## FY27 NPP LDRD Type B Pre-Proposal

# Development of a hybrid MCP-PMT with an integrated TimePix4 readout for EIC Detector II

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Proposal title: “Development of a hybrid MCP-PMT with an integrated TimePix4 readout for EIC Detector II”

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Other Investigators: Babak Azmoun, Martin Purschke [, Michael Minot (Incom Inc.), Thorbjoern Schoenbeck (ASI, Netherlands)]

Indicate if this is a cross-directorate proposal: No

If yes, identify other directorates/organizations: N/A

Proposal Term: From: 10/01/2026 To: 09/30/2028

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Several Particle Identification (PID) subsystems of the future Electron-Ion Collider (EIC) Detector II will require single photon detection with a high efficiency, spatial and temporal resolution, as well as an extended photosensor lifetime and a high-performance data driven readout. We propose to build a functional 2” Micro-Channel Plate Photomultiplier (MCP-PMT) with a 2x2 matrix of TimePix4 chips integrated into its ceramic anode plate, as a photon detector prototype for these PID subsystems.

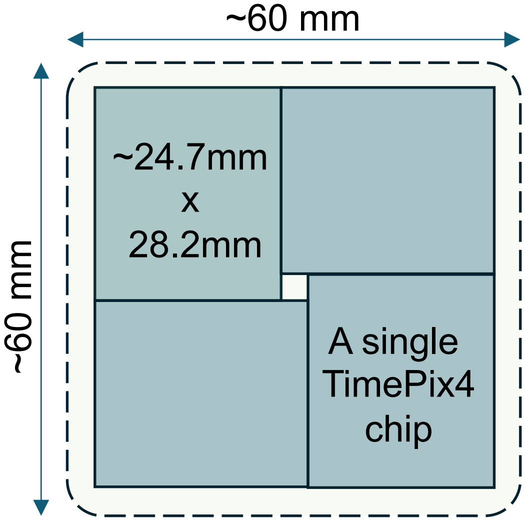
Program: NP

Return on Investment & broader impact on the activities at the laboratory: Proposed R&D will allow BNL to acquire expertise in building large area vacuum photosensors with an integrated readout. Such hybrid MCP-PMTs, both in a 2” and a 4” formfactor implementation, can find their application in other new NP and HEP experiments with BNL participation, and existing experiment upgrades where a high-performance single photon detection is required. They can further be used in medical applications like Positron Emission Tomography (in a multi-photon mode of course).

Total planned funding in FY27 and FY28: $250k / year for 2 years

# Technical concept

- Place TimePix4 chips inside of the MCP-PMT vacuum volume and pack four of them in a conventional 2” MCP-PMT footprint



~60 mm

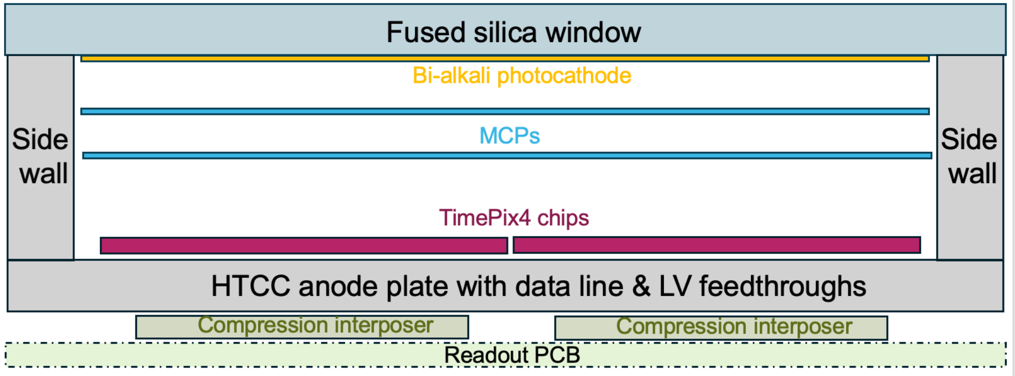
~60 mm

~24.7mm x 28.2mm

A single TimePix4 chip

A 2” MCP-PMT with
70-75% geometric efficiency

Side view of the stackup



Fused silica window

Bi-alkali photocathode

MCPs

TimePix4 chips

Side wall

Side wall

HTCC anode plate with data line & LV feedthroughs

Compression interposer

Compression interposer

Readout PCB

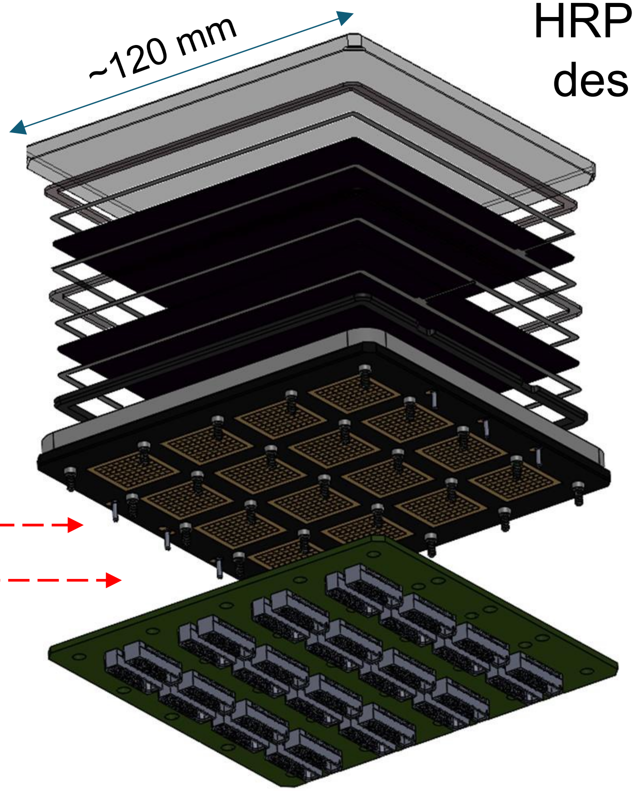
- Expected performance: few hundred μm spatial and <60 ps temporal resolution, achieved with a gain as low as few times $10^4$
  - Meaning a drastic improvement in the photosensor lifetime (reduced ion backflow) as well as in a hit occupancy these photosensors will tolerate

