RD_FCC: WP7 µ-RWELLs

Status 2021 & Plans 2022

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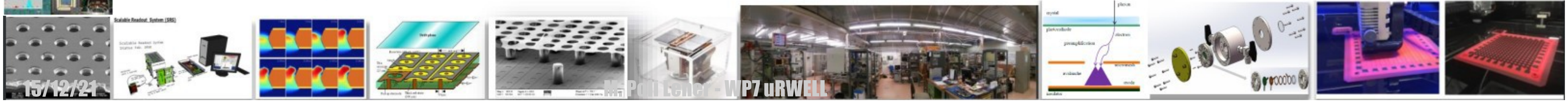
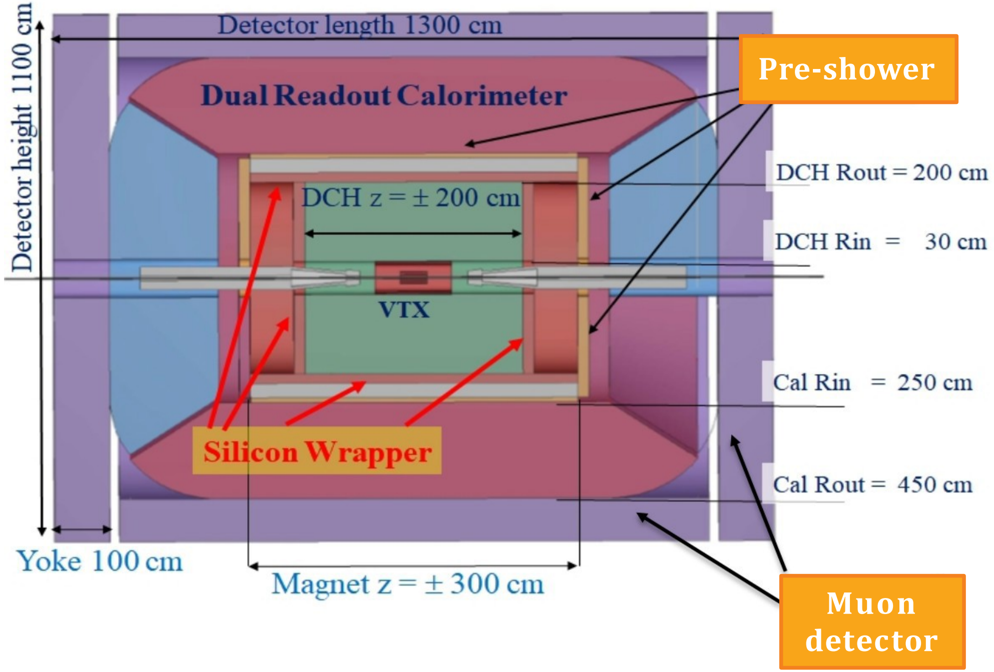
1 – INFN Torino
2 – INFN Ferrara
3 – LNF-INFN
4 – INFN Bologna



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

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



Pre-shower — Oct.'21 TB

Tiles: 50x50 cm^2 with X-Y readout
Strip length: 50cm
Strip pitch: 0.4mm
Input FEE capacity ~ 70 pF

TOT: 330 m^2, 1.5×10^6 channels

Muon detector

Tiles: 50x50 cm^2 with X-Y readout
Strip length: 50cm
Strip pitch: 1.5mm
Input FEE capacity ~ 270 pF

TOT: 4000 m^2, 5×10^6 channels

Requirements:

- **Efficiency ≥ 98%**
- **Space resolution ≤ 100 μm (pre-shower)**
  ≤ 400 μm (muon)
- **Mass production → Technology Trasfer to Industry**
- **Reduction of FEE channels → surface resistivity optimization**
- **FEE Cost reduction → custom made ASIC (TIGER)**

WP7 μ-RWELLs: meeting & conference 2021

4 riunioni di gruppo per la coordinazione del programma 2021 & preparazione TB

Presentazioni 2021:

- EPS-HEP Conference 2021, *“The preshower and the muon detection system of the IDEA detector for FCC-ee”*, July 26-30
- RD51 Collaboration Meeting, “Charge spread in μ-RWELLs”, *November* 15 – 19

Status WP7 – 2021

Programma WP7 - 2021

L'R&D prevede **lo studio delle prestazioni spaziali** in funzione del **valore di resistività** del piano resistivo (DLC):

- **I rivelatori hanno active area di 16x50 cm^2, lettura 1D,** diverso **strip pitch** e **resistività** del DLC :
- **pre-shower → strip pitch 0.4 (0.8) mm**

  resiitivity → 10, 30, 50, 70, >100-200 MOhm/square
- **rivelatore di muoni → strip pitch 0.8 - 1.2 - 1.6 mm**

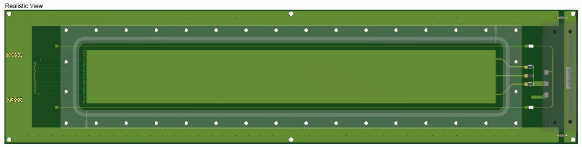
  resiitivity → 35, 15 MOhm/square

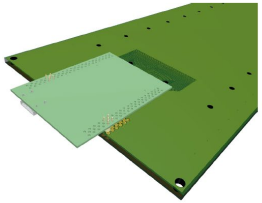
Ritardi workshop di Rui:

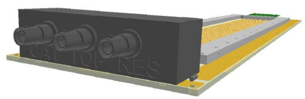
- **pre-shower → N. 10 proto consegnati durante il TB e testati su fascio (problema su DLC dei proto >100-200 MOhm/square – non consegnati)**
- **muon → consegna prevista per fine dicembre 2021 (non testati al TB)**

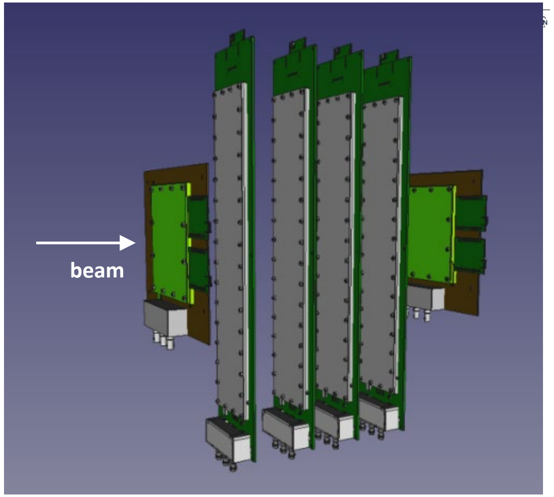
I **rivelatori pre-shower**, equipaggiati con elettronica APV, sono **testati su fascio** al **SPS-H8-CERN in ottobre (20/10 – 3/11 /2021)**

