A simple model for the gain drop in micro-Resistive WELL

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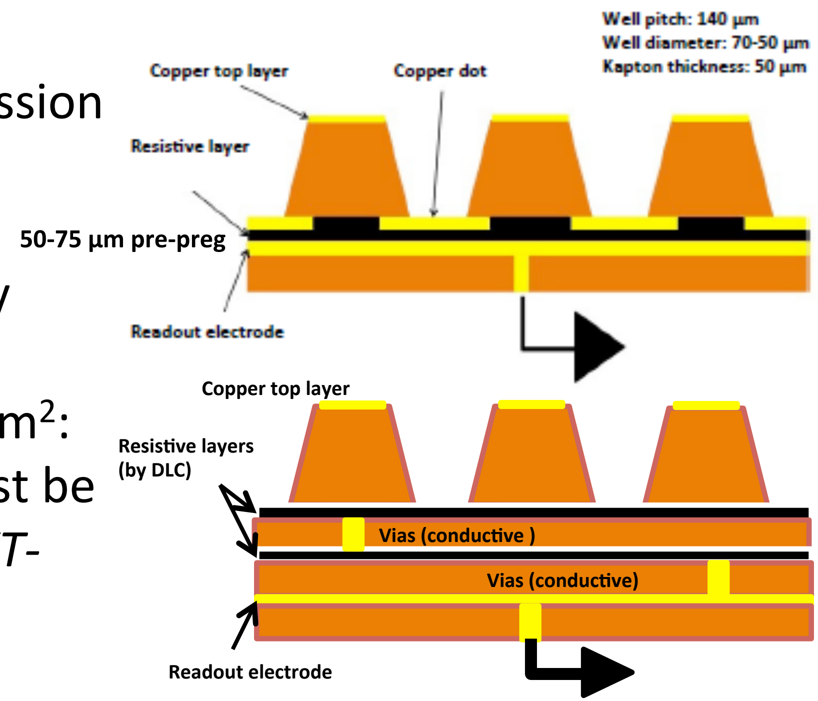
The µ-RWELL architecture

The **µ-RWELL(*) PCB** is realized by coupling:

1. a "**suitable patterned GEM foil**" for the "amplification stage"

2. a **"resistive stage"** for the discharge suppression & current evacuation
   - **i. "Low particle rate" (LR)** << 100kHz/cm^2**:** single resistive layer → surface resistivity (~100 MΩ/☐)
   - **ii. "High particle rate" (HR**)** >> 100kHz/cm^2: more sophisticated resistive scheme must be implemented (*performed by MPDG_NEXT-LNF financed by GR5-INFN*)

3. a **simple readout PCB** board → OK



(**) the final goal being O(1 MHz/cm^2)

(*) the first prototype of such a type of detector (at that time called *Blind-GEM* detector) has been proposed in the 2009 by the author.

The µ-RWELL features

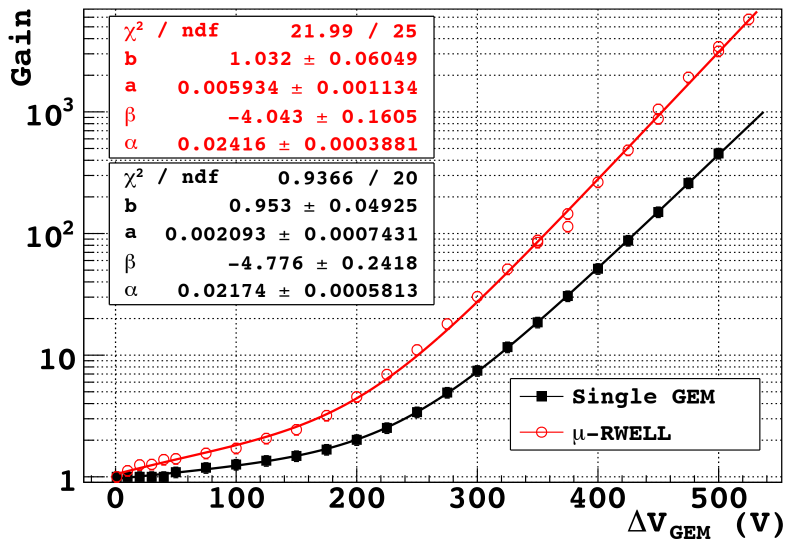
The **µ-RWELL** has features & performance in common either with **GEM or Micromegas (MMs)**:

- from **GEM** it takes the **amplifying scheme** with the peculiarity of a **"well defined amplifying gap"**, thus ensuring very **high gain uniformity** (even better because of the absence of transfer/induction gaps)

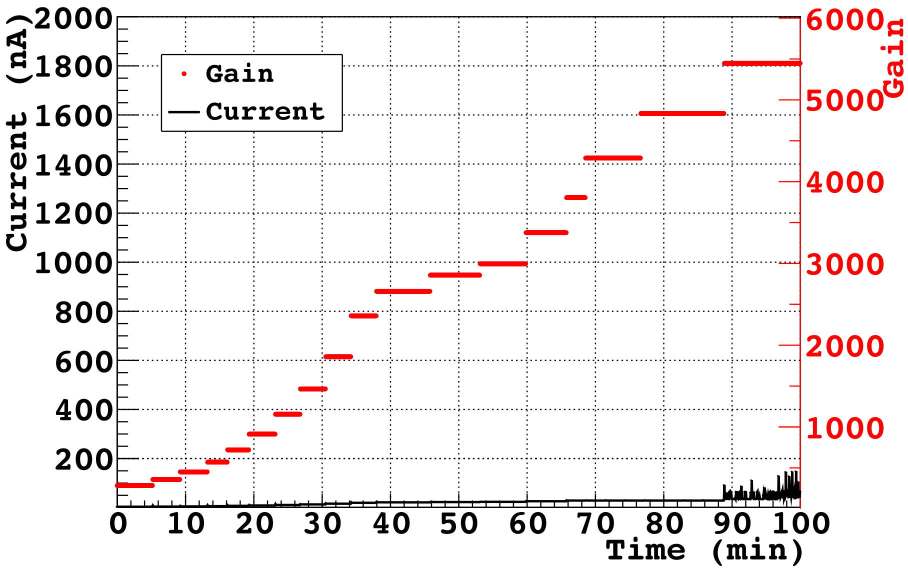
- from **Micromegas** it takes the **resistive readout** scheme that allows a **strong suppression** of the amplitude of the **discharges**

