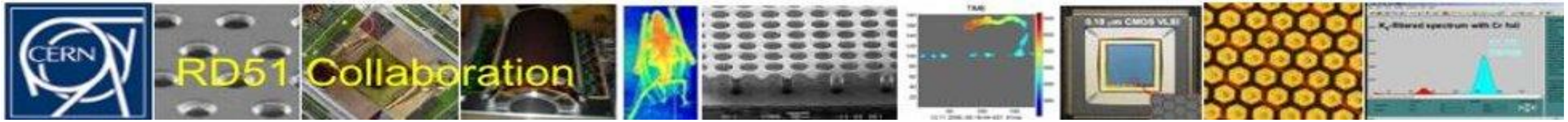
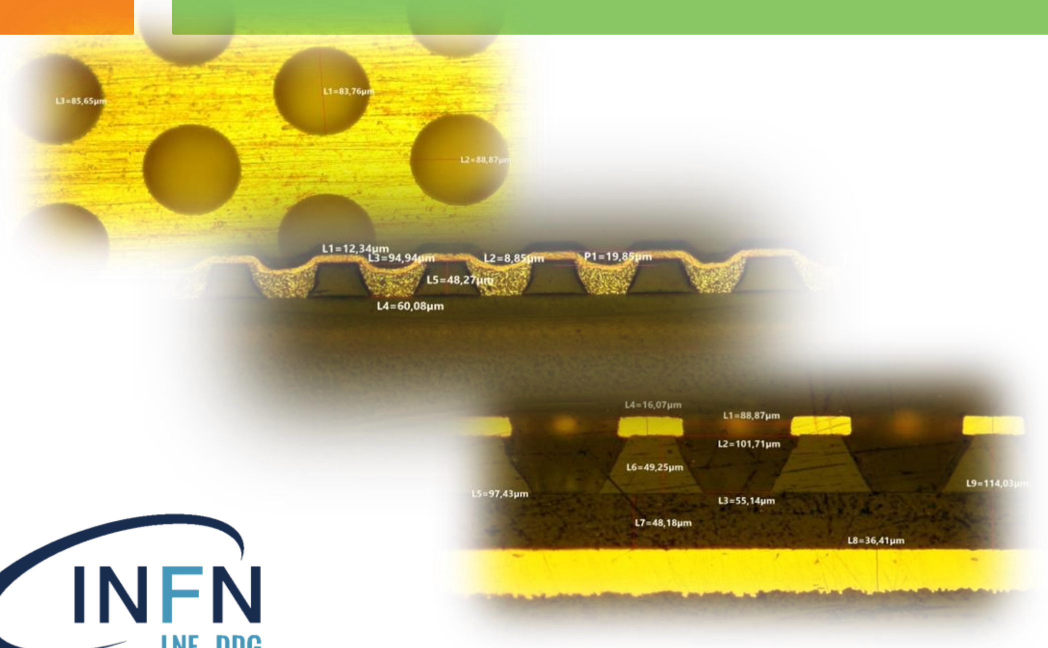


The micro-RWELL for R1/R2

Status & plans



G. Bencivenni

On behalf of DDG - LNF

LHCb Italia meeting - 15 Nov 2022

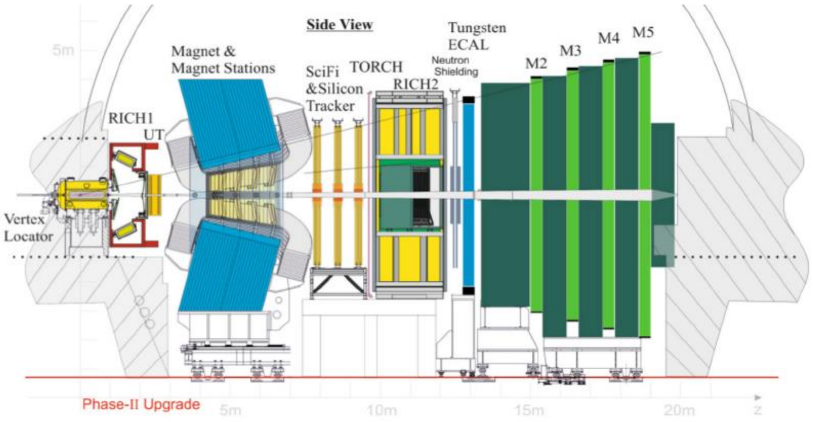
LHCb upgrade II (Run5 – Run6)

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 10y at M2R1, G=4000

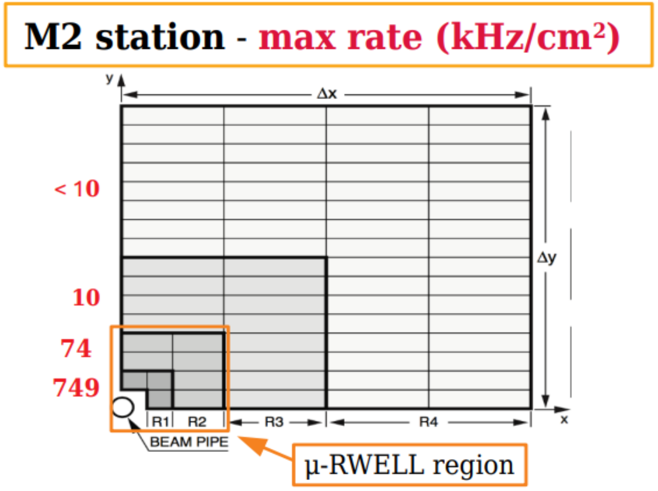
Detector size & quantity (4 gaps/chamber - redundancy)

