

ePIC MPGD Trackers Test beam Plans & Other ongoing R&Ds

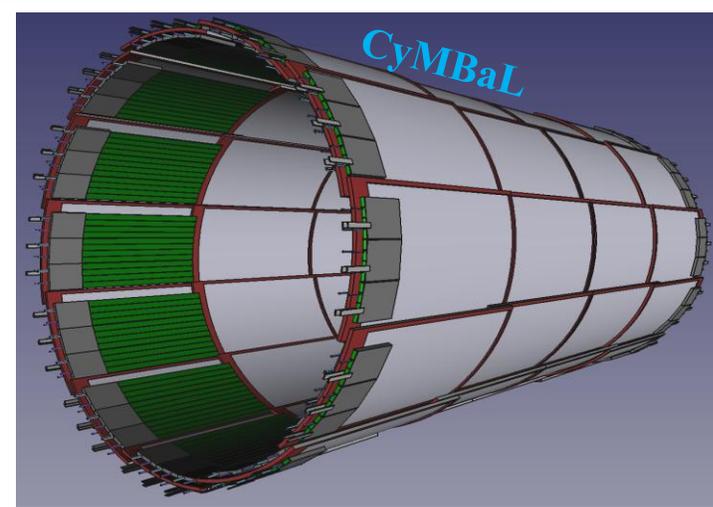
Kondo Gnanvo, Surabhi Tarafdar, Annalisa D'Angelo, Stefano Gramigna, Francesco Bossu, Fabien Jeanneau

7th DRD1 Collaboration Meeting - February 23 – 27, 2026, CERN

- ❖ Overview of ePIC MPGD Trackers & Test beam
 - CyMBaL: Module description – Test beam plans, goals & requirements
 - MPGD-BOT: Module description – Test beam plans, goals & requirements
 - MPGD-ECT: Module description – Test beam plans, goals & requirements

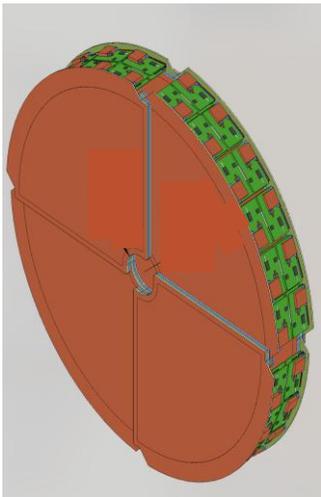
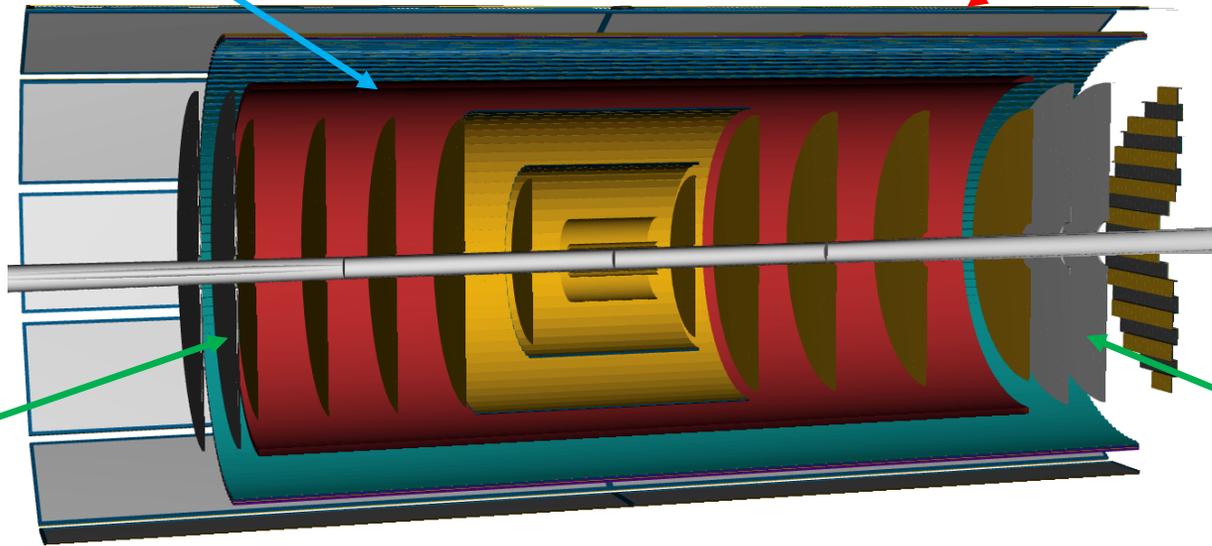
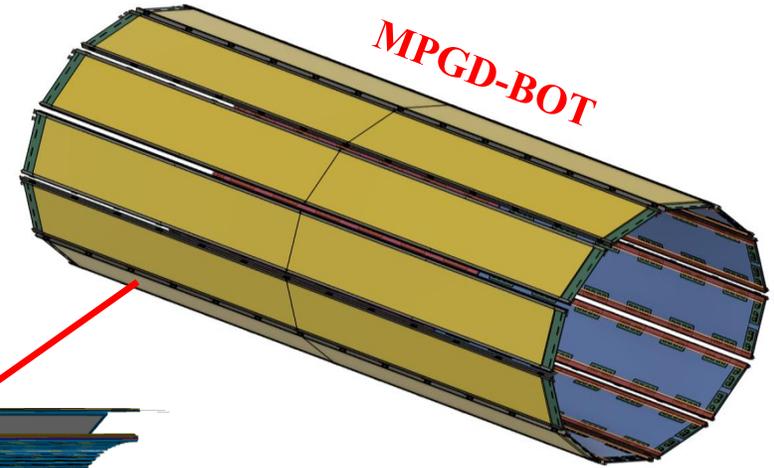
- ❖ Double-side Thin-Gap GEM- μ RWELL Prototypes
 - R&D goals and test beam plans, goals & requirements

- ❖ μ RWELL-PICOSEC Prototypes
 - R&D goals and test beam plans, goals & requirements



Barrel Trackers

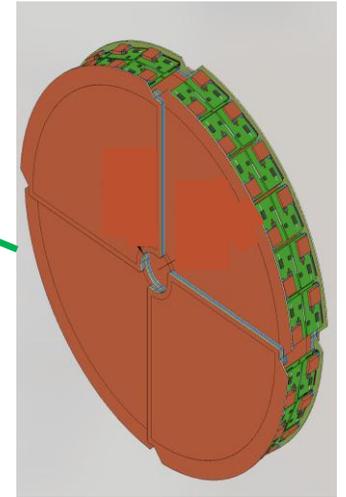
- **CyMBaL: Cylindrical Micromegas Barrel Layer**
 - ✓ Micromegas based
- **MPGD-BOT: Barrel Outer Tracker**
 - ✓ Thin gap GEM- μ RWELL hybrid based



Lepton MPGD-ECT

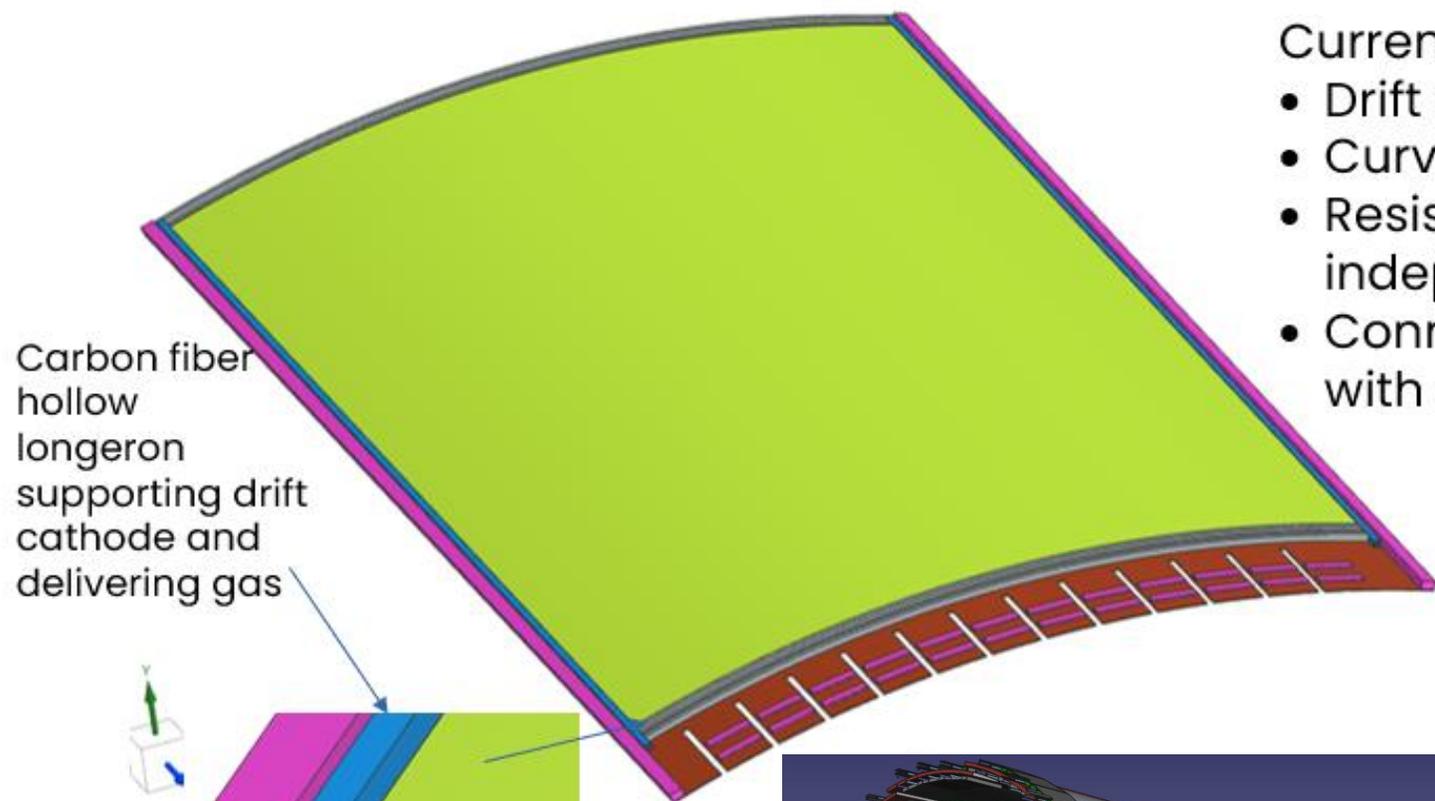
End cap trackers

- **MPGD-ECT: End Cap Tracker**
 - ✓ GEM- μ RWELL based



Hadron MPGD-ECT

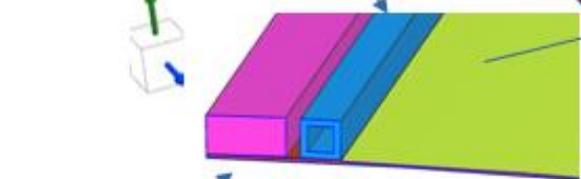
CyMBaL: Cylindrical Micromegas Barrel Layer



