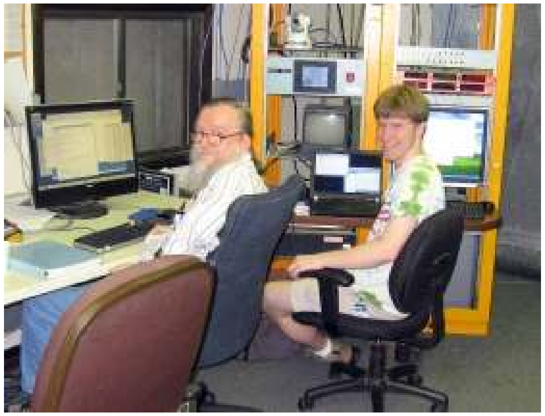
# Psec-Resolution Time-of-Flight Detectors T979

Argonne, Chicago, Fermilab, Hawaii, Saclay/IRFU, SLAC

Camden Ertley
University of Chicago
All Experimenters Meeting
July 14, 2008
(Bastille Day!)

# T979 People/Institutions

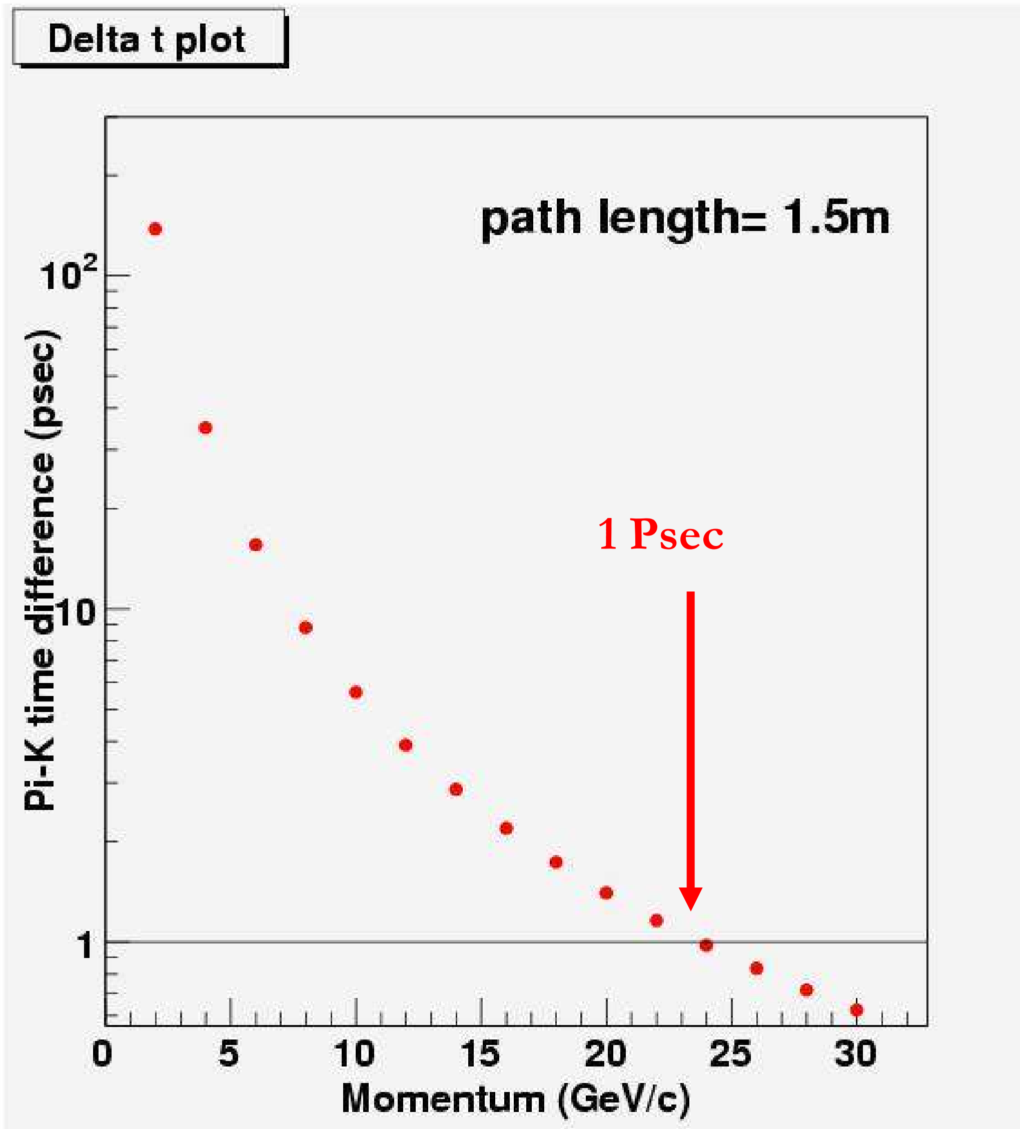
- Argonne National Laboratory
  - John Anderson, Karen Byrum, Gary Drake, Ed May
- University of Chicago
  - Camden Ertley, Henry Frisch, Heejong Kim, Jean-Francois Genat, Andrew Kobach, Tyler Natoli, Fukun Tang, Scott Wilbur
- Fermilab
  - Michael Albrow, Erik Ramberg, Anatoly Ronzhin, Greg Sellberg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



# Motivation- Following the quarks

- A substantial fraction of the HEP community has converged on a small number of collider experiments- Atlas, CMS, ILC
- Budget > 1 billion $/year
- Output is 3-vectors for most particles, plus parton type (e,mu,tau,b,c,..) for some- there is still some fundamental information we could get, and need.
- Worth the investment to identify the kaons, charmed particles, b's, …- go to 4-vectors. Nothing more left for charged particles!
- Possible other application- photon-vertexing. Add converter in front- know velocity, with transit-time vertex photons. (e.g. H->gg, LHCb, K->$\pi$ $\nu$ $\nu$).
- Serious long-term detector R&D will pay off in many fields- one example- H. Nicholson- proposed use of high-res time/pos in DUSEL water-Cherenkov full coverage. Great education for young folks too!
- MTest is a key facility for the future of the field. We appreciate it!

# K-Pi Separation over 1.5m




Assumes perfect momentum resolution (time res is better than momentum res!)

