Incom LAPPD Pilot Production Update & Collaboration with Early Adopters

Mu2e II Workshop

December 8, 2017

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Incom LAPPD "Preliminary" Results & Timeline

- DOE Pilot Production Facility Funding - April 2014
- Incom Pilot Production Facility - November 2015
- LAPPD Commissioning Trials Initiated - December 2015

  #1 -> #8 - Dec. 2015 to Aug. 2016, Seal & Connectivity Trials

  #9 – 9/14/2016, First Sealed Tile – Aluminum Photocathode

  #12 – 12/21/2016, QE (365nm Max/Avg/Min) = 16.5% /11.1% /6.7%

  #15 – 03/31/2017, QE 365nm (Max/Avg/Min) = 35.1% /30.3% /21.6%

  #22 – 10/10/2017, QE 365nm (Max/Avg) = 14.7% / 12.6%, High Gain MCPs, Peaked SPE PHD

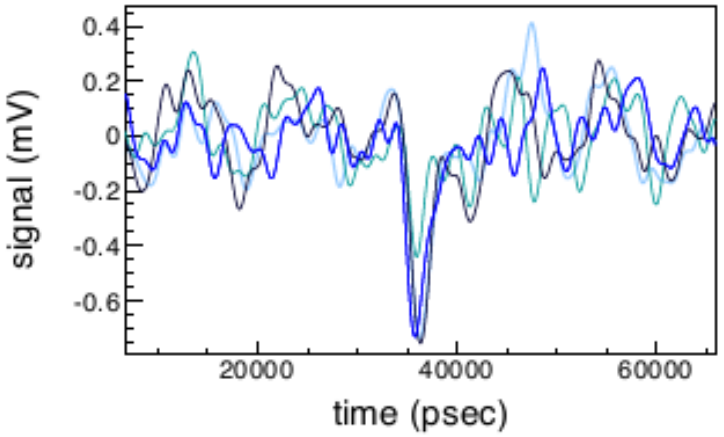
  #25 - 12/10/2017, QE 455nm (Avg) = 10.2% ±1.5%, Gain=6X10^7 @ 975V, Peaked SPE PHD

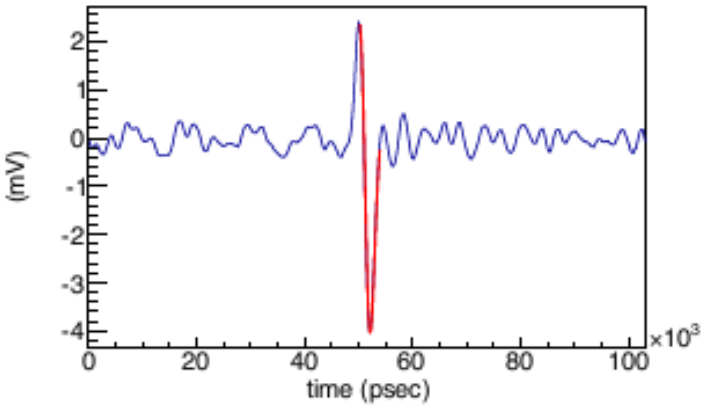
- Exploitation Phase Begins - QI 2018

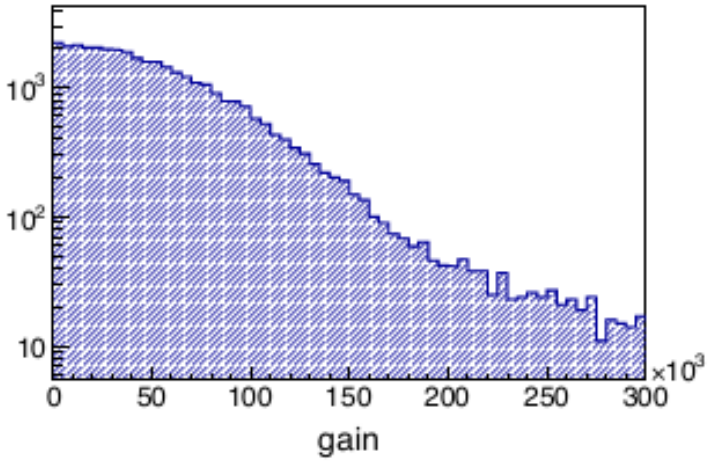
  Operate Pilot Production on a routine basis

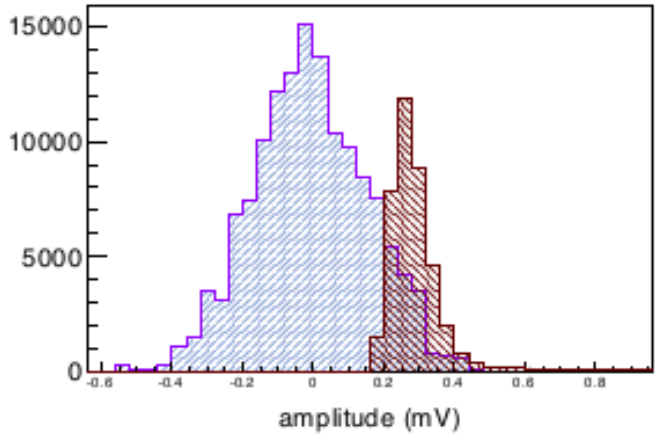
  Produce prototypes for early adopters

LAPPD #9 Testing at Iowa State
(Matt Wetstein, ANNIE)



