The µ-Rwell technology for the IDEA detector

Federico Matias Melendi on behalf of the RD_FCC collaboration

University and INFN Ferrara - mlnfrc@unife.it

18-24 July 2024

Università degli Studi di Ferrara

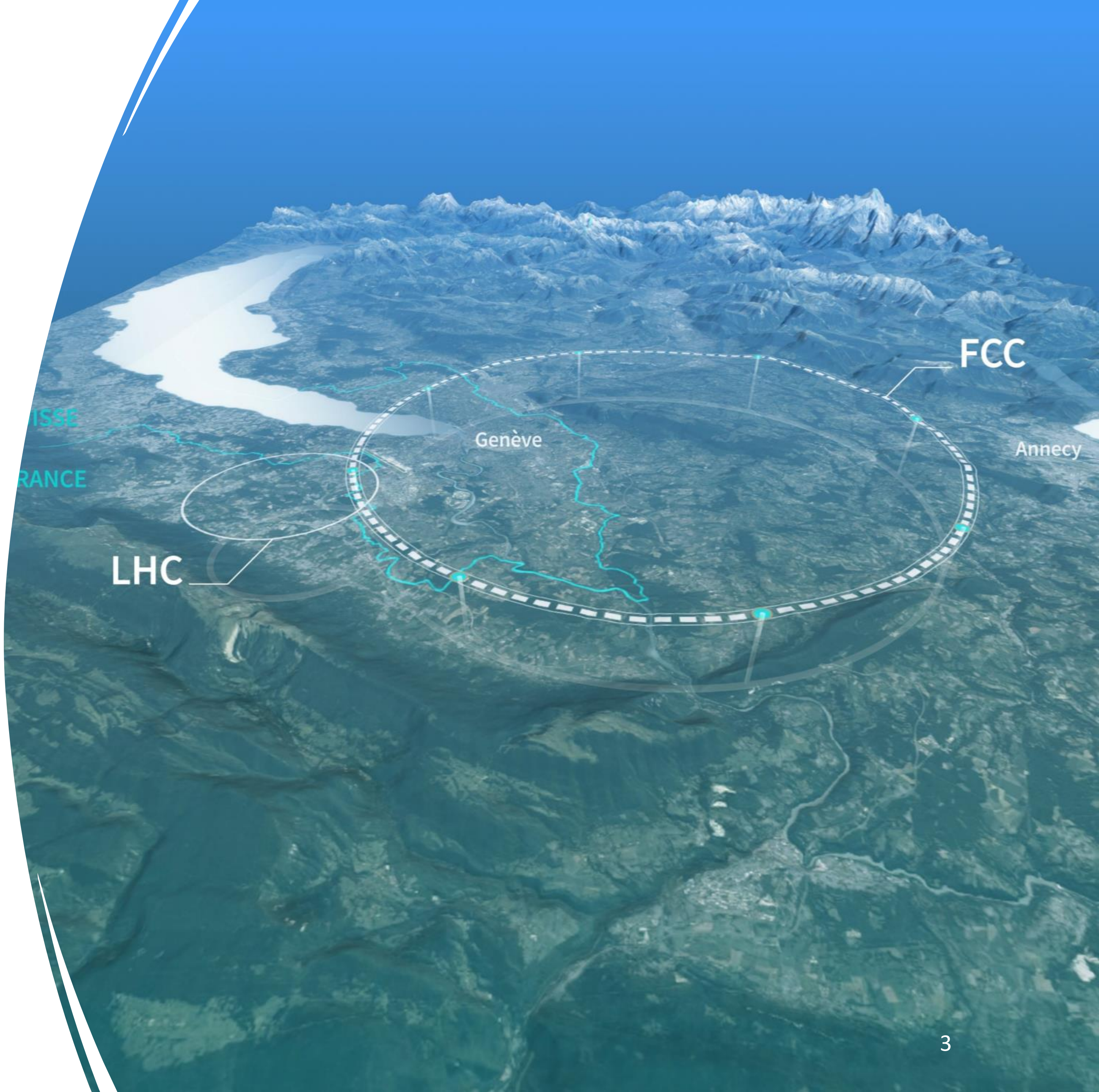
INFN FERRARA Istituto Nazionale di Fisica Nucleare Sezione di Ferrara

OUTLINE

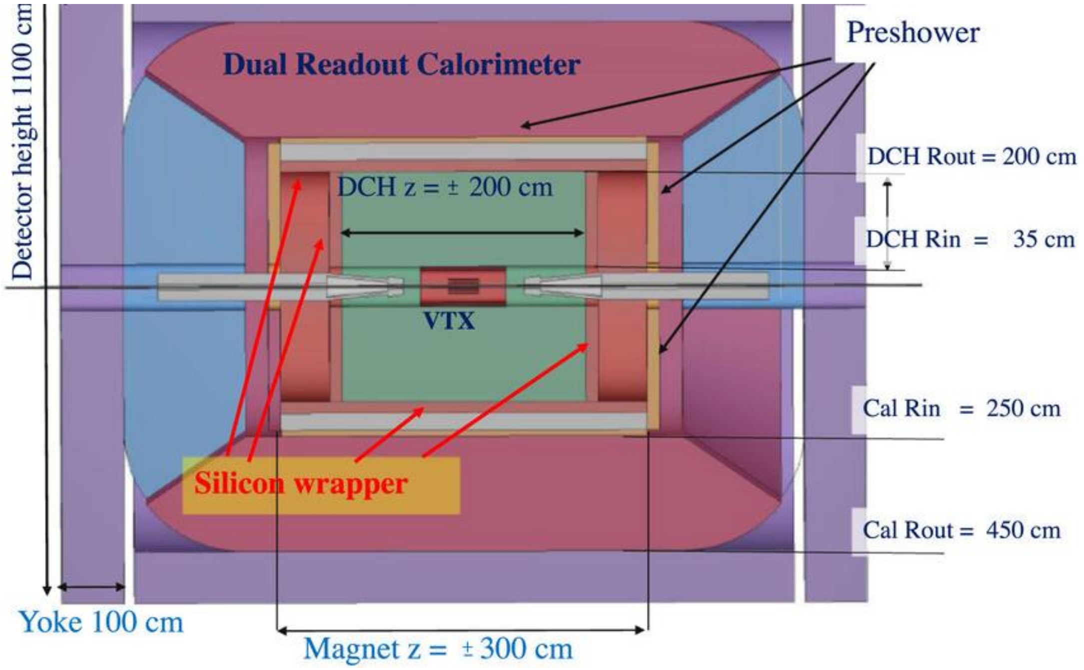
- FCC & IDEA introduction
- μ-RWELL technology and optimization
- μ-RWELL & TIGER integration

The FCC project

- The Future Circular Collider (FCC) study is developing designs for higher performance particle colliders that could follow on from the Large Hadron Collider (LHC).
- A new tunnel is planned with a circumference of 90.7 km, an average depth of 200 m and eight surface sites for up to four experiments.
- The tunnel would initially house the **FCC-ee**, an electron–positron collider for precision measurements. A second machine, the **FCC-hh**, would then be installed in the same tunnel, reusing the existing infrastructure

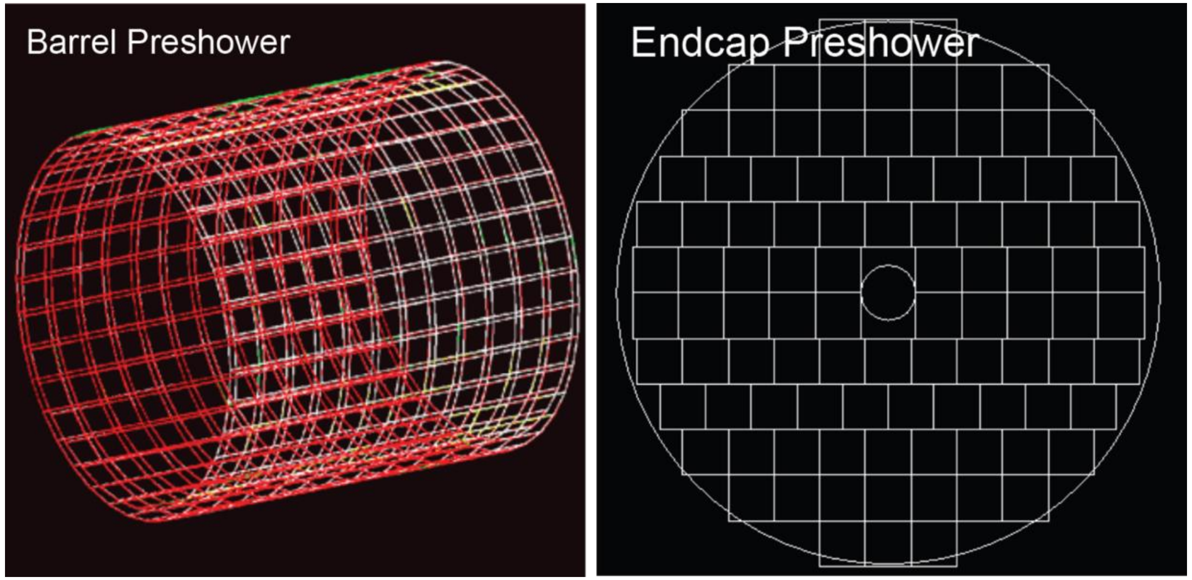


IDEA detector layout



IDEA 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 **μRWELL** detectors in the return yoke



