Introduction to LAPPD and Achievements of the last 3 Years

Henry Frisch
For the LAPPD Collaboration

Outline

1. What Are We Trying to Achieve? Need for Transformational Detector Development
   a) Collider- Flavor, Family QN Flow
   b) Howard- Long baseline ν Detectors
   c) Medical Imaging (PET in particular)
2. Achievements and challenges in the 5 Areas:
   1) MCP's, 2) Hermetic Packaging, 3) Cathodes, 4) Electronics, and 5) Integration

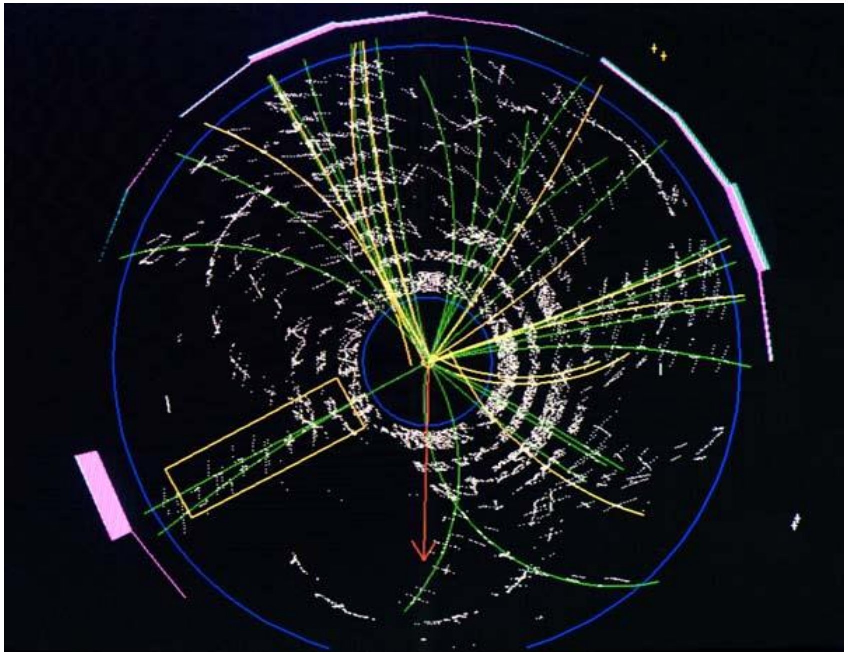
What are we trying to achieve?

Brief description of the context, motivating needs

Colliders:

Need: 1) identify the quark content of charged particles

2) vertex photons



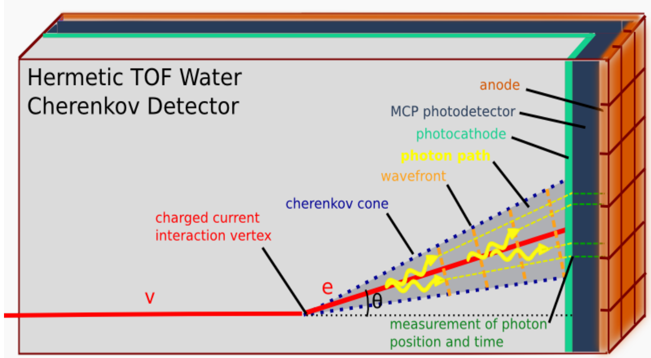
Extract *all* the information in each event (4-vectors) – only spins remain…

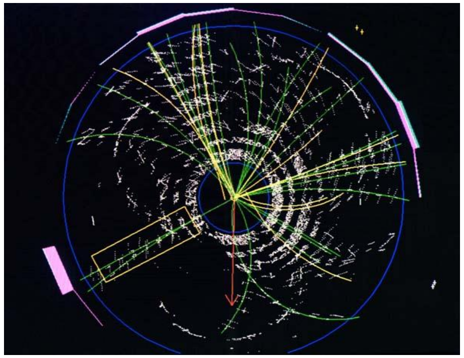
(SRI rubric)

Approach: 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.

Benefit: Discoveries in signatures not possible now

DUSEL Detector Motivation vs Collider

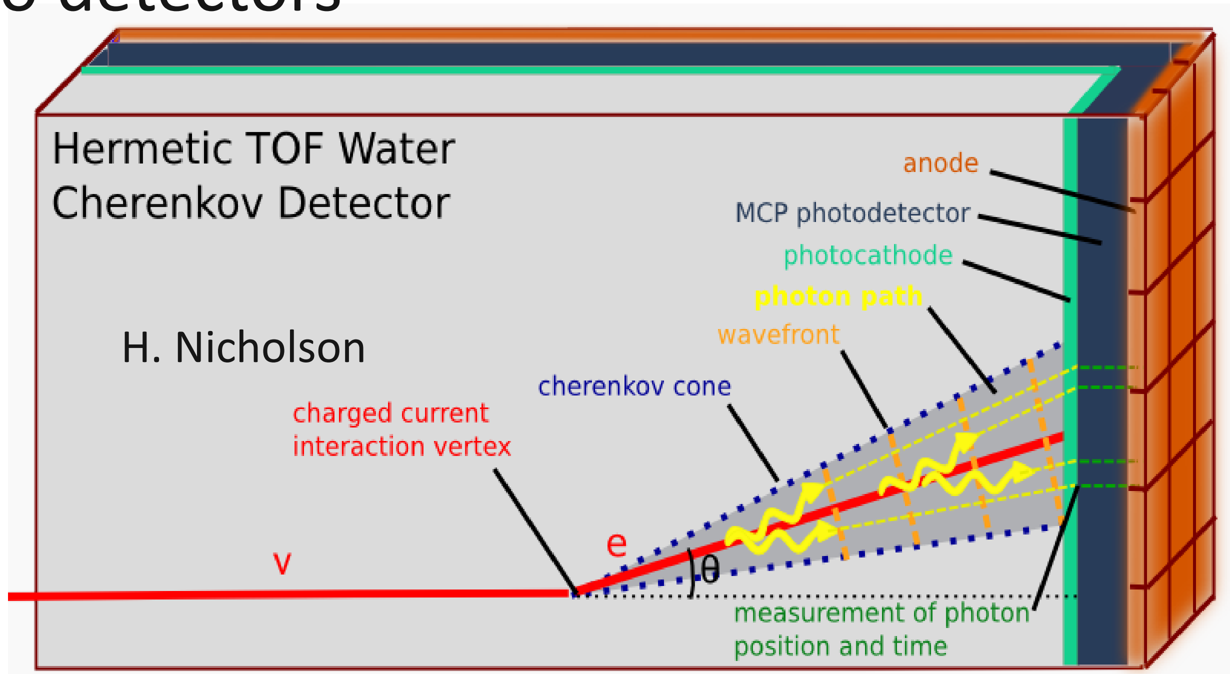




- Howard recognized that these detectors could be used in large water-Cherenkov ν detectors
  - DUSEL plan was 150-300 M$ for PMT"s, all non-US
  - Howard advocated high-risk high-return (see PCAST report);
  - Ancillary benefits-
    - Non-implosive (low volume, can be thick glass)
    - Insensitive to Earth's magnetic field
  - Howard spoke of a 4'x8' panel with a single fiber readout (!).
- The LAPPD R&D addressed both large-area and fast time resolution applications – good time resolution is intrinsic.

Neutrino Physics

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



Measure the arrival times and positions of photons (LTPC) and reconstruct tracks in water via time-sliced (100ps) 2D readout.

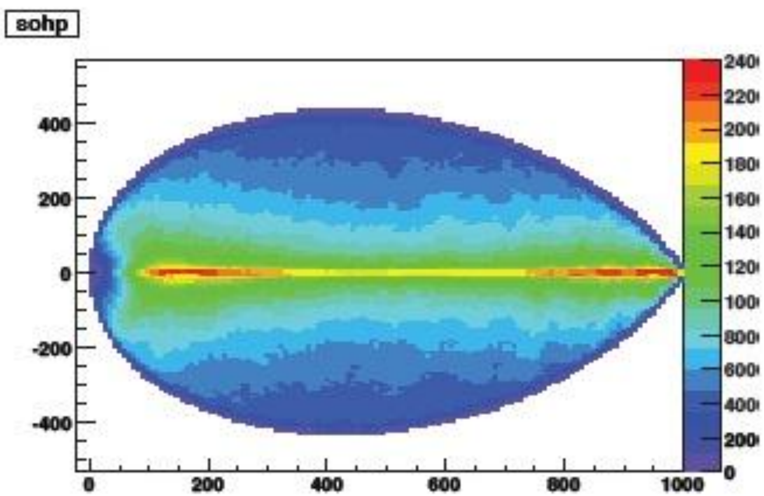
A possible factor of 5 less volume needed per $.
(simulation effort is in progress).

Can we build a photon TPC?

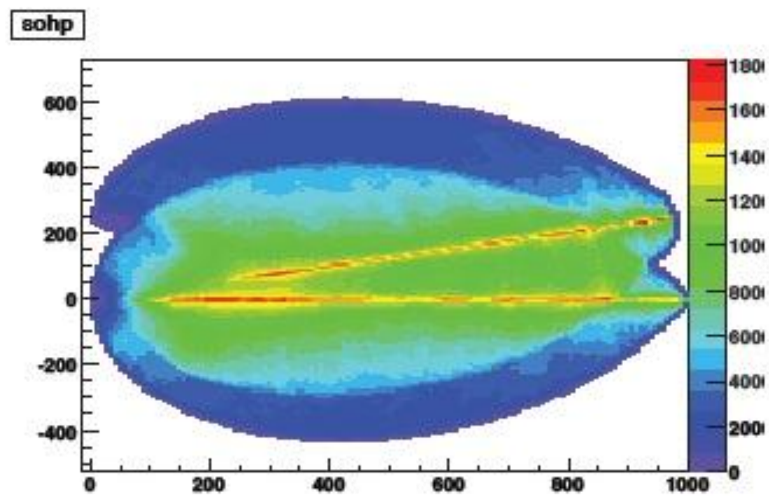
Track Reconstruction Using an "Isochron Transform"

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

(mention Ypsilantis proposal but with LAPPD's here)

Medical Imaging- TOFPET

TOF adds 3rd dimension to Positron-EmissionTomography

TOF (Effective Efficiency) Gain for Whole-Body PET (35 cm)

Hardware	Δt (ps)	TOF Gain
BGO Block Detector	3000	0.8
LSO Block (non-TOF)	1400	1.7
LSO Block (TOF)	550	4.2
$LaBr_3$ Block	350	6.7
LSO Side Coupled	250	9.3
LSO Small Crystal	210	11.1
LuI_3 Small Crystal	125	18.7
$LaBr_3$ Small Crystal	70	33.3

- *Incredible* Gains Predicted
- *Nothing* Else Can Give Us Gains of This Size!