The μ-RWELL performance

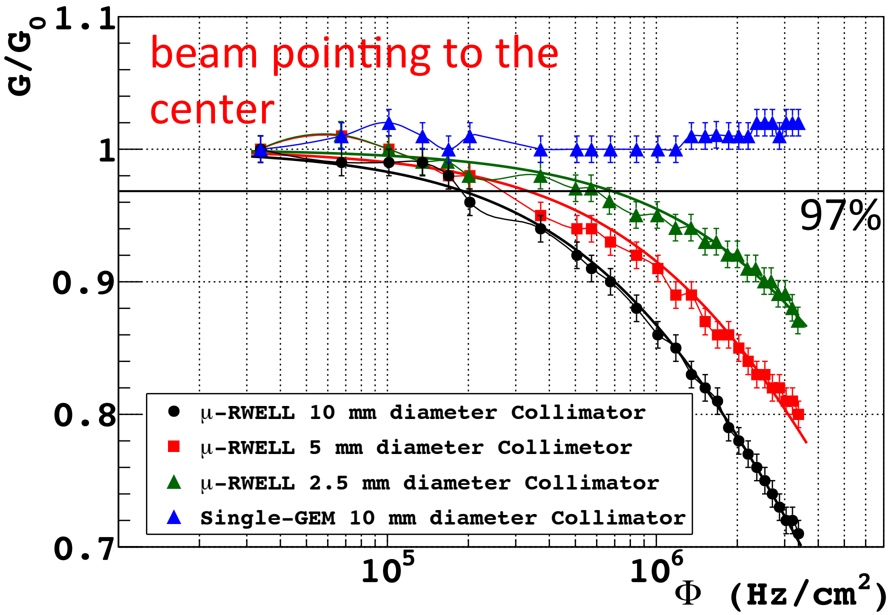
The prototype (5x5 cm^2 active area) has been tested with Ar:CO_2 70:30 and Ar:iC_4H_{10} 90:10 gas mixtures, irradiated with 5.9 keV X-rays generated by a PW2217/20 Philips Tube.



Gas gain (current mode) measured in Ar:CO_2 70:30



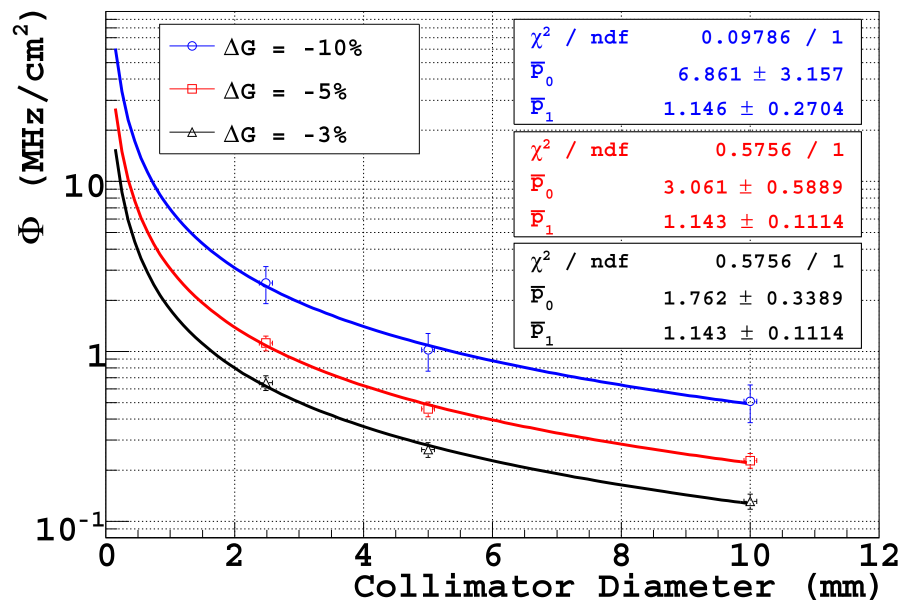
The µ-RWELL performance



The presence of the resistive layer has a drawback represented by the reduced capability of the detector to stand high particle fluxes

A suitable segmentation of the resistive layer can tune the rate capability of the detector.

