eRD108: MPGD for ePIC

FY24 Progress Report & FY25 Proposal

EIC Project R&D and DAC Meeting

Aug 29th 2024

F. Bossù on behalf of

eRD108 consortium

eRD108 Consortium and ePIC MPGD-DCS

Project ID: eRD108

Project Name: R&D on cylindrical MPGDs towards an EIC detector

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Florida Institute of Technology (FIT): Marcus Hohlmann
CEA Saclay: Francesco Bossù, Maxence Vandenbroucke
Temple University (TU): Matt Posik, Bernd Surrow
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Project Members:

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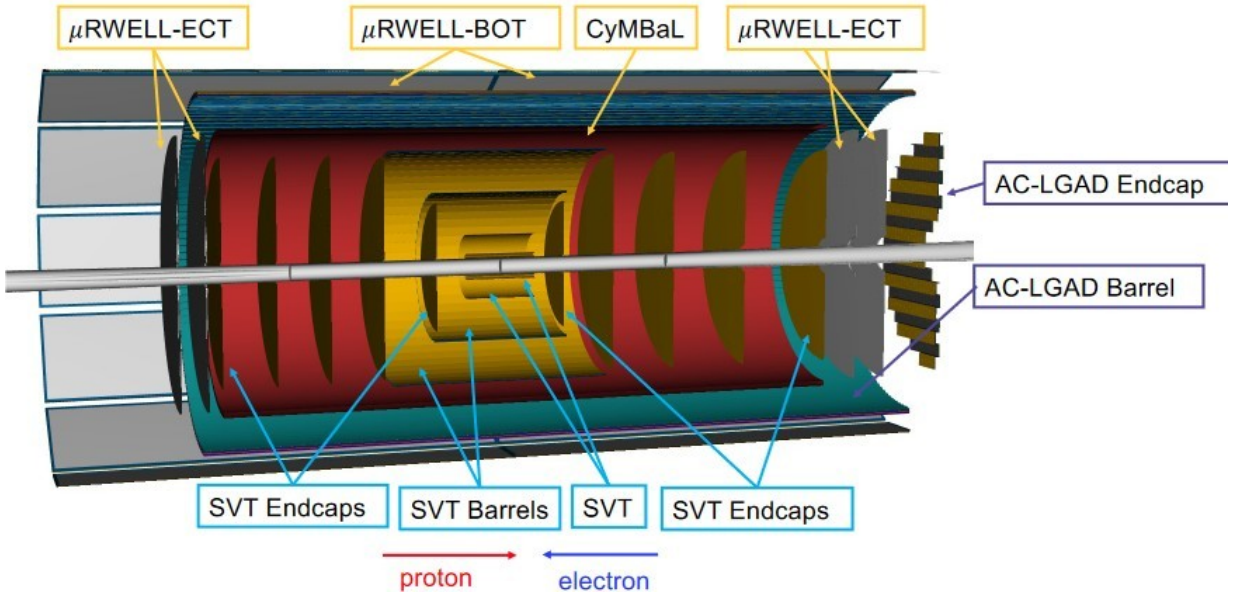
eRD108

ePIC MPGD Detector Subsystem Collaboration

MPGD in ePIC tracking system



MPGDs complement the silicon tracker:
- redundancy hit points
- faster hits for track finding

Three systems:
- **CyMBaL**: Cylindrical Micromegas Barrel Layer at R=55cm
- **μRWELL Barrel Outer Tracker**: planar detectors at the DIRC surface
- **μRWELL End Cap Tracker**: disks in the forward and backward regions

eRD108 program about Cylindrical MPGD detectors with 2D readout:

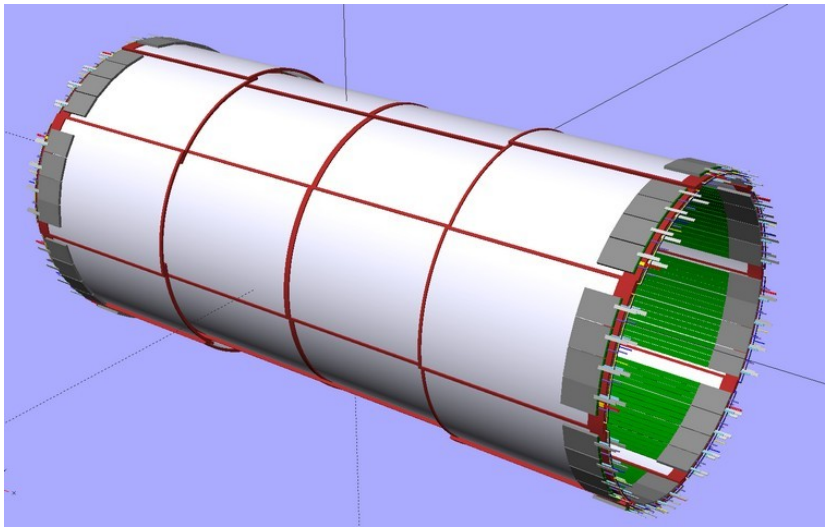
- Development of 2D cylindrical Micromegas detectors: funded in FY24
- Development of a cylindrical μRWELL prototype: completing the FY23 program

