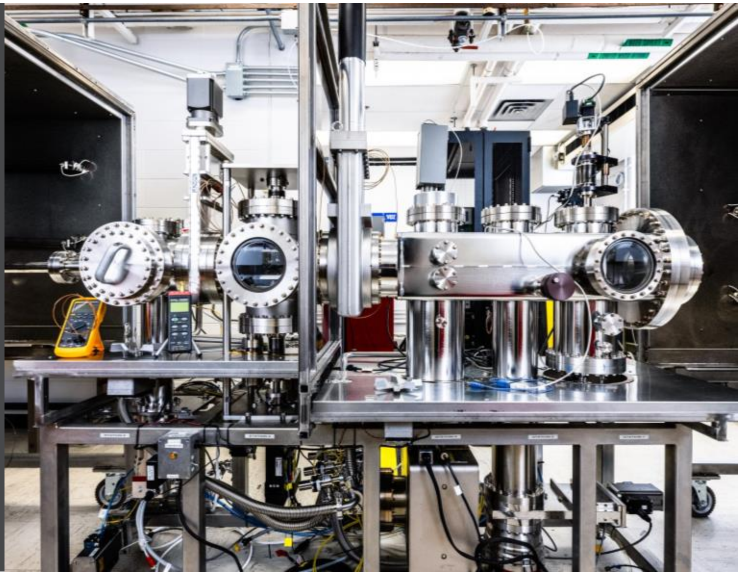
2025 SoLID Collaboration Meeting

MCP-PMT R&D UPDATE



JUNQI XIE

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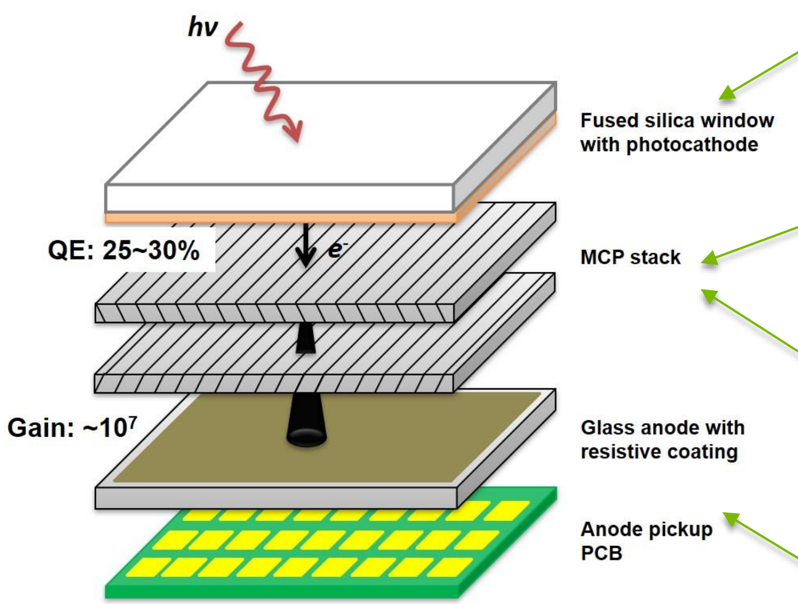
OUTLINE

- ❑ Argonne early MCP-PMT development
- ❑ LAPPD/HRPPD magnetic field test results
- ❑ LAPPD validation in high-rate environment at JLab Hall C
- ❑ Status of new 10x10 cm MCP-PMT fabrication facility
- ❑ Planned Hamamatsu MCP-PMT test for SoLID SPD

RECAP: ARGONNE EARLY MCP-PMT DEVELOPMENT

The **Electron-Ion Collider (EIC)** demands excellent particle identification (PID) over a wide range of momenta. Cherenkov (RICH) detectors are essential for high momenta PID.

- **High magnetic field tolerance**
- **Fine pixel readout**
- **Fast timing**



Low-cost full glass design

Fused silica window extending sensitivity down to UV range

Small pore size (10 µm) MCPs for higher magnetic field tolerance and fast timing

Reduced spacing internal geometry further improve the magnetic field tolerance and timing resolution;

Capacitively coupled electronic readout through glass/fused silica for pixelated readout scheme

