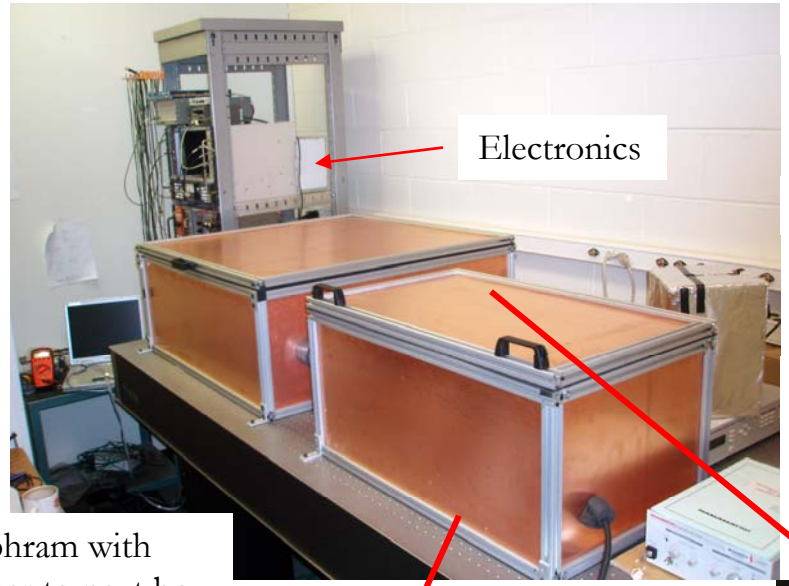
PSec Level Time-of-Flight Measurements at Argonne's Laser Lab and Fermilab's Test Beam

Karen Byrum

Lyon Fast Timing Workshop

15 & 16 October, 2008

Laser Test Stand at Argonne

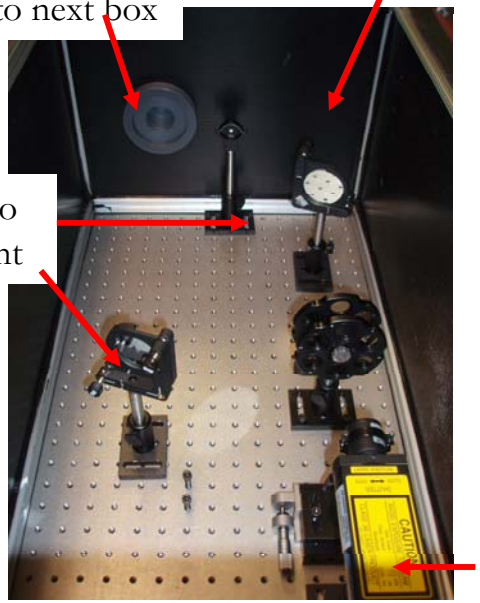


Hamamatsu PLP-10 Laser (Controller w/a laser diode head) 405 & 635nm head.

Pulse to pulse jitter < 10psec (Manufacture Specs)

