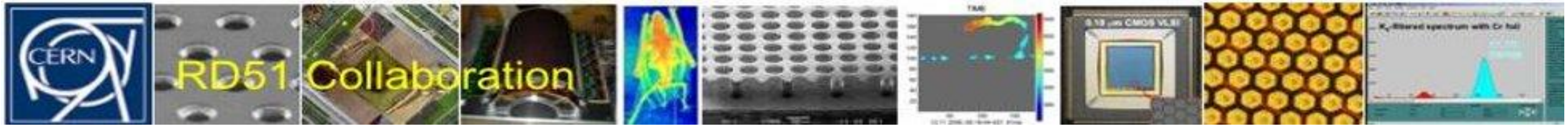
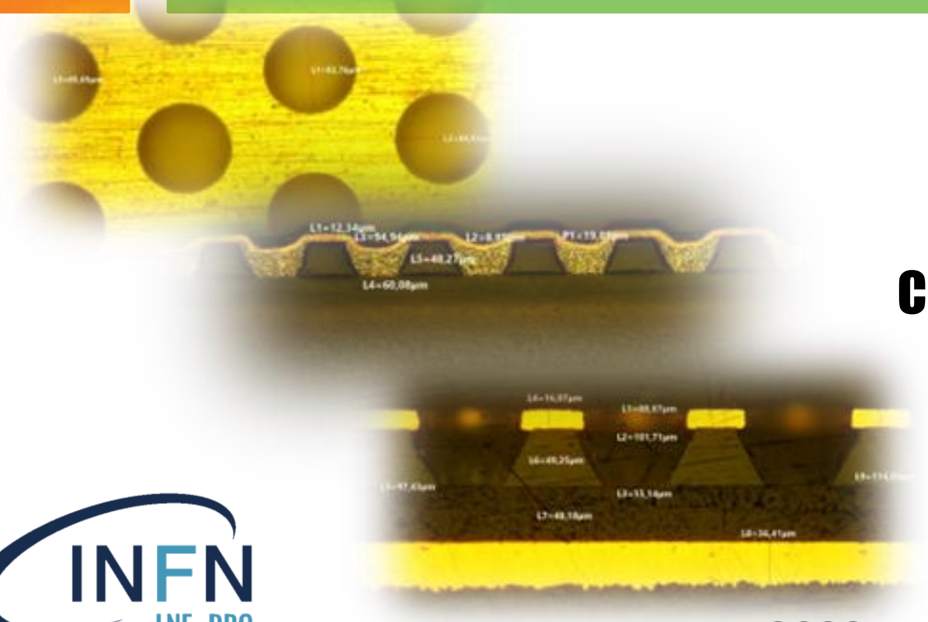


The micro-RWELL technology:

from the R&D to the technology transfer towards Industry



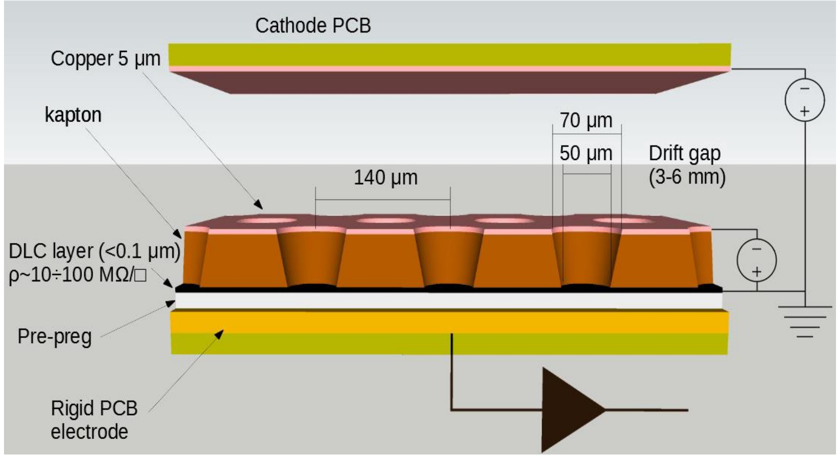
G. Bencivenni
on behalf of
DDG - LNF-INFN
CERN-CH, INFN – Bologna, INFN – Ferrara, ELTOS SpA

INFN LNF - DDG

IFD2022 – INFN Workshop on Future Detectors, Bari- 17-19 Oct. 2022

The µ-RWELL

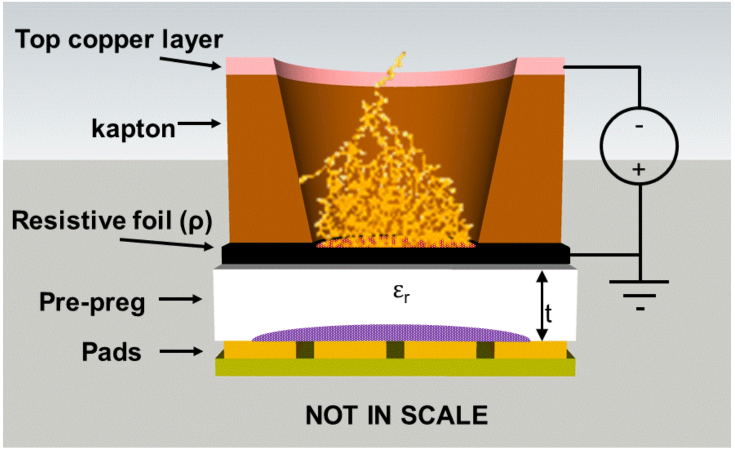
G. Bencivenni et al., The micro-Resistive WELL detector: a compact spark-protected single amplification-stage MPGD, 2015 JINST 10 P02008



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

- **Cathode**
- **µ-RWELL_PCB:**
  - a **WELL** patterned **kapton foil** (w/**Cu-layer on top**) acting as **amplification stage**
  - a **resisitive DLC** layer(*) w/ **ρ~10÷100 MΩ/□**
  - a standard **readout PCB** with **pad/strip** segmentation