- **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.~~



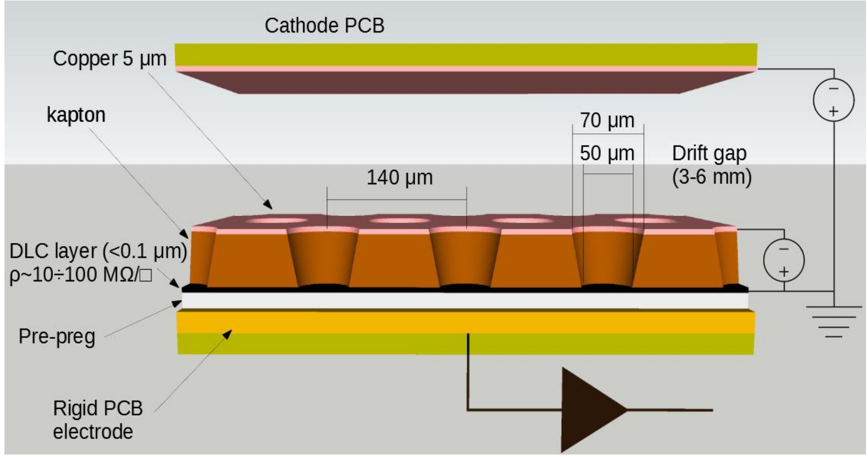
Rates (kHz/cm²)	M2	M3	M4	M5
R1	749	431	158	134
R2	74	54	23	15
R3	10	6	4	3
R4	8	2	2	2

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



The μ-RWELL (reminder)

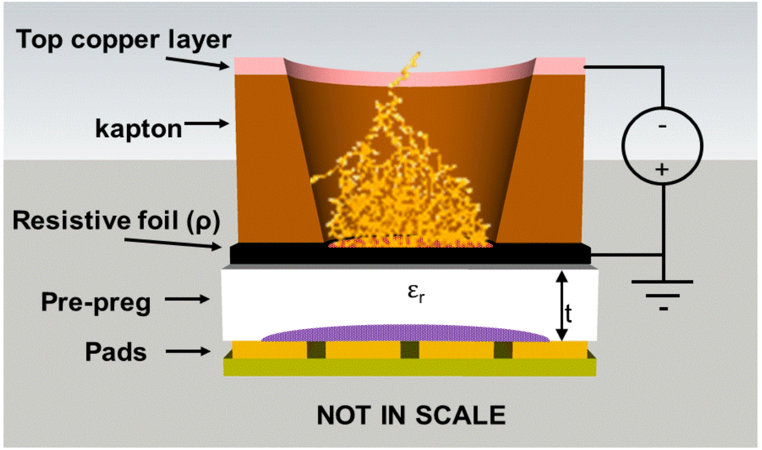
G. Bencivenni et al., The micro-Resistive WELL detector: a compact spark-protected single amplification-stage MPGD, 2015 JINST 10 P02008



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

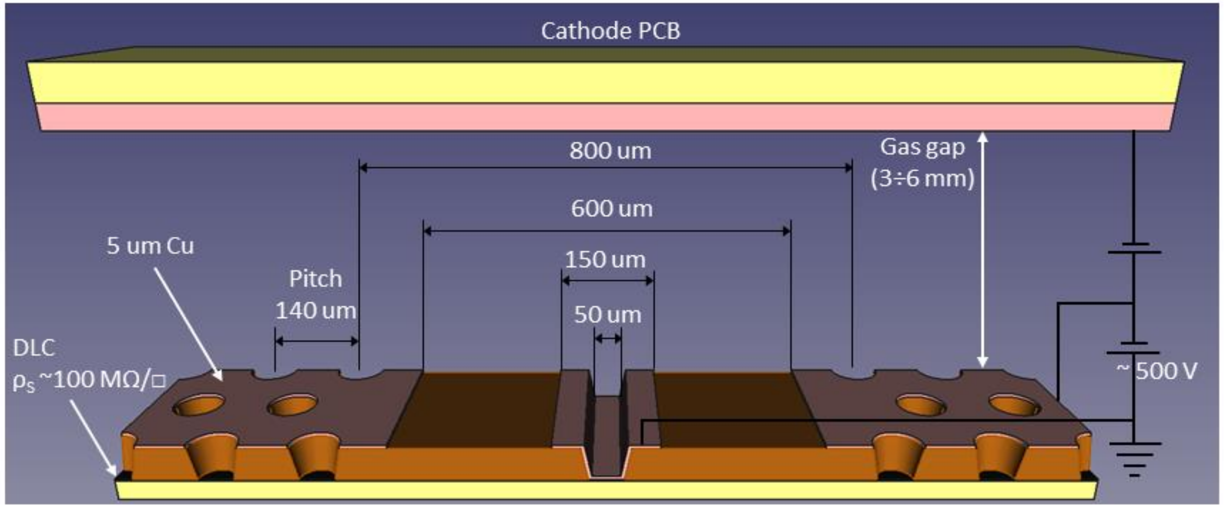


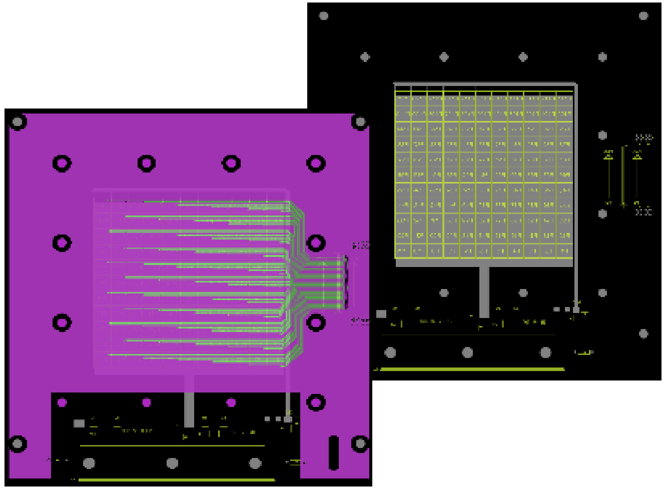
The **"WELL"** acts as a **multiplication channel** for the ionization produced in the drift gas gap.