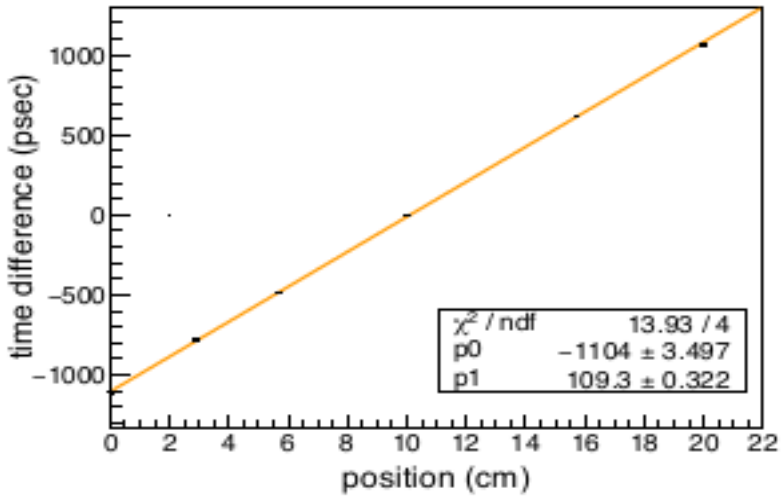


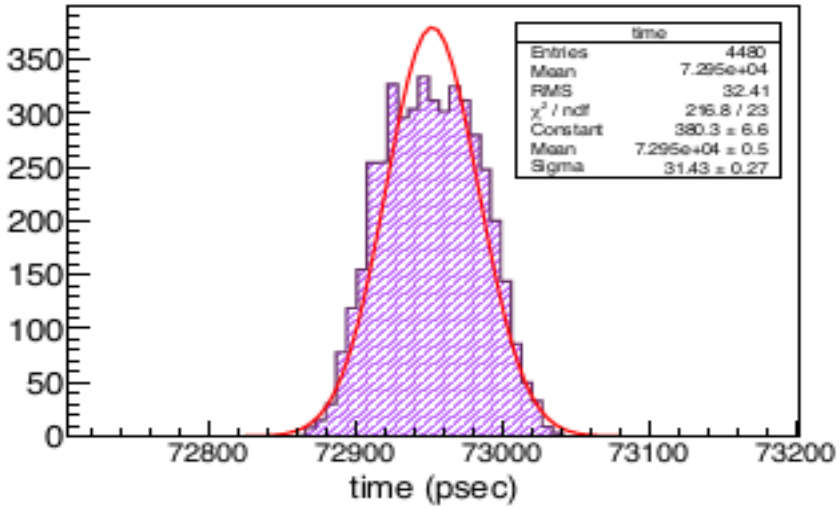


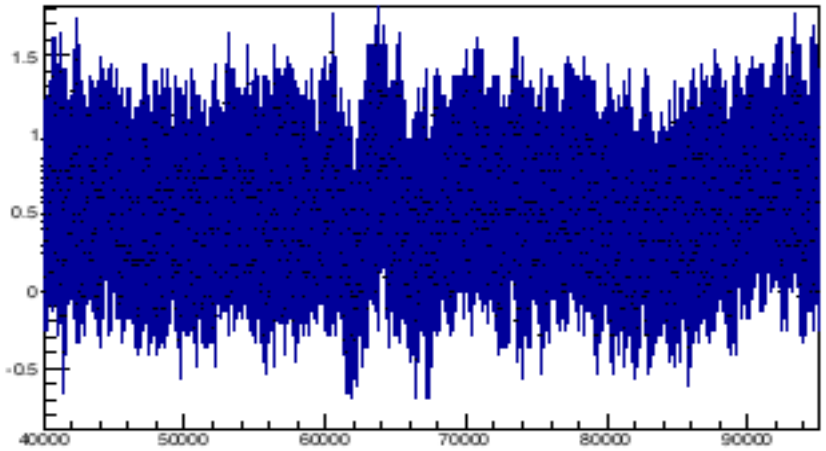


LAPPD #12 Testing at Iowa State

(Matt Wetstein, ANNIE)







Iowa State Testing Summary

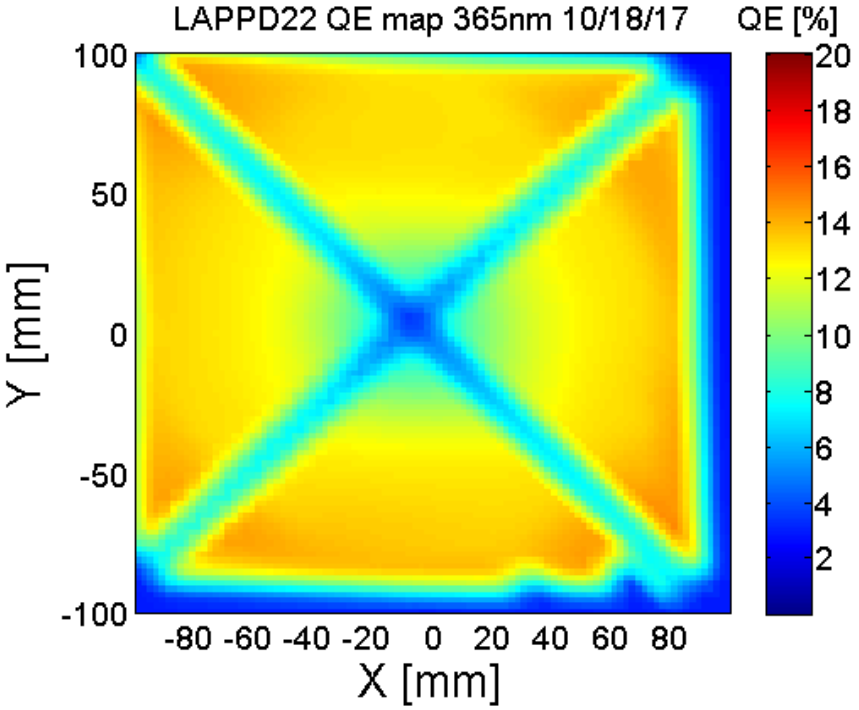
LAPPD #9

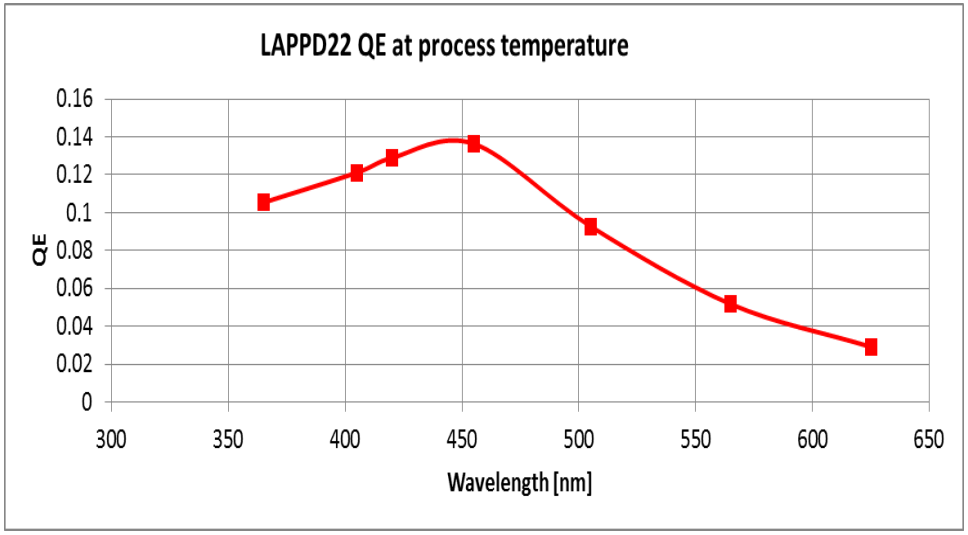
- Successful first operation of an LAPPD
- Able to study single PE pulse heights
- Signals were small compared to noise, but resolvable

