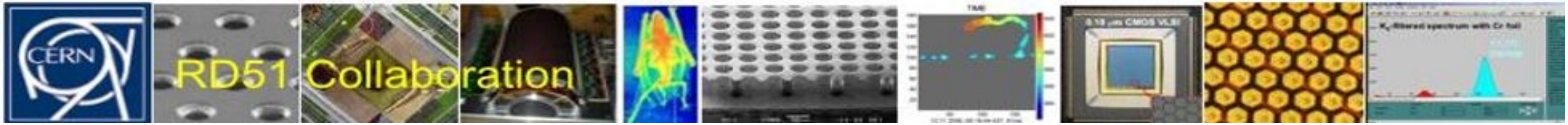
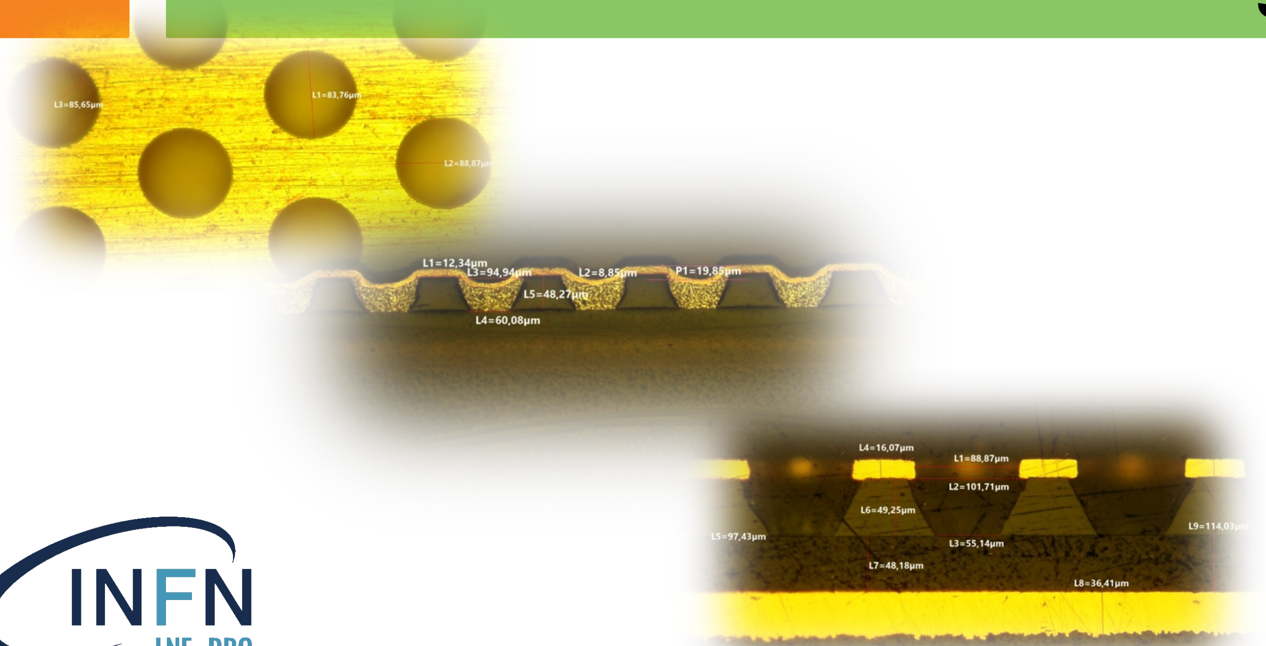


The state of art of the μ-**RWELL** technology for high-rate purpouses

M. Poli Lener

G. Bencivenni, R. De Oliveira, G. Felici, M. Gatta, M. Giovanetti, G. Morello



INFN
LNF - DDG

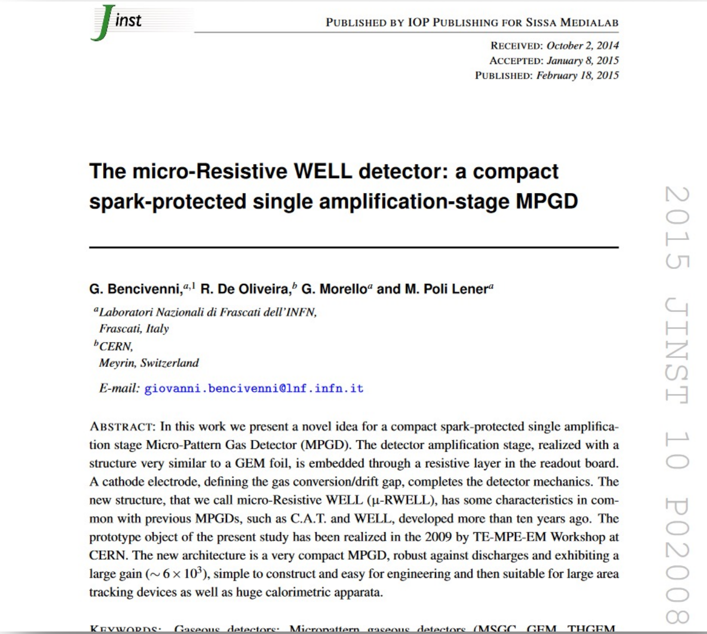
Why a new Micro-Pattern Gas Detector

The R&D on µ-RWELL detector(*) is mainly motivated by the wish of improving

stability under irradiation → discharge containment

& simplify as much as possible the

construction/assembly → time consuming/complex operation/mass production



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The micro-Resistive WELL detector: a compact spark-protected single amplification-stage MPGD

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[a] *Laboratori Nazionali di Frascati dell'INFN, Frascati, Italy*
[b] *CERN, Meyrin, Switzerland*

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ABSTRACT: In this work we present a novel idea for a compact spark-protected single amplification stage Micro-Pattern Gas Detector (MPGD). The detector amplification stage, realized with a structure very similar to a GEM foil, is embedded through a resistive layer in the readout board. A cathode electrode, defining the gas conversion/drift gap, completes the detector mechanics. The new structure, that we call micro-Resistive WELL (µ-RWELL), has some characteristics in common with previous MPGDs, such as C.A.T. and WELL, developed more than ten years ago. The prototype object of the present study has been realized in the 2009 by TE-MPE-EM Workshop at CERN. The new architecture is a very compact MPGD, robust against discharges and exhibiting a large gain ($\sim 6 \times 10^3$), simple to construct and easy for engineering and then suitable for large area tracking devices as well as huge calorimetric apparata.

KEYWORDS: Gaseous detectors; Micropattern gaseous detectors (MSGC, GEM, THGEM

2015 JINST 10 P02008

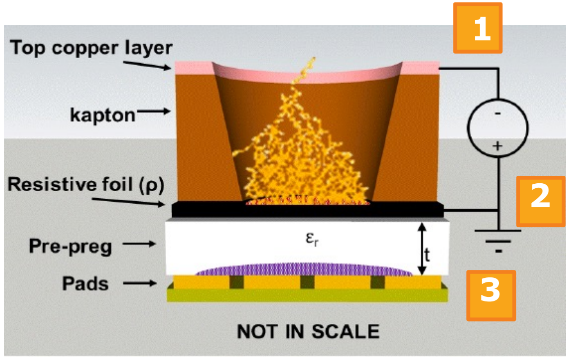
(*) G. Bencivenni et al., "**The micro-Resistive WELL detector: a compact spark-protected single amplification-stage MPGD**", 2015 *JINST* **10** P02008

The µ-RWELL

The **µ-RWELL is a resistive MPGD** composed of two elements:

- **µ-RWELL_PCB**
- **Cathode**

The µRWELL_PCB is realized by coupling the **resistive (grounded) amplification stage** with the **readout PCB** through a thin **prepreg foil.**



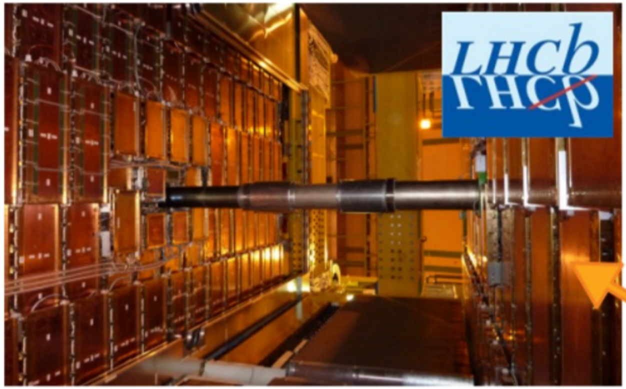
1 a **WELL** patterned **kapton foil** (with a **Cu-layer on the top**) acts as **amplification stage**

2 a **resisitive DLC** layer(*) (Diamond-Like-Carbon), with **ρ~40÷100 MΩ/□**

3 a standard **readout PCB** with **pad** segmentation

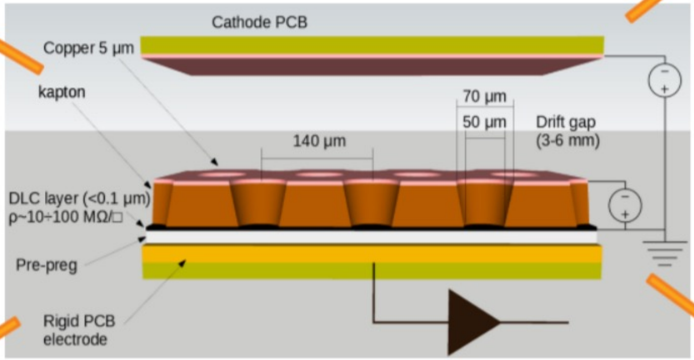
(*) DLC foils are currently provided by the Japan Company – BeSputter. New DLC machine @ CERN (Max DLC size: 50x200 cm2)

