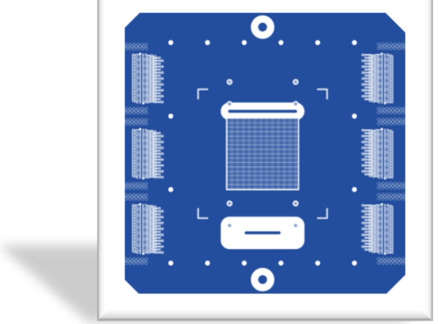
# MPGD_NEXT

Dal 2016 il gruppo di Roma Tre partecipava al Task 3:

**High Performance Micromegas**



GOAL: Development of Resistive Micromegas detectors, aimed at operation under very high rates (~10 MHz/cm$^2$)

- R&D BASIC STEPS:
  - **Optimization of the spark protection resistive scheme**
  - **Implementation of Small pad readout** (allows for low occupancy under high irradiation)
  - **Implementation of integrated electronics (back bonded RO chips)**
- We aim at a pixelized detector with pad size O(mm$^2$).

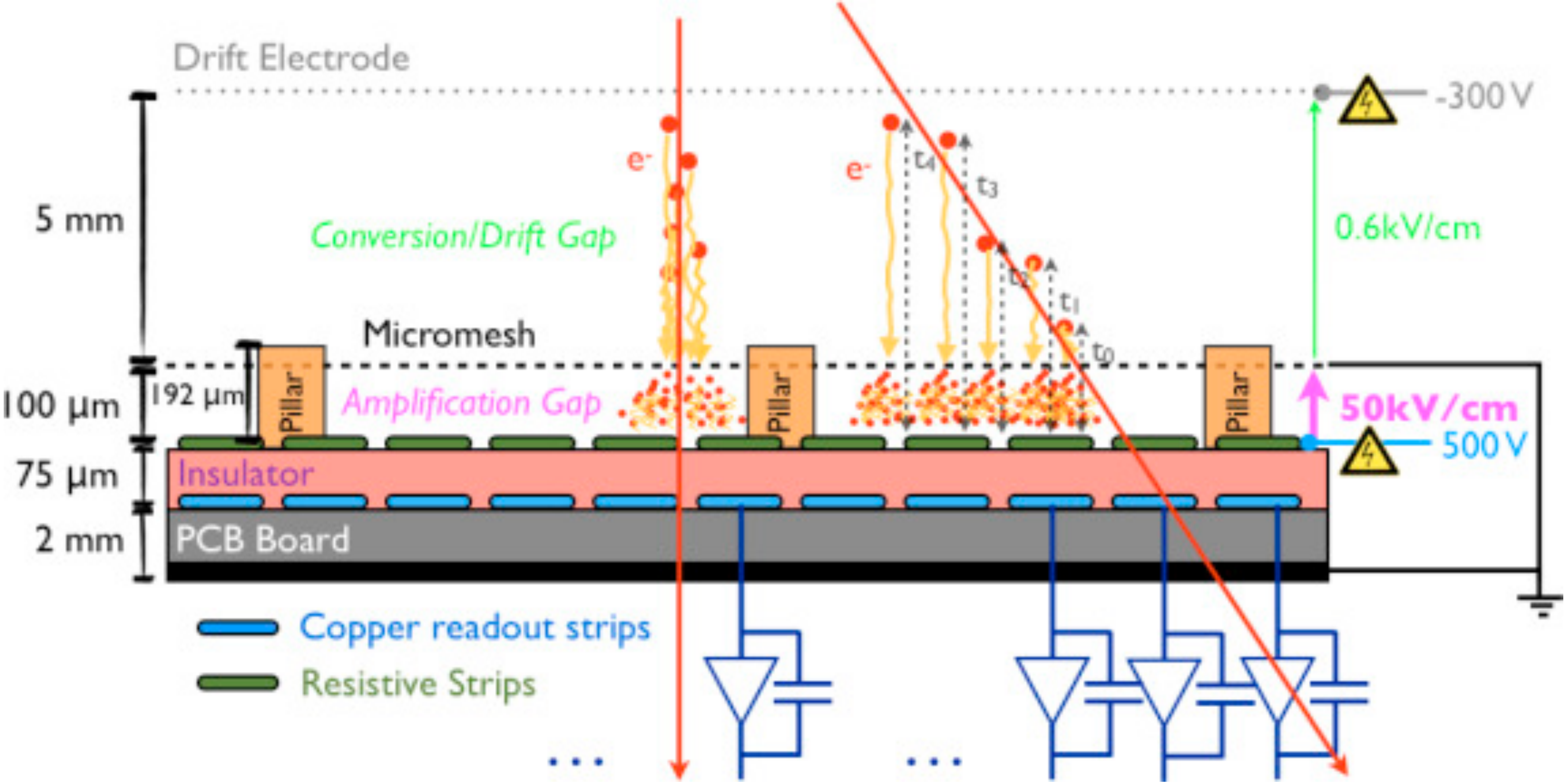
APPLICATIONS:

- Large area fine tracking and trigger with high rate capability (LHC-HL upgrades and Future Colliders)
- Sampling Hadron Calorimetry

PEOPLE:

- Roma Tre: M. Biglietti, M. Iodice, F. Petrucci, E. Rossi, G.Salamanna, M.T. Camerlingo
- INFN NA & LE & CERN: M. Alviggi, V. Canale, M. Della Pietra, C. Di Donato, E. Farina, S. Franchino, P. Iengo, L.Longo, G. Sekhniaidze, O. Sidiropoulou

# Micromegas detector



# Project Timeline MPGD-NEXT 2016-2017-2018-2019

2016

✓ 1. Optimize the design of resistive micromegas with small size pad readout; [succesful]

✓ 2. Optimize the construction; [successful]

2017 + 2018

✓ 3. Optimize the parameter of construction (resistivity,…) and operations (gas mixture,…);
[FIRST successful test with DLC double resistive layer with different resistivities]
[ONGOING TESTs with a NEW DLC prototypes made with PCB standard SBU (Sequential Build technique), taking advantage of the copper-clad DLC foils]

✓ 4. Establish the optimal trade-off between dimensions and channel routing to read-out electronics; [ONGOING Prototype with back-bonded FE chips]

→ DELAYED
Aiming at a final demo at the end of 2019

✓ 5. Establish safe operation up to a rate of O(1MHz/cm$^2$)
[Very Good results up to >100 MHz/cm$^2$ with X-Rays ]

2018 → 2019 → 2020?

6. Construction of medium size prototype (~20x20 cm$^2$) (and cosmics tests)

7. Test-beam and High Irradiation Test

8. Start a process of technology transfer to industries.

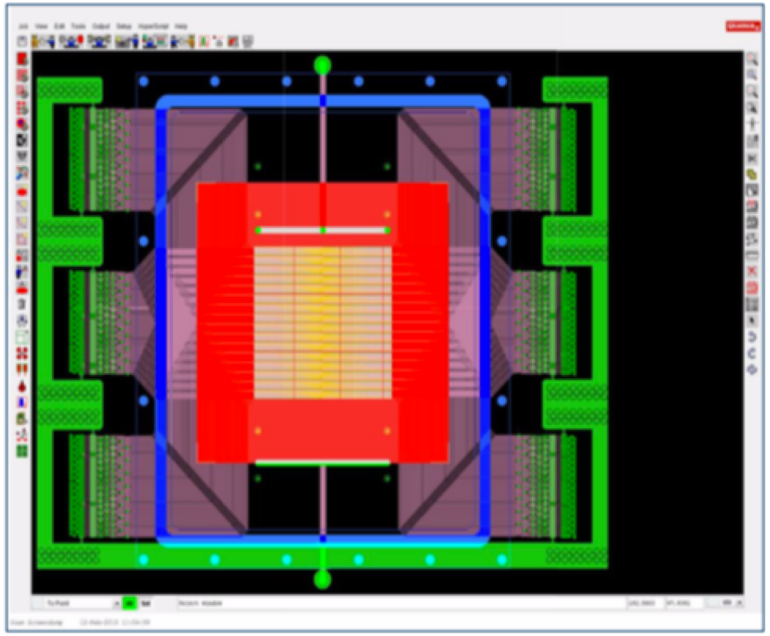
# Detector R&D : Small Pads Resistive micromegas

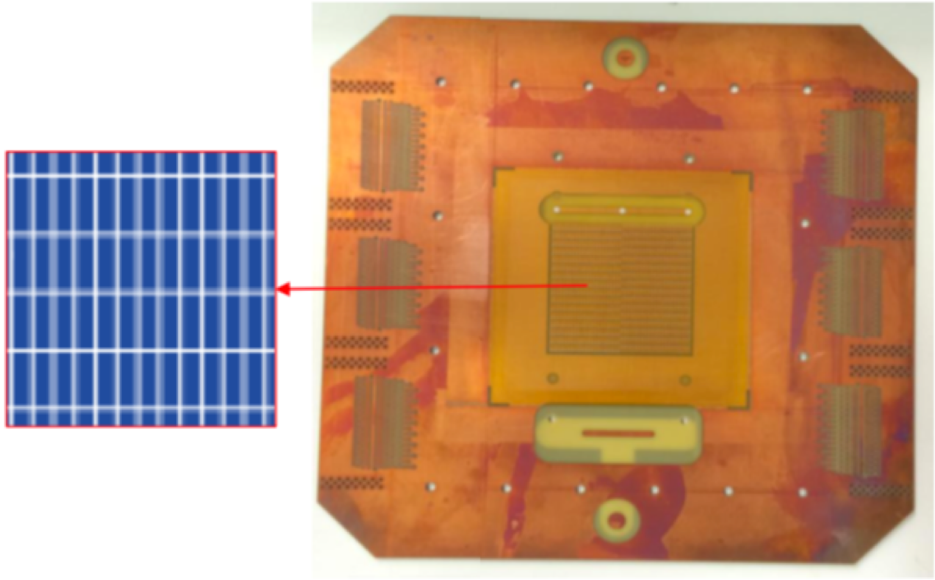
Layout of the common anode for all the small pad prototypes:

- Matrix of 48x16 pads;
- Each pad: 0.8mm x 2.8mm;

(pitch of 1 and 3 mm in the two coordinates);

- Active surface of 4.8x4.8 $cm^2$ with a total of 768 channels.



