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Small-Pad Resistive Micromegas

Rate capability for different spark protection resistive schemes

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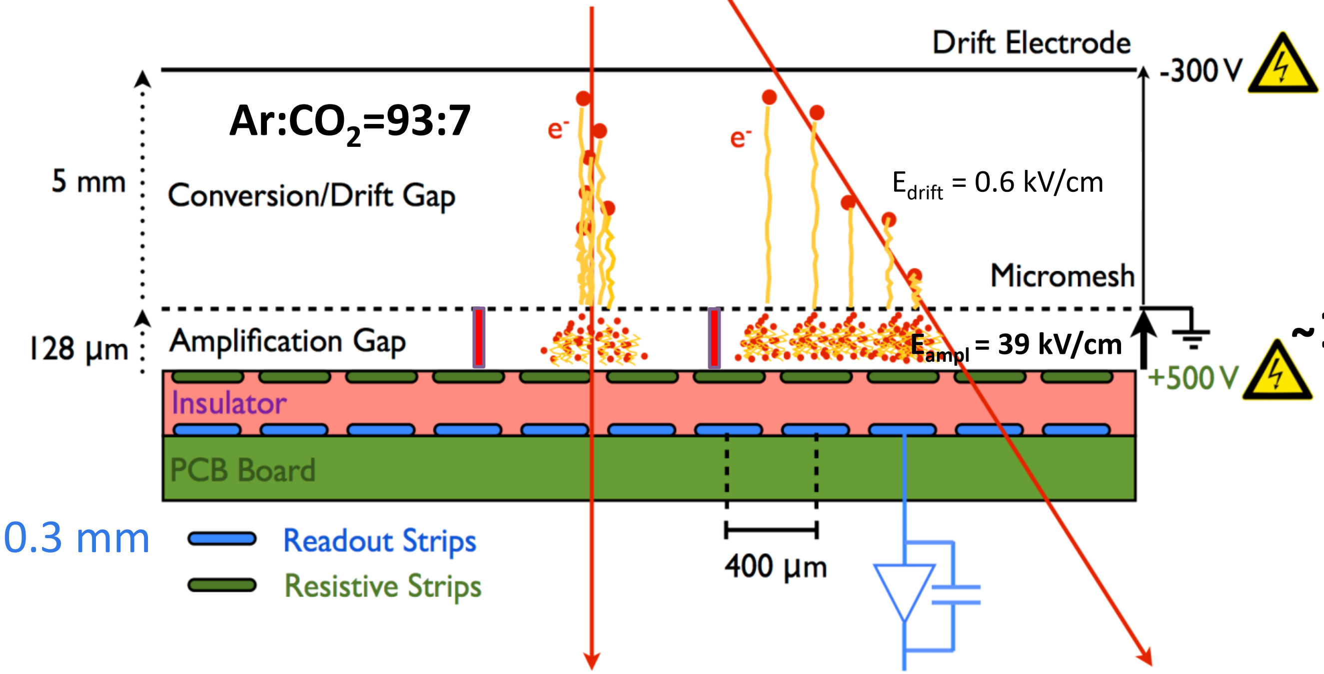
Contents

- Brief introduction on the Micromegas technology towards O(10 MHz/cm^2) particle rate operation;
- Comparison of detector performance with different sparks suppression resistive layouts;
- Study on the rate capability (X-rays);
- Study on sparks probability (~300 MeV/c charged pion beam).

MICRO-Mesh-Gaseous-Structure (MICROMEGAS) technology

Planar proportional mode – Micro Pattern Gaseous Detector (MPGD)

Resistive strip MM detector sketch



5 mm Drift Gap → e^- /ion pairs

~120 µm Amplification Gap →

Electron avalanche multiplication

Discharge vulnerability

Resistive strips quench the possible discharges in similar way as the resistive layer in the RPC detectors.

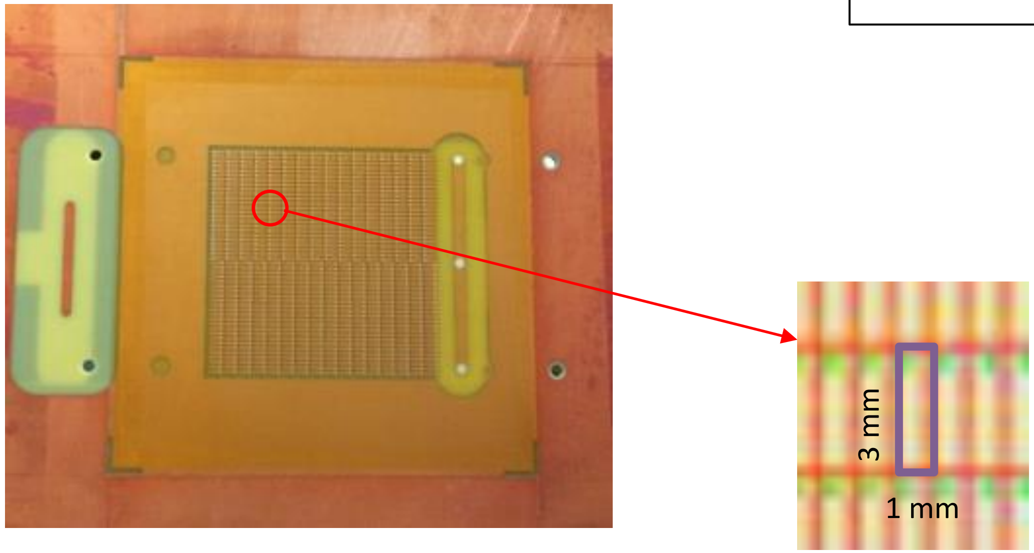
Towards high rate operations

Since the current HEP experiments look towards high intensity collisions, our R&D aims to develop a new generation of resistive Micromegas detectors able to efficiently operate at 10 MHz/cm^2 particle rates.

Miniaturization of readout electrodes, lowering their occupancy

1x3 mm^2 PAD geometry required new sparks suppression resistive layout

R&D project is centered on the optimization of **sparks suppression resistive layout** for the small pad geometry



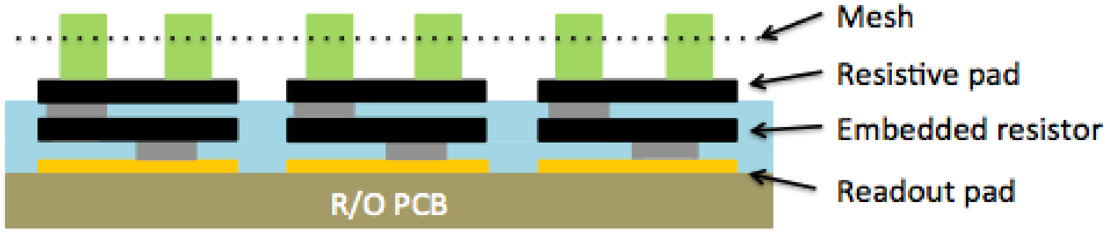
Common properties shared by all prototypes:

- 768 readout Pad matrix on 4.8x4.8 cm^2 active area;
- Circular pillars with r = 200 um, height 100-120 um (bulk technique) and 6 mm pitch;

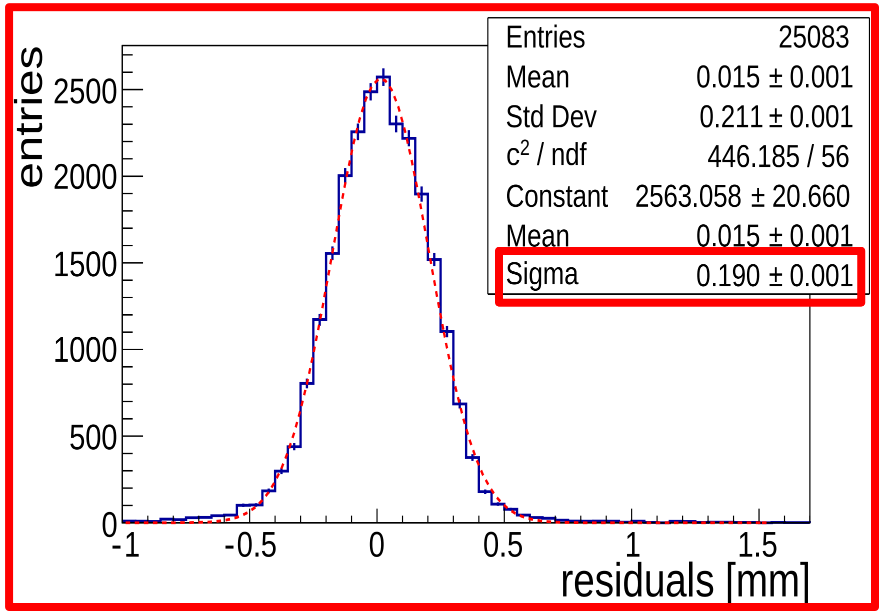
Sparks suppression resistive layout: PAD-P (scheme 1)

