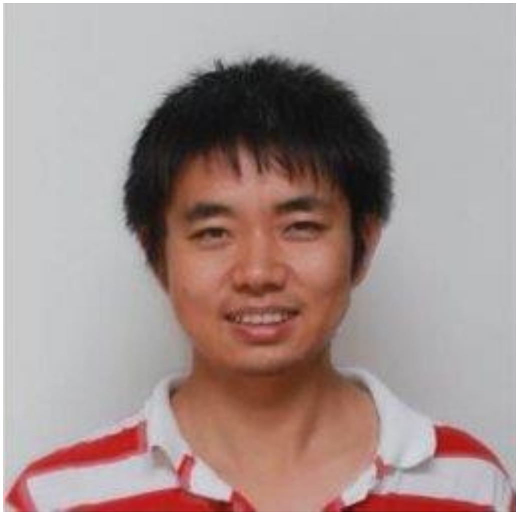
Argonne NATIONAL LABORATORY

Characteristics of MCP-PMT/LAPPD^{TM} in magnetic field



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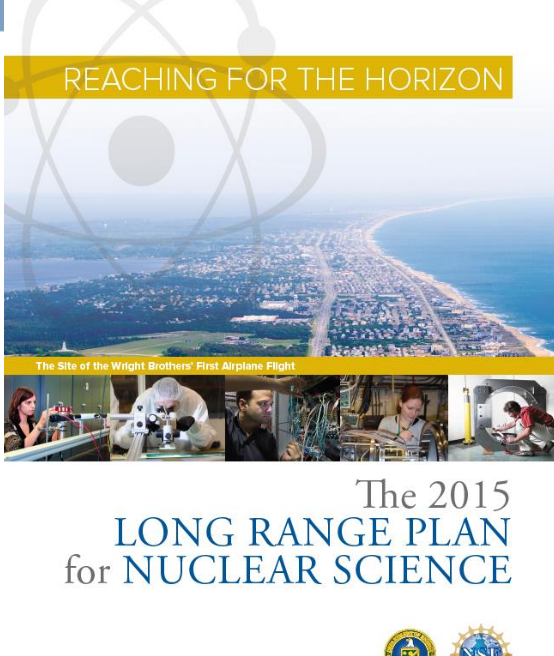
Motivation

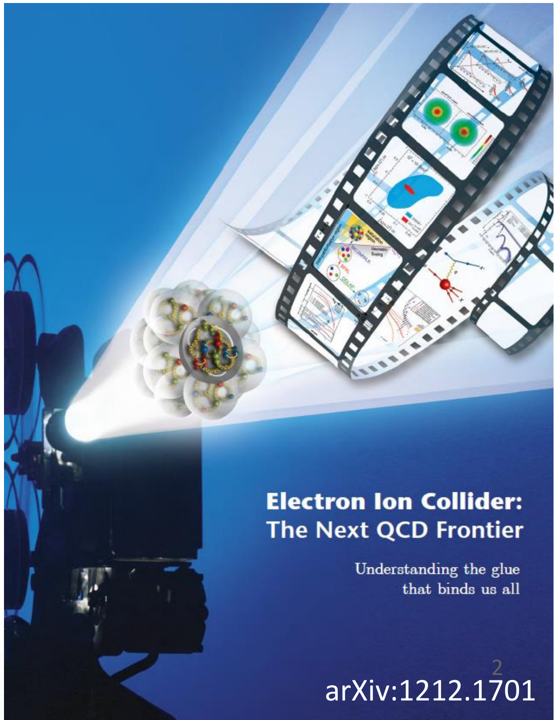
- The world's first Electron Ion Collider (EIC) has been recommended in the 2015 Long Range Plan for Nuclear Science as the highest priority for a new facility construction in US.

- Excellent particle identification (PID) ($e/\pi/K/p$) over a wide range of momentum is essential for the proposed measurements, requiring low cost large area Multi-channel Plate (MCP) type detector with high time and spatial resolution, high rate capability, radiation tolerance and magnetic field tolerance.

- Incom, Inc., the industrial partner of LAPPD collaboration, recently successfully commercialized the production of LAPPD^{TM} (following talk from M. Foley), making it possible to construct EIC PID sub-systems with LAPPD^{TM}.