The IDEA pre-shower

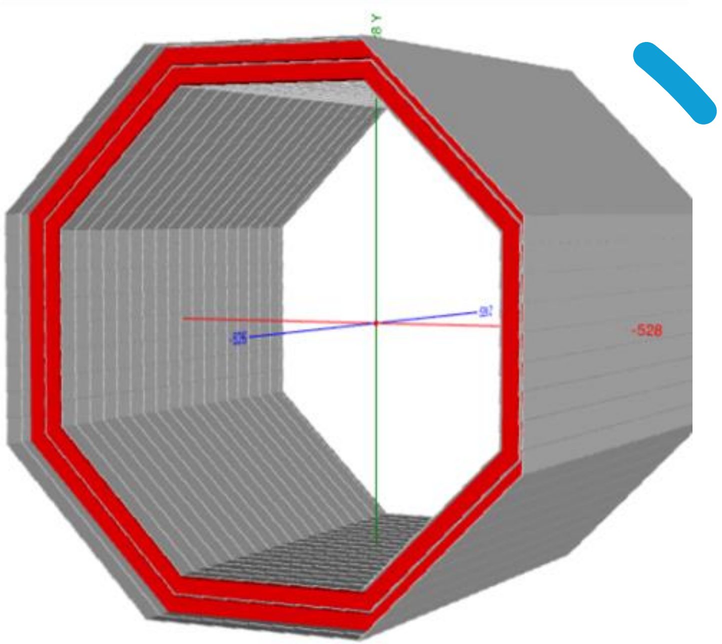
High resolution after of magnet to improve cluster reconstruction

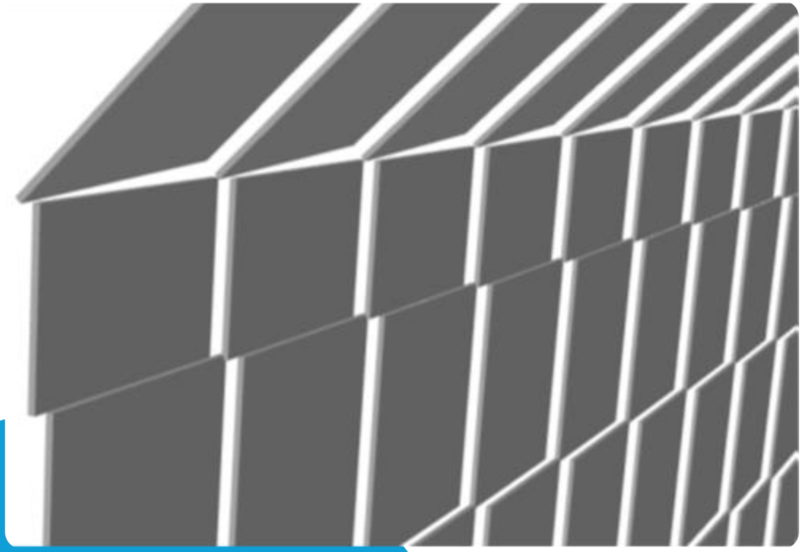
Requirements:

- Efficiency > 98%
- Spatial Resolution < 100μm
- Total Area ~ 130m^2

Detector layout:

- 50x50 cm^2 μ-RWELL with X-Y readout
- N° of channels ~ 1.3M
- Strip length 50cm





The idea muon detector

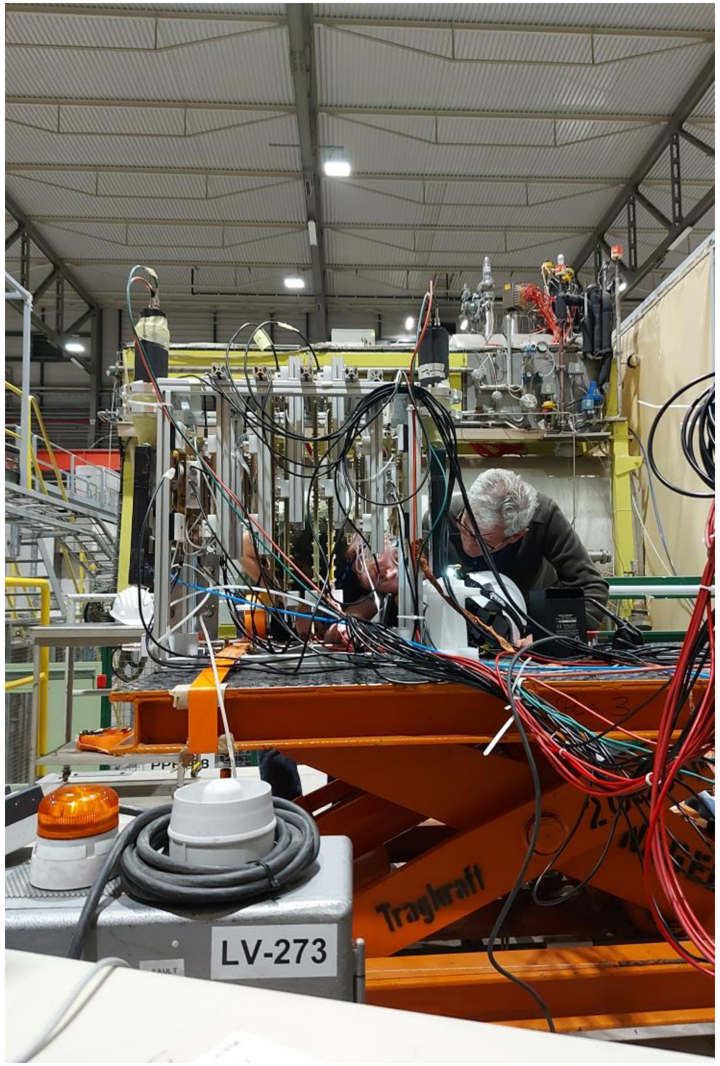
Reconstruction and Tag the muon

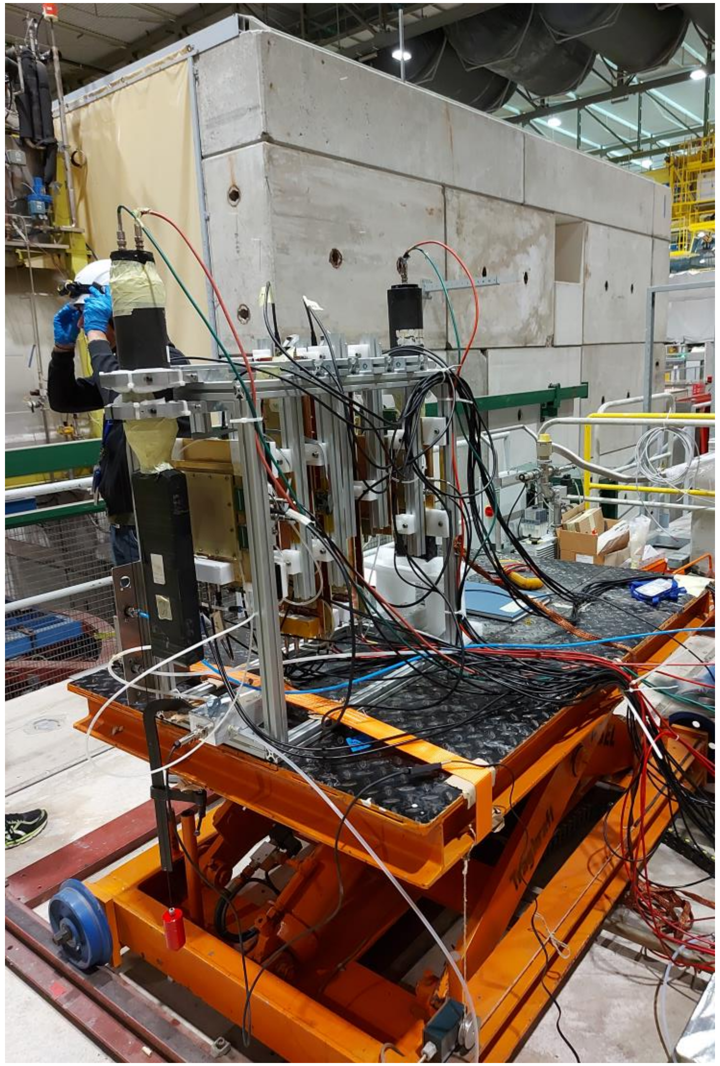
Requirements:

- Efficiency > 98%
- Spatial Resolution < 400μm
- Total Area ~ 1530m^2

Detector layout:

- 50x50 cm^2 μ-RWELL detector with X-Y readout
- N° of channels ~ 5 M
- Strip length 50cm





