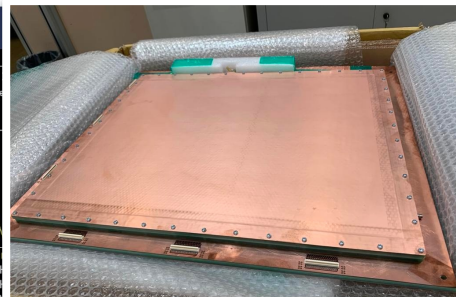
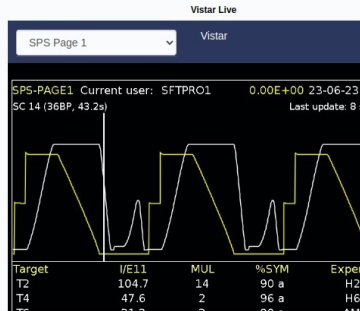
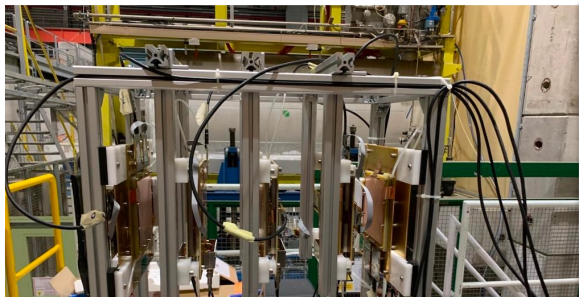


μ – Rwell for HI-LUMI

Hi-Luminosity Program - Annalisa D'Angelo - INFN Roma Tor Vergata



μ – Rwell for HI-LUMI

Hi-Luminosity Program - Annalisa D'Angelo - INFN Roma Tor Vergata

Roma Tor Vergata		
Researchers	Position	FTE
Annalisa D'Angelo	P.O.	50%
Lucilla Lanza	RTDb	70%
Alessandro Rizzo	ENEA	100%
Elena Sidoretti	PhD Student	100%
Total FTE		3.2

Catania		
Researchers	Position	FTE
Mariangela Bondì	Tecnologo	66%

Genova		
Researchers	Position	FTE
Marco Battaglieri	INFN DR	35%
Marco Spreafico	PhD	90%
Paolo Musico	INFN Dir. Tecn	15%
Total FTE		1.4

Ferrara		
Marco Contalbrigo	INFN I Ric	50%

Roma 1		
Evaristo Cisbani	ISS	90%



μ – Rwell for HI-LUMI

Hi-Luminosity Program

Outline:

The problem:

- DC tracking update to obtain x2 CLAS12 luminosity → Stage 2 – x10 CLAS12 luminosity

The solution:

- μ -Rwell technology
- Detector configuration

2024/2025 Results and future Activity:

- 2D read-out options – 2023 test results
- GEM - μ -Rwell option

Manpower and Synergies:

- DRD -1
- Synergy among INFN groups interested in μ -Rwell technology → RG-H & EIC

Financial request

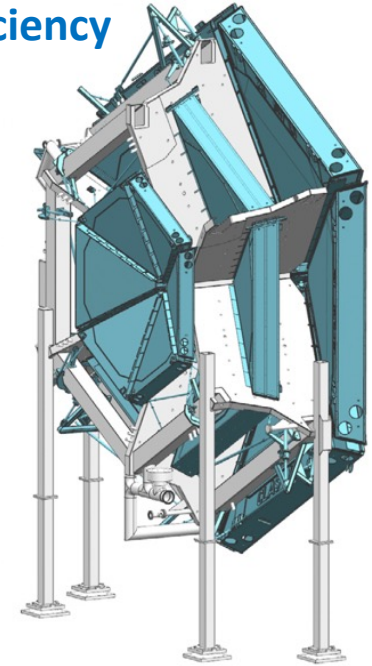
$\mu - Rwell$ for HI-LUMI

CLAS12 Detector Upgrade: increase x2 the nominal luminosity $\mathcal{L} = 10^{35} \text{ cm}^{-2} \text{ sec}^{-1}$

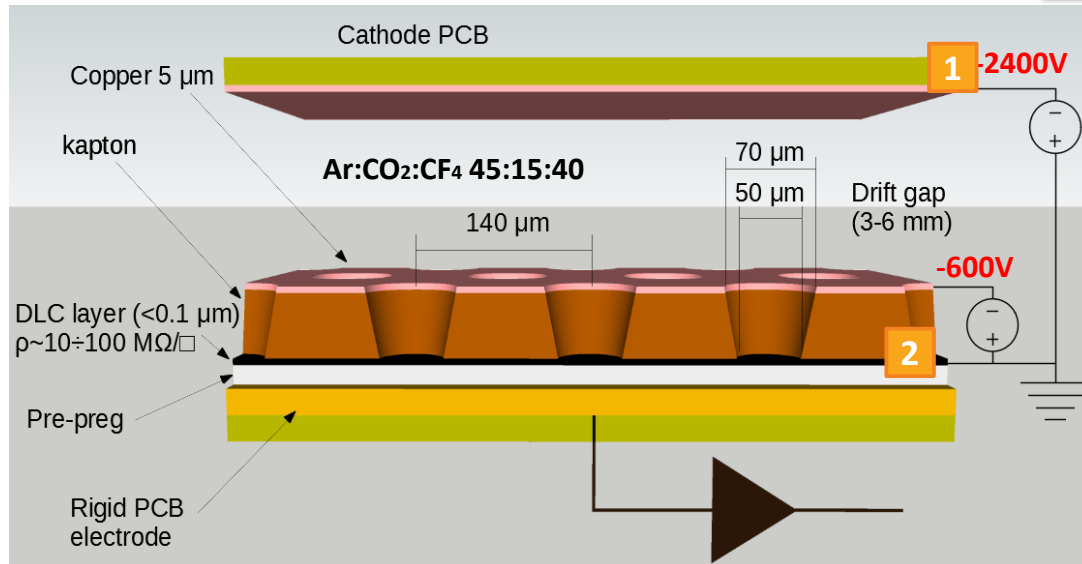
Presently achieved on a 5 cm LH2 target at $I_e = 75 \text{ nA}$

Limitation: occupancy of Region 1 - **AI – assisted tracking is improving efficiency**

- ❑ overlap/replace one tracking plane to DC Region 1 with MPGD tracker – **major project**, R&D is on going
- ❑ DC chambers in Region 1 are made of 2 superlayers, of 6 layers each, and should be replaced with 6 layers of 2D $\mu - Rwell$.
- ❑ Requirements:
 - ✓ Tracking resolution: $100 \mu m$
 - ✓ Timing resolution: 10 ns
 - ✓ Rate: 100 KHz/cm^2
 - ✓ Low material budget



μ – Rwell for HI-LUMI



- The “WELL” acts as a multiplication channel for the ionization produced in the gas of the drift gap
- The resistive stage ensures the quenching of the spark amplitude

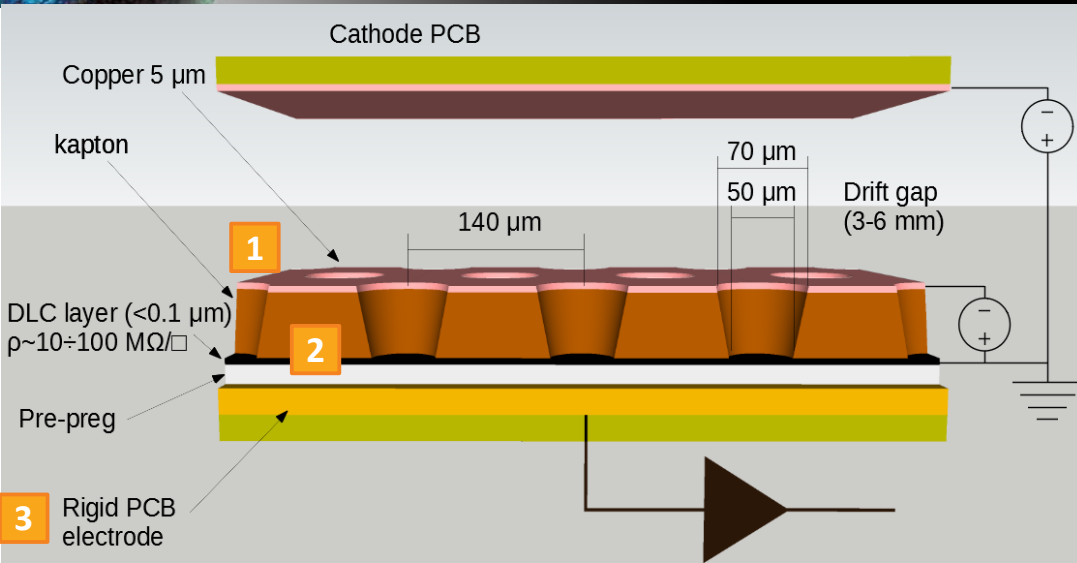
The μ -RWELL is a Resistive MPGD detector (Micro Pattern Gas Detector)

The device is composed of two elements:

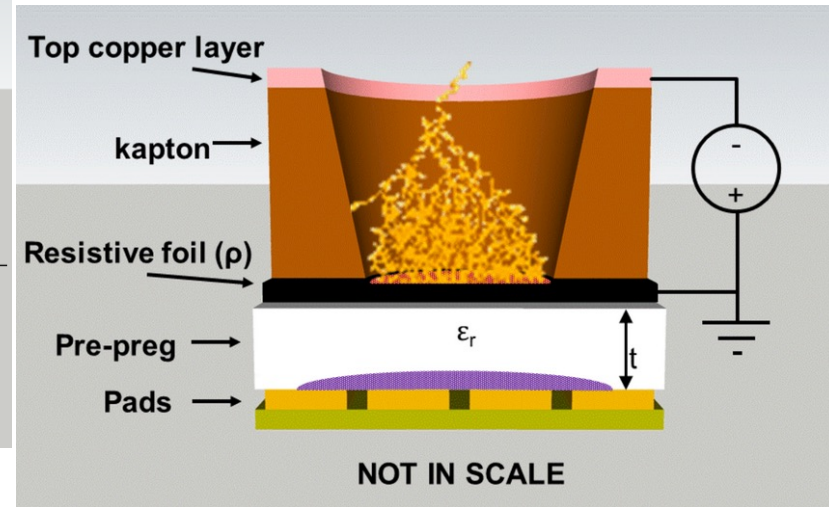
- 1 drift/cathode PCB defining the gas gap ($5 \mu\text{m}$ Cu layer on the bottom side)
- 2 μ -RWELL_PCB (detector core) Multilayer circuit: Well Pattered Polyimide \oplus resistive film \oplus readout PCB

Standard Gas mixture: Ar:CO₂:CF₄ 45:15:40 mixture (it also works with Ar:CO₂ «green» mixture)

μ – Rwell for HI-LUMI



The core is the μ -RWELL_PCB, realized by coupling three different elements:



1 a WELL patterned kapton foil acting as **amplification stage** (GEM-like)

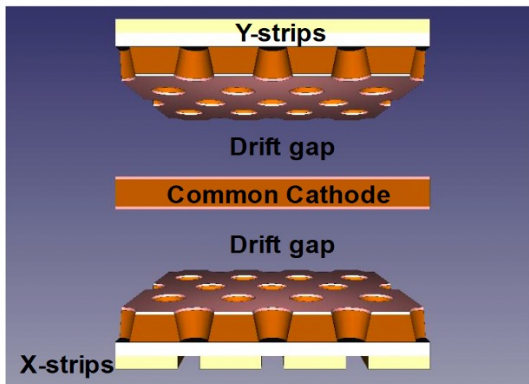
2 a **resistive DLC layer (Diamond-Like-Carbon)** for **discharge suppression** with surface resistivity $\sim 50 \div 100 \text{ M}\Omega/\square$

3 a standard readout PCB

Applying a suitable voltage between the **top Cu-layer** and the **DLC** the WELL acts as a **multiplication channel** for the **ionization** produced in the conversion/drift gas gap.

