RECENT PROGRESS ON DEVELOPMENT OF MCP-PMT AT ARGONNE NATIONAL LABORATORY

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ARGONNE MCP-PMT FOR EIC-PID

The **Electron-Ion Collider (EIC)** demands excellent particle identification (PID) over a wide range of momenta. Cherenkov (RICH) detectors are essential for high momenta PID.

**Key Issue: Photosensors**

- **Photo Detectors**: The most important challenge is to provide a low-cost, highly-pixelated photosensor working in the high radiation and high magnetic field environment.
- This problem is not yet solved.

- **Large-Area Picosecond PhotoDetector (LAPPD)**
  - Promising but still not fully applicable for EIC needs.

- Optimize LAPPD design relying on ANL MCP-PMT fabrication and characterization expertise
  - Magnetic field tolerance
  - Fine pixel readout
  - Fast timing

R&D testbed: 6x6 cm²
@ ANL

Commercialization: 20x20 cm²
@ Industrial partner (Incom, Inc.)

An order of magnitude lower price per active area comparing to current commercial MCP-PMTs.
a) Full glass/fused silica design with mature fabrication process and low-cost;

b) Fused silica (or borosilicate glass with wavelength shifter) window extending sensitivity down to UV range for better Cherenkov light detection;

c) Newly developed small pore size MCPs for higher magnetic field tolerance and fast timing;

d) Reduced spacing internal geometry further improves the magnetic field tolerance and timing resolution;

e) Capacitively coupled electronic readout through glass/fused silica for pixelated readout scheme.
Optimization of biased voltages for both MCPs: version 1 -> 2
Smaller pore size MCPs: version 2 -> 3
Reduced spacing: version 3 -> 4
Further improvement if needed:
Smaller pore size: 6 μm, version 4 -> 5 (future if required)
DETAILED PARAMETERS AND PERFORMANCE OF ARGONNE MCP-PMT

ANL low-cost MCP-PMT with 10 μm pore size MCPs and reduced spacing

<table>
<thead>
<tr>
<th>MCP</th>
<th>Pore size</th>
<th>10 μm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length to diameter ratio</td>
<td>60:1</td>
</tr>
<tr>
<td></td>
<td>Thickness</td>
<td>0.6 mm</td>
</tr>
<tr>
<td></td>
<td>Open area ratio</td>
<td>70 %</td>
</tr>
<tr>
<td></td>
<td>Bias angle</td>
<td>13°</td>
</tr>
<tr>
<td>Detector geometry</td>
<td>Window thickness</td>
<td>2.75 mm</td>
</tr>
<tr>
<td>Spacing 1</td>
<td>2.25 mm</td>
<td></td>
</tr>
<tr>
<td>Spacing 2</td>
<td>0.7 mm</td>
<td></td>
</tr>
<tr>
<td>Spacing 3</td>
<td>1.1 mm</td>
<td></td>
</tr>
<tr>
<td>Shims</td>
<td>0.3 mm</td>
<td></td>
</tr>
<tr>
<td>Tile base thickness</td>
<td>2.75 mm</td>
<td></td>
</tr>
<tr>
<td>MCP-PMT stack</td>
<td>Internal stack height</td>
<td>5.55 mm</td>
</tr>
<tr>
<td></td>
<td>Total stack height</td>
<td>11.05 mm</td>
</tr>
<tr>
<td>Gain</td>
<td>Gain</td>
<td>$2.0 \times 10^7$</td>
</tr>
<tr>
<td>Time</td>
<td>Rise time</td>
<td>394 ps</td>
</tr>
<tr>
<td>Characteristic</td>
<td>TTS RMS time resolution</td>
<td>88.6 ps</td>
</tr>
<tr>
<td></td>
<td>TTS resolution</td>
<td>35 ps</td>
</tr>
<tr>
<td>Magnetic Field</td>
<td>Magnetic field tolerance</td>
<td>Over 1.5 T</td>
</tr>
</tbody>
</table>