(*) DLC foils are currently provided by the Japan Company – BeSputter

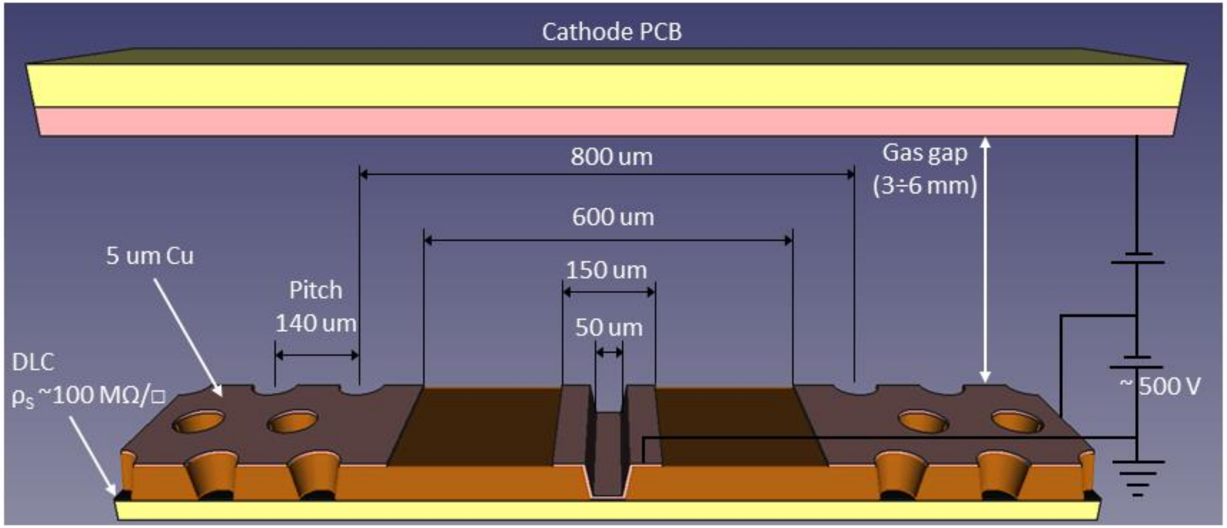


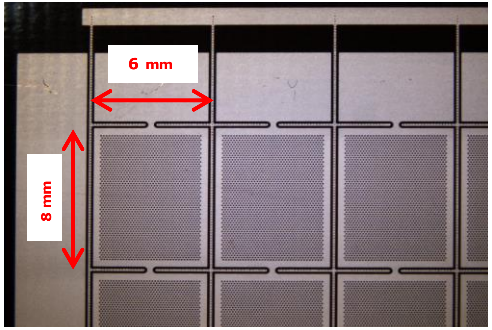
The **"WELL"** acts as a **multiplication channel** for the ionization produced in the drift gas gap.

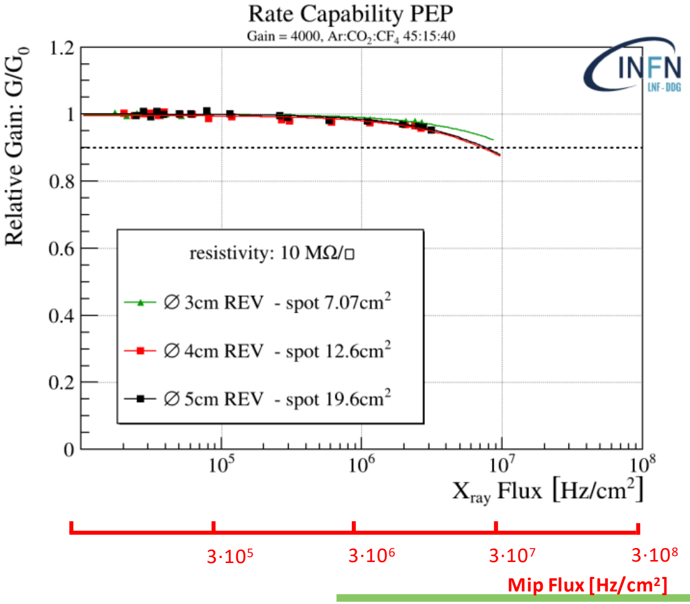
The **resistive stage** ensures the **spark amplitude quenching.**

Drawback: capability to stand high particle fluxes reduced, but **largely recovered** with appropriate **grounding schemes** of the **resistive layer**

The HR layout







The PEP layout (Patterning – Etching – Plating) is the state of art of the high rate layout of the µ-RWELL

- Single DLC layer
- Grounding line from top by kapton etching and plating (pitch 1/cm)
- No alignment problems
- High rate capability
- **Scalable to large size** (*up to 1.2x0.5 m for the upgrade of CLAS12*)

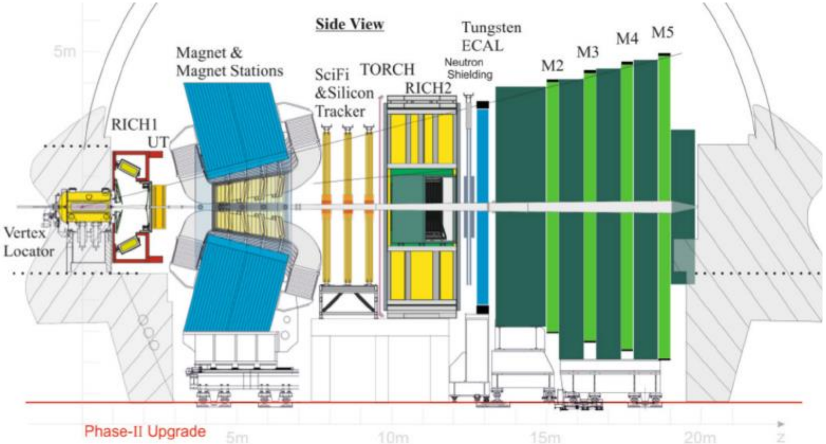
LHCb upgrade II (Run5 – Run6)

LHCb muon apparatus Run5 – Run6 option detector requirements

- Rate up to **1 MHz/cm²** on detector single gap
- Rate up to **700 kHz** per electronic channel
- Efficiency quadrigap >=99% within a BX (25 ns)
- Stability up to **1C/cm²** accumulated charge in 10 y of operation (M2R1, G=4000)

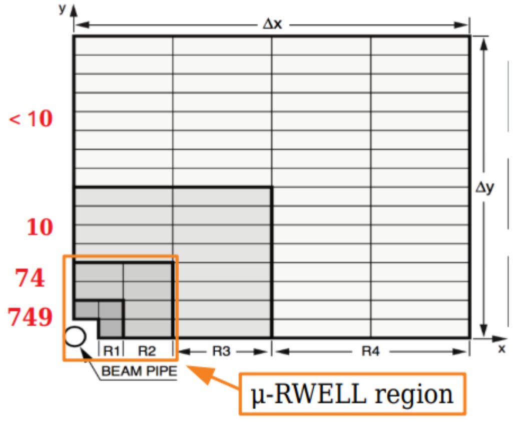
Detector size & quantity (4 gaps/chamber - redundancy)

