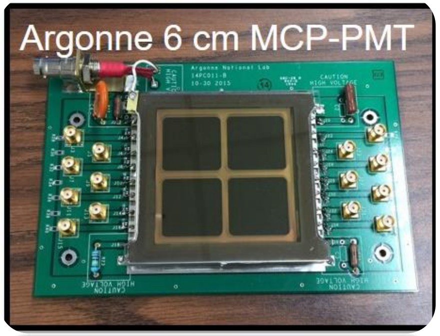
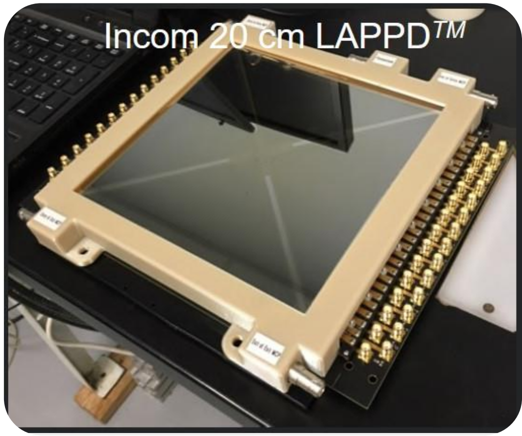
DEVELOPMENT OF ARGONNE MCP-PMT AND EXPLORING LAPPD APPLICATION FOR PARTICLE IDENTIFICATION





JUNQI XIE

Medium Energy Physics
Argonne National Laboratory
9700 S Cass Ave., Lemont, IL 60439
jxie@anl.gov

1st EIC Yellow Report Workshop at Temple University

19-21 March 2020
Temple University
US/Eastern timezone

DEVELOPMENT OF MCP-PMT FOR EIC-PID

Key Issue: Photodetectors

- **Photo Detectors:** The most important challenge is to provide a reliable highly-pixelated photodetector working at 2-3 Tesla. This problem is not yet solved.

T. Ullrich, CPAD 2018

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

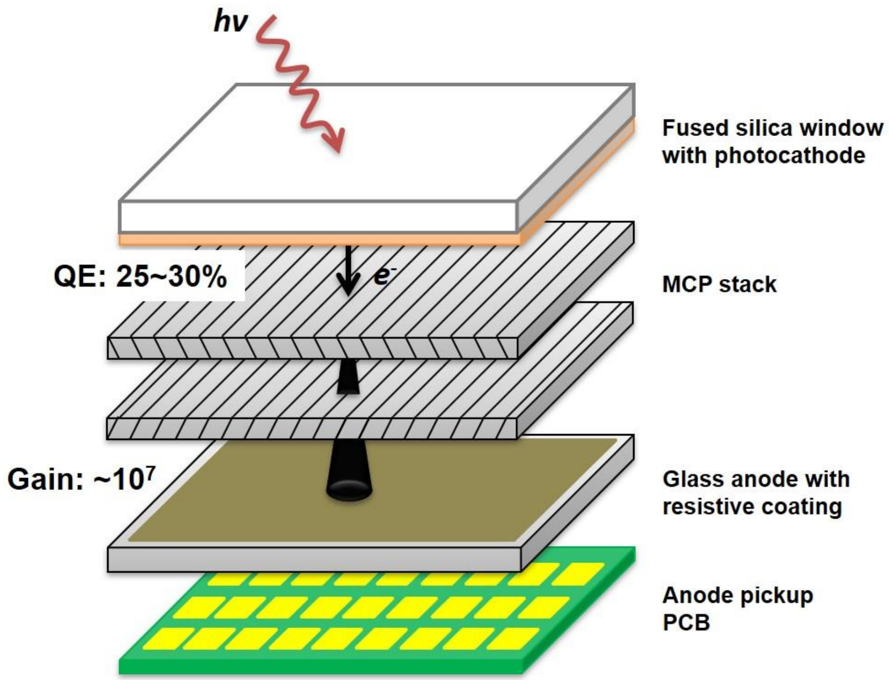
❑ **Current focus at Argonne National Laboratory:**

- Magnetic field tolerance
- Fine pixel readout
- Fast timing

❑ **Other requirement:**

- QE uniformity
- Life time
- After pulse
- Stability etc…

LOW-COST FULL GLASS/FUSED SILICA DESIGN



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

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

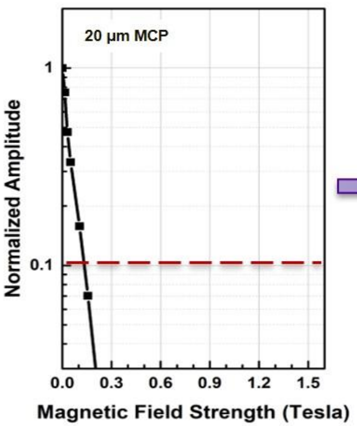
c) Newly developed 10 μm pore size MCPs for higher magnetic field tolerance and fast timing;

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

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

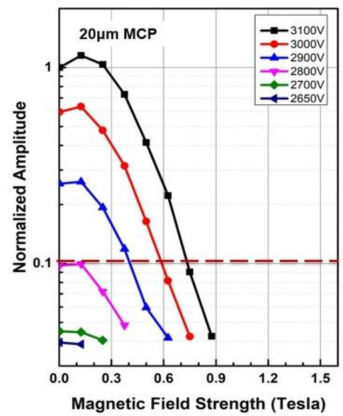
IMPROVEMENT OF ARGONNE MCP-PMT PERFORMANCE IN MAGNETIC FIELD

ANL version 1
Internal resistor chain



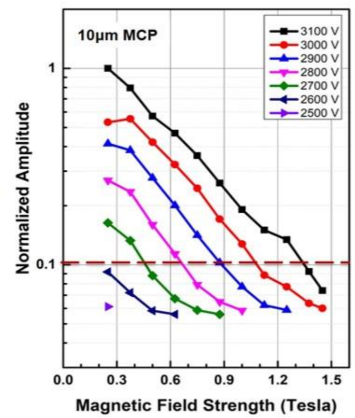
0 < B < 0.15 T

ANL version 2
IBD design 20 μm MCP



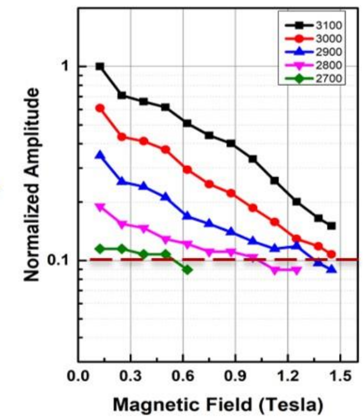
0 < B < 0.7 T

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

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)

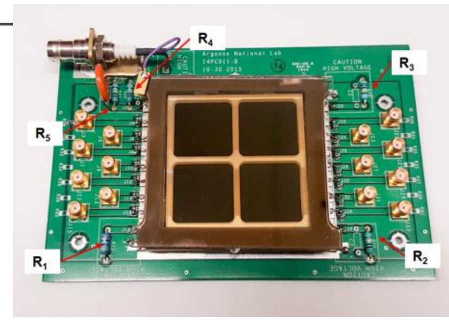
To be published on JINST (2020)