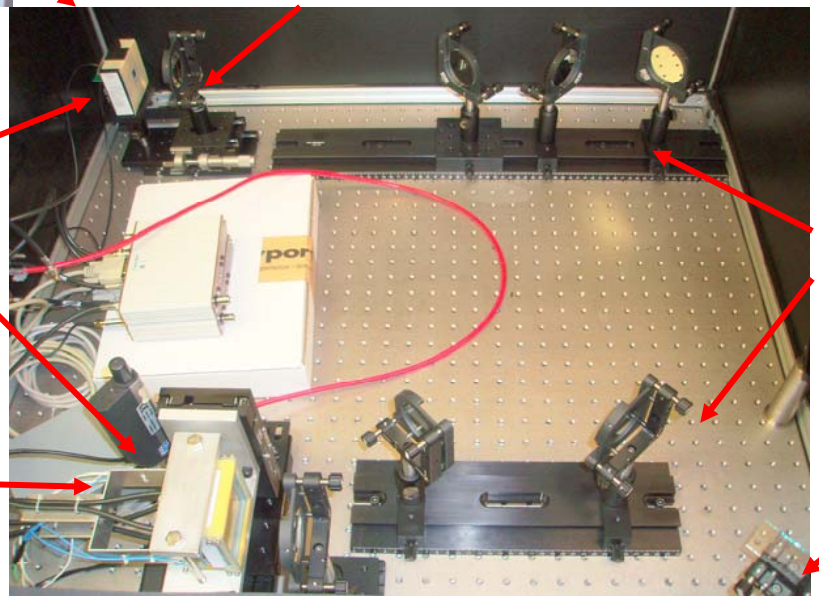
Lens to focus beam on MCP

Diaphram with shutter to next box



Mirrors to direct light

MCPs



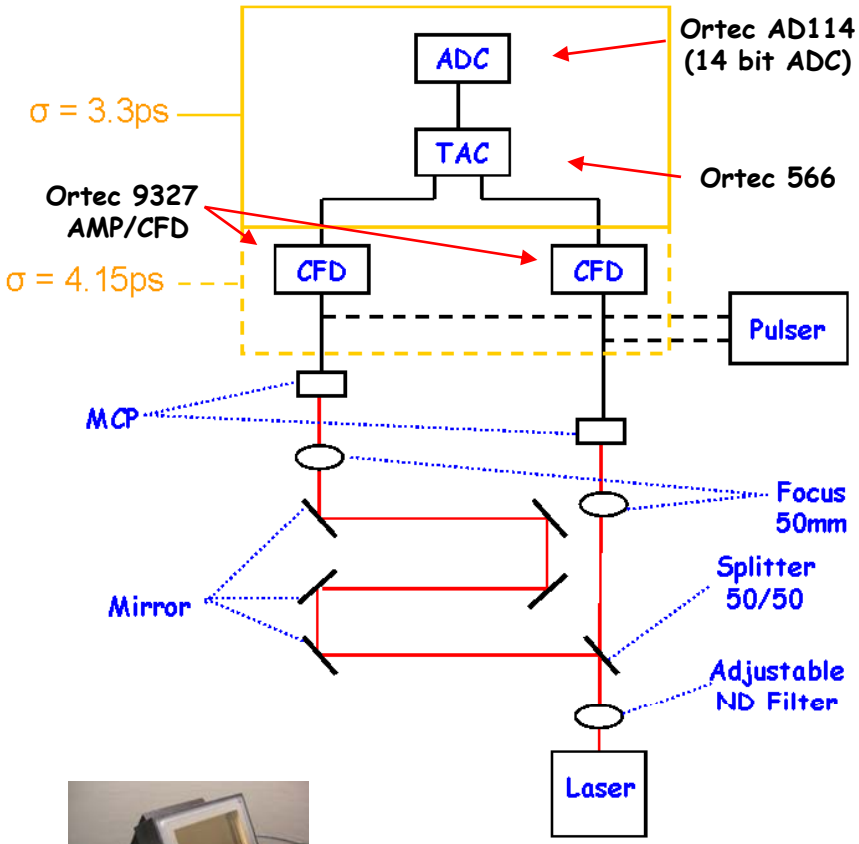
Mirrors to delay light

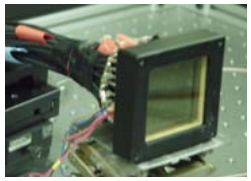
X-Y Stager

50/50 beam splitter

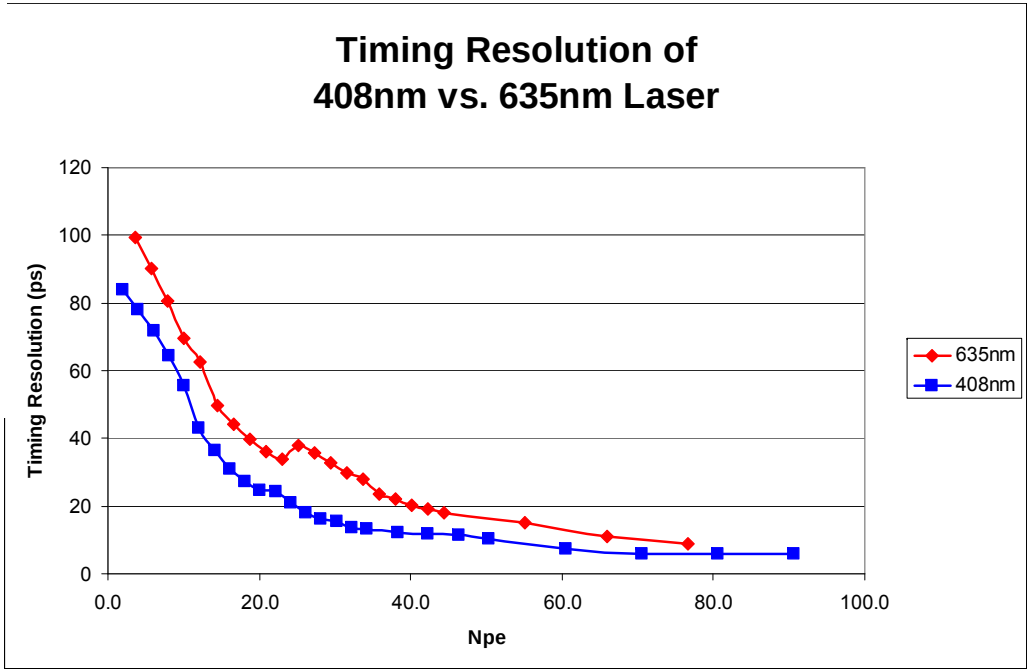
Laser Head

Tubes first tested at Argonne Laser Lab





- Measure Δt between 2 MCP's (i.e root2 times σ); no corr for elect.
- Results: 408nm
  - –7.5ps at ~50 photoelectrons
- Results: 635nm
  - –18.3ps at ~50 photoelectrons



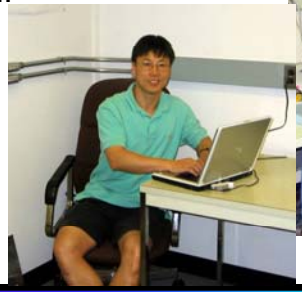
What's next in the laser lab.

- Laser Lab DAQ reconfigured w/ 3 channels (both testbeam DAQ chains possible)
- Timing Comparison of two 25micron & two 10 micron tubes underway
- Ready for transmission line device
- Laser Lab Upgrades:
  - Add software programming of xy scanning capabilities for characterizing tubes
  - Add one more channel ($10k) of readout
  - Add quantum/photon detection efficiency equipment/readout options

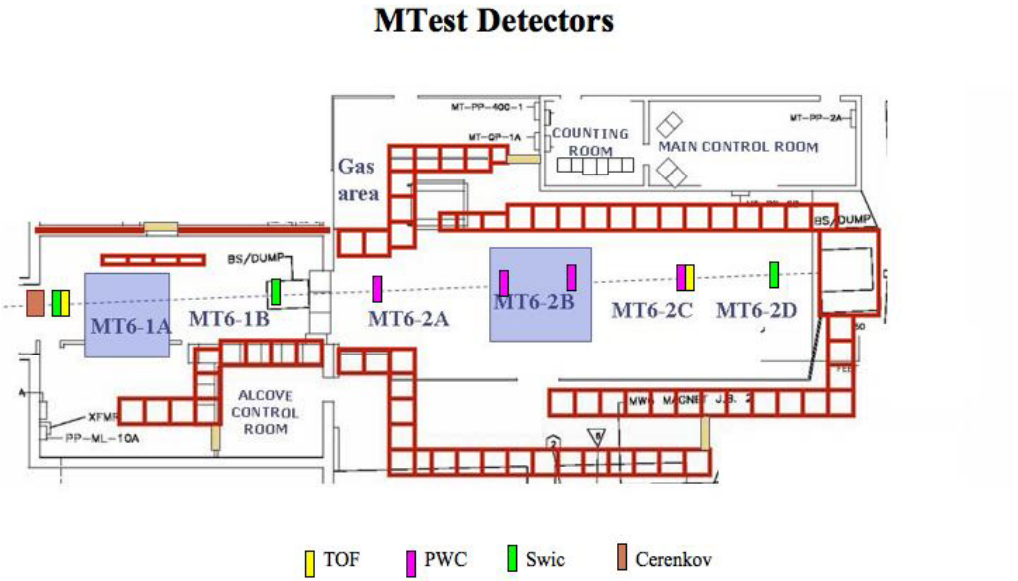
PSEC Test Beam Community – T979

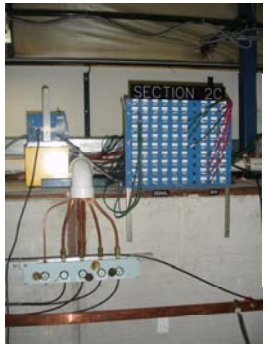
Goal is to develop affordable time of flight measurement for single particles to better than 10 psec

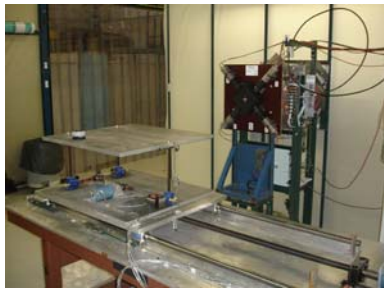
- **Argonne National Laboratory**
  - John Anderson, Karen Byrum, Gary Drake, Ed May
- **Fermilab**
  - Michael Albrow, Erik Ramberg, Anatoly Ronzhin, Greg Sellberg
- **Hawii**
  - Gary Varner
- **Saclay/IRFU**
  - Emilien Chapon, Patrick LeDu, Christophe Royon
- **SLAC**
  - Jerry Va'vra
- **University of Chicago**
  - Camden Ertley, Henry Frisch, Heejong Kim, Jean-Francois Genat, Andrew Kobach, Tyler Natoli, Fukun Tang, Scott Wilbur



