Report from the 2024 RICH testbeam

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on behalf of the LHCb RICH test beam group

University of Edinburgh

LHCb Upgrade II Meeting, Birmingham - 9 July 2024

Outline

RICH Upgrades

- Upgrade Ib test for the electronics
- Upgrade II sensors

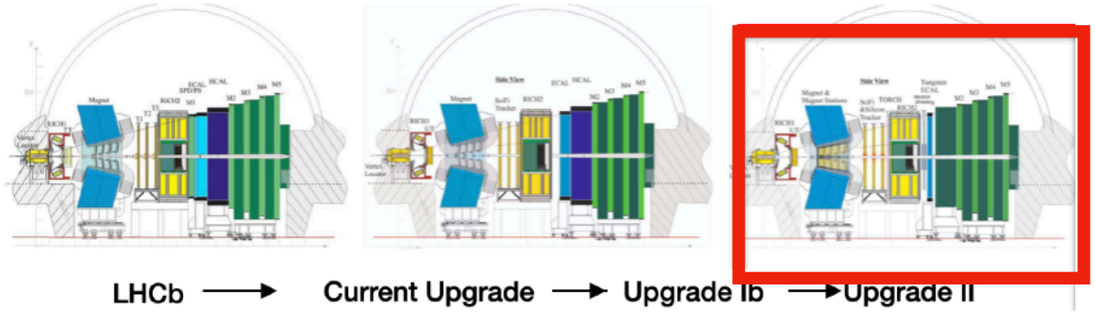
RICH test beam timeline

RICH 2024 Spring test beam at SPS

- MaPMTs and SiPMs setup
- LAPPD setup

Next steps / plans

RICH Upgrade II sensors and coupling with fast electronics



LHCb Upgrade Ib

Only the electronics will change, adding the timing information using current MAPMTs (FastRICH) See Steve's talk

LHCb Upgrade II See Antonis' talk

➡ Upgrade II sensors should be have to be fast with improved spatial resolution

See table presented by C.D'Ambrosio, 6th Workshop on LHCb upgrade II

➡ Main technologies considered, R&D planned for each,
in particular **SiPMs and MCP based solutions (eg Large Area Picosecond Photon Detector, LAPPD)**

➡ State-of-the-art photodetectors do not satisfy the requirements for operation at the RICH photodetectors plane (photons hit rate and density, radiation hardness, etc.) for the whole experiment lifetime (corresponding to 300 fb-1 integrated luminosity), using the present detector geometry

➡ Strong R&D on photon detectors neeeded

Involvement of the LHCb RICH UK group

➡Development of the electronics by Steve's group in Cambridge

➡Different solutions considered for the Upgrade II photon detectors: SiPMs at RAL (see Constantino's talk) and LAPPD in Edinburgh (test in the lab already presented in the LHCb UK upgrade meeting last year)

