Updates on the Small Pad Resistive Micromegas Detectors

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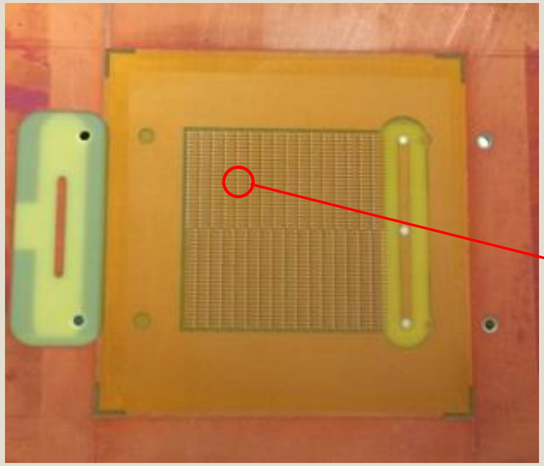
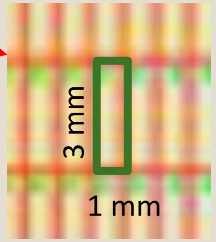
Small PAD MICROMEGAS prototypes

This R&D aims to realize **robust** MICROMEGAS technology prototypes efficiently operating in **O(10 MHz/cm^2)** rate range for particle tracking. Two classes of prototypes: Pad-Patterned (PAD-P) and uniform layer DLC (two techniques: standard and Sequential Build Up produced with copper clad DLC)

Lowering the occupancy of readout electrodes

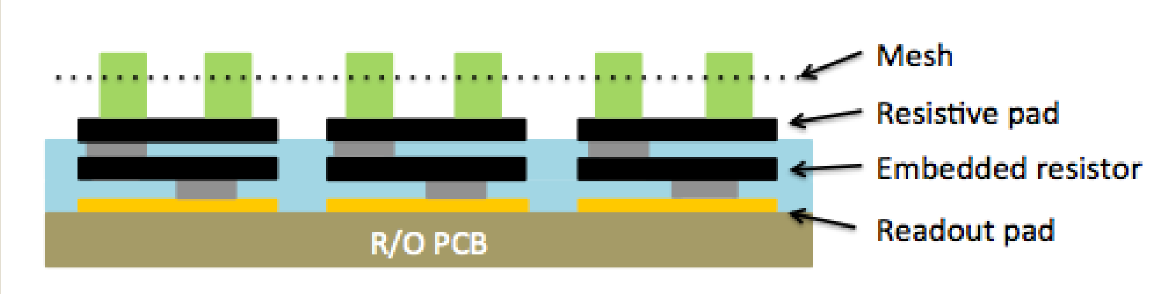


768 readout Pad matrix on 4.8x4.8 cm^2 active area.



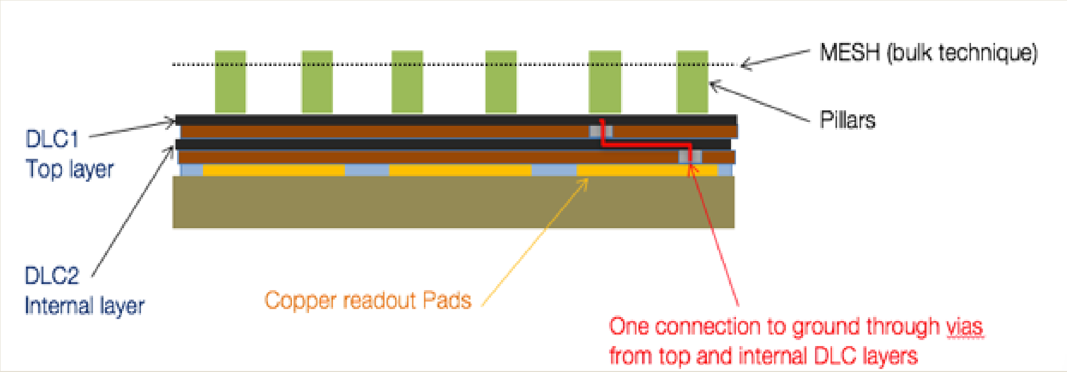
Optimization of **sparks suppression resistive** layout

PAD-Patterned Embedded resistor type (SCHEME 1);



Ref. [1] M. Alviggi, et al / JINST 13 (2018) no.11, P11019

DLC type (and its latter version SBU-SCHEME 2)

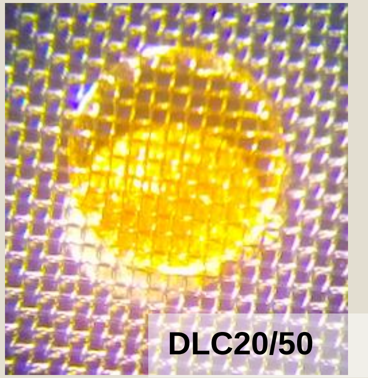


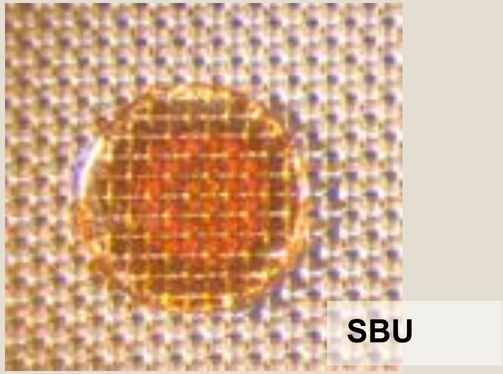
Ref. [2] Alviggi et al. / NIM Research Sec. A, Vol. 936, 21 Aug 2019, pp 408-411

Sequential Build Up (SBU) technique (see **Rui's talk on Wednesday**)

New DLC spark suppression resistive layout prototypes are under study, realized with different constructive approach to prevent discharge appearance (close to the edges and uncovered vias), observed in the DLC prototype with low resistivity.

- SBU1, SBU2: Sequential Build Up:
  - DLC foils copper cladded on both sides;
  - easier photolitographic construction process;
  - improving of the centering of the pillars with the silver vias;



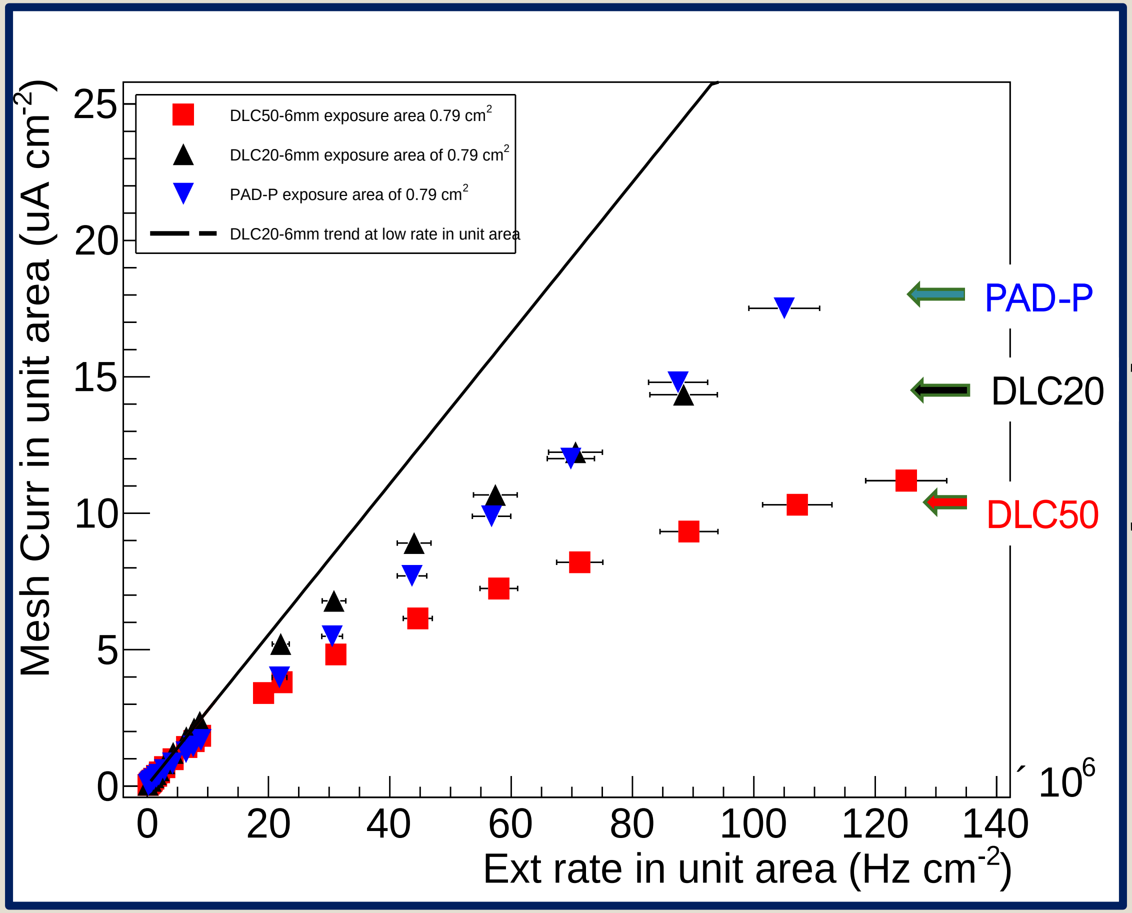


<u>Varied features of DLC-SBU series</u>:

