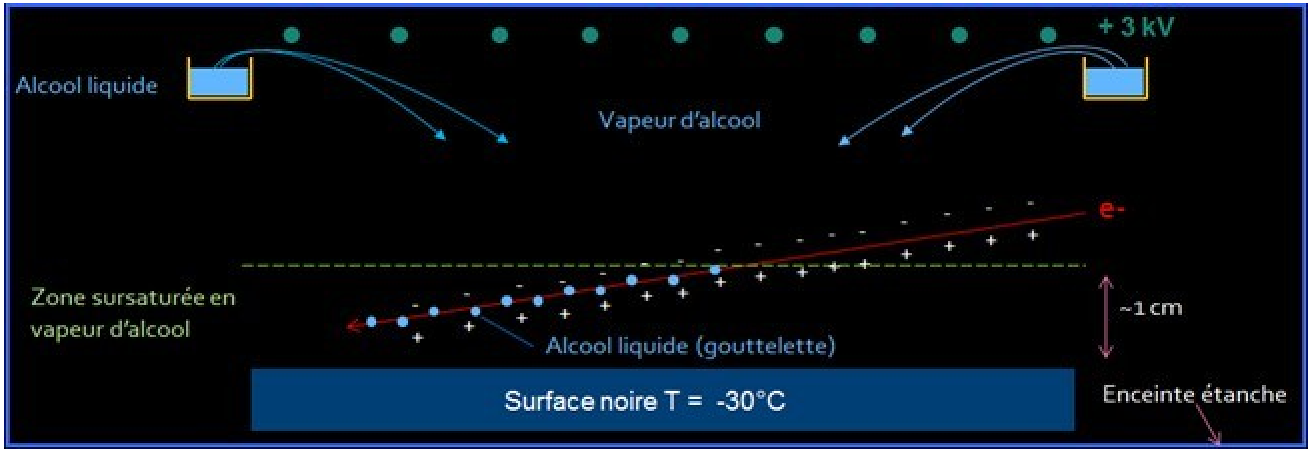
Detectors

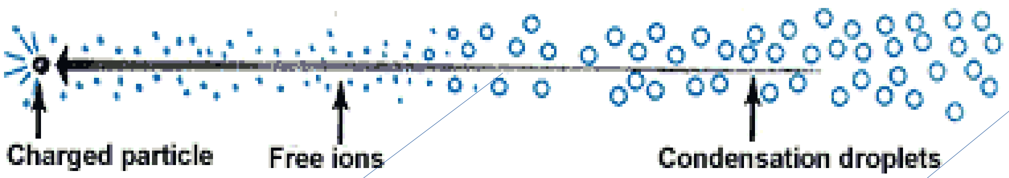
Clouds Chamber: Gaseous/Liquid

- C.T. R. Wilson 1911
- C.Anderson positron discovery 1932

Muon discovery 1936





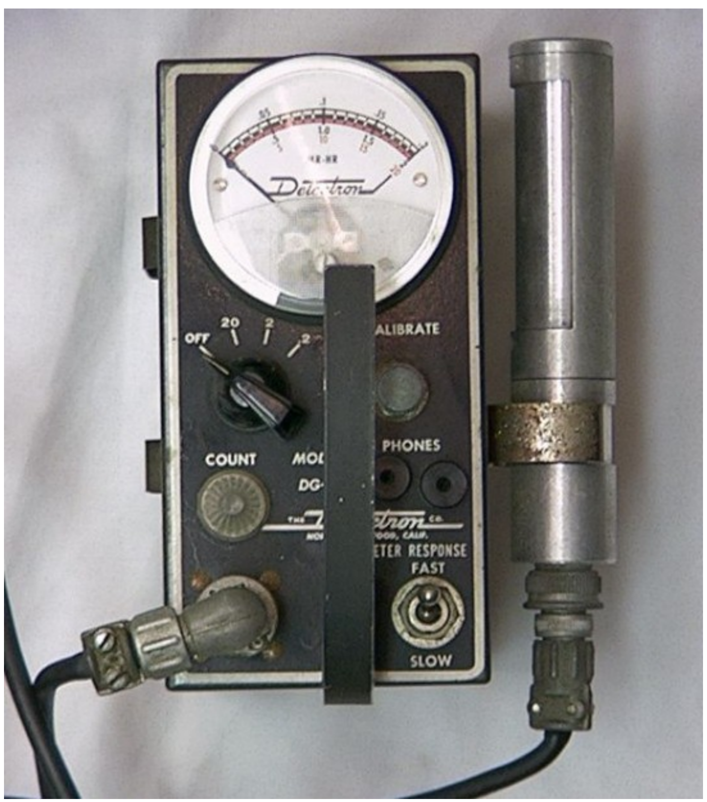


Broken cloud chamber
Physicist sad!