➡ Participation in RICH test beams

Test beam group

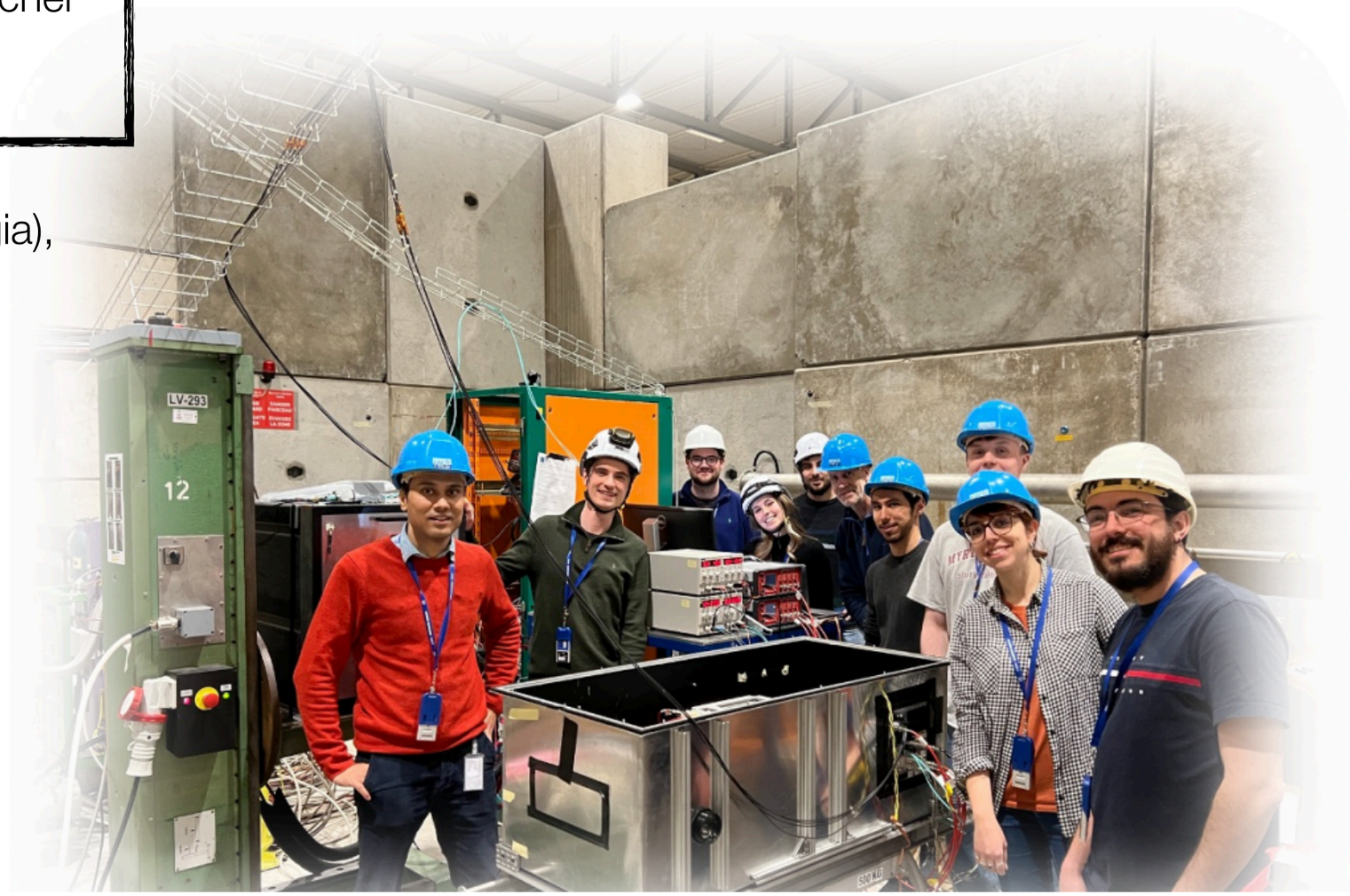
RICH test beam campaigns at CERN SPS scheduled twice per year

Great atmosphere, group full of young people!

Pratik Gheewalla, Michael Kane, Federica Oliva, Deb Sankar, Constantinos Vrahas (Edinburgh)
Josh Bex, Steve Wotton (Cambridge)
and for the common time reference David Bacher and Rui Gao (Oxford)

Federica Borgato (Padova), Lisa Fantini (Perugia), Simon Ghizzo (Genova)
Floris Keizer (test beam coordinator), Lorenzo Malentacca, Didier Piedigrossi (CERN)

Strong UK involvement



Test beam timeline

Towards the Upgrades..

July 2023 | September 2023 | January 2024 | April/May 2024

TEST BEAM PREPARATION..

TEST BEAMS..

Upgrade Ib & Upgrade II

This Meeting, last year, slides

Autumn Test Beam 2023 at SPS

LHCb UK RAL, results from previous test beams and updates on

LAPPD at the September TB

Spring Test Beam at SPS

Analysis, tests in the lab..

WORK IN PROGRESS!

