ANL MCP-PMT in magnetic field test

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on behalf of the Detector R&D group

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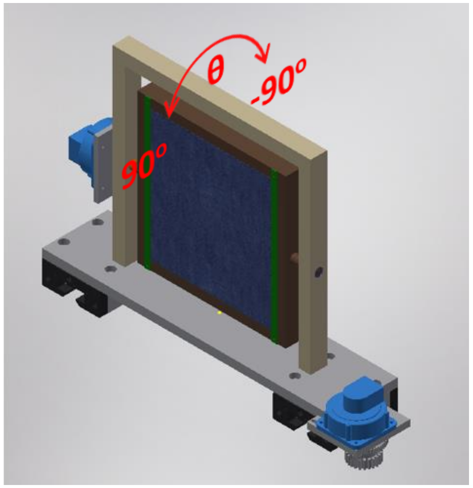
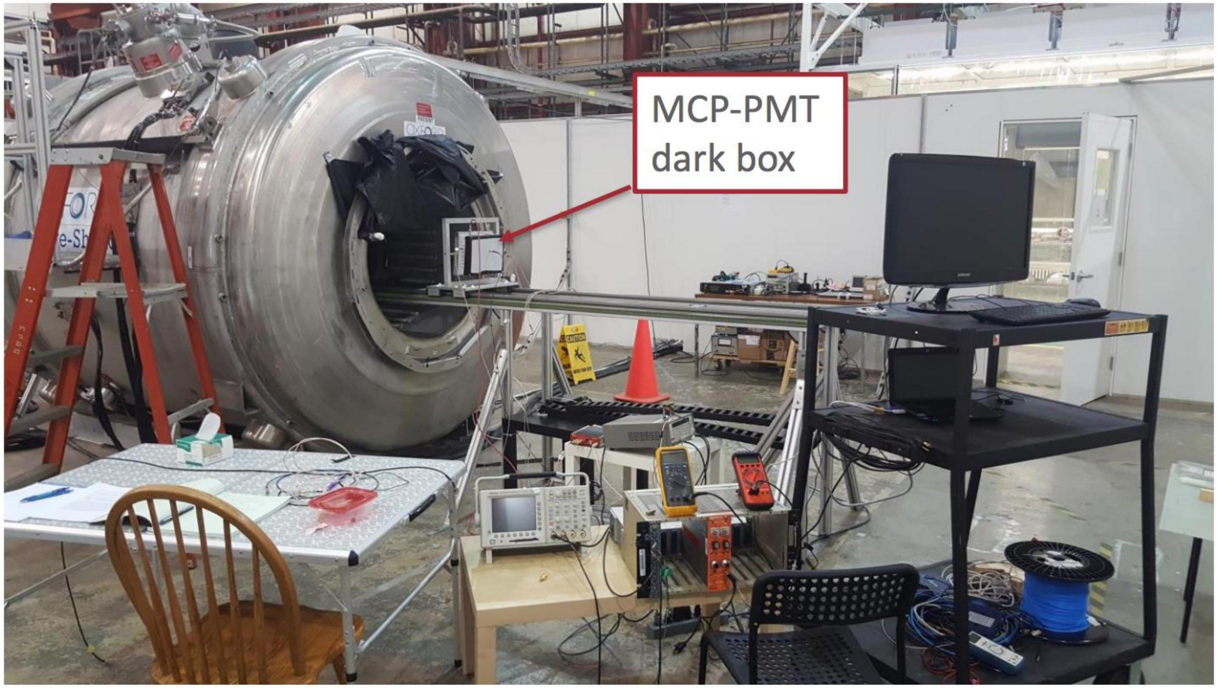
ANL Magnetic Field Test Facility