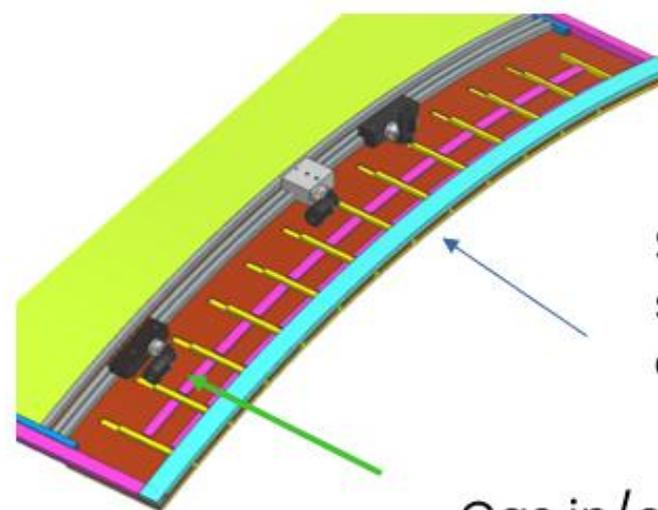
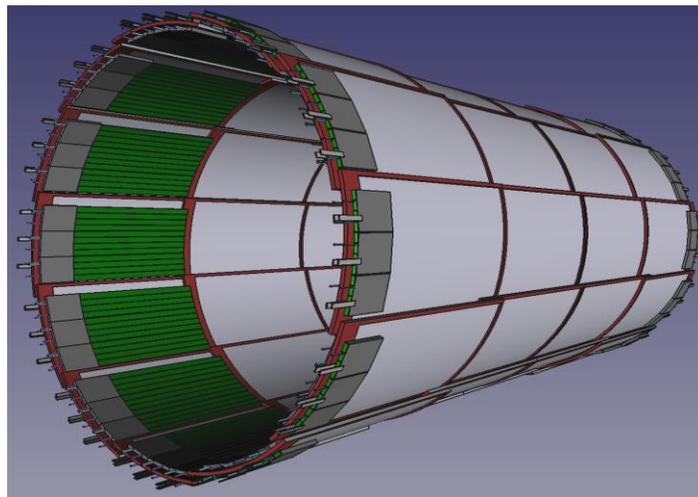
Carbon fiber hollow longeron supporting drift cathode and delivering gas

Current design status of the size 1:1 test article

- Drift gap: 3 mm
- Curvature radius : 56.5 cm
- Resistive layer divided in 4 zones with independent HV connections
- Connectors: low profile 40 pins KEL connectors with associated micro-coaxial cables



Plastic support for attachments to external supports



Stiffeners to secure connectors

Gas in/out

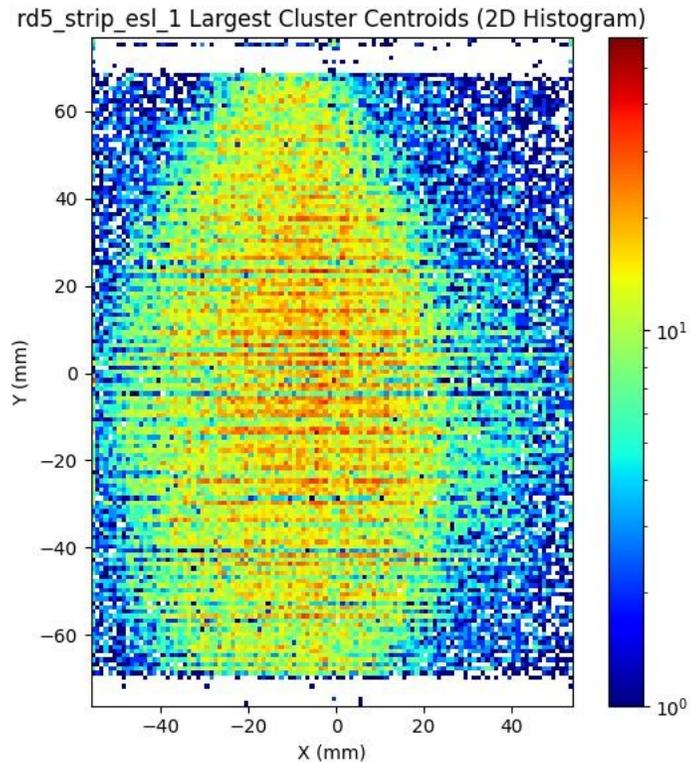
CyMBaL: Setup and Goals and requirements

Goals

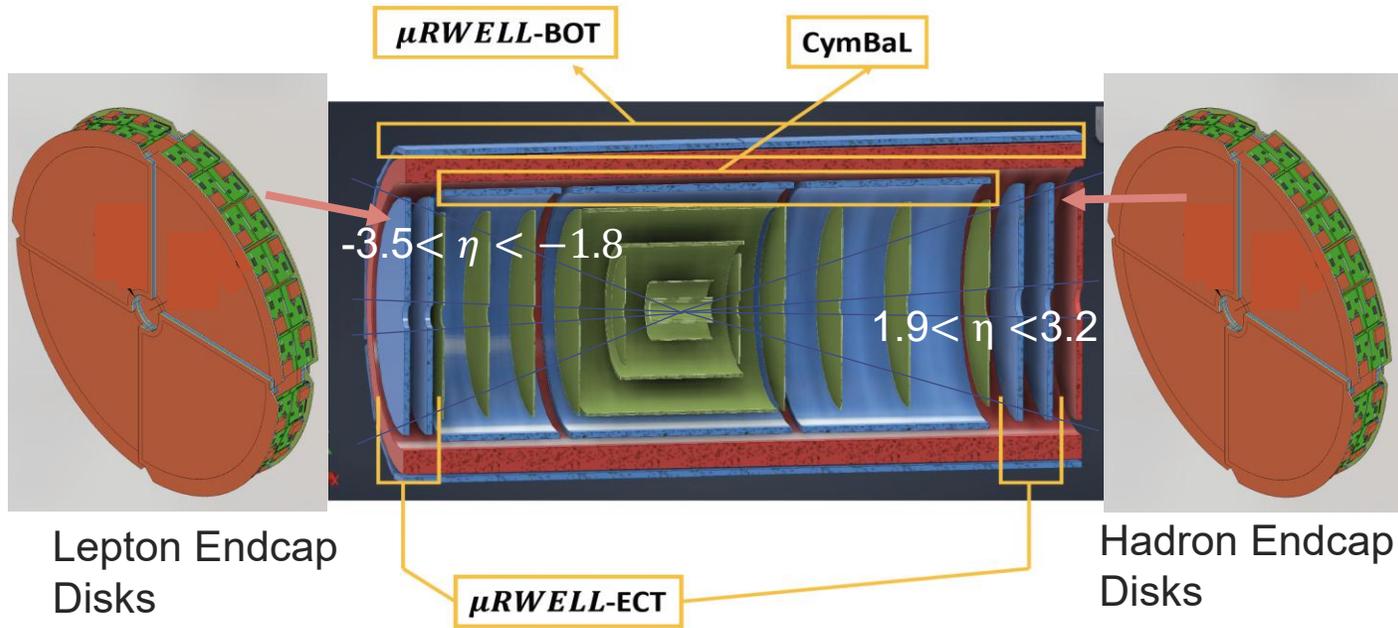
- ❖ Test of the scale 1 prototype (see previous slide)
- ❖ Spatial resolution and efficiency studies
- ❖ Time resolution?
- ❖ Inclined tracks reconstruction
- ❖ 1 mm and 3 mm drift gaps

Reqiruements

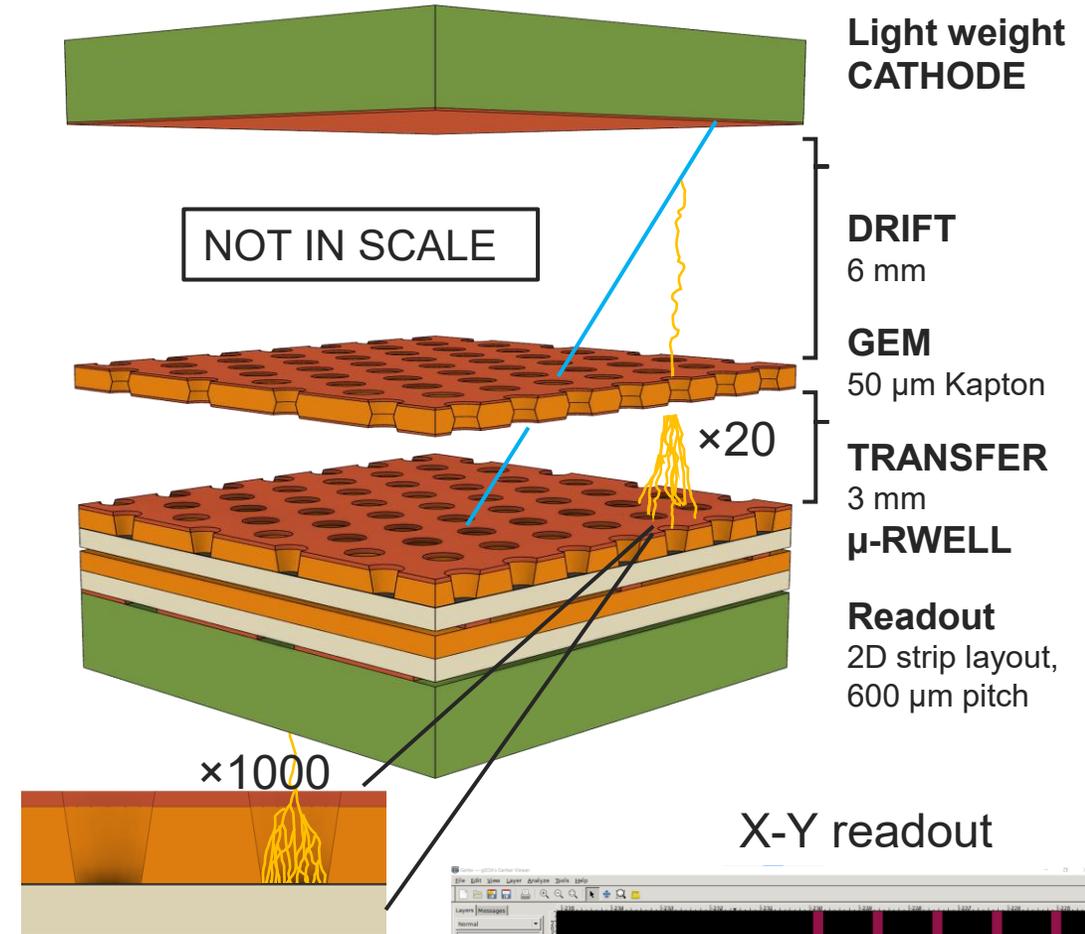
- ❖ Trigger from DRD1
- ❖ Ar/CO₂/ISO (93/5/2)
- ❖ Silicon pixel reference
- ❖ Readout with DREAM electronics
- ❖ Test bench like in November 2025
- ❖ DESY table desirable for position scan



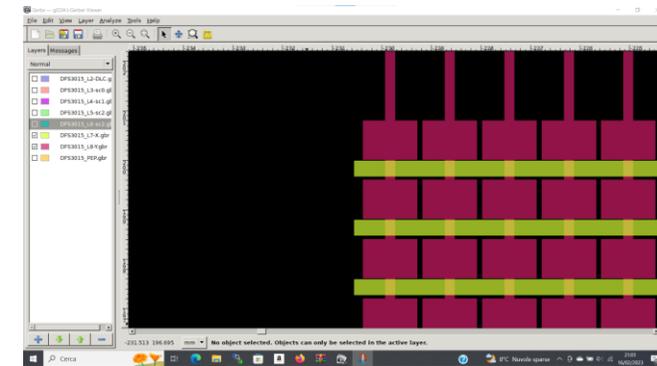
ePIC MPGD Endcap Trackers: MPGD-ECT



GEM – μRWELL technology



X-Y readout



❖ Two MPGD Endcap Tracking (ECT) disks both in the **hadronic** and in the **leptonic regions** increase the number of hits in the $|\eta| > 2$ region to improve pattern recognition.

