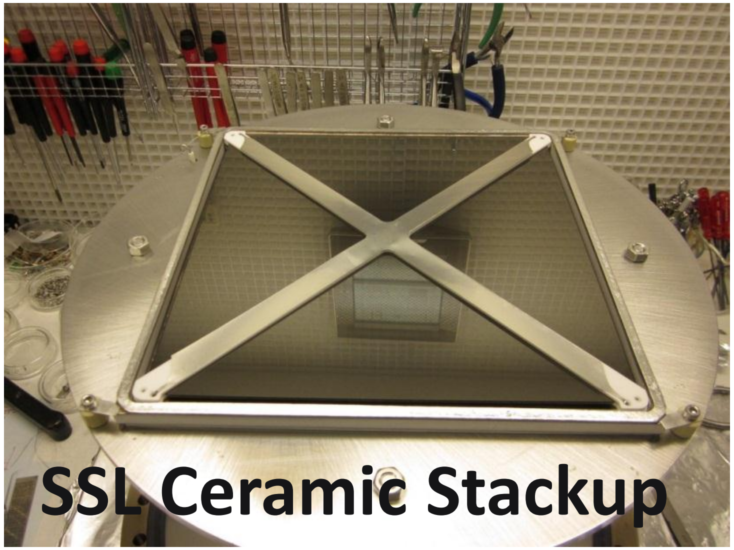
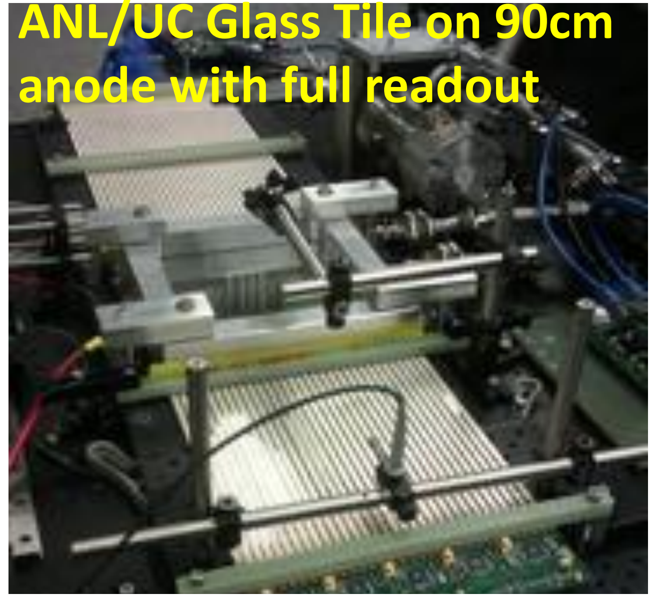
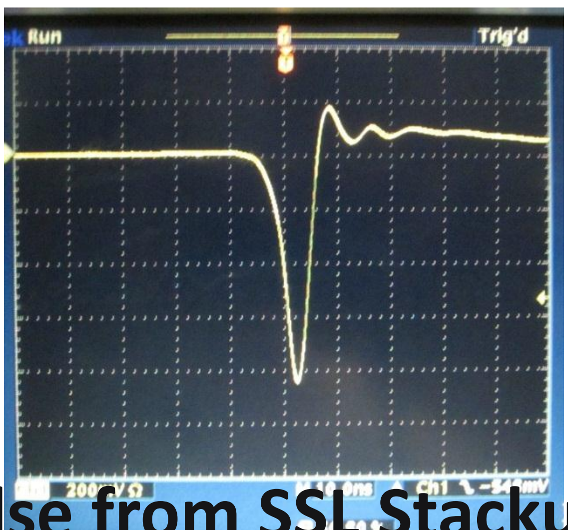
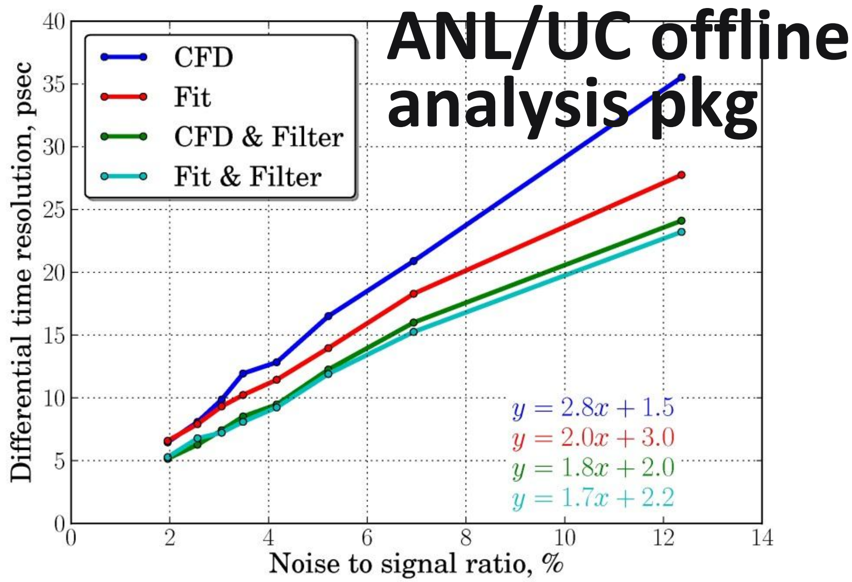
Developing Large-Area Pico-second Photodetectors

HJF for the LAPPD Collaboration









OUTLINE

- Introduction
- Motivation and Applications
- Changes Since Last 2012 Bejing Mtg
  - Transition from R&D to Industry (SBIR, SSTR, TTO)
  - SSL Stackup of the Ceramic Tube
  - Much more knowledge of ALD, MCA's,…
  - Glass Design Maturation
  - Electronics, Analysis, System Integration
  - Documentation: Papers on Anode, ANL/UC Testing, PSEC4, and SSL/ANL Overviews (Ossy)
- Plans, Prognosis, Problems, Patience

The Initial LAPPD Collaboration

The Development of Large-Area Fast Photo-detectors

April 15, 2009

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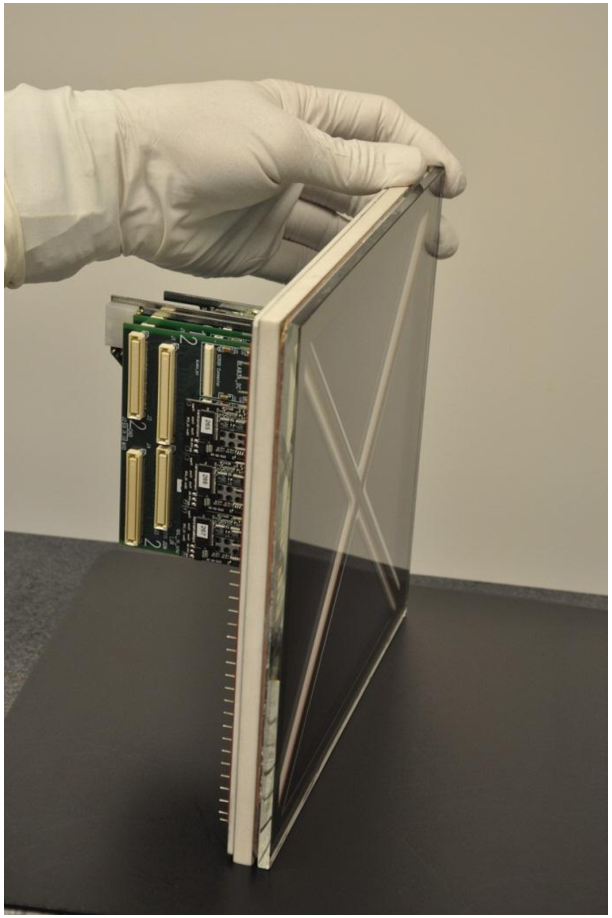
3 National Labs, 6 Divisions at Argonne, 3 US small companies (Arradiance, Muons,Inc, and Synkera); SSL/UC Berkeley and the Universities of Chicago and Hawaii

Goal of 3-year R&D- commercializable modules.

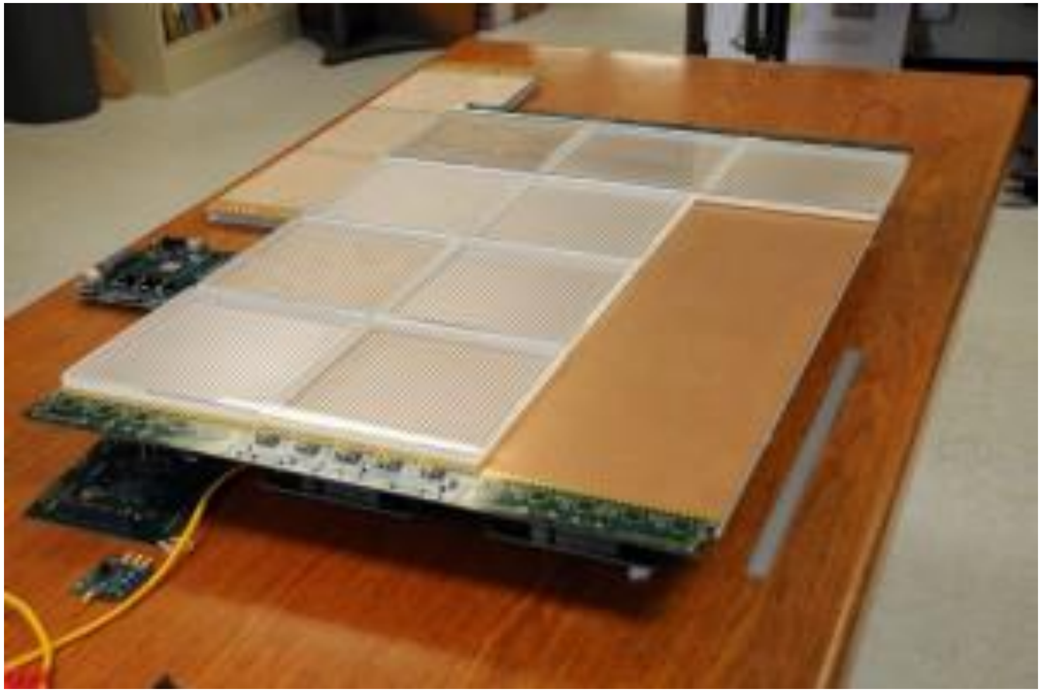
Have since added effort at UIUC, WashU, UIC, Minotech

