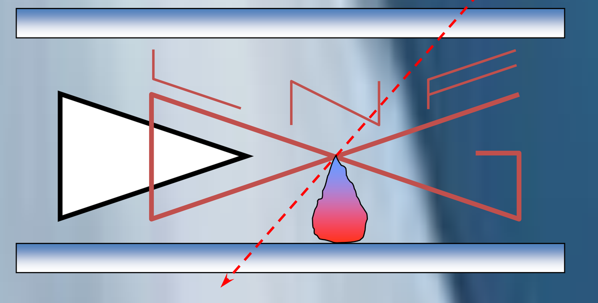
THE micro-RESISTIVE WELL (μ-RWELL) DETECTOR FOR LARGE AREA MUON SYSTEMS AT FUTURE CIRCULAR COLLIDERS



M. Poli Lener[1], G.Bencivenni[1], M. Gatta[1], G. Felici[1], G.Morello[1], R. De Oliveira[2], A. Ochi[3]

[1] Laboratori Nazionali di Frascati – INFN, Frascati, Italy [2] CERN, Geneva, Switzerland, [3] Kobe University, Kobe, Japan

International Workshop on the High Energy Circular Electron Positron Collider , 12-14 November 2018 Beijing (China)

Abstract

The micro-Resistive WELL (μ-RWELL) is a compact, simple and robust Micro-Pattern Gaseous Detector (MPGD) suitable for operating in harsh environment and covering large area Muon apparatus at future HEP Colliders (FCC-ee/hh, CepC, SppC), where detection surfaces of O(10000) m² are expected. The detector amplification stage is realized with a polyimide structure micro-patterned with a blind-hole matrix, embedded through a thin Diamond Like Carbon (DLC) resistive layer in the readout PCB. The surface resistivity of the DLC (10-200 MΩ/□) has to be optimized for the correct operation of the detector in terms of response speed, quenching of discharges in gas, spatial resolution and gain. Different detector layouts have been studied: the most simple one based on a single-resistive layer has been designed for low-rate applications (up to 30-40 kHz/cm²); while more sophisticated schemes are under study for high-rate purposes (up to 2-3 MHz/cm²). The technology transfer to the industry of the single-resistive layer scheme has been extensively tested and validated and it is ready for applications in HEP (LHCb, SHiP). The high rate version of the μ-RWELL is under development in collaboration with the CERN PCB-Workshop and it is based on different current evacuation schemes such as the double resistive layer and the single-resistive layout with conductive/resistive-grid grounding.

The μ-RWELL: motivations

Due to the micrometric distance between electrodes, MPGDs suffer from spark occurrence that can damage the detector or FEE.

The resistive layer acts as discharge quencher:

- a streamer generated in the amplification volume induces a large current through the resistive layer
- a local drop of the amplification stage is generated
- the discharge is locally suppressed

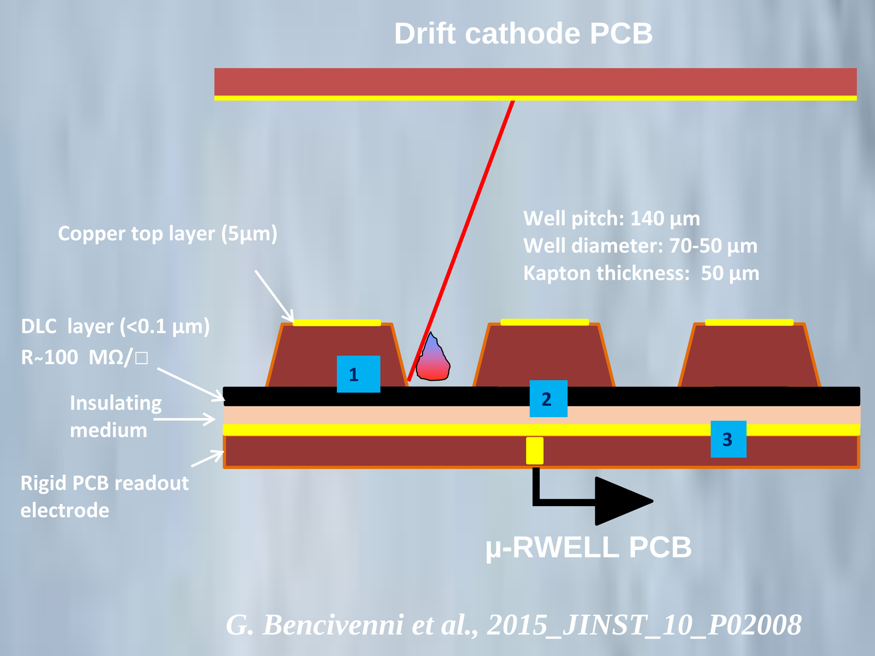
As a drawback, the capability to stand high particle fluxes is reduced, but an appropriate grounding of the resistive layer with a suitable pitch solves this problem (see High Rate scheme & new layouts)

