

RD_FCC: WP7 μ -RWELLS

Status 2022 & Plans 2023

Marco Poli Lener
LNF-INFN

Amoroso A.¹, Balossino I.², Bencivenni G.³, Bertani M.³, Cafaro V.⁴, Cibinetto G.², De Lucia E.³, Domenici D.³, Farinelli R.², Felici G.³, Garzia I.², Gatta M.³, Giacomelli P.⁴, Giovanetti M.³, Gramigna S.², Lavezzi L.¹, Melchiorri M.², Mezzadri G.², Morello G.³, Papalino G.³, Scodreggio M.², Sosio S.¹

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



WP7 μ -RWELLS: meeting & conference 2022

3 riunioni del WP7 nel 2022 per l'analisi dati TB

June 2022

16 Jun RD_FCC: Riunione attività 2022 **NEW**

May 2022

12 May III riunione 2022 - Attività uRWELL **NEW**

March 2022

24 Mar II riunione 2022 - Attività uRWELL **NEW**

January 2022

19 Jan I riunione 2022 - Attività uRWELL **NEW**

3 Presentazioni a Conferenze nel primo semestre

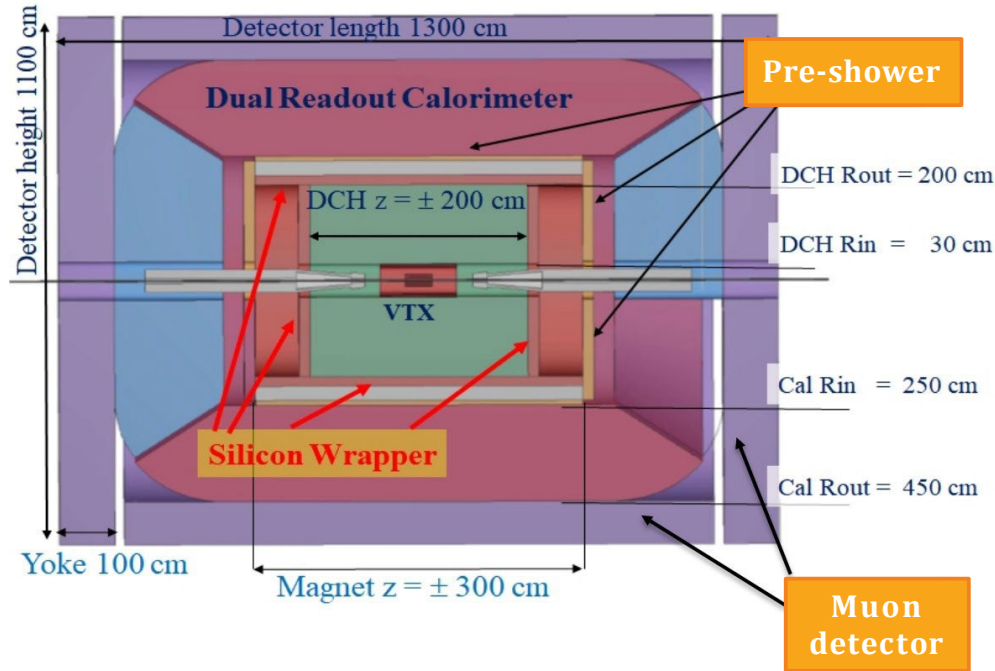
Stato dei proceeding ?????

The μ RWELL-based preshower and muon detectors of the IDEA detector concept	Paolo Giacomelli	Bologna	Talk	VCI 2022	2022	SI
Preshower and muon detector at FCC-ee	Giulio Mezzadri	Ferrara	Talk	FCC physics workshop	2022	No
RD_FCC u-RWELL	R. Farinelli	Ferrara	Poster	Elba 2022	2022	SI

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 cm² with X-Y readout

Strip length: 50cm

Strip pitch: 0.4mm

Input FEE capacity ~ 70 pF

TOT: 330 m², 1.5×10^6 channels

Muon detector

Delivered 22

Tiles: 50x50 cm² with X-Y readout

Strip length: 50cm

Strip pitch: 1.5mm

Input FEE capacity ~ 270 pF

TOT: 4000 m², 5×10^6 channels

Requirements:

- **Efficiency $\geq 98\%$**
- **Space resolution $\leq 100 \mu\text{m}$ (pre-shower)
 $\leq 400 \mu\text{m}$ (muon)**
- **Mass production → Technology Transfer to Industry**
- **Reduction of FEE channels → surface resistivity optimization**
- **FEE Cost reduction → custom made ASIC (TIGER)**

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):

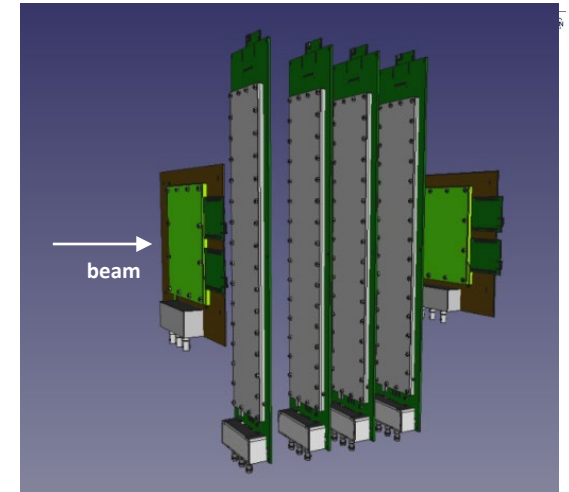
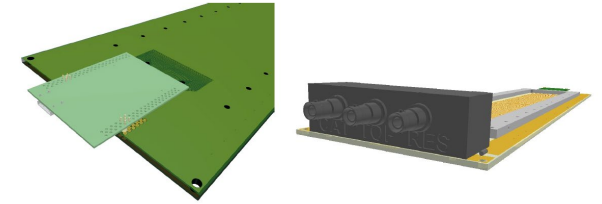
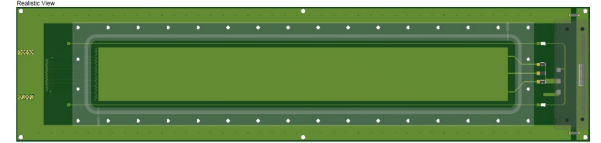
- I rivelatori hanno active area di $16 \times 50 \text{ cm}^2$, lettura 1D, diverso strip pitch e resistività del DLC :
- pre-shower → strip pitch 0.4 (0.8) mm
resistivity → 10, 30, 50, 70, >100-200 MOhm/square
- rivelatore di muoni → strip pitch 0.8 - 1.2 - 1.6 mm
resistivity → 35, 15 MOhm/square

