eRD110 – Photosensors

FY24 report & FY25 proposal

Alexander Kiselev (BNL) on behalf of the eRD110 Consortium:

Argonne National Laboratory, Brookhaven National Laboratory, Catholic University of America, Friedrich-Alexander-Universit¨at Erlangen-N¨urnberg, Helmholtzzentrum f¨ur Schwerionenforschung, Istituto Nazionale di Fisica Nucleare (Genova), Istituto Nazionale di Fisica Nucleare (Trieste), Thomas Jefferson National Accelerator Facility, University of Glasgow, University of South Carolina, Yale University

ePIC / EIC Project Detector Advisory Committee meeting, August 29, 2024

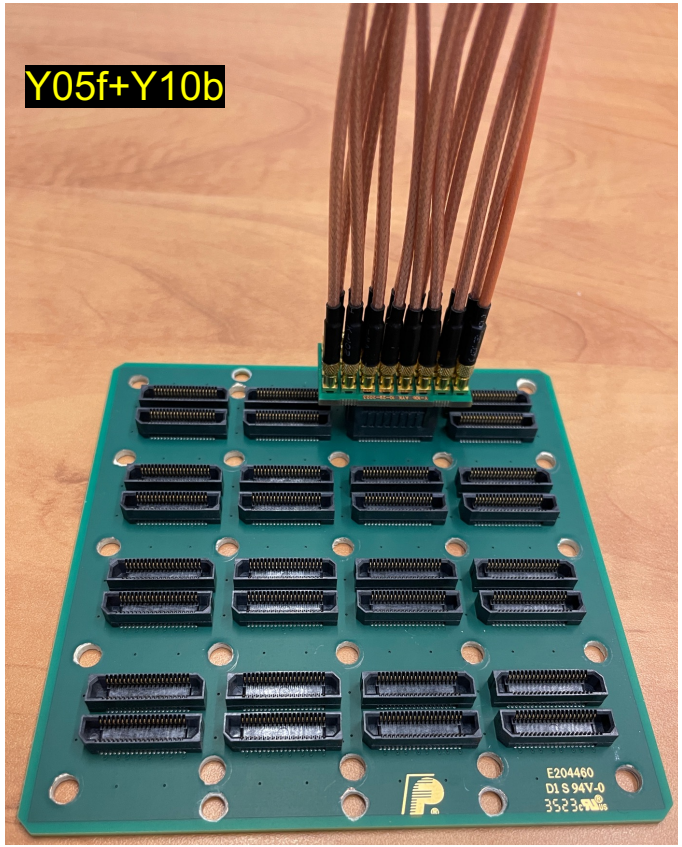
FY24 report

HRPPD / MCP-PMT evaluation activities & funding

eRD110 proposal topics as of August 2023	Actual funding	Status & plans
Samtec interposers purchase	Not funded	Ordered using FY23 carryover money
HRPPD passive interface	Not funded	Built using FY23 carryover money
HRPPD ASIC backplane	Not funded	
B field studies at Argonne	MCP-PMT evaluation only	Postponed; now moved to early 2025
B field studies at INFN	Not funded	
Beam test at Fermilab	Cancelled	Focus on lab studies in 2024
HRPPD ageing studies at INFN	FY24 funding granted	Technique developed using an LAPPD
HRPPD QE evaluation at Argonne	Not funded	
HRPPD PDE evaluation at BNL	Not funded	
Timing upgrade at BNL	FY24 funding granted	Pretty much completed
MCP-PMT evaluation at Glasgow	FY24 funding granted	Setup upgrade completed

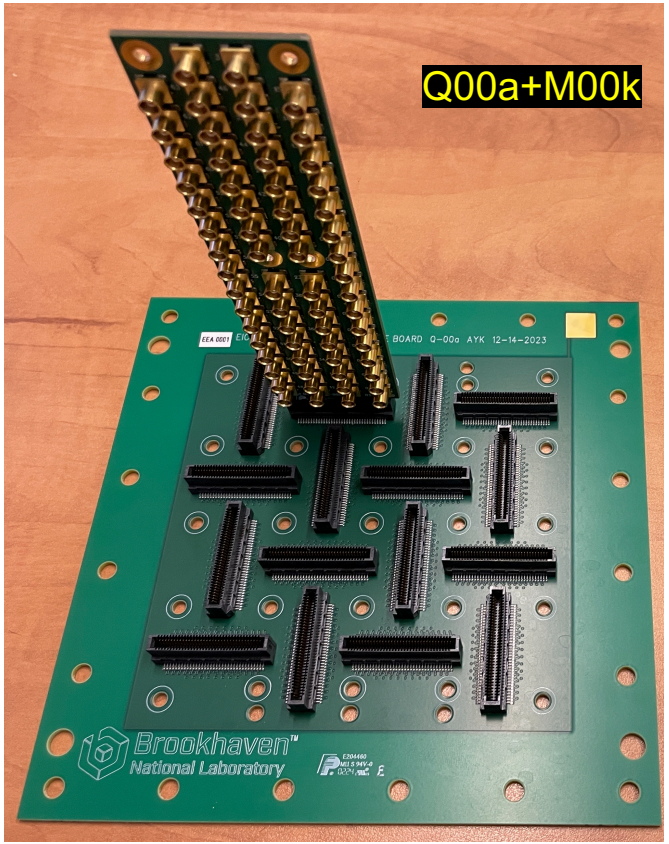
None of the "HRPPD evaluation" items was approved

EIC HRPPD passive interfaces



For setups with a low electronics channel count

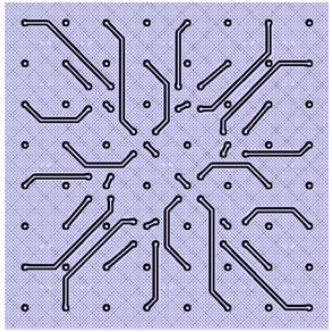
- Samtec -> MMCX adapter; MMCX -> MCX pigtail cables, grounding caps



