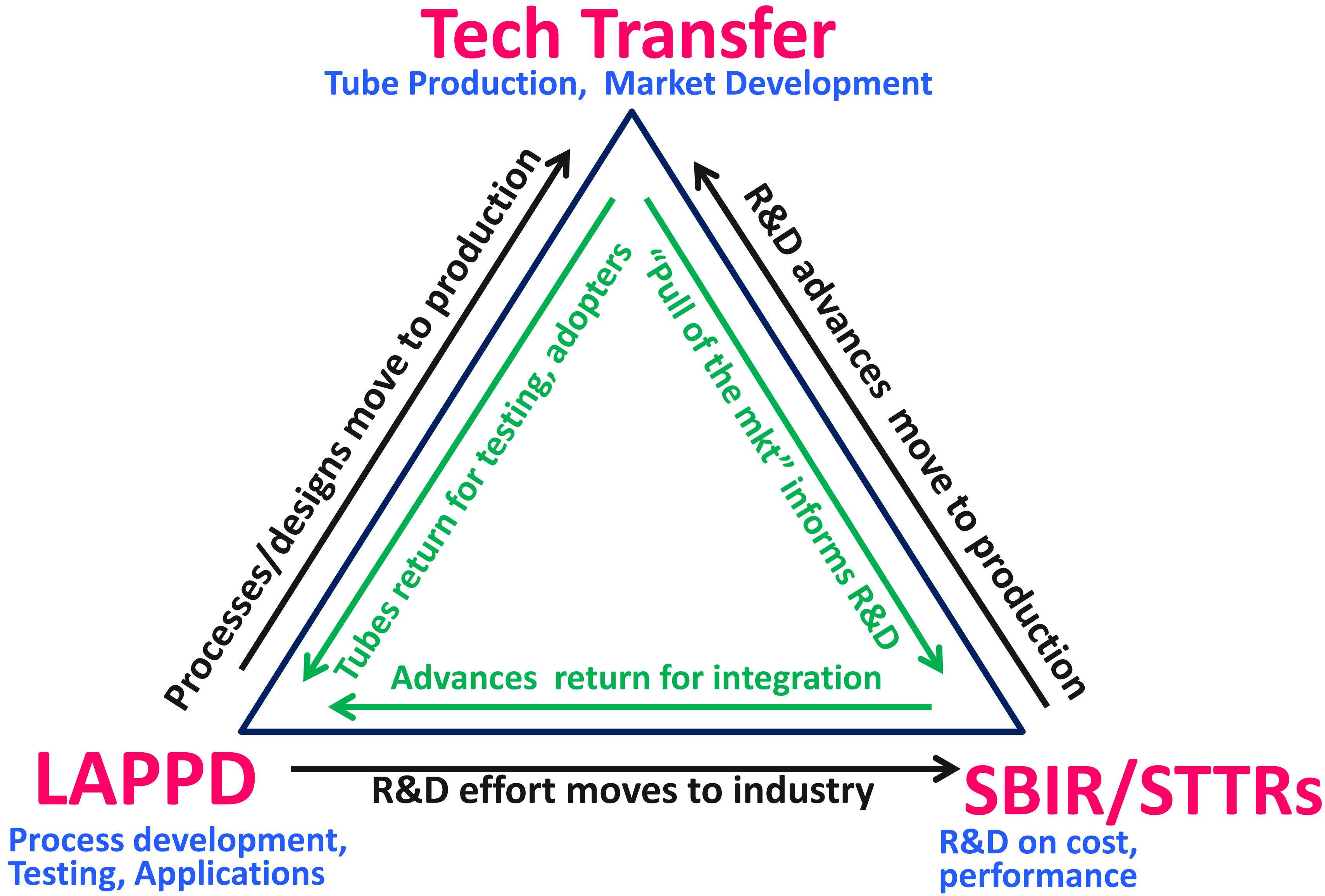
Technology Transfer: Summary of LAPPD SBIR/STTR Submissions

Henry Frisch
For the LAPPD Collaboration

Outline

1. The 2012 Funding Opportunity Announcement (FOA)
    1. Section 36: High-Speed Electronic Instrumentation for DAQ and Processing
    2. Section 37b: Photon Detectors
    3. Section 38: Technology Transfer Opportunity: Detectors (450K$ Phase I, 3M$ Phase II)
        a. Large Area Fast Photodetectors for Particle Detection (LAPPD)
2. Responses to the FOA

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



Confidentiality

"Dear Henry,

I consulted Ken Marken who is the SBIR program manager in the HEP office. The short answer to your questions is that any material submitted to the SBIR Office is confidential, including the name of the company and title/abstract. What you can use during the review is any information you have received from the companies directly. I presume many have made contacts with the LAPPD collaboration while preparing the proposals. Let me know if you have further questions."

