Recent results from the Resistive-CP group

Rate capability of μ-RWELL with X-ray

2021/02/09

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on behalf of the Resistive-CP group

Outline

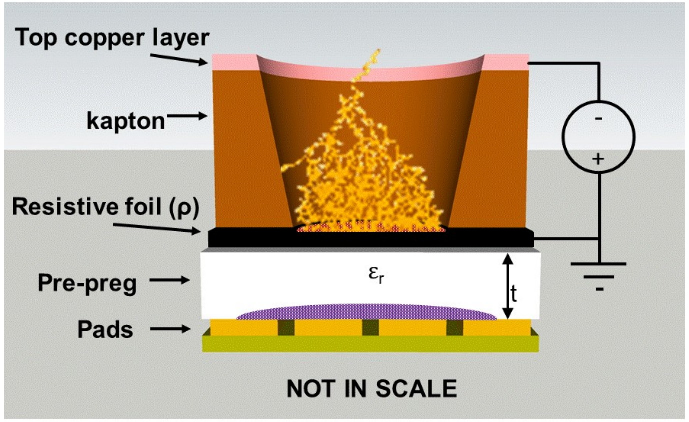
- X-ray PEDP rate capability results (*Z. Yi*)
- The LNF setup
- Results for different evacuation schemes
  - μ-RWELL (DRL, SG)
  - MicroMegas (DLC20, *M. Iodice*)
- Conclusions & future steps

The μ-RWELL architecture

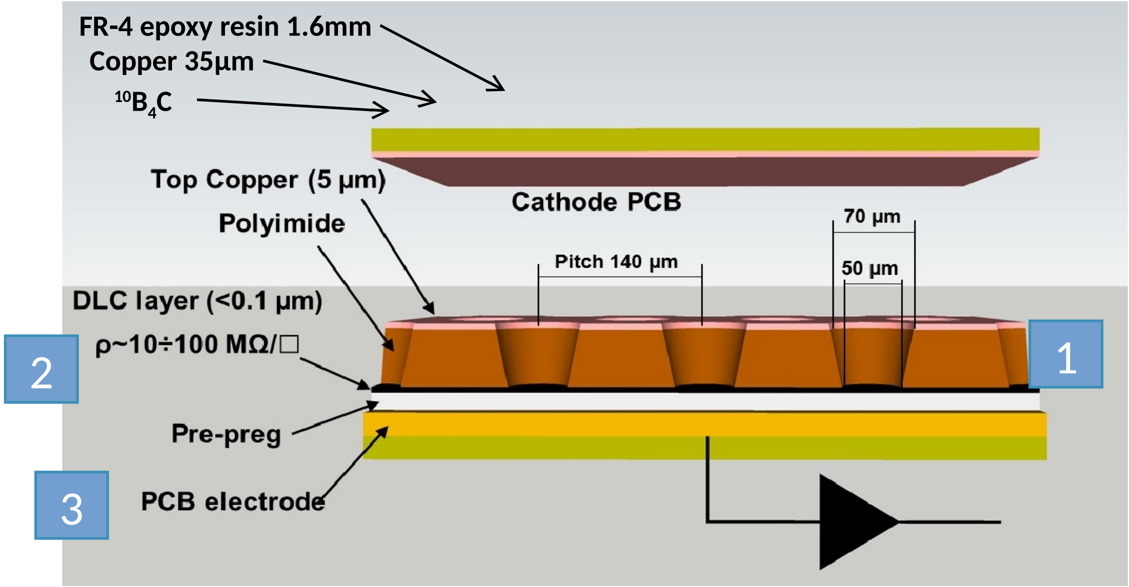
1 a **WELL** patterned Apical foil acting as **amplification stage** (GEM-like)

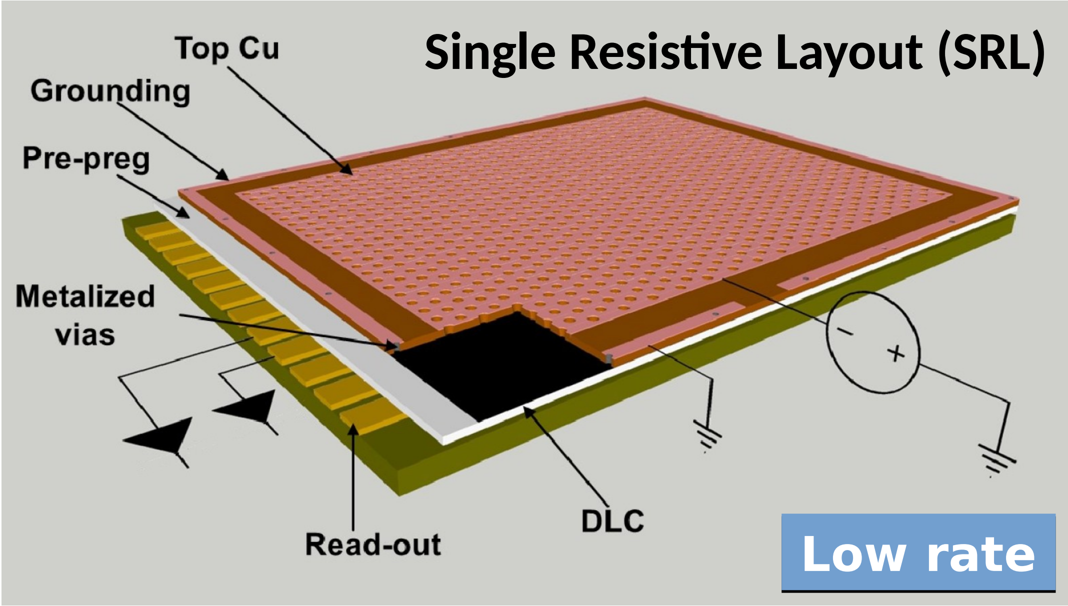
2 **a resistive DLC layer** for discharge suppression w/ surface resistivity ~ 10÷200 MΩ/□

3 a standard readout PCB



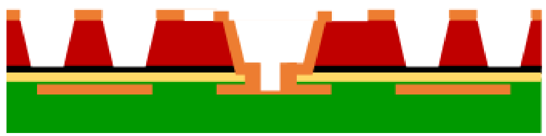
Resistive stage:
+ spark suppression, charge spread
- rate capability reduction





X-ray PEDP ratecap results

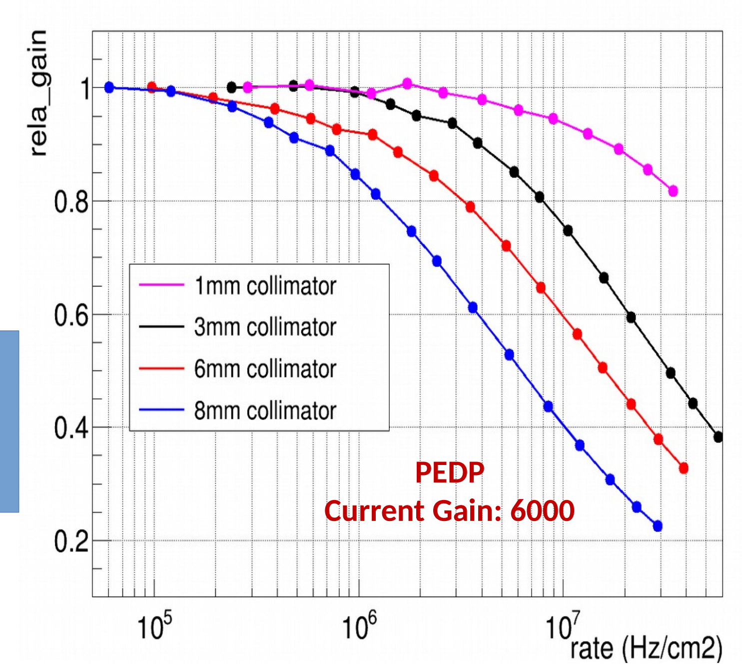
Effect noted by Zhou Yi with **X-rays**: for the new **PEDP** prototypes (pattern-etch-drill-plate) there is a **dependance of the rate capability on the spot size** (collimators from 1mm to 50mm diameter).



PEDP µRWELL

Conductive hole pitch: 5 mm

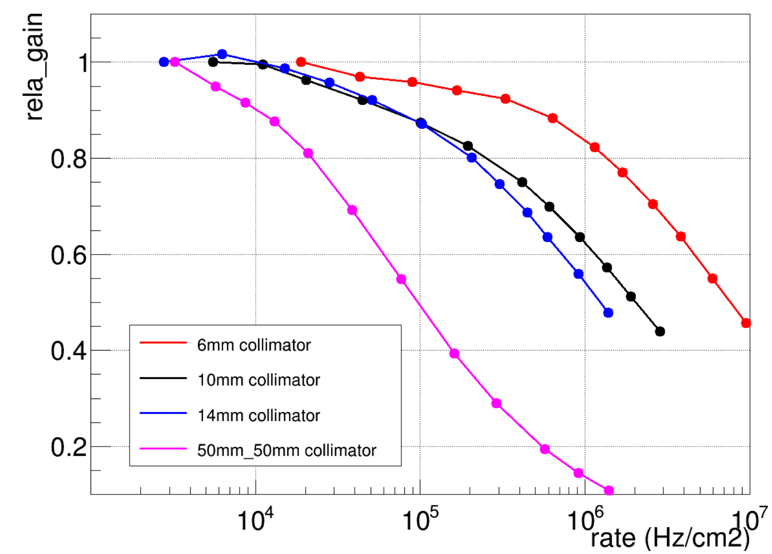
DOT-like grounding scheme



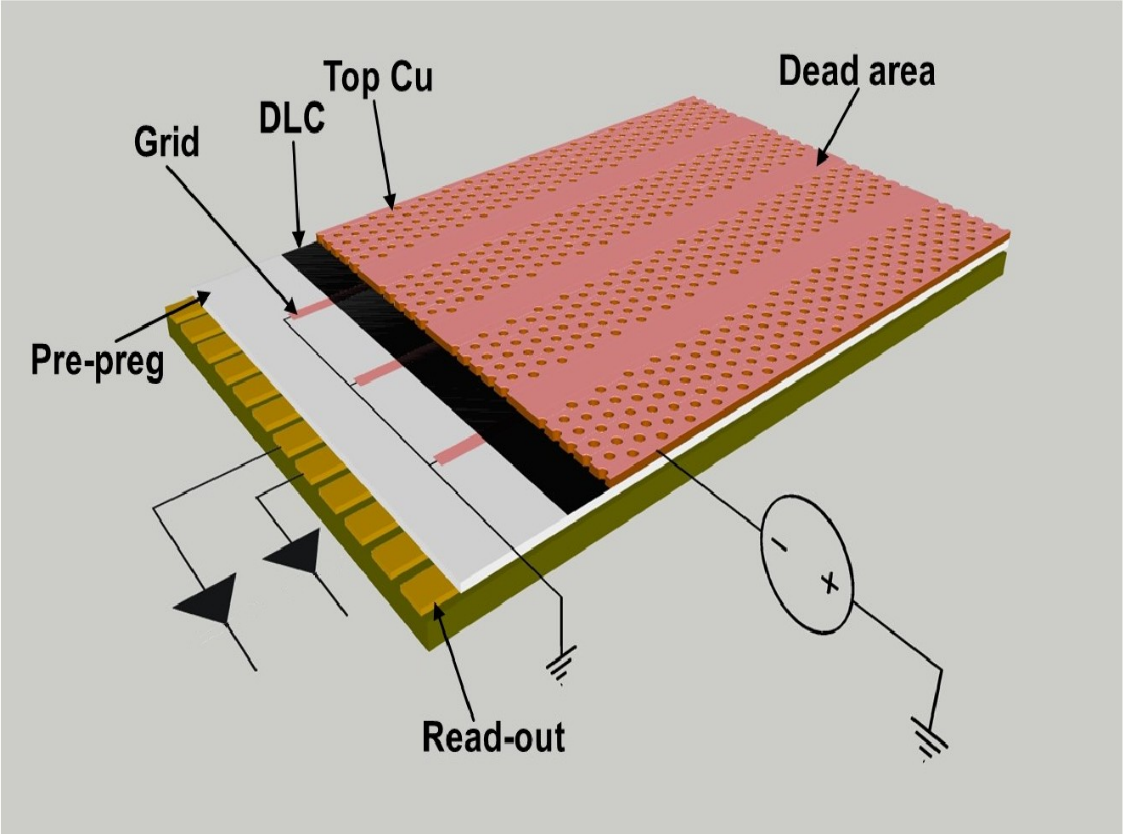
In order to understand this effect, Frascati starts the same test with different evacuation schemes:
(DOT-like) DRL, DRL-buried
(Grid-like) SG-1 and SG-2.

