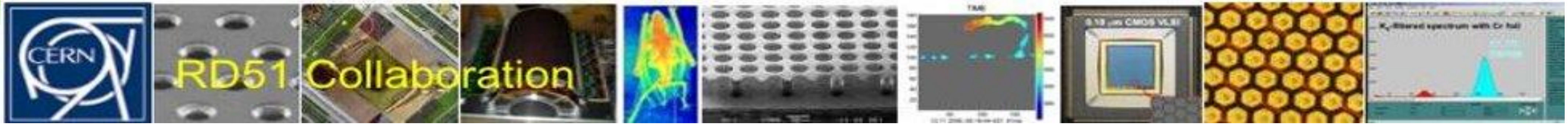


The μ-RWELL technology for the IDEA MUON and pre-shower system

G. Bencivenni (*)

On behalf of
Bologna, Ferrara, LNF, Torino WP5-RDFCC

(*) Laboratori Nazionali di Frascati – INFN, Frascati (IT)

INFN LNF - DDG

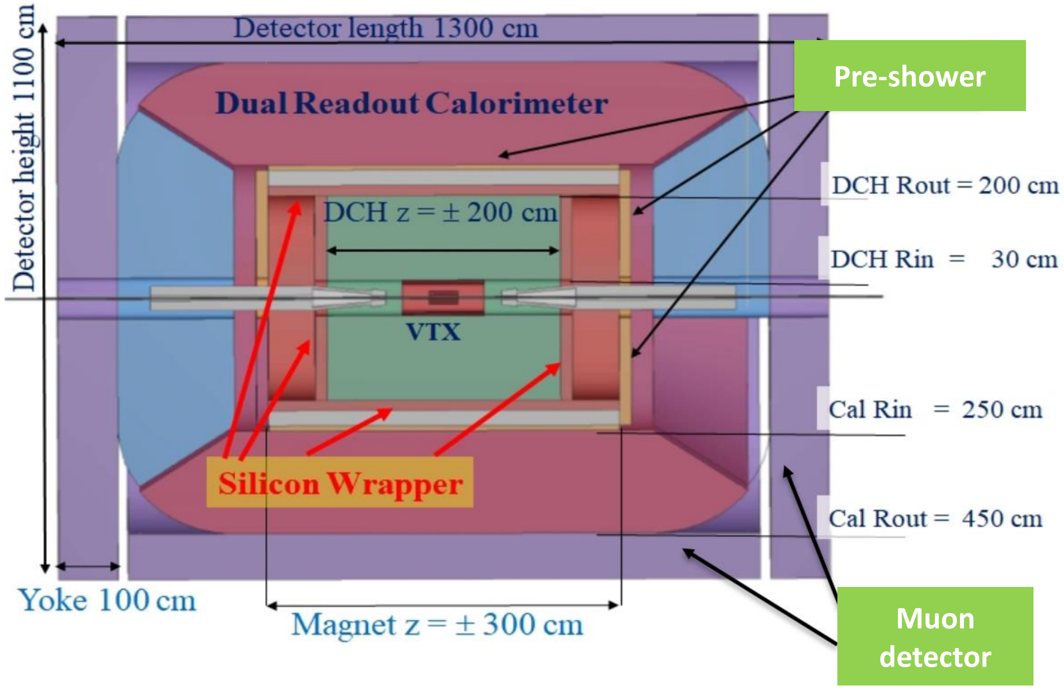
AIDA innova

2nd FCC Italy-France Workshop, Venezia 4th Nov 2024

IDEA apparatus & the μ-RWELL

Pre-shower: high resolution detector after the magnet to maximize the energy resolution of the dual readout calorimeter and tag π^0 and γ.

Muon system: reconstruct and tag the muon using three layers within the iron return yoke, and reconstruct the LLP.



Requirements

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

Instrumented surface/FEE

Preshower:
- 130m², 520 det., 3x10⁵ chs. (0.4 mm strip pitch)

Muon:
- **1500m², 6000 det., 5x10⁶ chs., (1.2mm strip pitch)**

GOALS

- **Reliability ⊕ high gain**
- **Easy Manufacturing**
- **Mass production** → Technology Transfer to Industry
- **FEE cost reduction** → custom made ASIC

The µ-RWELL: the layout

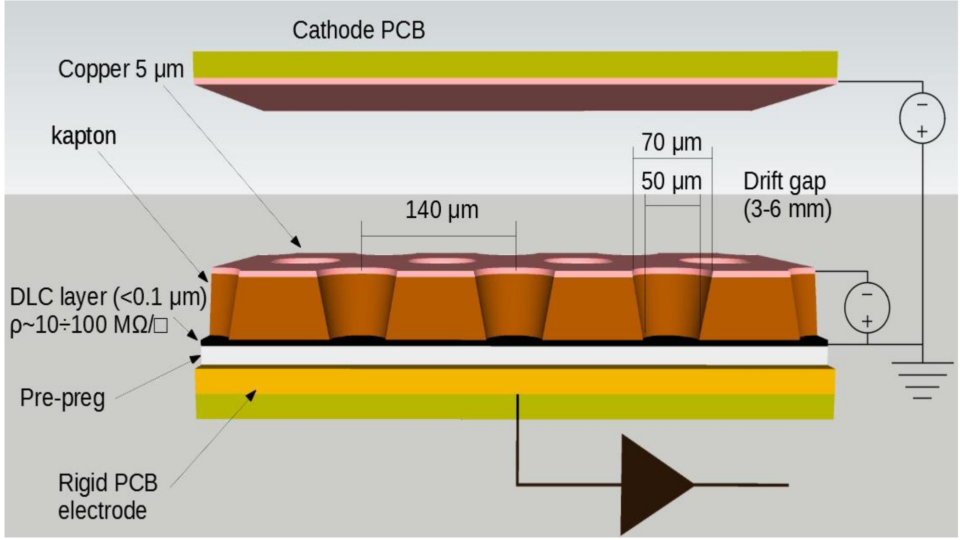
The **µ-RWELL** is a **resistive MPGD, with a GEM derived amplification stage,** composed of two elements:

- **Cathode**
- **µ-RWELL PCB**

– a **WELL** patterned **kapton foil** (with **Cu-layer on top**) acting as **amplification stage**

– a **resisitive DLC film** with **ρ~50÷100 MΩ/□**

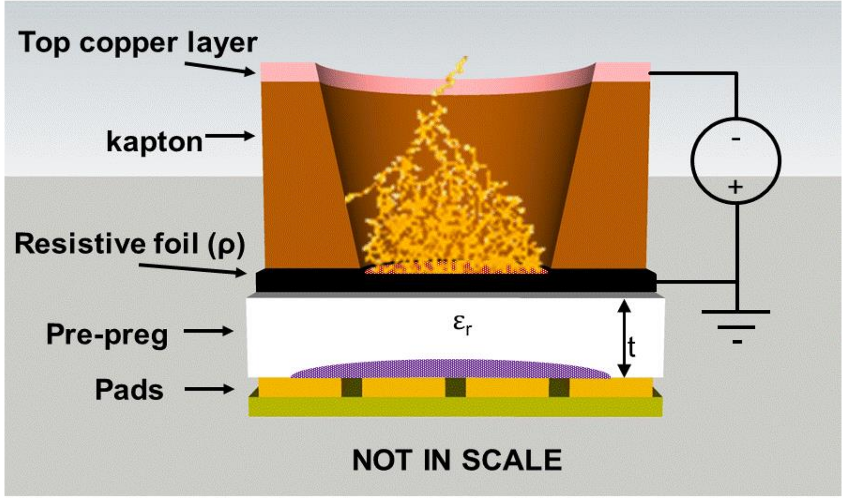
– a standard **readout PCB** with **pad/strip** segmentation



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

The μ-RWELL: principle of operation

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.



The charge induced on the resistive foil is dispersed with a *time constant*, $\tau \sim \rho \times C$ [*M.S. Dixit et al., NIMA 566 (2006) 281*]:

- the **DLC surface resistivity** → ρ
- the **capacitance per unit area**, which depends on the distance between the resistive foil and the pad/strip readout plane → **t**
- the **dielectric constant** of the insulating medium → ε_r

$$C = \varepsilon_0 \times \varepsilon_r \times \frac{S}{t}$$

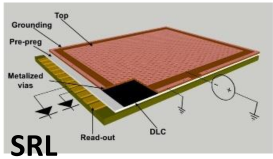
- The main effect of the **introduction of the resistive stage** is **the suppression of the transition from streamer to spark**, with a consequent **reduction of the spark-amplitude**
- As a drawback, t**he capability to stand high particle fluxes is reduced**, but **appropriate grounding schemes** of the resistive layer solves this problem (*see High-Rate layouts*)

The R&D steps

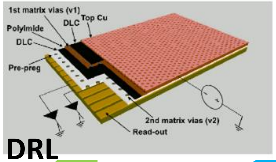
R&D on low-rate layout

R&D on high-rate layout

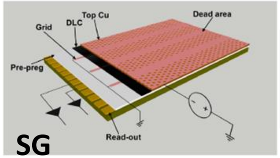
Initial Concept in the 2009, but we really started the R&D on this new MPGD on the 2014



SRL

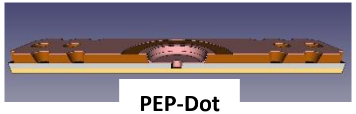


DRL



SG

PEP-Groove

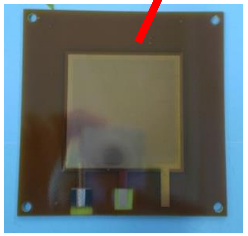


PEP-Dot

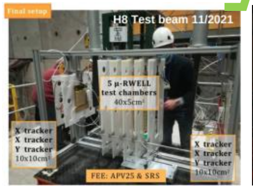
R&D start

TT @ ELTOS

2009 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024

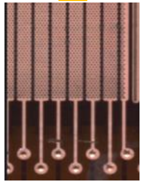


IDEA slice test: DC+ preshower+ dual_calo+ muon

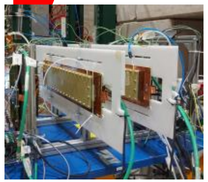


DLC Resistivity

Readout segmentation + 2D readout



2D readout

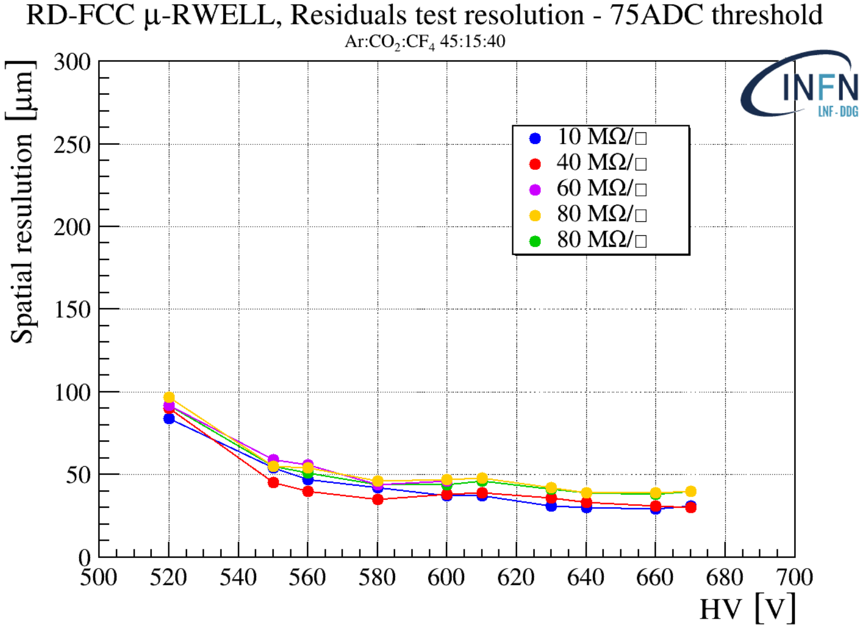


TIGER FEE

R&D on large area and 2D readout

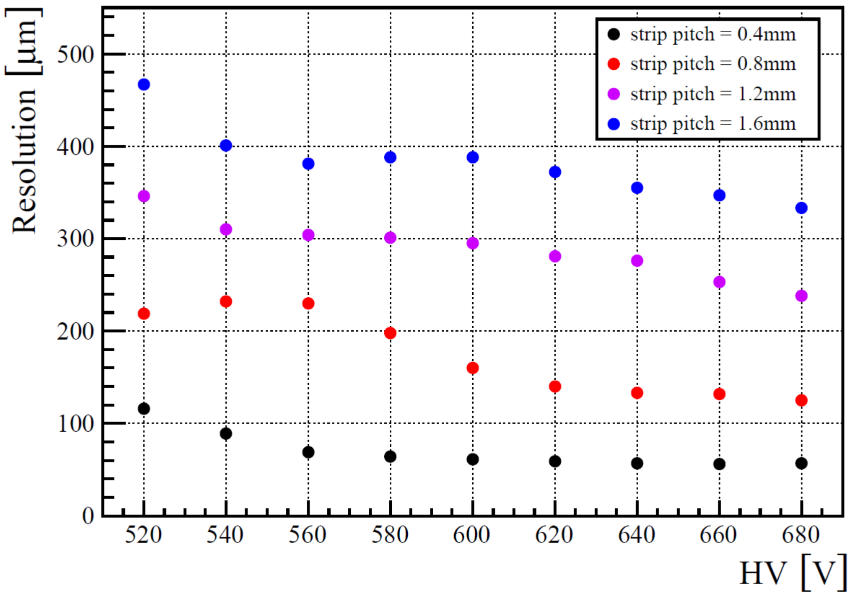
1-D Tracking studies

Resistivity scan



With a **0.4 mm strip pitch** and **0.15 mm strip width**, no effects were observed within this resistivity range. Additionally, DLC resistivity uniformity is not a critical parameter for spatial resolution.

R/O pitch scan



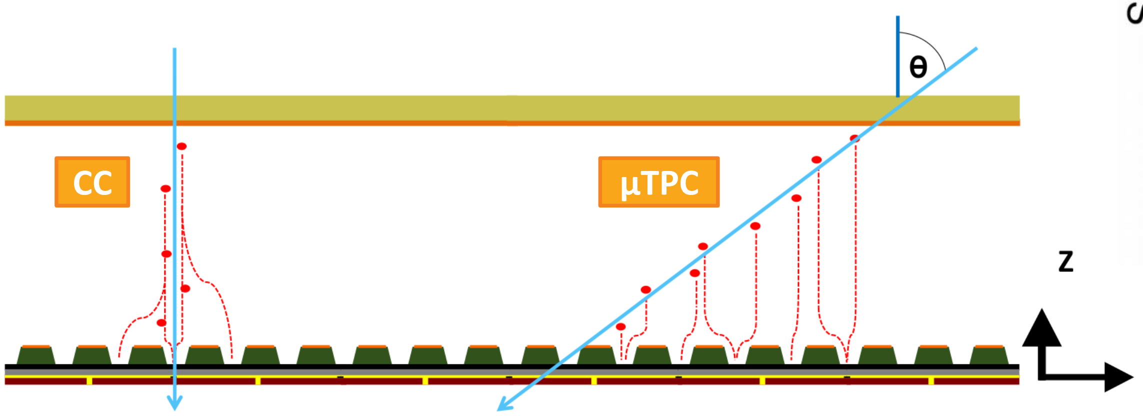
Increasing the r/out strip pitch will **reduce** the spatial resolution: σ_x → **√12⊗pitch**

1-D tracking (inclined tracks)

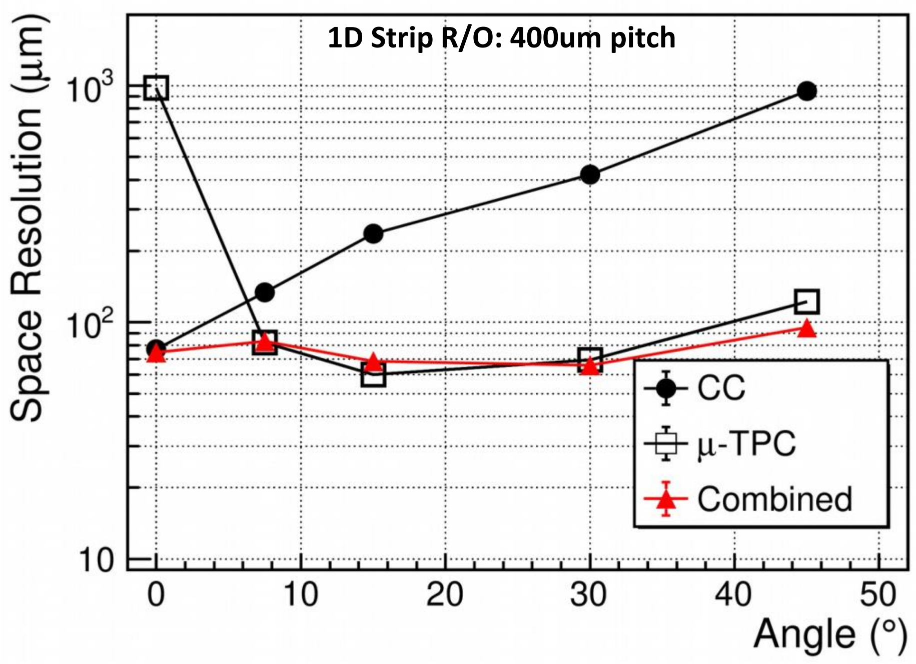
M. Giovannetti et al., *On the space resolution fo the µ-RWELL*, 2020 JINST 16 P08036

For **inclined tracks** and/or in presence of high B fields, the **charge centroid (CC)** method gives a **very broad spatial resolution** on the anode-strip plane (typical effect observed on MPGDs).