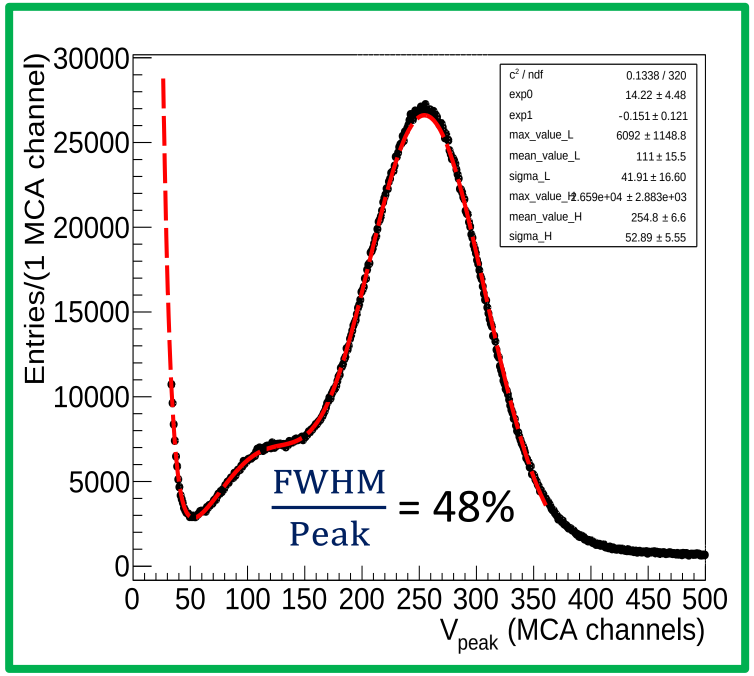
Two planes of independent carbon resistive pads; the overlapped pads in the different planes are interconnected by silver vias, as shown in the picture.

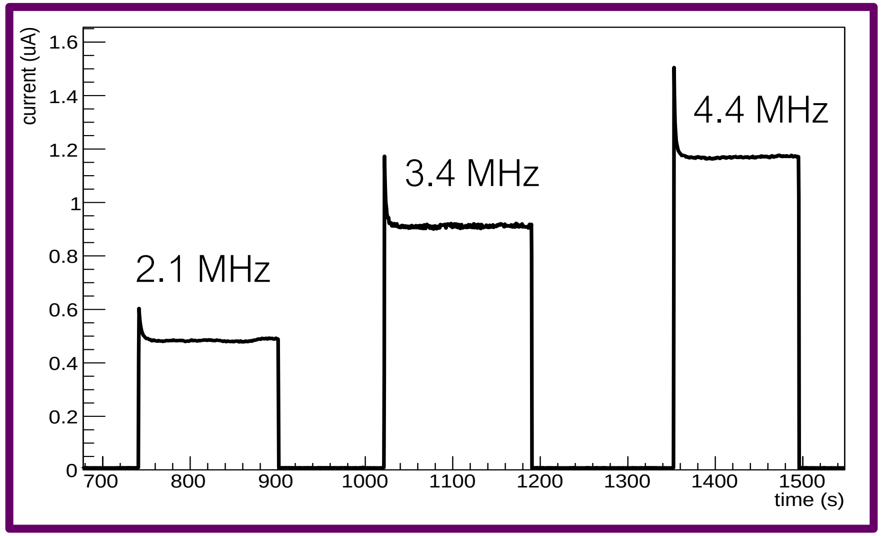
PAD-Patterned Embedded resistor type (SCHEME 1);



Fair spatial resolution (~200 um) on the precision coordinate (1 mm pitch), moderate energy resolution and sizeable effects of charging-up (gain reduction by ~20%) are visible in the current as function of time.







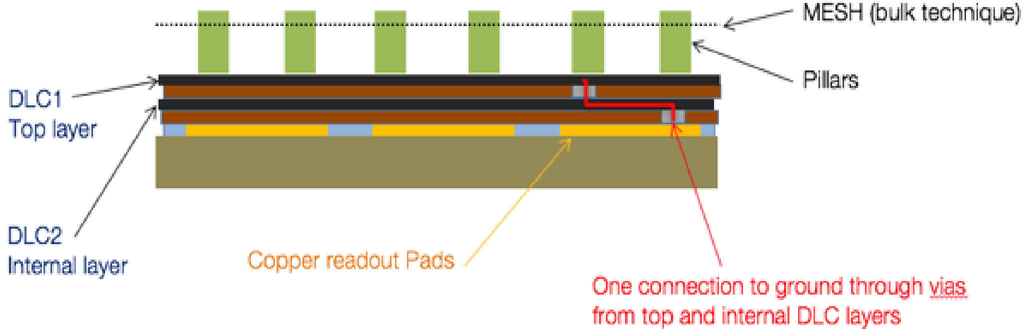
Sparks suppression resistive layout: DLC (scheme 2)

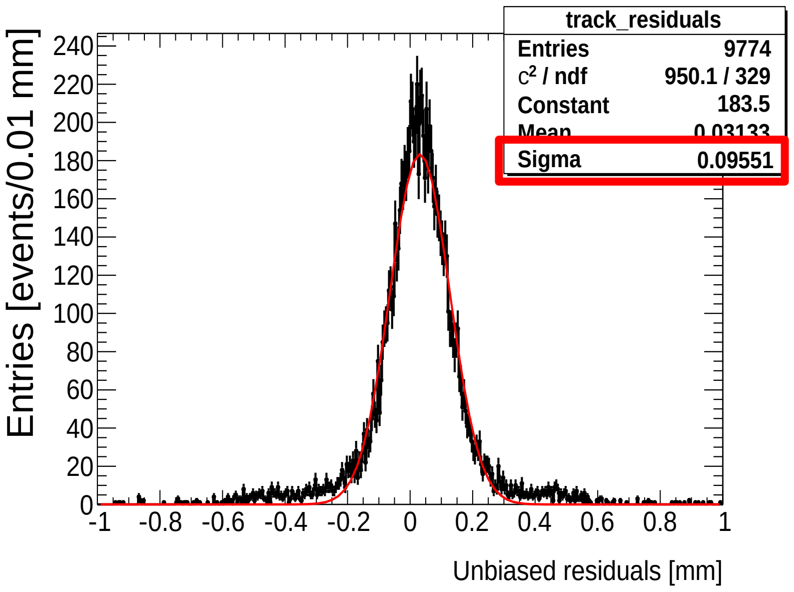
The two planes with independent pads are replaced by two continuous DLC foils in this scheme:

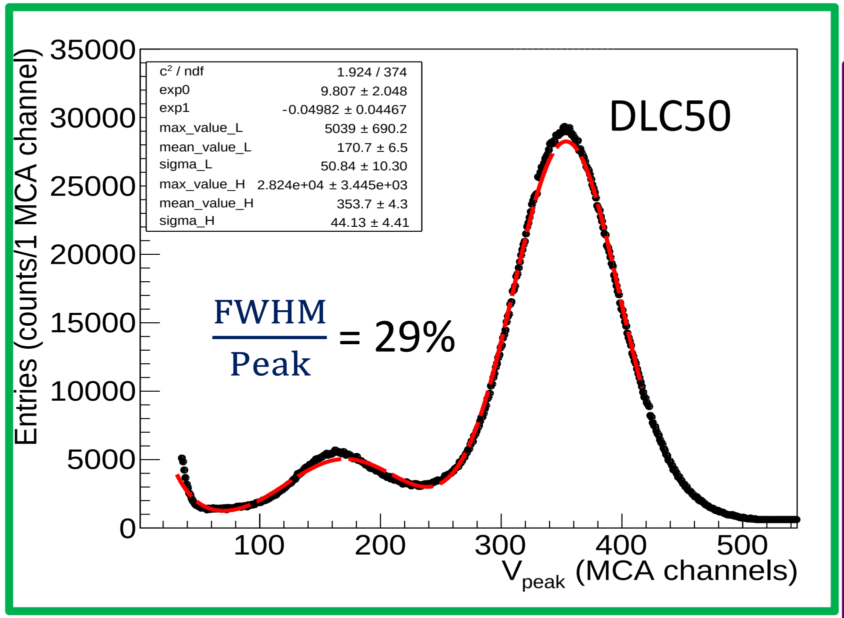
- Strong impact on the production (easiness and costs);
- Minimization of charging up;

Better **spatial resolution (< 100 μm)** on precision coordinate, better **energy resolution** and no (or very little) charging up effects in **current as function of time**.

