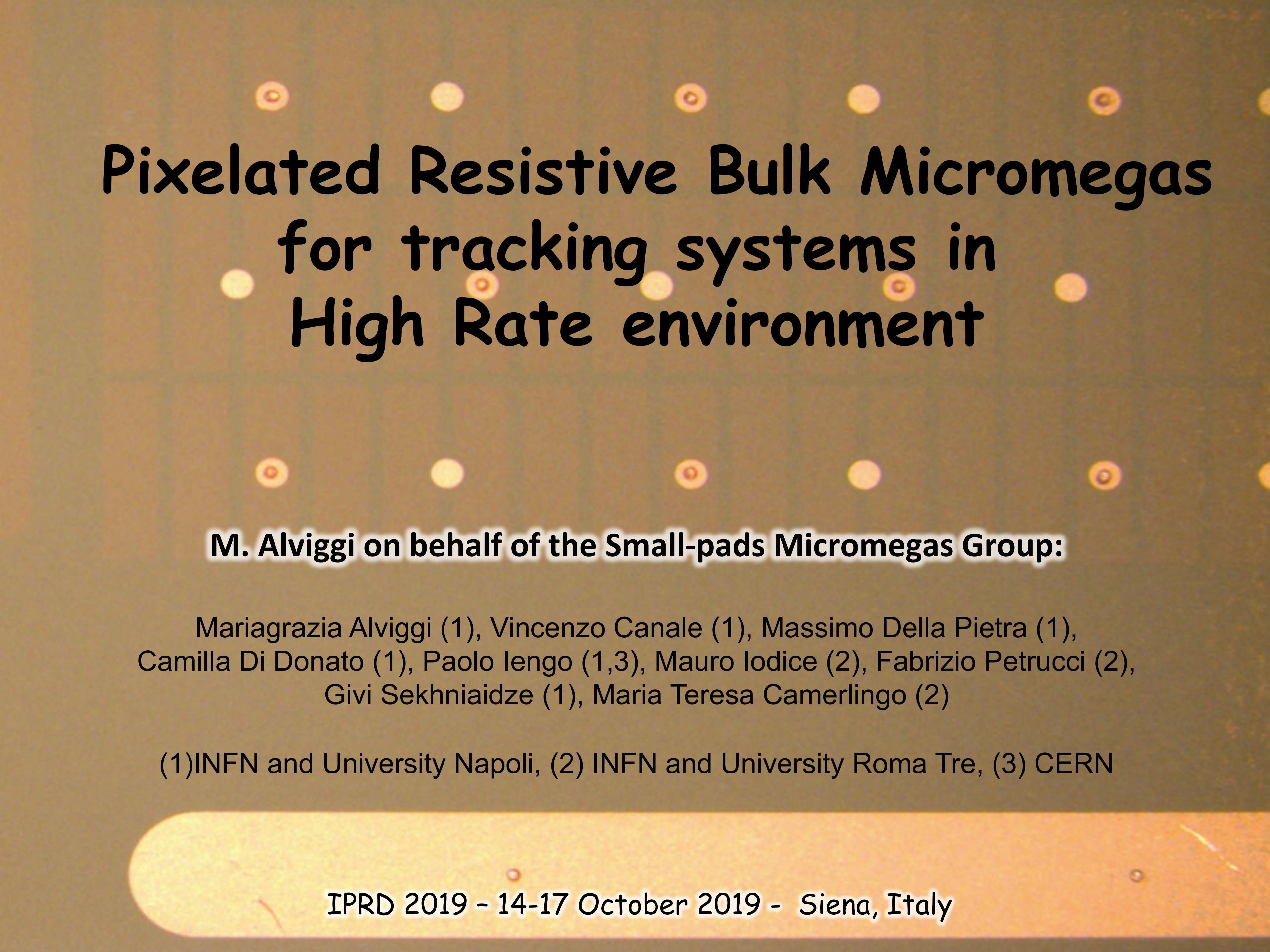


Pixelated Resistive Bulk Micromegas for tracking systems in High Rate environment

M. Alviggi on behalf of the Small-pads Micromegas Group:

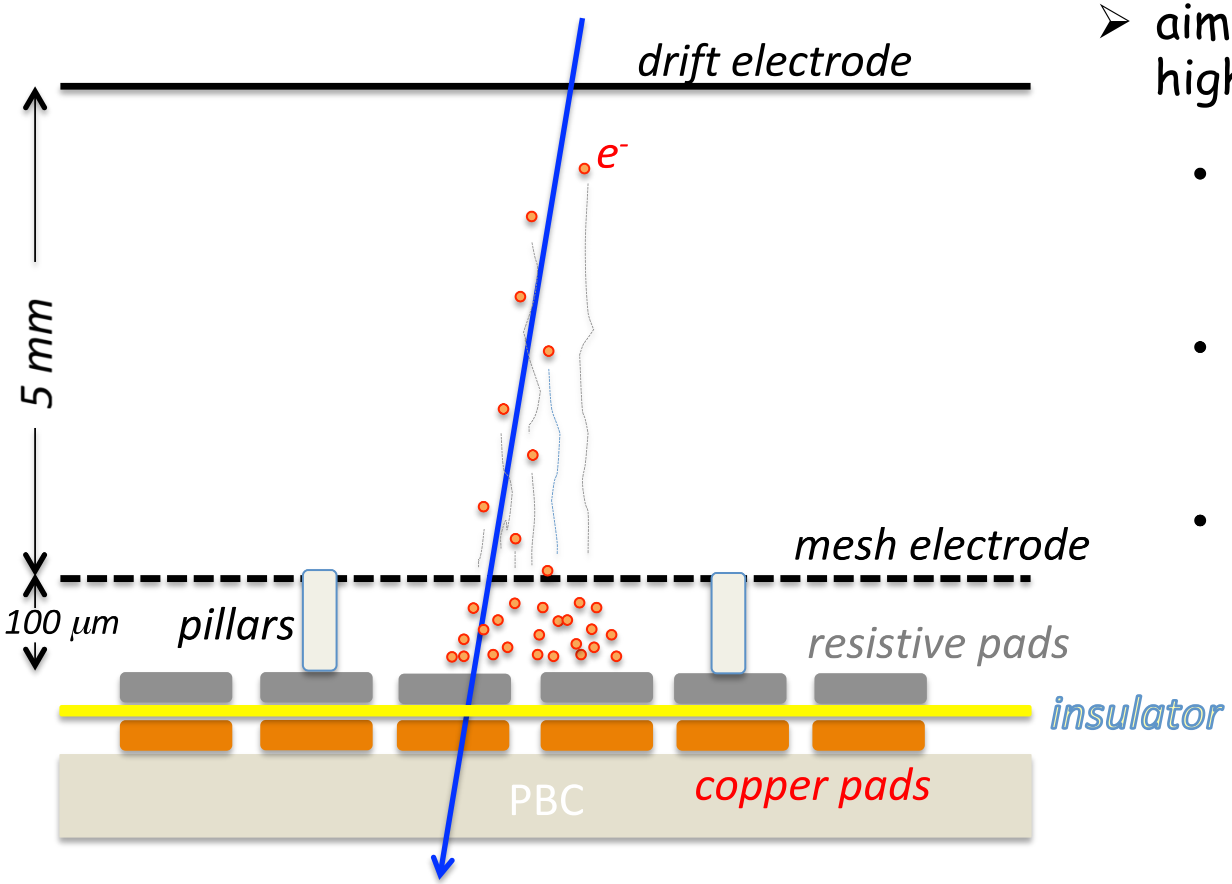
Mariagrazia Alviggi (1), Vincenzo Canale (1), Massimo Della Pietra (1),
Camilla Di Donato (1), Paolo Iengo (1,3), Mauro Iodice (2), Fabrizio Petrucci (2),
Givi Sekhniaidze (1), Maria Teresa Camerlingo (2)

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

IPRD 2019 – 14-17 October 2019 - Siena, Italy

Small Pads Resistive Micromegas

Resistive MicroMeGas technology consists in 'covering' the copper anode pads with a resistive 'structure' to suppress discharges



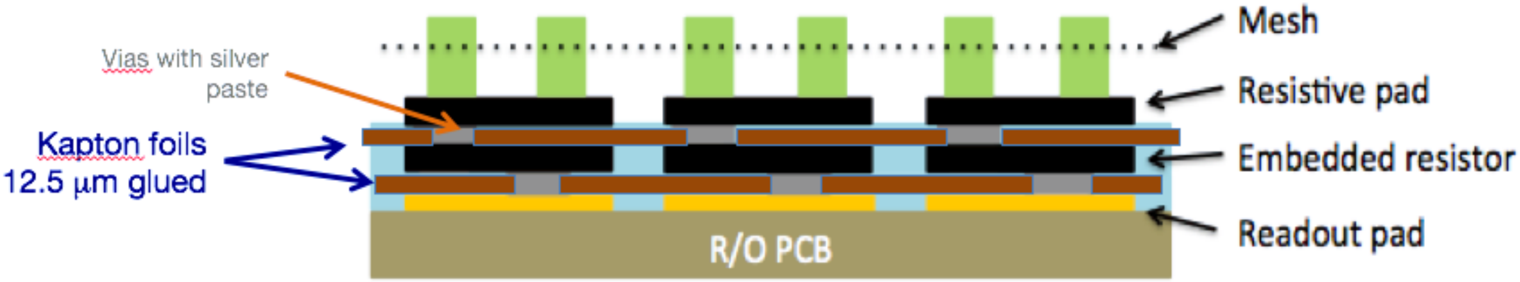
- aimed for operation at very high rate ~10 MHz/cm^2
  - fine readout granularity, to reduce occupancy
  - optimize the spark resistive protection
  - simplify the construction tecnique for industrial production

Resistive layer realization tecniques

CERN MPT workshop, R.deOliveira&coll.

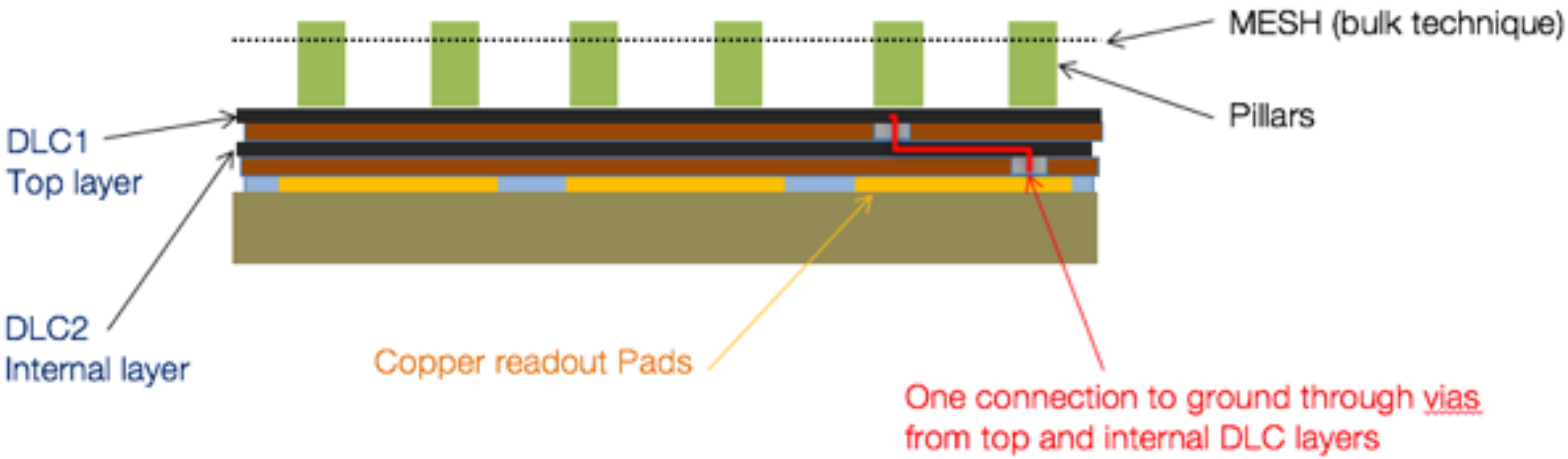
Embedded resistors PAD-Patterned (PAD-P)

resistive pads and embedded resistors realized through resistive paste, kapton insulating foils in between with holes filled with conductive silver paste



