University of Chicago

Argonne NATIONAL LABORATORY

LAPPD

Simulations Guided Efforts to Understand MCP Performance

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LAPPD Collaboration Meeting

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U.S. DEPARTMENT OF ENERGY

An opportunity

- ALD gives us the unique ability to vary electrical, secondary electron yield (SEY) and geometric properties of MCPs independently.
- Compared with commercial MCPs, which are typically made from a single material (lead-glass), we can produce MCPs with much wider variety of properties, other properties held fixed.
- Can explore limiting cases and place stronger constraints on MCP models.

MCP characterization – Experimental Method

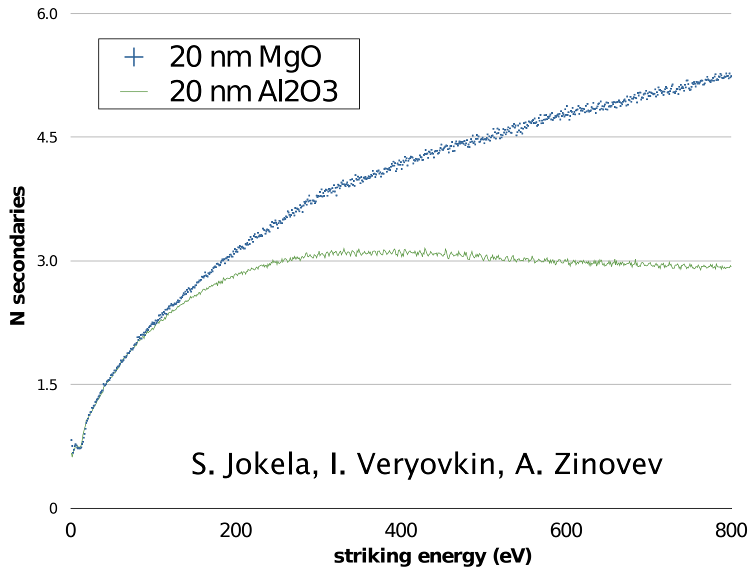
Our main focus: 2 samples:
•20 nm Al2O3
•20 nm MgO

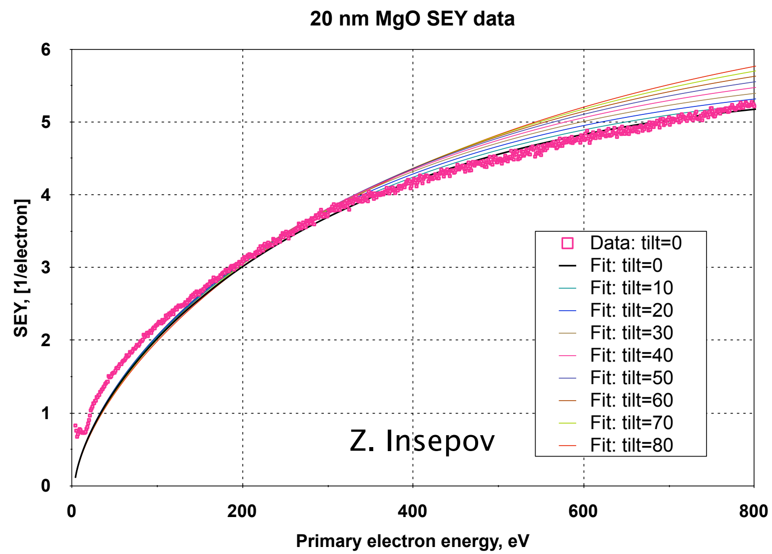
Two materials demonstrate similar secondary electron yield for striking energies below 100 eV...

The curves start to diverge at high energies.

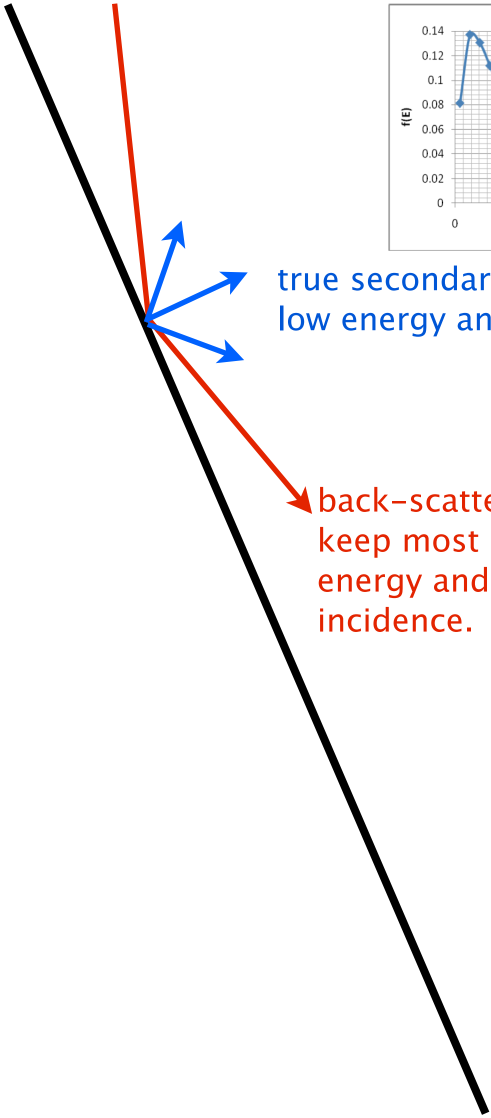
Is the MCP avalanche driven by the smaller fraction of high energy strikes?

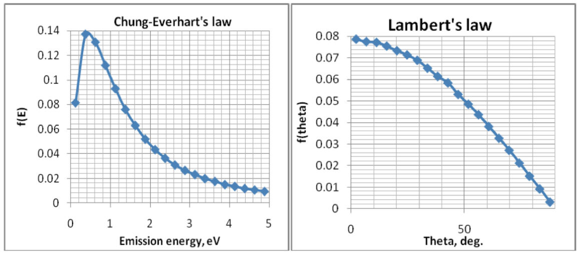
What is the role of backscattering?





