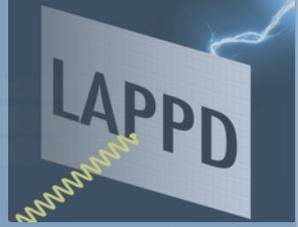




University of Chicago



# MCP Systems Testing at ANL

B Adams, M Chollet, A Elagin, H Frisch, R Obaid, E Oberla,  
A Vostrikov, B Wagner, P Webster, M Wetstein

J Elam, A Mane

S Jokela, I Veryovkin, A Zinovev

V Ivanov, Z Insepov

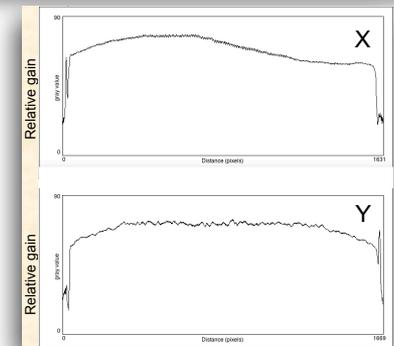
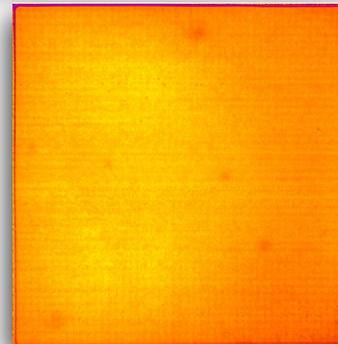
J Gregar, R Metz, R Northrop, D Walters, J Williams

JF Genat, E May

O Siegmund, J McPhate

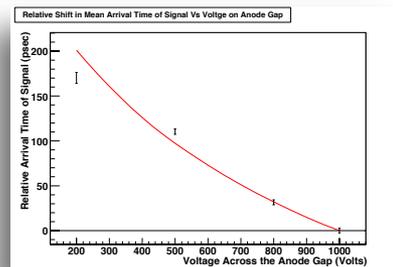
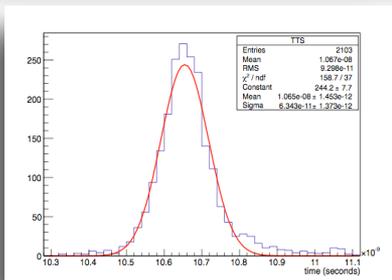
## Berkeley SSL

- Wide variety of resources with special emphasis on very fine (micron-level) imaging capabilities
- Able to quickly and accurately map out gain uniformity, dark noise, hot spots.
- Particular focus on ceramic-body LAPPD design:
  - MCPs with resistive gridspacers
  - ceramic packaging
  - stripline anodes
  - U Hawaii electronics



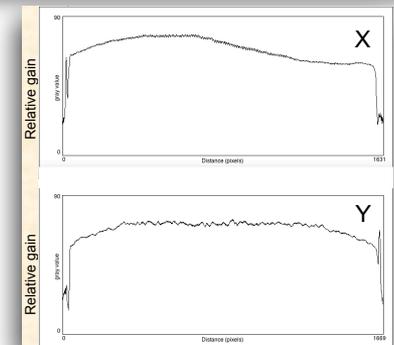
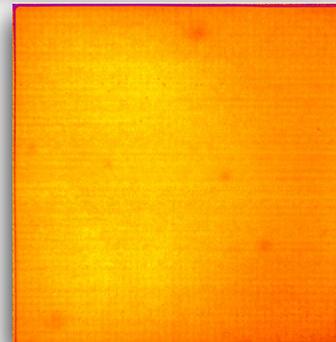
## ANL Laser Facility

- Fast laser, uniquely suited to perform precision timing measurements
- Able to measure jitter in MCP time response referenced to the sub-picosecond laser pulses.
- Developed for testing components of the “frugal”, glass-body LAPPD design:
  - MCPs with resistive gridspacers
  - glass packaging
  - stripline anodes
  - U Chicago electronics



## Berkeley SSL

- Wide variety of resources with special emphasis on very fine (micron-level) imaging capabilities
- Able to quickly and accurately map out gain uniformity, dark noise, hot spots.
- Particular focus on ceramic-body LAPPD design:
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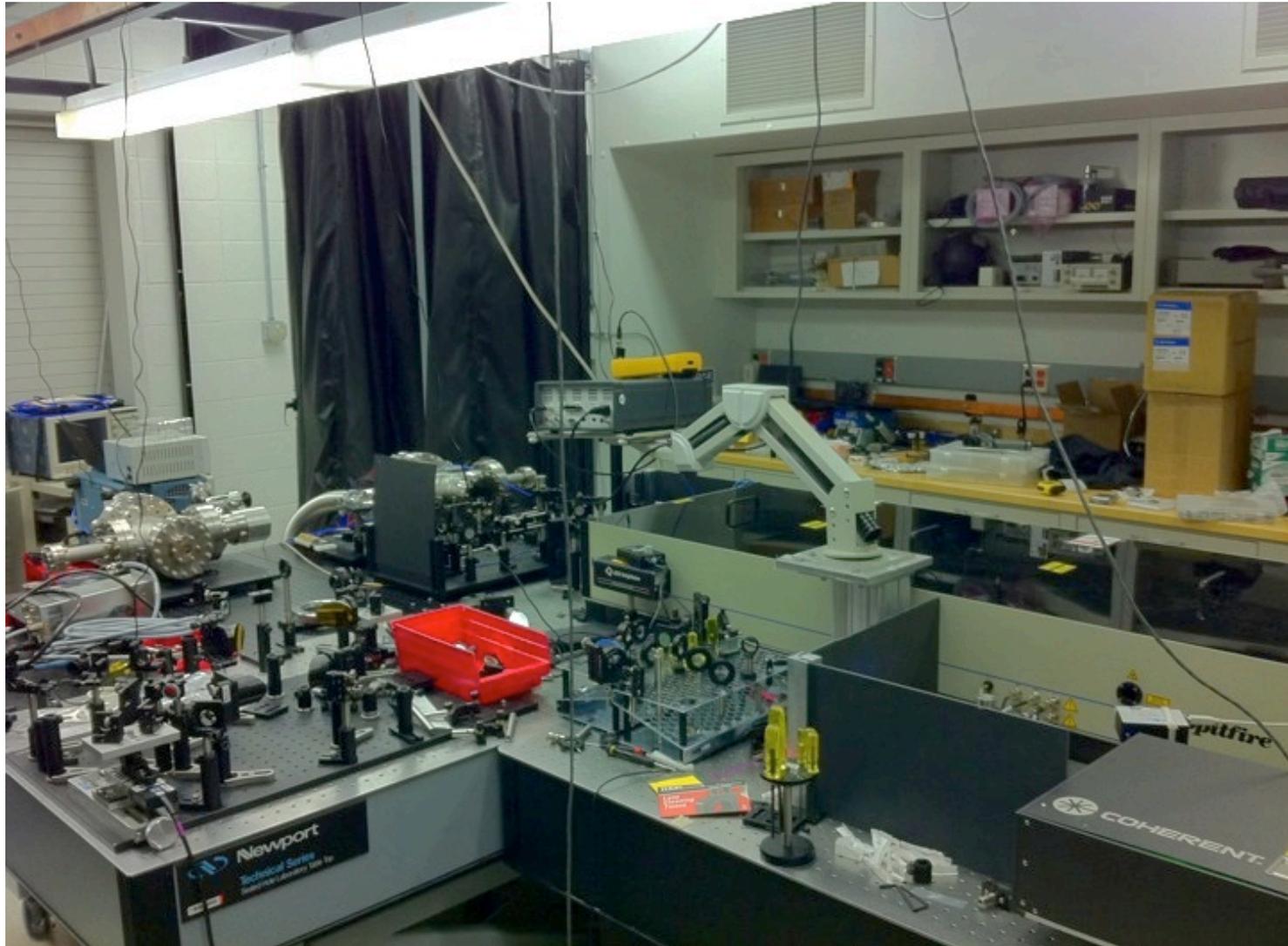




