Use MCP-PMT as Time-of-Flight in SoLID

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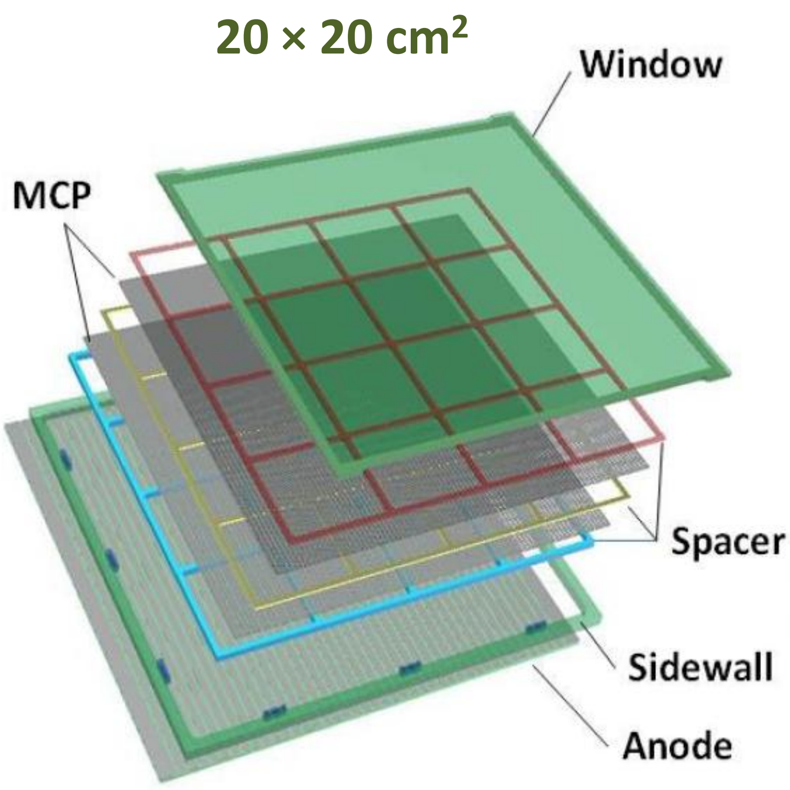
SoLID Collaboration Meeting