Fermilab's Meson Test Beam User Facility







Spacious control room

Signal and HV cables

Gas delivery to 6 locations

4 station MWPC spectrometer

Two motion tables

Erik Ramberg – All Experimenters meeting

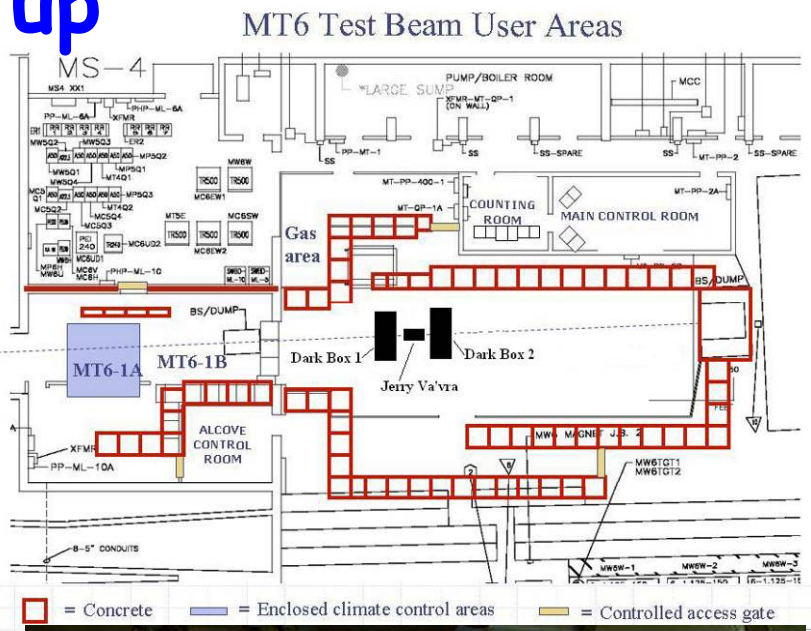
Fermilab Test Beam Goals

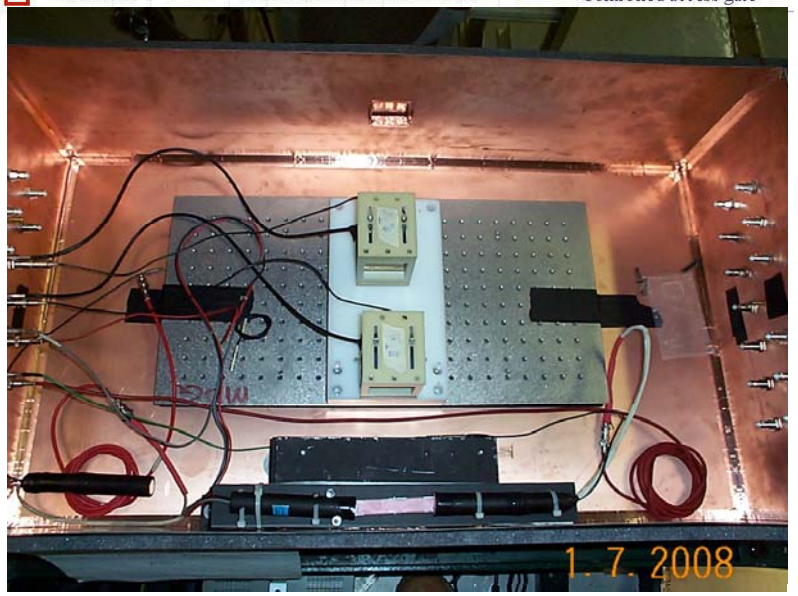
1. To measure the timing resolution of Jerry Va'vra's 10μm pore MCPs with new silvered radiator.
2. To measure the timing resolution at known S/N and Npe with 25μm pore MCPs to compare with the ANL blue/red laser curves and simulation.
3. To measure the timing resolution of two SiPMs (3mm x 3mm and 1mm x 1mm).
4. To setup and test a DAQ system for future tests (first run).
5. To obtain waveforms of MCP signals with a fast sampling scope (40Gsamples/sec) to compare to simulation and DAQ

Camden Ertley – All Experimenters meeting

Fermilab Test Beam Setup

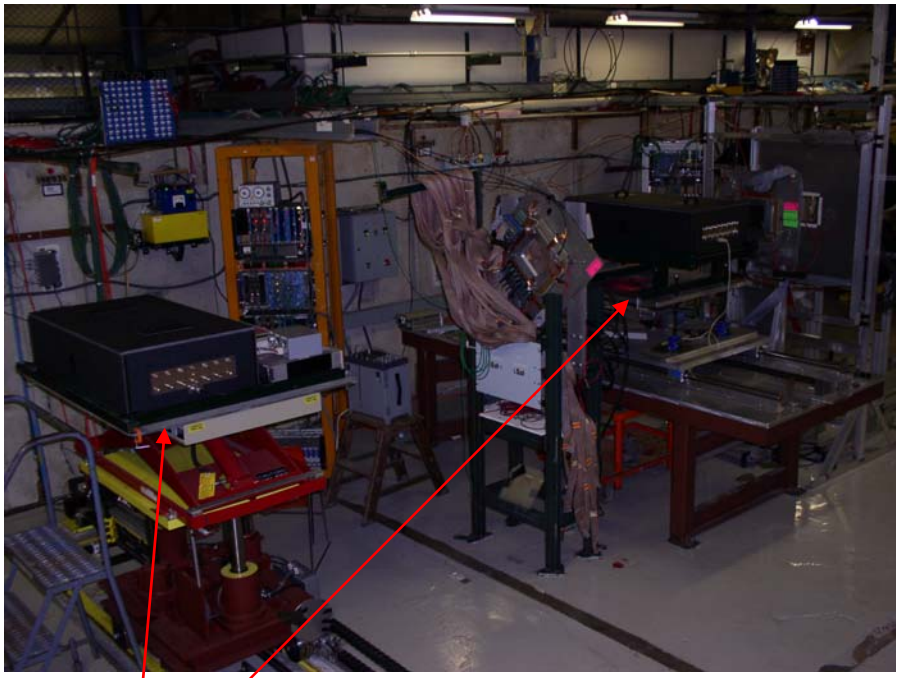
- Three dark boxes (Anatoly- wonderful!)
  - 2mm x 2mm scintillator
    - 2 PMTs for coincidence triggering in each box.
  - 2 MCPs or SiPMs in each box
- 3 DAQ systems
  - DAQ-1
    - uses FERA readout for fast data collection
  - DAQ-2
    - CAMAC
    - Allows other users to quickly connect to our system
  - Tektronix TDS6154C oscilloscope
    - 40 Gsample/sec (total of channels)