# What we've built

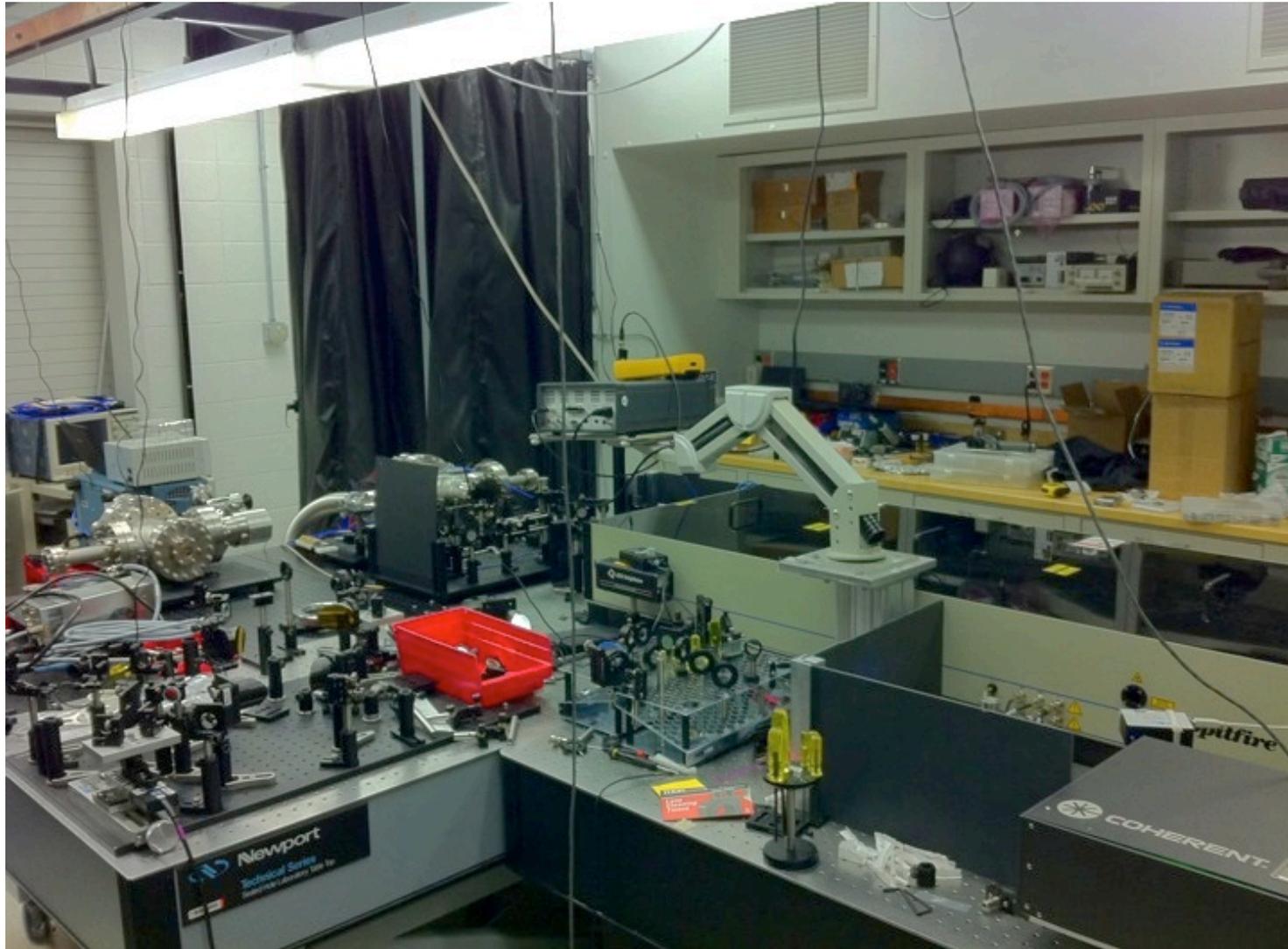


# What we've built



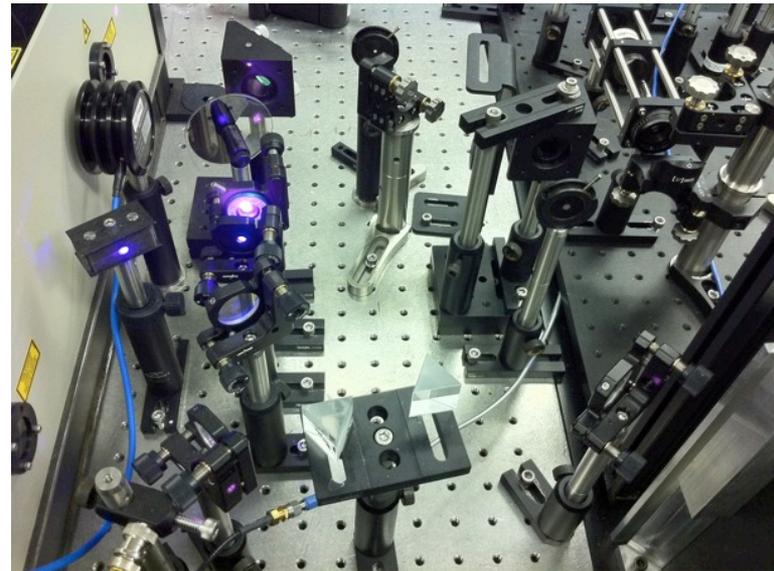
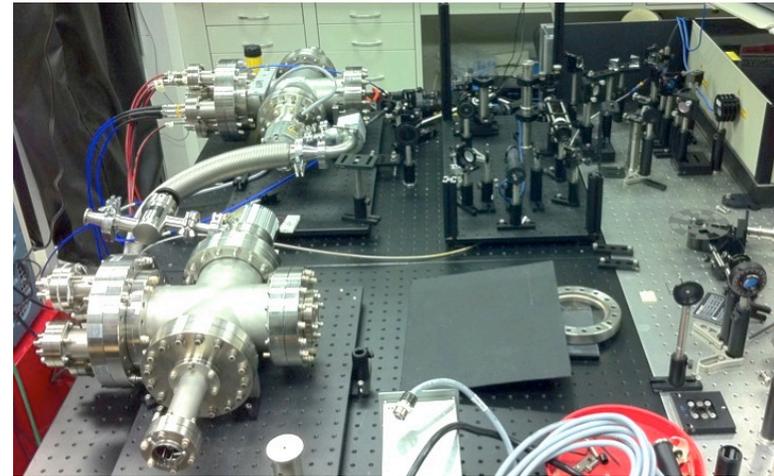
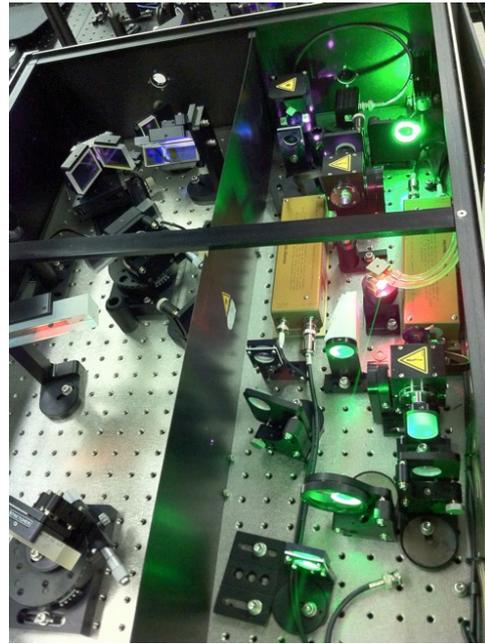
# What we've built

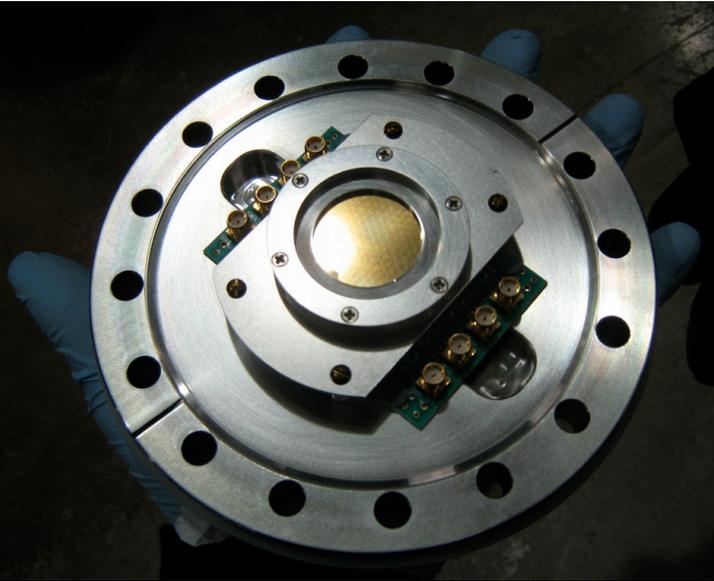
Final draft of paper to be submitted to Review of Scientific Instrumentation to be submitted this month



# What we've built

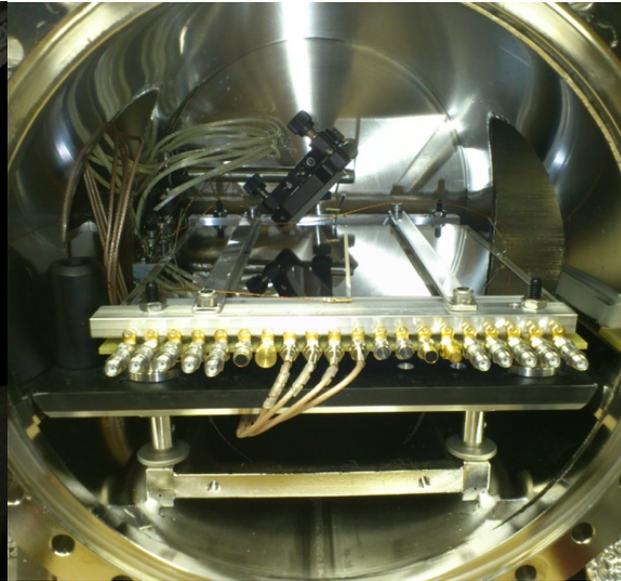
- A fast (sub-psec), pulsed laser with precision UV optics, capable of
  - Precision timing measurements using the laser as an external trigger
  - Finding single-PE mode by attenuating laser to the point where only a small fraction of pulses produce any signal
  - capable of illuminating small spots on the MCP (potentially single pores)
- multi-GHz RF electronics
  - several oscilloscopes with 3–10 Gz analog bandwidth
  - high gain, low noise RF amplifiers
  - high-frequency splitters, filters, etc
- Vacuum systems for testing various detector components
- Capability for testing sealed tubes





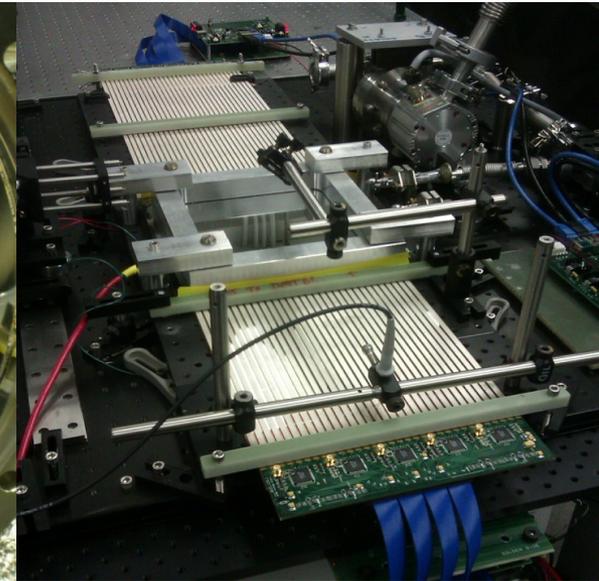
## 33mm Testing

- Operational experience
- Testing fundamental properties of MCPs
- Study wide variety of sample prototypes



## 8" Testing

- Demonstrate working 8" MCPs
- Test near complete detector systems with realistic anode
- Optimize and measure key resolutions



## Complete detector systems

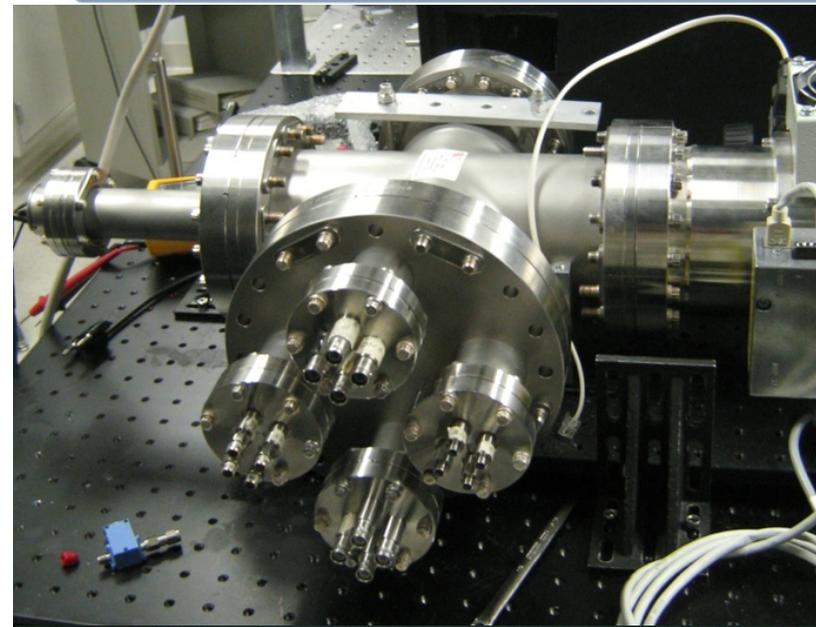
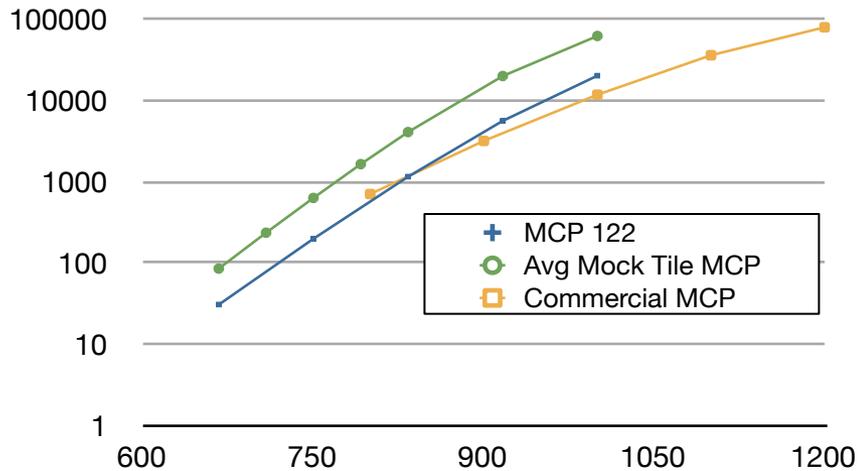
- Demonstrate complete sealed-tube detector
- Study characteristics of 80cm anode
- Test integrated front-end electronics in fully operational conditions

