High Granularity Small-Pad Resistive Micromegas for Rates above MHz/cm^2

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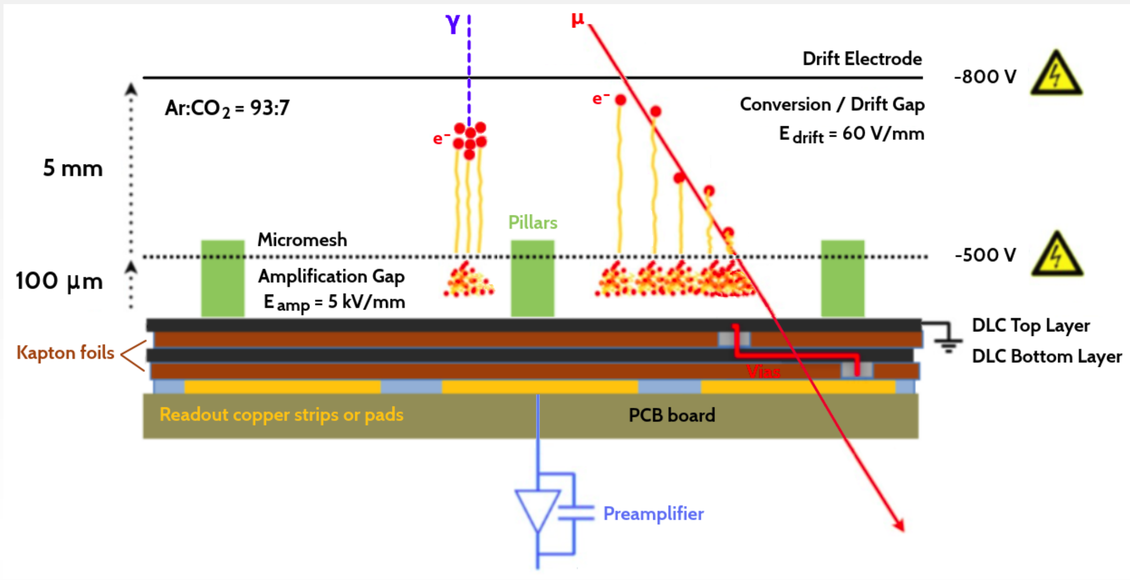
Micromegas detector technology



- Resistive Micromegas, which belongs to the family of the Micro Pattern Gaseous Detectors (MPGD), demonstrated to be a solid detector technology for HEP experiments
- Drift region (~5 mm width, E~60 V/mm) and Amplification region (~100 µm width, E~5 kV/mm) separated by a metallic micro-mesh, supported by 0.8 mm diameter pillars
- This geometrical and electrical configuration guarantees a fast ion evacuation, fundamental for high rate applications
- Restive anodic plane to suppress discharge intensity

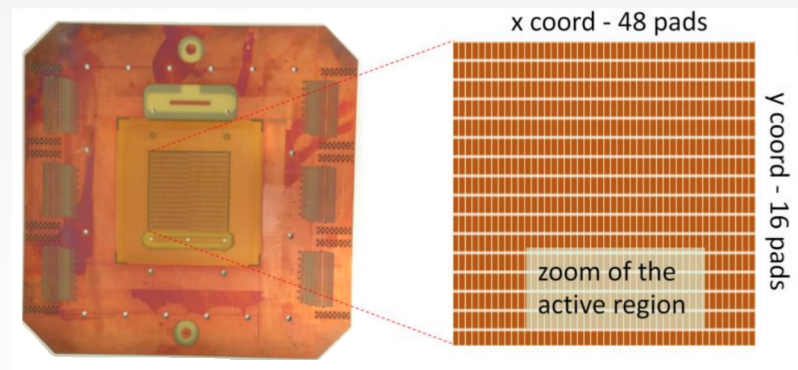
RHUM project

Roadmap for RHUM R&D project (Resistive High granUlarity Micromegas)

- Develop an MPGD able to efficiently work at particle rates up to several tens MHz/cm^2
- Implement a small pad readout to reduce the occupancy
- Optimize the spark protection resistive scheme to have stability of operation at high rate/gain
- Demonstrate the detector scalability to large surfaces
- Simplify the construction techniques for industrial production