Working/in-contact with Incom, CatIglass, Photonis, ElectronTubes, Perkin-Elmer (last 3 are tube manufacturers)

Two Parallel Paths ("Portfolio of Risk")



SSL Ceramic Tile



ANL/UC/Incom/SSL Glass Tile

THE TWO- CERAMIC AND GLASS- PACKAGES

Glass: attraction is cost: cheap materials, frit seals, silk-screen anode, no-pin design- was aimed at *very* large areas;

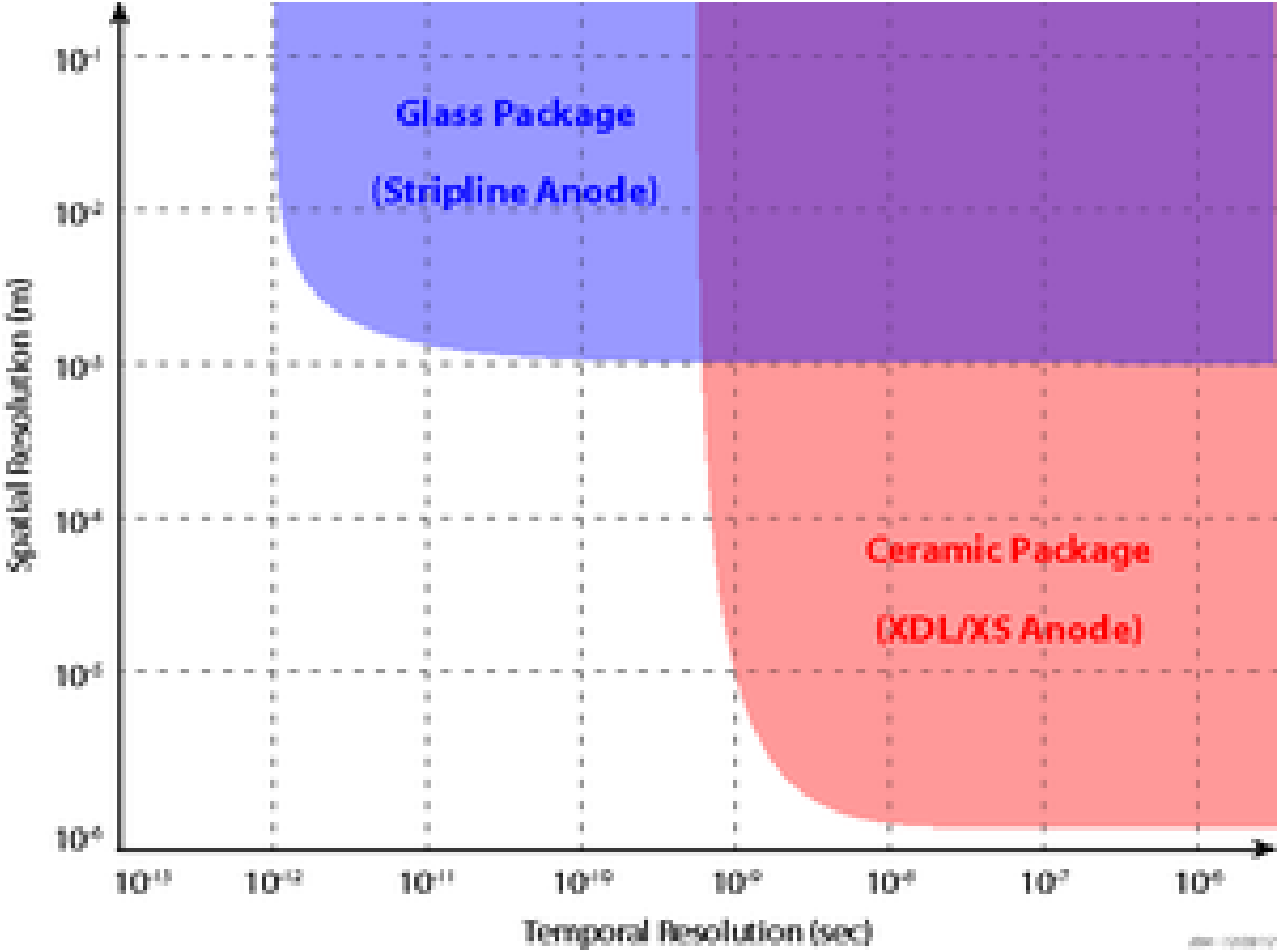
Ceramic: SSL has decades of experience with a developed process for ceramic tubes that inform the glass effort:

- Materials, mechanical and thermal properties, design;
- QC, multi (many)-step cleaning, cleanliness required, scrubbing, in-situ testing before assembly;
- Photocathode deposition, monitoring, and validation;
- Vacuum-transfer assembly;
- Testing: life-time, gain mapping,
- Performance: I-V range, lifetime, resolution to 2 μm, charge-cloud, life-time, robustness (space certified);
- Transport, storage, handling.

The **ceramic tube has complementary applications:**

1. **Thick film anodes fired on ceramic allow high space resolution (down to 2μm), 2D readout with crossed delay-lines, complicated fine-line patterns;**
2. **Applications requiring ruggedness- space flight, military use, harsh vibro-acoustic environments (NASA, Air Force,….)**

Complementary in: Technology, Risk, and Capabilities

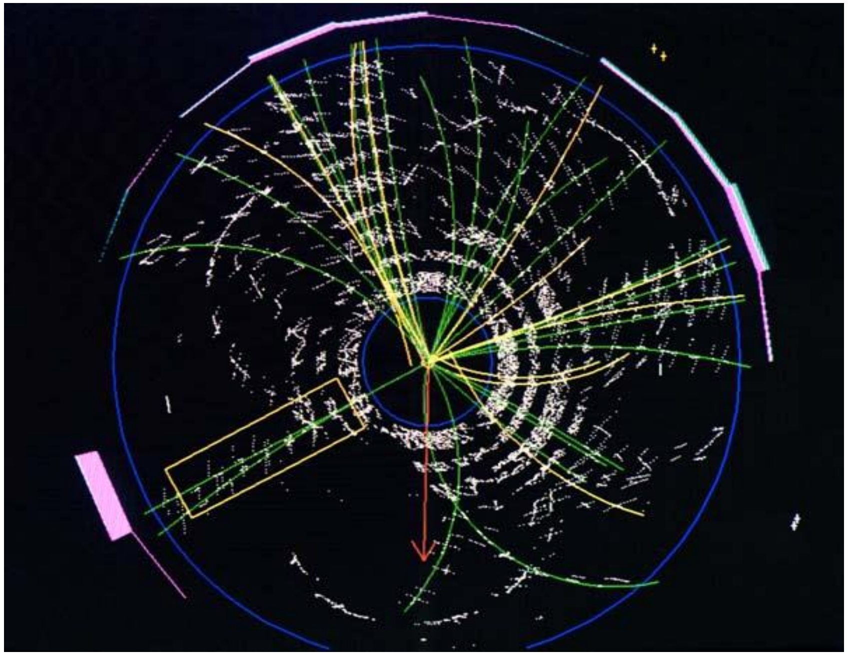


Motivation-Colliders:

Need: 1) identify the quark content of charged particles

2) separate vertices at the LHC; vertex photons

Theme: extract *all* the information in each event (4-vectors)



See HJF Snowmass white paper

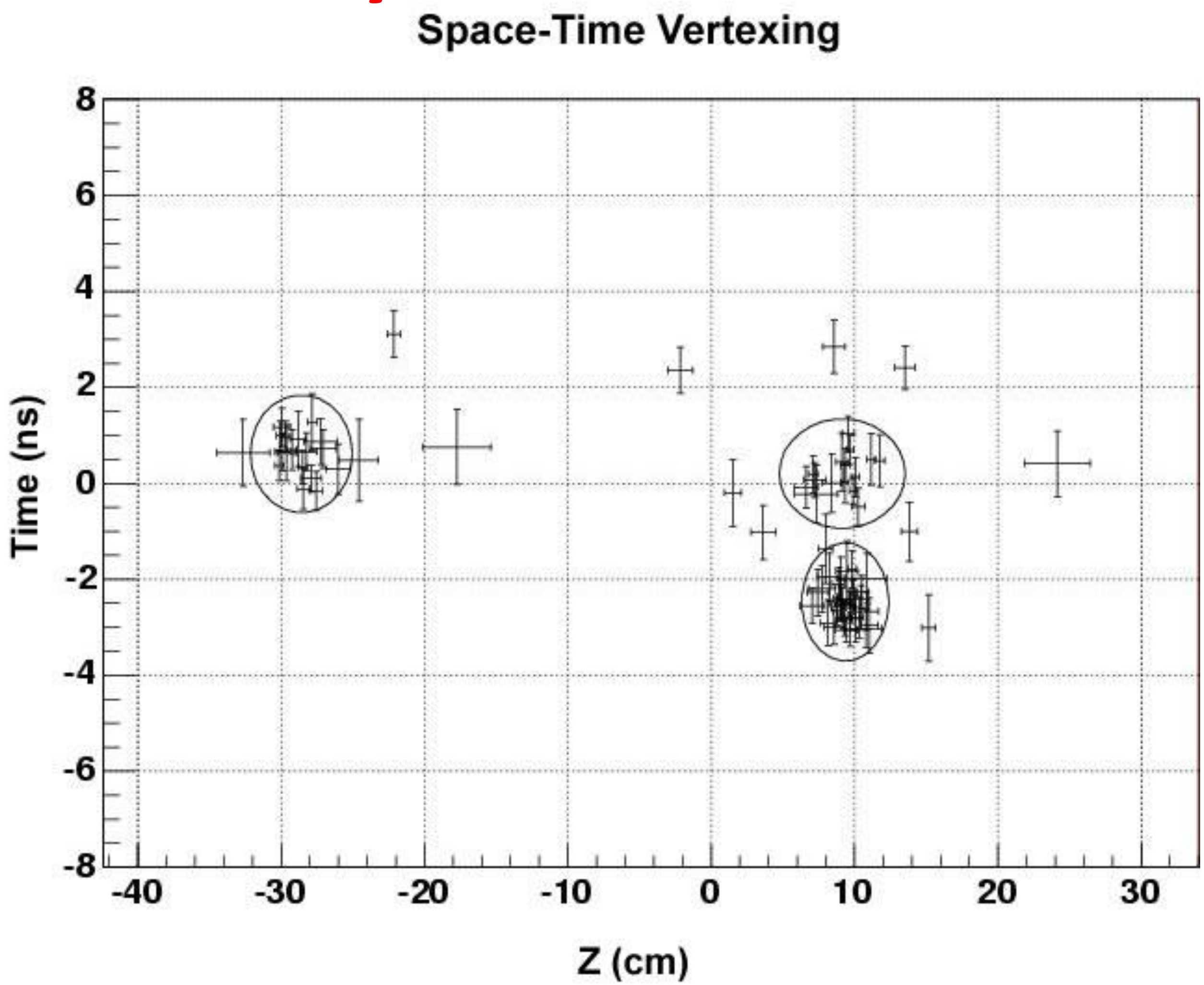
New idea-measure the difference in arrival times of photons and charged particles which arrive a few psec later.