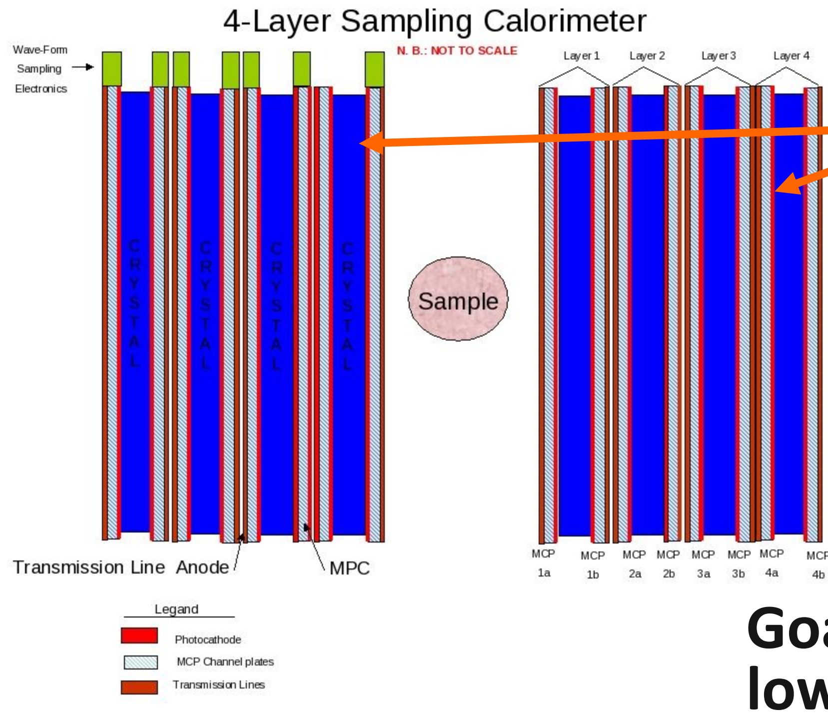
Bill Moses's talk at the Clermont Workshop (see http:hep.uchicago.edu/psec)

Geometry of large panels gives another factor of 10-30

(Simulations by H. J. Kim, C.-M. Kao, Univ. of Chicago)

Application 3- Medical Imaging (PET)

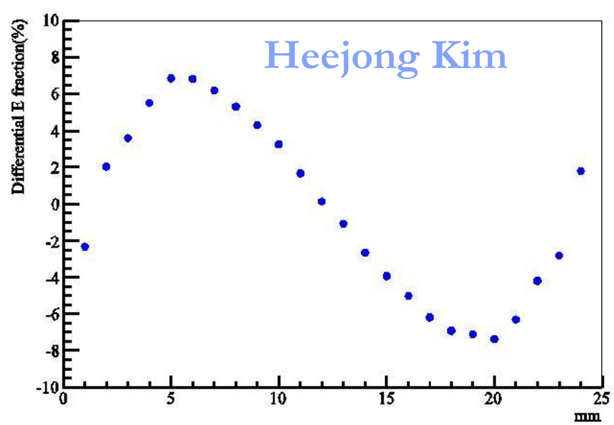
Can we solve the depth-of-interaction problem and also use cheaper faster radiators?



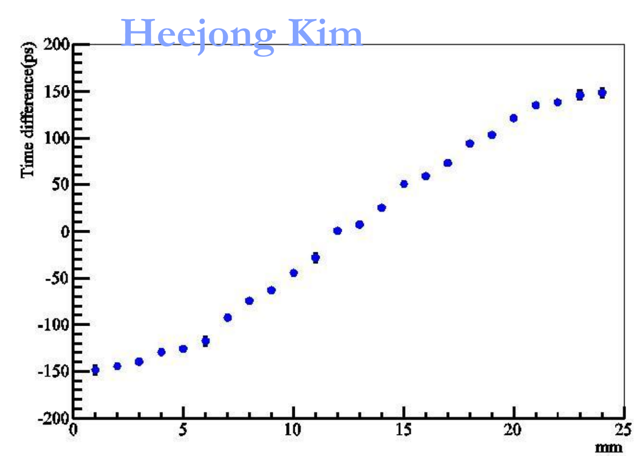
Alternating radiator and cheap 30-50 psec planar mcp-pmt's on each side

Simulations by Heejong Kim (Chicago)

Goal: factor of 100 lower dose rate



Depth in crystal by time-difference



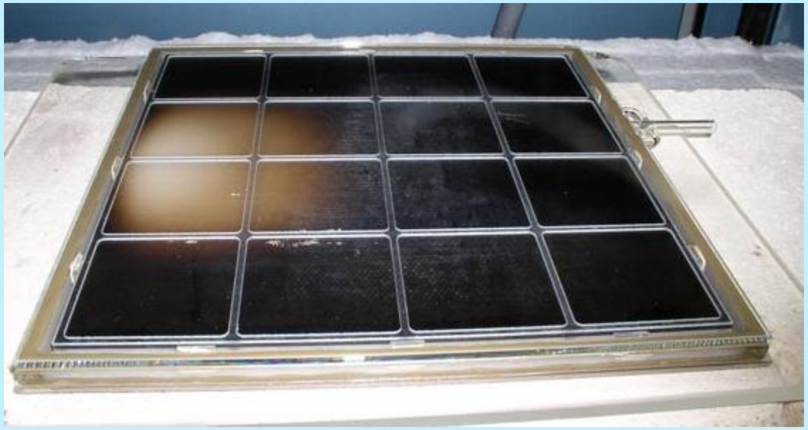
Depth in crystal by energy-asymmetry

Achievements

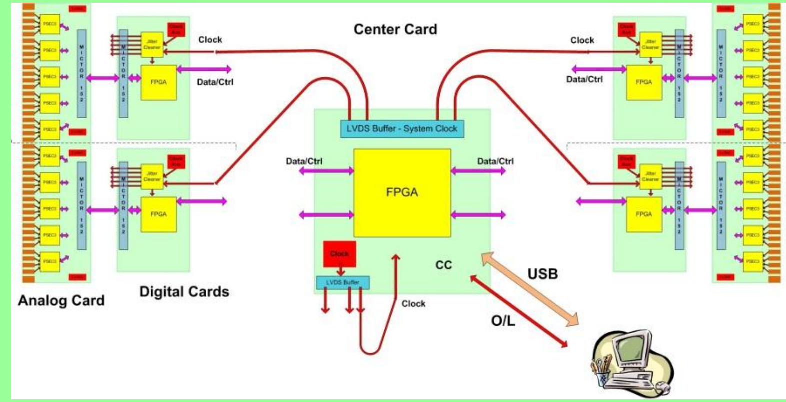
Summary of achievements- intro to the present status talks that follow

