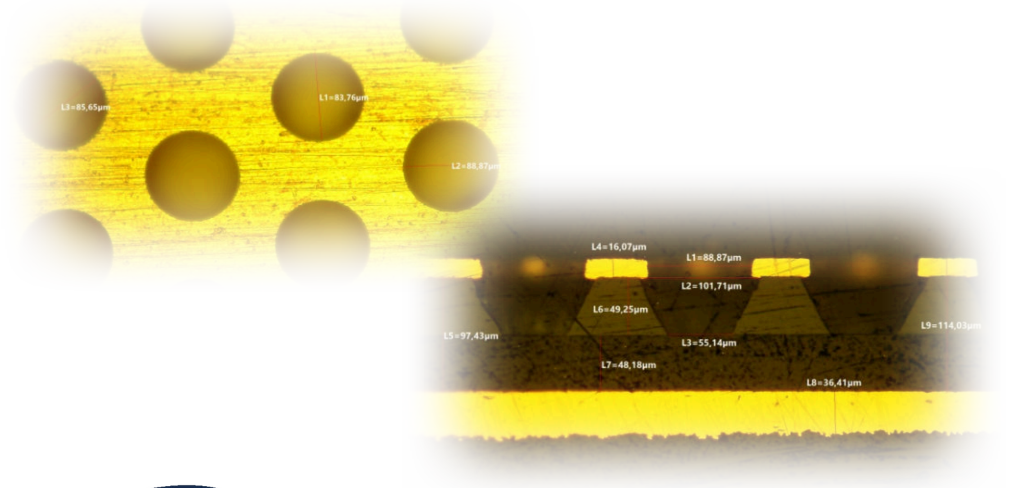
The µ-RWELL for future HEP challenges

Review of the DDG activities



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LNF – INFN [1]
CERN [2]

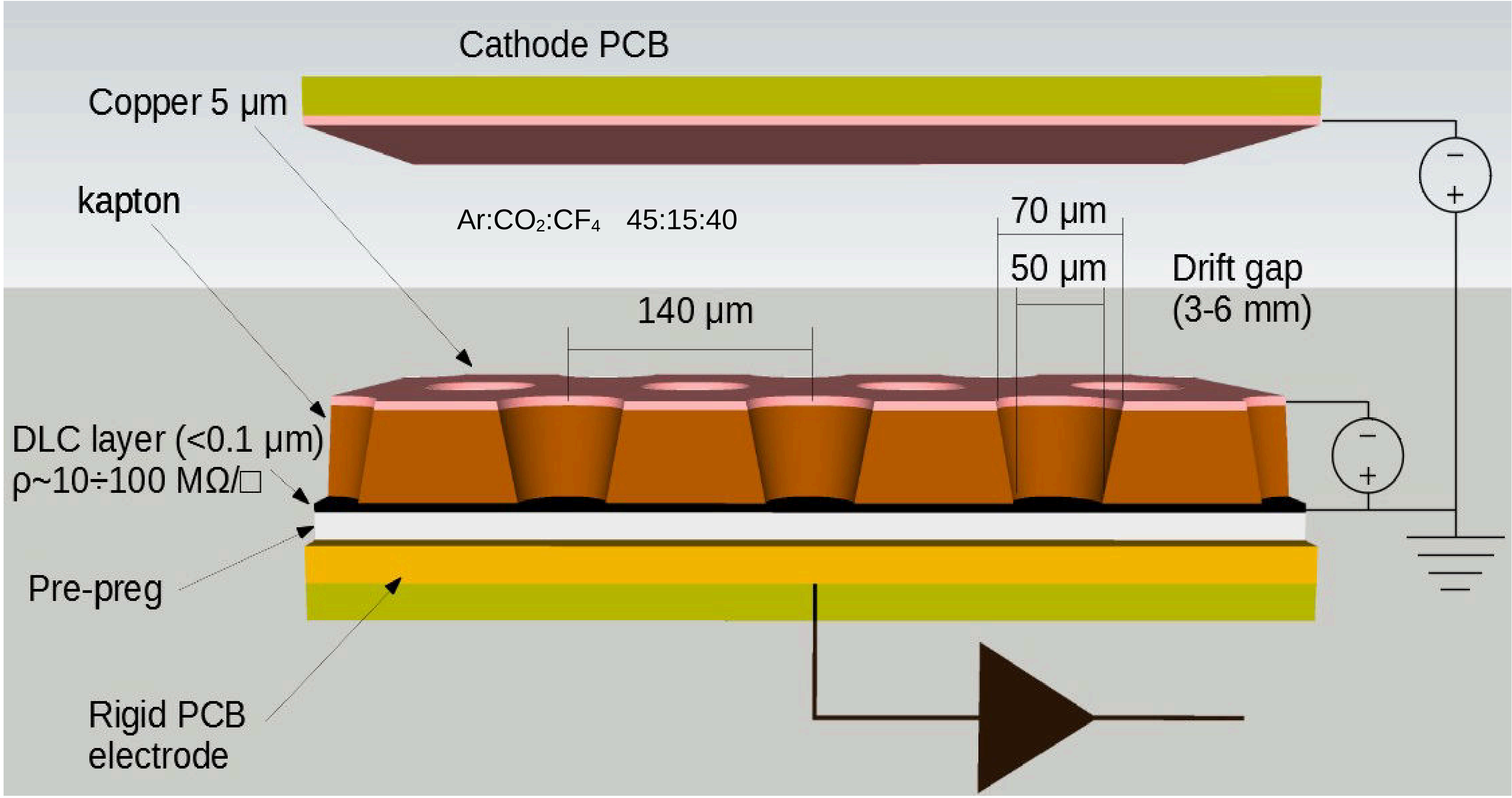
INFN LNF - DDG

AIDA innova

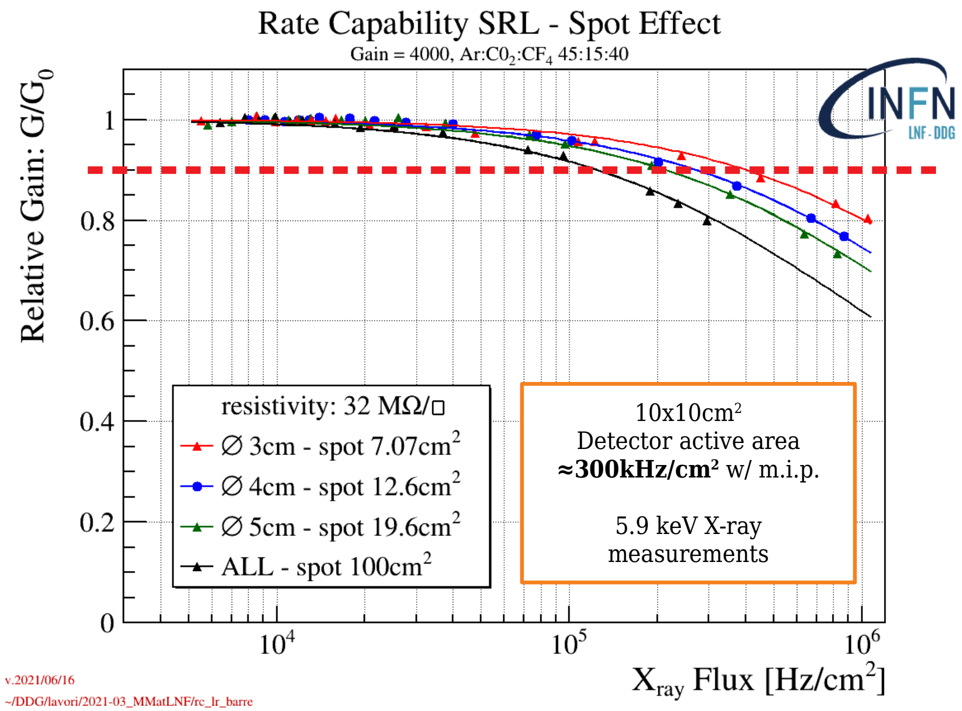
MPGD24, Oct 14th 2024

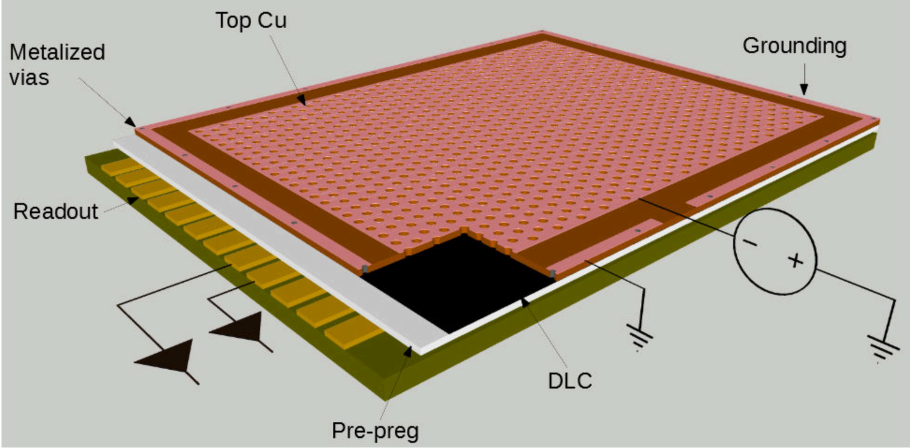
This research has been supported by the E.U. Project AIDAInnova Task 7.3 (European Union's Horizon 2020 Research and Innovation programme, grant agreement N.101004761)

The µ-RWELL


Cathode PCB
Copper 5 µm
kapton
Ar:CO2:CF4 45:15:40
70 µm
50 µm
Drift gap
(3-6 mm)
140 µm
DLC layer (<0.1 µm)
ρ~10÷100 MΩ/□
Pre-preg
Rigid PCB
electrode

The low-rate layout: Single Resistive Layout (SRL)

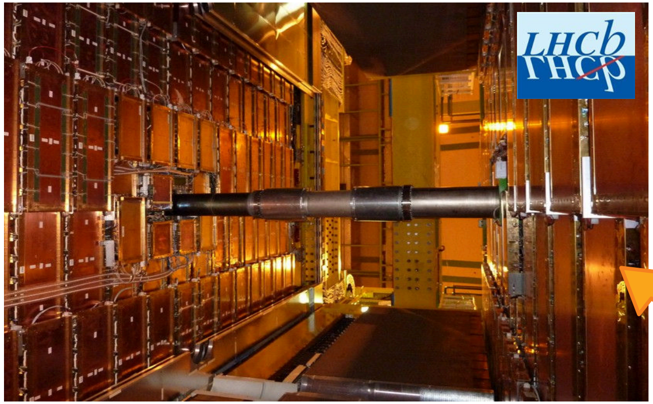




- **Single DLC layer**
- **Grounding at** the **perimeter** of the active area
- **Limitation for large area:** detector response depends on particle incidence point
- **Limited rate capability**

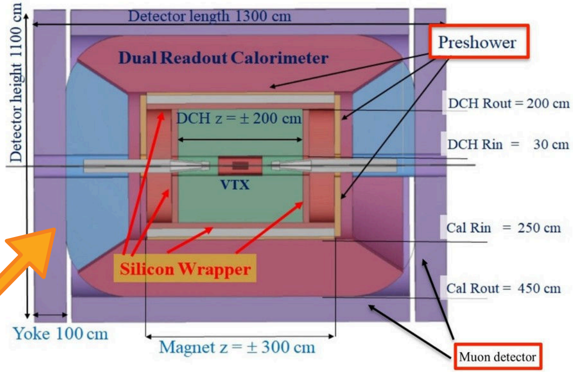
! **Different primary ionization ⇒ Rate Cap.$_{\text{m.i.p.}}$ = 3×Rate Cap.$_{\text{X-ray}}$**

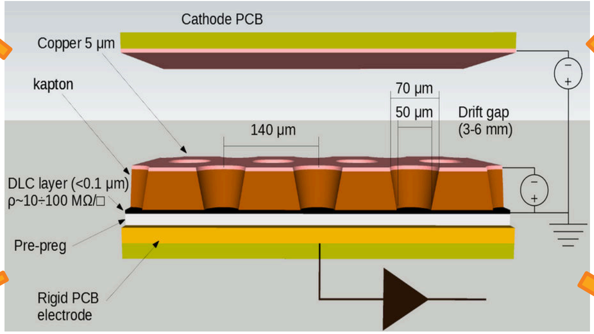
DDG-LNF R&D PROJECTS

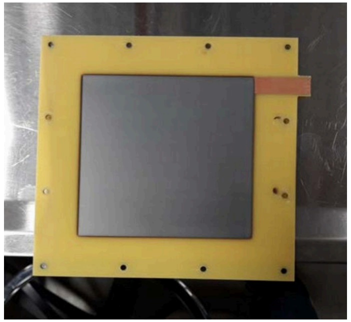


High rate

Tracking

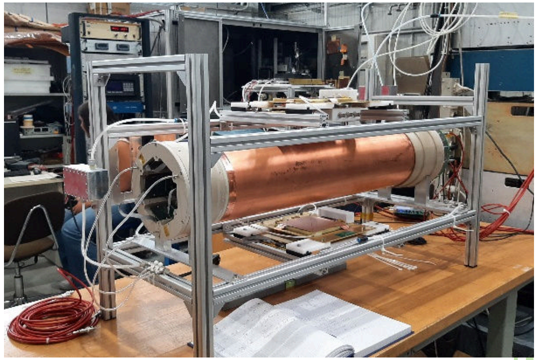






Thermal neutrons

C-WELL



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

High rate μ-RWELL for the LHCb experiment

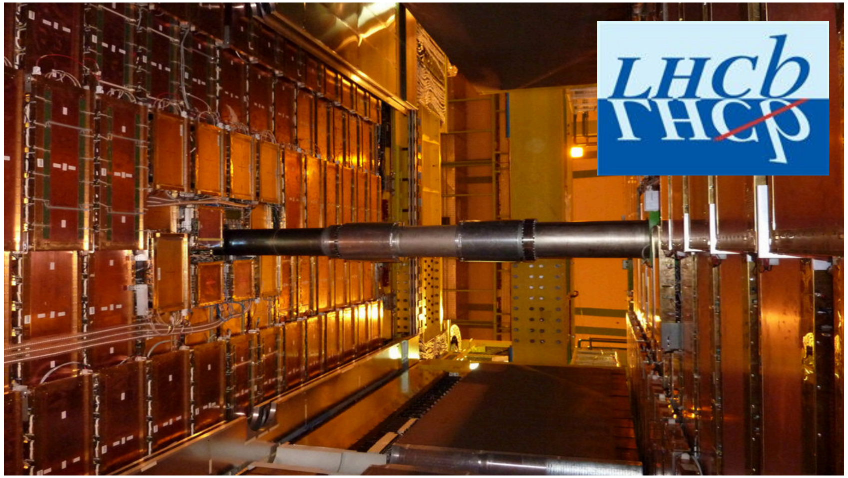
LHCb upgrade II (Run5-6)

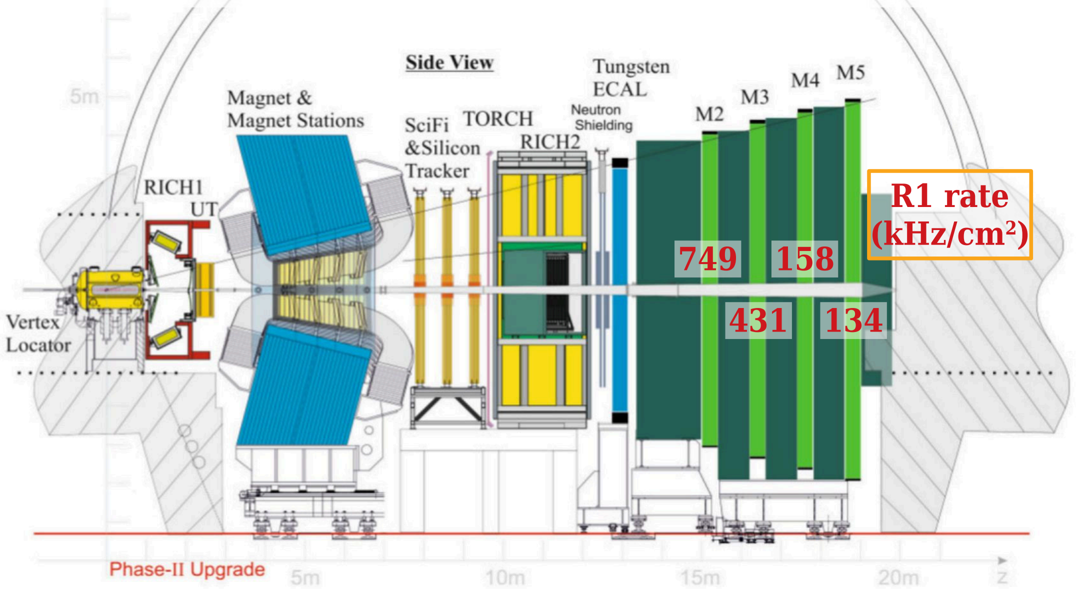
LHCb muon RUN 5-6 option: μ-RWELL → Detector requirements:

- Rate up to **1 MHz/cm²** on detector single gap
- Rate up to **700kHz** for FEE channel
- Efficiency (4 gaps) **> 99% within BX** (25 ns)
- Stability up to 1 C/cm² accumulated charge in 10y of operation

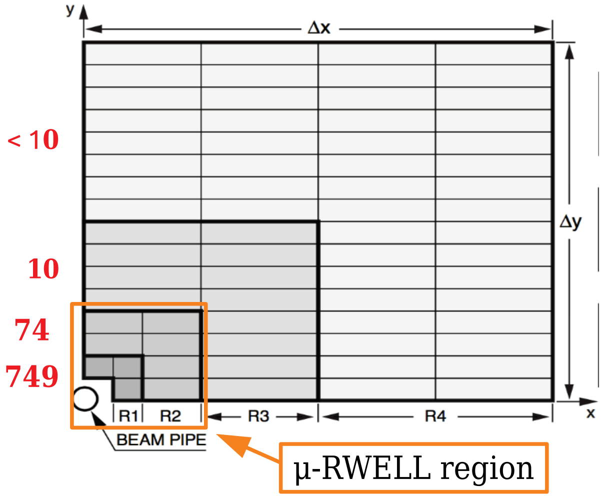
Detector size & quantity (4 gaps/chamber)

