International Conference on Technology and Instrumentation in Particle Physics

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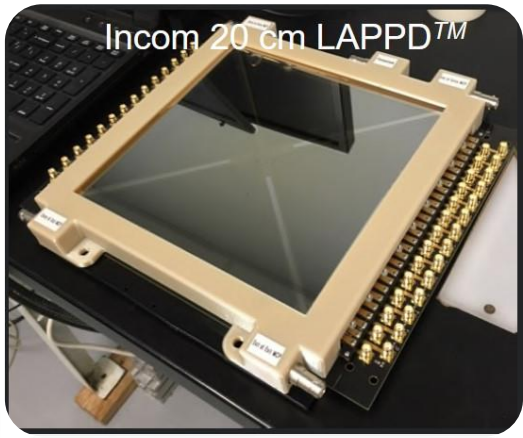
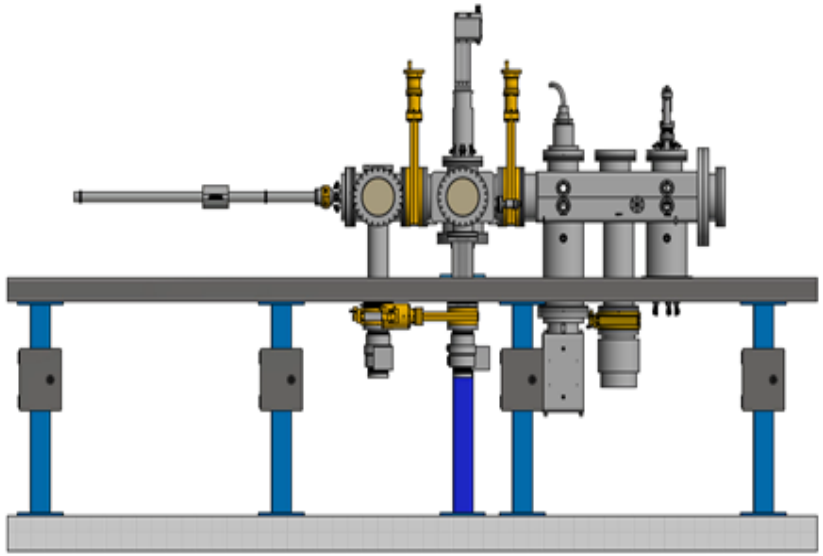
Argonne NATIONAL LABORATORY

RECENT PROGRESS ON DEVELOPMENT OF MCP-PMT AT ARGONNE NATIONAL LABORATORY





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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.

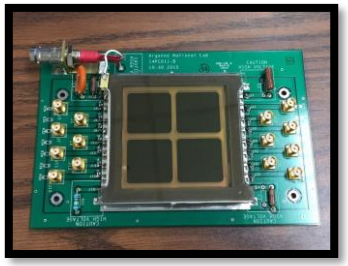
- **Large-Area Picosecond PhotoDetector (LAPPD)**
  - Promising but still not fully applicable for EIC needs.

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

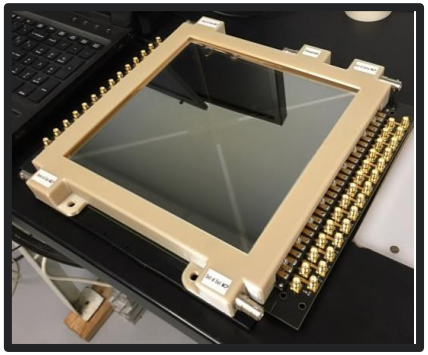
❑ **Optimize LAPPD design relying on ANL MCP-PMT fabrication and characterization expertise**

- Magnetic field tolerance
- Fine pixel readout
- Fast timing

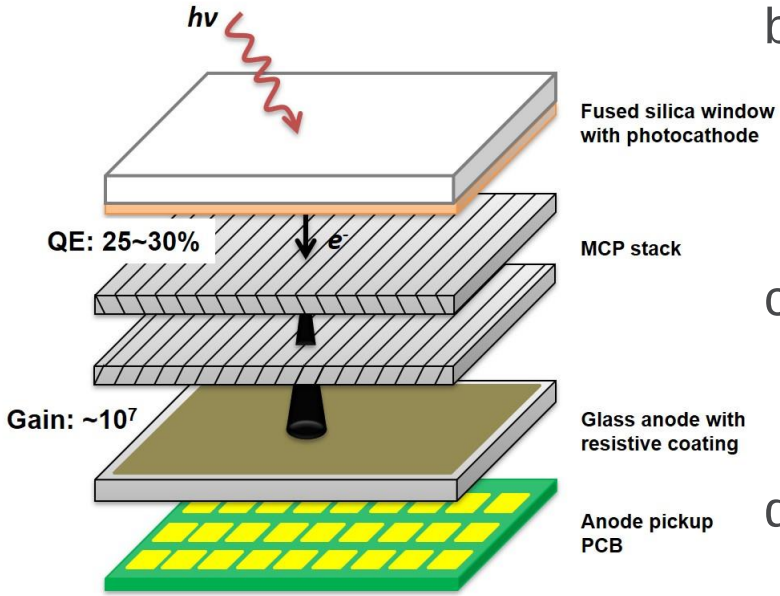
R&D testbed: 6x6 cm^2 @ ANL



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;