The detector architecture

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

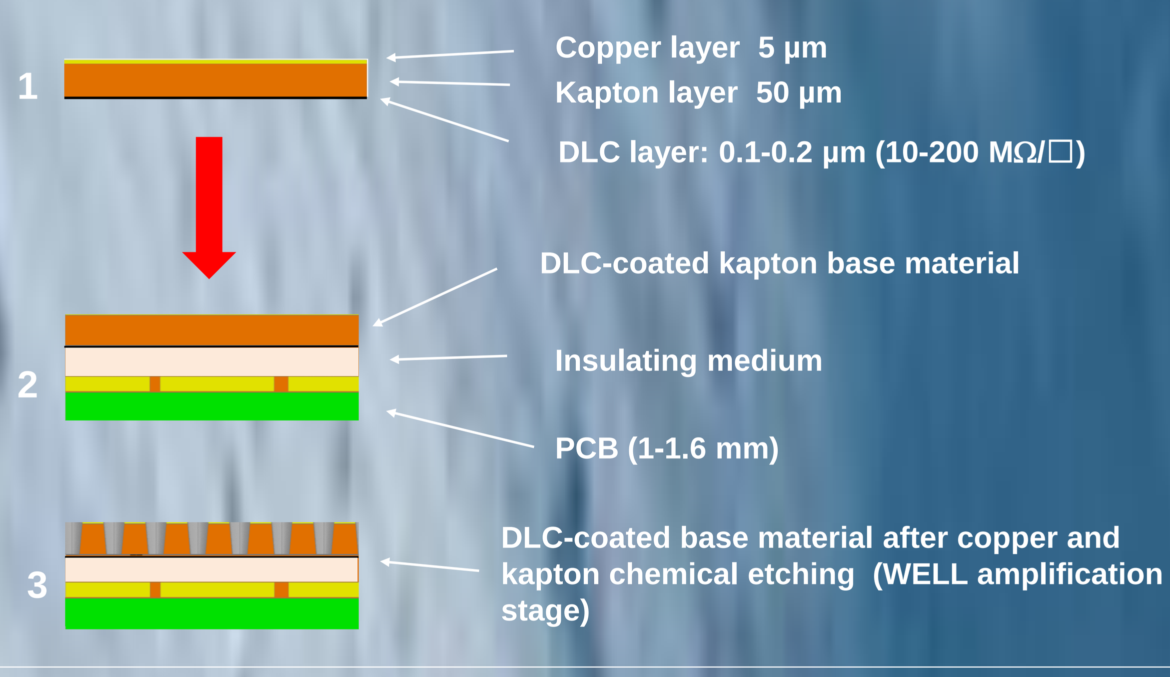
The *μ*-**RWELL_PCB, the core of the detector,** is realized by **coupling:**

1. "**WELL patterned kapton foil**" as "**amplification stage**"
2. "**resistive layer**" for discharge suppression & current evacuation:
   i. "**Single resistive layer" (SL) <100 kHz/cm²**: single resistive layer → surface resistivity ~100 MΩ/□ (LHCb, SHIP; NA-62 upgrade)
   ii. "**Double resistive layer" (DL) > 1 MHz/cm²**: more sophisticated resistive scheme must be implemented (MPDG_NEXT- LNF) suitable for LHCb-Muon upgrade, FCC-ee/hh, CppC, CepC
3. a **standard readout PCB**



