Small-pad resistive Micromegas for high-rate environment

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On behalf of the RHUM collaboration:

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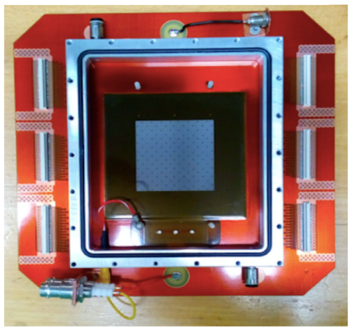
The RHUM project

RHUM

Resistive High granUlarity Micromegas



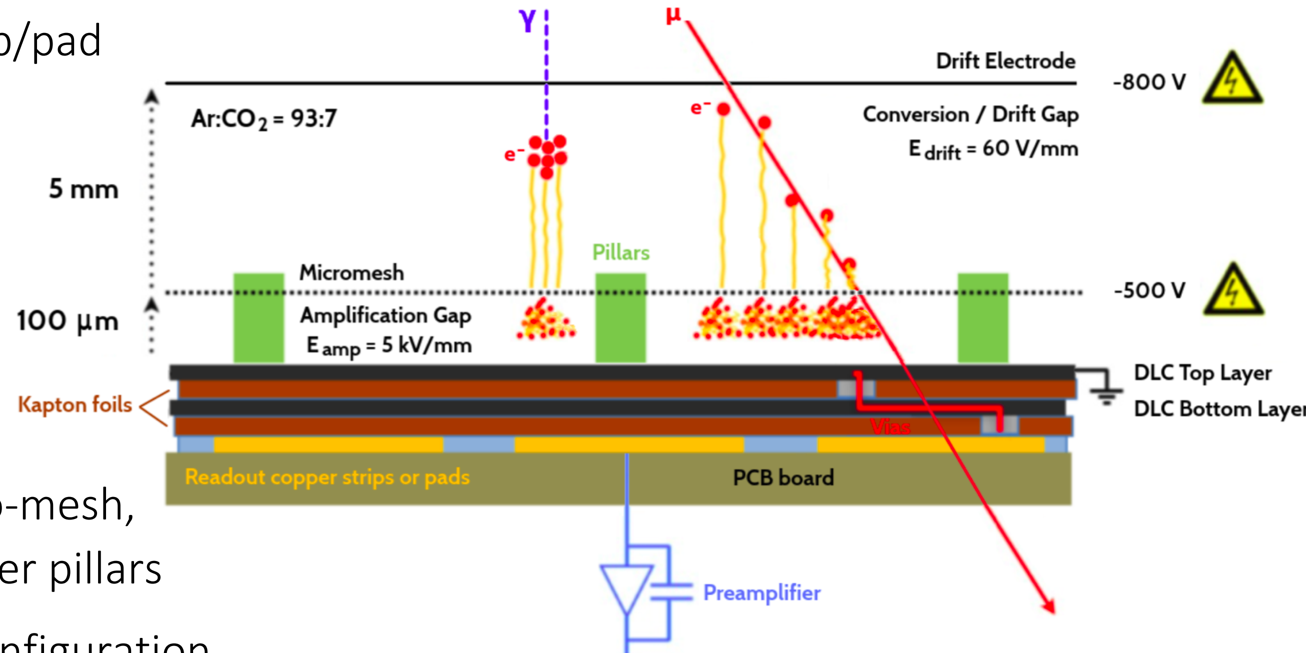
- Develop a MicroPatternGaseousDetector, based on the Micromegas technology, able to work efficiently at particle rates up to several MHz/cm^2
- Implement a small pad readout to reduce the occupancy
  - O(mm^2) for high rate capability and good spatial resolution in both coordinates
- Optimize the spark protection resistive scheme to achieve stable operation at high rate/gain
- Demonstrate the detector scalability to large surfaces
- Simplify the construction techniques for industrial production
- R&D started in 2015 (INFN and University of Napoli and Roma Tre) in collaboration with CERN and with the CERN PCB Workshop (Rui De Olivera) for prototype construction.

Possible applications in HEP

- Very fwd muon tracking extension in existing experiments
- Muon detector/TPC @ future accelerators
- Readout for sampling calorimeter
- ...