The 4 `Divisions' of glass LAPPD

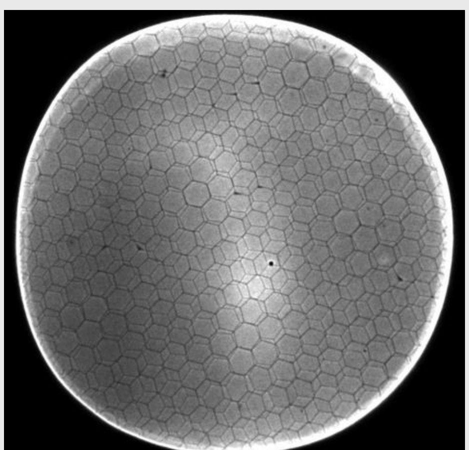
Hermetic Packaging



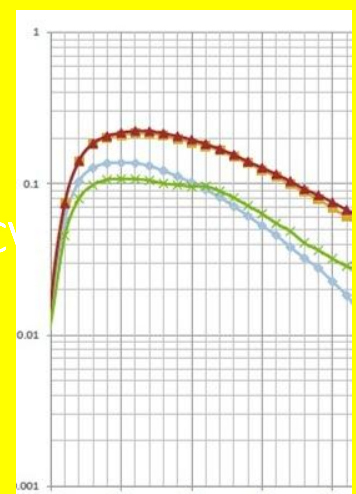
Electronics/Integration



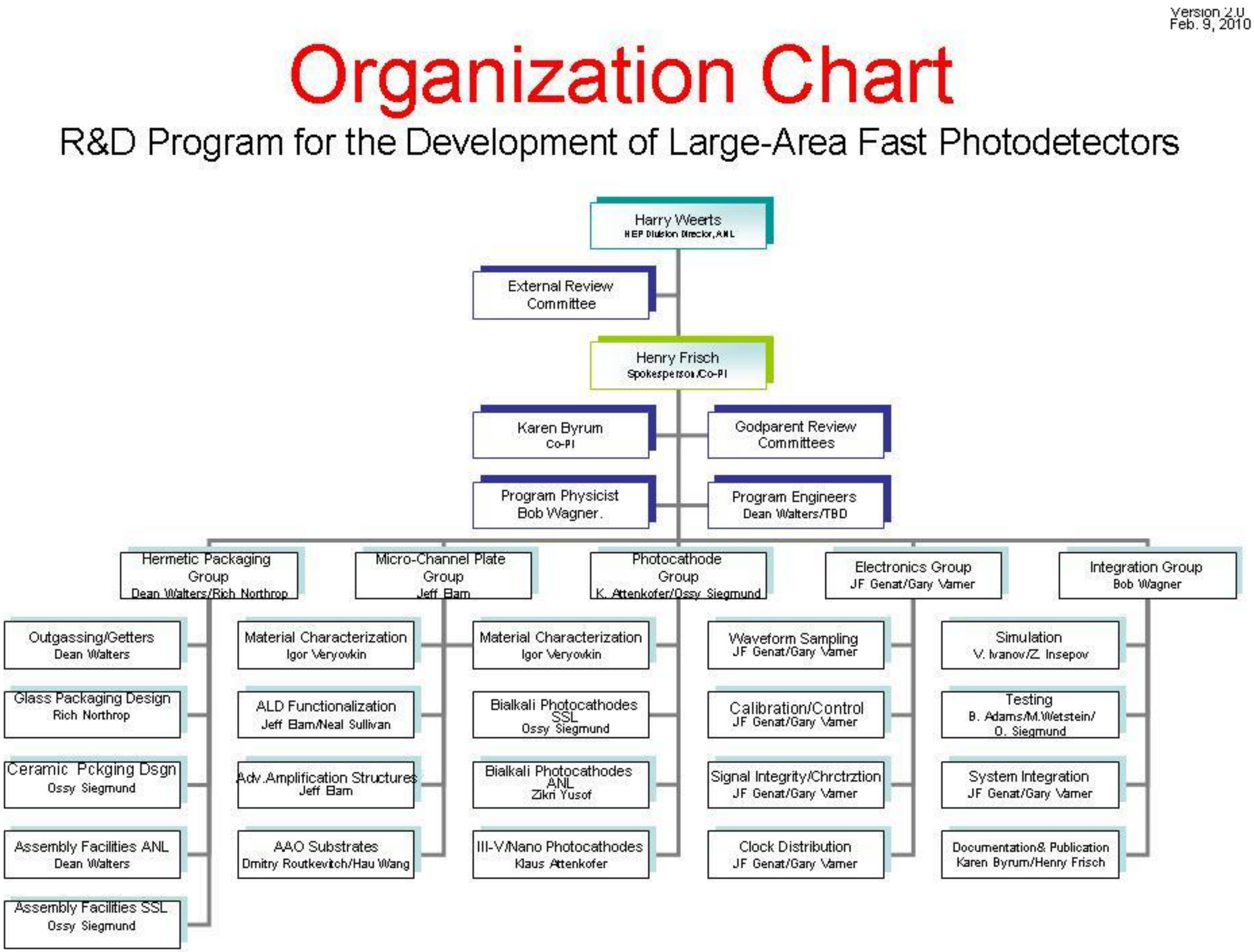
MicroChannel Plates



Photocathodes



The Large-Area Psec Photo-Detector Collaboration-2010

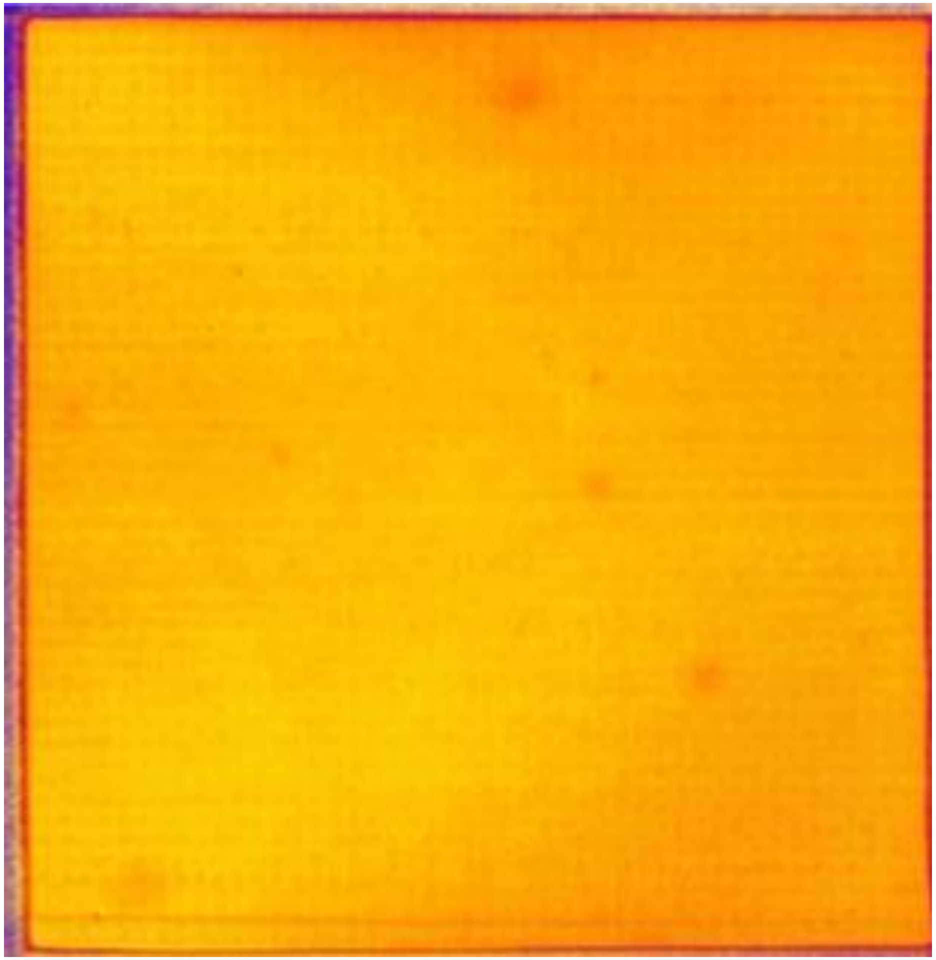


MCP's

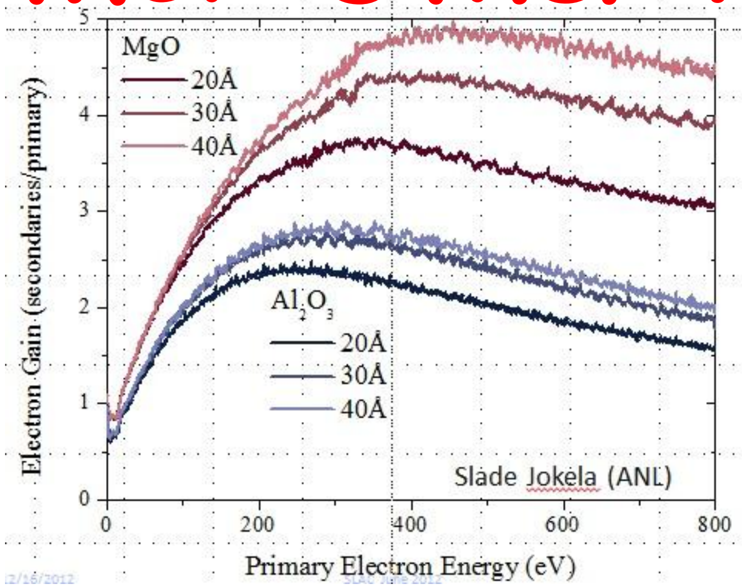
MCP Major Achievements

Development of 8" 20μ Substrates (Michael's Talk)

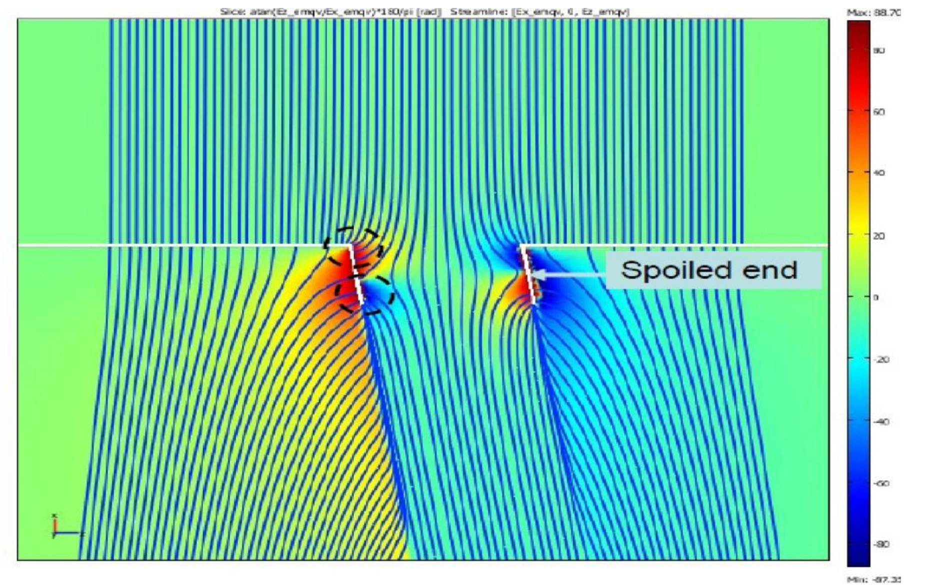
Gain Map of ALD-Functionalized 8" MCP (Jeff, Anil, and Ossy's Talks)



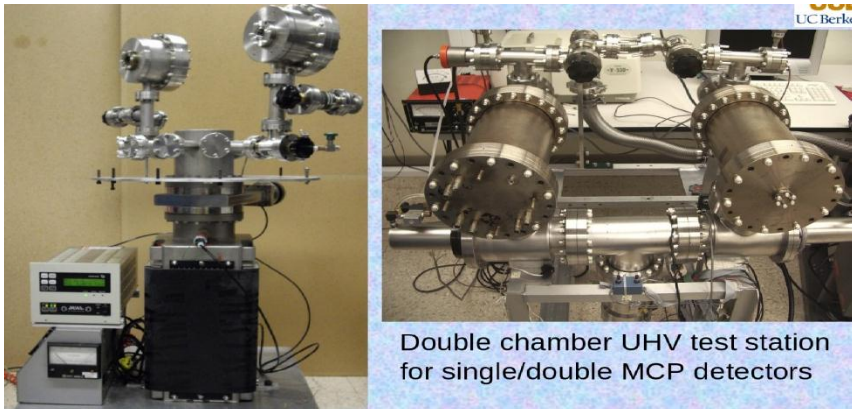
MCP Other key Achievements



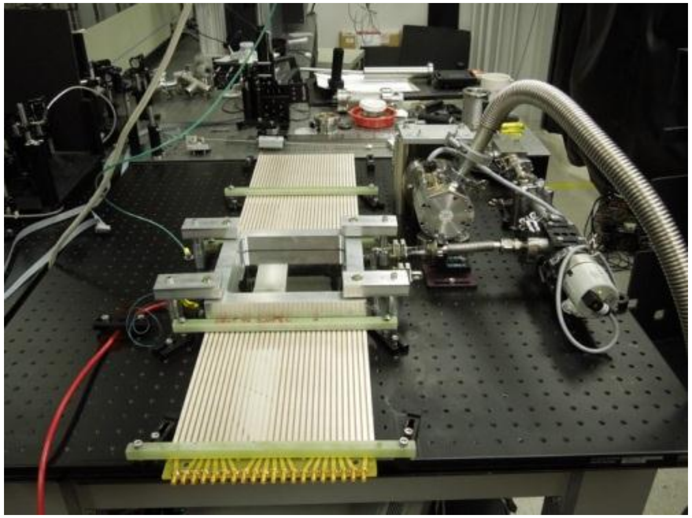
Measurement of Secondary Emission in materials



Detailed simulations of MCP behavior



SSL Extensive Test Facilities for Rapid Turnaround ALD Feedback (much more than shown)



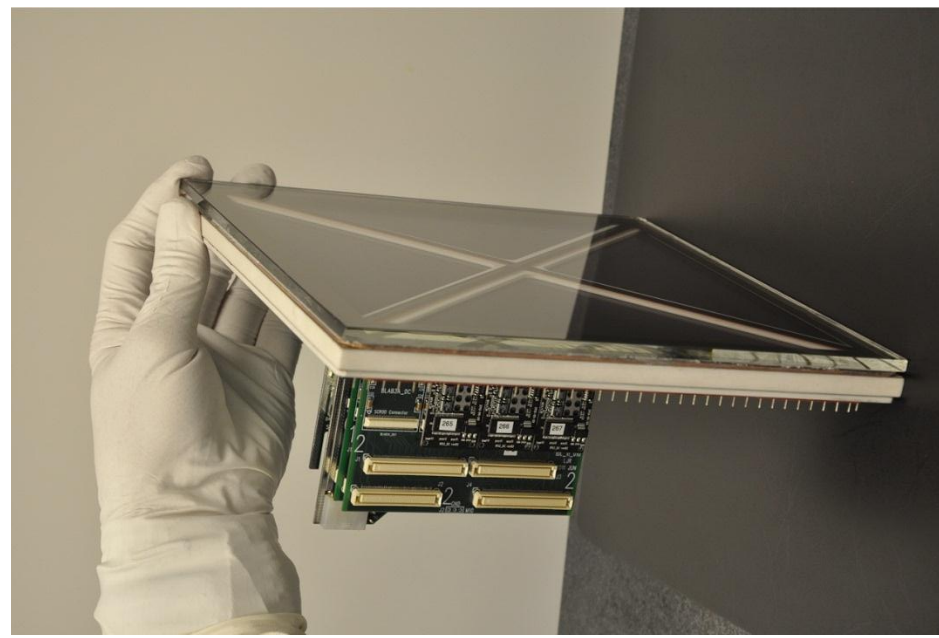
Femto-sec laser teststands at APS

Hermetic Packaging

Packaging Major Achievements

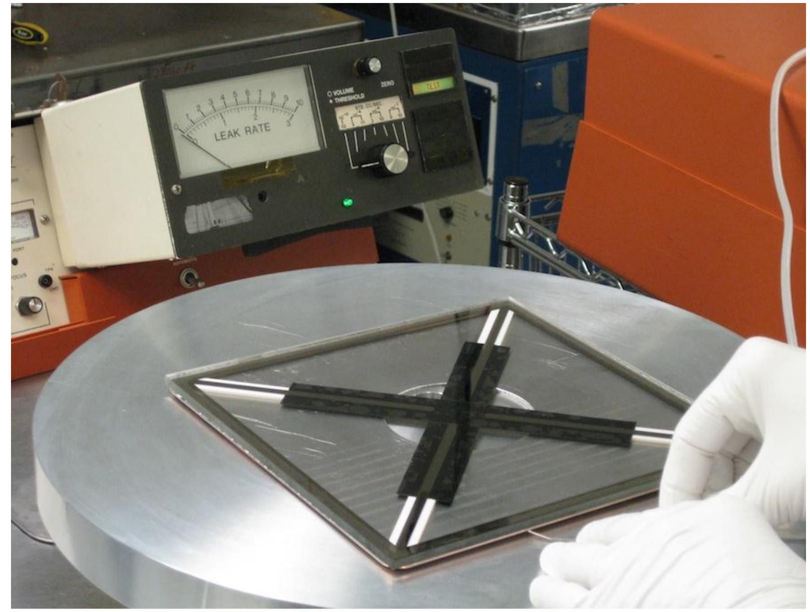
Development of a `frugal' glass tile package with internal HV divider, capacitive GHz readout (Andrey's and Matt's Talks)