# Characteristics we need

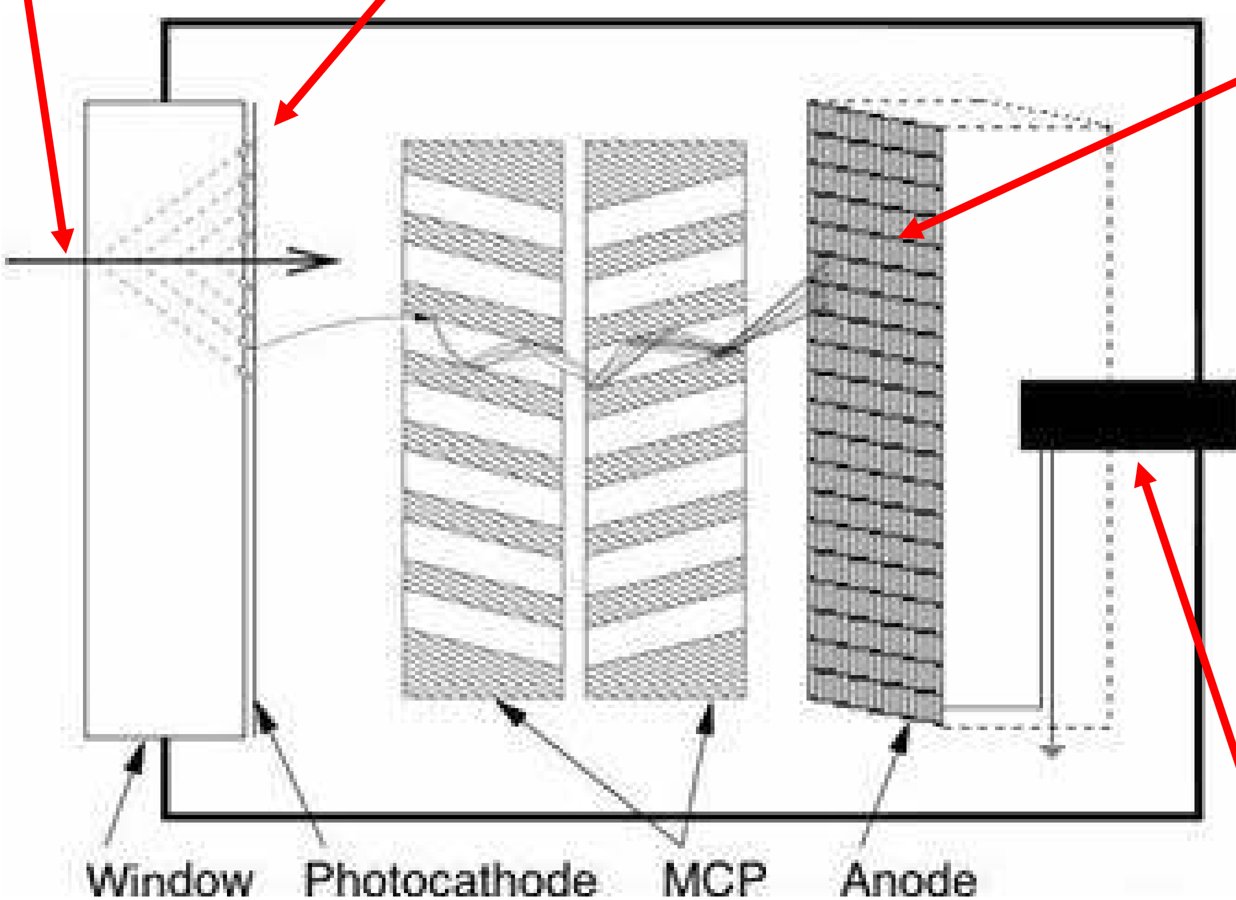
- Feature size <~ 300 microns
- Homogeneity -ability to make uniform large-area – e.g. 30 $m^2$ for CDF-III or ATLAS
- Fast rise-time and/or constant signal shape
- Lifetime (rad hard in some cases, but not all)
- System cost << silicon micro-vertex system

# Idea 1: Generating the signal

## Use Cherenkov light: fast, directional

Incoming rel. particle

Custom Anode with Equal-Time Transmission Lines + Capacitative. Return

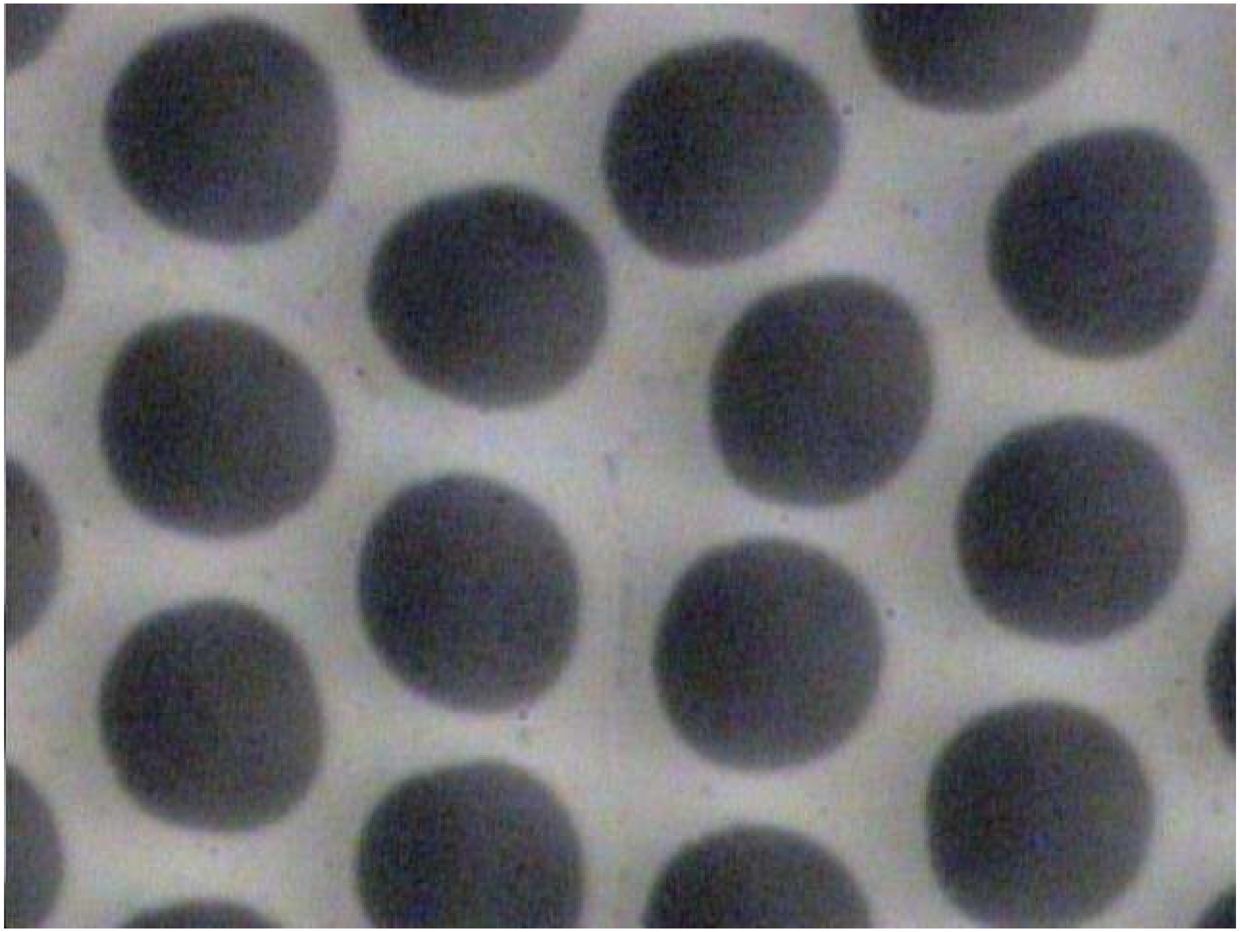



A 2" x 2" MCP- actual thickness ~3/4"

