INFN Istituto Nazionale di Fisica Nucleare
LABORATORI NAZIONALI DI FRASCATI
www.lnf.infn.it

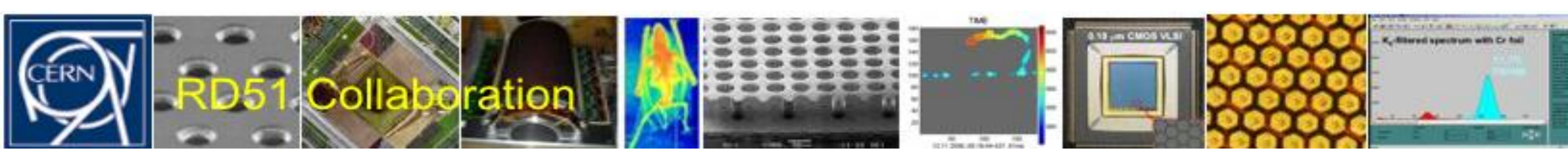
Advances on micro-RWELL gaseous detector

G. Morello[1]

G. Bencivenni[1], L. Benussi[1], L. Borgonovi[3], R. De Oliveira[2], P. De Simone[1], G. Felici[1], M. Gatta[1], P. Giacomelli[3], A. Ochi[6],M. Poli Lener[1], A. Ranieri[4], M. Ressegotti[5], I. Vai[5]

1. Laboratori Nazionali di Frascati dell'INFN
2. CERN
3. INFN Sezione di Bologna
4. INFN Sezione di Bari
5. INFN Sezione di Pavia
6. Kobe University

24th January 2017



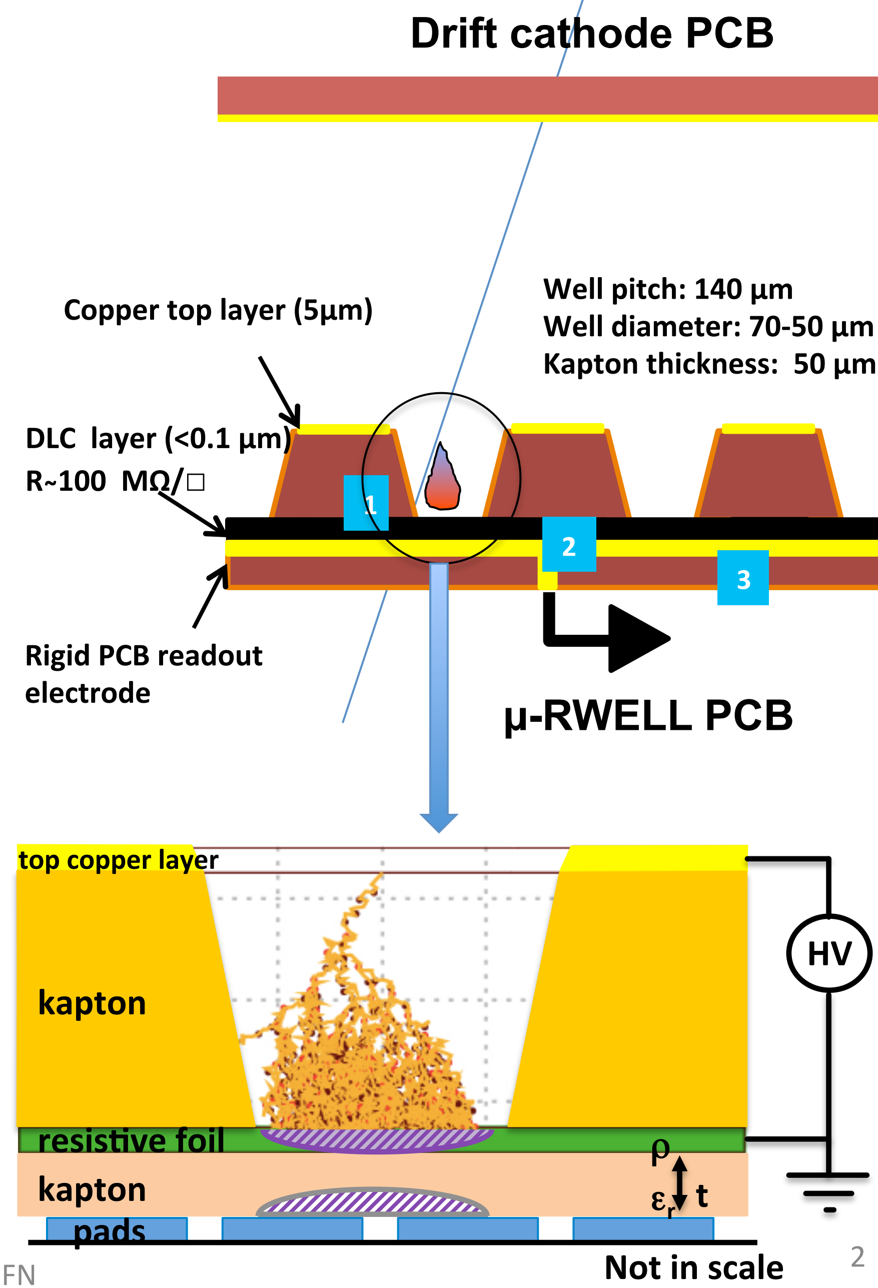
The detector architecture

The **µ-RWELL is composed of** only **two elements**:
the **µ-RWELL_PCB** and the **cathode**

The **µ-RWELL_PCB, the core of the detector,** is realized by **coupling:**

1. a "WELL patterned kapton foil" as **"amplification stage"**
2. a **"resistive sheet"** for the discharge suppression & current evacuation
   - **i. "Single resistive layer" (SL)** < 100 kHz/cm^2**:** single resistive layer → surface resistivity ~100 MΩ/☐ (CMS-phase2 upgrade; SHIP)
   - **ii. "Double resistive layer" (DL)** > 1 MHz/cm^2: more sophisticated resistive scheme must be implemented (MPDG_NEXT- LNF) suitable for LHCb-Muon upgrade
3. a **standard readout PCB**

G. Bencivenni et al., 2015_JINST_10_P02008



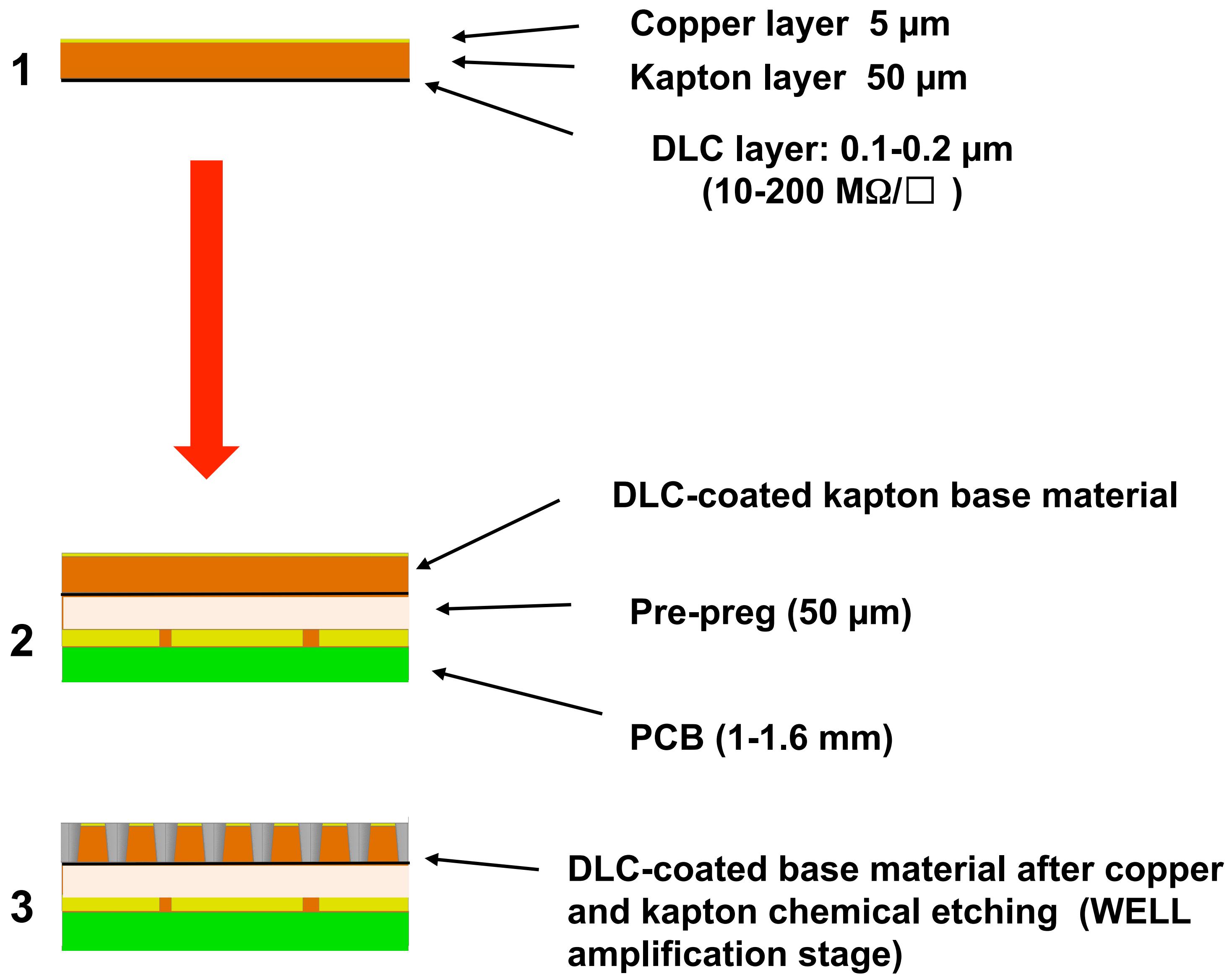
Why the resistive?

