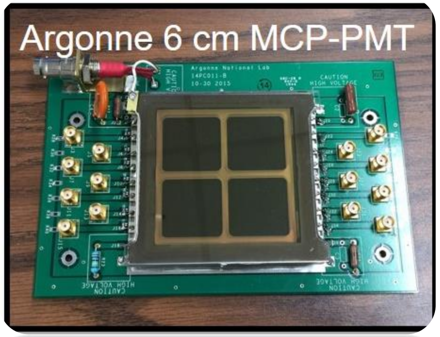
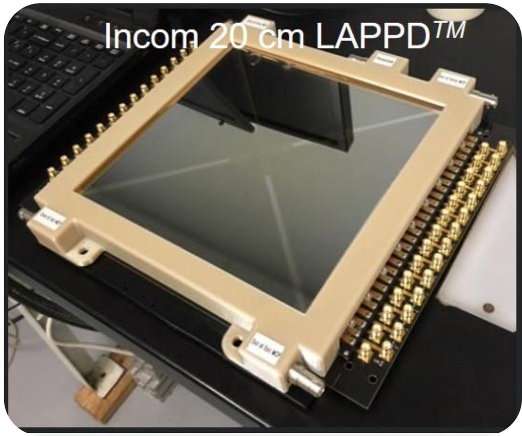
CPAD Workshop 2022
November 29, 2022 to December 2, 2022

PERFORMANCE OF MCP-PMT AND LAPPD IN MAGNETIC FIELD FOR RICH DETECTORS





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ARGONNE MCP-PMT FOR EIC-PID

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.

Key Issue: Photosensors

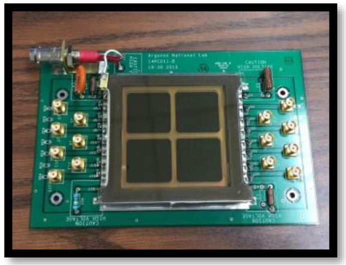
- **Photo Detectors:** The most important challenge is to provide a low-cost, highly-pixelated photosensor working in the high radiation and **high magnetic field** environment.
- This problem is not yet solved.

- **Large-Area Picosecond PhotoDetector (LAPPD)**
  - Promising but still not fully applicable for EIC needs.

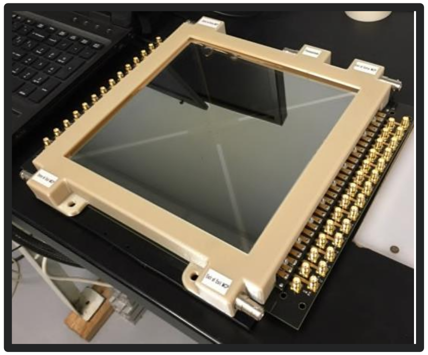
An order of magnitude lower price per active area comparing to current commercial MCP-PMTs.

- **Optimize LAPPD design relying on ANL MCP-PMT fabrication and characterization expertise**
  - **Magnetic field tolerance**
  - Fine pixel readout
  - Fast timing

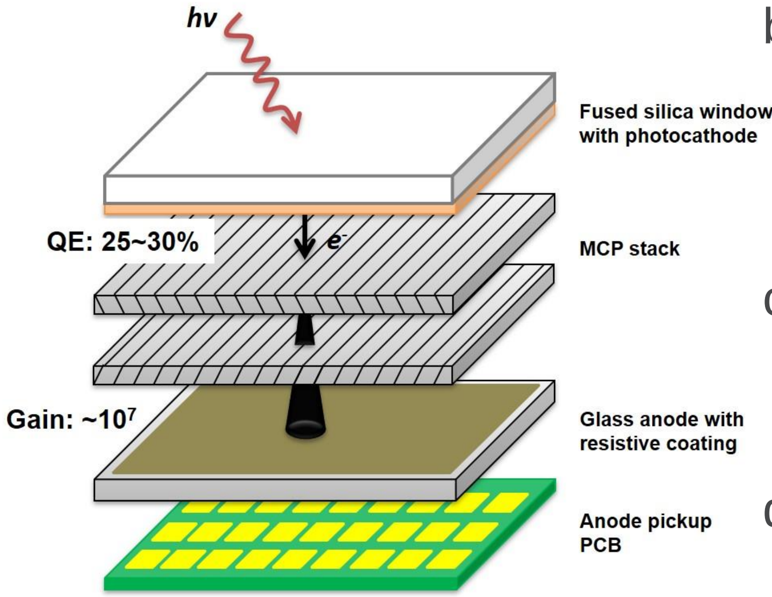
R&D testbed: 6x6 cm^2 @ ANL



Commercialization: 20x20 cm^2 @ Industrial partner (Incom, Inc.)



