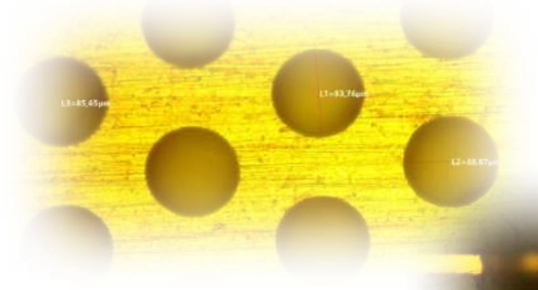
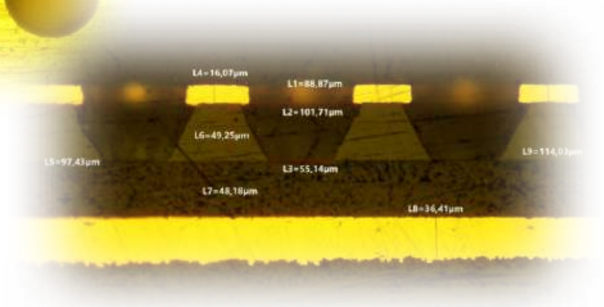
# Technology Transfer

## on high rate µ-RWELL





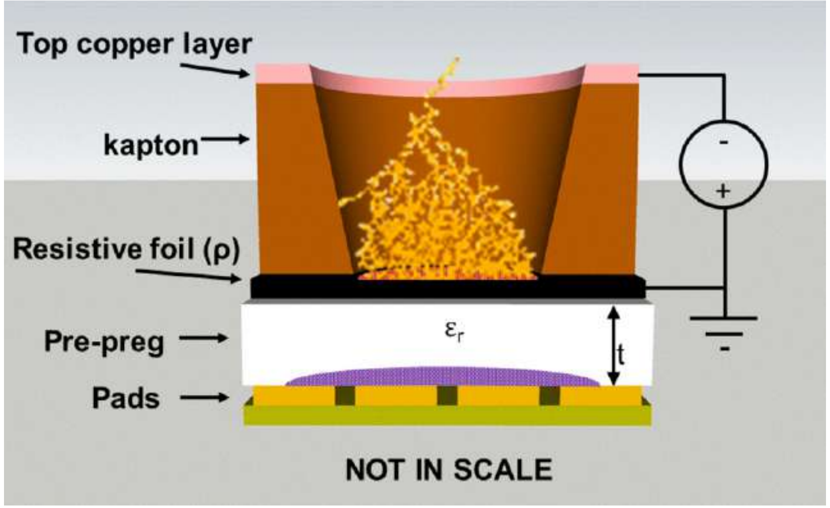

**Matteo Giovannetti [LNF-INFN]**

on behalf of
LNF-INFN (leading group)
Bologna-Ferrara INFN teams
R. De Oliveira – CERN-EP-DT-MPT Workshop
R. Pinamonti, M. Pinamonti – ELTOS S.p.A.

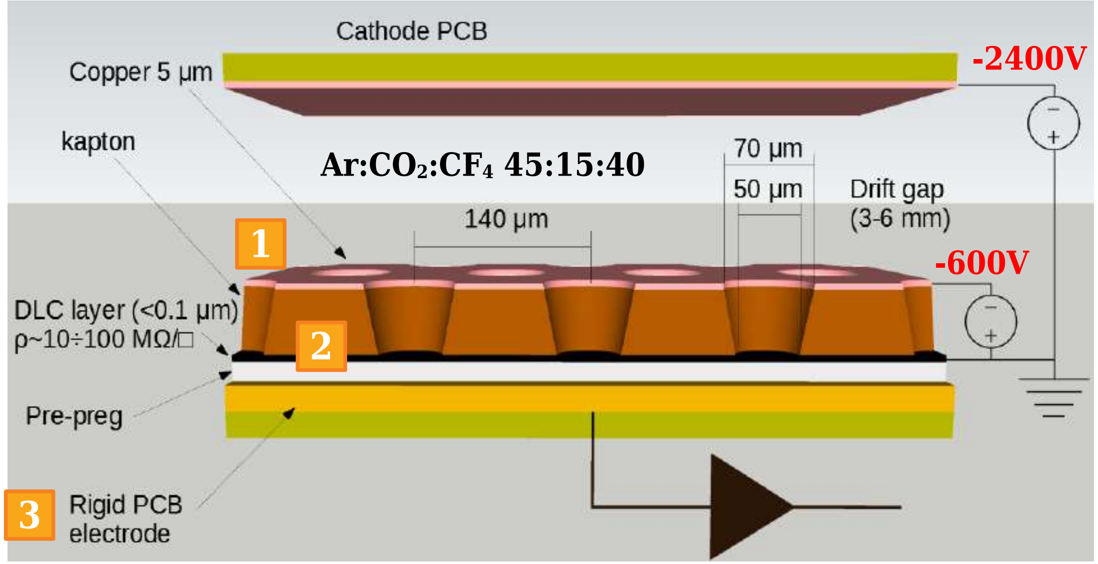

RD51 collaboration meeting, CERN, June 21th 2023

# The μ-RWELL detector (reminder)

The μ-RWELL is a Micro Pattern Gaseous Detector (MPGD) composed of only two elements: the μ-RWELL_PCB and the cathode. **The core is the μ-RWELL_PCB**, realized by coupling three different elements:




Applying a suitable voltage between the **top Cu-layer and the DLC** the WELL acts as a **multiplication channel for the ionization** produced in the conversion/drift gas gap.




1 **a WELL** patterned kapton foil acting as **amplification stage** (GEM-like)

2 a **resistive DLC layer (Diamond-Like-Carbon)** for discharge suppression with surface resistivity ~ 50÷100 MΩ/□

3 a standard readout PCB

# Task objectives

**DELIVERABLE - m30**

- **D7.3:** μ-RWELL prototypes co-produced by industry under the guidance and supervision of the research team. A complete report will be provided (Task 7.3)

**MILESTONE - m36**

- **MS27:** build a 0.3×0.3 $m^2$ prototype and the readout plane, with the new structure

# Operative Meetings

**21st Sept. 2021** - joint INFN-ELTOS-CERN meeting

- standardizing manufacturing procedures of µ-RWELL layout

**1st-3rd Dec. 2021** - CERN-INFN meeting

- status of the R&D on the High Rate layout
- 2D layout based on the readout of a segmented amplification stage

**7th–10th Dec. 2021** – 1st test batch in ELTOS

- DLC patterning
- PCB planarizing tests

**7th–8th Mar. 2022** - 2nd test batch in ELTOS

- PCB planarizing tests
- Kapton DLCed foil coupling with PCB-readout

**28th-31th Mar. 2022**
1st AIDAinnova
Annual meeting

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**28th-31th Mar. 2022**
1st AIDAinnova
Annual meeting

**31st Oct. 2022** - joint INFN-CERN meeting
- Discussion with Rui about the results obtained
- Planning 2023 production

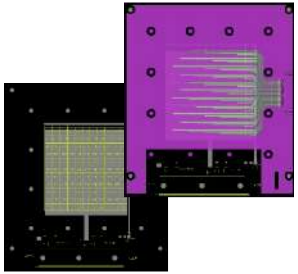
**5th Dec. 2022** - joint INFN-ELTOS meeting
- Planning 2023 production

**20th-22th Mar. 2023** - 1st production batch in ELTOS
- DLC patterning
- PCB palnarizing (prepreg thickness scan)

**24th-27th Apr. 2023**
2nd AIDAinnova
Annual meeting

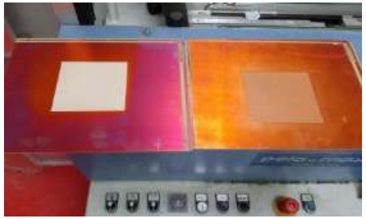
# WP7.3.2: Technology Transfer (flow chart)

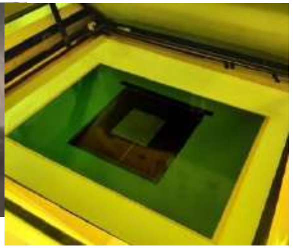
LAYOUT design



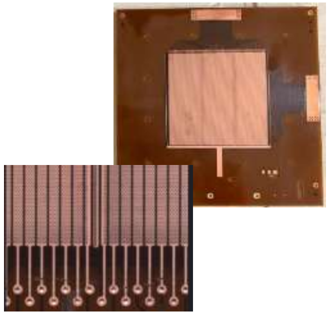
Feedback from tests

PCB production





Final detector manufacturing



DCL foil production (*)