RECAP: ARGONNE EARLY MCP-PMT DEVELOPMENT

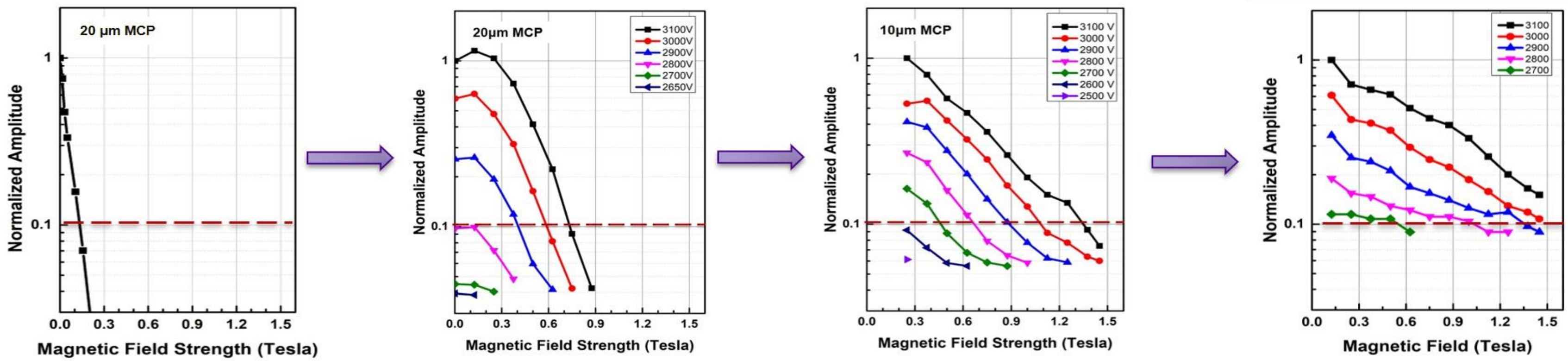
Improvement of Argonne MCP-PMT Performance in **Magnetic field**

ANL version 1
Internal resistor chain

ANL version 2
IBD design 20 μm MCP

ANL version 3
IBD design 10 μm MCP

ANL version 4
IBD design 10 μm MCP
reduced spacing



0 < B < 0.15 T | **0 < B < 0.7 T** | **0 < B < 1.3 T** | **0 < B < at least 1.5 T**

Baseline device

Advanced device

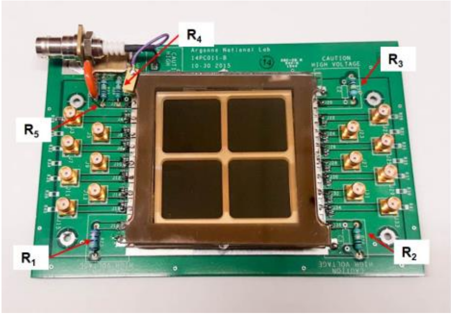
- Optimization of biased voltages for both MCPs: **version 1 -> 2**
- Smaller pore size MCPs: **version 2 -> 3**
- Reduced spacing: **version 3 -> 4**
- Further improvement available if needed

RECAP: ARGONNE EARLY MCP-PMT PERFORMANCE

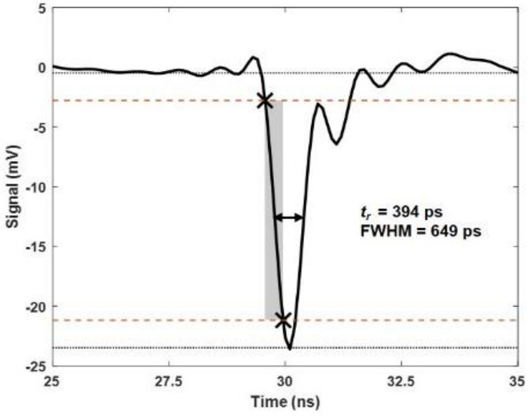
ANL **low-cost** MCP-PMT with 10 μm pore size MCPs and reduced spacing

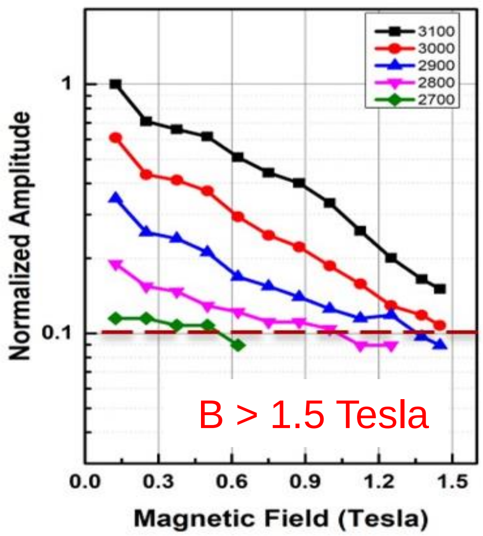
MCP	Pore size	10 μm
	Length to diameter ratio (L/d)	60:1
	Thickness	0.6 mm
	Open area ratio	70 %
	Bias angle	13º
Detector geometry	Window thickness	2.75 mm
	Spacing 1	2.25 mm
	Spacing 2	0.7 mm
	Spacing 3	1.1 mm
	Shims	0.3 mm
	Tile base thickness	2.75 mm
MCP-PMT stack	Internal stack height	**5.55 mm**
	Total stack height	11.05 mm