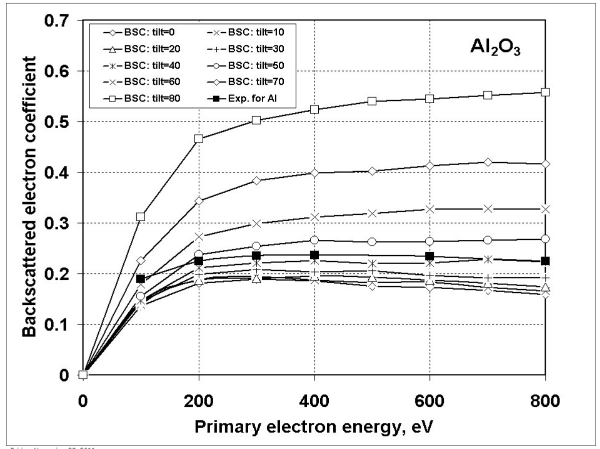
MCP characterization – Experimental Method

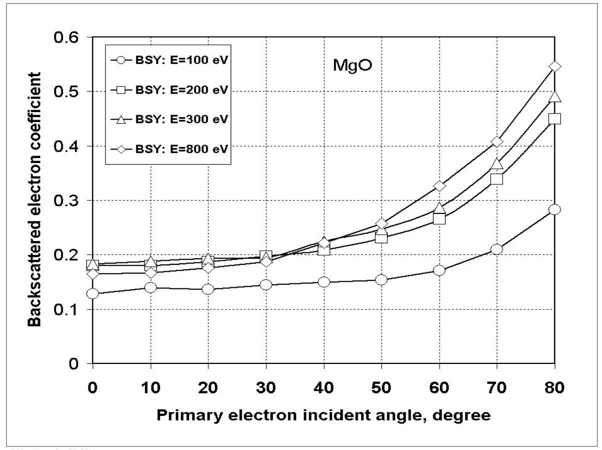




true secondaries are typically low energy and isotropic

back-scattered electrons keep most of the original energy and remain at grazing incidence.



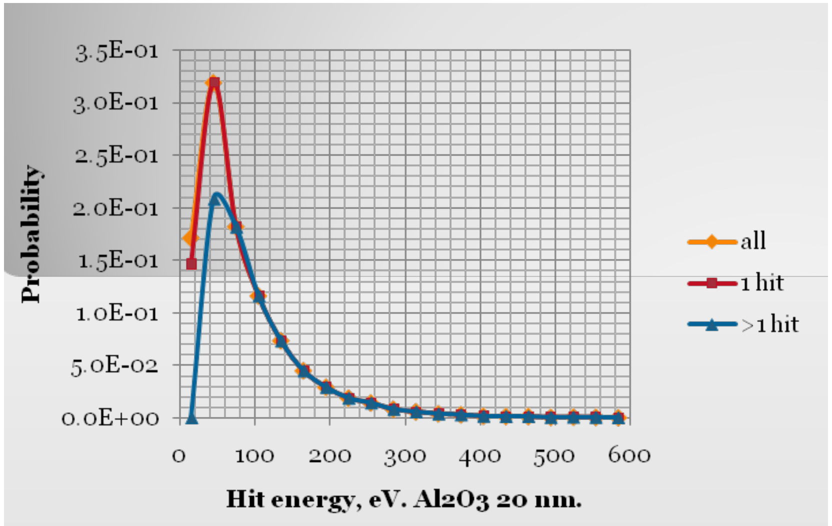


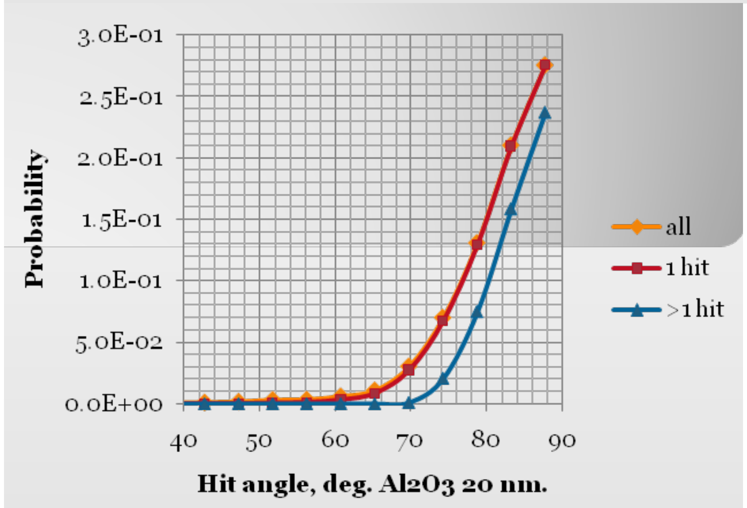
BS probabilities are calculated form a theoretical model.
Overall normalization is left to tune....

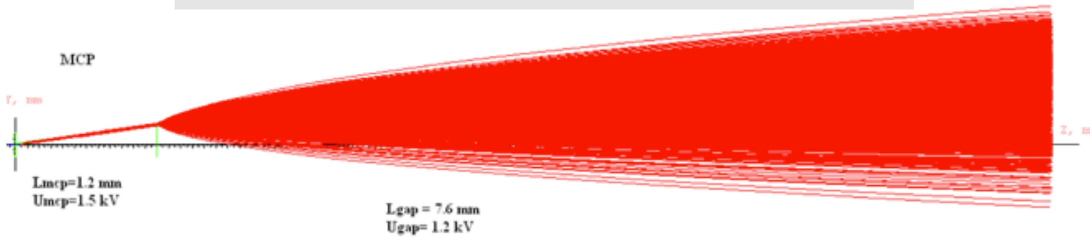
Details in Simulations:

The LAPPD Simulations Program

- Goal to develop a predictive, pseudo-physical MCP model to help guide MCP design.
- Help improve understanding of what is going on inside the pores.
- Takes experimental materials characterization as input.
- Two components:
    - **true secondary electron yield (SEY)**
    - **specular reflection of incident primary electron, eg backscattering or BS**
- SEY at normal incidence is measured.
- SEY at grazing incidence is extrapolated using a theoretical material model
- quasi-elastic reflection of the primary electron is derived from a theory.
- Normalization of the BS probability is a tunable parameter (controls the fraction of highly energetic electrons in the pore).



