APPLICATION OF MCP-PMT/LAPPD FOR EIC PARTICLE IDENTIFICATION

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We recommend a high-energy, high-luminosity polarized Electron Ion Collider as the highest priority for new facility construction following the completion of FRIB.

The committee unanimously finds that the science that can be addressed by an EIC is compelling, fundamental, and timely.

EIC white paper, *Developed by US QCD community over two decades.*
THE ELECTRON ION COLLIDER

World’s first Polarized electron-proton/light ion and electron-Nucleus collider

Both designs use DOE’s significant investments in infrastructure, with potentially two interaction points.
EIC DETECTOR REQUIREMENT

Requirement are mostly site-independent with some slight differences in the forward region (IR integration)

In Short:

• Hermetic detector, low mass inner tracking, good PID (e and π/K/p separation) in wide range, calorimetry

• Moderate radiation hardness requirements, low pile-up, low multiplicity
EIC-PID BASED ON CHERENKOV DETECTION

**EIC-PID: Imaging Cherenkov detectors are the primary technology**
- **h-endcap**: A RICH with two radiators (gas + aerogel): $p/K$ separation up to $\sim 50$ GeV/c
- **e-endcap**: A compact aerogel RICH: $p/K$ separation up to $\sim 10$ GeV/c
- **barrel**: A high-performance DIRC: $p/K$ separation up to $\sim 6-7$ GeV/c
EIC-PID PHOTOSENSORS

Low-cost, reliable highly-pixelated (3x3 mm², minimal cross talk) photodetector with high magnetic field tolerance (>1.5 Tesla), long lifetime, high rate capability (≥200 kHz/cm²), and radiation hardness (10 Mrad with 10¹⁵ n/cm²) is needed for Cherenkov detectors for EIC Particle Identification.

SiPM: radiation harness is the major concern, also system cooling design and cost. Photonis pixelated Planacon meets all requirements and available. Cons: Very expensive.

Low-cost LAPPD with performance reaching the requirement could be an alternative of Planacon.
ARGONNE 6 CM MCP-PMT & LAPPD™

Small form factor LAPPD (6 cm MCP-PMT) was produced at Argonne for R&D. Knowledges, Design and Experiences were transferred to Incom to support commercialization of 20 cm LAPPD™.

➢ The Argonne 6 cm MCP-PMT and Incom 20 cm LAPPD™ share the same MCPs and similar internal configuration and signal readout.

➢ The Argonne 6 cm MCP-PMT serves as R&D test bed for performance characterization and design optimization; Incom 20 cm LAPPD™ is the final commercialized product.

➢ Close collaboration and communication (bi-weekly meeting, joint SBIR program), optimized configurations are directly transferred to Incom production line for mass production.

Commercialization: 20x20 cm²
ARGONNE TEST CAPABILITIES

Optical Table for photocathode test

ps-Laser Facility for timing characterization

ANL g-2 Magnetic Field Test Facility

JLab/Fermilab Test Beam Facilities
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 is planned: 6 μm, version 4 -> 5 (future)
MCP-PMT TIMING RESOLUTION IMPROVEMENT

Rise time

<table>
<thead>
<tr>
<th>ANL version 2</th>
<th>ANL version 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="20μm MCP graph" /></td>
<td><img src="image2" alt="10μm MCP graph" /></td>
</tr>
<tr>
<td>$t_r = 536$ ps</td>
<td>$t_r = 439$ ps</td>
</tr>
</tbody>
</table>

Timing resolution (SPE)

<table>
<thead>
<tr>
<th>Counts</th>
<th>Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="20μm MCP graph" /></td>
<td><img src="image4" alt="10μm MCP graph" /></td>
</tr>
<tr>
<td>$\sigma_{TTS} \sim 63$ ps</td>
<td>$\sigma_{TTS} \sim 20$ ps</td>
</tr>
</tbody>
</table>