Implementing the **µTPC mode[1]**, using the knowledge of the **drift time** of the electrons **each ionization cluster is projected inside the conversion gap**, and **the track segment** in the gas gap **is reconstructed.**



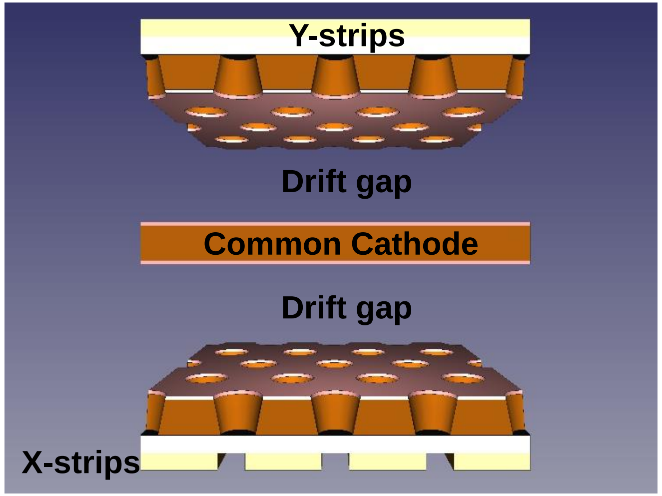
[1] introduced for ATLAS MMs by T. Alexopoulos



Combining the CC and µTPC reconstruction (through a wheighted average) **a resolution well below 100 µm** could be reached over a wide incidence angle range.

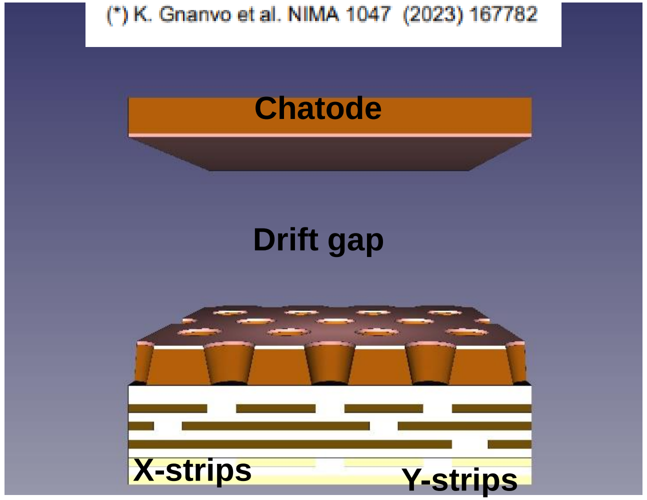
2-D Tracking layouts

N.2 u-RWELLs 1D (2⊗1D)



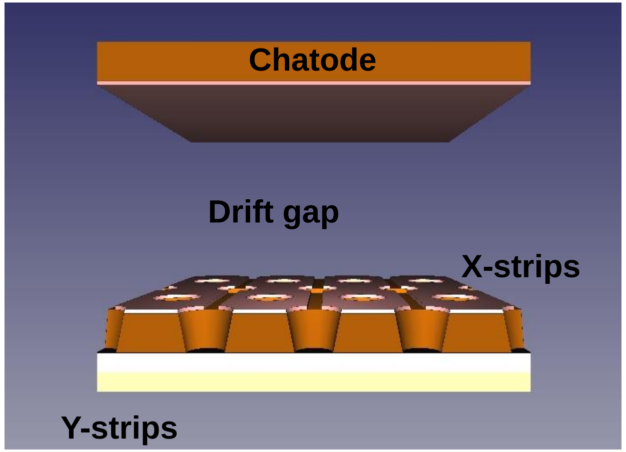
Operation at **lower gas gain** wrt the «COMPASS» r/out (X-Y r/out decoupled)
- 0.4 mm (0.8mm) X-Y strip pitch for **pre-shower (Muon).**

u-RWELL - Capacitive Sharing r/out



The **charge sharing** is performed through the **capacitive coupling** between a **stack of layers of pads** and **the r/out board.**
- 1.2 mm X-Y strip pitch.
Reduce the **FEE channels**, but the total **charge is shared between** the **X & Y** r/out.

u-RWELL TOP r/out



The **TOP-readout layout** allows to work at **low gas gain** wrt the «COMPASS» r/out (X-Y r/out decoupled).
- 0.8 mm X-Y strip pitch.
X strips patterned on the TOP of the amplification stage introduces **dead zone in the active area.**

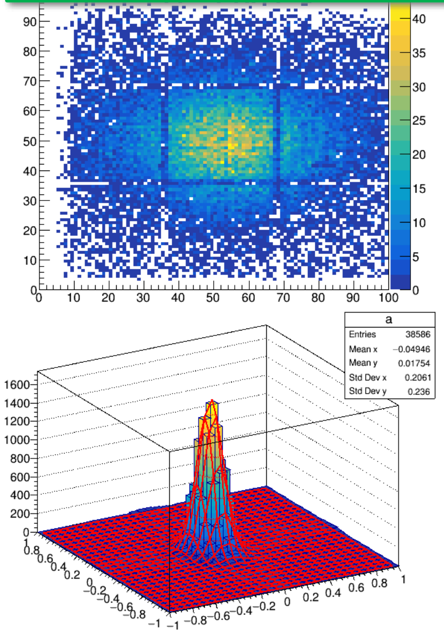
2D layouts performance

0.4 mm X-Y strip pitch

PROFILE 2D

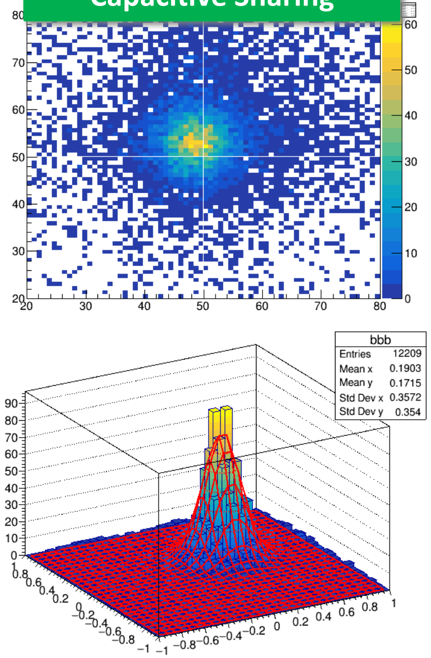
RESIDUAL 2D

n.2 1D μ-RWELL [2×1D]



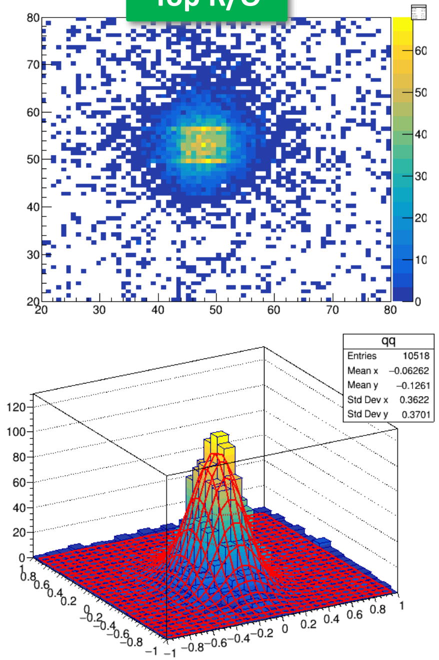
0.4 mm X-Y strip pitch
σ_X = 85μm
σ_Y = 121μm

Capacitive Sharing



1.2 mm X-Y strip pitch
σ_X = 142 μm
σ_Y = 147 μm

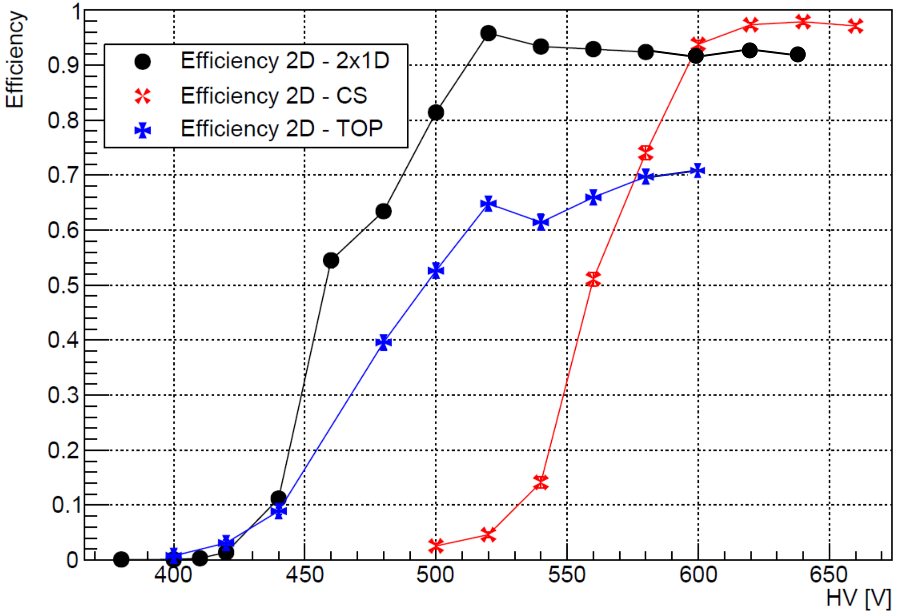
Top R/O



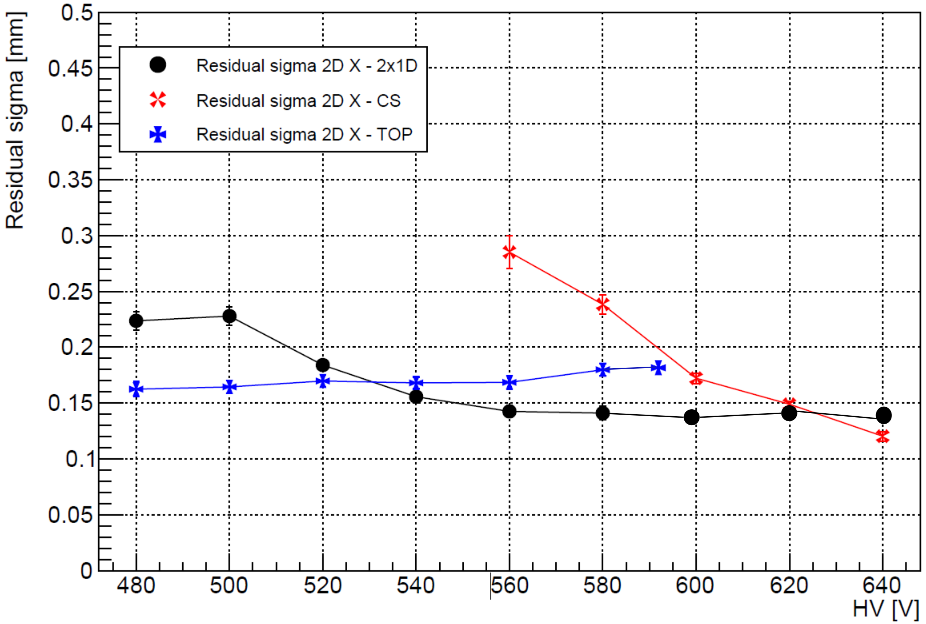
0.8 mm X-Y strip pitch
σ_X = 173 μm
σ_Y = 250 μm

2D layouts performance

2D layouts – 10x10 cm²

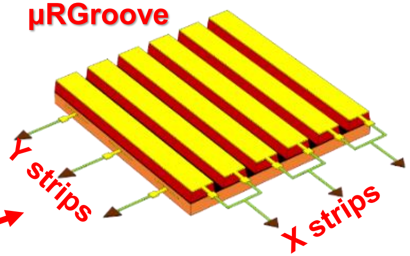


2D layouts – 10x10 cm²



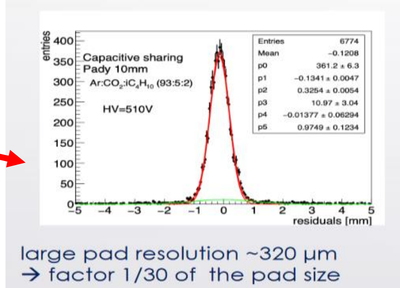
- **2x1D:** spatial resolution **< 200µm (pitch 0.8 mm)**, **low voltage** operating point ~520V, **efficiency ~ 95%**
- **CS:** spatial resolution **<200µm (with pitch 1.2 mm), high voltage** operating point, ≥ 600V, **efficiency ~ 98%**
- **Top r/out:** spatial resolution **< 200µm (pitch 0.8 mm), low voltage** operating point ~520V, **efficiency ~70%**

New technology solutions



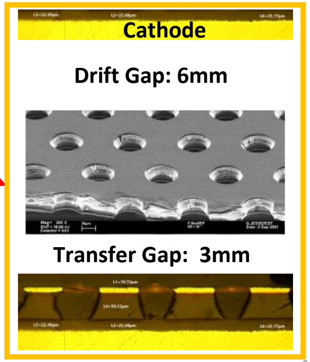
Z. Yi

- **μ-RGroove → evolution** of the **top/r-out** layout, where the amplification stage is based on **«grooves»** rather than **«wells».** This design could facilitate the implementation of the **strip readout** on the **top**, **without introducing dead-zones (Z. Yi in RD51**).



M. Iodice

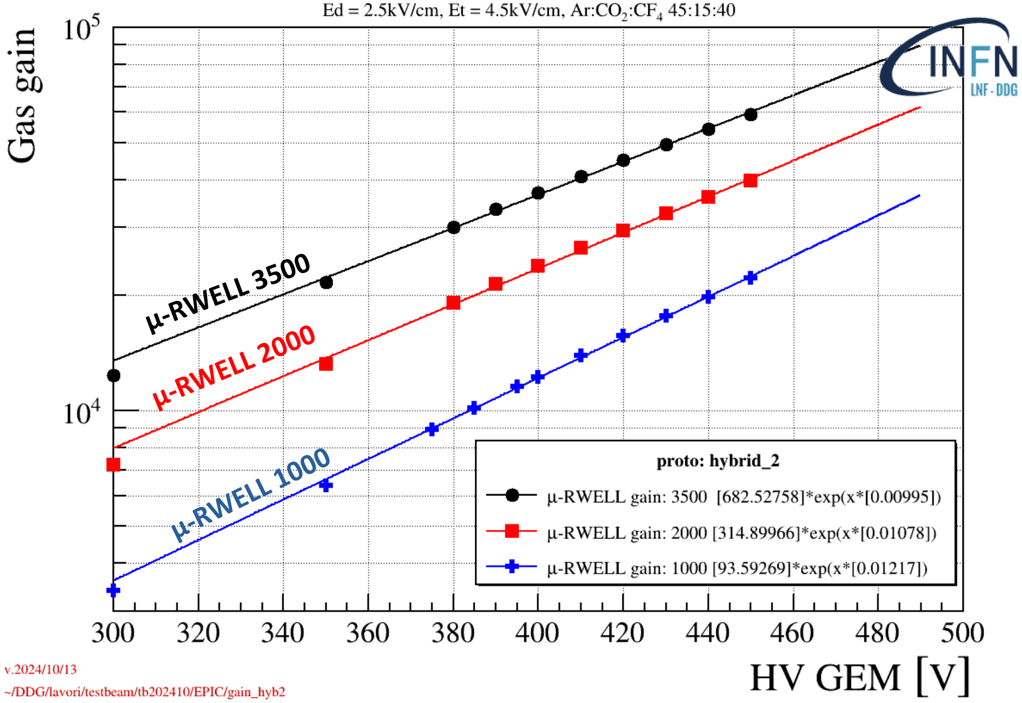
- **μ-RWELL with CS layout with pad readout →** new design in which the **readout PCB** is segmented into **pads instead of strips**. This choice allows for collecting **all the charge on a single readout electrode** with an increase of FFE channels (30%). With a pad size of ~ 1 cm^2, a **spatial resolution of ~ 300 μm** has been achieved (**M. Iodice in RD51**).