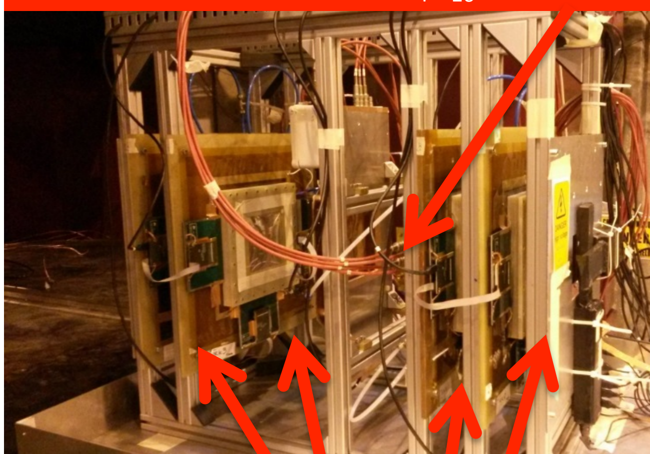
IMPORTANT: <u>for a m.i.p. the primary ionization is 7 times smaller than 5.9 keV X-rays, so with the proper segmentation a flux of ~1 MHz/cm^2 for m.i.p should be achievable</u>



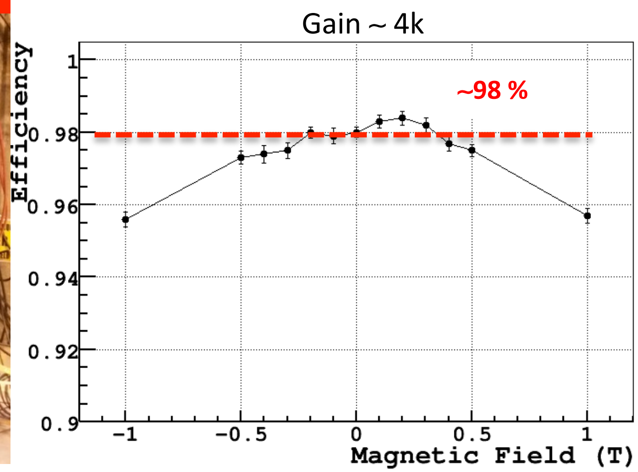
The μ-RWELL performance

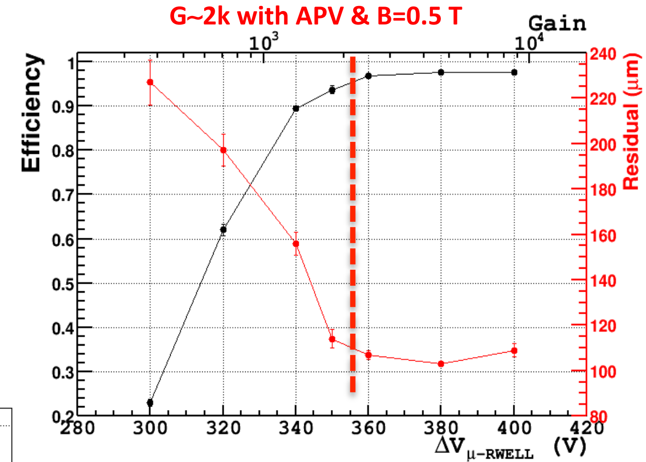
The μ-RWELL (10x10 cm² proto, single resistive layer, 80 MΩ/□) has been tested @ H4 facility (SPS) with 150 GeV/c muons in Goliath magnet (B up to 1 T)

μ-RWELL prototype **400 μm pitch strips**
APV25 (CoG analysis) Ar/iC_4H_{10} = 90/10



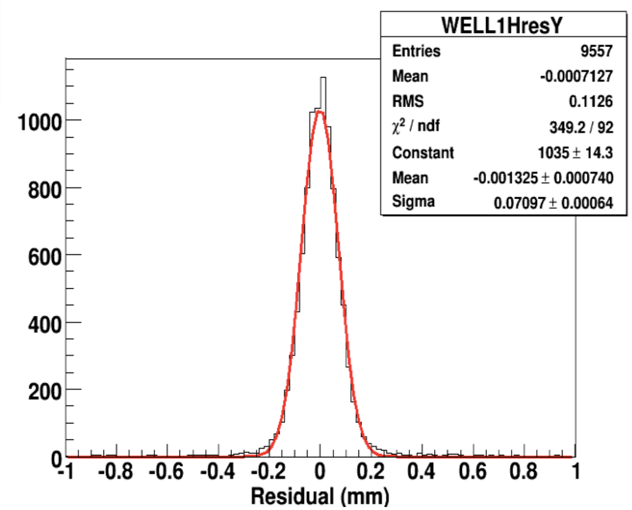
GEMs Trackers





Center of Gravity method

Orthogonal tracks



σ_{RWELL} = (52+-6) μm @ B= 0T after TRKs contribution substraction

To be published on NIM A

The gain drop

It's easy to understand that the larger is the resistance of the layer, the longer will take the charge to reach the ground. This creates temporary charging-up of the resistive layer with consequent drop of gain.

The gain of a μ-RWELL can be written as follows

$$G_0 = e^{\beta + \alpha V_0}$$

that allows to write a gain drop as

$$G = e^{\beta + \alpha (V_0 - \delta V)} = G_0 e^{-\alpha \delta V}$$

Assuming that the gain drop is only due to the resistive layer, by Ohm's first law we have

$$\delta V = i\Omega$$

being i the current measured on the resistive layer, depending obviously by the primary ionization N_0, by the gain of the detector and by the radiation rate R

$$i = eN_0 GR$$

so that we can write

$$G = G_0 e^{-\alpha i \Omega} = G_0 e^{-\alpha e N_0 G \Phi \pi r^2 \Omega}$$

The gain drop

That is

$$\frac{G}{G_0} e^{\alpha e N_0 G \Phi \pi r^2 \Omega} = 1$$

Expanding with the Maclaurin series and reordering the terms we have

$$\alpha e N_0 G_0 \Phi \pi r^2 \Omega \left(\frac{G}{G_0} \right)^2 + \frac{G}{G_0} - 1 = 0$$