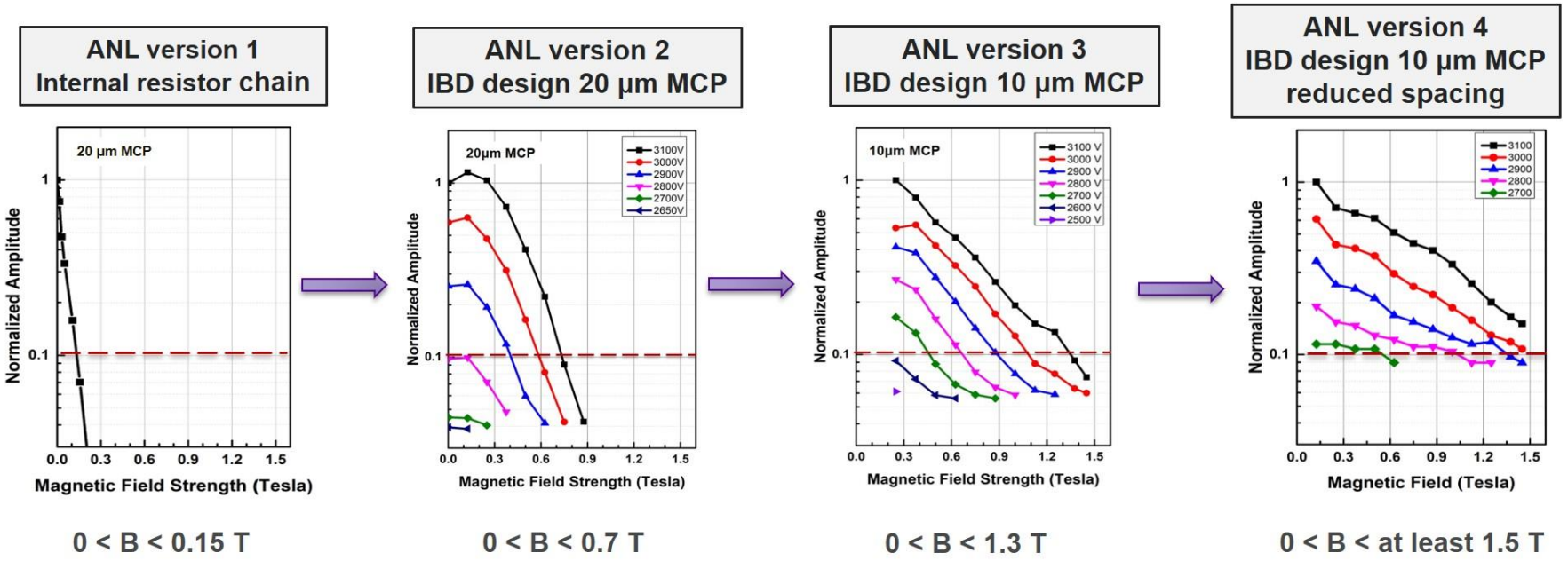
b) Fused silica (or borosilicate glass with wavelength shifter) window extending sensitivity down to UV range for better Cherenkov light detection;

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

d) Reduced spacing internal geometry further improves 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



Babar and CLEO Magnets: 1.5T

- 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:

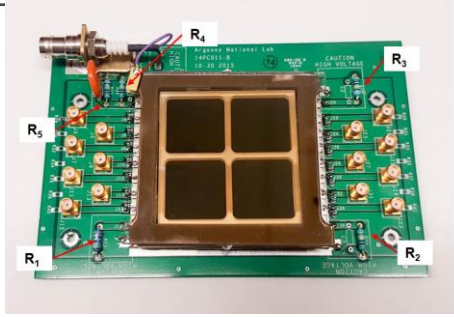
  Smaller pore size: 6 μm, version 4 -> 5 (future if required)

