Would Psec TOF Be Useful To LHCb?

Henry J. Frisch
Enrico Fermi Institute
University of Chicago

OUTLINE

1. What would you do with it if you had it?
2. How does one get much better time resolution?
3. Some technical details
4. Plan for the future- 3yr development

Apologies for sloppy talk- I finished the big DOE proposal today

What would TOF<10psec do for you?

- (disclaimer- I know next to nothing about LHCb, b-physics, or the Collab. goals..- I'm making this up….needs work- would be delighted to see someone pick this up.)

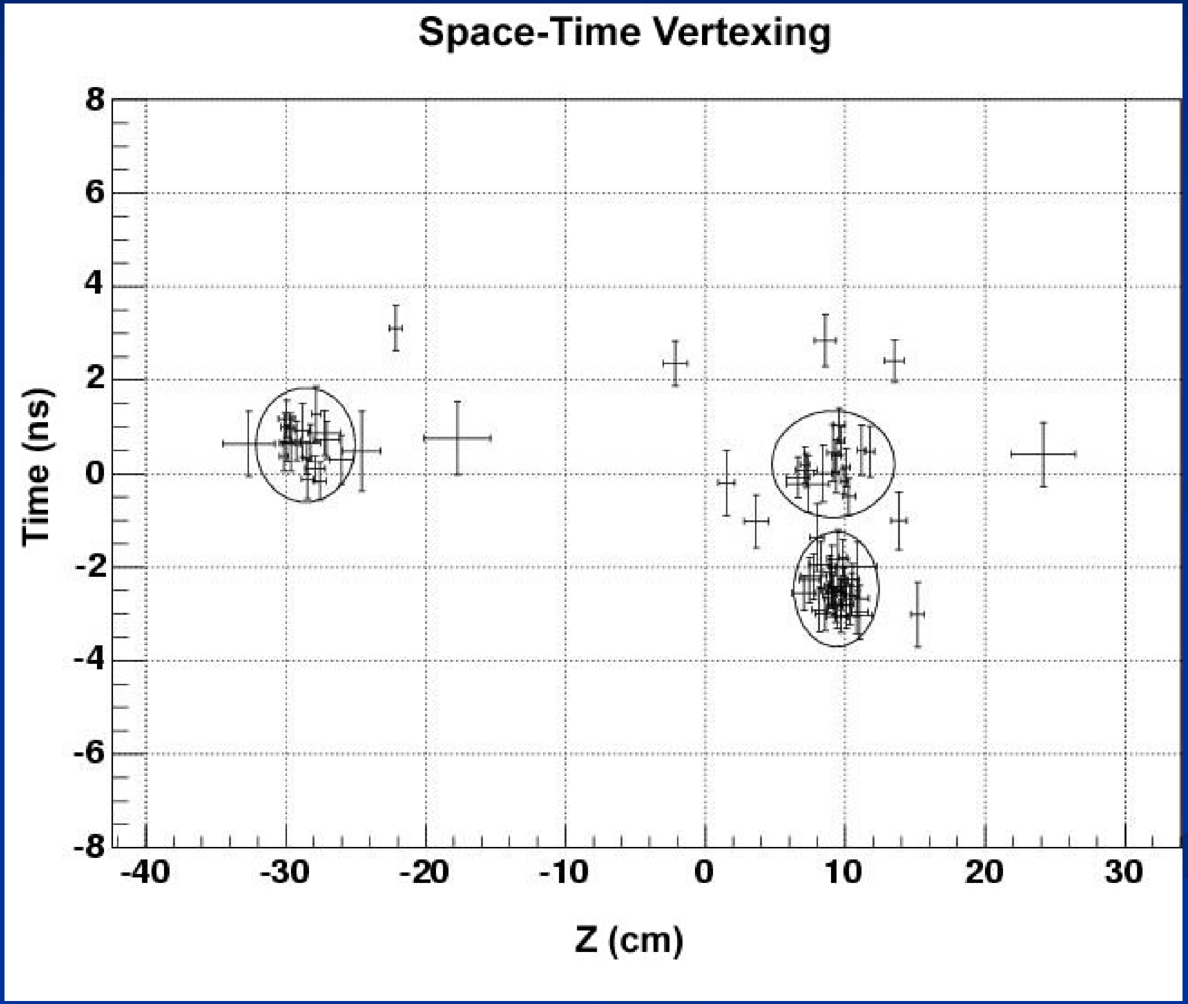
1. If you can stand a little active material in front of your em calorimeter, convert photons- 10 psec is 3mm IN THE DIRECTION of the photon flight path- can vertex photons. **Do pizeros, etas, K_L and K_S**, …
2. This allows **all neutral signature mass reconstruction-** new channels. e.g. **the CP asymmetry in BS->π K^0** (J.Rosner suggestion)
3. Eta's in general are nice: e.g. **BS->J/psi eta** (again, J.R.)
4. With two planes and time maybe get to 1 psec,=300 microns along flight path- **can one vertex from timing?**
5. Searches for **rare heavy long-lived things** (other than b's)- need redundancy.
6. May help with pileup- **sorting out vertices**.

Performance Goals

Quantity	Present	Baseline	HJF
Time resolution-charged particles (psec)	12 (6)(2.3*	10	<1
Time resolution-photons (psec)	---	10	1-3
Space resolution- charged (mm)	0.1*	1	0.1
Space resolution- neutrals (mm)	--	5	1-3
Thickness (inches)/plane	1*	2	2
Cost ($/30 sq-meters/plane)	60M$	3.0M$	1.2M$
Schedule for development (from t_0- i.e. funding of MCP project)	---	3 yrs	5 yrs
* With a 2" square Burle MCP in beam- 6 psec on bench,2.3 expected			

Example of vertexing from CDF

- EM timing (Dave Toback, HJF, et al)
- Vertices overlap in time, and in space, but usually not both
- Resolution is good wrt 7 cm

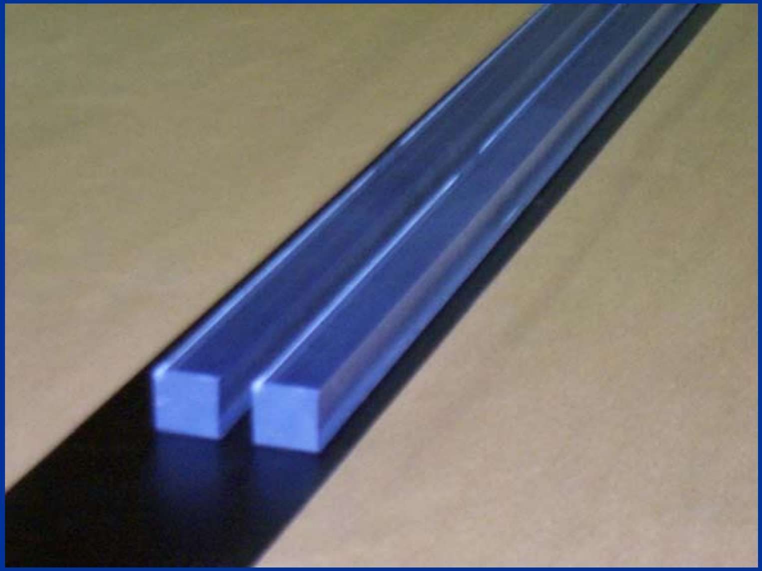


Why has 100 psec been the # for 60 yrs?

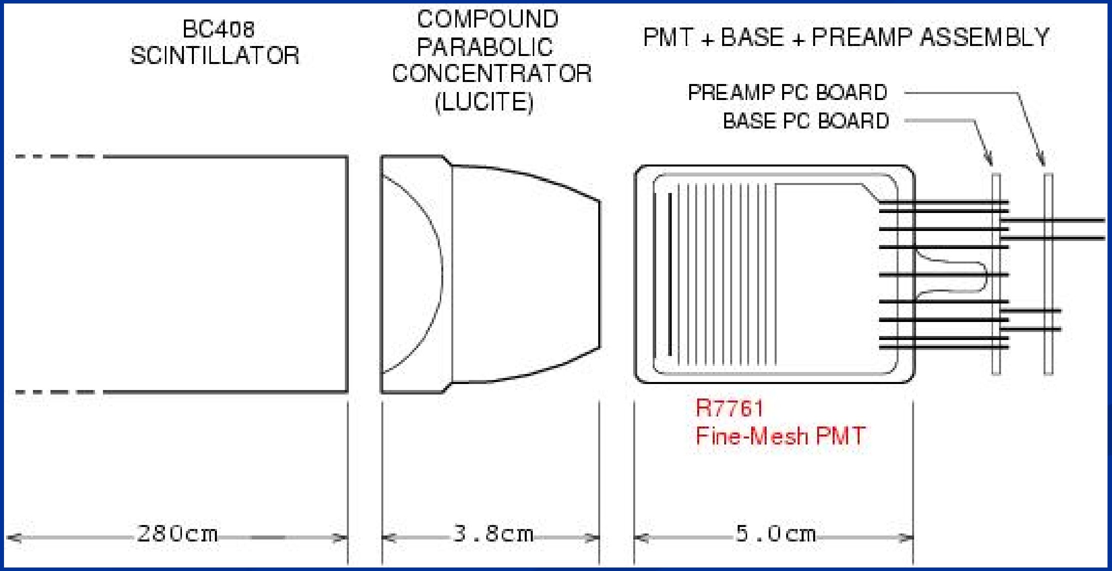
Typical path lengths for light and electrons are set by physical dimensions of the light collection and amplifying device.