Light source is Cherenkov light in the window/radiator.

Searches- opens window on CKM-forbidden signatures

(Note: conventional TOF resolution is 100 psec -factor of 100 worse than our goal= 1" is 100 psec, so need a small scale-length).

Major problem coming up at LHC- vertexing at high luminosity (quote Joe Incandela)



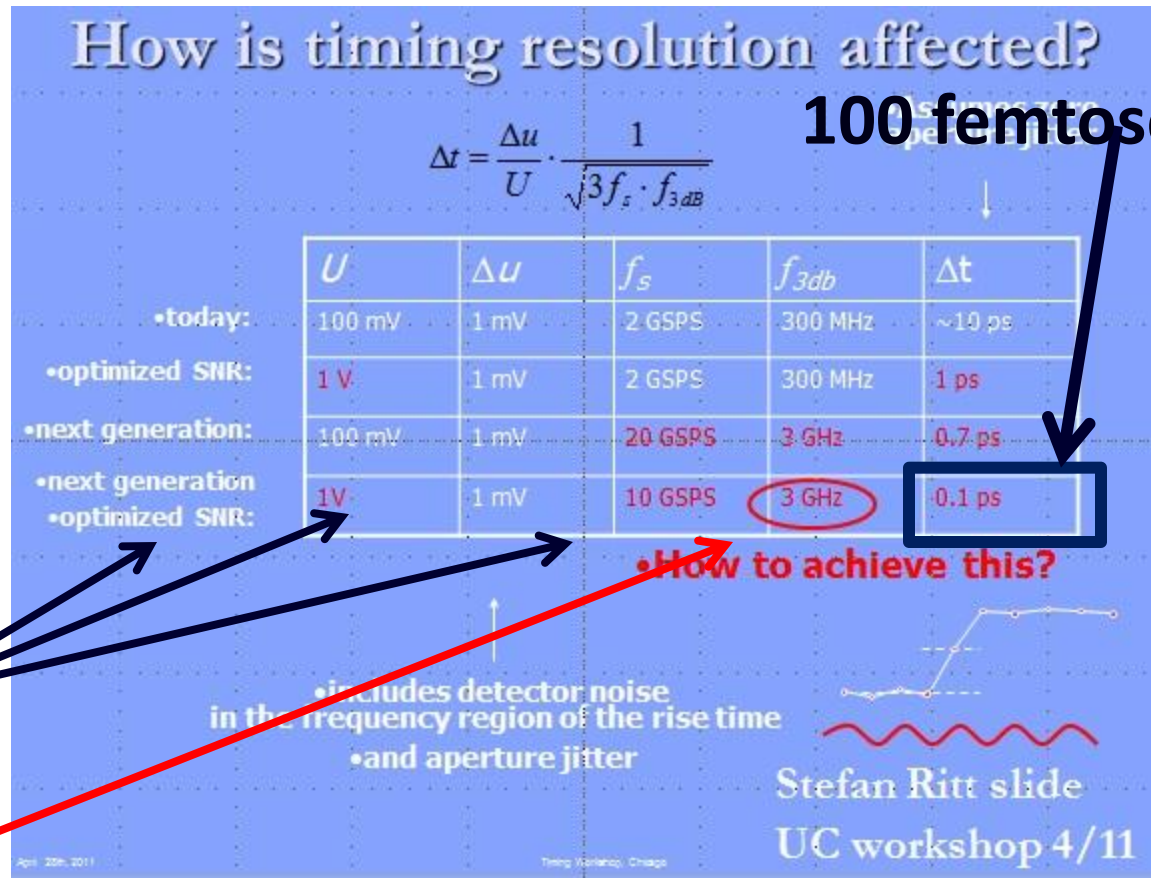
Example need- Higgs to gamma-gamma at the LHC - tie the photons to the correct vertex, and more precisely reconstruct the mass of the pair

Future colliders: Can we go deep sub-picosec?: the Ritt Parameterization

(agrees with JF MC)

Stefan Ritt slide, doctored

100 femtosec

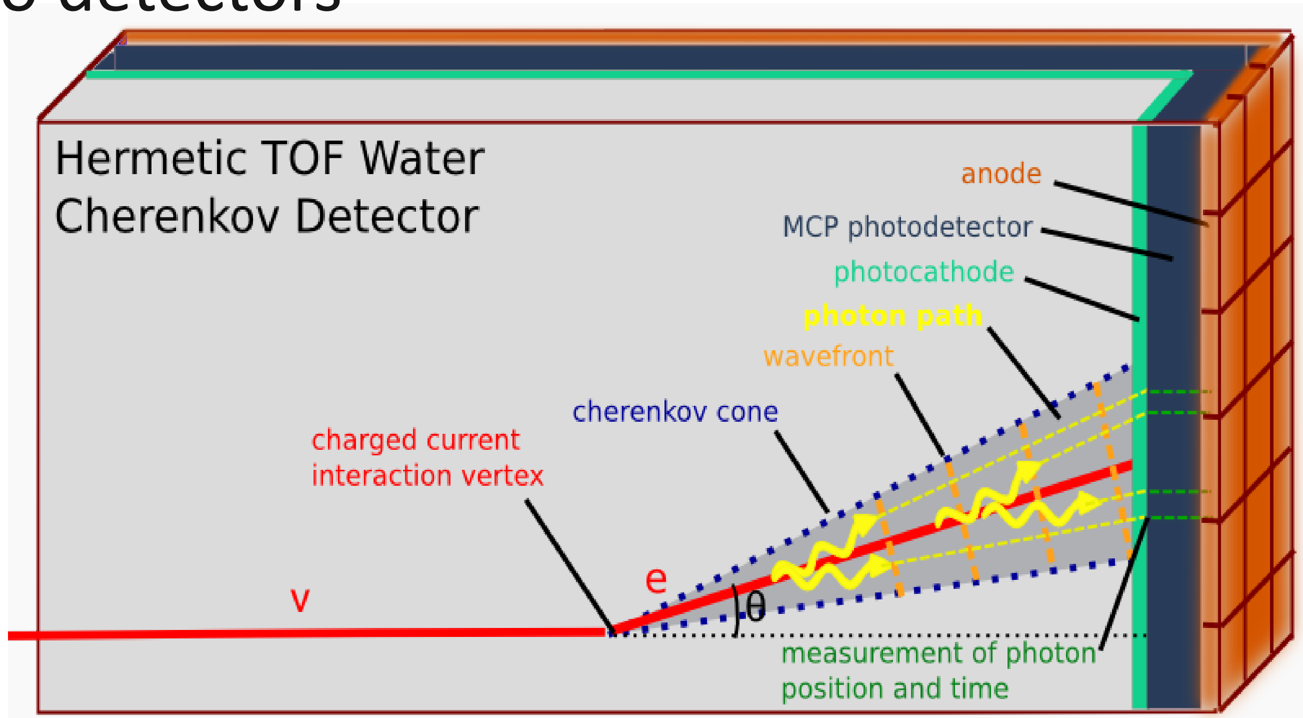


S/N, f_Z: DONE

abw: NOT YET

Neutrino Physics

Need: lower the cost and extend the reach of large neutrino detectors



Approach: measure the arrival times and positions of photons and reconstruct tracks in water

Benefit: Factor of 5 less volume needed, cost.

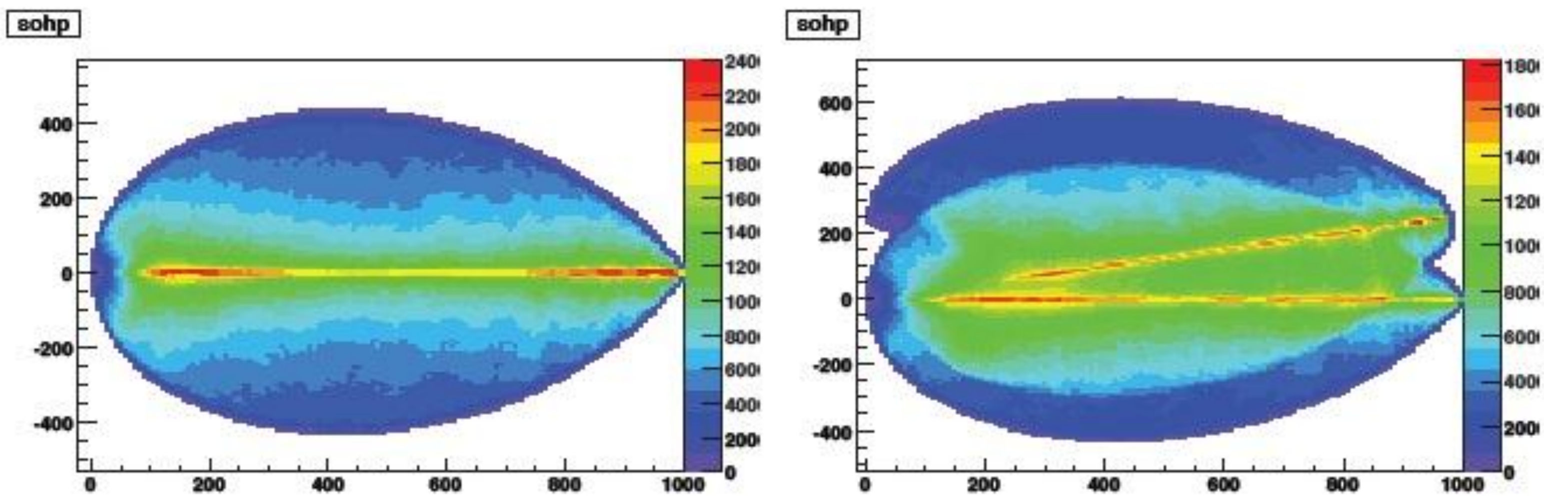
Competition- large PMT's (Hamatsu), Hybrid PMT's (China), Liquid Argon

Can we build a photon TPC?