# 33 mm Testing Program



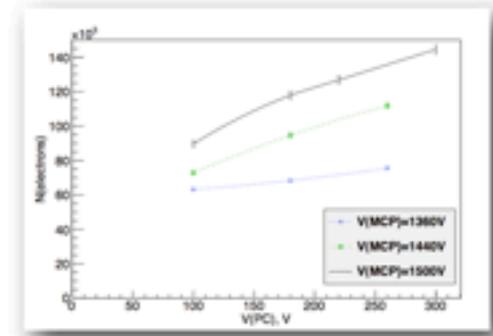
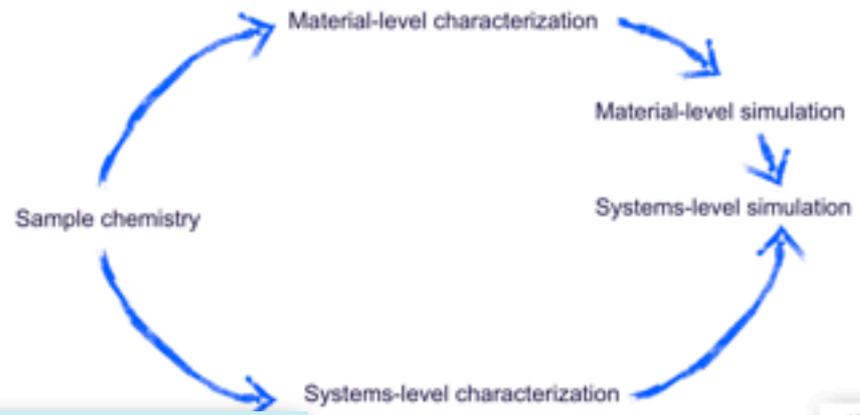
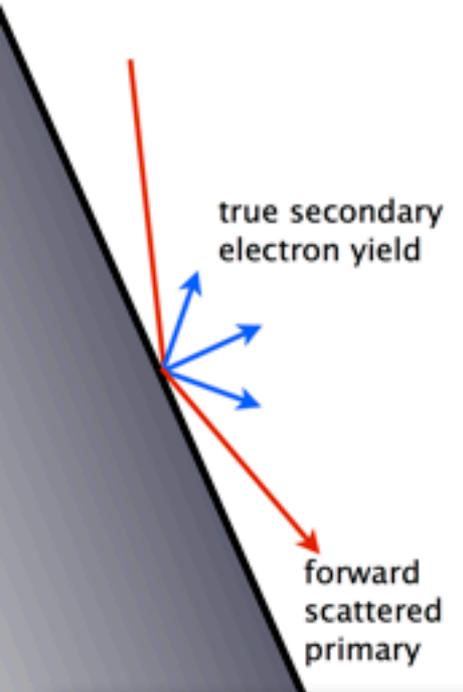
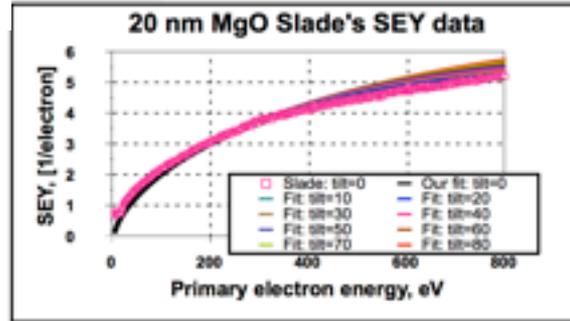
## 33mm Program

- Played a critical role in demonstrating our LAPPD, ALD-MCPs
- Also critical in developing operational experience and refining our measurement techniques
- 33mm format with ALD coating enables low cost, rapid testing of many MCP designs/chemistries/parameters for comparison with simulations

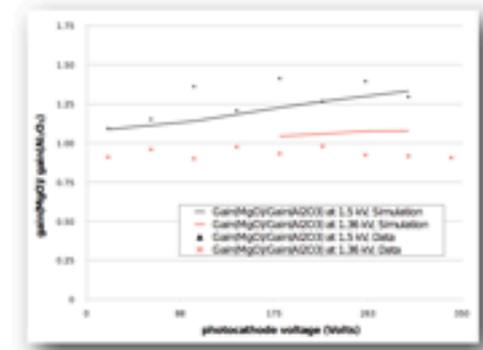
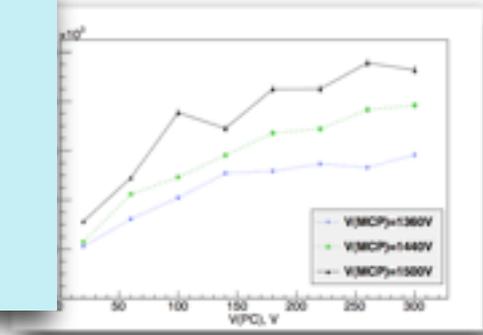


# 33mm Program – Achievements

S. Jokela, Z. Insepov



V. Ivanov



- We've done much work with matching first-principles MCP simulations with data for a variety of MCP materials and parameters.
- Draft of a paper is in internal review

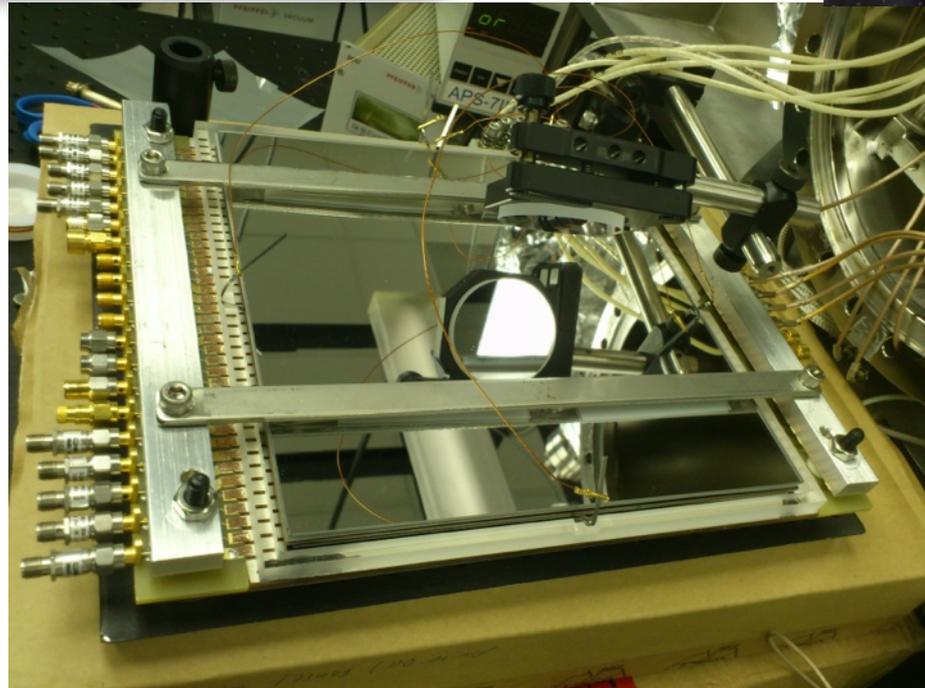
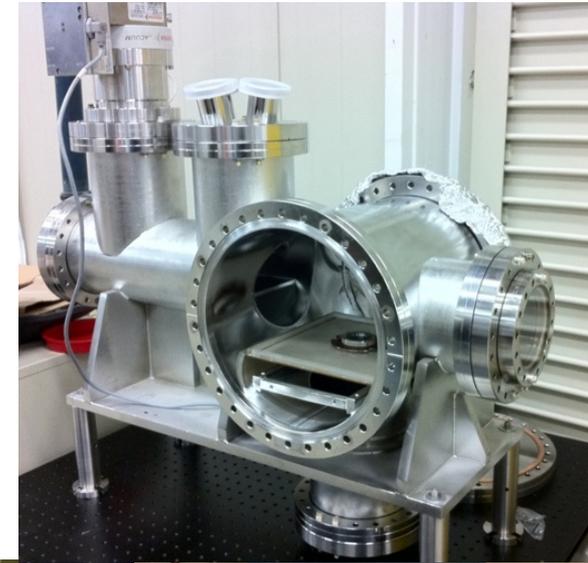


# 8" Testing Program



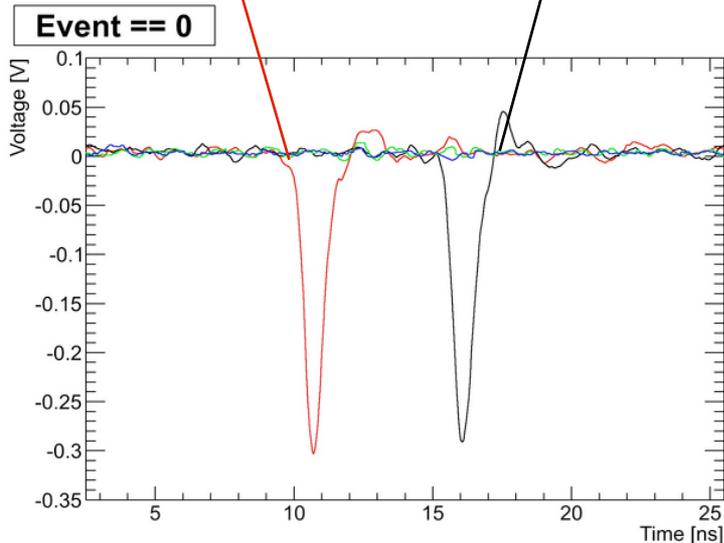
## 8" Program

- To demonstrate full-sized detector systems.
- To study operation with the “frugal anode” design (silk-screened silver microstrip delay lines)
- To benchmark some of the key resolutions to be expected in sealed-glass LAPPDs

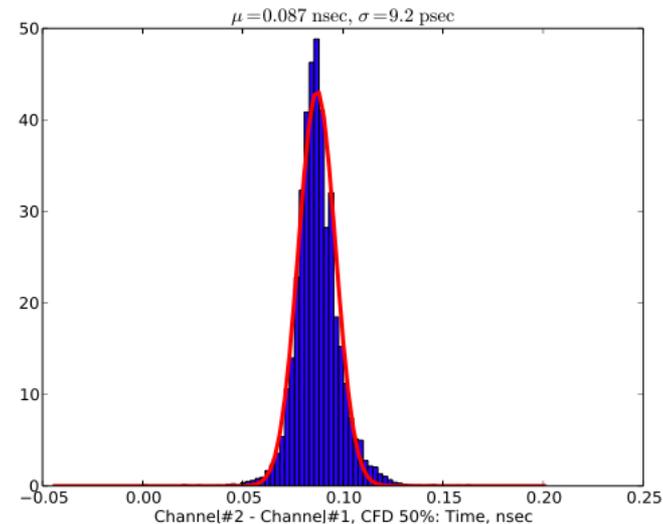
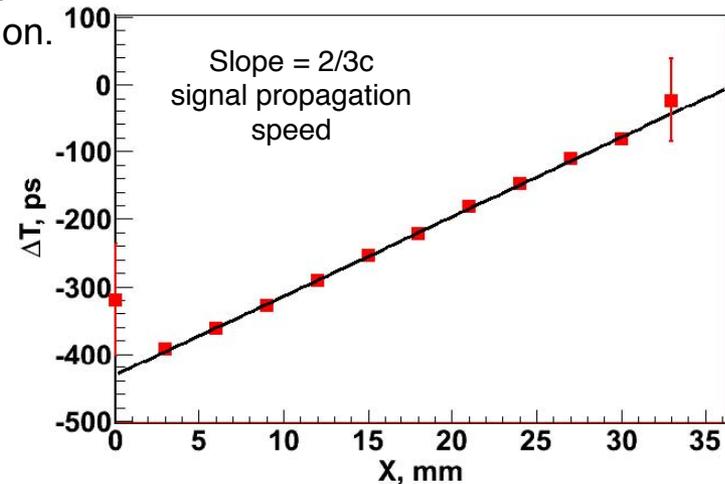


# 8" Program

Photon position is determined by signal centroid in the transverse direction and difference in signal arrival time in the parallel direction.



Difference in arrival time as a function of laser position



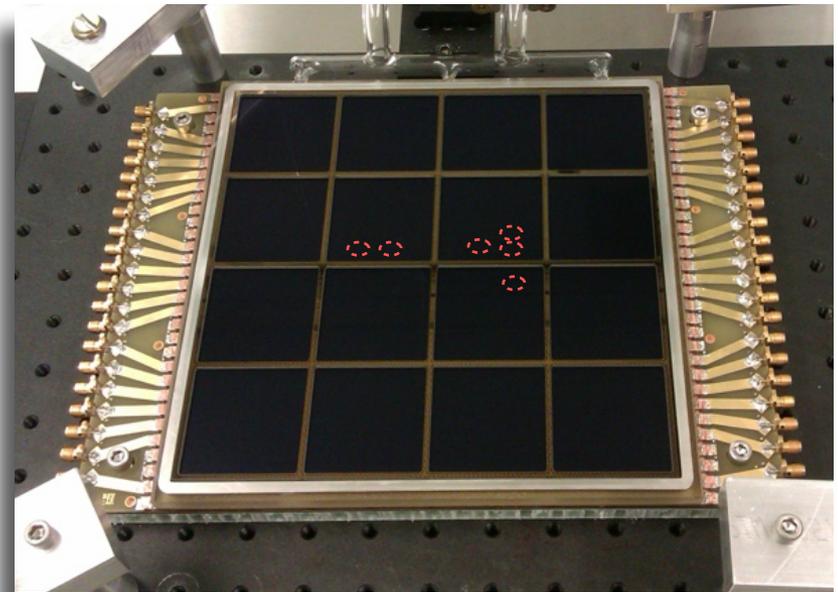
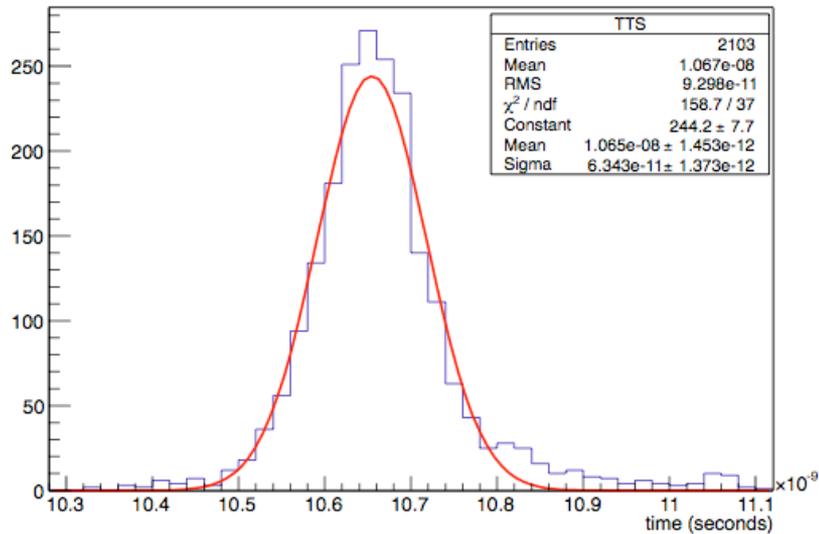
Differential time resolution  
between two ends of an optimized  
anode ( $\sim 10$  PE):  $\sim 9$  psec ( $\sim 1$ mm)