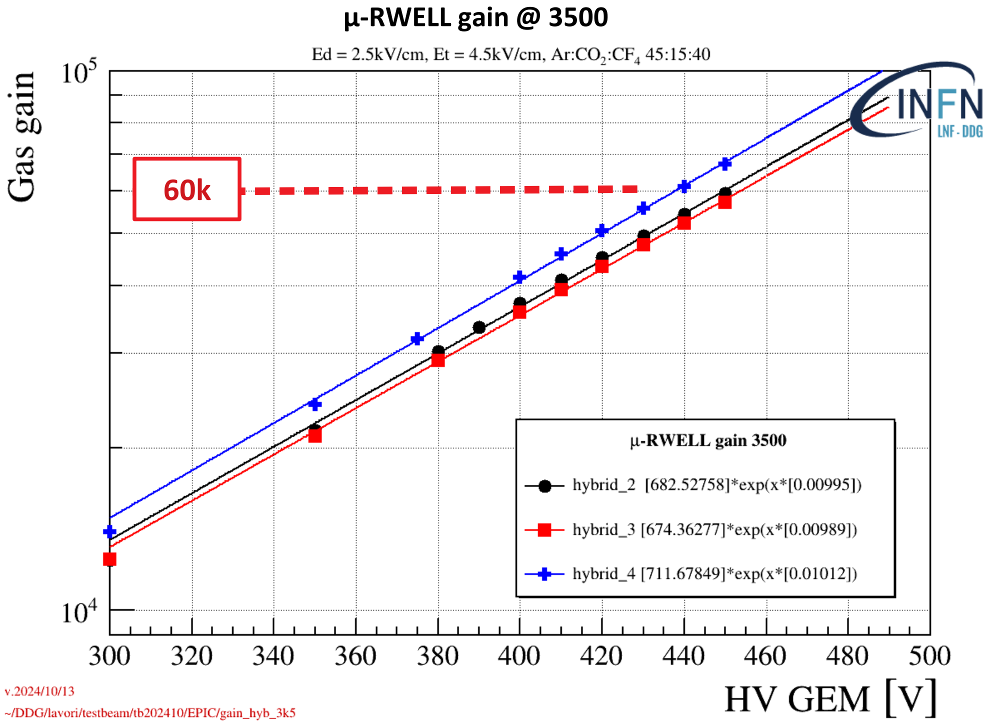
- **GEM + μ-RWELL with CS layout with strip/pad readout →** a hybrid design featuring **a GEM pre-amplification** stage to **lower the operating point**, greatly **enhancing detector stability** while maintaining **high spatial performance** with millimeter strip-pitches

GEM + µ-RWELL

3 different gains for the µ-RWELL



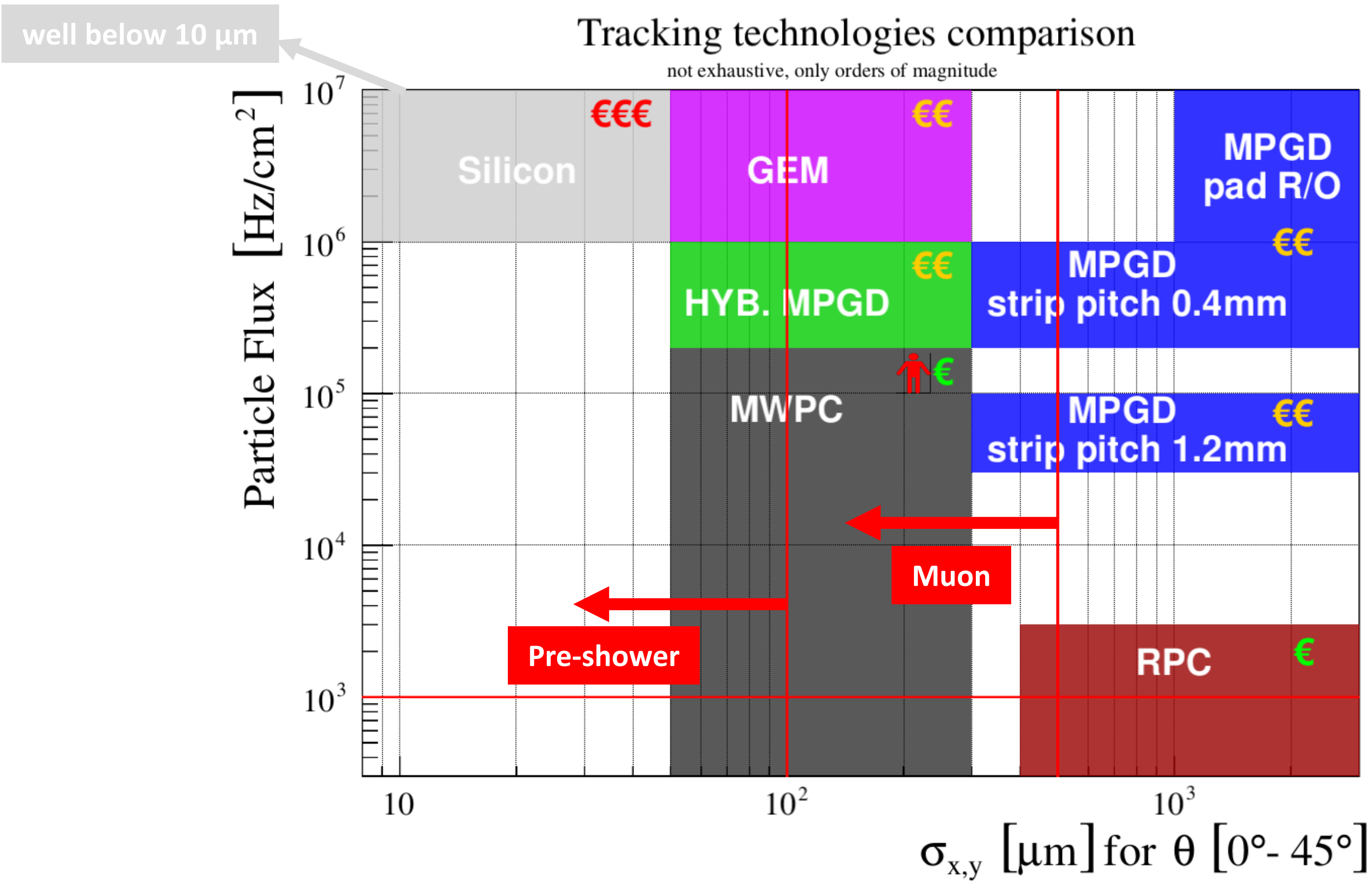
3 different detectors



GEM gain
@ 450V ≈ 20

A very stable detector: it doesn't show **any hint of instabilities** even at a **gain of 60k.**
We stopped because the FEE saturates.

Tracking technologies comparison



Technology Transfer to Industry

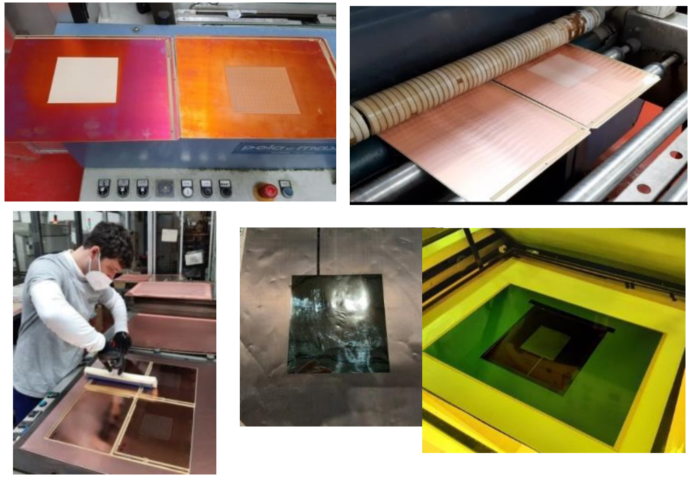
Detector Manufacturing & TT

The **µ-RWELL_PCB is a rigid-flex PCB** based on **SBU technology**, that is **compatible with standard industrial processes**.
The **ELTOS** is the industrial partner **involved in the manufacturing of the µ-RWELL**.

The **ELTOS SpA** was founded in 1980 in Arezzo, Italy.

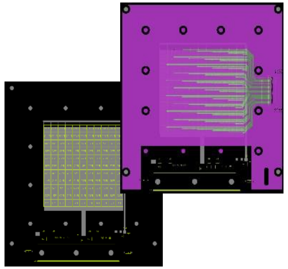
The Company has a **large experience in the construction of MPGDs,** including technologies such as **Thick-GEM (THGEM)** and **MicroMegas**.

The **involvement of a private industry** in this R&D **opens the way** for the use of µ-RWELL technology **across various fields of applications.**



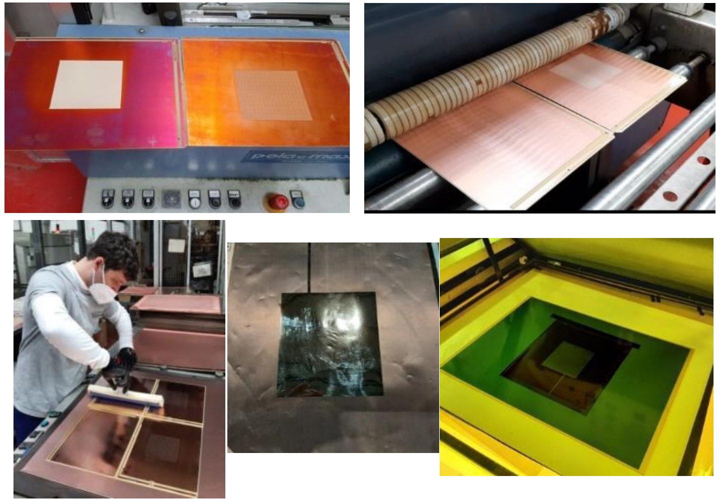
Detector Manufacturing flow chart

LAYOUT design



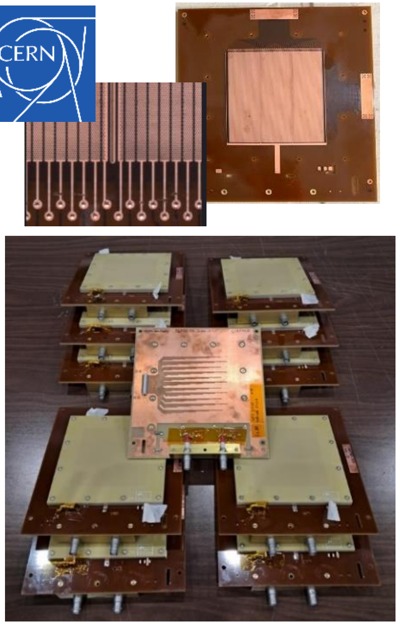
DLC foil production

PCB production



Feedback from tests

Final detector manufacturing



Detector manufacturing steps

Step 0 – Detector PCB design @ **LNF**

Step 1 – CERN_INFN DLC (C.I.D) sputtering machine installed @ **CERN**

- In operation since Nov. 2022
- Production by **LNF-INFN** technical 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 simultaneously

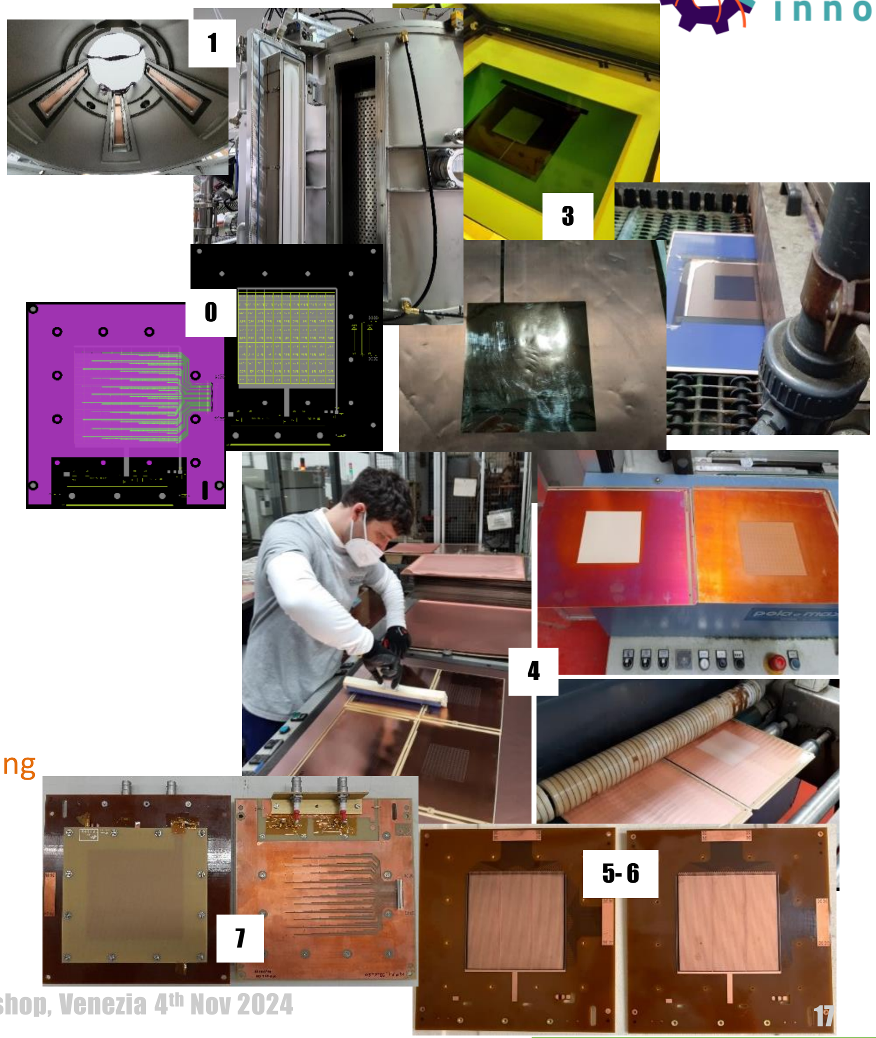
Step 5 – Top copper patterning by **CERN**

- Cu amplification holes image and HV connections by Cu etching

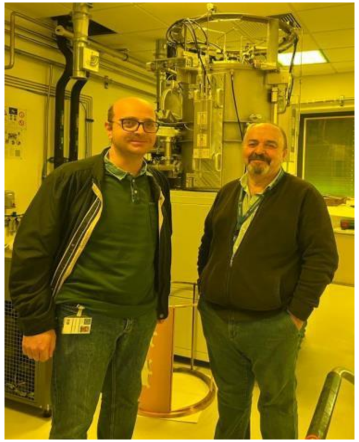
Step 6 – Amplification stage patterning by **CERN**

- PI etching → amplification-holes

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



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**

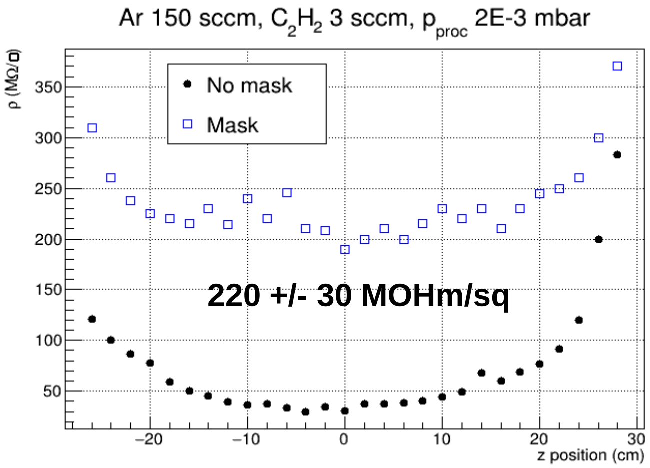
In **2023,** the activity on CID focused on the **tuning** of the **machine on small foils: good** results in terms of **reproducibility and uniformity.**