LAPPD #12

- First LAPPD testing with a real photocathode
- Able to demonstrate good resolutions in the multi-PE limit
- Unable to get good single PE response, given small pulse size

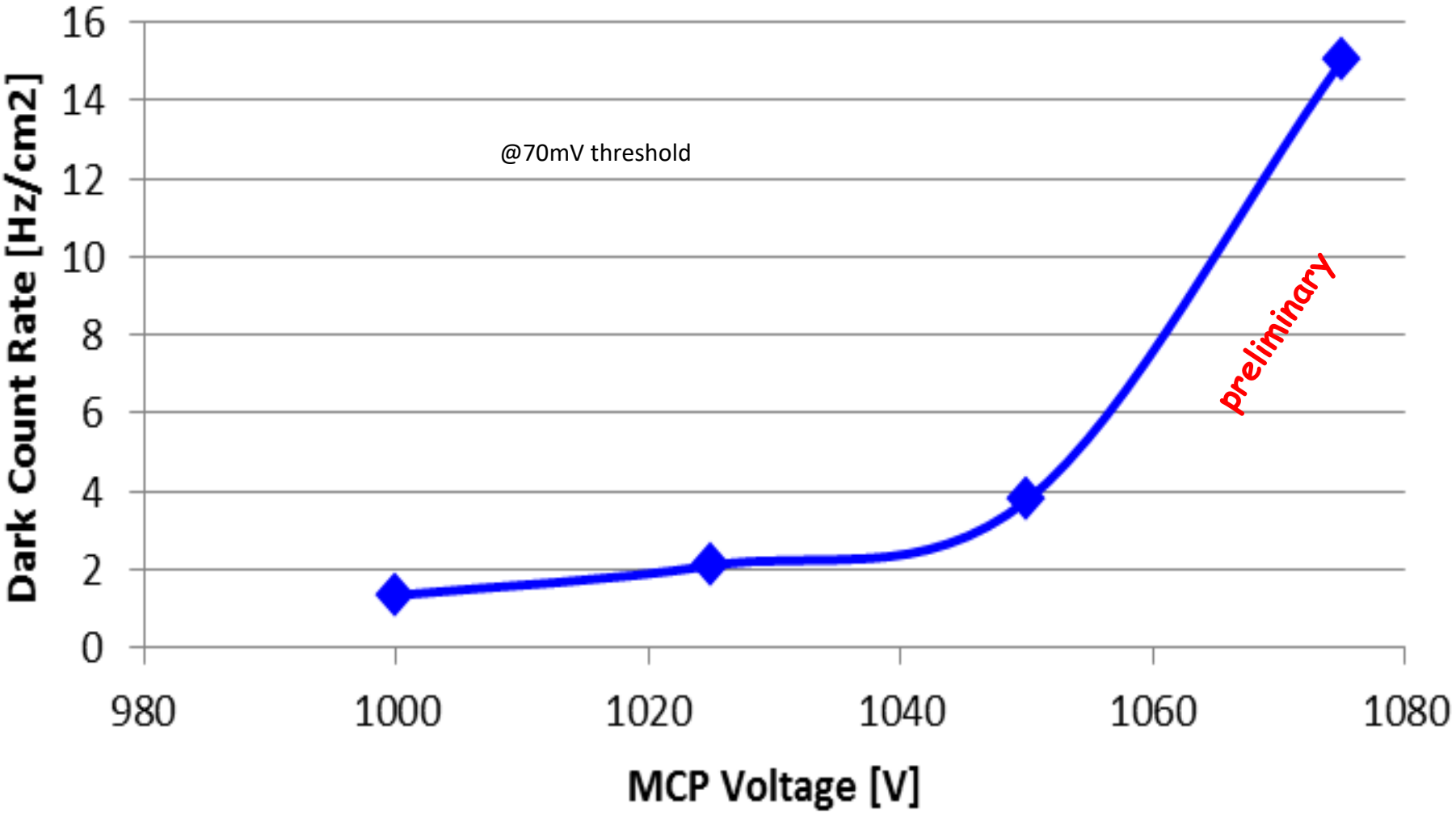
LAPPD #22 - QE Scan



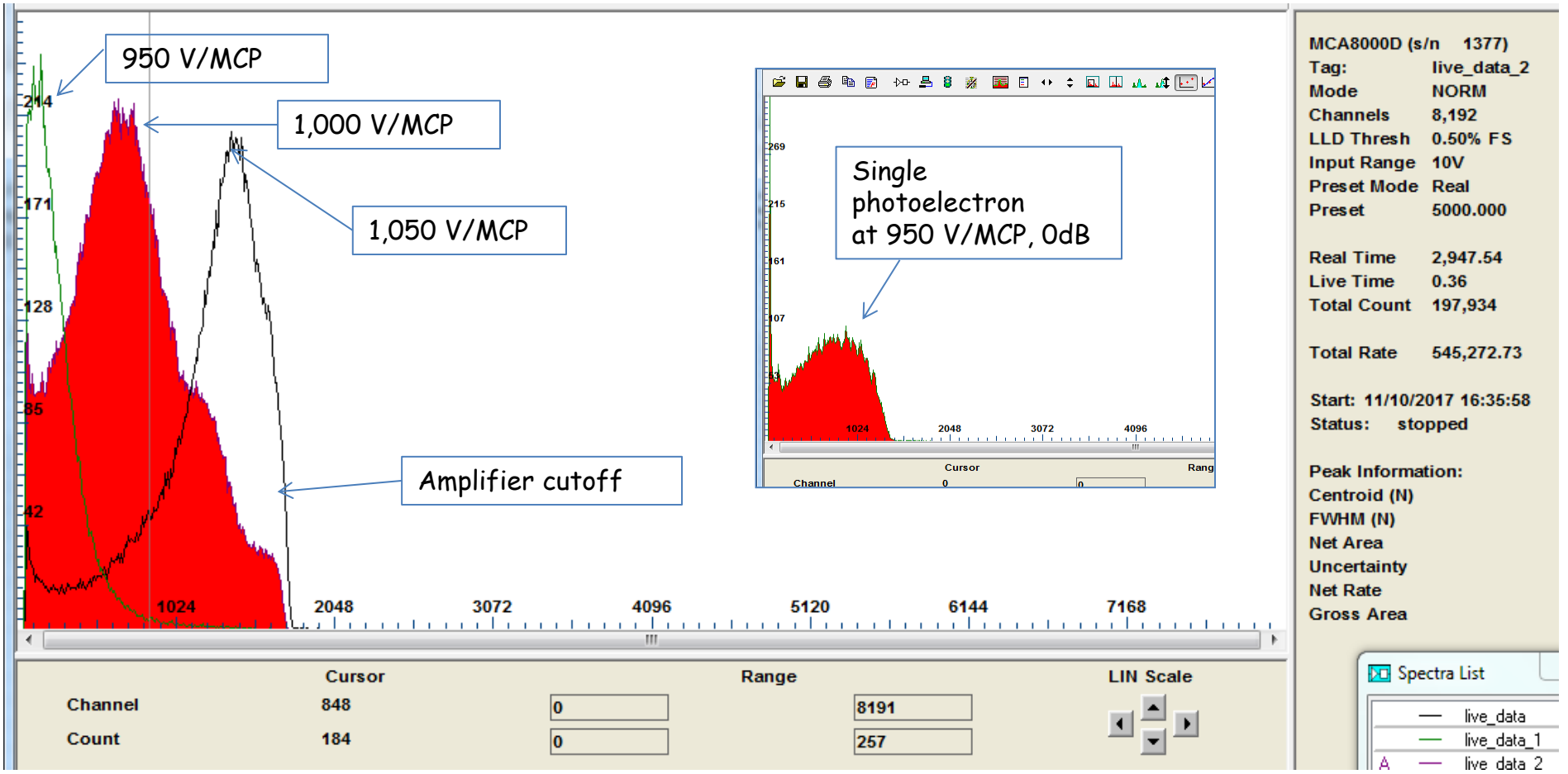


With X-Spacers Excluded:
Mean QE=12.58, QE_{max}: 14.74%
Standard Deviation (σ): 1.18 or 9.4% of mean

LAPPD #22 Dark Count Rate – PC On (-50V)

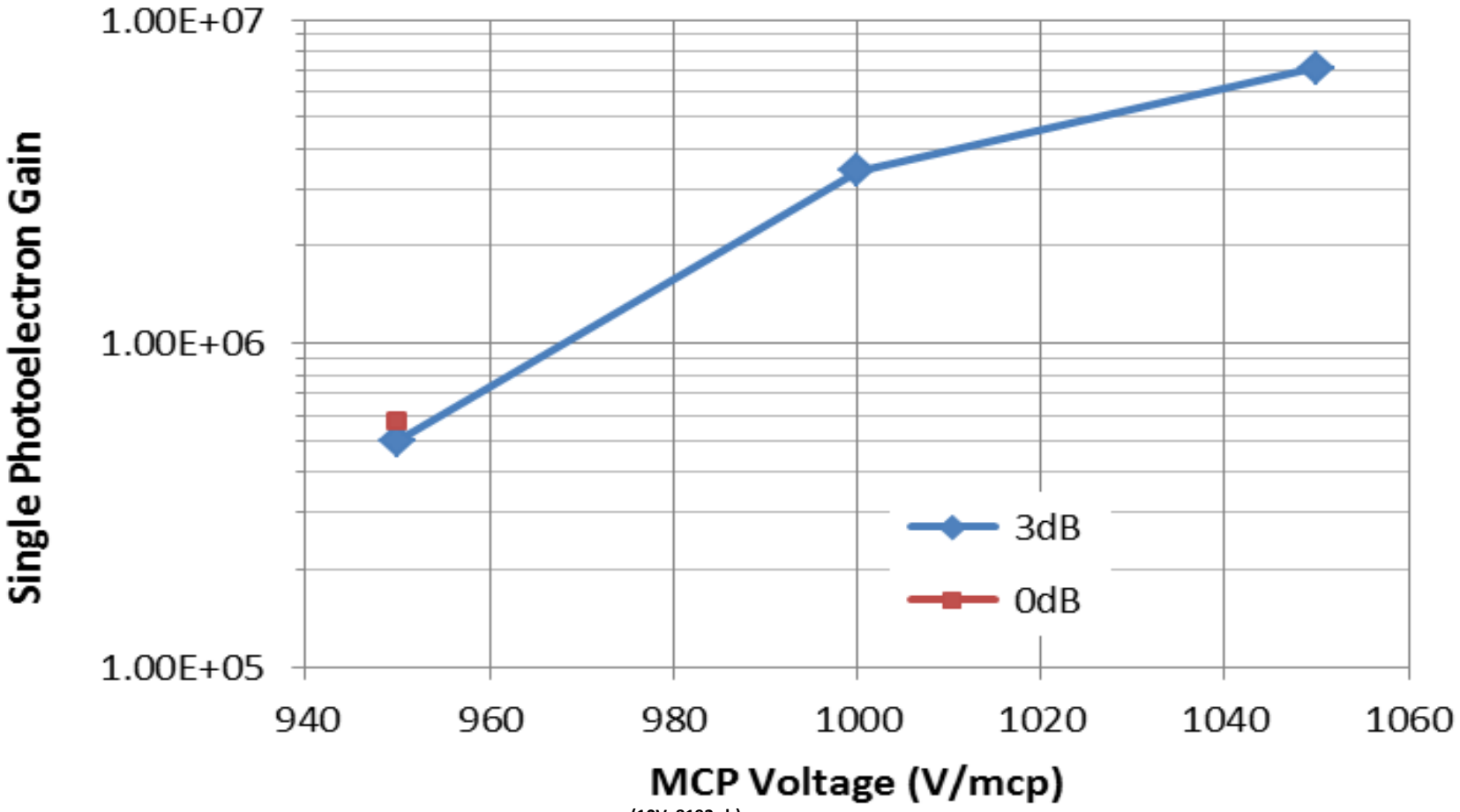


LAPPD #22 - PHDs for Single Photoelectrons



Data collected with 3dB attenuation at the Amptek amplifier input
Insert: Single photoelectron at 950 V/MCP, 0dB