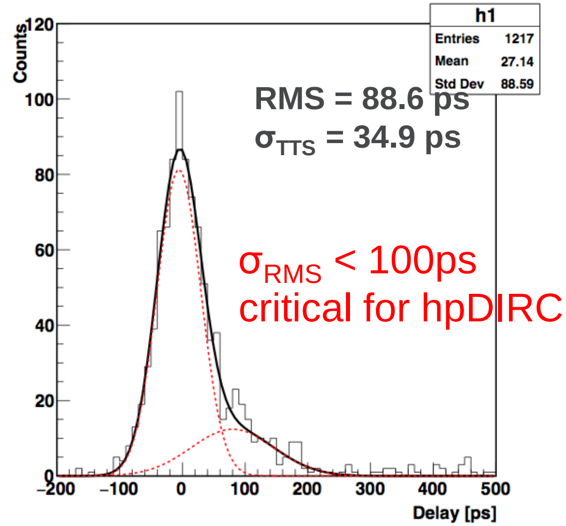
Gain Characteristic	Gain	2.0×10^7
Time Characteristic	Rise time	**394 ps**
	TTS RMS time resolution	88.6 ps
	TTS resolution	35 ps
Magnetic Field	Magnetic field tolerance	**Over 1.5 T**



Early 6x6 cm MCP-PMT



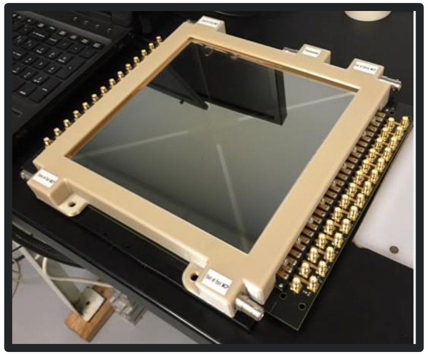




RECAP: LAPPD/HRPPD COMMERCIALIZATION

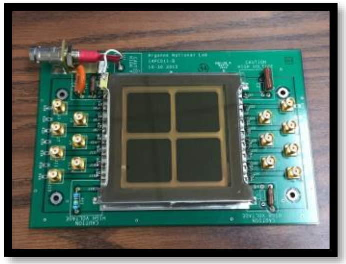
R&D results and parameters are shared with Incom for LAPPD/HRPPD commercialization

Commercialization @ Incom, Inc.



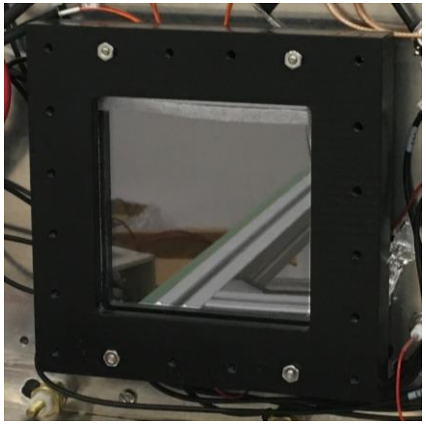
20x20 cm^2 LAPPD

R&D testbed: 6x6 cm^2 @ ANL



Technology transfer

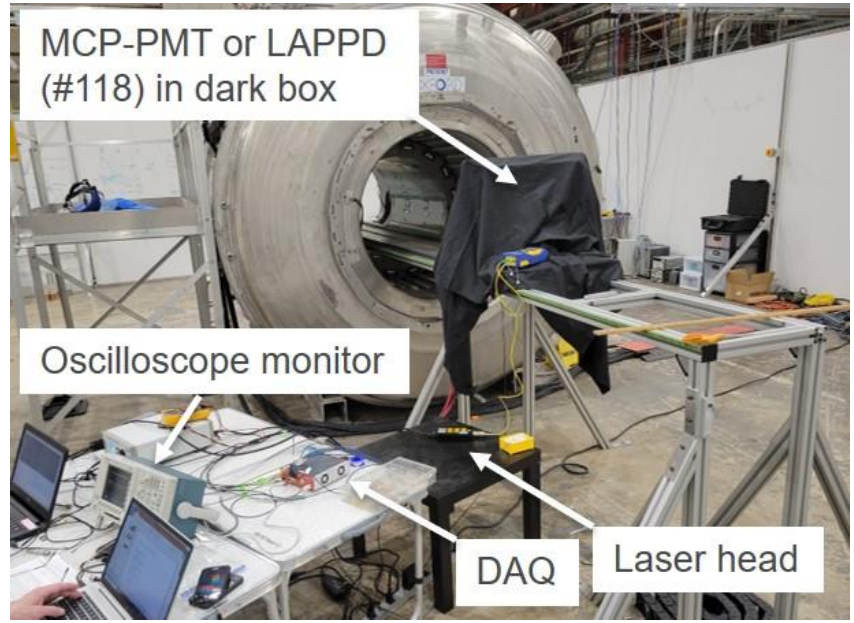
10x10 cm^2 HRPPD



Commercialized HRPPD is considered as the baseline photosensor for ePIC pfRICH and DIRC.

MAGNETIC FIELD TOLERANCE TESTING AT ANL

Magnetic field strength:
- 0.02 T to 1.45 T (up to 4 T)



Photon source:
- Picosecond laser system
- Fiber optics
- Digital attenuator.

