Recent achievements on μ-RWELL

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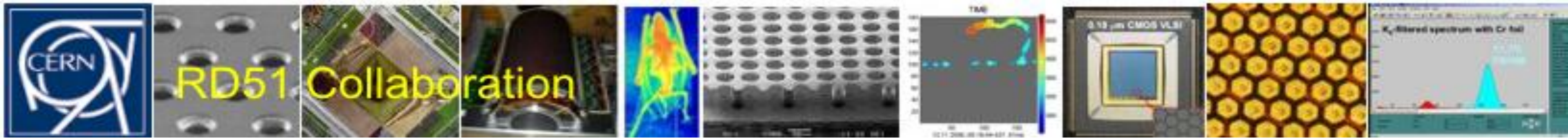
RD51 mini week, December 13th 2016

1. Laboratori Nazionali di Frascati dell'INFN
2. CERN

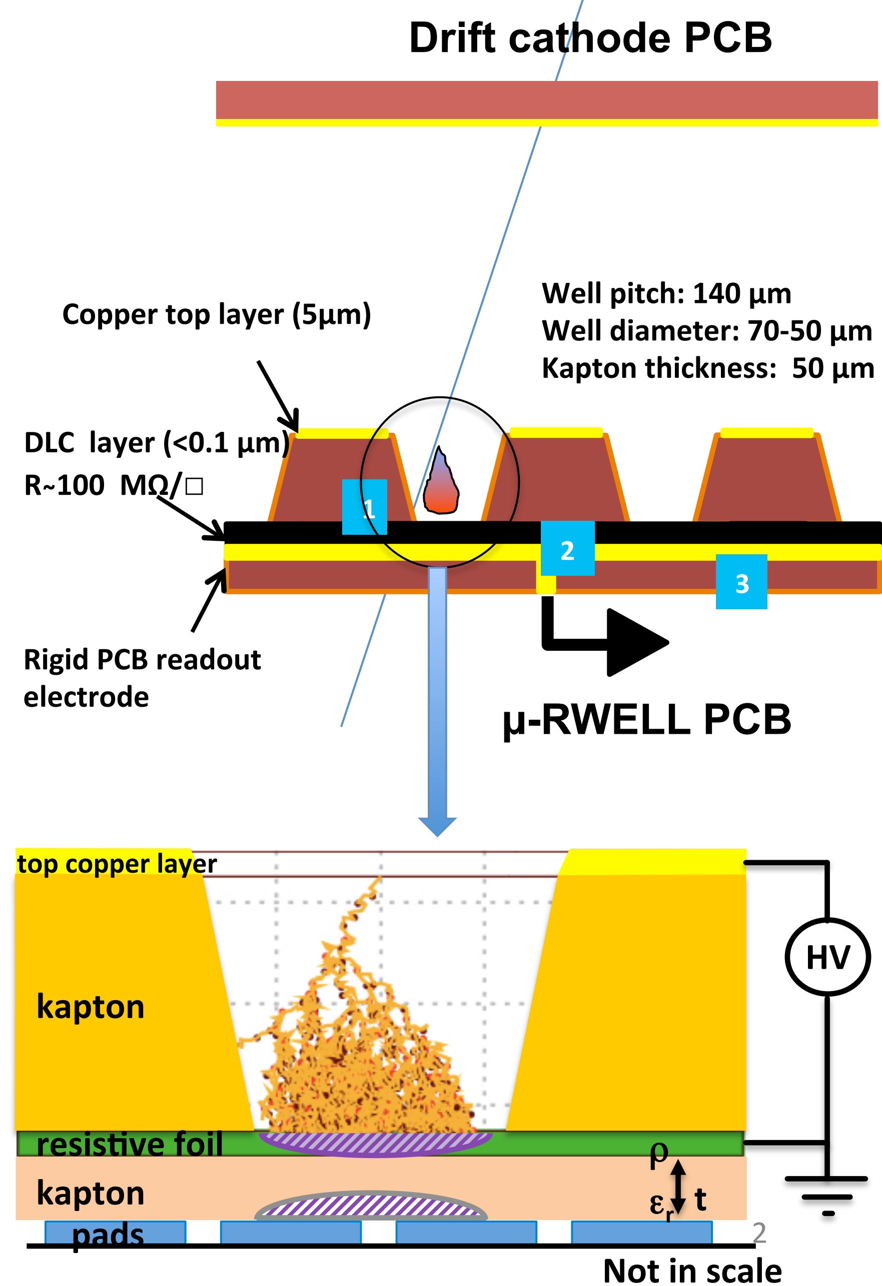


The detector architecture

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

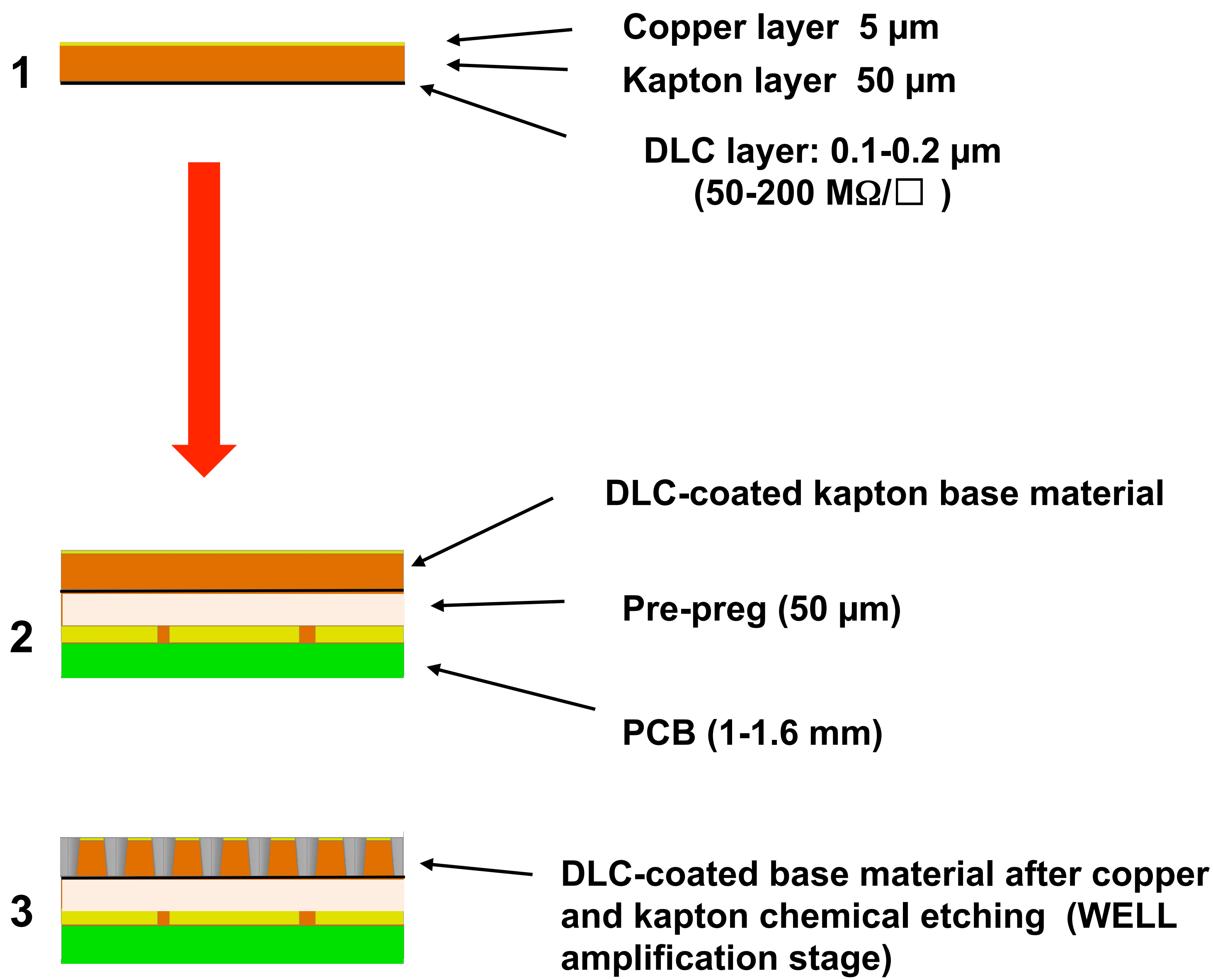
The **μ-RWELL_PCB, the core of the detector,** is realized by **coupling:**

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

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



The µ-RWELL_PCB for High Rate (LHCb)

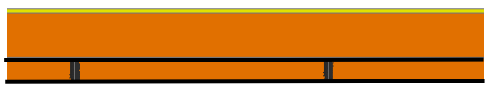
1

Copper layer 5 µm

Kapton layer 50 µm

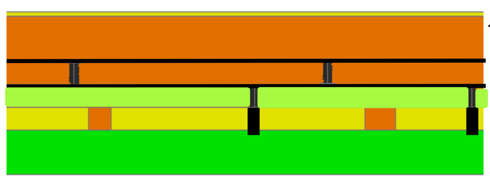
DLC layer: 0.1 – 0.2 µm
(50-200 MΩ/☐)