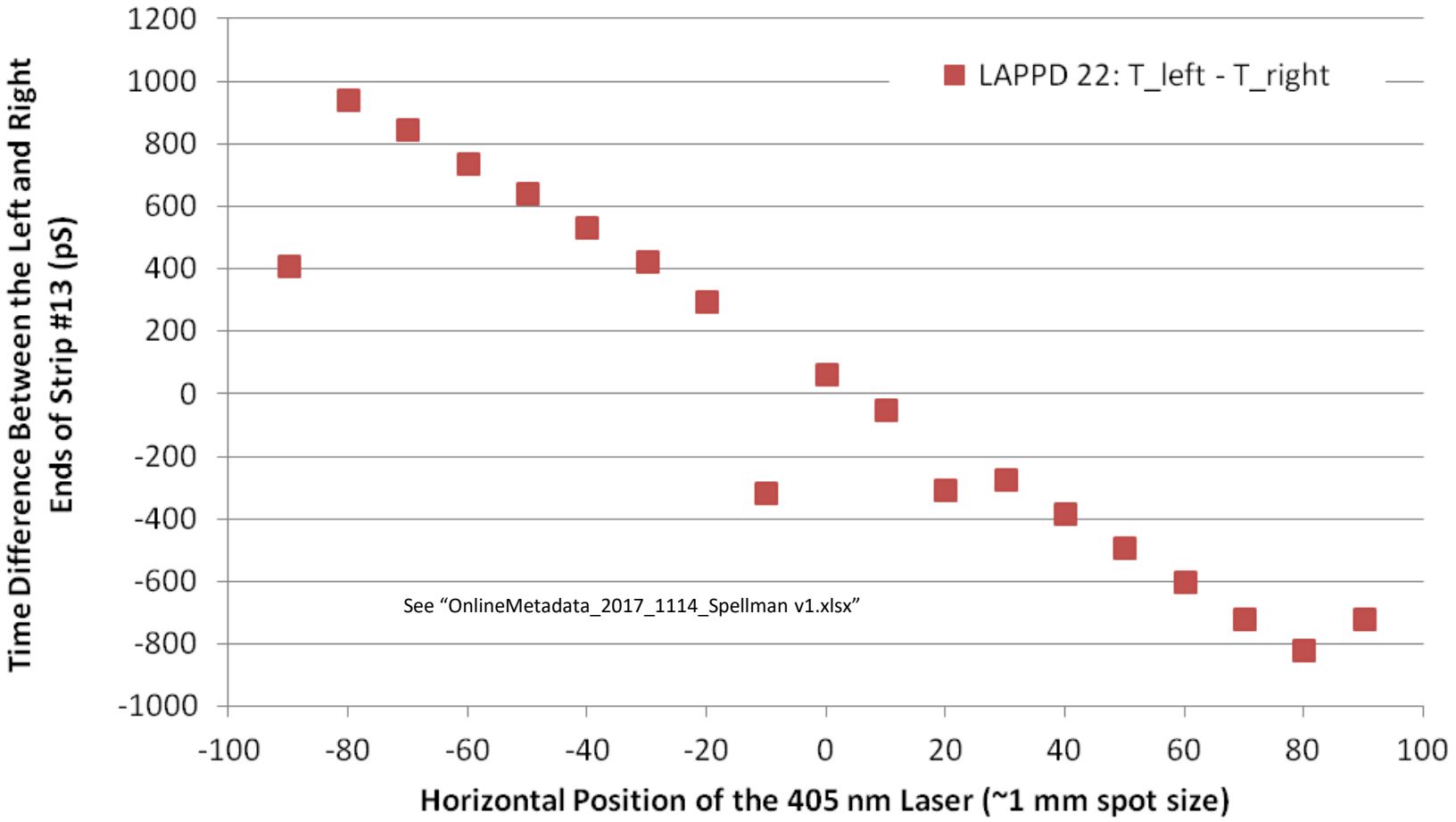
LAPPD #22 – Single PE Gain



Filename		MCP V (10V, 8192 ch)	MCA Centroid (ch)	Attenuation	Amplifier voltage (mV)	Charge (fC)	Gain
2017-11-10 1609	950	850		0	1038	92	5.74E+05
2017-11-10 1630	950	132		3	161	80	5.02E+05
2017-11-10 1725	1000	690		3	842	545	3.41E+06
2017-11-10 1806	1050	1401		3	1710	1138	7.11E+06

See file “Onlinemetadata_20171110_Spellman with plots.xlsx”

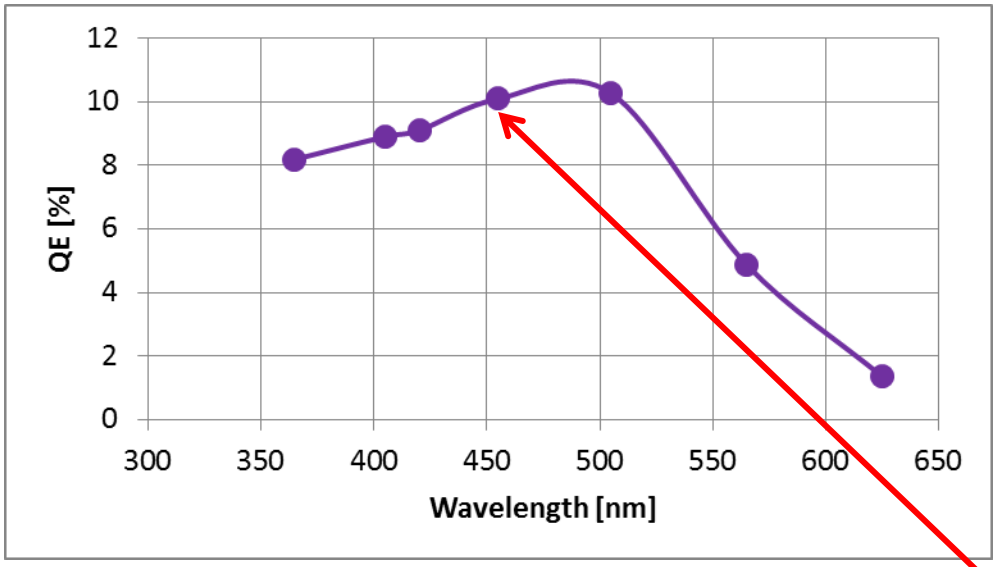
LAPPD 22 - Timing and Derived Position Along a Single Strip