Layout prototipi









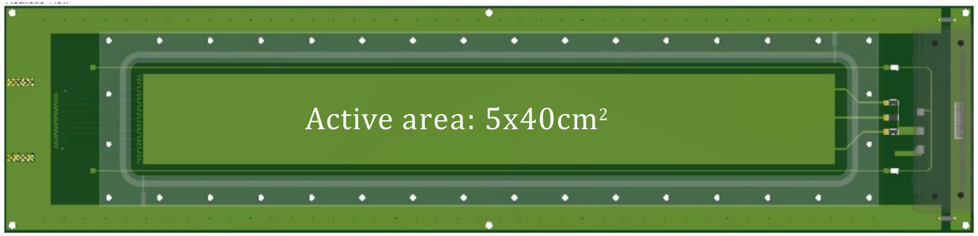
Beam setup

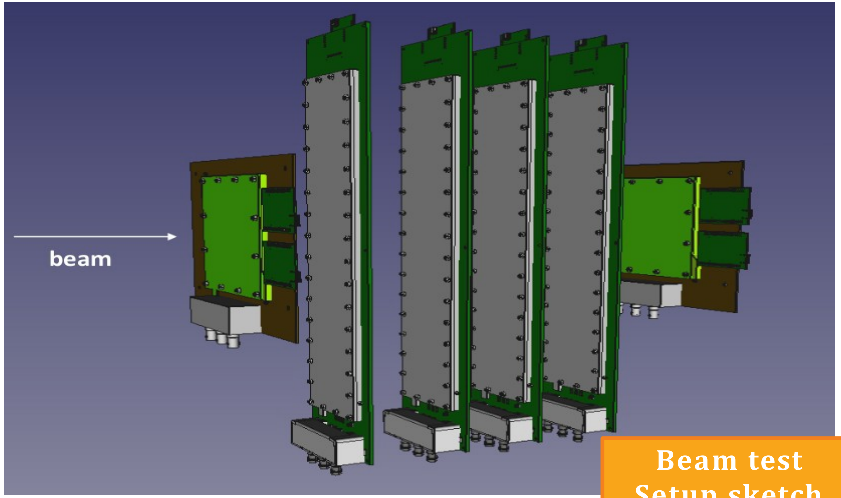
Experimental Setup

TB GOAL:

- Charge spread measurement to optimize readout geometry (strip pitch/width/length vs DLC surface resistivity)
- Measurement of the space resolution & efficiency as a function of the detector surface resistivity for 0.4mm pitch strip (1-D readout)
- Tuning of μ-RWELL resistive stage simulations

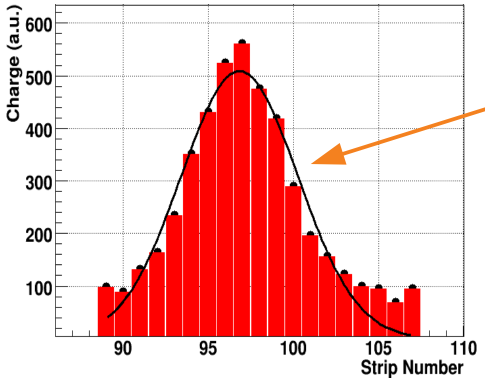
All the measurement done with Ar/CO2/CF4 45:15:40.



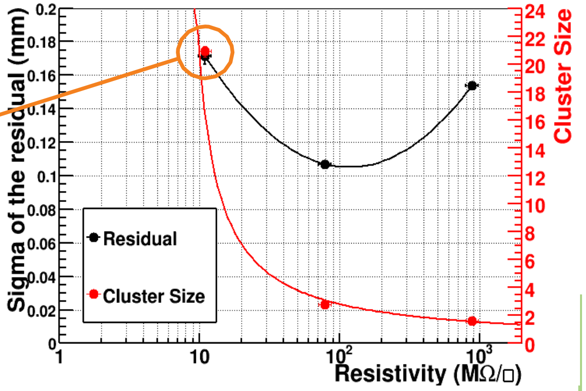


Beam test Setup sketch

Charge collected by the APV25 on the Strip readout (resistivity ~ 10 MΩ/□)



APV25 & 400 μm strip pitch →capacity = 15 pF



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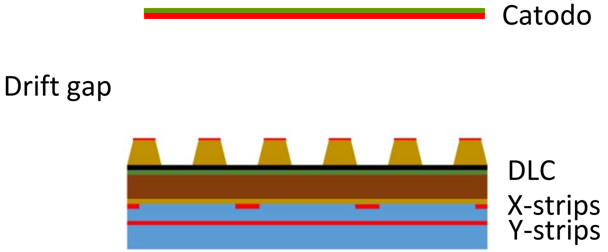
Programma WP7 – 2022

Programma WP7 – 2022: detector

L'R&D per il 2022 prevede la **costruzione di rivelatori con lettura 2D X-Y** con resistività del DLC e strip pitch ottimizzati sulla base delle misure effettuate nel TB-2021.

Possibili layout per il rivelatore 2D

#1 u-RWELL bi-dimensionale

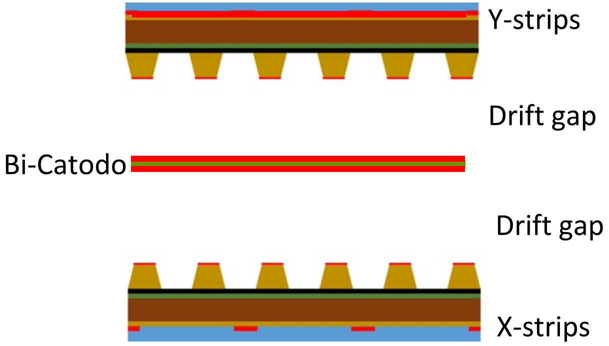


R&D su 2D in sinergia con i gruppi CERN/USTC (CP-DLC collaboration di cui fa parte LNF-DDG).
L' ottimizzazione riguarda:

- larghezza delle strip X-Y (60 e 350um)
- distanza tra i due piani di strip (25 um)
- distanza tra DLC e la X-strip (70 um → 28 um per signal amplitude optimization)

Tecnologia di realizzazione PCB più sofisticata
Buone prestazioni ma guadagno x2 wrt a 1D

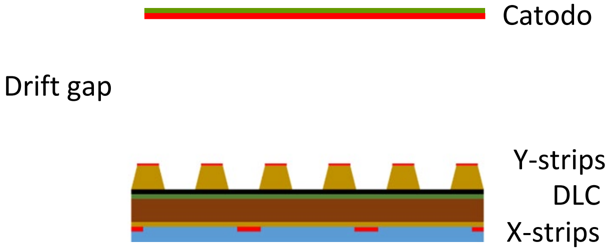
#2 u-RWELLs mono-dimensionali



Layout che permette di lavorare a guadagni inferiori (strip di lettura X-Y disaccoppiati).