These are now on the order of an inch. One inch is 100 psec

That's what we measure- no surprise! (pictures from T. Credo)



Typical Light Source (With Bounces)

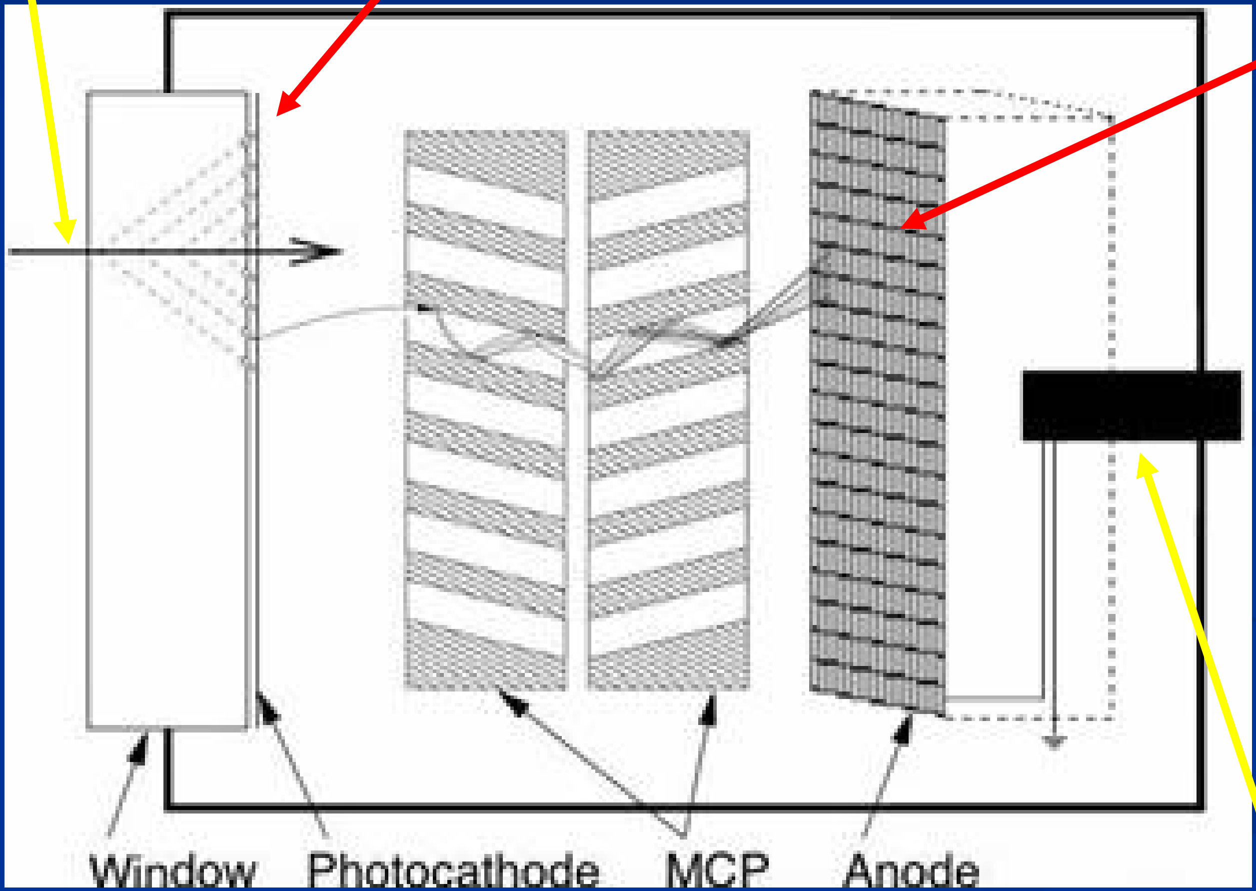


Typical Detection Device (With Long Path Lengths)

Solutions: Generating the signal

Use Cherenkov light - fast

Incoming rel. particle



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

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

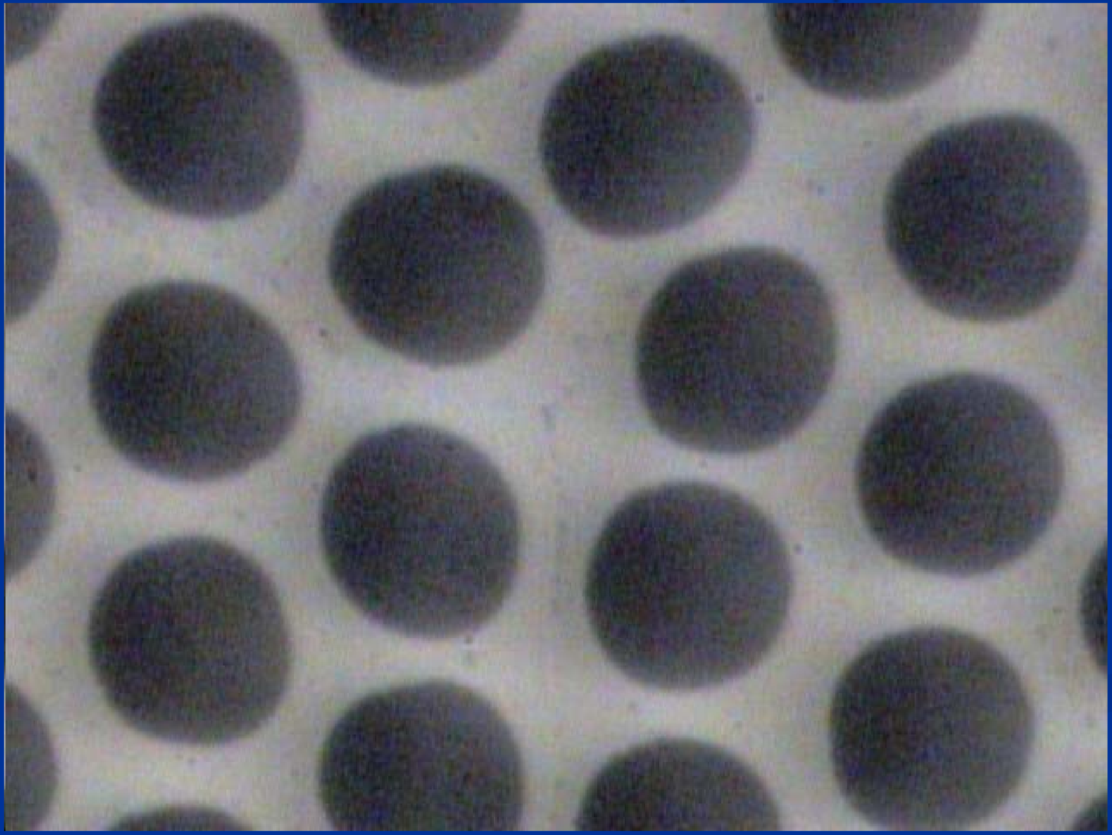
e.g. Burle (Photonis) 85022- with mods per our work

Collect charge here-differential Input to 200 GHz TDC chip

Micro-channel Plates

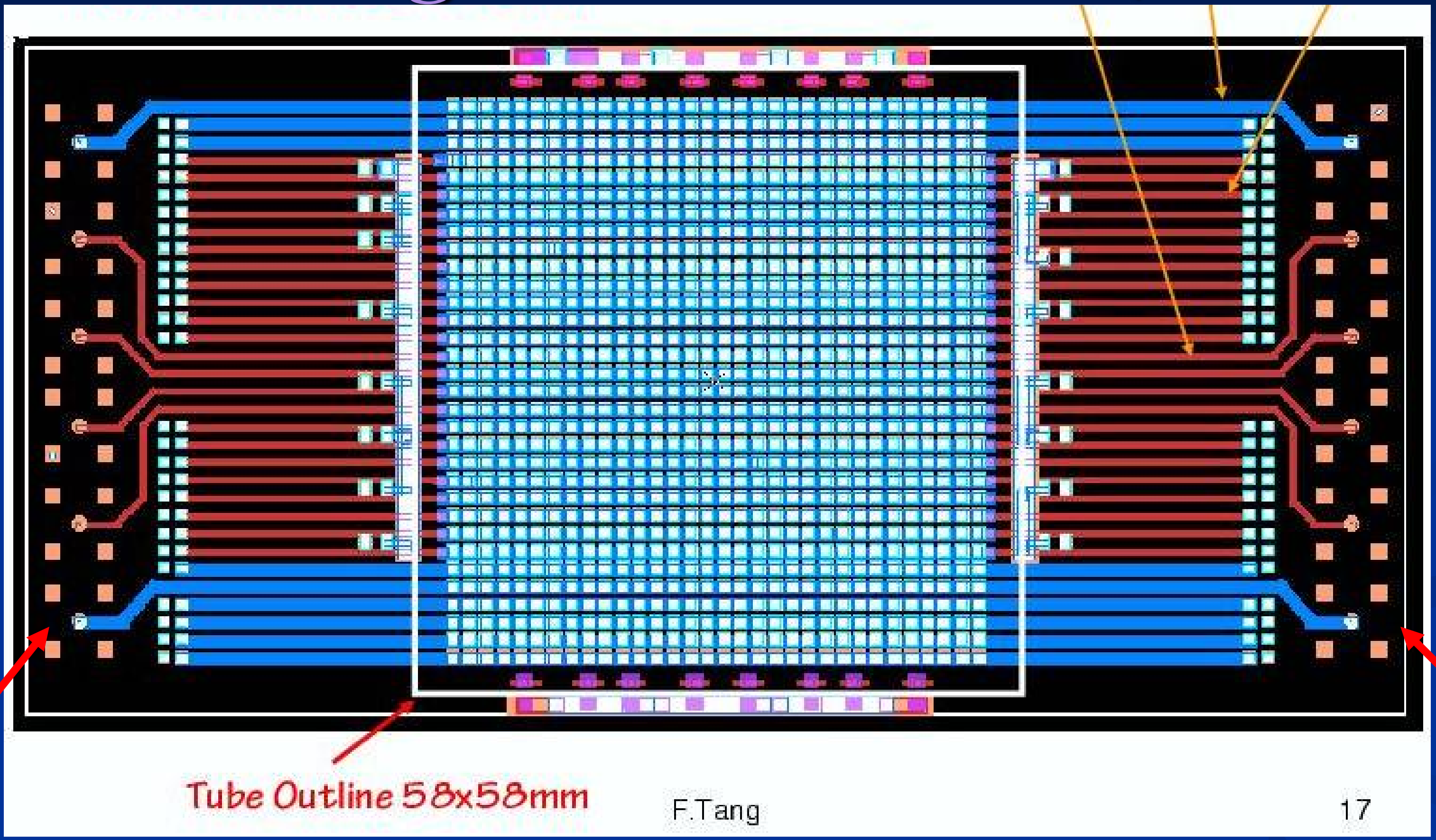
Currently the glass substrate has a dual function-

1. To provide the geometry and electric field like the dynode chain in a PMT, and
2. To use an intrinsic lead-oxide layer for secondary electron emission (SEE)