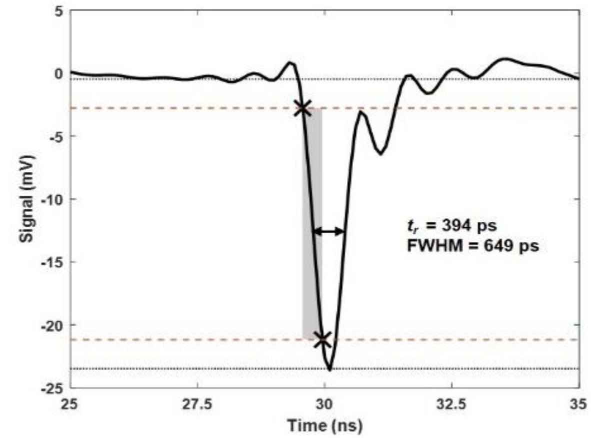
DETAILED PARAMETERS AND PERFORMANCE OF ARGONNE MCP-PMT

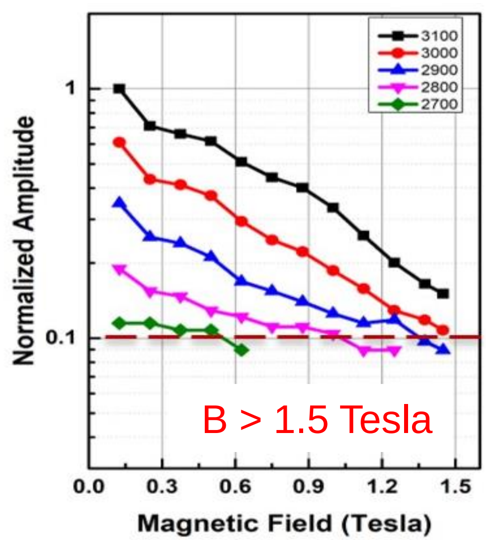
ANL Version 4, 10 μm MCP-PMT with reduced spacing

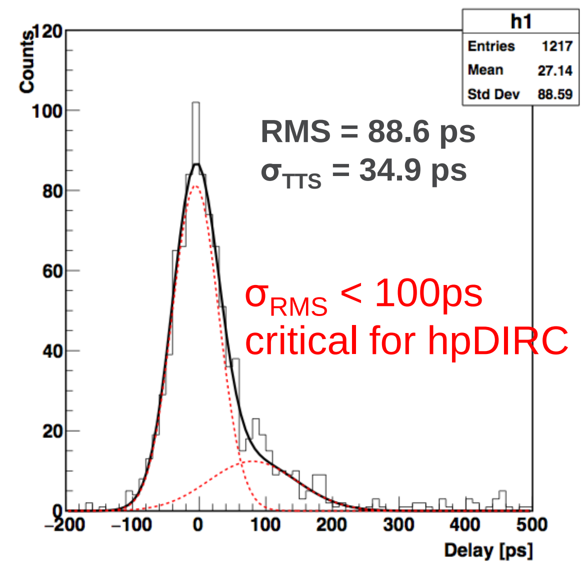
MCP	Pore size	10 μm
	Length to diameter ratio (L/d)	60:1
	Thickness	0.6 mm
	Open area ratio	70 %
	Bias angle	13º
Detector geometry	Window thickness	2.75 mm
	Spacing 1	2.25 mm
	Spacing 2	0.7 mm
	Spacing 3	1.1 mm
	Shims	0.3 mm
	Tile base thickness	2.75 mm
MCP-PMT stack	Internal stack height	**5.55 mm**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