Tecnologia di realizzazione PCB molto semplice
Prestazioni 2D da verificare

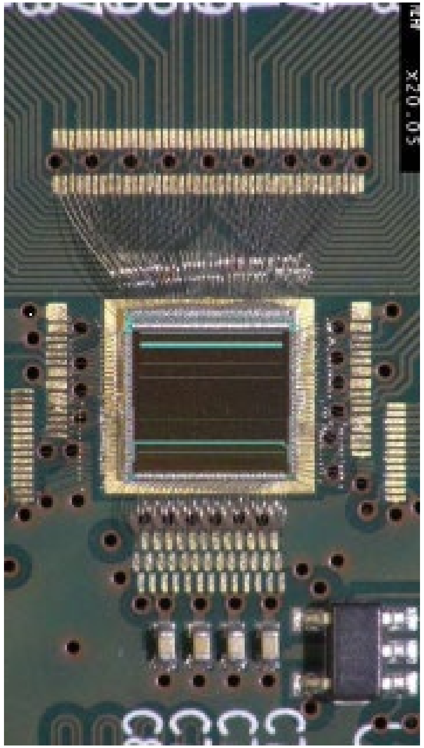
#3 u-RWELL bi-dimensionale



Layout che permette di lavorare a guadagni inferiori (strip di lettura X-Y disaccoppiati).
Lettura coordinata Y sul top amplificazione

Tecnologia di realizzazione PCB molto semplice
HV su DLC mentre TOP e X-strips GROUNDED
Prestazioni 2D da verificare

Programma WP7 – 2022: electronics



TIGER ASIC chip, developed by INFN Turin, will be **tested on uRWELL with GEMROC** readout developed for the BESIII experiment by INFN Ferrara (per la CGEM)

GEMROC modules are based on a discontinued FPGA by ALTERA

In **2022** a R/out **system based on System On Modules (SOM) and compatible with GEMROC interface cards will be developed**

Programma WP7 – 2022: Muon detector simulation

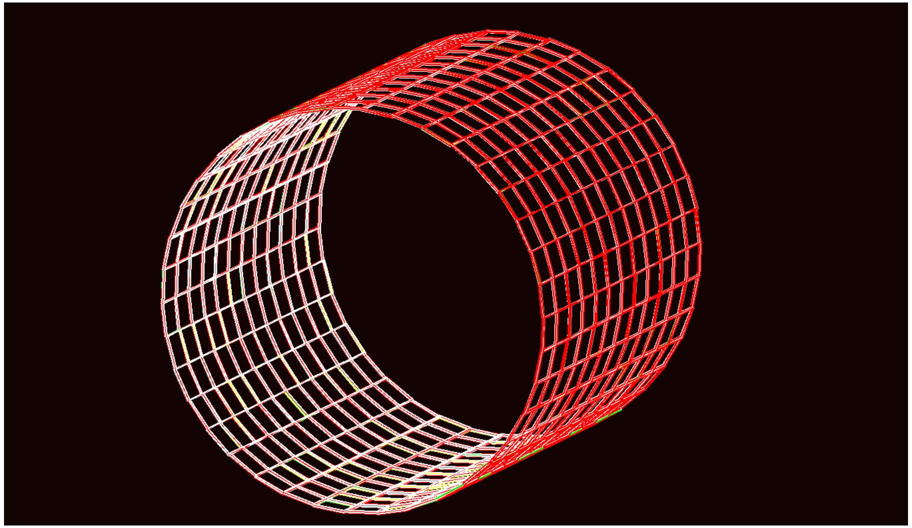
Provide a **description of the geometry of muon detector and pre-shower**

- **Simplified geometry** to avoid chasing modifications from mechanical optimization
- **Fine details** (e.g., dead spaces, modularity) will be **handled at reconstruction level**

The description will include a simple **implementation of the return yoke of the solenoid**

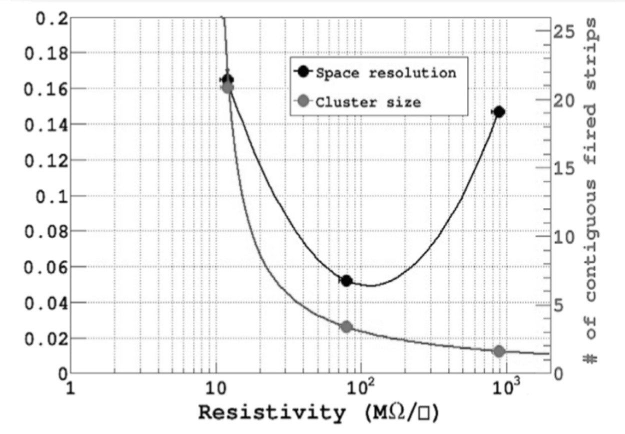
The **description will be implemented within the official IDEA framework**

- First with Geant4 directly using EDM4HEP as output (in progress)
- Later will be ported to DD4HEP



More information by I. Garzia's talk

Programma WP7 – 2022: uRWELL simulation (synergy with Cremlinplus and AIDAINNOVA)



Resistive simulation – in progress

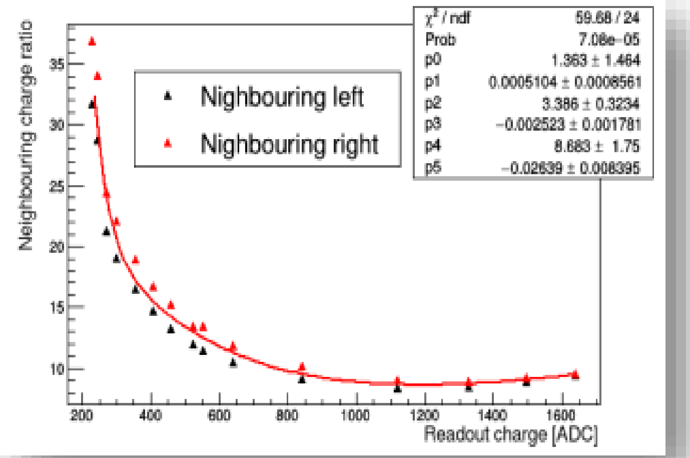
Describe the **charge dispersion at the anode which depends on the time constant determined by the DLC surface resistivity** and the **capacitance per unit area.**