- Recycle know-how developed during EIC High-Rate Picosecond Photodetector (HRPPD) design and test production, see next slide

- Hopefully, be the first ones to build a functional MCP-PMT in a multi-TimePix4 TSV (Through Silicon Vias) tileable configuration

# Available expertise

- Incom
  - One of the (very) few vendors active in multi-anode MCP-PMT R&D
  - In-house ALD MCP production, photocathode deposition, MCP-PMT sealing and testing
  - Have successfully completed production of the first ten EIC HRPPDs (a 4” MCP-PMT variety)
- BNL
  - Multi-layer High-Temperature Co-fired Ceramic EIC HRPPD anode and compression interposer based interconnect designs
  - Several HRPPD test stations, including a femtosecond laser and aging setups, as well as a setup to perform B-field resilience measurements



EIC HRPPD design

- ASI
  - Several implemented and in-progress TimePix3/4 based specialized detectors
  - Expertise in related FPGA hardware and programming
  - TimePix4 license

| 3D-ED | Ultrafast EM | 4D-STEM | Ultrafast EELS |
|---|---|---|---|
| M3 T3 T4 | T3 T4 | M3 T3 T4 | M3 T3 T4 |
| • M&T3: 1x1, 2x2, 2x4, 4x4<br>• T4: 1x1, 2x2<br>• Fully integrated workflow with SerialEM, Instamatic, CEOS PanthaRhei, NanoMEGAS | • T3: 1x1, 2x2, 2x4<br>• T4: 1x1<br>• Integration with other timing devices and pump probes via TDC<br>• Python interface<br>• Luna analysis package | • M3&T3: 1x1, 2x2, 2x4<br>• T4: 1x1, 1x2, 2x2<br>• Fully integrated solution and workflow with LiberTEM<br>• Live Preview, virtual detectors<br>• Prepared for riCOM | • M3&T3: 1x1, 2x2, 2x4<br>• T4: 1x1, 1x2, 2x2<br>• CEOS PantaRhei integration<br>• Live Preview and synchronization with scan engine |

# Work plan

- Year 1: R&D with a demountable vacuum chamber setup
  - Decide on the footprint parameters; design and prepare MCPs, side walls, windows, fixturing
  - Design and build compression interposer interconnect and FPGA interface
  - Use TimePix4 on FR4 carrier board as a 1:1 mockup of the final MCP-PMT design anode plate
  - Use a robust low efficiency (metal) photocathode + a pair of MCPs in a demountable chamber
  - Model and / or tune stackup gaps, cooling setup, *bump bonding and bakeout regimes*
  - Establish expected performance parameters: gain, thresholds, spatial & temporal resolution
  - Order Kyocera High-Temperature Co-fired Ceramic (HTCC) anode plates

- Year 2: Build and test a functionalized sealed 2” MCP-PMT
  - Kyocera ceramic anode plate, 2x2 TimePix4 chips, MCPs, side walls, …
  - …, Bi-alkali photocathode on a fused silica window, UHV sealed package

  - Cooling system, high-speed interconnect & FPGA interface will be inherited from Year 1

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Make anode plates | → | Attach (frit) side walls | → | Bump bond TimePix4 chips | → | Build a functional MCP-PMT | → | Do final testing |
| Kyocera | | Incom | | ASI | | Incom | | BNL |

# Summary Slide & Budget request

- We propose building a novel 2” MCP-PMT with four TimePix4 ASICs integrated into the anode plane design, for single photon Cherenkov PID subsystems of EIC Detector II and other NP / HEP experiments
- We have all the necessary expertise to accomplish this task on a time scale of two years
- This R&D will strengthen BNL leading role in high-end physics instrumentation

| | Year 1 | Year 2 |
|---|---|---|
| Demountable vacuum chamber construction labor and materials @ BNL | $10k | |
| 10% FTE Alexander Kiselev | $20k | $20k |
| 5% FTE Babak Azmoun | $10k | |
| 5% FTE Martin Purschke | | $10k |
| Procurement of Kyocera anodes & Neoconix compression interposers | $70k | |
| MCP-PMT design and fixturing @ Incom | $35k | |
| Procurement of MCP-PMT components (side walls, windows, spacers, etc) | | $25k |
| MCP-PMT assembly / testing labor and materials @ Incom | | $60k |
| TimePix4 ASICs, interfacing M&S @ ASI (labor is in-kind) | $45k | $70k |
| **Total** | **$190k** | **$185k** |

*BNL overhead is not included*