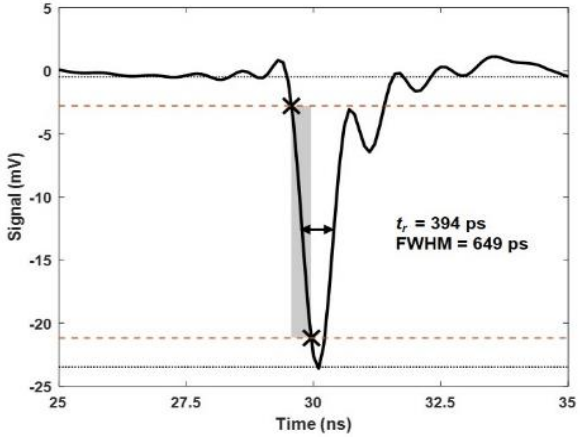
J. Xie et al 2020 JINST 15 C04038

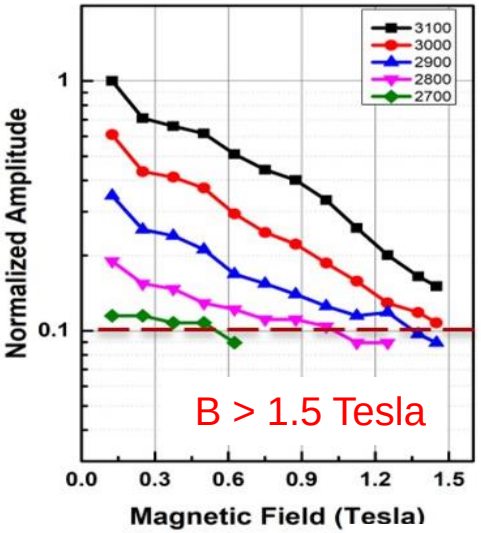
DETAILED PARAMETERS AND PERFORMANCE OF ARGONNE MCP-PMT

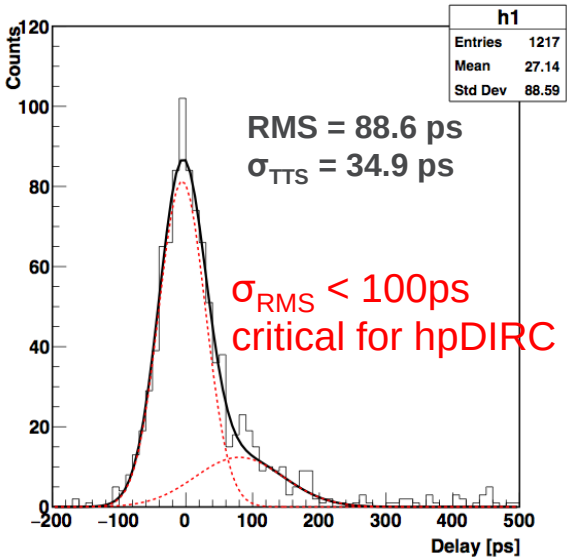
ANL **low-cost** MCP-PMT with 10 μm pore size MCPs and reduced spacing

MCP	Pore size	10 μm
	Length to diameter ratio (L/d)	60:1
	Thickness	0.6 mm
	Open area ratio	70 %
	Bias angle	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**









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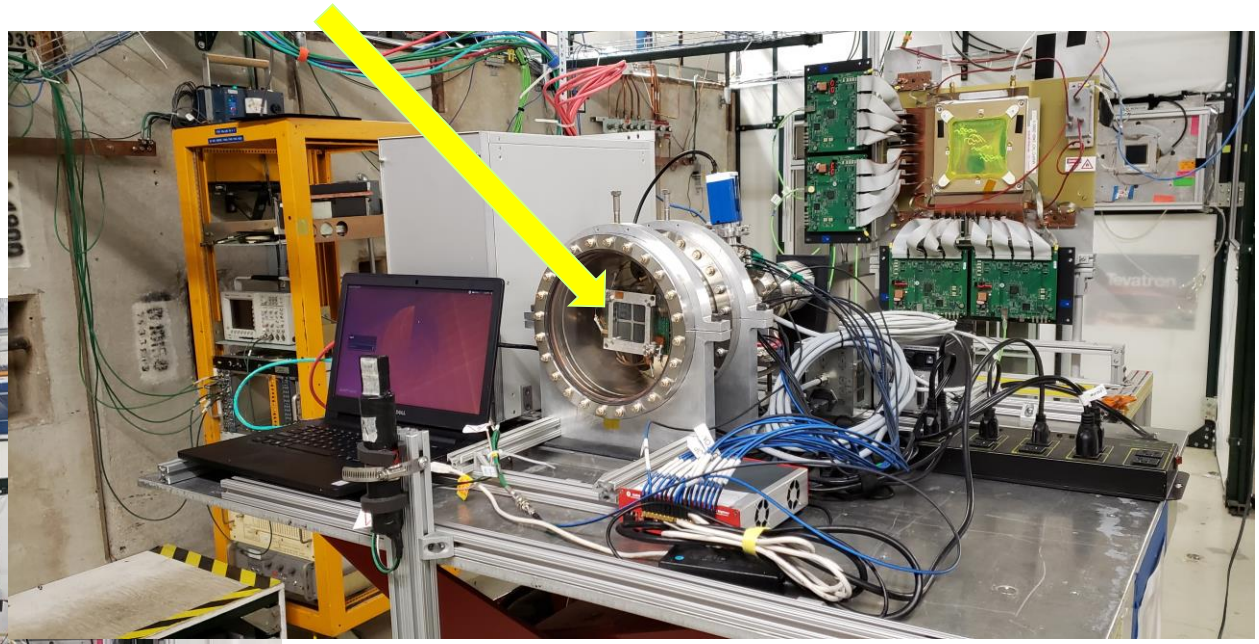
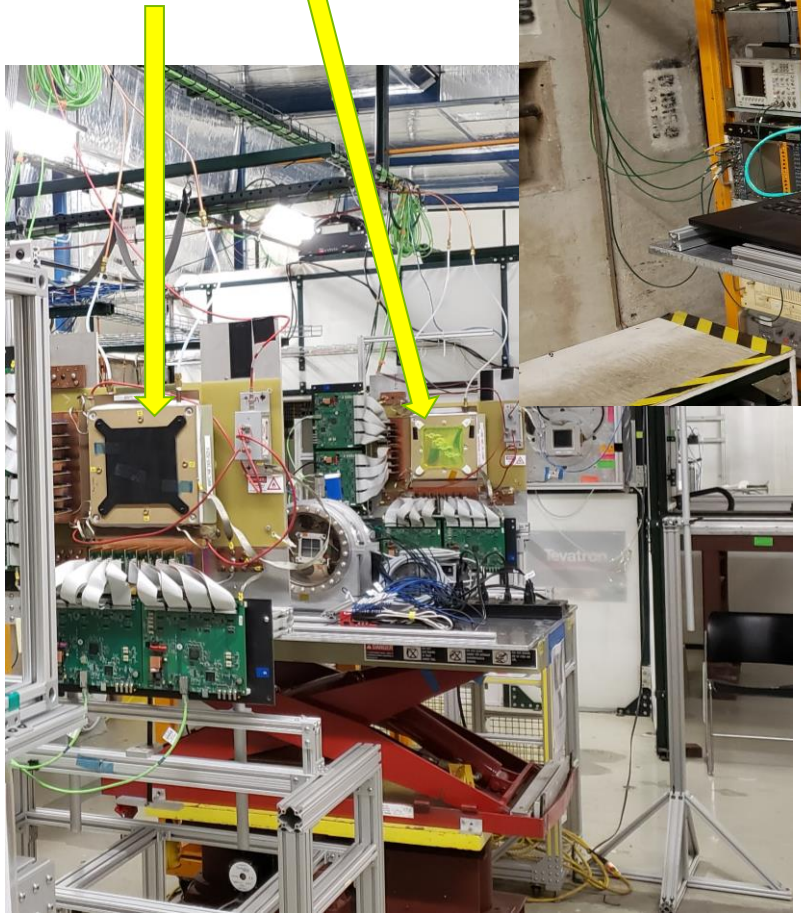
FINE PIXELATED READOUT THROUGH GLASS/FUSED SILICA ANODE