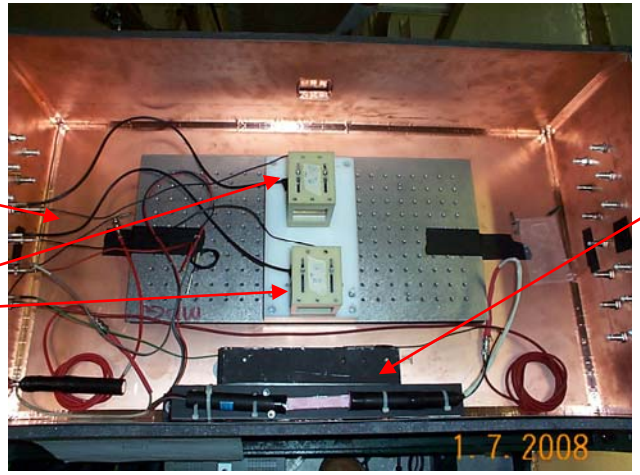




Camden Ertley – All Experimenters meeting

Fermilab's Meson Test Beam Facility



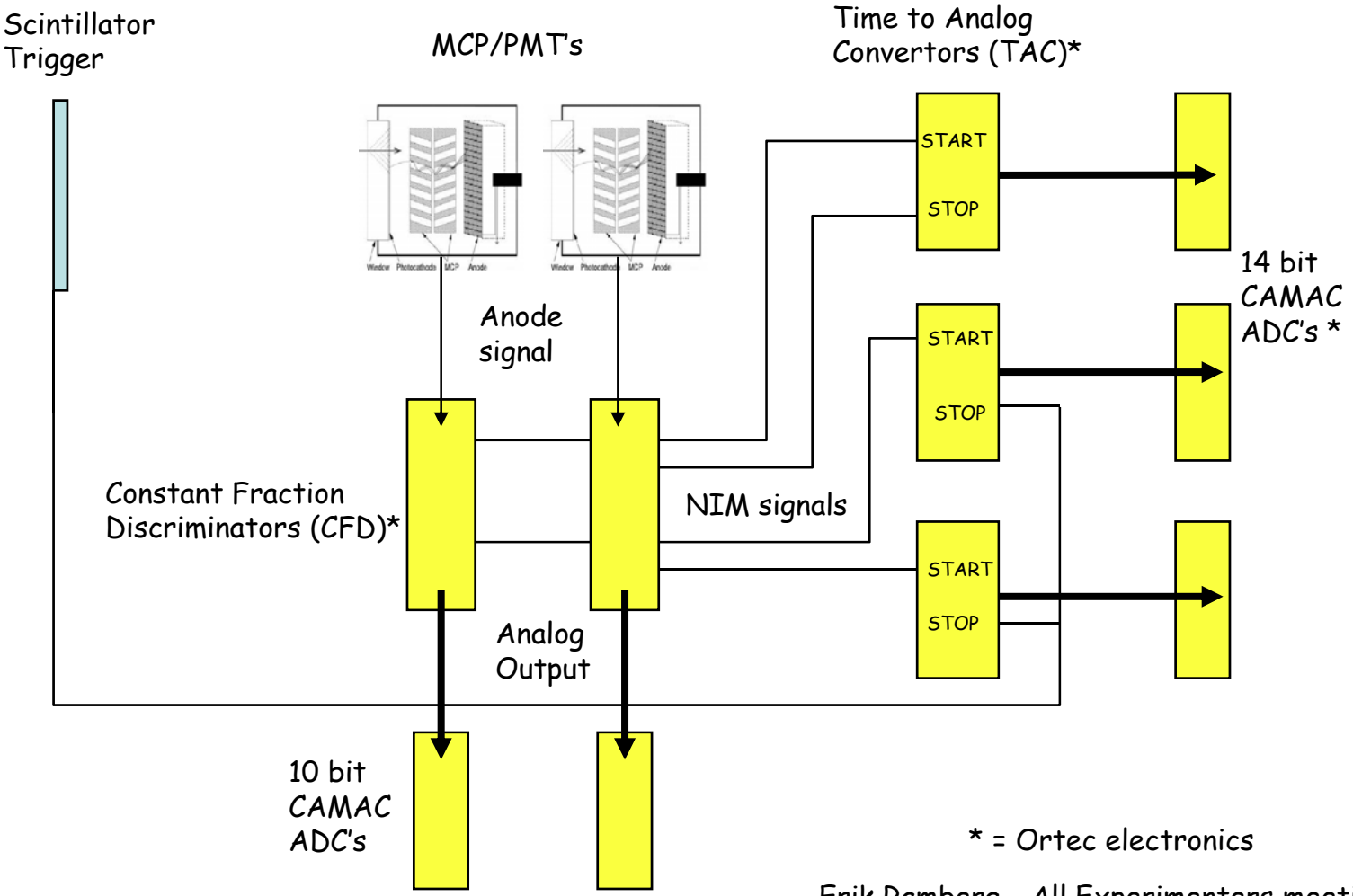


Dark Box

MCPs

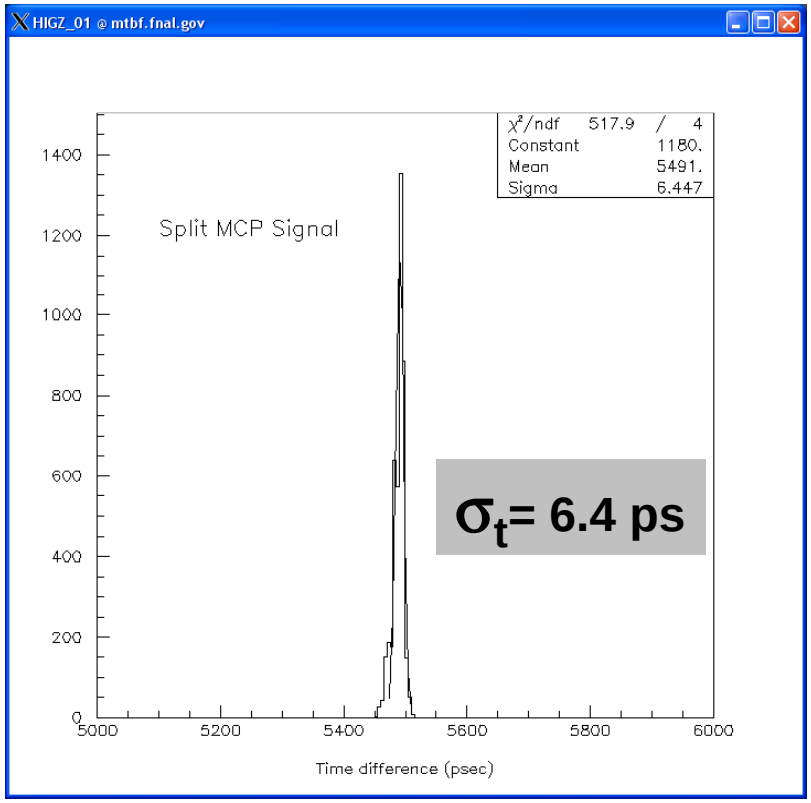
Trigger scintillator

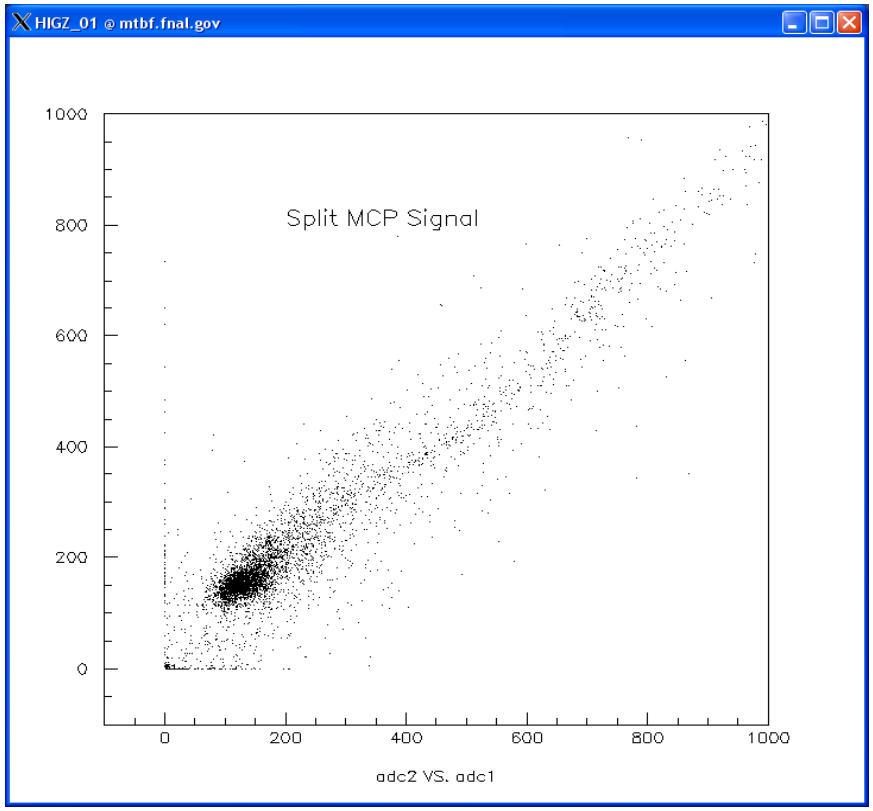
Electronic Measurement



Erik Ramberg – All Experimenters meeting

MTest Calibration Results from Split Signal from one MCP/PMT

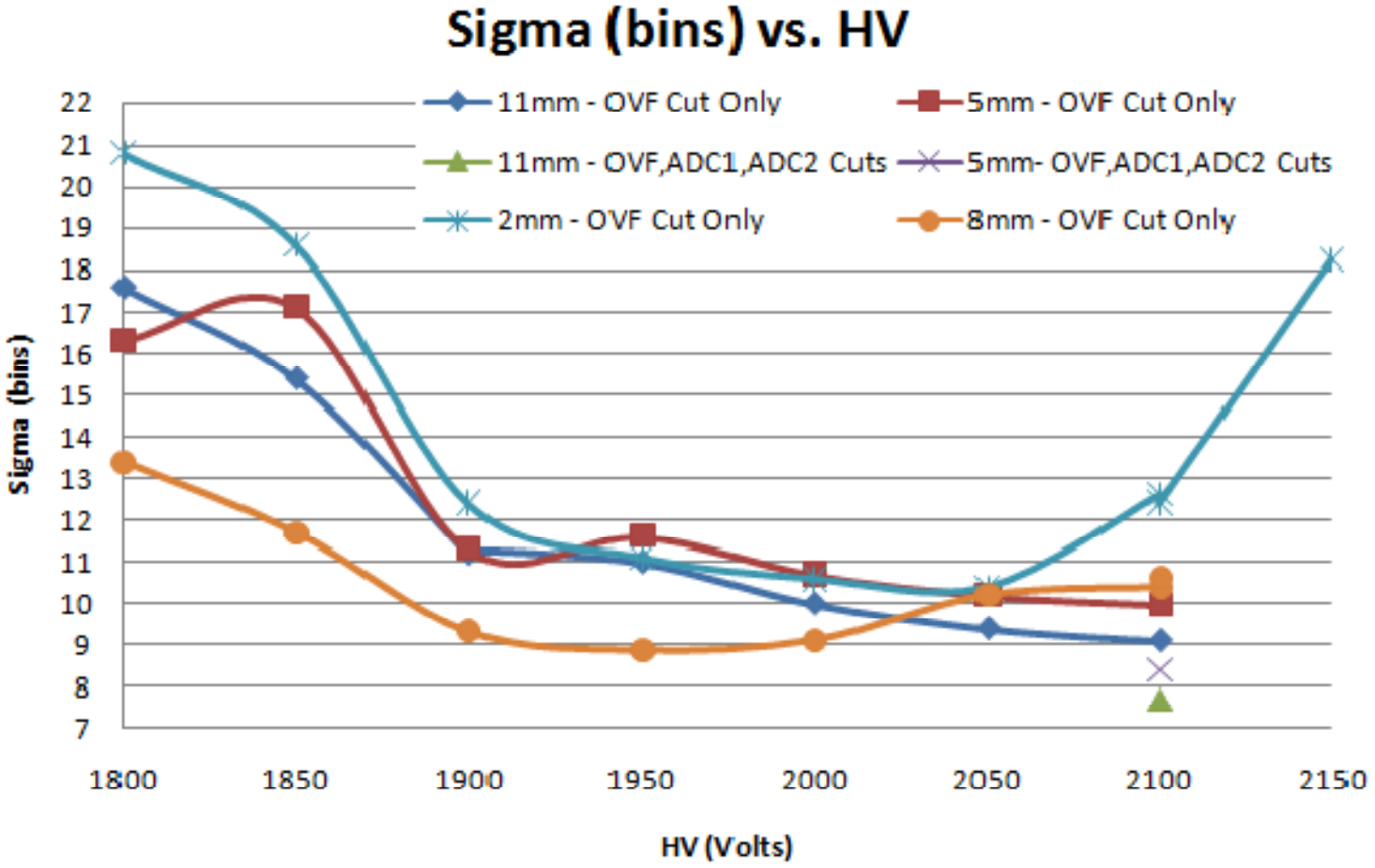