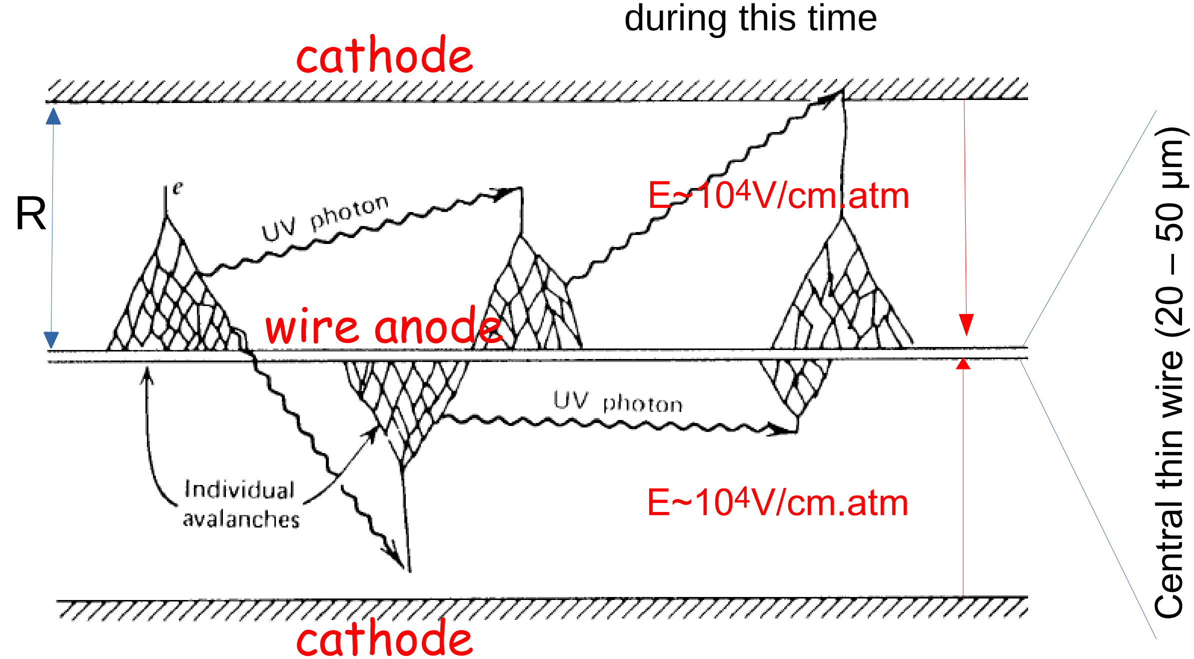
Detectors(Gaseous)

Geiger Counter

- H.Geiger-Muller 1928
  - Detection: Alpha(He), Beta (e+/e-), Gamma(photon), Muons
  - Gaseous: He, Ne, Ag
  - Avalanche: $n = n_0 e^{\alpha(E)x}$ (α Townsend coeff. function E or R)
  - > 10^8 electrons: sparks!!!
  - Particles counting only:
    - no measurement : position,energy,...



Dead time ! 10 ms!!!
No signal detected
during this time



Detectors(Gaseous)

Muon

Geiger Counter

- Used as a Trigger device
  New Evidence for the Existence of a Particle of Mass Intermediate Between the Proton and Electron
  Phys. Rev. 52, 1003 – Published 1 November 1937