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



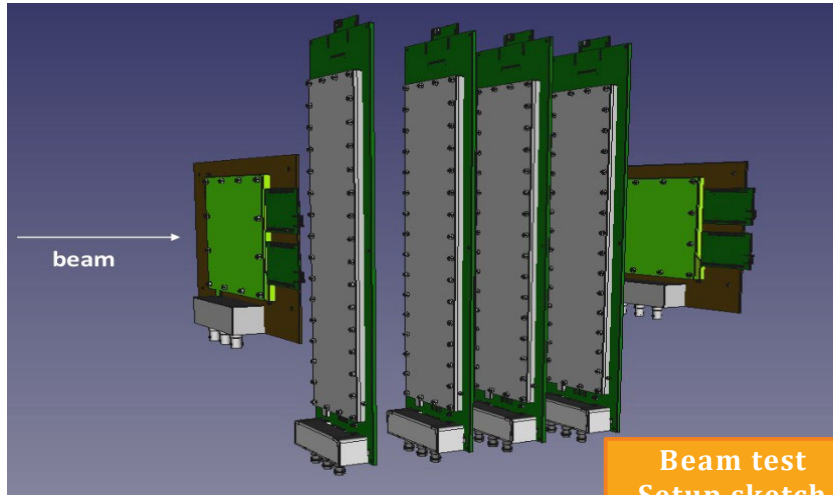
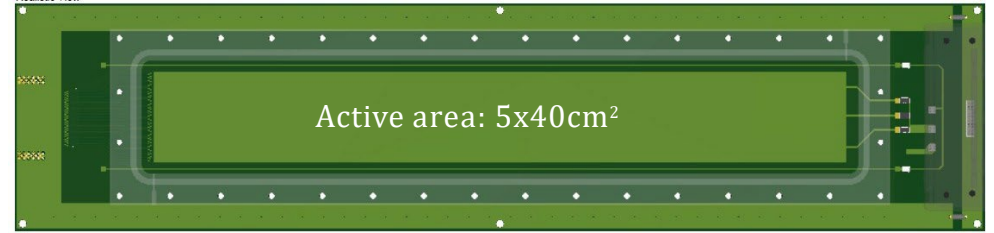
Beam setup

Experimental Setup

TB GOAL:

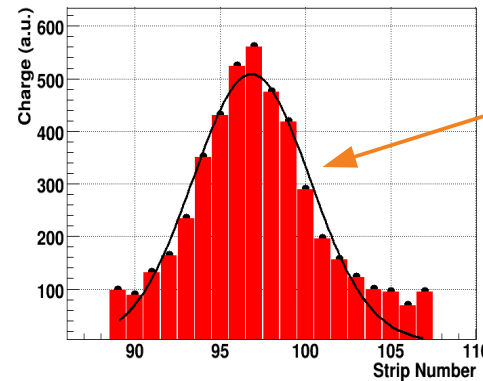
- **Charge spread** measurement to optimize readout geometry (strip pitch/width/length vs DLC surface resistivity)
- Measurement of the **space resolution & efficiency** as a function of the detector **surface resistivity** for 0.4mm pitch strip (1-D readout)
- **Tuning** of μ -RWELL **resistive stage**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

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

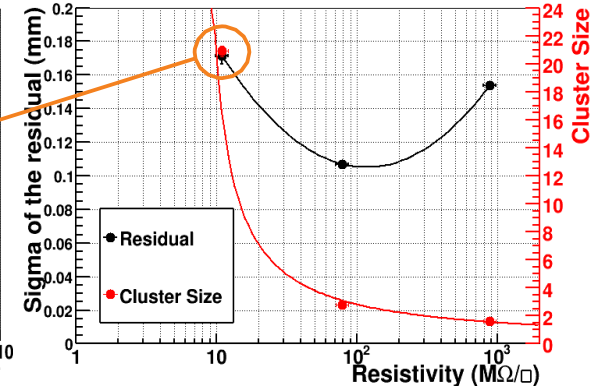


Beam test Setup sketch

Charge collected by the APV25 on the Strip readout (resistivity $\sim 10 \text{ M}\Omega/\square$)



