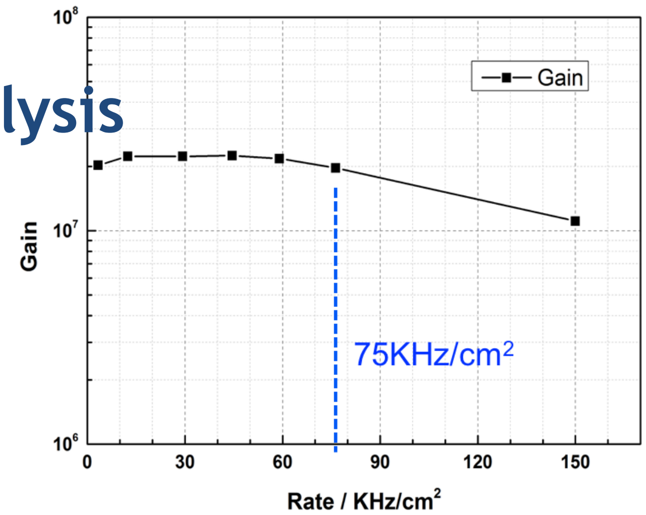
Status by end of FY2016

- Completed DOE milestone of 10 sealed functional MCP-PMTs
- Improved photocathode QE to maximum capability of 18.5%
- Current detectors exhibit excellent performance: high gain over 10^7, timing resolution of 35 ps for single photoelectron, 20 ps for multi-photoelectrons
- Devices were sent out to early users for evaluation and incorporation to experiments
- Improvement required:
  - Magnetic field tolerance is not good
  - Pad readout is requested
  - Better timing (<10ps) may be achievable

FY17 Fermi beamline test data analysis

- Mainly test of the rate capability of the MCP-PMTs
- Did not observe obvious decrease of MCP-PMT gain below 75 KHz/cm^2, indicating good rate capability tolerance.

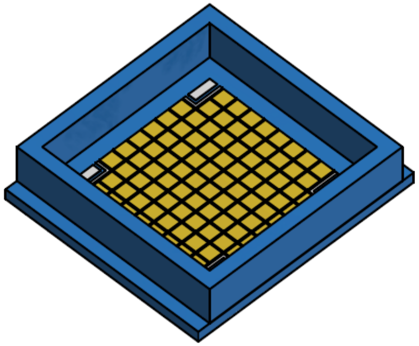
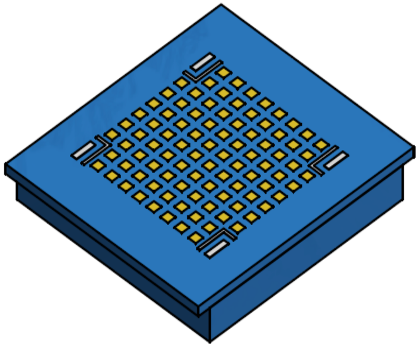
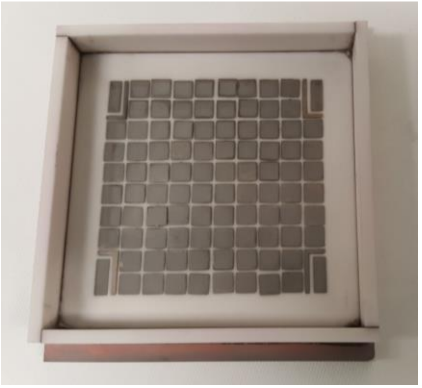
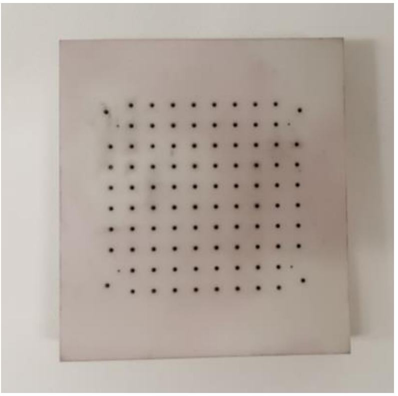


FY17 Detector optimization: Pixelated readout

Current readout design is based on strip line readout
Various applications require pad readout