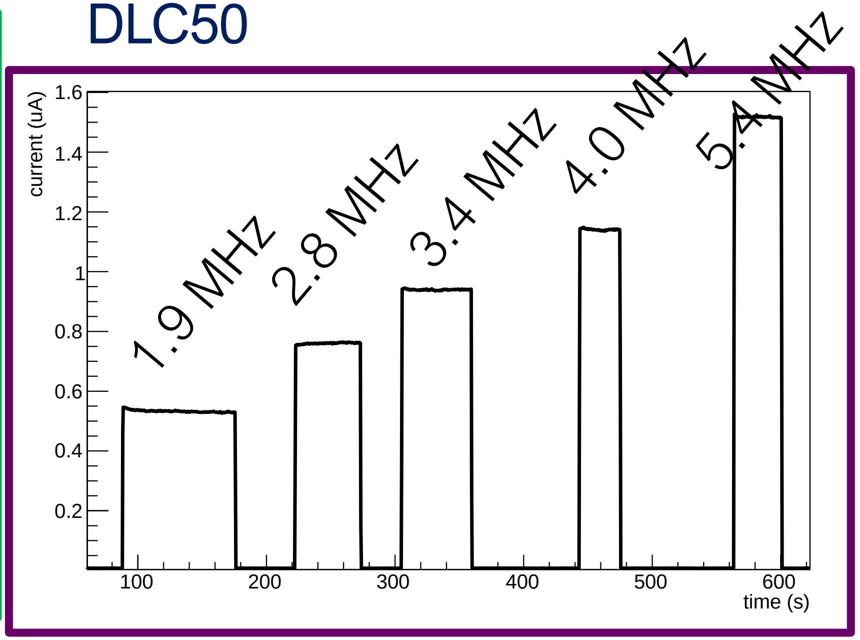
DLC type and its latter version SBU (SCHEME 2)





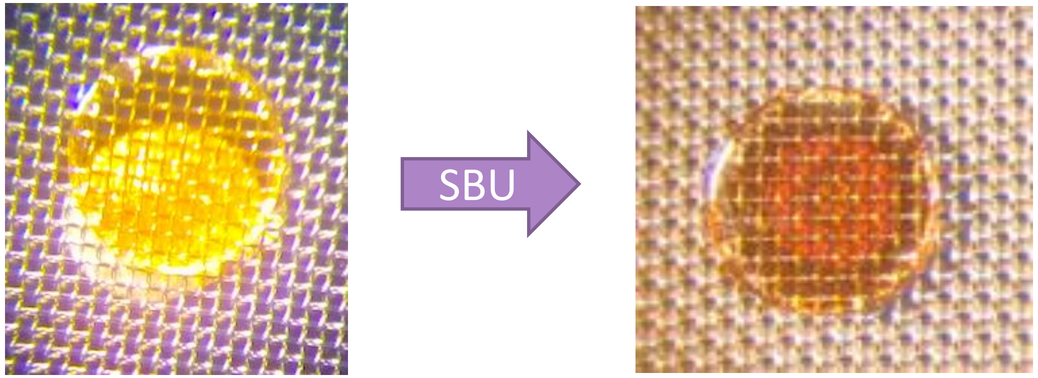


DLC50



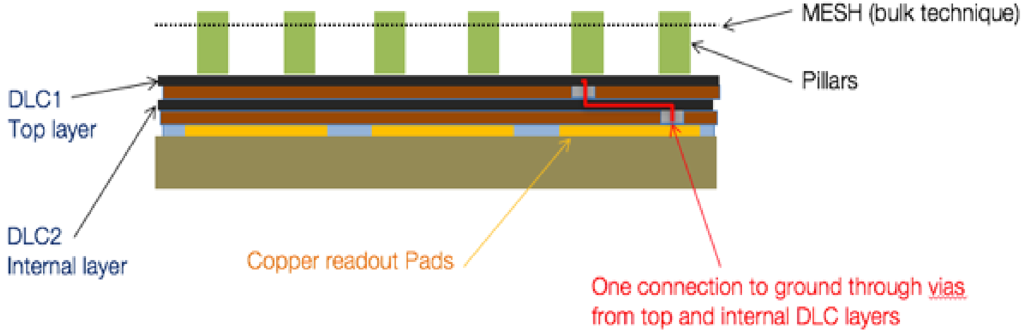
Technological improvement of DLC prototypes (scheme 2)

During the characterization studies of DLC prototypes, a non perfect alignment between vias and pillars in construction process was found, resulting in a larger discharge probability:



New Sequential Build Up technique: Improvement in building the vias in the DLC foils (using copper cladded DLC foils) and of the precision of vias covering with pillars.

DLC type and its latter version SBU (SCHEME 2)

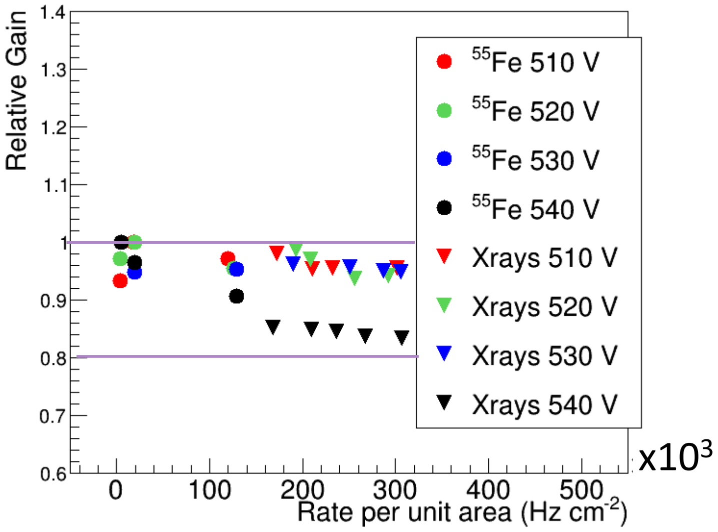


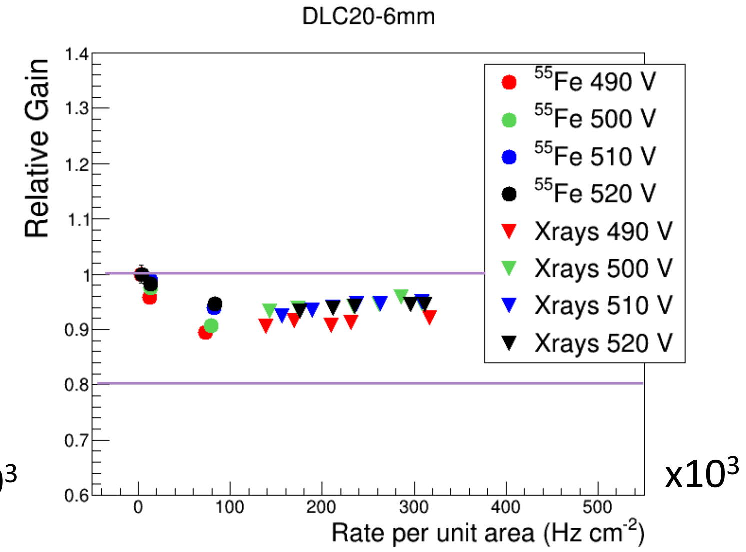
Different prototypes built with the DLC/SBU technique:

- **DLC50:** high resistivity 50-60 MΩ/sq DLC foils;
  6 mm vias pitch side and 12 mm vias pitch side;
- **DLC20:** low resistivity 20 M **Ω** /sq DLC foils;
  6 mm vias pitch side and 12 mm vias pitch side;
- **SBU1:** combination of DLC foils with 5 M**Ω**/sq and 35M**Ω**/sq resistivity, implemented with SBU technique;
  6 mm vias pitch in the entire plane;
- **SBU2:** copy of SBU1.