LOW-COST FULL GLASS/FUSED SILICA DESIGN



a) Full glass/fused silica design with mature fabrication process and low-cost;

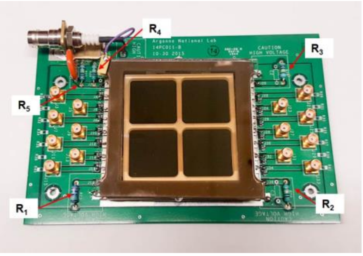
b) Fused silica (or borosilicate glass with wavelength shifter) window extending sensitivity down to UV range for better Cherenkov light detection;

c) Newly developed small pore size MCPs for higher magnetic field tolerance and fast timing;

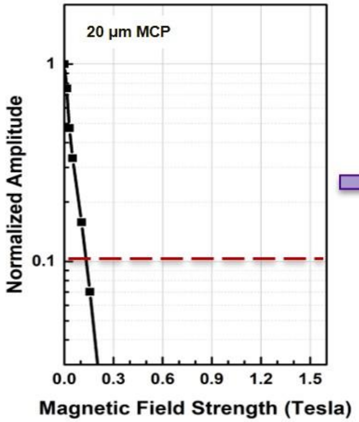
d) Reduced spacing internal geometry further improve the magnetic field tolerance and timing resolution;

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

IMPROVEMENT OF ARGONNE MCP-PMT PERFORMANCE IN MAGNETIC FIELD

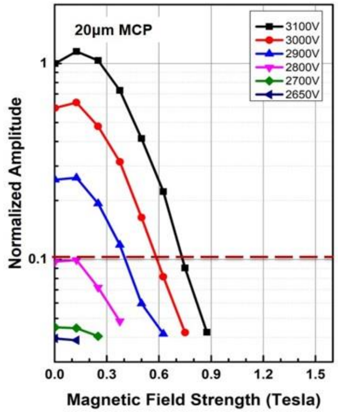


ANL version 1
Internal resistor chain



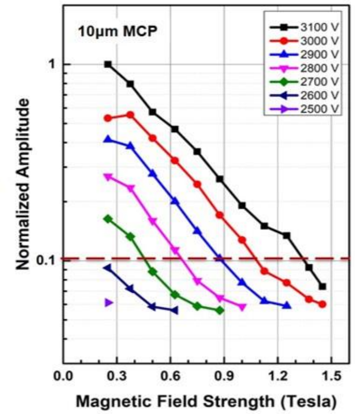
0 < B < 0.15 T

ANL version 2
IBD design 20 µm MCP



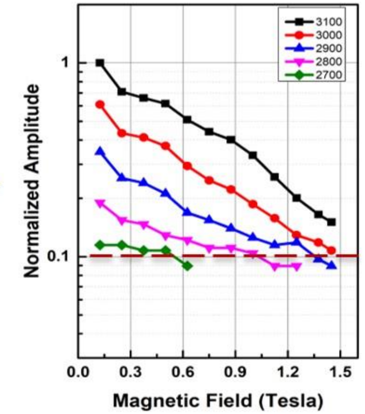
0 < B < 0.7 T

ANL version 3
IBD design 10 µm MCP



0 < B < 1.3 T

ANL version 4
IBD design 10 µm MCP
reduced spacing



0 < B < at least 1.5 T

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

Smaller pore size: 6 µm, version 4 -> 5 (future if required)

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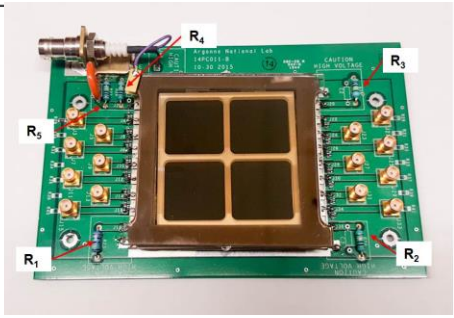
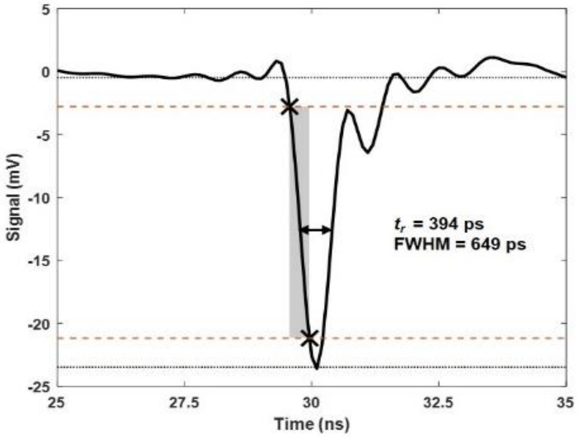
RECAP: DETAILED PARAMETERS AND PERFORMANCE OF ARGONNE MCP-PMT

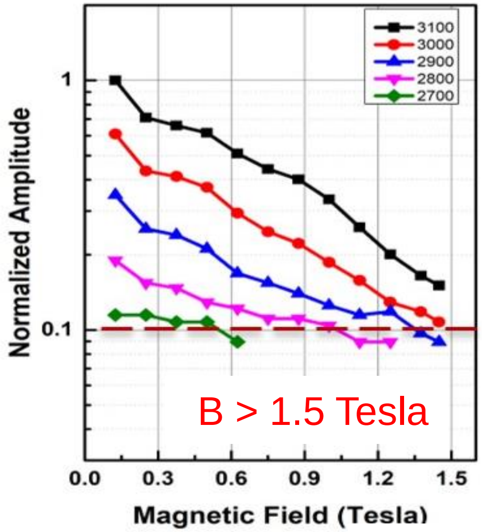
ANL **low-cost** MCP-PMT with 10 μm pore size MCPs and reduced spacing