*DLC Magnetron Sputtering machine co-funded by INFN- CSN1

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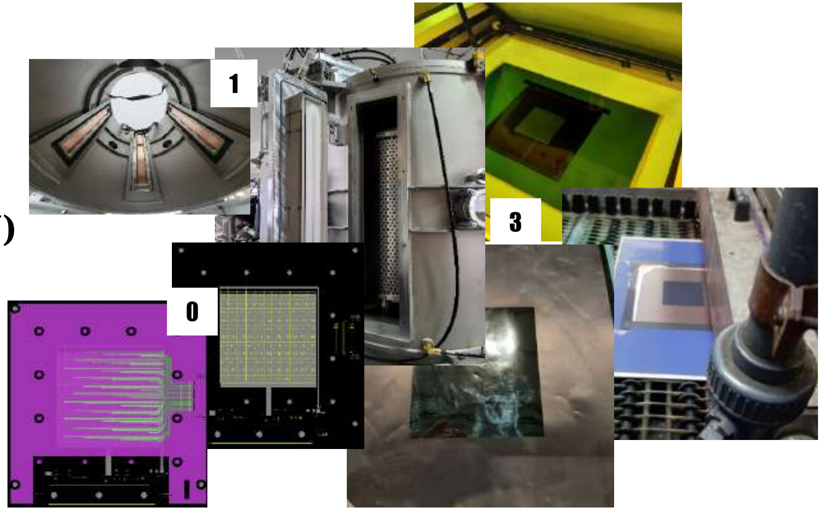
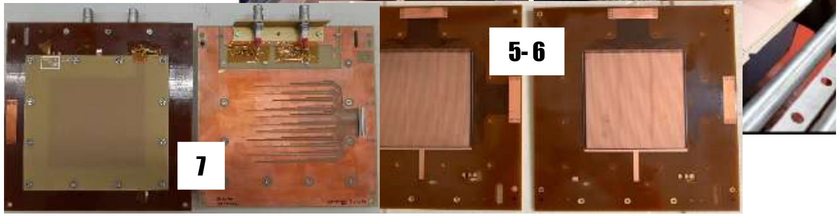


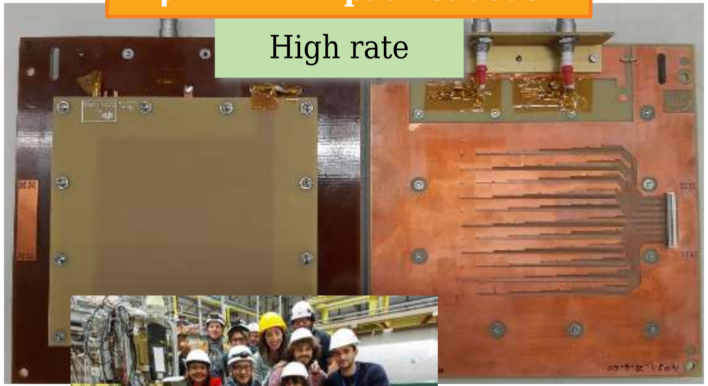


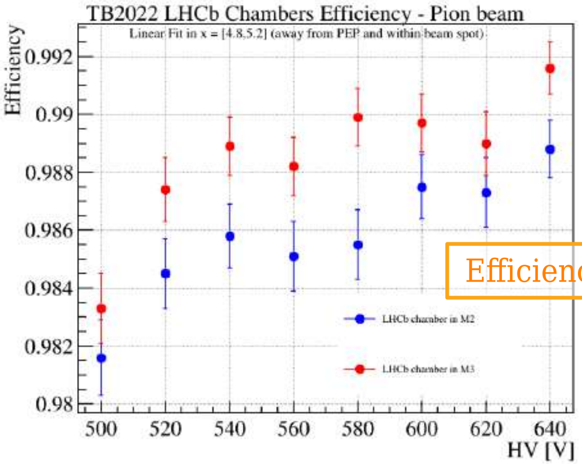


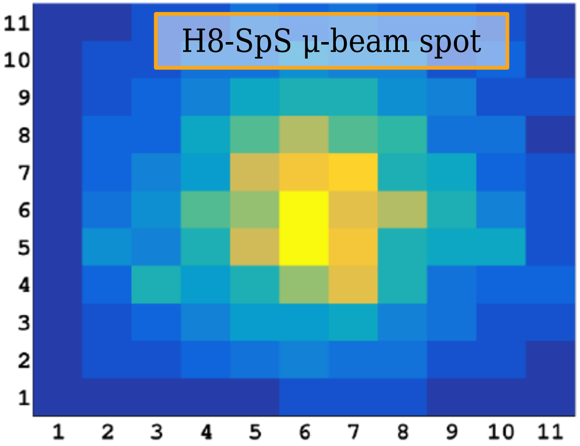
# WP7.3.2: μ-RWELL layouts co-built by ELTOS & CERN (Oct.'22)

**μ-RWELL – pad readout**

High rate

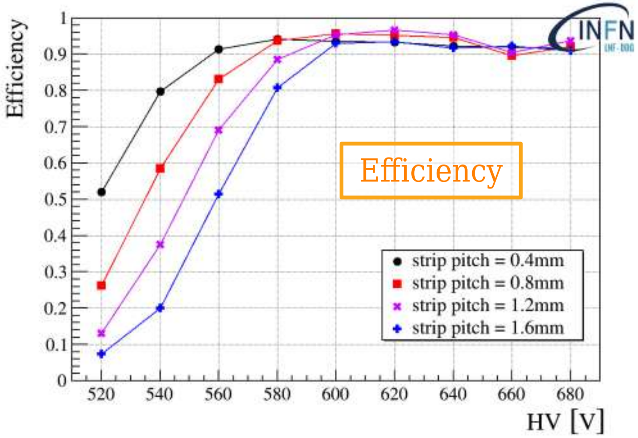


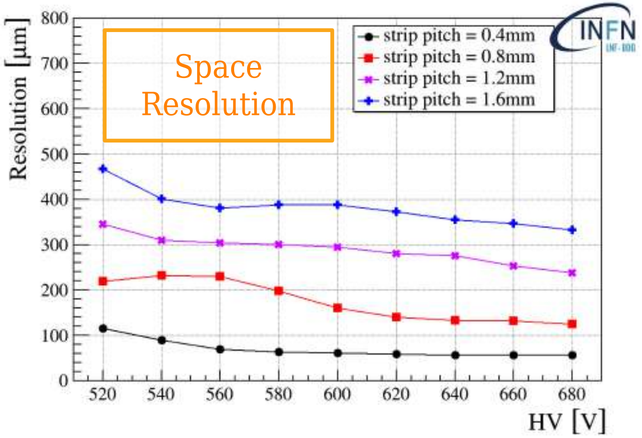



**μ-RWELL – 1D readout**

Tracking



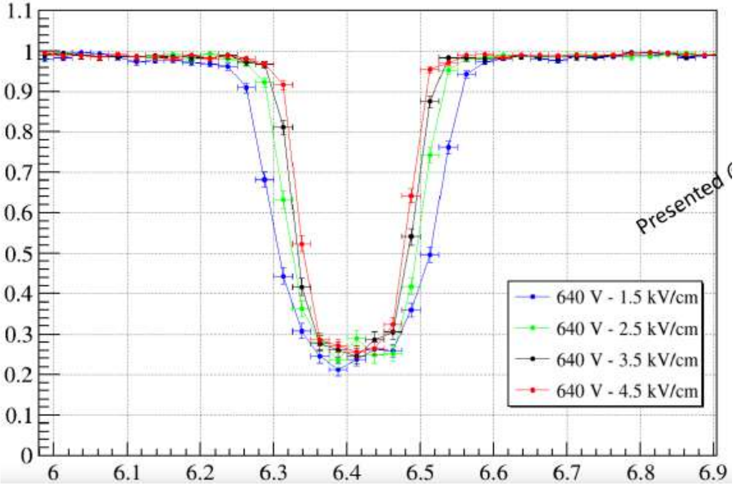
# WP7.3.2: (June ’23) PEP optimization

**2022**

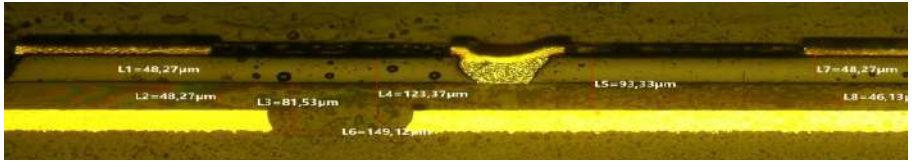
**PEP μ-RWELL:**
DLC grounding by conductive groove