- **R1÷R2: 576 detectors, size 30x25 to 74x31 cm², 90 m² detector (130 m² DLC)**
- ~~R3: 768 detectors, siz 120x25 to 149x31 cm², 290m² det.~~
- ~~R4 : 3072 detectors, size 120x25 to 149x31 cm², 1164 m² det.~~



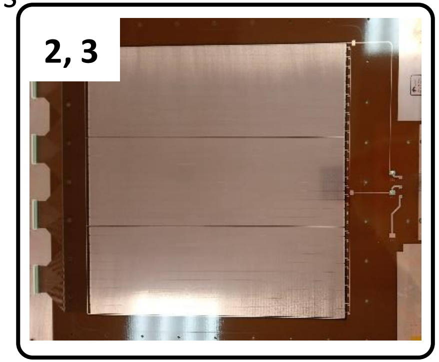
Rates (kHz/cm²)	M2	M3	M4	M5
R1	749	431	158	134
R2	74	54	23	15
R3	10	6	4	3
R4	8	2	2	2
Area (m²)	**M2**	**M3**	**M4**	**M5**
R1	0.9	1.0	1.2	1.4
R2	3.6	4.2	4.9	5.5
R3	14.4	16.8	19.3	22.2
R4	57.6	67.4	77.4	88.7

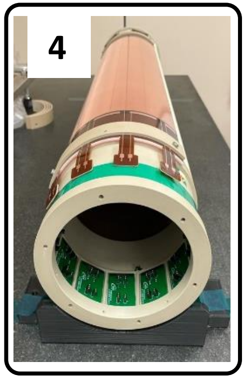
M2 station - max rate (kHz/cm²)

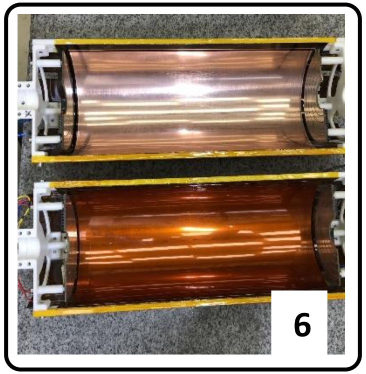


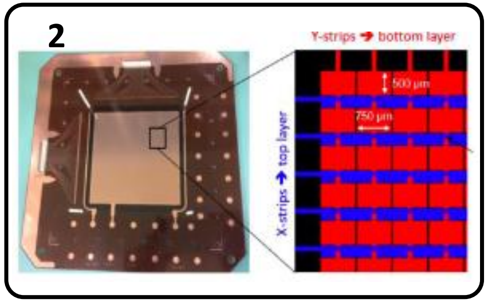
µ-RWELL in HEP/NP & beyond

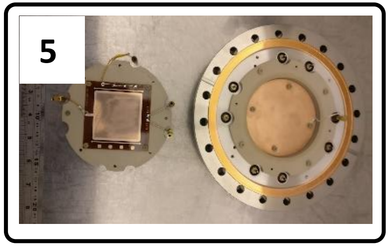
1. **FCC-ee**: pre-shower & muon systems of the IDEA apparatus → *large area (~4000m^2) to be instrumented w/tracking detectors*
2. **CLAS12 @ JLAB:** upgrade of the muon spectrometer → *large area (1.2x0.5m^2) low-mass tracking detectors*
3. **X17 @ n_TOF EAR2**: small -TPC for the detection of the X17 boson → *low mass tracking detectors*
4. **EURIZON**: R&D on IT based on cylindrical micro-RWELL for a SCTF → *low mass tracking detectors*
5. **UKRI:** thermal neutron detection with pressurized ^{3}He-CF4 gas mixtures → *neutron tracking device*
6. **TACTIC @ YORK Univ.:** radial TPC for nuclear reactions w/astrophysical significance → *low mass flexible tracking detectors*
7. **URANIA-V**: funded by CSN5 for neutron detection → *large pad (10x10cm^2) tile detectors for radiation portal monitor*
8. **Muon collider:** HCAL R&D → *pad tile detectors*