A new pad readout was designed and currently under fabrication

- Inside and outside pads are made of copper and connected through a VIA
- Base and side walls are made of ceramic

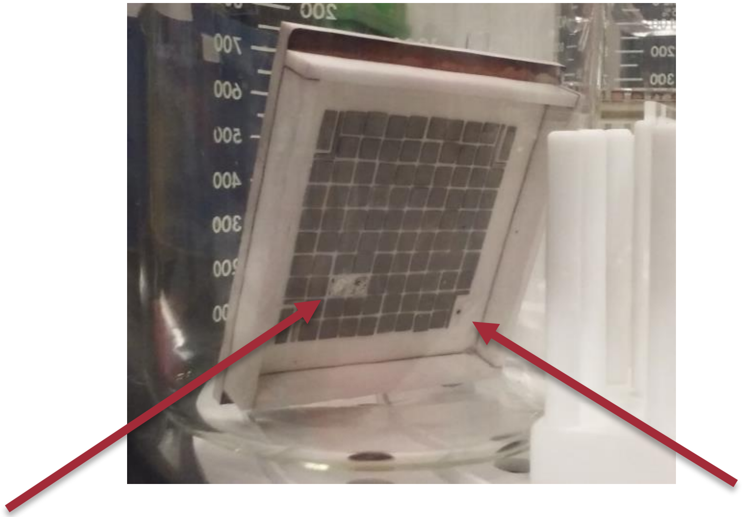





However, the received pad tile from Innosys Inc. has several defects:

- The readout pads on the inner side of the anode plate is not flat as requested
- The outside connections to these anode pads are not implemented.
- The side wall of the tile base is only 3mm thick, while we specified 5mm.

FY17 Detector optimization: Pixelated readout

After we cleaned the tile base, sonicated for less than 10 min, three pads (two readout pads and one HV pad) detached from the anode plate, and an open hole showed up under the HV pad that fell off.



Unfortunately, the pixelated design with VIAs failed due to technique difficulty

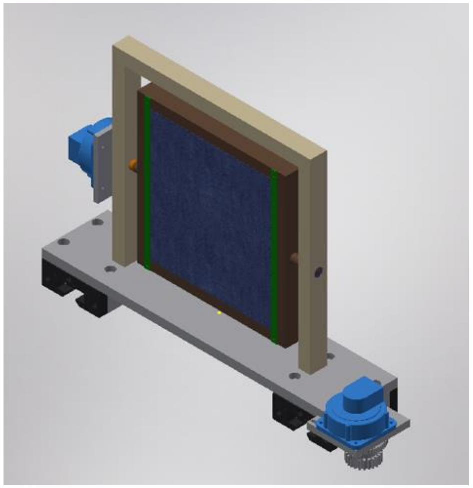
Current effort and plan on pixelated readout:

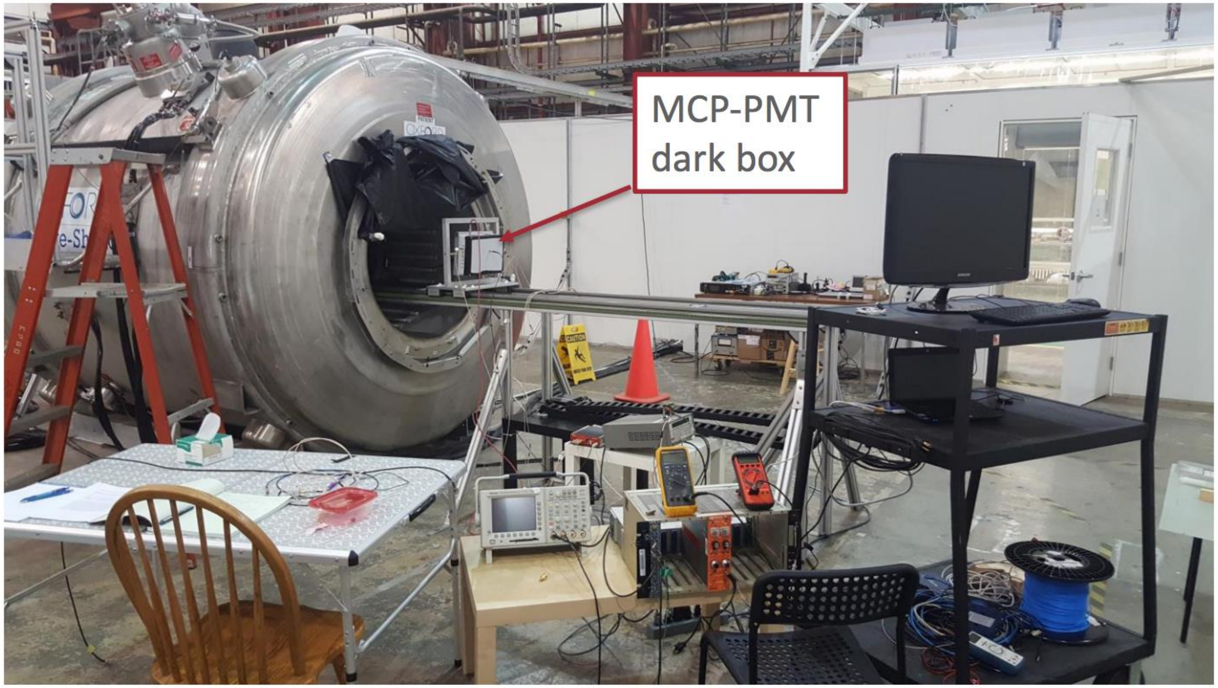
Innoysys Inc. is making a second attempt to provide us a new pad tile, will see how it goes.

Meanwhile, we shifted our effort on pixelated readout detector through capacitive coupling design:

- The lower glass is coated with resistive ALD layer, 10kΩ
- Pad sizes are directly designed on the electronic board

EIC Detector Magnetic Field Test Facility



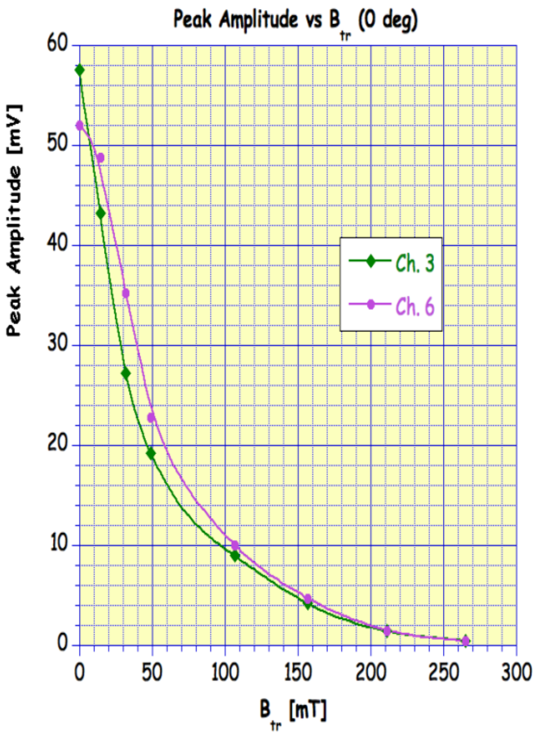


(left) Self-designed test stand with the capability of testing MCP-PMTs up to 20 x 20 cm^2
(right) Picture of MCP-PMT magnetic field test setup at ANL in building 366.

