2012 Project X Physics Study

Timing properties of MCPs with ALD

Andrey Elagin

THE UNIVERSITY OF CHICAGO

on behalf of the LAPPD collaboration

- *Introduction (LAPPD)*
- *MCP & ALD*
- *Timing*
- *Conclusions*

June 18, 2012

Large Area Picosecond Photo Detectors (LAPPD)

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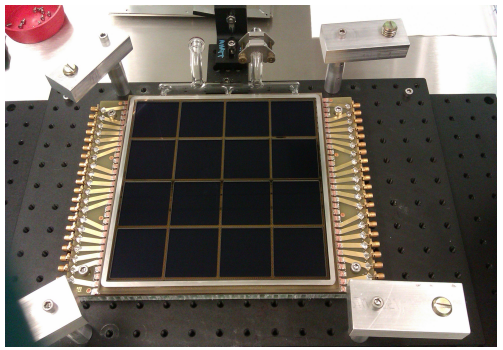

Goals:

- *Large area*
- *Picosecond timing*
- *Cheap*

Applications:

- **Picoseconds on large area**
- *Neutrinos*
- *Kaons*
- *Collider*
- *Muon cooling*
- *PET scan*
- *X-ray*
- *Neutrons*

Super Module

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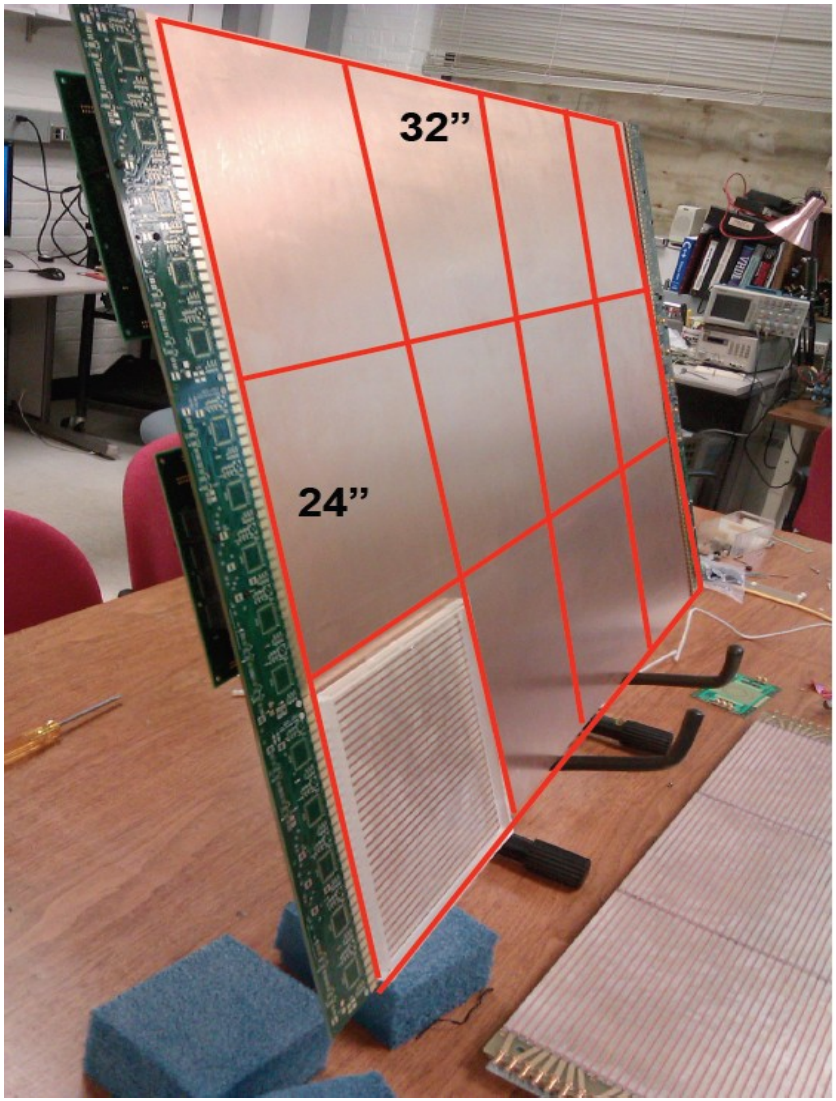
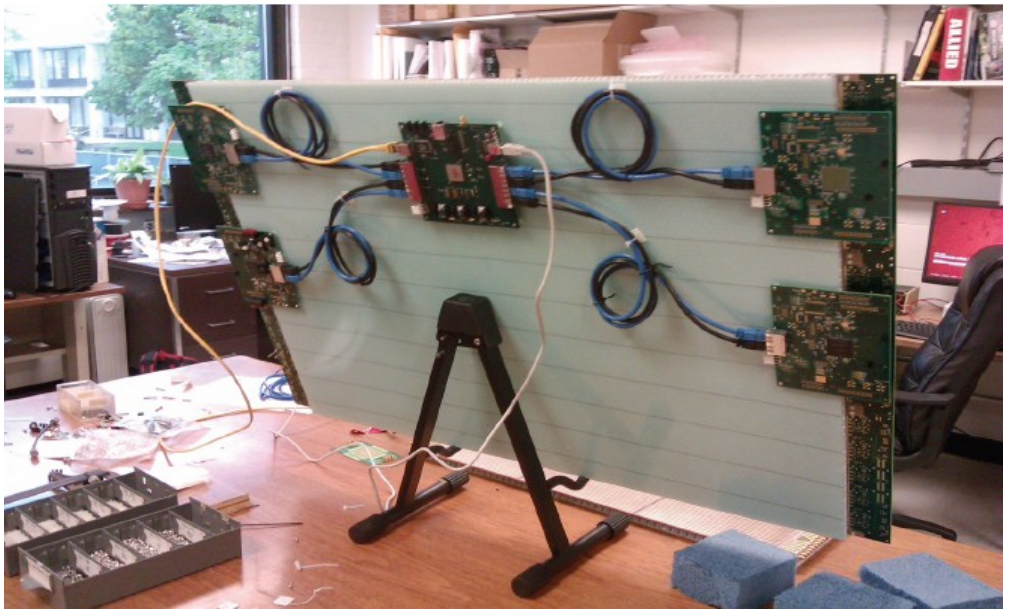


- ***<u>Thin</u> planar glass body detector***
- ***MCPs share single delay line anode***
- ***Fully integrated electronics***



Non-Cryogenic Liquid Detector

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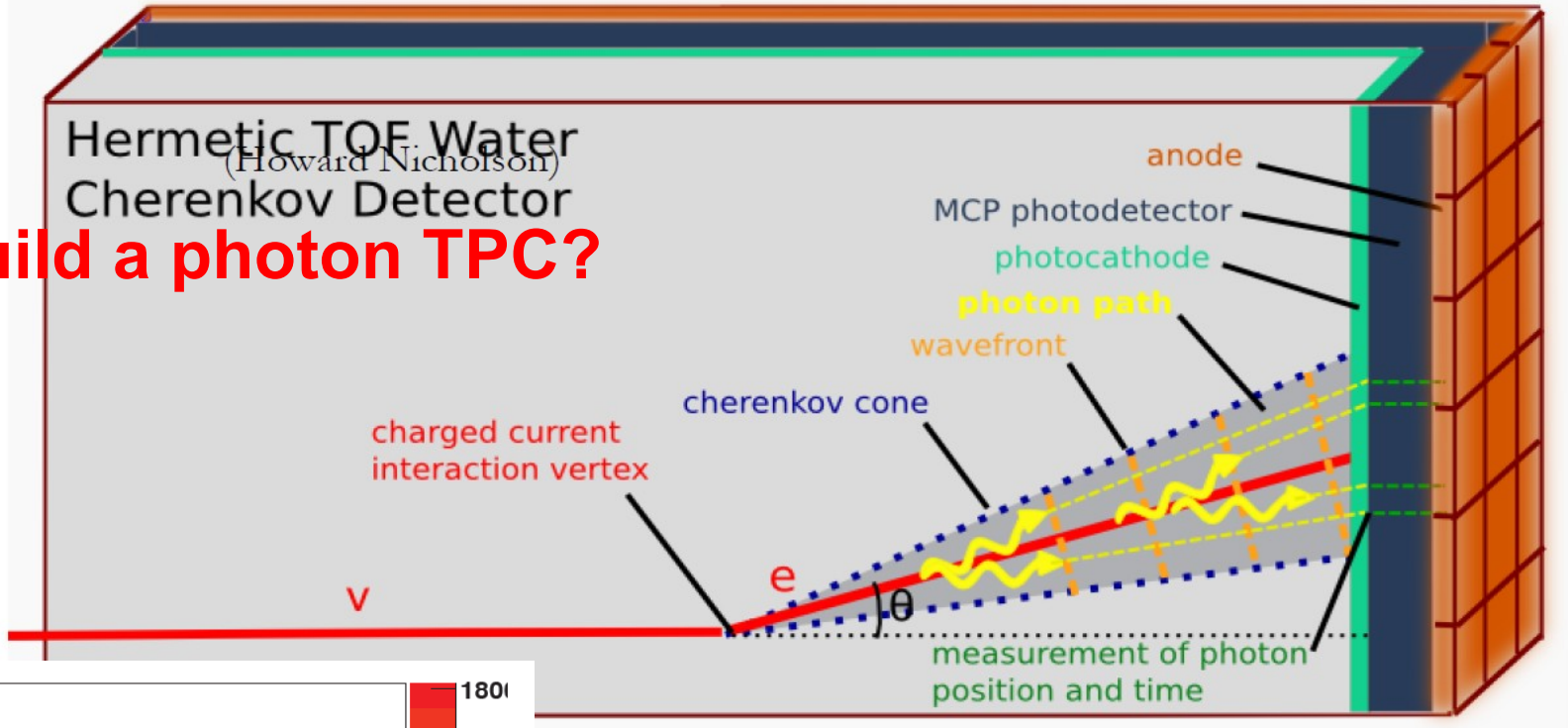
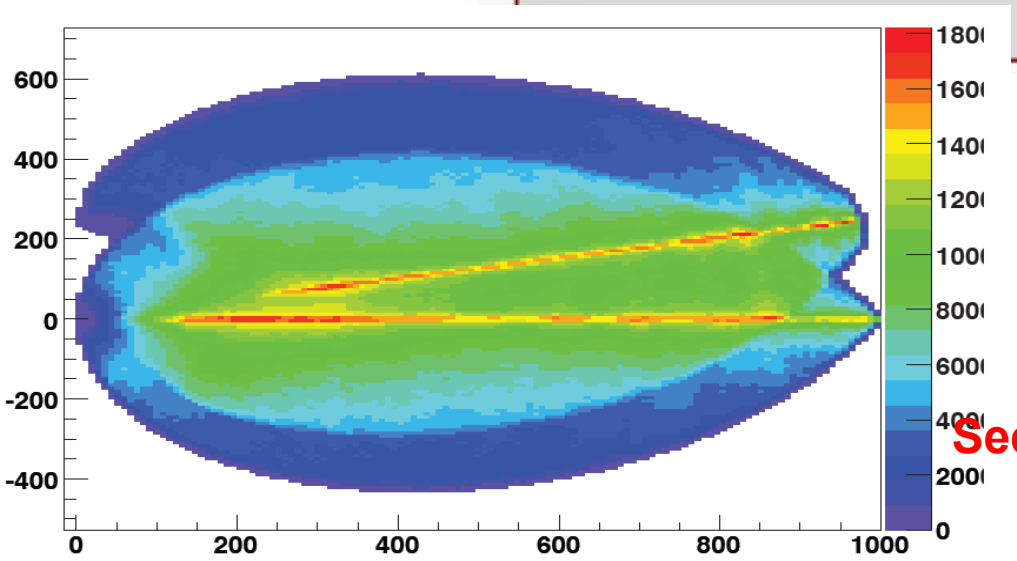
Can we build a photon TPC?