Rate Capability in different rate ranges of (55Fe/Cu-target) X-rays

Ar:CO_2=93:7

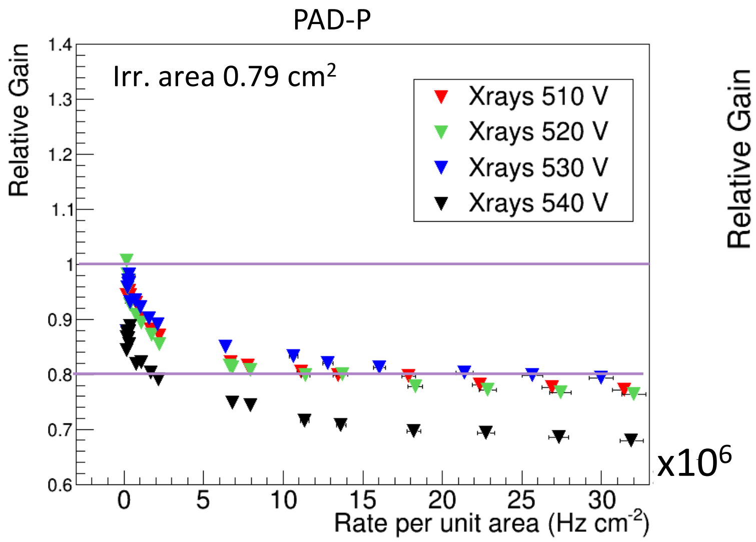


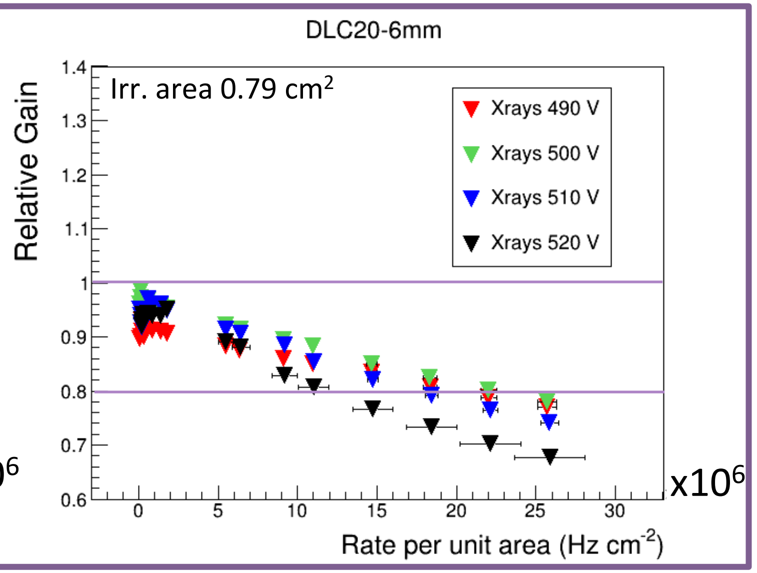


PAD-P and DLC20 have the same gain factor when PAD-P = DLC20+20V (back-up).

Range < 0.5 MHz cm^{-2}:

In PAD-P 540 V: charging-up affects the gain drop;
In DLC20: quite constant gain.





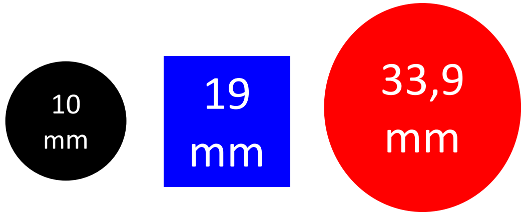
Full X-rays rate range:

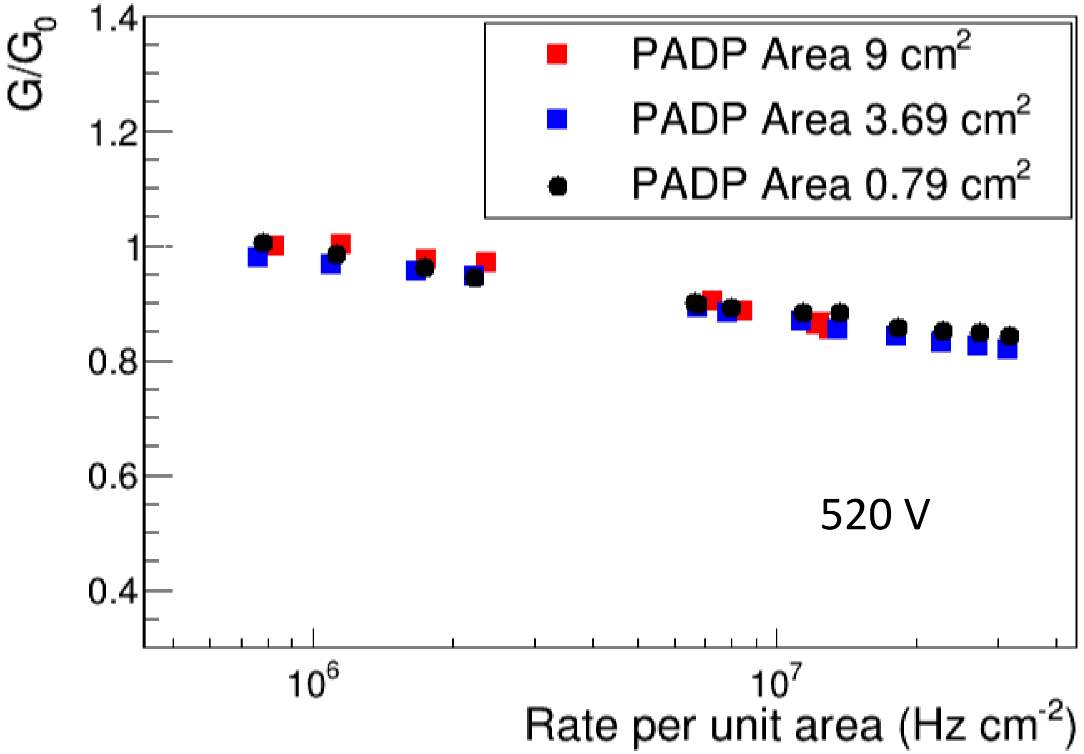
In PAD-P: charging-up almost saturates at **20 MHz/cm²**; while the ohmic contribution starts to be more relevant at higher rate.

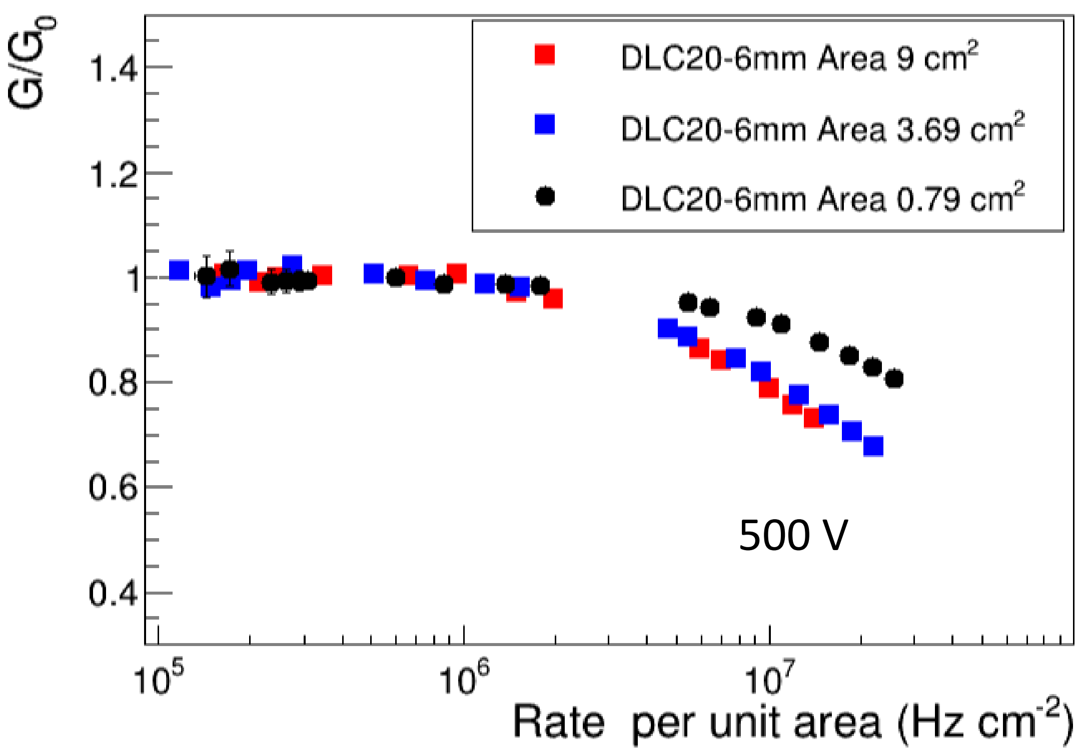
DLC20: ~20-30 % drop at **20 MHz/cm²** (ohmic voltage drop).