https://science.energy.gov/np/nsac/



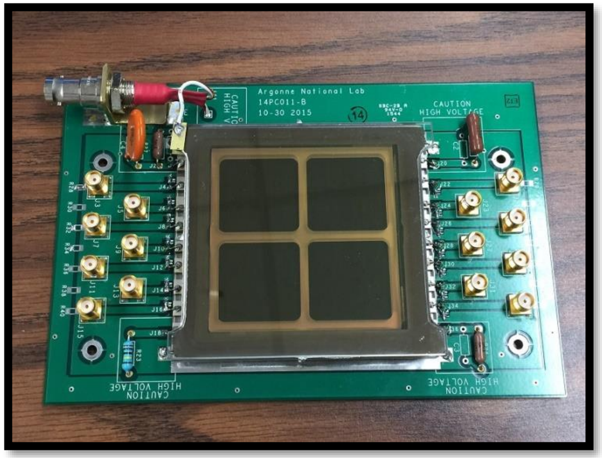
arXiv:1212.1701

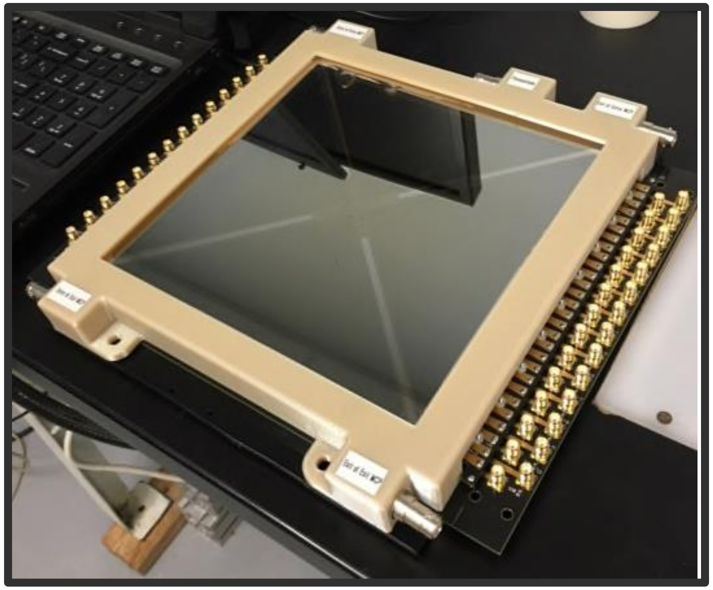
Argonne 6 cm MCP-PMT & LAPPD^{TM}

World largest MCP-PMT: Large Area Picosecond PhotoDetector (LAPPD^{TM})

Commercialization: 20x20 cm^2

R&D test bed: 6x6 cm^2





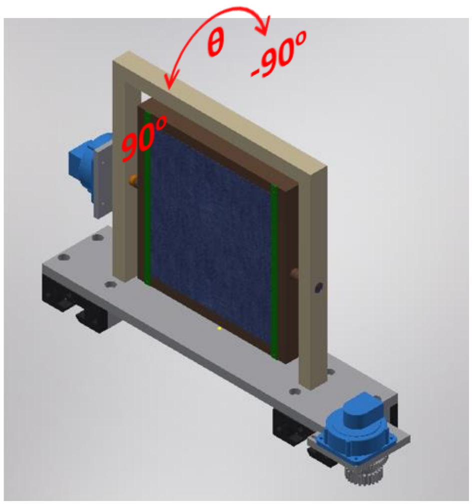
- The Argonne 6 cm MCP-PMT and Incom 20 cm LAPPD^{TM} share the same MCPs and similar internal configuration and signal readout.
- The Argonne 6 cm MCP-PMT serves as R&D test bed for performance characterization and design optimization; Incom 20 cm LAPPD^{TM} is the final commercialized product.
- Optimized configurations are transferrable to Incom production line for mass production.