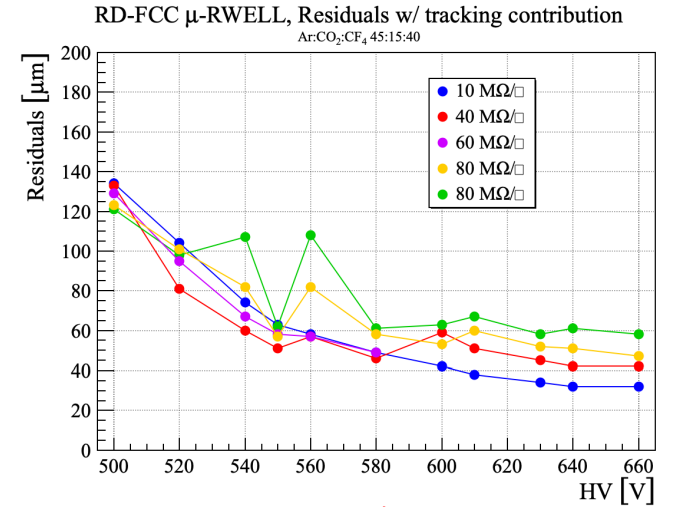
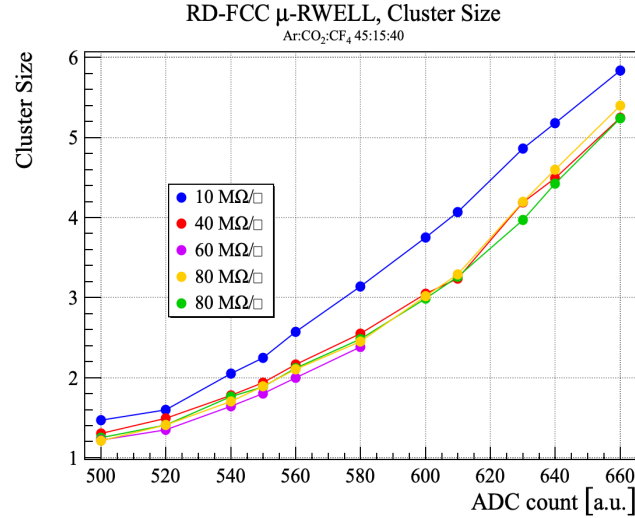
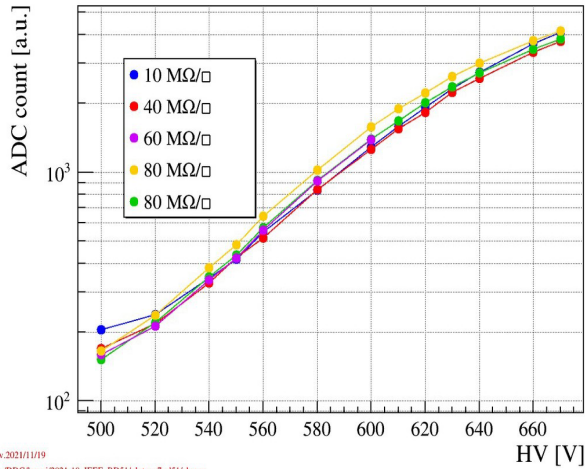
APV25 & 400 μm strip pitch
 \rightarrow capacity = 15 pF



G. Bencivenni et al., NIM A 886 (2018) 36

Results (before VCI)

All the measurement with Ar/CO₂/CF₄ 45:15:40,
Drift Field 3.5 kV/cm and **ortogonal incidence**
(APV ADC THR=50 ADC)



v.2021/1/19
~DDG/laveri/2021-10_JEEE_RD51/plot_wg7_n151/charge

Nuova analisi nella presentazione di ERIKA (NO SPOLIER)

Residuals of a test chamber
w.r.t. the trackers & other
tested chamber used as
trackers

Programma WP7 – 2022

Programma WP7 - 2022

- Inizio analisi TB 2022 (Matteo, Riccardo, Erika)
- Progettazione uRWELL 1D/2D in sinergia con Clas12 → OK
- Ordine uRWELL 1D&2D (4+2 uRWELL) → OK
- Realizzazione camere @ CERN → produzione già partita, camere consegnate a metà luglio
- Progettazione & ordine materiali per setup TB 2022 → OK
- Progettazione & ordine frame in PEEK → OK, arriveranno a inizio luglio

Prossima
slide

Prossimi 6 mesi del 2022

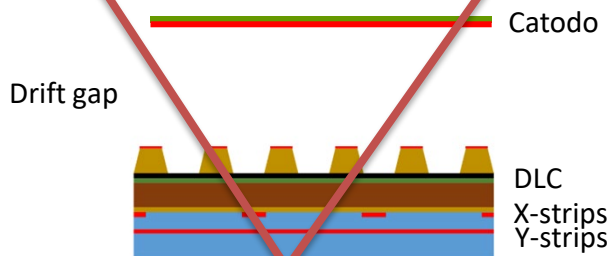
- Conclusione analisi TB 2022 con traccia ortogonale (Erika, Riccardo)
- Inizio analisi TB 2022 con traccia inclinata (Isabella, Lia, Riccardo) vedi slide riunione del 15/12/2022 - <https://agenda.infn.it/event/31871/>
- Analisi camere con pitch doppio con traccia ortogonale (Mariangela)
- Realizzazione setup TB 2022
- Anticipazione della progettazione camere uRWELL per il 2023
- Ordine DLC Gigi & Annalisa

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~~



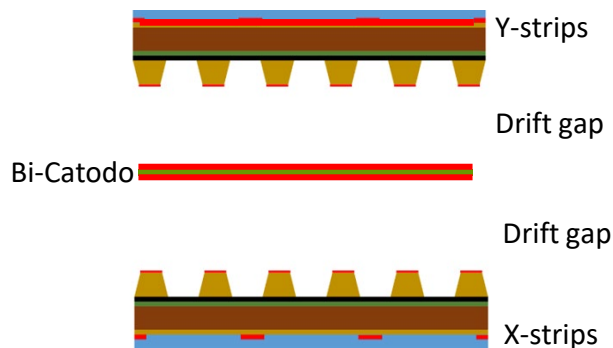
~~R&D su 2D in sinergia con i gruppi CERN/USTC (CP-DLC collaboration di cui fa parte LNF-DDG).~~