In **2024**, the challenge has been 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 still to be done (July 2024)**

The graphite target

The three external cathodes



Electrical Hot Cleaning

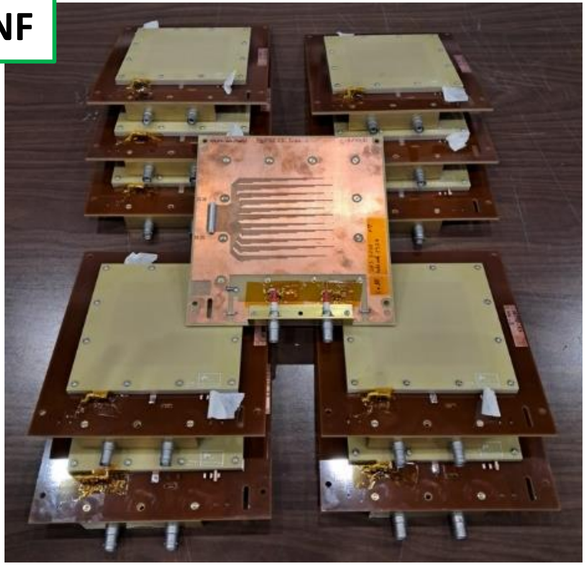
@ CERN

At the end of the manufacturing process at CERN, a **conditioning procedure** is performed:

- Standard **PCB washing**
- **Electrical cleaning in dry air** (**90°C** in an oven) from **300 V to 700 V** (each step with current < 1 nA)
- **Detector closure** and final **test at 600 V in ambient air**

Pilot co-production test

@ LNF

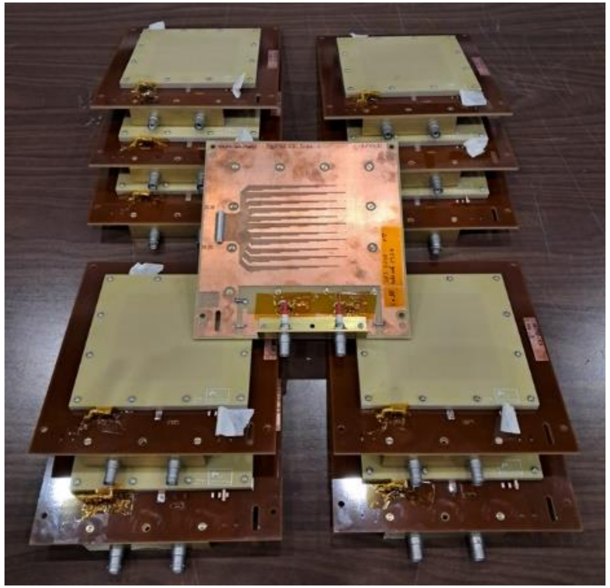


The 16 co-produced prototypes have been extensively tested with X-rays:

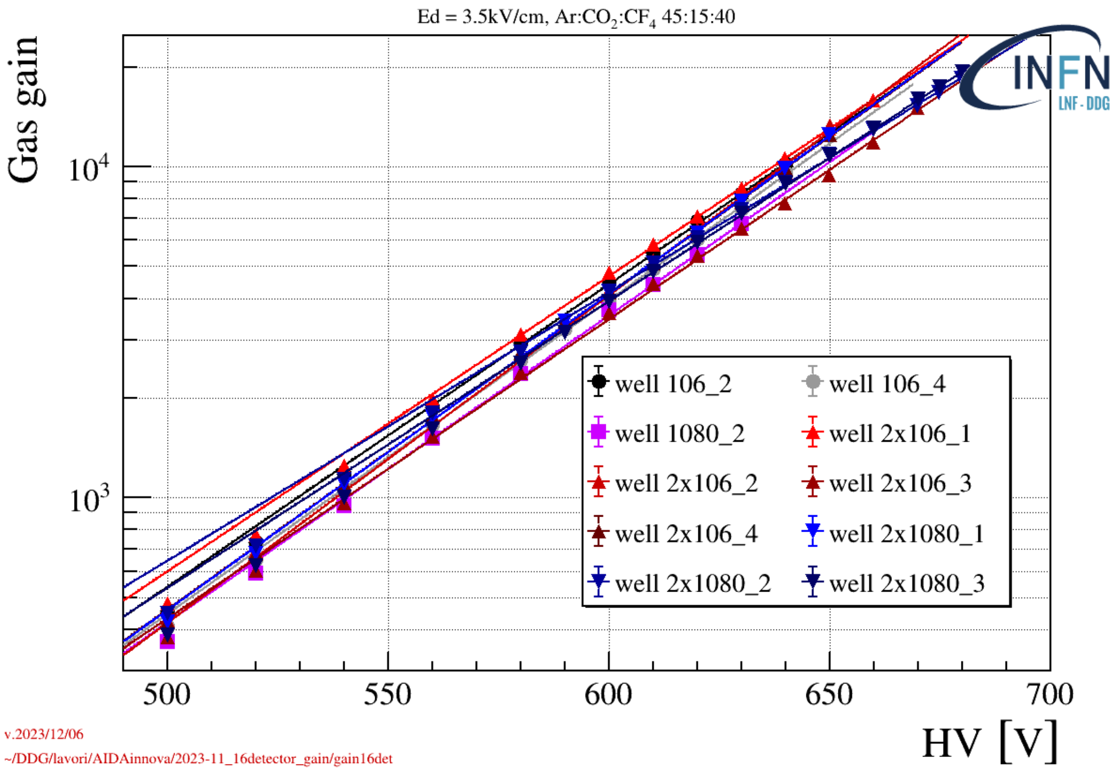
- **15/16 are fine**
- **1/16 needs to be re-cleaned**

Production yield > 93%

Co-production pilot results

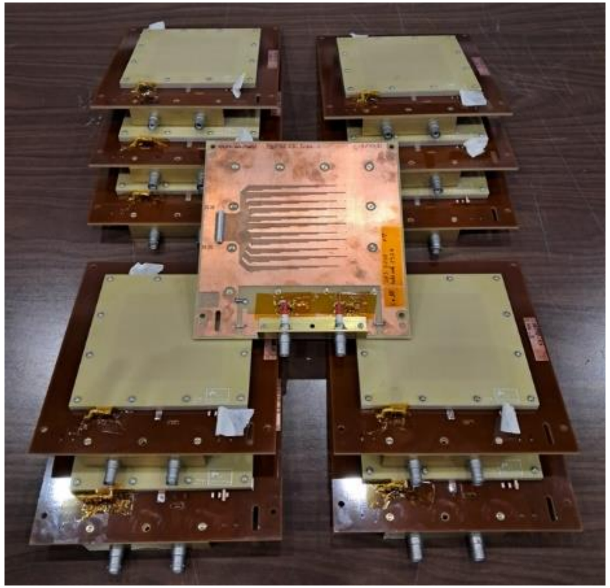


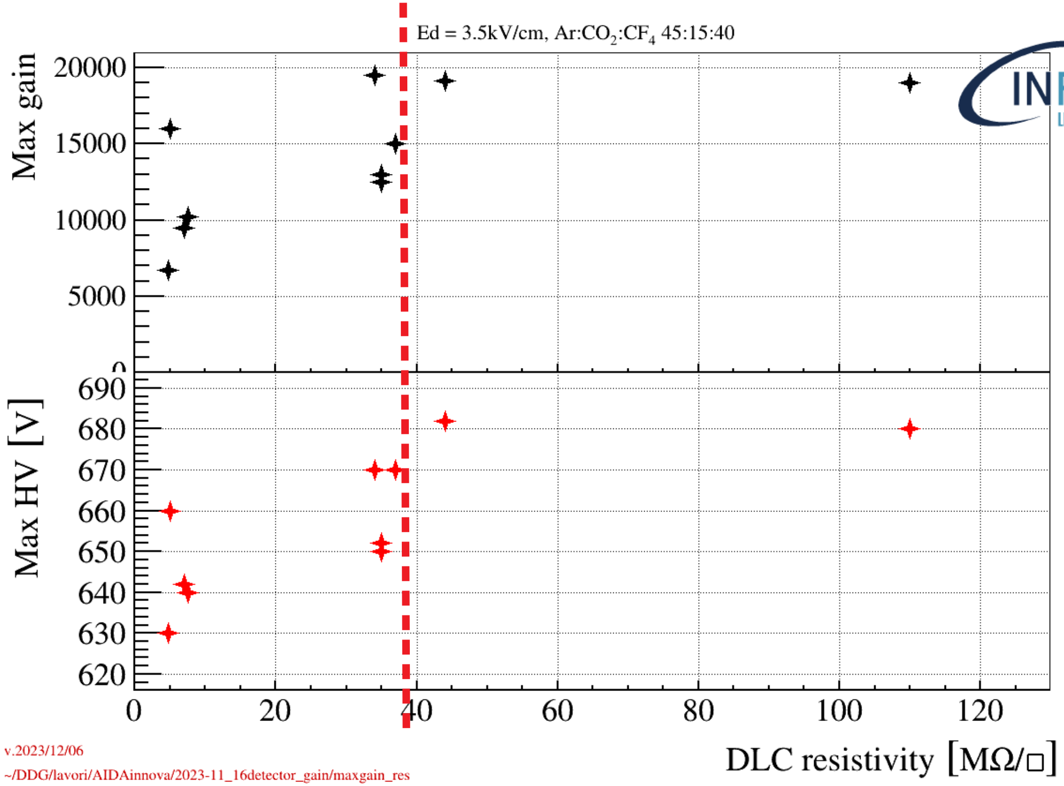
- **16** co-produced protos have been delivered and tested
- **10/16 (LNF) + 5/16 (CERN)** are fine
- **1/16 should be re-cleaned**



Characterized with **X-ray gun** → **Gas gain** measurement

Max-gain vs resistivity



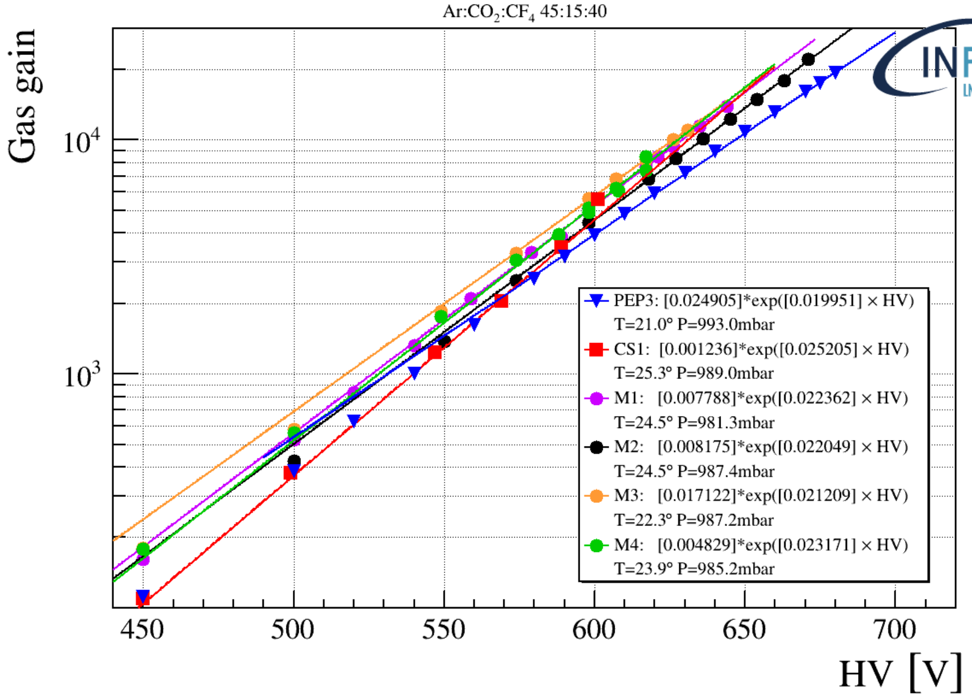


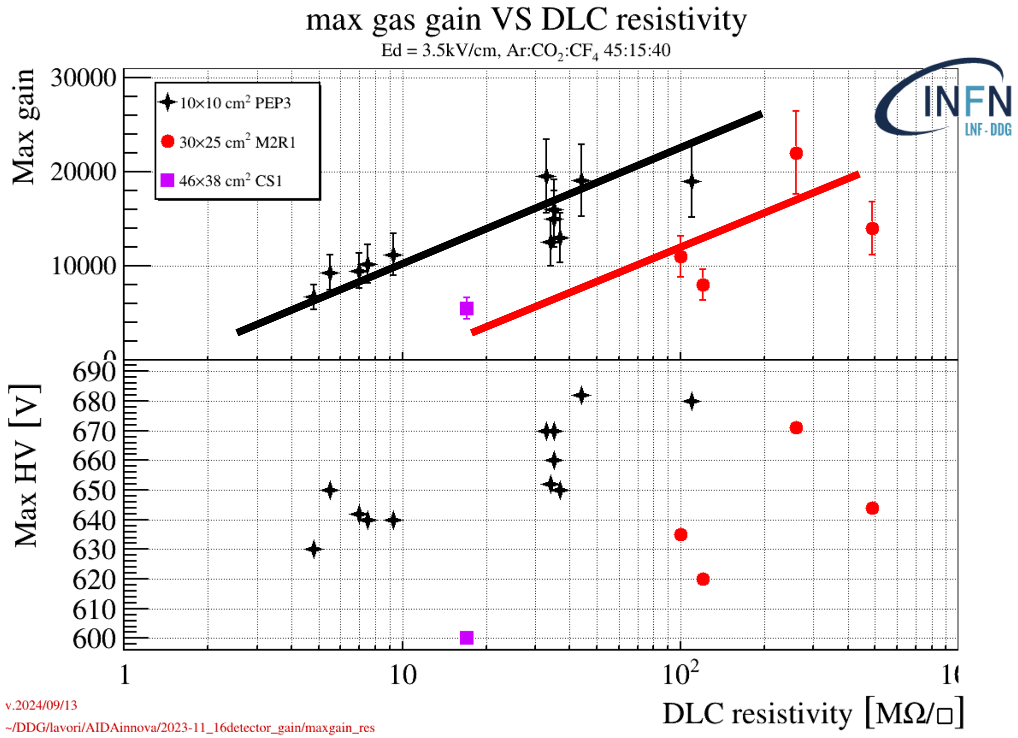
- **16** co-produced protos have been delivered and tested
- **10/16 (LNF) + 5/16 (CERN)** are fine
- **1/16 should be re-cleaned**

The **maximum gain** is larger for **ρ ≥ 40 MOhm/square**

Max-gain: large size vs small size

CS_01 13 MOhm/sq, area 46x38 cm^2
M2R1 260 MOhm/sq, area 30x25 cm^2



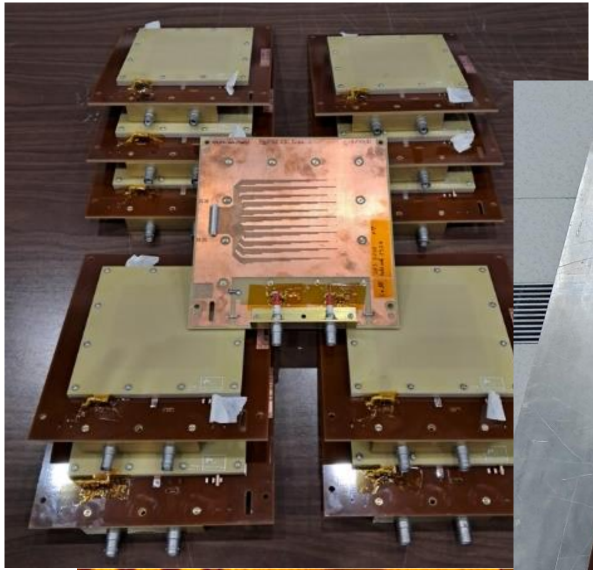


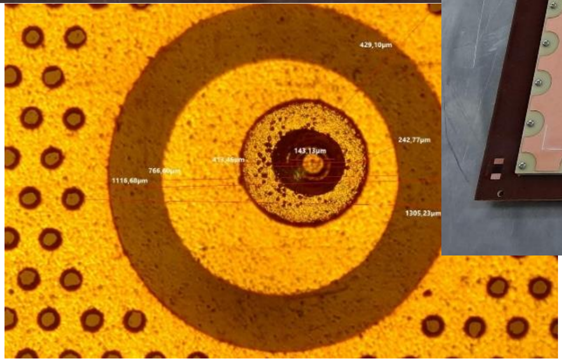
For large-size detectors, the max-gain increases with the DLC resistivity, although, compared to the small-size detectors, the **gain curve for the larger size is shifted towards lower values.**

Summary

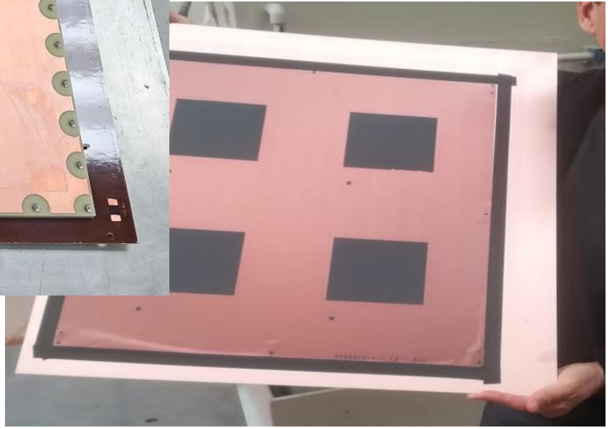
The µ-RWELL is a well-established technology with excellent performance.