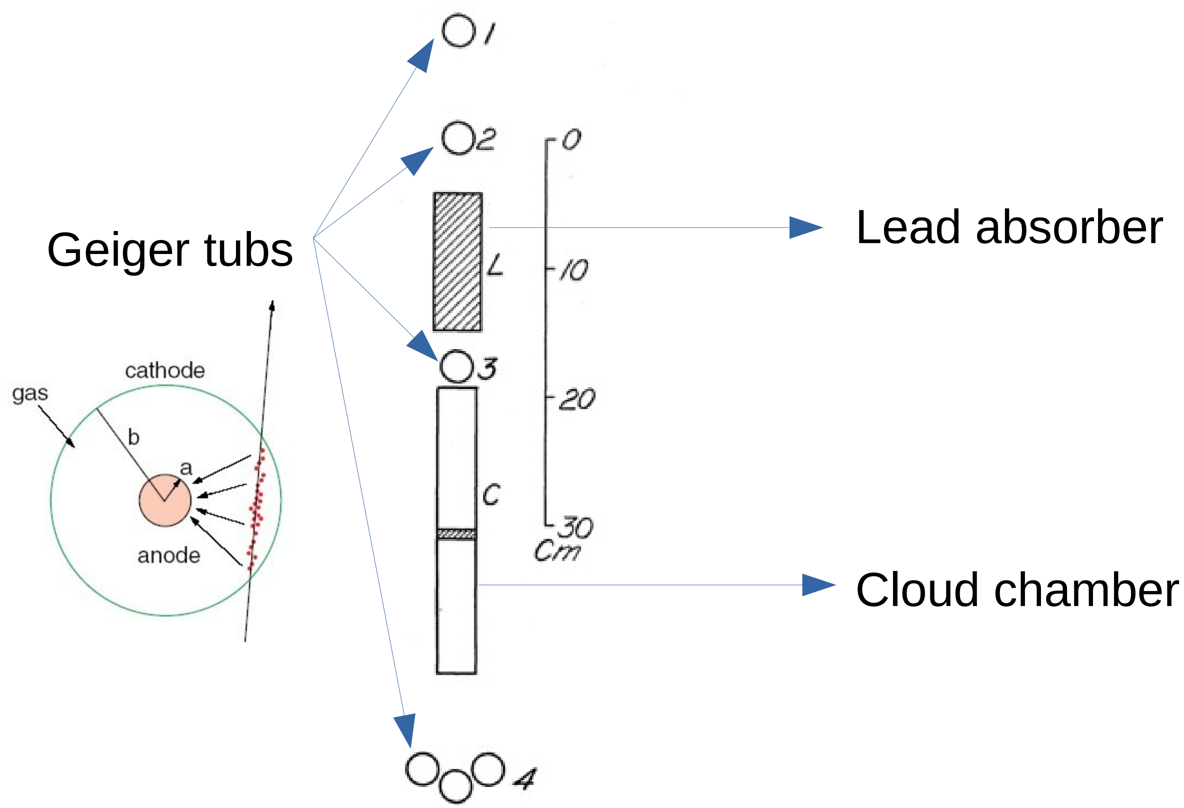


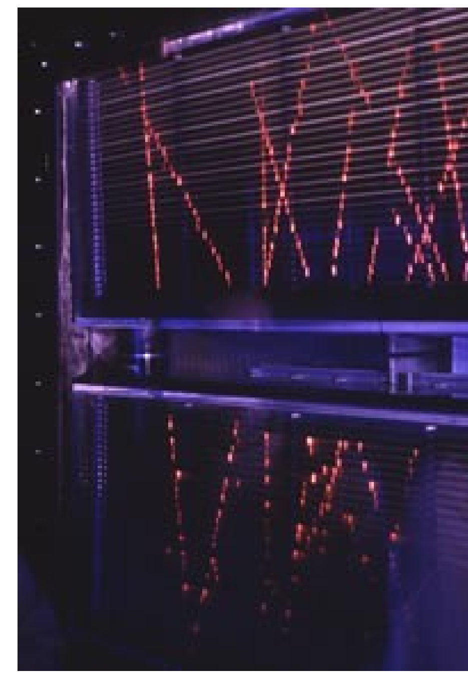
FIG. 1. Geometrical arrangement of apparatus.

