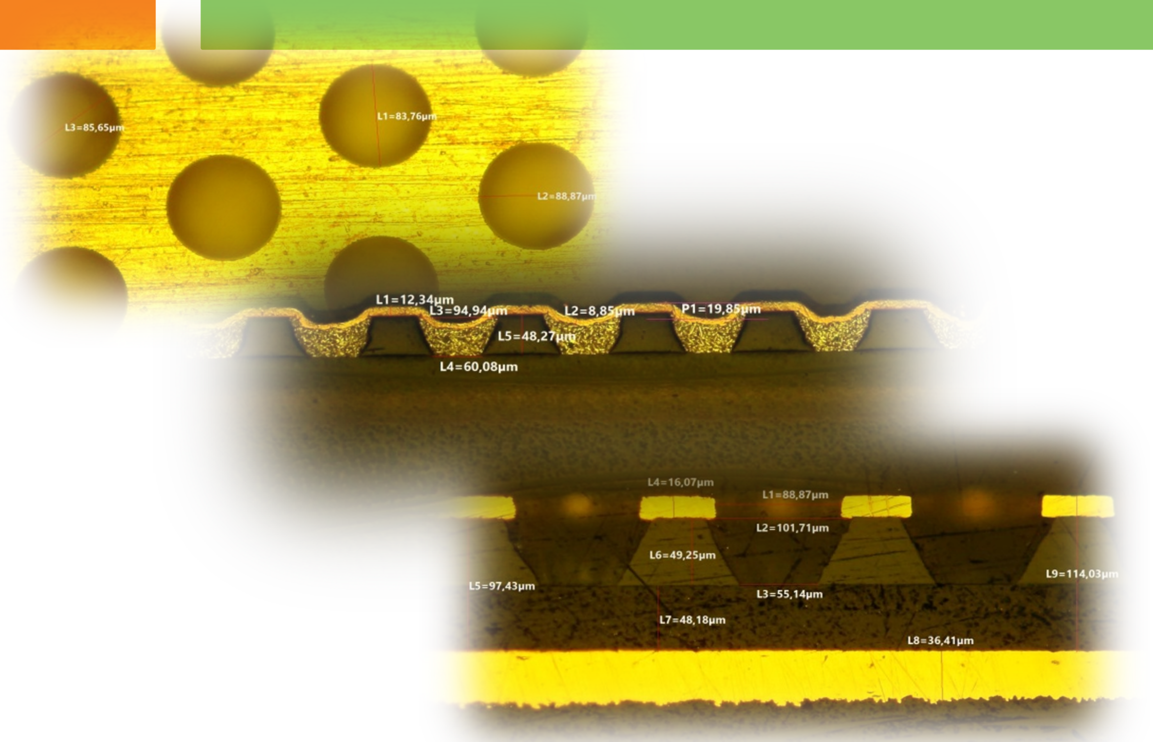
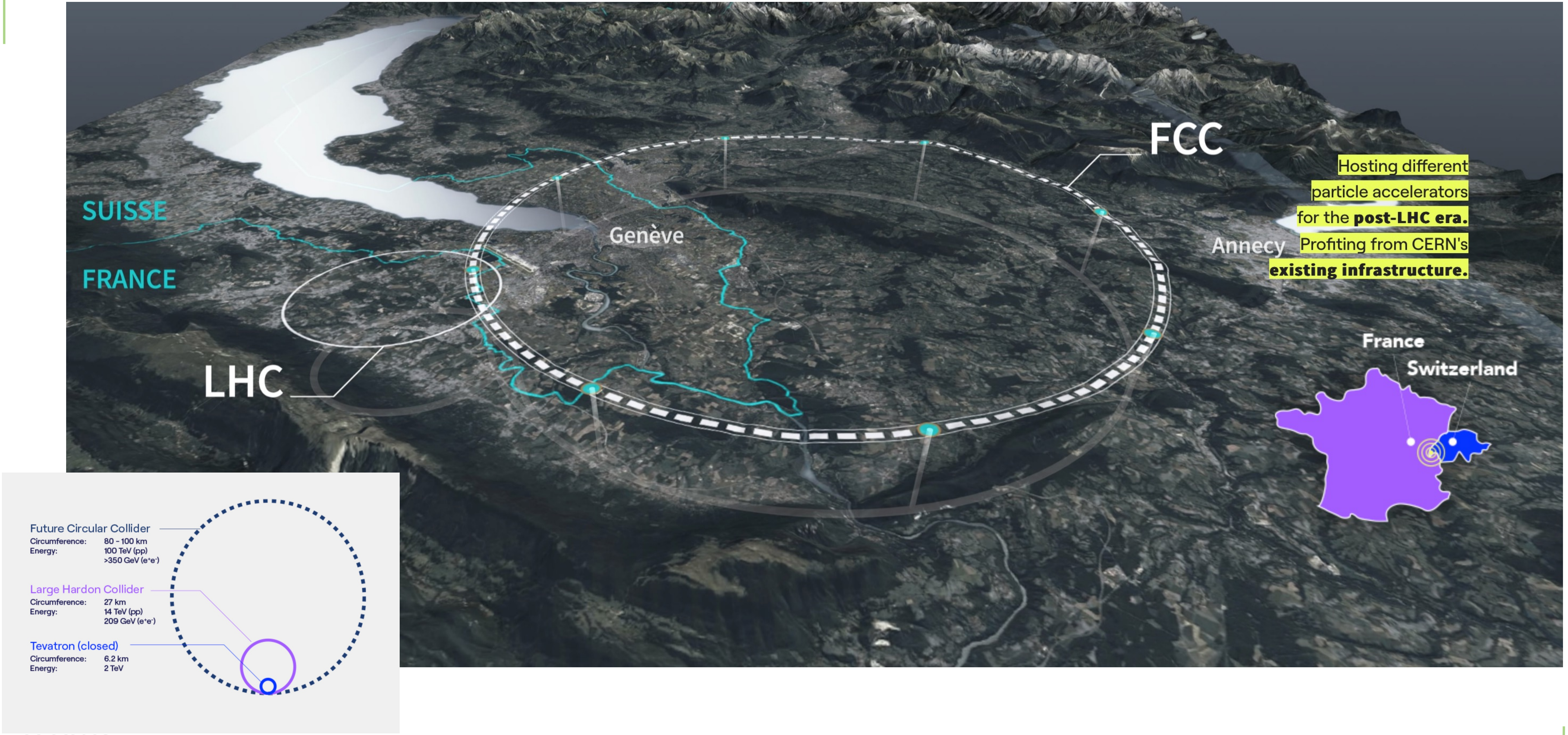
µ-RWELLs for IDEA experiment at FCC_ee



M. Poli Lener
on behalf of

INFN Bo, Fe, LNF , To

Future Circular Collider @ CERN



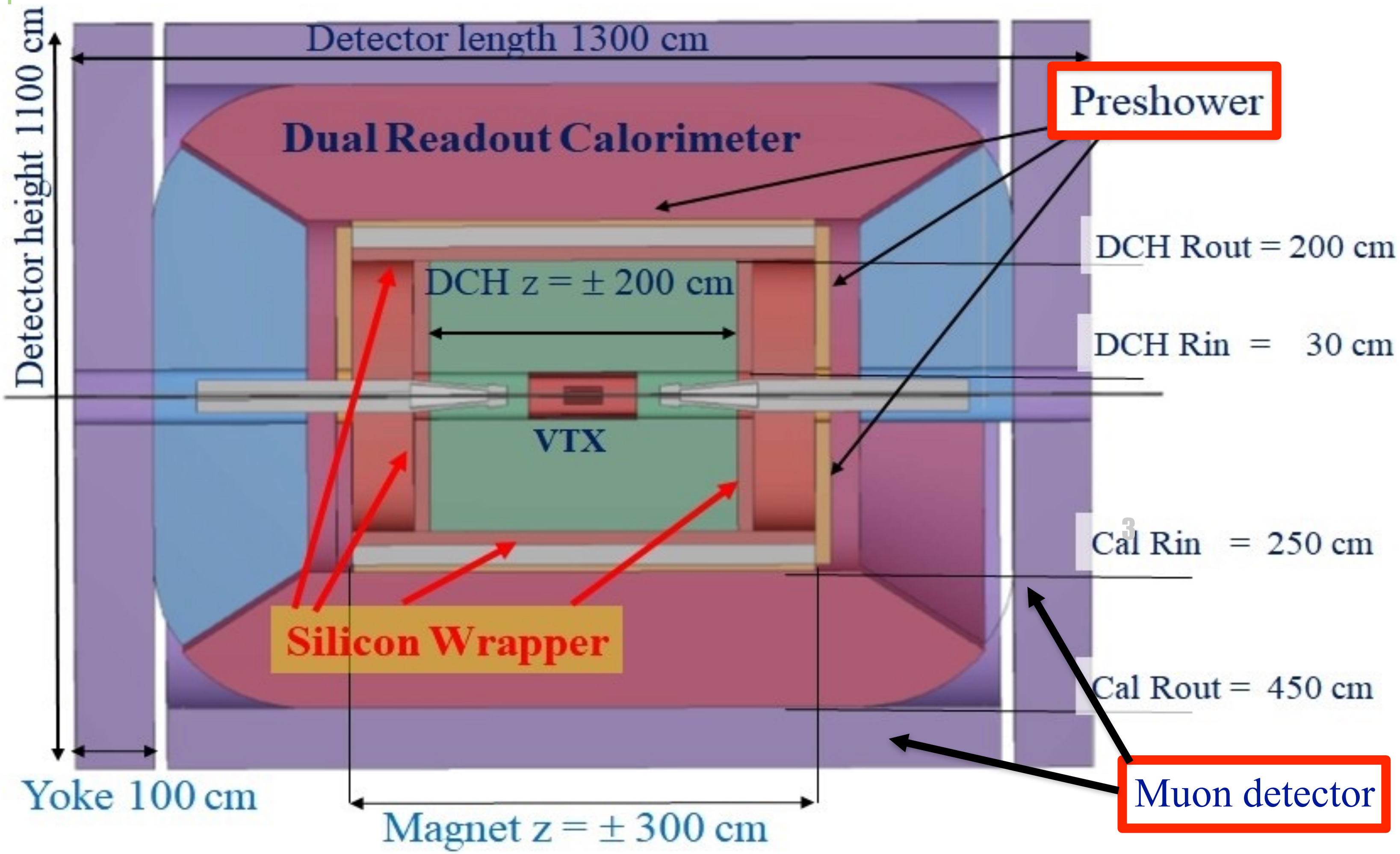
Hosting different particle accelerators for the **post-LHC era.** Profiting from CERN's **existing infrastructure.**