Use approach from *Nucl.Instrum.Meth.A566:281-285,2006 (DIXIT)*

The **simulated spatial and temporal charge evolution will be convoluted to the intrinsic rise-time of the detector and the electronics shaping time effects** and then **compared with results from test beam**

Inter-strip (X-talk) induction studies – planned

The **probability to induce a signal on neighbor strip** studied **as a function of the charge readout by the central strip**, and the **relative delay between the two signals (central strip and neighbor)**



AIDAInnova – status 2021

AIDAInnova WP7: Gaseous Detectors Milestones & Deliverables

Deliverable

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

Milestone

- **MS28:** Build a 0.3×0.3 m^2 prototype and the readout plane with the new structure

1st Operative Meeting LNF-ELTOS-CERN: 21st Sept 2021
2nd Operative Meeting LNF-ELTOS: 7th Dec 2021

GOAL: Standardizing manufacturing procedures of 1-D μ-RWELL layouts → TT to ELTOS

AIDAInnova WP7: Gaseous Detectors
Medium term program in ELTOS

Step 0: DLC sputtering deposition on Kapton foils with the new CERN_INFN sputtering machine (@CERN)

Step 1: producing μ-RWELL_ PCB (1-D pad/strip readout 10x10 cm^2)
- with top patterned (pad/strip side)
- without patterning bottom layer (connector side)

Step 2: DLC patterning → two options under investigation:
- photo-resist application/developing + patterning with BRUSHING-machine (in ELTOS)
- photo-resist application/developing + patterning with JET-SCRUBBING-machine (not in ELTOS)

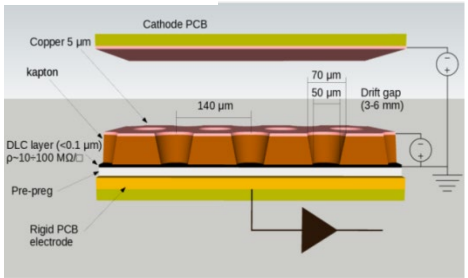
Step 3: DLC foil gluing on PCB → three options under investigation:
- Standard (ELTOS procedure) **double 106-prepreg** (~2x50μm thick)
- **pre-smoothing** of PCB with early-stripping of suitable prepreg (115°C/15min) + standard **single 106-prepreg** (~50μm thick)
- **single 1080-prepreg** (~75μm thick)

Step 4: **top copper patterning** for successive kapton etching to create evacuation vias

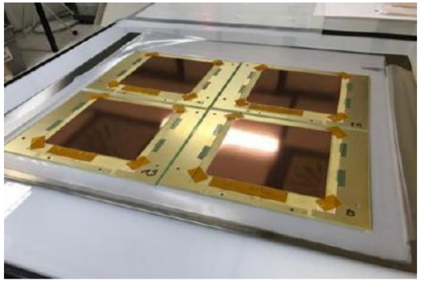
Step 5a (at CERN) → kapton etching + plating + ampl-holes …for detector completion

Step 5b (at ELTOS) → **preliminary test of kapton etching on small scale PCB**

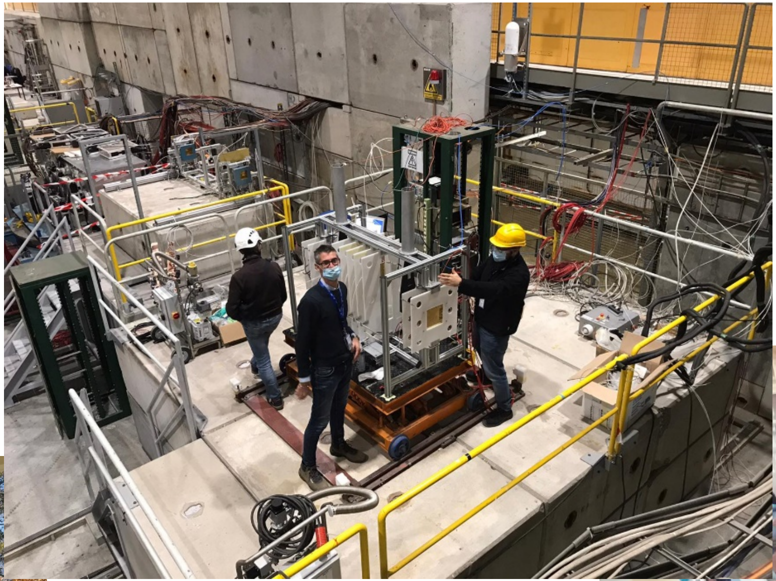
uRWELL sketch

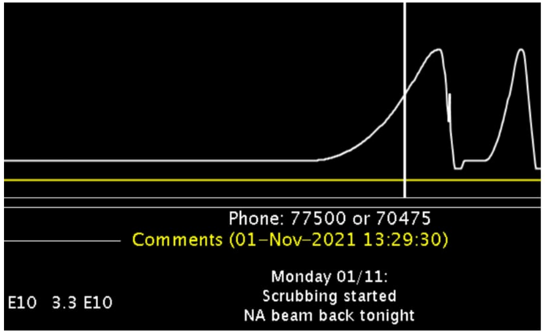


Gluing DLC on PCB @ ELTOS



Tentative schedule:
→ Step 1+2+3+4: Feb/March. 2022
→ Step 5b: Sept./Oct. 2022





Thanks for your attention

Richieste Finanziarie WP7 - 2022

LNF (2.95 FTE)

1.1 – Produzione di 4 prototipi 2D (2 pre-shower + 2 Muon) 15 k€ (Consumo)

1.2 – Contatti con Ditte/CERN per costruzione prototipi 4 k€ (Missioni)

~~1.3 – bombole pre-miscelate 2 k€ (Altri consumi)~~

1.4 – Test Beam al CERN x2 persone x2 settimane 5 k€ (Missioni) (SJ)

1.5 – Spese di trasporto materiale al TB 2 k€ (Trasporti) → 1 k€

Fe (1.8 FTE)

2.1 Test Beam al CERN x2 persone x2 settimane per microRWell 5 k€ (Missioni) (SJ)

2.2 Contatti con ditte e CERNper costruzione rivelatori 2 k€ (Missioni)

2.3 Sistema di readout per TIGER basato su System On a Module (SOM), compatibile con GEMROC mother board esistenti (SOM + componenti + layout e prototipizzazione scheda) 12 k€ (Consumo)