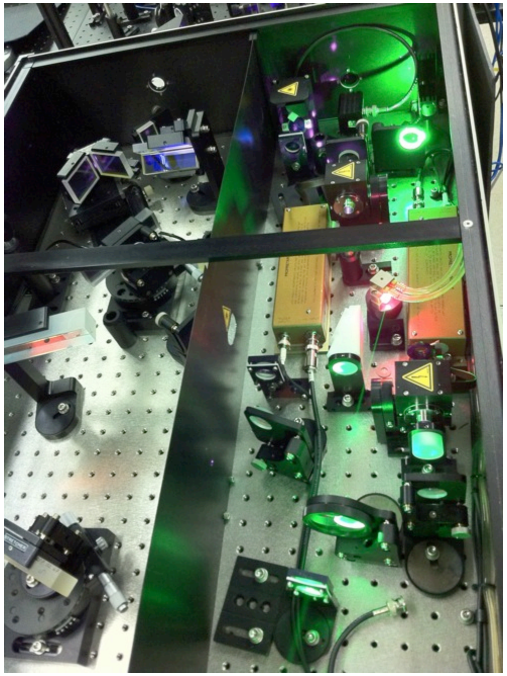


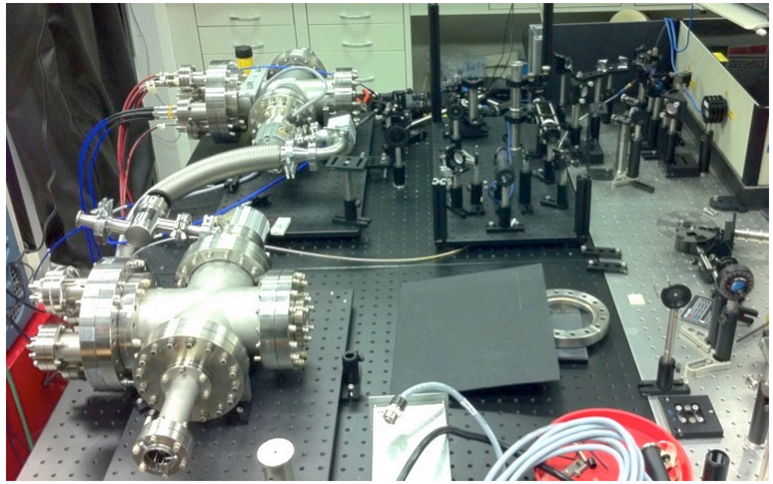


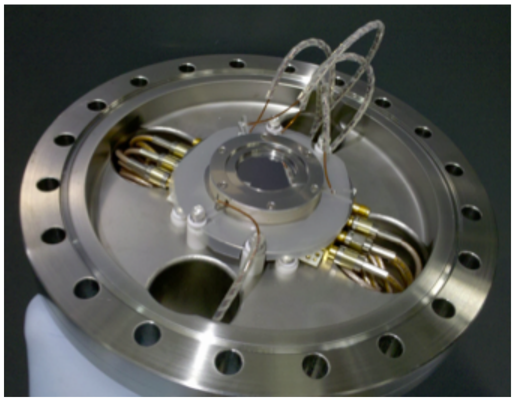
Facilities and Resources:

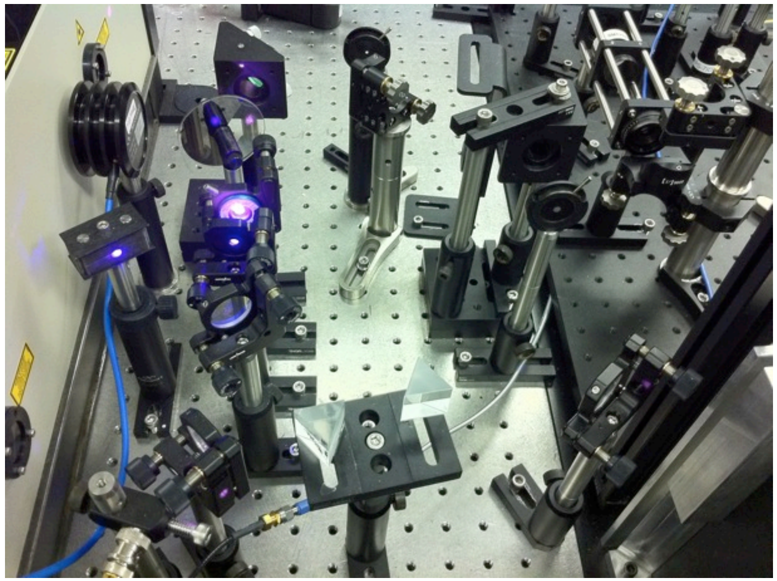
ANL MCP Characterization Lab:

- A fast (sub-psec), pulsed laser with precision optics
  - 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
- Vacuum systems for testing 33 mm photocathode-MCP-anode stacks approximating a complete device
  - 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” MCP testing system (now commissioning)
- Fixtures for testing sealed-tube detectors (now commissioning)
- multi-GHz RF electronics
  - several oscilloscopes with 3-10 Gz analog bandwidth
  - high gain, low noise RF amplifiers
  - high-frequency splitters, filters, etc