Because of the micrometric distance between electrodes, every MPGD suffers from spark occurrence that can damage the detector or the FEE.
A resistive readout quenches the discharge:

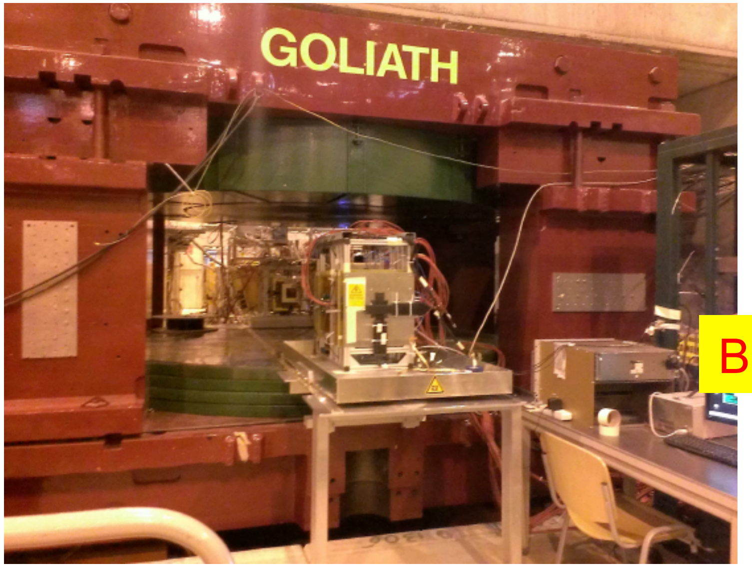
- The Raether limit is overcome
- The charge is deposited on the resistive layer
- The charge density spreads with ***τ = RC***
(M.Dixit, NIM **A 518** (2004) 721)
- The resistive layer is locally charged-up with a potential ***V=Ri***, reducing the ΔV applied to the amplification stage
- The amplification field is reduced
- The discharge is locally suppressed

Obviously this has a drawback correlated to high particle fluence, that's why we studied the performance of the detector as a function of the resistivity

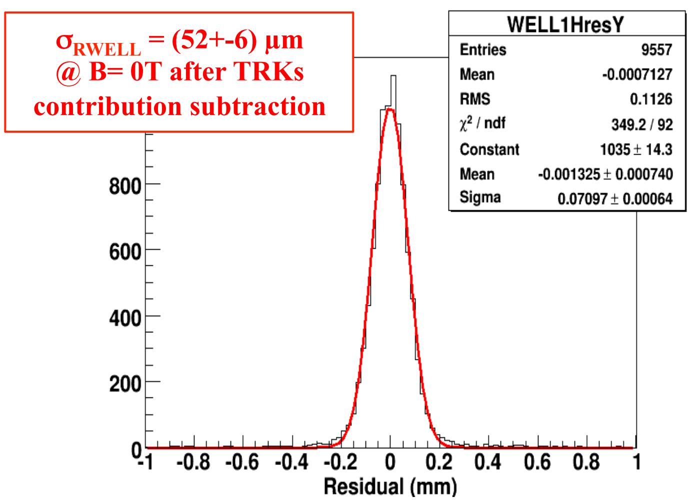
The µ-RWELL_PCB for Low Rate (CMS/SHiP)



The μ-RWELL performance: Beam Tests

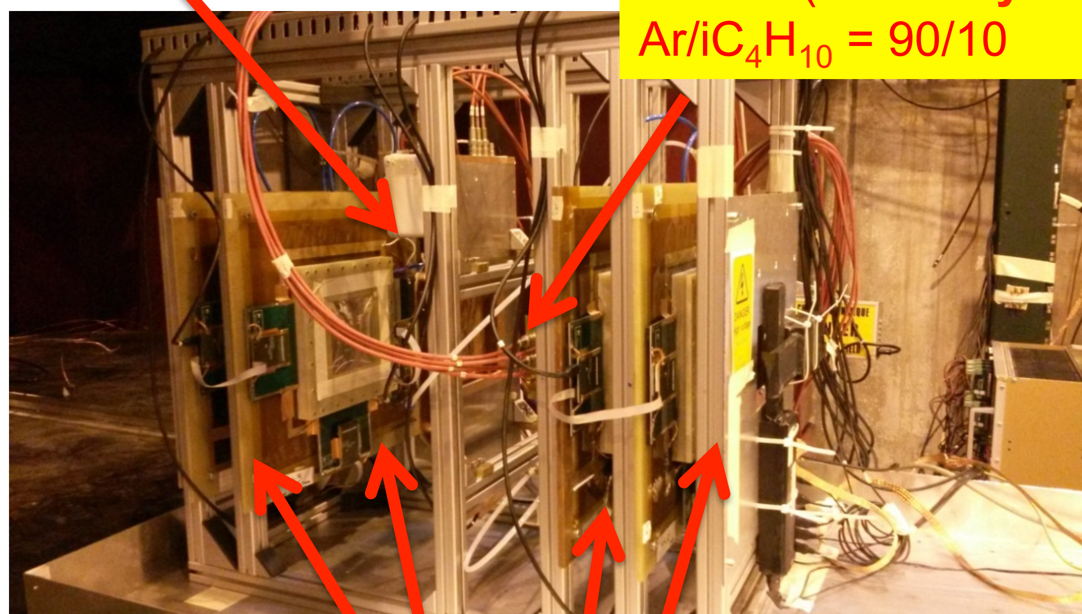


H4 Beam Area (RD51)
Muon beam momentum: 150 GeV/c
Goliath: B up to 1.4 T



μ-RWELL prototype
12-80-880 MΩ /□
400 μm pitch strips
APV25 (**CC analysis**)
Ar/iC_4H_{10} = 90/10

BES III-GEM chambers

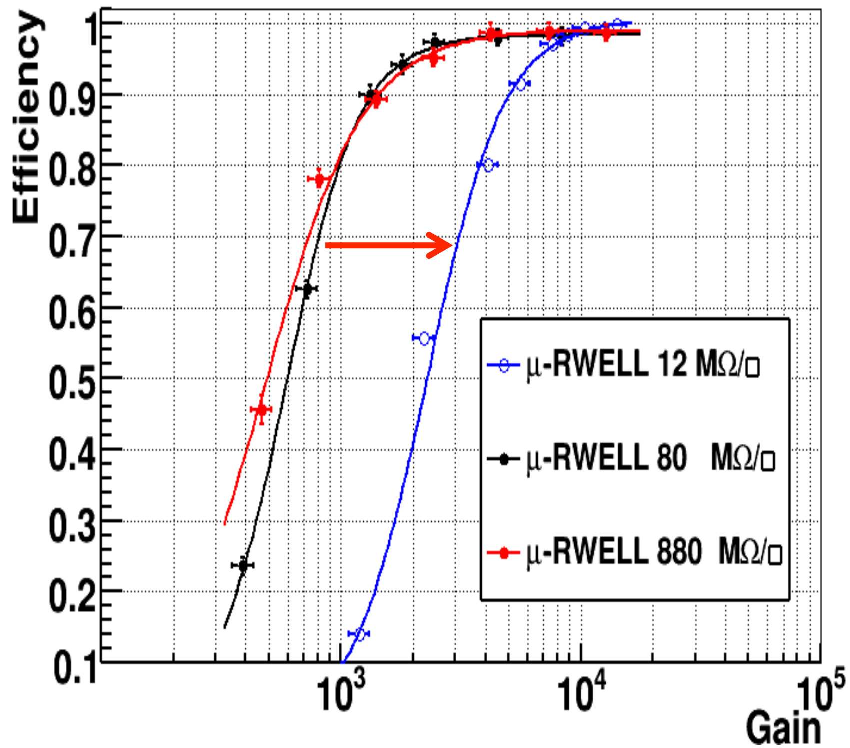


GEMs Trackers

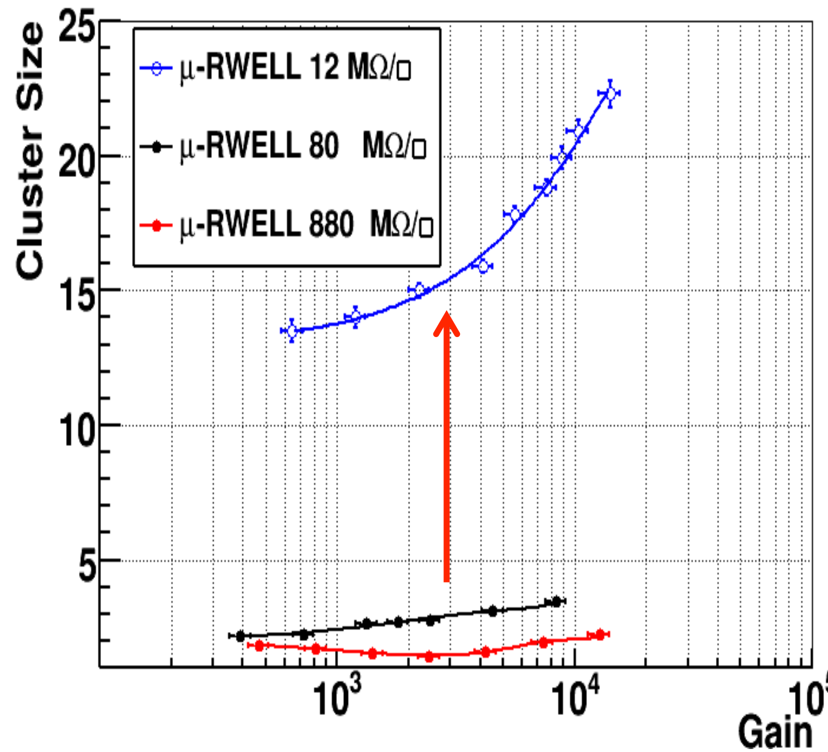
μ-RWELL: tracking efficiency

CC analisys

Ar/ISO=90/10



Ar/ISO=90/10

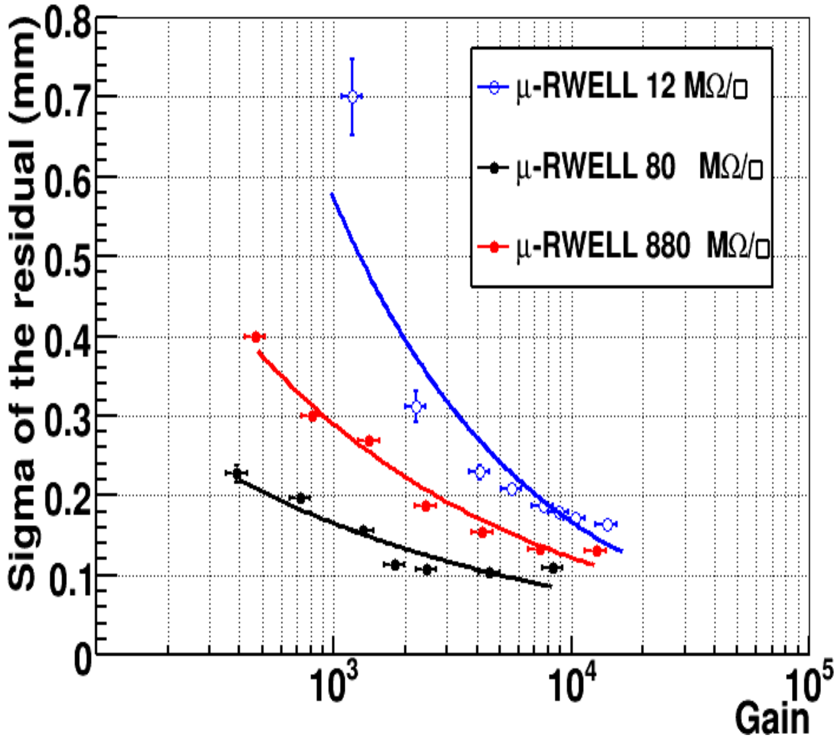


At **low resistivity the spread of the charge** (cluster size) on the readout strips **increases**, thus requiring a **higher gain** to reach the **full detector efficiency.**