μ-RWELL technology & optimization

μ-RWELL technology

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

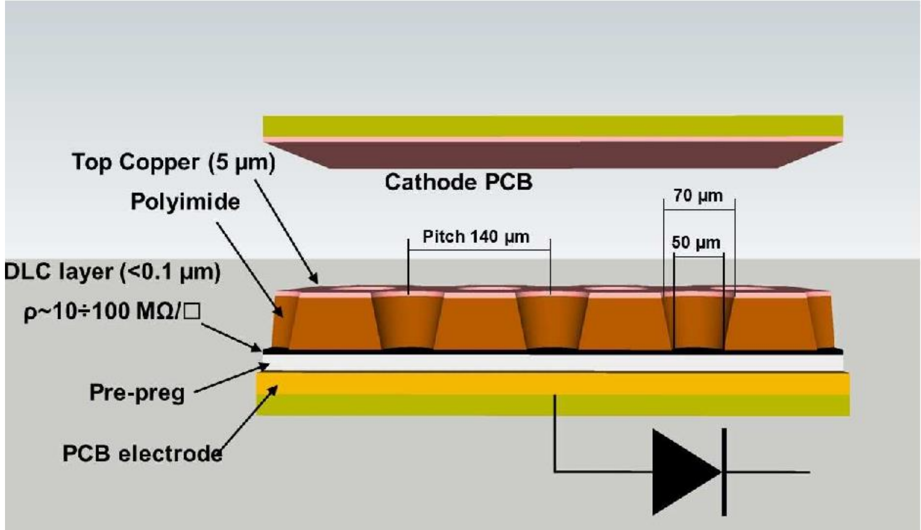
- Cathode
- μ-RWELL PCB

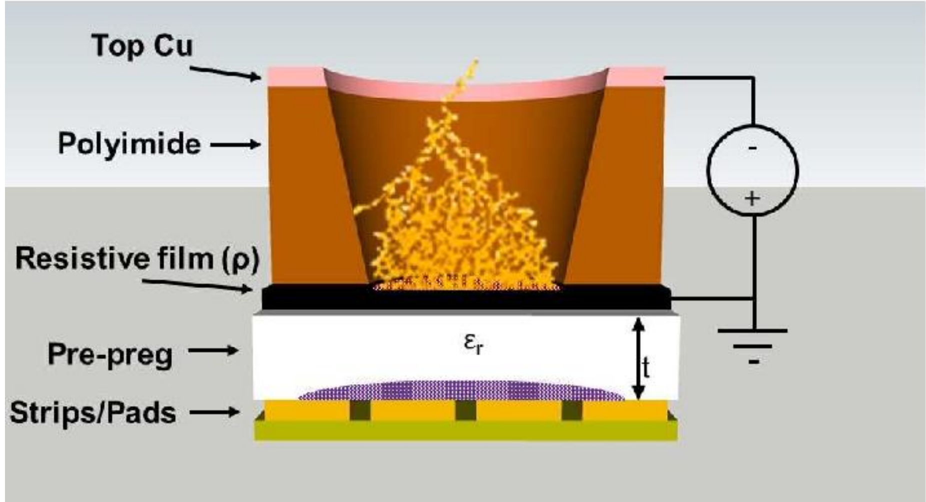
The μ-RWELL PCB consists of:

- a WELL patterned kapton foil (with Cu-layer on top) acting as amplification stage
- a resistive DLC film with ρ ~ 50÷100 MΩ/□
- a standard readout PCB with pad/strip segmentation

Well known performance on 10x10cm^2 prototypes:

- Efficiency > 98%
- Spatial resolution < 100μm
- Rate capability >> 10MHz/cm^2



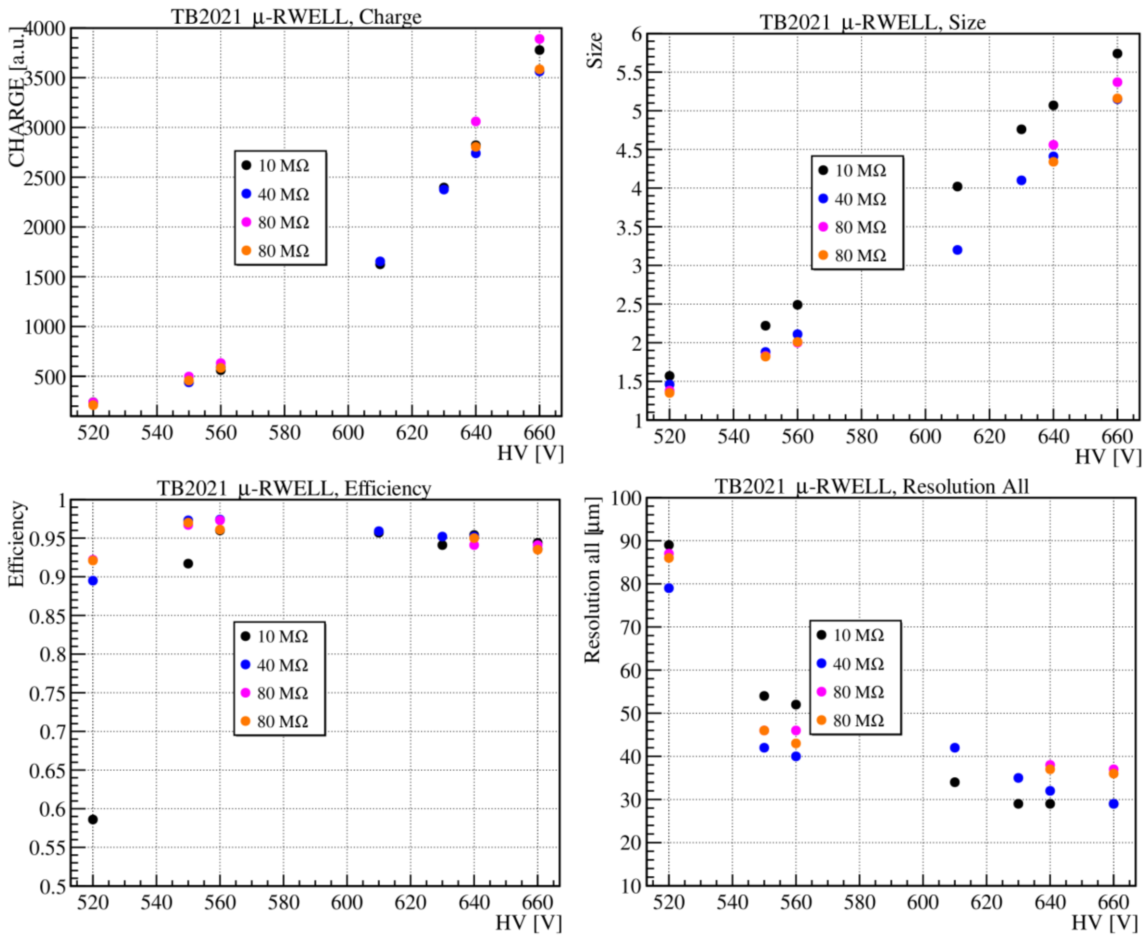


Test beam results 2021: 1D μ-RWELL

Configuration: 1D μ-RWELL coupled with APV25

Resistivity scan at fixed pitch

- Active area = 400x50 mm^2
- Resistivity = 10-80 $M\Omega/\square$
- Strip pitch = 0.4 mm
- Strip width = 0.15 mm



- Same performance for the 20-80 $M\Omega/\square$
- Efficiency knee at 550 V, $\sigma x < 100\ \mu m$

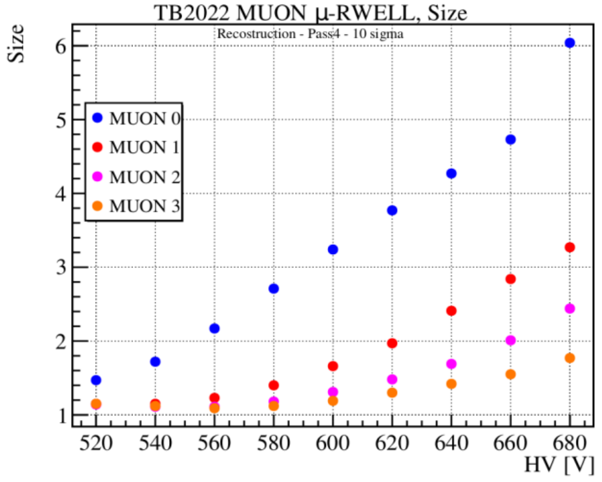
Test beam results 2022: 1D μ-RWELL

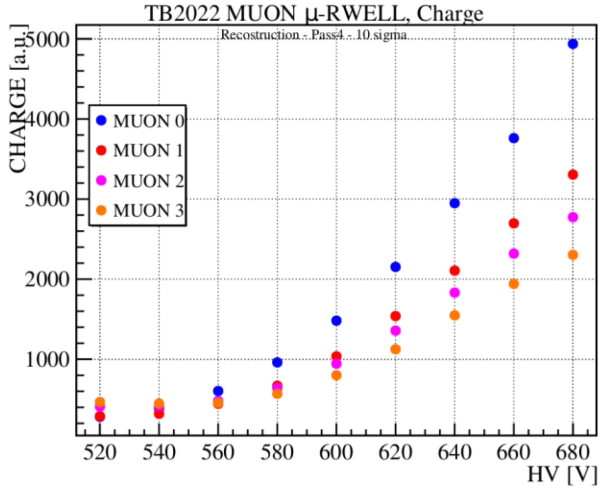
Configuration: 1D μ-RWELL coupled with APV25

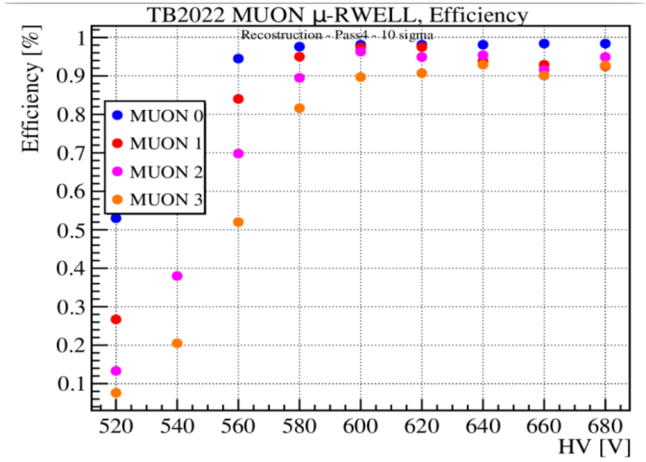
Pitch scan at fixed resistivity

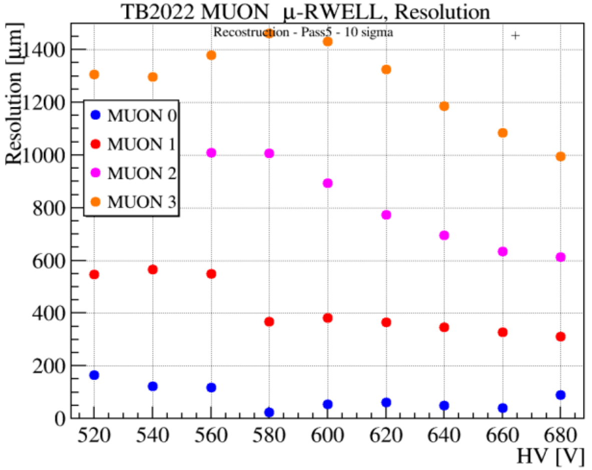
- Active area = 400x50 mm2
- Resistivity = 30 $M\Omega/\square$
- Strip pitch = 0.4-1.6 mm
- Strip width = 0.15 mm