Future Circular Collider
Circumference: 80 - 100 km
Energy: 100 TeV (pp)
>350 GeV (e^+e^-)

Large Hardon Collider
Circumference: 27 km
Energy: 14 TeV (pp)
209 GeV (e^+e^-)

Tevatron (closed)
Circumference: 6.2 km
Energy: 2 TeV

IDEA detector layout



- New, innovative, cost-effective concept
  - Silicon vertex detector
  - Short-drift, ultra-light wire chamber
  - Dual-readout calorimeter
  - Thin solenoid coil *inside* calorimeter system
  - Muon system made of 3 layers of uRWELL detectors in the return yoke

https://pos.sissa.it/390/

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

IDEA⟶ µ-RWELL for pre-shower and muon apparatus

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

Pre-shower & Muon requirements:

Tiles: 50x50 cm^2 with X-Y readout

Efficiency ≥ 98%

Space resolution ≤ 100 µm (Pre-shower)

≤ 400 µm (Muon)

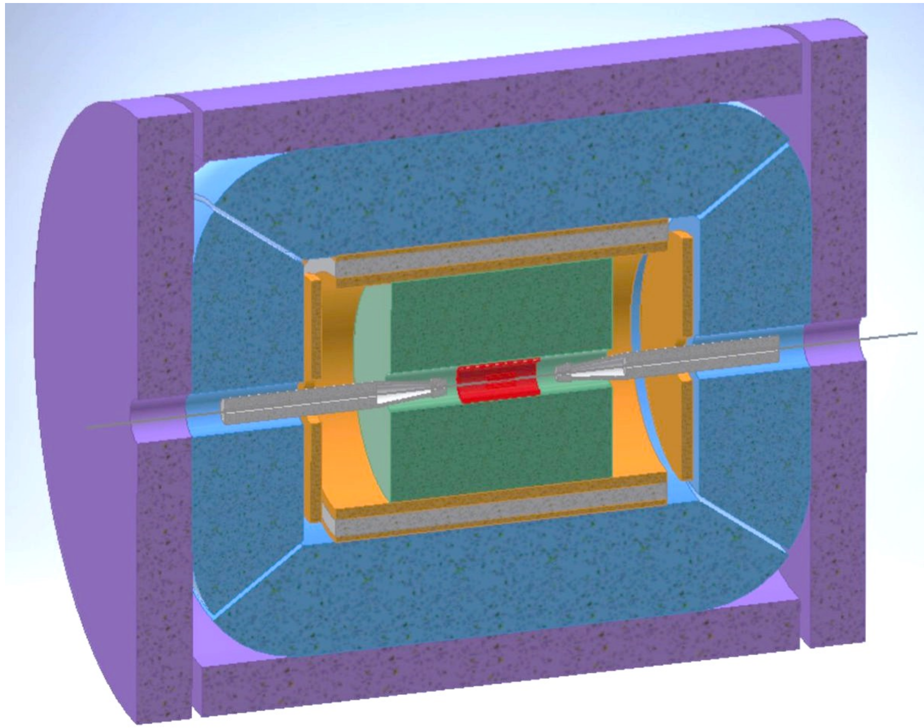
Instrumented Surface/FEE:

130 m^2, 520 det., 3×10^5 ch. (0.4 mm strip pitch)

1500 m^2,1520 det., 5×10^6 ch. (1.2 mm strip pitch)

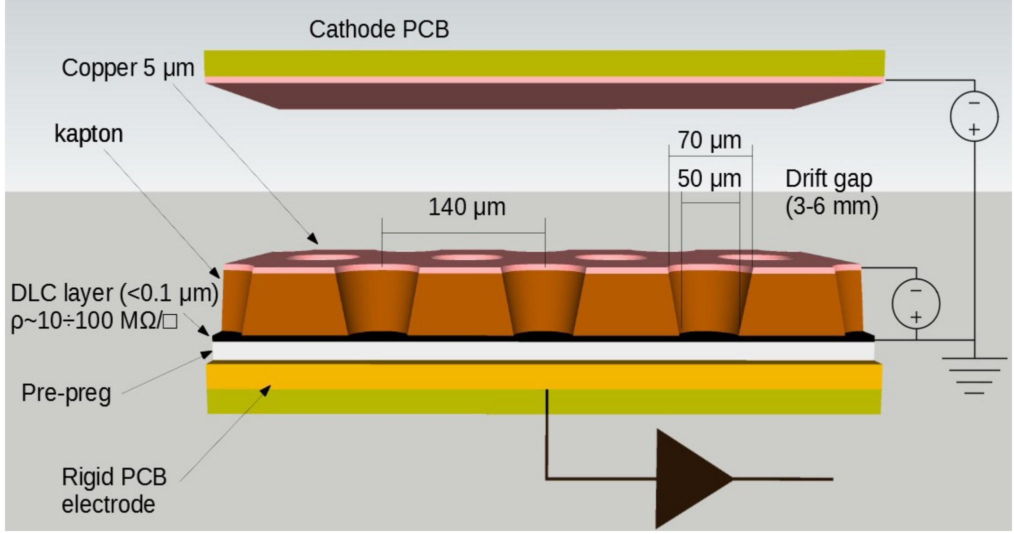
Mass production → Technology Trasfer to Industry

FEE Cost reduction →custom made ASIC (TIGER)



The μ-RWELL

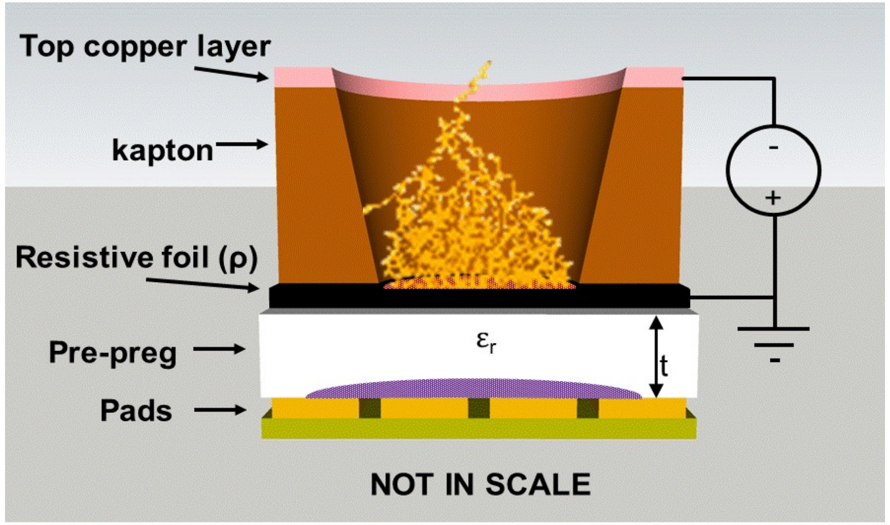
G. Bencivenni et al., The micro-Resistive WELL detector: a compact spark-protected single amplification-stage MPGD, 2015 JINST 10 P02008



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.**

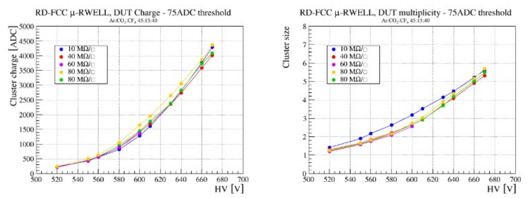
Drawback: capability to stand high particle fluxes reduced, but **largely recovered** with appropriate **grounding schemes** of the **resistive layer**

u-RWELL R&D for FCC_ee

u-RWELL R&D for FCC

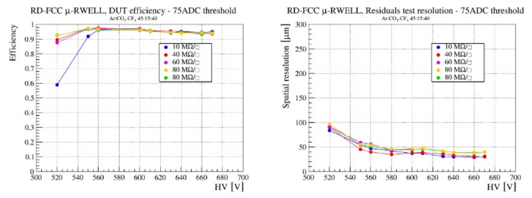
TB with DC + pre-shower + CALO+ Muon

2020



(a) Cluster charge for different HV.

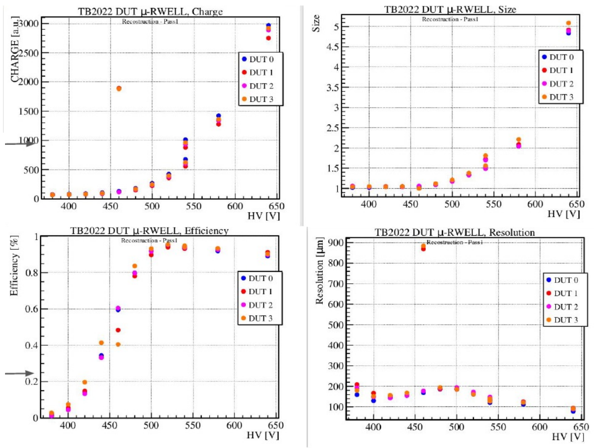
(b) Strip cluster size for different HV.

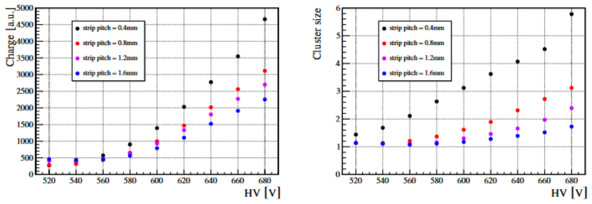


(c) Tracking efficiency for different HV.

(d) Residuals width for different HV.