INFN-LNF DDG active projects

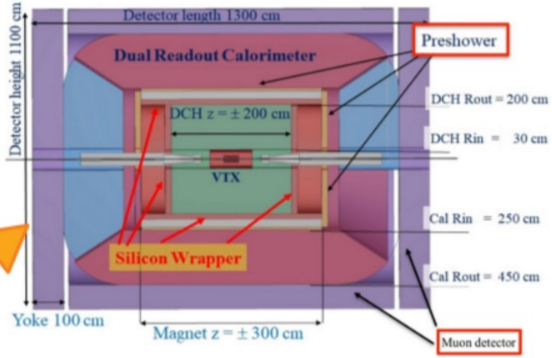


Triggering device
high rate

LHCb

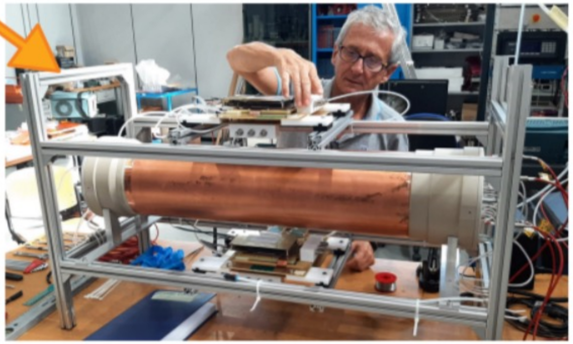


IDEA



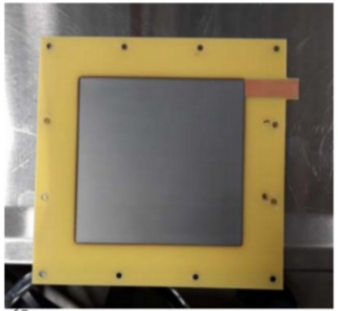
Tracking device
Low rate

EURIZON



Tracking device
Low rate

uRANIA



$$n+{}^{10}_{5}B \begin{cases} {}^{7}_{3}Li(1.02MeV)+\alpha(1.78MeV) & 6\% \\ {}^{7}_{3}Li(0.84MeV)+\alpha(1.47MeV)+\gamma(0.48MeV) & 94\% \end{cases}$$

Neutron detection Low rate

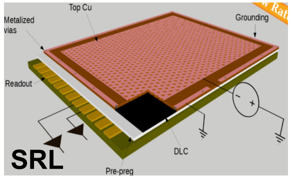
µ-RWELL R&D History

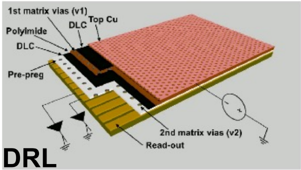
INFN LNF - DDG

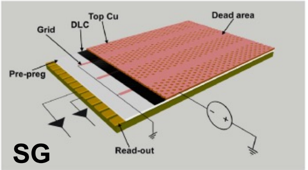
R&D on low-rate layout

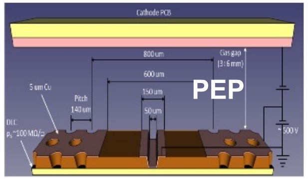
R&D on high-rate layout

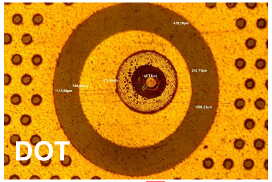
New u-RWELL ideas (in collaboration with RD51)