~~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~~

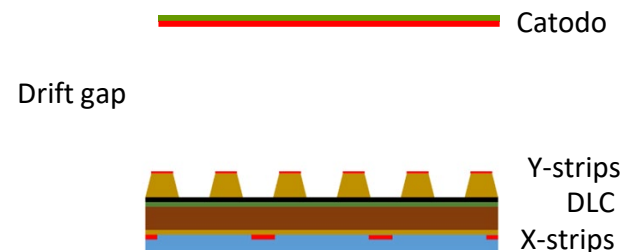
#2 u-RWELLs mono-dimensionali



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

Tecnologia di realizzazione PCB semplice
Prestazioni 2D da verificare

#3 u-RWELL bi-dimensionale



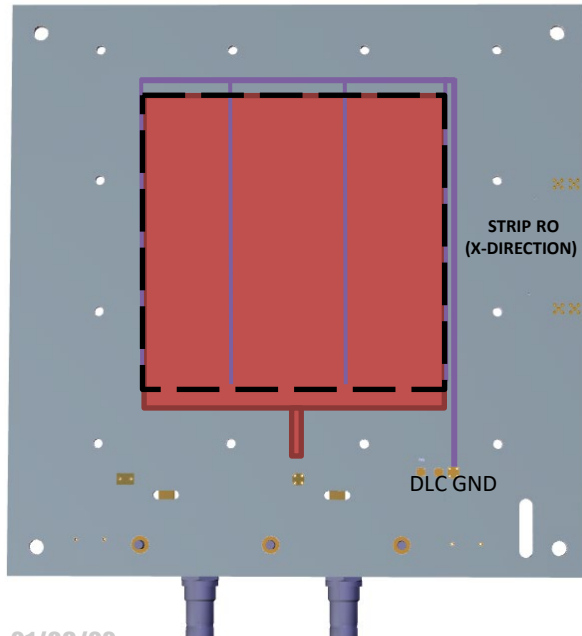
Layout che permette di lavorare a guadagni inferiori (strip di lettura X-Y disaccoppiati).
Lettura coordinata Y sul top amplificazione

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

Programma WP7 – 2022: detector

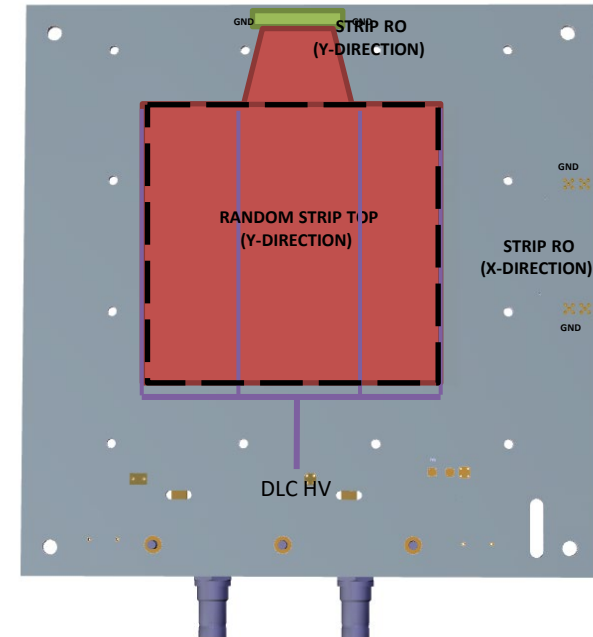
L'R&D per il 2022 prevede la **costruzione di rivelatori con lettura 2D X-Y** con resistività del DLC e strip pitch ottimizzati sulla base delle misure effettuate nel TB-2021.

u-RWELLS mono-dimensionali
PEP -1D



Strip pitch= 0.76 mm
Strip width= 0.15 mm
Resistivity= 50-60 MOhm/sq

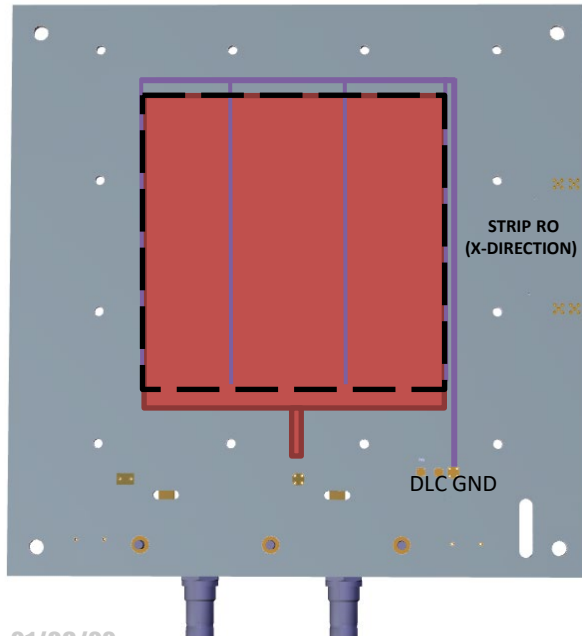
u-RWELL bi-dimensionale
PEP -2D



Programma WP7 – 2022: detector

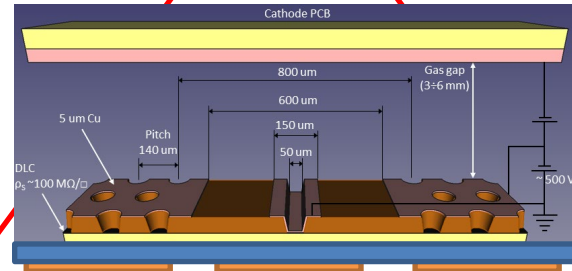
L'R&D per il 2022 prevede la **costruzione di rivelatori con lettura 2D X-Y** con resistività del DLC e strip pitch ottimizzati sulla base delle misure effettuate nel TB-2021.

u-RWELLS mono-dimensionali
PEP -1D



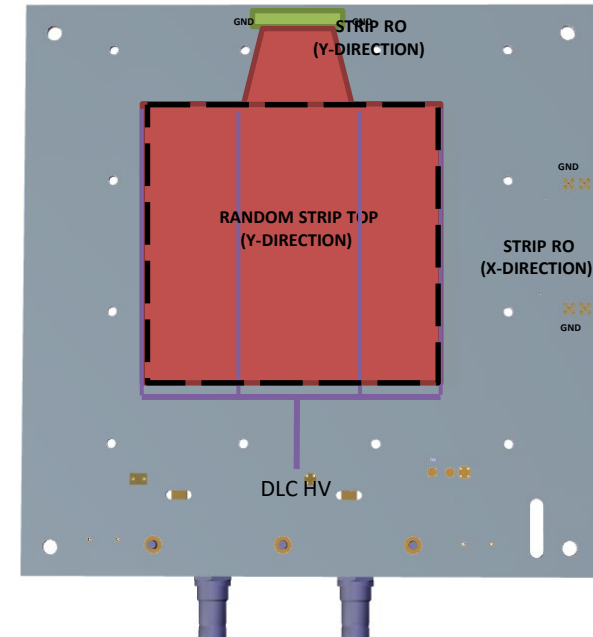
Strip pitch= 0.76 mm
Strip width= 0.15 mm
Resistivity= 50-60 MOhm/sq