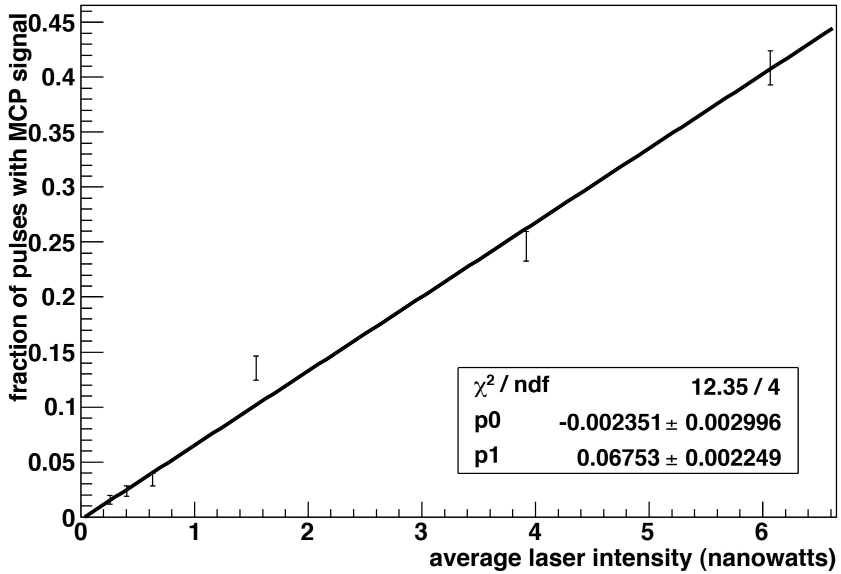




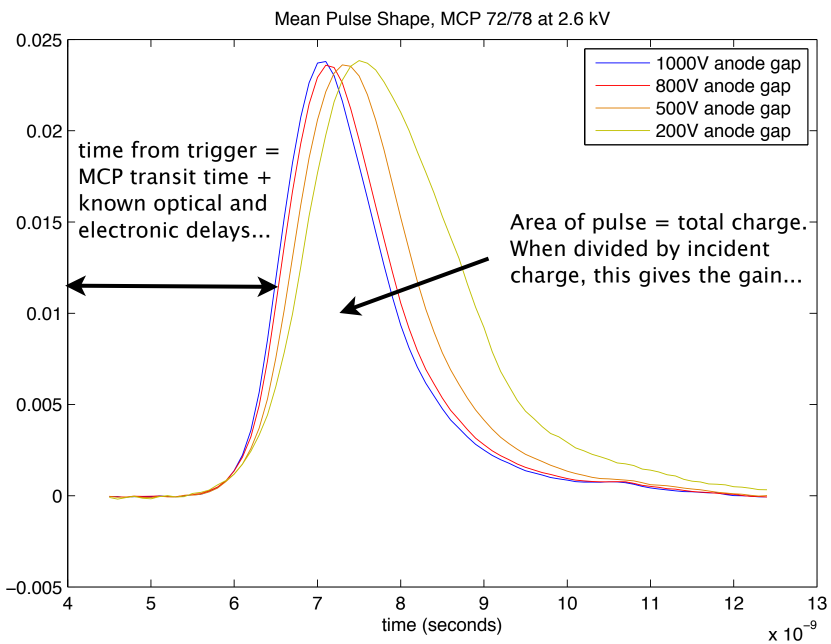
The APS-Team

Method

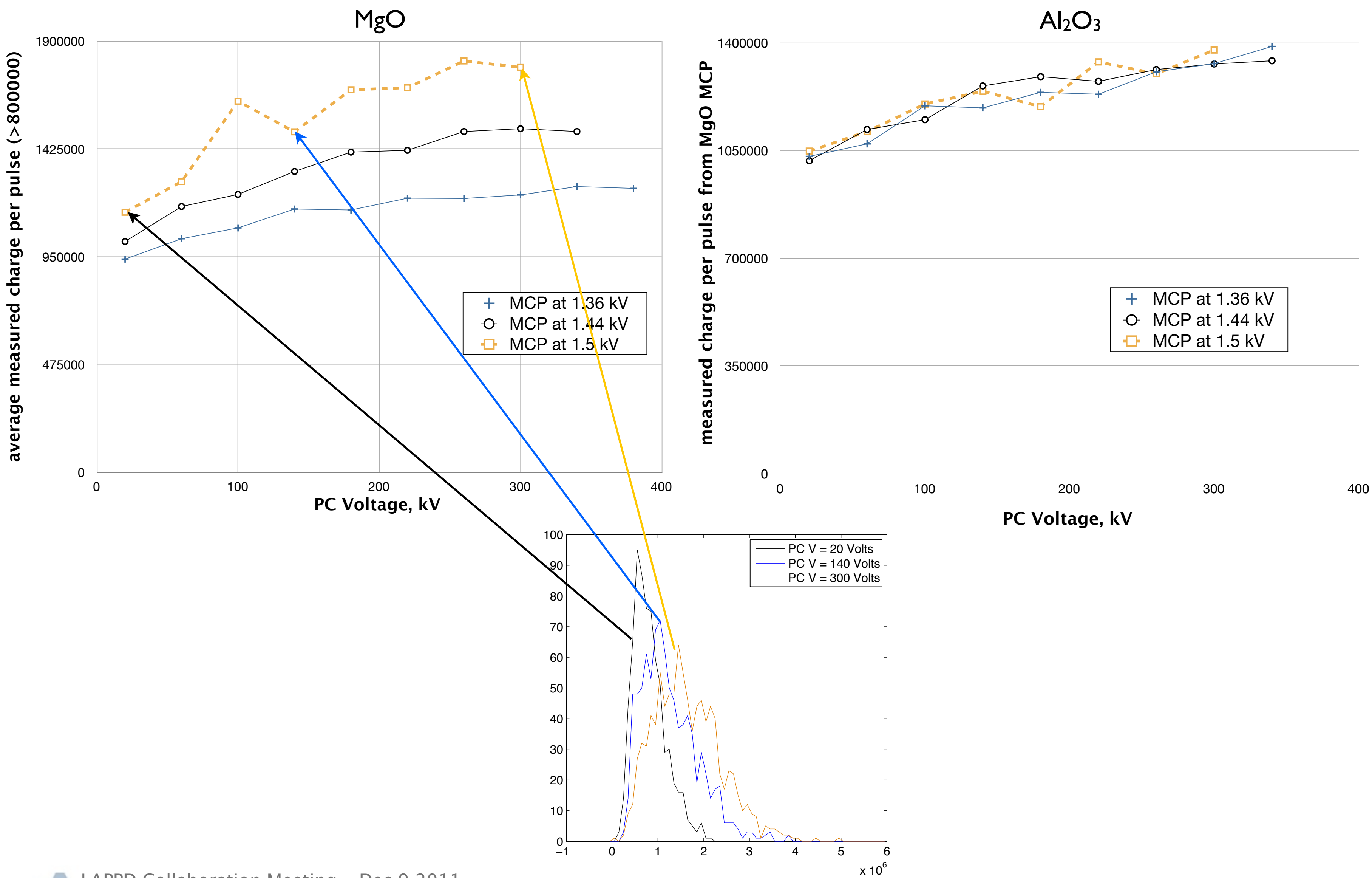
- Control the number of photoelectrons (PEs) by attenuating the laser to the point where only a small fraction of pulses produce signal.
- Trigger on laser pulses to achieve very precise measurements of transit time
- Control size and position of beam to isolate individual spots on the MCP
- Record each pulse separately to produce statistical distributions.
- Integrate and fit the pulses to determine arrival time and gain.
- Able to discriminate between signal pulses and dark-current (random firing of the MCP)
- Single plate testing allows us to study gain-voltage behavior without saturation.
- Single plate is coupled to a low-noise amplifier