Pad R/O = 9×9cm$^2$
Grounding:
- pitch = 9mm
- width = 1.5mm

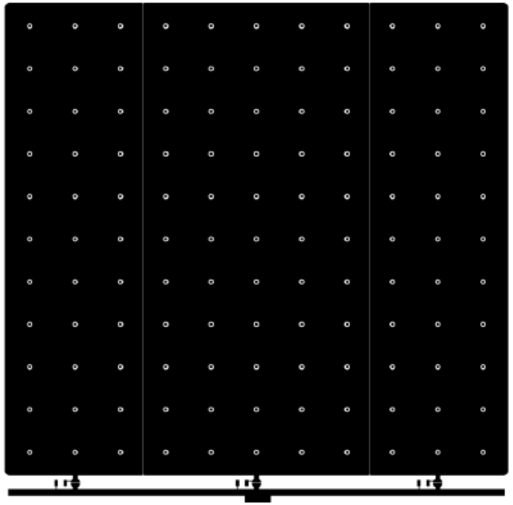
→ 84% geometric acceptance



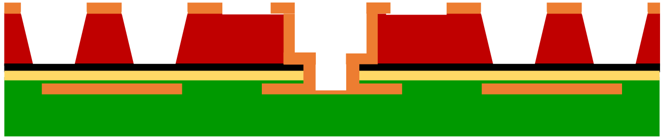





**2023**

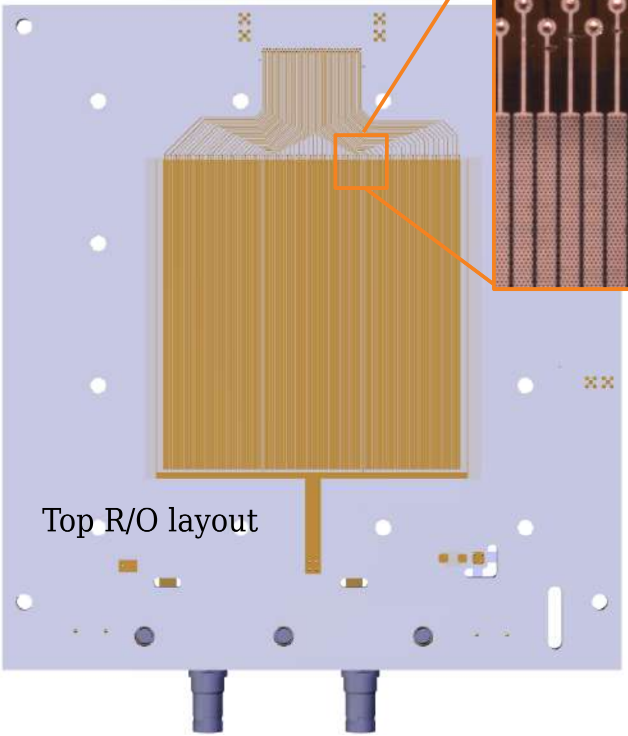


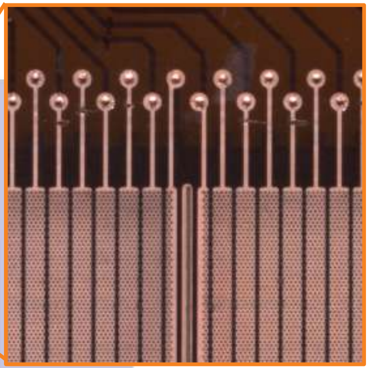
**PEP-dot μ-RWELL:**
DLC grounding by conductive dot connected to the readout
Dot rim = 1.6mm | Pad R/O = 9×9cm$^2$
→ 97% geometric acceptance



# WP7.3.2: (June '23) 2D Read Out

## 2D – TOP readout





Top R/O layout

**TOP R/O**
Pitch 750µm
Width 650µm

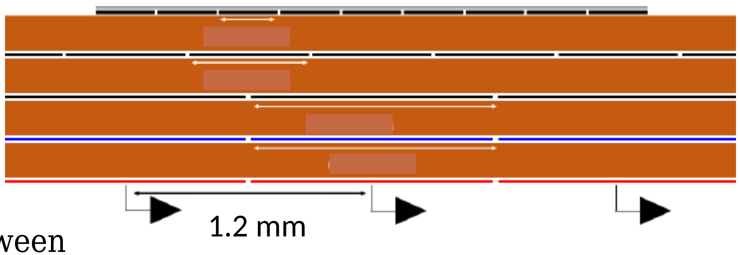
**Strip R/O**
Pitch 750µm
Width 300µm

No PEP in the active area
Kapton foil between DLC and strip R/O:
stacking 25+12+25µm (pre-preg/kapton/pre-preg)
$\rho_S$= 20 MΩ/□

## 2D – capacitive sharing

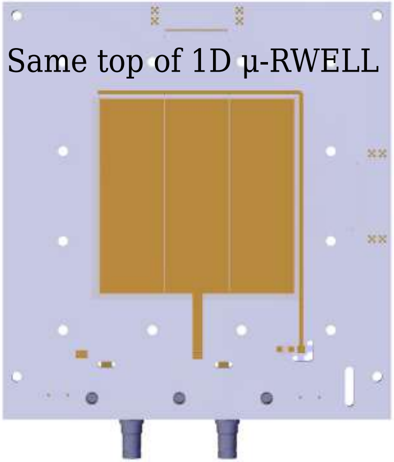
Inspired by another
µ-RWELL R&D:
K. Gnanvo et al., NIM A
1047 (2023) 167782

Trasversal view



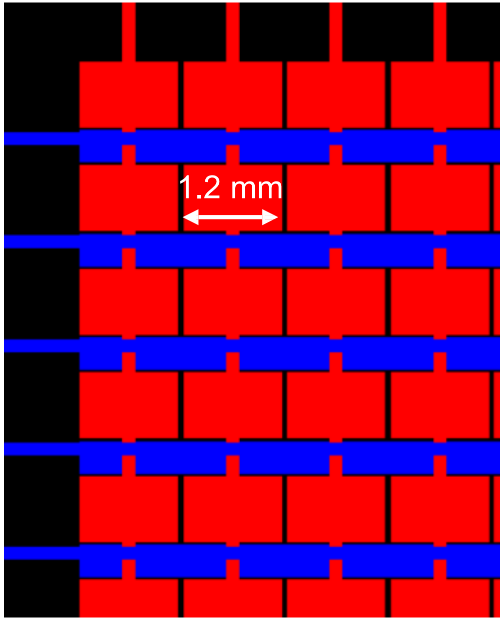

**Capacitive coupling** between
TOP and R/O:
3 layers of pads (L=0.3/0.6/1.2mm)

No PEP in the active area
$\rho_S$= 60 MΩ/□




Y-strips - bottom layer

X-strips - top layer



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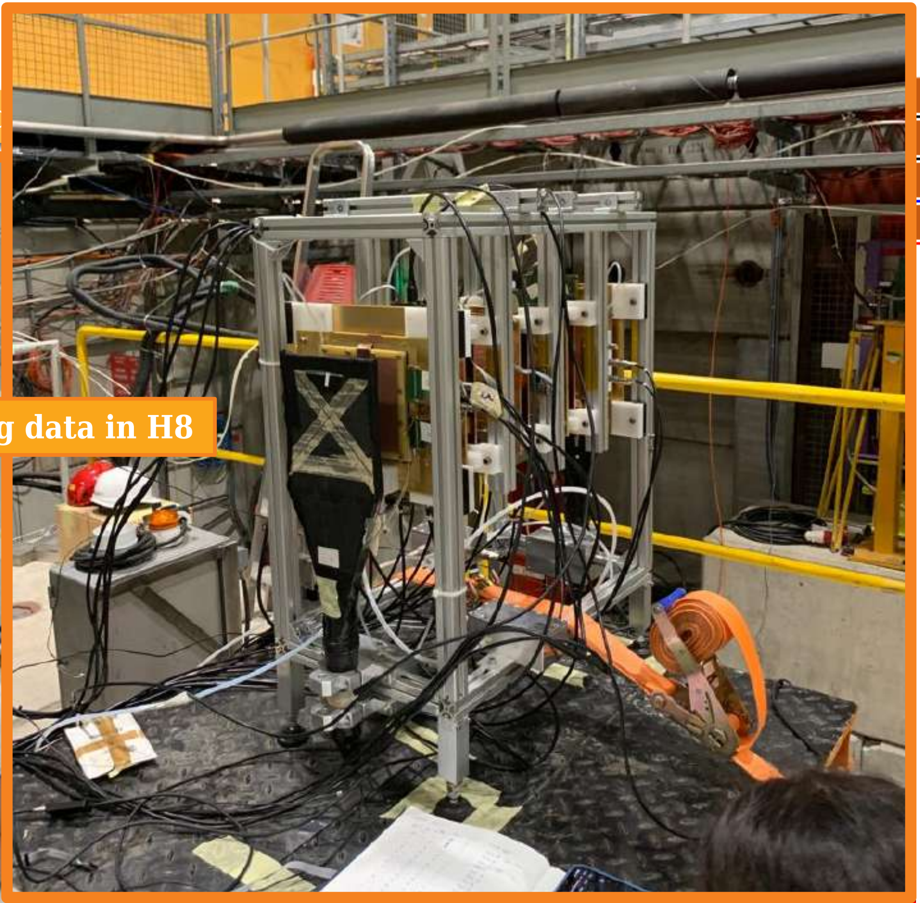
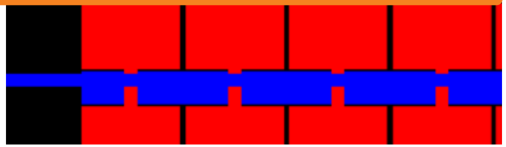
2D - TOP readout