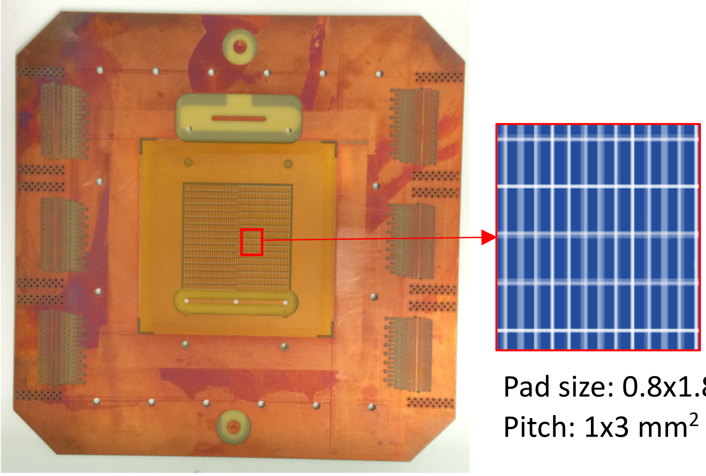


# Two different implementations of the Resistive layer

Two series of small pad resistive micromegas prototypes built so far with **pad dimension 3 mm²**.

The two series differ for the implementation of the resistive protection system against discharges :

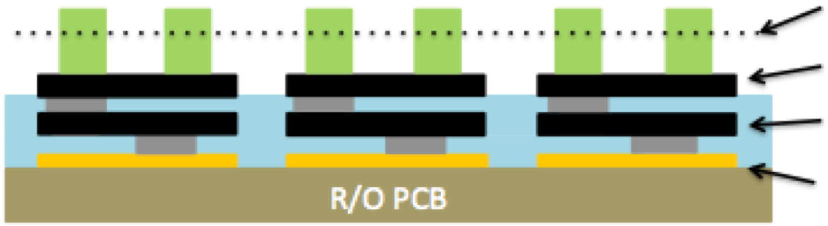
DETECTOR LAYOUT



Pad size: 0.8x1.8 mm²
Pitch: 1x3 mm²

## Side view of SERIES 1 prototype:

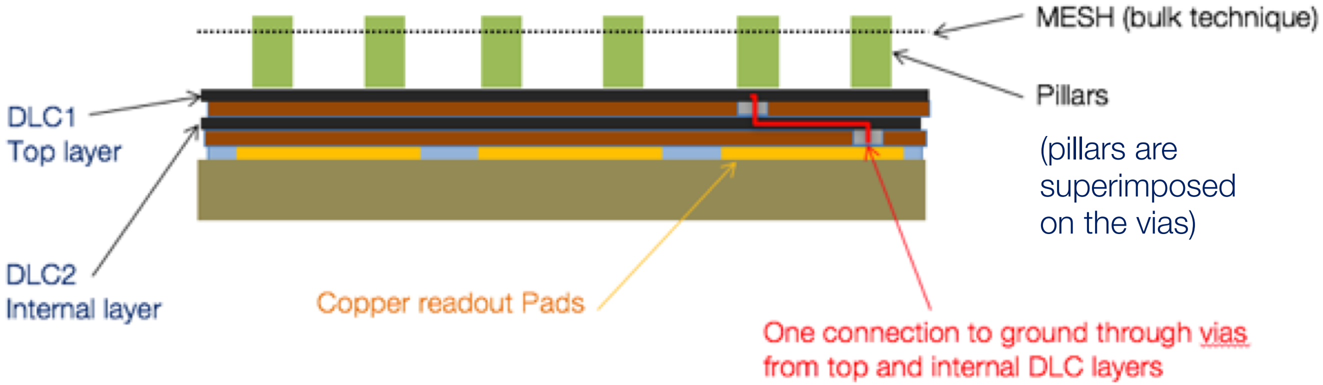
PAD-Patterned resistive layer (screen printing)




Resistive pad to anode pad Resistance: ~3-7 MOhm

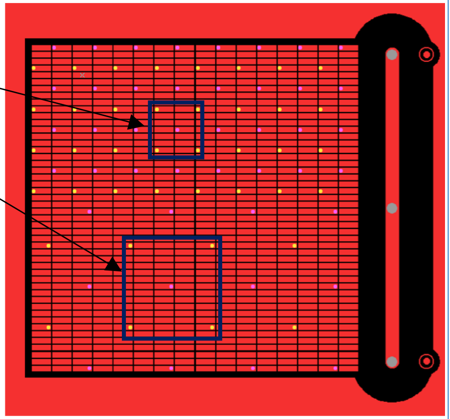
## Side view of SERIES 2 prototype:

Double DLC (Diamond Like Carbon) uniform resistive layer a' la uRWell (see G.Bencivenni et al. 2015_JINST_10_P02008




grounding vias every 6 mm

grounding vias every 12 mm



2 Prototypes tested with different DLC Foils:

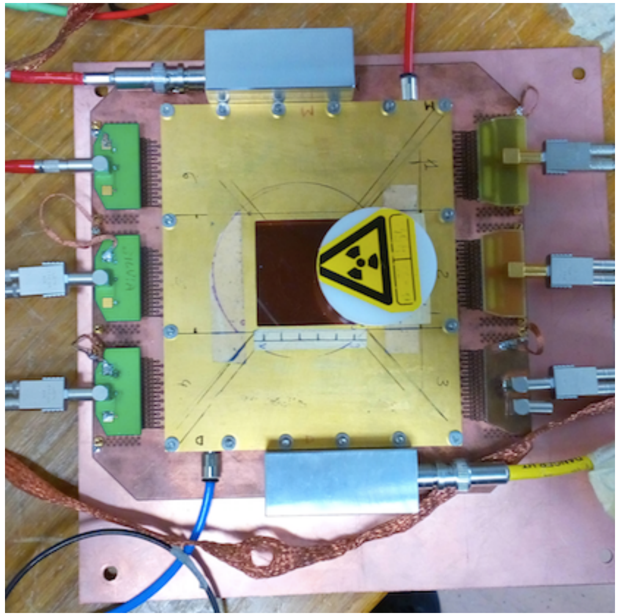
- High ~50-70 MOhm/sq (DLC50)
- Low 20 MOhm/sq (DLC20)

# Characterization of the detectors

**Measurements with sources and X-rays**

Two radiation sources have been used:

- $^{55}Fe$ sources with 2 two different activities
  - "Low activity" (measured rate ~1 kHz)
  - "High activity" (measured rate ~100 kHz)
- 8 keV Xrays peak from a Cu target with different intensities varying the gun excitation current



Gas mixture: $Ar:CO_2$ 93:7

$^{55}Fe$ source

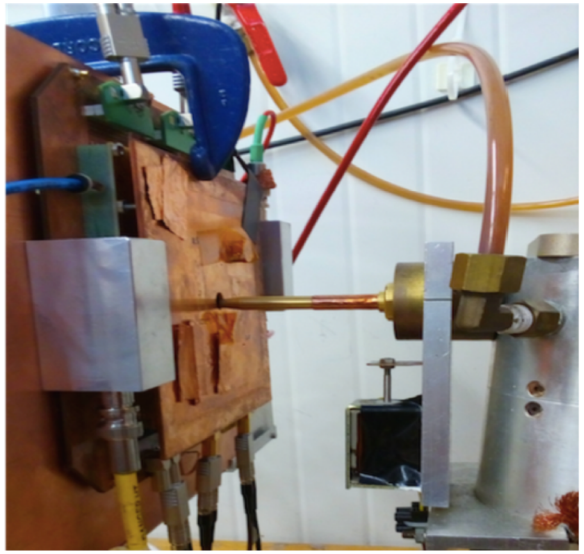
**Gain** measured with different methods

- Reading the detector current from readout pads OR from the mesh with a picoammeter and counting signal rates from the mesh
- Signals amplitude (mesh) from a Multi Channel Analyser

At High Rates (with X-Rays):