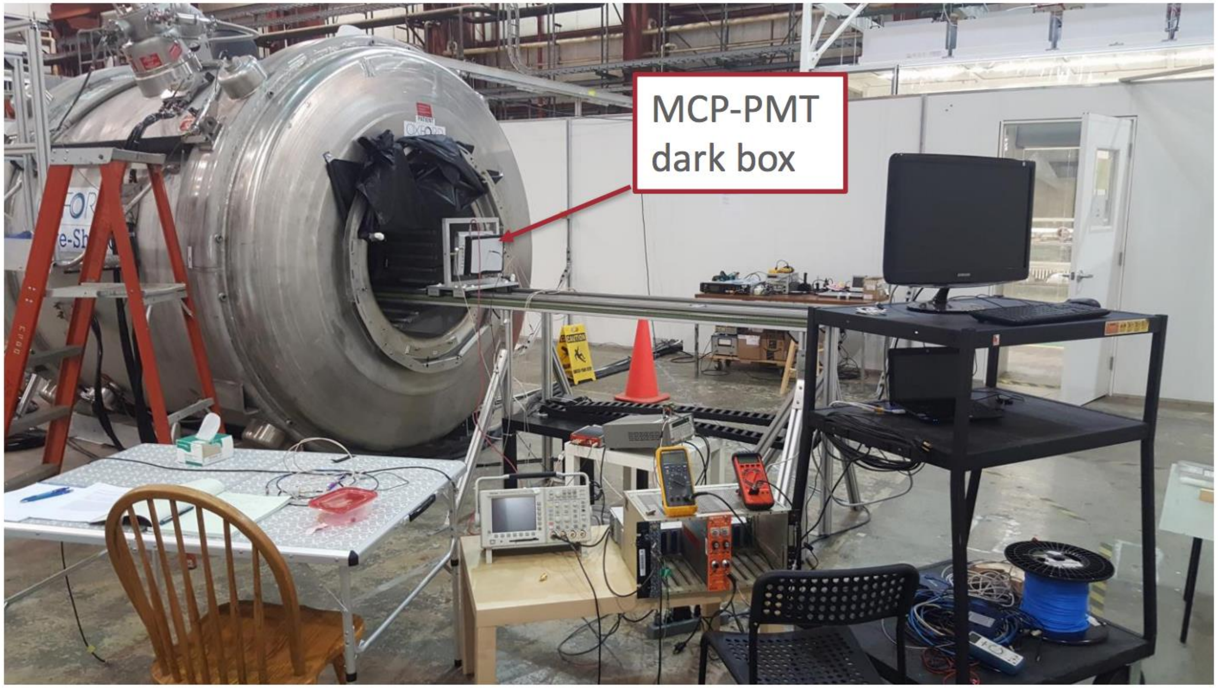
Argonne g-2 Magnet Facility

Argonne researchers recently acquired a decommissioned magnet from magnetic resonance imaging (MRI) scanner from hospital that will be used as proving ground for instruments used in high-energy and nuclear physics experiments.

	Requirement for g-2	Magnet specification
Magnetic field strength	1.45 T	up to 4 T
Stability	< 120 ppb/h	90 ppb/h
Homogeneity	< 200 ppb/cm	7 ppb/cm (with gradient coils)
Bore diameter	> 60 cm	~68 cm (with gradient coils) ~90 cm (w/o gradient coils)

Argonne MCP-PMT Magnetic Field Test Facility

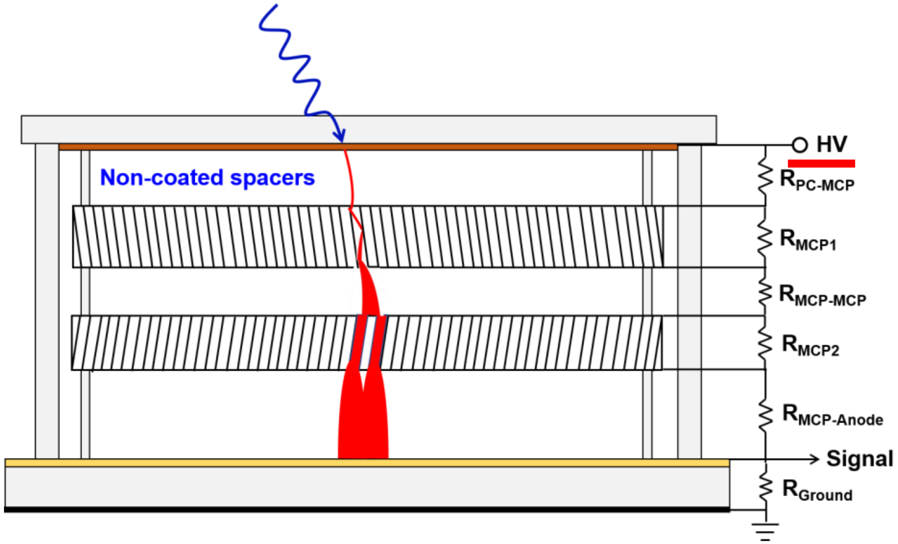


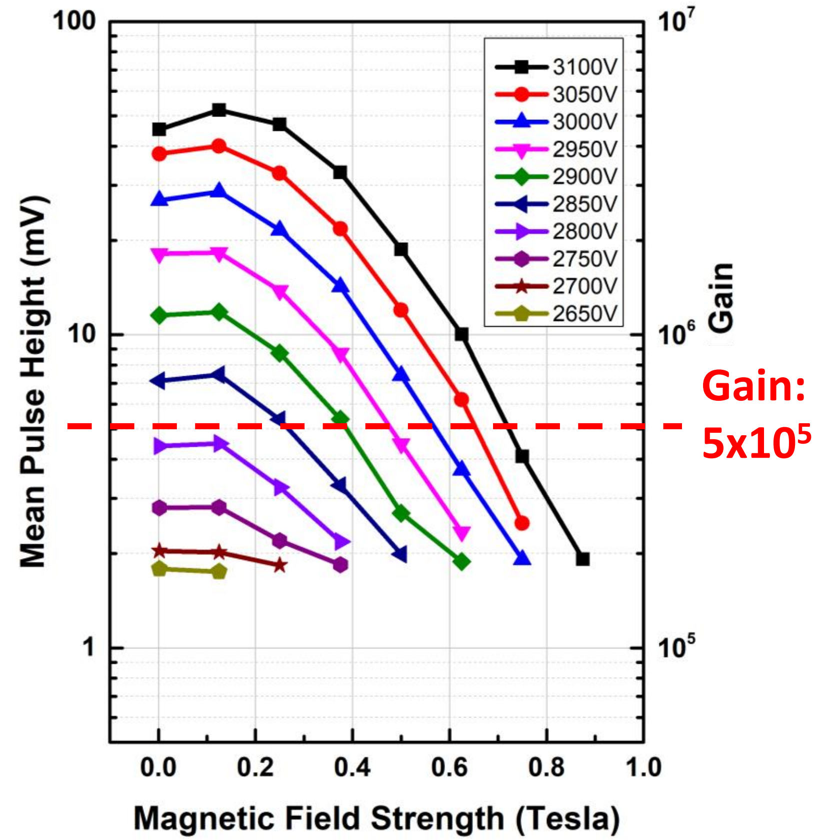


(left) Self-designed test stand with the capability of testing MCP-PMTs up to 20 x 20 cm^2
(right) Picture of MCP-PMT magnetic field test setup at ANL in building 366.