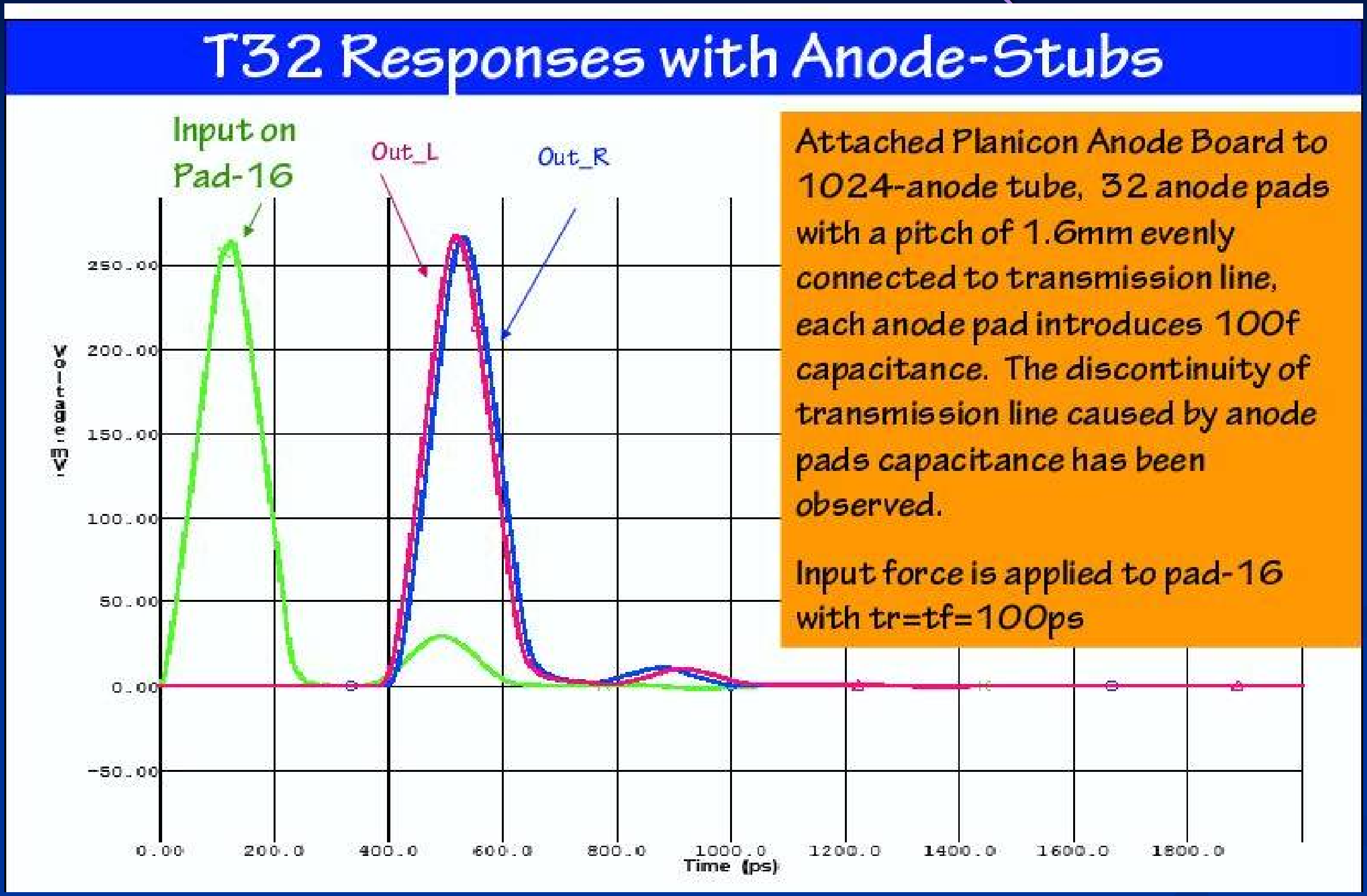
Micro-photograph of Burle 25 micron tube- Greg Sellberg (Fermilab)- ~2M$/m^2- not including readout

Get position AND time
Anode Design and Simulation(Fukun Tang)



- Transmission Line- readout both ends=> pos and time
- Cover large areas with much reduced channel account.

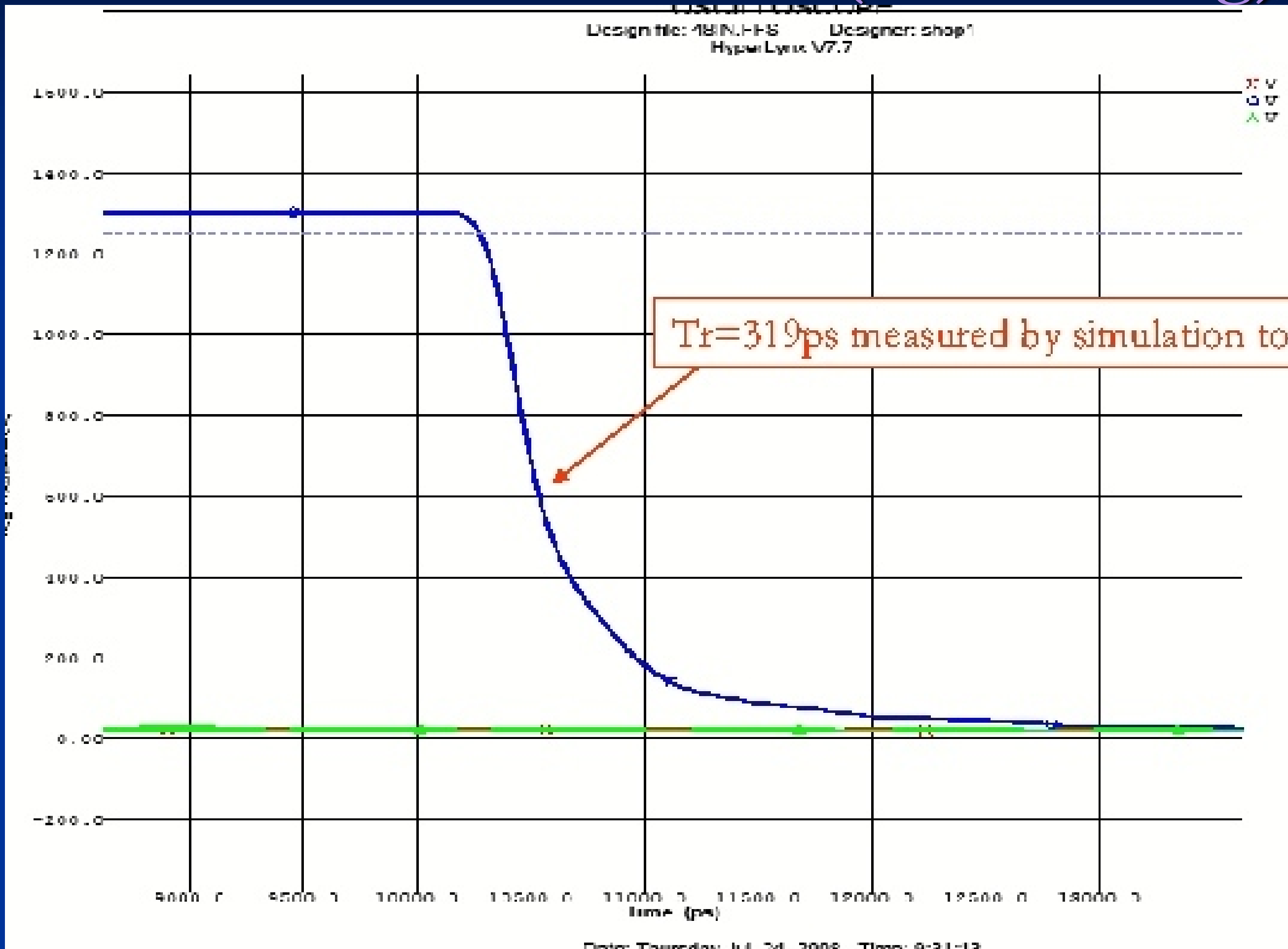
Comparison of measurements (Ed May and Jean-Francois Genat and simulation (Fukun Tang)



- Transmission Line- simulation shows 3.5GHz bandwidth- 100 psec rise (well-matched to MCP)
- The time difference yields a velocity of 64ps/cm against 68ps predicted

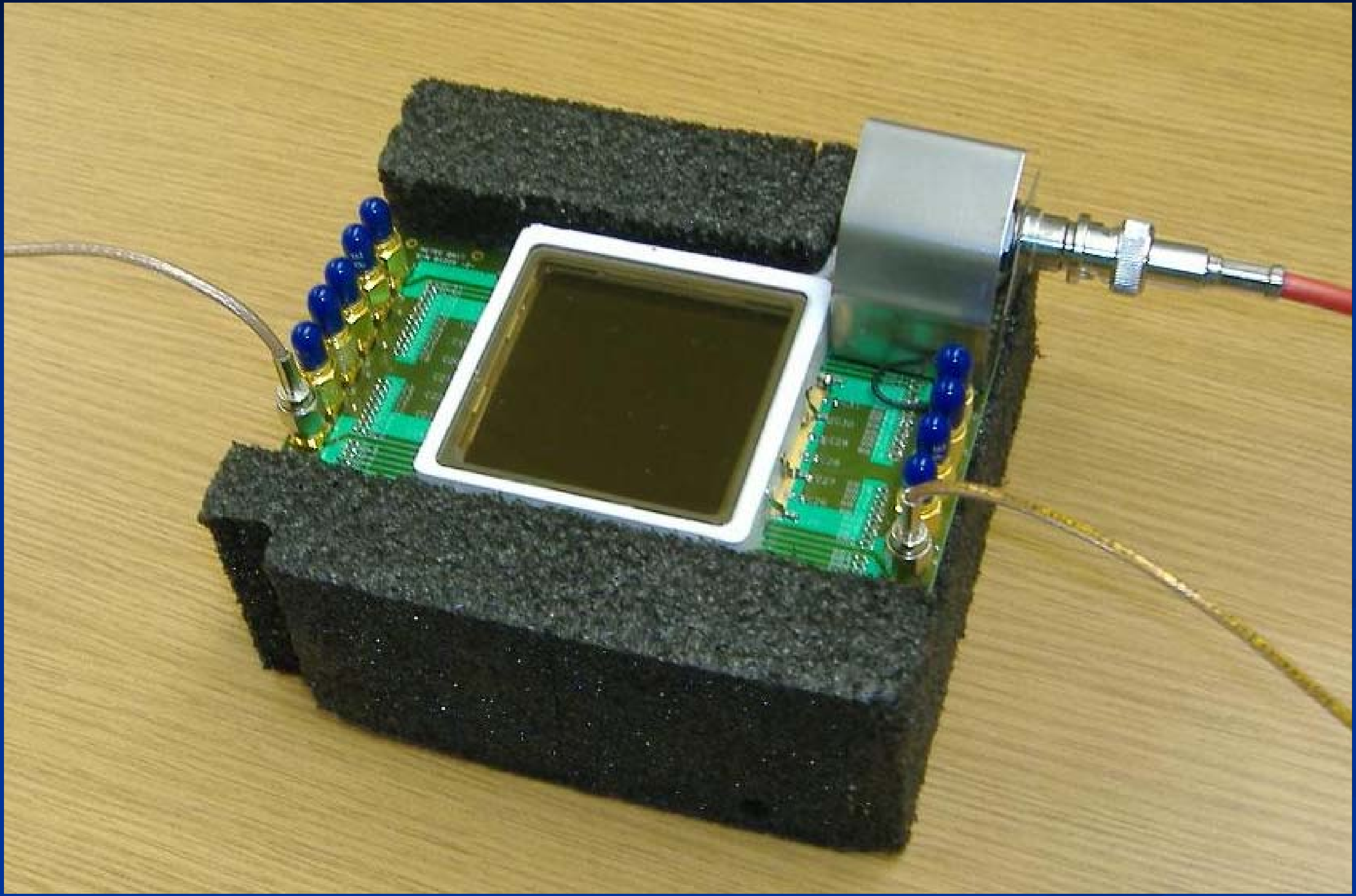
Scaling Performance to Large Area

Anode Simulation(Fukun Tang)

