The Development of Large-Area Pico-second Photodetectors

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Henry Frisch, Enrico Fermi Institute, Univ. of Chicago
For the LAPPD Collaboration

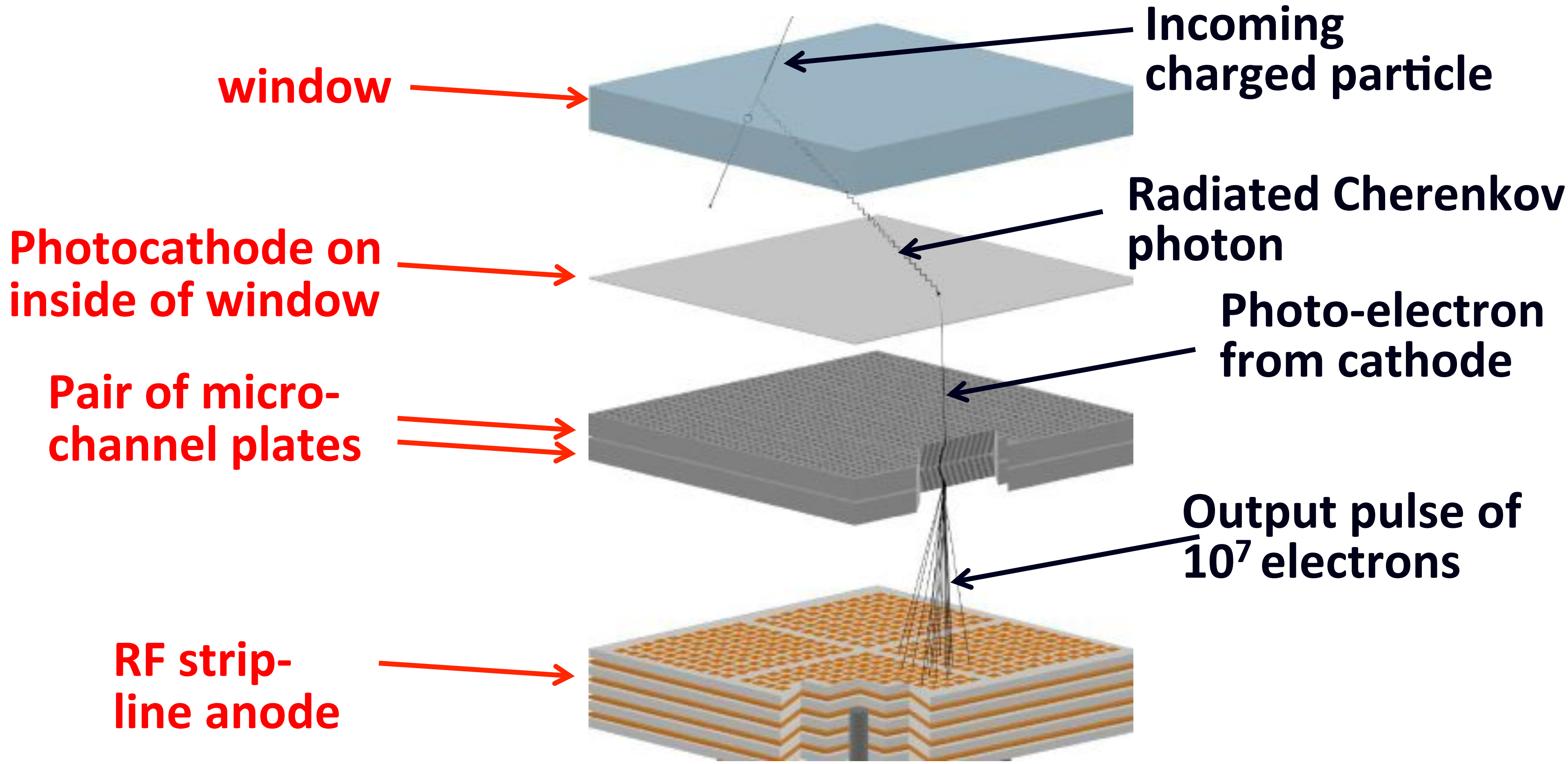
- New Types of Detectors Can Change Whole Areas of Science, Medical Imaging, Nuclear Non-proliferation
- Technical details of LAPPD: Atomic Layer deposition MCPs, GigaHz E&M, Glass and Ceramic packaging, Circuit (ASIC) design, Tech Transfer to Industry,
- Photocathodes- challenges of large areas
- Opportunities – many PhD theses in many fields- a broad collaborative effort, including industry

Acknowledgements- LAPPD collaborators, Howard Nicholson and the DOE HEP, ANL Management, and the NSF.

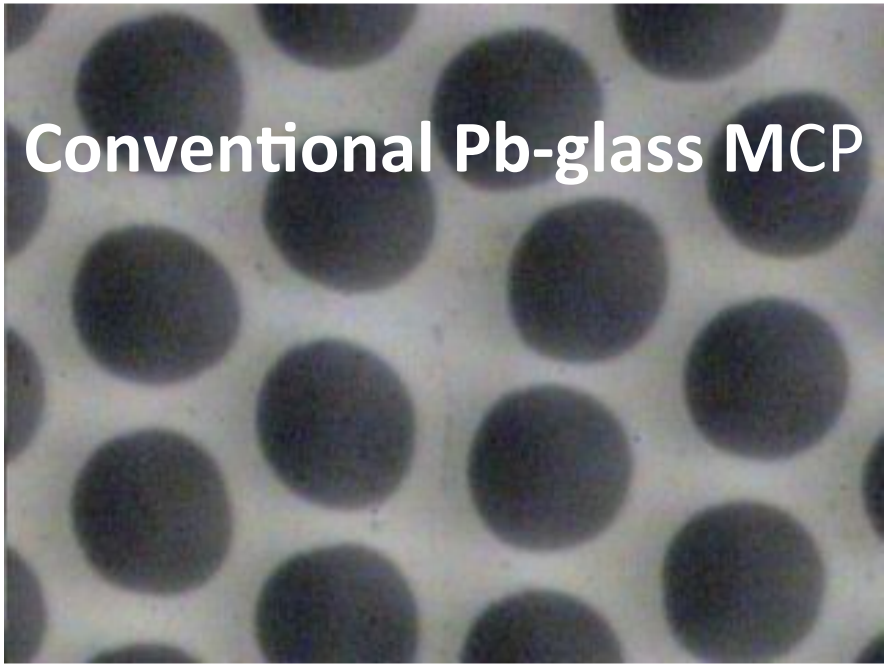
How Does it Work?