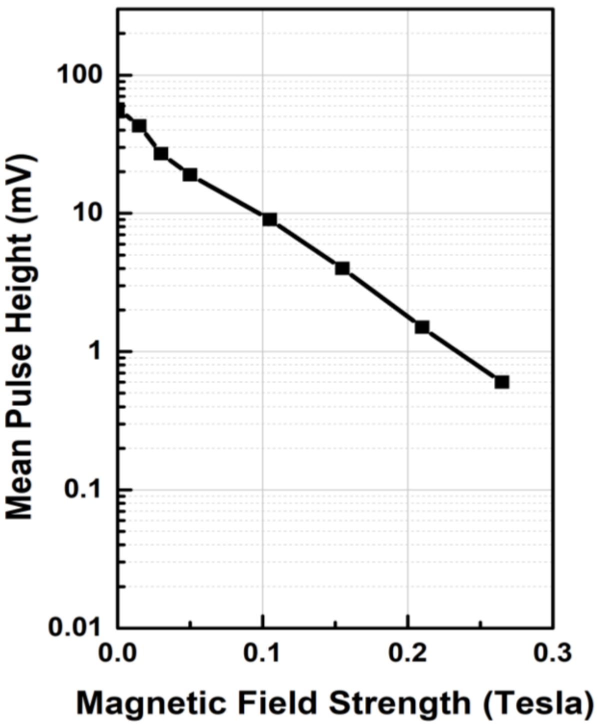


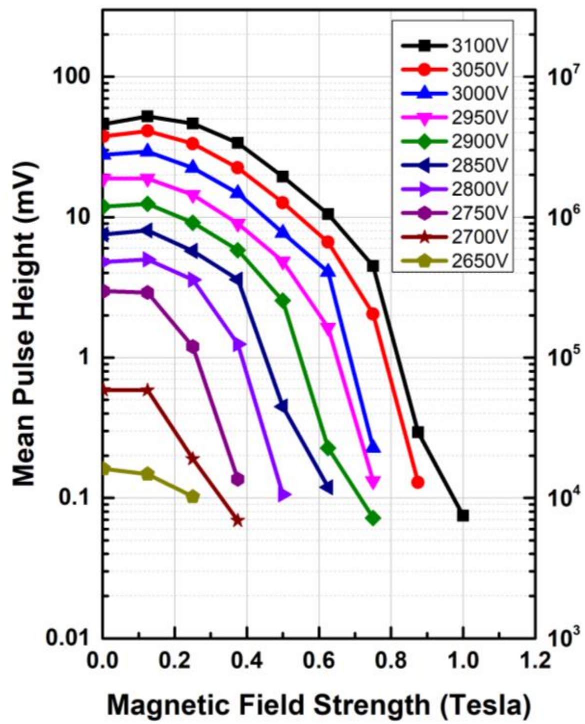
(left) Self-designed test stand with the capability of testing MCP-PMTs up to 20 x 20 cm^2
(right) Picture of MCP-PMT magnetic field test setup at ANL in building 366.

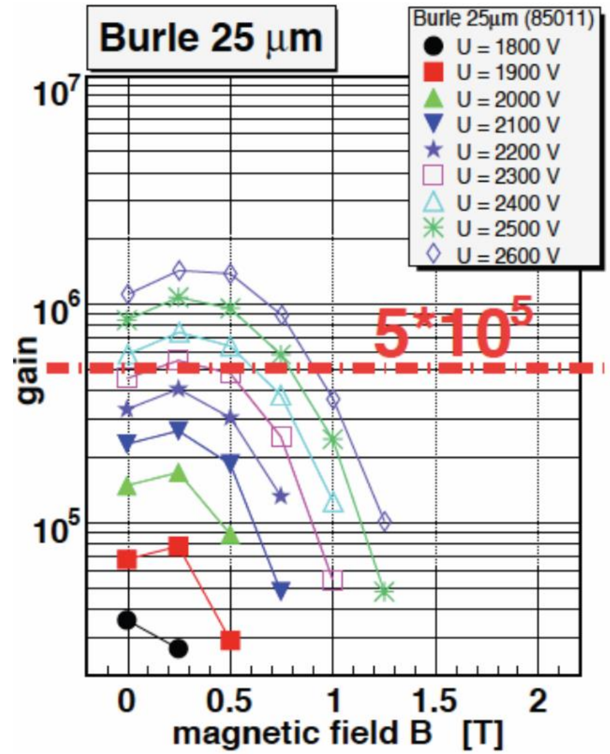
- A transporter with the capability of testing MCP-PMTs up to 20 cm x 20 cm
- All components are made of non-magnetic materials
- Electrically controlled router

