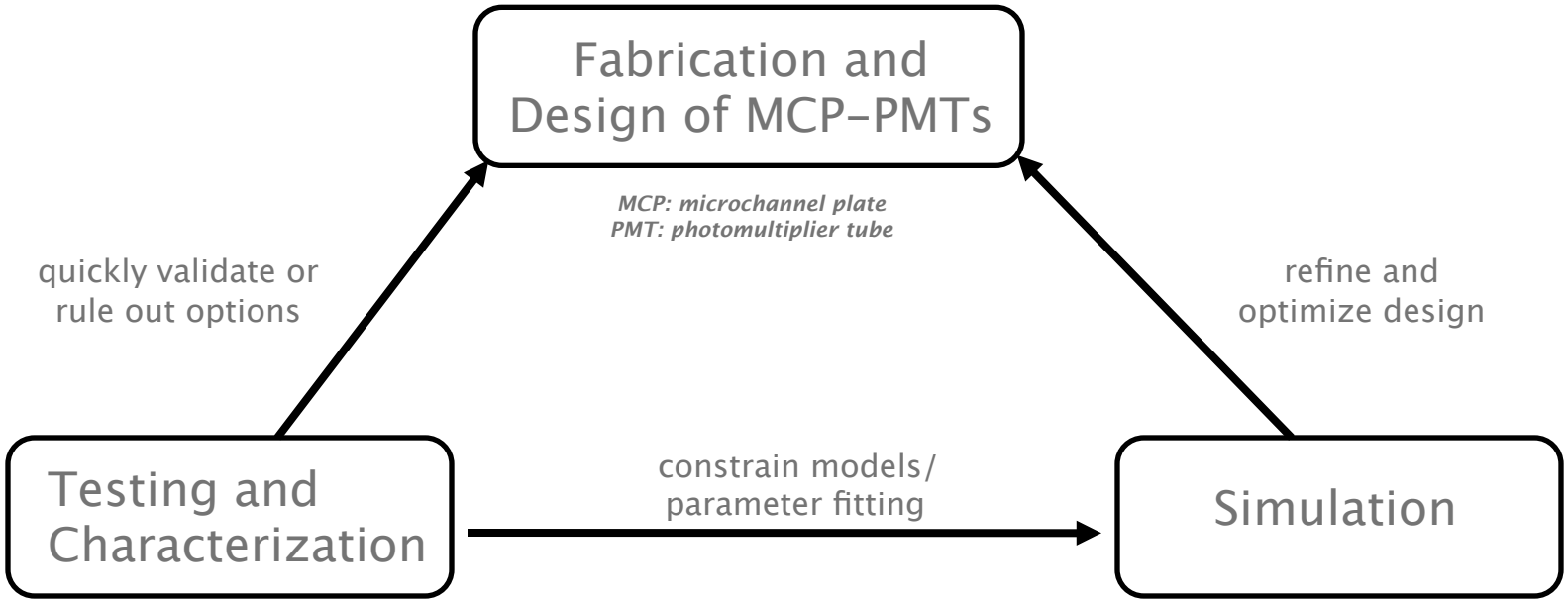
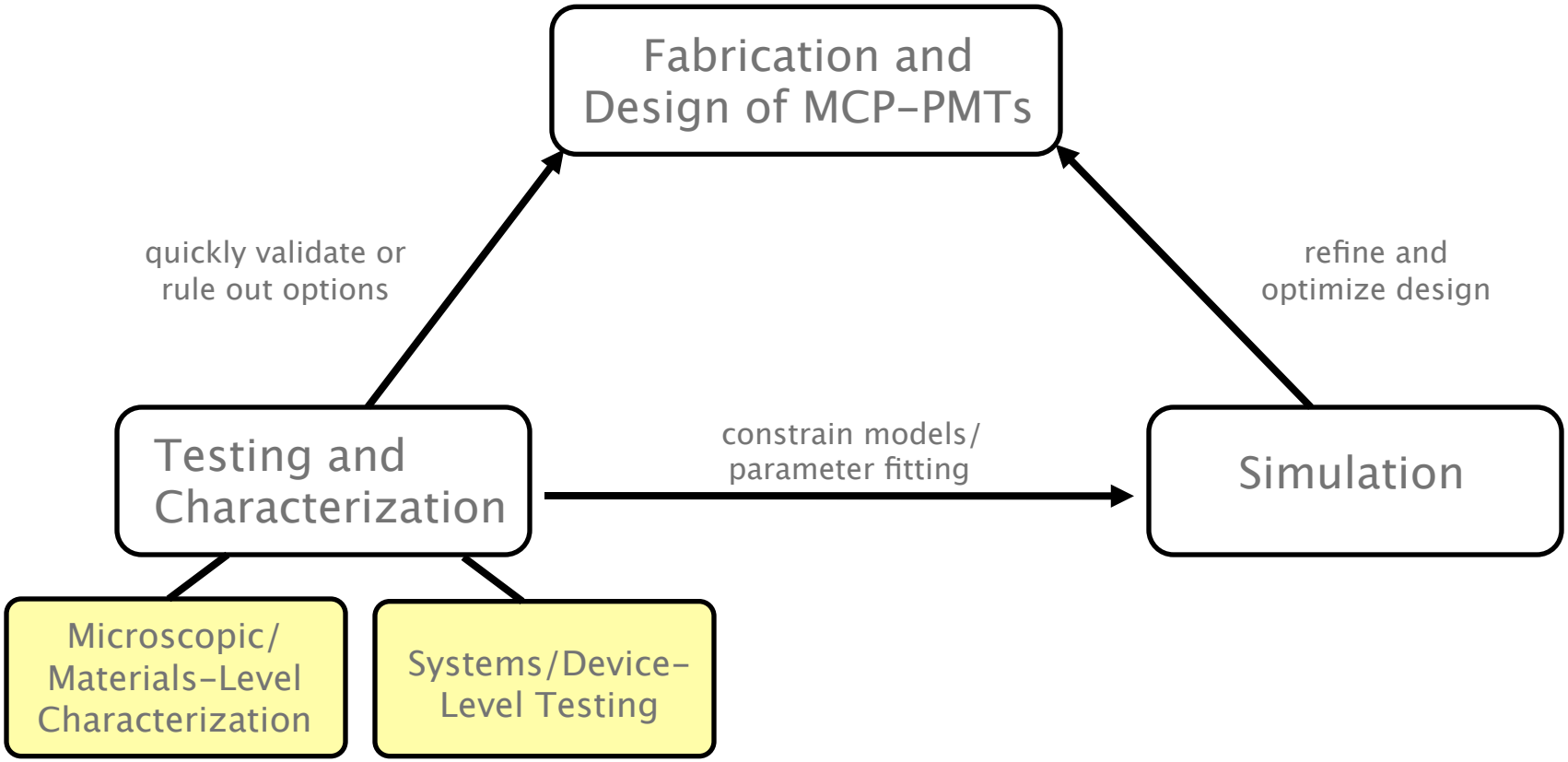
MCP Systems-Level Characterization at the APS