2D Tracking Layout

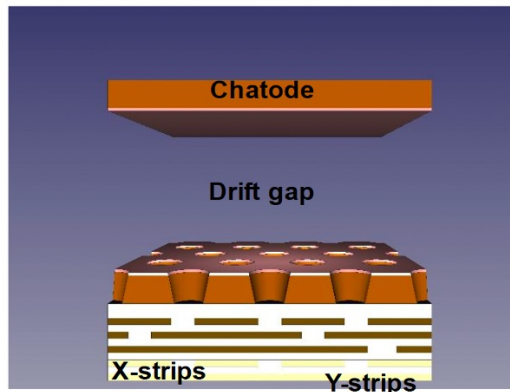
N.2 u-RWELLS 1D (2×1D)



October 2022 test beam

- 780 μm pitch
- 300 mm width
- 10 x 10 cm^2 active surface
- 128 channels

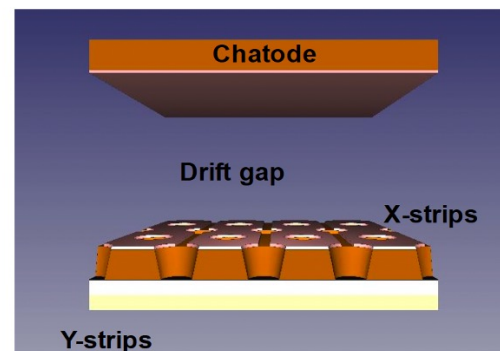
u-RWELL - Capacitive Sharing r/out



June 2023 test beam

- 1200 μm pitch
- 300 μm vs 1000 μm strips width
- 10 x 10 cm^2 active surface
- 83 channels
- “Compass-like” strip configuration
- Capacitive sharing

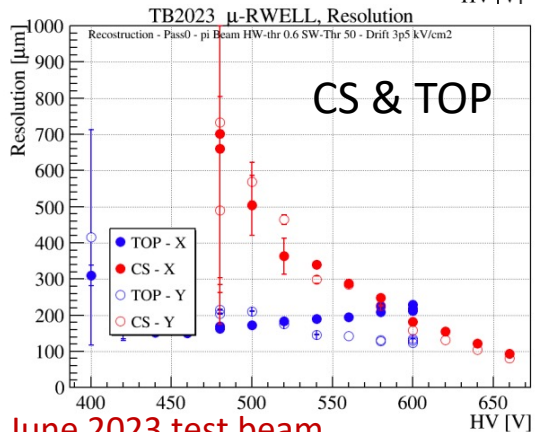
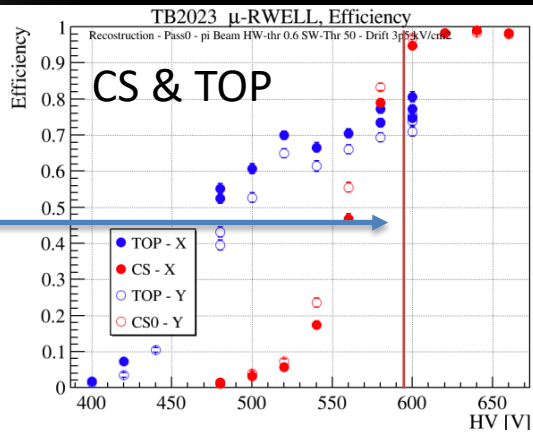
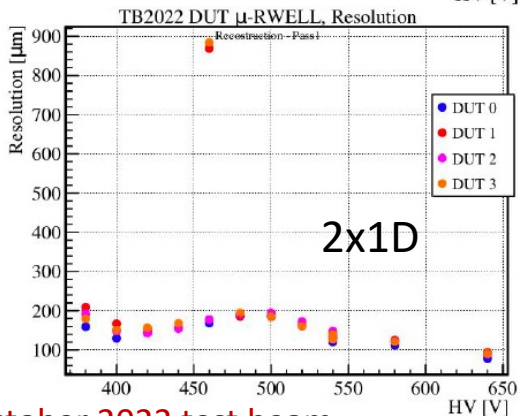
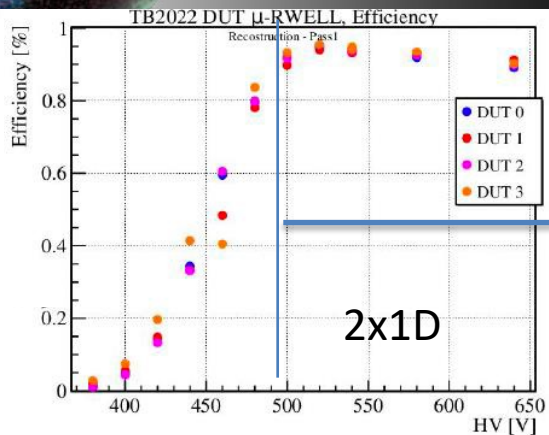
u-RWELL TOP r/out



June 2023 test beam

- 780 μm pitch
- 300 μm width
- 10 x 10 cm^2 active surface
- 128 channels
- X-strips Top read-out
- Y-strips standard read-out

Results on 2D tracking



1D pitch 0.78 mm

Reference performances:

- 96% efficiency
- 120 μm resolution

CS pitch 1.2mm

- Due to the charge spread the **working point is shifted to high voltage/gain**
- Spatial resolution improves at high gain reaching **150 μm** with a strip pitch of 1.2 mm

Top-read-out pitch 0.78 mm

- low-voltage/gain operation but **low efficiency level (80%)** due to the geometrical dead zone on the segmented amplification stage

October 2022 test beam

June 2023 test beam

μ – Rwell for HI-LUMI

μ -RWELL + GEM

Nuclear Inst. and Methods in Physics Research, A 936 (2019) 401–404



Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima



Development of μ -RWELL detectors for the upgrade of the tracking system of CMD-3 detector

L. Shekhtman*, G. Fedotovich, A. Kozyrev, V. Kudryavtsev, T. Maltsev, A. Ruban

Budker Institute of Nuclear Physics, 630090, Novosibirsk, Russia
Novosibirsk State University, 630090, Novosibirsk, Russia



ARTICLE INFO

Keywords:
Tracking detectors
Micro-RWELL
Micro-pattern gas detectors

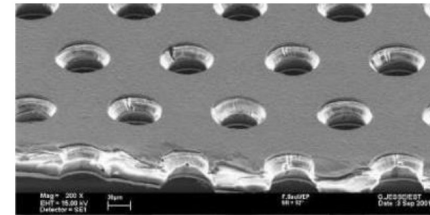
ABSTRACT

An upgrade of tracking system of Cryogenic Magnetic Detector (CMD-3) is proposed using microresistive WELL technology. CMD-3 is a general purpose detector operating at the VEPP-2000 collider at Budker Institute of Nuclear Physics and intended for studies of light vector mesons in the energy range between 0.3 GeV and 2 GeV. The new subsystem consists of double-layer cylindrical detector and the end-cap discs. Two prototypes, micro-RWELL and micro-RWELL-GEM were built and tested. Gas amplification of micro-RWELL detector was measured with several gas mixtures and maximum gain between 20000 and 30000 was observed. However, maximum gain is fluctuating from measurement to measurement by a factor of 2 and thus a safety margin of 2–3 is needed to provide reliable operation of the device. In order to increase the signal GEM was added to micro-RWELL, new prototype was tested with the same gas mixtures and gains above 10^5 have been demonstrated. Time resolution achieved for both prototypes are 7 ns for micro-RWELL and 4 ns for micro-RWELL-GEM.

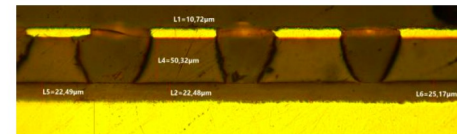
L. Shekhtman, Nuclear Inst. and Methods in Physics Research, A 936 (2019) 401–404



Drift Gap: Shekhtman 3mm – LNF+Roma2 6mm



Transfer Gap: Shekhtman 3mm – LNF+Roma2 3mm



Developed for **CMD3 upgrade disks** (4 sectors 50×50cm²)

The GEM **must be** stretched: sizes larger than 50×50cm² could be critical (depending on the gas gaps size).

μ - Rwell + GEM - GAIN

L. Shekhtman, Nuclear Inst. and Methods in Physics Research, A 936 (2019) 401–404

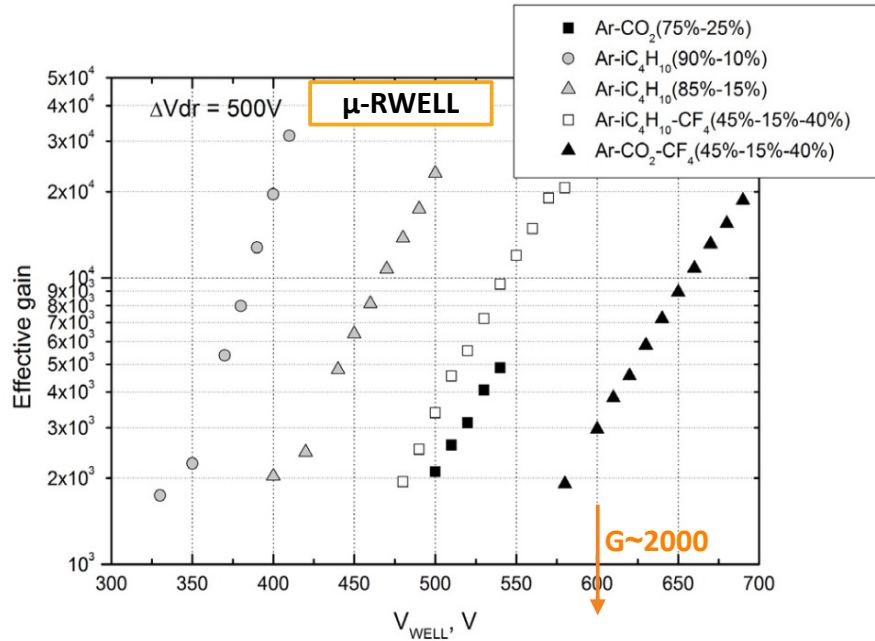


Fig. 4. Gain as a function of voltage on the top electrode of μ -RWELL for different gas mixtures. Voltage across the drift gap is 500 V.