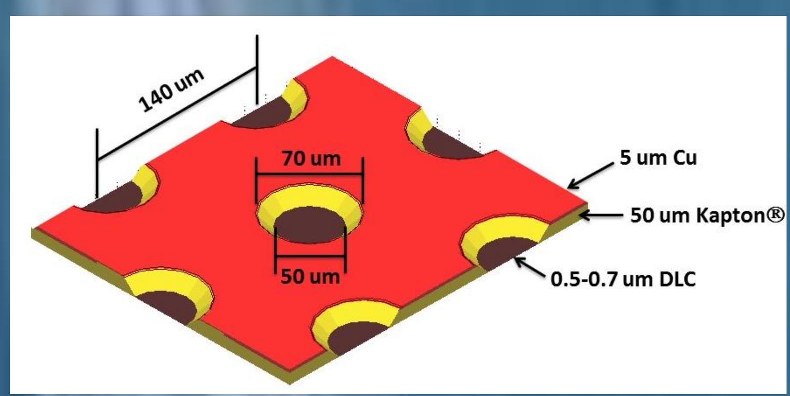
G. Bencivenni et al., 2015_JINST_10_P02008

Low Rate scheme – single resistive layer

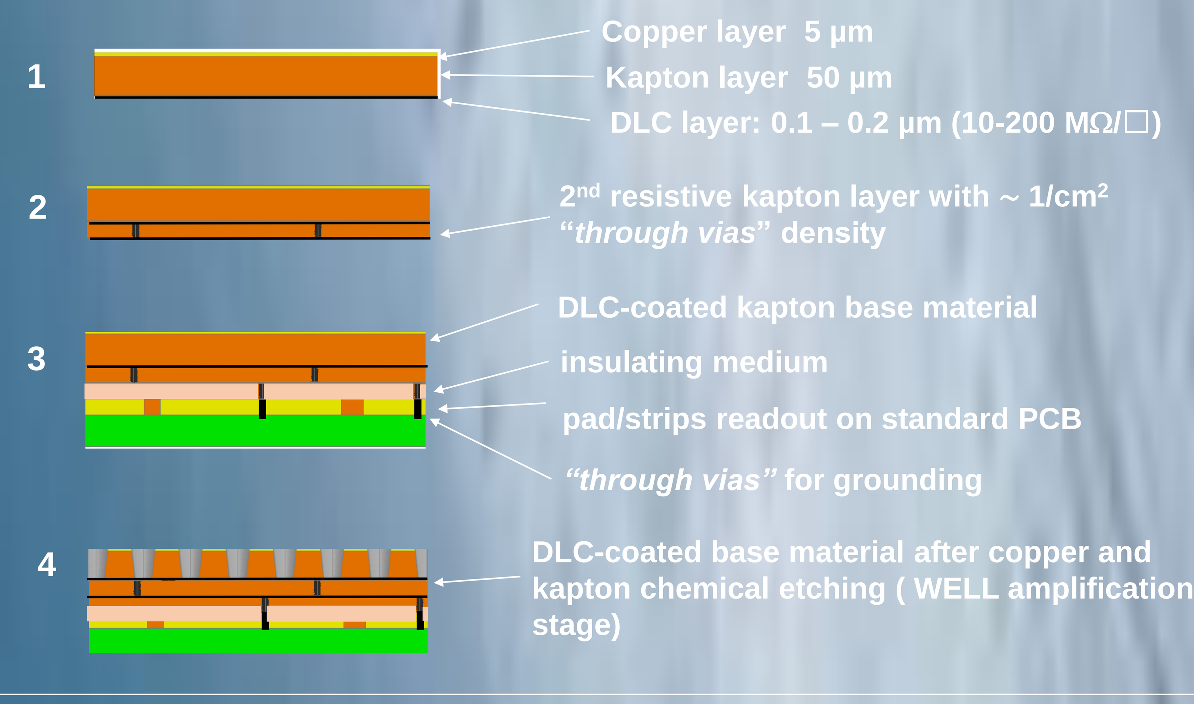


Resistive Layouts

Two different scheme of the resistive stage have been developed depending on the experiment/application requirements

