14th Pisa Meeting on Advanced Detectors
La Biodola, Isola d'Elba (Italy)
May 27 - Jun 2, 2018

Large Area Picosecond Photodetector (LAPPD) Pilot Production and Development Status

Photo Detectors and PID, Monday May 28, starting at 18:50

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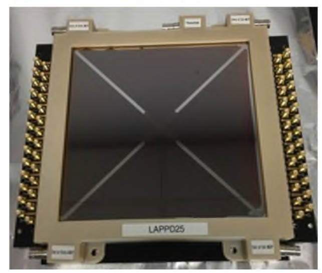
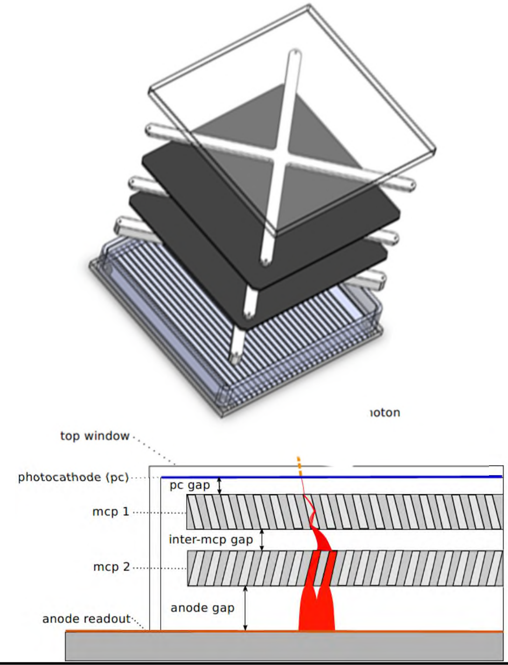
Presentation Outline

- Motivation for LAPPD
- LAPPD #25 Performance Results
- GEN II Development Status
- How Would Low Psec Timing & High Spatial Resolution Influence Your Design of Experiment?

LAPPD Advantages

LAPPD™ is an MCP based photodetector, capable of imaging with single-photon sensitivity at high spatial and temporal resolutions in a hermetic package with an active area of 400 cm².





- **Single Pixel**
- **Nanosecond resolution**
- **High background noise**
- Sensitive to magnetic fields
- Small coverage
- Bulky

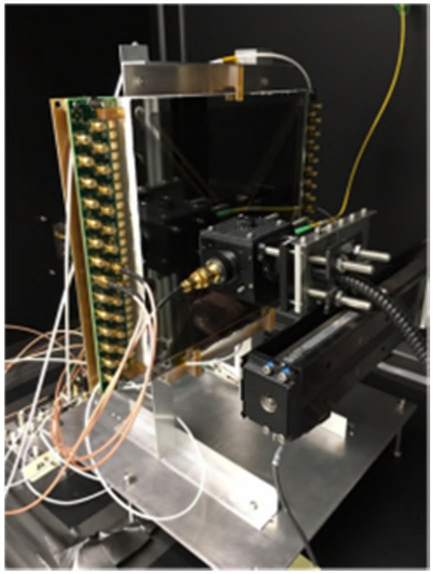
- **Millimeter spatial resolution**
- **< 100 picosecond resolution**
- **Very low noise**
- Large Area (16X Planacon)
- Compact
- Operates in magnetic field

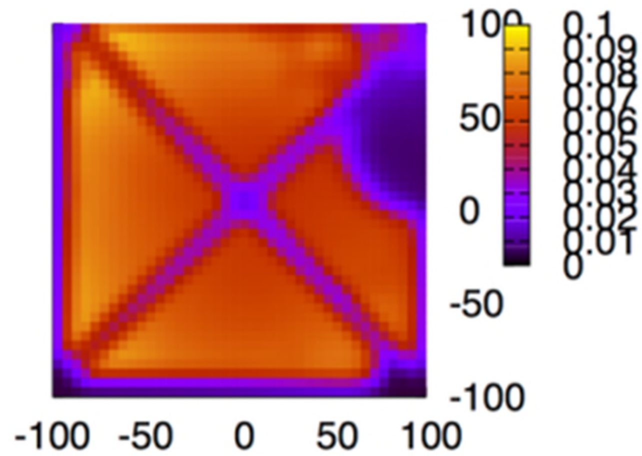
- **20μ Chevron Pair ALD-MCPs**
- **28 silver strip Anode, 50 Ω**
- Large Area, No Feedthroughs
- Borosilicate Glass Housing
- Fused Silica Glass Window