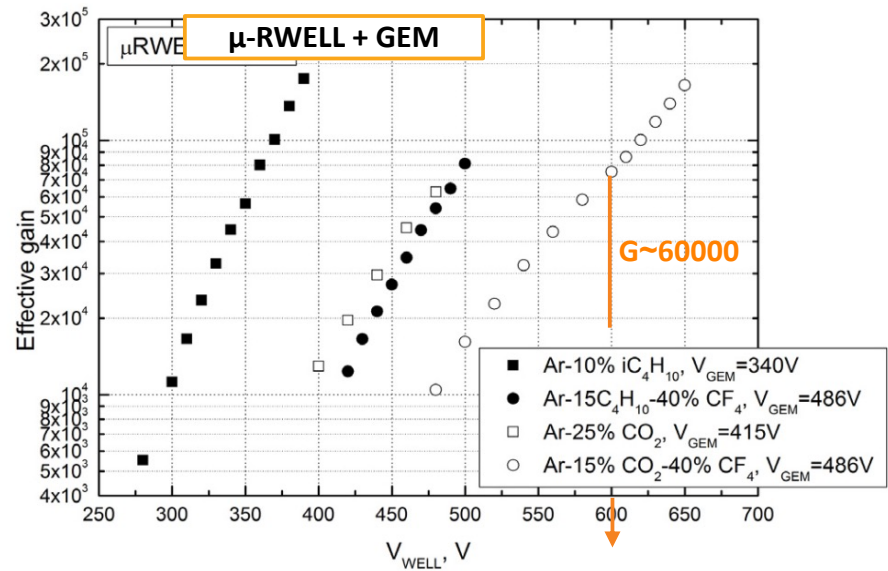
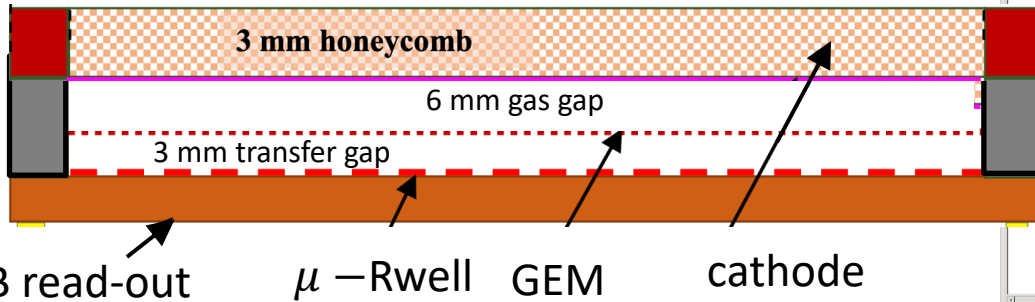


Fig. 5. Gain as a function of voltage on the top electrode of μ -RWELL for GEM voltages providing additional gain of 50–100 and for different gas mixtures. Voltage across the drift gap is 500 V.

μ – Rwell for HI-LUMI

GEM - μ Rwell Technology

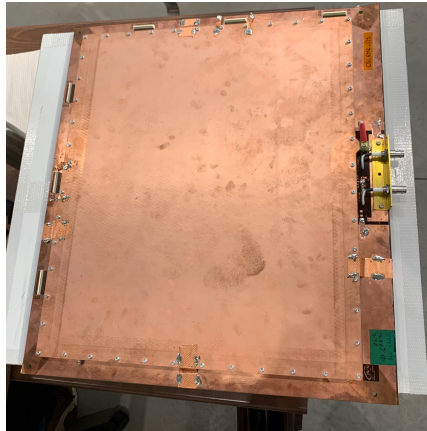


- 2D CS readout reduces the **gain** from 10^4 to $3-4 \cdot 10^3$ → the detector stability is put at risk
- GEM- μ Rwell hybrid configuration will be tested to increase the gain higher than 10 000
- A test beam will take place in Oct/Nov 2025 to test 2 10x10 cm² GEM+ μ Rwell hybrids

μ – Rwell for HI-LUMI

Test of Large Area Prototype steps @ LNF: CS - 40x46 cm²

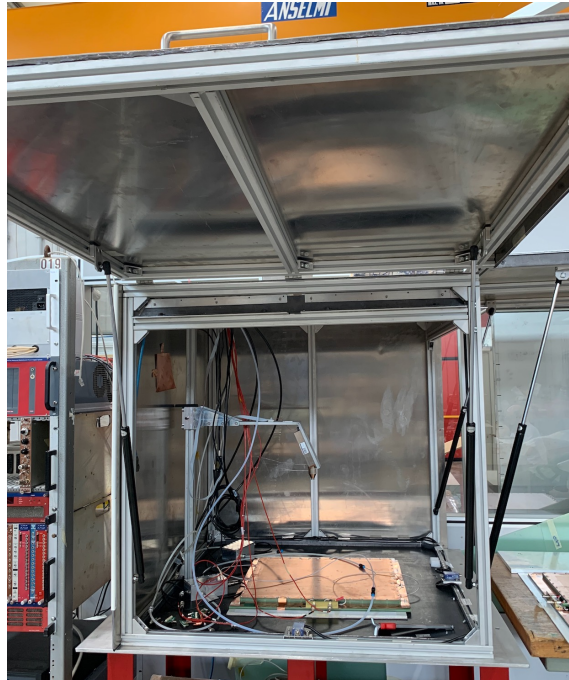
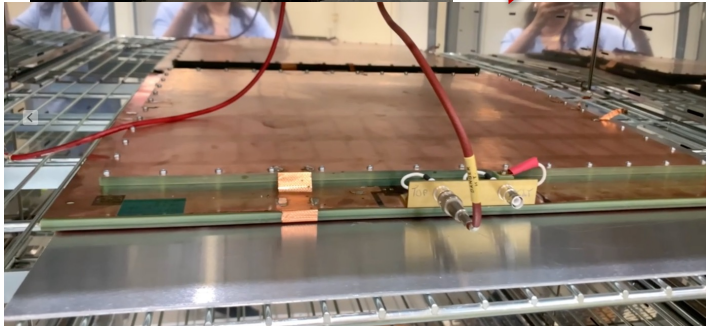
Data analysis is ongoing



