µRWELL-PICOSEC: Precision Timing with Resistive Micro Well (µRWELL) Detectors

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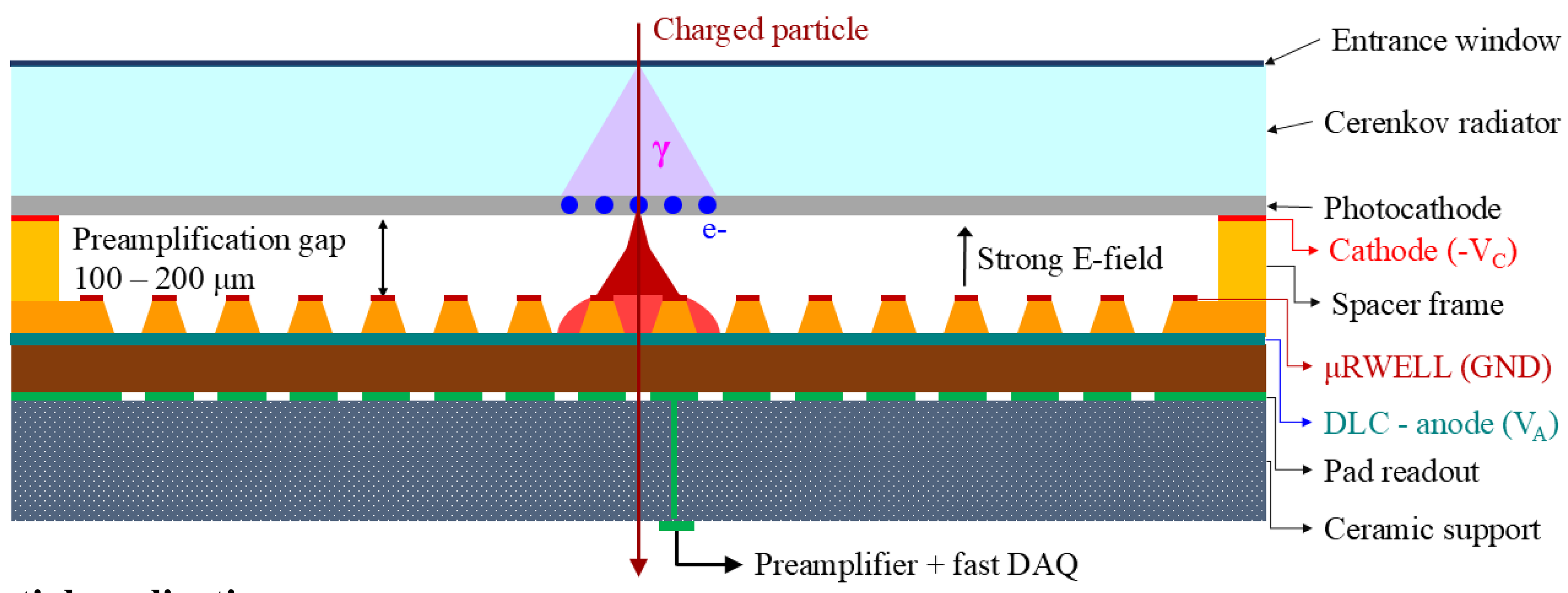
µRWELL-PICOSEC: Precision Timing with Gaseous Detectors

Concept: Combines a µRWELL electron amplification in gas with photoelectrons produced by a photocathode from VUV photons generated by relativistic charged particles crossing a Cerenkov radiator

- Cherenkov photons: Relativistic charged particles traversing a radiator ➔ prompt Cerenkov photons
- Photoelectrons: Cherenkov photons converted into photoelectrons in VUV photocathode
- Pre-amplification: Amplification of the photoelectrons in ~200 µm drift gas in a strong electric field
- µRWELL amplification: Second amplification of the charges in a strong electric field
- Electronic Signal: Collection of the induced charges on pick up pad electrode.



Potential applications:

Large area, cost-effective detector for precision timing (T_0) and Time-of-Flight (TOF) for charged particles identification (PID) of future nuclear physics (NP) / high energy physics (HEP) experiments.

