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

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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](http://psec.uchicago.edu)

- Thank Dr. Marcel Demarteau (ANL)
**Micro-Channel Plate-PMTs**

- Ceramic body prototype
- Glass window
- Photocathode
- Micro-Channel Plates (MCPs)
- Anode Strips
- Glass window
- Front-End Elec.

20 × 20 cm²
LAPPD program was a new instrumentation initiative, not an ongoing program; no pre-existing group, started with transient seed funding.
Photocathode

- **Argonne National Lab**
  - Atomic Layer Deposition (ALD)
  - Using Burle ALD equipment
  - 7”×7” flat K$_2$CsSb photocathode was produced
  - Max QE: 22% (350 nm, average: 16%)

- **UC Berkeley**
  - Chemical Vapor Deposition (CVD)
  - Deposited Na$_2$KsSb 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
  - Achieved 3.8 ps with 50 P.E.
  - Naively $\sigma_T \sim 1/\sqrt{N_{PE}}$
  - 190um position resolution

3.8 ps translates in 190 $\mu$m position resolution with 50 photo-electrons
Future Plan of LAPPD

- **Year 1 (2013)**
  - First sealed ceramic tube.
  - First small \((5 \times 5 \text{ cm}^2)\) 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
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**: $\gg 0.01 \text{ C/cm}^2$
  - $10^6$ gain $\rightarrow 6 \times 10^{10} \text{ PE/cm}^2$ (1kHz P.E./cm$^2$ $\rightarrow$ 700 days)

- **Noise Level**: $< 0.1/\text{cm}^2/s$
  - comparable to cosmic

- **Saturation Current**: Unknown
  - Conventional Hamamatsu MCPs: $> 2 \times 10^{-6} \text{ A/cm}^2$
  - $10^6$ gain $\rightarrow 1 \times 10^7 \text{ PE/s/cm}^2$

- **Radiation Hardness**: Unknown

- **Cost**: $6000 \text{ (MCP)} + 4000 \text{ (Electronics + DAQ)}$
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
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 Al₂O₃ SEE layer
- Single MCP tests in DC amplification mode imaging and gain very similar to conventional MCPs.
- MCP pair gain of > 10⁷ with > 10⁵ 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

Measured!