



Junio 10, 2026



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RPC - Cámaras de Placas Resistivas

[Taller: Aplicaciones Interdisciplinarias de Detectores de Partículas](#)

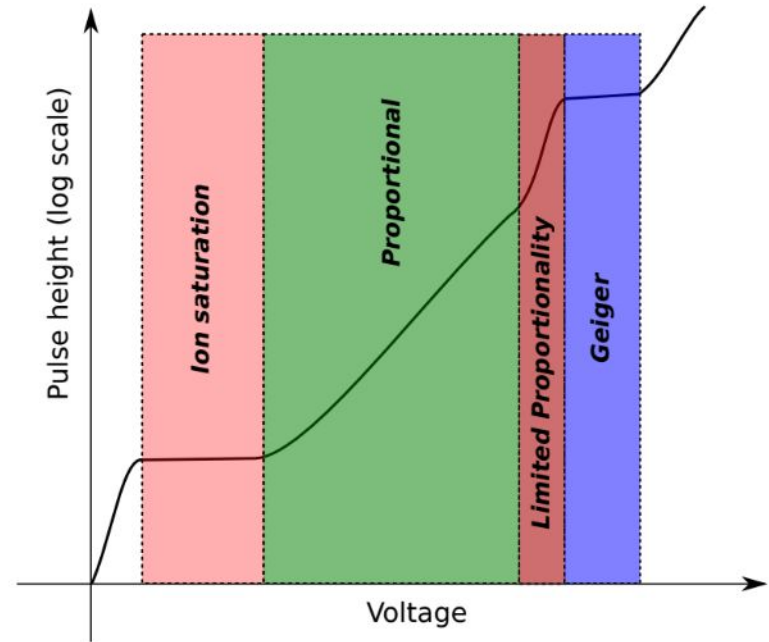
Gas detectors

Geometry

- Cylindrical – E.g. GM counter, proportional counter, straw tube
- Planar – E.g. RPC, PPAC

Features

	RPC
• Energy	NO
• Timing	YES
• Position	YES



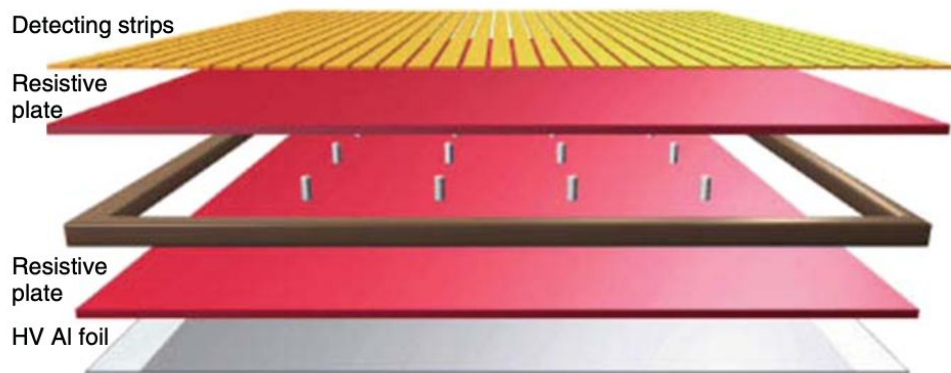
Resistive Plate Chambers (RPC)

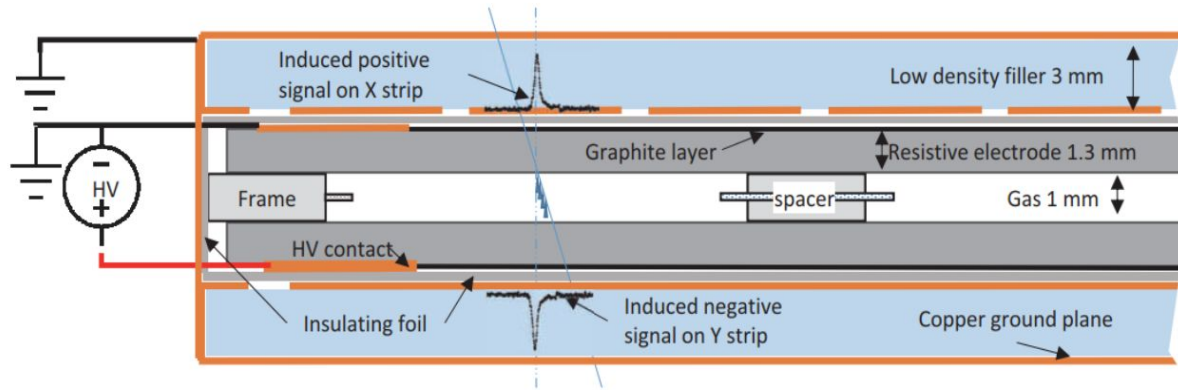
Gaseous detector developed by R. Santonico and R. Cardarelli in the early 1980.