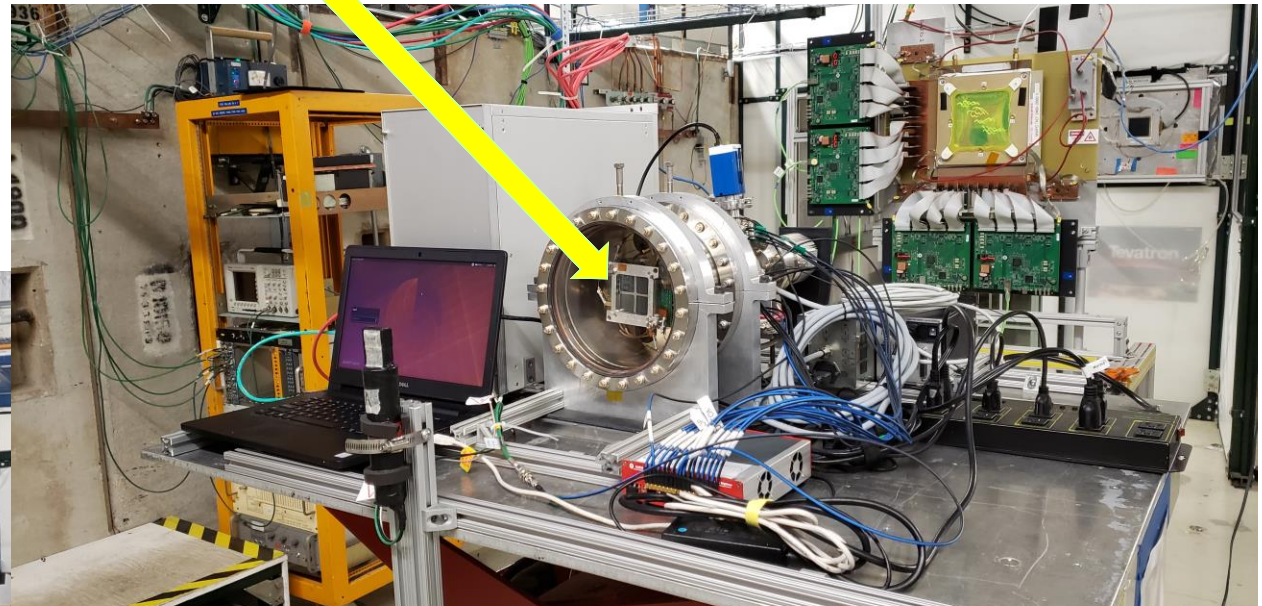




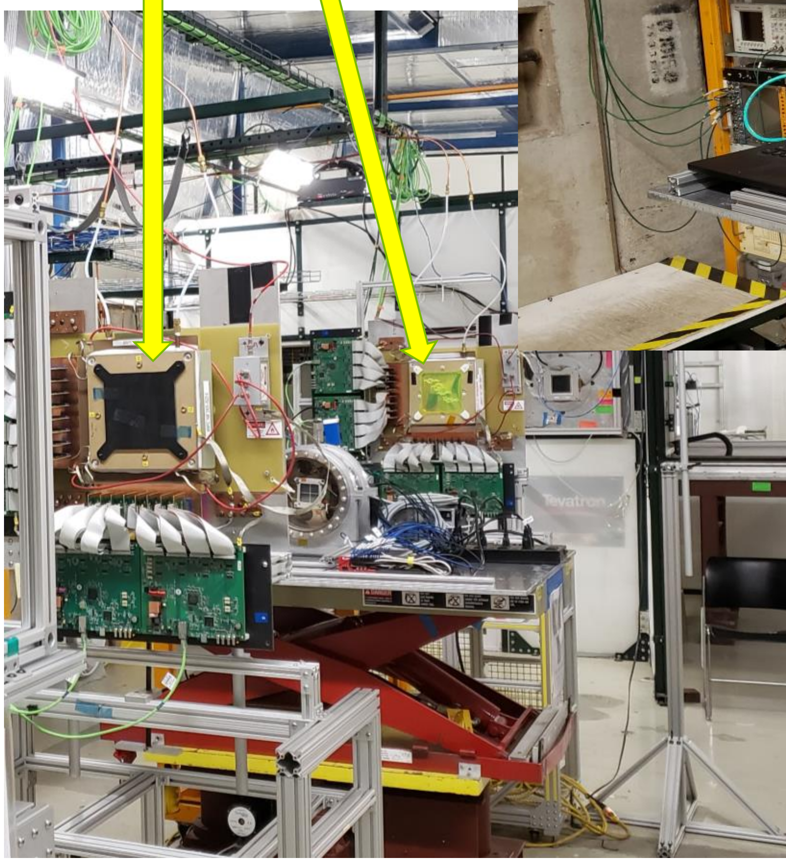
To be published on JINST (2020)

FINE PIXELATED READOUT THROUGH GLASS/FUSED SILICA ANODE

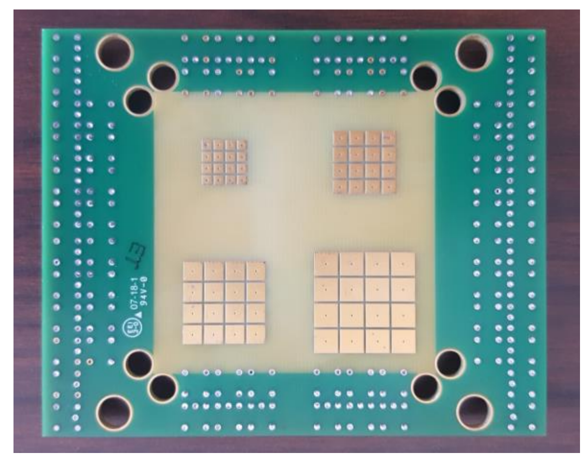
Argonne MCP stack (glass anode) in Fermilab test beam



MWPC tracking used



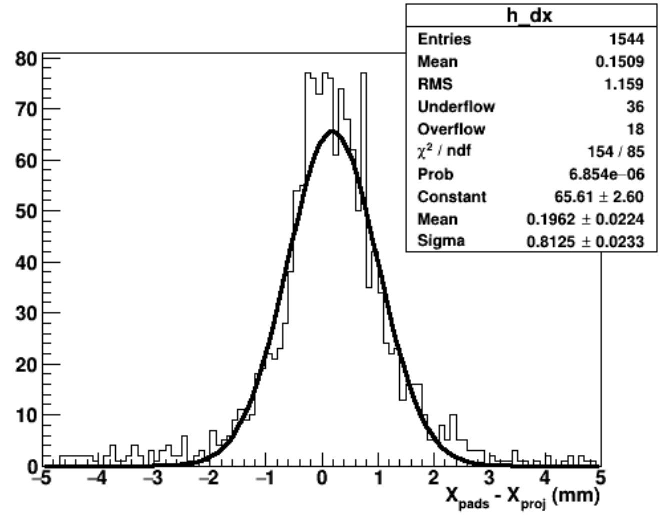
4 different pixel sizes (2x2,3x3,4x4 and 5x5 mm^2) implemented for testing

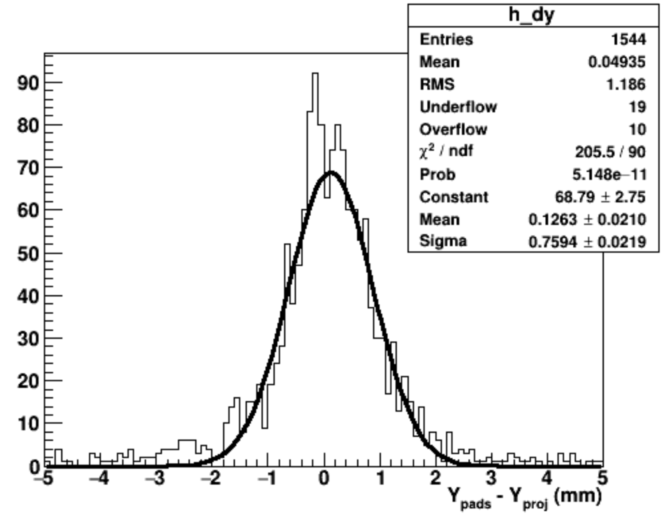


POSITION RESOLUTION

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

4 mm x 4 mm pixel as example



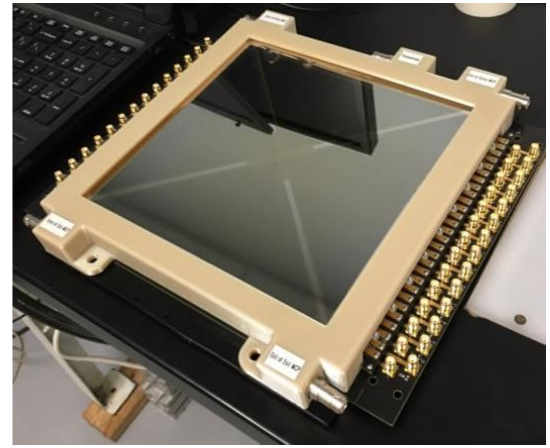


	X res (mm)	Y res (mm)
2x2 mm	1.4	1.7
3x3 mm	0.94	0.95
4x4 mm	0.81	0.76
5x5 mm	1.1	0.97

- 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)