and finally

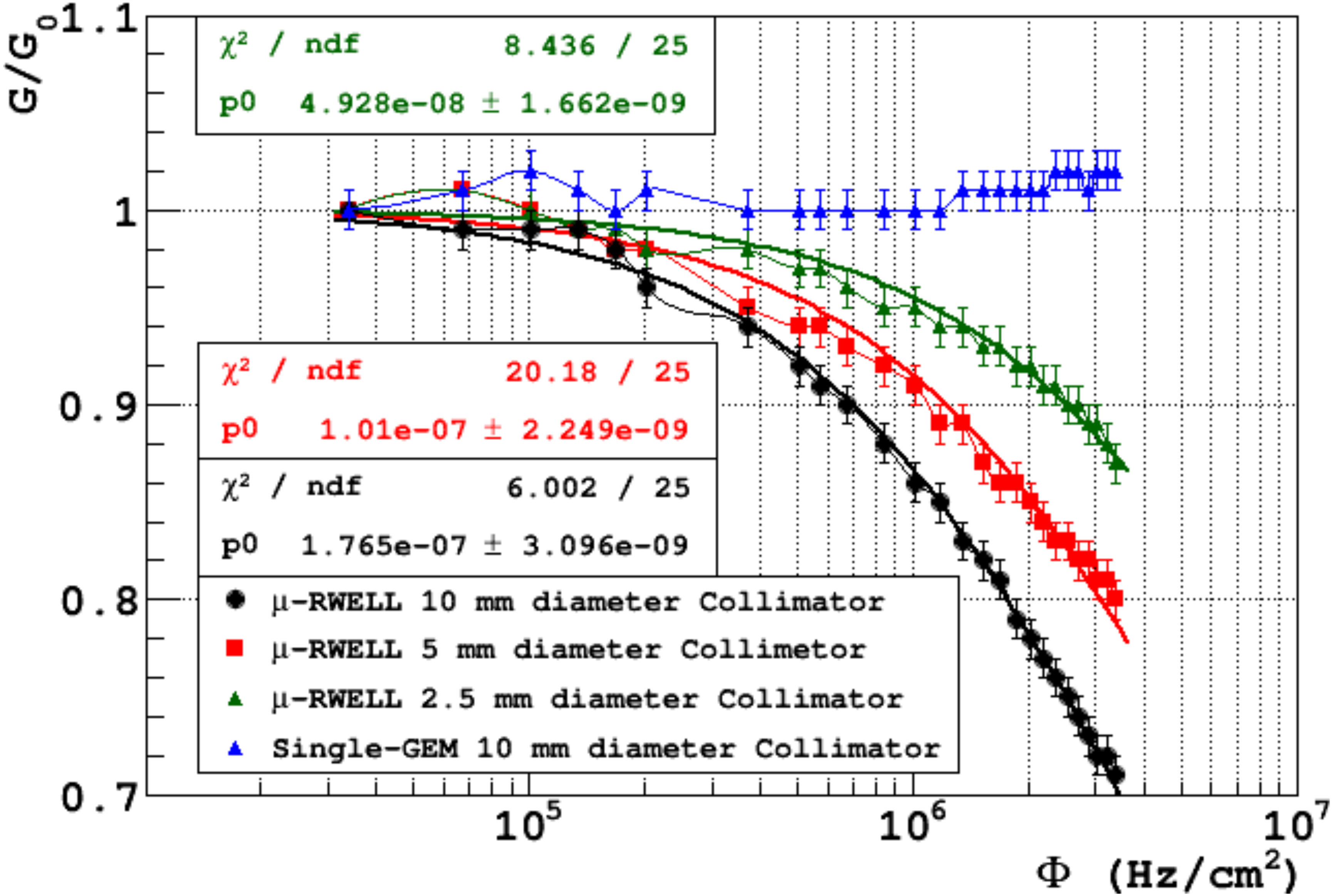
$$\frac{G}{G_0} = \frac{-1 + \sqrt{1 + 4 p_0 \Phi}}{2 p_0 \Phi}$$

where

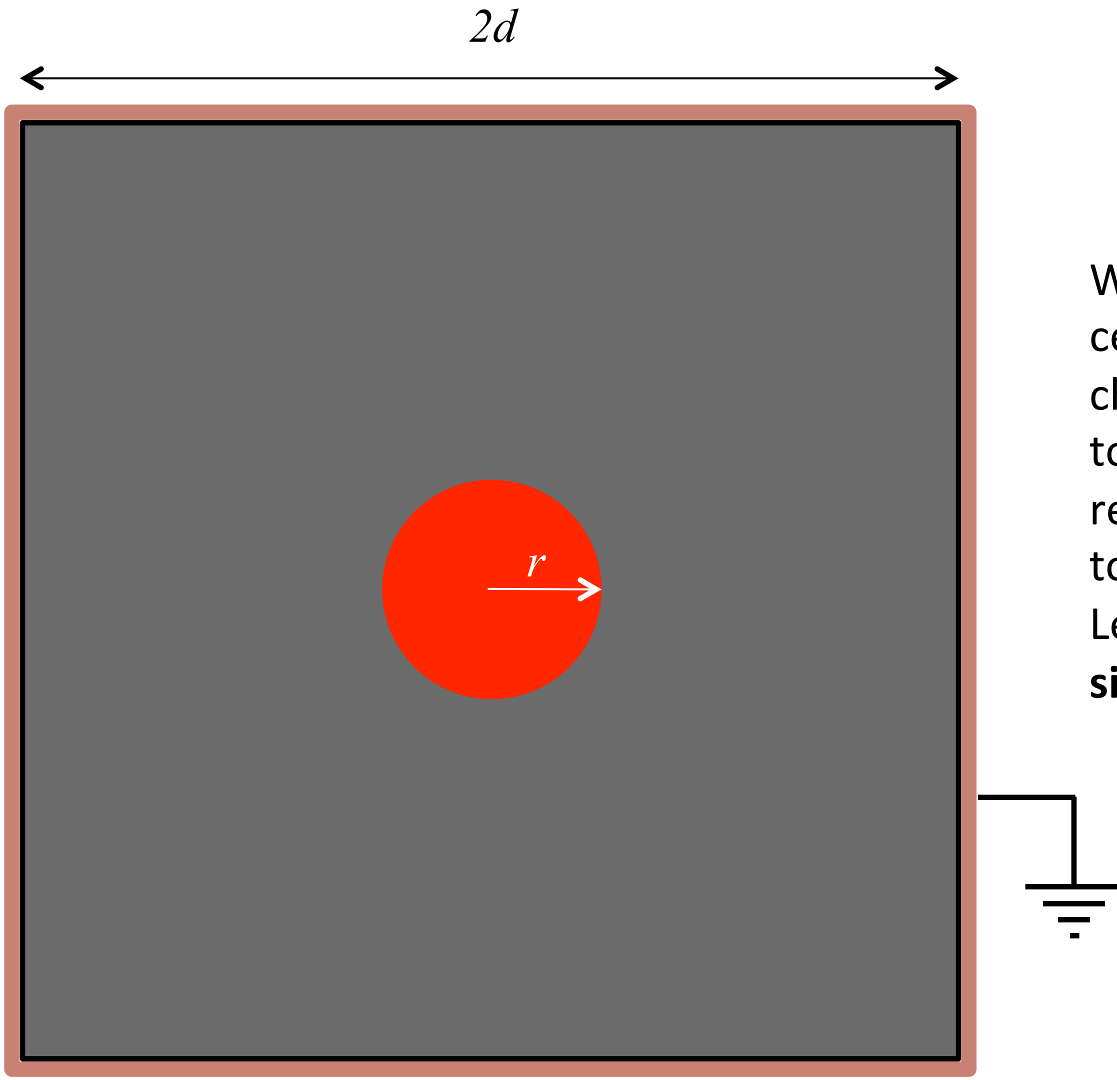
$$p_0 = \alpha e N_0 G_0 \Omega \pi r^2$$