Anodic plane and spark protection resistive scheme

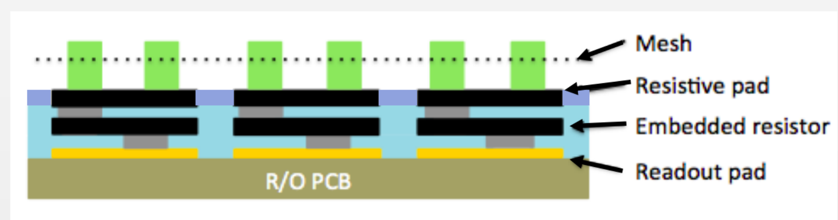
- Readout plane segmented in pads O(mm^2) to ensure high rate capability and good spatial resolution in both coordinate
- All the prototypes share the same anodic plane segmentation: 16 x 48 = 768 readout pads (1 mm x 3 mm), covering 4.8 x 4.8 cm^2 active area

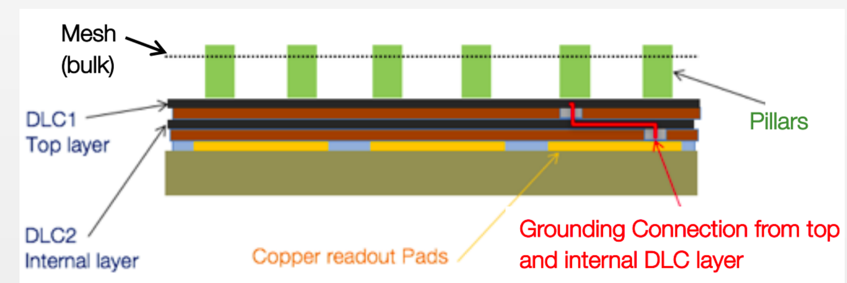


- Different implementation of the resistive protection system against discharges

PAD-patterned
Prototype name: PAD-P3
Resistive pads connected to the readout copper pads through embedded resistor
Each pad is completely separated from the neighbours
Resistance from top pad to copper pads ~ 7-5 MΩ

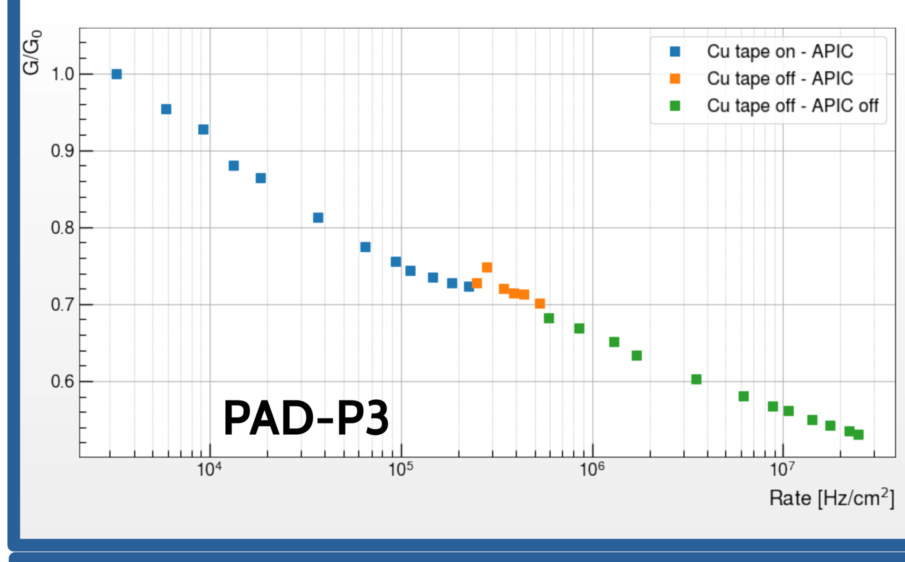
Diamond-Like Carbon uniform layers
Prototype names: DLC20, SBU3, DLC-SG (with elongated pillars, 5.3 mm long)
Two parallel layers of DLC connected through conducting vias
Resistivity of 20-50 MΩ/□ for various prototypes