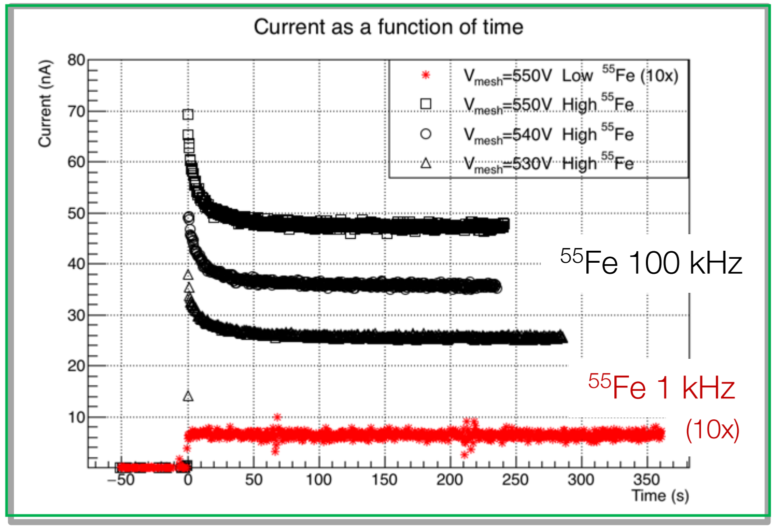
- Rates measured at low currents of the X-Ray gun
- Extrapolating Rate Vs X-Ray-current when rates not measurable reliably anymore

Xrays Gun

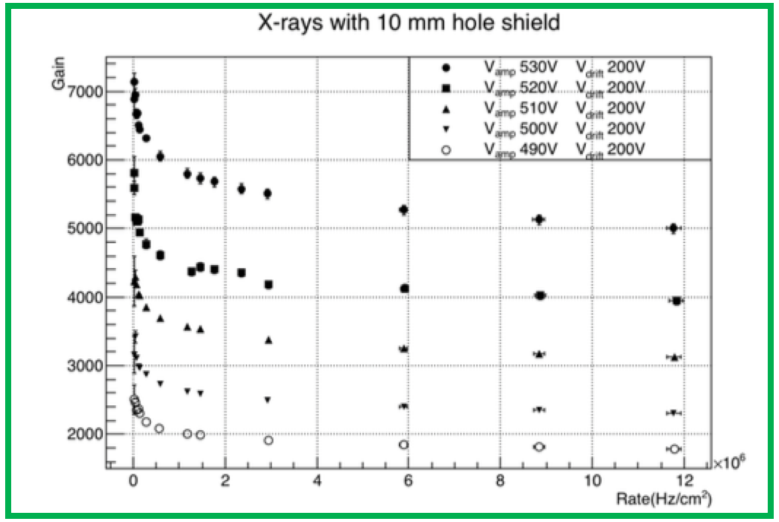


# Summary of PAD-P Results

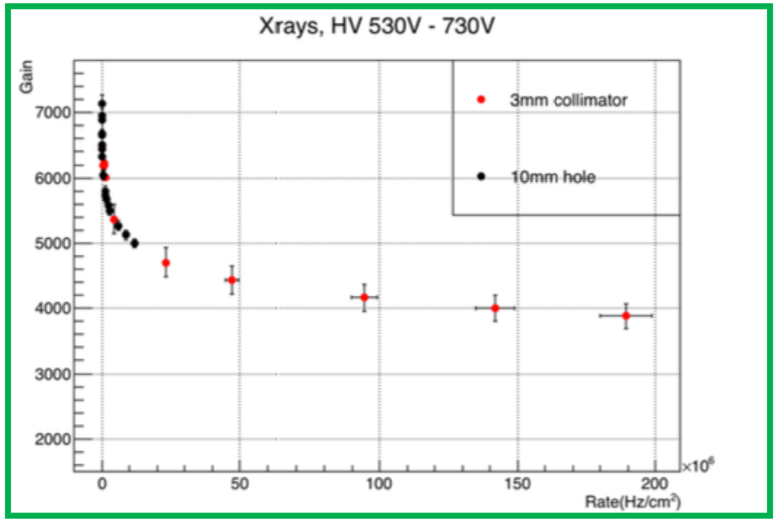
M. Alviggi, et al. *"Construction and test of a Small-Pads Resistive Micromegas prototype"*, JINST 13 (2018) no.11, P11019



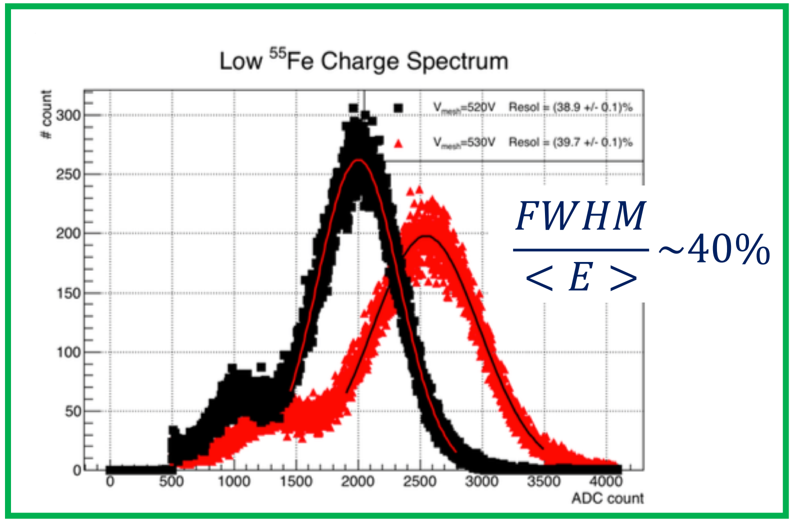

Reduction vs time of the detector current with High intensity $^{55}$Fe source [CHARGING-UP]




Gain reduction ~30% up to 12 MHz/cm$^2$ [CHARGING-UP + Ohmic Voltage Drop]

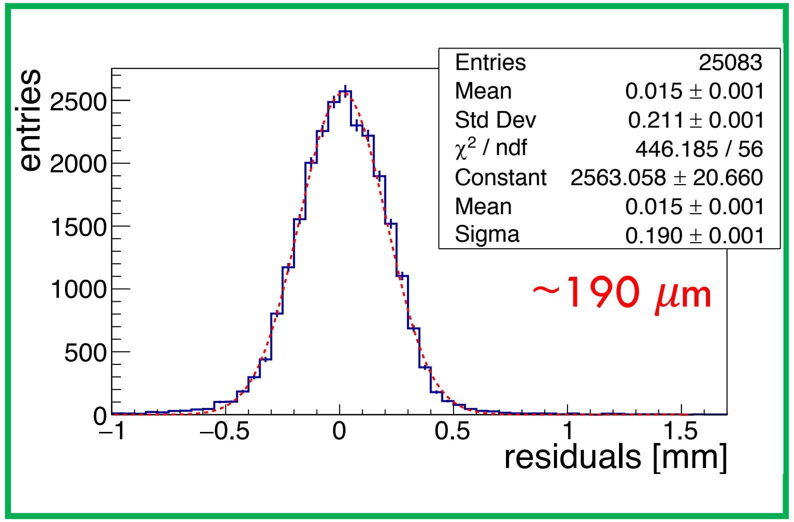



Gain drop increases as rate goes up.
**Still able to reach gain of $4\times10^3$ at a rate of 150 MHz/cm$^2$ of 8 keV photons**

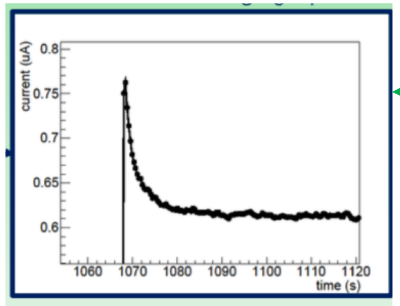



Modest Energy resolution

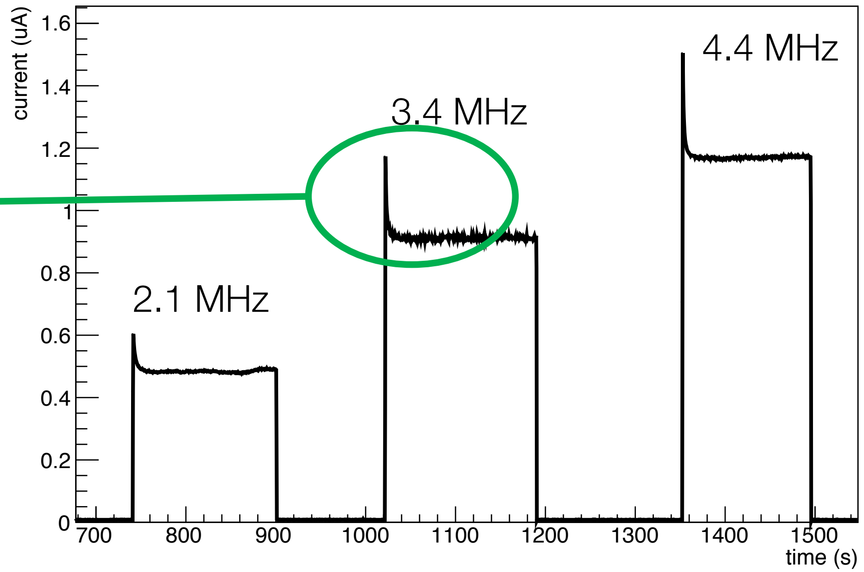
TEST-BEAM
spatial resolution along the "precision coordinate" (1mm pad-pitch)
~190 µm



