New Readout Scheme for Large Area Timing & Position RPCs

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1. ABSTRACT

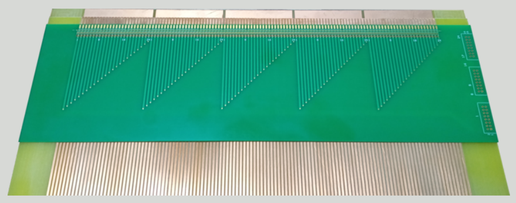
A **new readout technique** was developed with the initial premise of keeping the number of channels in the front-end electronics (FEE) as low as possible when scaling up the sensitive area of a **Resistive Plate Chamber (RPC)**. The readout here presented significantly reduces the dependency between the detector area and the number of electronic channels, without substantial reduction of its performance: a 30 cm x 30 cm double stack multi-gap timing RPC was operated along several weeks with cosmic rays, achieving a **2D spatial resolution well below 1 mm** and **time resolution lower than 100 ps**, while its efficiency was kept above 98%.

2. INTRODUCTION

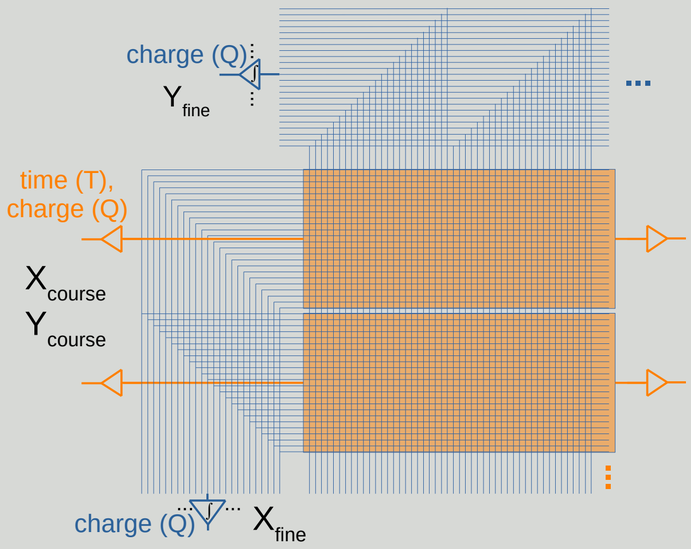
RPCs are deployed across diverse fields, for instance in High Energy Physics (HEP) for particle triggering and tracking over large areas, but also for Particle Identification (PID), if built to achieve high timing resolutions. In fact, RPCs could perform PID without additional detectors, measuring simultaneously and accurately position and time. In the field of muon tomography, RPCs were first used in 2012 [1] to infer the presence of materials with high atomic number (Z). More recently, the **Muon Scattering Tomography (MST)** technique was also used with RPCs, showing the presence of several high Z materials after few minutes of acquisition [2]. RPCs are indeed well suited for muographic techniques since they can be built at relatively low cost, covering large areas with high efficiency, spatial and time resolutions. However, the electronics used in the FEE is the major cost contributor of the detector, reaching prohibitive values if one needs to cover a surface well above 100 m^2, the area that must be instrumented to scan a shipping container. A novel RPC readout codification was therefore designed and tested with the main purpose of addressing the aforementioned problem, partially decoupling the number of FEE channels from the sensitive area of the detector, while keeping high spatial and timing resolutions.

3. NOVEL READOUT

- 120 thin strips subdivided into 5 groups of 24 strips
- the same electronic channel reads, in parallel, one strip per group
- **only 24 preamplifiers needed to read 120 strips**

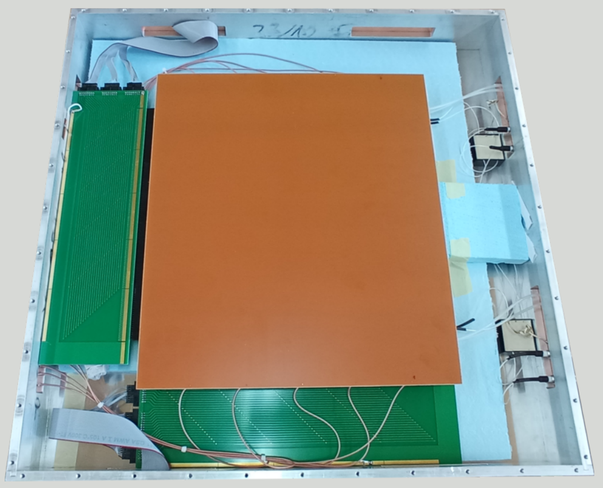


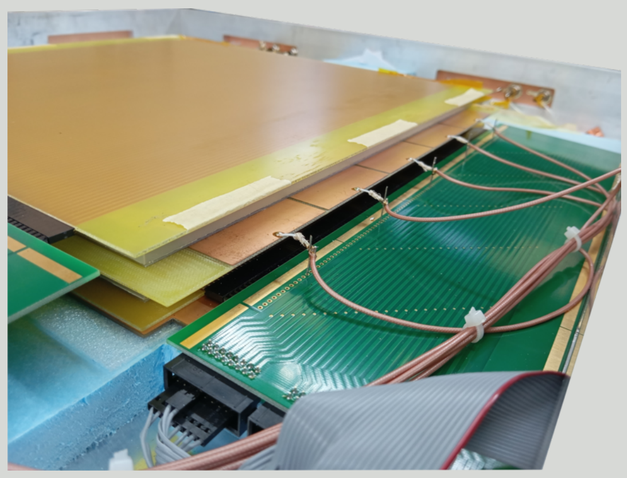
- **fine position** within the groups determined with sub-millimetric precision by charge interpolation
- **coarse position** obtained from 5 wide strips for disentanglement between the 5 groups