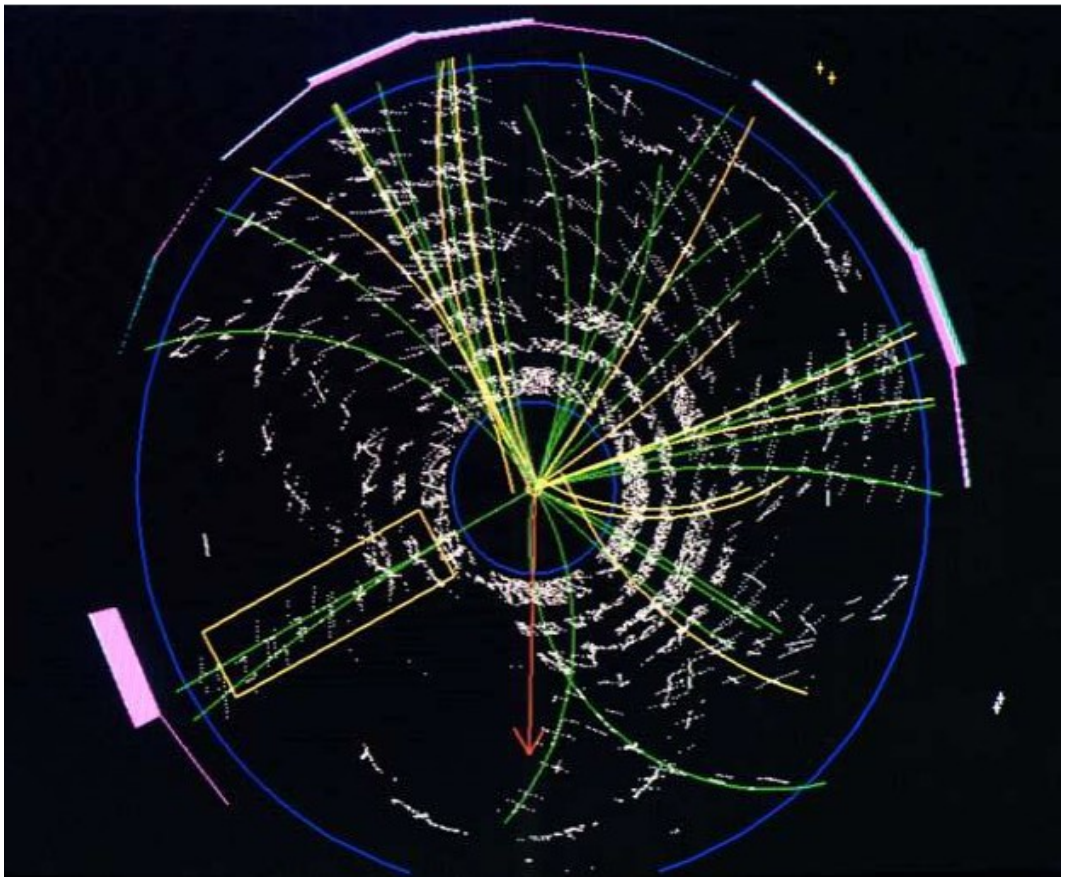




See Matt Wetstein talk today

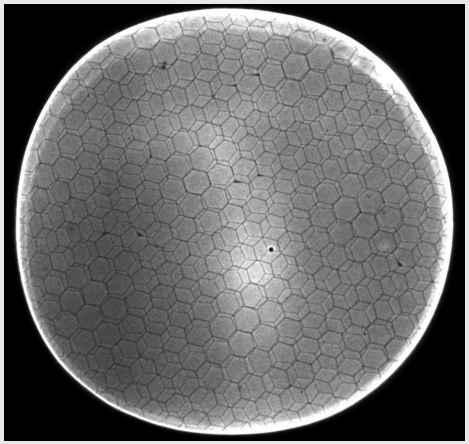
Particle Identification

Can we start talking about particles instead of jets?

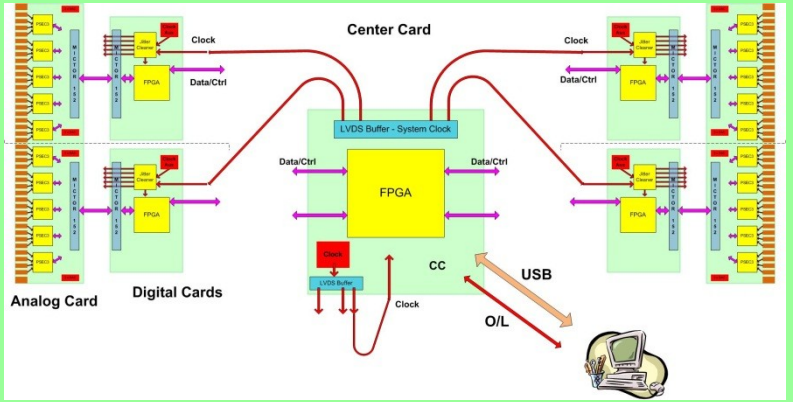


LAPPD components

MicroChannel Plates

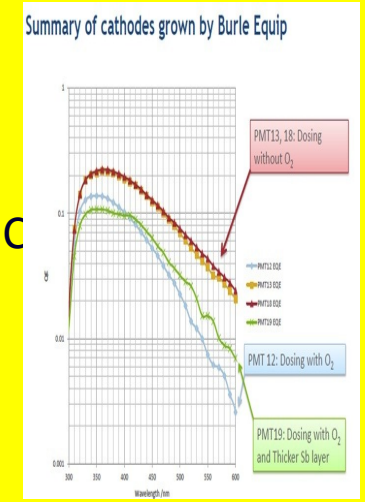


Electronics/Integration

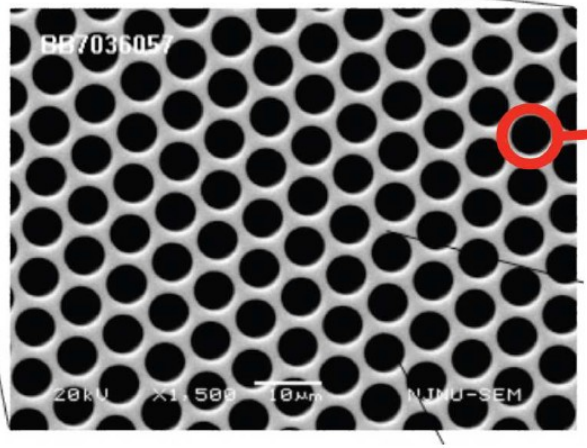


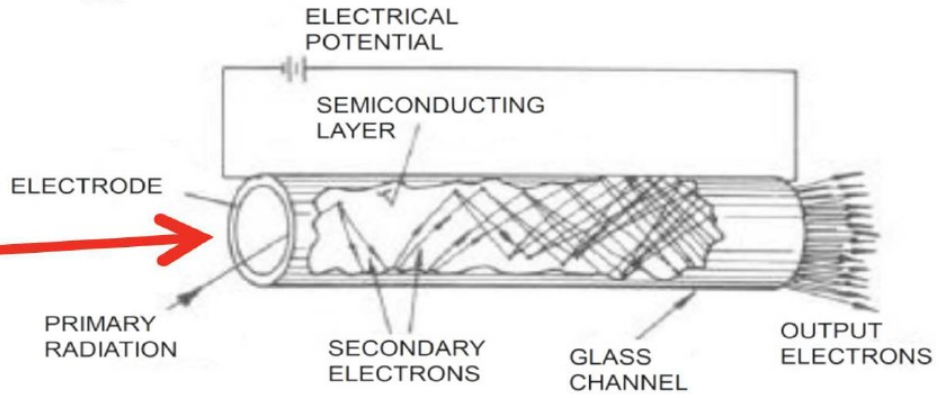
Hermetic Packaging

Photocathodes



MCP fundamentals





Many electron multipliers per unit area

- **Glass substrate with micron pores**
- **Each pore acts as an electron multiplier**
  - ***secondary electron emission (SEE)***
  - ***high voltage applied***
- **Usually very expensive**

Commercial MCP vs LAPPD MCP

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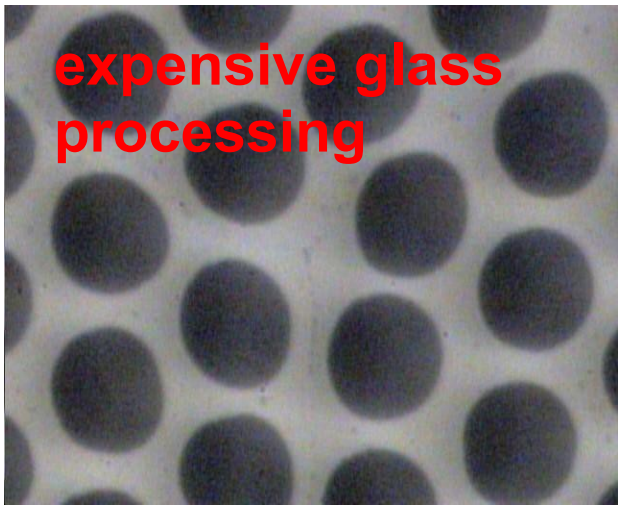
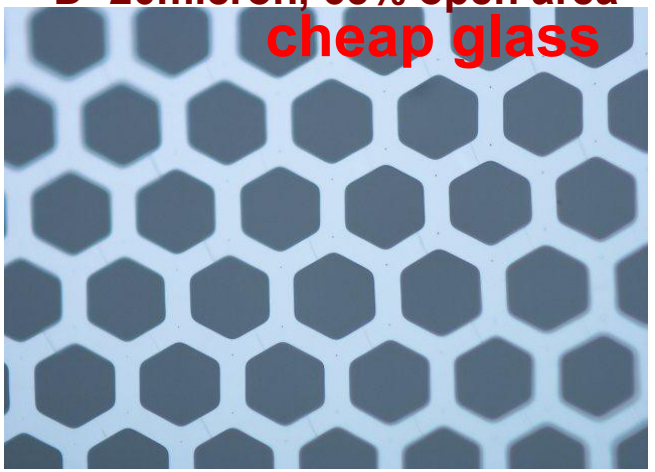
Conventional Pb-glass MCP



Incom glass substrate

D~20micron, 65% open area



Three functions in one glass plate

- *Pores*
- *Resistive layer to provide electric field in the pore*
- *Pb-oxide layer serves as SEE layer*

Separate the three functions

- *Pores (L/D~60)*
- *Resistive layer applied using Atomic layer deposition (ALD)*
- *SEE layer applied using ALD*

MCP by Atomic Layer Deposition (ALD)