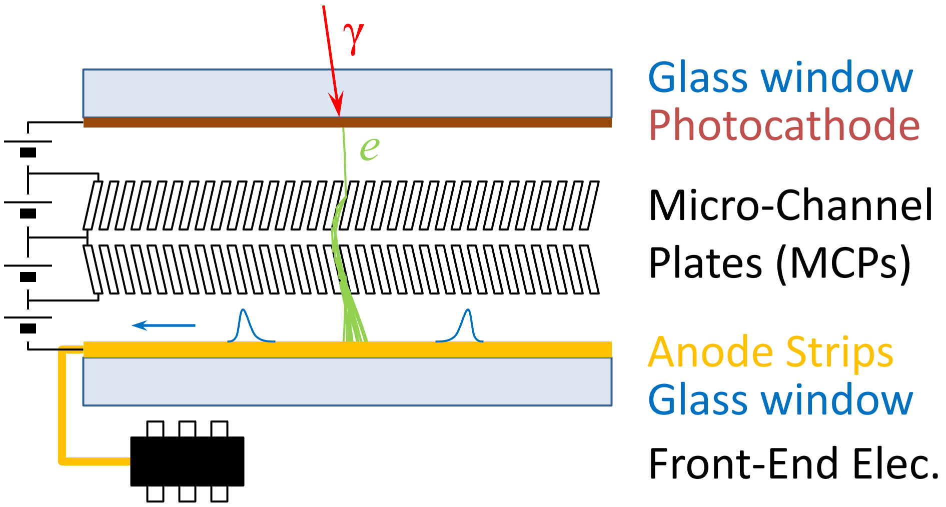
Mar 22, 2013

Overview

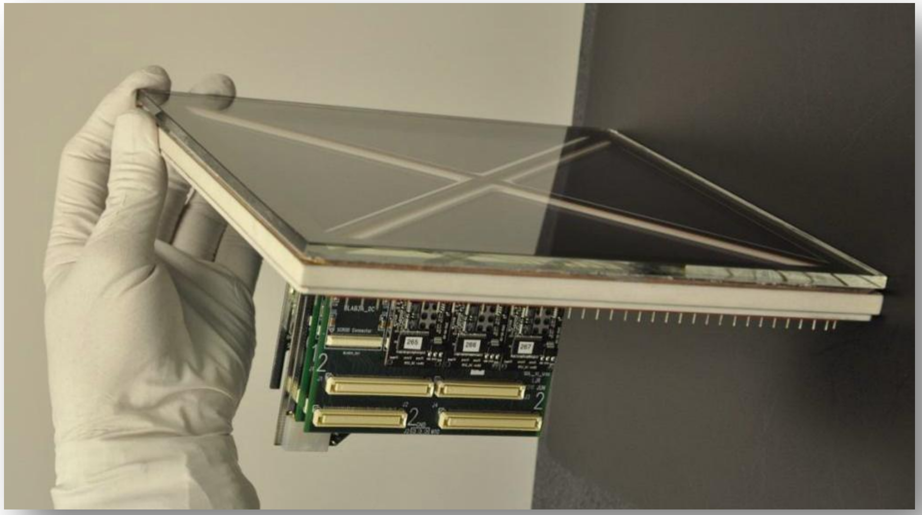
- Large area planar photo-detectors are under development by Large-Area Pico-second Photo Detector (LAPPD) collaboration
  - Newly funded by DOE and NSF since fall 2009:
    - Members mainly from ANL, FNL, Uchicago, Uhawaii, UCB and three small US companies.
  - Goal: develop a family of large-area robust photo-detectors with ***good position and timing resolution*** that can be tailored for a wide variety of applications where large-area ***economical*** photon detection is needed.
  - Use of renovated micro-channel plates (MCPs)
  - http://psec.uchicago.edu
  - Thank Dr. Marcel Demarteau (ANL)

Micro-Channel Plate-PMTs





Ceramic body prototype



Overall Progress

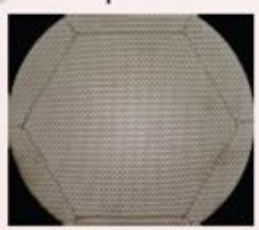
LAPPD program was a new instrumentation initiative, not an ongoing program; no pre-existing group, started with transient seed funding

R&D 100 Award

SBIR/STTR ($3M)