2



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

3



DLC-coated kapton base material

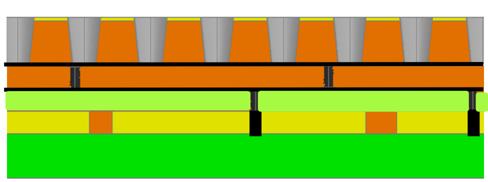
2nd resistive kapton layer

insulating layer

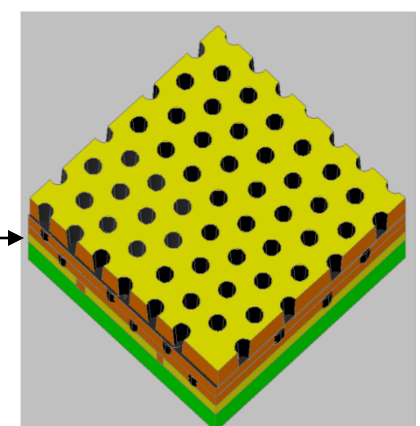
pad/strips readout on standard PCB

"through vias" for grounding

4

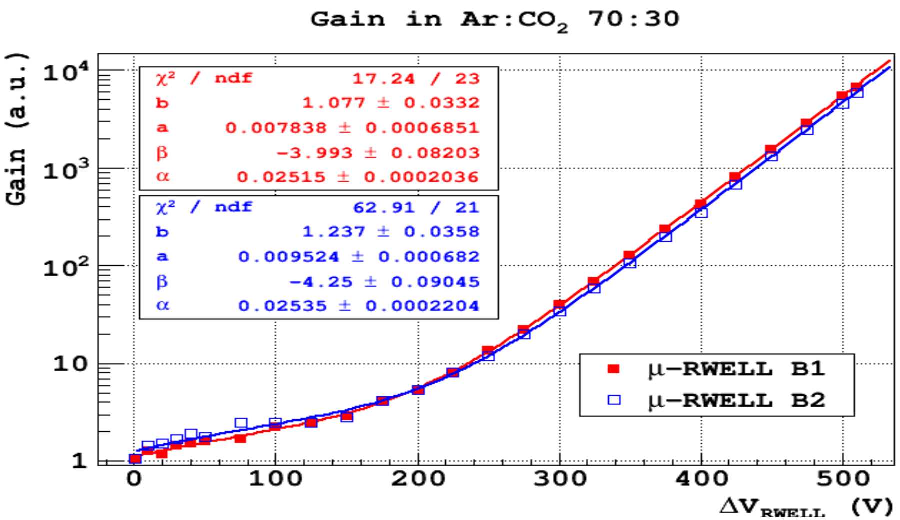


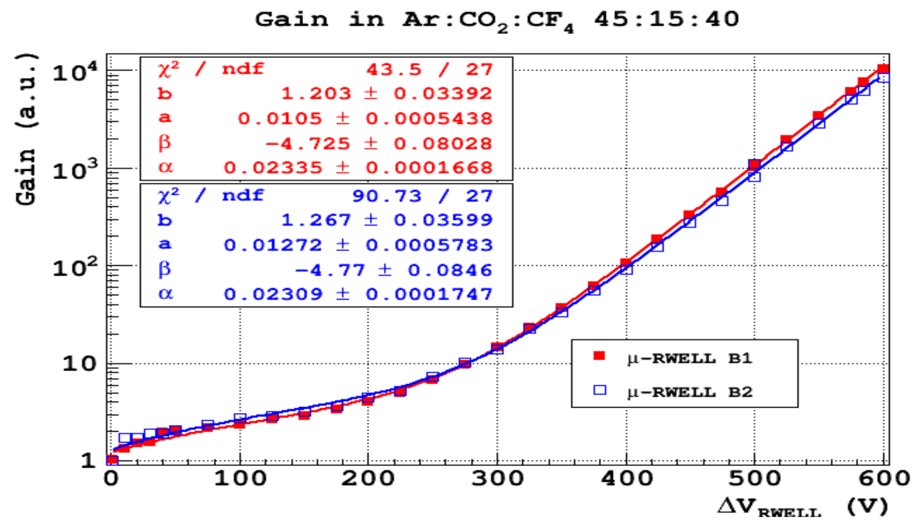
DLC-coated base material after copper and kapton chemical etching (WELL amplification stage)

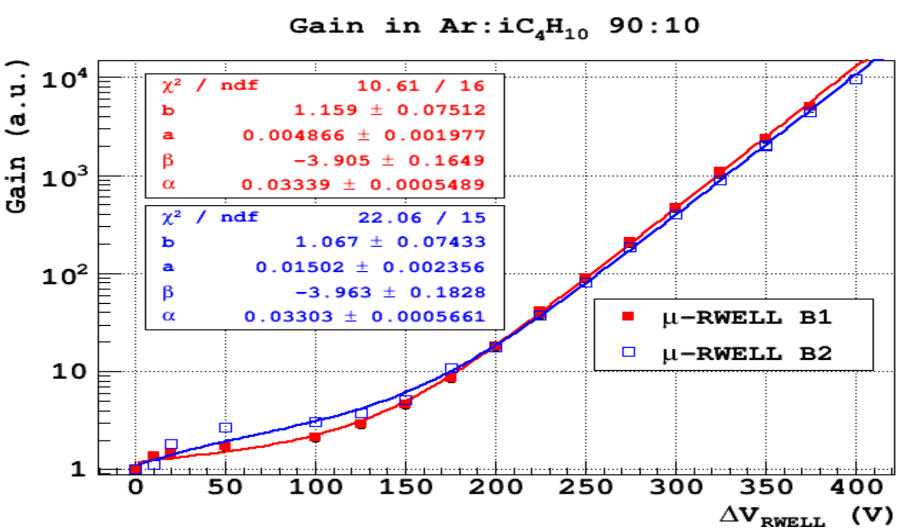


X-ray measurements

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)**.



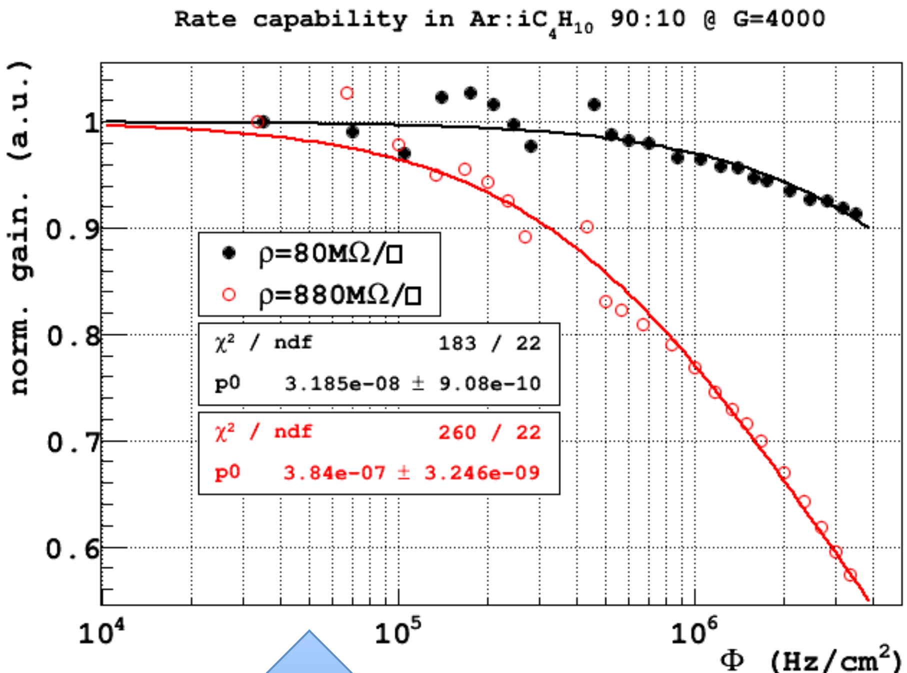




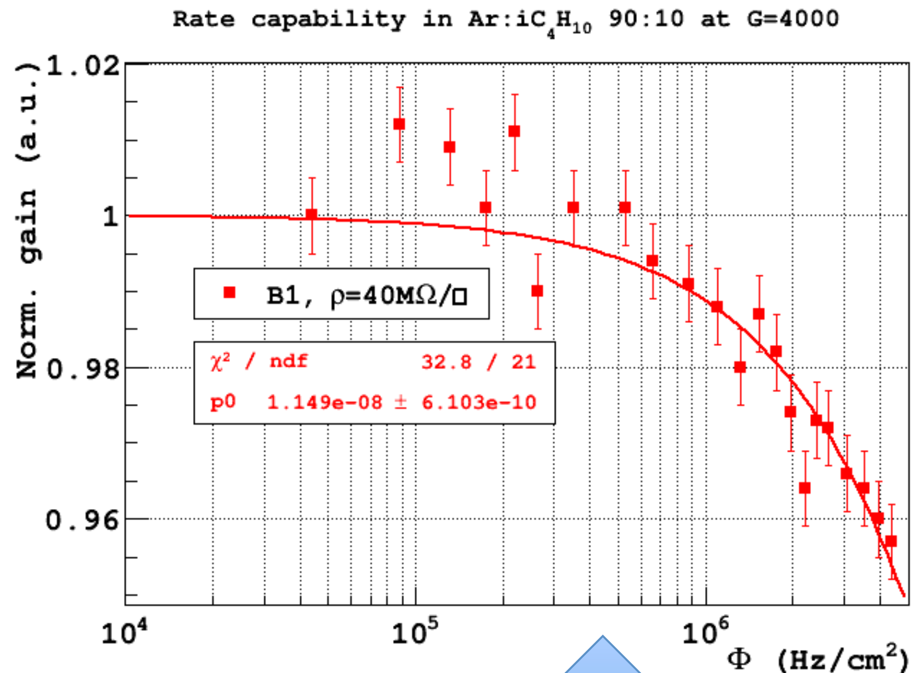
Measurement performed in current mode.
Gain measured up to 10000.
Similar behaviour for the two chambers.

