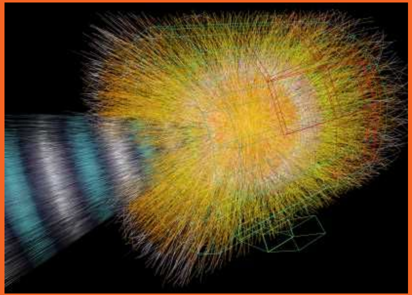
Second NNBAR
Sweden-Brazil
STINT Workshop

Time Projection Chamber



The HIBEAM-NNBAR tracking & PID detector

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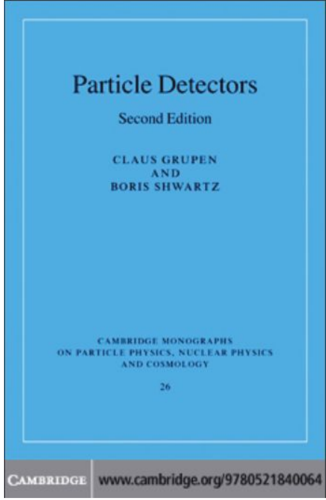
Outline

créditos dos slides emprestados:

- C. Joran
- E. Garutti

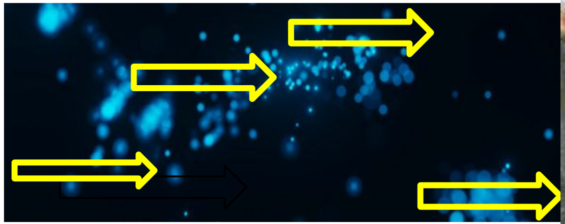
- Particle detection principles
  - interactions of radiation with matter
  - gaseous detectors
- Time Projection Chambers
- NNBAR TPC
- LADEP-UNICAMP activities

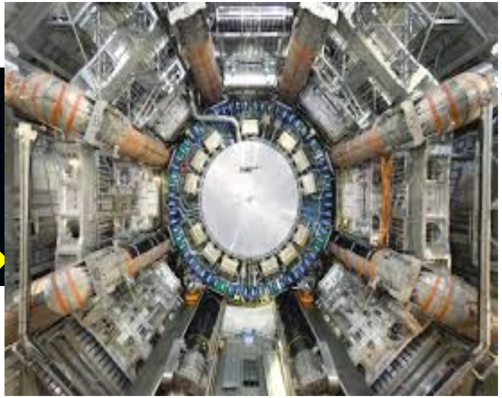
Physics of Particle Detection



Every effect of particles or radiation can be used as a working principle for a particle detector.

Claus Grupen





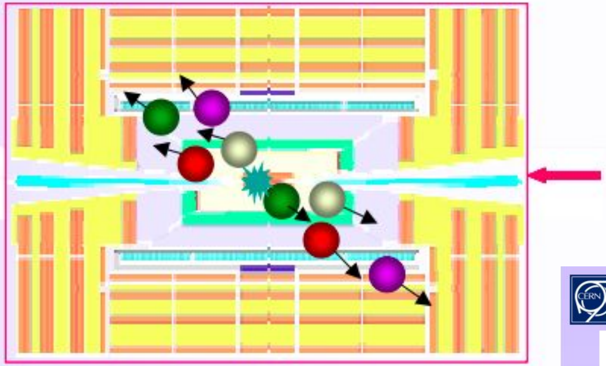
Introduction

The 'ideal' particle detector should provide…

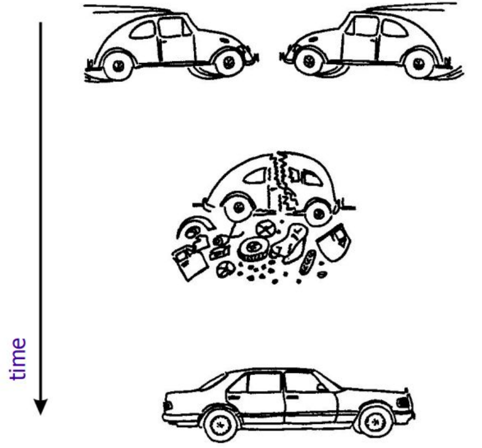
- coverage of full solid angle (no cracks, fine segmentation)
- measurement of momentum and/or energy
- detect, track and identify all particles (mass, charge)
- fast response, no dead time

- practical limitations (technology, space, budget) !

e^+e^-, ep, pp, $p\bar{p}$



end products
- charged particles
- neutral particles
- photons



Cartoon by Claus Grupen, University of Siegen

- **Particles are detected via their interaction with matter.**
- **Many different physical principles are involved (mainly of electromagnetic nature). Finally we will always observe ionization and excitation of matter.**

Introduction

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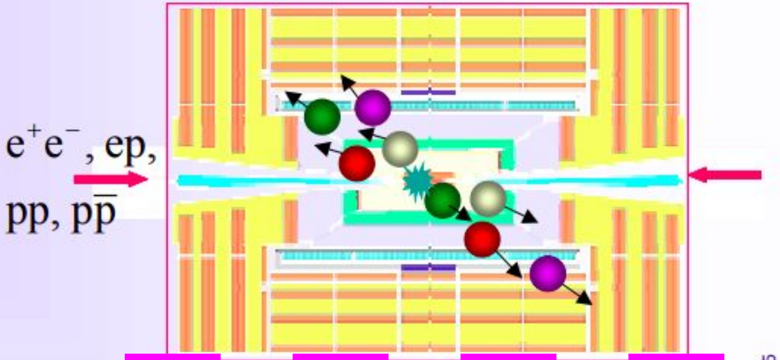

end products
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- **Many different physical principles are involved (mainly of electromagnetic nature). Finally we will always observe ionization and excitation of matter.**

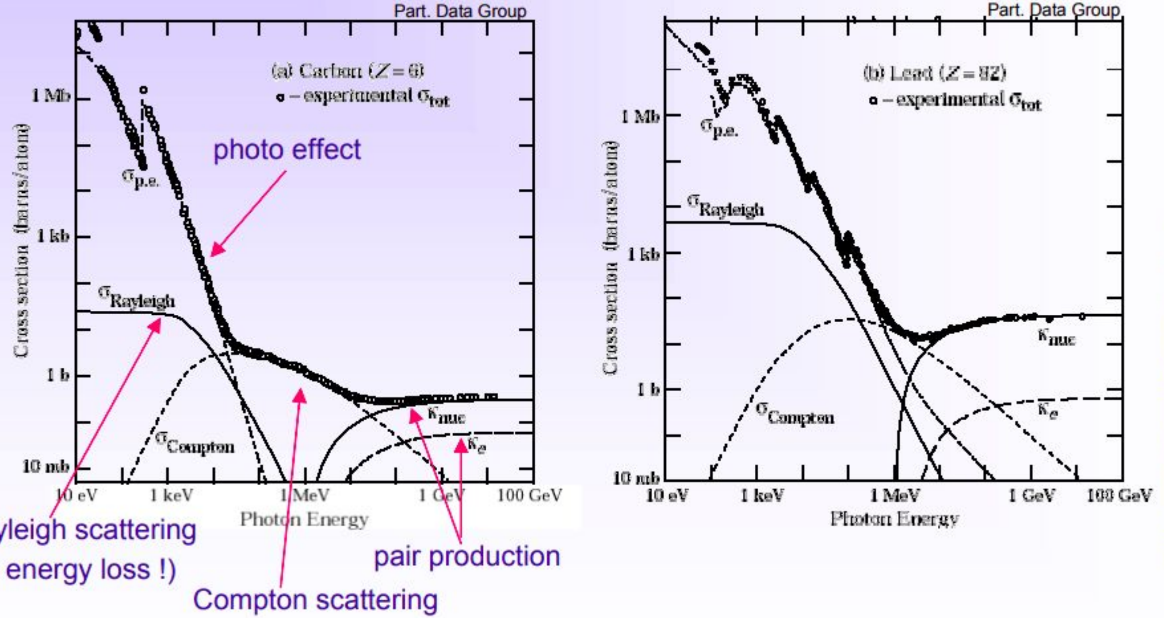
Interações da radiação com a matéria : fótons

4. Calorimetry

Interaction of photons

In summary: $I_\gamma = I_0 e^{-\mu x}$

μ: mass attenuation coefficient $\mu_i = \frac{N_A}{A}\sigma_i \quad [cm^2/g]$ $\quad \mu = \mu_{photo} + \mu_{Compton} + \mu_{pair} + \dots$



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Interações da radiação com a matéria : partículas neutras

- PRINCÍPIO BÁSICO:
  - partículas neutras precisam gerar ou interagir com partículas carregadas para gerarem sinais mensuráveis em detectores. Alguns exemplos:
  - π^0 : $\pi^0 \rightarrow 2\gamma$; $\pi^0 \rightarrow \gamma + e^- + e^+$; $\pi^0 \rightarrow e^- + e^+ + e^- + e^+$ ...
  - neutrinos:

CC Charged Current Reaction	$\upsilon_e + d \rightarrow p + p + e^-$
NC Neutral Current Reaction	$\upsilon_x + d \rightarrow \upsilon_x + p + n$
ES Elastic Scattering Reaction	$\upsilon_x + e^- \rightarrow \upsilon_x + e^-$

IBD (CC): $\bar{\nu}_e + p^+ \rightarrow n^0 + e^+$

Obs.: γ SECUNDÁRIOS INTERAGEM PRODUZINDO PARTÍCULAS CARREGADAS

Interações da radiação com a matéria : partículas neutras

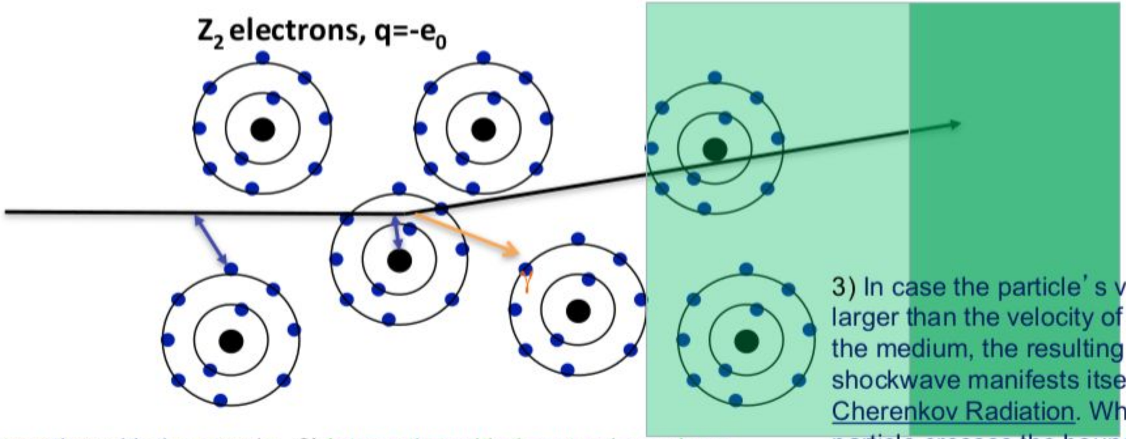
- nêutrons:

    - Espalhamento:
        - colisão com núcleos, mudando de direção e energia.
    - Absorção:
        - Os nêutrons podem ser absorvidos por núcleos no material, levando a várias reações nucleares, como captura ou fissão.
    - Difusão:
        - Os nêutrons podem difundir-se pelo material, passando por movimento aleatório devido a colisões com outras partículas, resultando em um deslocamento líquido

Interações da radiação com a matéria : partículas carregadas

Three type of electromagnetic interactions:

1. Ionization (of the atoms of the traversed material)
2. Emission of Cherenkov light
3. Emission of transition radiation



1) Interaction with the atomic electrons. The incoming particle loses energy and the atoms are excited or ionized

2) Interaction with the atomic nucleus. The particle is deflected (scattered) causing multiple scattering of the particle in the material. During this scattering a Bremsstrahlung photon can be emitted.

3) In case the particle's velocity is larger than the velocity of light in the medium, the resulting EM shockwave manifests itself as Cherenkov Radiation. When the particle crosses the boundary between two media, there is a probability of the order of 1% to produced and X ray photon, called Transition radiation.