Requires large-area, gain > 10^7, low noise, low-power, long life, $\sigma(t)$<10 psec, $\sigma(x)$ < 1mm, and low large-area system cost

Realized that an MCP-PMT has all these but large-area, low-cost:
(since intrinsic time and space scales are set by the pore sizes- 2-20μ)



Nanolayer MCP Construction



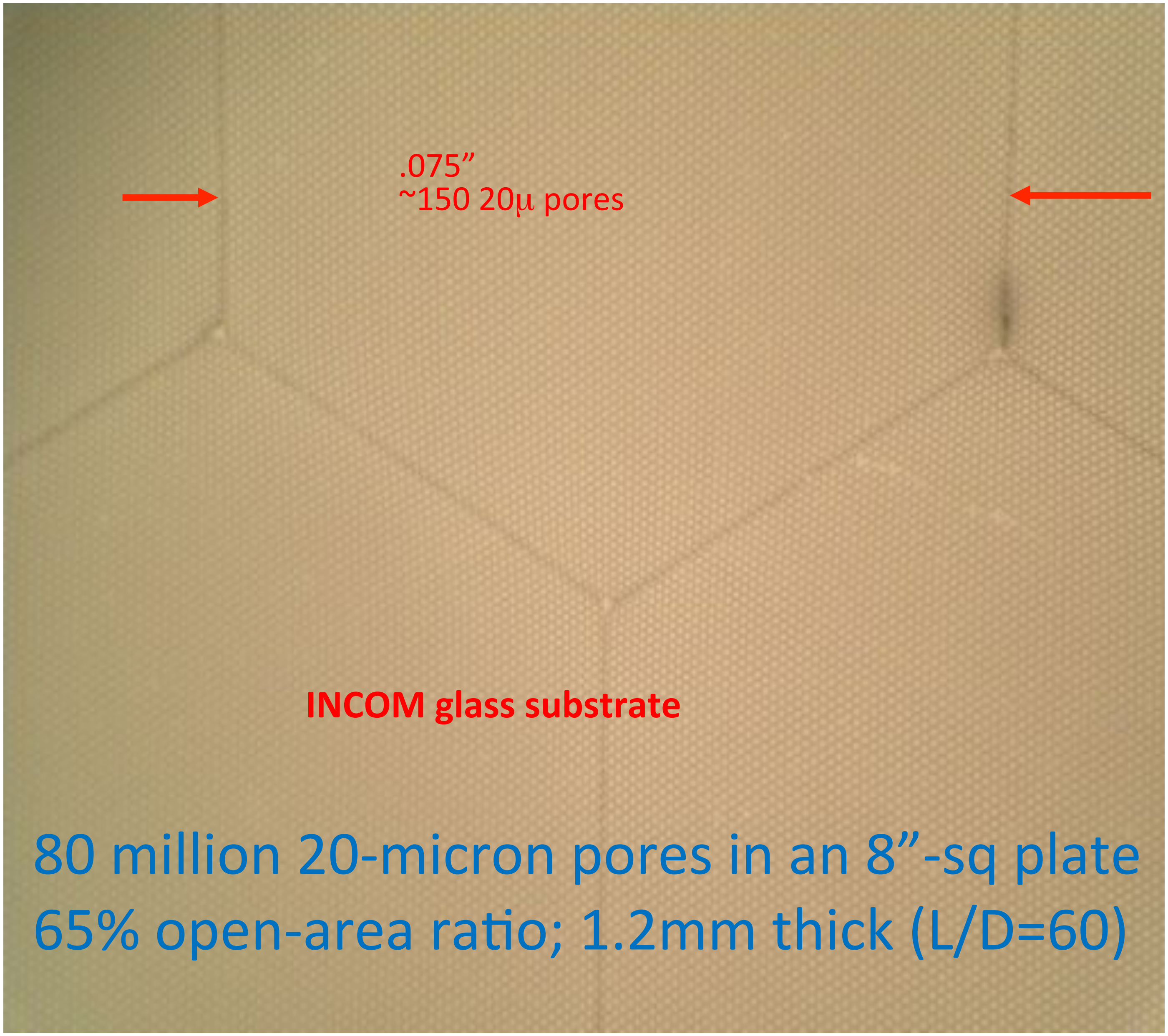
Chemically produced and treated Pb-glass does 3-functions:

1. Etched clad fiber substrate provides pores,
2. Hydrogen – reduced glass layer establishes MCP resistance,
3. Alkali/Pb - reduced glass layer provides secondary electron emission,

Separate the three functions:

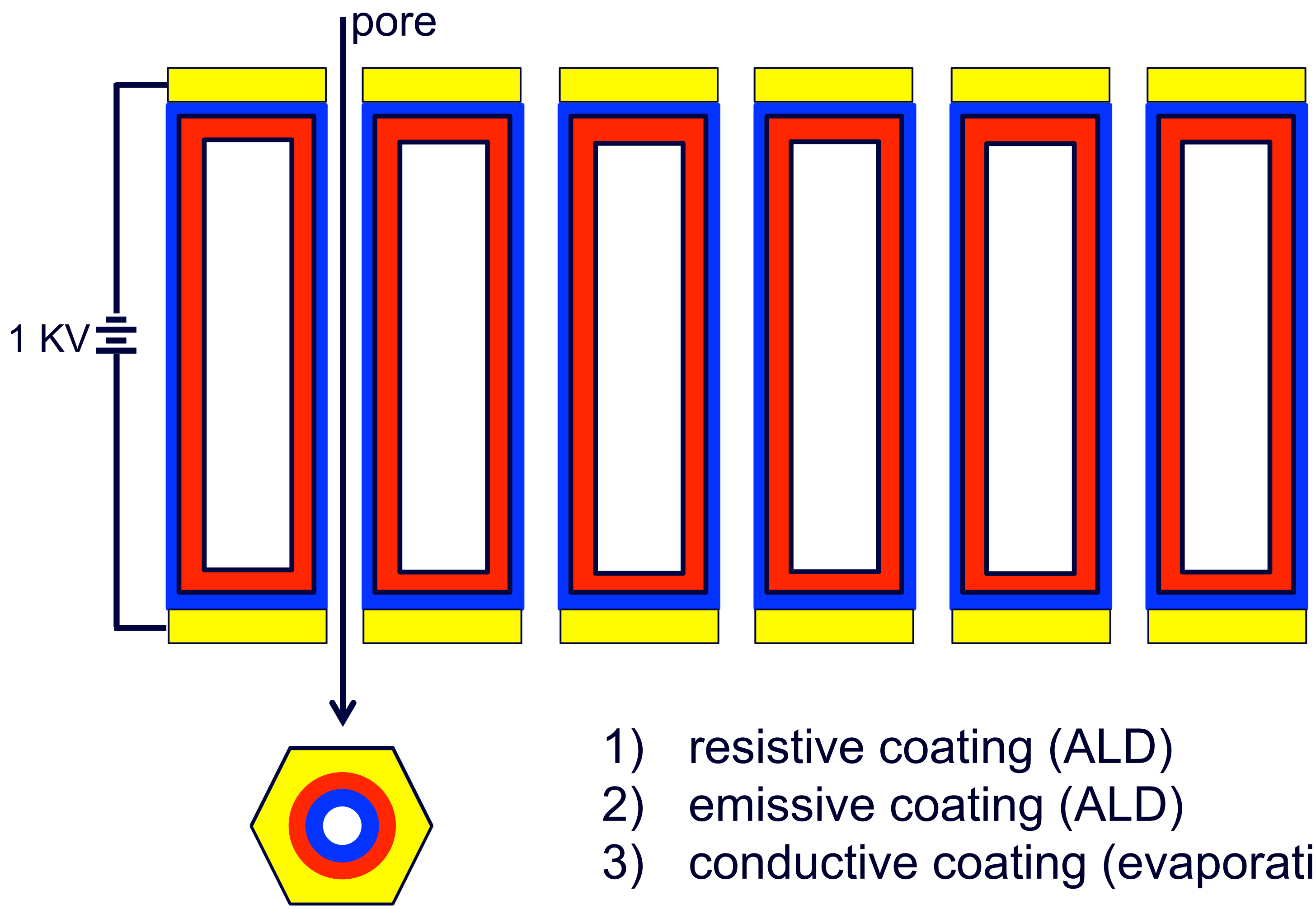
1. Hard glass microcapillary array substrate provides pores,
2. Tuned Resistive Layer (ALD) provides current for electric field,
3. Specific Emitting (ALD) layer provides SEE,