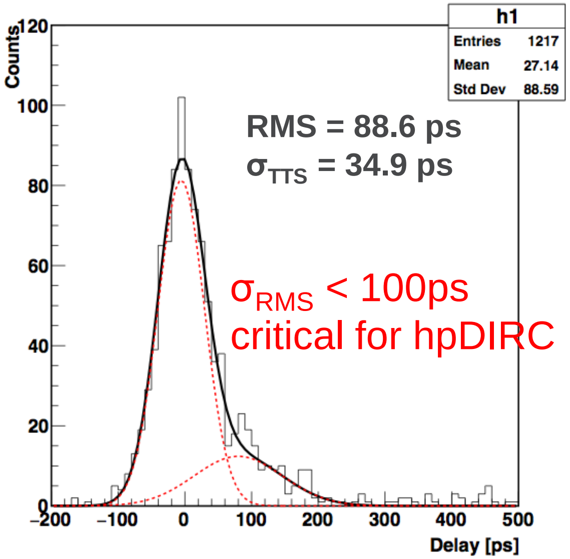
MCP	Pore size	10 μm
	Length to diameter ratio (L/d)	60:1
	Thickness	0.6 mm
	Open area ratio	70 %
	Bias angle	13°
Detector geometry	Window thickness	2.75 mm
	Spacing 1	2.25 mm
	Spacing 2	0.7 mm
	Spacing 3	1.1 mm
	Shims	0.3 mm
	Tile base thickness	2.75 mm
MCP-PMT stack	Internal stack height	**5.55 mm**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









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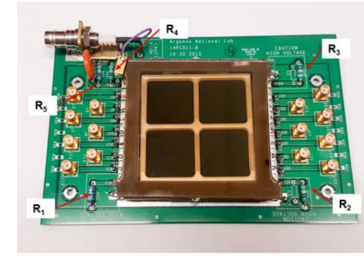
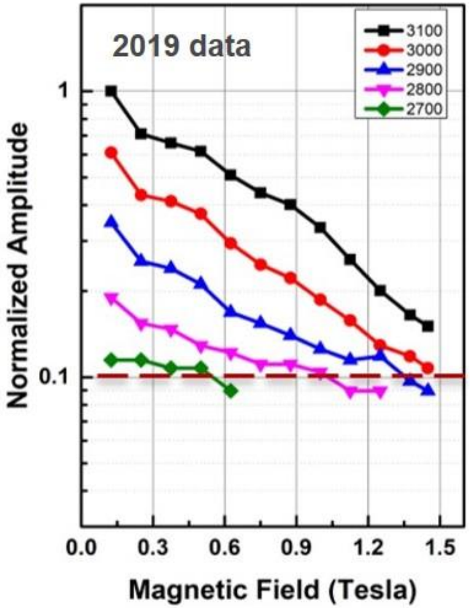
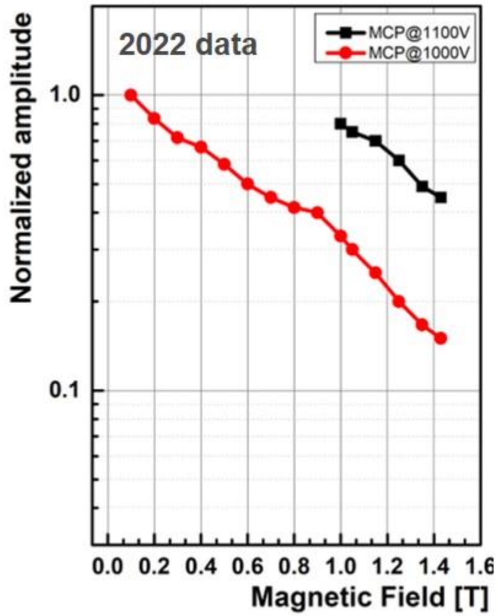
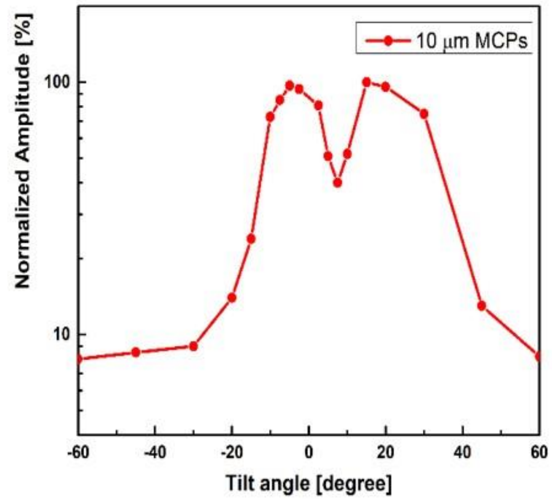
STABILITY OF MAGNETIC FIELD TOLERANCE