Track Reconstruction Using an "Isochron Transform"

Results of a toy Monte Carlo with perfect resolution

Color scale shows the likelihood that light on the Cherenkov ring came from a particular point in space. Concentration of red and yellow pixels cluster around likely tracks



Single track

Two tracks displaced from a common vertex

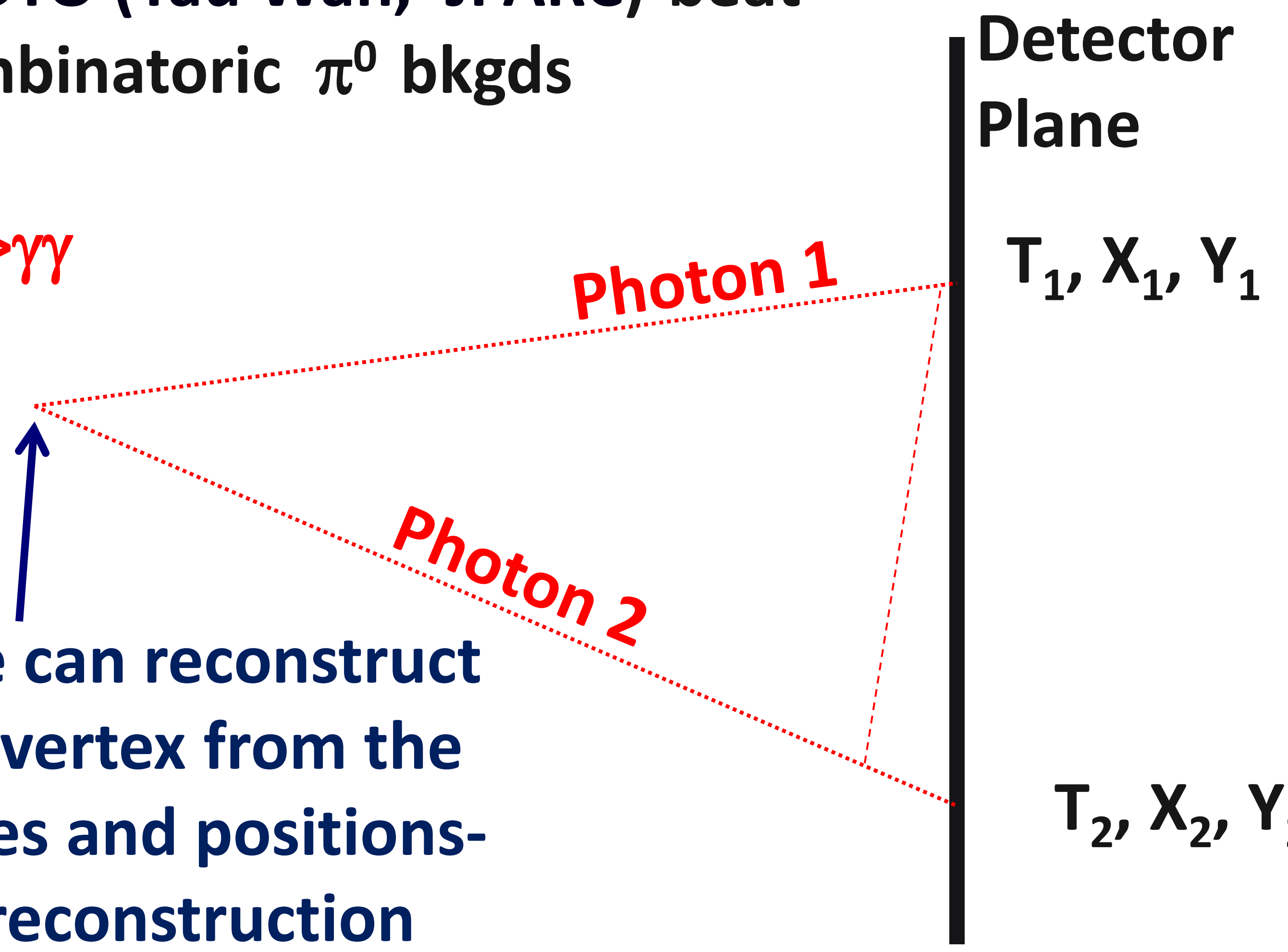
Work of Matt Wetstein (Argonne,&Chicago) and group

Rare Kaon Decays- backgd rejection by reconstructing π^0 vertex space point:

E.g. for KOTO (Yau Wah, JPARC)-beat down combinatoric π^0 bkgds

Vertex $\pi^0 \to \gamma\gamma$

T_v, X_v, Y_v, Z_v



One can reconstruct the vertex from the times and positions- 3D reconstruction

Cherenkov-sensitive Sampling Quasi- Digital EM/Had-separating Calorimeters

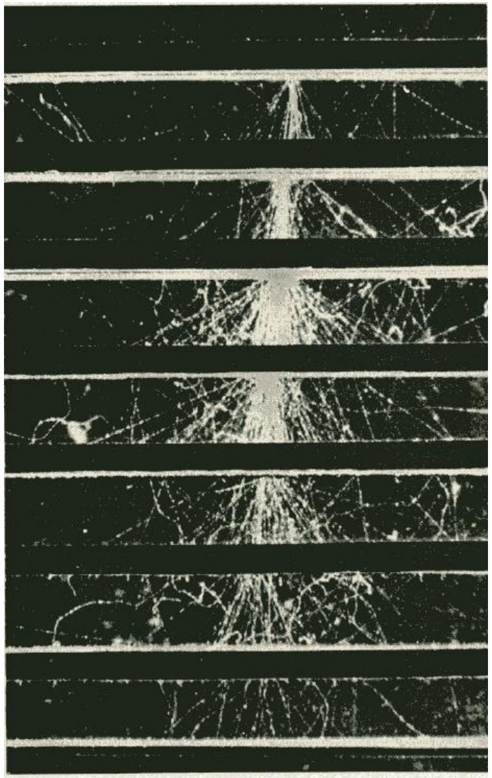
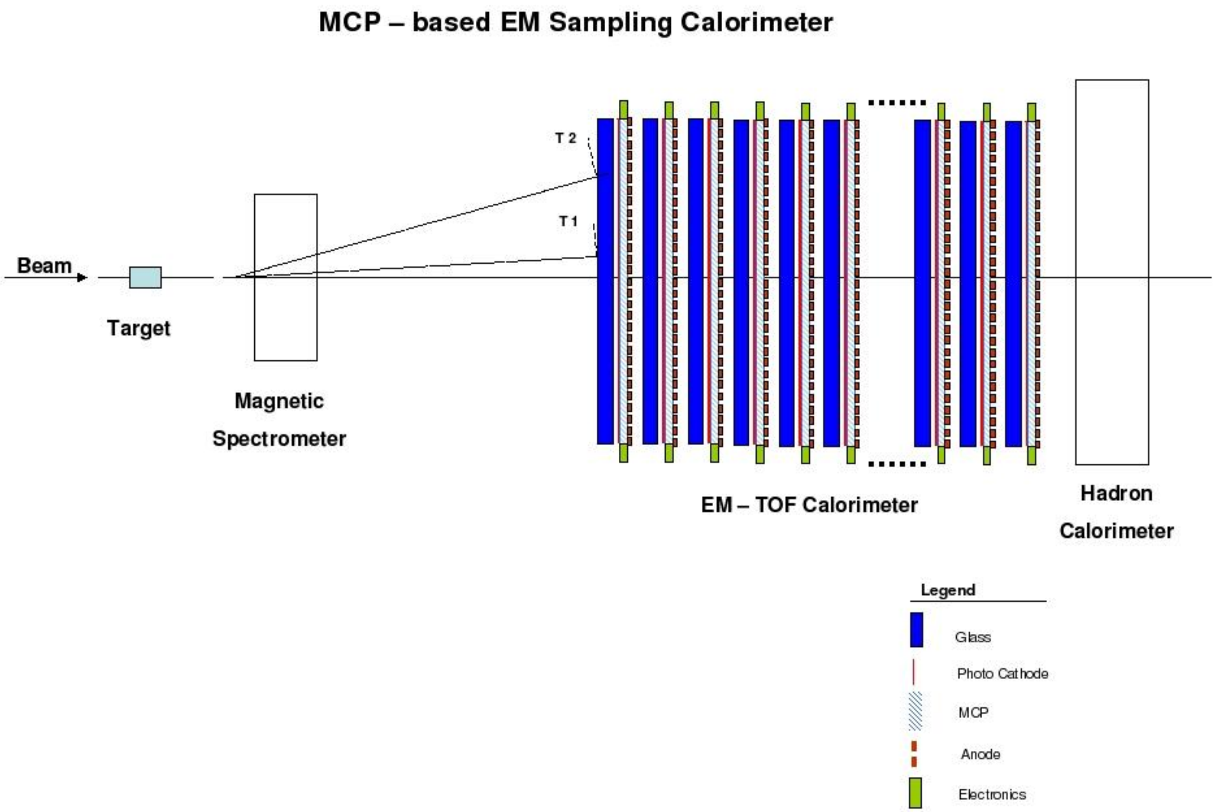


Fig. 5.1.1. Cloud-chamber picture of a large cascade shower. The plates across the chamber are lead, 1.27 cm thick. From C. Y. Chao.