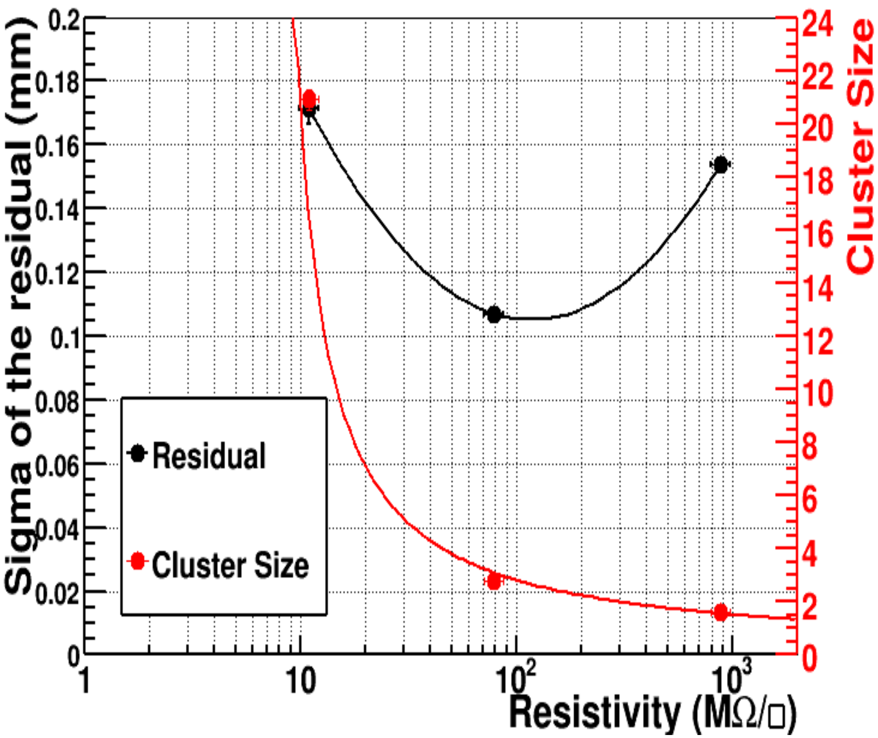
Space resolution: orthogonal tracks

CC analisys

Ar/ISO=90/10



Ar/ISO=90/10



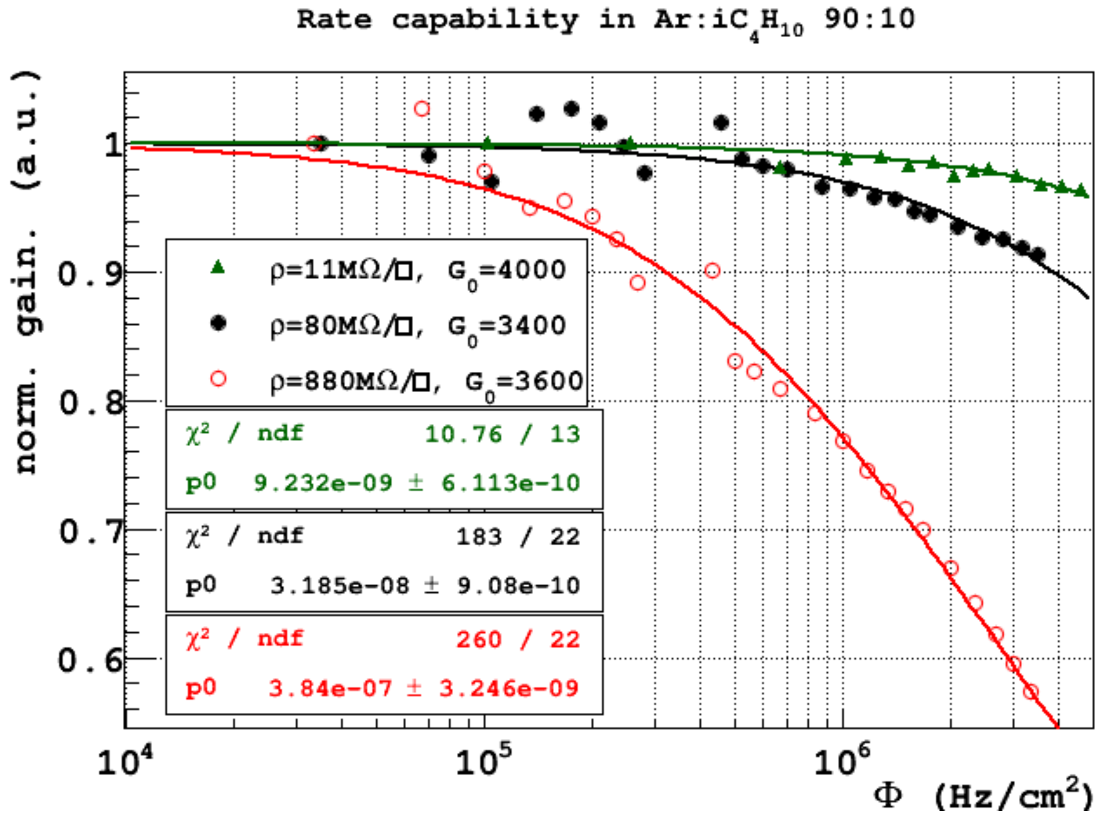
The **space resolution** exhibits a **minimum around 100MΩ/□.**

At **low resistivity** the **charge spread increases** and then **σ is worsening.**

At **high resistivity** the **charge spread is too small (Cl_size → 1)** then the Charge Centroid method becomes no more effective **(σ → pitch/√12).**

Rate capability with X-rays

Rate capability fitted with the function: $$\frac{G}{G_0} = \frac{-1+\sqrt{1+4p_0\Phi}}{2p_0\Phi}$$



Local irradiation, collimator radius 1.25 mm

Evaluation of the flux where $\Delta G/G_0$ = - 3%

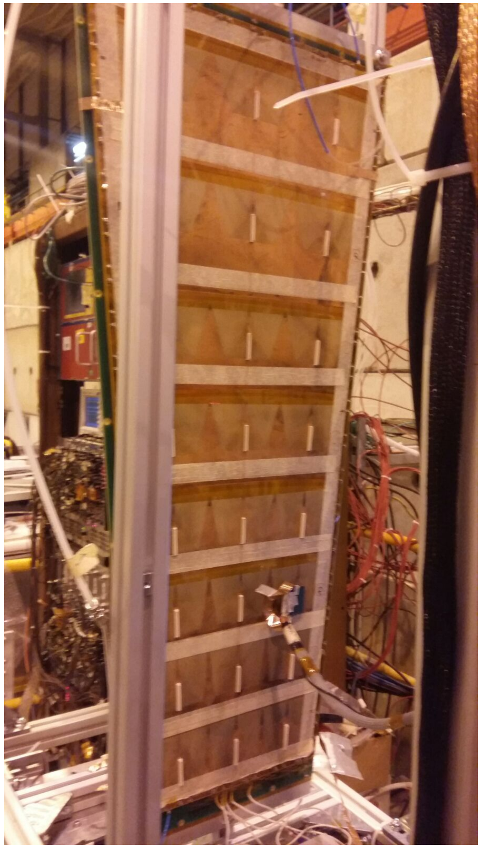
Φ = 850 kHz/cm²; **Φ = 77 kHz/cm²; Φ = 3.4 MHz/cm²;**

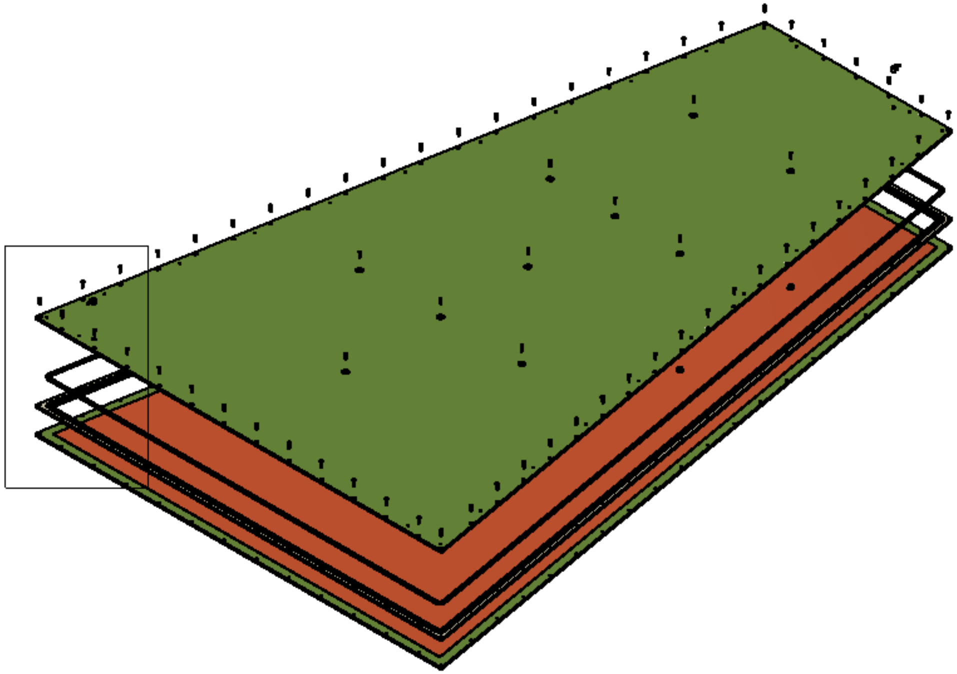
LARGE AREA

In the framework of the **CMS-phase2 muon upgrade** we are developing **large size μ-RWELL.** The **R&D** is performed in strict collaboration with **Italian industrial partners** (**ELTOS & MDT**). The work is performed in **two years** with following schedule:

1. Construction & test of the first **$1.2x0.5m^2$ (GE1/1) μ-RWELL** **2016**
2. Mechanical study and mock-up of $1.8x1.2\ m^2$ (GE2/1) μ-RWELL **2016-2017**
3. Construction of the first **$1.8x1.2m^2$ (GE2/1) μ-RWELL (only M4 active)** **01-09/2017**

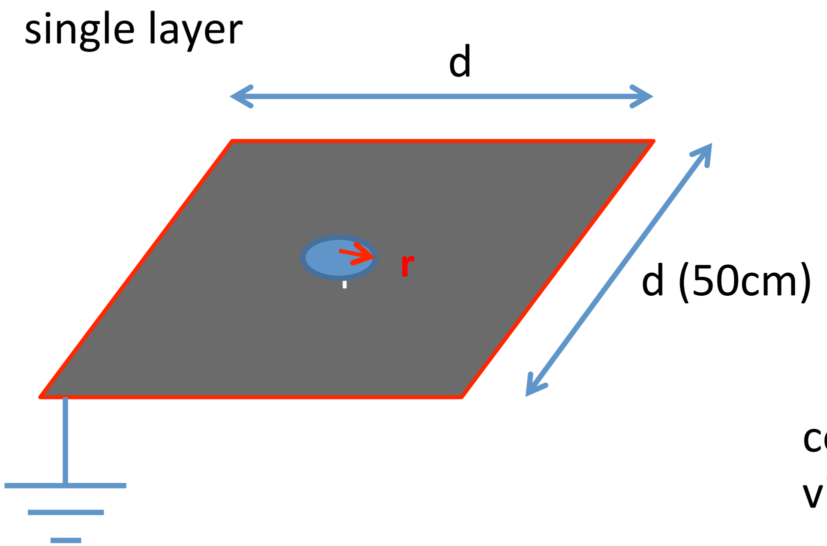
~40 times larger than small protos !!!