RMS = 88.6 ps
$\sigma_{TTS} = 34.9$ ps

$\sigma_{RMS} < 100$ ps

critical for hpDIRC

B > 1.5 Tesla

J. Xie et al 2020 JINST 15 C04038

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FINE PIXELATED READOUT THROUGH GLASS/FUSED SILICA ANODE

Argonne MCP stack (glass anode) in Fermilab test beam

MWPC tracking used

4 different pixel sizes (2x2, 3x3, 4x4 and 5x5 mm$^2$) implemented for testing
4 mm x 4 mm pixel as example

- All resolutions ~1 mm with small pixels, reaching the requirements for EIC Cerenkov sub-systems.
- Potentially limited by track pointing resolution capability of MWPCs (1 mm pitch)
- 2x2 may be worse due to leakage of signals (poor containment since it is a smaller area)
NEW ARGONNE 10X10 CM² MCP-PMT FABRICATION SYSTEM

✓ Large practically applicable device size: designed for 10x10 cm²
✓ High and uniform QE: uniform heating and substrate rotate mechanism

Construction is currently undergoing.
Aim to complete commissioning of the full system within FY21.

Beneficial projects:
- Pixelated, magnetic field tolerant MCP-PMT for Electron ion collider;
- Radio-pure MCP-PMT for Neutrino less double beta decay;
- Pixelated, fast timing MCP-PMT for Medical isotope detection;
- ……
CURRENT STATUS OF LAPPD COMMERCIALIZATION

The Argonne R&D results were adapted by Incom for LAPPD commercialization: 20x20 cm²

Gain & Timing

Gen-I LAPPD with stripline readout

Gen-II LAPPD with pixel readout

Gain: $4 \times 10^6$ with MCP HV @ 900V

$\sigma$ (TTS) = 64 psec
EXPLORE APPLICATION OF LAPPD\textsuperscript{TM} FOR NUCLEAR PHYSICS PARTICLE IDENTIFICATION

**SoLID**  
SoLID (Solenoidal Large Intensity Device) Light gas Cherenkov counter

**EIC**  
JLEIC: mRICH, hpDIRC and dRICH; TOPSiDE: gaseous-RICH
TEST OF GEN-I STRIPLINE LAPPD AT JLAB

Received Gen-I LAPPD

<table>
<thead>
<tr>
<th>Window material</th>
<th>Fused silica</th>
</tr>
</thead>
<tbody>
<tr>
<td>Readout anode</td>
<td>Inside stripline</td>
</tr>
<tr>
<td>Quantum Efficiency</td>
<td>Mean: 7.3%, Maximum: 11%</td>
</tr>
<tr>
<td>Gain</td>
<td>$5.4 \times 10^6$ with MCPs @ 975V</td>
</tr>
<tr>
<td>Time resolution</td>
<td>56 ps</td>
</tr>
</tbody>
</table>

Experimental high rate background environment

Detector package:
- Cherenkov tank (CO$_2$ at 1 atm)
- Scintillator planes
- Calorimeter blocks
- Photosensors: LAPPD or 4x4 MaPMTs

The first JLab Hall C test shows that the LAPPD might work in the Hall C harsh environment to separate Cherenkov events.

Needs high QE, pixelated LAPPDs for follow up testing.

Ref: C. Peng et al., arXiv:2011.11769

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The 2\textsuperscript{nd} JLab Hall C confirms that the LAPPD works at high rate environment.
With pixelized readout, utilizing geometrical information of pixels could improve the separation.
R&D on optimization of MCP-PMT towards particle identification is ongoing, focusing on design development:
- Magnetic field tolerance
- Timing resolution
- Pixel readout

MCP-PMT with smaller pore size and reduced spacing exhibits significantly improved magnetic field tolerance and timing resolution.

Fine pixel of 3x3 mm$^2$ with position resolution of ~1 mm was achieved with Argonne MCP stack (glass anode) in Fermilab test beam.

Large area picosecond photodetector (LAPPD$^\text{TM}$) adapting the R&D was under commercialization with performance comparable to MCP-PMTs in market.

Tests of the LAPPDs at JLab show encouraging results for their application in nuclear physics programs.
ACKNOWLEDGMENTS

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And many others …

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Thank you for your attention!

Questions?