FY26 R&D Status USHFCC Muon Group

- MPGD Effort –

April 21, 2026

Precision Muon Timing and ToF-based PID with µRWELL-PICOSEC Technology

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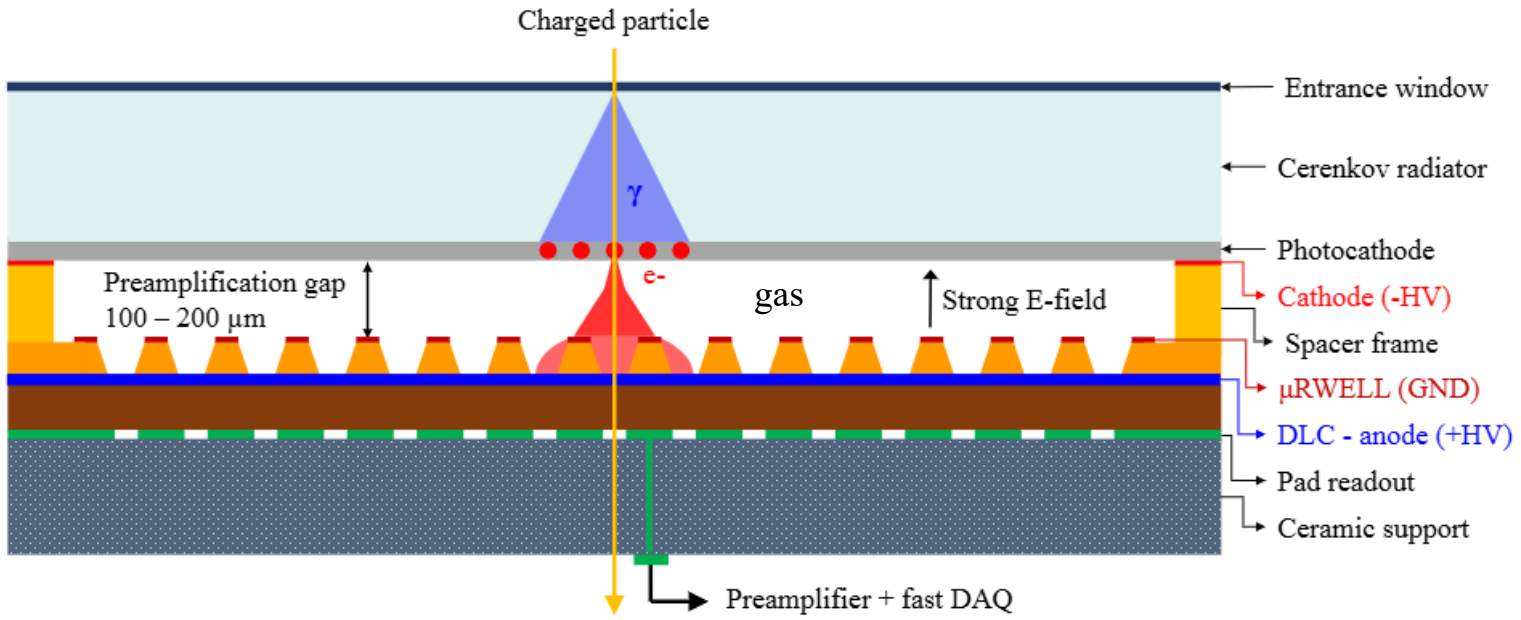
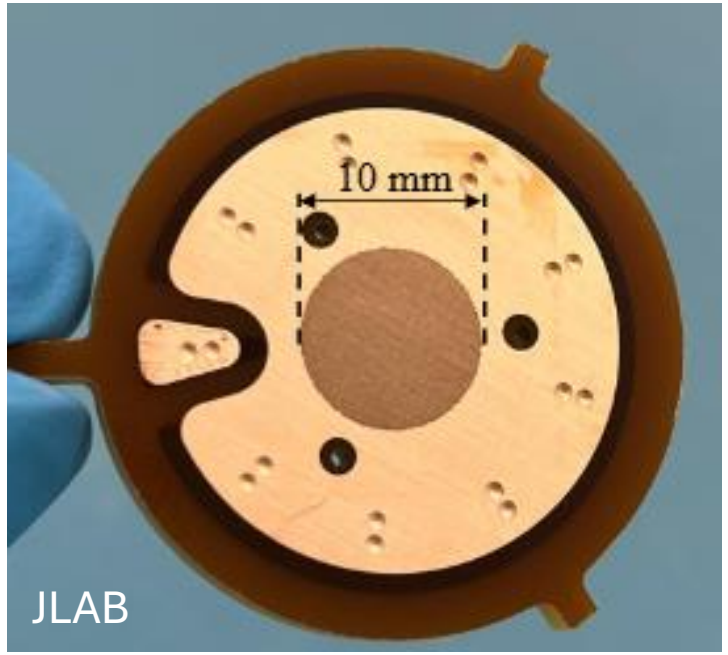
Motivation (dual use):