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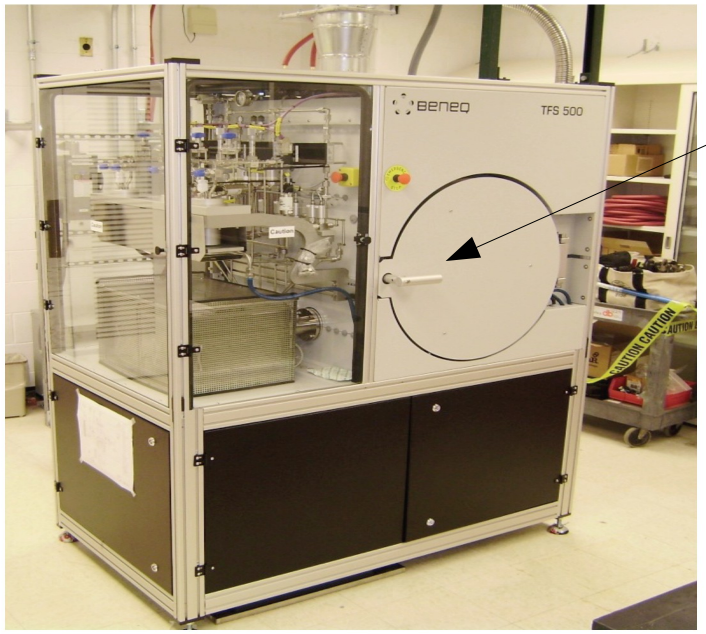
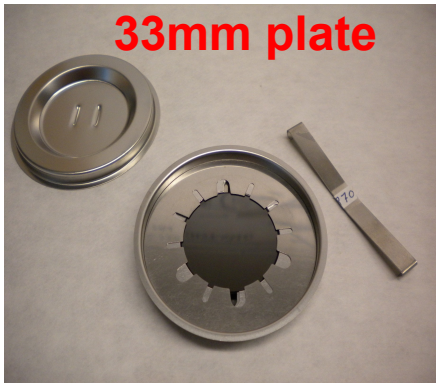
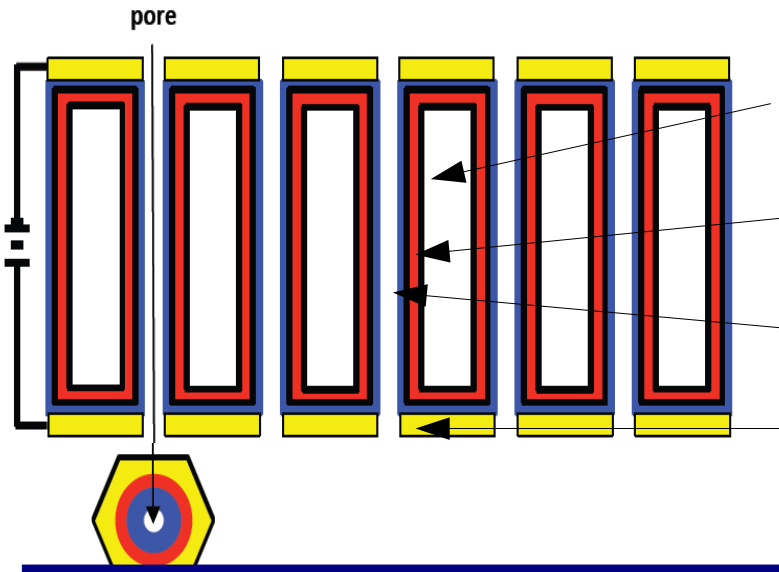


Beneq reactor for ALD
@Argonne National Laboratory



Wide parameter space:
- relative composition of materials
- temperature
- different materials and thickness

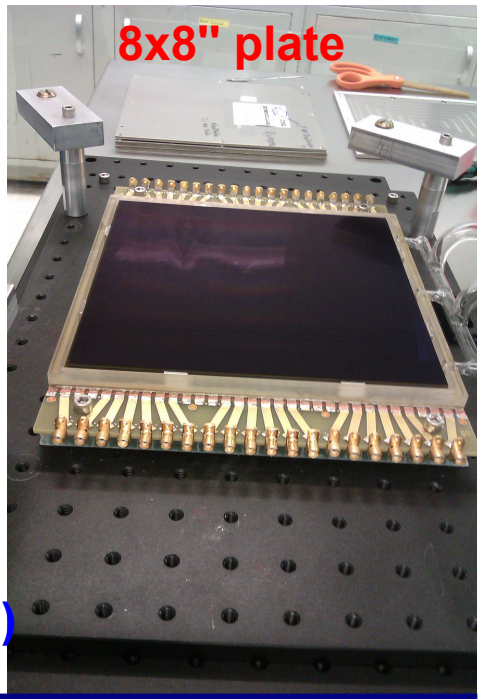


Porous glass

Resistive coating ~100nm (ALD)

Emissive coating ~ 20nm (ALD)

Conductive coating
(thermal evaporation or sputtering)



LAPPD vertical slice

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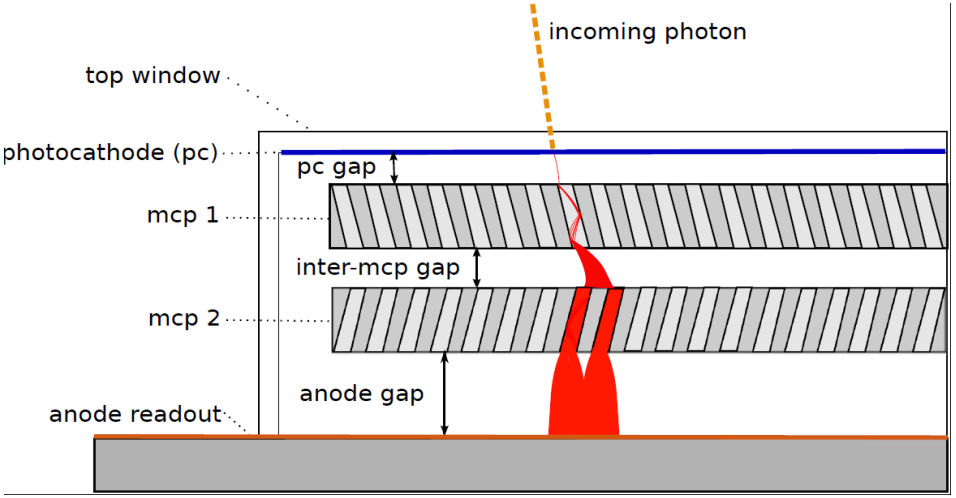
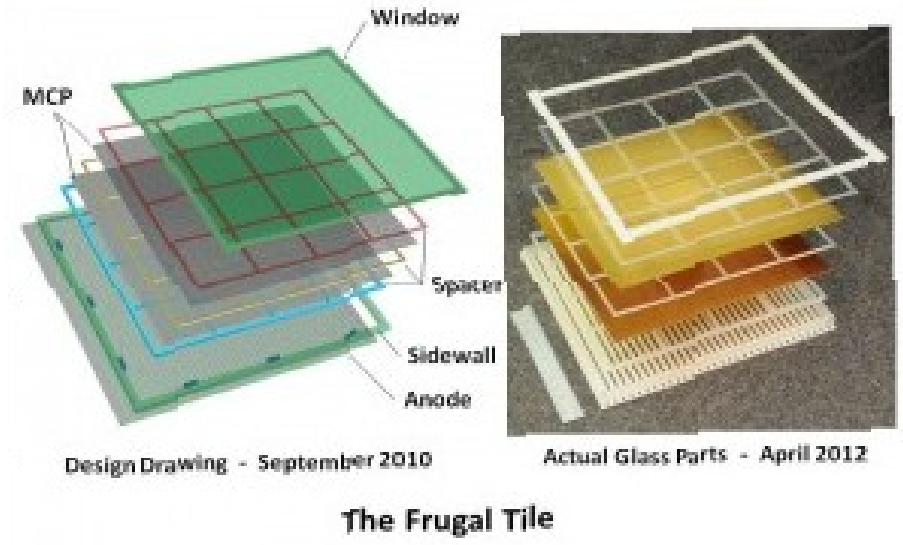
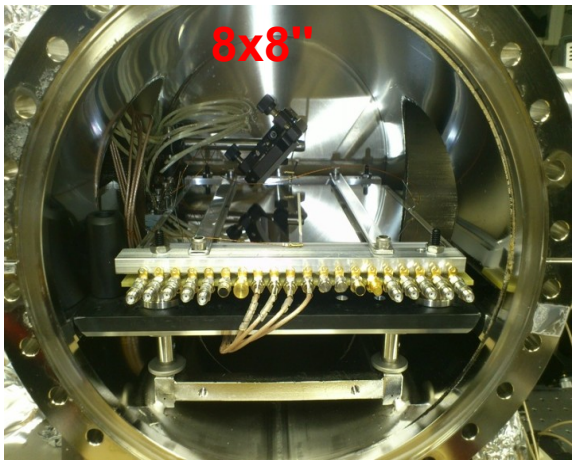
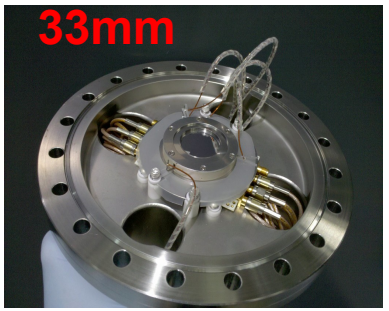


- Enclosed in vacuum (10^{-7} – 10^{-8} torr)
- Photocathode (aluminum at the moment; low quantum efficiency is compensated by high UV light intensity)
- Stack of MCP plates
  - Chevron geometry (8° bias angle)
  - ~1kV across each MCP
  - ~200V acros gaps
- Anode (delay line 1.6 GHz bandwidth)
- Readout with high bandwitdth scope or LAPPD made DAQ