Timing noise level per channel = **4.6 ps**

ADC1 should = ADC2
This is evidence of noise and differential non-linearities

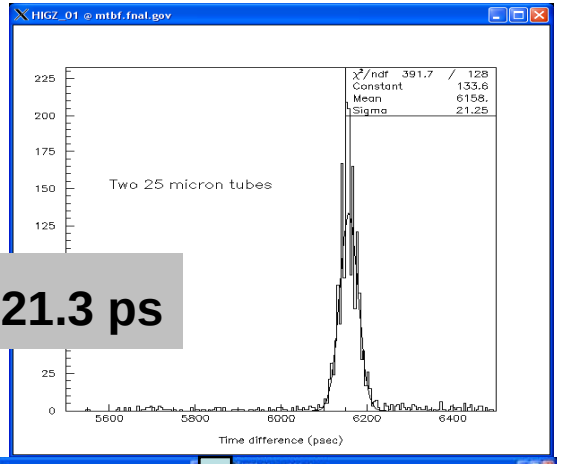
Resolution vs HV and Radiator Thickness



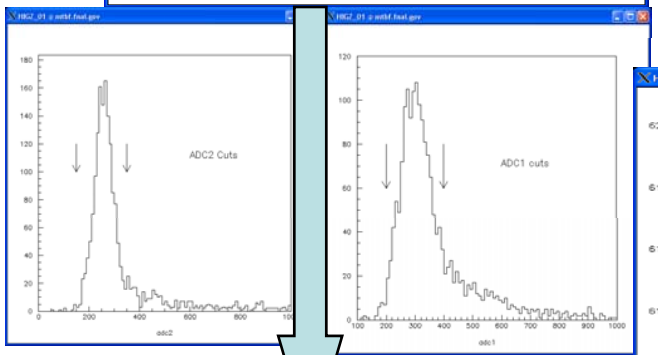
Erik Ramberg – All Experimenters meeting

Results from Photonis 25 μm Pore MCP/PMT

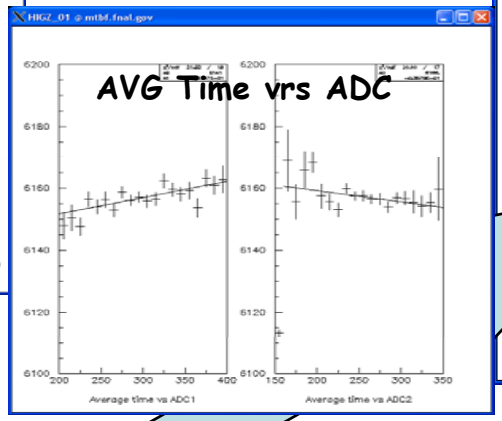
radiator is 8mm quartz

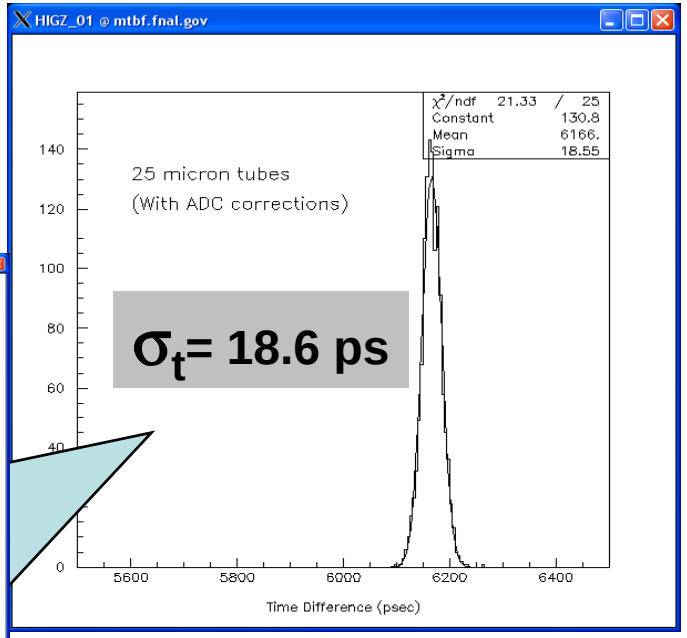