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

Concept: **µRWELL-PICOSEC detector (MPGD with Cherenkov radiator)**





Approach:

- **Design, construction, and test of 10cm x 10cm prototype with 100 channels**
- **Photocathode made from non-hygroscopic Diamond-like Carbon (DLC) instead of CsI**
- **Beam test at CERN in summer 2026**

FY 26 Funding Process & Status

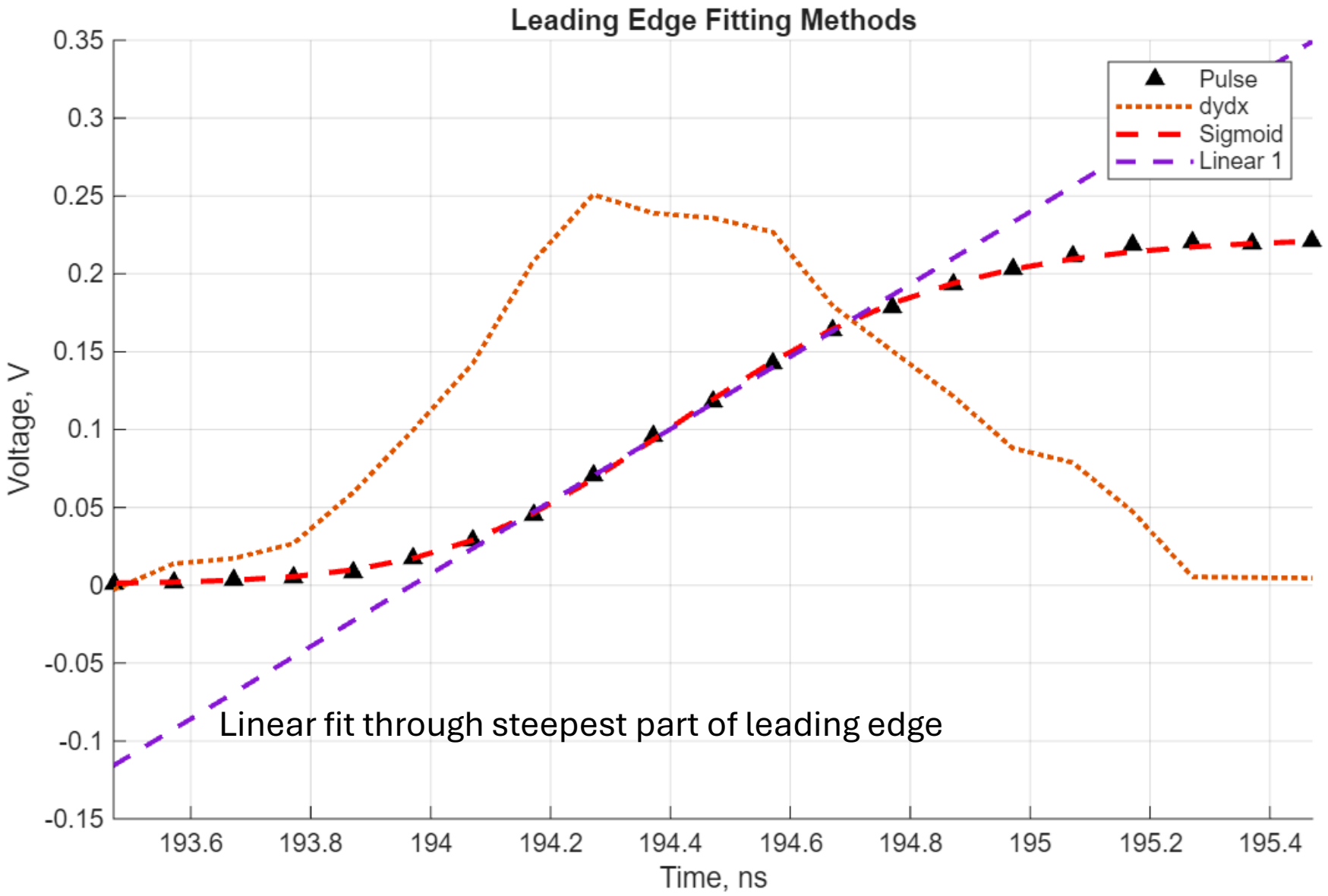
- FIT
  - First contacted by BNL about contract on Dec 2, 2025
  - Funding arrived from BNL on **Jan 13, 2026**
  - $15k to support Ph.D. student for spring semester (through May 9)
  - $19k total (incl. IDC)
  - Funds have been fully expended