Update on 2D readout R&D and scale 1:1 prototype

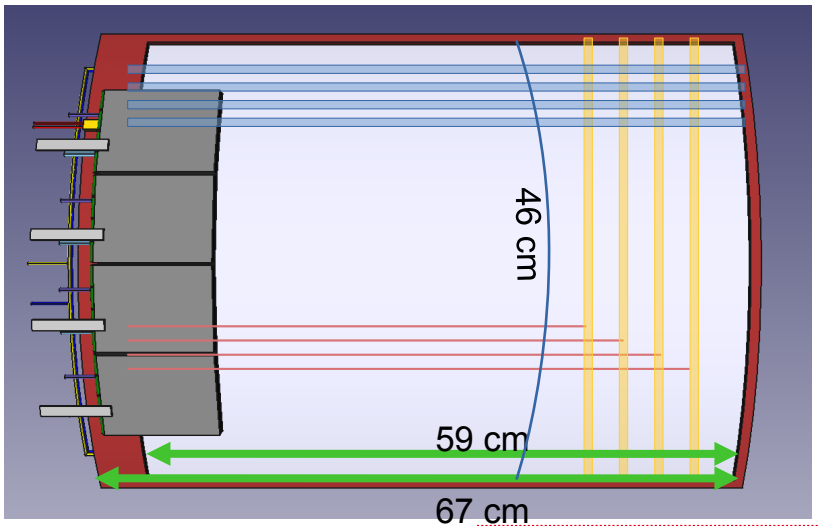
CEA Saclay

CyMBaL

CyMBaL: Cylindrical Micromegas Barrel Layer



Design of a module



Requirements:

- Spatial resolution ~150μm
- Time resolution ~10ns
- Light, less than 1% X0
- Hermetic
- Tight space: ~5cm in R
- Magnetic field: ~2T

- 32 module: 8 modules in ϕ times 4 modules in z
- Overlaps in ϕ and in z for hermeticity
- 1024 readout channels/module
- 32K readout channels

Module dimensions

Z = 67 cm

R*phi = 48 cm

Active zone dimensions

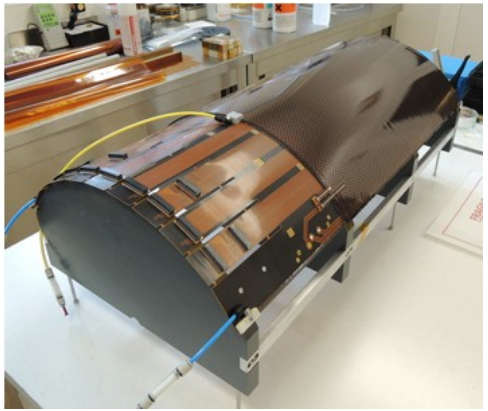
Z = 59 cm

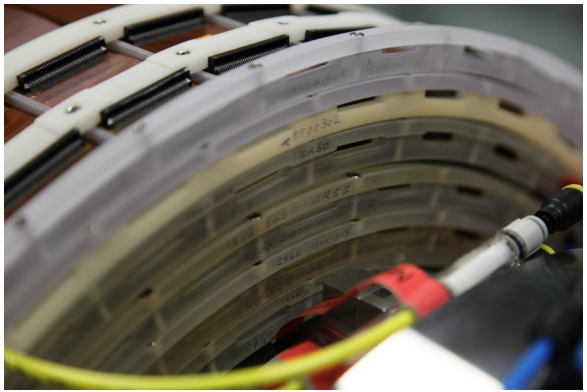
R*phi = 46 cm

CyMBaL – Technology and planned R&D

CLAS12 resistive Micromegas

- Material budget ~0.4%
- Working in high radiation environment and in B=5T
- Taking data since 2017
- Fit in tight spaces





Upgrade for ePIC: 2D readout

R&D planned activity in FY24

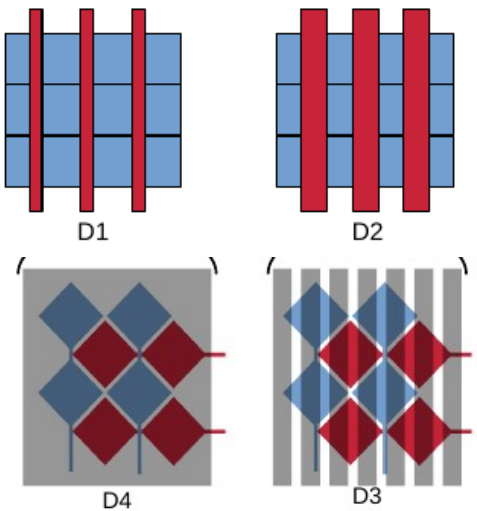
- Finalization of the analysis of the 2023 test beam data on the 2D prototypes
- Complete the tests on resistive patterns and 2D readout with additional prototypes
- Design and production of a large scale prototype with a 2D readout using CLAS12 mechanics
- Mechanical mock-up for a scale 1:1 prototype
- Test performance of a small 2D prototype with a 1mm drift gap with different gas
- Test the use of carbon fiber instead of FR4 to lower even further the material budget

CyMBaL – Test 2D prototypes

12x12 cm2 prototypes to test:

- 2D readout patterns
- Resistive layer motifs
- very-low material budget (0.2% X0)

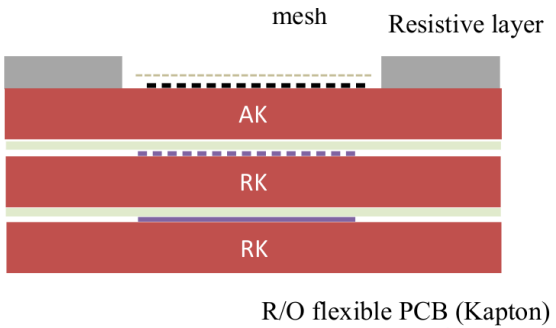
R/O Patterns and resistive motifs



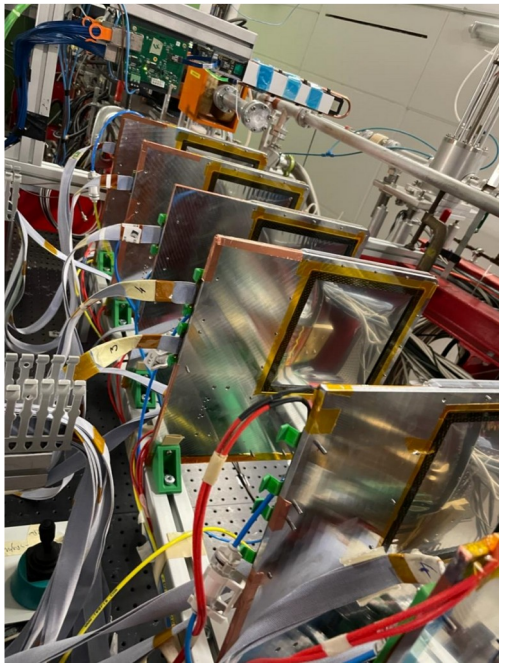
- Pitch and interstrip variations
- ASACUSA like motifs
- Variation of resistive layer (full, strips, grid)