Original purpose was to provide a competitive alternative to large scintillator counters.

Important Features:

- high detection efficiency (>95%)
- excellent temporal and spatial resolutions
- ease of constructing large-format single frame detector



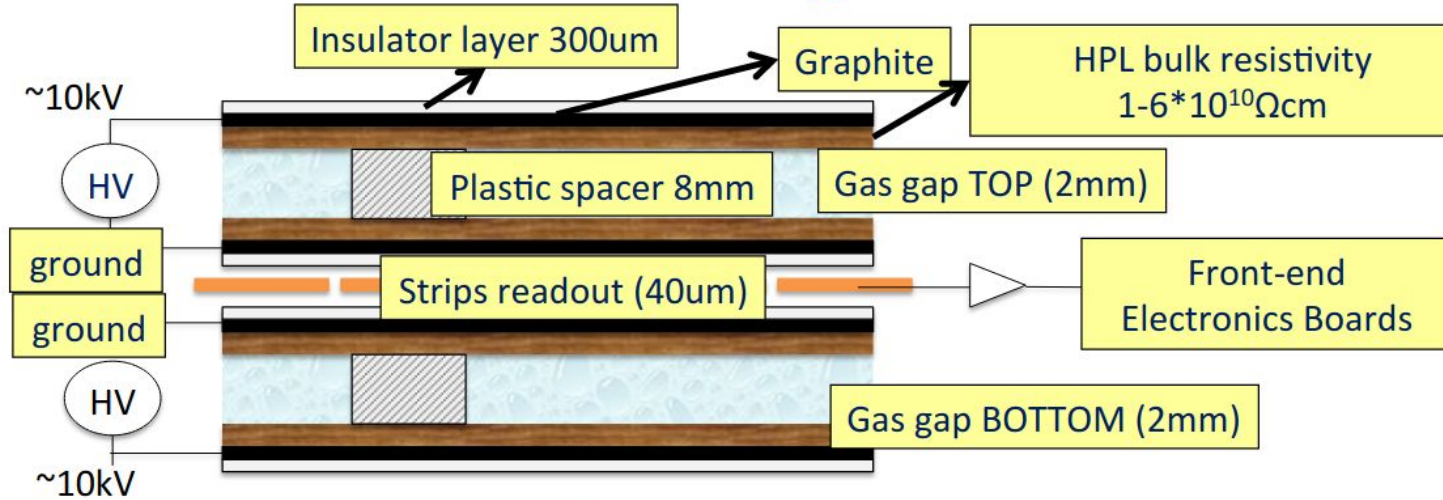


RPC gas gap sandwiched between the two read out strip panels

Gas gap components

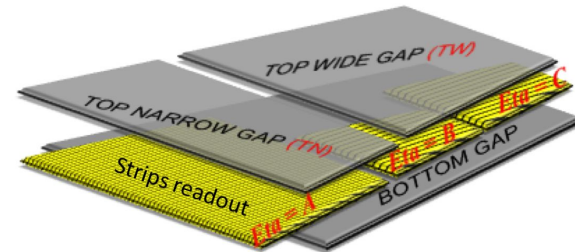
- a. High Pressure Laminates electrode plates ($10^9-10^{13}\Omega\cdot\text{cm}$)
- b. Graphite electrodes
- c. Insulating PET foil
- d. Spacers

Double gap RPC (CMS)

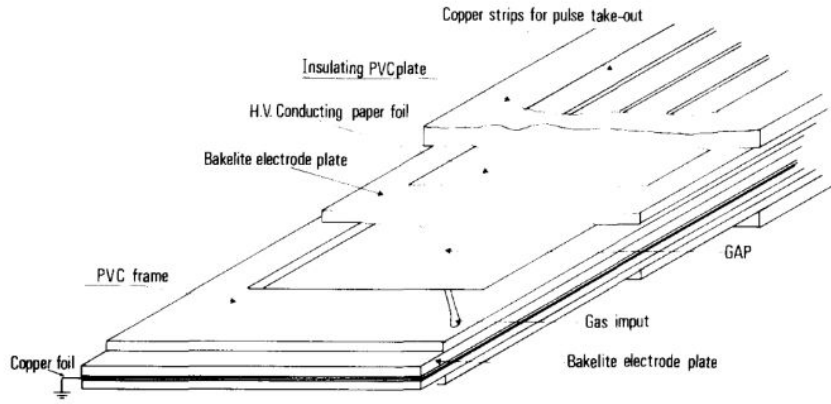


CMS Standard gas mixture:

- 95,2% $\text{C}_2\text{H}_2\text{F}_4$ (Freon)
- 4,5% iC_4H_{10} (Isobutane)
- 0,3% SF_6 (Sulphur Hexafluoride)



The idea remains!