- Larger the strip pitch, lower the charge signal requiring a higher gain to reach full efficiency.
- Efficiency knee at 600 V, $\boldsymbol{\sigma x}$ < $\mathbf{600\mu m}$ (for 0.8 mm pitch)



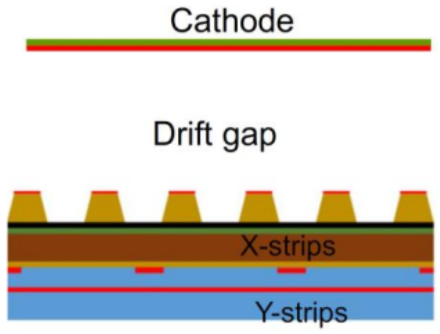




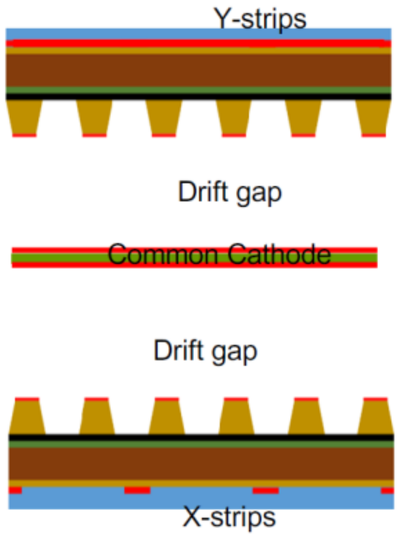


2D layouts possible for μ-RWELL

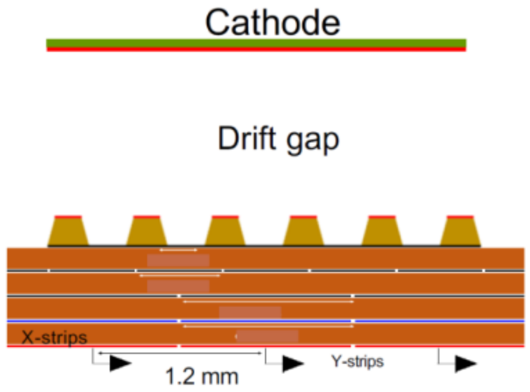
RWELL 2D «COMPASS» [*]



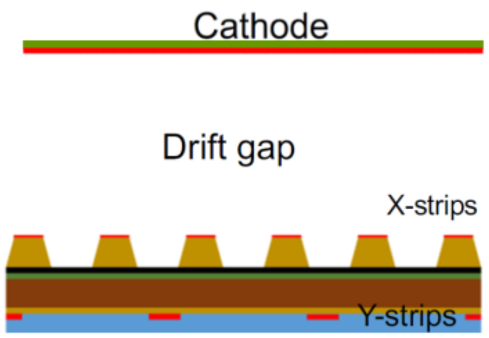
N.2 u-RWELLs 1D (2x1D)



u-RWELL - Charge Sharing r/o [*]



u-RWELL TOP r/o



- Good perfomances
- High gas gain, due to coupling of the X and Y strips

- Works at lower gas gain wrt the «COMPASS» readout

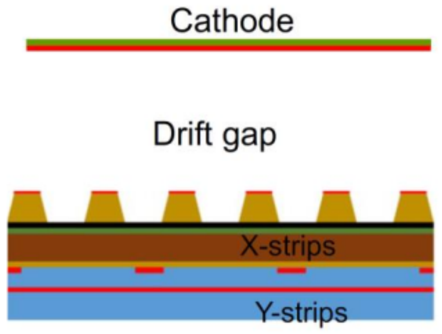
Charge transfer and charge sharing using capacitive coupling between a stack of layers or pads and the r/o.

- Reduces the FEE channels
- Total charge is divided between X & Y r/o

- The TOP layout allows to work at lower gas gain wrt the "COMPASC" (X-Y r/o are decoupled)
- The X coordinate on the TOP of the amplification stage induces same dead zone in the active area

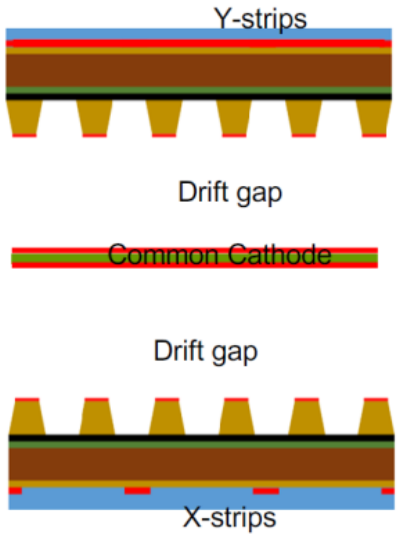
2D layouts possible for μ-RWELL

RWELL 2D «COMPASS» [*]



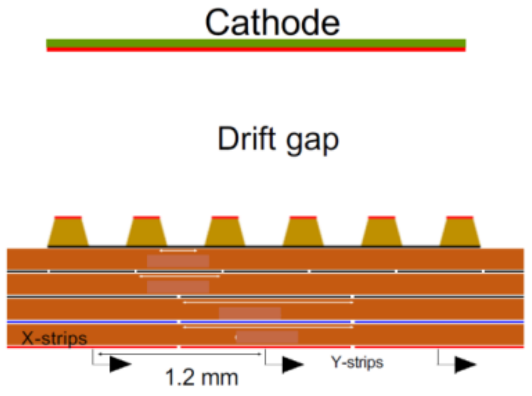
- Good perfomances
- High gas required, due to coupling of the X and Y strips

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



• Works at lower gas gain wrt the «COMPASS» readout

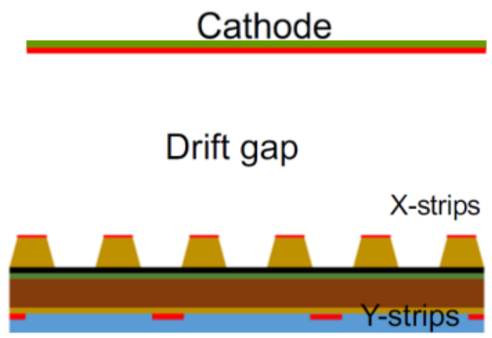
u-RWELL - Charge Sharing r/o [*]



Charge transfer and charge sharing using capacitive coupling between a stack of layers or pads and the r/o.

- Reduces the FFE channels
- Total charge is divided between X & Y r/o

u-RWELL TOP r/o

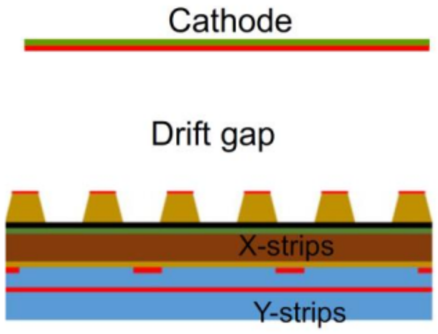


- The TOP layout allows to work at lower gas gain wrt the "COMPASC" (X-Y r/o are decoupled)
- The X coordinate on the TOP of the amplification stage induces same dead zone in the active area

Tested configurations

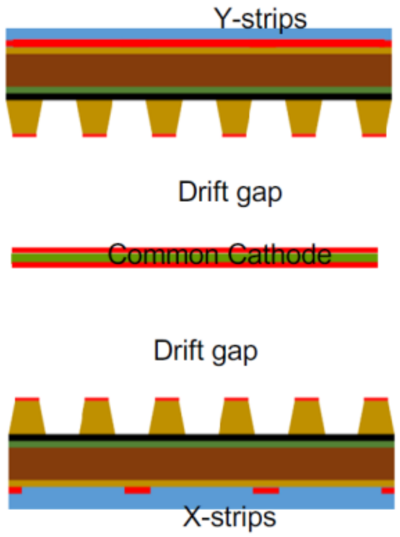
2D layouts possible for μ-RWELL

RWELL 2D «COMPASS» [*]



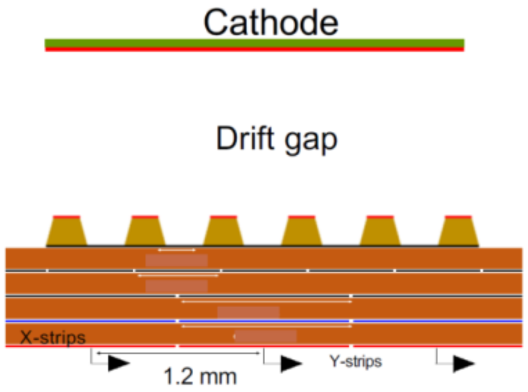
- Good perfomances
- High gas required, due to coupling of the X and Y strips

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



- Works at lower gas gain wrt the «COMPASS» readout

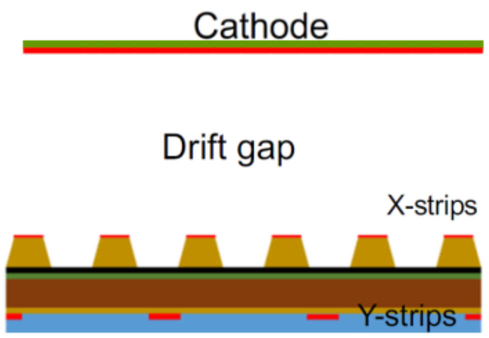
u-RWELL - Charge Sharing r/o [*]



Charge transfer and charge sharing using capacitive coupling between a stack of layers or pads and the r/o.