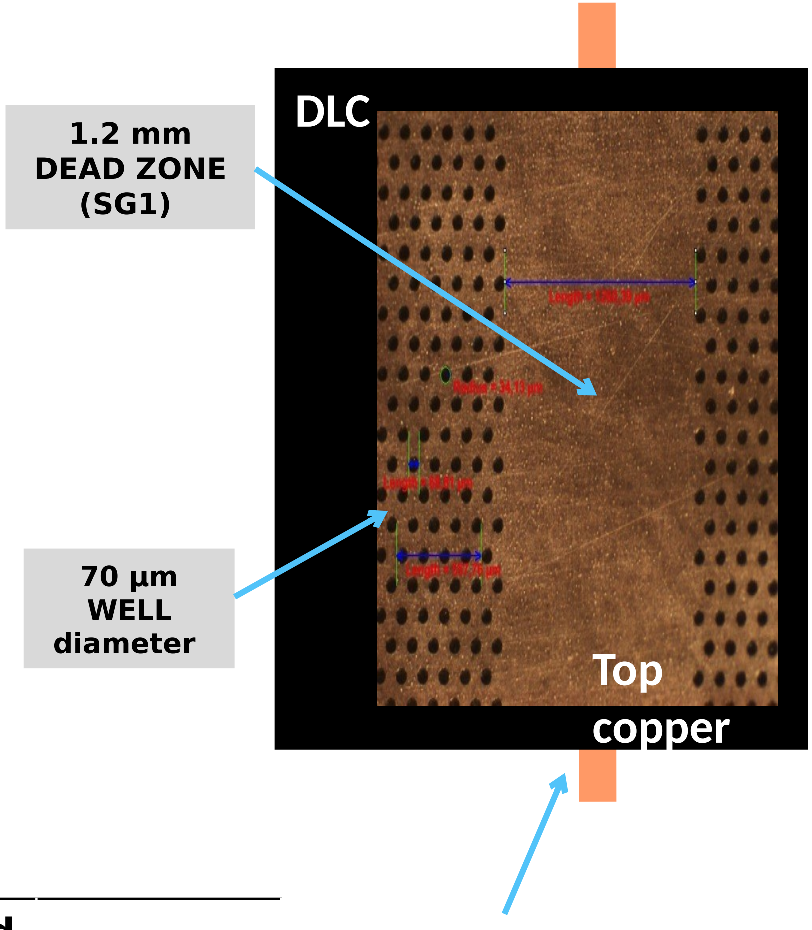
A comparison with MicroMegas has been also done.

Three parameters seem crucial for a comparison among the different technologies:
surface resistivity, ground pitch and spot size.



Silver Grid layout



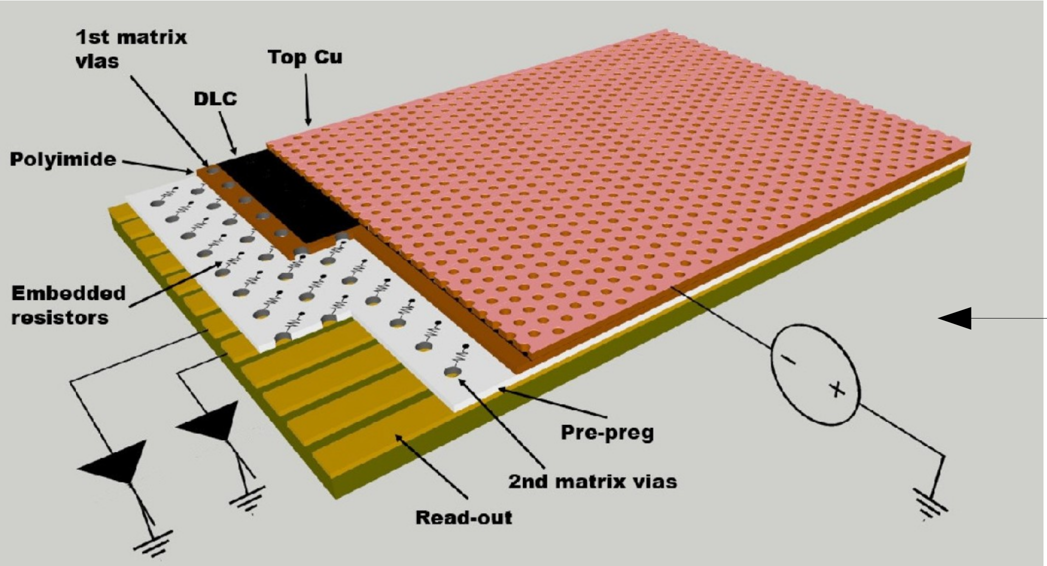


DLC layer (65 MΩ/□)

GRID-like grounding scheme

MODEL	DEAD AREA (mm)	Ground pitch (mm)	Geom. Accept.
SG2++	0.6	12	95%
SG2	1.2	12	90%
SG1	2.0	6	66%

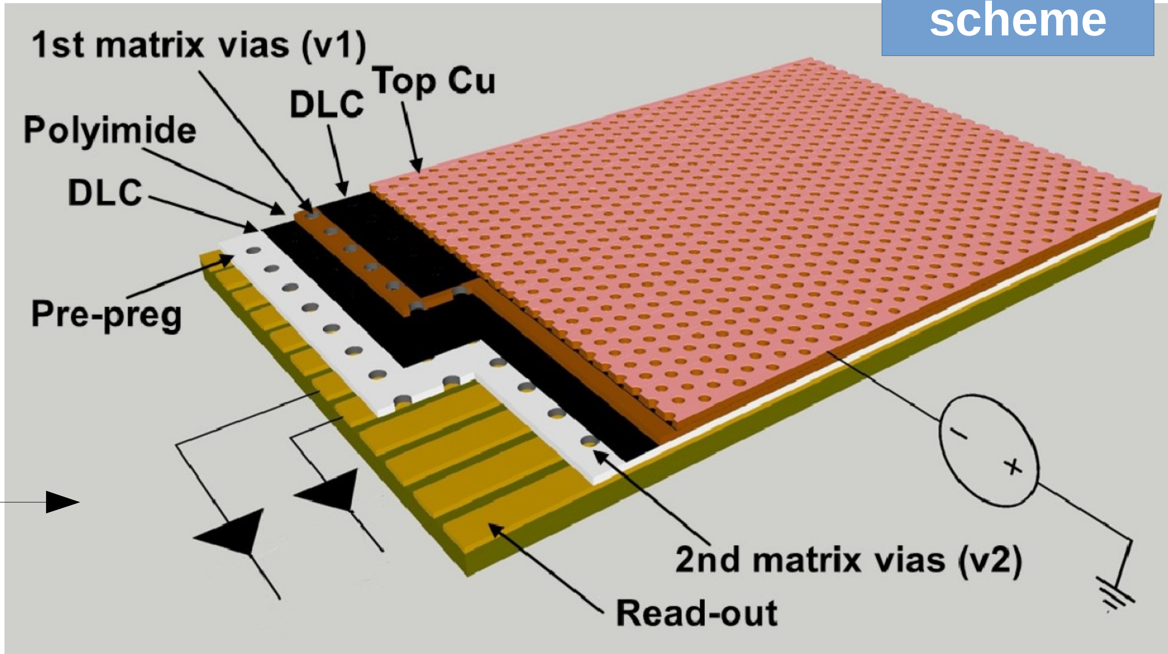
Double Resistive Layers layout



DRL-buried layout

DLC layer (~50 MΩ/□), 1cm pitch vias matrix, grounded through screen printed resistors (1 MΩ) to the readout.

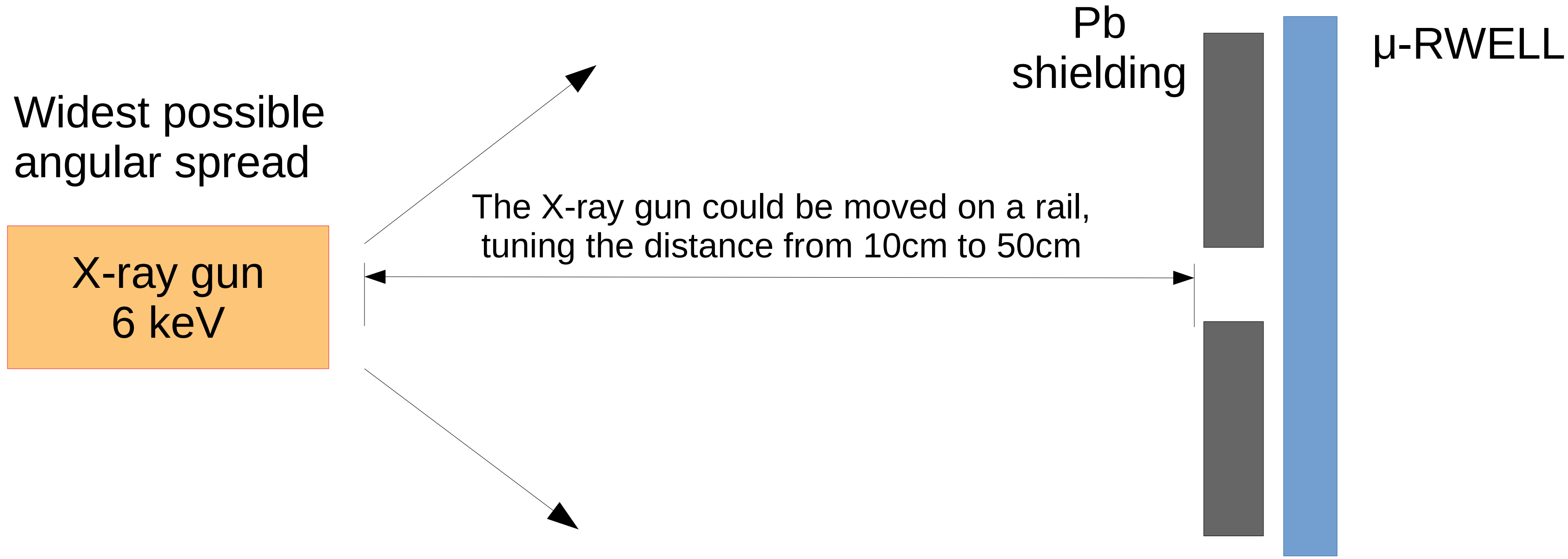
DOT-like grounding scheme

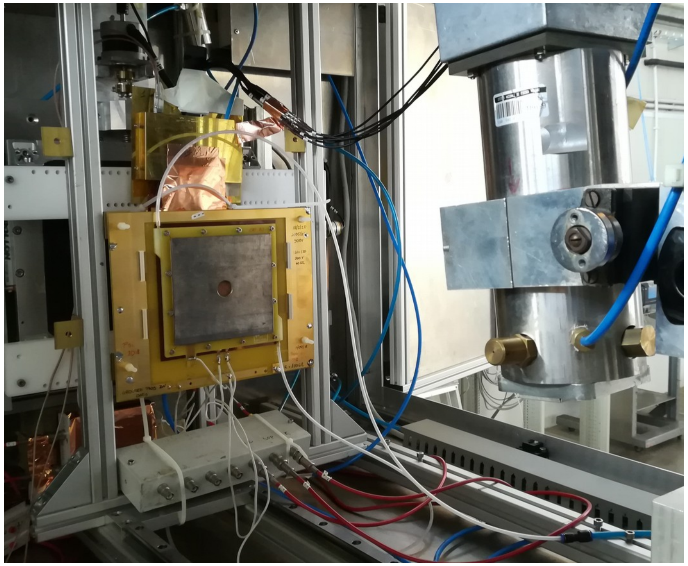


DRL layout

Two DLC layers (54 MΩ/□), connected between them with a 7mm pitch vias matrix, and then grounded to the readout.