~~2.4. Premixed gas bottles per test uRWELL 2 k€ (Altri consumi)~~

Bo (3.0 FTE)

3.1 – Contatti con Ditte/CERN per costruzione rivelatori 2 k€ (Missioni)

~~2.2 – Bombole gas Ar, CO_2, CF_4 2 k€ (Altri consumi)~~

3.3 – Test Beam al CERN x2 persone x2 settimane 5 k€ (Missioni) (SJ)

To (0.8 FTE)

4.1 Test Beam al CERN x2 persone x2 settimane per microRWell 5 k€ (Missioni) (SJ)

4.2 Test boards TIGER & TIGER breakout boards 4.5 k€ (Consumo)

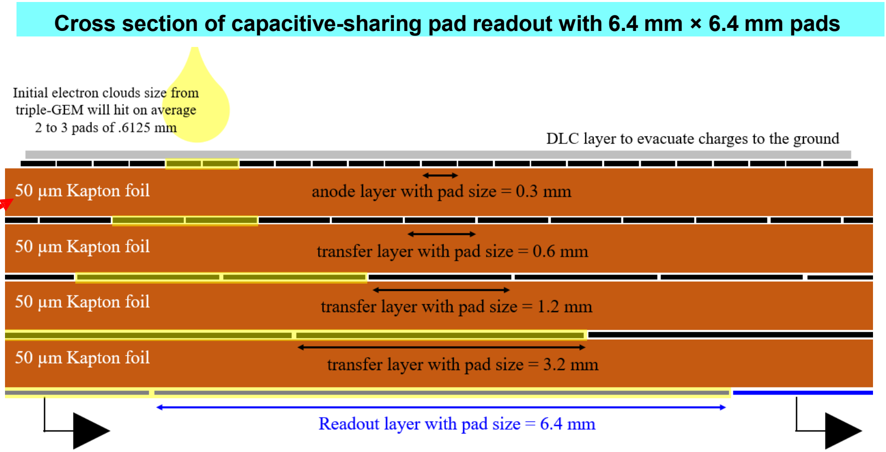
Capacitive-sharing readout: Principe & Motivation (K.GNAVO)

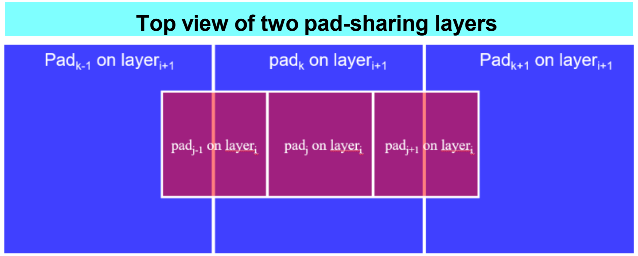
Principe of capacitive-sharing readout structures:

- Vertical stack of pads layers ⇨ Transfer of charge from MPGD via **capacitive coupling**
- A given arrangement of the pads position from one layer to the layer underneath as well as the doubling in size of the pad pitch allows:
  - Transverse sharing of the charges between neighboring pads of the layer (i+1) from vertical charged transfer from layer (i) through capacitive coupling
  - Principle of transverse charge-sharing through capacitive coupling i.e., **capacitive- sharing** is illustrated on the cross-section sketch on the left
- The scheme preserves of the position information i.e. spatial resolution with large readout strips or pads: Goal 50 µm for 1-mm strip r/o and 150 µm for 1 cm² pad r/o
- Basic proof of concept established with **800 µm** X-Y strip

Motivation & some key facts of capacitive-sharing readout:

- Develop high performance & low channel count readout structures for MPGDs:
- Reduce the number of readout electronic channels for large area MPGDs
- Low-cost technology for large area ⍰ standard PCB fabrication techniques

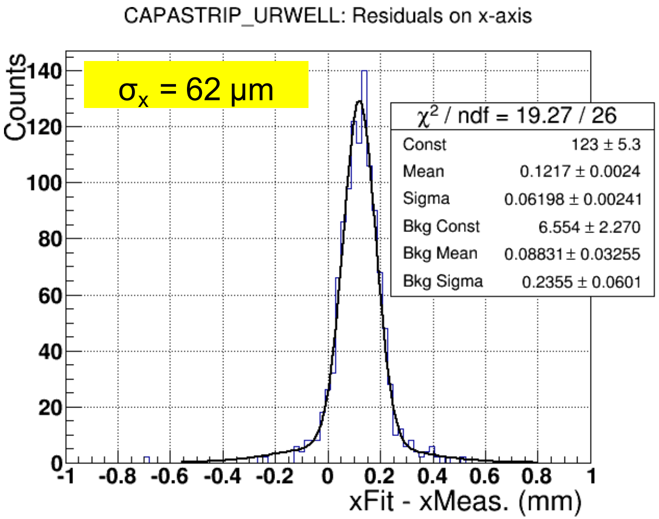


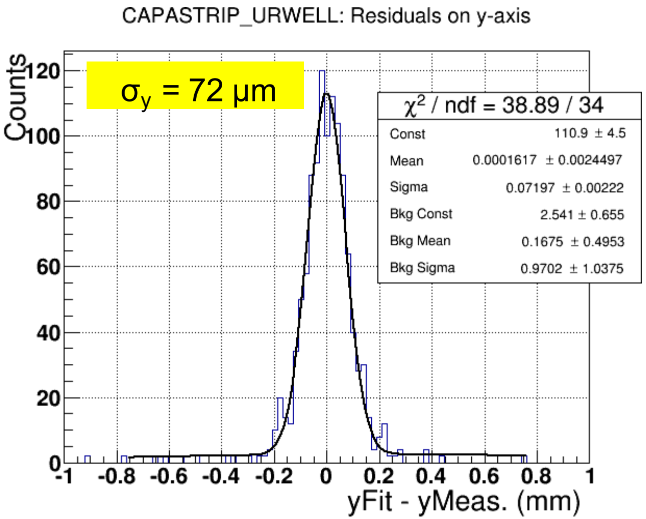


Capacitive-sharing **X-Y strip** readout: µRWELL prototype

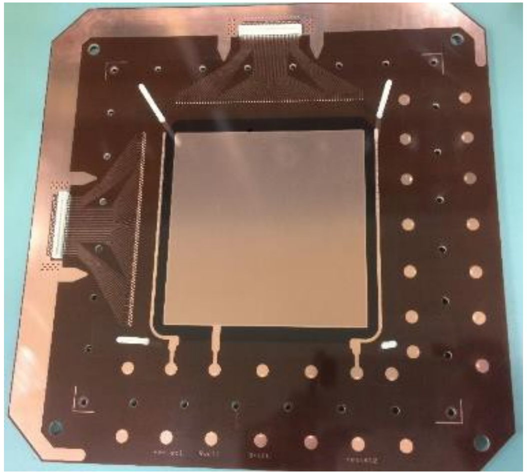
10 cm × 10 cm µRWELL with capacitive-sharing 2D strip readout