- JLAB
  - Funding arrived from BNL very late on **Apr 13, 2026**
  - $21k (hardware, labor, travel to CERN beam test)
  - Funds being expended now

FIT Update

- Objective:
  - Prepare **software** for analysis of data from summer 2026 beam test at CERN
  - **Fast turn-around to give near real-time feedback to the team at the test beam**
- Achievements so far:
  - Recruited Ph.D. student Scott Demarest to the project
  - FIT joined PICOSEC collaboration at CERN to get access to existing datasets from previous beam test campaign for learning data analysis software suite (in MATLAB) & to share future results from s/w development with community
  - Scott has been investigating possible improvements to the analysis using data from single-pad detectors
    - Exploring methods of charge calculation and their effects on time walk corrections and timing
    - Categorizing pulse shapes to understand how fitting methods perform with respect to pulse type
    - **Evaluating alternative methods for leading edge pulse timing**

µRWELL-PICOSEC Analysis Software at FIT



Digitized leading edge of MPGD pulse with standard Sigmoid fit

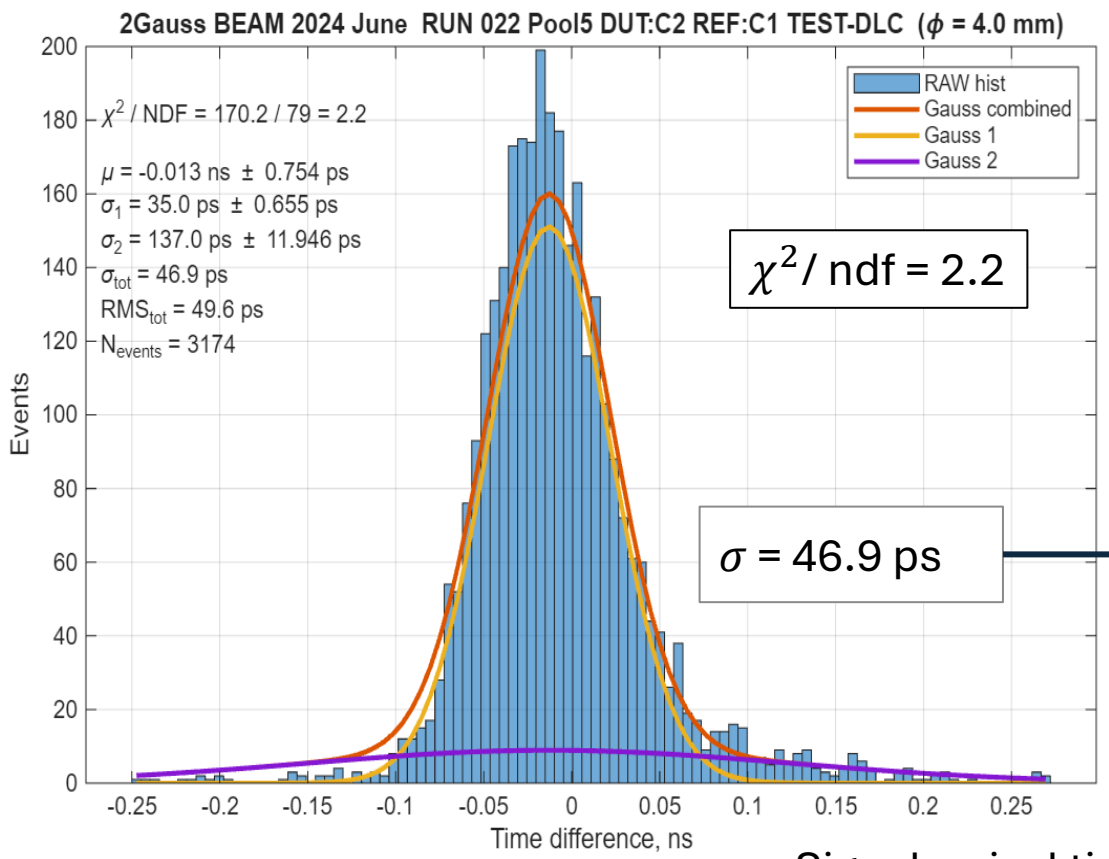
Derivative

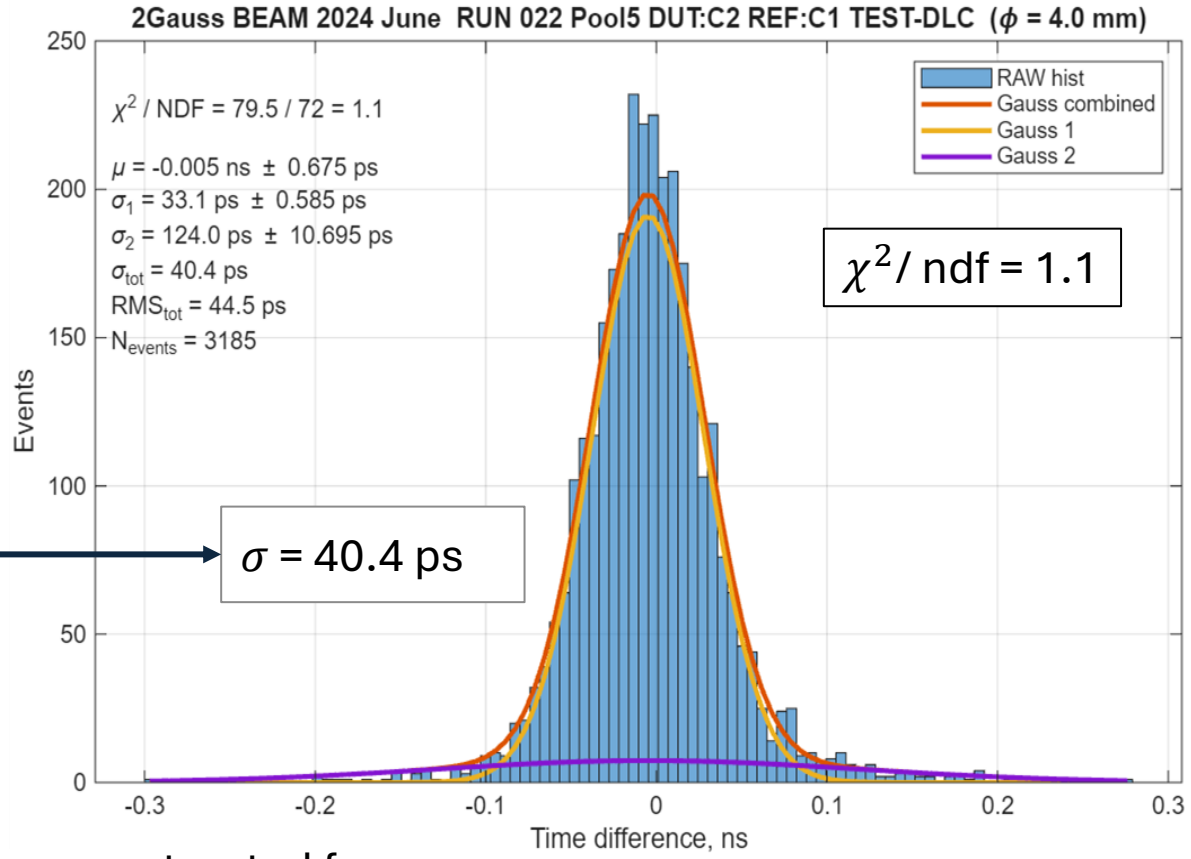
S. Demarest

µRWELL-PICOSEC Analysis Software at FIT

Even though a linear fit to the pulse shape uses fewer datapoints than the sigmoid, it appears to give a meaningful time resolution improvement. We are investigating further optimizations.