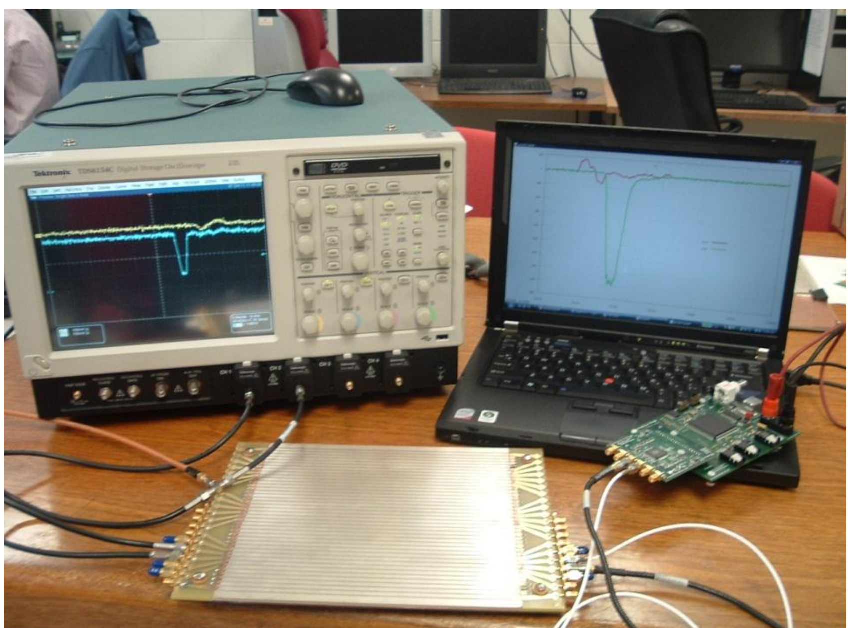
Best regards,

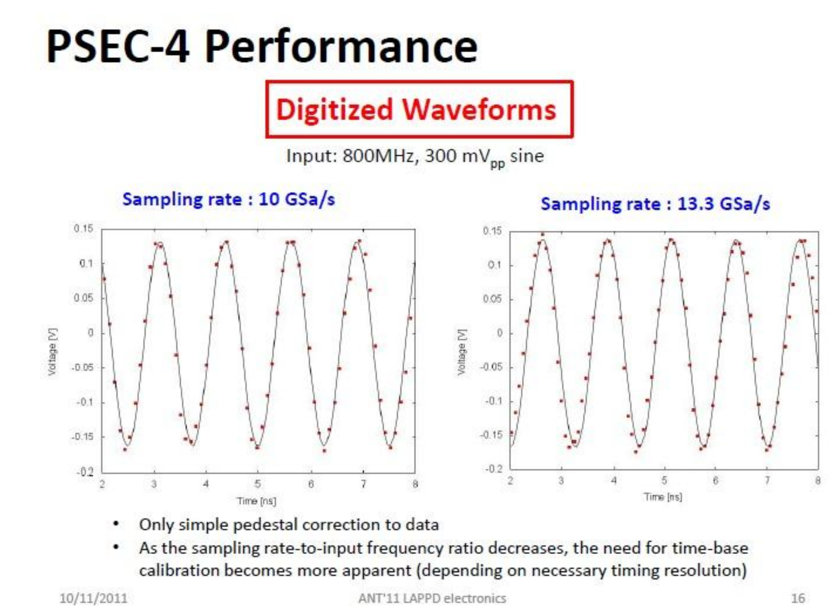
Peter

We have gotten permission from each of the companies to present the proposal to the Committee. I have not quoted the names of the companies and details from the proposals- even still, I ask that the Committee treat this as confidential.

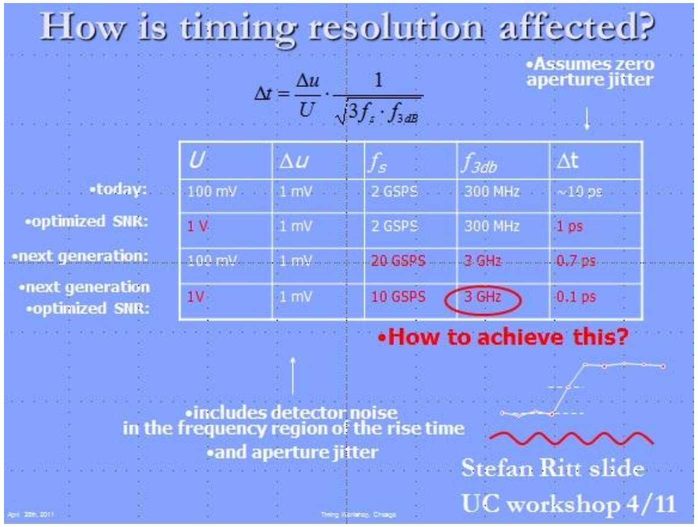
Section 36a

FOA: "..applications are sought to develop **special purpose chips..for use..in large particle detectors.** Desirable features include **low noise, low power consumption**,. .high adaptability to situations requiring multiple parallel channels. Desirable functions include.. **analog wave-form sampling, picosecond resolution time-to-digital converters,** ..."



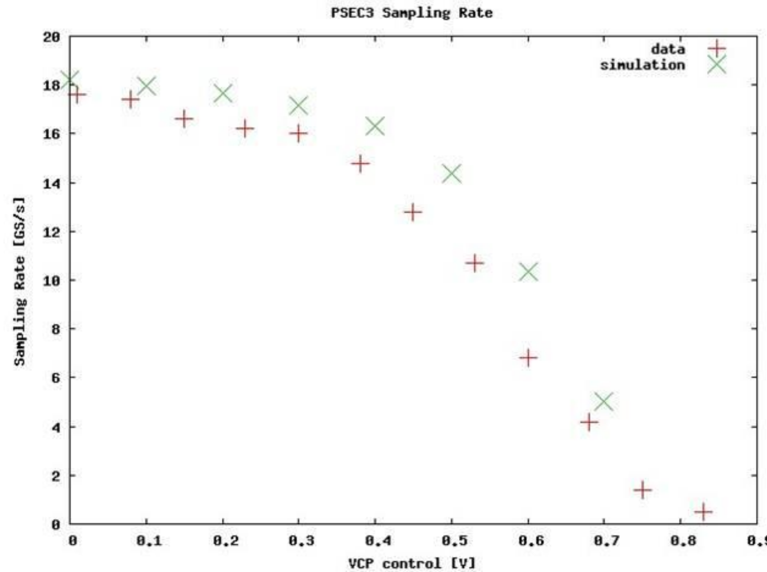


36a Need: Longer latency, higher bandwidth

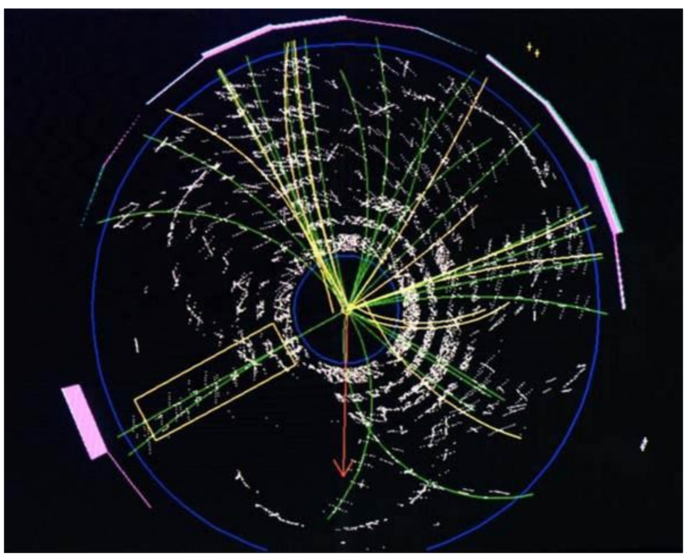


	U	Δu	f_s	f_{3db}	Δt
•today:	100 mV	1 mV	2 GSPS	300 MHz	~10 ps
•optimized SNR:	1 V	1 mV	2 GSPS	300 MHz	1 ps
•next generation:	100 mV	1 mV	20 GSPS	3 GHz	0.7 ps
•next generation •optimized SNR:	1V	1 mV	10 GSPS	3 GHz	0.1 ps