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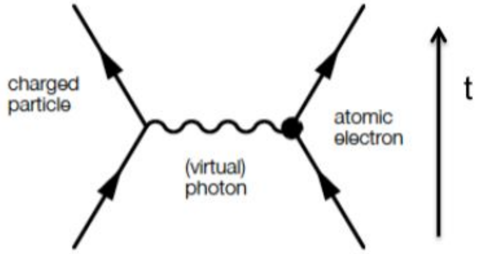
Interações da radiação com a matéria : resumo

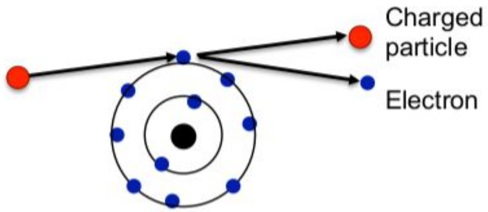
Charged particles	Photons, γ
Ionisation and excitation	Photoelectric effect
Bremsstrahlung	Compton scattering
	Pair creation
Cherenkov radiation	
Transition radiation	

TPC

Interações da radiação com a matéria : partículas carregadas

Energy loss by ionization – dE/dx





First calculate for $Mc^2 \gg m_e c^2$:

Energy loss for heavy charged particle [dE/dx for electrons more complex]

The trajectory of the charged particle is unchanged after scattering

$$\frac{dE}{dx} \propto \frac{Z^2}{\beta^2} \ln\left(a\beta^2\gamma^2\right) \qquad \gamma = \frac{1}{\sqrt{1+\beta^2}}$$

a = material-dependent constant

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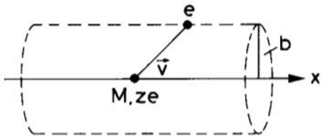
Interações da radiação com a matéria : partículas carregadas

Bohr's calculation of dE/dx

Particle with charge Ze and velocity v moves through a medium with electron density n.

Electrons considered free and initially at rest



The momentum transferred to the electron is:

Symmetry!

$$\Delta p_\perp = \int F_\perp dt = \int F_\perp \frac{dt}{dx} dx = \int F_\perp \frac{dx}{v} \qquad \Delta p_\parallel : \text{ averages to zero}$$

Gauss law: *The electric flux through any closed surface is proportional to the enclosed electric charge*

$$F_\perp = eE_\perp$$

$$\Delta p_\perp = e \int E_\perp \frac{dx}{v} \quad \leftarrow \quad \int E_\perp (2\pi b)\, dx = 4\pi(ze) \rightarrow \int E_\perp dx = \frac{2ze}{b}$$

$$= \frac{2ze^2}{bv}$$

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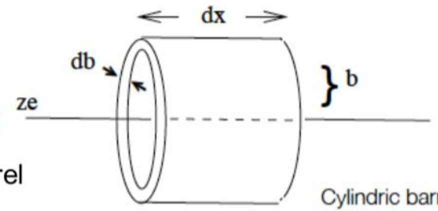
Bohr's calculation of dE/dx

$$\Delta E(b) = \frac{\Delta p^2}{2m_e} \quad \text{with} \quad \Delta p_\perp = \frac{2ze^2}{bv}$$

Energy transfer to a single electron



Cylindric barrel with N_e electrons

For n electrons distributed on a barrel

$n = N_e \cdot (2\pi b) \cdot db\, dx$

Energy loss per path length dx for distance between b and b+db in medium with electron density N_e:

$$-dE(b) = \frac{\Delta p^2}{2m_e} \cdot 2\pi N_e b\; db\; dx = \frac{(2ze^2)^2}{2m_e (bv)^2} \cdot 2\pi N_e b\; db\; dx = \frac{4\pi N_e z^2 e^4}{m_e v^2} \cdot \frac{db}{b} dx$$

(-) Energy loss !

$$-\frac{dE}{dx} = \frac{4\pi N_e z^2 e^4}{m_e v^2} \cdot \int_{b_{min}}^{b_{max}} \frac{db}{b} = \frac{4\pi N_e z^2 r_e^2 m_e c^2}{\beta^2} \ln \frac{b_{max}}{b_{min}} \qquad (r_e m_e c^2 = e^2)$$

Diverges for b ➛ 0; integration only for relevant range [b_{min}, b_{max}]

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Interações da radiação com a matéria : partículas carregadas

Bohr's calculation of dE/dx

Stopping power: $-\frac{dE}{dx} = \frac{4\pi N_e z^2 r_e^2 m_e c^2}{\beta^2} \ln \frac{b_{max}}{b_{min}}$

Determination of the relevant range [b_{min}, b_{max}]:

b_{min} : for head-on collisions in which the kinetic energy transferred is maximum

$$\rightarrow E_{max}(b_{min}) = \frac{(2ze^2)^2}{2m_e v^2 b_{min}^2}$$

$$b_{min} = \frac{ze^2}{\gamma m_e v^2}$$

$$\leftarrow E_{max} = \frac{1}{2}\gamma^2 m_e (2v)^2 = 2m_e c^2 \beta^2 \gamma^2$$

(calculated from conservation of momentum)

b_{max}: particle still moves faster than the e in the atomic orbit (~ electron at rest).
electrons are bound to atoms with an average orbital frequency $\langle \upsilon_e \rangle$
the interaction time has to be smaller or equal to $1/\langle \upsilon_e \rangle$

$$b_{max} = \frac{\gamma v}{\langle \upsilon_e \rangle}$$

or distance at which the kinetic energy transferred is minimum E_{min}= I (mean ionization potential)

In this interval the stopping power does not diverge: Bohr classical formula

$$-\frac{dE}{dx} = \frac{4\pi N_e z^2 r_e^2 m_e c^2}{\beta^2} \ln \frac{\gamma^2 m v^3}{ze^2 \langle \upsilon_e \rangle} = \frac{4\pi N_e z^2 r_e^2 m_e c^2}{\beta^2} \ln \left(\frac{2m_e c^2 \beta^2 \gamma^2}{I} \right)$$

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Interações da radiação com a matéria : partículas carregadas

Behte-Bloch equation

Quantum mechanic calculation of Bohr stopping power

Valid for heavy charged particles ($m_{incident}$>>m_e), e.g. proton, k, π, μ

$$-\left\langle \frac{dE}{dx} \right\rangle = 2\pi N_a r_e^2 m_e c^2 \rho \frac{Z}{A} \frac{z^2}{\beta^2} \left[\ln\left(\frac{2 m_e c^2 \beta^2 \gamma^2}{I^2} W_{max} \right) - 2\beta^2 - \delta(\beta\gamma) - \frac{C}{Z} \right]$$

$2\pi N_a r_e^2 m_e c^2$ =0.1535 MeV cm^2/g

$$\frac{dE}{dx} \propto \frac{Z^2}{\beta^2} \ln\left(a\beta^2\gamma^2\right)$$

Fundamental constants

- r_e=classical radius of electron
- m_e=mass of electron
- N_a=Avogadro's number
- c =speed of light

Absorber medium

- I = mean ionization potential
- Z = atomic number of absorber
- A = atomic weight of absorber
- ρ = density of absorber
- δ = density correction
- C = shell correction

Incident particle

- z = charge of incident particle
- β = v/c of incident particle
- γ = $(1-\beta^2)^{-1/2}$
- W_{max}= max. energy transfer in one collision

Note: the classical dE/dx formula contains many features of the QM version: $(z/\beta)^2$, & ln[]

$$\frac{-dE}{dx} = \frac{4\pi N_e z^2 r_e^2 m_e c^2}{\beta^2} \ln \frac{b_{max}}{b_{min}}$$

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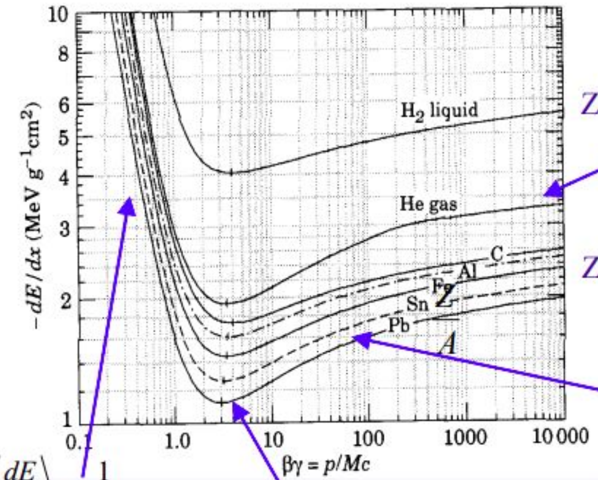
Interações da radiação com a matéria : partículas carregadas



Z/A = 1

"Fermi plateau"

Z/A~0.5

$$\left\langle \frac{dE}{dx} \right\rangle \propto \ln \beta^2\gamma^2$$

"relativistic rise"

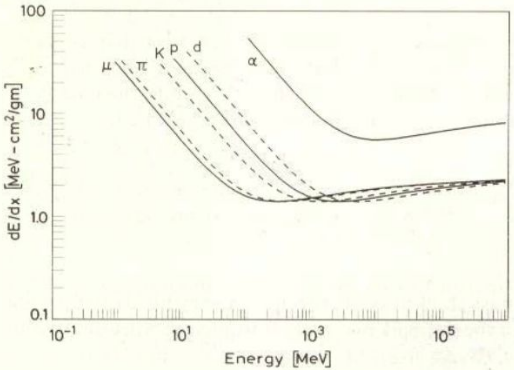
$$\left\langle \frac{dE}{dx} \right\rangle \propto \frac{1}{\beta^2}$$

"kinematical term"

$\beta\gamma \approx$ 3-4
minimum ionizing particles, MIPs

Except in hydrogen, particles of the same velocity have similar energy loss in different materials.

Consequence: dE/dx measurements can be used to identify particles



$$\beta\gamma = \frac{p}{E}\frac{E}{m} = \frac{p}{m}$$

- universal curve as function of $\beta\gamma$ splits up for different particle masses, if taken as function of energy or momentum

→ a simultaneous measurement of dE/dx and p,E → particle ID

Elétrons: atenção especial

Energy loss for electrons

Bethe-Bloch formula needs modification

Incident and target electron have same mass m_e

Scattering of identical, undistinguishable particles

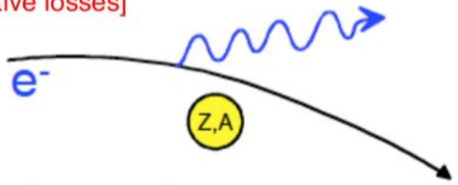
$$-\left\langle \frac{dE}{dx} \right\rangle_{Ionization} \propto \ln(E)$$

Dominating process for E_e > 10-30 MeV is not anymore ionization but

Bremsstrahlung: photon emission by an electron accelerated in Coulomb field of nucleus

[radiative losses]

$$-\left\langle \frac{dE}{dx} \right\rangle_{Brems} \propto \frac{E}{m^2}$$



energy loss proportional to $1/m^2$ → main relevance for electrons (or ultra-relativistic muons)

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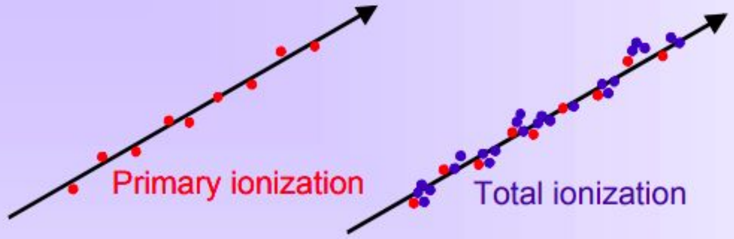
Detectores gasosos

Princípio Básico de Operação

Ionization of Gases



Lohse and Witzeling, Instrumentation In High Energy Physics, World Scientific, 1992

Fast charged particles ionize atoms of gas. Often resulting primary electron will have enough kinetic energy to ionize other atoms.

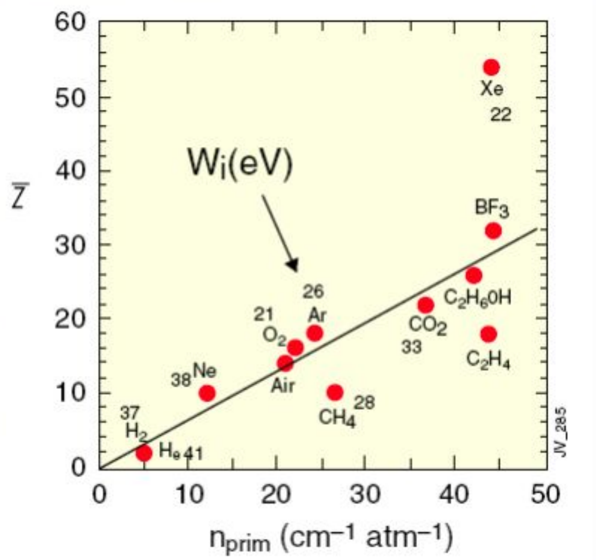
$$n_{total} = \frac{\Delta E}{W_i} = \frac{\frac{dE}{dx}\Delta x}{W_i}$$

$$n_{total} \approx 3\ldots4 \cdot n_{primary}$$

n_{total} - number of created electron-ion pairs

Δ_E = total energy loss

W_i = effective <energy loss>/pair



Number of primary electron/ion pairs in frequently used gases.