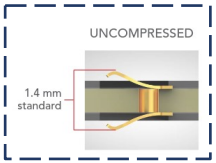
For systematic ¼ active area scans

- Samtec interface to the existing 64-channel edge-to-MCX adapter cards

EIC HRPPD assembly with a passive backplane



pad pattern compressed from 3.25mm to 2.00mm pitch



Fused silica window

MCPs, spacers, etc

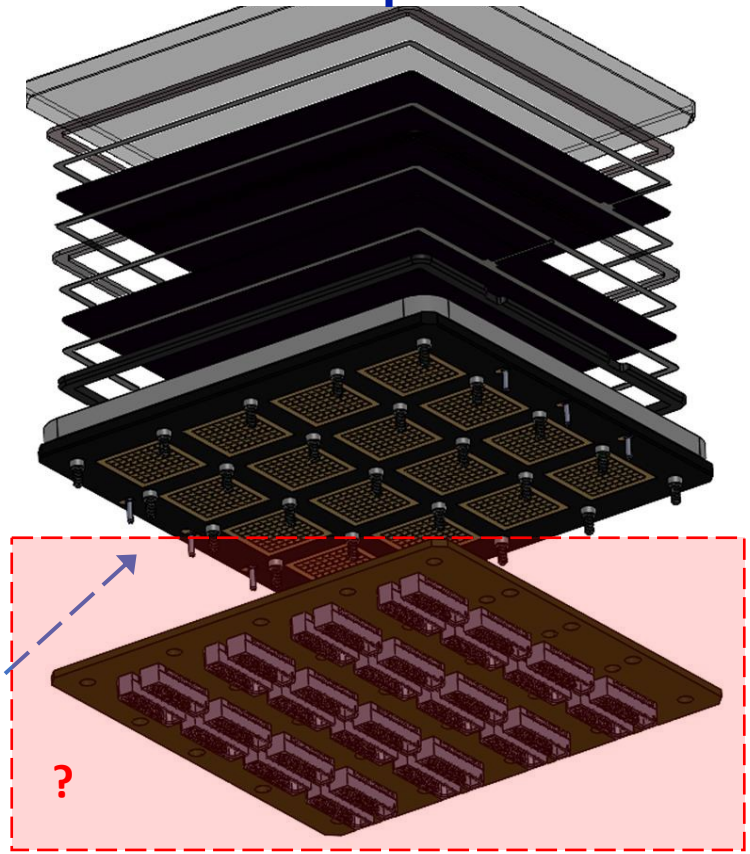
Side wall

Anode plate (Y03h), a pre-routing ceramic circuit board

Compression interposers (not shown)

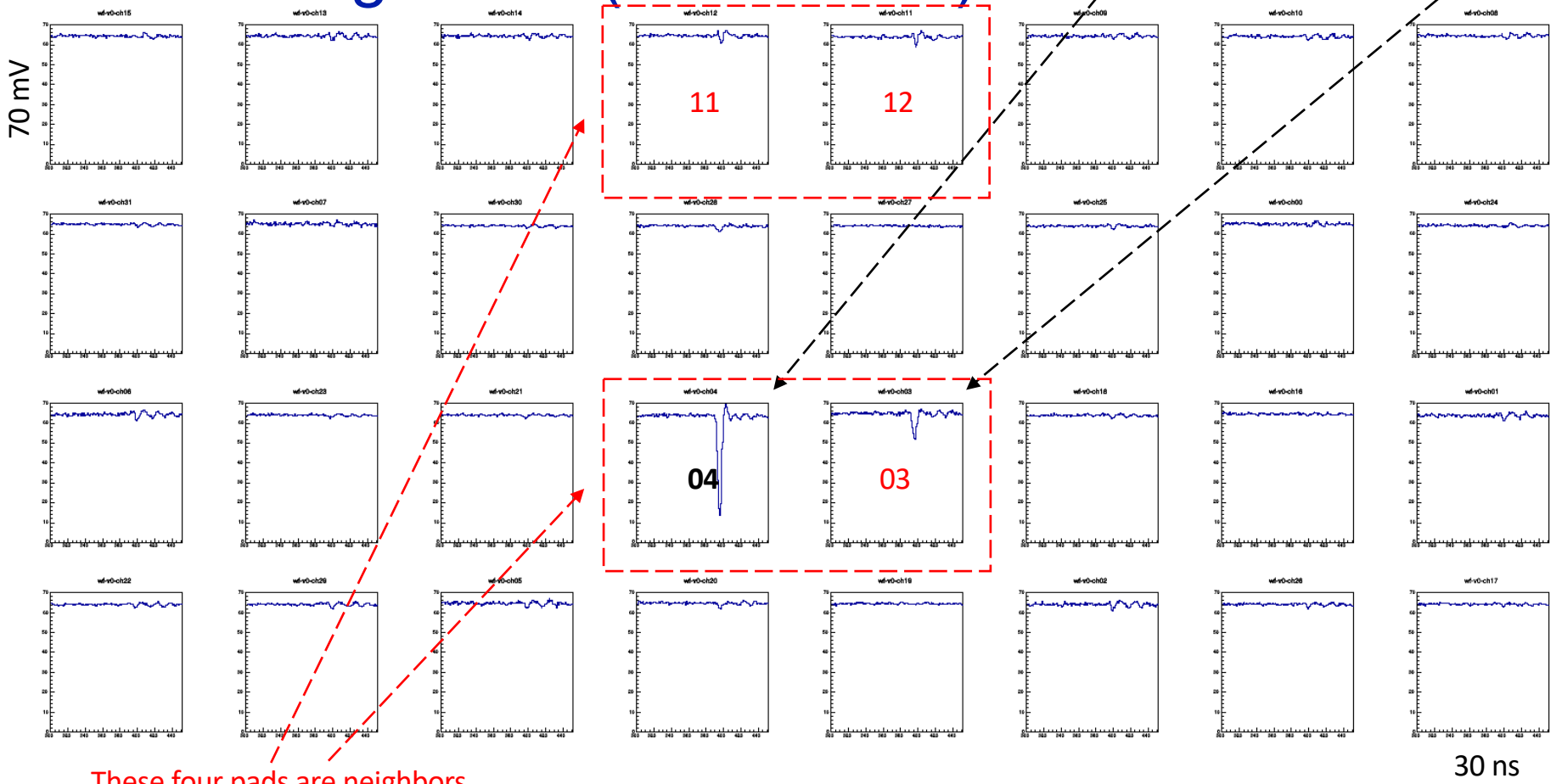
Interface PCB (Y05f)