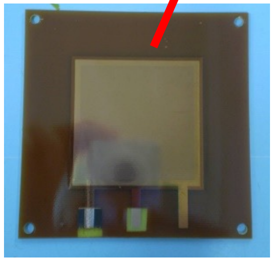




R&D start

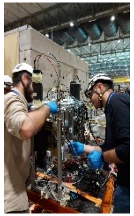
TT @ ELTOS

2009 — 2014 — 2015 — 2016 — 2017 — 2018 — 2019 — 2020 — 2021 — 2022 — 2023

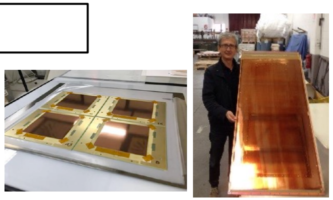


TB @ CERN

TB @ high rate @ PSI

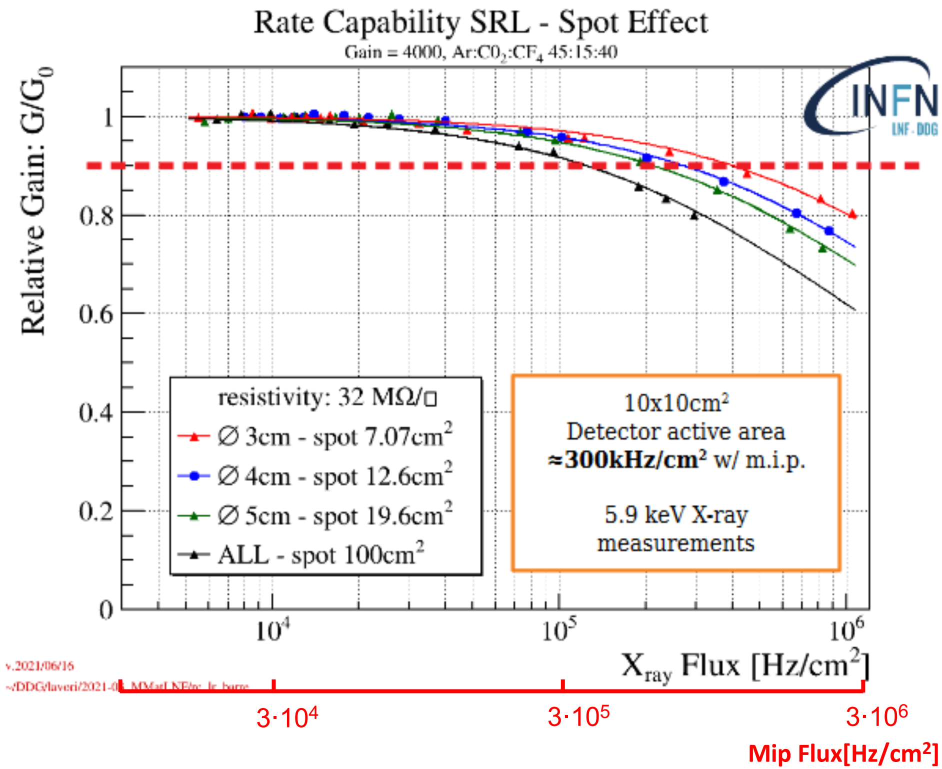


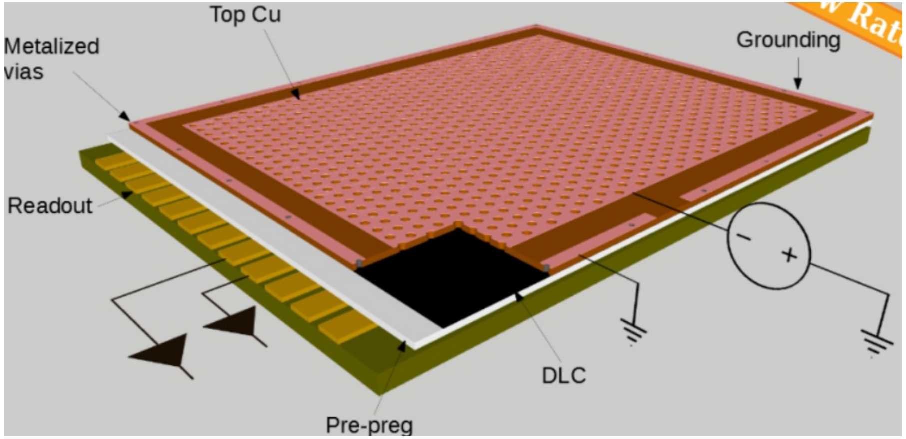
TB @ CERN



TT @ ELTOS

The low-rate layout: SRL

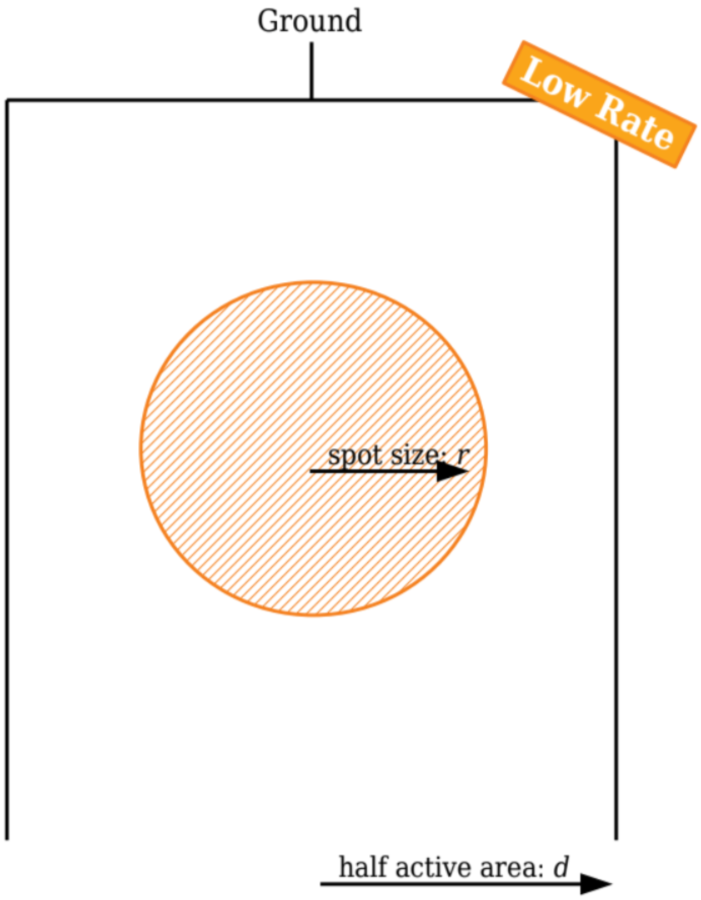


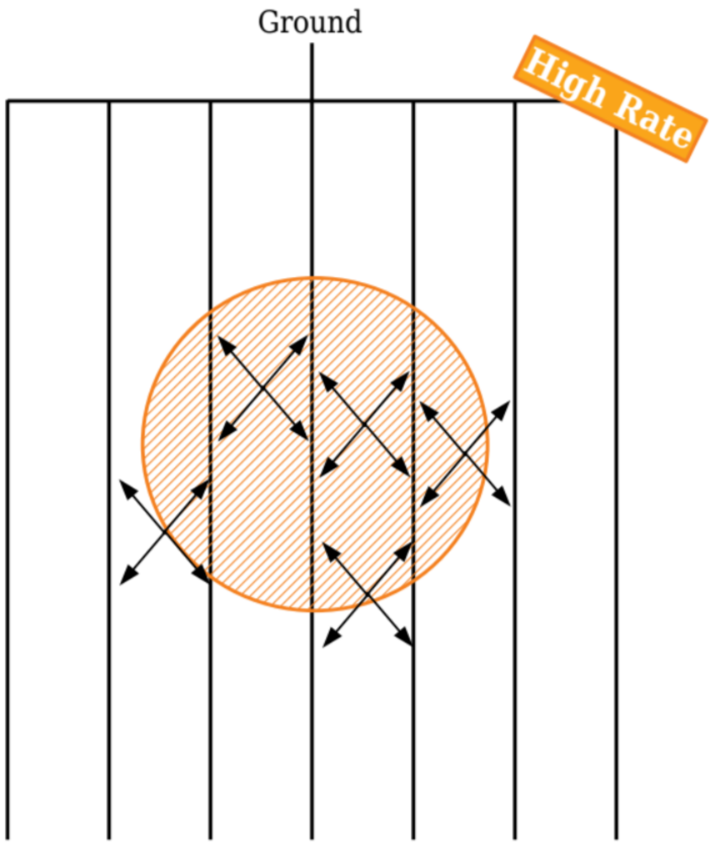


Single Resistive Layer (SRL)

- **2-D current evacuation scheme based on a single resistive layer**
- grounding around the perimeter of the active area
- limitation for large area: the path of the current towards ground connection depends on the particle incidence point → detector response inhomogeneity → **limited rate capability <100 kHz/cm^2**

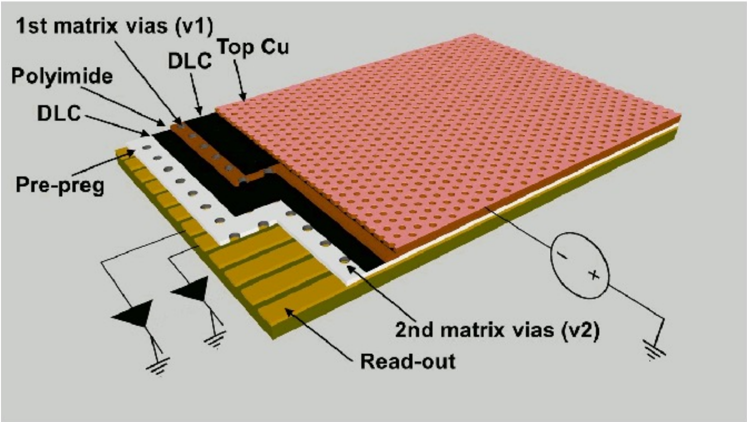
The high rate layout idea





A sort of tiling with smaller low rate schemes.

High-rate layouts: DRL

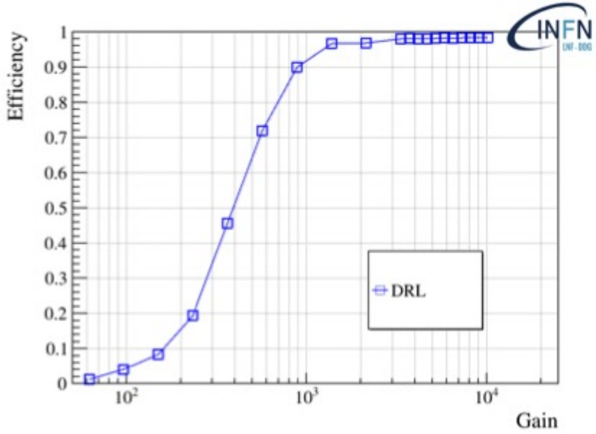


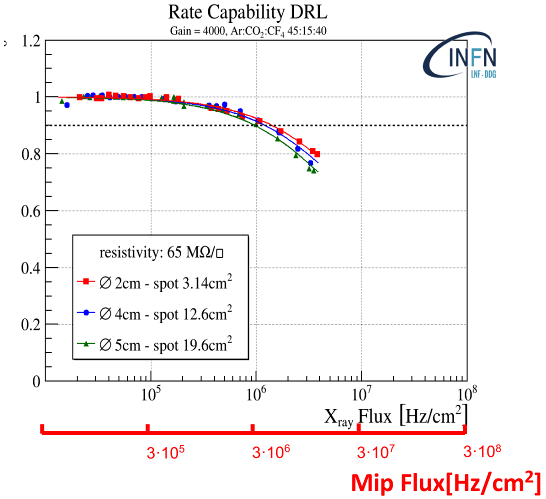
Double Resistive Layer

- 3-D current evacuation scheme
- two stacked resistive layers connected through a matrix of conductive vias
- Resistive stage grounding through a further matrix of vias to the underlying readout electrodes
- pitch of the vias with a density less than 1/cm^2
- No- dead zone in the active area

DRL layout behavior

DRL shows **very good performance**, but it has production **limitations due to the double matrix of vias which** require complex manufacturing

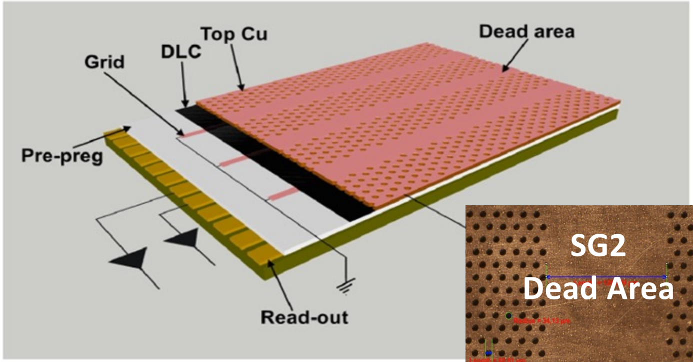


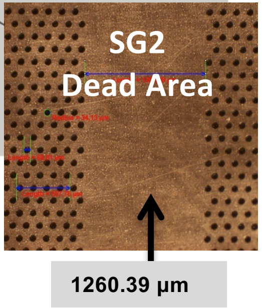


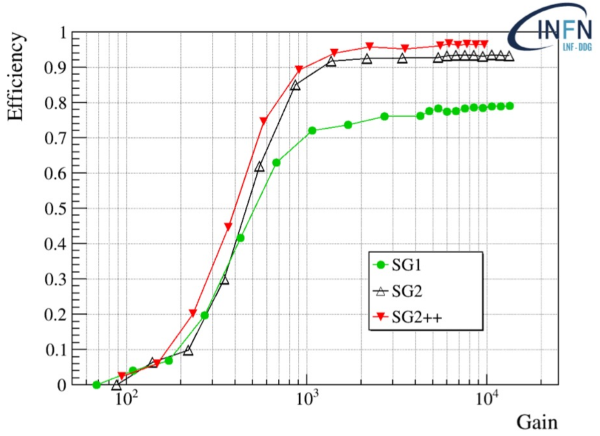
High-rate layouts: SG

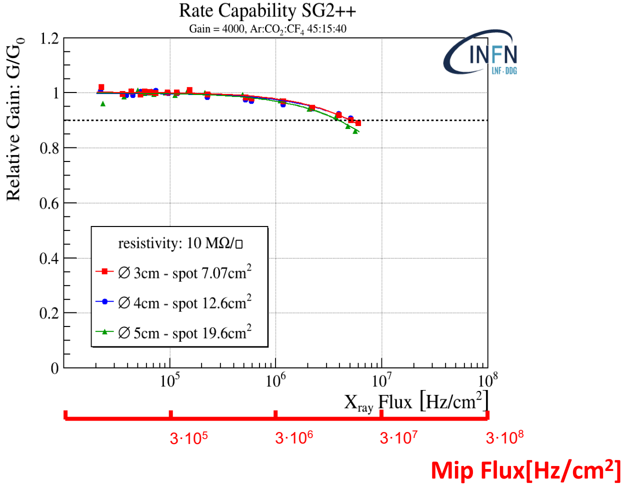
The Silver Grid layer

- simplified HR scheme based on a SRL
- 2-D evacuation scheme by means a conductive grid realized on the DLC layer
- grid lines can be screen-printed or etched by photo-lithography
- pitch of the grid lines of the order of 1/cm
- Dead zone of 2 mm (SG1), 1.2 mm (SG2) and 0.6 mm (SG2++)