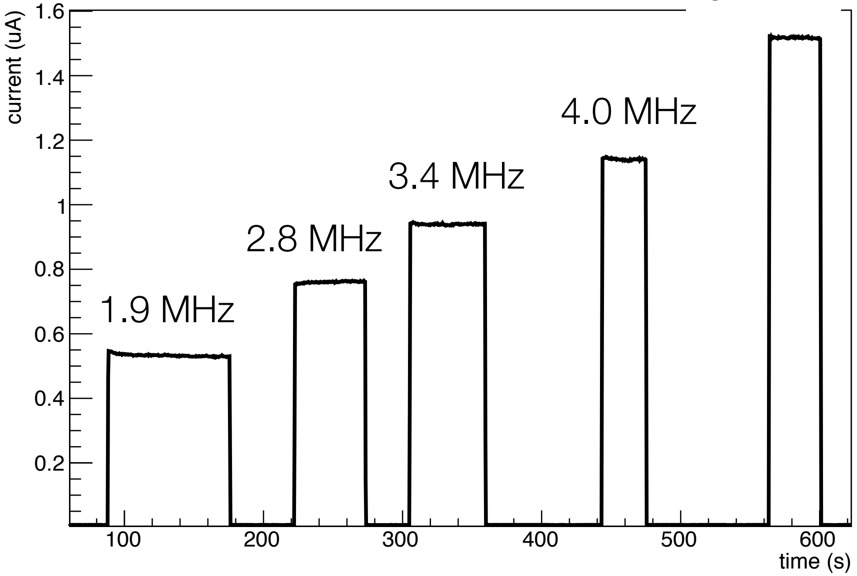
# PAD-P vs DLC – Charging-up effect




PAD-P AT 527 V



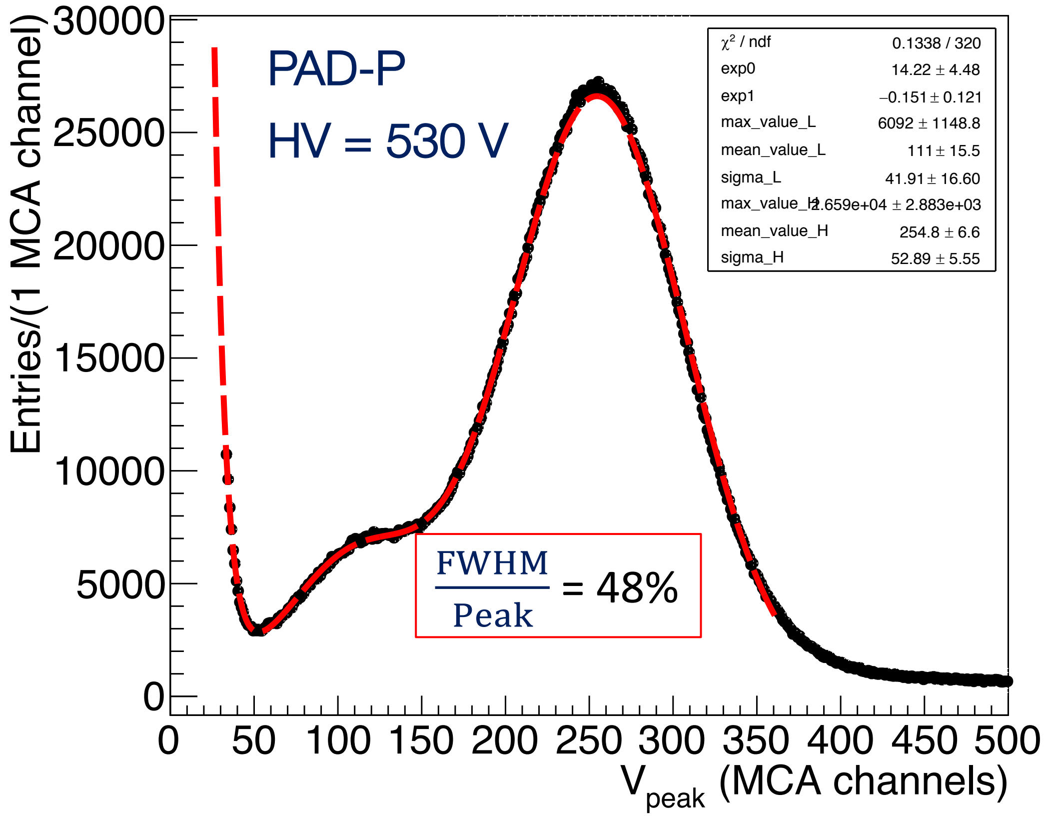

DLC50 AT 504 V

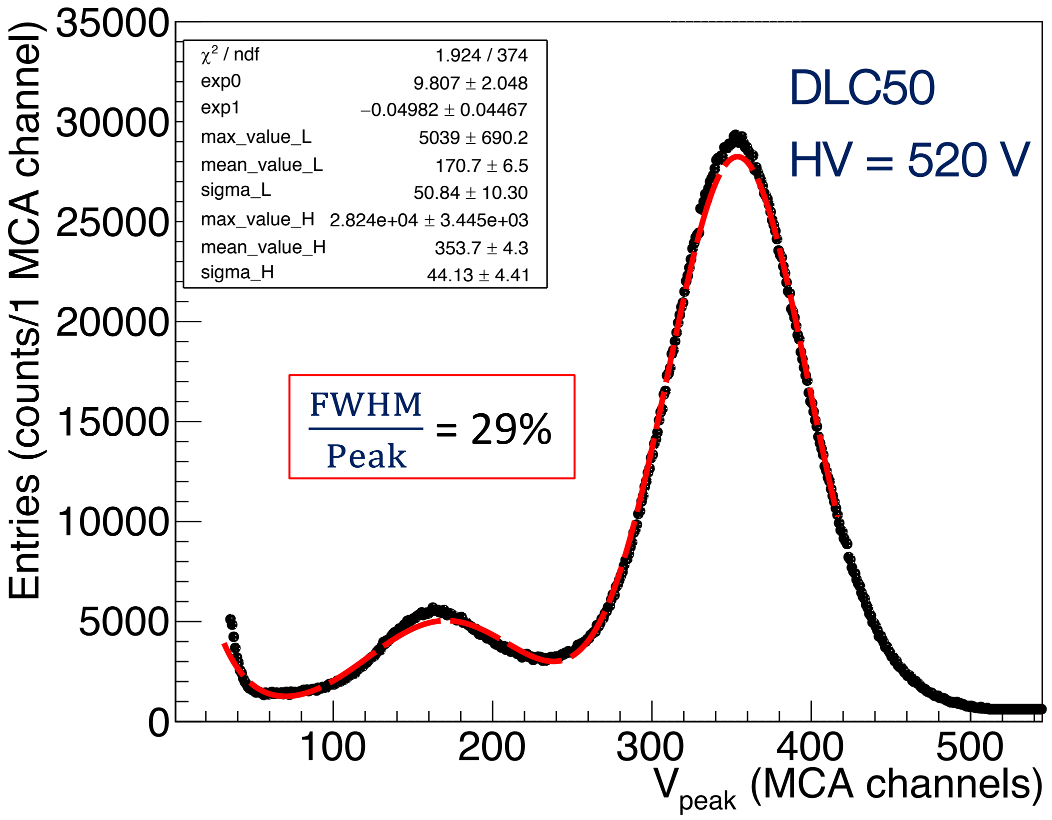



Current measurement Vs Time with X-Rays on/off and increasing rate (X-Ray current) at each step

- PAD-P response compatible with dielectric charging-up of exposed Kapton surroundings the resistive pads
- DLC detectors (both DLC20 and DLC50) do NOT show any charging-up effects (expected from the uniformity of the resistive – no exposed dielectric, with the exception of the pillars)