- Reduces the FFE channels
- Total charge is divided between X & Y r/o

u-RWELL TOP r/o



- The TOP layout allows to work at lower gas gain wrt the "COMPASC" (X-Y r/o are decoupled)
- The X coordinate on the TOP of the amplification stage induces same dead zone in the active area

Consider this two configurations

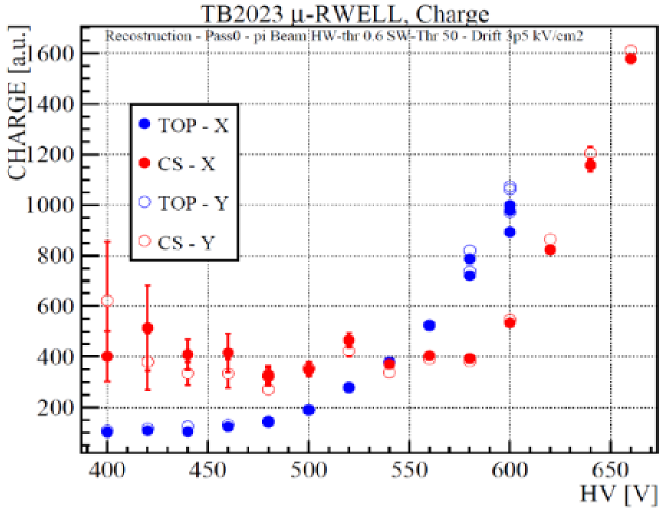
Test beam results 2023: 2D μ-Rwell

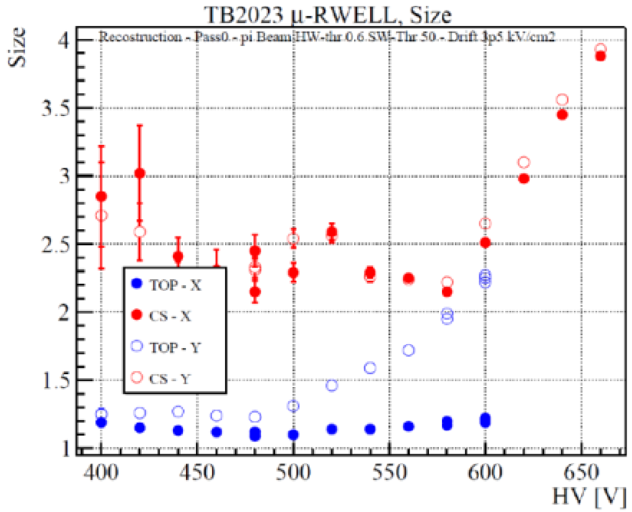
TOP r/o:

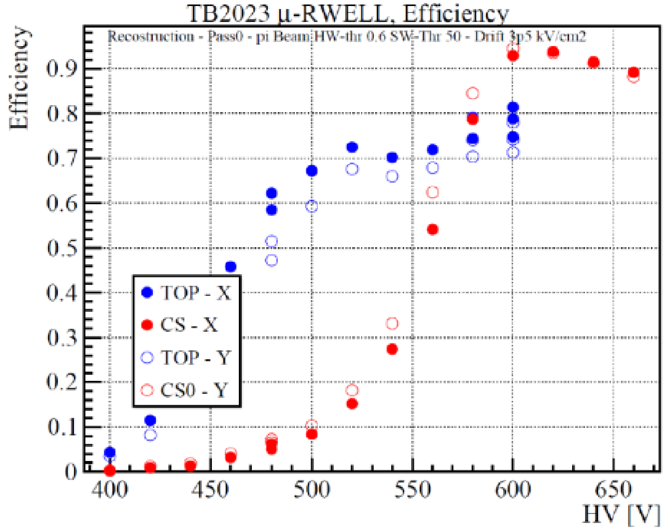
- The **total charge isn't divided** between X & Y
- Efficiency knee at ~ 500V
- **Low efficiency** plateau due to dead zone (~ 70%)
- Cluster Size does not change on X (TOP r/o), while changing on the Y (due to the DLC spread)
- Digital Spatial Resolution on the X

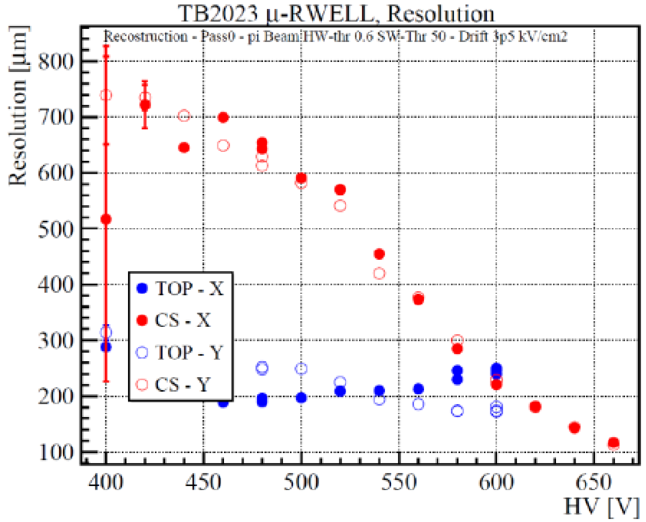
CS r/o:

- Efficiency knee at ~ 600V
- **High efficiency** plateau (~95%)
- **Cluster size increases to 4 strips** → Charge sharing mechanism work
- Spatial resolution improves at higher gain reaching 150μm (with a strip pitch of 1.2mm)