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

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







A. Lehmann NIMA 595 (2008) 173–176

Internal resistor chain design

Gain drops quickly

0< B < 0.15 T

Individual biased design

B field tolerance

0< B < 0.8 T

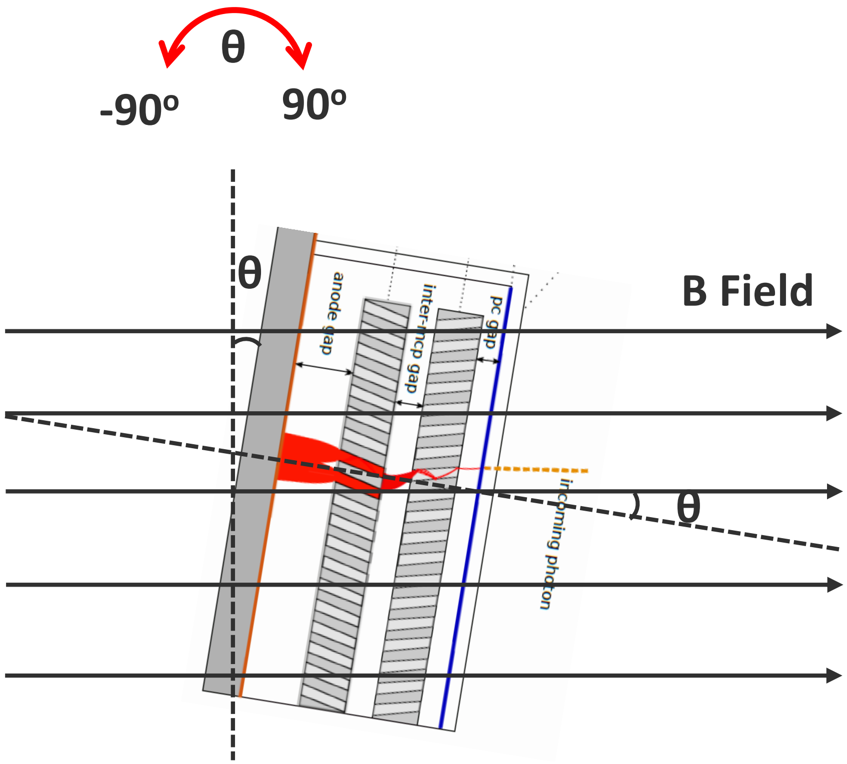
Burl 25um pore size MCP-PMT

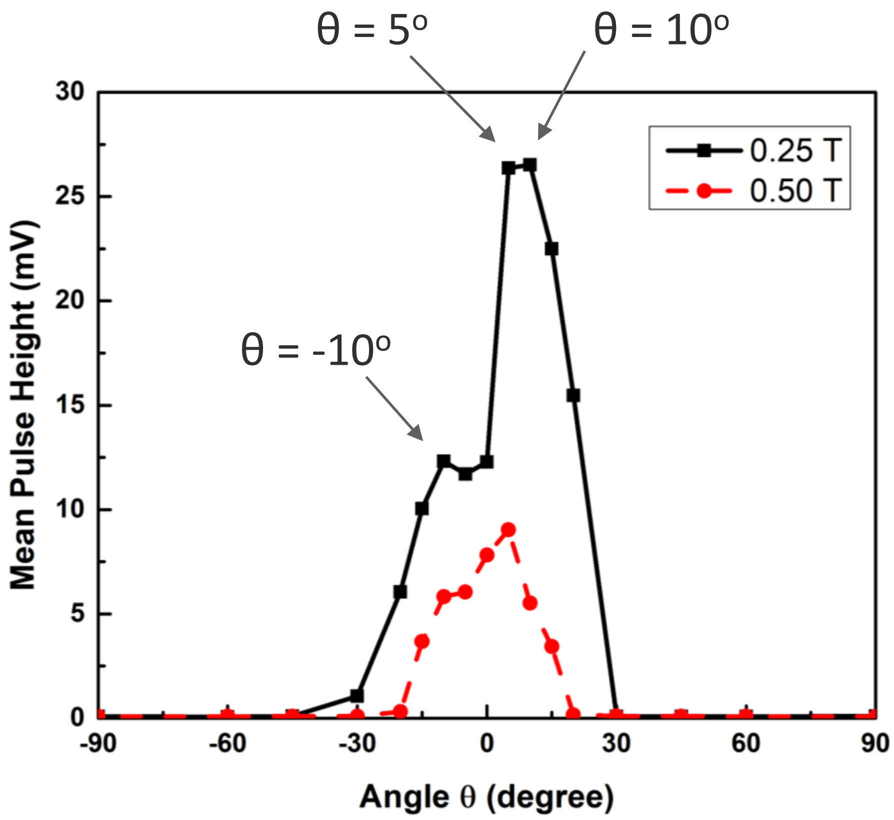
B field tolerance

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

Angle dependence measurement





Standard MCP-PMT design exhibit magnetic field tolerance up to 0.8 T at 0° test angle.