Micromegas technology

- Resistive MicroMeGas technology
  ➔ cover readout copper strip/pad with a resistive insulator to suppress discharges
- Drift region of ~5 mm width (➔ E~60 V/mm) and Amplification region of ~100 µm (E~5 kV/mm) separated by a metallic micro-mesh, supported by 0.8 mm diameter pillars

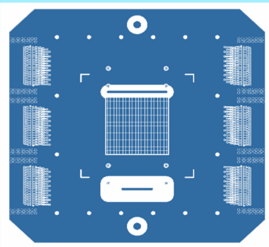


- Geometrical and electrical configuration to guarantee a fast ion evacuation
  - fundamental for high rate applications
- Demonstrated to be a solid detector technology for HEP experiments

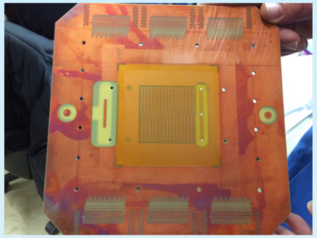
The small-area Prototypes

- Several prototype built and tested with a common readout scheme but different spark protection resistive schemas

Readout PAD anodic plane
(common to all prototypes)



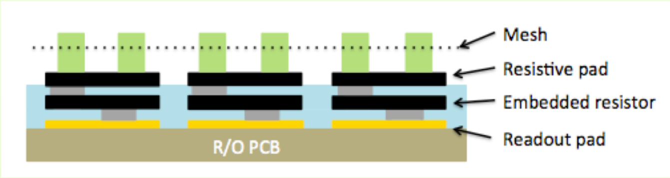
4.8 x 4.8 cm^2 active region
768 pads, 0.8 x 2.8 mm^2 each
48 pads – 1 mm pitch (“x”)
16 pads – 3 mm pitch (“y”)



Routing to six Panasonic connectors

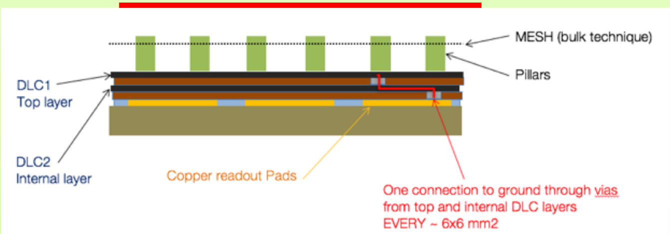
Configurations of the resistive layers
Two main categories: **Pad-patterned** and **uniform DLC layers**

Pad-patterned



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

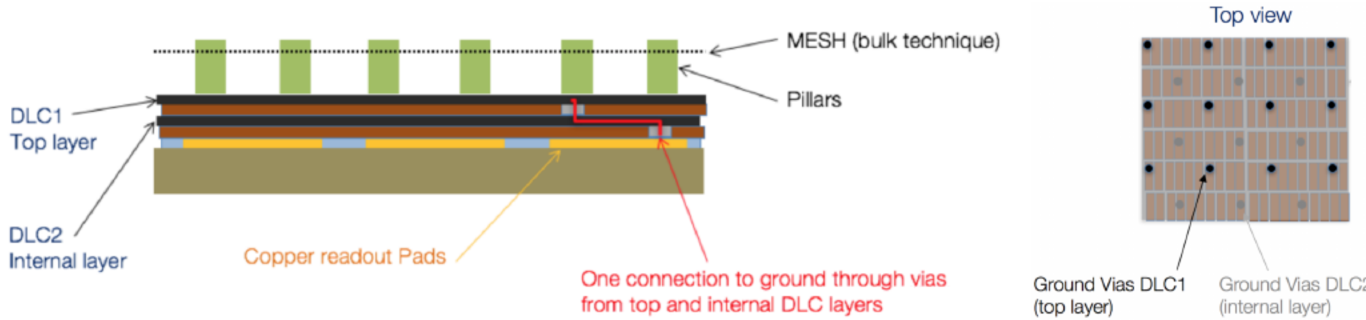
Uniform Double DLC



- Prototype names: DLC20, SBU3, DLC-SG
- Two parallel layers of DLC connected through conducting vias
- Resistivity of 20-50 MΩ/□ for various prototypes

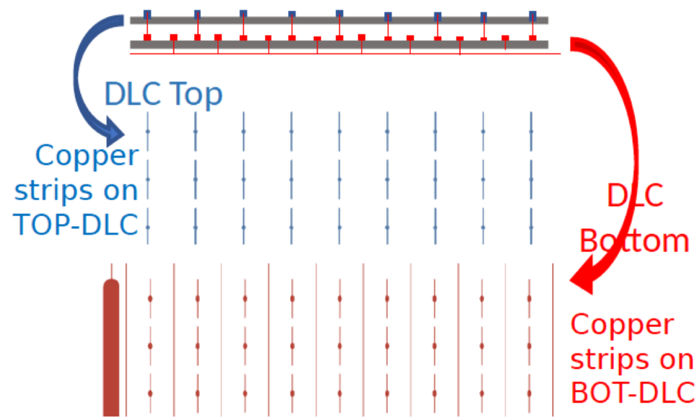
DLC Prototypes: dot and strip version

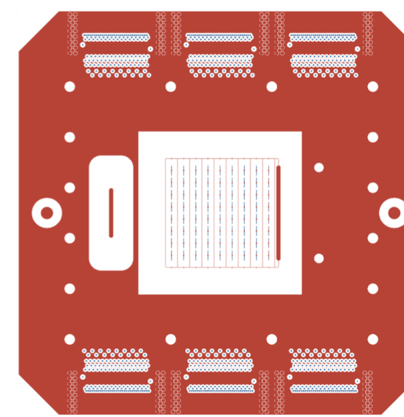
Double DLC "standard" dot version



Double DLC new "Strip" version
by Rui De Oliveira

- Mix of standard DLC-SBU and Silver-Grid (SG) used in uRWell
- Main goal: keep separate sectors with grounding boundaries to avoid any dependence on the irradiated surface
- Drawback → longer pillars → smaller active area