UV intensity (nW)



MCP characterization – Results



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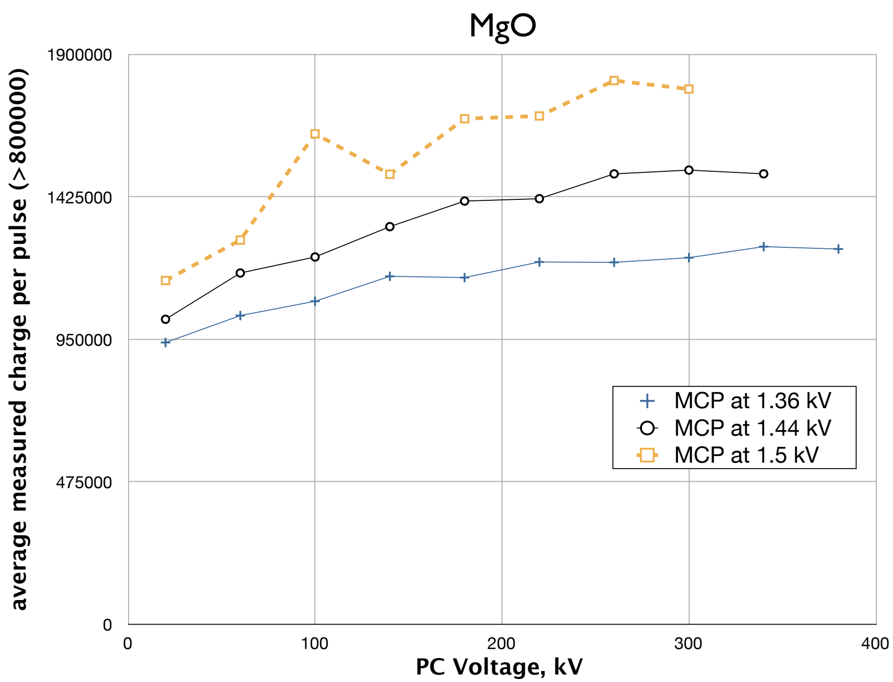
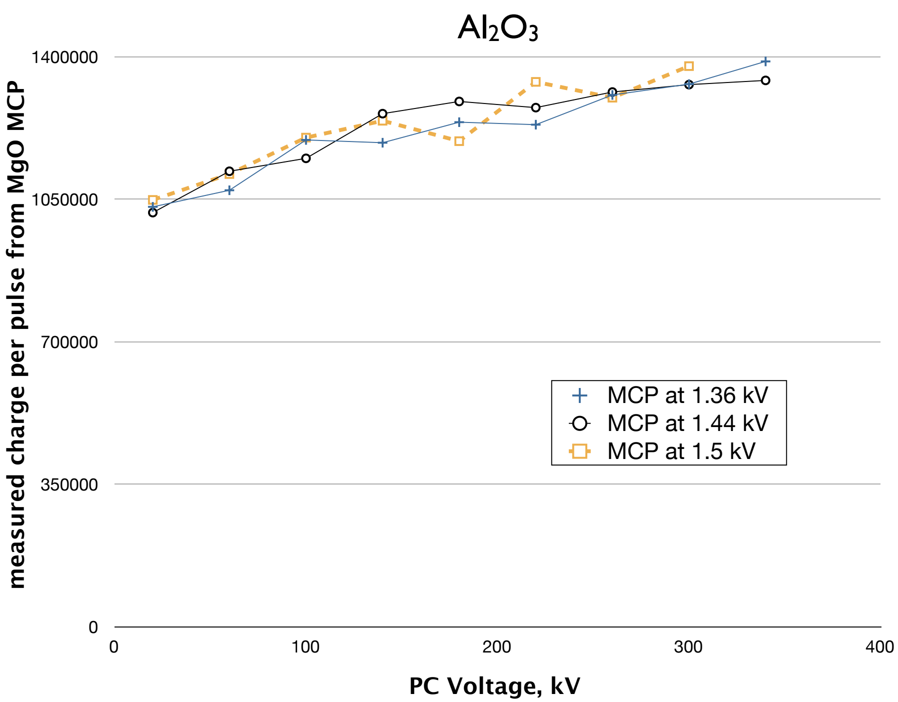
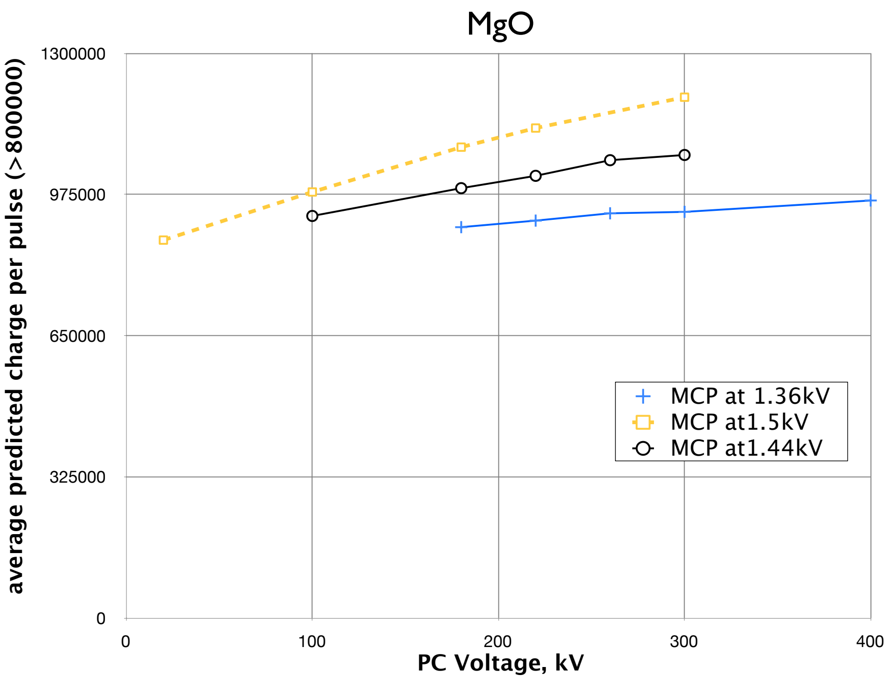
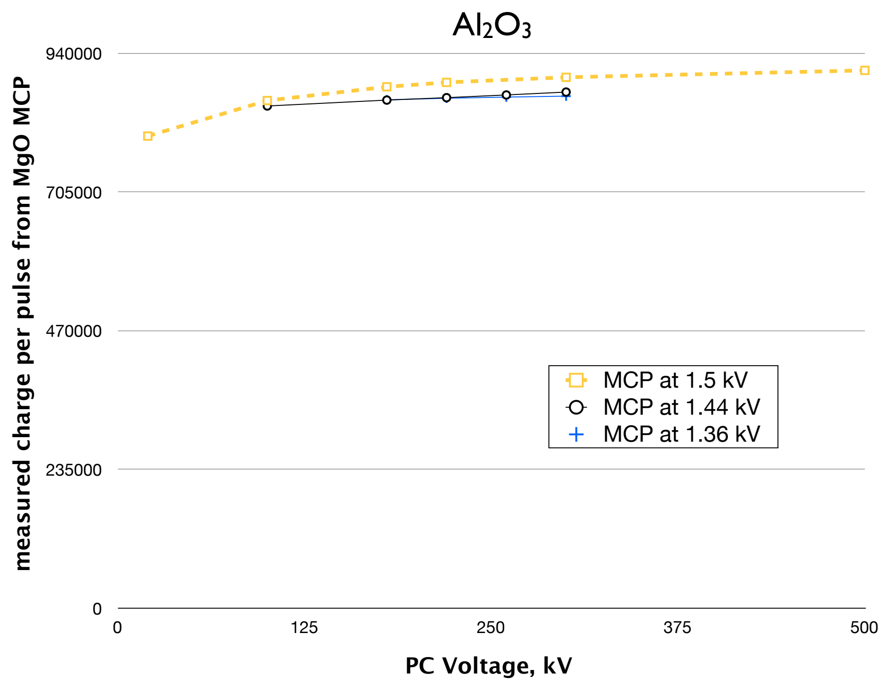