- R1 + R2 of M2-M5: **576 det.**, size 30x25 to 74x31 cm², **90 m² det**



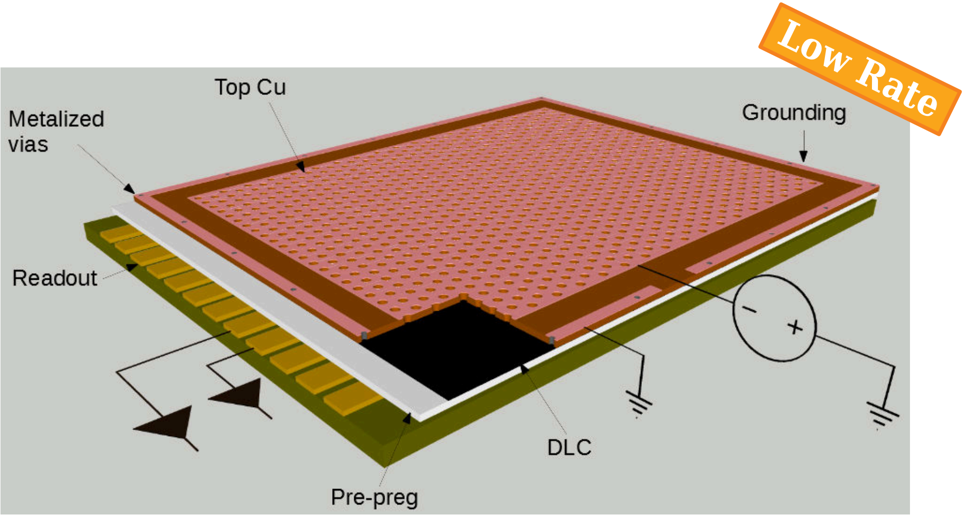


M2 station - **max rate (kHz/cm²)**

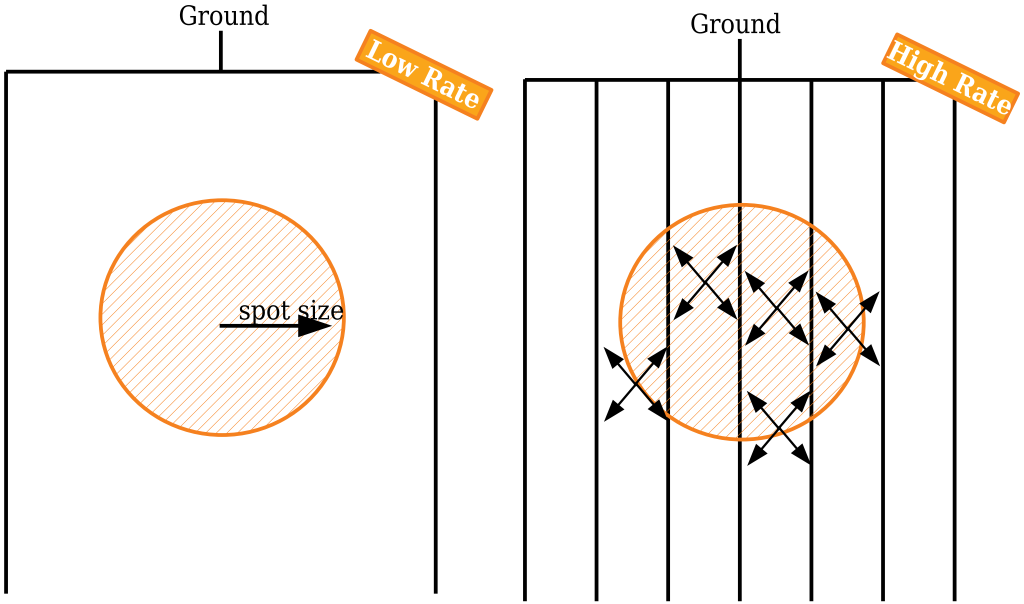


High-rate layouts: principle of operation

To overcome the **intrinsic rate limitations** of the Single Resistive Layout, it is necessary to introduce a **high-density grounding network** for the resistive stage (DLC).



Single Resistive Layout (SRL)

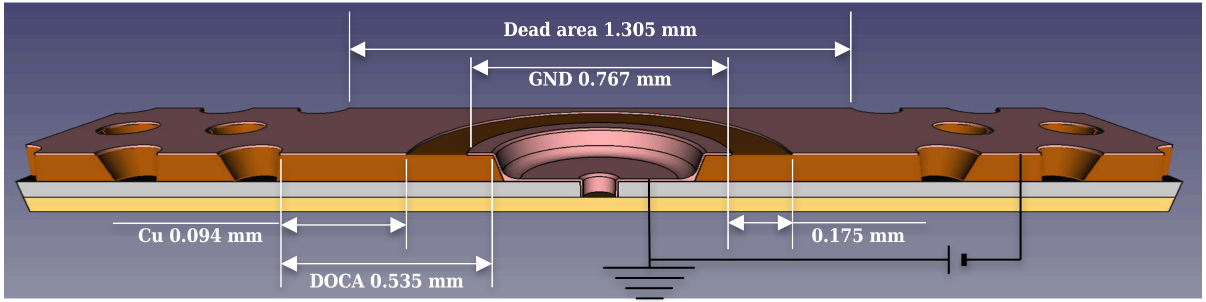


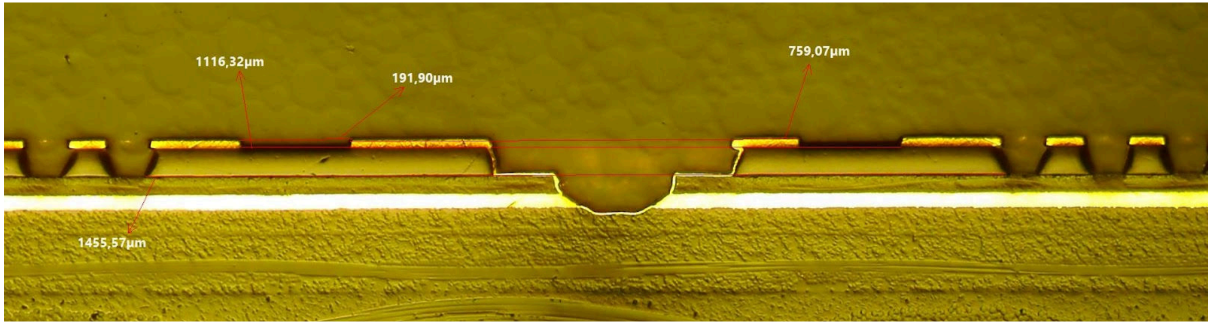
Segmentation of the DLC with conductive micro-strips/dots with a typical pitch of 1cm: a sort of **tiling** of the active area using a set of smaller SRL.

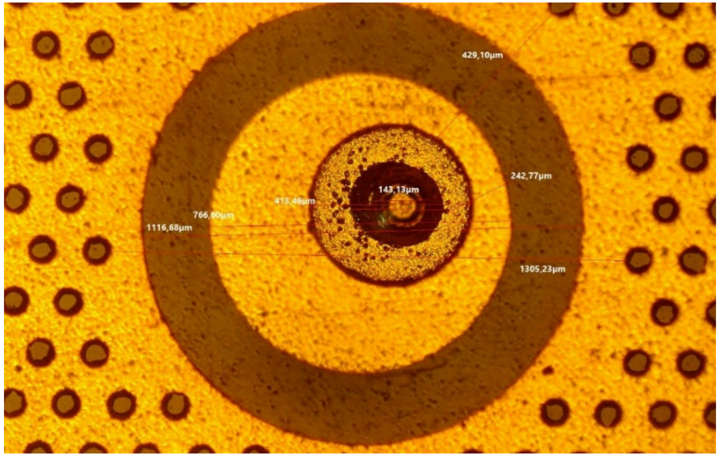
The PEP-DOT µ-RWELL

DLC-GND pitch [mm]	Dead Zone [mm]	GND width [mm]	Insulation gap [mm]	DOCA [mm]
9	1.3 (1.6%)	0.767	0.175	0.535

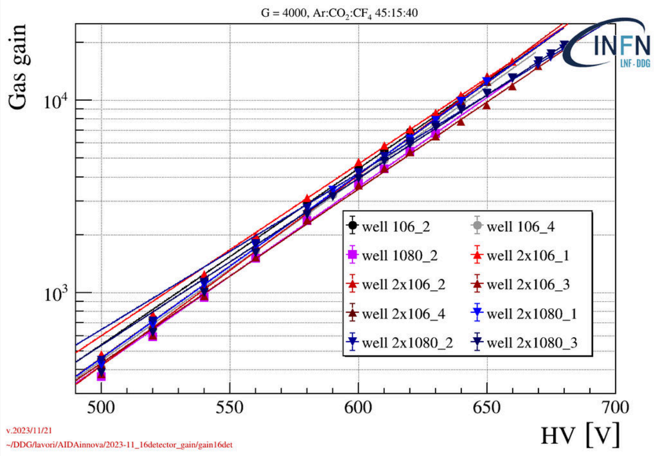
- The most recent high rate layout: **P**atterning–**E**tching–**P**lating
- The DLC ground connection is established by creating **metalized vias from the top Cu layer through the DLC**, down to the pad-readout of the PCB
- The dead zone is ~2%

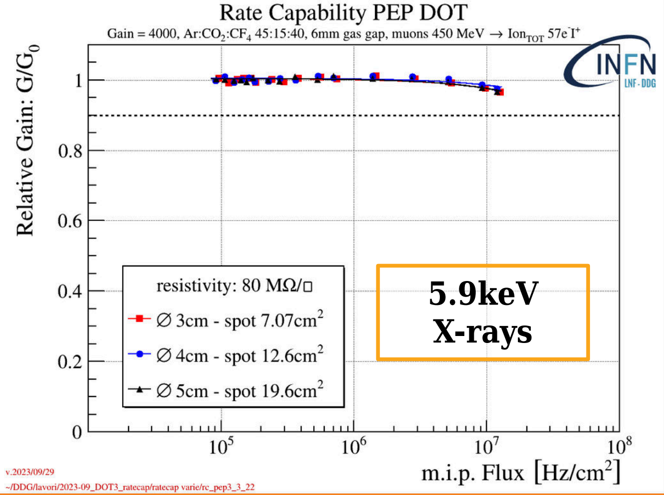


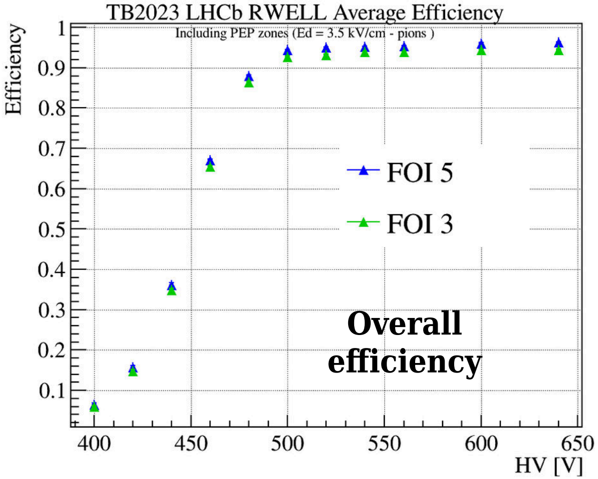


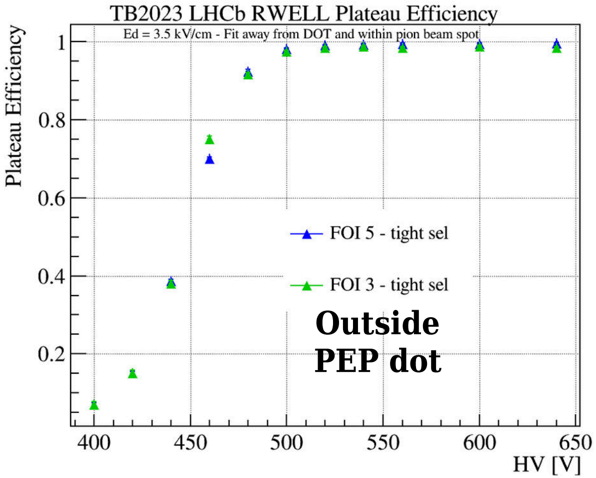


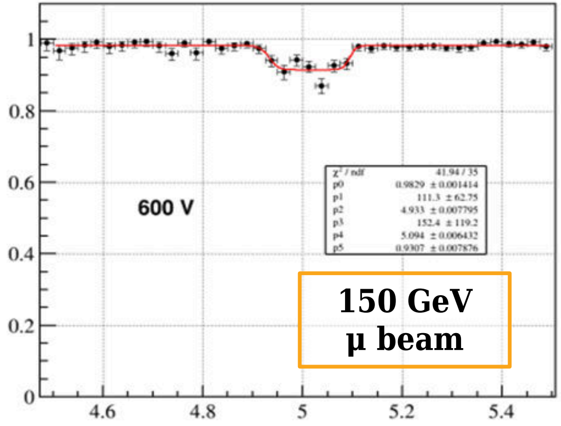
PEP-dot – results

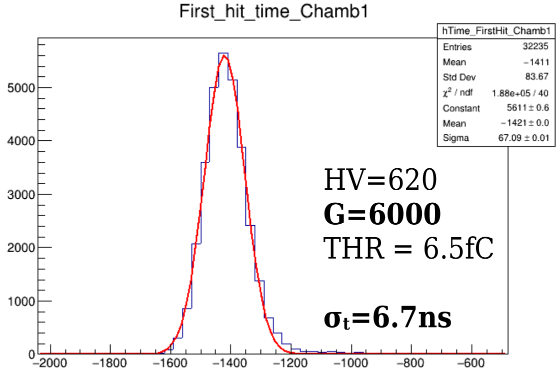




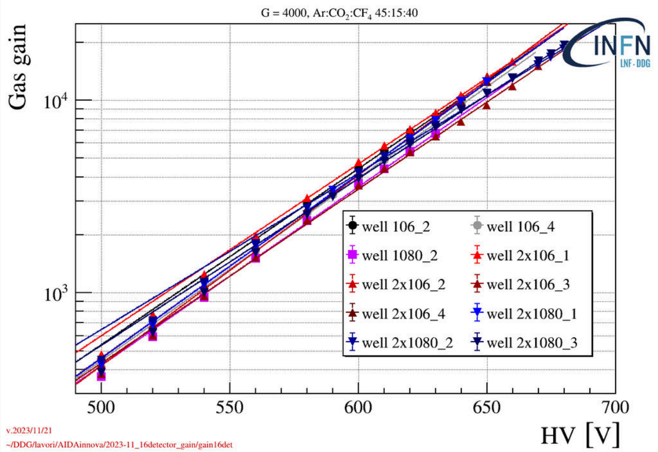


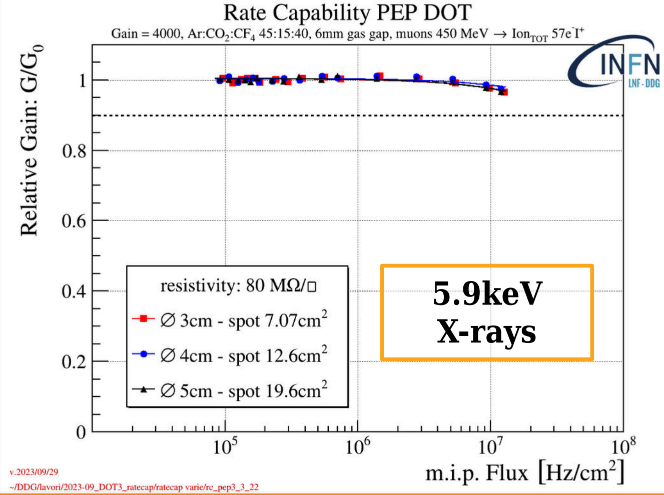


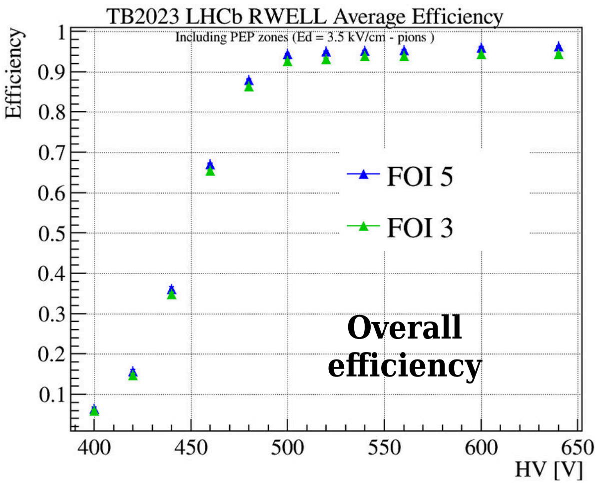


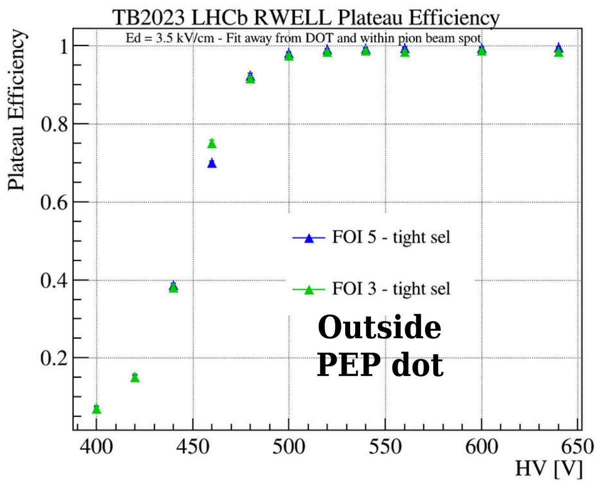


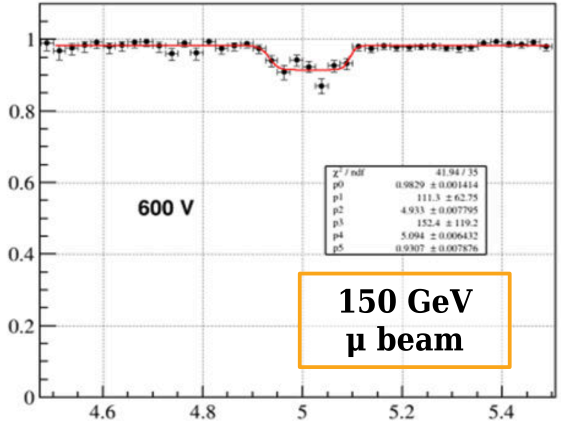
PEP-dot – results

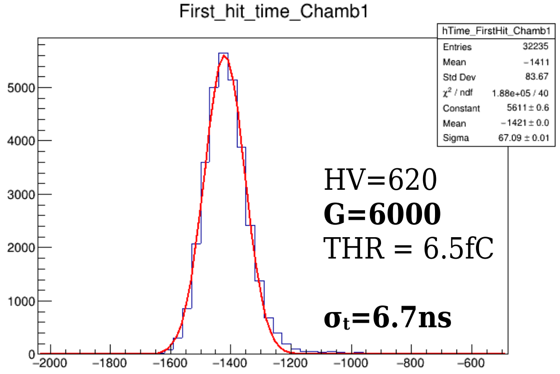










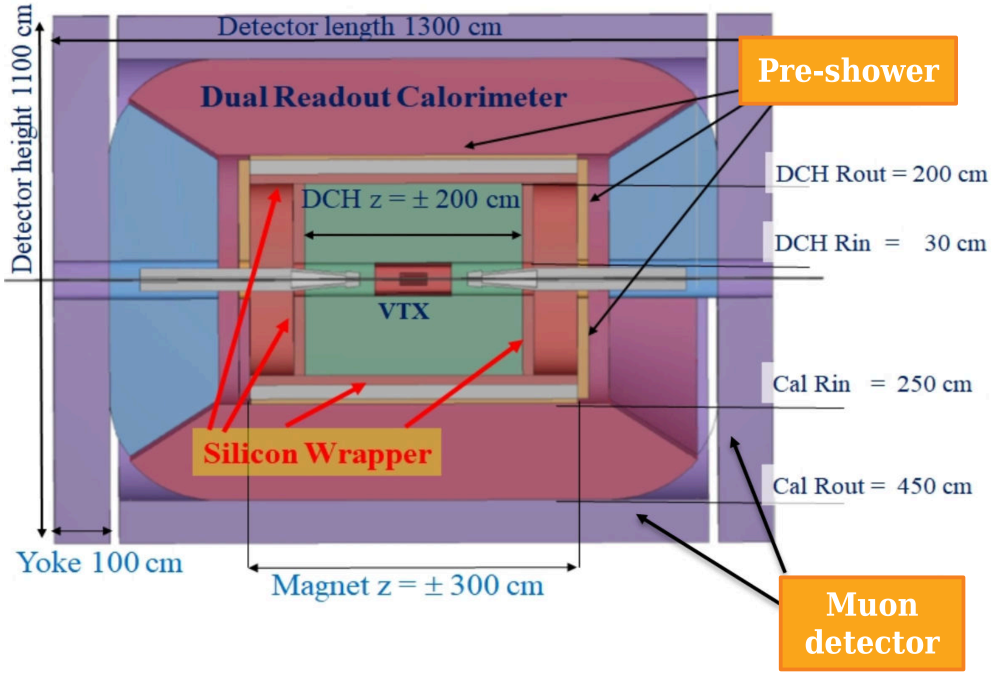


There will be an addenda later in the talk

Tracking μ-RWELL for FCC-ee

FCC-ee → μ-RWELL for tracking and muon system

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



Requirements

Tiles: 50x50 cm² with X-Y readout
Efficiency >98%
Space resolution:
- 100μm (preshower)
- 500μm (muon)