Rate Capability with X-rays

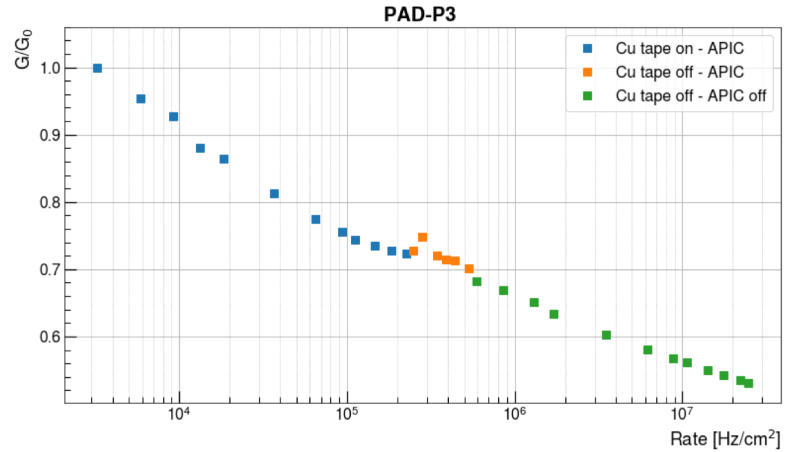
- Measured using 8 keV X-rays peak from a Cu target with different intensities (~4 order of magnitude) @ CERN GDD lab

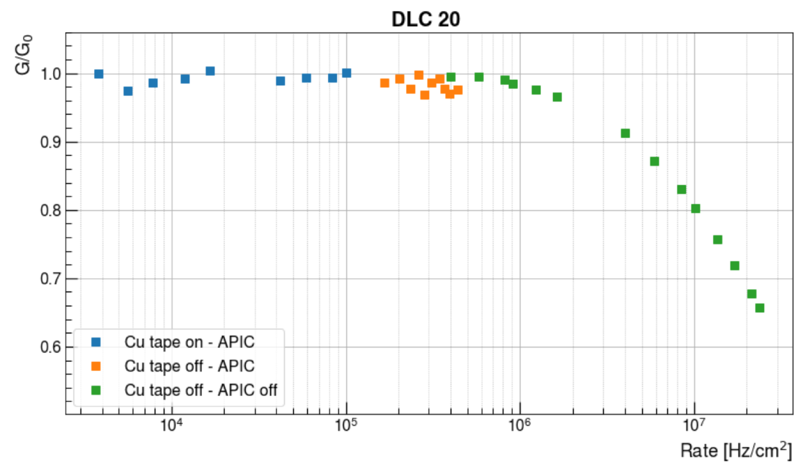
PAD-P resistive scheme

- Relatively fast gain loss for rates < 0.1MHz/cm^2 due to charging-up effect
- Slower ohmic voltage drop through the individual pads at higher rates