e.g. Burle (Photonis) 85022- with mods per our work

Collect charge here-differential Input to 200 GHz TDC chip

# Major advance for TOF measurements:



**Micro-photograph of Burle 25 micron tube- Greg Sellberg (Fermilab)**

1. Development of MCP's with 2-10 micron pores
2. Transmission line anodes
3. Sampling electronics

# Simulation and Measurement

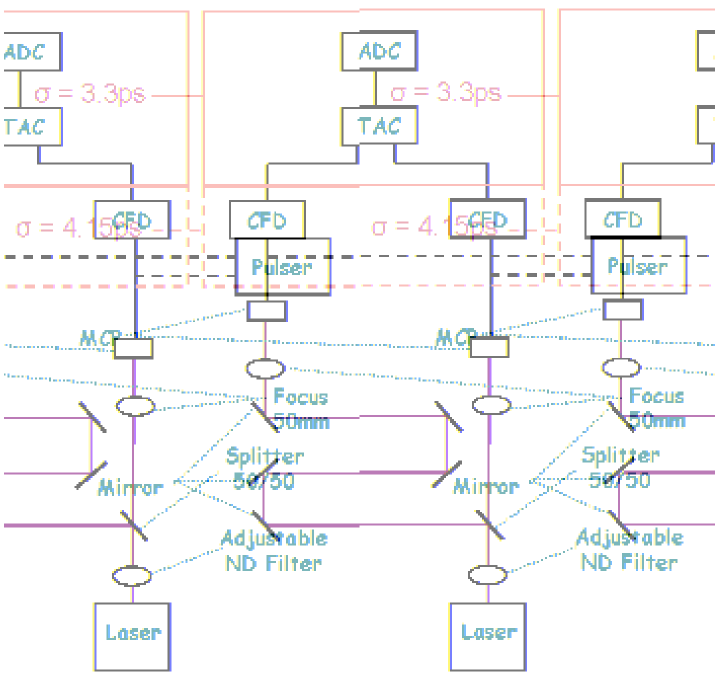
- Have started a serious effort on simulation to optimize detectors and integrated electronics
- Use laser test-stands and MTEST beam to develop and validate understanding of individual contributions- e.g. Npe, S/N, spectral response, anode to input characteristics,…
- Parallel efforts in simulating sampling electronics (UC, Hawaii) and detectors (UC,Saclay,Muons.inc).

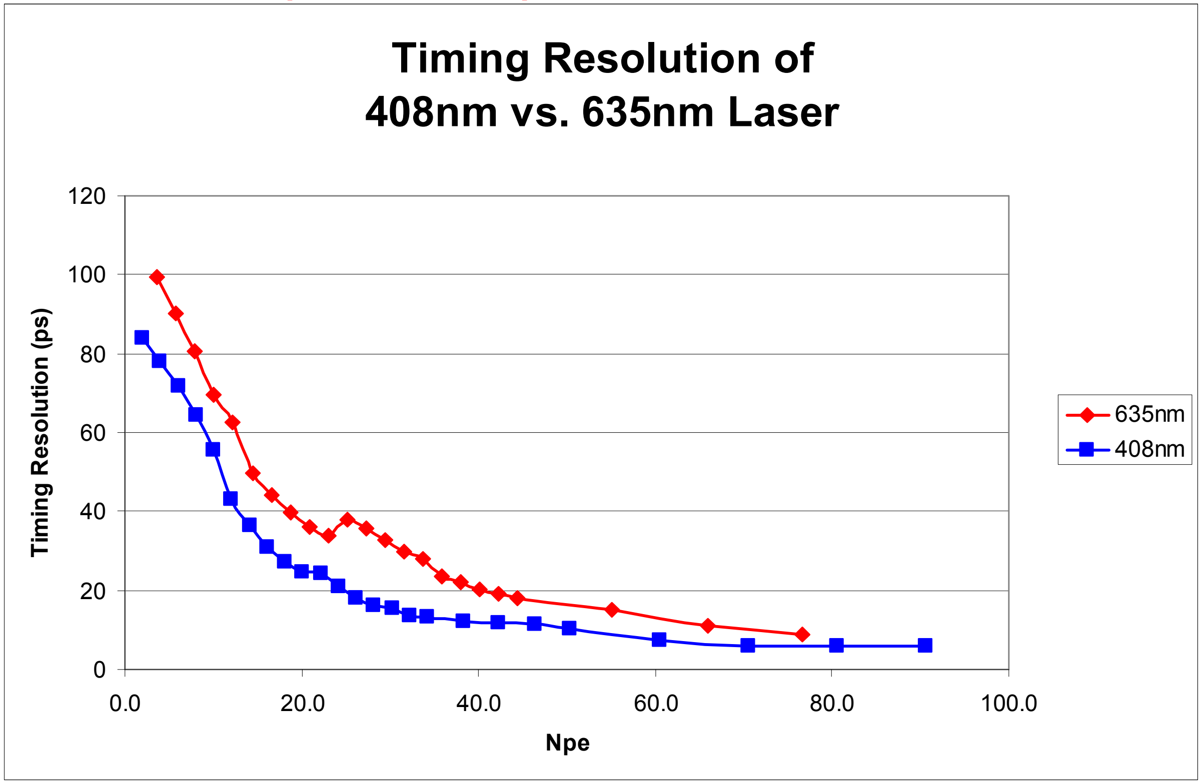
# Where we are-much progress!

- Using `off-the-shelf' photo-detectors, clumsy (i.e. inductive, capacitative) anodes, electronics-, but not yet new technologies -are at ~ 5-6 psec resolution with laser bench tests.
- Jerry Va'vra has answered many of the questions we had even a year ago on what limits present performance. Have (crude) models in simulation to compare test results to now
- Much experience with sampling- fast scopes, Gary Varner, Saclay group, Stefan Ritt- up to 6 GHz. Simulation package developed -=>understanding the electronics issues
- First test beam exposure few weeks ago…
- Clock distribution at psec (local) jitter (John Anderson)

# 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



# Understanding the contributing factors to 6 psec resolutions with present Burle/Photonis/Ortec setups- Jerry Vavra's Numbers

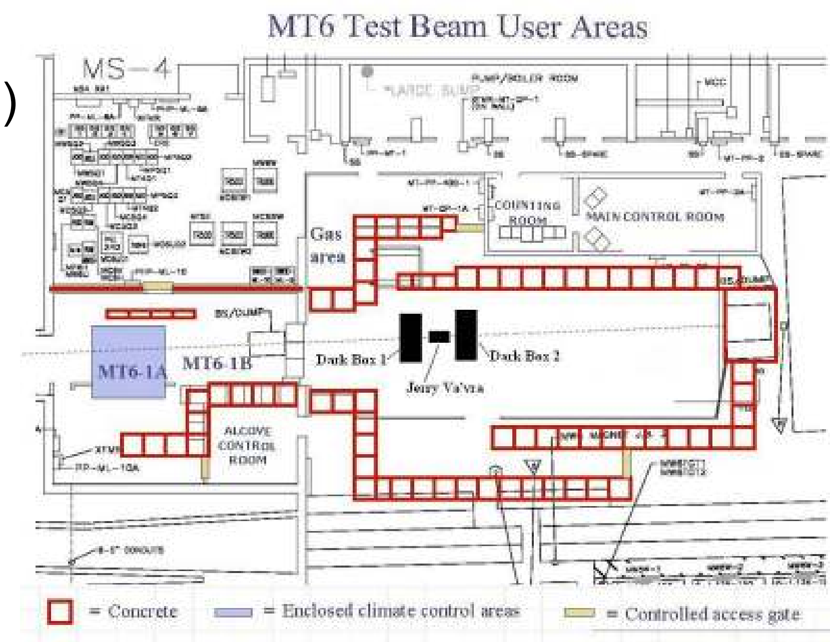
1. TTS: 3.8 psec (from a TTS of 27 psec)
2. Cos(theta)_cherenk 3.3 psec
3. Pad size 0.75 psec
4. Electronics 3.4 psec