- Pitch is 800 µm ➔ twice COMPASS readout strip design
- X-strip and Y-strips on two separate layers with No connecting vias ➔ Easy fabrication for large area, low-mass capability
- Strip parameters: top strip (y-strips) = 250 µm, bot strip (x-strips): 750 um × 500 µm ➔ require tuning for equal charge sharing
  - Top and bottom strip area overlap minimized by design to minimize cross talk and capacitance etc …
- 3 capacitive-sharing pad layers with: 200 µm, 400 µm and 800 µm pad size respectively
- Tested in electron beam in Hall D @ JLab (Sept-Oct 2021)

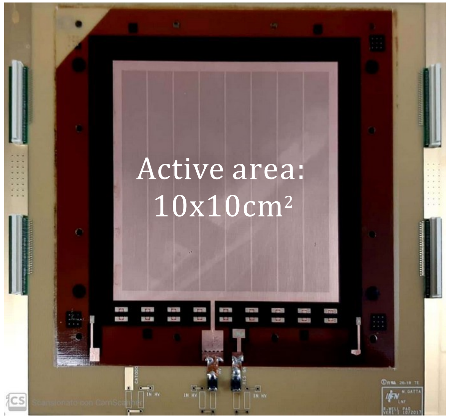




capaSh-XY-Strip uRWELL



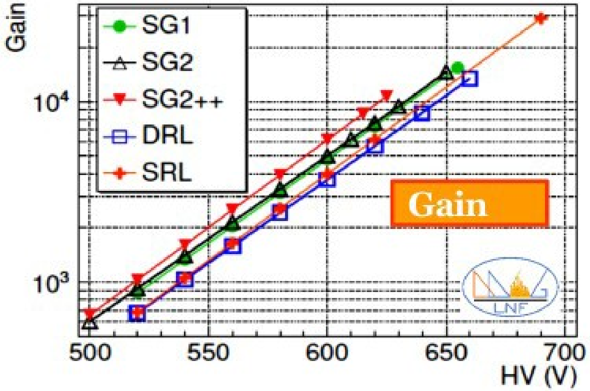
Detector Comparison



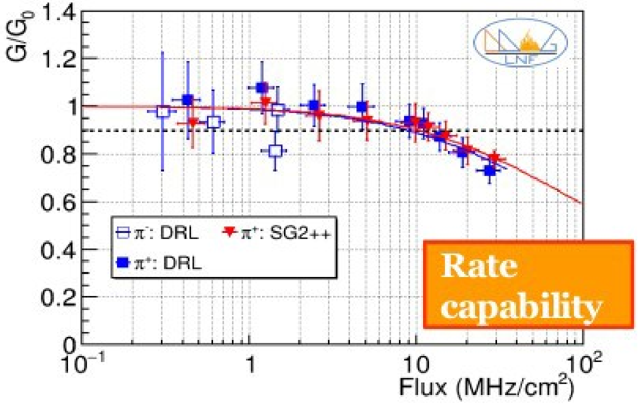
μ-RWELL trackers		μ-RWELL test	FEE signal
$10x10cm^2$	Active area	$5x40cm^2$	
300μm / 400μm / 10cm	Strip width/pitch/lenght	150μm / 400μm / 40cm	÷ 2
100μm	Strip distance from DLC	50μm	× 2
Standard (70μm)	Amplification WELL diameter	Larger (to be measured)	÷ ?
30÷40MΩ/□	DLC surface resistivity	10÷80MΩ/□	

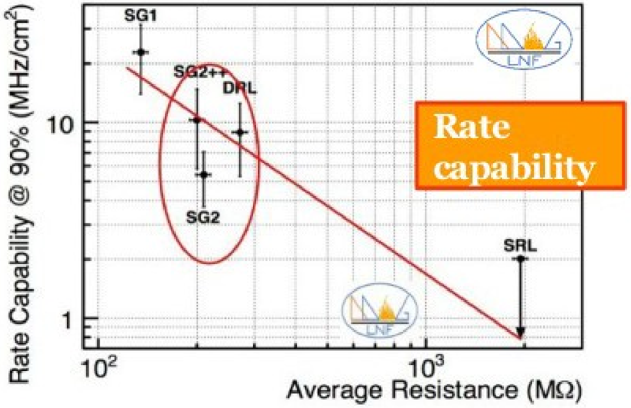
µ-RWELL performance overview

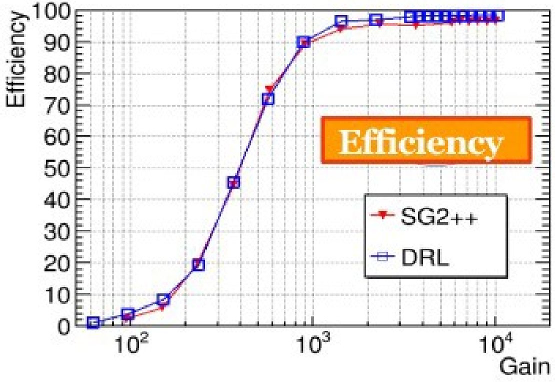
Gain up to 10^4



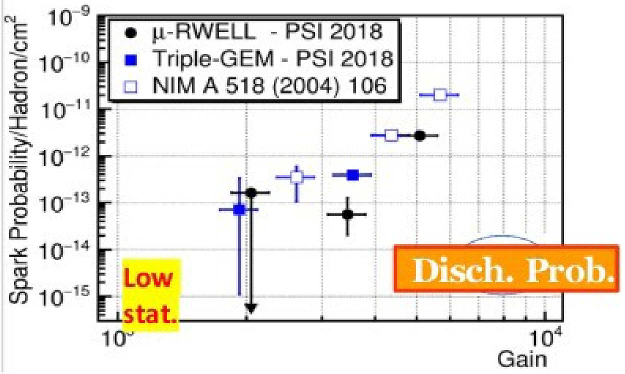
Rate Capability (@ G= 5000) ~ 5-10 MHz/cm^2