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° and 8°, indicating the effect of upper and lower MCP angles are different. Simulation is necessary to explain the different effect.

LAPPD for EIC PID detectors

A program proposed for EIC-LAPPD development

Junqi Xie

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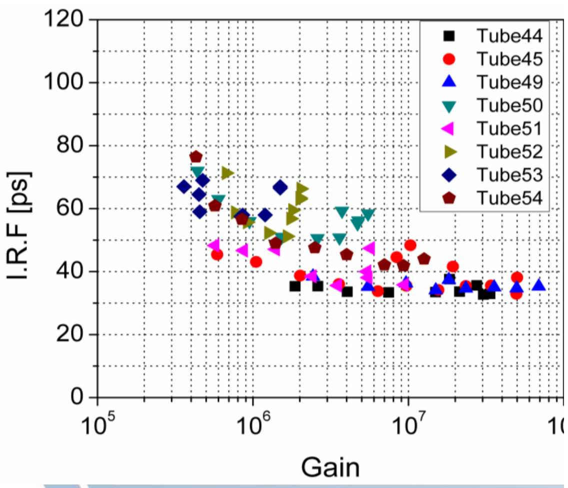
ANL MCP-PMT with LAPPD design

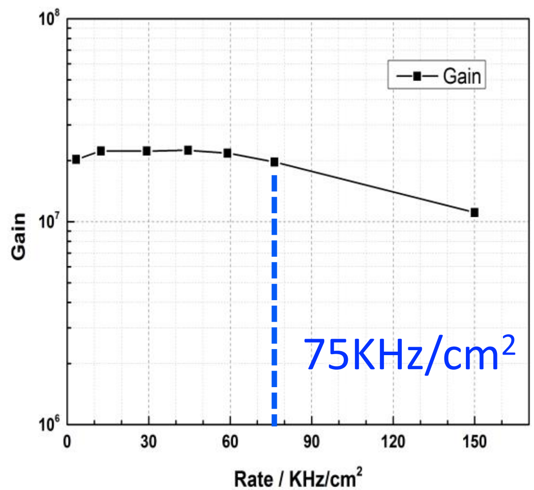
- 20 μm pores, L/D = 60, MCP thickness 1.2mm, 8-degree bias angle
- Gain as high as **$7X10^7$**
- Time resolution $\sigma_{overall}$ **~35 ps, TTS <20 ps**
- Laser start time jitter: σ_{laser} **~30ps**
- Rate capability: **> 75KHz/cm^2**
- B field tolerance: **0.8 T without optimization**