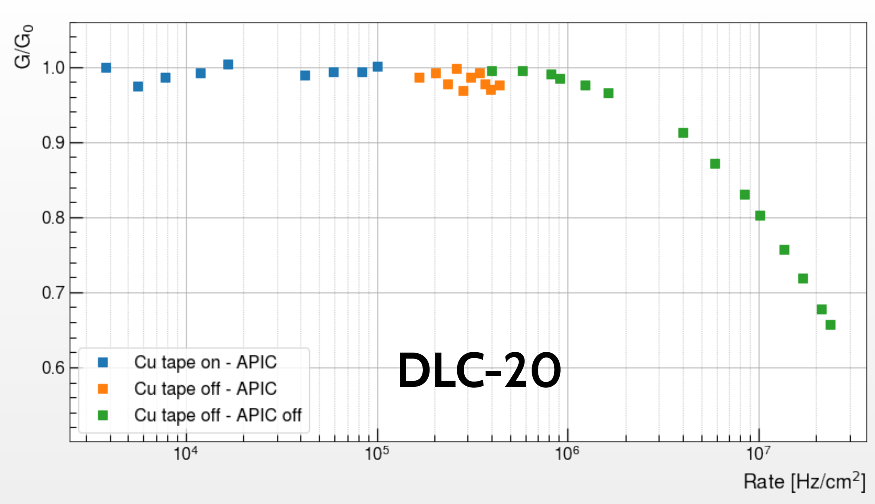




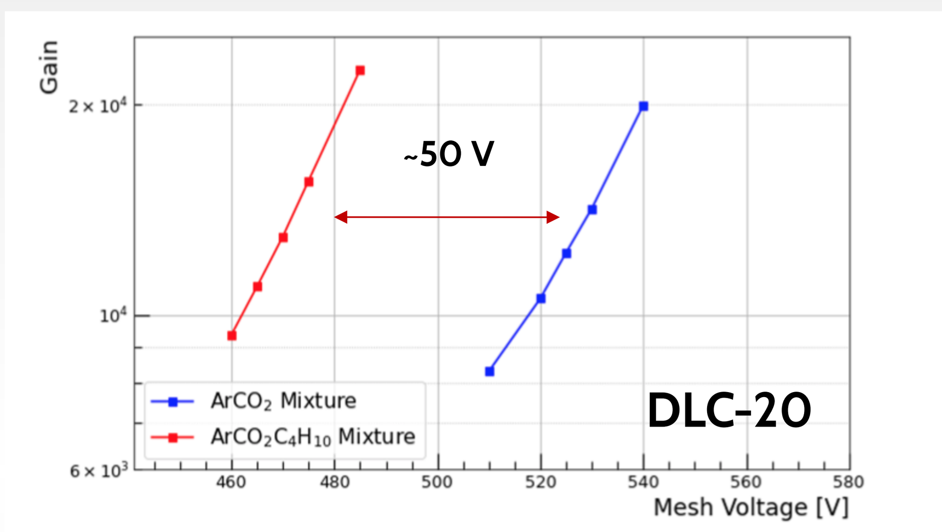
Rate capability

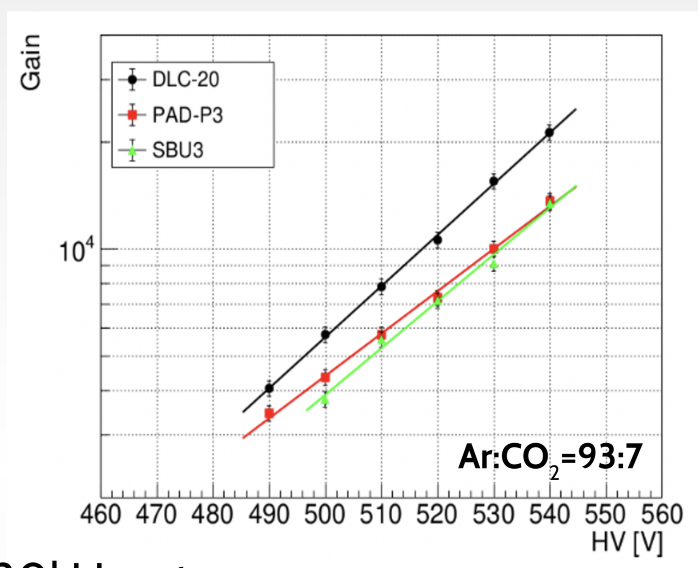
- 8 keV X-rays peak from a Cu target with different intensities
- Using Cu filters, more than 4 orders of magnitude of fluxes have been explored
- Different behaviors for two different resistive schemes have been observed:
  - PAD-P3 loses gain slowly, but at constant rate, mostly due to the charging-up effect
  - DLC-20 has constant gain, up until ~1 MHz/cm^2, above which its gain loss is fully accounted by Ohmic gain drop





