Development and (preliminary) test of a Micro-Pattern Resistive Plate detector

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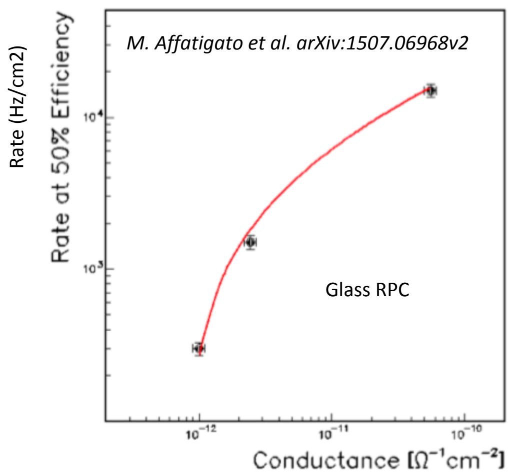
Introduction

- Rate capability of Resistive Place Chambers (RPC) depends – among other factors - by the plate resistivity
- The development of RPC with low resistivity is one of the most interesting research lines in view of extending the rate capability of these devices.

$$\mathrm{RateCapability} \propto \frac{1}{\rho Q d}$$

ρ = bulk resistivity (Ω x cm)
Q = average charge
d = total thickness of resistive plates



- Possible drawbacks of lowering electrodes resistivity
  - Increase of the noise
  - Increase of operating current
  - Increase in formation rate of pollutants

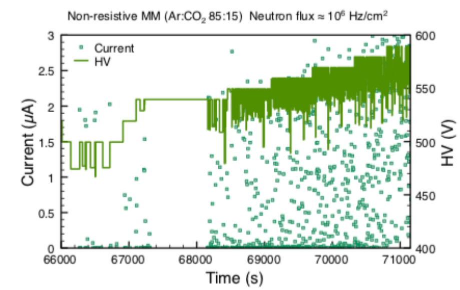
- We present an attempt of building an RPC-like device with techniques developed for micro-pattern gaseous detectors.

Introduction

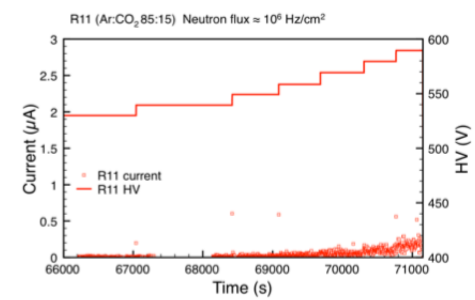
- Micro-patterning is a well established technique to build a large variety of gaseous detectors
  - GEM
  - Micromegas
  - µRWELL
  - …

- The Micro Pattern Gaseous Detector (MPGD) community is in fact very active in developing and optimising detectors based on this construction technique

- With the introduction of a resistive layer, pioneered by the ATLAS Micromegas, the intensity of discharges in MPGD devices can be largely suppressed, allowing the use of such a detector in large experiments.



J. Wotschack et al. CERN-PH-EP-2010-061



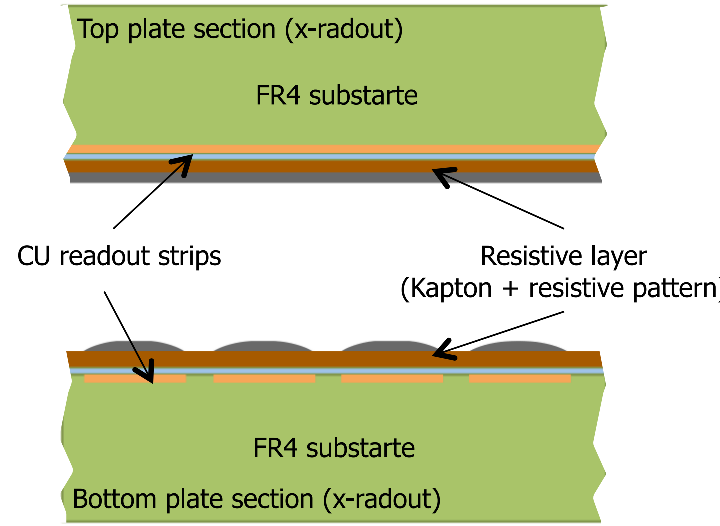
- MPGD detectors are often used as tracking device in applications where the particle rate is not sustainable for wire chambers (CMS and ATLAS muon system upgrades); the single-layer time resolution being limited to O(several ns) as far as the pure gas behavior is considered.