CURRENT STATUS OF LAPPD COMMERCIALIZATION

Commercialization: 20x20 cm^2



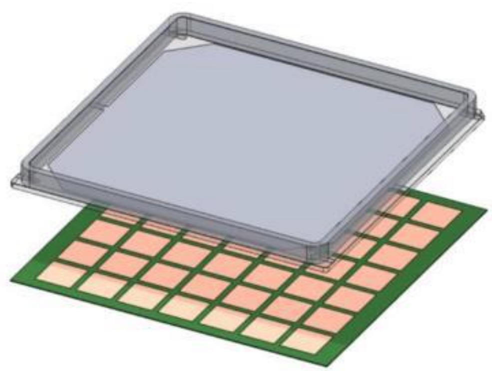
Different readout schemes

Gen I

Stripline readout

Products Available

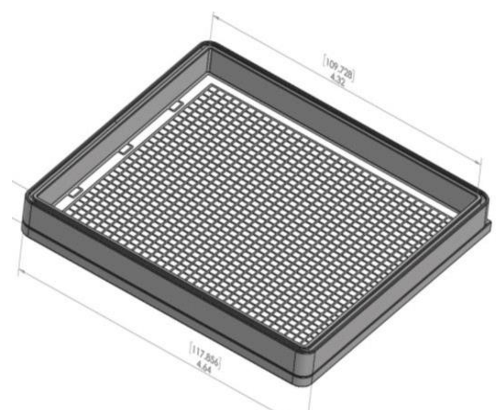
Gen II



Capacitive coupling

Prototypes Available

Gen III



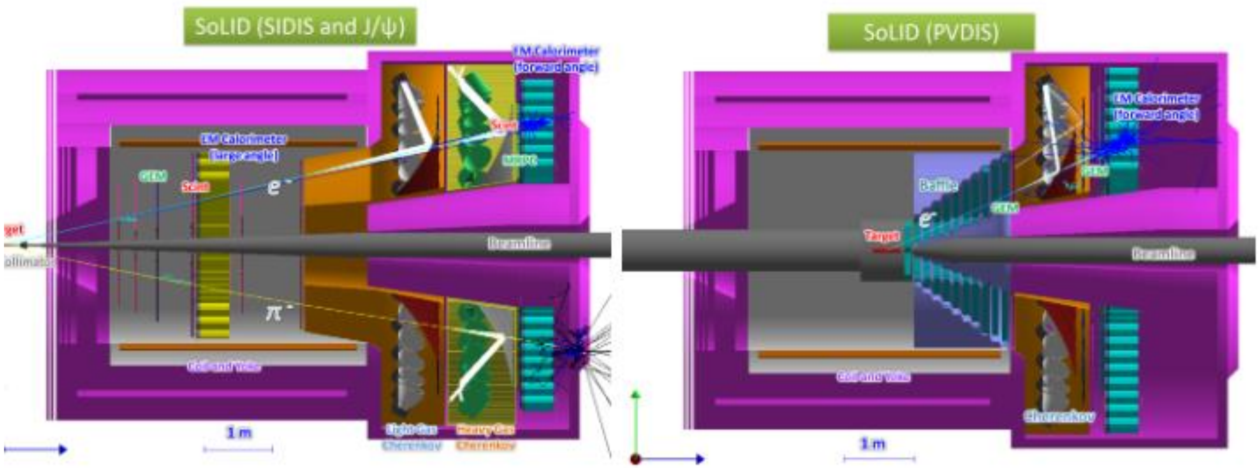
Low temperature
co-fire ceramic

Under development

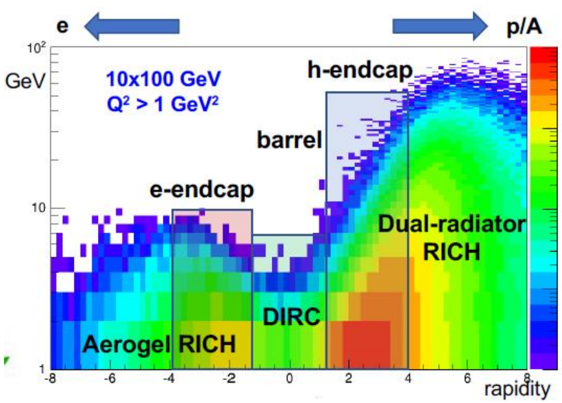
Argonne NATIONAL LABORATORY

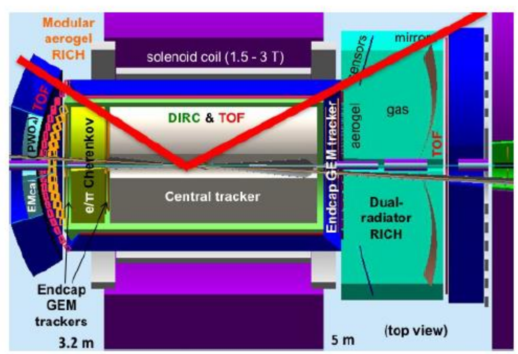
EXPLORE APPLICATION OF LAPPD^{TM} FOR NUCLEAR PHYSICS PARTICLE IDENTIFICATION

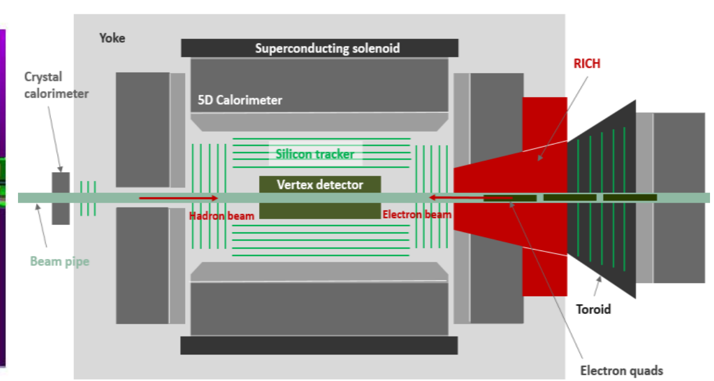
SoLID *SoLID (Solenoidal Large Intensity Device) Light gas Cherenkov counter*