Dark box:
- Movable on a trail into the magnet

DAQ:
- CAEN DT5742b desktop digitizer

Rotation in the magnetic field:
- Photosensor tips into or out of the region of stronger magnetic field
- Move the photosensor in or out at each angle to compensate for the change in field strength

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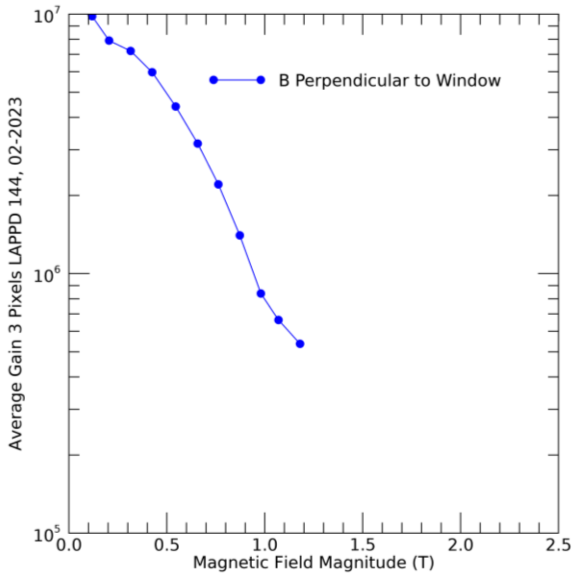
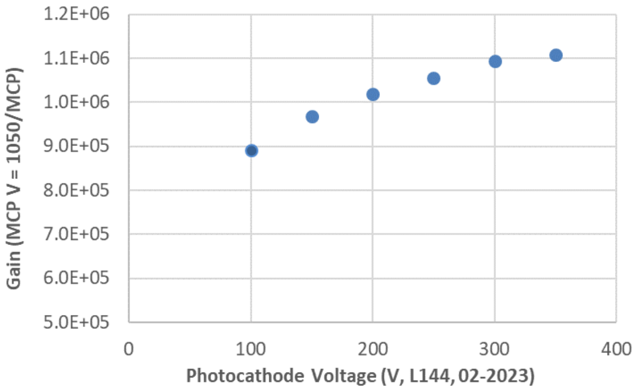
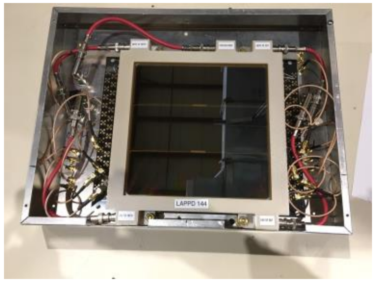
LAPPD PERFORMANCE IN MAGNETIC FIELD

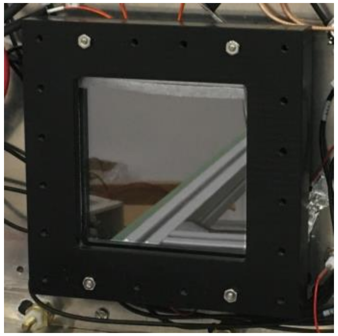




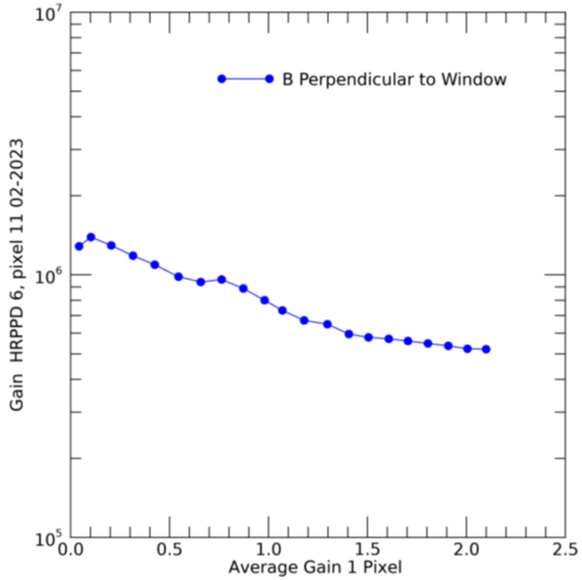


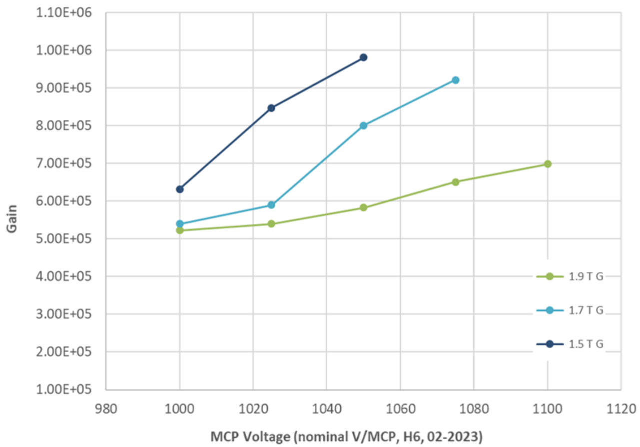
- ❑ The gain declines as the field strength increases, up to 0.9 Tesla for 20 µm pore MCPs.
- ❑ Gain can be recovered at higher field strengths by increasing the bias voltages.