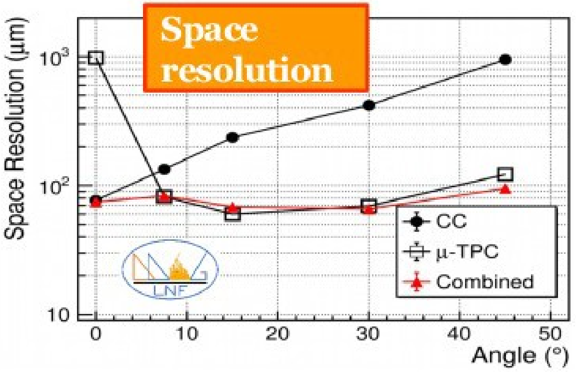




Efficiency ~ 98%



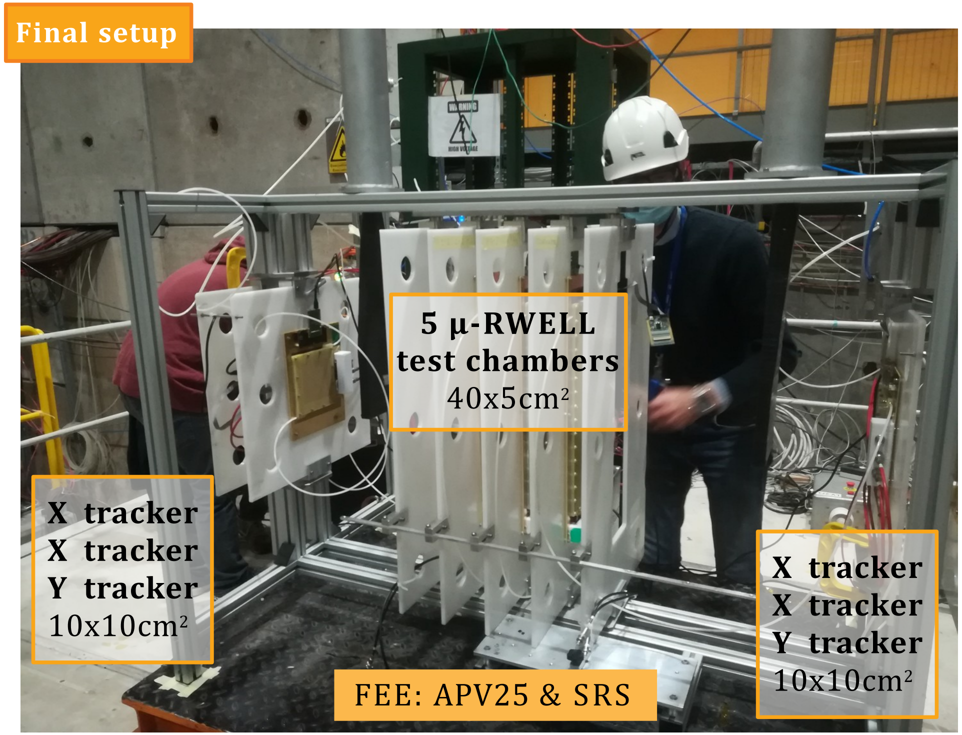
Discharge probability ~ 10^{-13} @ 4000



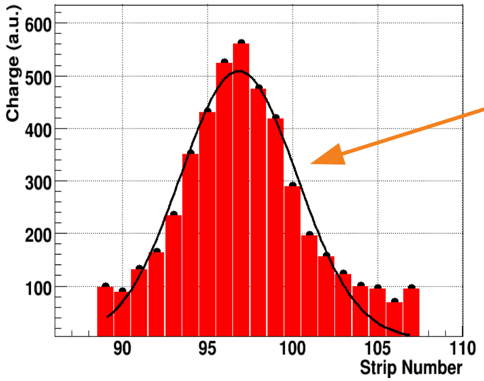
Space resolution ~ 100 µm

Experimental Setup

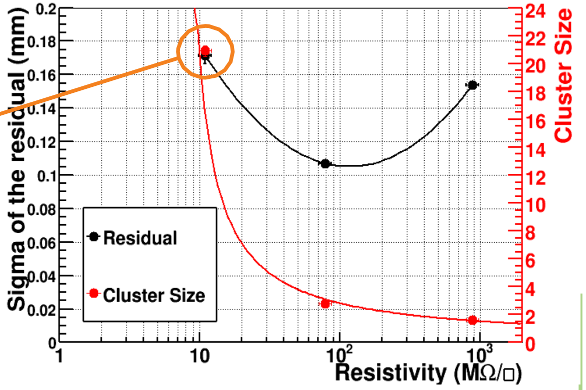
TB plan: measurement of the space resolution & efficiency as a function of the detector surface resistivity for 0.4mm pitch strip (1-D readout).
All the measurement done with Ar/CO2/CF4 45:15:40.



Charge collected by the APV25 on the Strip readout (resistivity ~ 10 MΩ/□)



APV25 & 400 μm strip pitch
→capacity = 15 pF



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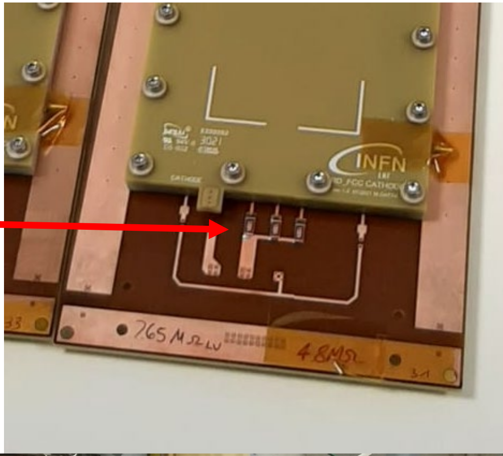
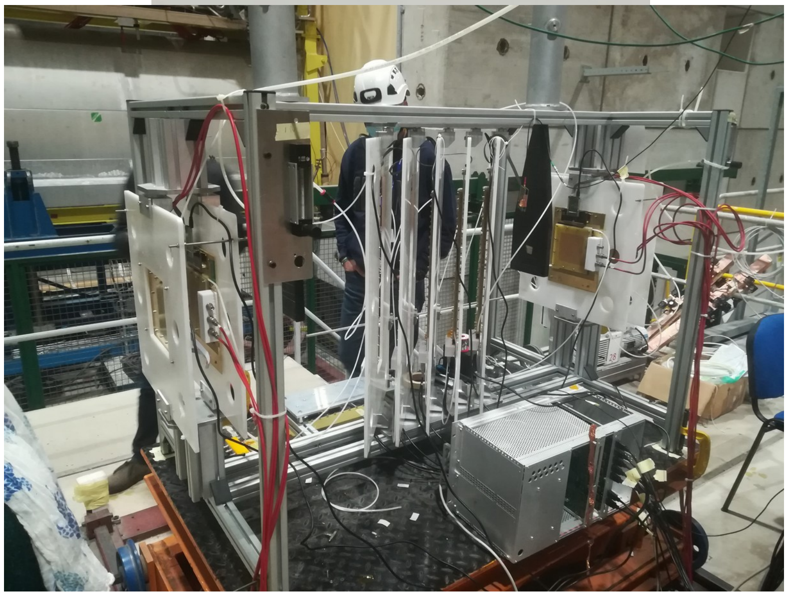
TB Data set