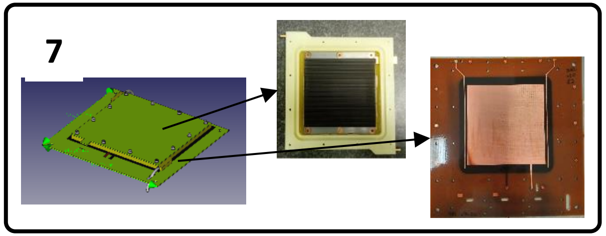




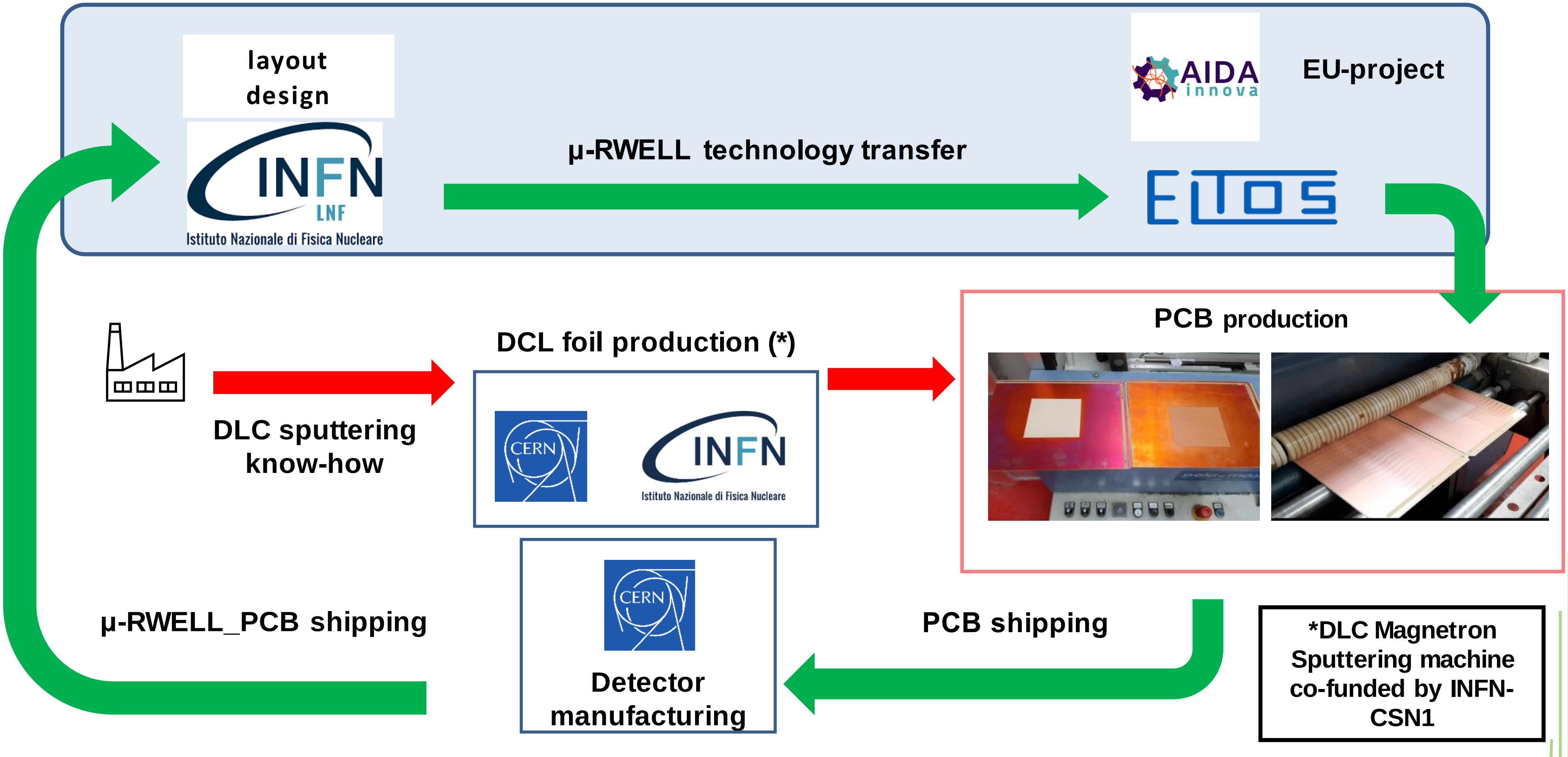








Technology transfer (I)



Technology transfer (II)

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

Step 1 - CERN_INFN DLC sputtering machine @ **CERN (+INFN)**
- delivery foreseen by the end of Oct. 2022
- **INFN** crew tbd & trained

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

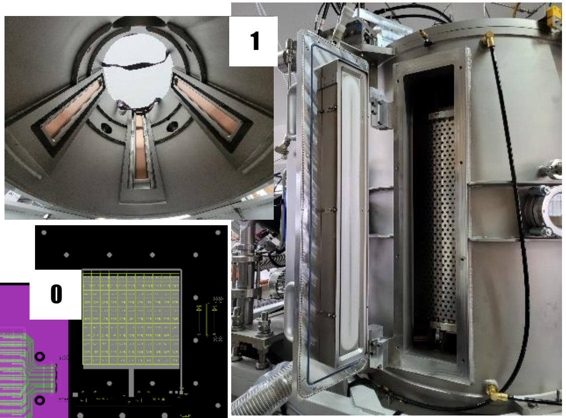
Step 3 - DLC patterning by **ELTOS**
- photo-resist ⊕ patterning with BRUSHING-machine

Step 4 - DLC foil gluing on PCB by **ELTOS**
- double 106-prepreg ~2x50μm thick
- PCB planarizing w/ screen printed epoxy ⊕ single 106-prepreg

Step 5 - Top copper patterning by **CERN** (in future by **ELTOS)**
- Holes image and HV connections by Cu etching

Step 6 - Amplification stage patterning by **CERN**
- PI etching ⊕ plating ⊕ ampl-holes

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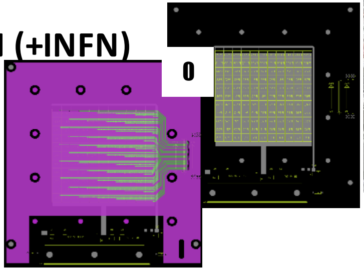
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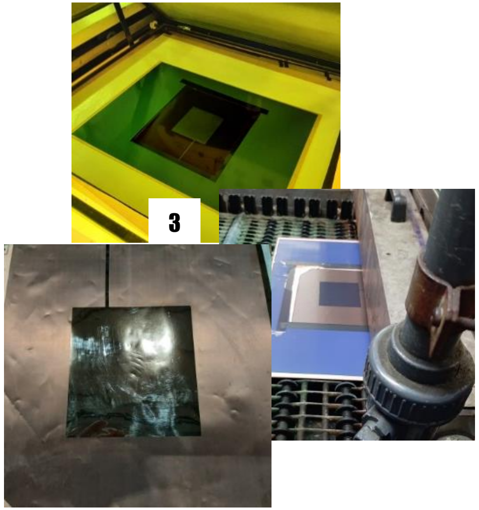
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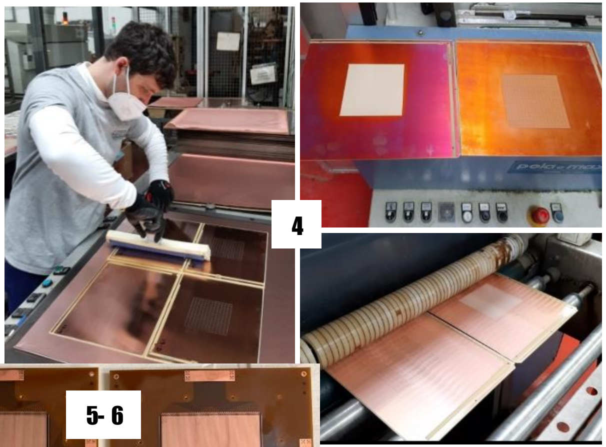
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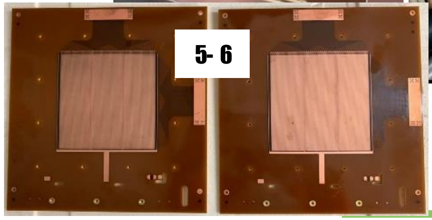
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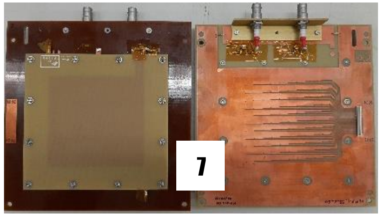