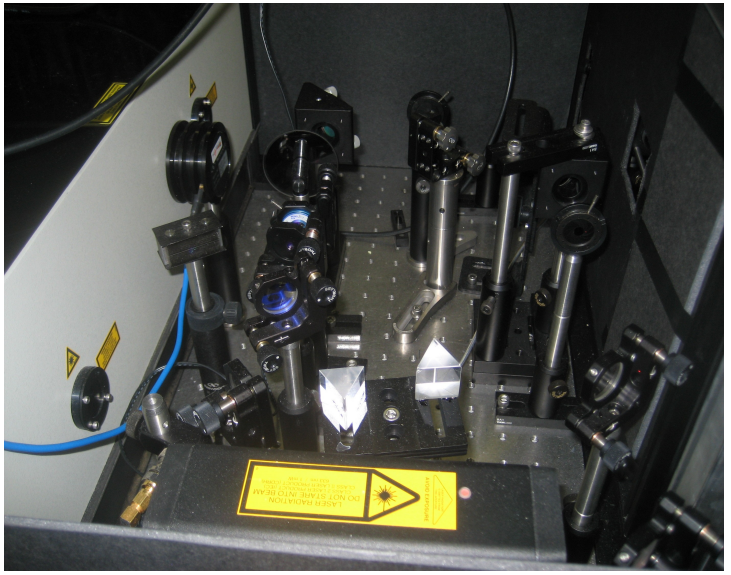
Laser Testing Setup

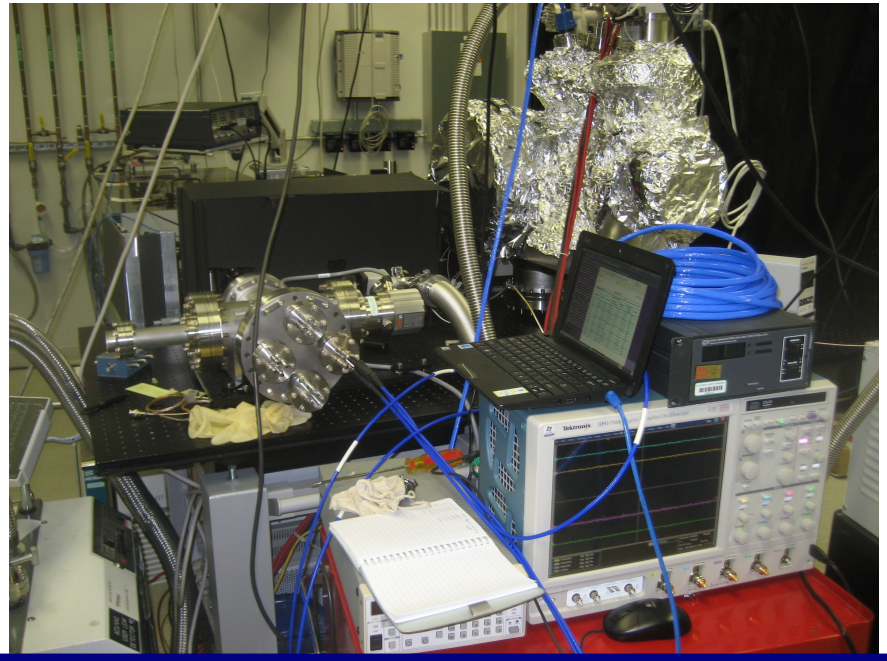
@ Advanced Photon Source Division (APS) Argonne National Laboratory

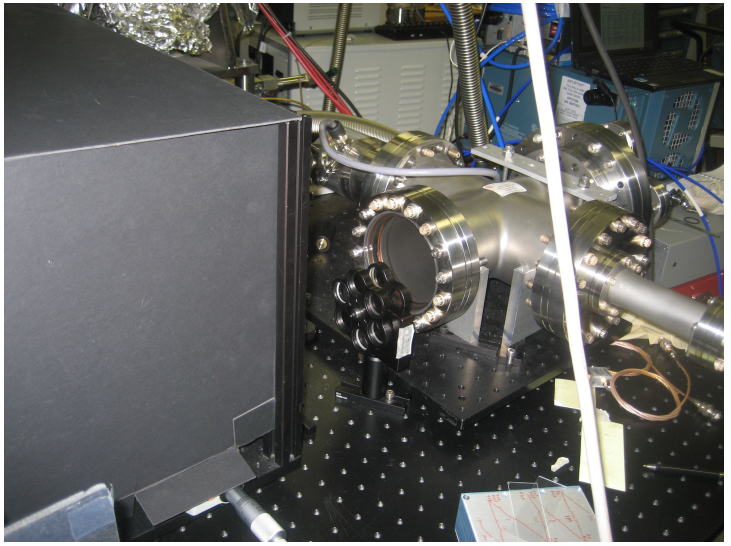
University of Chicago

Sub-picosecond laser

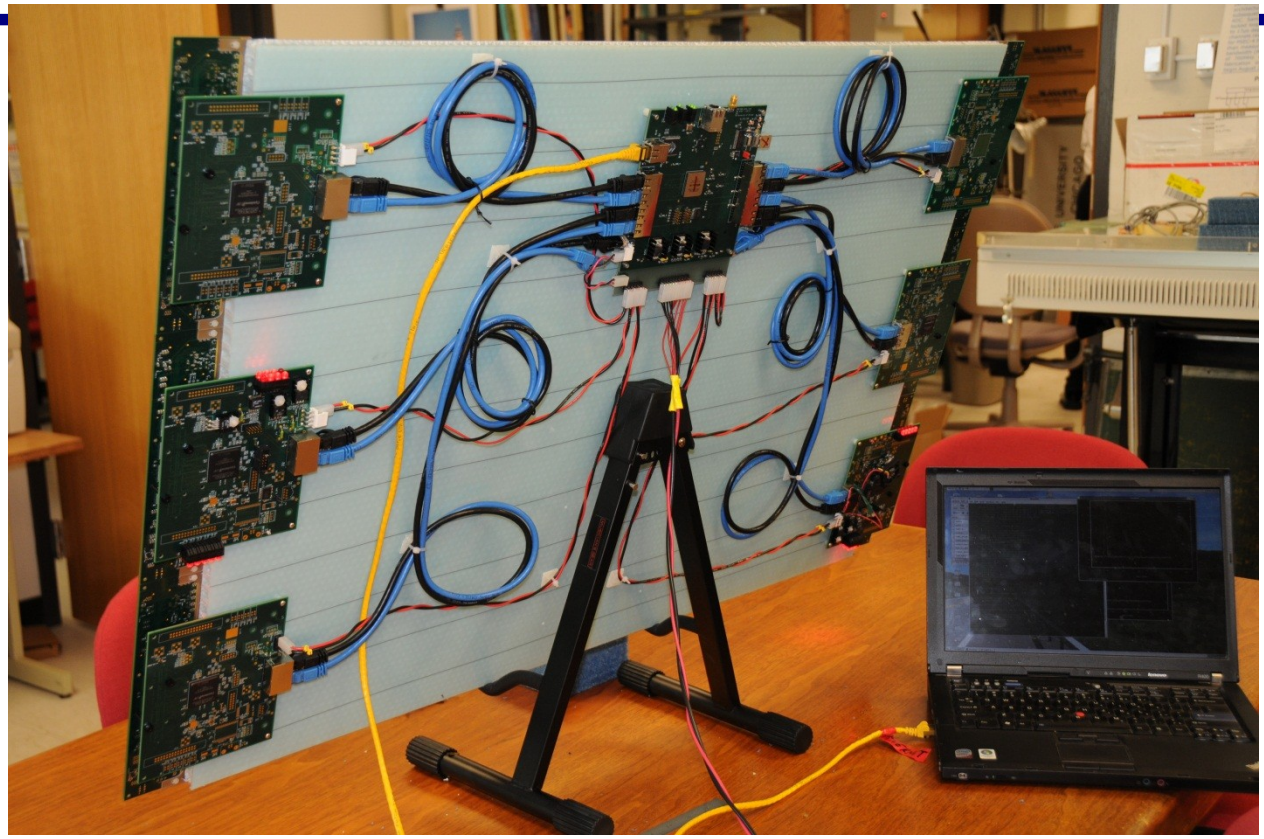
- Ti:Sapph 800nm; power ~800 mW
- pulse duaration O(10) femtoseconds
- 1KHz repetion rate
- Non-linear optics to produce
- 266nm UV light







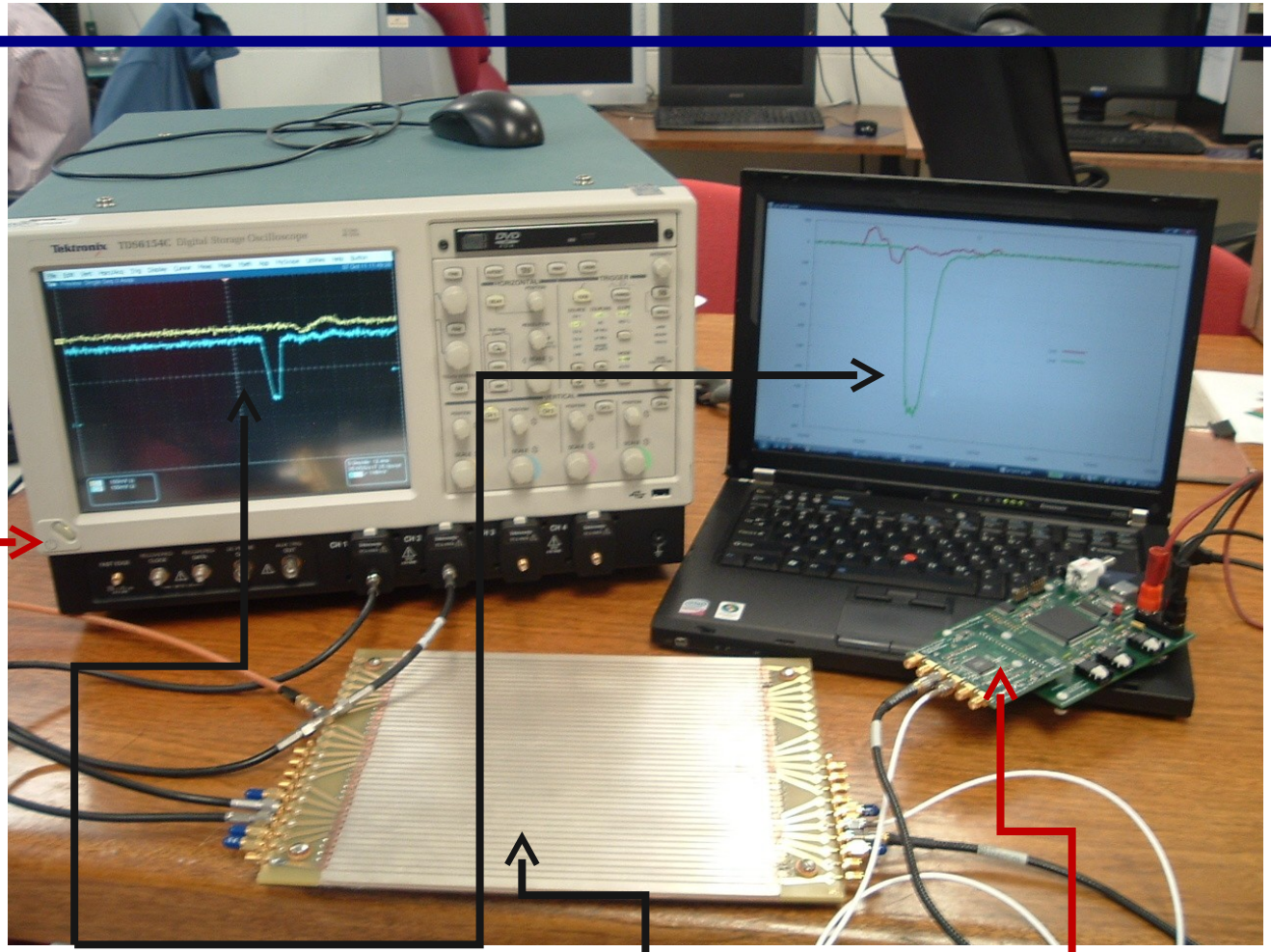
Electronics



- Analog card (PSEC4 chip) for every 6 channels:
  - waveform sampling
- Digital card (FPGA) for every 5 chips (30 channels):
  - charge, time, shape
- Central card (FPGA) 1 per supermodule:
  - time and position; system control, CPU interface

Scope-on-a-chip

Designed by Eric Oberla (UC grad student)