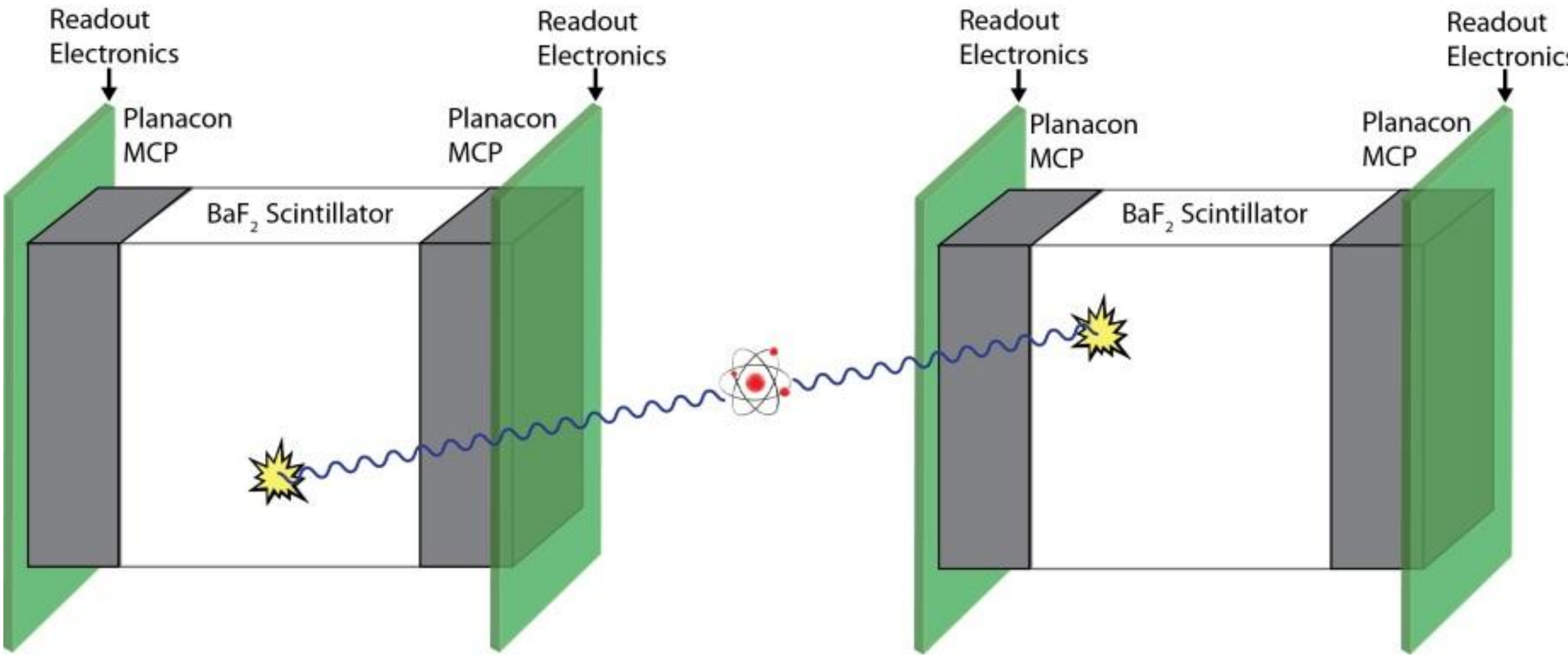


A picture of an em shower in a cloud-chamber with ½" Pb plates (Rossi, p215- from CY Chao)

A `cartoon' of a fixed target geometry such as for JPARC's KL-> pizero nunubar (at UC, Yao Wah) or LHCb

Also see Ronzhin and HJF Snowmass white paper

Medical Imaging -PET



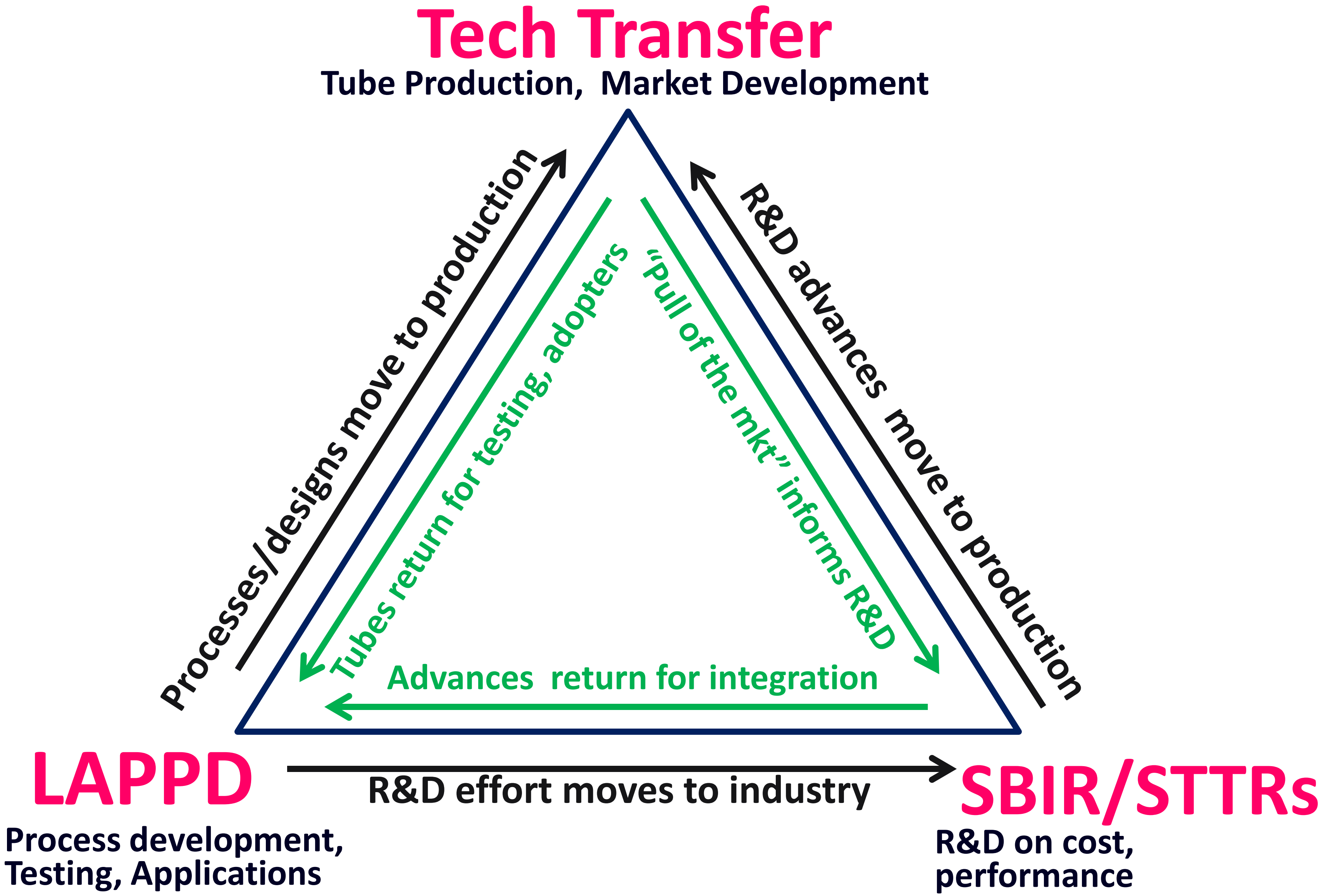
Example small setup being built at UC (Eric Oberla graphic)

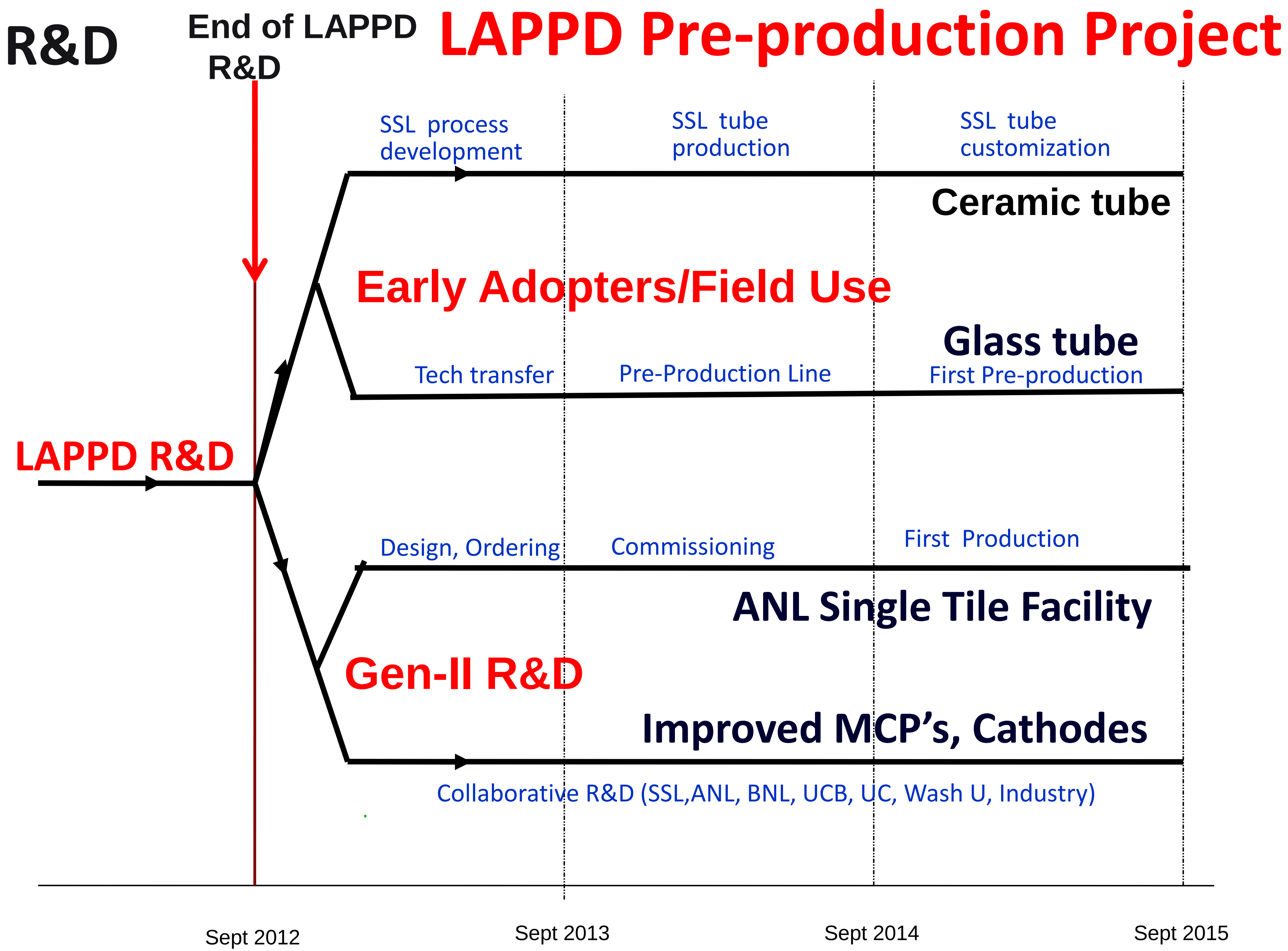
Gains due to much larger solid angle for coincidence, TOF. Studies under way at UC (with Kao, Kim, and Chen), industry

