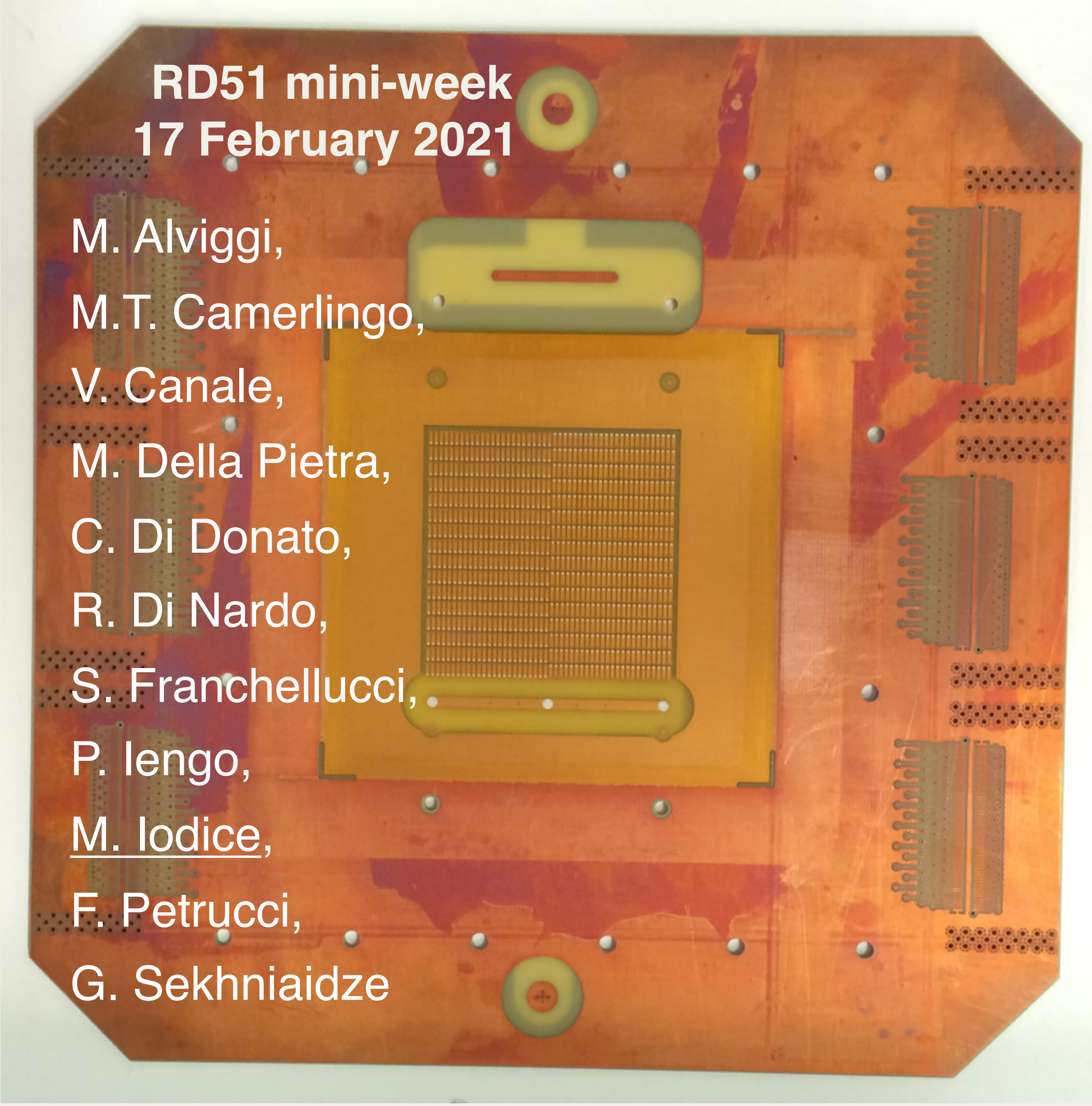
RHUM

Resistive High granUlarity Micromegas

Development of resistive Micromegas detectors with high granularity readout (small pad / pixels) for high rate applications

RECENT UPDATES based on the work of **S. Franchellucci** and **M.T. Camerlingo**



RD51 mini-week
17 February 2021

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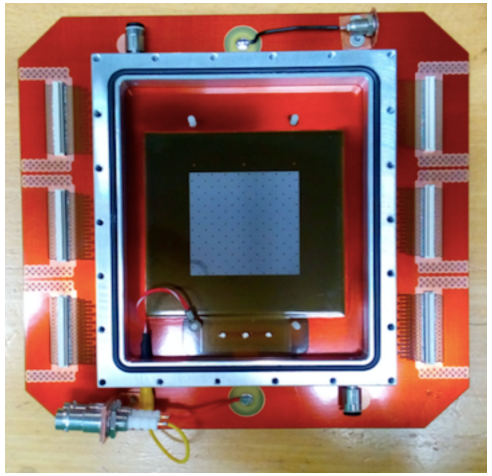
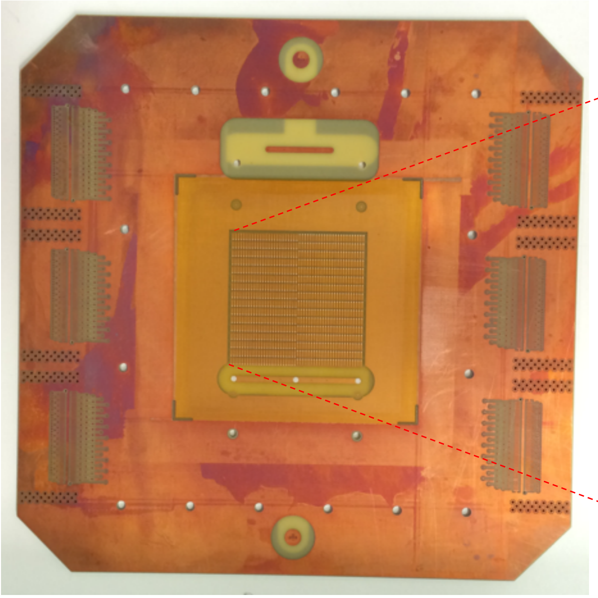
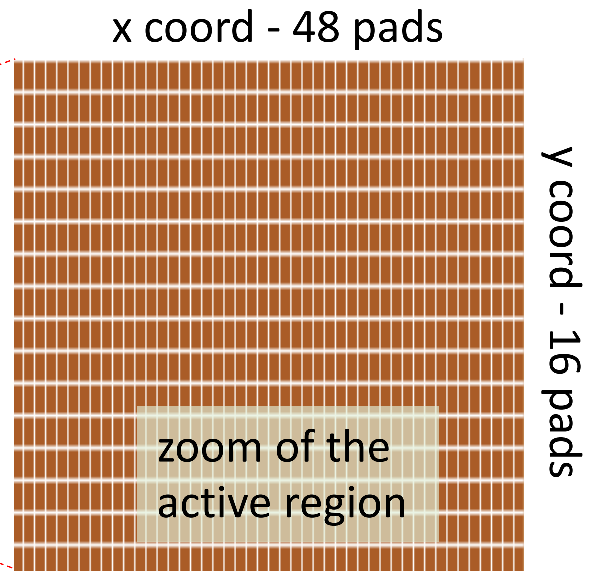
Small Pad Resistive Micromegas



Reminder on the layout

- Matrix of 48x16 pads – 768 channels
- Each pad: 0.8mm x 2.8mm - pitch of 1 x 3 mm^2
- Active surface of 48x48 mm^2



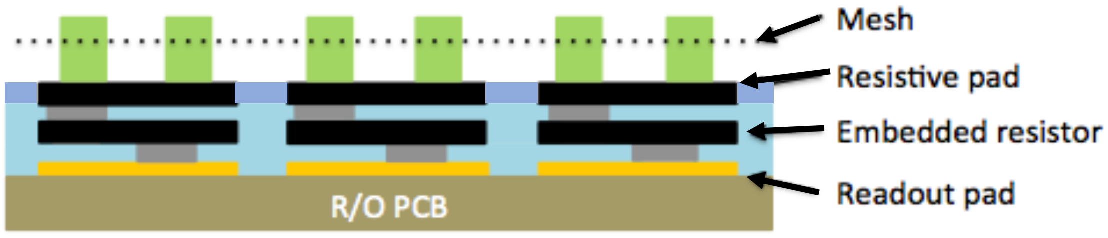


Two different implementations of the Resistive layer

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

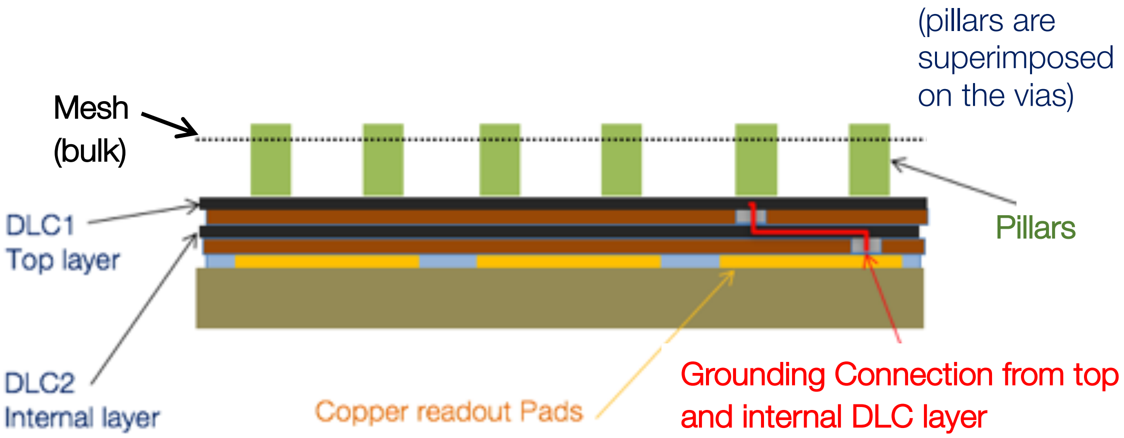
Different implementation of the resistive protection system against discharges :

PAD-Patterned resistive layer



- Embedded resistors by Screen-Printing
- Resistive pads by paste filling of photoimaging created vessels
- each pad is totally separated from the others, for the anode, as well as for the resistive part