This function includes the dependence on the expected gain and on the rate, here exploited as the product of the tube activity times the collimator surface

The gain drop



The resistance Ω: a simple model



We pointed the X-ray gun in the center of the active area. The charges drift on the resistive layer towards the ground, facing a resistance Ω along their path towards the ground.
Let d be **the half of the active area side** and r **the collimator radius**.

The resistance Ω: a simple model

We consider the case $r << d$ so that we can approximate the active area with a circle. The charge produced at a distance ξ in the interval $]0,r]$ covers an averge path

$$< d - \xi >= \frac{\int_0^r \int_0^{2\pi} (d-\xi)\, \mathrm{d}\xi \mathrm{d}\theta}{\int_0^r \int_0^{2\pi} \mathrm{d}\xi \mathrm{d}\theta} = d - \frac{r}{2}$$

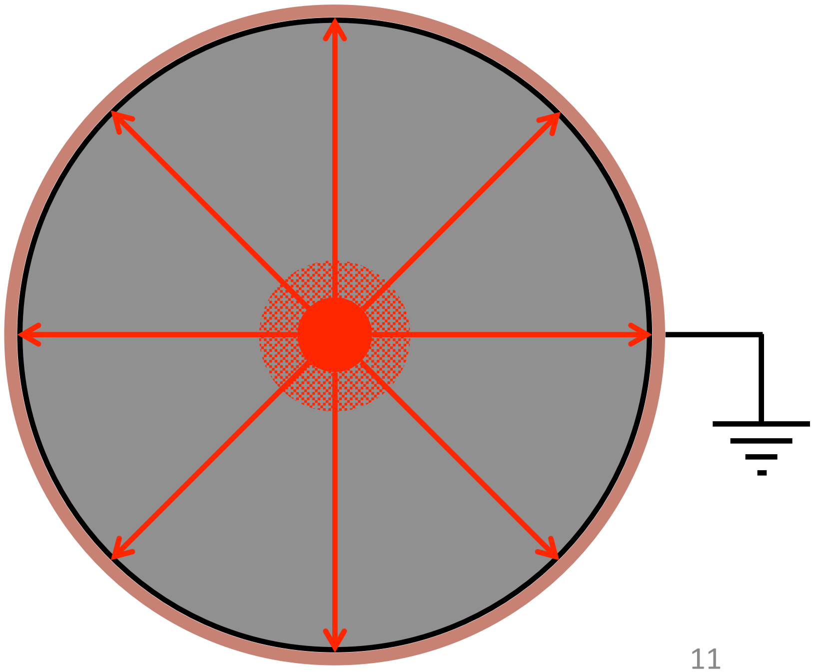
This looks like the charge is all concentrated in a circle with radius *r/2*. From here the charges drift towards the ground crossing a surface

$$S = \delta \int_0^{2\pi} \frac{r}{2} \mathrm{d}\theta = \delta \pi \mathrm{r}$$