Latest updates about RICH Spring test beams in the general TB meeting, during the LHCb week

Agenda

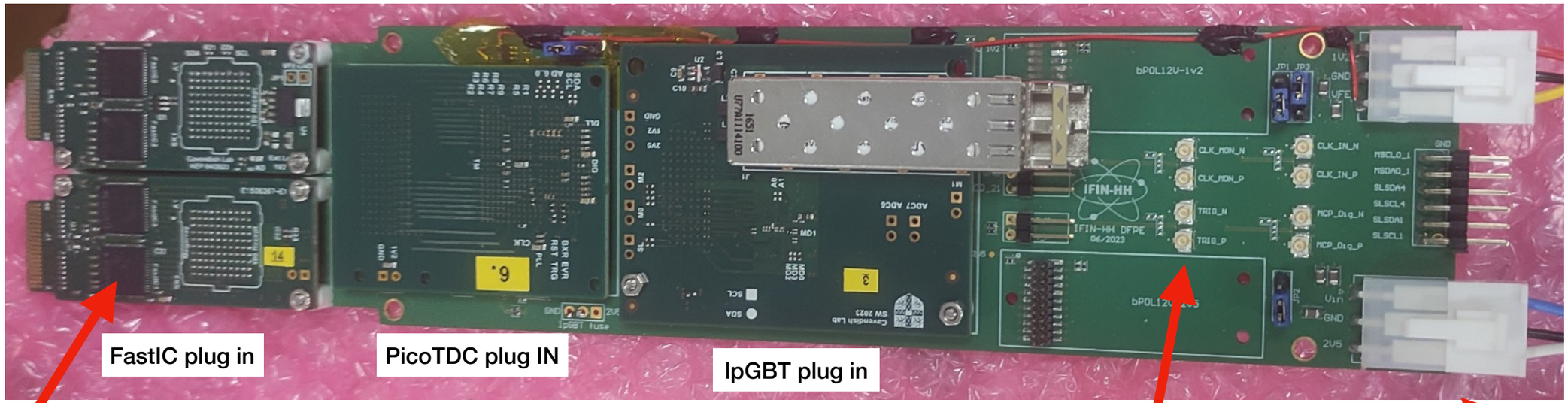
Fast electronics chain used in the test beam

Coupled to MAPMTs(ECR and ECH), SiPMs and LAPPD

2023 beam tests
+April/May 2024

VFE 3.3V,
picoTDC+lpGBT
1.2 V

MuDAQ as backend during test beams

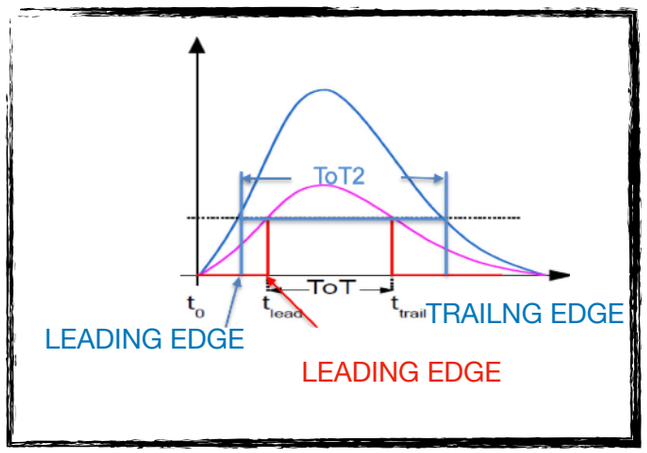


1 FastIC plug in can host 4 FastIC, 8 channels each

64 channels readout per board

Injection of the time reference (2 channels of the picoTDC)