X-ray measurements setup



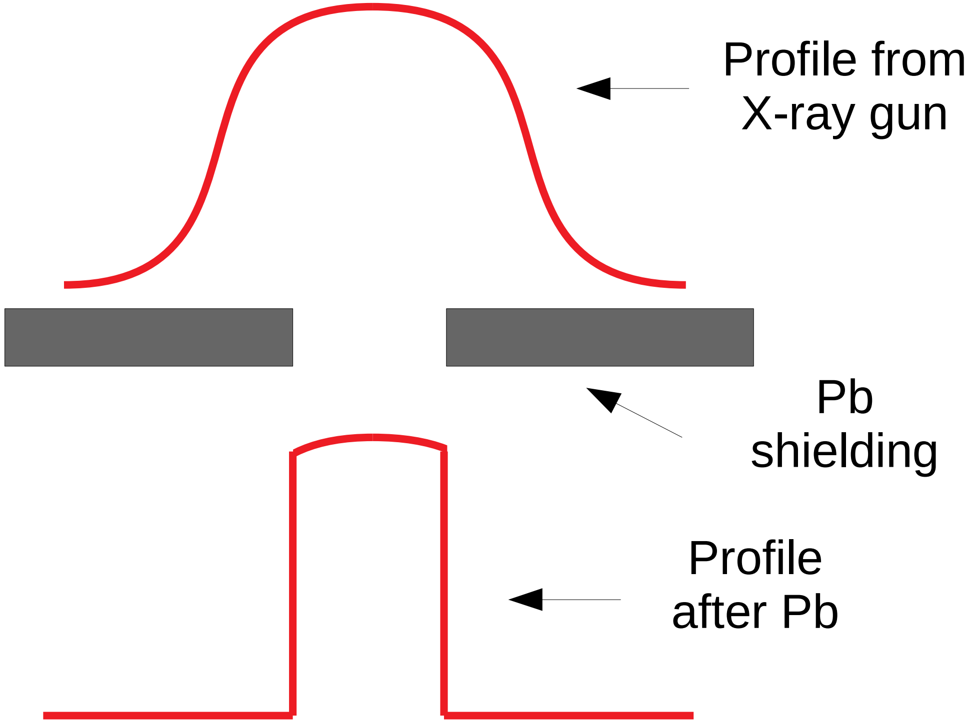


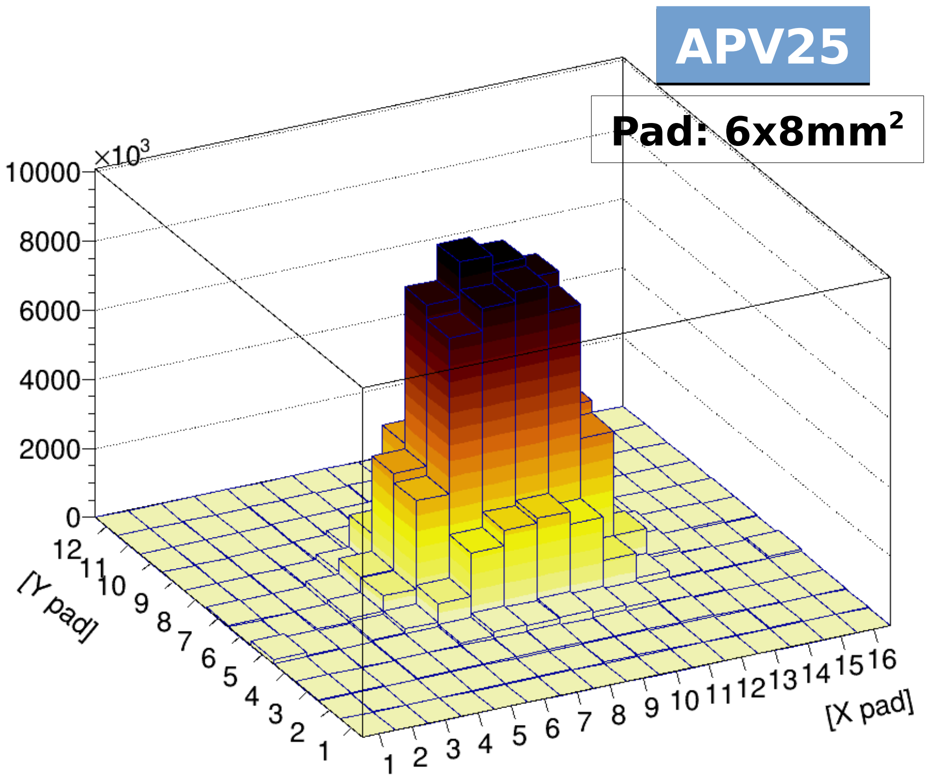
The **Pb shielding** is larger than the active area of the detector, with a **circular hole** in the center.
We chose 20, 30 and 40mm Ø (see next slide), larger than the grounding pitch.

X_0(Pb) = 2μm → we use a **1mm thick Pb foil** to ensure the total shielding.

Heavy cathode (1.6mm FR4 + 35μm Cu): measured attenuation factor x50 → 98% of the X-ray absorbed.

Choice of Pb hole diameters

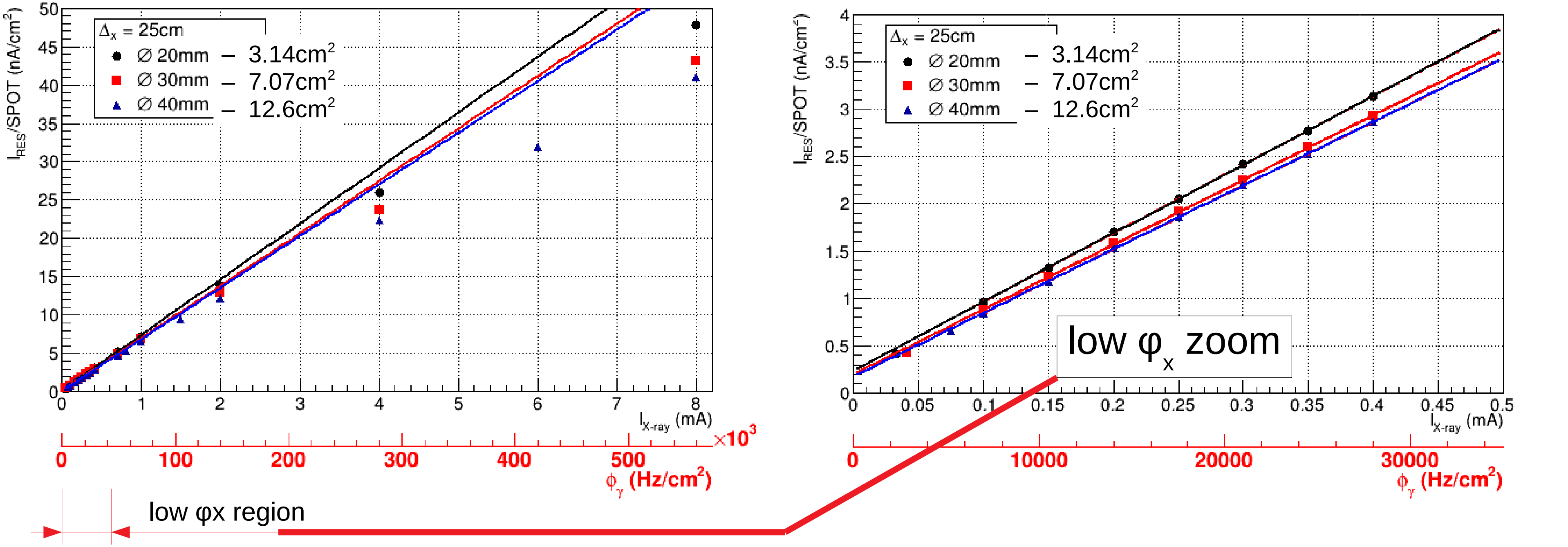




The use of the Pb shieldings ensures a **nearly uniform X-ray irradiation** over the spot. Using the APV25 it was possible to check the spot dimensions, compatible with the nominal Pb diameters.

Example of data taking

DRL μ-RWELL, G = 4000, ρ=54 MΩ/□, **Conductive hole** pitch 7mm, Ar/CO_2/CF_4 - 45/15/40



Low $I_{x\text{-ray}}$ → Linear fit → Extrapolations:

$i_{ext} = m' \cdot I_{x\text{-ray}} + q'$ → i_{ext} extrapolation at high $I_{x\text{-ray}}$

$\Phi_{x\text{-ray}} = i_{ext}/e \cdot N \cdot S \cdot G_0$ → $\varphi_{x\text{-ray}}$ extrapolation at high $I_{x\text{-ray}}$

$G/G_0 = i_{res}/i_{ext}$

Maximum I_{RES} @ $I_{x\text{-ray}}$ = 8mA :

Ø20mm → 150nA
Ø30mm → 305nA
Ø40mm → 510nA

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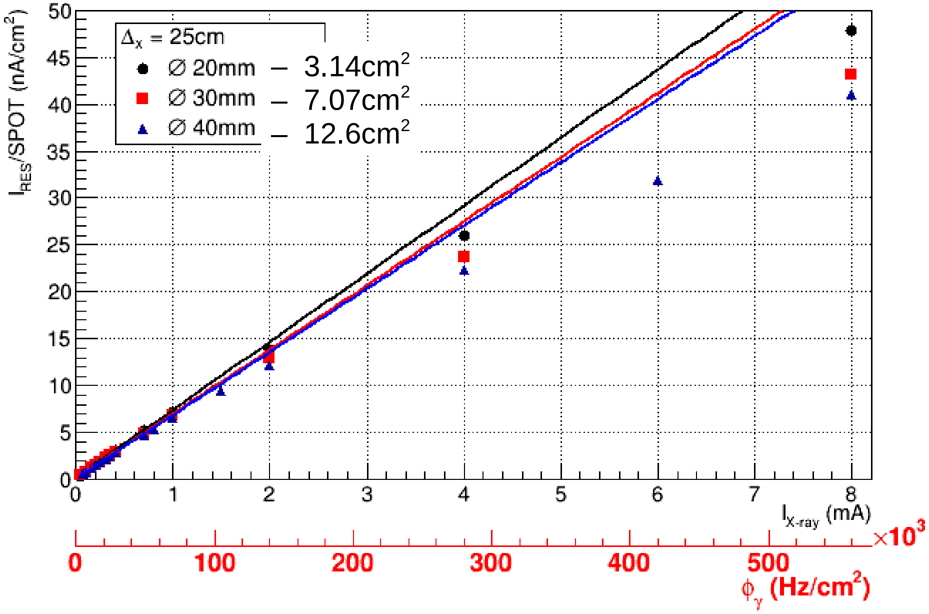