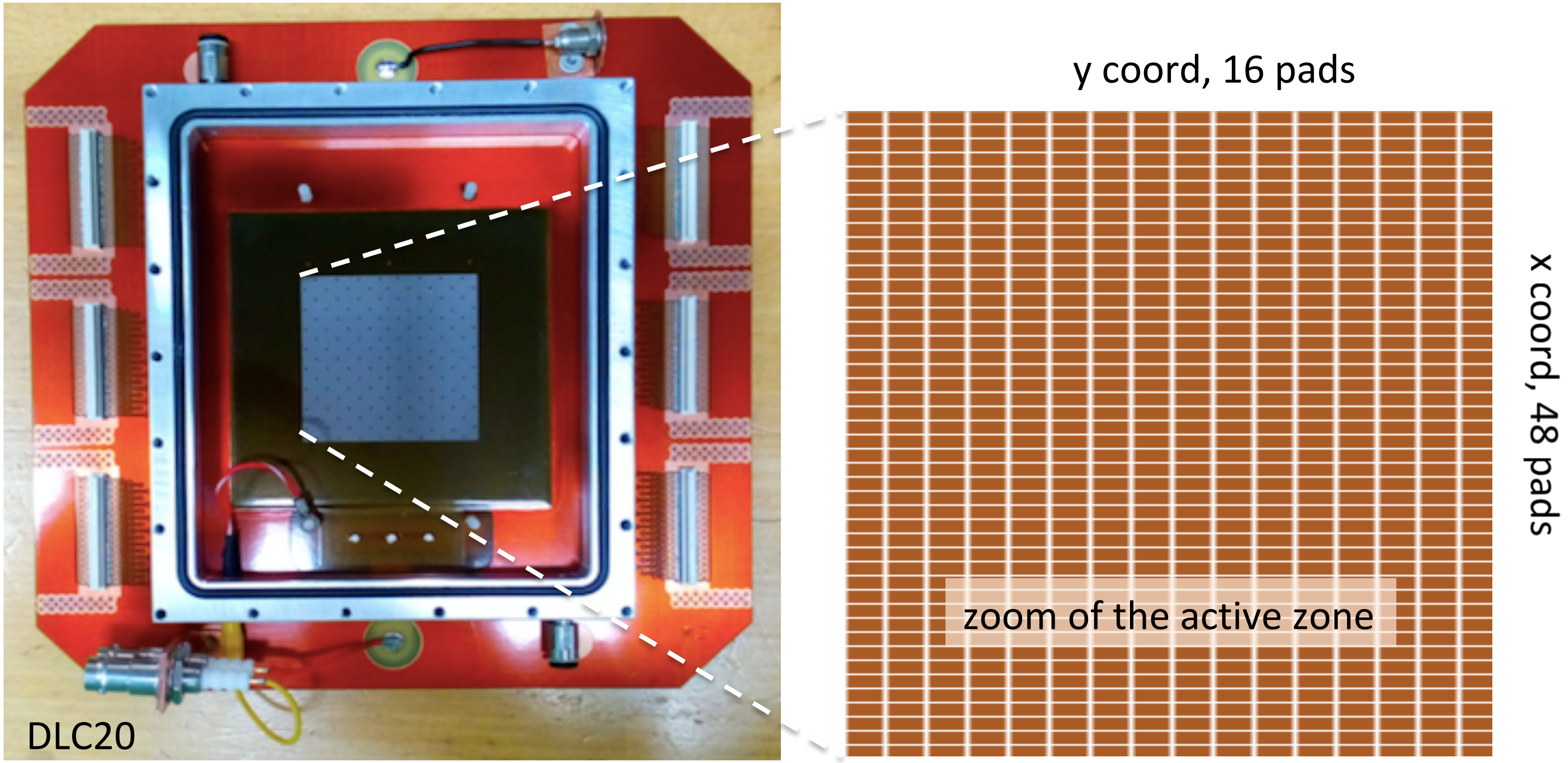
Diamond Like Carbon (DLC)

uniform resistive layer obtained sputtering carbon (evaporated from a graphite target) on a kapton foil, two DLC foils interconnected through conductive (silver paste) vias for the charge evacuation



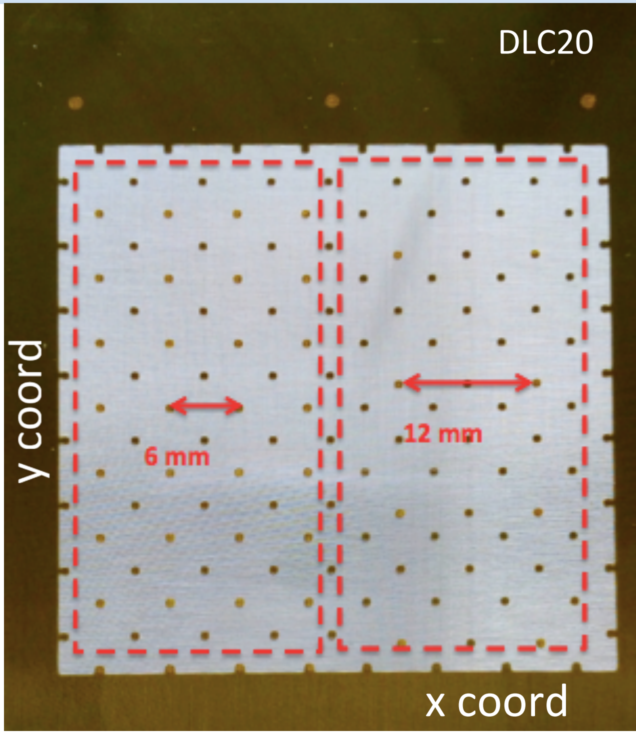
Prototypes: *geometrical characteristics*

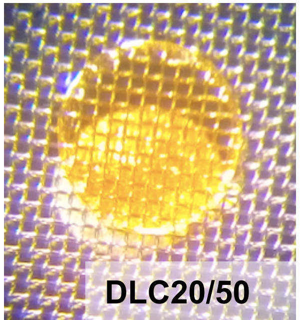
- Matrix of 48x16 pads – 768 channels
- Pads dimensions: 0.8x2.8 mm^2 , pitch 1x3 mm^2, total active area ≈ 4.8x4.8 cm^2
- pillars matrix pitch every 6 mm, overlapping with conductive vias when present

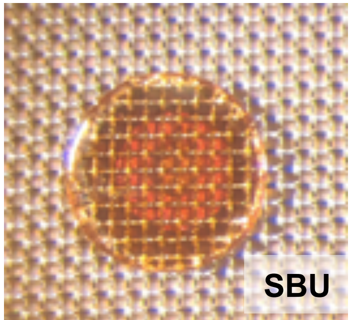


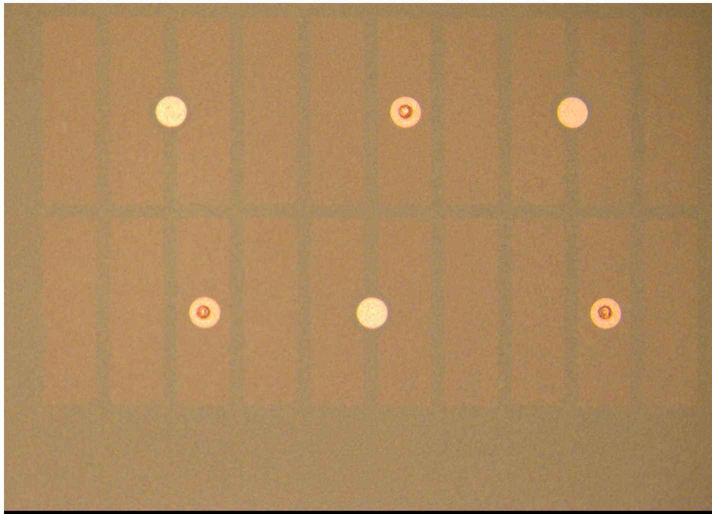
Prototypes:

- **PAD-P: Embedded resistor PAD-Patterned**
  - mean value of the embedded resistors ≈ 3-6 MΩ
- **DLC50, DLC20: 'standard' DLC, sputtered on kapton**
  - surface resistivity 50-70 MΩ/□
  - surface resistivity 20 MΩ/□
  - two regions, with conductive vias every 6 or 12 mm
- **SBU1, SBU2: Sequential Build Up** of **DLC foils copper cladded on both sides** (copper finally removed – left only on vias)
  - easier photolitographic construction process
  - improving of the centering of the pillars with the silver vias (every 6 mm)
  - for both: 1st layer (nearest to gas gap) resistivity 5 MΩ/□, 2nd layer 35 MΩ/□





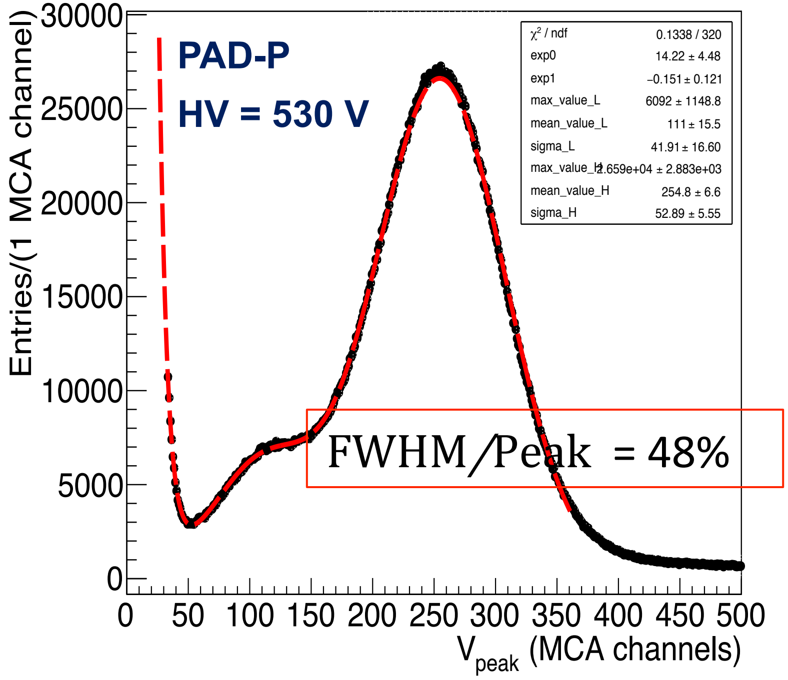


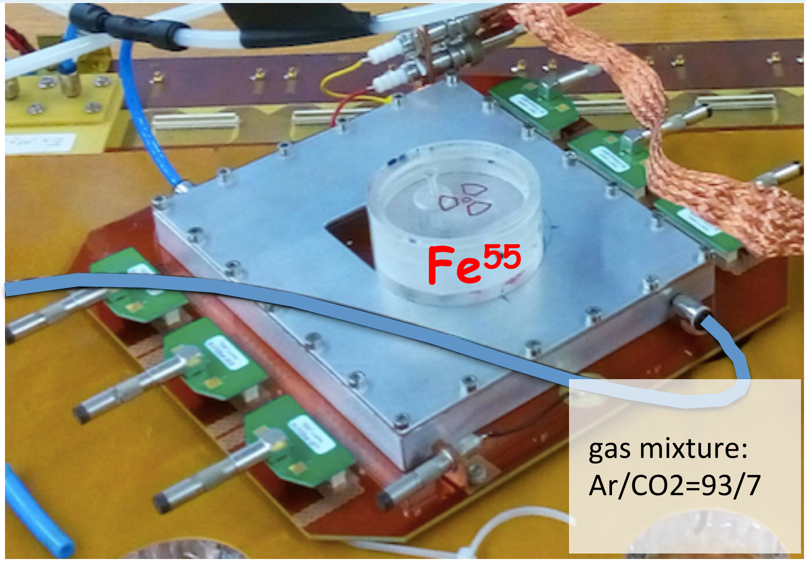


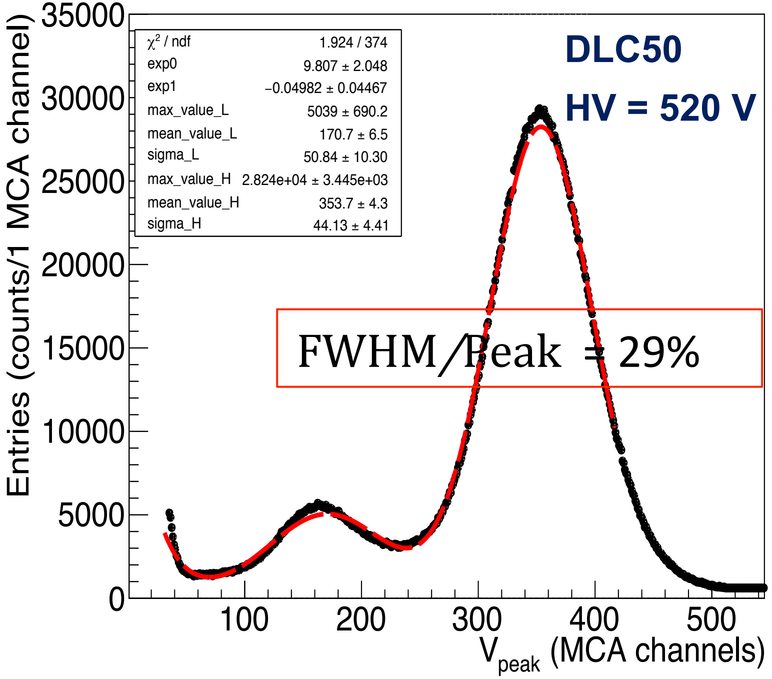
SBU 2th layer with silver vias to pads

Tests with ^{55}Fe source: *energy resolution*

Modest energy resolution for PAD-P, presumably due to field disuniformity on the pads edges