2021





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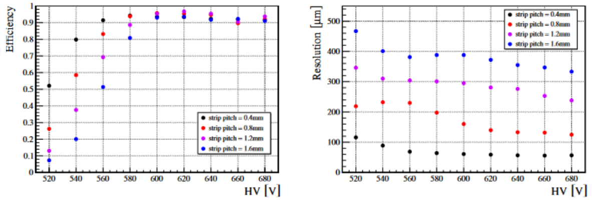

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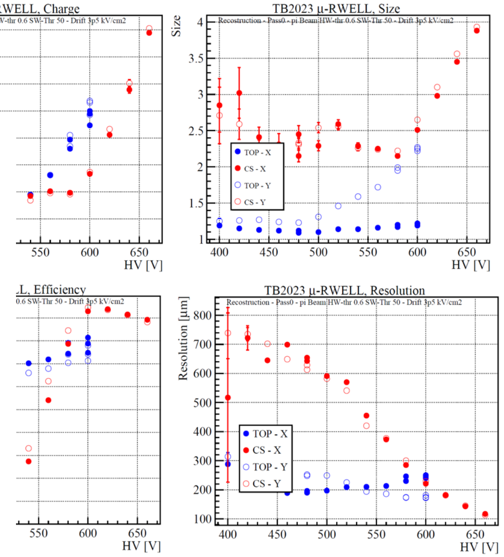
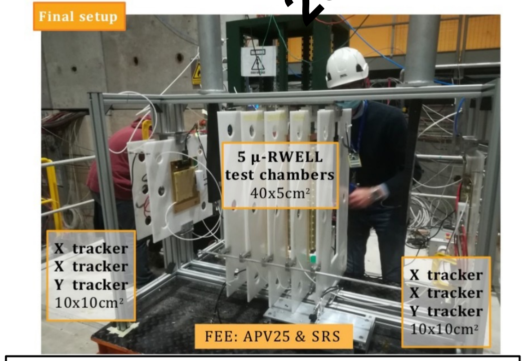


1D PERFORMANCE

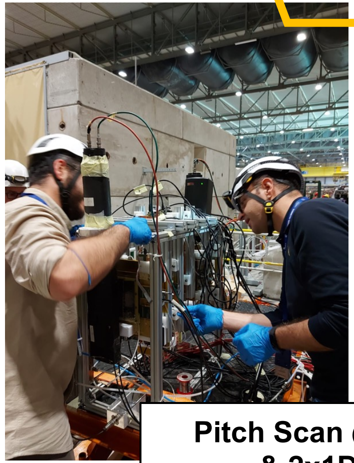
2D performance

2022

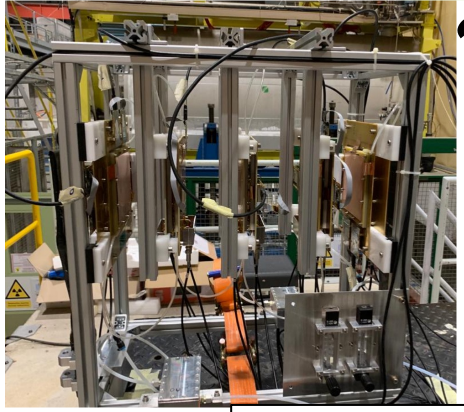
2023



Resistivity Scan @ fixed pitch

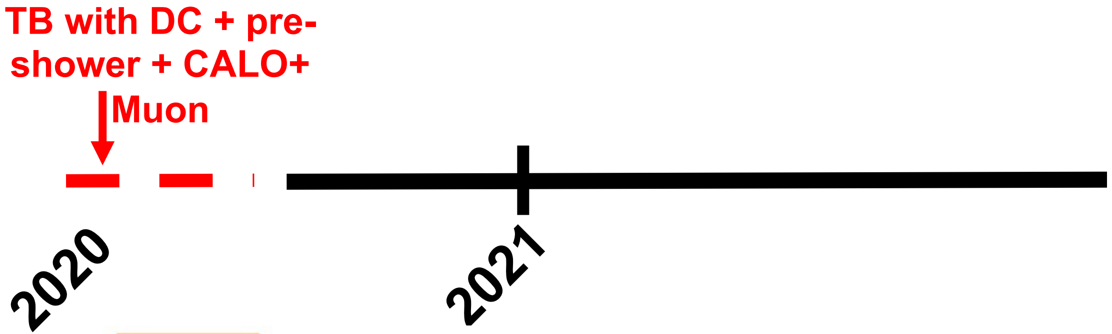


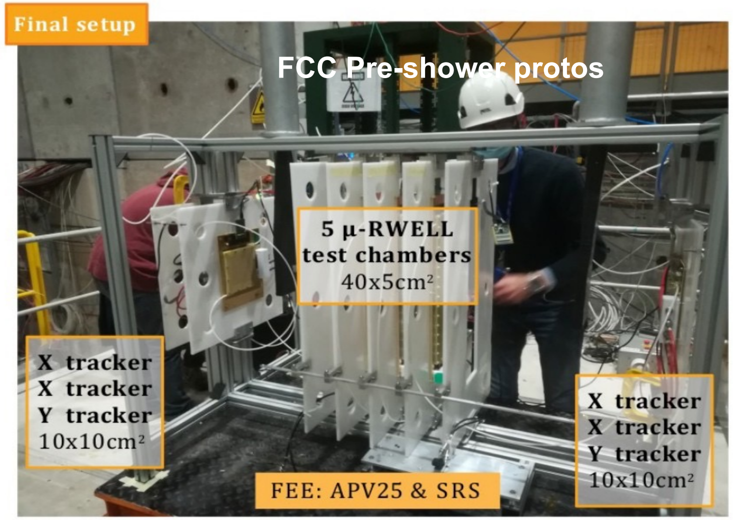
Pitch Scan @ fixed resistivity & 2x1D performance



2D layouts

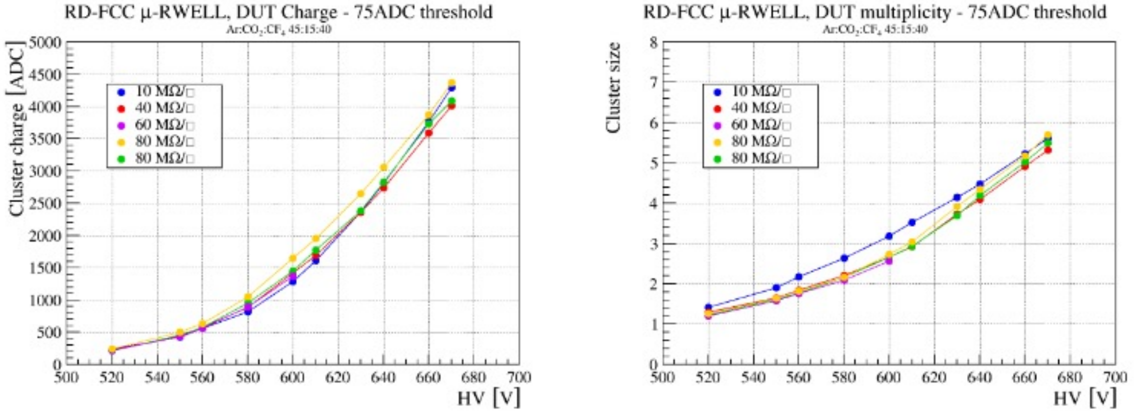
R&D for FCC: 1D R/out





Active area= 400x50 mm2
Pre-preg thickness= 50 um
Resistivity= 10 ÷80 MΩ/□
Strip pitch= 0.4 mm
Strip width = 0.150 mm
Ratio p/w= 2.66

Resistivity Scan @ fixed pitch



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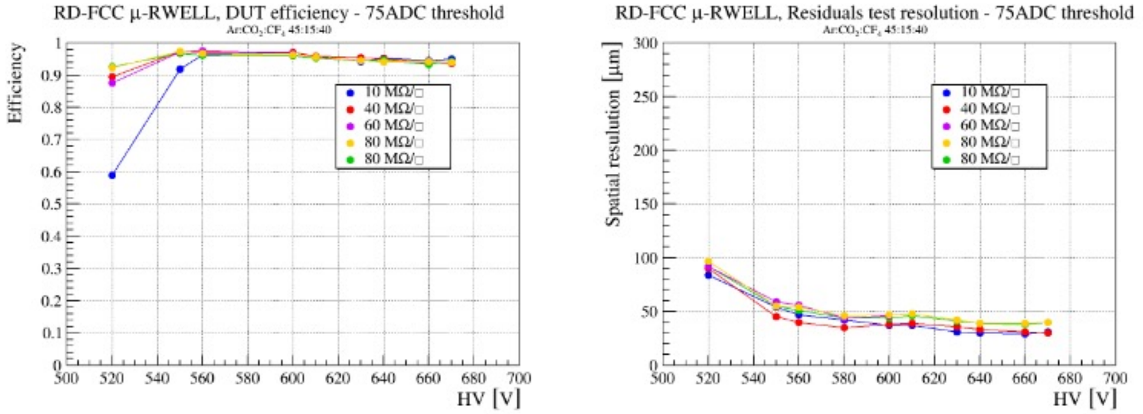
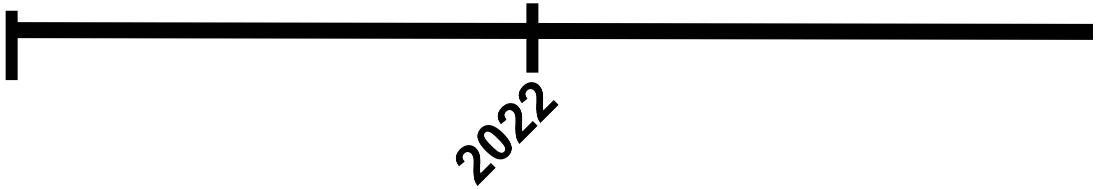


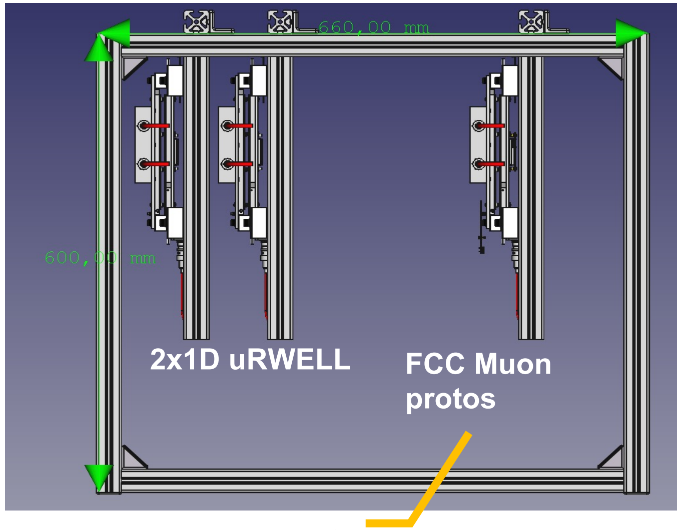
(c) Tracking efficiency for different HV.

(d) Residuals width for different HV.