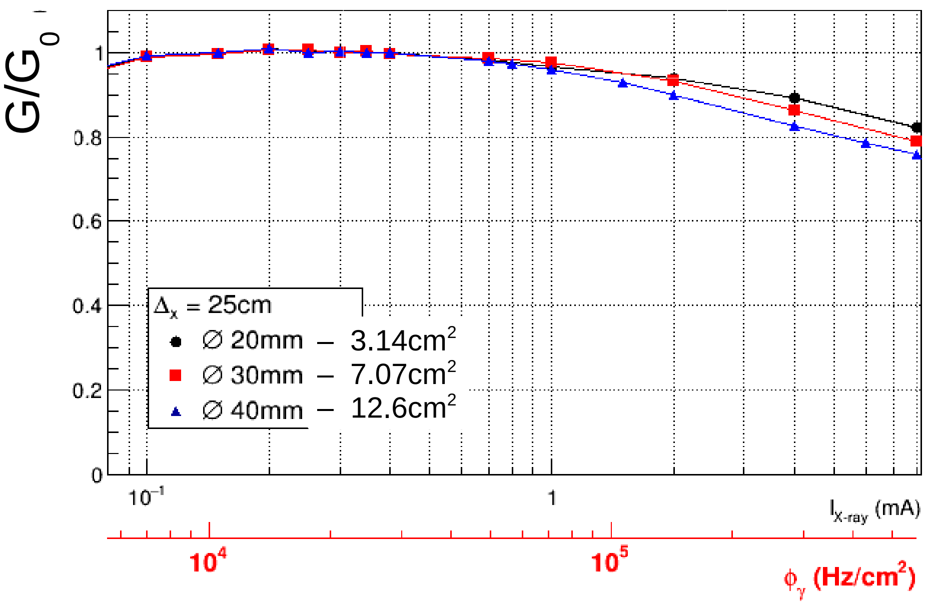

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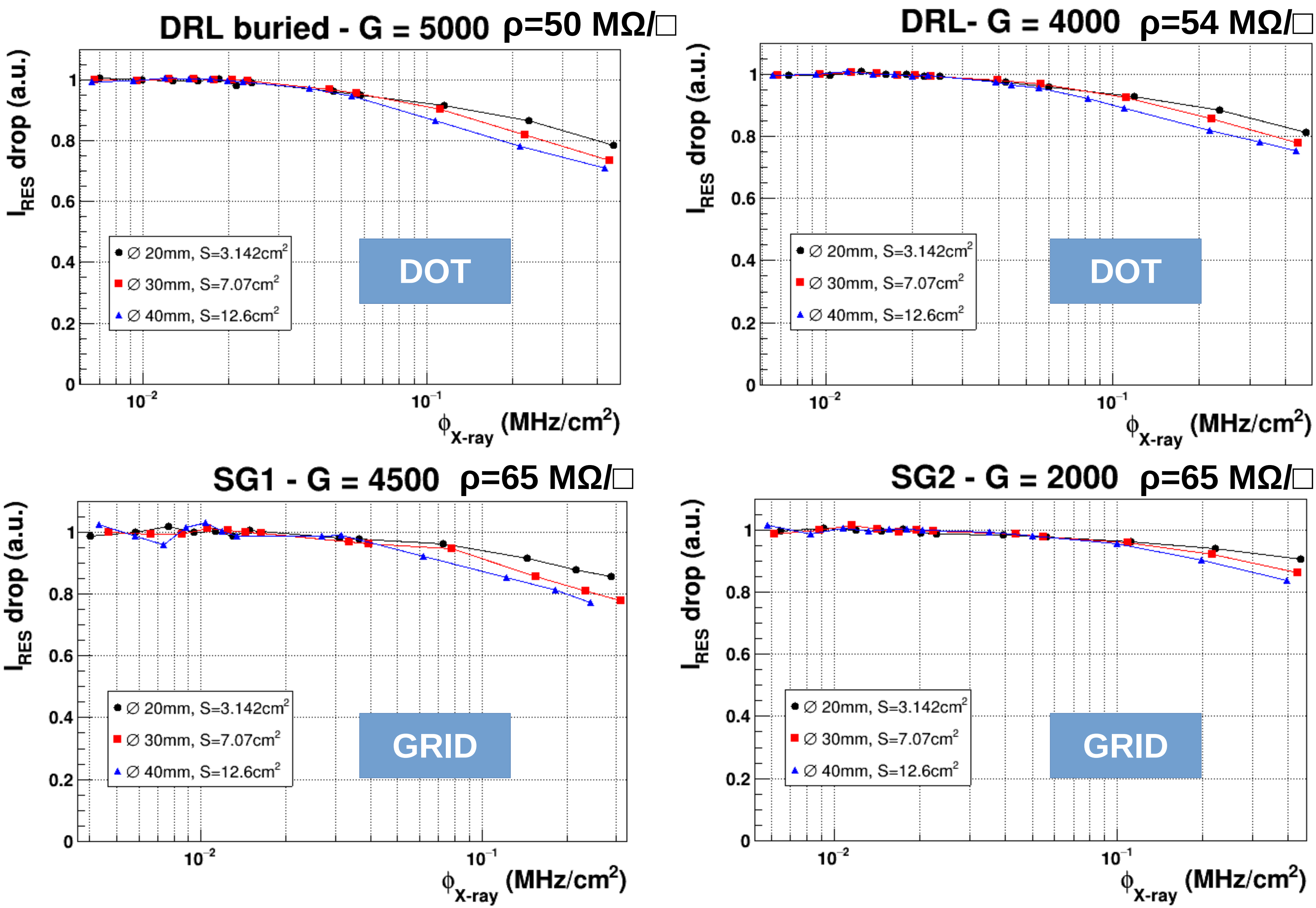
X-ray rate capability for LNF layouts



Different chambers, same behaviour: NEGLIGIBLE SPOT EFFECT

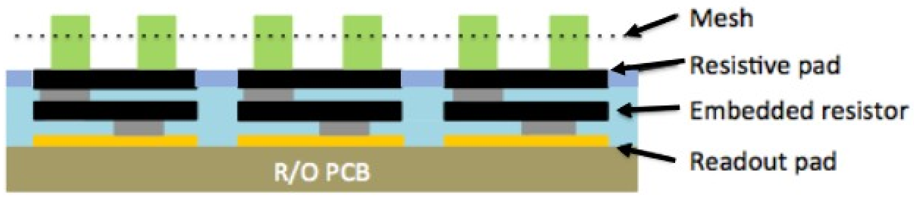
High Rate MicroMegas

Test campaign with X-ray on high rate MicroMegas:
testing different surface resistivity values and
current evacuation schemes.

See M. Iodice talk 17/02/21

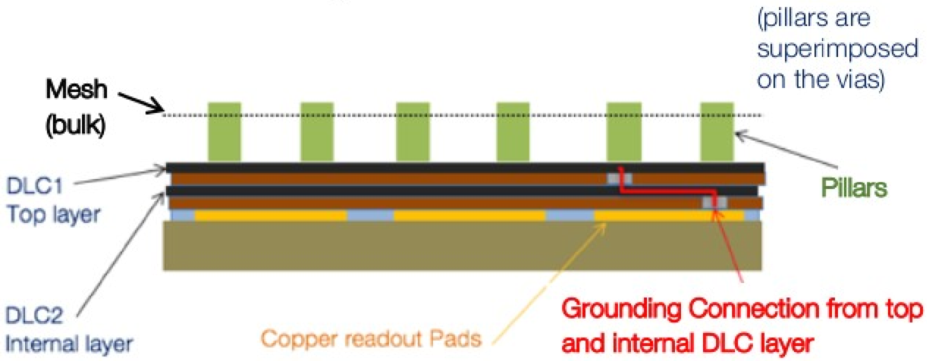
The Double DLC MM has a similar resistive stage than our DRL scheme.

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



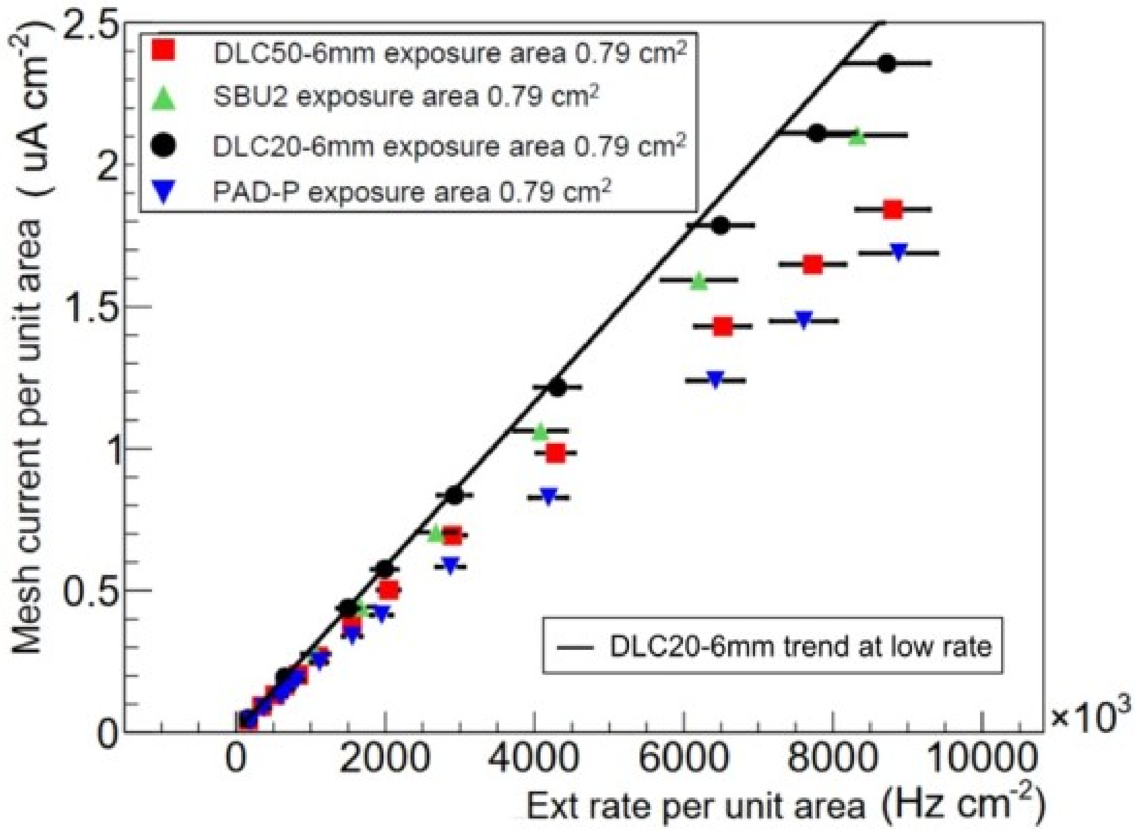
- Same concept of uRWell (see G.Bencivenni et al. 2015_JINST_10_P02008)
- Double DLC layer with connection vias to ground every "few" mm

DLC20: 20MΩ/□, DLC50: 50-70MΩ/□

M. Iodice et al 2020 JINST 15 C09043

High Rate MicroMegas

G=6500, gas mixture Ar/CO_2 93/7

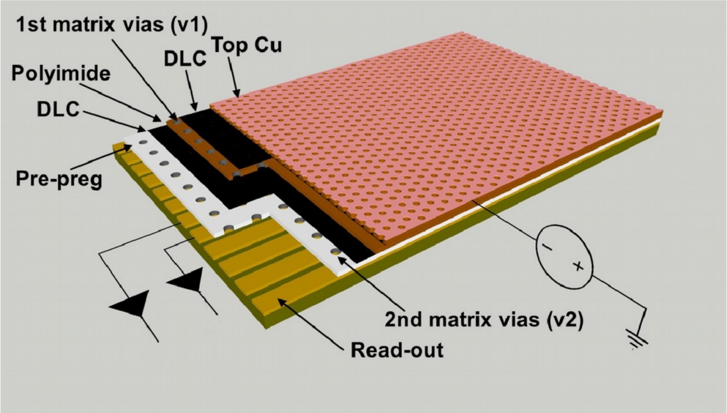


X-ray measurements 8keV.