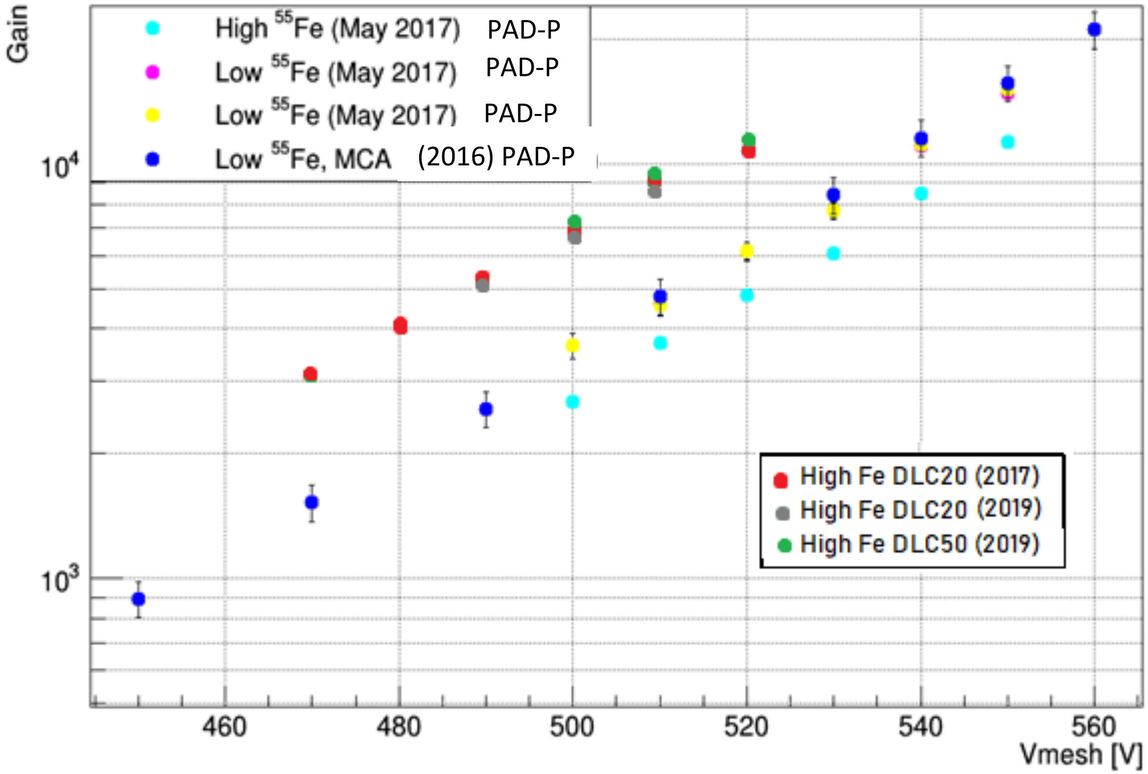






Much better for all DLC prototypes, due to the resistive layer, and then field, uniformity

Tests with ^{55}Fe source: *gain*



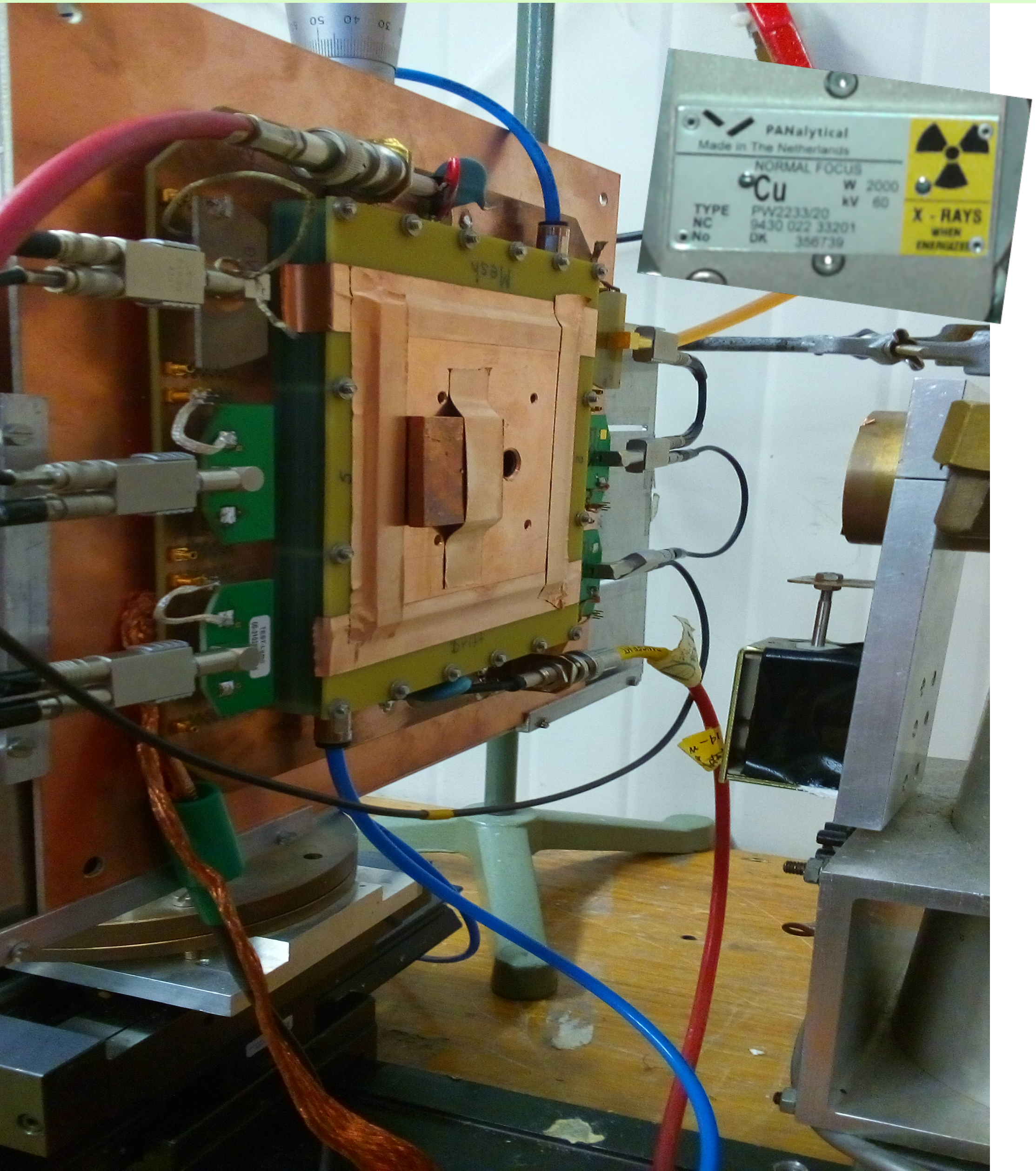
- different detectors construction processes and gap amplification thickness
- different measurement methods (current/rate, MCA, preampl. calibration, discr. threshold..) and time (gas P, T)

Prototypes behaviour comparison done with same V_{drift} (300V) and at the 'same gain' conditions:

- PAD-P V_{ampl} = 527 V
- DLC20 V_{ampl} = 510 V
- DLC50 V_{ampl} = 504 V

} G ~ 8000

Tests with X-Rays:



@CERN GDD Lab

X-Ray gun:

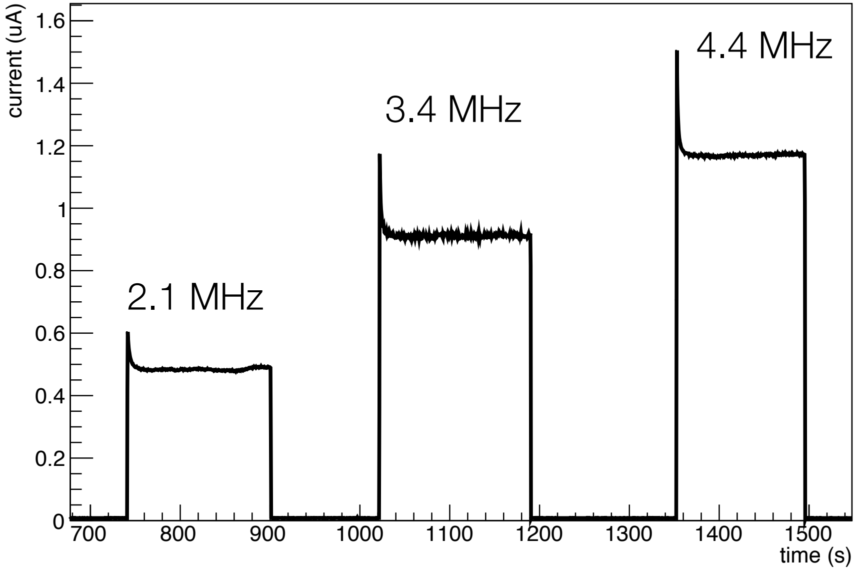
- 8KeV photons from Cu anode

Test detector response with:

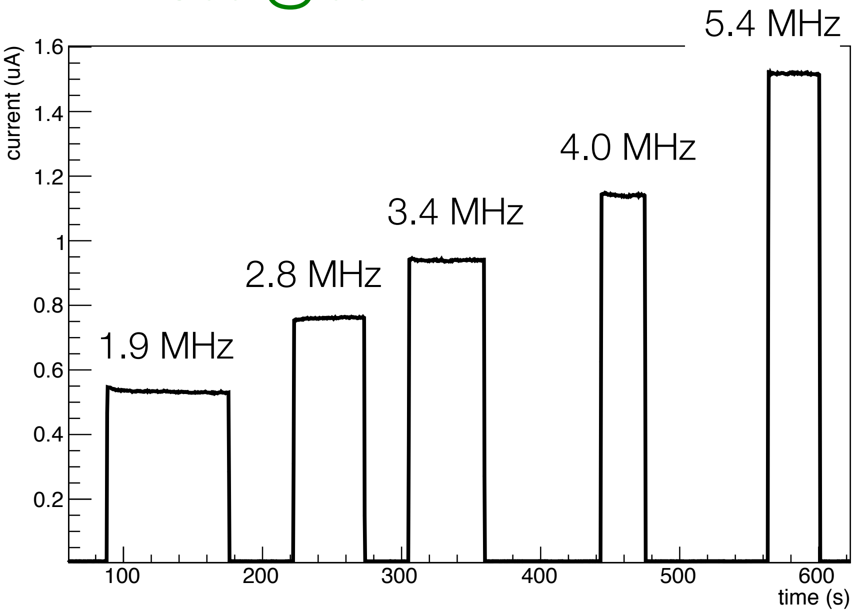
- increasing X-Rays rate
- different exposure areas, screening the detector through a perforated Cu plate
- charge evacuation vias every 6mm or 12mm for DLC20/50

Tests with X Rays: *charging up*

PAD-P @ 527 V



DLC50 @ 504 V

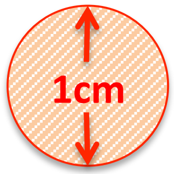


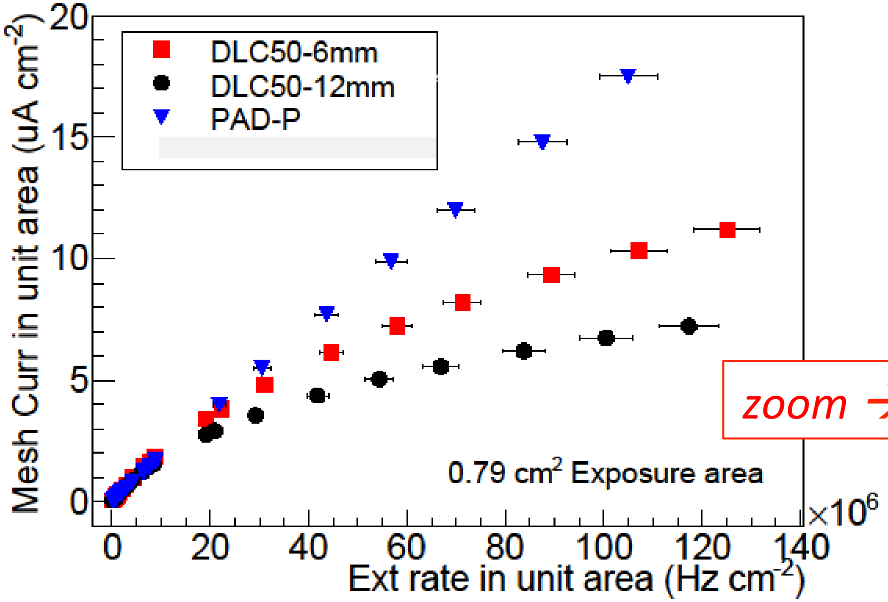
- PAD-P shows a decrease of the current every time the X-Ray gun is switched on
- a possible explanation is the charging up of the dielectric among pads, reducing the electric field