- Aim: reaching similar performance as standard bakelite RPC for time resolution and ability to efficiently work at particle rates of O(>100 kHz/cm2)

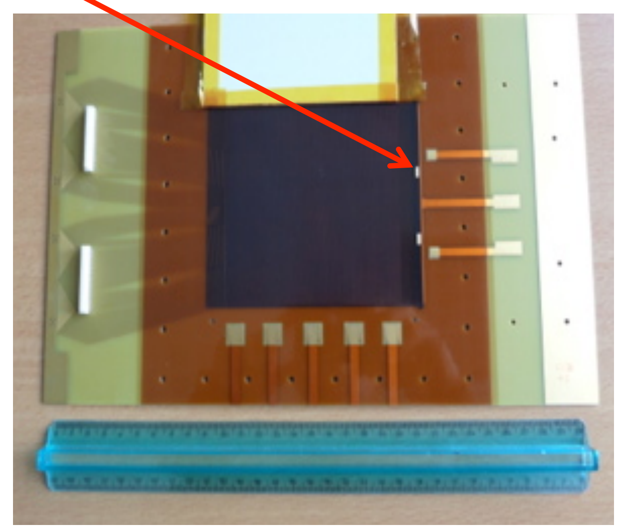
Detector layout

- The first prototype:
  - Built at CERN
  - Two equal electrode plates made of 2 mm thick fibre-glass (FR4) substrate with 17 µm Cu layer from which readout strips are obtained by etching
  - Strip pitch of 400 µm and width of 300 µm
  - A 50 µm insulating Kapton® foil is glued on top of the readout strip, carrying resistive strips
  - Resistive strip width and pitch similar to RO Cu strip
- HV is applied to the resistive strips
- Connection between the HV line and the resistive strip is implemented with two vias in the Kapton® filled with Ag-based epoxy paste
- 250 readout strips for each view, covering an active area of 10x10 cm^2
- The two plates are separated by a 2 mm gap and are rotated by 90° with respect to each other, providing a 2D tracking capability
- An cross-shaped FR4 frame has been used to keep the electrodes 2 mm apart. It needed to be covered by Kapton to limit discharges along the side walls