Instr. surface/FEE

Preshower:
- 130m², 520 det., $3x10^5$ chs. (0.4 mm strip pitch)

Muon:
- **1500m², 6000 det., $5x10^6$ chs.,** (1.2mm strip pitch)

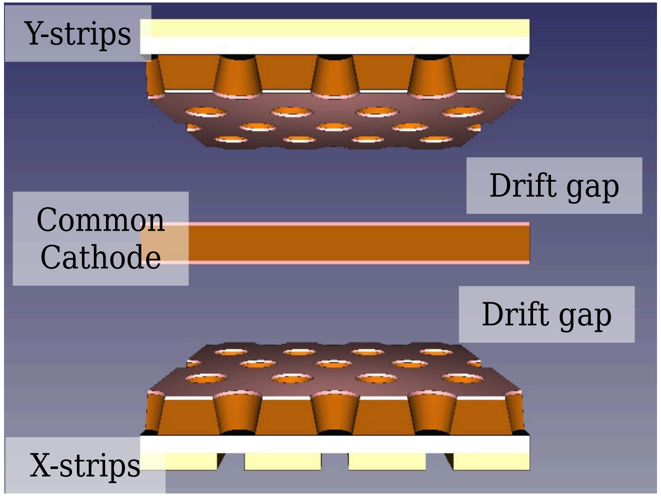
GOALS:

Mass production → Technology Transfer to Industry
FEE cost reduction → custom made ASIC

See R. Farinelli's talk on 15th Oct.:
→ μ-RWELL muon system and pre-shower for FCC-ee

2-D Tracking layouts

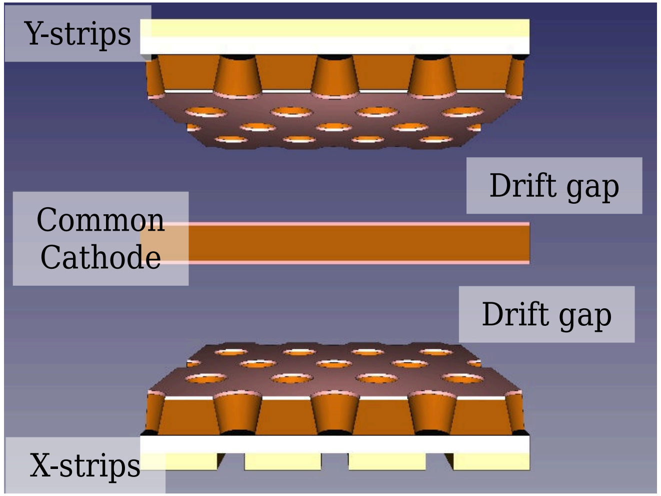
n.2 μ-RWELL 1D [2×1D]



The layout with **two separate detectors** equipped with its own r/out is operated at lower gas gain, with respect to the single detector with 2D R/O (COMPASS-like) - Tested @ TB2022

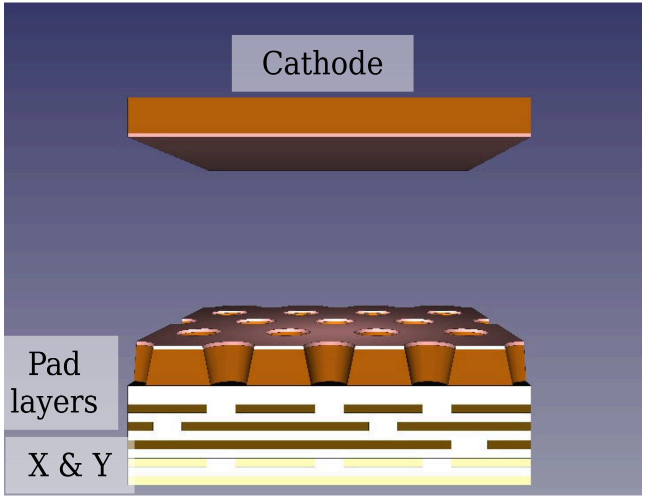
2-D Tracking layouts

n.2 µ-RWELL 1D [2×1D]



The layout with **two separate detectors** equipped with its own r/out is operated at lower gas gain, with respect to the single detector with 2D R/O (COMPASS-like) - Tested @ TB2022

Capacitive Sharing [*]

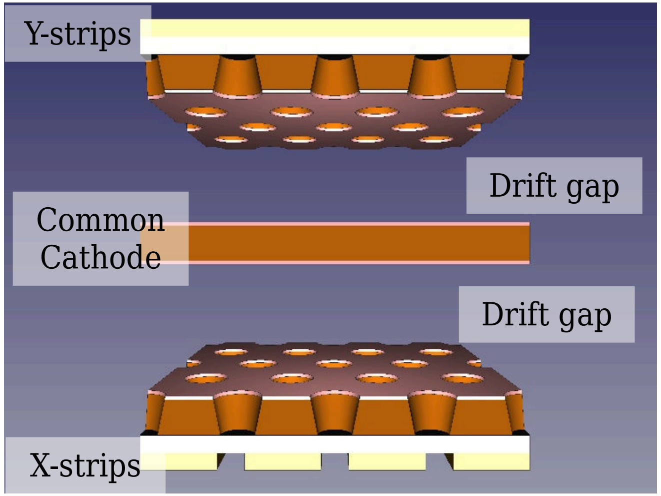


The charge sharing through the **capacitive coupling** between a stack of layers of pads and the R/O board. Reduce the FEE channels, and **the total charge is divided between the X & Y** R/O - Tested @ TB2023

[*] K. Gnanvo et al., NIM A 1047 (2023) 167782

2-D Tracking layouts

n.2 µ-RWELL 1D [2×1D]



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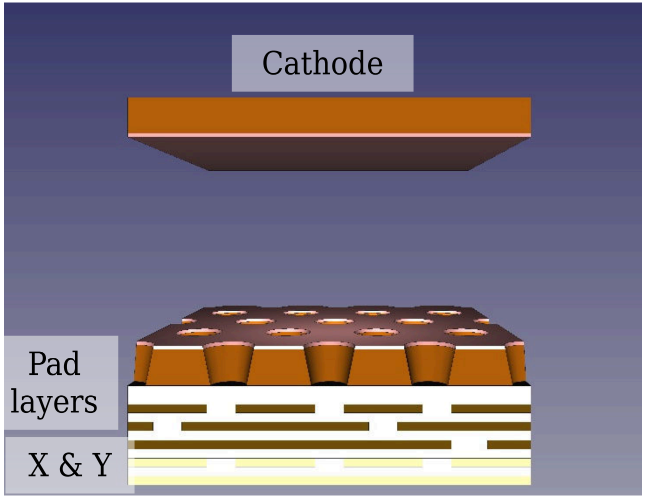
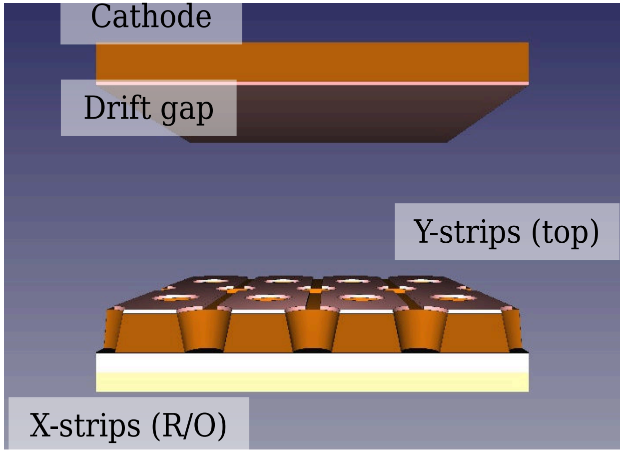
Capacitive Sharing [*]



The charge sharing through the **capacitive coupling** between a stack of layers of pads and the R/O board. Reduce the FEE channels, and **the total charge is divided between the X & Y** R/O - Tested @ TB2023

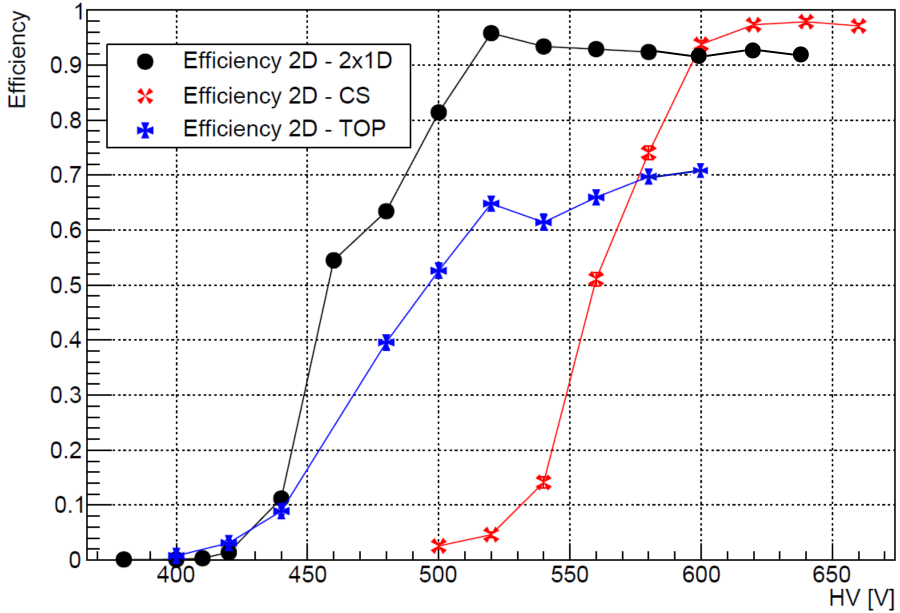
Top R/O

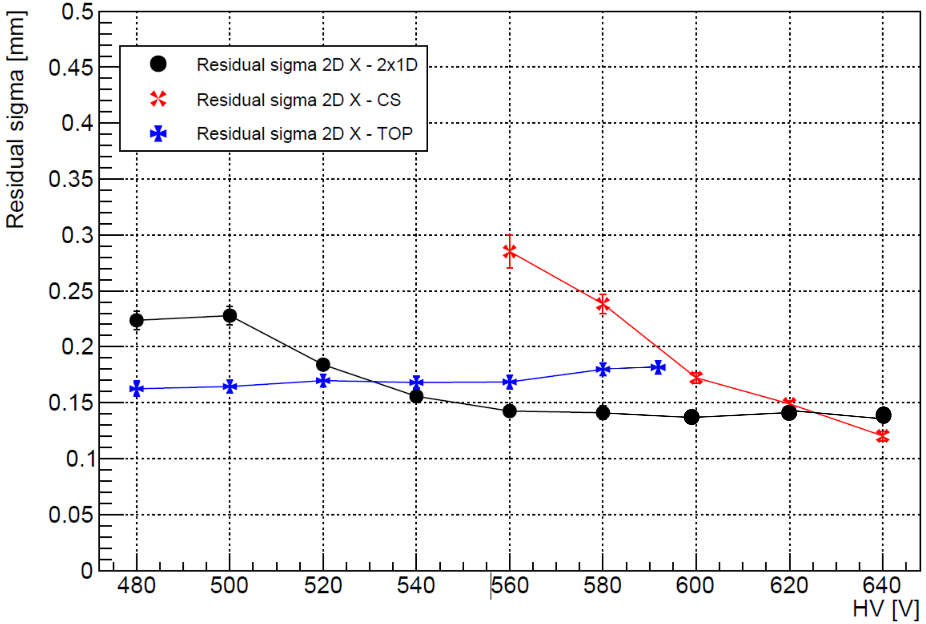


The TOP-readout layout allows to work at lower gas gain w.r.t a COMPASS-like R/O: X-Y are decoupled. X-coordinate on the TOP of the amplification stage introduces **dead zone** in the active area - Tested @ TB2023

[*] K. Gnanvo et al., NIM A 1047 (2023) 167782

2D tracking layout performance



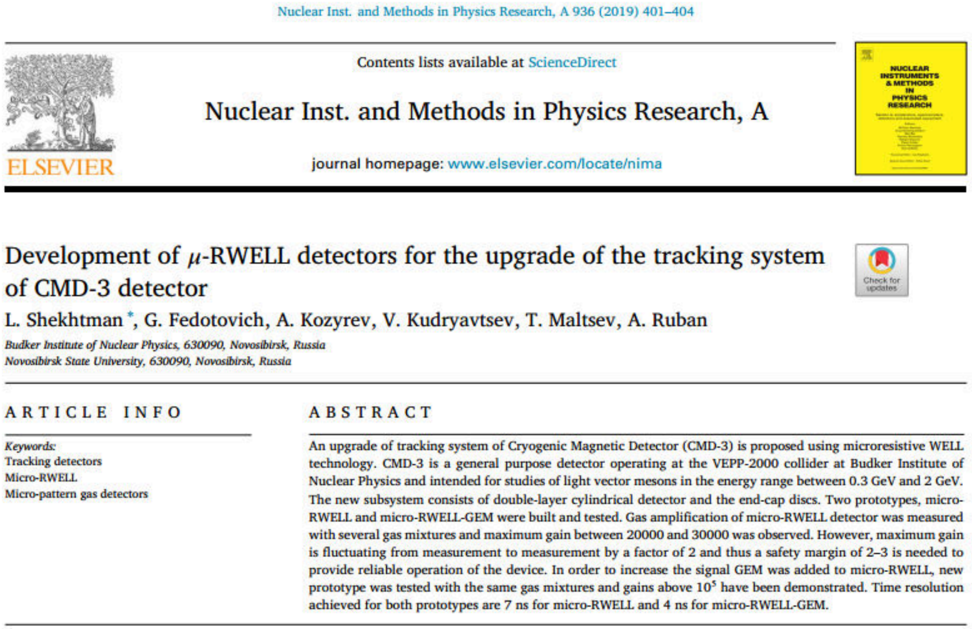


2x1D: spatial resolution < 200um (pitch 0.8 mm), low voltage operating point ≃ 520V, efficiency ≃ 95%
CS: spatial resolution <200um (with pitch 1.2 mm), high voltage operating point, **≥ 600V,** efficiency ≃ 98%
TOP R/O: spatial resolution < 200um (pitch 0.8 mm), low voltage operating point ≃ 520V, **efficiency ≡ 70%**

In collaboration with G. Cibinetto, R. Farinelli, L. Lavezzi, M. Gramigna, P. Giacomelli, E. De Lucia, D. Domenci, A. D’angelo, M. Bondi, M. Scodeggio, I. Garzia, M. Melindi

See R. Farinelli’s talk on 15th Oct. → µ-RWELL muon system and pre-shower for FCC-ee

µ-RWELL + GEM preamplification


Nuclear Inst. and Methods in Physics Research, A 936 (2019) 401–404

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/nima

Development of μ-RWELL detectors for the upgrade of the tracking system of CMD-3 detector

L. Shekhtman *, G. Fedotovich, A. Kozyrev, V. Kudryavtsev, T. Maltsev, A. Ruban

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ARTICLE INFO

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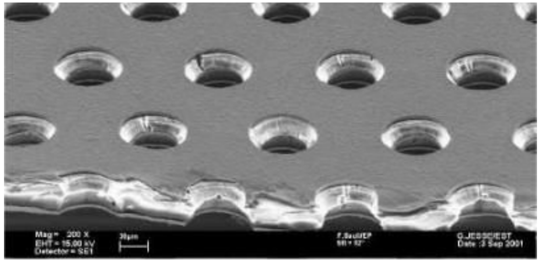
Micro-pattern gas detectors

ABSTRACT

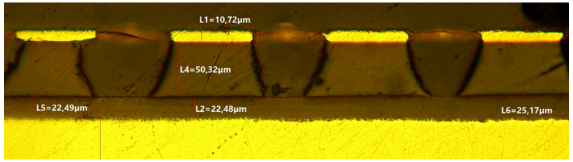
An upgrade of tracking system of Cryogenic Magnetic Detector (CMD-3) is proposed using microresistive WELL technology. CMD-3 is a general purpose detector operating at the VEPP-2000 collider at Budker Institute of Nuclear Physics and intended for studies of light vector mesons in the energy range between 0.3 GeV and 2 GeV. The new subsystem consists of double-layer cylindrical detector and the end-cap discs. Two prototypes, micro-RWELL and micro-RWELL-GEM were built and tested. Gas amplification of micro-RWELL detector was measured with several gas mixtures and maximum gain between 20000 and 30000 was observed. However, maximum gain is fluctuating from measurement to measurement by a factor of 2 and thus a safety margin of 2–3 is needed to provide reliable operation of the device. In order to increase the signal GEM was added to micro-RWELL, new prototype was tested with the same gas mixtures and gains above 10^5 have been demonstrated. Time resolution achieved for both prototypes are 7 ns for micro-RWELL and 4 ns for micro-RWELL-GEM.