Real digitized traces from anode

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

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

Gain with the MCP stack

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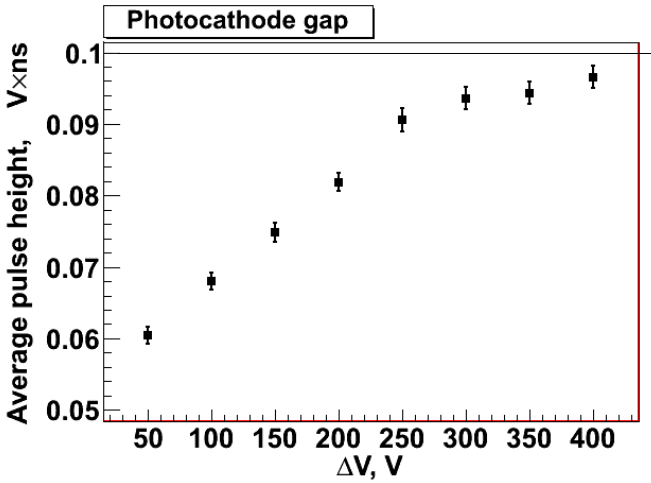
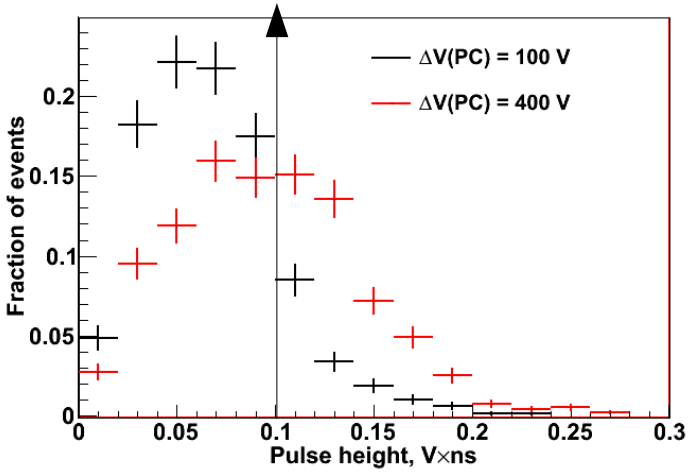
pair of 40 MOhm 33mm MgO plates

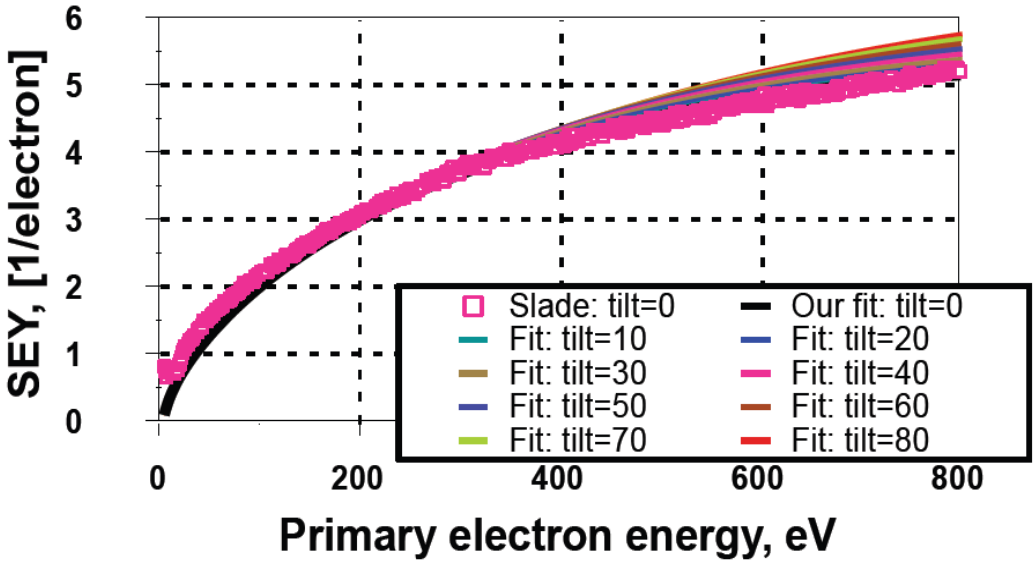


~2x10^7 electrons out

~2x10^7 electrons out



20 nm MgO SEY data



MCP pulses and timing

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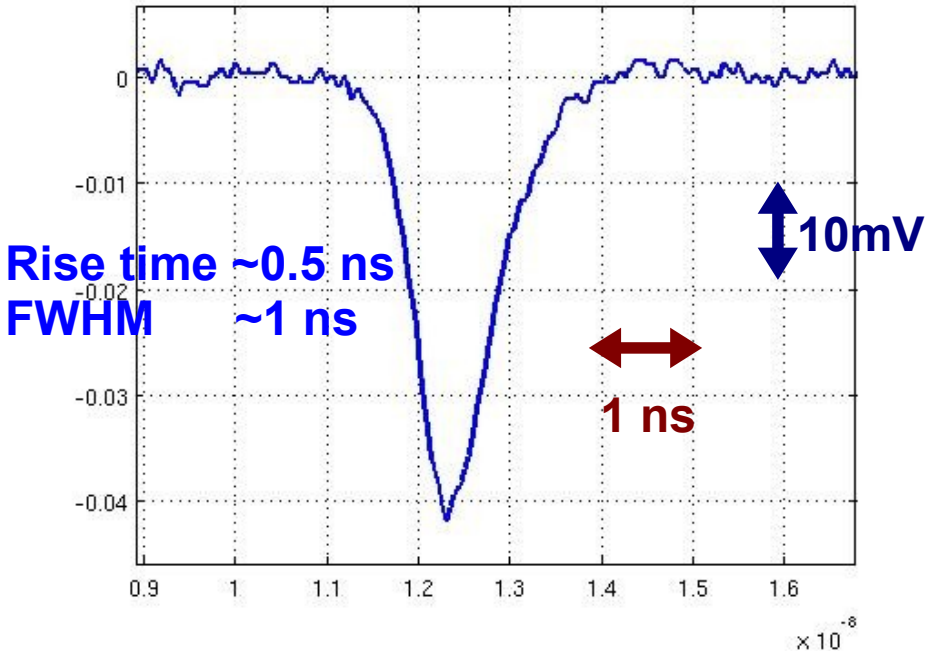


Timing analysis approach

- Fit rising edge
- Use constant fraction discriminant

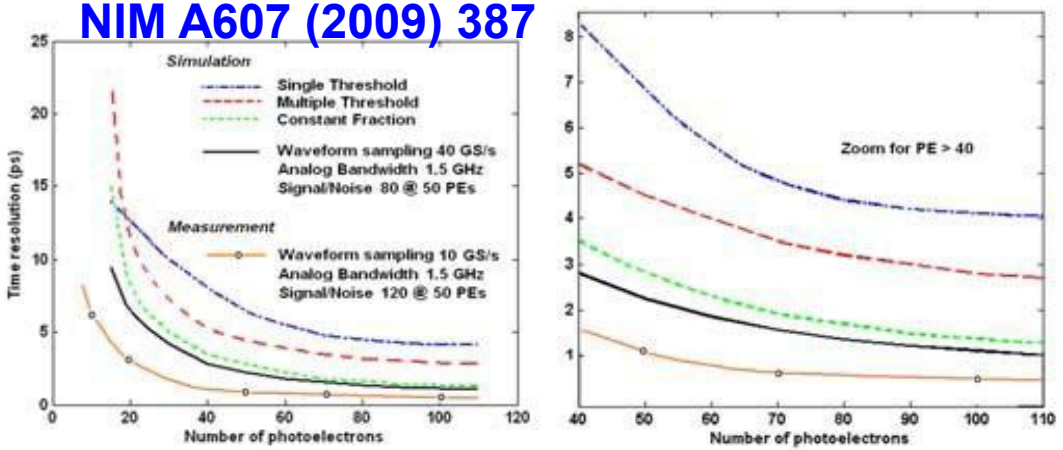
Questions

- Time resolution
- Position resolution

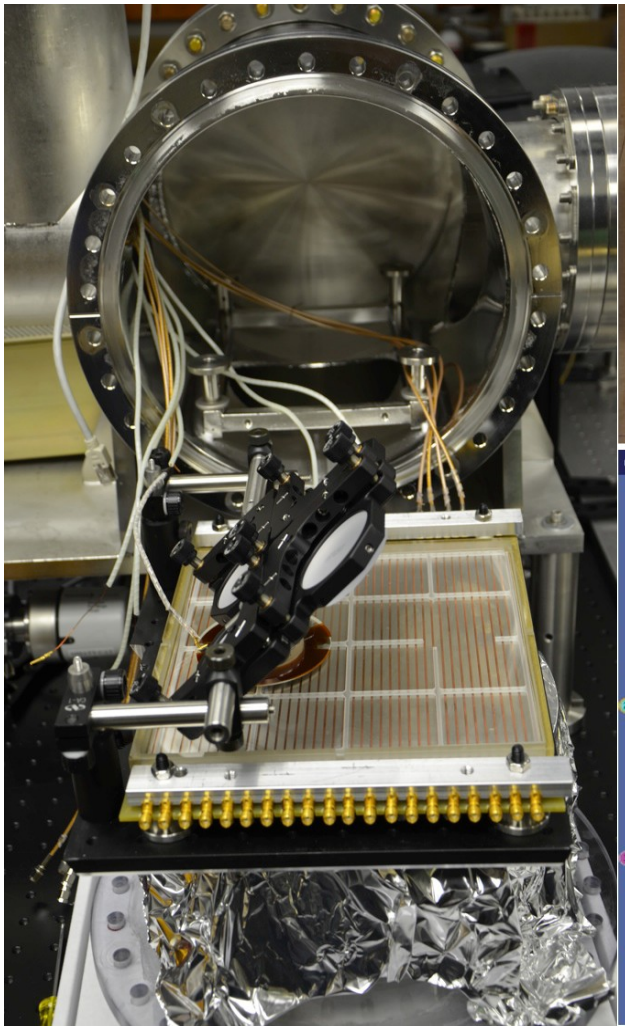
Time resolution determinants:

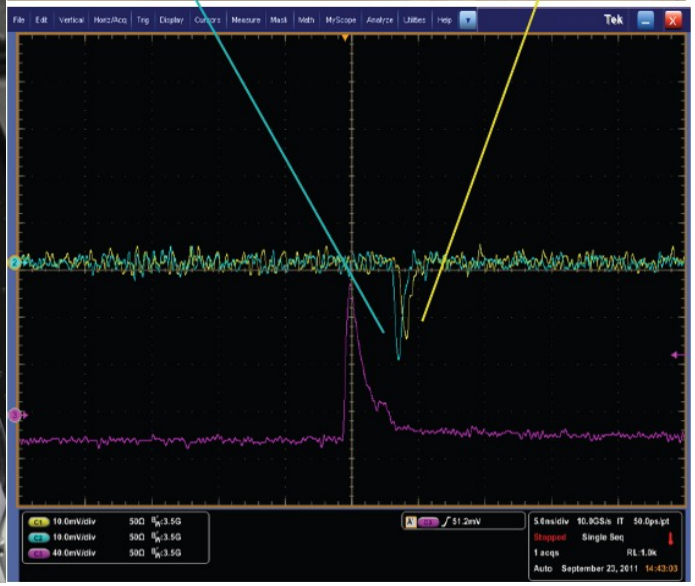
1) Signal to noise
2) Analog Bandwidth
3) Sampling rate
4) Signal statistics