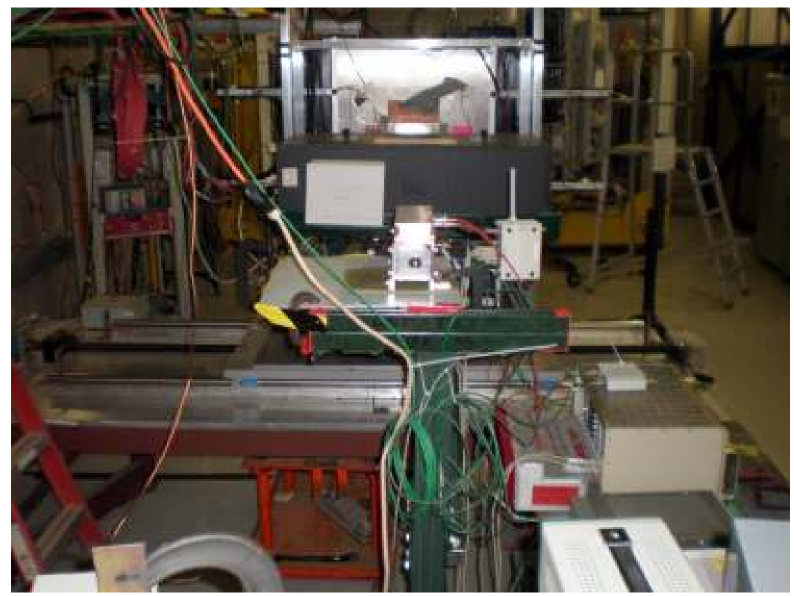
# Fermilab Test Beam Goals

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

# Fermilab Test Beam Setup

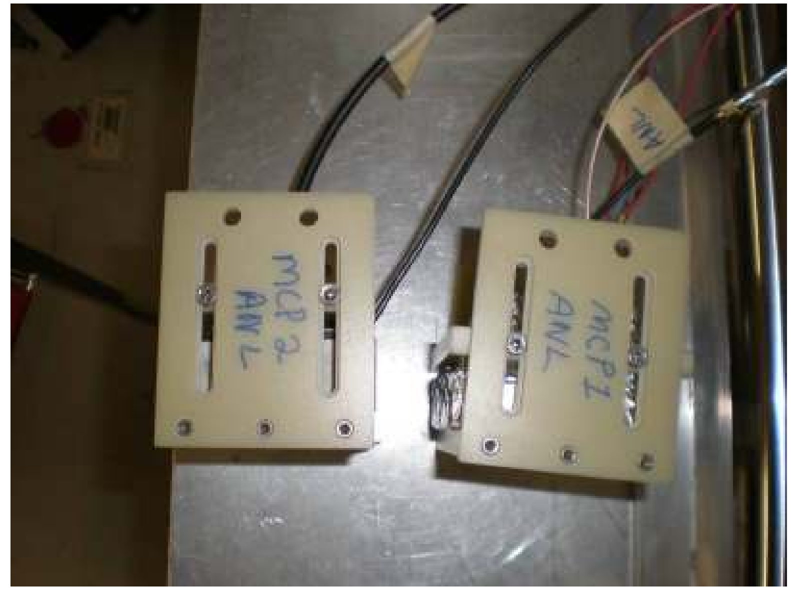
- Three dark boxes (Anatoly- wonderful!)
  - 2mm x 2mm scintillator
    - 2 PMTs for coincidence triggering in each box.
  - 2 MCPs or SiPMs in each box
- 3 DAQ systems
  - DAQ-1
    - uses FERA readout for fast data collection
  - DAQ-2
    - CAMAC
    - Allows other users to quickly connect to our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

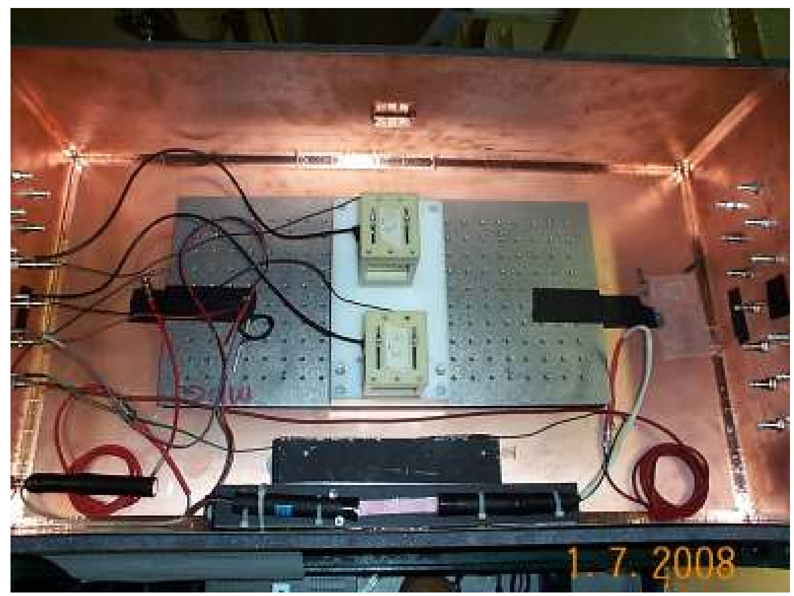


# Fermilab Test Beam Setup

- MCP 1 & 2 (dark box 1)
  - Photonis 85011-501
    - 25 μm pore
    - 64 anode (4 anodes tied together and read out)
    - 2 mm quartz face
    - MCP 1 had an updated ground plane, but was very noisy.
    - University of Chicago's MCPs
- MCP 3 & 4 (dark box 2)
  - Photonis 85011-501
    - 25 μm pore
    - 64 anode (4 anodes tied together and read out)
    - 2 mm quartz face
    - Erik Ramberg's MCPs



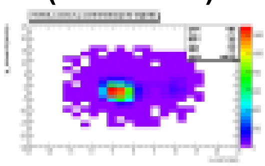



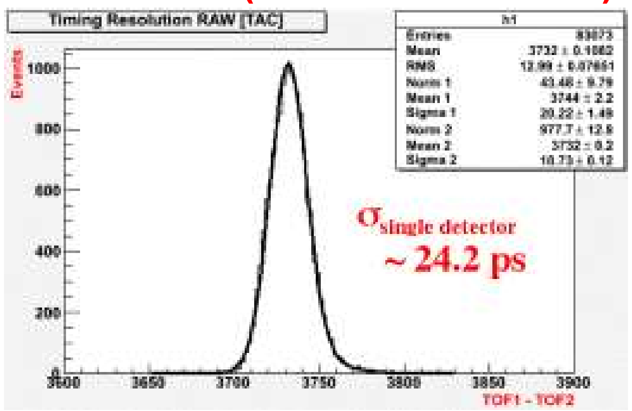
# SLAC & Fermilab Test Beam Results

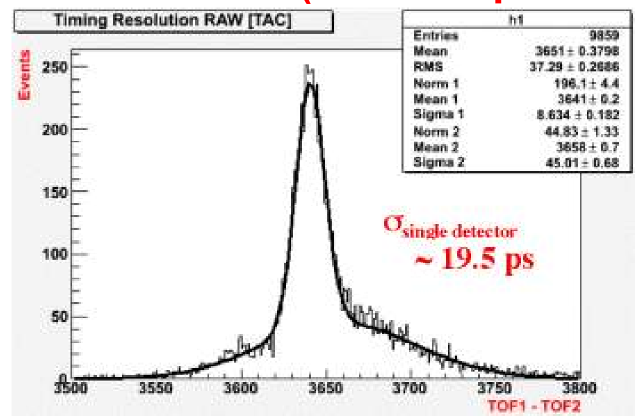
J.Va'vra, SLAC, Camden Ertley (UC/ANL)