L. Shekhtman, Nuclear Inst. and Methods in Physics Research, A 936 (2019) 401–404

Drift Gap: Shekhtman **3mm** – LNF+Roma2 **6mm**



Transfer Gap: Shekhtman **3mm** – LNF+Roma2 **3mm**

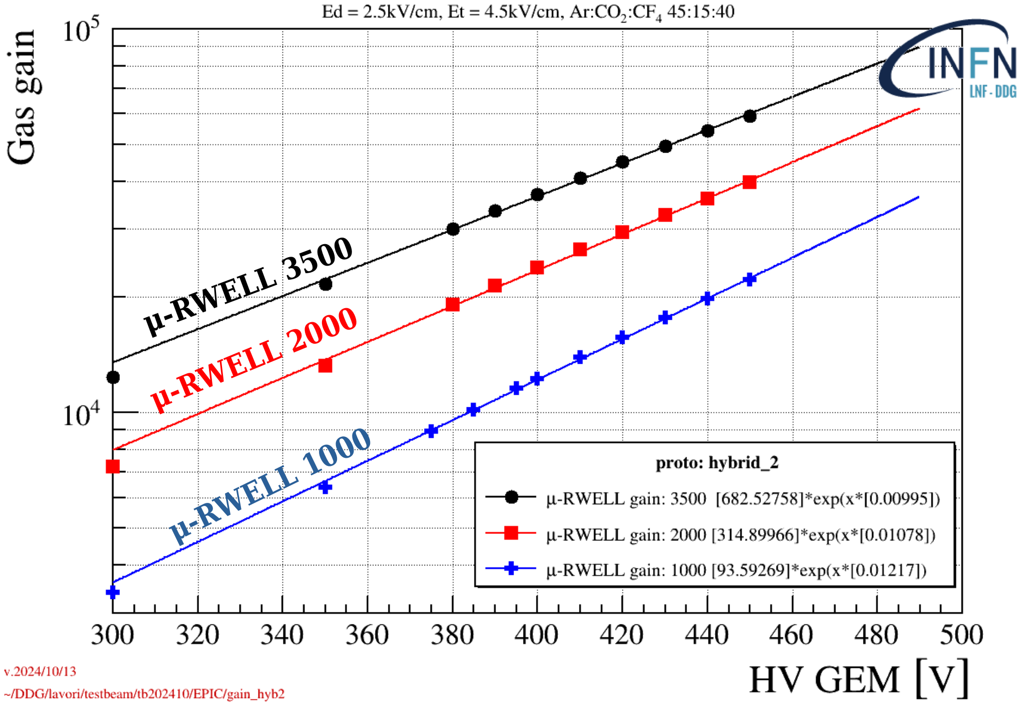


In collaboration with **Rome2 ePIC group**

µ-RWELL + GEM – gas gain

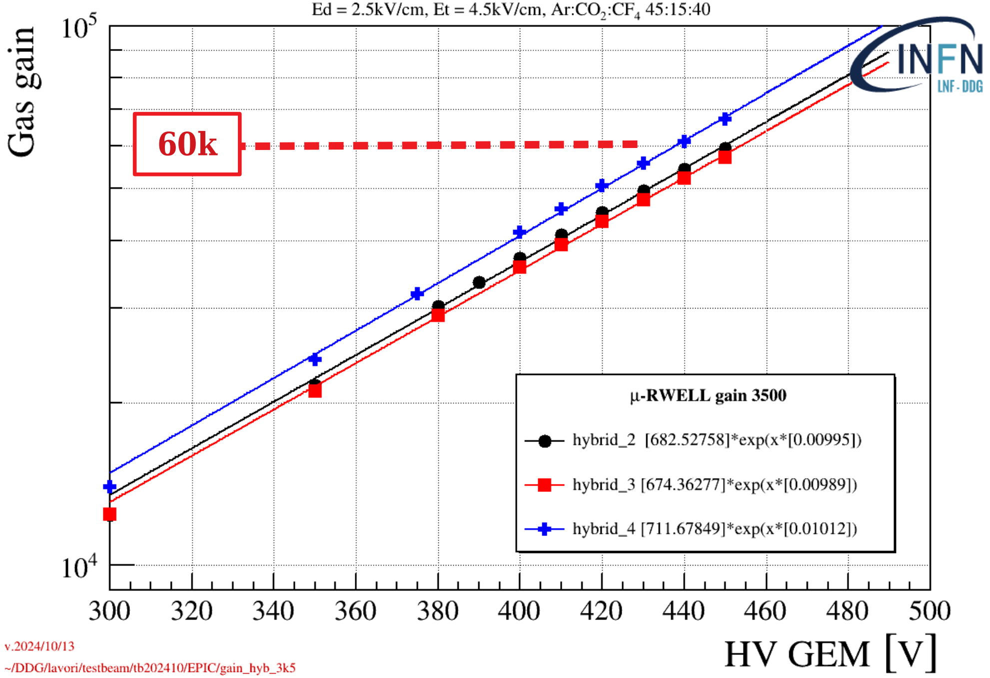
VERY PRELIMINARY: 9-Oct-2024

3 different gains for the µ-RWELL



3 different detectors

µ-RWELL gain @ 3500



GEM gain @ 450V ≈ 20

A very stable detector: it doesn't show any hint of instabilities even at **60k.**
We stopped because the FEE will surely saturate at that point

Planned to be tested as soon as possible with APV25.
Goal: space resolution with a COMPAS-like readout.

Cylindrical-RWELL for low-momentum experiments

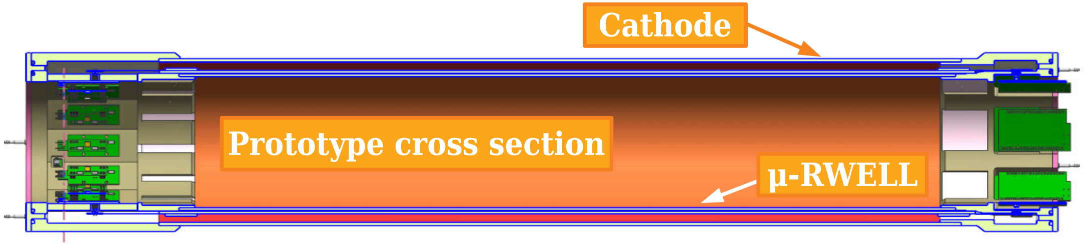
Low X_0 Cylindrical µ-RWELL

Thanks to the LNF and INFN-Fe Eurizon collaboration

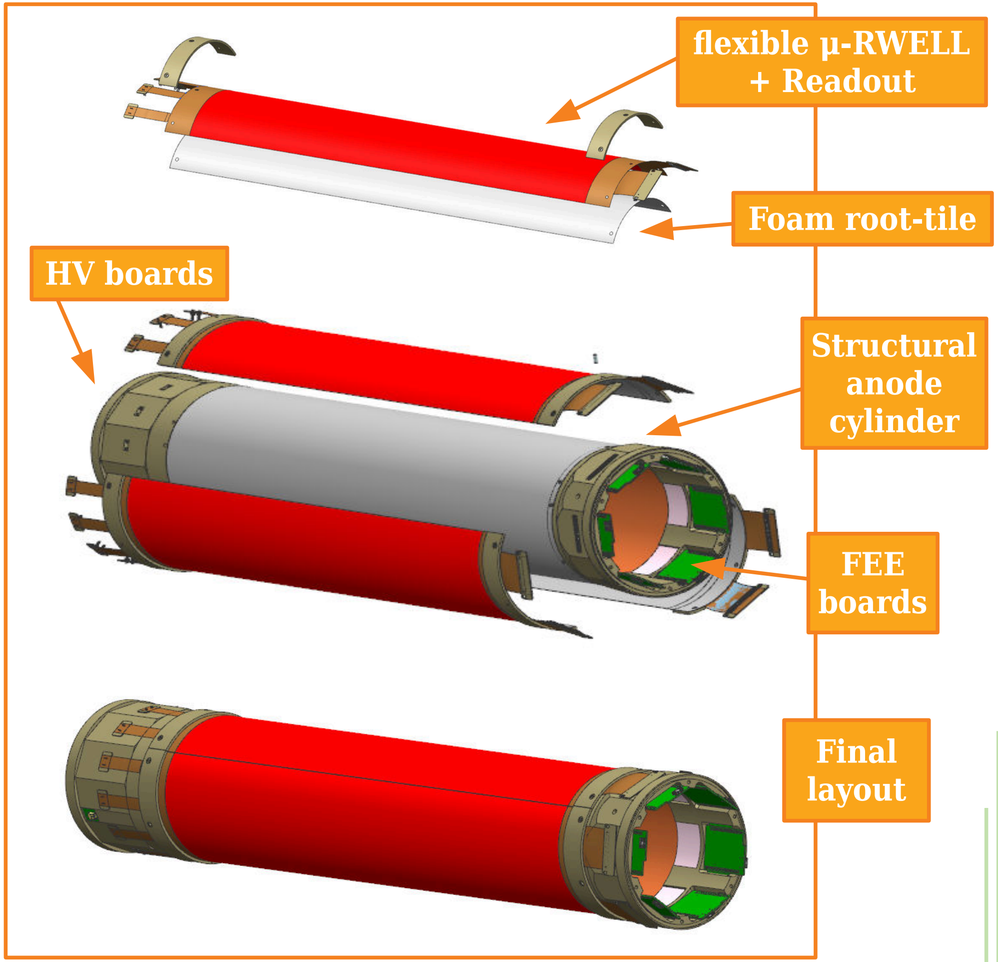
eurizon — European network for developing new horizons for RIs

Exploiting the **flexible** characteristic of the amplification stage of the µ-RWELL, as well as the readout → development of a **low-mass (0.6÷1% X0) modular Inner Tracker** for low-energy e^+e^- colliders: the **C-WELL**.

- From standard µ-RWELL on rigid PCB supports → a **full flexible detector tile**
- **Three tiles** have been glued on composite/foam roof-tiles, then mounted on the anode cylindrical support
- A **full cylindrical-cathode** will close (externally) the detector

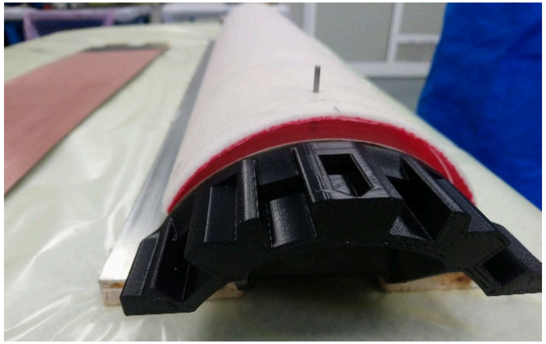


Detector size
- external diameter ≈20cm
- global length ≈ 100cm
- active length≈ 60cm



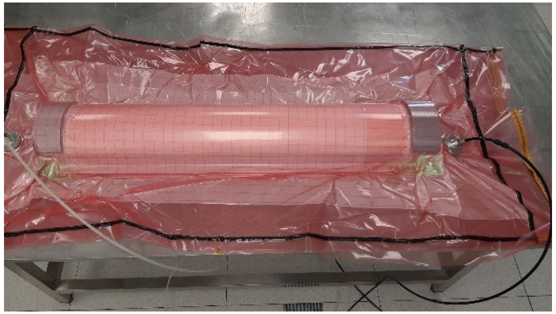
The roof-tile assembly

The roof tile is composed of a Structural Adhesive Film (30 µm) coupled to a layer of Millifoam® (2 mm) where the flexible PCB is glued, under vacuum, with epoxy.



The roof-tile Millifoam support

The flexible µ-RWELL PCBs produced at CERN-EP-DT MPT Workshop. Each foil is divided in four HV sectors



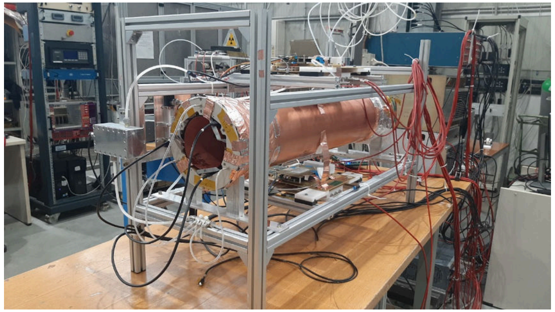
Gluing the µ-RWELL-PCB onto the roof tile, followed by an epoxy curing cycle under vacuum.

The final rooftile is coupled to the anode support

Final assembly

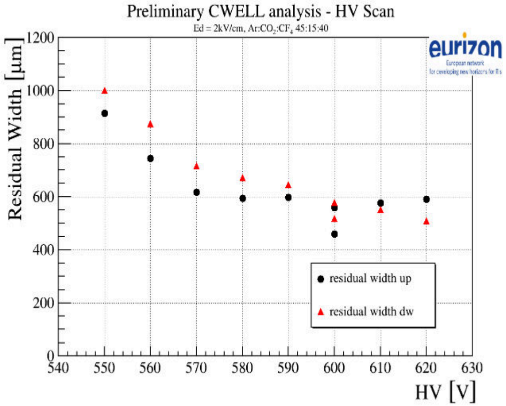
The final assembly **didn't require a highly sophisticated sliding machine**, thanks to the **large distance (10 mm)** between the roof tiles and the internal surface of the cathode. The tile gluing and the detector assembly took **14 days.**

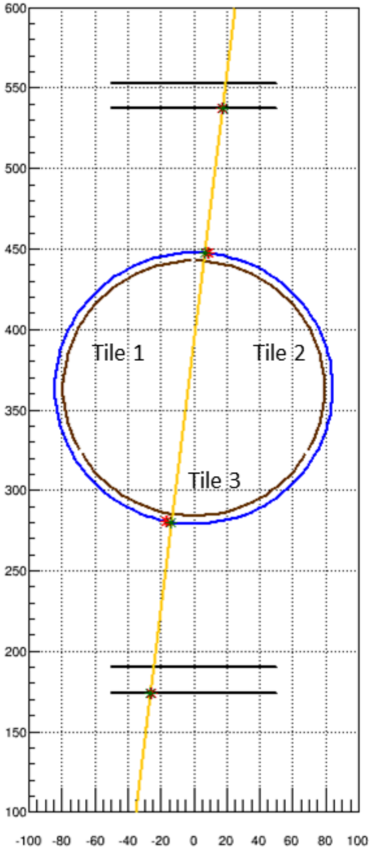
Cosmic ray test



Tracking system: 4 1D μ-RWELLs
Gas: $Ar:CO_2:CF_4$ 45:15:40

→ large residuals due to inclined tracks





Technology Transfer to Industry

µ-RWELL Technology Transfer

Step 0 – Detector **PCB design** @ LNF + CERN-MPT

Step 1 – CERN_INFN **DLC sputtering machine** @ CERN (+INFN)
- In operation since Nov. 2022
- Production by LNF-INFN crew

Step 2 – **Producing readout PCB** by ELTOS
- pad/strip readout

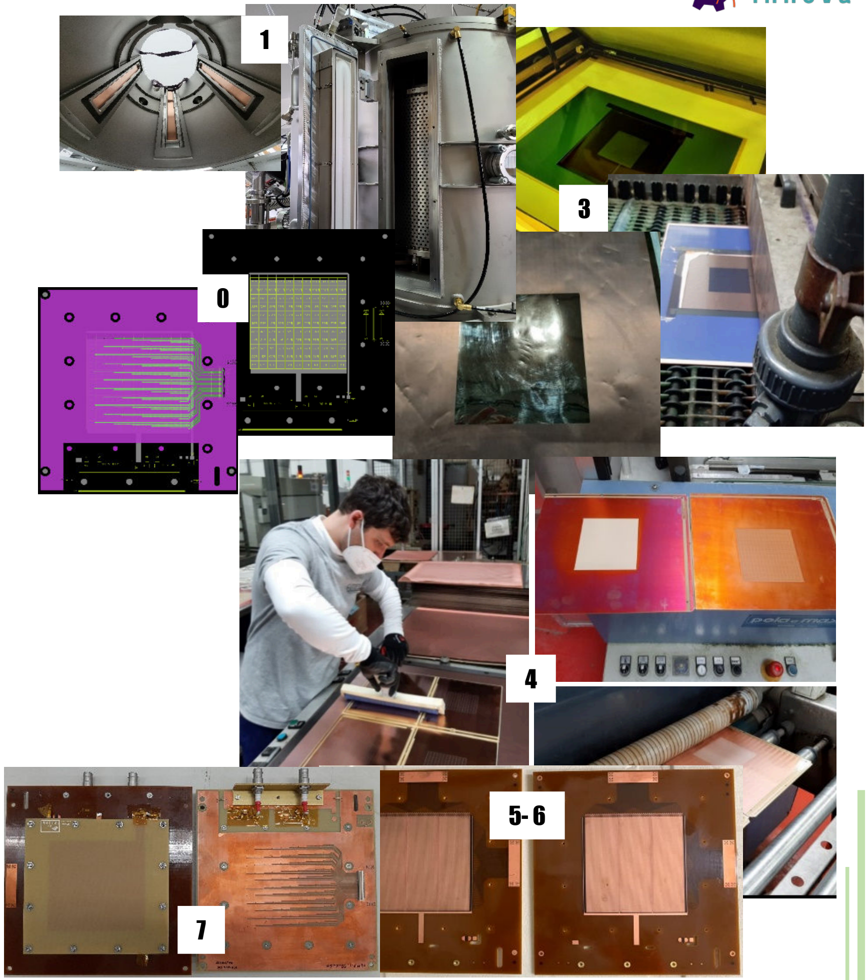
Step 3 – **DLC patterning** by ELTOS
- photo-resist → patterning with BRUSHING-machine

Step 4 – **DLC foil gluing** on PCB by ELTOS
- Large press available, up to 16 PCBs workable at the same time

Step 5 – **Ground network connections** creation by CERN
- **PEP** layout: Cu **P**atterning → PI **E**tching → Cu **P**lating

Step 6 – **Amplification stage** patterning by CERN
- Cu amplification holes image and HV connections by Cu etching
- PI etching → plating → amplification-holes

Step 7 – **Electrical cleaning** and detector closing @ CERN



This research has been supported by the E.U. Project AIDAInnova Task 7.3 (European Union's Horizon 2020 Research and Innovation programme, grant agreement N.101004761)

Update on the DLC Sputtering

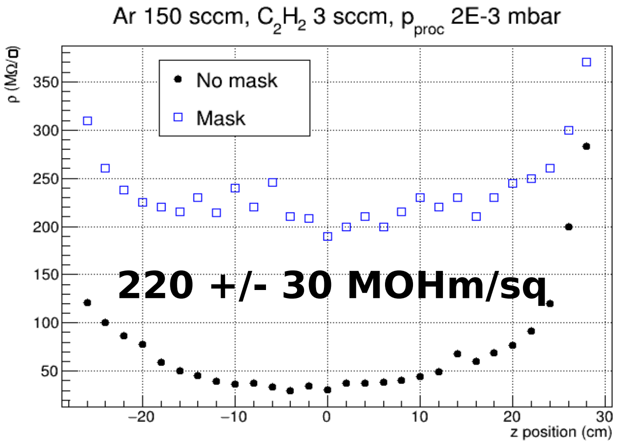
The **CID** (CERN-INFN-DLC) sputtering machine, a **joint project between CERN and INFN**, is used for preparing the **base material of the detector**. The potential of the DLC sputtering machine is:

- **Flexible substrates** up to **1.7×0.6m²**
- **Rigid substrates** up to **0.2×0.6m²**

In **2023,** the activity on CID focused on the **tuning** of the **machine on small foils: good** results in terms of **reproducibility and uniformity.**

In **2024**, the challenge is the **sputtering of large foils:**

- **DLC+Cu** sputtering on 0.8×0.6m² successfully done (May/June 2024)
- **DLC on 1.7×0.6m²** large 0/50/0 Apical foils successfully done (June 2024)
- **DLC on 1.7×0.6m²** large 5/50/0 Apical foils successfully done (July 2024)



Many thanks to the CID team!!