Same performance except the **10 MΩ/□ proto**
Efficiency knee @ 550 V, σ_x < 100 um

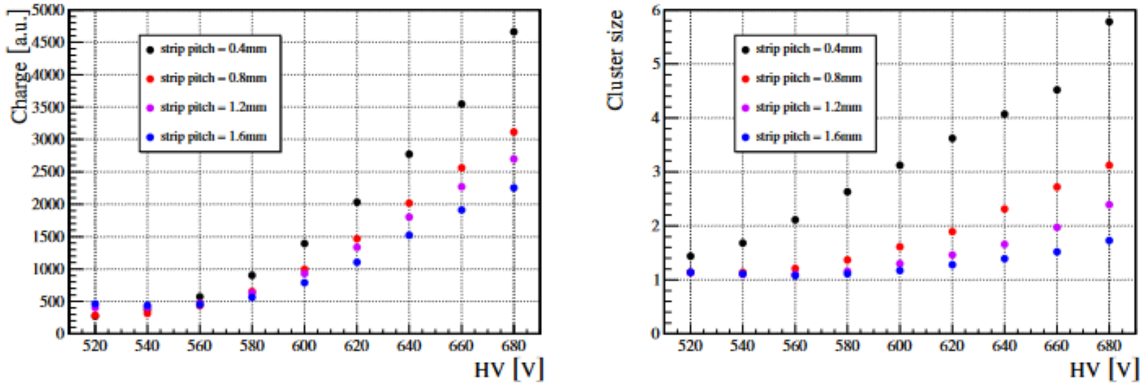
R&D for FCC: 1D R/out





Active area= 400x50 mm2
Pre-preg thickness= 50 um
Resistivity= 30 MΩ/□
Strip pitch= 0.4-1.6 mm
Strip width = 0.15 mm
p/w ratio= 2.66 – 10.66

R/O pitch scan @ fixed resistivity



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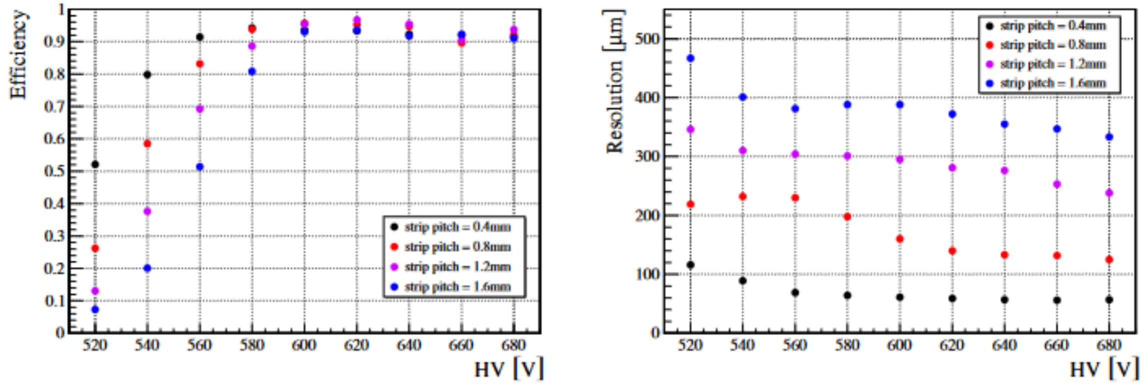


(c) Tracking efficiency for different HV.

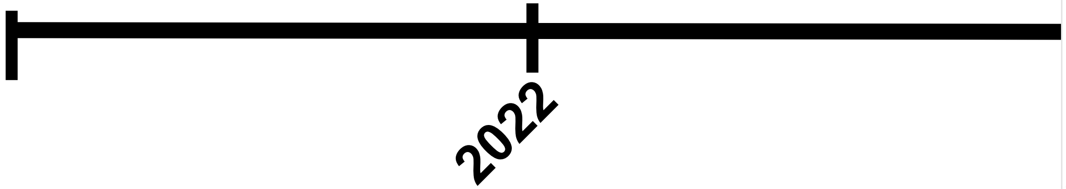
(d) Residuals width for different HV.

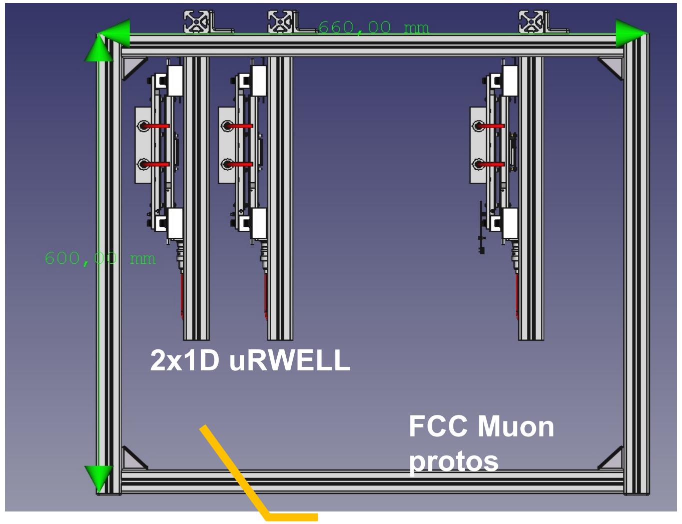
Larger is the strip pitch, lower is the charge signal requiring a higher gain to reach full efficiency.

Efficiency knee @ 600 V & σ_x < 400 um for a strip pitch = 1.6 mm

A high p/w ratio implies a worsening of the detector performance

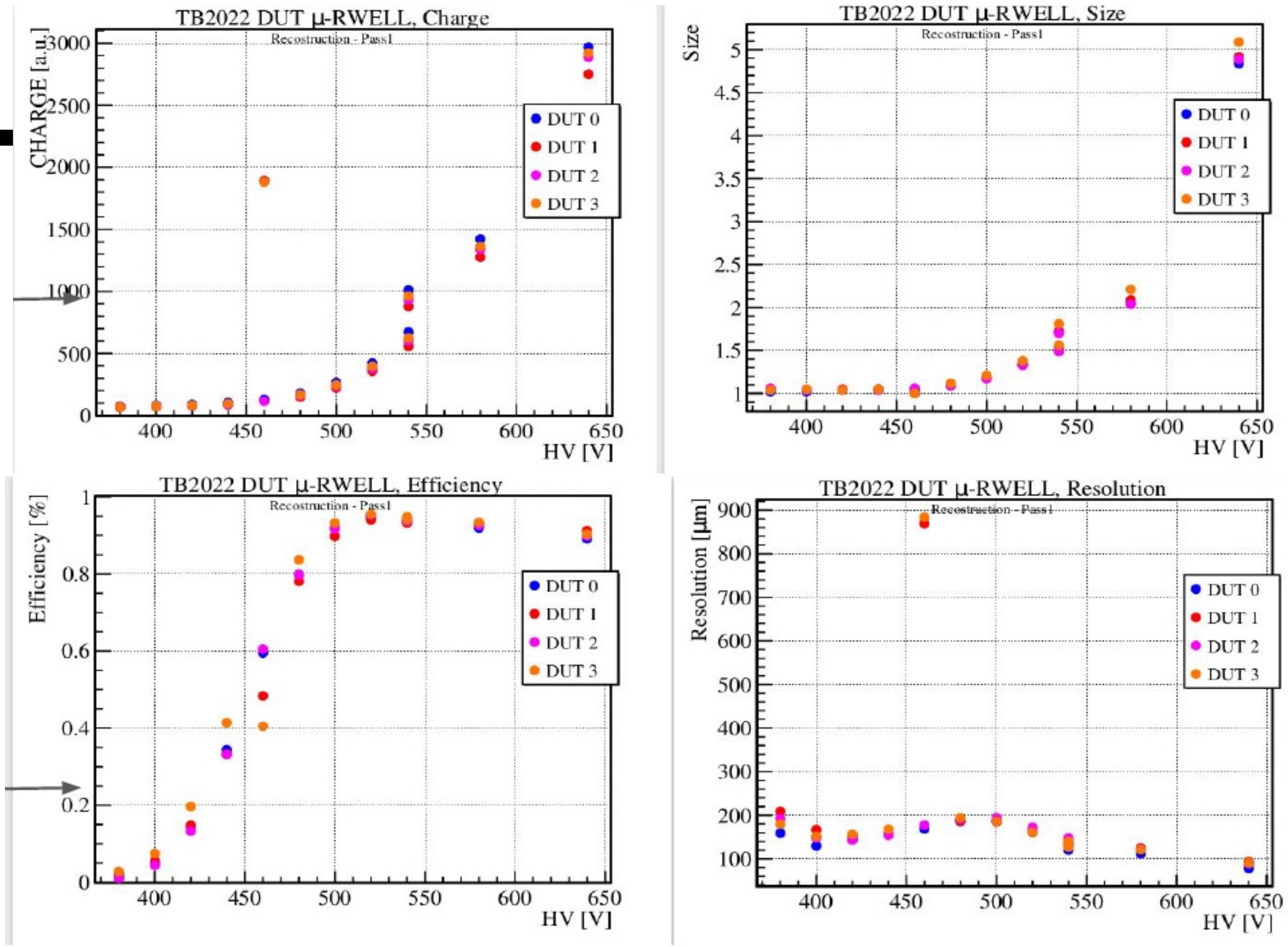
R&D for FCC: 1D R/out





Active area= 100x100 mm2
Pre-preg thickness= 20 um
Resistivity= 50 MΩ/□
Strip pitch= 0.76 mm
Strip width = 0.3 mm
Ratio p/w= 2.53

2x1D performance

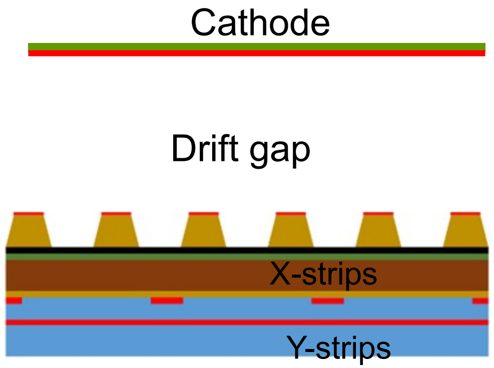


The 1D proto show very good performace @ 500 V to be compared with 2D ones (TB 2023)

Efficiency knee @ 500 V & σx < 200 um for a strip pitch ~ 0.8 mm

Possible 2D layout

RWELL 2D «COMPASS» [*]



The «COMPASS» R/out requires higher gas gain due to the coupling of the X and Y R/out strips.