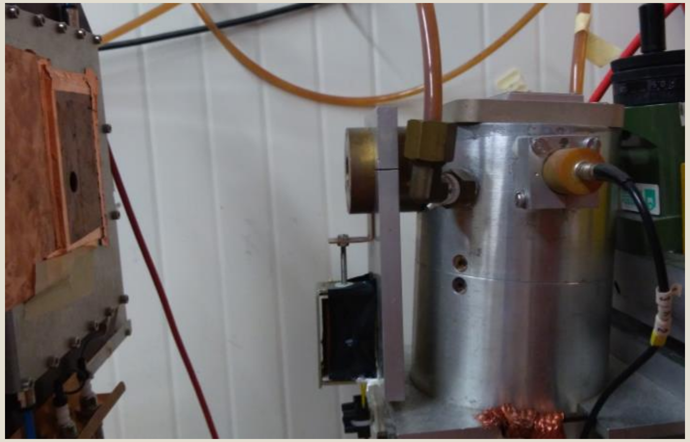
- **DLC50:** high resistivity 50-60 MΩ/sq DLC foils;
  6 mm vias pitch side and 12 mm vias pitch side;
- **DLC20:** low resistivity 20 M **Ω** /sq DLC foils;
  6 mm vias pitch side and 12 mm vias pitch side;
- **SBU1:** combination of DLC foils with 5 M**Ω**/sq and 35M**Ω**/sq resistivity;
  6 mm vias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

Latest results: X-rays studies

Studies of **rate capability** and robustness at very high rates with the (8 keV Cu target) Xrays gun in the R&D51 laboratory



Same gain factor at low rate, (93:7)%Ar:$C0_2$



Investigations and comparison on effects due to:

- **Resistive sparks suppression layout**;
- **DLC resistivity**;
- Vias pitch;
- **Exposure area**;

Larger resistivity and longer vias pitch cause higher effective amplification voltage drops.

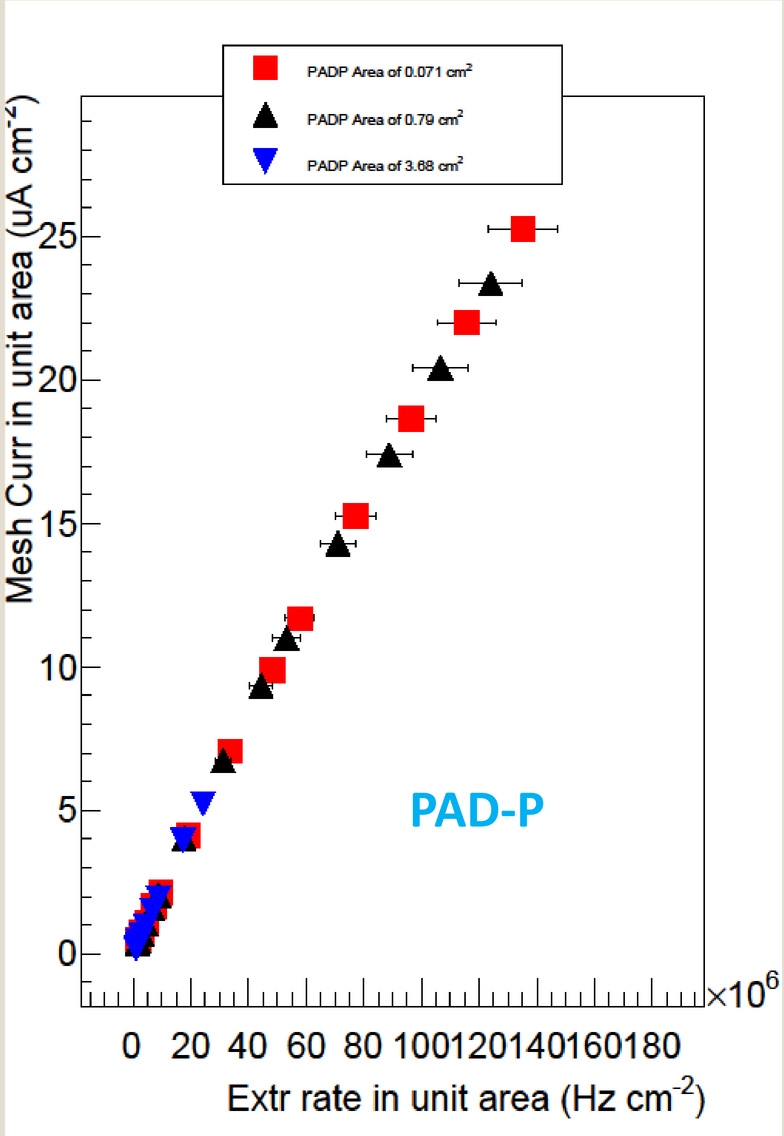
(3 mm radius) 0.071 cm^2 area is of order of 1 pad – local studies

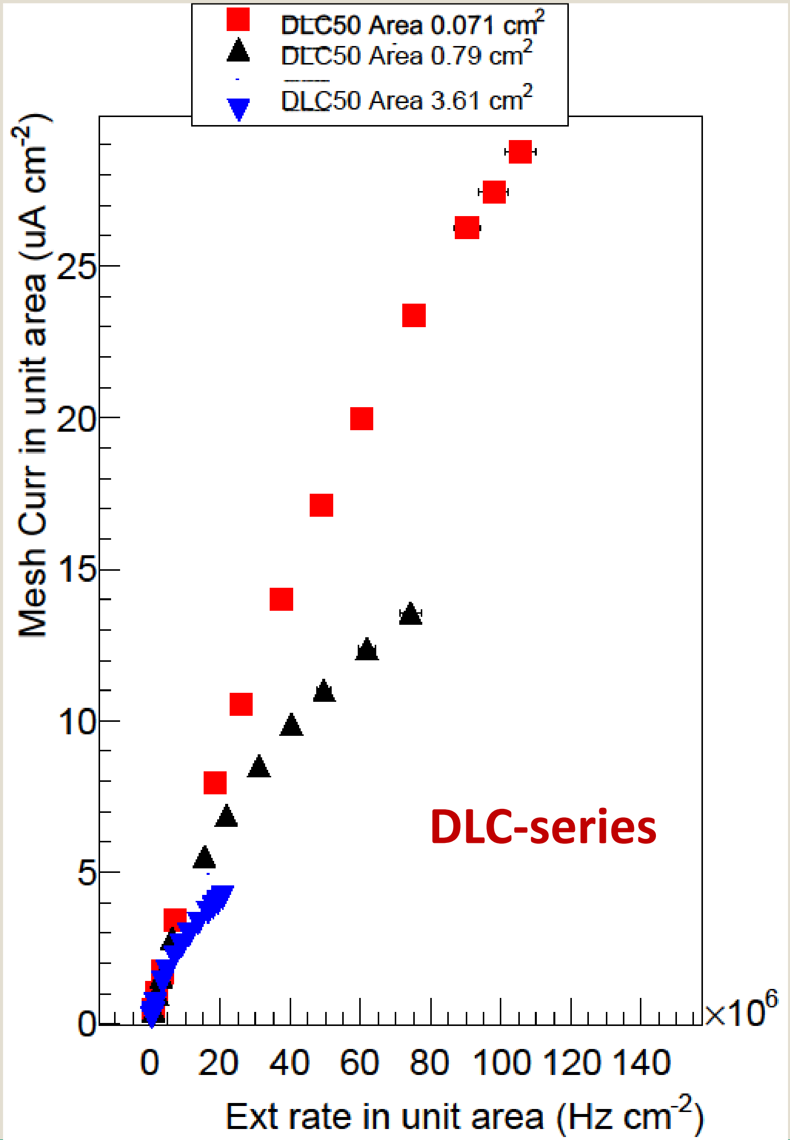
(10 mm radius) 0.79 cm^2 reference area – at least 1 irradiated pad/vias sector