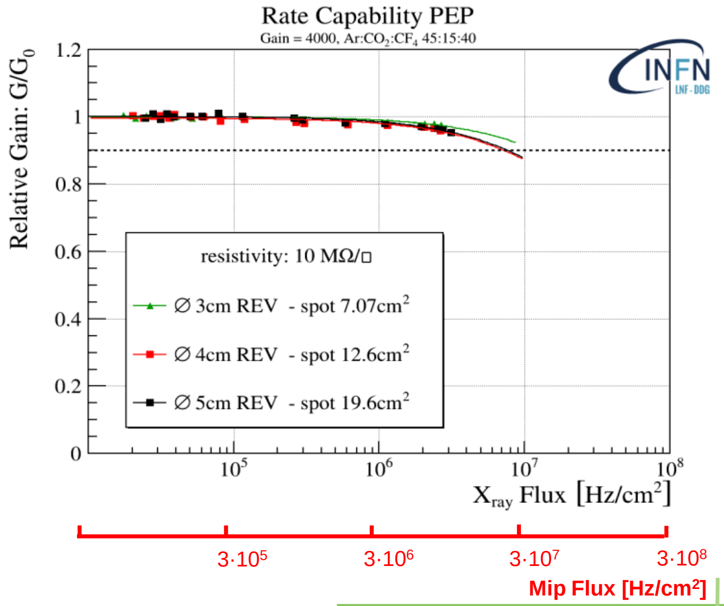
The **resistive stage** ensures the **spark amplitude quenching.**

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 developed **for LHCb**

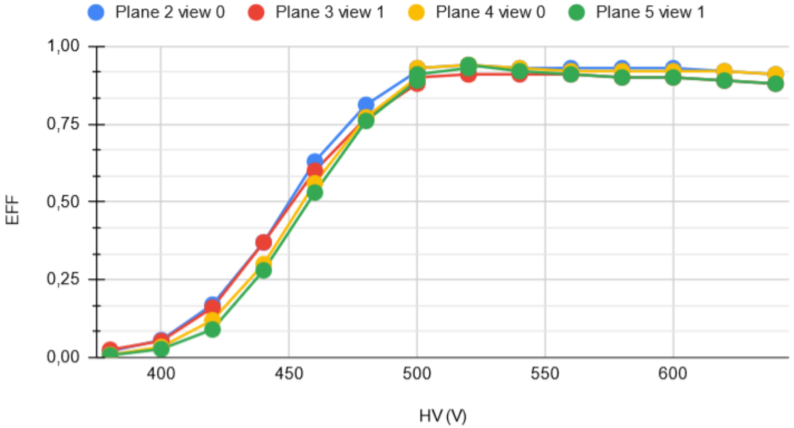
- **Single DLC** layer
- **Grounding line from top** by kapton etching and plating (pitch down to 1/cm)
- **No alignment** problems
- **High rate** capability
- **Scalable to large size** (up to 1.2x0.5 m for the upgrade of CLAS12)

QA & QC

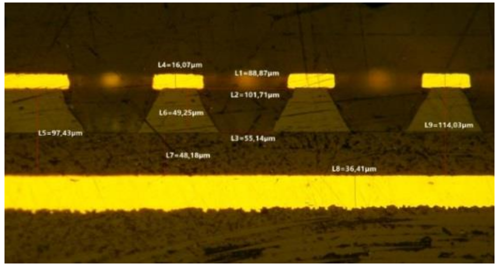
The technology (based on **SBU** layout) has been **largely improved** in the last year, thanks to the introduction of the “**dry-electrical-cleaning”,** a sort of a hot HV conditioning leading to a soft clean of the residual imperfections of the detector manufacturing.

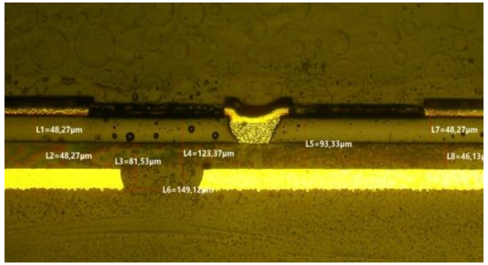
Detector stability improved → up to **200V** large plateau, **estimated gain up to 4÷5×10^{4}** (to be measured).

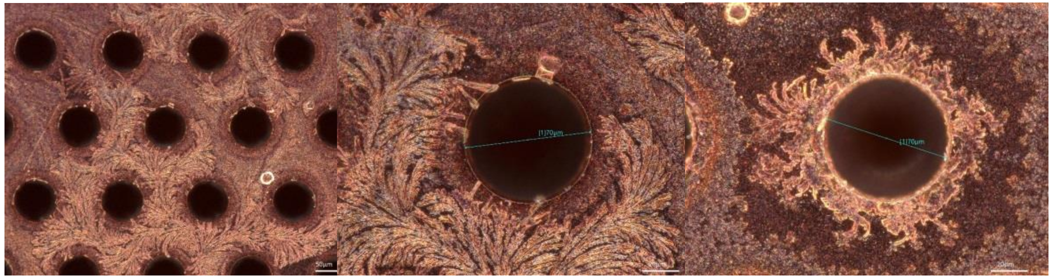
Very preliminary



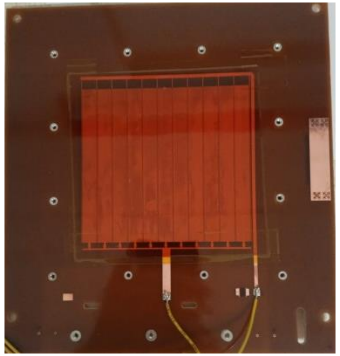
Optical metallographic survey (in ELTOS) as well as **SEM analysis** (at CERN) are used to take all construction steps under control as well as checking effects for possible aging/etching (by fluorine …).