WARNING



Noise indotto sulla strip in
concomitanza (sotto) della linea PEP
- X17 TB in questi giorni -

u-RWELL bi-dimensionale
PEP -2D



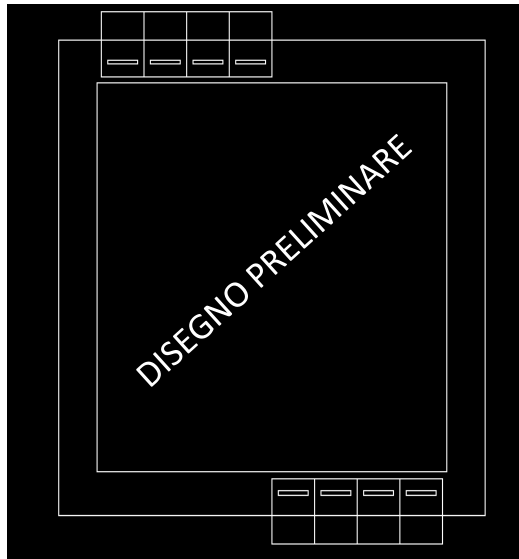
Programma WP7 – 2023

Programma WP7 – 2023: detector

L'R&D per il 2023 prevede la **costruzione di rivelatori con lettura 2D X-Y** di 500 x 500 cm² active area (la scelta del readout verrà fatta in base ai risultati ottenuti al TB di Ottobre 2022)

Active area size:

500 mm x 500 mm



Per la progettazione:

- Dimensioni area attiva: 50x50 cm² in sinergia con X17 & Clas12
- Spessore PCB & Catodo: 3.2 mm

- Lettura 1D, 2D, entrambe?
- Pitch & width strip: pitch 780 μ m \rightarrow N.5 APV/view – width: 150 μ m
- Caso r/o 1D: larghezza settori TOP: 10 cm

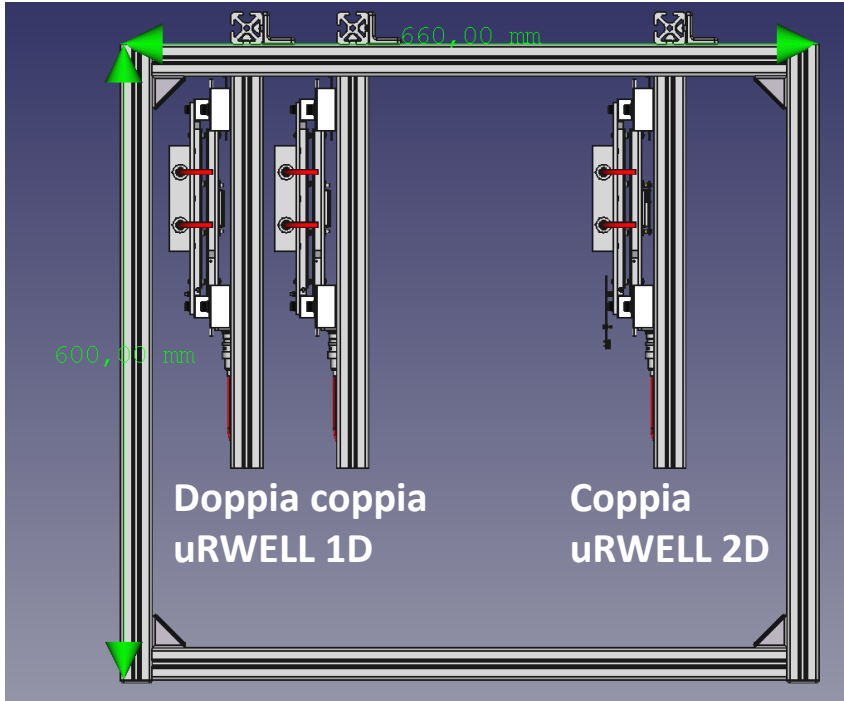
- Indipendentemente dal r/o, pitch PEP: 10 cm
- Resistività DLC: 30 MOhm/sq

Chiaramente dobbiamo avere analizzato in maniera definitiva i risultati TB 2021 (Erika, Riccardo) + analisi pitch doppio (Mariangela)

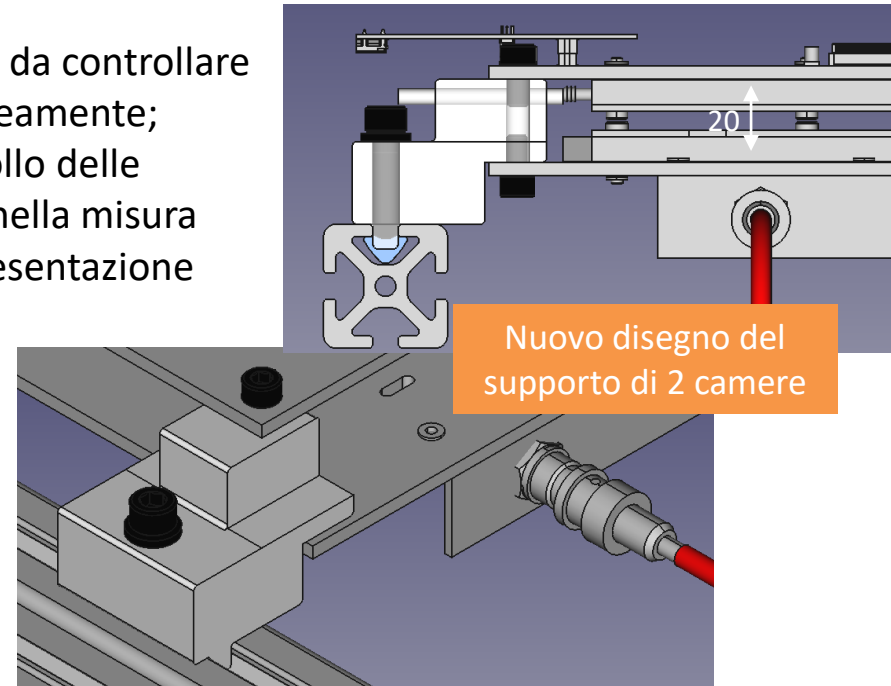
Progettazione setup TB (by Gianfranco)