HRPPD PERFORMANCE IN MAGNETIC FIELD



	HRPPD#6
Detector size	10x10 cm
Pore size	10 µm
Readout scheme	Directly Coupled Readout
Quantum Efficiency (365 nm)	5.3%
Gain	$10^6 – 10^7$
Support geometry	No cross





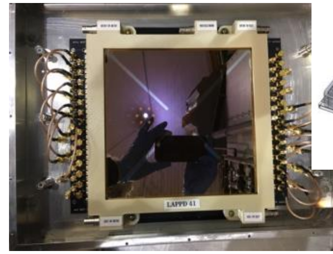
- ❑ Good magnetic field tolerance above 1.5 Tesla with 10 µm MCPs
- ❑ Gain can be recovered by increasing bias voltages

TEST OF GEN-I STRIPLINE LAPPD AT HALL C

Received Gen-I LAPPD

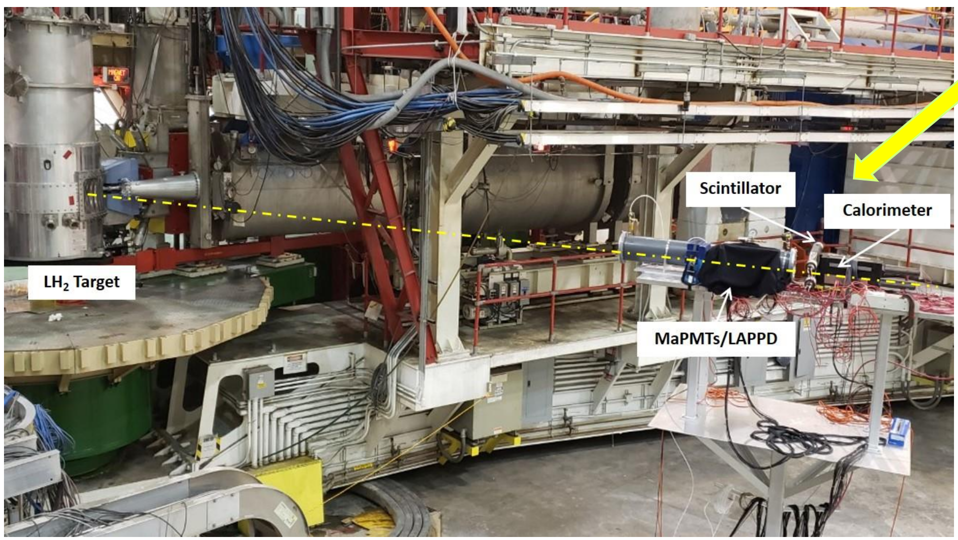
Window material	Fused silica
Readout anode	**Inside stripline**
Quantum Efficiency	**Mean: 7.3%, Maximum: 11%**
Gain	5.4×10^6 with MCPs @ 975V
Time resolution	56 ps

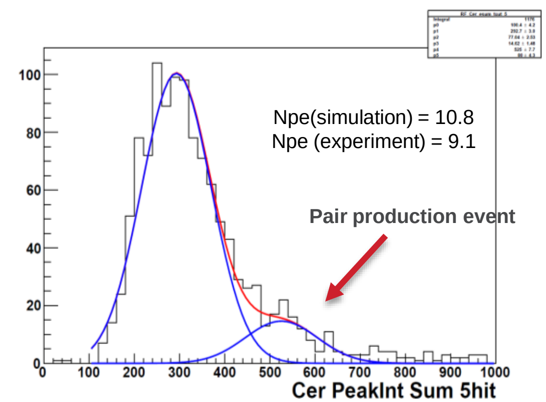
Experimental high rate background environment



Opportunistic effort well before SoLID pre-R&D

Detector package:
Cherenkov tank (CO_2 at 1 atm)
scintillator planes
calorimeter blocks
Photosensors: LAPPD or 4x4 MaPMTs





Ref: C. Peng et al 2022 JINST 17 P08022

- **The first JLab Hall C test shows that the LAPPD might work in the Hall C environment to separate Cherenkov events.**
- **Needs high QE, pixelated LAPPDs for follow up testing.**

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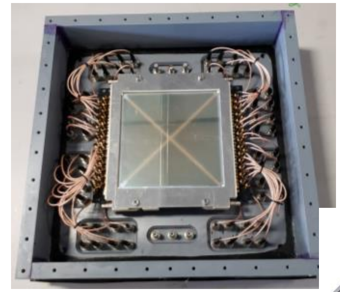
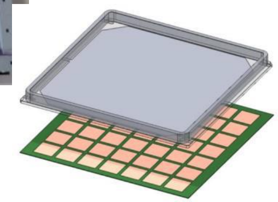
TEST OF GEN-II PIXELATED LAPPD AT JLAB