4x4 spots, each with 8x8 square pads; 3.25mm pitch



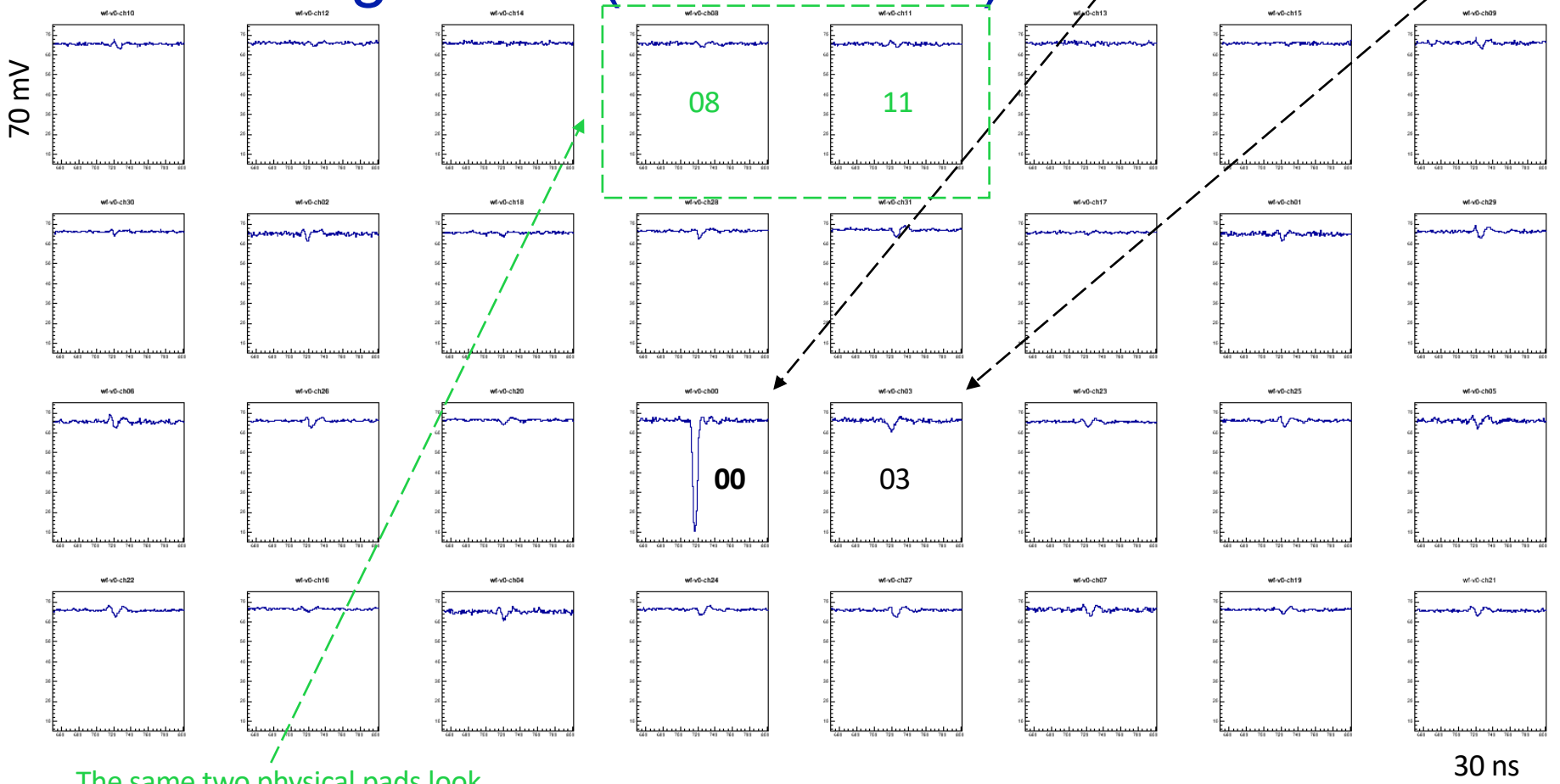
Charge path: (1) vacuum side anode pads -> anode plane stackup -> air side pads -> compression interposers -> (2) interface PCB -> MMCX adapter PCB -> pigtail RG-316 (?) cables -> 6” RG-174 cables -> V1742 digitizer

Crosstalk signature (Y05f board)



Waveforms of 8x4 neighboring pads (single event)

Crosstalk signature (Q00a board)



Waveforms of 8x4 neighboring pads (single event)

Electronics channel routing of a single 8x4 pad area

Channel numbering 00 .. 31 as connected to a single V1742 digitizer
(physically different for these two backplane types)

Neighbors on the Samtec connector (cross-talk evidence)

Y05f backplane

15	07	G	14	06	13	05	G	12	04	11	03	G	10	02	09	01	G	08	00
31	23	G	30	22	29	21	G	28	20	27	19	G	26	18	25	17	G	24	16

Samtec ERF8 / ERM8 connector pinout

Matching set of four channels

Q00a backplane

G	30	28	26	24	22	20	18	16	14	12	10	08	06	04	02	00	G
G	31	29	27	25	23	21	19	17	15	13	11	09	07	05	03	01	G

Essentially all channels are neighbors
(and no ground separation between finger rows either)

One half of a Samtec MEC8-DV connector pinout

A good indication that crosstalk does NOT originate inside of the HRPPD ceramic backplane, but rather in a passive interface PCB of a suboptimal design

Study with a Vector Network Analyzer

Brookhaven National Laboratory

Signal fed into this channel on one side of a **Y05f-Y05f back-to-back sandwich**

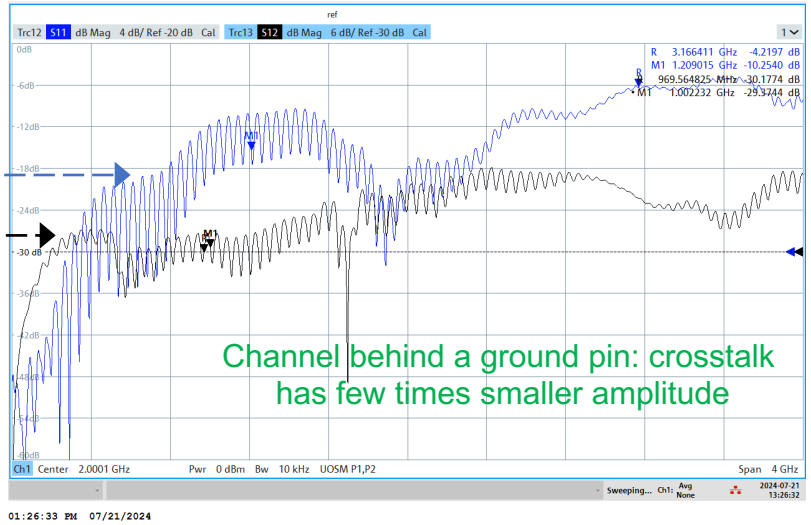
Y05f backplane
Samtec ERF8 / ERM8
connector pinout