Overall time resolution

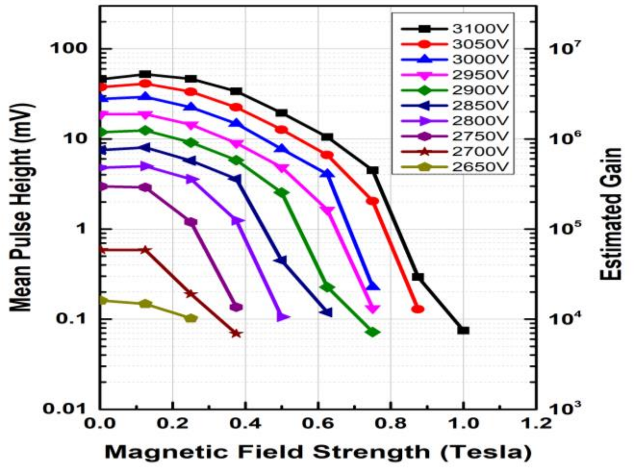
$$\sigma_{I.R.F.}{}^2 \sim \sigma_{.T_{MCP}}{}^2 + \sigma_{.T_{laser}}{}^2$$



Rate capability

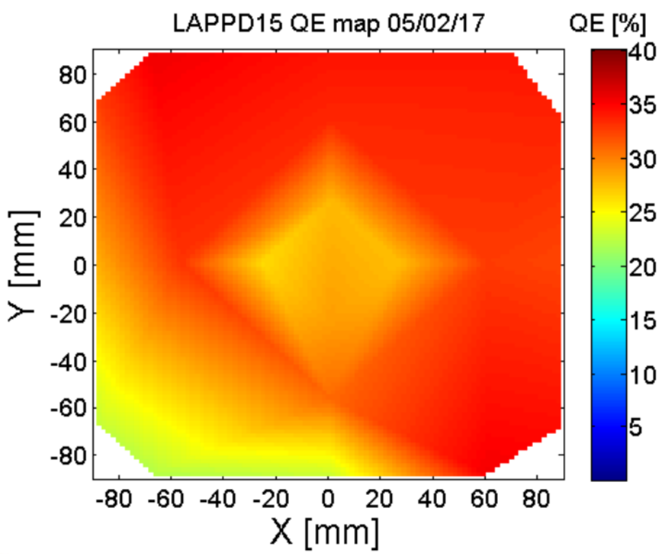


B field tolerance



Incom Inc. 20 x 20cm^2 LAPPD production

- **Incom Inc. has successfully manufactured several sealed LAPPDs**
  - QE over 30% at 8x8 inch^2 area
  - Gain ~ 10^7 at 1000V/plate
  - **Dark count rate: 1ct/s/cm^2**



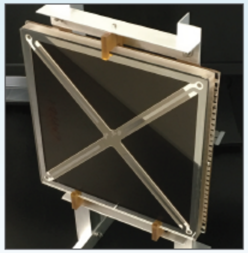
- **LAPPD is expected to be a low cost option when compare to competitive technology**

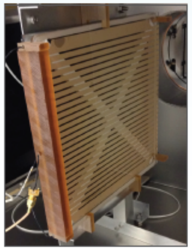
INCOM
Bright Ideas in Fiber Optics

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 x 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:
Michael J. Minot, Director of R&D
mjm@incomusa.com or (508) 909-2369

INCOM
Bright Ideas in Fiber Optics

DOE-NP proposal calls for optimization of LAPPD

U.S. Department of Energy

Small Business Innovation Research (SBIR) and
Small Business Technology Transfer (STTR) Program

Topics
FY 2018
Phase I
Release 1

July 17, 2017

Participating DOE Research Programs

- Office of Advanced Scientific Computing Research
- Office of Basic Energy Sciences
- Office of Biological and Environmental Research
- Office of Nuclear Physics