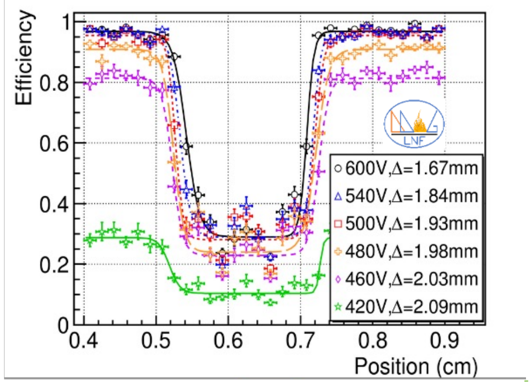




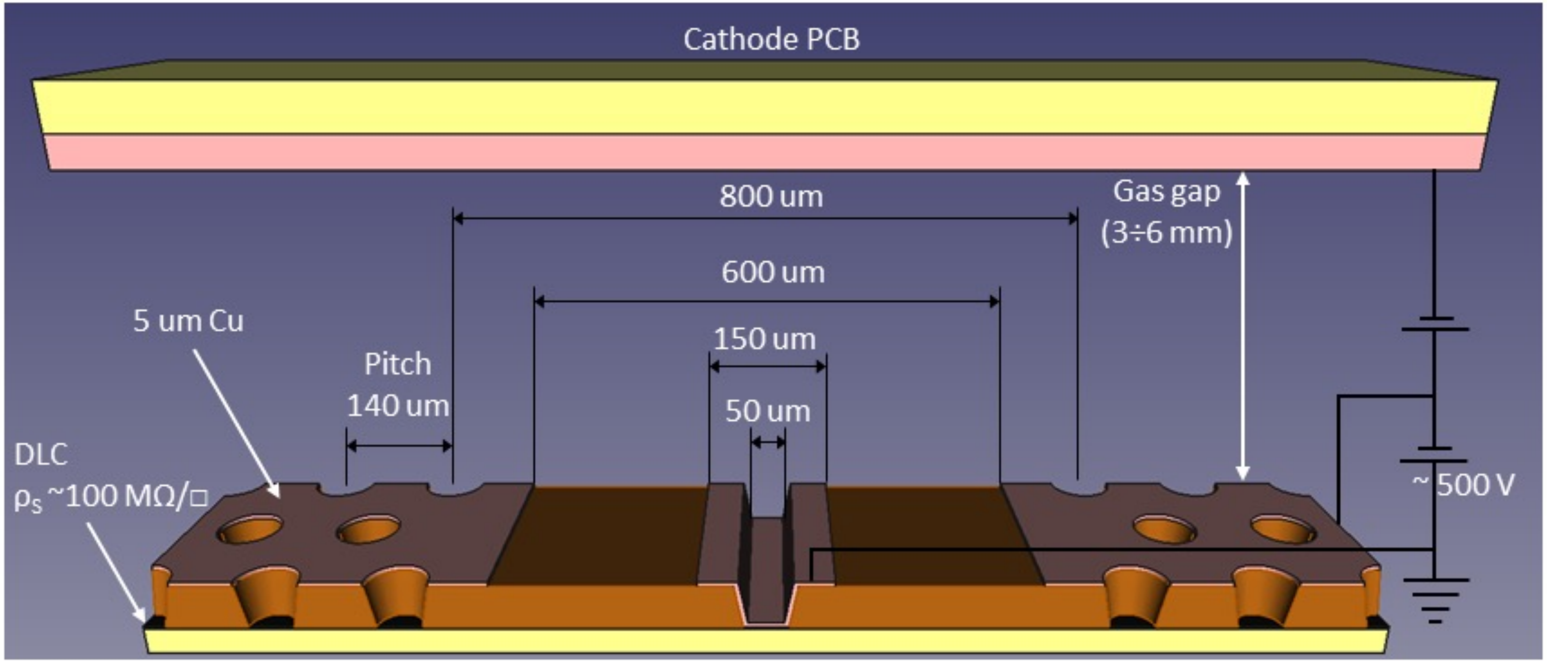
SG layouts behavior

The SG2++ shows **good performance** and it is more simple than **DRL, BUT the alignment** of the **conductive grid pattern on DLC** wrt the **amplification pattern on the top is** a bit **critical**

Effect of SG1 dead zone



High-rate layouts: PEP - groove



PEP (Patterning – Etching – Plating)

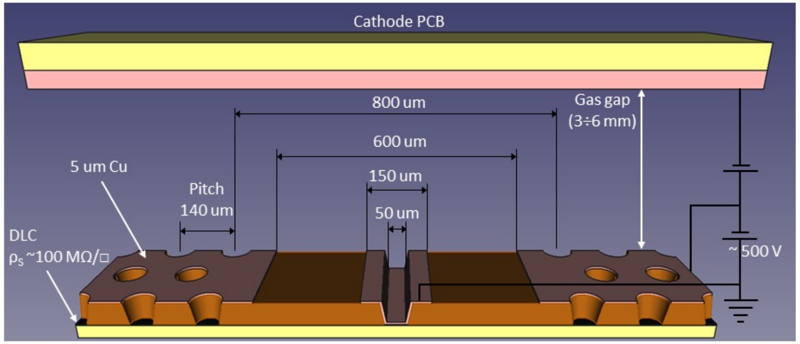
- Single DLC layer
- Grounding from top by kapton etching and plating
- No alignment problems
- **Scalable to large size**

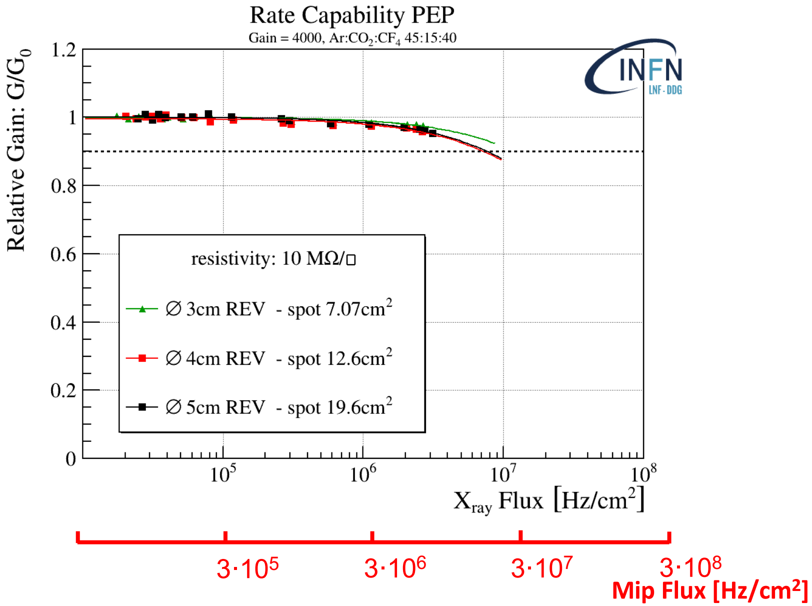
High-rate layouts: PEP - groove

2022 – PEP

The PEP (Patterning – Etching – Plating)

- Single DLC layer
- Grounding from top by kapton etching and plating
- No alignment problems
- **Scalable to large size**
- **Dead zone of 0.8 mm (by design), >1 mm (achieved)**





PEP-groove μ-RWELL

DLC grounding by conductive GROOVE

groove pitch = 9mm – groove width = 1.5mm

PRE-PREG thickness= 50 um

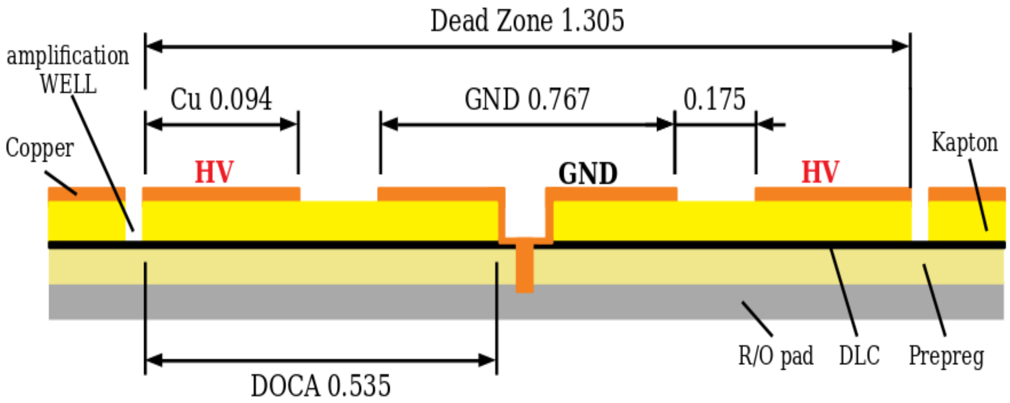
Geometrical dead zone = 11%

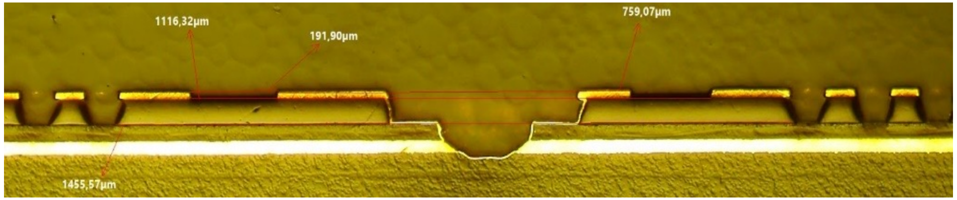
Pad R/O 9x9mm^2

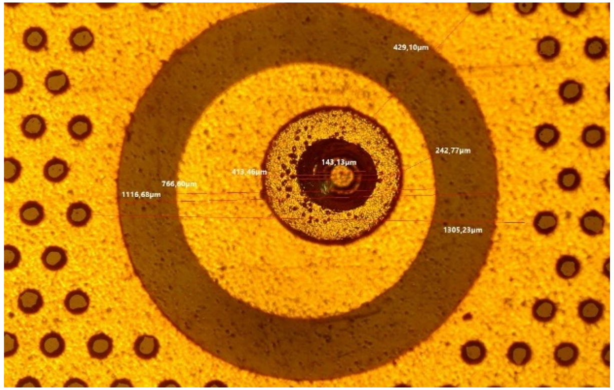
High-rate: PEP-DOT layout

The PEP-DOT

- Single DLC layer
- Grounding from top by kapton etching and plating
- No alignment problems
- **Scalable to large size**
- **Optimized dead zone**