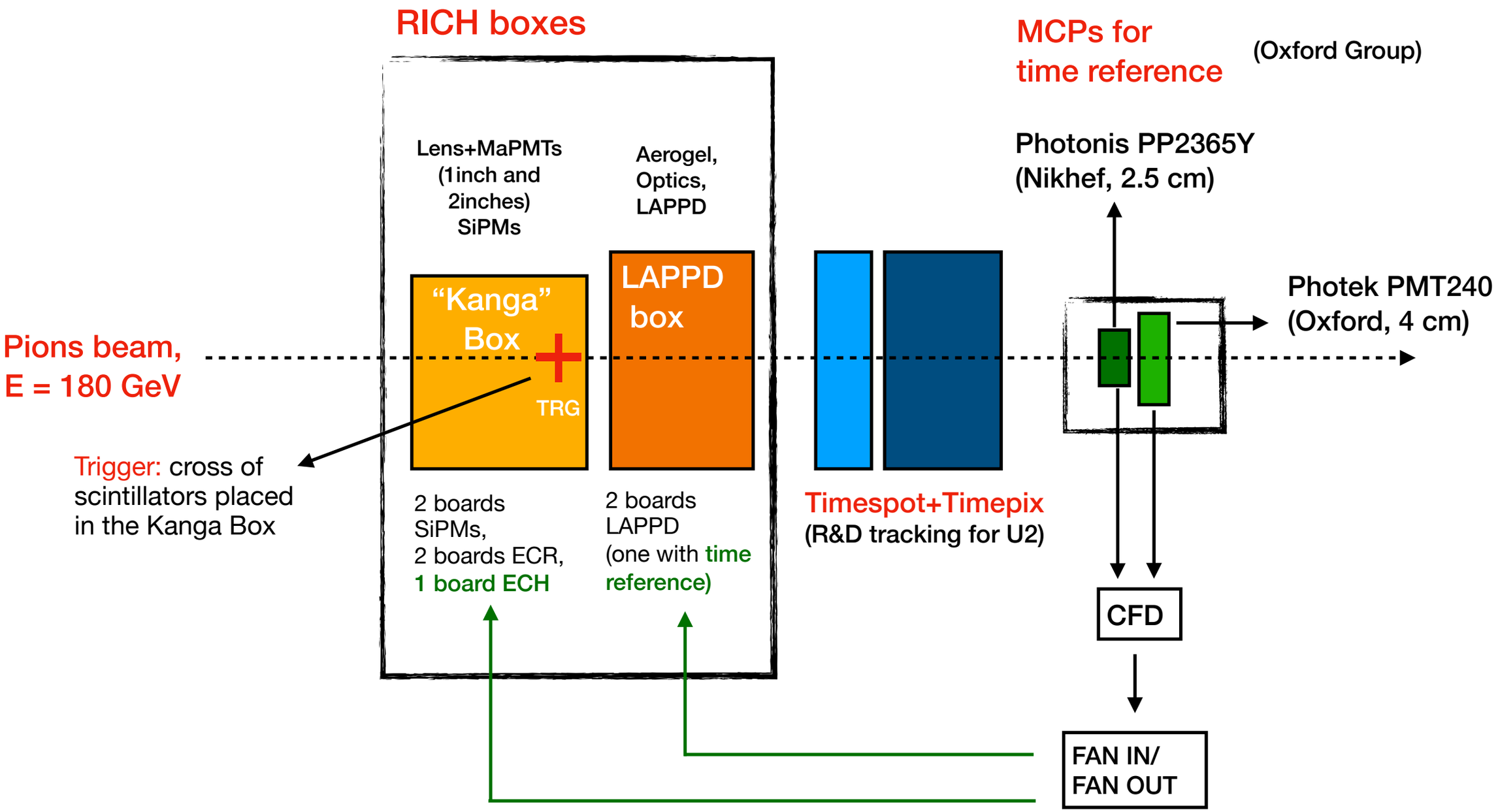
Optical link



- Leading and trailing edge for each signal provided by the PicoTDC
- LHCb RICH test beam software used to compute the Time of Arrival, ToA, (with respect to the time reference) and the Time over Threshold, ToT, (trailing edge - leading edge)

Manual and automatic threshold scans (J.Bex) in the lab and in the test beam area to study the FastIC behaviour

Setup@CERN SPS Spring 2024



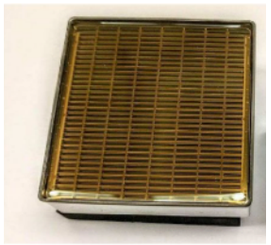
2 RICH dark boxes, 7 readout boards, 448 channels in total readout in parallel