Il disegno del setup si basa sull'idea di 2 camere in enemy:

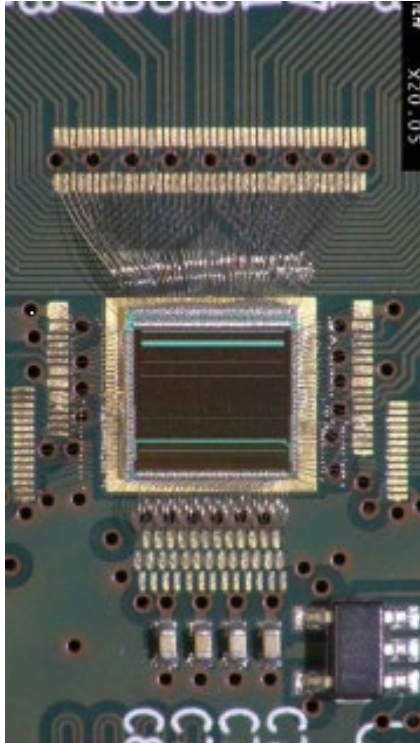
- canali HV & APV minimizzati;
- meno camere da controllare contemporaneamente;
- miglior controllo delle sistematiche nella misura dei residui (presentazione Erika)



Da implementare supporti scintillatori Fe



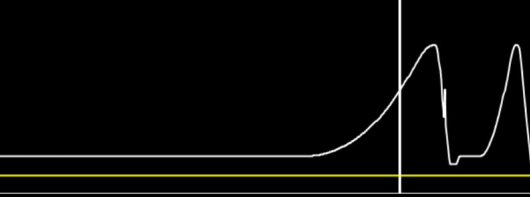
Programma WP7 – 2022: electronics - stato



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



Phone: 77500 or 70475
Comments (01–Nov–2021 13:29:30)

Monday 01/11:
Scrubbing started
NA beam back tonight

E10 3.3 E10

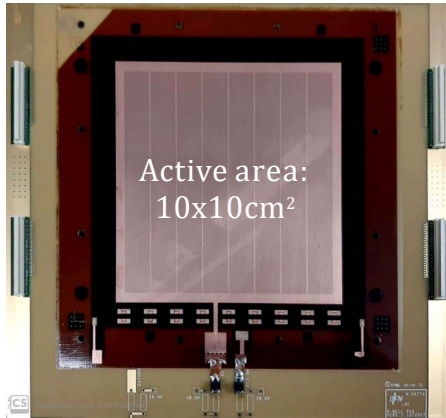


**Thanks for your
attention**

M. Poli Lener - WP7 uRWELL



Detector Comparison



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

Anagrafica & richieste finanziarie

Anagrafica @ LNF

2022

Ricerca					
Nome	Età	Contratto	Qualifica	Aff.	%
1 Bencivenni Giovanni		Dipendente	Primo Ricercatore	CSN I	5
2 Bertani Monica		Dipendente	Ricercatore	CSN I	5
3 De Lucia Erika		Dipendente	Primo Ricercatore	CSN I	5
4 Domenici Danilo		Dipendente	Ricercatore	CSN I	5
5 Franesini Francesco		Dipendente	Assegno di Ricerca	CSN I	0
6 Giovannetti Matteo		Associato	Dottorando	CSN I	15
7 Morello Gianfranco		Dipendente	Ricercatore	CSN I	5
Numero Totale Ricercatori			7	FTE: 0.40	

Tecnologia					
Nome	Età	Contratto	Qualifica	Aff.	%
1 Boscolo Manuela		Dipendente	Primo Tecnologo	CSN I	10
2 Felici Giulietto		Dipendente	Dirigente Tecnologo	CSN I	5
3 Pellegrino Luigi		Dipendente	Primo Tecnologo	CSN V	0
4 Poli Lener Marco		Dipendente	Tecnologo	CSN I	5
Numero Totale Tecnologi			4	FTE: 0.20	

Tecnici					
Nome	Età	Contratto	Qualifica	Aff.	%
Numero Totale Tecnici			0	FTE: 0.00	

Annotazioni

attività in UE-FCCIS e in UE-CREMLINPLUS sinergiche con RD_FCC

nominativo	qualifica	LHCb	AIDAInn	RD_FCC	AIDAInn	FCC_IS	Cremlin
bencivenni	I-RIC	40	10	5			5
poli lener	Tecn	60	10	5			5
morello	RIC	60	10	5			5
domenici	RIC	0	0	5	10		5
de lucia	RIC	60	10	5			5
felici	Dir Tecn	20	0	5	0		5
giovannetti	Dottorando	70	0	15			0
bertani	RIC	0	0	5	5		0
Boscolo	I-Tecn			20		50	
Pellegrino	I-Tech			0		10	
Zobov	Dir. Tecn			0		10	40
Behtouei	Assegno					100	
Franesini	Assegno			0		100	

Richieste Finanziarie WP7 – 2022 & 2023

2022

LNF

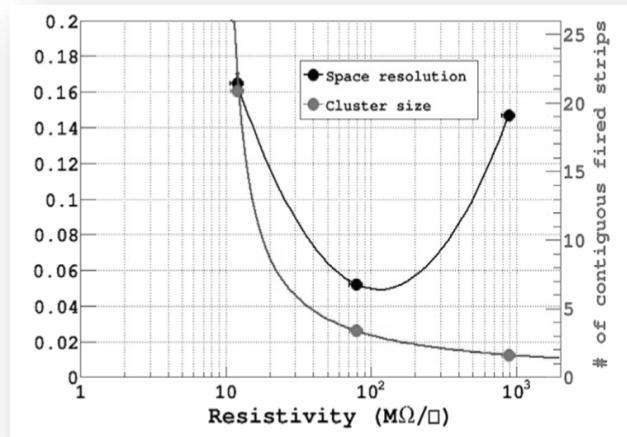
1.1 – Produzione di 4 prototipi 2D (2 pre-shower + 2 Muon)	15 k€ (Consumo)
1.2 – Contatti con Ditte/CERN per costruzione prototipi	4 k€ (Missioni)
1.3 – Bombole pre-miscelate	2 k€ (Altri consumi)
1.4 – Test Beam al CERN x2 persone x2 settimane	5 k€ (Missioni) (SJ bloccato a Maggio 2022)
1.5 – Spese di trasporto materiale al TB	2 k€ (Trasporti) → 1 k€