Changes Since Last Bejing Meeting

- Focus is transition from R&D to Industry
- However in parallel build a healthy R&D effort on photocathodes, timing (bandwidth), innovative manufacturing techniques (cost- the `frugal' tile)
- Assembly and test facilities: SSL "big tank", ANL..
- Ceramic tube stackup at SSL and lessons-learned
- Glass design for SSL assembly
- Detailed Papers on: Anodes, Photocathodes, Testing
- Management: Creation of Executive Committee, Incom TTO,

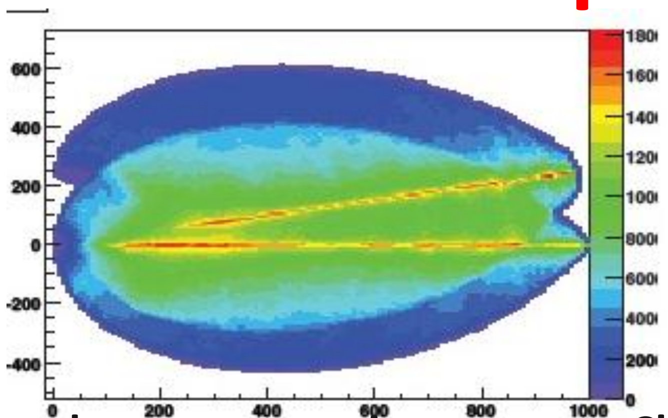
The Transition from 3 Years of R&D to Applications: Roles of SBIR/STTR and TTO



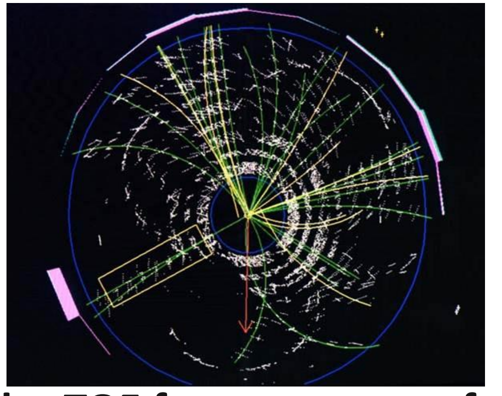


Organization of Pre-production Project

The Relationship of SBIR/STTR/TTO to Needs



Pizero-electron separation on water Ch. cters



Collider TOF for vertex sep., family flow

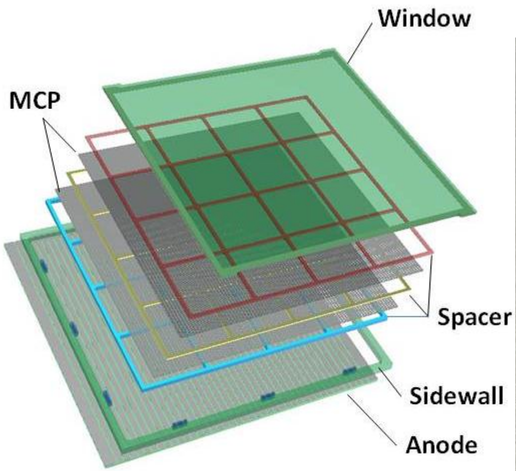
Higher performance
Or
Lower Cost
Are
The main benefits

("F,Q,C- pick any two")

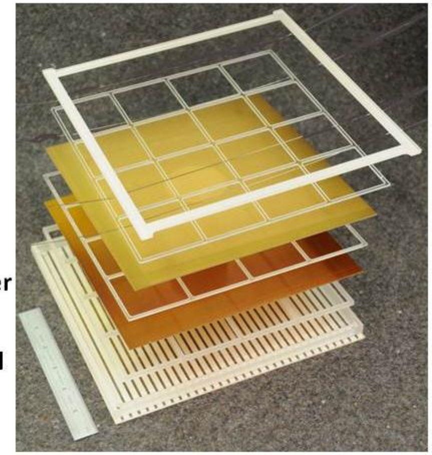
LAPPD Markets: Need. Applications. Benefit. and Competition

Application	Market Need	Approach	Benefit	Competition
Non-cryogenic Tracking Neutrino Detectors	HEP-Fermilab	Very-large-area, bialkali-cathode	Bkgd rejection, Cost, Readiness	Liquid Argon
LE Neutron Detection	Neutron Diffraction	B or Gd Glass, no cathode	Time and Position resolution, pulse shape γ/n differentiation, Large area	He3, B tubes
LE Neutron Detection	Transportation Security	B or Gd Glass, no cathode	Large area pulse shape γ/n differentiation, Large area	He3, B tubes
LE Anti-Neutrino Detection	Reactor Monitoring	Large-area, bialkali-cathode	Efficiency, Cost	PMT's, SiPMs
HE Collider Vertex Separation	CERN	Psec TOF	Resolution, Radiation-Hard	Silicon Vertex
HE Collider Particle ID	CERN, Future Lepton Collider	Psec TOF	Resolution, Reach in P_T	None
π^0/η Reconstruction and ID	Rare K Decays (JPARC), Fermilab	Psec TOF	Combinatoric Bkgd Rejection	Conventional TOF
Strange Quark ID	RHIC (BNL), ALICE (LHC) Collider	Psec TOF	Resolution, Reach in P_T	dE/dx
Positron-Emission Tomography	Clinical Medical Imaging	TOF, Large Area	Lower Dose Rate, Faster throughput	SiPM

The Half-Meter-Squared SuperModule



Design Drawing - September 2010



Actual Glass Parts - April 2012

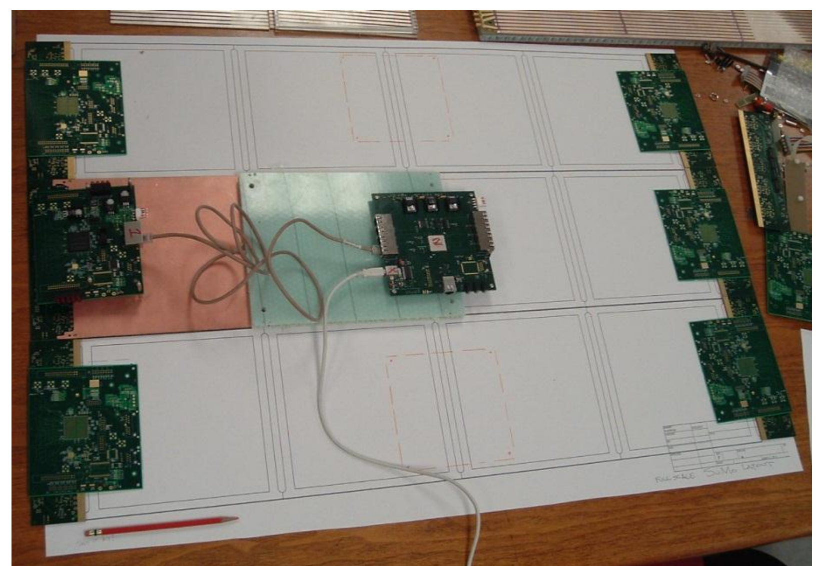
A `tile' is a sealed vacuum-tube with cathode, 2 MCP's, RF-strip anode, and internal voltage divider

HV string is made with ALD

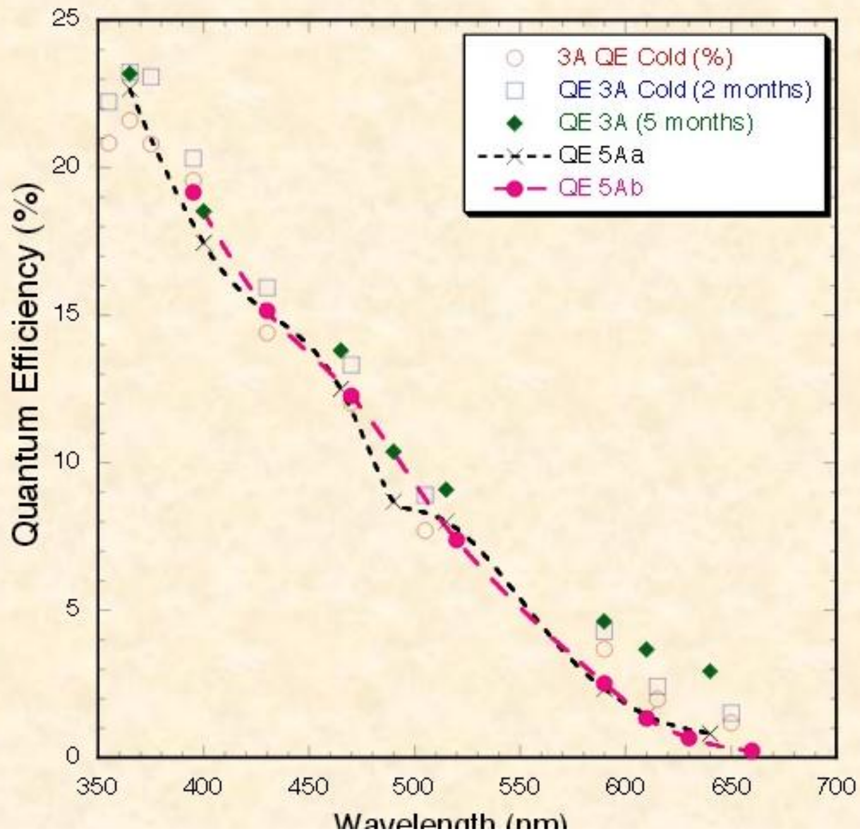
A `tray' holds 12 tiles in 3 tile-rows

15 waveform sampling ASICS on each end of the tray digitize 90 strips

2 layers of local processing (Altera) measure extract charge, time, position, goodness-of-fit



Progress since last mtg: cathodes



Cathode looks quite uniform all over from visual opacity observations.