Chosen limit on acceptable rate capability: 20% gain drop

Rate Capability dependence on irradiated area



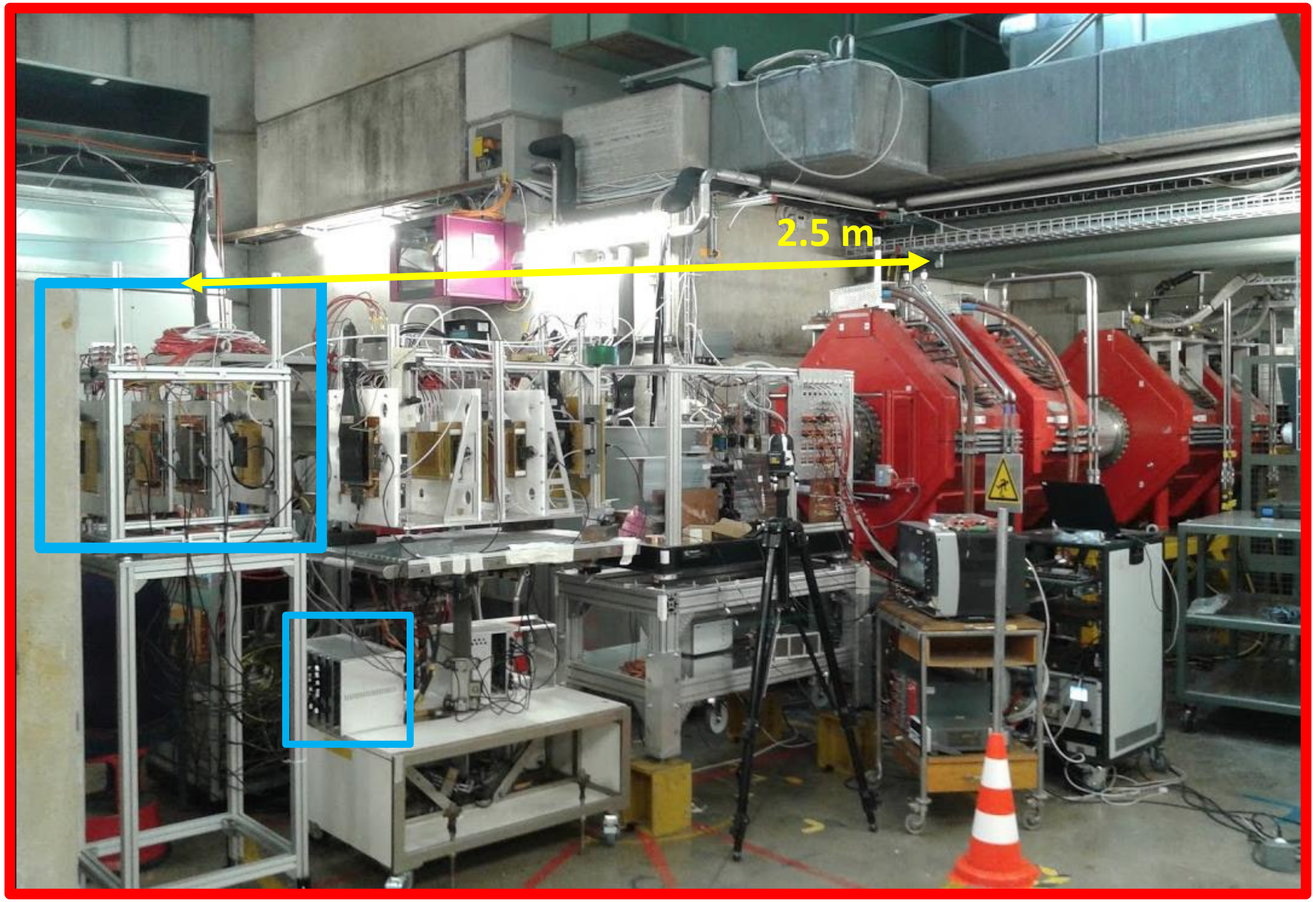




In DLC20, we observed the voltage drop depends on the irradiated area for areas < 3.69 cm^2. **The gain drops in DLC20-6mm do not scale for areas > 3.69 cm^2. They are comparable for 3.69 cm^2 and 9 cm^2 areas.**

Test beam with a 300 MeV/c charged pion beam

PSI πMU1 beam facility



The particle rate in the position of our setup was much lower (O(0.1 MHz/cm^2), as measured with an external trigger) with respect to the value in the beam focus (O(MHz/cm^2))

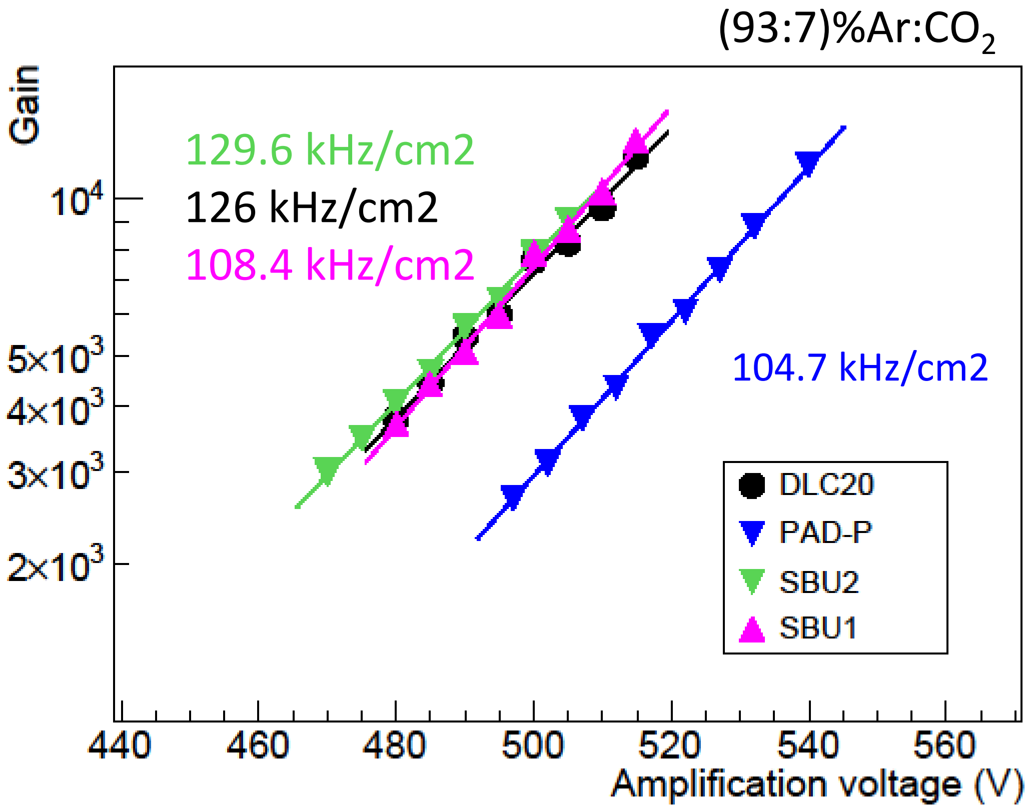
1) Preliminary discharge studies;
2) Acquisition of data with APV chips+SRS (as FE electronic) – Analysis on tracking performance still in progress;
3) First irradiation of SBU1 and SBU2;