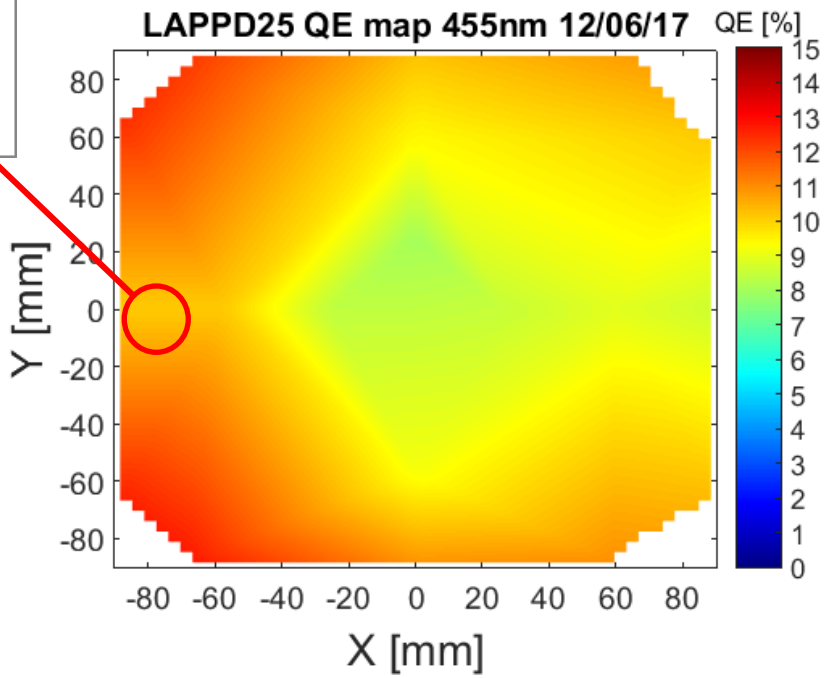
A ~1mm diameter 405 nm 60 pS laser spot was moved laterally along an anode strip:

- Laser spot position is derived by measuring the time of arrival of the MCP pulse at each end of the strip and knowing the time a pulse takes to propagate across the entire strip.
- Linearity deviations occur at the ends, and at the transit across the X-spacer, where dark pulses are included in the measurement.

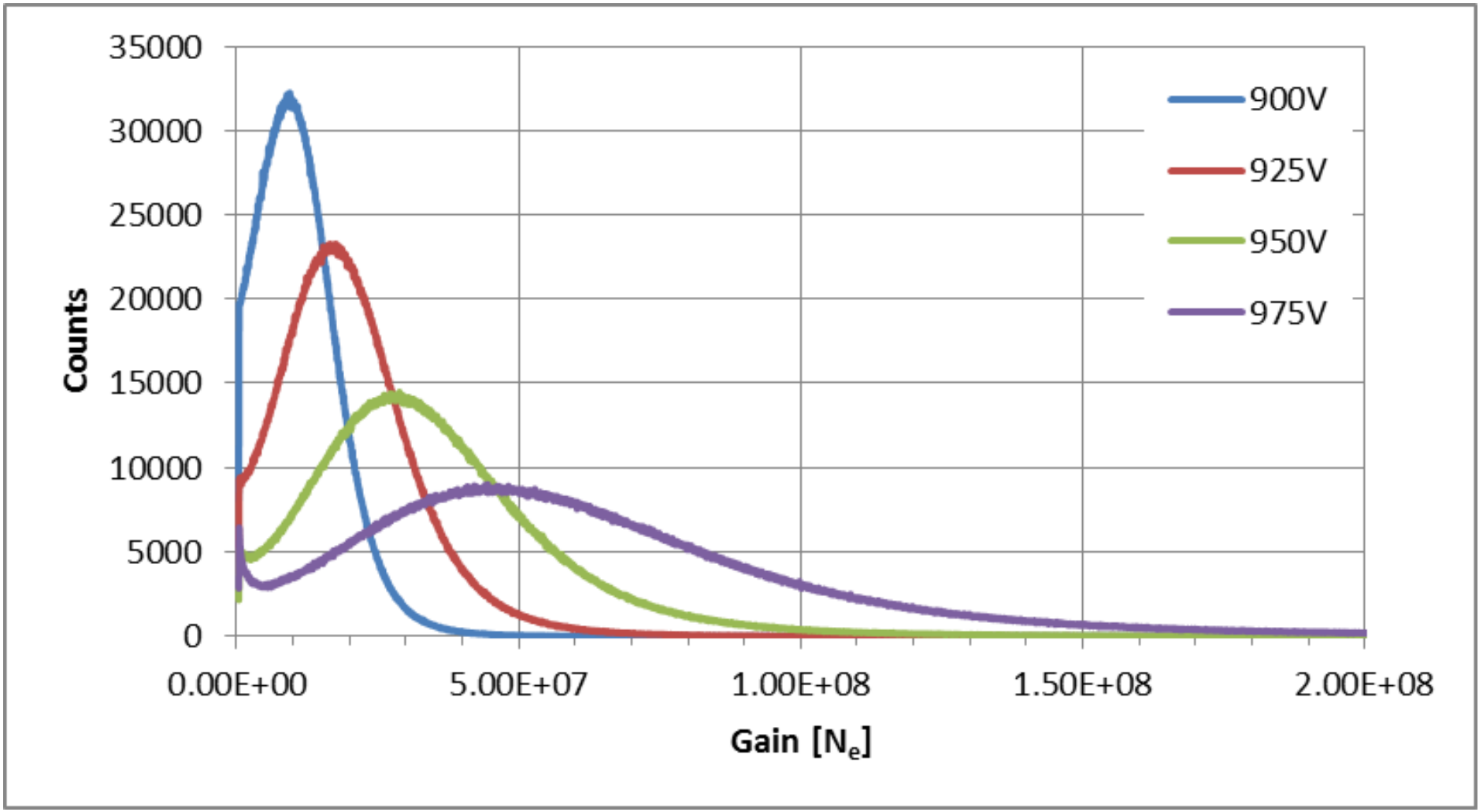
LAPPD #25 – Photocathode QE vs. Wavelength