HV filter on



Conditioning
In the Oven



X-Ray characterization

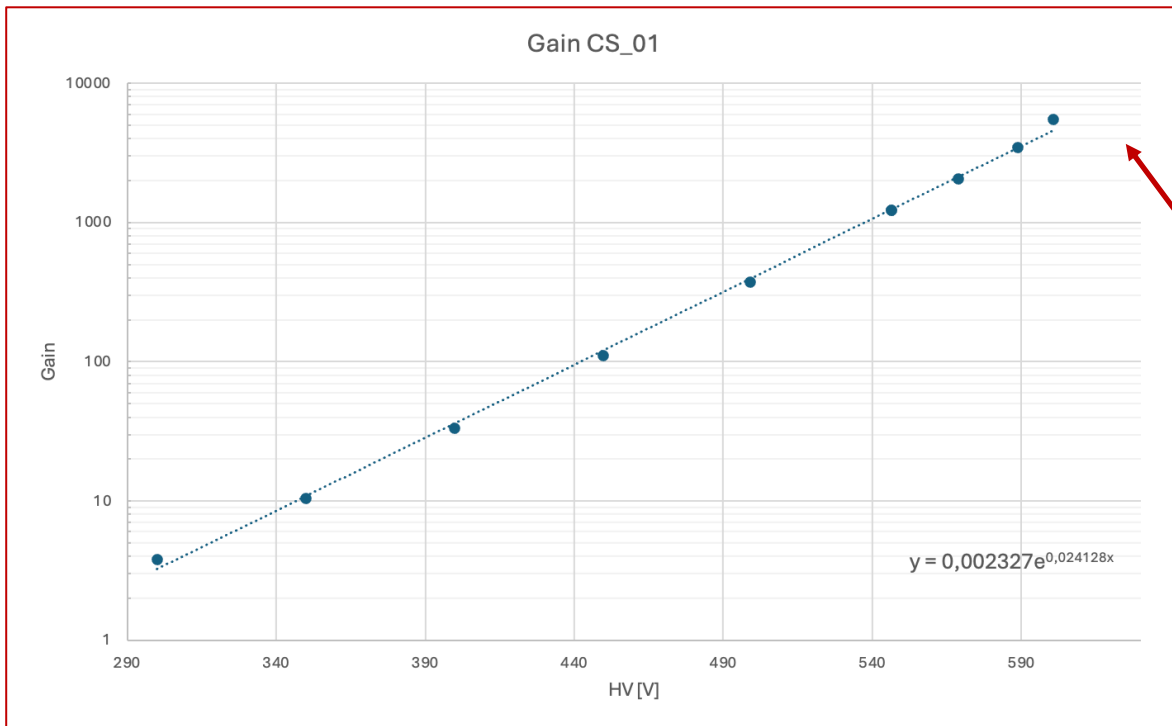


Cosmic-rays Data Acquisition

μ – Rwell for HI-LUMI

Test of Large Area Prototype steps @ LNF: CS - 40x46 cm²

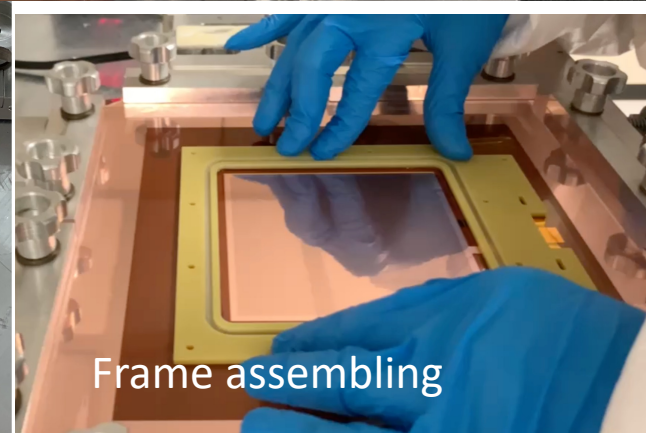
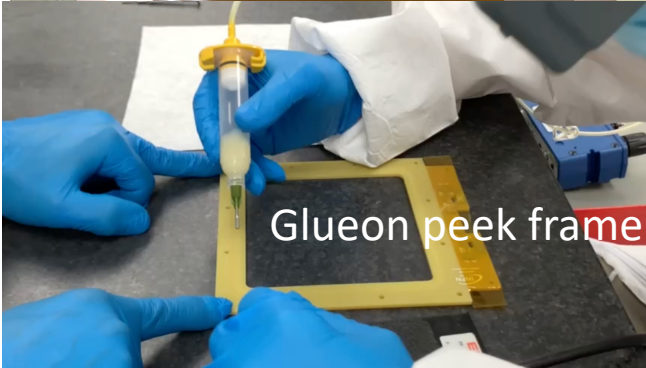
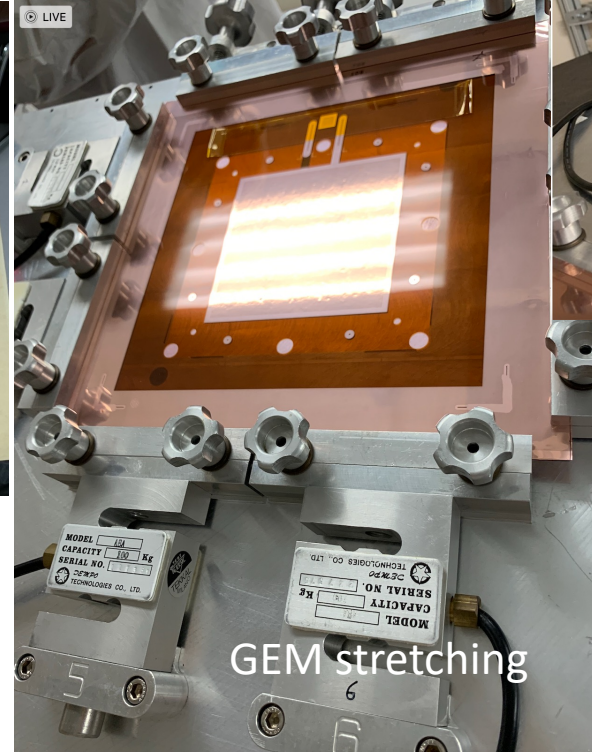
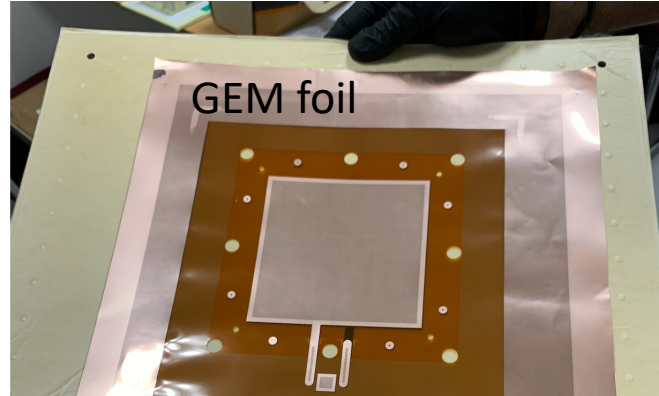
Data analysis is ongoing



First results confirm
that maximum gain is
~ 5000

μ – Rwell for HI-LUMI

First GEM- μ Rwell 10x10 cm² prototypes assembly



Test laboratory at Roma Tor Vergata

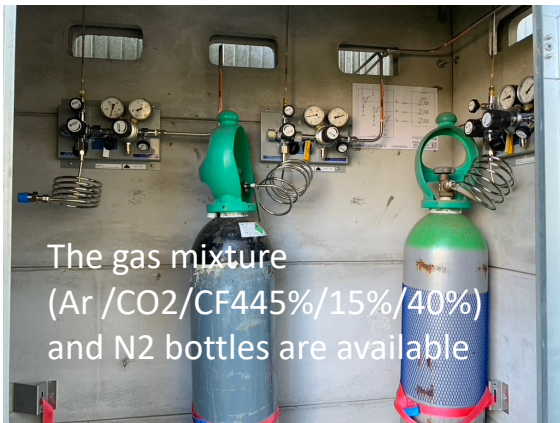
The gas distribution system has been installed



APV25 based SRS DAQ



The gas mixture (Ar /CO₂/CF₄45%/15%/40%) and N₂ bottles are available



The oven and the CAEN HV supply are available



Megger Tester



Flow controller



2024 Activities: VMM3 test at Genova

uRWELL RO electronics

- JLAB12 involvement in uRWELL FEE and Streaming Read Out
- JLab will design custom readout based on VMM3 (on uRWELL PCB)
- Switch from APV25-based RO to VMM3 not trivial
- In 2023 CERN made available some SRS-VMM3 systems

Work plan 2024*

- Learn the new VMM3 ops (SRS crate)
- Test a 10x10 uRWELL with cosmic
- Tets a 50x50 uRWELL with comics and at CERN (sj)
- Move the DAQ system to JLab to test the CLAS12 LargeArea uRWELL prototype

*Coordinated with JLab HallB and FastElectronics-Group

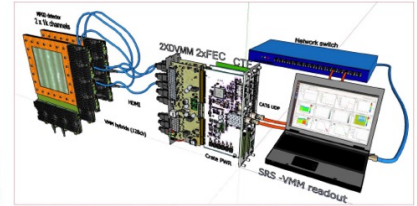
SRS The Scalable Readout System SRS with VMM3 frontend, so far implemented as a triggerless, multichannel readout system for gas

Readout System with 8 VMM= 128*8=1024 CH

SCEM	ITEM	CHF	# ITEM	TOTAL
07.89.00.008.1	RD51 DVMM V5.3	1857	1	1857
07.89.00.101.0	RD51 SRS FEC V6 CARD	1595	1	1595
07.89.00.027.2	RD51-SRS Minicrate 2K	1623	1	1623
07.89.00.115.4	TRANSCEIVER 1.25 GBD SFP 3.3V	93,5	1	93,5
07.89.00.007.2	RD51 VMM V5 128 channel hybrid	741	8	5928
07.89.00.220.2	HDMI CABLE D-A 5m STANDARD CABLE	23,5	8	188
Total				11284,5

Readout System with 16 VMM= 128*16=2048 CH

SCEM	ITEM	CHF	# ITEM	TOTAL
07.89.00.008.1	RD51 DVMM V5.3	1857	2	3714
07.89.00.101.0	RD51 SRS FEC V6 CARD	1595	2	3190
07.89.00.027.2	RD51-SRS Minicrate 2K	1623	1	1623
07.89.00.115.4	TRANSCEIVER 1.25 GBD SFP 3.3V	93,5	2	187
07.89.00.007.2	RD51 VMM V5 128 channel hybrid	741	16	11856
07.89.00.220.2	HDMI CABLE D-A 5m STANDARD CABLE	23,5	16	376
	CTF board (synchronization FECs) or switch	??	1??	
Total				20946



1 FEC for 8 VMM hybrids / 1024 detector channels connected via HDMI AD cables to DVMM. 2 FEC's with CTF (common clock) for 16 hybrids / 2048 ch. DVMM cards with local HDMI connector including 70 W power for 16 VMM hybrids. Power / housing for 2 FECs and CTF via 1 Minicrate (not shown). 1 GB Ethernet 10GbE uplink from FEC to Network via SFP+ jack, fiber or optical 1 GBE for network with Jumbo packet support ESS DAQ. Software with Vmm Controls. Installed under Linux.

More information/documentation:
<https://indico.cern.ch/event/1242811/contributions/5291414/attachments/2601279/4491548/SRS%20in%20in%202023%2002272023.pdf>

Responsibilities

- Electronics/RO: INFN-GE (P.Musico, M.Battaglieri)
- Detectors: UniRMTV, LNF (A.d'Angelo, G.Bencivenni)
- Trigger: INFN-CT, UniME (M.Bondi)
- Tests : all groups



2025 Activities

2D readout R&D strategy and Instrumentation

- 2 50x50 cm² 2D prototypes with GEM pre-amplifier, optimized 2D and CS readout
- X-Ray Gun with support and shielding structure – tagged DRD-1 item
- GEM - stretcher

SYNERGIES

- DRD – 1 initiative (WP-1)
- Forward tracking disks for ePIC-EIC
- Future recoil detector for RG-H (Ferrara)

On-going collaboration with INFN Catania and INFN Genova

- Construction of a cosmic-ray/test beam stand with plastic scintillators triggers (Catania)
- Test of new readout electronics based on VMM3 chip (Genova)



μ – Rwell for HI-LUMI

Hi-Luminosity Program

INFN Manpower Strategy

Objective: strengthen the collaboration among different INFN groups interested in the μ -Rwell technology:

- Catania
- Ferrara
- Genova
- LNF (Gianni Bencivenni leadership)
- Roma Tor Vergata
- Roma 1



Synergies in prototypes design and realization → **Reduction of the prototype costs**

Collaboration during test beams and data analysis, new VMM3 electronics tests, etc.

Optimization of technical work (ex: mechanical parts designed at LNF and made at RomaTV),

INFN pole for μ -Rwell technology:

technical know-how, young scientists training, Italian alternative to CERN

μ – Rwell for HI-LUMI

Large Area Prototype



2024 Milestones

30/06/2024 – 100 %

Hi-LUMI: Caratterizzazione prototipi (10 x 10 cm²) per ottimizzazione readout 2D con capacitive spreading.