X-ray measurements

Single layer scheme



Double layer scheme



DIFFERENT Y SCALE

Local irradiation, collimator radius 0.125 mm

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

Φ_{80} = 850 kHz/cm^2; Φ_{880} = 77 kHz/cm^2

1 resistive cell 5 x 5 cm^2

Φ_{B1} = 2.8 MHz/cm^2

2 resistive cells 1 x 1 cm^2

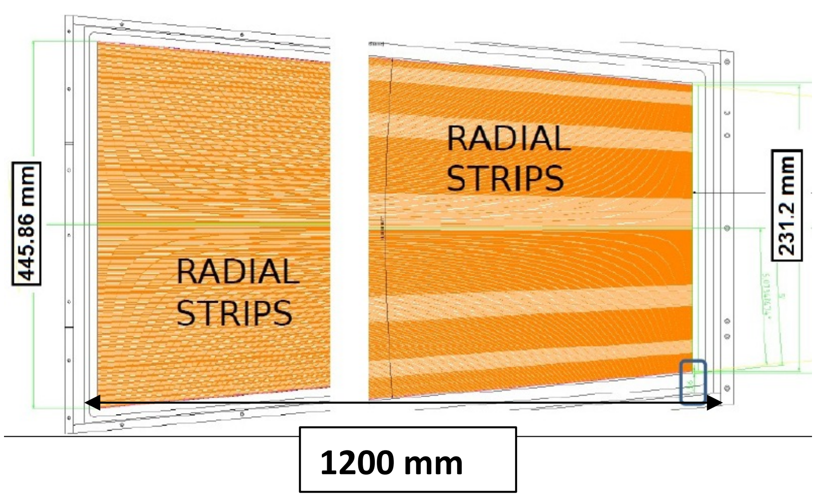
LARGE AREA

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:

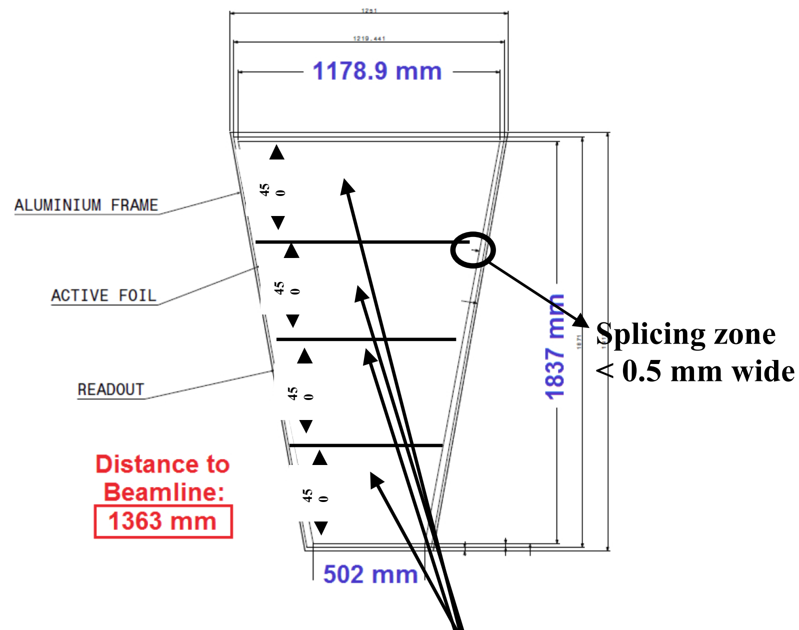
1. Construction & test of the first **1.2x0.5m^2 (GE1/1) μ-RWELL** **2016**
2. Mechanical study and mock-up of 1.8x1.2 m^2 (GE2/1) μ-RWELL **2016**
3. Construction & test of the first **1.8x1.2m^2 (GE2/1) μ-RWELL** **12/2017- 6/2018**

~40times larger than small protos !!!

1.2x0.5m^2 (GE1/1) μ-RWELL



~300 times larger than small protos !!!

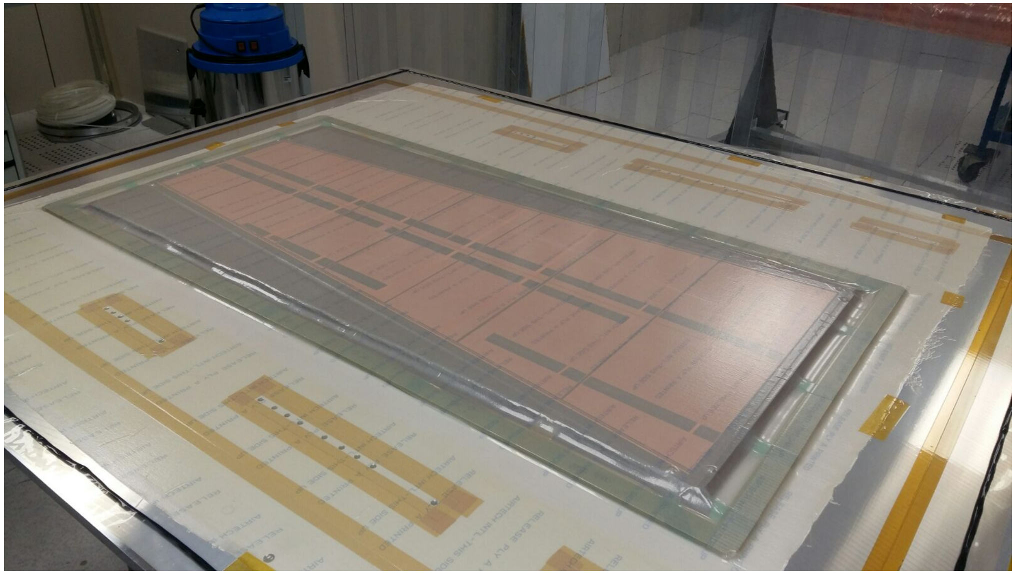


1.8x1.2m^2 (GE2/1) μ-RWELL

Four PCB μ-RWELL spliced with the same technique used for large ATLAS MM + only one cathode closing the detector

Large area prototype

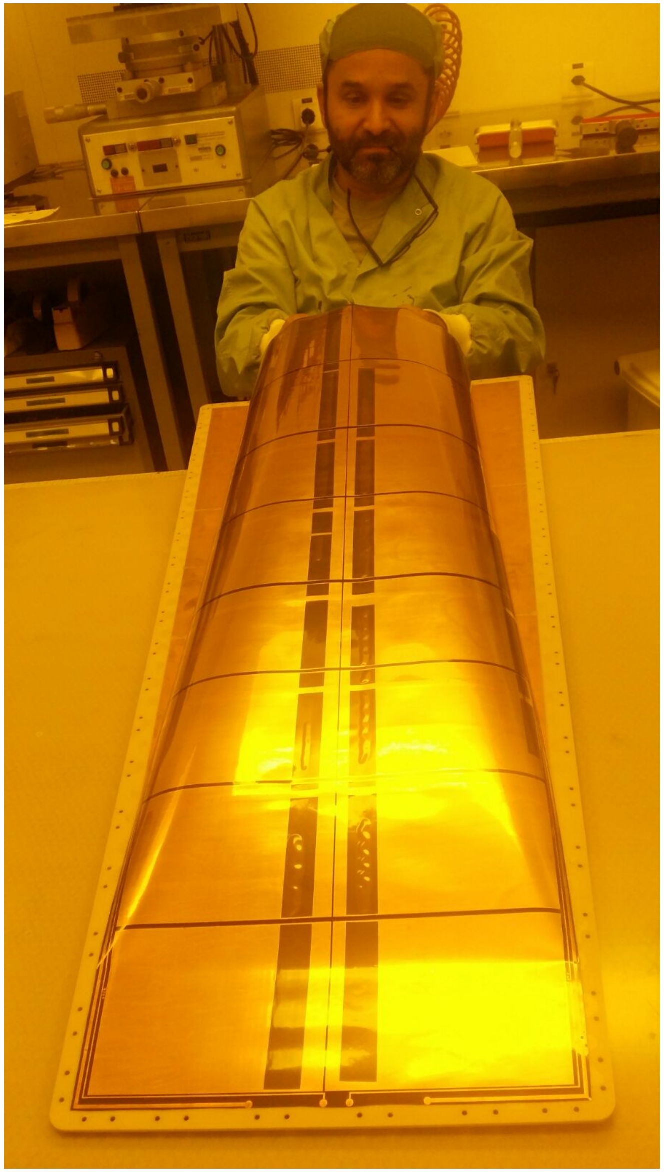
- A large area prototype, following the **single resistive layer scheme**, has been realized for tests. The amplification stage suffered delamination (copper removal) in some sectors during the etching process. The origin of the problem is the combination of a wrong operation done by Eltos with the choice of a corrupted base material.
- The amplification stage has been glued on the readout PCB with the **vacuum bag technique**.
- The detector has been completed with a frame and a cathode



Large area prototype

- Anyway the HV sectors drew in some cases anomalous currents and we needed an intervention by Rui.
- The whole stack composed of readout and u-RWELL has been washed in a ultrasonic bath, with the consequence of a separation of the foil from the PCB.
- After supplying up to 1 kV, four sectors were labeled as "good"

  (R >10 GΩ when ΔV = 500 V).
- The foil has been glued again on the PCB with a 100 um thick **FILM GLUE** produced by **3M company**.