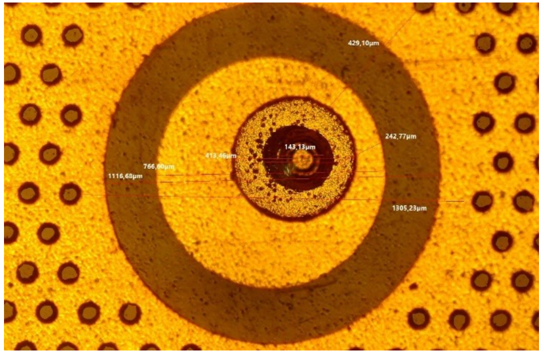
DLC grounding by**conductive DOT**
Pad R/O = 9×9cm^2
Grounding: - pitch = 9mm
- rim = 1.3mm

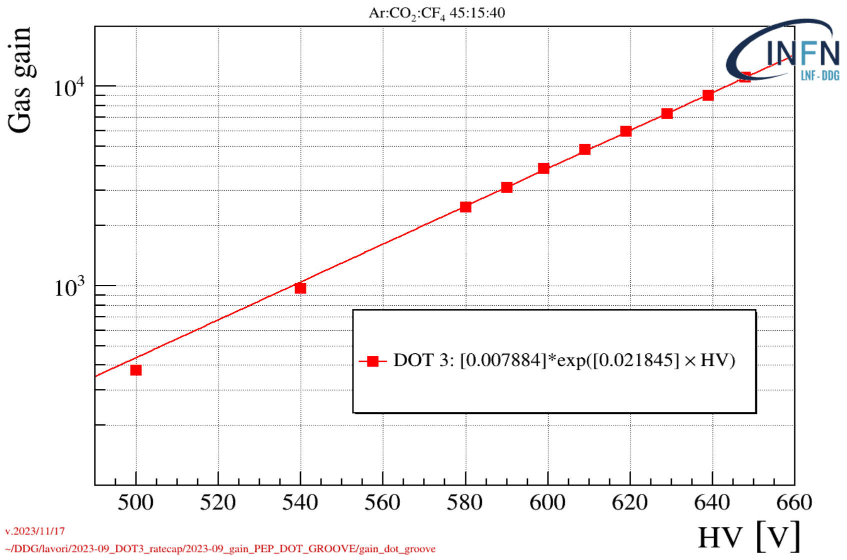
→ **97% geometric** acceptance

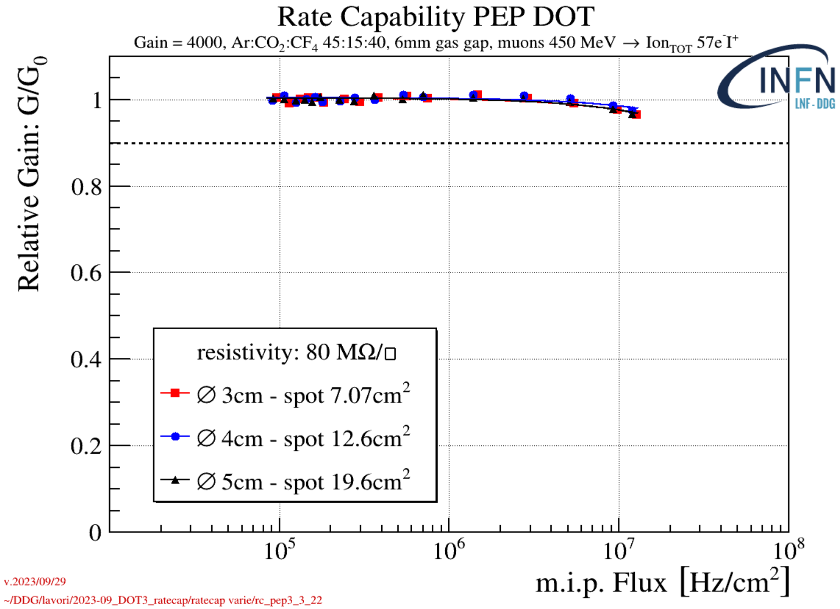
High-rate: PEP-DOT layout

DOT layouts exhibit
satisfactory performance:

- **gas gain** of up to **10^4**
- **rate capability** (@ 90% drop) > **10 MHz/cm²**

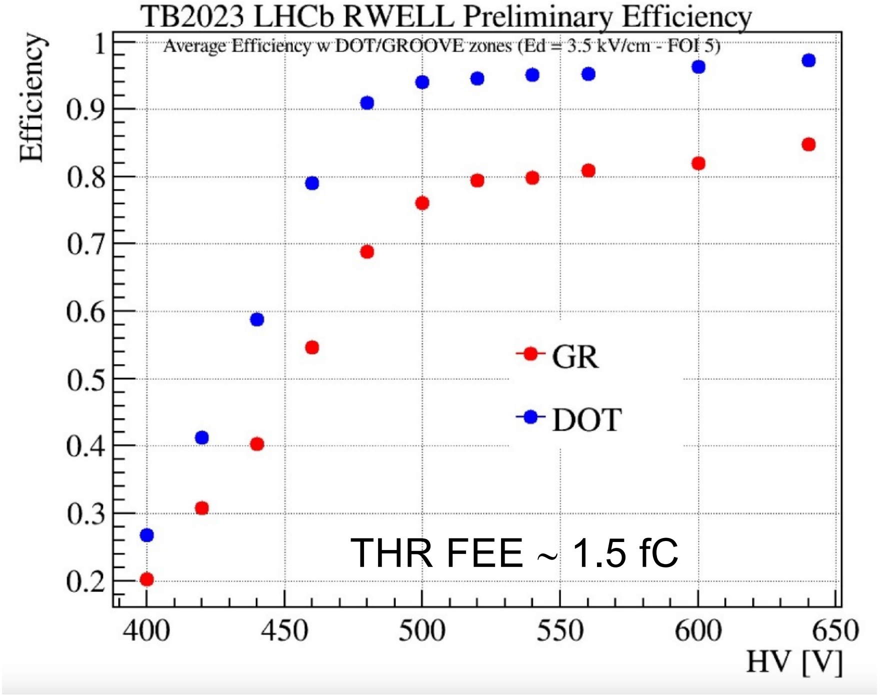




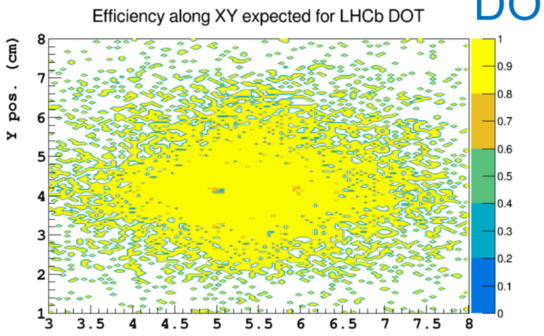


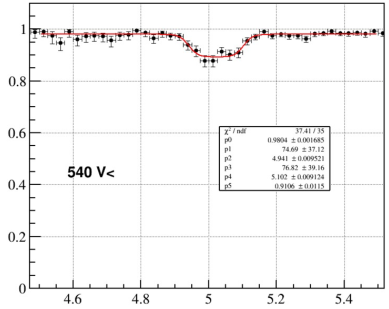
TB2023 (APV25) : comparison PEP – DOT layouts

Results from RD-FCC setup (APV)

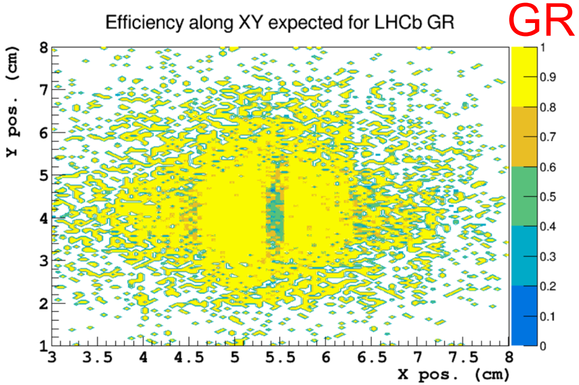


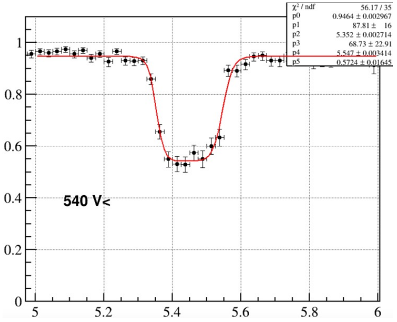
DOT





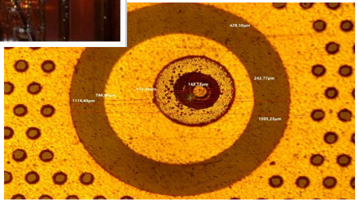
GR





uRWELL for Muon triggering (LHCb)

Inner regions of the Muon system for the LHCb Upgrade II are designed to be instrumented with μ-RWELL technology.



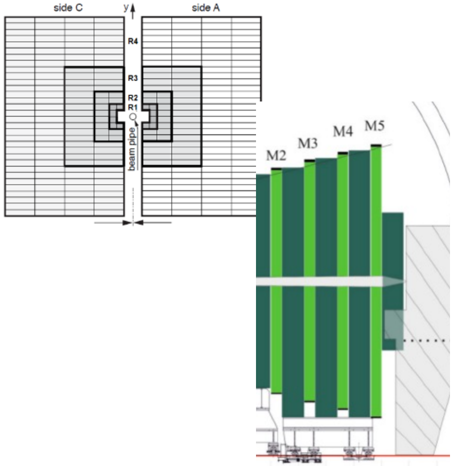
Requirements for Run 5-6 (2035-2042) (*):

- Rate up to 1 MHz/cm^2 per single detector gap
- Efficiency (4-gaps)>95% within a BX (25 ns)
- Stability for 10 y of operation (up to 1 C/cm2)

Maximum expected rate

Rates (kHz/cm^2)	M2	M3	M4	M5
R1	749	431	158	134
R2	74	54	23	15
R3	10	6	4	3
R4	8	2	2	2

Area (m^2)	M2	M3	M4	M5
R1	0.9	1.0	1.2	1.4
R2	3.6	4.2	4.9	5.5
R3	14.4	16.8	19.3	22.2
R4	57.6	67.4	77.4	88.7



Each MWPC will be replaced with a **stack of 4 gaps** in the region **R1 and R2**

- **R1÷R2: 576 gaps, size 30x25 to 74x31 cm^2, 90 m^2 det., 130 m^2 DLC**

For R3 and R4 region this technology is not a suitable solution due only to the large input capacitance of the detector.