Best Single-PE time resolution for 8" x 8"  
economical, large-area anode:

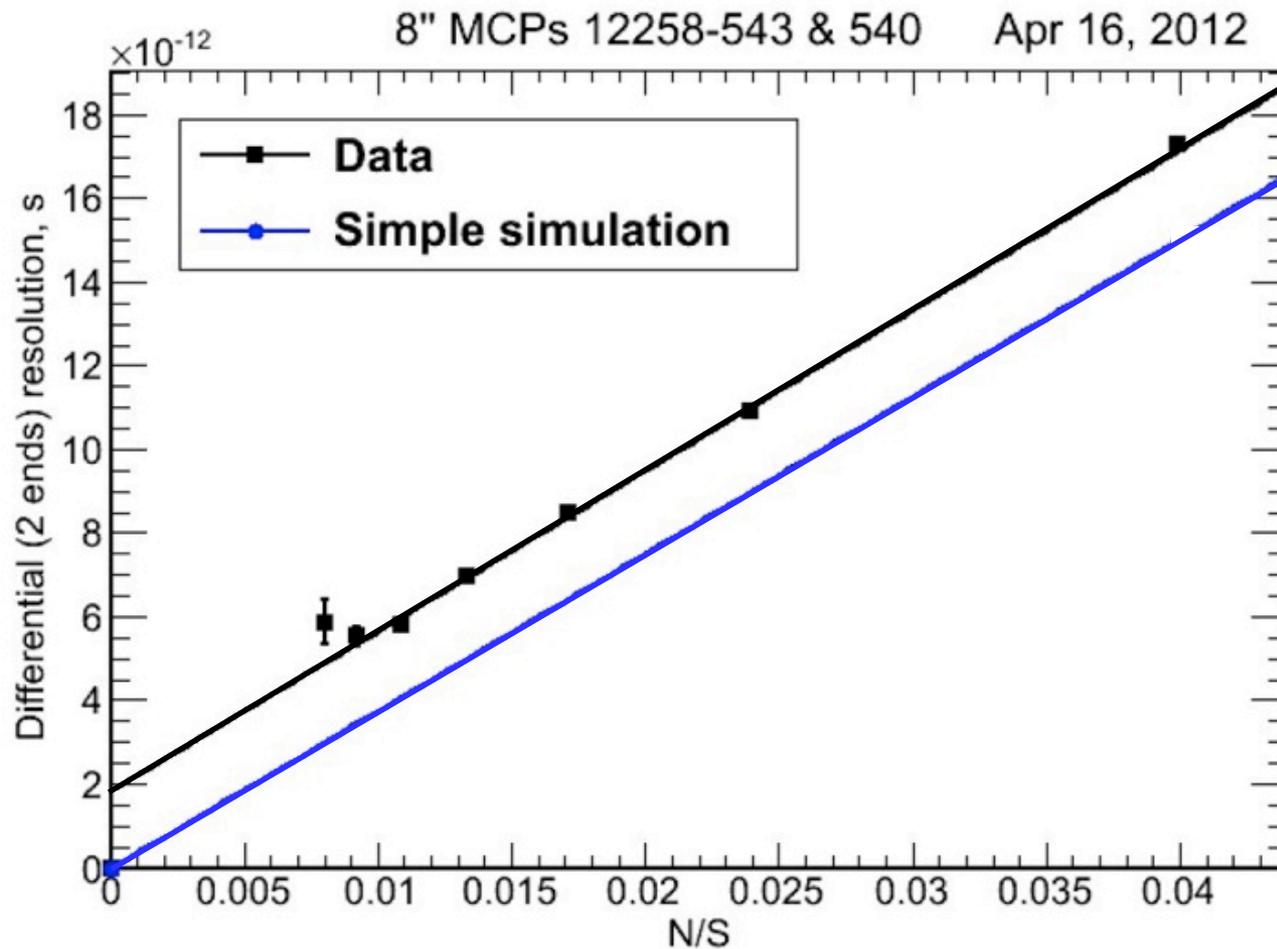
**~63 psec**

Single PE time resolutions at many  
positions on the 8" MCPs

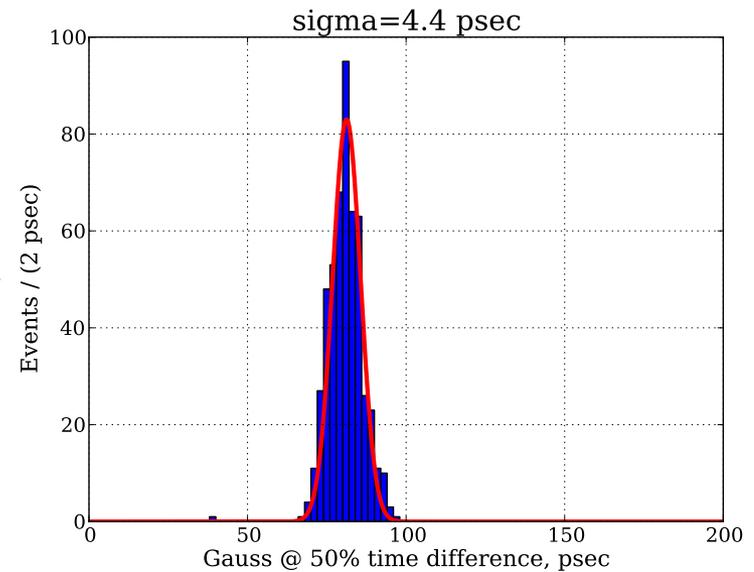
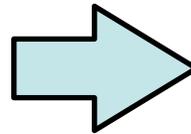
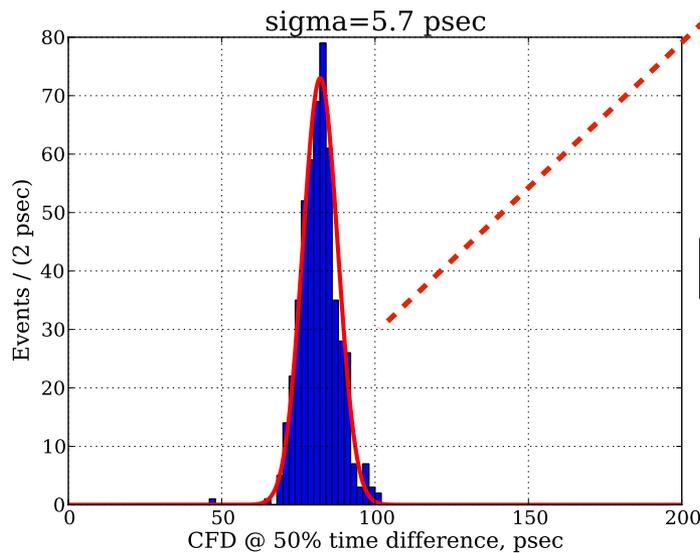
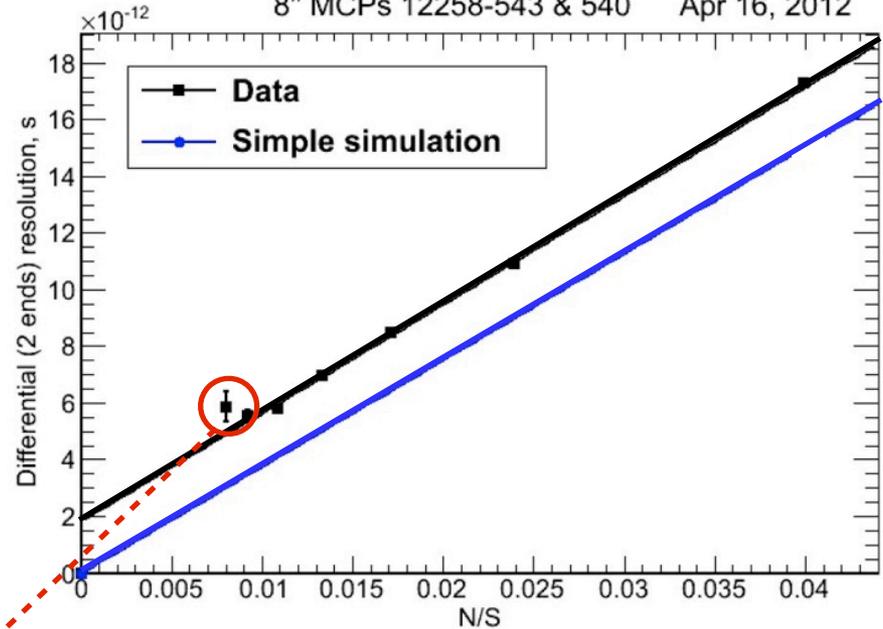
**Consistently better than 80  
picoseconds**



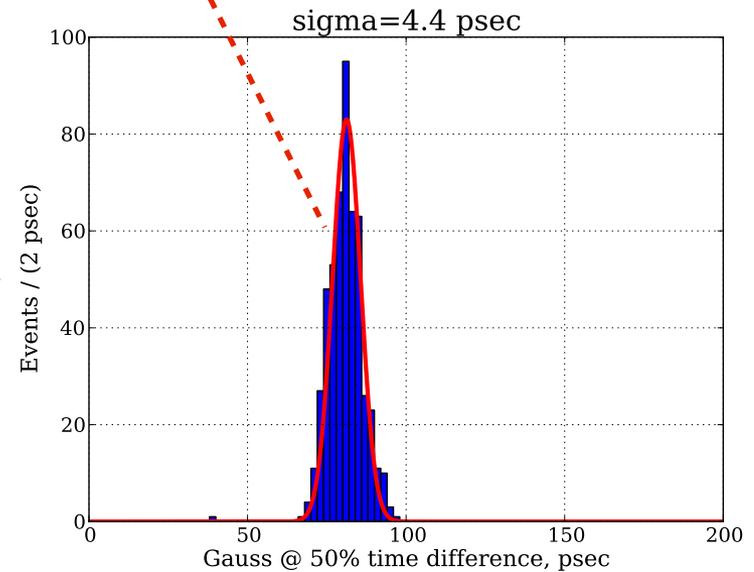
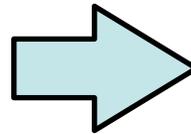
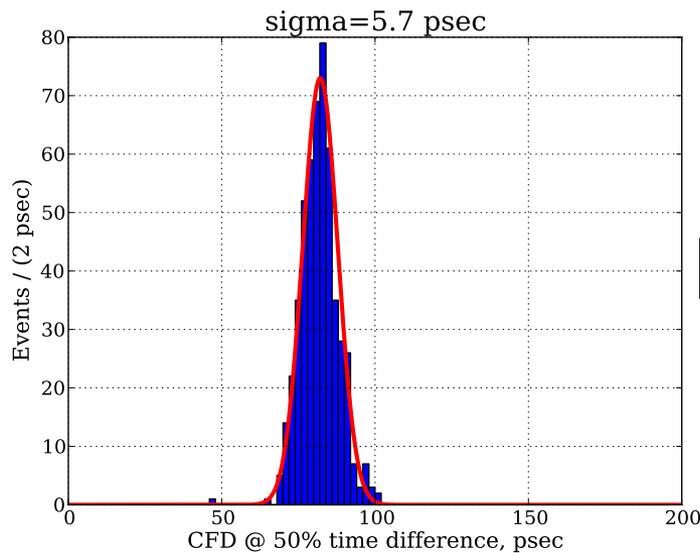
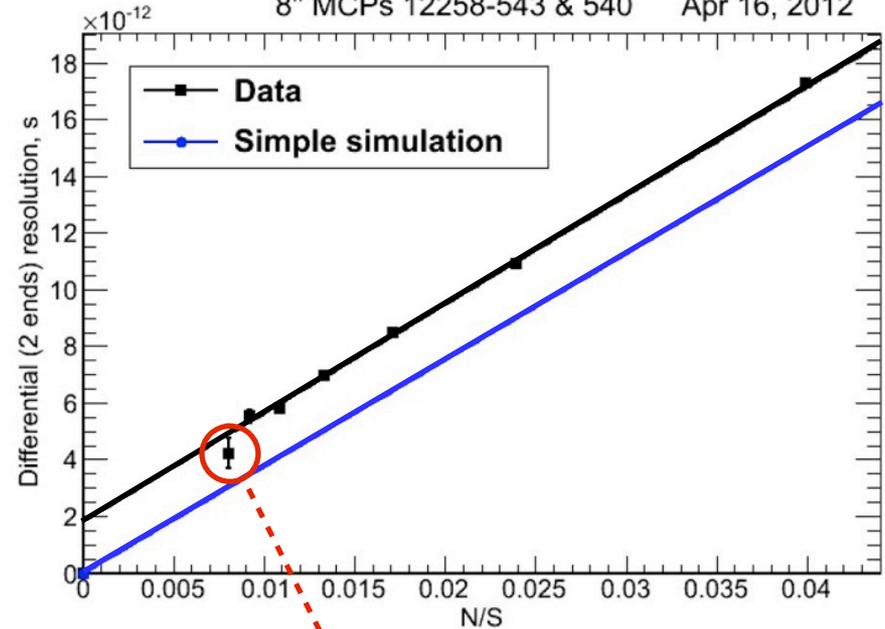
With large signals from many photoelectrons (approaching those expected in collider applications), differential timing approaches few picosecond levels.