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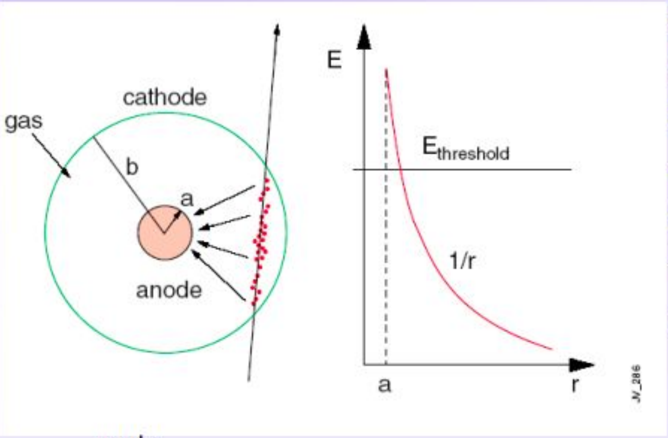
Método Básico de Detecção

Single Wire Proportional Chamber



Electrons liberated by ionization drift towards the anode wire.

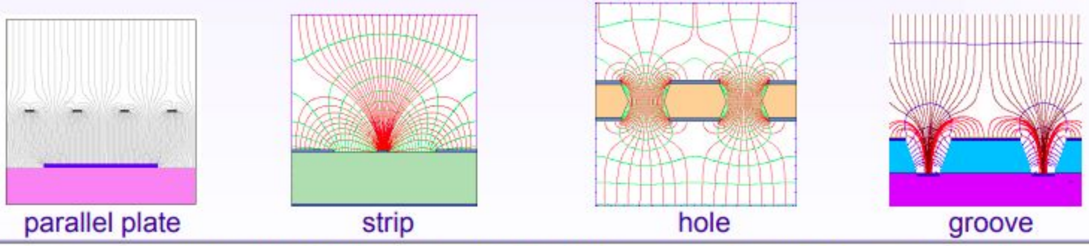
Electrical field close to the wire (typical wire Ø ~few tens of μm) is sufficiently high for electrons (above 10 kV/cm) to gain enough energy to ionize further → avalanche – exponential increase of number of electron ion pairs.

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

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

C – capacitance/unit length

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



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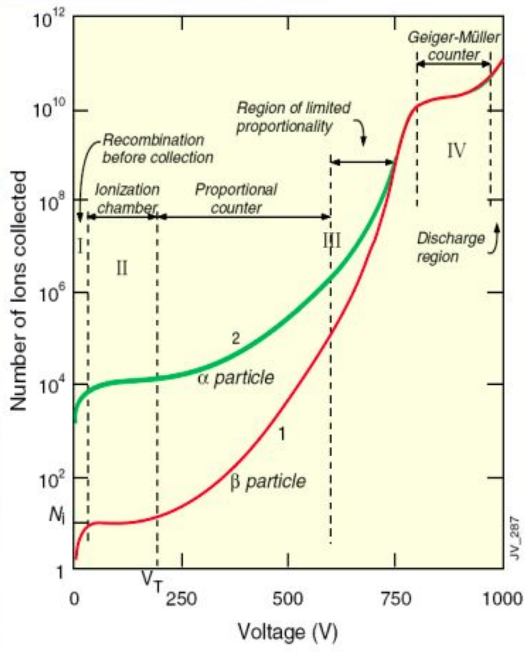
Modos de Operação

SWPC – Operation Modes

2a. Gas Detectors

- 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 strong quenchers or 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; strong quenchers needed as well



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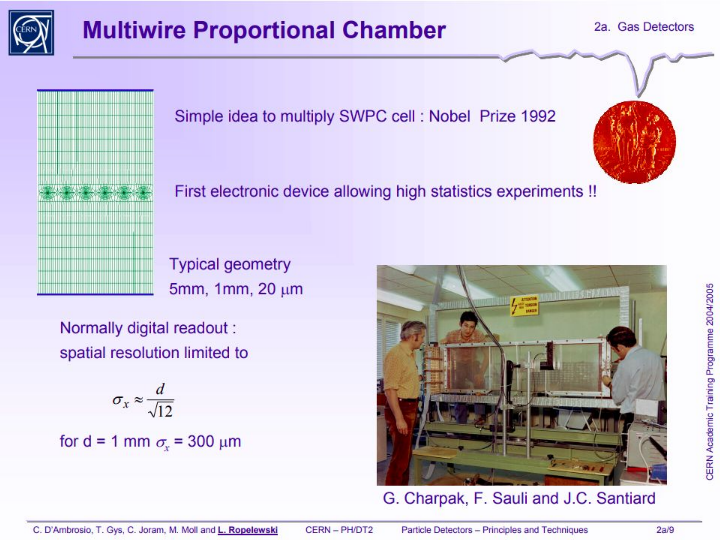
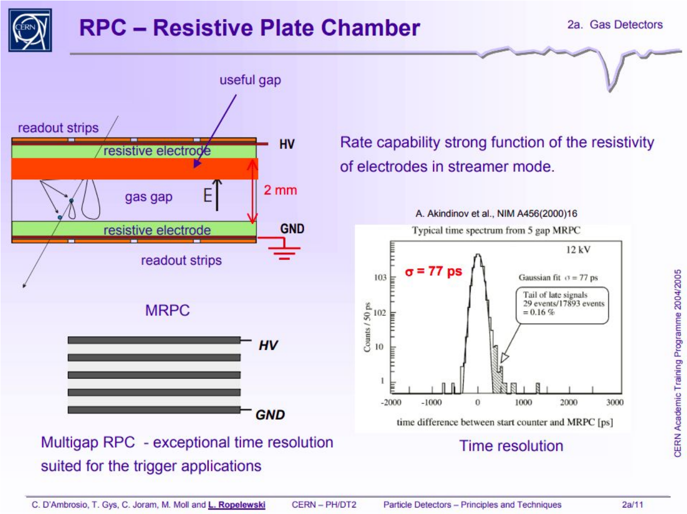
Variações da ideia





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Nuclear Instruments and Methods in Physics Research

Volume 217, Issues 1–2, 15 November 1983, Pages 30-42

Plastic streamer tubes and their applications in high energy physics

E. Iarocci

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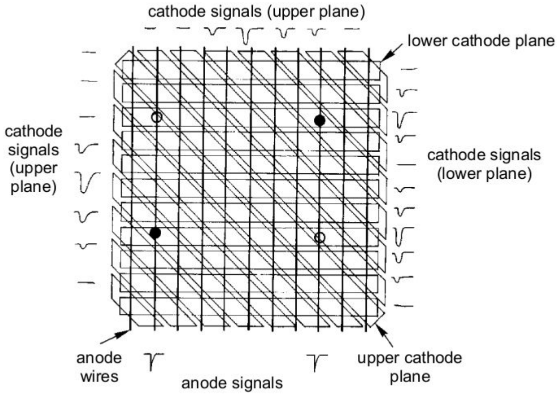
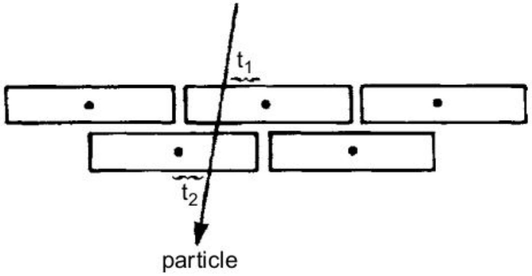
Abstract

A review of the basic performance and technology of plastic streamer tubes is presented, together with their applications and developments essentially in the field of digital tracking calorimetry, based on either digital patters or charge readout, or both, with different pick-up electrode arrangements.

Detectores Planares (2D)



Tracejamento (3D)



CÂMARAS DE ARRASTO (DRIFT CHAMBERS)

v^- : velocidade dos elétrons do gás

192 *7 Track detectors*

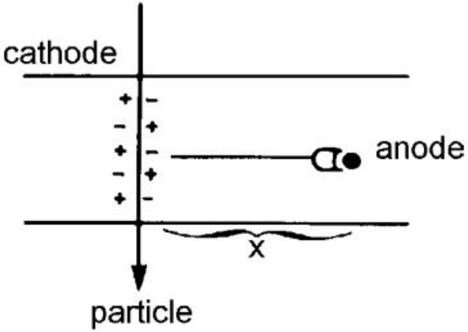


Fig. 7.6. Working principle of a drift chamber.

v^- cte

$$x = v^- \cdot \Delta t$$

v^- (t)

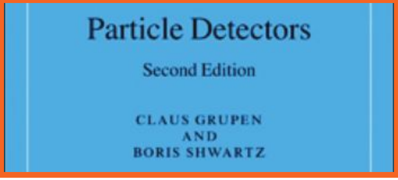
$$x = \int v^-(t)\, \mathrm{d}t$$

ganhamos uma nova coordenada, usando o mesmo tipo de detector gasoso !

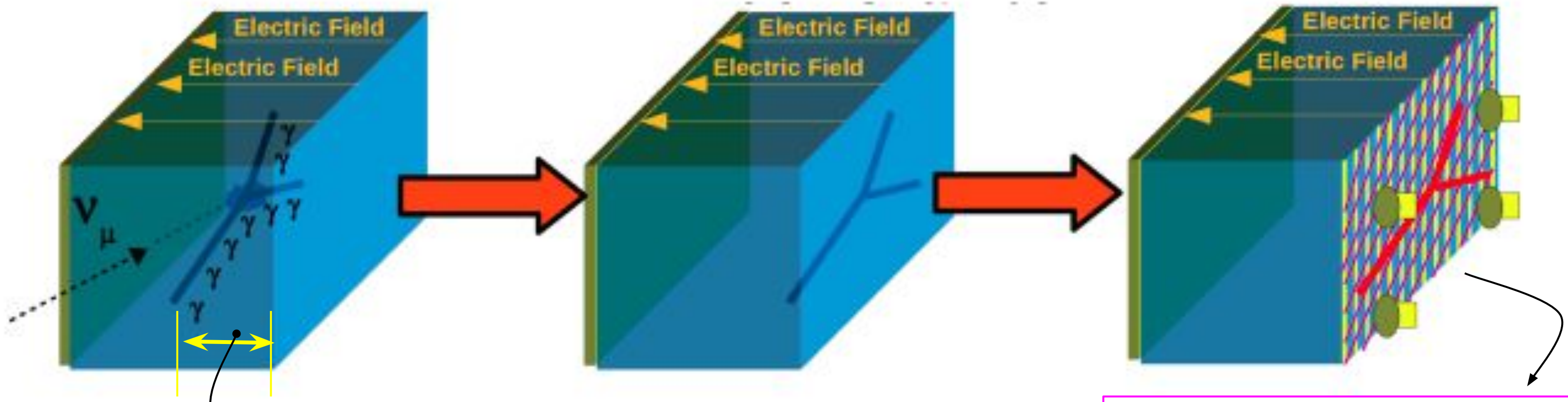
Câmara de Projeção Temporal
Time Projection Chamber - TPC

7.3.3 Time-projection chambers (TPCs)

The *crème de la crème* of track recording in cylindrical detectors (also suited for other geometries) at the moment is realised with the *time-projection chamber* [63]. Apart from the counting gas this detector