Difference between signal arrival times in single-channel µRWELL MPGD and microchannel plate reference detector:





Signal arrival times reconstructed from Sigmoid Fit (left) vs. Tangential Linear Fit (right)

S. Demarest

FIT Plans for remainder of FY26

- Extend the analysis to existing data from multi-channel prototypes
- Provide rapid feedback during upcoming beam test

JLab Update: Delay of JLab funds availability for this R&D project

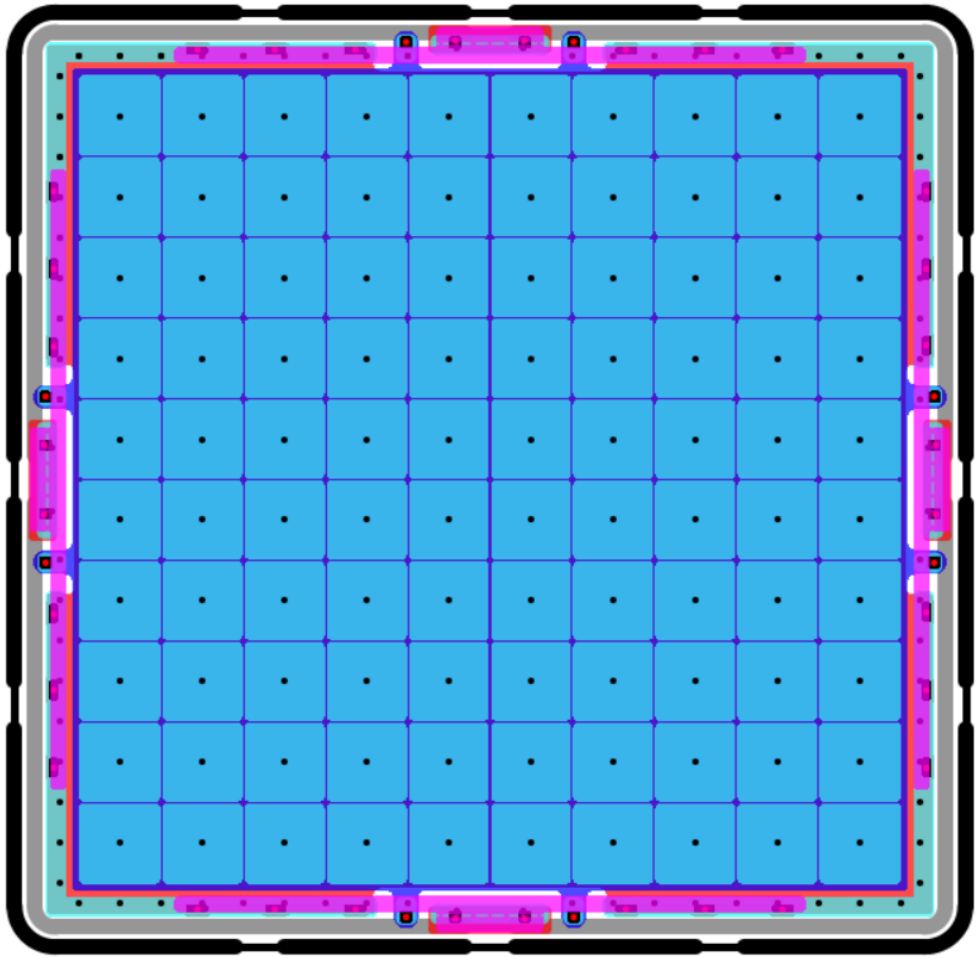
- Delay in part due to October gov't shutdown and due to the ramifications of the "Involuntary Separation Program" at JLab
- Consequently, procurement and plans for beam test were severely delayed
  - μRWELL PCB fabrication, Cerenkov crystal material, and DLC photocathode deposition are all delayed
  - For the upcoming beam test ➔we will borrow parts from past projects (LDRD)
- Now contract is signed and the funds are available at JLab ➔ we can start procurement