- DLCs detectors do not show this behaviour
- infact their surface is uniformly resistive and has (almost, apart from pillars…) no dielectric

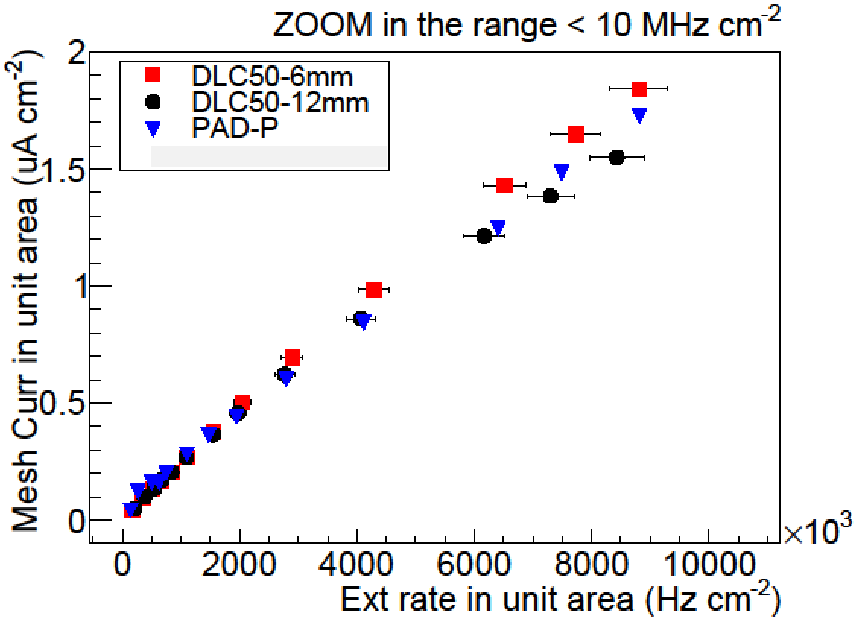
X-Rays: *PAD-P, DLC50-6/12mm comparison*

at fixed X-Rays exposure area = 0.79 cm²





zoom →



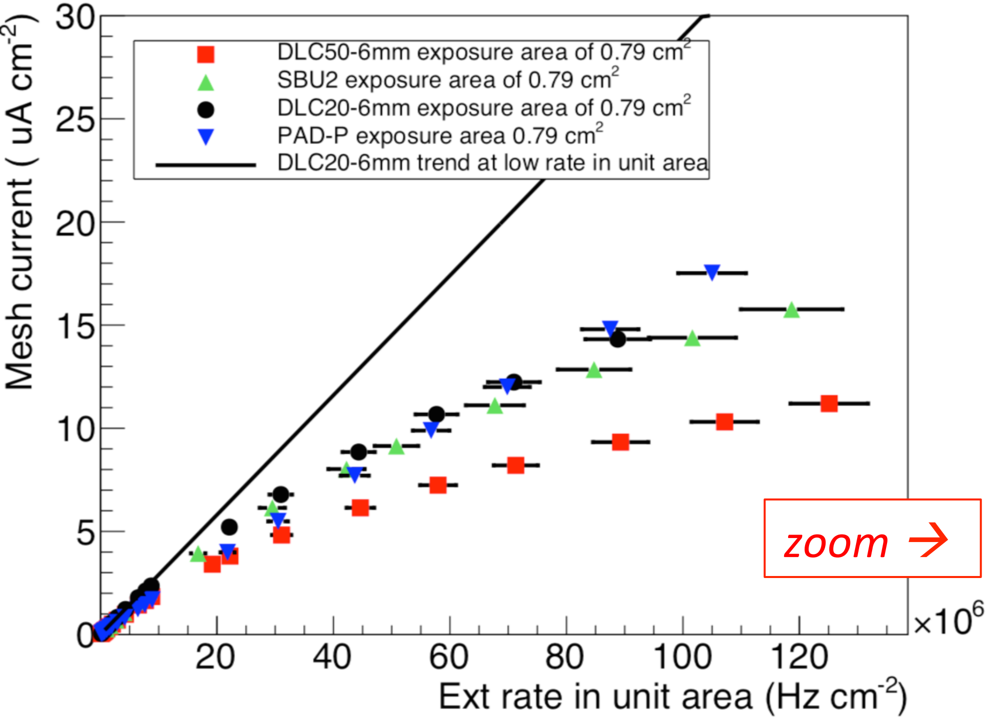
- at very high rate > 10 MHz/cm², current decreases due to the voltage drop through the embedded resistors/ resistive layers
- DLC50 current bend much more then PAD-P
- charge evacuation vias every 6 mm better then 12 mm, as expected

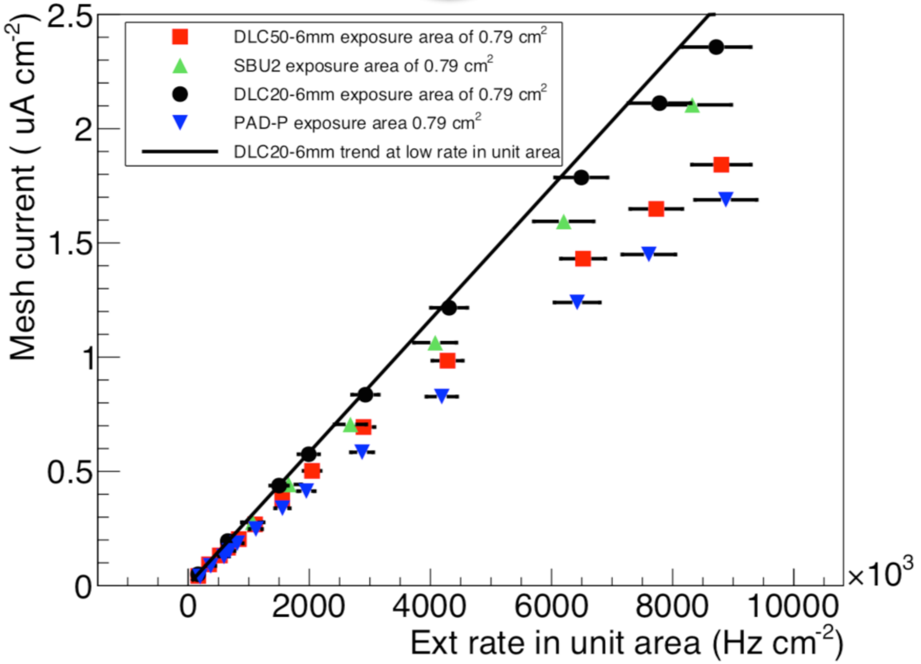
- at rate < 10 MHz/cm², PAD-P below DLC50-6mm, probably for charging-up effect..

- Rate, measured up to 300 kHz/cm² , shows linear behaviour with the X-Ray current; after that value the rate has been linearly extrapolated from the X-Ray current

X-Rays: *PAD-P, DLC20/50-6mm, SBU2 comparison*

at fixed X-Rays exposure area = 0.79 cm²





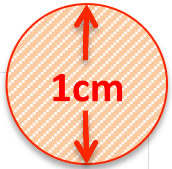
- PAD-P still shows the best behaviour
- DLC20-6mm and SBU2 show a significantly better behaviour than DLC50-6mm (lower resistivity)

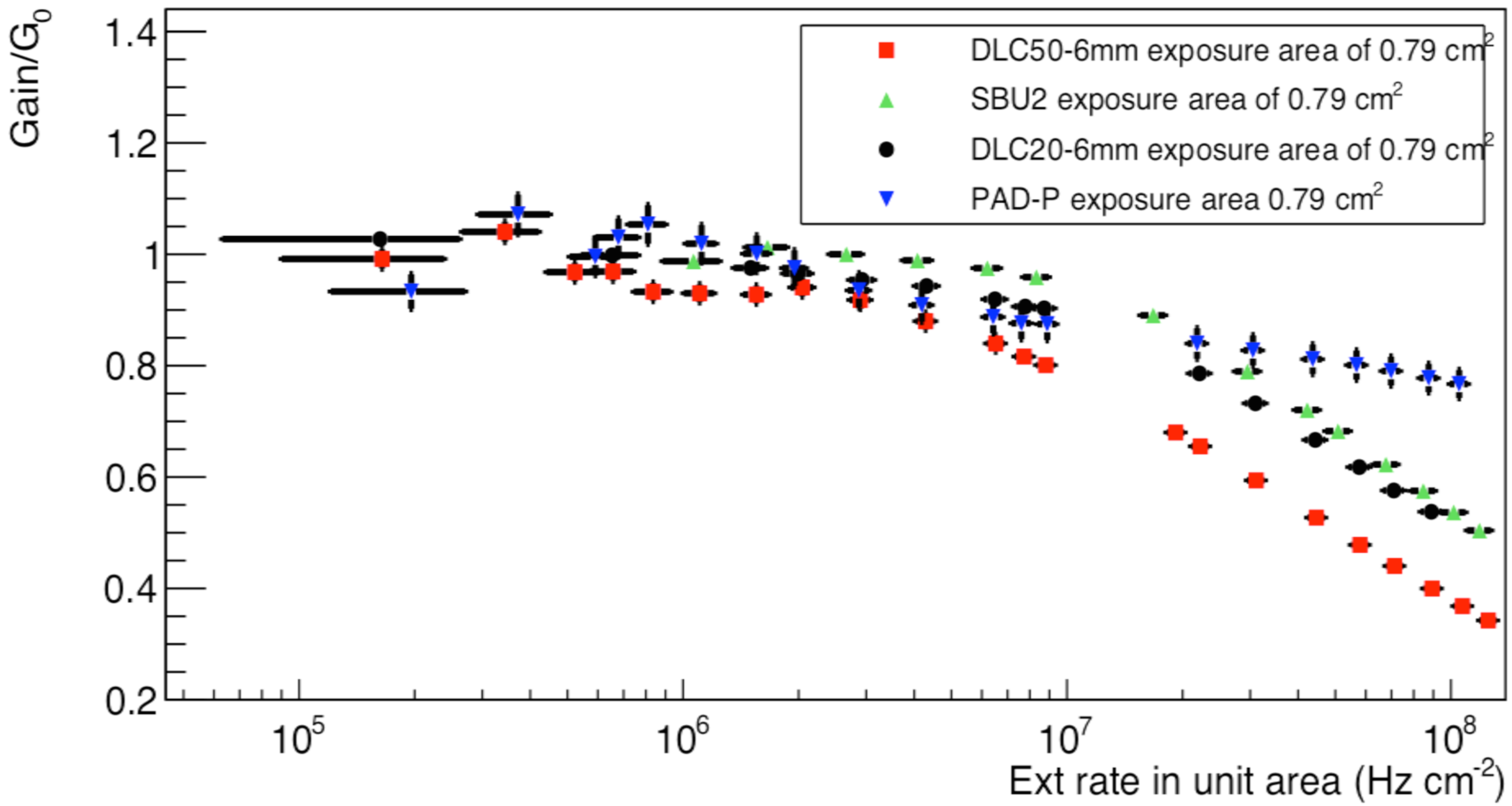
- at rate < 10 MHz/cm², PAD-P is, as in the previous slide, below then the others (charging-up effect)