Development of a complete ceramic package system design (Jason's and Ossy's talks)

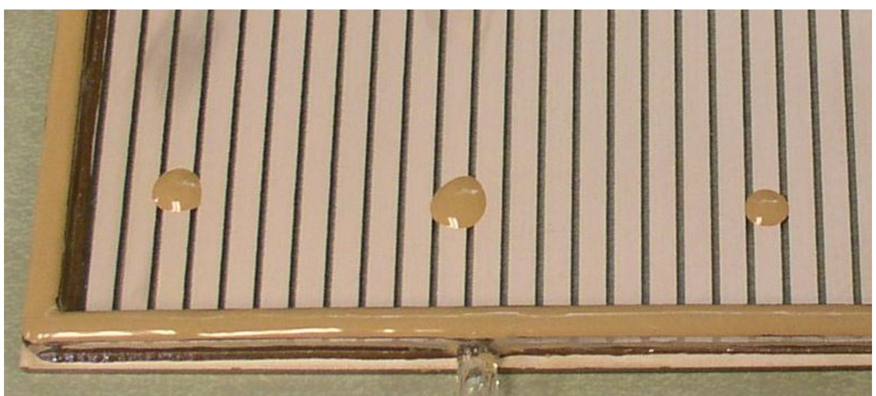


Packaging Other Achievements

Commissioning of SSL `big tank'



Leaktight top-seal at SSL (Jason's and Andrey's talks

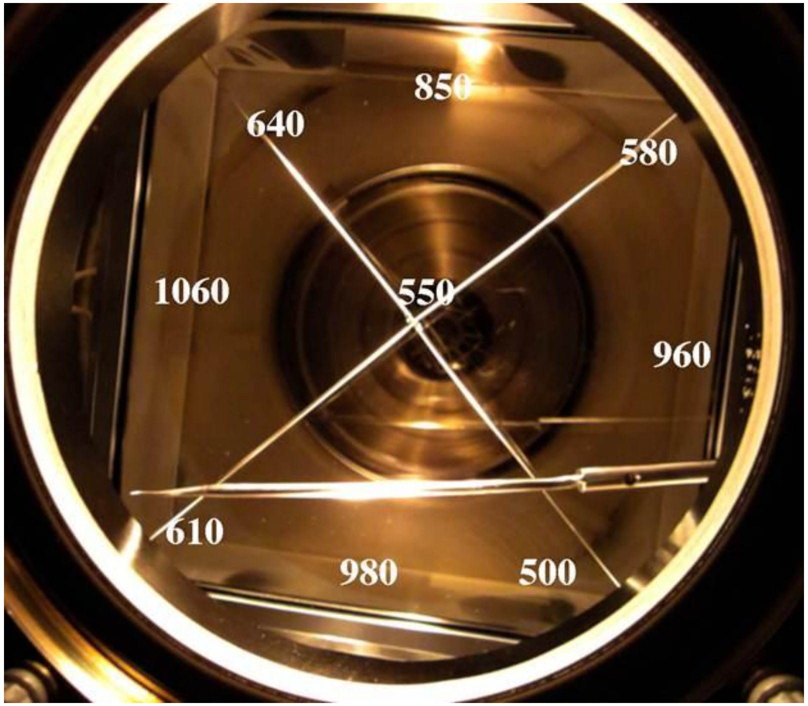


Development of glass frit seal across the anode strips

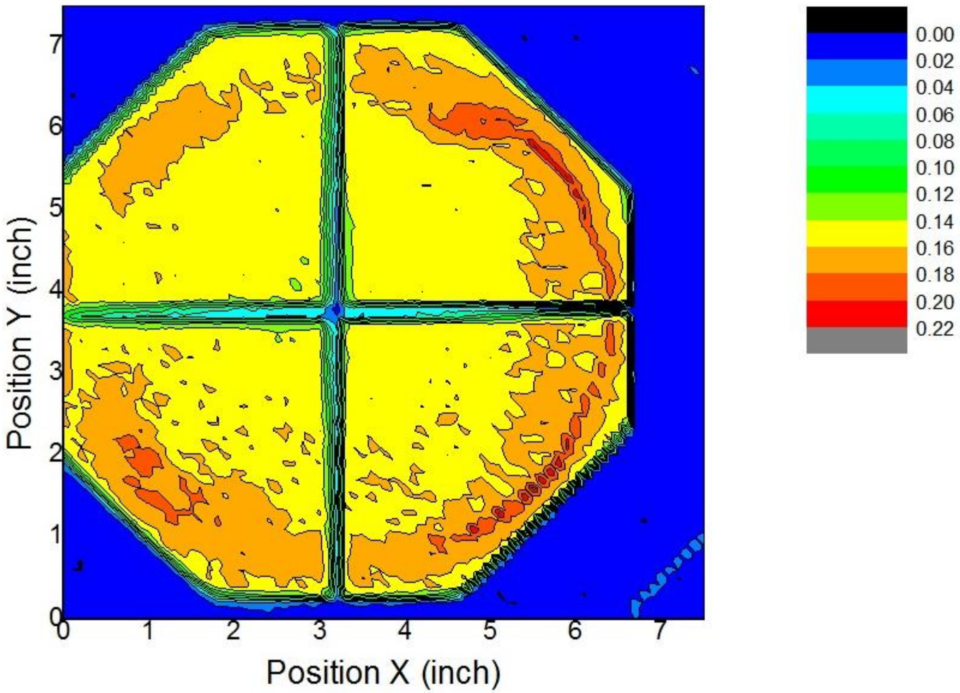
0.5 m^2 modular RF tray package

Cathodes

Cathode Major Achievements

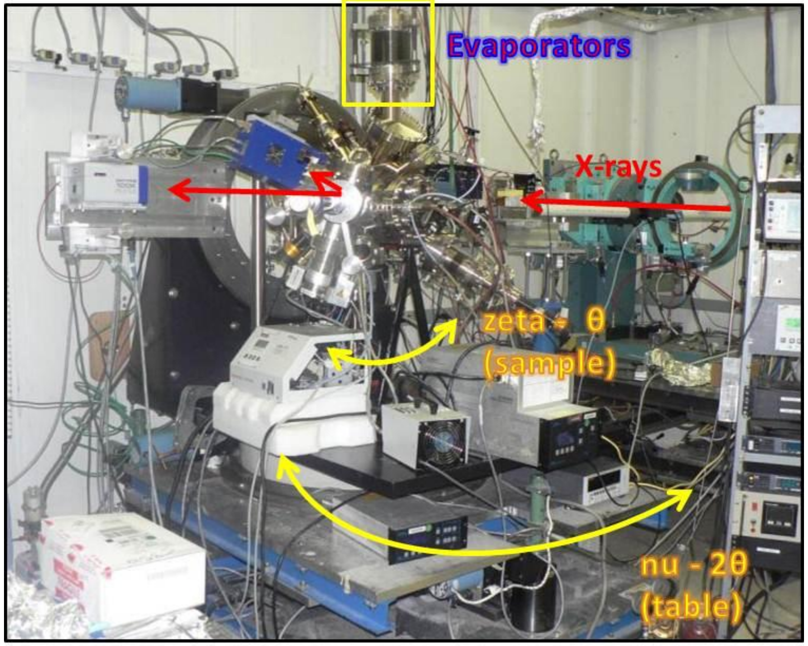


A successful 8" Bialkali Cathode (Ossy's Talk)

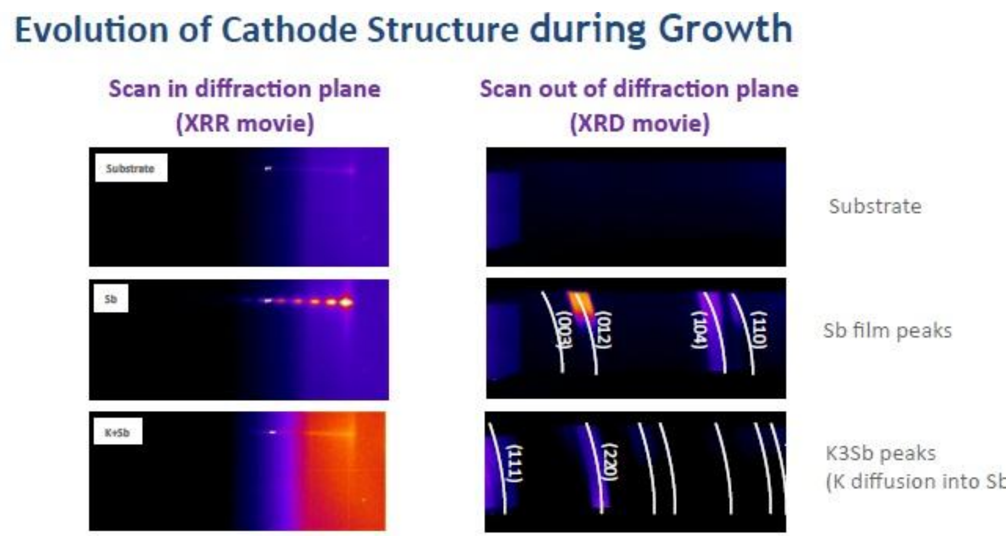


A 7" Bialkali made in the Burle Equip at ANL (Ossy's Talk)