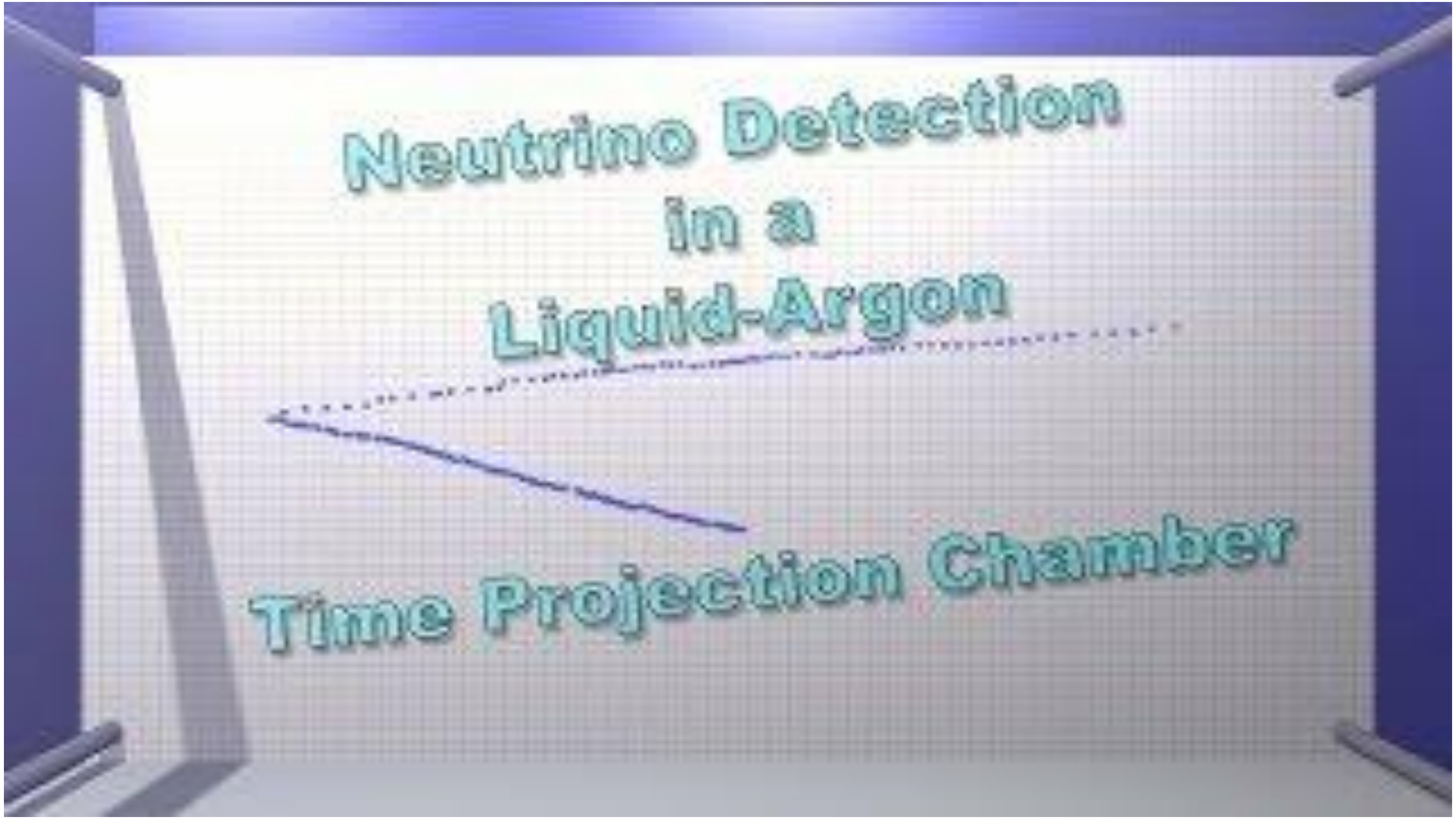
TPC: princípio de funcionamento



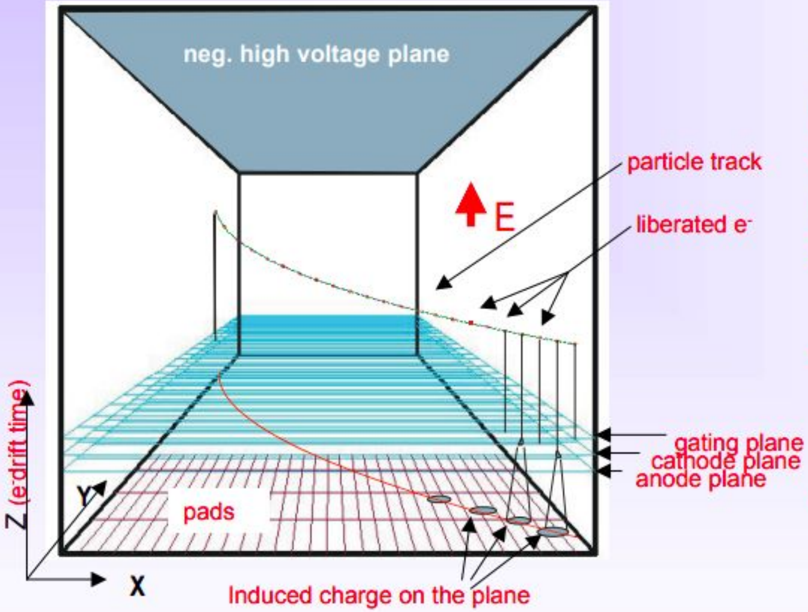
$$x = v^{-} \cdot \Delta t$$

Projeção (2D) dos traços no plano dos eletrodos de coleta de carga

1D + 2D = 3D


Neutrino Detection
in a
Liquid-Argon
Time Projection Chamber

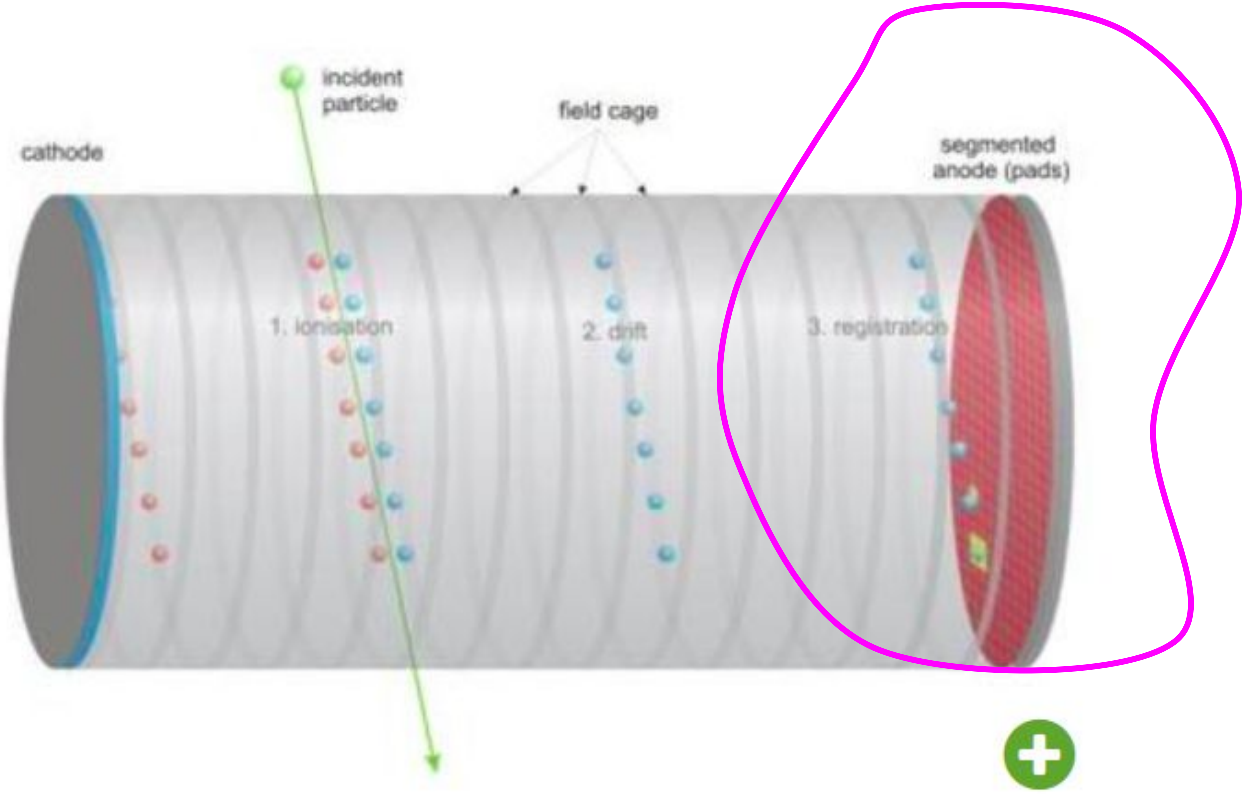
TPC – Time Projection Chamber



Time Projection Chamber
full 3D track reconstruction:
x-y from wires and segmented cathode of MWPC (or GEM)
z from drift time

- **momentum** resolution
  space resolution + B field
  (multiple scattering)
- **energy** resolution
  measure of primary ionization

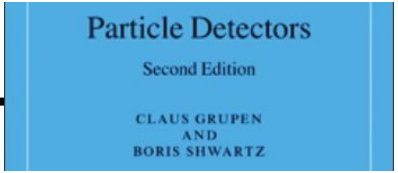
TPC: princípio de funcionamento



Temos cargas (e^-) nos nosso eletrodo positivo

elas são suficientes?

Amplificadores e coletores de carga



MPGD: micro-pattern gas detectors

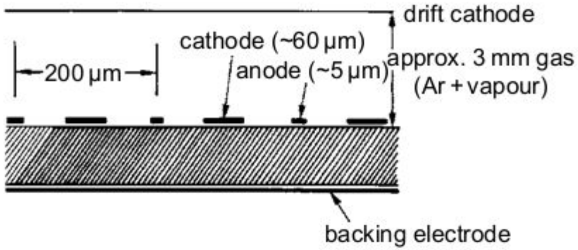


Fig. 7.35. Schematic arrangement of a microstrip gas detector

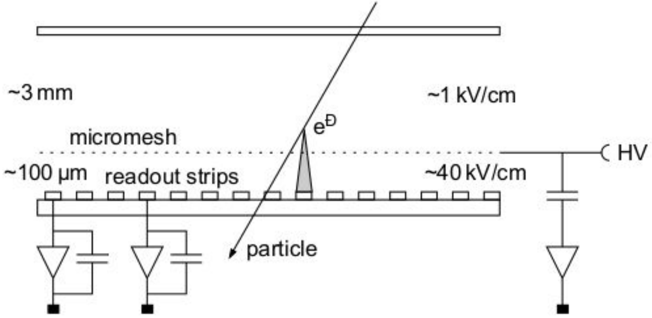


Fig. 7.36. The layout of the Micromegas detector [11, 95].

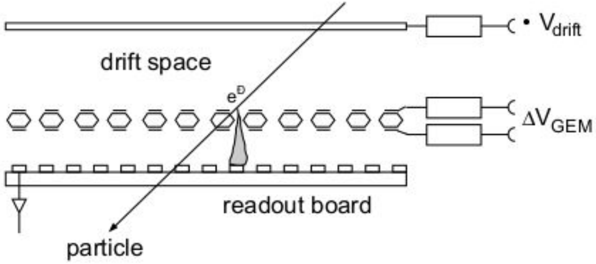
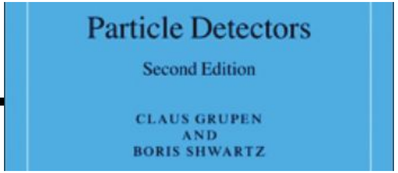


Fig. 7.37. Detailed layout of a GEM detector

Amplificadores e coletores de carga



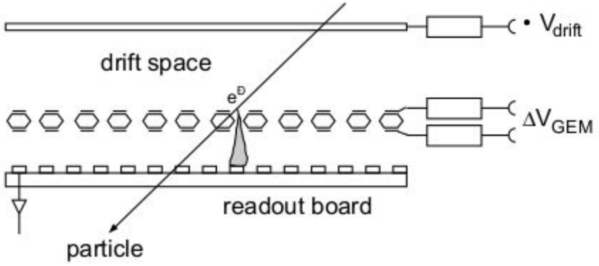
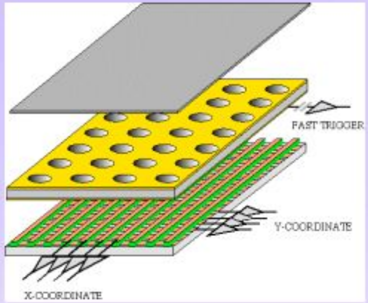


Fig. 7.37. Detailed layout of a GEM detector

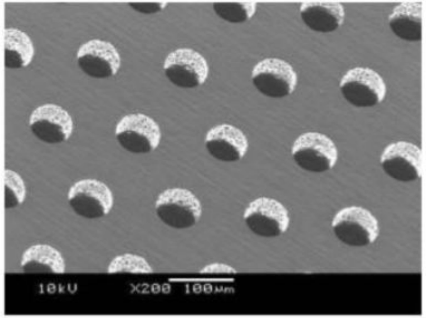
Another structure providing charge multiplication is the *Gas Electron Multiplier* (GEM). This is a thin ($\approx 50\,\mu m$) insulating kapton foil coated with a metal film on both sides. It contains chemically produced holes of 50–100 µm in diameter with 100–200 µm pitch. The metal films have different potential to allow gas multiplication in the holes. A GEM schematic view and the electric field distribution is presented in Figs. 7.37 and 7.38.