30. NUCLEAR PHYSICS INSTRUMENTATION, DETECTION SYSTEMS AND TECHNIQUES

Maximum Phase I Award Amount: $150,000	*Maximum Phase II Award Amount: $1,000,000*
Accepting SBIR Applications: YES	*Accepting STTR Applications: YES*

The Office of Nuclear Physics is interested in supporting projects that may lead to advances in detection systems, instrumentation, and techniques for nuclear physics experiments. Opportunities exist for developing equipment beyond the present state-of-the-art at universities, national scientific user facilities, and facilities worldwide. Next-generation detectors will be needed for the 12 GeV Continuous Electron Beam Accelerator Facility (CEBAF) Upgrade at the Thomas Jefferson National Accelerator Facility (TJNAF), at the future Facility for Rare Isotope Beams (FRIB) under construction at Michigan State University, at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Lab, and at a proposed future Electron-Ion Collider (EIC). Also of interest is technology related to future experiments in fundamental symmetries, such as neutrinoless double-beta decay (NLDBD) experiments and the measurement of the electric dipole moment of the neutron (nEDM). In the case of NLDBD experiments, extremely low background and low count rate particle detection are

https://science.energy.gov/~/media/sbir/pdf/TechnicalTopics/FY2018_Phase_1_Release_1_Topics.pdf

(2) Particle identification detectors such as:

- Low cost large area Multi-channel Plate (MCP) type detector with high spatial resolution, high rate capability, radiation tolerance, magnetic field tolerance, and timing resolution of < 10 ps for time-of-flight detectors. The accompanying readout system (i.e. electronics, application-specific integrated circuit, etc.) should be compatible with the above requirements;

Low cost large area Multi-channel Plate (MCP) type detector **(LAPPD)**
high spatial resolution: **pixelated readout optimization (under developing)**
high rate capability: **75 kHz/cm^2 (good, tested at Fermi)**
radiation tolerance: **need to test, ANL can complete in FY18 with Si radiation test together**
magnetic field tolerance: **up to 1.5 T, currently 0.8 T for LAPPD (critical for EIC application)**
timing resolution of < 10 ps: **currently 20ps, for EIC PID 10 ps is not mandatory**
accompanying readout system: **Electronics developed in LAPPD project**

EIC dRICH Detector cost estimation

Dual-radiator RICH cost estimate, by comparison with the CLAS12 RICH cost

- Photo-detector area ~ 8500x6 cm^2 :
  - 1920 (MCP-PMTs) units at 12K per unit → 23 MUSD
  - 1920 (SiPMs) units at 2K per unit → 3.8 MUSD
- Electronics, assuming 3mm pixel:
  - 1920 (MCP-PMTs) x 280 (channels/PMT) x10 (USD/channel) → 5.4 MUSD
  - 1920 (SiPMs) x 280 (channels/SiPM) x 12 (USD/channel) → 6.5 MUSD
- Aerogel volume 180000 cm^2: Aerogel cost ~ 3K per liter → 540 KUSD
- Spherical mirror: Radius of curvature 280 cm, area ~ 3x6 m^2 → ~ 1.8 MUSD
- Mechanics: → ~ 600 KUSD
- Services, gas system, etc... → ~ 300 KUSD

Total cost: ~ 34 MUSD (MCP-PMTs) or 14 MUSD (SiPMs)

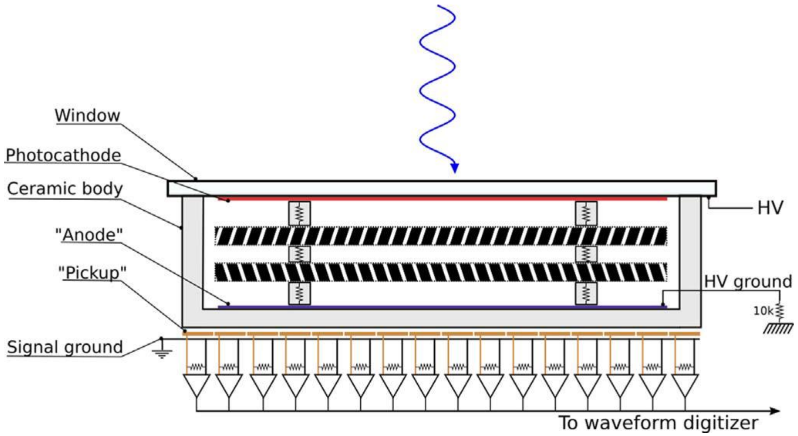
dRICH cost estimation by Alessio Deldotto@infn