- A transporter with the capability of testing MCP-PMTs up to 20 cm x 20 cm
- All components are made of non-magnetic materials
- Rotatable axis dedicated for angle dependence study

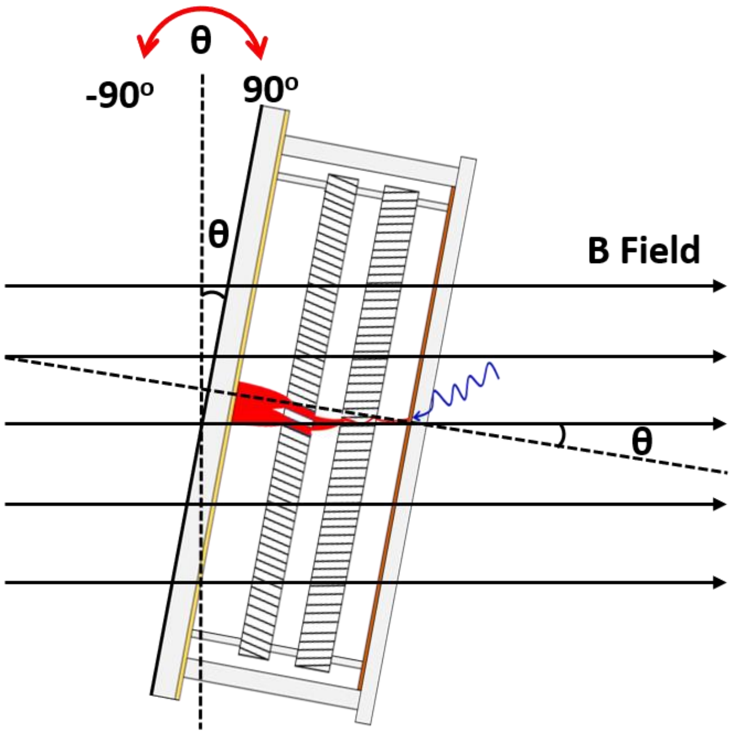
Performance of 6x6 cm^2 MCP-PMT in magnetic field

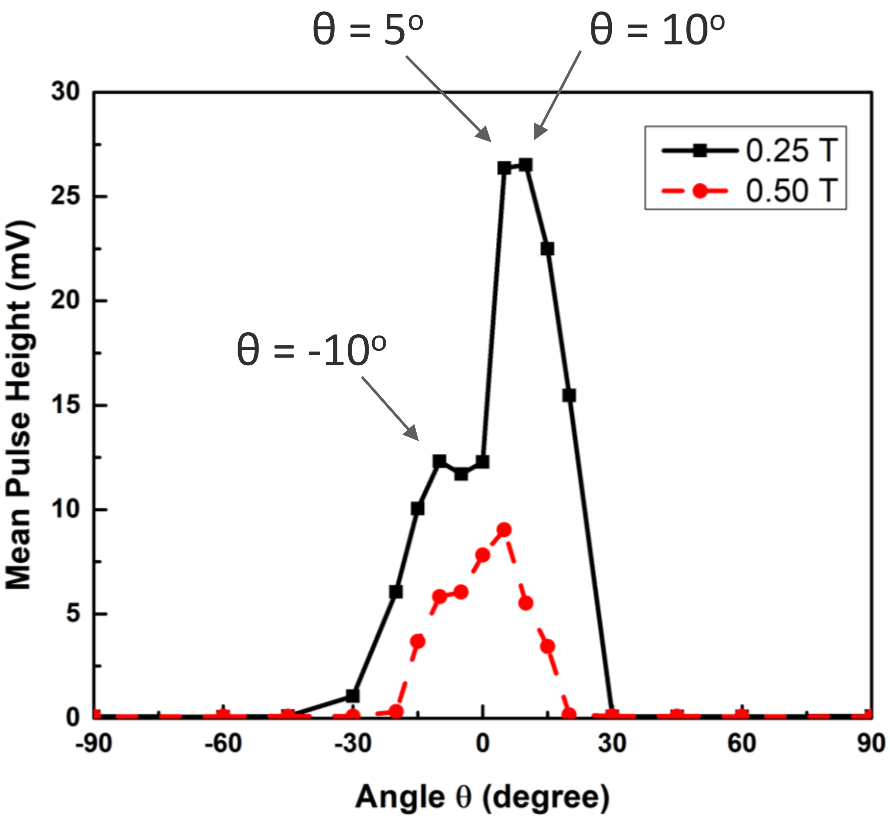




- Single voltage was applied to the MCP-PMT with an external HV divider.
- MCP-PMT shows good performance in magnetic field.
- Baseline tests show for a device with Gain > 5×10^5 , Magnetic Field tolerance is observed above 0.7 T.