Low material budget

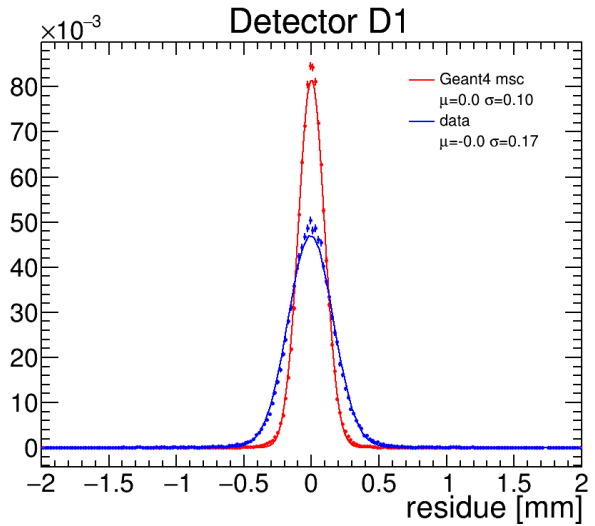
- Achieved by stretching the flexible PCB on a carbon frame



CyMBaL – 2023 Test Beam analysis

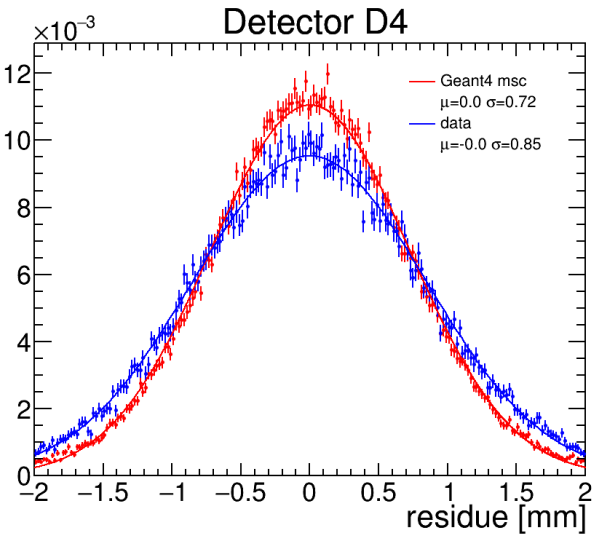


- Data taken in June 2023 at MAMI
- 880 MeV electron beam
- ALPIDE-based reference telescope
- Tested several prototypes
- Important multiple scattering effect
- Geant4 simulations to cross check



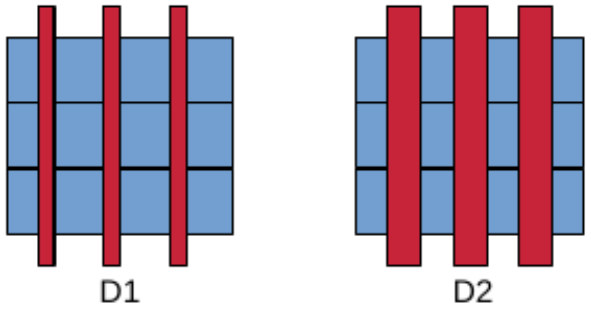
~30cm from ref tracker

Data
MC



~78cm from ref tracker

CyMBaL – 2023 Test Beam analysis

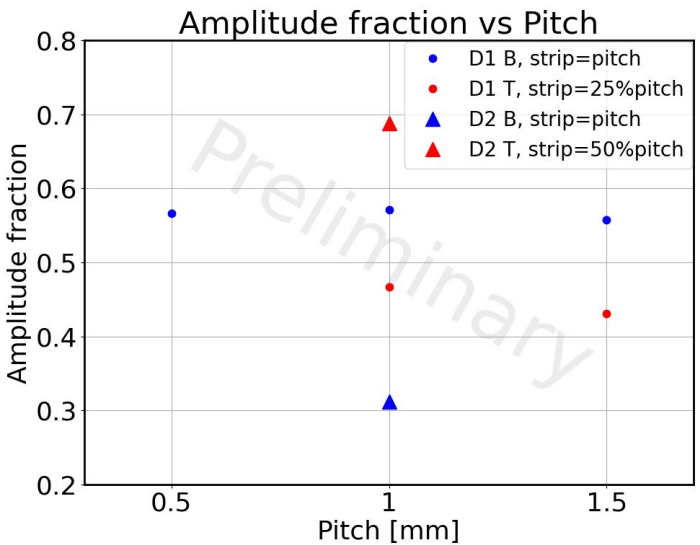


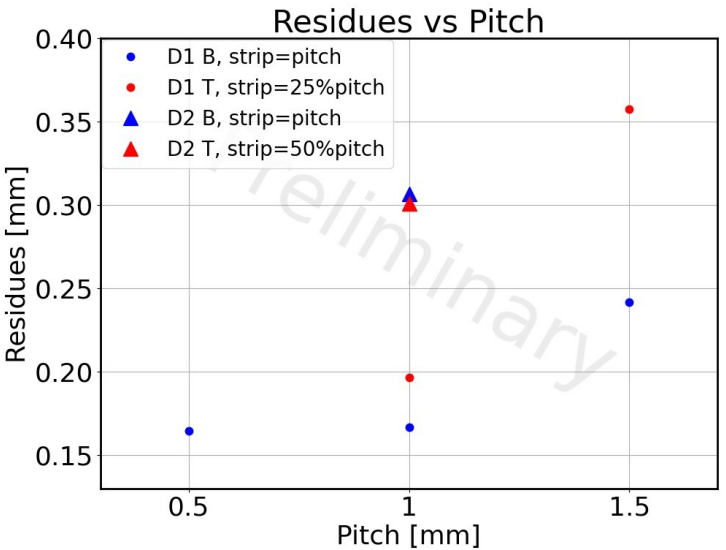
D1:
- pitch variation from 0.5 mm to 1.5 mm
- top layer interstrip 25%