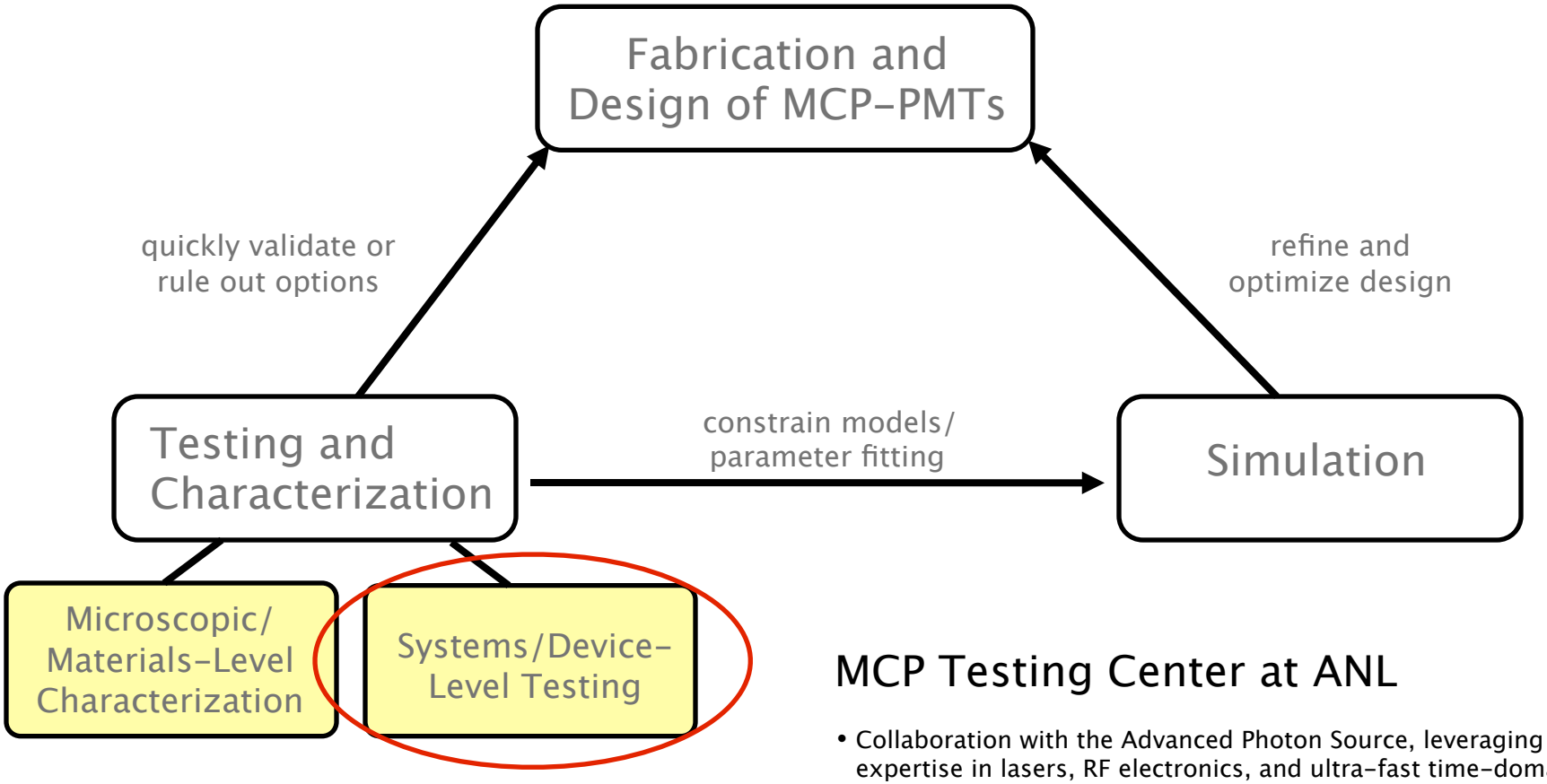
B. Adams, M. Chollet, M. Wetstein
for the LAPPD Collaboration

DOE-HEP Site Review

May 25 2011


Fabrication and
Design of MCP-PMTs
MCP: microchannel plate
PMT: photomultiplier tube
quickly validate or
rule out options
refine and
optimize design
Testing and
Characterization
constrain models/
parameter fitting
Simulation

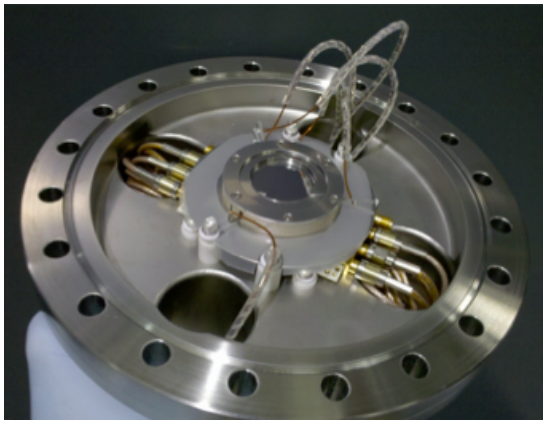

Fabrication and Design of MCP-PMTs
quickly validate or rule out options
refine and optimize design
Testing and Characterization
constrain models/ parameter fitting
Simulation
Microscopic/ Materials-Level Characterization
Systems/Device-Level Testing



MCP Testing Center at ANL

- Collaboration with the Advanced Photon Source, leveraging their expertise in lasers, RF electronics, and ultra-fast time-domain measurements.
- Study the performance of MCP assemblies under realistic, near-device-level operating conditions
- Uniquely suited for precision timing measurements

Characterization program:



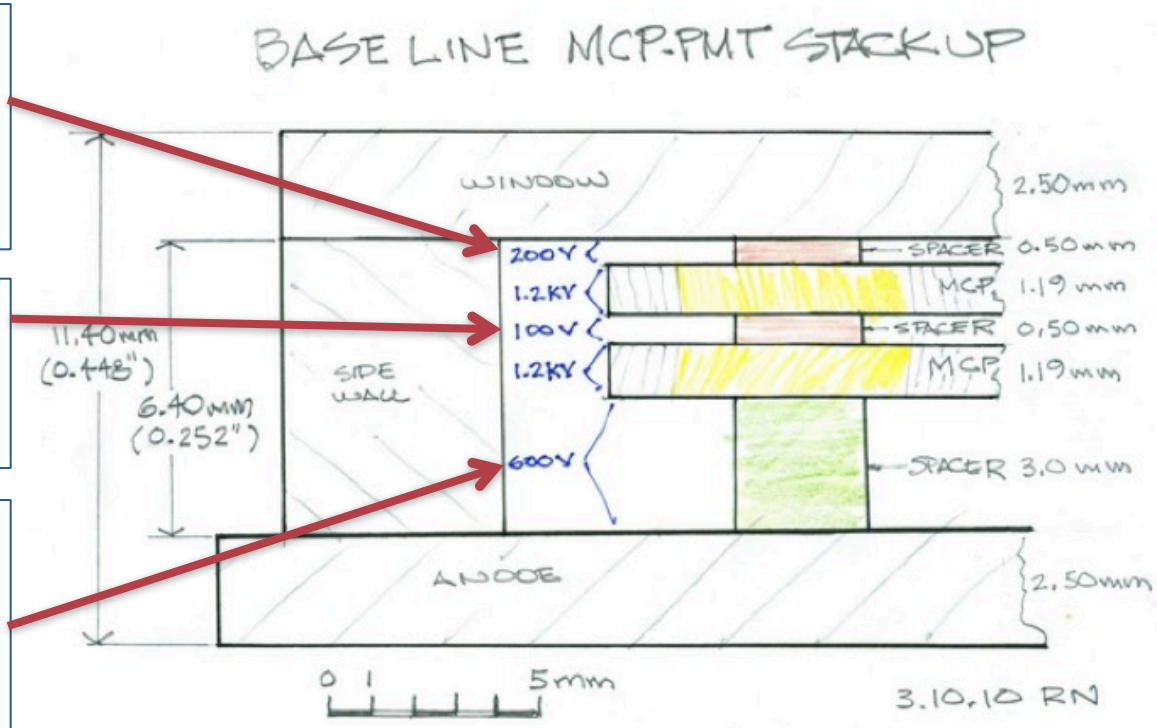
Gap spacing voltages:

Determine optimal operational voltages. How do these optimal voltages depend on particular choice of MCPs? Explore tradeoffs between gain, timing, saturation.

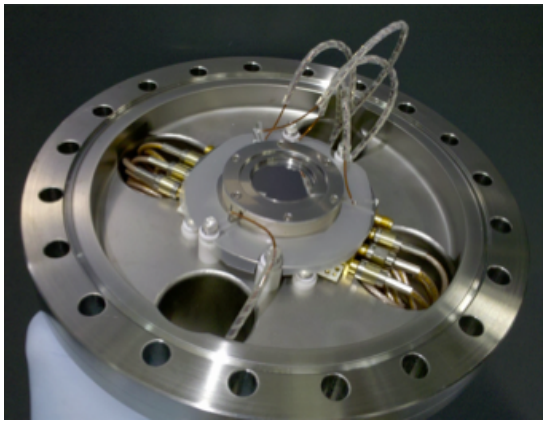
Gap 1: “first strike” Impacts on variability of transit time and amplification

Gap 2: Impact on saturation of MCP pair, spatial spread of signal

Gap 3:spatial and temporal spreading of the charge cloud. Space charge effects. Interface with anode.



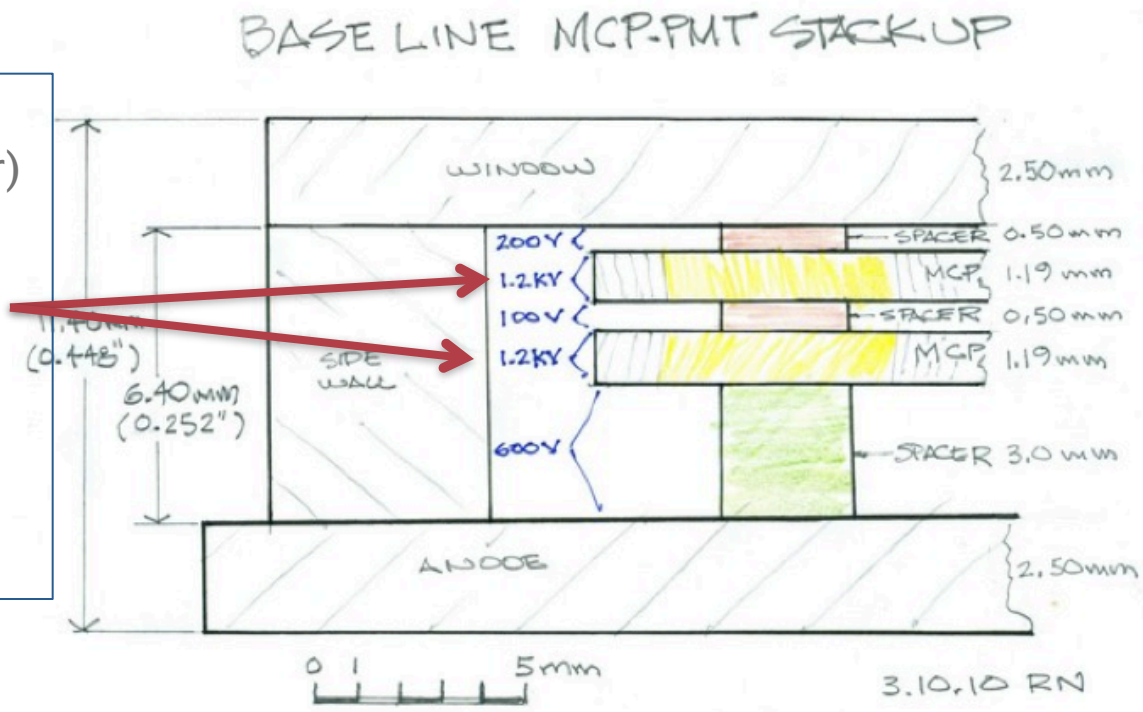
Characterization program:



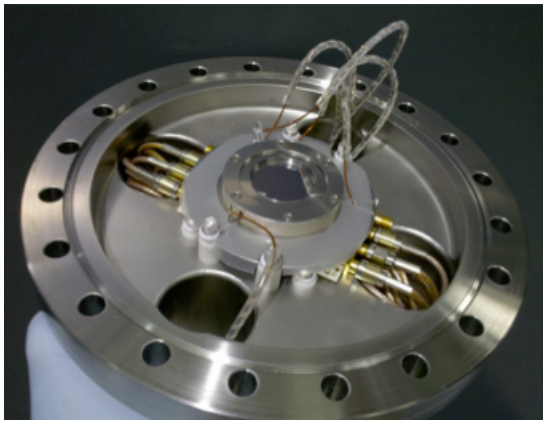
MCP performance:

Atomic Layer Deposition (ALD) gives us the unique ability to vary electrical, secondary electron yield (SEY) and geometric properties of MCPs independently. What impact do each of these properties have on the overall timing, gain, and saturation of the MCP, all others held fixed?

- Geometry (pore size, L/D)
- Chemistry (SEE, resistive layer)
  - Plate quality
  - Uniformity
  - Noise
  - Stability
- Resistivity
  - Saturation
  - Relaxation time