Kanga Box setup - MaPMTs and SiPMs

MAPMTs currently installed in LHCb

1-inch Hamamatsu R13742,
8x8 pixel matrix, pixel size 2.88 x 2.88 mm^2

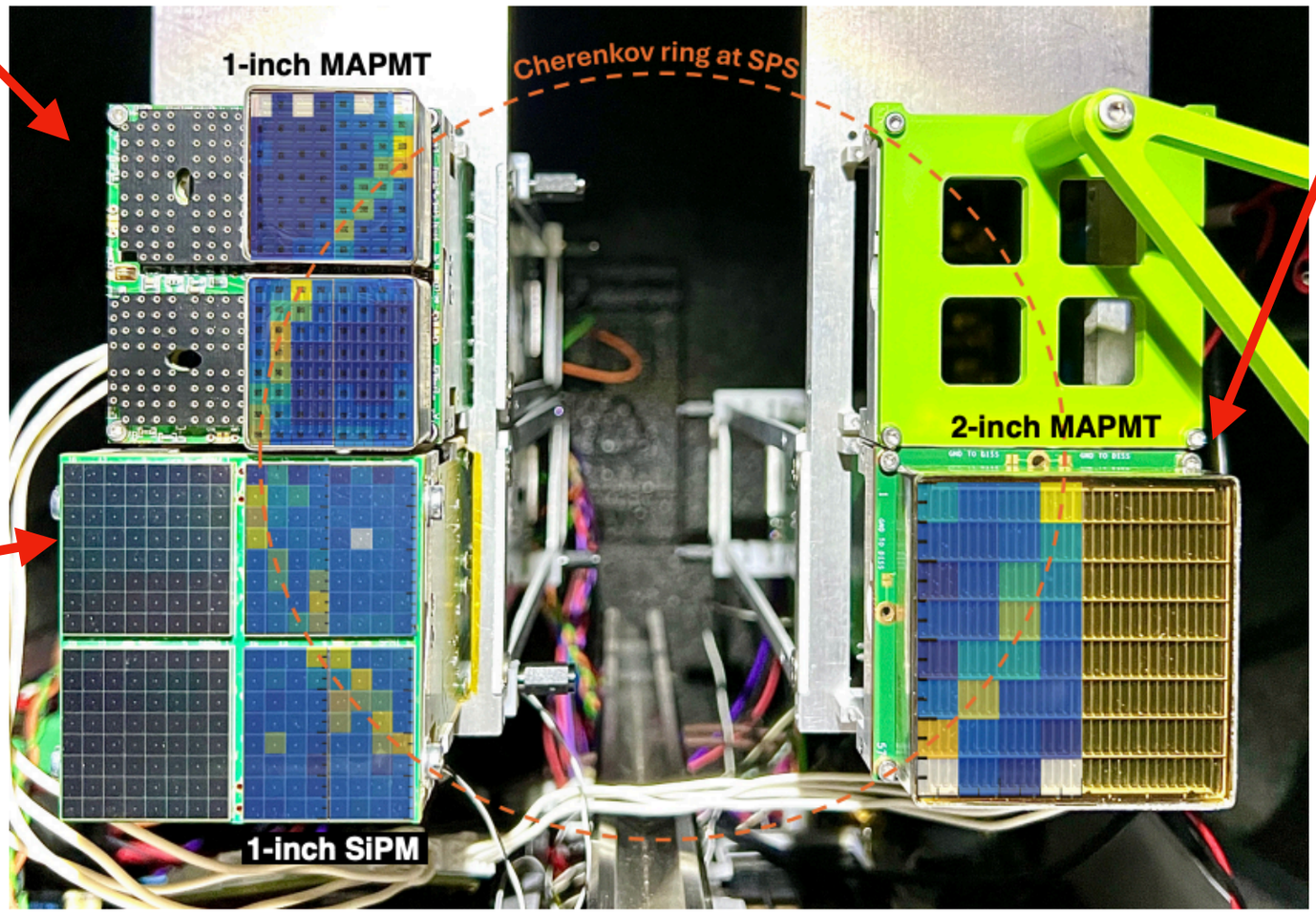
R13742



R13743

2-inch Hamamatsu R13743,
8x8 pixel matrix, pixel size 6 x 6 mm^2

HitMap overlapped to the sensors inside the Kanga Box



SiPMs for the Upgrade II

Hamamatsu
S14161-3050HS-08
3x3 mm^2 pixels

See Floris's poster at Pisa Meeting 2024

LAPPD for the LHCb RICH upgrade 2 photon detectors

LAPPD (INCOM US)