MPGD-ECT disks

- ❖ GEM- μRWELL hybrid configuration guarantees gain higher than 10^4
- ❖ 2D strip read-out a “COMPASS-like” scheme
- ❖ 600 μm pitch guarantees a spatial resolution better than 150 μm
- ❖ time resolution ~10 ns

On-detector Front End Boards (FEBs) based on SALSA chips

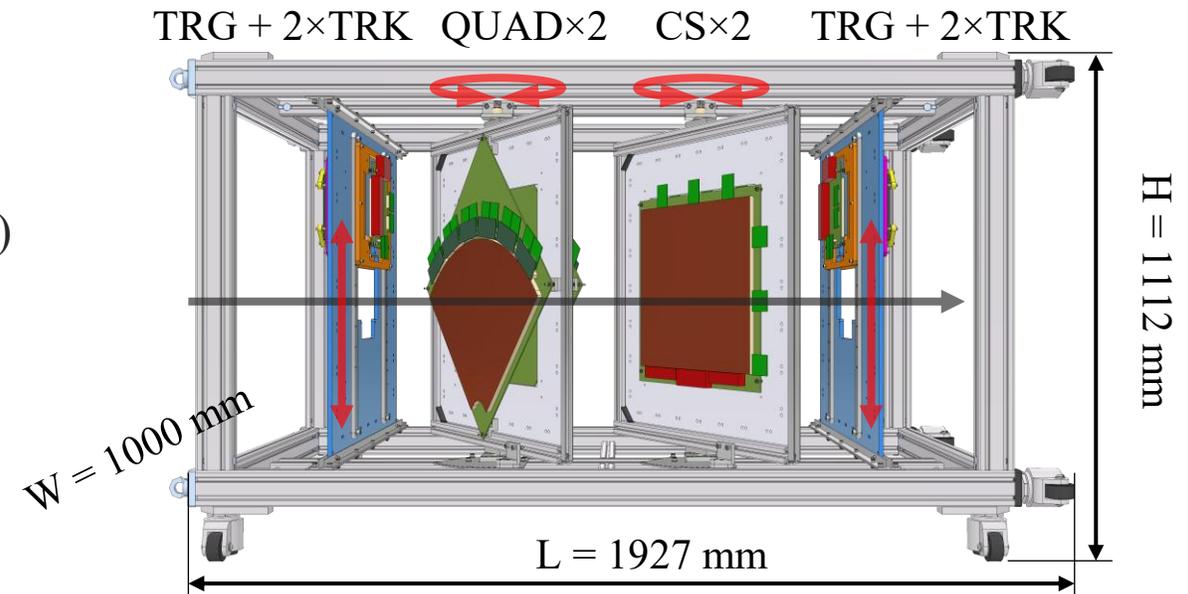
MPGD-ECT: Setup, Goals & Requirements

Objectives:

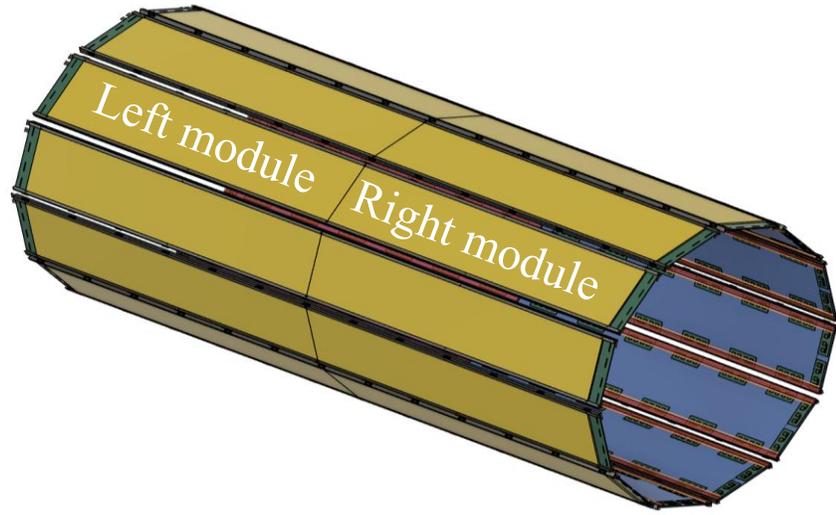
- ❖ Performance studies with different gas mixtures
- ❖ Performance mapping with standard gas mixture (position scan)
- ❖ Angle of incidence scan with standard gas mixture
- ❖ Time performance studies

Requests:

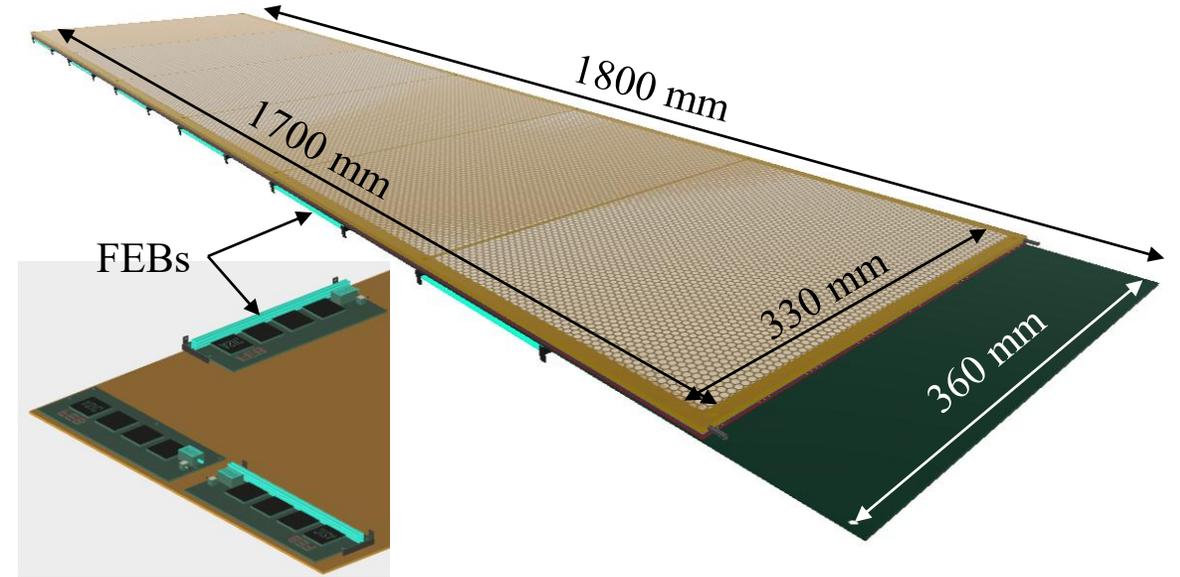
- ❖ 5 gas lines (4 IN, 1 OUT)
- ❖ Gas needs
 - Ar, CO₂, CF₄, N₂
 - Premix Ar:CO₂:CF₄ (45:40:15) or Ar:CO₂ (80:20)
 - Premix to test Ar:CO₂:iC₄H₁₀ (93:2:5) + TBD
- ❖ Large red moving table!!! (For position scans with our large setup)



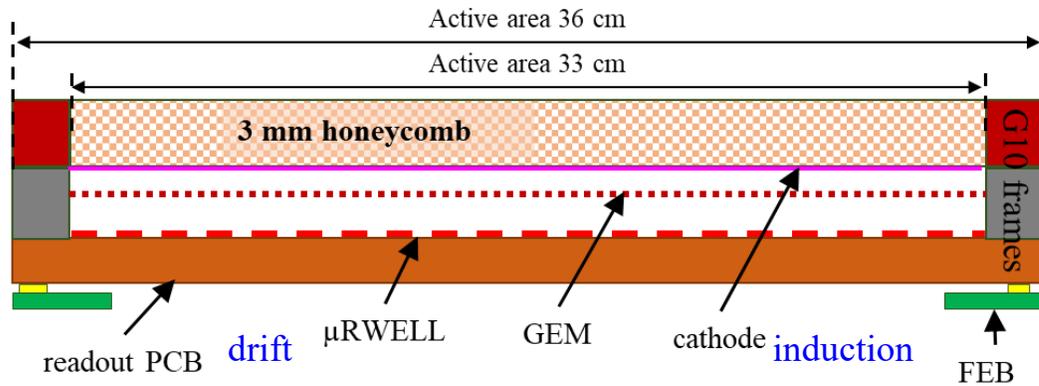
DET	Pitch (μm)	Active Area	Readout	Capacitive Sharing
TRK	400	10x10 cm ²	2D XY	No
QUAD	600	R = 45 cm	2D XY	No
CS	1200	46x40 cm ²	2D XY	3 Layers (300 μm)
TRG	NA	15x15 cm ²	SiPM	NA



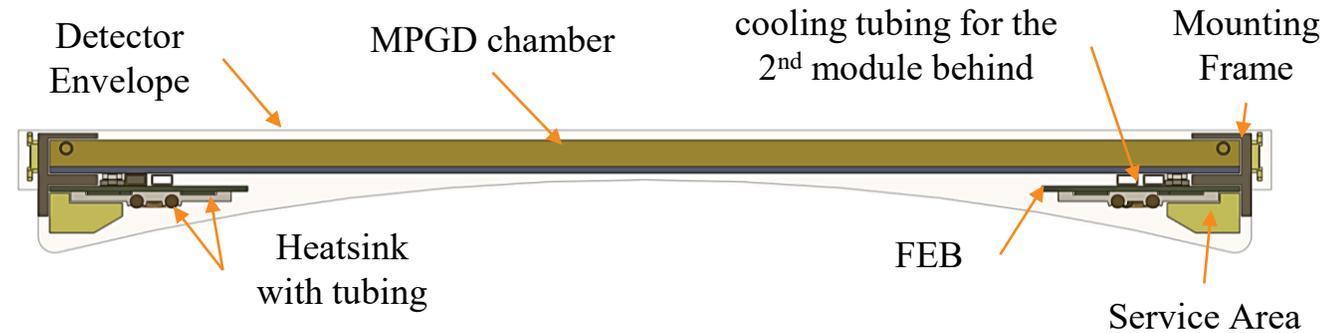
MPGD Barrel Outer Tracker (MPGD-BOT)



MPGD-BOT module: Full scale test article (aka prototype)



Thin-gap GEM- μ RWELL Hybrid Detector



MPGD-BOT module cross sectional view

https://www.jlab.org/sites/default/files/eic_rd_prgm/files/2023_Proposals/20230714_eRD_tgMPGD_Proposal_FY23_Final_EICGENRandD2023_16.pdf

MPGD-BOT prototype beam test goals

- ❖ HV scans for spatial resolution & efficiency studies
- ❖ Performance in magnetic field up 1.5 T field (**pions beam**)
- ❖ Gas mixtures studies: stability vs. performance