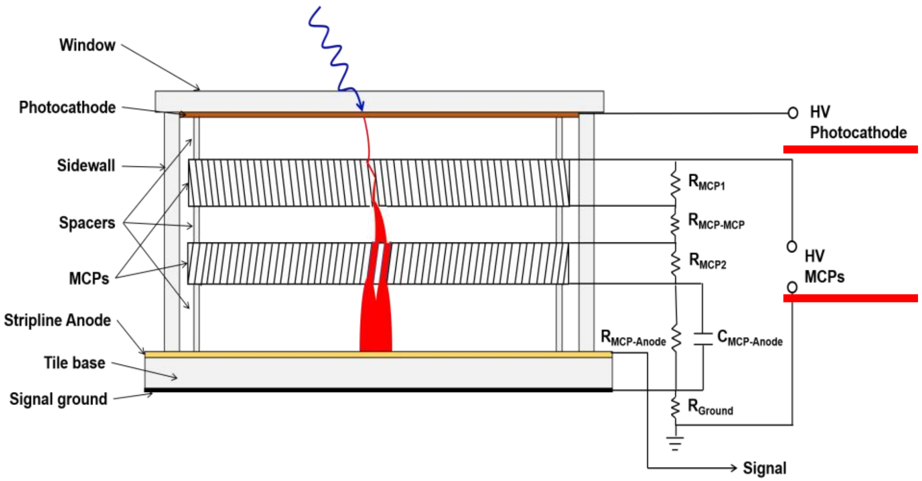
Angle dependence

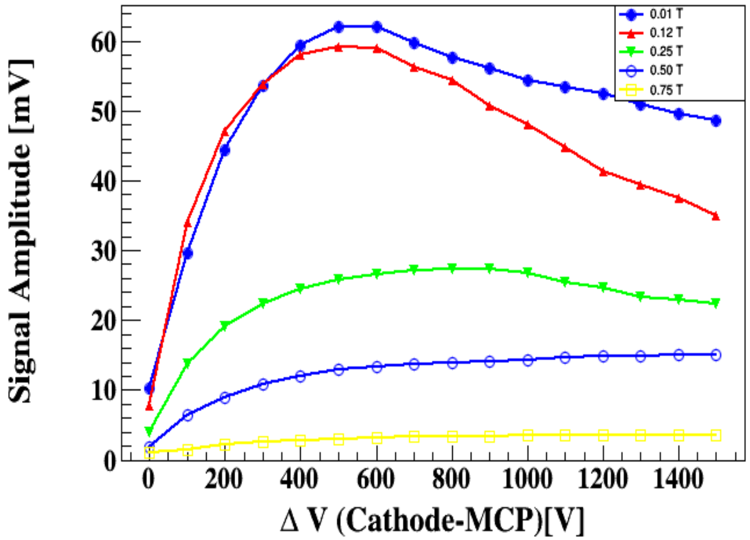




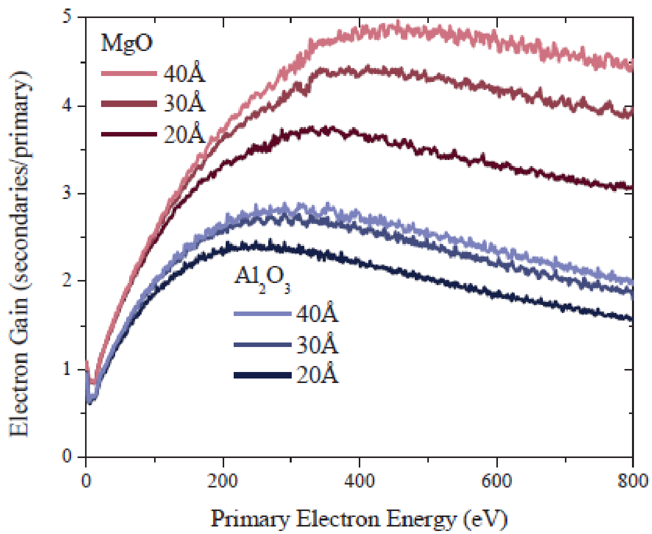
- The MCP-PMT performance in magnetic field is clearly angle related, due to the 8° MCP bias angle, the highest gain is obtained around 8°.
- Notice the two peaks around ±8°, indicating the effect from upper and lower MCP bias angles are different. Simulation is undergoing to explain the different effect.