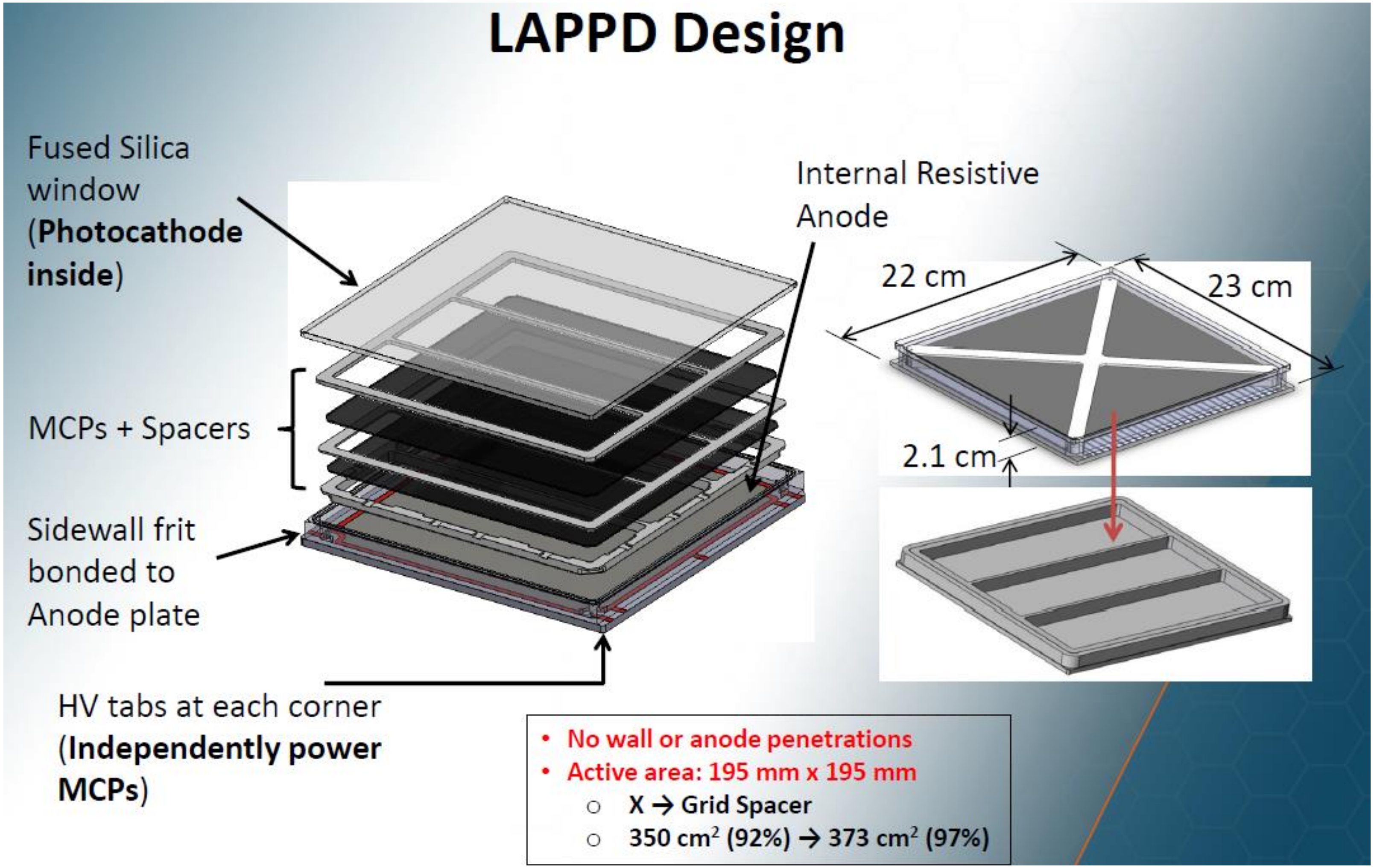




- ❑ Magnetic field tolerance is over 1.5 Tesla, the performance does not decay, shows similar behavior before and after three years.
- ❑ The gain of MCP-PMT decreases as magnetic field increases, the gain was recovered at higher field strengths by increasing the MCP voltage.
- ❑ The gain of MCP-PMT shows angle dependence to the magnetic field direction, magnetic field affects the amplification process inside the pores.

COMMERCIAL INCOM 20X20 CM^2 LAPPD

The Argonne R&D results were adapted by Incom for LAPPD commercialization: 20x20 cm^2, 10x10 cm^2



MAGNETIC FIELD TOLERANCE TESTING SETUP

Magnetic field strength:

- 0.02 T to 1.45 T

Photon source:

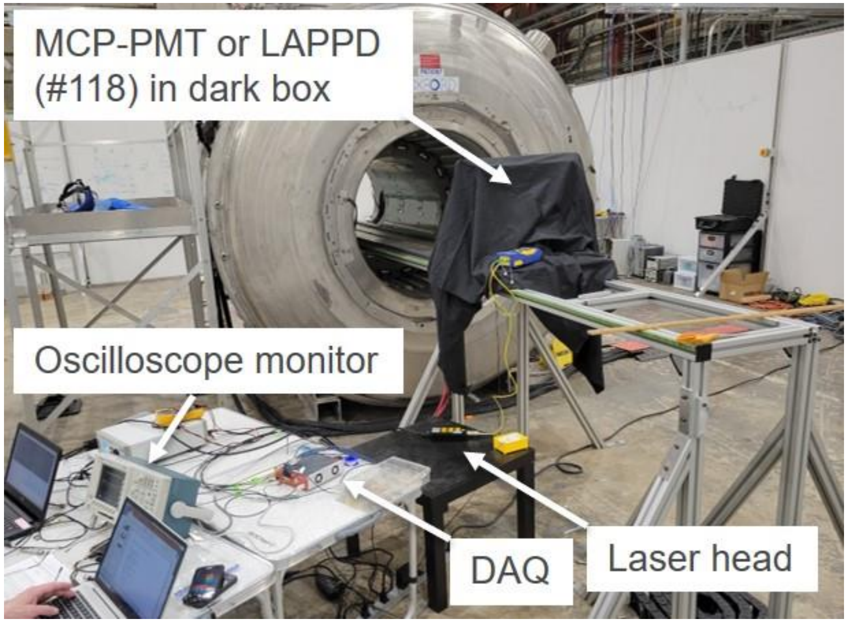
- Picosecond laser system
- Fiber optics
- Digital attenuator.

Dark box:

- Movable on a trail into the magnet

DAQ:

- CAEN DT5742b desktop digitizer



Rotation in the magnetic field:

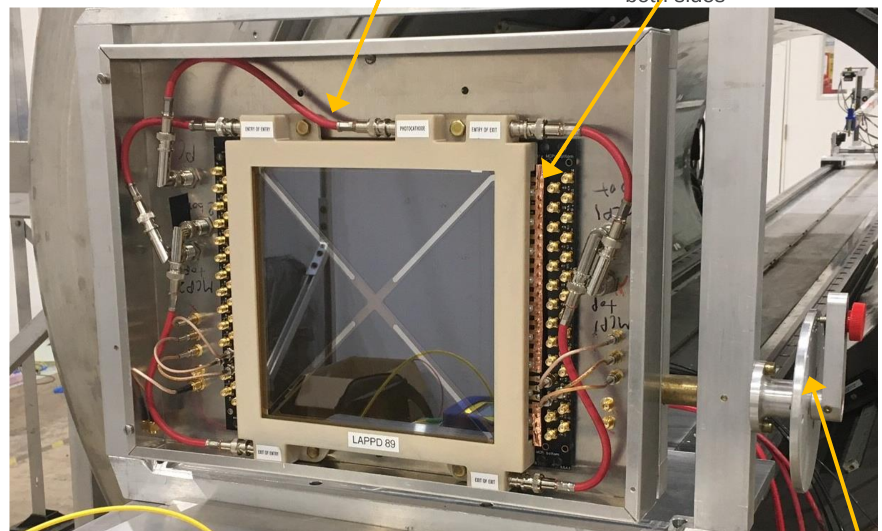
- Photosensor tips into or out of the region of stronger magnetic field
- Move the photosensor in or out at each angle to compensate for the change in field strength

HIGH VOLTAGE AND SIGNAL CONNECTIONS

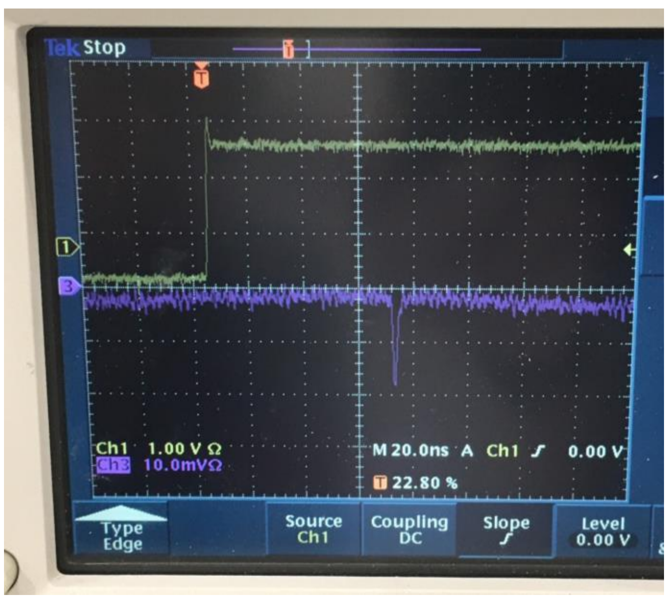
- Three strips, both ends were brought out to a Caen DT5742 DRS_4 waveform sampler.
- Five high voltages were brought in.
- Excellent pulse waveforms from the stripline LAPPDs.