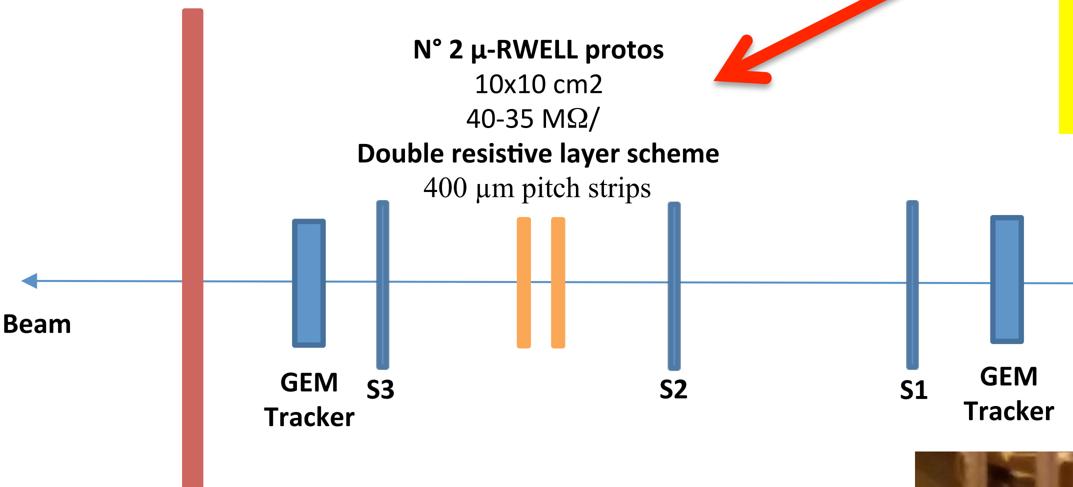


Beam Test Setup

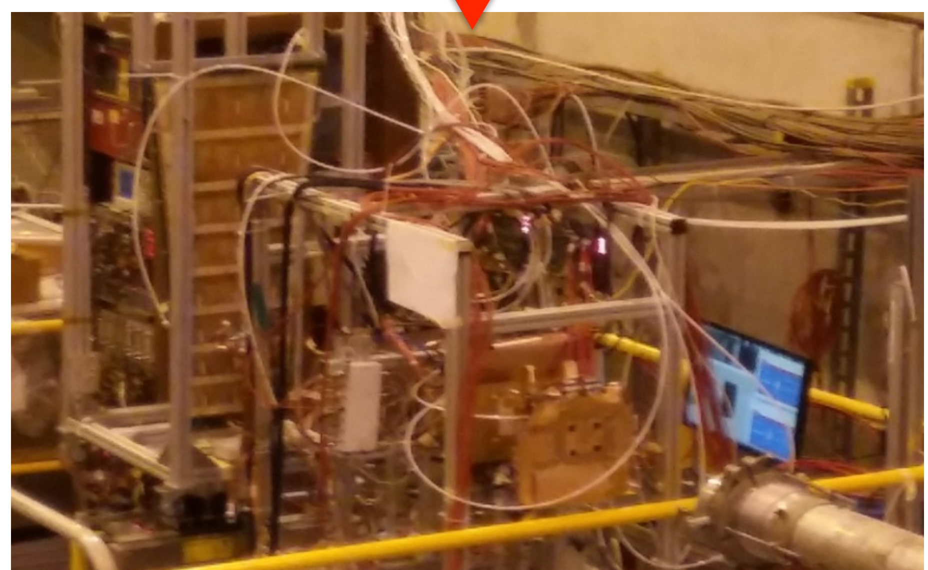
H8 Beam Area (18th Oct. 9th Nov 2016)
Muon/Pion beam: 150 GeV/c

3 μ-RWELL prototypes
40-60-70 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



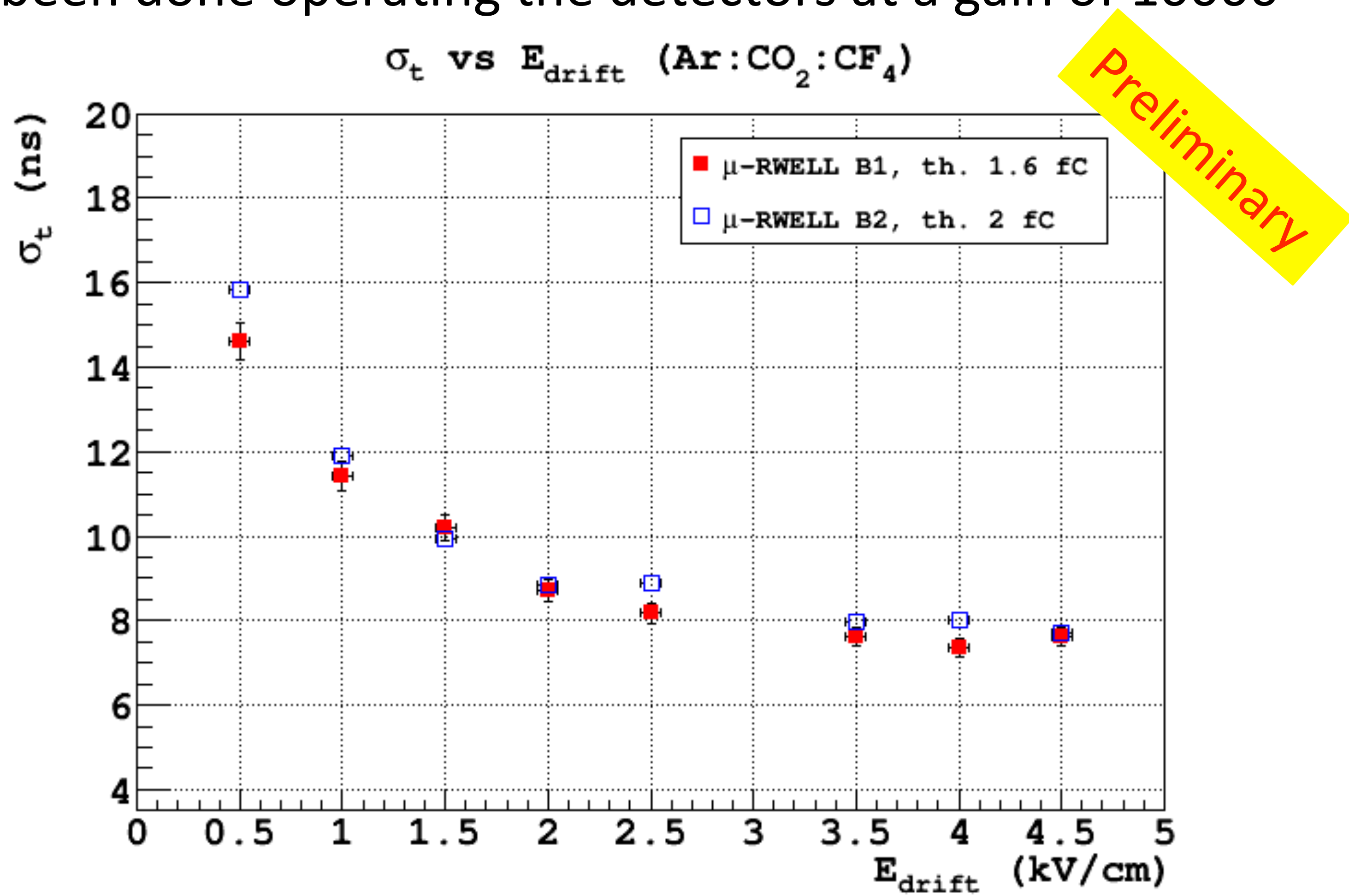
N° 1 μ-RWELL proto
100x50 cm2
70 MΩ/
Single resistive layer scheme
800 μm pitch strips



The goal is the <u>time resolution measurement</u> due to intrinsic process in the gas, mainly limited by FEE performance