R. Santonico and R. Cardarelli, NIM 187 (1981)

- Usage of inexpensive materials like **bakelite**
- Simplified construction
- Readout with capacitive coupling and reasonable position resolution
- Large area particle detection

The resistive electrode

The time evolution of charge deposited on an electrode can be described by

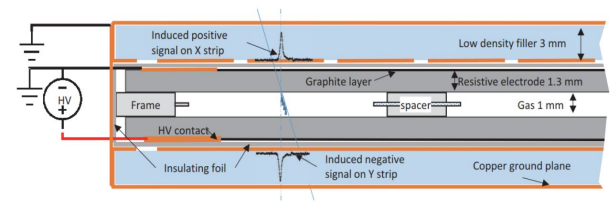
$$Q(t) = Q_0(t) \exp(-t/\tau)$$

$$\tau = \rho \epsilon_0 \epsilon_r$$

where Q is the charge deposited and τ is the relaxation time

- Allows localization of the discharge making only small part of the detector inactive
- Localization of charge can be exploited to obtain reasonable position information
- Provides inbuilt protection to electronics from sparks and discharges

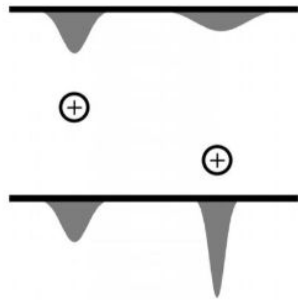
Standard gap free parameters



A wide range of parameters can be chosen to optimize a standard gap for specific purposes

- **Gas gap size.** The gap size regulates the signal duration (and therefore the charge) which is approximately proportional to it. Taking as reference the 2 mm gap widely used so far (total delivered charge some 20 pC and time resolution about 1 ns, mainly depending on the amplitude correction accuracy) substantially narrower gap sizes show a proportionally smaller signal charge and lower time fluctuations. This means an increased rate capability and timing accuracy. This improved performance requires however, to be preserved, a front end electronics with a lower charge threshold.
- **Electrode resistivity and thickness.** The electrode resistivity regulates, for a given working current, the voltage applied to the electrodes and therefore subtracted to the gas. A **decrease of resistivity increases the rate capability.** It is to be stressed however that a high rate capability obtained mainly via a very low resistivity would generate potential **aging problems**. It is therefore safer to increase the rate capability by lowering the charge-threshold of the front end electronics. The electrode thickness affects the total electrode resistance (thinner electrodes → lower resistance) and the electrode capacitance. Thinner electrodes increase the fraction of charge induced on the read out pads

Signal induction by motion of charge



F. Sauli, Gaseous
Radiation Detectors,
Cambridge University
Press

The Shockley-Ramo theorem is given by

$$i = E_v ev$$

where i is the instantaneous current flowing in the electrode due to the motion of a single electron, E_v is the electric field and v is the velocity of the electron

- The signal is generated on the readout as soon as ions and electrons start moving in the gas due to the electric field
- Since the electrons have higher mobility compared to ions, electron component is mostly used.