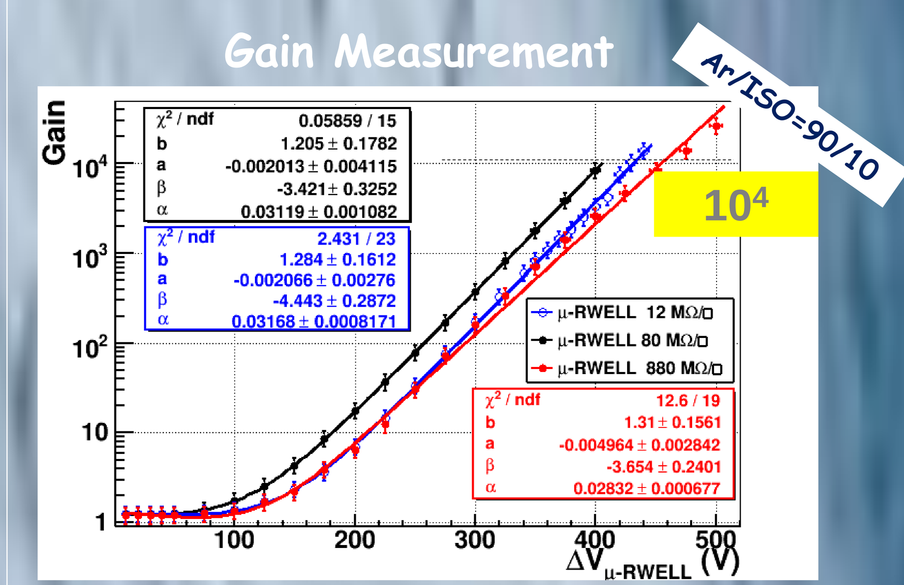


High Rate scheme – double resistive layers



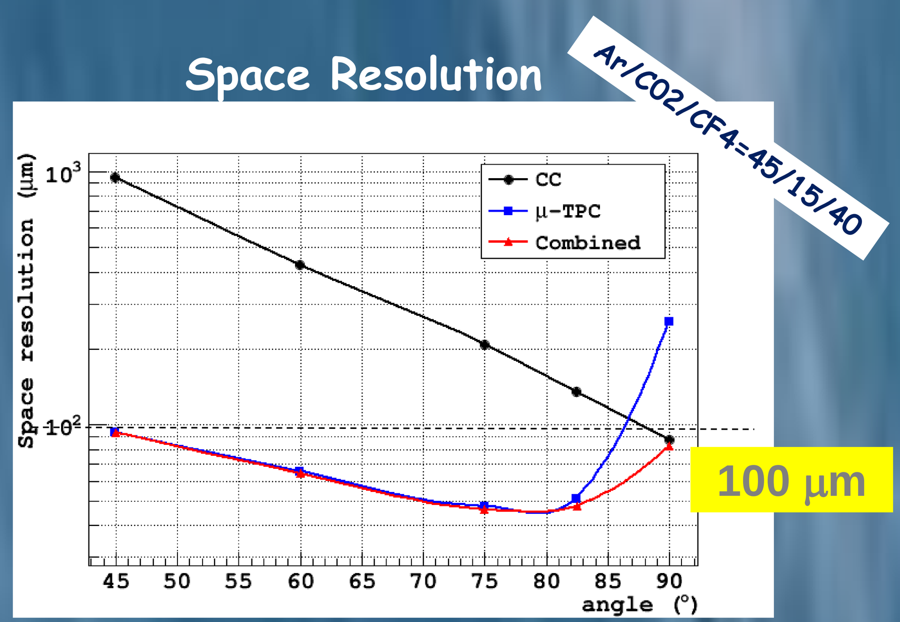
Detector Performance

Gain Measurement



The prototypes, with different surface resistivities, have been tested with X-rays with several gas mixtures in current mode. Detectors safely reach a gain ≥ 10000 [G. Bencivenni et al., NIM A 886 (2018) 36]