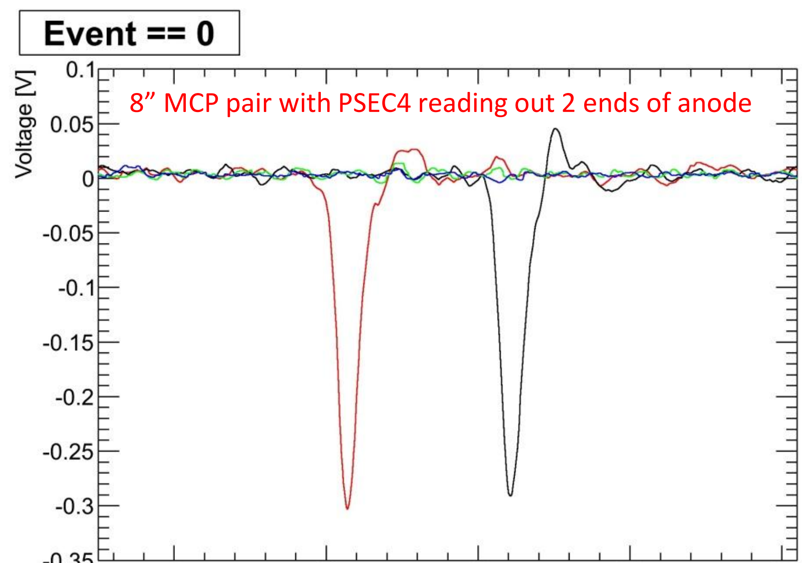
Resolution vs Sampling Rate &AWB



Present Psec4 Sampling rate



Collider need for 6-8μs latency



Psec4 256-deep latency (12-bits)

Section 36a- Response 1

A company responded with

"Special Purpose Chips and Devices for Large Particle Detectors: A Deeper [Buffer] and Higher Bandwidth PSEC-5 Chip"

Goals of SBIR submission:

1. Bandwidth > 3 GHz (possibly up to 6);
2. 25 GS/sec;
3. Longer latency- (possibly 6-8μsec for LHC);
4. Noise < 500 μV
5. Low power

Facilities, Experience, Level of Interest

1. All necessary instrumentation and software design tools and commercial licenses (N.B.);
2. Manual & semi-automatic probe stations capable up to 40 GHz, EMI and EMC systems (lots of fancy stuff);
3. Micro-fabrication capabilities for micro-electronics, MEMS, etc.;
4. Extensive experience in a wide variety of processes, including some rad hard;
5. Genuine interest- co-owner flew to Chicago to take part in our recent workshop on PSEC-5 specs and design (see LAPPD web).

Section 37b

FOA: “..Applications include the following:

A. 1) High QE visible light photon detectors.

B. 2) Development of lower cost photo-detection technology and production methods scalable to large detectors….

C. 4) Large-area photon-sensors with significantly improved space and time resolution….

D. 7) Vacuum technology-based photo detection techniques;..

E. 9) High QE X-ray photo-sensors (1 here, from BNL).

Section 37b- Response 1

A company responded with

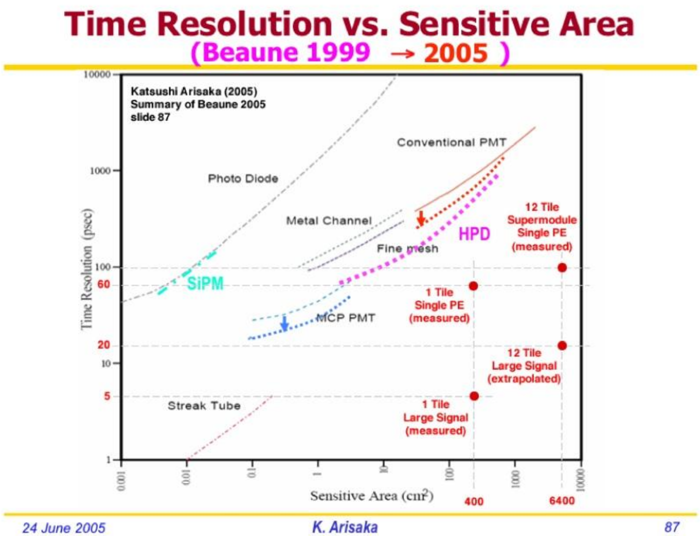
“Large Area Microchannel Plate (sic) for Improved Space and Time Resolution”

Goals of STTR Fast-Track submission:

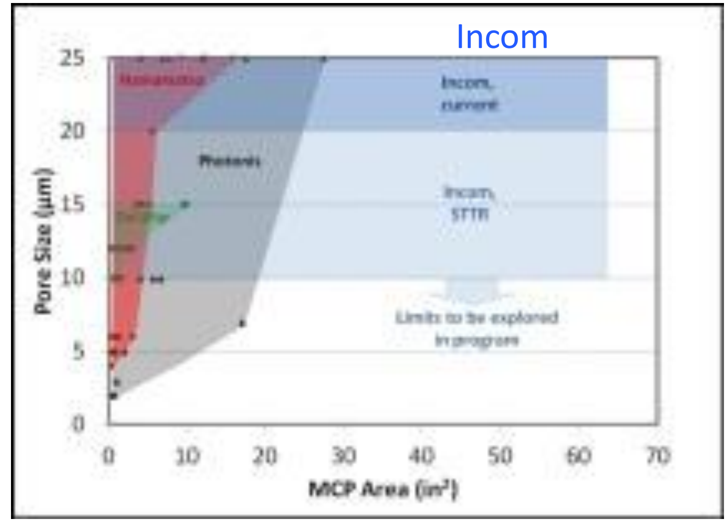
1. Develop 10μm large-area plates for improved time and space resolution;
2. Reduce the cost of MCP’s to support the construction of large-area, low-cost photodetectors;
3. Improve uniformity;
4. Achieve higher MCP performance

“In addition, in this program one specific application for large-area high-resolution MCP’s will be identified, and performance levels..will be achieved.”

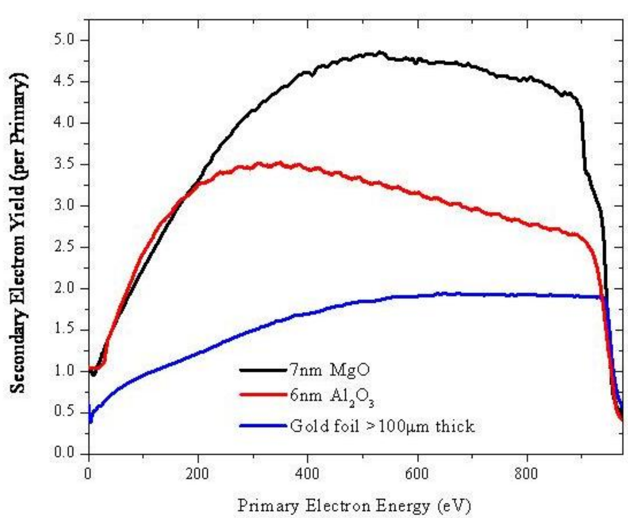
37b Needs: Lower cost, higher performance