- this plots can be seen in terms of gain→next slide

X-Rays: *PAD-P, DLC20/50-6mm, SBU2 comparison*

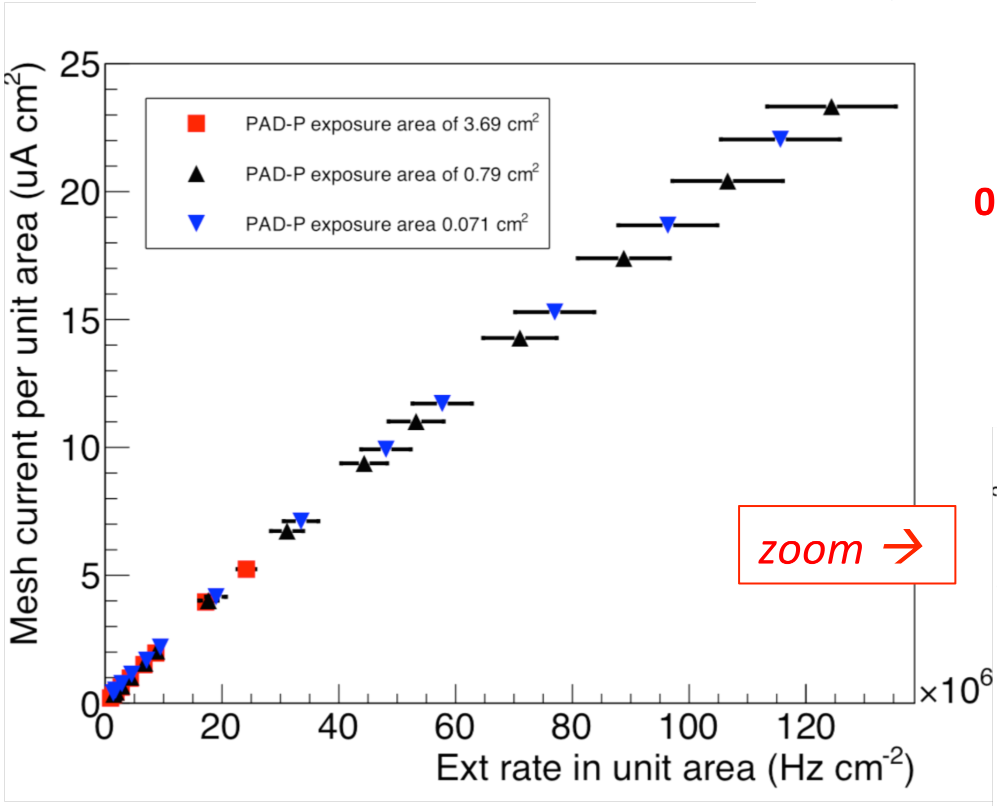
at fixed X-Rays exposure area = 0.79 cm^2





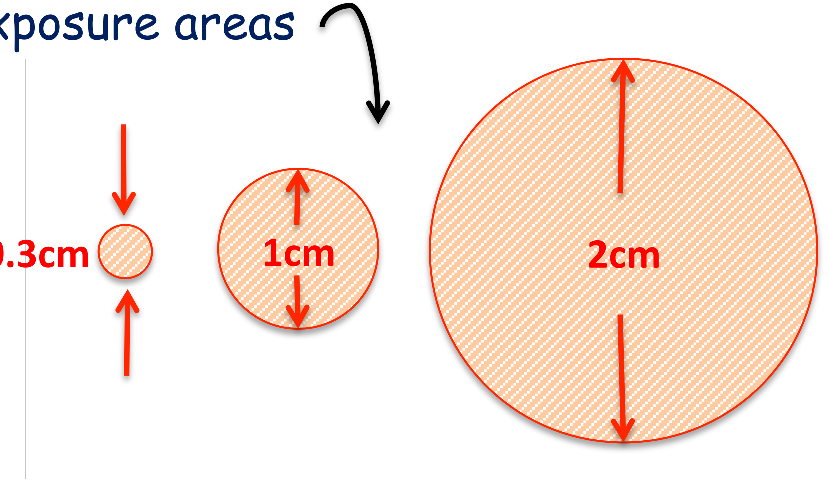
- PAD-P, DLC20-6mm and SBU2 drop less then 10 % till 10MHz/cm^2
- PAD-P shows a very good behaviour even at 100MHZ/cm^2 (20-30% drop)
- DLC50-6mm drop less then 10% till few MHz/cm^2

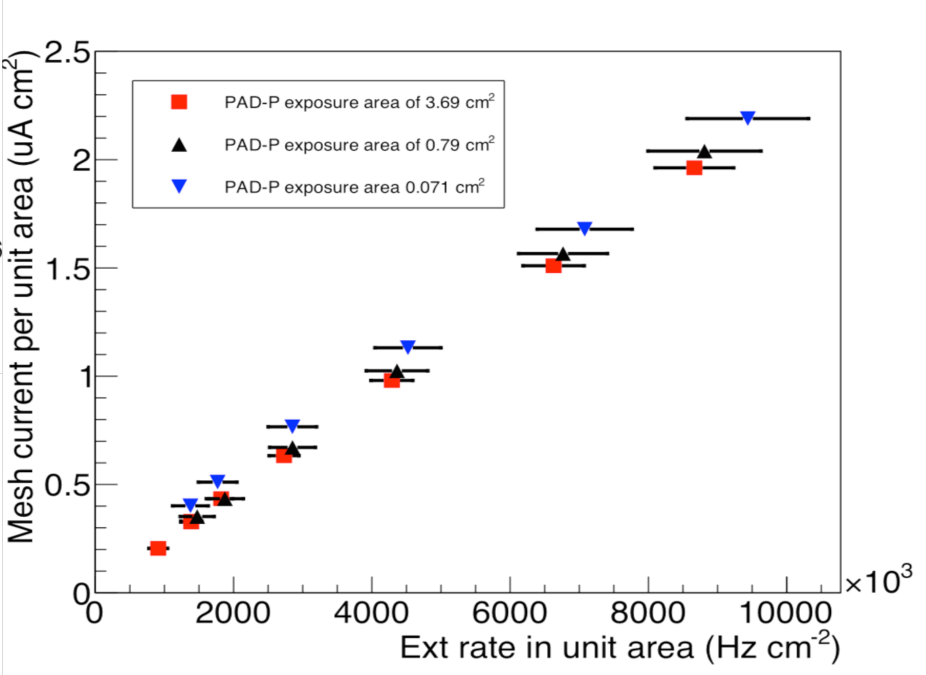
X-Rays: *PAD-P dependence on irradiation area*



zoom →

X-Rays exposure areas

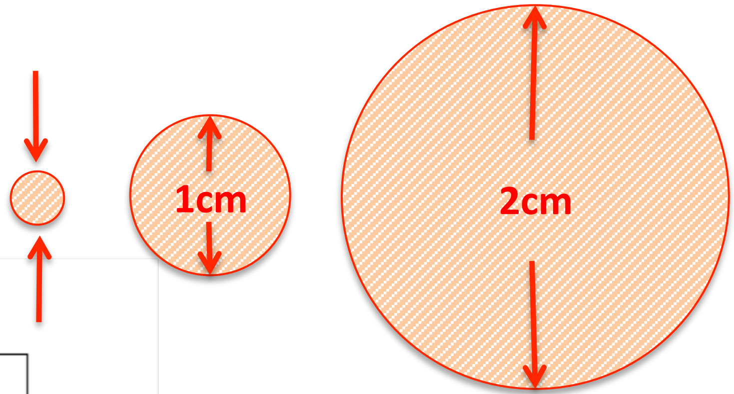


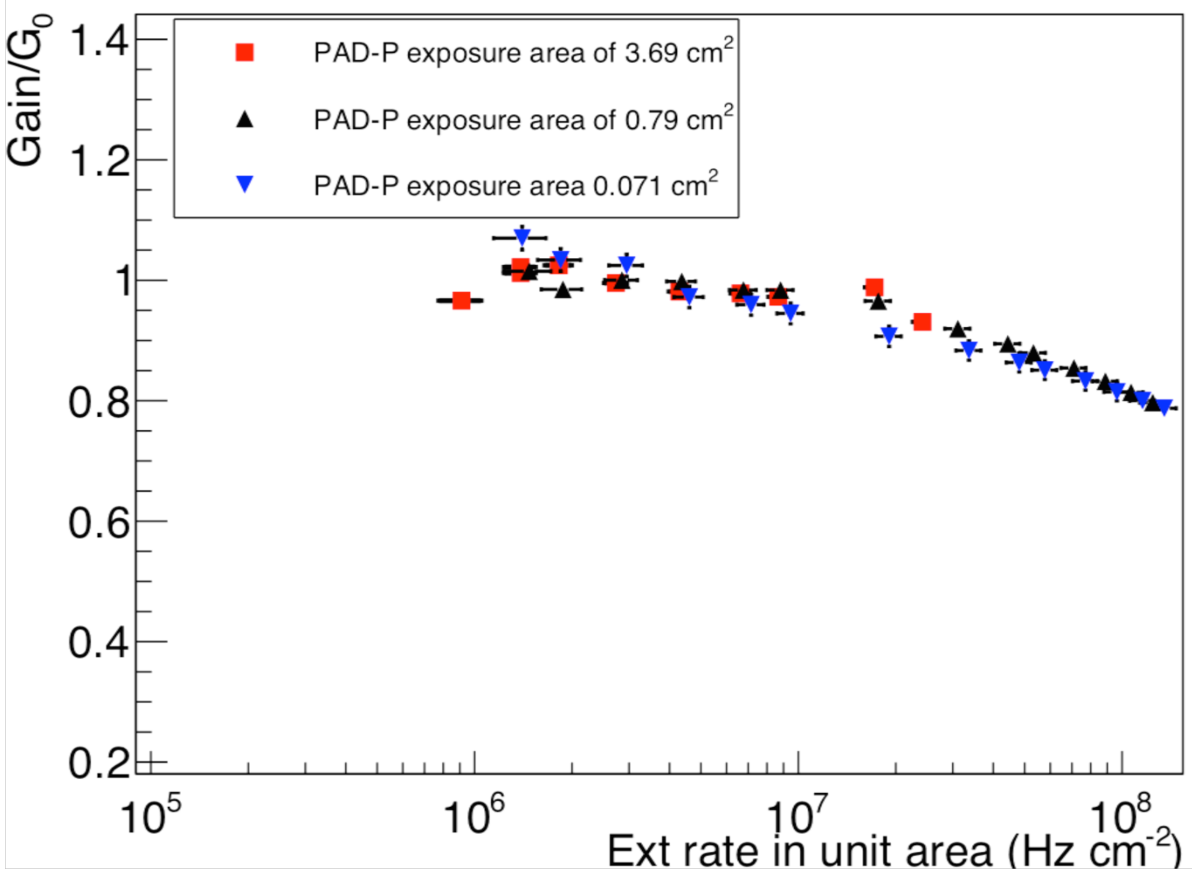


- PAD-P doesn't show any different current drop wrt different exposure areas (in the explored range)
- then, in terms of gain→next slide