**SLAC tests (10 GeV electrons):** **Fermilab tests (120 GeV protons):**

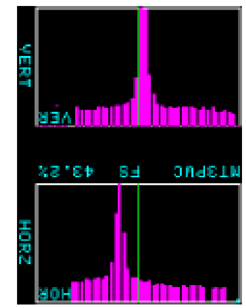
SLAC Beam spot (s ~2-3mm):

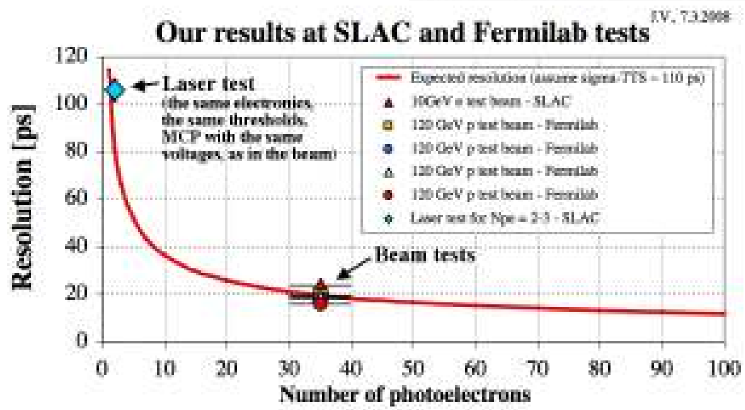





Fermilab beam spot (s ~7mm + halo):



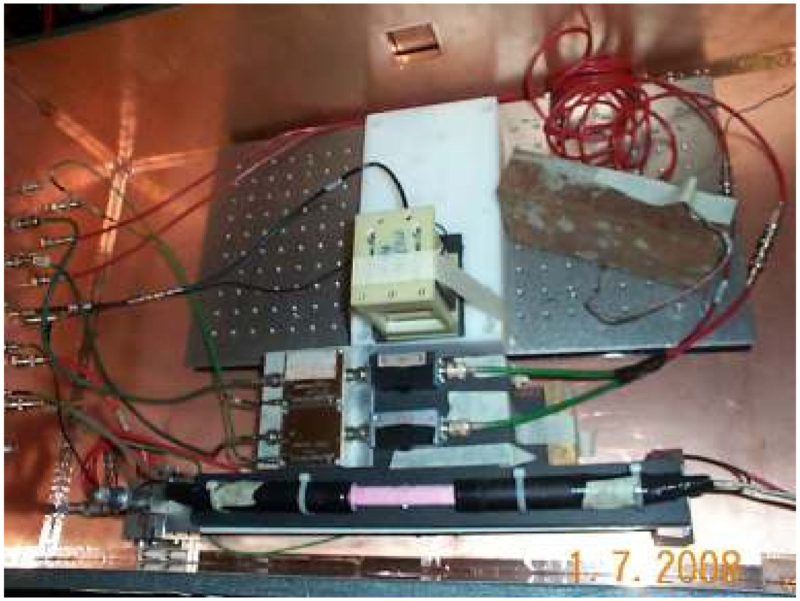



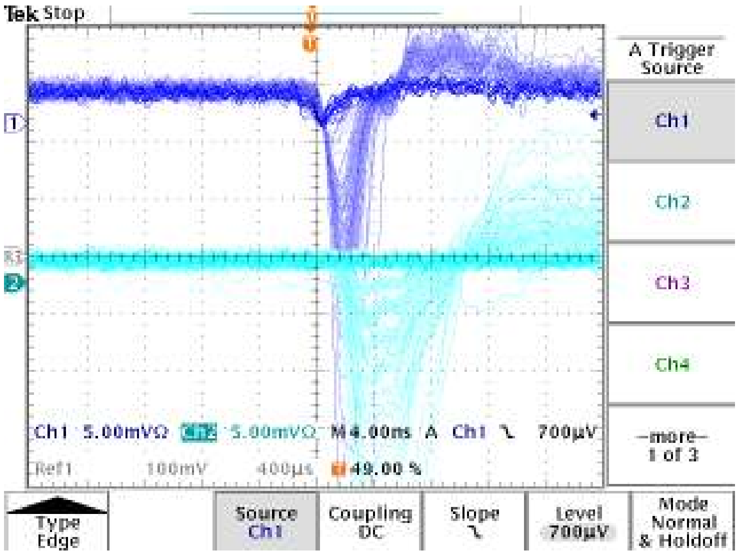

- **Aim: (a) low gain to minimize aging effects at SuperB, (b) be linear in a region of Npe = 30-50.**
- **1-st test at SLAC: typical resolution results: $s_{\text{single detector}}$ ~23-24 ps**
- **2-nd test at Fermilab: typical resolution results: $s_{\text{single detector}}$ ~17-20 ps**
- **Results are consistent with a simple model.**
- **We have reached a Super-B goal: $\sigma$ ~ 20ps**

# SiPM Fermilab Test Beam Results

Anatoly Ronzhin, FNAL

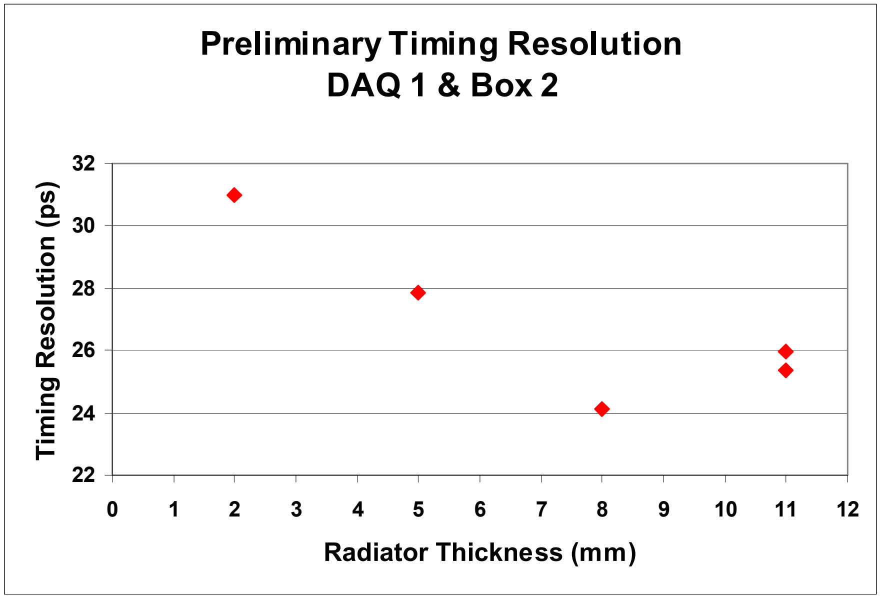
- SiPM 1
  - Hamamatsu 3 x 3 $mm^2$
  - Quartz radiator 6 x 6 x 12 $mm^3$
    - 1.5mm “effective thickness”
    - ~10 photoelectrons
- SiPM 2
  - Hamamatsu 1 x 1 $mm^2$
  - Quartz radiator 6 x 6 x 6 $mm^3$
    - 0.5mm “effective thickness
    - ~3 photoelectrons
- Obtained 70ps timing resolution
  - Single photoelectron timing is ~121ps for SiPM 2
  - Single photoelectron timing for SiPM 1 will be measured