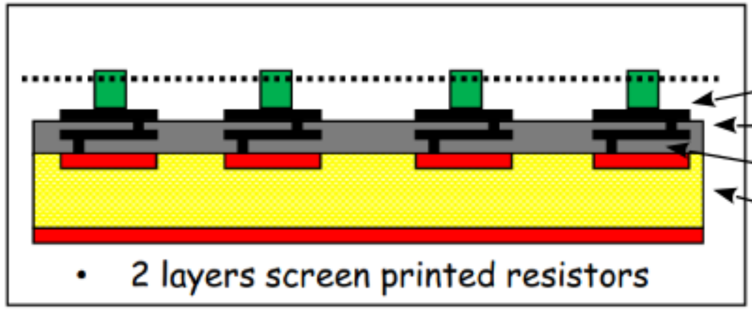
Double DLC (Diamond Like Carbon) uniform resistive layer



- Same concept of uRWell
  (see G.Bencivenni et al. 2015_JINST_10_P02008)
- Double DLC layer with connection vias to ground every “few” mm

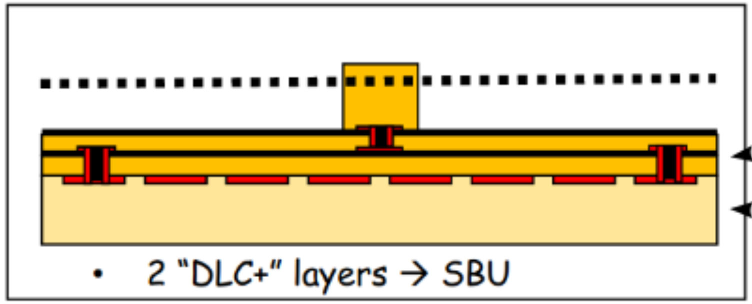
and a New "Paddy" PROTOTYPE

PAD-P2
(Embedded resistor)



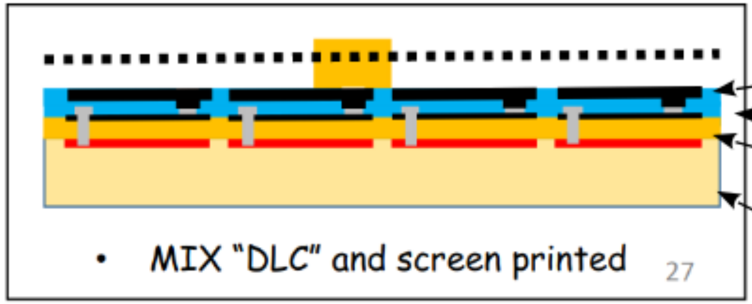
top resistive pad
coverlay insulator
embedded resistive pad
PCB with copper readout pads

SBU1 and **SBU2**
(DLC plane layout)



DLC planes
+ polyimide insulator
PCB with copper readout pads

PAD-P3
(Embedded layout, mixed construction technique)



top resistive pad
coverlay insulator
segmented DLC plane
+ polyimide insulator
PCB with copper readout pads

[from Rui De Oliveira "INSTR 2020"]

…waiting for more SBU prototypes from Rui

WE WILL COMPARE:

- THE NEW **PADDY3** PROTOTYPE WITH
- **DLC20** (double layer 20 MOhm/sq DLC - the best performing DLC type so far)

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

Gain measurement methods:

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

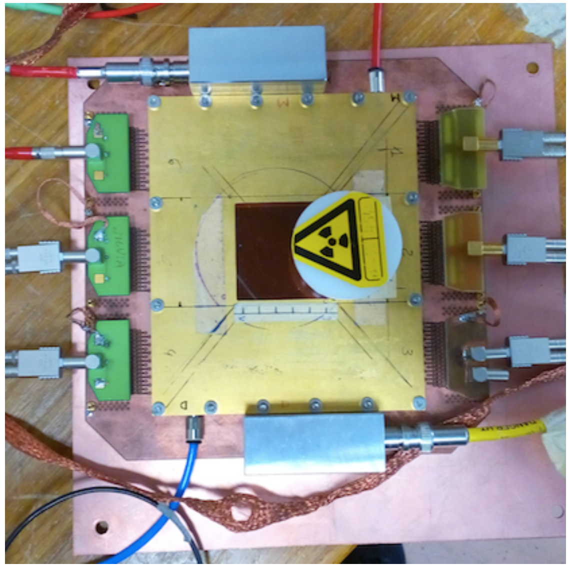
At High Rates (with X-Rays):

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

Gas mixture:

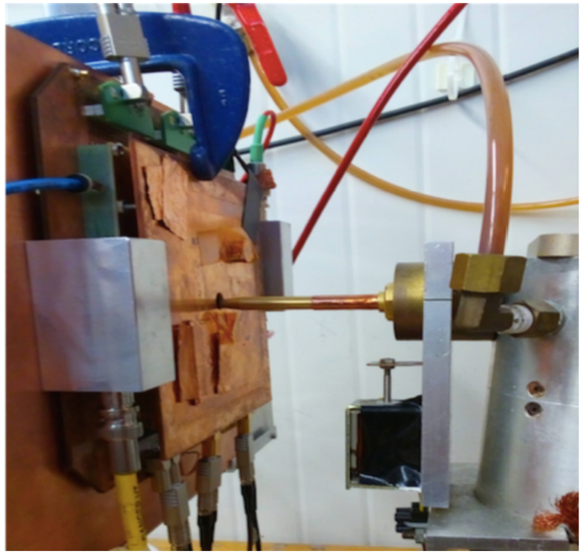
$Ar:CO_2$ 93:7

Chosen as the safest gas to operate under high irradiation for long time



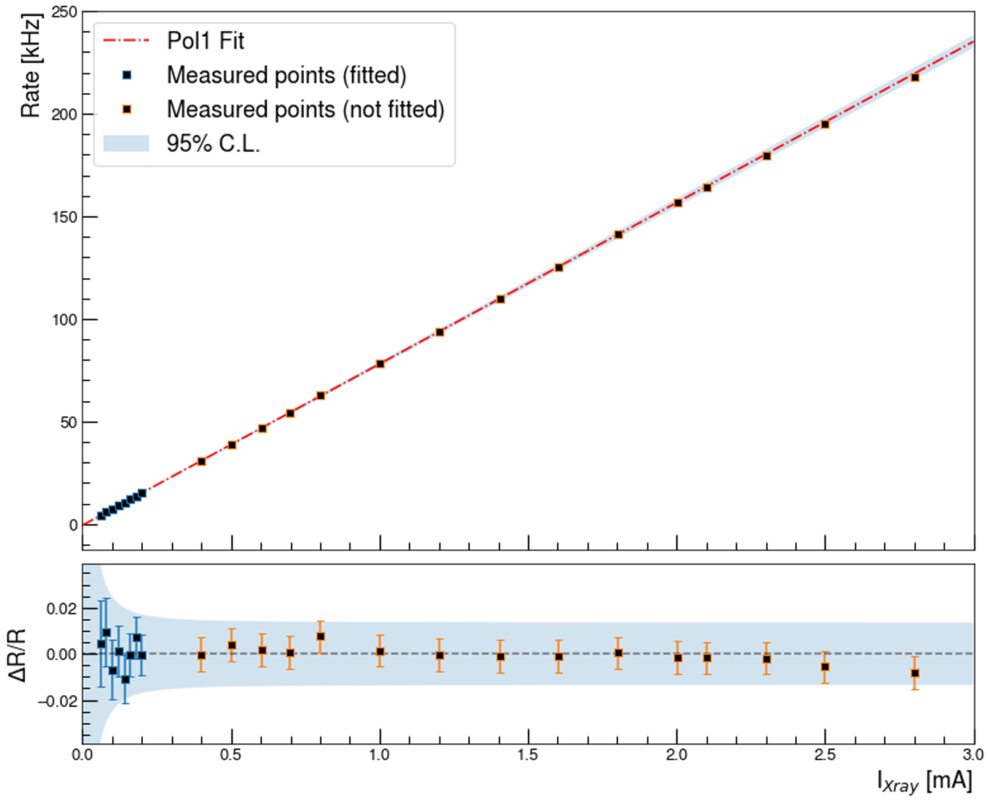
^{55}Fe source

Xrays Gun



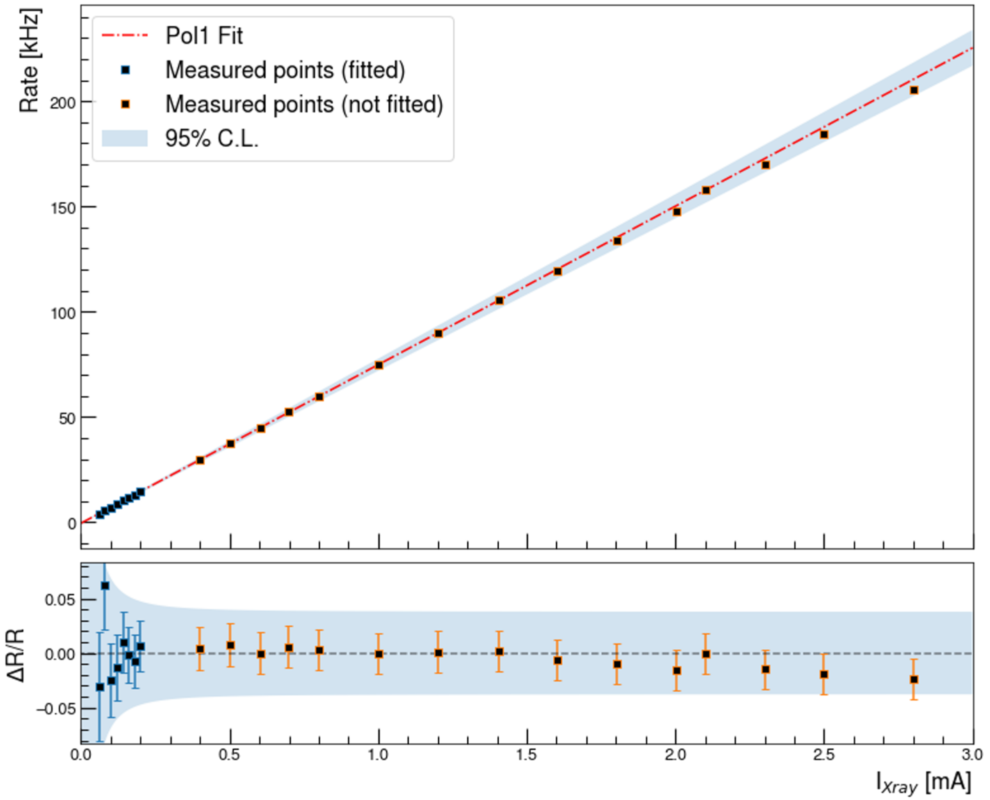
X-rays Linearity and Rates Extrapolation