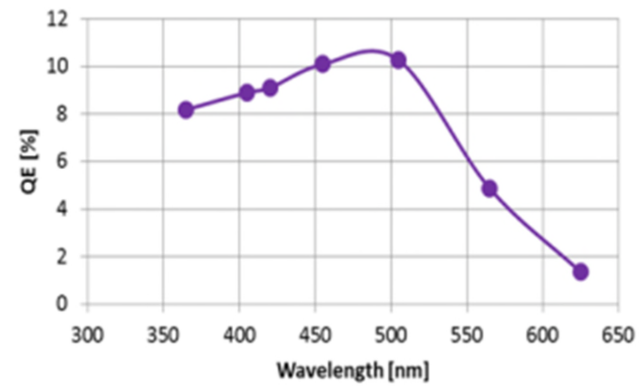
LAPPD #25 Performance Summary

Parameter	LAPPD 25
MCP resistance (Entry/Exit; MΩ)	10.7 / 14.2 MΩ at 875 V
QE	@365 nm: Max: 10%, Mean: 7.1%, s = 0.8% @455 nm: Mean: 10.2%
Gain	7.5 $\times 10^6$ @ 850/950 V (entry/exit)
Dark rate (Single 13.5 cm2 strip)	9.5 Cts/s cm2 @ 50 volts on the P/C, 850 V/MCP, and Threshold of 7.6x105 gain
After pulses	Typical for MCP PMT – about 3.5%
Along-strip **Spatial Resolution** Cross-strip	2.8 mm RMS (measured as 33.4 psec) 1.3 mm RMS
Time Resolution	64 psec resolution TTS MCP Pulse Rise time: 850 psec, FWHM: 1.1 nsec

Photocathode QE - LAPPD #25





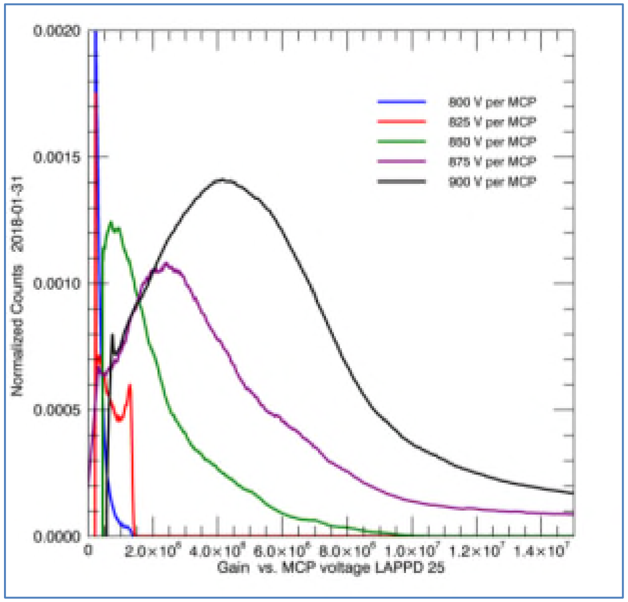


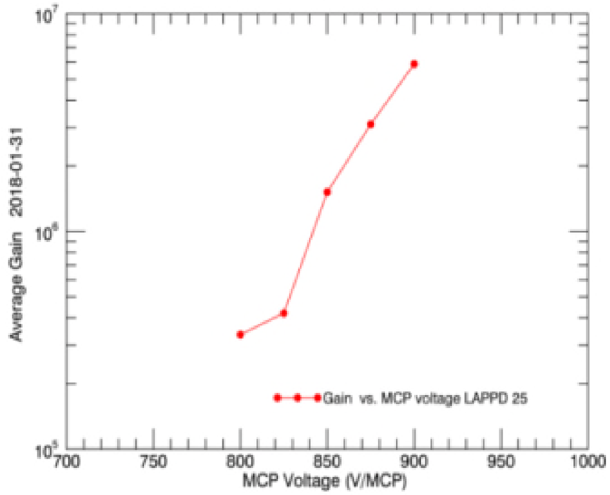
- Light source scanned in 5 mm steps across the window
- Illumination: ~10 mm dia.
- 365 nm UV LED

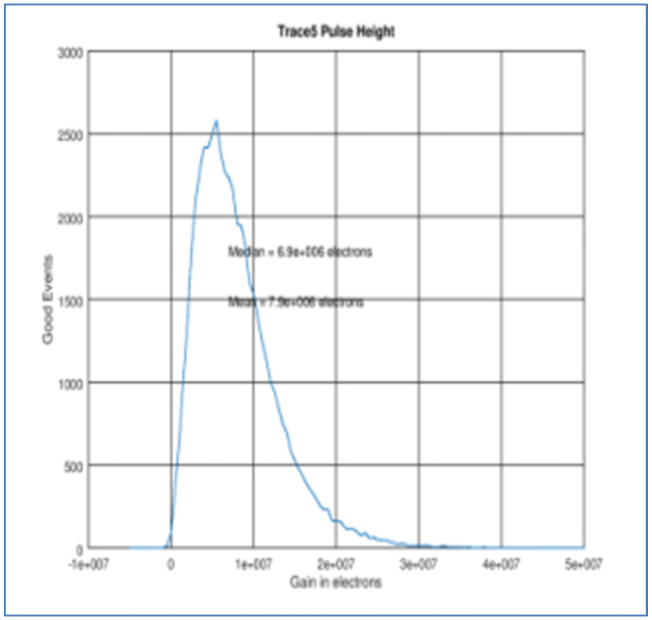
Large Area Photocathode production process is established
QE >20% demonstrated in sealed LAPPDs

LAPPD S/N	Maximum %	Average %	Minimum %
LAPPD #13:	23.5	18.6±3.3	13.5
LAPPD #15:	25.8	22.3±3.0	15.7
LAPPD #22:	14.7	10.6	
LAPPD #25:	10	7.1	
LAPPD #29:	19.6	13.0±6.0	3
LAPPD #30:	22.9	17.2±2.5	13