Electrode materials

Glass

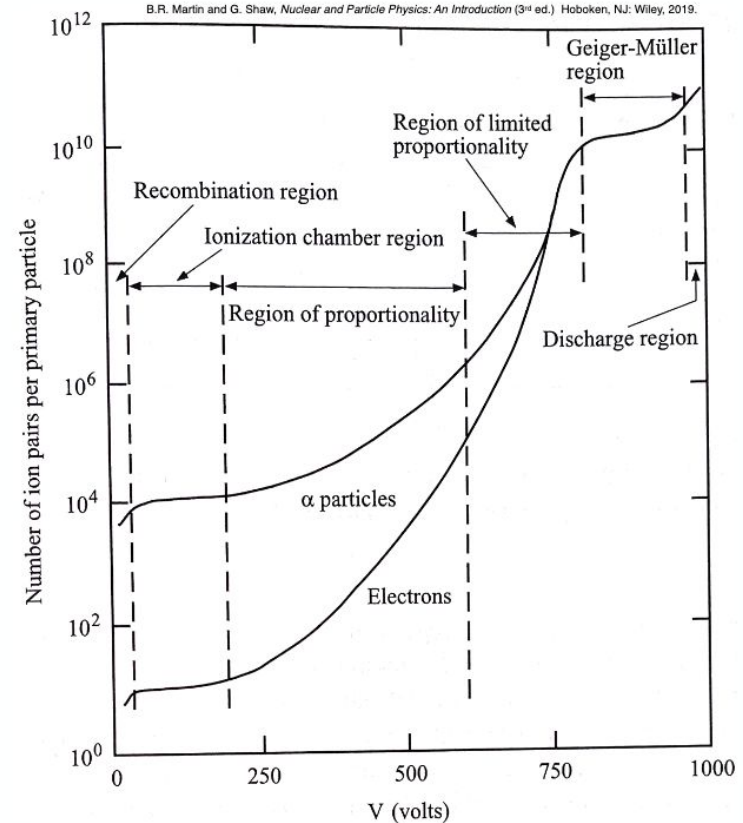
- Hard and rigid
- Surface smoothness excellent
- Typical resistivity $\sim 10^{12} - 10^{13} \Omega\text{cm}$
- Semiconductive glasses can be produced with $\sim 10^{10} \Omega\text{cm}$ resistivity but are expensive
- Suitable mostly for low count rate or cosmic ray experiments

Bakelite

- Comparatively flexible
- Surface finish above average. Requires oil coating for better performance
- Typical resistivity $\sim 10^{10} - 10^{12} \Omega\text{cm}$
- Suitable for collider experiments
- Requires humidified gas mixture
- Needs R & D on rate capability for use in future collider facilities with increased luminosity and particle flux

Modes of operation

- In proportional region, electrons and ions trigger secondary ionization \Rightarrow avalanche \Rightarrow very large gains
- Strength of avalanche still proportional to ionization energy loss (\Rightarrow particle ID)



Modes of operation

Avalanche Mode

- After ionization, charge multiplication reaches to an extent that its own field prevent further multiplication
- This is also known as the saturated avalanche
- Charge induced is ~ 1 pC
- Requires low-noise preamplification electronics
- Higher count rates are possible
- Better time resolution

Streamer Mode

- When the applied voltage is increased beyond the saturated avalanche regime a streamer or mild spark is created.
- A conductive channel is formed across the electrodes and the small discharge area remains inactive for a larger amount of time.
- Charge induced is $\sim 10-100$ pC
- Requires no preamplification electronics
- Cannot be operated in high count rate environment

Modes of operation (Gas mixtures)

Avalanche Mode

- **Freon:** Main medium of interaction
- **Isobutane:** Recombination photon quencher
- **SF₆:** Arrests the development of avalanche

Typical gas composition:

Freon	i-butane	SF ₆
95	~5	0.3

Streamer Mode

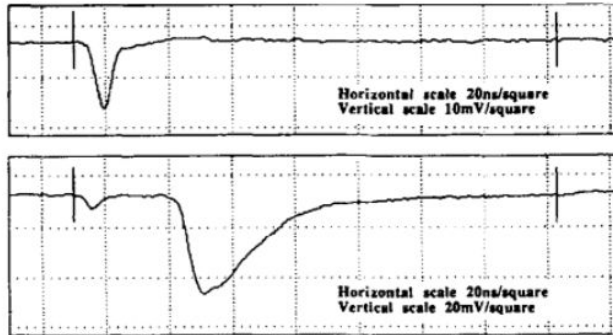
- **Argon:** Medium of interaction
- **Freon:** Slightly electronegative gas that controls avalanche development
- **Isobutane:** Recombination photon quencher
- **SF₆:** Arrests the development of avalanche

Typical gas composition:

Ar	Freon	i-butane	SF ₆
48	48	4	Very little or NA

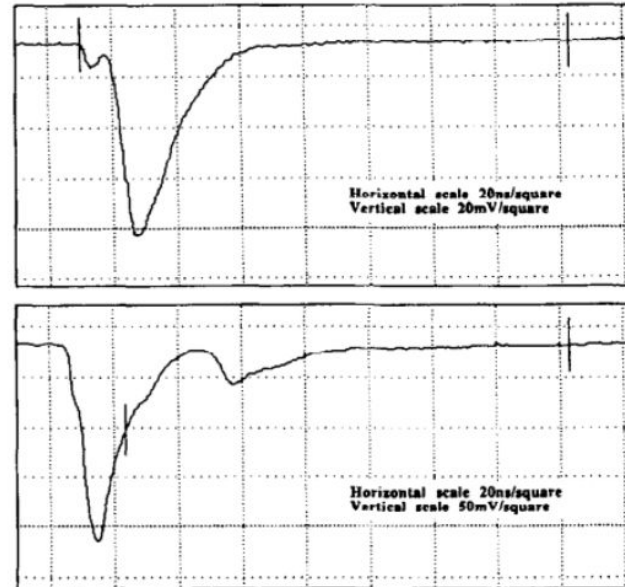
Modes of operation (pulses)