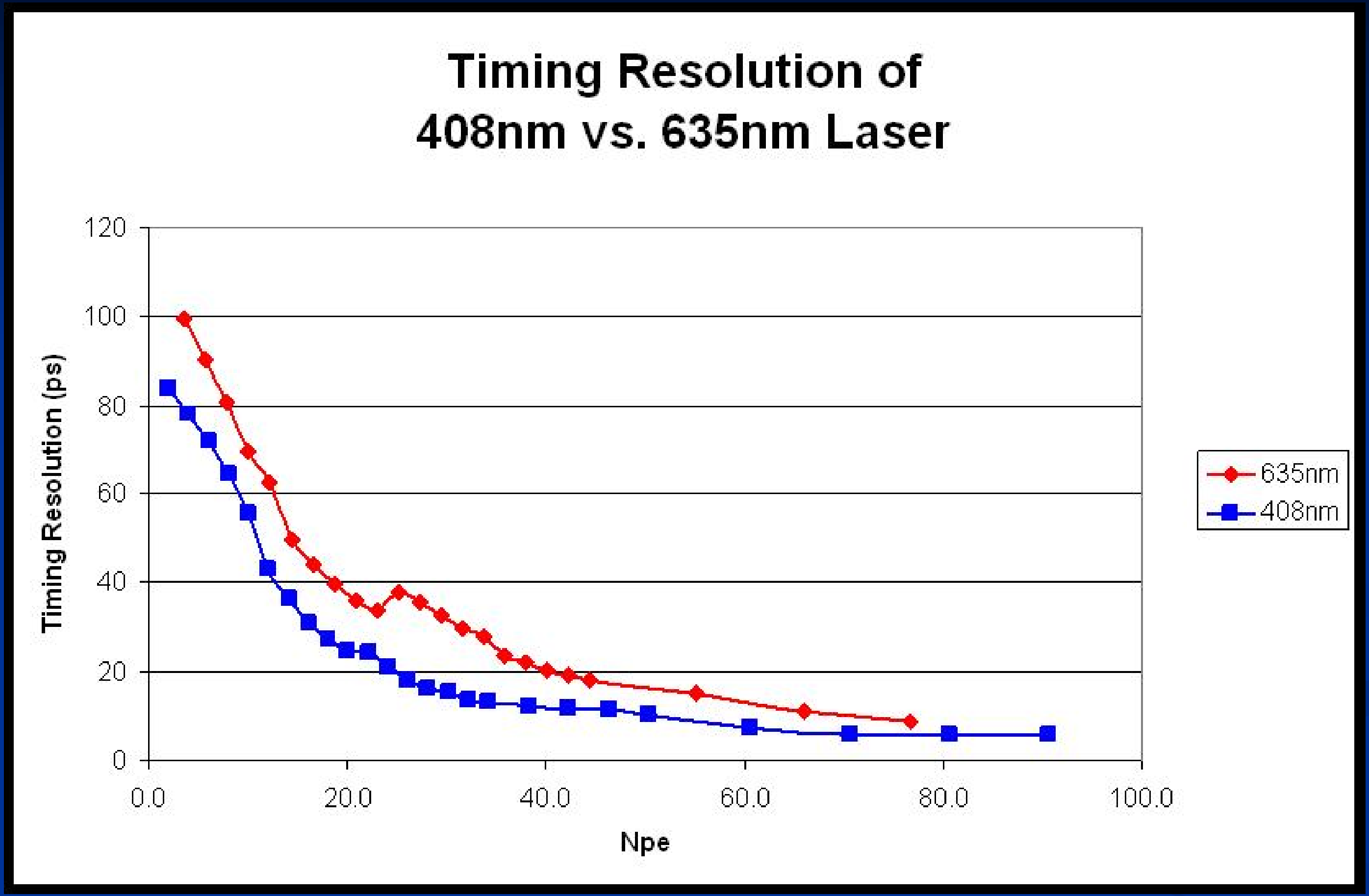


- 48-inch Transmission Line- simulation shows 1.1 GHz bandwidth- still better than present electronics.

Photonis Planicon on Transmission Line Board



Couple 1024 pads to strip-lines with silver-loaded epoxy (Greg Sellberg, Fermilab).



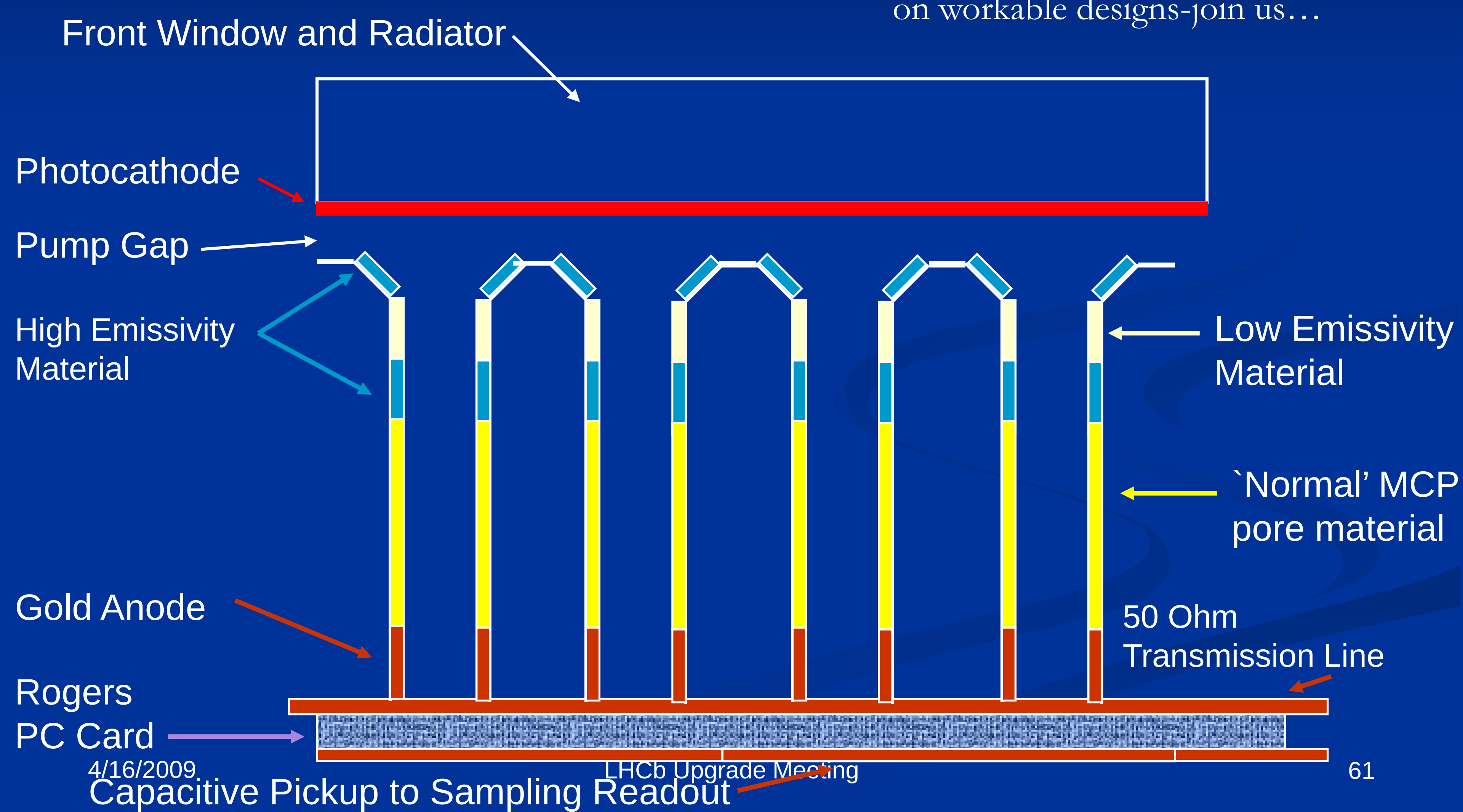
- Camden Ertley results using ANL laser-test stand and commercial Burle 25-micron tube- lots of photons
- (note- pore size may matter less than current path!- we can do better with ALD custom designs (transmission lines))

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

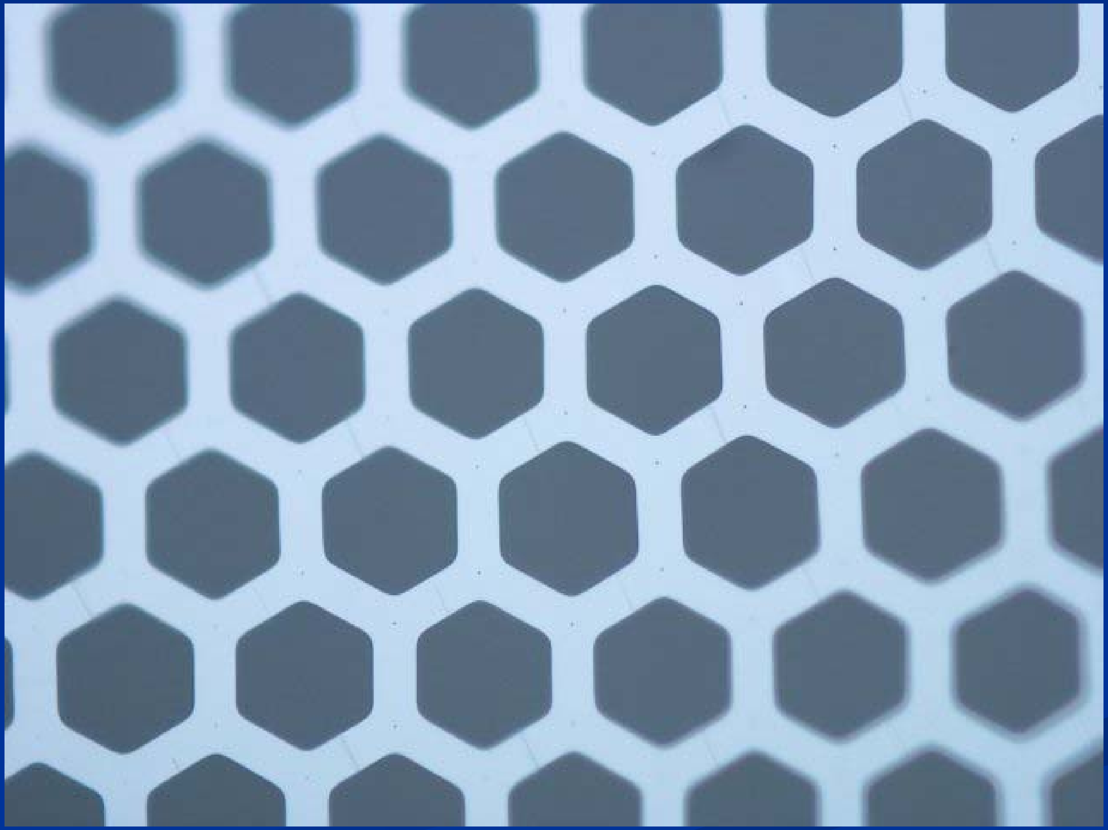
Large-area Micro-Channel Plate Panel "Cartoon"