132 LAPPD would provide equivalent area coverage as 1920 MCP-PMTs

SiPMs have a high dark current rate per area, and also get noisier when they get radiation damage. Other reasons for MCP-PMT other than SiPMs?

- **LAPPD is a very promising sensor (maybe the only) candidate for proposed EIC PID detectors: price, performance**
- **Cost and technical performance, including high speed, spatial resolution, pixelated readout and high B tolerance are the driving forces for optimization of LAPPD**
- **EIC timeline requires mass production of optimized LAPPD in 7 years (construction starts ~2025), needs quick action**

Effort for pixelated readout - capacitive coupling



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ELSEVIER

Capacitively coupled pickup in MCP-based photodetectors using a conductive metallic anode

E. Angelico[a,*], T. Seiss[a], B. Adams[b], A. Elagin[a], H. Frisch[a], E. Spieglan[a]

[a] Enrico Fermi Institute, University of Chicago, 5640 S Ellis Ave, Chicago, IL 60637, United States
[b] Incom, Inc., 294 SouthBridge Rd, Charlton, Massachusetts 01507, United States

- Various applications require pixelated readout
- Signal pickup via capacitive coupling is demonstrated using NiCr anode and ceramic base
- Incom was awarded a 1M two year Phase II SBIR for the pixelated readout design (DOE-NP is serious about optimization of LAPPD for EIC applications)

Incom, Inc. Development of Gen-II LAPPD™ Systems for Nuclear Physics Experiments Topic: 24a