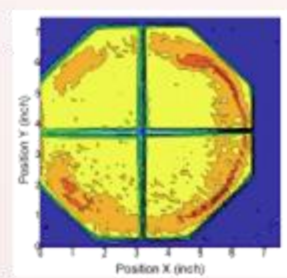
ALD Technology Licensed

Met all sub-component milestones for constructing full device



MCP Technology select

PSEC4, fastest sampling chip, 17 GHz

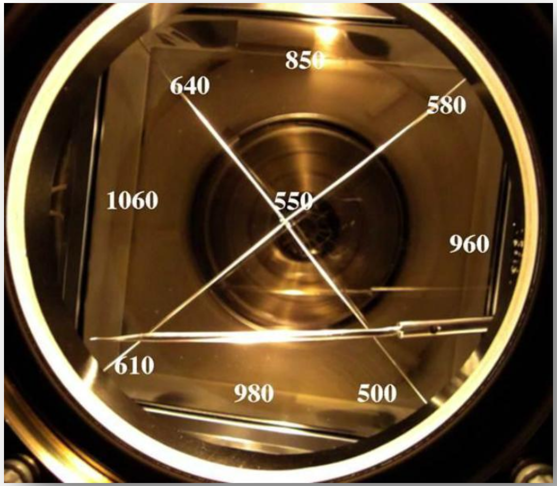


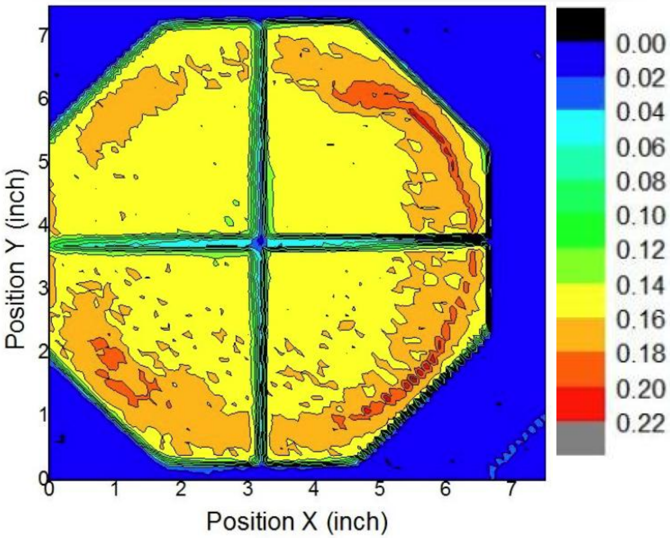
7" Photocathode

t=0 t=1yr t=2yr t=3yr

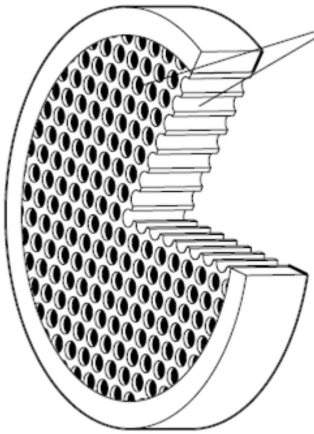
Photocathode

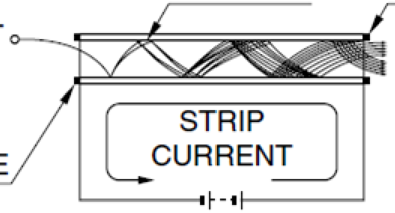
- Argonne National Lab
  - Atomic Layer Deposition (ALD)
  - Using Burle ALD equipment
  - 7”×7” flat K_2CsSb photocathode was produced
  - Max QE: 22% (350 nm, average: 16%)
- UC Berkeley
  - Chemical Vapor Deposition (CVD)
  - Deposited Na_2KSb photocathode on 8” windows
  - 25% QE (350nm) with good uniformity (15%) and stability



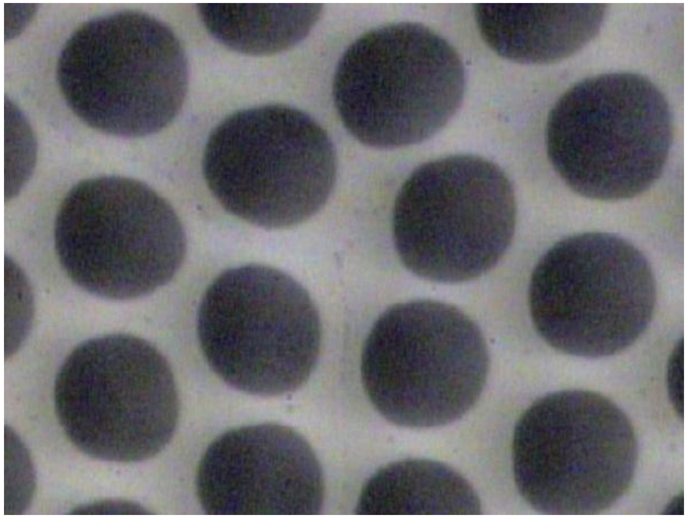


Micro-Channel Plates





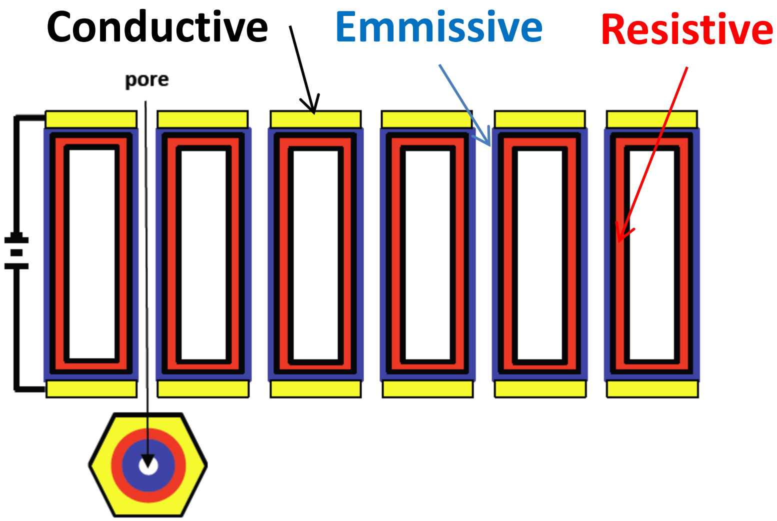
- Conventional Pb-glass MCP
  - Chemically produced and treated
  - Provides three functions:
    - Provides pores
    - Resistive layer supplies electric field in the pore
    - Pb-oxide layer provides secondary electron emission