- SoLID @ **JLab**; ePIC Detector Upgrade / Second detector @ **EIC**; Muon timing detector @ **FCC-ee**

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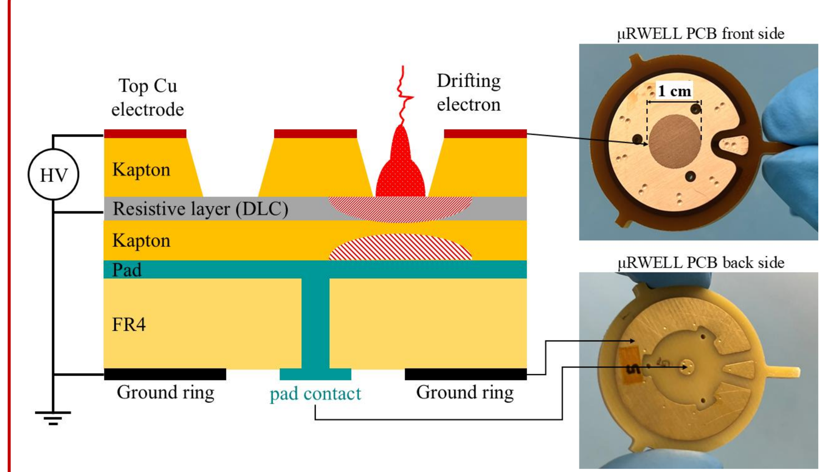
Single-pad µRWELL-PICOSEC Prototype

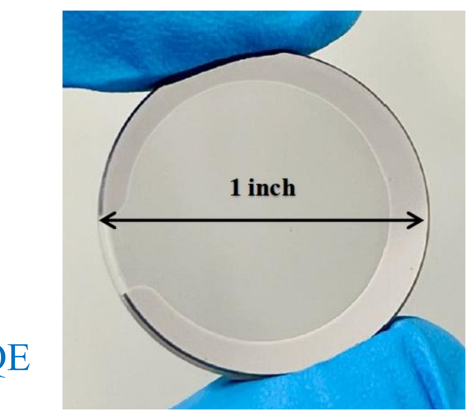


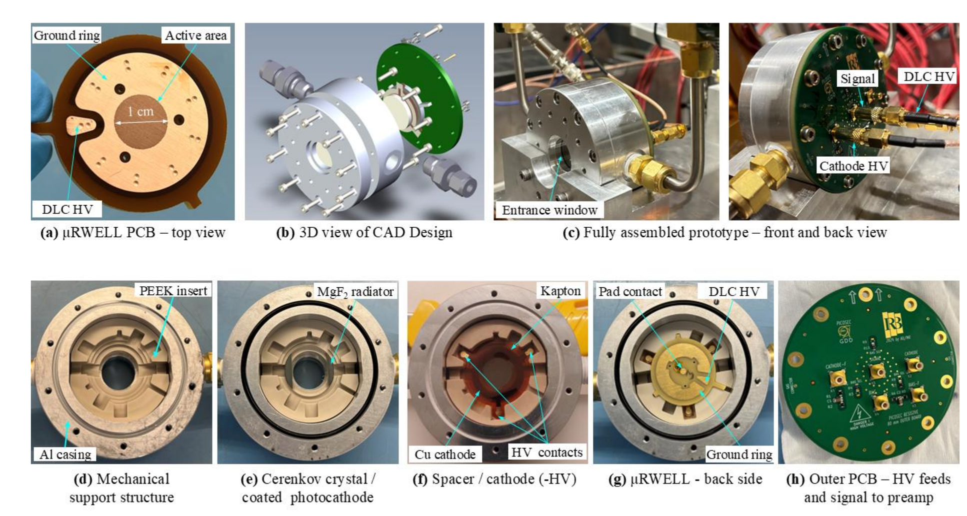
µRWELL PCB for single-pad µRWELL-PICOSEC prototype

- Second amplification stage of a µRWELL-PICOSEC detector
  - *G. Bencivenni et al.* 2015 JINST 10 P02008
- Fast gas mixture: Ne:CF_4:C_2H_6 (80:10:10)
- Pick-up pad readout + low noise RF amplifier electronics