2D - capac



Right now taking data in H8




N
Ka
st
$\rho_S$= 20 MΩ/□

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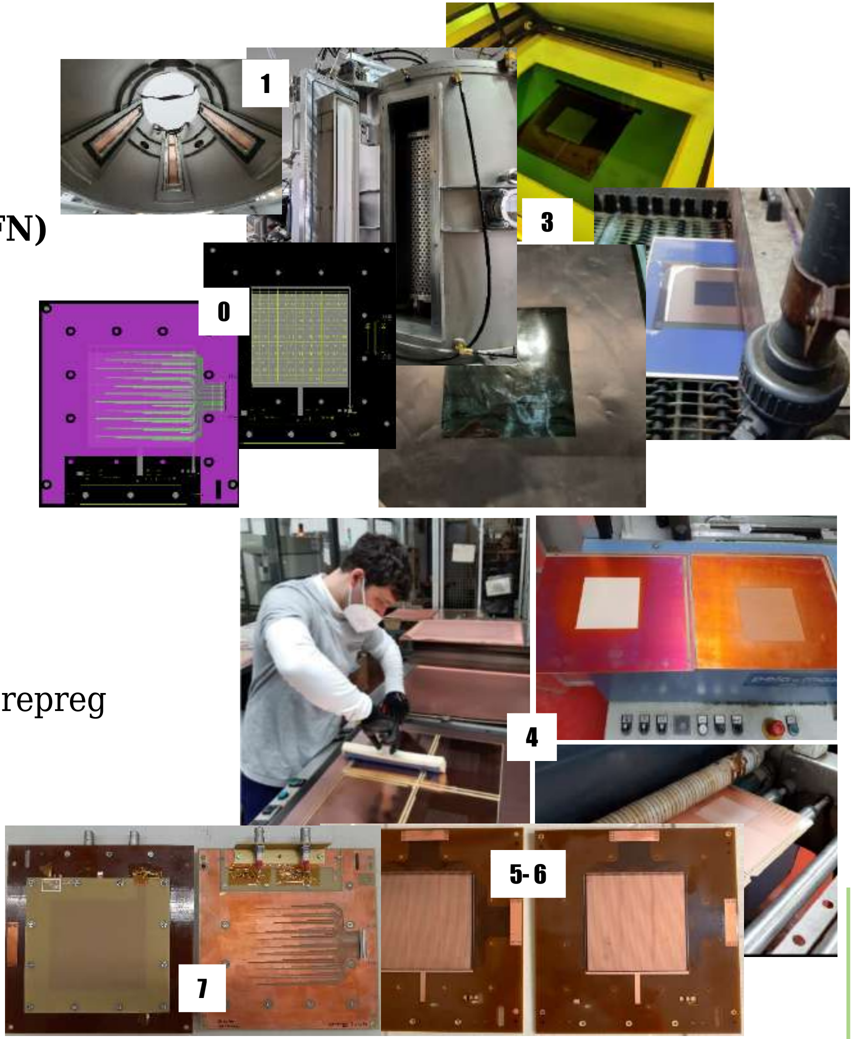

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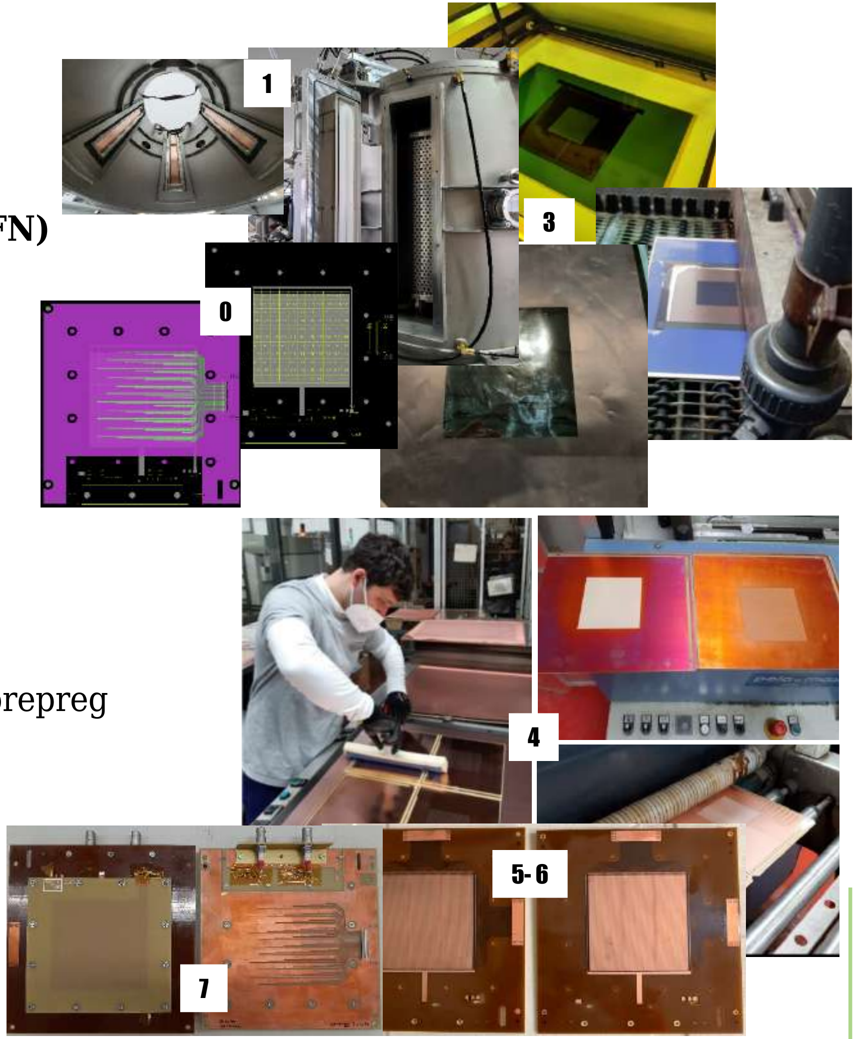


# WP7.3.2: update on the CERN-INFN DLC machine

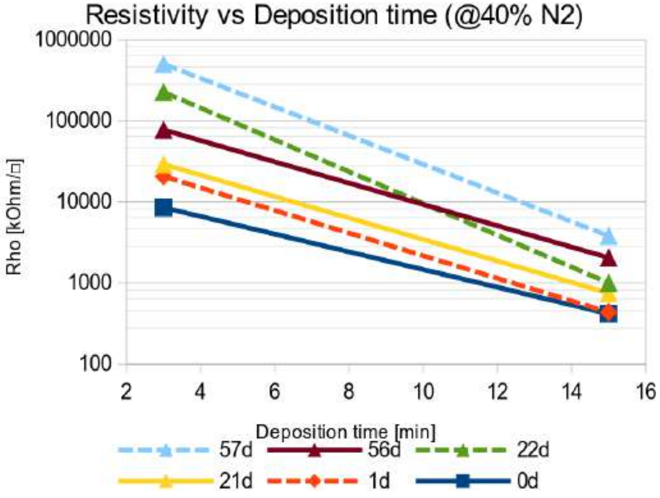
**31st Oct. 2022** – Delivered
**31st Oct. - 4th Nov. 2022** – Commissioning & test training
**21st - 23rd Nov. 2022** – First DLC sputtering test
- Ar + $N_2$ doping (increase $sp^3$ bonds → resistivity)

