Pixelated Resistive Micromegas for High-Rate Environment

Mariagrazia Alviggi *

on behalf of RHUM R&D project group:

M. ALVIGGI [1], M.T. CAMERLINGO [2] [3], V. D'AMICO [2], M. DELLA PIETRA [1], C. DI DONATO [1], R. DI NARDO [2], C. GIMMILLARO [2], P. IENGO [1] [3], M. IODICE [2], F. PETRUCCI [2], G.SEKHNIAIDZE [1], M. SESSA [2]

(1) INFN and University Napoli, (2) INFN and University Roma Tre, (3) CERN

*email: mariagrazia.alviggi@na.infn.it

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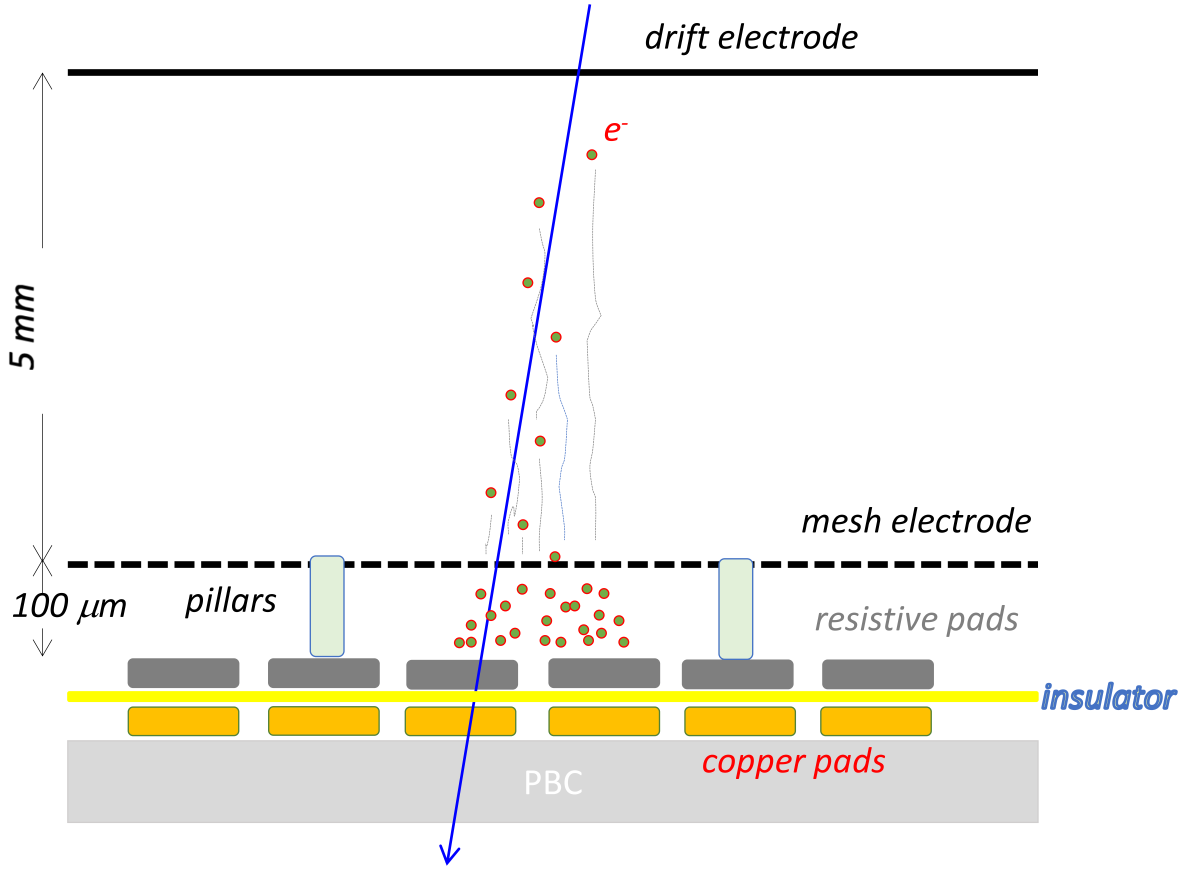
Small Pads Resistive Micromegas

Conceptual scheme:

Resistive MicroMeGas technology consists in 'covering' the copper 'small' anode pads, O(mm^2), with a resistive 'structure' (for ex. pads as in figure) to suppress discharges



Main purpose:

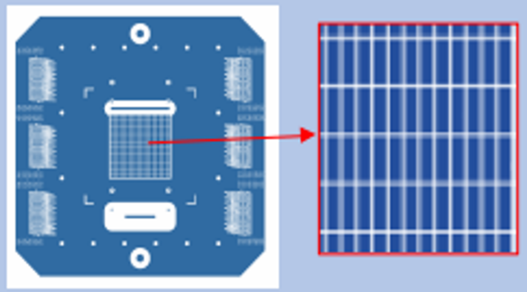
get a tracking detector operating at very high rate ~10 MHz/cm^2

through:

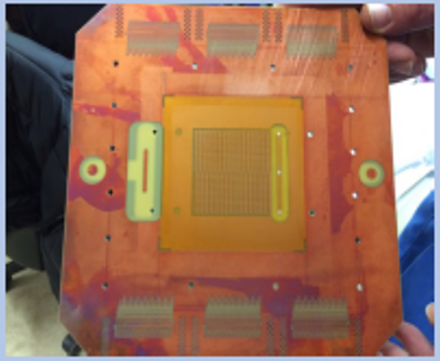
- fine readout granularity, to reduce occupancy;
- optimization of the spark resistive protection, to have stability of operation at high rates/gains;
- demonstration of the scalability of the detector to large surfaces;
- simplification of the construction tecnique for industrial production

Prototypes and their Spark Resistive Protection Layouts

Readout PAD anodic plane
(common to all prototypes)



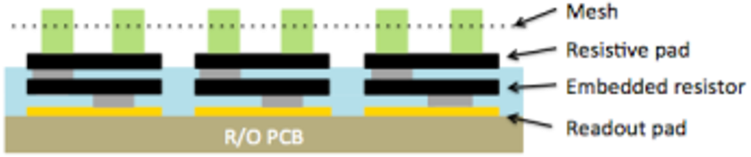
4.8 x 4.8 cm^2 active region
768 pads, 0.8 x 2.8 mm^2 each
48 pads – 1 mm pitch ("x")
16 pads – 3 mm pitch ("y")



Signals routed to six Panasonic connectors

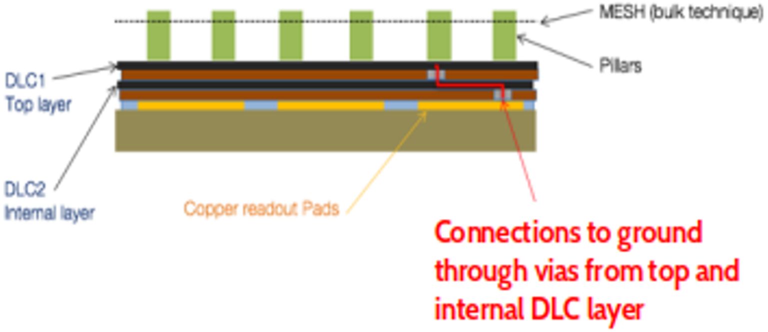
CONFIGURATIONS of the resistive layers
two main categories: Pad-patterned and uniform DLC layers

PAD-Patterned



- Two planes of independent resistive pads with the same geometry of the copper readout pads
- New technique based on etched DLC layer for the intermediate embedded resistor