GEM – Gas Electron Multiplier

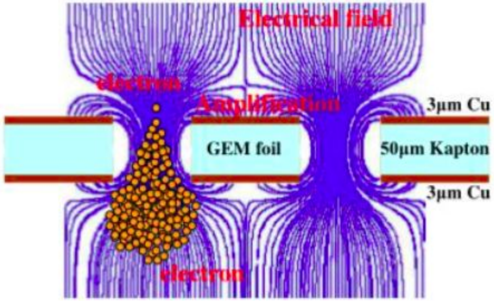


Full decupling of the charge ampification structure from the charge collection and readout structure.
Both structures can be optimized independently !

Double side flexible printed circuit board

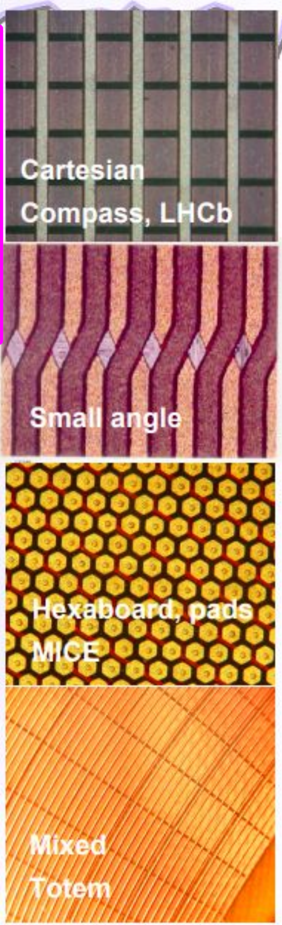


Electric field



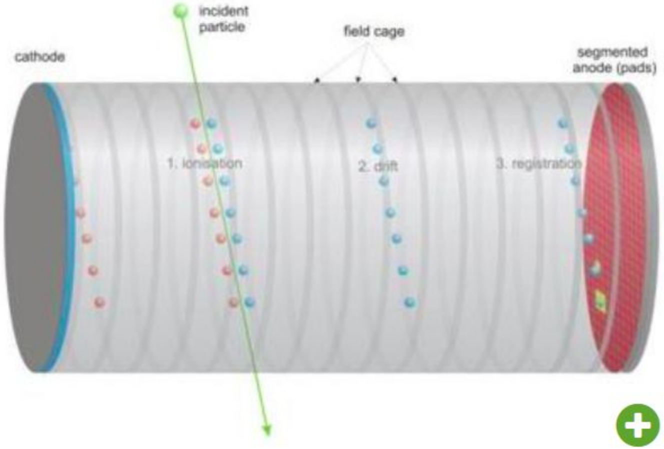
Hole diameter	70µm
Hole pitch	140µm
Thickness	50µm
Cu thickness	5µm

Developed by F.Sauli (CERN) in 1997.
NIMA 386(1997)531

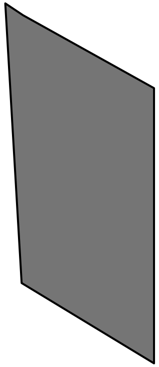


TPC: a nossa escolha (hibeam-nnbar) em sua essência

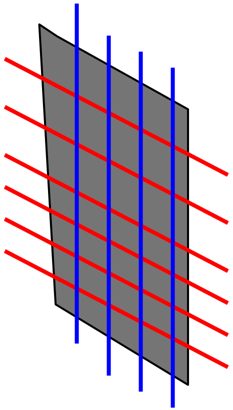
TPC



GEM

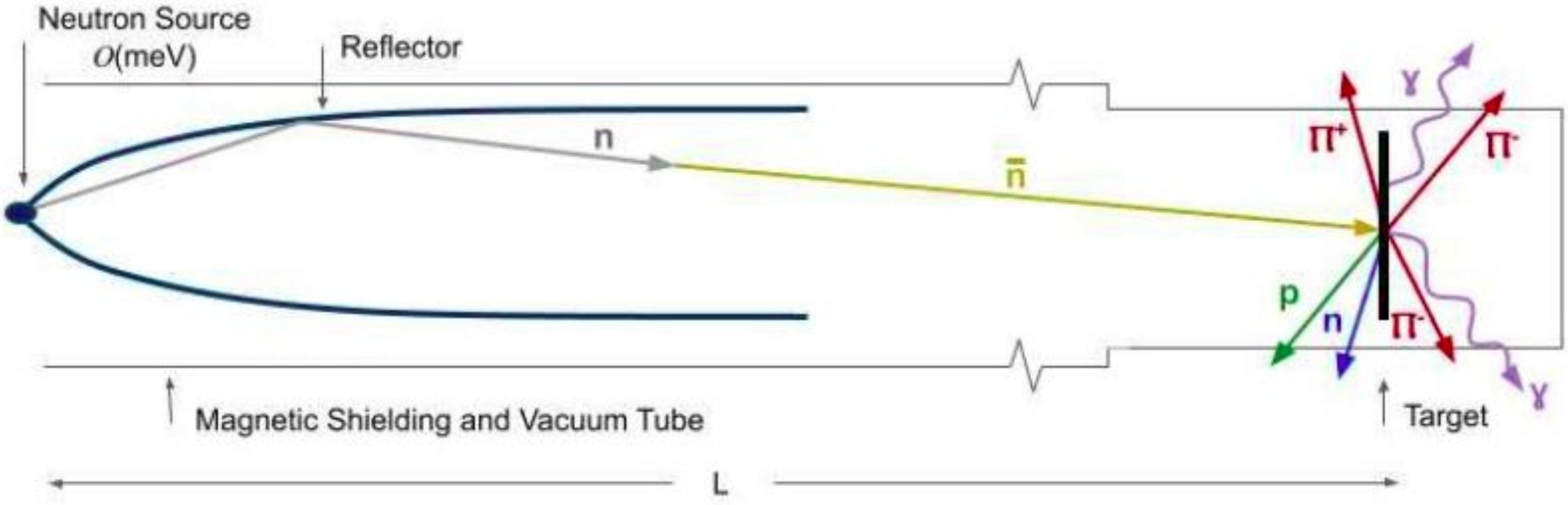


Coletor de carga



A TPC do HIBEAM-NNBAR

Lembrando nossa produção de n-$\bar{n}$



Bernhard Meirose - 2nd HIBEAM NNBAR Sweden-Brazil STINT Workshop - 2024-04-30

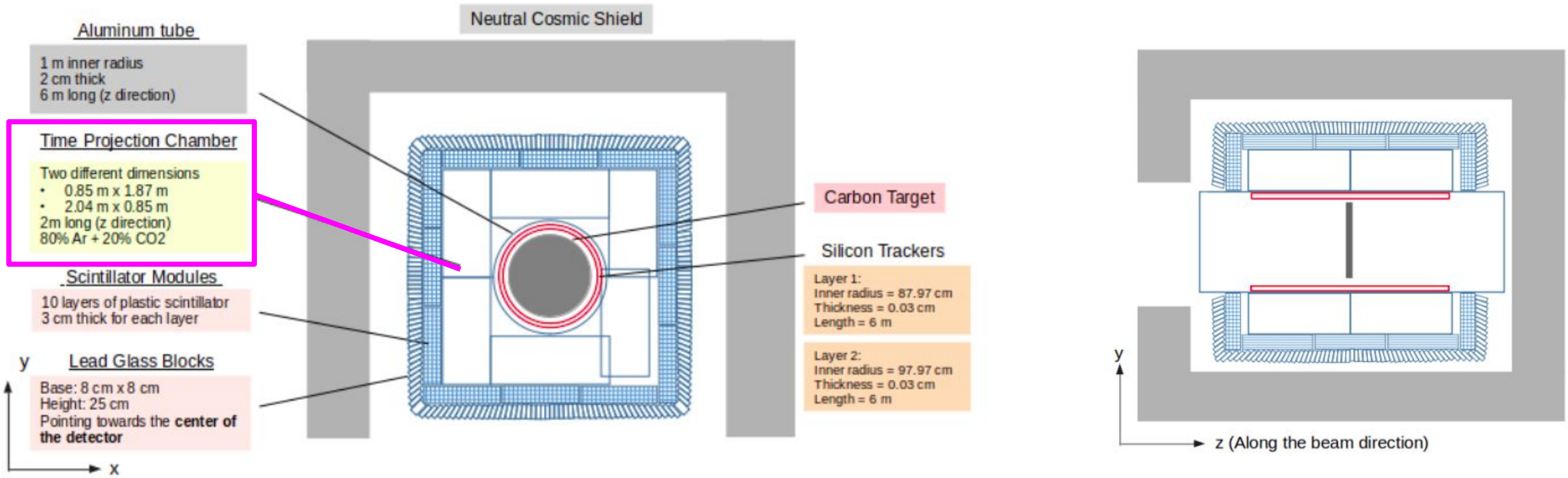
A TPC do HIBEAM-NNBAR

Journal of Instrumentation

PAPER • OPEN ACCESS

The development of the NNBAR experiment

To cite this article: F. Backman *et al* 2022 *JINST* **17** P10046



(b) *y*-*z* view

(a) *x*-*y* view

NNBAR - desenho de base e requisitos

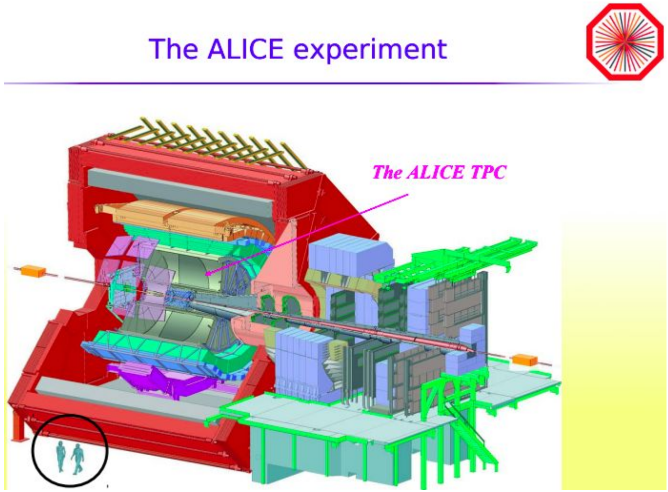
- Vértice comum do qual surgem várias trilhas de píons carregadas
  - pode ser reconstruído (com precisão de ~ mm).
  - requer excelente identificação de partículas (PID).
  - deve ser possível discriminar entre píons carregados de prótons de
- Como: medições da perda de energia, dE/dx

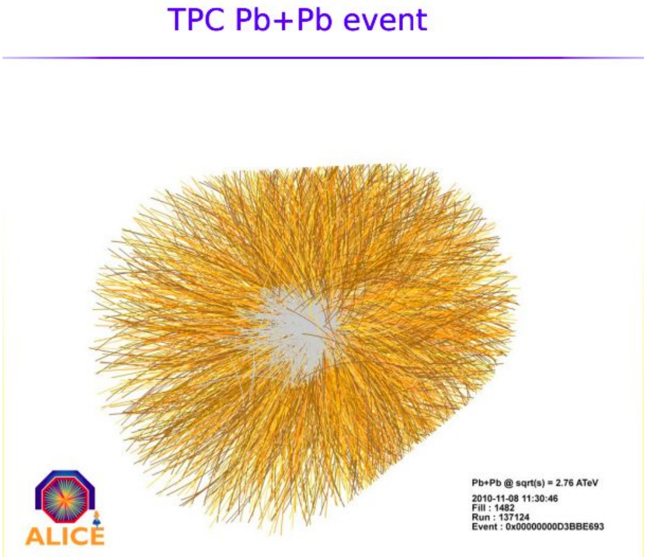
As câmaras de projeção temporal (TPCs) são adequadas para esta tarefa.