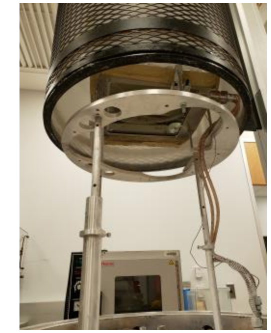
SoLID pre-R&D

Received Gen-II LAPPD

Window material	B33 glass (with wavelength shifter coating)
Readout anode	**Capacitive coupled 25mm x 25mm pixel** 20 µm pore size MCPs, thick ceramic anode
Quantum Efficiency	**Mean: 15%, Maximum: 17%**
Gain	9.5×10^6 with MCPs @ 875V
Time resolution	79 ps

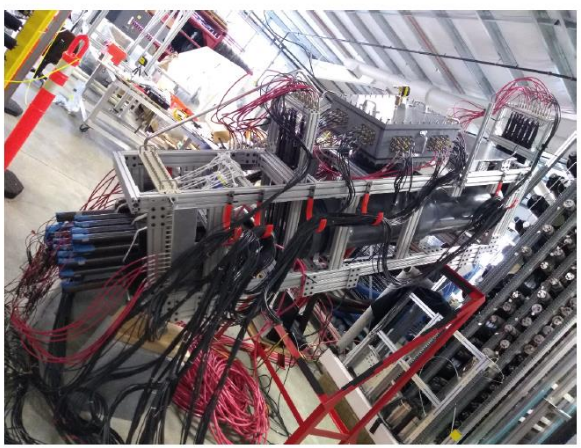


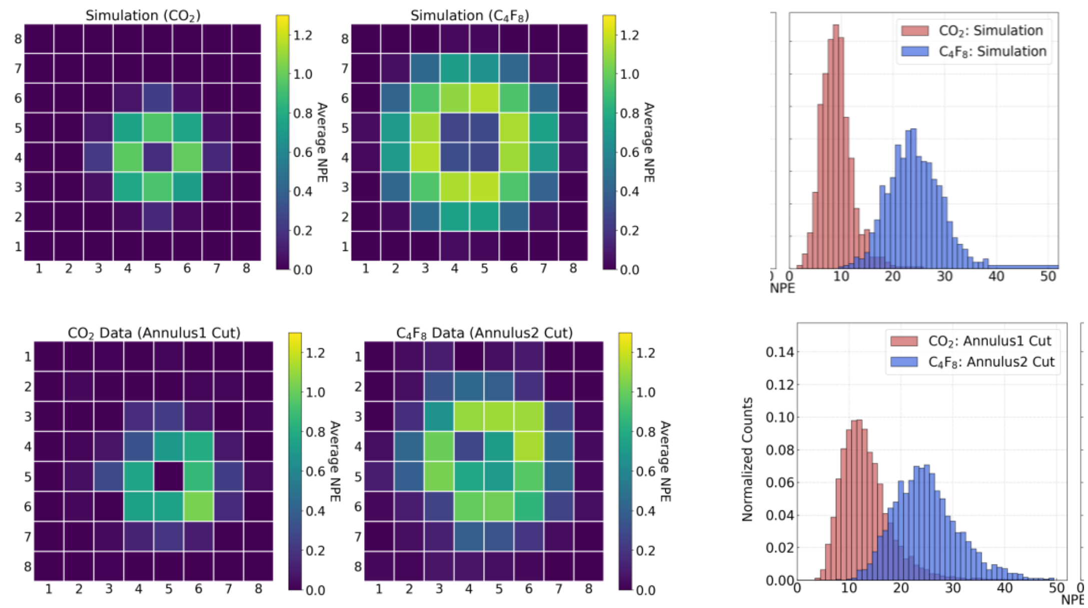




Coated with wavelength shifter at Temple Univ.

Similar detector setup but larger volume



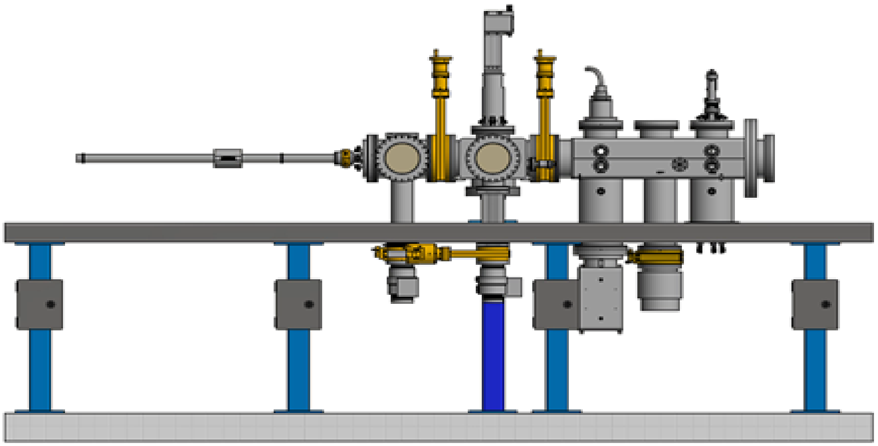


Simulation (upper) and experimental (lower) of average NPE per event for the LAPPD beam test agree with each other.