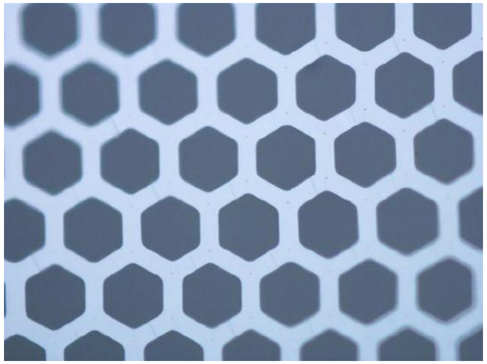


Typical pore size: 20 – 40 um

MCP by LAPPD

- MCP produced with ALD
  - Separate three functions, more freedom for optimization
  - Glass substrate with pores
  - Tuned Resistive layer provides current for electric field
  - Specific Emitting layer provides secondary electron emission
- Good performance with lower cost
  - Gain > 10^7 for pair MCPs
  - Tilting pore angle optimized for better acceptance





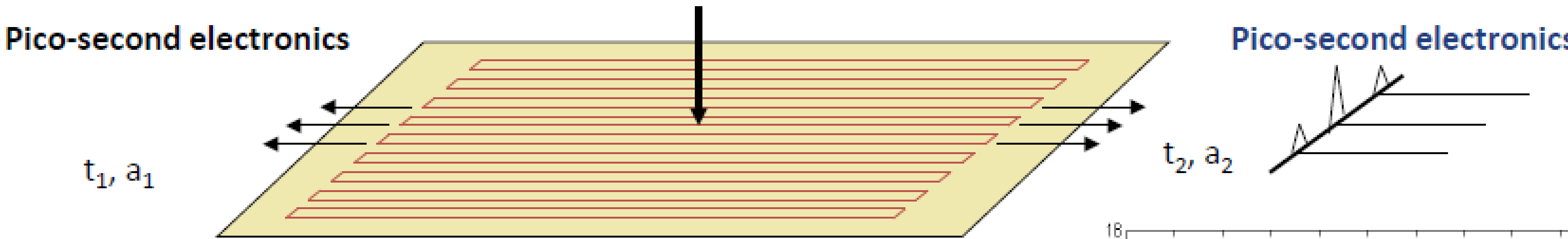
Glass Substrate by INCOM
Borosilicate, 20 um pores

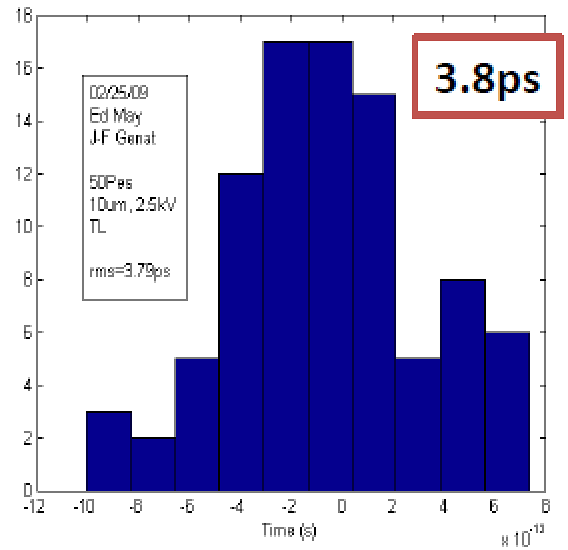
Readout Electronics

- Transmission line read by waveform sampling chips
  - 5 mm strips, Bandwidth > 1.5 GHz, Sampling rate: 40 GS/s

Time Resolution

- Transmission line readout and pulse sampling provide fast timing (2-10ps).
  - Transmission line should have a signal bandwidth matched to the detector