D2:
- 1 mm pitch,
- Interstrip 50%

Resistive layer: full, high resitivity ~10MΩ/□

Credit: Samy Rafael Plocher

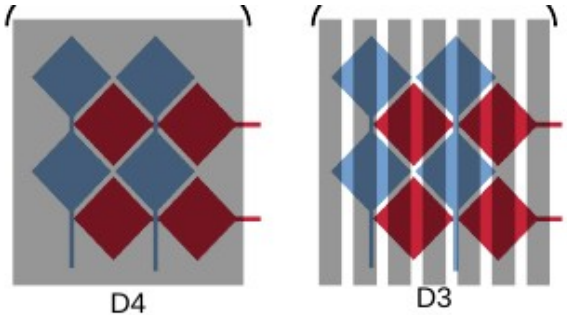




Amplitude fraction, 25% low, 50% too high: the sharing of the signal is not uniform, interstrip with values round 30% should work better

Residues (uncorrected): D1 provides less than 200µm with 1mm pitch

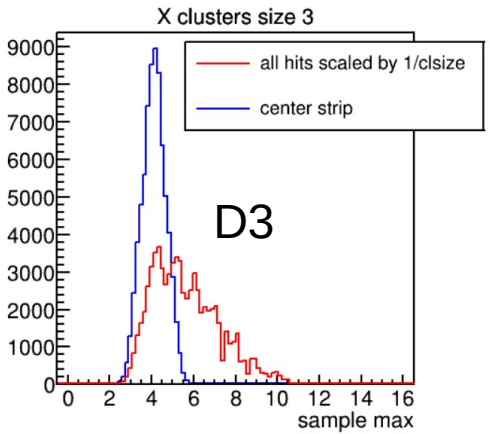
CyMBaL – 2023 Test Beam analysis

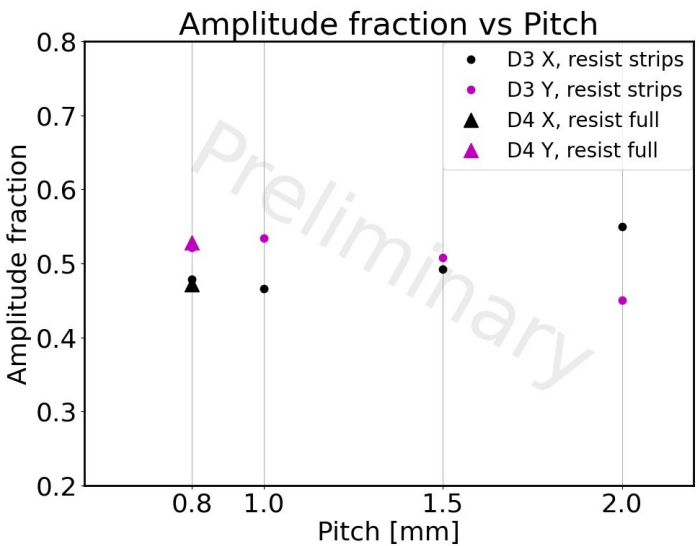


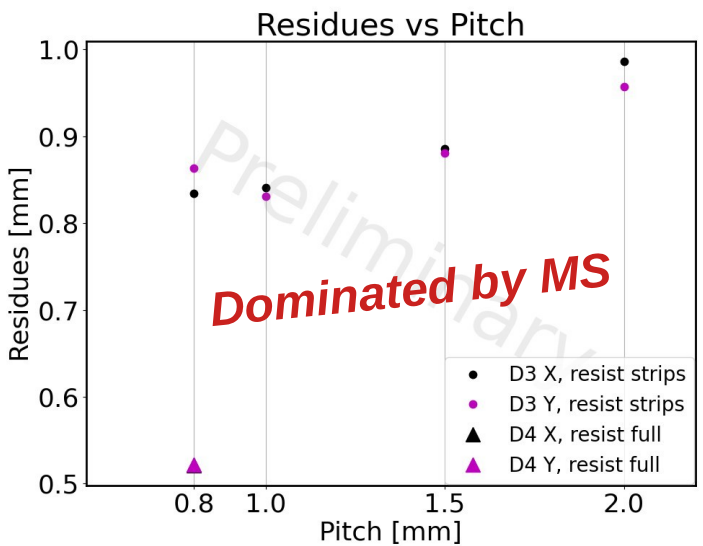
D3 and D4 : ASACUSA-like patterns

Resistive layer:

- D3: resistive strips of 500µm pitch
- D4: full layer with resistivity ~500kΩ/□







D3 visible drift of the signal max along the resistive strips

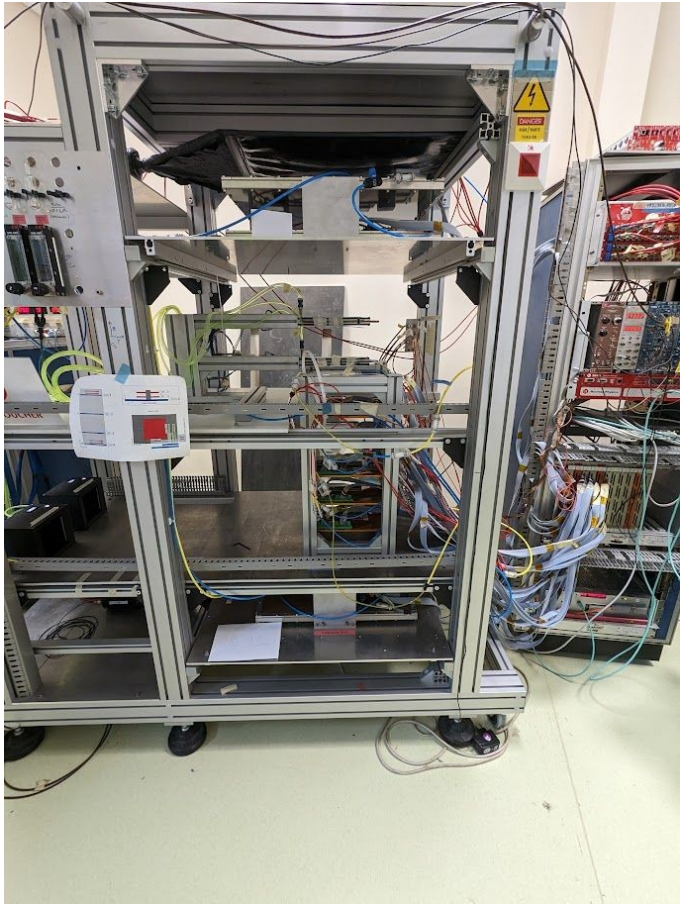
Amplitude fraction, better sharing, as both r/o layers are on the same plane

Residues (uncorrected): Dominated by multiple scattering

CyMBaL – Tests in Saclay

- Cosmic rays test bench refurbished
- Silicon telescope (same as in beam test) added to the system
- Mechanical structure to hold up to six prototypes
- Synchronization of MM and ALPIDE DAQs
- Development of software tool for the data taking and analysis optimization
- The DAQ system is now adapted to be portable to a next beam test

Credit: Dylan Neff



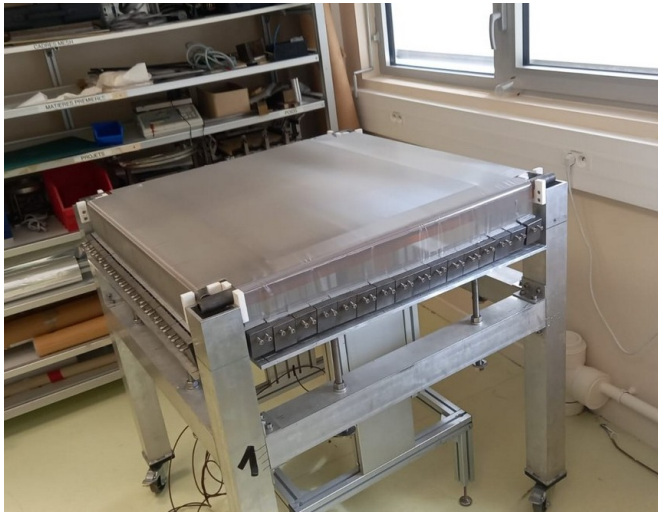
CyMBaL – Toward a scale 1:1 prototype

Main tasks

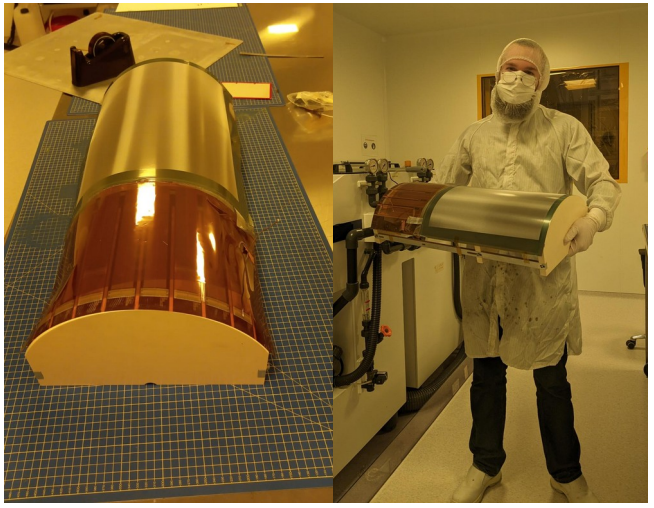
- Refurbishing of the production of resistive cylindrical MM tiles
  - Tensioning system
  - Change of the photoresistive material
  - Production of a CLAS12 tile to validate the process
- Design of the readout PCB
  - Choice of the 2D pattern
  - Connector choice

CyMBaL – Toward a scale 1:1 prototype

Refurbishing of the production of resistive cylindrical MM tiles



Mesh tensioning system: it allows us to reach low tension values



- Bulk of a metallic and a resistive CLAS12 PCB
- Bent in shape

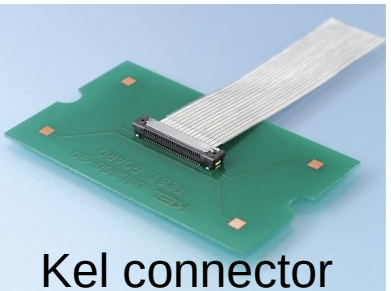
Photo-resistive material:

- Pyralux out of production
- Switched to Vacrel (already used in the past)
- Difference in the film thickness (from 64 µm to 50 µm)
- Difference in composition:
  - Check adherence
  - Adjustments of the development stage
- Tests with 40x40cm2 detectors ongoing