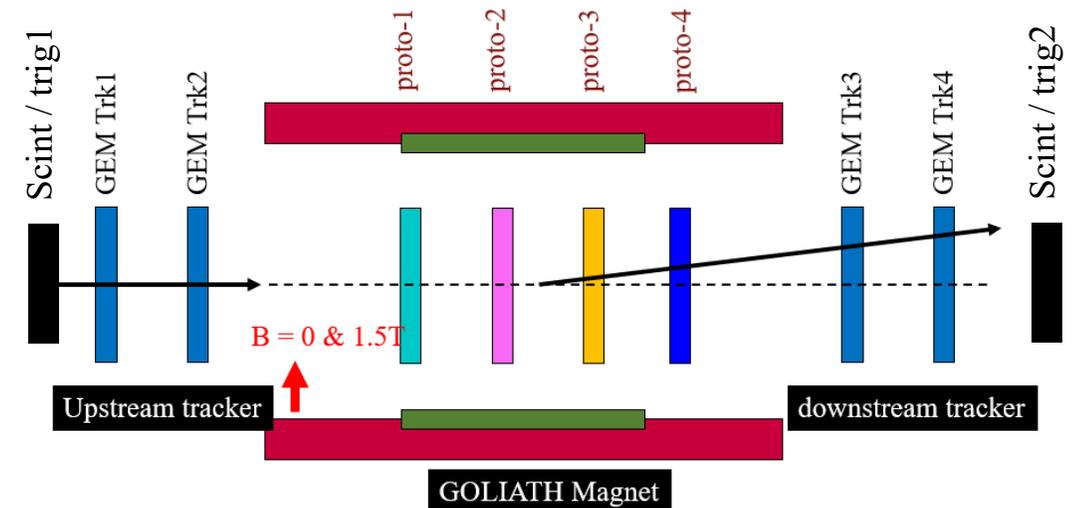
Setup: MPGD-BOT prototype inside GOLIATH magnet

- ❖ MPGD-BOT support frame: $\sim 200 \text{ cm} \times 40 \text{ cm} \times 40 \text{ cm}$ (in GOLIATH)
- ❖ Upstream & downstream GEM frames: Two $\sim 40 \text{ cm} \times 40 \text{ cm} \times 20 \text{ cm}$
- ❖ Readout with APV25+SRS with JLab CODA DAQ
- ❖ Scintillator / PMT coincidence trigger

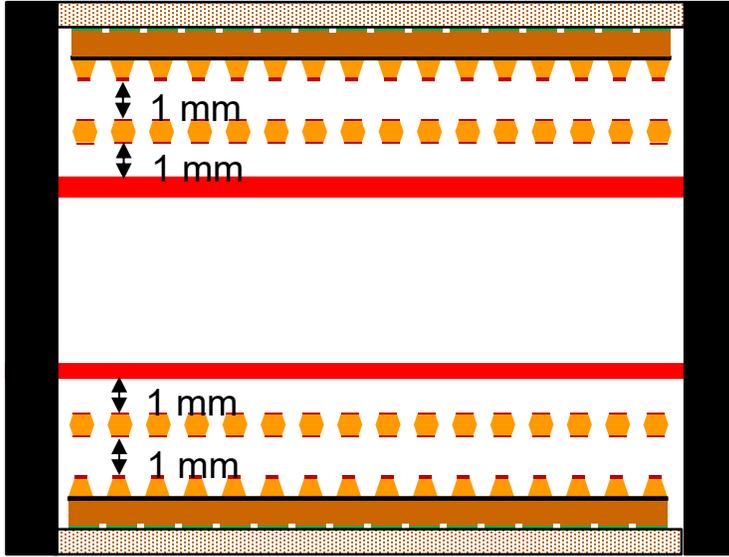
Requirements

- ❖ Access to GOLIATH magnet (**all beam time if possible**)
- ❖ Two **fixed stands** upstream & downstream GOLIATH magnet for the GEM trackers
- ❖ Gas needs:
 - ❖ Ar:CO₂ 80/20, Ar:CO₂:iC₄H₁₀ 93:2:5 (or 93:5:2 if flammable or availability concerns)
 - ❖ Will use gases from INFN mixing system if operational for performance studies in gas

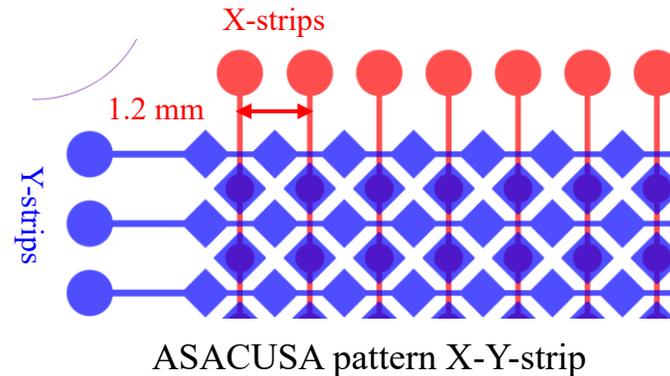
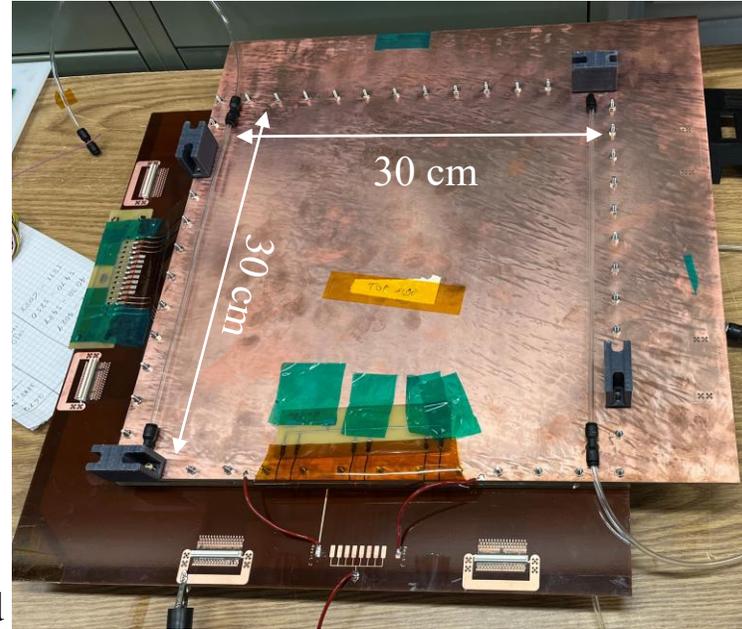
Layout of beam test setup



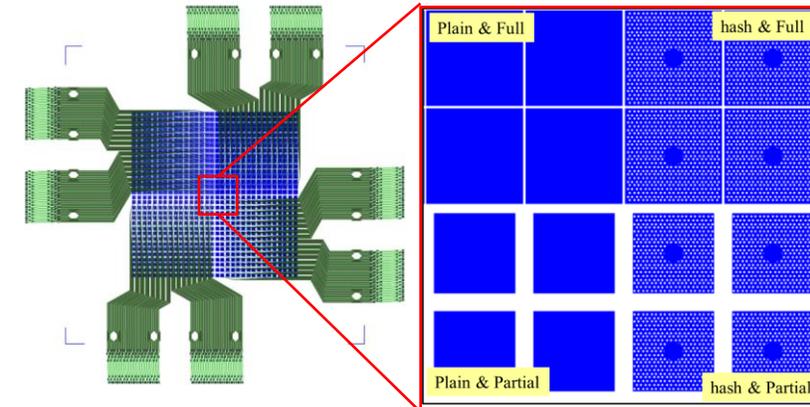
S. Tarafdar - PI (JLab)



Medium prototype with X-Y strip readout



Small prototype with pad readout



Pad readout PCBs

- 3.2 mm pitch
- 4 quadrants with pad patterns

❖ Double-sided thin-gap GEM- μ RWELL hybrid detectors with capacitive-sharing readout.

❖ Two prototypes in beam test

❖ Position resolution & HV scan

❖ Performance in B-field

❖ **Share setup and gas needs with MPGD-BOT**

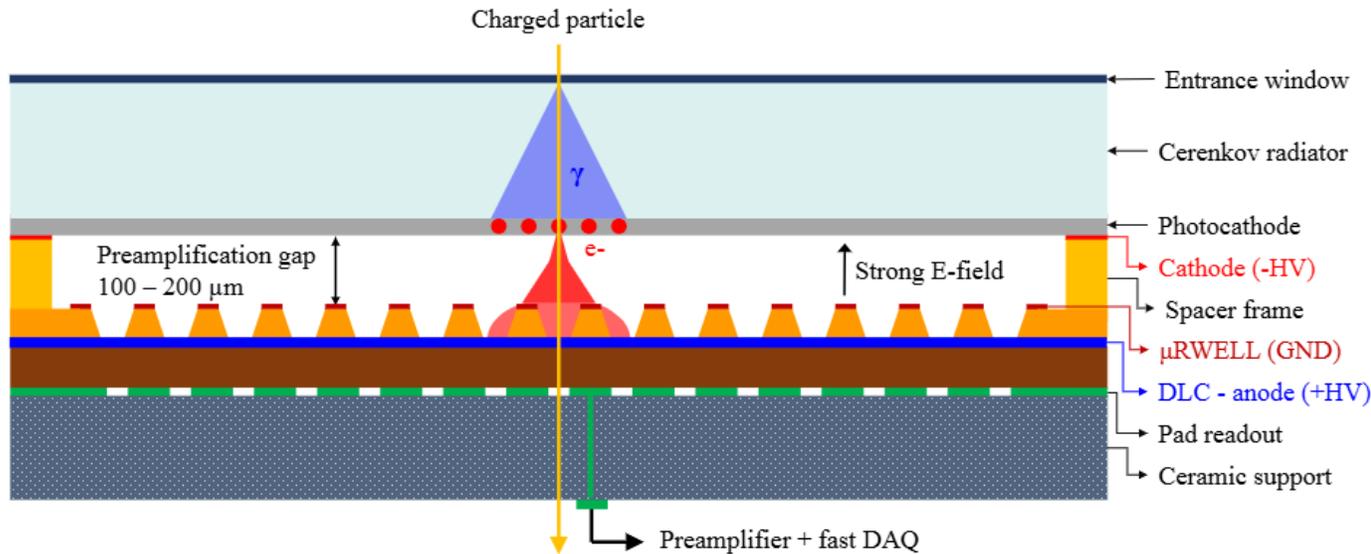
https://www.jlab.org/sites/default/files/eic_rd_prgm/files/2023_Proposals/20230714_eRD_tgMPGD_Proposal_FY23_Final_EICGENRandD2023_16.pdf

M. Hohlmann - PI (FIT) & K. Gnanvo (JLAB)

Motivation (dual use):

1. Detection of delayed charged particles from long-lived particle decays in muon system, e.g. $H \rightarrow X_{LLP}^0 X_{LLP}^0 \rightarrow \ell^+ \ell^- \ell^+ \ell^-$
2. Particle identification using time-of-flight (ToF) detector outside central tracker (“barrel timing wrapper”)

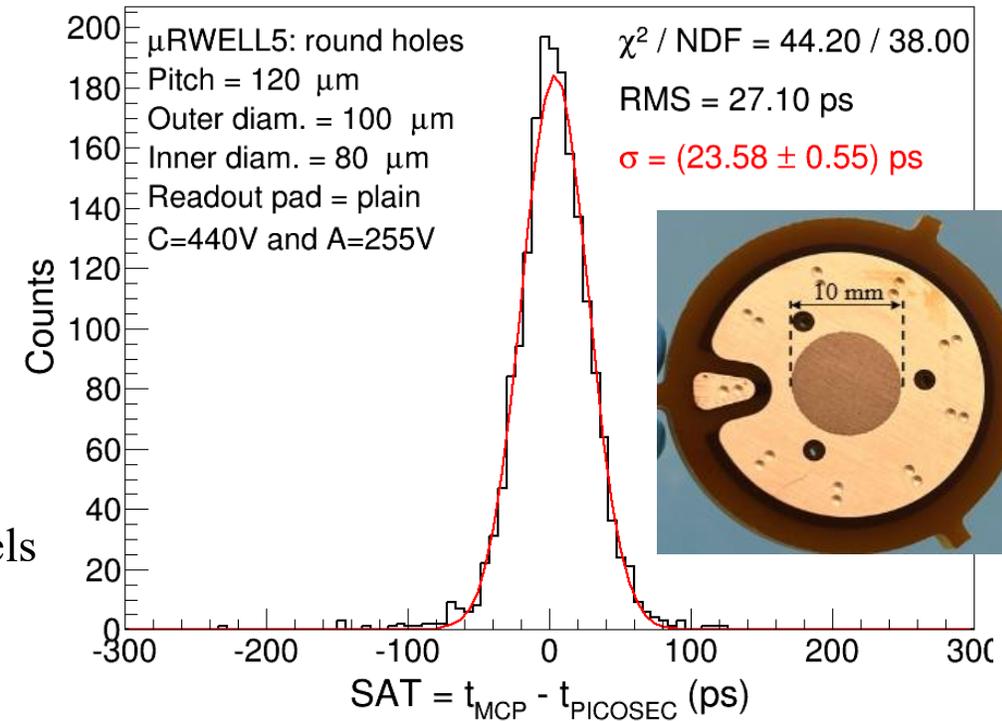
Concept: μ RWELL-PICOSEC detector (MPGD with Cherenkov radiator)