Incom Micropore Substrate



Incom.inc, Charlton Mass

New MCP Structure (not to scale)

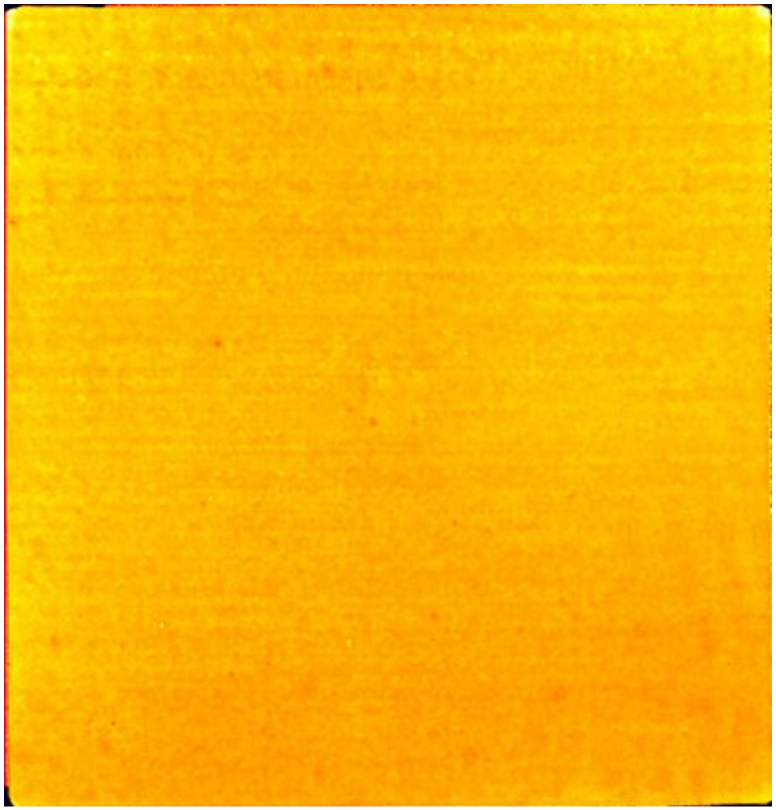


1) resistive coating (ALD)
2) emissive coating (ALD)
3) conductive coating (evaporation)

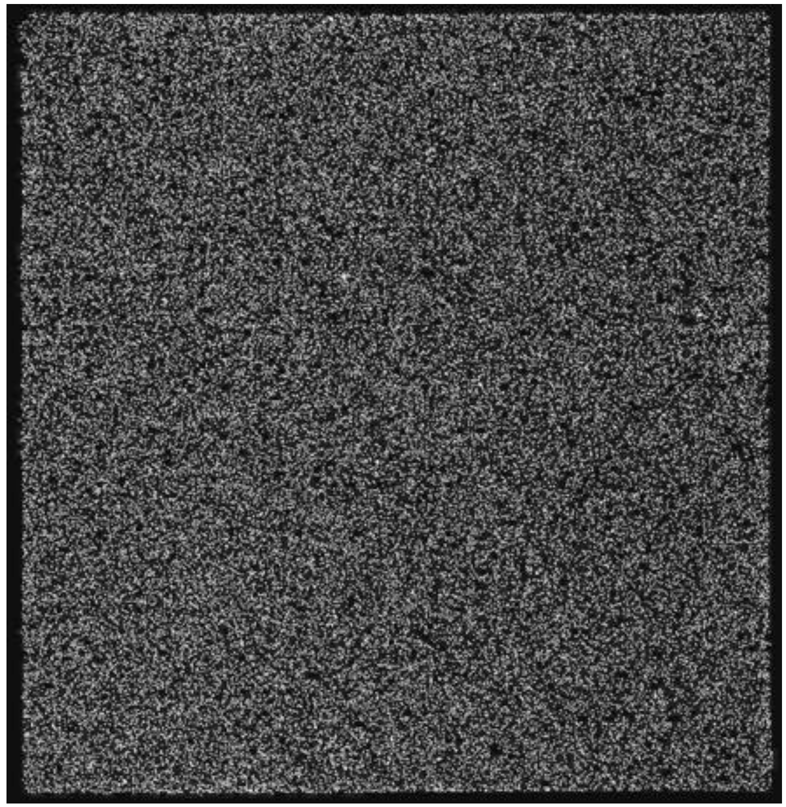
Jeff Elam

Status of 20cm Microchannel Plates

Most recent MCPs are 20µm pore Incom substrates with Argonne Lab. atomic layer deposition, 60:1 L/D, in pairs with MCP resistances ~15 to 60 MΩ. The gain is very uniform (±10%) and the background is very low (0.055 events cm^{-2} sec^{-1}), with gains in the region of 5 x 10^6 at ~ 900V per MCP.



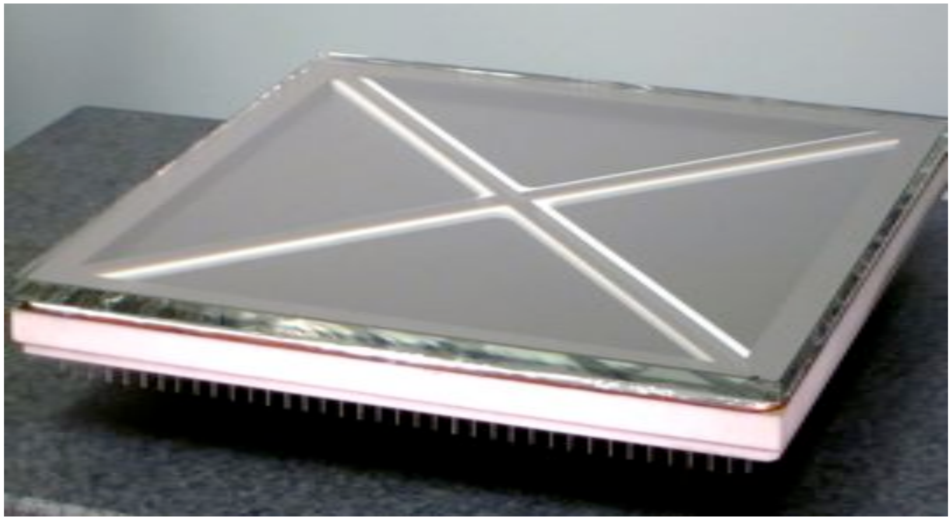
Gain map image for a pair of 20 µm pore, 60:1 L/D, ALD borosilicate MCPs, 950v per MCP, 184 nm UV.