Detector sketch



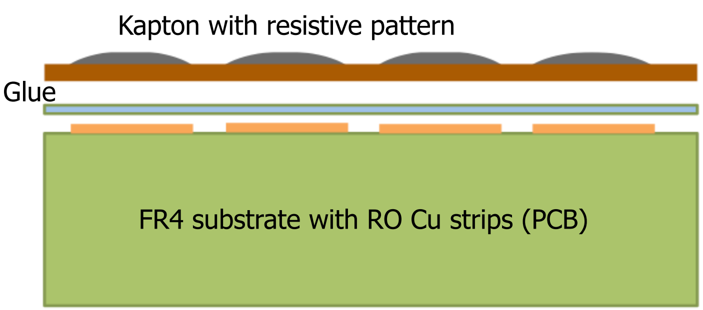
Sketch of the FR4 spacer frame

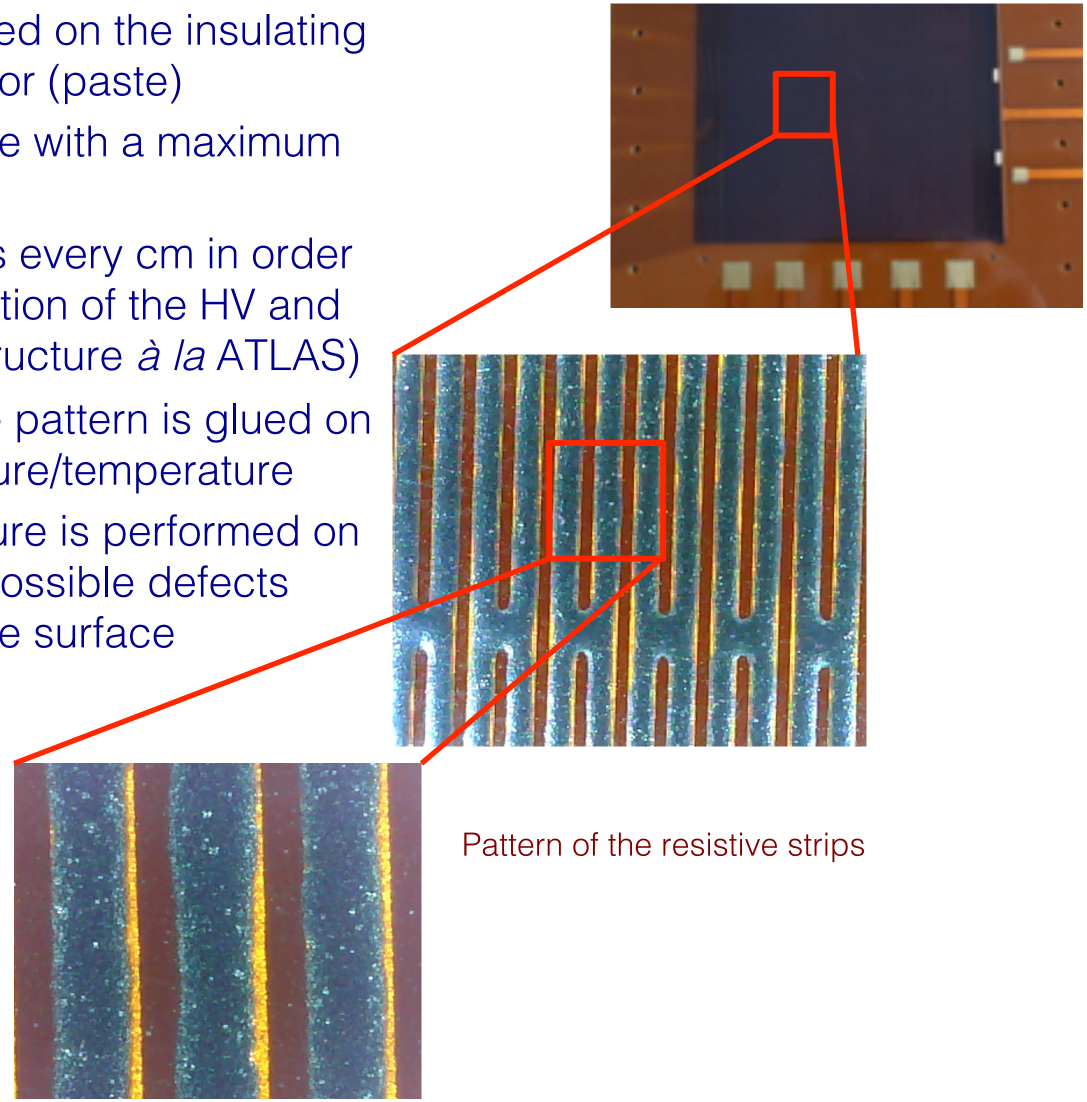


Single board of the resistive strip detector

Characterisation of resistive layer

- Resistive strips are screen-printed on the insulating layer with 100 kΩ polymer resistor (paste)
- The cross-section has a D-shape with a maximum height of 15-20 μm.
- They are interconnected in pairs every cm in order to guarantee an uniform distribution of the HV and of charge evacuation (ladder structure *à la* ATLAS)
- Kapton foil carrying the resistive pattern is glued on the FR4 substrate at high pressure/temperature
- A mechanical polishing procedure is performed on the surface in order to smooth possible defects and imperfections of the resistive surface