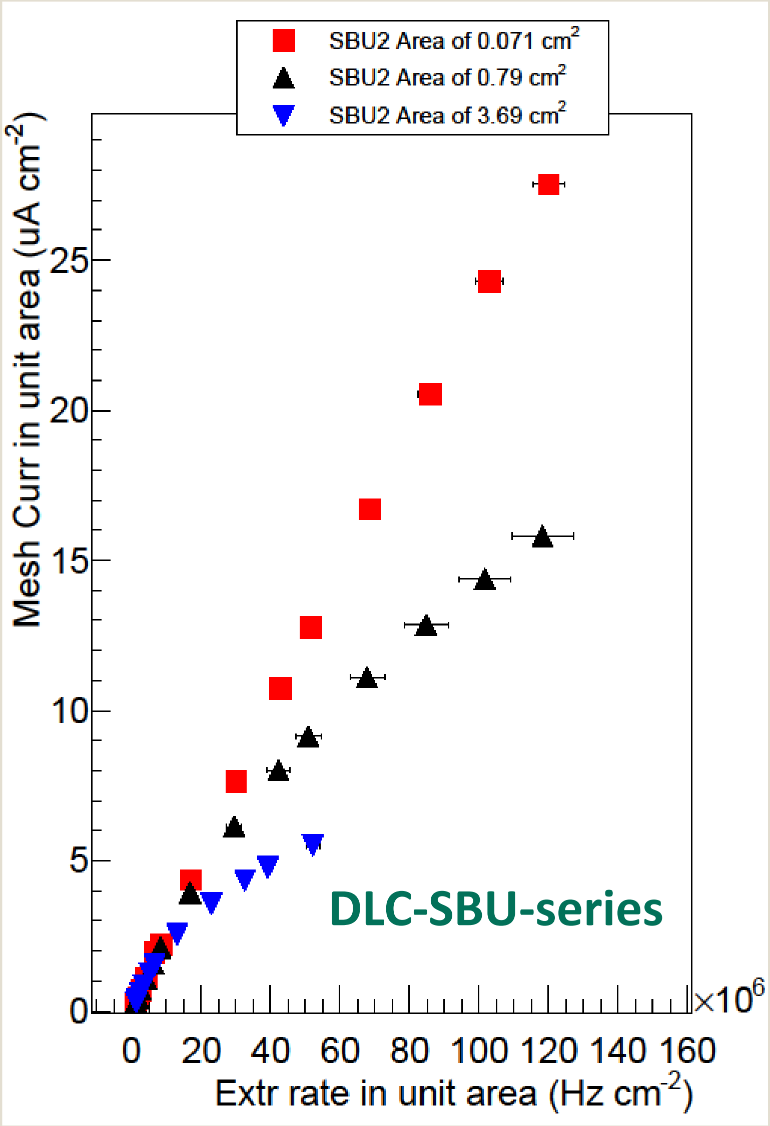
(19 mm side) 3,69 cm^2 area – more irradiated pads/vias in the same time