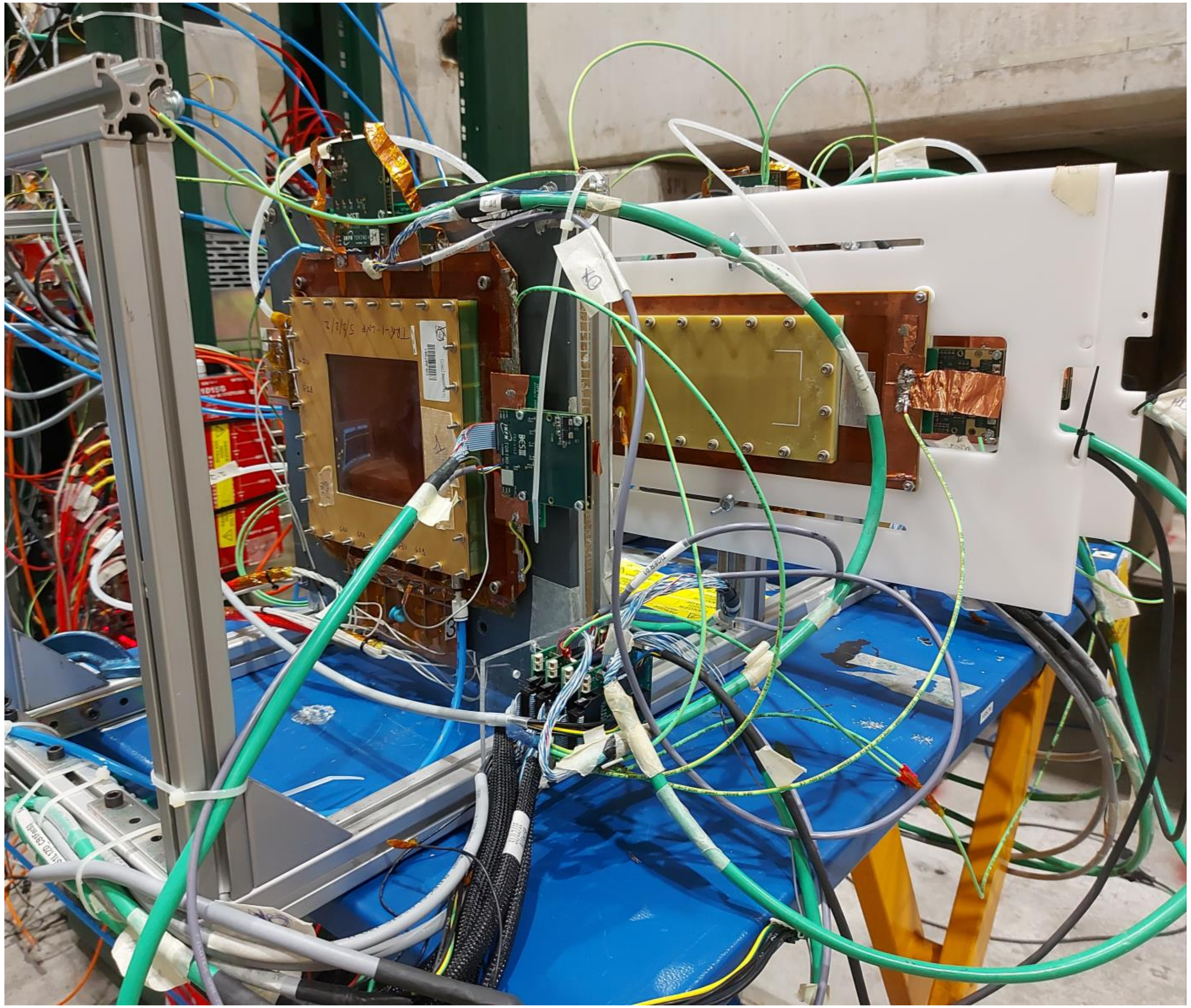








1D μ-RWELL with TIGER/GEMROC DAQ -Testbeam July 2024 -

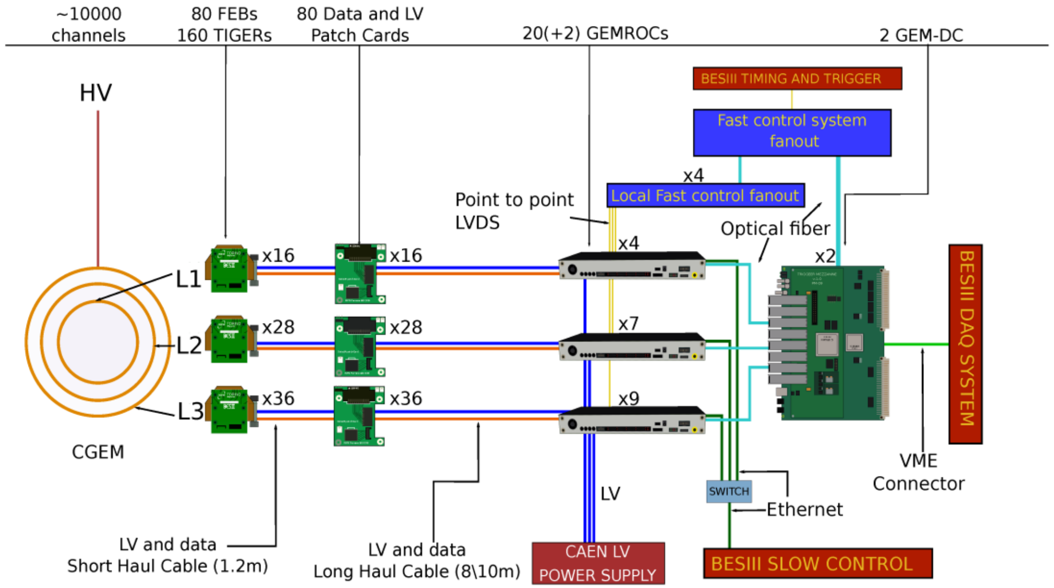


TIGER/GEMROC electronics

- TIGER/GEMROC DAQ has been developed for BESIII CGEM-IT
- It is a Modular and scalable system
- Designed for GEM detectors, but appropriate for similar MPGDs

The DAQ chain is based composed by:

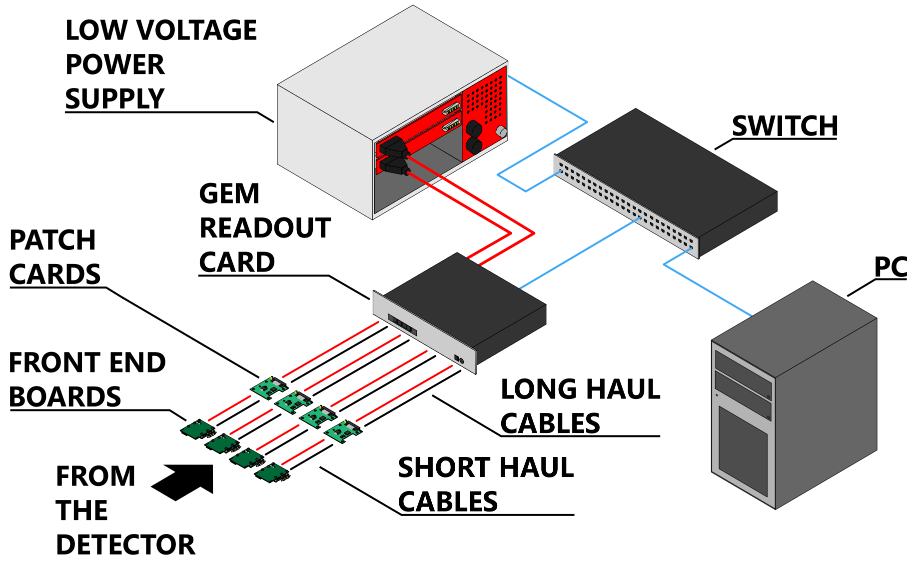
- Front End Boards (FEBs), each FEB hosts 2 TIGERs
- Data and Low Voltage Patch Cards (DLVPC)
- GEM Read-Out Cards (GEMROC)



For more details: The CGEM-IT readout chain - A. Amoroso et al 2021 JINST 16 P08065

GEMROC electronics

Intel/ALTERA ARRIA V GX family FPGA development kit + interface card



The GEMROCs' tasks are:

- Distribute digital and analog voltage levels
- Configure the TIGERs
- Monitor currents and temperatures during operation
- Collect and organize output data from the TIGERs
- Receive trigger signal for trigger-matched operation

For more details: The CGEM-IT readout chain - A. Amoroso et al 2021 JINST 16 P08065

TIGER electronics

- First tests with a μ-RWELL 10x10cm^2 prototype
- Noise level very low (~1 fC)
- Input capacitance up to 100 pF
- TDC resolution < 50 ps
- Average gain ~ 10.75 mV/fc
- Maximum power consumption ~ 12mW/ch

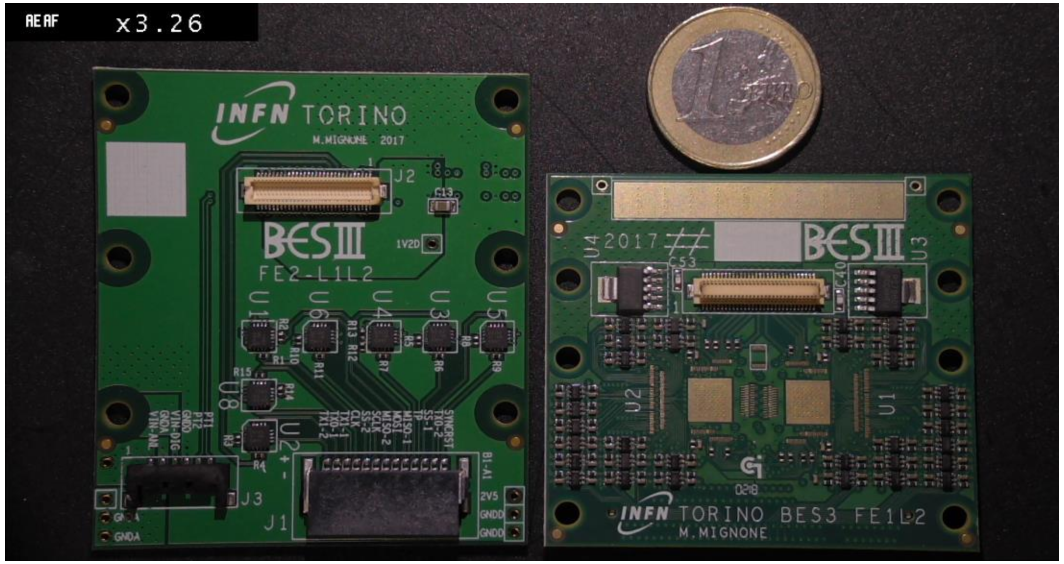
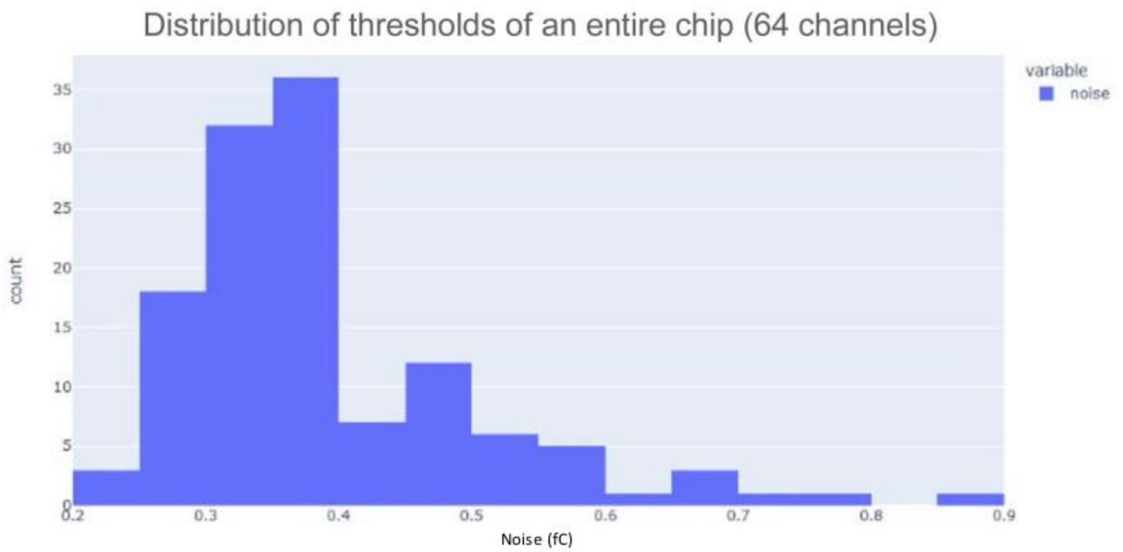


Photo by M.Mignone



For more details: The CGEM-IT readout chain - A. Amoroso et al 2021 JINST 16 P08065

