Micromegas with high-granularity readout: stability and performance at high particle rates

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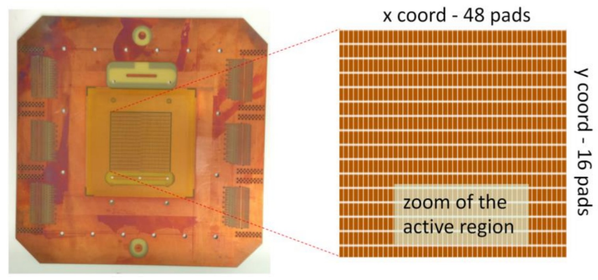
Introduction

Today the Micromegas are a mature technology. They are currently being implemented in large scale experiments, as ATLAS. Extending the rate capabilities of this technology while maintaining its fine spatial resolution and good stability against sparks is a great challenge. The RHUM (**R**esistive **H**igh gran**U**larity **M**icromegas) collaboration is focusing its R&D activities on the novel **Resistive Small-pad Micromegas** detectors. The main objective is to create a high precision tracker able to work with fluxes up to 10 MHz/cm^2, without significant efficiency loss. The research is looking to design a robust detector that can guarantee radiation hardness and effective spark quenching, up to integrated charges of tens C/cm^2. To cope with the high number of readout channels and allow for the size scalability of the detector avoiding dead areas, the integration of the readout electronics has been implemented in the back of the detector.

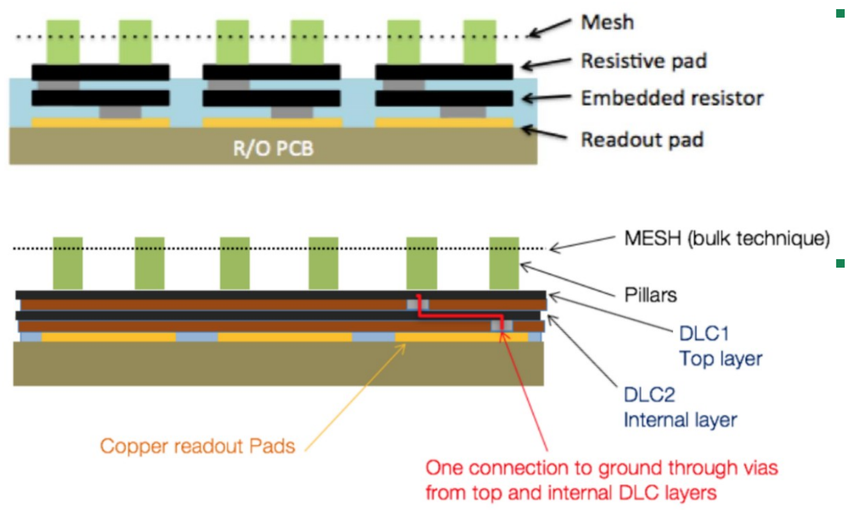
Layout

Current anode layout for the Small-pads detectors:

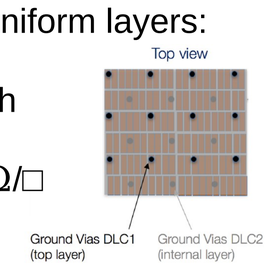
- plane segmented in a 48x16 matrix
- Small-pads dimensions 0.8x2.8 mm^2 (1x3 mm^2 pitch)
- Total active area of 4.8x4.8 cm^2



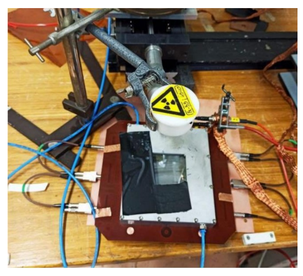
Resistive schemes

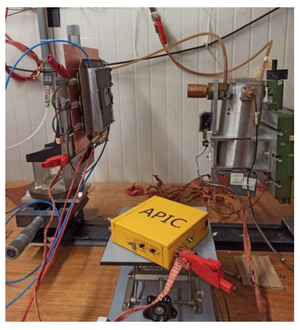


- **PAD-P**atterned:
  - Resistive pads exposed in the active area connected to the r/o copper pads through embedded resistors.
  - Resistance from top pad to copper pads ~ 7-5 MΩ
- **D**iamond-**L**ike **C**arbon uniform layers:
  - Two parallel layers of DLC connected through conducting vias
  - Resistivity of 20-50 MΩ/□ for various prototypes



Characterization set-up





Characterization measurements carried out with two different exposures:

(1) ^{55}Fe radioactive sources

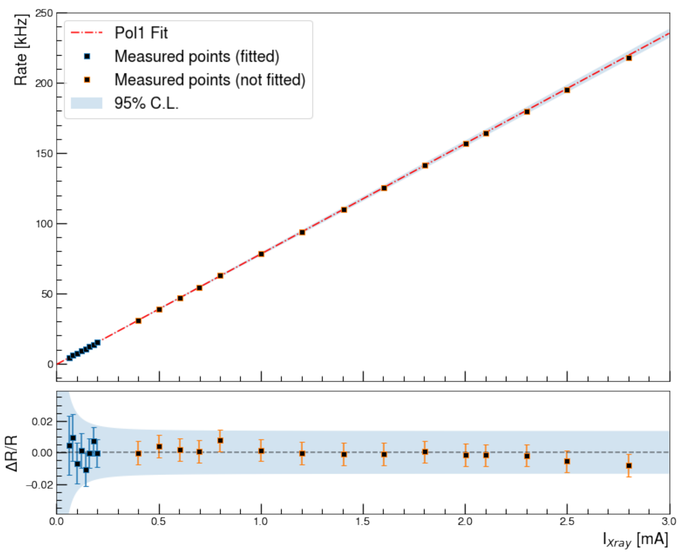
(2) Cu X-ray gun (8 keV - ionization ≫ MIP)

Gas mixture used: **$ArCO_2$** (93:7)

➔Aging free gas, safest to operate with high irradiation for long exposures

Gain measurement procedure

Measuring the current and the signal rate from the mesh, evaluating gain as: $G = \frac{I_{mesh}}{e\, n_0\, f}$



With X-Ray gun rates are directly measured for low intensities, and then are extrapolated for high rates.

Method validation:

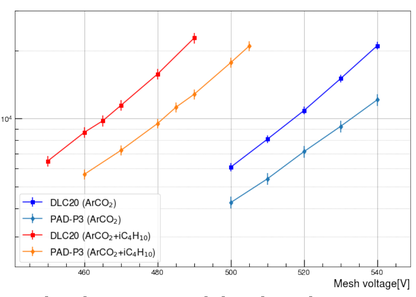
✔Checked the linearity of the X-Ray gun (I_{Xray} vs Rate)

✔Extrapolation method from small range of I_{Xray} validated

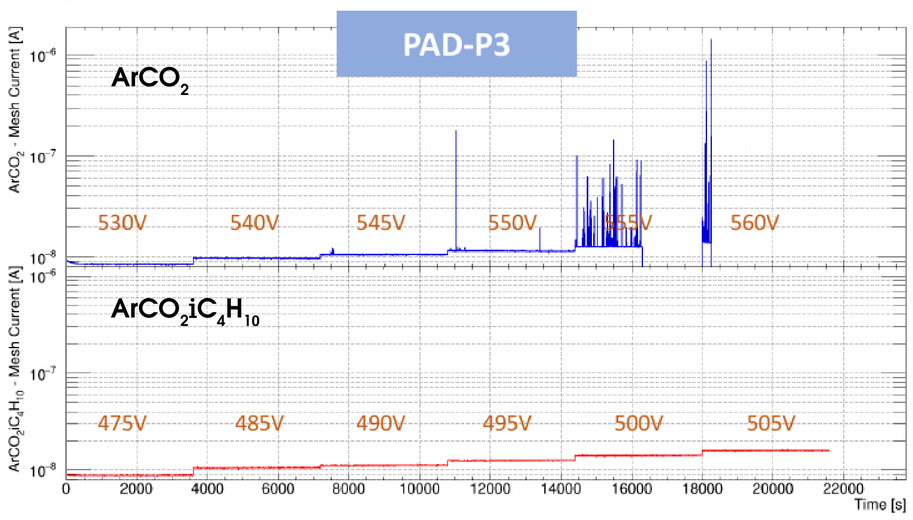
Tests with new gas

To extend the stability range of the detectors a small portion of iso-butane was added forming a new mixture:

$ArCO_2iC_4H_{10}$ (93:5:2)



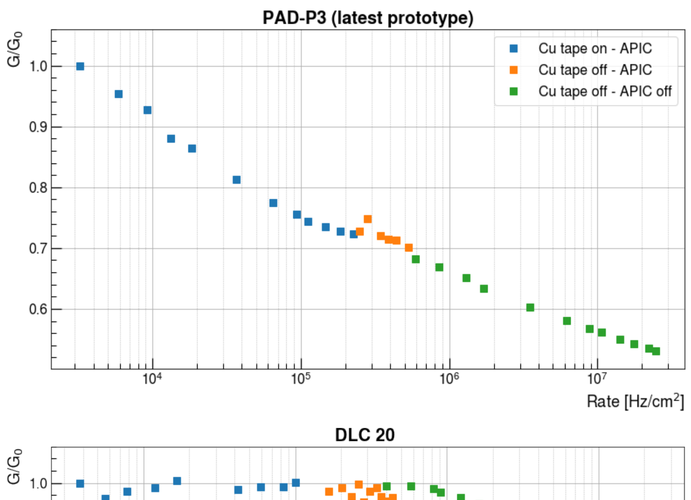
Stability measurements have been carried out with both gas mixtures, applying a constant irradiation for long times. With the addition of iso-butane, it has been possible to reach stable working conditions for higher Gains (G>20k).