With improved fitting to the rising edge of the MCP pulses, we reconstruct an even narrower TTS!

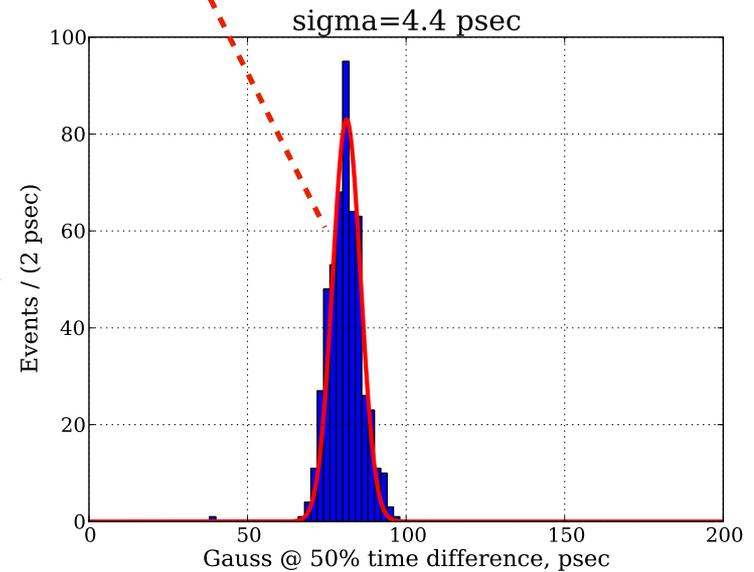
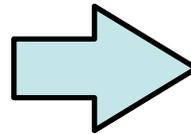
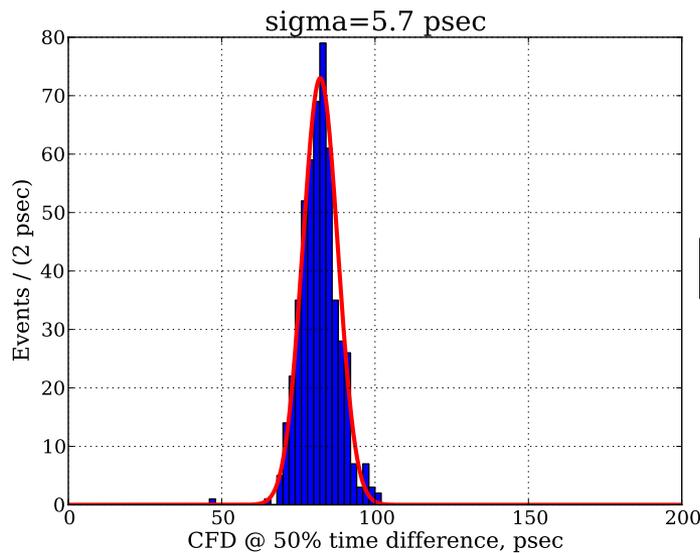
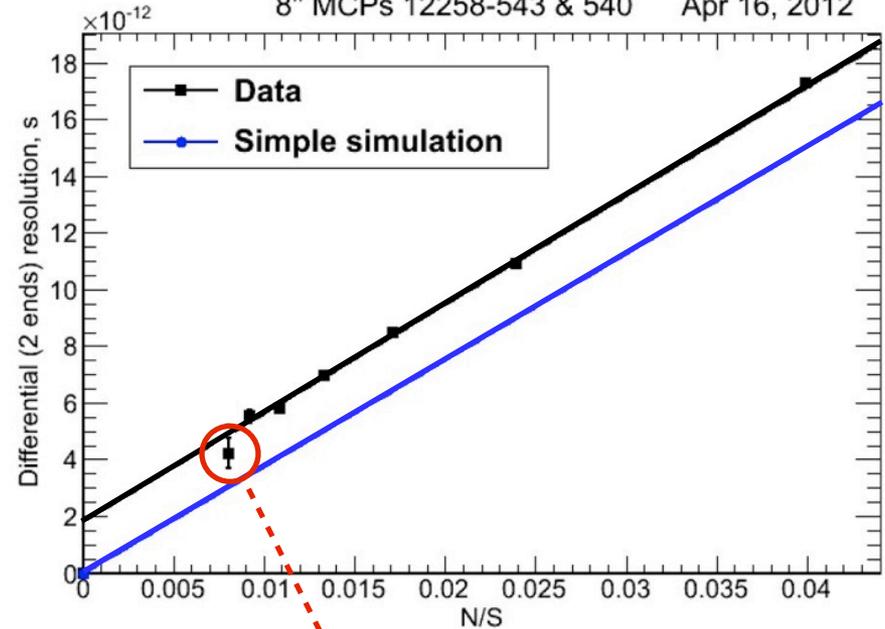


With improved fitting to the rising edge of the MCP pulses, we reconstruct an even narrower TTS!

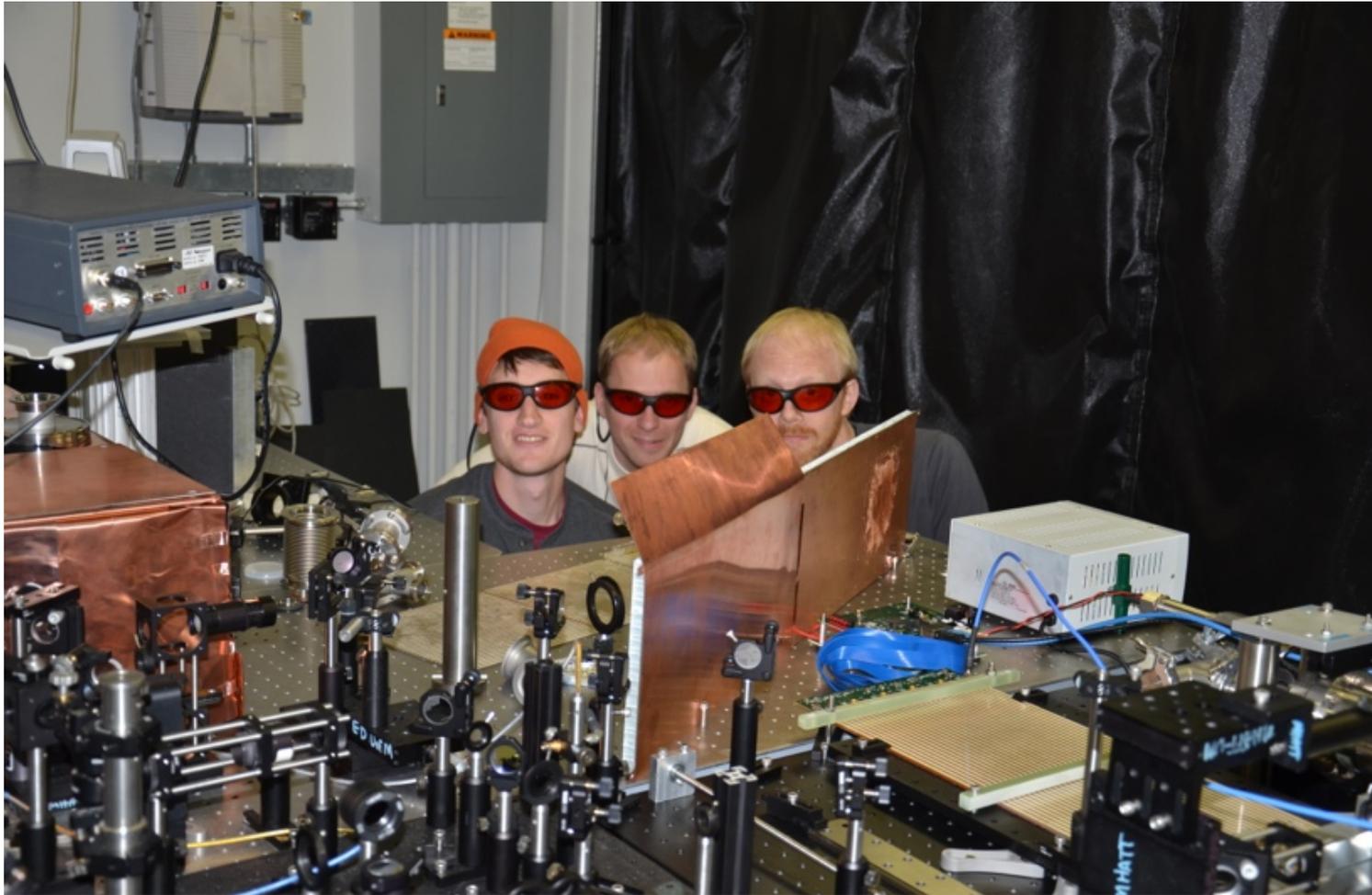


With improved fitting to the rising edge of the MCP pulses, we reconstruct an even narrower TTS!