Rates Vs I_{XRays} on Paddy3 with Cu absorbers on the X-ray gun



Rates measured with MCA accounting for deadtime

Very good linearity and perfect extrapolation from 0.2 to 2.5 mA

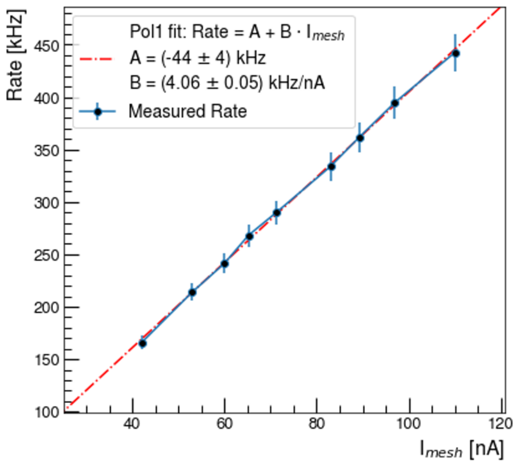


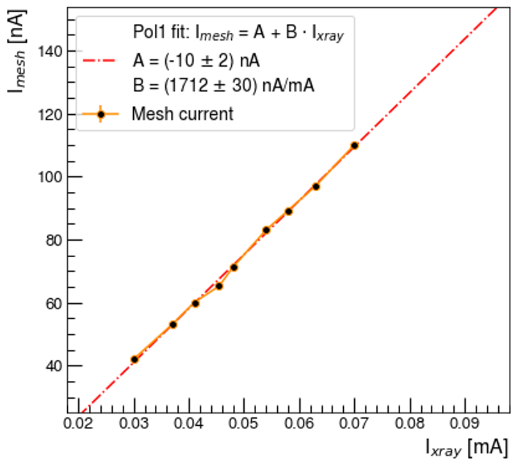
Rates measured with a discri+scaler

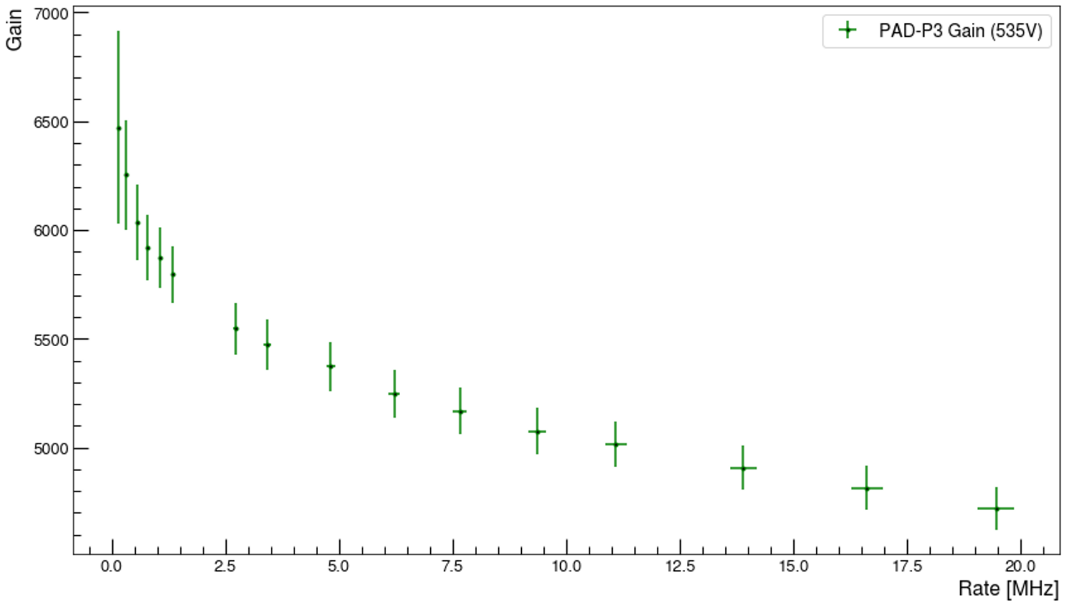
Deviations due to pile-up observed for rates >150-200 kHz

X-rays High Rates Measurements – Paddy3

Cu absorbers removed from the X-ray gun – all measurements with a mask of 1 cm Ø





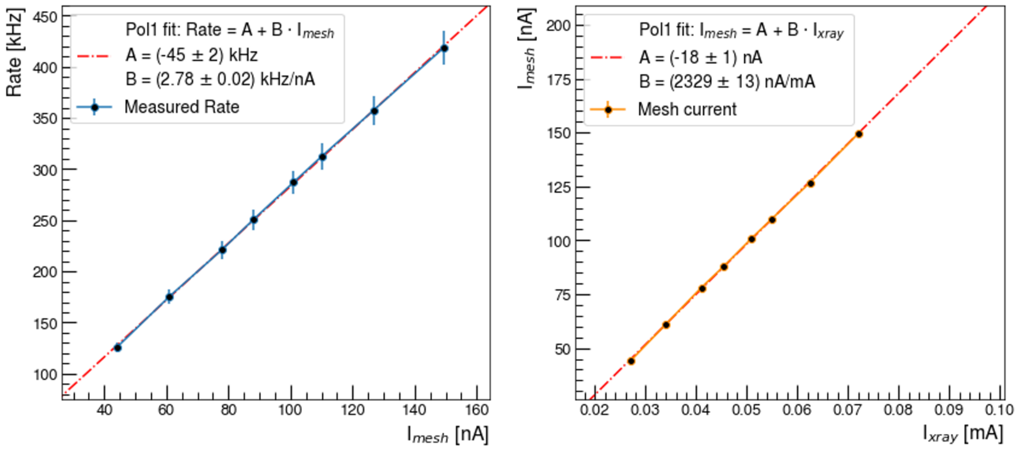


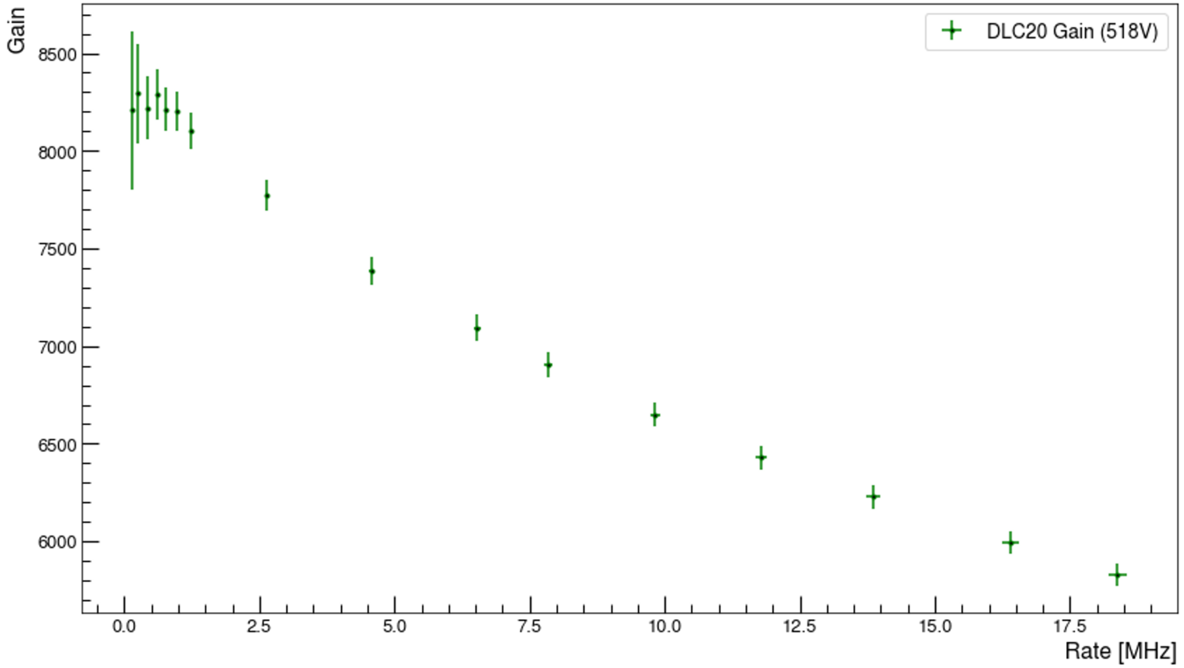
- Double linear fit: Rate Vs I_{mesh} and I_{mesh} Vs I_{xrays}
- Rate extrapolation from I_{mesh} in the linear region
- Measurements at high rates removing all possible impedances (e.g. preamplifier)

- Significant gain drop for "low rates" as was observed on Paddy predecessor (Paddy2 – see e.g. INSTR2020)
- Drop at Low rates is dominated by charging-up
- About 25% gain drop from ~100 kHz/cm2 to 20 MHz/cm2 (consistent with data on Paddy2)