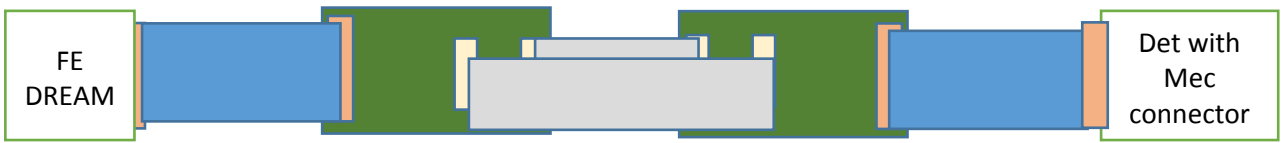
CyMBaL – Toward a scale 1:1 prototype

Design of readout PCB

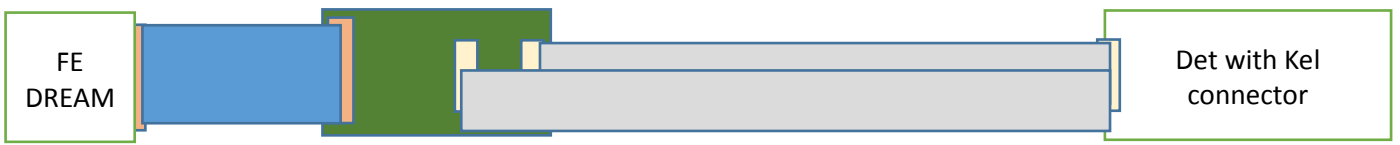
- Choice of the readout pattern depends on the finalization of the tests on the small 2D prototypes. Expected by December.
- Tests of a new small form factor connector:
  - 40 pin Kel connector with flat micro-coaxial cables already procured
  - Transition card Mec8 → Kel connector has been designed
  - Tests will start in September


Kel connector

Connector and cable validation



With Kel connectors on detector



CyMBaL – Plans

Toward the scale 1:1 prototype

- Finalization of 2D pattern tests: End 2024
- CLAS12 tile production and test: Fall 2024
- Design of the 2D PCB: End 2024
- Design of mechanics for a ePIC prototype: End 2024
- Procurement and production: Apr 2025
- Tests: July 2025

Additional tasks in FY24

- Mitigation studies for large angle tracks:
  - 1-mm gap small prototype to check spatial resolution and efficiency with different gases.
    - Modification of the small prototype to fit a 1-mm gap ongoing
    - Tests: March 2025
  - Thin carbon fiber support as replacement of the FR4
    - Suppliers inquired for a 100µm thick foils
    - Design and tests: Mid 2025

The completion of the FY23 and FY24 programs will bring us to readiness for CD3.
Therefore no funding request for FY25 R&D

Preparation for JLAB Beam Test

Kondo Gnanvo, Marcus Hohlmann, Pietro Iapozzuto,
Alexander Kiselev, Huong Nguyen
BNL, Florida Institute of Technology, JLAB, U. Virginia

Solutions for problems encountered earlier with Cylindrical µRWELL Prototype

- Drift foil (Al-mylar) had developed dents during tests at FNAL (Fig.1)
  - Solution: Mechanical refurbishment of drift foil
    - Added honeycomb on outside of foil (Fig.2)
    - Results show stable drift foil with smooth Al cathode inside (Fig.3)
- We observe large leakage current on one sector under HV & we suspect humidity absorption in the uRWELL kapton or dust particles deposited in the µRWELL holes (Fig. 4)