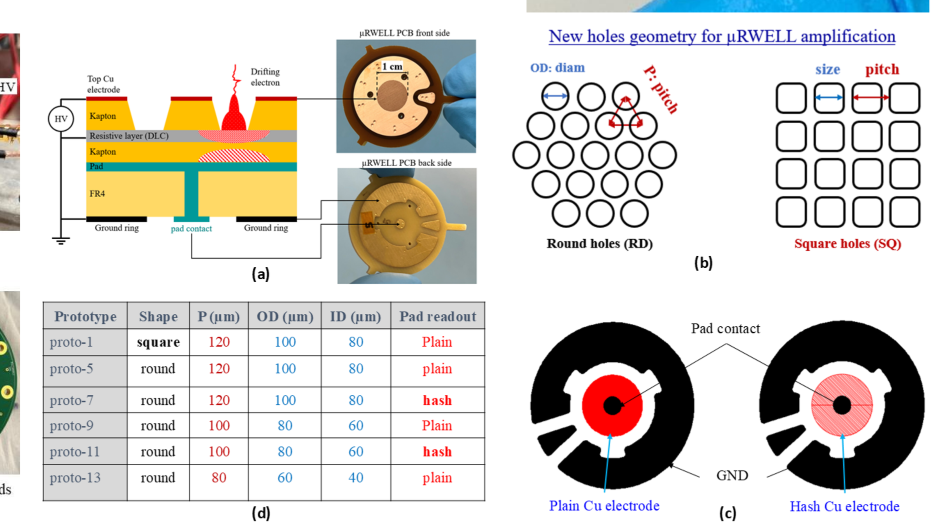
Cerenkov crystal radiator coated with semi-transparent VUV photocathode

- Radiator: Magnesium Fluoride (MgF2) crystal ➔ transparency in VUV region
- Photocathode candidates:
  - Cesium Iodide (CsI) ➔ high QE but sensitivity to humidity & ion bombardment
  - Diamond-like carbon (DLC), Titanium, Boron carbide (B_4C) ➔ robust but low QE