- Several 2D readout layouts have been tested, demonstrating spatial resolution up to 100 µm over a large particle incidence angle range (0°- 45°).
- New layouts to improve stability, maximize gain, and enhance overall detector performance are under study.
- A significant effort is being made to well define and simplify the manufacturing process and facilitate the technology transfer to industry.
- The DLC sputtering process — a crucial manufacturing step— is now fully under our control.



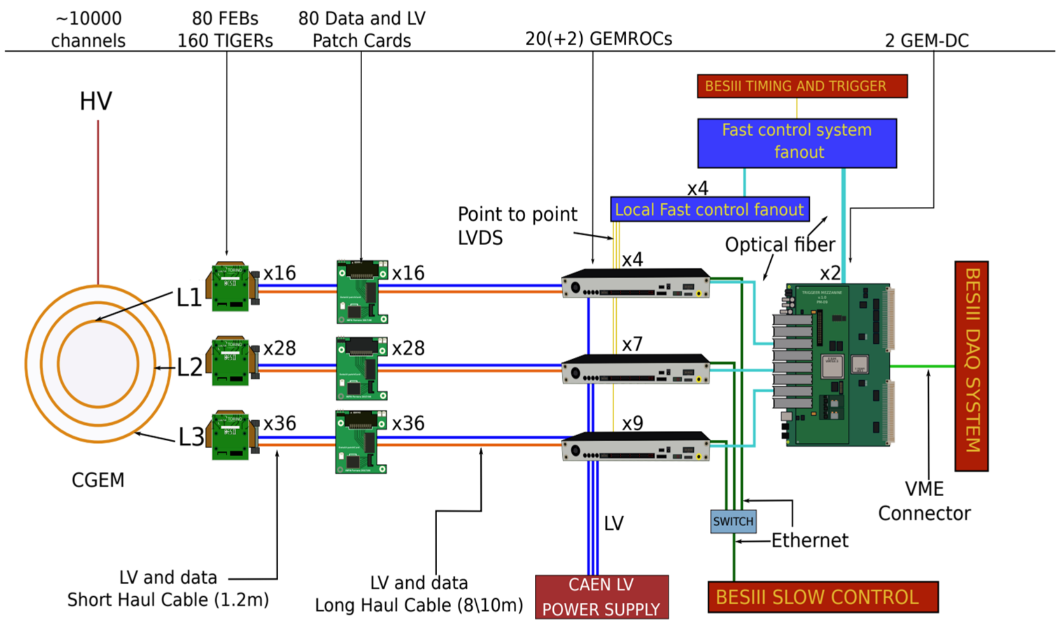


MANY THANKS



SPARE SLIDES

Front end electronics: TIGER



TIGER chip features

- 64 channels
- Event rate 100 kHz/ch
- Input dynamic range up to 50 fC
- Time resolution < 5 ns
- ENC < 2000 e^- rms with 100 pF input capacitance

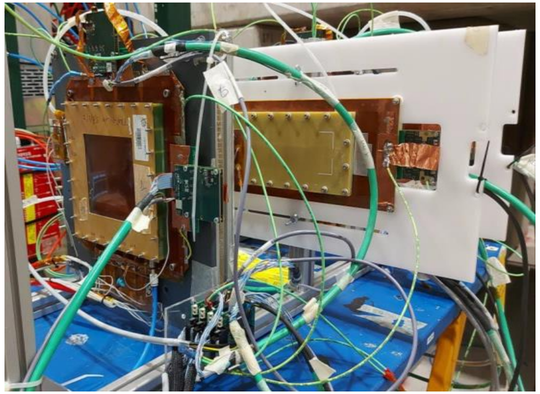
Readout chain

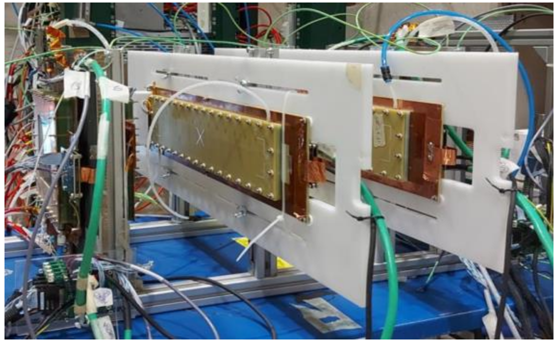
The full readout chain is well known.
A complete setup is under deployment in Beijing for the **BESIII CGEM-IT** where a cosmic ray data taking is ongoing since Dec. 2019

WP5 2024 – Front-end electronics

Detector under test:

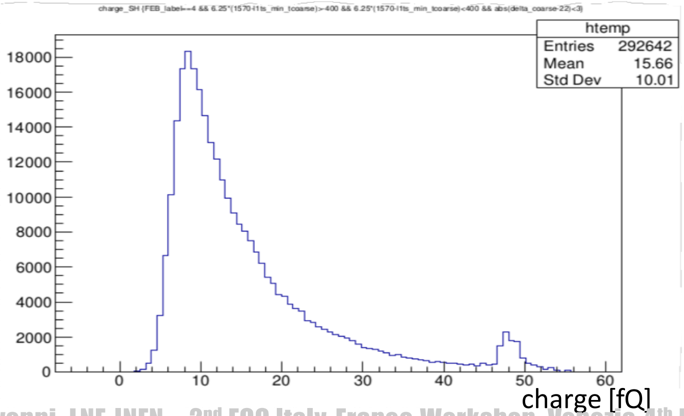
- Active area = 400x50 mm^2
- Resistivity = 80 MΩ/□
- Strip pitch = 0.4-1.6 mm
- Strip width = 0.15 mm
- 1D readout

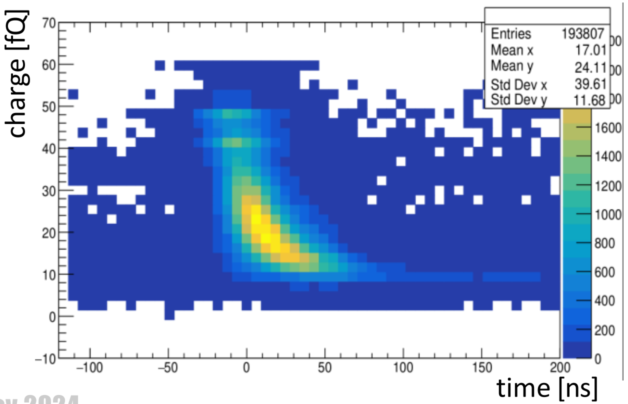




The data taking consisted of HV scan, Drift scan and Thr. scan, with $Ar:CO_2:CF_4$

Data **analysis is ongoing**, and will be the task of the **next months**



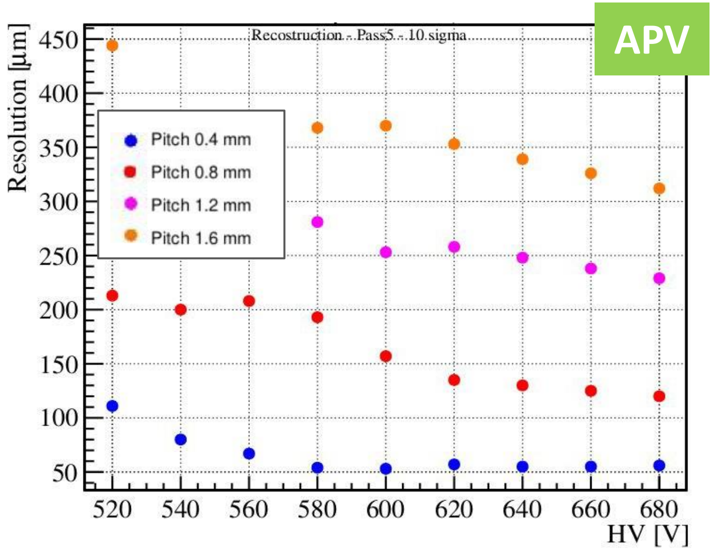


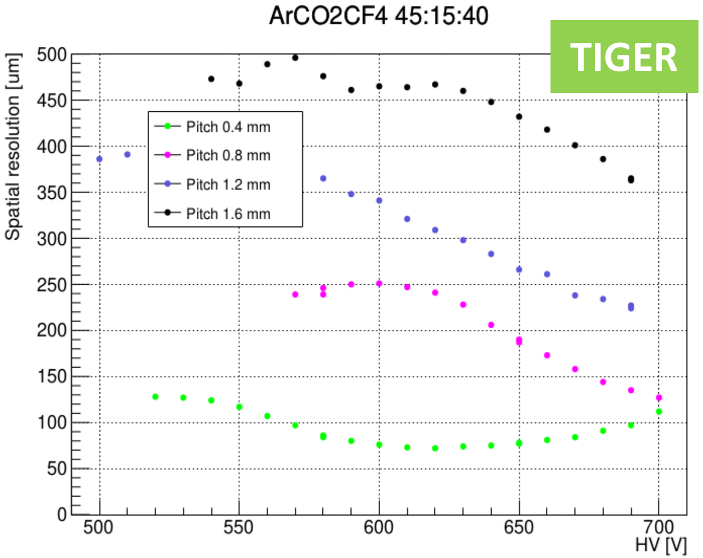
WP5 2024 – Front-end electronics

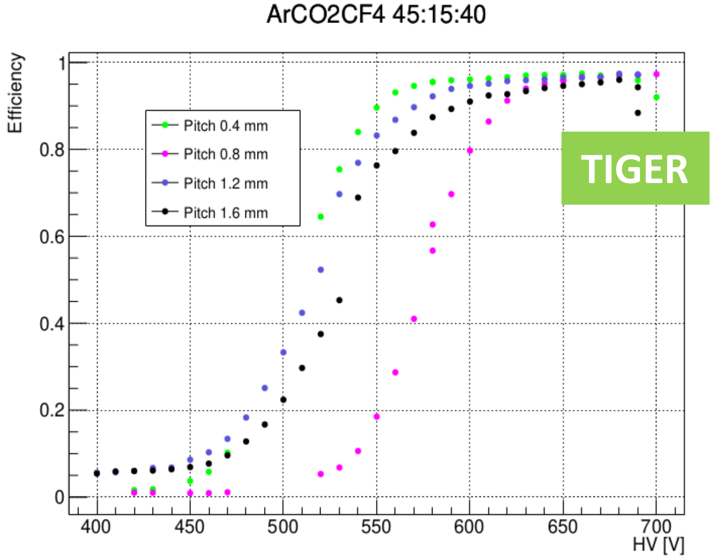
Similar results are obtained with **TIGER** electronics and **APV**, even though small differences are present in the two setups (noise, threshold): **1-2 fC with APV and 2-4 fC with TIGER.**

The grounding scheme must be improved in future setups.

A spatial resolution of **100 µm** is achieved with a **0.4 mm strip pitch**, a shift between the efficiency plateaus of **0.4 mm** and **0.8 mm** pitch is observed, as expected (due to larger noise on the 0.8 mm detector)



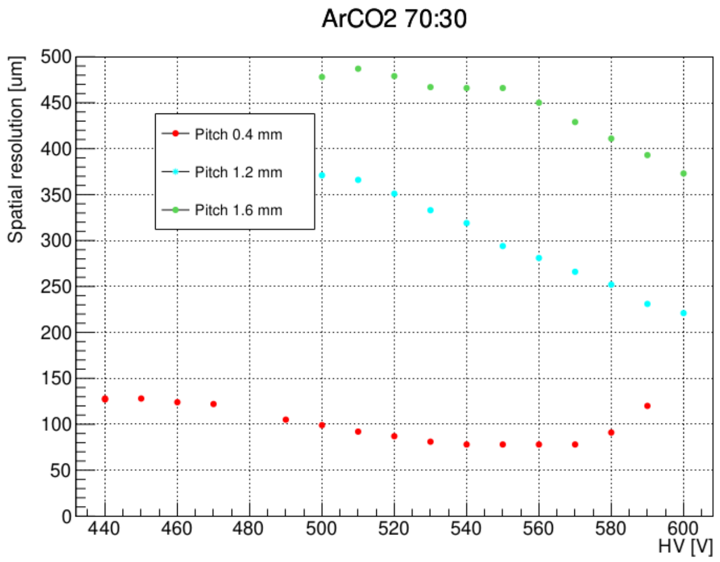


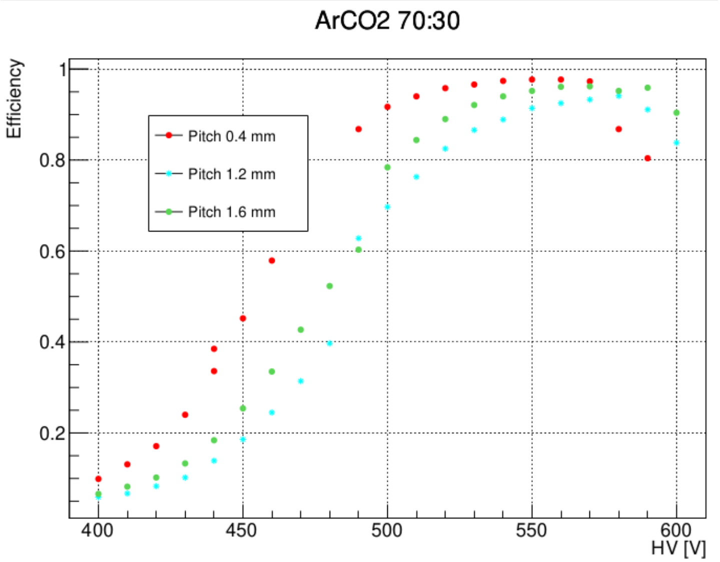


Testing CF_4-free gas mixtures

The gas mixtures based on **CF_4 are effective for fast electron drift** but are not considered eco-friendly.

Alternatives to CF_4 are needed. Here, we compare the performance of a µ-RWELL using **Ar:CO_2 (70/30)** and **Ar:CO_2:CF_4 (45:15:40).** A shift in the working point of approximately **50-100V** is observed due to the different Argon ratios, along with a **reduction in the plateau** width of about **50V**.