# PAD-P vs DLC – Energy Resolution



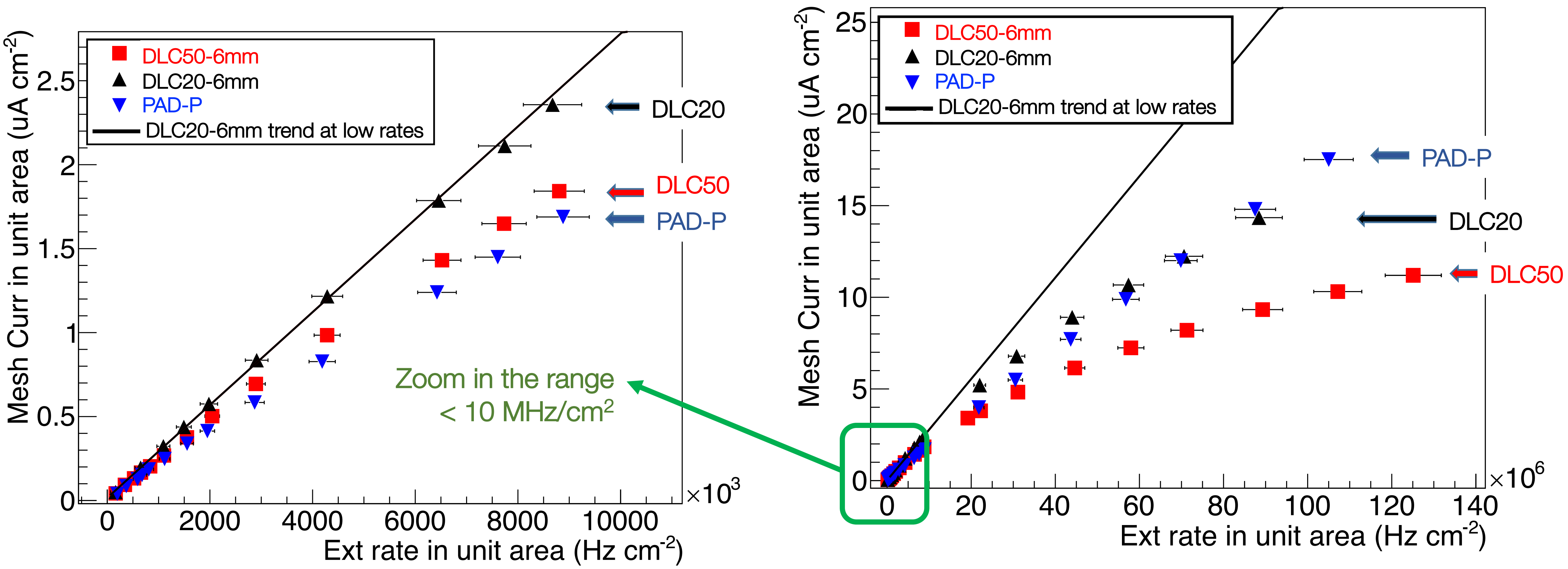




DLC prototypes have much better energy resolution

- more uniform electric field
- no pad border effects

# PAD-P, DLC20-6mm, DLC50-6mm

X-rays Exposure area 0.79 $cm^2$ (shielding with 1cm diameter hole)




DLC20-6mm shows a significantly better behaviour than DLC50-6mm (LOWER RESISTIVITY)

PAD-P below DLC for rates < 10 MHz/cm2 (charging-up+Ohmic drop)

**PAD-P and DLC20-6mm have a comparable behaviour in the explored region (up to ~90 MHz/cm2)**

- Similar voltage drop

As expected DLC20 better than DLC50 (due to lower resistivity)

# Test Beam SPS H4 at CERN – SETUP

## SPS H4 CERN 2016, 2017

Beam: muons/pions 150 GeV/c (low/high rates)

- Prototypes Tested:

  PAD-P, DLC50

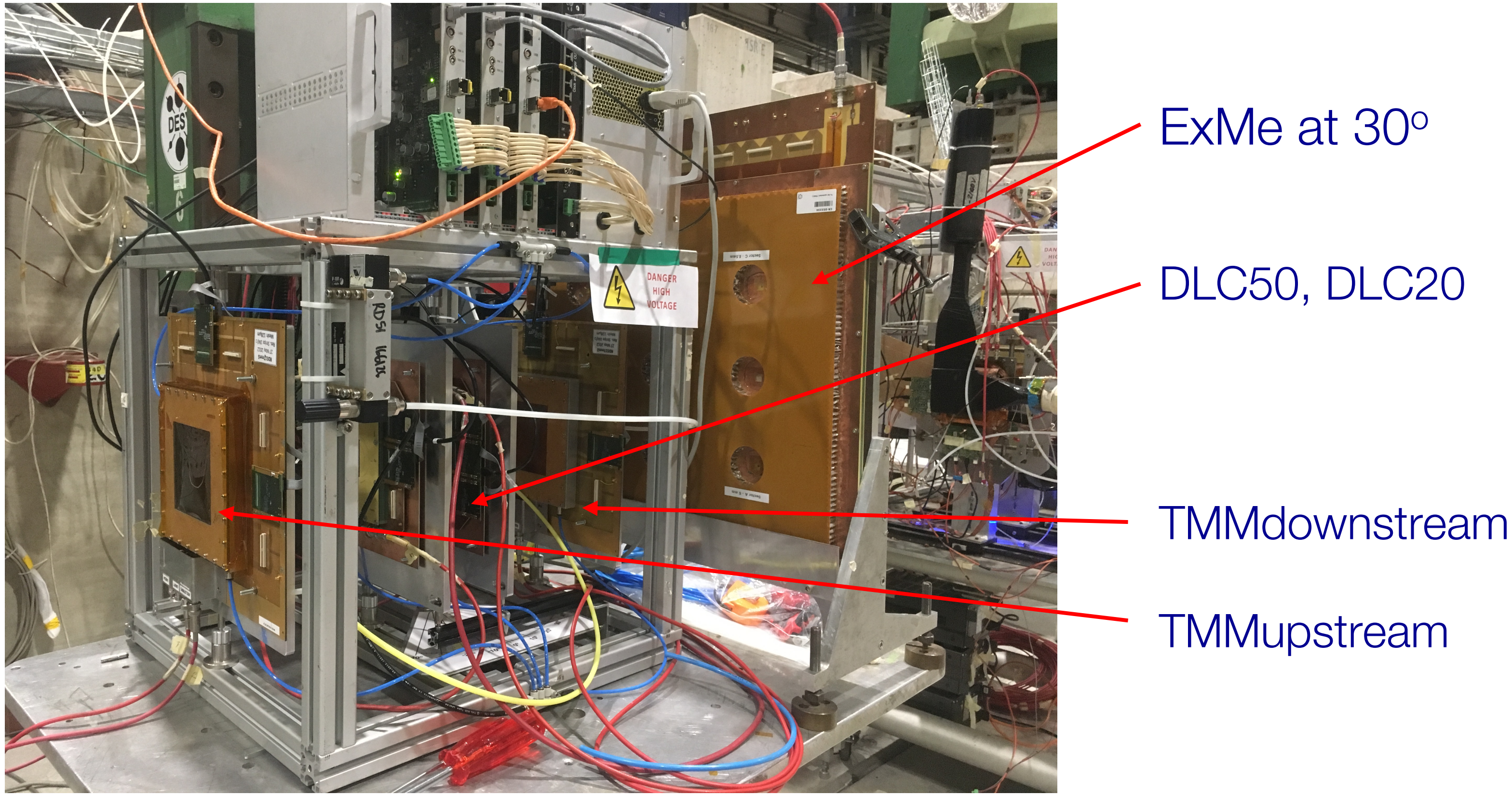
(see M.Alviggi, et al. JINST 13 (2018) no.11, P11019)

## SPS H4 CERN OCTOBER 2018

Beam:

- $1^{st}$ period: muons/pions 150 GeV/c
- $2^{nd}$ period: pions 80 GeV/c
- Prototypes Tested:

  DLC20, DLC50

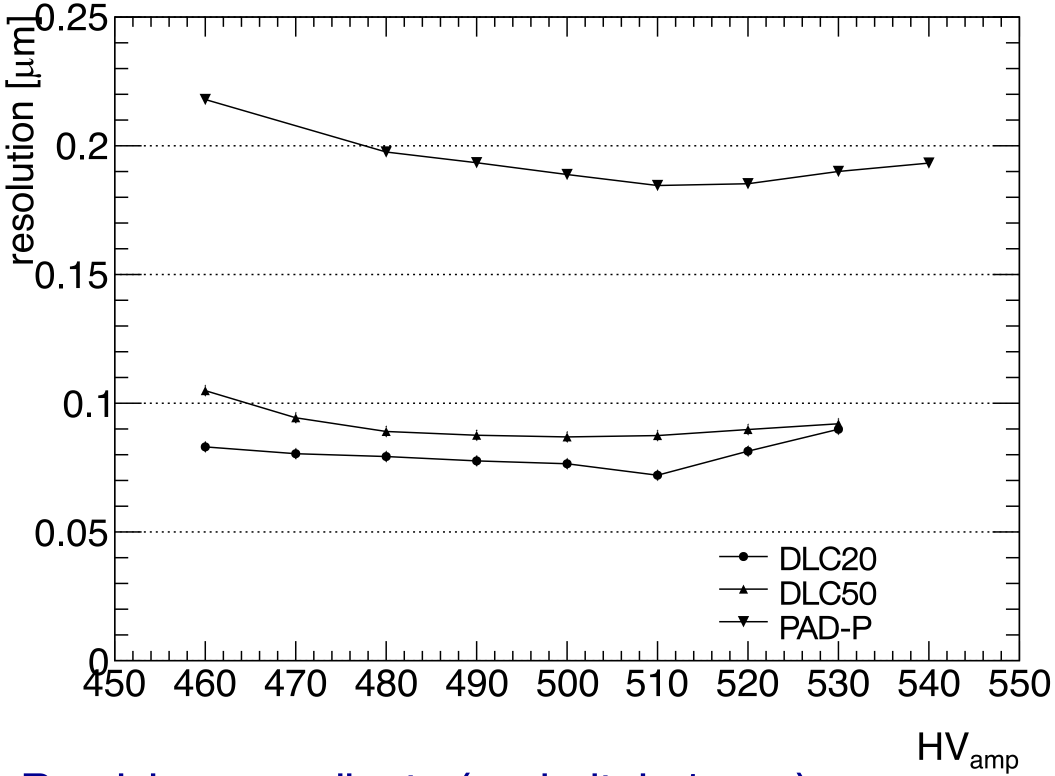



OCTOBER 2018 SETUP: Chambers under test: DLC50 (50-70 MOhm/sq), DLC20 (20MOhm/sq), ExMe

- Tracking system: 2 Tmm strips micromegas (x-y readout) for external tracking
- Operating gas on DLC20, DLC50: Ar:CO2 93:7 Gas studies on ExMe: Ar:CO2 93:7 and 85:15 – Ar:CO2:Iso 88:10:2 (Poster Maxence Vandenbroucke)
- Scintillators for triggering
- DAQ: SRS + APV25 with custom DAQ

# Spatial Resolution and cluster-size

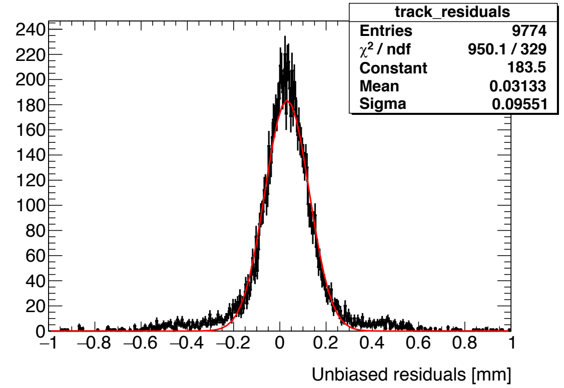
**Position resolution:**
difference between the cluster position and the extrapolated position from external tracking chambers.