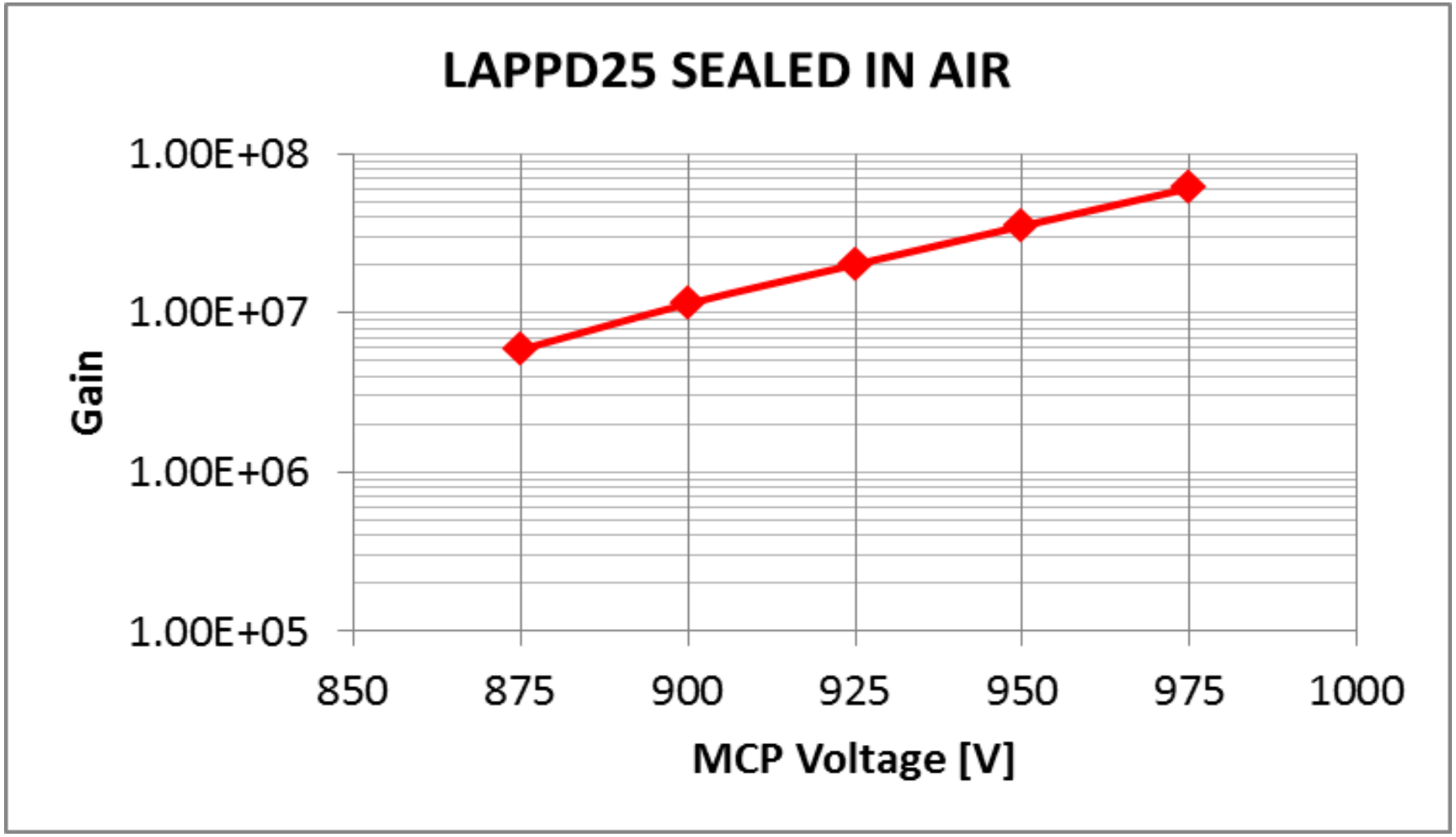
Mean QE: 10.2% ± 1.5%



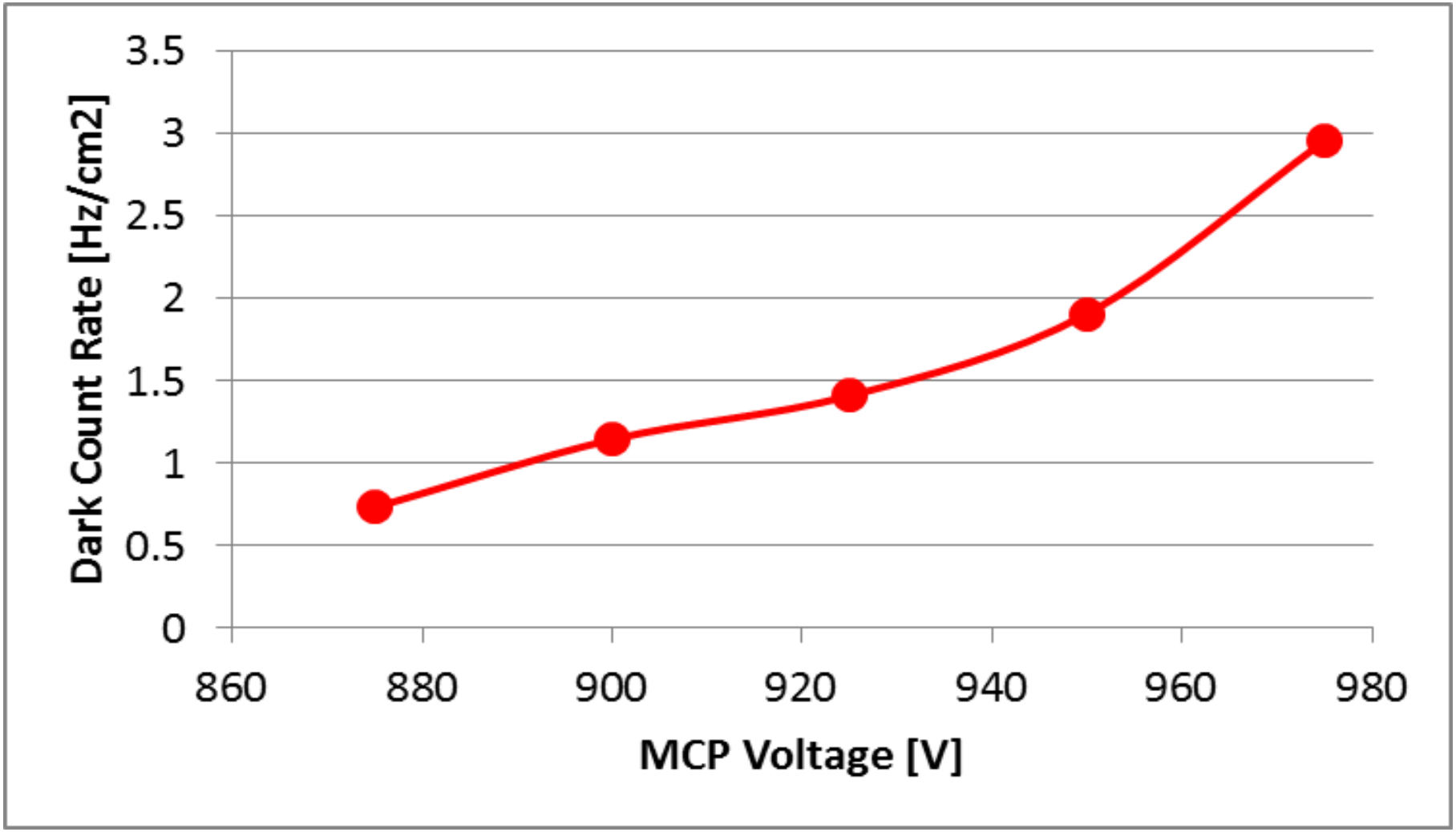
LAPPD #25 – Single PE PHDs



LAPPD #25 – Gain vs. Voltage



LAPPD #25 - Dark Count Rate



Innovators & Early Adopters

- Collaborators with an expressed willingness to evaluate early LAPPD prototypes, sharing round-robin test results and technical performance feedback.
  - Opinion leaders able to influence the adoption of LAPPD for established or future technical programs.
  - Ability to evaluate prototype performance under practical conditions or facilities not available to Incom Inc. Examples: magnetic fields, neutron beam, Cherenkov light, Fermi Lab Particle Beams, Neutrino-less Double-Beta Decay, life testing, etc.
- Incom is committed to working with early adopters to insure that LAPPD are available to be evaluated for appropriate applications.
  - Measurement & Test Workshop to facilitate hands on experience with LAPPD, and establish standardized M&T procedures.
  - Short term loan & leasing agreements
  - Purchase with discounts to Early Adopters with DOE funded programs.

LAPPD™ Early Adopter Programs – What About Your Program?

PRINCIPAL INVESTIGATOR & SPONSOR	PROGRAM TITLE
Bill Worstell, Incom Inc.	TOF Proton Radiography for Proton Therapy
Henry Frisch (U of Chicago)	LaRiaT (Liquid Argon Beam-line Experiment, Fermi Lab)
	Sub-psec TOF for collider vertex and particle ID
	Track reconstruction in a small water Cherenkov counter
	Double-beta decay development
Mayly Sanchez, Matthew Wetstein, Iowa State	ANNIE - Atmospheric Neutrino Neutron Interaction Experiment
Mickey Chiu (BNL)	Phenix Project - "eIC Fast TOF"
Erik Brubaker, Sandia National Lab/CA	Neutron Imaging Camera
John Learned, U. of Hawaii, and Virginia Tech	Short Baseline Neutrino (NuLat)
Lindley Winslow (MIT)	Search for Neutrino-less Double-Beta Decay (NuDot) Using Fast Timing Detectors
Andrey Elagin (U of Chicago)	Neutrino-less Double-Beta Decay
Bill Worstell, Incom Inc, Bob Wagner & Junqi Xie. ANL, Jefferson Laboratory	Magnetic Field Tolerant Large Area Picosecond Photon Detectors for Particle Identification
Andrew Brandt, University of Texas, Arlington	Life Testing of LAPPD