7

CID: the CERN-INFN DLC machine

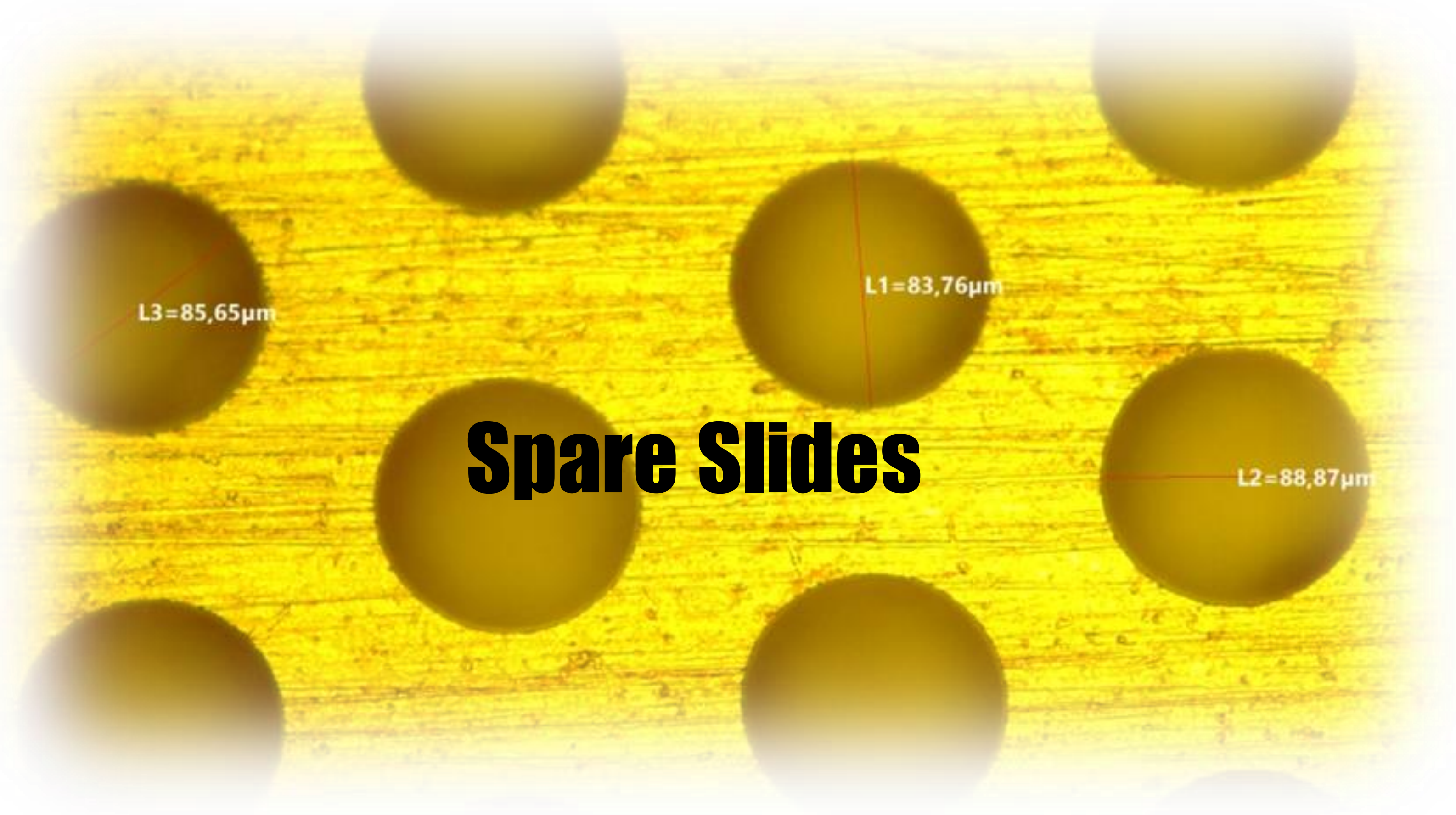
… some infos extract from the machine Contract

- The machine shall be able to coat **flexible substrates** with areas of **up to 1.7 m × 0.6 m**
- The machine shall be able to coat **rigid substrates** with areas of up to **0.2 m × 0.6 m**
- **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
- The Contractor shall provide **training for the CERN-INFN personnel** concerned, at the CERN site. The aim of the training course is to ensure that personnel is able to:
  - Program and pilot the process with the machine
  - Conduct a failure analysis on the machine

Summary

- The **driving force** behind the development of the **resistive MPGDs** is the **spark quenching** and **charge spreading** technique to optimize readout plane
- **DLC coatings** opened the way to develop new detector structures.
  The **µ-RWELL** is one of the examples of **emerging MPGD** technologies that are evolving and profiting from the on-going developments on DLC
- The challenge for the next years is the **TT of resistive-MPGD technology** to PCB industry
- **Key-point of the industrialization** has been the acquisition of a **DLC magnetron sputtering machine co-funded by CERN and INFN** that will enter in operation in 2023
- Other items under study:
  - **2D strip readout** → 2D w/top readout, 2D with capacitive sharing
  - **Global irradiation** (GIF, X-ray tube, Calliope source)
  - **Eco-gas fast mixtures** (*essentially for LHCb*)
  - **APV25 w/SRS** is a user-friendly electronics for testing MPGD. **VMM3** integration **w/SRS** in progress (RD51).
    The **Bari group** (*G. De Robertis, F. Iaciulli, F. Loddo*) is developing a new ASIC **(FATIC)** that will be tested for the µ-RWELL (LHCb). Under study an update version of TIGER (developed for BESIII CGEM by Torino group)
- **Sinergy** among **different groups** working on different resistive MPGD technologies (µ-RWELL/MM) for common tooling (DLC machine) should be promoted for the development of **high-performance hybrid structures**