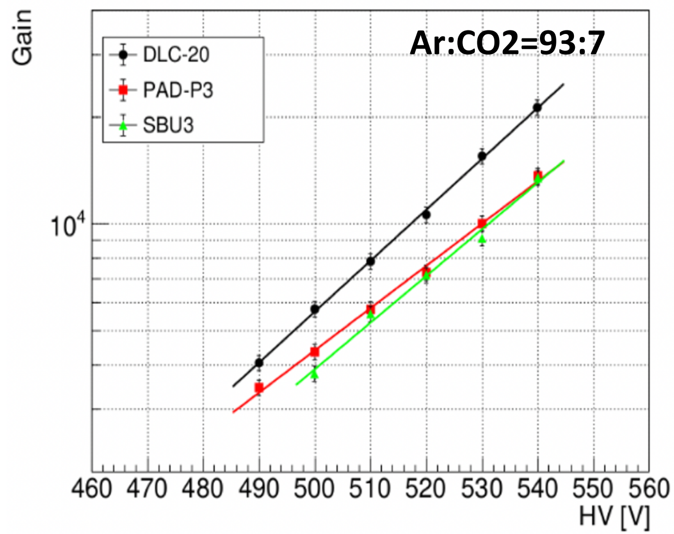
DLC and SBU prototypes

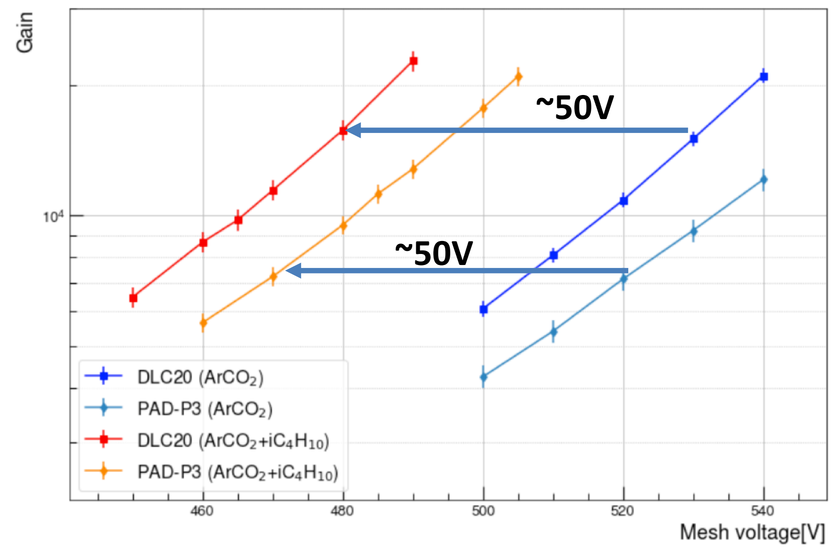
- Gain essentially stable up to ~1-2 MHz /cm^2
- At higher rates gain loss is fully accounted by ohmic gain drop
- At 10 MHz /cm^2 ~20% Gain drop





Gain measurements with ^{55}Fe source

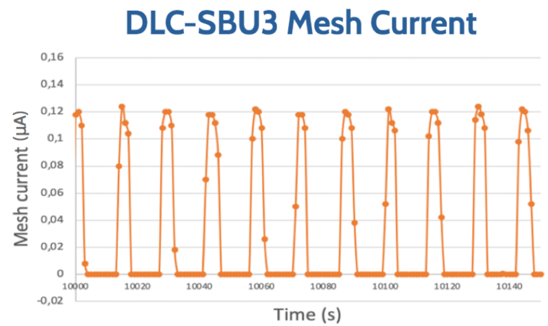


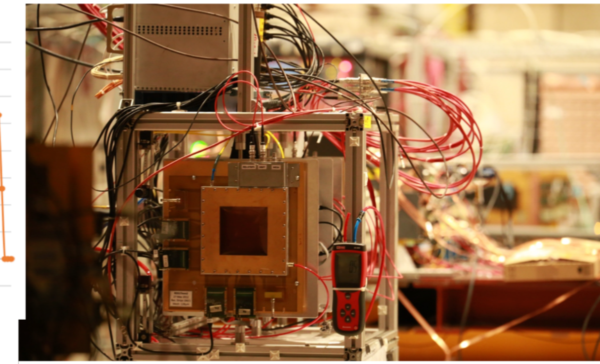


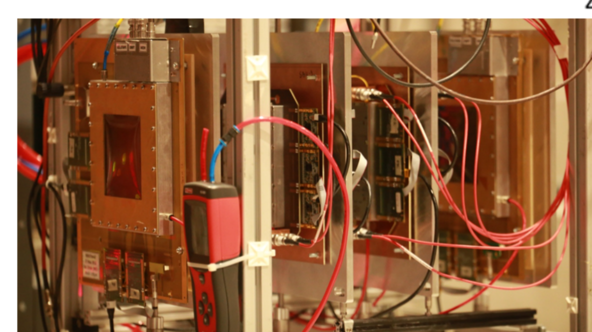
- Measurements performed using ^{55}Fe source with ~20kHz rate
- Lower gain of PAD-P type wrt DLC observed systematically for most of the prototypes. Most likely due to the dielectric charging-up of the kapton surrounding the resistive pads. The different slope of PAD-P3 could be due to an increase of charging- up with gain
- Detector stability improved by adding 2% isobutane to the gas mixture (Ar:CO2:iC4H10 93:5:2)
  - ~50V difference between the two mixtures for a given gain
  - ~20k Gain reached at very high irradiation rates (>10 MHz/cm2) in stable conditions