Cathode Other Achievements



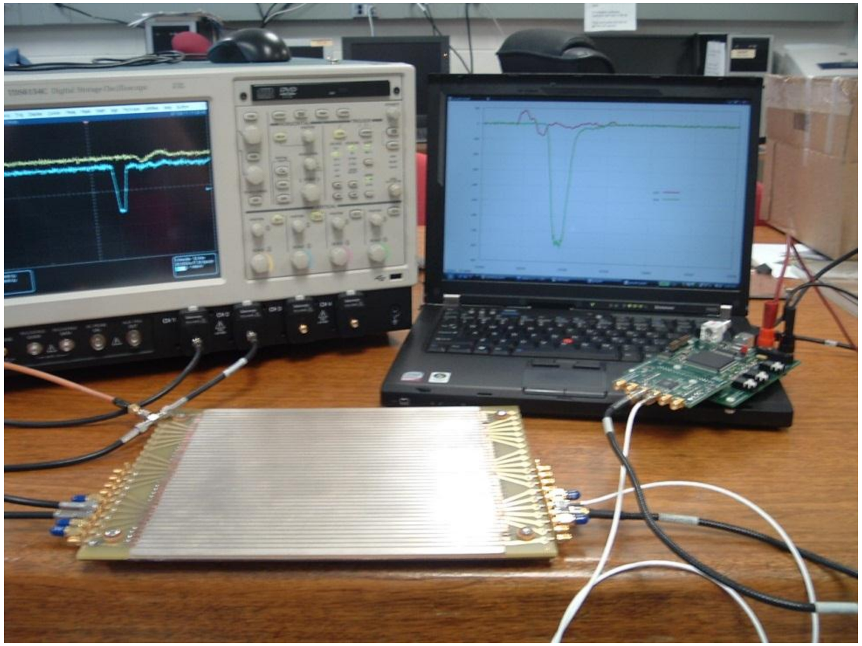
Seeded collaboration on `Theory-based Photocathode development (Attenkofer et al.-BNL, UC, ANL, UCB, Wash-U collaboration)



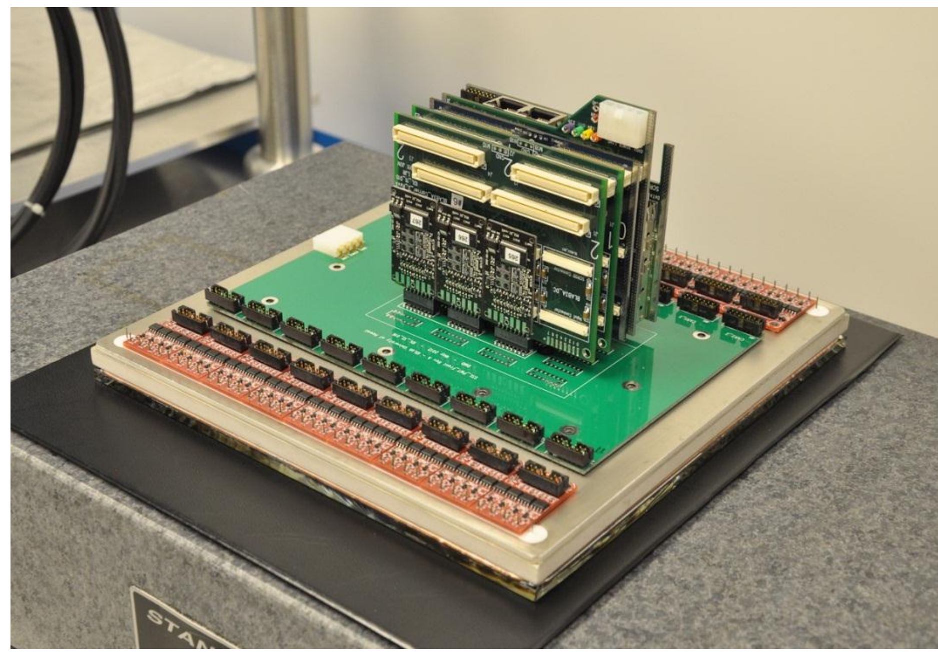
In-situ movies of cathode growth (Cathode collaboration)

Electronics

Electronics Major Achievements

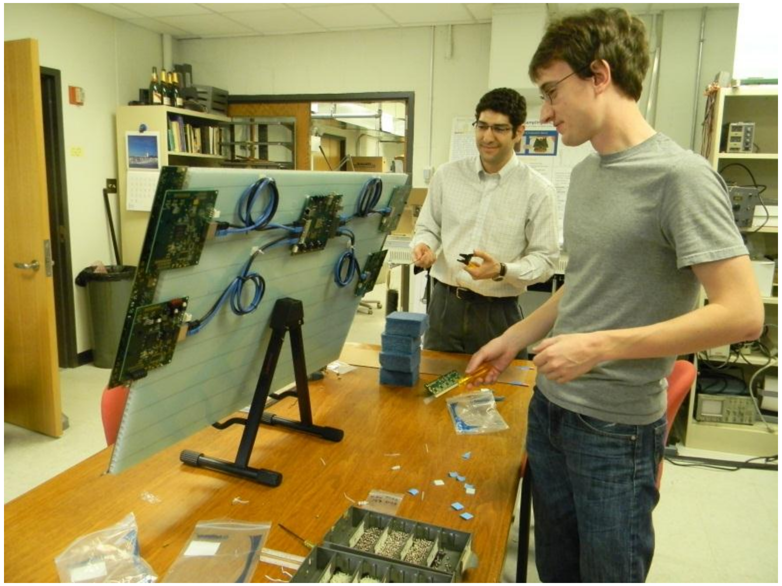


Development of 15 GS/sec waveform sampling ASIC (Gary's Talk)

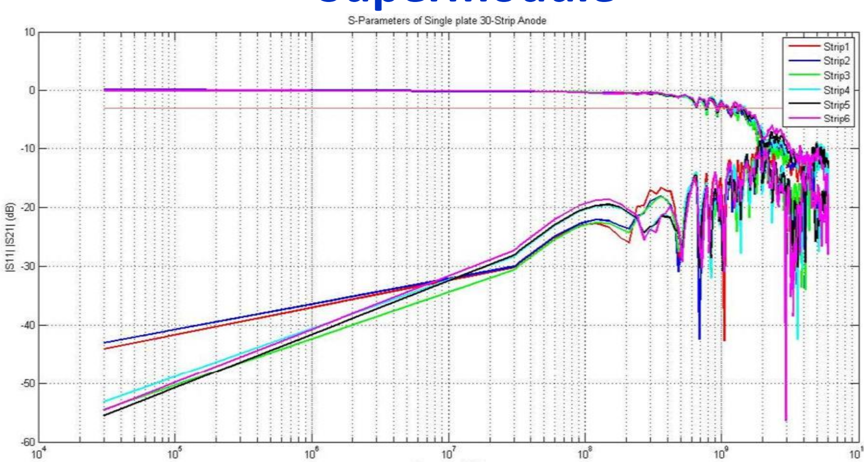


Development of a complete system for the ceramic tube (Gary's talk)

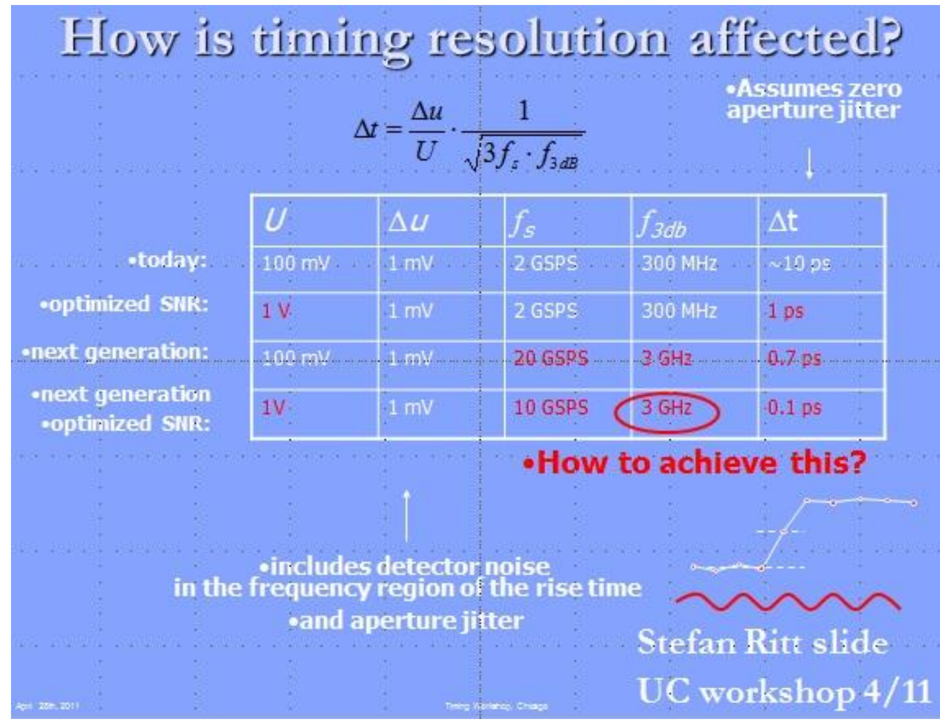
Electronics Other Achievements



Development of a complete DAQ for the Supermodule



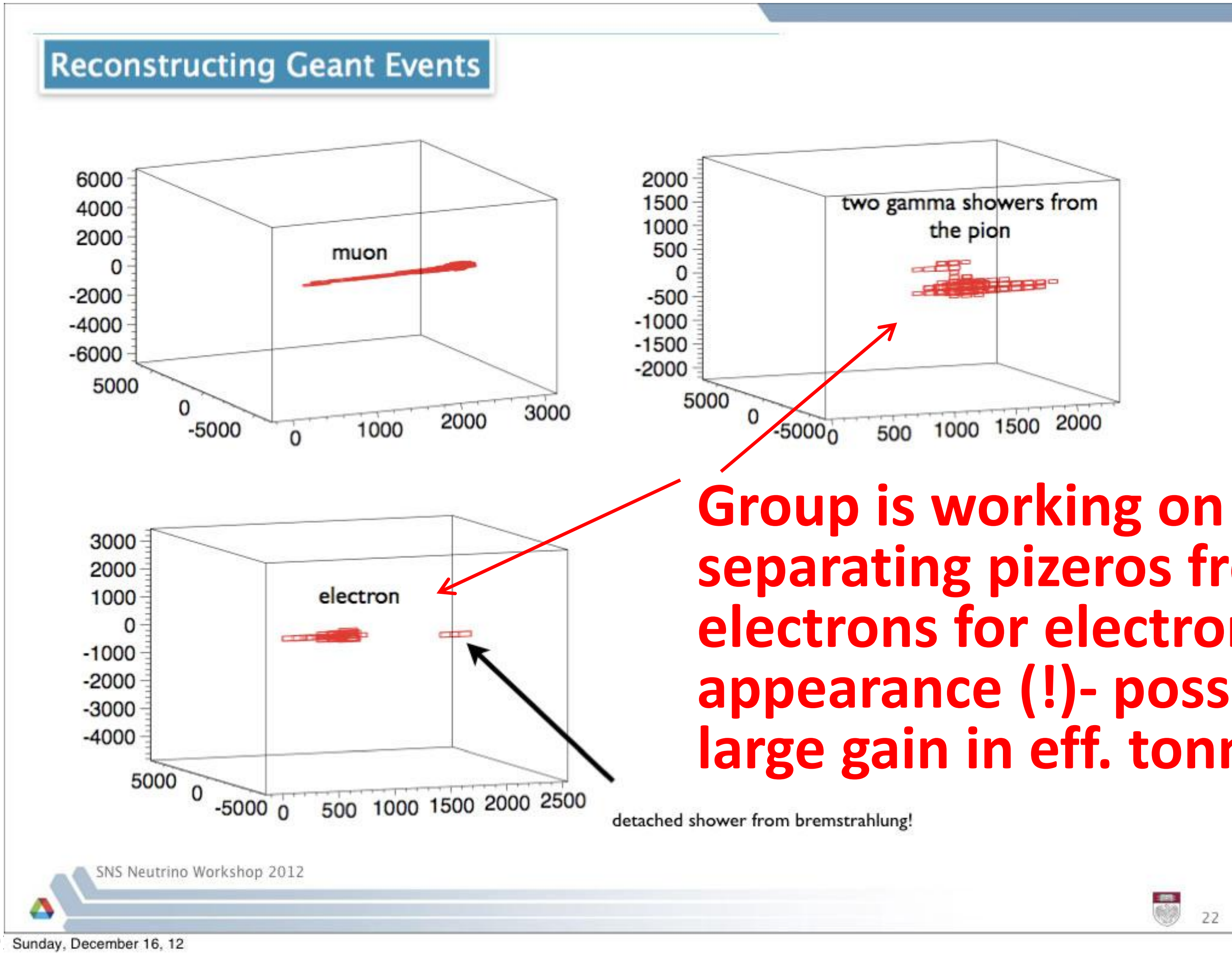
An understanding, including measurements, of anode bandwidth (submitted to NIM)