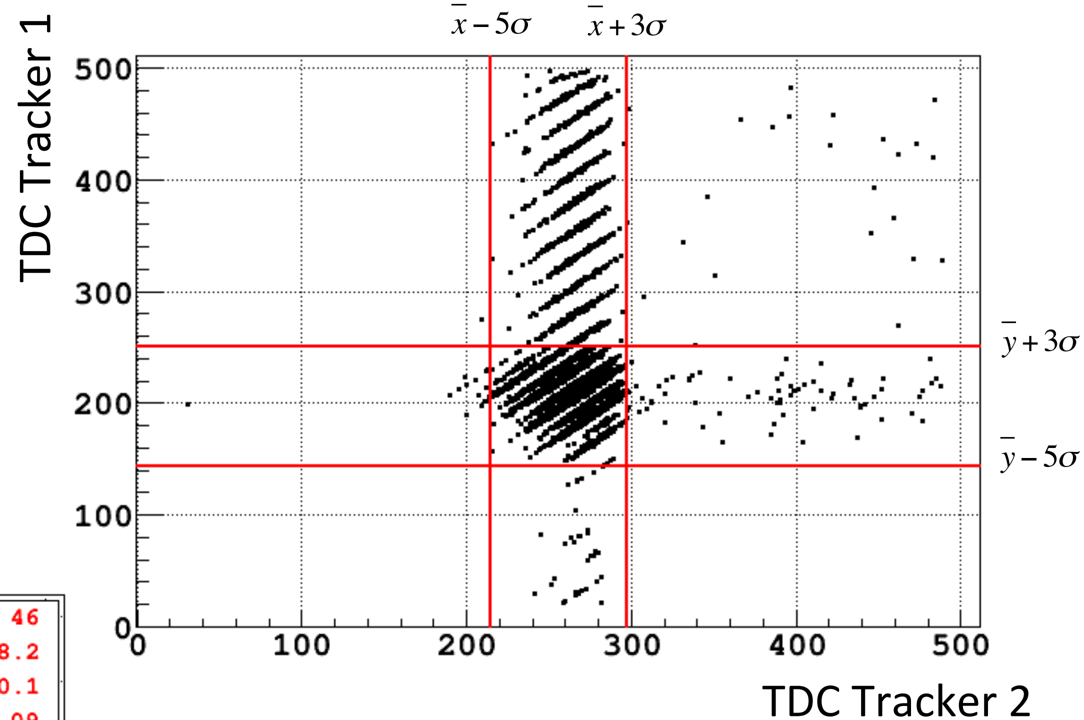
E drift optimization

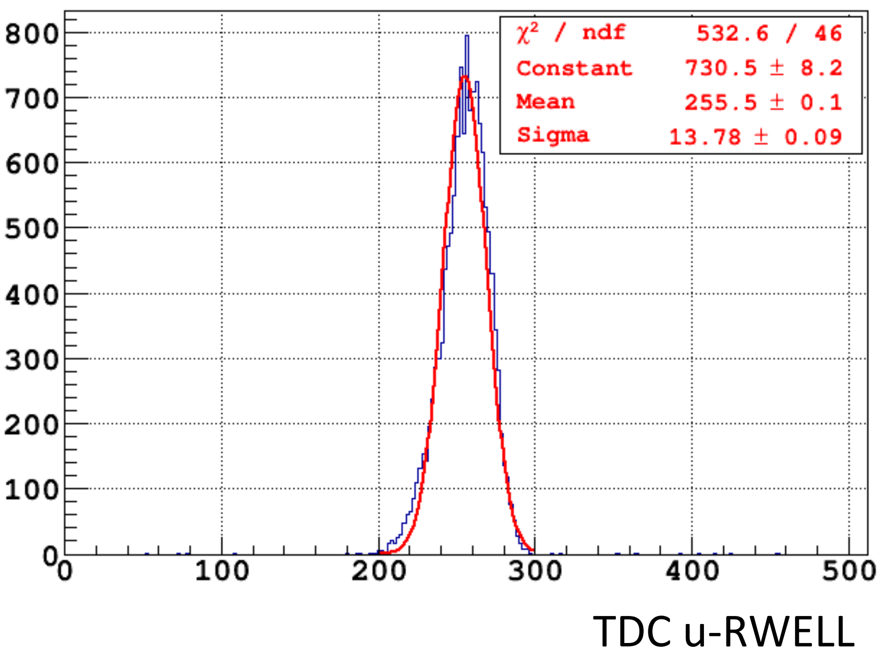
- A first optimization of the detector operation has been done with a scan of the Drift field. The mesurement have been done operating the detectors at a gain of 10000



Efficiency & time resolution measurement

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

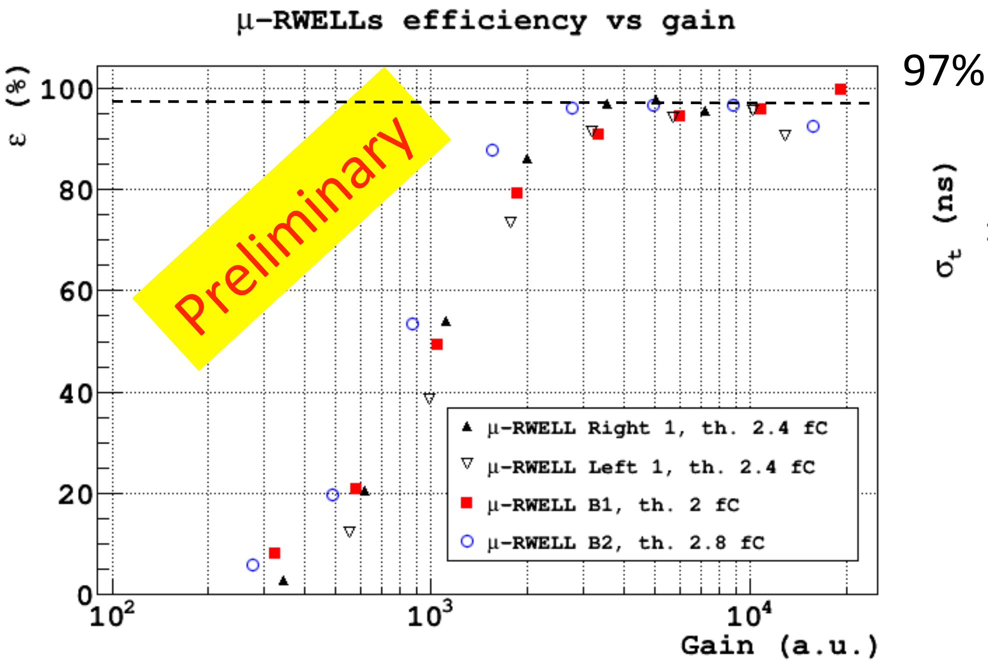


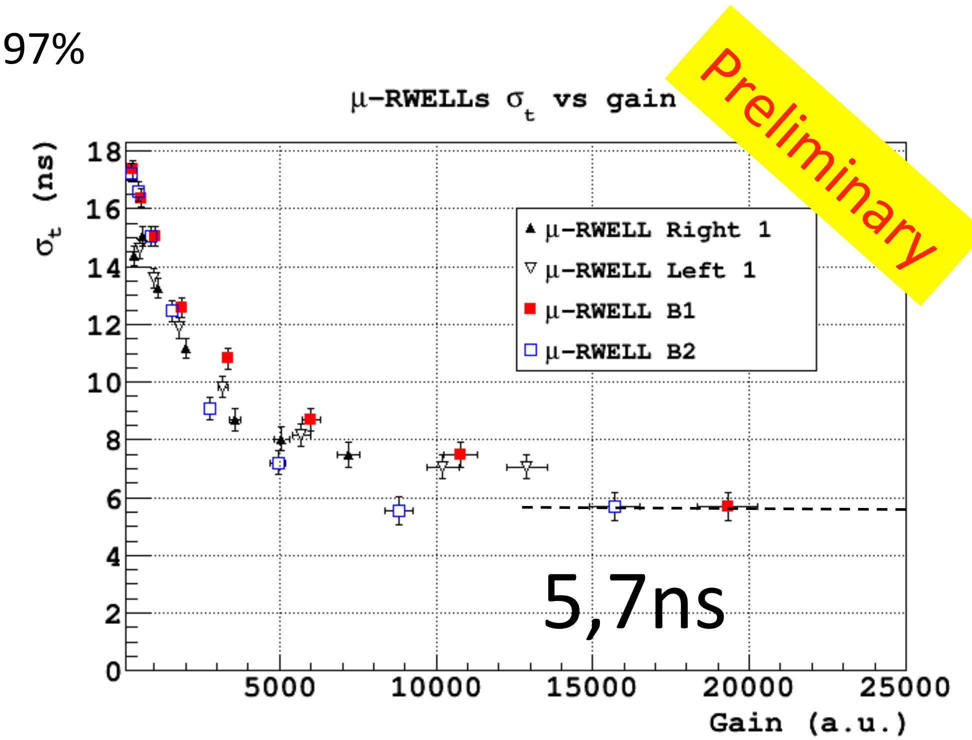


The TDC distribution is then fitted with a simple gaussian and the sigma is then **deconvoluted** by the contribution of the VFAT.

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

Performance vs Gain with Ed=3,5 kV/cm
(our group + CMS: L. Benussi, L. Borgonovi, P. Giacomelli, M. Ressegotti, C. Riccardi, I. Vai)

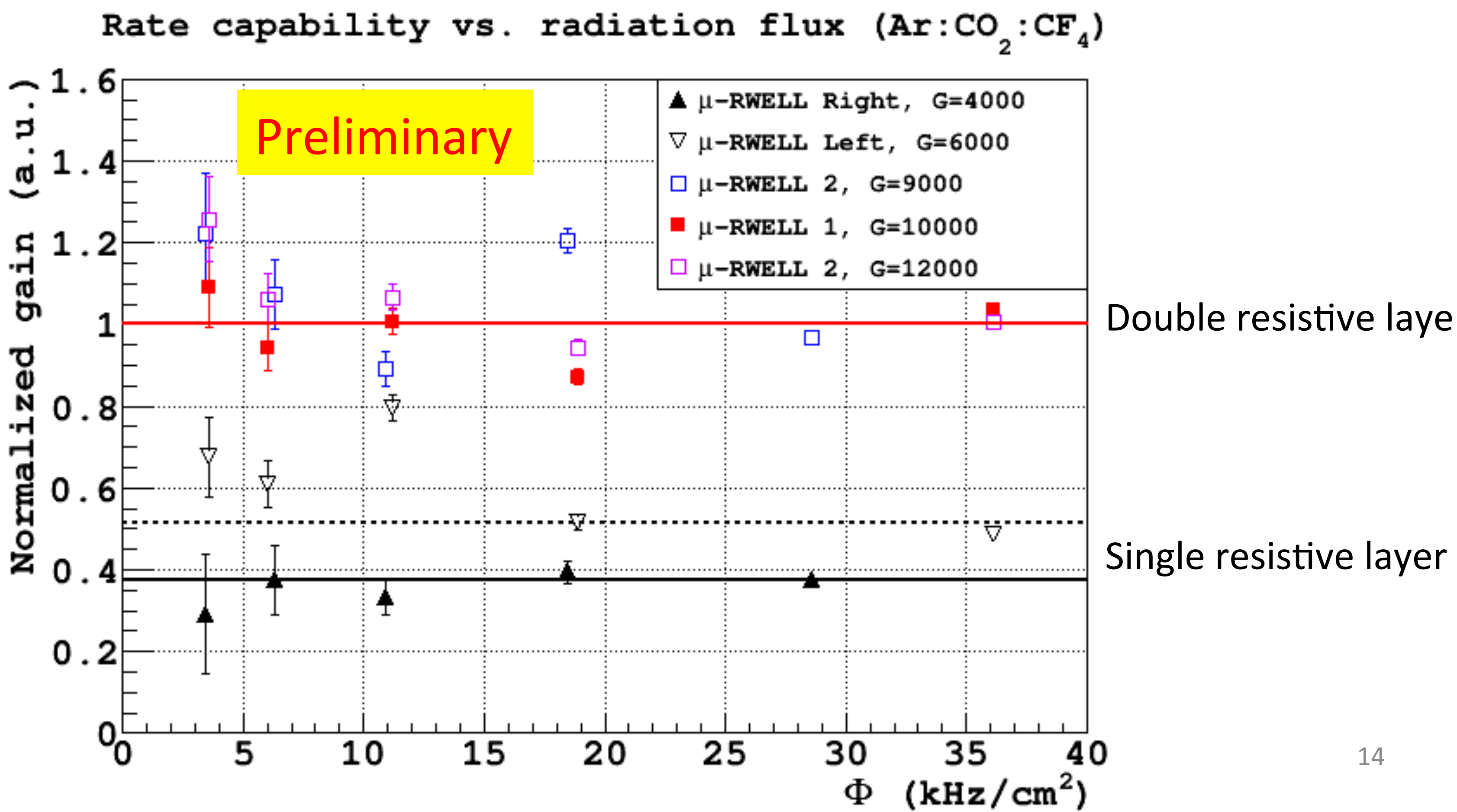




Measurements done with GEM by LHCb group at LNF gave σ_t = 4.5 ns with VTX chip, constant fraction discriminator.