Assembly of a single-channel µRWELL-PICOSEC prototype



Geometric parameters of a µRWELL-PICOSEC PCB

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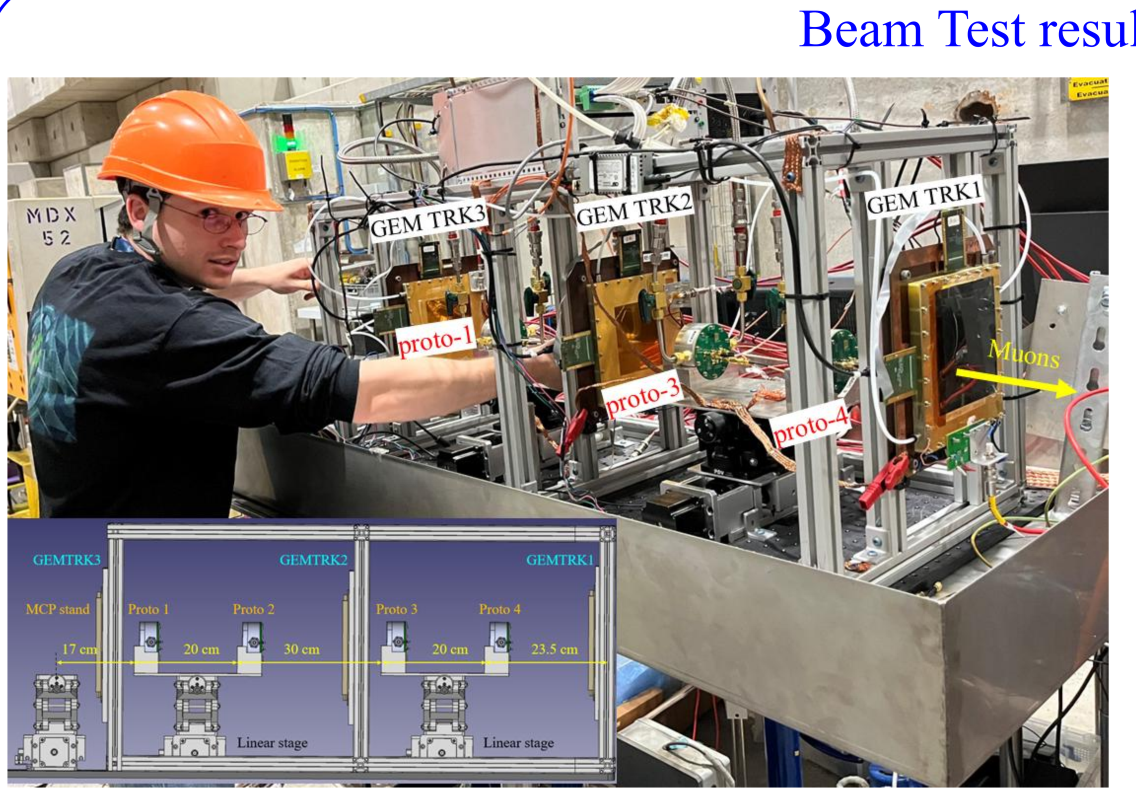
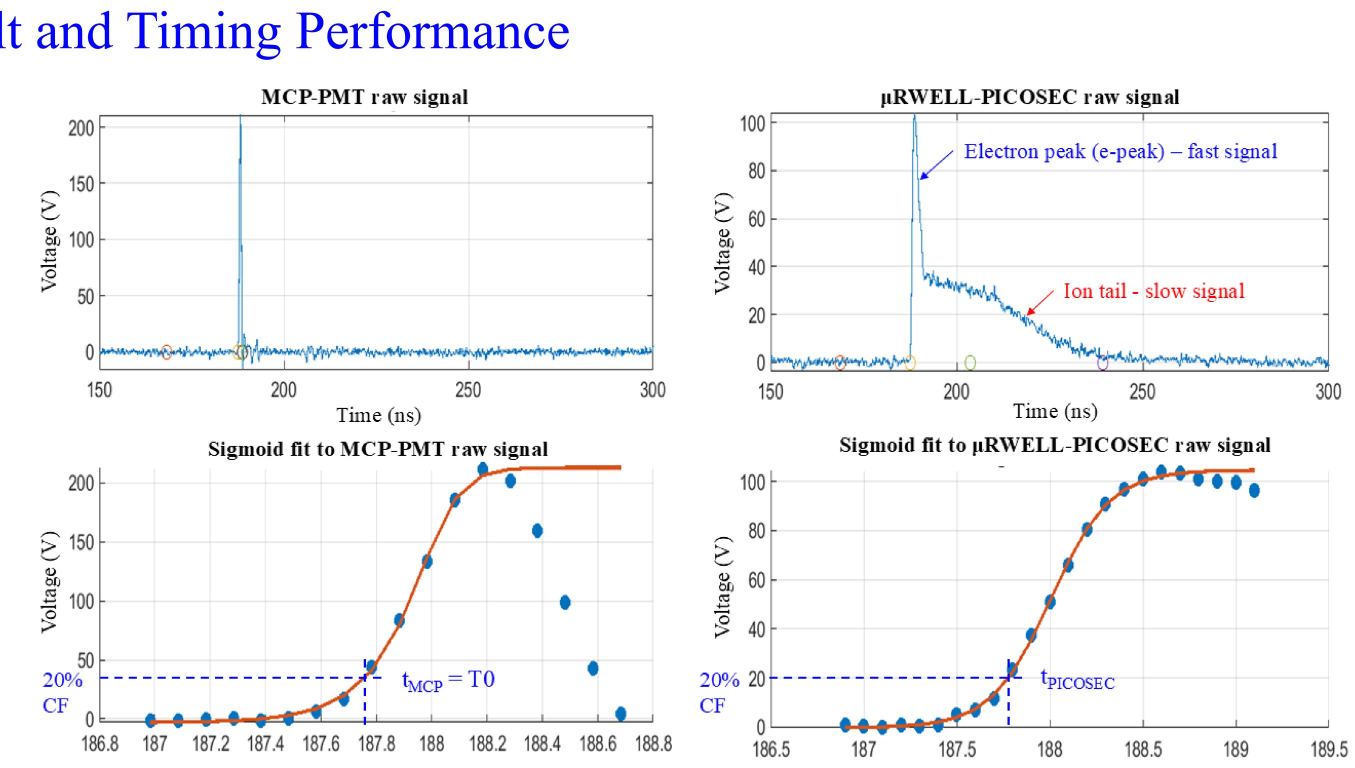
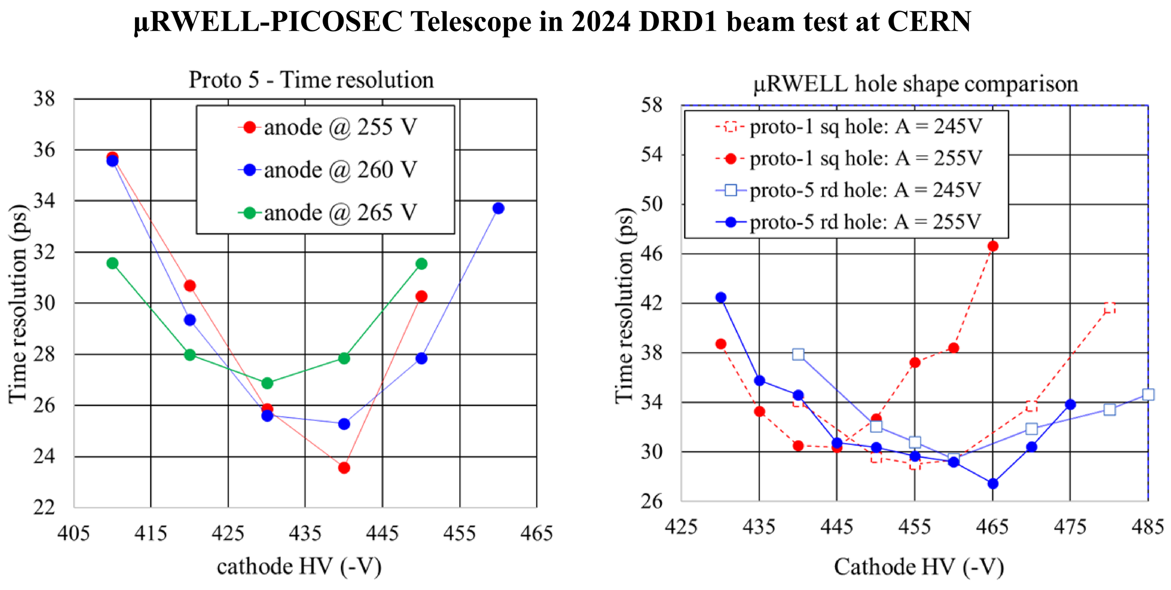
Beam Test result and Timing Performance