Precision coordinate (pad pitch 1 mm)

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

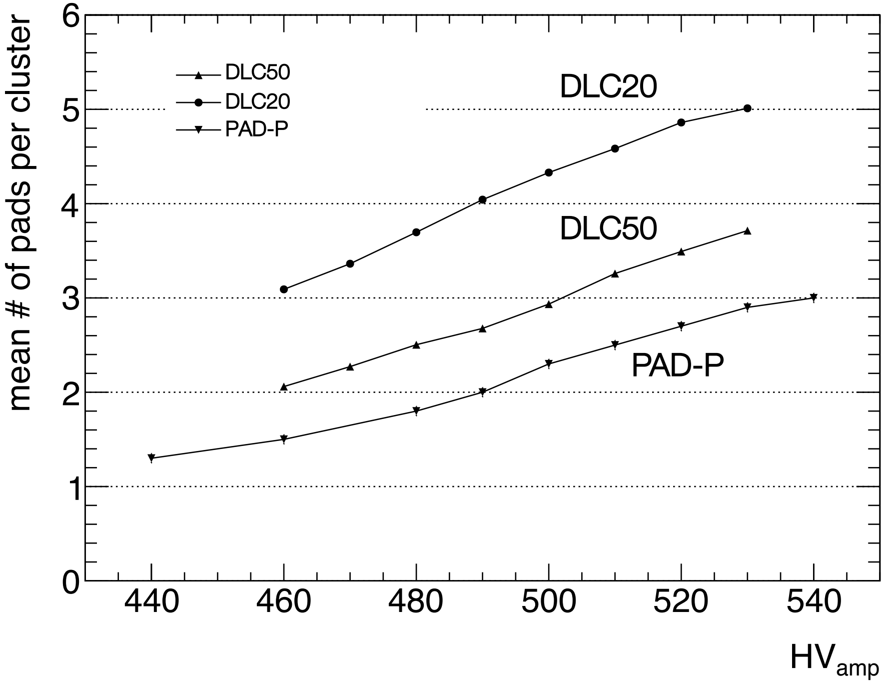
- More uniform charge distribution among pads in the clusters




Unbiased Residuals of DLC20 at 510 V

$$\sigma_{resol} = \sqrt{\sigma_{resid}^2 - \sigma_{track}^2}$$

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

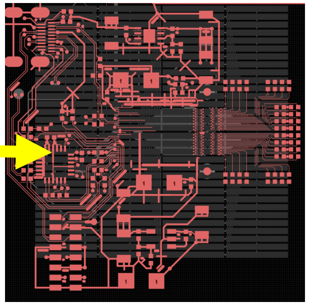



Cluster-size for all prototypes vs HV

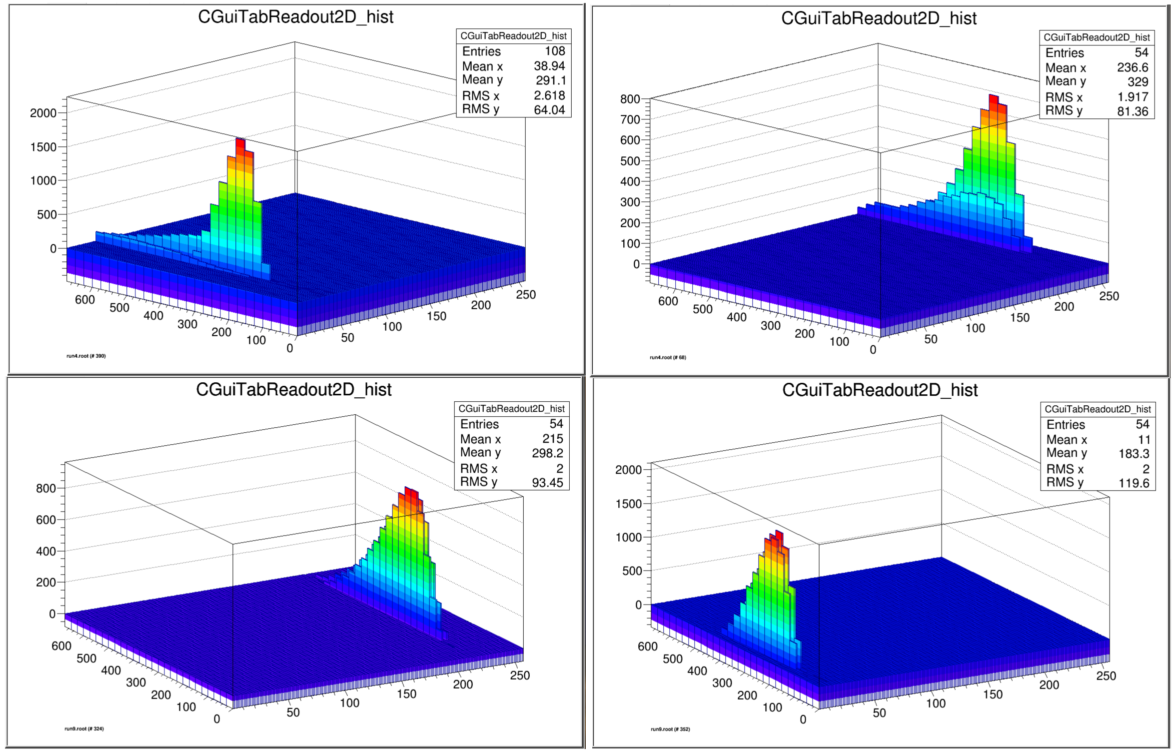
- Larger Cluster size for DLC due to uniform layer. Larger clusters for lower resistivity (DLC20 Vs DLC50)

# the prototype with Integrated Electronics


- Prototype with integrated electronics on the back-end of the anode PCB built to solve the problem of the signal routing when scaling to larger surface
- APV FE Layout implemented



APV FE Layout




First tests look promising:

- Nice Pedestals structure and signal response from APV using Fe55 source and random trigger for DAQ → BUT ONBLY on some channels
- We know the reason (issue in the elx Layout → fixing it in the next proto !

# Activities up to December 2019

1. Test of the integrated electronics prototype
2. Test of the new DLC-Layer prototype

Test beam @ PSI September-October 2019

- Molti obiettivi del task raggiunti con successo (o lo saranno nei prossimi mesi);
- risultati pubblicati su JINST e NIM e riportati a molte conferenze;
- il rivelatore finale di medie dimensioni è in fase di progettazione;
- il progetto sviluppato in ambito MPGD_NEXT è alla base di nostre proposte di finanziamento sia in Aida2020++ che in una call RD51 del CERN.

→ *Abbiamo chiesto al Presidente di CSN5 e ai referee di mantenere la sigla MPGD_NEXT, magari sotto Dotazioni, per il 2020:*

- *come contenitore per questi progetti;*
- *come piccolo finanziamento (5 kEuro) per il completamento del rivelatore di medie dimensioni.*

# Activities foreseen in 2020.

**Resources:**

- Small contribution from CSN5 (5kE requested)
- Call RD51 Common Project?
- AIDA2020++?