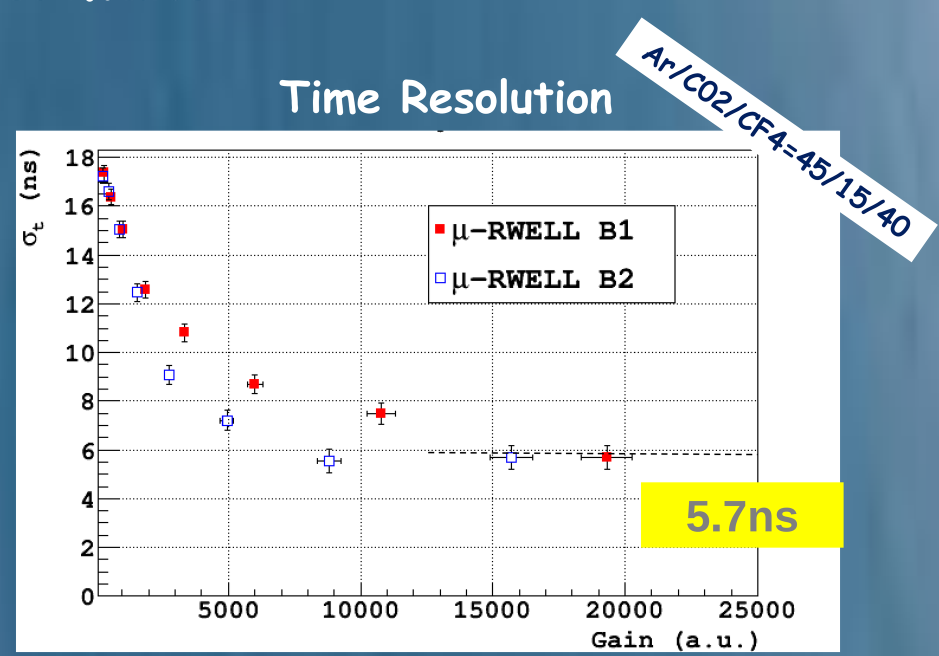
Space Resolution



Improving space resolution for inclined tracks with APV: the combination of the Charge Centroid and the μ-TPC mode with 1 kV/cm drift field allows to achieve a space resolution below 100 μm for a wide range of incident angle

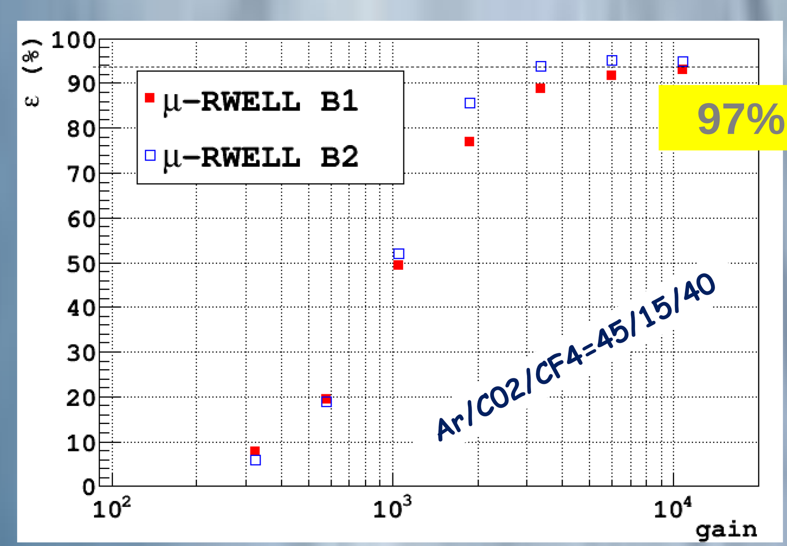
Thanks to the collaboration of Fe-INFN: G.Cibinetto, L.Lavezzi & R.Farinelli

Time Resolution



A time resolution of 5.7 ns has been measured with VFAT2. The saturation at 5.7 ns is dominated by the FEE. To be compared with past measurements done by our LHCb with GEM: σ_t = 4.5 ns with VTX chip and CF discriminator [G. Bencivenni et al., NIM A 494 (2002) 156]

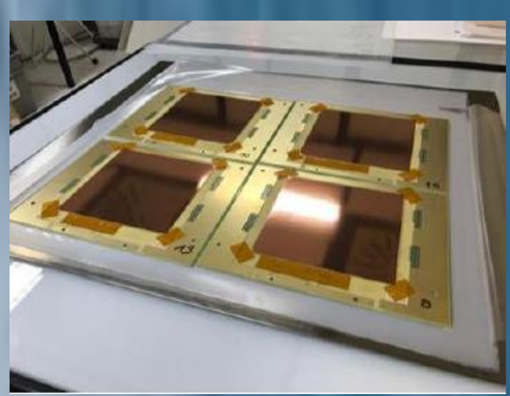
Tracking Efficiency vs B



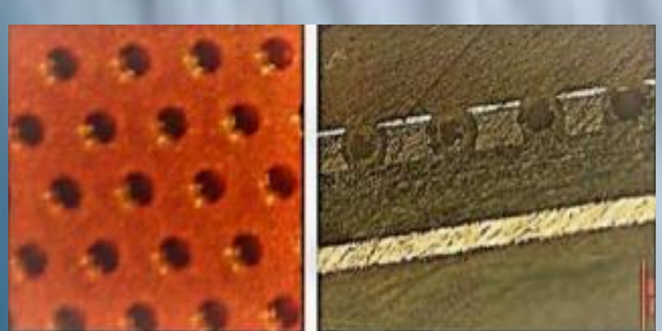
Tracking efficiency above 97% at gain~3000 measured with VFAT2 FEE [G. Bencivenni et al.,NIM A 886 (2018) 36]