Currently editing the rough draft of a NIM paper on first 8"x8" results

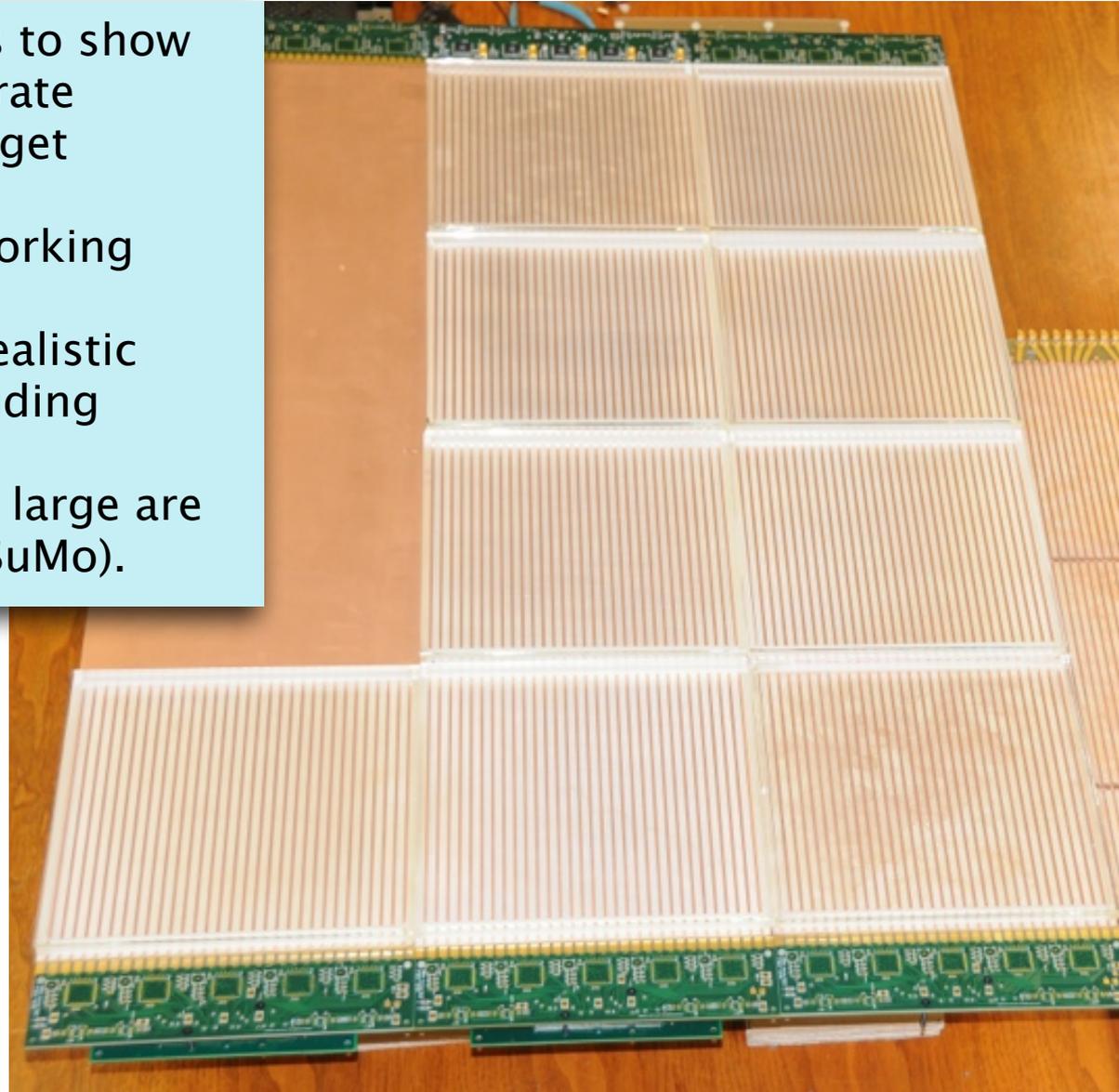


# Complete Detector Testing



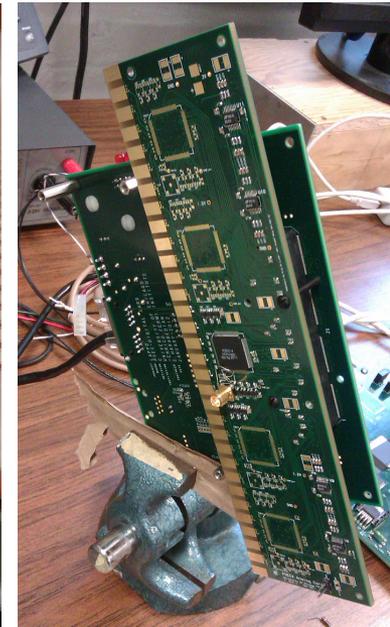
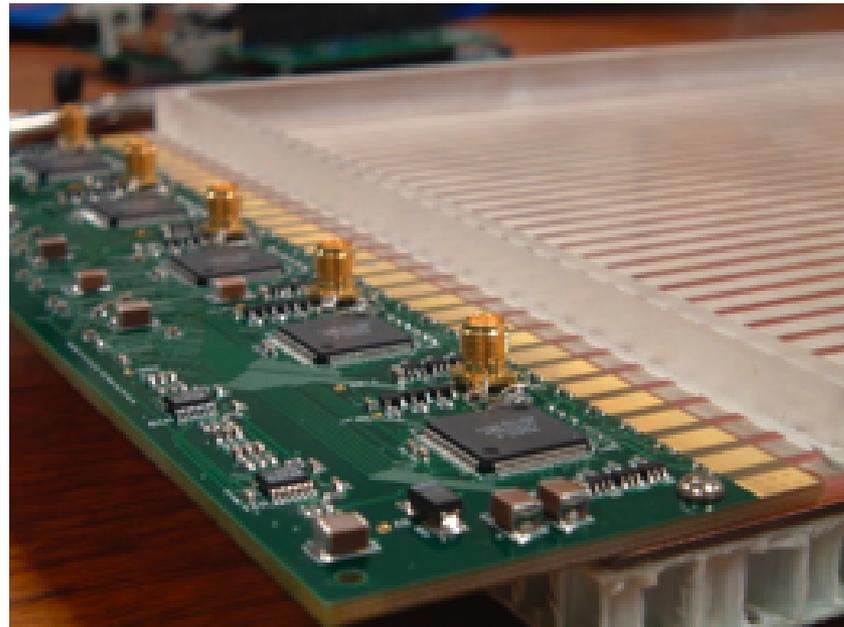
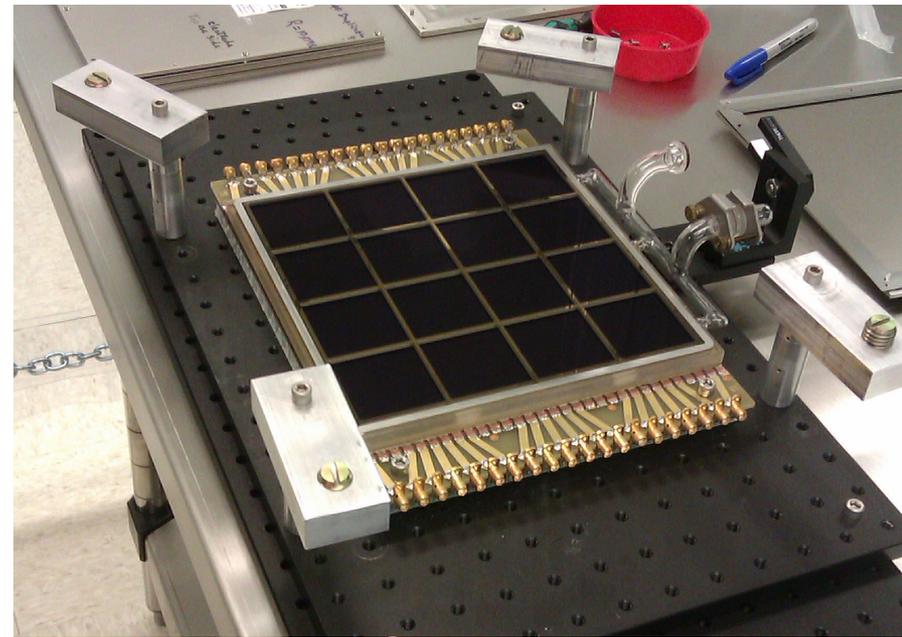
## Full Detector Testing

- The goal, the big picture is to show that we can make and operate sealed glass tubes with target resolutions.
- Want to gain experience working with complete end-to-end detectors systems under realistic operating conditions, including front-end electronics.
- Want to work towards very large area coverage – SuperModule (SuMo).



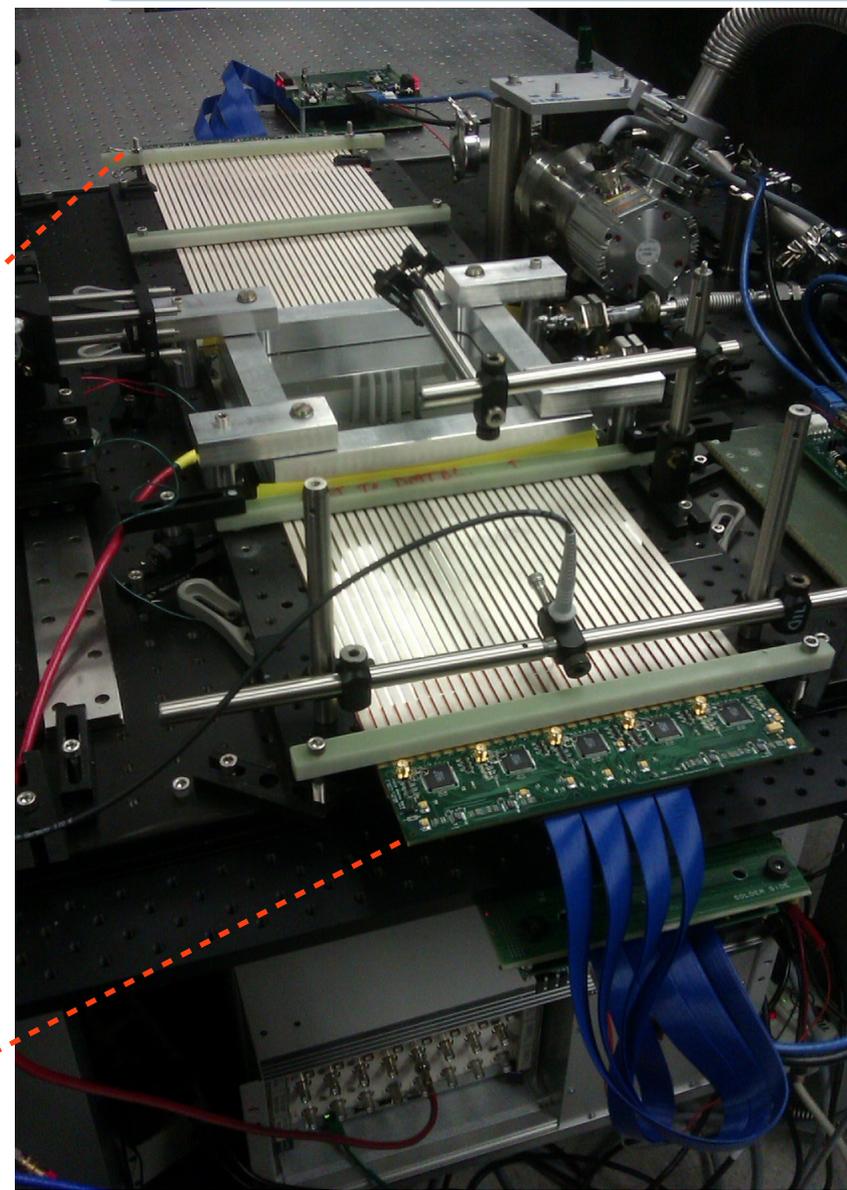
## Full Detector Testing

- “Demountable LAPPD” is a sealed 8”x8” glass detector built to the full specs of our final design, except for an o-ring top-seal, a robust, metallic photocathode, and continuous pumping.
- Capable of being studied in concert with our PSEC4-based front-end system.



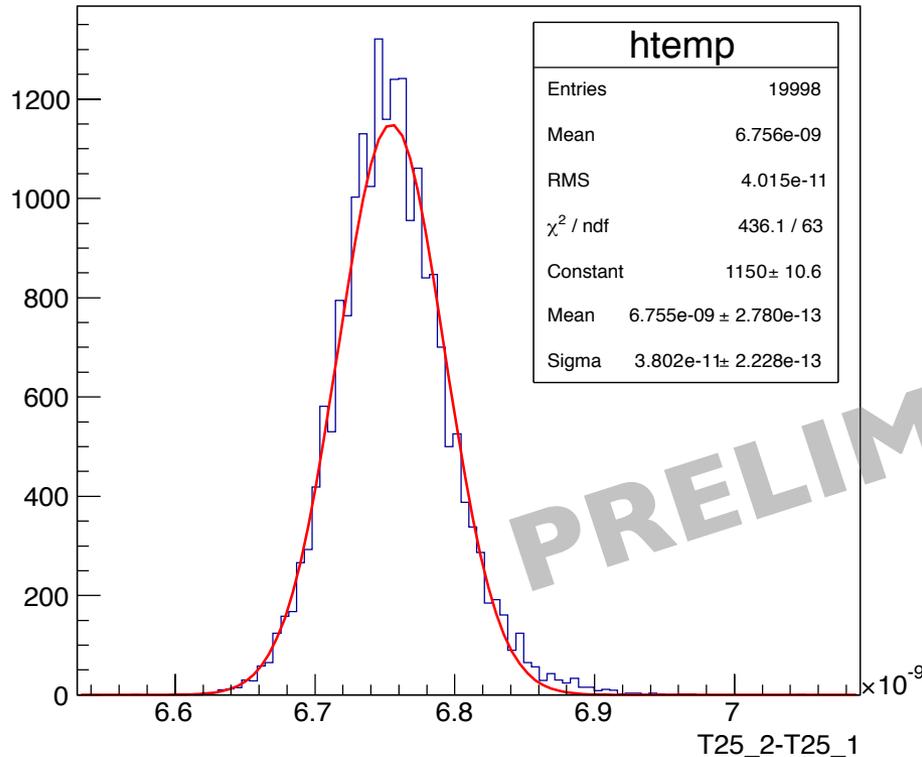
## “SuMo Slice”

We are now testing a functional demountable detector with a complete 80 cm anode chain and full readout system (“SuMo slice”).