GAS MIXTURE: Ar:CO2= 93:7

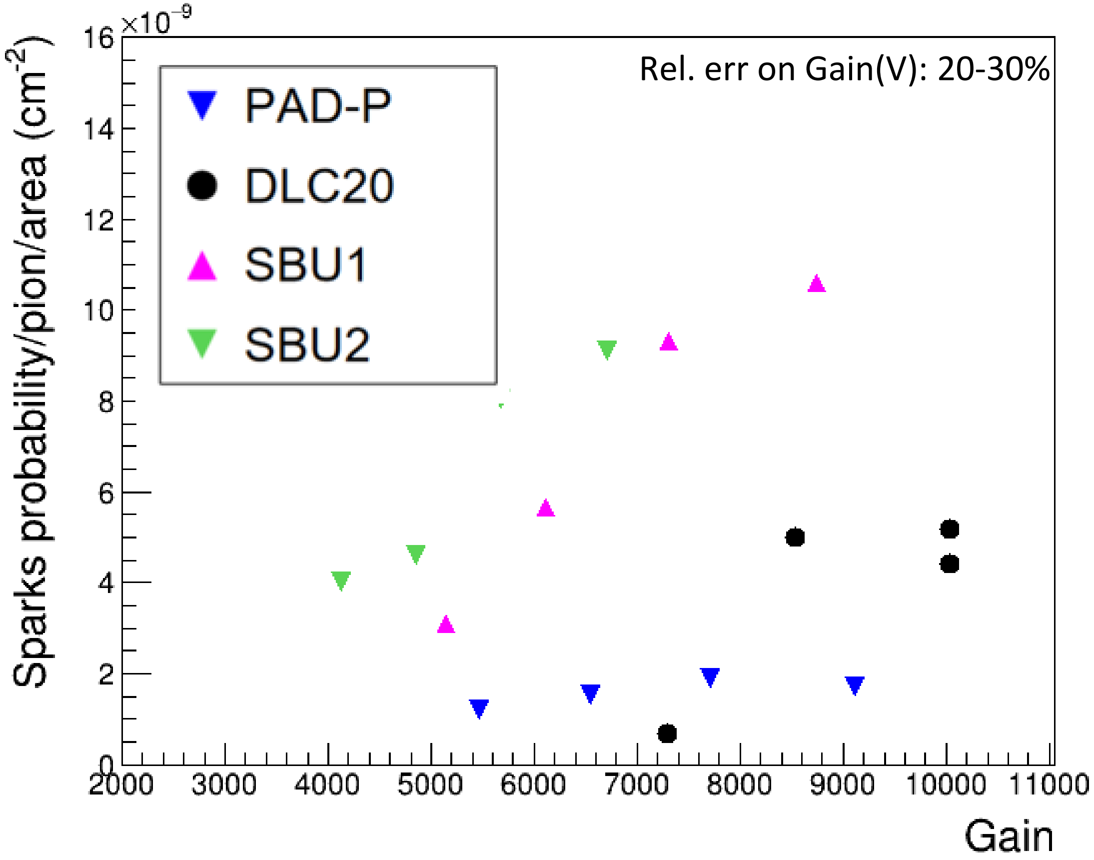
Studies on sparks probability

Spark counting: spark is counted in correspondence of > 30% current variation.

Spark probability: $\frac{\#\ \text{sparks}}{\text{Time window} \cdot \text{Area} \cdot \text{Particle rate}}$



Gain factors agree with the measurements in lab with ^{55}Fe/Xray at low rate



High sparks probability in SBU may be related to lower DLC resistivity.

At fixed gain factor > 7500:   PAD-P is the most robust prototype.

Conclusions

For 10 MHz/cm2 applications, the mm^2 PAD readout electrodes required new sparks suppression resistive layout.
Two different layouts were implemented on several prototypes.

- Spatial and Energy resolution (from previous test beam): Best performance obtained with the **DLC20** prototype:
  - excellent spatial resolution due to larger charge spread over more pads (<100 um on the precision coordinate);
  - Very good energy resolution <30% FWHM better than **PAD-P** due to the more uniform electric field (no pad edge effects).

The detector performance have been compared in similar conditions of Ar/CO_2 gas mixture and of GAIN ~ 6500 –7000:

- Rate Capability:

PAD-P:	No dependance on the irradiated area, ~20% (< 530 V) gain drop at 20 MHz/cm^2, gain drop is dominated by charging-up.
DLC 20:	Gain reduction is ~20% (< 520 V) at 20 MHz/cm2 when the irradiated area has 2r = 1 cm (as PAD-P); it increases to ~30% for larger areas.

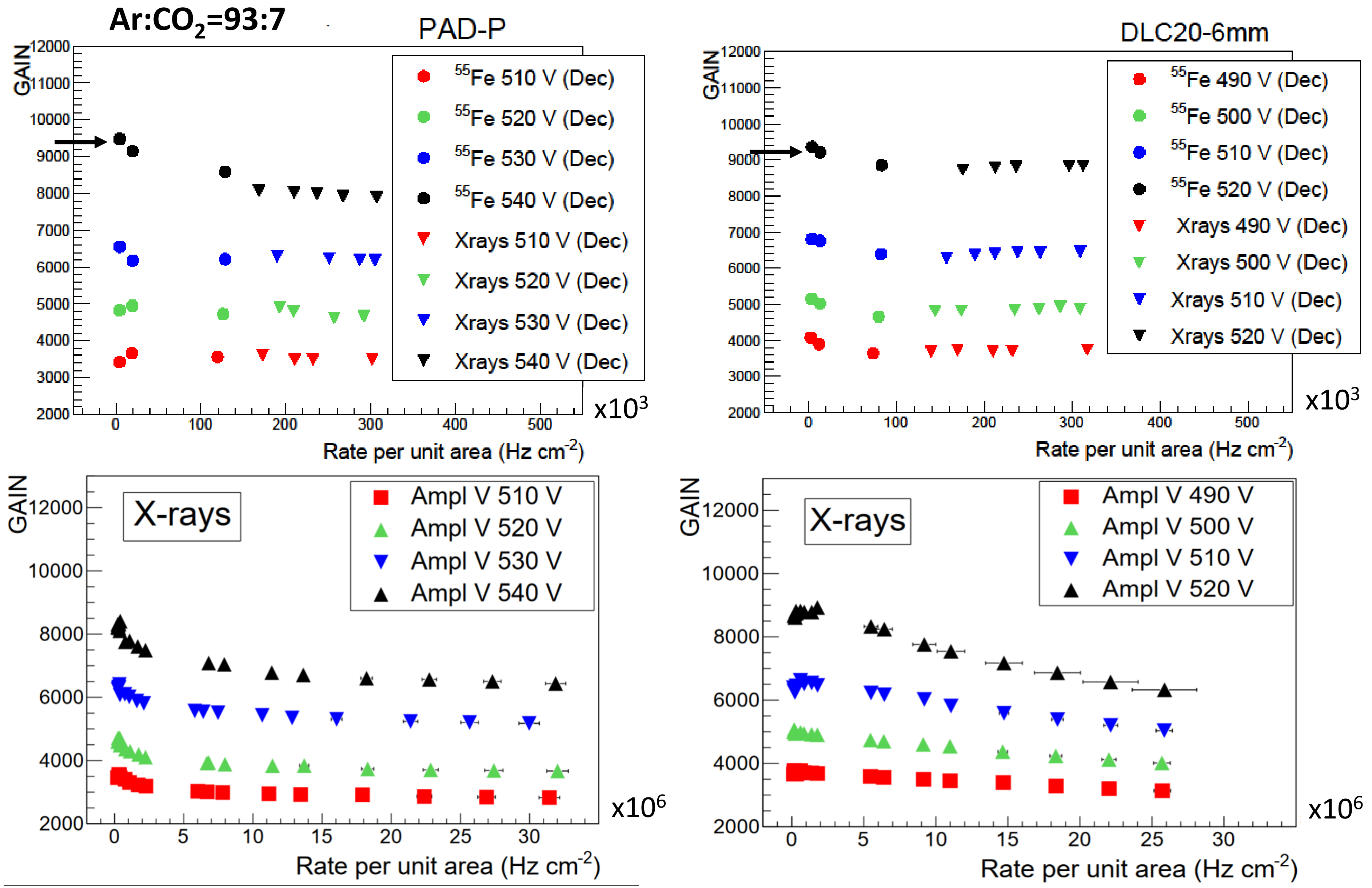
- Discharge probability and robustness:

PAD-P:	It is very stable up to gains >> 10^4; sparks prob <= $2 \cdot 10^{-9}$ /(pion · cm^2) in the investigated gain range.
DLC 20:	It is quite robust but not as well as PAD-P; sparks prob <= $5 \cdot 10^{-9}$ /(pion · cm^2) in the investigated gain range.