3.8 ps translates in 190 μm position resolution with 50 photo-electrons

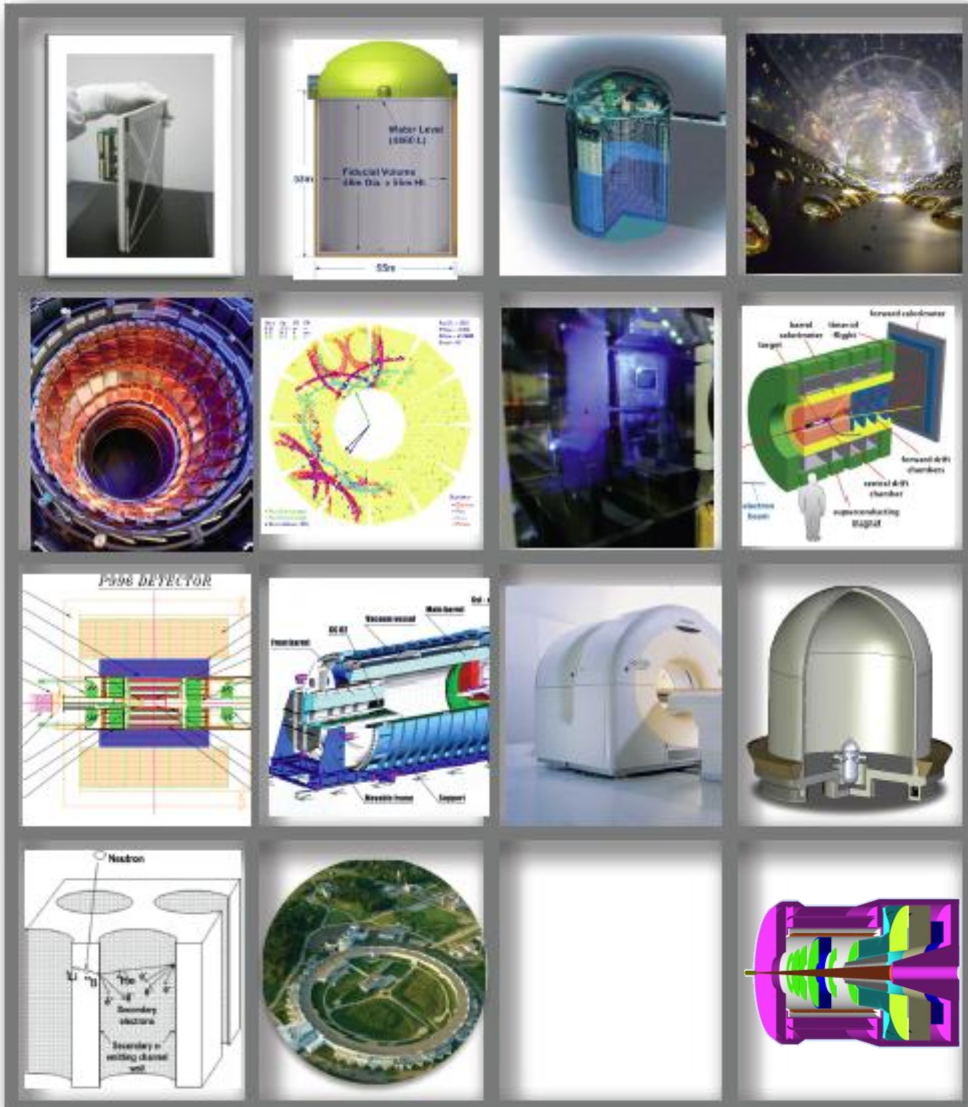
- Achieved 3.8 ps with 50 P.E.
- Naively $\sigma_T \sim 1/\mathrm{sqrt}(N_{PE})$
- 190 um position resolution

Future Plan of LAPPD

- Year 1 (2013)
  - First sealed ceramic tube.
  - **First small (5×5 cm^2) glass body tube.**
  - Complete 8” single tile processing system design.
- Year 2 (2014)
  - Improve/optimize ceramic tube fabrication.
  - Demonstrate individual processing steps.
  - **Fabricate first 8” glass body tube.**
- Year 3 (2015)
  - Establish routine production
  - Customizations for early adopter