Avalanche Mode

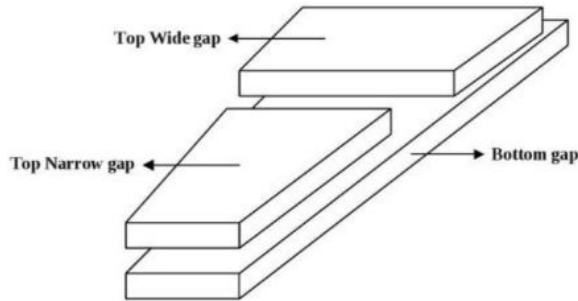
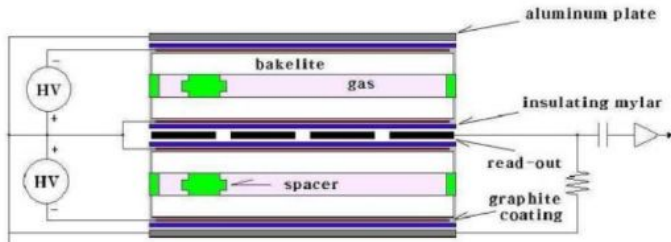


R. Cardarelli et al, NIM A 382 (1996)

Streamer Mode



Avalanche RPCs in experiments – Double gap (CMS Endcap)

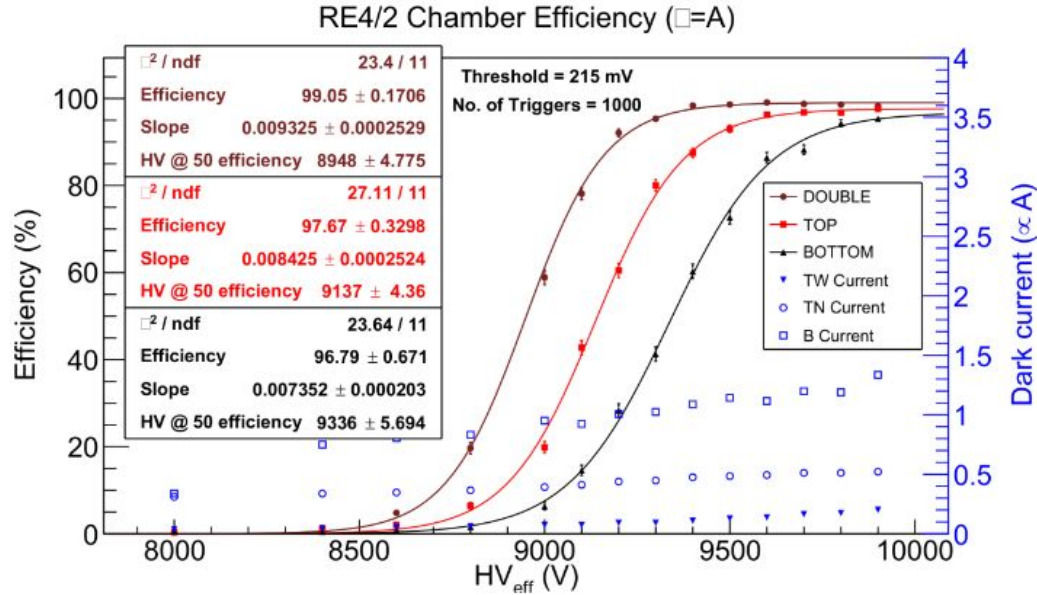


- Usage of double gap improves the efficiency of the RPC
- The efficiency of 1 gap would compensate for the inefficiency of the other per event
- Readout only on one side of the RPC

Electrode material	Gap thickness	Electrode thickness
Bakelite	2 mm	2 mm
<ul style="list-style-type: none"> • Freon (95.2%), i-butane (4.5%) and SF₆(0.3%) • Bulk resistivity $\rho \sim 1 - 6 \times 10^{10} \Omega\text{cm}$ • Dimension/area : $\sim 2 \text{ mm}^2$ 		