- Além disso: é importante que as energias e direções das partículas sejam medidas

NNBAR - desenho de base e requisitos

- Escolha do “modelo”
  - A TPC do ALICE





Time Projection Chamber

Two different dimensions
- 0.85 m x 1.87 m
- 2.04 m x 0.85 m

2m long (z direction)
80% Ar + 20% CO2

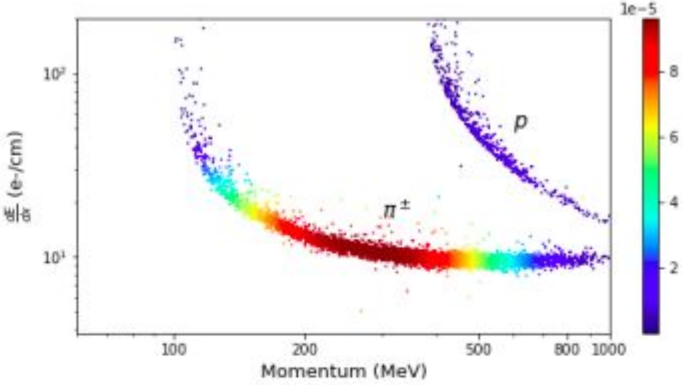
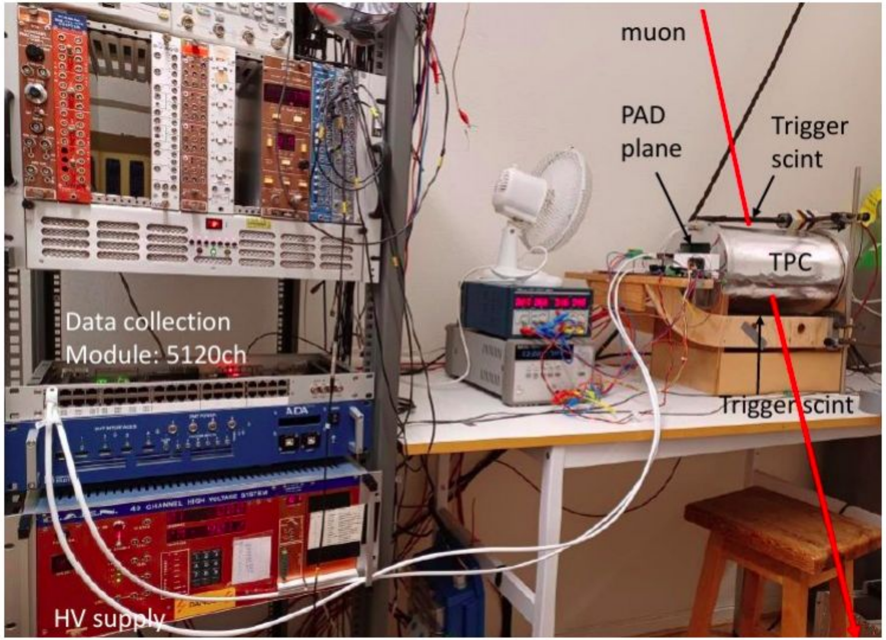


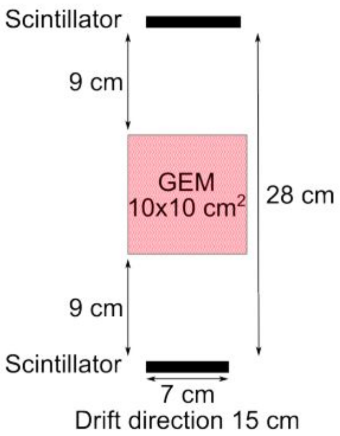
Figure 7. The expected mean energy loss in the TPC, $\frac{dE}{dx}$, for simulated pions and protons.

TPC: protótipos (R&D)

TPC

Cosmics Setup





A. Oskarsson

2024-04-17 PROTOTYPES STATUS - NNBAR/HIBEAM AFTERNOON WORKSHOP 3

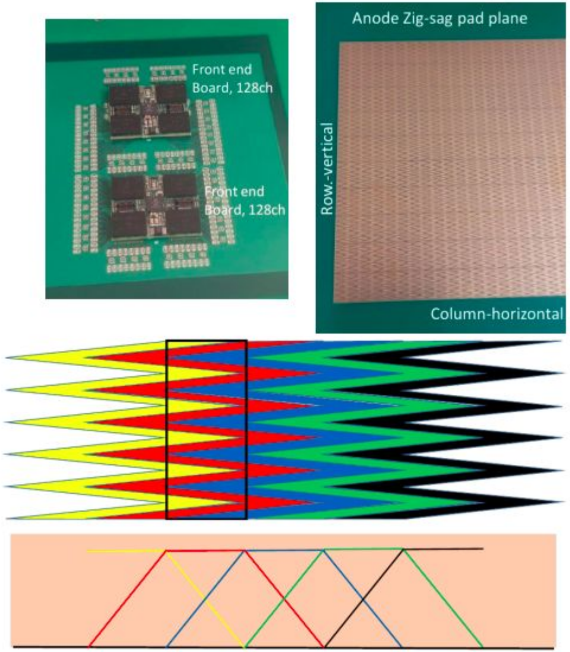
TPC: protótipos (R&D)

TPC

Readout

- TPC
  - 30 cm drift length
  - Drift field 250 V/cm
- ZIGZAG GEM
  - 10 cm x 10 cm
  - 256 pads in 10 pad rows
  - pitch 4.5 mm
- Frontend Board
  - SALTRO chips
  - 256 channels
  - 20 MHz sampling

A. Oskarsson

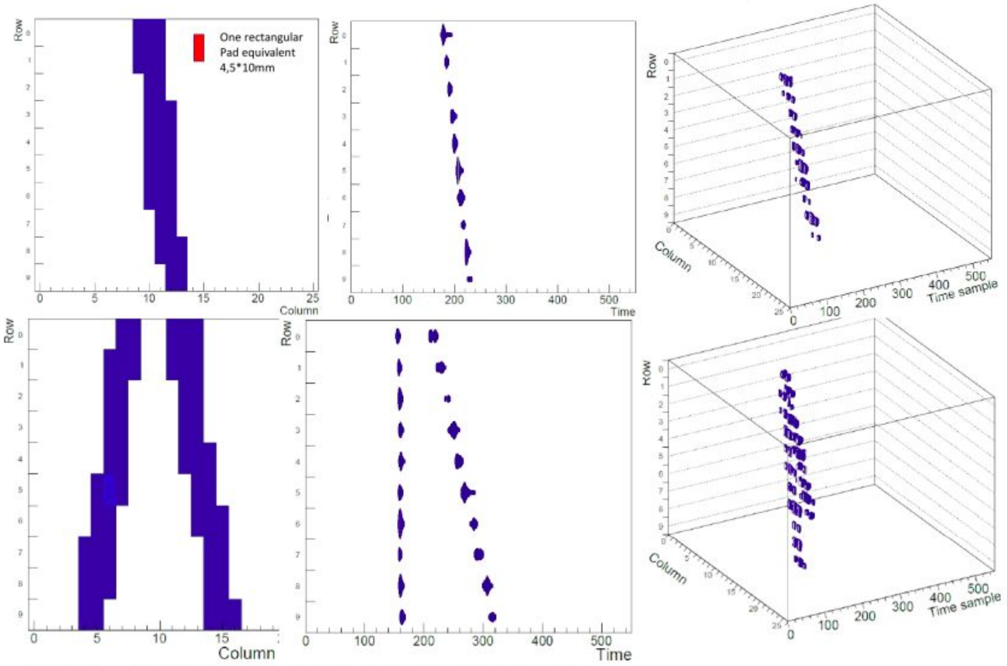


2024-04-17 PROTOTYPES STATUS - NNBAR/HIBEAM AFTERNOON WORKSHOP 4

TPC: protótipos (R&D)

TPC

Tracks



- Expected resolution after signal averaging 5-10% of pad width (=0.5 mm)
- Multiple tracks surprisingly frequent
  - Air showers? Pair production?

A. Oskarsson

TPC tests and R&D
@ UNICAMP

UNICAMP

IFGW

LADEP

LAboratório de DEtectores de Partículas

TPC R&D itens under discussion

- Charge collection: zig-zag pads optimization
  - maximize spatial resolution keeping a reasonable number of readout channels

ELSEVIER

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

Volume 236, Issue 1, 1 May 1985, Pages 64-68

1st proposal: 1985

Design Studies for a TPC Readout Plane Using Zigzag Patterns with Multistage GEM Detectors

B. Azmoun, P. Garg, T.K. Hemmick, M. Hohlmann, A. Kiselev, M.L. Purschke, C. Woody, A. Zhang

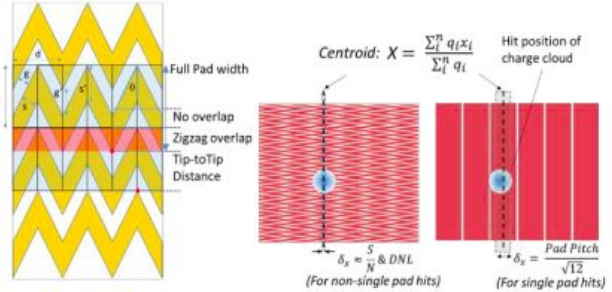
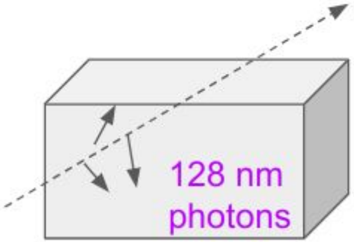


Fig. 1 The sketch on the left shows the 4 basic parameters of the zigzag pattern, including the pitch, zigzag period, gap width, and trace width, denoted by *p*, *d*, *g*, and *s* respectively. (*θ*, *s'*, and *g'* are resultant parameters representing the characteristic angle, the trace width, and gap width at the zigzag apex.) The sketches on the right demonstrate charge sharing and centroid calculations for a zigzag and rectangular pad readout. 6 channels are shown for each pattern with a pitch of 2mm. (The drawings on the right are to scale.)

Time: t_0 from primary scintillation



- In what extent it could help the track tagging?
- Assumption: From Table 4, which shows the number of tracks per 50ns, we conclude that ~ 1200 tracks would be expected during the ~ 25 μs time-frame.

Sub-detector	Intensity per 50ns Particle of origin Photon	Electron/Positron	Neutron
TPC	0.60	2.4	0.09
Scintillators (all)	670	6.5	52
Scintillators/stave	0.17	0.0018	0.014
Lead-glass (all)	31	0.53	
Lead-glass/block	0.002	0.00003	

Table 4: Intensity of particles entering and being produced in a detector sub-system for Configuration 3.

Backgrounds from low energy neutrons near the detector

Billy's work written up by DM

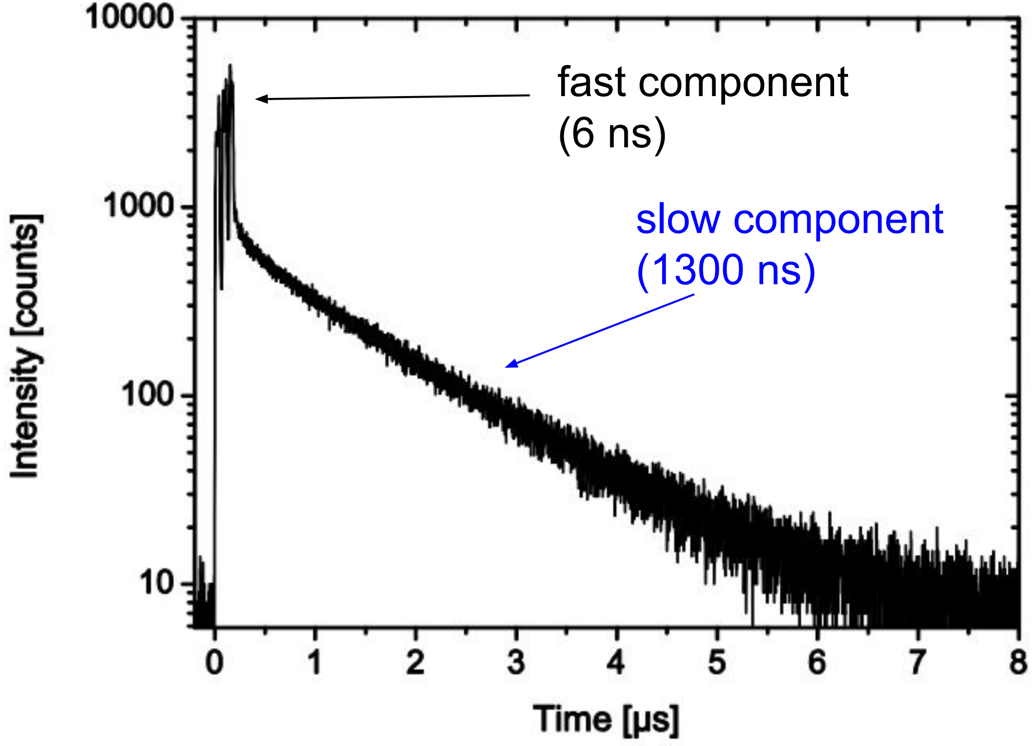
November 2022

Ask Bernhard for your own copy…

$$\Delta t = 1.2e3 \text{ ev} / 25e\text{-}6 \text{ us} \sim 48 \text{ MHz} \sim 20 \text{ ns}$$