Single PE Gain vs. MCP voltage, Tile #25







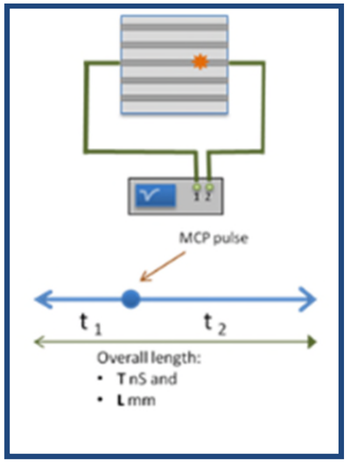
Left: Single PE Pulse height distributions, charge sensitive amplifier, and ADC, for different MCP voltages.

Middle: Average gain vs. MCP voltage (gain doubles for every 50 volts).

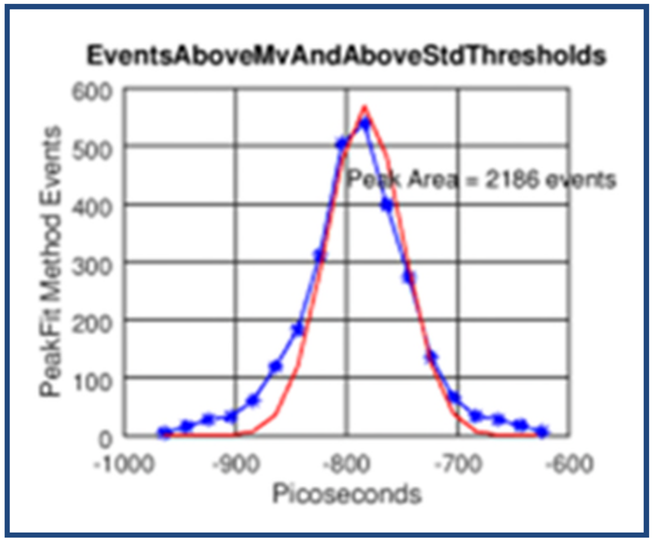
Right: Single PE Gain from unamplified charge pulses, from DRS4 waveform sampler, at MCP voltages 850/950 (entry/exit MCP).

Spatial Resolutions - LAPPD #25

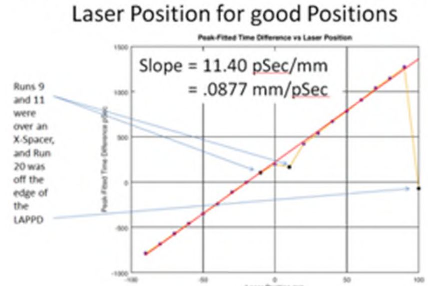
Along a Strip



Relative time of arrival, for a single laser position on the strip



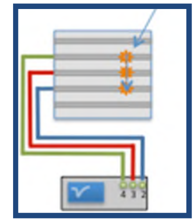
Linear Fit of Peak-Fitted Time Difference vs Laser Position for good Positions

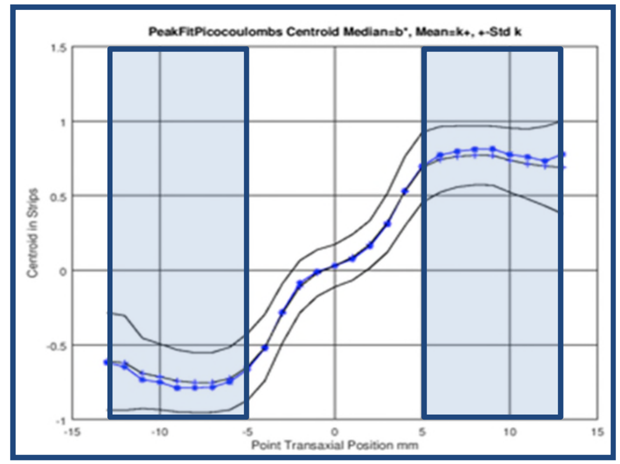


DRS4 waveform samplers

- **Pulses observed at both ends of a strip.**
- Relative arrival time leads to position of charge.
- **LAPPD 25: 11.4 pS/mm,** Uncertainty on position is: 32 pS sigma / 11.4 pS per mm =
- **2.8 mm sigma**.