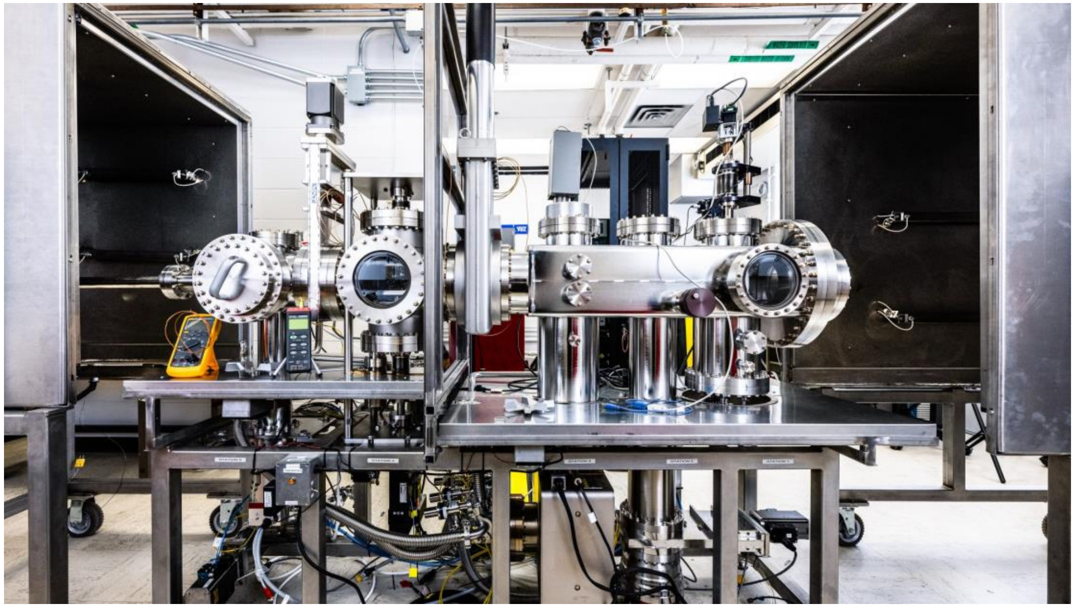
Ref: J. Xie et al 2024 JINST 19 P08011

- **The 2nd JLab Hall C confirms that the LAPPD works in the current hall C rate environment**

NEW ANL LAB FACILITY:
10X10 CM MCP-PMT FABRICATION FACILITY



10×10 cm² MCP-PMT fabrication facility at Argonne



PROCESS DEVELOPMENT

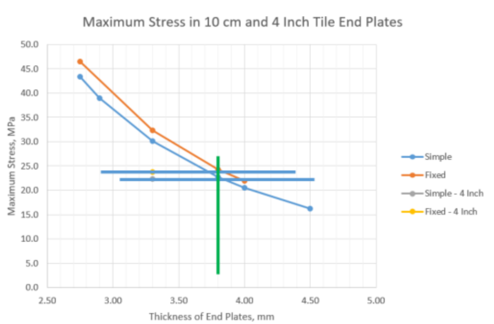
Photocathode deposition

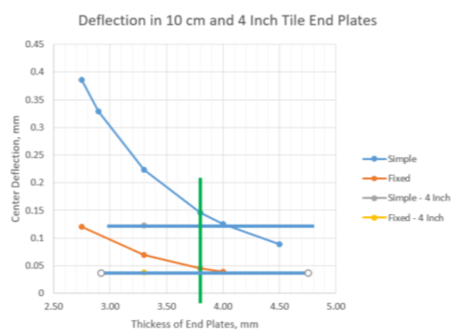
- ✓ Completed individual source evaporation studies.
- ✓ Redesigned the source holder: increase space to hold enough evaporator sources.
- ✓ Achieved bialkali (K-Cs-Sb) photocathode with correct transparency.

Hermetic sealing

Initial several trails resulted in leaking and glass implosion under vacuum

- ✓ Performed stress and deflection studies on the 10x10 cm^2 glass
- ✓ Redesigned envelope tile with thicker window and anode glasses.
- ✓ Achieved leak-tight hermetic seal without implosion.