σ_t= 21.3 ps



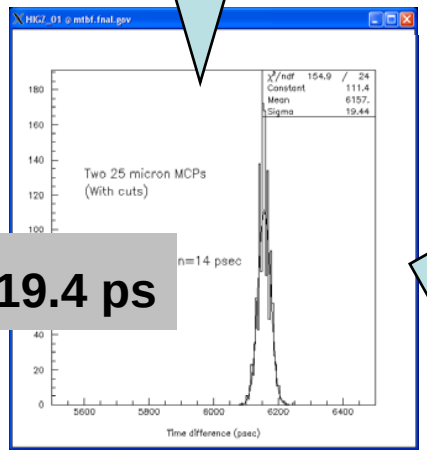
Cut out tails of ADCs





σ_t= 18.6 ps

σ_t(device+noise) = 13.1 ps



σ_t= 19.4 ps

Apply small PH slewing correction

σ_t(per device, excluding noise) = 12.3 ps

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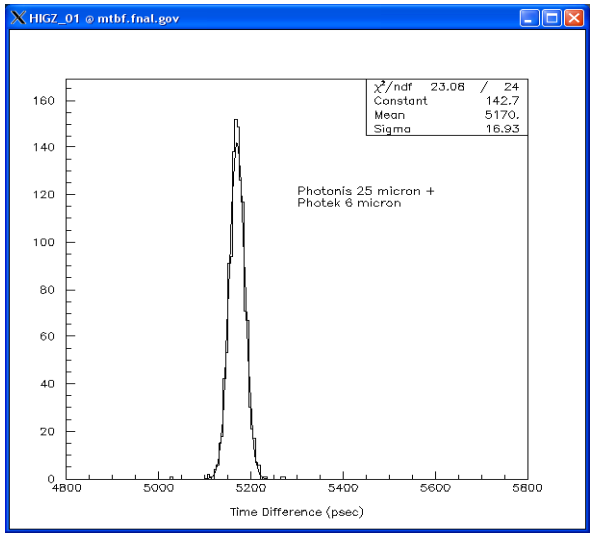
Results for Photek single channel MCP-PMT 210 (10 mm diameter, 5 μm pores)

- Radiator is simply the 5 mm quartz window.