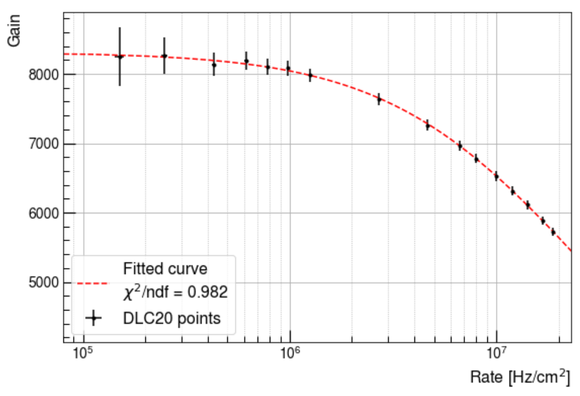


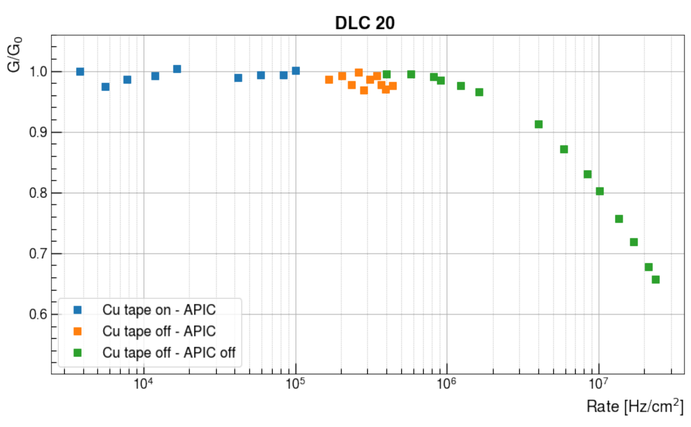
High rates capabilities

With the help of Cu absorbers, more than 4 orders of magnitude of fluxes have been studied. Different behaviors for two different resistive schemes:

- PAD-P loses gain slowly, but at ~constant rate, mostly due to the *charging up* effect
- DLC has constant gain, up until ~1MHz/cm2, where its gain loss is fully accounted by *Ohmic gain drop*.

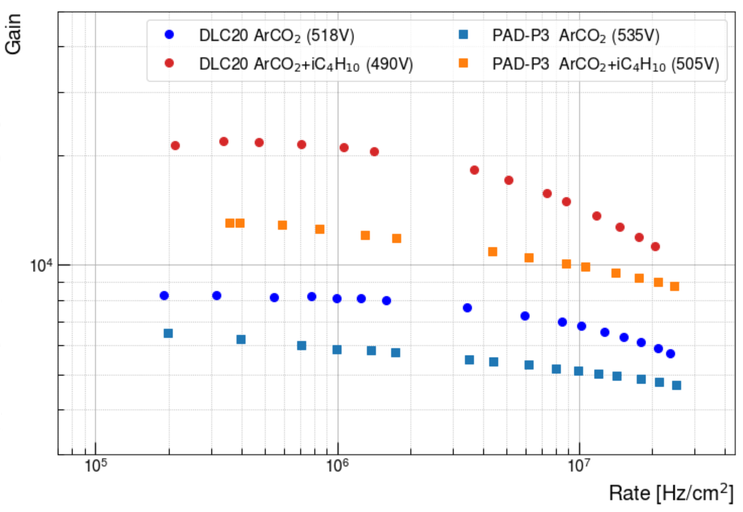






High gains

Tests carried out with the new gas mixture showed the possibility to reach Gains above 20k also in extremely high irradiation conditions. In terms of performances, this is an unprecedented result, as never before the Small-pad detectors were able to cope, with excellent stability, rates greater then O(10MHz/cm^2) at such Gains.



Conclusions

❖Multiple detectors with different resistive schemes have been tested, with $ArCO_2$ 93:7, at a Gain ~10k (and average collected charge - with X-rays - of 2x10^6 electrons) , showing very satisfactory results in terms of rate capability

❖Stability tests demonstrated that even higher gains can be safely reached with the addition of only 2% of iso-butane to the gas

❖Future outlook:

- Get a more detailed understanding of the charging up effect
- Carry out ageing studies with the new gas

Acknowledgments

We would like to thank the CERN MPT workshop (in particular R. de Oliveira and his group) for the discussions and the construction of the detectors, and the whole RD51 Collaboration (in particular E. Oliveri) for the support with the tests at the CERN GDD Laboratory.

TIPP 2021 International Conference on Technology and Instrumentation in Particle Physics