DLC20 shows a better behaviour than DLC50 and other prototypes.

M. Iodice et al 2020 JINST 15 C09043

MM & μ-RWELL: ratecap



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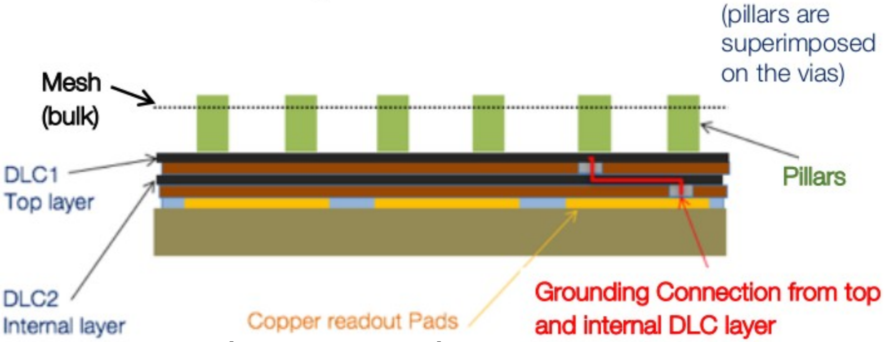
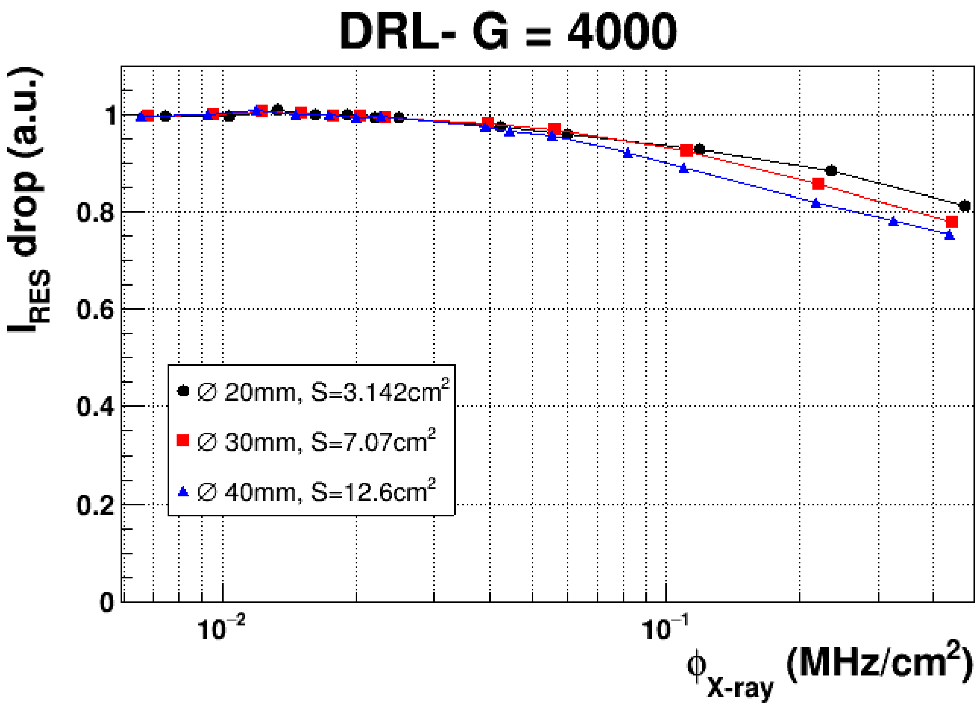
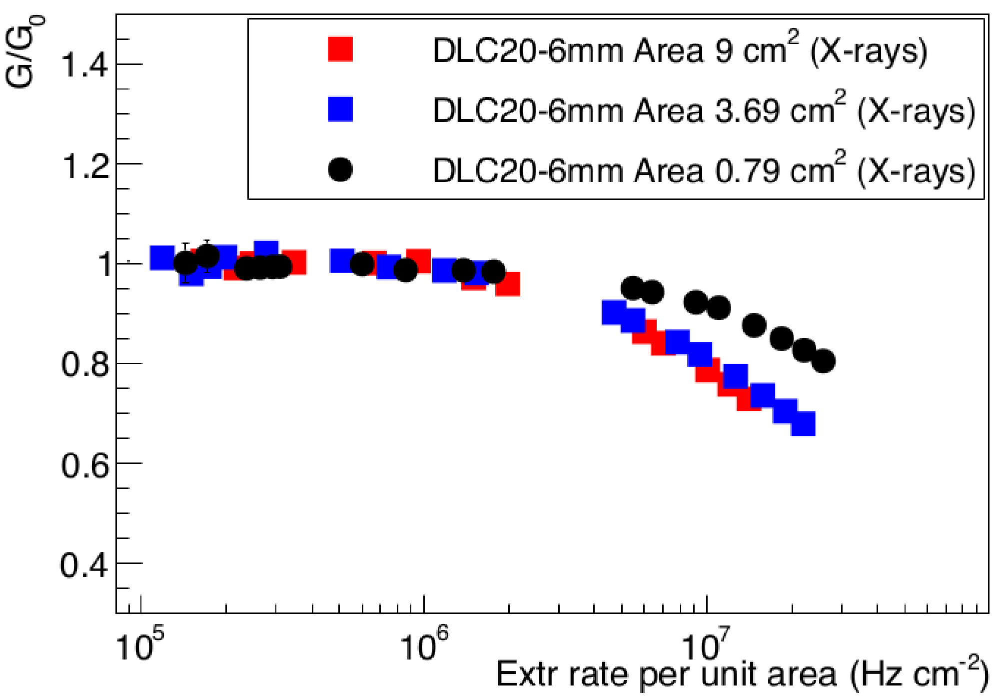


$Ar/CO_2/CF_4$ – 45/15/40
X-ray 5.9 keV → N=187 e-I pairs
Gain = 4000, **ρ=50-70 MΩ/□**
Heavy cathode

Ar/CO_2 – 97/3
X-ray 8 keV → N=285 e-I pairs
Gain = 6500, **ρ=20 MΩ/□**
Light cathode





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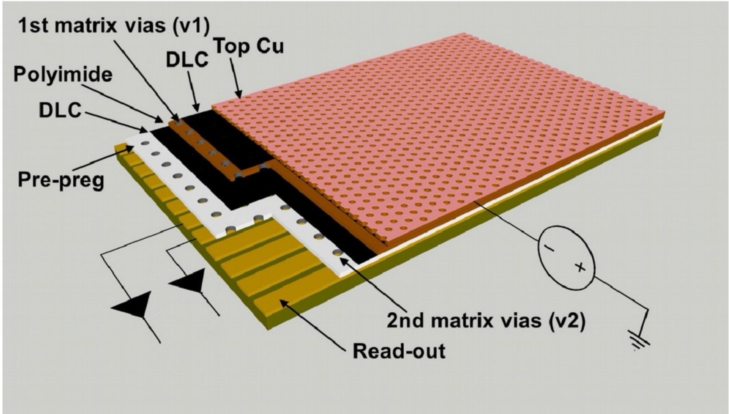
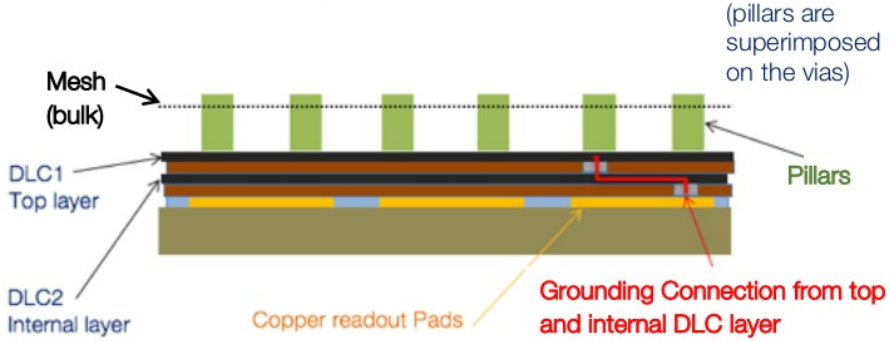