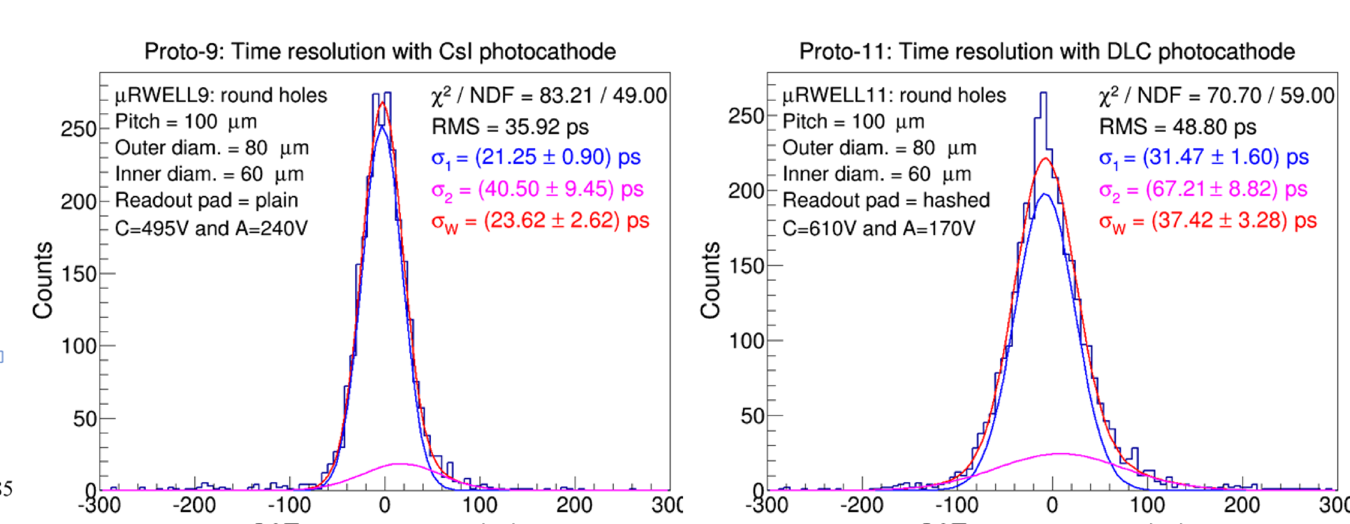
µRWELL-PICOSEC Telescope in 2024 DRD1 beam test at CERN



Waveform signal of µRWELL-PICOSEC and timing reference MCP-PMT



Time resolution as a function of cathode and anode voltages



Time resolution performance with different photocathodes: CsI (right); (b) DLC (right)