N.B.- this is a `cartoon'- working on workable designs-join us…

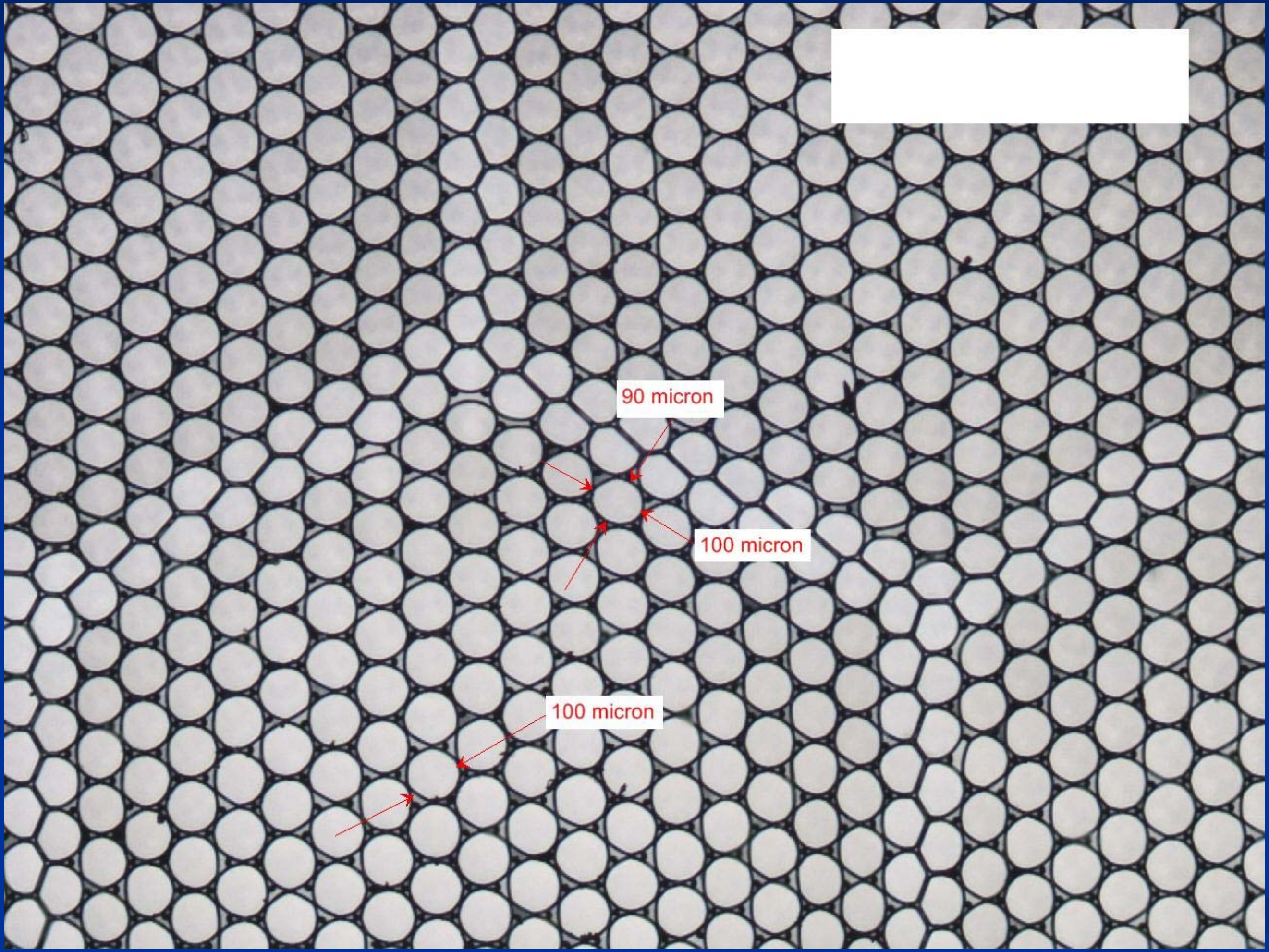


Incom glass capillary substrate

- New technology- use Atomic Layer Deposition to `functionalize an inert substrate- cheaper, more robust, and can even stripe to make dynode structures (?)



Another pore substrate (Incom)



Front-end Electronics

Critical path item- probably the reason psec detectors haven't been developed

- We had started with very fast BiCMOS designs- IBM 8HP- Tang designed two (really pretty) chips
- Realized that they are too power-hungry and too 'boutiqu
for large-scale applications
- Have been taught by Gary Varner, Stefan Ritt, Eric DeLanges, and Dominique Breton that there's a more clev
and elegant way- straight CMOS – sampling onto an array of capacitors
- Have formed a collaboration to do this- have all the expert groups involved (formal with Hawaii and France)- see talks by Tang and Jean-Francois at Lyon

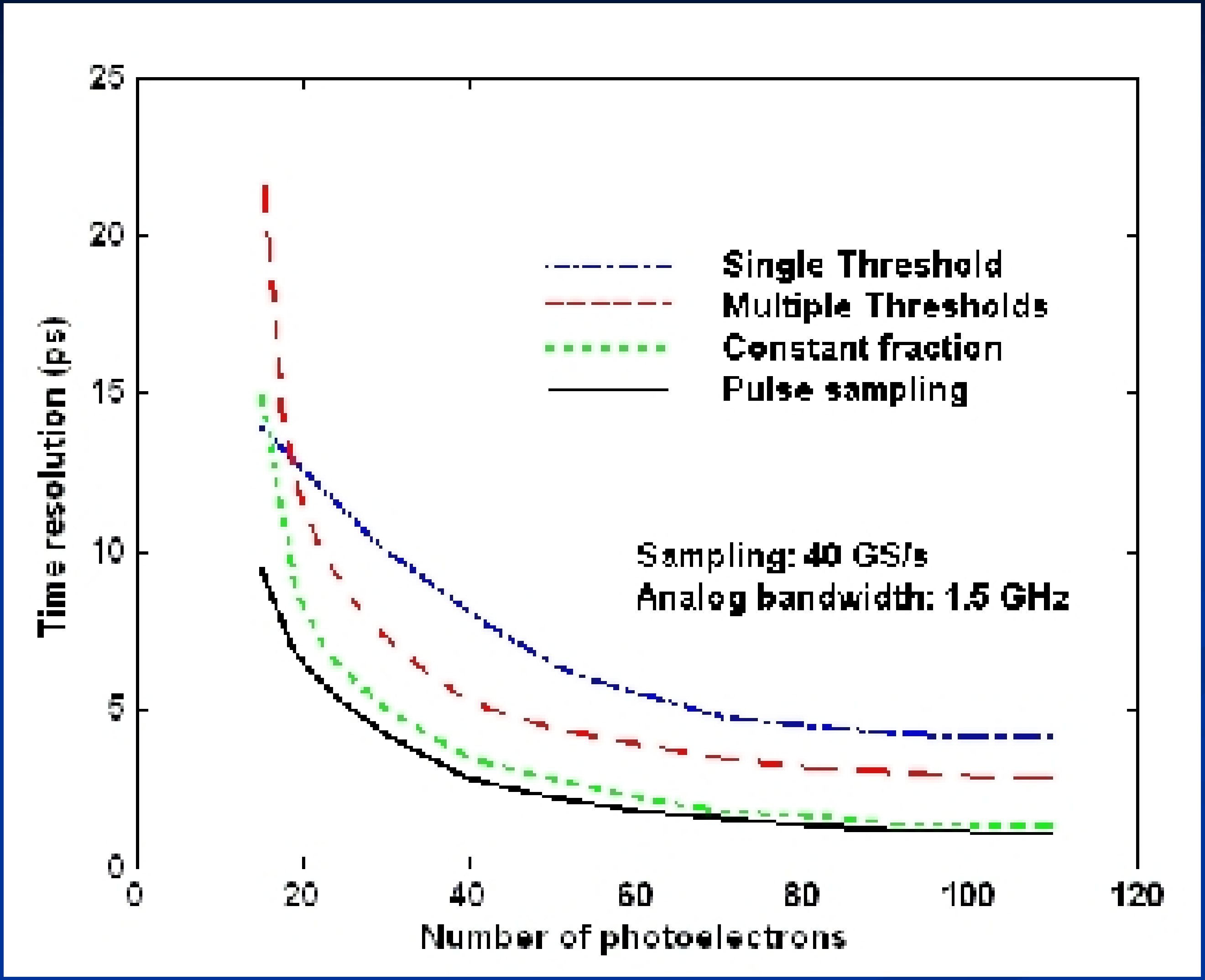
II STATE OF THE ART

Several circuits have already been designed in the HEP community for fast pulse sampling, mainly to record photo-multipliers pulse shapes. As detailed in section I, fast timing requires higher sampling rates, but smaller dynamics ranges.

	Hawaii		Orsay/Saclay		PSI		PSEC
	Lab 3	Planned Blab2	Sam	Planned	DRS3	Planned DRS4	This proposal
Sampling frequency	20 MHz-3.7 GHz	1-10 GHz	0.7-2.5 GHz	10 GHz	10 MHz-5 GHz	5 GHz	40 GHz
Analog bandwidth	900 MHz	850 MHz	300 MHz	650 MHz	450 MHz	> DRS3	> 1 GHz
Number of Channels	9	16	2		12/6/2/1	8/4/2/1	16
Triggered mode	Common Stop	Channel trigger on sums	Common Stop		Common Stop	Common Stop	Channel trigger
Resolution		10 bit	11.6 bit		11.6 bit	11.5 bit	8-10 bit
Samples	256	4/8 rows of 512	256	2048	1024-12288	1024-8192	64
Clock	33 MHz	33 MHz	66 MHz		20 MHz	tsamp/2048	60 MHz
Max latency			5ms		0.6 ms		
Input Buffers		TIA (5kOhm gain)	Yes	No	No	No	Yes
Differential Inputs	No	Pseudo-diff	Yes		Yes	Yes	Pseudo diff
Input Impedance	50 Ohms Ext	30-70 Ohms adjustable	> 10 MOhm			7-11pF	
Readout clock		1 GHz Wilkinson	16 MHz		33 MHz	33 MHz	60 MHz
Readout time	150µs	512µs	< 2 µs		30ns * n samples	30ns * n samples	< 1 µs
Locked delays	Ext DAC	Ext DLL	Int DLL		Ext PLL	Int PLL	
On-chip ADC	Yes	1 GHz Wilkinson	No		No	No	Yes
R/W simultaneous		Yes	No		No	Yes	No
Power/ch	50mW	20mW/sample 0.2W/read	150 mW		1-13mW	2-20mW	
Dynamic range		1mV/1V	0.65mV-2V		0.35mV/1.1V	0.35/1V	1V
Xtalk	Average << 10%	< 0.1%	0.30%		<0.5%	<0.5%	
Sampling jitter		TBD	40ps		200ps (Ext PLL)	Ext PLL	10ps
Power supplies	2.5V	2.5V	0-3.3V		2.5V	2.5 V	1.8V
Process	TSMC 0.25	TSMC 0.25	AMS 0.35	AMS 0.18	UMC 0.25	UMC 0.25	CMOS 0.13
Chip area	2.5 mm2	12 mm2	10 mm2		25 mm2	25 mm2	1 mm2
Cost/channel		500$/40 10$/2k	15.7$/12k			10-15$	