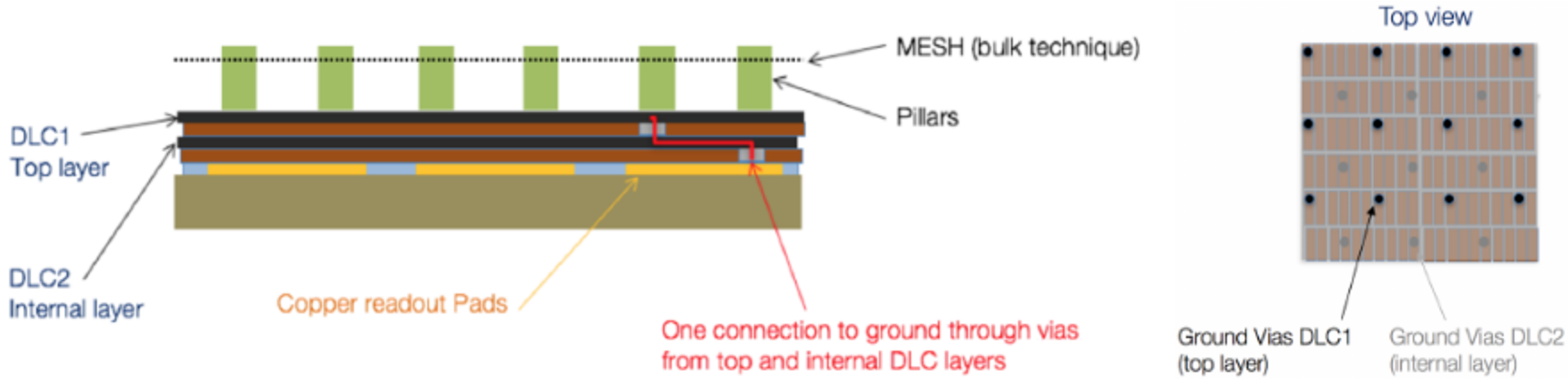
Uniform Double DLC



- Uniform double DLC layers with grounding connections
- Sequential Build-Up technique (based on copper-clad DLC) implemented in recent years
- Grounding vias either DOT or STRIP

The DOT and STRIP versions of the DLC type

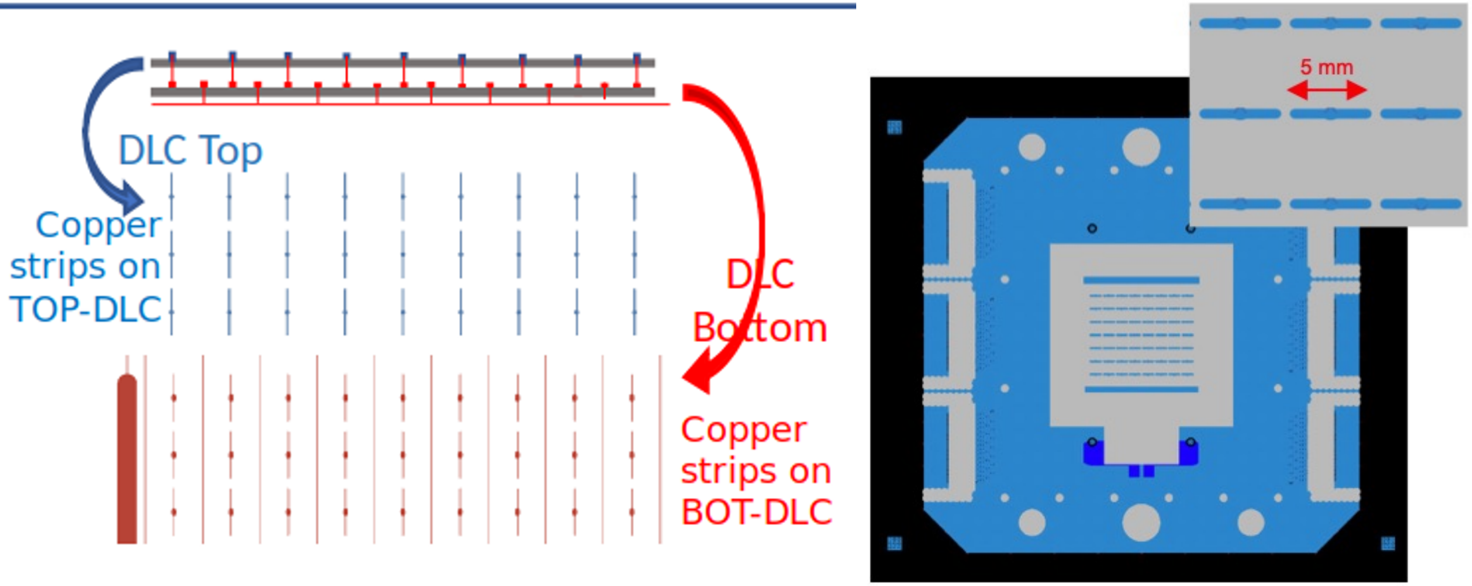
Double DLC "Standard" DOT version



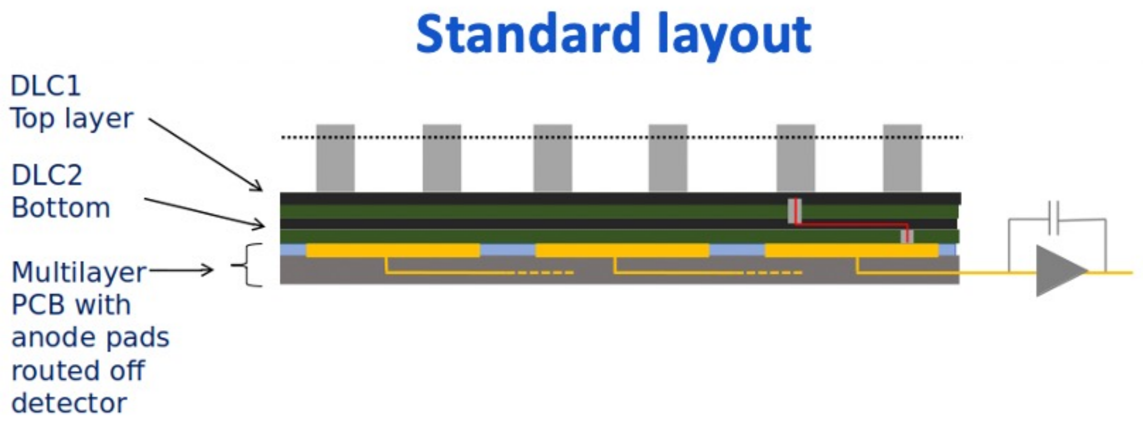
Double DLC new "Strip" version

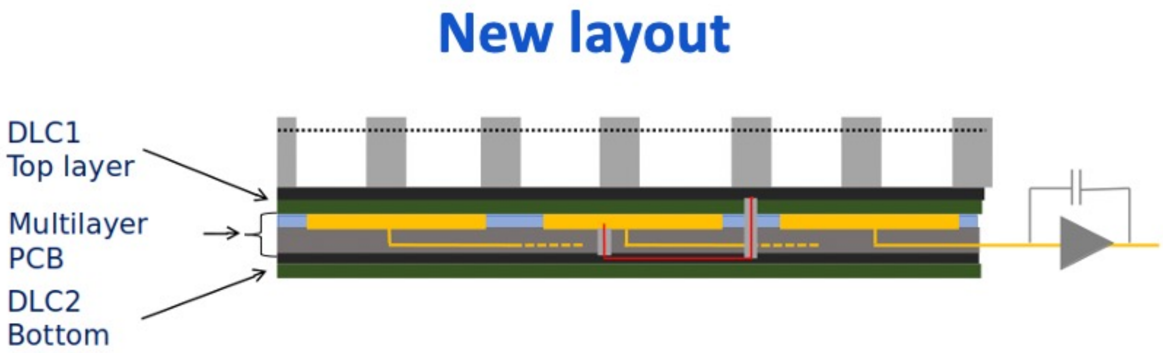
by Rui De Oliveira

- 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



Other variation on the Uniform Double DLC 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

Summary of the Small-Pads MM Prototypes

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

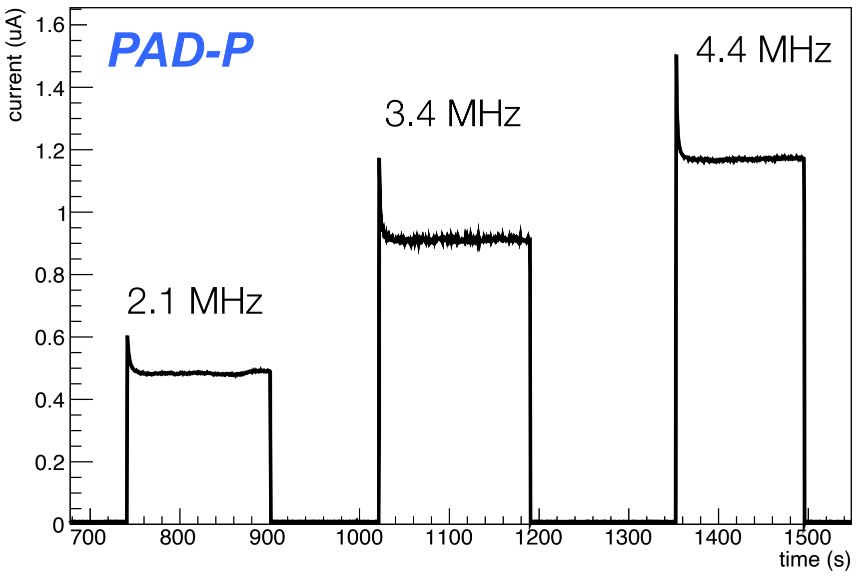
DLC-SBU (SBU3) [Sequential Build-Up technique exploiting copper clad DLC]
Resistivity: Top 22 ± 1 MΩ/□ – Bottom 42 ± 8 MΩ/□
Readout pads between the resistive DLC foils