15	07	G	14	06	13	05	G	12	04	11	03	G	10	02	09	01	G	08	00
31	23	G	30	22	29	21	G	28	20	27	19	G	26	18	25	17	G	24	16

Crosstalk observed on the other side

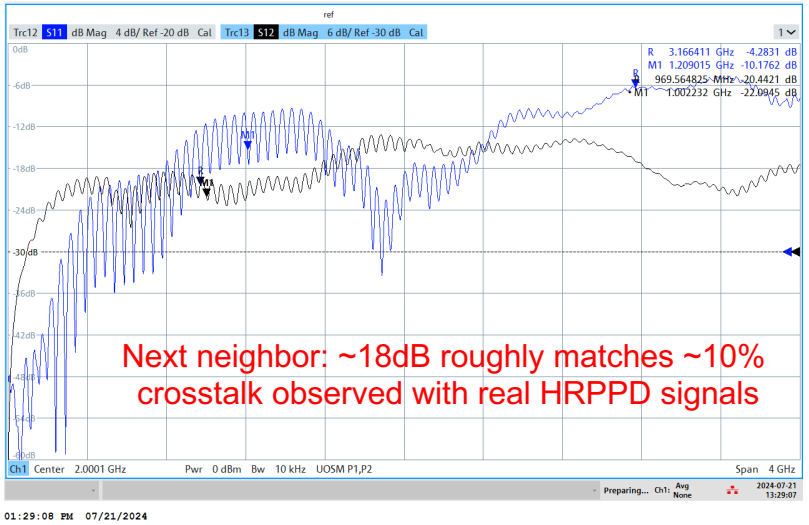
Reflected signal

Crosstalk



Channel behind a ground pin: crosstalk has few times smaller amplitude

Horizontal axis: 100 kHz .. 4 GHz



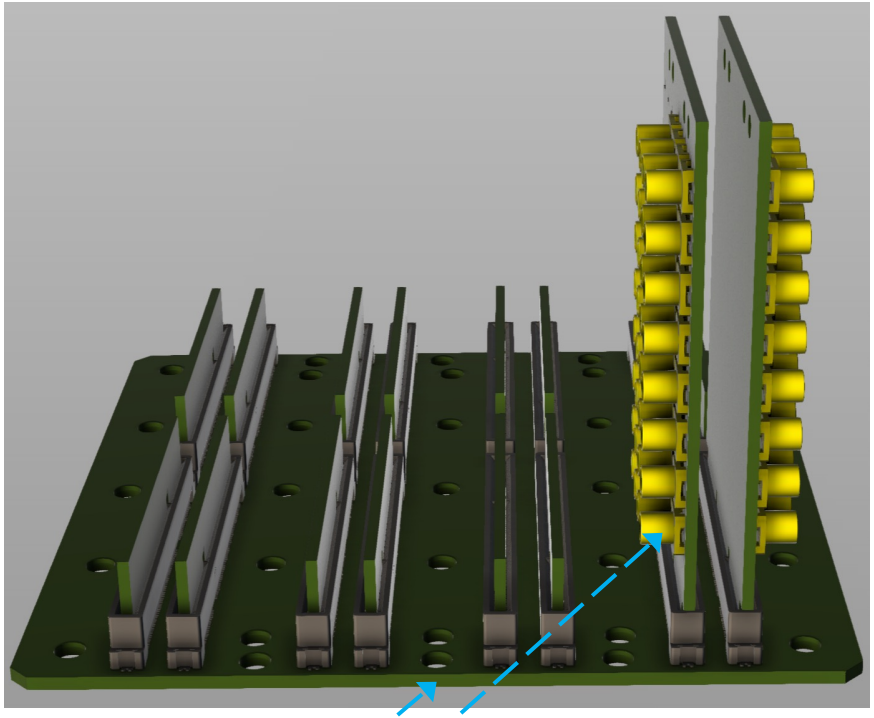
Next neighbor: ~18dB roughly matches ~10% crosstalk observed with real HRPPD signals

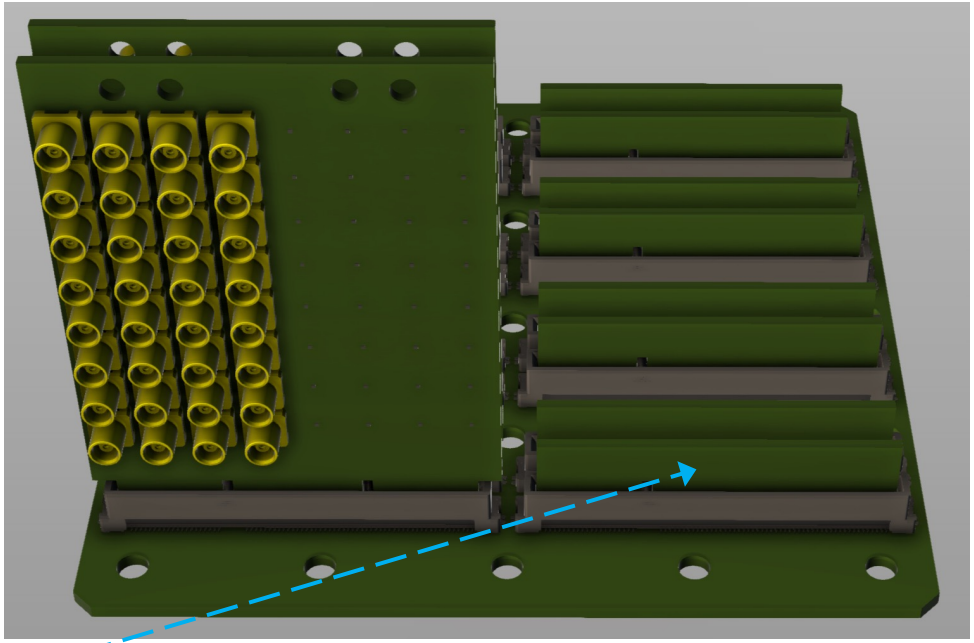
Horizontal axis: 100 kHz .. 4 GHz

Vertical axis: -60 dB .. 0 dB

See the last two talks here for many more details

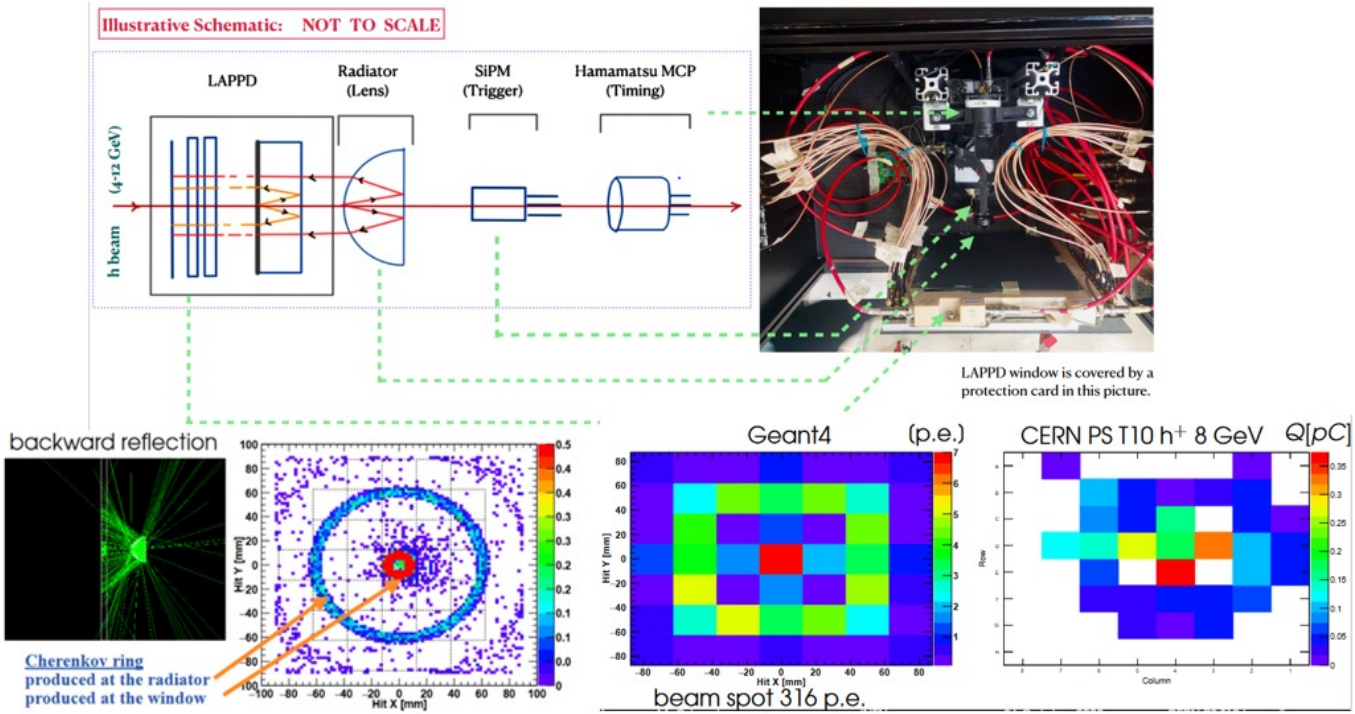
Re-designed HRPPD interface backplane





- Multi-layer boards, 140-pin Amphenol Cool Slim Edge connectors, -GSGSGSG- trace isolation
  - Q02b: backplane itself (can be used with vertically mounted ASIC plugin cards if needed)
  - M02b: MCX adapter cards in 1-2 selected slots
  - S02b: 50 Ohm termination boards in all other slots