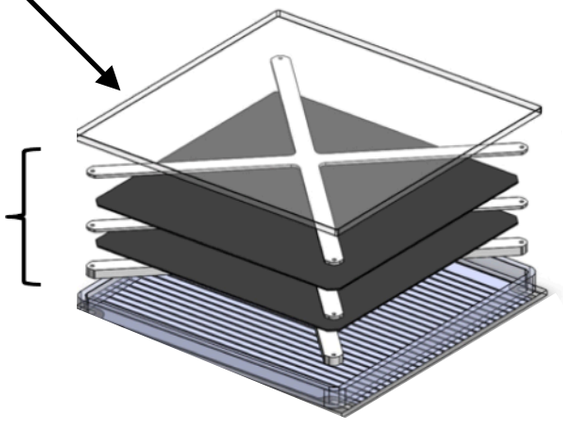
Micro Channel Plate photomultiplier,
Dimension 20 x 20 cm^2

Advantages:

- Time resolution lower than 60 ps
- High gain (~ 10^7)
- capable of imaging single photons

LAPPD scheme

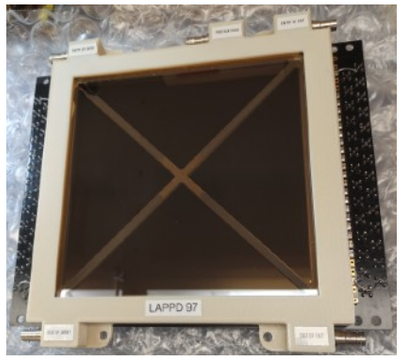
Fused silica window with **photocathode** *on inside surface*

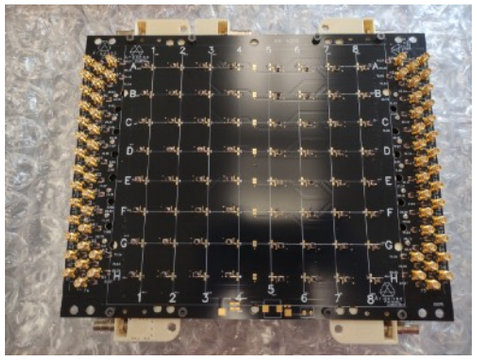


Gen II LAPPD 97 @ Edinburgh

- Gen II LAPPD, pixel readout, **20 µm pores**
- Spectral response 160-650 nm
- 5 taps for independent voltage control of the photocathode and entry/exit of each MCP
- readout board used for initial tests directly provided from INCOM, **pixel Pitch to pitch** distance **25 mm**, effective dimension 24 x 24 mm^2
- **High Rate Photodetector (HRPPD)** supplied by INCOM **soon in Edinburgh**, with **10 µm pores,** and directly coupled pixellated anode, which will have better time resolution and spatial footprint

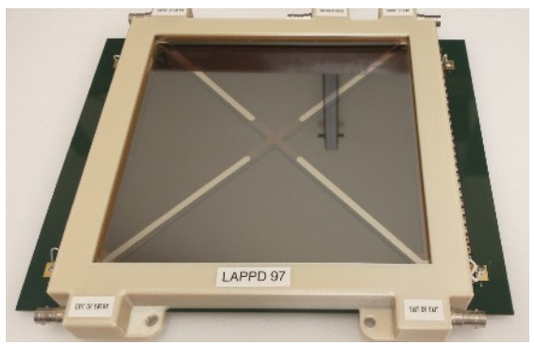
Previous tests in Edinburgh
Default INCOM readout board 64 pixels
Pixel size:
25 mm pitch to pitch
(24 x 24 mm^2 active area, 1 mm dead gap)