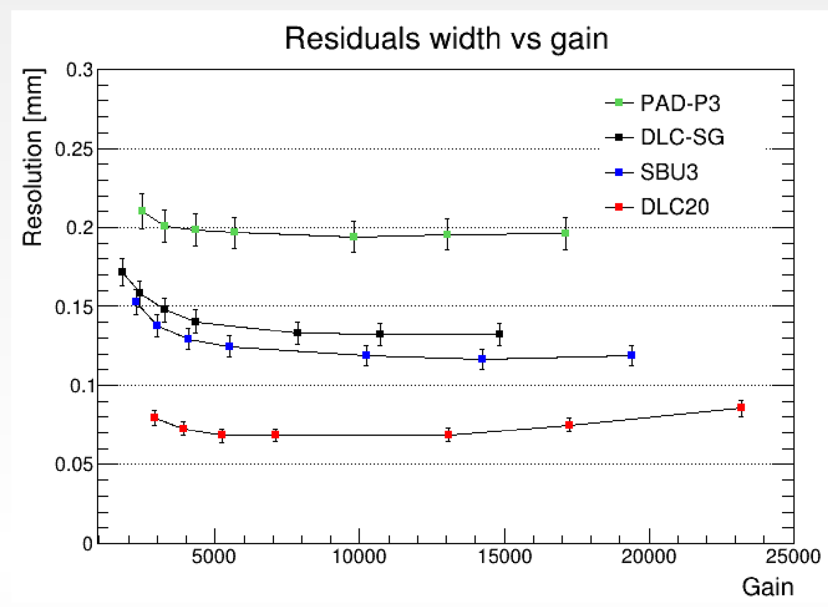
Gain measurements

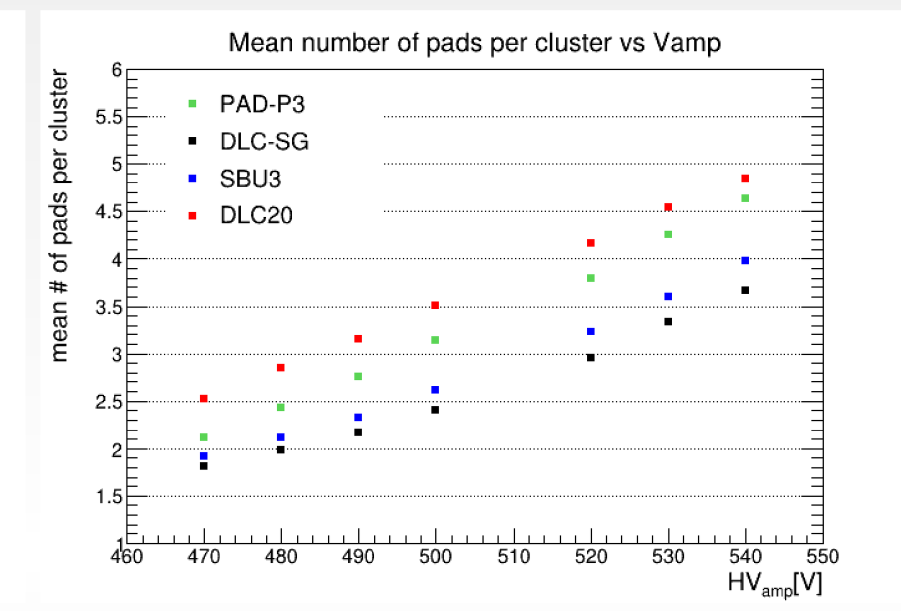




- Measurements performed using ^{55}Fe source with ~20kHz rate
- Lower gain of PAD-P type with respect to DLC sistematiically observed for most of the prototypes. Most likely due to the dielectric charging-up of the kapton surrounding the resistive pads.The different slope of PAD-P3 could be due to an increase of charging-up with gain
- 2% of isobutane allows to reach the same gains at lower amplification voltage and guarantees a better detector stability during operation

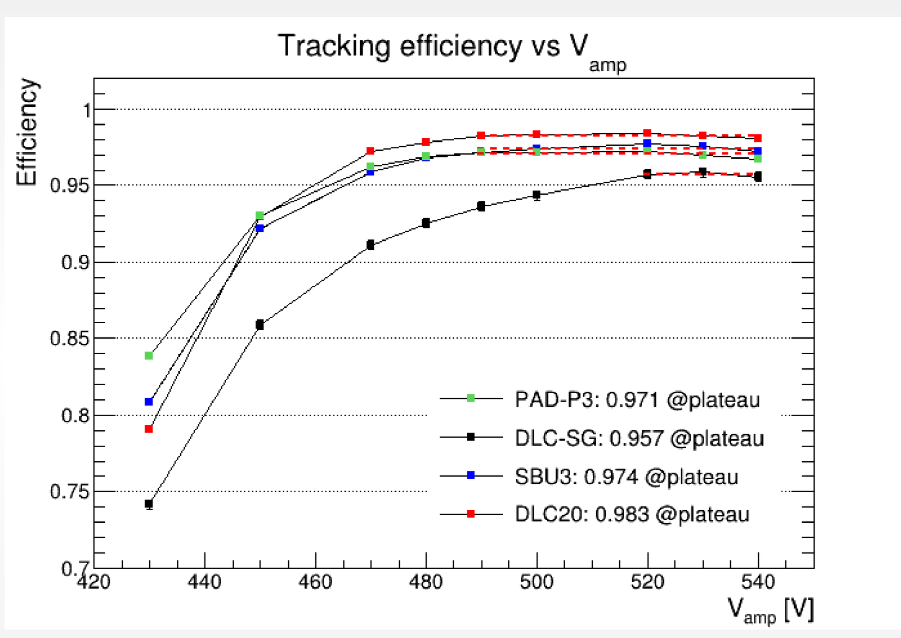
Position resolution





- Test beam data recorded at SPS with ~100 GeV muon beam
- Position in every detector computed using the cluster centroid. External tracking, performed using two resistive-strips Micromegas with two-dimensional readout
- Position resolution obtained fitting the residual distribution in the precision coordinate w.r.t. the reconstructed muon track
- Position resolution affected by several parameters (resistivity, capacitive coupling among the pads and different charge spread) impacting the cluster size

Detector efficiency



- Test beam data recorded at SPS with ~100 GeV muon beam
- Detector efficiency measured requiring clusters within 1.5 mm from the extrapolated track position in the precision coordinate
- For most of the prototypes detector efficiency > 97%
- Lower efficiency (~1% less) for DLC-SG, due to the larger pillar size

Conclusions and perspectives

- Different spark protection resistive layouts have been implemented on several small-pad Micromegas prototypes
- From tests and comparison among them we reached:
  - stable operation up to ~10 MHz/cm^2 with gain ~10^4
  - detector efficiency > 97%
  - position resolution < 100 µm
- Future R&D activities will focus on: tracking in high rate environment, detector scalability to larger area, time resolution and ageing studies

Reference 1: M. Alviggi et al., Construction and test of a small-pad resistive Micromegas prototype, JINST 13(2018)P11019
Reference 2: M.Iodice et al., Small-Pad Resistive Micromegas: Rate capability for different spark protection resistive schemes, JINST 15(2020)C09043

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