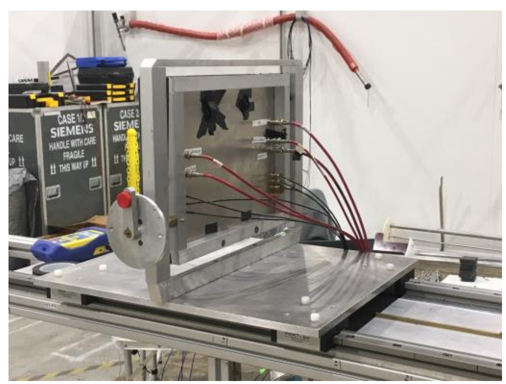
High voltage interior cables

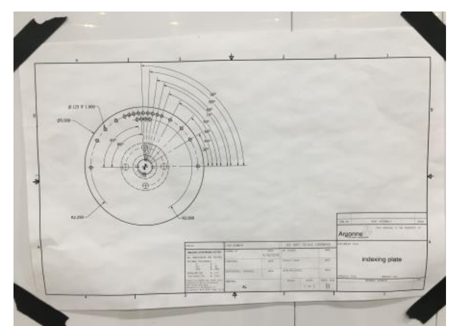
Unused striplines grounded to SMA shields, both sides



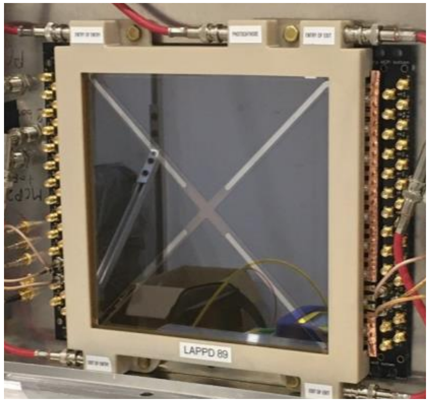
Rotation – discrete positions set with holes