Detectors(Gaseous)

Spark Chambers

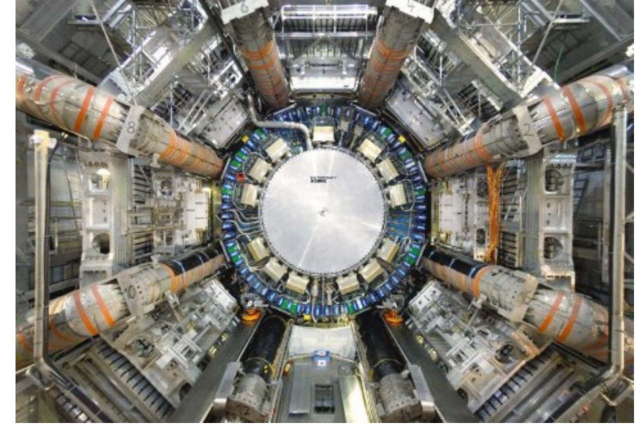
- Pairs of metal plates are connected to a HV ~10 kV creating a strong electrical field between the plates.
  Charged particles passing across the plates ionize the gas
  and create a conducting trace that leads to a spark between the two plates
  which is then photographed.

A spark chamber at the physics museum of the Sapienza University of Rome



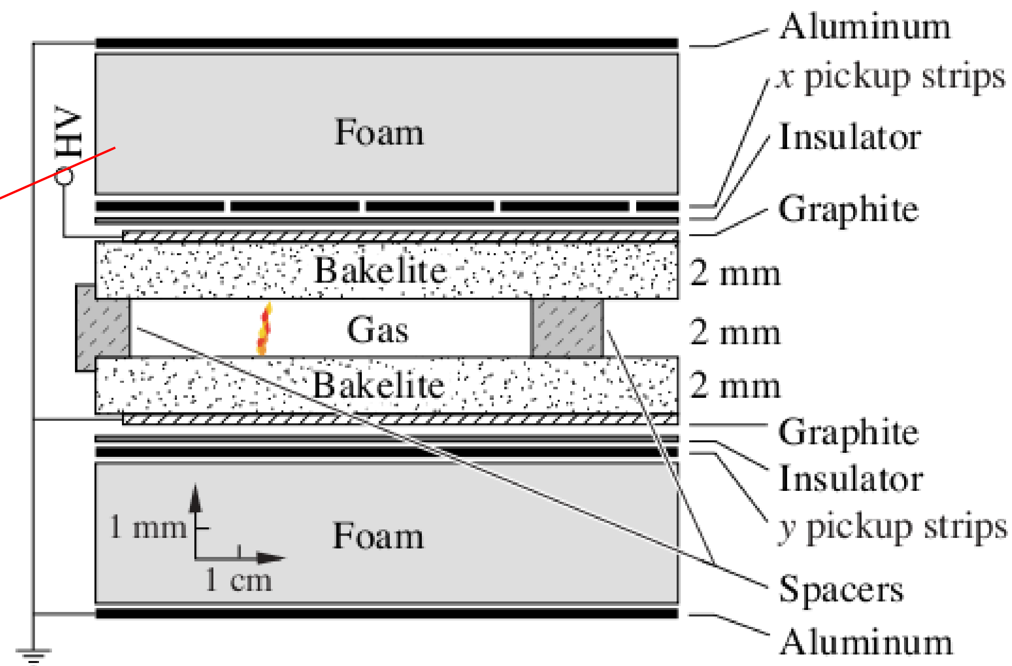
Remark:
HV applied 0,1 s à 1 μs
to avoid saturation

Detectors(Gaseous)



RPC: Resistive Plate Chamber

- ATLAS Muons spectrometer Trigger
- Time Resolution ~2ns!
- ~10KV between Bakelite plans
- Passage of the particle induced discharge (~ 300mV signal)
- Spatial resolution < ~1mm
- No wire !!!!
- Streamer (or avalanche) mode ATLAS/CMS



Detectors(Gaseous)

RPC: Resistive Plate Chamber

- ATLAS Muons spectrometer Trigger
- RPCs are robust detectors (no wire)
- The signal formation happens in the conversion gap as soon as the ionization electrons amplify and the avalanche develops. The signal is induced instantly on the readout strips placed on the outside of the resistive plates. RPCs are therefore fast detectors and achieve time resolutions in the ns range (or better)
- In standard RPCs the resistive plates are Bakelite with a bulk resistivity of ≈1010 Ohm/cm (CMS, ATLAS, Babar, …)
- The weak point of the RPCs is their rate limitation owing to the high bulk resistivity in the resistive plates, leading to local charging up, followed by a loss of efficiency.
- RPCs are considered safe up to rates of about a few kHZ/cm2