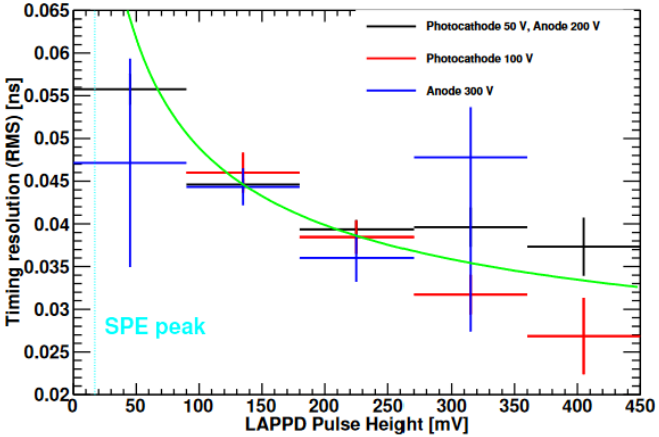
2022 LAPPD beam test data analysis



- CERN PS beam line, 20 μm pore Gen II LAPPD (capacitively coupled)
- Focus: timing performance characterization with a particle beam

2022 LAPPD beam test data analysis

INFN groups: Trieste, Genova



$$\sigma_t = p_0 + \frac{p_1}{\sqrt{V_{peak}/1V}}$$

Single photon time resolution: 75 ps

Asymptotic limit for large amplitude (multiple detected photons) : 18 ps

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journal homepage: www.elsevier.com/locate/nima

Full Length Article

Characterization of LAPPD timing at CERN PS testbeam

Deb Sankar Bhattacharya [a], Andrea Bressan [a,b], Chandradoy Chatterjee [a], Silvia Dalla Torre [a], Mauro Gregori [a], Alexander Kiselev [c], Stefano Levorato [a], Anna Martin [a,b], Saverio Minutoli [d], Mikhail Osipenko [d,*], Richa Rai [a], Marco Ripani [d], Fulvio Tessarotto [a], Triloki Triloki [a]

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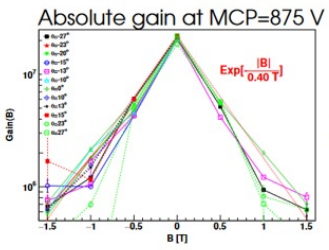
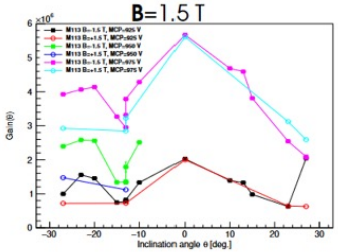
➢ Analysis finalized and a NIM paper published in 2024

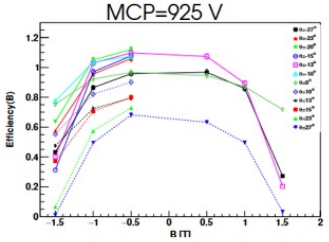
LAPPD performance in a magnetic field

Essentially a carryover of the approved FY23 program

- **First campaign with a field intensity up to 0.5 T (November 2023)**
- **Second campaign with a field intensity up to 1.5 T (March 2024)**





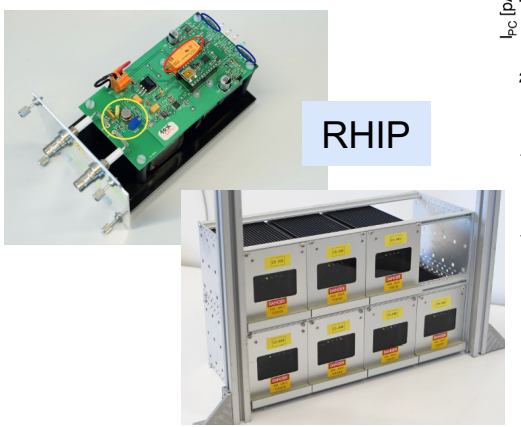


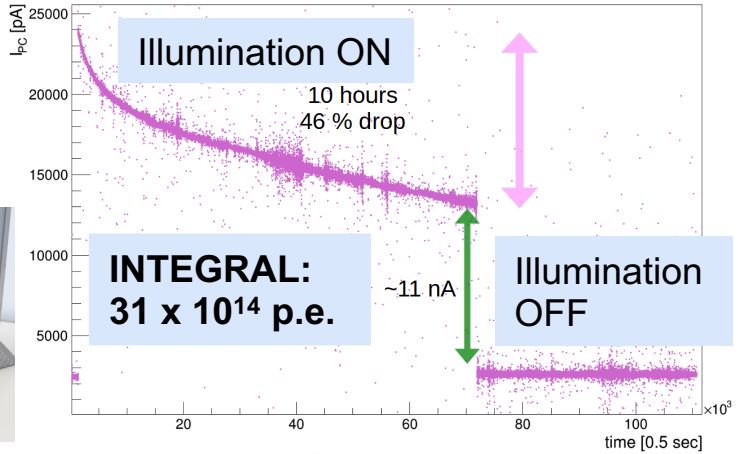
- tests performed at CERN MNP-17 and M113 magnets,
- LAPPD gain drops exponentially with **B**-magnitude,
- gain reduction was almost independent of the field angle, except $\theta = -13$ deg. and $|\theta| \geq 20$ deg.,
- at **B**>0 MCP bias could be increased on +100 V beyond limits, reaching at 1.5 T 1/3 of **B**=0 gain,
- efficiency is also reduced in magnetic field, especially at $\theta = -13$ deg. and $\theta \geq 13$ deg.,
- most of inefficiency **B**-dependence can be recovered by increase of MCP and PC biases.

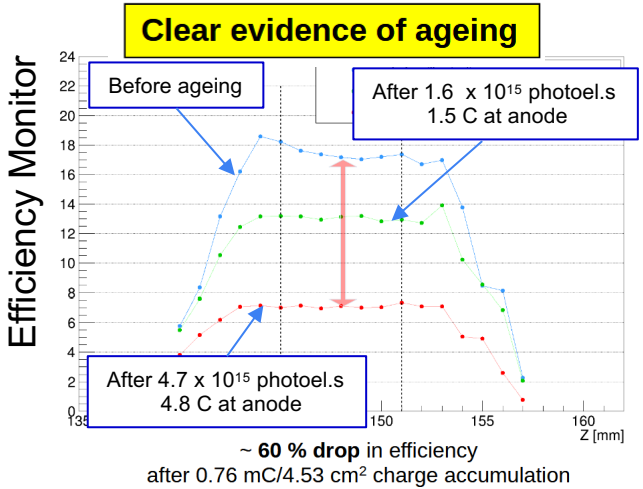
NIMA publication on the way !