(*) CERN-LHCC-2021-012 ; LHCB-TDR-023
http://cds.cern.ch/record/2776420?ln=it

Summary

The μ-RWELL layout for the high rate with pad readout is a mature device, also thanks to the technology spread that is giving an important boost to its development.

The advances in the last two years lead to large improvements in terms of stability and production yield.

Fine tuning oof the amplification stage → reduction of the well pitch from 140 μm to 90 μm allows a possible increase of the gas gain of about a factor 2

Tuning of the PEP-DOT layout and standardization of the manufacturing has been finalizzed for pad readout detector.

The high rate DOT layout for strip readout detector has not yet been designed and realized.

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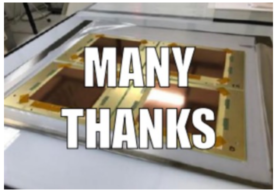
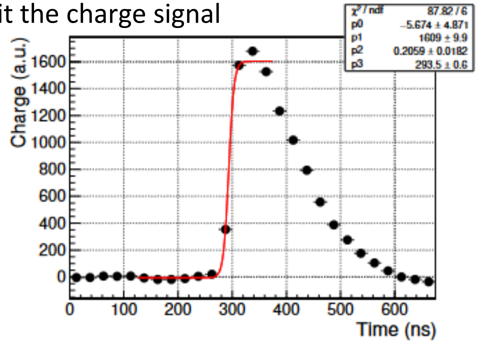


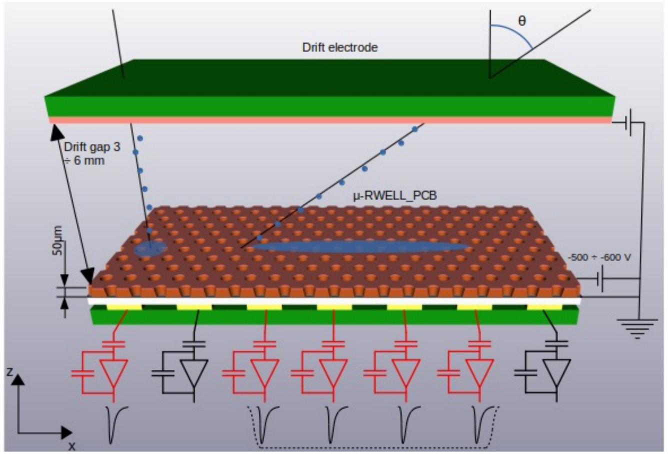
Spare Slide

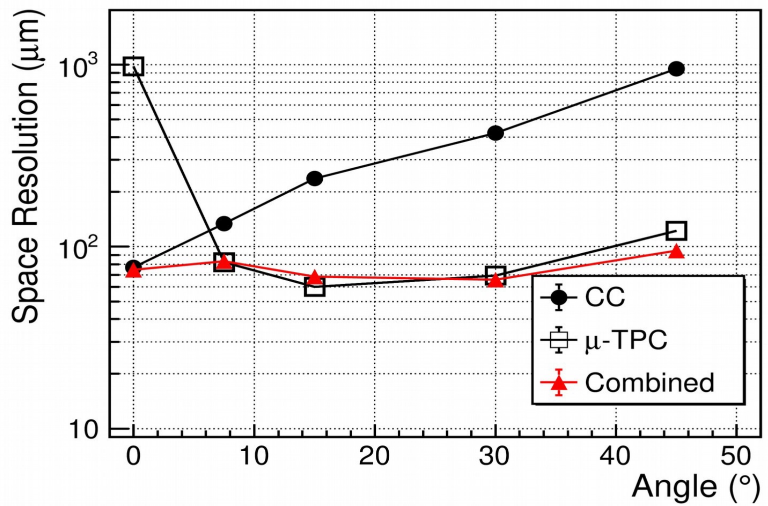
uRWELL as tracking device (I)

For inclined tracks and/or in presence of high B field, **the charge centroid method gives a very broad spatial distribution** on the anode-strip plane.
An improvement of the position reconstruction is given by the µTPC algorithm(*): the three-dimensional reconstruction of the particle track inside the detector drift gap is performed using the arrival time of the induced signals on the readout

µTPC example: Fermi-Dirac is used to fit the charge signal





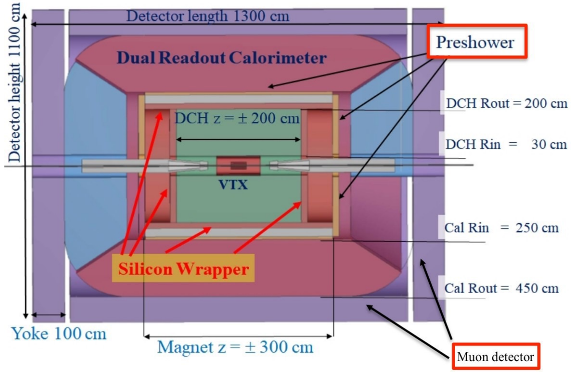


(*) *T. Alexopoulos et al., NIM A 617 (2010) 161*

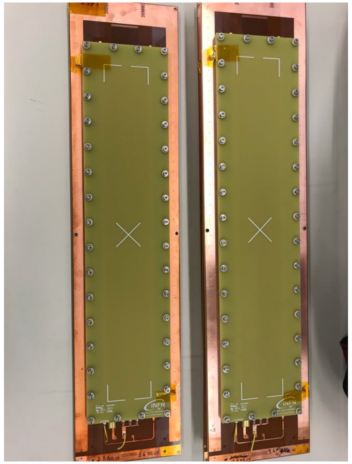
In collaboration with G. Cibinetto, R. Farinelli, L. Lavezzi

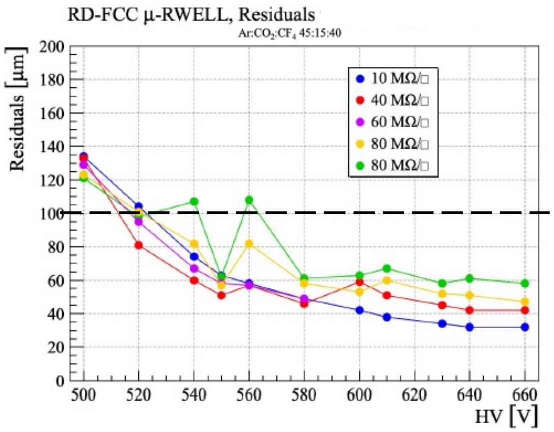
uRWELL as tracking device (II)

The IDEA detector is a general purpose detector designed for experiments at future e+e- colliders (FCCee and CepC). Pre-shower detector and the Muon system are designed to be instrumented with μ-RWELL technology.

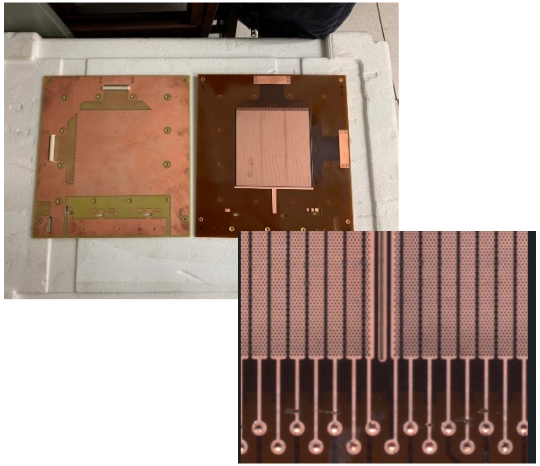


TB 2021 campaign
u-RWELL prototypes with resistivity varing between 10 and 80 Mohm/sq. (strip pitch=0.4 mm)

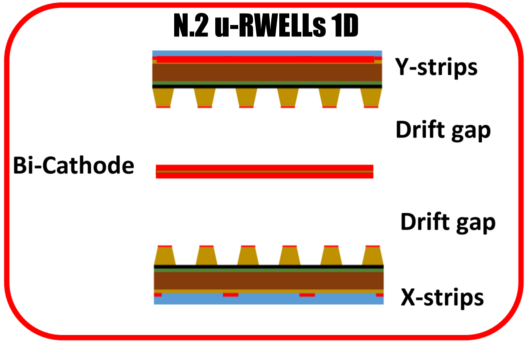


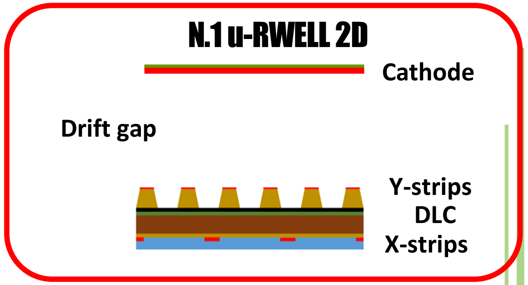


TB 2022 campaign
u-RWELL prototypes with strip pitch varing between 0.4 to 1.6 mm
u-RWELL with 2D readout