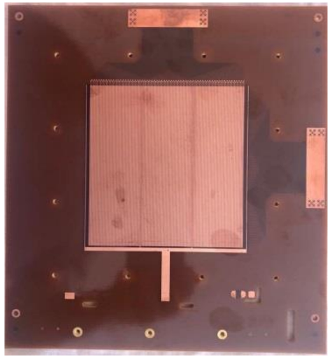


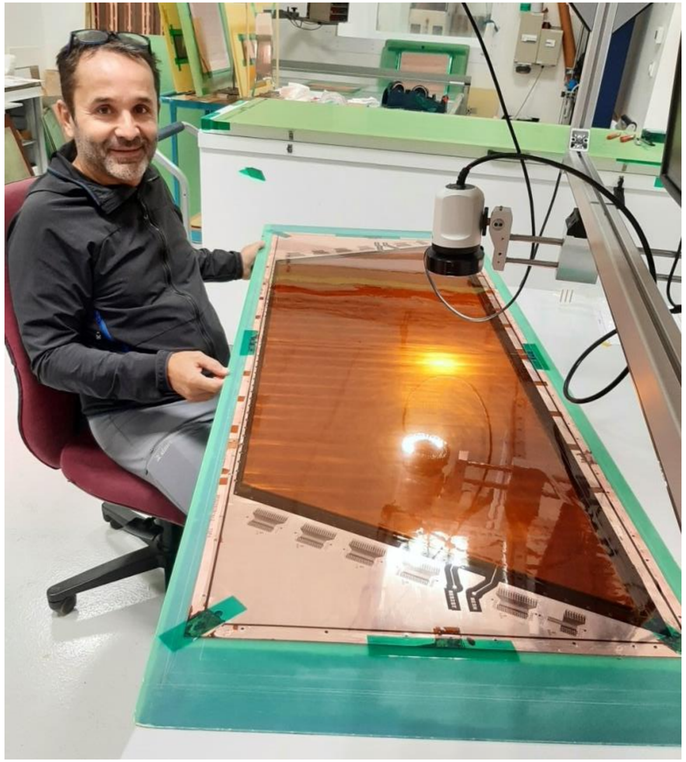


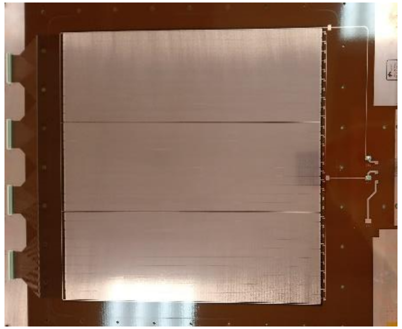


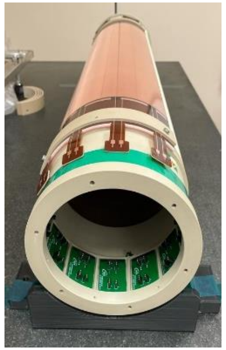
Technology spread

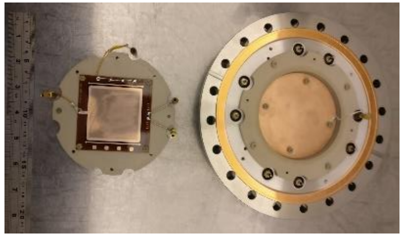


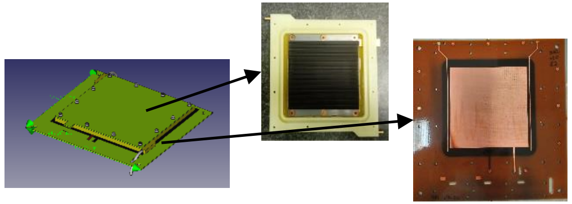








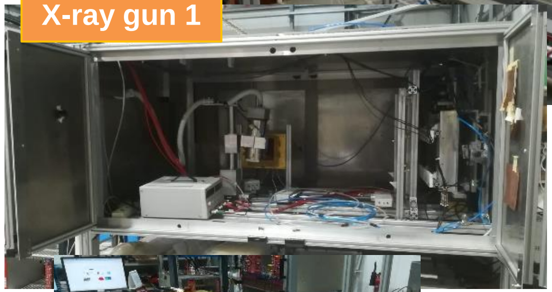




The **improvement of the quality and yield** is a clear **by-product of the technology spread** (Iin particular CLAS12 upgrade at JLAB).