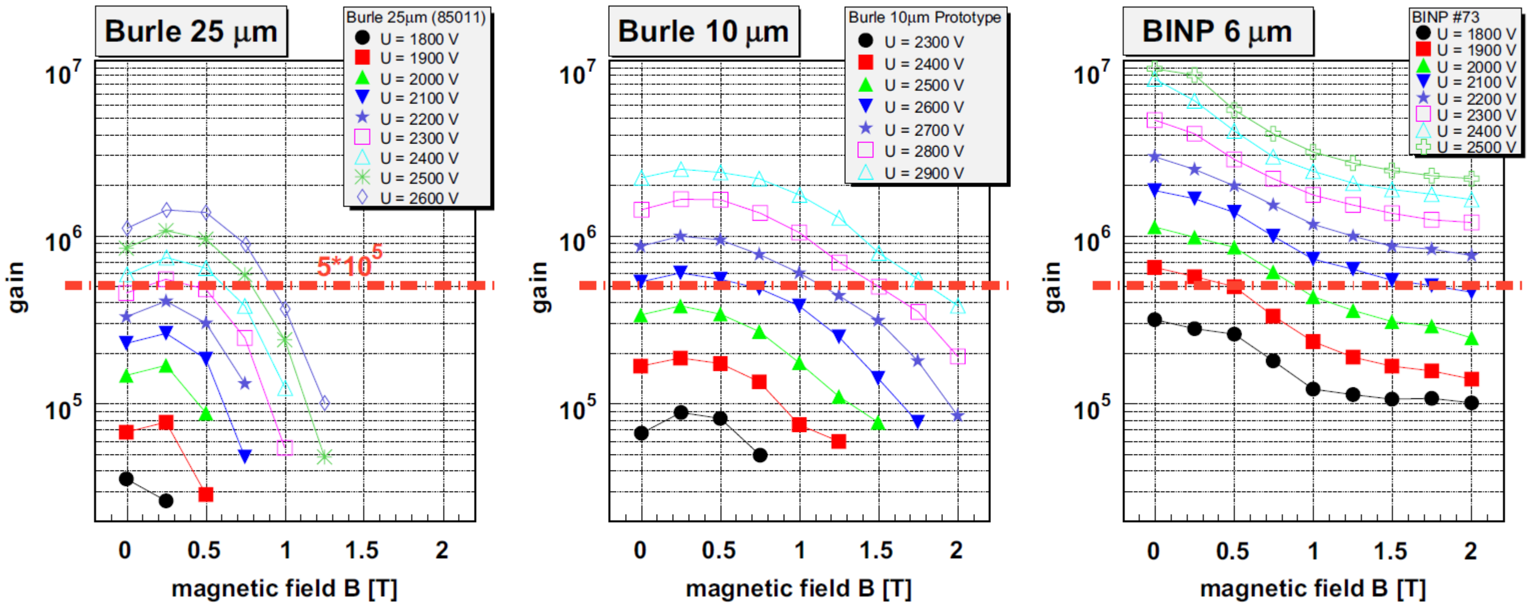
Phase II SBIR Project Narrative

Small Business name: Incom Inc.	Principal Investigator: Michael R. Foley
Topic / subtopic: Topic 24-a. **NUCLEAR PHYSICS INSTRUMENTATION, DETECTION SYSTEMS AND TECHNIQUES, (4) Particle identification detectors;** DOE Opportunity # DE-FOA-0001645	
Application Type: **Phase II SBIR**	
Project Title: **Development of Gen-II LAPPD™ Systems For Nuclear Physics Experiments**	

Credit: Andrey Elagin & Michael Foley

Propose a SBIR/STTR program to address B field tolerance

Technical hurdles to achieve B field tolerance are challenging but achievable: Large Area Small Pore (6 micron) MCPs, and spacing optimization



A. Lehmann NIMA 595 (2008) 173–176

A program well aligned with ANL interest and Incom development plan:

- Scale up of 6 micron (or 10 micron) MCPs to 8''X8''
- Redesign of tiles to eliminate magnetic materials
- Optimization of spacing between photocathode – MCPs – Anode
- Simulation packages, etc.
- Other ideas? ...

Suggestions, comments, and feedback…

Back up

Planacon price quote

PHOTONIS

PHOTONIS USA Pennsylvania, Inc. | 1000 New Holland Ave. | Lancaster, PA 17601-5688 USA
Telephone: 1-800-366-2875 (USA & Canada) or 717-295-2704 | FAX: 717-295-6096 | E-mail: l.suter@photonisusa.com

Quote Number:	23153	Contact:	Junqi Xie
Date:	28 Sep 2015	Telephone:	630-252-1868
Customer Ref No:	Planacon	Fax:	
Valid Until:	21 Dec 2015	E-mail:	jxie@anl.gov

Bill To	Ship To
Argonne National Lab 9700 S Cass Avenue Bldg 201 Lemont, IL 60439 US	Argonne National Lab 9700 S Cass Avenue Bldg 201 Lemont, IL 60439 US

In response to your request, PHOTONIS USA PA, Inc. is pleased to quote as follows:

#	Quantity	Product	Delivery	Unit Price
1	1 - 10 each	XP85112/A1 Planacon **5cm x 5cm area, 10 μm pore, 8X8 array**	Approximately 120 Days ARO or sooner	$13,880.00
2	1 - 10 each	XP85122 Planacon **5cm x 5cm area, 10 μm pore, 32X32 array**	Approximately 120 Days ARO or sooner	$16,120.00
3	1 - 10 each	XP85022 Planacon **5cm x 5cm area, 25 μm pore, 32X32 array**	Approximately 120 Days ARO or sooner	$11,070.00
4	1 - 10 each	XP85012/A1 Planacon **5cm x 5cm area, 25 μm pore, 8X8 array**	Approximately 120 Days ARO or sooner	$8,830.00