ΔHV(photocathode-top MCP) dependence

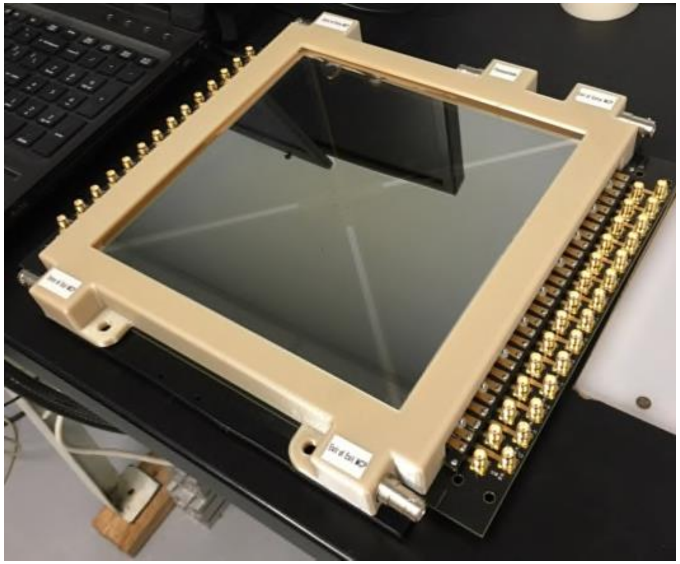




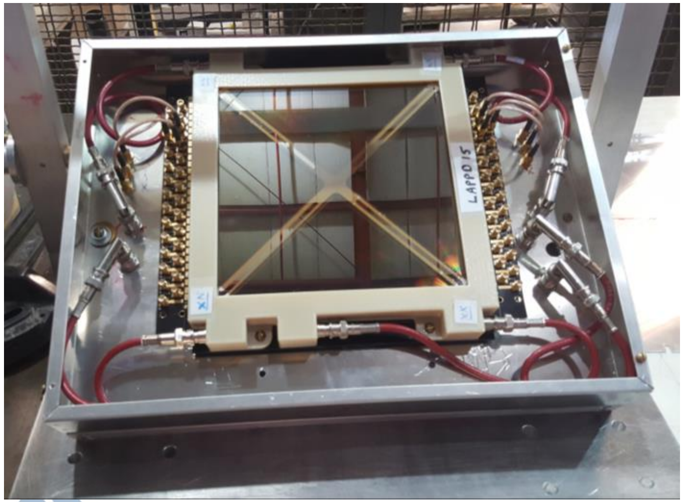
- HV(MCPs) was fixed, varies the HV of first gap ΔHV(photocathode–top MCP) by adjusting HV (Cathode).
- Gain increases as ΔHV increases to a maximum then decreases, this can be explained by the MCP gain dependence of primary electron energy.