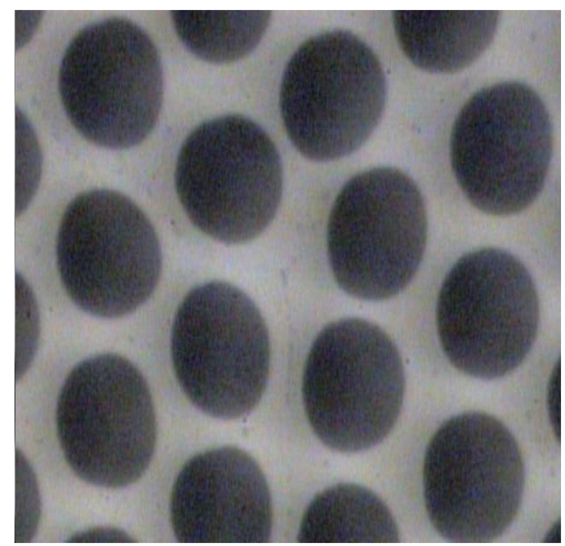
Arisaka's 2005 Δt vs Area Plot



Pore size vs Area: Present vs Proposed



New SEY-layer materials, geom



Commercial Pb-glass MCP 25µm substrate

(compare to Michael's)

Facilities, Experience, Level of Interest

1. Experience in large-area micro-capillary substrate production;
2. In-house cleaning, quality characterization (QC), transport, documentation/tracking (data-bases);
3. Connections to other markets (neutrons, X-rays);
4. Demonstrated high level of commitment, risk-taking, expertise;

Section 37b- Response 2

A company responded with

" Development of a Non-Vacuum Transfer Process for Large-Volume Commercial Tile Production"

Goals of SBIR Phase-I submission:

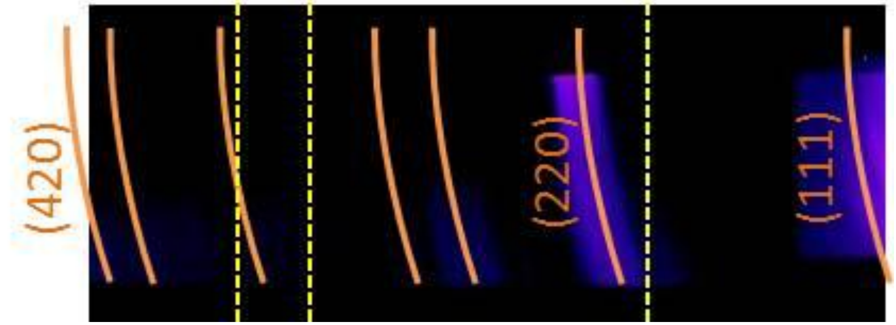
1. Establish Feasibility of the Tubulation method by making a photocathode with QE>20%;
2. Tuning physical properties of the Sb thin film, temperature dependency of the diffusion reaction, and vapor transport of the alkali mixture…;
3. Measurements of QE in situ, surface morphology at the NSLS at BNL;
4. Initial measurements of the effect of the vapor on MGO and Al_2O_3;
5. Prepare for Phase-II measurements of MCP gain, noise after alkali vapor deposition;

37b Needs: large-volume low-cost production

PMT showing tubulation (on right)

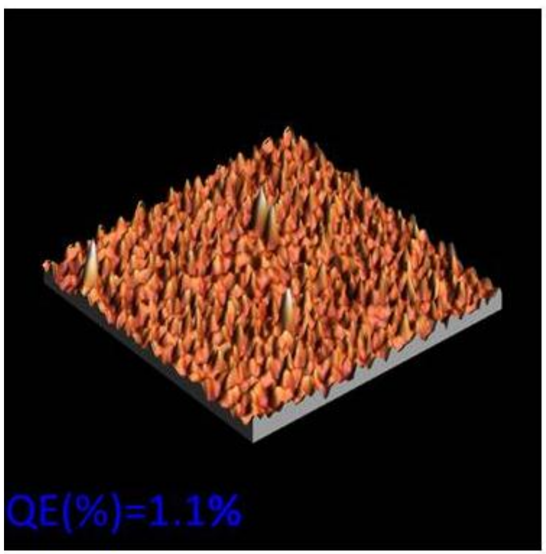
Credit: Wikipedia

In-situ Xray diffraction of cathode growth



Credit: Oses, Attenkoffer-BNL, SUNY,UC,ANL, UCB

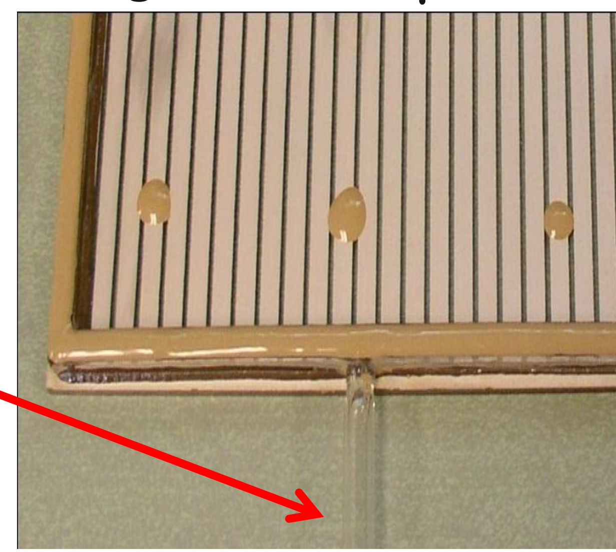
AFM of CsK_2Sb cathode



Credit: Oses, Attenkoffer-BNL, SUNY,UC,ANL, UCB

Tubulation

Commercial Pb-glass MCP 25μm substrate



Credit: Joe Gregar, ANL Glass Shop

Facilities, Experience, Level of Interest

1. Facilities for material preparation, dry-gas material handling, coating,;
2. Material characterization facilities;
3. Expertise in thin film vapor deposition, hot wall evaporation, binary/ternary compound synthesis,e-beam evaporation;
4. Expertise in complex morphology films;
5. Collaborative with the Attenkofer/Smedley BNL-UCB-UC-ANL… effort at the BNL NSLS- access to X-ray beams, instrumentation;
6. Ongoing LAPPD effort by APS group with 33mm test setup.

Section 37b- Response 3

A company responded with

“Theory-Based High-QE Photocathode Development”

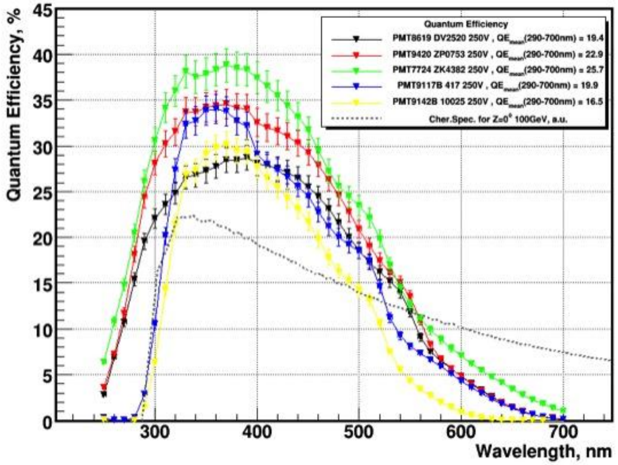
Goals of SBIR submission:

1. Pre-synthesize stoichiometrically balanced K_2CsSb ternary (or binary subcomponents) targets;
2. Grow, measure QE of crystalline films made with hot-wall evaporation, e-beam deposition;
3. Study the parameter space of cathode thickness, reflectivity, and transmission;

In Phase II, correlate measured QE with chemistry, morphology using in-situ XRD (X-ray diffraction), XRR (X-ray reflectivity), XPS (X-ray Photelectron Spectroscopy, and AFM.