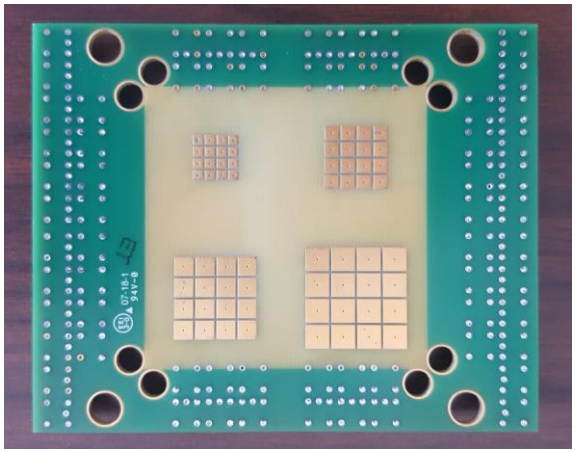
Argonne MCP stack (glass anode) in Fermilab test beam



MWPC tracking used



4 different pixel sizes (2x2,3x3,4x4 and 5x5 mm^2) implemented for testing



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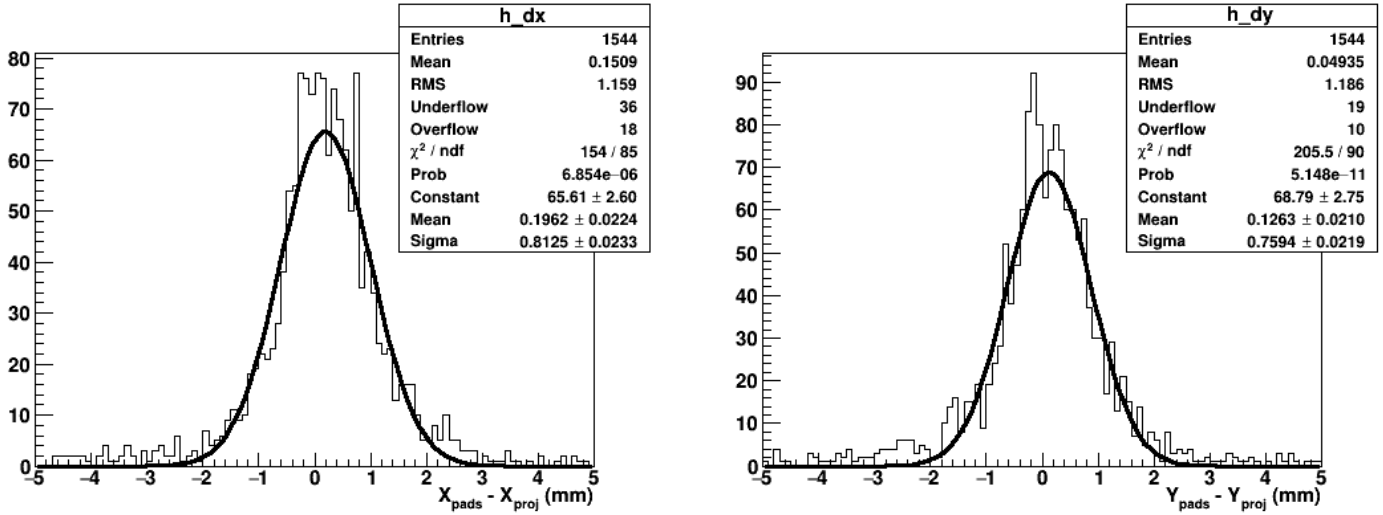
POSITION RESOLUTION