Thank you for your attention

Back-up

Gain factor in different rate ranges of (55Fe/Cu-target) X-rays

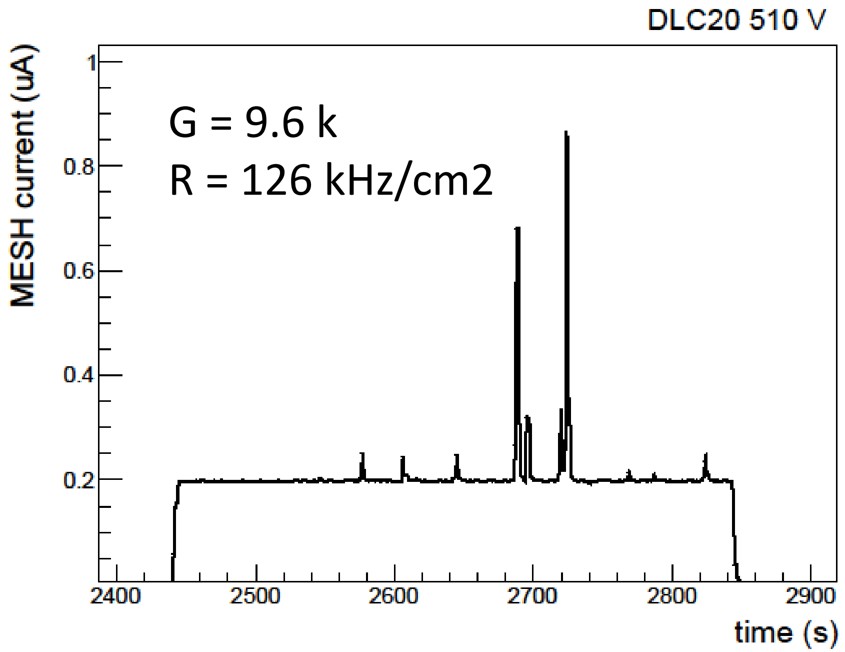


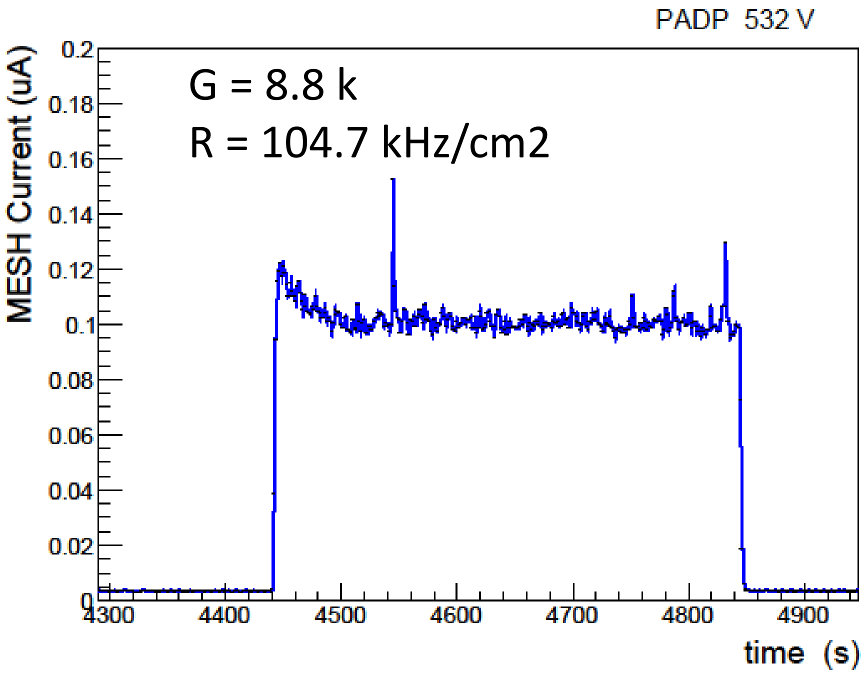
$$G = \frac{I_{Mesh}}{nt\ f\ e}$$

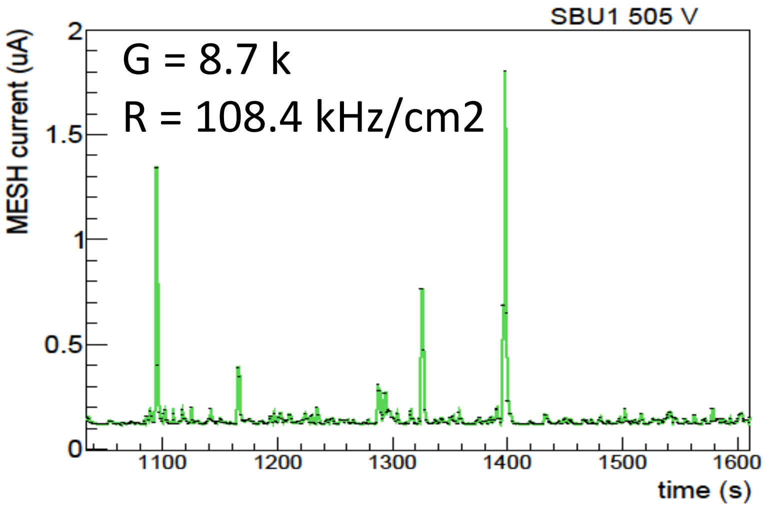
Mesh current: I_{mesh}
couples of electrons and ions: n
transparency: t~ 1
Rate: f
Elementary charge: e

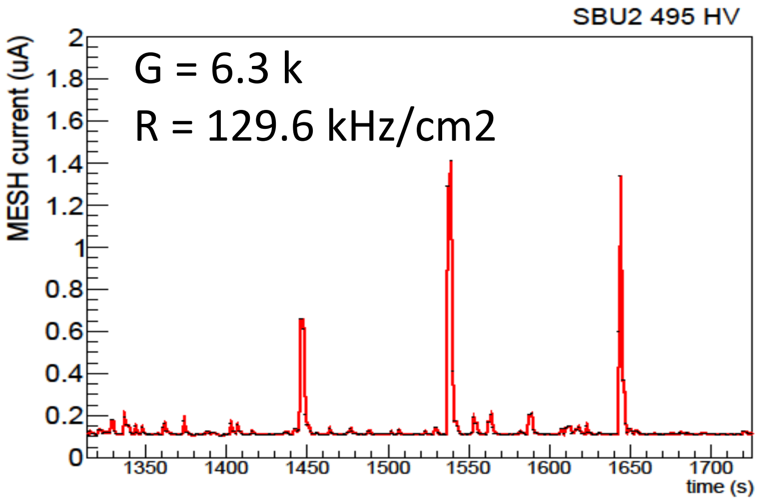
In figures, only statistical contribution of gain error are reported