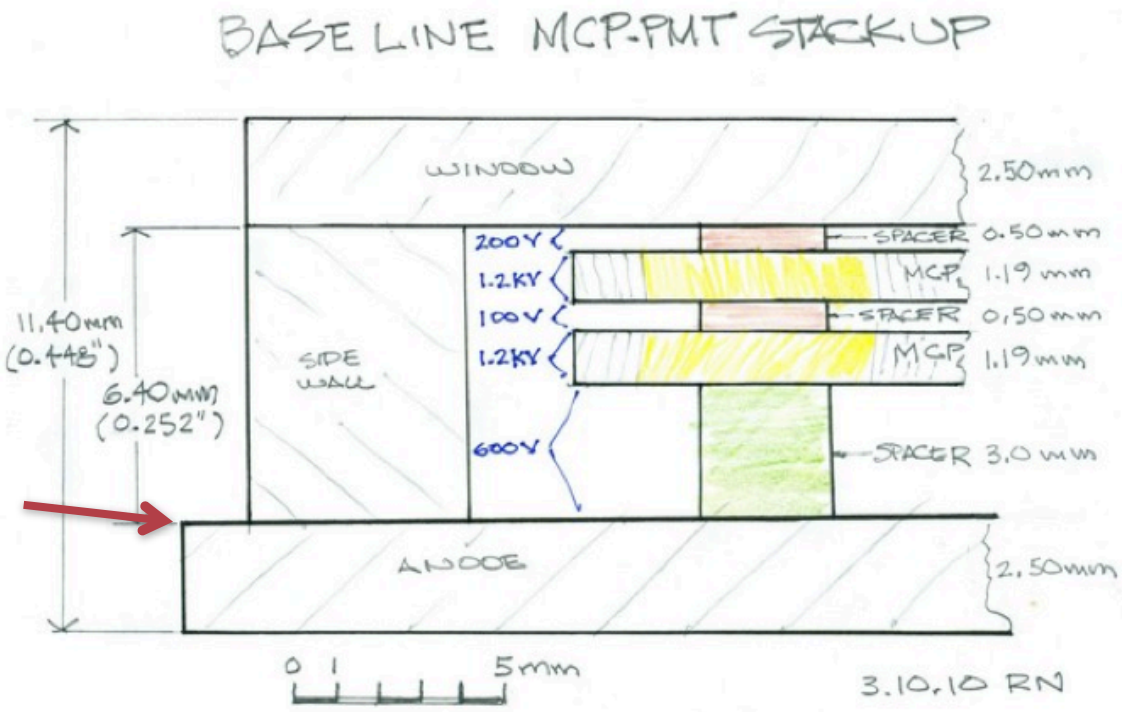
Characterization program:



Anode Design:

What is the best anode design for a particular application. How does one reduce channel counts and cost without sacrificing timing or spatial resolution? How to maintain multi-GHz analog bandwidth and 50 ohm impedance?

Anode Structure, Signal Processing



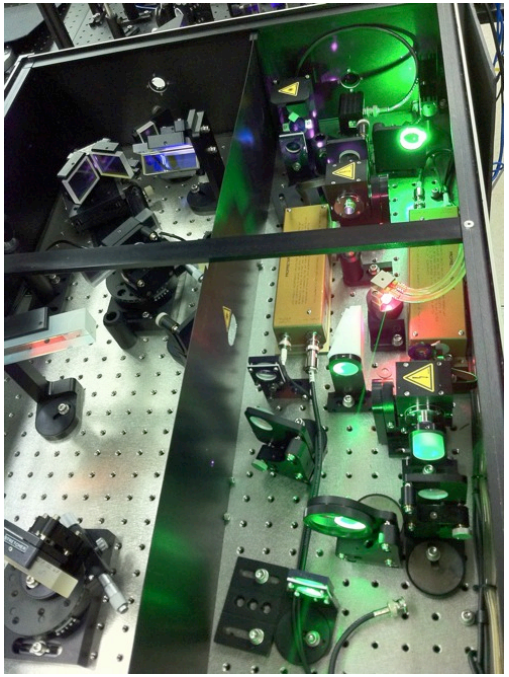
Facilities and Resources:

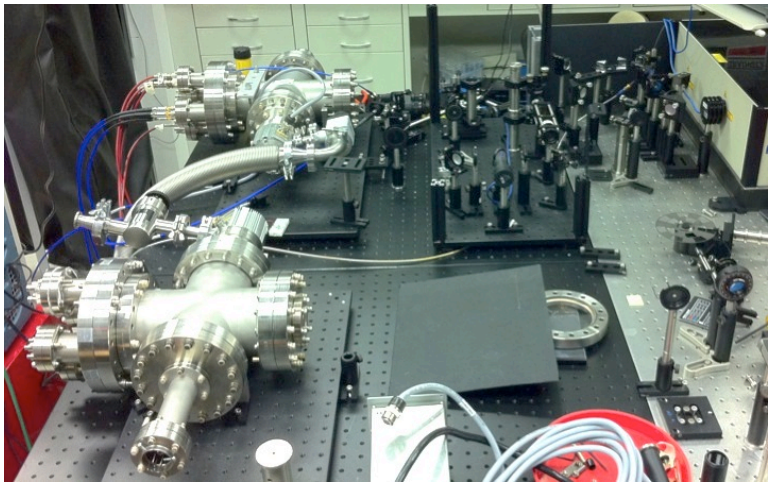
Facilities and Resources:

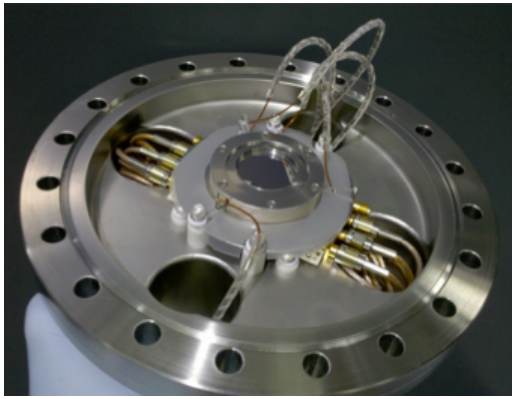
Facilities and Resources:

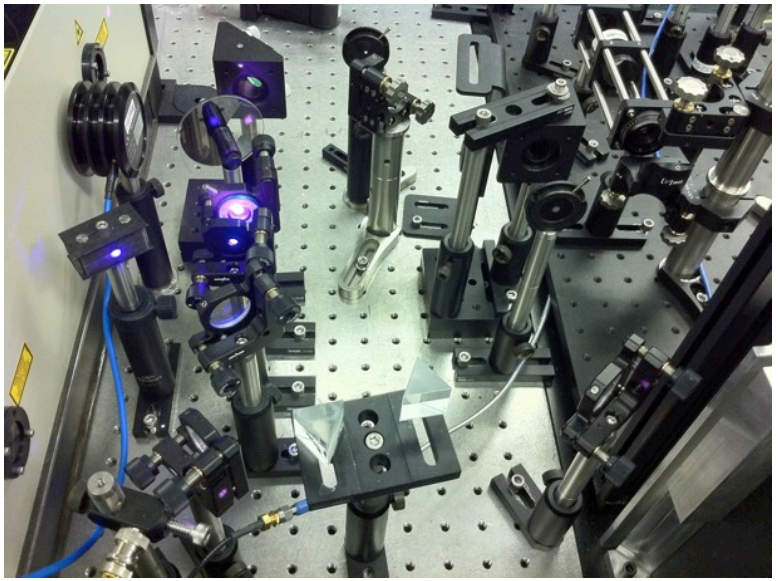
Dedicated Characterization Lab

- Pulsed 800 nm Ti:Sapph laser
  - pulse durations O(10) femtoseconds
  - 1000 Hz repetition rate
  - non-linear optics to produce UV(266 nm) and blue light (400nm)
  - average power ~800 mWatt
  - optics capable of micron-level translations and potential to focus on single pores
- Multiple vacuum systems for 33 mm testing
  - Capable of holding variable stacks of 1-3 MCPs and simple photocathode
  - able to accommodate multiple readout designs
  - capable of 10-7 torr
  - 2 complete systems with parts for a third
- 8" testing system, to be completed within the month
- Fixtures for testing sealed-tube detectors
- multi-GHz RF electronics
  - several oscilloscopes with 3-10 Gz analog bandwidth
  - high gain, low noise RF amplifiers
  - high-frequency splitters, filters, etc
- Automated data acquisition system
- Standardized data formats, analysis code, and formation of a data-analysis working group