Fig.1

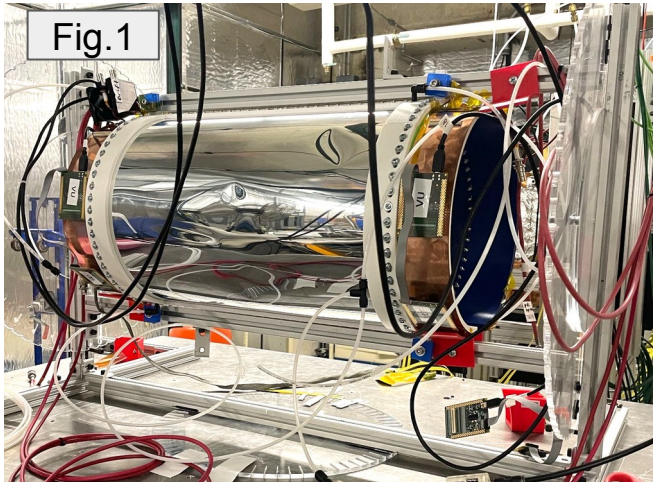


Fig.4

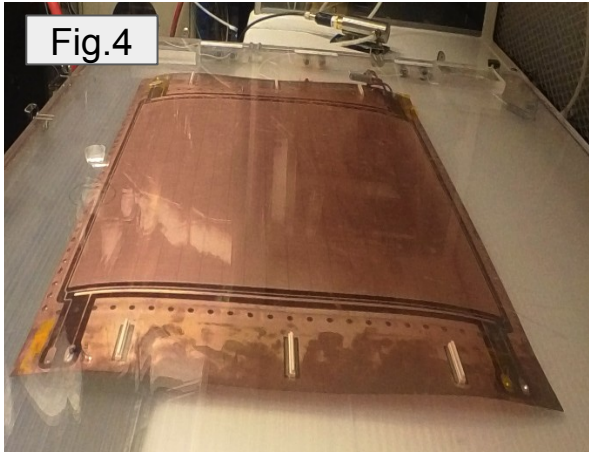


Fig.3

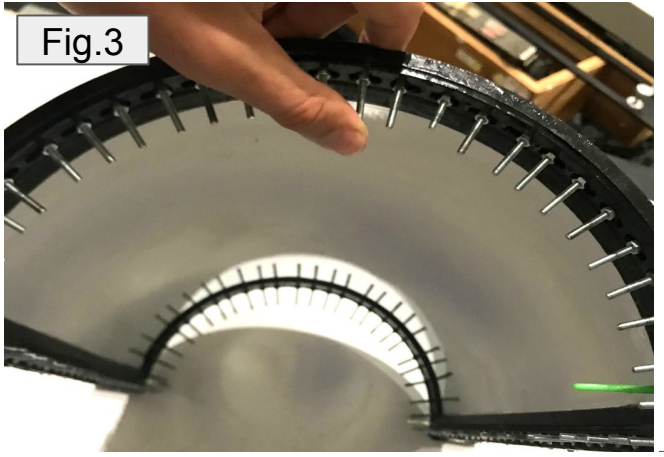
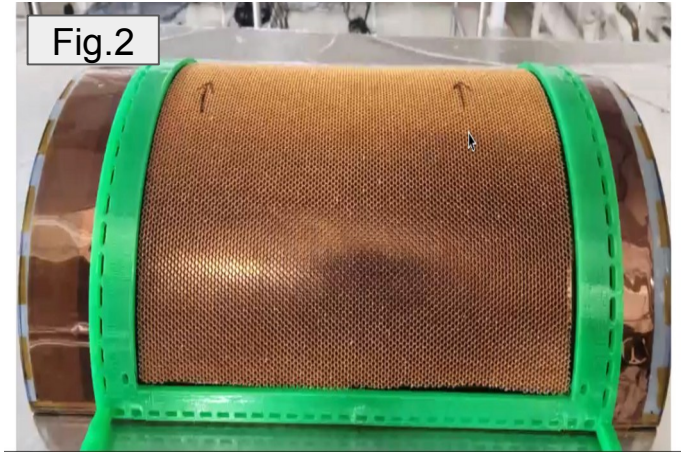


Fig.2

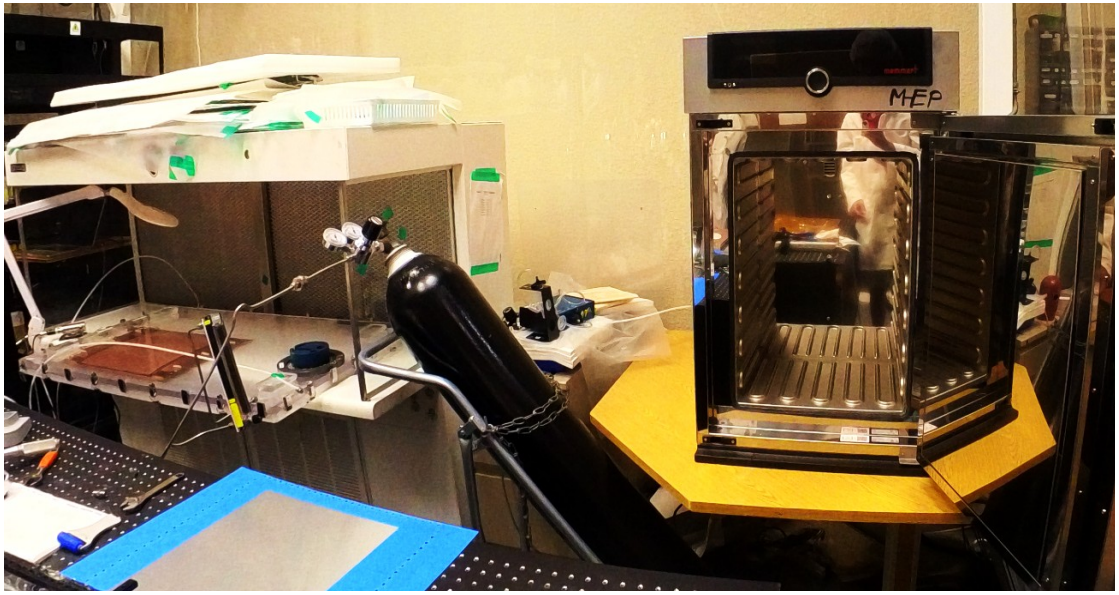


μRWELL Foil Refurbishment Process

- Clean foil with tacky roller
- Monitor dust in cleanroom & gas box

- Bake foil in oven @50°C for 24 hours
- HV test and measuring leakage currents

- If insufficient, possible high-pressure washing of μRWELL foil per CERN recommendation



μRWELL Frame Preparation Process

- 3D-reprinting of frames; no epoxy resin coat applied as resin can flake off
- Gas leak testing and HV test for drift foil with a mock-up foil
- Installing μRWELL foil into assembly
- Gas leak test and HV test on final assembled detector with μRWELL foil

μRWELL prototype timeline

8/2024	Re-assembly and preparation of μRWELL detector
9/2024	HV and gas leak testing
12/2024	Source & cosmics tests at FIT
2/2025	Participation in beam test at JLAB
	(requires $10k in FY25 support for shipping detectors & travel)

μRWELL: DAC Recommendations: August 28 & 29, 2023

Recommendations: **Outer Barrel μRWELL Layer**

1) Explore the possibility of employing professional design engineers.

Response: **Seung Joon Lee** (JLab senior engineer) joins the PED effort and is leading the mechanical design of the full scale prototype

2) Plan for construction and testing of a full-scale prototype with actual μRWELL foil.

Response: we are projecting a full-scale outer μRWELL to be built staring in a few months

Recommendations: **Endcap μRWELL layers**

2) Explore the possibility of employing professional design engineers.

Response: **Seung Joon Lee** (JLab senior engineer) joins the PED effort and is leading the mechanical design of the full scale prototype

2) Accelerate the design and development of a prototype.

Response: We have INFN Roma II (**Dr. Annalisa D'Angelo**) in, and they plan to buy an engineering test article for the disks.

3) Plan for earliest possible beam tests of a prototype as this is a new technology employed on a large scale.

Response: INFN Roma II plans to buy an engineering test article for the disks.

Backup

CyMBaL: DAC Recommendations: August 28 & 29, 2023

Recommendations: **Micromegas Barrel Tracker**

1) Resolve issues between DAQ systems for MM prototype and beam telescope. Produce beam test results from MAMI.