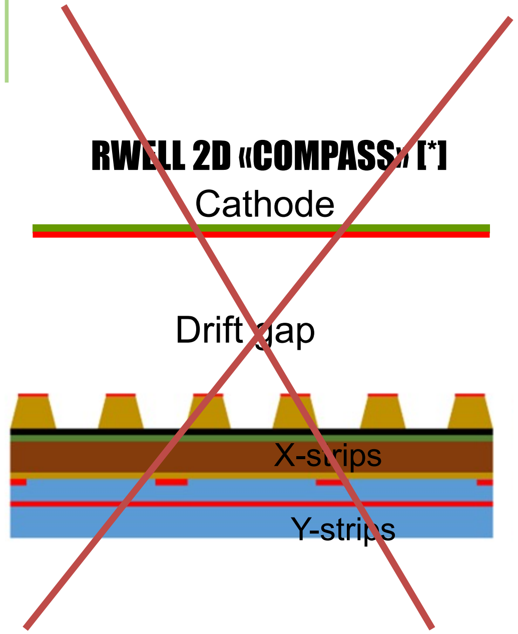
Good perfomance

No easy optimization of the charge sharing on X-Y views

(*) Y. Zhou et al. NIMA 927 (2019) 31

Possible 2D layout

RWELL 2D «COMPASS» [*]



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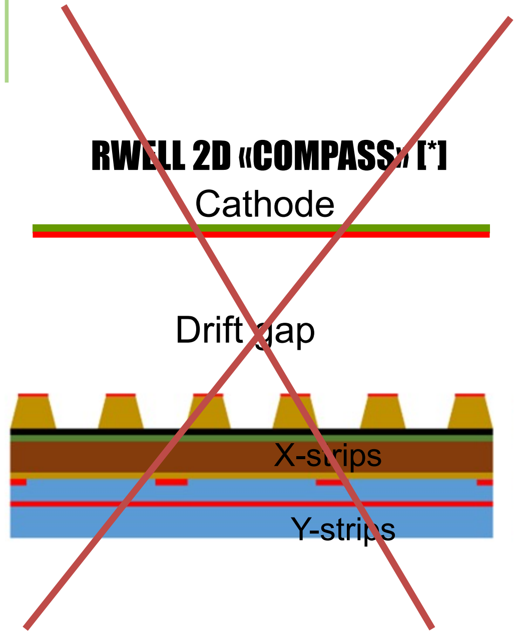
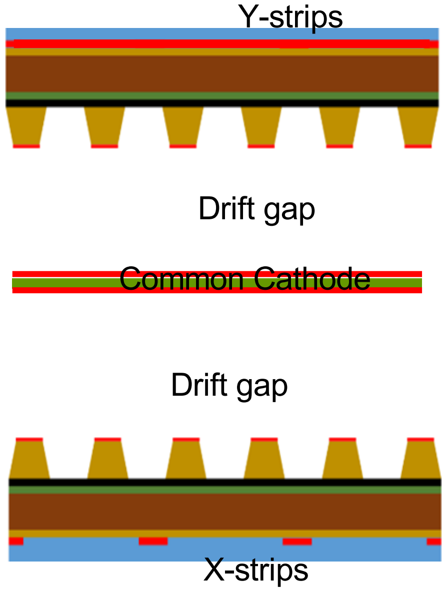


N.2 u-RWELLs 1D (2x1D)



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This option centainly allows to work at **lower gas gain** wrt the «COMPASS» R/out (X-Y r/out are decoupled)

→ **TB2022 results:**

- **IDEA pre-shower:** Efficiency knee @ 550 V, σ_x < 100 um with 0.4 mm strip pitch for the
- **IDEA Muon:** Efficiency knee @ 600 V & σ_x < 400 um for a strip pitch = 1.6 mm

Possible 2D layout

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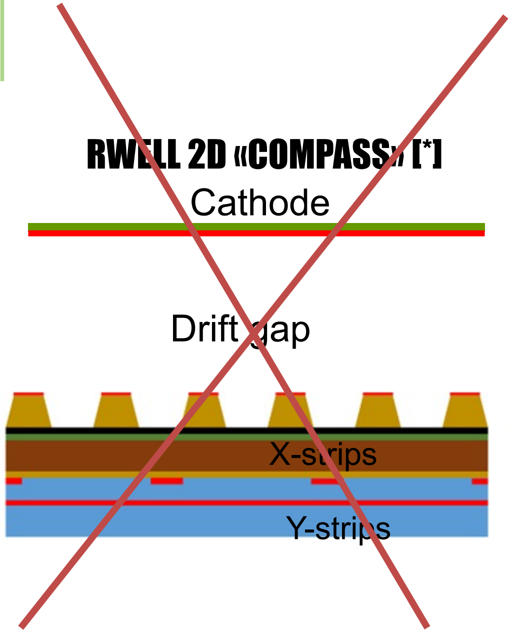

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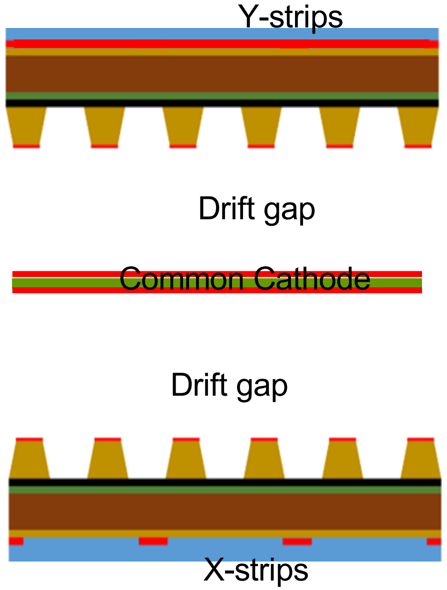

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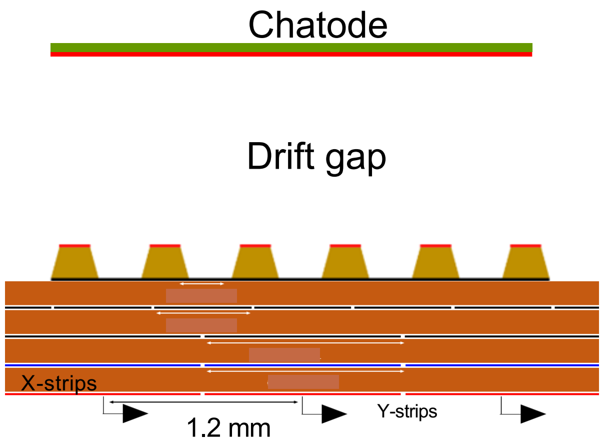
u-RWELL - Charge Sharing r/o (*)

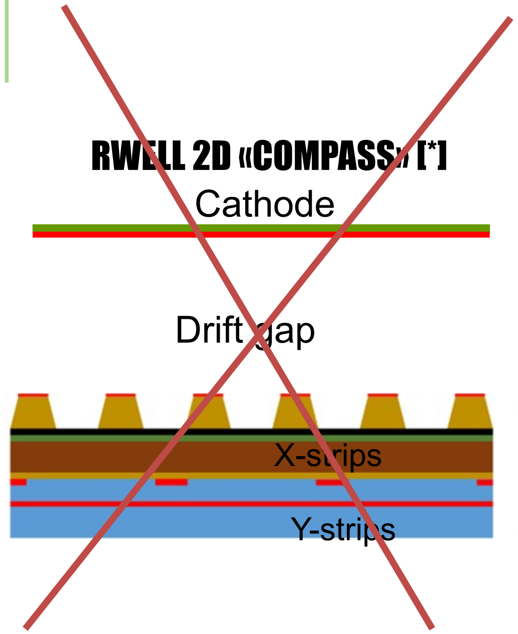


The charge sharing structures: the **charge transfer** and **charge sharing** using **capacitive coupling between a stack of layers** of pads and **the r/out board.**
This technique offers the possibility **to reduce the FEE channels**, but the **total charge is divided between the X & Y r/out** (similar to the «COMPASS» R/out)

(*) K. Gnanvo et al. NIMA 1047 (2023) 167782

Possible 2D layout

RWELL 2D «COMPASS» [*]



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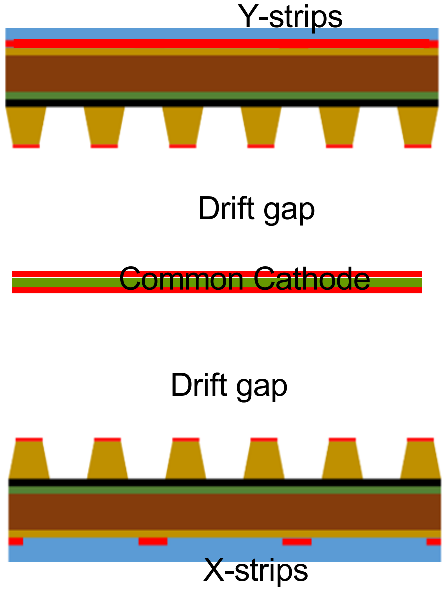

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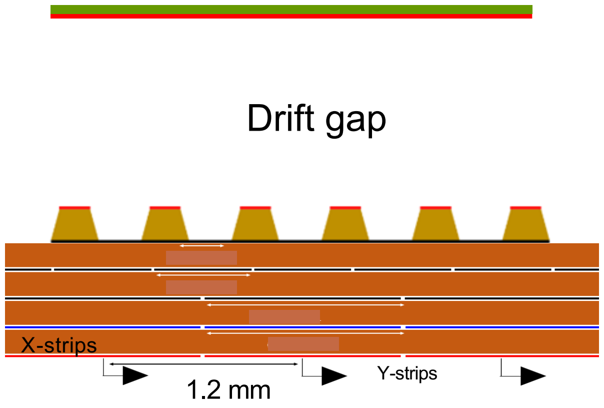

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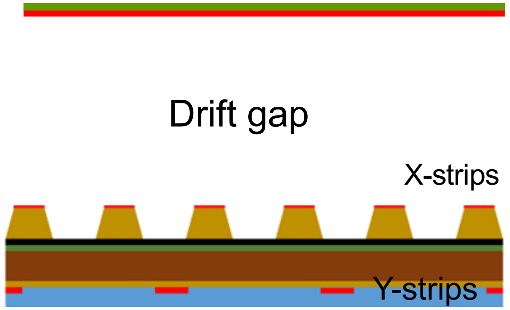
u-RWELL TOP r/o

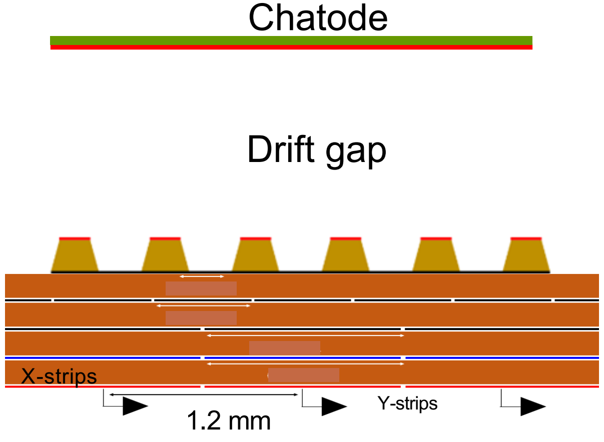


The **TOP layout** centainly allows to work at **lower gas gain** wrt the «COMPASS» r/out (X-Y r/out are decoupled)