	PMT210	PMT212
Anode Size	10 mm	12 mm
Electron Gain	10^6	10^6
Peak/Valley	2:1	1.5:1
Dynamic Range cps	40,000	40,000
Pulse Rise Time	100 ps	100 ps
Pulse FWHM	170 ps	170 ps
Transit Time Jitter	30 ps	30 ps
MCP Pore Size	5/6	5/6

Thanks to Photek (UK) for loan of two PMT210's



σ_t(Photek + electronics) = 11 ps

σ_t(Photek alone) = 9.6 ps

Better timing resolution from smaller pore size AND large light collection area

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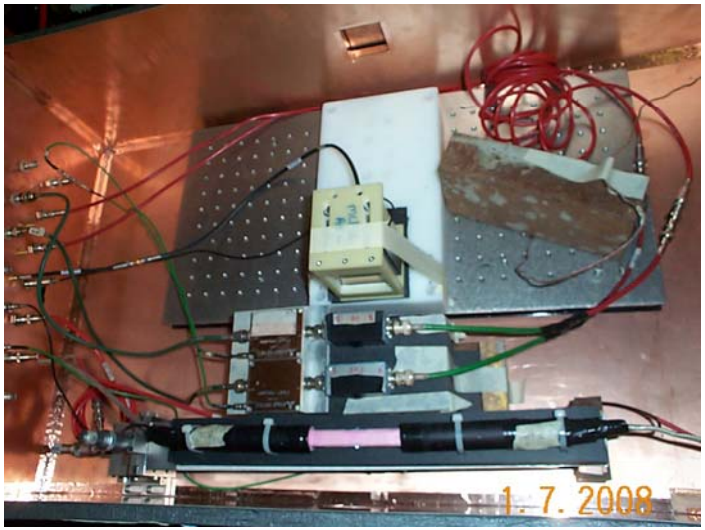
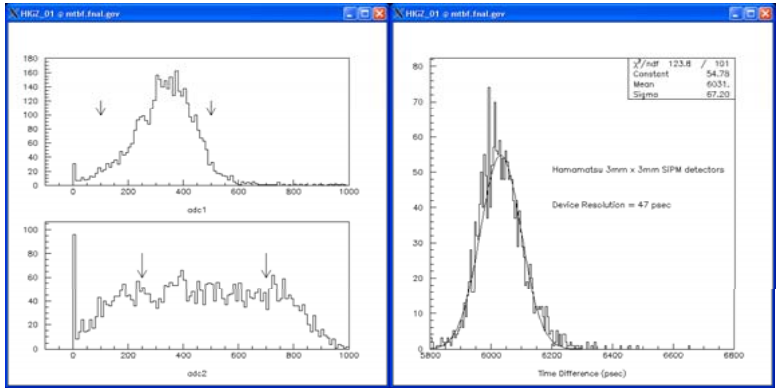
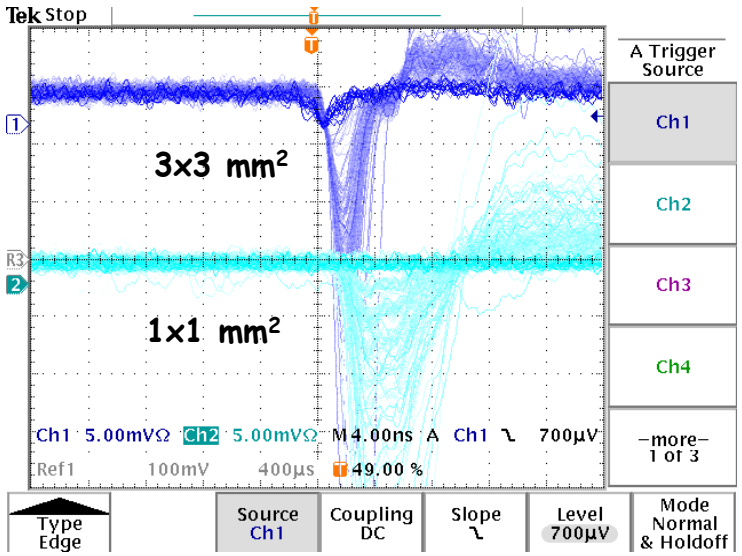
SiPM Results

- SiPM = “Silicon PMT”, which is a multi-pixel Geiger mode silicon device for photon counting
- SiPM’s used is Hamamatsu 3 x 3 mm^2 with 6 x 6 x 16 mm^3 polyethylene block radiator





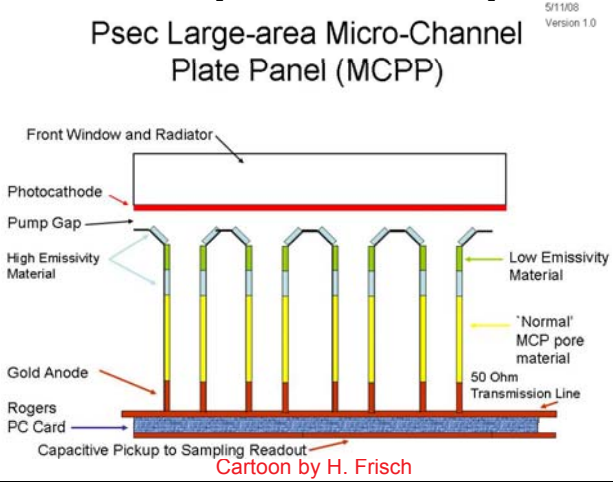


- Obtained 48 ps timing resolution per device, even with poor light collection on one device. (See Anatoly Ronzhin’s posters 1059 and 1060)

Erik Ramberg – All Experimenters meeting

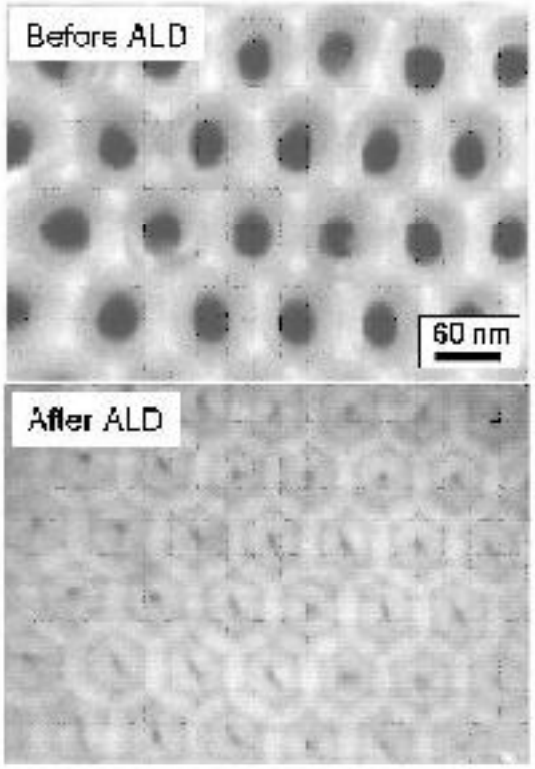
Development of Large-Area Psec Resolution TOF Systems

- **Status**
  - **Developed a Laser Lab teststand facility with commercial DAQ electronics**
  - **Measured timing properties of commercial MCP devices in laser teststand and in Fermilab testbeam**
- **Future Activities FY09 & Beyond:**
  - **Continuation of the development of a 40-GS/sec sampling chip (ASIC): ANL responsible for system aspects- psec clock dist., FPGA DAQ, calibration, control**
  - **Bench testing of ASIC to characterize performance**
  - **Laser teststand, MCP characterization including gain and uniformity as a function of timing, timing studies, DAQ software development using laser lab facility at ANL**
- **Future Part II: Move beyond commercial MCP devices**
  - **The development of new MCP structures to improve timing properties (atomic layer deposition)**
  - **The development of large-area photodetector panels using MCPs**



Cartoon by H. Frisch

Detector Sensor R&D Program: We are proposing to use material science expertise at ANL to move beyond commercially-available MCP devices.