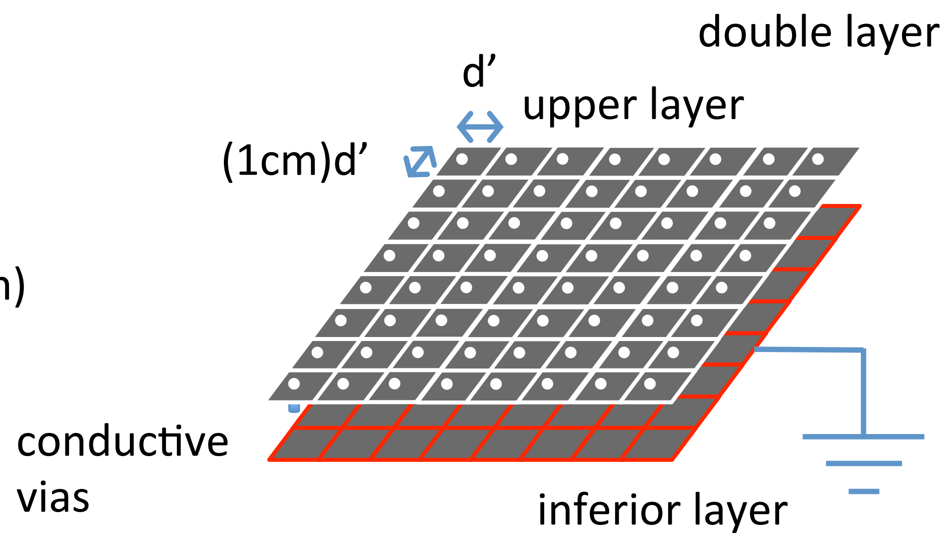




$1.8x1.2m^2$ (GE2/1) μ-RWELL

The two different schemes





(*) point-like irradiation, r<<d
Ω is the resistance seen by the current generated by a radiation incident in the center of the detector cell

$$\Omega \sim \rho_s \times d/2\pi r \qquad\qquad \Omega' \sim \rho_s' \times 3d'/2\pi r$$

$$\Omega/\Omega' \sim (\rho_s/\rho_s') \times d/3d'$$

$$\text{If } \rho_s = \rho_s' \rightarrow \Omega/\Omega' \sim \rho_s/\rho'_s * d/3d' = 50/3 = 16.7$$

(*) Morello's model: appendix A-B (G. Bencivenni et al., 2015_JINST_10_P02008)

The µ-RWELL_PCB for High Rate (LHCb)

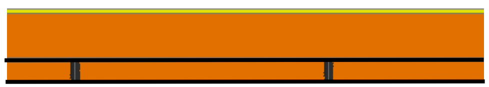
1

Copper layer 5 µm

Kapton layer 50 µm

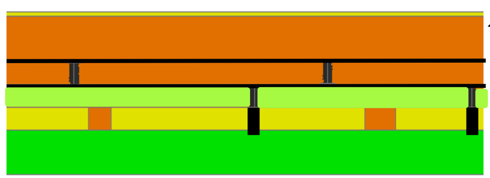
DLC layer: 0.1 – 0.2 µm
(10-200 MΩ/☐)

2



2^{nd} resistive kapton layer with ~ $1/cm^2$ "*through vias*" density

3



DLC-coated kapton base material

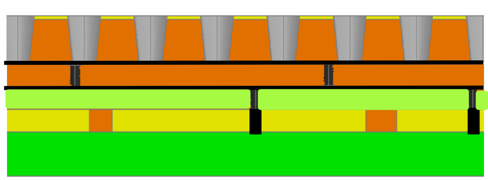
2^{nd} resistive kapton layer

insulating layer

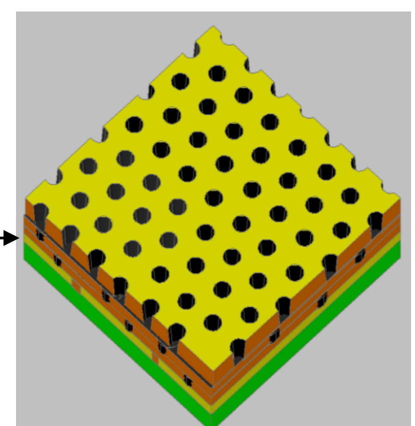
pad/strips readout on standard PCB

***"through vias"* for grounding**

4

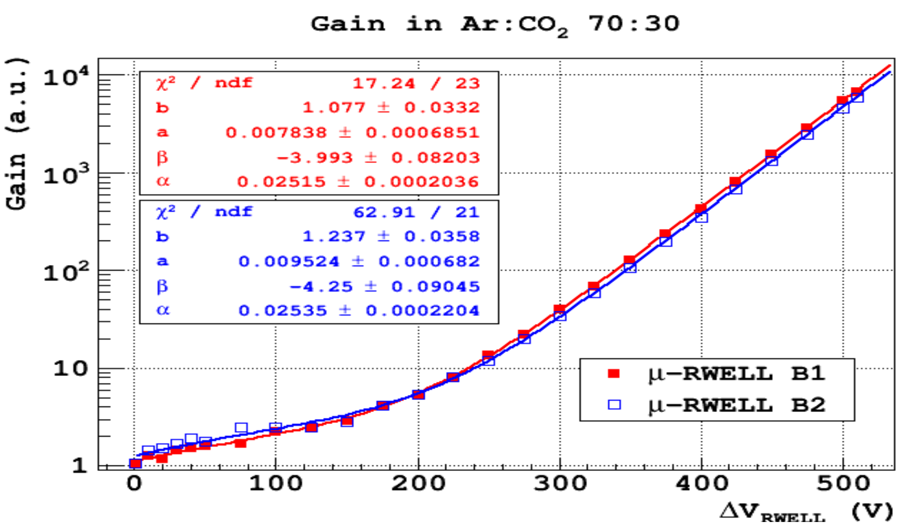


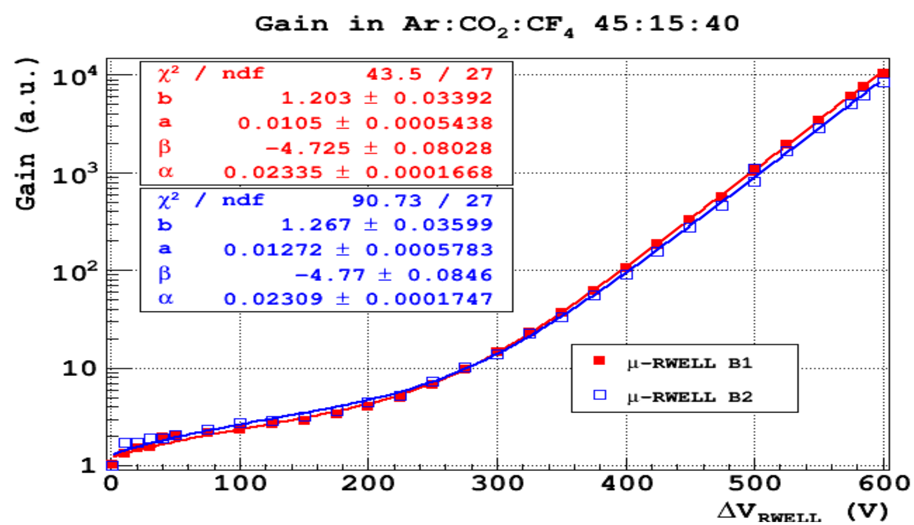
DLC-coated base material after copper and kapton chemical etching (WELL amplification stage)

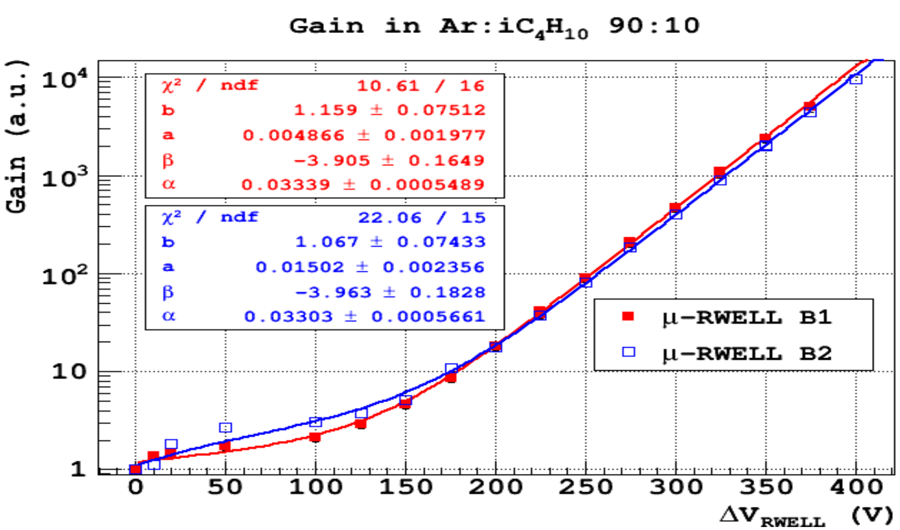


X-ray measurements

Two prototypes with the **double resistive layer scheme** (ρ=40 MΩ/☐) have been completed last Summer; the detectors have been tested with a 5.9 keV X-rays flux **(local irradiation)**.



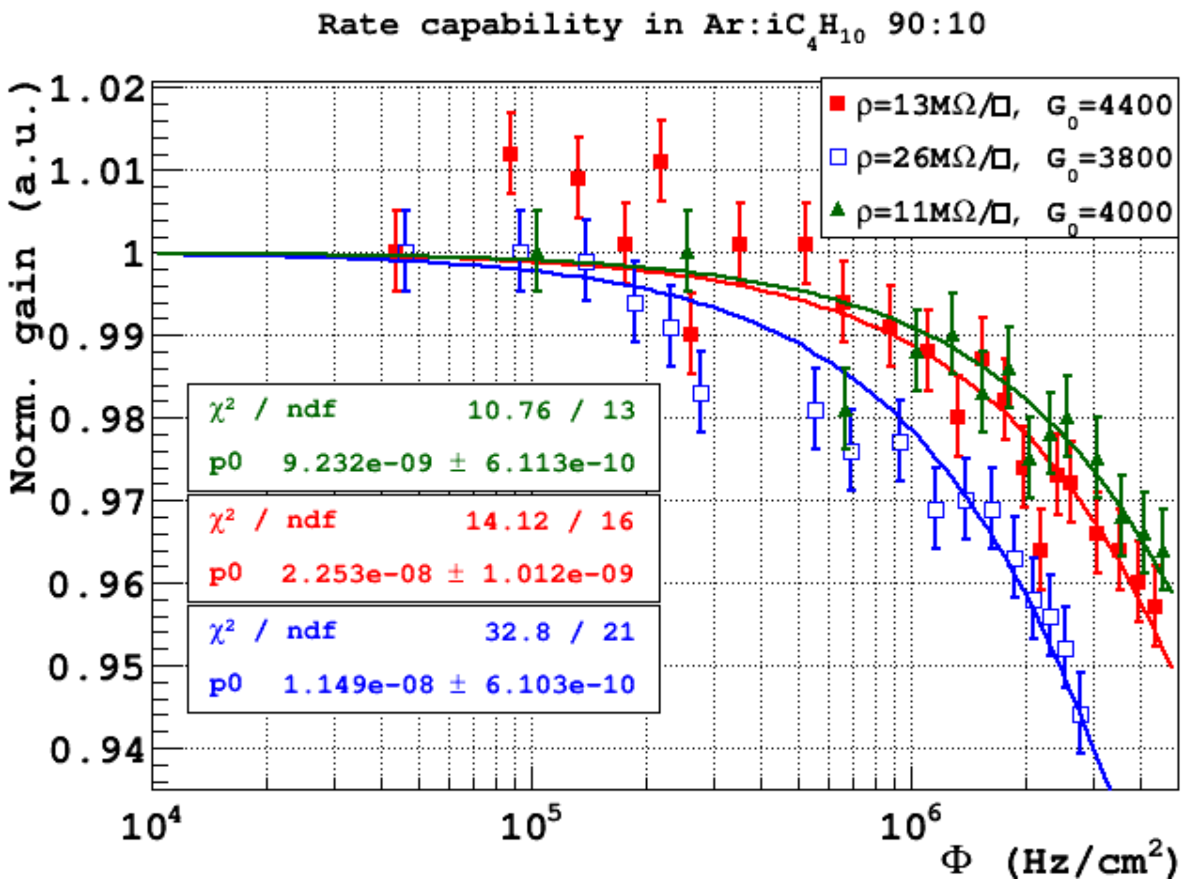




Measurement performed in current mode.
Gain measured up to 10000.
Similar behavior for the two chambers.