Exposure area dependence

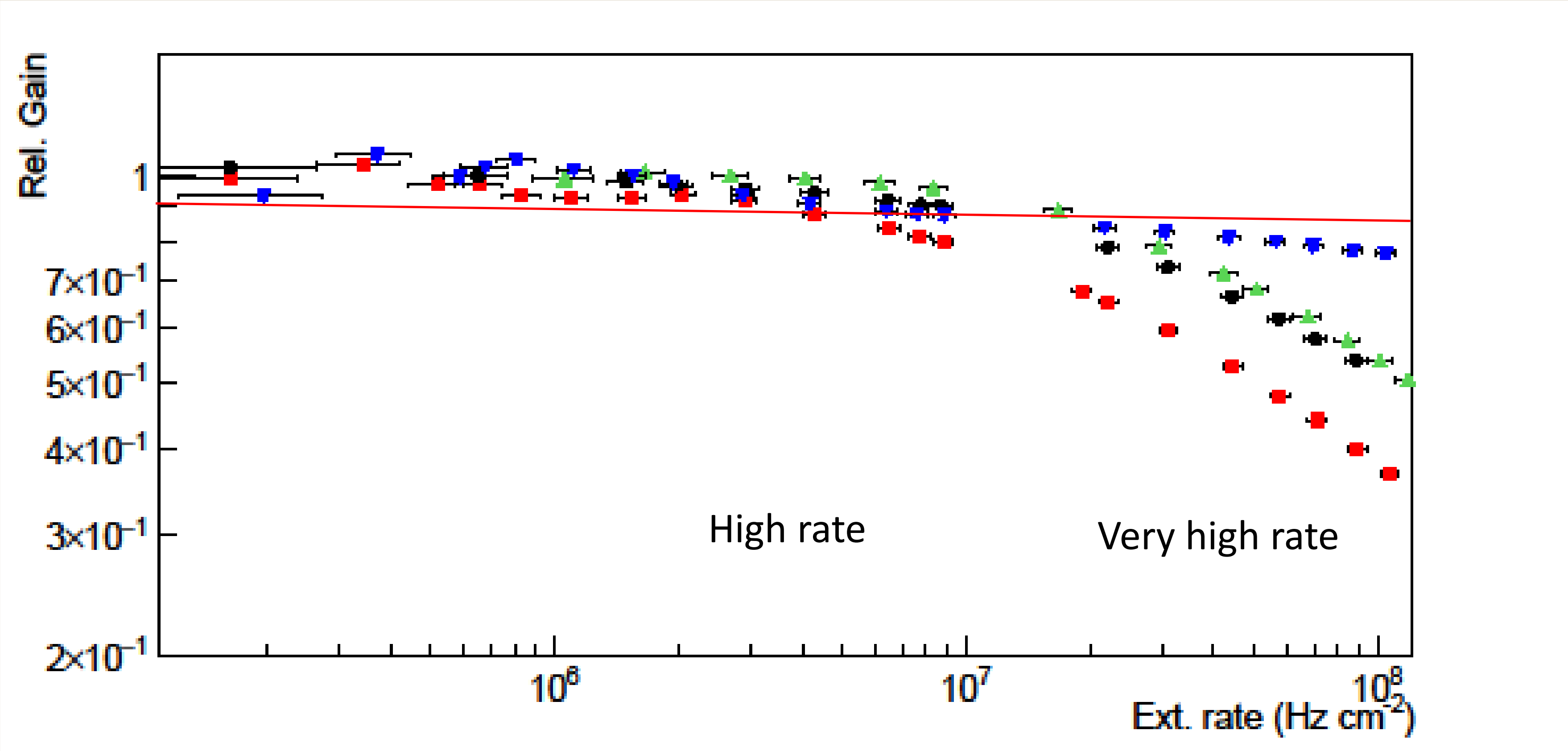
Size of exposure area







Relative Gain

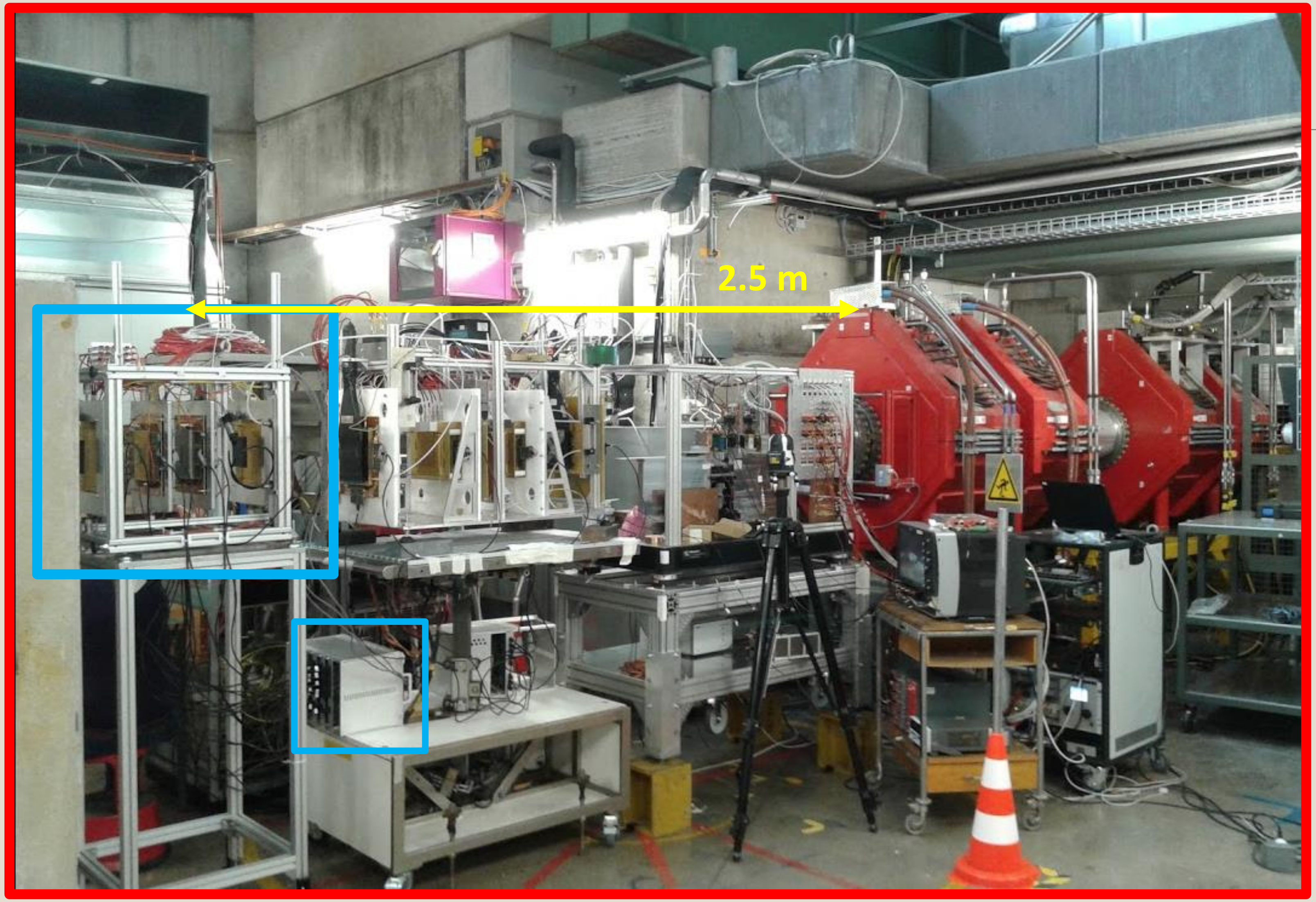


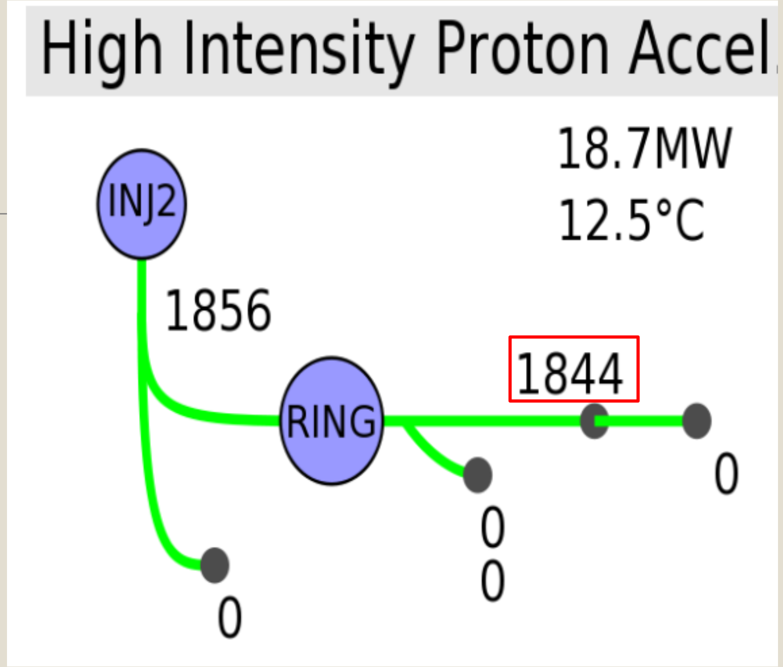
(93:7)%Ar:CO_2

Direct info on voltage drop and rate capability;
(threshold value on deviation from the low rate value: 10%)

G0 ≈ 6000

PSI πMU1 beam facility





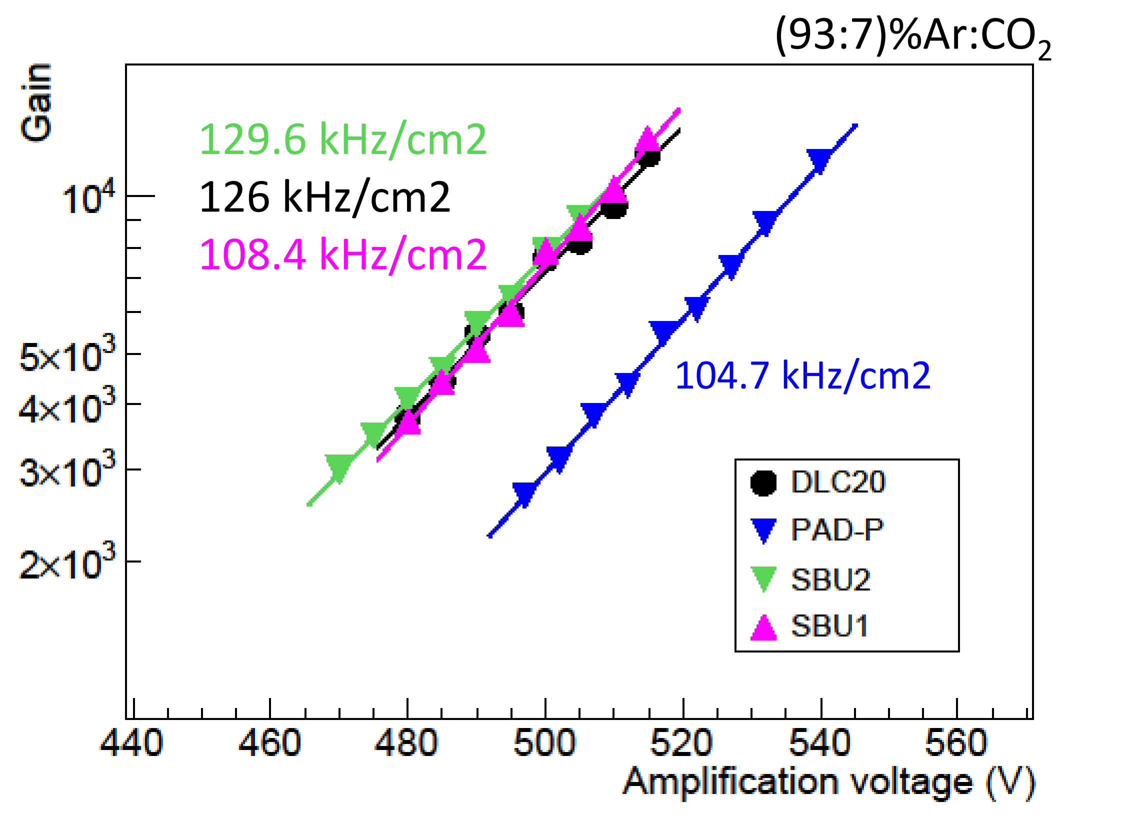
Proton beam current on target

In exit of the target: positive pion with 300 MeV/c as max momentum (and 7% of proton contamination) in continuum

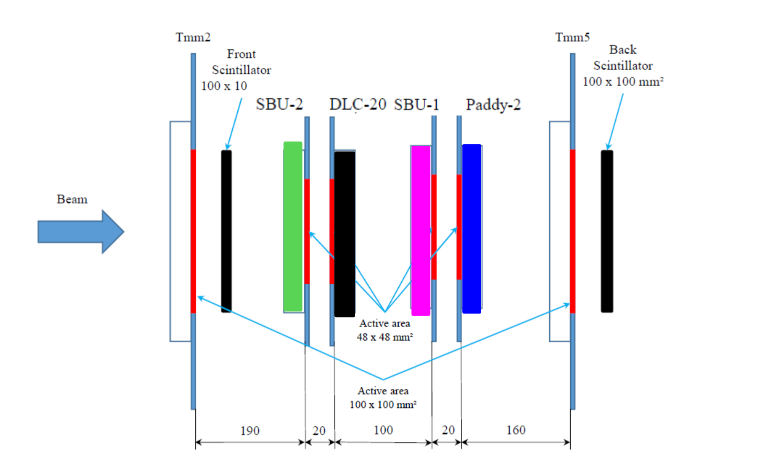
Latest results: Beam Test (Gain)