31/12/2025 – 90 %

Hi-LUMI: Realizzazione set-up per caratterizzazione prototipi a grande area 50x50 cm²

2025 Milestones

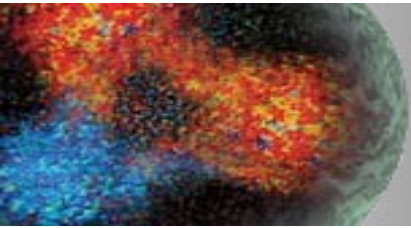
30/06/2025 Hi-LUMI: Caratterizzazione prototipi (10 x 10 cm²)
GEM- μ Rwell

31/12/2025

Hi-LUMI: Realizzazione GEM- μ Rwell grande superficie

Richieste Strumenti ed Apparti Roma Tor Vergata

Item	Costo K €
2 fogli GEM Layout 50x50 incluso design e tooling	5
2 cornici in peek 50cm x50 cm	3
Tubo a Raggi X	9.5
Materiale per supporto e schermaggio DRD-1 item	8.5
Strumentazione per incollaggio GEM su frame in peek	4
Gas premiscelato Ar:CO2:CF4 (45:15:40) e 2 bombole Azoto	3
12 Misuratori di tensione	10
Lastra in Alluminio rettificato e componenti meccanici per tendi-GEM DRD-1 item	3
Totale	46
Missioni	
Missioni per turni di misura CLAS – Hall-B	18.5
Missioni per test beam al CERN (sub giudice?)	6.5
Missioni per riunioni CT/GE	3
Totale Missioni	28
Totale richieste	74



μ – Rwell for HI-LUMI

Hi-Luminosity Program

Back-up Slide

μ – Rwell Technology

The μ -RWELL is a Resistive MPGD detector (Micro Pattern Gas Detector)

The device is composed of two elements:

- drift/cathode PCB defining the gas gap ($5\mu\text{m}$ Cu layer on the bottom side) Used Gas : Ar:CO₂:CF₄ 45:15:40 mix
- μ -RWELL_PCB (detector core)
 - Multilayer circuit: Well Pattered Polyimide \oplus resistive film \oplus readout PCB

Amplification stage: → $50\mu\text{m}$ thick Kapton (Apical®) foil

With a $5\mu\text{m}$ Cu layer on the top side

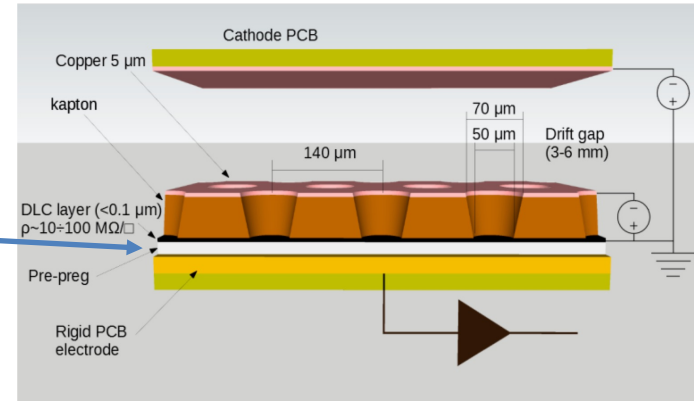
Resistive stage: → DLC (Diamond-Like-Carbon) film sputtered on the bottom side of the polyimide foil

Surface resistivity: $\rho = 10 \div 100\text{ M}\Omega/\square$

the resistivity is a function of the DLC thickness

strongly suppresses the transition from streamer to spark

⇒ Allows to achieve **large gains** ($> 10^4$), without affecting the capability to operate under **high particle fluxes**



G. Bencivenni et al.; 2015_JINST_10_P02008

μ – Rwell Technology

The “WELL” acts as a multiplication channel for the ionization produced in the gas of the drift gap

The charge induced on the resistive layer is spread with a time constant:

$$\tau \sim \rho \times c$$

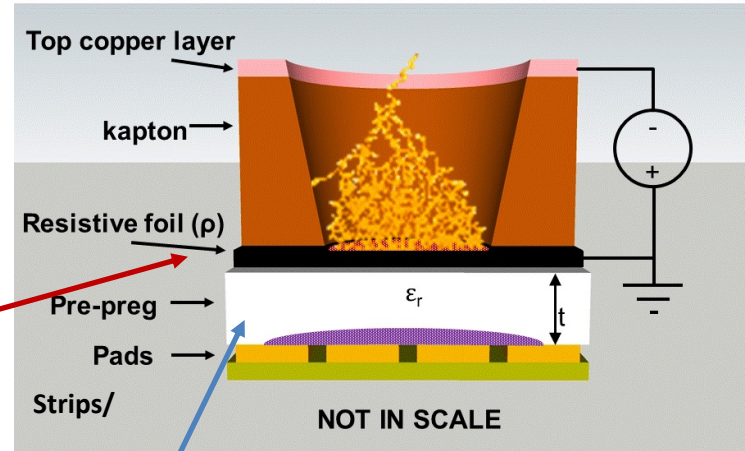
[M.S. Dixit et al., NIMA 566 (2006) 281]:

ρ → the DLC surface resistivity

c → the capacitance (per unit area), depending on the distance between the DLC and the readout plane

$$C = \epsilon_0 \times \epsilon_r \times \frac{S}{t} = 120 \text{ pF} \times L(m) \quad - \quad w=0.2 \text{ mm}, \quad p=0.4 \text{ mm} \text{ strip read-out}$$

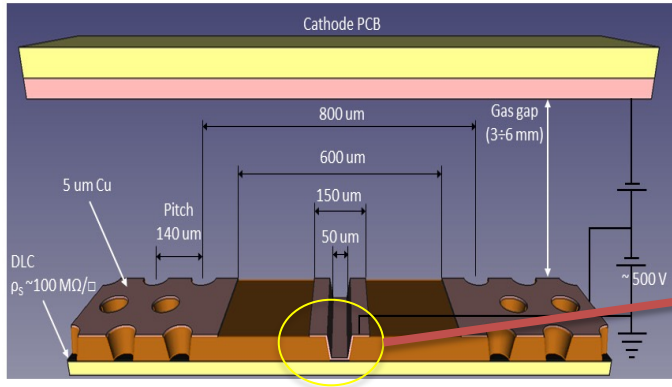
- The resistive stage ensures the quenching of the spark amplitude
- As a *drawback*, the capability to stand high particle fluxes is reduced, but appropriate grounding schemes of the resistive layer solves this problem



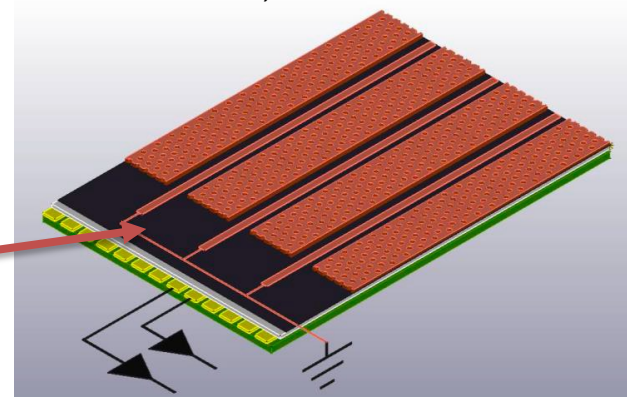
μ – Rwell Technology

Studies have been focused on the DLC grounding layout to increase the rate capability while maintaining a safe resistivity \Rightarrow The solution is to reduce as much as possible the current path towards the ground connection introducing a high density “grounding network” on the resistive stage of the detector

PEP – Patterning-Etching-plating



*The micro-RWELL layouts for high particle rate,
G.Bencivenni et al., 2019-JINST-14-P05014*



The active area is discontinued by grooves that uncover the DLC; then a copper plating, carefully separated from the copper in the active sectors, is disposed to connect the DLC to the ground.

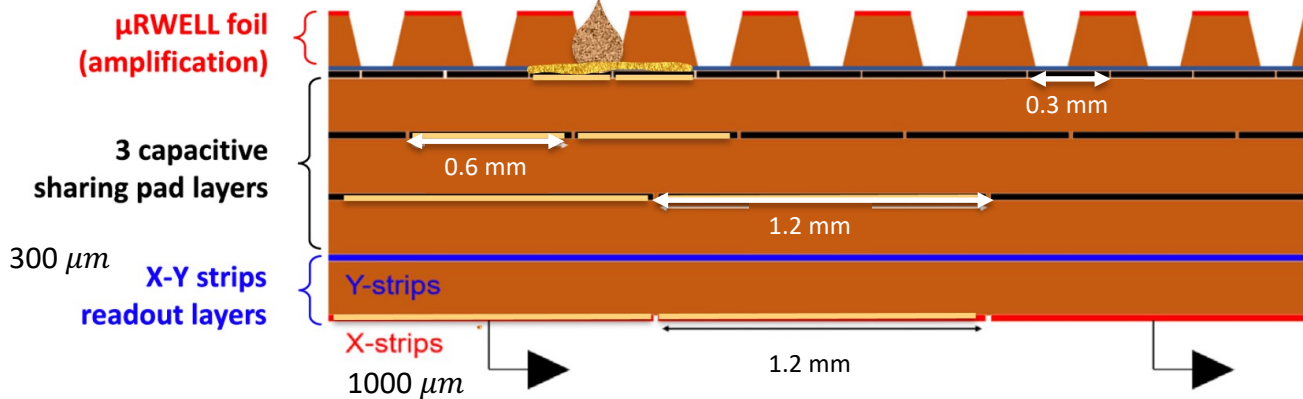
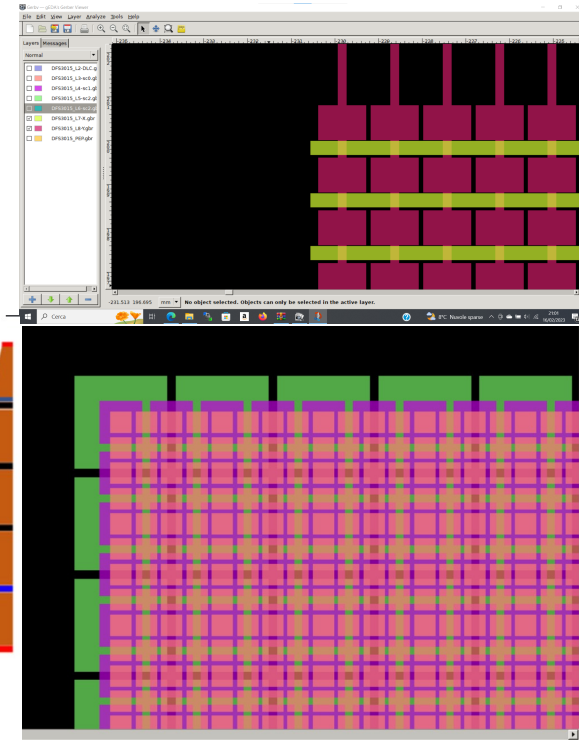
A small dead zone on the amplification stage must be introduced for high stability operation

\rightarrow next talk by Mariangela Bondì

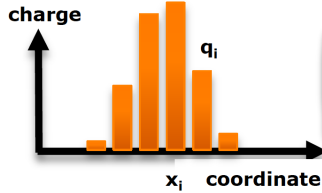
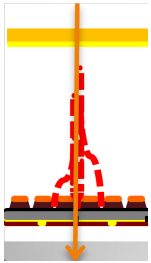
μ – Rwell Technology