LAPPD ageing studies

- **A preparatory exercise for the HRPPD ageing studies (once an HRPPD becomes available at INFN)**
  - **Ageing studies illuminating a group of 4 (6 x 6) mm² pads**
    - **A second group of pads of 4 pads used as detector performance control**
  - **A characterizing aspect of our approach:**
    - **thanks to the availability of fully floating picoampermeters** *(custom RHIP: http://dx.doi.org/10.22323/1.322.0068)* **we can measure the current at the photocathode and, therefore, directly monitor the number of extracted photoelectrons; this approach makes possible the direct extrapolation of the ageing studies to the experiment needs**







Femtosecond laser system

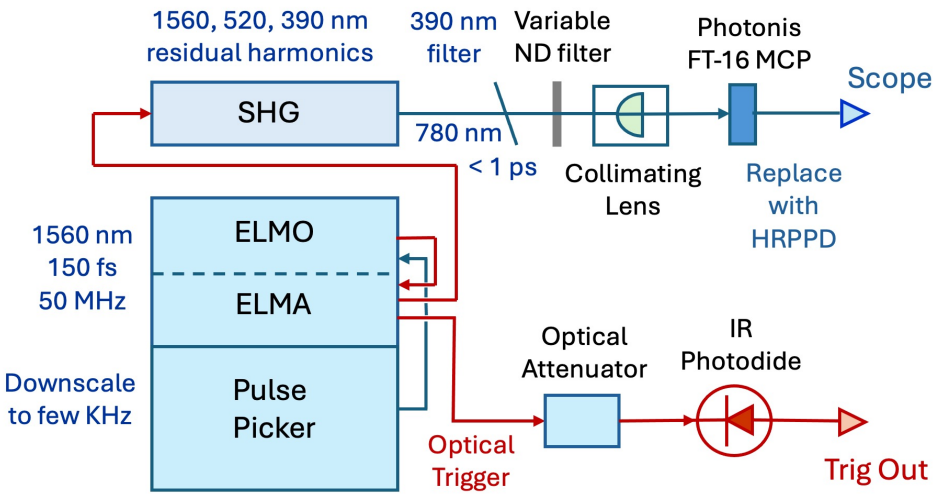
Brookhaven National Laboratory

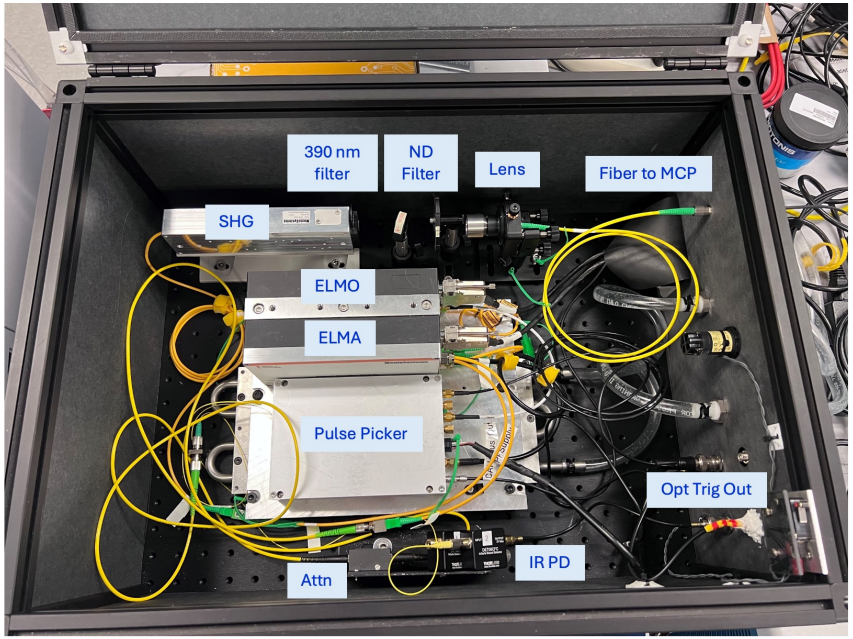
Menlo Systems Elmo 780 Erbium Fiber Femtosecond Laser