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







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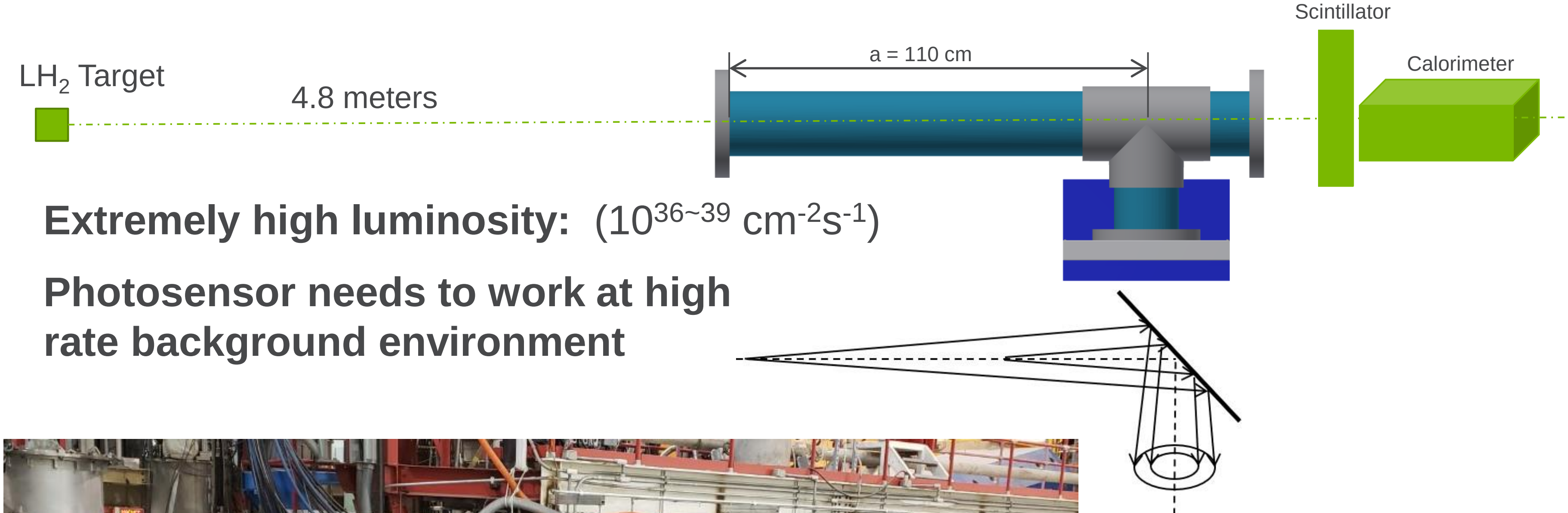
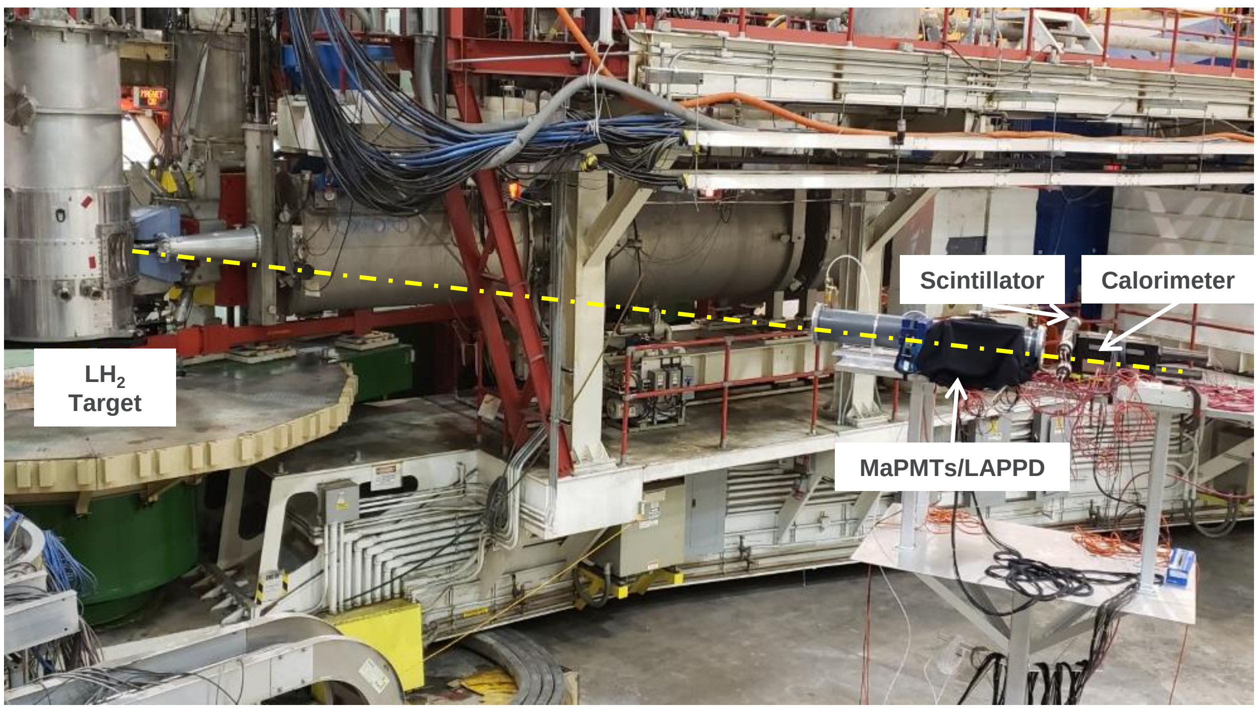
SOLID TELESCOPE CHERENKOV SETUP IN HALL C



Extremely high luminosity: ($10^{36\sim39}$ $cm^{-2}s^{-1}$)

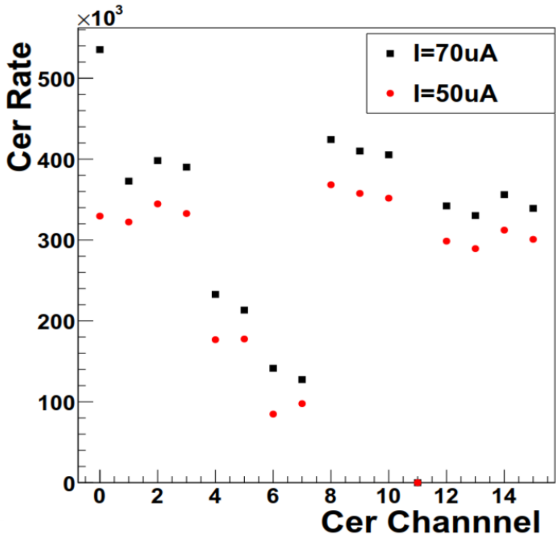
Photosensor needs to work at high rate background environment

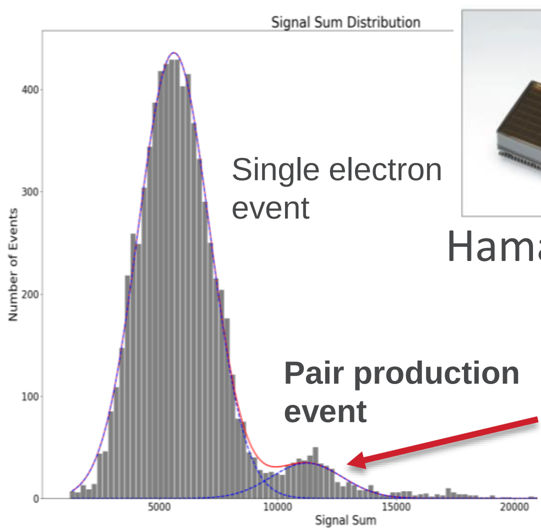


- 8.1 GeV electron beam on LH_2 target
- Setup is 4.8 meters away facing target
- **High rate background real experimental open environment**
- Scintillators and calorimeters as trigger
- CO_2 as gaseous radiator
- Accommodate 2x2 MaPMT array and LAPPD

CHERENKOV EXPERIMENT RESULTS WITH MAPMTS

The event rate for each quadrant is ~400 kHz, that is ~ 1.5 MHz rate per MaPMT, or **64 kHz/cm²**.