2023

LNF

1.1 – Produzione di 4-6 prototipi 2D 50x50 cm2 (1D o 2D readout)	25-30 k€ (Consumo – stiamo richiedendo offerta @ Rui)
1.2 – Contatti con Ditte/CERN per costruzione prototipi	6 k€ (Missioni)
1.3 – Bombole pre-miscelate	2 k€ (Altri consumi)
1.4 – Test Beam al CERN x2 persone x2 settimane	5 k€ (Missioni)
1.5 – Spese di trasporto materiale al TB	2 k€ (Trasporti)

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



Resistive simulation – in progress

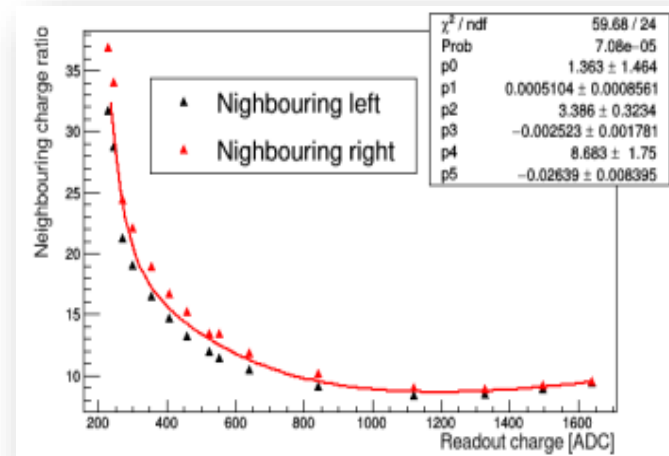
Describe the **charge dispersion at the anode which depends on the time constant determined by the DLC surface resistivity and the capacitance per unit area.**

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)

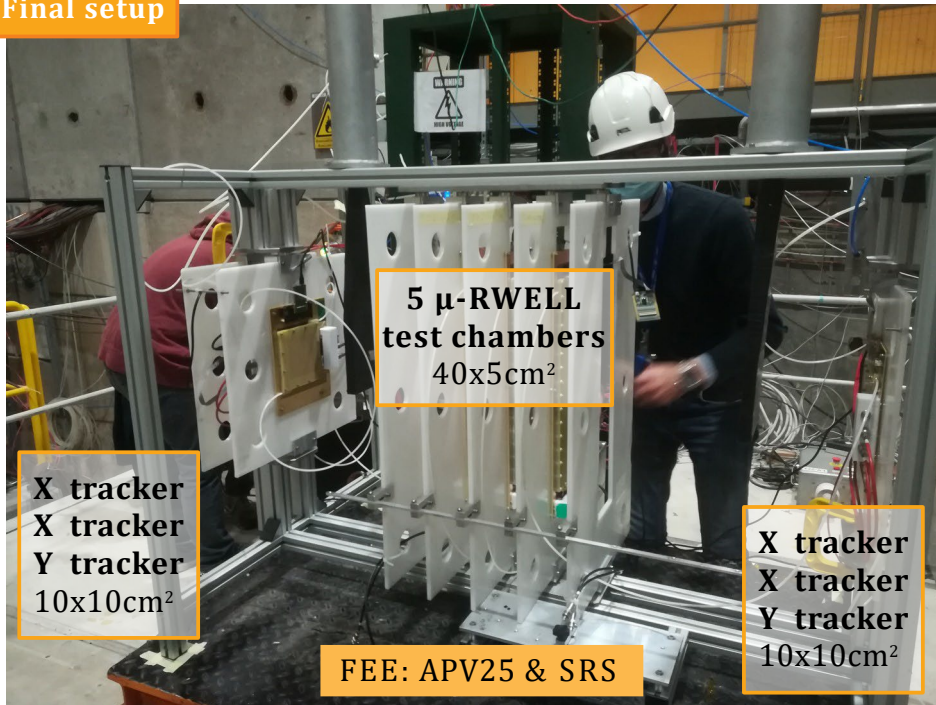


Experimental Setup

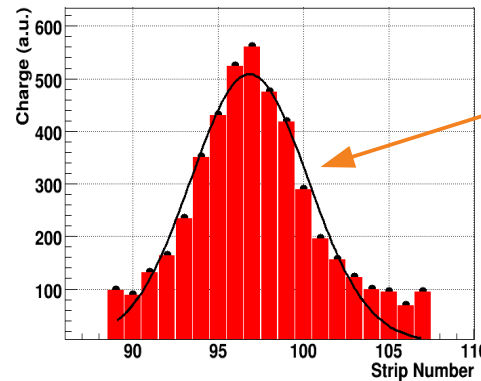
TB plan: measurement of the space resolution & efficiency as a function of the detector surface resistivity for 0.4mm pitch strip (1-D readout).

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

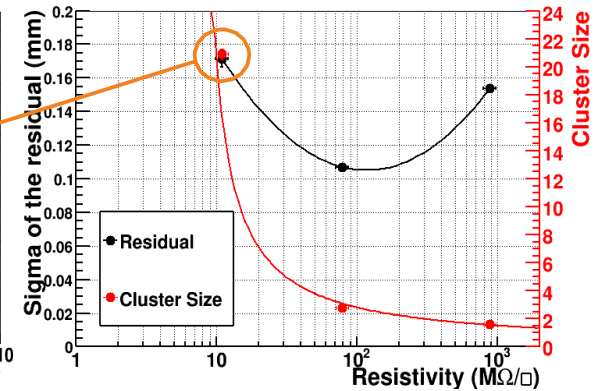
Final setup



Charge collected by the APV25 on the Strip readout (resistivity $\sim 10 \text{ M}\Omega/\square$)



APV25 & 400 μm strip pitch
 \rightarrow capacity = 15 pF



G. Bencivenni et al., NIM A 886 (2018) 36

TB analysis

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



First Step: Matteo, Erika, Riccardo (*)
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.