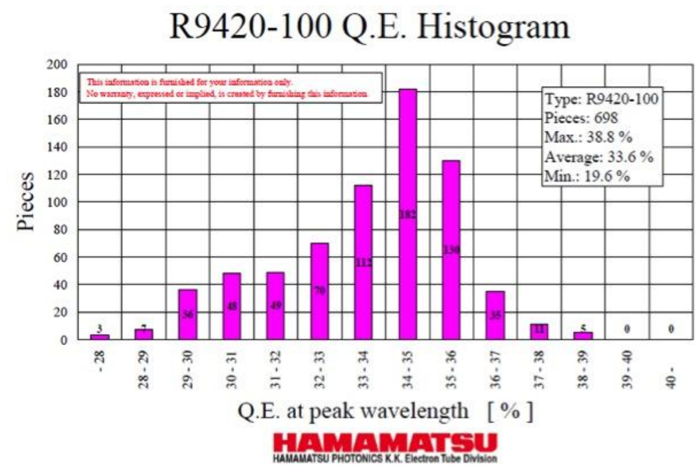
37b Needs: High QE Cathodes (>40%)

High QE's measured in PMT's



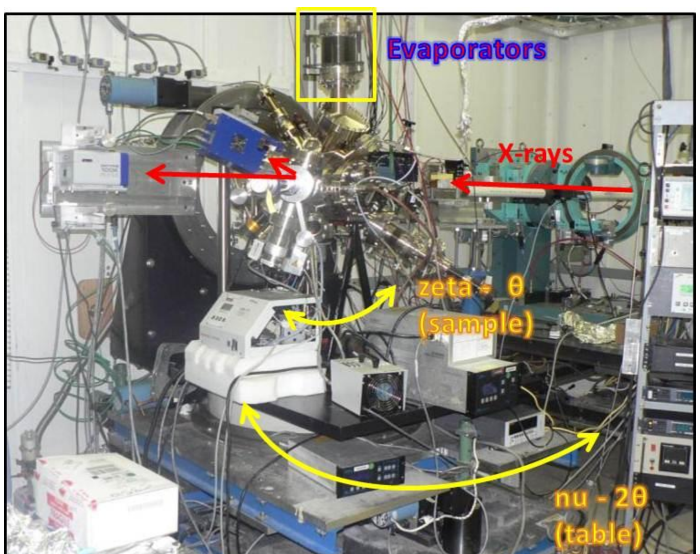
Credit: R. Mirzoyan,, 2nd PC Wkshop, UC

Lack of process control in recipe-driven PCs



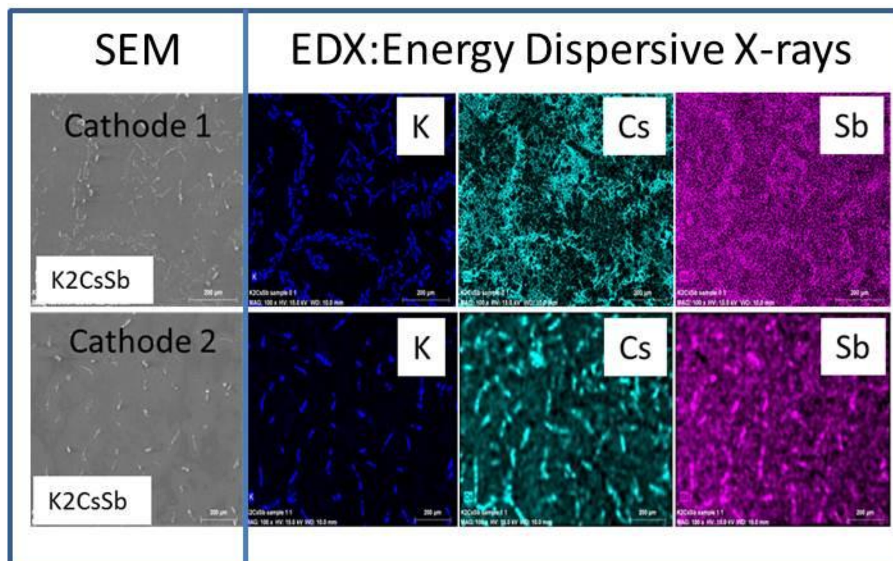
Credit: R. Mirzoyan,, 2nd PC Wkshop, UC

BNL in-situ cathode growth at NSLS



Credit: Oses, Attenkoffer-BNL, SUNY,UC,ANL, UCB

SEM and EDX in-situ during cathode growth



Credit: Oses, Attenkoffer-BNL, SUNY,UC,ANL, UCB

Facilities, Experience, Level of Interest

1. Facilities for material preparation, dry-gas material handling, coating,;
2. Material characterization facilities;
3. Expertise in thin film vapor deposition, hot wall evaporation, binary/ternary compound synthesis,e-beam evaporation;
4. Expertise in complex morphology films;
5. Collaborative with the Attenkofer/Smedley BNL-UCB-UC-ANL… effort at the BNL NSLS-access to X-ray beams, instrumentation;
6. Ongoing LAPPD effort by APS group with 33mm test setup.

Section 37- Response 4

A company responded with:

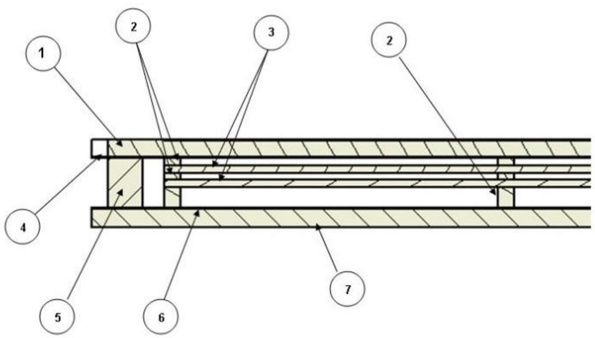
“A High BandWidth LAPPD Anode”

Goals of SBIR submission:

1. Development of a 4D (3D+time) finite-difference time-domain (FDTD) e-m simulation model for RF striplines;
2. Perform full 4D FDTD simulation of current RF-stripline anodes and verify the accuracy of the simulation model;
3. Develop a RF stripline anode circuit with analog bandwidth (ABW) > 3 GHz using the full 4D FDTD model: understand frequency and ABW limits;
4. Perform full 4D FDTD modeling of the complete detector, including MCP’s, with the goal of sub-psec performance.