“capacitive-sharing readout structures” for electronic channels reduction

- charge transfer and charge sharing for large pitch (strip or pad) anode readout PCB layers using capacitive coupling between a stack of layers of pads.
- Capacitive-sharing readout structures offer a very good spatial resolution capability with **significant reduction of electronic channels** required to read out large-area MPGD trackers



μ – Rwell Technology

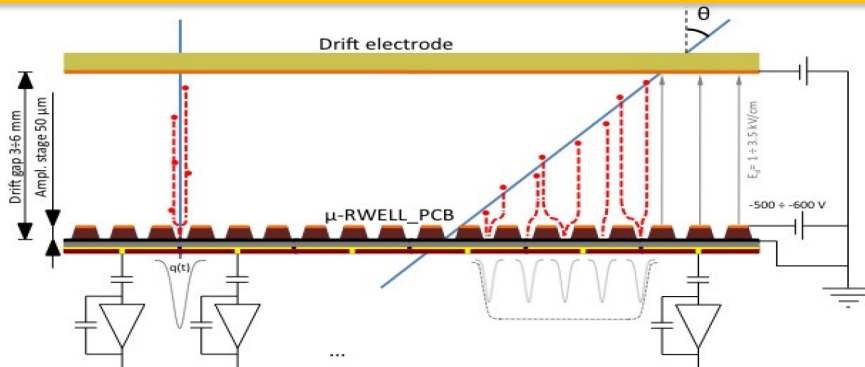


$$x_{hit} = \frac{\sum x_i \cdot q_i}{Q_{tot}}$$

Charge Centroid reconstruction method

The track position is determined as a weighted average of fired strips

GOOD FOR ORTHOGONAL TRACKS



FOR INCLINED TRACKS &/or HIGH B FIELD

the Charge Centroid method gives a **very broad spatial distribution** on the anode-strip plane.

μ TPC reconstruction

The spatial resolution is strongly dependent on the impinging angle of the track → A non-uniform resolution in the solid angle covered by the apparatus → Large systematical errors.



μ – Rwell Technology

The μ -RWELL exhibits several interesting features:

- Compactness
- Easy assembly
- Easy powering
- Intrinsic spark quenching

μ -RWELL performances:

- Gas gain $\rightarrow 10^4$
- Rate capability HR version $\rightarrow 10$ MHz/cm²
- Spatial resolution \rightarrow down to 60 μ m
- Time resolution $\rightarrow 5$ -6 ns

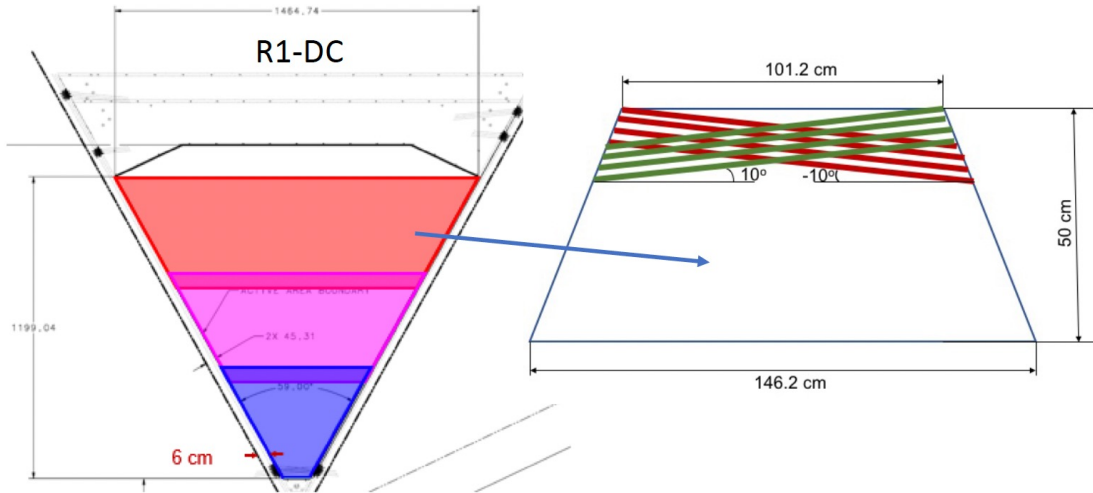
Fast time response and high spatial resolution make this detector **suitable** for the high luminosity upgrade.

INFN R&D phase is addressing the following topics, in a step-by-step strategy:

- **2D readout scheme:** 2 x 1D vs 2D à la “COMPASS” vs Bottom/Top Readout
- **Electronics channels reduction:** minimum pitch compatible with 100 μ m resolution vs capacity sharing
- **High-rate** capability and improved grounding scheme
- **Large area** detectors
- **R1 detector design** optimization

The R1 detector configuration

- The DC-R1 active area is a trapezoid with a height of 151 cm, a large base of 146.2 cm, and a small base of 10.4 cm
- With available foil sizes for MPGD detectors, such an area cannot be covered with a single foil. The whole module can be constructed from three sections
- The largest of the three sections will be prototyped as part of the initial R&D. The readout will be based on APV25 chip, currently used in many GEM detectors. Exploring newer chips (SAMPA and VMM3) for the main detector.



→ next talk by *Mariangela Bondi* for tracking simulations

- The largest segment is a trapezoid with a large base of 146.2 cm, the height of the chamber will be 50 cm, the small base of 101.2 cm
- The readout concept is U-V strips with $\pm 10^\circ$ stereo angles relative to the base of the trapezoid, strips traced on two sides of the readout plane will be used.
- The charge share will be through capacitive coupling. The pitch size of the readout 0.8 mm, the strip width 0.4 mm.
- The total number of U&V readout strips is about 685.

Prototyping @ JLAB

- μ RWELL with capacitive sharing readout provides 2D points in front of drift chambers
- Simulation studies with background merging and μ RWELL + DC + AI result in improved inefficiency of better than 0.1 % per nA, (15% @ 150 nA) better than upgrade design goal
- CLAS12 readiness for higher luminosities is key for future success
- Beam-tests of a large-area μ RWELL during the last days of RG-C were not successful



- End of May, significant leaks at both the supply and return manifolds were found
- Using a different gas mixture, the measured efficiency was significantly improved (but still not better than 70%)

μ – Rwell – INFN Activity

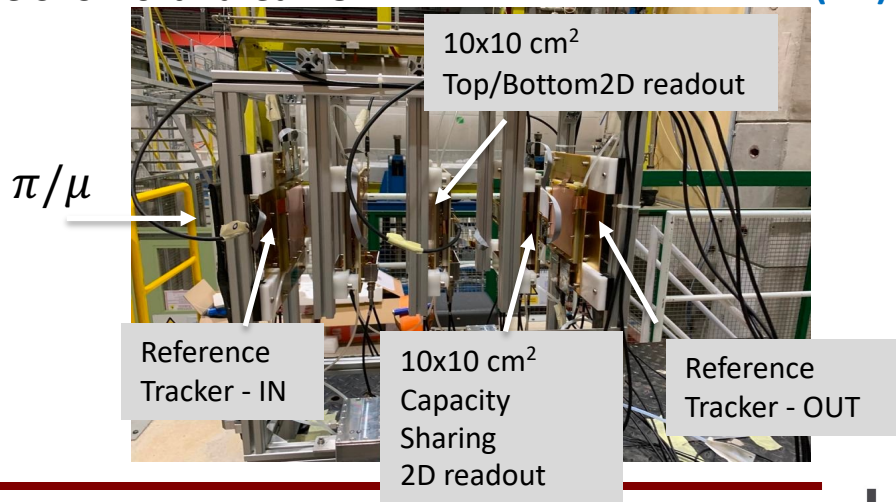
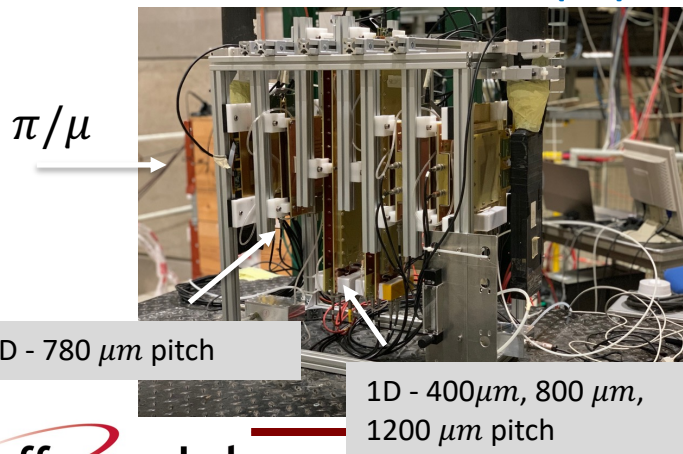
2022/2023 μ -RWELL prototyping strategy at INFN in collaboration with LNF group of Gianni Bencivenni:

- 1D prototypes for pitch optimization
- 10x10 cm² prototypes for 2D read-out optimization
- 10x10 cm² 2D prototypes with capacity sharing read-out
- 50x50 cm² large area detector with 2D read-out and capacitive sharing read-out

2 Test Beam runs at CERN@ μ/π beamline of the SPS North area H8

14 – 28 June 2023 (2D)

5 – 19 October 2022 (1D)