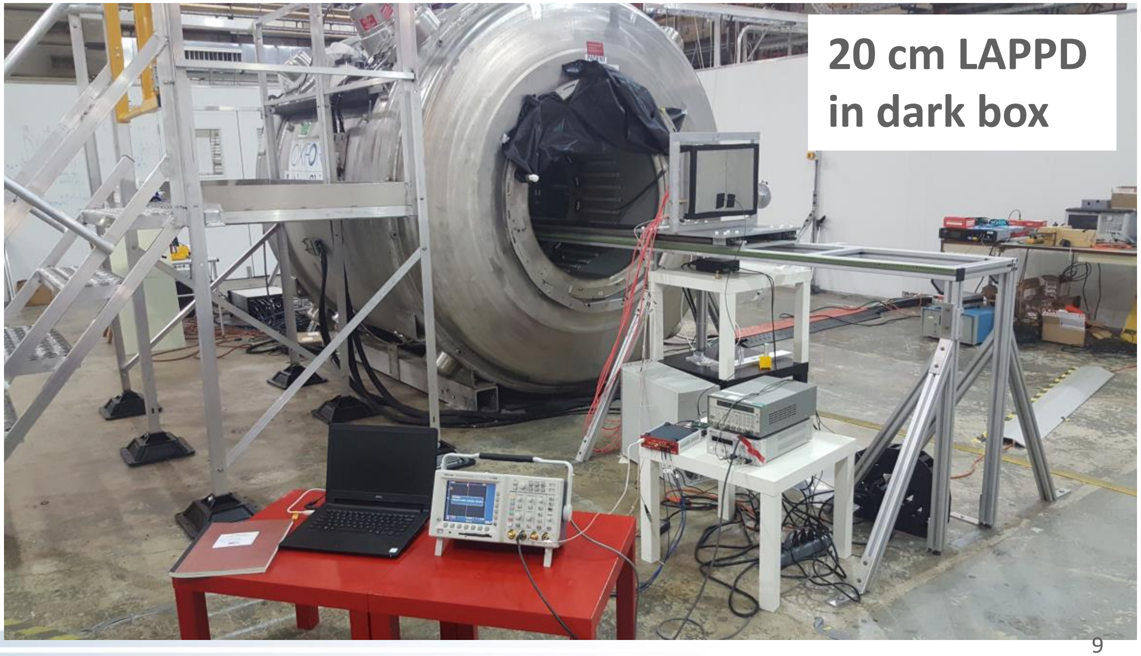


LAPPD^{TM} installed at magnetic field test facility



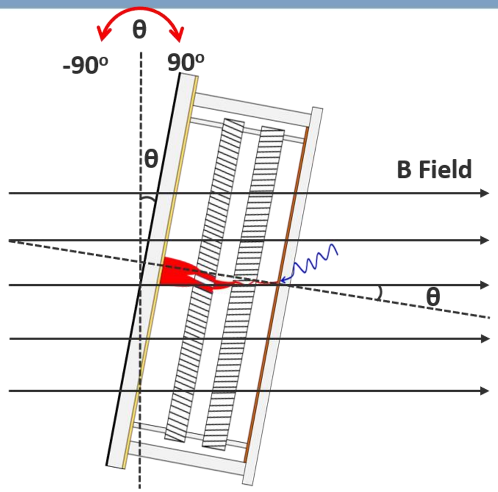
Feature	Parameter
Photodetector Material	Borosilicate Glass
Window Material	Fused Silica Glass
Photocathode Material	Multi-Alkali (K_2NaSb)
Spectral Response (nm)	160-850
Wavelength – Maximum Sensitivity (nm)	≤ 365 nm
Photodetector Active Area Dimensions	195mm X 195mm
• Minimum Effective Area	34,989 mm^2
• Active fraction with Edge Frame X-Spacers	92%
Anode Data Strip Configuration	28 silver strips, Width = 5.2 mm, gap 1.7 mm, nominal 50 Ω Impedance
Voltage Distribution	5 taps for independent control of voltage to the photocathode and entry and exit of MCP

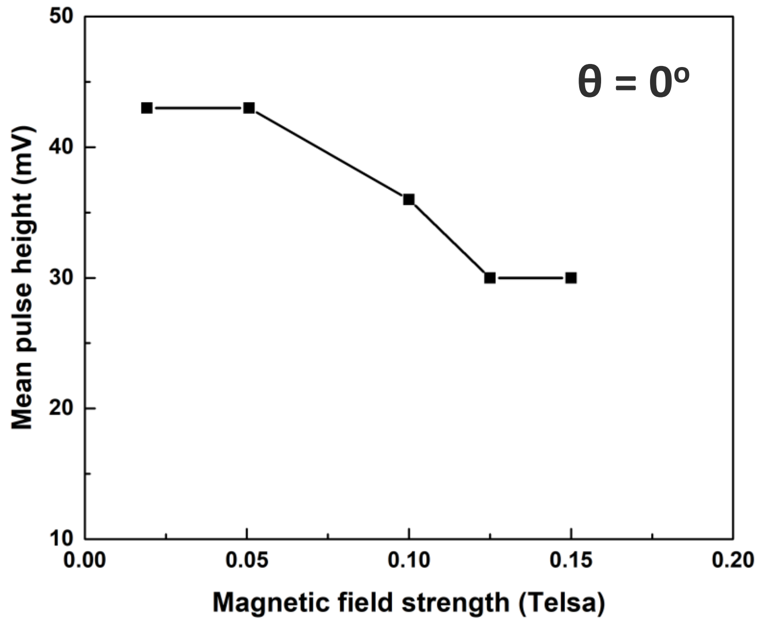


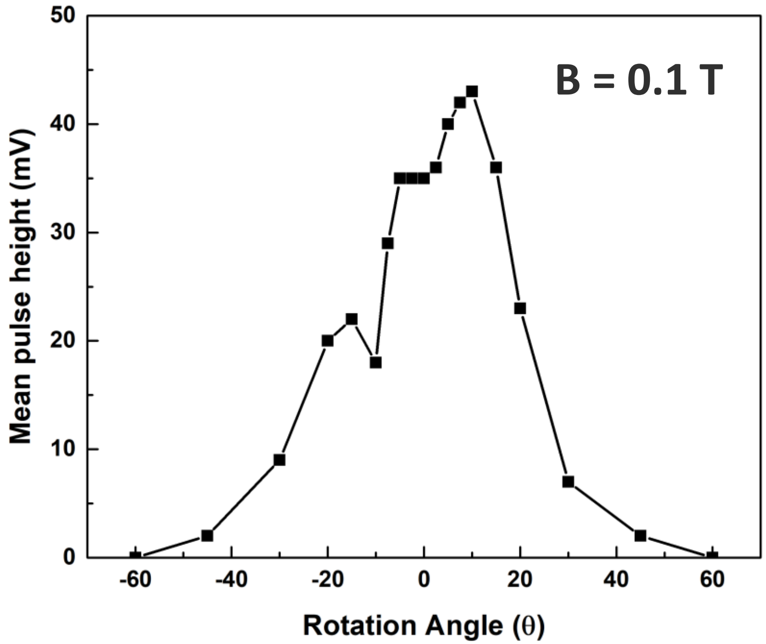


LAPPD^{TM} performance in magnetic field

Due to the magnetic sensitive components (Kovar is used as shims in the current LAPPD^{TM}), we can not go to high magnet field test, a new LAPPD^{TM} with non-magnet components is scheduled to be fabricated and tested in Sep. 2018. The results here demonstrate the capability of the facility for 20 cm LAPPD^{TM}.