**Manpower (Anagrafica RM3):** M. Iodice (10%), F. Petrucci (10%), M.T. Camerlingo (10%), M.Biglietti (10%)

**Activity:**

- Finalize DLC prototype design with optimal performace;
- Finalize embedded electronics design;
- IF (additional founding) then : construction and test of medium size prototype (~20x20 $cm^2$)

# BACKUP

# Comparison of different configurations

| | PAD-P | DLC50-6mm | DLC50-12mm | DLC20-6mm | DLC20-12mm |
|---|---|---|---|---|---|
| **Configuration of the Resistive layer** | Pad-patterned screen printed resistive layers with embedded resistors | DOUBLE DLC foil with resistivity ~50-70 MOhm/sq | | DOUBLE DLC foil with resistivity ~20 MOhm/sq | |
| **Connection to ground** | Each pad through Embedded resistor R~3-6 MOhm | 6mm pitch of grounding vias | 12 mm pitch of grounding vias | 6mm pitch of grounding vias | 12 mm pitch of grounding vias |

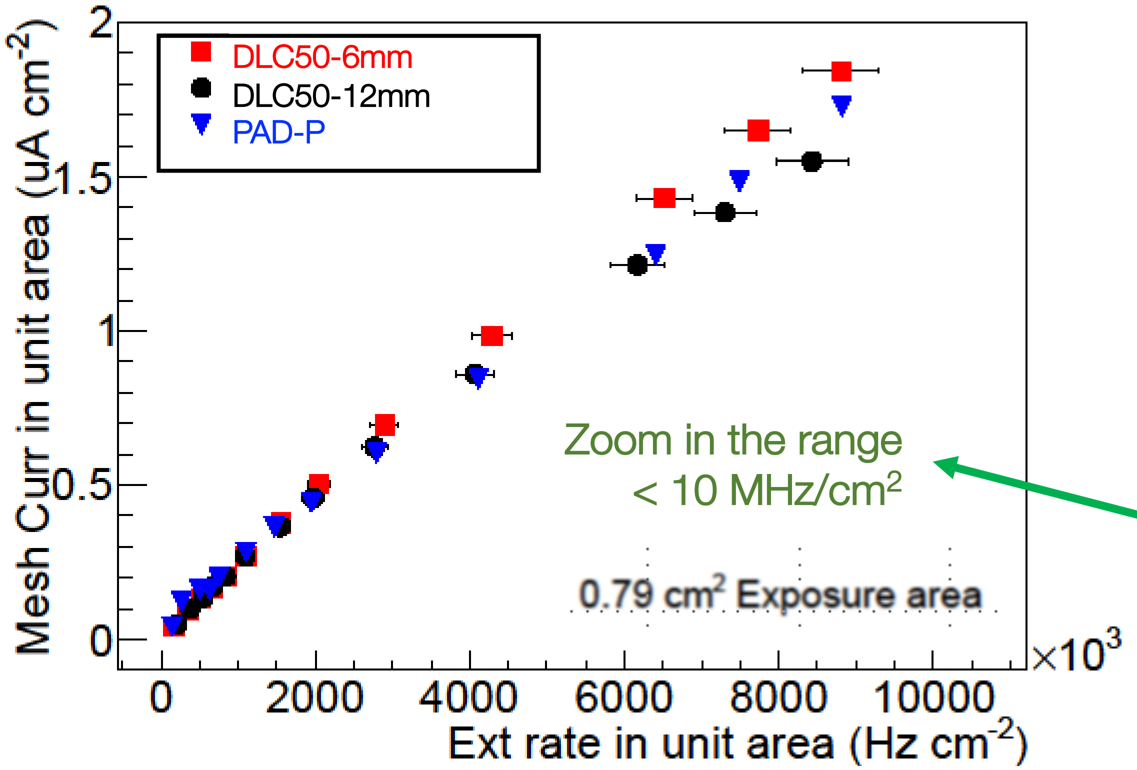
In the following:

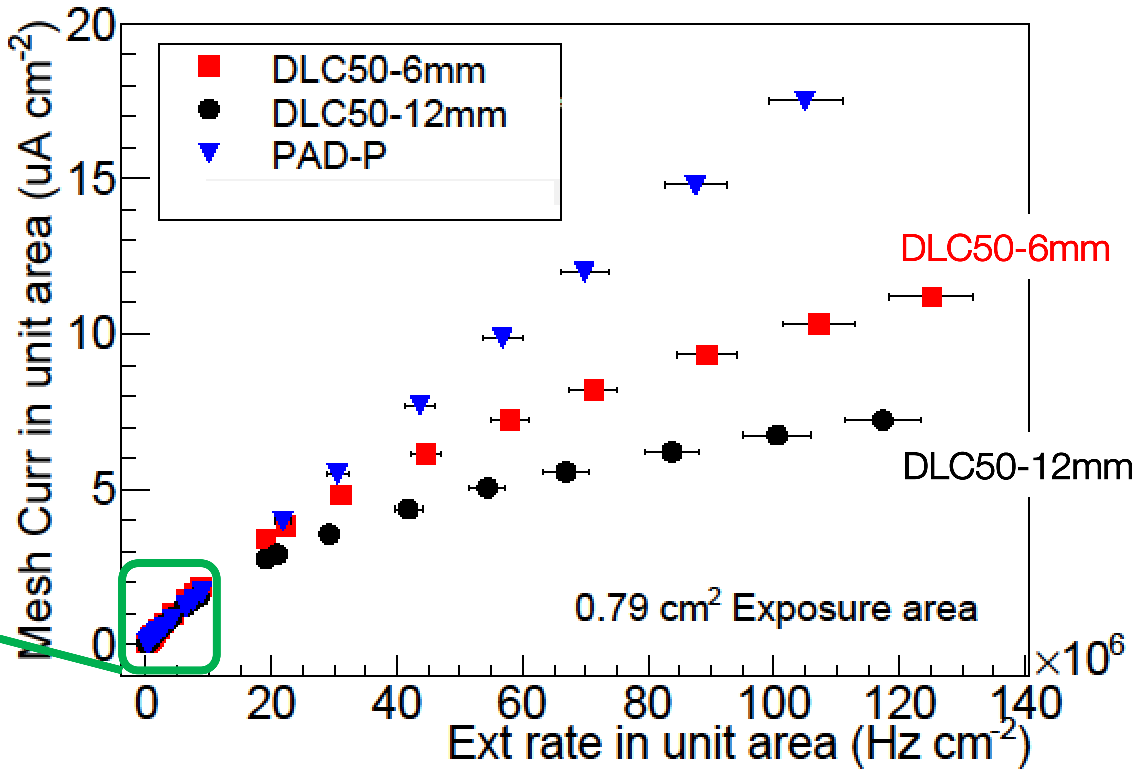
- All detectors tested with Ar/CO2 93/7, and Vdrift = 300 V;  The drift gap is 5 mm
- Detectors Comparison at High rates done with **SAME GAIN** conditions
  - PAD-P HV = 527 V
  - DLC20 HV = 510 V
  - DLC50 HV = 504 V

  } G ~ 8000 (at 100kHz)

# High Rates – PAD-P vs DLC50-6-12mm

X-rays Exposure area 0.79 cm² (shielding with 1cm diameter hole)




No significant differences among PAD-P and DLC50 below 10 MHz/cm2

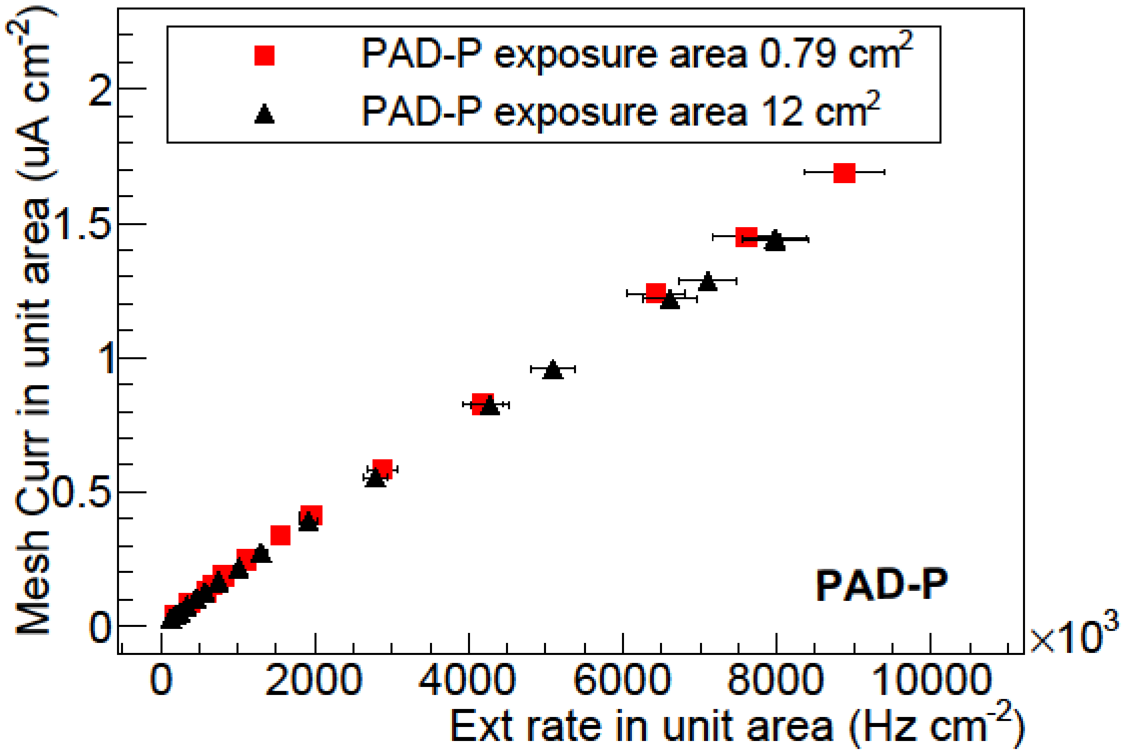
PAD-P: still a good behaviour up to ~100 MHz/cm2

