Signal formation in a TPC

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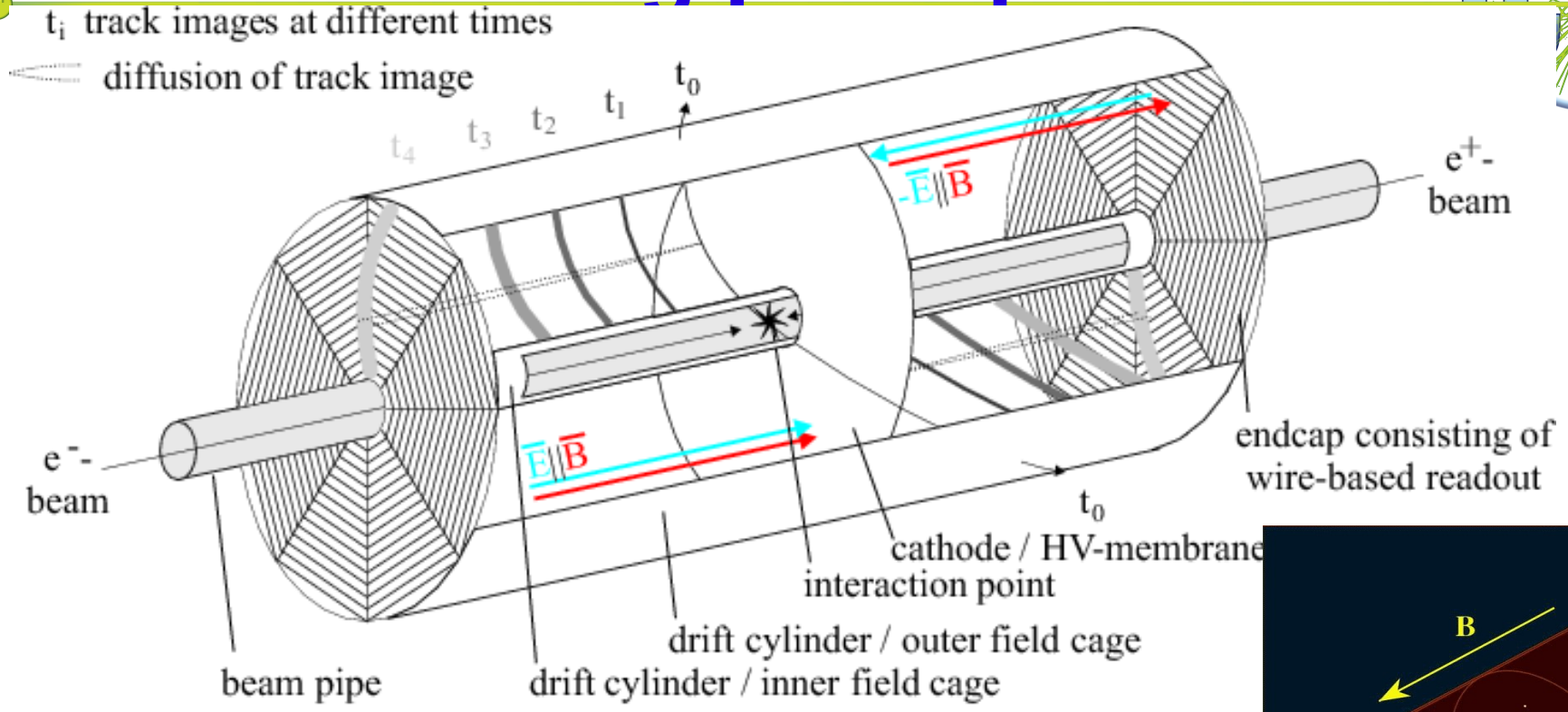
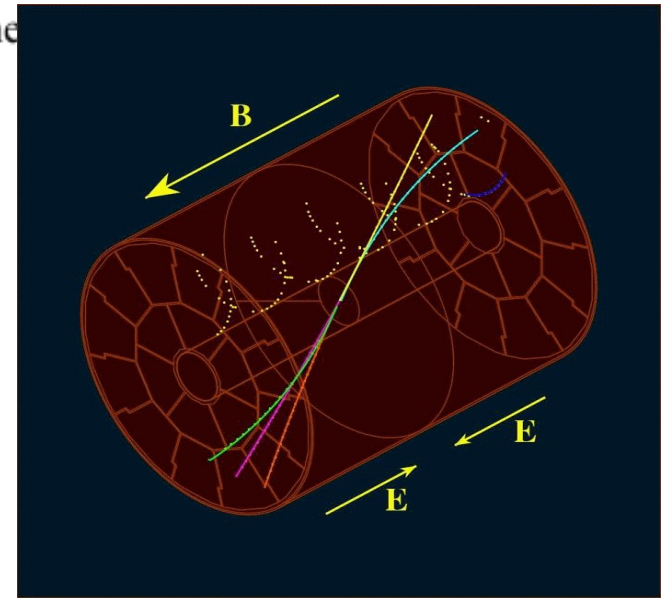
TPC – working principle