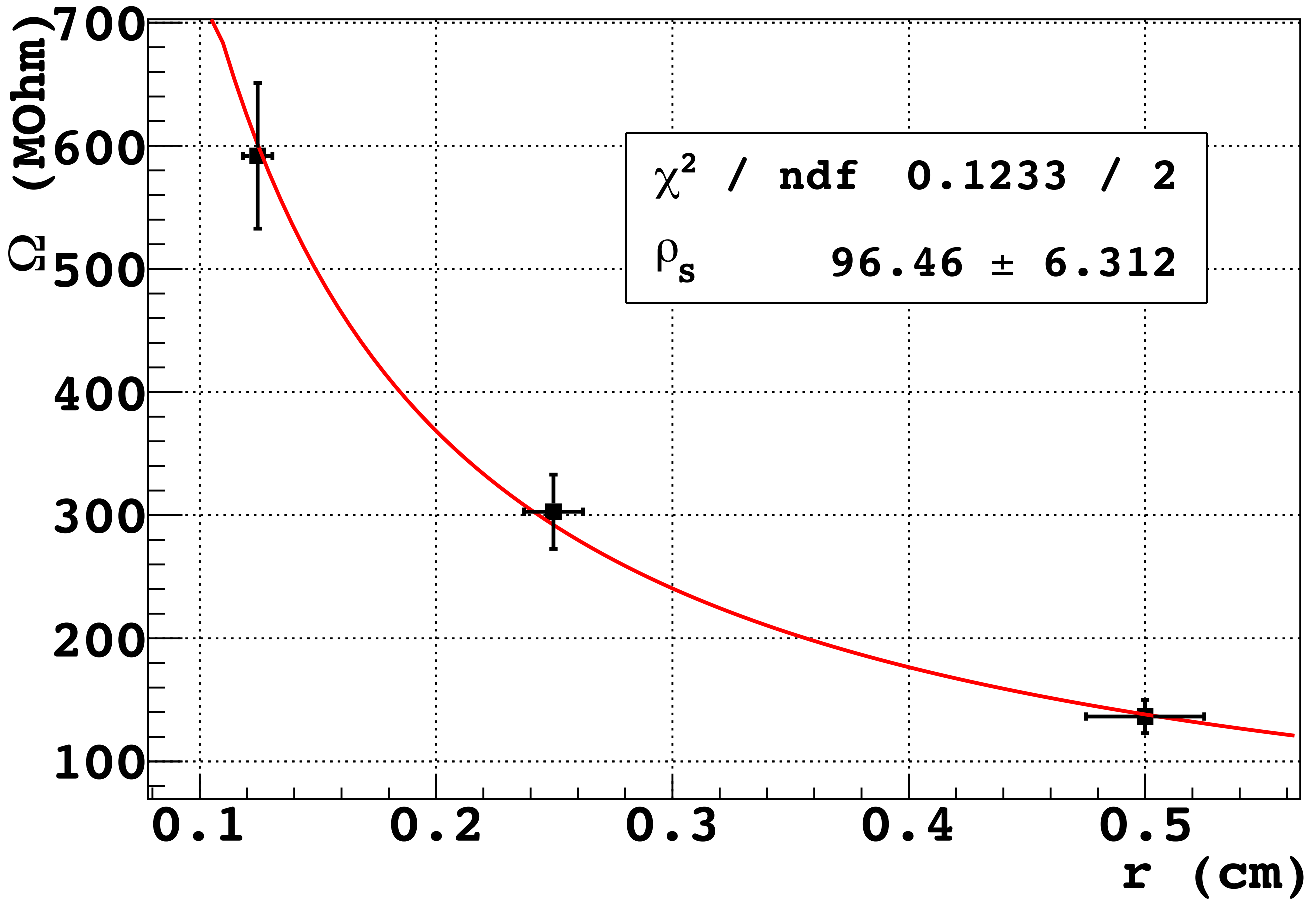
And by second Ohm's law

$$\Omega = \rho_v \frac{d - \frac{r}{2}}{\delta \pi r} = \rho_S \frac{d - \frac{r}{2}}{\pi r}$$