4. DETECTOR

- 2 multi-gap timing RPCs, one on each side of the wide strip readout, with 6 gas gaps each, 300 μm wide, and glass 1 mm thick ($\rho \approx 4x10^{12}$ Ω.cm at 25°C)
- active area of 30 x 30 cm^2

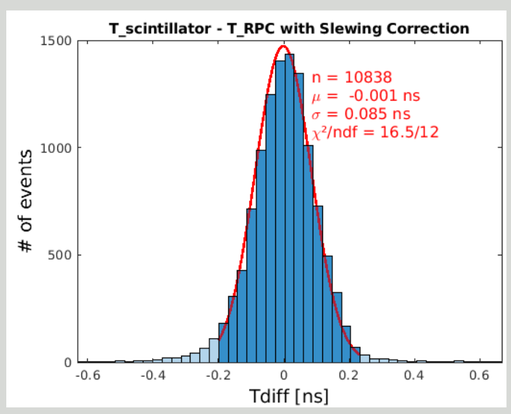




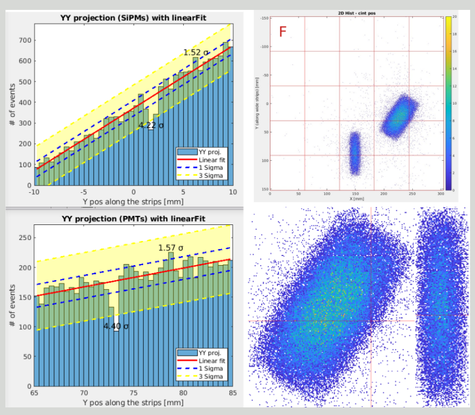
- 120 longitudinal thin strips (1.54 mm wide and 2.54 mm pitch)
- 5 longitudinal wide strips (5.9 cm wide and 6.1 cm pitch)
- 120 transversal thin strips (1.54 mm wide and 2.54 mm pitch)

5. RESULTS

long run with cosmic rays - trigger generated by 2 SiPMs and 2 scintillators coupled to PMTs, both located below and above the RPC:



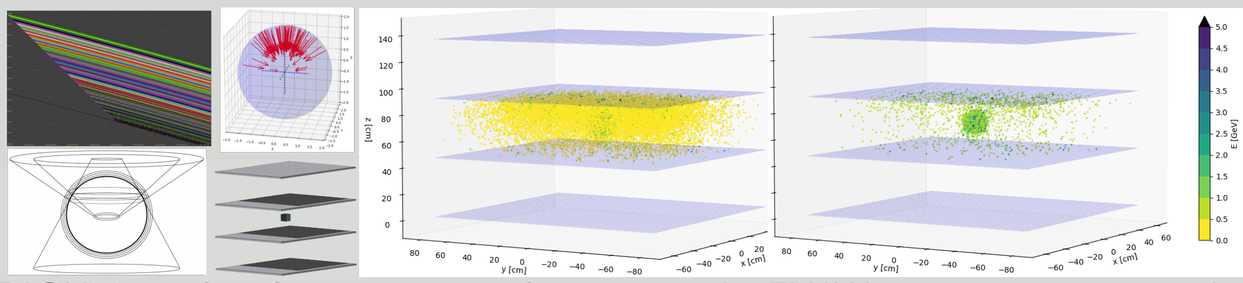
$\sigma_{RPC} = 74ps$
(scintillator contribution deconvoluted)



sub-millimetric resolution
(fishing line spacers of 300μm clearly visible)

6. APPLICATION - MUON SCATTERING TOMOGRAPHY

LEFT: top-left: **FLUKA atmospheric model** [3], 100 layers from 0 to 70 km above sea level with different densities; bottom-left: scoring between three cones for specific geomagnetic latitude and longitude; top-right: **muon generator** following a $\boldsymbol{cos^2(\theta)}$ distribution (zenithal angle) and $\boldsymbol{E^{-2.7}}$ distribution (above 2GeV; flat below this energy); bottom-right: geometry of 4 RPCs with a 10 cm^3 tungsten block at the center.



RIGHT: results of a two step simulation using the FLUKA cosmic ray source and Earth atmospheric model; applied restrictions: only scatters above 1.5° (left), removing also muons below 500 MeV (right).

7. CONCLUSION & FUTURE WORK

- **New readout codification**, developed to **reduce channels of FEE** (driving cost of the detector), and tested with a timing RPC (30 cm x 30 cm).
- 24+24 charge sensitive preamps used to read 120+120 thin strips (X-Y dim.).
- +5 current sensitive fast preamps to read 5 additional large strips.
- The novel readout made it possible to achieve a **2D high spatial resolution ($<$ 1 mm) + timing measurements ($<$ 100 ps (σ))**.
- **NEXT WORK:** a large scale, 120 cm x 90 cm RPC is under construction and will be tested with the same number of channels and readout technique.

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- Fundação para a Ciência e Tecnologia, Portugal (CERN/FIS-INS/0006/2021)
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9. REFERENCES

[1] P Baesso et al., JINST 7 P11018, 2012

[2] J. Saraiva et al., NIMA 1050, 168183, 2023

[3] G. Battistoni et al., Annals of Nuclear Energy 82, 10-18, 2015