- Large gas filled volume
- Particles traversing the volume ionize the gas
- Electrons drift towards the endcaps
- Signal is amplified and generates a 2D picture
- Measuring drift time allows the reconstruction of 3rd dimension

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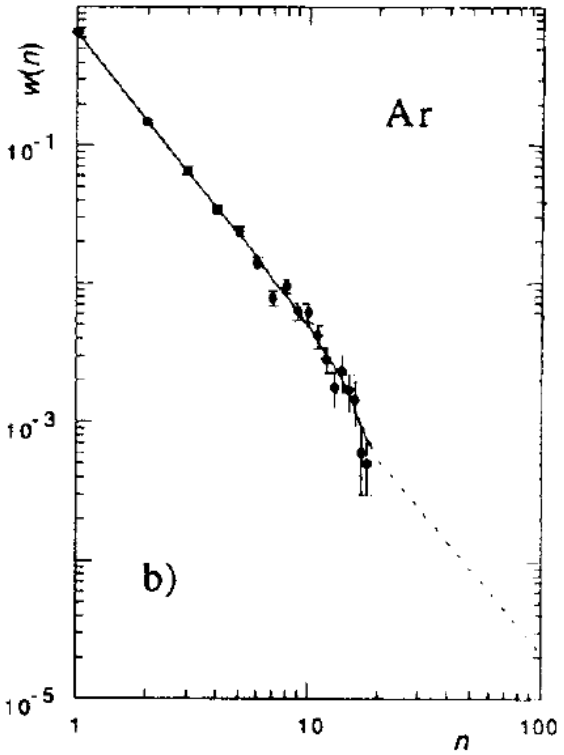
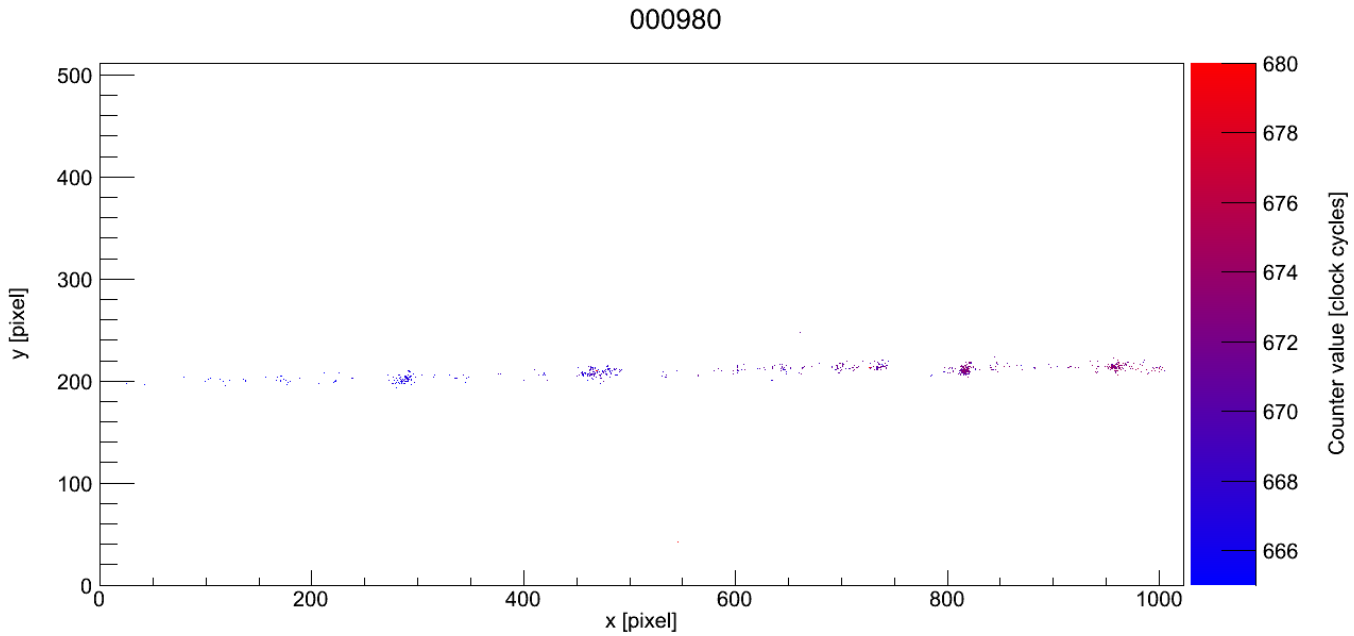
Ionization