X-rays High rates measurements – DLC20

Same as before – all measurements with a mask of 1 cm Ø

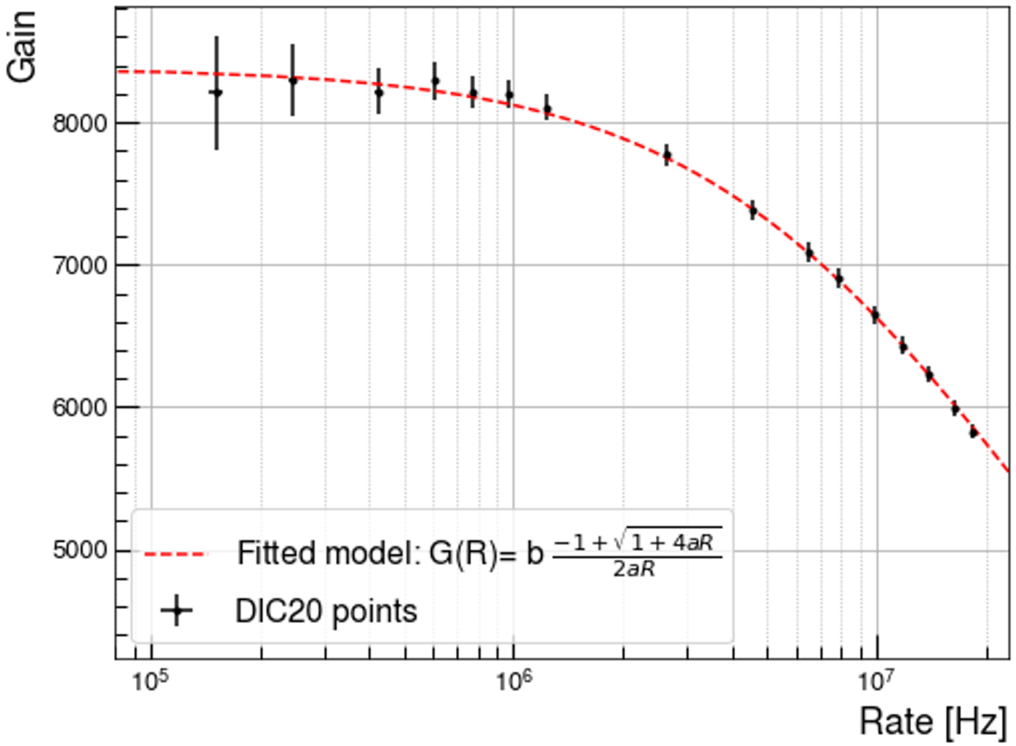


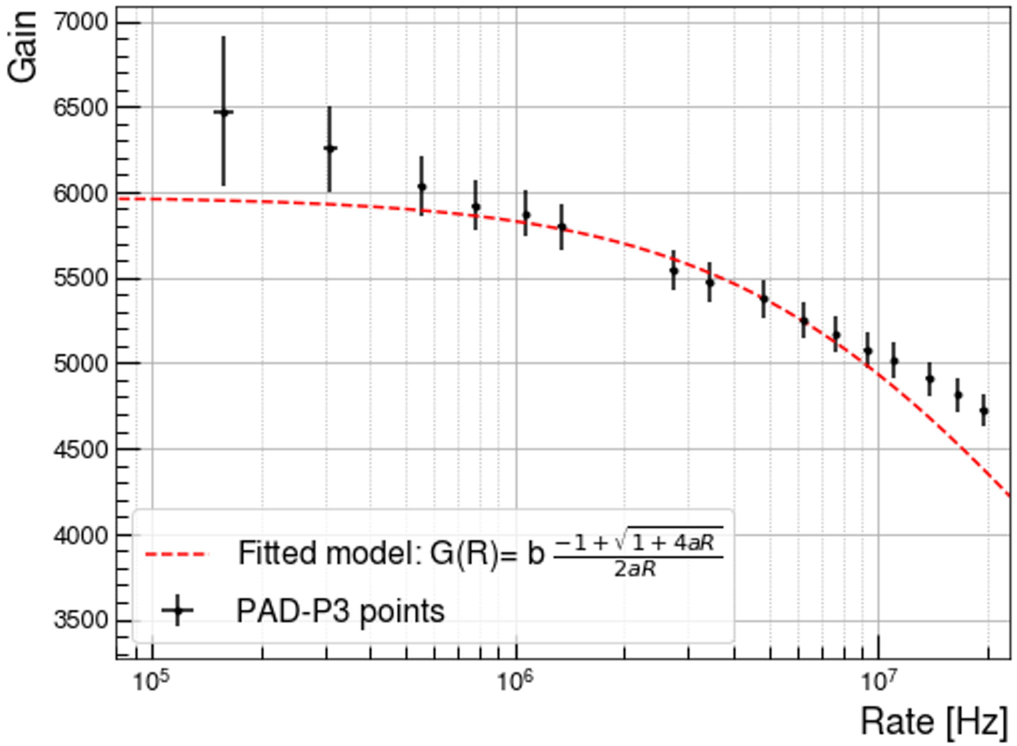


- Double linear fit: Rate Vs I_{mesh} and I_{mesh} Vs I_{xrays}
- Rate extrapolation from I_{mesh} in the linear region
- Measurements at high rates removing all possible impedances (e.g. preamplifier)

- Gain constant (~8300) up to few MHz/cm2
- Gain at high rates dominated by ohmic Voltage drop
- 30% gain drop at 20 MHz/cm2

PADDY3 and DLC20 gain behavior at HIGH RATES



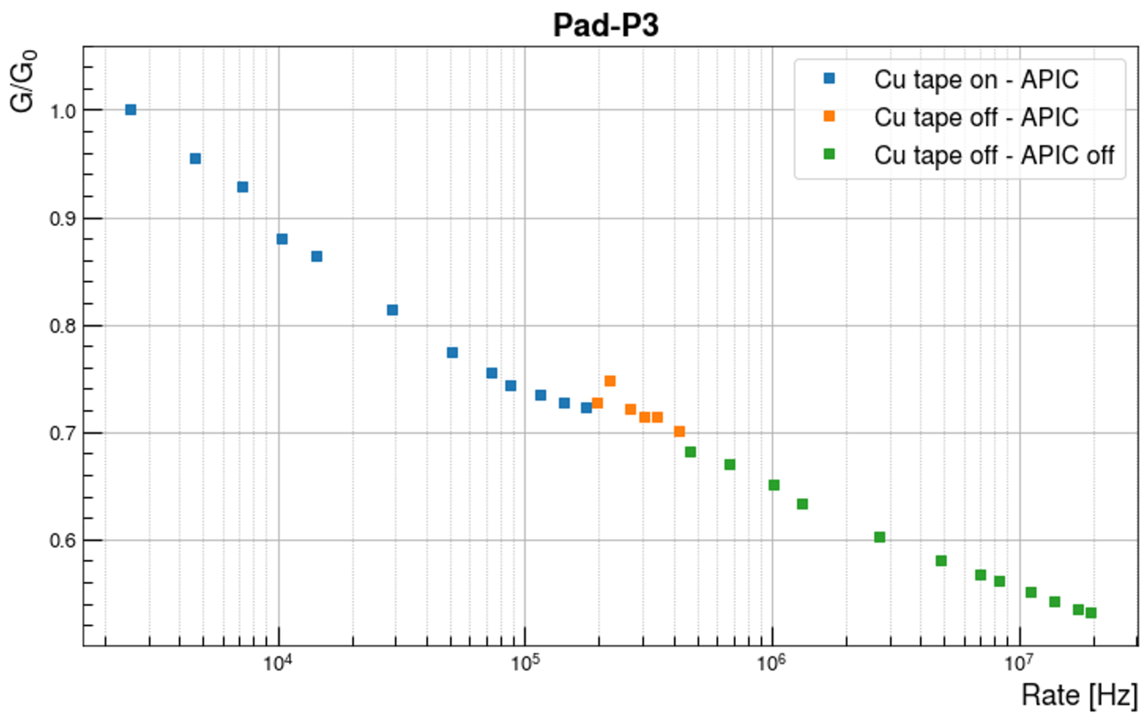


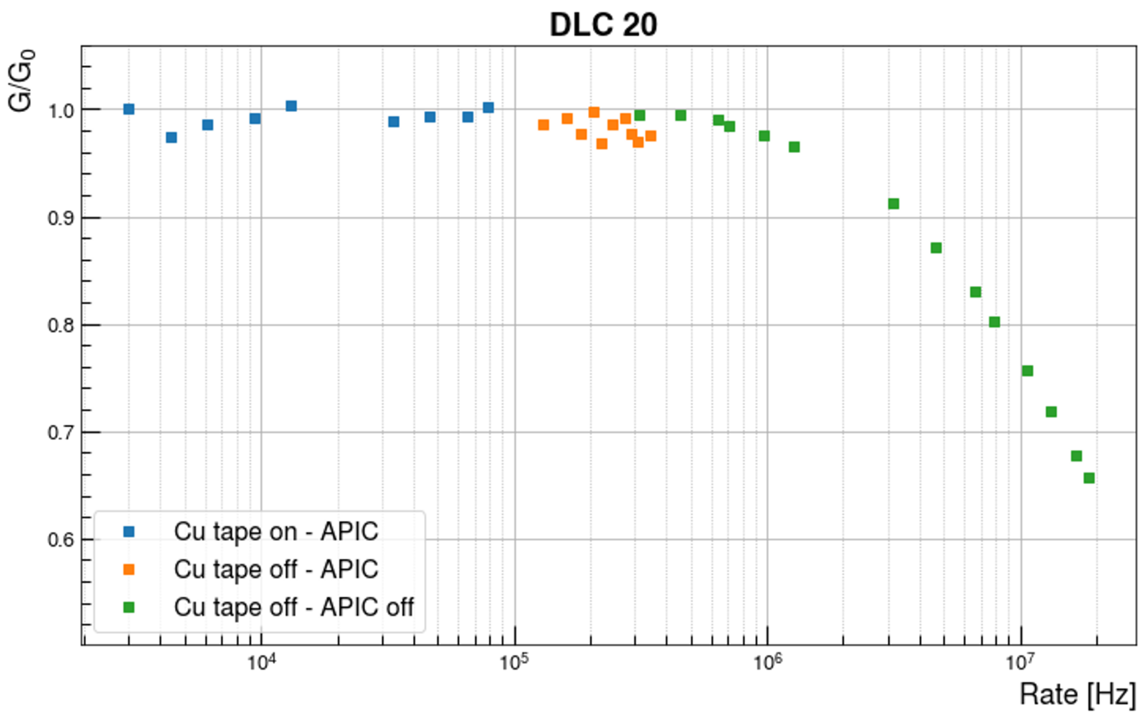
Fit attempted with the model in G. Bencivenni et al. 2015 JINST 10 P02008 considering a Ohmic drop

- Fit in good agreement with data for DLC20
- Fit failure on Paddy3 as expected due to the different contribution to the drop (charging-up)