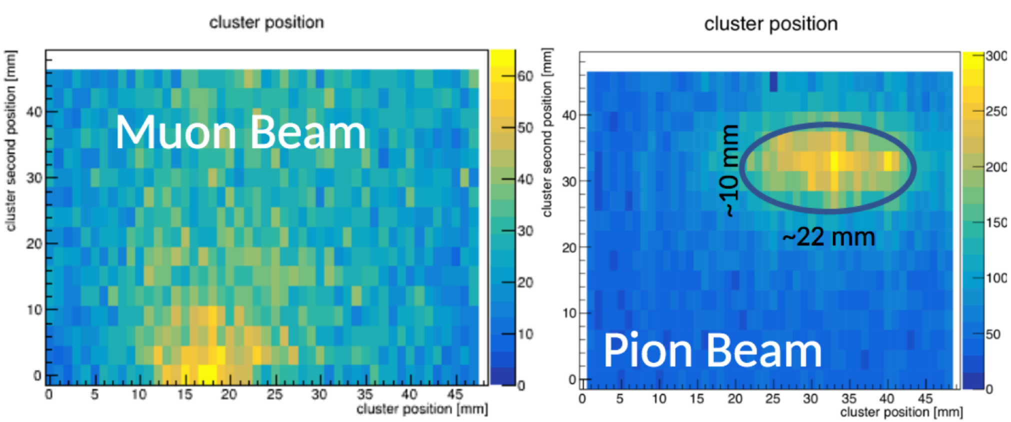
Experimental setup

- 4 small-pad MM under test
- 2 resistive XY strip MM for trackers
- 2 scintillators for the trigger
- DAQ: SRS+APV25
- Muon and pion beams (up to 1.9 MHz)
- Detectors operated with both Ar:CO2 93:7 and Ar:CO2:C4H10 93:5:2 gas mixtures