# Fermilab Test Beam Results

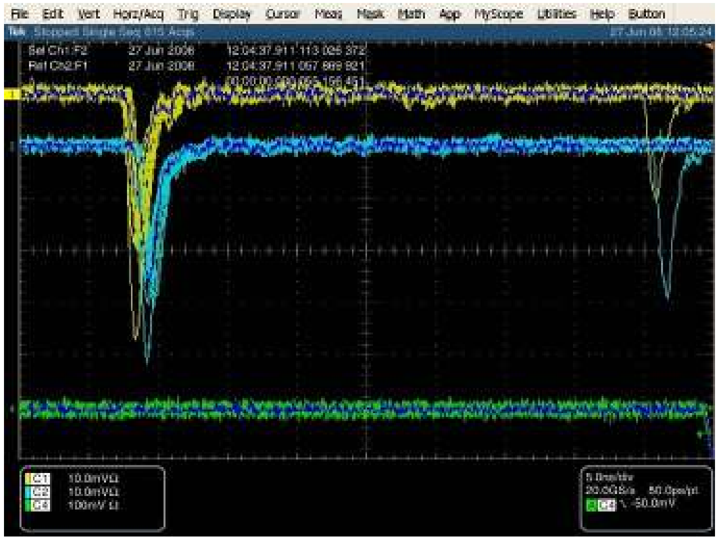
- **Preliminary results with DAQ-1**
  - Obtained ~24ps with MCP 3 & 4
    - Cuts on pulse height were made
    - 8mm total radiator
    - 1.9kV
- **Preliminary results with scope.**
  - 8ps intrinsic timing jitter.
  - Obtained ~26ps with MCP 3 & 4
    - 5mm total radiator
    - 2.0 kV

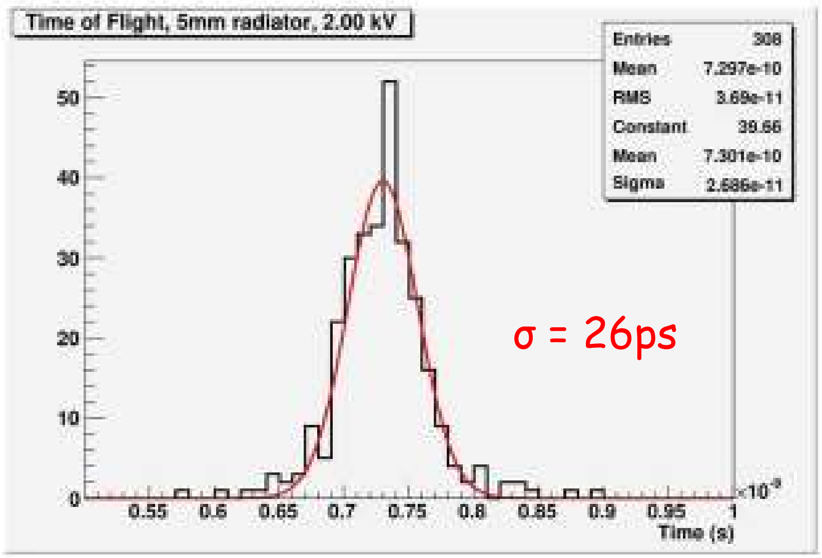



Ch1: MCP3
10mV/div

Ch2: MCP4
10mV/div

5ns/div





# Future Work

- We would like to schedule future test beam runs as we have new devices and electronics ready
- Same process as now- use laser test-stand for development, validation of simulation- then move to testbeam for comparison with simulation with beam.

  – Changes to the MCPs
    - 10um pore MCPs (two in hand)
    - Transmission-line anodes (low inductance- matched)- in hand
    - Reduced cathode-MCP_IN MCP_OUT-anode gaps- ordered
    - ALD module with integrated anode and capacitive readout- proposed (ANL-LDRD)

  – Changes to electronics readout
    - Add Ritt and/or Varner sampling readouts (interleave 10 GS) –in works
    - First test via SMA; then integrate chips onto boards?
    - Development of 40 GS CMOS sampling in IBM 8RF (0.13micron)- proposal in draft

  – New applications/geometries (LHC/Albrow)-proposed

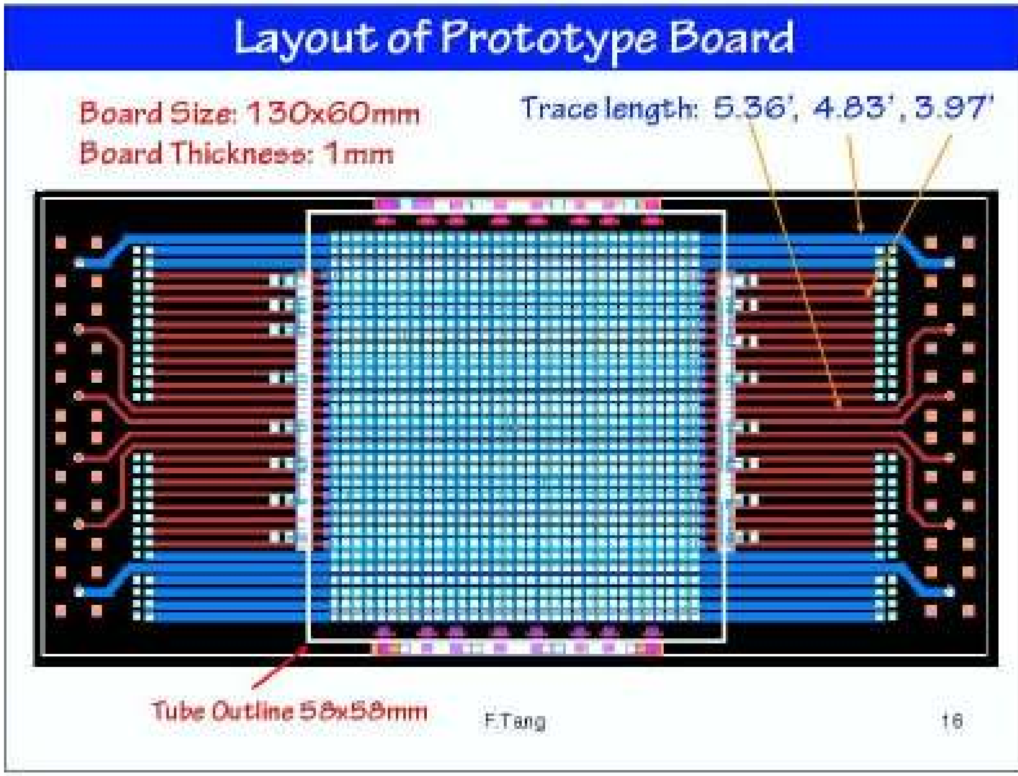
  – Test timing between two similar SiPMs, new devices

# Jerry's #'s re-visited : Solutions to get to <several psec resolution.

1. **TTS: 3.8 psec (from a TTS of 27 psec)**
   MCP development- reduce TTS- smaller pores, smaller gaps, filter chromaticity, ANL atomic-deposition dynodes and anodes.
2. **Cos(theta)_cherenk 3.3 psec**
   Same shape- spatial distribution (e.g. strips measure it)
3. **Pad size 0.75 psec-**
   Transmission-line readout and shape reconstruction
4. **Electronics 3.4 psec –**
   fast sampling- should be able to get < 1psec (simulation)