Difference between the pad mean position (CG) and the track pointing

4 mm x 4 mm pixel as example

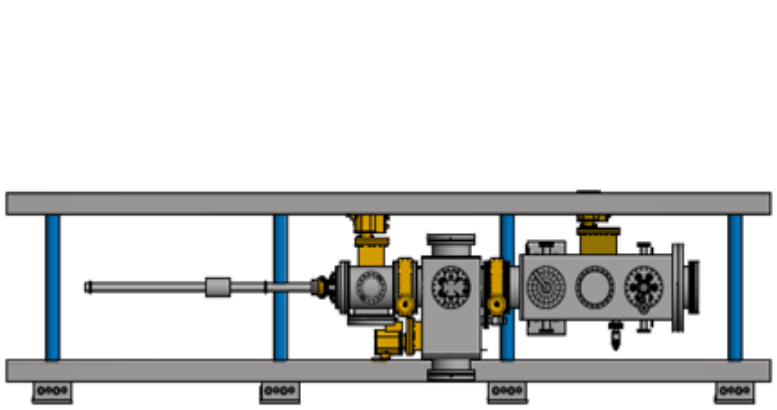


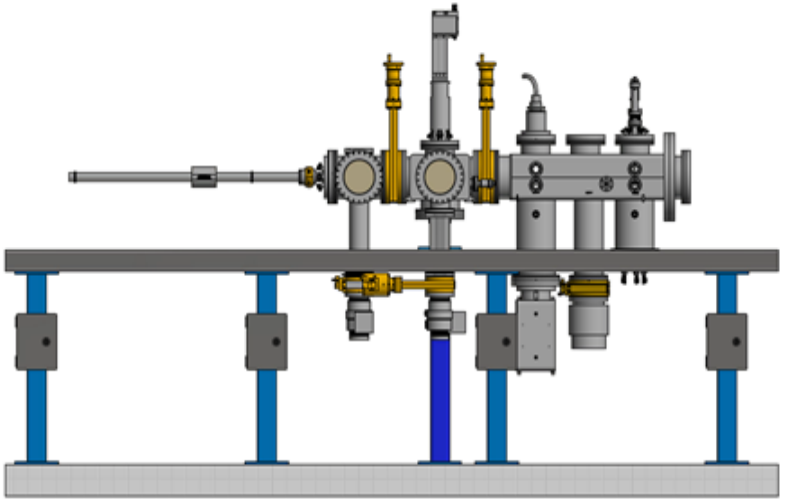
	X res (mm)	Y res (mm)
2x2 mm	1.4	1.7
3x3 mm	0.94	0.95
4x4 mm	0.81	0.76
5x5 mm	1.1	0.97

- All resolutions ~1 mm with small pixels, reaching the requirements for EIC Cerenkov sub-systems.
- Potentially limited by track pointing resolution capability of MWPCs (1 mm pitch)
- 2x2 may be worse due to leakage of signals (poor containment since it is a smaller area)

NEW ARGONNE 10X10 CM^2 MCP-PMT FABRICATION SYSTEM

- ✓ Large practically applicable device size: designed for 10x10 cm^2
- ✓ High and uniform QE: uniform heating and substrate rotate mechanism





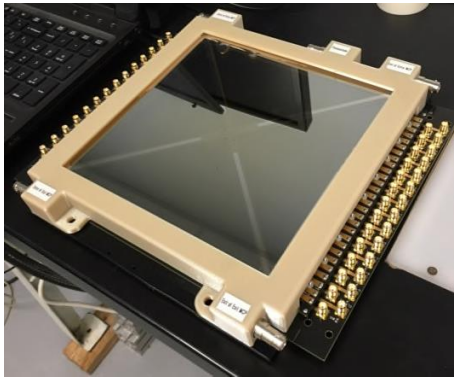
Construction is currently undergoing.
Aim to complete commissioning of the full system within FY21.

Beneficial projects:

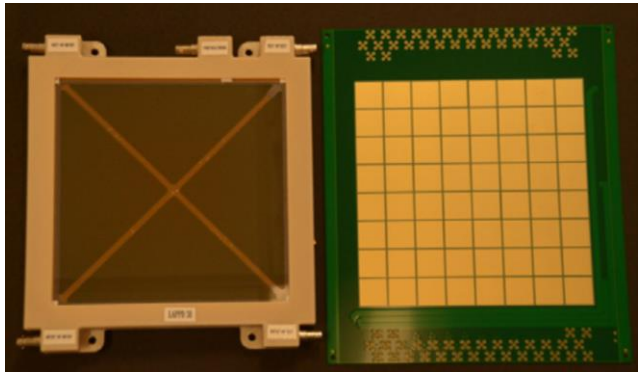
- ❑ Pixelated, magnetic field tolerant MCP-PMT for **Electron ion collider**;
- ❑ Radio-pure MCP-PMT for **Neutrino less double beta decay**;
- ❑ Pixelated, fast timing MCP-PMT for **Medical isotope detection;**
- ❑ ……