- MgO MCP is more sensitive to photocathode voltage (first strike energy)
- MgO MCP is more sensitive to MCP voltage over the range: 1.36–1.5 kV
- Slope (not just offset) of the pulse height versus photocathode voltage curves seem to depend on MCP voltage in the MgO. Slope of these curves should be identical if each strike is statistically independent of the next. Could be pointing to BS!

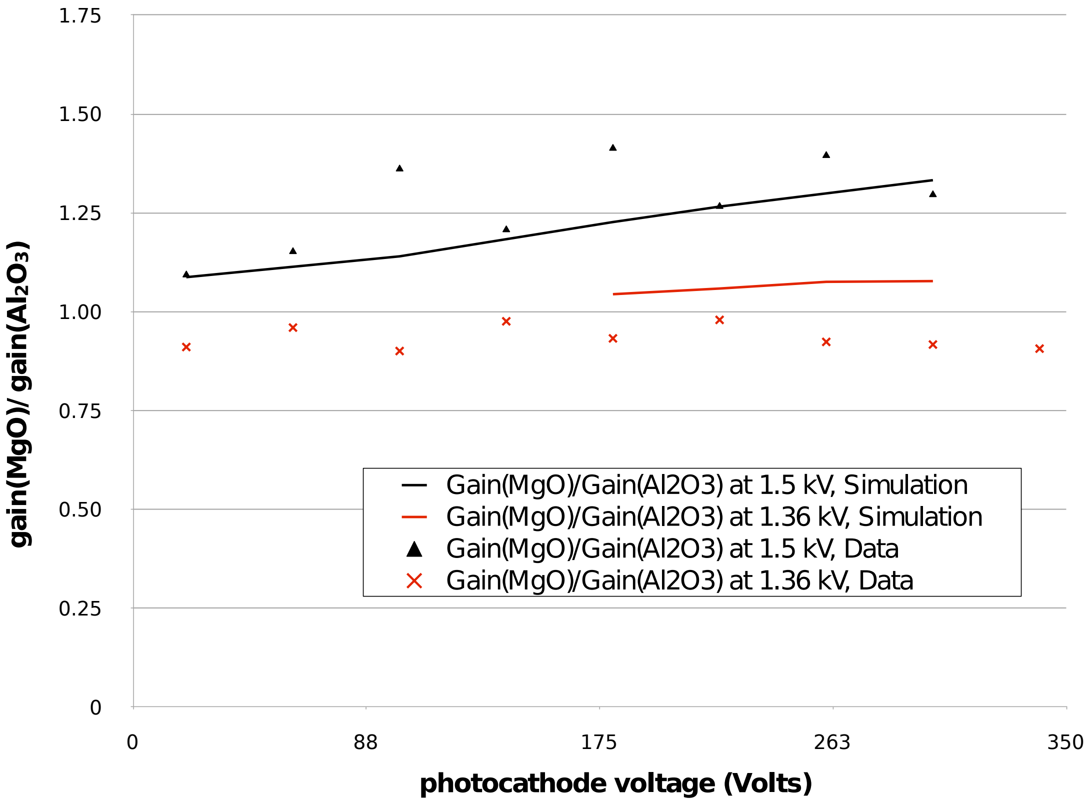
MCP characterization – Results





We observe similar dependences in the Monte Carlo...