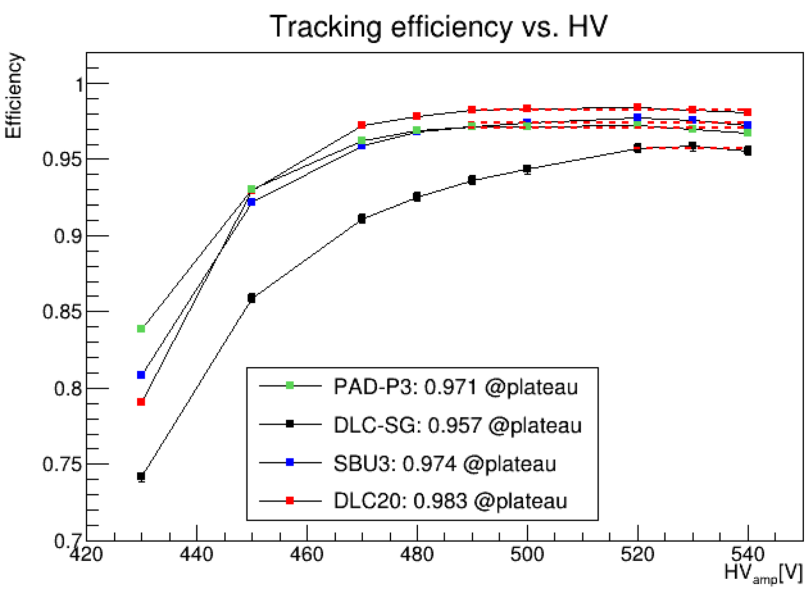


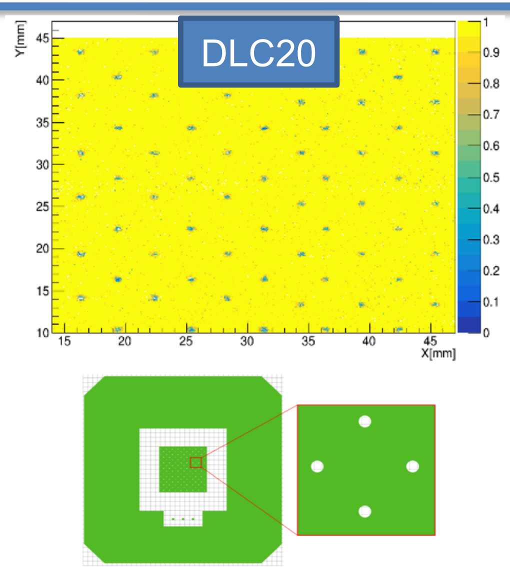




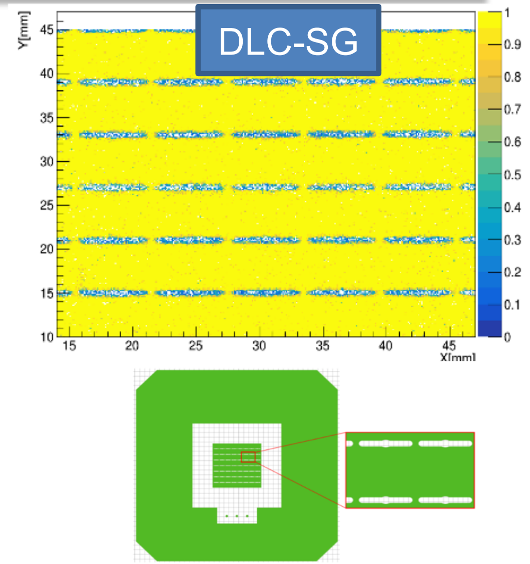


Test beam @ CERN: detector efficiency





Pillars:2.8% geometrical coverage

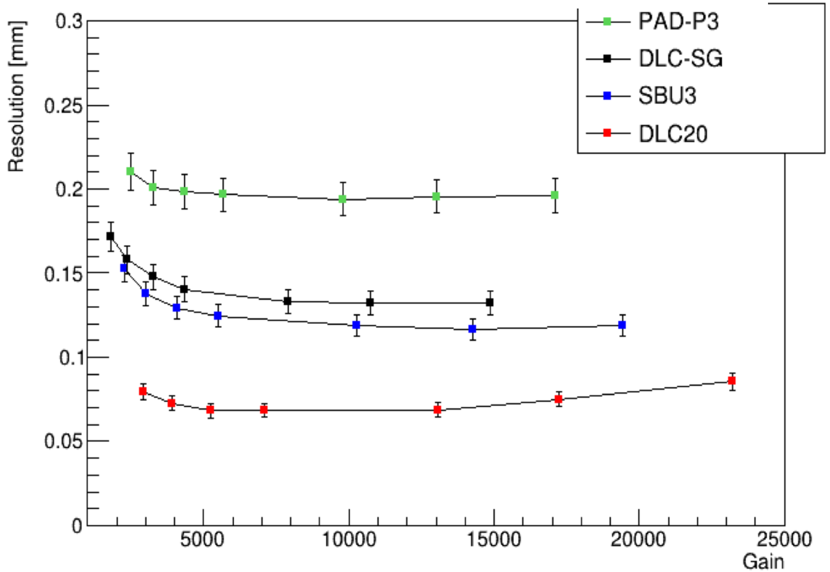


Pillars: 7.7% geometrical coverage

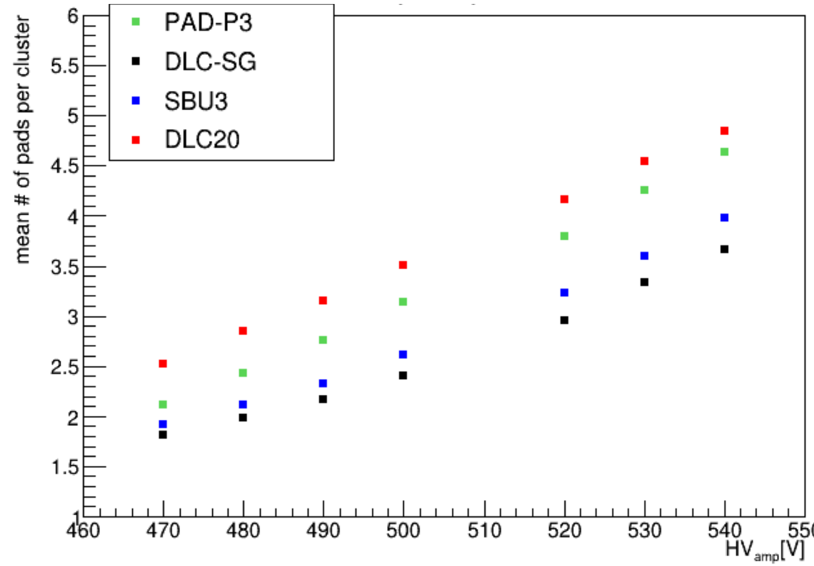
- Clusters required to be within 1.5 mm from the extrapolated track position in the precision coordinate
- Detector efficiency > 97% for most of the prototypes!
- Slightly lower efficiency (of ~1-2%) for DLC-SG
  - due to the pillars geometry (larger size) adopted for this prototype