X-Rays: *PAD-P dependence on irradiation area*

X-Rays exposure areas

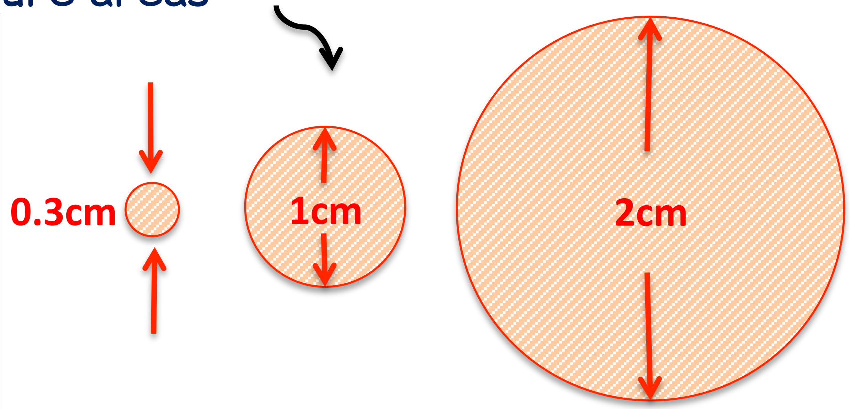


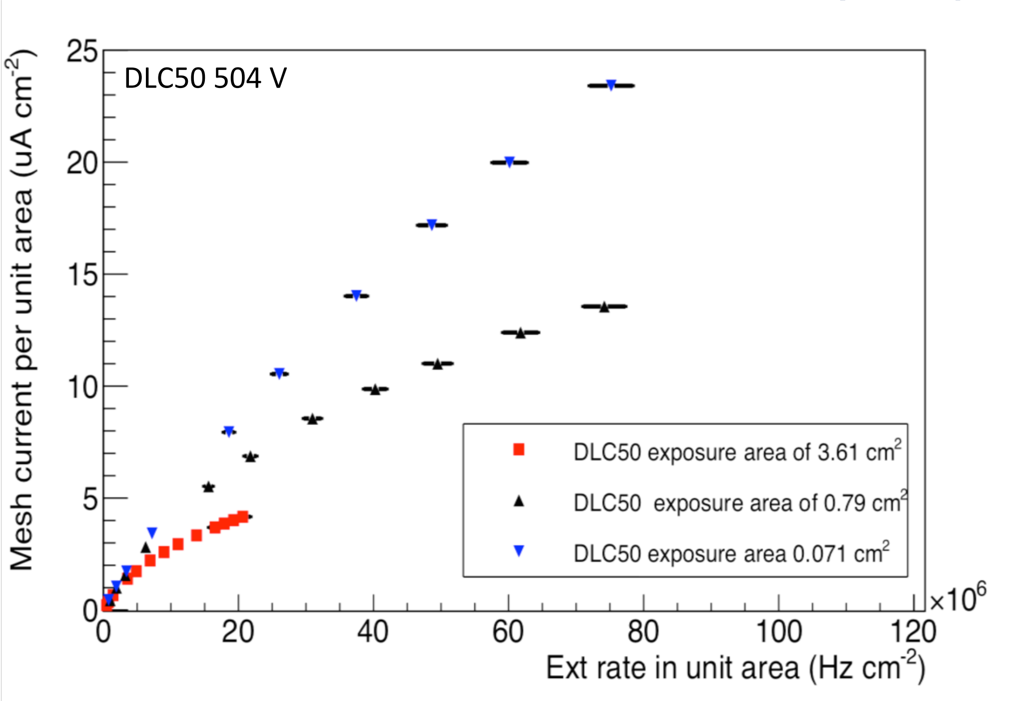


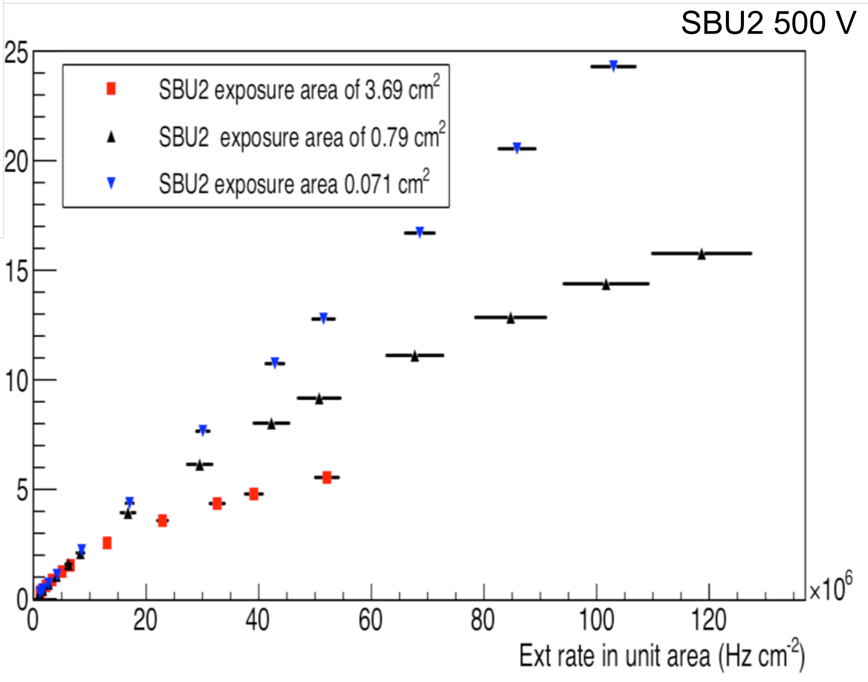
- PAD-P doesn't show any gain drop dependence from the exposure area (in the explored range)

X-Rays: *DLC50-6mm, SBU2 dependence on irradiation area*

X-Rays exposure areas

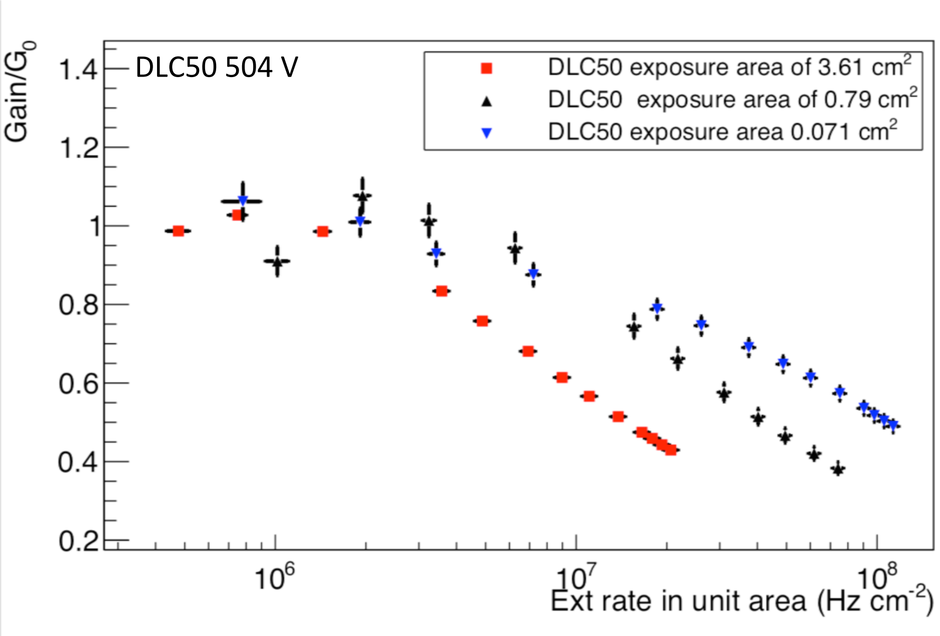




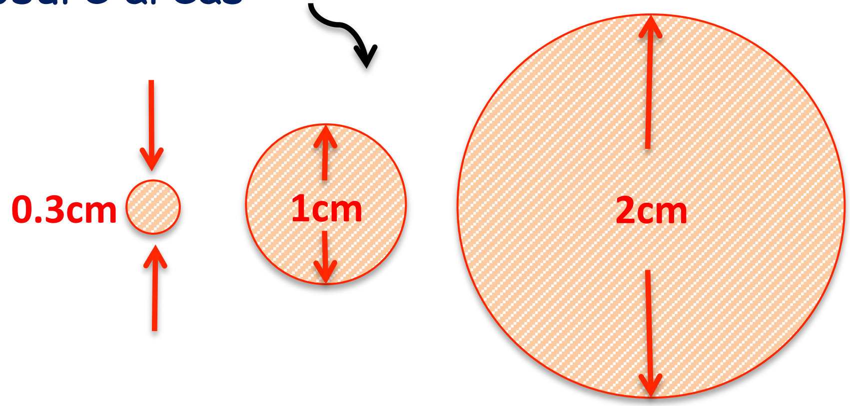


- DLC50-6mm and SBU2 exibit instead a different current drop, wrt the exposure area, above few MHz/cm^2
- then, in terms of gain→next slide

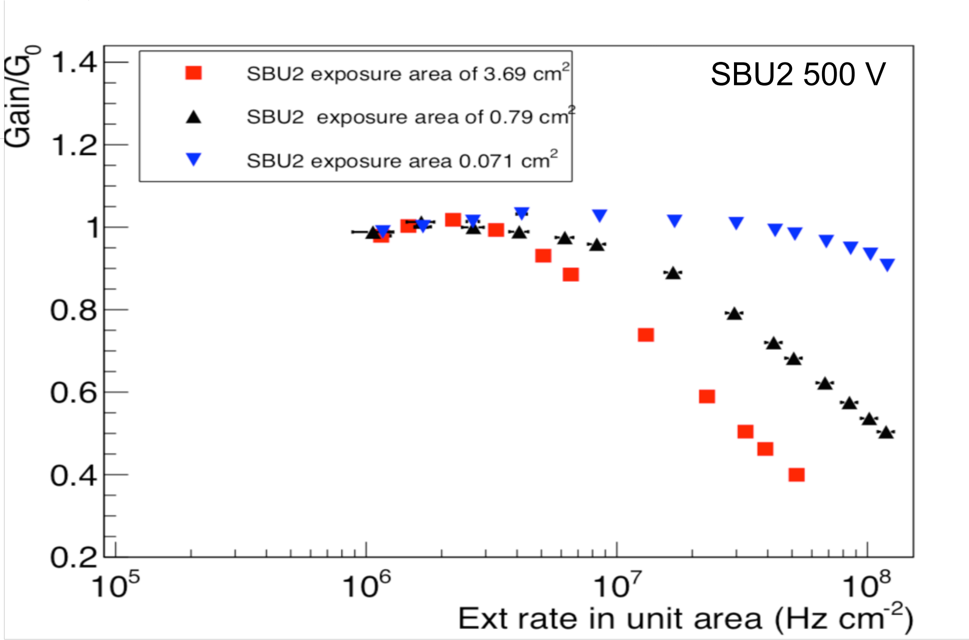
X-Rays: *DLC50-6mm, SBU2 dependence on irradiation area*



X-Rays exposure areas



- DLC50-6mm and SBU2 exibit instead a different gain drop, wrt the exposure area, over few MHz/cm^2

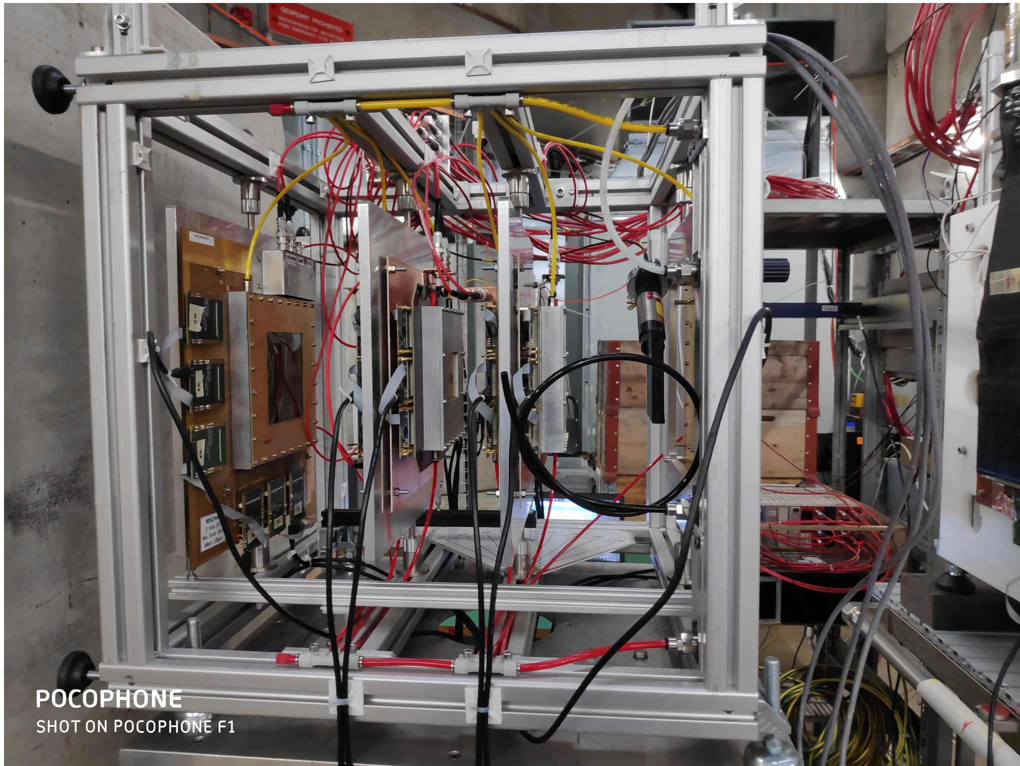


Test Beams @ CERN & PSI

2016/17	2018	2019
SPS H4@CERN μ, π at 150 GeV/c low/high rate	SPS H4@CERN μ, π at 150 GeV/c π at 80 GeV/c	πM1@PSI π at 300 MeV/c p contamination 7%
PAD-P, DLC50	DLC50, DLC20	PAD-P, DLC20, SBU1&2