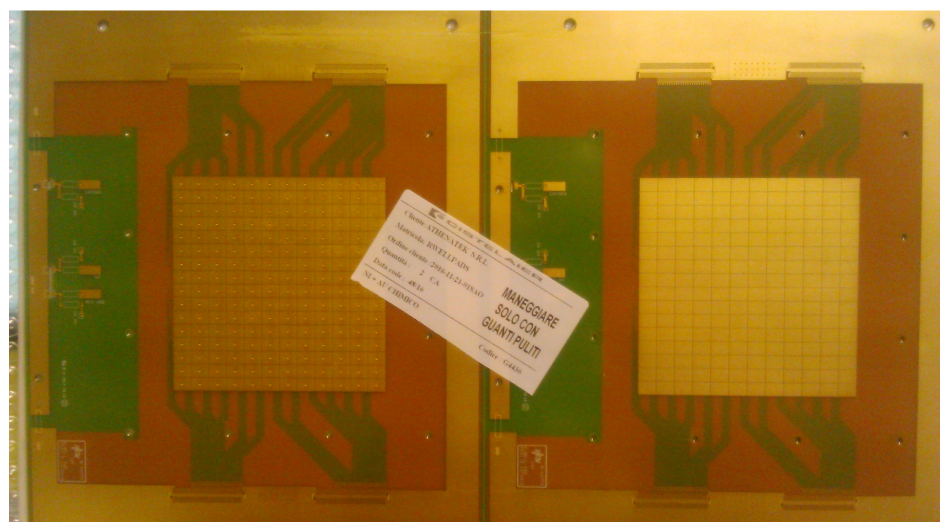
Performance vs Rate

The detector 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)



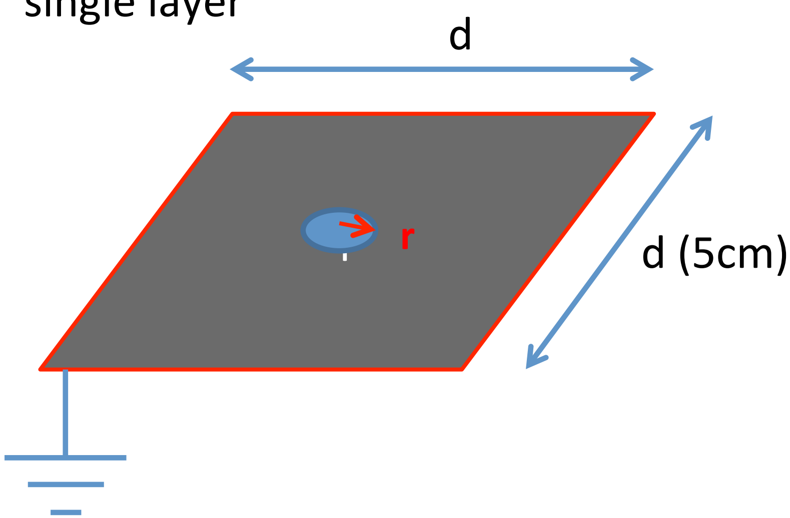
Outlook

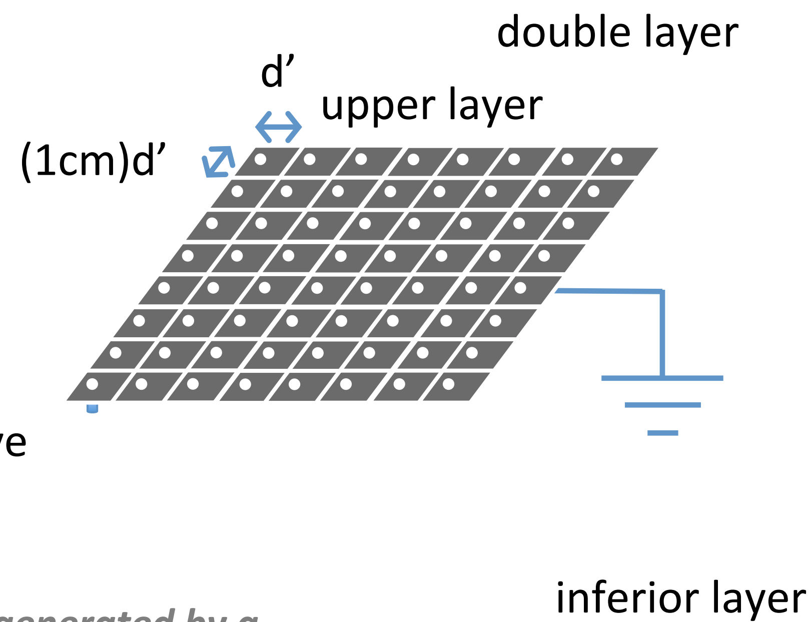
- **Ageing test at GIF++** of the large area detector (SL) and small detectors (DL)
- **Test beam at PSI** (ΠM1) to evaluate the rate capability under "uniform" irradiation
- **Test beam at BTF** for time performance measurement with VTX chip
- **Construction of large area** μ-RWELLs with **GE1/1** and **GE2/1** dimensions (CMS)
- **Construction of prototypes** with double resistive layer scheme and pad readout (LHCb)



Spare

The two detector layouts (II)





(*) 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

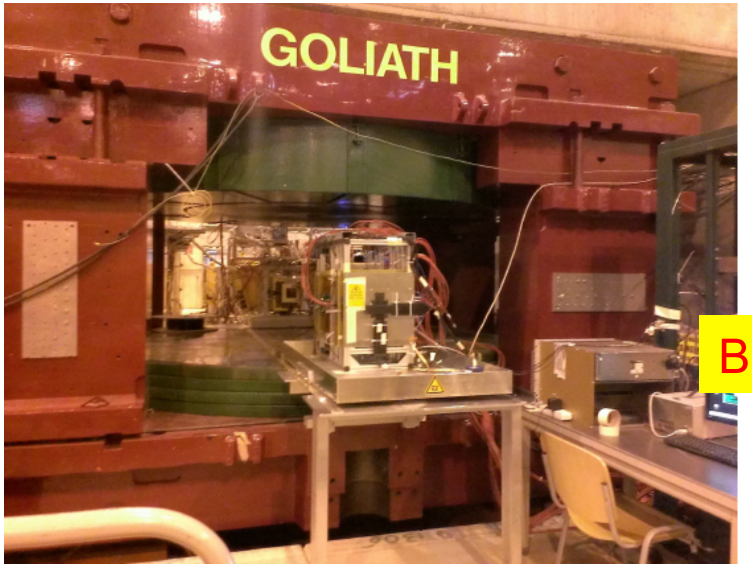
$$\Omega \sim \rho_s \times d/2\pi r \qquad \Omega' \sim \rho_s' \times d'/\pi r$$

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

$$\text{If } \rho_s = 2\rho_s' \rightarrow \Omega/\Omega' \sim \rho_s/\rho'_s * d/3d' = 2 * 5/3 = 3.3$$

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

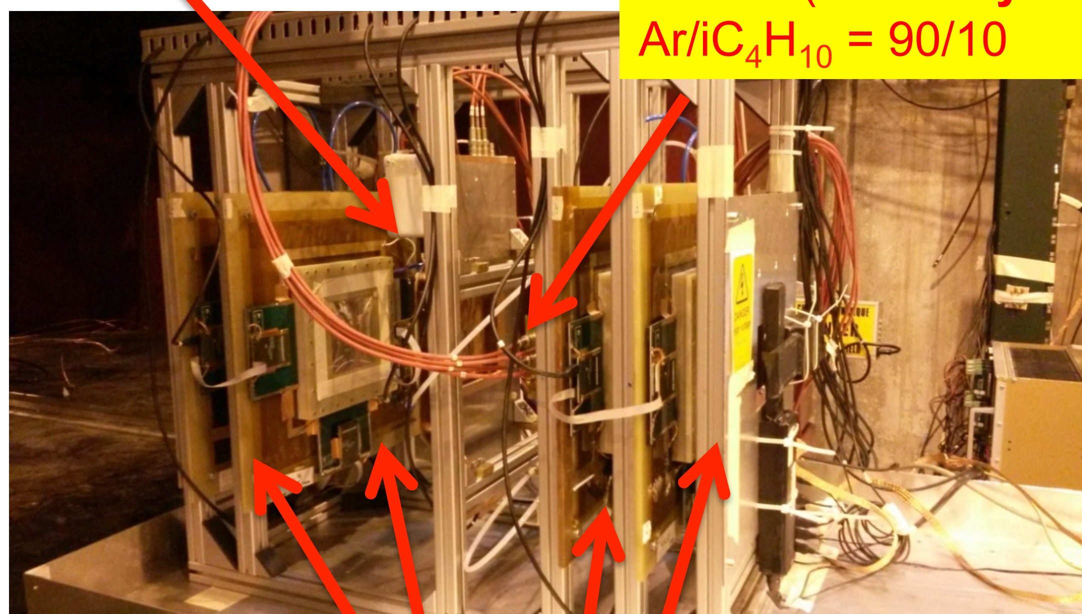
The µ-RWELL performance: Beam Tests



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

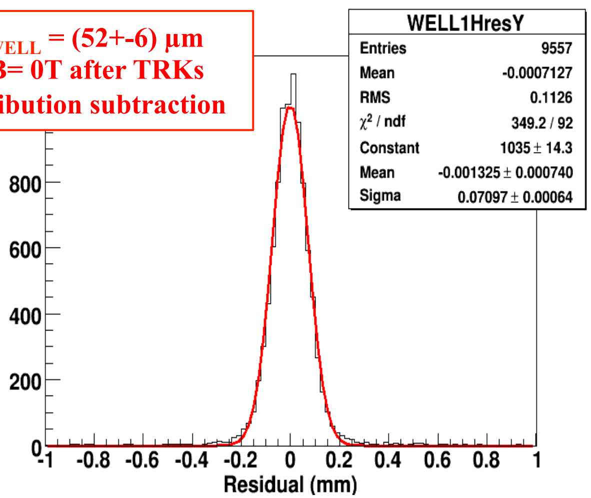
µ-RWELL prototype
12-80-880 MΩ /□
400 µm pitch strips
APV25 (**CC analysis**)
Ar/iC_4H_{10} = 90/10