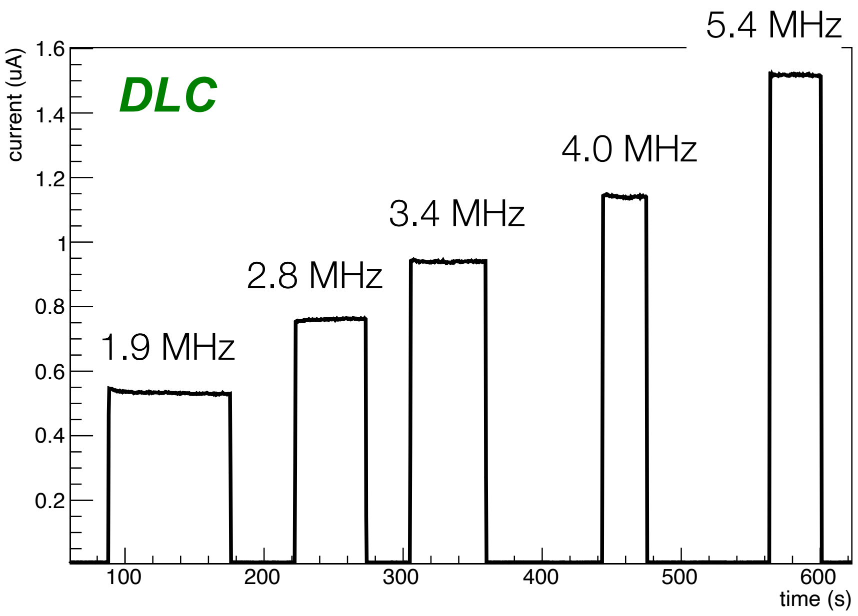
DLC-SG [Strip Grid grounding scheme]
Resistivity: Top 40 ± 2 MΩ/□ – Bottom 38 ± 6 MΩ/□
Readout pads between the resistive DLC foils
Longer pillars to cover the grounding copper strips

Tests with X-Rays: charging up

- PAD-P types show a decrease of the current/gain (~ 25%) when the X-Ray gun is switched on
- a possible explanation is the charging up of the dielectric (kapton) among pads, with a consequent reduction of the electric field

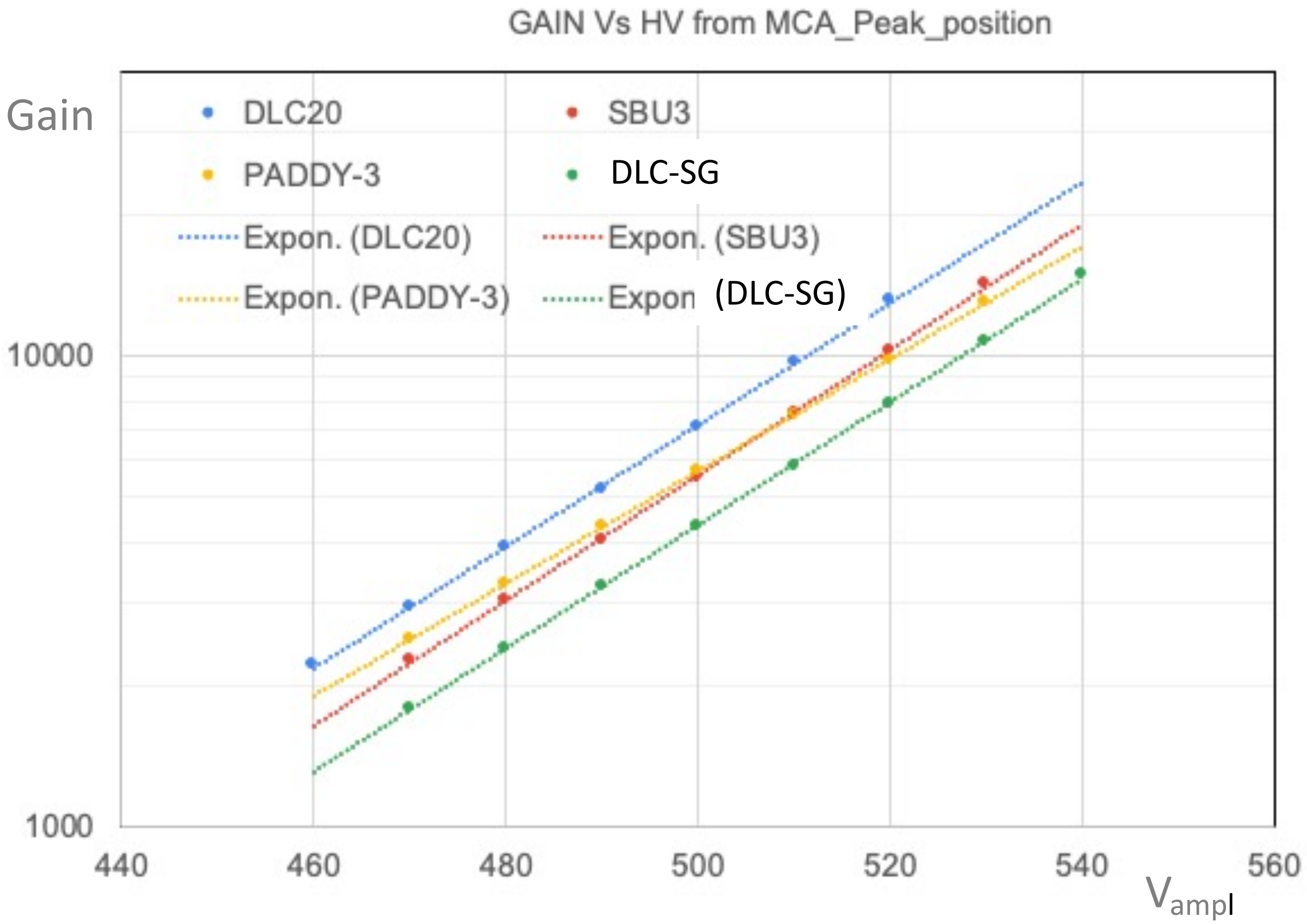
- DLC types do not show any sizeable charging-up effects (less than few %)
- infact their surface is uniformly resistive and has almost no dielectric, apart from pillars…