An understanding, including measurements and simulation, of the determinants of timing (published in NIM)

Other Impacts

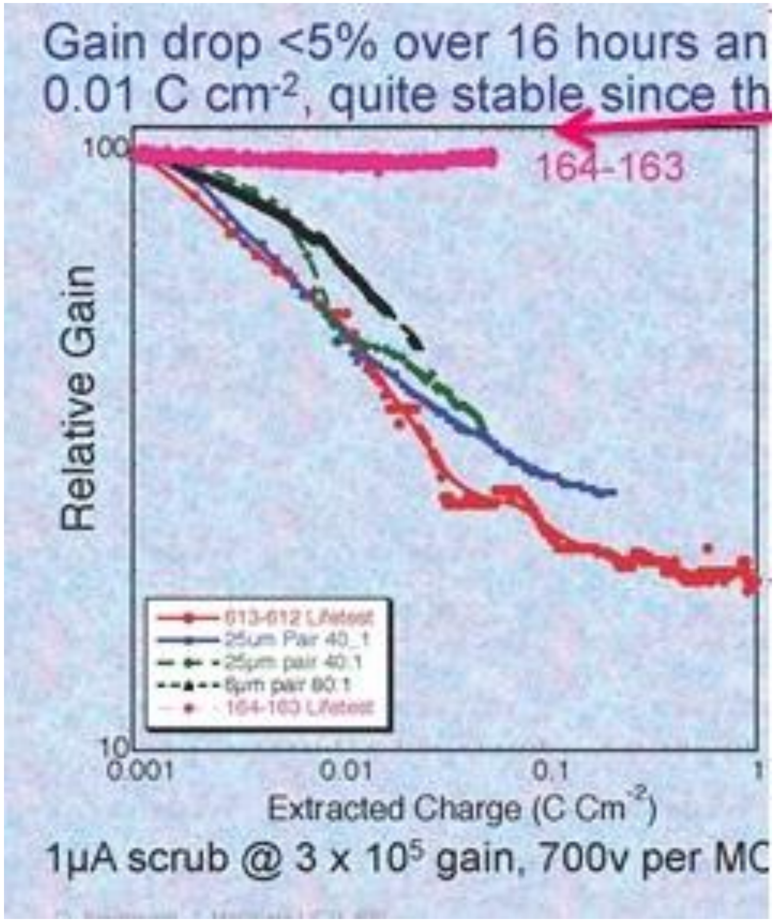
Matt and Mayly have formed a group working on LAPPD n event vertex and track reconstruction



Group is working on separating pizeros from electrons for electron appearance (!)- possible large gain in eff. tonnage

Other Impacts

Industry has taken note of the unscrubulous (sic) property of ALD-functionalized plates- has a very large effect on the throughput, and hence the economics, of MCP-based tube production.



See Ossy's talk for an update.

Other Impacts

We may have had influence in interesting industry in probing the limits of high QE for photocathodes*

Second Photocathode Wo ×

psec.uchicago.edu/workshops/2nd_photocathode_conference/talks.php

Imported From Firef... Psec Veljko Radeka Wins I... Library Blog Maps SPIRES ANL_phone UC_phone SWA excelitas

Second Workshop on Photocathodes: 300nm-500nm

Photocathode Workshop: agenda, talks

June 29-30, 2012 at The University of Chicago

Day 1

Speaker	Title	PPT	PDF
Karen Byrum (ANL-HEPD) Henry Frisch (UC)	Goals of the Workshop	PPTX	PDF
Razmik Mirzoyan (MPI-Munich)	What Are the Highest QE's Measured So Far?	PPT	PDF
John Smedley (BNL)	Determining Parameters in the Spicer-Model and Predicted Maximum QE	PPTX	PDF
Inés Montaño (Sandia)	Minimizing Negative and Maximizing Positive Effects of Electron Scattering		PDF
Xiuling Li (UIUC)	Influence of Structure and Composition on Conductivity and Optical Properties		
Andy Cormack (ET Enterprises)	Overview and Critique on Design Concepts for Sources		PDF
Charles Sinclair (Cornell)	Getter Sources Versus Metallic Evaporation Sources	PPTX	PDF
Oswald Siegmund	Challenges in Photocathode Deposition for Large-Area MCP Proximity-Focus Devices		PDF
Ray Conley (BNL)	Comparison of Evaporation, Sputtering and CVD Techniques for Growth of Multi-Component Systems		

Day 2

Speaker	Title	PPT	PDF
Sen Qian (IHEP)	Cathode Development in China	PPT	PDF
Matthew Highland (ANL-MSD)	Solid State Solutions, Phase Diagrams and Phase Transitions	PPT	PDF
Jeffrey Elam (ANL-ESD)	In situ Measurement Tools	PPTX	PDF
Miguel Ruiz Osés (Stony Brook)	Visualizing Crystal Growth and Solid State Chemistry During the Recipe	PPTX	PDF
Zikri Yusof (ANL-HEPD)	Changes In Cs_2Te Photocathode Fermi Level Due to Heating		PDF

Conference Home | Agenda | Talks | Travel & Parking | Accommodations | Participants

Lots of Industrial folks at the workshop- recent big advances by ADIT, Hamamatsu and Photonis; still don't know the limit. (R&D component of our program.)

*an in joke

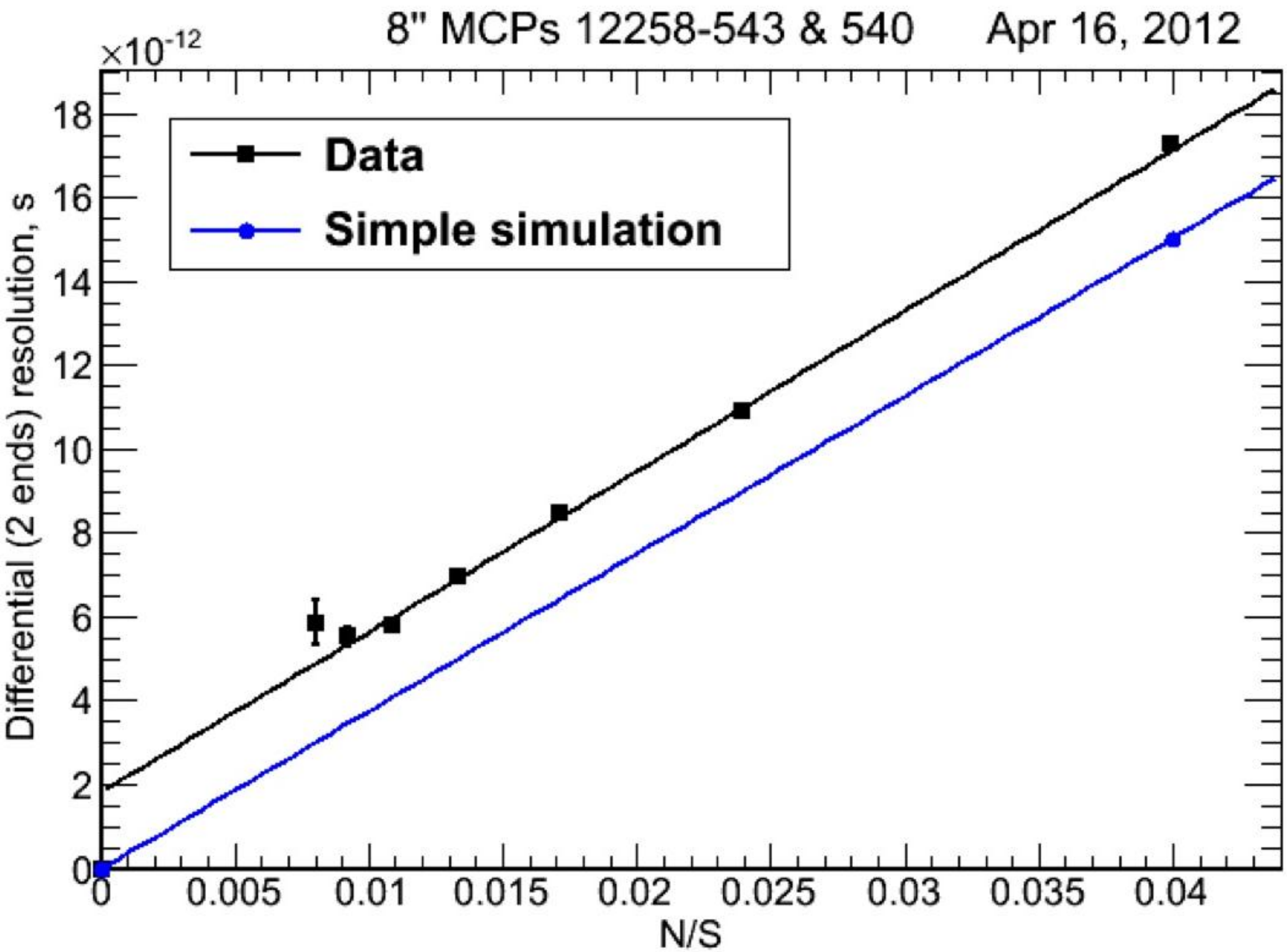
Other Impacts

Giving young talented people (future Ypsilantis's, Charpaks, Cronins, Nygrens, ..) the opportunity to work on instrumentation with a big impact (attractive to academic departments, e.g. UC).

