

LAPPD / HRPPD status and FY23 plans

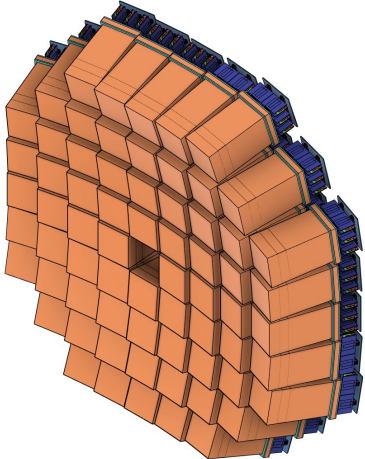
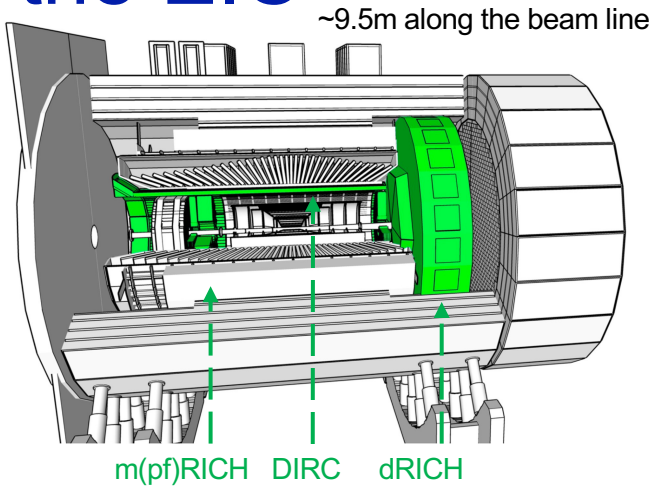
Alexander Kiselev (BNL)

eRD110 Consortium Meeting, February 20, 2023

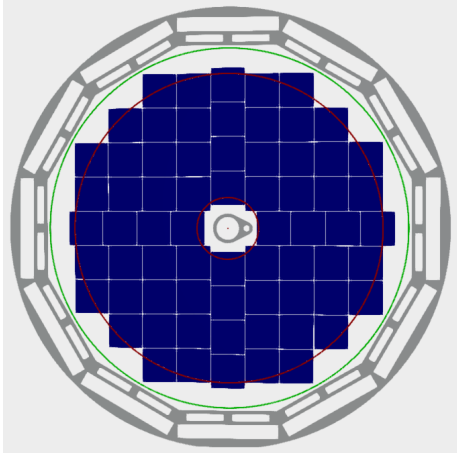
Possible LAPPD applications for the EIC

- mRICH / pfRICH: low dark noise, ToF capability (vs SiPMs)
- DIRC: expected to be more cost-efficient (vs other MCP-PMTs)
- dRICH: problematic, because of the magnetic field orientation

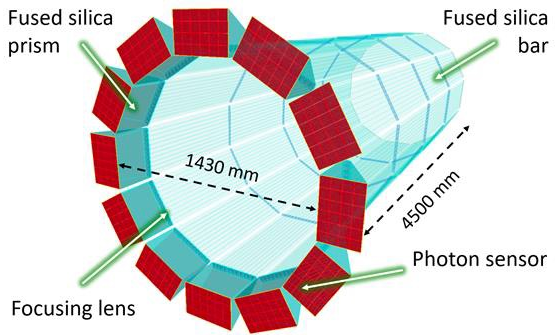
mRICH / pfRICH	either DC-coupled or Gen II, 10cm formfactor
DIRC	DC-coupled, 10cm



mRICH: 68 HRPPDs total



pfRICH sensor plane: 68 HRPPDs total



DIRC: 12*3*2 = 72 HRPPDs total

FY22 milestones completion

- 20 μm pore Gen II LAPPD magnetic field tolerance measurements at Argonne - Summer 2022; STATUS: accomplished
- Various Gen II LAPPD readout boards designed for the Fermilab beam test and delivered to BNL - May-June 2022; STATUS: accomplished
- Test stand setup and commissioning at INFN - April 2022; STATUS: accomplished in June 2022

- Fermilab beam test with a new capacitively coupled 10 μm pore LAPPD - June 2022; STATUS: accomplished, data analysis in progress (report due in December 2022)
- Gen II LAPPD single photon position resolution report by BNL (bench tests and beam tests with finely pixelated readout boards) - September 2022; STATUS: to be completed, preliminary results reported at ICHEP in July 2022