Connection between Low and High Rates

Rate scan over > 4 orders of magnitudes





- Charging-up effects significant at rates ~10s kHz/cm2

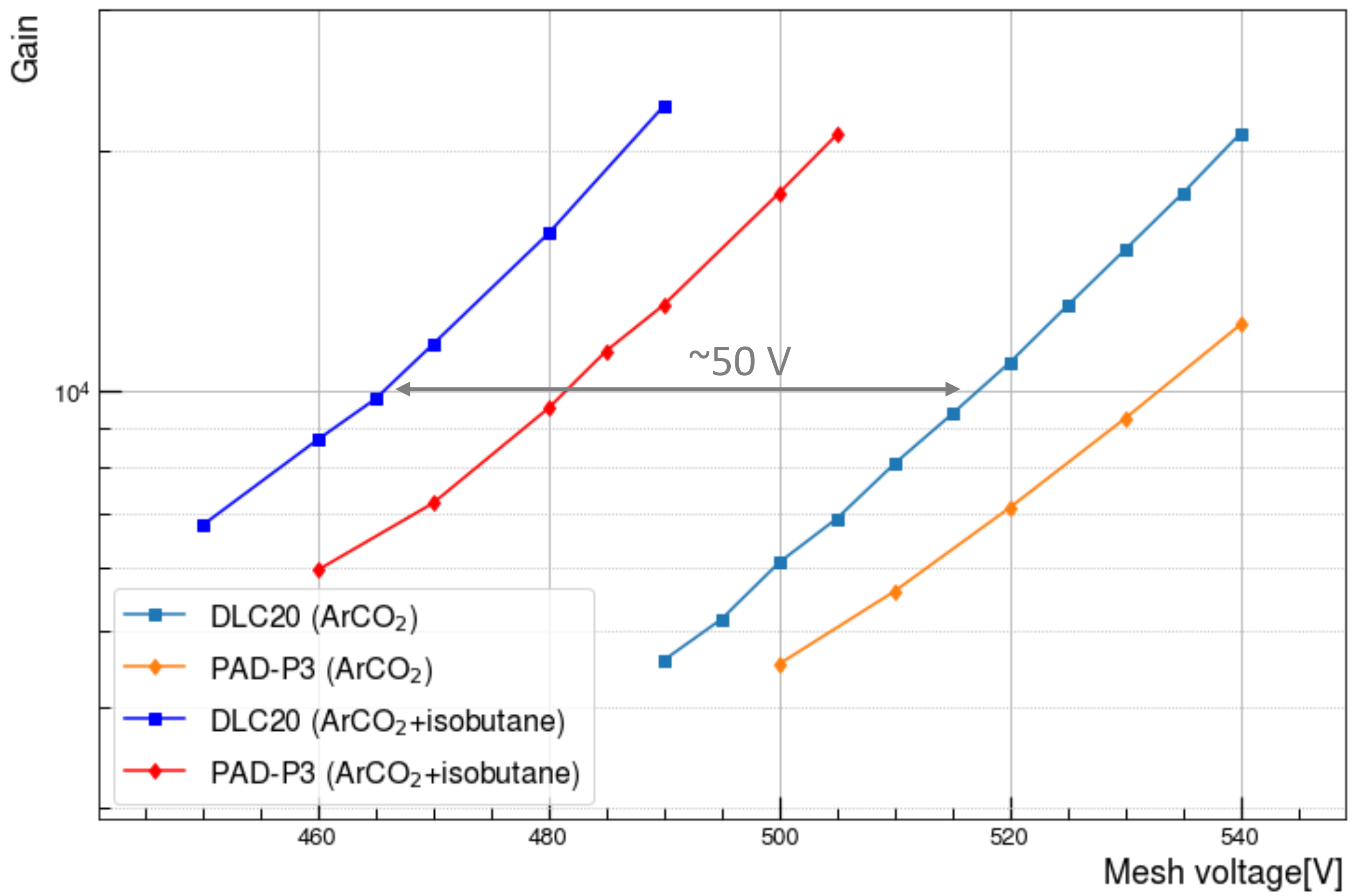
Adding a pinch of isobutane

- As for current tests/validation of the Ar/CO2/Isobutane 93/5/2 gas mixture in ATLAS MM *(see G. Mancini's talk)*
- Added 2% of Isobutane (below the flammable limit) in our standard gas mixture
- Very high gain reachable in very stable conditions

Equivalent voltage at G = 10k

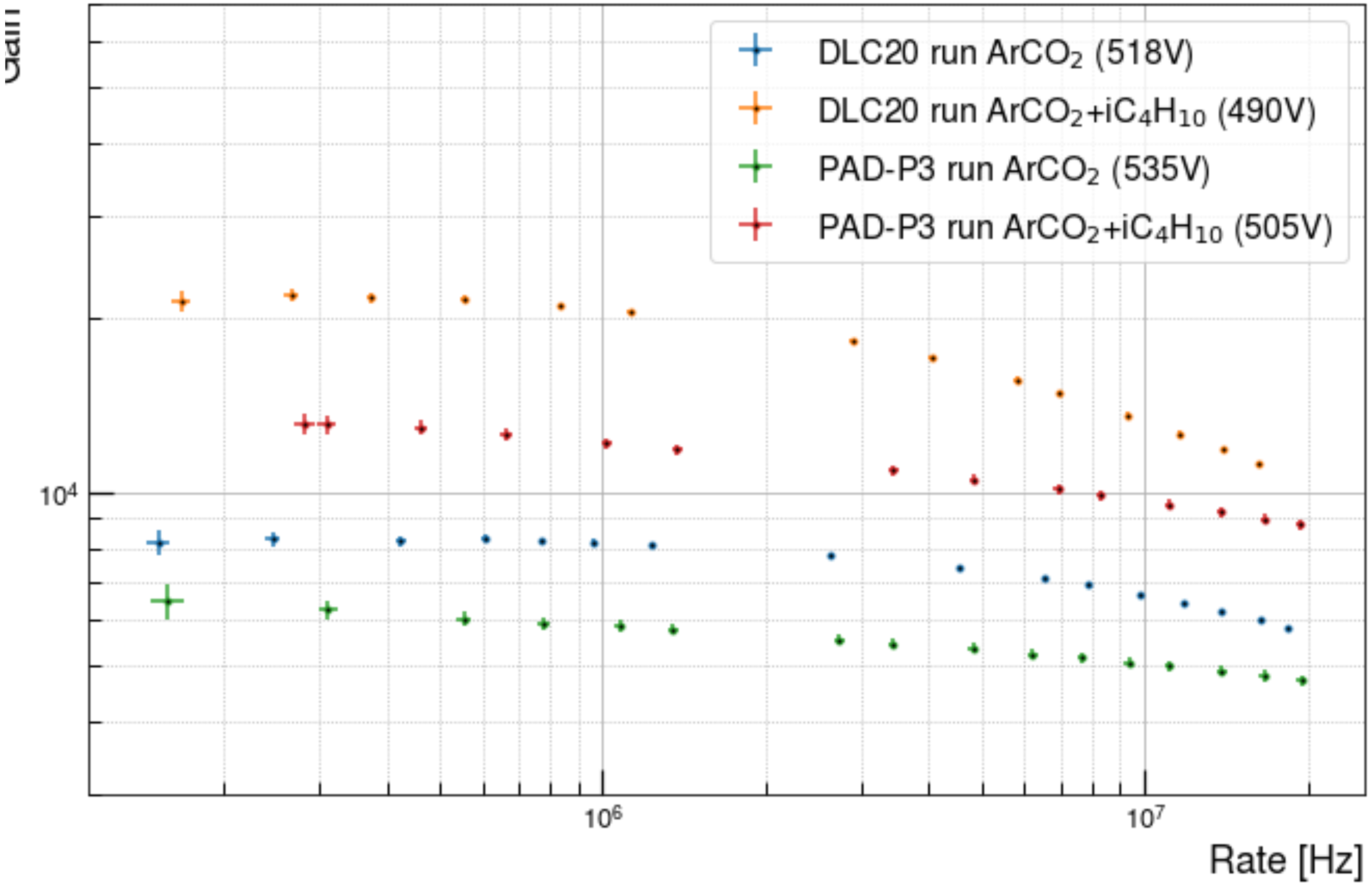
GAS	DLC20	Paddy3
Ar/CO2	518	533
Ar/CO2/iso	465	483

A shift of ~50 V between the two gases



Gain Vs rates for the two gas mixtures

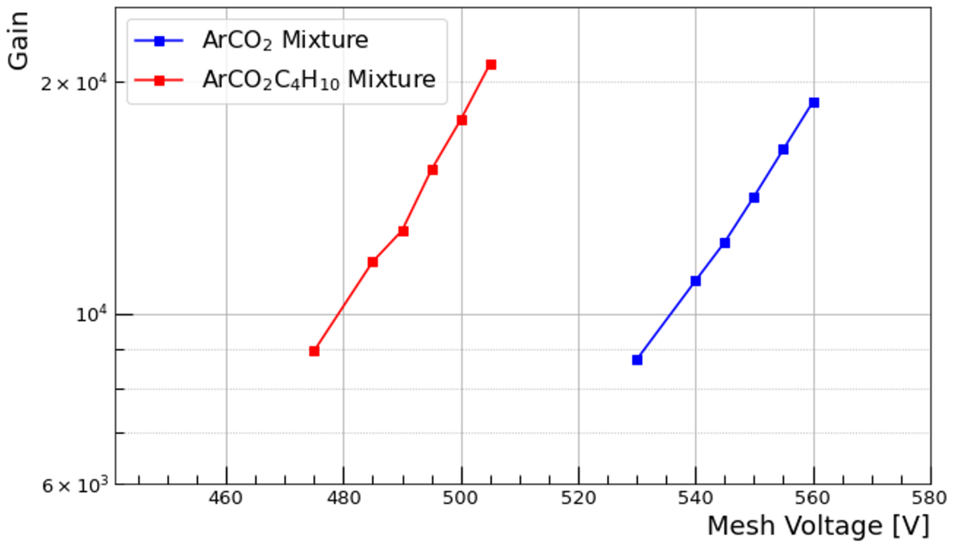
- Ar/CO2/Isobutane allows to test VERY HIGH GAINS
- Gain of both prototypes G > 10k at 10 MHz/cm2