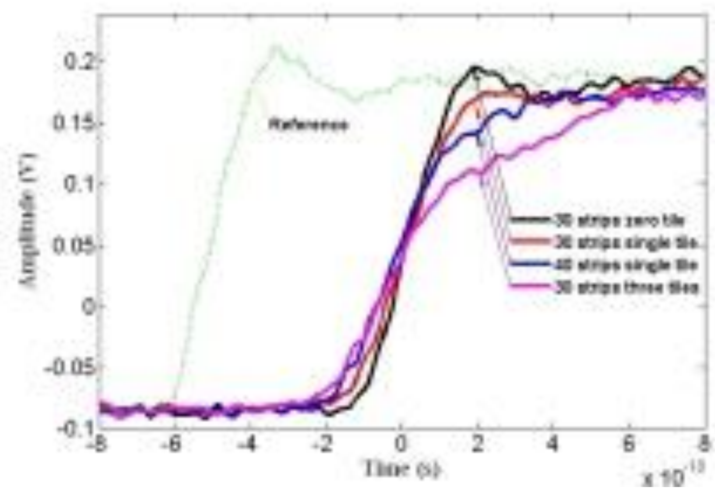
37b Needs: Bandwidth > 3 GHz for Δt < 1 psec

MCP-PMT as 3D waveguide

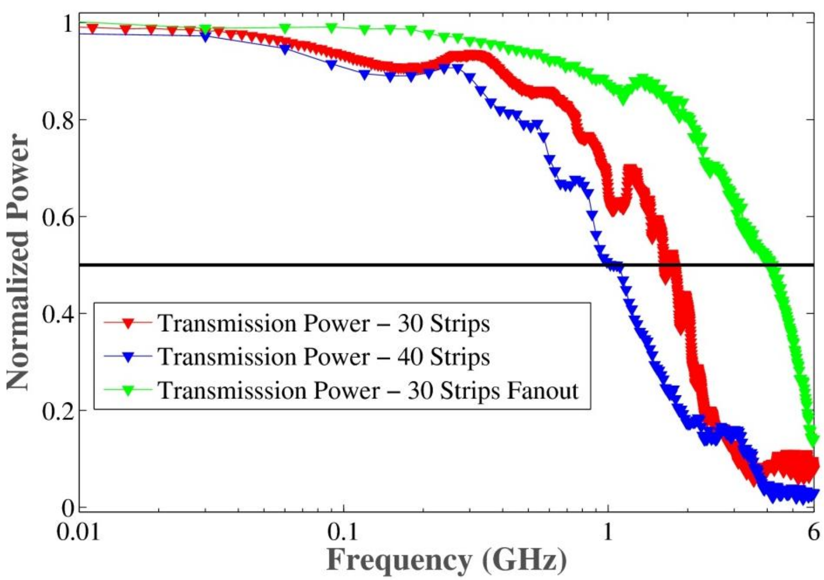


1. Top window with photocathode on inside
2. Grid spacers
3. Microchannel plates
4. HV contact
5. Side wall
6. Anode transmission lines
7. Bottom window

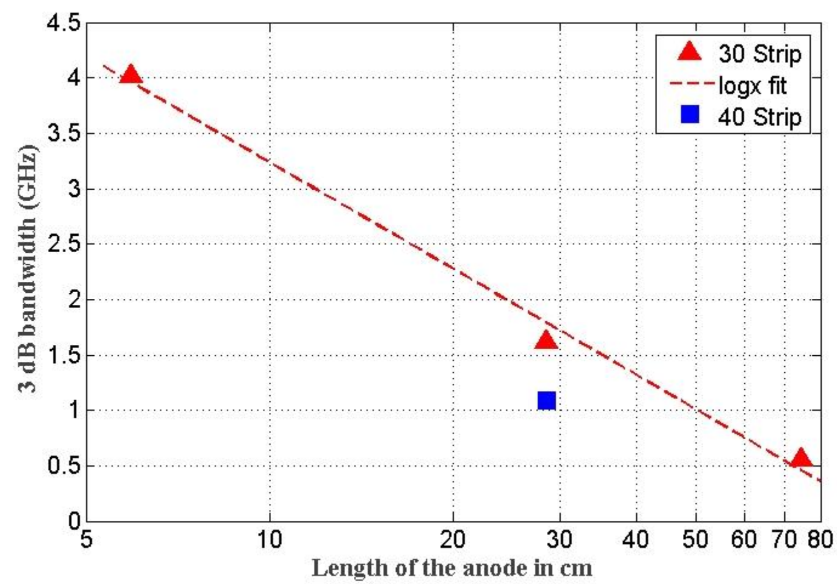
Anode risetimes (step function)



Analog bandwidth of `frugal' anode



Bandwidth 3db point vs Anode length



Facilities, Experience, Level of Interest

1. Specializes in microfabrication of vacuum electronics devices, microwave and mm-wave electronics, including microwave integrated circuits (MICs), vacuum electronic devices, and microwave power modules, transmitter and receiver design (N.B.), imaging systems using MICs, optoelectronics and electro-optics;
2. Proprietary fine-difference time-domain e-m simulation code developed for complex RF-device and circuit design;
3. Code designed to handle non-linear current sources, coupling, cross-talk, higher mode excitations in large arrays;
4. Computation resources include commercial simulation/modeling software;
5. High band-width diagnostic equipment up to 120 GHz.

Section 37- Response 5

A company responded with:

“ Development of a Portable Calibration and Test Facility for Large Area Picosecond Photon Detectors (LAPPD)”

Goals of SBIR submission:

1. Development of a low-cost portable, calibration system for 8” MCP-PMTs;
2. Demonstration of TOF-PET with resolution < 50 psec using fast scintillators;
3. Demonstration of direct TOF-PET imaging;
4. Providing proof-of-concept for the transformative role of LAPPDs in time-resolved PET to manufacturers in the $1B PET market;

Facilities, Experience, Level of Interest

1. Extensive experience with many-channel systems, firmware, software, user interfacing of industrial systems;
2. Deep HEP instrumentation expertise, with experience on colliders, water-Cherenkov counters, trigger systems;
3. Electronics, mechanical, assembly, and testing facilities for imaging technologies including SIPMTs, PMT's;
4. Medical imaging products, including PET cameras installed in a major hospital;
5. Deep interest in high precision TOF-PET, and developing that large-volume market.

Section 38: Technology Transfer

FOA: “Grant applications are sought in the following subtopics:

a) Large Area Fast Photodetectors for Particle Detection (LAPPD)

The LAPPD Collaboration, based at ANL, has been developing an innovative large-area (8”x8”) photodetector for use in particle physics experiments. The detectors represent an alternative to multi-channel PMT’s, possibly at lower cost, with several advanced features.

The detectors use low-cost glass ..capillary plates functionalized with ALD… An anode design of high-bandwidth strip-lines allows excellent time(~nsec) and space resolution (~mm), multiple-hit capability, and economical coverage of large areas with a small number of electronics channels. The signals are digitized by waveform-sampling chips; the digital signals are processed locally and sparsified data is collected via Gigabit fibers… Possible applications are non-cryogenic tracking neutrino detectors, and precision TOF measurements of particles at colliders and in rare kaon experiments. The current R&D program has established proof-of-principle of the basic technological components.”