Mariana Shopova, ArXiv: [arXiv:1605.06798v1](https://arxiv.org/abs/1605.06798v1)

Efficiency vs Gap



$$HV_{\text{eff}} = HV_{\text{app}} \frac{P_0 T}{T_0 P}$$

$$P_0 = 990 \text{ mbar}$$

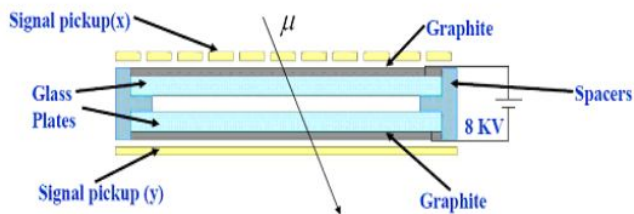
$$\eta = \frac{\epsilon_{\text{max}}}{1 + e^{-\lambda(HV_{\text{eff}} - HV_{50\%})}}$$

$$T_0 = 293 \text{ K}$$

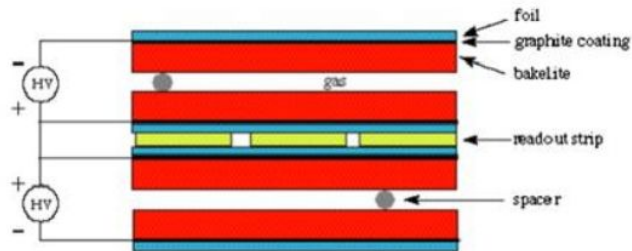
V. K. S. Kashyap et al, Pramana – J Phys. 88.79 (2017)

S. Colafranceschi et al 2014 JINST 9 C10033

Experiment	Avalanche	Subsystem	Resistive Plates	Mode	Gaps
ALICE		μ Spectrometer	Bakelite	Avalanche	1
ATLAS		μ Spectrometer	Bakelite	Avalanche	1
CMS		μ Spectrometer	Bakelite	Avalanche	2



Single gap



CMS double gap

Gas mixture and GWP

Gases used in RPC and Global Warming Potential (GWP)

Gas	Freon-r134a	i-butane	SF ₆
GWP	1430	3	23900

- Freon r134a and SF₆ have high GWP
- Alternative gas candidates are:

Gas	HFO-1234ze	HFO-1234yf
GWP	6	4

- These gases currently do not show performance similar to that of r134a mixtures in the avalanche mode and can be used as additional components to reduce overall gas mixture GWP
- More R & D ongoing to find good alternatives

1. M. Capeans et al, 2015 *IEEE Nuc. Sci. Symp. and Med. Imag. Conf. (NSS/MIC)*, 2015, pp. 1-4
2. R. Guida et al, <https://doi.org/10.1016/j.nima.2019.04.027>

RPC descendant (Multi-gap RPC)

- Built to improve the time resolution of RPCs drastically while still retaining good efficiency
- Very fine division of gas gap in the order of 100s of microns
- Electrostatic division of voltage
- Time resolution ~ 50 ps
- With optimized designs, they can be good candidates for PET imaging

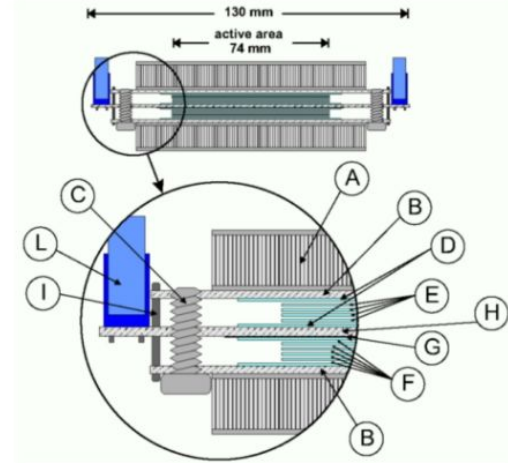


Figure 3. Cross-section of the double-stack MRPC of the ALICE-TOF system. A: 10 mm thick honeycomb panel; B: PCB with cathode pick-up pads; C: M5 nylon screw to hold the fishing-line spacer; D: 550 μm thick external glass plates; E: four 400 μm thick internal glass plates; F: five gas gaps of 250 μm ; G: 250 μm thick mylar film; H: central PCB with anode pick-up pads; I: pin to bring cathode signals to central read-out PCB; L: flat-cable connector (for MRPC signal transmission to the front-end electronics).