We computed Ω from the fit and we plot it vs r



The resistance Ω: a simple model



Compatible with the value of **100 MΩ/☐** declared by the deliverer

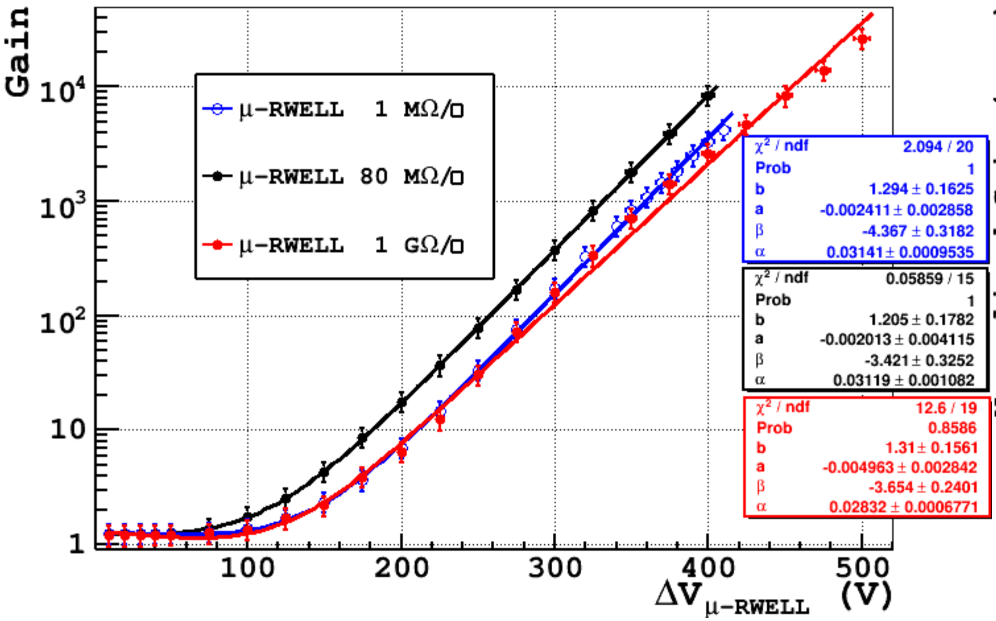
μ-RWELL: other prototypes

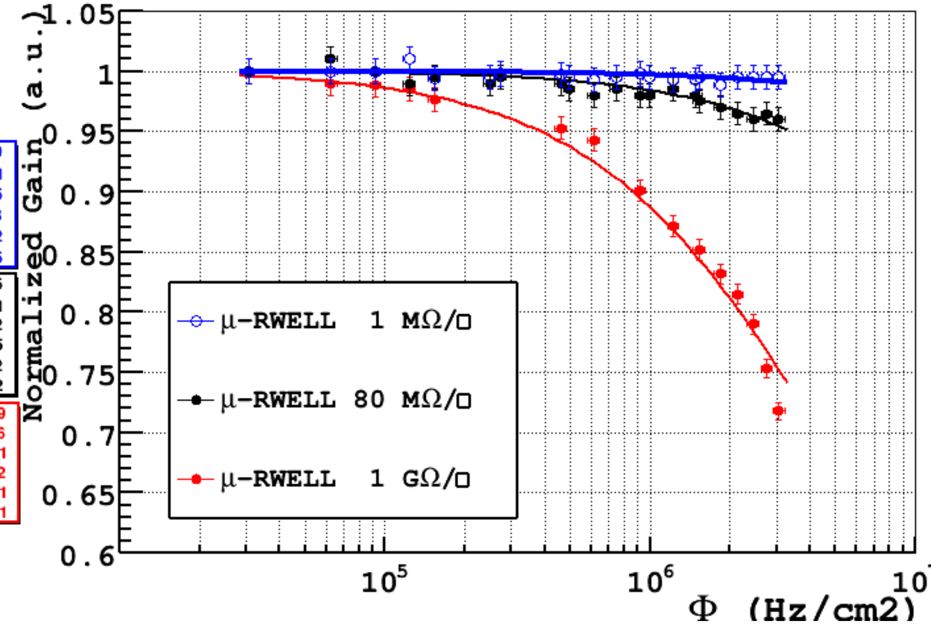
	μ-RWELL 1 MΩ/□	**μ-RWELL 80 MΩ/□**	**μ-RWELL 1 GΩ/□**
Hole Pitch [μm]	140	100	100
External /Internal Hole Diameter [μm]	70/50	55/50	72/30
Active Area [cmxcm]	10x10	5x5	5x5
Note	With copper dots Double resistive layers	Without copper dots One resistive layer	Without copper dots One resistive layer

μ-RWELL: other prototypes

X-ray tube, Ar:iC_4H_{10} 90:10

2,5 mm Diameter Collimator





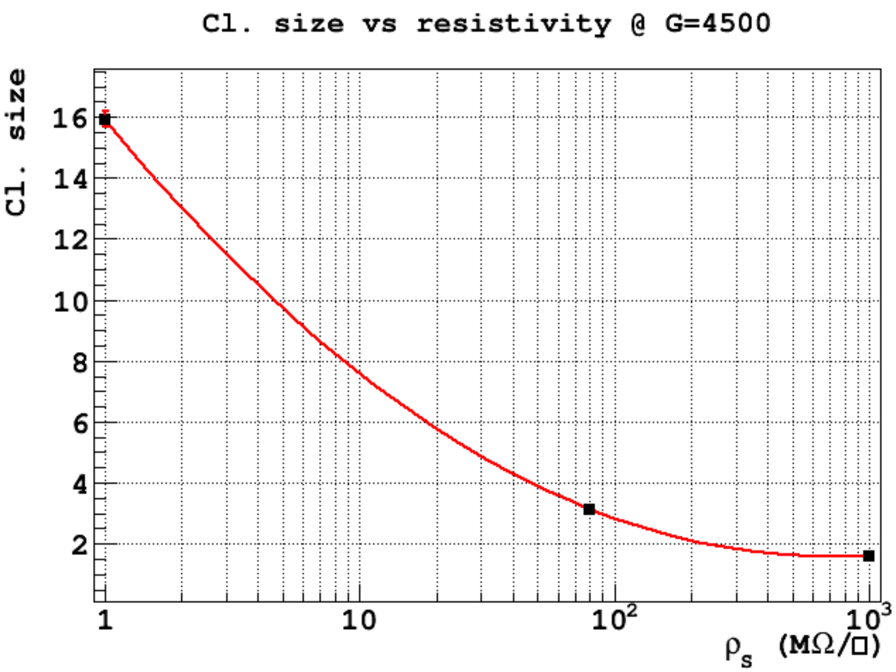
Fit Results:

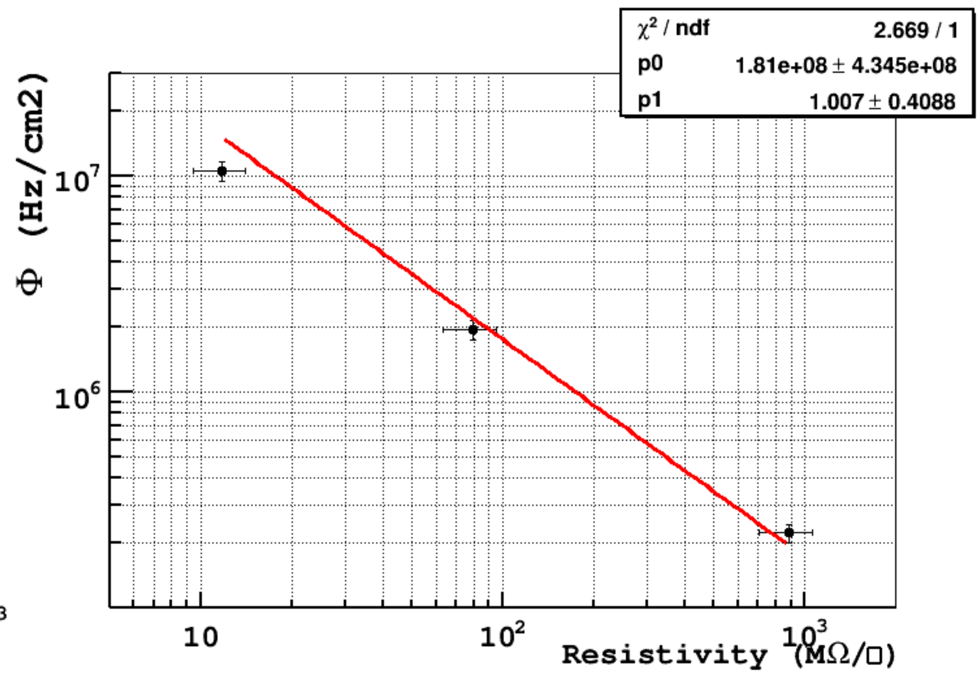
Resistivity declared by the deliverer: **1 GΩ/☐**; from fit **ρ_S= 883.8 ± 176.7 MΩ/☐**