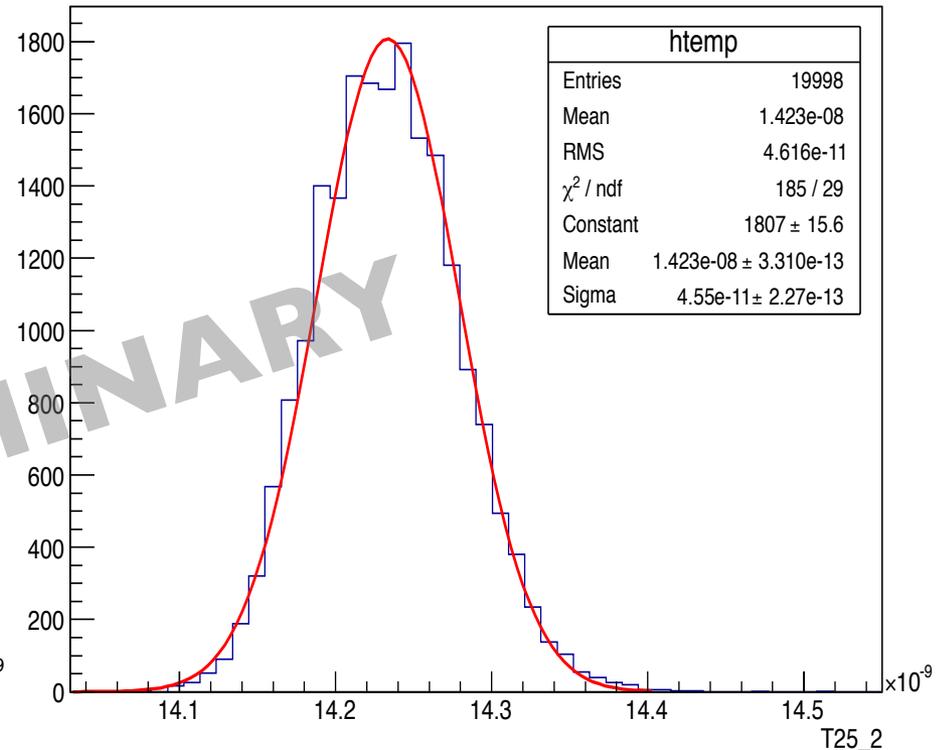


First results with 90 cm-long anode:

## 38 picosecond differential time resolution



## 46 picosecond Transit Time Spread

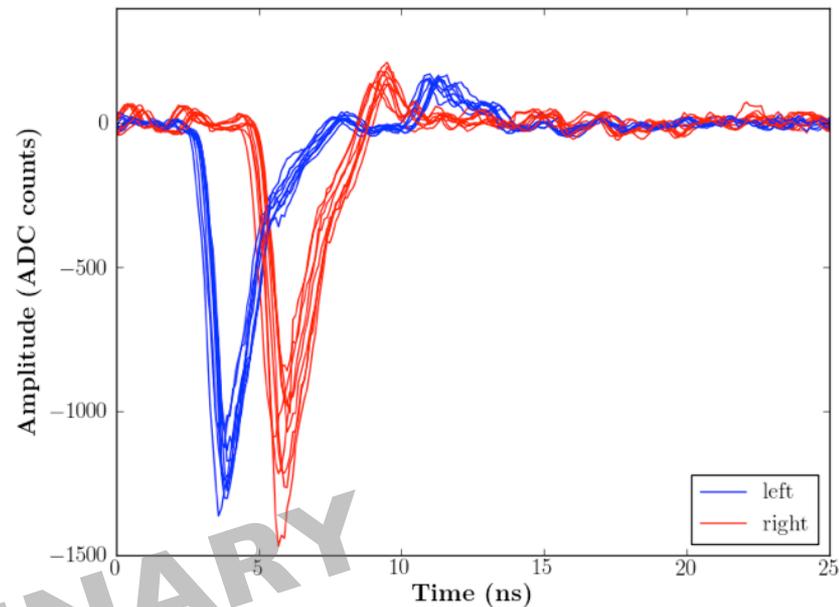
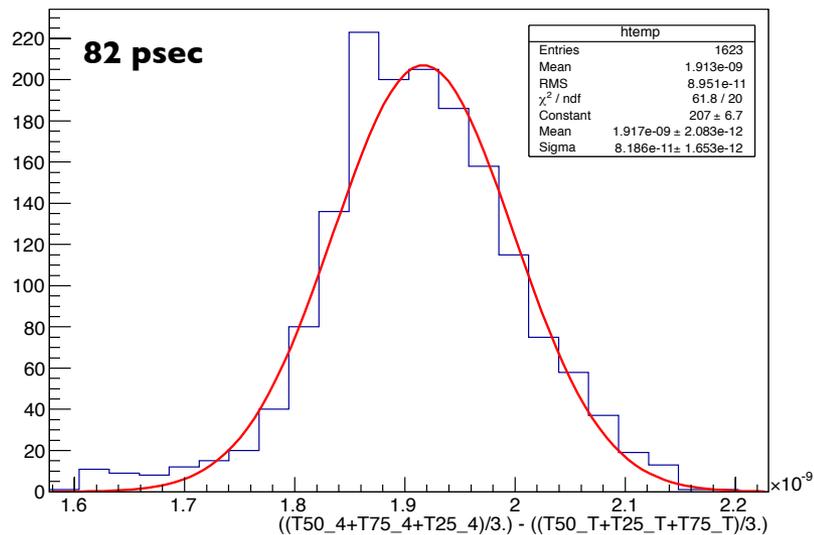


We get similar results even if we instrument only one side and take the differential timing between the signal and its' reflection!

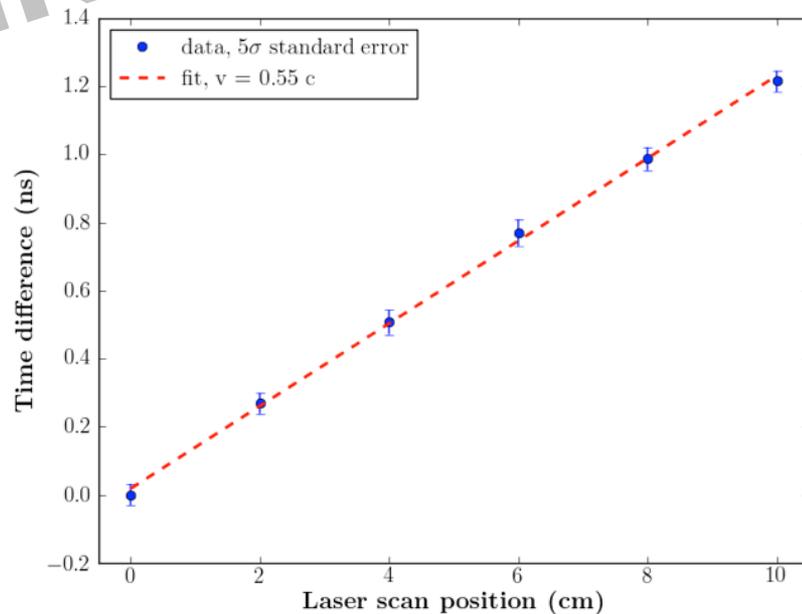
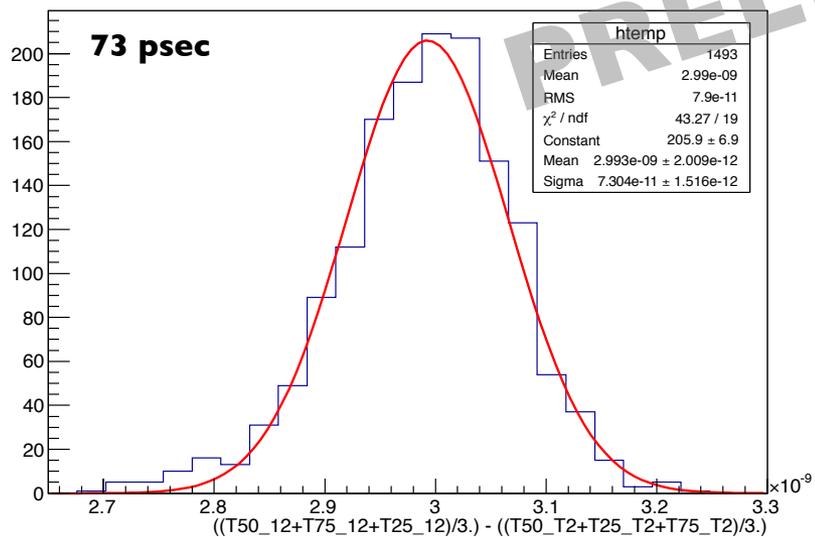


# SuperModule Testing – Full PSEC Readout

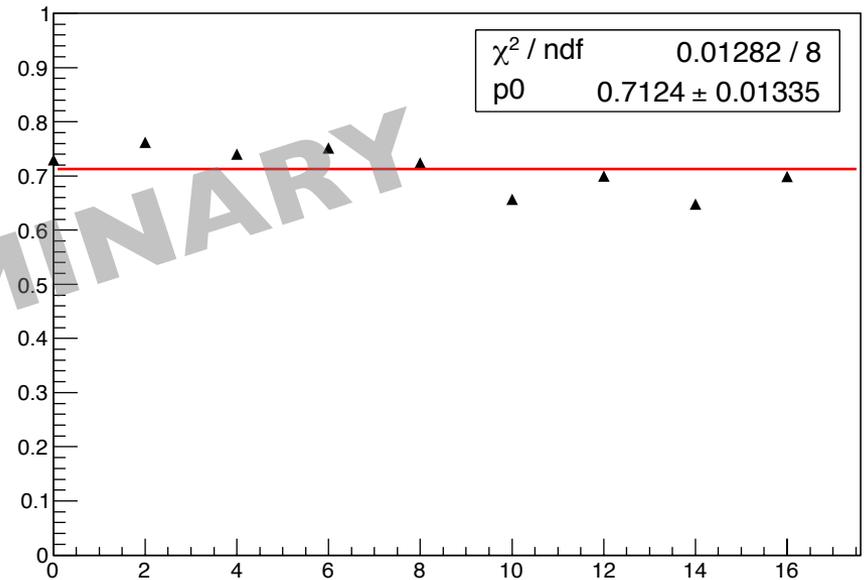
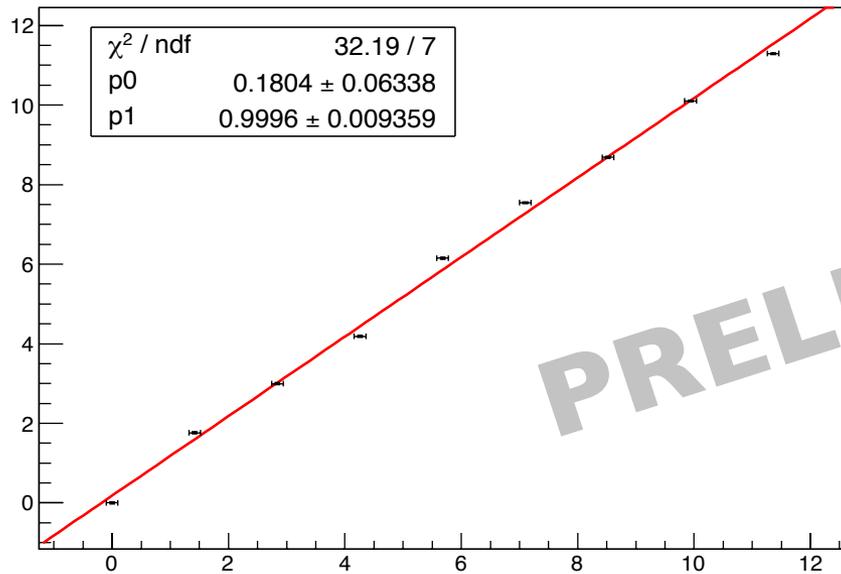
TTS, near side



TTS, far side side



Position in the transverse direction, reconstructed even using a naive, out-of-the-box 5-strip centroid algorithm gives us resolutions consistently below 1 mm.