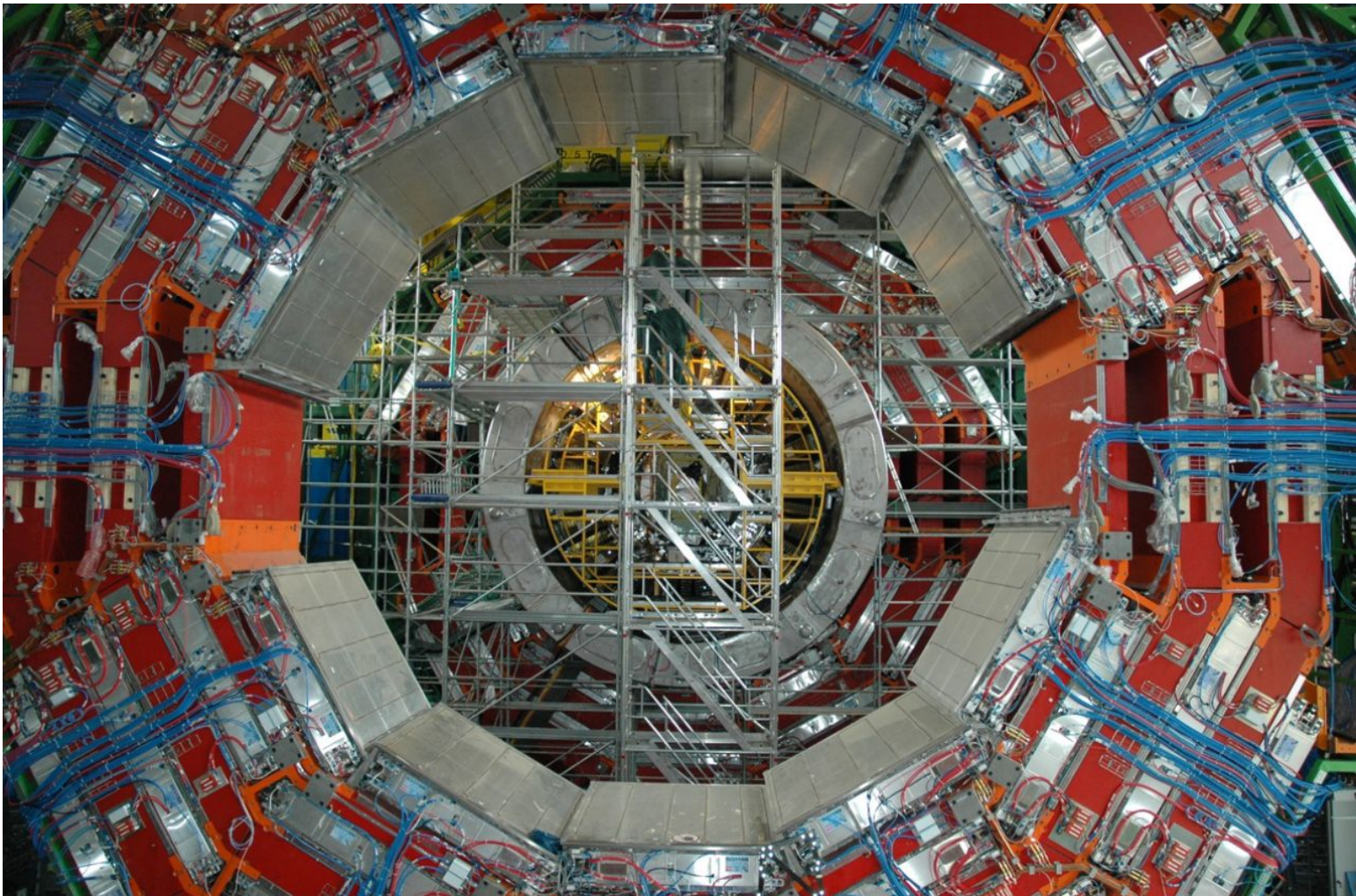
A. Akindinov et al, Nuclear Physics B (Proc. Suppl.) 158 (2006) 60–65

Applications (Muography)

- RPCs being able to cover large area are excellent candidates for muography studies like surveys of geological structures and isolated ore bodies or weak zones in mines, detecting a reservoir or boulders during tunnelling etc.
- They could be a cheaper alternative to large scintillation detector based setups
- Compactness and portability of muography setups with RPCs can be explored
- The muon tomography technique can be used to identify contraband materials in large shipping containers