Double **DLC** (Diamond Like Carbon)
uniform resistive layer



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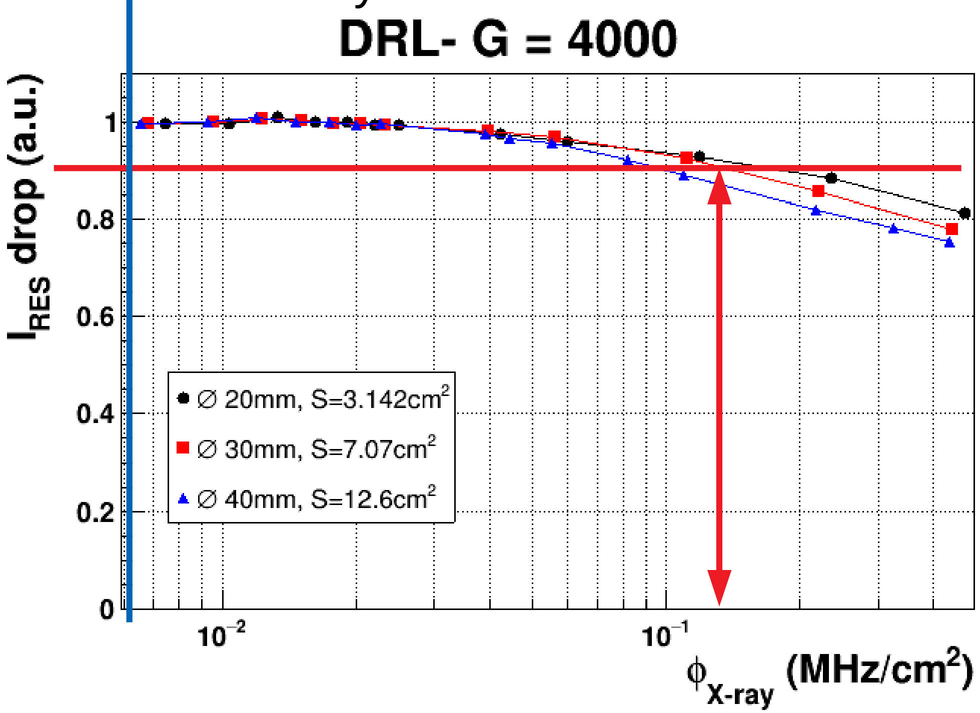
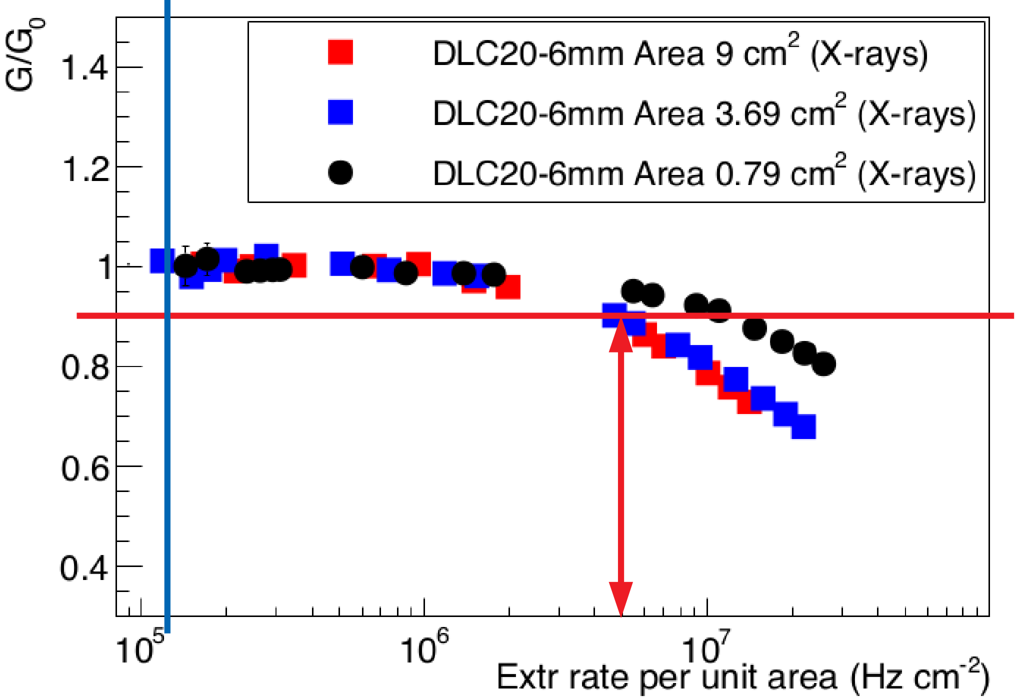
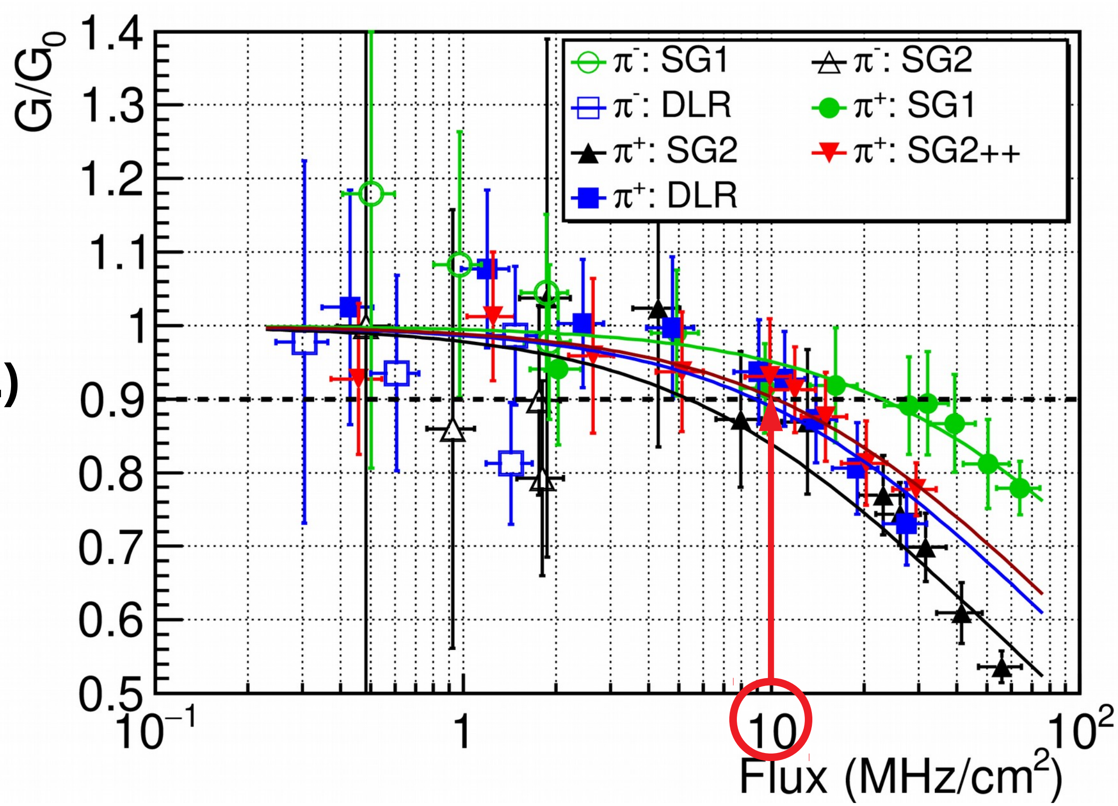




µ-RWELL rate capability @ PSI ’18

A larger Rate Capability has been previously measured @ PSI.

Beam conditions:
π^+ 350 MeV/c **(m.i.p.)**
spot Ø 28mm **(6cm^2)**



G/G$_0$=90%

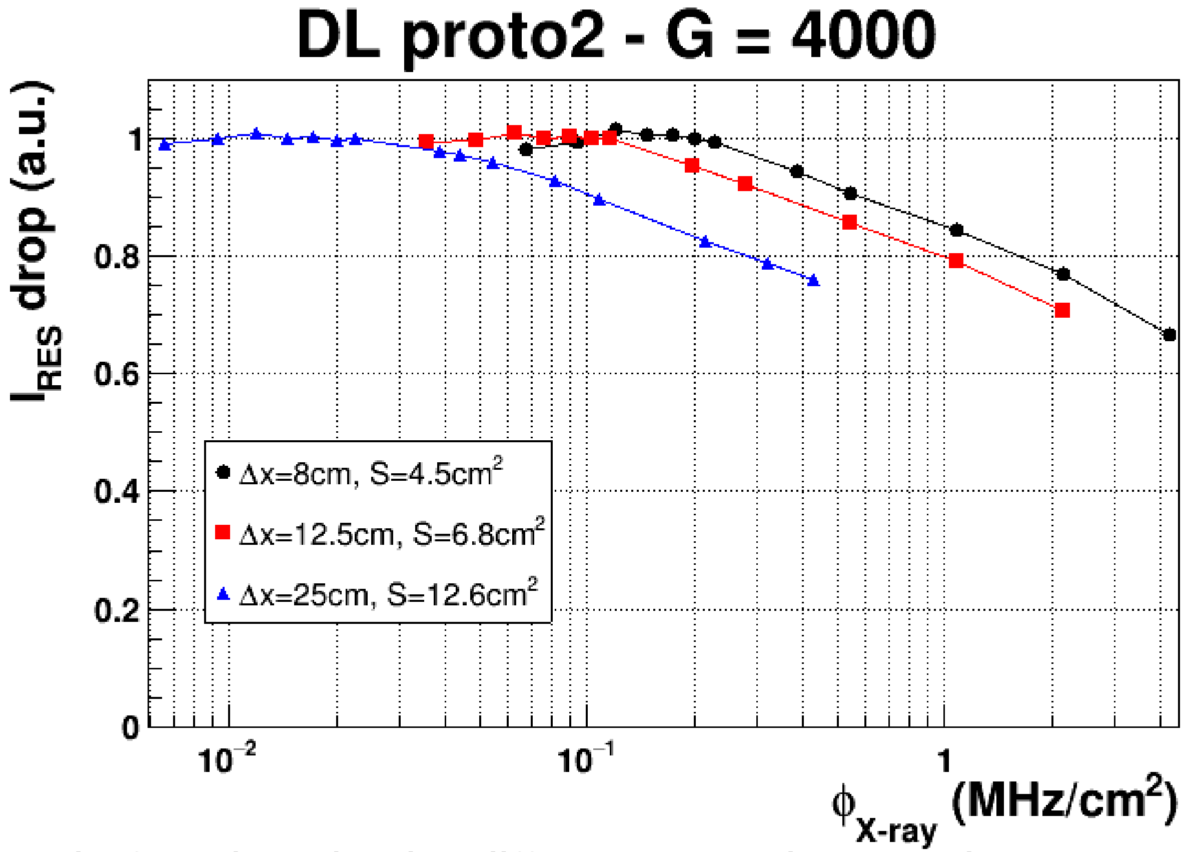
Same chambers used with X-Ray.
GEM detectors used for defining both flux and gain drop.

Rate capability with **m.i.p.** → **10 MHz/cm^2.**

G. Bencivenni et al 2019 JINST 14 P05014

Is the extrapolation well done?

Hypothesis: a fit in a flux range where the detector response is not linear lead to a large deviation from the true rate capability.
In order to check this hypothesis we have measured the rate capability at <u>different distances from the X-ray gun</u>. This allows us to explore <u>different flux ranges</u> for the first points.



Same detector as before (DRL). The different spot size could not explain the differences among the three curves. **The effect of a wrong extrapolation seems evident.**

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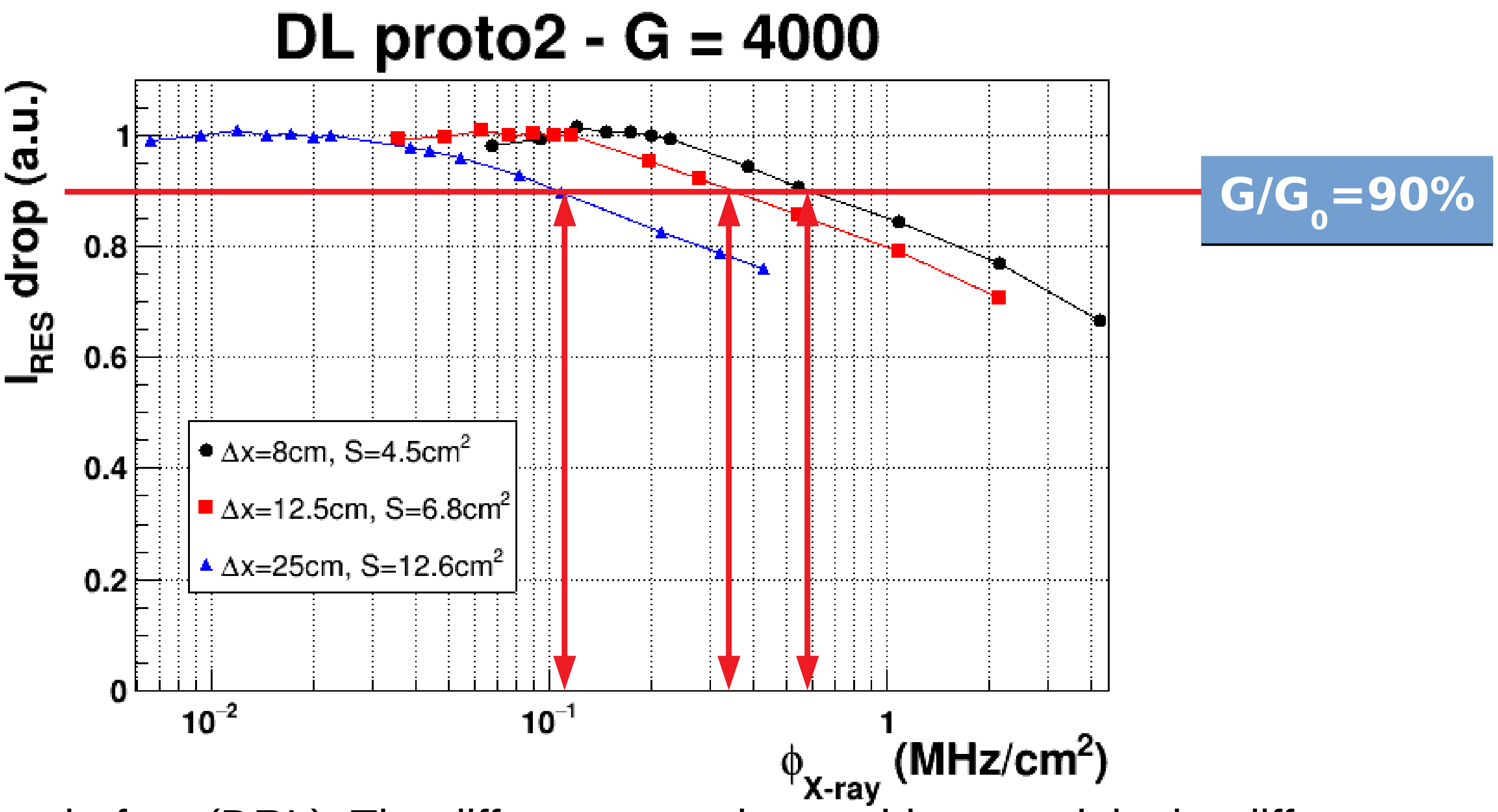