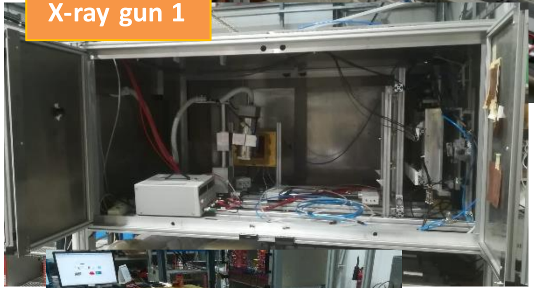
Spare Slides



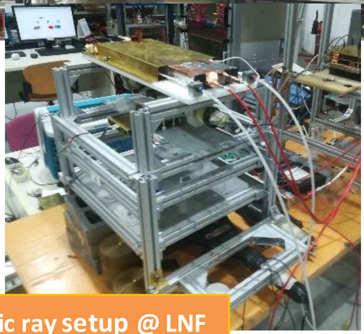
Test facilities

X-ray setup @ LNF

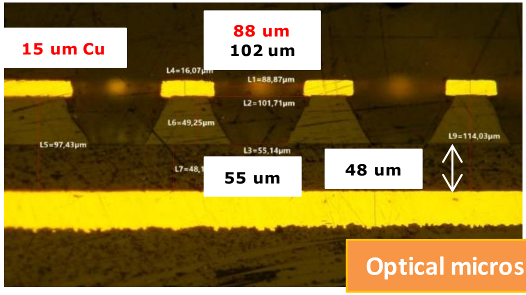
X-ray gun 1



X-ray gun 2

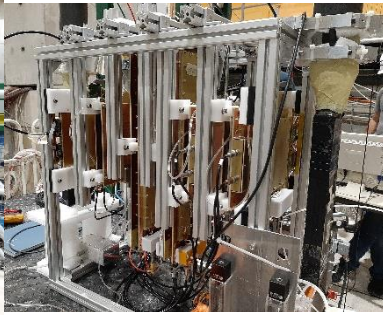


Cosmic ray setup @ LNF



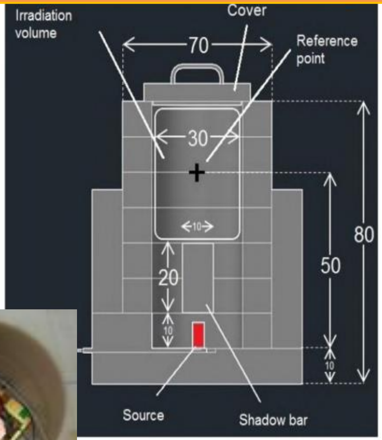
Optical microscope survey

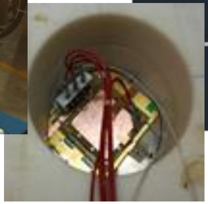
CERN – SpS H8C



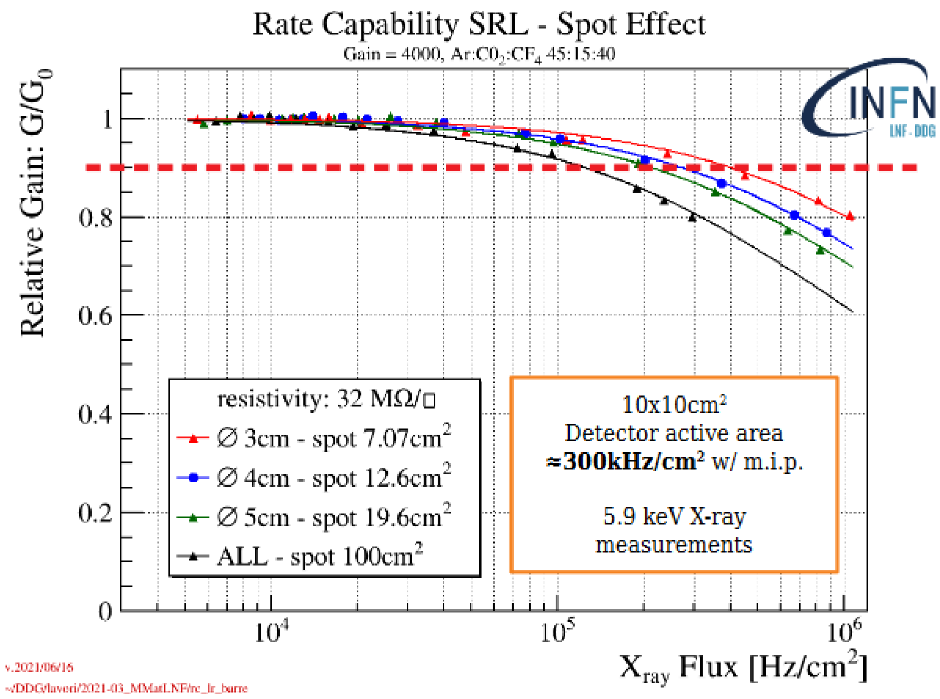
PSI – π-M1

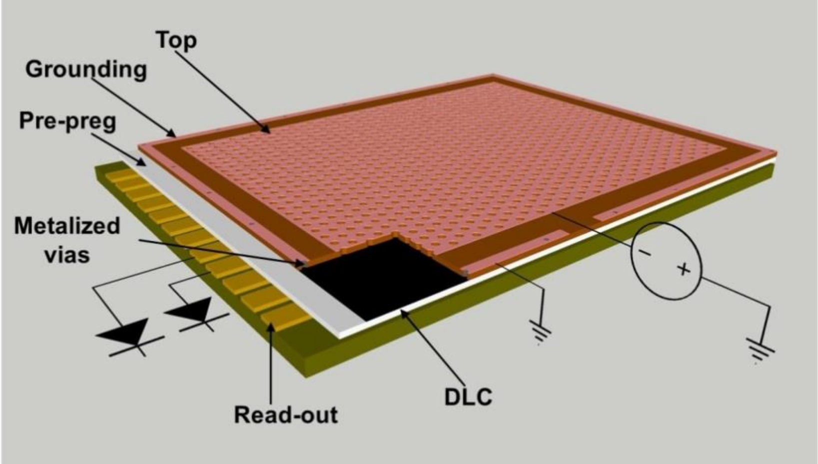
ENEA HOTNES thermal neutron facility





The low-rate layout

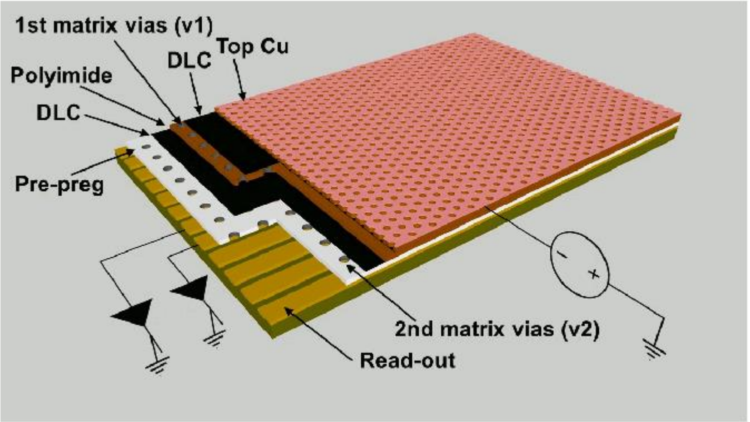




Single Resistive Layer (SRL)