- Single and multiple photon timing resolution bench tests report by INFN - September 2022; STATUS: test beam to accomplish this goal is taking place at CERN in October 2022; preparation to the test beam is completed

- Magnetic field tolerance report by Argonne - September 2022; STATUS: to be completed
- Preliminary assessment of the LAPPD / HRPPD feasibility for the EIC detector - by December 2022; STATUS: in preparation

Talk: [CPAD 2022](#)

Talk: [ICHEP 2022](#)

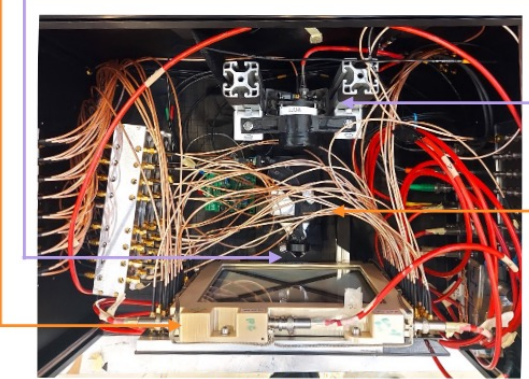
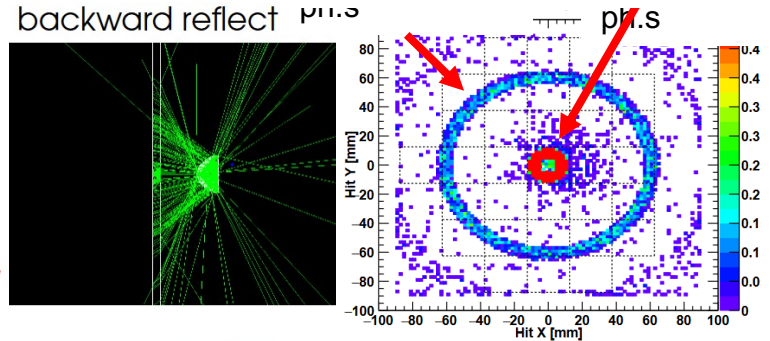
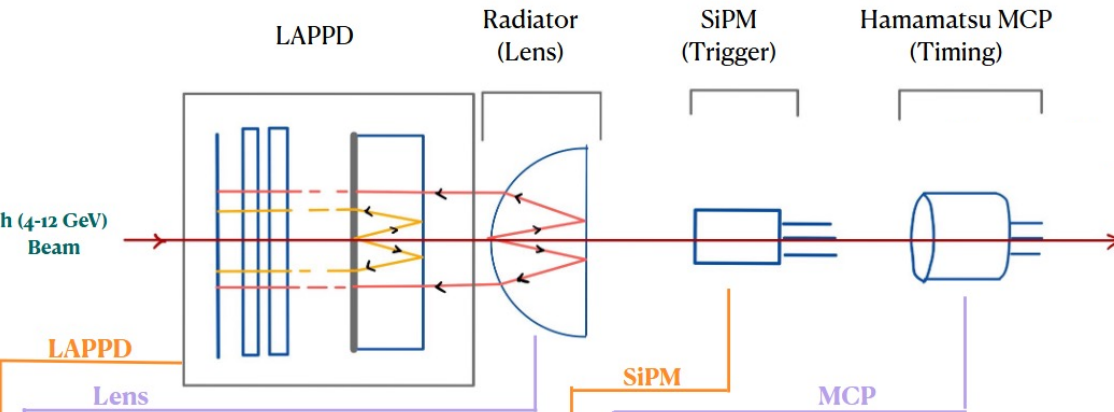
Talk: [CPAD 2022](#)

Talk: [ePIC GD/I Mtg](#)