in principle is doable

Time spectrum of Ar



onsemi

SiPM rise time

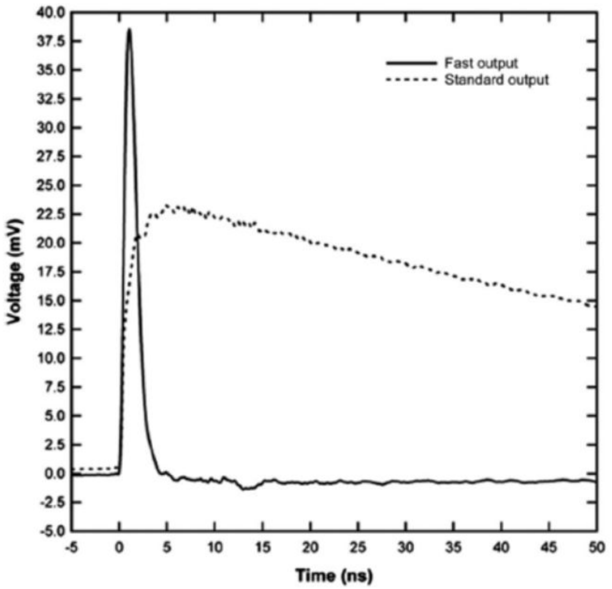


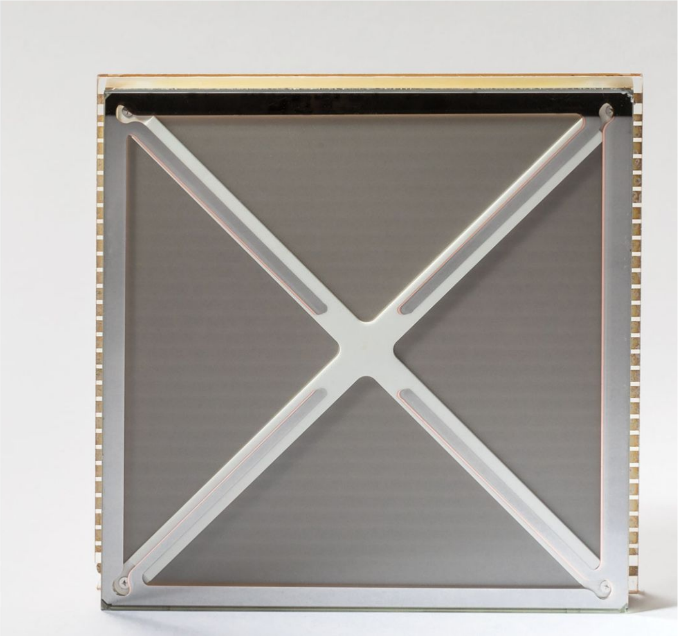
Figure 5. Example fast and standard output signals from an ON Semiconductor SiPM.

-

LAPPDs

- Large Area Picosecond PhotoDetector

20 CM SQUARE LAPPD™

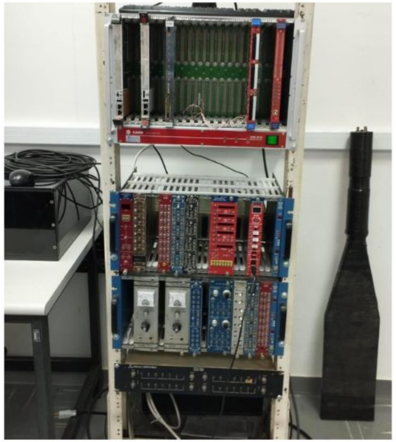


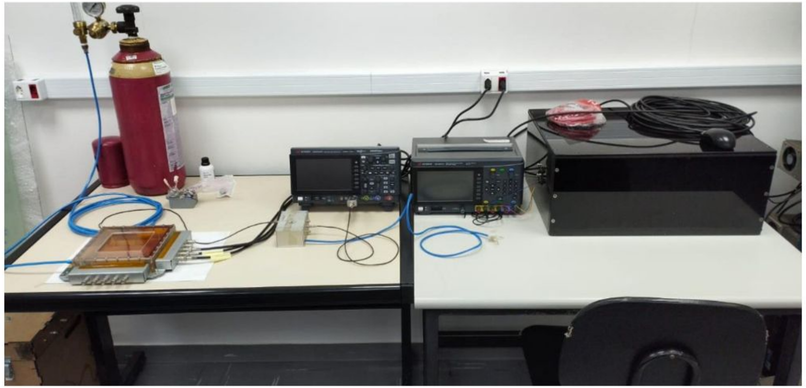
FEATURES

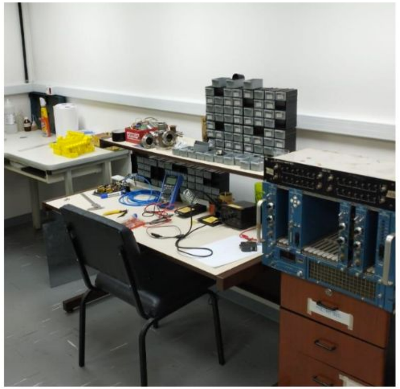
- Large area 200 mm x 200 mm
- Quantum Efficiency > 20% (90% uniformity)
- Chevron pair of 203 mm x 203 mm ALD-GCA-MCPs
- Gain > 1×10^7
- Independent control of voltage to the photocathode and MCPs
- High temporal resolution
- 1mm Spatial resolution
- Dark count rate less than 150 Hz/s/Cm^2

TPC R&D @ UNICAMP

LADEP
LABORATÓRIO DE DETECTORES DE PARTÍCULAS





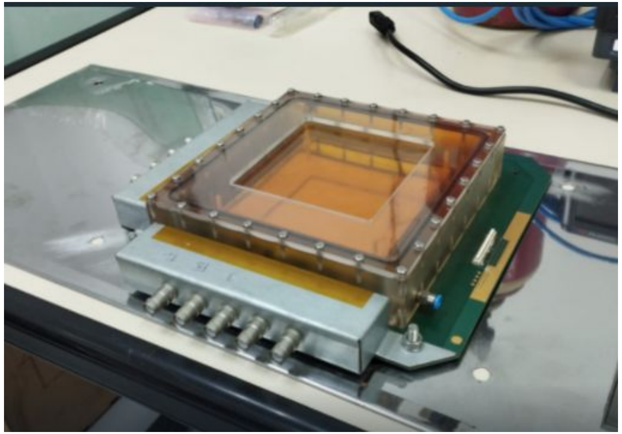
TPC R&D @ UNICAMP: multipurpose chamber + GEM kit

Test Chamber

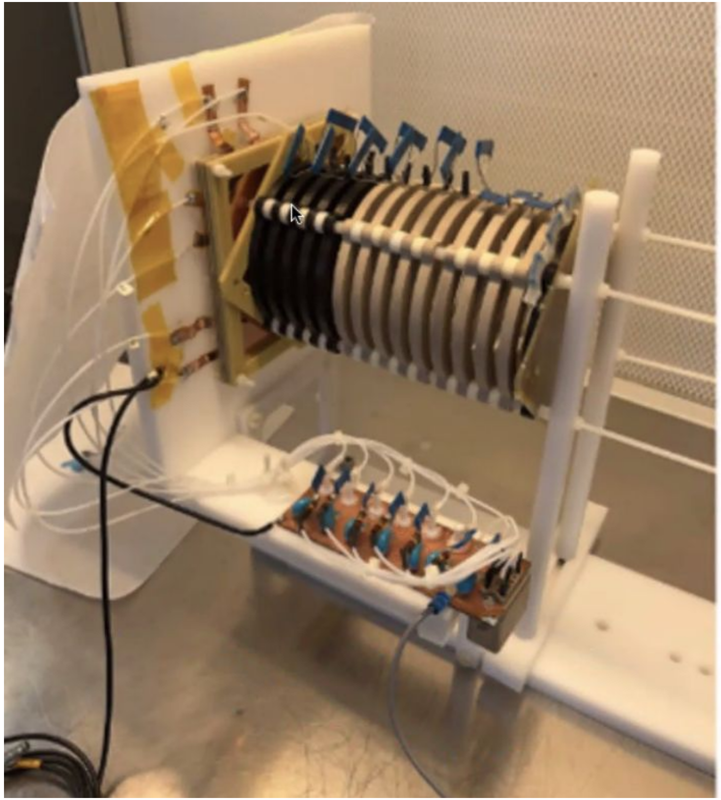
- Black-box
- Vacuum (~ 10^{-6} torr)
- Cryo (LAr in the finger)