ELMO = Primary Laser Oscillator

ELMA = Optical Amplifier

SHG = 2nd Harmonic Generator

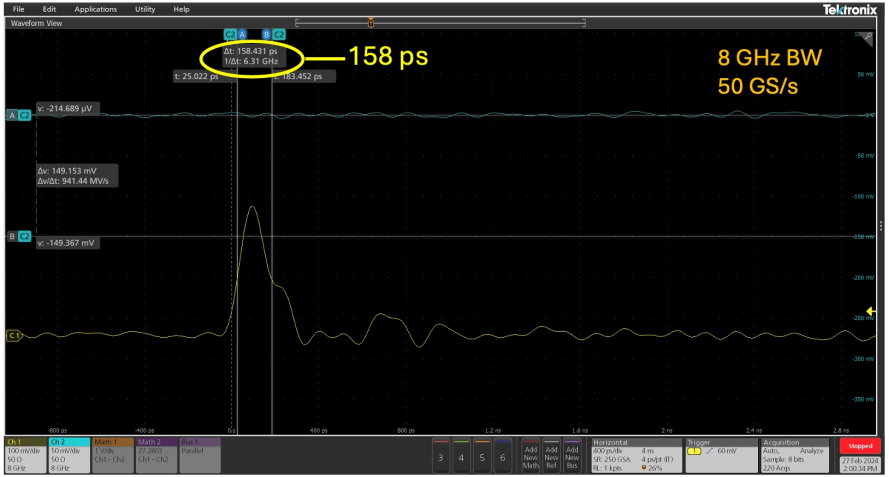




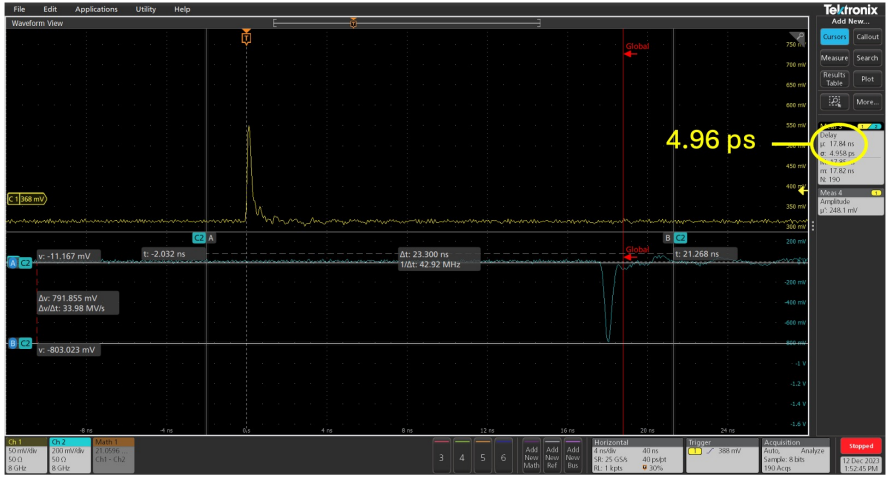
Measurements with Photonis MCP-PMT

Brookhaven National Laboratory

IR Photodiode Pulse
Rise Time ~ 70 ps
Pulse Width < 160 ps

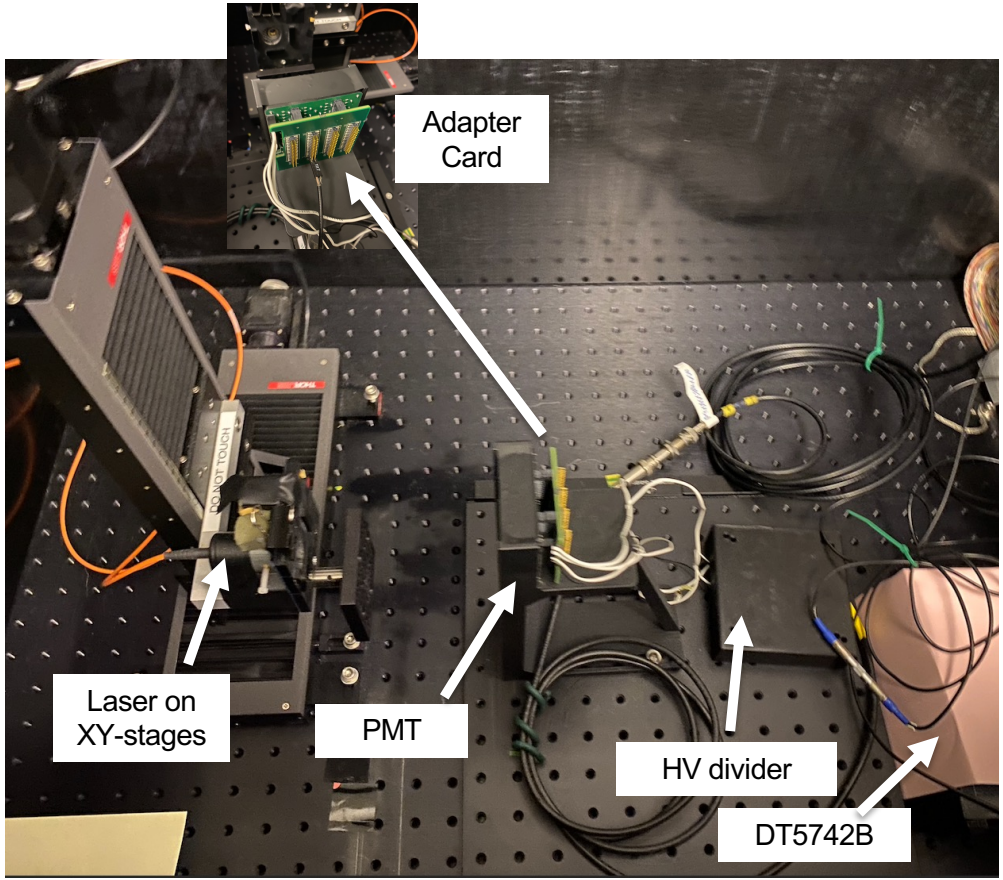


Time Jitter between Photodiode Trigger and MCP < 5 ps

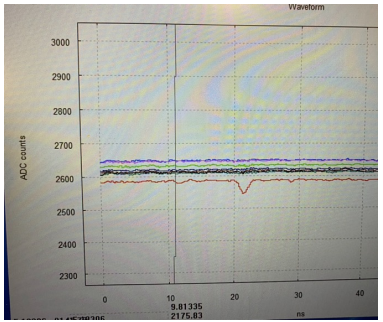


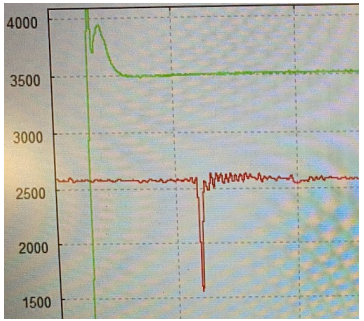
Conclusion: we should be able to make timing measurements with a resolution < 10 ps

Photek & Photonis MCP-PMT evaluation

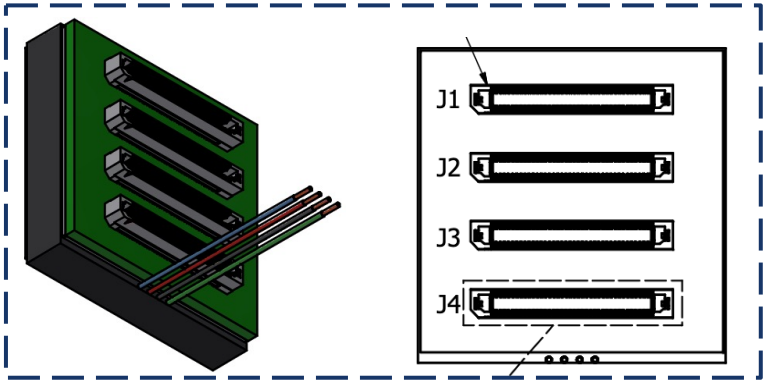


- Borrowed Planacon XP85112-S-BA MCP-PMT from GSI
  - This is the one which was thoroughly tested at Erlangen by A. Lehmann
  - Will be on loan until Dec 2024 and used as a reference tube for UoG setup
- Constructed HV divider
- Outsourced adapter board for connecting to CAEN 32-channel V1742 digitizer
- 32 MCX cables currently in manufacture

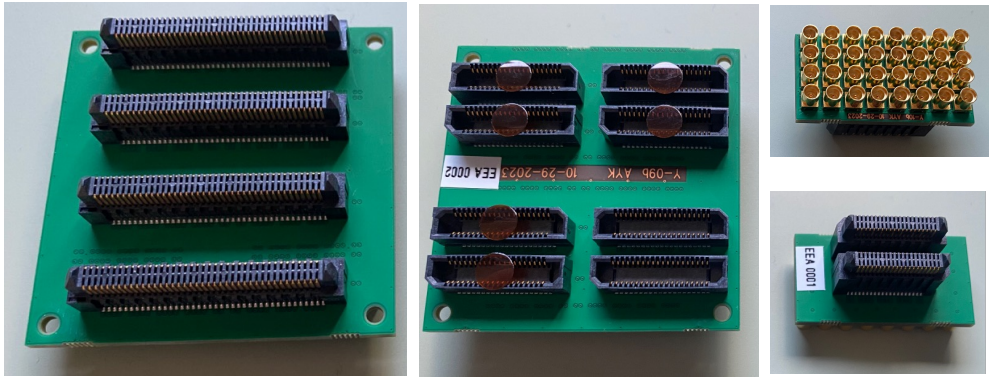




Photek & Photonis MCP-PMT evaluation



2” Photek Auratek stock configuration



An adapter to “HRPPD world” (Y05f-like board + MMCX)

- Photek Auratek MAPMT253 16x16 pixel Multi-anode MCP-PMT ordered by JLab in Dec 2023
  - Shipment to Glasgow delayed (now: October 2024)
- Adapter boards available (see pictures above), MMCX-MCX cables made
- A 32-channel V1742 digitizer and a PCI card by CAEN delivered
- Waiting for budget set up agreement between UoG/Jlab lawyers to purchase further items for improving test stand (e.g. reference calibrated photodiode)