# New Anode Readout-

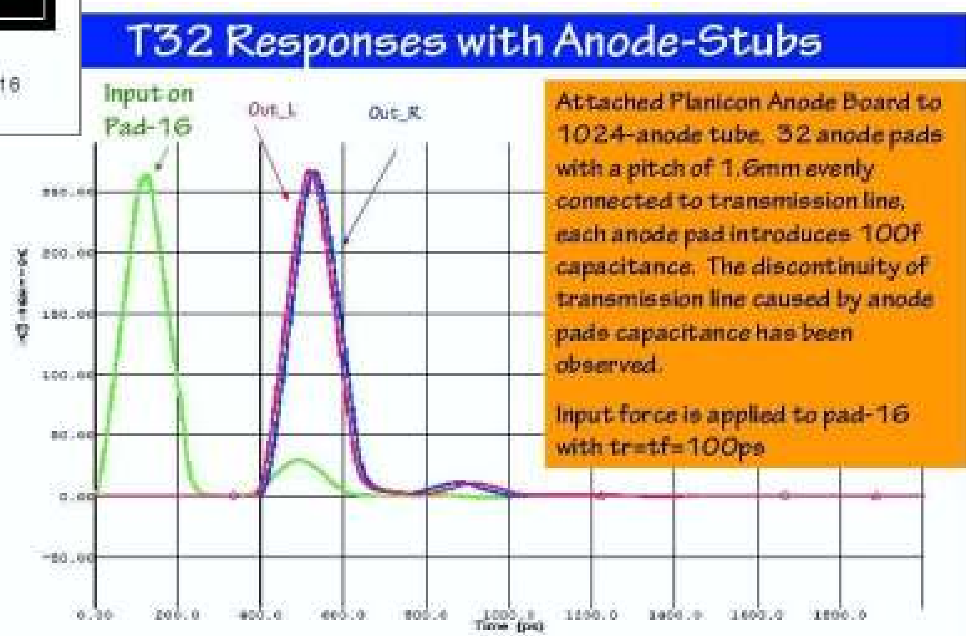
Get time AND position from reading both ends of transmission lines



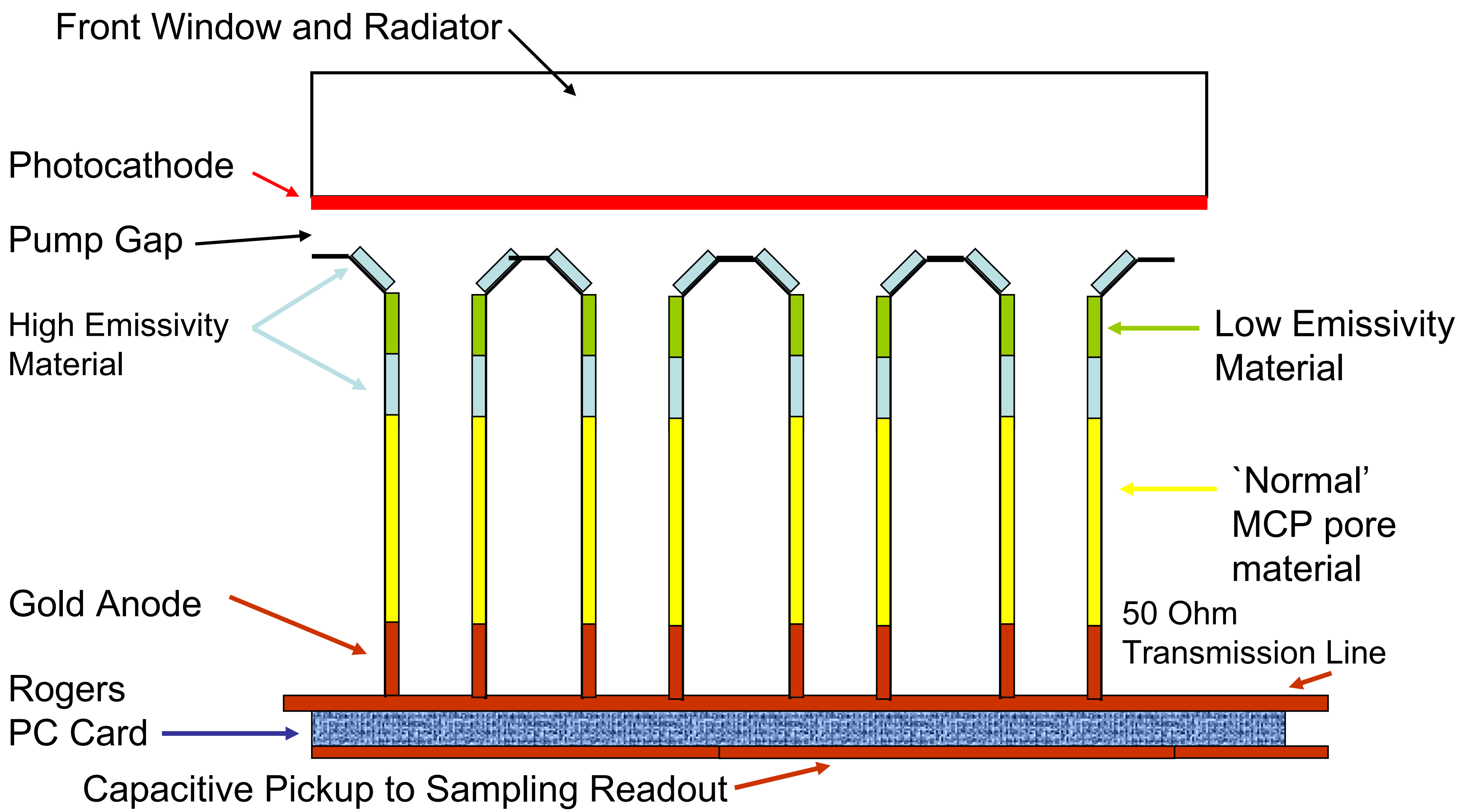

32 50 ohm transmission lines on 1.6 mm centers (Tang); attach to 1024 anode pads (Sellberg)