Test facilities and synergies

X-ray setup @ LNF



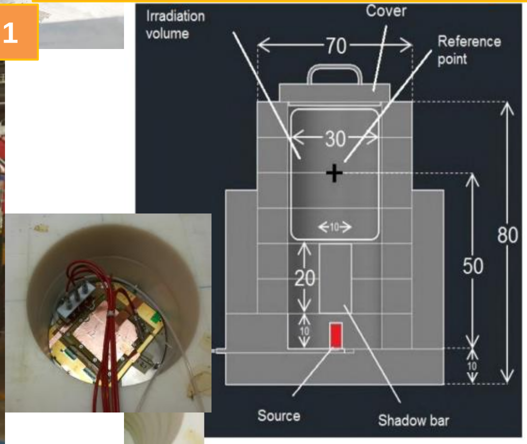
X-ray gun 1

X-ray gun 2

Cosmic ray setup @ LNF

CERN – SpS H8C

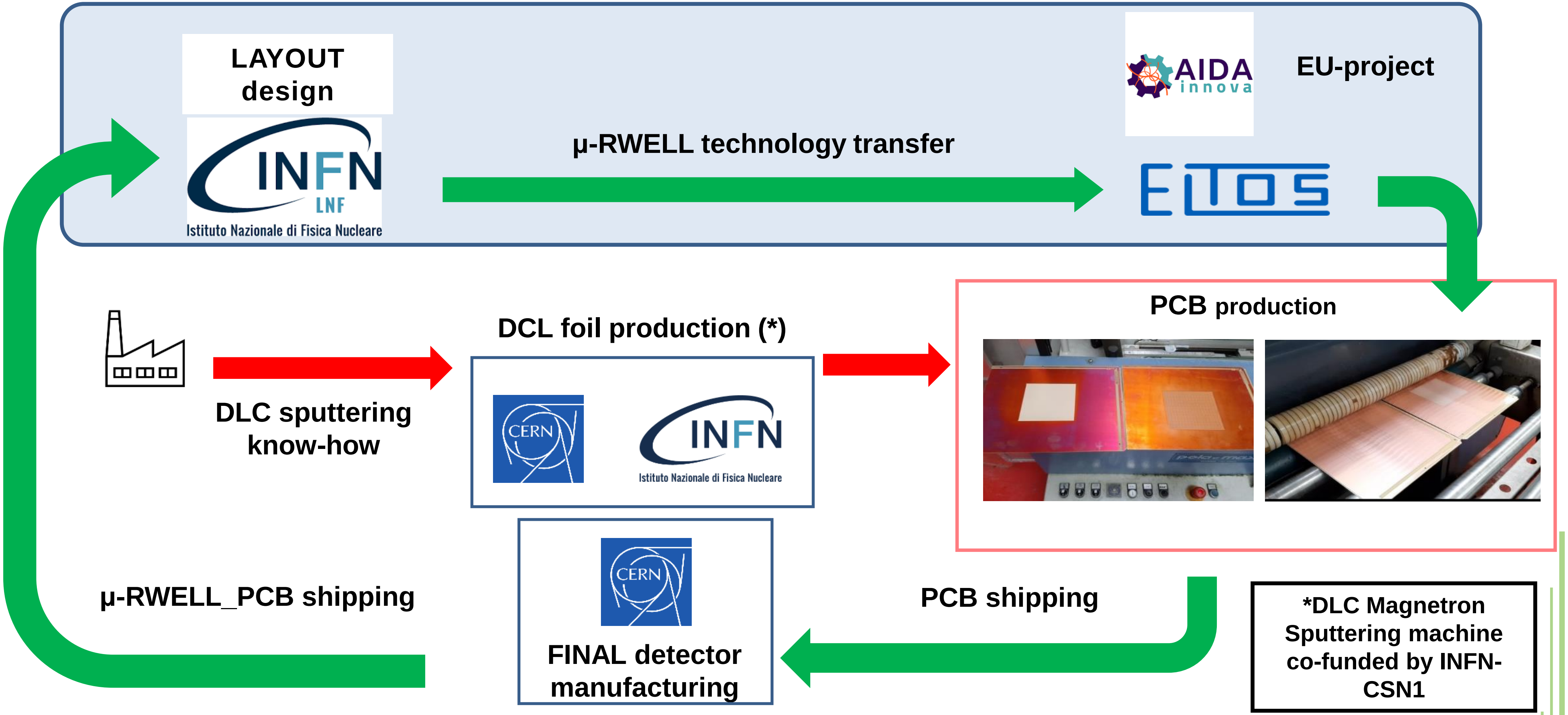
PSI – π-M1



ENEA HOTNES thermal neutron facility

Several **test facilities** in Frascati (LNF/ENEA), CERN (H8C) and PSI (PiM1) are exploited for detectors characterization. **Synergies** with external groups (Ferrara, Bologna, RM2-CLAS12) gave an important boost to the technology. For sure the involvement of other LHCb-Muon groups would be desirable in the near future, in particular in view of the phase of major commitment for the integration tests.

Technology transfer (I)



Technology transfer (II)

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

Step 1 - CERN_INFN DLC sputtering machine @ **CERN**
- Installed and commissioned beginning of Nov 2022
- **Operated by CERN + LNF (& INFN) staff**

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

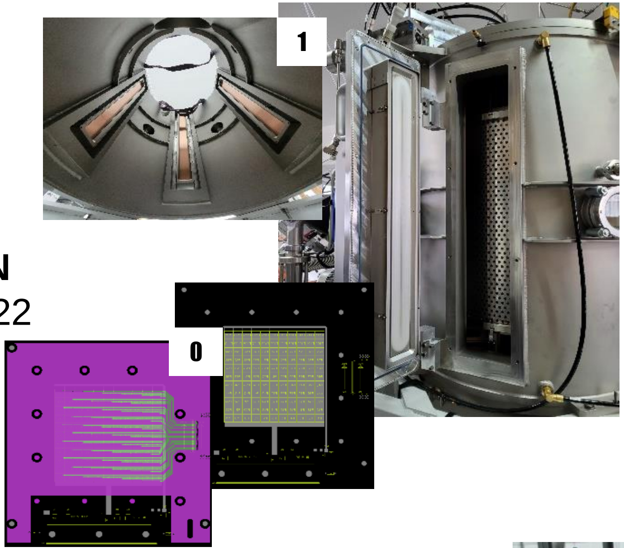
Step 3 - DLC patterning by **ELTOS**
- photo-resist ⊕ patterning with BRUSHING-machine