Across Strips

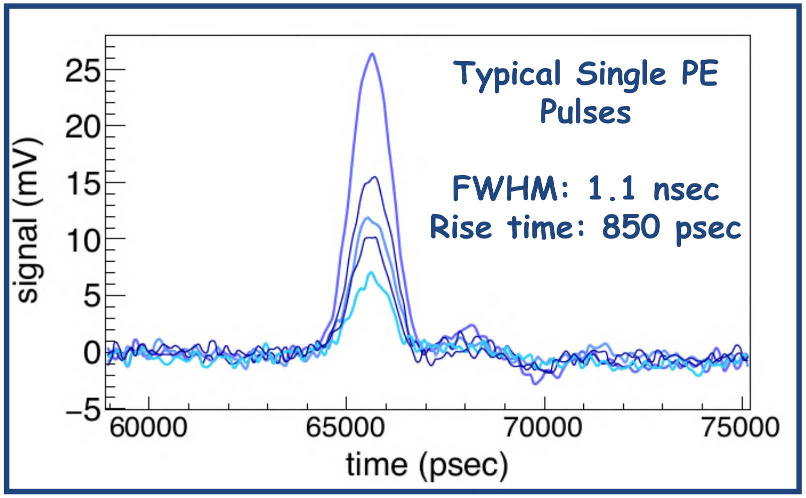


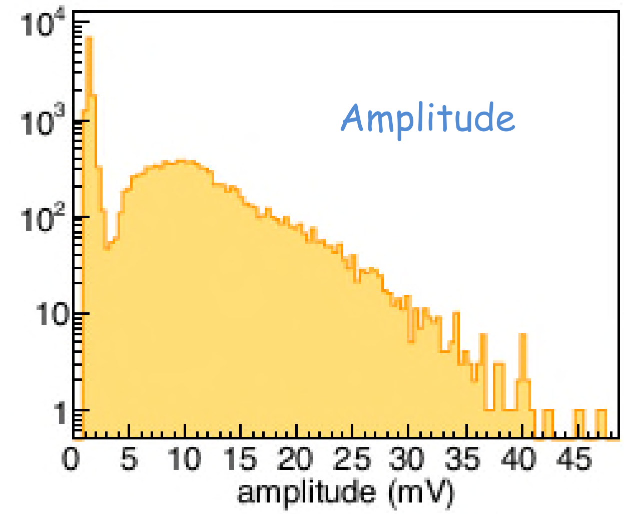


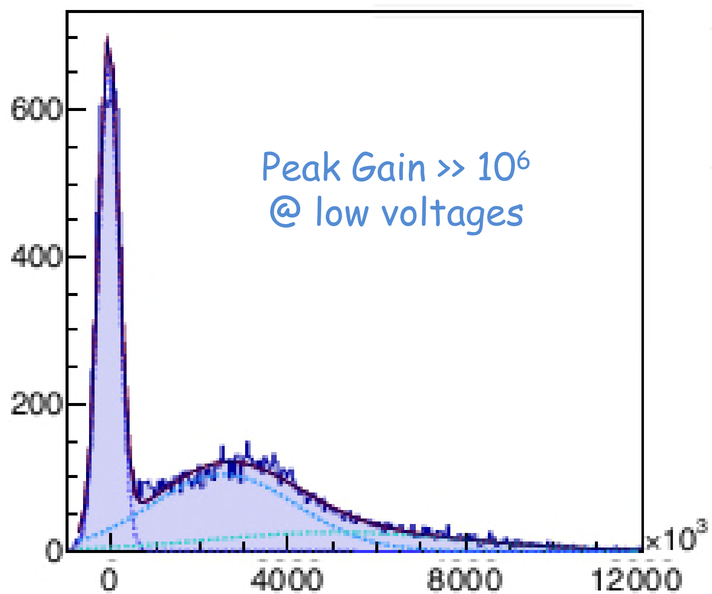
- **Position calculated by centroiding** three adjacent cross-strip signals.
- Calculated position shown together with a one-s uncertainty boundary.
- **1.3 mm rms uncertainty**