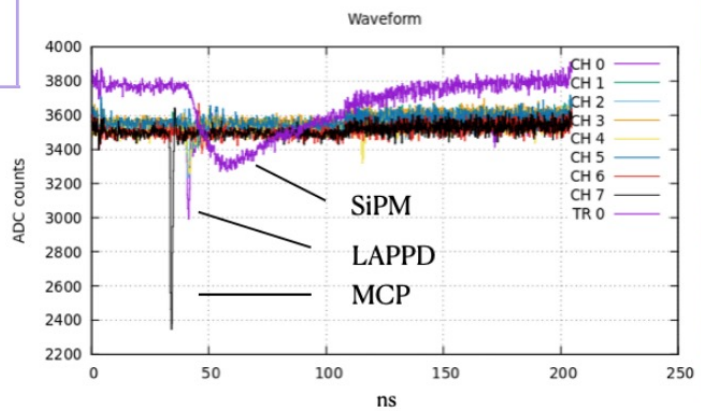
See also appendix B.1 in FY23 proposal

Beam test at CERN, October 2022

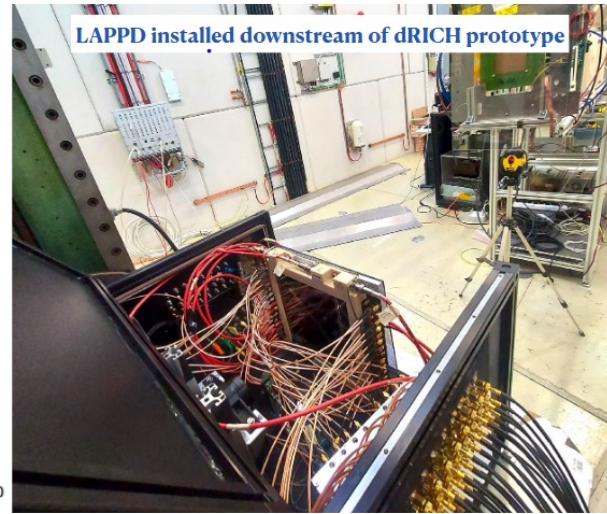
Simulation studies



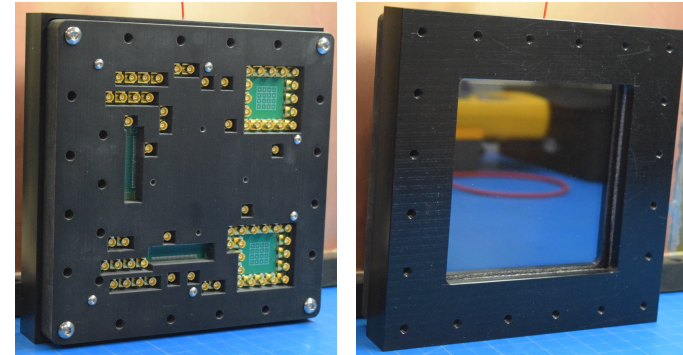
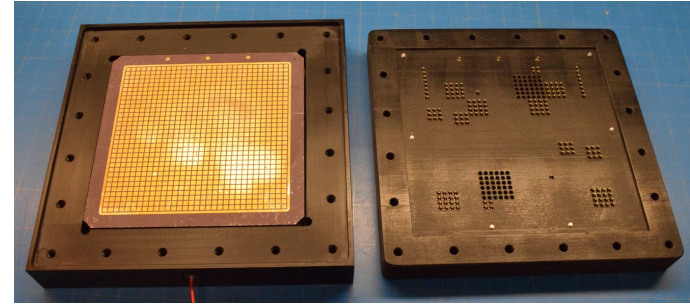
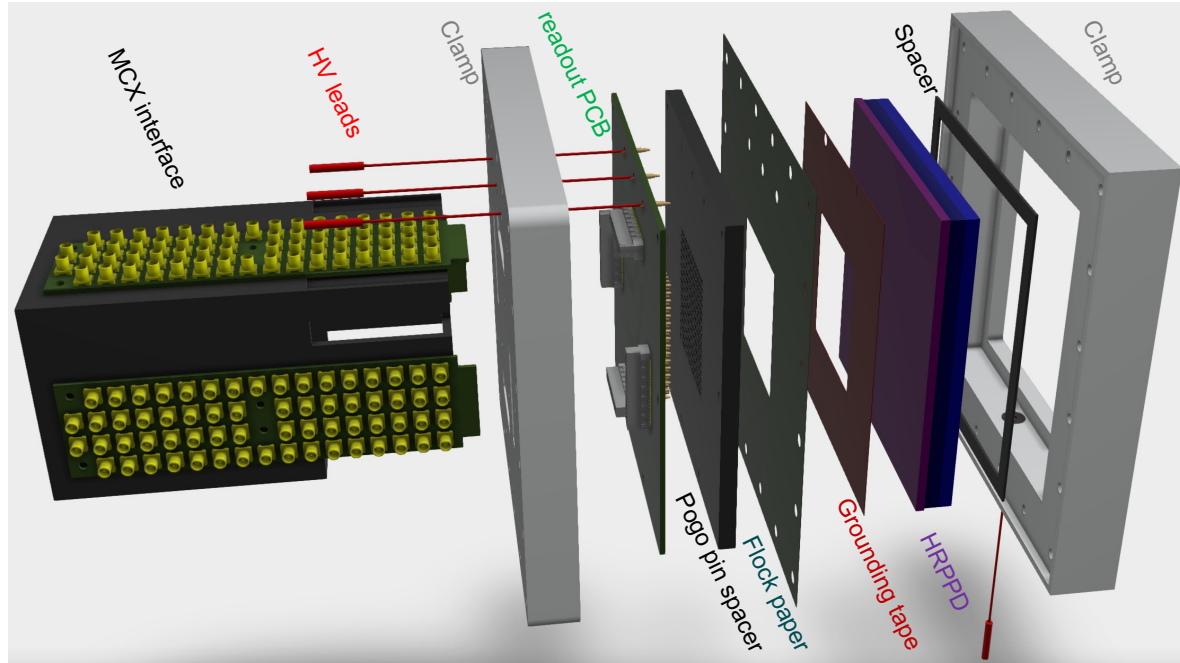
Setup inside the dark-box