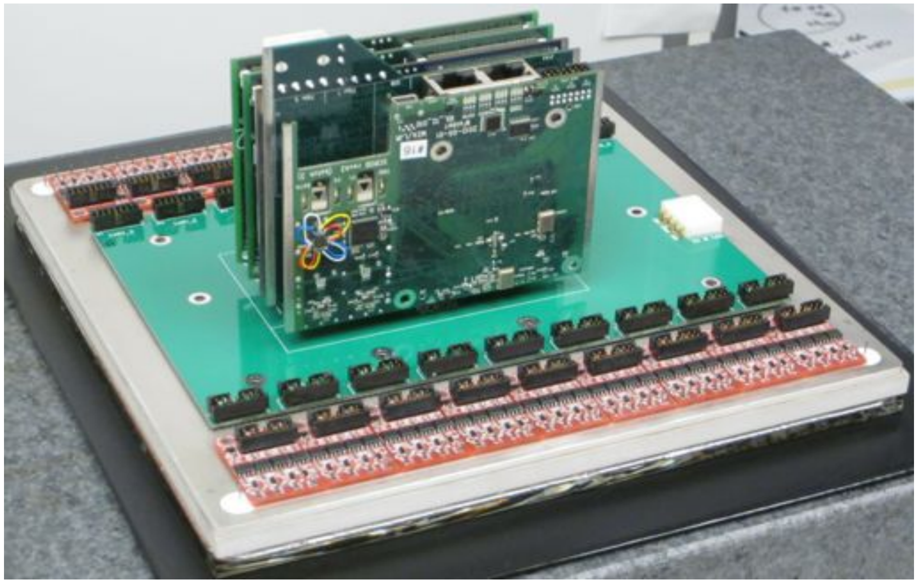
Background event image for a pair of 20 µm pore, 60:1 L/D, ALD MCPs. 0.055 events cm^{-2} sec^{-1}.

Status of LAPPD Sealed Tubes

Have made one tube process to date with achieved a >25% uniform bialkali cathode and was able to be used for imaging and timing with external electronics while in the process tank. Unfortunately the seal leaked during unload. Subsequent seal tests have been done successfully and we will make another tube process shortly in the next few months.

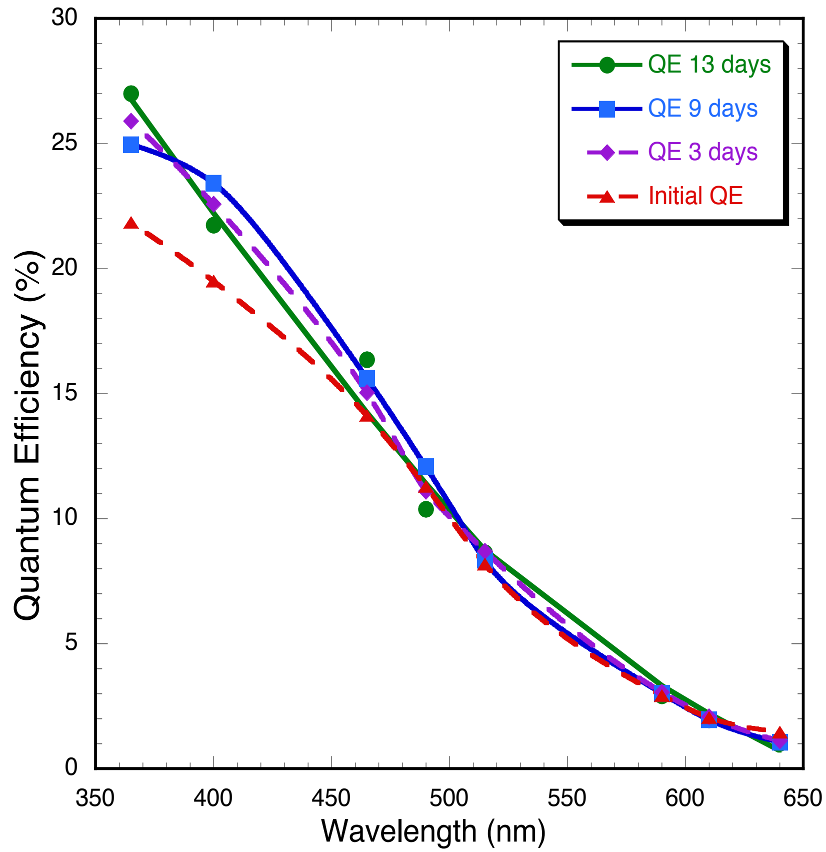


20 cm sealed tube mechanical assembly. The B33 entrance window, and MCPs are internally supported by ceramic "X"'s. Anode connections are via pins on the base.

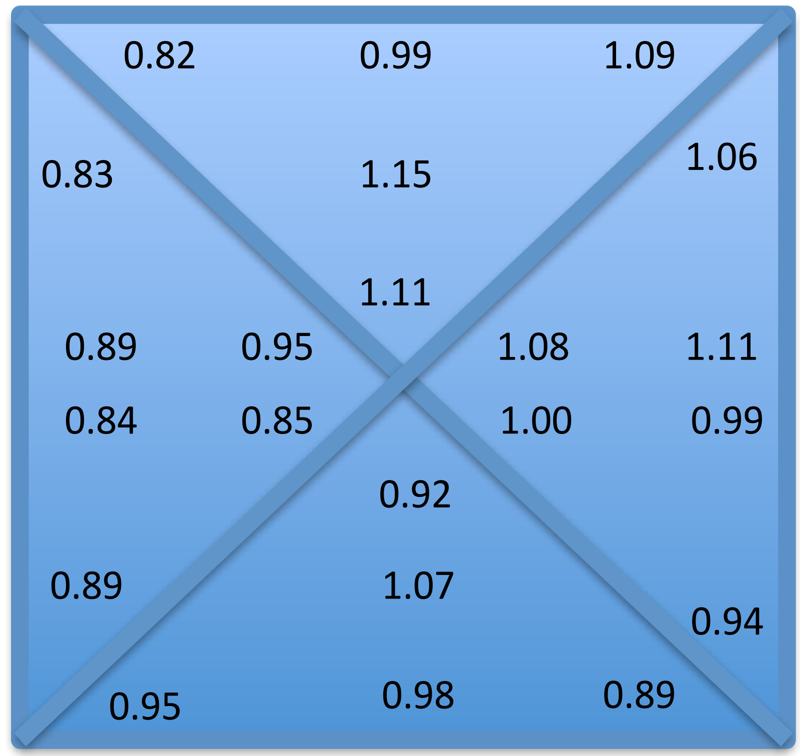


Strip anode readout electronics for the 20 cm tube. Amplifier boards placed on the rows of anode pins feed signals to the central event digital processing board stack

Status of 20cm PhotoCathodes



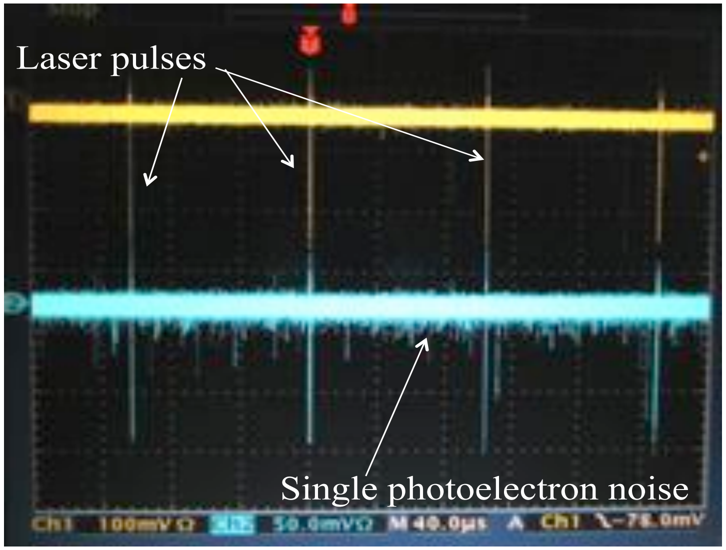
Quantum efficiency as a function of wavelength and time for a 20 cm bialkali (Na_2KSb) photocathode, deposited and attached to a 20 cm MCP detector.