Test beam @ CERN: spatial resolution

Spatial resolution vs Gain

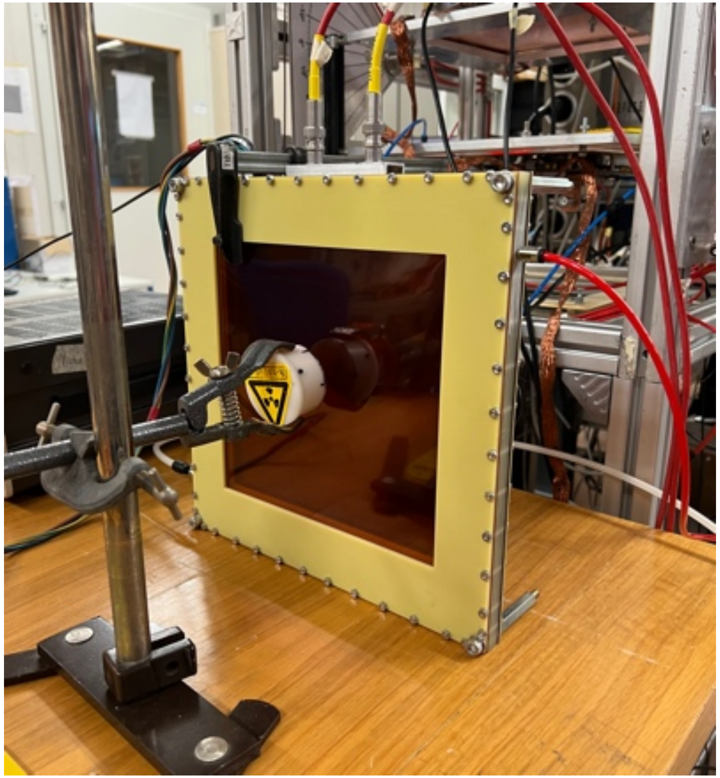


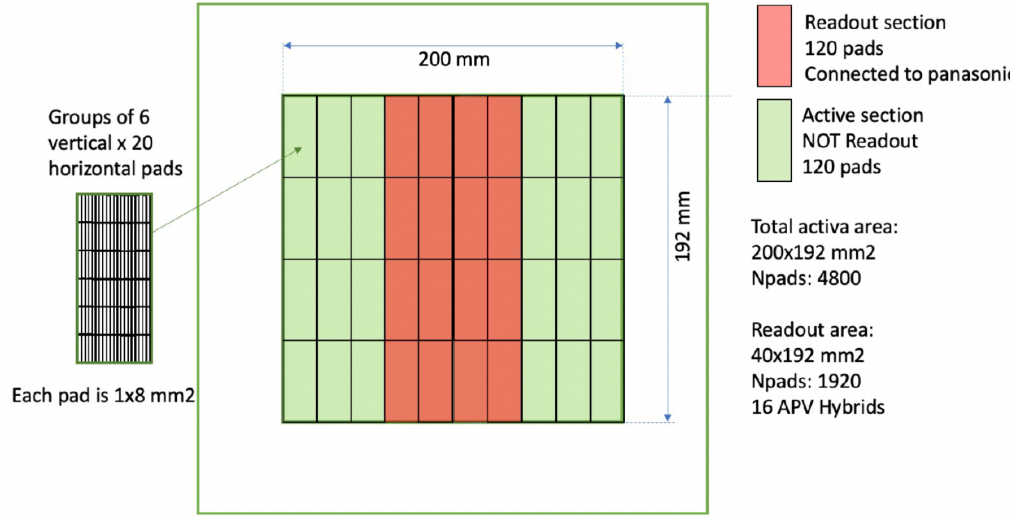
Mean number of pads per cluster vs HV



- Position in each detector computed from the charge-weighted pad position the (cluster centroid)
  - Extrapolation uncertainty~50µm (subtracted in quad) , systematic uncertainty ~5%
- 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