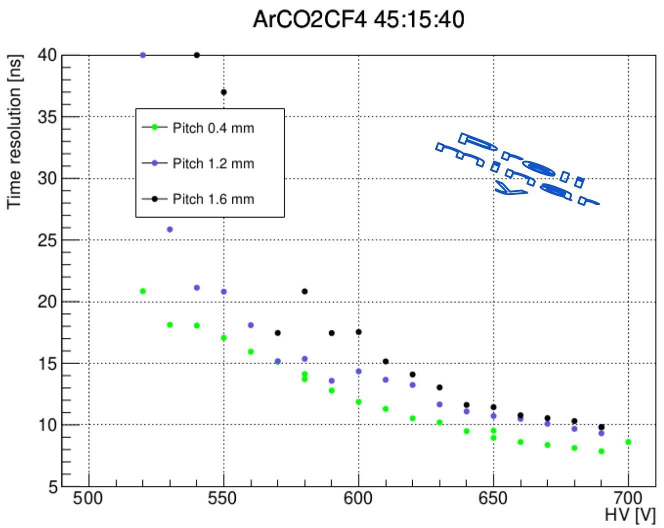


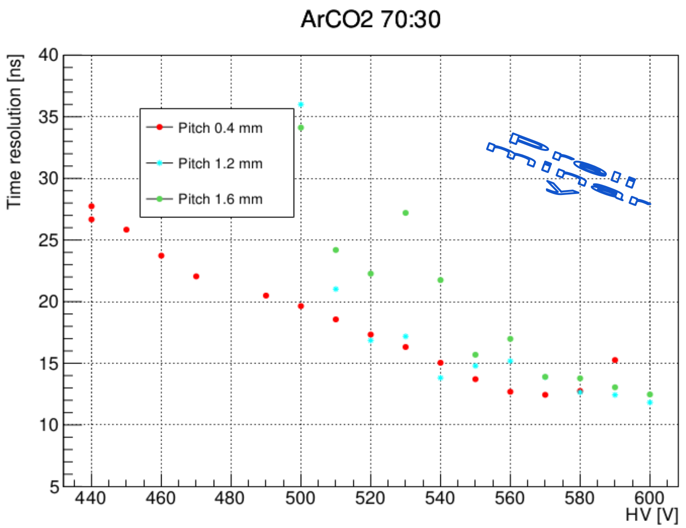
Testing CF_4-free gas mixtures

Comparing the time performance of the two gas mixtures:

- **12 ns** is achieved with Ar with **Ar:CO_2**
- **7.8 ns** is achieved with **Ar:CO_2:CF_4**

The contribution of the electronics (approximately **2 ns**) and time-walk are included.





Spot Effect for SRL – Manufacturer plot

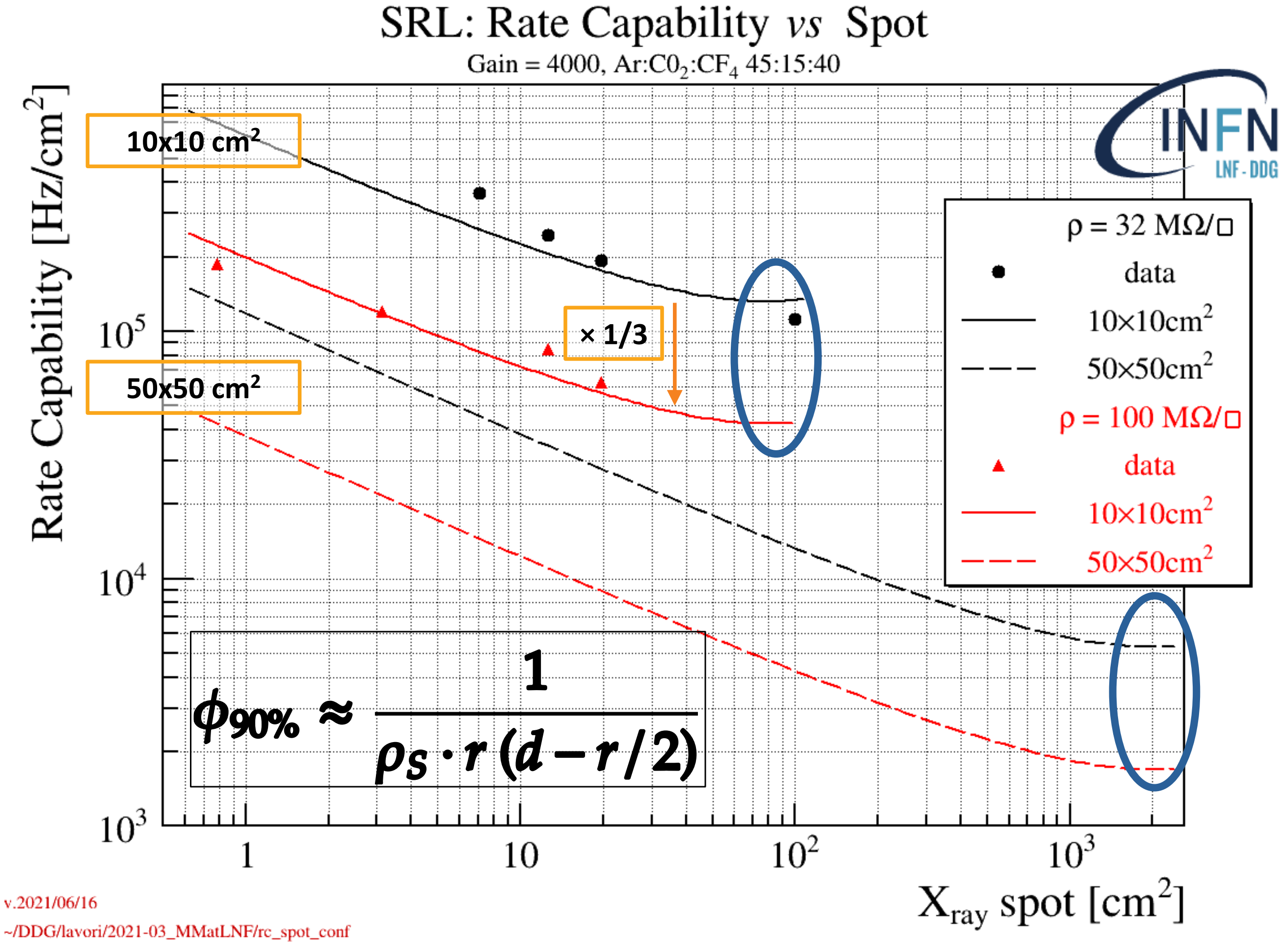
From the mathematical model of the resistive stage of a µ-RWELL:

1. detectors with **same size** 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)

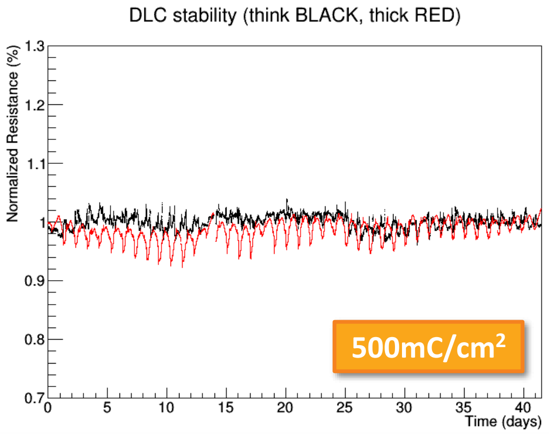
Different primary ionization ⇒ Rate Cap.$_{m.i.p.}$ = 3×Rate Cap.$_{X\text{-ray}}$

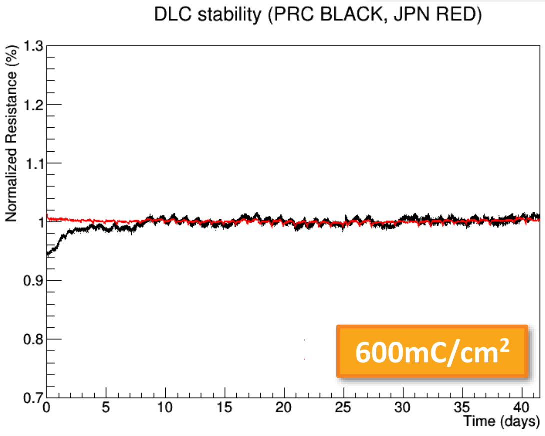


Irradiation test of DLC and μ-RWELL

- **DLC foils**: monitoring of the resistivity of two foils under x-ray irradiation.
- **μ-RWELL detectors**: prototypes irradiated with different radiation.

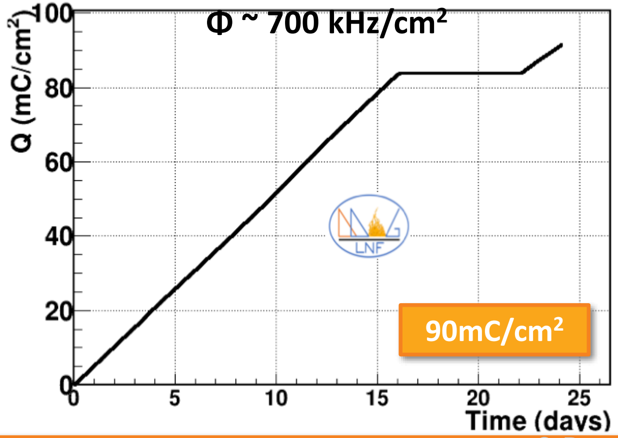
Bare DLC foils



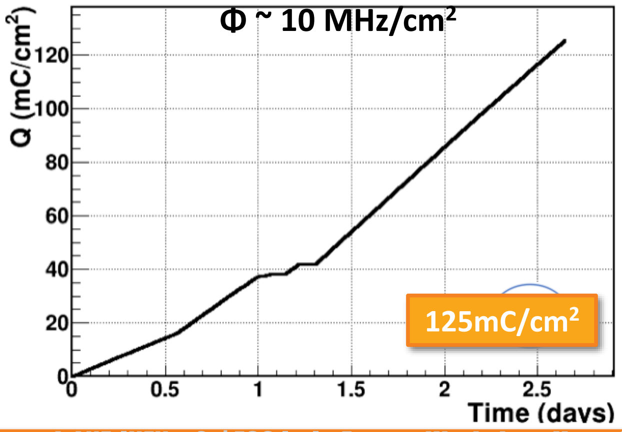


μ-RWELL DETECTORS

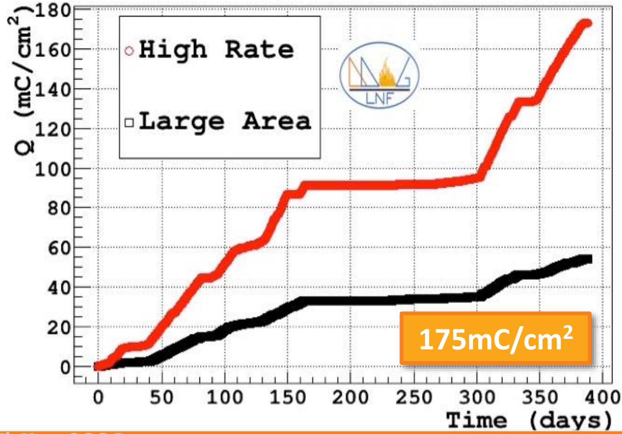
X-Ray gun- spot 50 cm²



PSI-1, beam spot ~ 9 cm²



GIF++ - Full area, Flux ~ 200 kHz/cm²



µ-RWELL + GEM

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

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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

Budker Institute of Nuclear Physics, 630090, Novosibirsk, Russia
Novosibirsk State University, 630090, Novosibirsk, Russia

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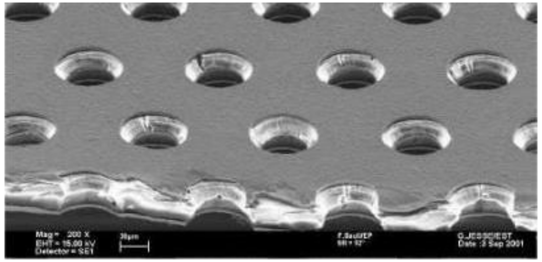
Micro-RWELL
Micro-pattern gas detectors

ABSTRACT

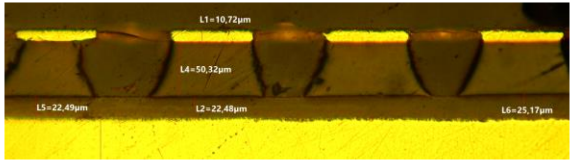
An upgrade of tracking system of Cryogenic Magnetic Detector (CMD-3) is proposed using microresistive WELL technology. CMD-3 is a general purpose detector operating at the VEPP-2000 collider at Budker Institute of Nuclear Physics and intended for studies of light vector mesons in the energy range between 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**



Developed for **CMD3 upgrade disks** (4 sectors 50×50cm^2)

The GEM **must be** stretched: sizes larger than 50×50cm^2 could be critical (depending on the gas gaps size).

μ-RWELL + GEM: gas gain

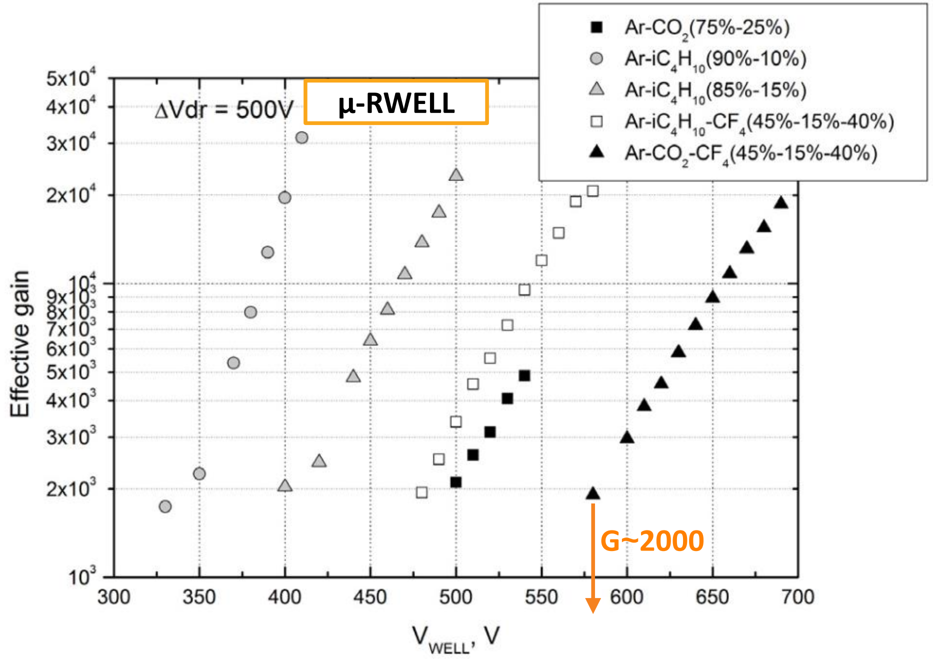


Fig. 4. Gain as a function of voltage on the top electrode of *μ*-RWELL for different gas mixtures. Voltage across the drift gap is 500 V.

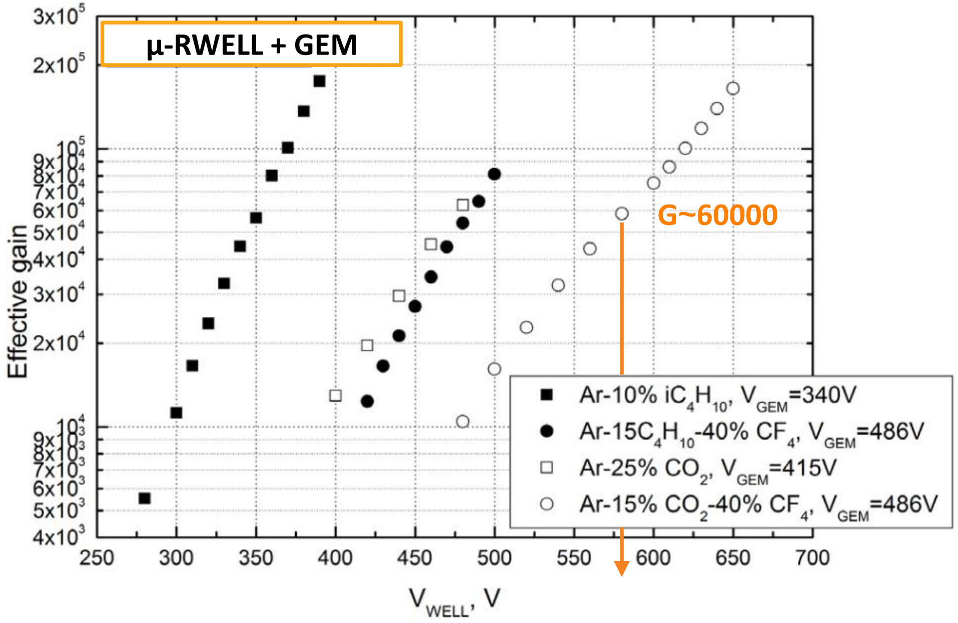


Fig. 5. Gain as a function of voltage on the top electrode of *μ*-RWELL for GEM voltages providing additional gain of 50–100 and for different gas mixtures. Voltage across the drift gap is 500 V.