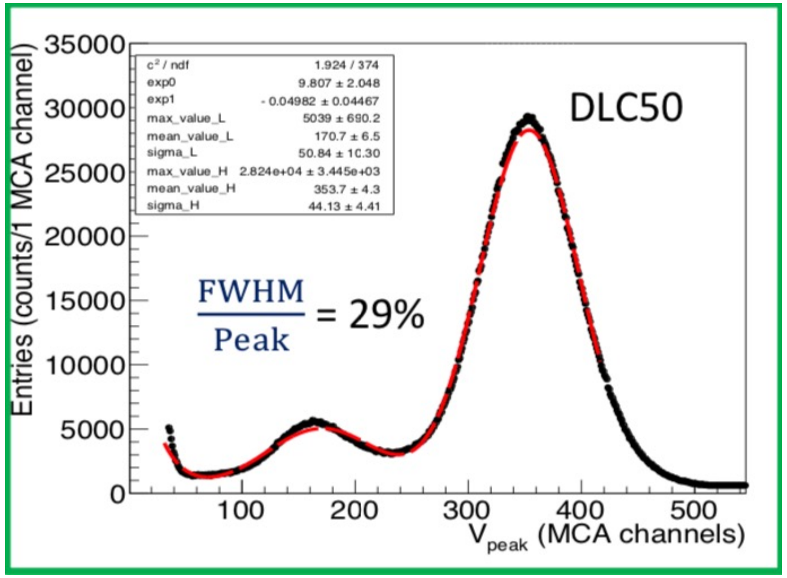


Current measurement vs Time during cycles of X-Rays irradiation

Tests with ^{55}Fe source: GAIN



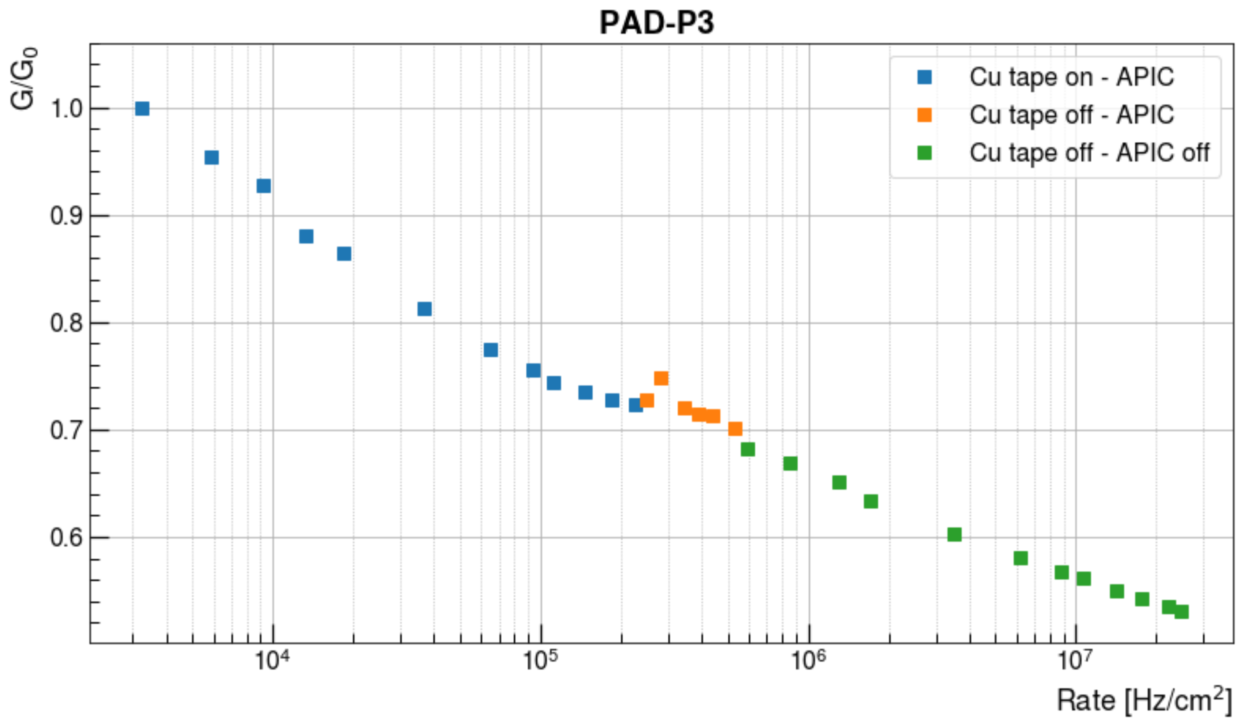
- Gas mixture Ar:CO2=93:7
- ^{55}Fe source rate ~ 20kHz



Energy resoution for DLC-type generally better then for PAD-P type

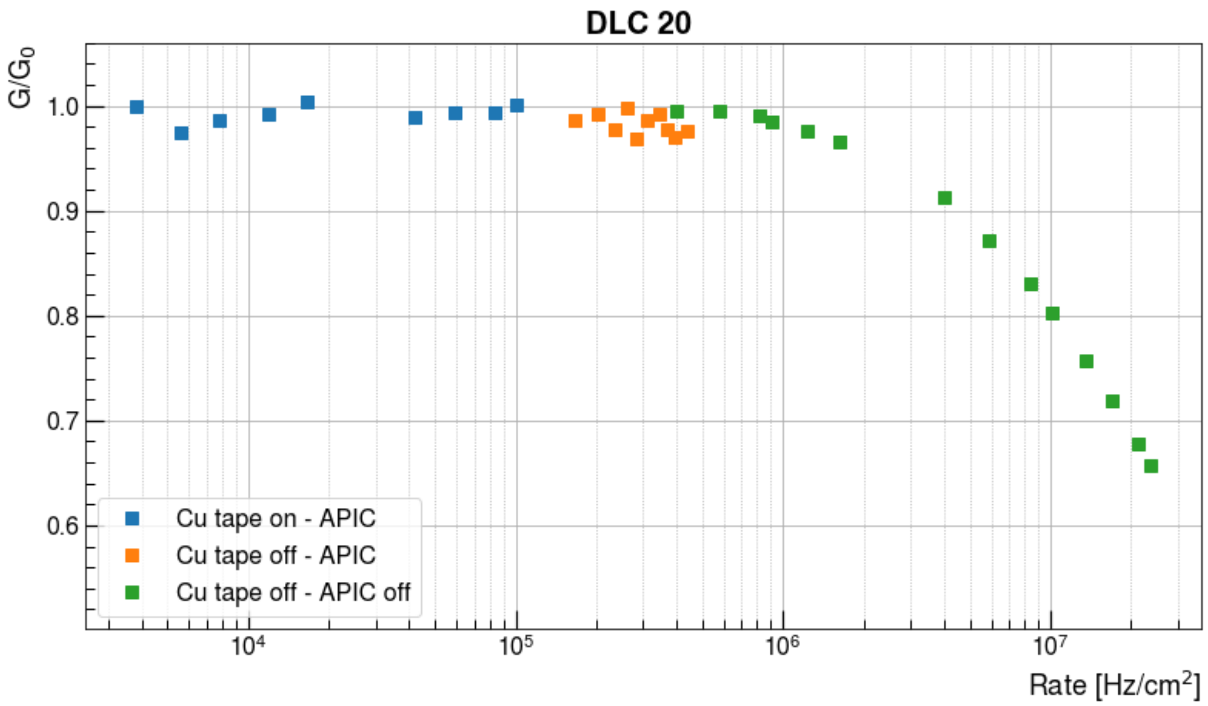
- Lower gain of PAD-P type with respect to DLC observed for all prototypes
- Different slope of PAD-P3 possibly due to an increase of charging-up with the gain
- Traslations in the gain curves could be due to small differences in the amplification gap height

High rates with X-Rays



PAD-P scheme:

- ‘fast’ gain drop at “low” rates ($<0.1 MHz/cm^2$) due to charging-up
- ‘slower’ ohmic voltage drop through the individual pads from 0.1 MHz/cm^2 on… (depending on pad resistivity value)



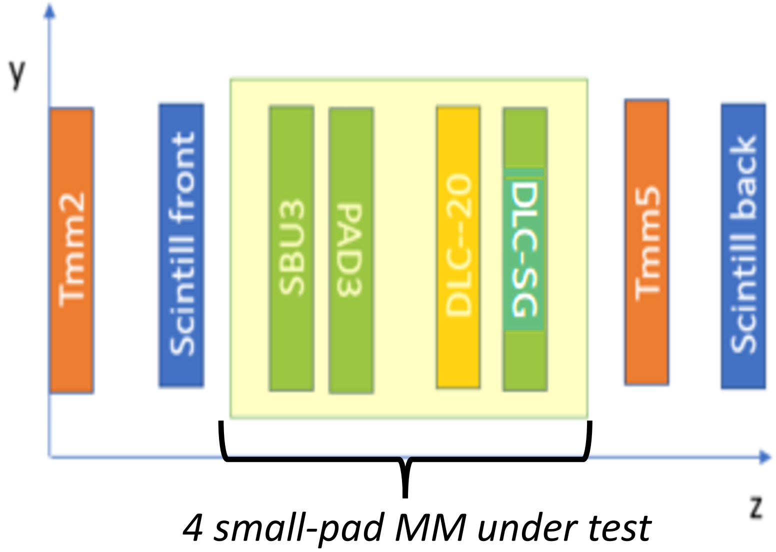
DLC and SBU series:

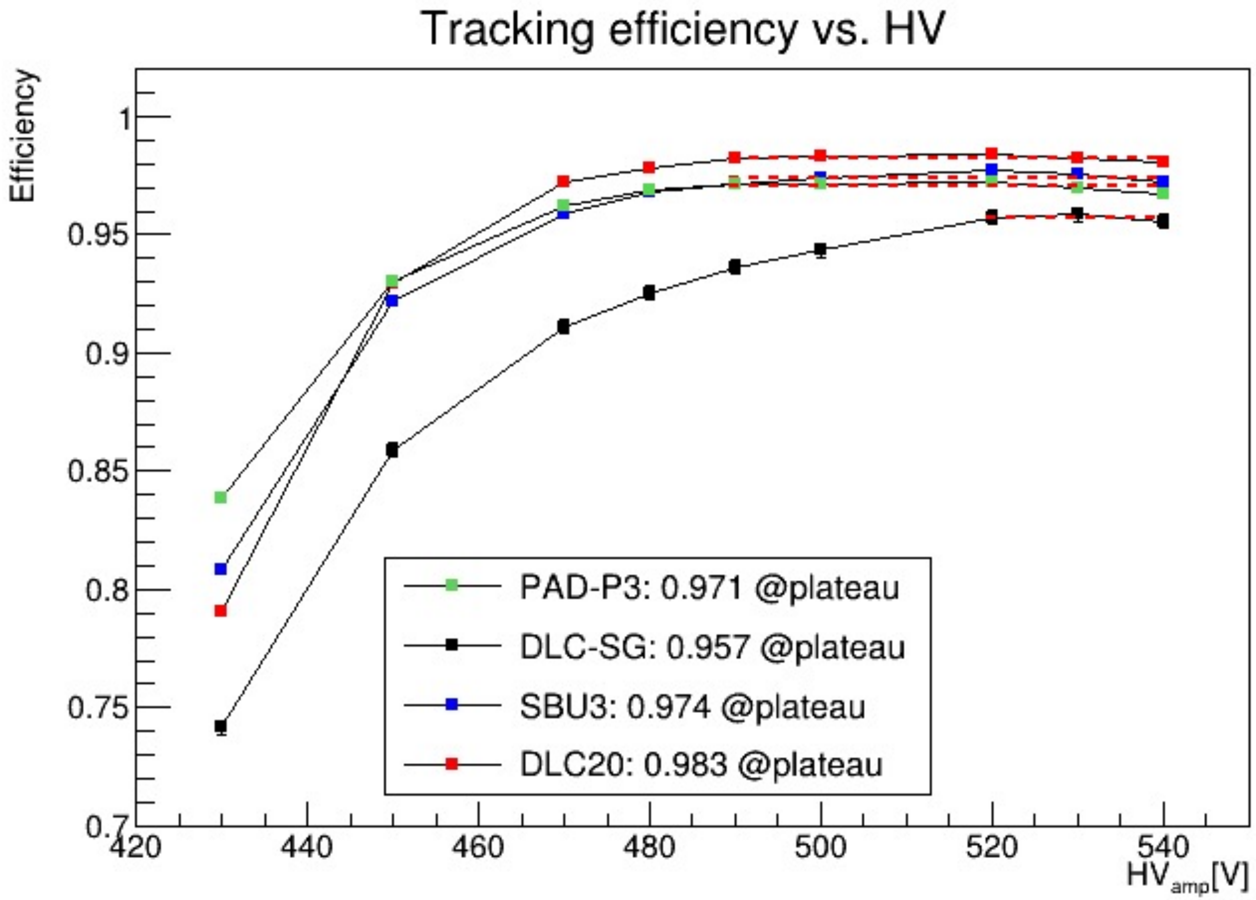
- stable gain up to 1 MHz/cm^2
- significant ohmic voltage drop at higher rates (depending on DLC resistivity value)

Detector Efficiency

@ test beam

- Muon beam
- Ar:CO2=93:7 gas mixture





- efficiency measured through external tracking in the two TMM(2,5) (2D strip micromegas)
- Tracking efficiency: clusters are required to be within 1.5 mm from the extrapolated track position in the precision coordinate

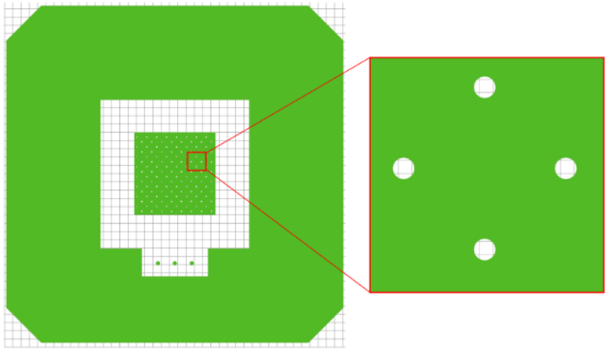
For most of the prototypes: **detector efficiency > 97%**

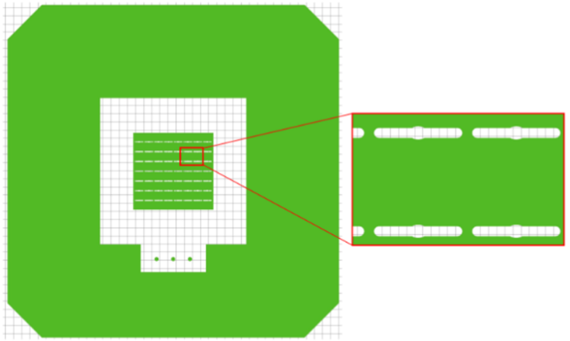
only for DLC-SG is ~1% less, due to the larger size of the pillars

Detector Efficiency

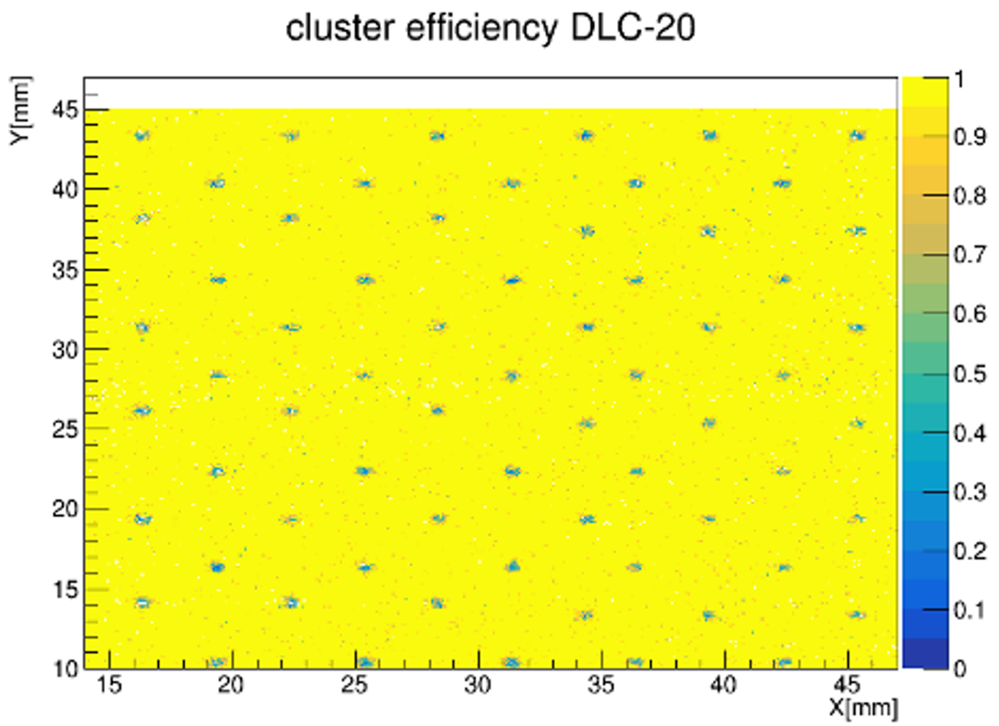
- Pillars observed as local inefficiency regions:

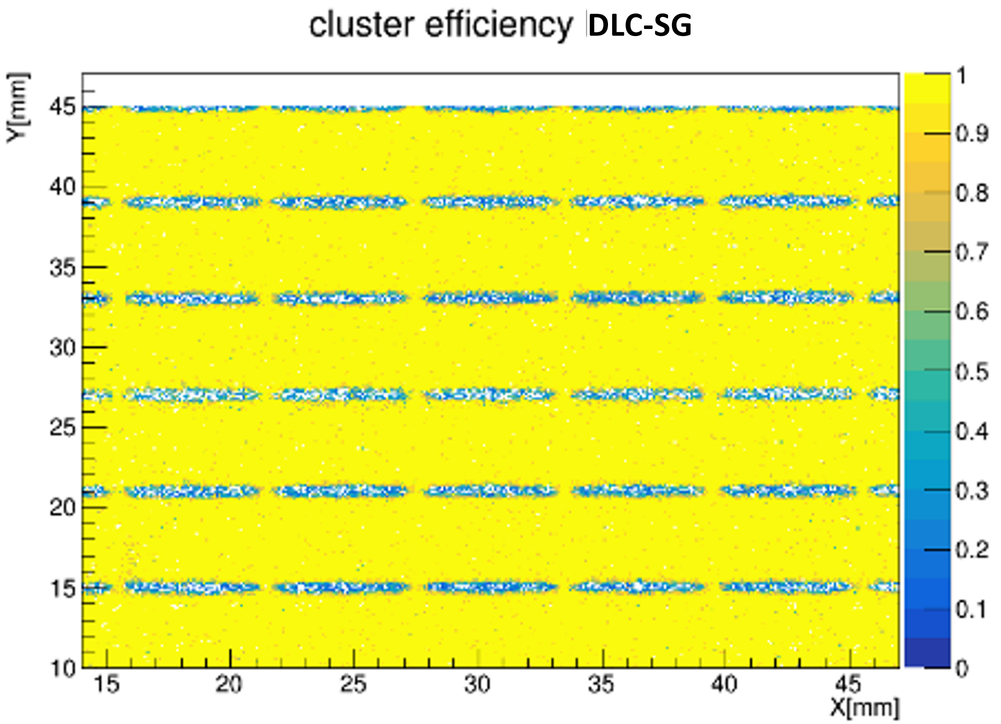
Circular pillars
0.8 mm diameter
2.8% geometrical coverage