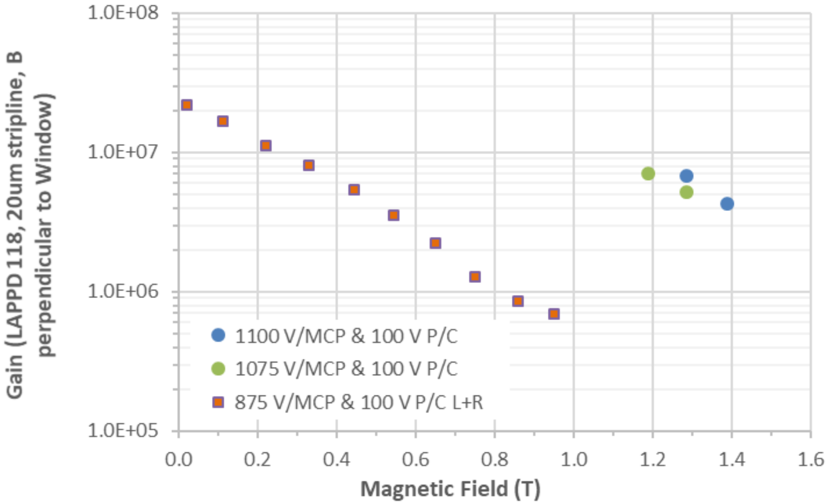


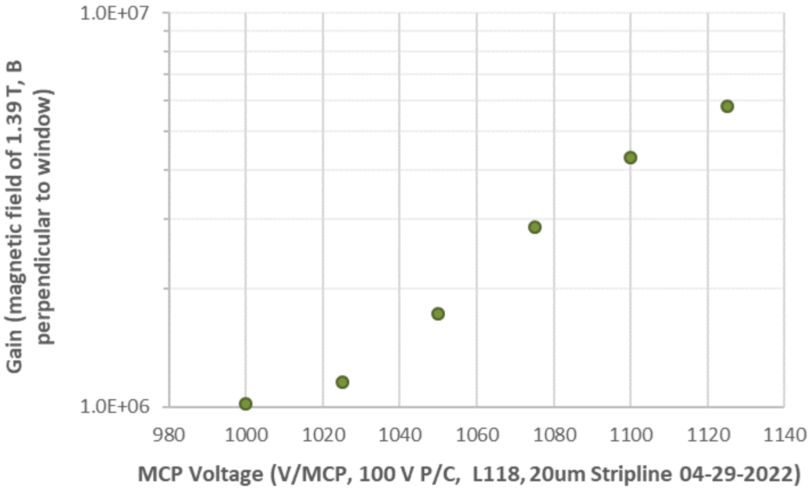




COMMERCIAL LAPPD PERFORMANCE IN MAGNETIC FIELD

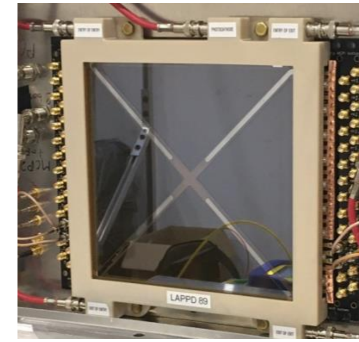


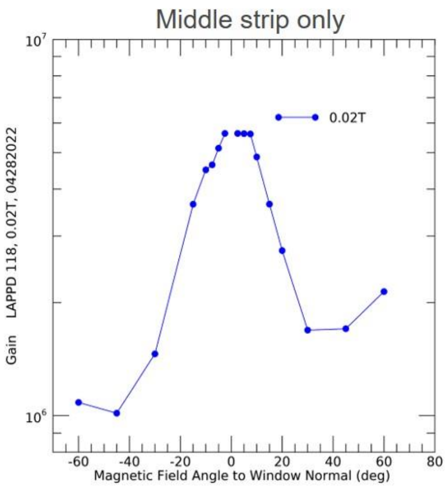


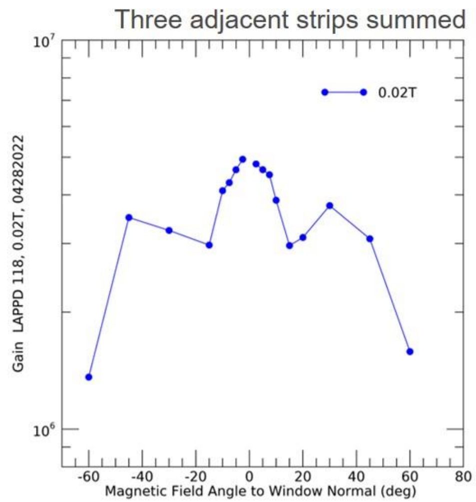


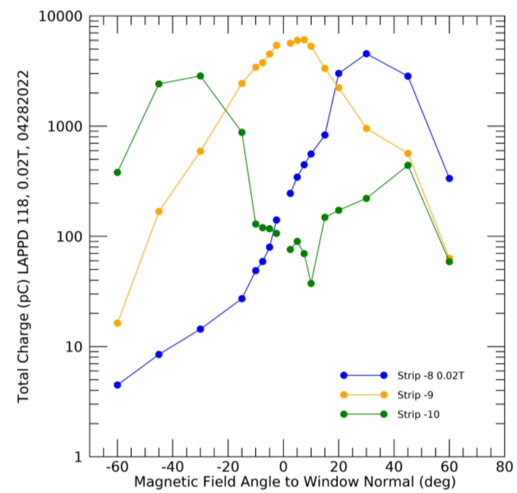
- ❑ LAPPD shows similar behavior trends as R&D MCP-PMT
- ❑ Gain is shown as a function of magnetic field strength. The gain declined from over 2×10^7 to 7×10^5 as the field strength was increased from 0.02 T to ~0.9 T. It was recovered at higher field strengths by increasing the MCP voltage.
- ❑ At a field strength of 1.39 T, the gain was recovered to 6×10^6 by increasing the MCP voltage.

GAIN VS. ROTATION ANGLE: 0.02 T





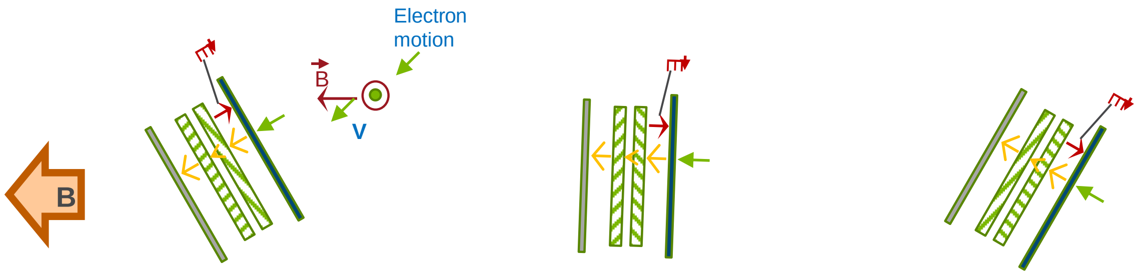




- Gain decreases as the LAPPD is rotated, and the B field is no longer parallel to photoelectron motion.
- Electron landing zone on the anode **moves** with relative B angle

GAIN VS. ROTATION ANGLE: LAPPD 118

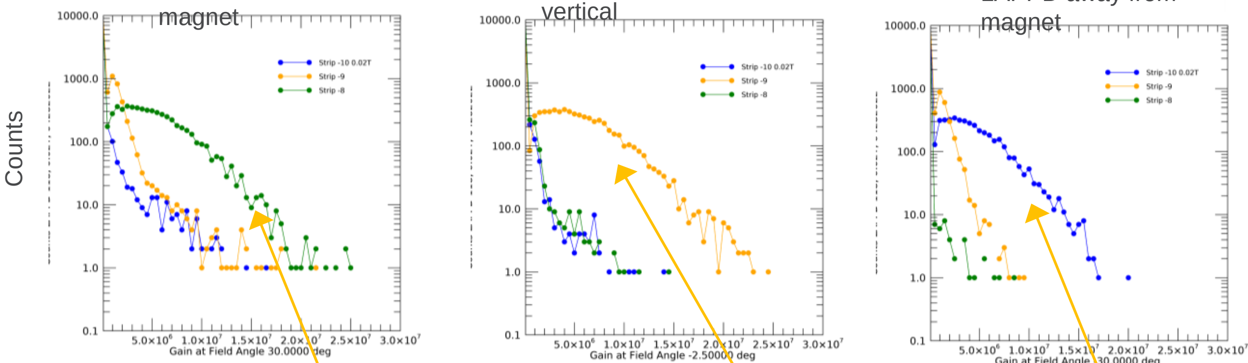
- Pulse height distributions show motion of electrons from one strip to another
- Striplines are in and out of the page
- Motion of electrons appears to be perpendicular to strips, instead of parallel to strip – position data