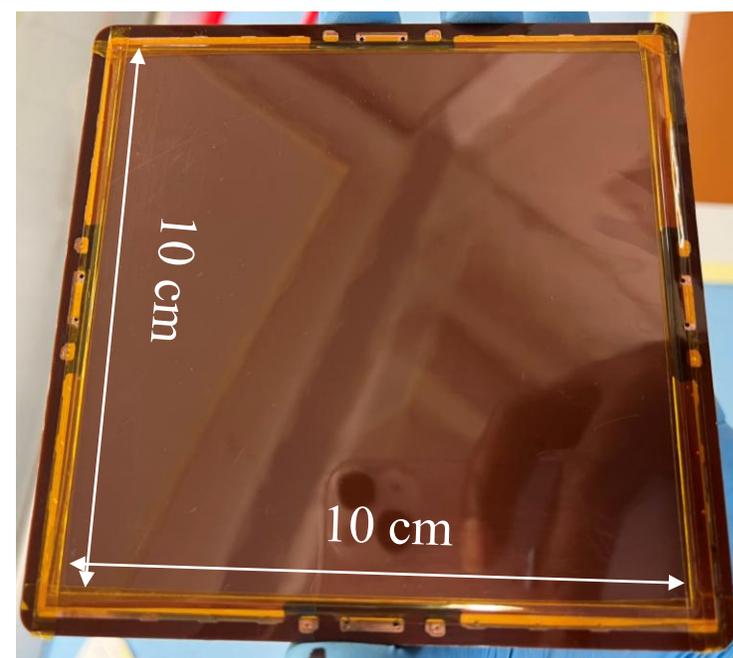


Approach:

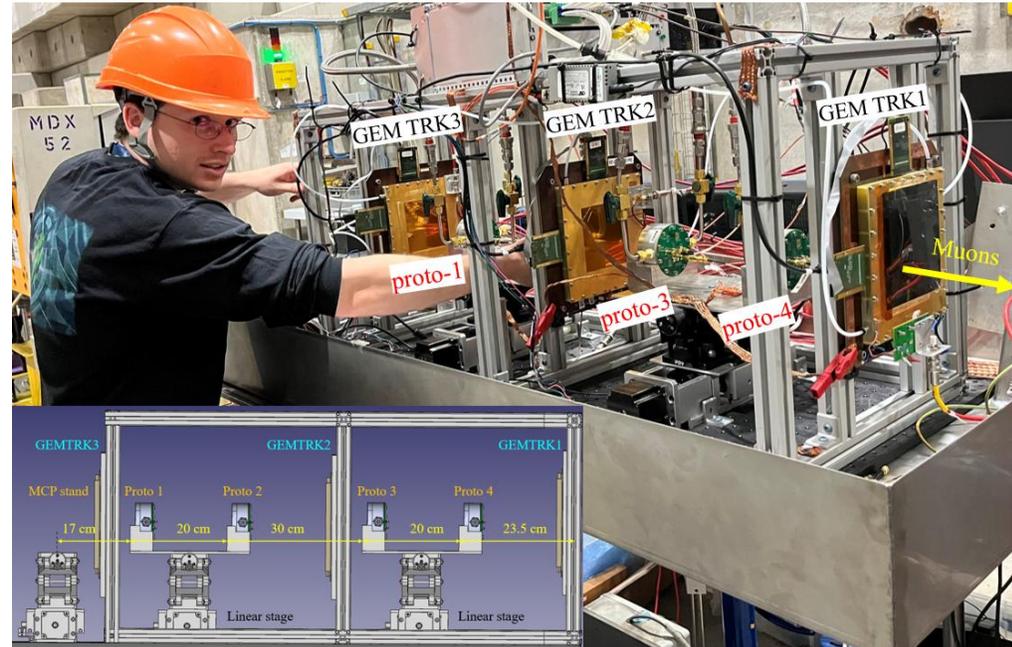
1. Design, construction, & test of 10cm×10cm prototype with 100 channels
2. Photocathode:
 - non-hygroscopic Diamond-like Carbon (DLC) instead of CsI
3. Beam test at CERN in summer 2026

First beam test results with single-pad μ RWELL-PICOSEC prototype

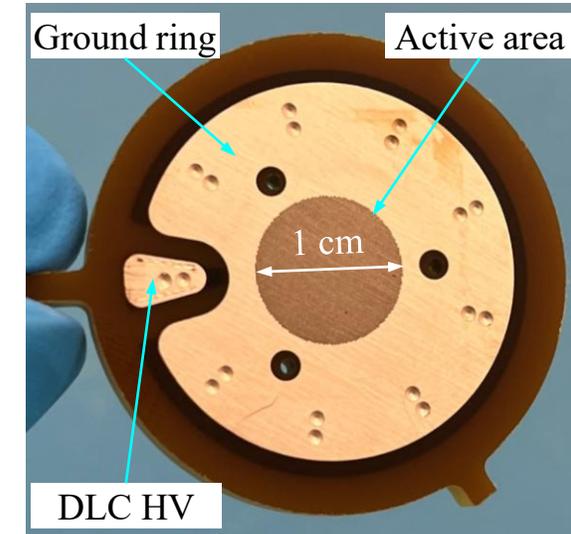




Large prototype (100-pads readout)



JLab PICOSEC telescope



Single-pad prototype

Large prototype: (preferably in CERN PICOSEC Telescope)

- ❖ New prototype with some minor modifications (HV contacts)
- ❖ Test primarily with DLC photocathode
- ❖ Single & Multi-channels with SAMPIC
- ❖ Voltage and Position scans for response uniformity
- ❖ Drift gap studies

Single-pad prototypes: (JLab PICOSEC-MM Telescope)

- ❖ 50 μ m and new 75 μ m μ RWELL prototypes
- ❖ Primarily with DLC photocathode
- ❖ Voltage and Position scans for response uniformity
- ❖ μ RWELL hole geometry and sizes
- ❖ Drift gap studies

Physics Scope and planned measurements: Characterization of ePIC MPGD tracker full scale 1:1 PED test articles

- ❖ **MPGD-BOT setup:** Standalone telescopes (include Generic R&D double thin-gap protos) → thin gap hybrid GEM- μ RWELL test article
- ❖ **MPGD-ECT setup:** Standalone telescope for hybrid GEM- μ RWELL full scale engineering test article + 46 cm \times 40 cm prototypes
- ❖ **CyMBaL setup:** Standalone telescope for curved full size Micromegas + small prototypes

Measurements: Efficiency, timing and position resolution studies through

- ❖ HV scans, position scan, angle scan, gas mixture studies (timing)
- ❖ performance in magnetic field (GOLIATH Magnet for MPGD-BOT setup)

Beam requirements when relevant (muons, pions, electrons, momentum, polarity, rate – high/low/scan)

- ❖ High momentum muons, narrow pions and (electrons?) all OK → rate scan desirable at the beginning of the test beam campaign

Required gas (mixtures and approximate amount – important to know asap)

- ❖ Ar-CO₂ (80/20) for the reference trackers (2 -3 bottles) & Ar-CO₂-CF₄ 45/10/45 (existing bottle)
- ❖ Ar-CO₂-iC₄H₁₀ 93/2/5 (3 bottles) or 93/5/2 (2 bottles)
- ❖ Alternatively: Ar (3 bottles) , CO (2 bottles), iC₄H₁₀ (2 bottles) for the INFN 3-gas mixing system → will benefit JLab and Saclay as well

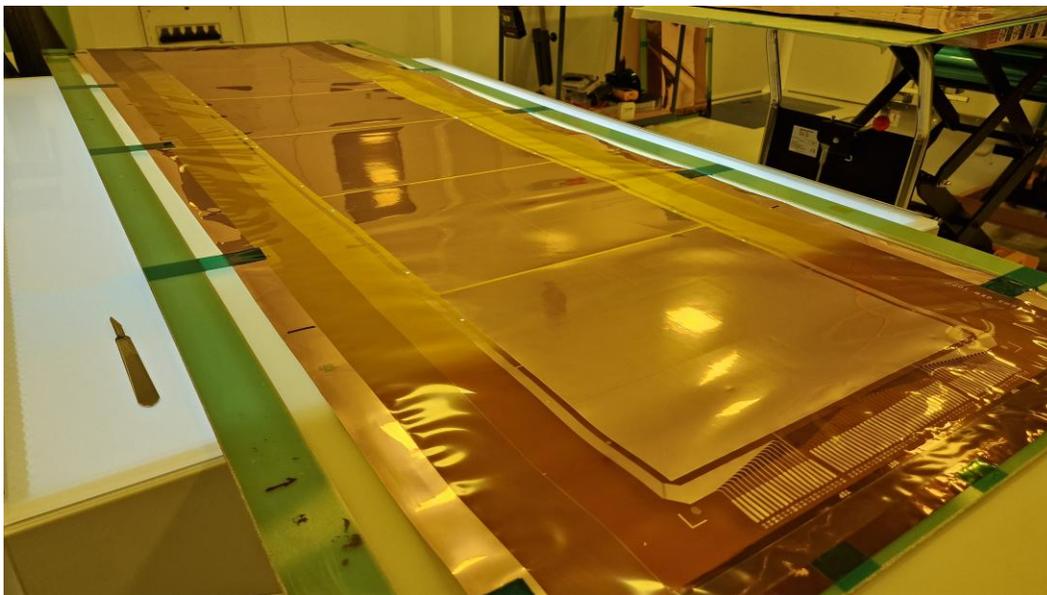
Required infrastructure:

- ❖ Two DESY tables (if possible) for MPGD-ECT and CyMBaL setups
- ❖ DRD1 Trigger signal for CyMBaL setup
- ❖ Two stands upstream & downstream GOLIATH magnets for MPGD-BOT setup