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Conclusions

Standing the validity of the PSI results:

- No relevant dependence on the spot size for μ-RWELL (grid and dot)
- No relevant dependence on the spot size for MM (dot)
- Extrapolation effect on the rate capability measurement with X-ray

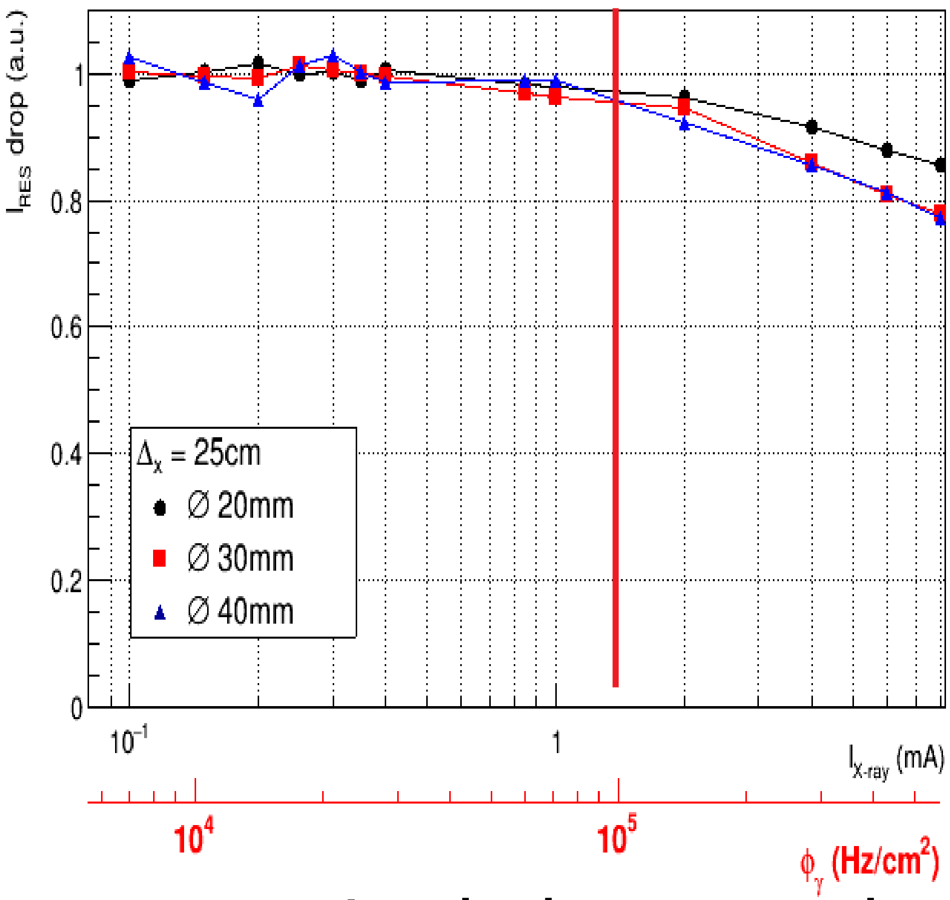
Outlook

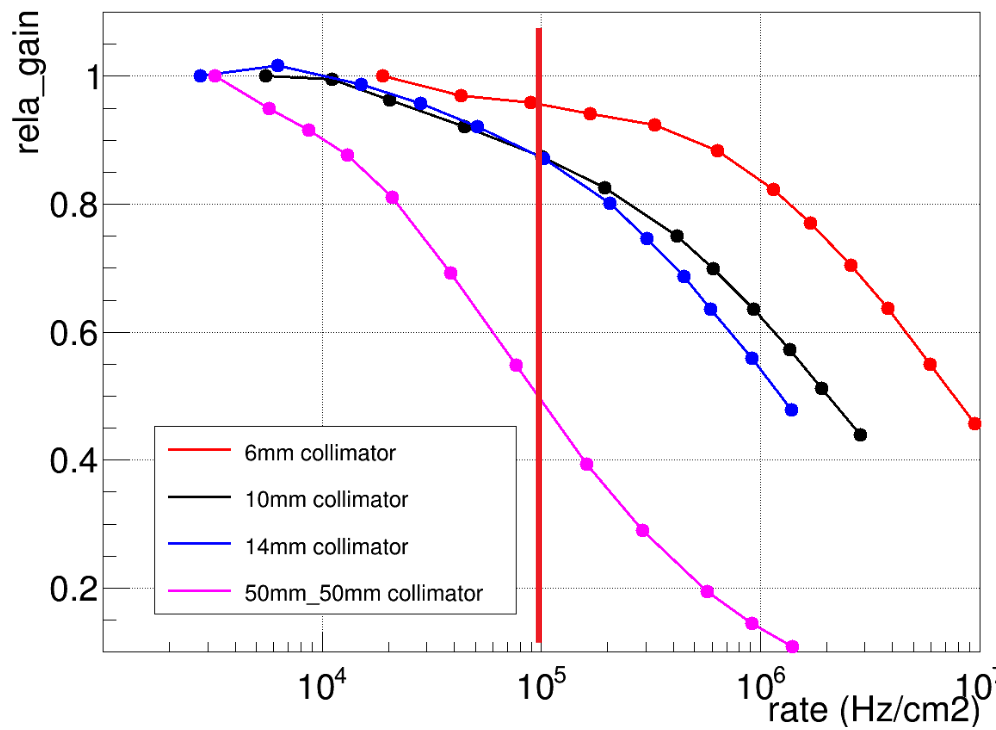
- Light cathode for μ-RWELL for X-ray measurements
- A different approach for the extrapolation, based on a global fit of the data
- Due to the spread of resistive detectors in our field, we propose to clearly define a shared method for rate capability measurements inside the resistive CP:
  - spot definition (RMS, FWHM, sigma)
  - G_0 extrapolation
- In this framework LNF will soon host MMM (Mauro’s MicroMegas)...
- … waiting for Zhou Yi

SG1 – PEDP comparison

SG1 u-RWELL
Gain = 4500, ρ=70 MΩ/□
Grid pitch 6mm, dead area 2mm
geom. acceptance 66%

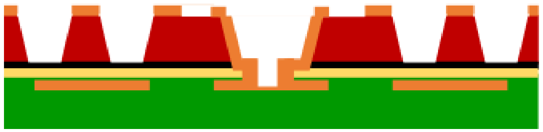
PEDP u-RWELL
Gain = 6500, ρ=**???** MΩ/□
Conductive hole pitch 5mm





Is strip charge evacuation better than dot one?