X-ray measurements

Rate capability fitted with the function: $$\frac{G}{G_0} = \frac{-1+\sqrt{1+4p_0\Phi}}{2p_0\Phi}$$



Φ = 2.8 MHz/cm^2; Φ = 3.4 MHz/cm^2; Φ = 1.6 MHz/cm^2

2 resistive cells 1 x 1 cm^2

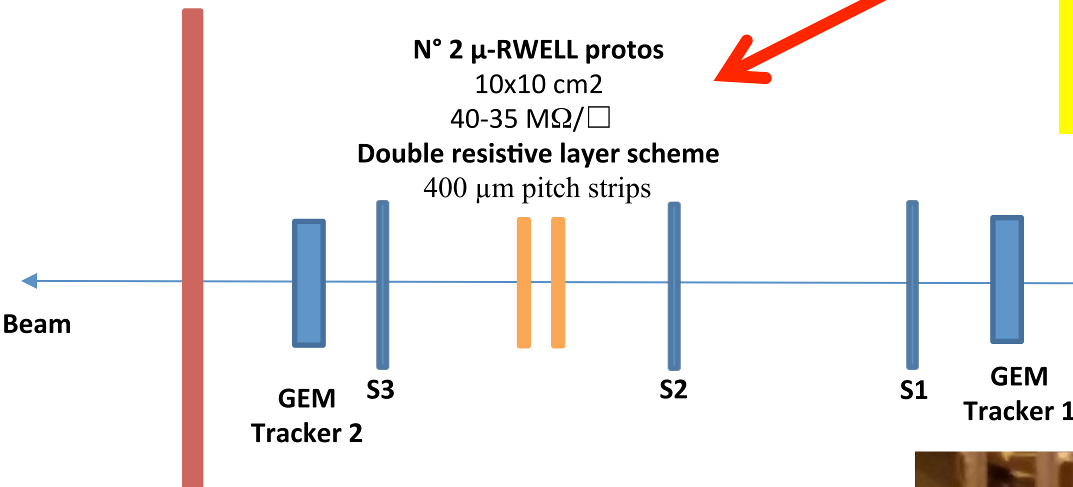
Beam Test Setup

H8 Beam Area (18th Oct. 9th Nov 2016)

Muon/Pion beam: 150 GeV/c

3 μ-RWELL prototypes
40-35-70 MΩ /□
VFAT (digital FEE)
$Ar/CO_2/CF_4$ = 45/15/40

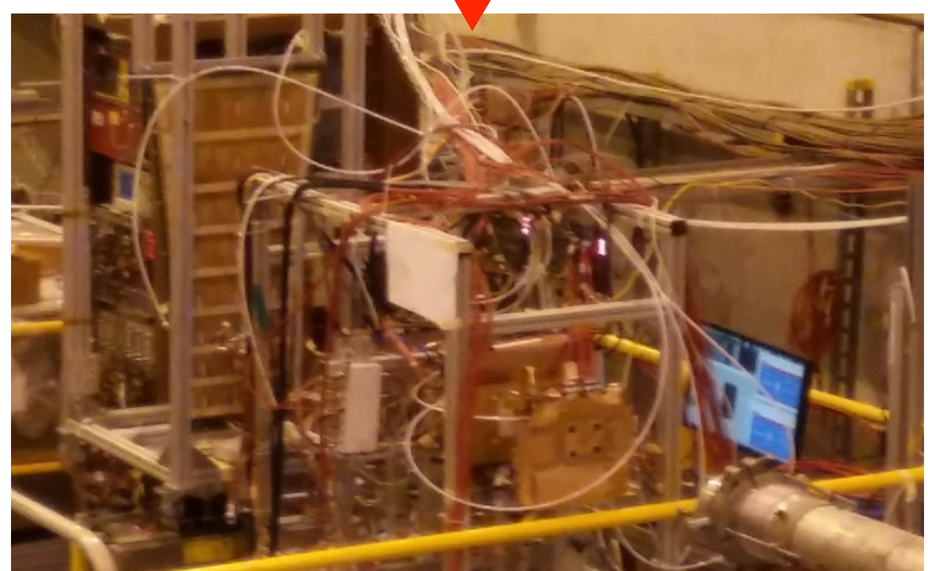
N° 2 μ-RWELL protos
10x10 cm2
40-35 MΩ/□
Double resistive layer scheme
400 μm pitch strips



N° 1 μ-RWELL proto
100x50 cm2
70 MΩ/□
Single resistive layer scheme
800 μm pitch strips

Trigger=S1+S2+S3

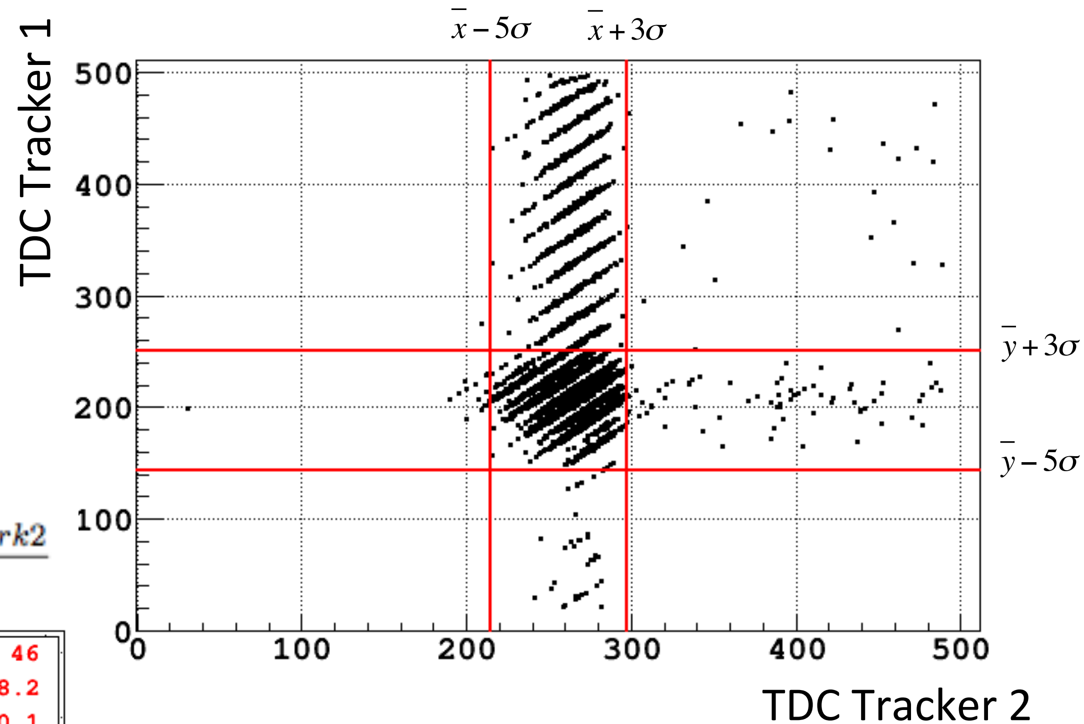
The goal was the <u>time resolution measurement (never done before)</u>

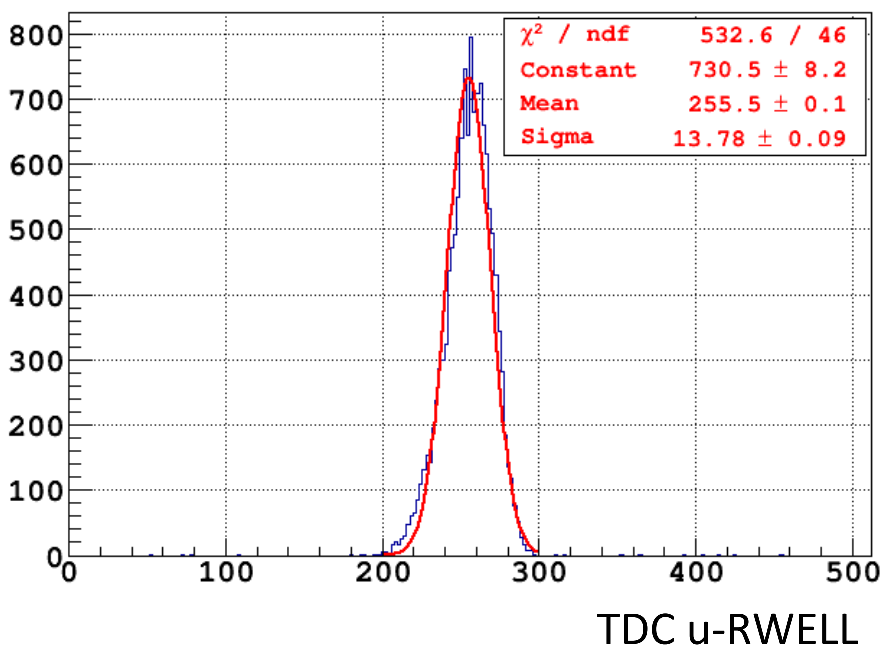


Efficiency & time resolution measurement

The efficiency (as extracted by TDC measurement) has been evaluated asking for **TDC coincidence** selected in a proper range.
Then the ratio of the triplets on the doublets gives the value.

$$\varepsilon = \frac{TDC_{\mu-RWELL} \wedge TDC_{trk1} \wedge TDC_{trk2}}{TDC_{trk1} \wedge TDC_{trk2}}$$