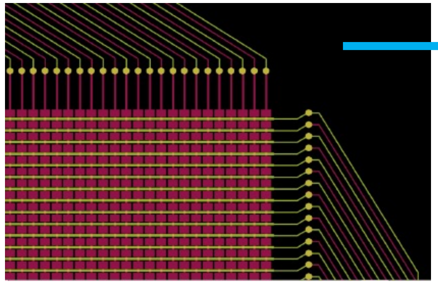
→ X coordinate on the TOP of the amplification stage introduces same **dead zone in the active area**

Possible 2D layout

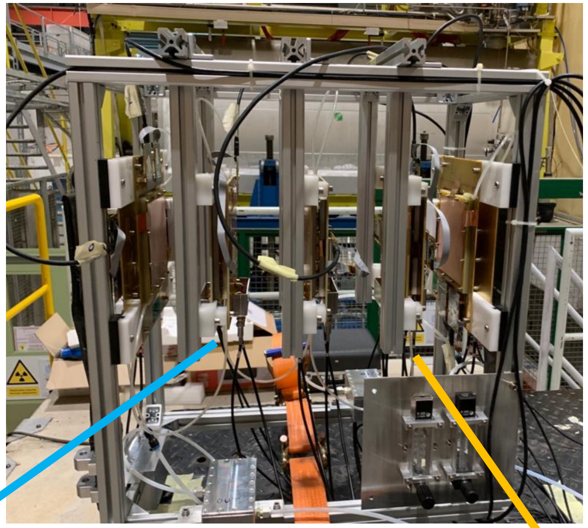
u-RWELL - Charge Sharing r/o (*)



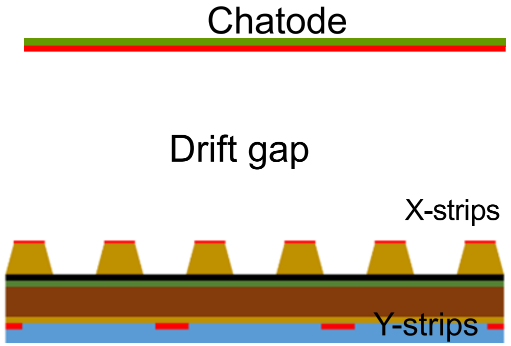
CS Readout board



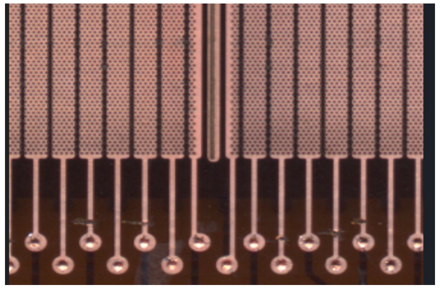
Active area= 100x100 mm2
Resistivity= 50 MΩ/□
Strip pitch= 1.2 mm
Strip width = 1.1 mm
Several layer between DLC and R/out



u-RWELL TOP r/o



X coordinate on the TOP of the amplification stage

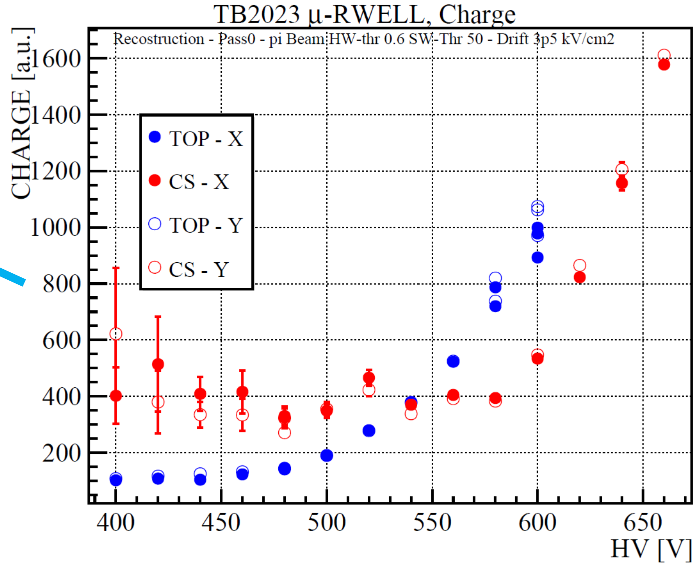


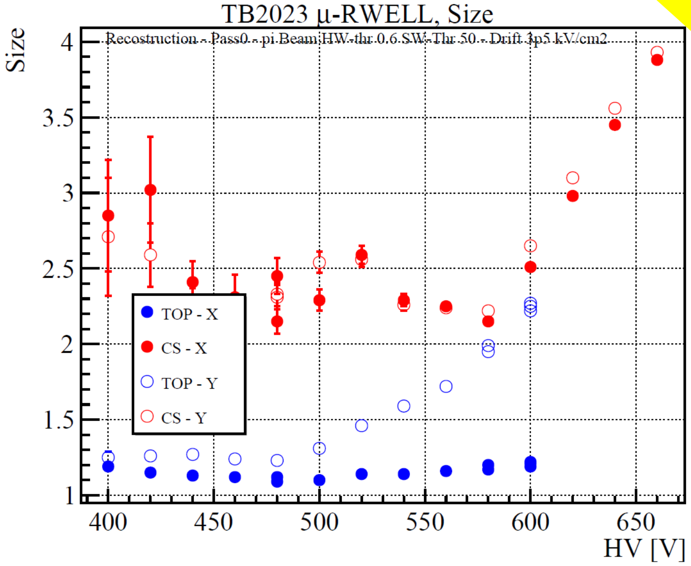
Active area= 100x100 mm2
Resistivity= 50 MΩ/□
Strip pitch= 0.8 mm
Strip width = 0.7 mm
Dead zone (TOP) ~ 15%
Pre-preg thickness= 70 um

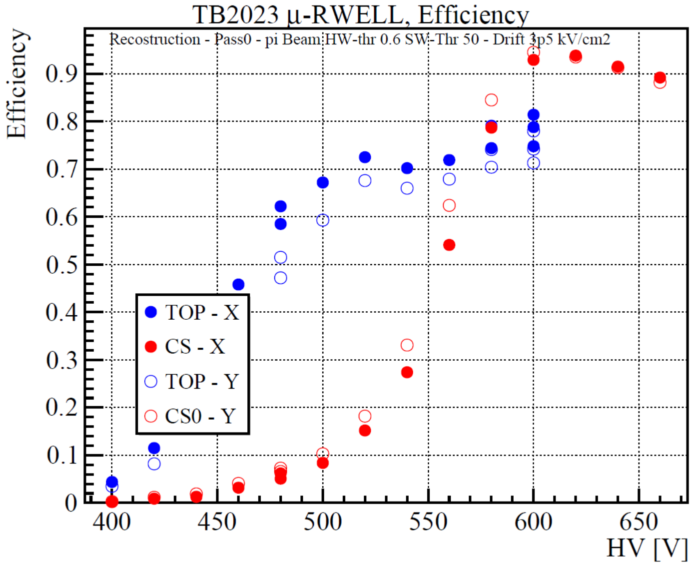
R&D for FCC: 2D R/out

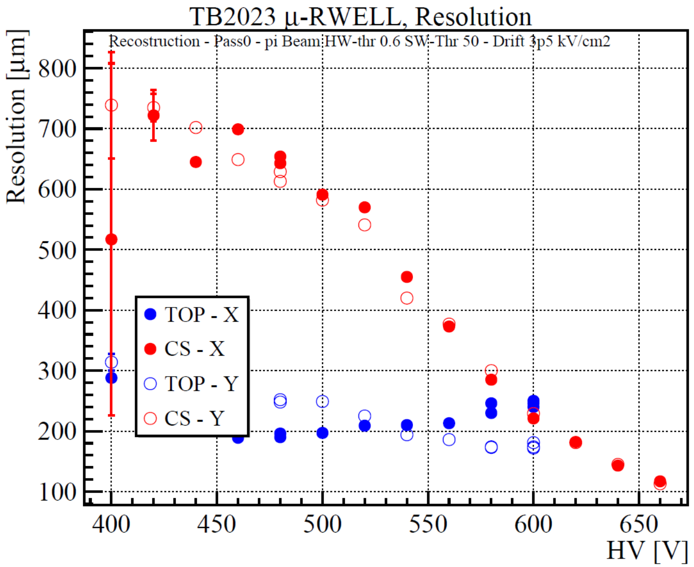
An ugual charge sharing on the X-Y coordinates is shown for both 2D r/out

preliminary


TB2023 µ-RWELL, Charge


TB2023 µ-RWELL, Size


TB2023 µ-RWELL, Efficiency


TB2023 µ-RWELL, Resolution

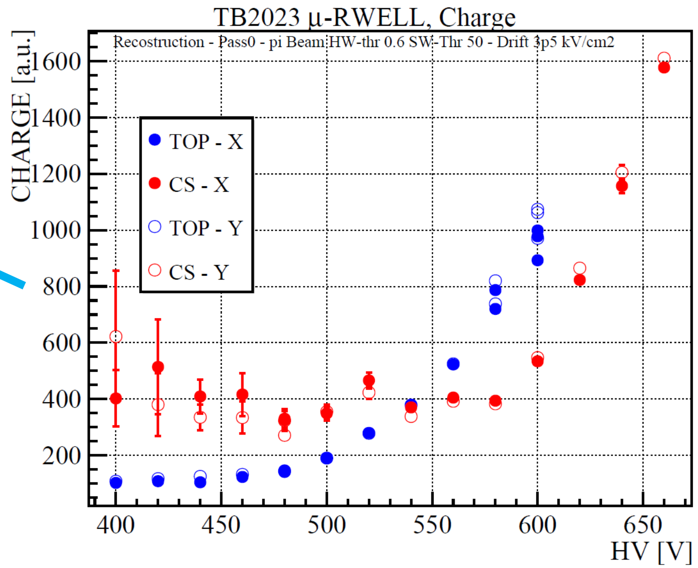
R&D for FCC: 2D R/out

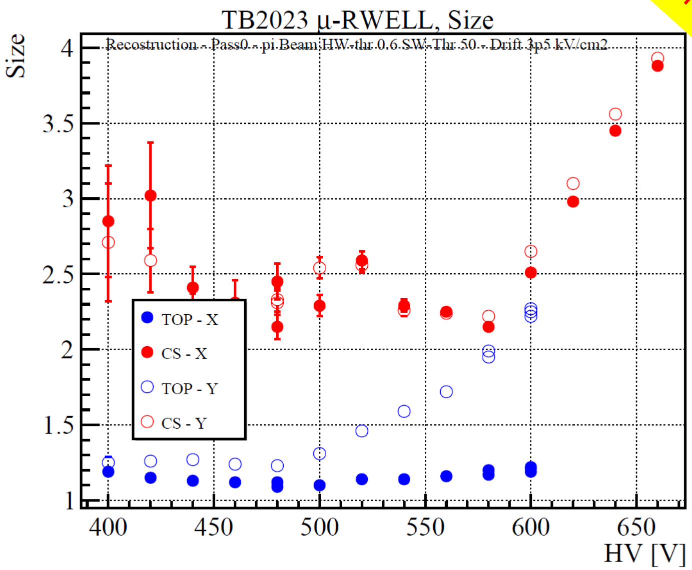
An ugual charge sharing on the X-Y coordinates is shown for both 2D r/out