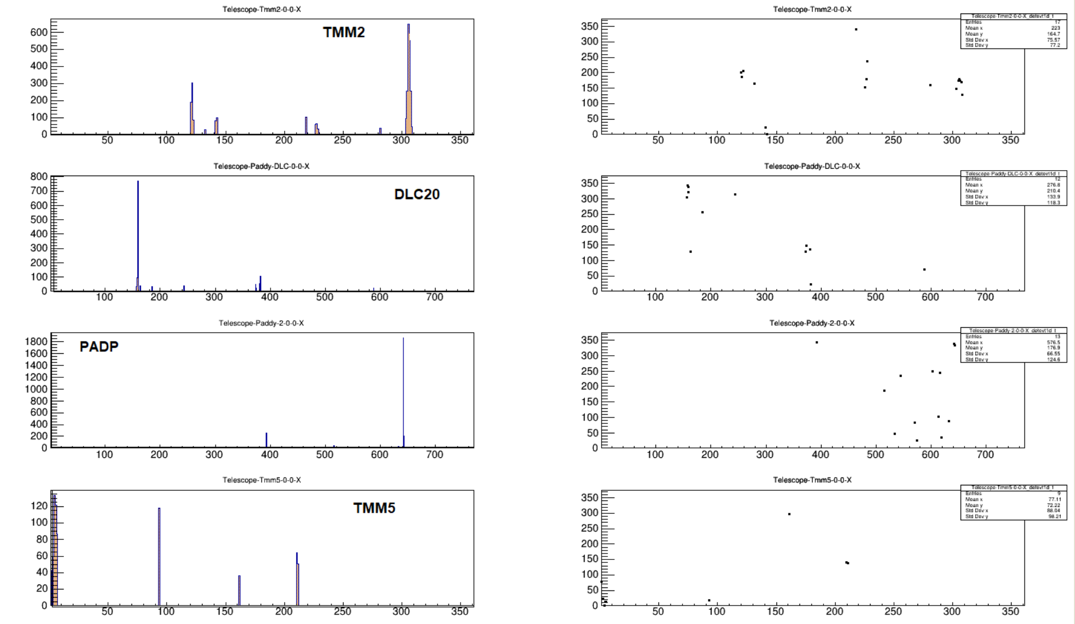
Gain measurements

DLC prototypes has similar gain curve

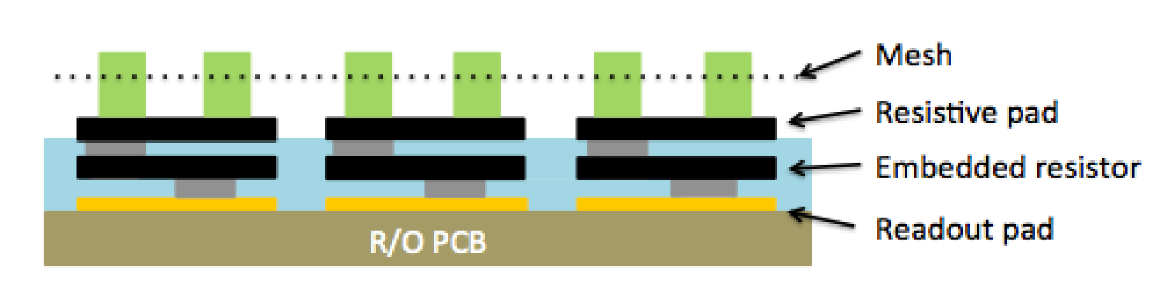


Estimated from the current acquired from the mesh

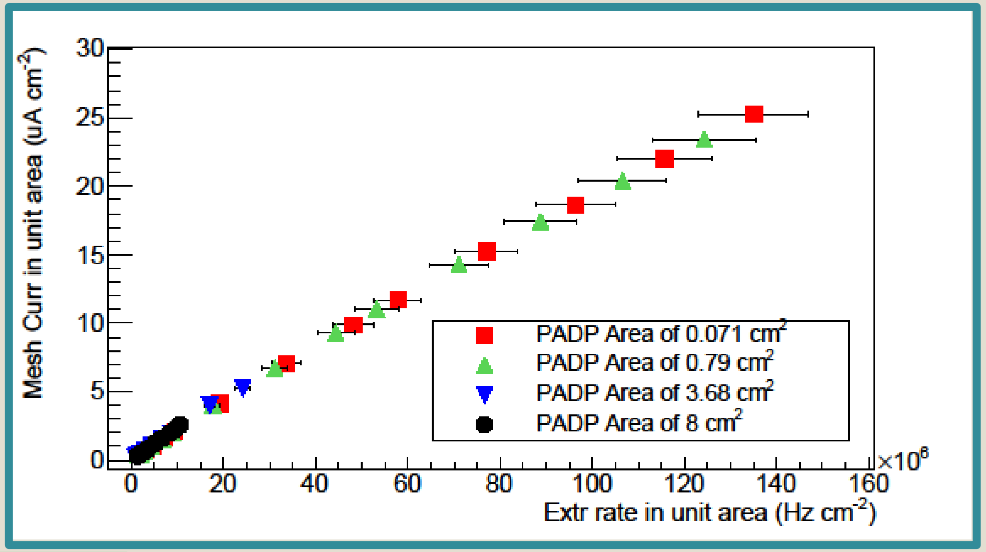




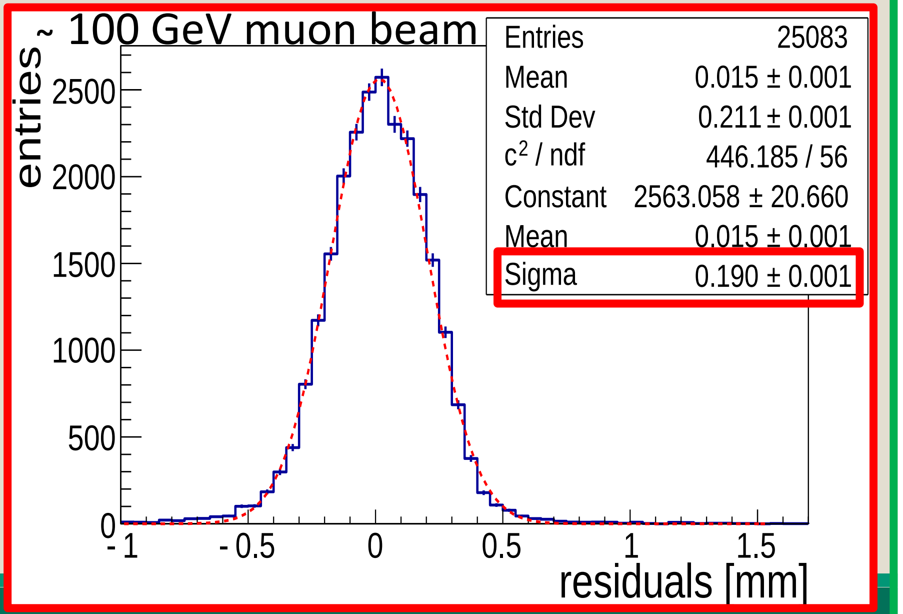
Summary on **PAD-P** scheme (1):