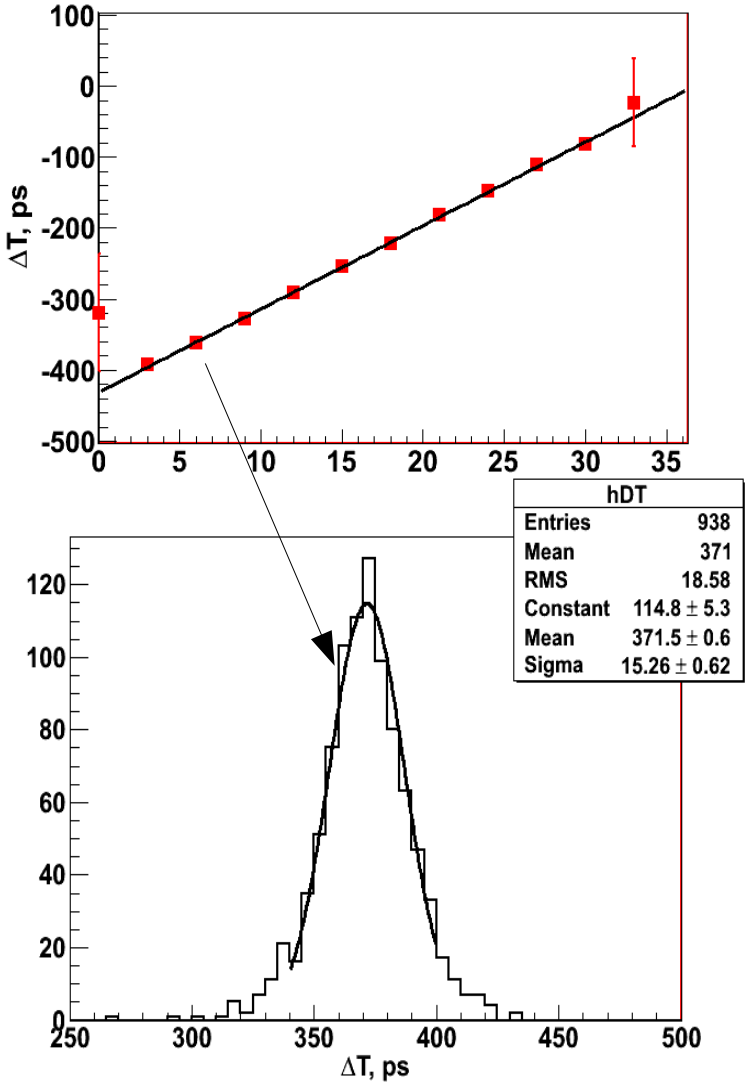
NIM A607 (2009) 387



First test with 8" setup





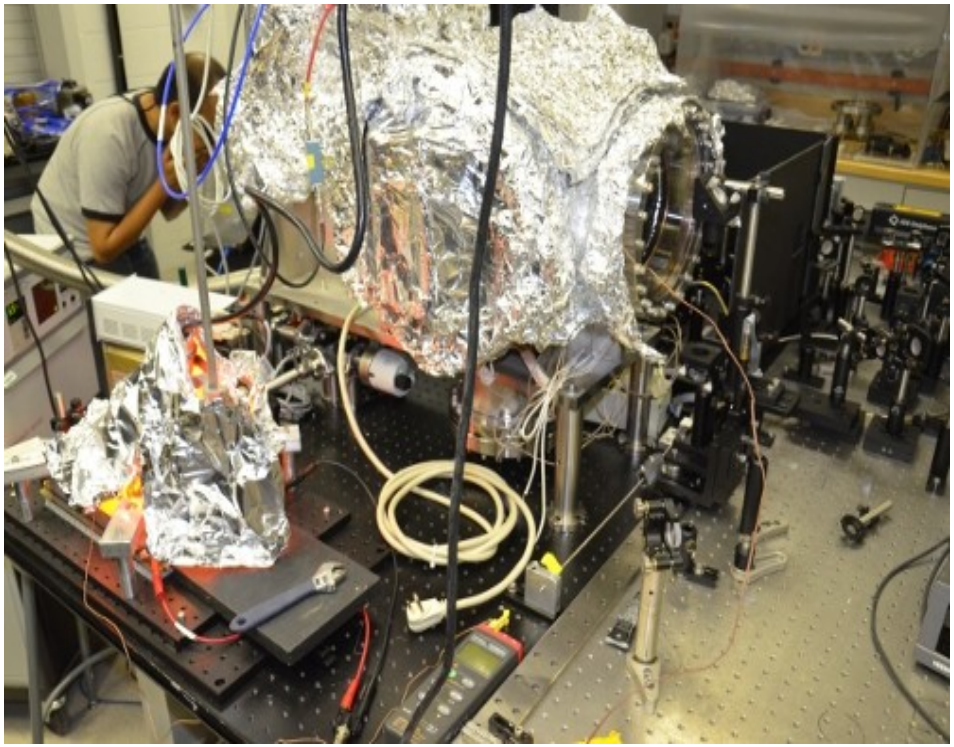


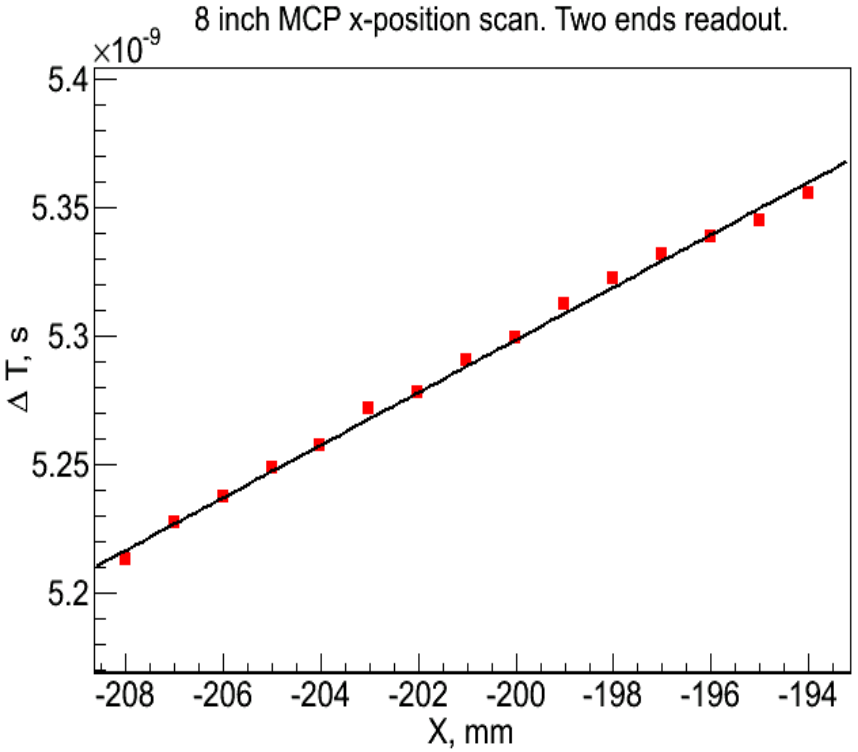
Slope 10ps/mm corresponds to 2/3 c signal propagation speed along the anode stripline

ΔT = 15ps

Position scan

automated translation stage capable of micron precision





Slope 10ps/mm corresponds to 2/3 c signal propagation speed along the anode stripline

ΔT = 15ps → ΔX = 1/2 ΔT 2/3c = 1.5mm

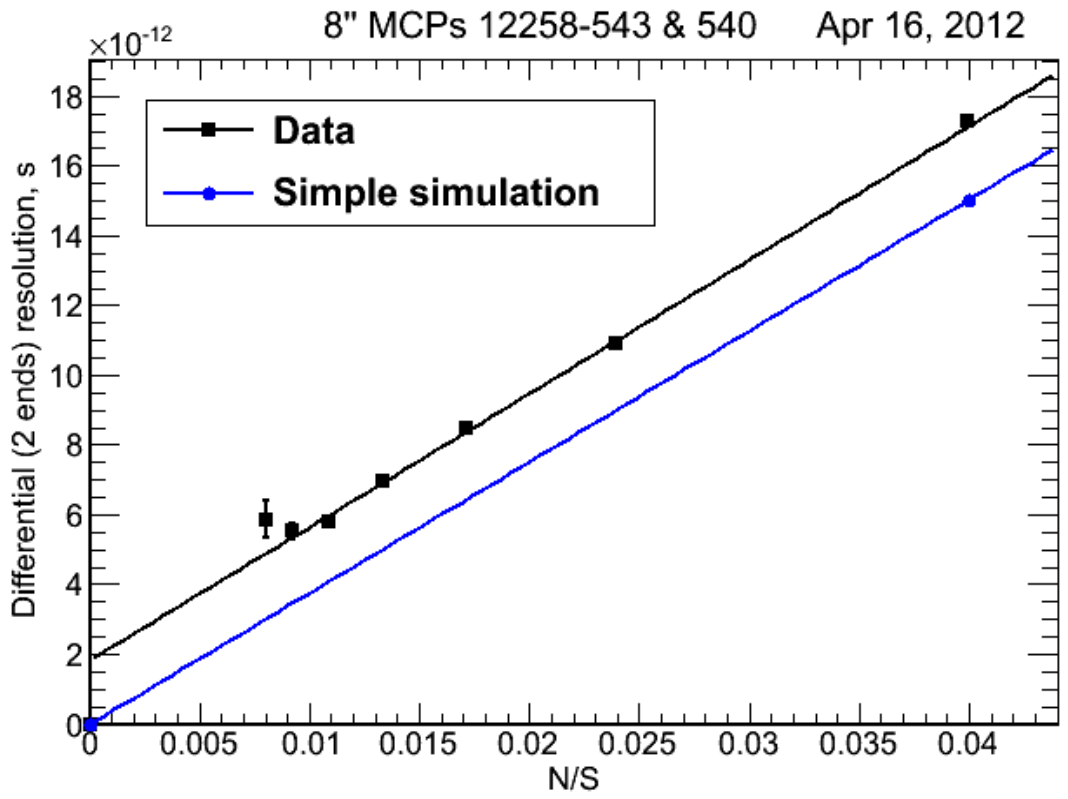
Differential time resolution

Simulation

- Generated pulses with fixed shape. 100 ps spacing between points to simulate 10Gs/s scope sampling
- Simulate noise: each point smeared with RMS = Amplitude*X%
- Noise is independent at each point

Data

- Pulses comes from MCP plates
- Noise is dominated by laser pockel-cell (deterministic noise)



6 ps in ΔT → 0.6 mm in ΔX

2 ps in ΔT → 200 microns (consistent with laser beam)