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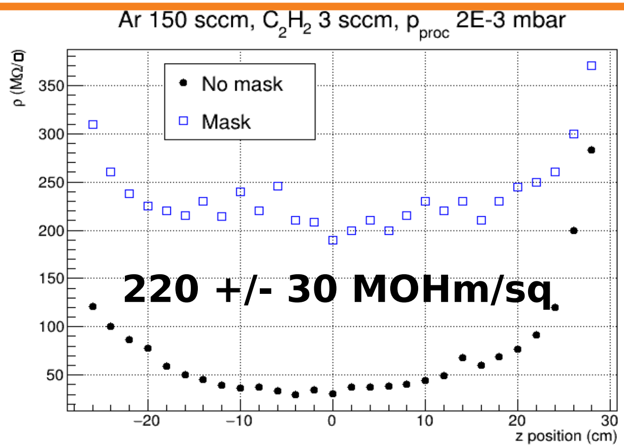

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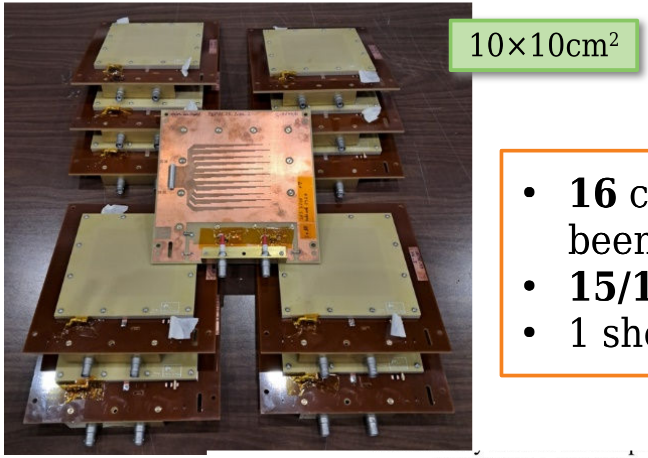
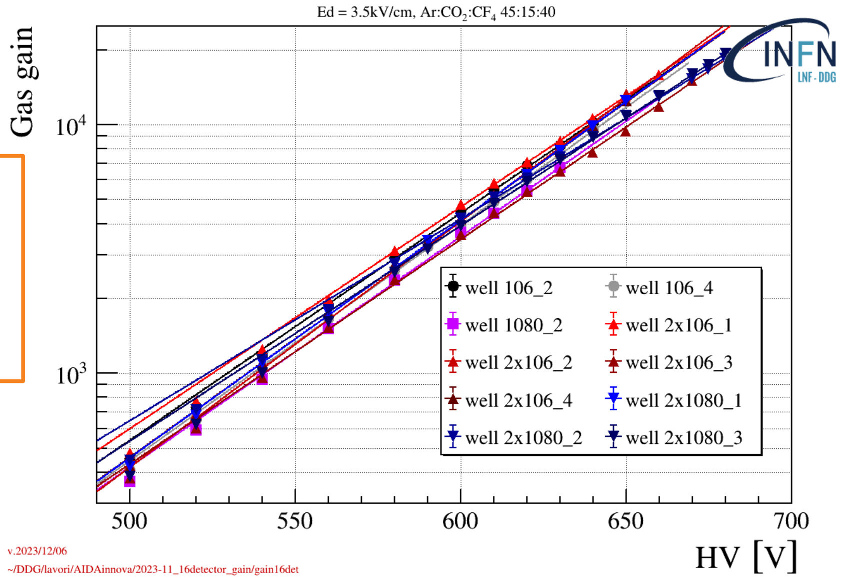
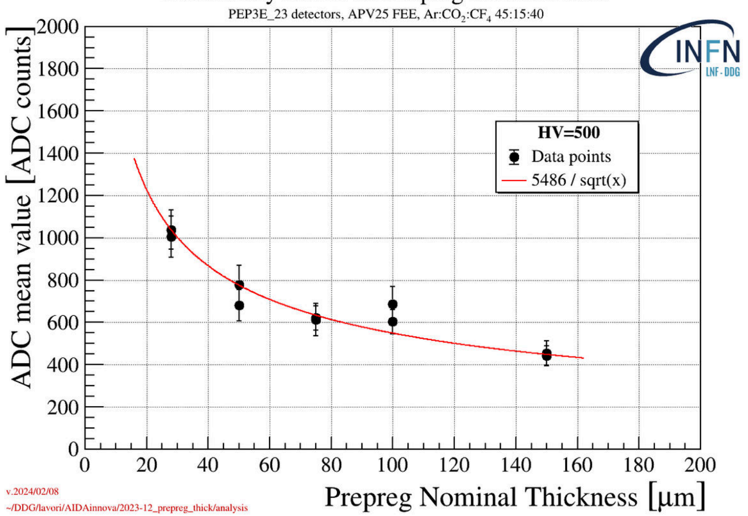
2023 – 10x10 co-production pilot test



- **16** co-produced protos have been **produceded**
- **15/16 are fine → 94% yield**
- 1 should be re-cleaned

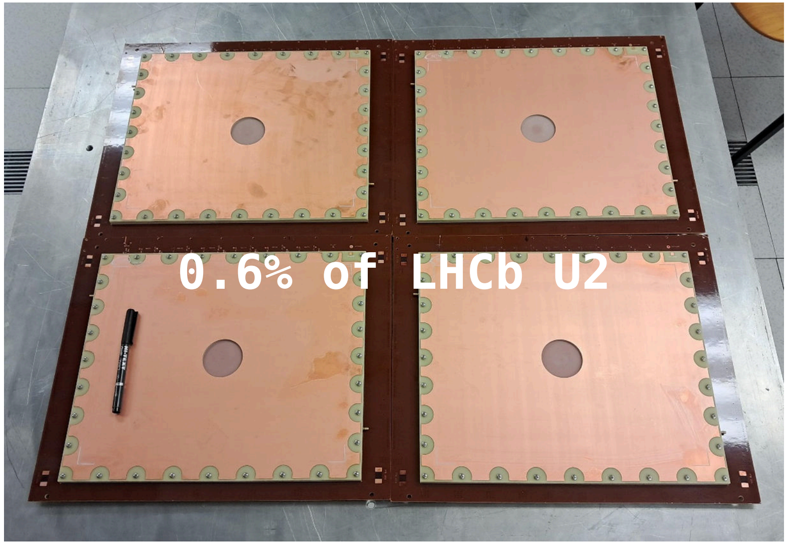




- Characterized with **X-ray gun → Gas gain** measurement
- Measure of the **pulse amplitude** (APV25) vs Gas gain

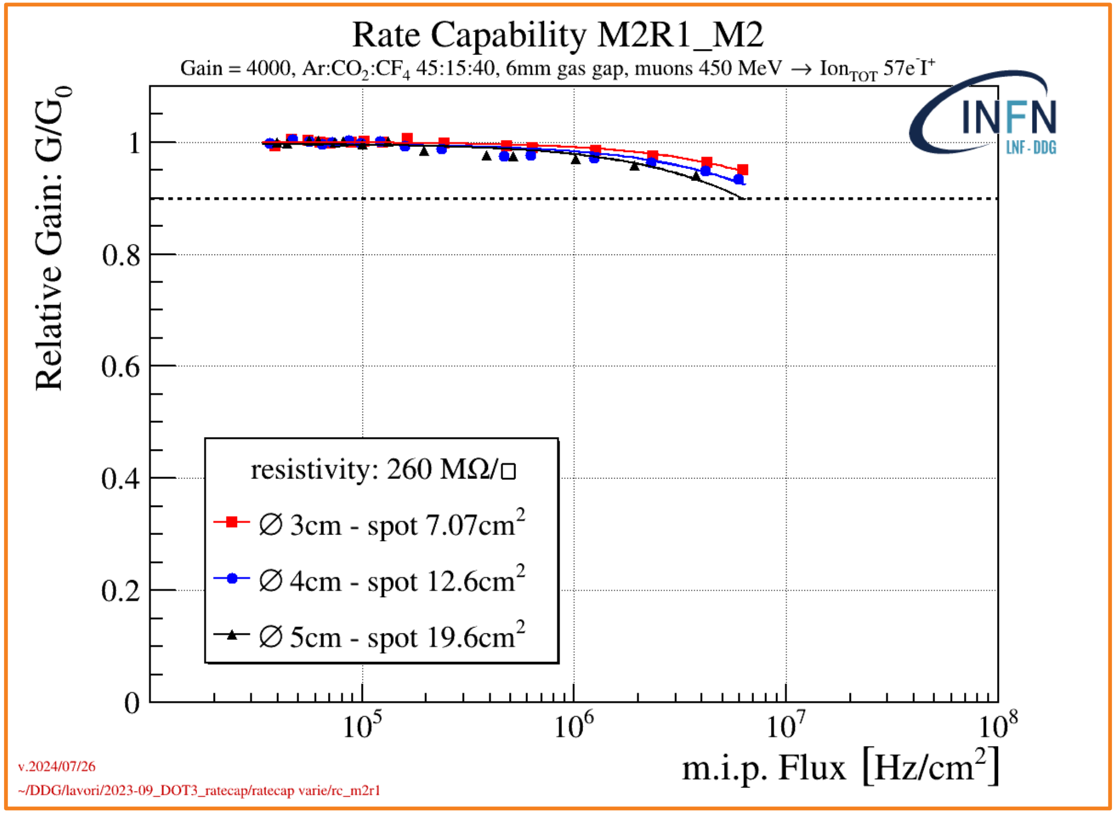
28μm thick prepreg maximize both the **amplitude of the signa**l induced on the pad readout, and **S/N ratio** (measurement done with APV25)

July 2024 - M2R1 prototypes

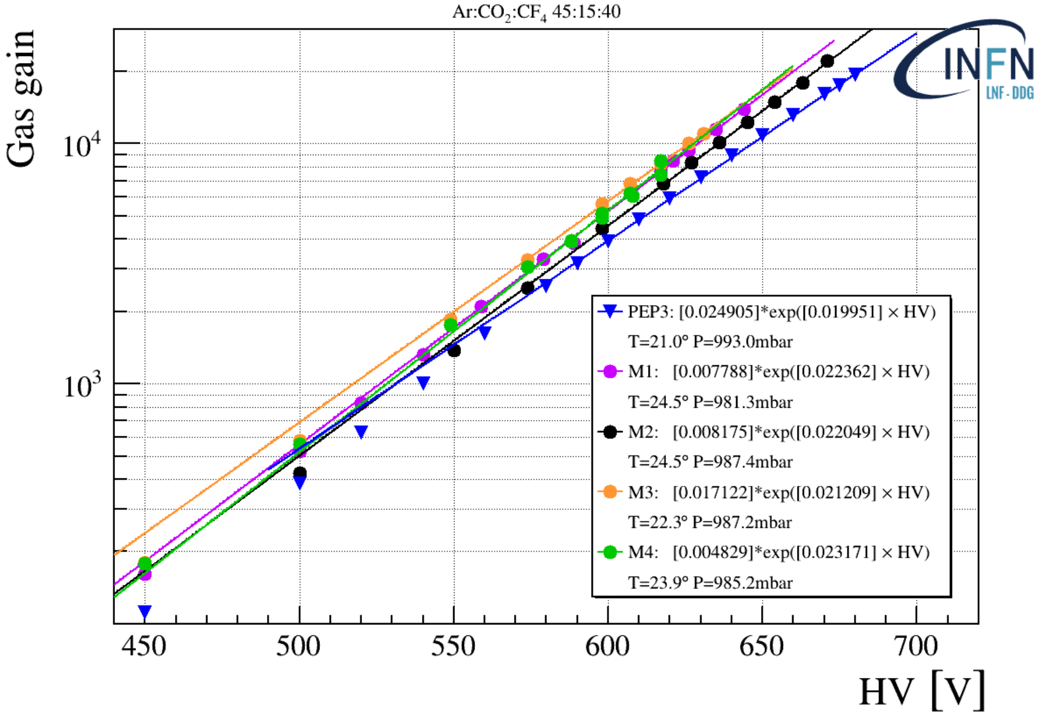


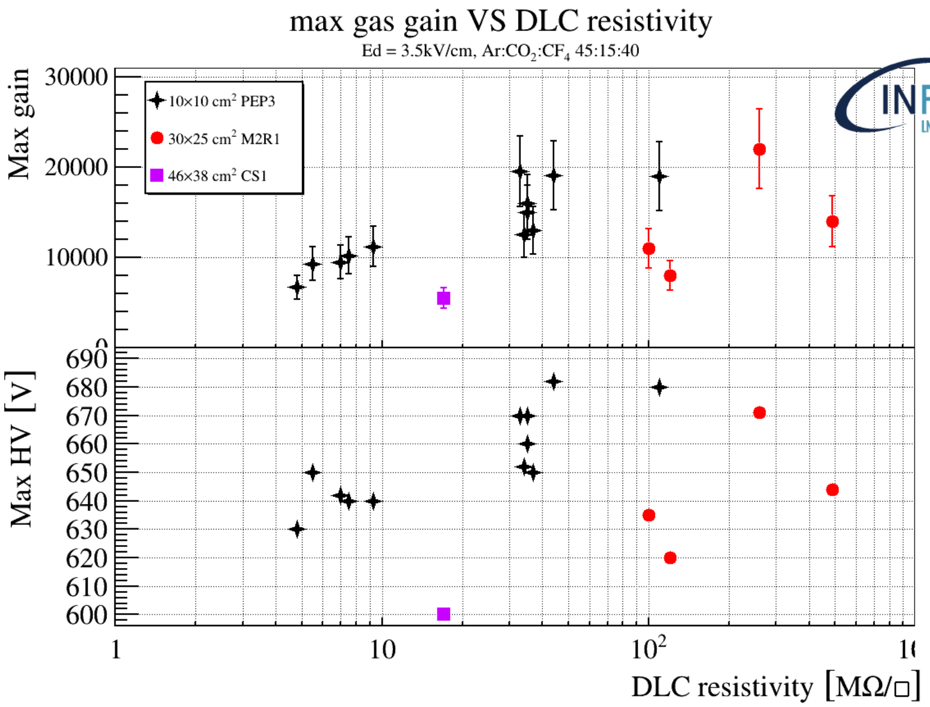
Large size detectors are right now under test

30x25cm² active area
952 R/O pads (9x9mm²)



10x10 and M2R1 - summary





The **gas gain calibration** curve are **very similar**, thus the process for creating the amplification stage is stable and **doesn't depend on the size of the detector.**

Correlation: the **max-gain** increases with the DLC **resistivity**.

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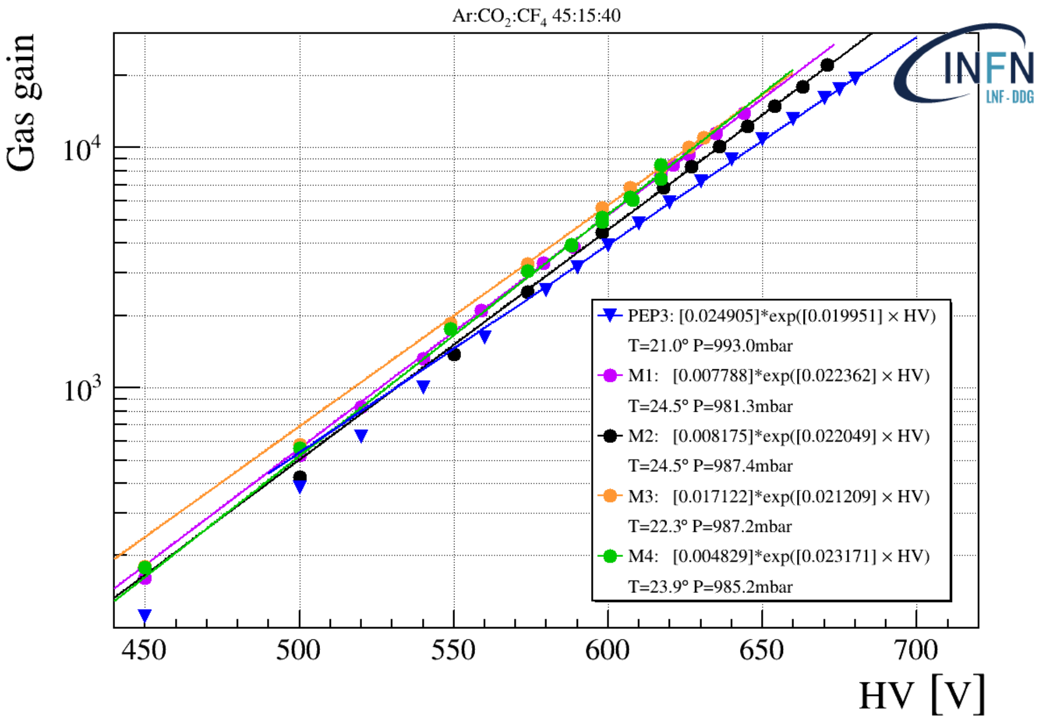

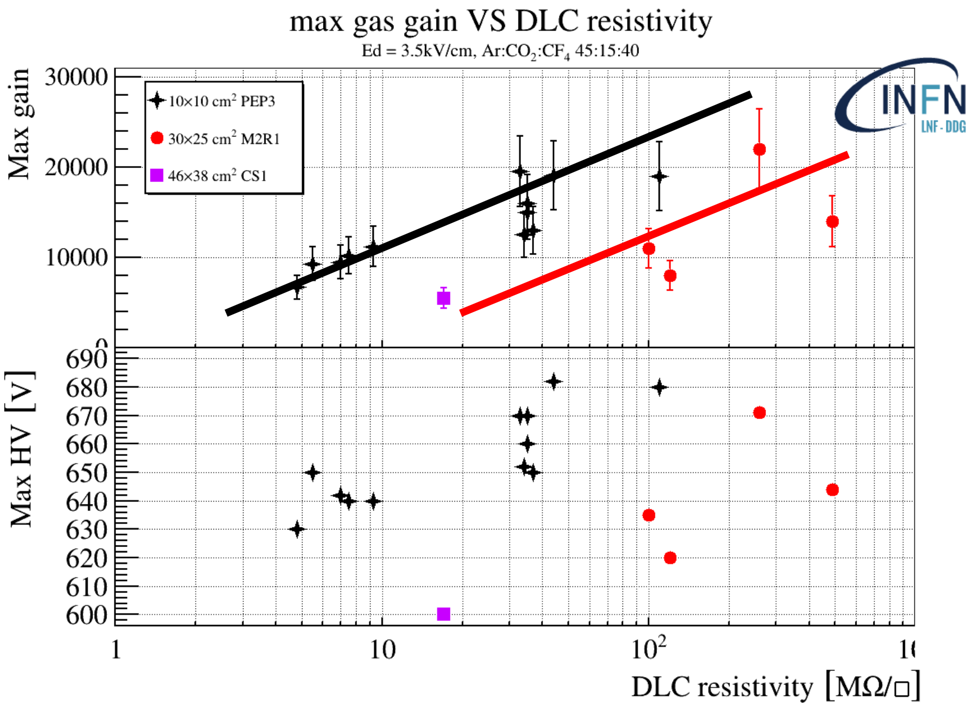

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Correlation: the **max-gain** increases with the DLC **resistivity**.