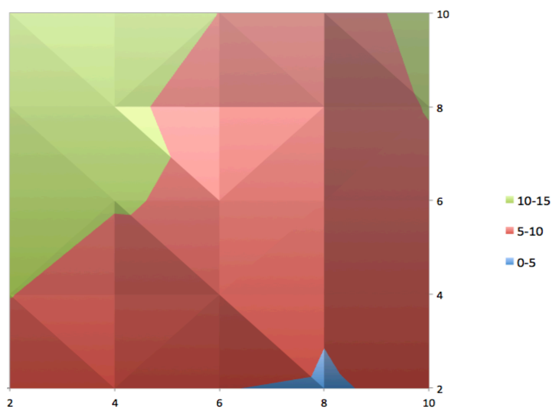


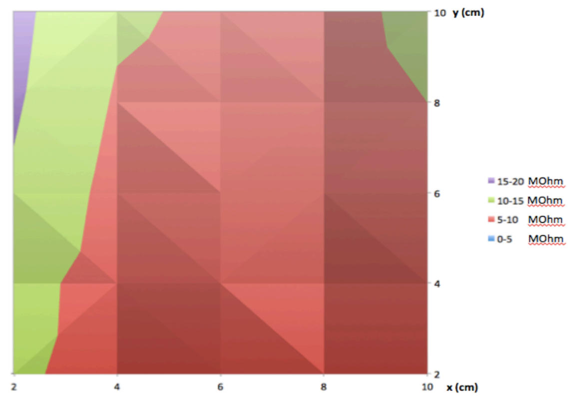


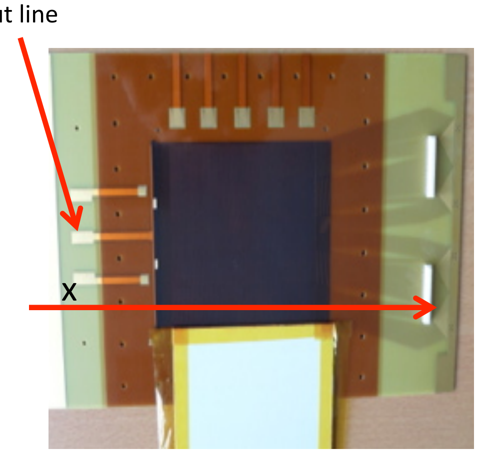
Pattern of the resistive strips

Characterisation of resistive layer

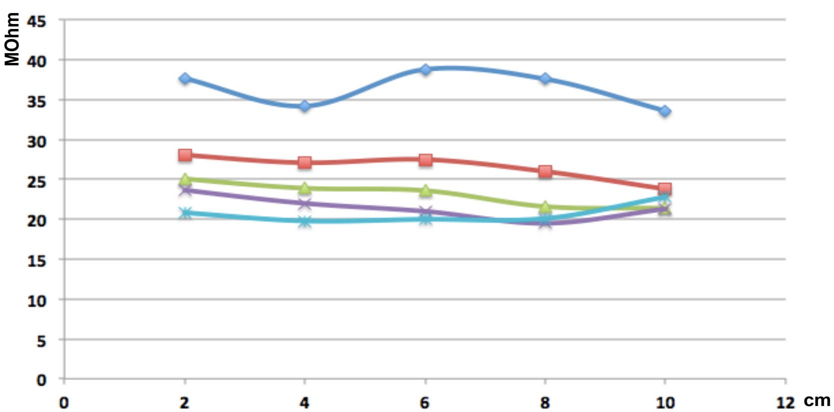
- The obtained resistivity shows a good homogeneity over the full detector surface, of the order of ≈5-10 $10^6\Omega/\square$