The 20x20 cm² prototype

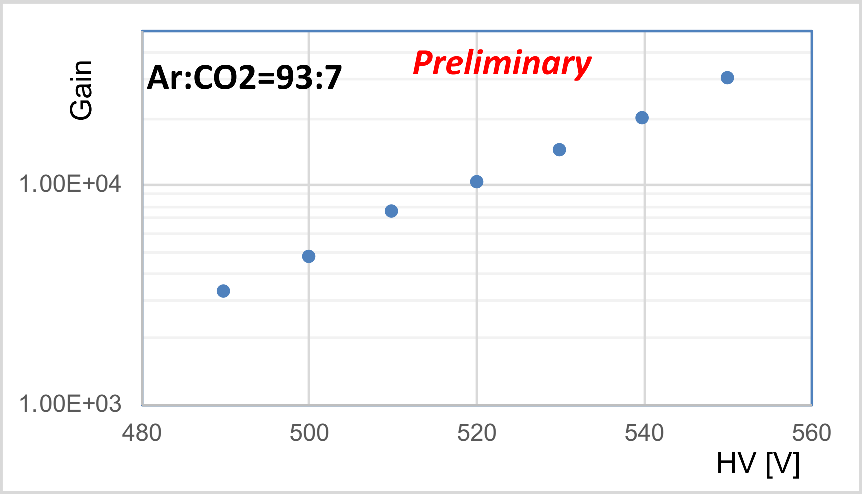


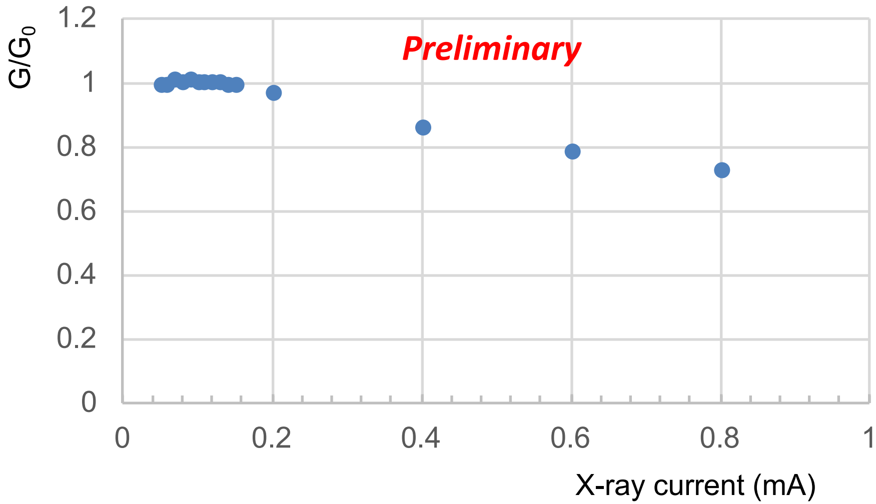


The big brother:

- **active area: 200x192 mm^2**
- Pads 1x8 mm^2 - Total Number of Pads: 4800
- Double layer DLC with grounding vias every 8 mm
- Panasonic connectors on the back of the detector
- Partially readout: 1920 connected pads out of 4800 tot pads

The 20x20 cm^2 prototype – Preliminary results





Gain measured with ^{55}Fe source at ~10KHz

- Gain of 10^4 reached at ~520V in ArCO2 (93:7)
  - Similar to DLC20 prototype
- FWHM/mean ~ 18%

Preliminary results on rate capability with X-rays

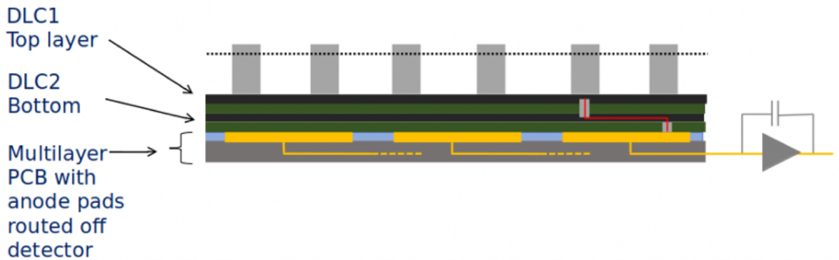
- No collimator→ full area illuminated
  - Detector very stable during the test
- Gain stable up to a X-ray current of 0.2 mA
- Only 15% gain loss at 0.4mA, corresponding roughly to ~10MHz/cm^2

Summary

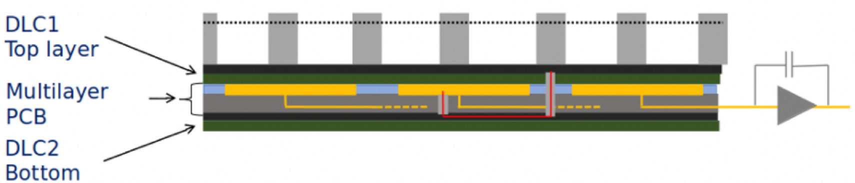
- Several Small Pads Micromegas prototypes have been built employing different solutions for the resistive layout
  - Spark protection resistive schemes explored based on embedded resistors or using uniform Diamond-Like Carbon (DLC) resistive foils
- Performance achieved:
  - stable operation up to 20 MHz/cm^2 with gain $>10^4$
  - detector efficiency > 97%
  - position resolution < 100 μm
- New large(r) area prototype built
  - Preliminary results very promising
  - Very stable working condition event at high rate
- Future R&D activities:
  - tracking in high rate environment $O(2MHz/cm^2)$, performance studies with larger area prototype, time resolution and ageing studies

Backup

Standard layout



New layout



Read-out pads (in yellow in the figures), normally placed under the two resistive DLC foils.

In the new layout they are in between them →

- capacitance increase to collect a larger fraction of the signal

Pad-Patterned (PAD-P3)

Resistance from top resistive pad to anode pad:
15-25 MΩ
Independent PADs, limited or negligible charge spread

Standard DLC (DLC20)

Resistivity: Top and Bottom foils ~20 MΩ/□
Grounding vias every 6 mm (12 mm) in the left (right) half of the detector
Read-out pads below the resistive DLC foils

DLC-SBU (SBU3) [Sequential Build-Up technique exploiting copper clad DLC]
Resistivity: Top 22 ± 1 MΩ/□ – Bottom 42 ± 8 MΩ/□
Readout pads between the resistive DLC foils

DLC-SG [Strip Grid grounding scheme]
Resistivity: Top 40 ± 2 MΩ/□ – Bottom 38 ± 6 MΩ/□
Readout pads between the resistive DLC foils
Longer pillars to cover the grounding copper strips