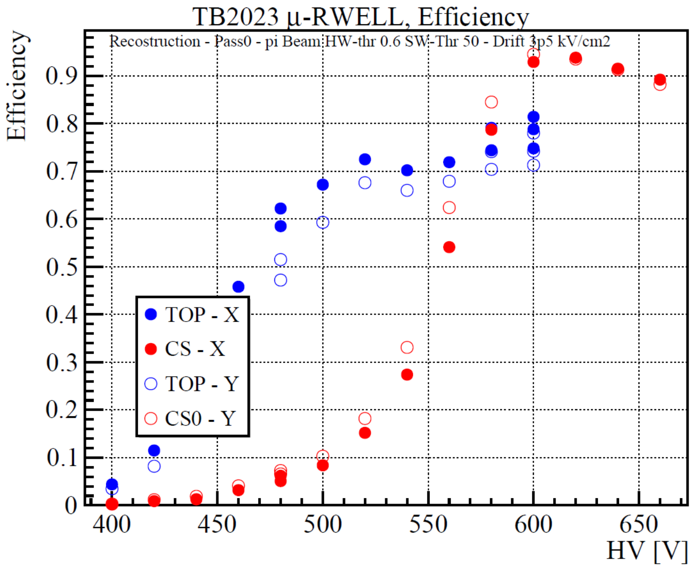
TOP r/o:

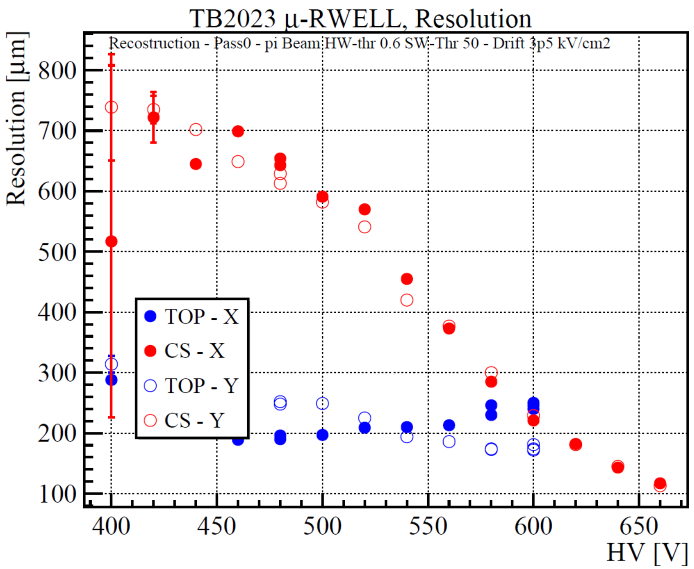
- **The total charge isn't divided between X & Y view;**
- **Efficiency knee @ 500 V** (such as 1D proto);
- **Low efficiency plateau (~70%) due to dead zone**
- Cluster Size does not change on X (TOP layer), while changing on the Y (due to the DLC spread);
- **Digital spatial resolution** on the X (Strip size ~ 1.5), strip Size>, improving on the Y (due to DLC spread)

preliminary









R&D for FCC: 2D R/out

preliminary

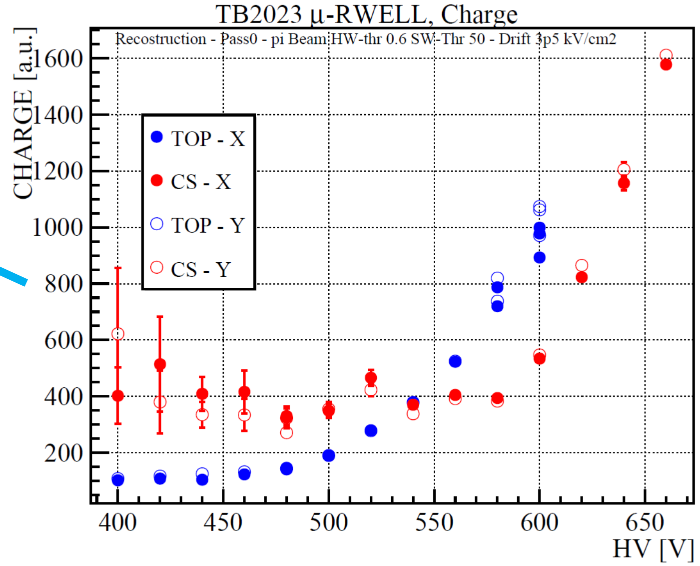
An ugual charge sharing on the X-Y coordinates is shown for both 2D r/out

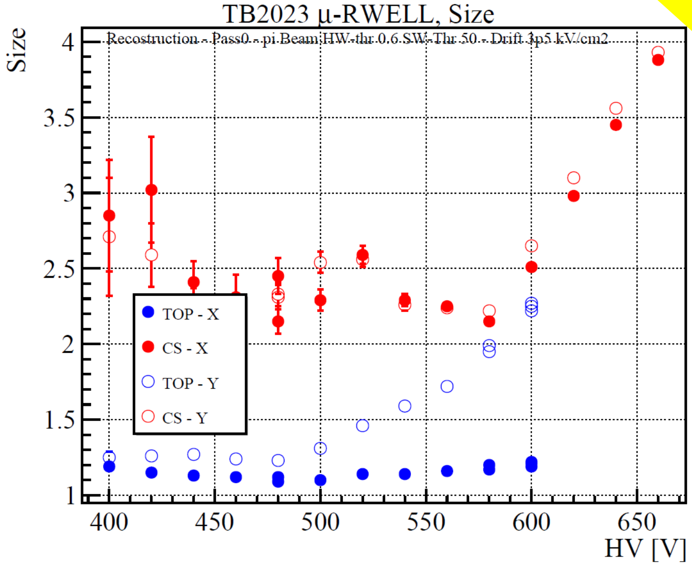
TOP r/o:

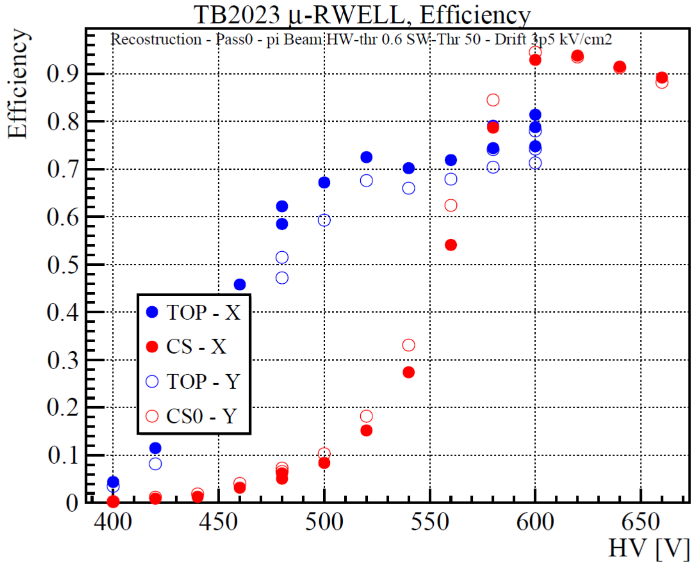
- **The total charge isn't divided between X & Y view;**
- **Efficiency knee @ 500 V** (such as 1D proto);
- **Low efficiency plateau (~70%) due to dead zone**
- Cluster Size does not change on X (TOP layer), while changing on the Y (due to the DLC spread);
- **Digital spatial resolution** on the X (Strip size ~ 1.5), strip Size>, improving on the Y (due to DLC spread)

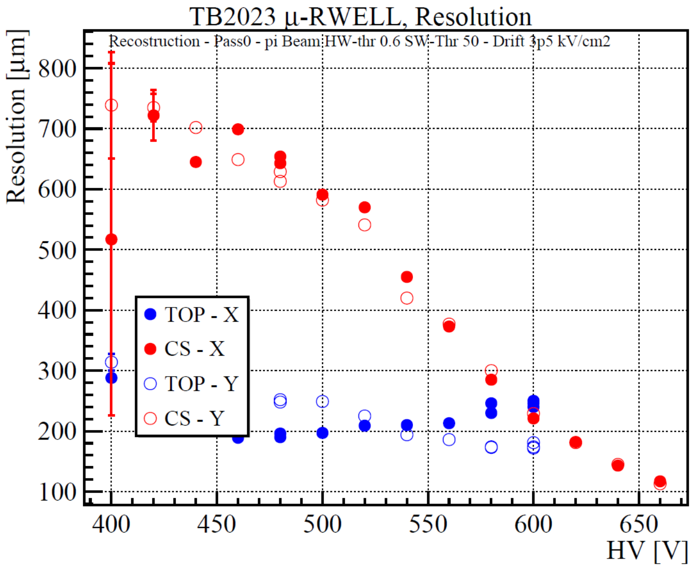
CS r/o:

- **The total charge is divided between X & Y view;**
- **Efficiency knee @ 600 V;**
- **High efficiency plateau (~95%)**
- Cluster size increase to 4 strips (Charge Sharing mechanism work)
- **Spatial resolution** improves at higher gain reaching **150 um with a strip pitch of 1.2 mm**