CURRENT STATUS OF LAPPD COMMERCIALIZATION

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

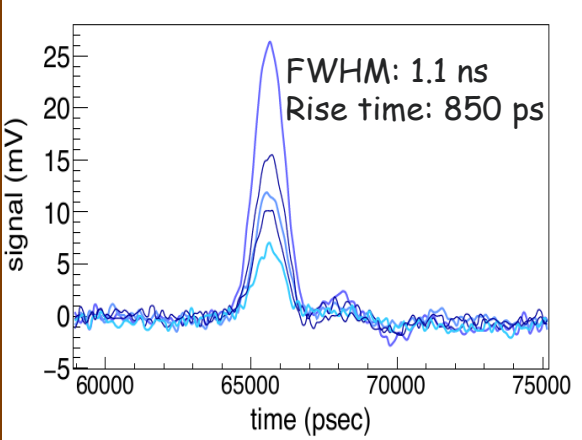


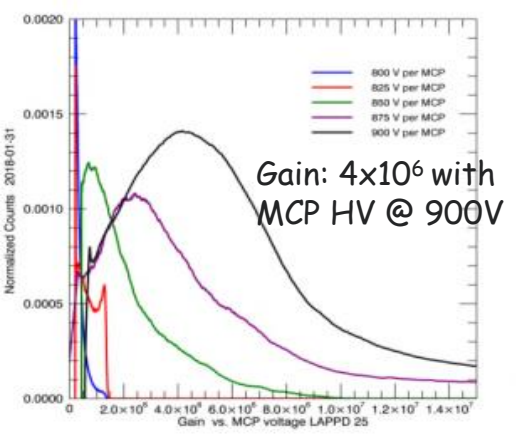
Gen-I LAPPD with stripline readout

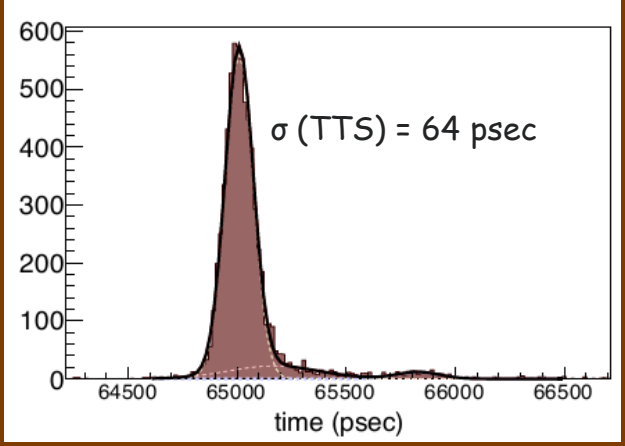


Gen-II LAPPD with pixel readout

Gain & Timing

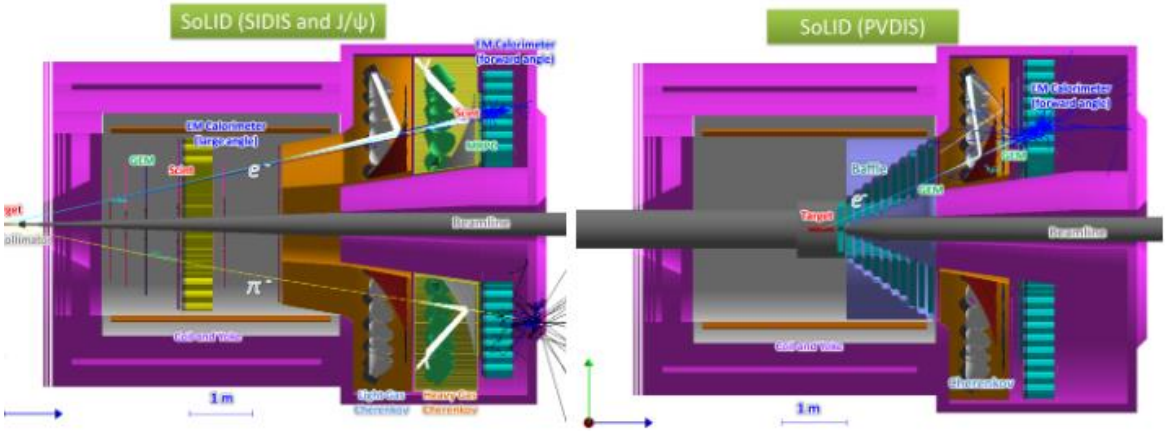




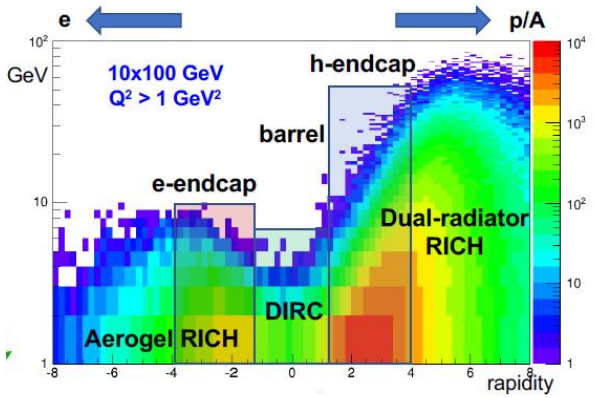


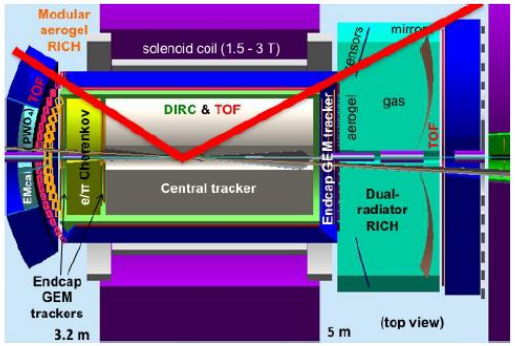
EXPLORE APPLICATION OF LAPPD^{TM} FOR NUCLEAR PHYSICS PARTICLE IDENTIFICATION

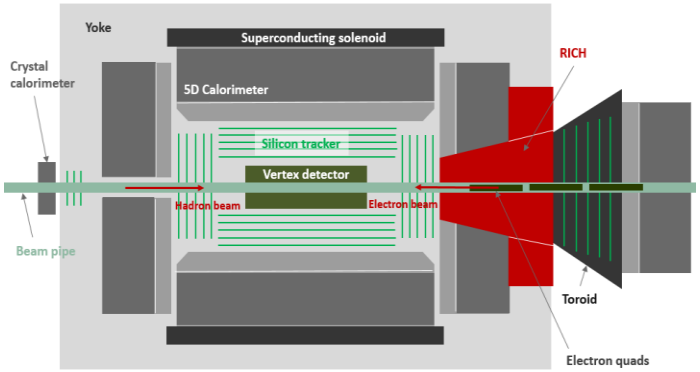