FY25 proposal

Proposed FY25 activities and budget request

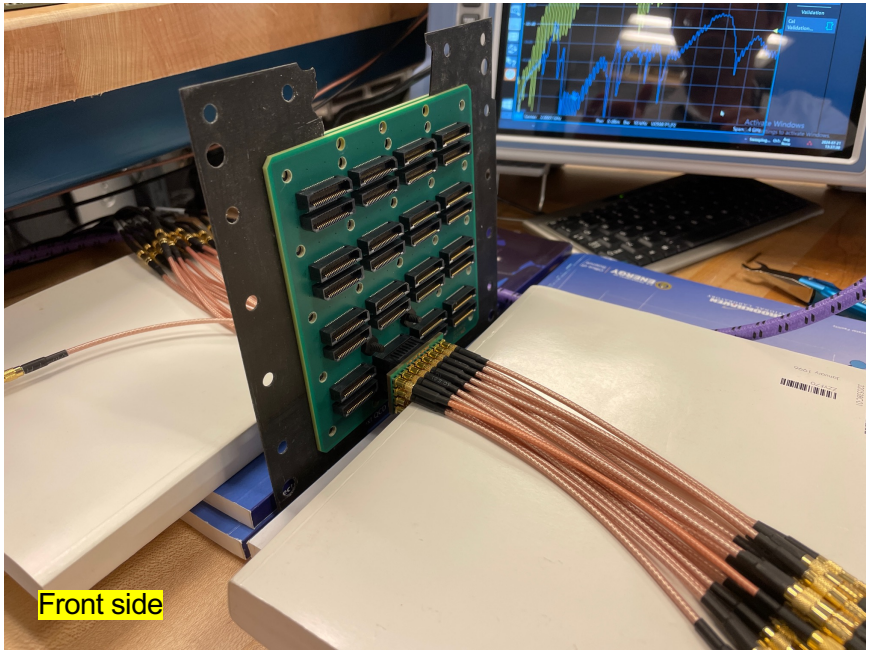
- Essentially a continuation / finalization of approved FY24 activities:

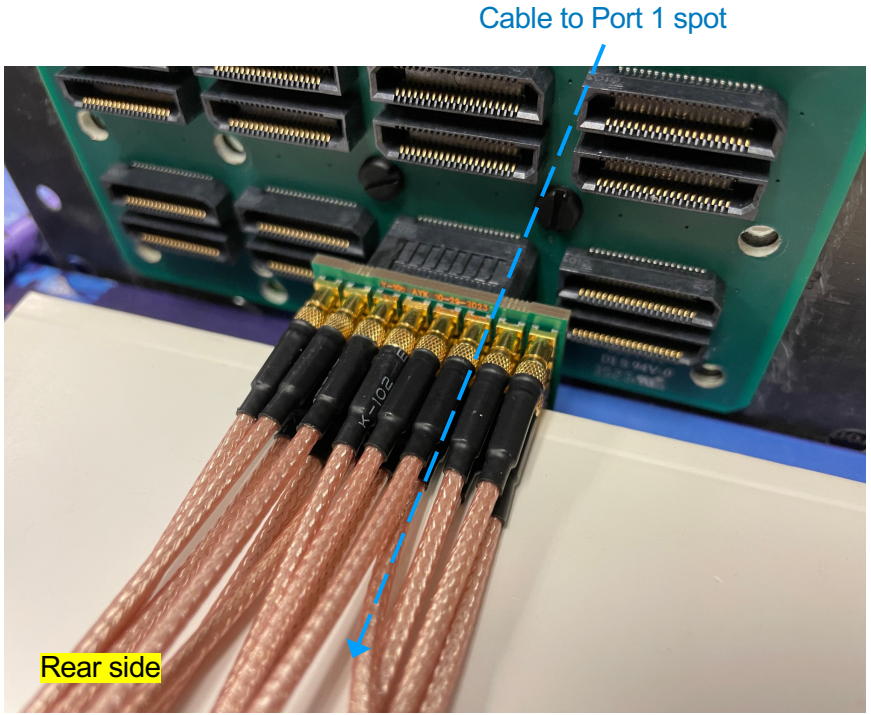
Activity	Group(s)	Funding request
B field studies at Argonne	ANL / BNL / JLab / USC	FY24 carryover
HRPPD ageing studies	INFN	$20k
HRPPD timing studies	BNL	$7k
MCP-PMT performance evaluation	Glasgow	None

- Deliverables are comprehensive reports on concluded activities in the above table, by the end of FY25:
  - Confirmation of Photek MCP-PMT resilience to expected ePIC B-field
  - Confirmation of HRPPD resilience to expected extracted charge for ePIC pfRICH
  - Evaluation of HRPPD timing performance as a fallback option for hpDIRC application
  - Assessment of Photek MCP-PMT as an HRPPD fallback option for ePIC pfRICH

Backup

Y05f-Y05f sandwich setup



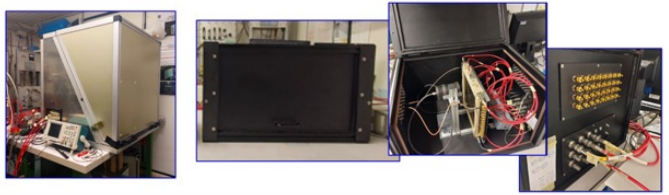


- A Y10b-Y05f-interposer-Y05f-Y10b sandwich
  - Where Y05f is a backplane and Y10b a small Samtec -> MMCX adapter
- 2x8 MMCX->MCX cable pigtails on both sides
  - Permanently connected to V1742 DRS4 digitizer inputs (50 Ohm termination) except for a pair of Port 1 / Port 2 cables
- Rear sandwich side channel B2 -> ZNLE Port 1 (in all the subsequent plots)
- Front sandwich side -> to Port 2 (scan through all 16 MMCX connectors -> 16 plots total)

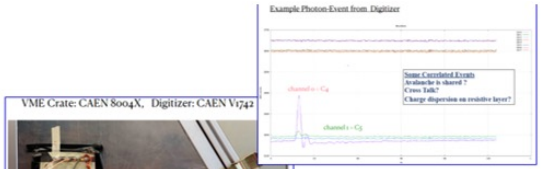
LAPPD studies by INFN groups - HIGHLIGHTS

- **INFN groups: Trieste, Genova**

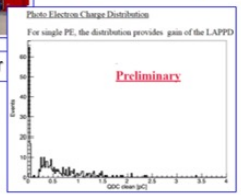
- **FY2022: Completion of the lab equipment for LAPPD characterization at INFN**

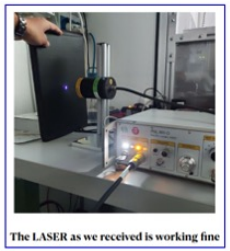


Initial dark-box; then, optimized dark-box modified to improve light-tightness and operative needs



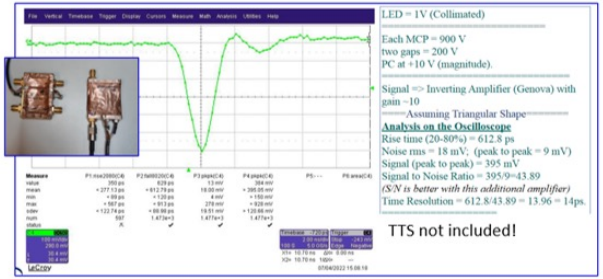
First exercises with the digitizer



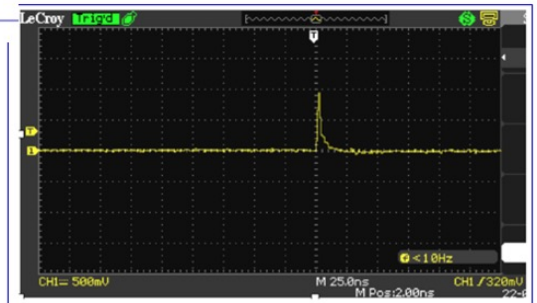


The LASER as we received is working fine

Getting familiar with the new head (405 nm) of the PICOQUANT pulsed laser source



Using the pre-amplificator: signal analysis at the scope



A pulse from the LAPPD with the LASER incident on it