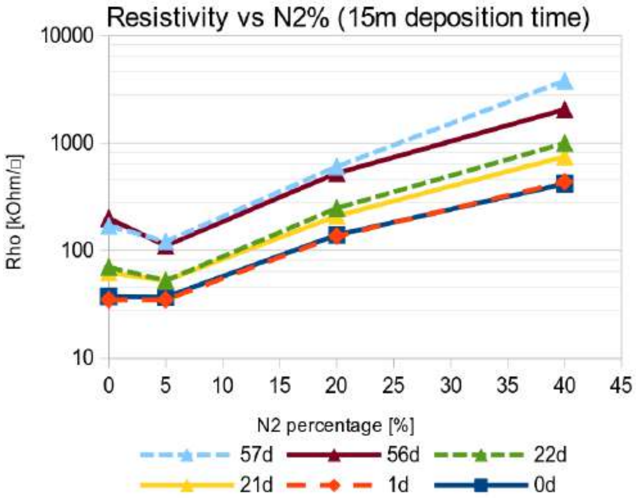
**19th - 28th Jun. 2023** – Second DLC sputtering test
- Ar + $C_2H_2$ doping (study H presence in the plasma)

Some 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.

The machine shall be able to **sputter or co-sputter different materials,** in order to create a coating layer by layer or an adjustable gradient in the coating.



# WP7.3.2: Mar.’23 ELTOS production – DLC patterning

Step 2:

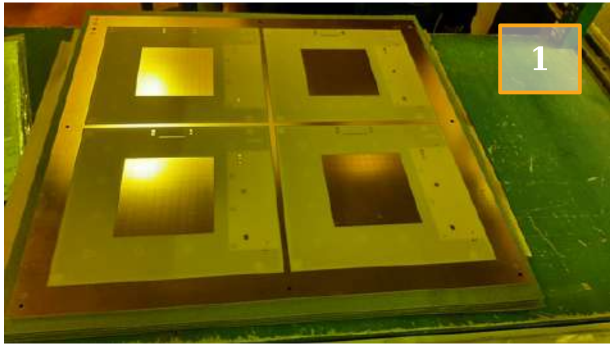
1) **PCB** production

**<u>Step 3:</u>**

2) Photoresist **lamination** for DLC protection

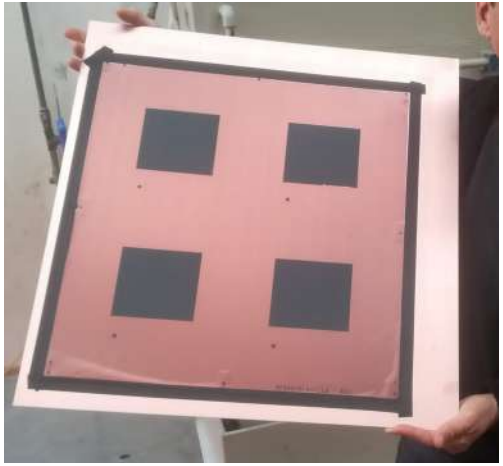
3) Photoresist **development**

4) **DLC patterning** with brushing machine
(@CERN different approach: JET-SCRUBBING)

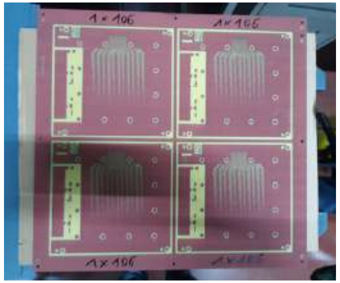






# WP7.3.2: Mar.’23 ELTOS production – DLC-foil gluing

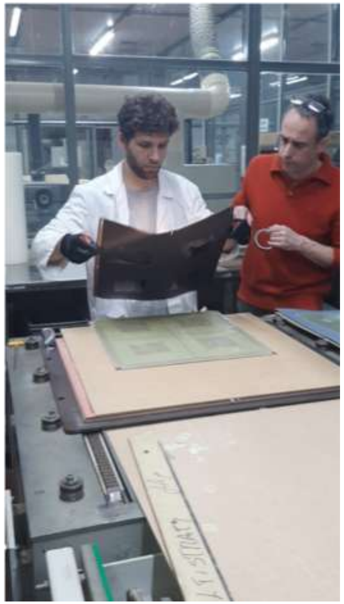


**Step 4:** Cu-Kapton-DLC gluing on PCB

**Goal:** 16 PEP-dot detectors (9×9mm$^2$ pad R/O),
with **different pre-preg thickness:**
systematic study of signal **pulse width as a function of coupling capacitance** between DLC and R/O pad.

Waiting for shipment to CERN and detector finalization (Step 5-7)

| Pre-preg | Δx [μm] |
|---|---|
| 106 | 50 |
| 1080 | 75 |
| x2 106 | 100 |
| x2 1080 | 150 |



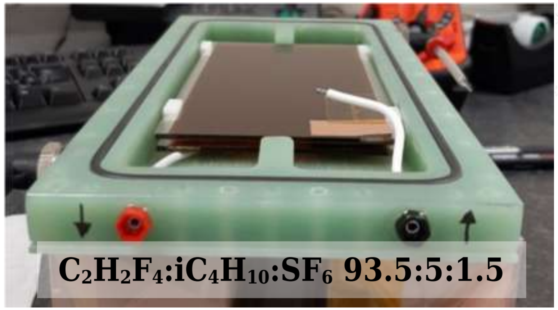
Main parameters:
Pressure 180 N/cm$^2$
Temperature 210 °C

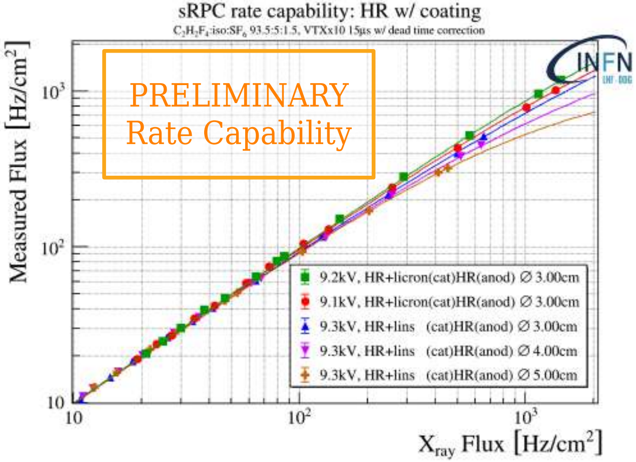
# sRPC – an MPGD-tech based RPC


Glass 140×78 mm²
DLC 120×64 mm²

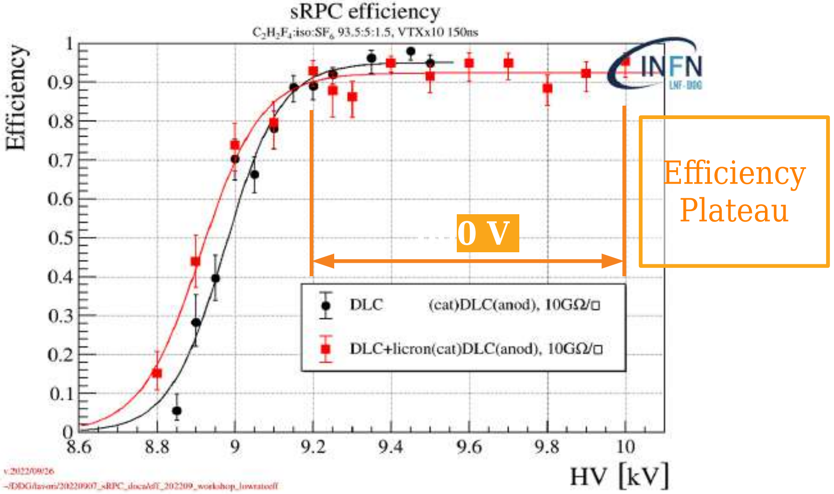
DLC-based RPC:

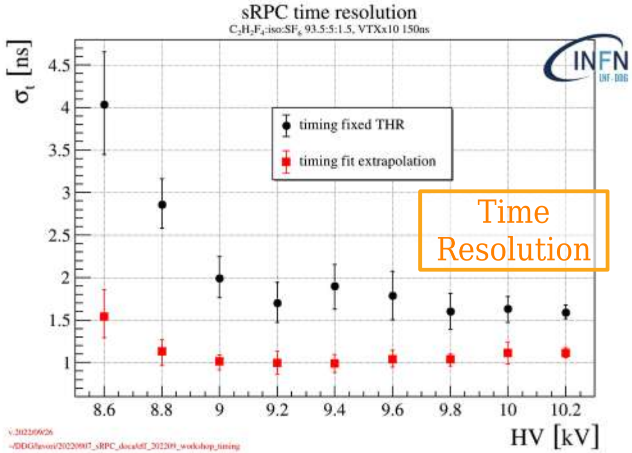
- **From bulk resistivity to surface resistivity**: easy tunable resistivity w.r.t. bakelite or glass
- µ-RWELL inspired **High Rate schemes**
- Flexible substrate




A promising novel technology, from MPGD material and technology experience.