Checks @ LNF: Matteo, Marco
- 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

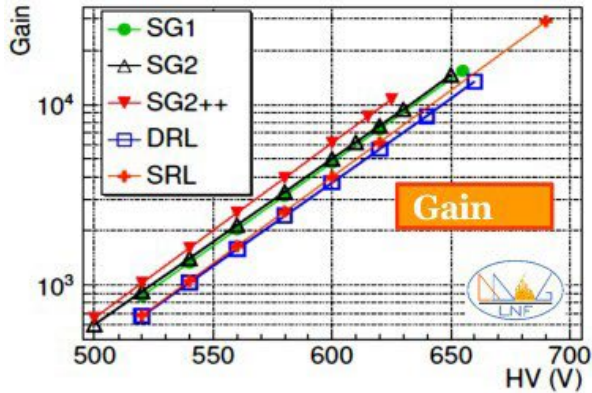


Second Step: Isabella, Lia Riccardo
Analisi in uTPC:
- ADC counts vs HV
- Spread charge vs resistivity
- Risoluzione spaziale vs resistivity (B&B / with tracking)
- Efficienza overall & micro-settori

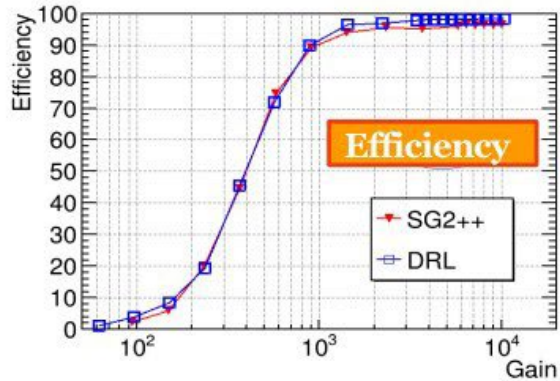
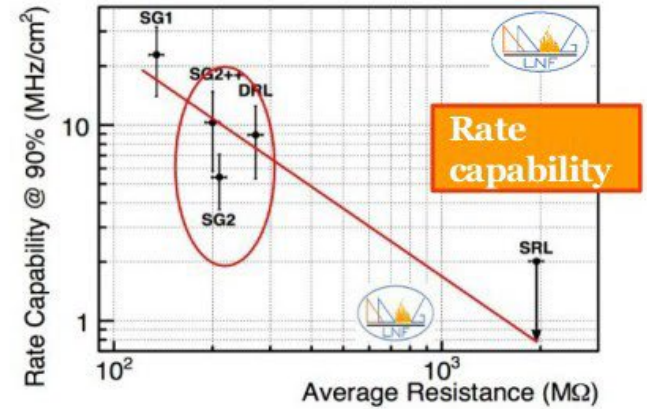
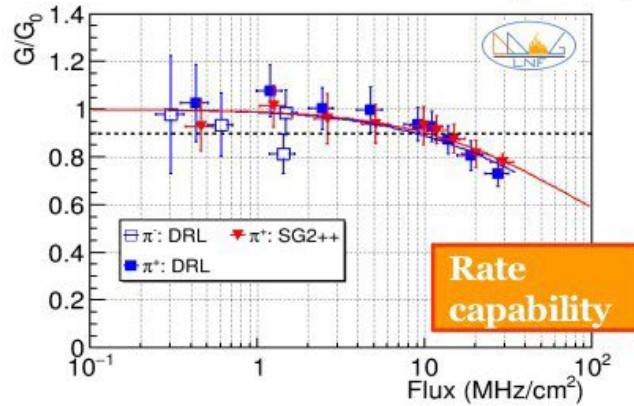
(*) More information in R. Farinelli's talk

μ -RWELL performance overview

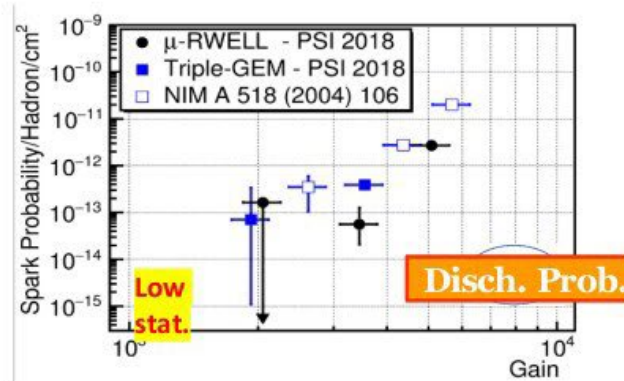
Gain up to 10^4



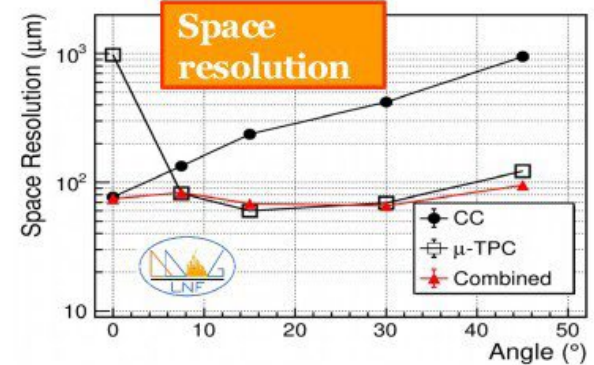
Rate Capability (@ G= 5000) \sim 5-10 MHz/cm²



Efficiency \sim 98%



Discharge probability $\sim 10^{-13}$ @ 4000



Space resolution \sim 100 μ m

Principe of capacitive-sharing readout structures:

- ❖ Vertical stack of pads layers \Rightarrow 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 cm^2 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 \square standard PCB fabrication techniques