- **2-D current evacuation** scheme based on a single resistive layer
- **grounding** around the **perimeter** of the active area
- **limited rate capability <100 kHz/cm^2**

High-rate layouts

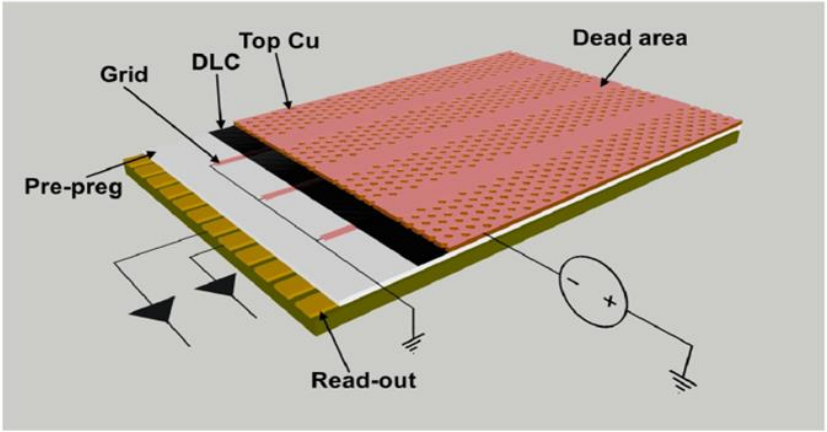


Double Resistive Layer

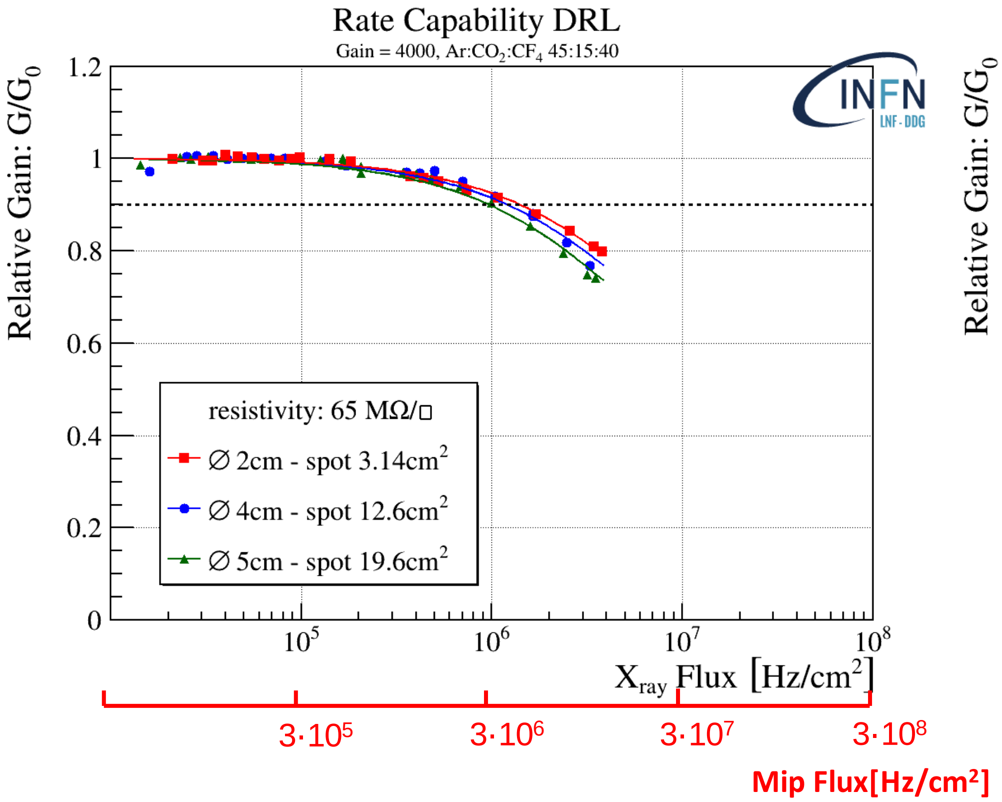
- **3-D current evacuation** scheme
- two stacked resistive layers connected through a matrix of conductive vias
- Resistive stage grounding through a further matrix of vias to the underlying readout electrodes
- pitch of the vias with a density less than $1/cm^2$