Better separation with pixelated photosensors

Hamamatsu 8500

Pair production event in SANE Cherenkov detector

Contents lists available at ScienceDirect

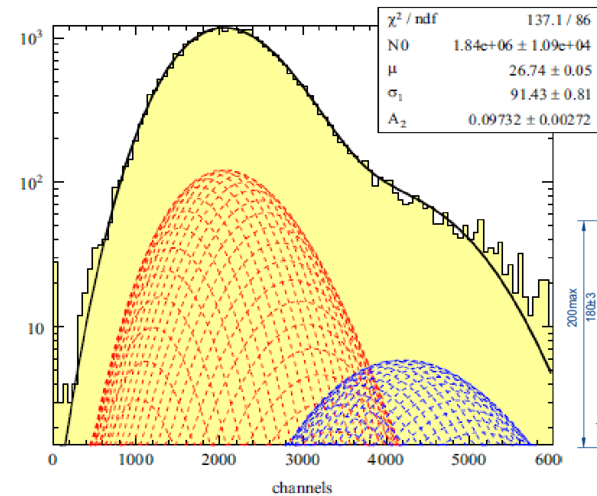
Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

A threshold gas Cherenkov detector for the Spin Asymmetries of the Nucleon Experiment

Whitney R. Armstrong [a,*], Seonho Choi [b], Ed Kaczanowicz [a], Alexander Lukhanin [a], Zein-Eddine Meziani [a], Brad Sawatzky [a,c]

[a] Department of Physics, Temple University, Philadelphia, PA 19122, USA
[b] Seoul National University, Seoul 151-747, Korea
[c] Thomas Jefferson National Accelerator Facility, Newport News, Va 23606, USA



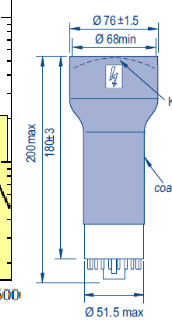


Fig. 18. A typical ADC spectrum showing the one and two track peaks and the convolution fit.

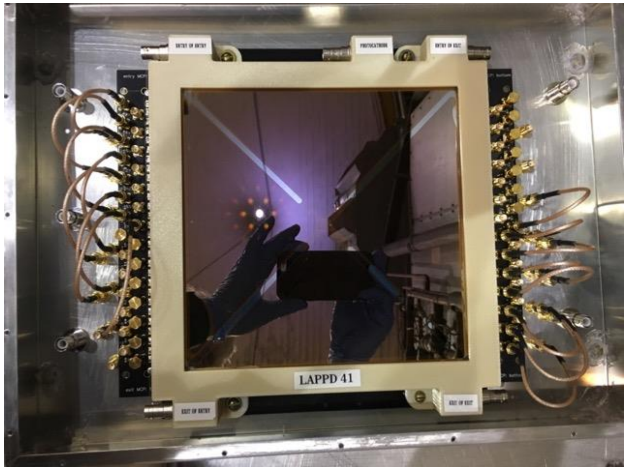
Photonis XP4318B

W. Armstrong et al., Nucl. Instr. Meth. A ***804*** *(2015) 118*

CHERENKOV EXPERIMENT RESULTS WITH LAPPD

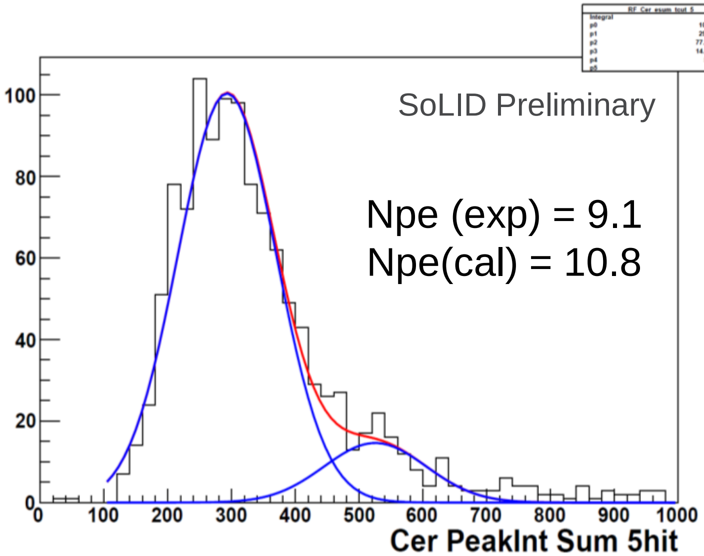
Received LAPPD#41: Gen I

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

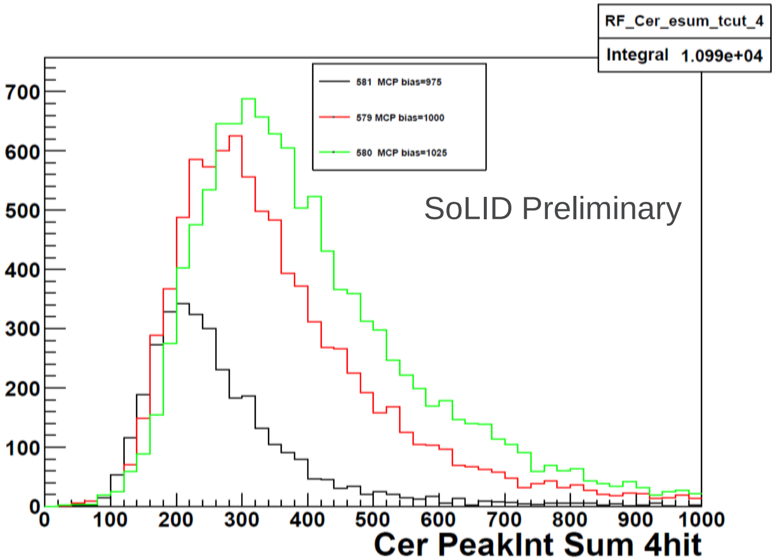


Results

Event cut	MaPMT	LAPPD
Scin+ calo	0.81 M	7.1 M
Cher + scin + calo	0.056 M	0.16 M
Detection efficiency	**6.9%**	**2.2%**