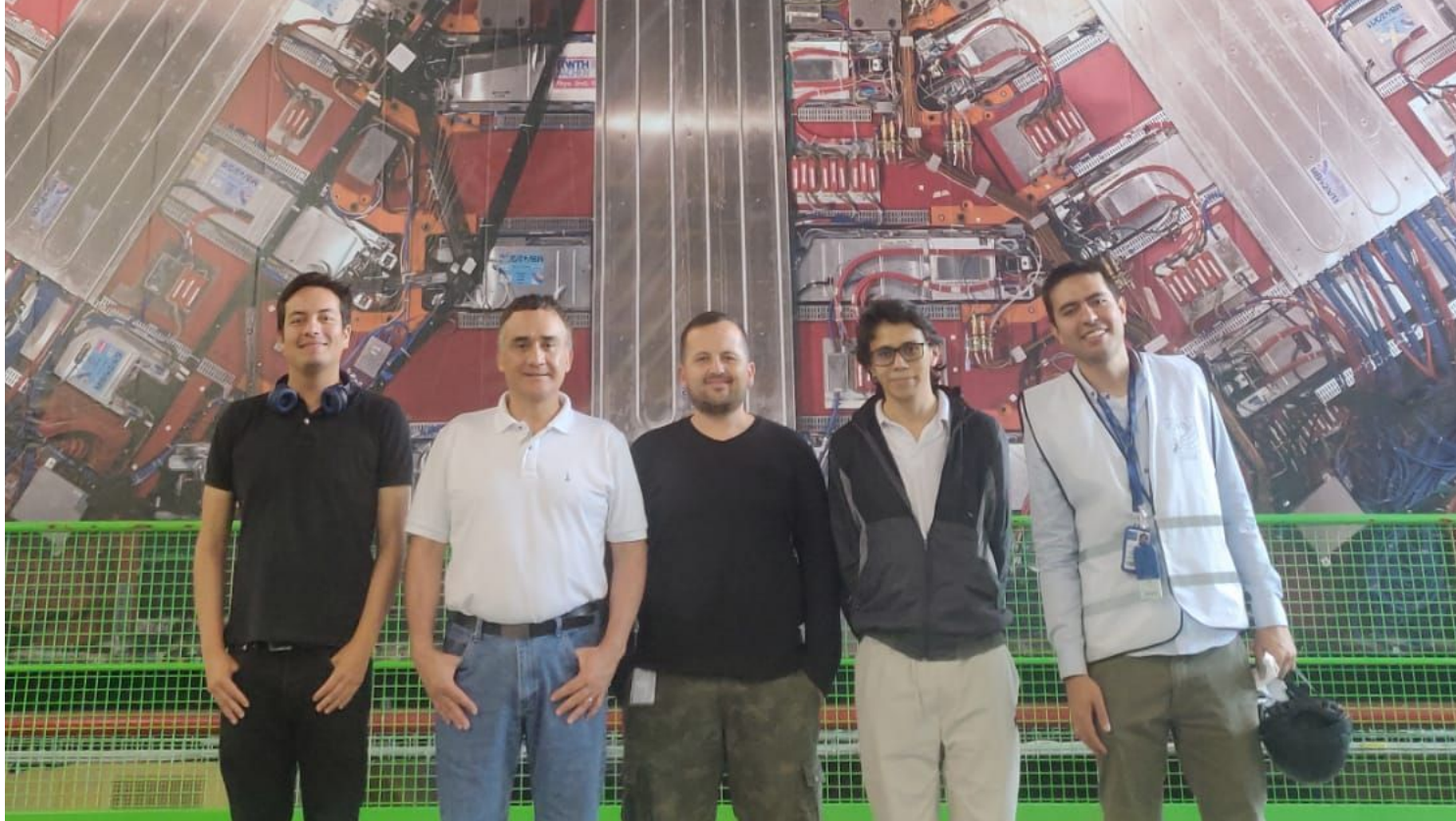
P. Baesso et al 2014 JINST 9 C10041

J. Wang et al 2016 JINST 11 C11008



RPC
Barrel
system

Involvement of Uniandes





Ready for the
adventure?

References

- [F. Takahashi et al. \(Particle Data Group\)](#), to be published in Int. J. Mod. Phys. A 41, 2630011 (2026)
- [Status and perspectives of the «Standard RPCs»](#) RPC-2024 Conference, Santiago de Compostela 9 Sep 2024 By R. Santonico
- [Detectors](#) Rachel Yohay, Florida State University, CERN Summer Student Lecture Programme, July 4, 2025
- [Fundamentals of Resistive Plate Chamber \(RPC\)](#), Varchaswi K S Kashyap, Workshop on Advanced Radiation Detector and Instrumentation in Nuclear and Particle Physics (RAPID2021)