SoLID *SoLID (Solenoidal Large Intensity Device) Light gas Cherenkov counter*



EIC *JLEIC: mRICH, hpDIRC and dRICH; TOPSiDE: gaseous-RICH*







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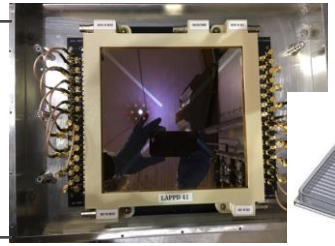
TEST OF GEN-I STRIPLINE LAPPD AT JLAB

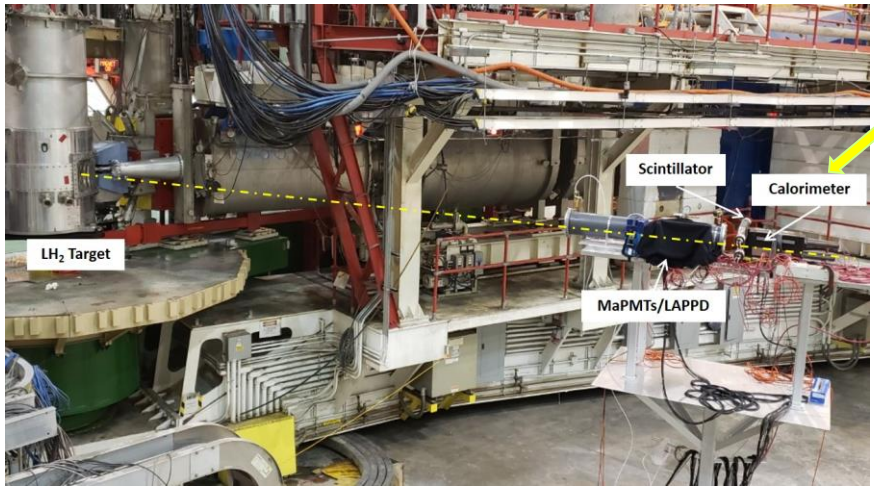
Received Gen-I LAPPD

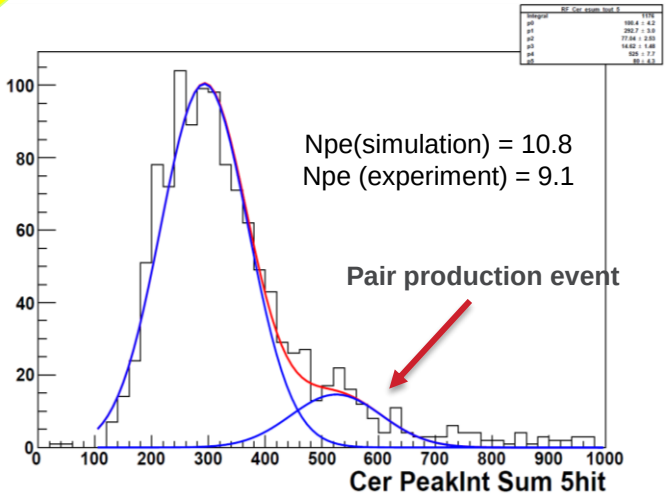
Window material	Fused silica
Readout anode	**Inside stripline**
Quantum Efficiency	**Mean: 7.3%, Maximum: 11%**
Gain	5.4×10^6 with MCPs @ 975V
Time resolution	56 ps