Online Signals



DC-coupled HRPPD evaluation



- Setup was commissioned mid December
- Then HRPPD #4 got broken
- Saw signals, confirmed small charge sharing
- Expecting #6 after Argonne tests

FY23 R&D plan

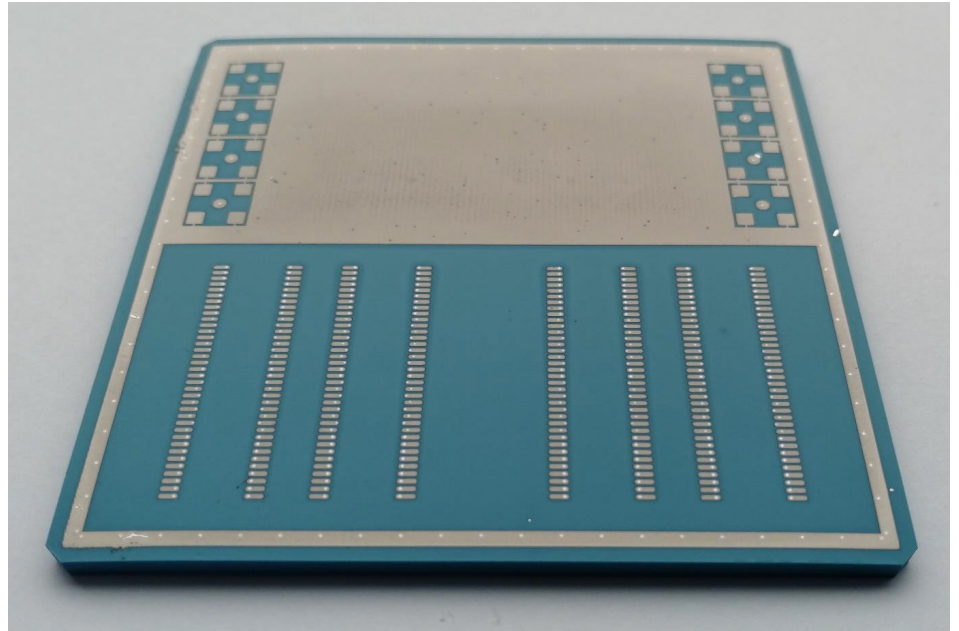
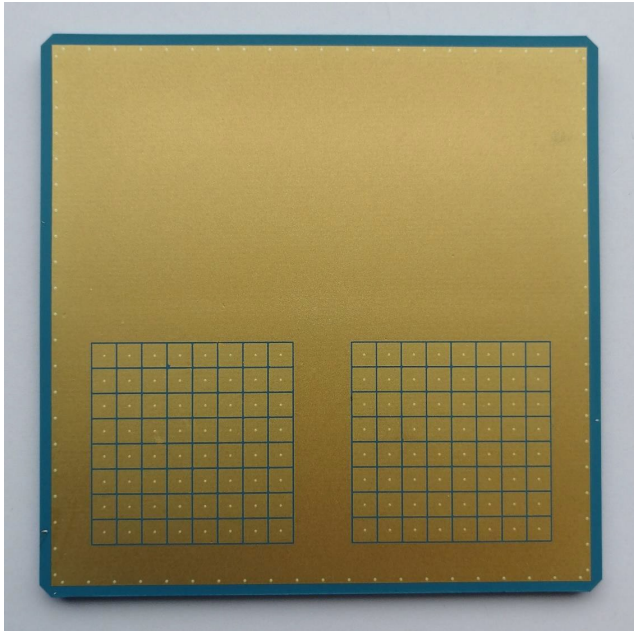
2.3 R&D plan for FY23