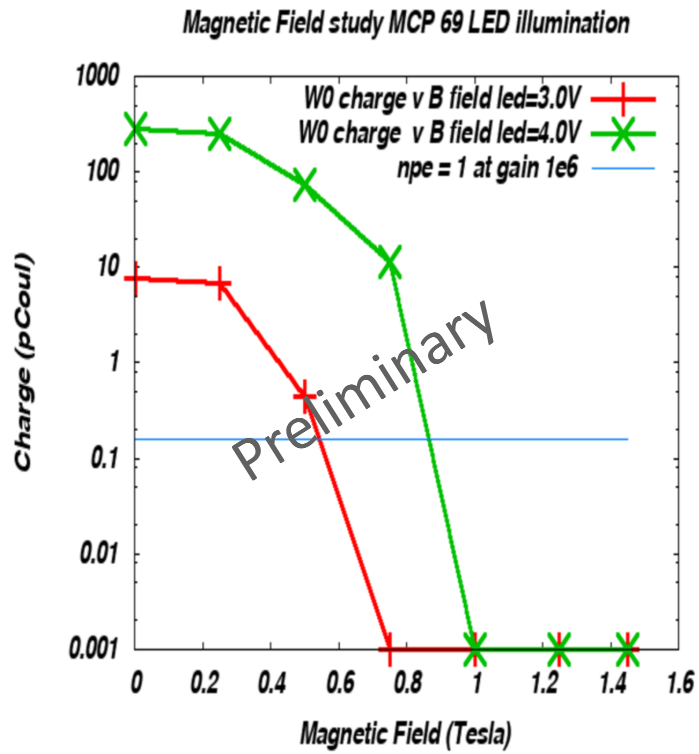
- A transporter with the capability of testing MCP-PMTs up to 20 cm x 20 cm
- All components are made of non-magnetic materials
- Electrically controlled router
- MCP-PMT center is well aligned with the center of the magnetic facility

First test experiment was done June 12-27: High voltage, magnetic field strength and angle dependences were all tested.

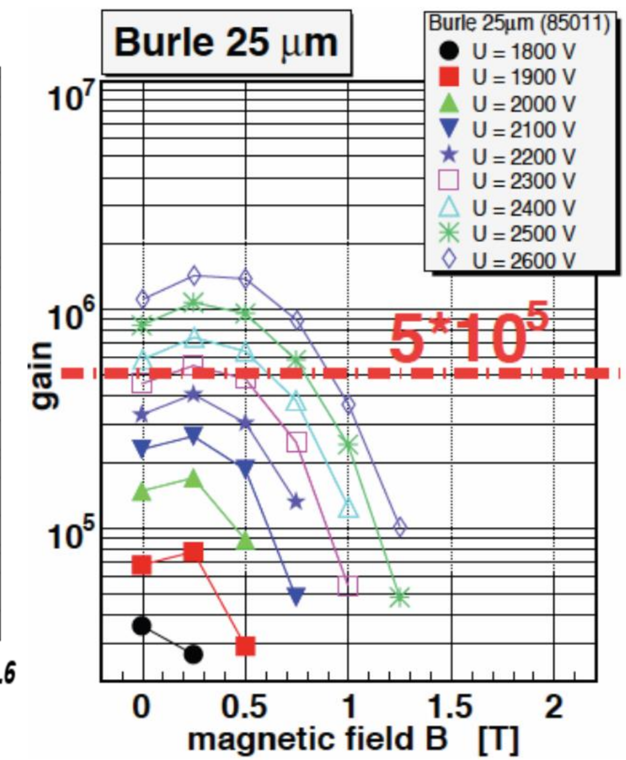
Performance of 6x6 cm^2 MCP-PMT in magnetic field



Internal resistor chain design
Gain drops quickly
0< B < 0.15 T



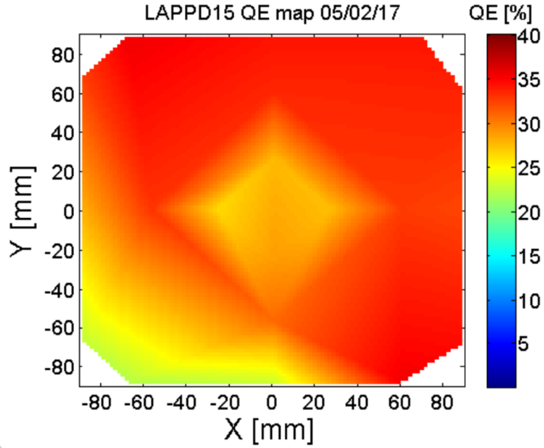
Individual biased design
B field tolerance
0< B < 0.8 T



Burl 25um pore size MCP-PMT
B field tolerance
0< B < 1.0 T

- Obvious improvement from internal resistor chain design to individual biased design, optimization of biased voltages for both MCP is important.
- Comparable performance of LAPPD (Not optimized yet) to Burl tube in B field
- Performance dependence on high voltage and angle are currently under analysis