Simulation of loaded transmission line

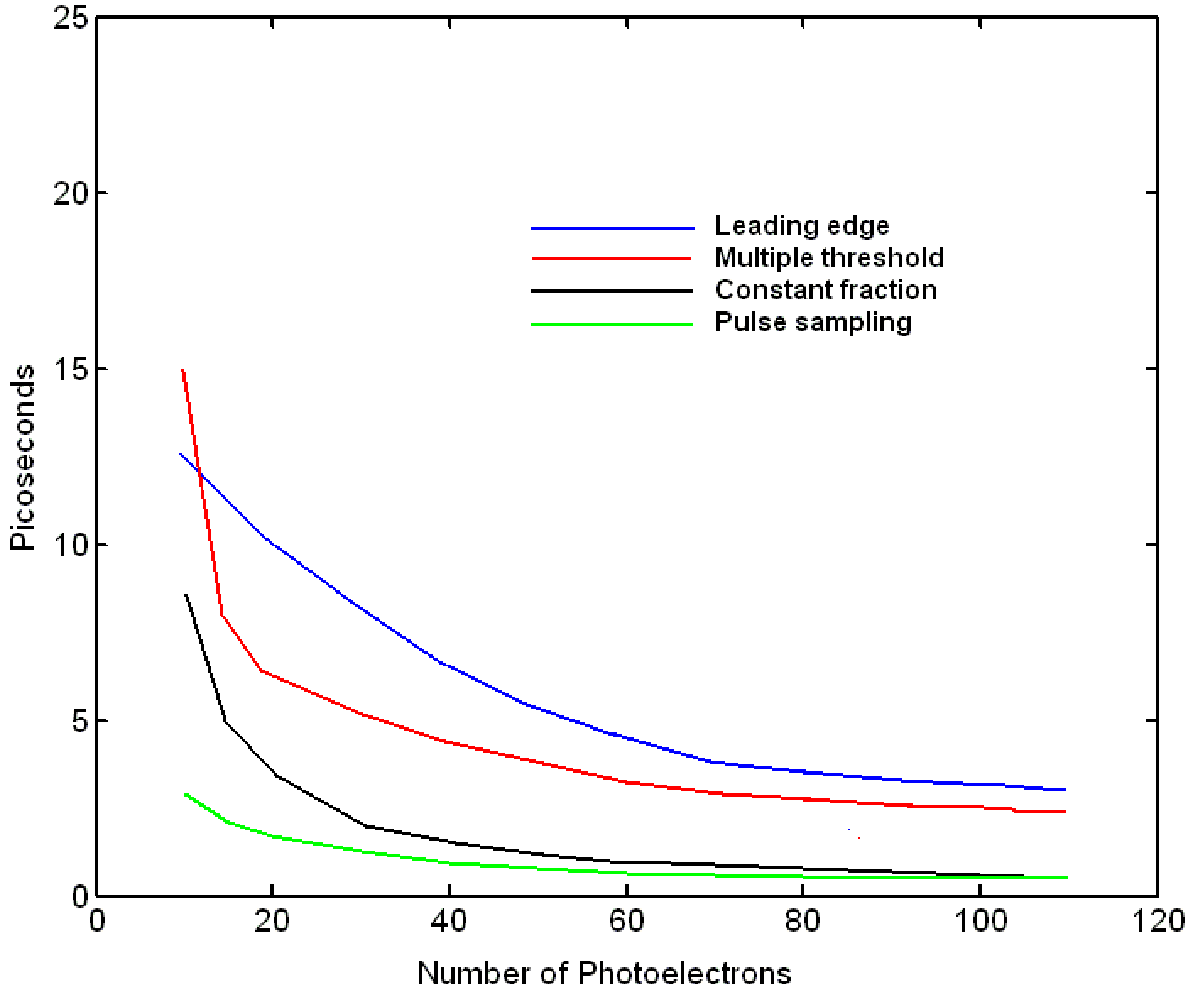
With mock MCP pulse and anode pads (Tang)



# Psec Large-area Micro-Channel Plate Panel (MCPP)- LDRD proposal to ANL (with Mike Pellin/MSD)



# Electronics Simulation-development of multi-channel low-power cheap (CMOS) readout




S/N=80

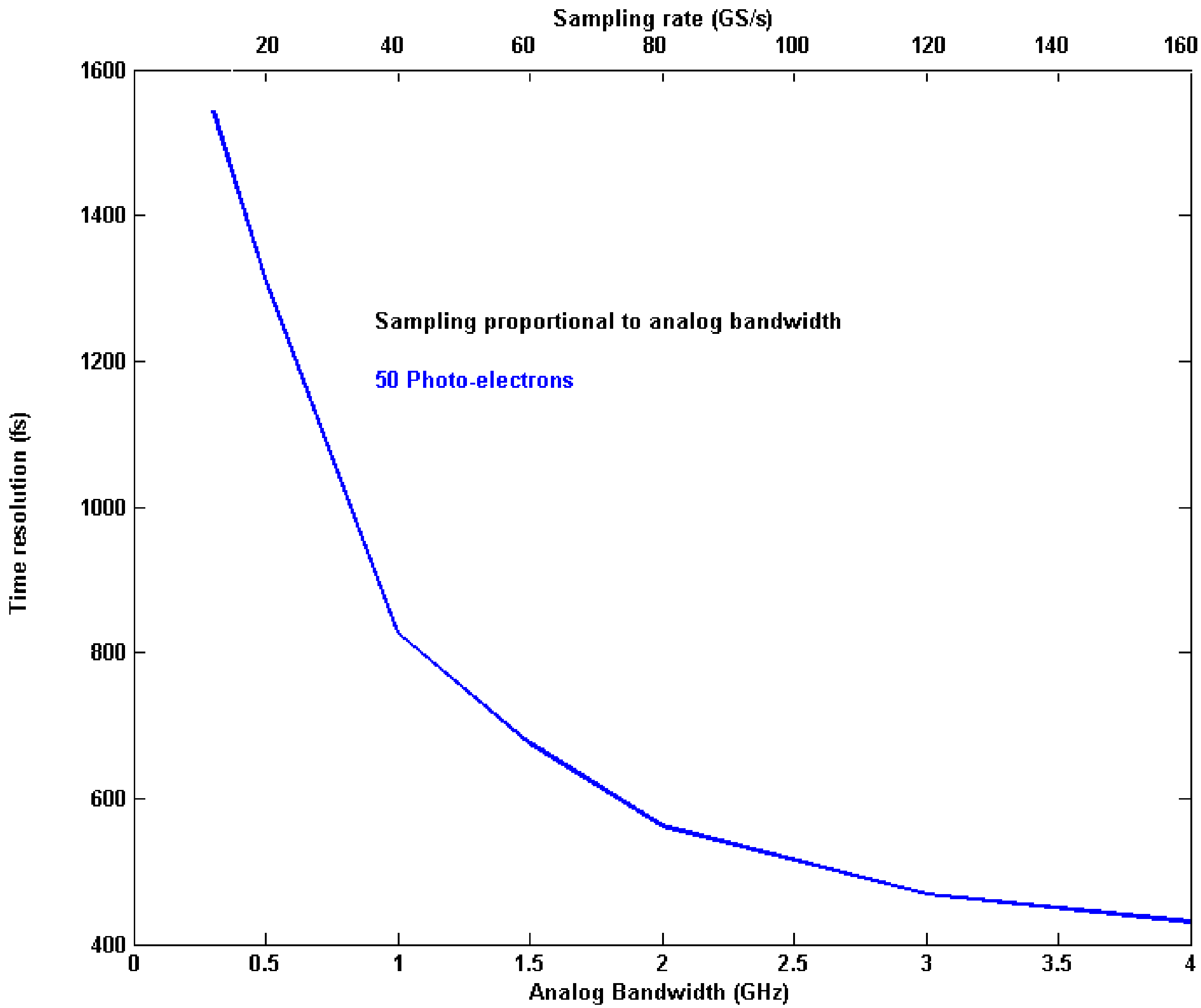
ABW= 1 GHz

Synthesized MCP signal

8 bit A-to-D

Jean-Francois Genat

# Electronics Simulation- Sampling analog bandwidth on input at fixed S/N and sampling/ABW ratio




S/N=80
Synthesized MCP signal
8 bit A-to-D

Jean-Francois Genat

# Summary

- Successful first run- got Jerry's Super-B data, SiPM data, 25-micron MCP data with radiators
- First look at MCP data makes it plausible that it falls on our laser teststand and simulation curves for S/N,Npe- analysis in works
- Got safety, dark-boxes, cables, DAQ, Elog, great bunch of collaborators, new students, etc. in place- very good start!
- Have new devices/readouts in the works- start of a program.
- We're really grateful to Fermilab and all who support the Mtest testbeam.