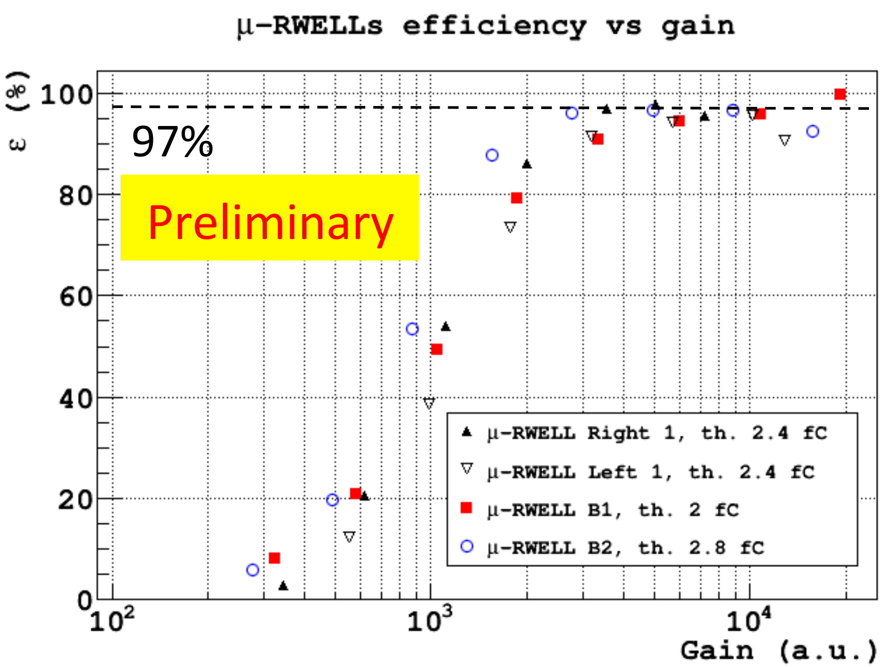


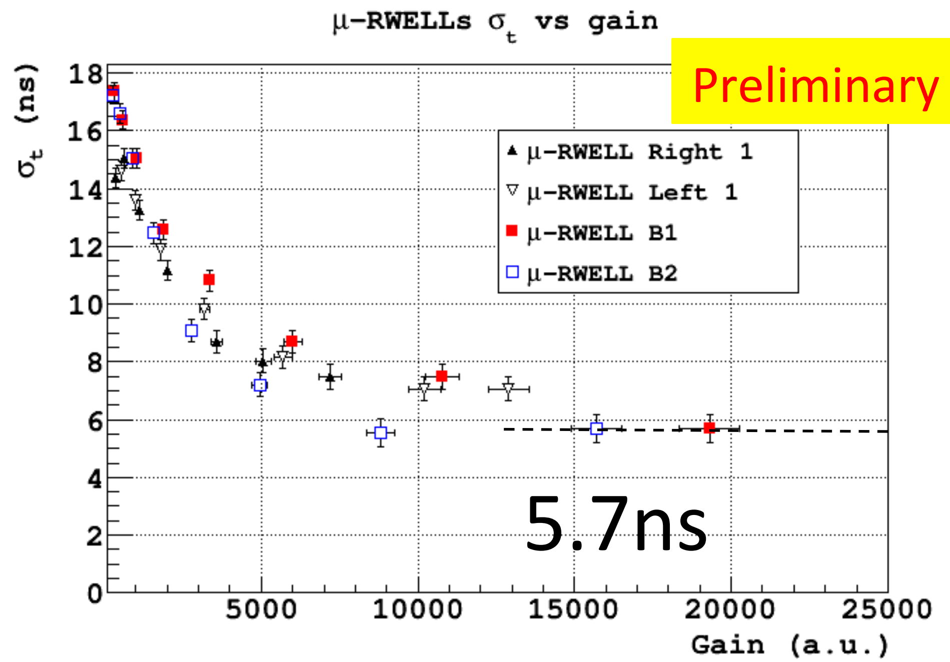
The TDC distribution is then fitted with a simple gaussian and the sigma is then **deconvoluted** by the contribution of the VFAT.

$$\sigma_t^2 = \sigma_{TDC}^2 - \left(\frac{25}{\sqrt{12}}\right)^2$$

J. A. Merlin, Etude de fonctionnement à long terme de détecteur gazeux l'environment à haut flux de CMS, PhD thesis, 2016

Performance vs Gain with Ed=3.5 kV/cm





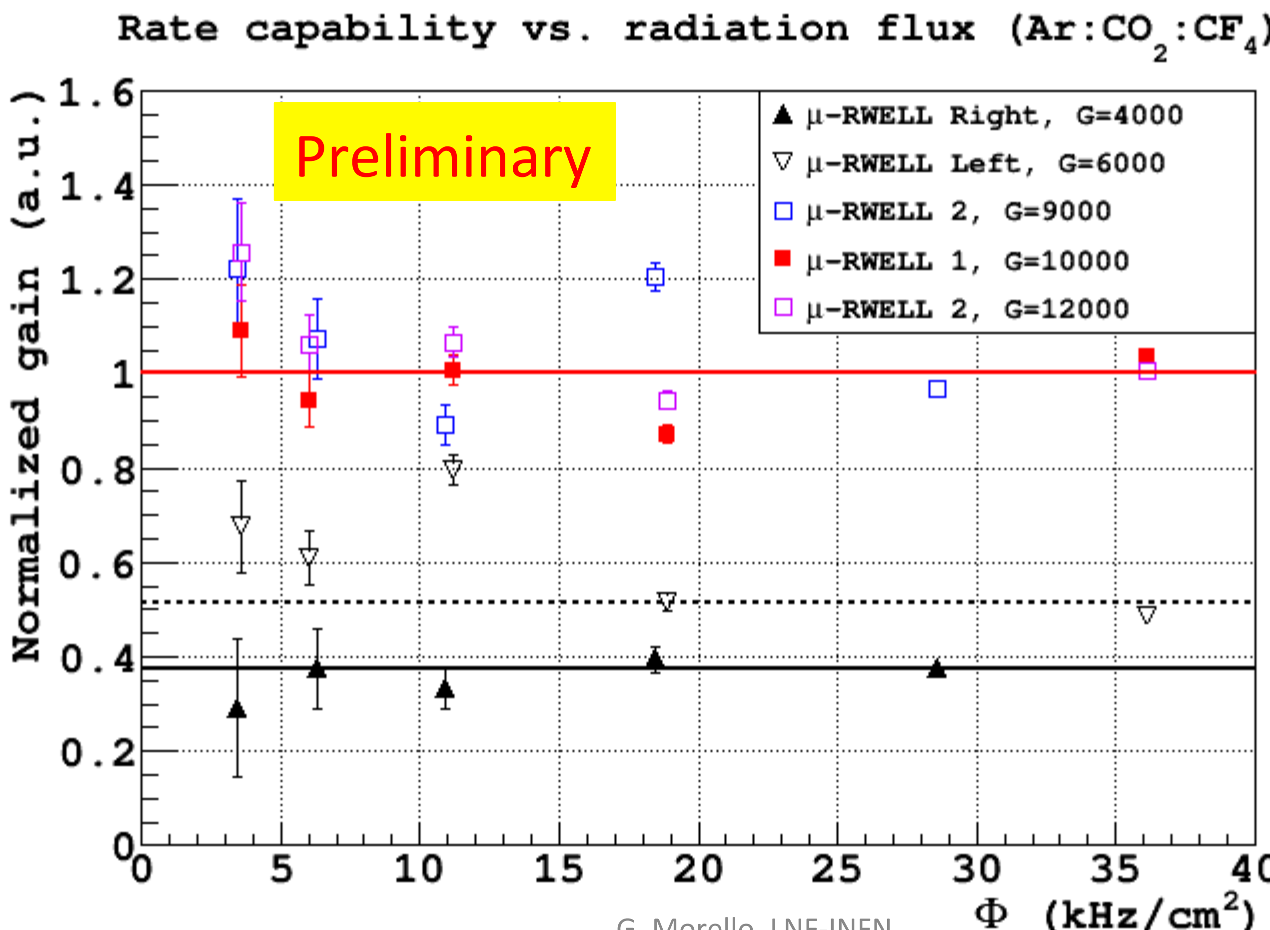
Measurements done with GEM by LHCb group gave σ_t = 4.5 ns with VTX chip, constant fraction discriminator [1]. We wish to perform the same measurement with μ-RWELL at BTF (LNF).

Different chambers with **different dimensions and resistive schemes** exhibit a **very similar behavior** although realized in **different sites** (large detector partially realized outside CERN).

*[1] G. Bencivenni et al, "Performance of a triple-GEM detector for high rate charged particle triggering", NIM **A** 494 (2002) 156*

Performance vs Rate

The detectors rate capability (with Ed=3.5 kV/cm) has been measured in current mode with a pion beam and irradiating an area of ~3 x 3 cm^2 (FWHM) ("local" irradiation, ~10 cm^2 spot)

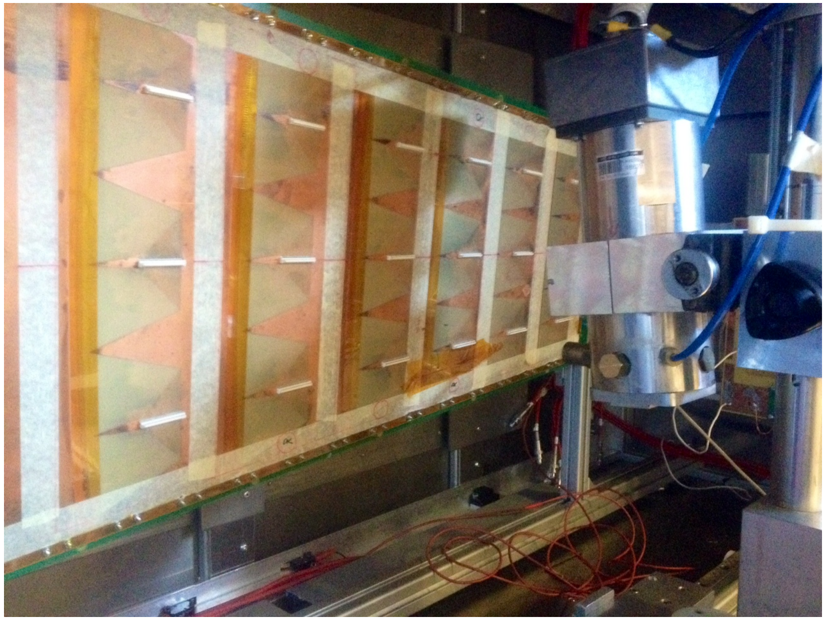


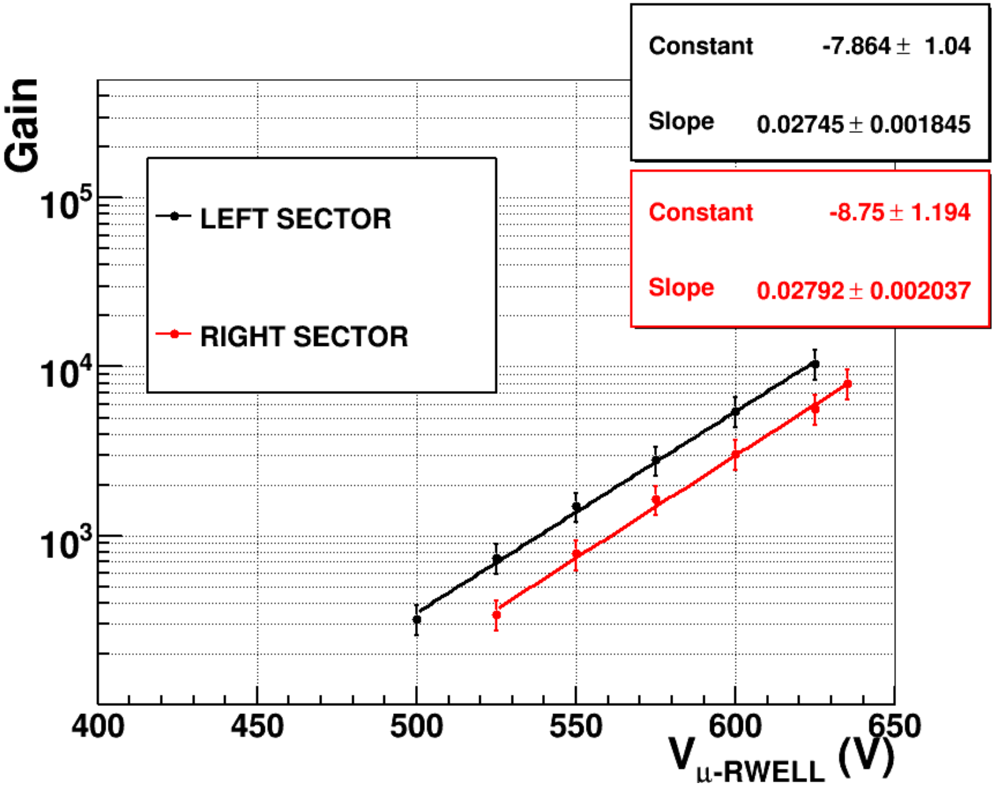
Double resistive layer
(High Rate scheme)

Single resistive layer
(Low Rate scheme)

Detector Gain

The prototype has been characterized by measuring the **gas gain, rate capability** in **current mode** with an **5.9 keV X-rays (local irradiation, ~1cm^2 spot)**.