   Response: As shown in the slides, the reconstruction of the data has been done successfully and the analysis performed. Unfortunately, the level of multiple scattering prevents us to draw firm conclusions from this test

2) Continue with full scale prototyping, focusing on critical issues to prepare for CD2/3.

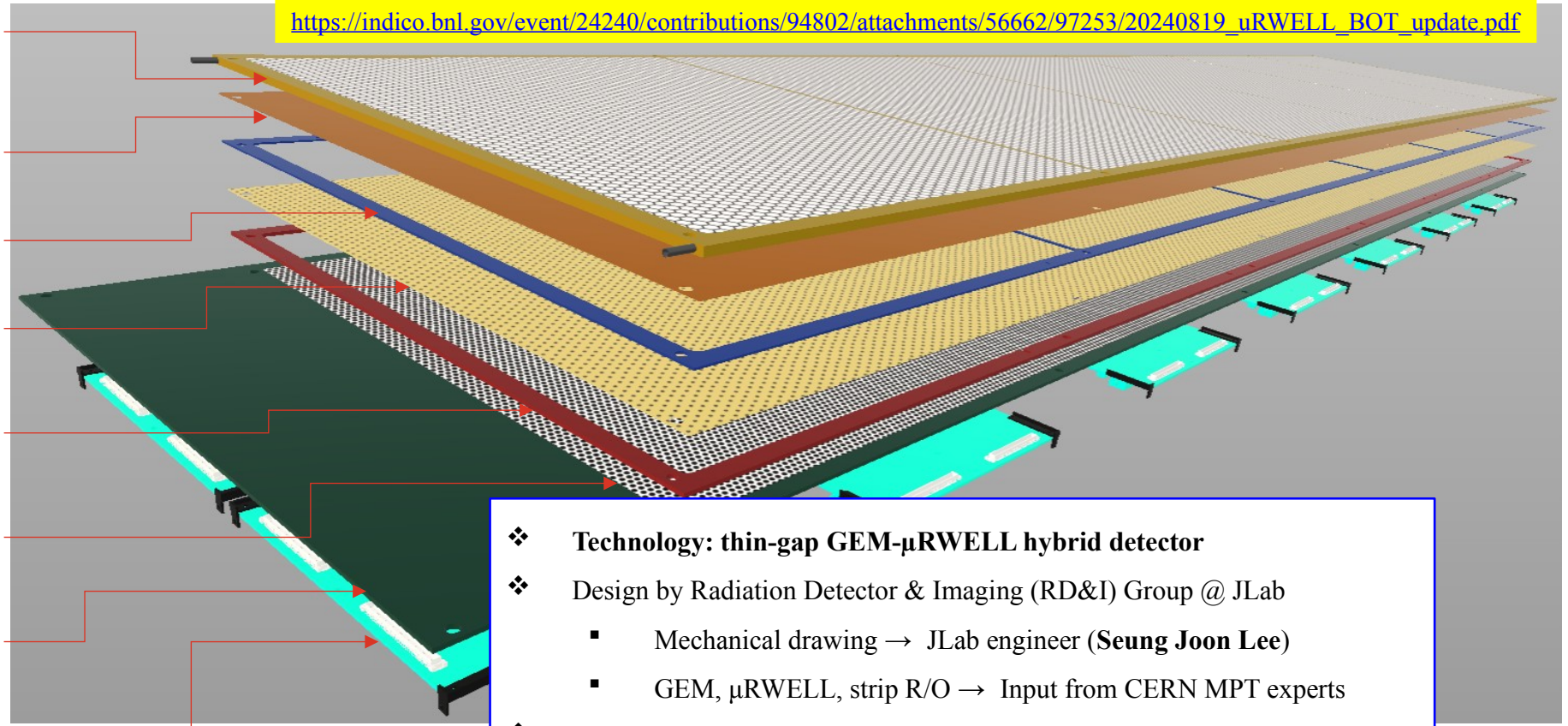
   Response: We have shown the progress toward the scale 1:1 prototype

3) Complete thin-gap design studies as soon as possible.

   Response: The adaptation of the small prototype for the 1mm gap is ongoing and tests will be completed in the first half of 2025

PED Engineering Test Article: Design & fabrication of **full scale** µRWELL-BOT module

https://indico.bnl.gov/event/24240/contributions/94802/attachments/56662/97253/20240819_uRWELL_BOT_update.pdf



- **Technology: thin-gap GEM-µRWELL hybrid detector**
- Design by Radiation Detector & Imaging (RD&I) Group @ JLab
  - Mechanical drawing → JLab engineer (**Seung Joon Lee**)
  - GEM, µRWELL, strip R/O → Input from CERN MPT experts
- Construction and preliminary tests of the module - 05/2025
- Test article module expected in beam test @ FNAL - 07/2025

Plans & timeline for PED Engineering Test Article: µRWELL-BOT module

https://indico.bnl.gov/event/24240/contributions/94802/attachments/56662/97253/20240819_uRWELL_BOT_update.pdf

- **Jan 2024 – Dec 2024:** Mechanical drawing of all parts of the detector almost completed
- **Dec. 2024 – Jan. 2025:** Complete design of GEM foils, µRWELL PCB and U-V capacitive-sharing readout → JLab RD&I – CERN MPT
- **October 2024 – March 2025:** Set up class 1000 Clean Room and infrastructure for assembly and test of the module @ JLab
- **End January 2024:** Expected delivery of the GEM foils, µRWELL PCB and U-V capacitive-sharing readout
- **March 2025 – June 2025:** HV test of the GEM foils, µRWELL PCB and assembly into a detector in clean room
- **June / July 2025 – :** Characterization of µRWELL-BOT engineering test article in cosmic and in beam test (Fermilab or CERN)