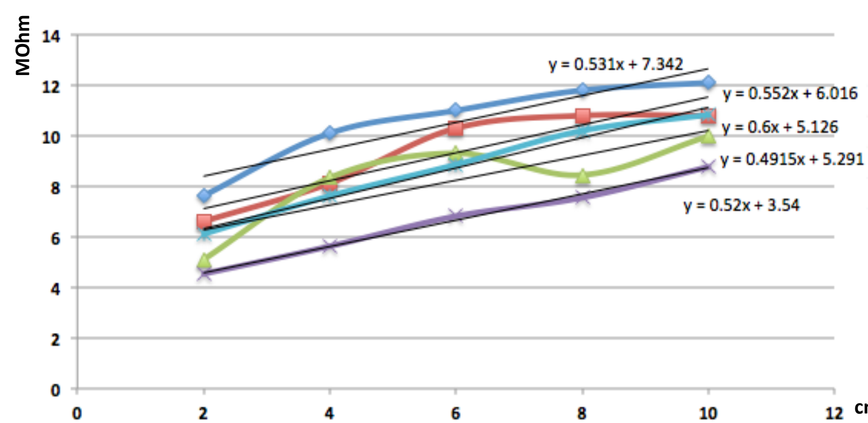






Resistance map (in MΩ) measured with a 1cm² probe with respect to the high voltage supply point for the two plates..



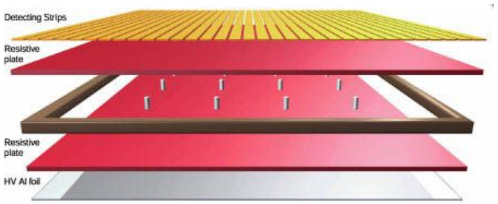


Resistance measured with two 1cm² probes, 1 cm apart, with respect each other as function of the distance from the HV input

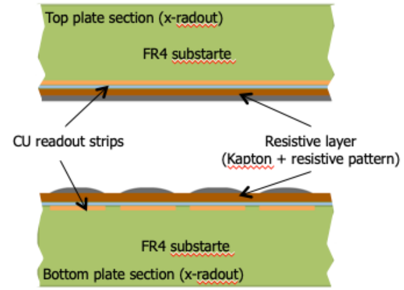
Resistance measured with a 1cm² probe with respect to the high voltage supply as function of the distance from the HV input