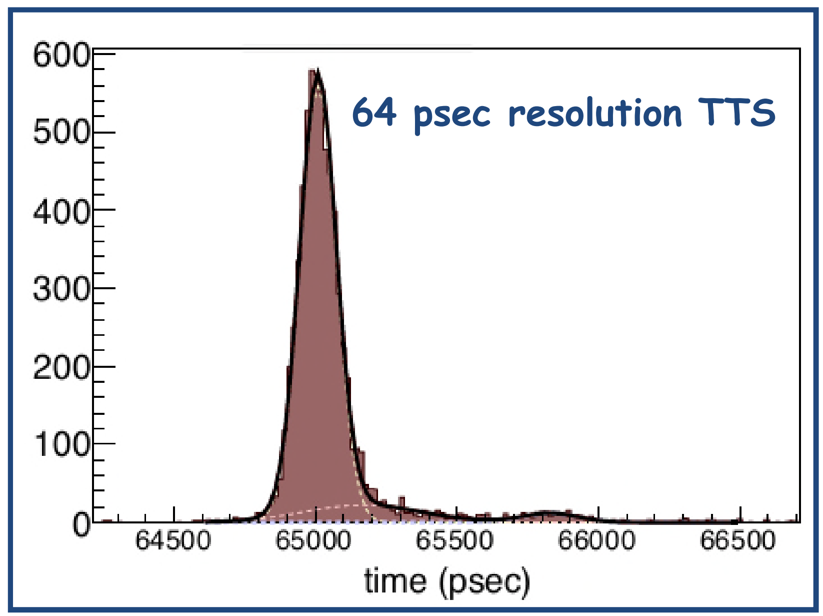
Time Resolution LAPPD #25

Testing at Iowa State University, Matt Wetstein, ANNIE Program









GEN II LAPPD

Joint development between Incom Inc., and the University of Chicago

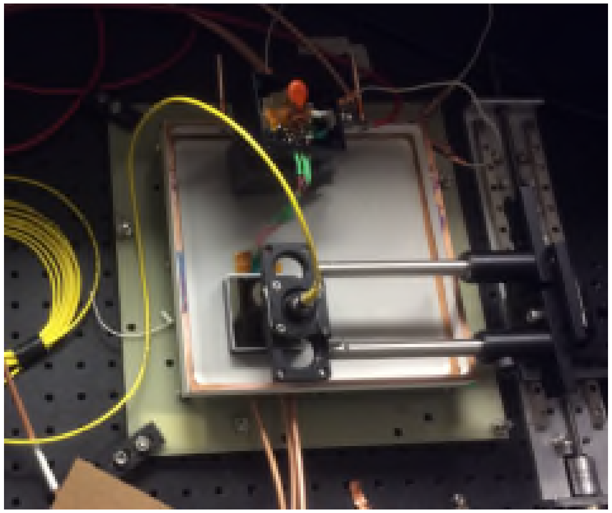
GEN II addresses four key developments:

1. A robust ceramic body,
2. Capacitive signal coupling: to an external PCB anode
3. Pixelated anodes: to enable high fluence applications,
4. In-situ photocathode deposition: low cost, high volume

Ceramic packaging & capacitive coupling are being implemented at Incom.

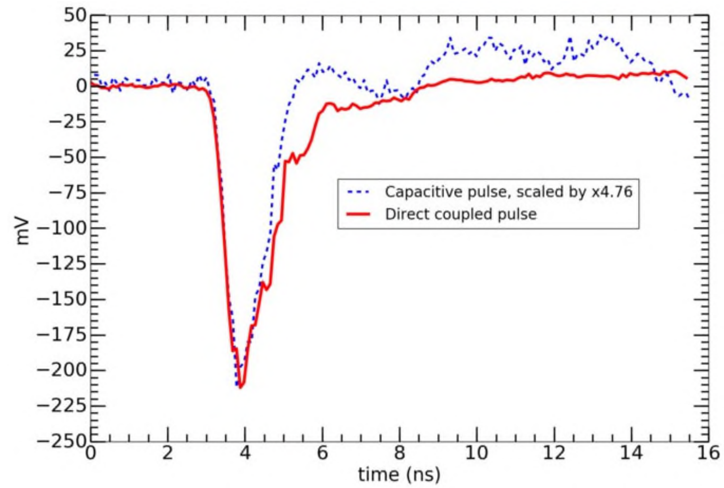
In-situ photocathode remains under development at U of Chicago

GEN II Capacitive Coupling



A thin metal DC ground plane is deposited onto the inside of the detector.

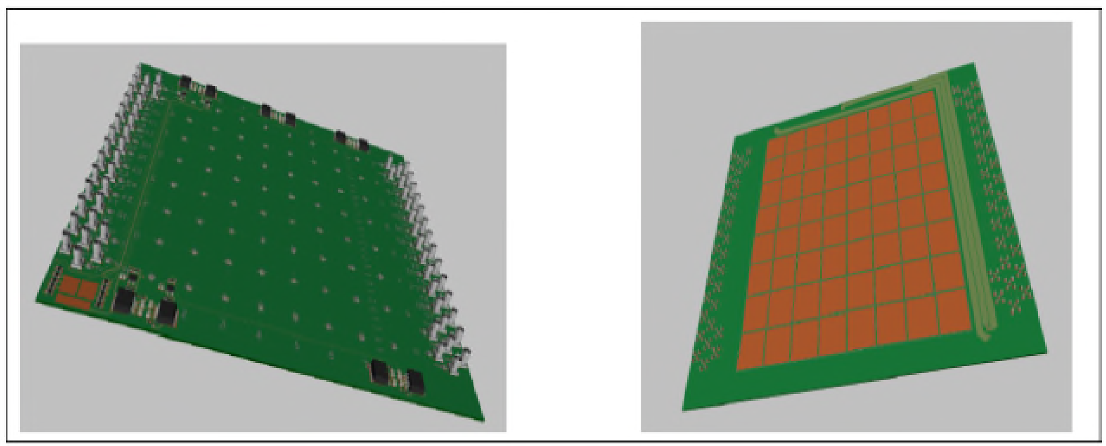
88% of an MCP fast signal pulse was capacitively coupled through the ceramic, to strips or pads on the outside.



- B.W. Adams,et al, "An internal ALD-based high voltage divider and signal circuit for MCP-based photodetectors", Nucl. Instr. Meth. Phys. Res. A 780 (2015) 107-113
- Private Communication, Todd Seiss and Evan Angelico, University of Chicago. Inside-Out Tests of Incom Tiles, June 23, 2016
- Angelico, Evan et al., "Development of an affordable, sub-pico second photo-detector", University of Chicago, Poster 2016

PCB with signal-pickup pads is placed under Gen-II tile

4-GHz amplifier over the back of each pad converts signals to a differentially signal that connects to the perimeter.