JLab update: Large (10 cm×10 cm) µRWELL-PICOSEC prototype

Large (10 cm×10 cm) µRWELL-PICOSEC prototype with 100-pads readout:

- µRWELL PCB design modification for easy and safe assembly ➔ in fabrication at CERN
- Cerenkov radiator (MgF_2) coated with 2.5 nm diamond-like carbon (DLC) (in hand)
- 50-ch. fast custom preamplifiers & 64-ch. SAMPIC digitizer (in hand)
- Modified mechanical housing unit and outer pad boards (in hand)
- Telescope with timing (MCP-PMT) & tracking (GEM) (in hand)

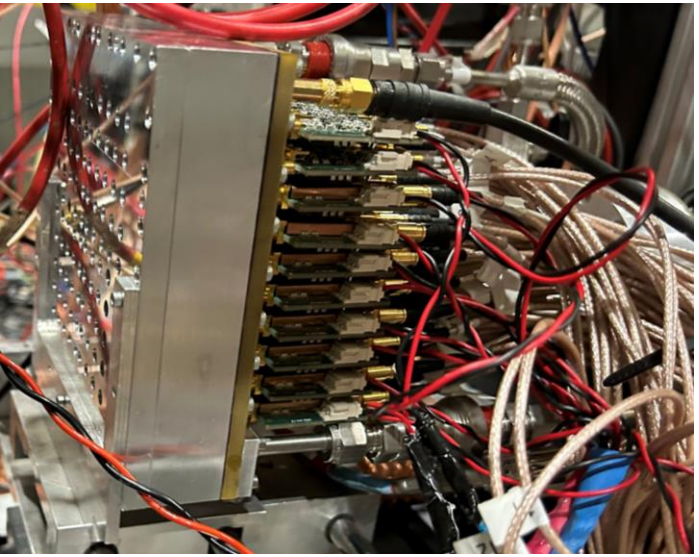
New µRWELL PCB design



JLab Update: Preparation for beam test in July 2026 @ CERN

We will participate in DRD1 beam test July 15th - August 3rd in SPS H4 high energy muon line at CERN

- Study the performance of large area 100-pad μRWELL-PICOSEC prototype (new μRWELL PCB design)
  - HV scan runs for time resolution performance optimization with DLC photocathodes
  - Position scan for time resolution performance uniformity.
- Most detector parts in hand for the July test beam except the new μRWELL PCB
  - We are still hoping to receive the item in time for the beam test starts
  - Shipment of test beam equipment from JLab to CERN should be no later than June 7th



μRWELL-PICOSEC prototype in its Al housing with connected fast preamps

64-ch SAMPIC digitizer

μRWELL-PICOSEC telescope used in 2024 beam test @ CERN

FY27 PLANS

Fast Timing for Muon System with MPGDs

JLAB Plans for FY27

❖ **Performance optimization with various single-channel prototypes with new µRWELL structure**

- New (**75 µm thick)** µRWELL Kapton foil (instead of standard 50 µm) ➔ expect improved time resolution
- Study of µRWELL prototypes with different hole diameters and pitches ➔ performance optimization
- Optimization of the Cerenkov radiator and photocathode materials and geometry ➔ performance optimization
- Fast gas studies ➔ cost-effective & environmentally friendly alternatives to Ne:CH_4:CF_4 (80:10:10)

❖ **Development of even larger (20 cm × 20 cm) µRWELL-PICOSEC detector with 2-cm pad readout**

- Large area critical for application in realistic experiment like Muon system of the FCC
- Area of 20 cm × 20 cm seems a good starting point compromise between performance and challenges
- 2-cm pad readout to ensure low number of electronics channels ➔ cost and integration consideration
- We will design & fabricate low mass and large area prototypes with integrated pre-amplifier electronics

FIT Plans for FY27

- Analyze Summer 2026 data & contribute to a publication
- Further development of s/w
- Analyze data from new JLAB prototypes

- JLAB & FIT working on details of funding request -