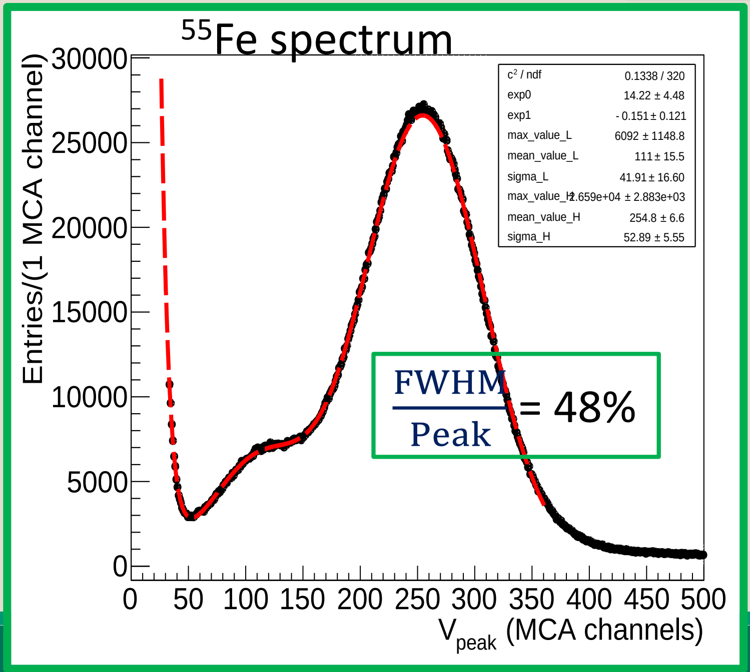


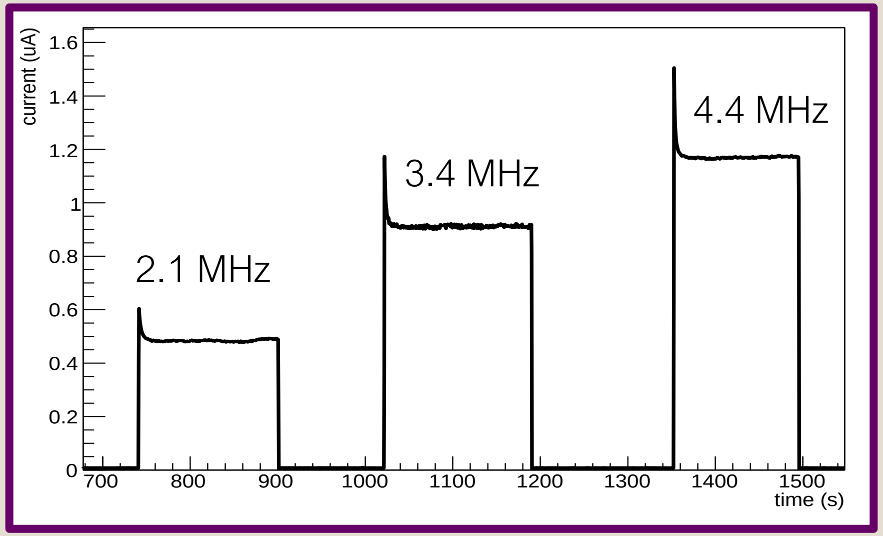
8 keV (Cu target) Xrays



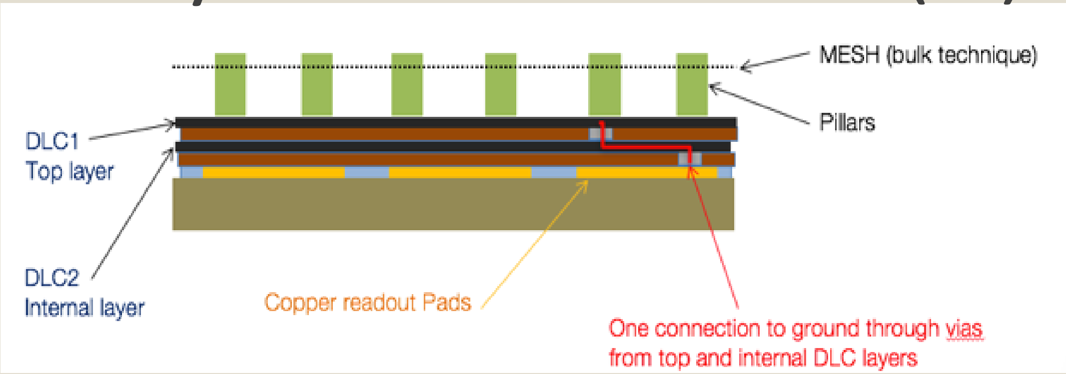
Good rate capability at rate higher than 10 MHz cm^{-2} , current/cm^2 vs rate independent from area, discrete spatial resolution on the precision coordinate, low energy resolution and currents as function of time affected by charging-up effects.



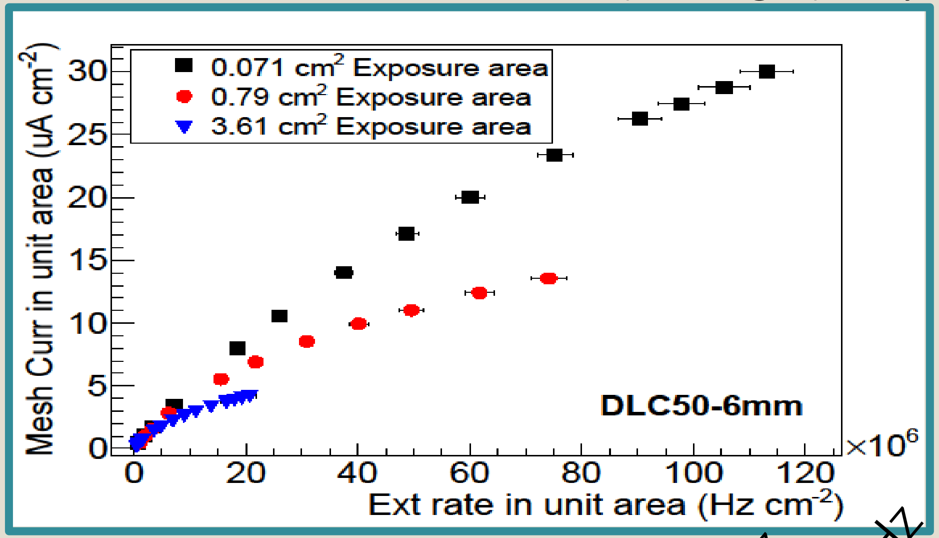




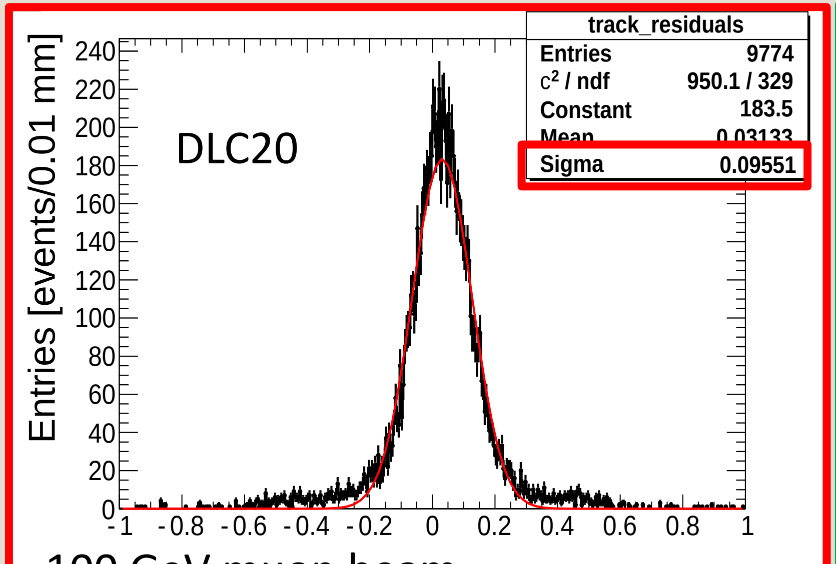
Summary **DLC** scheme (2):



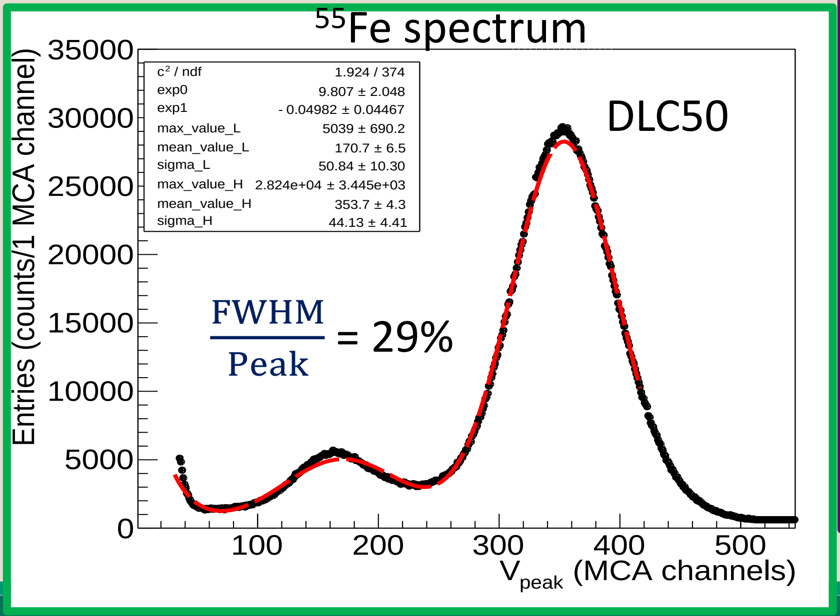
8 keV (Cu target) Xray

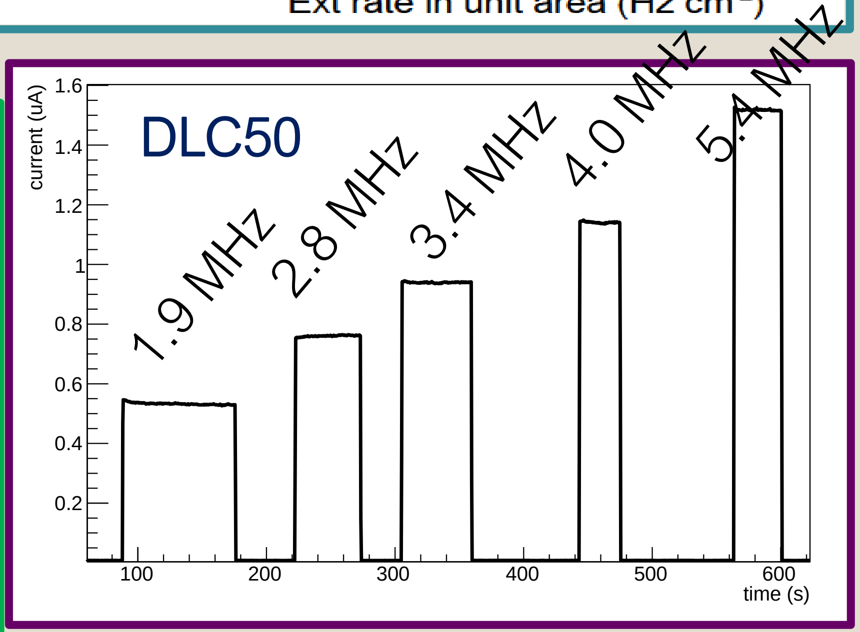


Good rate capability up to-10 MHz cm^{-2}, mesh current does not scale linearly with the spot size, better spatial resolution on precision coordinate, better energy resolution and no (or very little) charging up in currents as function of time.