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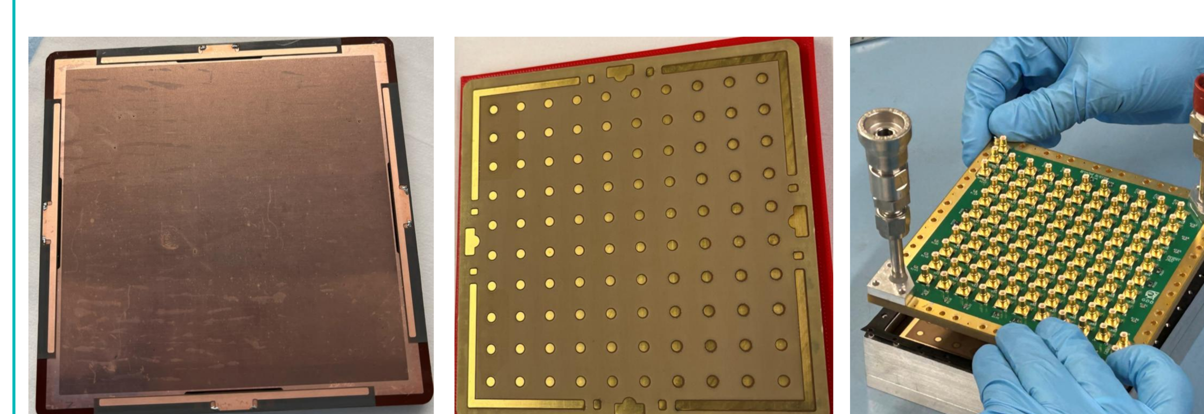
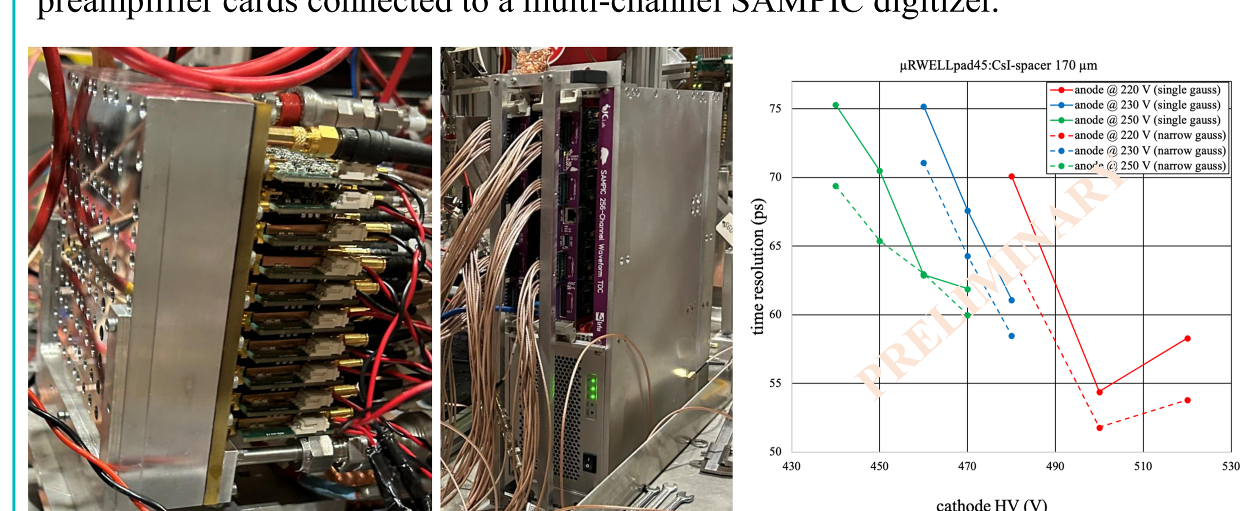
Large Area µRWELL-PICOSEC Prototype

A large area (10 cm × 10 cm) µRWELL-PICOSEC prototype with 100-pads readout PCB was designed fabricated successfully tested in the 150 GeV / c muon beam at the CERN SPS H4 test area in July 2024



100-pads µRWELL PCB front | 100-pad µRWELL PCB back | 100-pads prototype

The prototype was instrumented with 10 × 10-channels custom-made low noise RF preamplifier cards connected to a multi-channel SAMPIC digitizer.