“Possible markets include particle detection..,neutrino detection in reactor monitoring in transportation security, and medical imaging…”

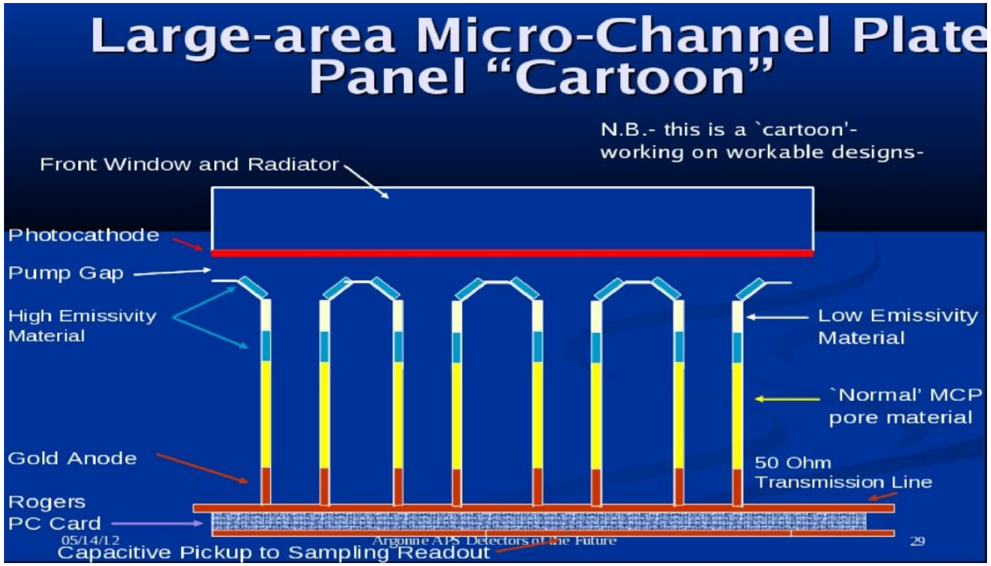
Section 38a- 3 responses (ttbook)*

1. We know of 2 responses to build complete tiles working closely with LAPPD from companies with relevant experience;
2. A third response was application-specific, and would rely on LAPPD to make the detectors, or smaller versions;
3. Given the magnitude, the importance, and the uncertainty, it's probably best to wait and see how this plays out. We believe that the theater is large enough, and the potential markets exist, so that all commercial players can come out ahead. (nuf said).