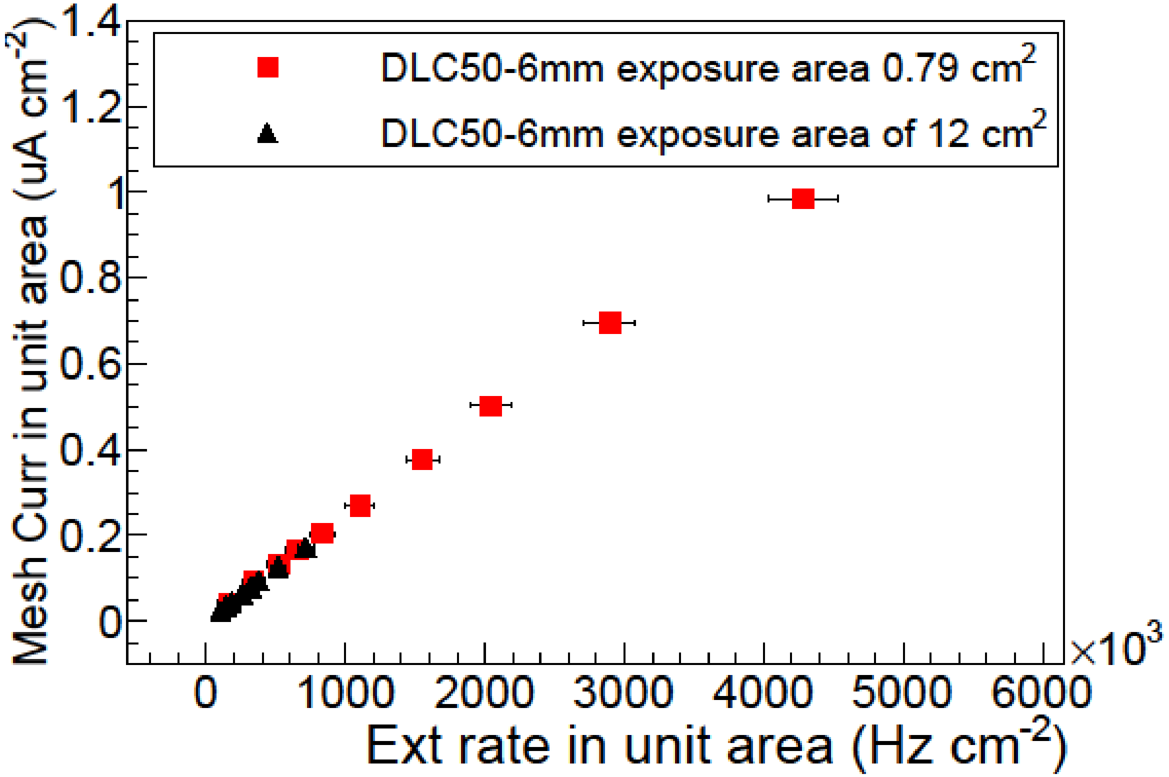
DLC-50:

- Onset of voltage drop due to high current/high resistance.
- Clear difference between the regions with 6mm and 12 mm grounding vias pitch

# Dependence on the exposed area

PAD-P X-rays exposure area 0.79 $cm^2$ and 12 $cm^2$




PAD-P: Response to illumination on 0.79 $cm^2$ and on 12 $cm^2$ does not show any significant difference up to the measured limit of ~8 MHz/cm2

(total current was ~18 uA, close to the limit of the power supply)

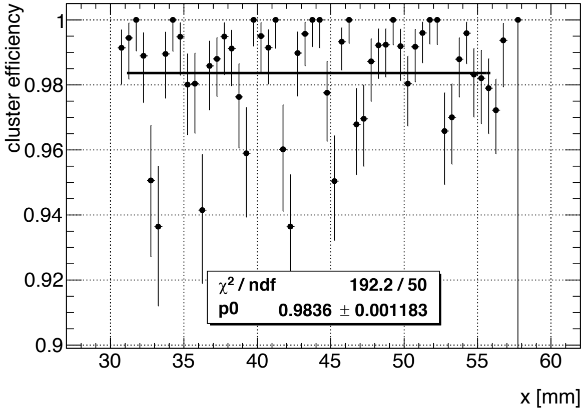
Measurements limited at 700 kHz/cm2

No significant difference between 0.79 $cm^2$ and 12 $cm^2$ up to the measured limit of ~700 kHz/cm2

- Measured range limited to 700 kHz/cm2 by onset of discharges

Unfortunately, due to discharges, no data for DLC20

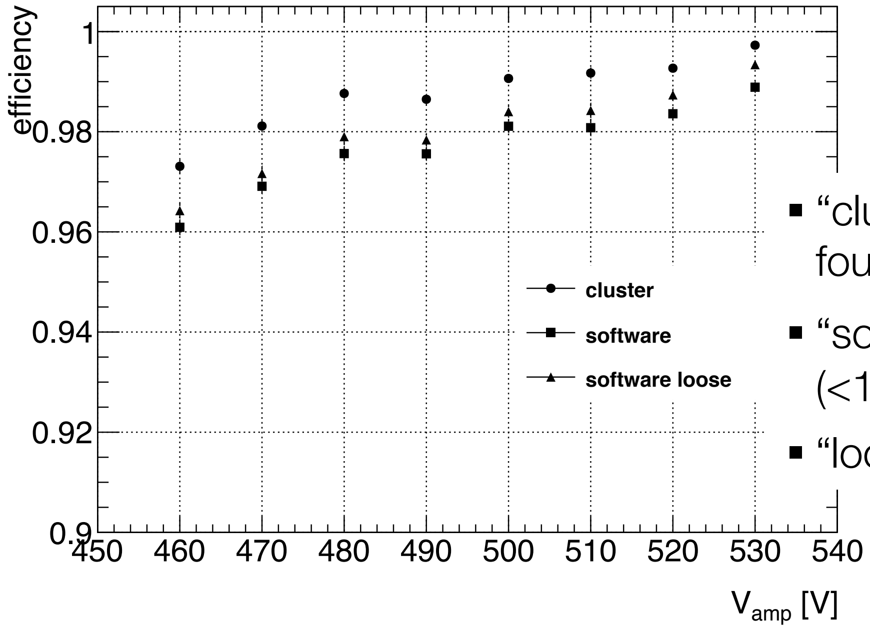
# TB Results - Efficiencies




Cluster Efficiency of DLC50 @ 500 V
Vs extrapolated track impact position

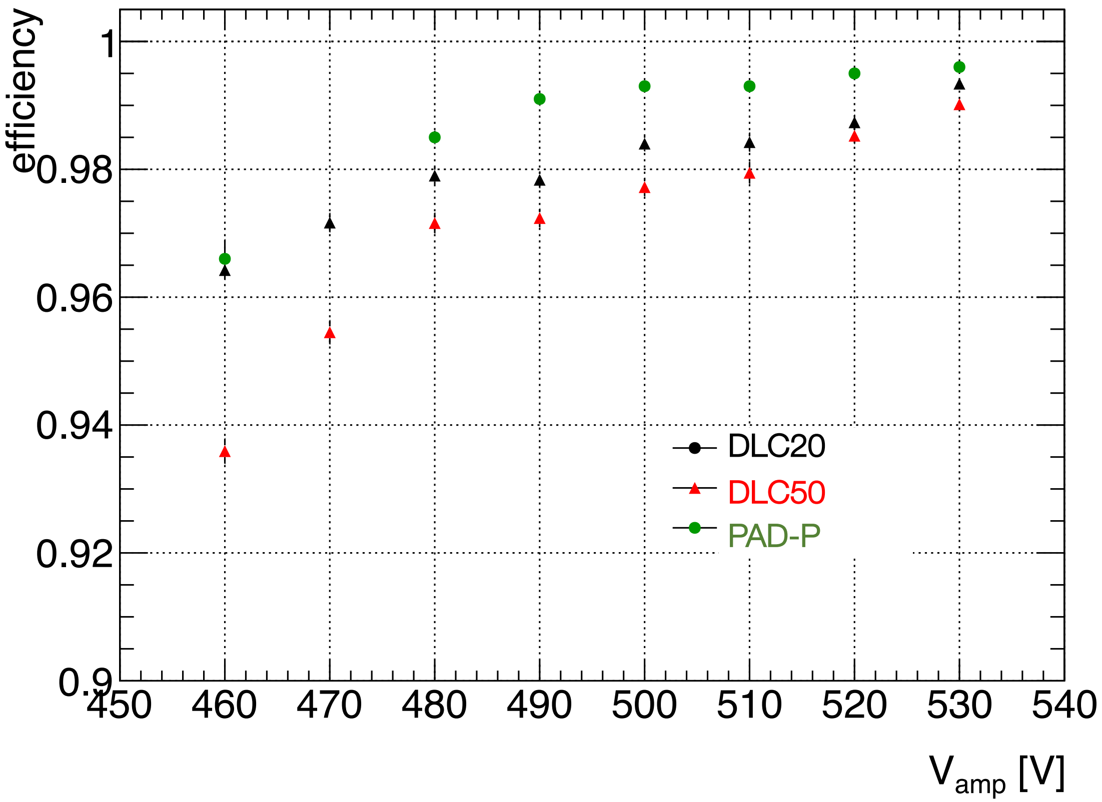
- Inefficiencies are clearly seen in correspondence of pillars.
- These inefficiencies decrease with HV

“Cluster” and “software” efficiencies for DLC20 Vs HV




- “cluster”: any cluster found in the detector
- “software”: within 5σ (<1mm) from the track
- “loose” within 1.5 mm

EFFICIENCY Comparison of all chambers (software-loose)




Differences at the level of 1% still under investigation.
Possible causes:
different gains, different charge spread and cluster-size, ...