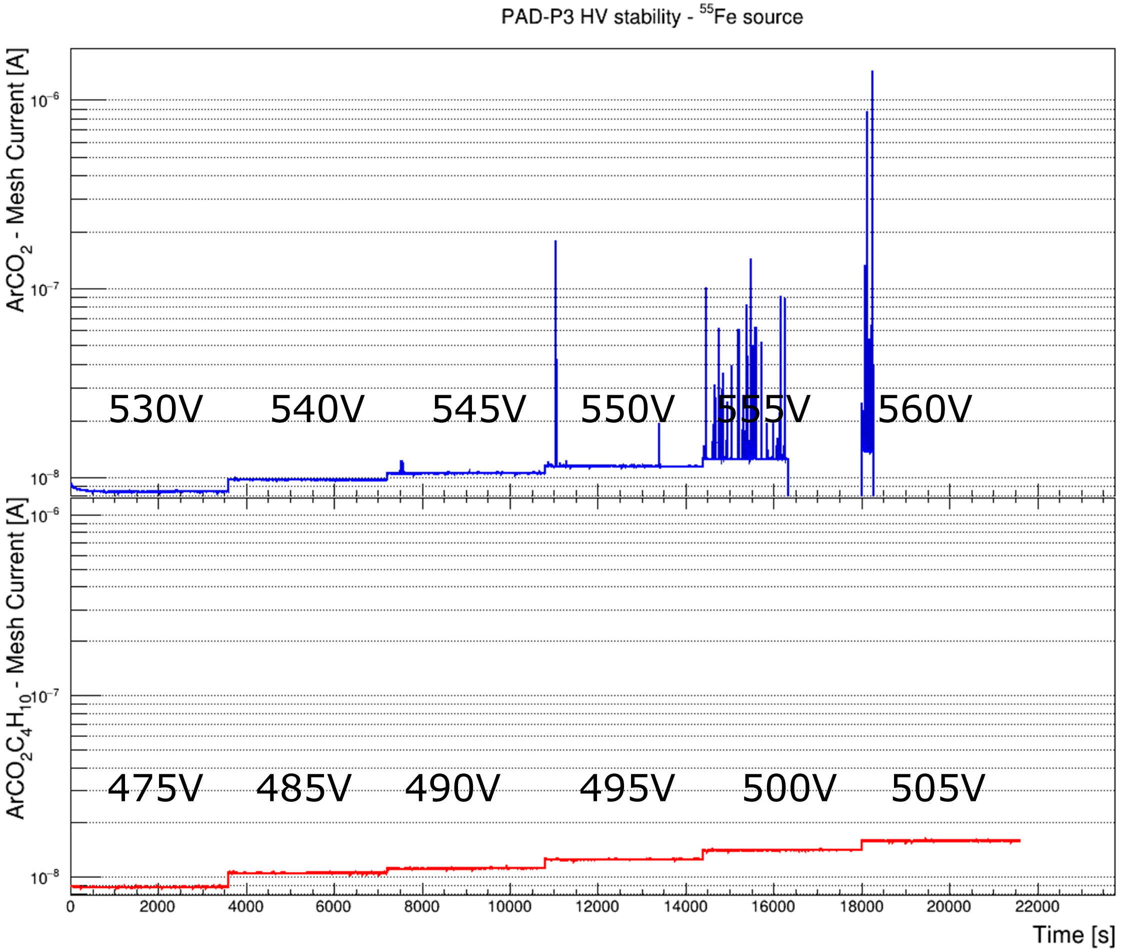


Reminder: tests with 8 keV X-rays

→ Equivalent ionisation ~ 4x MIP

Stability check with 55Fe source – Paddy3





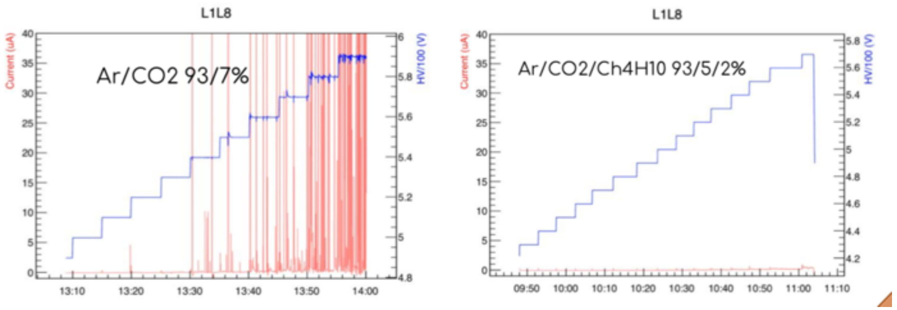
55Fe source – rates ~ 10s kHz

- Ar/CO2: onset of discharges at 555 V (G ~17k)
- Ar/CO2/Iso: stable up to 505 V (G>20k) not tested further

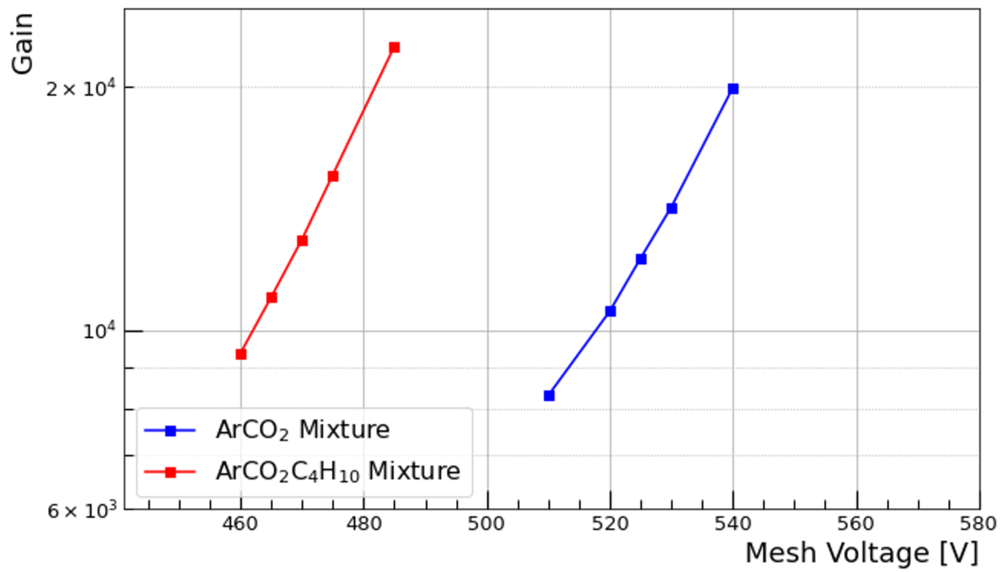
Each step 1 hour long

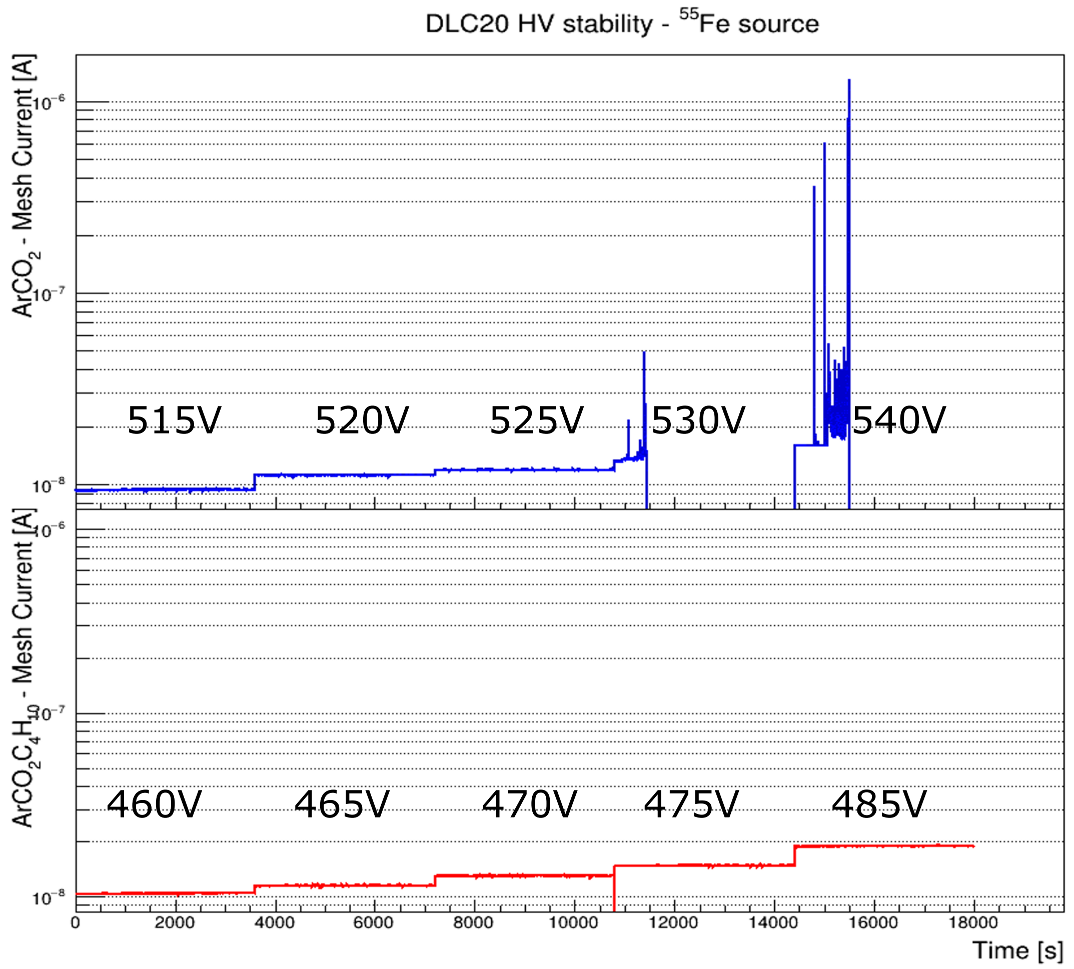
Currents ~10s nA

Dramatic difference observed in ATLAS MM *(G. Mancini's talk)*



Stability check with 55Fe source – DLC20





55Fe source – rates ~ 10's kHz

- Ar/CO2: unstable at 530 V (G ~14k)
- Ar/CO2/Iso: stable up to 485 V (G>20k) not tested further