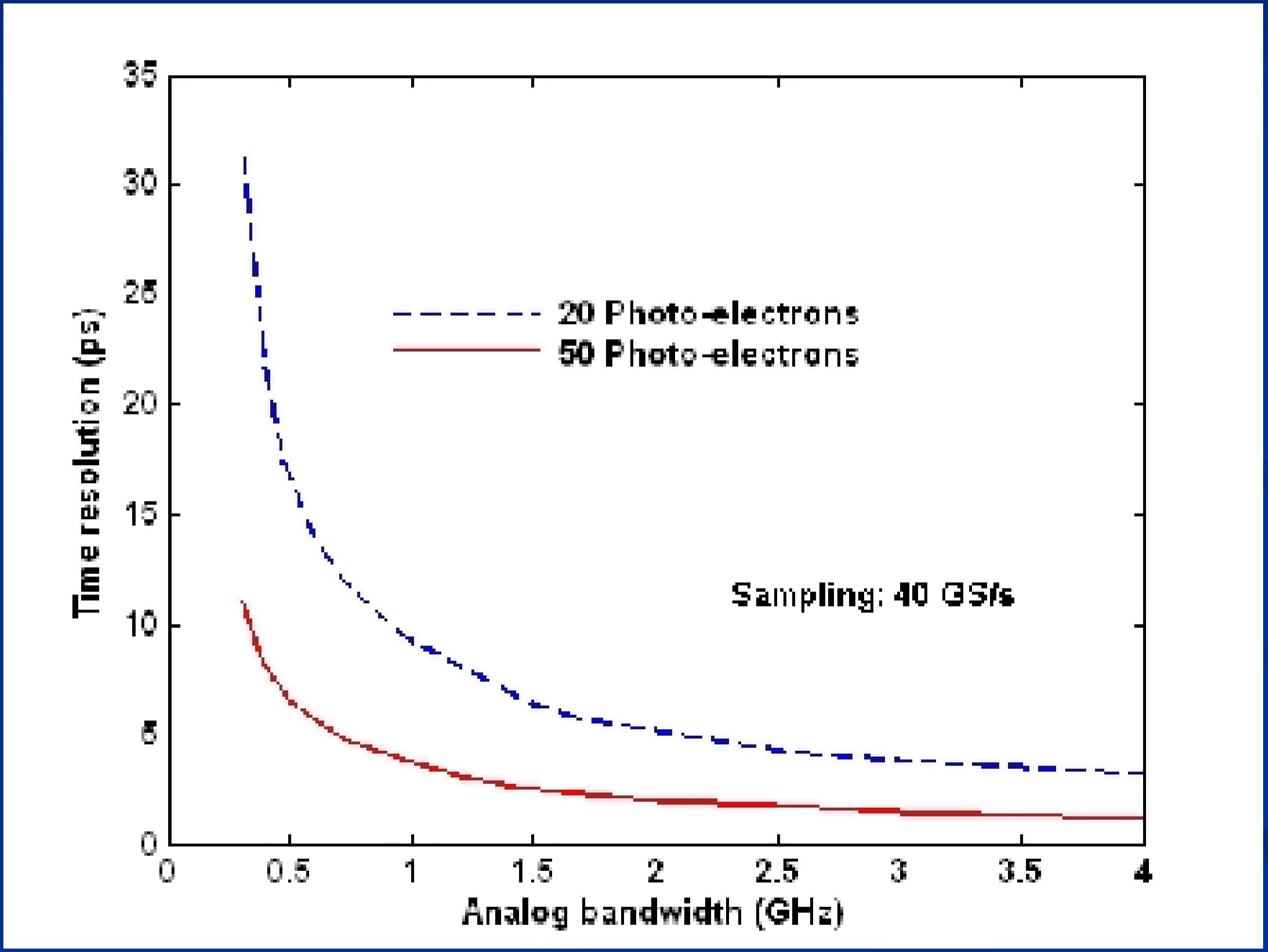
Table 1. State of the art, this proposal. The yellow column is from Gary Varner's group at the University of Hawaii (USA) [12], the light blue from Dominique Breton from the University of Paris-Sud (Orsay) [10] and Eric Delagnes from CEA (Saclay), (France) [11]. The orange column from Stefan Ritt at PSI (Switzerland) [13]. The dark blue is this proposal.

Front-end Electronics



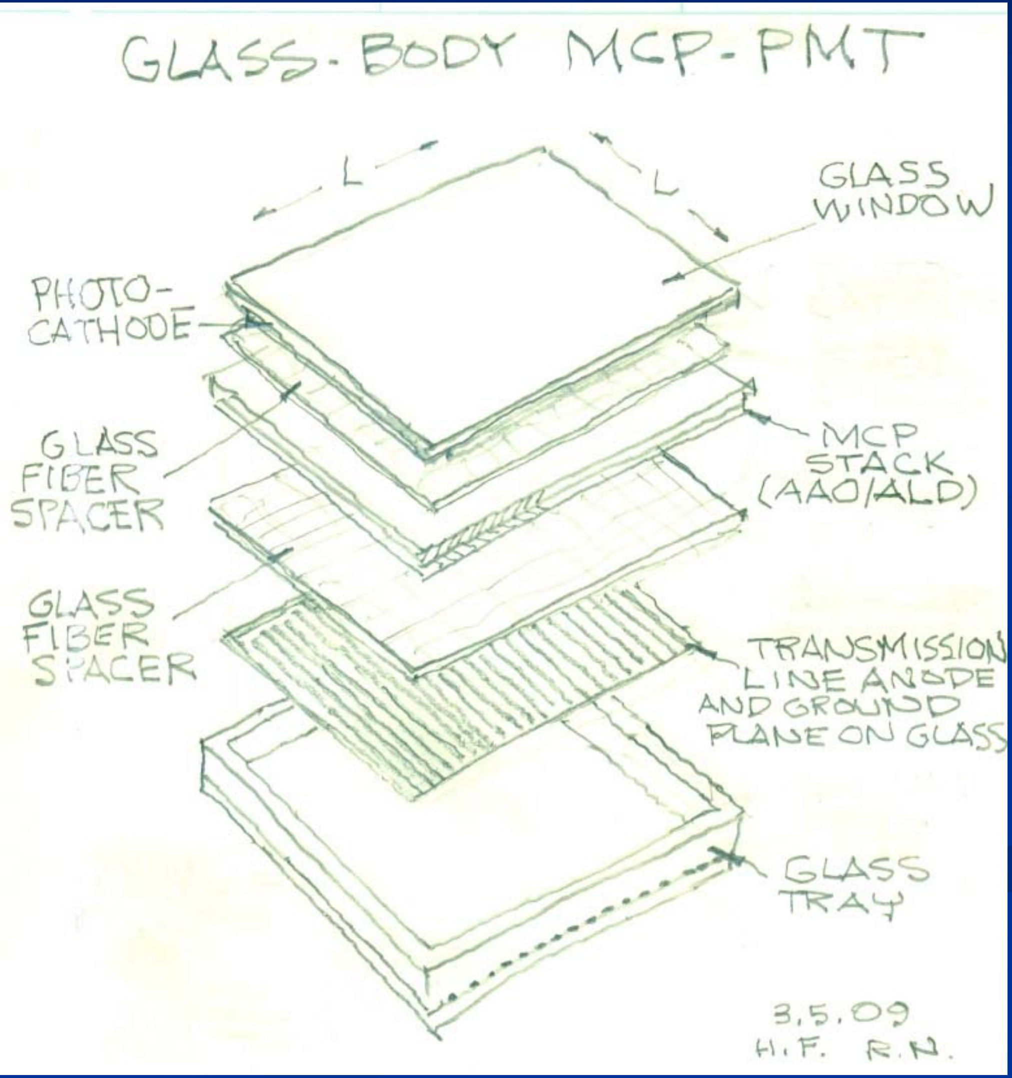
- Wave-form sampling does well- CMOS (!)

Front-end Electronics-II

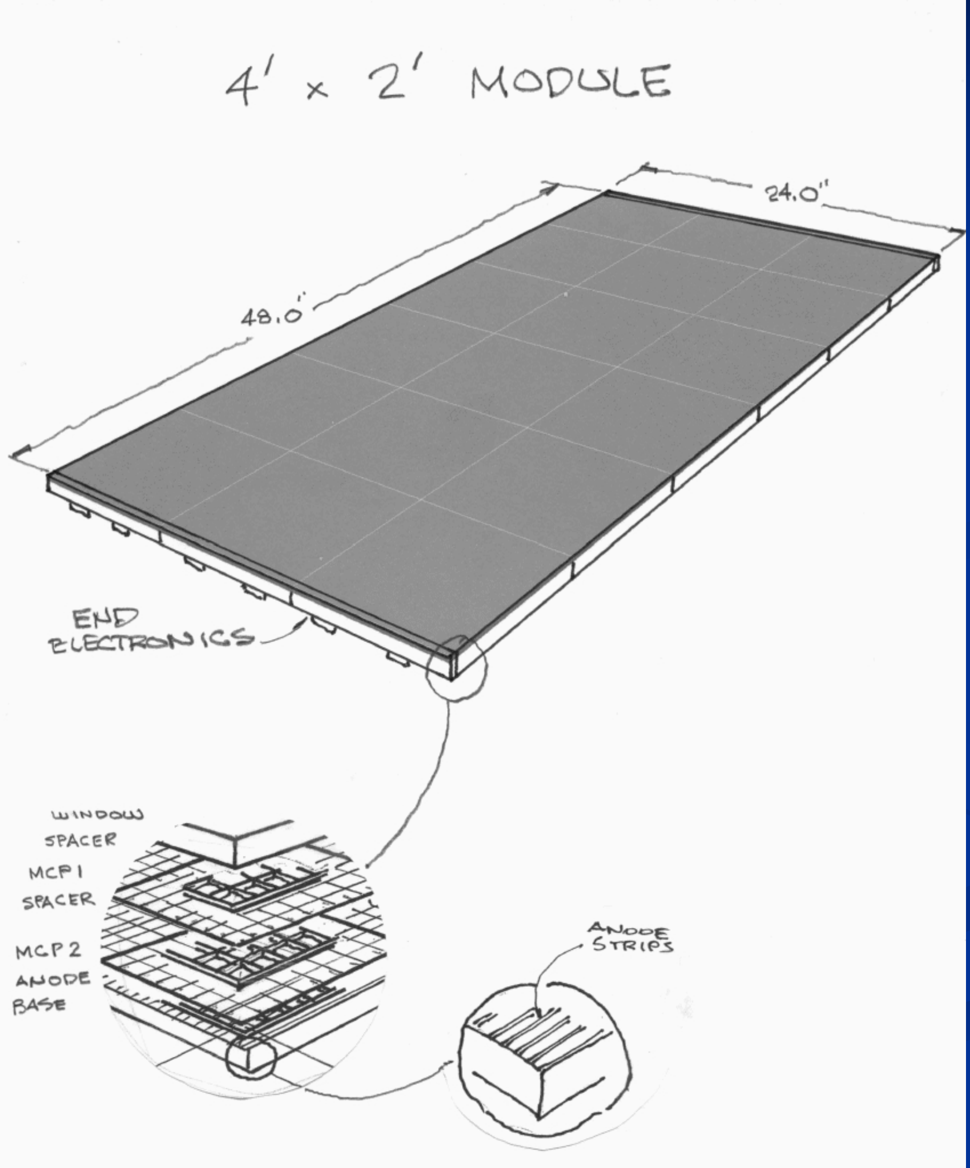


Cartoon of a `frugal' MCP

- Put all ingredients together- flat glass case (think TV's), capillary/ALD amplification, transmission line anodes, waveform sampling