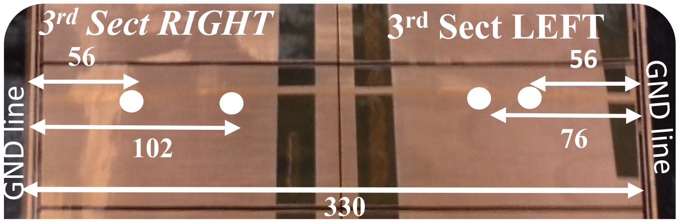


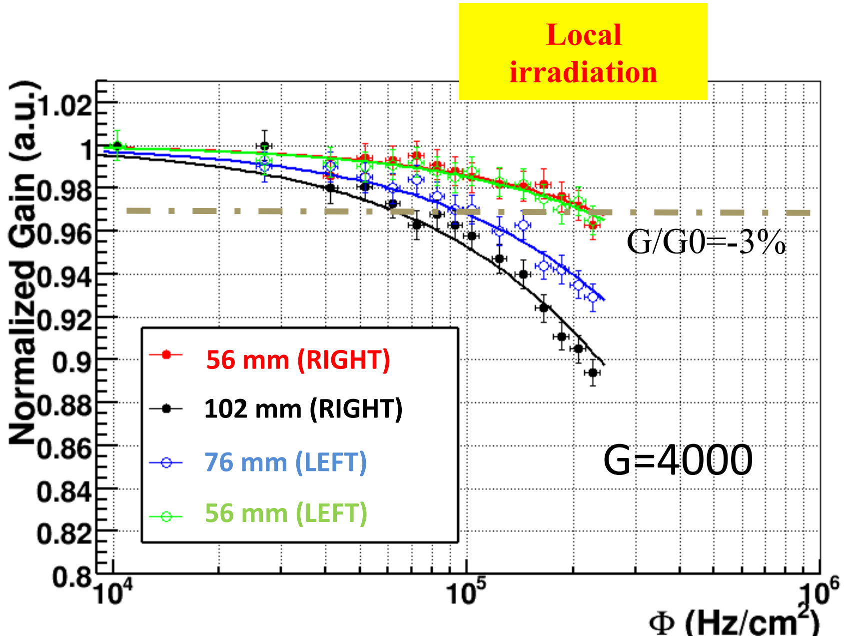


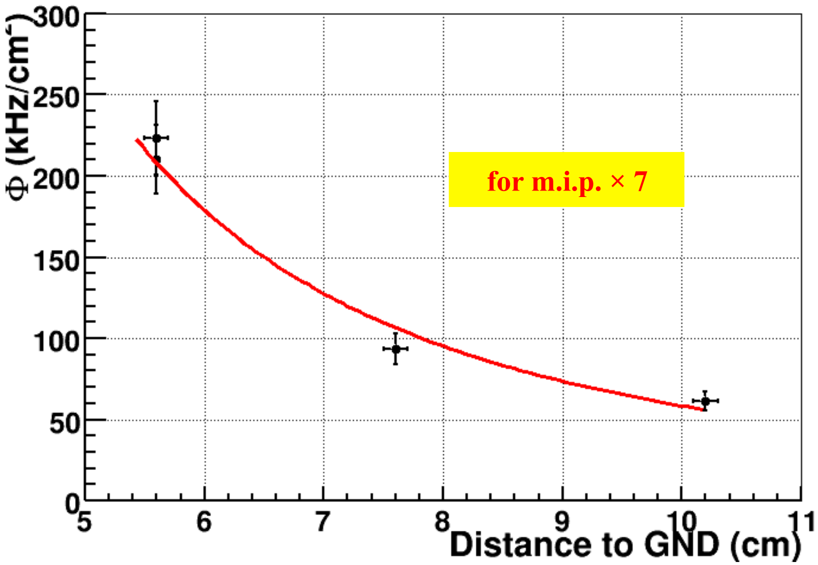
A shift of ~ 25 V has been measured between the two sectors probably due to the different geometry of the amplification stage (to be confirmed with microscope check – left/right asymmetry)

Rate Capability with X-rays

(under local ~1 cm^2 irradiation)





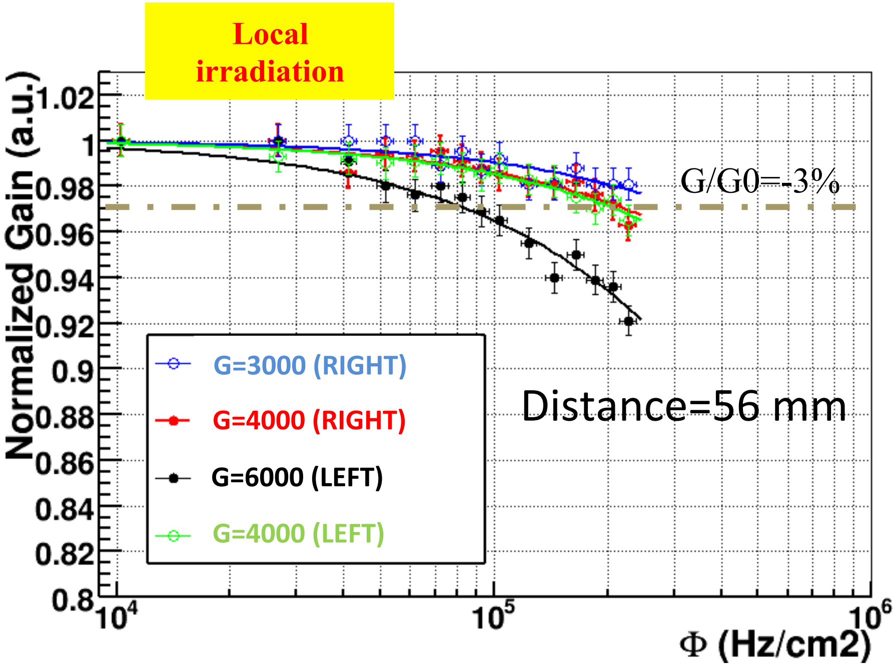


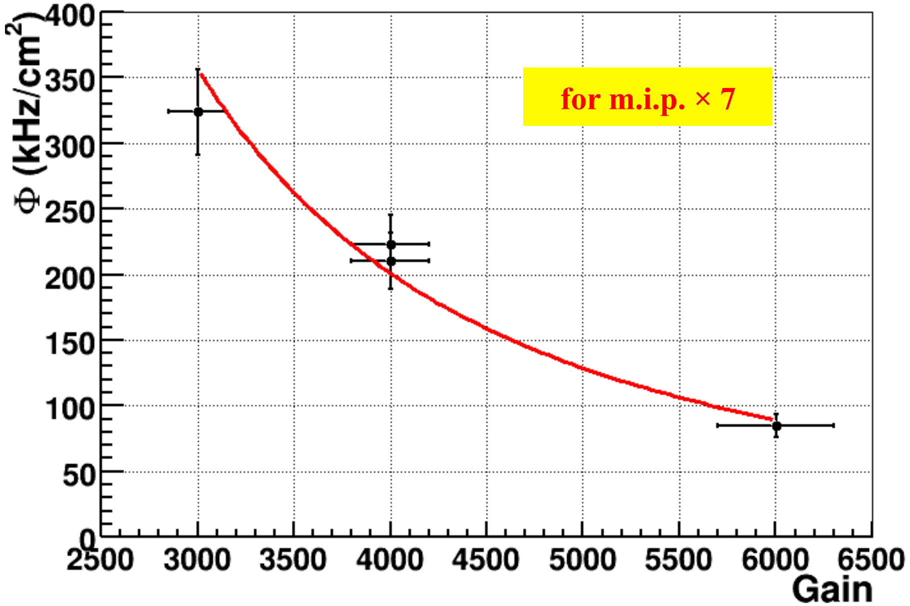
The larger is the distance of the irradiation point from the GND lines, the lower is the rate capability

The gain drop effect is **well understood** in the framework of the **resistive model detector**

Rate Capability with X-rays

(under local ~1 cm^2 irradiation)





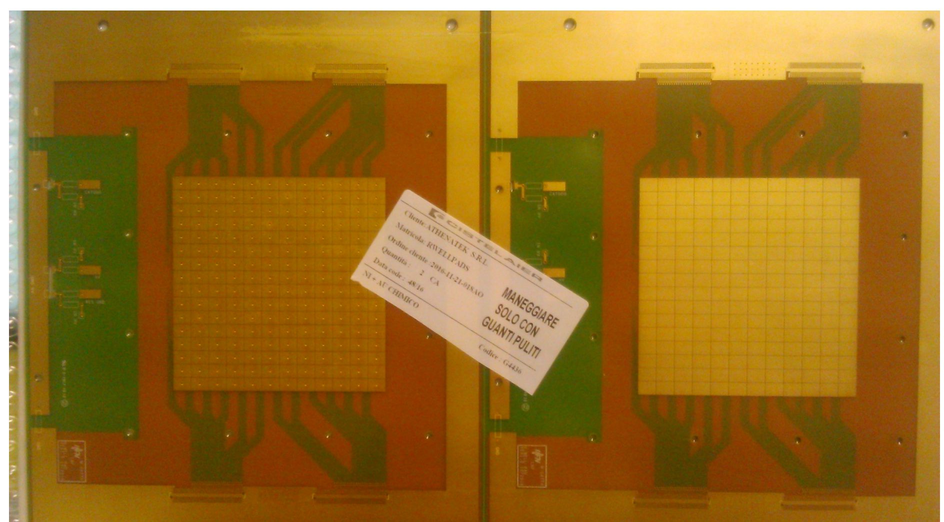
The higher is the gain, the lower is the rate capability

Conclusions

- **Low rate**: small and large area prototypes built and tested with beam and X-rays
  - A well defined roadmap towards the Technological Transfer to industry
- **High rate** scheme still under study: the prototypes built show very promising performance

Outlook

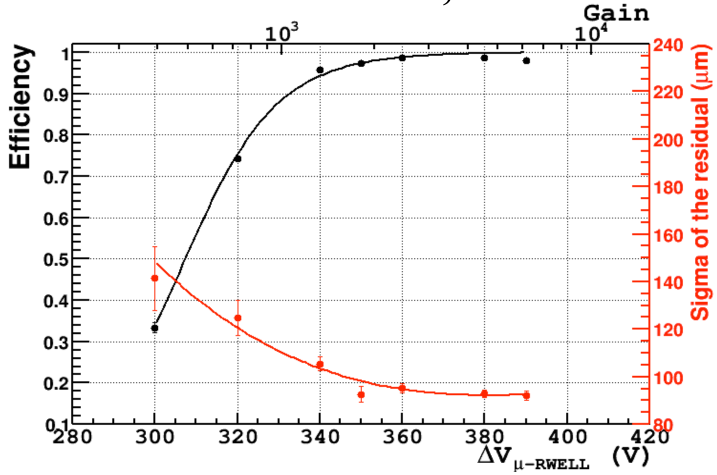
- **Ageing test at GIF++** of the large area detector (SL) and small detectors (DL)
- **Test beam at PSI** (ΠM1) to evaluate the rate capability under "uniform" irradiation
- **Test beam at BTF** for time performance measurement with VTX chip
- **Construction of large area** μ-RWELLs with **GE2/1** dimensions (CMS)
- **Construction of prototypes** with double resistive layer scheme and pad readout (LHCb)