The work plan foresees activity in five different areas:

- Development of the mechanical and electrical interface to the HRPPD with a direct pixel readout
- Characterization of the more advanced LAPPD and HRPPD prototypes with a goal of obtaining a detailed understanding of the role of several key parameters affecting the sensor performance, such as: the MCP pore diameter, the thickness and material of the readout board (in resistive anode devices), spacing between the stack elements inside the detector, as well as a direct comparison of resistive-anode versus internally pixelized HRPPD
- Tests of LAPPDs and HRPPDs in a high magnetic field oriented at non-zero angles to the detector plane, specific to the particular anticipated locations of these sensors in the ePIC detector PID sub-systems. B-field tests are independently planned at ANL and at CERN of different tiles with direct and capacitively-coupled readout and different MCP pore size. The tests are complementary, given the need to determine and validate the B-field performance across tiles with various characteristics.
- Further LAPPD / HRPPD spatial and timing resolution optimization for different pad sizes, also using moderate low-noise signal preamplification
- A joint effort with eRD101 to study in a test beam mRICH equipped with LAPPD is considered

HRPPD packaging & pixellation

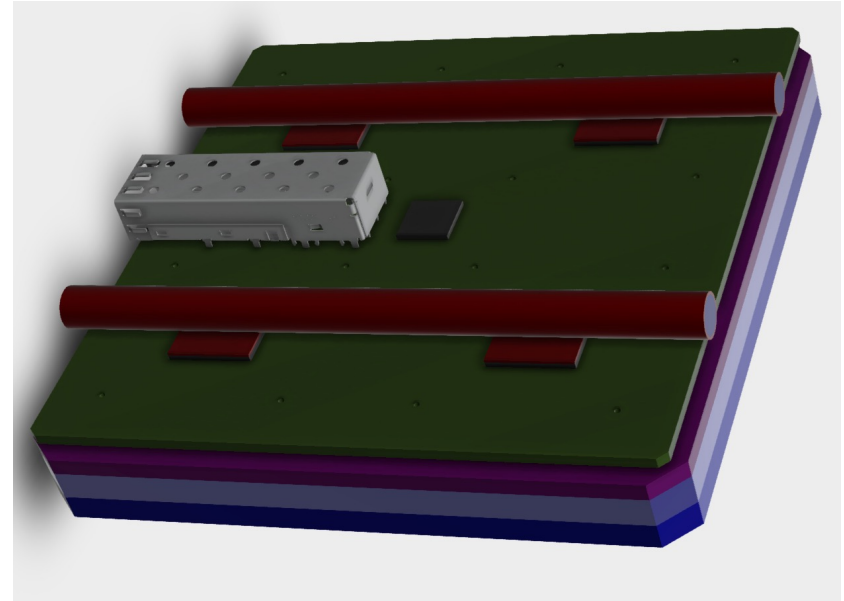
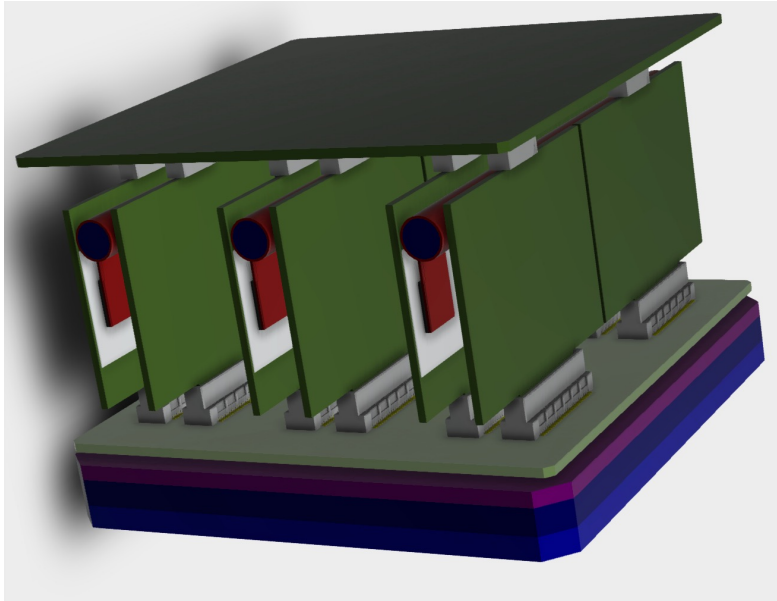
- Techtra produced a second (thinner) 3" HRPPD anode base plate prototype
- Flatness is a bit of an issue, but plating became better
- Will see both parts at Incom & BNL in ~two weeks