Status and plans 2023

The 2023 program can be summarized in the following points:

done

- ✓ **Finalization of the TB 2022 analysis (NA – H8C, 4-20 October 2022) with µ-RWELL prototypes with 1D strip readout:**
  - 100x100 mm2 area attiva & strip pitch 0.76 mm
  - 50x400 mm2 area attiva & strip pitch 0.4÷1.6 mm
- ✓ **Production of µ-RWELL with** readout a strip 2D (100x100mm2 active area) the so called:
  - TOP r/out – strip pitch 0.76 mm
  - Charge Sharing r/out – strip pitch 1.2 mm
- ✓ **Beam Test** (NA – H8C, 14-28 giugno 2023) of the previous layouts 2D**.** The test has been performed with the APV25
- ✓ Prototypes production **500x500 mm2 active area:** layout **TOP r/o** with **strip pitch of 1.2 mm (in order to minimize the dead area), while for the** CS r/o, we do not consider necessary readout optimizations. **The prorotypes will be ready for gen/feb-24. T**est @LNF with X-ray & cosmic and afterwards a TB are foreseen.

to be done

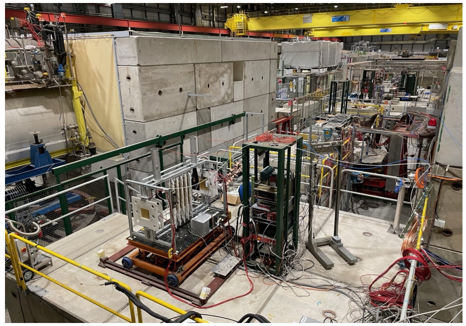
- ✓ **Finalization of the TB 2023 analysis (**NA – H8C, 14-28 giugno 2023) with **µ-RWELL proto with 2D strip** readout. Comparison of the 2D performance: proto layout 2D (CS & TOP) vs proto layout 2x1D

2024 Program

The 2024 program will be foreseen the following items:

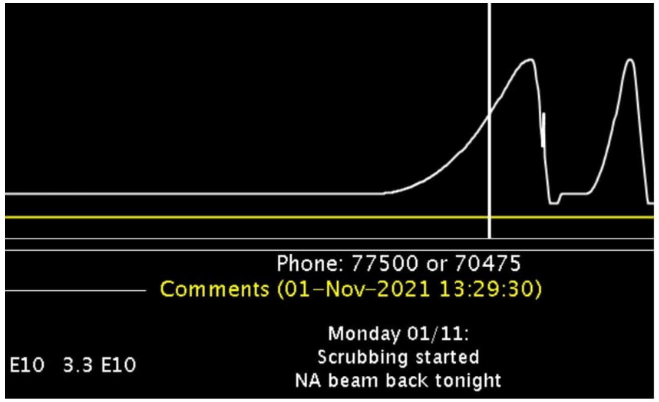
1. Study **gas gain optimization** with **different geometry of the amplification stage** (pitch well, external/internal well diameters) with 100x100 mm2 prototypes. **These studies have been perfomed with GEM detector but never with uRWELL**→ with a reduction of the well pitch from 140 µm to 90 µm, **a possible increase of the gas gain of about 2 is foreseen**
2. Production of N.2 500x500 mm2 prototypes (second half of 2024): the choice of 2D layout will be based on the results obtained in the previous test. Test @LNF with X-ray & cosmic (with tracking system) will be performed.
3. **Continuation** of testing of the **µRWELL production** processes at **ELTOS /CERN** and **DLC machine** at CERN (see Gianni and Gianfranco talks on Thursday)

Summary



- The µ-RWELL is becoming a mature device, also thanks to the technology spread that is giving an important boost to its development.
  - It is also considered for an upgrade of the LHCb Muon apparatus and for the spectrometer of CLAS12 Jlab (White paper for Snowmass), EIC, X17 @nTOF

- Preshower and muon detectors designed with the µ-RWELL technology
  - Studies aimed at defining the best DLC resistivity and strip pitch for the requested spatial resolution for preshower and muon system
  - Good 2D µ -RWELL prototype performance has been measured and layout optimization has been adopted
  - Production of the µ-RWELL layouts with the final active area
  - Continue partnership with ELTOS (preparation) and CERN (finalization) to complete technology transfer
- Ready for the final design for next FCC-ee descriptive document (2025-2027)

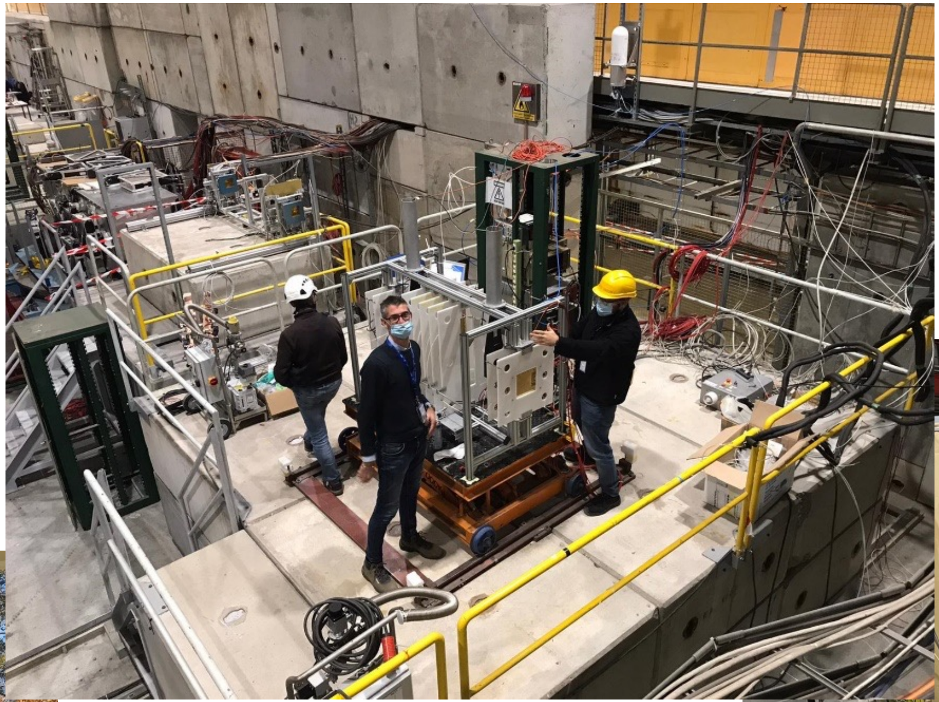


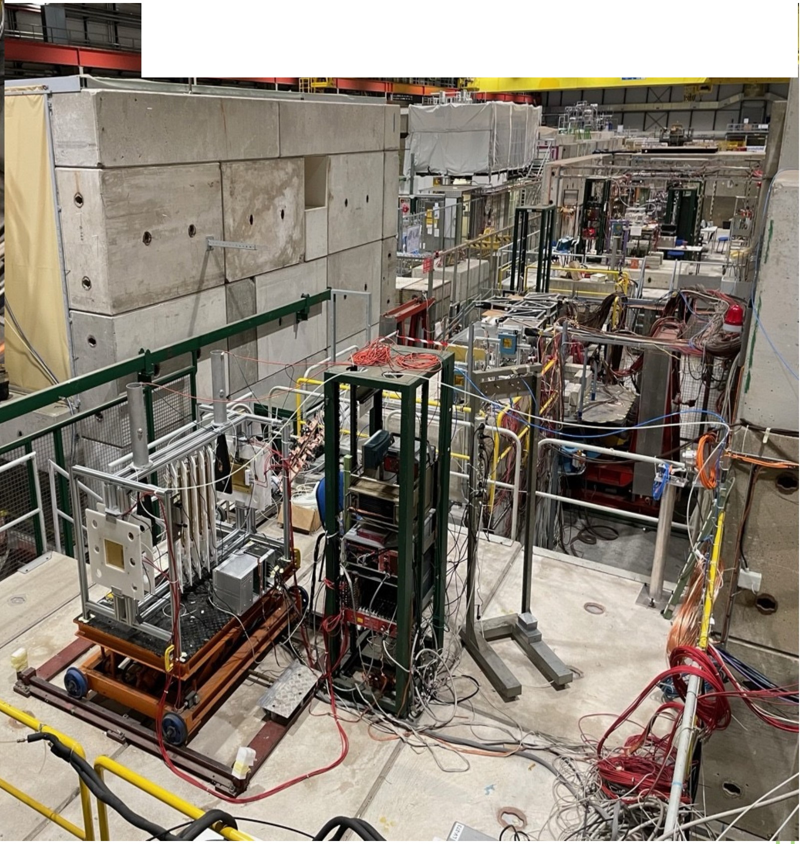
E10 3.3 E10

Phone: 77500 or 70475

Comments (01-Nov-2021 13:29:30)

Monday 01/11:
Scrubbing started
NA beam back tonight





Thanks for your attention

spare slides

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

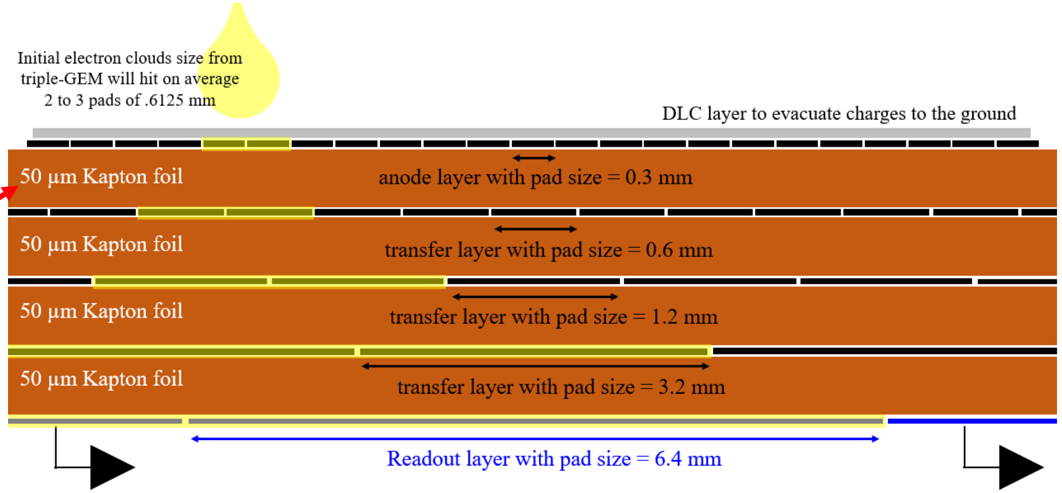
Principe of capacitive-sharing readout structures:

- 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 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 ⍰ standard PCB fabrication techniques

Cross section of capacitive-sharing pad readout with 6.4 mm × 6.4 mm pads



Top view of two pad-sharing layers