- Optimization S/N vs HV resistor filters
- HV scan 0° - for trackers & test chambers (with muons & pions)
  → Test chambers resistivity: [10,15,20,40,60,80,80] MΩ/□
- HV scan 40° for test chambers (with muons)
- Angle scan [0,10,20,30,40]° test chambers
- (Drift field 0.5 kV/cm, with muons, [640/660/680]V x angle)
- Drift field scan 0° - [0.01,0.05,0.1,0.5,1,2,3,3.5,4,5] kV/cm

About 200 runs to be analized





TB analysis

Riccardo

Zero Step:
Software ricostruzione e dati su macchina @ FE ✔
Debug codice ricostruzione e accesso

Matteo, Erika, Riccardo

First Step:
Analisi a zero gradi in CC (*)
- ADC counts vs HV
- Spread charge vs resistivity
- Risoluzione spaziale vs resistivity (B&B / with tracking)
- Efficienza overall & micro-settori

To be concluded before Vienna Conf.

Isabella, Lia Riccardo

Second Step:
Analisi in uTPC:
- ADC counts vs HV
- Spread charge vs resistivity
- Risoluzione spaziale vs resistivity (B&B / with tracking)
- Efficienza overall & micro-settori

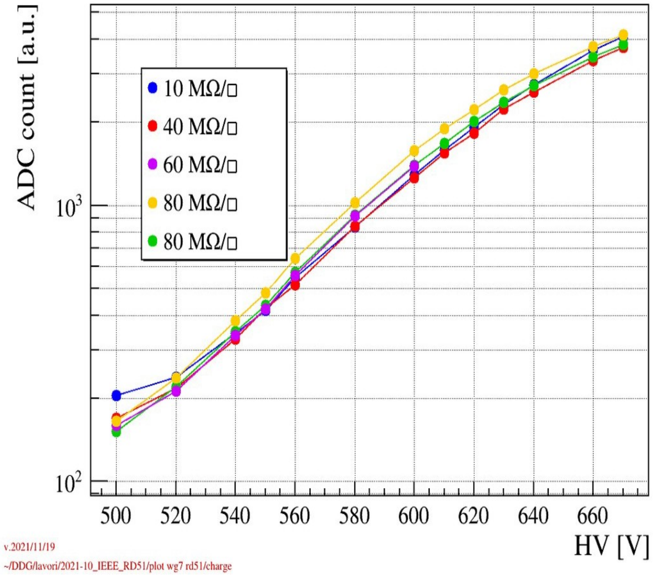
Matteo, Marco

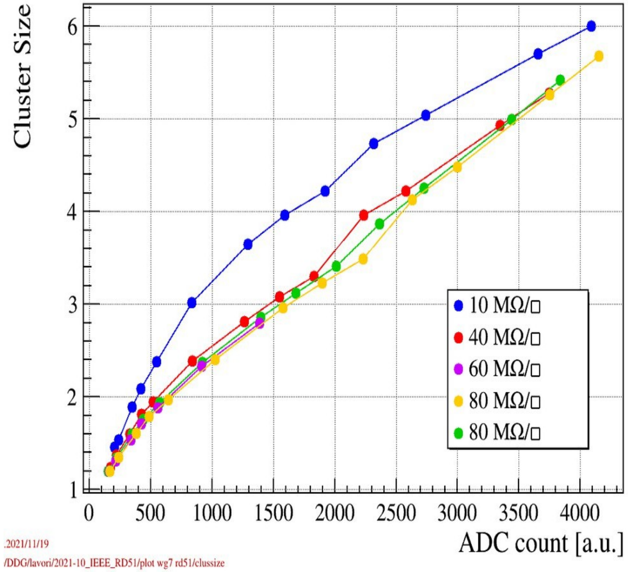
Checks @ LNF:
- Rimisurare resistività
- Misura piedistallo APV con diversi schemi di resistenza filtro HV:
  a) 100kΩ, 1 MΩ, 10 MΩ,
  b) 3 settori vs unico settore con e senza resistenza
- Misura di guadagno di alcune test chambers (10, 40, 80MΩ/□)
- Misura del massimo HV su test chambers

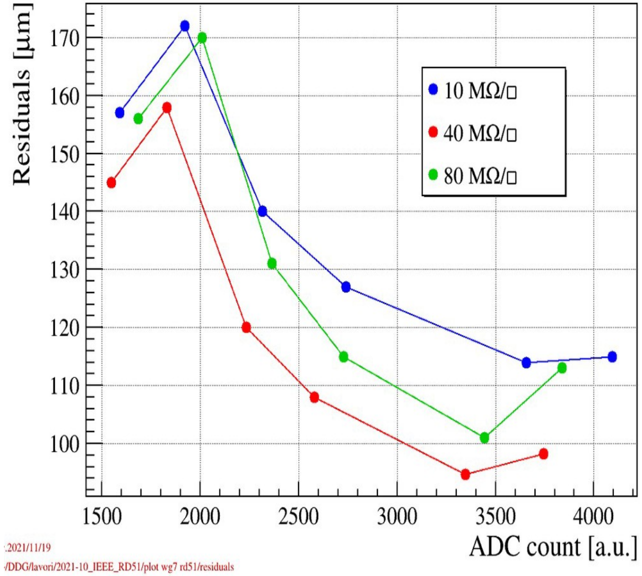
(*) More information in R. Farinelli's talk

Preliminary results

All the measurement with Ar/CO2/CF4 45:15:40,
Drift Field 3.5 kV/cm and ortogonal incidence.







Good gain uniformity among prototypes.
Lower than 10x10 μ-RWELL (due to larger amplification holes).

Cluster Size:
higher for 10MΩ/□ proto
Flat for the other resistivity values.
Compatible with the 2018 published plot.

Residuals of test chambers w.r.t. the trackers.
No tracker contribution subtracted.
Next step: back to back analysis.