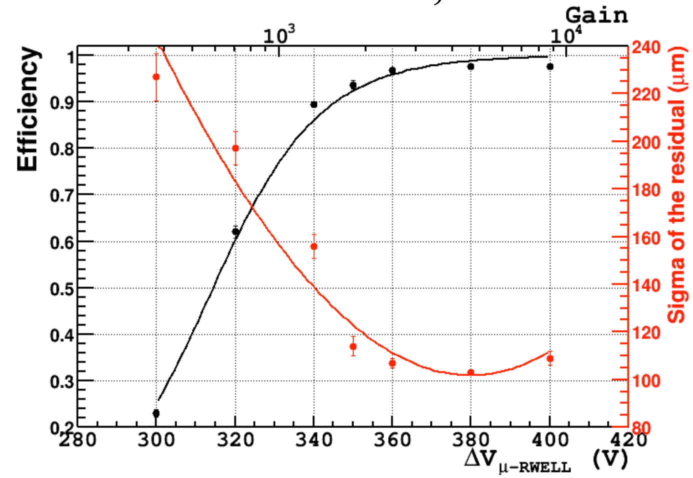
μ-RWELL: B≠0 with Ar/ISO=90/10

CC analisys

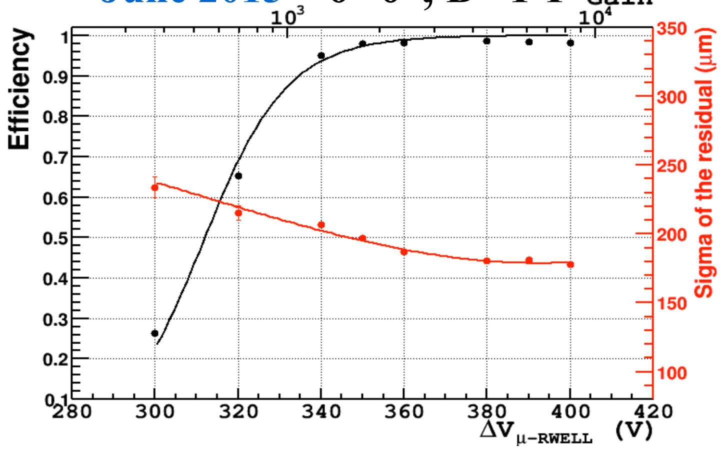
June 2015 – θ=0°, B= 0 T



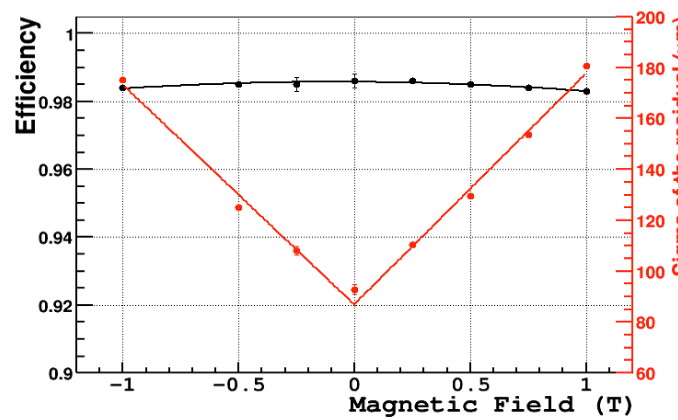
Dec 2014 – θ=0°, B= 0.5 T



June 2015 – θ=0°, B= 1 T



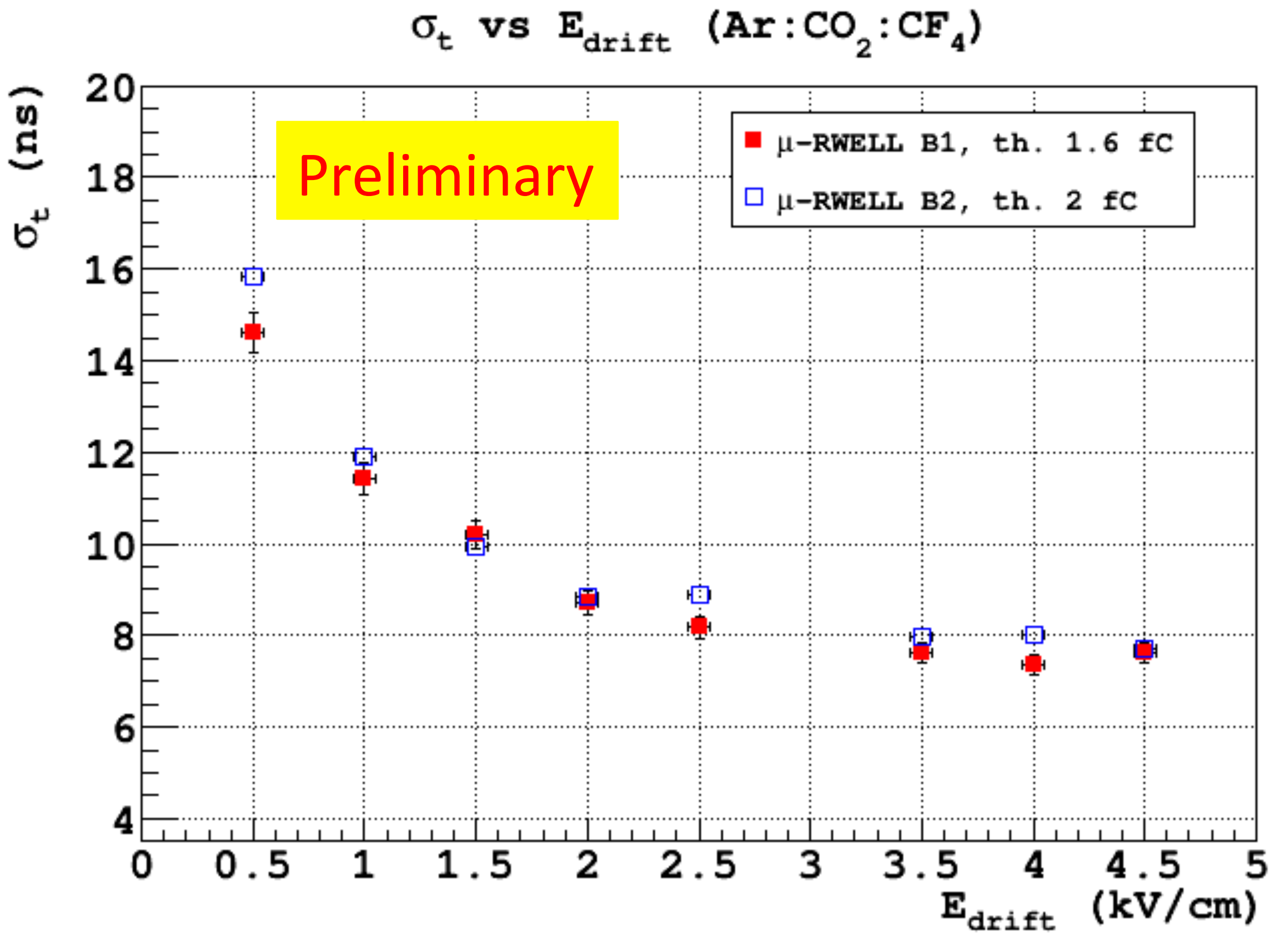
June 2015 - θ=0°



For **θ=0° and 0 < B < 1 T** → **σ < 180 μm** and **ε > 98%**

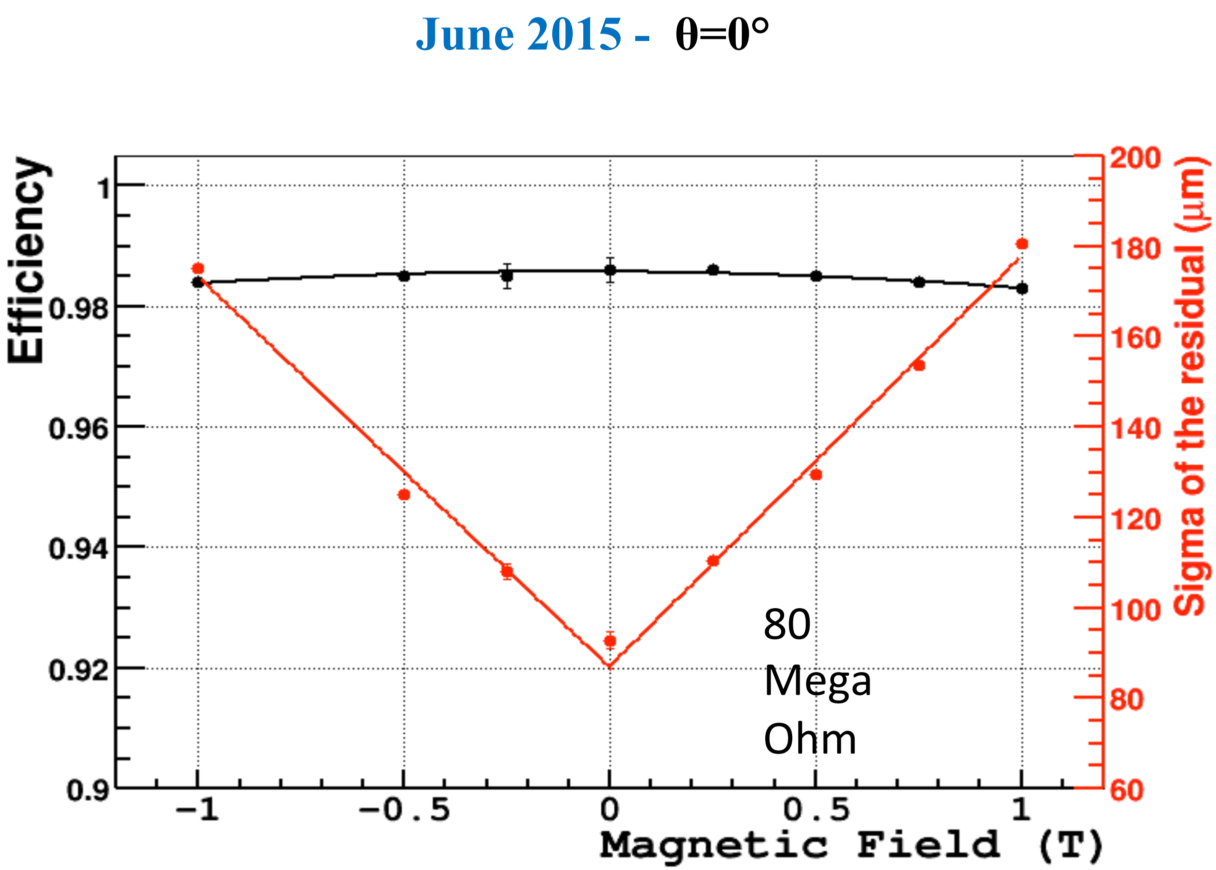
E drift optimization

- A first optimization of the detector operation has been done with a scan of the Drift field. The measurement have been done operating the detectors at a gain of 10000



μ-RWELL: B≠0 with Ar/ISO=90/10

CC analisys



For **θ=0° and 0 < B < 1 T** → **σ < 180 μm** and **ε > 98%**