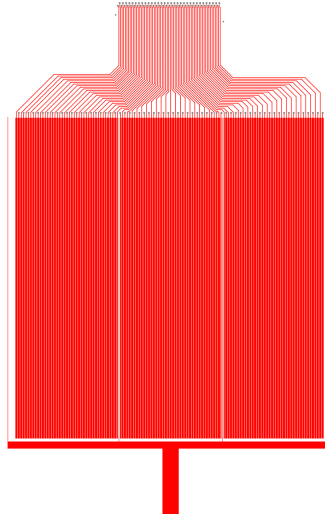


μ – Rwell – INFN Activity

2D – readout: step by step approach

1. The first prototype was a set of **2x1D** detectors each having the following specs, rotated by 90 degrees:

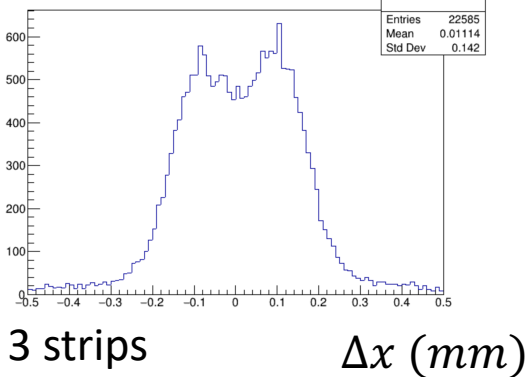
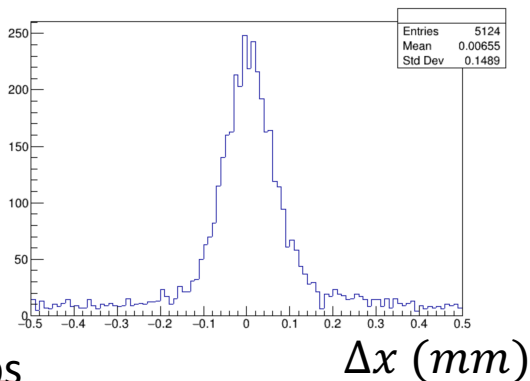
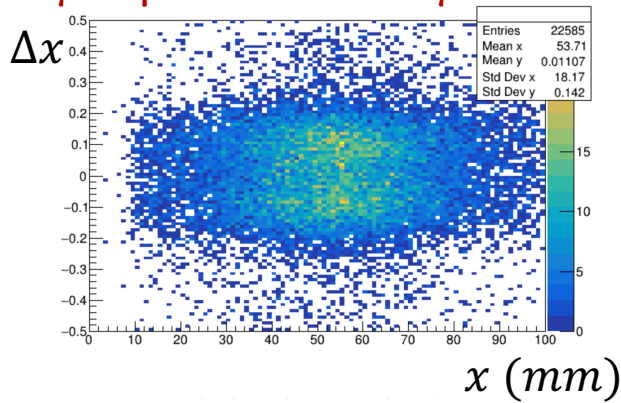
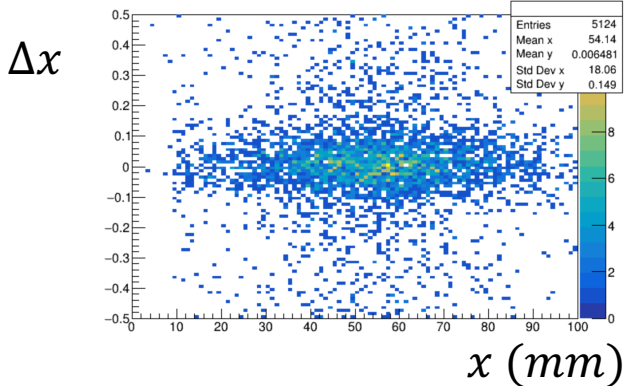
- 780 μm pitch
- 300 μm width
- 10 x 10 cm^2 active surface
- 128 channels



Oct. 2022 Test Beam: SPS North Area H8

μ – Rwell – INFN Activity

Spatial resolution with 780 μm pitch and 300 μm width



Increasing the pitch read-out the resolution is strongly affected by the number of strips among which the charge is distributed

The detector response becomes digital

$$\sigma \rightarrow \frac{\text{pitch}}{\sqrt{12}}$$

μ – Rwell – INFN Activity

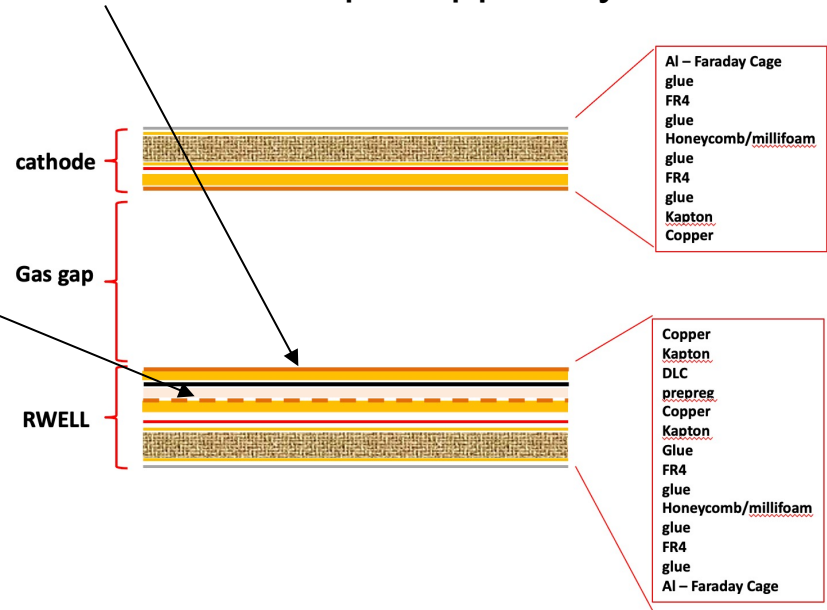
2D – readout: step by step approach

2. The second prototype reads the 2-nd coordinate on the “top” copper layer

Same readout geometry as in the bottom:

- 780 mm pitch
- 300 mm width
- 10 x 10 cm² active surface
- 128 channels

The effect charge collection on the «top» layer is the object of investigation.

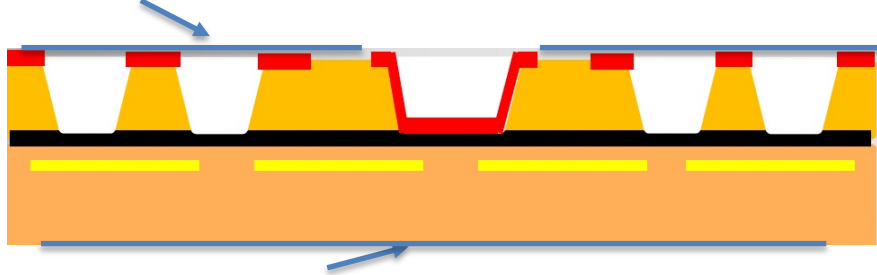


μ – Rwell – INFN Activity

2D – readout: step by step approach

2. The second prototype reads the 2-nd coordinate on the “top” copper layer

X – strip readout on the «top»



Y – strip readout at the «bottom»

The prototype has been designed by INFN staff and purchased at CERN.

2D readout :

X strips are collected on the **top** layer

Y strip are collected in a standard way at the **bottom** layer

No charge capacitive sharing concept is applied

CAD Design Manpower:

Maurizio Gatta (LNF)

Enrico Tuti (ROMA TV)

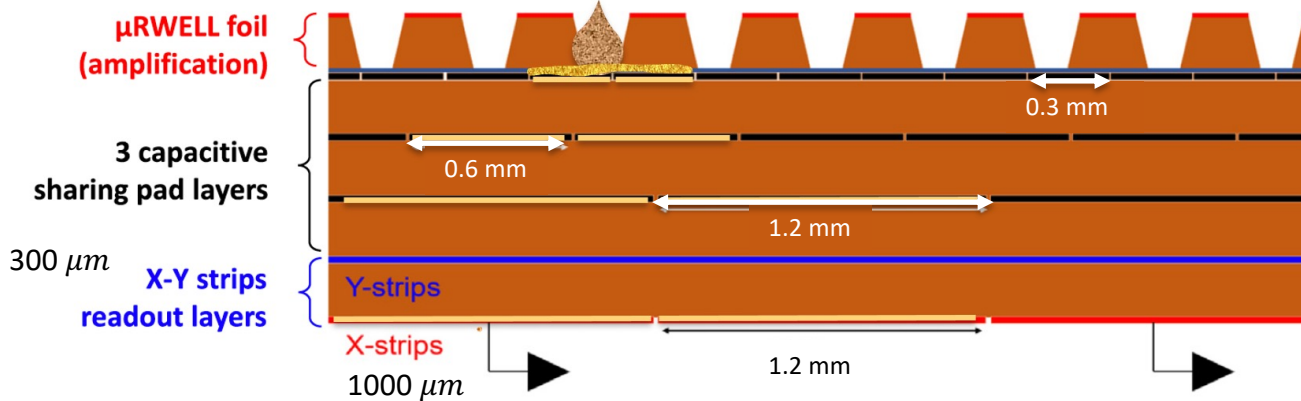
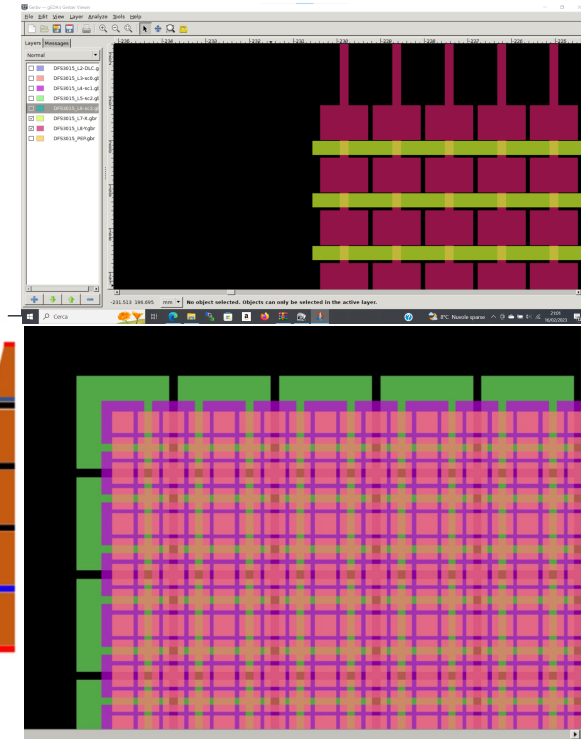
μ – Rwell – INFN Activity

2D – readout: step by step approach

K. Gnanvo et al Nuclear Inst. and Methods in Physics Research, A 1047 (2023) 167782

3. The third prototype reads both coordinates on the bottom in “COMPASS-like” strips configuration with capacity sharing read-out:

- 1200 μm pitch
- 300 μm vs 1000 μm strips width
- 10 x 10 cm^2 active surface
- 83 channels

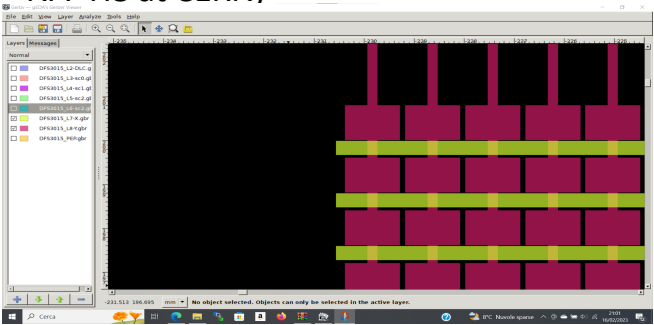


Large area detector

- A 40 x 46 cm² detector has been purchased from Rui De Oliveira @ CERN by Roma Tor Vergata
- The detector has the same 2D read-out scheme as the 10x10 cm² capacity sharing version prototype (being tested during at SPS - NA- H8 at CERN)