Experimental high rate background environment

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





Ref: C. Peng et al., arXiv:2011.11769

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

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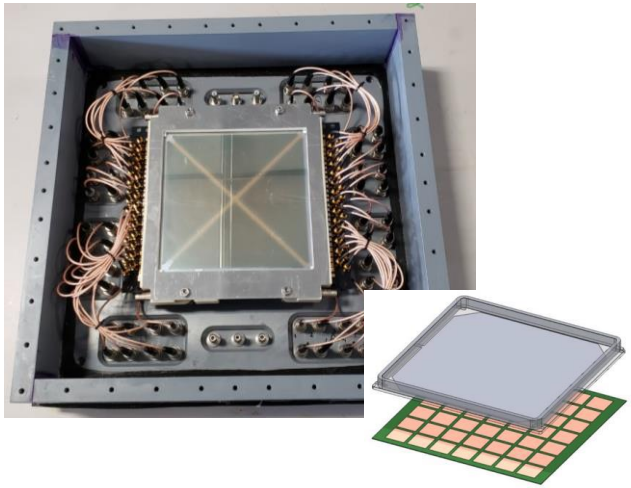
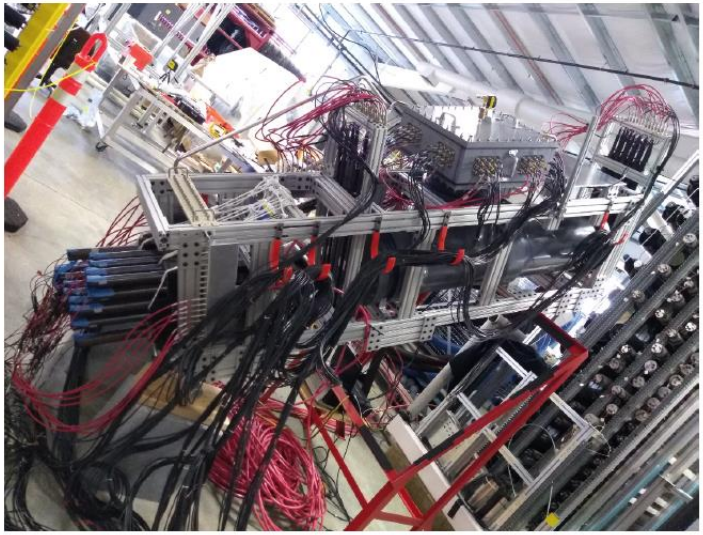
TEST OF GEN-II PIXEL LAPPD AT JLAB

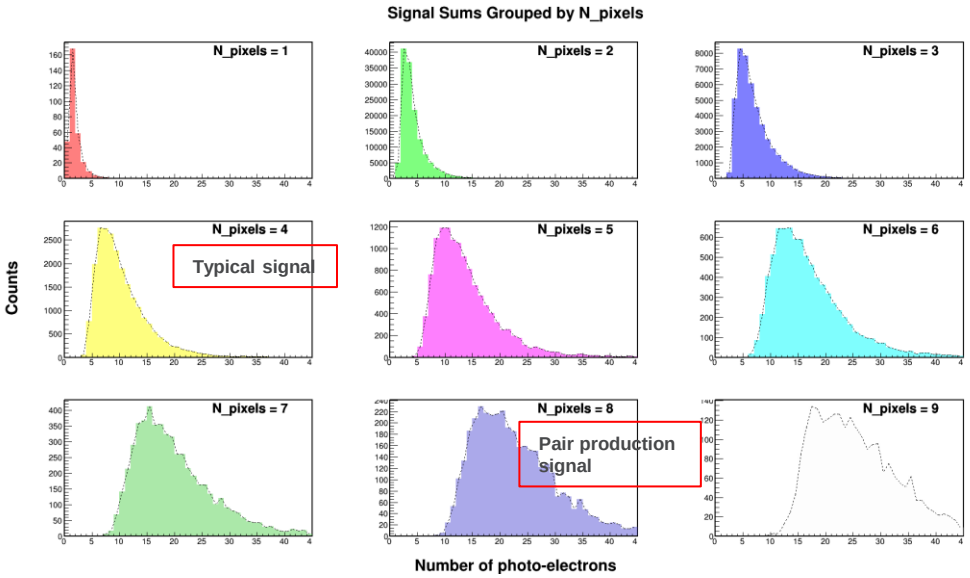


Received Gen-II LAPPD

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

Similar detector setup but larger volume, accommodate 8x8 MaPMTs





- **The 2nd JLab Hall C confirms that the LAPPD works at high rate environment.**
- **With pixelized readout, utilizing geometrical information of pixels could improve the separation.**

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SUMMARY

- R&D on optimization of MCP-PMT towards particle identification is on going, focusing on design development:
  - Magnetic field tolerance
  - Timing resolution
  - Pixel readout
- MCP-PMT with smaller pore size and reduced spacing exhibits significantly improved magnetic field tolerance and timing resolution.
- Fine pixel of 3x3 mm^2 with position resolution of ~ 1 mm was achieved with Argonne MCP stack (glass anode) in Fermilab test beam.
- Large area picosecond photodetector (LAPPD^{TM}) adapting the R&D was under commercialization with performance comparable to MCP-PMTs in market.
- Tests of the LAPPDs at JLab show encouraging results for their application in nuclear physics programs.

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And many others …

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Thank you for your attention!

Questions?