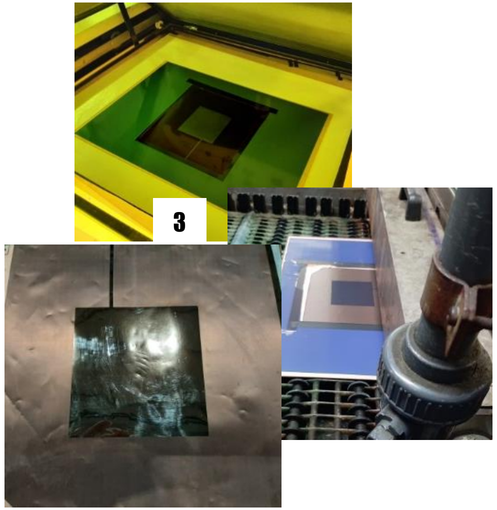
Step 4 - DLC foil gluing on PCB by **ELTOS**
- double 106-prepreg ~2x50μm thick
- PCB planarizing w/ screen printed epoxy ⊕ single 106-prepreg

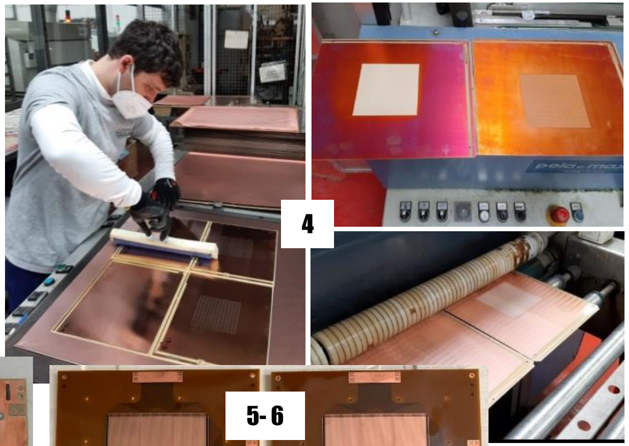
Step 5 - Top copper patterning by **CERN** (in future by **ELTOS)**
- Holes image and HV connections by Cu etching

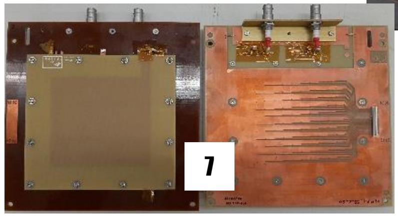
Step 6 - Amplification stage patterning by **CERN**
- PI etching ⊕ plating ⊕ ampl-holes

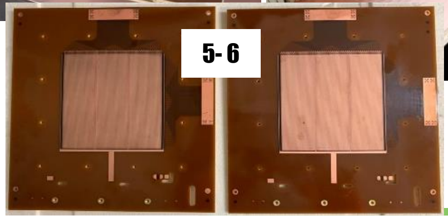
Step 7 – Final electrical cleaning and detector closing @ **CERN**





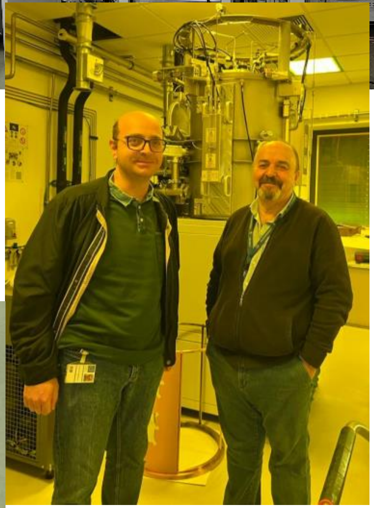






CID: the CERN-INFN DLC machine

- **Flexible substrates, coating** areas **up to 1.7 m × 0.6 m**
- **Rigid substrates, coating** areas 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
- **Sputtering & co-sputtering different materials,** in order to create a coating layer by layer or an adjustable gradient in the coating



- **Installation,** week 43
- **Commissioning** & **training** of the CERN-INFN teams, week 44
- **Next test-phase**, week 47
- **1 week/month** joint CERN-INFN test runs