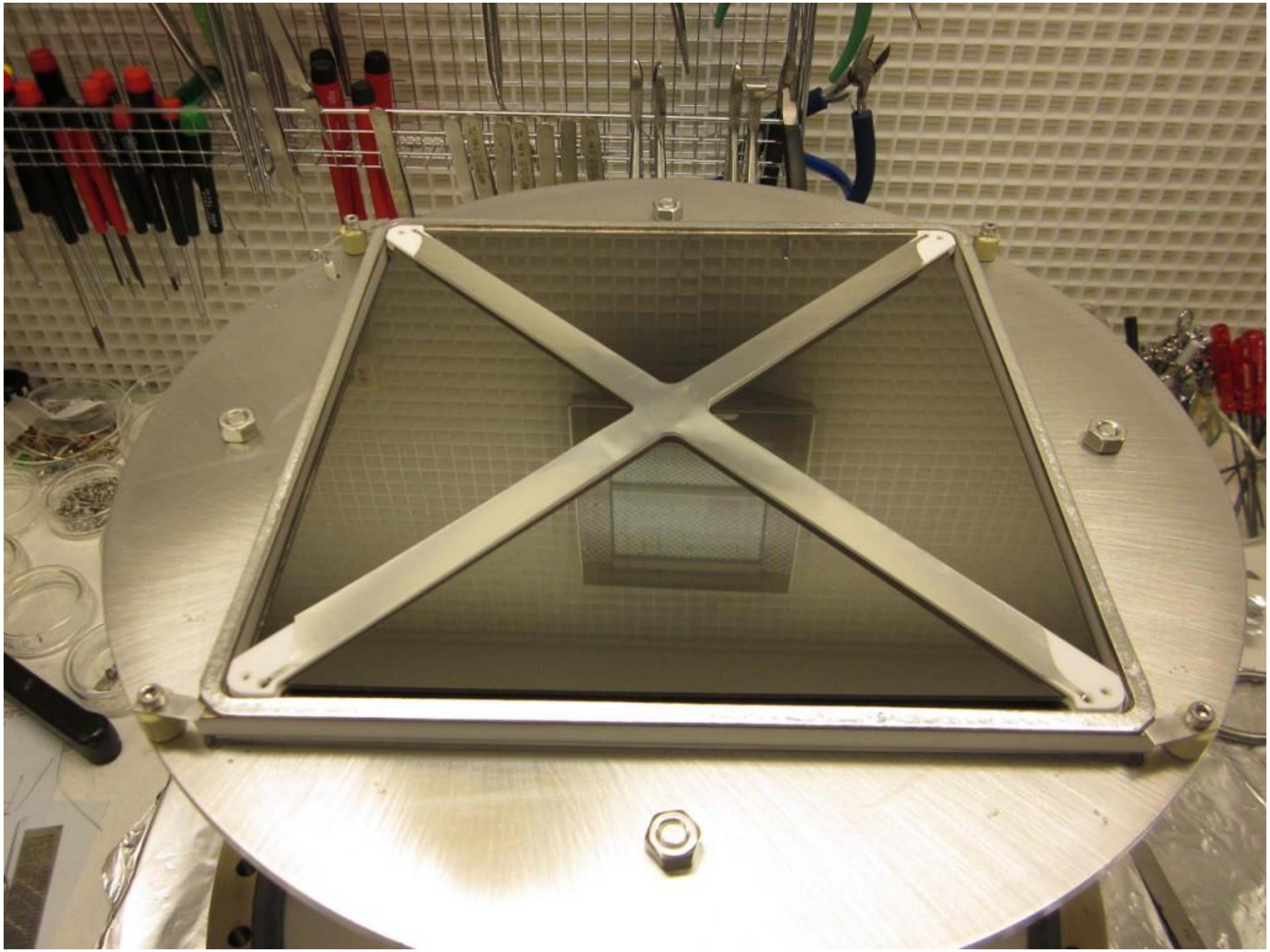
The cathode shoot process was very "conventional" all reactions went as they should for a good cathode.

QE numbers are almost exactly what we got in the smaller tank on our best 8" cathode – maybe slightly bluer

WE ARE READY TO SHOOT A CATHODE FOR A TUBE

Ossy Siegmund slide- stable long-term

Progress since last mtg: ceramic package



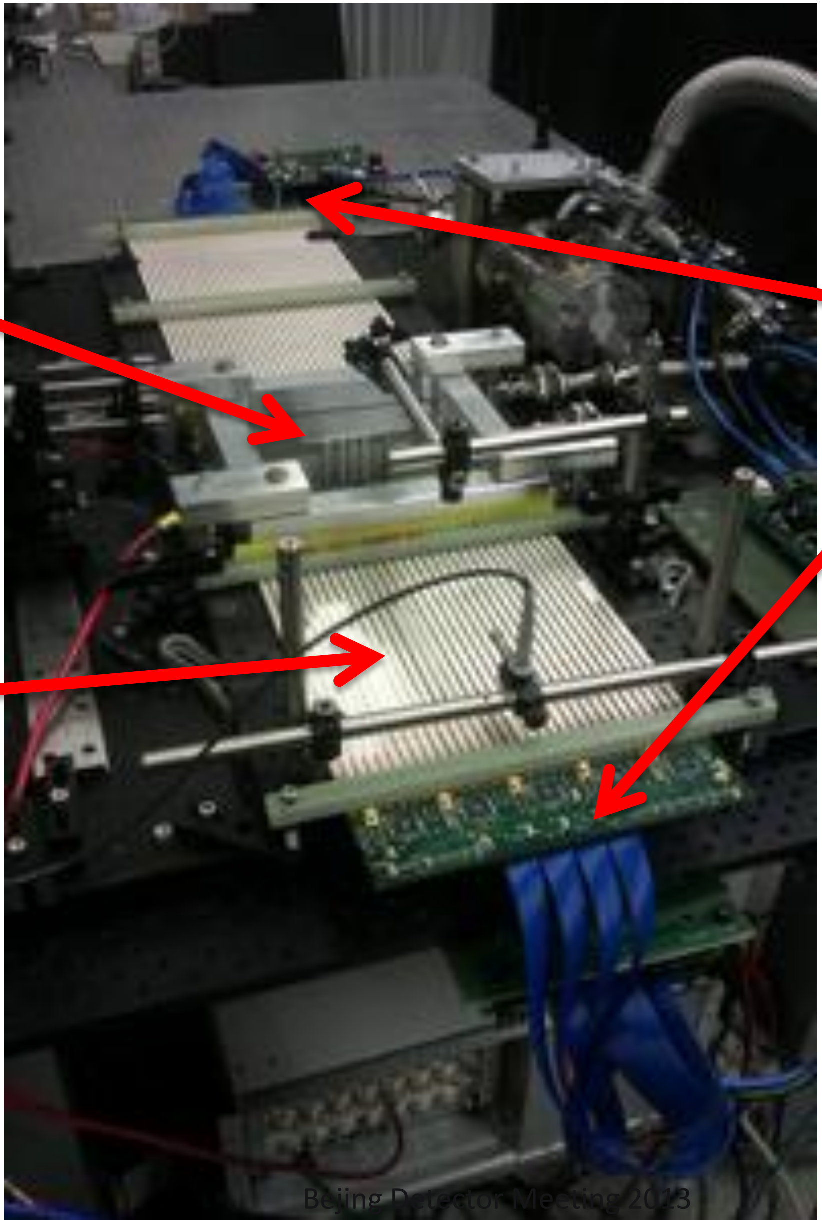
Stackup of two 8” MCP’s in progress of 1st tube assembly

Progress since last mtg: ceramic package

Pulse from the two 8" MCP's in progress of 1st tube assembly

Progress since last mtg: large area glass tile/tray package (ANL/UC)