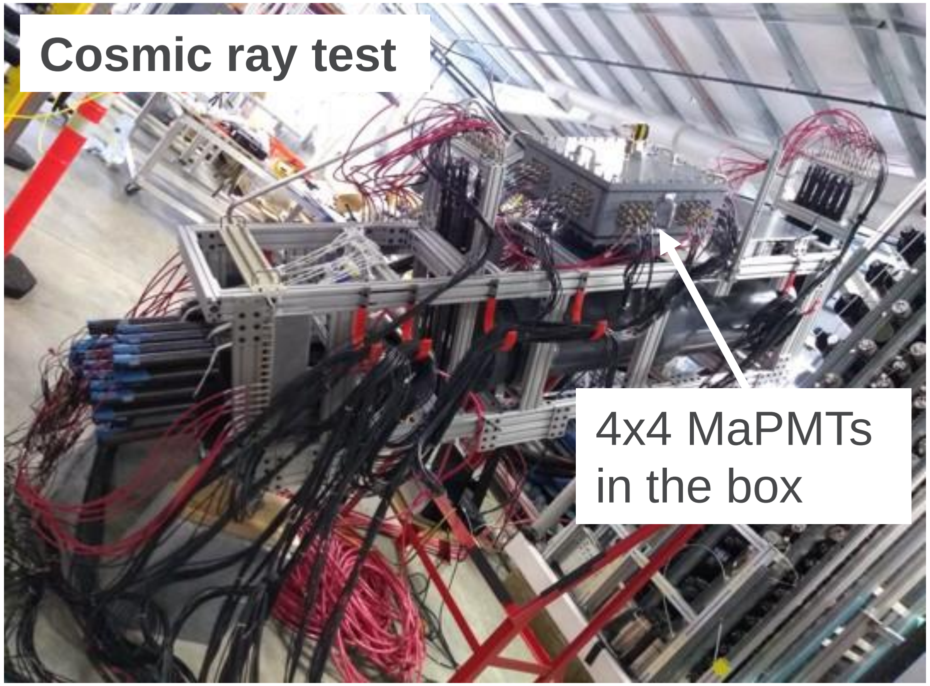


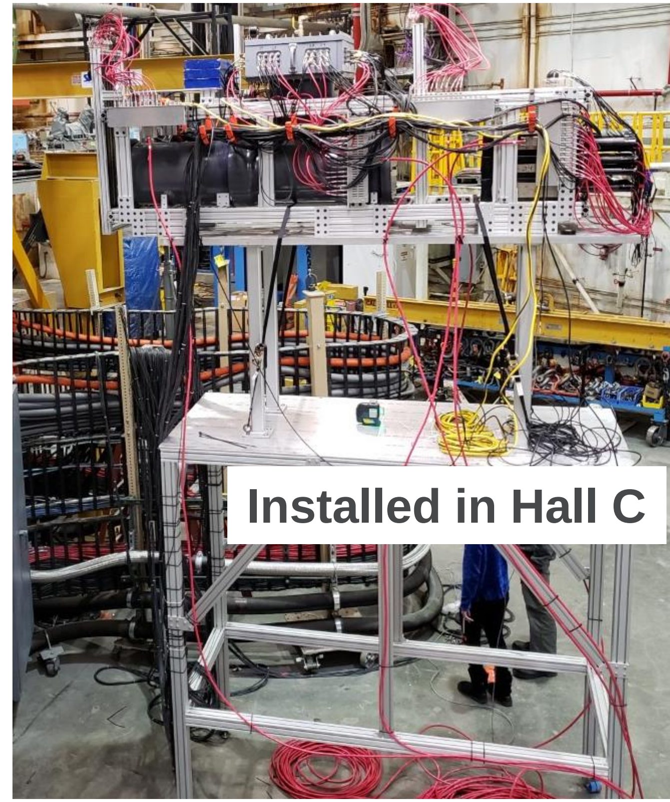
LAPPD HV scan



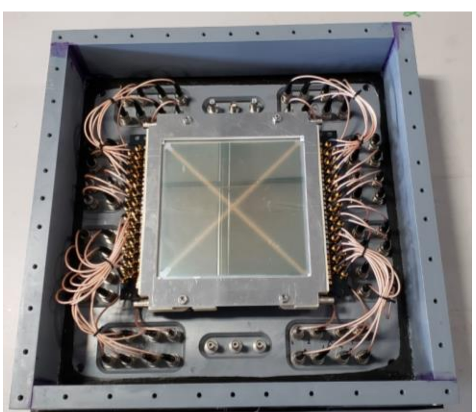
JLab Hall C test shows that the LAPPD might work in the Hall C harsh environment to separate Cherenkov events. Needs high QE, pixelated LAPPDs for follow up testing.

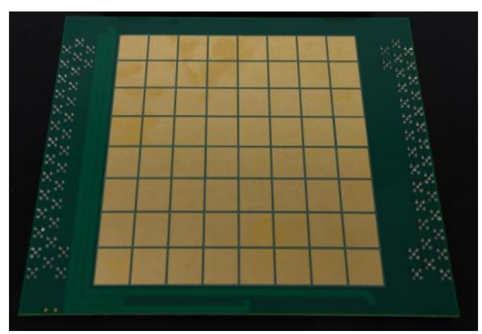
PIXELATED GEN II LAPPD VALIDATION WITH SOLID PRE-R&D LIGHT GAS CHERENKOV PROTOTYPE (INSTALLED MAR. 15)