$\sigma_{MCP-PMT} = \sqrt{\sigma_1^2 - \sigma_{Laser}^2 - \sigma_{Ele.}^2}$

System: $\sigma_1 = 37.2$ ps  
Laser jitter: $\sigma_{Laser} = 30$ ps  
Electronics: $\sigma_{Ele.} = 7$ ps  
$10 \mu m$ MCP-PMT: $\sigma \sim 20$ ps

Suppressed back scattering signal

The ~100 ps RMS timing precision is practically important to enable $3\sigma \pi/K$ separation for the full phase space with designed EIC HPDIRC.
INTEGRATION OF THE PERFORMANCE IMPROVEMENT INTO INCOM DEVICE

Development of New 10 cm × 10 cm High Rate Picosecond Photodetector (HRPPD)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Large Area Picosecond Photodetector (LAPPD™)</th>
<th>High Rate Picosecond Photodetector (HRPPD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Picosecond Time of Flight</td>
<td>PET, TOF, UV Imaging</td>
</tr>
<tr>
<td>Detector Size</td>
<td>20 cm × 20 cm</td>
<td>10 cm × 10 cm</td>
</tr>
<tr>
<td>UHV Package Design</td>
<td>X-Spacers window support -&gt; creates dead zones</td>
<td>X-Spacer free -&gt; large effective area</td>
</tr>
<tr>
<td>Window</td>
<td>Fused Silica, B33 Glass</td>
<td>UV Fused Silica, MgF₂</td>
</tr>
<tr>
<td>λ Sensitivity</td>
<td>200 (300 for B33) - 600 nm</td>
<td>115 - 400 nm</td>
</tr>
<tr>
<td>Photocathode</td>
<td>Bialkali</td>
<td>UV optimized Bialkali</td>
</tr>
<tr>
<td>MCP Pore Size</td>
<td>20 μm &amp; 10 μm</td>
<td>10 μm</td>
</tr>
<tr>
<td>MCP Stack</td>
<td>B-Field Optimized</td>
<td>B-Field Optimized</td>
</tr>
<tr>
<td>Anode</td>
<td>Direct readout of thick film strips or capacitive readout with application specific patterned anode</td>
<td>High density pixelated anode with direct or capacitive readout</td>
</tr>
<tr>
<td>Lower Tile Assembly</td>
<td>Side walls hermetically sealed to anode</td>
<td>Side walls hermetically sealed to anode</td>
</tr>
<tr>
<td>Connections</td>
<td>Through Frit Seal -&gt; 2 side abutable</td>
<td>Through anode -&gt; 4 side abutable with minimum dead space</td>
</tr>
</tbody>
</table>

Work with Incom on timely delivery of HRPPD applicable for EIC-PID.
BaF$_2$:Y fast component shows 260 ps rise time, 600 ps decay time, MCP-PMT is the only PMT for such fast light detection.

Slow component of BaF$_2$ scintillation light was significantly suppressed by BaF$_2$:Y doping.

Solar blind photocathode (Cs-Te) further suppresses the slow component, enabling fast calorimeter.
An MCP-PMT with low resistances \(~300 \text{ kOhms}, \) not functional at room temperature.

Clear signal was observed at liquid \(\text{N}_2\) condition with increase of the resistance.

MCP-PMT is workable at cryogenic temperature.
SUMMARY

The U.S. based high-energy high luminosity polarized Electron Ion Collider (EIC) is quickly moving towards DOE “Mission Need” statement.

The EIC physics program demands excellent tracking resolution and particle identification (PID) coverage over a wide range of momenta to achieve the highest precision.

Imaging Cherenkov techniques (dRICH, mRICH and HPDIREC) were considered for proposed EIC detector concepts for momentum coverage up to 50 GeV/c.

An important challenge for EIC-PID is to provide a reliable highly pixelated photosensor working in high radiation and high magnetic field environment.

Magnetic field immunity, timing resolution approached EIC-PID requirement and integrated into Inom process for device fabrication.

Solar blind and cryogenic workable MCP-PMTs are possible with R&Ds.
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The LAPPD collaboration, The EIC PID consortium

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Thank you for your attention!

Questions?
CD0 = DOE “Mission Need” statement; CD1 = design choice and site selection
CD2/CD3 = establish project baseline cost and schedule