Incom Inc. 20 x 20cm^2 LAPPD production



- **Incom Inc. has successfully manufactured several sealed LAPPDs**
  - Gain ~ 10^7 at 1000V/plate
  - Uniformity better than 10% over 400 cm^2 area
  - Dark count rate: 1ct/s/cm^2
  - Position determination through stripline readout over whole area

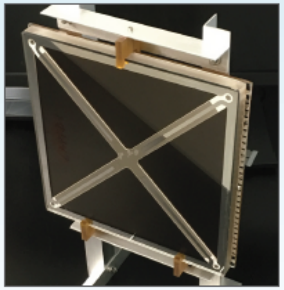
- **LAPPD will be available to deliver to Argonne for characterization and magnetic field testing in early FY18.**

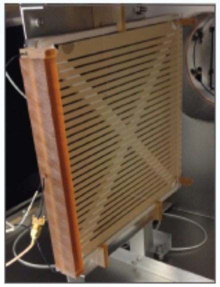
INCOM
Bright Ideas in Fiber Optics

LAPPD™ Large Area Picosecond Photodetector

FEATURES:

- World's Largest Area: 230 mm x 220 mm
- Low Profile: Only 22 mm thick
- High, Stable Gain: Resistive and emissive coatings applied via ALD
- Low noise: MCPs made with durable, low-alkali, borosilicate glass containing minimal Potassium 40





Package/Housing Characteristics

Housing Size	230 mm x 220 mm x 22 mm Thick
Housing Material	Borosilicate Glass
Window Material	Borosilicate or Fused Silica
Photocathode Material	Multi-Alkali (K_2NaSb)
Anode Configuration	28 silver strips, nominally 50Ω
Voltage Distribution	5 taps for independent control of voltage to the photocathode and entry and exit of MCP
Wavelength Sensitivity	<350 nm to >625 nm

Microchannel Plate (MCP) Characteristics

Arrangement	Two Positioned in a Chevron Pair
Dimensions	203 mm x 203 mm x 1.2 mm Thick
MCP Substrate	Borosilicate Glass
Capillary Pore Size	20 µm
Capillary Open Area Ratio (OAR)	65%
Typical Gain	1×10^7
Resistive and Emissive Coatings	Applied via Atomic Layer Deposition (ALD)
Secondary Emission (SEE) Layer Material	Al_2O_3

LAPPD Performance Demonstrated To Date

Quantum Efficiency (Q.E.) at 365 nm and 23°C	15% or better
Maximum Operating Voltage	3000 V
Temporal Resolution	Single PEs (photoelectrons): <100 ps, consistently; <60 ps, typically
	Large Pulses: < 5 ps, predicted
Spatial Resolution	Single PEs: 1-3 mm
	Large Pulses: <1 mm

For more information, contact:
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INCOM
Bright Ideas in Fiber Optics

How LAPPD R&D helps with Incom tile for EIC?

Incom SBIR Phase II "Gen-II LAPPD development for nuclear physics" was just awarded with 2 year 1M. DOE pushes Incom to optimize LAPPD for Nuclear physics community.

Incom has produced several tiles successfully. They have started to provide tiles to early users (ANNIE) for testing and applications. By time of EIC construction (7-10 Years?), LAPPD should be available on market for mass production.

EIC dRICH cost estimation is $34M, out of which $23M for MCP-PMTs, from discussion with Incom on phone meeting recently, the price is around $25K/LAPPD, 10 times less than the commercial photonis MCP-PMT (Plannacon, $15K/5x5cm^2)

Incom has close connection with ANL MCP-PMT development. At ANL, Incom is mainly interested in the sealing technique and magnetic field performance improvement.

First magnetic field test of the IBD design proves that the LAPPD MCP-PMT is comparable with photonis MCP-PMT, but still it can only survive at 0.8T magnetic field. Further optimization is required to push its magnetic field tolerance up to 3T at least.

One main direction is to reduce the spacing of cathode, MCP and anode. The spacing reduction may cause various risks, an early development at ANL can foresee these risks and provide an optimized design to Incom for adapting.