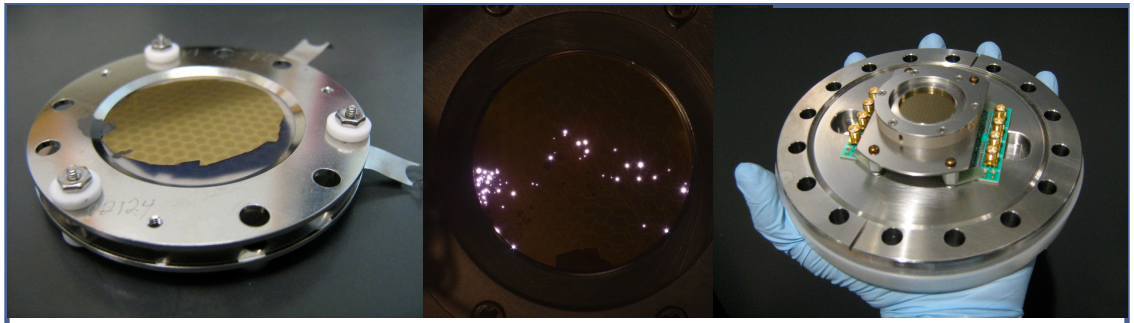


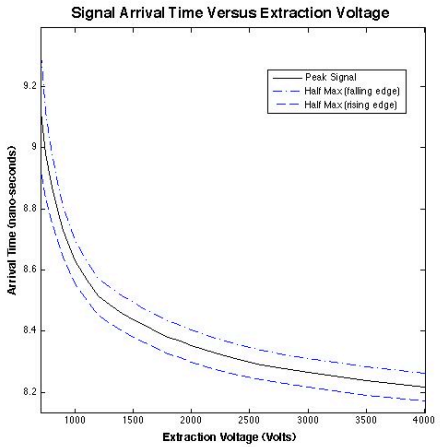


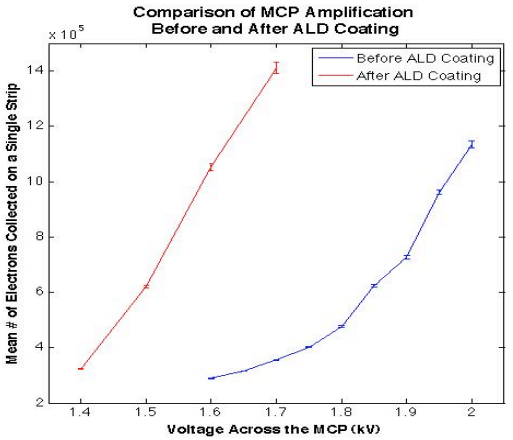


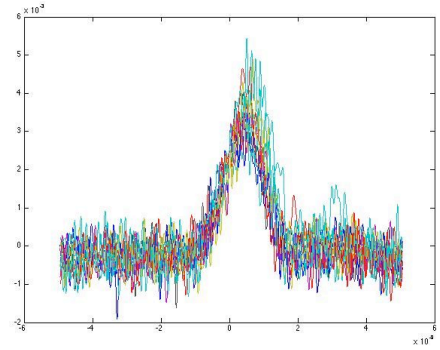
Year 1 achievements:

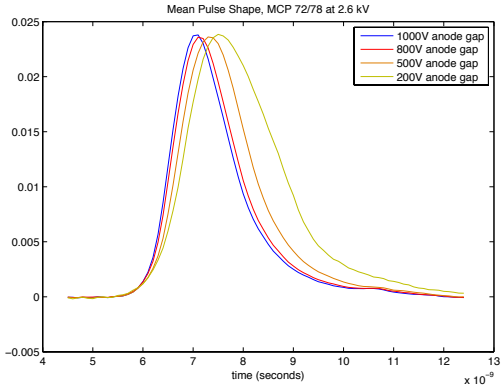
- Early study of timing characteristics from a Cesium-Iodide Photocathode
- Demonstration of enhanced gain from ALD coating on a commercial plate
- Developed operational experience working with MCPs
- Observation of first signals from ANL-fabricated, ALD-based MCPs
- Design and commissioning of characterization chambers





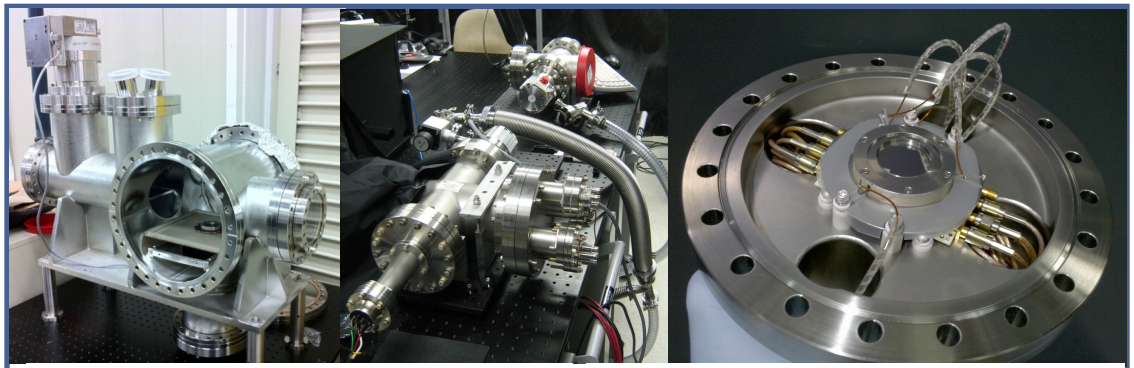




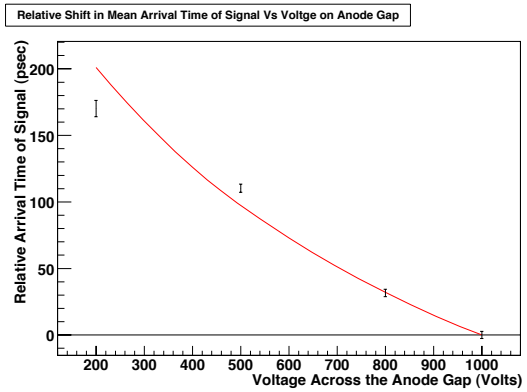


Year 2 achievements:

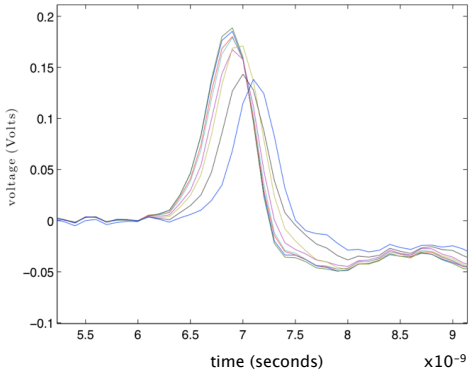
- Completion of laser characterization lab for systematic MCP testing in the time domain.
- Developed operational experience performing current-based, average gain measurements.
- Demonstrated > 10^5 amplification on Argonne-made, 33mm ALD functionalized glass plates.
- Demonstrated better than 200 psec time resolutions for single photoelectons in ALD MCPs
- Developed protocol for pulsed, single-photoelectron characterization.
- Close work with simulations and material characterization to improve fundamental understanding of MCP performance.
- Designed system for characterization of 8" MCPs, sealed tubes and lifetime testing



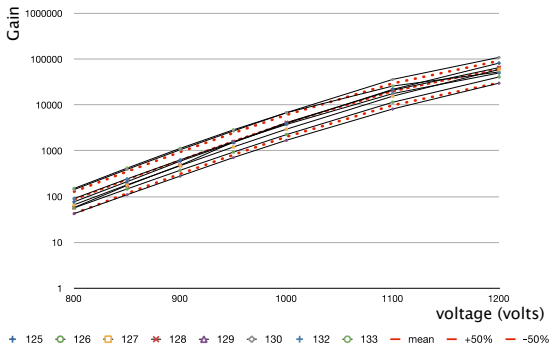
Relative shift in mean arrival time of signal VS anode-gap voltage



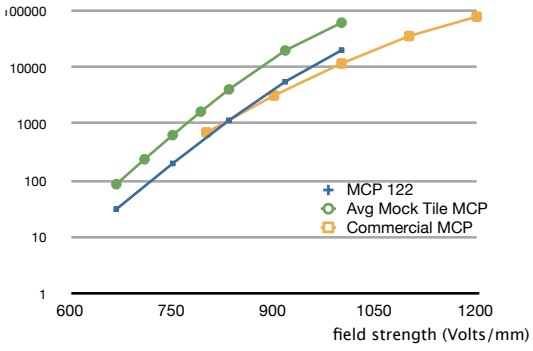
Average pulse shape for single MgO MCP at 1.5 kV, different photocathode voltages



Gain curves for mock tile MCPs

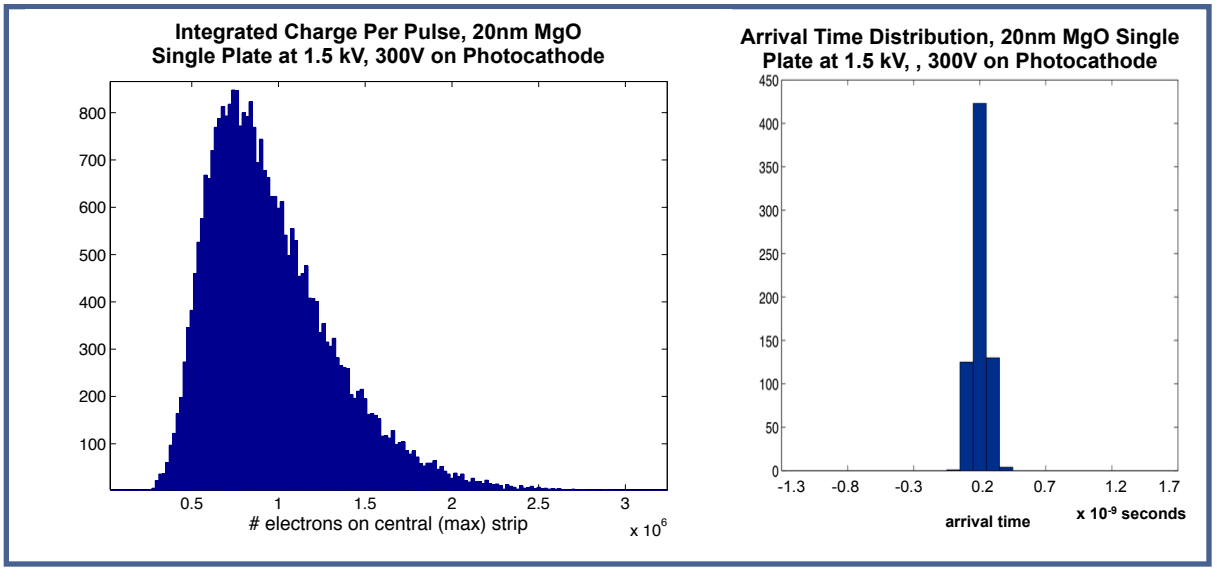


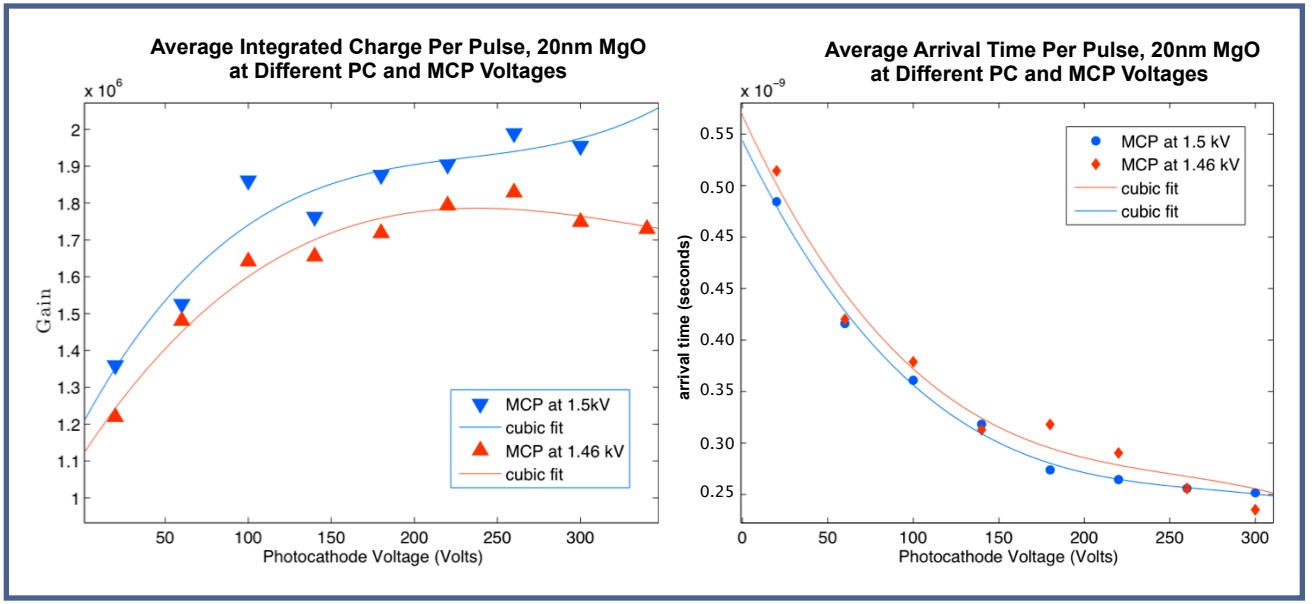
Comparison of ALD-MCP gains with commercial MCP



Current Work:

- Systematic comparison of gain and timing for MCPs with identical resistance, but three different SEY (secondary electron yield) compositions.
  - 20nm Al_2O_3
  - 20nm MgO
  - 2nm MgO
- Testing operation of single plates at high voltages.
- Comparison of MCP stacks with a common bottom plate.
- Systematic tests conducted for many different operational voltages, with the hope of placing strong constraints on models for avalanche formation.
- Plans for direct comparison of data with simulations and an upcoming publication

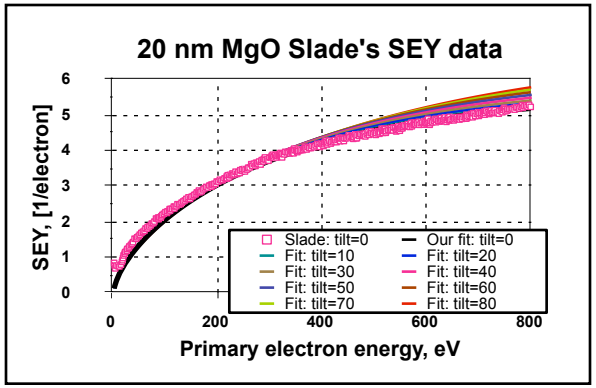


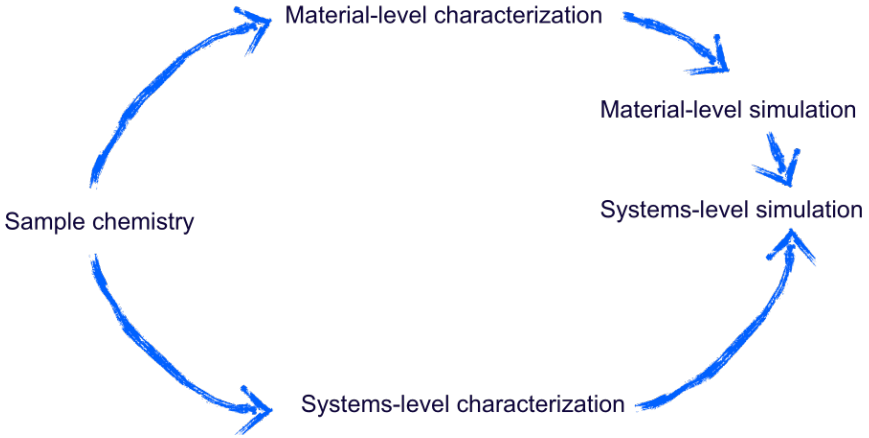


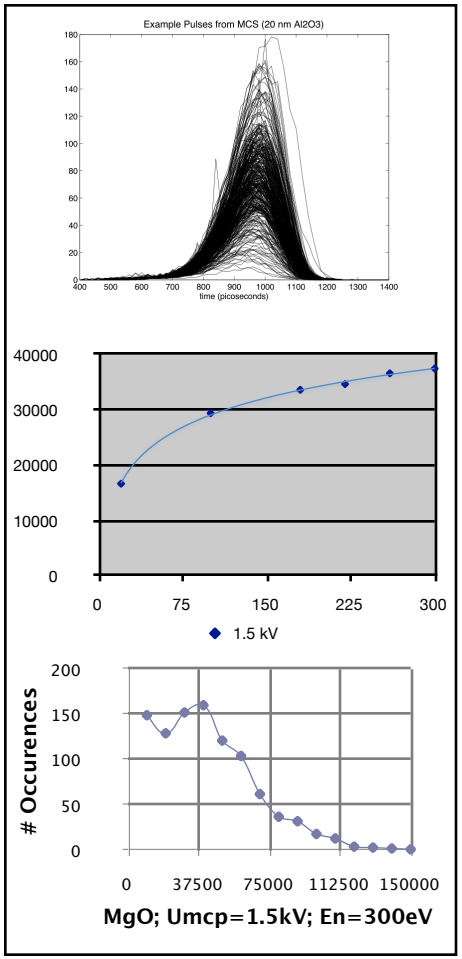
Current Work:

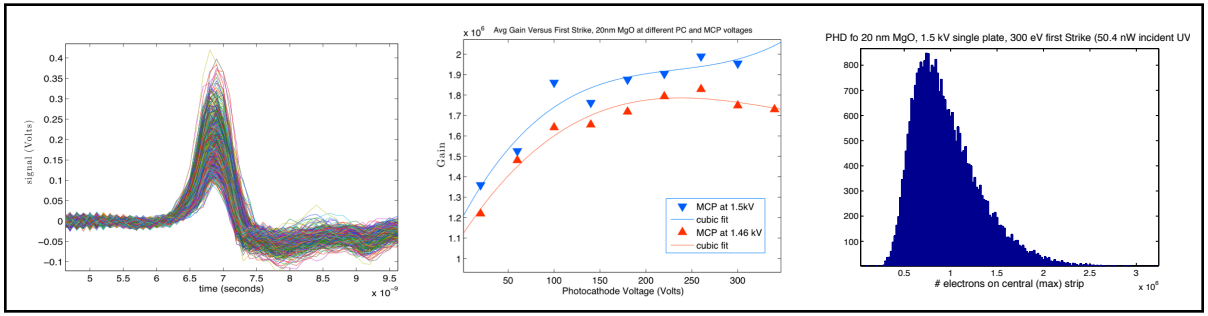
Complete MC-Data Cycle

- 3 MCP samples made with Identical resistance, but different SEY chemistry
- Simulations based on material-level characterization of SEY layers, guided by material-level simulations.
- MCP-level simulations to be tuned to data for 1 of the 3 MCP samples, taken at multiple operational voltages.
- Once tuned, predictions will be made on the performance of the other two samples, to be compared with data, afterwards...