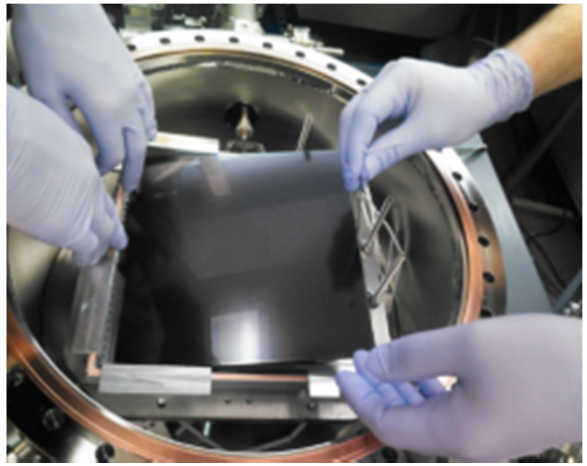


Six Step In-situ Air-Transfer Assembly

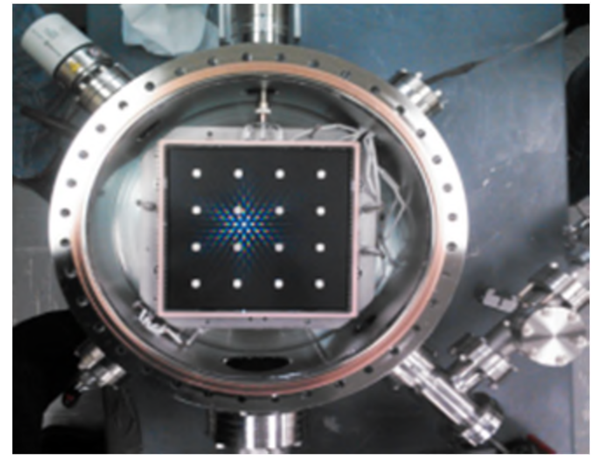
Transfer the window in air and make photo-cathode after the top seal

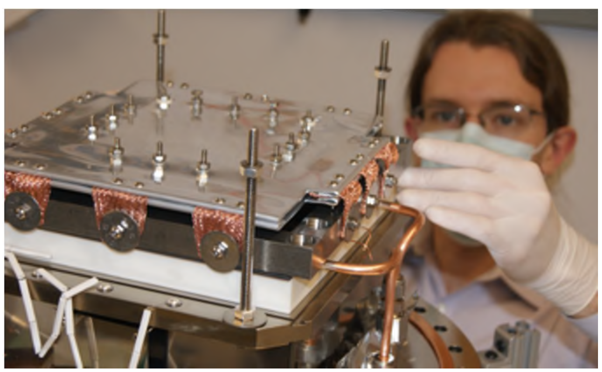
Step 1: pre-deposit Sb on the top window prior to assembly

Step 2: pre-assemble **MCP** stack in the tile-base



Step 3: Position Sb coated window for sealing





Step 4: Clamp assembly for high temperature bake using dual vacuum system

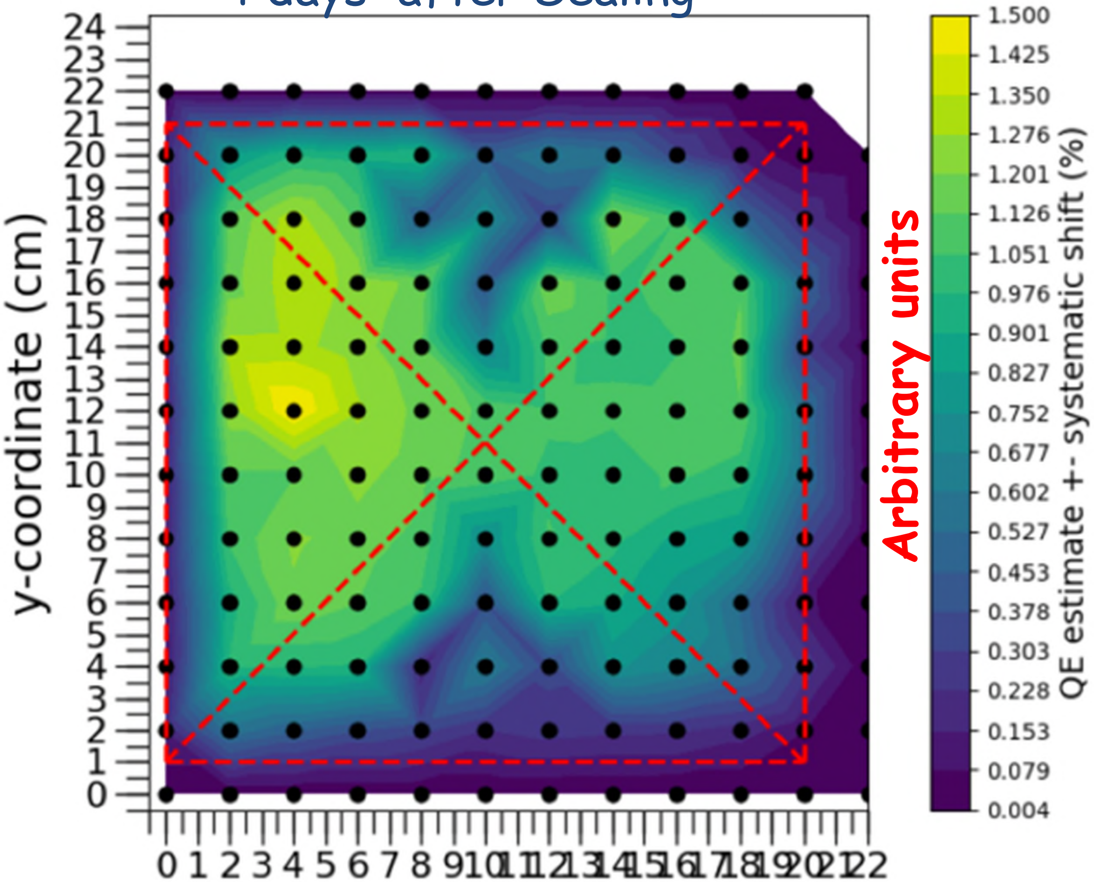
Step 5: Introduce Alkali vapor introduced to complete PC