Single photo-electron regime

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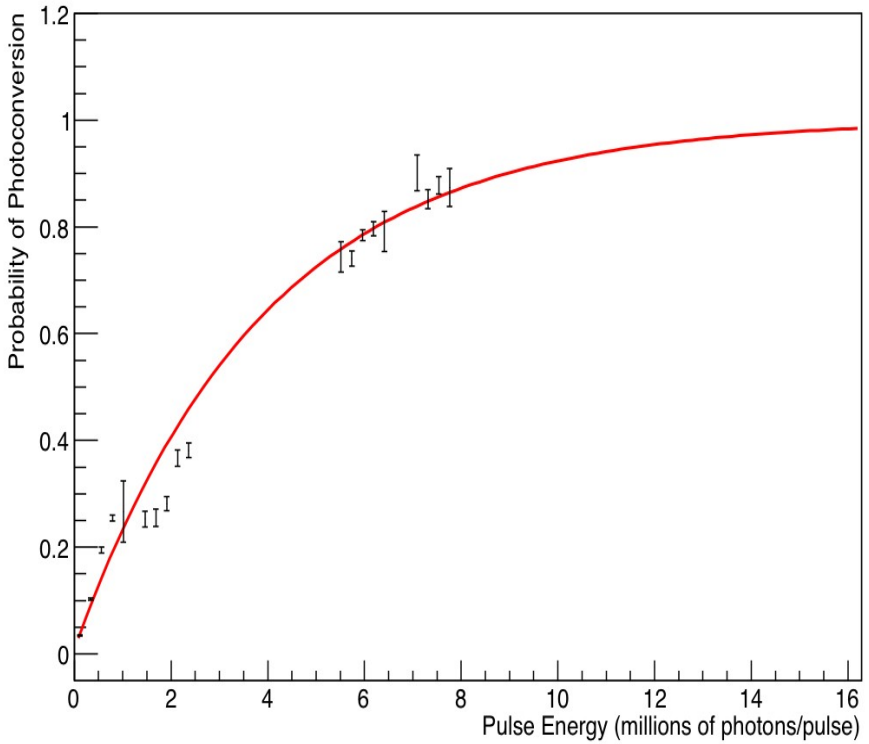

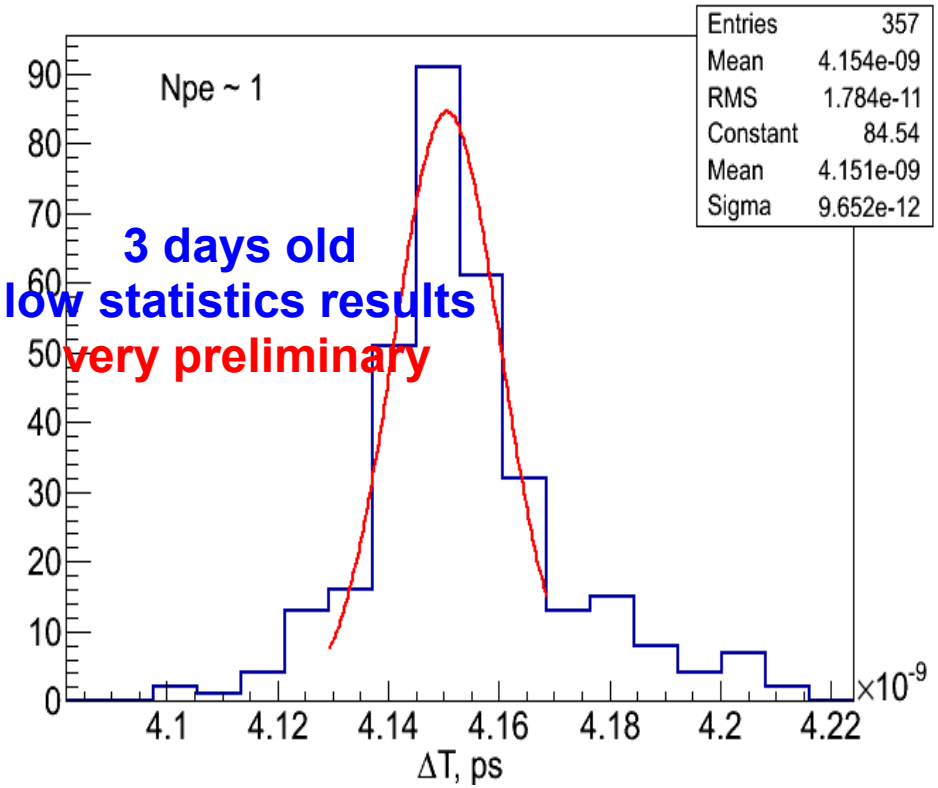

Demountable

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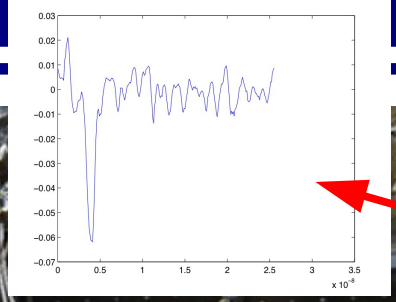
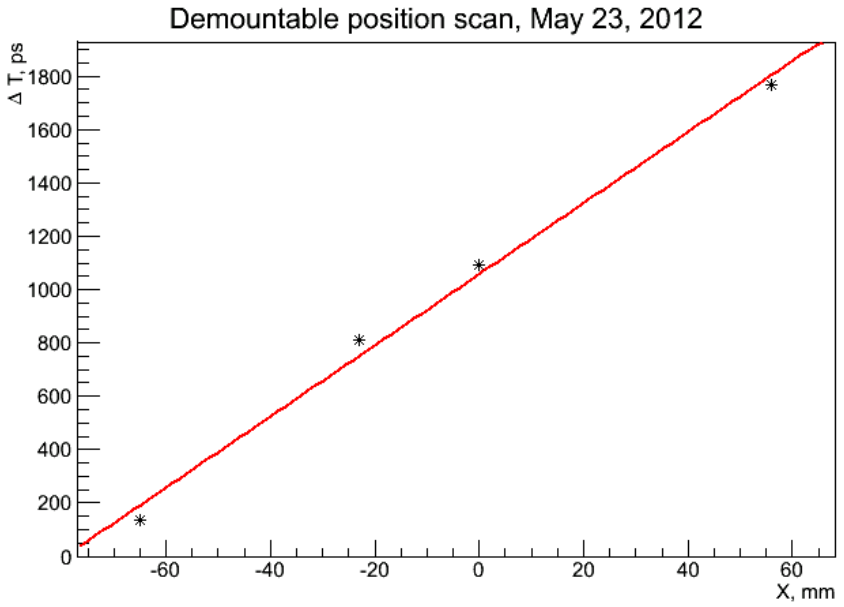


„Sealed tube“ prototype
- full vertical slice
- capable of data taking using LAPPD made electronics

What's different from final design
- active pumping
- aluminun photo-cathode



Limitations

Can we achieve sub-picoseconds?

Stefan Ritt slide

How is timing resolution affected?

$$\Delta t = \frac{\Delta u}{U} \cdot \frac{1}{\sqrt{3 f_s \cdot f_{3dB}}}$$

•Assumes zero aperture jitter

	U	Δu	f_s	f_{3dB}	Δt
•today:	100 mV	1 mV	2 GSPS	300 MHz	~10 ps
•optimized SNR:	1 V	1 mV	2 GSPS	300 MHz	1 ps
•next generation:	100 mV	1 mV	20 GSPS	3 GHz	0.7 ps
•next generation •optimized SNR:	1V	1 mV	10 GSPS	3 GHz	0.1 ps

•How to achieve this?

•includes detector noise in the frequency region of the rise time
•and aperture jitter

Stefan Ritt slide
UC workshop 4/11

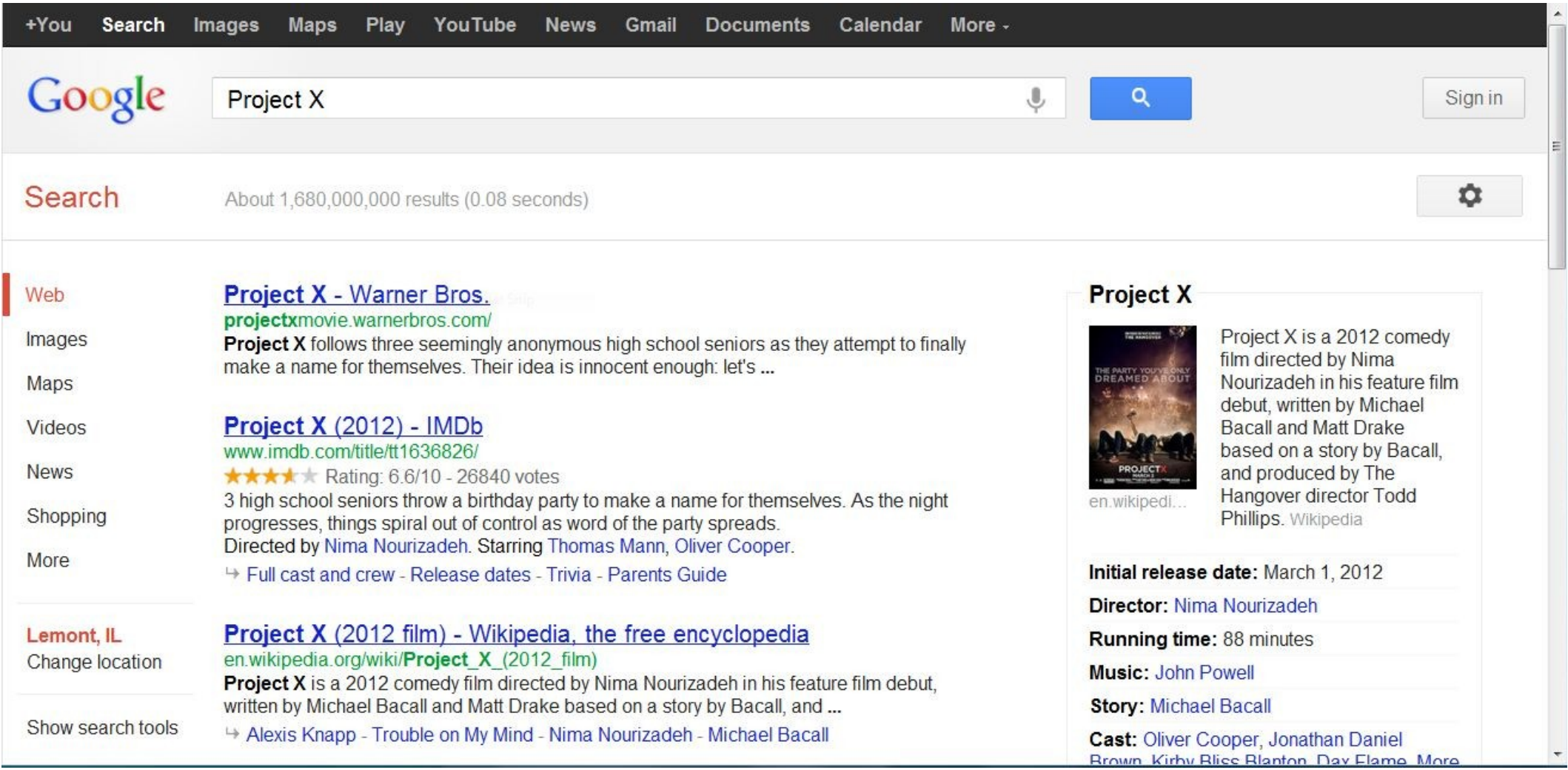
Conclusions and Outlook

University of Chicago

- Approaching picosecond domain on large area
- Demountable prototype shows very promissing performance
- Working on better tools (beam spot, signal to noise, etc) and algorithms (template fitting) to achive ultimate timing performance
- Watch us on the web:
  project web-page: http://psec.uchicago.edu/
  regular updates on the blog: http://psec.uchicago.edu/blogs/lappd/