BES III-GEM chambers

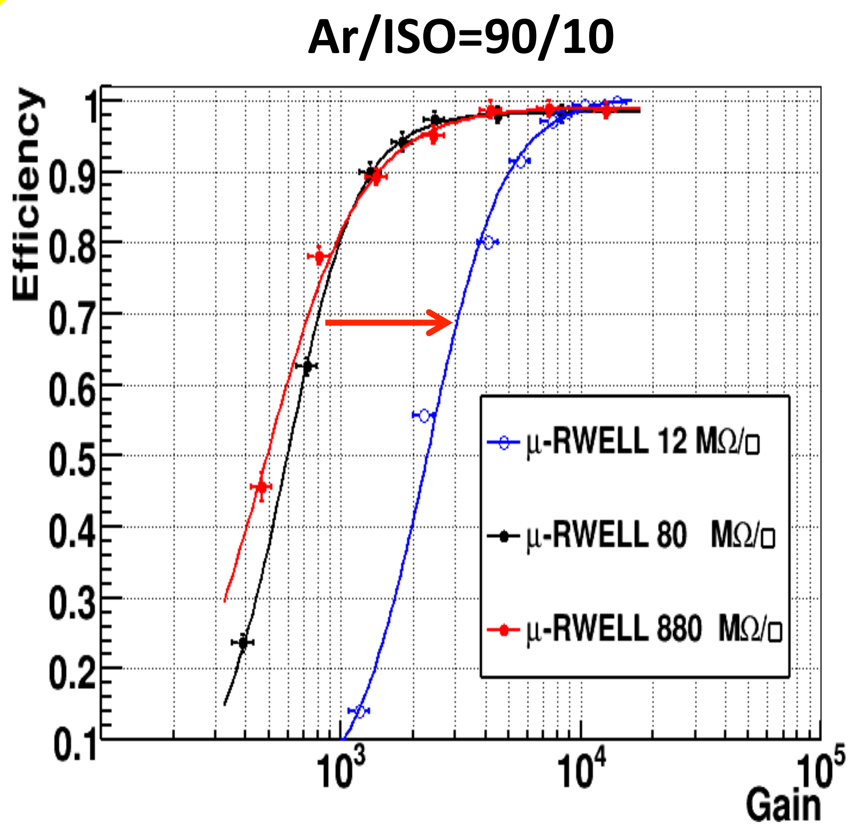


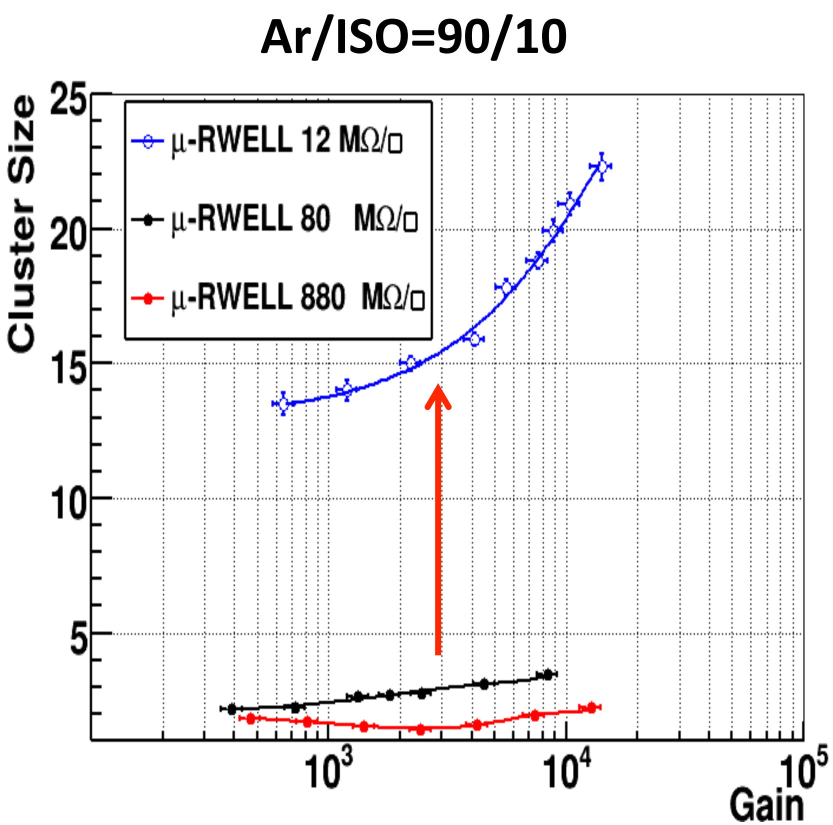
GEMs Trackers

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



µ-RWELL: tracking efficiency

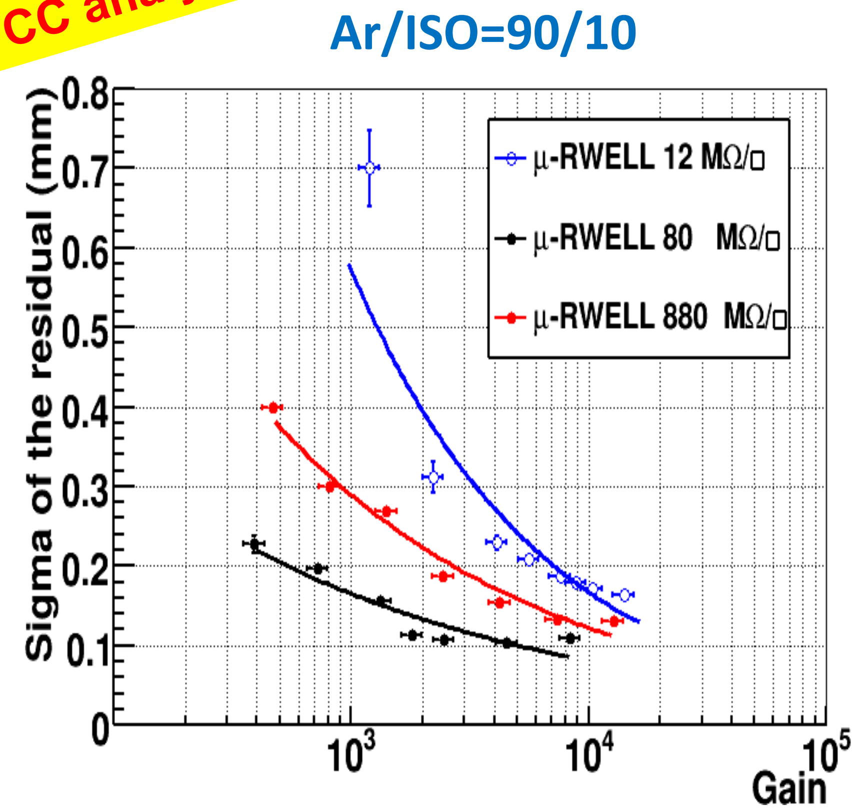


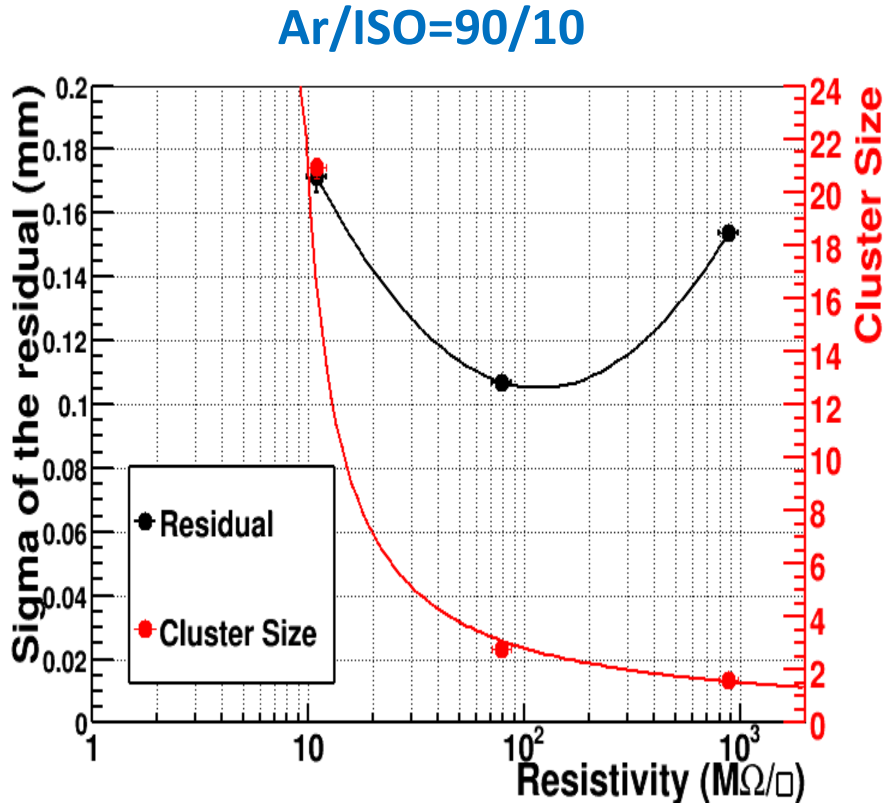


At **low resistivity the spread of the charge** (cluster size) on the readout strips **increases**, thus requiring a **higher gain** to reach the **full detector efficiency.**