Goal: variable pixellation “on demand”, potentially different for pf(m)RICH & DIRC

HRPPD front end electronics

- Consider departing from WFD ASICs and switching to ToA/ToT(ADC) ones
- EICROC: a solution for AC-LGAD ToF layers, supported by the EIC project
 - Will have a joint meeting with the experts beginning of March



HRPPD-to-ASIC interface

- Have a number of options how to interface EICROC-like electronics
 - Use Samtec high density compression interposers?
 - Fallback solutions: soldering or conductive epoxy gluing

COMPRESSION HARDWARE

ULTRA LOW PROFILE SYSTEMS FOR Z-RAY® INTERPOSERS

- Designed for Z-Ray®, the lowest profile, most flexible high-density micro interposer in the industry (ZA8 and ZA1 Series)
- Precise alignment, compression and retention of interposers with either dual compression (LGA) or single compression with solder balls (BGA)
- Ultra low profile
- Reduces risk of damage to the interposer
- ZSO Series for single compression with solder balls
- ZHSI and ZD Series for dual compression interposers

Protects solder ball joints when compressed

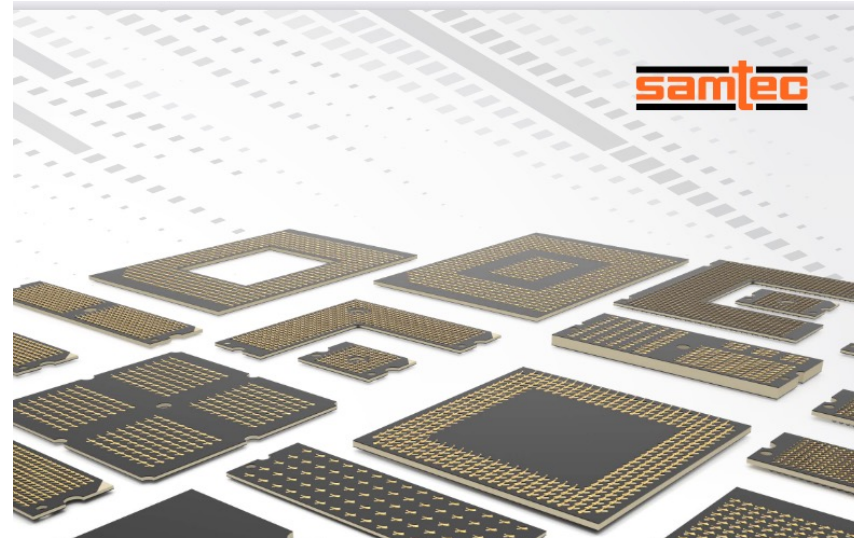
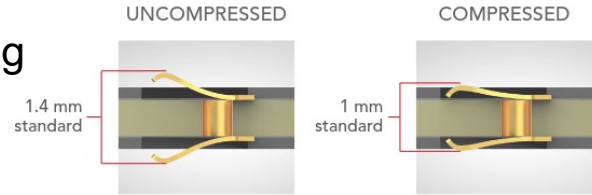
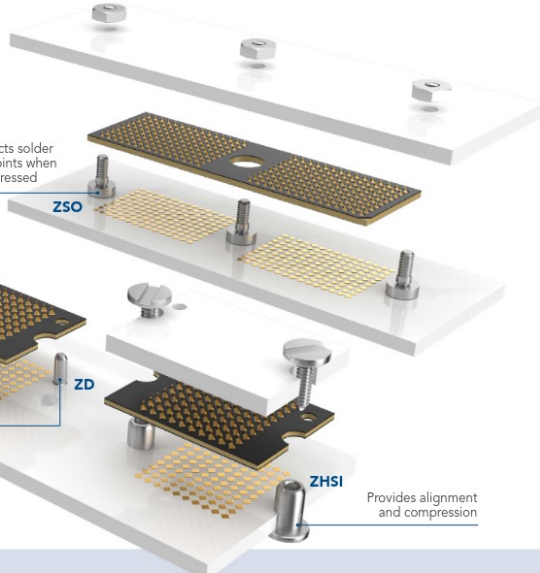
ZSO