TEST BEAM SETUP

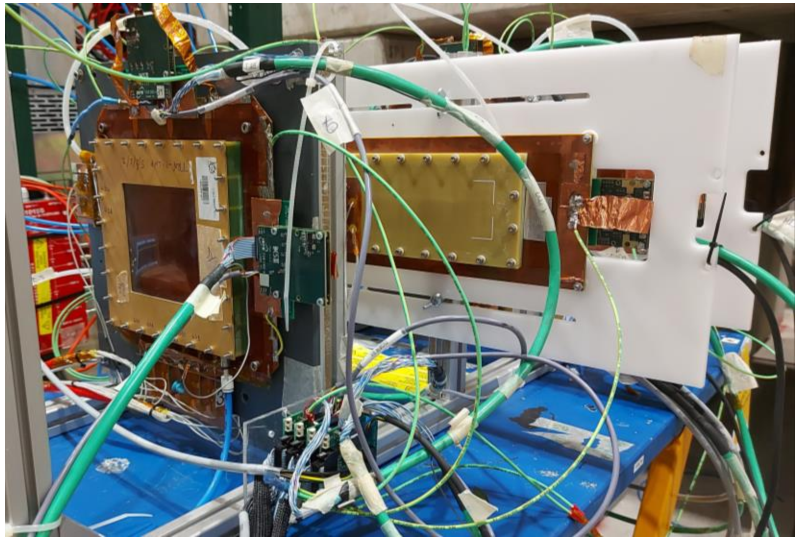
Detector under test features:

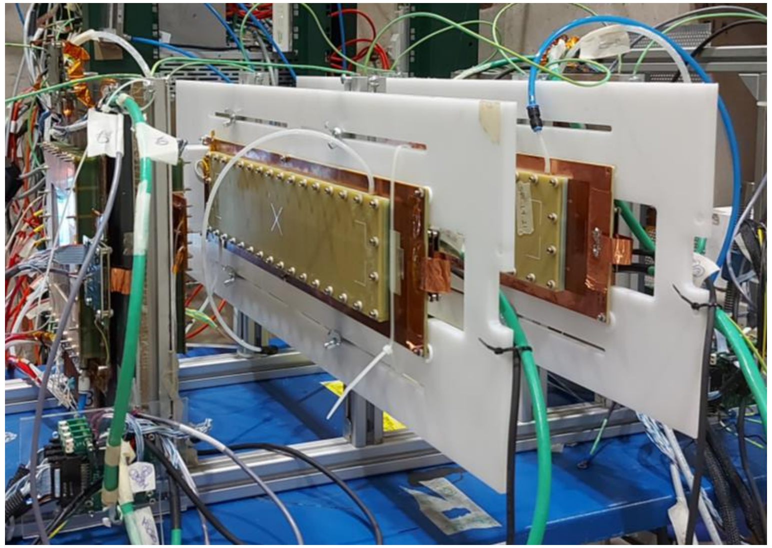
- Active area = 400x50 mm^2
- Resistivity = 80 $M\Omega/\square$
- Strip pitch = 0.4-1.6 mm
- Strip width = 0.15 mm
- 1D readout

Gas mixtures used:

- $ArCO_2$ (70:30)
- $ArCO_2$:CF_4 (45:15:40)

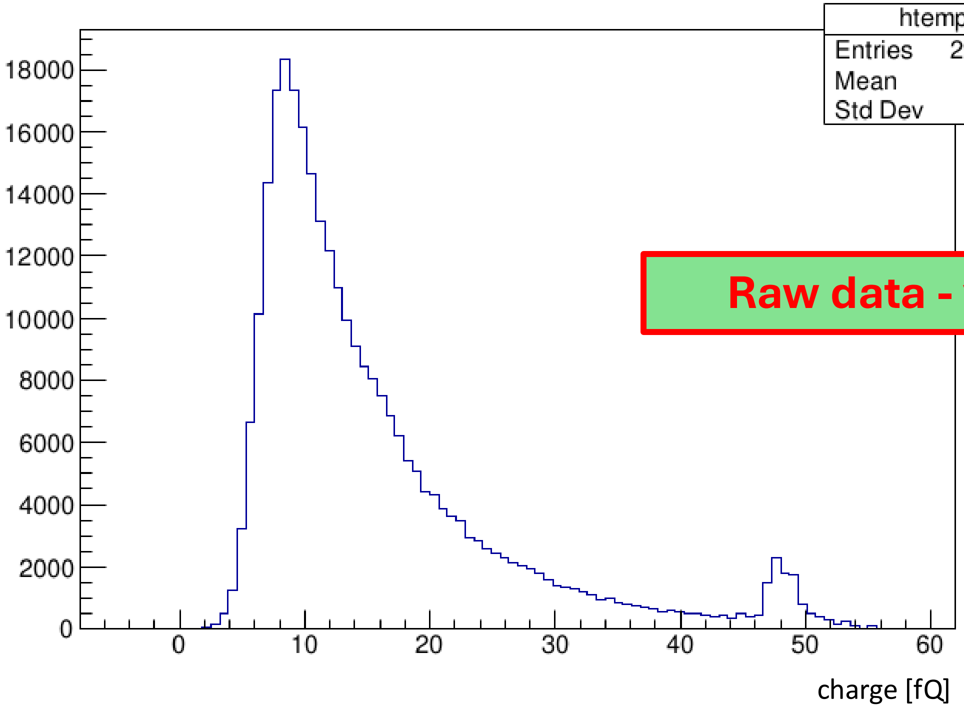
Triple-GEM trackers used



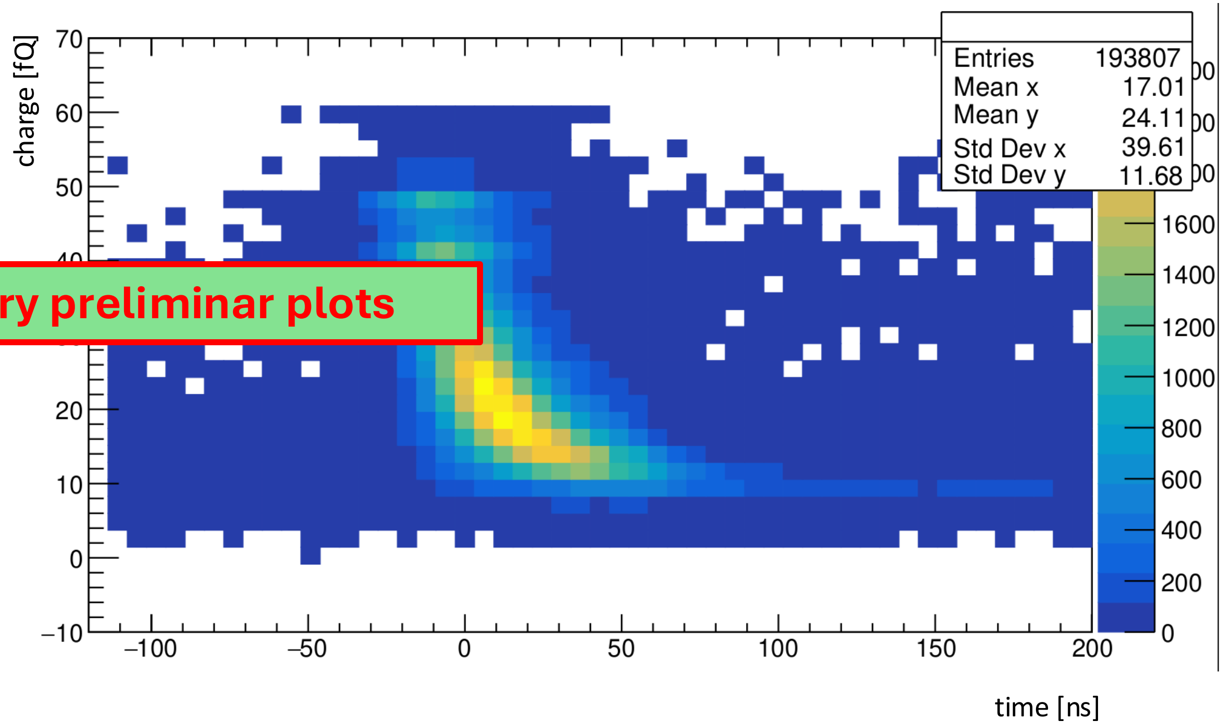


Test beam data taking

- The data taking consisted of HV scan, Drift scan and Thr. scan, with both Ar:CO_2 and Ar:CO_2:CF_4
- The data **anlysis is ongoing**, and will be the task of the **next months**