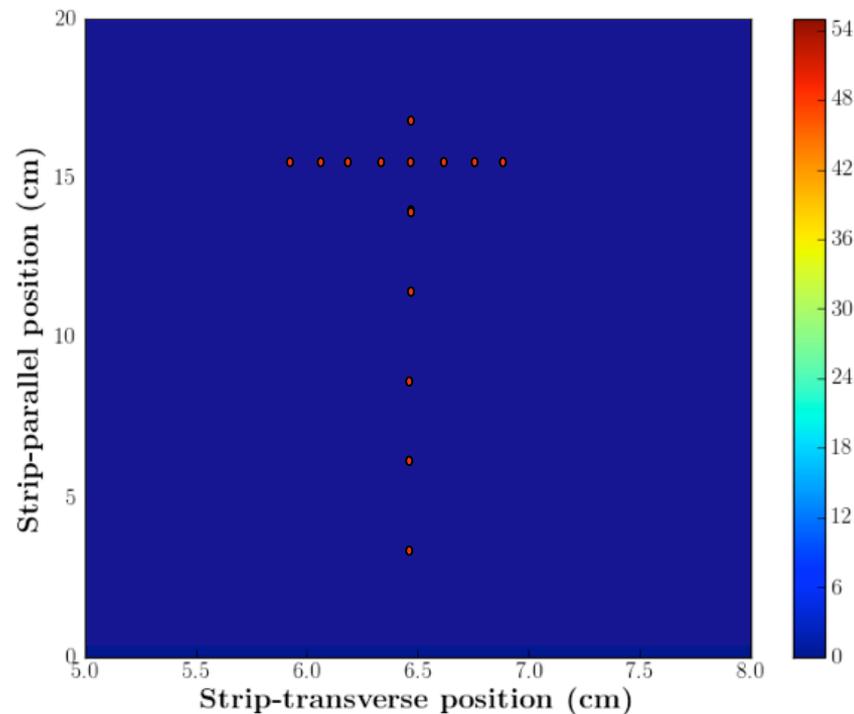


PRELIMINARY

For neutrino applications, imaging capabilities could be transformational to water Cherenkov detectors:

- MCPs are digital photon counters: able to separate between photons by: charge, space, and time
- The ability to reconstruct tracks based by mapping individual photons to tracks

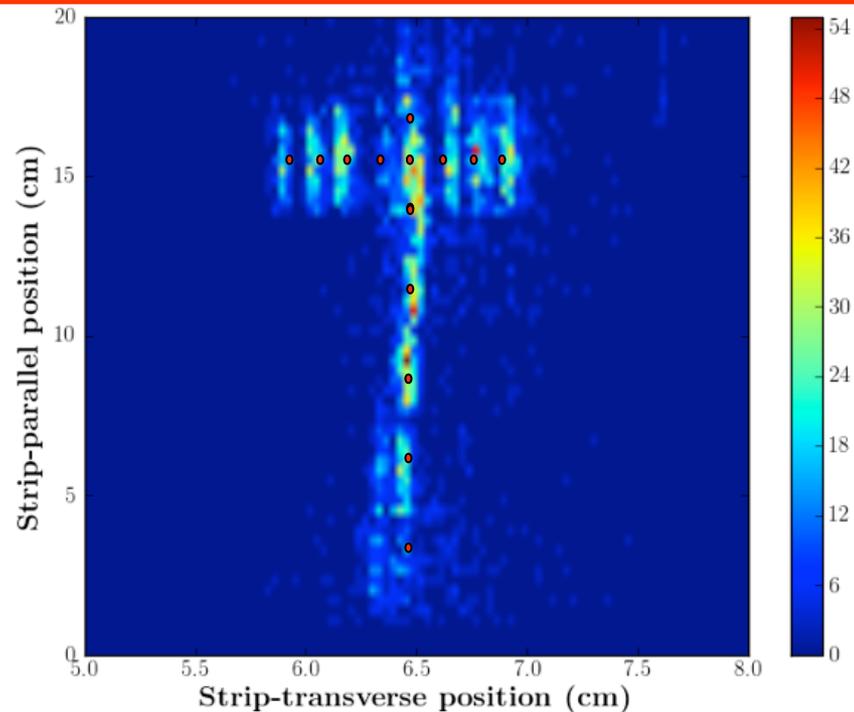
Given the sparseness of light in Cherenkov detectors, cm-level spatial resolution and  $\sim 100$  psec time resolution is sufficient.



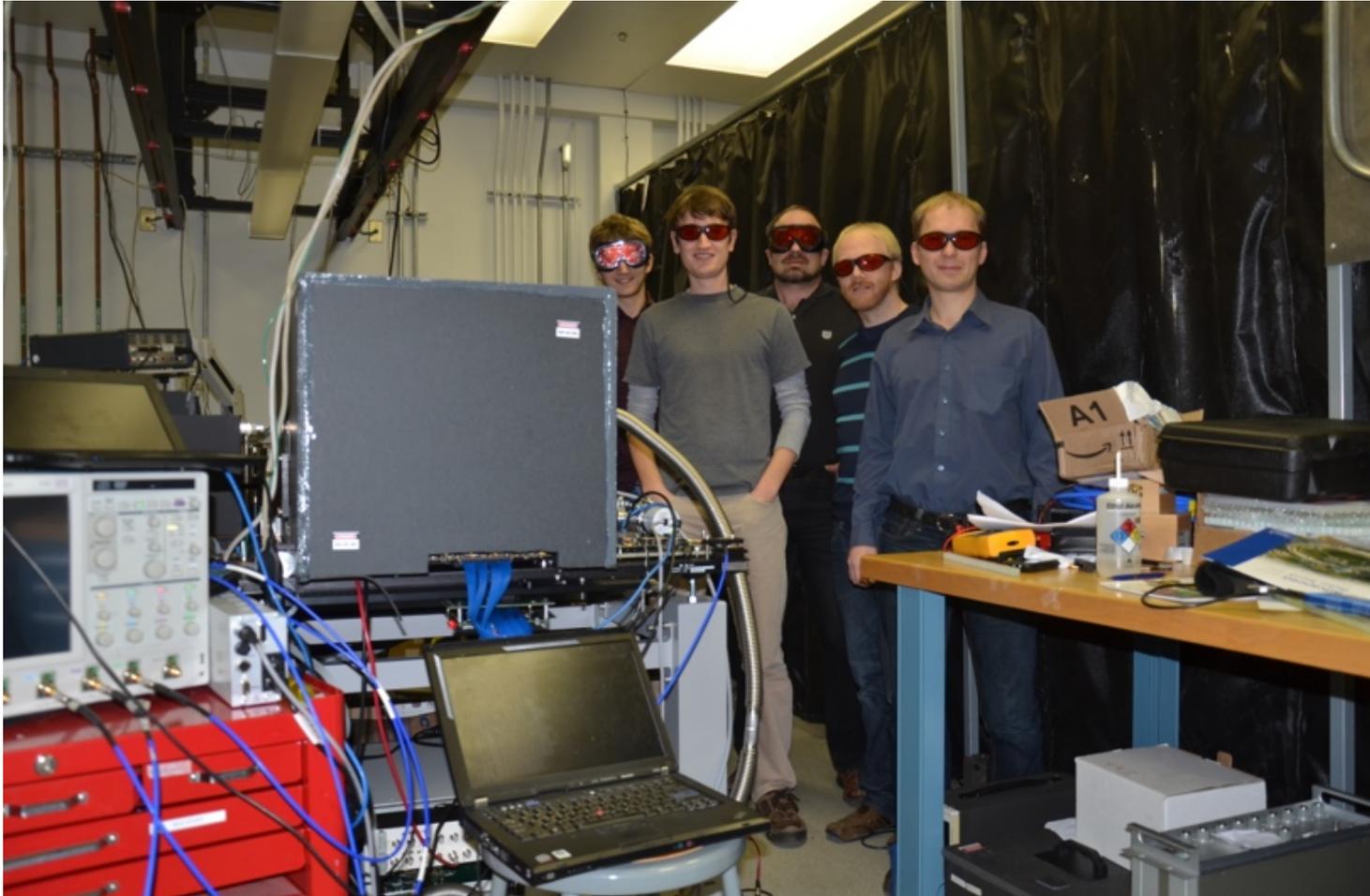
For neutrino applications, imaging capabilities could be transformational to water Cherenkov detectors:

- MCPs are digital photon counters: able to separate between photons by: charge, space, and time
- The ability to reconstruct tracks based by mapping individual photons to tracks

We are starting to demonstrate the ability to separate between photons on better than 1cm distance scales using differential arrival time and centroiding.



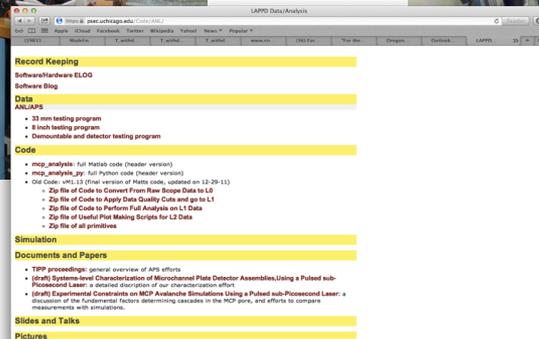
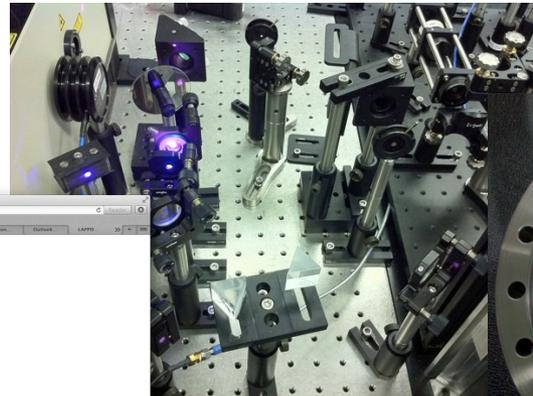
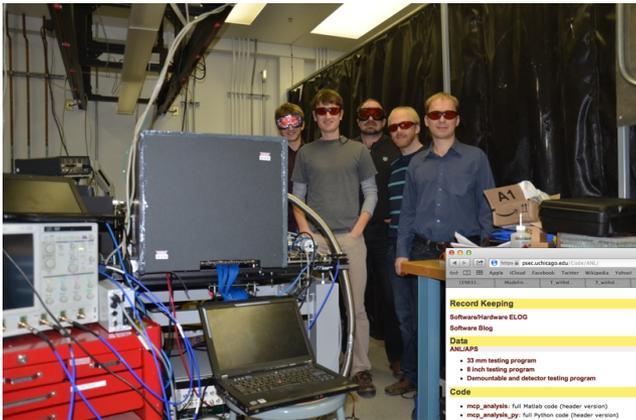
# Future Plans



- We've demonstrated repeatable  $<80$  picosecond single PE time resolutions at various test points on full-sized 8"x8" MCPs (largest ever made!)
- demonstrated large signal differential time resolutions approaching a single picosecond on 8" microchannel plates
- demonstrated working, near-complete sealed-tube glass detector systems (20cm x 80cm anode coverage) with fully integrated front-end electronics with  $<100$  picoseconds (out-of-the-box with raw uncalibrated chip data).
- demonstrated imaging capabilities with our 30-strip anode design with sub-cm resolutions



- We've also developed a vast pool of resources:
  - unique hardware
  - But also:
    - software
    - documentation
    - papers
    - human resource
    - techniques and procedures



<https://psec.uchicago.edu/Code/ANL/>

- We soon hope to be seeing complete, sealed-tube detectors.
- As we prepare to make LAPPDs available to the community, and as ANL builds the capability to make small batches of tiles, it is critical that our effort is able to:
  - Rapidly characterize new MCPs and grid-spacers
  - Quickly test sealed tube systems.
  - Continue developing operational experience with end-to-end detector systems
  - Continue to improve on the electronics and on algorithm development
- There are also many opportunities to further develop new MCP geometries, chemistries, simulations rebooting the 33mm program.
- We look forward to the next stage in this project.



Thank You