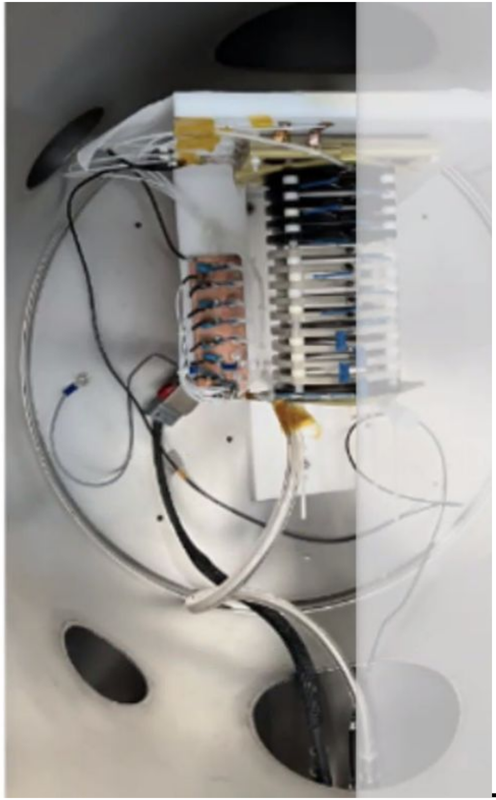
3ple GEM

- h_diam=70um, pitch=140 um, t_mylar=50um, t_copper=5um, 244x244 channels



Example of how to build a TPC test prototype for R&D





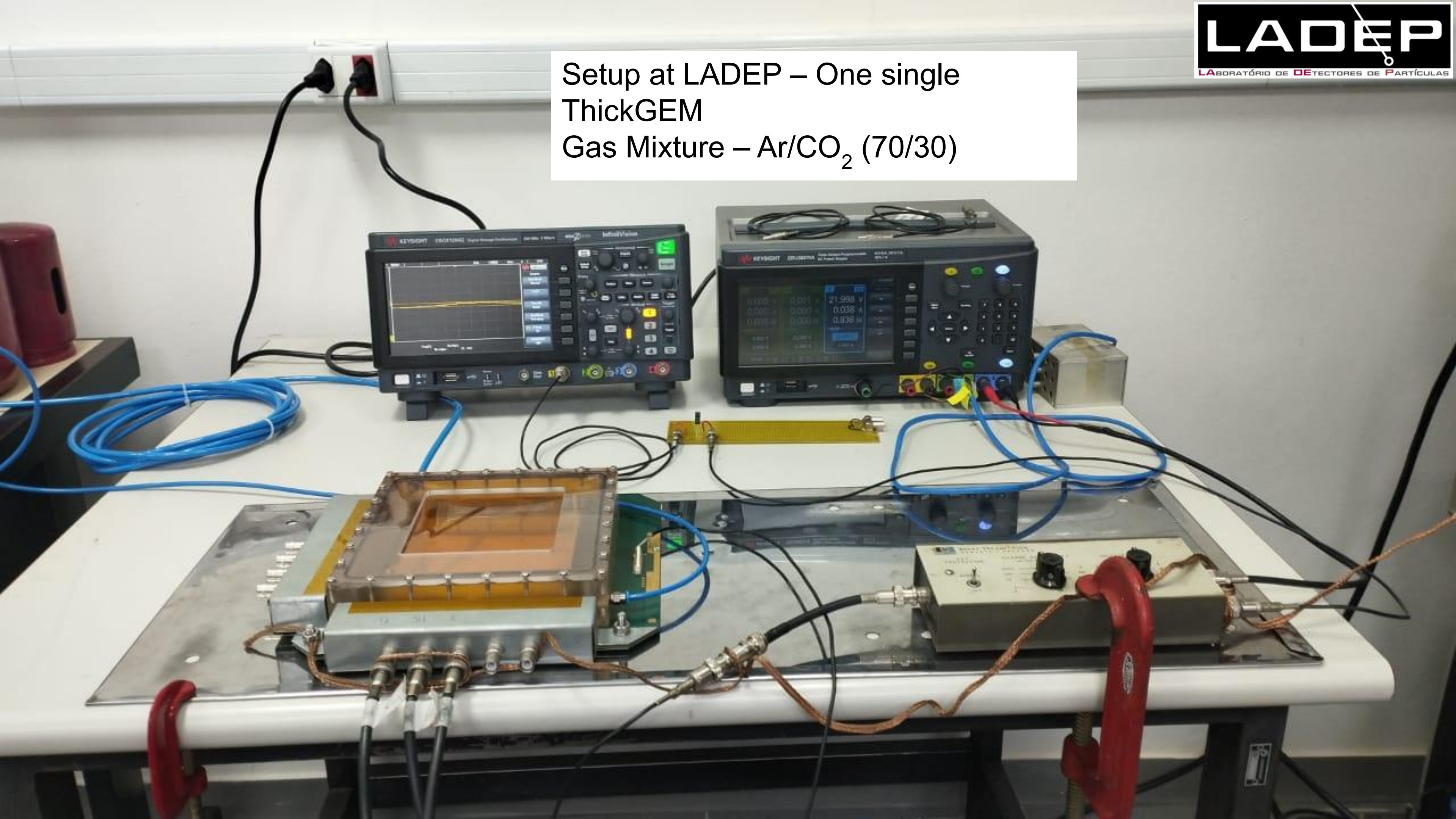
MANGO prototype detector

CYGNO collaboration (INFN - Italy)

CYGNO Experiment

Setup at LADEP – One single ThickGEM

Gas Mixture – Ar/CO_2 (70/30)



Next Step

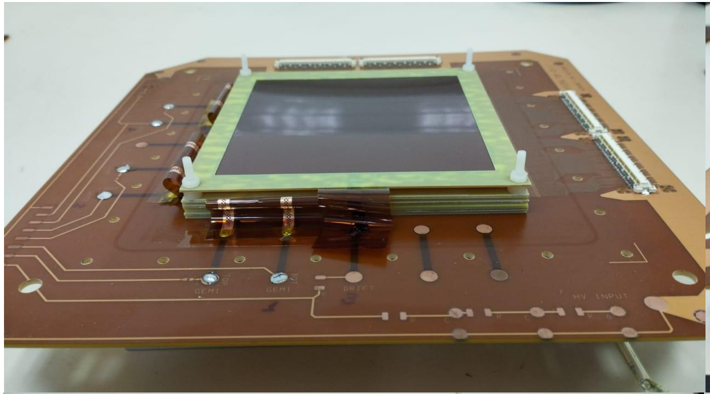
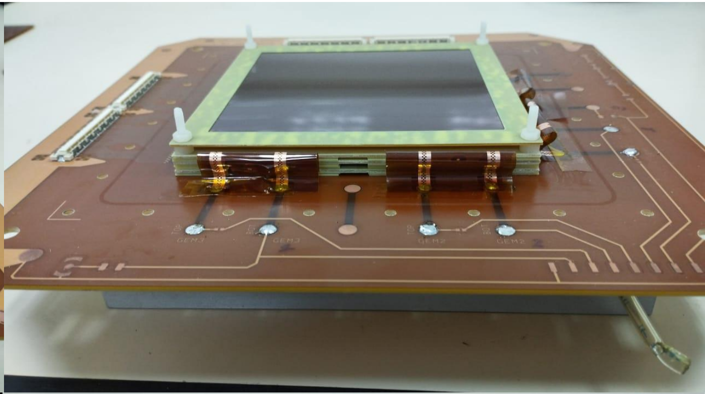
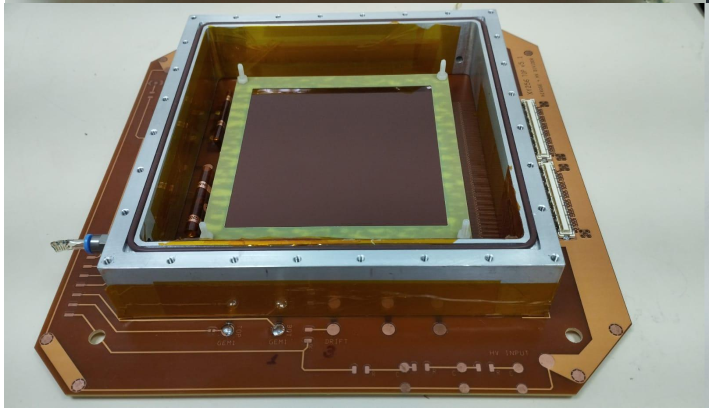
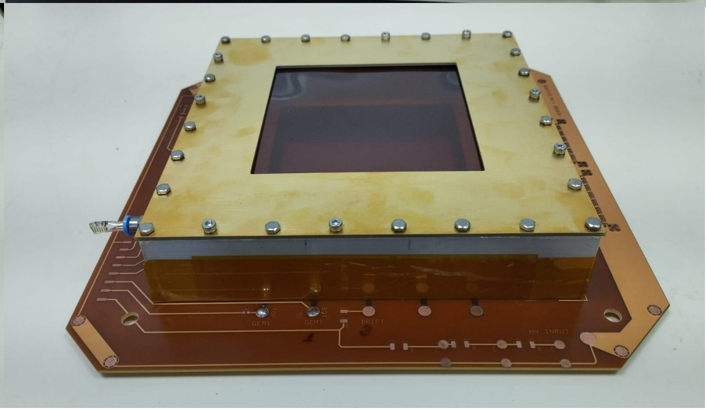
Cern Kit GEM

03 Standard GEM

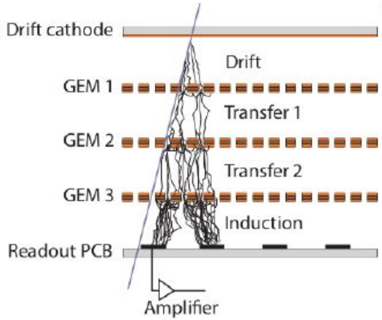
The same Spacing used on CMS:
3mm (drift) – 1mm (B1-T2) – 2mm (B2-T3) – 1mm (induction)

XY 256 (Readout)
Using Resistive Chain

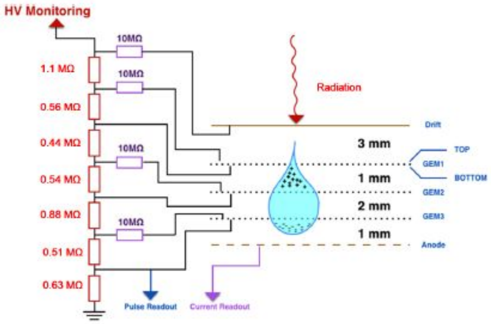
Gas Mixture – Ar/CO_2 (70/30)

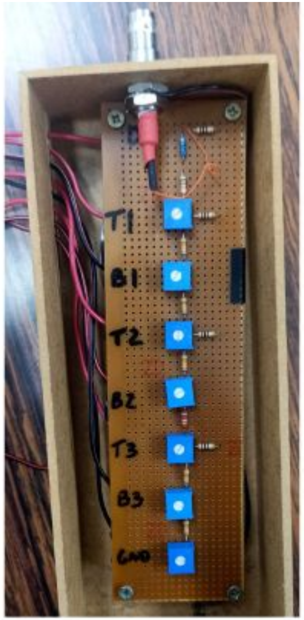





Gain tests by V-scan

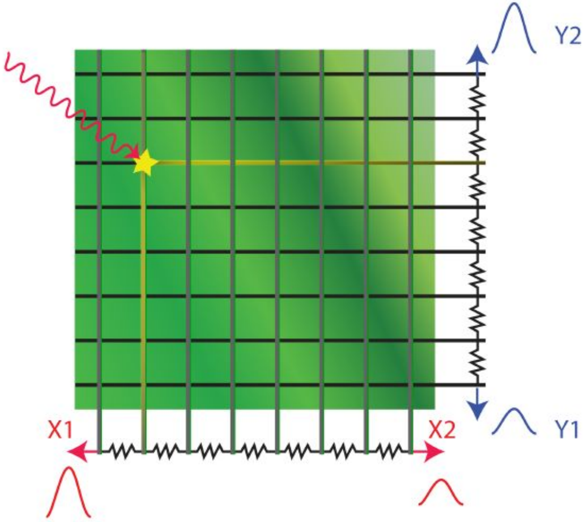


GE1/1 Gap Sizes	Typical Potentials	Typical Voltages	Typical El. Fields [kV/cm]
	3200 V		
3 mm		770 V	2.6
	2430 V	380 V	64.0
	2050 V		
1 mm		300 V	3.0
	1750 V	370 V	62.0
	1380 V		
2 mm		600 V	3.0
	780 V	350 V	60.0
	430 V		
1 mm		430 V	4.3
	0 V		





Readout System – Resistive Charge Division

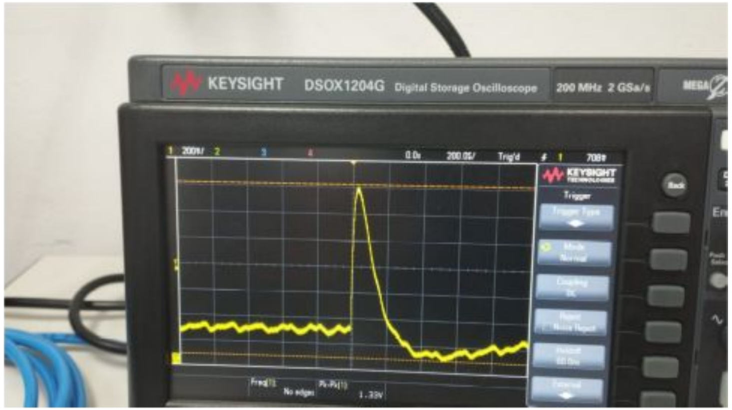


$$x = A\frac{Q_{X2} - Q_{X1}}{Q_{X2} + Q_{X1}}, \qquad y = B\frac{Q_{Y2} - Q_{Y1}}{Q_{Y2} + Q_{Y1}}$$

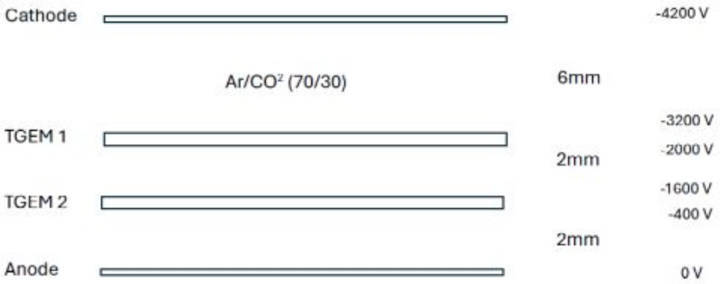
128 channels resistive chains

Single ThickGEM

Double ThickGEM



Charge Sensitive Preamplifier 8V/pC



GEM Next Steps

- Comprehensive characterization and comparison of GEM setups (standard, 1T, 2T)
  - Gain x V scan (different combinations)
- Test the Cern Kit GEM, using our V divider.
- Develop the readout system: simple approach using resistive chains.
- In parallel: Development of a cost effective and efficient technique to study the GEM foils holes geometry, distribution, and defects.

Equipe: E. J. T. Manganote (PVC) + G. Lickel (IC)

TPC

- Vessel has not been used for a while (since september/2023)
- Cleaned up 2 days ago
- Pumps, gas inlets, and seals checked
- Charge collection pads:
  - Optimization of zigzag geometry : Gabriel Gomes (PhD)
    - 1st step: Utilize the existing pads from the GEM setup for initial readout optimization (utilizing resistive chains).
    - In parallel: Assemble the zigzag pad (connectors and cables)
      - **simulations are an ongoing activity at UERJ (Jorge Amaral)**
- Fast Simulation implementation of the TPC: Joelson C. Silva (MsC) **+ André A. Nepomuceno (UFF)**
- Eletrônica de leitura: Vitor Palaveri (IC) **+ Tiago Quirino (UERJ)**

THANK YOU