Summary & Outlook

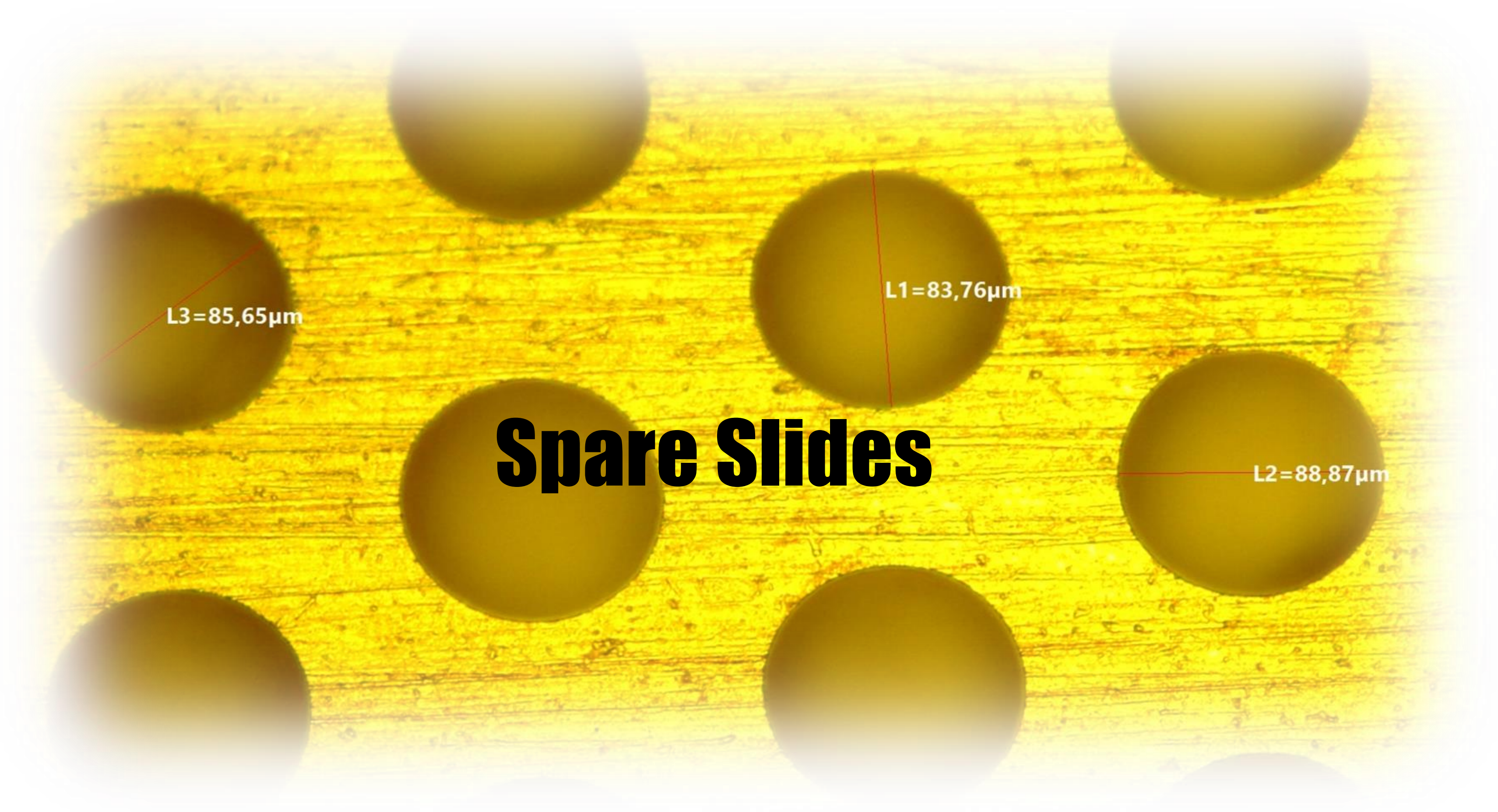
The advances in the **µ-RWELL technology** during the last two years lead to **large improvements** in **terms of stability** and **production yield**

- The challenge for the next two years is the **TT of resistive-MPGD** to the PCB industry (ELTOS)
- **Key-point** is the acquisition of the **DLC magnetron sputtering machine co-funded by CERN and INFN** that is going in operation in these days

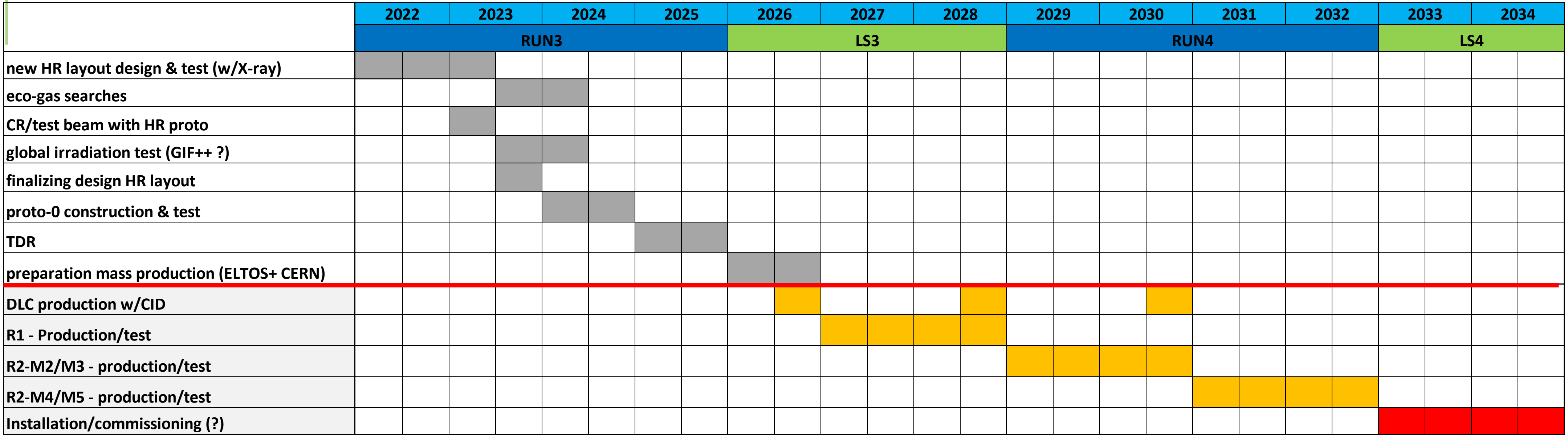
Mid-term To Do List:

- **Integration with the electronics (FATIC)** developed by **Bari** group, with the goal of a better understanding of the **requirements for a new dedicated ASIC**
  - **Test-bench** in Bari within the **end of the 2022**
  - **cosmic ray stand** within **spring 2023**
  - **Test beam** (eff in 25 ns, OR/maj..etc vs gas mix) within **summer 2023**
- **Optimization** of the **PEP** layout & design of the **M2R1/R2 proto-0** → **2023/24**
- **Global irradiation** (LNF X-ray tube, GIF++ w/Gas CERN group) → **2023/2024**
- **Eco-gas fast** mixtures (???)