# WP7.3.2 – Summary

The activity of WP7.3.2 task proceeds on **two parallel paths:**

1) The **industrialization** of a part of the construction steps of the µ-RWELLs at the **ELTOS** company (Arezzo – IT), in close **collaboration** with the **CERN-EP-DT-MPT** Workshop:
    - Advances in the TT; **more contruction steps** performed by ELTOS
    - Detector finalization (Kapton Etching, …) performed at CERN
2) The R&D with CERN on the various µ-RWELL layouts is focusing on different items:
    - Design/optimization of the PEP layout → **PEP-dot** (97% geom. acceptance)
    - Design of two **2D strip R/O** (capacitive sharing and top strip patterned)
    - Prototype gain characterization with X-ray @LNF-INFN
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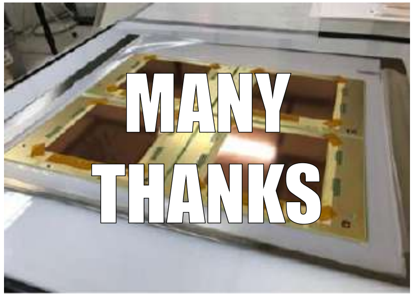


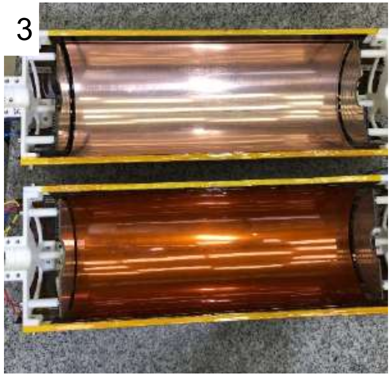
# Spare

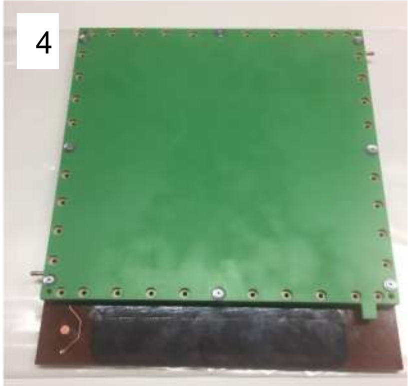
# μ-RWELL technology spread

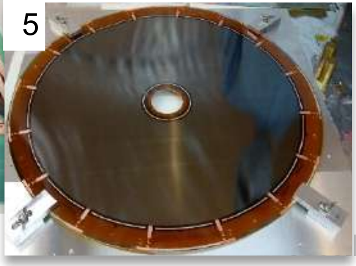
The μ-Resistive WELL is proposed in

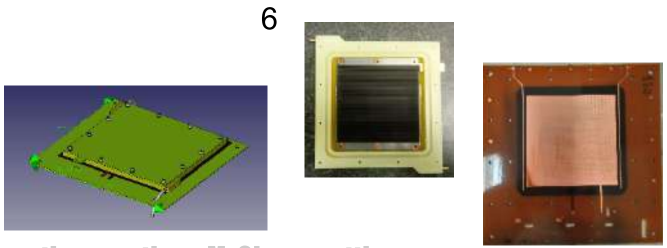
1. **CLAS12 @ JLAB:** the upgrade of the muon spectrometer
2. **X17 @ n_TOF EAR2**: for the amplification stage of a TPC dedicated to the detection of the X17 boson
3. **TACTIC @ YORK Univ.:** radial TPC for detection of nuclear reactions with astrophysical significnace
4. **Muon collider:** hadron calorimeter
5. **CMD3:** uRWELL Disk for the upgrade of the tracking system
6. **URANIA-V**: a project funded by INFN-CSN5 for neutron detection,
7. **UKRI:** neutron detection with pressurized $^{3}$He-based gas mixtures

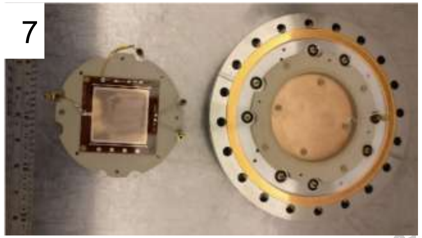




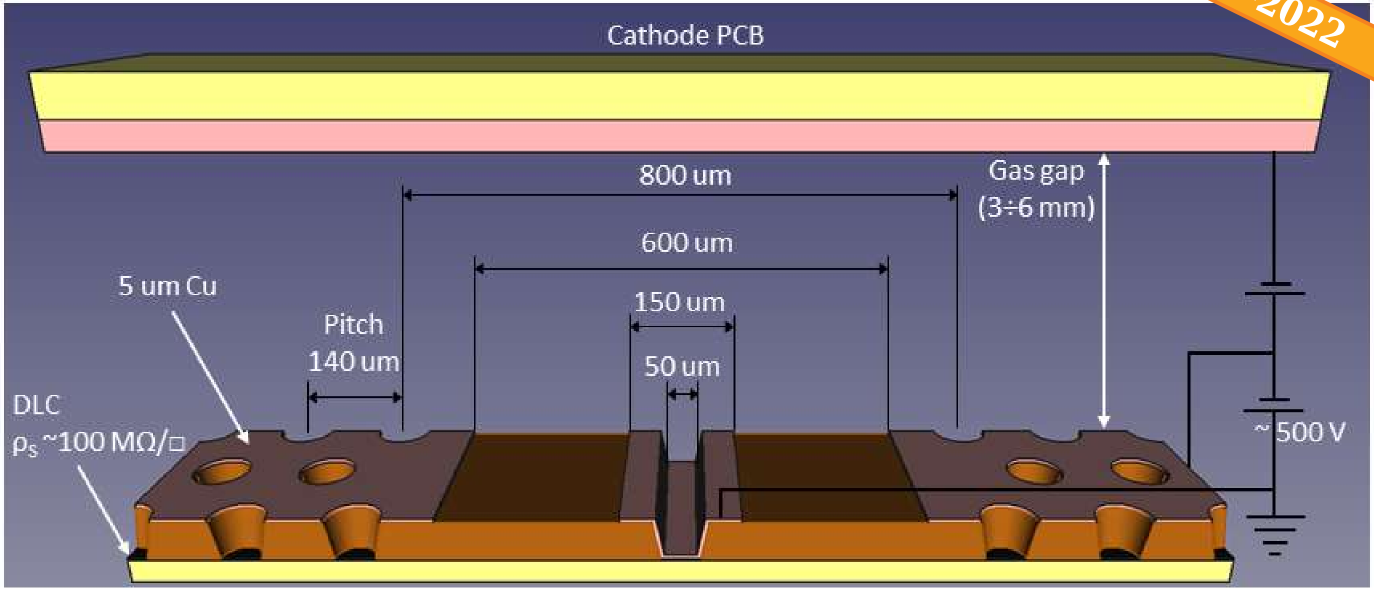



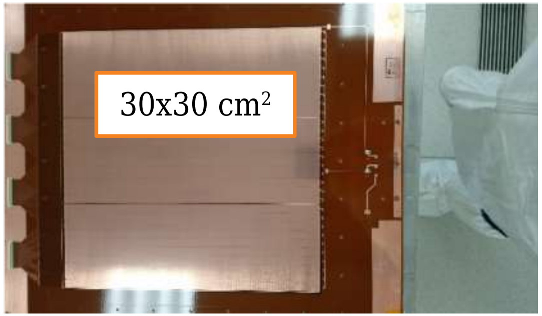
# The PEP High Rate layout

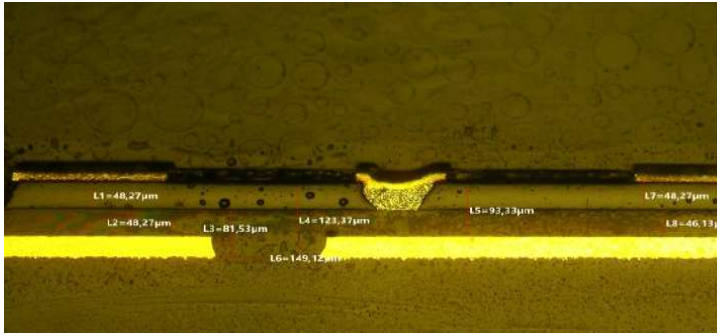
2021-2022



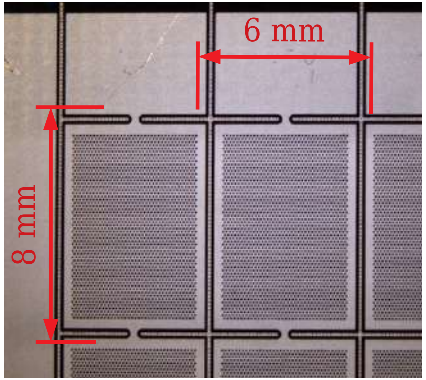

**PEP: Patterning – Etching – Plating**

- **Grounding from top**
  by kapton etching and plating
- **Scalable to large size**