Dr Matthew Malek, The University of Sheffield	Hyper-Kamiokande Upgrade (~10,000 LAPPD in 10 years)

LAPPD Measurement & Test Workshop

- Familiarize early adopters with the LAPPD, and provide early access.
- Provide researchers with raw data for their own evaluation and use, which might include using the data to evaluate LAPPD readiness for their program applications.
- Establish standardized measurement protocols.
- Evaluate alternative electronic readout options; examples include PSI DRS4 Evaluation Boards, Ultralytics LAPPD Readout Card, PSEC4 Eval boards, CAEN DRS4 Readout, other.
- First Ever Workshop - November 13-16, 2017
  - Kurtis Nishimura (U of Hawaii, working with John Learned, and Erik Brubaker, Sandia)
  - Josh Brown (Berkeley, working with Erik Brubaker, Sandia)
  - Julieta Gruszko (MIT, working with Lindley Winslow)
- Data Collected - Analysis underway, results expected in early December
  - Pulse height vs. laser trigger rate at fixed MCP voltages
  - Scans along and across strips for position and crosstalk assessment
  - Photocathode scans with 42 volts and 10 volts between the photocathode and MCP
  - 160,000 single photoelectron waveforms using DRS4 evaluation boards
- **Next Workshop – January 22 – 26, 2018 Spaces Available**

LAPPD Price?

Incom development contracts offset R&D costs, making prototype LAPPD™ available at a reduced cost for promising early adopter applications with DOE funding.

Current LAPPD pricing provides Incom cost recovery for unfunded R&D expenses.

Early Adopters are encouraged to include funding for LAPPD purchase in their grant proposals.

Incom's technology is scalable, and pending developments will significantly streamline fabrication and reduce manufacturing costs.

Costs are volume sensitive and will come down!

Incom projects a unit cost of **$10,000** each, with high volume (1,000 units).

Current Funding & Personnel Acknowledgements

- DOE, DE-SC0009717 ""Phase IIA TTO" - LAPPD Commercialization – Fully Integrated Sealed Detector Devices
- DOE, DE-SC0011262 Phase IIA - "Further Development of Large-Area Micro-channel 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 (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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