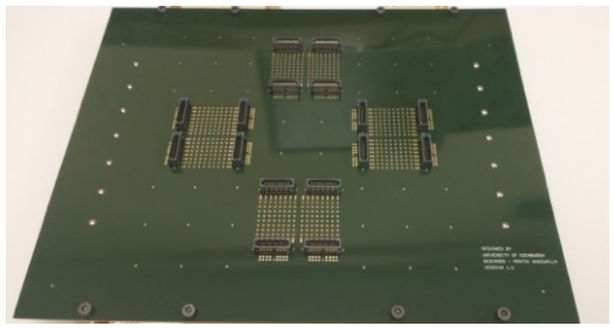




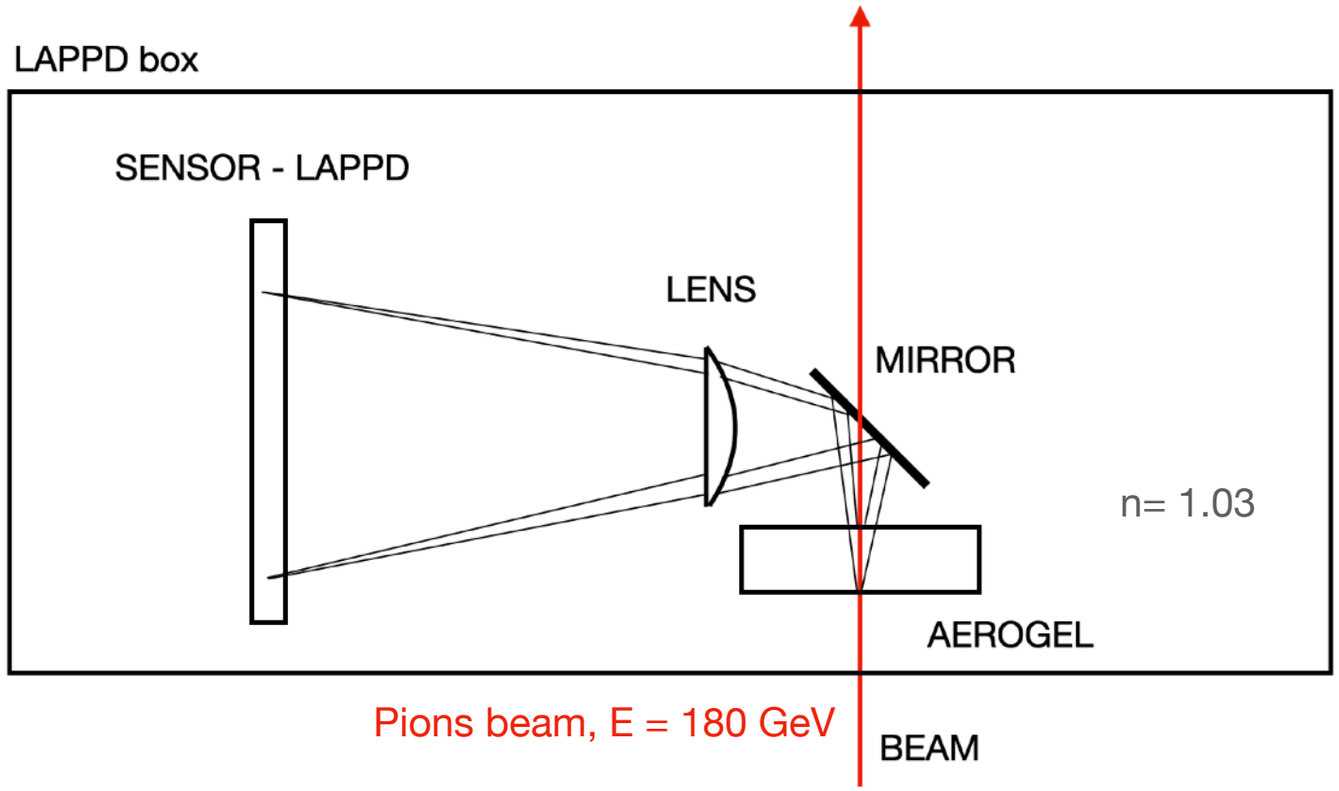
Edinburgh progress
Custom readout board V0, 512 pixels
Pixel size:
3 mm pitch to pitch
(2.9 x 2.9 mm^2 active area, 0.1 mm dead gap)