It seems that large size detector maximum gain islower that the 10x10 one.

Thermal neutron detection

Thermal neutron detection

(with sRPC)

A parallel R&D w.r.t. the µ-RWELL one

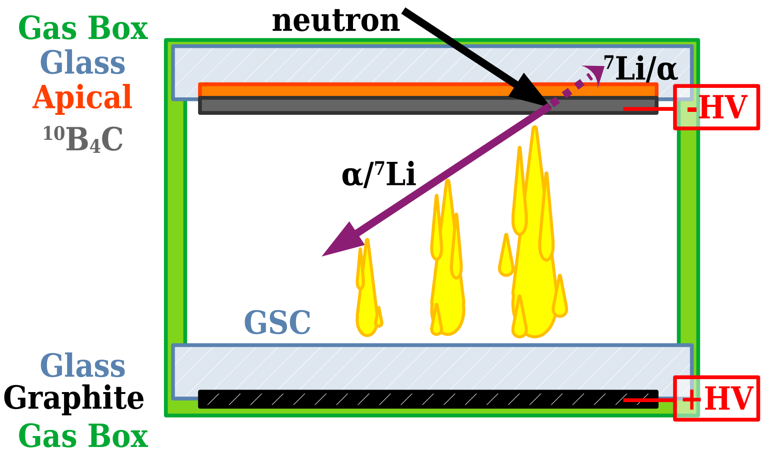
The sRPC hybrid layout

Detecting thermal neutrons (E_k ~25meV) **with $^{10}B_4C$:**
- $^{10}B_4C$ deposition on one of the two detector electrodes (ρ≈2 MΩ/□)
- Neutron converts in ionizing particle: **α/^{7}Li back to back**

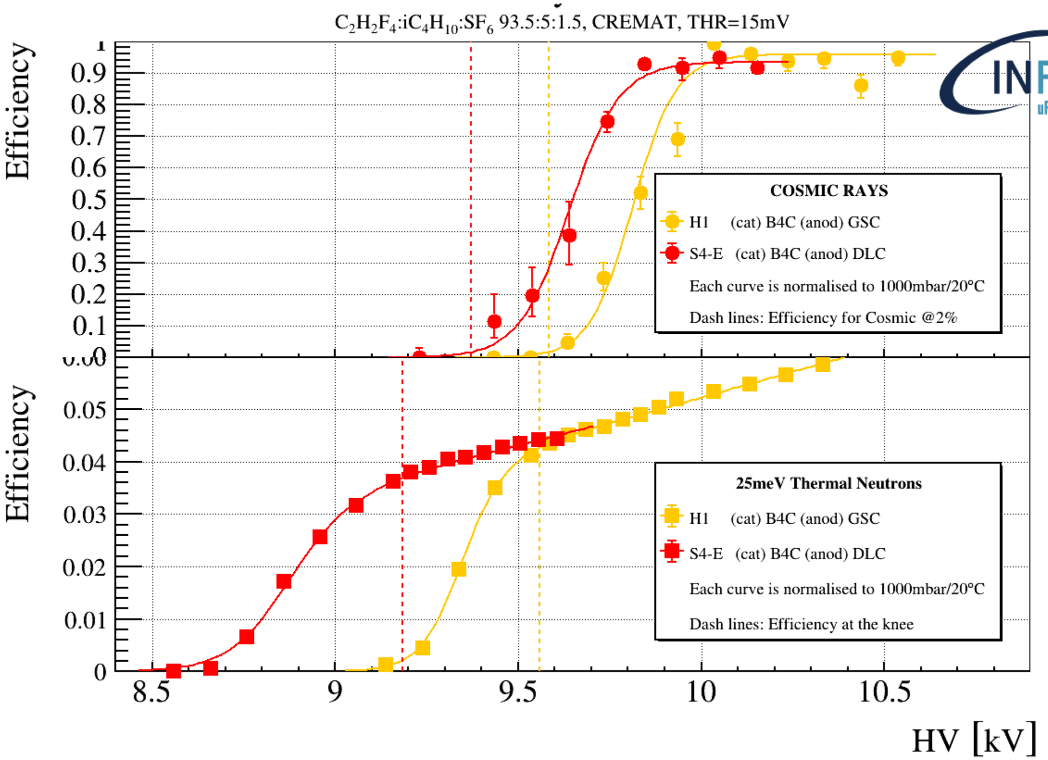
$$n + {}^{10}_{5}B \begin{cases} {}^{7}_{3}Li(1.02MeV) + \alpha(1.78MeV) & 6\% \\ {}^{7}_{3}Li(0.84MeV) + \alpha(1.47MeV) + \gamma(0.48MeV) & 94\% \end{cases}$$

Goal: **simplify the detector layout** and reduce production costs

A new sRPC hybrid layout: **^{10}B4C cathode** and a **float-glass anode** (HV through graphite coating, GSC-like [*]).



Cosmic rays vs 25meV neutrons



[*] M. Anelli et al., Glass electrode spark counters, Nucl. Instr. & Meth. A 300 (1991) 572.

Summary

The μ-RWELL is an established technology, with good performances. Our recent R&Ds focus mainly on increasing the **stability** of the detector and the **semplicity** of the production.

LHCb – the **PEP-DOT** is the most recent high rate scheme
→ The 10x10 prototypes satisfy the LHCb requirements, with a gas gain ≈10^4, a rate capability **O(1MHz/cm^2)** and a good time resolution (**7ns**, up to now dominated by the FEE).

RD-FCC/IDEA – see R. Farinelli's talk → μ-RWELL muon system and pre-shower for FCC-ee
→ **GEM preamp** stage: high gas gain (**6·10^4**), expected good performance with a COMPASS-like R/O

C-WELL – R&D completed with the proof of concept of the detector
→ The **modular geometry** works correctly, it was validated with **cosmic rays tracks**

Technology Transfer **–** establishing the PEP-DOT pipeline with ELTOS and CERN
→ The **DLC machine** team is able to sputter **large size foils** with **DLC** or **DLC+Cu**
→ Four **30x25cm^2 high rate μ-RWELLs** are right now under test. A Beam Test is planned in Novemember.

Thermal Neutron Detection – Thermal neutron detectors based on Resistive Gaseous Detectors and $^{10}B_4C$ converters have been successfully developed & tested.
→ The sRPC hybrid layout (GSC-like anode) shows good stability and promising results

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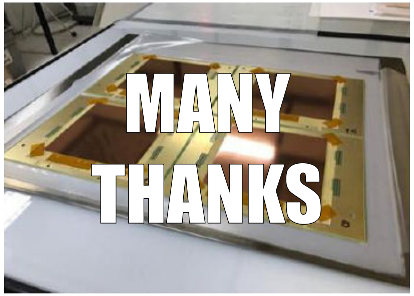

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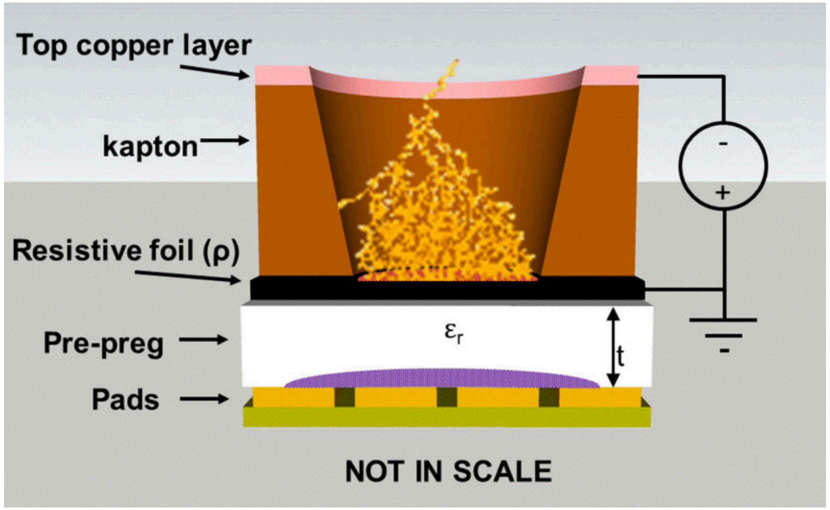
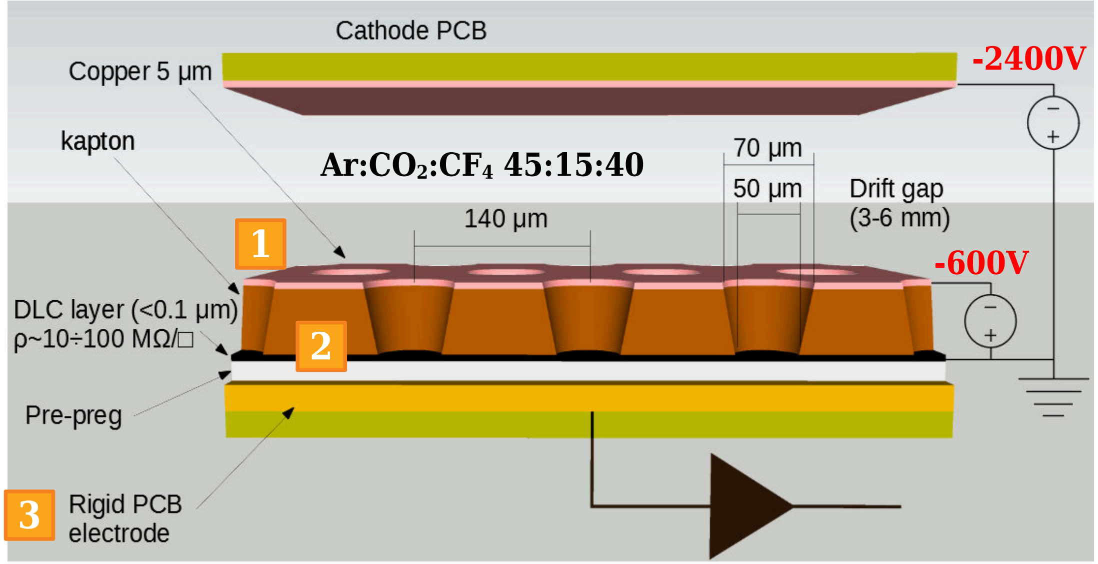
Spare

The µ-RWELL: detector scheme

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.

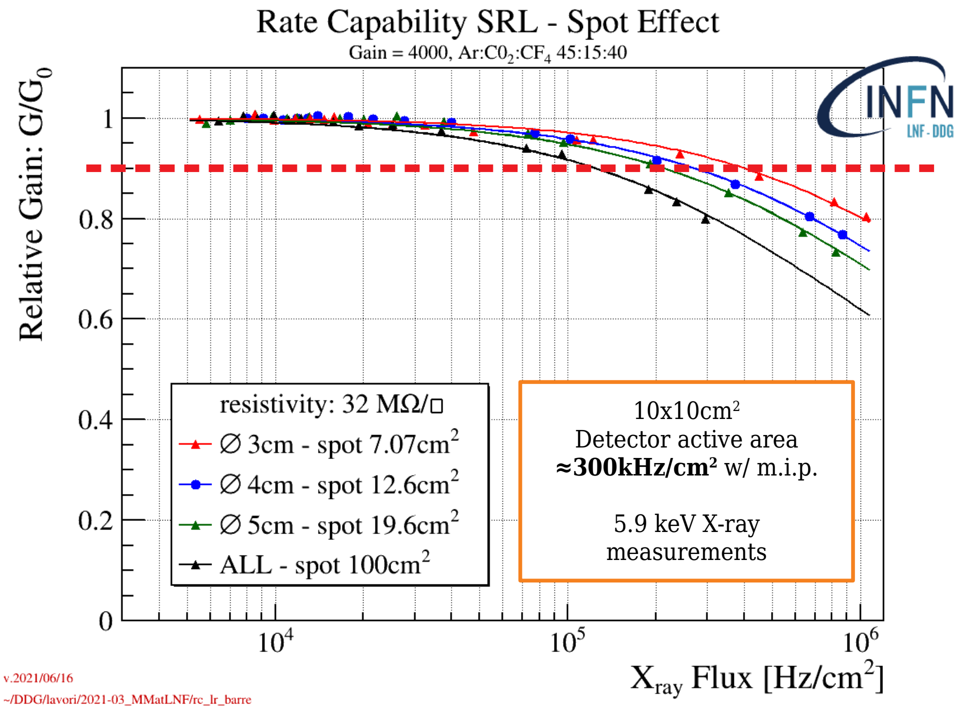


1 **a WELL** patterned kapton foil acting as **amplification stage** (GEM-like)

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

3 a standard readout PCB

The SRL resistive model



FLOW: DATA $\frac{G}{G_0} \rightarrow p_0$ → Extrapolation $\Omega \rightarrow \phi_{90\%}$

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

Prediction

$$\Omega(r) = \rho_S \frac{d - \frac{r}{2}}{\pi \cdot r}$$

$$\phi_{90\%} = \frac{\Delta V_{drop\,10\%}}{e \cdot N_0 \cdot G \cdot Spot \cdot \Omega}$$

← **ΔV$_{\text{drop 10\%}}$** from the gain measurement

$$\phi_{90\%} \approx \frac{1}{\rho_S \cdot r\,(d - r/2)}$$

Validation

$$\frac{G}{G_0} = \frac{-1 + \sqrt{1 + 4p_0\phi}}{2p_0\phi}$$

SPOT [cm^2]	p_0
12.6	1.4656E-6
19.5	2.0224E-6

$$\Omega(r) = \frac{p_0(r)}{\alpha \cdot e \cdot N_0 \cdot G \cdot \pi \cdot r^2}$$

G. Bencivenni et al., JINST 10 (2015) P02008

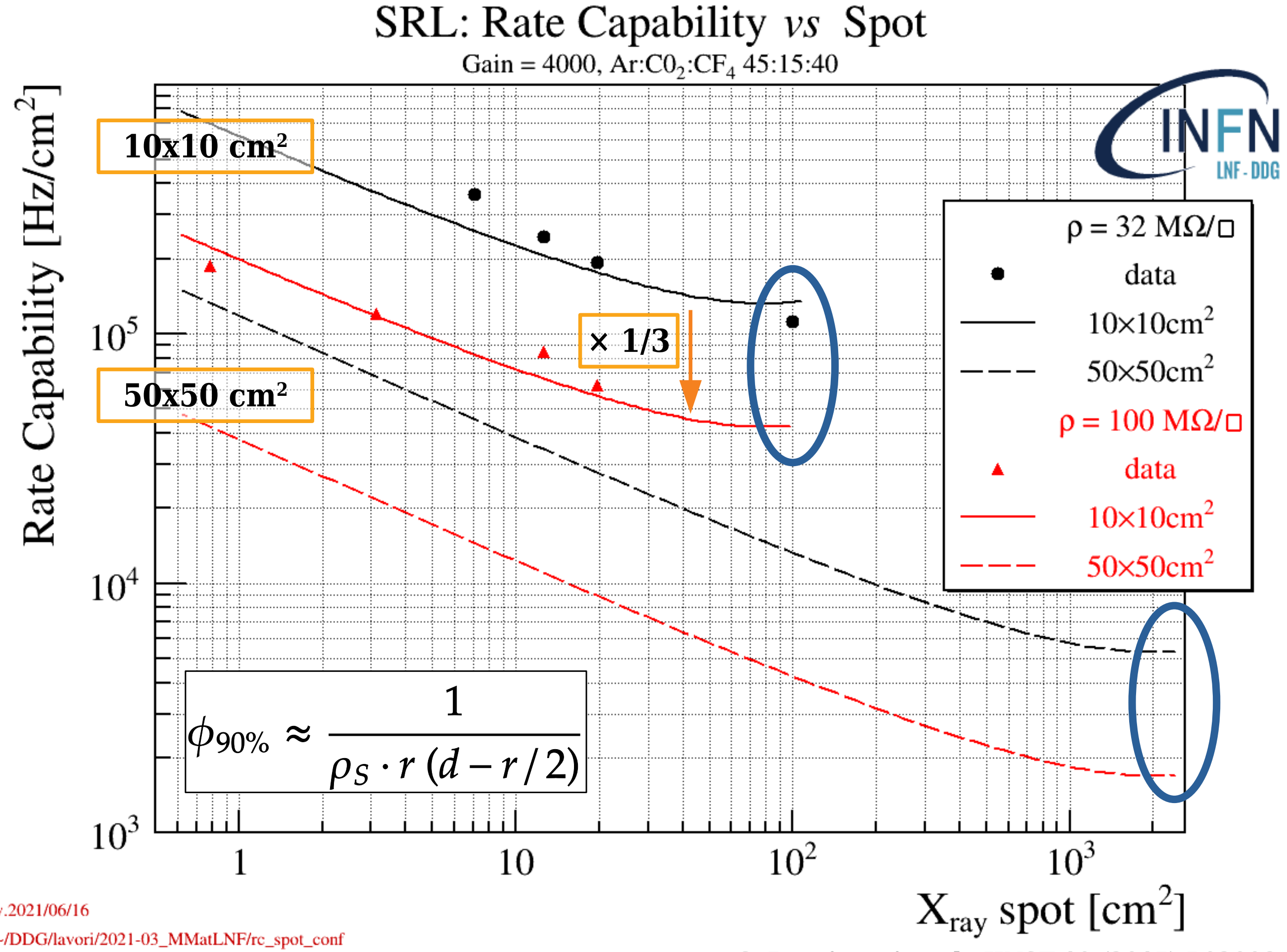
Rate capability vs spot-size & detector size

Comparison between a **model** of the resistive stage and **measurements** of the rate capability for SRL

1. detectors with same size (d) but different resistivity exhibit a rate capability scaling as the inverse of their resistivity.

2. for the SRL, increasing the active area from 10x10 cm2 to 50x50 cm2 the rate capability should go down few kHz/cm².

3. By using a **DLC** ground **sectoring every 10 cm**, large (50x50cm2) detectors could achieve **rate capability up to 100kHz/cm²** (with X-ray).