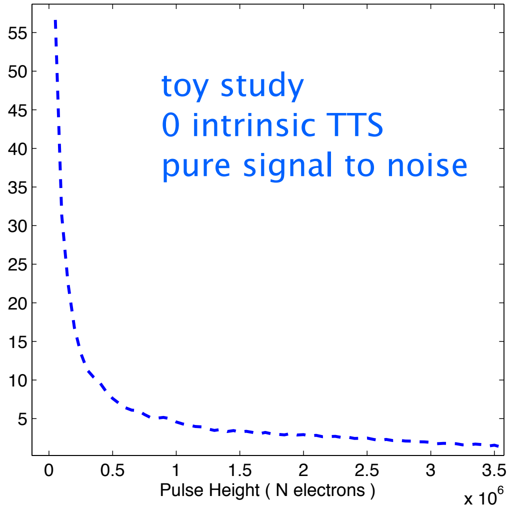
MCP characterization – Results

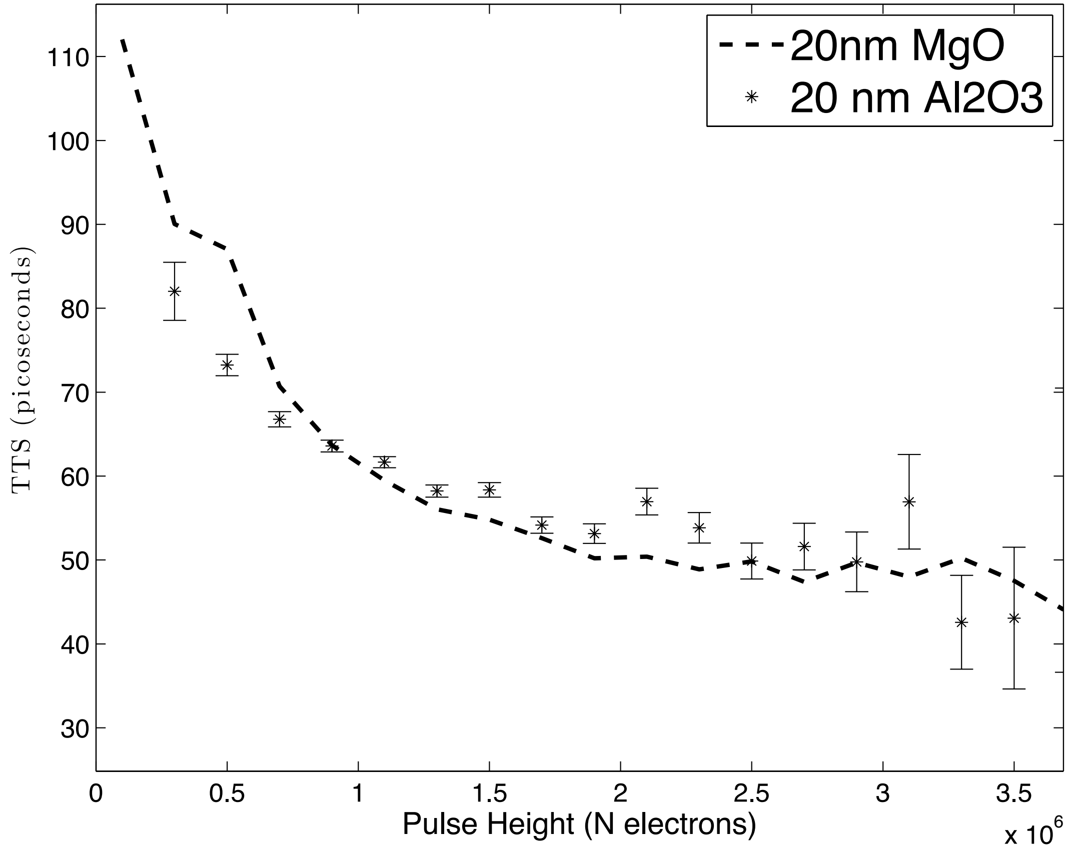


- Systematic uncertainties cancel out in the ratio of the gains for MgO and Al2O3.
- Predictions made by simulations match well with the data.

MCP characterization – Timing Questions

Timing sensitivity driven by signal to noise. For single plate operation, this is small. We are not yet sensitive to the few-picosecond resolutions predicted by simulations. Will repeat these TTS studies with MCP pairs in near future.