Y coordinate on the TOP of the ampl. stage

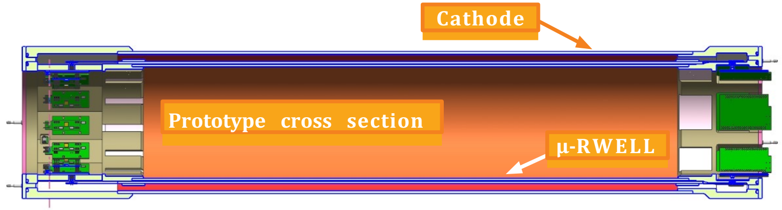


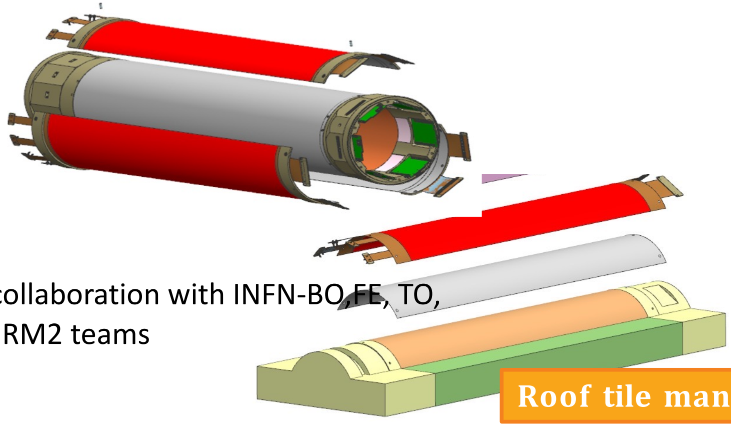


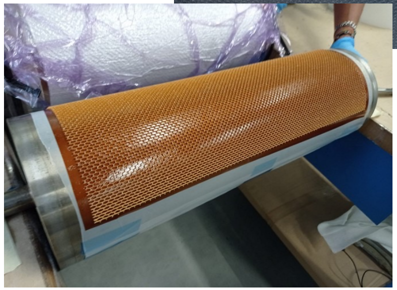
In collaboration with INFN-BO,FE, TO, CT, RM2 teams

uRWELL as tracking device (III)

Development of an ultra-light modular **cylindrical μ-RWELL** as **inner tracker** for the Super Charm Tau factory (EURIZON project).
The B2B layout (a double radial TPC) is designed to have a **very low material budget** (0.86÷0.96% X_0) and **modular roof-tile shaped components**: in case of failure/damage of the part, the structure should be opened and the damaged module replaced.

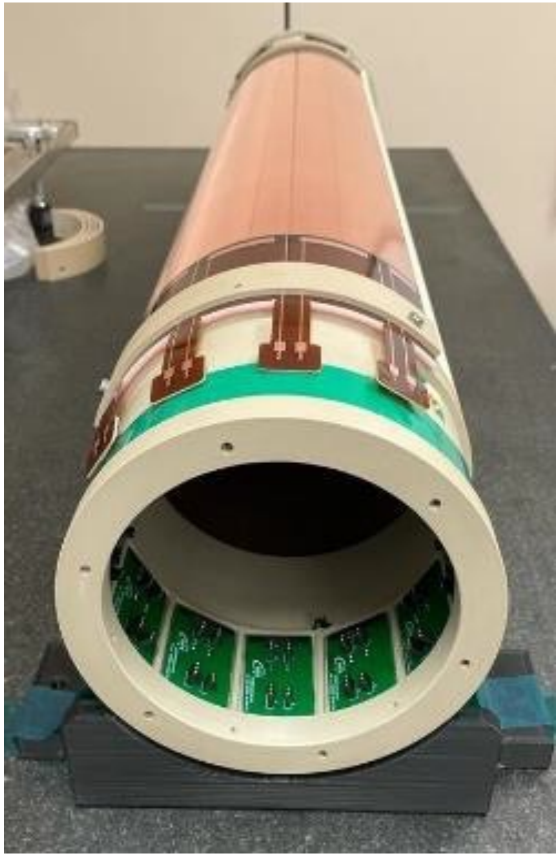






Roof tile manufacturing

In collaboration with INFN-BO, FE, TO, CT, RM2 teams

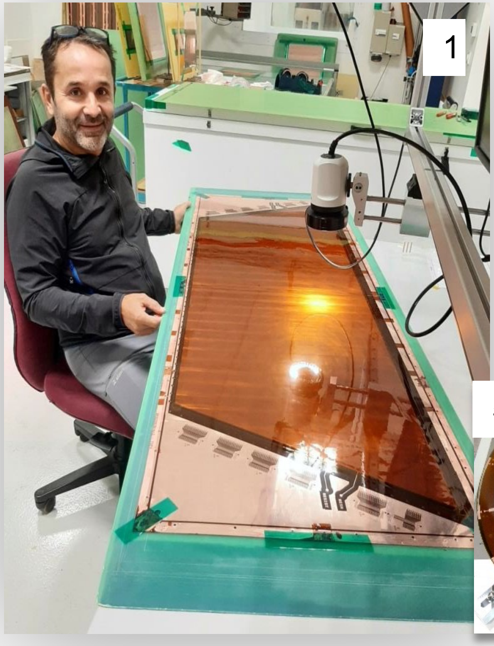


The first cylindrical low mass uRWELL

uRWELL technology spread

The micro-Resistive WELL is involved in

1. **CLASS12 @ JLAB:** the upgrade of the muon spectrometer
2. **X17 @ n_TOF EAR2**: for the amplification stage of a TPC dedicated to the detection of the X17 boson
3. **TACTIC @ YORK Univ.:** radial TPC for detection of nuclear reactions with astrophysical significnace
4. **Muon collider:** hadron calorimeter
5. **CMD3:** uRWELL Disk for the upgrade of the tracking system
6. **URANIA-V**: a project funded by CSN5 for neutron detection, an ideal spin-off of the EU-founded ATTRACT-URANIA
7. **UKRI:** neutron detection with pressurized ^{3}He-based gas mixtures

1


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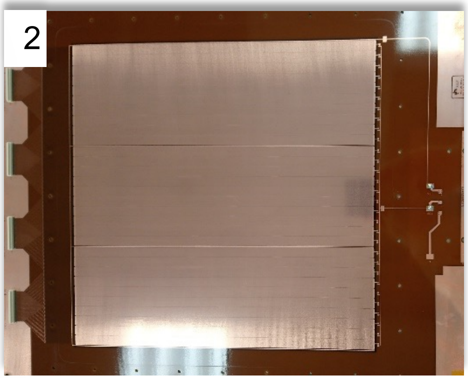

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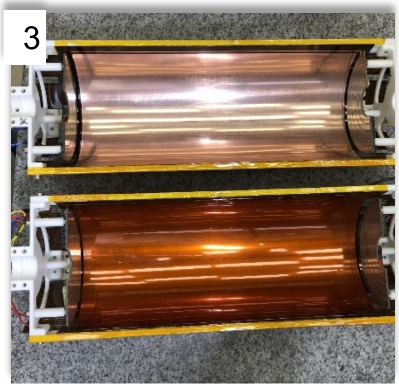

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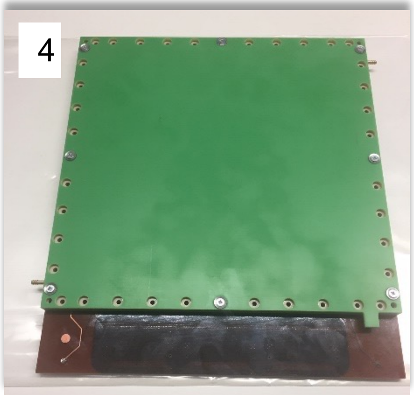

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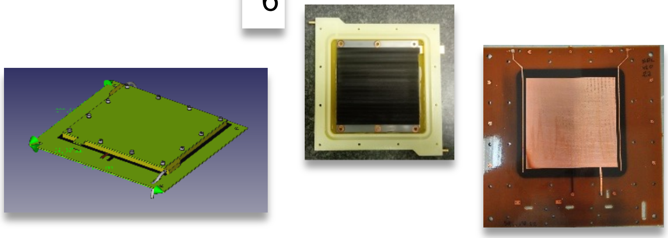

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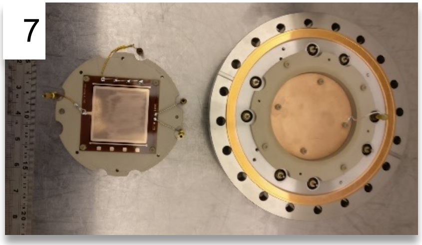
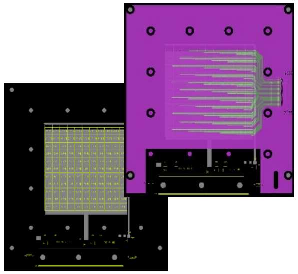


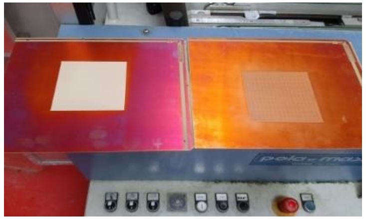
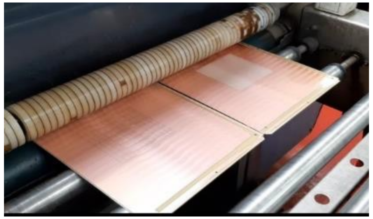
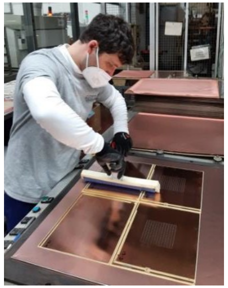
μ-RWELL Technology Transfer [flow chart]

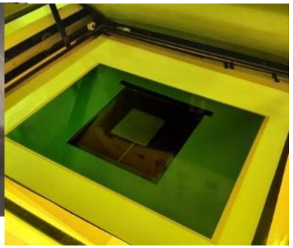
Feedback from tests

LAYOUT design

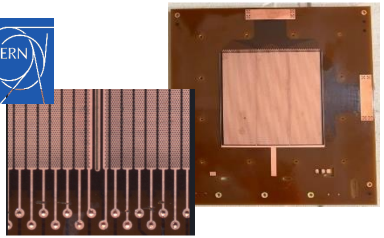
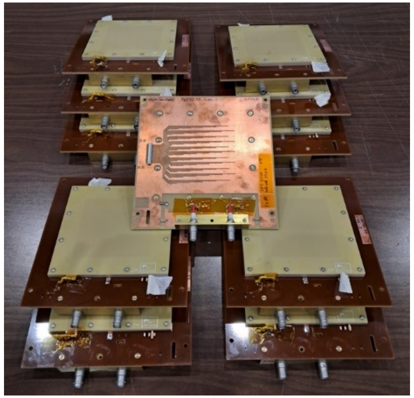


PCB production



Final detector manufacturing

DLC foil production[2]

The **TT is fundamental** in order to deliver the **~600 detectors** required for U2.