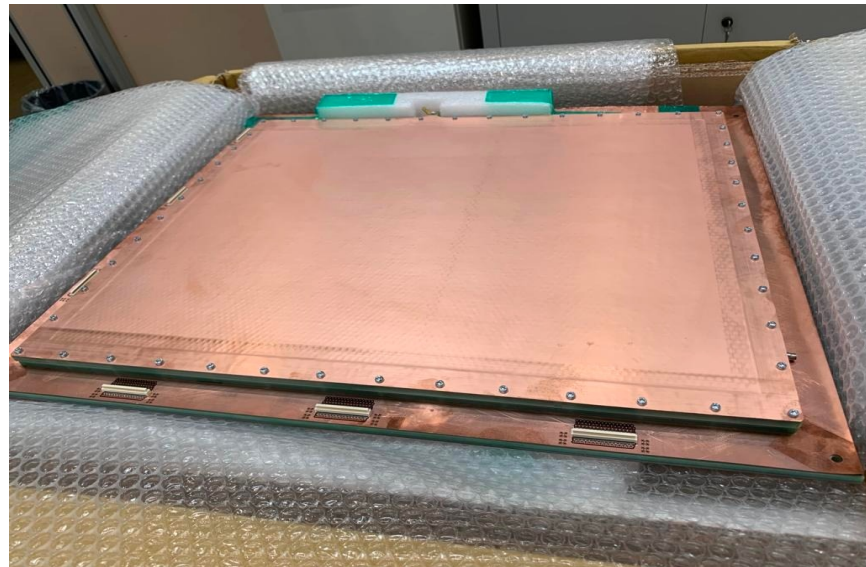
1200 μm pitch

6 mm gas gap

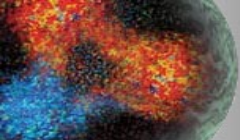


300 μm vs 1000 μm strips

Light – cathode
on honeycomb
support



Will be tested with X-rays and cosmic rays
at LNF and Roma Tor Vergata



Results and Perspectives

TOP read-out

Summary of Results detailed by Mariangela Bondi in the next talk

- The Top-readout efficiency is 80-82% (compatible with the geometrical acceptance of 87%).
- There is an issue with the efficiency plateau below 600V HV. The signal produced does not suffer from sharing between the 2 readout views.
- Spatial resolution is 250-350 μm , compatible with pitch/ $\sqrt{12}$

Capacity Sharing read-out

- The CS shows an efficiency plateau at 92-93% as a function of HV from 600 to 660V (too high!)
- The charge spread allows a very good spatial resolution, $<100 \mu\text{m}$ (at high HV).
- The average cluster size increases with HV.

2D read-out optimization:

FUTURE ACTIVITIES

- The CS readout could be improved by eliminating one layer of sharing, going from the actual 3 capacitive ones (0.3 - 0.6 - 1.2 mm) down to 2 (0.4 - 0.8 mm).



Results and Perspectives

2023 Milestones

Hi-LUMI caratterizzazione prototipi per ottimizzazione readout 2D 29-06-2023 **100 %**

Hi-LUMI disegno prototipo a grande area 31-12-2023 **100%**

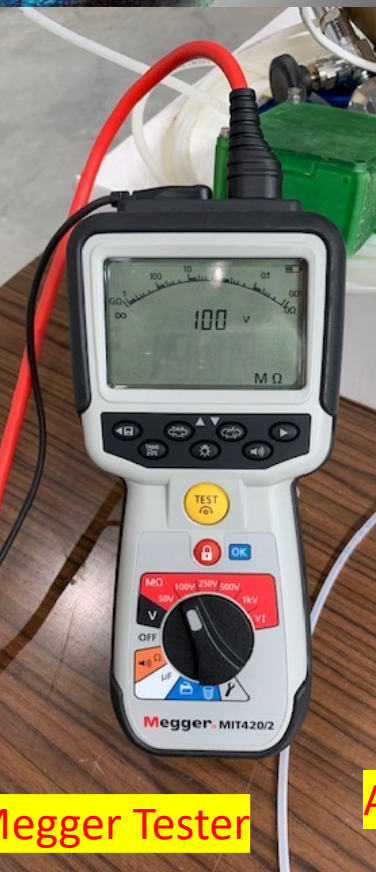
The detector read-out still needs optimization!

2D read-out optimization:

FUTURE ACTIVITIES

- The CS readout could be improved by eliminating one layer of sharing, going from the actual 3 capacitive ones (0.3 - 0.6 - 1.2 mm) down to 2 (0.4 - 0.8 mm).

Test laboratory at Roma Tor Vergata



Megger Tester



Ar:CF₄:CO₂



APV25 hybrids

SRS DAQ system



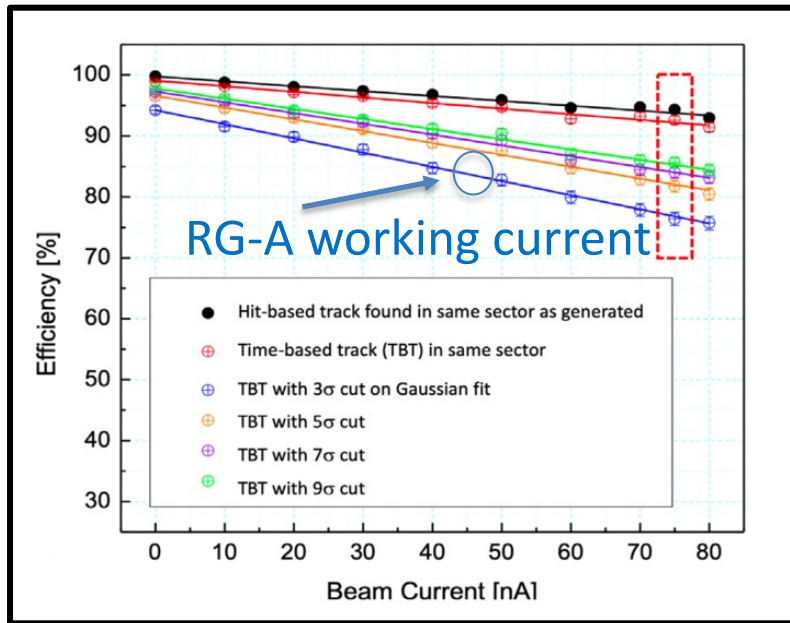
HV Power Supply

ADC and FEC cards

μ – Rwell for HI-LUMI

The problem: **CLAS12 Luminosity - Detectors Limitations**

Nominal CLAS12 luminosity $\mathcal{L} = 10^{35} \text{ cm}^{-2} \text{ sec}^{-1}$ is achieved on a 5 cm LH2 target at $I_e = 75 \text{ nA}$



Most Data Taking currently limited the current on target to $I_e = 45 \text{ nA}$ to maximize the figure of merit $\mathcal{L} \times \eta$ for three-prongs events.

$$\mathcal{L} = 0.7 \cdot 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$$

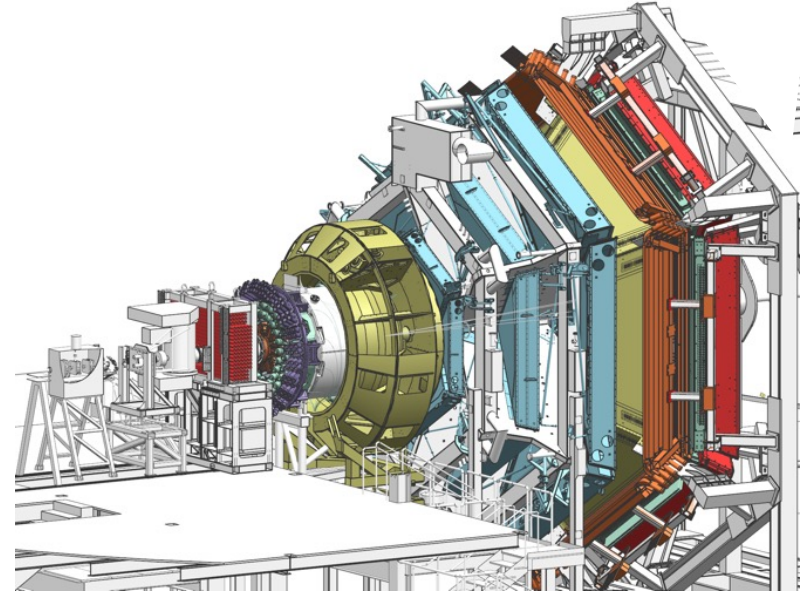
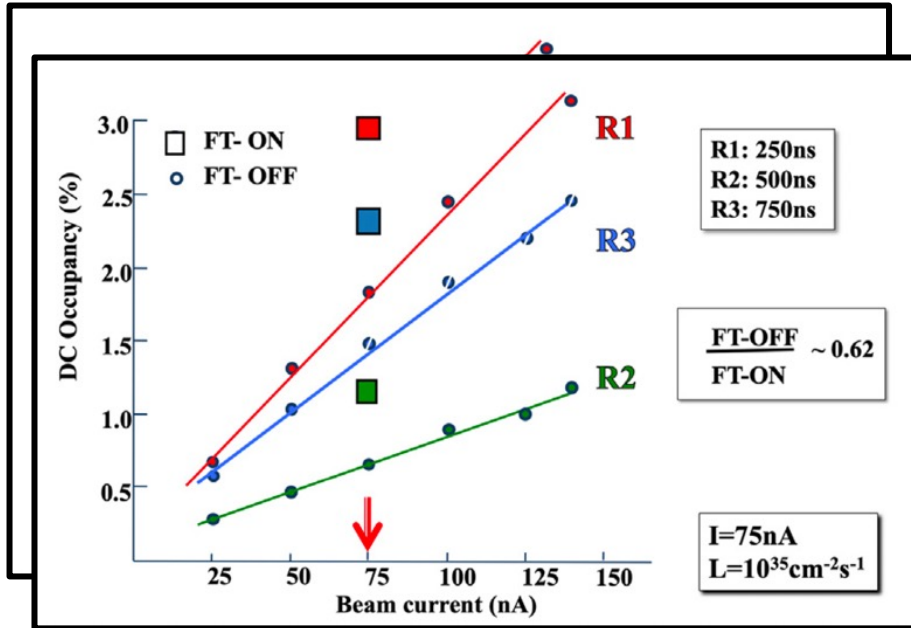
$$\eta_{3p} = 0.85^3 = 0.55$$

- **at present** experiments with 2-particles in the final state are getting only **~40% of the expected statistics**
- **AI – assisted tracking** has been developed to improve reconstruction efficiency → **PASS 2**
(See L. Lanza RG-K presentation)

μ – Rwell for HI-LUMI

The problem: **CLAS12 Luminosity - Detectors Limitations**

Main efficiency limitation is due to DC occupancy in R1



CLAS12 luminosity $\mathcal{L} = 2 \times 10^{35} \text{ cm}^{-2} \text{ sec}^{-1}$ is achieved on a 5 cm LH2 target at $I_e = 150 \text{ nA}$