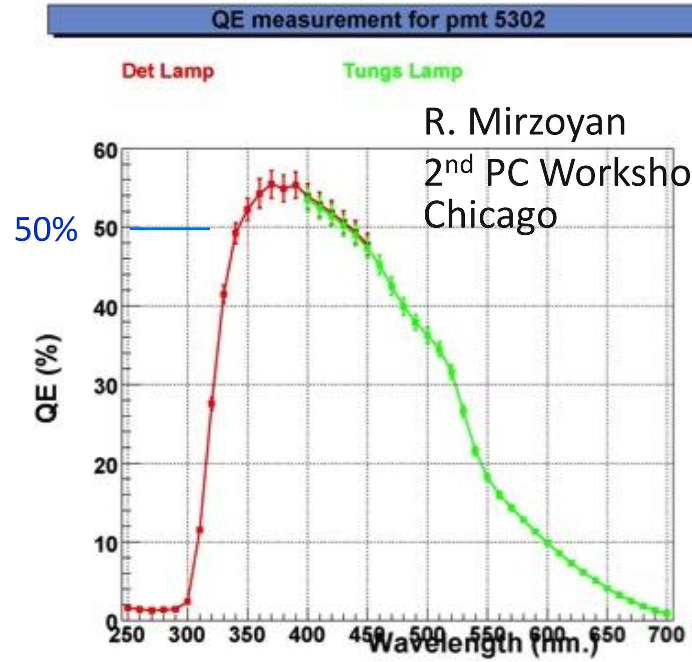
* To the best of our knowledge

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



R. Mirzoyan
2[nd] PC Workshop
Chicago

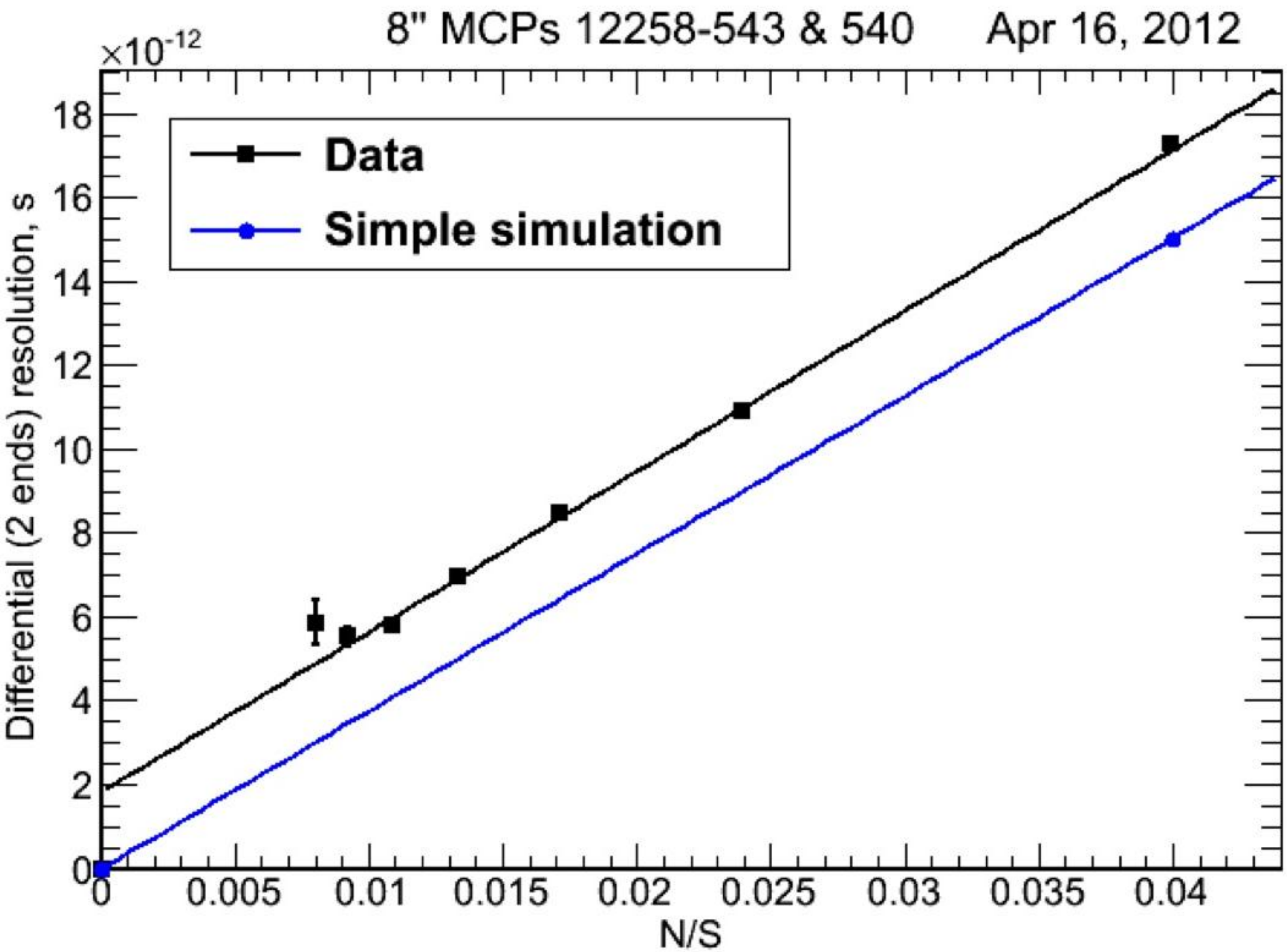
Photocathodes: VHQE

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

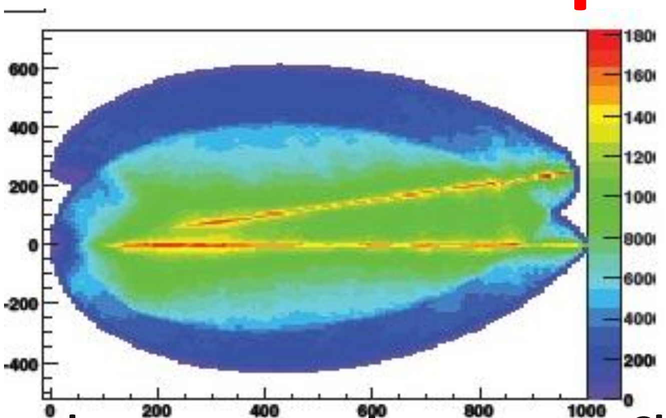
The End



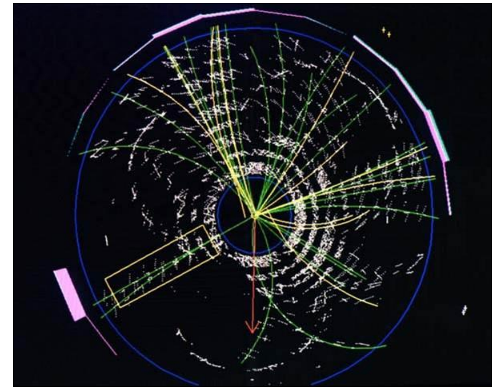
N = RMS of the noise; S = signal amplitude

BACKUP SLIDES

The Relationship of SBIR/STTR/TTO to Needs



Pizero-electron separation on water Ch. cters



Collider TOF for vertex sep., family flow

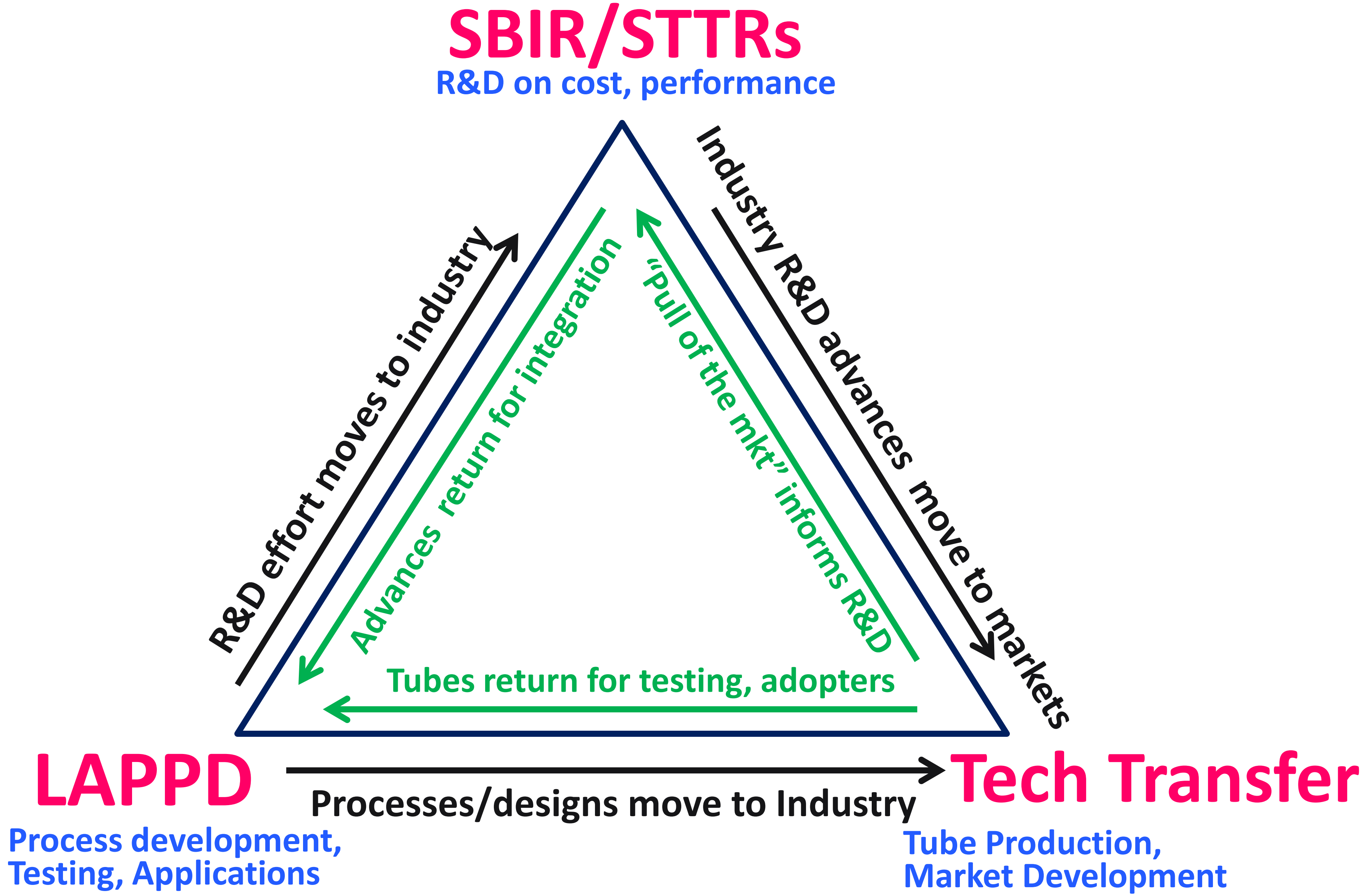
Higher performance
Or
Lower Cost
Are
The main benefits

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



The Ultimate End