Prototype instrumented with 100-ch amplifier cards | Multi-channel SAMPIC digitizer | Time resolution vs. anode and cathode voltages

Synergistic LDRD Program: Low-Mass µRWELL Detectors for High-Luminosity Experiments

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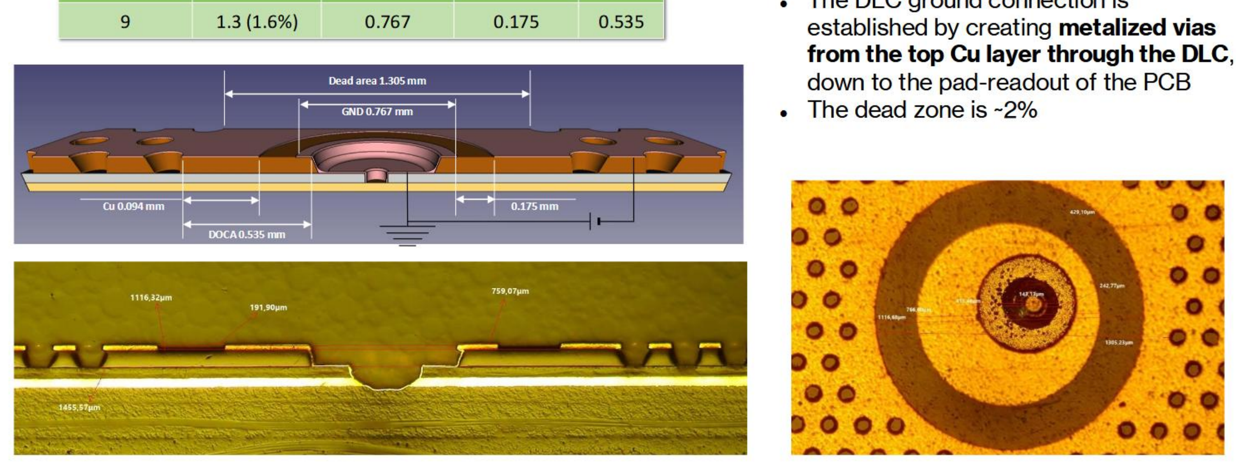
Motivation: Development of high-rate capabilities (up to several MHz/cm²) for µRWELL detector technologies.

Background and Significance: High-rate large area detector systems at the luminosity frontier of CEBAF at JLab such as the SoLID in Hall A or the high-luminosity upgrade of CLAS12 in Hall B

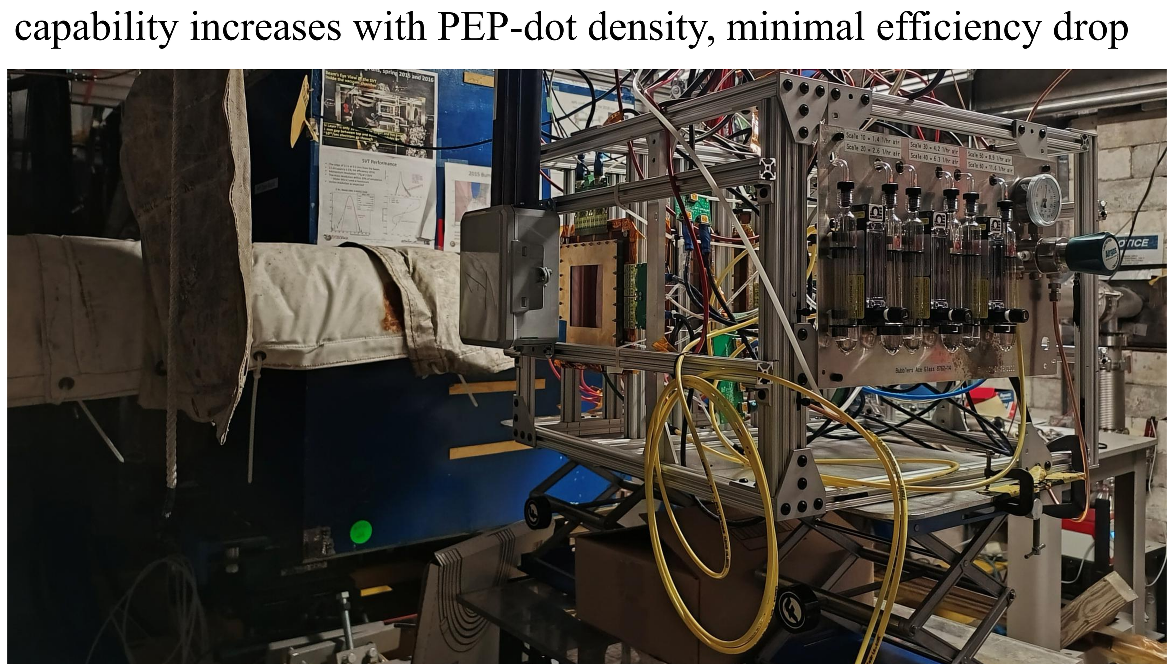
Technology: µRWELL with PEP-dot grounding scheme; Rate capability increases with PEP-dot density, minimal efficiency drop