Each step 1 hour long

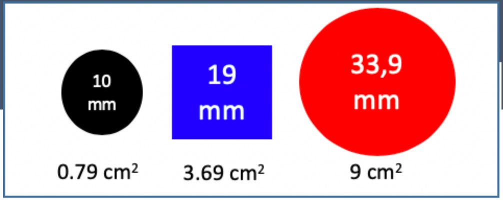
Currents ~10s nA

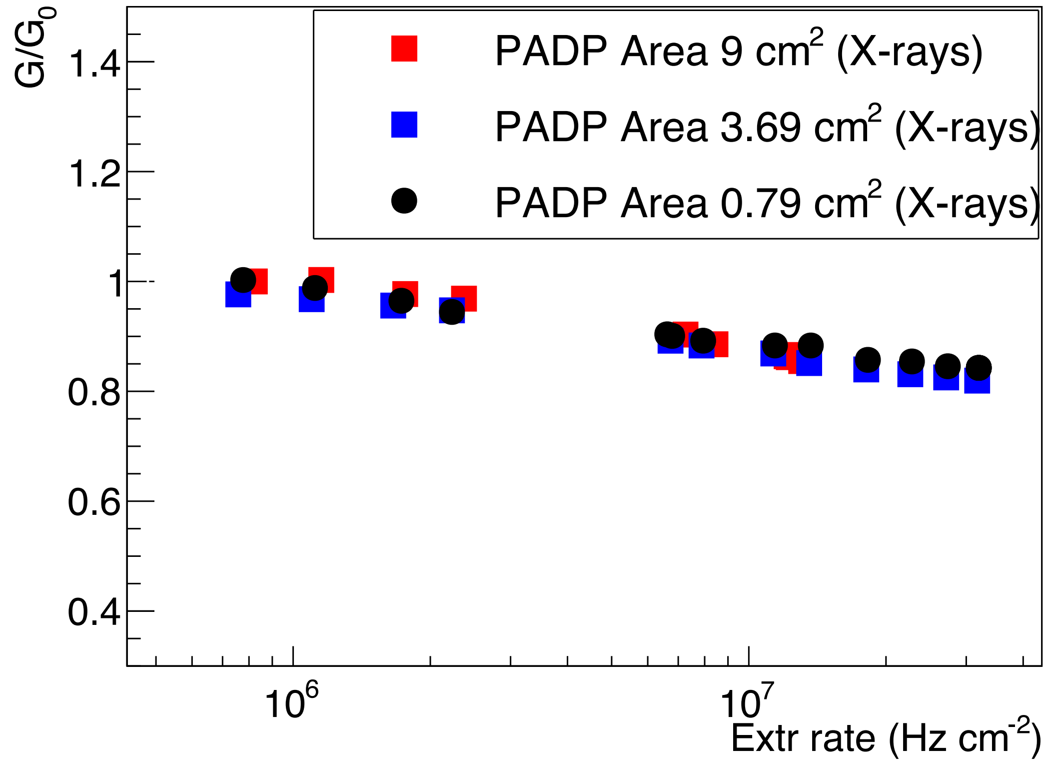
All measurements shown so far were taken with a mask of 1 cm in diameter (0.79 cm^2)

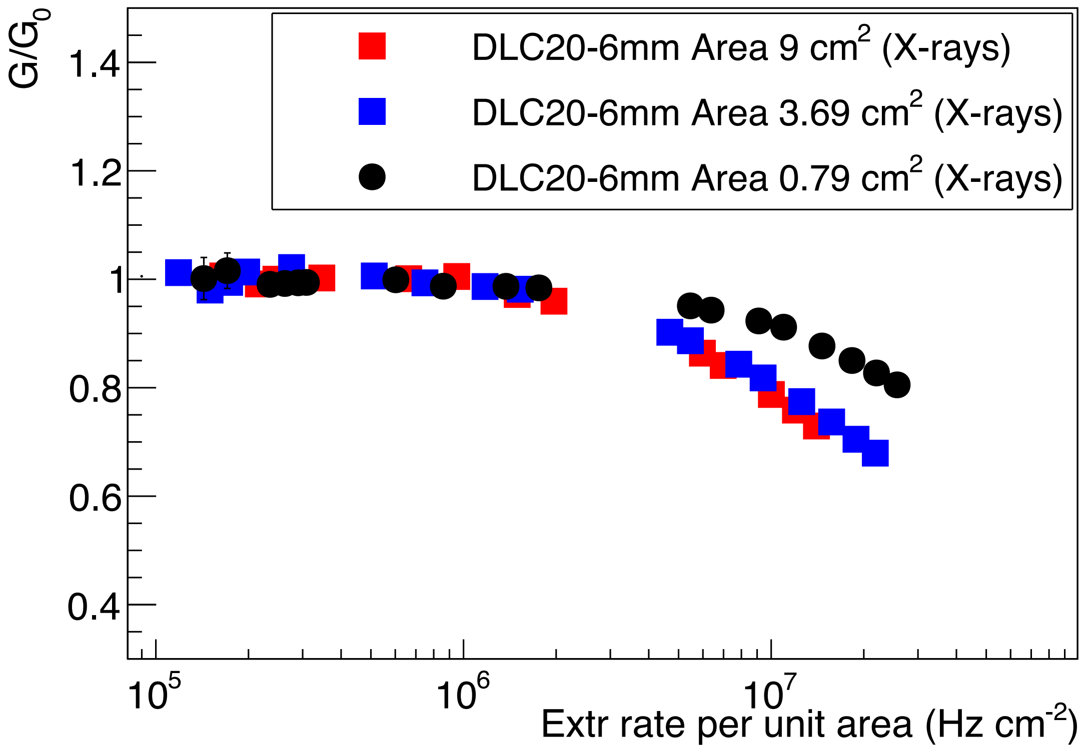
- *Is there any dependency on the irradiated area ?*

- In the next slide an “old” result is reported (shown at INSTR2021)
- We are currently carrying out further tests

Dependence on the exposed area





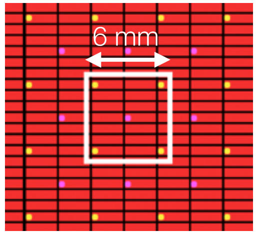


PAD-P:

- Thanks to independent pads there is no dependence on the exposed area

DLC:

- Dependence of gain on the irradiated area above ~5 MHz/cm^2
- **The gain drop do not scale for areas > 3.7 cm^2 - i.e., when the exposed area is >> cell dimension of grounding vias** (0.36 cm^2)

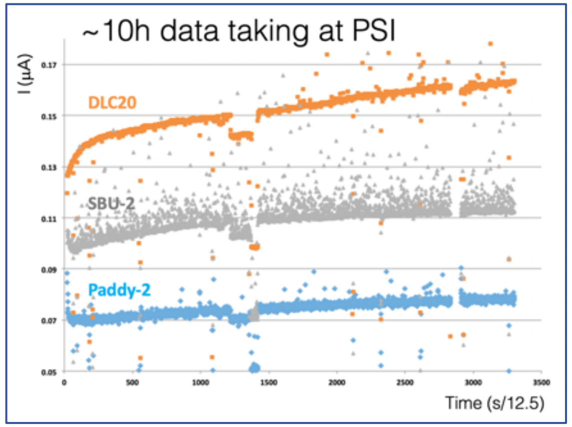


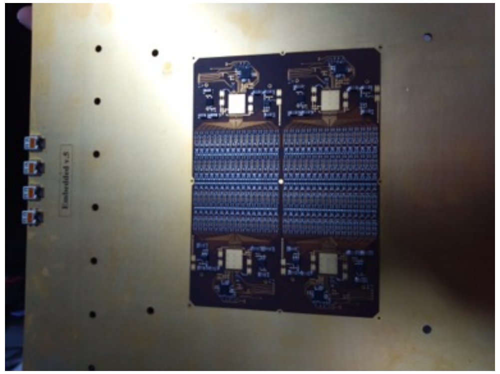
Summary and outlook

- Very satisfactory results obtained with DLC20 (new tests) and Paddy3 (new prototype)
- Confirmed the good stability and performance of the pad-patterned prototype (Paddy3) as well as "feature" of **significant charging-up**
- Very satisfactory performance with DLC20. Aiming at confirmation with new prototypes (production "issue": very difficult to get desired DLC resistivity)
- Extremely good results with 2% of isobutane added to the standard mixture (Ar/CO2 93/7)

SHORT TERM TASKS:

- Understanding the **charging-up** (the fall and rise of gain)
- New tests on the dependence on the irradiated area
- Confirmation of DLC20 results with new prototypes (under delivery)
- Test of Proto with **INTEGRATED front-end ELECTRONICS on the back of the pad patterned anode** (also under delivery….)





LONGER TERM TASKS:

- $Ar/CO_2/iC_4H_{10}$: performance studies and AGEING
- Moving to LARGE size small-pad Micromegas

BACKUP

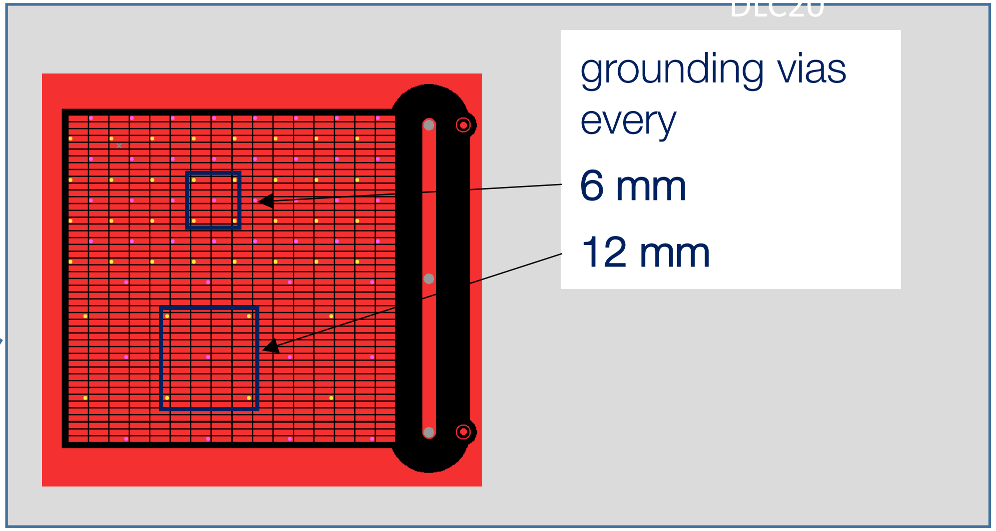
PROTOTYPES

PAD-P: Embedded resistor

- mean value of the embedded resistors ≈ 3-7 MΩ

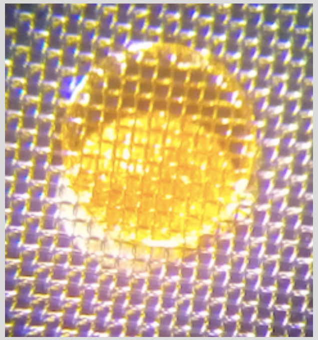
DLC20, DLC50: ‘standard’ DLC, sputtered on kapton

- surface resistivity 20 MΩ/□ (DLC20)
- surface resistivity 50-70 MΩ/□ (DLC50)
- two regions, with conductive vias every 6 and 12 mm

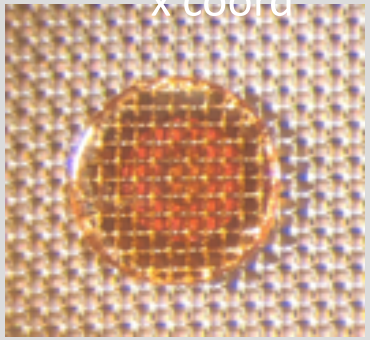


SBU1, SBU2: Sequential Build Up of DLC foils copper cladded on both sides

- easier photolithographic construction process
- improving of the alignment of vias and centering of the pillars with the silver vias (every 6 mm)
- for both prototypes: 1st layer (nearest to the pads) resistivity 35 MΩ/□ , 2nd layer 5 MΩ/□ (lower than requested)