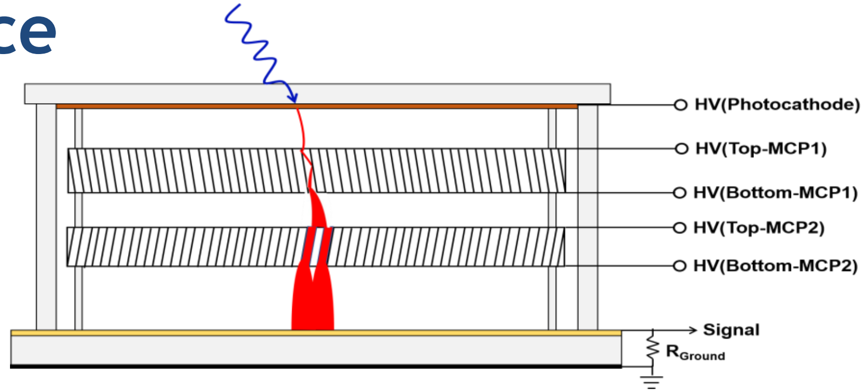


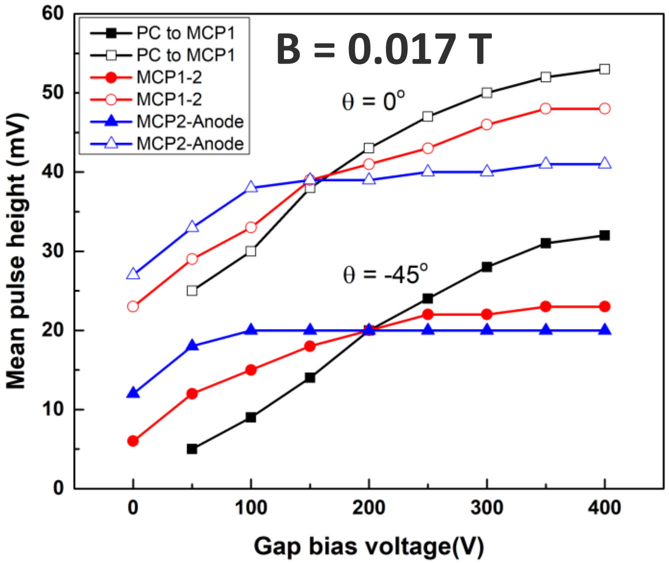


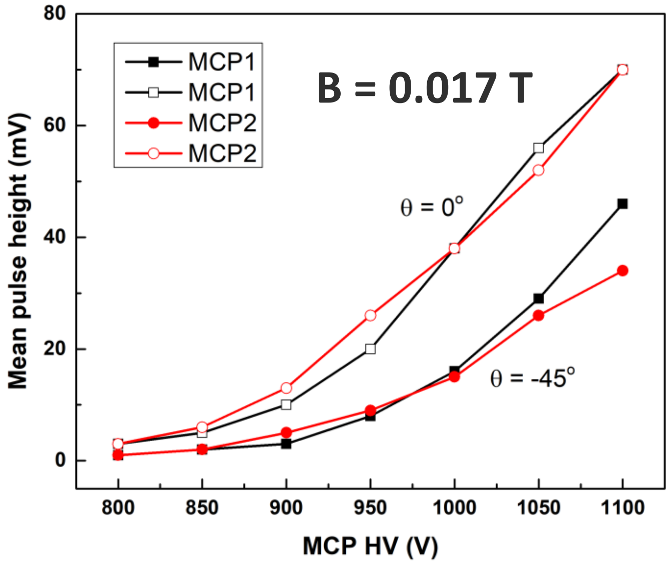
Magnetic field strength dependence **Rotation angle dependence**

- Similar behavior as 6 cm MCP-PMT: gain decrease as the magnetic field increases
- Two local gain maximum corresponding to the 13º bias angle of MCPs used in LAPPD^{TM}

Gap and MCP ΔHV dependence







- ➢ HV applied to all three gaps affects the gain of the LAPPD.
- ➢ HV between the photocathode and MCP1 gap has the greatest slope, indicating the strongest effect.
- ➢ LAPPD gain becomes a constant with the MCP2-Anode bias HV above a threshold.
- ➢ HV applied to MCPs seems to have NO preference, equally affects the LAPPD gain.

Summary

- LAPPD collaboration successfully commercialized the LAPPD^{TM}, and starts to explore various applications of LAPPD^{TM}.
- LAPPD has a great potential as a sensor candidate for the US based EIC.
- Magnetic field tolerance of the 6 cm MCP-PMT and LAPPD^{TM} are characterized for baseline results, showing magnetic field tolerance up to 0.7 Tesla.
- Magnetic tolerance is related to the rotation angle, with maxima at the angle where MCP pores are aligned with magnetic field direction.
- Bias voltages applied to the gaps affect the performance of LAPPD^{TM}, the strongest effect comes from the gap between photocathode and top MCP.

Future work

- LAPPD configuration needs optimization for EIC application.
- Smaller pore size and reduced spacing will dramatically improve the magnetic field tolerance and also benefit the timing resolution.
- Argonne and Incom are currently working on an optimized configuration for high magnetic field tolerant LAPPD^{TM} suitable for EIC application.

Acknowledgments

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And many others…

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Thank you for your attention!

Questions?