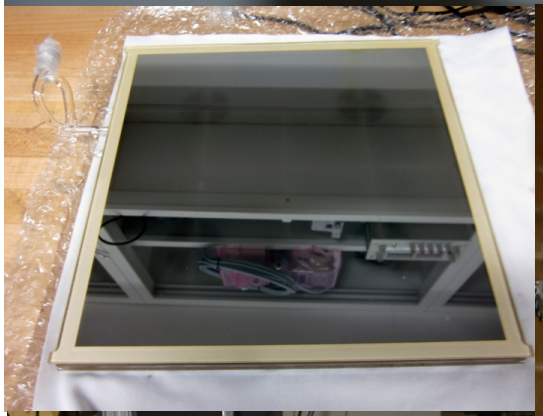


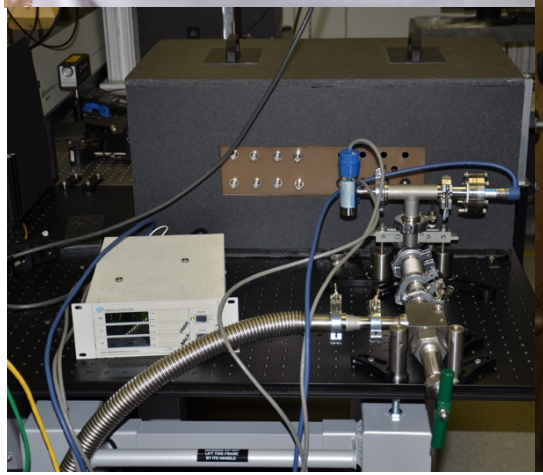


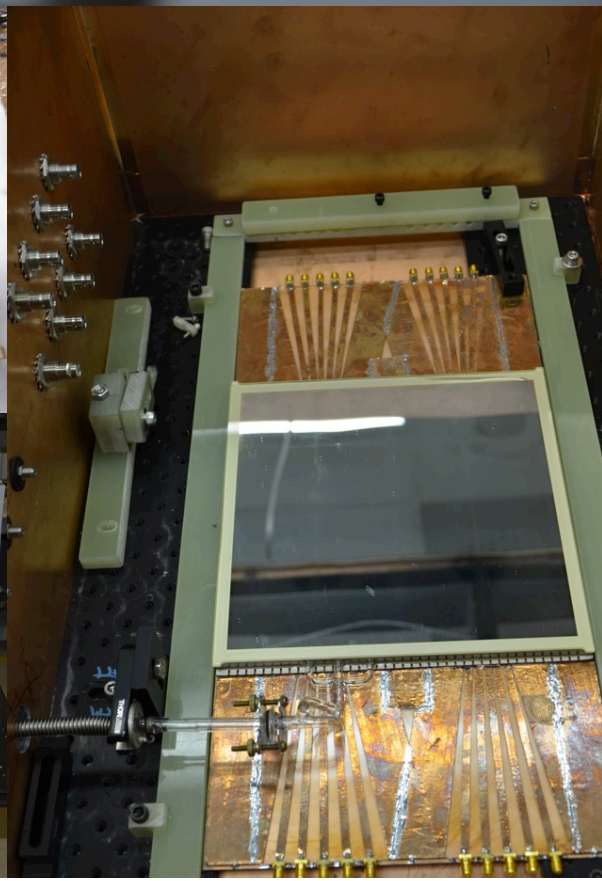


Mock Tile Testing:

- Received our first functional, sealed-tube MCP ("mock-tile"), built to the specs of an 8" MCP stack, but with 4 pairs of working, 33mm MCPs
- Constructed a system for mechanical support, electrical connection, vacuum connection, and signal readout from tile.
- Successfully coupled the tile to our vacuum system and achieved a vacuum of ~10^{-5} torr (as measured just outside the pump-port).
- A crack formed over the weekend, but without damaging the structural integrity of the internal parts.
- Leak tests found a break in the frit-seal near the crack.
- Attempts at repairing the broken seal were partially successful.
- Electrical tests to happen this week.
- Parallel effort prepare a next sealed tile are also under way.

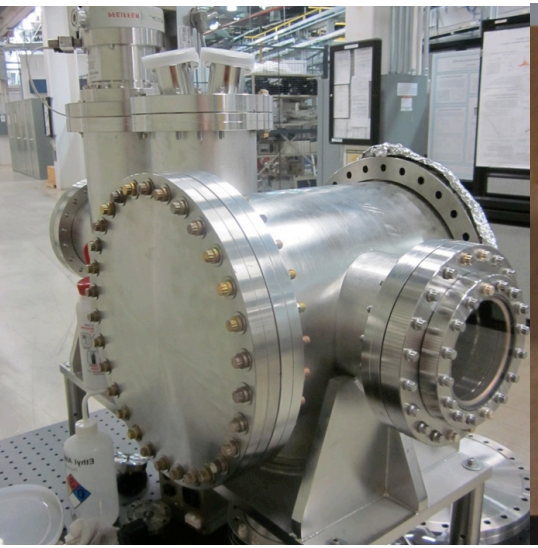


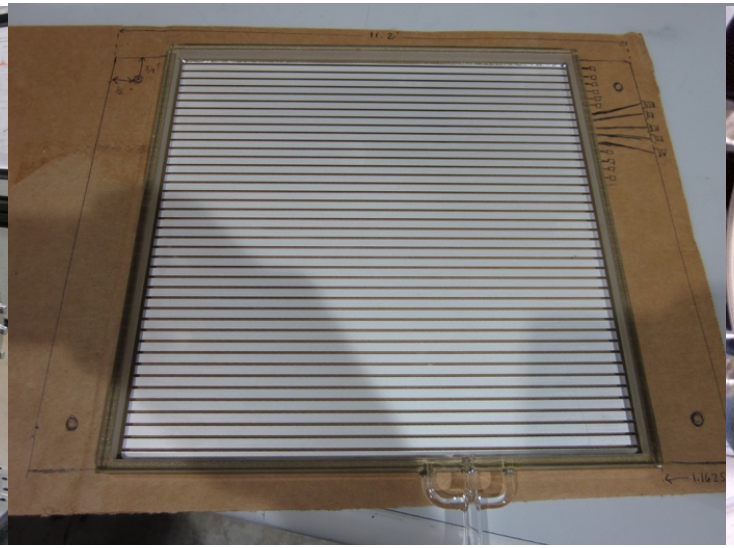


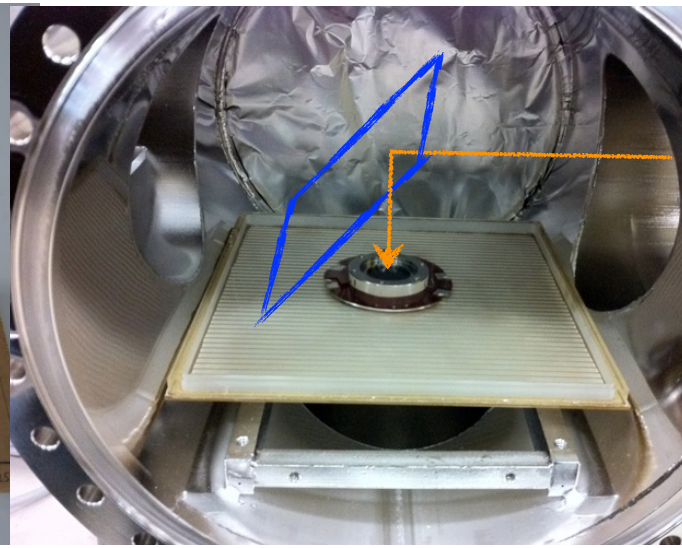


8” MCP Testing:

- 8” testing chamber is complete and successfully held 10^{-7} torr.
- Fixtures for mechanical assembly of 8” MCP stack designed to use spare glass parts for the sealed tube body.
- All but two of the components are now being made. Assembly should be finished within the month.
- Chamber will be used to test, both:
  - 8”MCPs and
  - 33mm samples on 8” transmission lines
- Looking forward to our first 8” MCP samples.







Future Plans:

Near Term:

- Systematic test of a 12 sample ensemble of MCPs with varying resistive and secondary emissive chemistries.
- Commissioning of the 8” testing system, successful operation of first working 8” MCPs
- Demonstration of first working sealed-tube detector
- Comparison of several anode designs, testing of PSEC chip on MCP signals
- Commissioning of aging/ scrubbing experiment

Long Term:

- Systematic batch testing of identical MCPs
- Integration of testing methods with Tile Factory
- Single pore testing, aging and saturation studies (double-pulsed measurements)
- Tests of potential single-MCP detectors