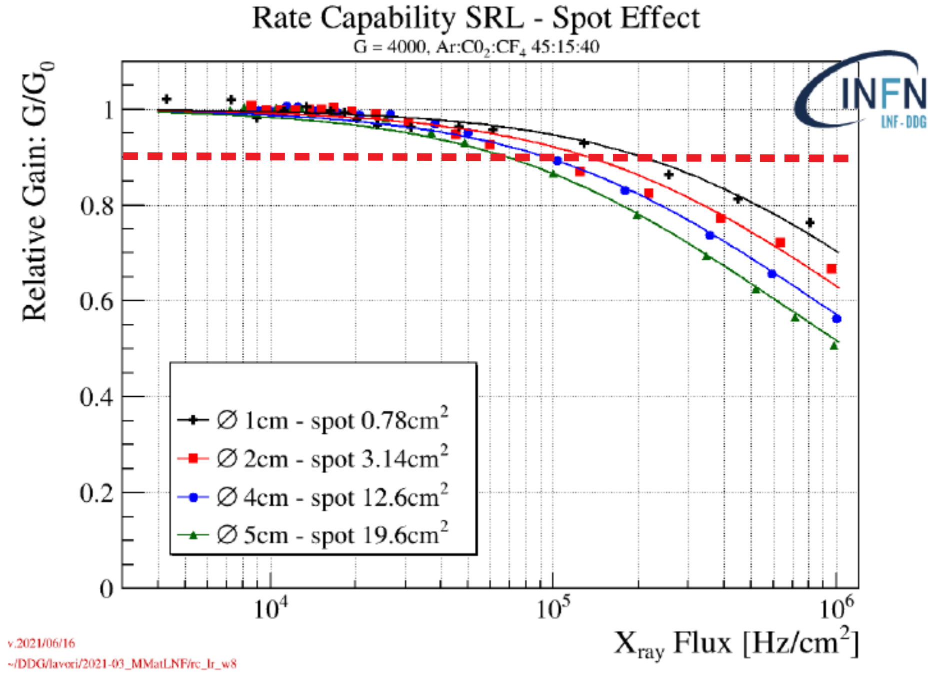




Unitary cell.
**black** - the exposed kapton is visible.

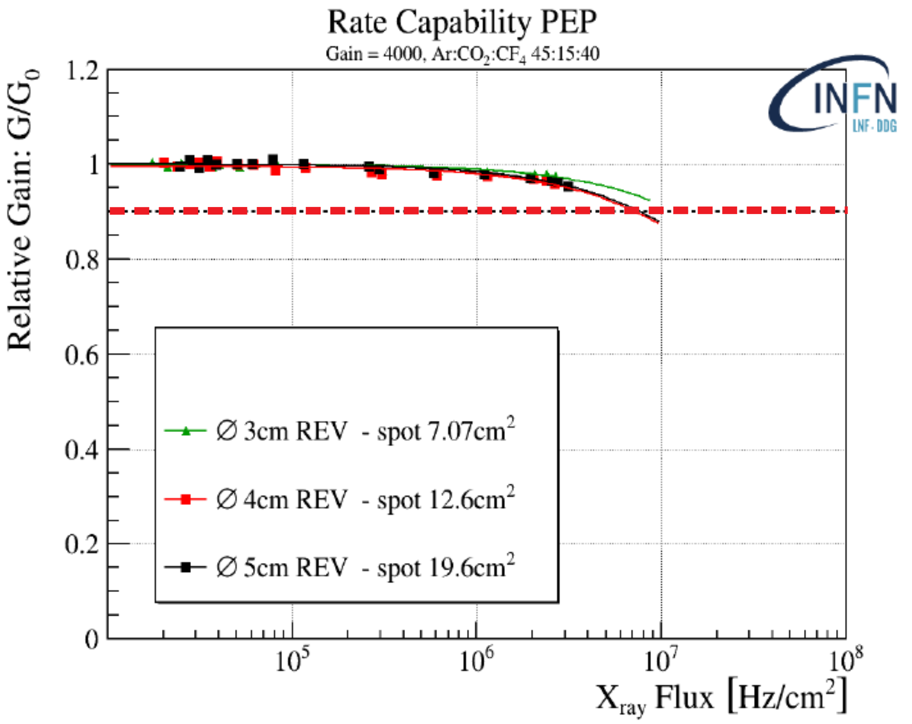


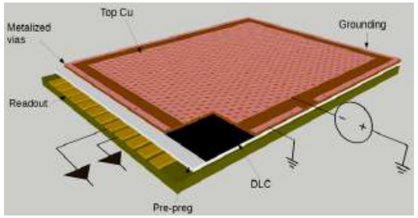
# Rate capability – X-Ray measurements

**Low Rate**



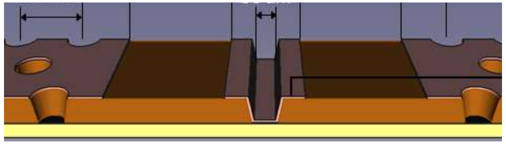

**High Rate**



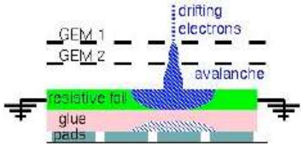



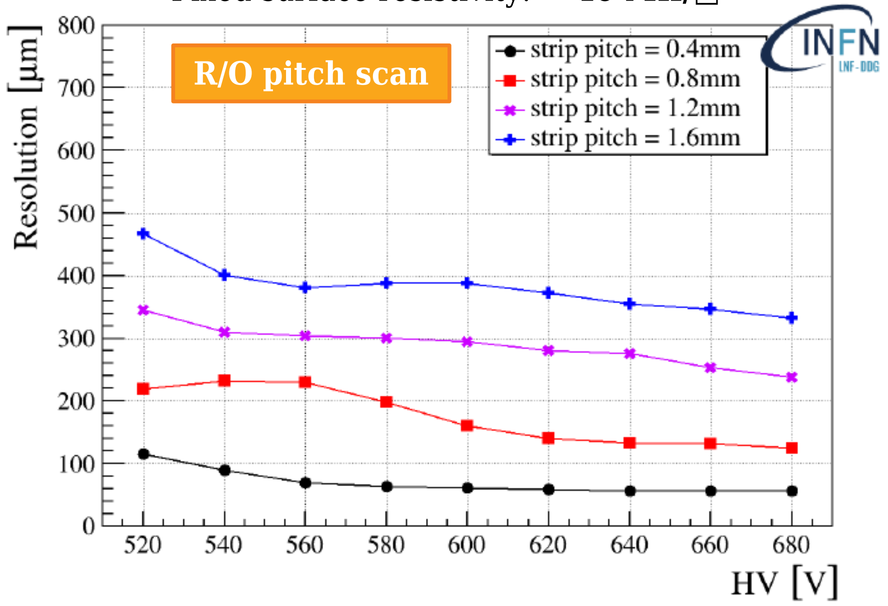

Rate capability compatible with m.i.p. as measured @PSI O(10MHz).