last week, not yet results…

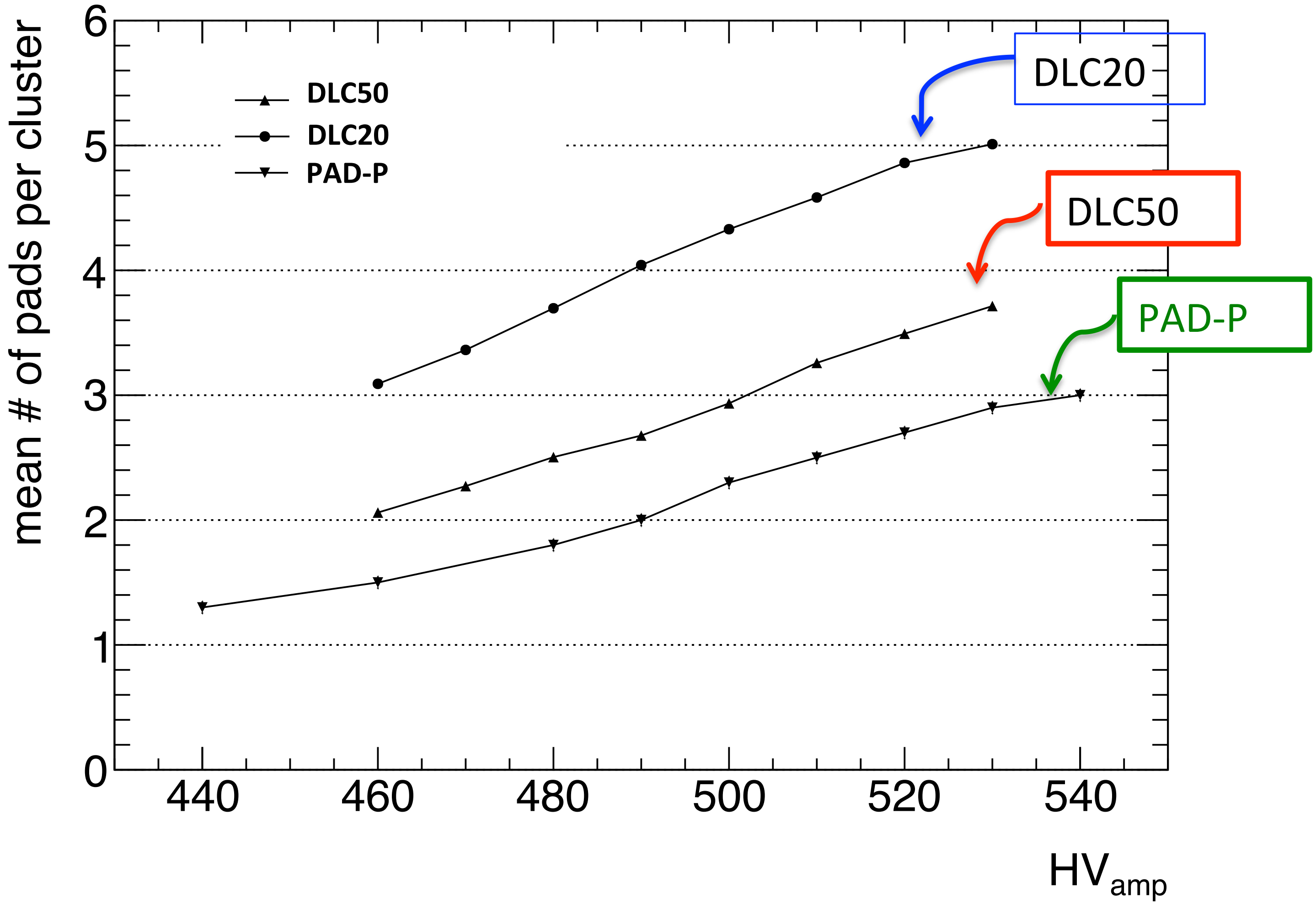
- Test Setup:
  - Two small scintillators for triggering
  - Two double coordinate (xy) bulk strips micromegas (10 x 10 cm^2) for tracking
  - Small-pads MM in between
  - gas mixture: Ar/CO$_2$=93/7 pre-mixed
  - DAQ: SRS+APV25



Test Beam Results: *cluster charge*

Precision coordinate x (pad pitch 1 mm)

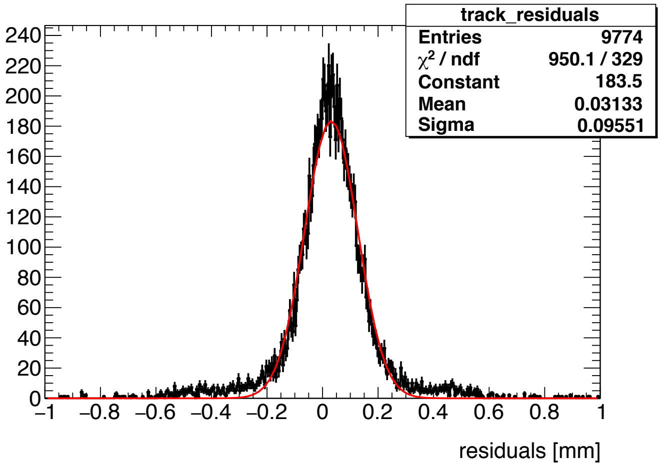
- larger cluster size for DLCs detectors due to the uniform resistive layer
- larger clusters for lower resistivity, DLC20 with respect to DLC50



Test Beam Results: *Position resolution*

Precision coordinate (pad pitch 1 mm)

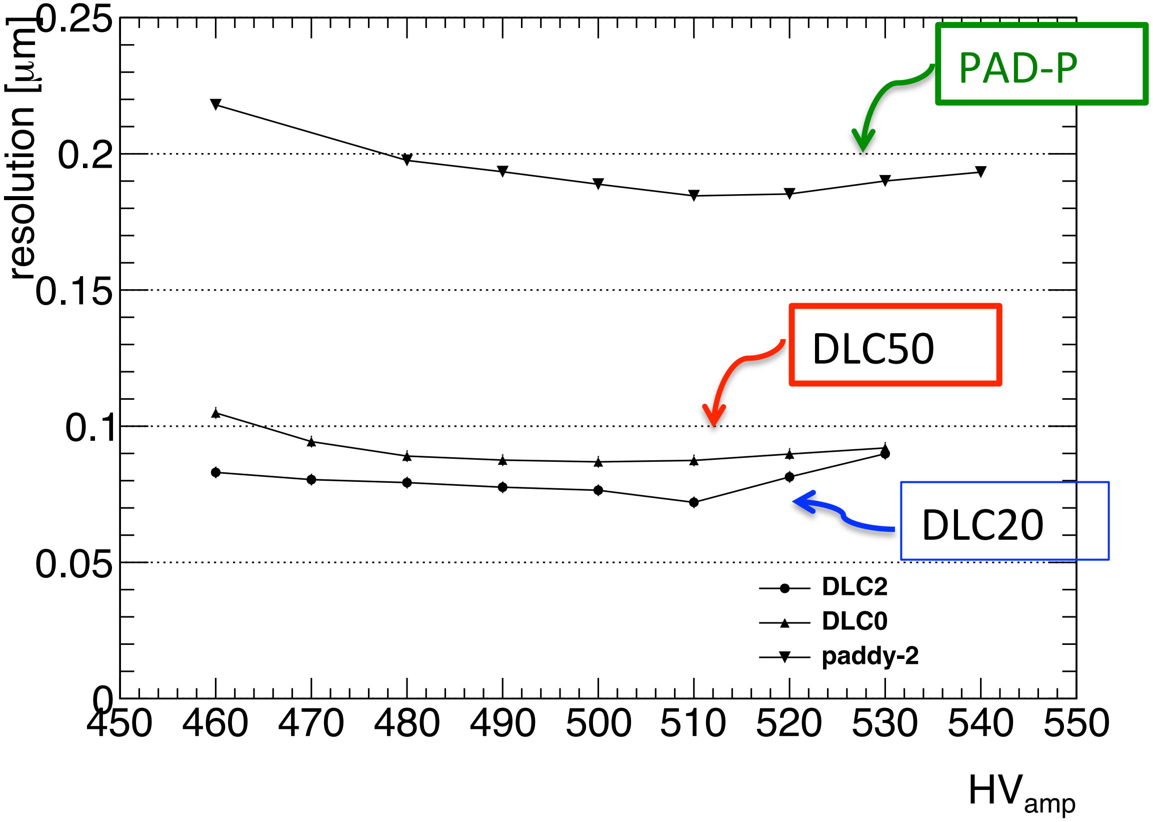
- Significant improvement of spatial resolution on the DLC prototypes (pad charge weighted centroid)
- More uniform charge distribution among pads in the clusters



Residuals of DLC20 at 510 V

$$\sigma_{resol} = \sqrt{(\sigma^2_{residuals} - \sigma^2_{track})}$$

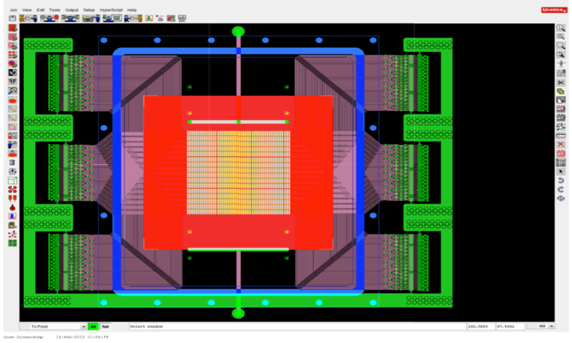
$(\sigma_{track} \simeq 50\ \mu m)$



(rise at high HV due to distortions induced by pad-charge saturation effects)

Toward Larger Size prototype…

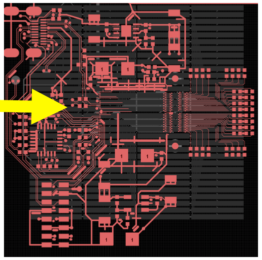
Layout not scalable for large dimensions (very dense routing)



EMBEDDED (back wire-bonded) electronics to get scalability

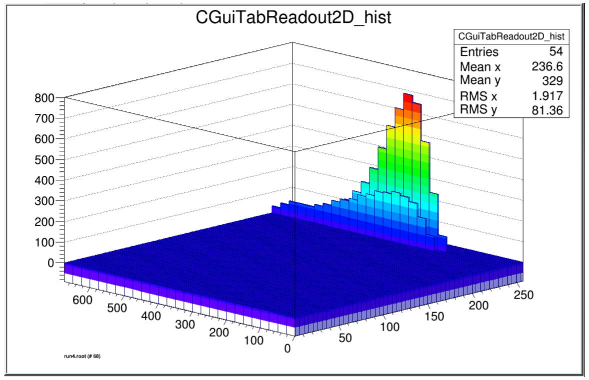
FIRST PROTOTYPE :

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



APV FE Layout

back embedded APV25 chip reassembled on the detector board



- signal response from APV using ^{55}Fe source and random trigger for DAQ → BUT ONLY on some channels
- reason has been understood (issue in the elx layout) and will be fixed it in the next prototype

Summary

	Pad-Patterned screen printed resistive layer	**DLC uniform resistive layer with grounding vias**
Energy Resolution	40-50 %	better than 30%
Spatial Resolution	~190 μm	~70 – 90 μm. Improves with lower resistivity (at the price of larger cluster size → higher occupancy)
RATE CAPABILITY	Charging-up: reduces the gain above tens kHz/cm^2	No evidence of charging-up on DLC
Rate<10 MHz/cm²	• Gain drops less then 10% due to (voltage drop through few MΩ resistance) • No dependence on size of the exposed area	• DLC20-6mm shows very good linearity. Behaviour strongly improves, in our prototypes, with lower both resistivity and grounding vias pitch • DLC50 and SBU2 show a clear dependence on the exposed area, DLC20-6mm was not tested on larger areas due to discharges.
10<Rate<100 MHz/cm²	• Gain drop is around 20-30% at 100 MHz/cm^2. Don‘t expect dependence with size (not tested due to the very high current, over the HV power supply limit)	• Significant drop, higher for the high resistivity prototype (DLC50)
ROBUSTNESS	• No discharges observed	• Discharges due to local defects? → to be optimised

Backup slides

ACKNOWLEDGEMENTS

CERN RD51 Collaboration for the continuous support and the CERN GDD Lab for MPGD tests.

R. De Oliveira, B.Mehl, O.Pizzirusso and A.Teixeira (CERN EP-DT)

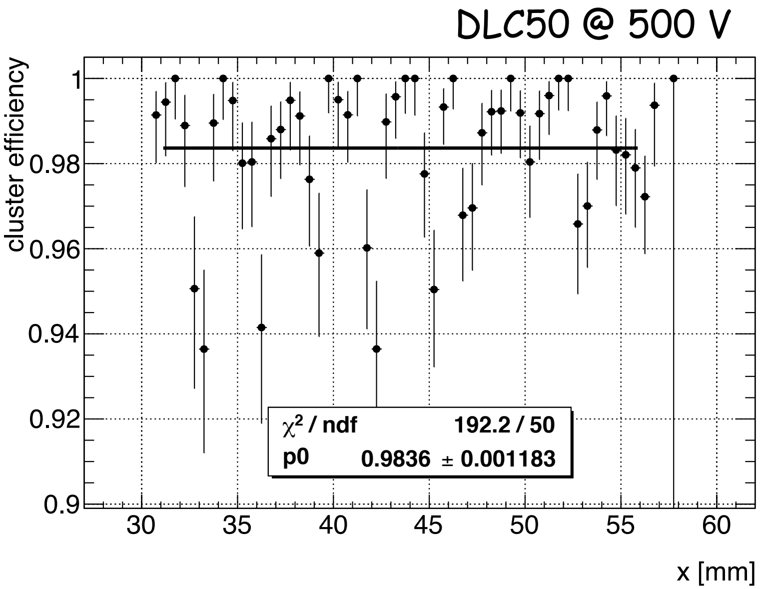
R&D based on previous developments of Pad micromegas for COMPASS and for sampling calorimetry:

- C. Adloff et al., *“Construction and test of a 1x1 m^2 Micromegas chamber for sampling hadron calorimetry at future lepton colliders*” NIMA 729 (2013) 90–101.
- M. Chefdeville et al. *“Resistive Micromegas for sampling calorimetry, a study of charge-up effects”*, Nucl. Inst. Meth. A 824 (2016) 510.
- F. Thibaud at al., *“Performance of large pixelised Micromegas detectors in the COMPASS environment”,* JINST 9 (2014) C02005.