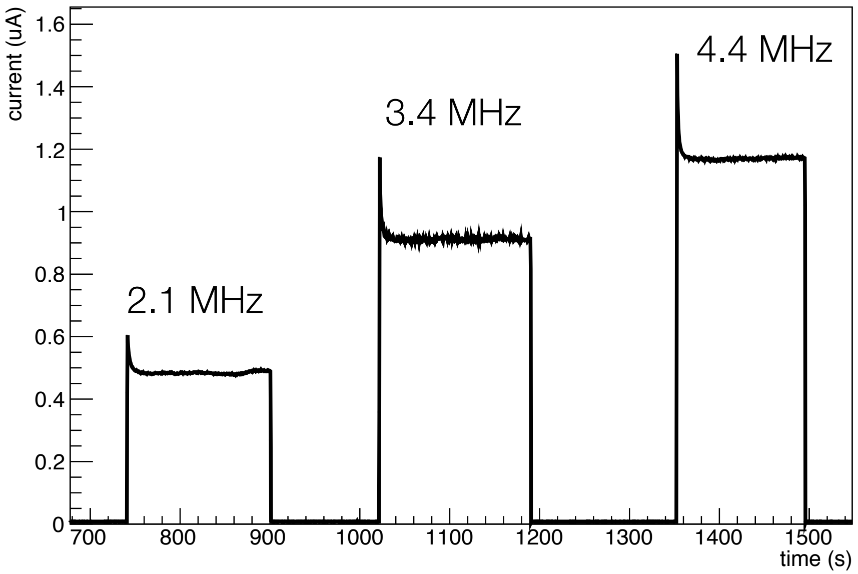
DLC20/50
Case of uncovered vias
→ can cause sparks



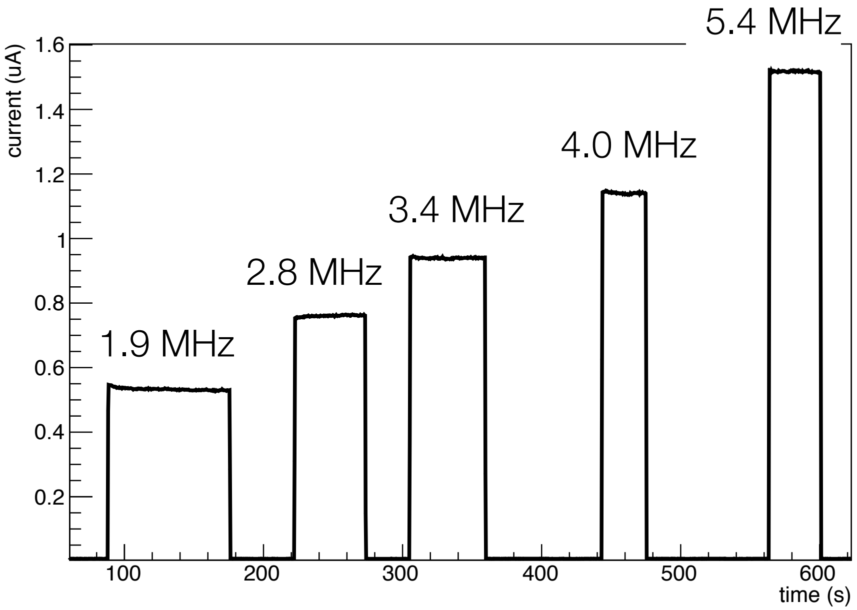
SBU
Perfect alignment
of vias

PAD-P vs DLC – Charging-up

PAD-P AT 527 V



DLC50 AT 504 V



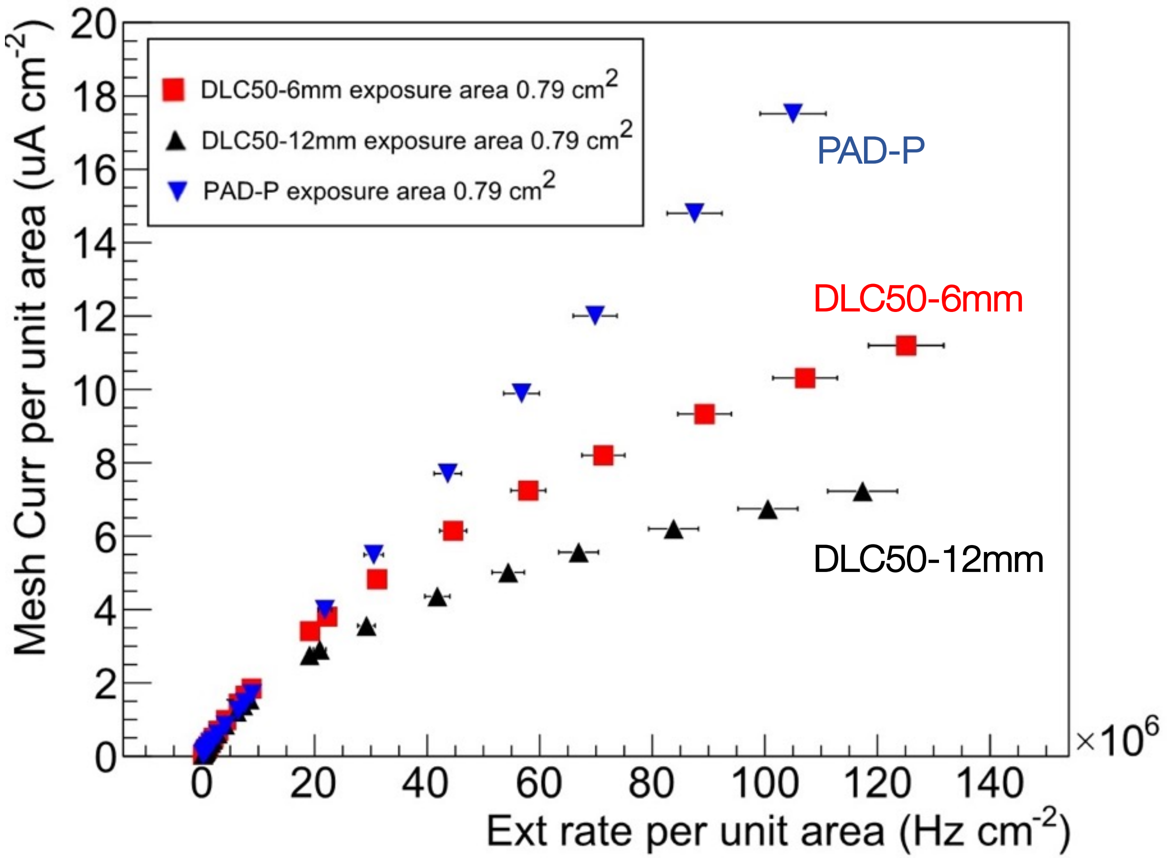
Current measurement Vs Time during cycles of X-Rays irradiation

- PAD-P response compatible with dielectric **charging-up** of exposed Kapton surroundings the resistive pads
- DLC detectors do show any sizable charging-up effects (expected from the uniformity of the resistive – no exposed dielectric, with the exception of the pillars)

Dependence on the grounding vias pitch

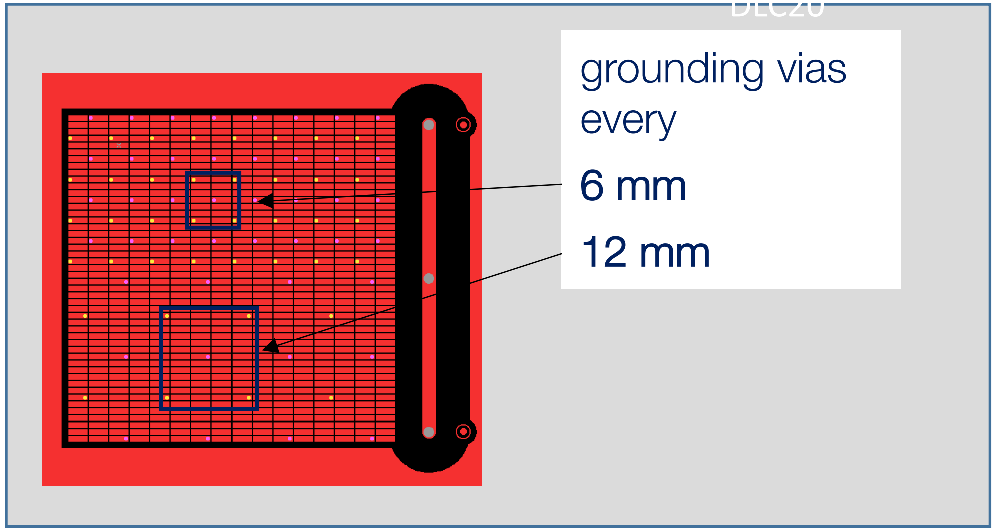
COMPARISON done at a gain of ~6500

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



DLC-50:

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

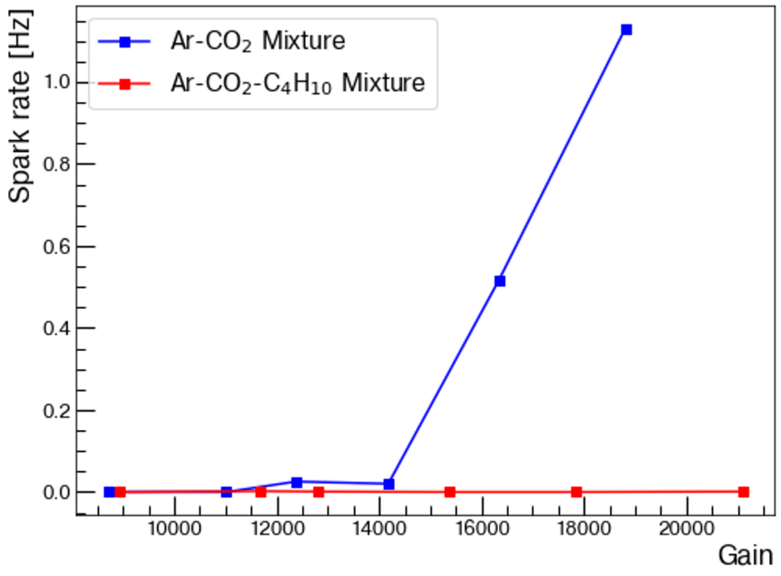


Stability check – Spark counting rate

- A spark is defined as any current measurement above 10 sigma from baseline
- Current measurement sampling ~3Hz

Much higher in reality
Issue with trips

PADDY3



DLC20