[2] DLC Magnetron Sputtering machine co-funded by INFN- CSN1

The CERN-INFN DLC machine

31st Oct. 2022 – Delivered
31st Oct. - 4th Nov. 2022 – Commissioning & test training
21st - 23rd Nov. 2022 – 1st DLC sputtering test

- Ar + N_2 doping

19th - 28th Jun. 2023 – 2nd DLC sputtering test

- Ar + N_2 doping (% and P scan)

25th - 29th Sep. 2023 – 3rd DLC sputtering test

- Ar + C_2H_2 doping

6th - 10th Nov. 2023 – 4th DLC sputtering test

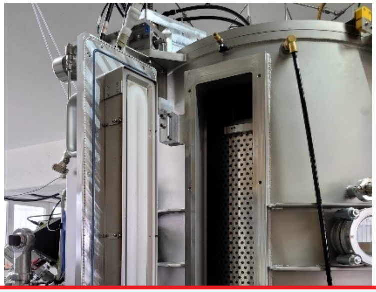
- Ar + C_2H_2 doping (uniformity test)

Technical features:

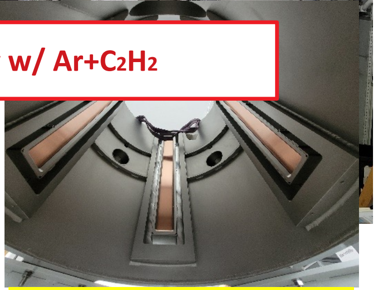
- **Flexible** substrates up to 1.7m×0.6m
- **Rigid** substrates up to 0.2m×0.6m

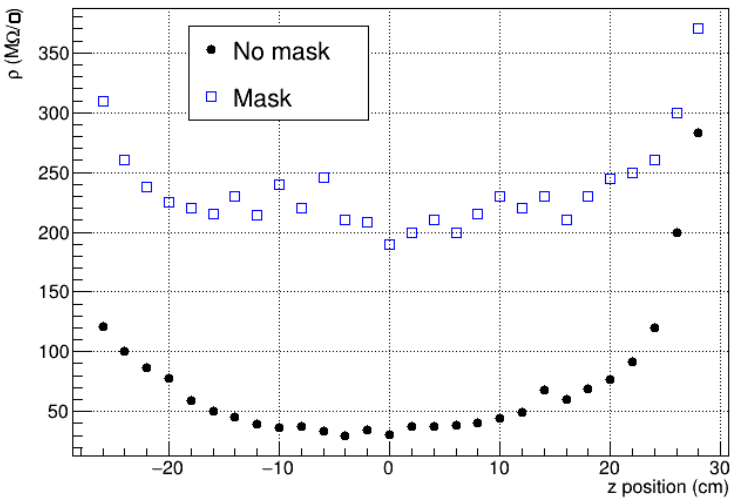
Five cooled target holders, arranged as two pairs face to face and one on the front, equipped with five shutters.

CID allows to **sputter** or **co-sputter different materials**, to create a coating layer by layer or an adjustable **gradient** in the coating.



2023 → Stable and uniform DLC resistivity w/ Ar+C_2H_2





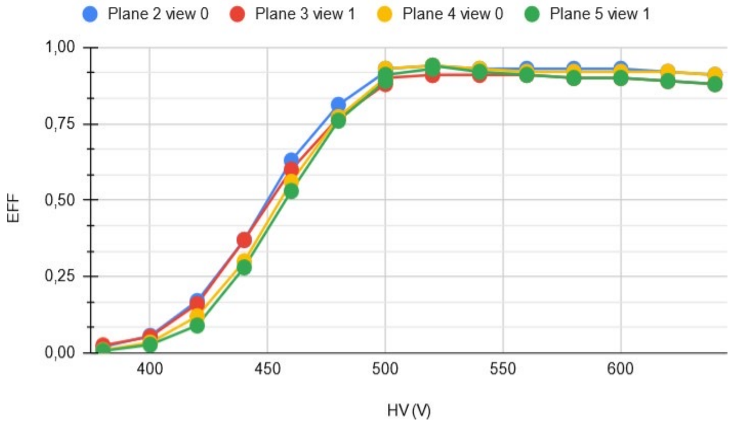
2024 → Sputtering large foils!!

QA & QC

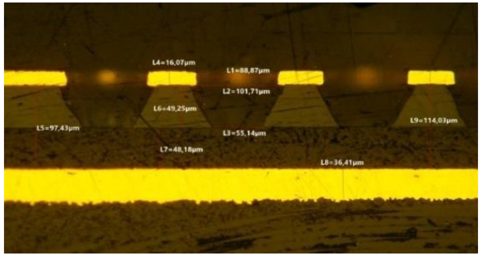
The technology (based on **SBU** layout) has been **largely improved** in the last year, thanks to the introduction of the “**dry-electrical-cleaning”,** a sort of a hot HV conditioning leading to a soft clean of the residual imperfections of the detector manufacturing.

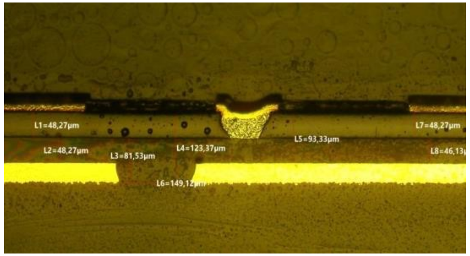
Detector stability improved → up to **200V** large plateau, **estimated gain up to 5×10^4**

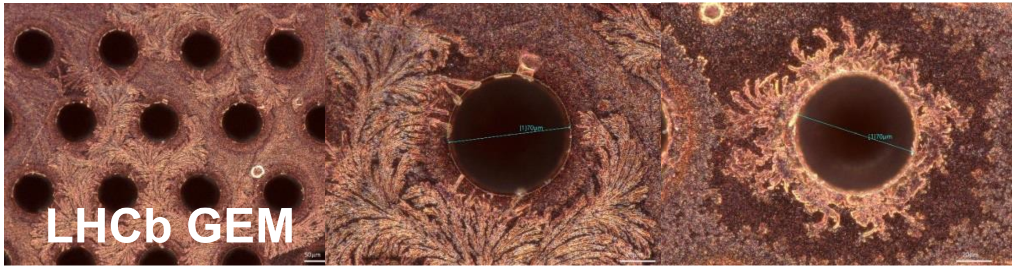
Preliminary



Optical metallographic survey (in ELTOS) as well as **SEM analysis** (at CERN) are used to take all construction steps under control as well as checking effects for possible aging/etching (by fluorine …).



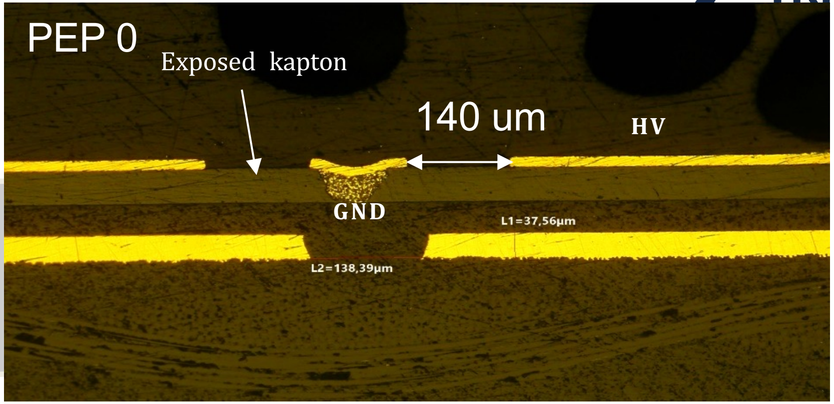


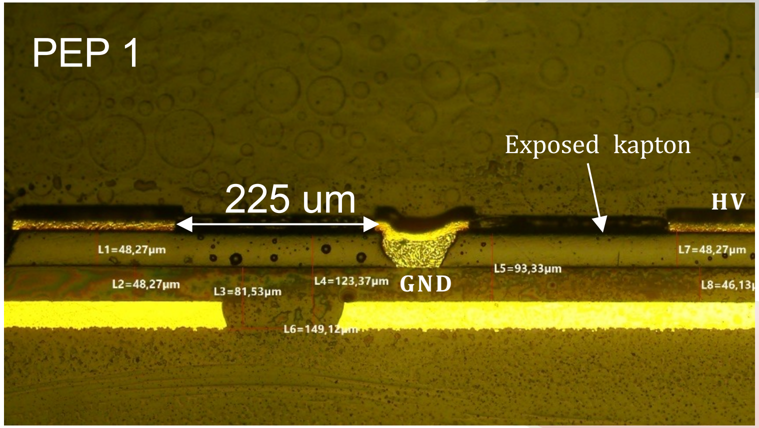


High-rate layouts: PEP evolution

PEP0 layout:

- distance between GND and HV too short
  → MSGC-like effect (current instabilities)
- good copper plating of the PEP





PEP1 layout:

- distance between GND and HV increased
  → detector stable up to gain of 8000
- good copper plating of the PEP

PEP2 layout:

- distance between GND and HV increased → detector stable up to gain of 10000
- Increased Cu area around the PEP
  → larger dead zone