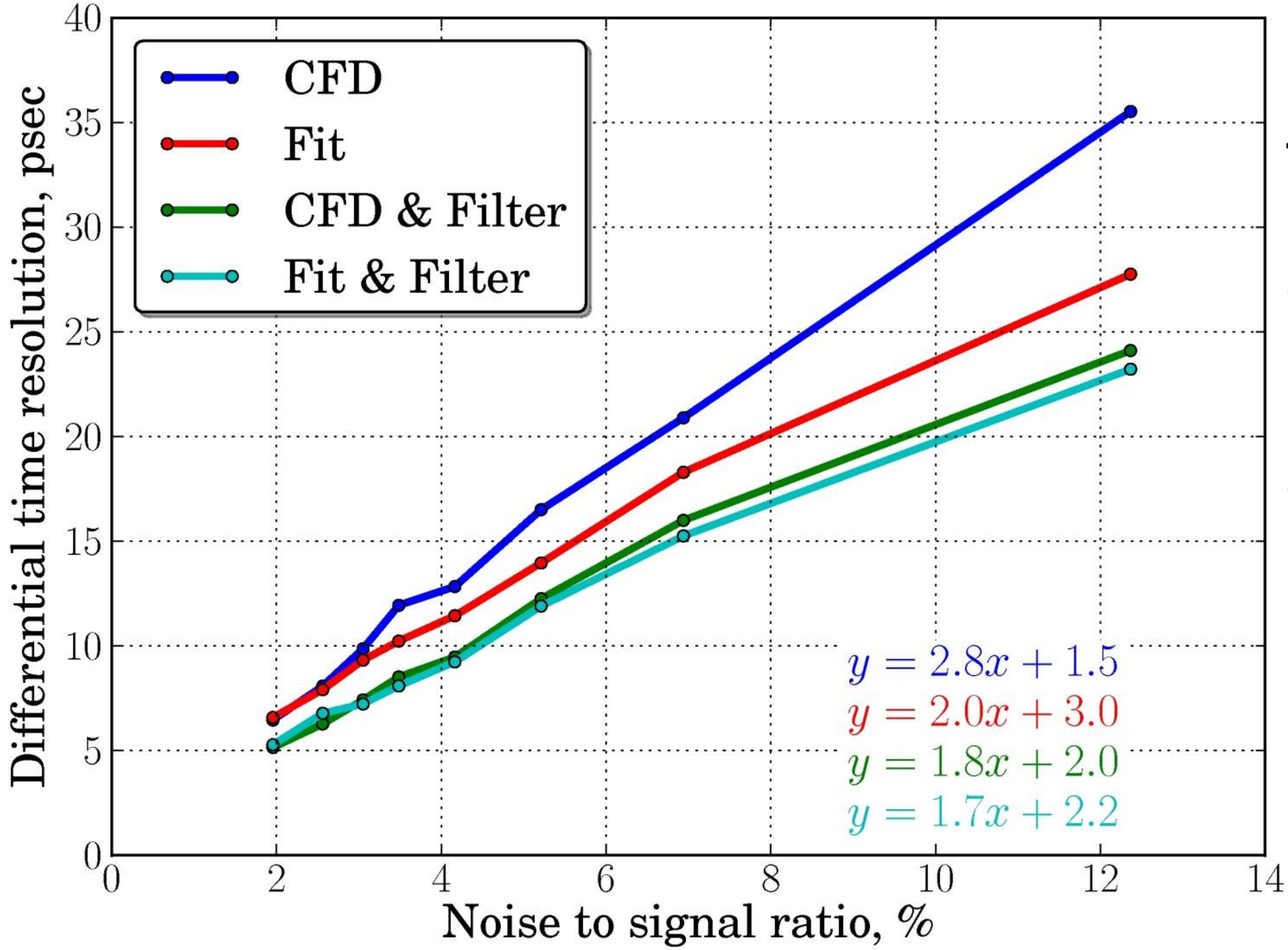
Full stack-up of 2 MCP's, glass spacers



90-cm 4-tile 30-strip `frugal' anode

30 channels of 10-15 GHz waveform sampling ASICS and digital readout X 2 ends

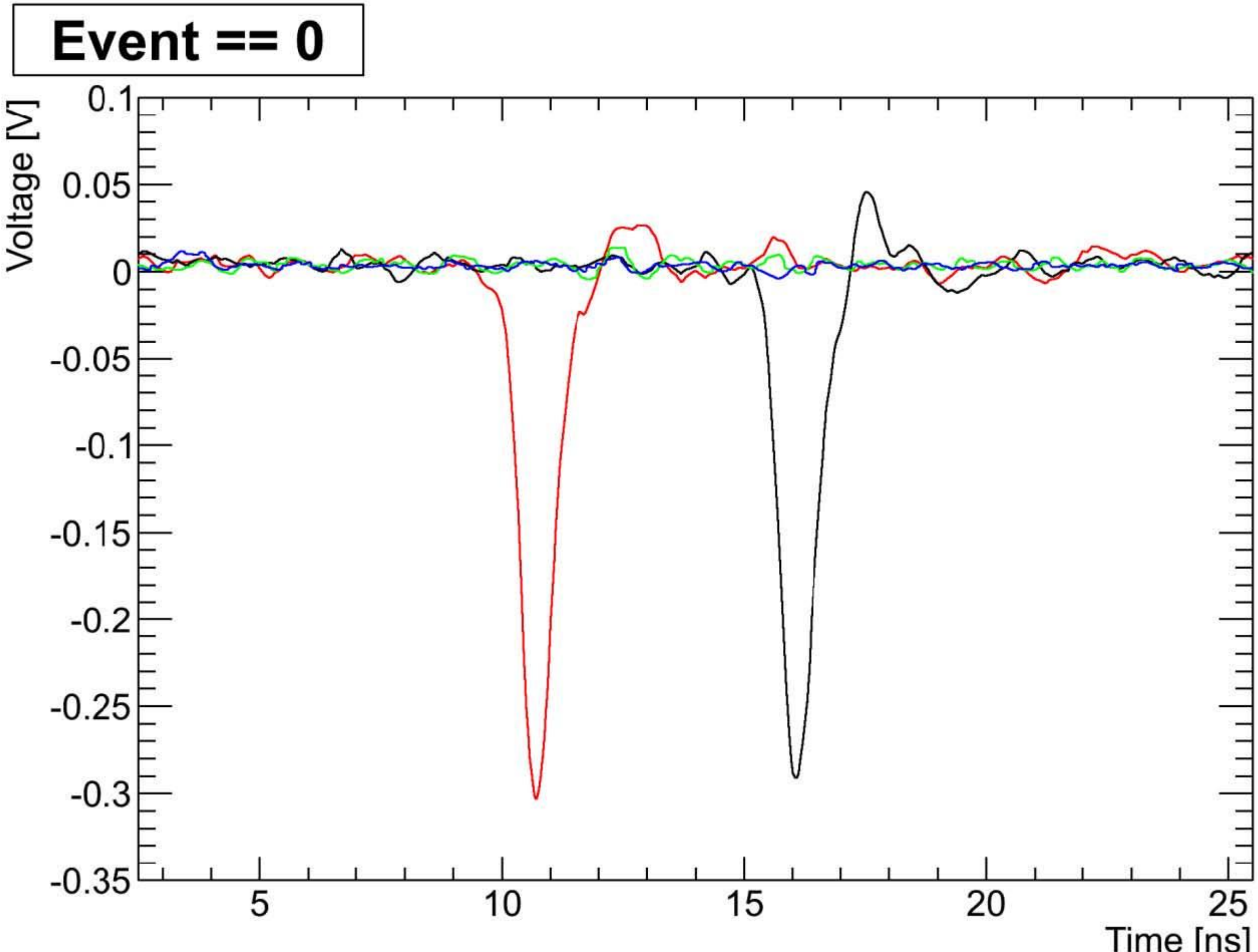
Progress since last mtg: large area glass tile/tray package (ANL/UC)



This is in a very noisy environment- now much better, so should do much better

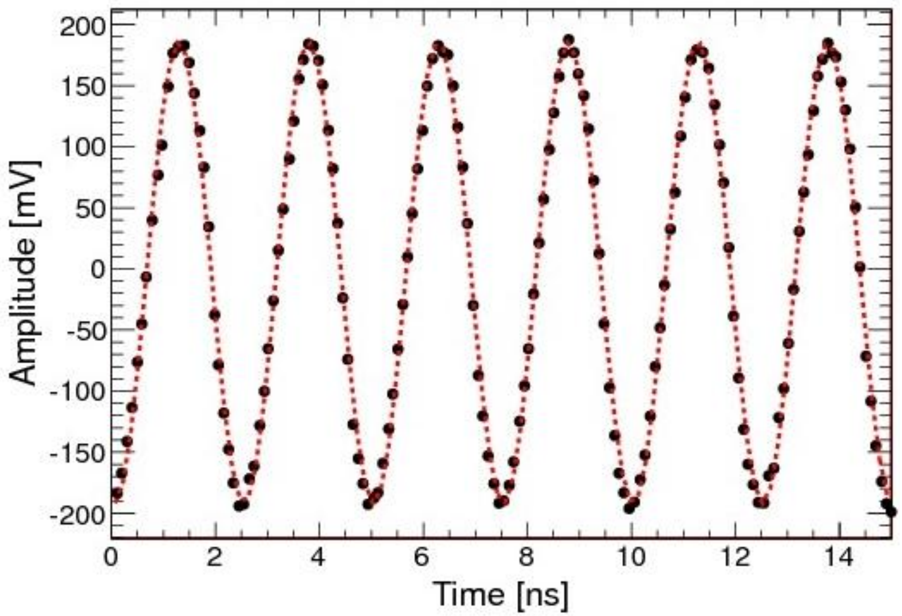
Differential RMS timing on 8" MCP/Anode setup

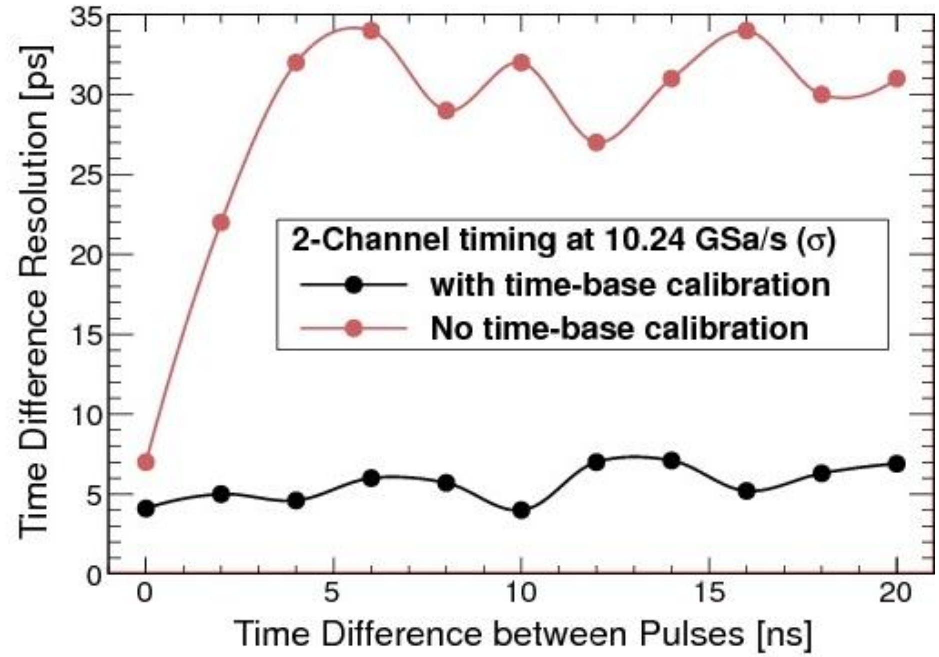
Progress since last mtg: electronics



Digitized pulses from PSEC4 and a pair of 8" plates- red is one end and black the other – full readout.

Progress since last mtg: electronics





PSEC4 performance- sine wave, and time resolution
We have started on PSEC5- deeper buffer, misc. fixes
Also TSMC instead of IBM

Papers

(I am proud of the group for doing this - lots of very hard work…)

From the Document Library:

225 Large Area Microchannel Plate Imaging Event Counting with Sub-Nanosecond Timing

Jeffrey W. Elam, Henry J Frisch, R Hemphill, Sharon Jelinsky, Anil U. Mane, Jason McPhate, Ossy Siegmund, Anton Tremsin, J Vallerga and Robert G. Wagner

IEEE Transactions on Nuclear Science, Vol. 60, No. 2, April 2013

218 A 15 GSa/s, 1.5 GHz Bandwidth Waveform Digitizing ASIC

Eric Oberla, Gary Varner, Henry J Frisch, Jean-François Genat, Hervé Grabas and Kurtis Nishimura

Submitted to NIM A (in refereeing)

214 A Test-Facility for Large-area Microchannel Plate Detector Assemblies Using a Pulsed sub-Picosecond Laser

Bernhard Adams, Matthieu C Chollet, Andrey Elagin, Razib Obaid, Alexander Vostrikov and Eric Oberla

To be published in Reviews of Scientific Instruments (cover article)

211 RF Strip-Line Anodes for Psec Large-Area MCP-based Photodetectors}

Bernhard Adams, Andrey Elagin, Henry J Frisch, Jean-François Genat, Hervé Grabas, David McGinnis, Rich Northrop, Richard Northrop, Razib Obaid, Eric Oberla, Matthew Wetstein and Fukun Tang

Published in NIM-A

THE ASK

- We would like BaF or other (relatively) dense fast crystals for the PET testing- are there samples etc. we could get?

The End

BACKUP SLIDES

Patience!