Technology Transfer to Industry

The engineering and industrialization of the μ-RWELL technology is one of the main goal of the project. Transferring the manufacturing process to industry will allow a cost-effective mass production: a must for the construction of muon systems at future HEP Colliders



Manufacturing process of the single resistive layer has been already tested at the ELTOS SpA (http://www.eltos.it)



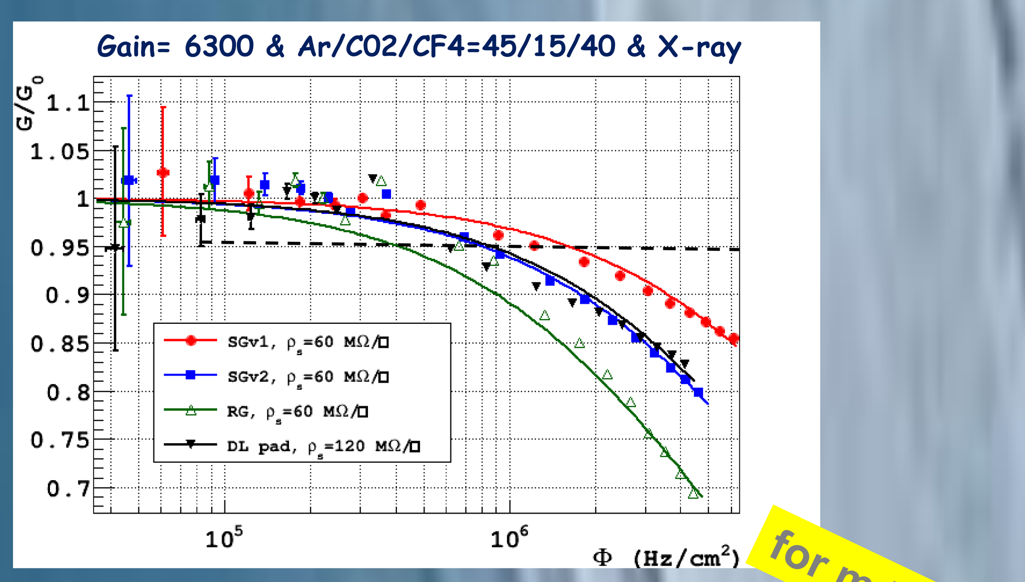
The DLC dry sputtering is performed by the Japanese company Be-Sputter ltd, while the etching of the polyimide to realize the micro-well pattern is performed at the PCB-Workshop of CERN (by one of the authors)

New layouts for the High Rate

To maintain a very short path for current drifting on the resistive layer and to simplify the construction process wrt the double resistive layer, new layouts are now under development with different current evacuation scheme (to be optimized)

High Rate scheme	Resistive layer	Pitch grid/vias	Type
Silver Grid 1 (SG1)	single	6 mm	conductive grid
Silver Grid 2 (SG2)	single	12 mm	conductive grid
Resistive Grid (RG)	single	6 mm	resistive grid
Double Layer (DL)	double	6 + 6 mm	conductive vias

Gain drop is only due to Ohmic effect on the resistive layer: the current collected on the DLC drift towards the ground facing an effective resistance Ω, depending on the evacuation scheme



Rate capability with X-ray @ gain drop 5%

Φ^{γ}_{SGv1} = 1.6 MHz/cm²; Φ^{γ}_{SGv2} = 0.80 MHz/cm²

Φ^{γ}_{RG} = 0.4 MHz/cm²; Φ^{γ}_{DL} = 0.85 MHz/cm²

Summary & Outlook

The μ-RWELL is a very promising technology showing important advantages for large area applications in harsh environment: the detector is compact, simple to assemble and intrinsically spark-protected. Besides high gas gain (>10⁴) and high tracking efficiency (97%), a space resolution well below 100 um has been measured for non-orthogonal tracks combining the CC and μ-TPC mode. The Technology Transfer to industry for the Low Rate layout has been completed and validated. For high rate applications several layouts have been realized with different current evacuation schemes: further optimization must be done, addressed by the measurement of the gain drop with X-rays and at high intensity hadron beam.