Resistivity declared by the deliverer: **80 MΩ/☐**; from fit **ρ_S= 79.3 ± 15.8 MΩ/☐**

Resistivity declared by the deliverer: **1 MΩ/☐**; from fit **ρ_S= 11.7 ± 2.3 MΩ/☐**

μ-RWELL: other prototypes





μ-RWELL Cluster Size in Ar/ ISO=90/10 @ SPS beam test

Rate with a ΔG=-3% Ar/Iso=90/10 & X-ray

Conclusions and outlook

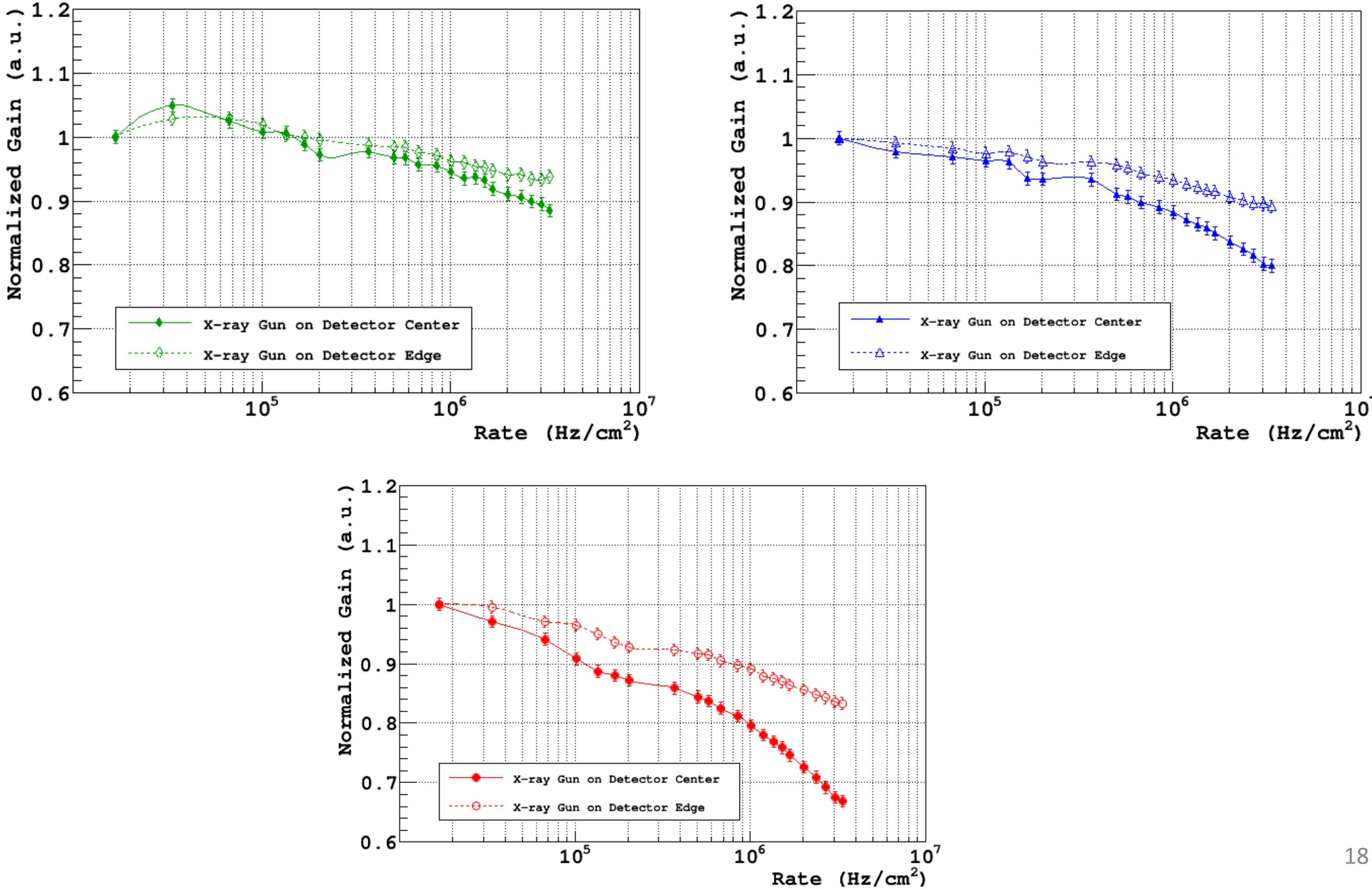
- Some μ-RWELL detectors have been built and tested: the technology is promising: ε~95% @ 1T, σ_x~50 μm @ 0 T
- A rate capability of 1 MHz/cm^2 seems to be achievable for m.i.p.

About the model:

- Work on extension is ongoing: what happens when the beam is not centered? What happens when the circular approximation cannot be applied?
- Anyway the voltage drop looks to be well described

SPARE

The μ-RWELL performance



The μ-RWELL performance