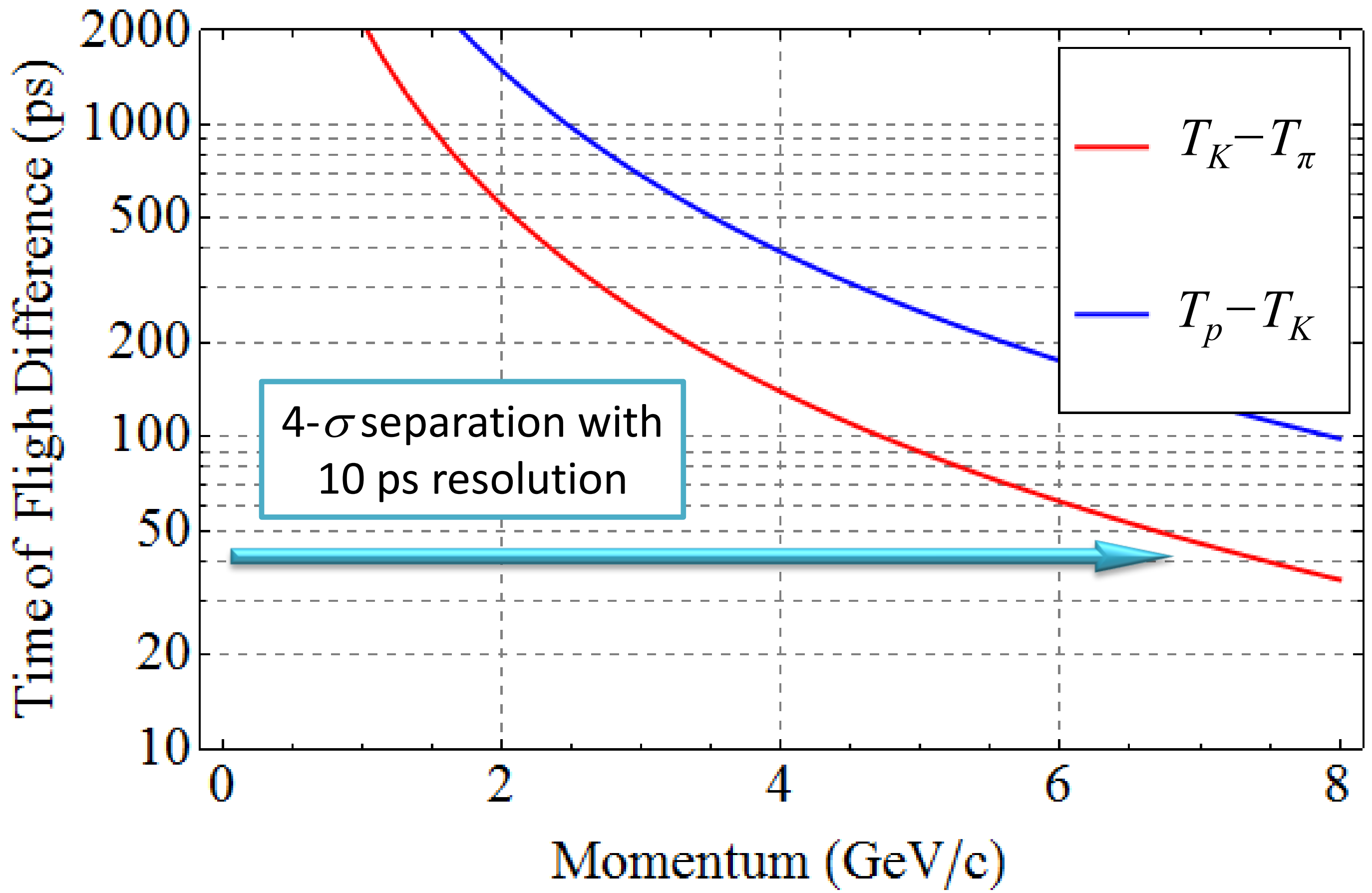
Possible Applications

- Large area photo-detectors with extended capability
- Neutrino experiments
- TOF at collider detectors
- TOF/RICH – PID applications
  - PANDA
  - **Glue-X**
  - **SoLID**
  - **EIC**
- Broader impact
  - X-ray detectors
  - PET
  - Neutron detection
  - Homeland security