Gas mixture: Ar:CF_4:iButane 95:3:2 → Argon-based mixture.

Rule of thumb: For a MIP ~ 30 interactions/cm and ~100 e^-/cm



Cluster size:
#e^- per interaction



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Drift Diffusion

Electrons drift in the electric field

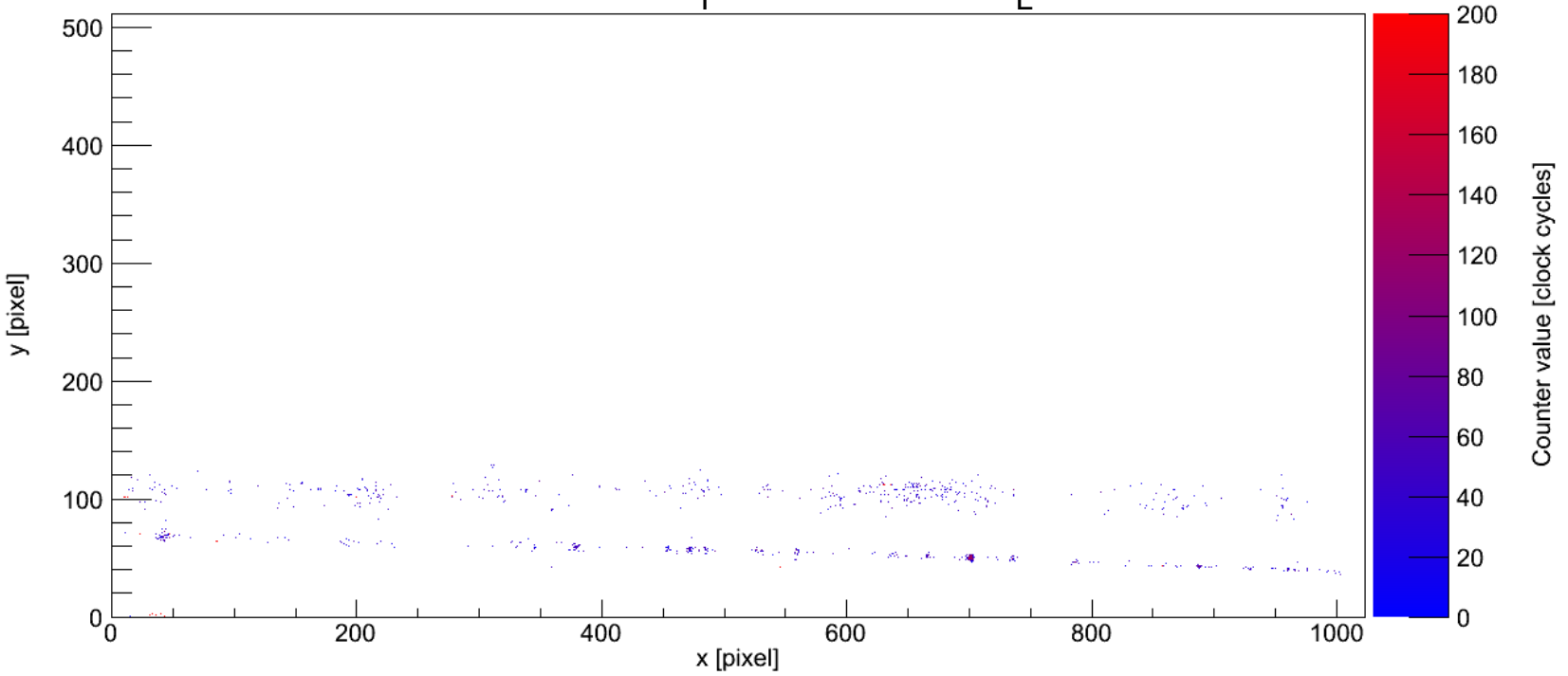
=> v_{drift} = 7.9 cm/µs at E_{drift} = 280 V/cm