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

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

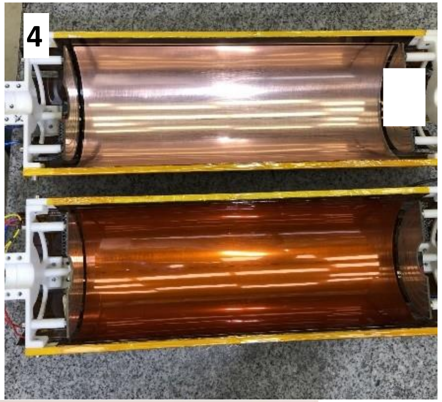
Tile BaseLine	Glue	0	33.5	0.000
	kapton	0	28.6	0.000
	Glue	0	33.5	0.000
	MILLIFOAM	0	1312.5	0.000
	Glue	0	33.5	0.000
	Kapton	0	28.6	0.000
				0.000
			Tot. Anode	0.378

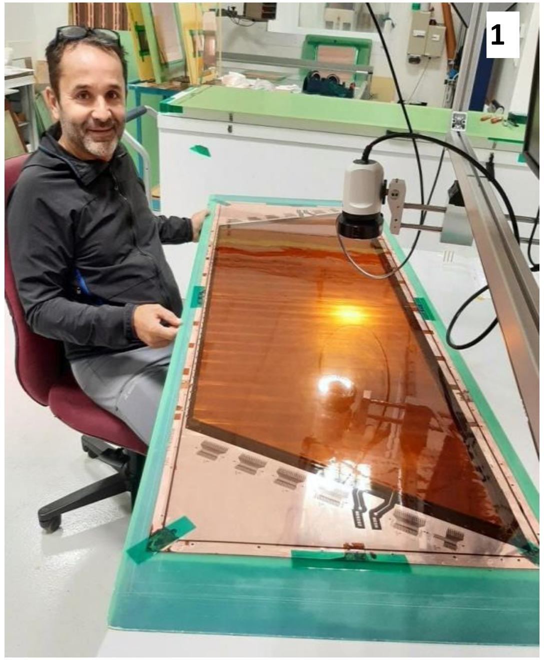
Far. Cage+Cathode Support + Cathod	Cu	3	1.43	0.021
	kapton	50	28.6	0.017
	glue	25	33.5	0.007
	FR4	100	19.3	0.052
	glue	25	33.5	0.007
	MILLIFOAM	3000	1312.5	0.023
	glue	25	33.5	0.007
	FR4	100	19.3	0.052
	glue	25	33.5	0.007
	kapton	50	28.6	0.017
	Cu Ground	3	1.43	0.021
				0.233
			X0 - single	0.611
	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

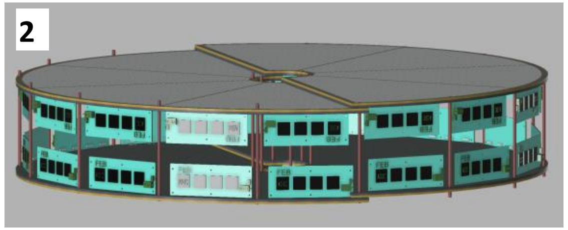
Technology spread

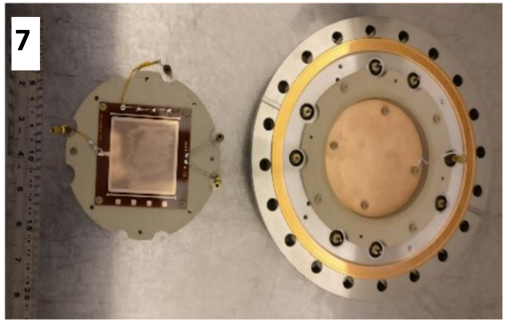
In the last years there has been a significant spread of the technology among several research groups working on Nuclear and Sub-Nuclear experiments

1. **CLAS12 @ JLAB (USA):** the upgrade of the muon spectrometer
2. **EPIC @EIC (BNL - USA):** endcap tracker disks based on a hybrid GEM+μRWELL technology
3. **X17 @ n_TOF EAR2 (CERN)**:TPC with a μRWELL based amplification stage, for the detection of the X17 boson
4. **TACTIC @ YORK Univ. (UK):** radial TPC for detection of nuclear reactions with astrophysical significance
5. **Muon collider:** R&D for a digital hadron calorimeter
6. **CMD3 (RU):** GEM+ μRWELL disk for the upgrade of the tracking system
7. **UKRI (UK):** thermal neutron detection with pressurized ^{3}He-based gas mixtures







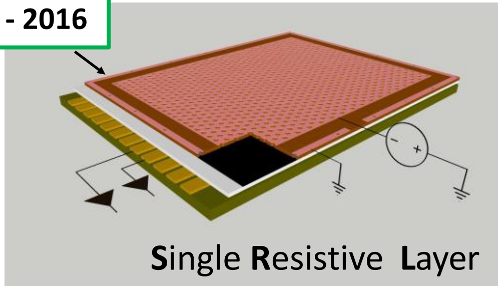


High-rate layouts evolution

G. Bencivenni et al., *The μ-RWELL layouts for high particle rate*, 2019 JINST 14 P05014

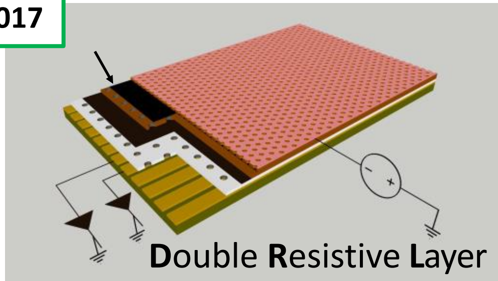
Extensive R&D has been performed to optimize the DLC grounding, enabling the detector to withstand up to 1MHz/cm^2

2014 - 2016



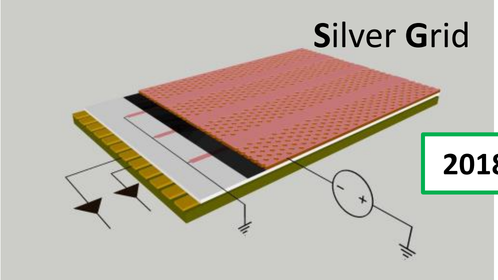
- **Single DLC layer with edge conductive line**
- **2-D current evacuation**
- rate capability **< 100 kHz/cm^2**
- **Easy for industry**

2017



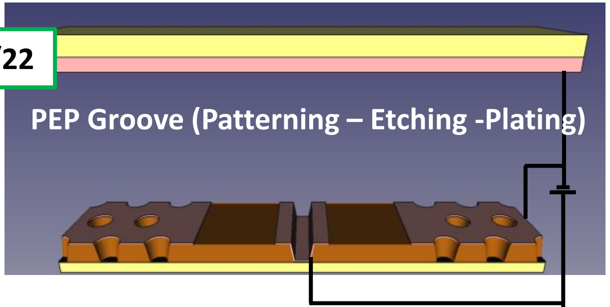
- **Two stacked resistive layers** with a **double matrix of conductive vias**
- **3-D current** evacuation
- Rate capability **> 10MHz/cm^2**
- **Complex manufacturing not easily engineered**

2018 - 2020



- **Single DLC layer**
- **2-D current evacuation** through **conductive grid on the DLC layer**
- rate capability **> 10MHz/cm^2**
- **Easily engineered,** BUT **complex Cu+DLC sputtering/alignment**

2021/22



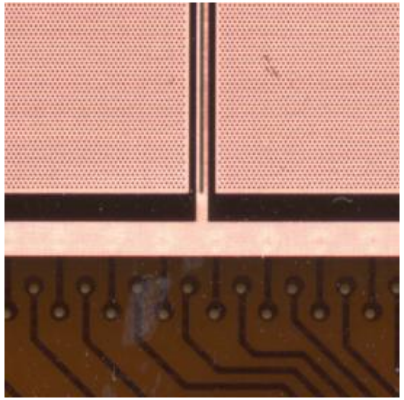
- **Single DLC layer**
- **2-D current evacuation: conductive grid by etching** from the **top Cu, through** the **kapton foil down to the DLC**
- **No grid alignment issues, scalable to large size – large dead zone** (>15%)
- **Easily engineered, because based on SBU technology**

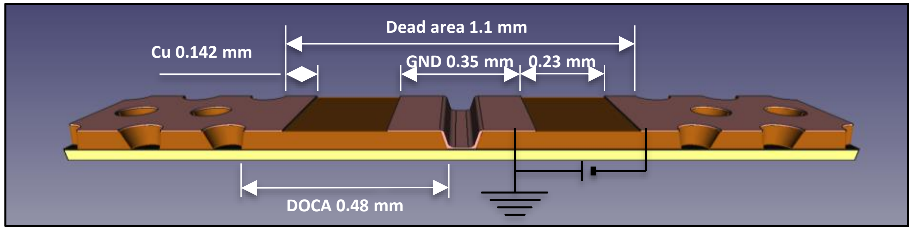
High-rate layouts: PEP layouts comparison

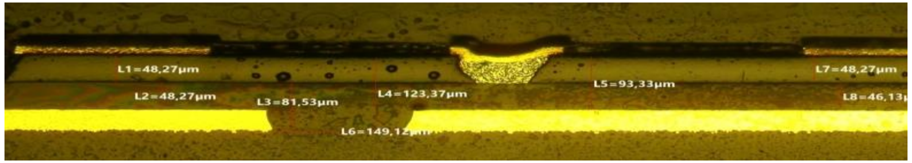
2022

PEP-Groove:
DLC grounding through conductive groove to ground line
Pad R/O = 9×9mm^2
Grounding:
- Groove pitch = 9mm
- width = 1.1mm

→ 84% geometric acceptance



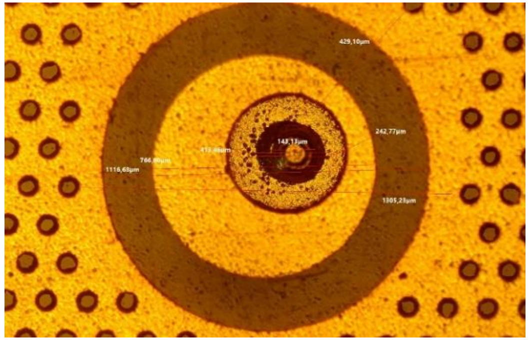




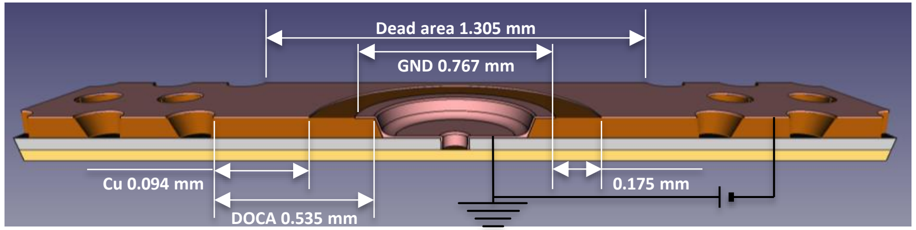
2023

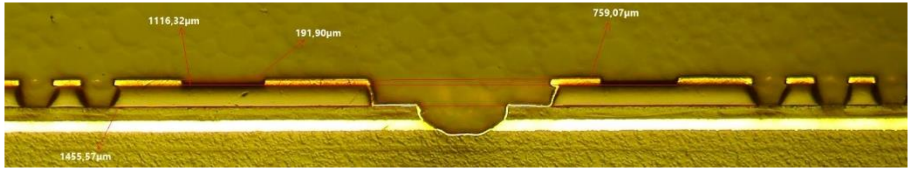
PEP-DOT:
DLC grounding through conductive dots connecting the DLC with pad r/outs
Pad R/O = 9×9mm^2
Grounding:
- Dot pitch = 9mm
- dot rim = 1.3mm

→ 97% geometric acceptance



DOT ≈ plated blind vias

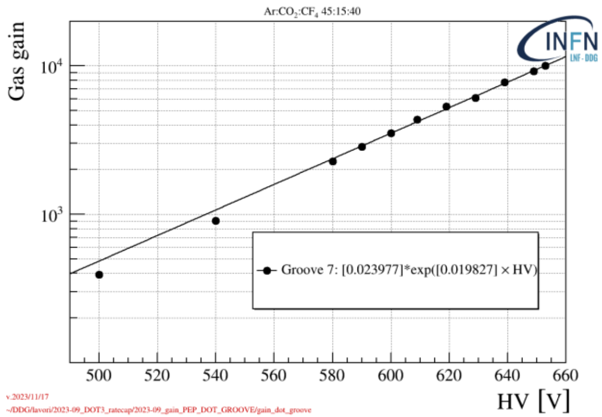


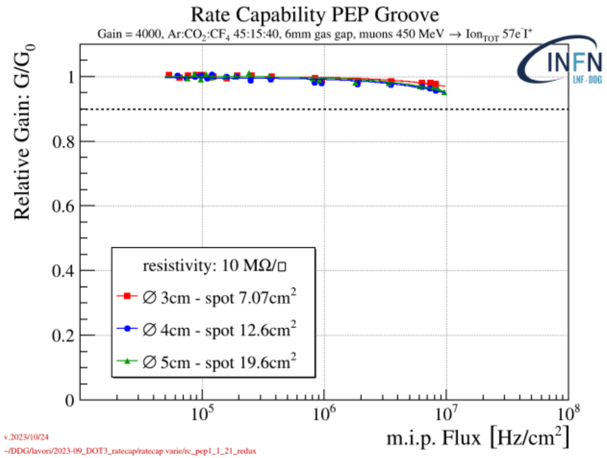


Groove vs DOT (X-ray characterization)

2022

PEP-Groove layout



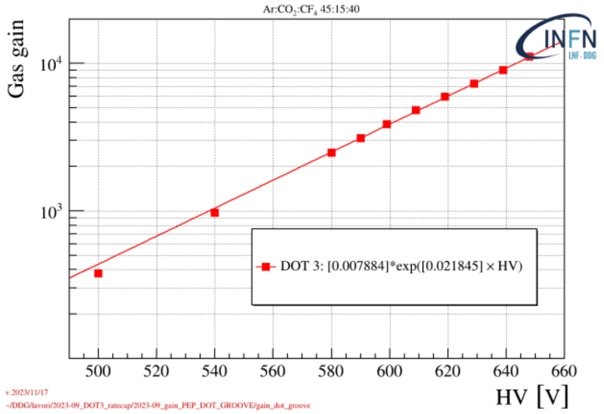


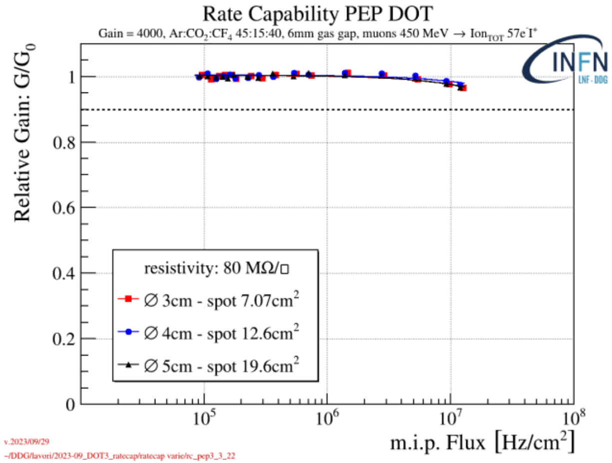
Both layouts exhibit **satisfactory performance:**

- **gas gain** up to **10^4**
- **rate capability** (@ 90% gain drop) > **10 MHz/cm²** , measured with **different irradiation spot size.**

2023

PEP-DOT layout

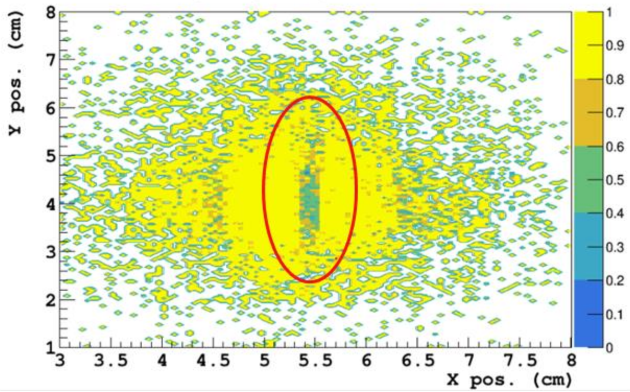


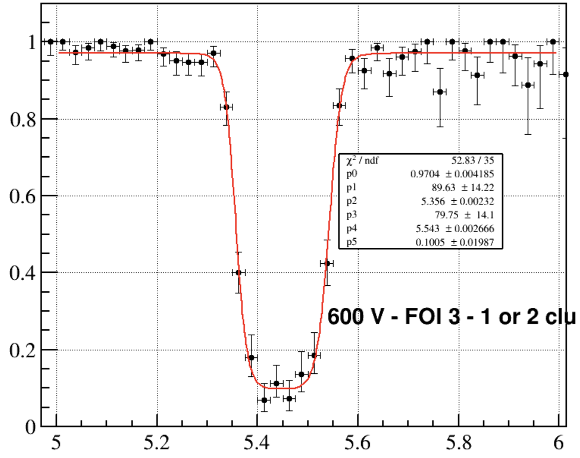


Groove vs DOT (test beam characterization)