~ 100 GeV muon beam

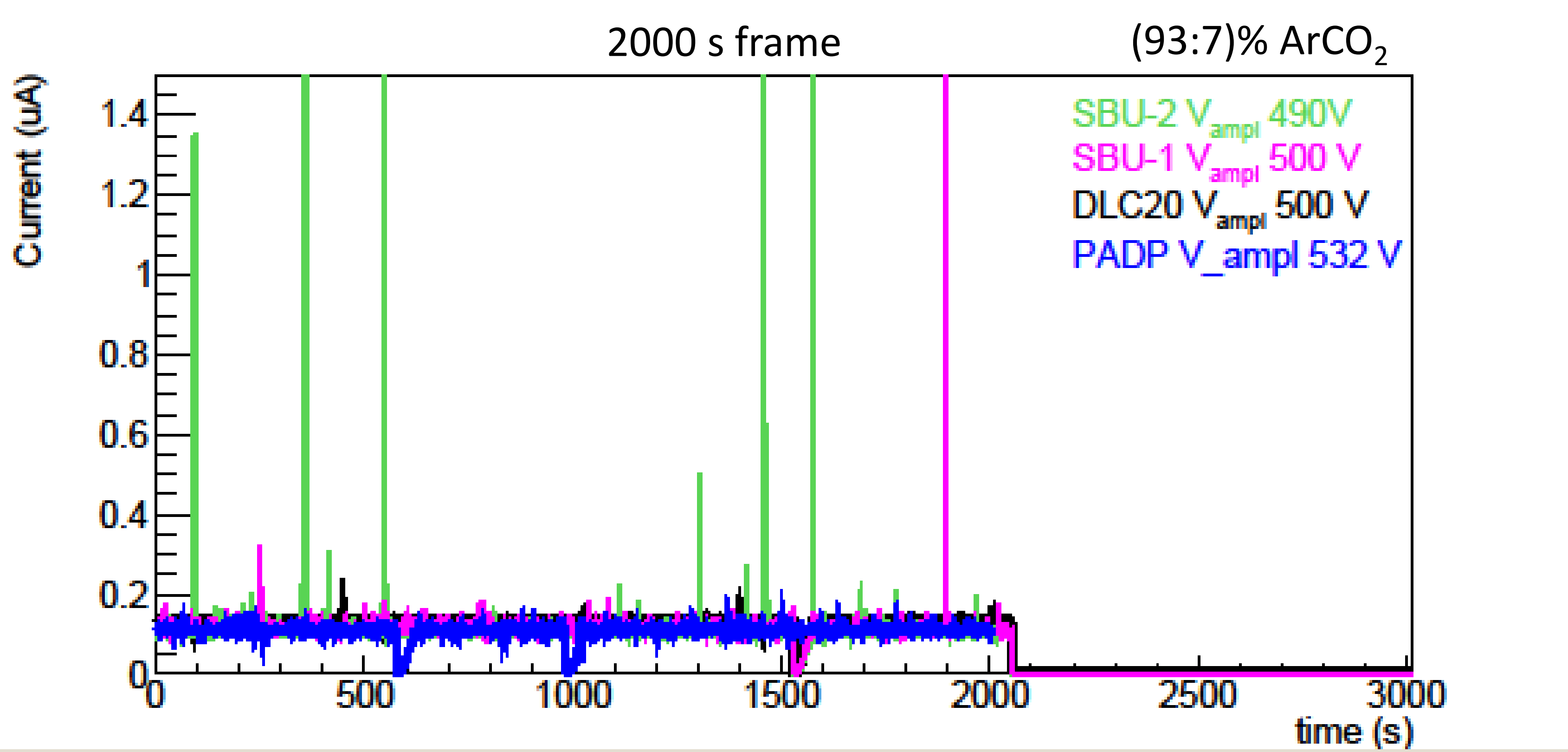




Discharge studies in the DLC-type

DLC and DLC-**SBU** prototypes show some instabilities with moderate discharges up to a gain of about 6000.
DLC50 (not shown) with higher resistivity has onset of discharges at higher gain.
PAD-P is VERY STABLE and show no-sparks up to a gain above 10000 (tested in lab with X-rays)

On the last day of PSI test beam, long current run were acquired

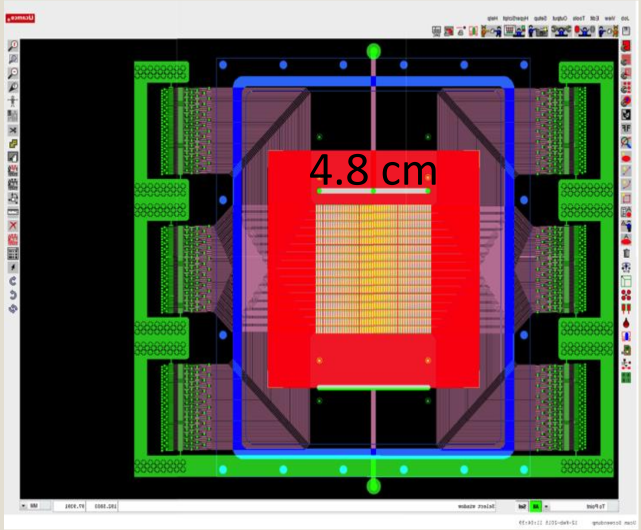


Detectors were exposed to different particle rates, according to their distance for the beam focus. Not normalised in the plot.

The current trends are compatible with those observed during Xray tests.

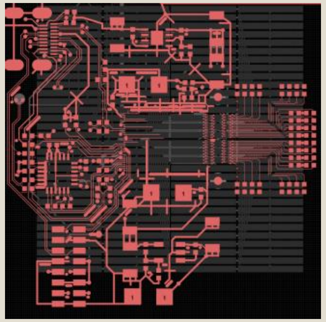
Embedded Electronics prototype

- Strip → Pad has an impact to N of FE channels and their routing



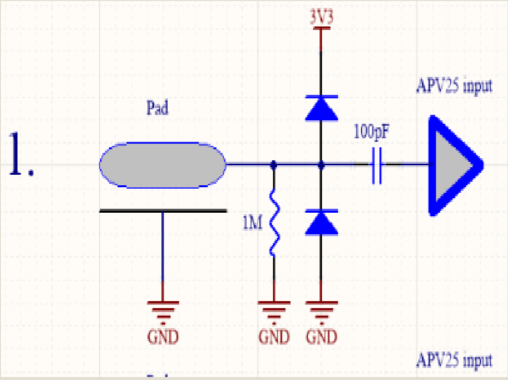
Parallel research activity: Optimization of FE and its placement in (back) Embedded electronics prototypes.

APV25 hybrid-like embedded on the detector board



~ 4.0 cm

Optimization of protection stage of Pad-APV input:



Connection in APV25 hybrid board (Full-protected)

FIRST PROTOTYPE (with DLC resistive scheme) :

- 3 regions with 32x4 pads, pitch 1x8 mm^2
- 1 region with 16x8 pads, pitch 1x3 mm^2

Due to the spark suppression by resistive layer, protective diodes could be removed. Pull-down resistor and AC coupling capacitor could be implemented using embedded technology….WORK IN PROGRESS

Conclusions & future plans

Both spark suppression resistive schemes allow to extend the rate capability of resistive Micromegas technology to rates O(1-10 MHz cm^{-2});

- At rate higher than O(10 MHz cm-2), the scheme PADP is preferred respect to scheme DLC, for many reasons:
  - smaller deviation with respect to the linear behavior in "current vs rate" trend at low rates;
  - current vs rate independent from exposed area in scheme PADP;
  - higher discharge robustness.
- The scheme DLC prototypes show better resolutions than PAD-P at lower rates.

Work in progress to optimize to optimize the layout of Embedded electronics.

Future plans:

- Interest on a new PADP prototype;
- To carry on the discharge studies in term of resistive schemes (and DLC resistivity), varying the gas mixture, too.