Elongated pillars (5.30 mm)
for DLC-SG prototype
7.7% geometrical coverage

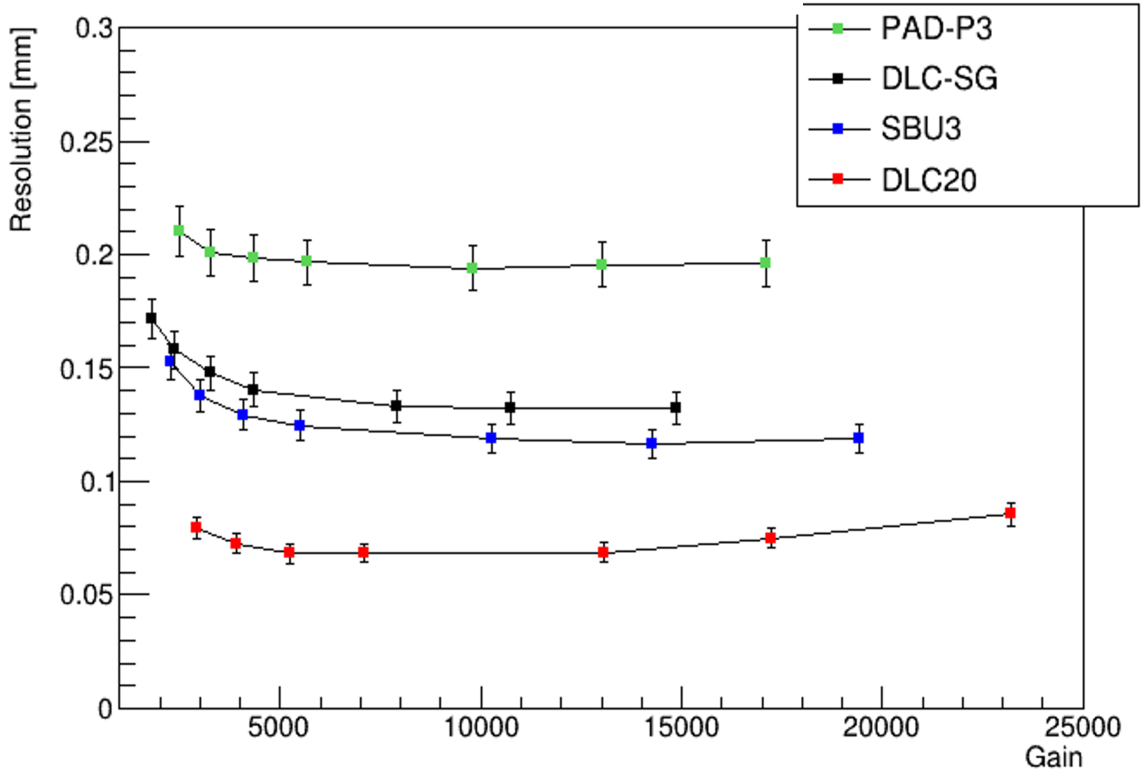




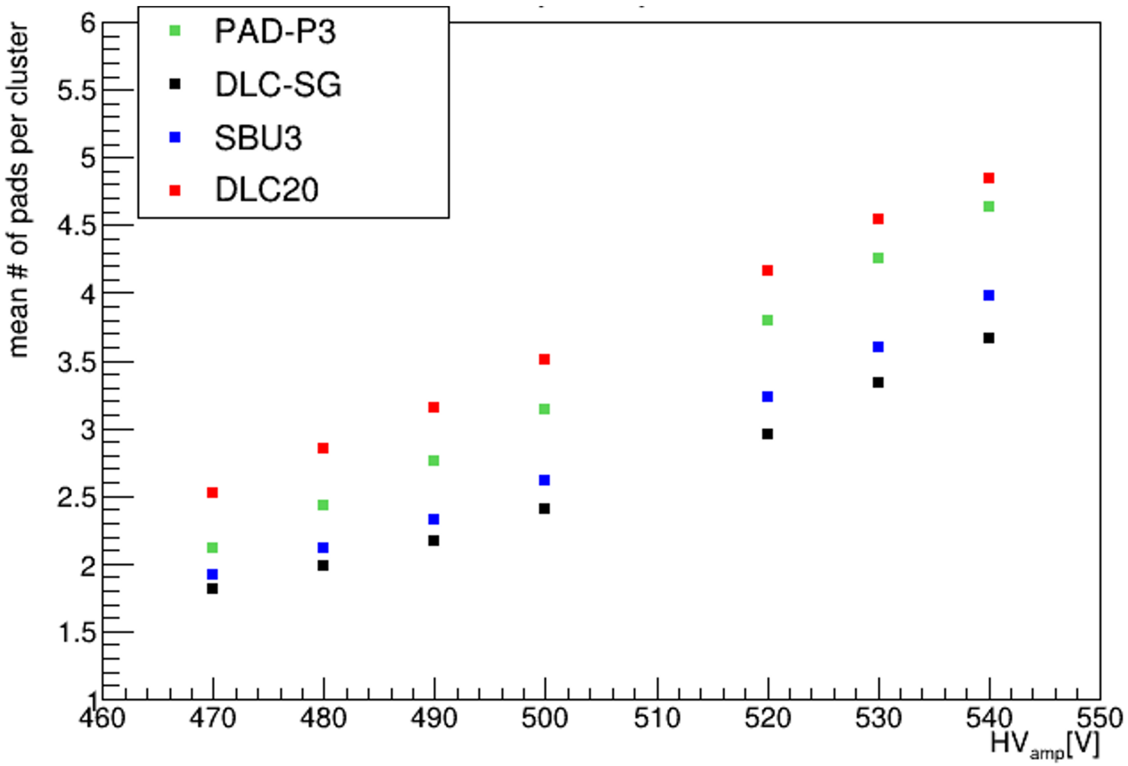
Position Resolution

- position in every detector calculated from the charge weighted pad positions (cluster centroid)
- resolution obtained fitting the residual distribution in the precision coordinate w.r.t. TMM tracks (extrapolation error ~50 μm, subtracted in quadrature)

Position resolution vs Gain:



Mean number of pads per cluster vs HV:

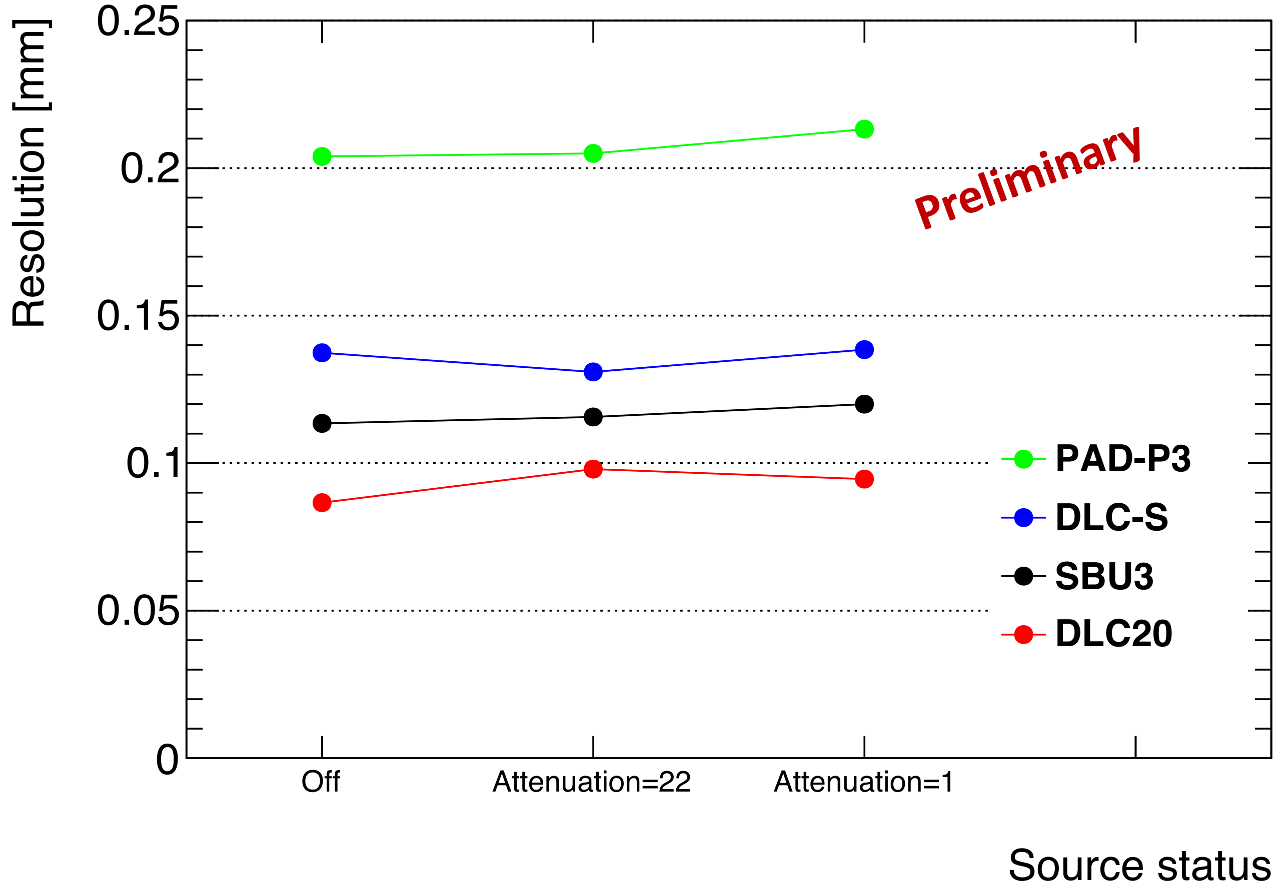


Resolution seems affected not only from the cluster size, but also from other parameters that differ among the protoypes (as resistivity and capacitive coupling of the pads). We plan to investigate the impact of the possible contributions as direct induction, capacitive coupling and resistive charge spread

Tracking performance under gamma irradiation

Test beam at GIF++ @CERN:

- High energy muon beam in high photon background produced from an intense source of ^{137}Cs (662 keV photons), intensity adjustable through attenuators
- A preliminary estimate of the counting rate in our detector position was of tens kHz/cm^2 at full intensity (Attenuation=1)
- Planning for another test beam period to take data closer to the source