DLC double resistive layer configuration re-arranged from micro-Resistive Well R&D:

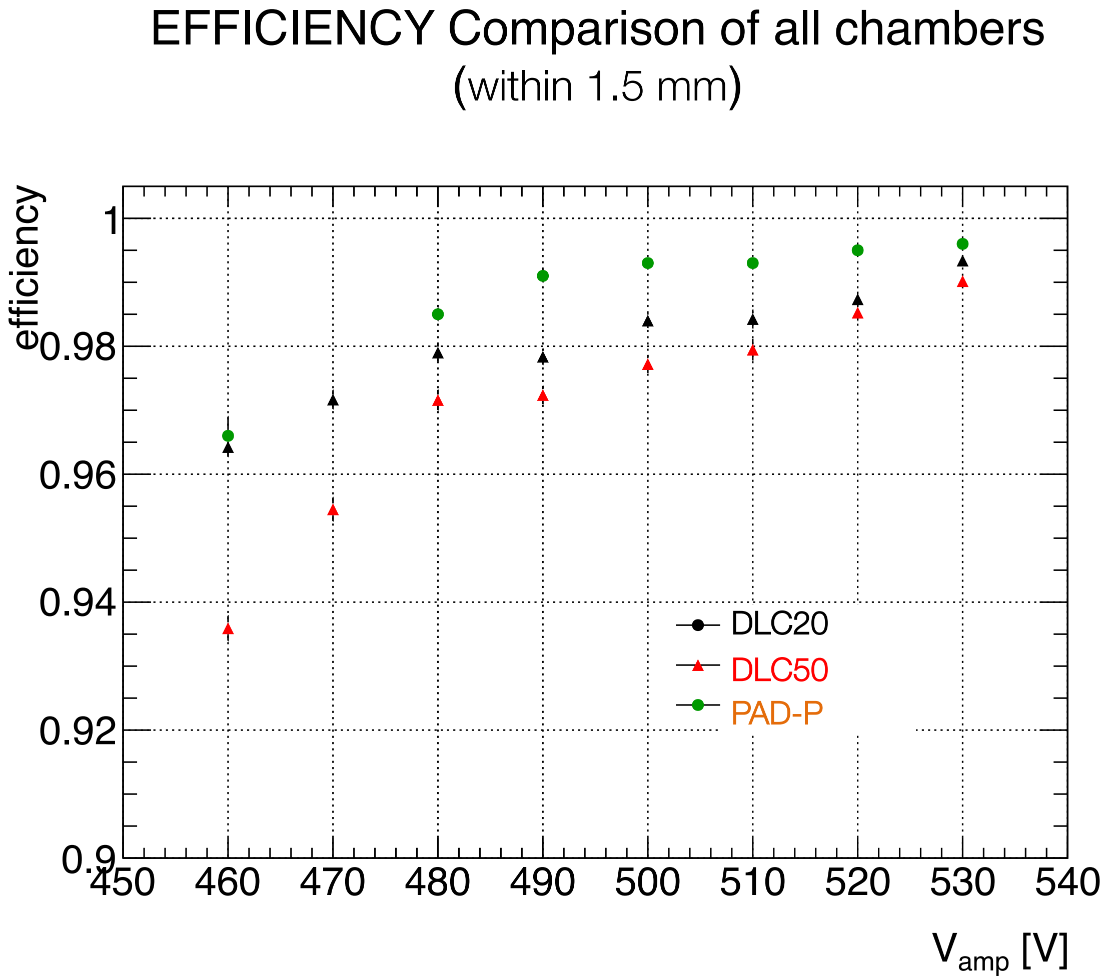
- G. Bencivenni et al., “*The micro-Resistive WELL detector: a compact spark-protected single amplification-stage MPGD*” 2015_JINST_10_P02008
- M. Poli-Lener “*The μ-RWELL detector for the the phase 2 upgrade of the LHCb Muon System Upgrade*” ICHEP 2018 (PoS forthcoming publication)

Test Beam Results: *Efficiency*



Cluster Efficiency vs extrapolated track impact position

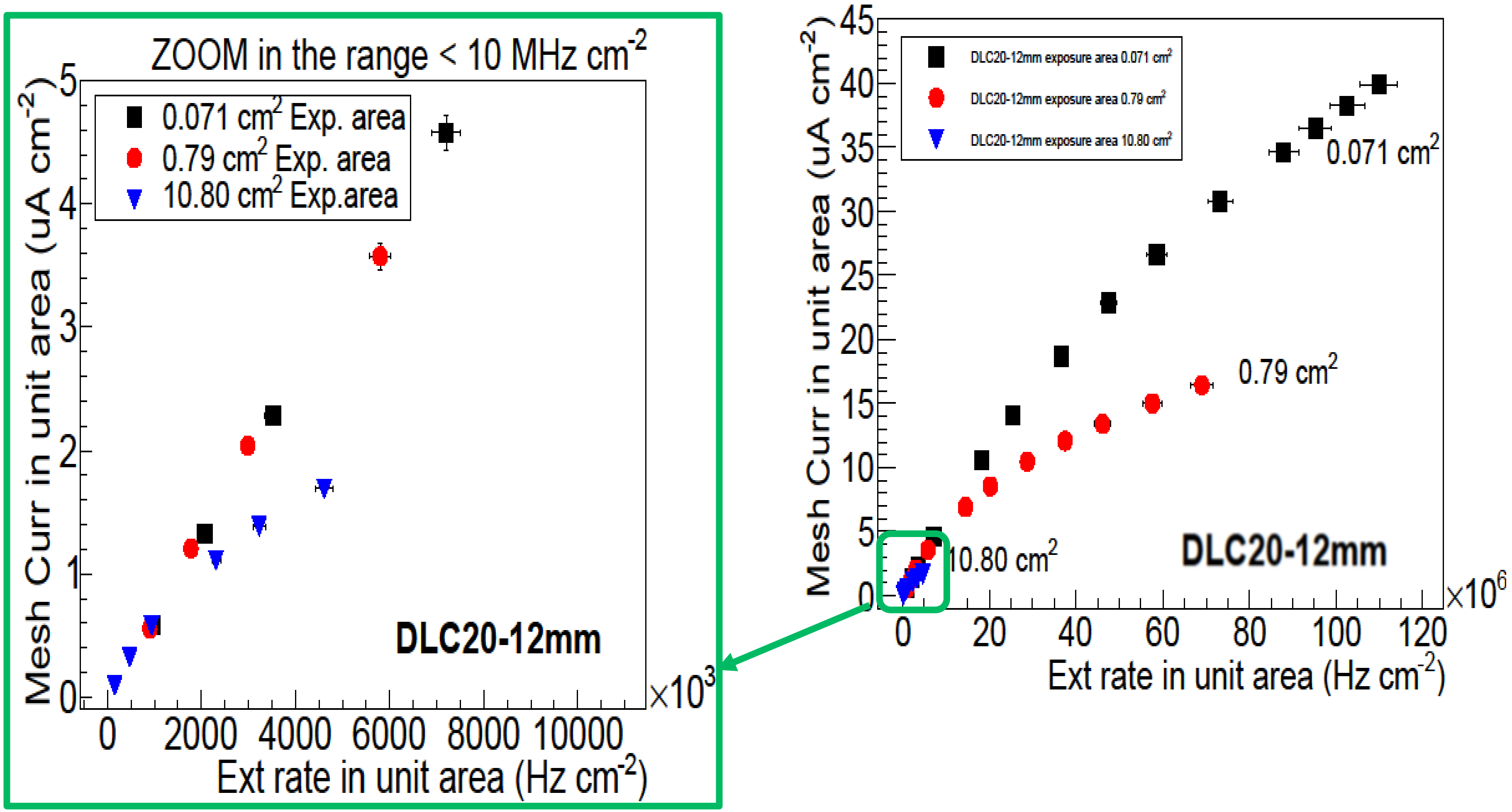
- inefficiencies correspond to pillars positions
- these inefficiencies decrease with HV



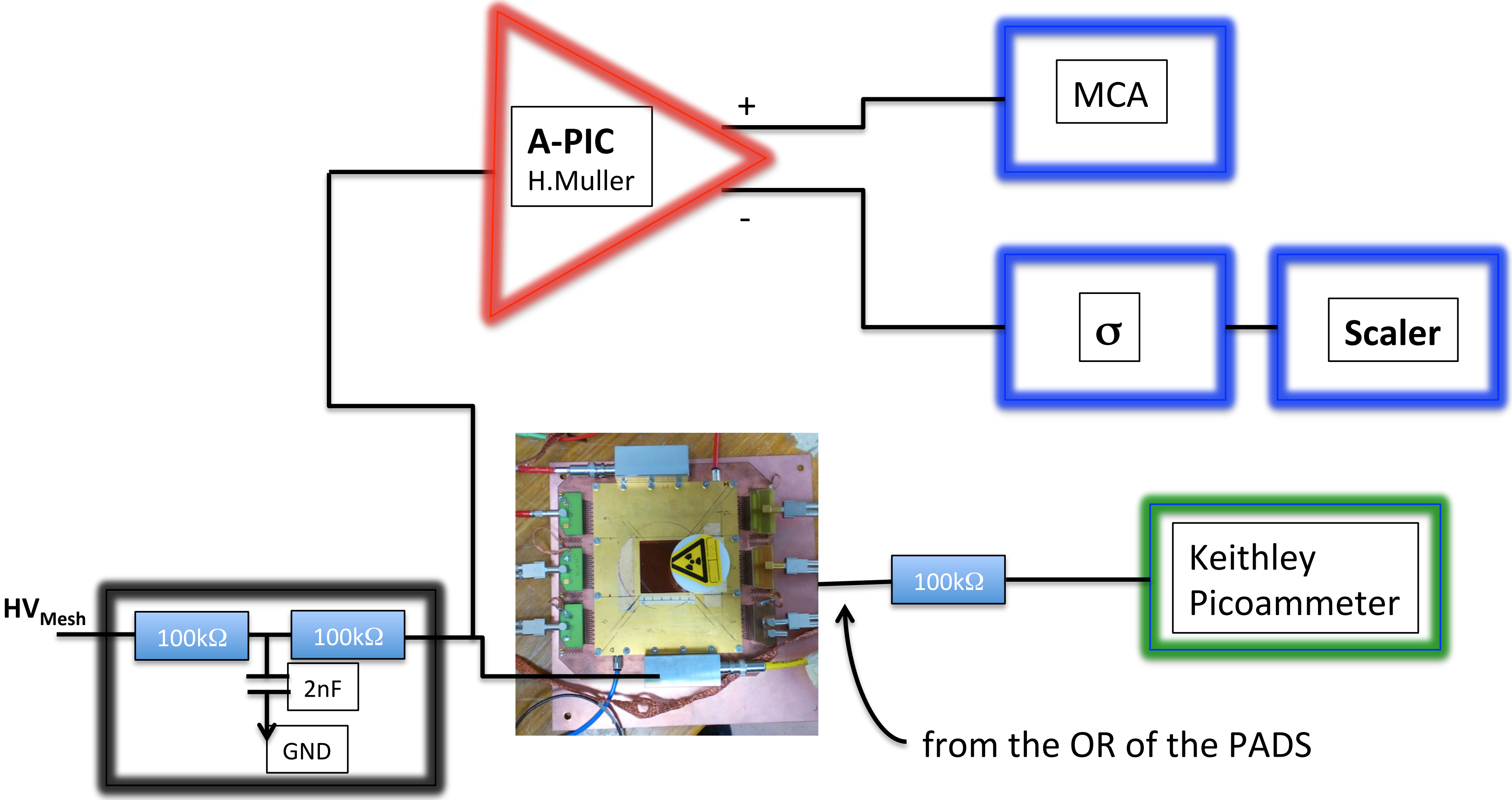
- we are still investigating about the observed differences in the plateau region at the level of 1%
- possible resons: different charge spread and cluster-size, different gains ...

X-Rays: DLC20-12mm dependence on the irradiated area

DLC20-12mm: December 2018 DATA (HV = 520 V)



^{55}Fe and X-Rays read out electronic chain



A-PIC
H.Muller

+

-

MCA

σ

Scaler

Keithley Picoammeter

100kΩ

HV$_{Mesh}$

100kΩ

100kΩ

2nF

GND

from the OR of the PADS