Quantum efficiency uniformity (normalized) of the photocathode in Fig 13 as a function of position, after attachment to the LAPPD tube. 1 cm spot beam at 400nm.

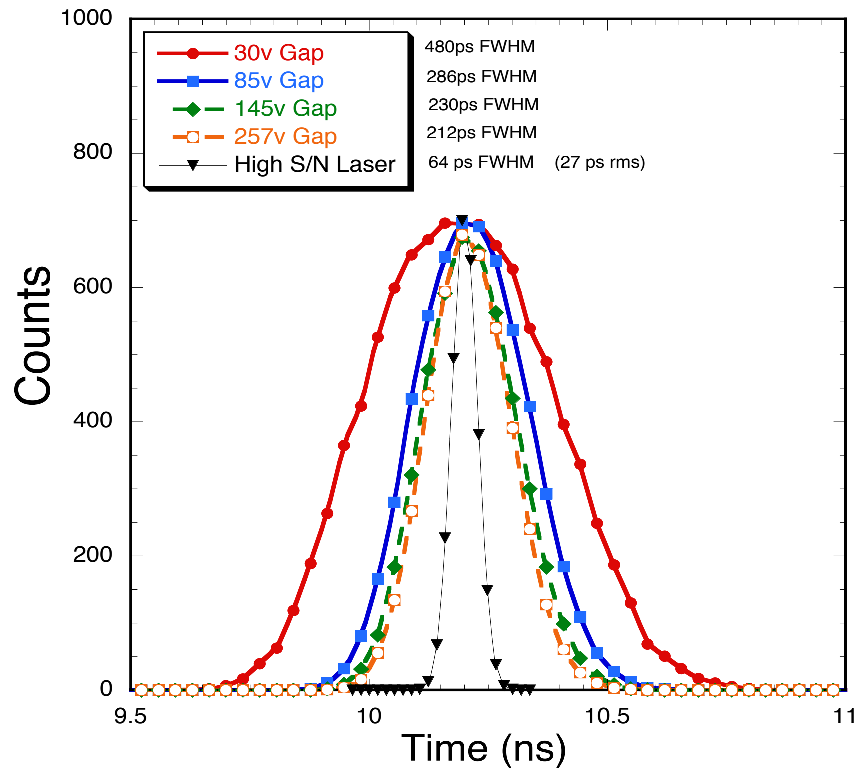
QE of SSL 20cm NaKSb cathodes

LAPPD Tube Initial Timing Test



Laser trigger signal (lower) and detected photon pulses (80 ps laser @ 640 nm) at 10 kHz rate, using the 20cm detector with a pair of 20 µm pore ALD MCPs LAPPD tube with cathode. Laser ~15e$^-$ equivalent.

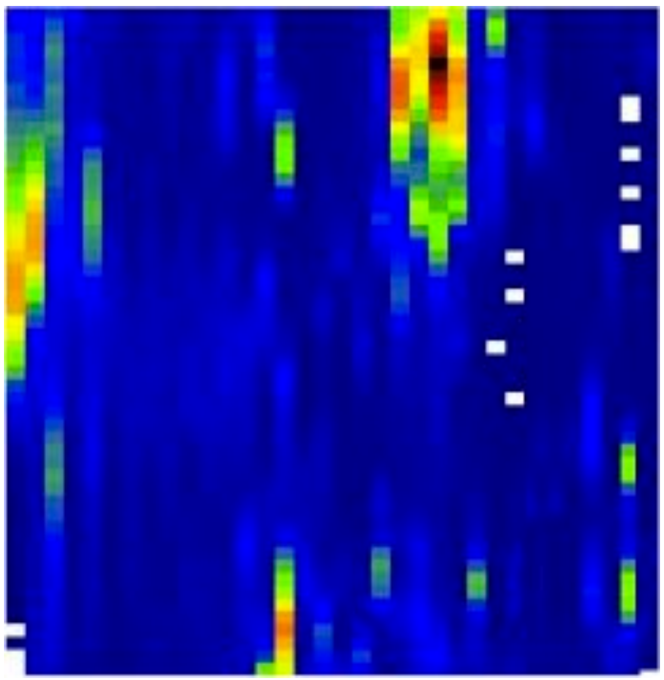
Far from ideal anode – strips joined as continuous delay line, poor impedence match & ground inside process tank, pedestal mount 30 cm high!.



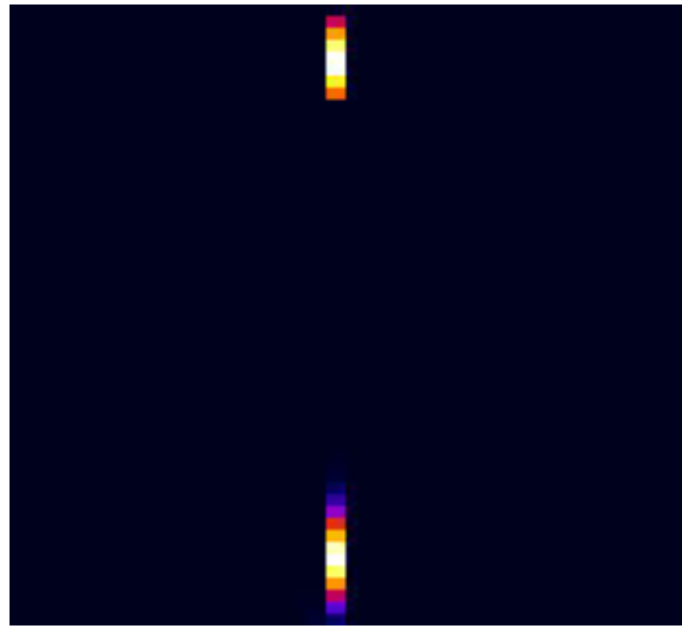
Jitter of the time stamp for detected laser pulses. 80 ps laser @ 610 nm, at 10 kHz rate 20cm detector with a pair of 20 µm pore ALD MCPs in the LAPPD tube with cathode Cathode/MCP gap ~1.5 mm.

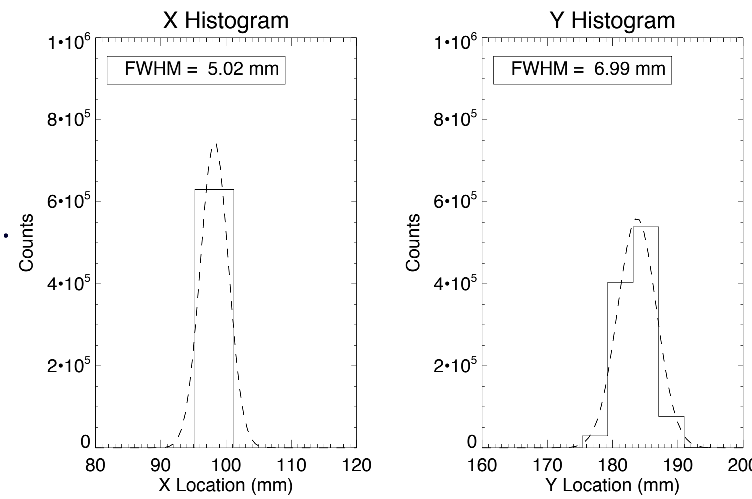
Imaging with LAPPD Tube

Imaging of the delay line readout implemented with the stripline readout of the 20 cm LAPPD tube test detector



Background event image after LAPPD detector window seal ~30 kHz rate, mostly in 3 spot areas.