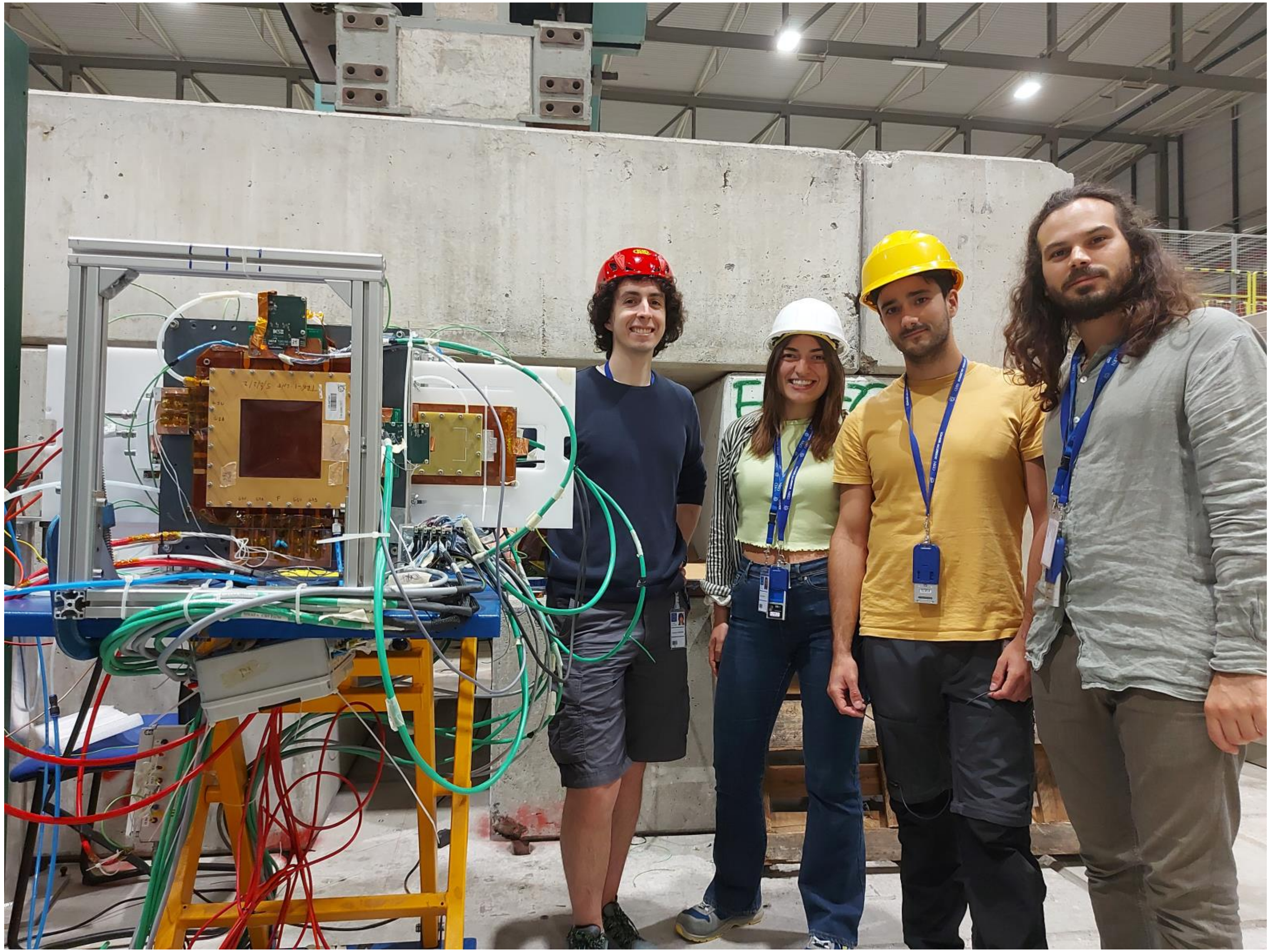
Raw data - very very preliminar plots



SUMMARY

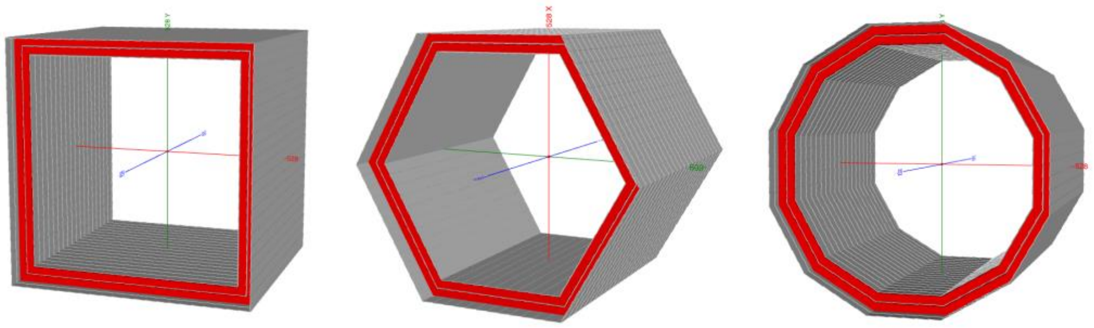
- Review of the proposal
- Resume of technological choices
- Description of previous testbeam results at CERN
- Overview on the TIGER/GEMROC DAQ
- Outline of the last test beam

Thank you for your *attention!*



BACKUP SLIDES

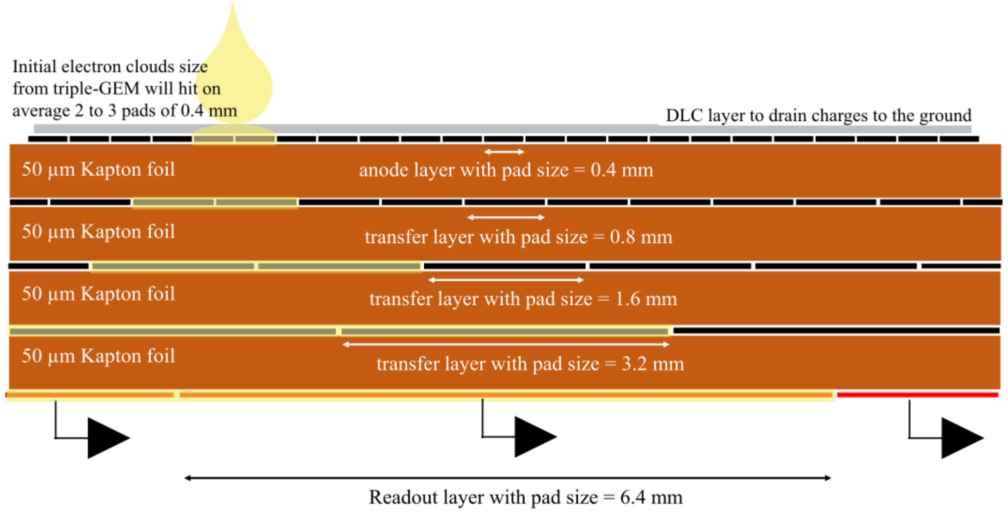
IDEA muon system



Capacitive Sharing readout: Principle & Motivation

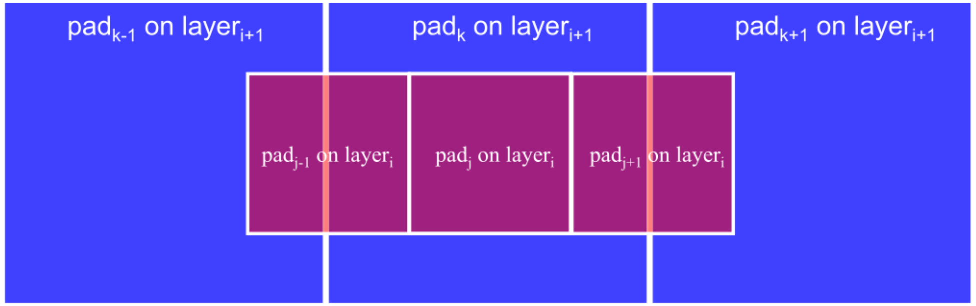
- Vertical stack of pad layers: charge transfer via capacitive coupling
- Pads have dedicated position from one layer to the layer underneath
- Doubling in size at each layer
- Transverse sharing of the charges between neighbouring pads of layer (i+1) from vertical charge transfer from layer (i)
- **The scheme preserves spatial information i.e. the spatial resolution obtained with the largest readout strips or pads**

Proof of concept established with 800 μm X-Y strips



Objective of the technology:

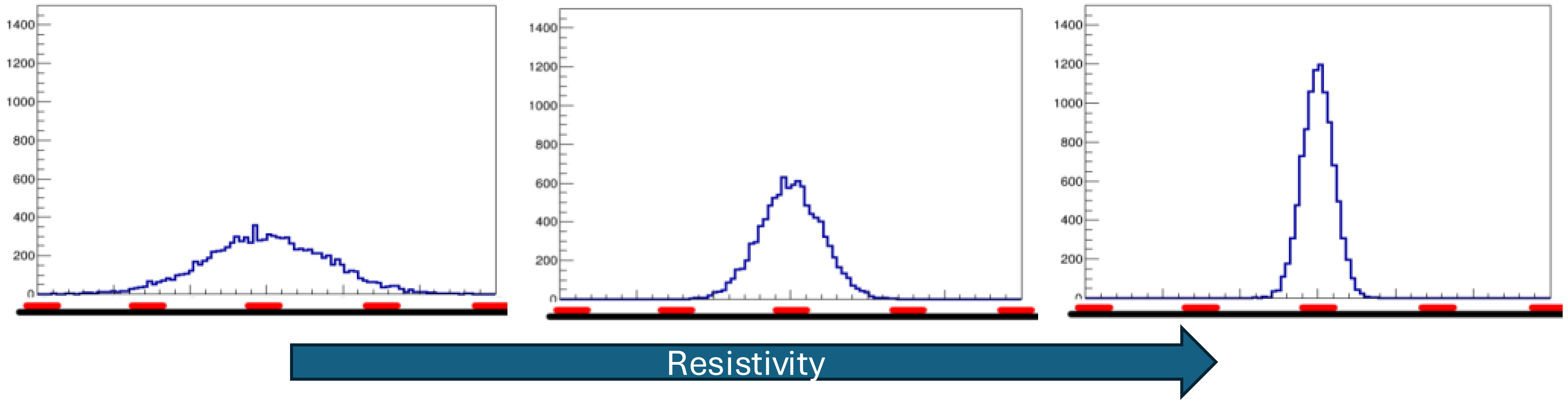
- Develop high performance and low channel count readout structures for MPGDs
- Reduce the number of readout electronic channels for large area MPGDs
- Low-cost technology for large area and standard PCB fabrication techniques



Goal: 50 μm for 1 mm strip r/o 150 μm for 1 cm2 pad r/o

Resistivity

[G.Bencivenni et al., “Performance of μ-RWELL detector vs resistivity of the resistive stage”, NIM A 886 (2018) 36]



TIGER PARAMETERS

TIGER Parameters

- Input capacitance up to 100 pF
- Input dynamic range from 2 to 50 fC
- Noise on the Energy branch < 1800 e- ENC (0.29 fC)
- Jitter on the Time branch < 4 ns
- Thermal load 12.5 mW per channel
- Rate capability 60 kHz per channel