- **Tim Credo, IMSA HS student, came in 2nd in the Intel Science talent search (did our first anodes- gave a talk at IEEE in Rome in 2004**
- **Matt Wetstein- Grainger Postdoctoral Fellowship in UC Physics Dept.**
- **Eric Oberla- Grainger Graduate Student Fellowship in UC Physics Dept.**
- **Mayly Sanchez- Early Career Award (LAPPD and nu's)**
- **Plus several superb students who have been mentored at ANL and elsewhere: Mark Kupfer (UIC), Razib Obaid (IIT/UC),…**

Lastly, pushing the boundaries

pico-seconds

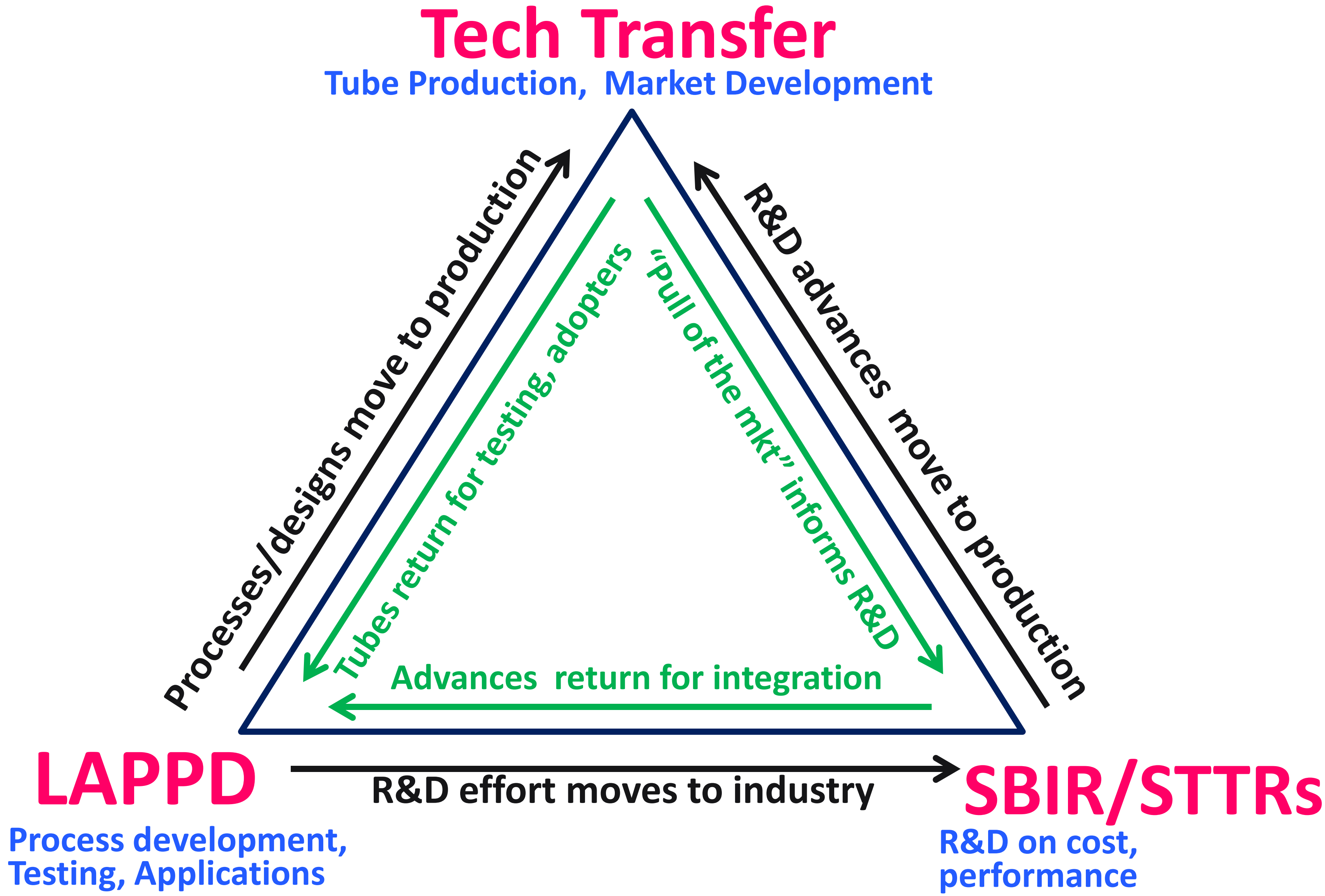


N = RMS of the noise; S = signal amplitude

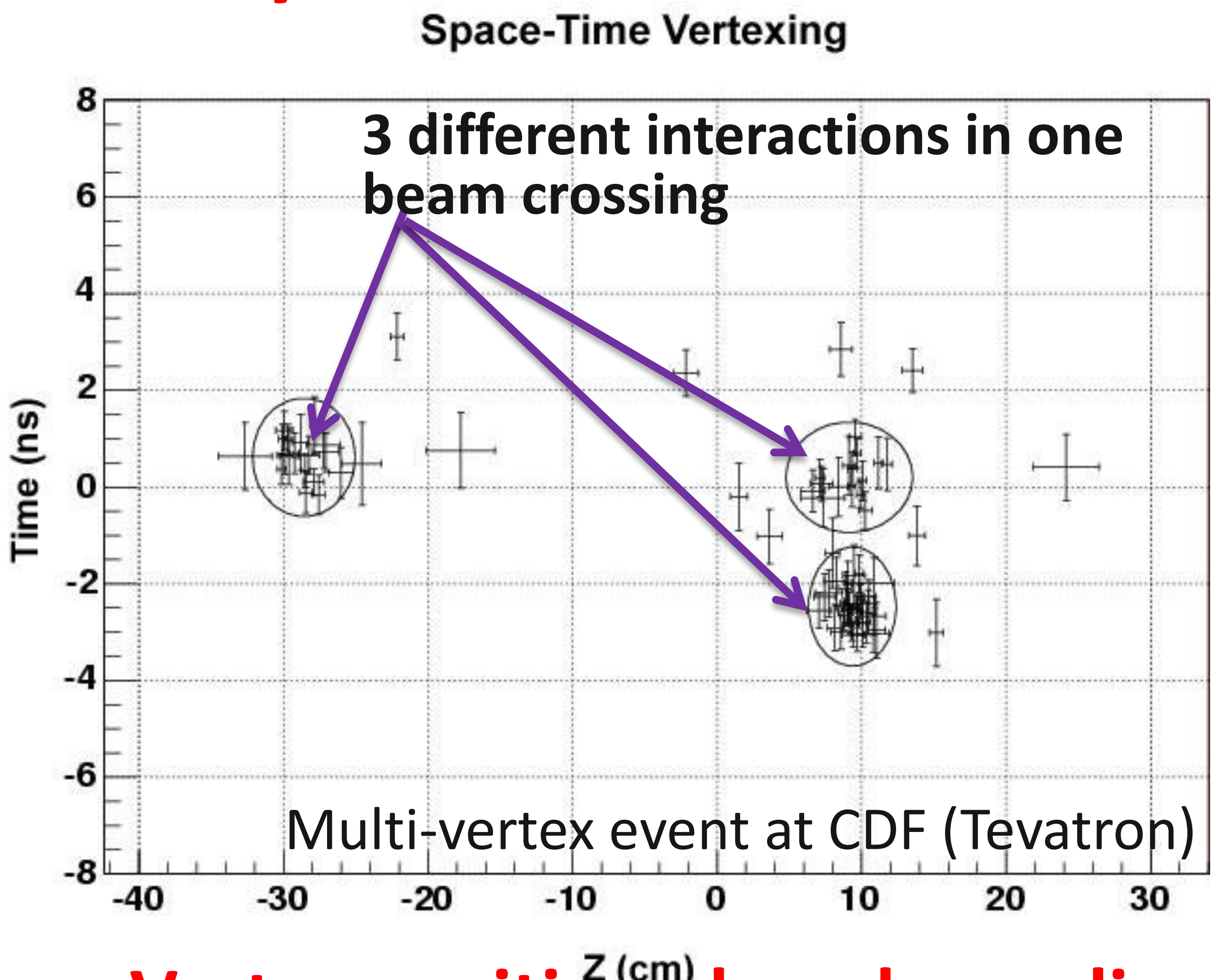
Thanks very much

BACKUP SLIDES

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



Major problem coming up at LHC- vertexing at high luminosity (e.g. Joe Incandela's UC seminar on CMS)



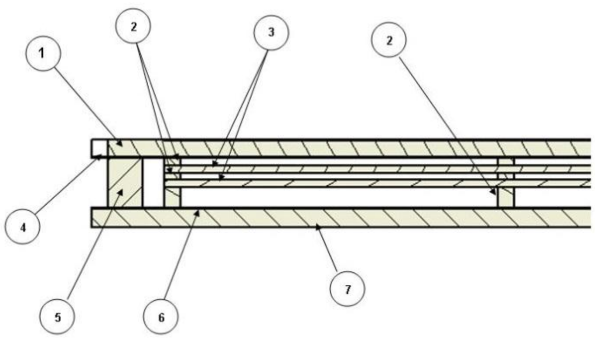
Time (ns)

Vertex position along beam line (cm)

Need, e.g.- Higgs to gamma-gamma at the LHC - tie the photons to the correct vertex, and more precisely reconstruct the mass of the pair

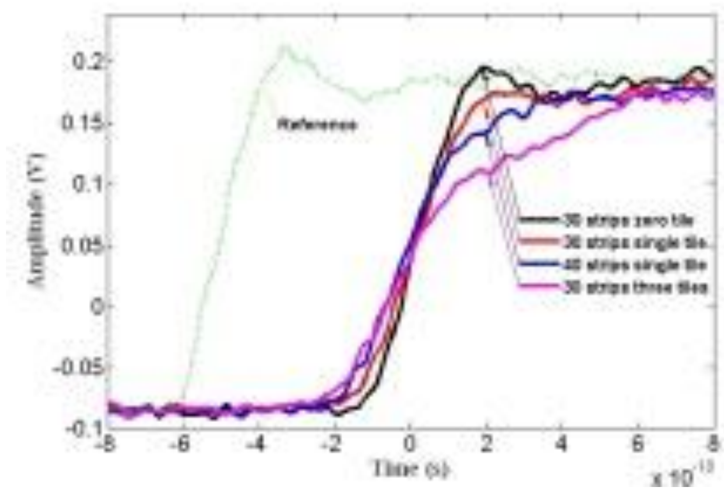
37b Needs: Bandwidth > 3 GHz for Δt < 1 psec

MCP-PMT as 3D waveguide

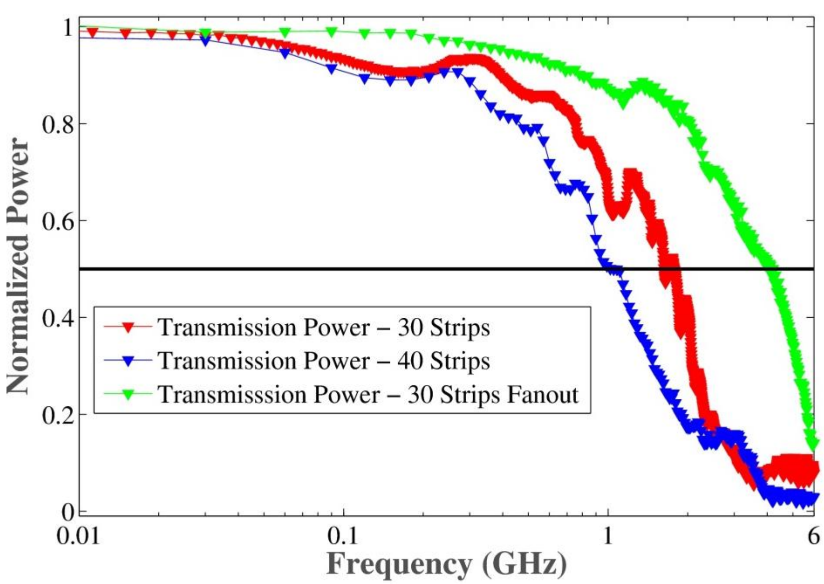


1. Top window with photocathode on inside
2. Grid spacers
3. Microchannel plates
4. HV contact
5. Side wall
6. Anode transmission lines
7. Bottom window