BACKUP

Detector major components are ready

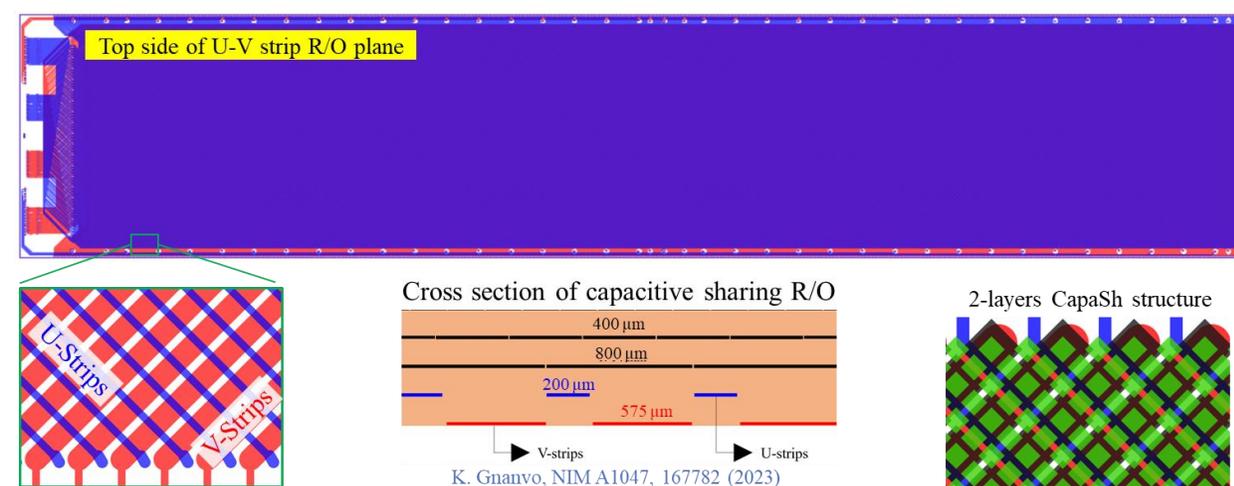
- ❖ GEM foil, μ RWELL / CapaSh-X-Y strip readout PCB and detector support frames are all in hand at JLab
- ❖ Clean room infrastructure and equipment at JLab almost complete
- ❖ Assembly start week of Oct.13th → Completed by December 15th
- ❖ Plan to test performance in beam in Spring-Summer 2026
- ❖ Test article validation in 2026 → Pre-production modules in 2027



GEM foil



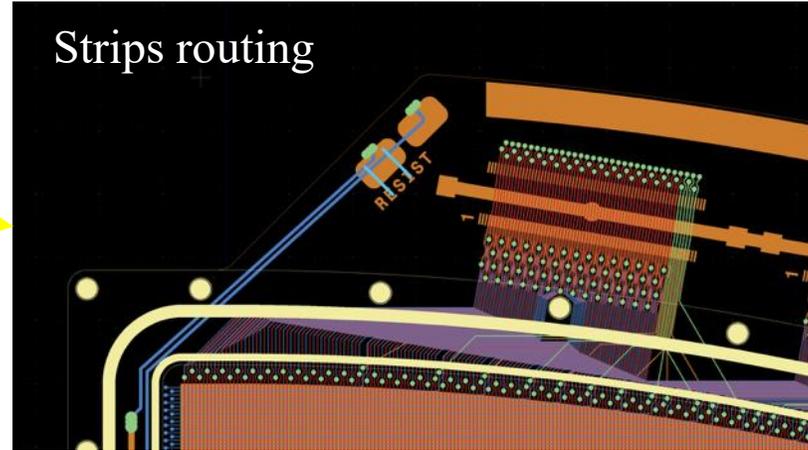
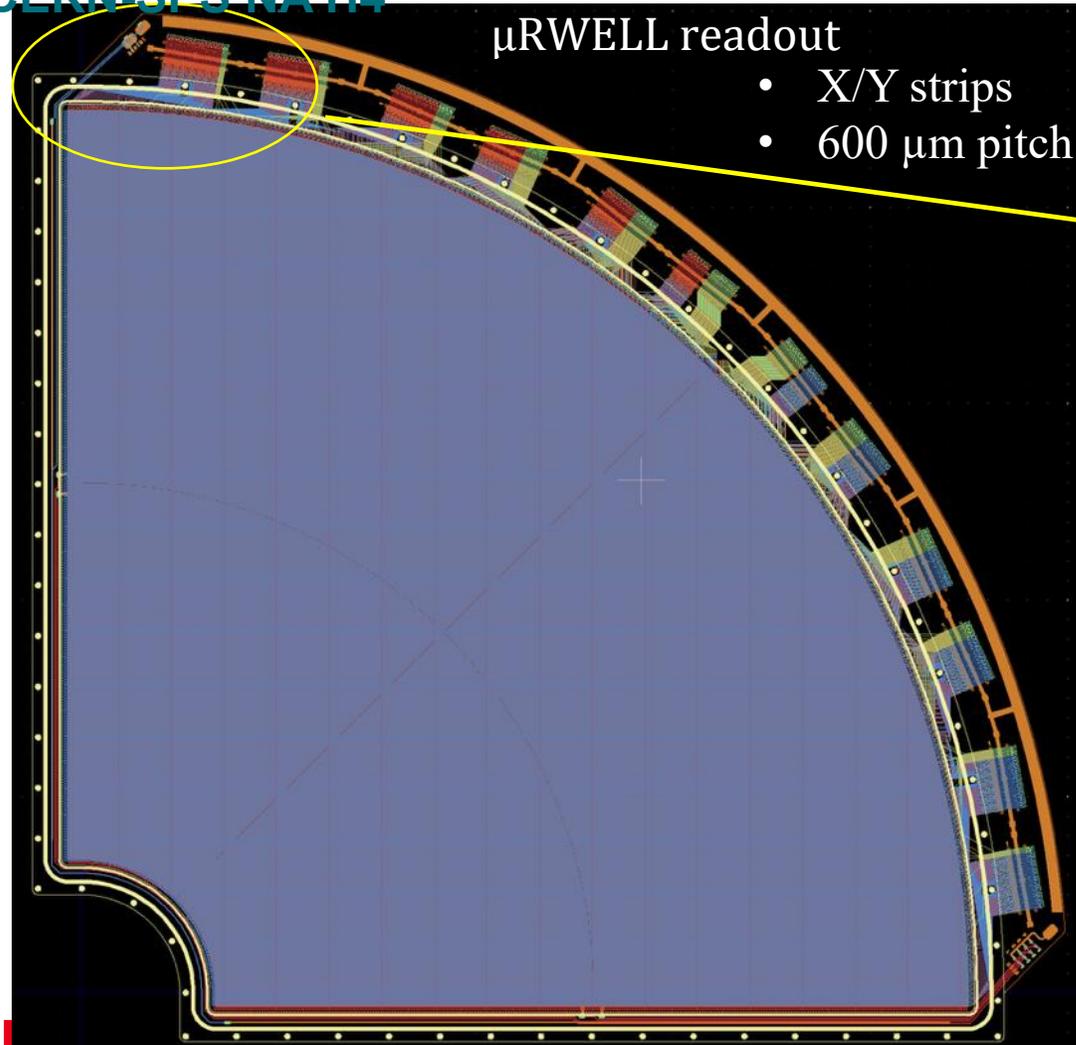
μ RWELL / CapaSh readout PCB: Front view



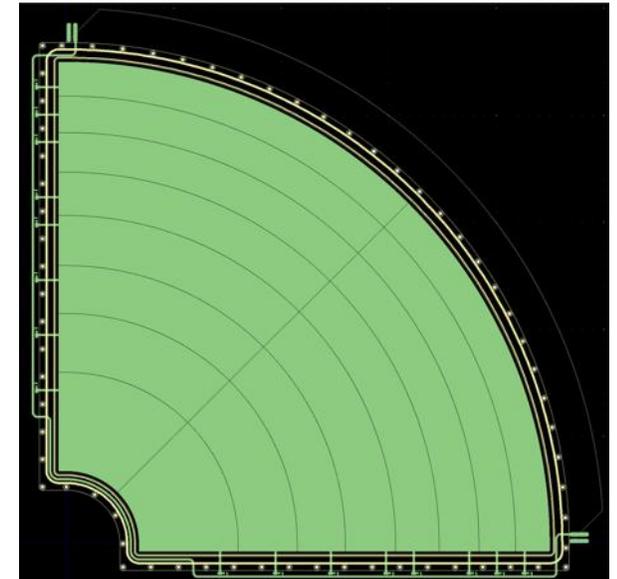
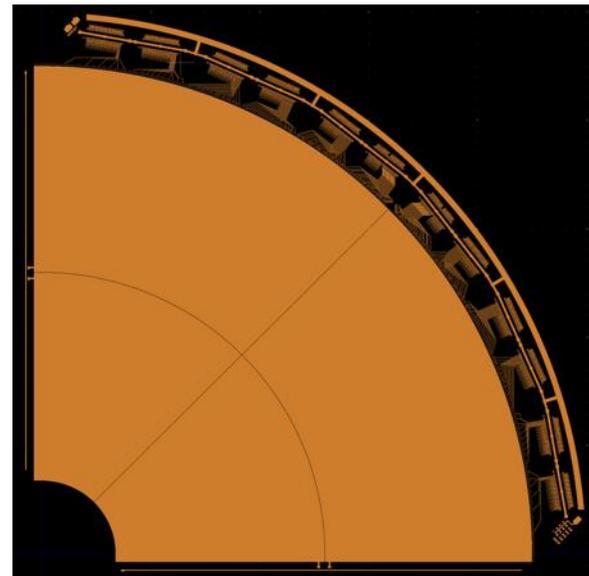
Capacitive sharing readout with X-Y strips @ 45°

ePIC MPGD Endcap Trackers: μ RWELL-ECT

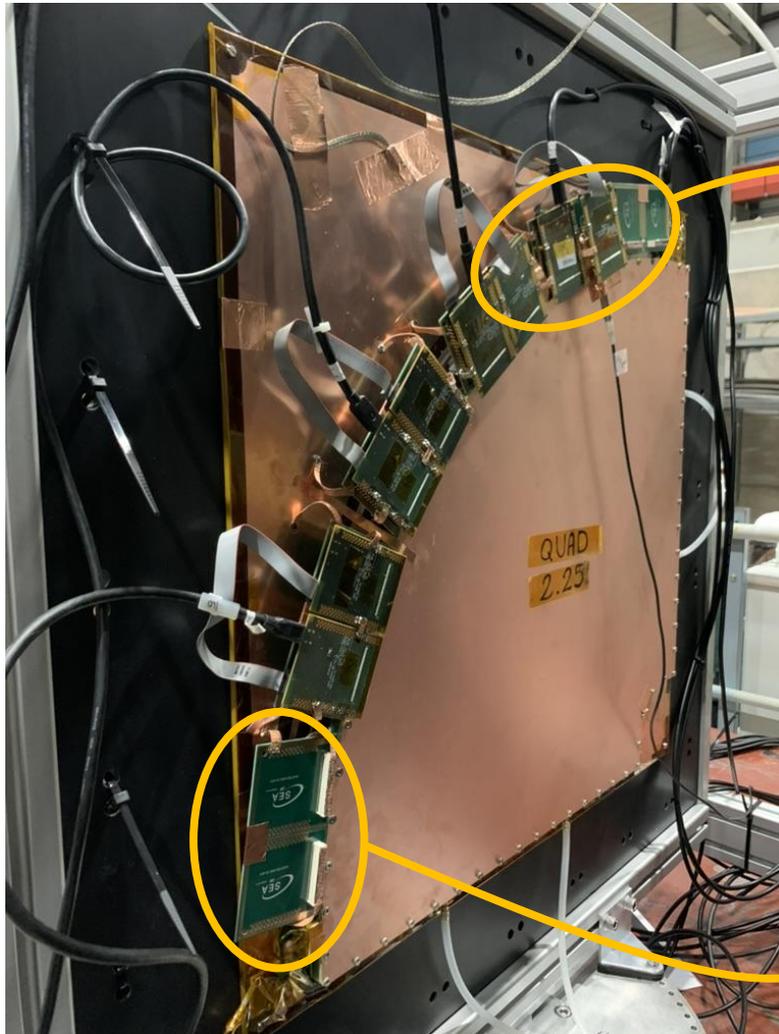
PED Test Article Module to be delivered and characterized in November Test Beam at CERN-SPS NA H4