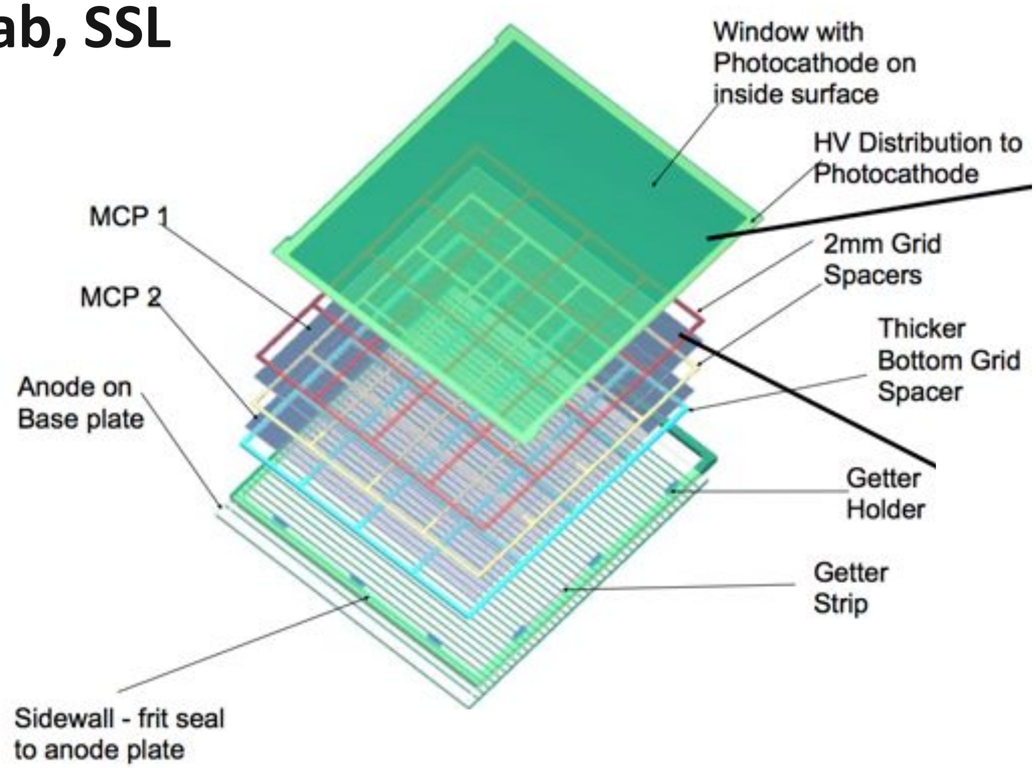


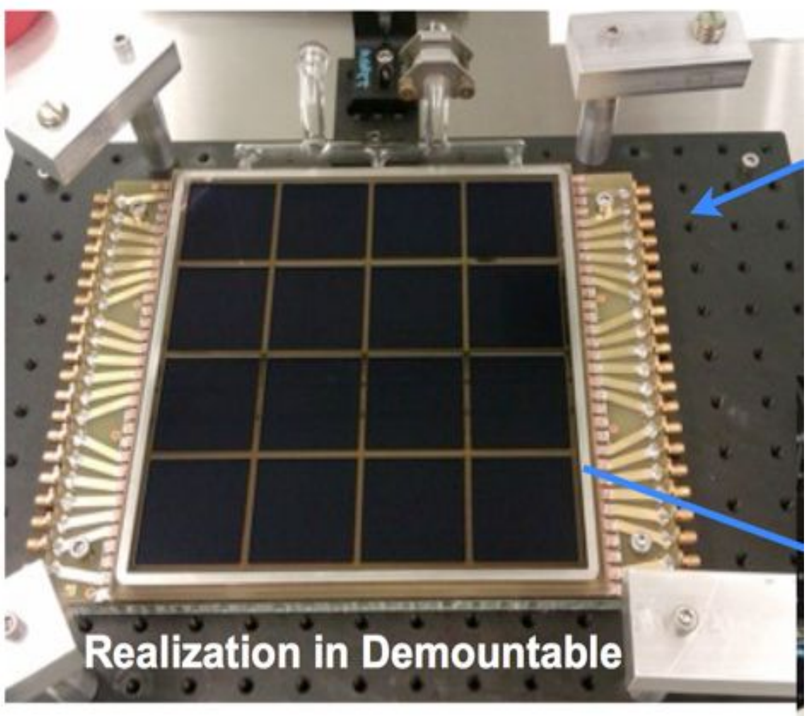
Images of a laser beam (~5mm spot) in two different positions on the sealed 20cm test detector (Fig. 2). 34 x 50 pixel binning.

Glass LAPPD Sealed Tube

U. Chicago, Incom, Argonne Lab, SSL

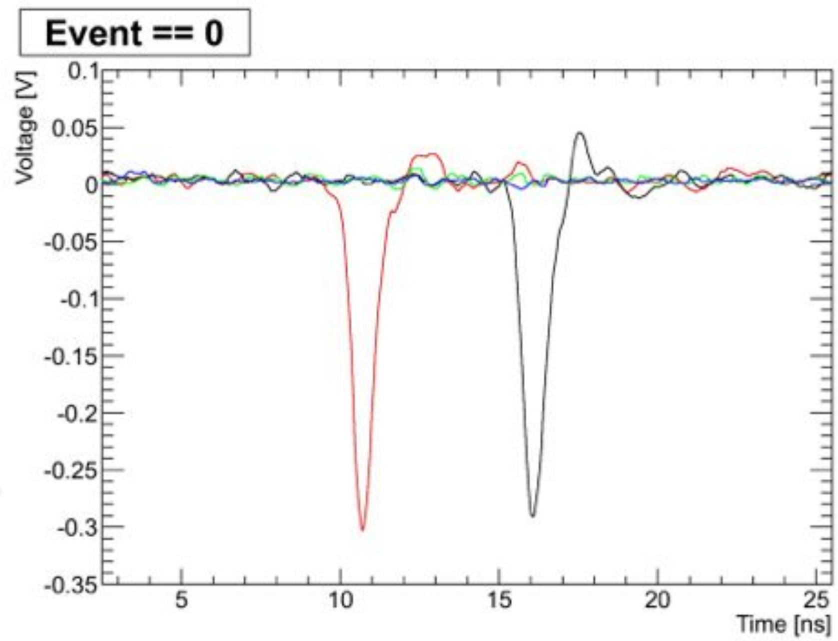
Same format 20cm MCPs, just glass envelope





8"-MCP Pair and Strip Anode Work

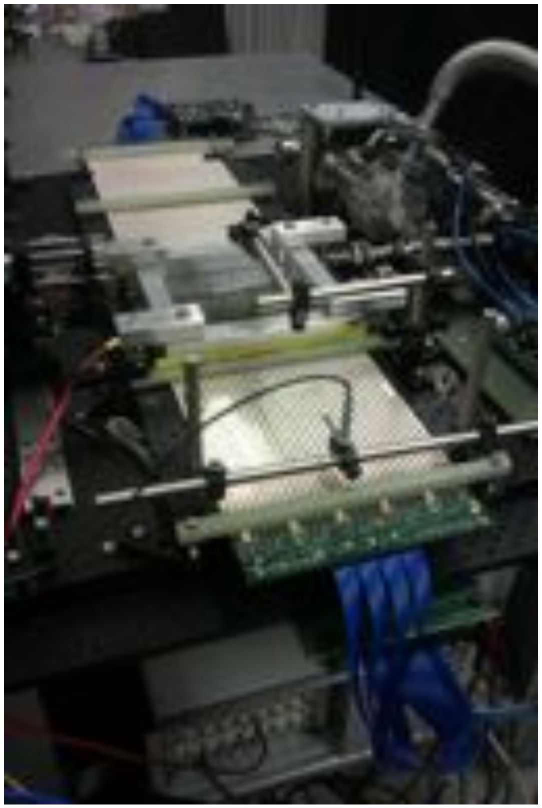
Laser mirrors and 8" anode for 8" MCP tests