Examples of spark events





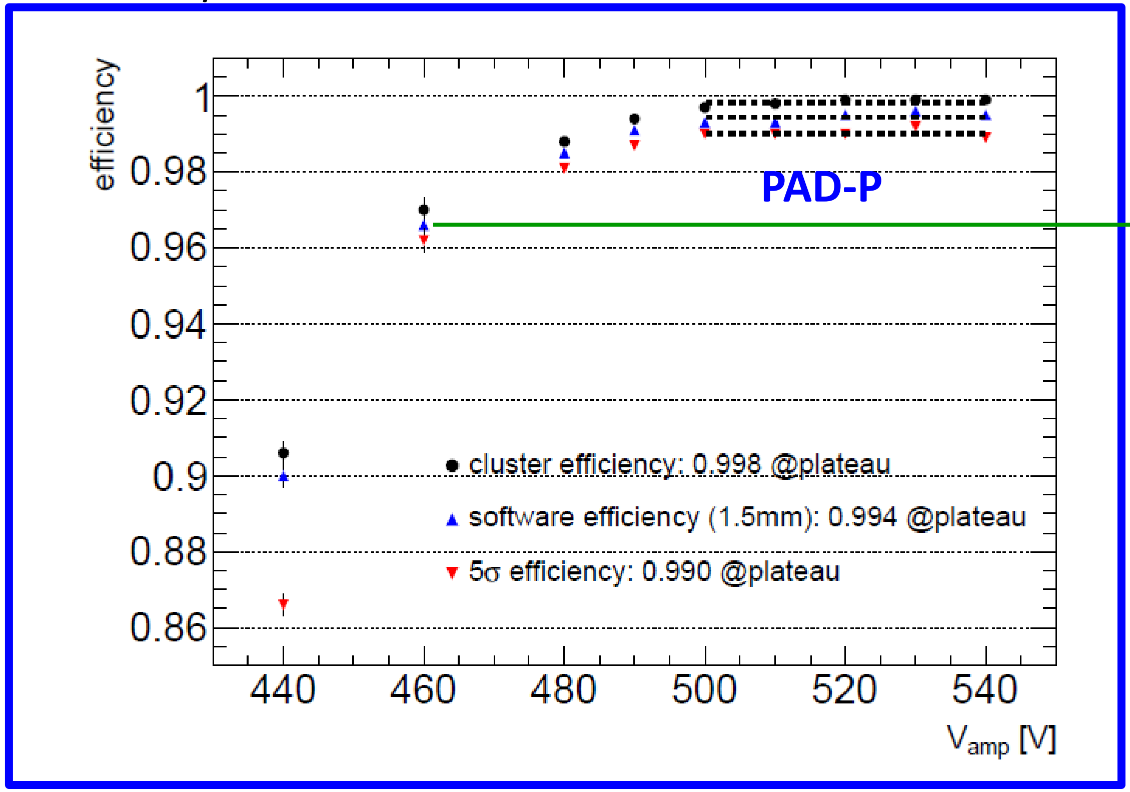


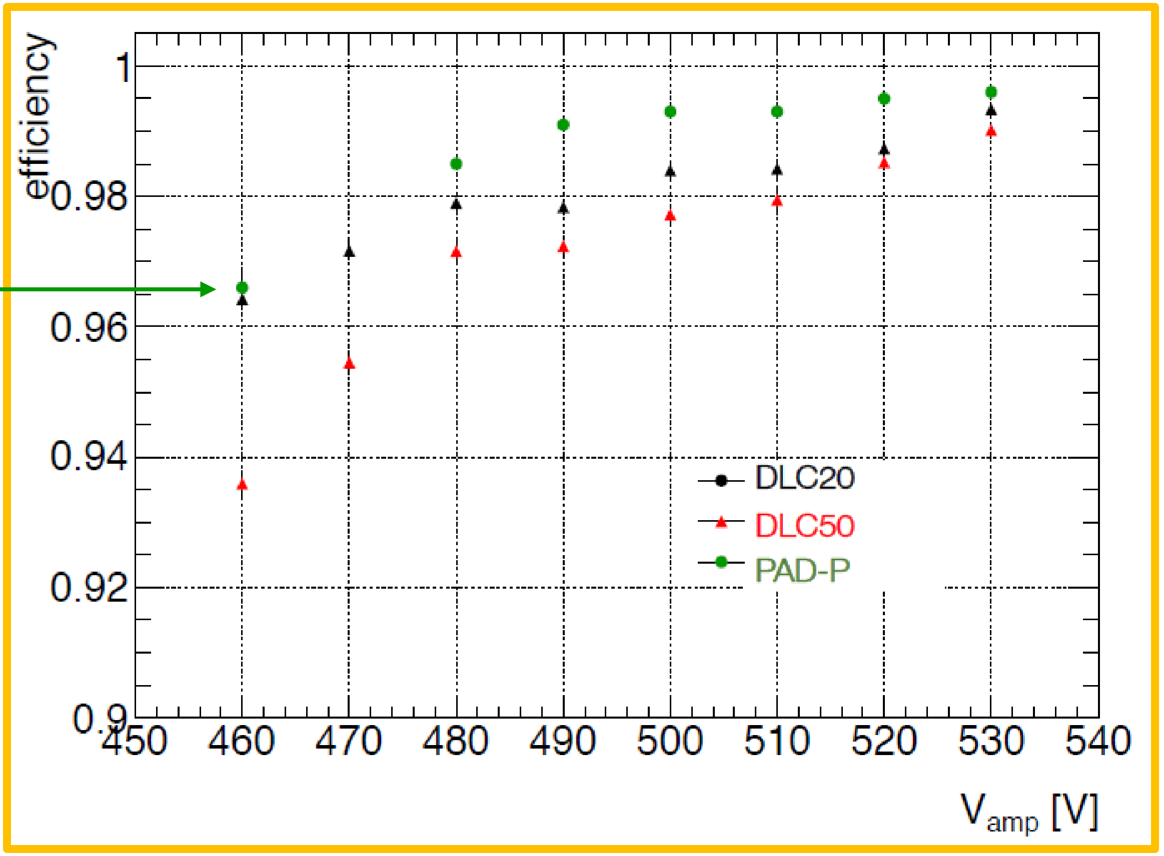


SPS-H4 Beam Test (Efficiency)

The DLC prototypes did not show clear plateau regions in the **efficiencies** as the PAD-P layout, for which the cluster efficiency is~ **99.8%,** the 1.0 mm tracking efficiency is~ **99.0%** and the 1.5 mm tracking efficiency is~ **99.4%** at plateau regions.

~ 100 GeV/c muon beam

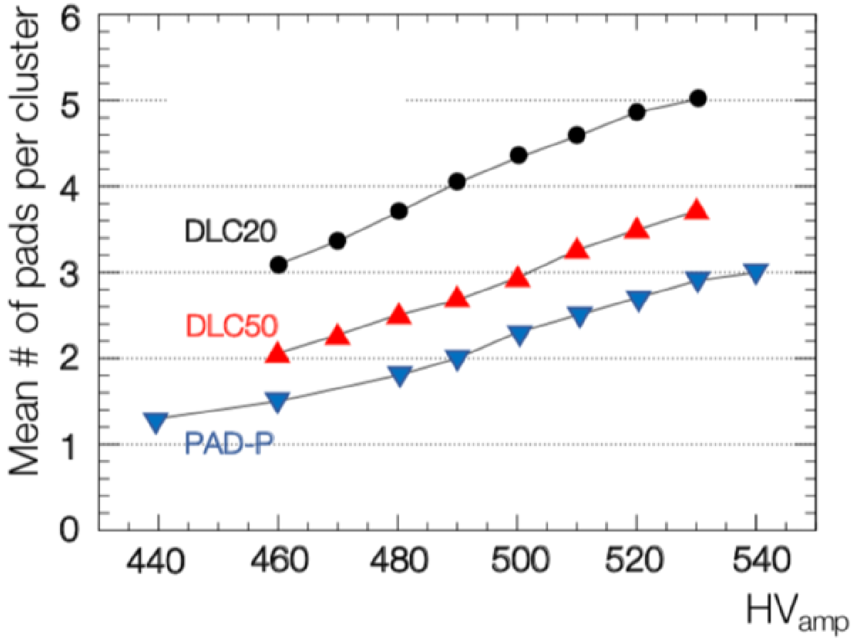


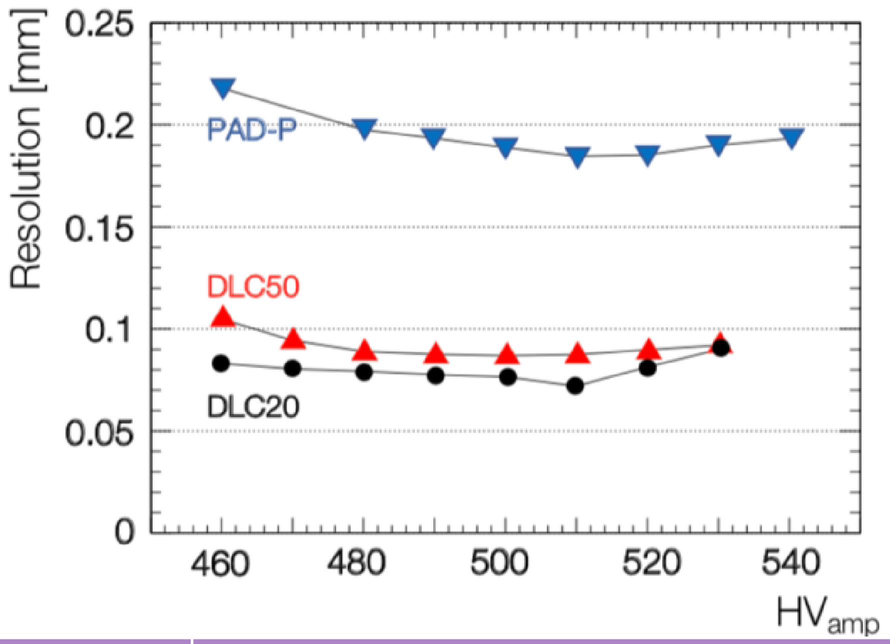


SPS-H4 Beam Test (Spatial resolution)

Precision coordinate (pad pitch 1 mm)

Significant improvement of spatial resolution on the DLC prototypes (charge is shared among more pads).





~ 100 GeV/c muon beam

	Spatial resolution (plateaux region)
PAD-P	~ 200 um
DLC20	< 100 um
DLC50	< 100 um