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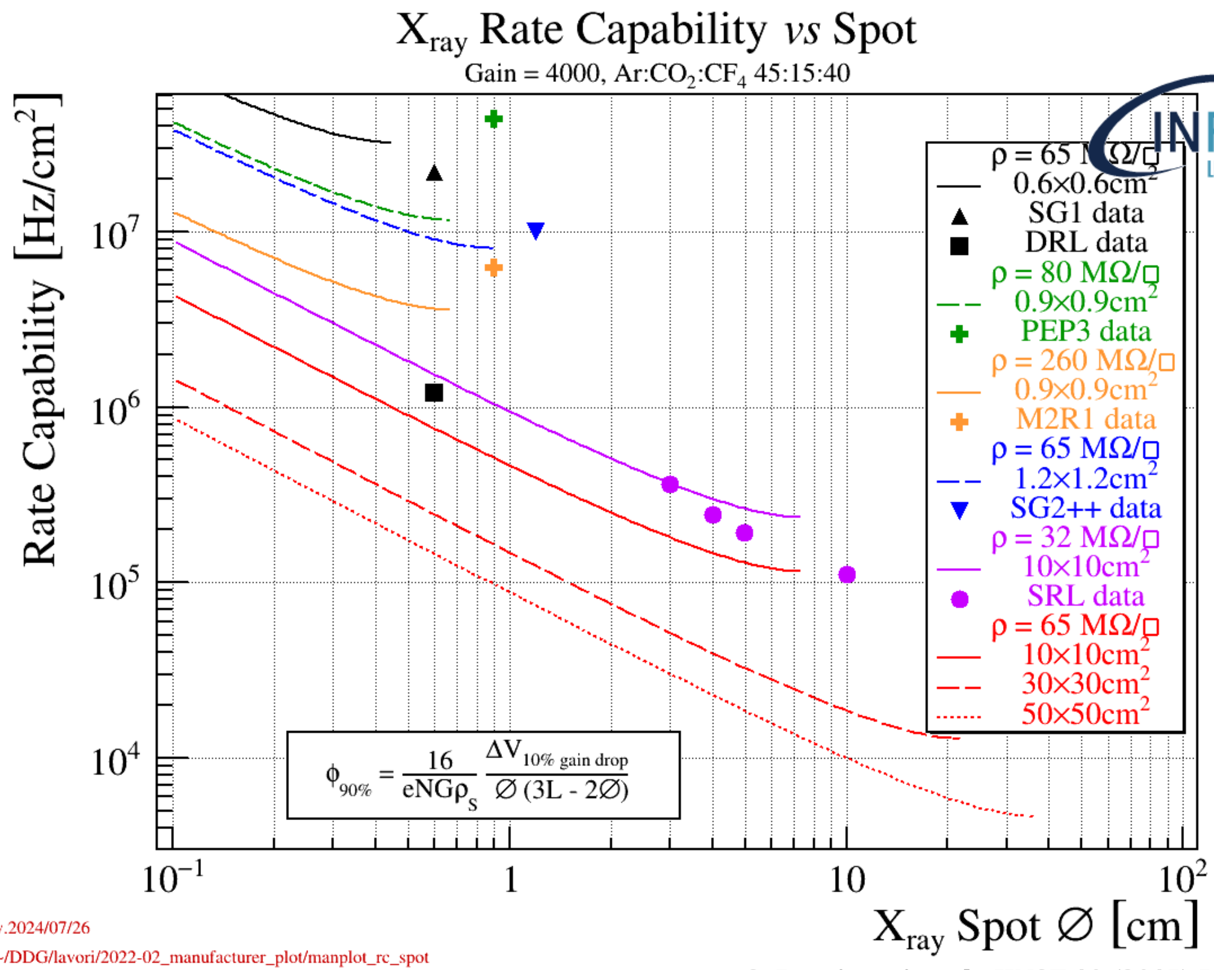

G. Bencivenni et al., JINST 10 (2015) P02008

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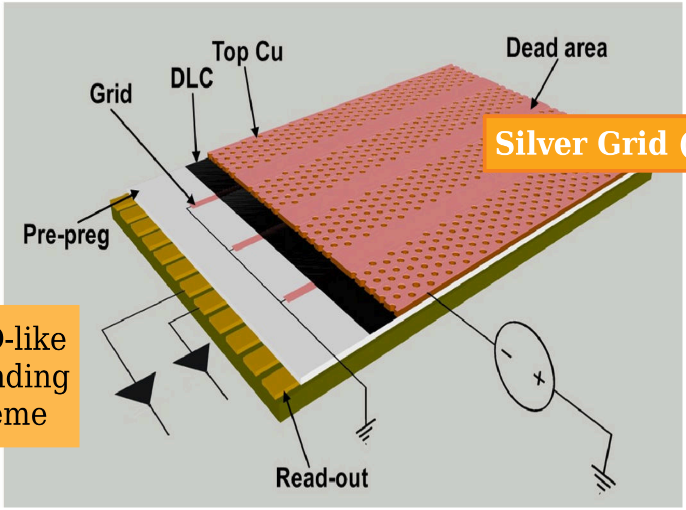
The High Rate layouts

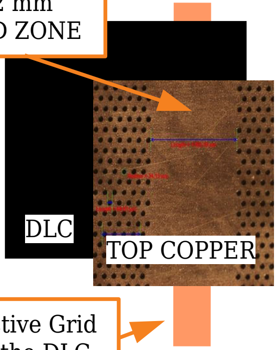
2017



Silver Grid (SG)

GRID-like Grounding scheme

1.2 mm DEAD ZONE



Conductive Grid Under the DLC

A **conductive grid** is patterned on the back of special DLC foils **(DLC + Cu technology: delicate manufacturing process)**.

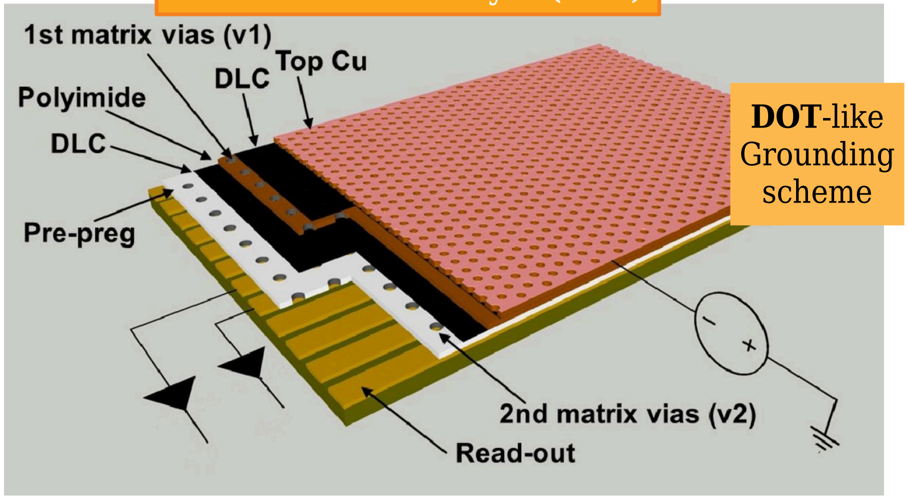
Necessity to introduce a **small DEAD AREA** above the grid, to avoid discharges (tuned to be 5% of the total area).

NOT SCALABLE to large size: distortions and alignment problems **during manufacturing.**

IS POSSIBLE to **check the resistance** of the layer after the detector is built

2018

Double Resistive Layer (DRL)

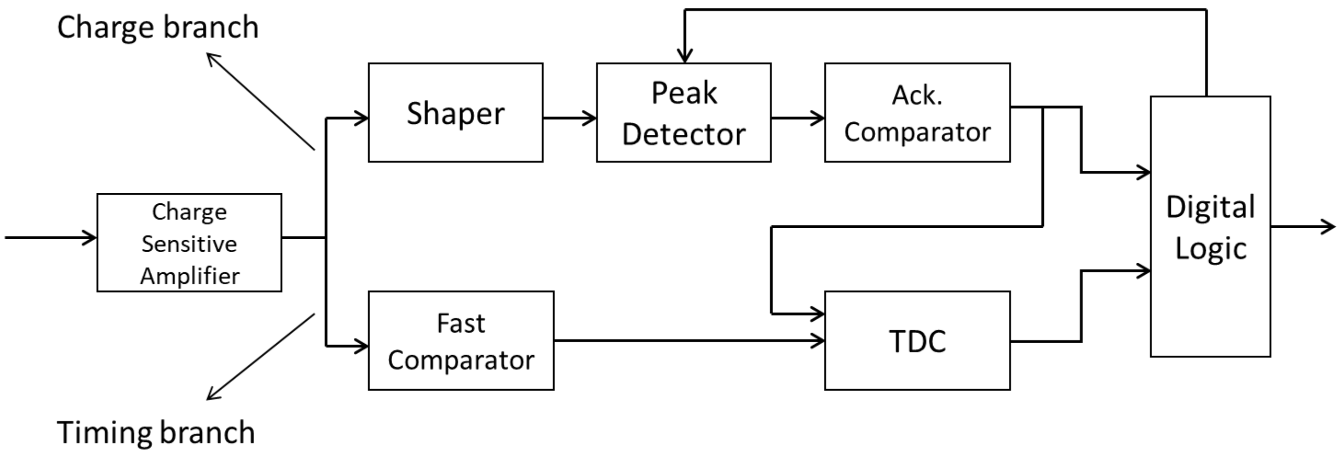


DOT-like Grounding scheme

Based on a **3-D** current evacuation scheme:
Two stacked resistive layer connected through a **matrix of conductive vias,** grounded through a further matrix of vias to the underlying readout electrodes.

MORE COMPLEX to buid **than SG** but reliable (for now only 10x10 prototypes).
NOT POSSIBLE to check the resistance of the two layers after the manifacture.

FATIC2 block diagram



Preamplifier features:
- CSA operation mode
- Input signal polarity: positive & negative
- Recovery time: adjustable

CSA mode:
- Programmable Gain: 10 mV/fC ÷ 50 mV/fC
- Peaking time: 25 ns, 50 ns, 75 ns, 100 ns

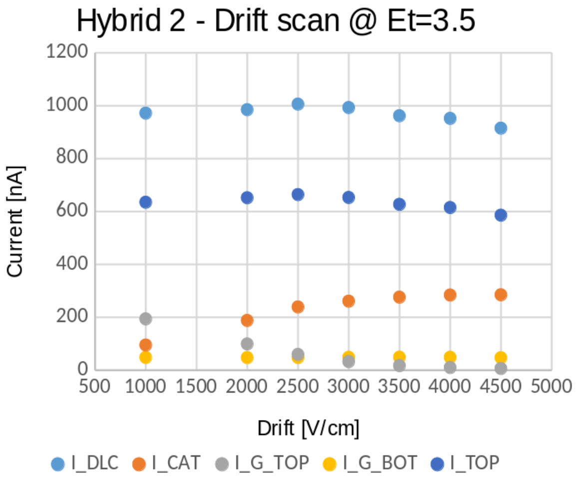
Timing branch:
- ✓ Measures the arrival time of the input signal
- ✓ Time jitter: 400 ps @ 1 fC & 15 pF (Fast Timing MPGD)

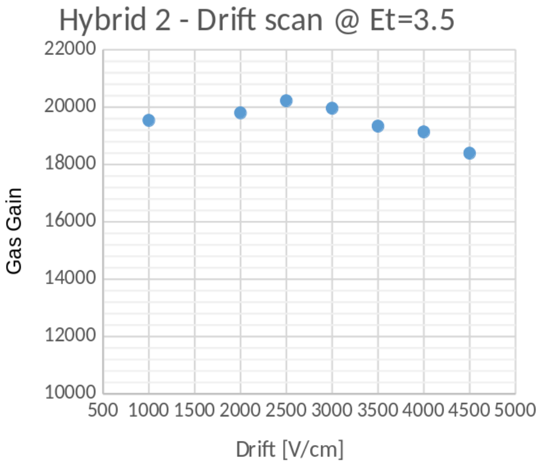
Charge branch:
- ✓ Acknowledgment of the input signal
- ✓ Charge measurement: dynamic range > 50 fC, programmable charge resolution

Hybrid – Ed Et scan

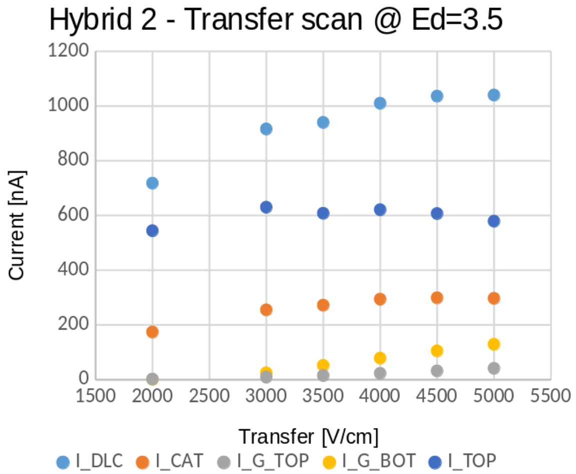
VERY PRELIMINARY: 9-Oct-2024

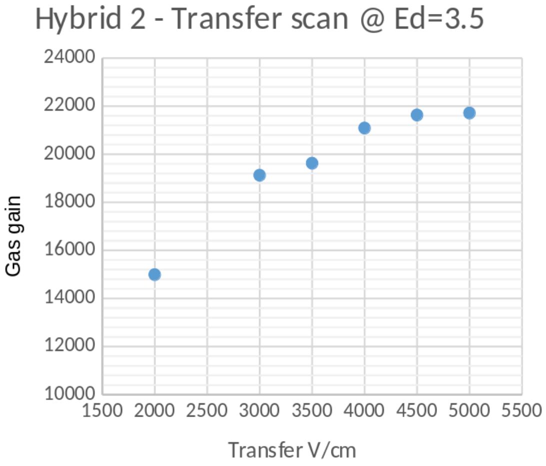
Drift gap: 6mm





Transfer gap: 3mm





X0 for Low Mass µ-RWELL

		Thikcness (um)	X0 (cm)	% X0
Anode Support	Cu Ground FEE	3	1.43	0.021
	kapton	50	28.6	0.017
	glue	25	33.5	0.007
	FR4	100	19.3	0.052
	glue	25	33.5	0.007
	MILLIFOAM	3000	1312.5	0.023
	glue	25	33.5	0.007
	FR4	100	19.3	0.052
				0.187

Amp. stage	Cu	5	1.43	0.035
	kapton	50	28.6	0.017
	DLC	0.1	12.1	0.000
	Pre-preg (106)	50	19.3	0.026
				0.078

Anode 2D	Cu	5	1.43	0.035
	kapton	50	28.6	0.017
	glue	25	33.5	0.007
	Cu	5	1.43	0.035
	kapton	50	28.6	0.017
				0.112

Tile BaseLine	Glue	0	33.5	0.000
	kapton	0	28.6	0.000
	Glue	0	33.5	0.000
	MILLIFOAM	0	1312.5	0.000
	Glue	0	33.5	0.000
	Kapton	0	28.6	0.000
				0.000
			Tot. Anode	0.378

Far. Cage + Cathode Support + Cathod	Cu	3	1.43	0.021
	kapton	50	28.6	0.017
	glue	25	33.5	0.007
	FR4	100	19.3	0.052
	glue	25	33.5	0.007
	MILLIFOAM	3000	1312.5	0.023
	glue	25	33.5	0.007
	FR4	100	19.3	0.052
	glue	25	33.5	0.007
	kapton	50	28.6	0.017
	Cu Ground	3	1.43	0.021
				0.233
			X0 - single	0.611
			X0 B2B	0.99

ELTOS production – DLC patterning

Step 2:

1) R/O **PCB** production

Step 3:

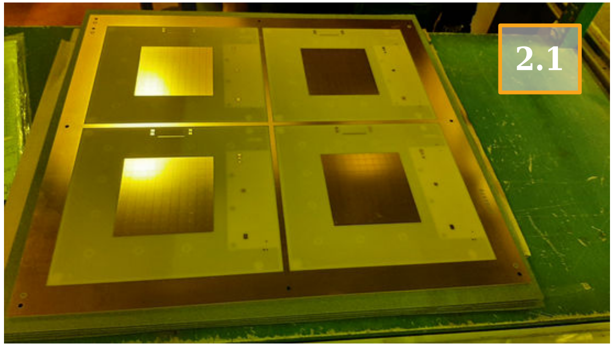
2) Photoresist **lamination** for DLC protection

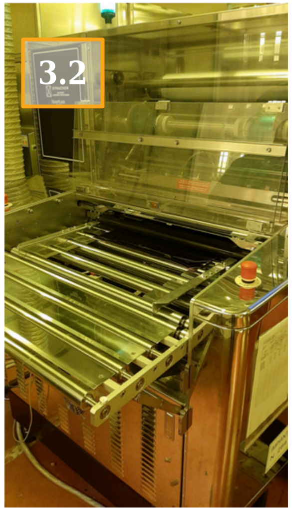
3) Photoresist UV-**exposure**

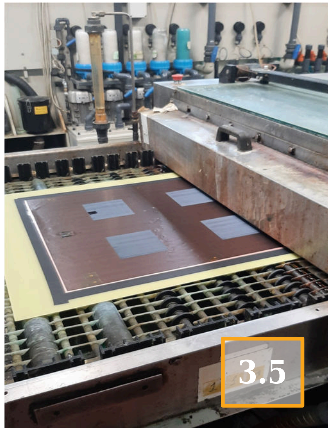
4) Photoresist **development**

5) **DLC patterning** with brushing machine

(@CERN different approach: JET-SCRUBBING)





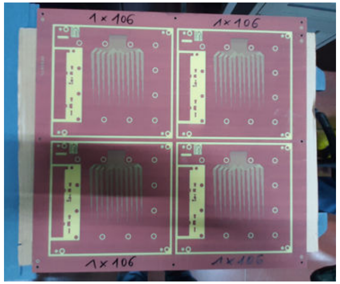


ELTOS production – DLC-foil gluing

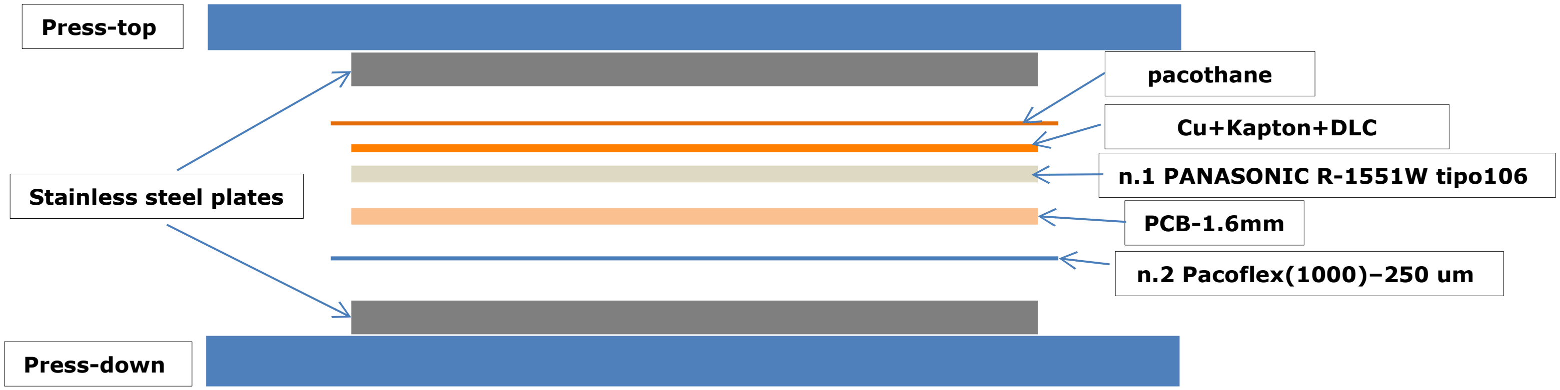
Step 4: Cu-Kapton-DLC gluing on PCB

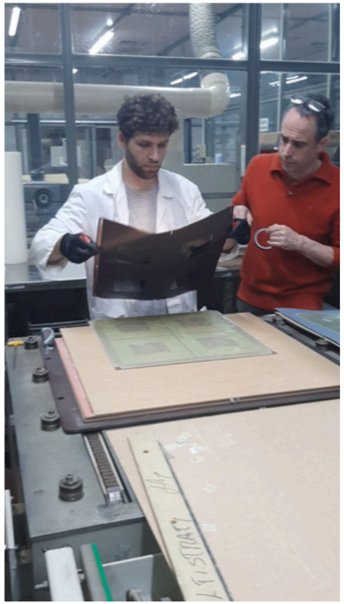
- 16 PEP-dot detectors (9×9mm^2 pad R/O), with **different pre-preg thickness**
- **11/16** detector **delivered/tested** up to now
- Study of signal **pulse amplitude vs coupling capacitance** between DLC and R/O pad.