Step 6: Pinch seal copper tube

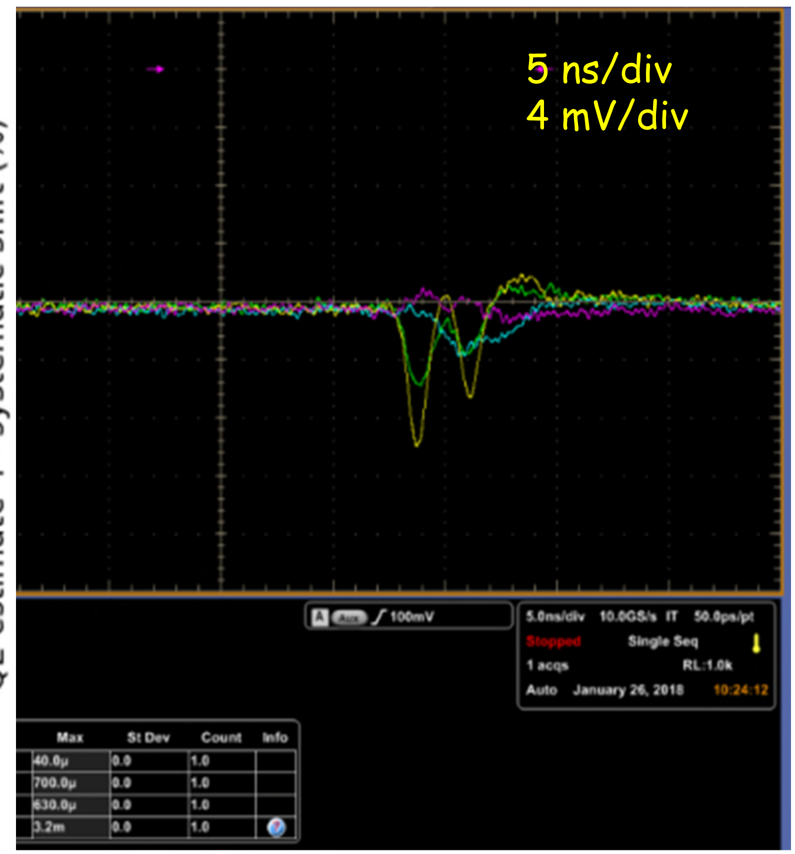
U-Chicago processing chamber

Sealed UC Tile #21 with In-Situ PC

Photo-Sensitivity Map
4 days after Sealing



Pulses next day after sealing



UC Tile #21 – Encouraging result - modest QE
and limited lifetime (no internal getter).

How Would Low Psec Timing & High Spatial Resolution Influence Your Design of Experiment?

Fermilab – U of Chicago
Psec Timing Meeting
March 2018

New opportunities enabled by PSEC timing?

Technology Agnostic!

Multiple applications were identified.

Fermilab-Chicago Psec Timing Planning Meeting
Saturday, Mar. 17, 2018: University of Chicago

Chairs: Frisch and Spiropulu

Session 1: Fermilab-Chicago Collaboration

Session 2: Increasing the Reach of the Current Fermilab Program

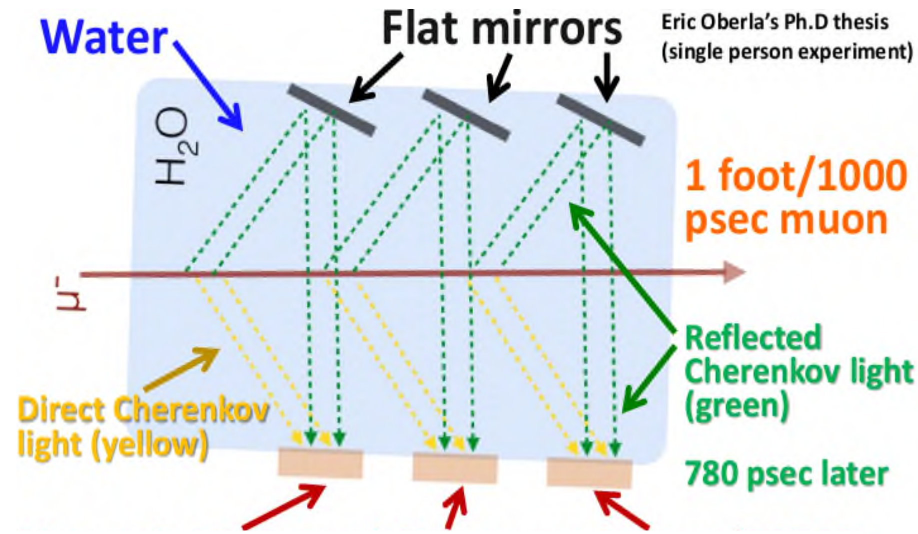
Session 3: Opportunities: Energy Frontier: Colliders