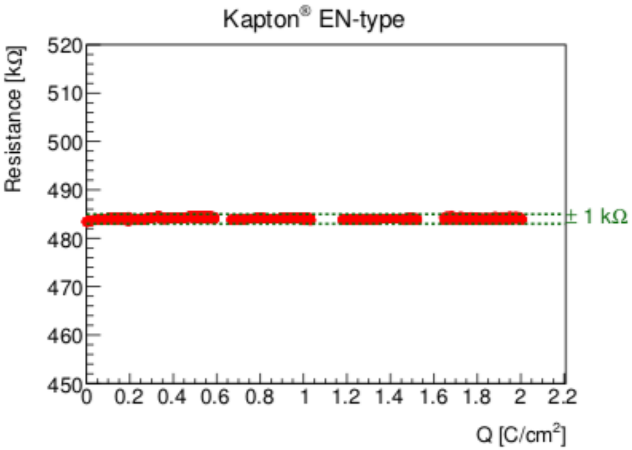
Comparison with RPC

- Resistive protection concept
  - In RPC (glass or phenolic bakelite) the conductive electrode is placed on the back side of the plate with respect to the side facing the gas volume → the relevant parameter for the avalanche quenching mechanism is the bulk resistivity of the plates
  - In our device (as other resistive MPGD) the resistive strips, facing the gas volume, are directly connected to HV. The charge evacuation takes place along the strips → the relevant parameter is then the surface resistivity
- Voltage drop:
  - Uniform along the surface for the RPC
  - Increases with the distance from the HV supply point for the resistive strip detector
- Charge carriers.
  - In RPC the carriers are ions, inducing the well known depletion effect
  - In our device the charge carriers are electrons and no depletion effect is expected, as was measured by an independent study. Moreover, very limited dependency of the resistivity of the foil with temperature and humidity was measured, making this layer very robust against performance degradation during operation
- Surface treatment
  - Lineseed oil in RPC
  - Mechanical polishing in the proposed device



Sketch of a CMS RPC (from: http://cms.web.cern.ch/news/resistive-plate-chambers)





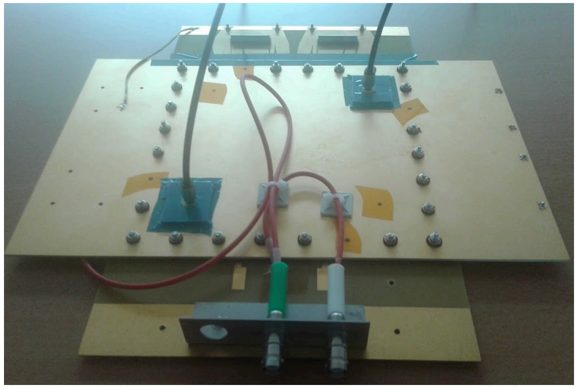
Surface resistance evolution of Kapton foil with resistive pattern similar to the one used in our detctor (from: O. Sidiropoulou, PhD Thesis: CERN-THESIS-2018-140

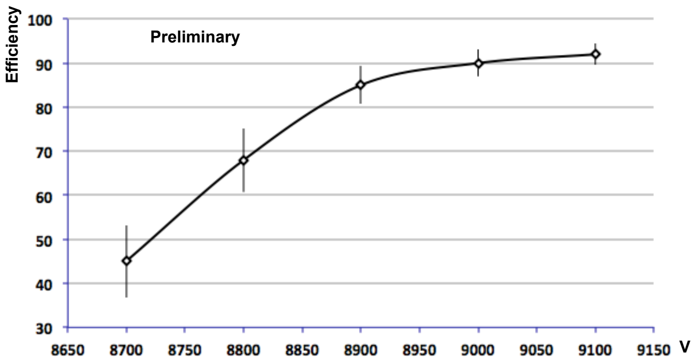
Possible advantages

- The advantages of such a device are:
  - Controlled surface resistivity
    → selection/tuning of the resistive paste
  - Good signal induction
    → thin separation between the resistive electrodes and the copper readout strips (can be operated in avalanche mode)
  - Reduced charge spread in the precision coordinate
    → strip-shaped resistive pattern
- All these features go in the direction of improving the rate capability

Preliminary tests

- Preliminary tests of the detector have been performed in 2019 with the gas mixture used for bakelite RPC for LHC experiments ($C_2H_2F_4$:C_4H_{10}:SF_6 94.7:5:0.3)
- Preliminary results are encouraging as the detector can be operated with good efficiency
- It however showed some instabilities, correlated to local defects of the structure
- Optimisation of the resistivity to higher values (new prototypes) is being now considered. The latter includes the test of DLC (diamond-like carbon) resistive layer instead of screen-printed strips, which is known to offer a smoother and more uniform surface
- Other treatments of the resistive surface (both chemicals and mechanics) are under evaluation, too


Assembled detector (x-y configuration)



Efficiency vs HV for the resistive strip detector

Conclusions and outlook

- We have built a resistive parallel plate detector with micro-pattern technique. It potentially offer several advantages to be used as trigger device in high rate environment.
- Preliminary results are encouraging. Performance studies are ongoing and a number of improvements are already considered, as optimisation of the resistive layer.

Thank you!