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

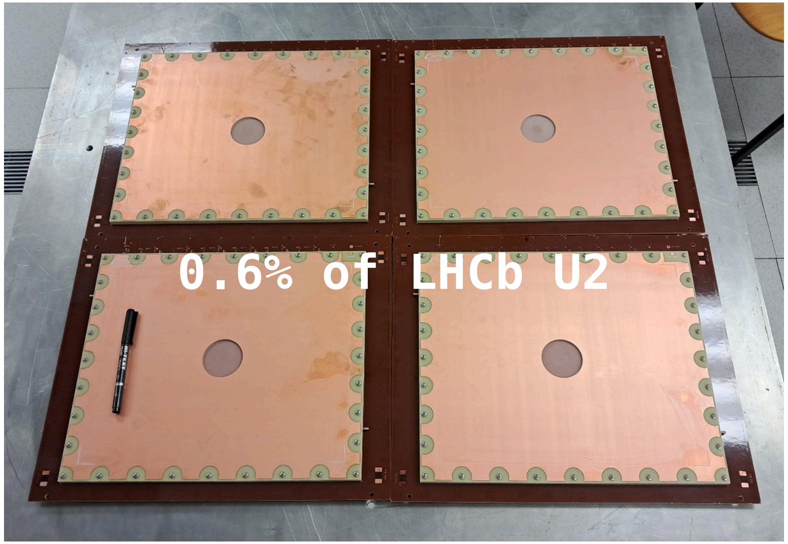


Main parameters:
Pressure 180 N/cm^2
Temperature 210 °C

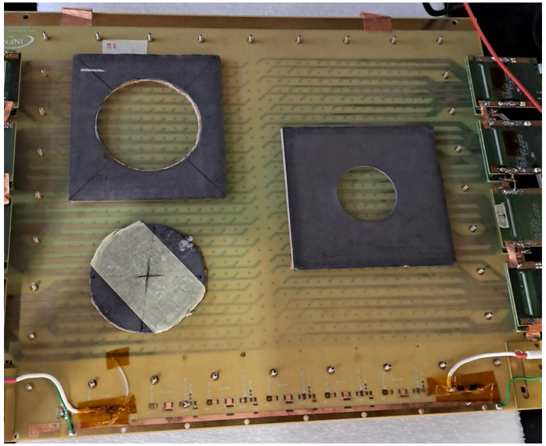


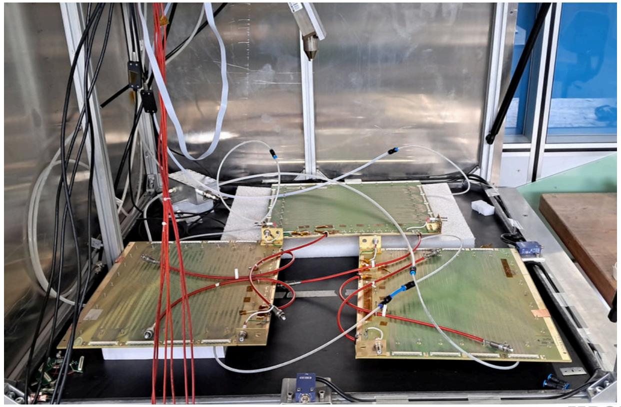


July 2024 - M2R1 prototypes



Large size detectors are right now under test
30x25cm² active area
952 R/O pads (9x9mm²)





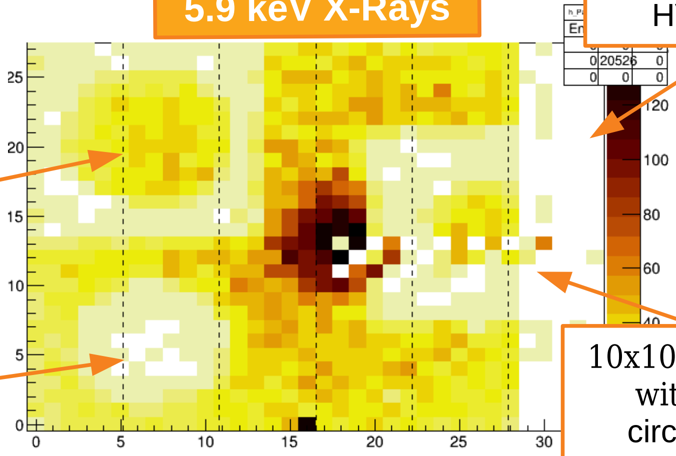
5.9 keV X-Rays

A disconnected HV sector

10x10cm² square with ⌀8cm circular hole

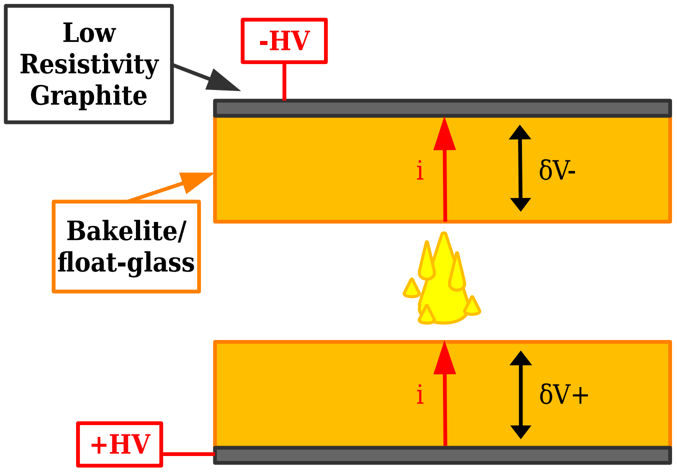
Circle ⌀8cm

10x10cm² square with ⌀5cm circular hole



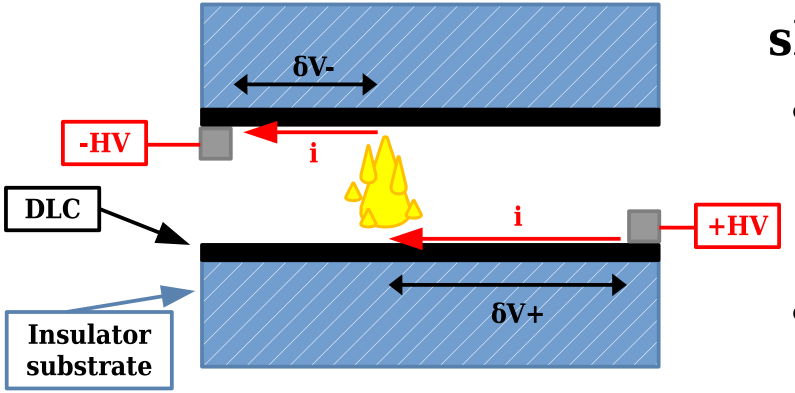
w/ APV25 internal trigger

The sRPC – Surface vs Bulk



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

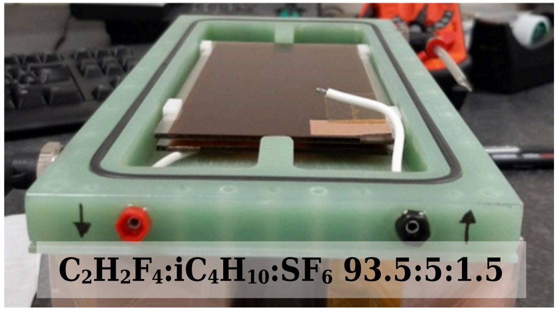
- Surface resistivity electrodes manufactured with sputtering techniques of Diamond-like-carbon (DLC) on flexible supports
  - The technology allows to realise large electrodes with a DLC **surface resistivity** in a **very wide range: 10 MΩ/□ ÷ 10 GΩ/□**
- High density current evacuation schemes, similar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

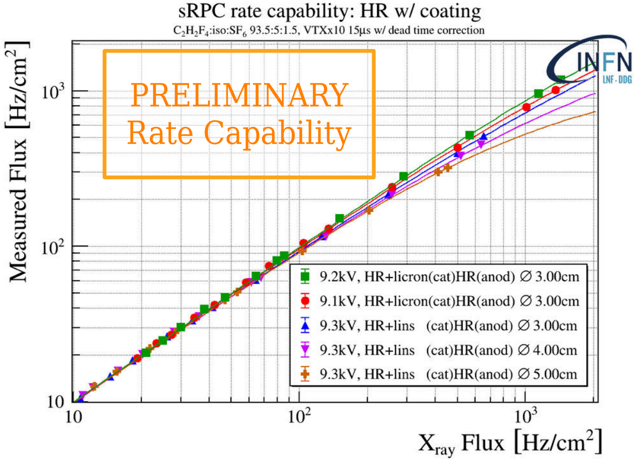
The sRPC – an MPGD-tech based RPC

Glass 140×78 mm^2
DLC 120×64 mm^2

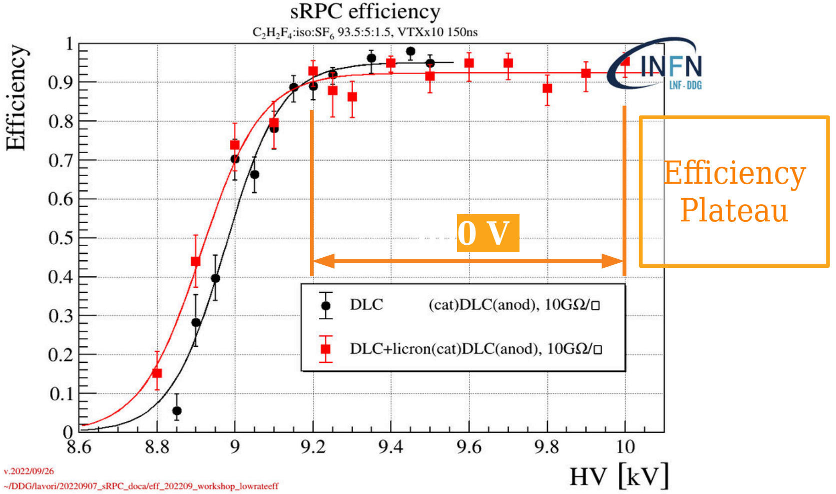
DLC-based RPC:

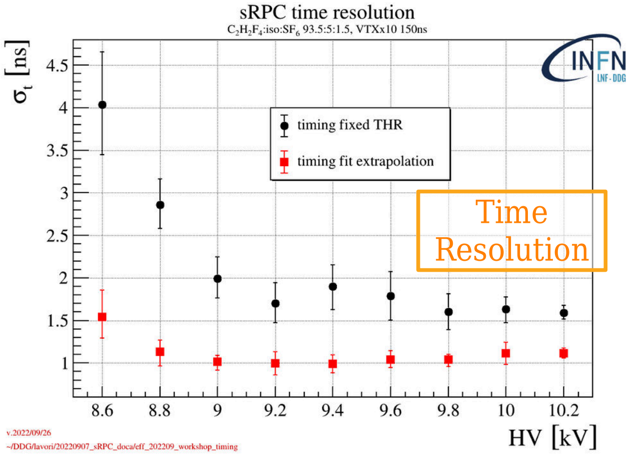
- **From bulk resistivity to surface resistivity**: easy tunable resistivity w.r.t. bakelite or glass
- µ-RWELL inspired **High Rate schemes**
- Flexible substrate





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





G. Bencivenni et al., 2023 JINST 18 C06026

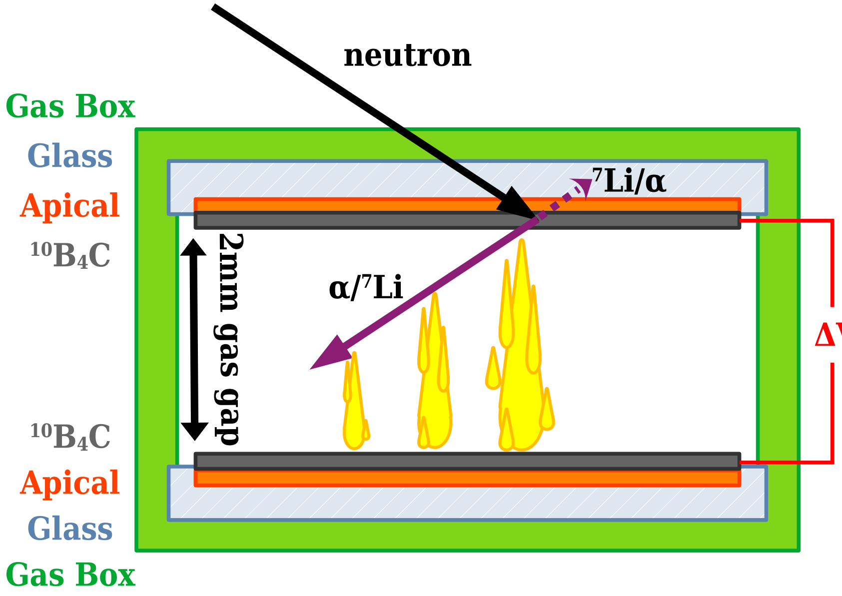
sRPC for thermal neutron detection

Detecting thermal neutrons (E_k ~25meV) **with $^{10}B_4C$:**

- $^{10}B_4C$ deposition on one of the two detector electrodes (ρ≈2 MΩ/□)
- Neutron converts in ionizing particle: **α/^{7}Li back to back**

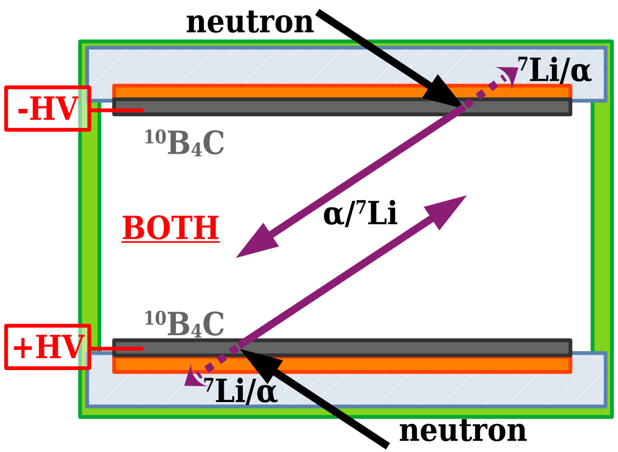
$$n + {}^{10}_{5}B \begin{cases} {}^{7}_{3}Li(1.02MeV) + \alpha(1.78MeV) & 6\% \\ {}^{7}_{3}Li(0.84MeV) + \alpha(1.47MeV) + \gamma(0.48MeV) & 94\% \end{cases}$$

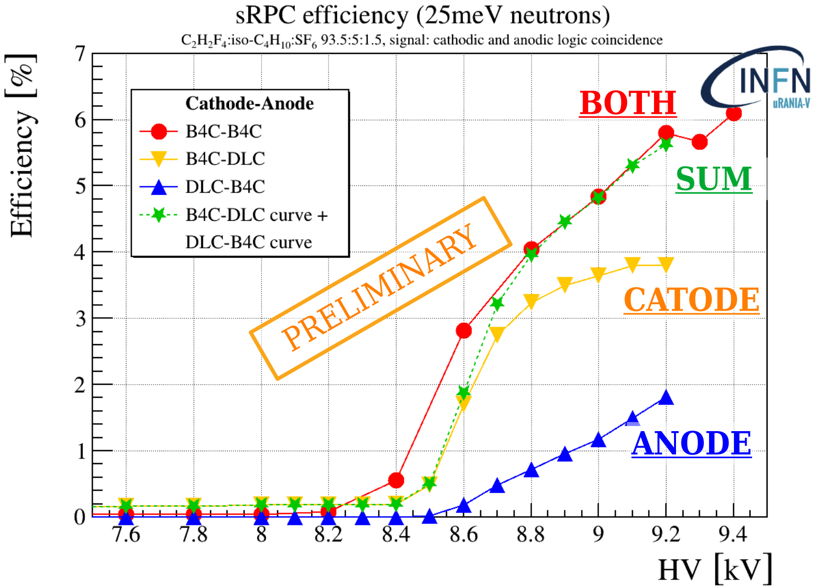
- $^{10}B_4C$ planar converter thickess optimization from µ-RWELL experience: **2.5 µm** thick → expected 4**% efficiency**
  - Expected **ε~8% for single sRPC** (2 converter electrodes)
  - Simple detector → possible to make a stack w/ more layer
- sRPC as neutron detector is operated at much lower voltage than for m.i.p. due to the larger ionization of α and ^{7}Li (≈20k e^-I^+ pairs)

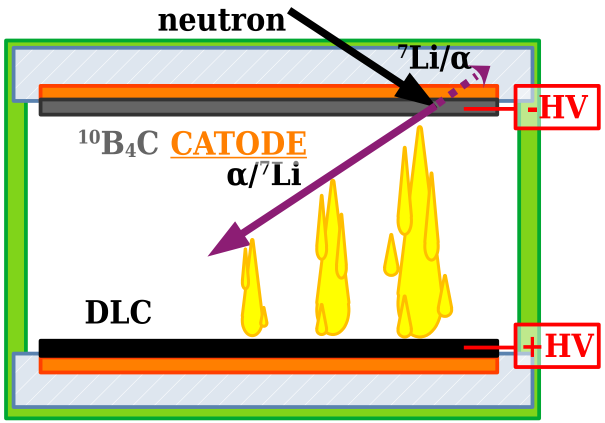


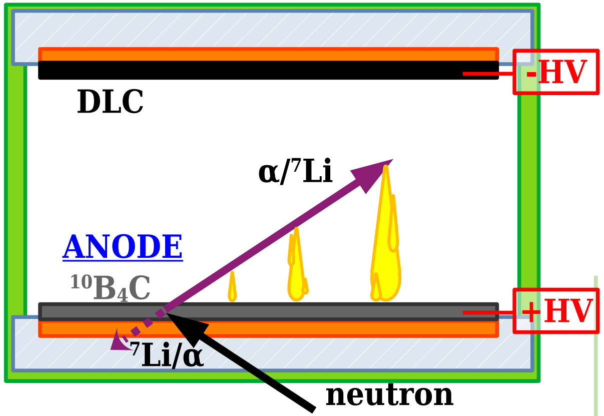
- α/^{7}Li emission is **uniform**
  ⇒ they enter the gas gap with a random angle.
- α/^{7}Li **mean path** is **shorter than 2mm**
  ⇒ cathode and anode have different behaviours

uRANIA sRPC – first results









Measured performed at HOTNES thermal neutron source, w/ 3 prototypes.

- $^{10}B_4C$ CAT – DLC AN : the expected 4% plateau was reached
- DLC CAT – $^{10}B_4C$ AN : efficiency strongly depends on the HV/gain due to small signals
- $^{10}B_4C$ CAT – $^{10}B_4C$ AN : the “double $^{10}B_4C$ prototype performs as the SUM of the two