Summarizing Our Progress

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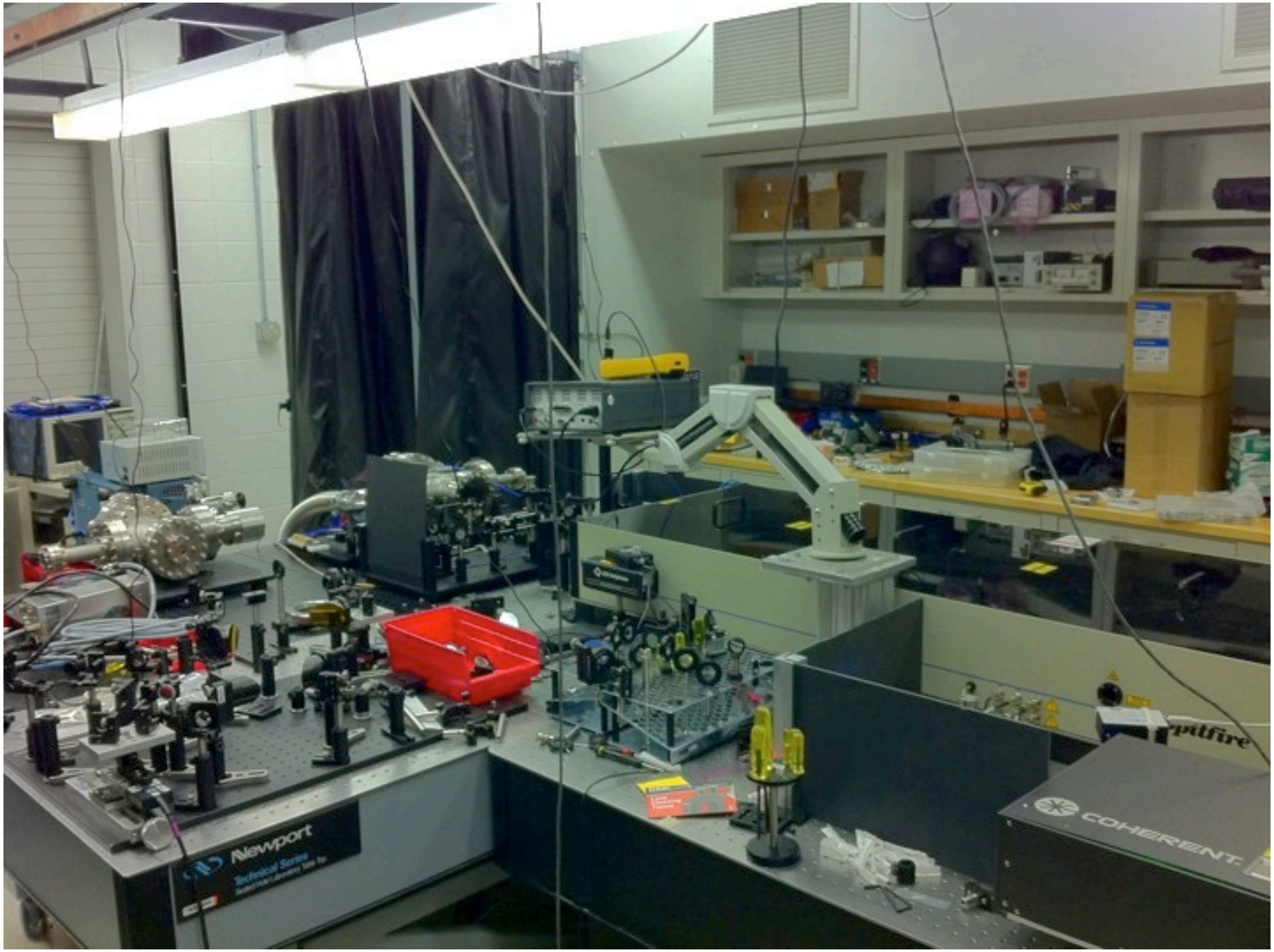
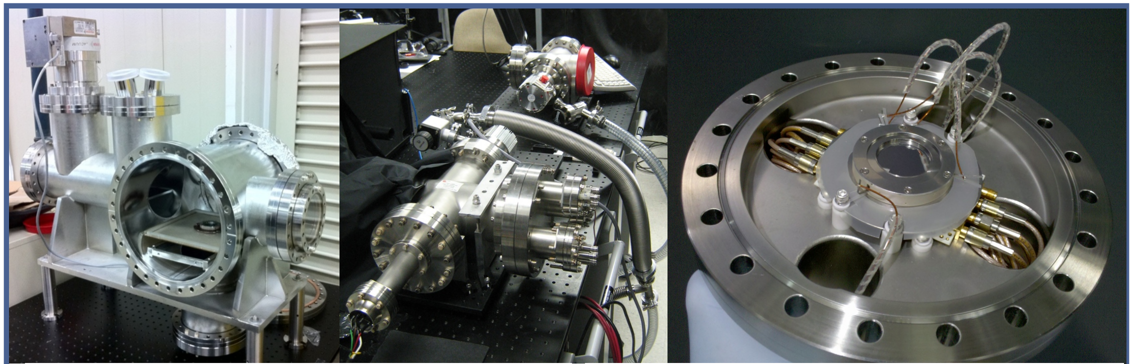
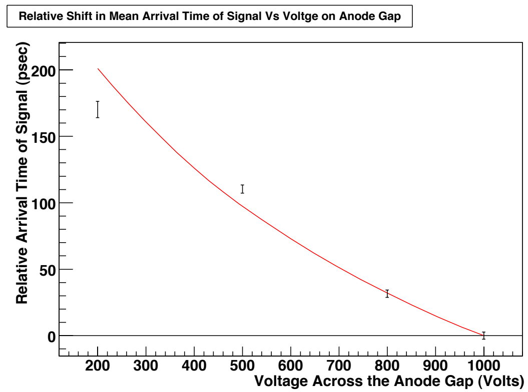


Year 2 achievements:

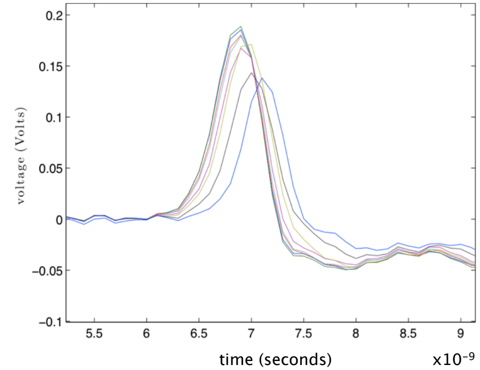
- Completion of laser characterization lab for systematic MCP testing in the time domain.
- Developed operational experience performing current-based, average gain measurements.
- Demonstrated > 10^5 amplification on Argonne-made, 33mm ALD functionalized glass plates.
- Demonstrated better than 200 psec 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



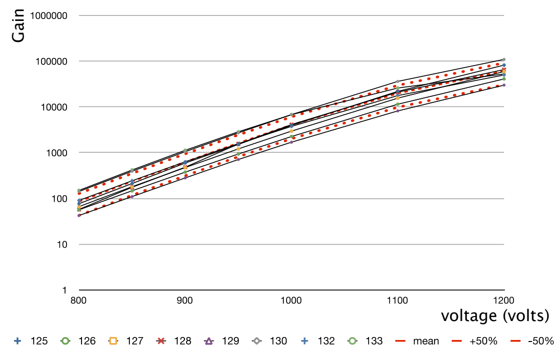
Relative shift in mean arrival time of signal VS anode-gap voltage



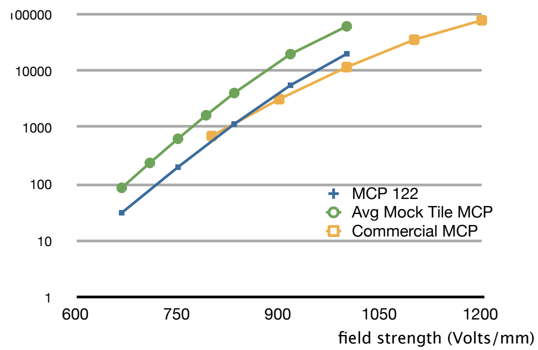
Average pulse shape for single MgO MCP at 1.5 kV, different photocathode voltages



Gain curves for mock tile MCPs



Comparison of ALD-MCP gains with commercial MCP



MCP characterization – Next steps and publication plan

Complete draft of a paper on MgO/Al2O3 comparison together and ready for godparent review.

Plans to write a paper on our experimental setup in Review of Scientific Instrumentation

Sequel papers hopefully soon to follow. This is a major focus of the project....

Medium to Long Term Planning for the 33mm Program

Wrapping up version 1.0 measurements

Finishing current measurements with set up as is...Approximately 2-3 more months

Planning version 2.0

Modifications for single pore illumination... “Double pulsing” studies... 6+ months

Some transitional measurements inbetween

Life time studies, batch uniformity studies...