They also diffuse: transverse diffusion $D_T(3.5T, 280\ V/cm) \sim 30\ \mu m/\sqrt{cm}$

longitudinal diffusion $D_L(3.5T, 280\ V/cm) \sim 200\ \mu m/\sqrt{cm}$

$$\sigma = \sqrt{\sigma_0 + D^2 z/n_{eff}}$$

=> for long drift distances (2.25 m) → $\sigma_T \sim 450\ \mu m$, $\sigma_L \sim 3\ mm \sim 38\ ns$



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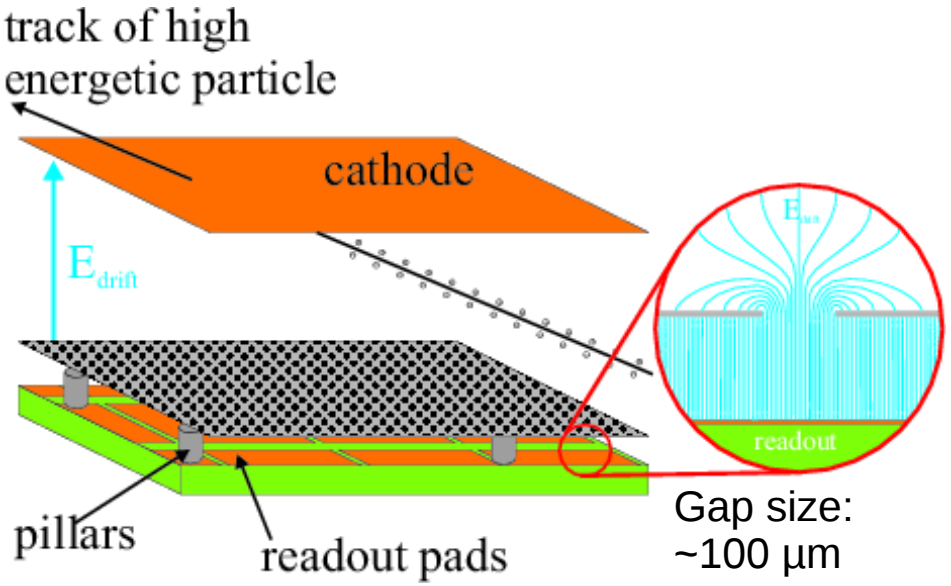
Gas amplification