Pulses from one strip of 8" anode with 8" MCP pair

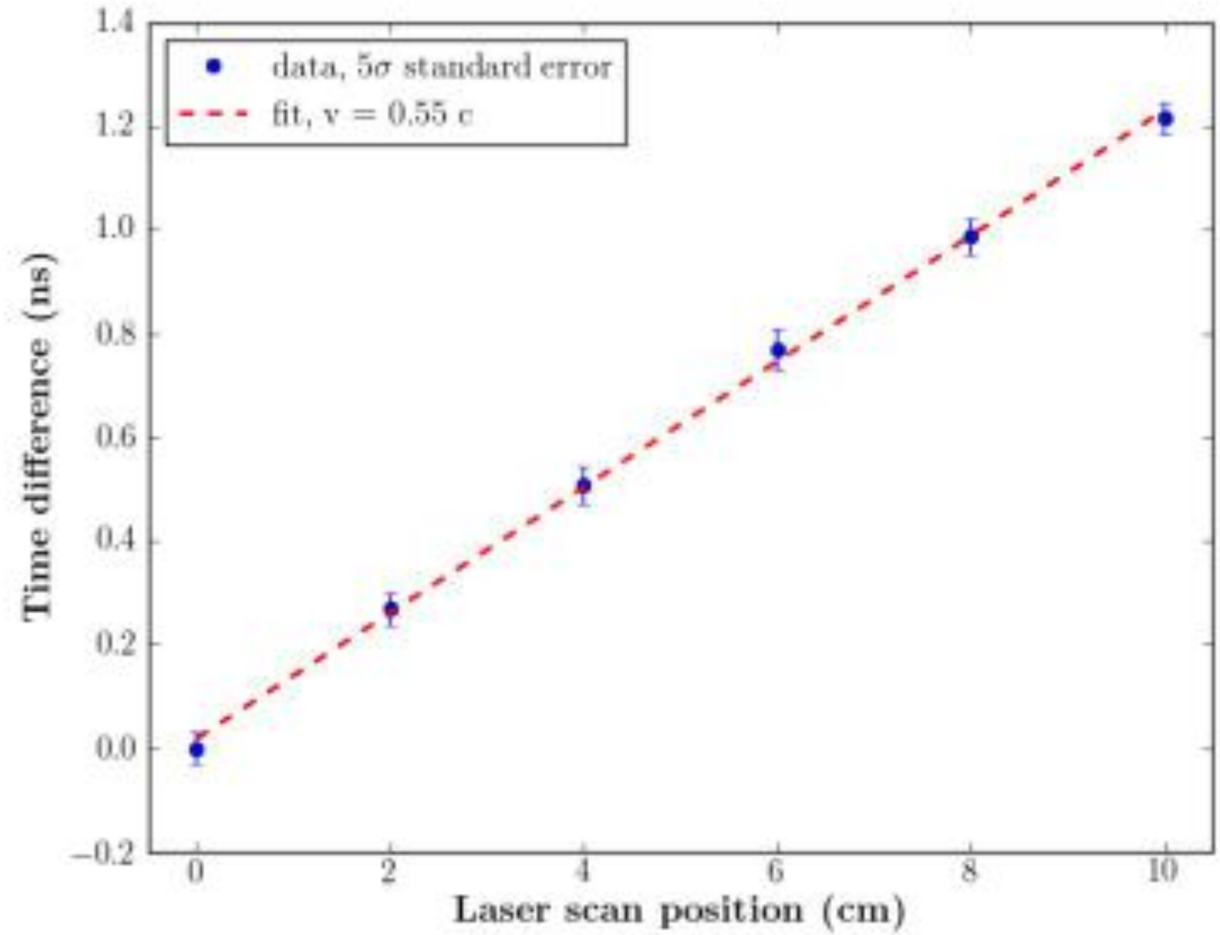
Matt Wetstein, Bernhard Adams, Andrey Elagin, Razib Obaid, Sasha Vostrikov, Bob Wagner