DLC-GND pitch [mm]	Dead Zone [mm]	GND width [mm]	Insulation gap [mm]	DOCA [mm]
9	1.3 (1.6%)	0.767	0.175	0.535

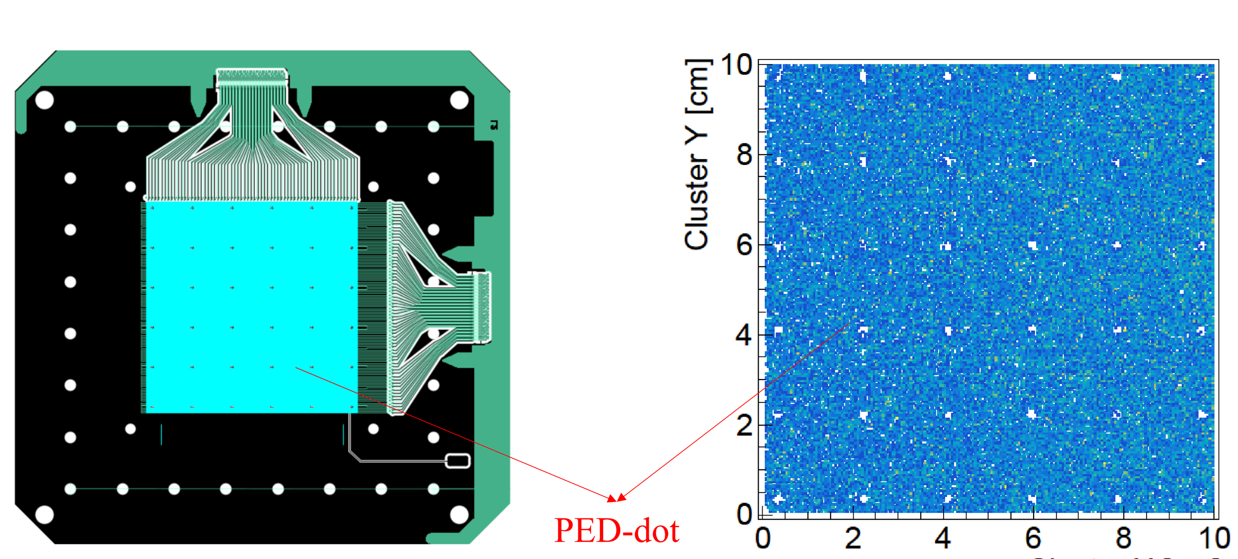
- The most recent high rate layout: Patterning–Etching–Plating
- The DLC ground connection is established by creating **metalized vias from the top Cu layer through the DLC**, down to the pad-readout of the PCB
- The dead zone is ~2%



µRWELL PCB with PEP-dot grounding scheme for high-rate application



High-rate µRWELL Prototypes under test in Hall B at JLab (2025)



High-rate µRWELL PCB (a)- Efficiency drop due to PED-dots is visible (b)

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Summary & Perspectives

- Fast timing µRWELL-PICOSEC technology with picosecond timing resolution is fast emerging field for Time of Flight PID applications in HEP and NP field.
- Preliminary beam test results with small µRWELL-PICOSEC prototypes show timing resolution of ~23 ps after optimization of µRWELL PCB features.
- The results suggested further optimization to achieve < 20 ps resolution
- Large area 10cm×10cm µRWELL-PICOSEC prototype was successfully tested with encouraging results for cost-effective fast timing detector technologies.
- We will explore funding opportunities to develop application as TOF PID options for future detector such as an EIC Second detector or FCC-ee detector
- In parallel, The development of µRWELL detector with PEP-dot grounding technology is a promising option for tracking detector in high-rate environment, combining good position resolutions, low material budget with simple mechanical construction, and low production costs.

Acknowledgement:

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