Spare Slides



Tentative schedule



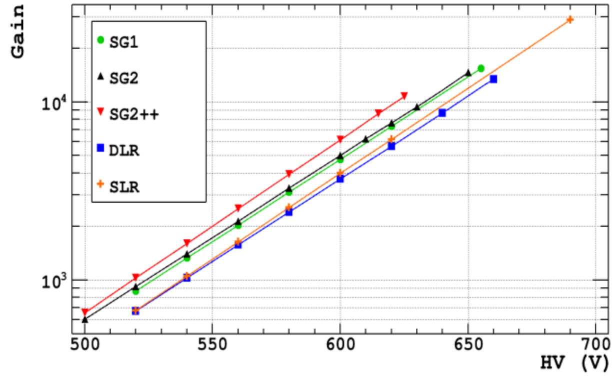
La costruzione segue i seguenti step(*):

- CERN→ produzione DLC con macchina sputtering CID
- Eltos → PCB, DLC patterning & gluing
- CERN → finalizzazione rivelatore con etching kapton (RUI)
- CERN → assemblaggio con frame e catodi e procedura di conditioning (RUI)
- CERN → test finale rivelatori e integrazione elettronica (personale INFN)

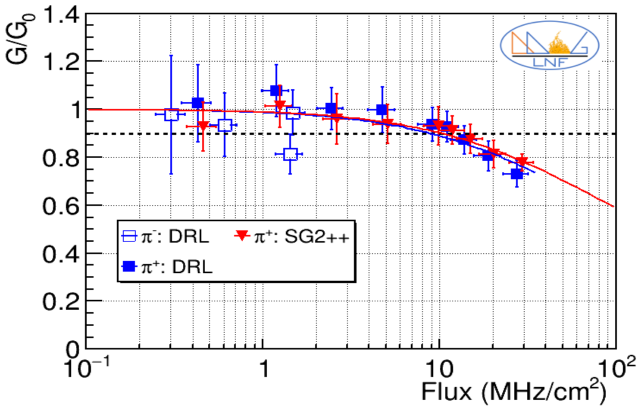
(*) **tempi e modalità di produzione definite con Rui & Eltos e considerando un solo «integration group»**

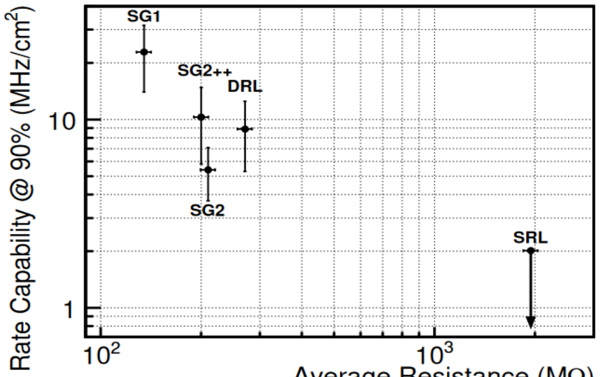
High-rate layouts performance w/m.i.p.

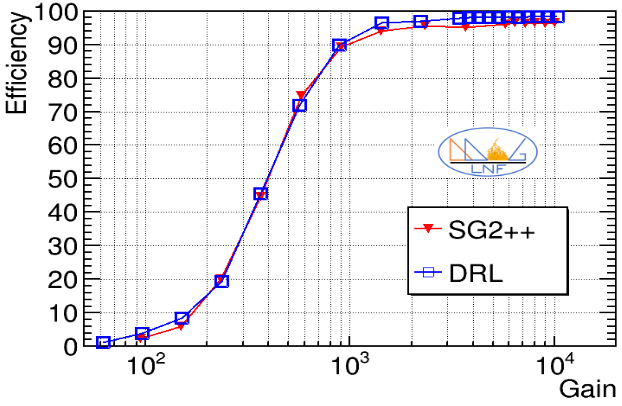
Gain up to ~10^4



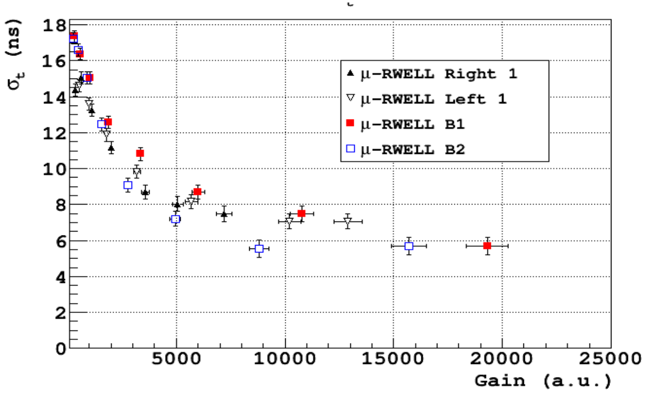
Rate capability up to 10–20 MHz/cm^2



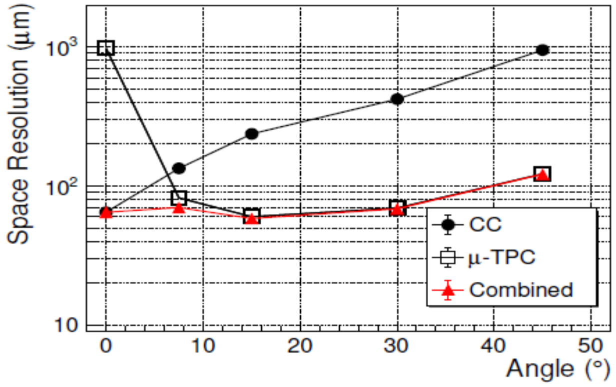




Efficiency ~97%



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