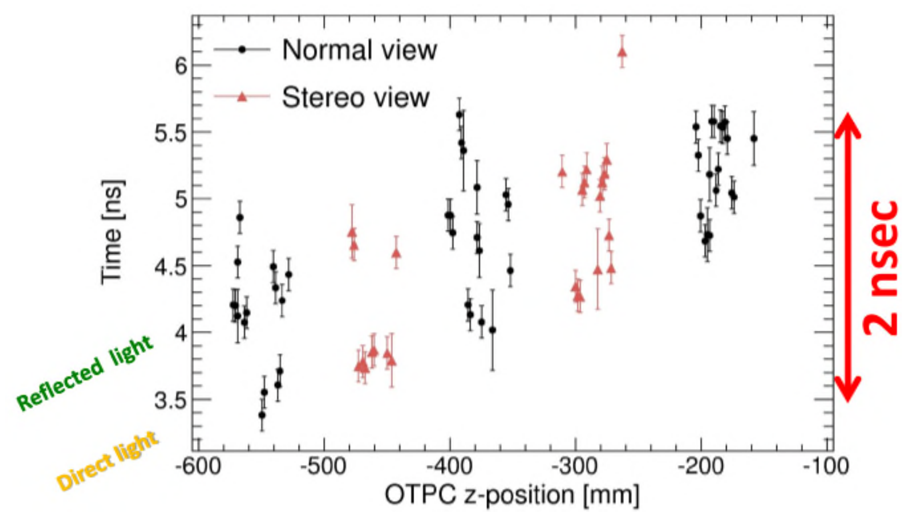
Session 4: Opportunities: Neutrinos I: CP-Violation and Ordering

Session 5: Opportunities: Neutrinos II Dirac/Majorana

Session 6: Long-Term Facility Planning

Optical Time Projection Chamber (OTPC)





Summary & Conclusions

I. GEN II - Capacitive coupling works!

A. Ceramic package has been demonstrated - UC tile #21

B. In-situ PC Deposition has been demonstrated

- Demonstrated over the entire 8x8" window
- MCPs still work after exposure to Cs

C. Development Continues:

- Glass-to-ceramic seal
- Improving HV distribution
- Optimized Cs_3Sb photo-cathode synthesis

II. GEN I - Incom LAPPD Pilot Production is now underway

A. GEN I LAPPD - Available Today!

- Artifacts to be resolved as production volume and experience increases.
- Providing early adopters a means to explore potential of PSEC timing.

B. "Typical" performances meet early adopter needs:

- Gain > $7X10^6$, or higher
- Max PC QE (#15) Max ~ 26%, Mean > 22%
- Time Resolution < 70 Picoseconds, and Spatial Resolution 3mm

Current Funding & Personnel Acknowledgement

- DOE, DE-SC0011262 Phase IIA - "Further Development of Large-Area Microchannel Plates for a Broad Range of Commercial Applications"
- DOE, DE-SC0015267, Development of Gen-II LAPPD™ Systems For Nuclear Physics Experiments
- DOE DE-SC0017929, Phase I – "High Gain MCP ALD Film" (Alternative SEE Materials)
- NIH 1R43CA213581-01A Phase I - Time-of-Flight Proton Radiography for Proton Therapy
- DOE, DE-SC0018445 Magnetic Field Tolerant Large Area Picosecond Photon Detectors for Particle Identification
- **DOE (HEP, NP, NNSA) Personnel**: Dr. Alan L. Stone, Dr. Helmut Marsiske, Dr. Manouchehr Farkhondeh, Dr. Michelle Shinn, Carl C. Hebron, Dr. Kenneth R. Marken Jr, Dr. Manny Oliver, Dr. Donald Hornback and many others.

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Grazie!

Selected LAPPD References & Links

- **http://www.incomusa.com/lappd-documents/**
- **http://psec.uchicago.edu/**
- Craven, Christopher A. et al - **"Recent Advances in Large Area Micro-Channel Plates and LAPPD™"** TIPP'17 International Conference on Technology and Instrumentation in Particle Physics, Beijing, People's Republic of China, May 22-26, 2017
- Lyashenko, Alexey et al "**Further progress in pilot production of Large Area Picosecond Photo-Detectors (LAPPD™)"** New Technologies for Discovery III: The 2017 CPAD Instrumentation Frontier Workshop, University of New Mexico, Albuquerque, NM October 12-14, 2017
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- M.J. Minot, et al., **Pilot production & commercialization of LAPPD™**, Nuclear Instruments and Methods in Physics Research A 787 (2015) 78–84