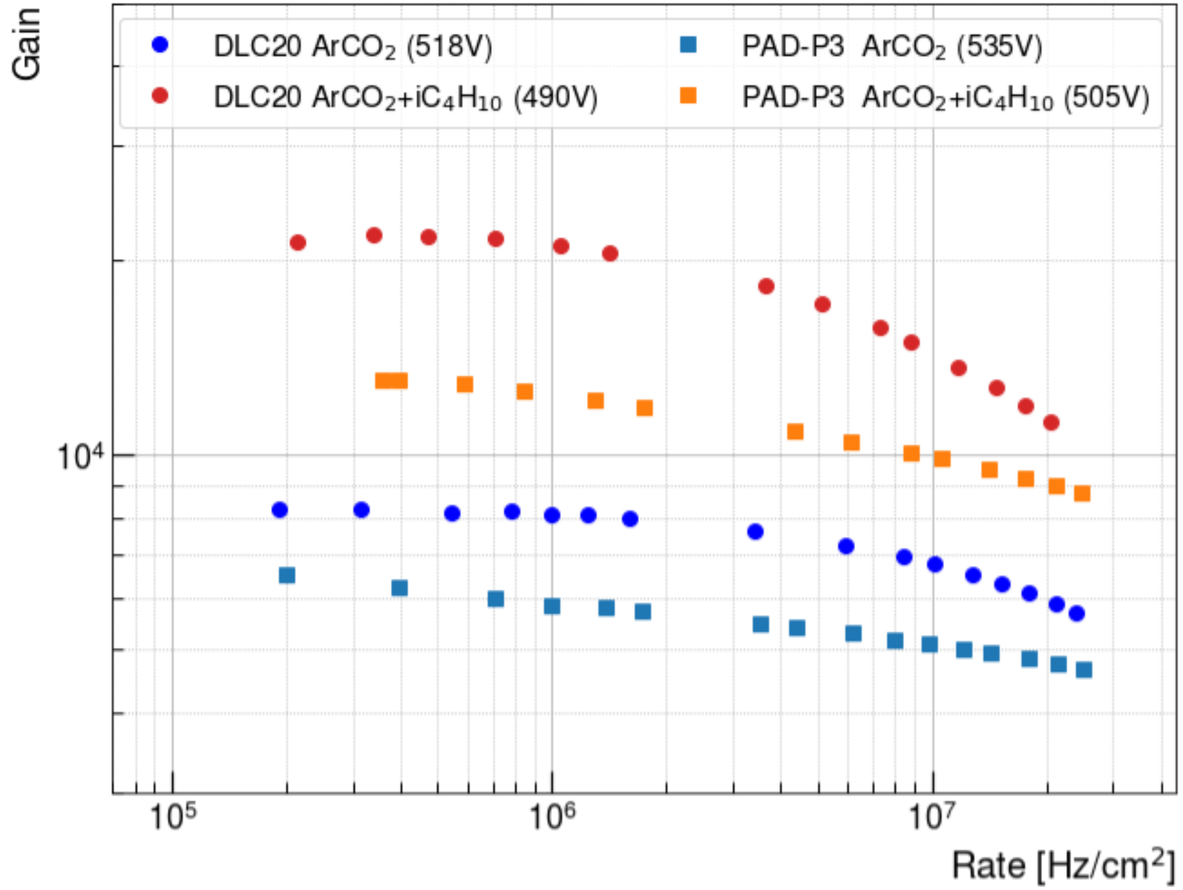


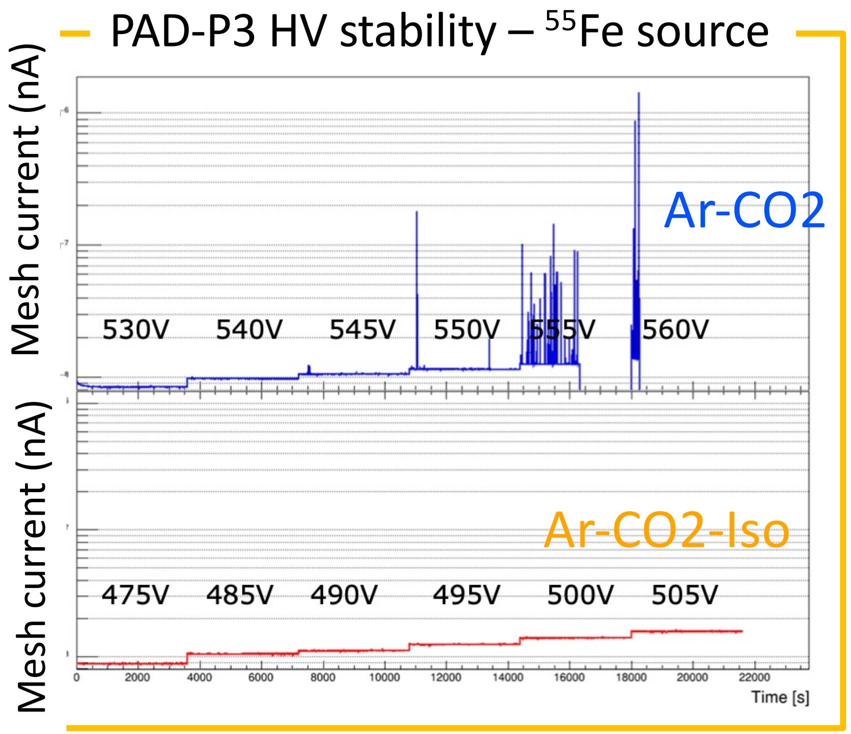
Gas Mixture studies

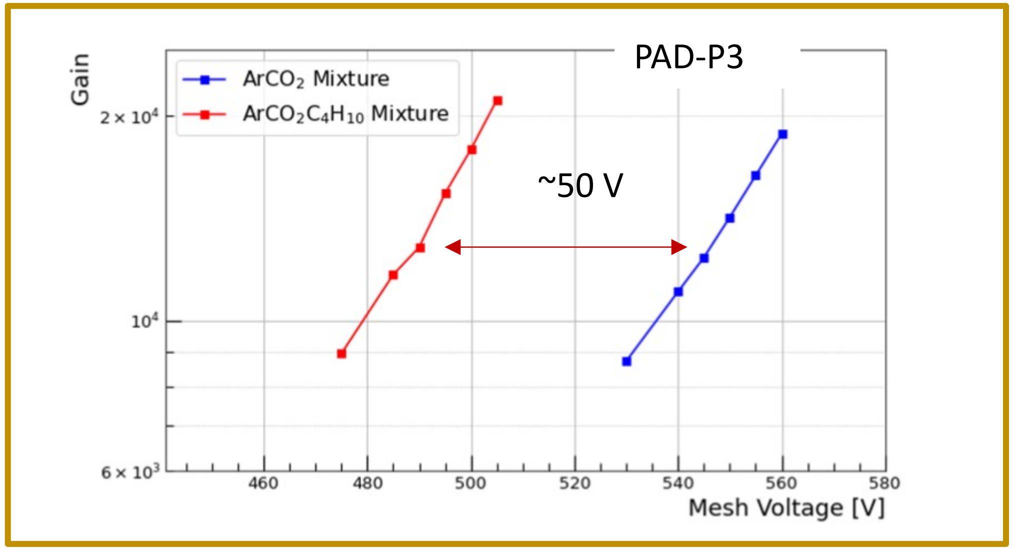
With Ar:CO2=93:7 gas mixture used so far, detectors showed some current instability at high gain values

Adding 2% isobutane to the mixture (Ar:CO2:iC4H10=93:5:2) avoided sparks

Stable conditions reached at gain >10k also under very high X-Rays irradiation rates (>10 MHz/cm2)





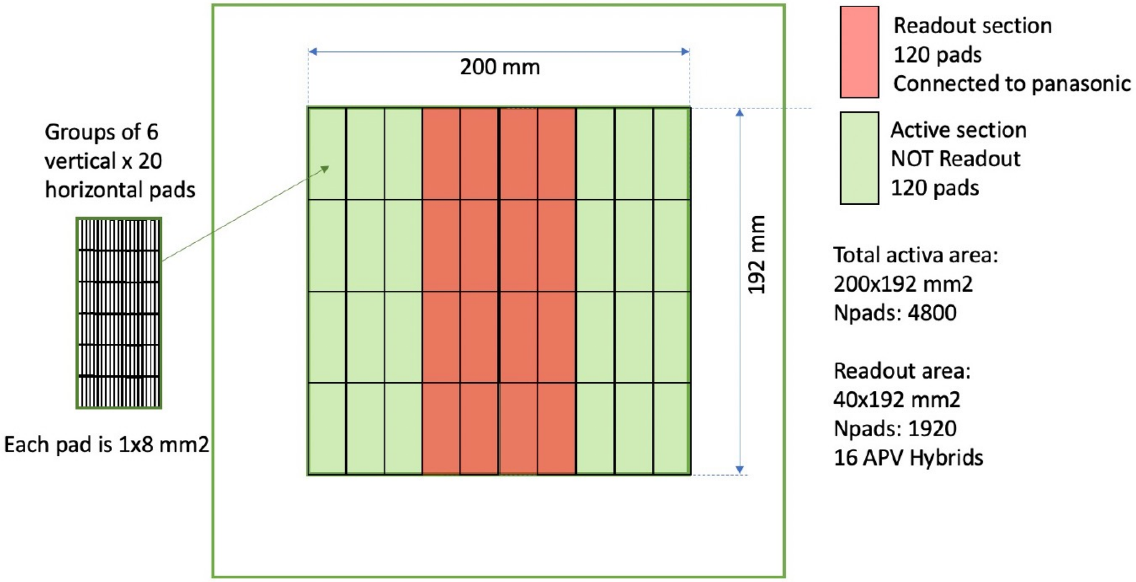


~50V difference between the two mixtures for a given gain

Next steps

Larger surface prototype

A larger area (20 x 20 cm^2) detector is under construction:

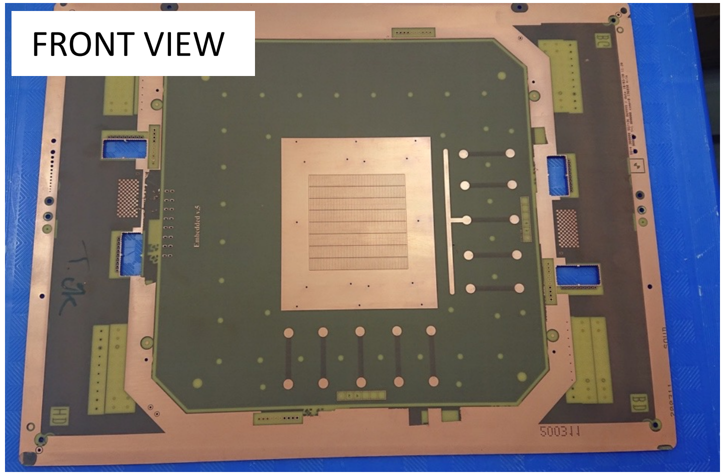


Active area: 200x192 mm^2

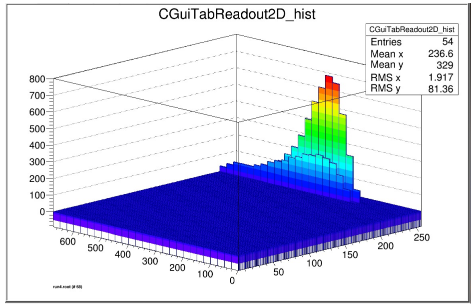
- Pads 1x8 mm^2 - Total Number of Pads: 4800
- Double layer DLC with grounding vias every 8 mm
- Panasonic connectors on the back of the detector
- Partially readout: 1920 connected pads out of 4800 tot pads

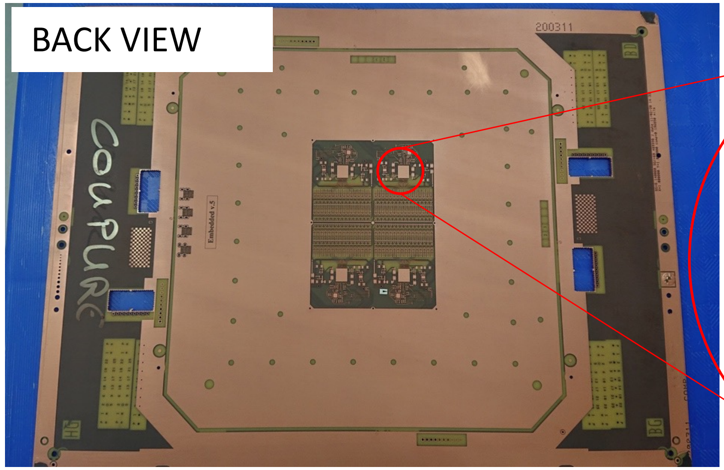
EMBEDDED (back wire-bonded) electronics

Scaling to larger surfaces only possible with electronics integrated on the back-end of the anode PCB (work in progress)

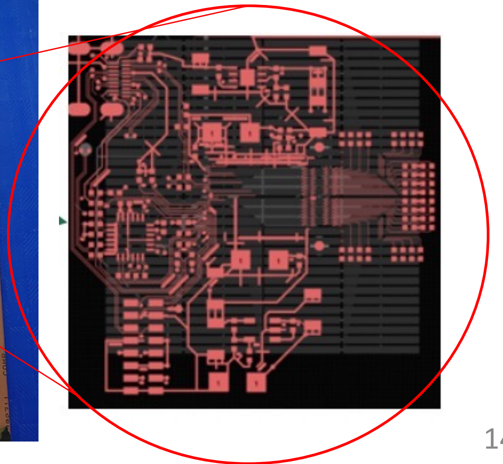


small prototype (64 x 64 mm^2) built and read through APV25 FE chip





APV25 layout



Conclusions

Different spark protection resistive layouts have been implemented on several Small Pads Micromegas protoypes. From tests and comparison among them we reached:

- stable operation up to 20 MHz/cm^2 with gain >10k
- detector efficiency > 97%
- position resolution < 100 μm

Ongoing/future work:

- continue the optimization of resistive layout and gas mixture choice finalized to the tracking in high rate environment
- address the detector scalability to larger area
- measure the time resolution
- perform ageing studies