30 deg: top of LAPPD toward magnet

-2.5 deg: LAPPD ~ vertical

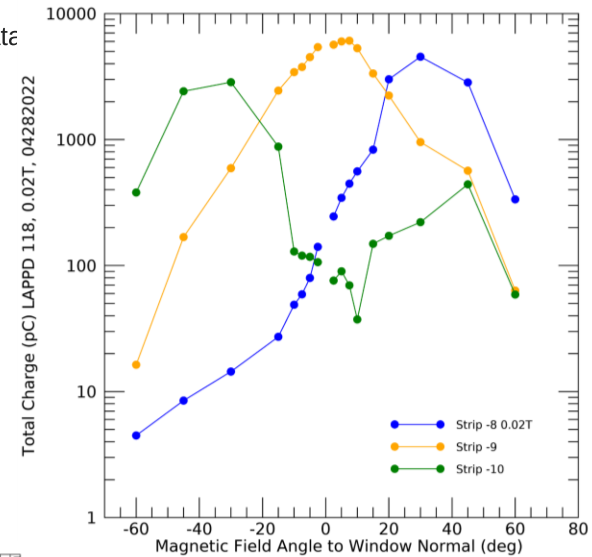
30 deg: top of LAPPD away from magnet

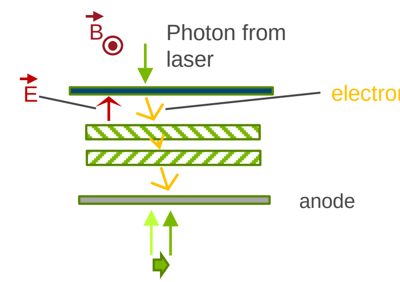


Adjacent strip on one side (-8)

Center strip (-9)

Adjacent strip on the other side (-10)





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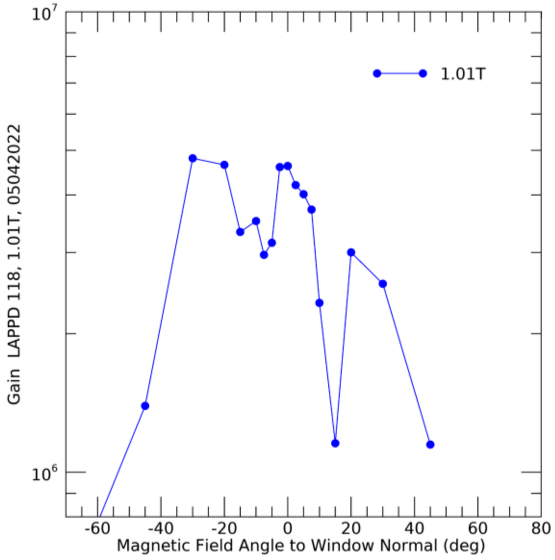
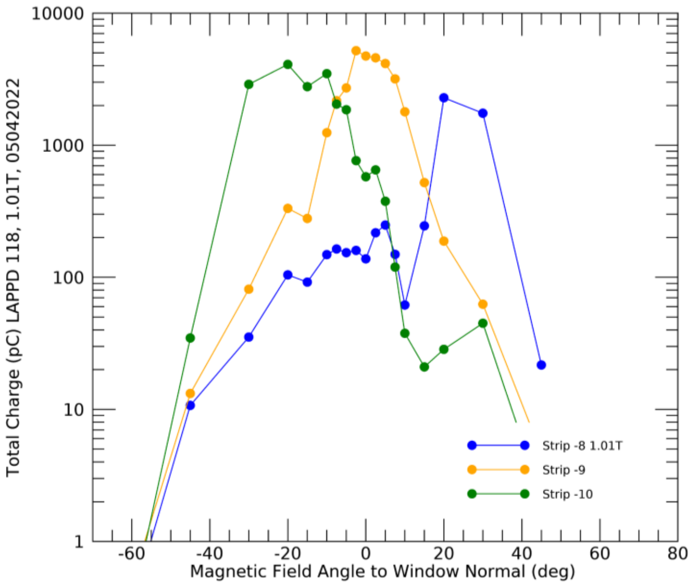
GAIN VS. ROTATION ANGLE AT LARGER B FIELD: 1 T





- Similar behavior as in small B field.
- Stronger angle affection in larger B field.
- Signal electron cluster landing zone on the anode **moves** with relative B angles.

SUMMARY

- R&D on optimization of MCP-PMT towards particle identification is concluded, especially for magnetic field tolerance improvement.
- MCP-PMT with smaller pore size and reduced spacing exhibits significantly improved magnetic field tolerance.
- MCP-PMT shows stable magnetic field tolerance over years.
- Large area picosecond photodetector (LAPPD^{TM}) adapting the R&D was under commercialization with performance comparable to MCP-PMTs in market.
- LAPPD shows similar performance trend as R&D MCP-PMT in magnetic field. Signal movement along magnetic field angle was observed.
- Future adaption of 10 um pore size MCP should further improve its performance in magnetic field.

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And many others …

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Thank you for your attention!

Questions?