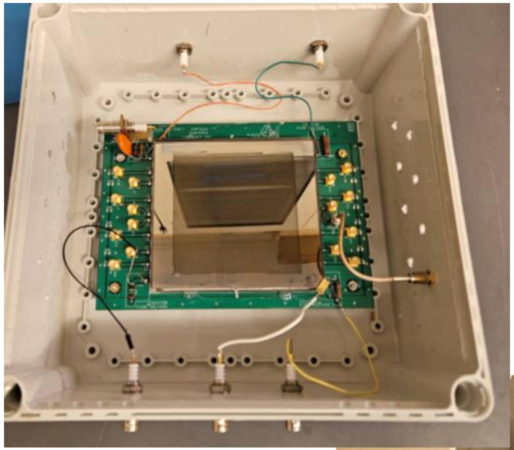
Hermetically sealed envelope
Tested under vacuum without implosion

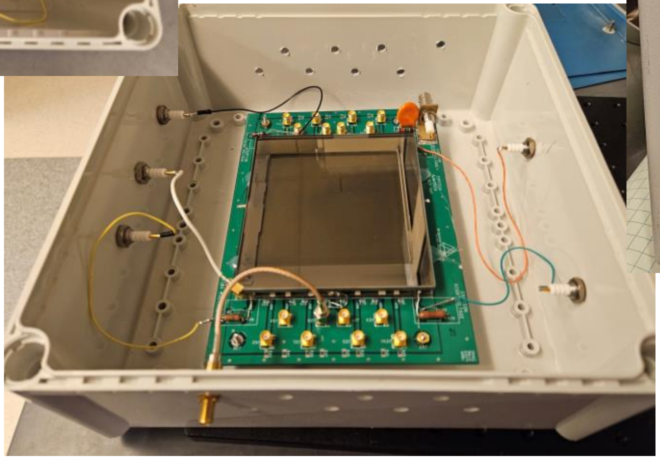
Note: Tile base pattern is designed specifically for SoLID application

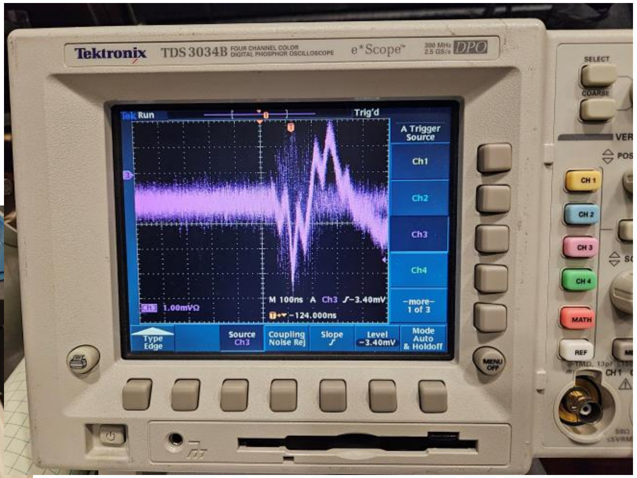
RECENT SEALED MCP-PMT

But did not last long enough

Recently, we are working towards a sealed MCP-PMT,
Encountering sealing issue in vacuum, lost vacuum quickly after taking out of the facility.







New trail is prepared to aim for a sealed prototype for test

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LAB FACILITY:
PHOTOSENSOR CHARACTERIZATION EQUIPMENT

Photocathode QE, I-V characterization station

MCP gain testing stand

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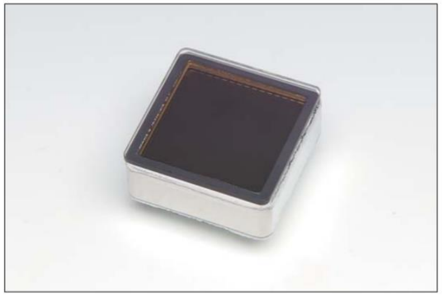
HAMAMATSU MCP-PMT TEST FOR SOLID SPD



FEATURES

- 16 matrix multianode
- Small dead space
- Fast time response
- High magnetic field immunity
- Long life time

Tasks:

1. MCP-PMT photocathode response map (complete 1 month after approval)

- Bench test, get baseline performance for the Hamamatsu MCP-PMT
- QE measurement, voltage-current (I-V) curve, QE map measurement

2. Magnetic field tolerance (complete 6 month after approval)

- Schedule the magnetic field test period
- MCP-PMT magnetic field compatible dark box and readout modification
- MCP-PMT magnetic field test under different bias voltages, different magnetic field strength
- Magnetic field test data analysis

3. MCP-PMT maximum anode current and anode or photocathode lifetime (complete 9 month after approval)

- Lifetime setup test stand modification with long time light exposure monitor capability
- Long time exposure for testing: Expect 6 months or longer?
- Occasional quantum efficiency, gain, timing resolution measurement

4. MCP-PMT photocathode radiation damage (need 6 months for schedule and preparation)

- Schedule radiation damage test period
- Radiation damage test stand design and construction
- Exposure of MCP-PMT to radiation source
- Multiple tests of QE, gain and timing resolution between exposures

SUMMARY & FUTURE TEST

Summary:

- Argonne early MCP-PMT development for EIC-PID
- LAPPD/HRPPD magnetic field test results
- LAPPD validation in high-rate environment at JLab Hall C
- Recent status of new 10x10 cm MCP-PMT fabrication facility
- Planned Hamamatsu MCP-PMT test for SoLID SPD

Future test:

- Prototype test of Argonne 10x10 cm MCP-PMT
- Full test of Hamamatsu MCP-PMT for SoLID SPD

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under contract number DE-AC02-06CH11357 and DE-SC0018445.

Thank you for your attention!
Questions?