Measured Position Sensitivity



4-tile `tile-row'
of Supermodule

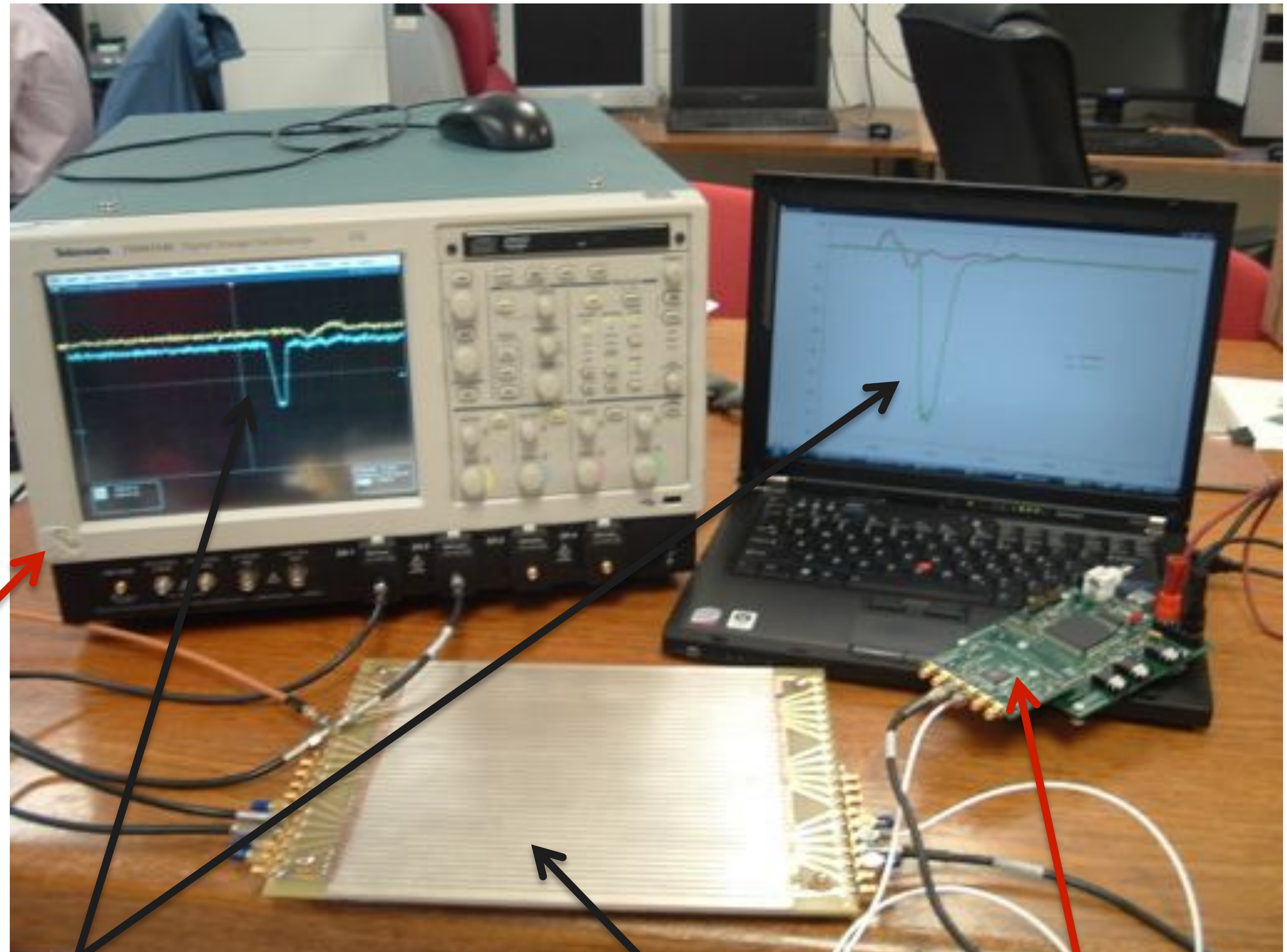
Razib



Time difference of 2 ends vs laser position

6-channel `Scope-on-a-chip'

Designed by Eric Oberla (UC grad student) working in EDG with EDG tools and engineers (H. Grabas, J.F. Genat)

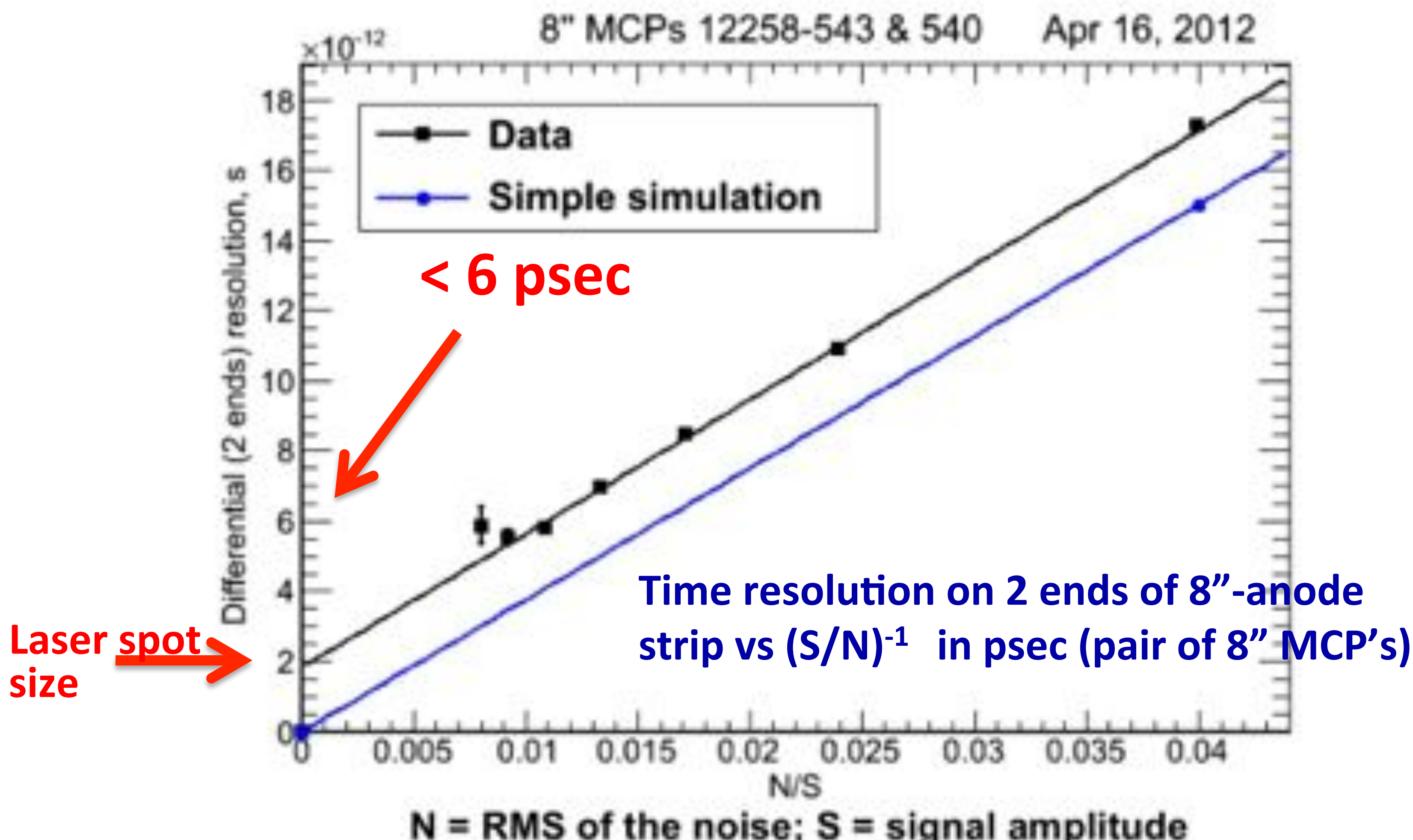


20 GS/scope 4-channels (142K$)

Real digitized traces from anode

17 GS/PSEC-4 chip 6-channels ($130 ?!)

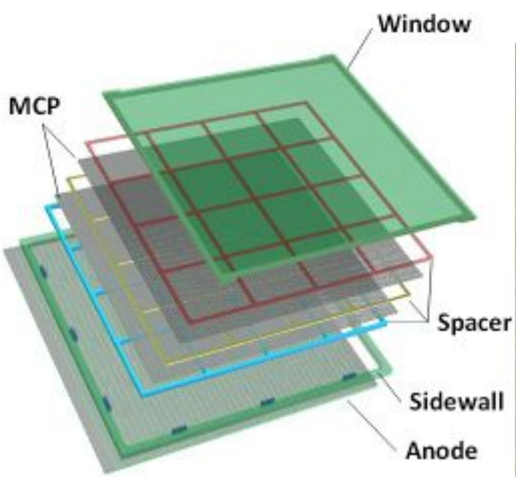
Timing Resolution Model/Measurements



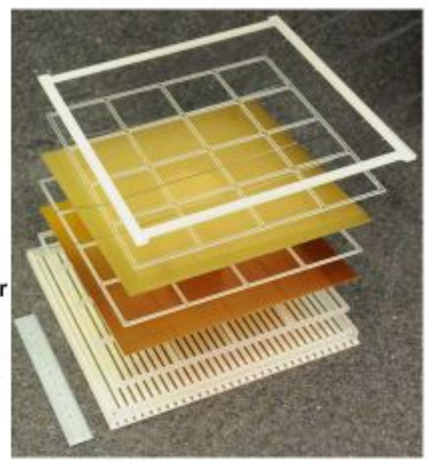
M. Wetstein, B. Adams, A. Elagin, R. Obaid, A. Vostrikov, …

The Half-Meter-Squared SuperModule

A `tile' is a sealed vacuum-tube with cathode, 2 MCP's, RF-strip anode



Design Drawing - September 2010



Actual Glass Parts - April 2012

A SuperModule holds 12 tiles in 3 tile-rows. 15 waveform sampling ASICS on each end of the tray digitize 90 strips. 2 layers of local processing (Altera) measure extract charge, time, position, goodness-of-fit

Comparison with existing detectors

K. Arisaka; UCLA