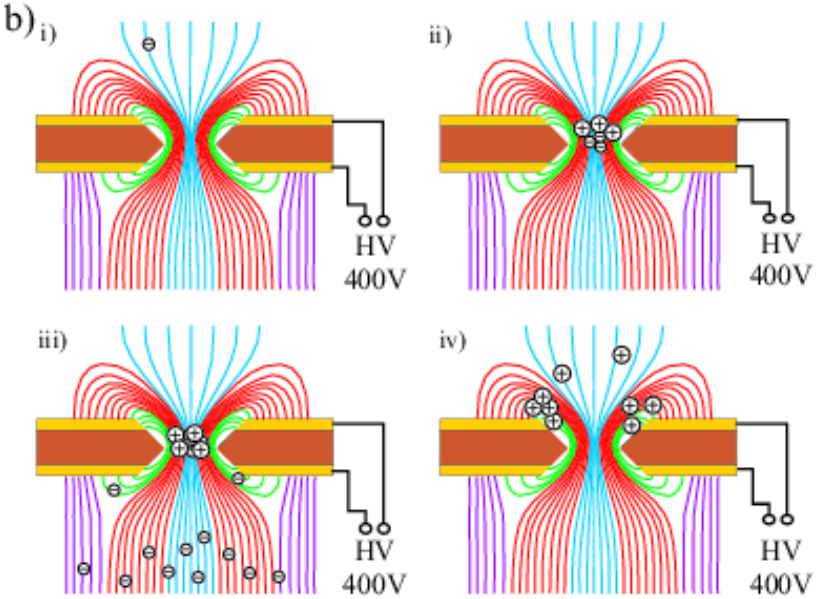
Two gas amplification stages are discussed:

Micromegas



Gap size:
~100 µm

GEMs



In both cases gas gains are distributed according to a Polya with a MVP of about 1000 – 5000 are being discussed.

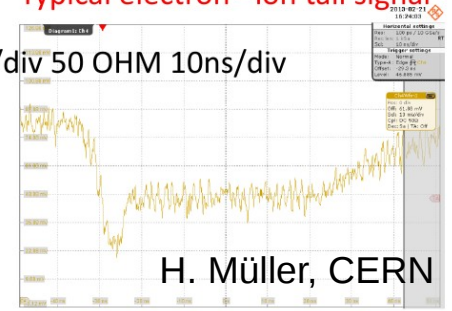
Charge Collection

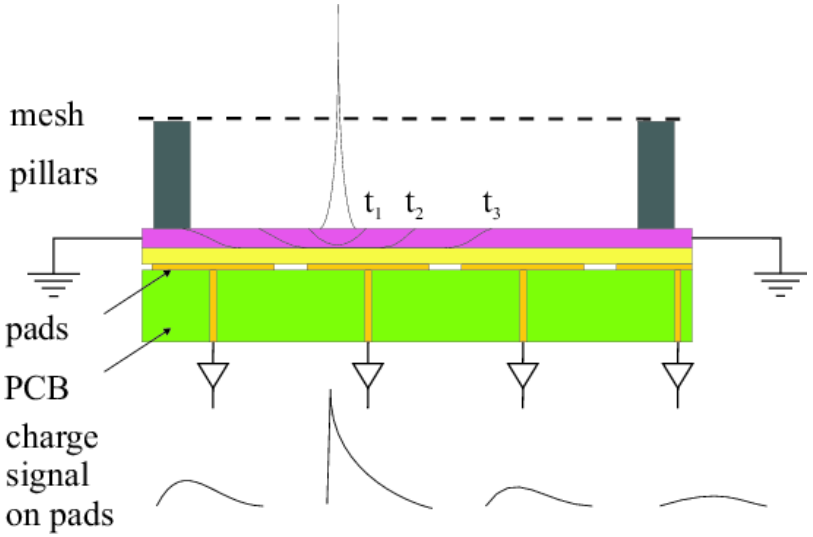
Electrons move towards pads, ions away from it
→ induction signal (Ramow,...)