Can dial size for occupancy, resolution- e.g. neutrinos 4'by 2'



Plans to Implement This

The Development of Large-Area Fast Photo-detectors

April 15, 2009

John Anderson, Karen Byrum, Gary Drake, Edward May, Alexander Paramonov, Mayly Sanchez, Robert Stanek, Hendrik Weerts, Matthew Wetstein[1], Zikri Yusof
High Energy Physics Division
Argonne National Laboratory, Argonne, Illinois 60439

Bernhard Adams, Klaus Attenkofer
Advanced Photon Source Division
Argonne National Laboratory, Argonne, Illinois 60439

Zeke Insepov
Mathematics and Computer Sciences Division
Argonne National Laboratory, Argonne, Illinois 60439

Jeffrey Elam, Joseph Libera
Energy Systems Division
Argonne National Laboratory, Argonne, Illinois 60439

Michael Pellin, Igor Veryovkin, Hau Wang, Alexander Zinovev
Materials Science Division
Argonne National Laboratory, Argonne, Illinois 60439

David Beaulieu, Neal Sullivan, Ken Stenton
Arradiance Inc., Sudbury, MA 01776

Mircea Bogdan, Henry Frisch[1], Jean-Francois Genat, Mary Heintz, Richard Northrop, Fukun Tang
Enrico Fermi Institute, University of Chicago, Chicago, Illinois 60637

Erik Ramberg, Anatoly Ronzhin, Greg Sellberg
Fermi National Accelerator Laboratory, Batavia, Illinois 60510

James Kennedy, Kurtis Nishimura, Marc Rosen, Larry Ruckman, Gary Varner
University of Hawaii, 2505 Correa Road, Honolulu, HI, 96822

Robert Abrams, Valentin Ivanov, Thomas Roberts
Muons,Inc 552 N. Batavia Avenue, Batavia, IL 60510

Jerry Va'vra
SLAC National Accelerator Laboratory, Menlo Park, CA 94025

Oswald Siegmund, Anton Tremsin
Space Sciences Laboratory, University of California, Berkeley,CA 94720

Dmitri Routkevitch
Synkera Technologies Inc., Longmont, CO 80501

David Forbush, Tianchi Zhao
Department of Physics, University of Washington, Seattle, WA 98195

[1] Joint appointment Argonne National Laboratory and Enrico Fermi Institute, University of Chicago

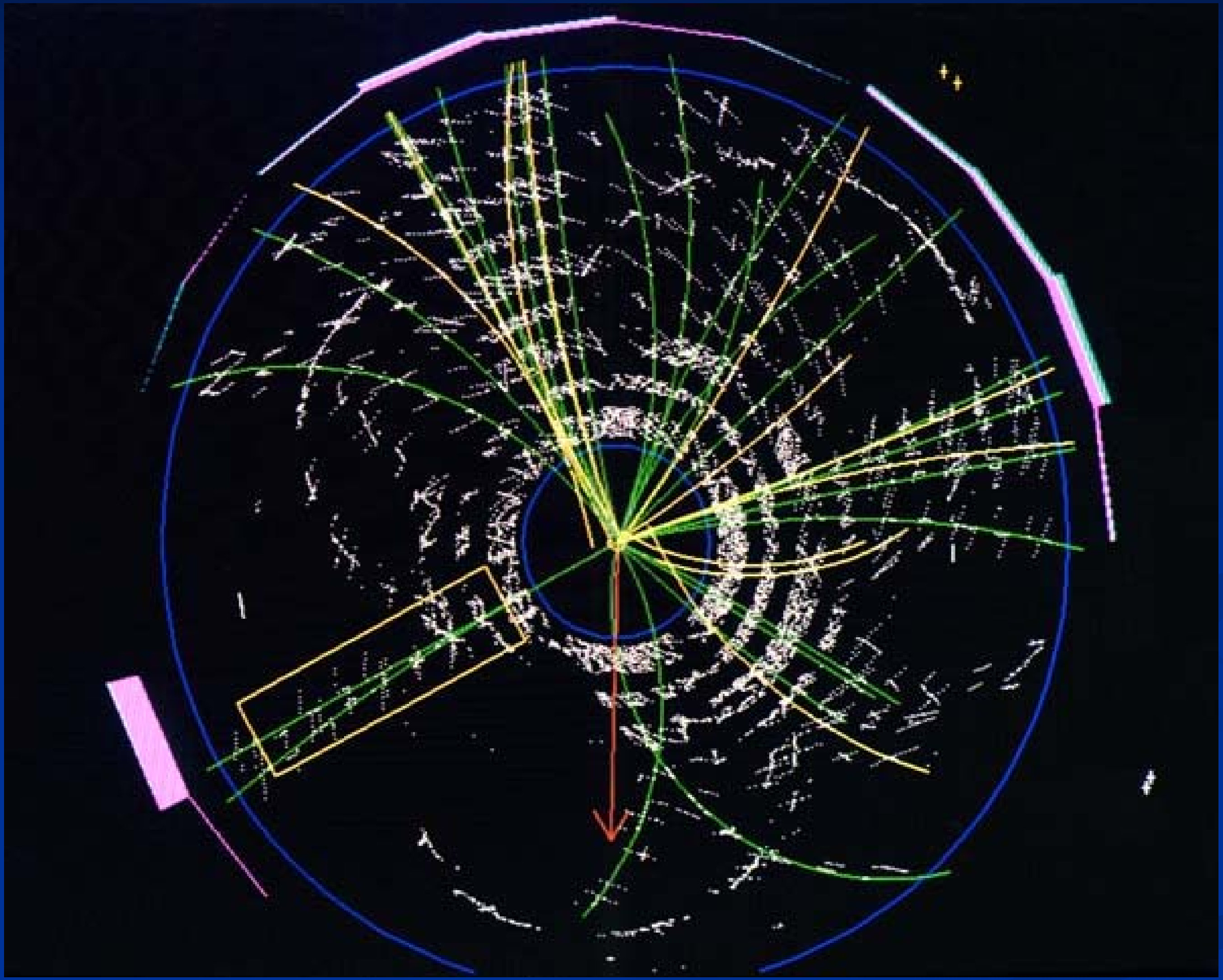
Have formed a collaboration to do this in 3 years. 4 National Labs, 5 Divisions at Argonne, 3 companies, electronics expertise at UC and Hawaii

R&D- not for sure, but we see no show-stoppers

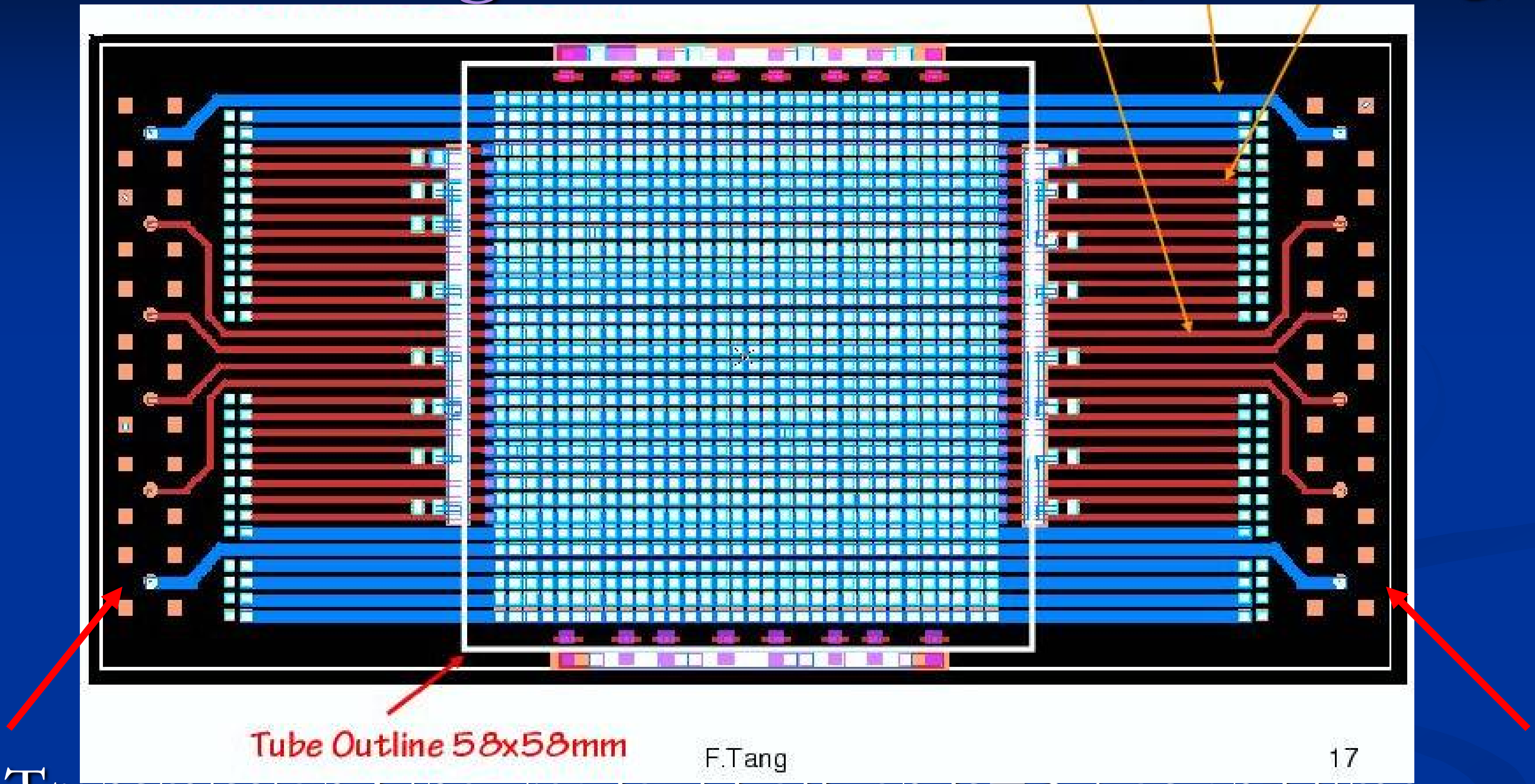
What can LHCb do? Need Serious Simulation of 1-10psec TOF

- Need a list of physics drivers- (e.g J/Psi-eta, pizero-Kzero CP Asym.,…)
- What is required rate, occupancy vs radius?
- What resolution is necessary for each analysis?
- What is budget, schedule?
- So need a serious simulation effort.
- Are there folks who would work with us on this and vice versa?