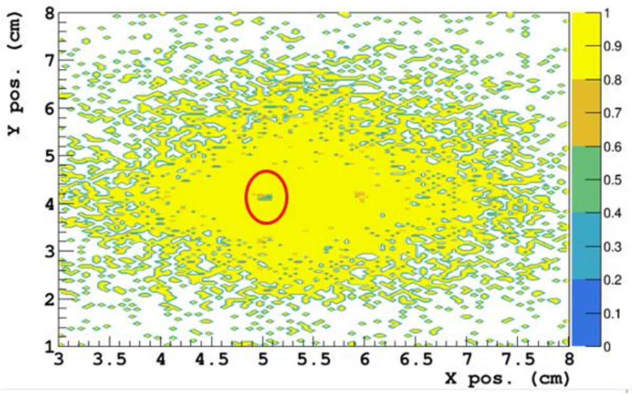
APV25 based Fee

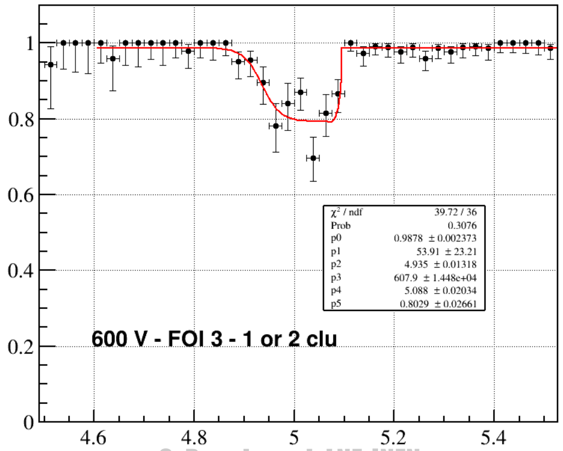
PEP-Groove layout

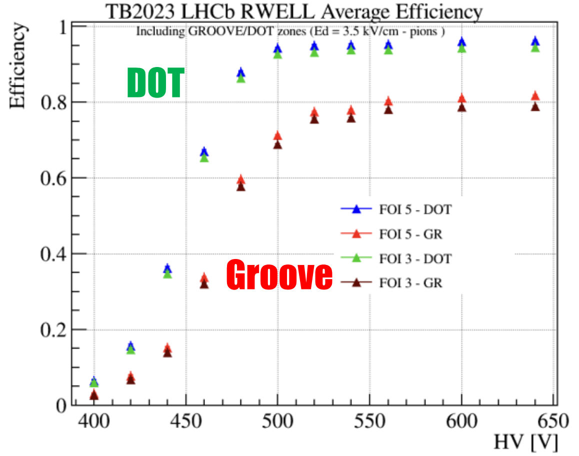


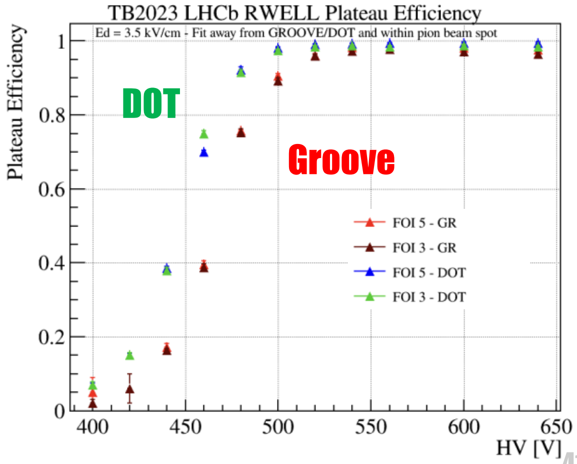


PEP-Dot layout



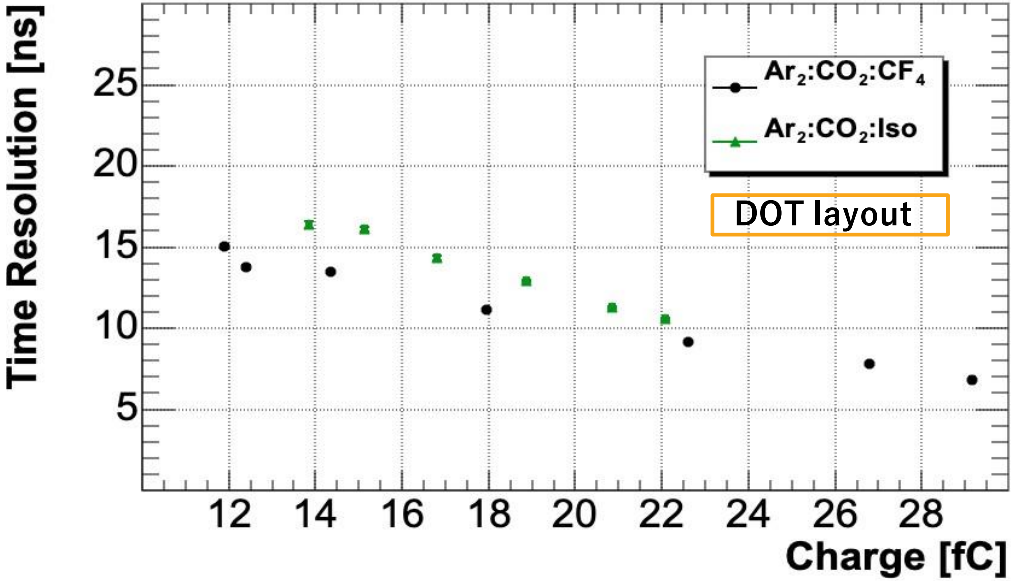


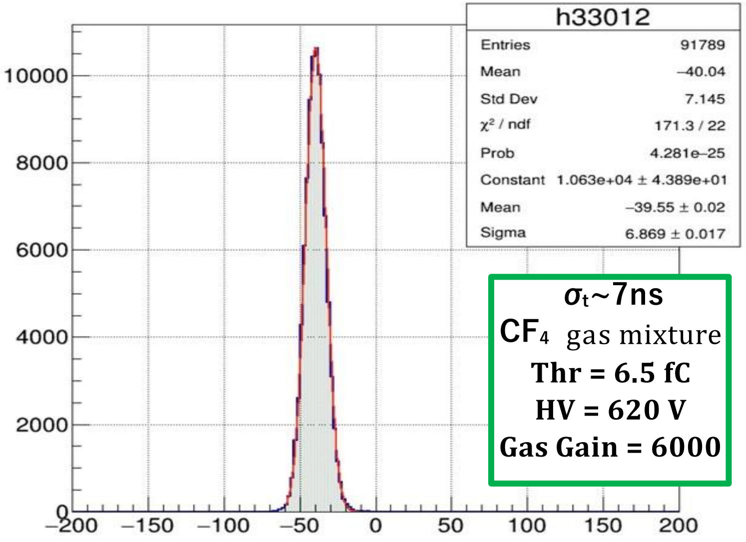




PEP DOT – time performance (preliminary)

FATIC based Fee





σ_t~7ns
CF_4 gas mixture
Thr = 6.5 fC
HV = 620 V
Gas Gain = 6000

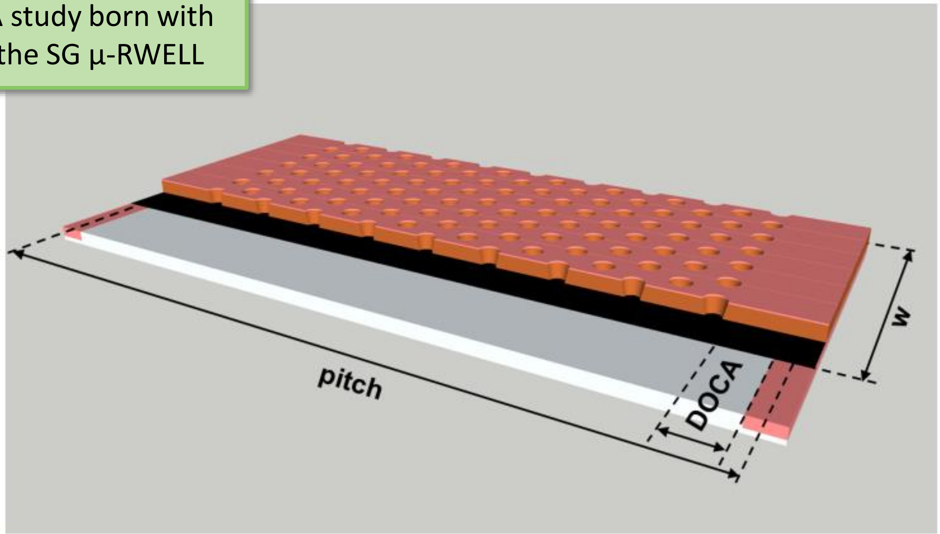
TB-2023 at H8C with **preliminary version of the FATIC chip** (developed by Bari Group) in the framework of the R&D for the **LHCb-Muon upgrade**. A new **test beam foreseen next Nov. '24** with **an updated version of the ASIC**, aiming to reduce the **FEE thr down 3 – 3.5 fC**

Detector washing and electrical cleaning

At LNF, we are installing a **detector washing station** with a stainless-steel tank and a high-pressure car-washing machine using deionized water.
After washing, the detector is placed in an **oven at 90°C**. After 24 hours, it is gradually powered by increasing voltage from 300V to 680V, following Rui's guidelines.

The DOCA

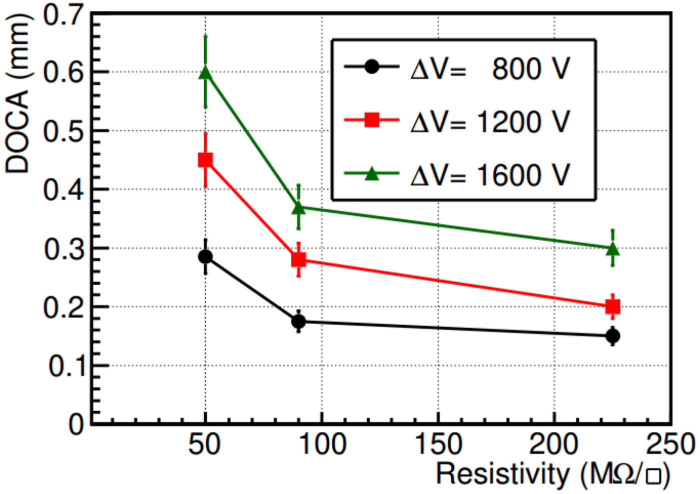
A study born with the SG μ-RWELL



Cross-section of a μ-RWELL with a conductive line on the DLC (High-Rate scheme).

The concept of **DOCA** (Distance-Of-Closest-Approach) before discharge is fundamental for the **stability** of the detector.

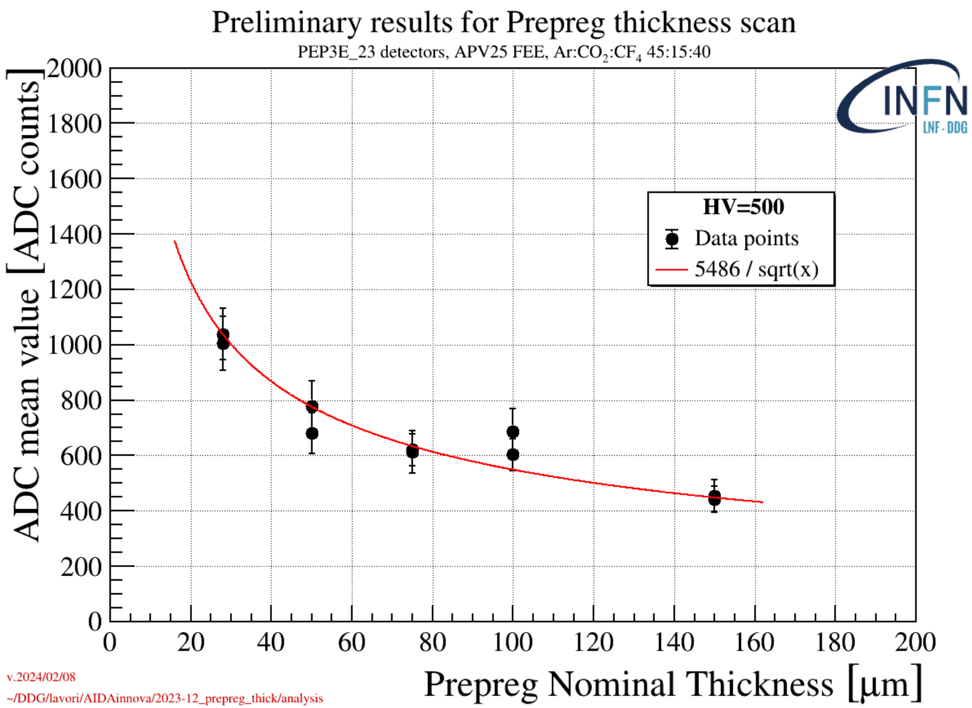
The **DOCA** is defined as the **distance between** the edges of the **conductive lines** and its **closest amplification hole**.

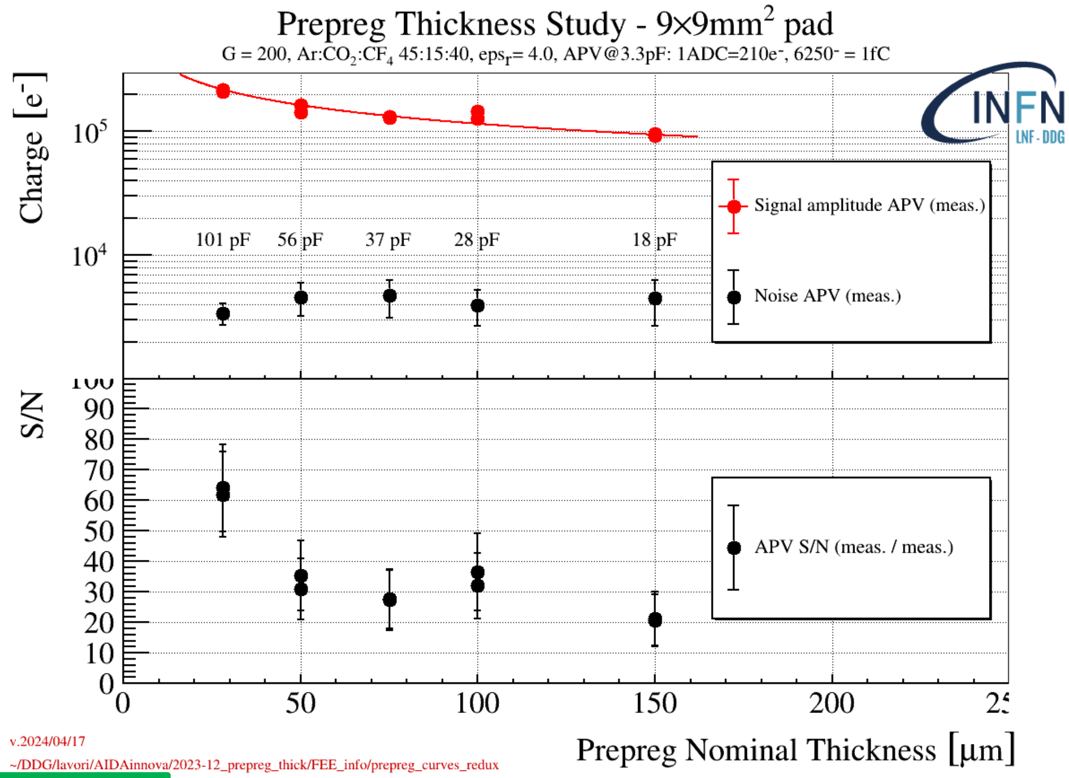


The **DOCA (before discharge)** as a function of the DLC **resistivity**, for different **voltages**.

The study has been performed with a custom tool, with two thin conductive movable tips.

Prepreg thickness optimization





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