PEDP: Patterning , Etching , Drilling & Plating

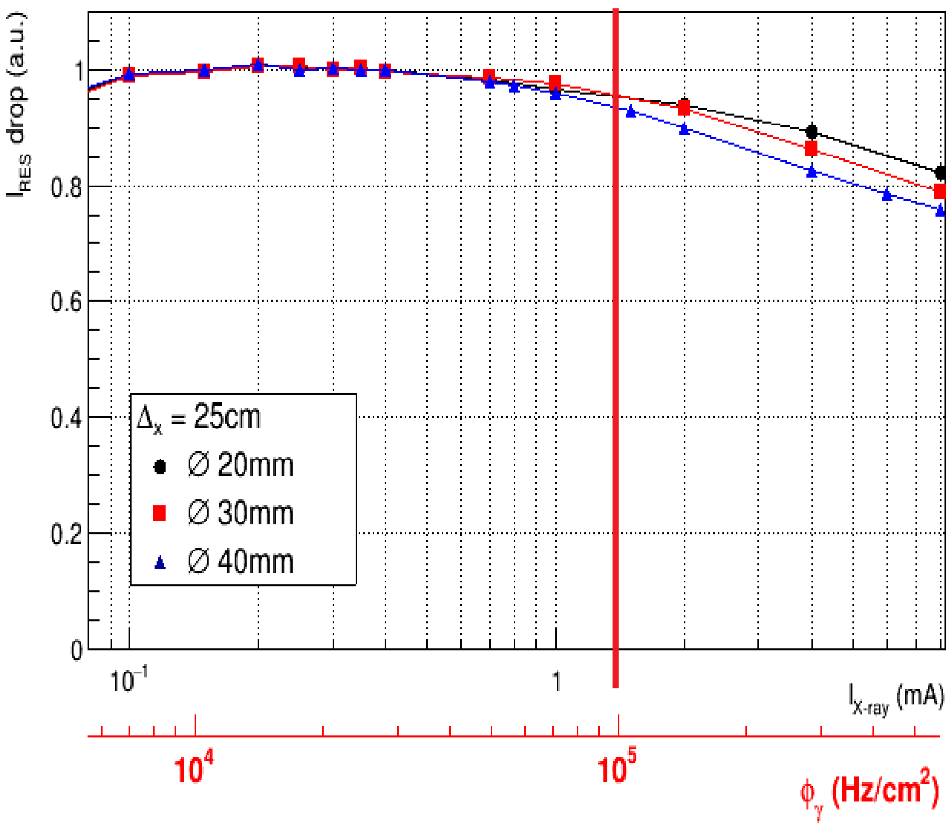


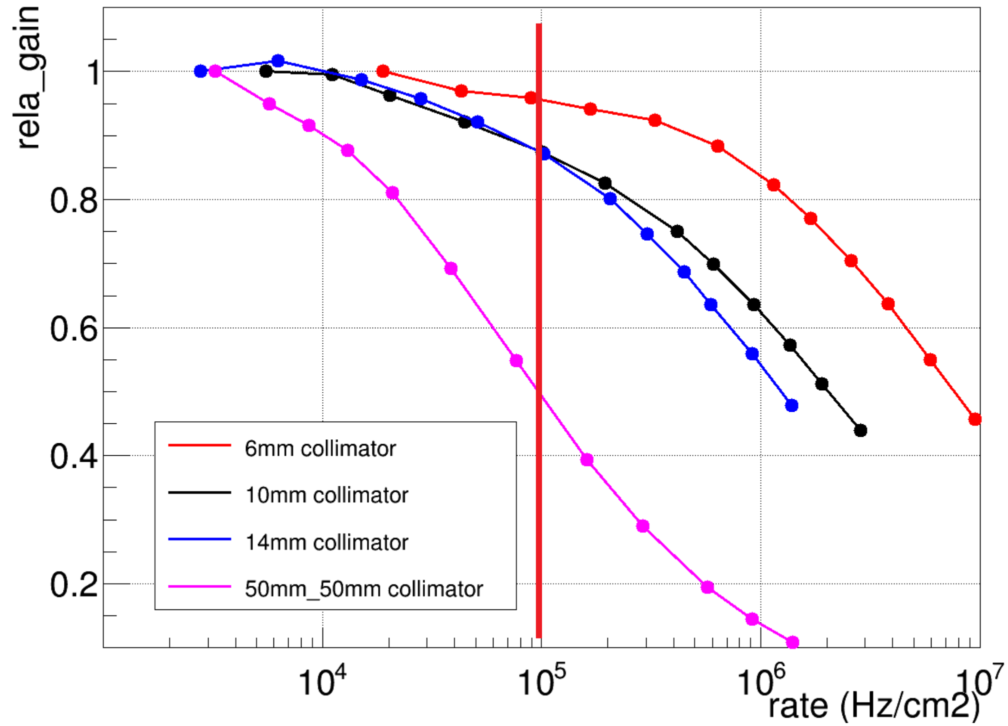
PEDP µRWELL
Conductive hole pitch: 5 mm

DL – PEDP comparison

DL u-RWELL
Gain = 4000, ρ=50-70 MΩ/□
Conductive hole pitch 7mm

PEDP u-RWELL
Gain = 6500, ρ=**???** MΩ/□
Conductive hole pitch 5mm





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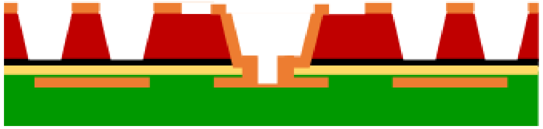
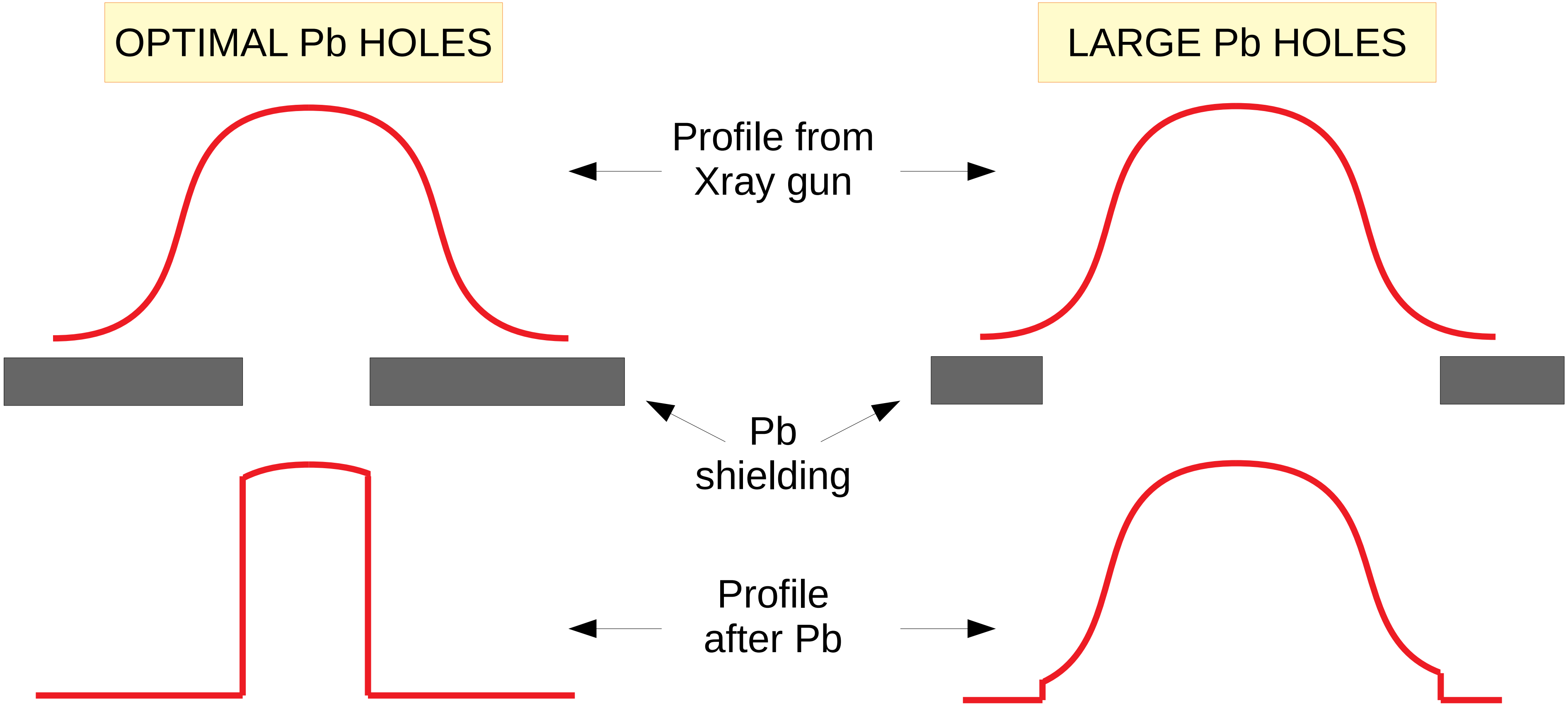


PEDP μRWELL
Conductive hole pitch: 5 mm

Our DL layout doesn't show any problems.

Choice of Pb hole diameters



The use of the Pb shieldings to determine the X-ray spot is effective only if the former is smaller. This condition is a compromise between distance from the Xray gun and the size of the hole. At a given distance and detector gain, and for the lowest possible Xray flux, we measure the current drawn by the detector. **If the ratio current/SPOT wouldn't change we are confident that the beam is homogeneous.**

In the end we choose **Δx=25cm** and **Ø = 20,30,40mm**

Checked also with APV25

$$\frac{G_k}{G_{0,k}} = \frac{i_k}{eNS\phi_k}\frac{eNS\phi_{0,k}}{i_{0,k}} = \frac{i_k}{i_{0,k}}\frac{\phi_{0,k}}{\phi_k}.$$

G/G_0 definition for the k^{th} µ-RWELL detector.

$$\frac{G_{GEM}}{G_{0,GEM}} = \frac{i_{GEM}}{eNS\phi_{GEM}}\frac{eNS\phi_{0,GEM}}{i_{0,GEM}} = \frac{i_{GEM}}{i_{0,GEM}}\frac{\phi_{0,GEM}}{\phi_{GEM}} = 1$$

$$\frac{\phi_{0,GEM}}{\phi_{GEM}} = \frac{i_{0,GEM}}{i_{GEM}}$$

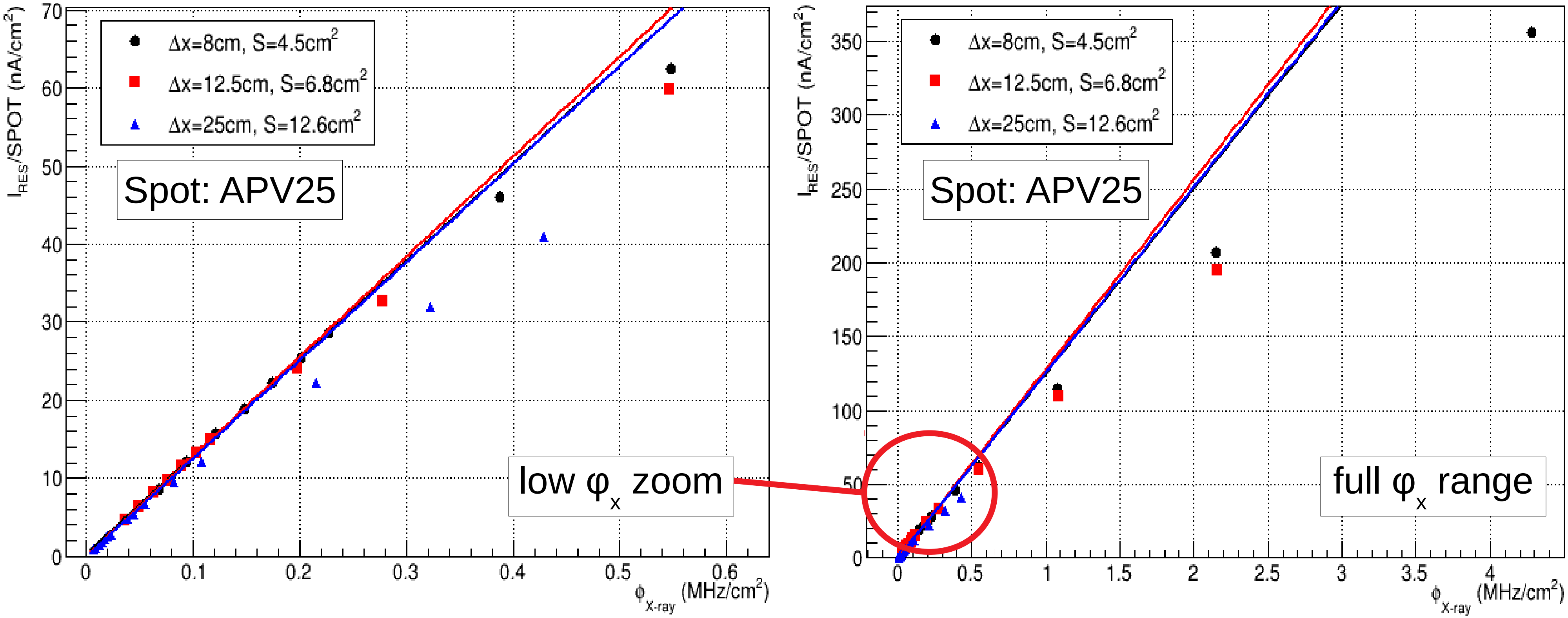
It is possible to use a GEM to measure the rate capability, under two assumptions:

- The GEM doesn't suffer rate effects ($G_{GEM}/G_{0,GEM}=1$)
- The impinging flux is the same on the GEM and the µ-RWELL

$$\frac{\phi_{0,GEM}}{\phi_{GEM}} = \frac{\phi_{0,k}}{\phi_k}$$

$$\frac{G_k}{G_{0,k}} = \frac{i_k}{i_{0,k}}\frac{\phi_{0,k}}{\phi_k} = \frac{i_k}{i_{0,k}}\frac{i_{0,GEM}}{i_{GEM}} = \mathcal{N}\frac{i_k}{i_{GEM}}.$$

Is the normalization well done?



This measurement seems to be affected by the normalization done at low flux from which we extrapolate: the reference gain (G_0) and the X-ray flux axis.

In order to check this hypothesis we have measured the rate capability at different distances from the X-ray gun. This allows us to explore different flux ranges for the first points.

The linear fit must be done for a flux range in which the detector is not affected by a gain drop. Our hypothesis is that a fit in a flux range in which the detector response is not really linear could lead to a large deviation from the true rate capability.