GEMs: no ion signal, electrons drift towards the pads
gap 2-3 mm, v_{drift}~2.5 cm/µs → t~100 ns

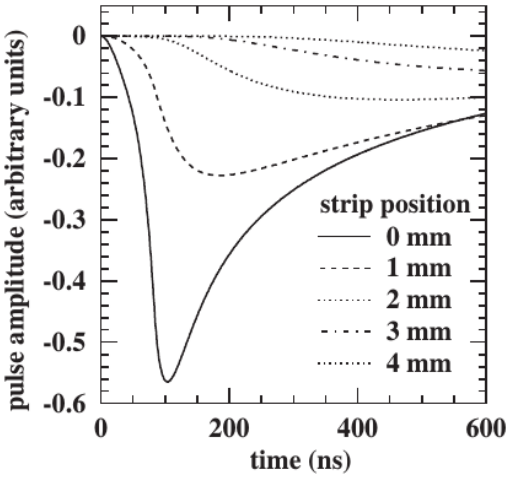
Micromegas: exponential increase in signal towards the pad:
Very fast e^- signal, slow ion signal
gap 100µm, v_{drift}~6 cm/100µs → t~150 ns
For protection reasons: a resistive layer is placed above the pads in the MM design.

Typical electron –ion tail signal





Signal at side pads are delayed and change the form.



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Signal Size (MIPs)

A pad row is about 6-8 mm high.

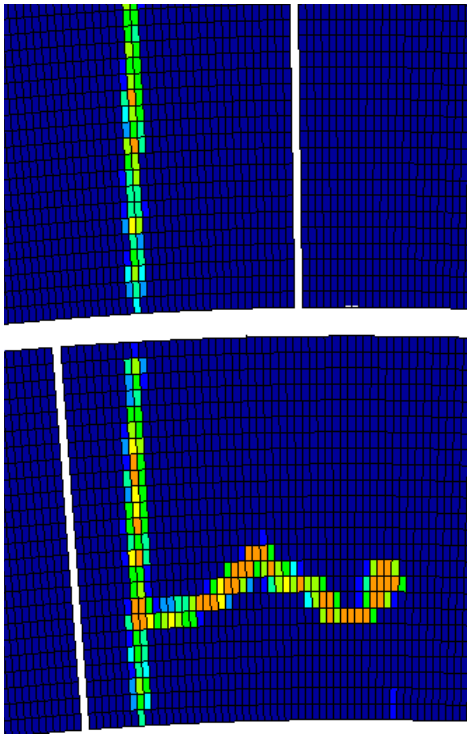
→ It collects about 60-80 primary electrons (for MIPS)

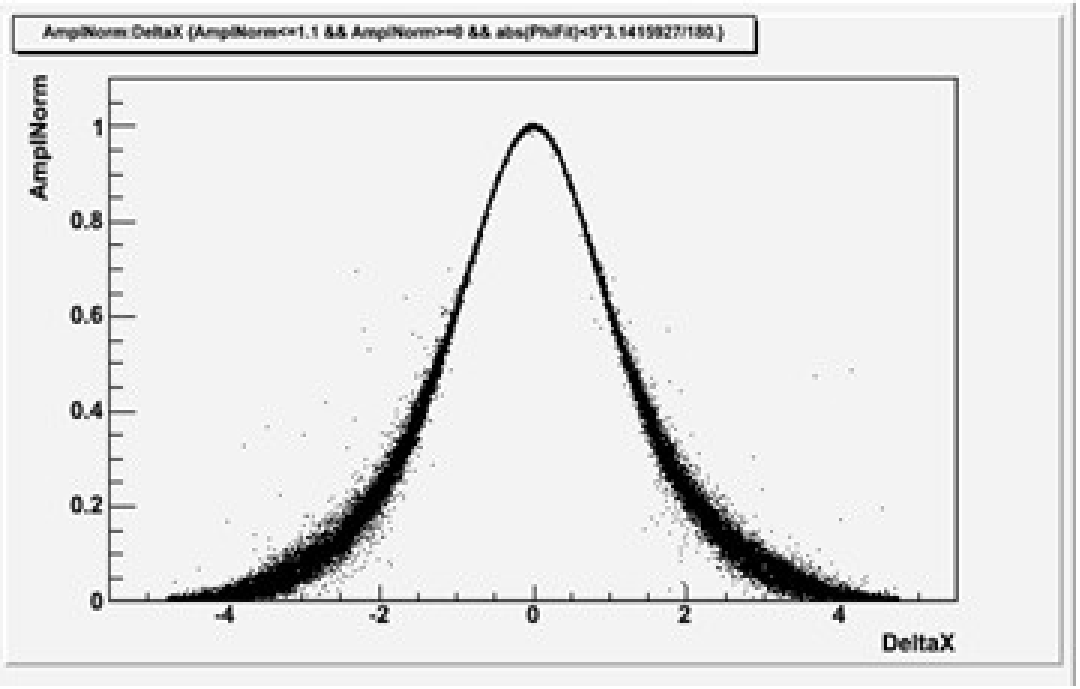
→ after gas gain: 60,000-300,000 electrons are collected.