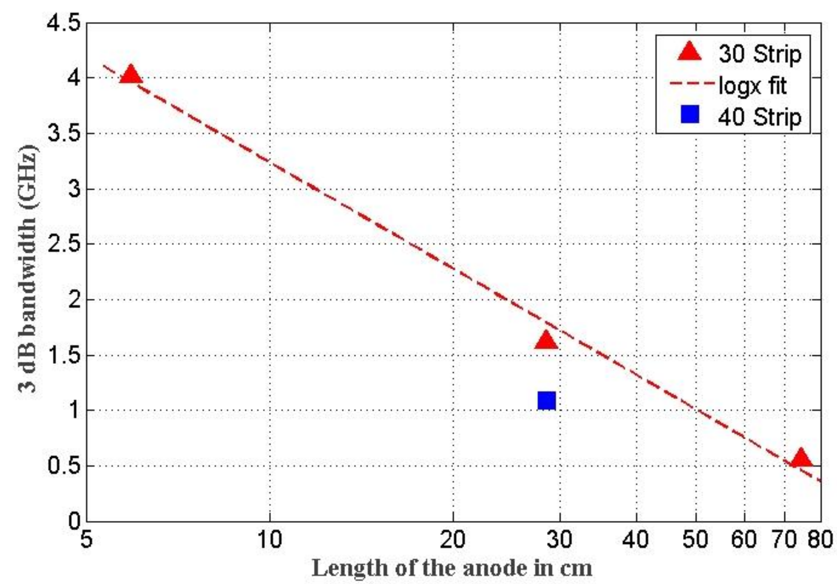
Anode risetimes (step function)



Analog bandwidth of `frugal' anode

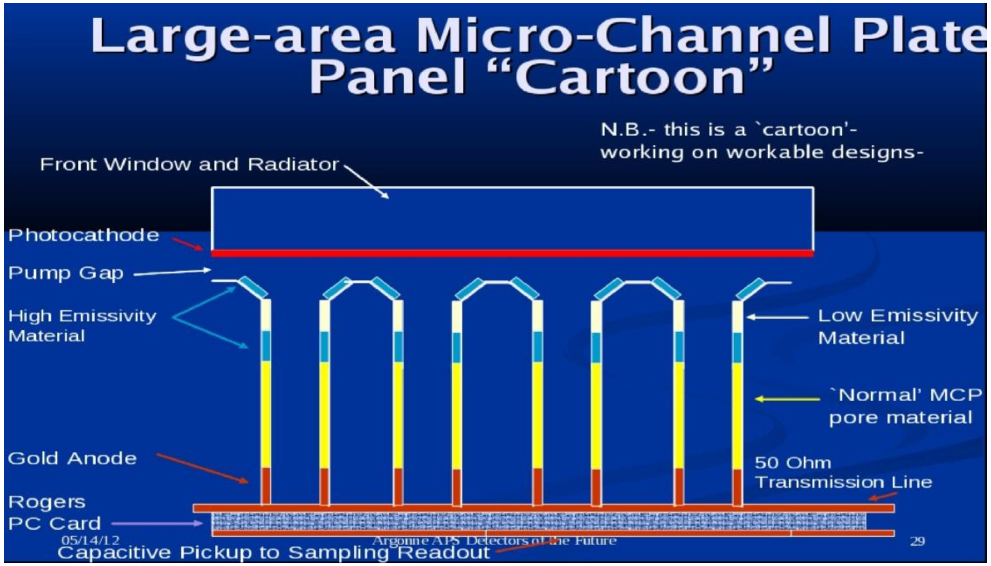


Bandwidth 3db point vs Anode length

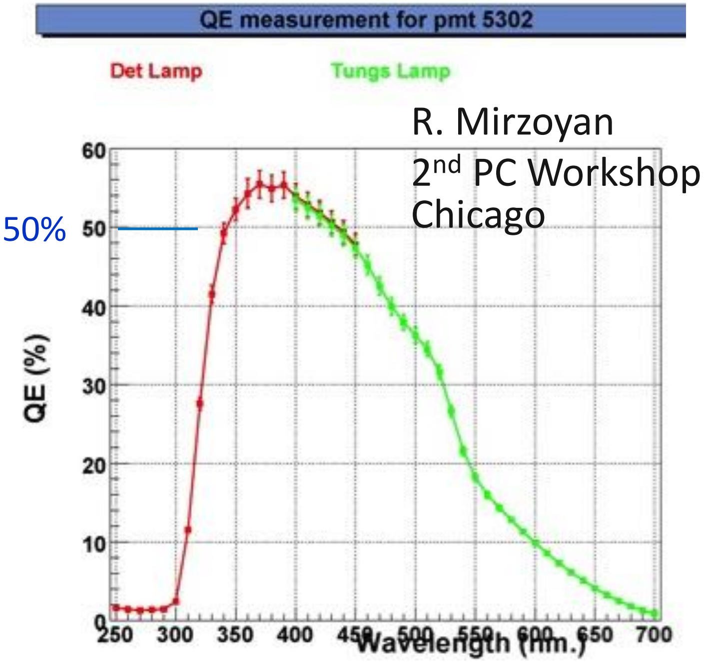


A Vision of the Upside of the Technology

Each of the 4 Areas of LAPPD has an unknown limit on development



Ultra-low TTS MCP development



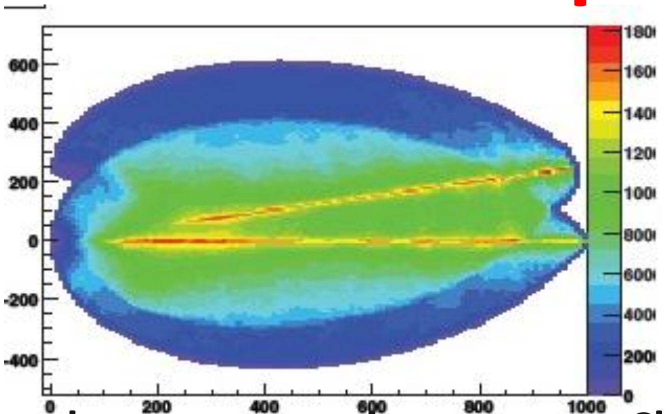
Photocathodes: VHQE

U	Δu	f_s	f_{3db}	Δt
100 mV	1 mV	2 GSPS	300 MHz	~10 ps
1 V	1 mV	2 GSPS	300 MHz	1 ps
100 mV	1 mV	20 GSPS	3 GHz	0.7 ps
1V	1 mV	10 GSPS	3 GHz	0.1 ps

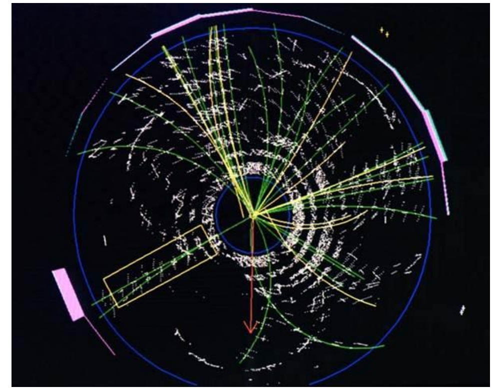
Electronics: Deep Sub-psec Time Resolution

Packaging: sealed flat-panel

The Relationship of SBIR/STTR/TTO to Needs



Pizero-electron separation on water Ch. cters



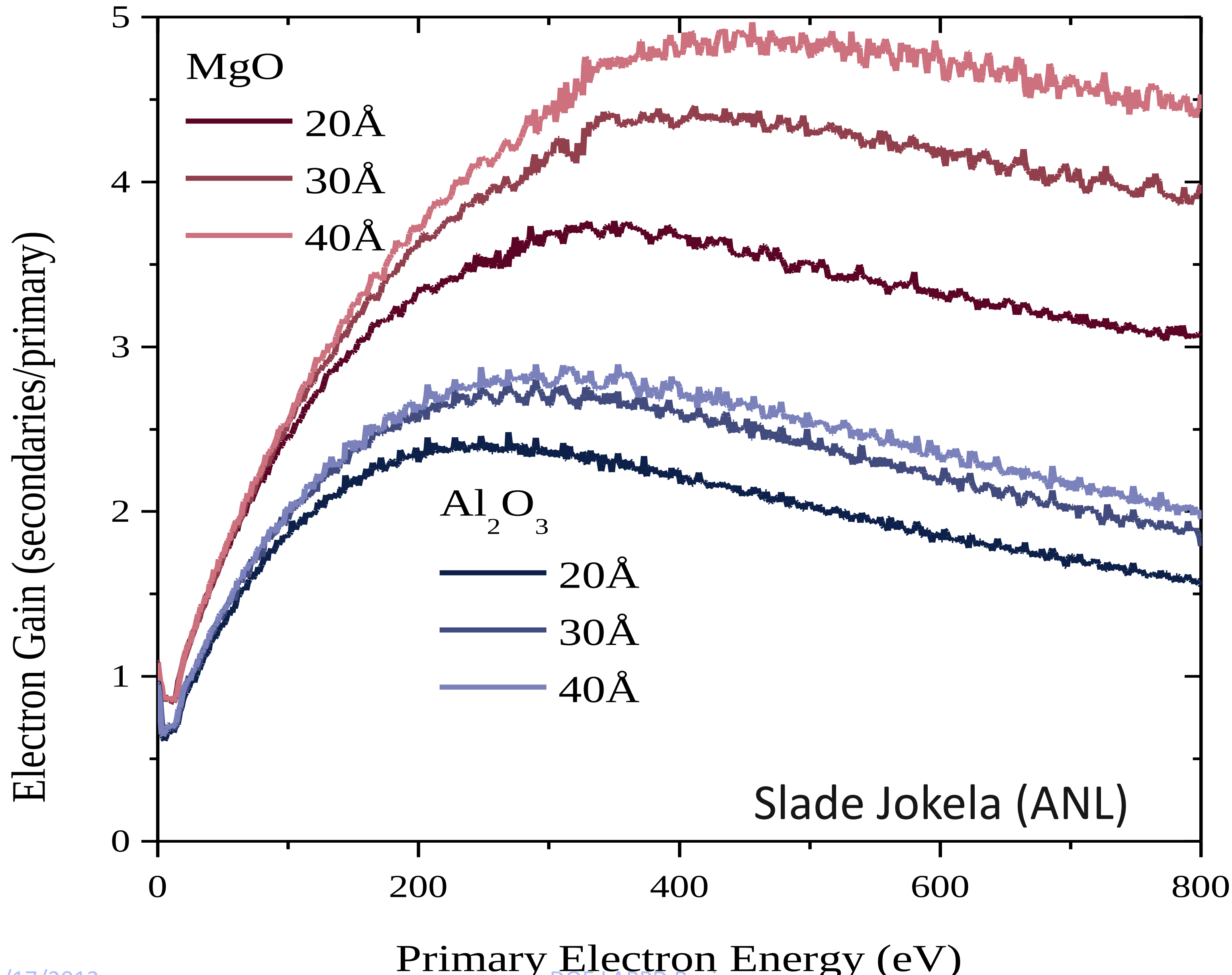
Collider TOF for vertex sep., family flow

Higher performance
Or
Lower Cost
Are
The main benefits

(“F,B,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


MgO
20Å
30Å
40Å
Al_2O_3
20Å
30Å
40Å
Slade Jokela (ANL)
Electron Gain (secondaries/primary)
Primary Electron Energy (eV)
0
1
2
3
4
5
0
200
400
600
800

The Ultimate End