Space resolution: orthogonal tracks

CC analysis





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

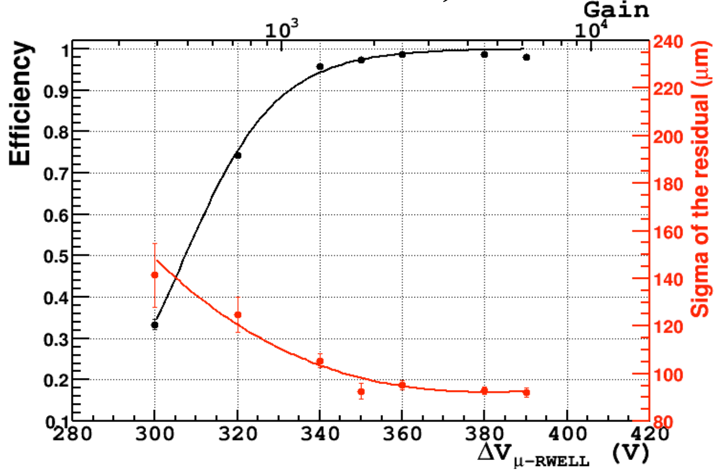
At **low resistivity** the **charge spread increases** and then **σ is worsening.**

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

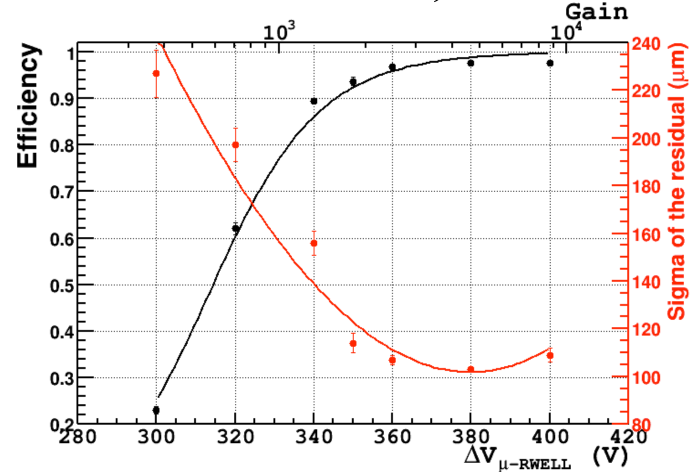
μ-RWELL: B≠0 with Ar/ISO=90/10

CC analysis

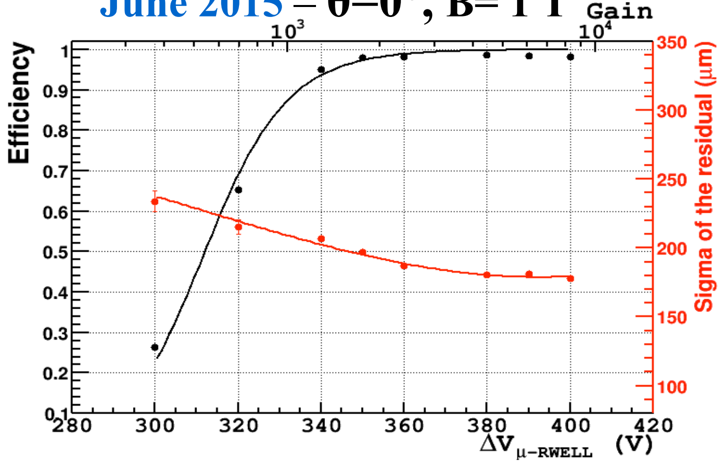
June 2015 – θ=0°, B= 0 T



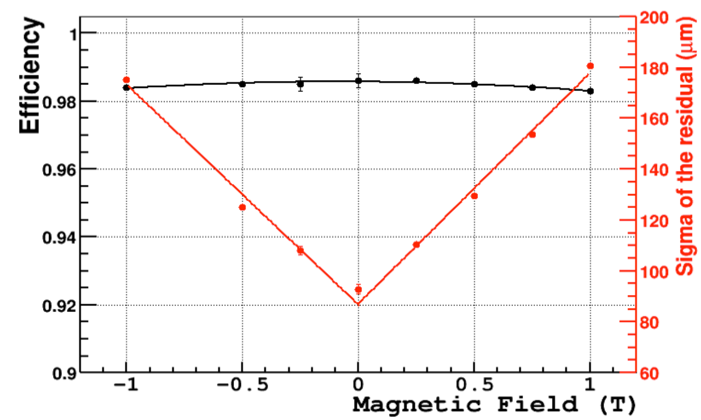
Dec 2014 – θ=0°, B= 0.5 T



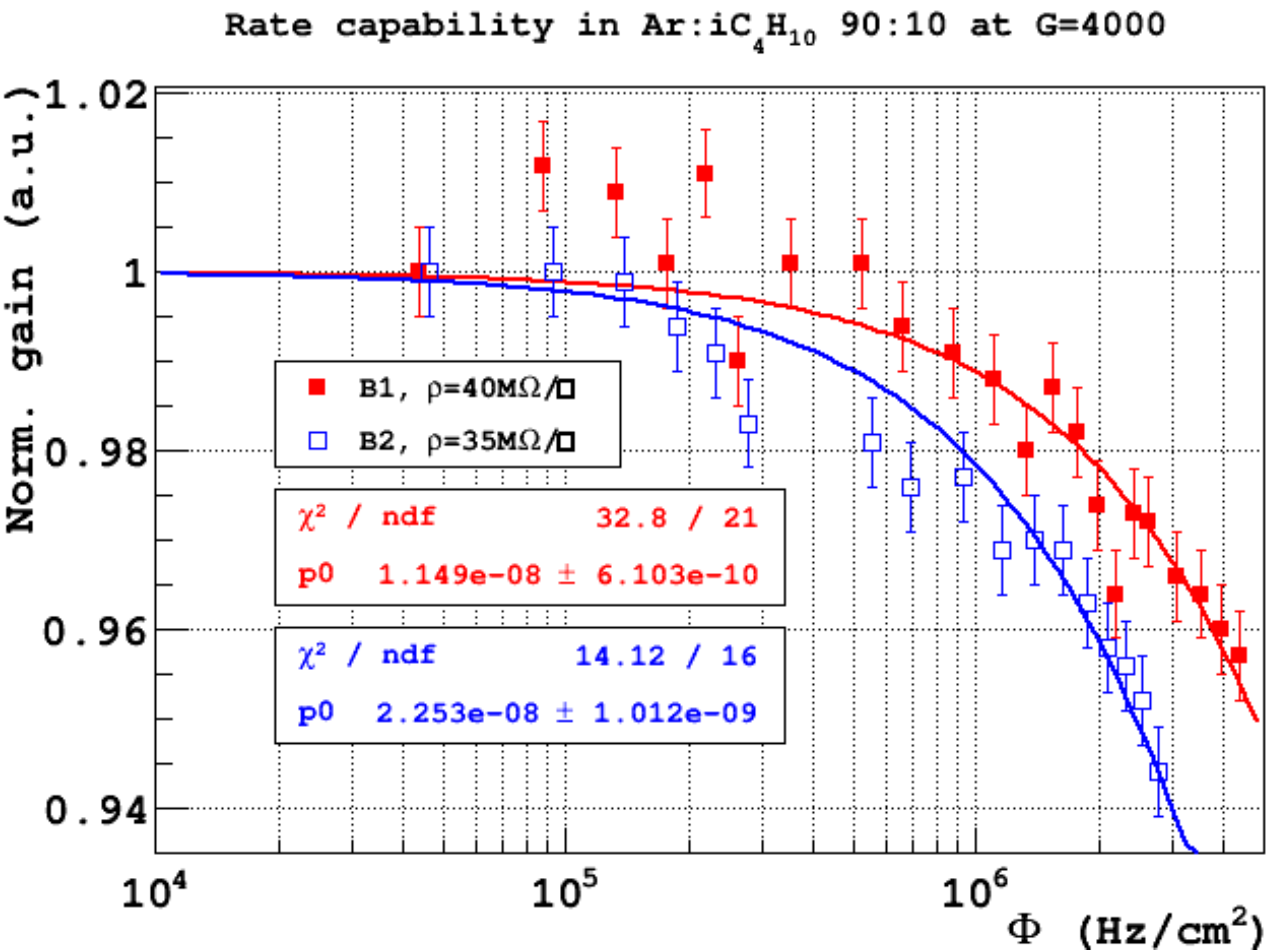
June 2015 – θ=0°, B= 1 T



June 2015 - θ=0°



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



Rate capability in Ar:iC4H10 90:10 at G=4000
Norm. gain (a.u.)
1.02
1
0.98
0.96
0.94
10^4
10^5
10^6
Φ (Hz/cm^2)
B1, ρ=40MΩ/□
B2, ρ=35MΩ/□
χ² / ndf 32.8 / 21
p0 1.149e-08 ± 6.103e-10
χ² / ndf 14.12 / 16
p0 2.253e-08 ± 1.012e-09