PID with TOF at 6 meters

Photons from Cherenkov Radiation in front window induced by relativistic charged particles



* Typical time resolution of RF signal from accelerator is 5 ps

Other Important Numbers

- MCP life time: >> 0.01 C/cm^2
  - 10^6 gain -> 6×10^{10} PE/cm^2 (1kHz P.E./cm^2 -> 700 days)
- Noise Level: < 0.1/cm^2/s
  - comparable to cosmic
- Saturation Current: Unknown
  - Conventional Hamamatsu MCPs: > 2×10^{-6} A/cm^2
  - 10^6 gain -> 1×10^7 PE/s/cm^2
- Radiation Hardness: Unknown
- Cost: $6000 (MCP) + $4000 (Electronics + DAQ)

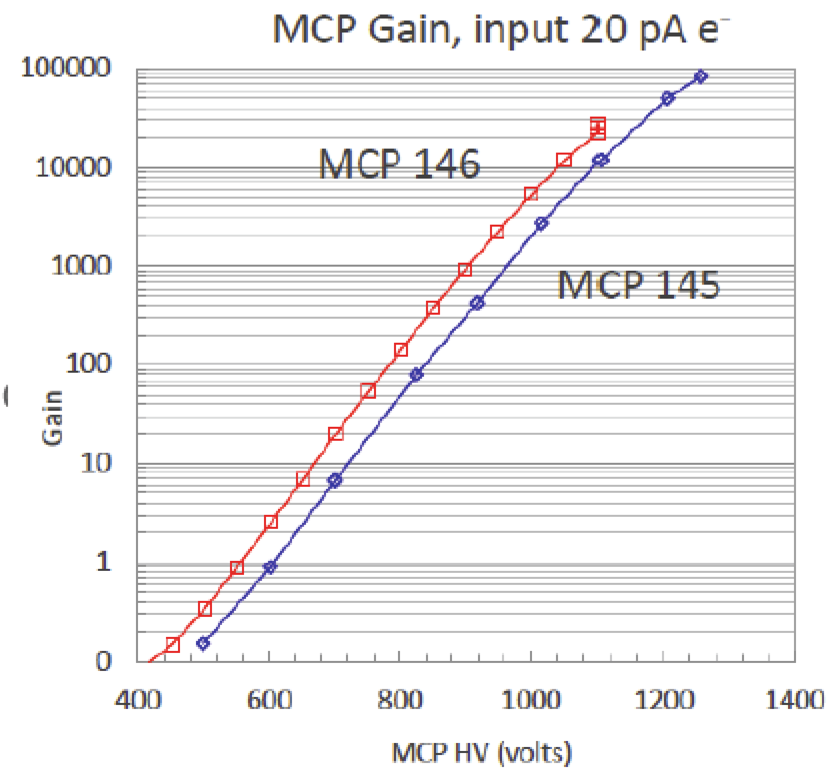
Plans and Resources

- Proposal submitted to DOE ECP by Y. Qiang
  - UPGRADE OF THE GLUEX SPECTROMETER FOR PHYSICS WITH STRANGE FINAL STATES
- Proposal to be submitted to Jlab LDRD by Y. Qiang and C. Zorn
  - Development of Cherenkov Particle Identification Detectors using Micro-Channel Plate Photo-Multiplier Tubes
- Both proposals require MCP-PMTs from LAPPD for testing
- LAPPD DOE review documents:
  - Dec 9, 2011: https://twindico.hep.anl.gov/indico/conferenceDisplay.py?confId=740
  - Dec 18, 2012: https://twindico.hep.anl.gov/indico/conferenceDisplay.py?confId=1201

BACKUP SLIDES

MCP Performance

- Single MCP, 33mm diameter, 20µm pore borosilicate MCP substrate, L:d = 60:1, 8 degree pore bias
- MCP disks functionalized with identical "Chemistry 2" resistive coating and Al_2O_3 SEE layer
- Single MCP tests in DC amplification mo[illegible] imaging and gain very similar to conventional MCPs.
- MCP pair gain of > 10^7 with > 10^5 in a single plate
  - Attractive for cost/simplicity



PSEC4 Waveform Sampling ASIC

- Resolution depends on # photoelectrons, analog bandwidth, and signal-to-noise.
- Simulations showed "pulse sampling" to give the best results