(X, Y) readout
→ no FEB in the active area



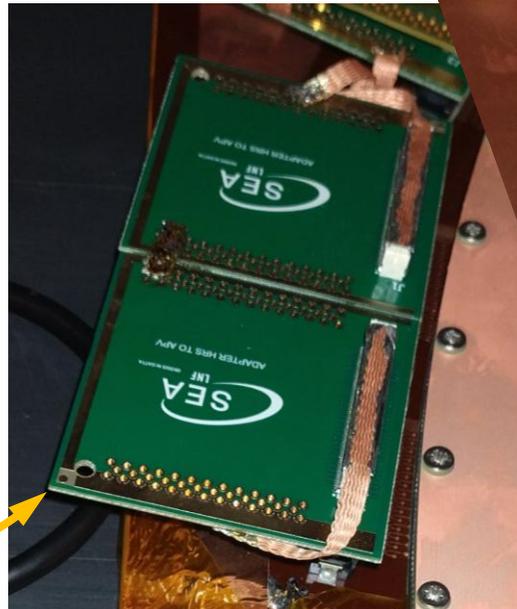
DAQ



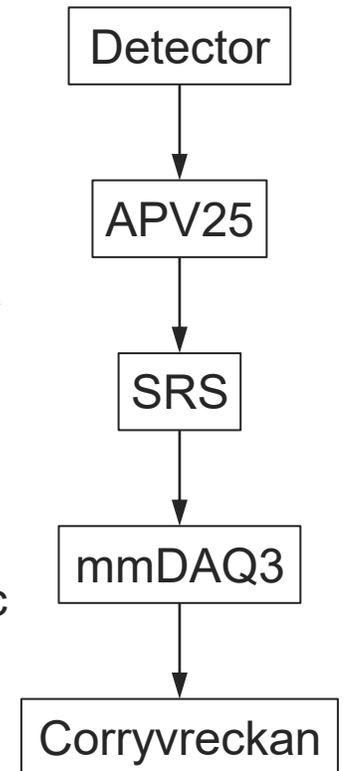
Trigger Signal Injection Board



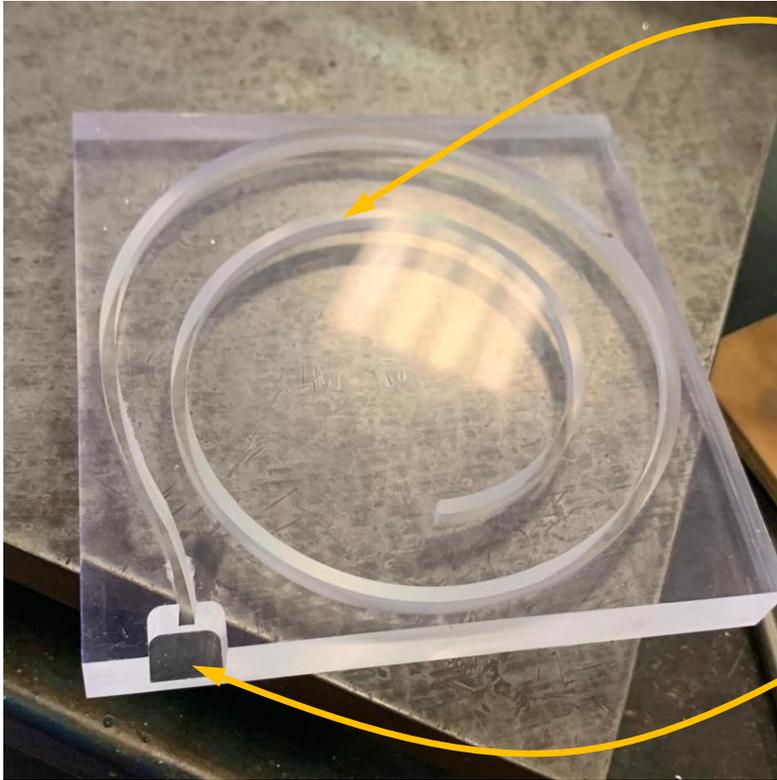
HIROSE to Panasonic Transition Board



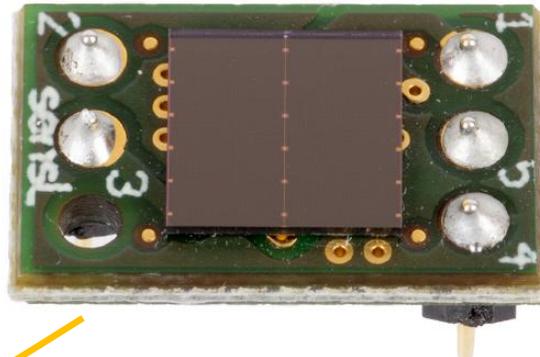
Data Pipeline



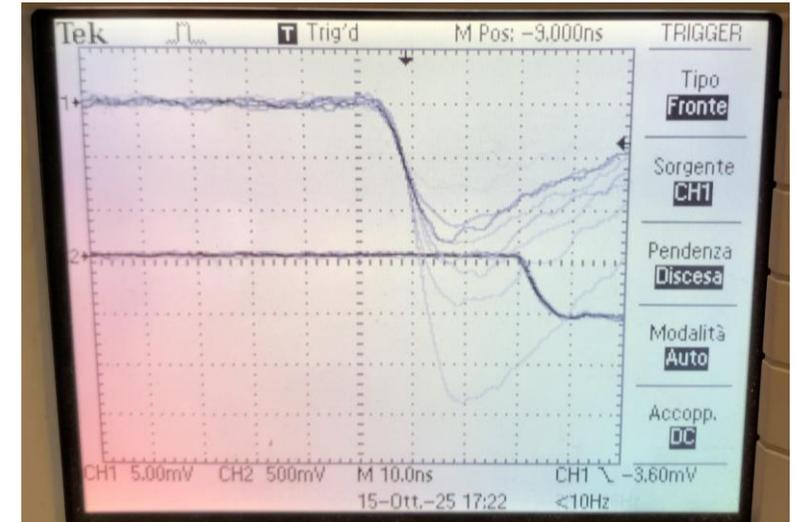
Trigger



×9 Ø1 mm wavelength shifter fibers
Bundled and embedded in the groove



Onsemi J-Series 30020
3x3 mm² SiPM Area

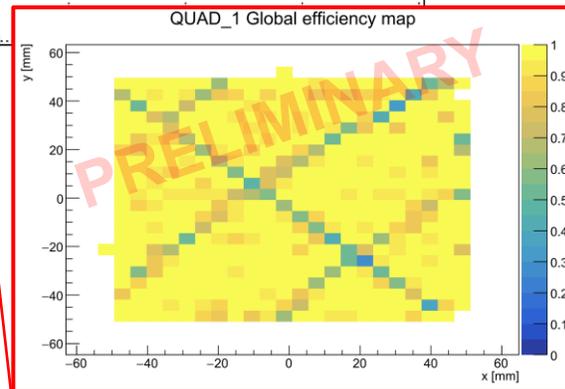
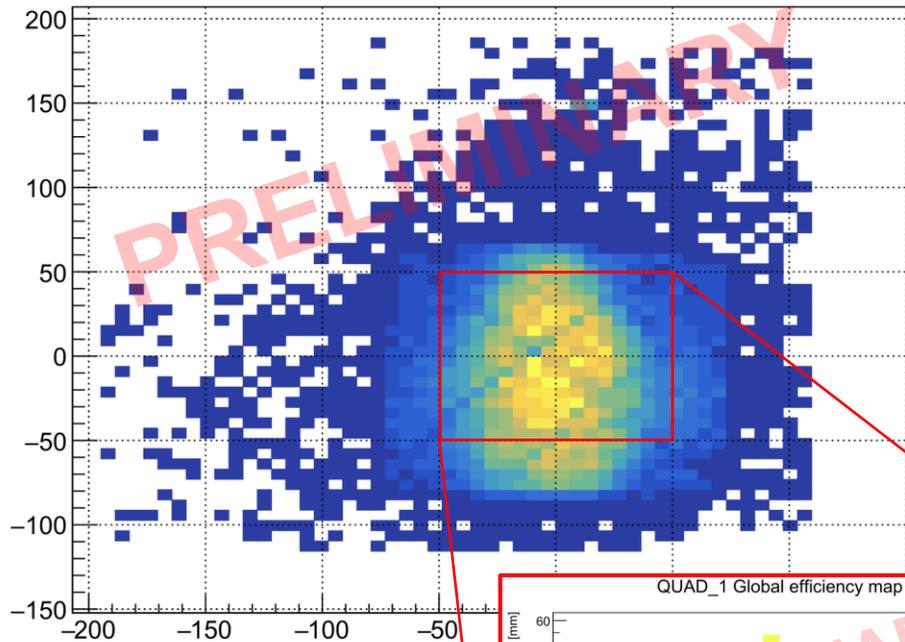


Non-amplified signal output
from cosmic rays

Also provides a time reference (t_0) to selected APVs for μ TPC reconstruction

Preliminary Results from TB-2025 Data

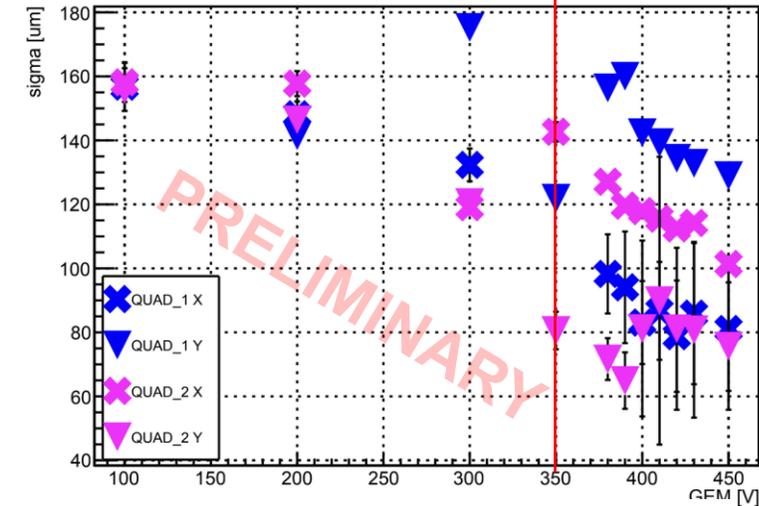
Highest charge cluster position QUAD1 (w/ grids)



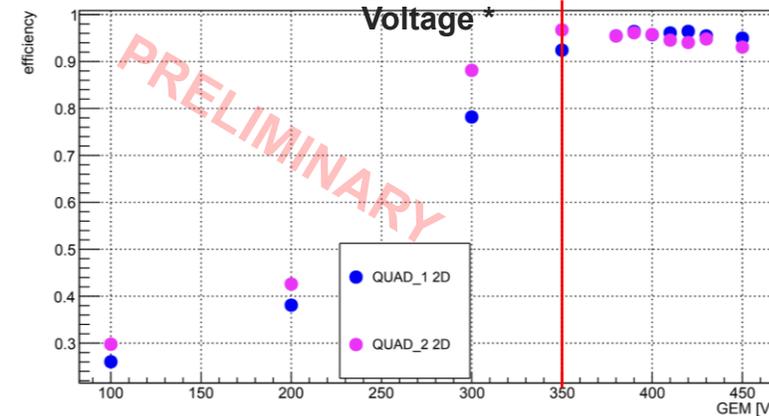
Preliminary performance satisfy requirements @ HV GEM = 350V