Thank you for the attention

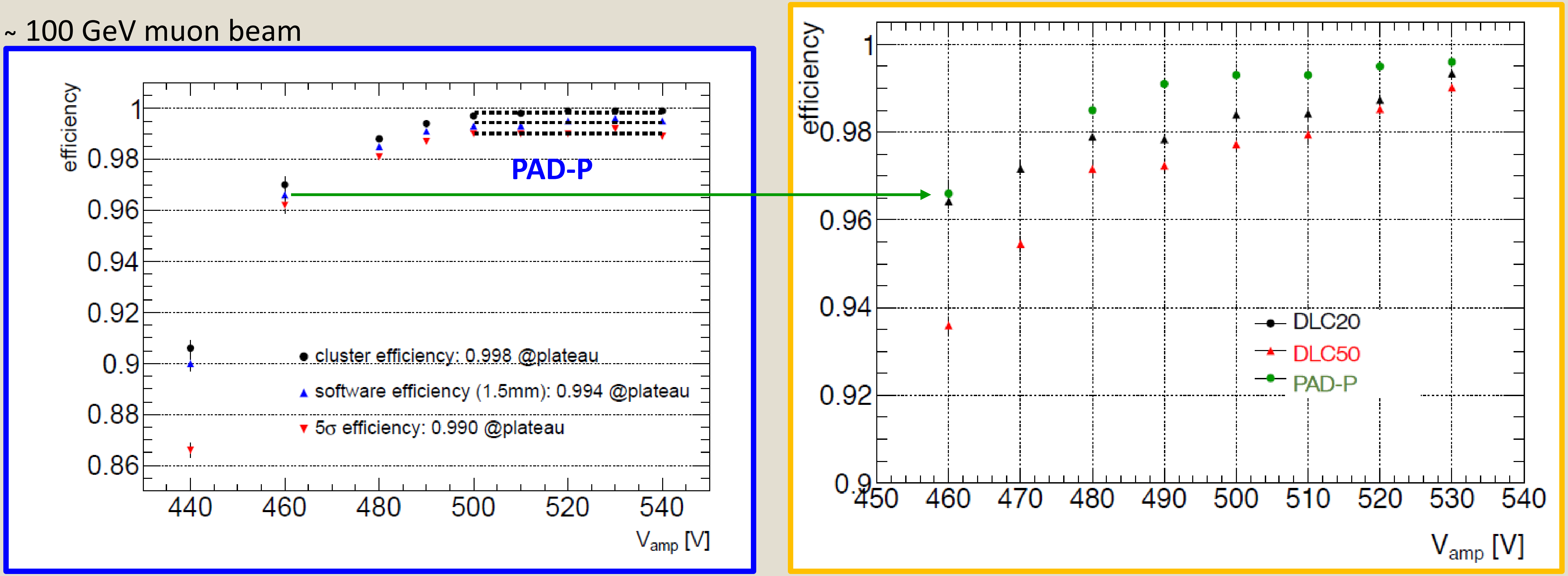
Back-up

Beam Test 2018 (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 (see Ref. [4]).

Still under-investigation to compare with PSI results

~ 100 GeV muon beam



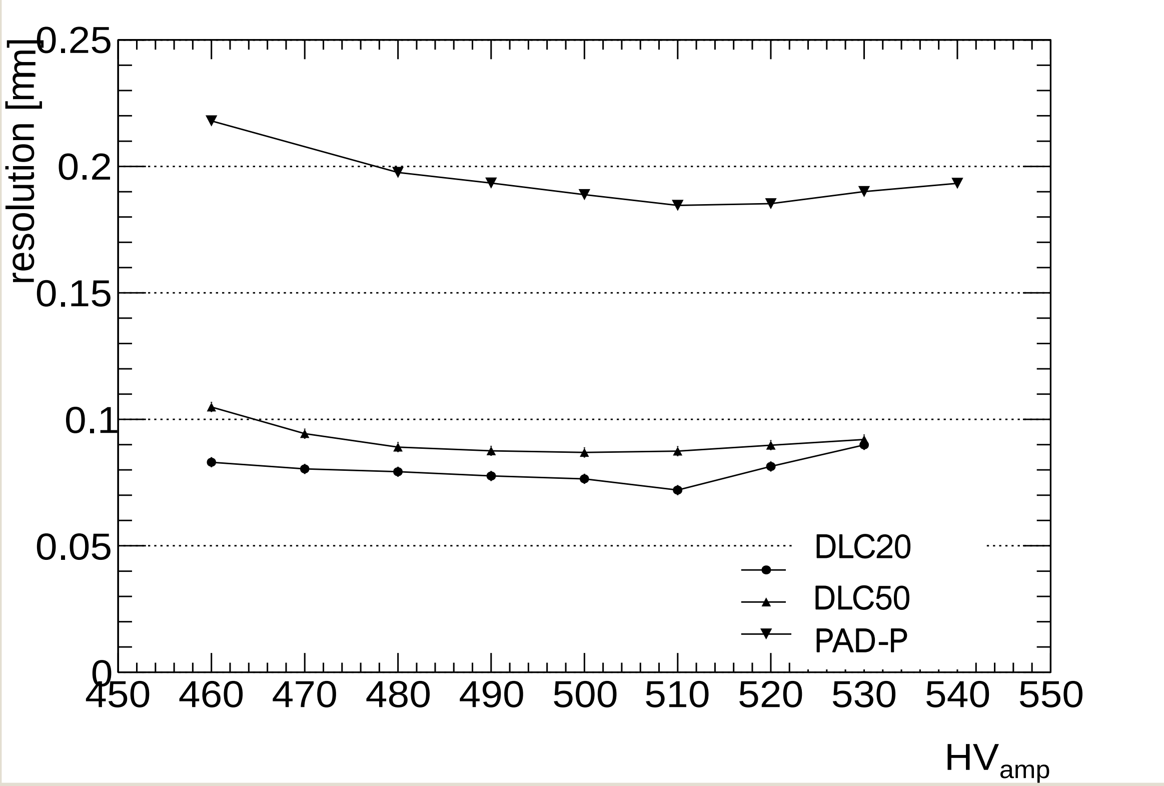
Ref. Alviggi et al. / NIM Research Sec. A, Vol. 936, 21 Aug 2019, pp 408-411

Beam Test 2018 (Spatial res)

Precision coordinate (pad pitch 1 mm)

Significant improvement of spatial resolution on the DLC prototypes (pad charge weighted centroid).

- More uniform charge distribution among pads in the clusters.



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

https://www.psi.ch/sites/default/files/import/sbl/BLPiM1EN/fig3.gif

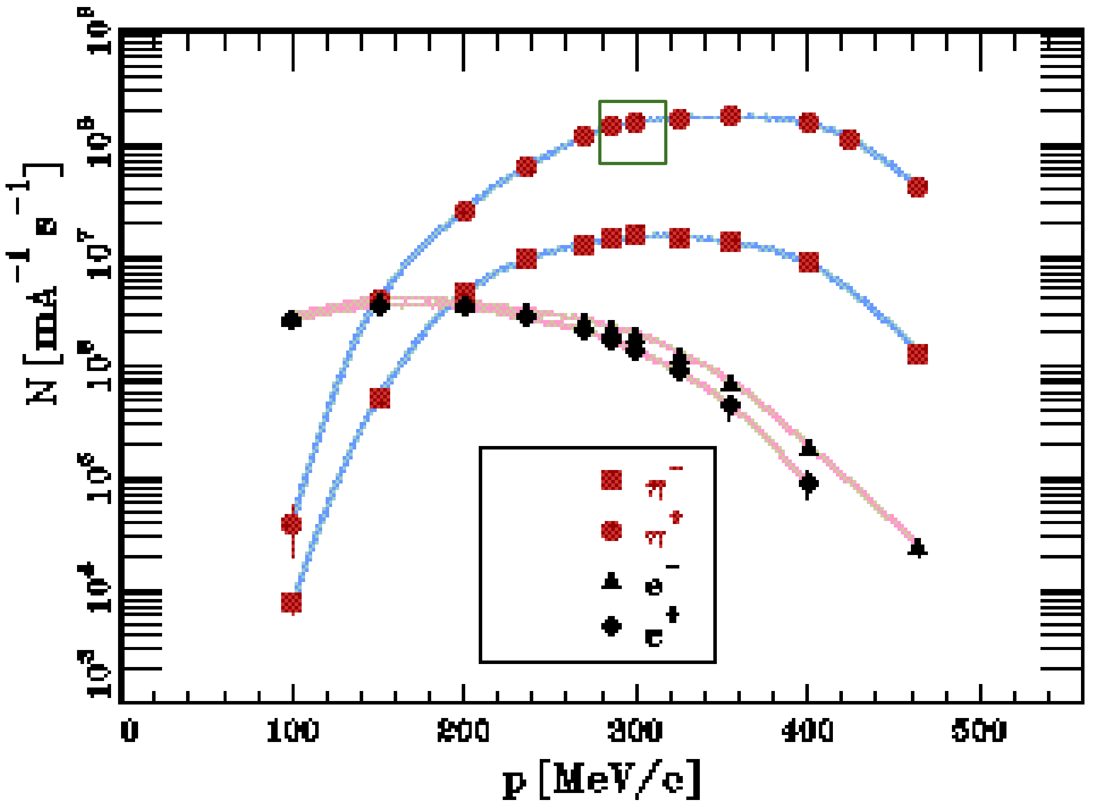


Table 1 : Characteristics of the piM1 beam line

Total path length	21 m
Momentum range	100-500 MeV/c
Solide angle	6 msr
Momentum acceptance (FWHM)	2.9 %
Momentum resolution	0.1 %
Dispersion at focal plane	7 cm/%
Spot size on target (FWHM)	15 mm horizontal
	10 mm vertical
Angular Divergence on target(FWHM)	35 mrad horizontal
	75 mrad vertical

Fig 3 gives the measured particle fluxes for the standard beam-line tune as a function of momentum with an uncertainty of 10% at the peak of the yield curves. The flux of muons is 100 times smaller than the corresponding pion flux at momenta around 300 MeV/c, and falls more slowly than for the pions toward low momenta. Since πM1 is the only beam line with a vacuum system separated from the proton-channel vacuum by a thin window, there are no "surface" muons available.