ZD

Provides alignment

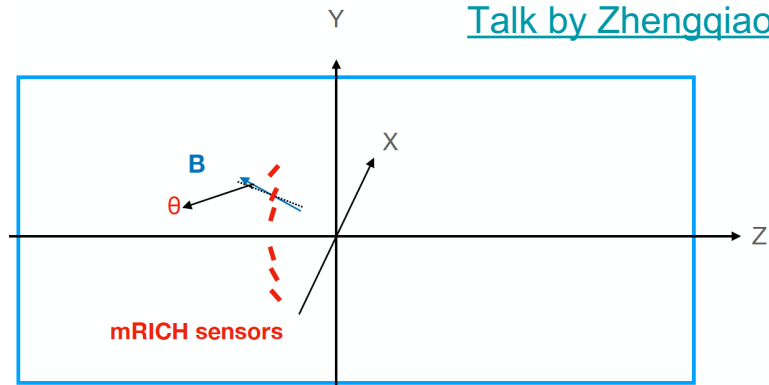
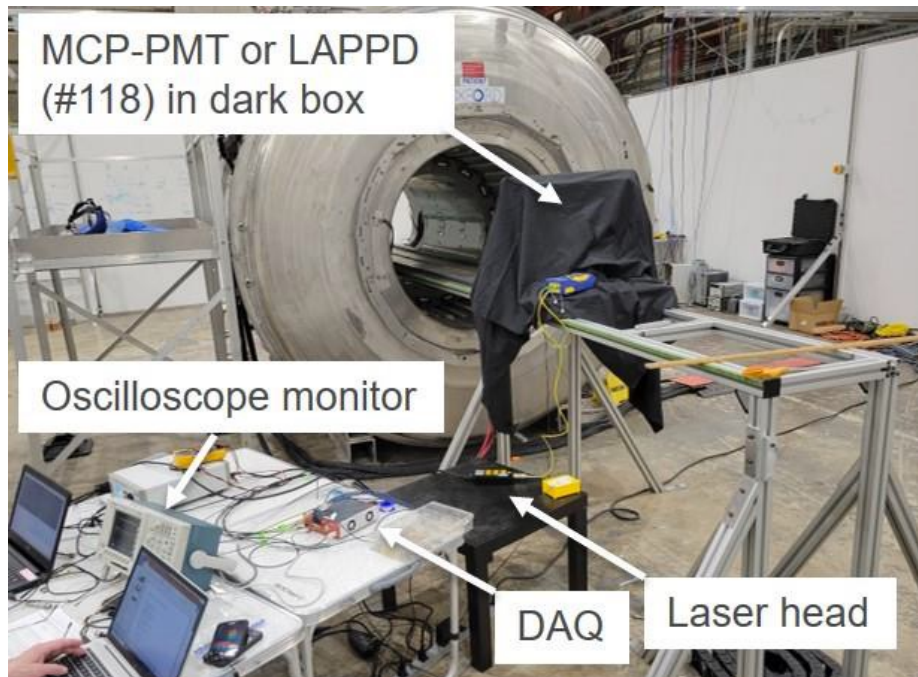
ZHSI

Provides alignment and compression



samtec

Magnetic field measurements in Argonne



Radius (mm)	Z (mm)	B (T)	theta (degree)
60	-1727	1.230	0.788
466	-1727	1.251	5.511
495	-1727	1.254	5.771
524	-1727	1.258	6.018
553	-1727	1.261	6.246
582	-1727	1.265	6.462
611	-1727	1.269	6.658
640	-1727	1.274	6.836

- Recently upgraded to 3T max field
- This campaign: 2x LAPPDs & 1x HRPPD
- Reference $\{B, \alpha\}$ configurations for pfRICH, mRICH, DIRC & dRICH provided

[Proposed measurement program](#)

FY23 milestones & FY24 preview

2.3.1 Proposed milestones for FY23

- Mechanical and electrical interface to the HRPPD with a direct pixel readout: May 2023.
- Characterization of three different state-of-the-art LAPPD/HRPPD prototypes, in particular gain and QE uniformity: Sep 2023.
- Gain and timing resolution characterization in magnetic field of two different advanced LAPPD/HRPPD prototypes (10 μm vs 20 μm pore size, angle dependence): April 2023. Report results: Sep 2023.
- Report on the simultaneous spatial and timing resolution optimization: Sep 2023.