The End-



Get position AND time
Anode Design and Simulation(Fukun Tang)



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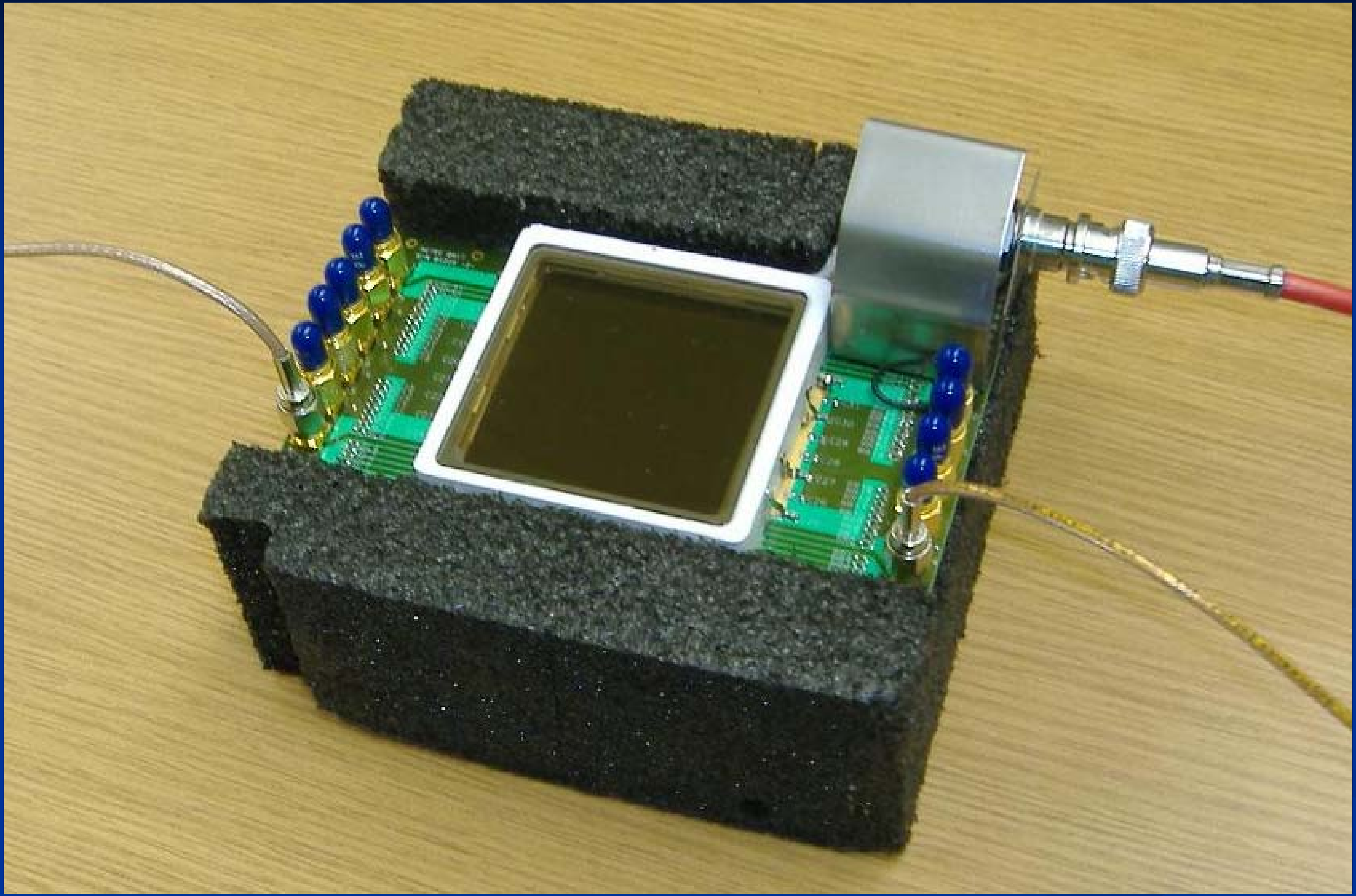

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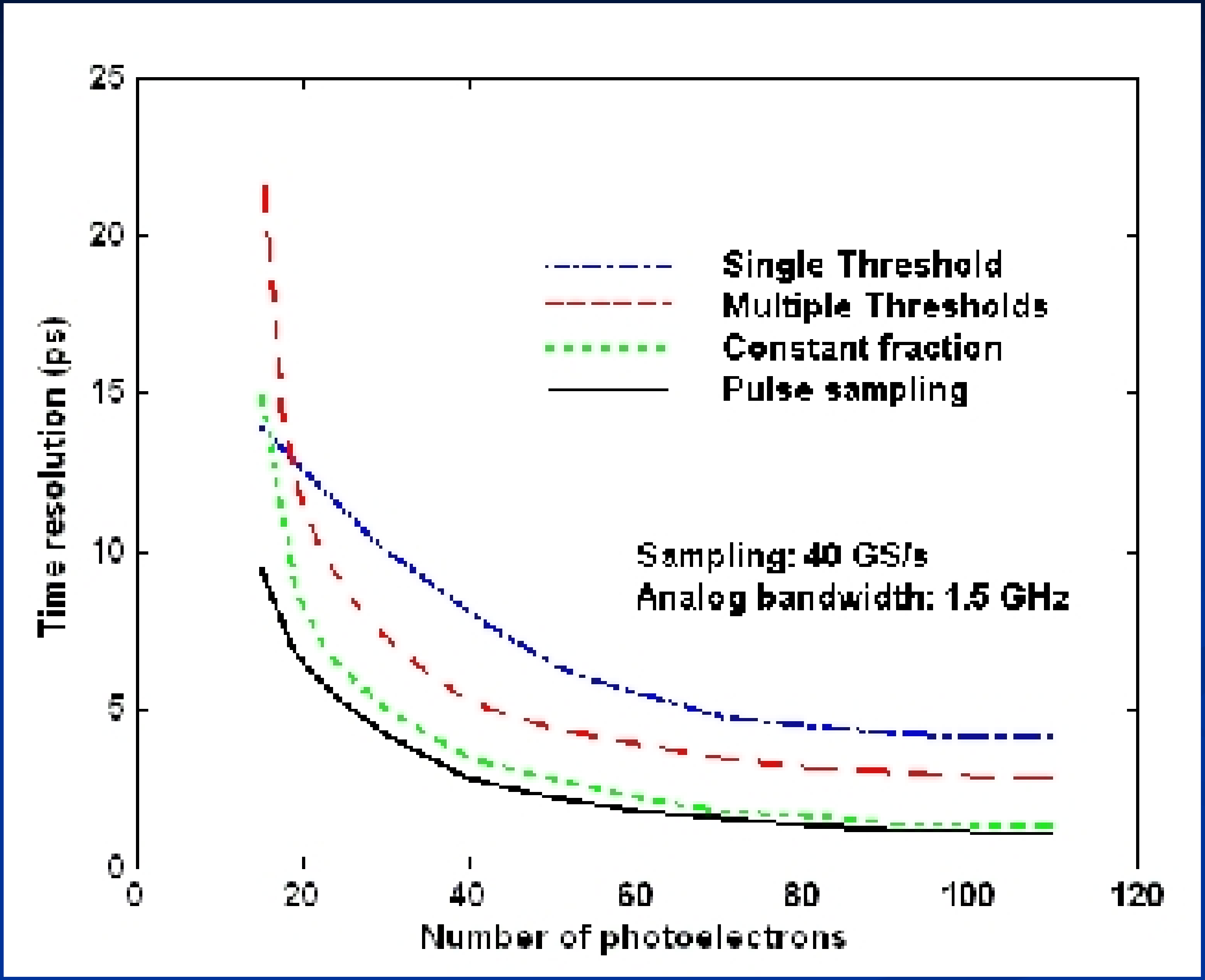

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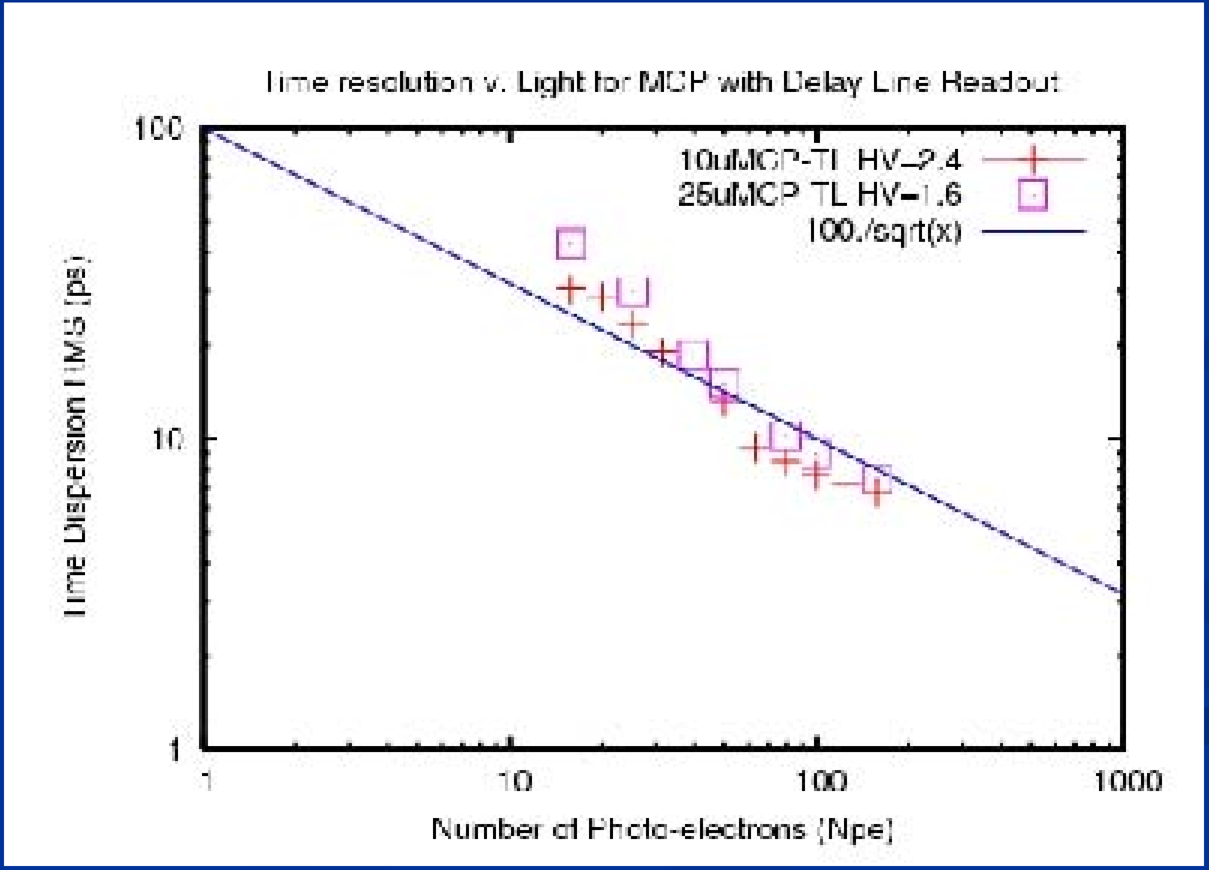
Time resolution v. Light for MCP with Delay Line Readout
10uMCP-TL HV=2.4
25uMCP TL HV=1.6
100./sqrt(x)
Time Dispersion RMS (ps)
Number of Photo-electrons (Npe)
100
10
1
1
10
100
1000

Application to a water Cherenkov Counter- effect on the physics