WLS coated Gen II LAPPD in tank box

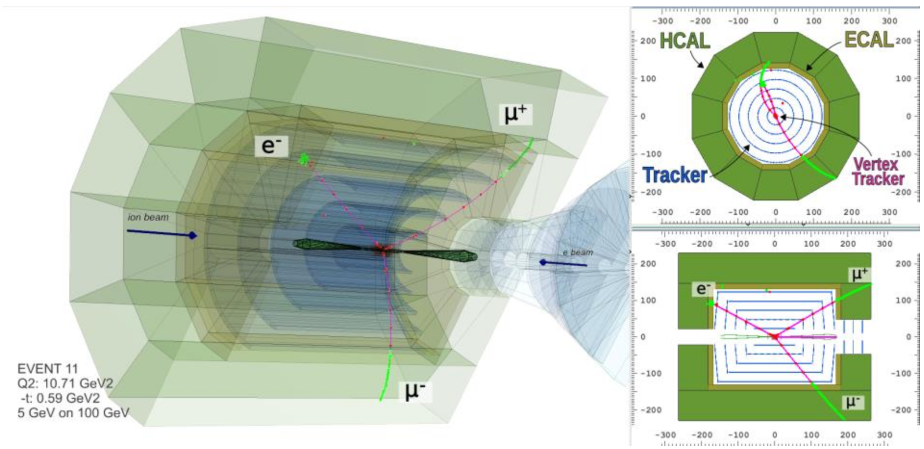


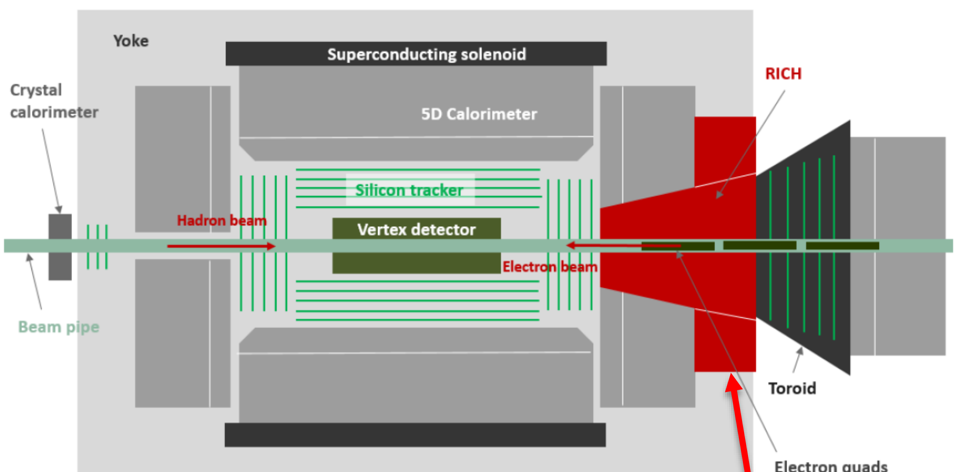


25mm x 25 mm pixel
size for Cherenkov
counter, no imaging

EIC SCIENCE AND DETECTOR: TOPSIDE

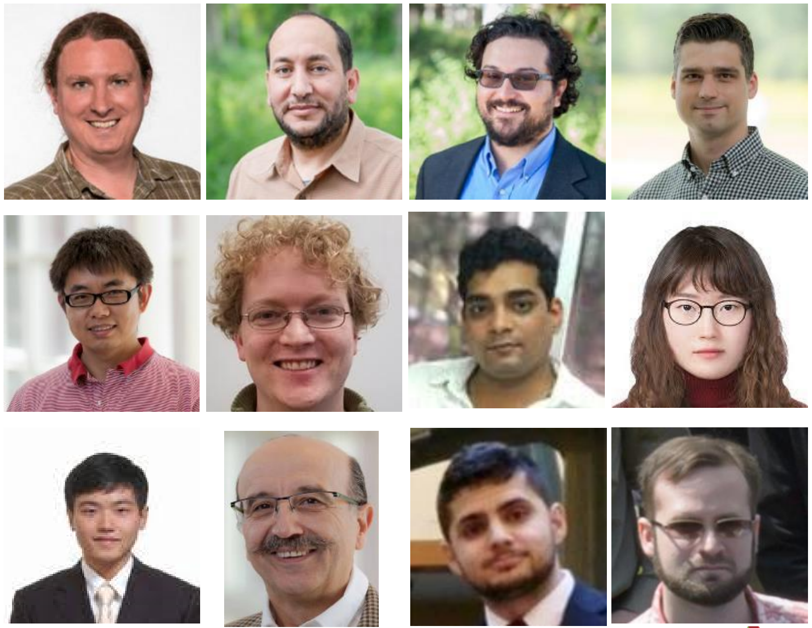
Major Lab Initiative at ANL





RICH with LAPPD @ TOPSiDE contributes to EIC-PID

- TOPSiDE
  - (*ongoing*) Prove viability of concept through closed-loop simulation/ reconstruction.
  - Optimize TOPSiDE for key EIC physics milestones
  - Release software stack when implementation complete
  - Support various YR sub-sections related to TOPSiDE



EIC-PID FERMILAB BEAMLINE VALIDATION OF ARGONNE MCP-PMT & LAPPD WITH SUB-SYSTEMS

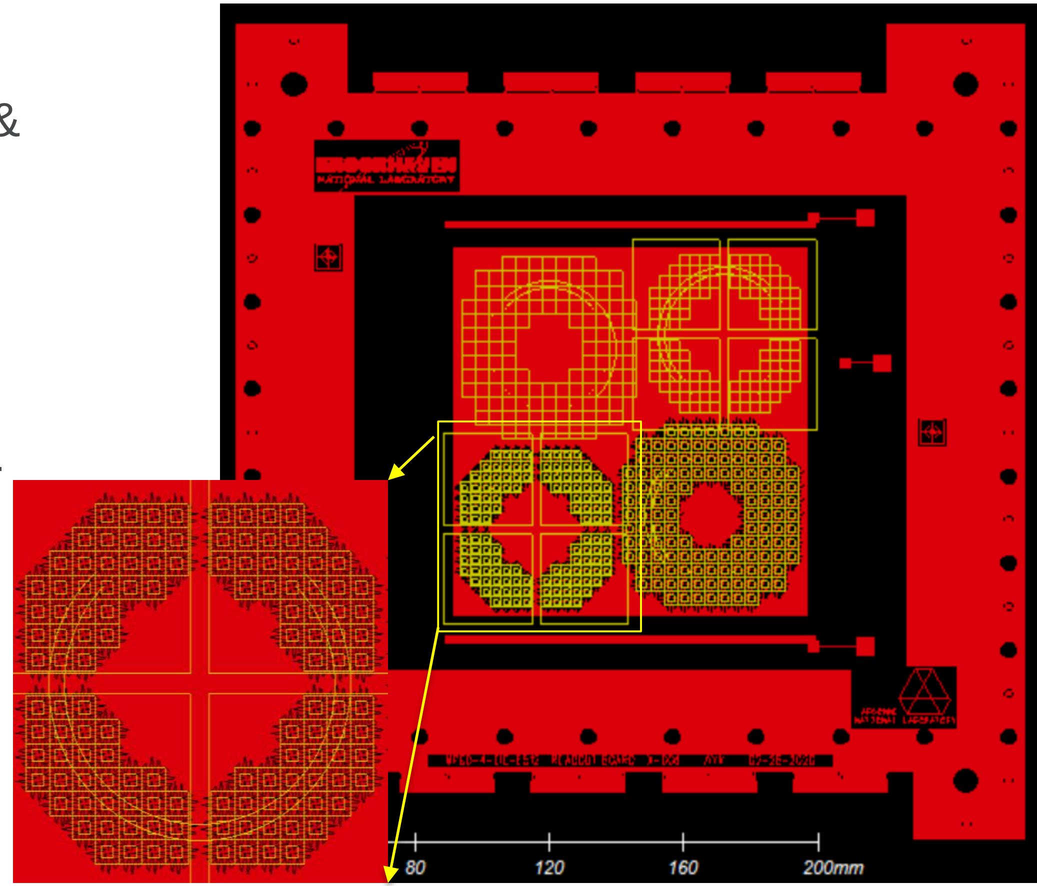
Projected timeline:

Spring 2020: Argonne MCP-PMT & Gen II LAPPD for proof-of-concept sensor validation (pixel and zigzag schemes)

Spring 2021: Gen II LAPPD for mRICH module, dRICH, TOPSiDE-RICH prototype (if not ready, delay to Spring 2022)

Spring 2022: Delivery of Gen III HRPPD from Incom to EIC-PID

Spring 2023: Gen III HRPPD for hpDIRC



Imaging readout PCB design for Argonne MCP-PMT based on eRD6 GEM board with pixel (upper two) and zigzag (lower two) schemes.

SUMMARY

- R&D on optimization of LAPPD 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.
- Exploration of LAPPD application in Nuclear Physics particle identification are undergoing:
  - High rate background environment for SoLID Cherenkov
  - Fermilab Cherenkov imaging beamline test and sub-system validation
  - RICH with LAPPD @ TOPSiDE contributes to EIC-PID

ACKNOWLEDGMENTS

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Argonne National Laboratory, Argonne, IL, 60439
B. Azmoun, M. Chiu, A. Kiselev, C Woody
Brookhaven National Laboratory, Upton, NY, 11973
B. Adams, C. Ertley, M. Foley, C. Hamel, A. Lyashenko, M. J. Minot, M. Popecki, M. Stochaj, W. Worstell
Incom, Inc., Charlton, MA 01507
A. Camsonne, J.-P. Chen, M. Jones, S. Malace, W. Xi, C. Zorn
Jefferson Lab, Newport News, VA, 23606
E. Kaczanowicz, M. Paolone, M. Rehfuss, N. Sparveris
Temple University, Philadelphia, PA, 19122

And many others …

EIC PID Collaboration (eRD14): PID Consortium for an integrated program for Particle Identification (PID) at a future Electron-Ion Collider

The above presentation has been created by UChicago Argonne, LLC, Operator of Argonne National Laboratory (“Argonne”). Argonne, a U.S. Department of Energy Office of Science laboratory, is operated under Contract No. DE-AC02-06CH11357.

Thank you for your attention!

Questions?