2.3.4 Preview of remaining R&D in FY24

The mechanical and electrical interface to the HRPPD with a direct readout may require further iterations using custom low force spring loaded LGA sockets. Beam test with either the mRICH (together with eRD101) or a simple proximity focusing RICH prototype equipped with a selected LAPPD photo-sensor type may not happen in FY23 and be postponed till FY24, pending the successful mRICH beam test validation with the MaPMT sensors in FY23. Newest Incom state-of-the-art LAPPD / HRPPD models may require separate evaluation in FY24. A joint with eRD109 effort in building an integrated sensor+ASIC board assembly is foreseen in FY24.

FY23 budget

	ANL	INFN GE/TS	INFN BO/FE/CS	MSU	BNL	JLab	UC EIC	USC
Photosensor	LAPPD	LAPPD	SiPM	LAPPD	LAPPD	LAPPD	SiPM	LAPPD
Laser for timing measurement			\$20,000					
Irradiation costs			\$14,000					
SiPM engineering run support			\$20,000					
FPGA eval board for SiPM Readout			\$7,500					
B-field facility maintenance, Helium consumption	\$10,000							
Staff effort support	\$18,000							
Engineering/technical support	\$15,000				\$5,000			
LAPPD, consumables for mag. field studies		\$6,000						
SiPMs (NDL sensors)							\$5,000	
Postdocs and students		\$20,000	\$40,000				\$5,000	
Travel		\$20,000		\$12,000	\$15,000	\$5,000		\$4,000
LAPPD/HRPPD rentals		\$24,000			\$24,000			
HRPPD interface					\$5,000			
PHOTONIS FT-8 reference MCP-PMT					\$12,000			
LAPPD readout boards and preamp interface					\$5,000			
LAPPD test stand equipment					\$3,000			
TOTAL	\$43,000	\$70,000	\$101,500	\$12,000	\$69,000	\$5,000	\$10,000	\$4,000

EIC leadership meeting with Incom Inc.

- Site visit on 01/12/2023
- Indico page: <https://indico.bnl.gov/event/18093/>
- EIC: Elke Aschenauer (remotely), Silvia Dalla Torre, Thomas Ullrich, Craig Woody, AK
- Incom Inc.: management team including Michael Detarando (CEO), LAPPD research team led by Michael Minot
- Now: prepare a “staged” EIC / Incom contract for the next ~18 months:
 - Specifications (EIC), SOW (Incom)
 - Phase I: finalize remaining R&D to the extent needed
 - Will be critical for the rest of the contract
 - Will partly depend on the outcome of the March e-endcap RICH review
 - Will to a large extent depend on the success of the “configurable LTCC pixellation” exercise
 - Phase II: procure 4-5 HRPPDs
 - Phase III: perform bench tests and beam test evaluation well ahead of the CD-2 review

eRD110 blessing is required by EIC Project

Risk mitigation strategy

Executive Summary

The objective of the R&D effort presented here is to mitigate technical, cost, and schedule risk related to readout sensors of EIC Cherenkov detectors and calorimeters. The call for this proposal requests that this R&D effort comes to a clear and well-informed decision for a baseline sensor solution for each of these detectors. The proposed R&D effort in FY23 (following the one submitted and funded in FY22) continues to be necessary to be able to form a decision that capitalizes on all state-of-the-art technologies to mitigate all of the risks specified above. This report also contains information on the results achieved during FY22 by the consortium. The decision about a low-risk photosensor baseline solution will be based on the assessment whether each sensor under consideration (1) satisfies the technical requirements of each detector, (2) has an acceptable cost, and (3) can be delivered by the manufacturer in the required quantities within the timelines of the project, and with consistent performance quality across the sensor units.

(1) Make EIC specs a requirement for sensor production

(2) By now we know the expected costs

(3a) We convinced ourselves Incom can scale the production

(3b) Will order five tiles by end of 2023 and see the spread

Full manufacturing (EIC Order) →

- **\$20,000 to \$10,000**
- **\$200/cm² to \$100/cm² for HRPPD**

(as confirmed on 01/12/2023)

Other news

- “EICROC for EIC HRPPD/MCP-PMT photosensors” meeting will take place in March 2023
 - A definitive “yes or no” assessment
 - If “yes”, work out R&D / PED plan together with eRD109
- LAPPD Workshop #3 will take place in April 2023
 - Special topic: ASIC electronics
- LAPPD #144 (late delivery from FY22) received at BNL as a four-month rental
- HRPPD #4 got broken over Christmas and was shipped back to Incom
- Expecting HRPPD #6 as a replacement after Argonne magnetic field tests
- BNL team ordered a Menlo Systems femtosecond laser for LAPPD research