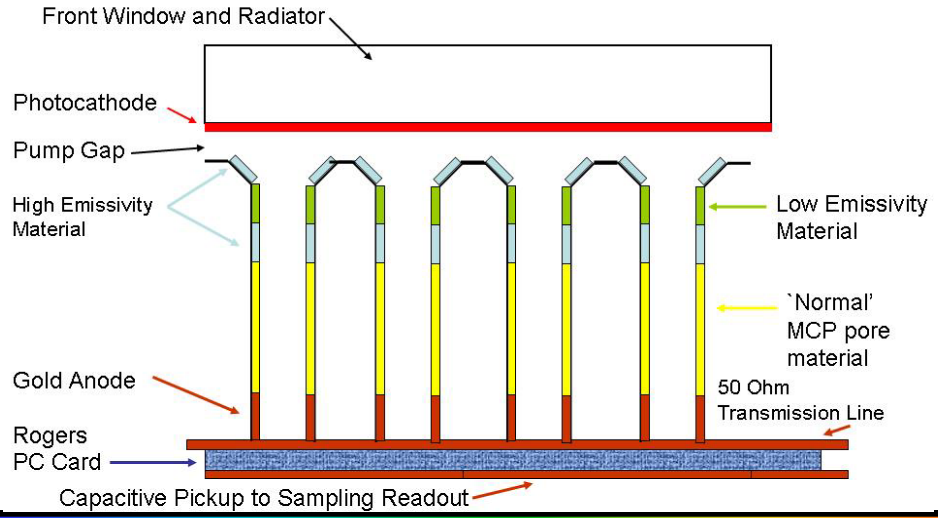


Atomic Layer Deposition (ALD) is a gas phase chemical process used to create extremely thin coatings.

Current 10 micron MCPs have pore spacing of 10,000 nm. Our state of the art for Photonis MCPs is 2 micron (although the square MCPs are 10 micron).

5/11/08
Version 1.0

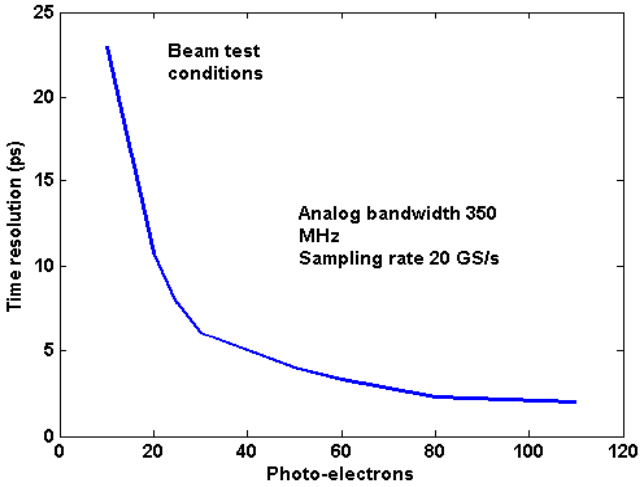
Psec Large-area Micro-Channel Plate Panel (MCPP)



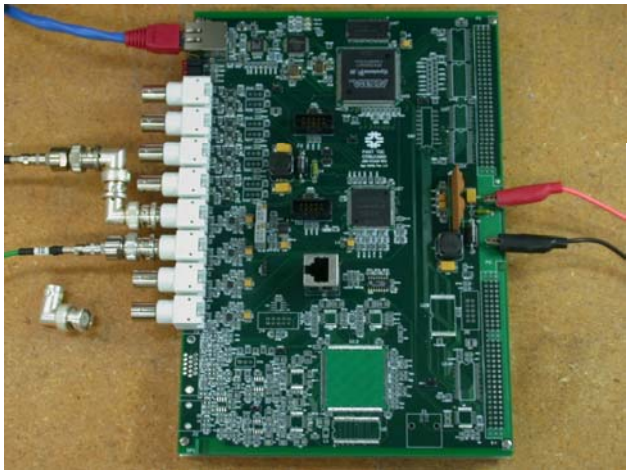
Development of Large Area Photodetector Panels

- Very early stages: - identified a group at argonne, but not all the “names”
- Multiple meetngs at both UChicago and ANL; Will be a collaboration across several divisions at Argonne and Chicago
- Plan is to write a TDR with an outline of what we propose to build. Identify names.

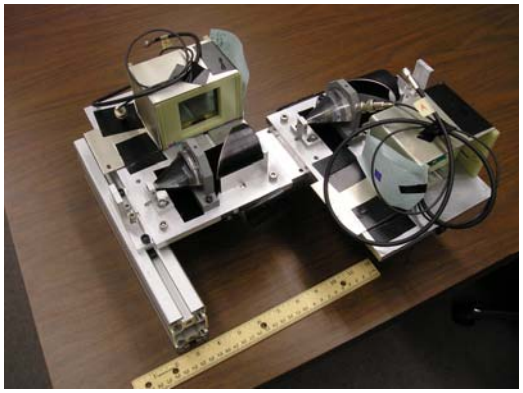
Other Projects the Group is Working on:



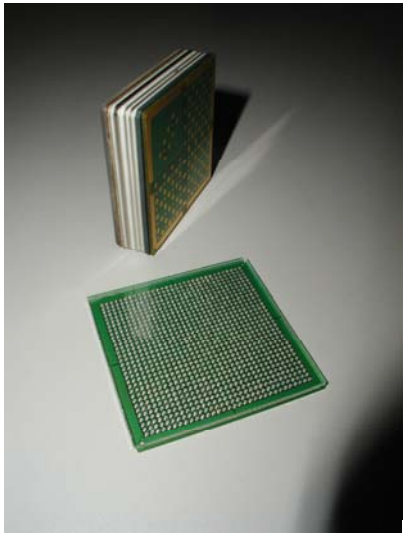
Advanced simulation efforts to understand how high speed sampling contributes to resolution



10 psec level timing measurement from FPGA board



Light generation from cone with half-Cerenkov angle, then paraboloid focus to MCP/PMT. Part of FP420 project



'Bump' bonding of 1024 anode boards

Erik Ramberg – All Experimenters meeting