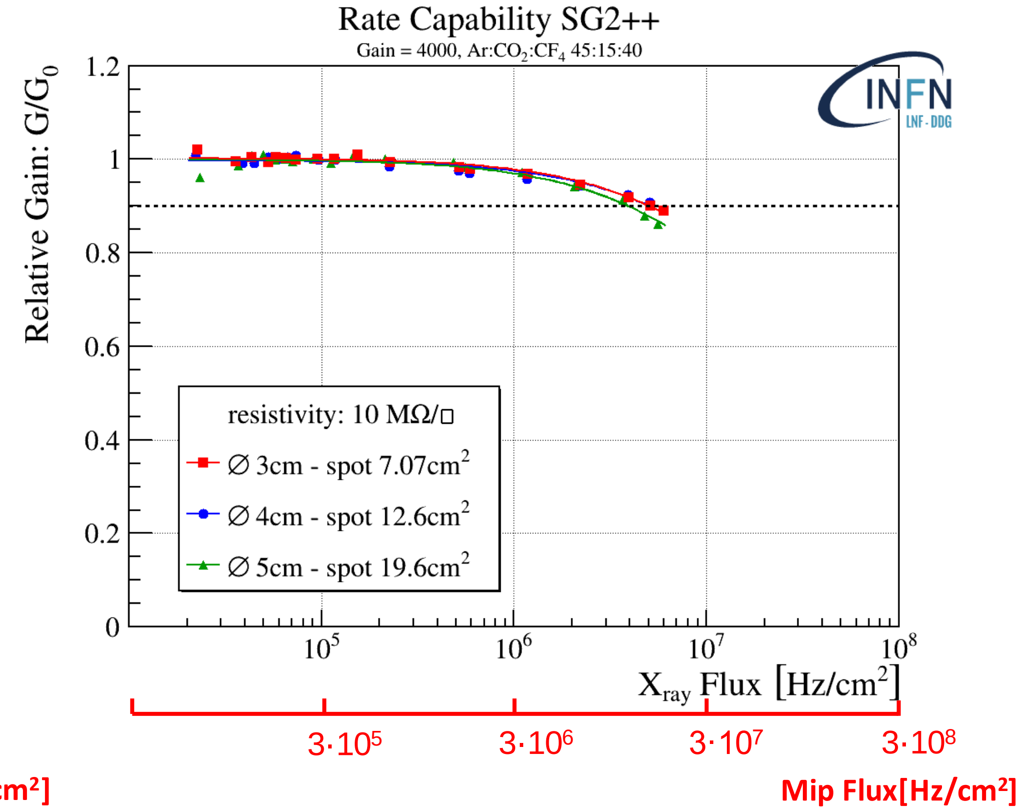
The Silver Grid

- simplified HR scheme based on SRL
- **2-D evacuation scheme** by means a conductive grid realized on the DLC layer
- grid lines can be screen-printed or etched by photo-lithography
- pitch of the grid lines of the order of 1/cm



High-rate layouts: performance w/X-rays

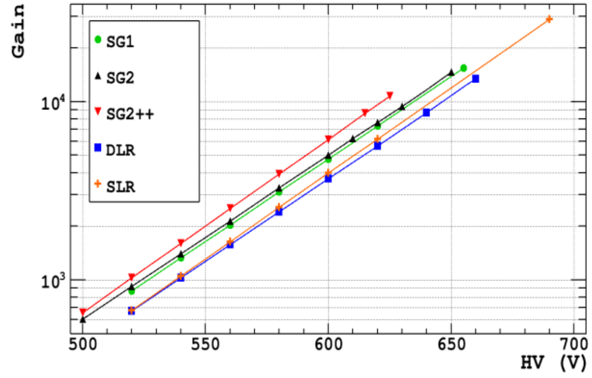




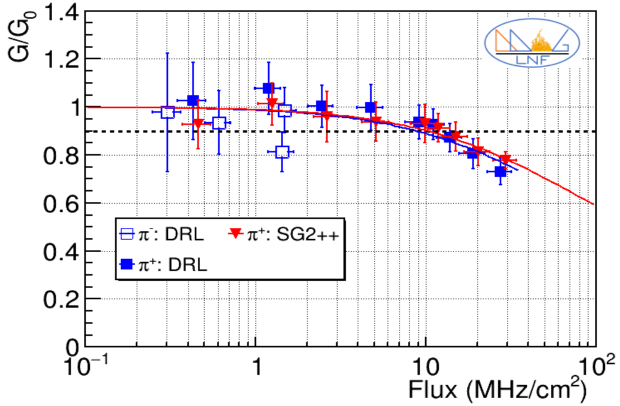
Rate capability w/m.i.p. ~ 3 times X-rays

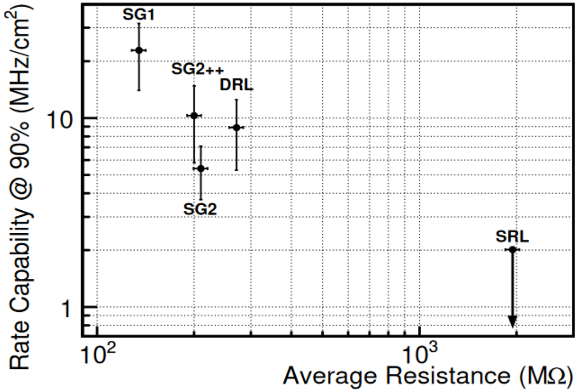
High-rate layouts performance w/m.i.p.

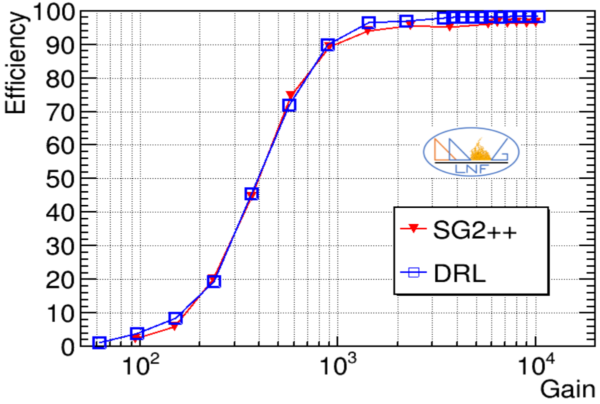
Gain up to ~10^4



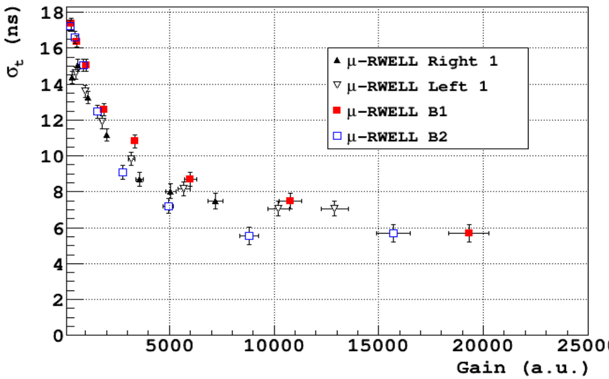
Rate capability up to 10 –20 MHz/cm^2



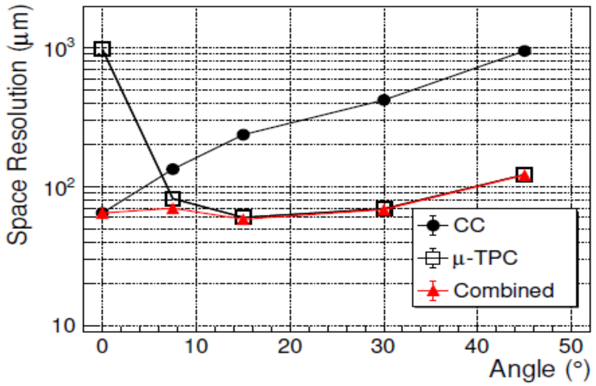




Efficiency ~97%



Time resolution 5-6 ns



Space resolution down to 60 μm

The micro-RWELL layouts for high particle rate, G. Bencivenni et al., 2019_JINST_14_P05014