Usually, central pad collects a large fraction

Side pads only smaller fraction,

track angles ≠90° increase the spread of the signal on more pads

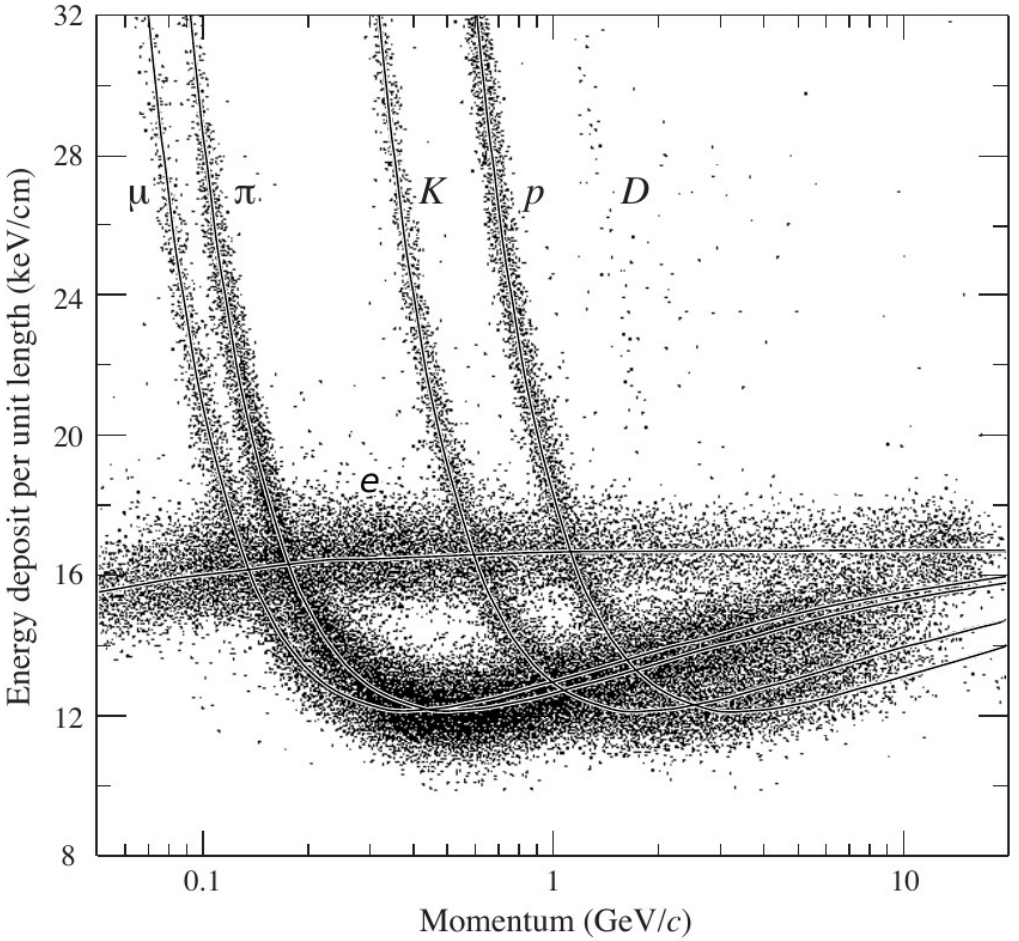




Pad response function of a MM with resistive layer

Signal Size (HIPs) + dischargs

Ionization density can be much larger
- HIPs → factor 10
- HIPs in forward direction



Discharges:
- Effect suppressed in MM by resistive layer
- rarely happens in GEMs, but then has full energy

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