Generous leeway for safe detector operation and optimization

Residuals' σ VS GEM Voltage *

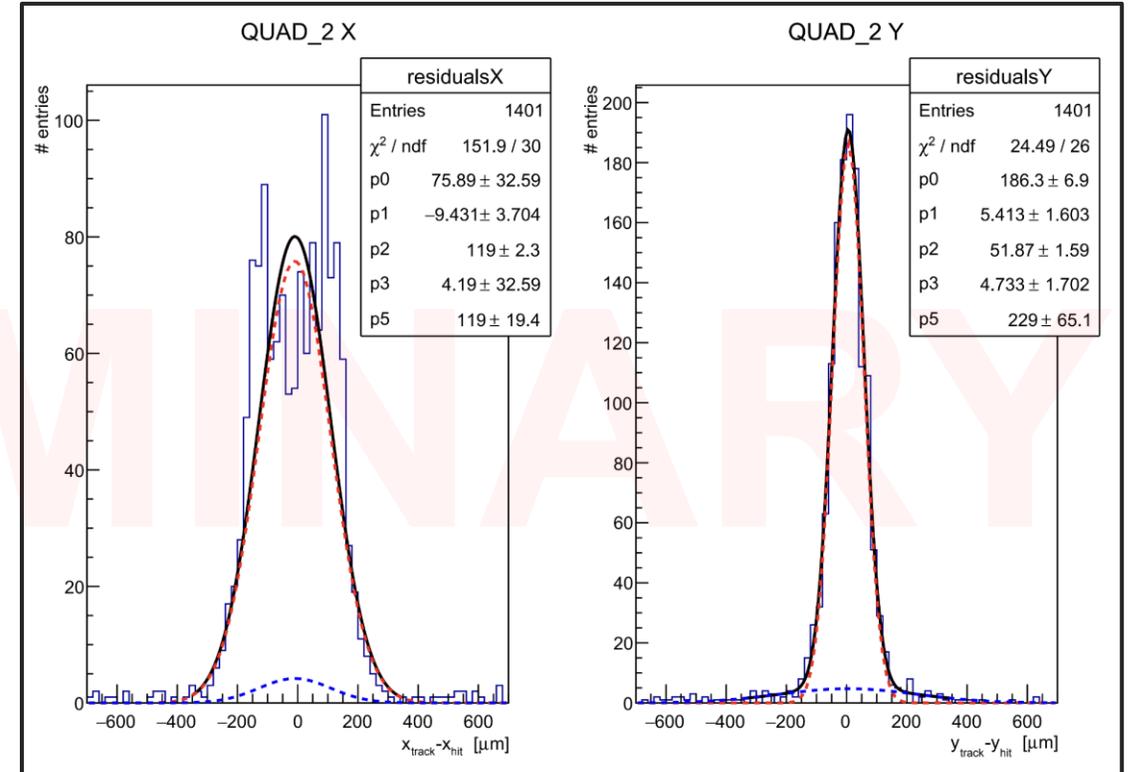
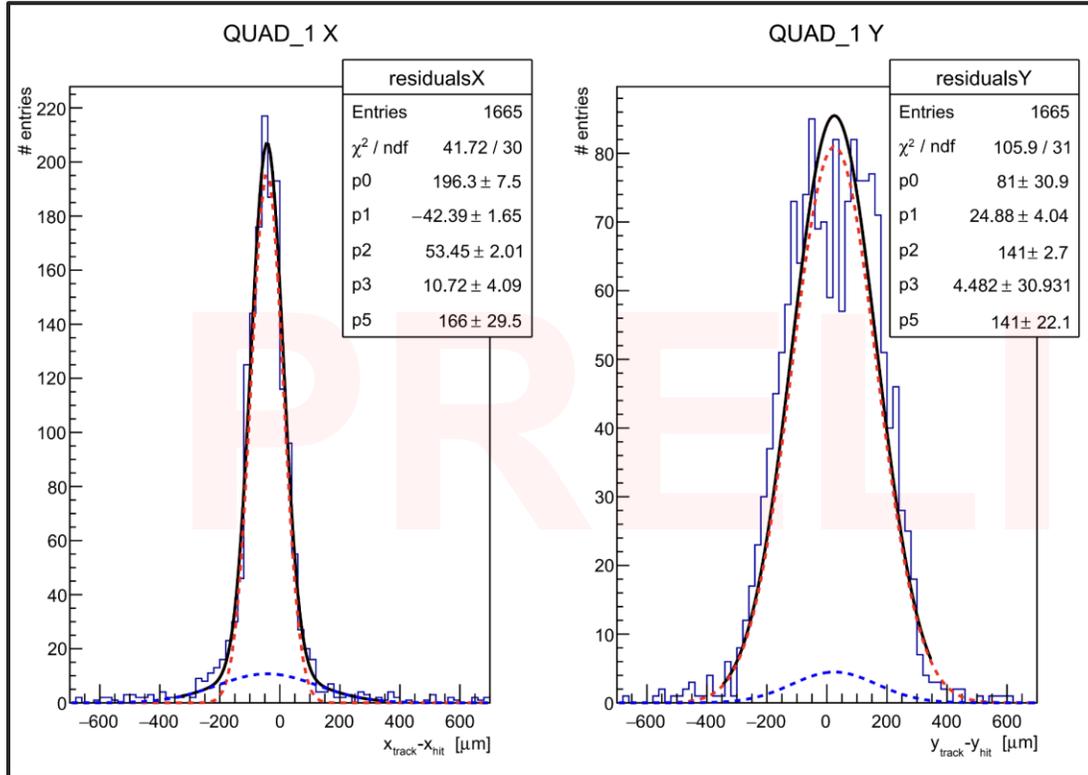


2D Efficiency [1x1 cm²] VS GEM Voltage *



* WELL = 550 V
TRSF = 4.5 kV/cm
DRFT = 2.5 kV/cm

Residuals Distributions



$\sigma_{x\text{eff}} = 80\mu\text{m}$

Lower view

520 μm strips width

$\sigma_{y\text{eff}} = 141\mu\text{m}$

Upper view

90 μm strip width

$\sigma_{x\text{eff}} = 120\mu\text{m}$

Upper view

90 μm strip width

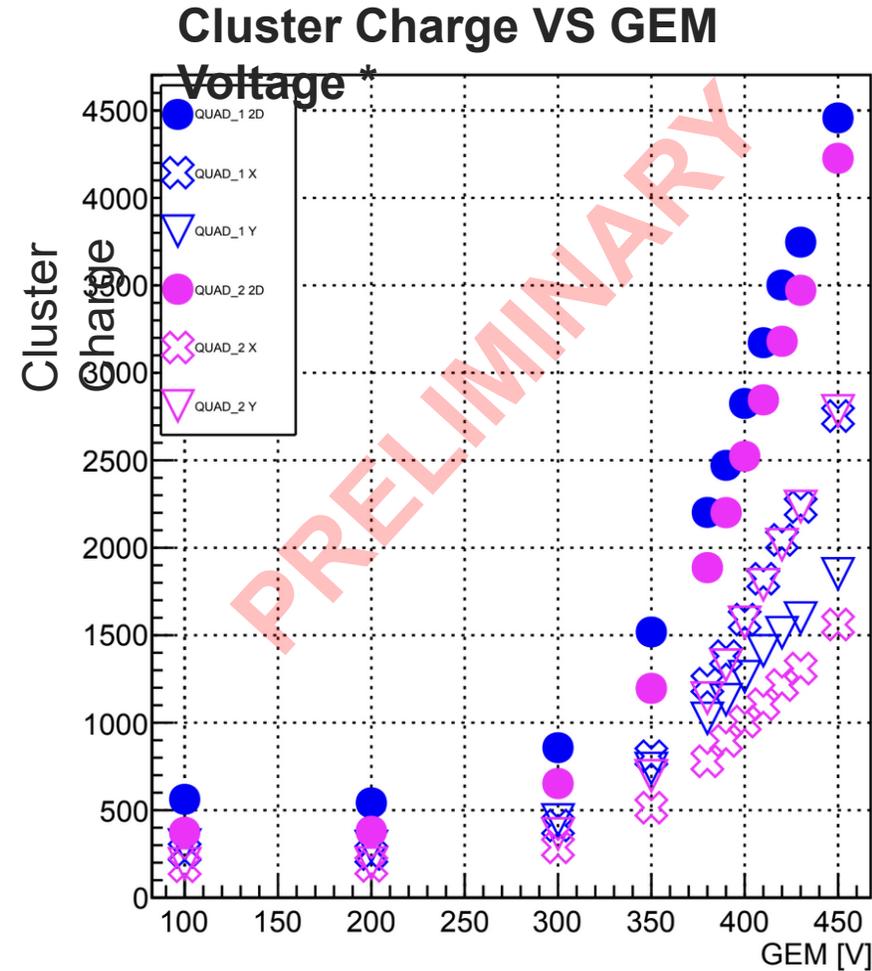
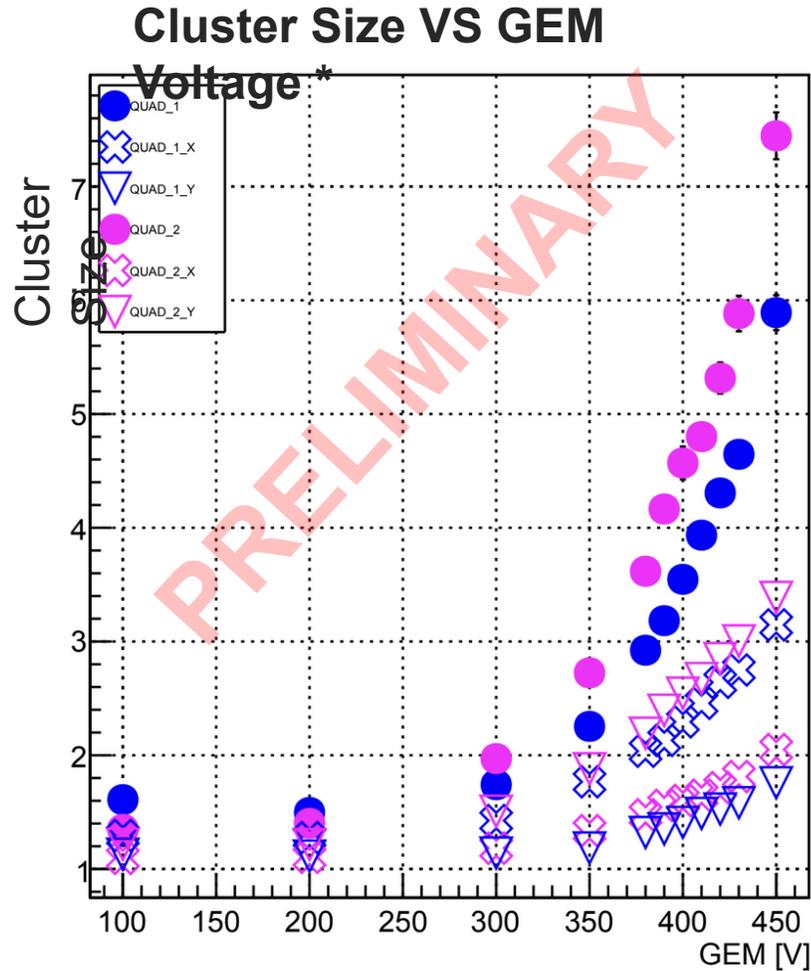
$\sigma_{y\text{eff}} = 88\mu\text{m}$

Lower view

520 μm strip width

The two quadrants are rotated by 90 degrees with respect to each other, hence the X-Y exchange

Size and Charge of the Signal Clusters



- QUAD1
- QUAD2

Charge sharing
visibly skewed
in favor of the
wider strips of
the lower view

* WELL = 550 V
TRSF = 4.5 kV/cm
DRFT = 2.5 kV/cm