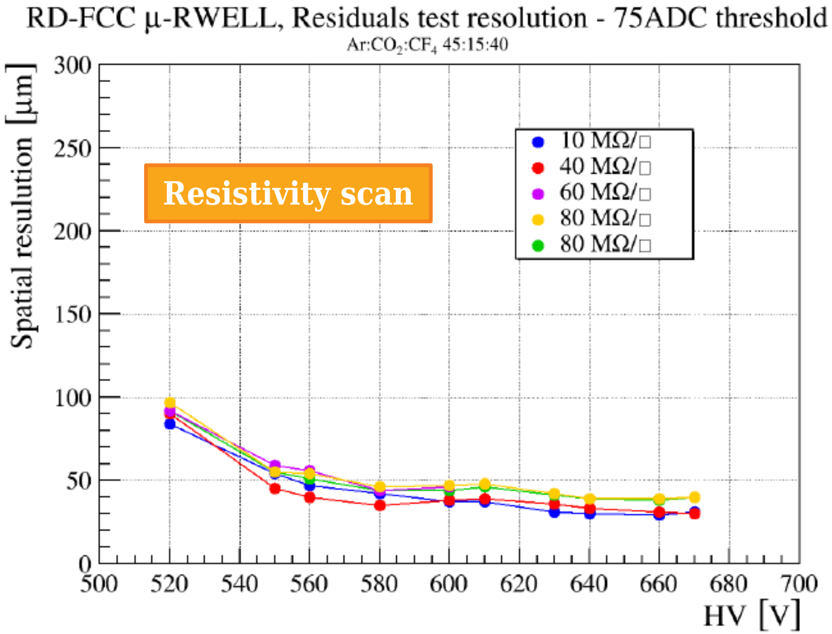
**Different primary ionization ⇒ Rate Cap $_{\text{m.i.p.}}$ = 3×Rate Cap $_{\text{X-ray}}$**



# μ-RWELL: DLC charge spread




**Fixed strip pitch (0.4 mm)** and width (0.15 mm)

Need to **reduce** # FEE **channels**

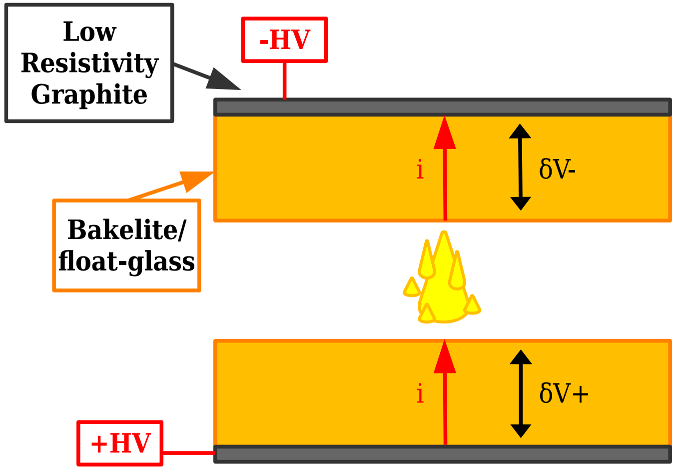
**=**

**Increase** the R/O **pitch**

As expected: reduction of the space resolution.

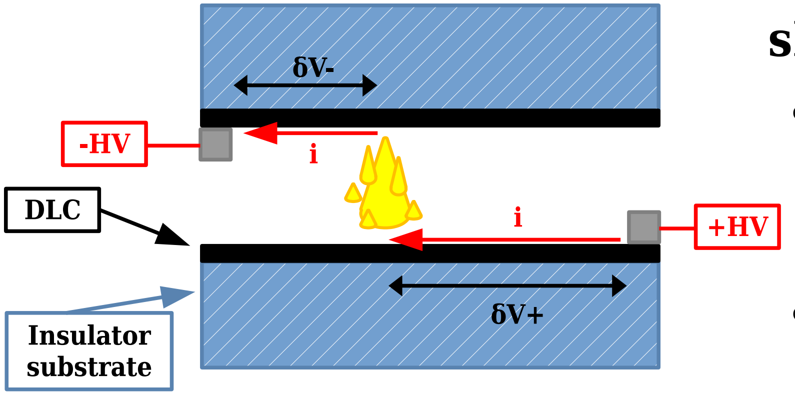
No effects in **this resistivity range**.
→ DLC resistivity uniformity is not a crucial parameter
Near future: charge dispersion through different R/O architecture → capacitive sharing R/O

# Bulk RPC vs Surface RPC




## Classical RPCs

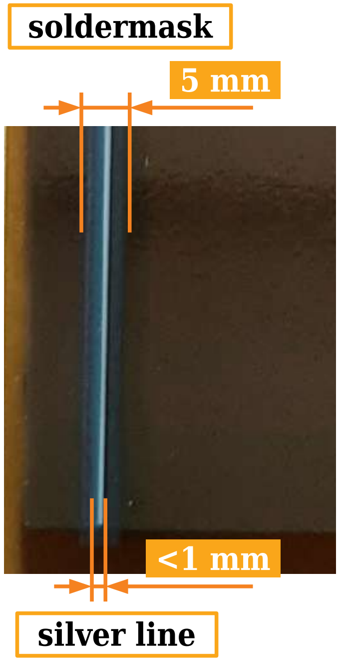
- Bulk resistivity electrodes (bakelite, float-glass, ...)
- Recovery time proportional to **volume resistivity, electrode thickness**
  - $\tau = \rho_V \varepsilon_0 (\varepsilon_r + 2d/g)$
  - Low volume resistivity and thin electrodes, together with the reduction of the gas gain (⊕high gain low noise pre-amp) is the standard recipe to increase the detector rate capability.

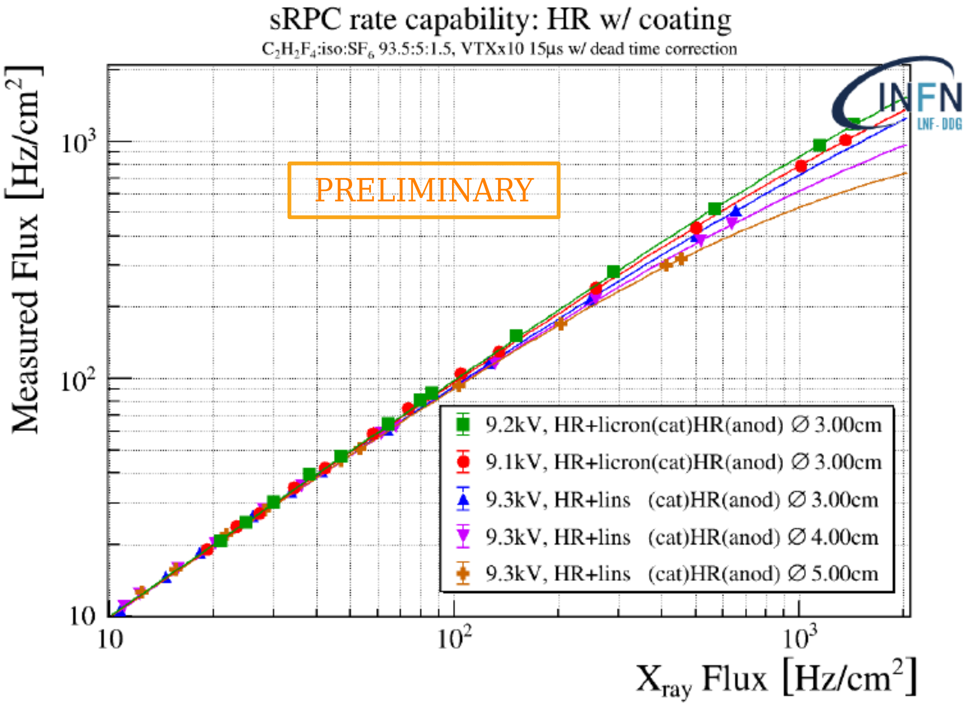



## sRPCs - surface RPC

- Surface resistivity electrodes manufactured with sputtering techniques of Diamond-like-carbon (DLC) on flexible supports
  - The technology allows to realise large electrodes with a DLC **surface resistivity** in a **very wide range: 10 MΩ/□ ÷ 10 GΩ/□**
- High density current evacuation schemes, similar to those used for resistive MPGD (μ-RWELL and MicroMegas), can be implemented to improve the rate capability of the detector

# High Rate layout – preliminary results




A **preliminary** measurement of the **rate capability** (defined as the radiation flux corresponding to an efficiency drop of 20%) of the high-rate layout has been **performed** by irradiating the detector **with a 5.9 keV X-ray gun** with a spot size comparable with the pitch of the conductive grid realized on the DLC ($\rho_{DLC}$≈1.6 GΩ/□).

**Rate capability of ~1 kHz/cm² with X-ray**