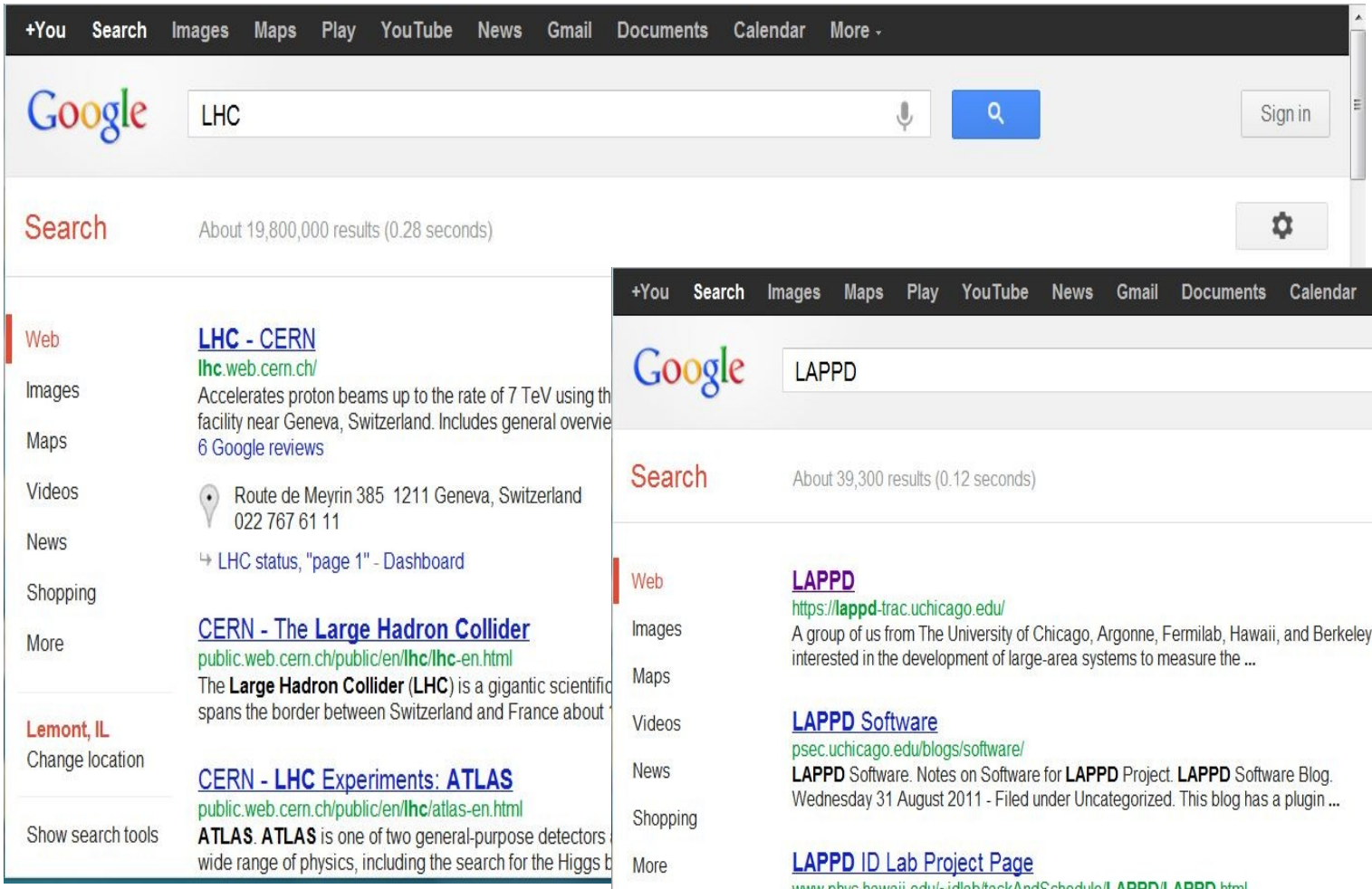
Back-up

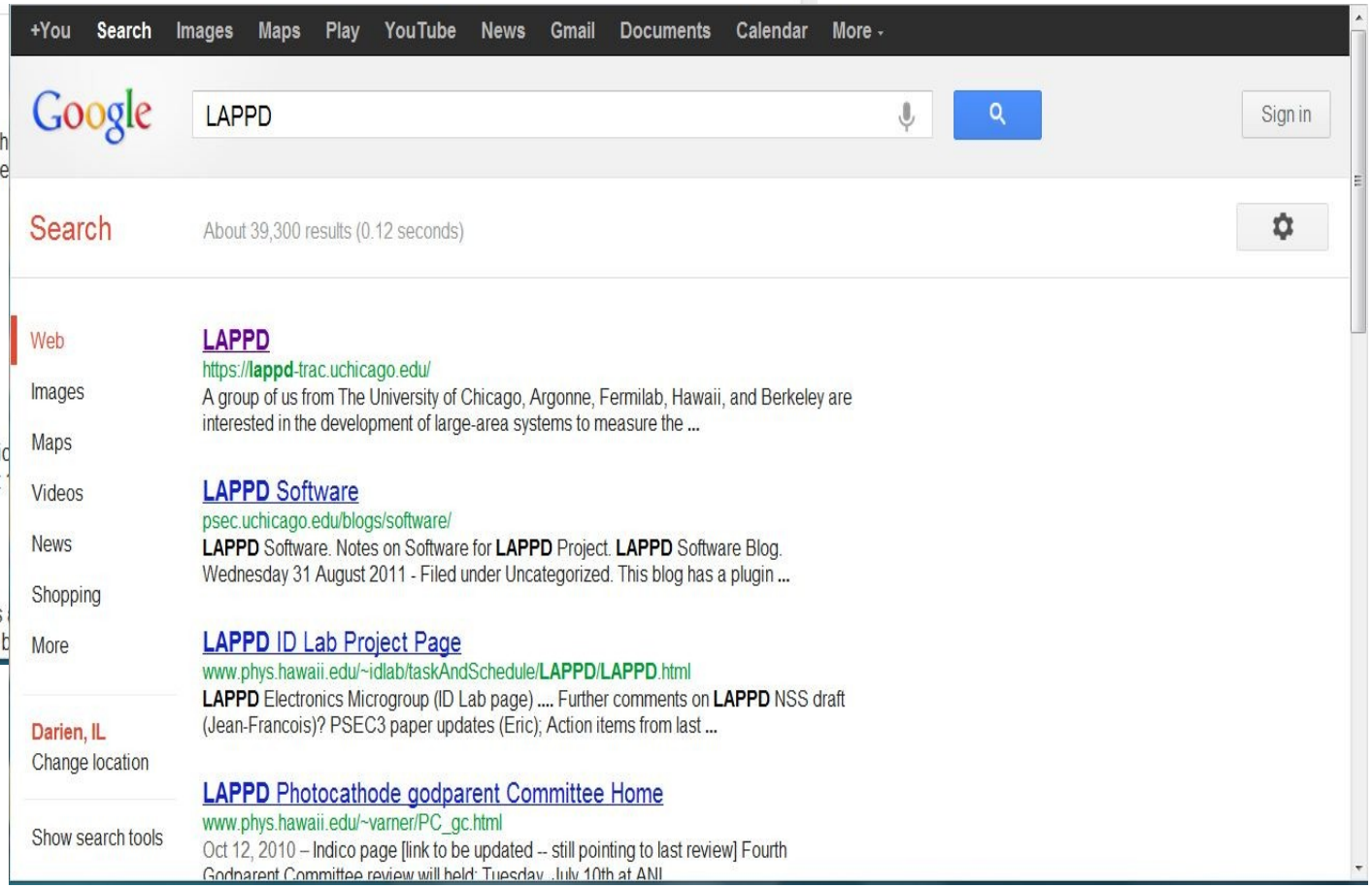
Project X


+You Search Images Maps Play YouTube News Gmail Documents Calendar More
Google
Project X
Sign in
Search
About 1,680,000,000 results (0.08 seconds)
Web
Images
Maps
Videos
News
Shopping
More
Lemont, IL
Change location
Show search tools
Project X - Warner Bros.
projectxmovie.warnerbros.com/
Project X follows three seemingly anonymous high school seniors as they attempt to finally make a name for themselves. Their idea is innocent enough: let's ...
Project X (2012) - IMDb
www.imdb.com/title/tt1636826/
Rating: 6.6/10 - 26840 votes
3 high school seniors throw a birthday party to make a name for themselves. As the night progresses, things spiral out of control as word of the party spreads.
Directed by Nima Nourizadeh. Starring Thomas Mann, Oliver Cooper.
Full cast and crew - Release dates - Trivia - Parents Guide
Project X (2012 film) - Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/Project_X_(2012_film)
Project X is a 2012 comedy film directed by Nima Nourizadeh in his feature film debut, written by Michael Bacall and Matt Drake based on a story by Bacall, and ...
Alexis Knapp - Trouble on My Mind - Nima Nourizadeh - Michael Bacall
Project X
en.wikipedi...
Project X is a 2012 comedy film directed by Nima Nourizadeh in his feature film debut, written by Michael Bacall and Matt Drake based on a story by Bacall, and produced by The Hangover director Todd Phillips. Wikipedia
Initial release date: March 1, 2012
Director: Nima Nourizadeh
Running time: 88 minutes
Music: John Powell
Story: Michael Bacall
Cast: Oliver Cooper, Jonathan Daniel

Named Projects (large and not so)

University of Chicago





Hermetic packaging

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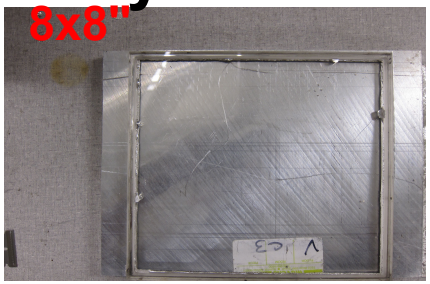
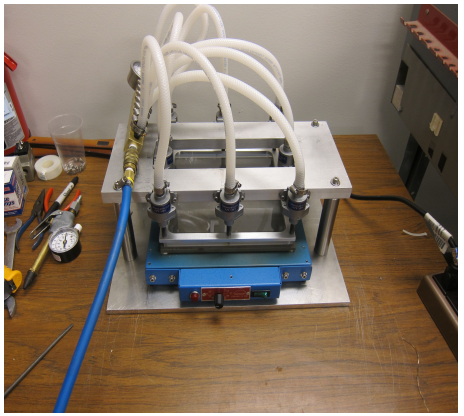
1) Glass sidewall over the anode plane: solved by frit sealing
2) Top window over the full vertical slice: work in progress

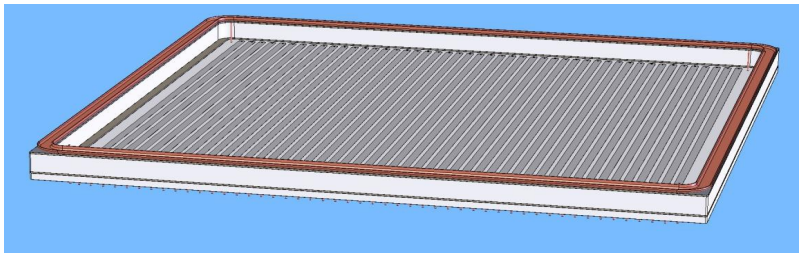
Primary path for the top seal: indium seal

ANL & UChicago effort glass body





Production Facility at SSL/UCB ceramic body



Parallel path: learn from industry (there are plenty vacuum sealed products around)