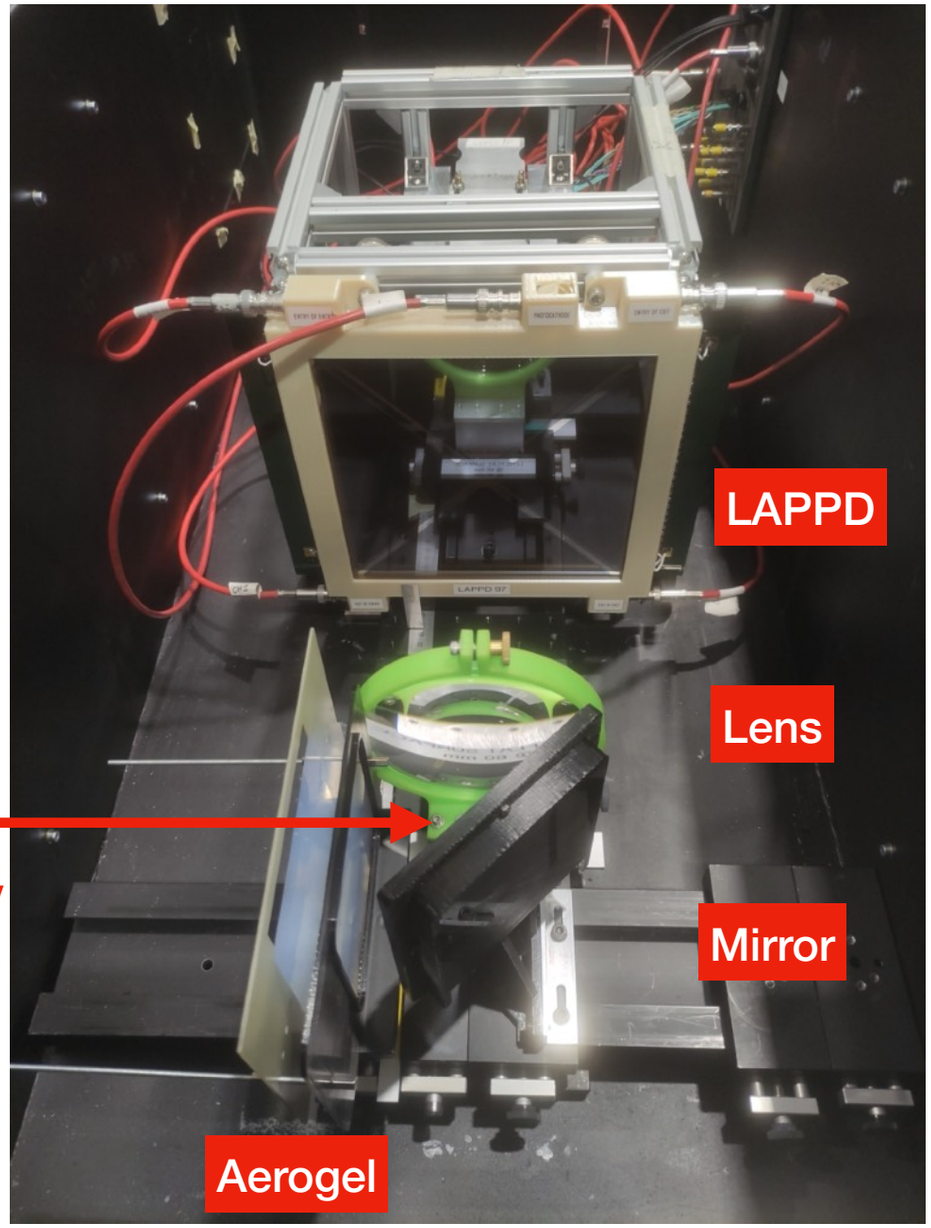
- ✓ Designed in Edinburgh by P.Gheewalla
- ✓ Assembled to the LAPPD in Edinburgh





LAPPD box setup





➡Setup already used by the Ljubljana group in 2022 using a matrix of MaPMTs

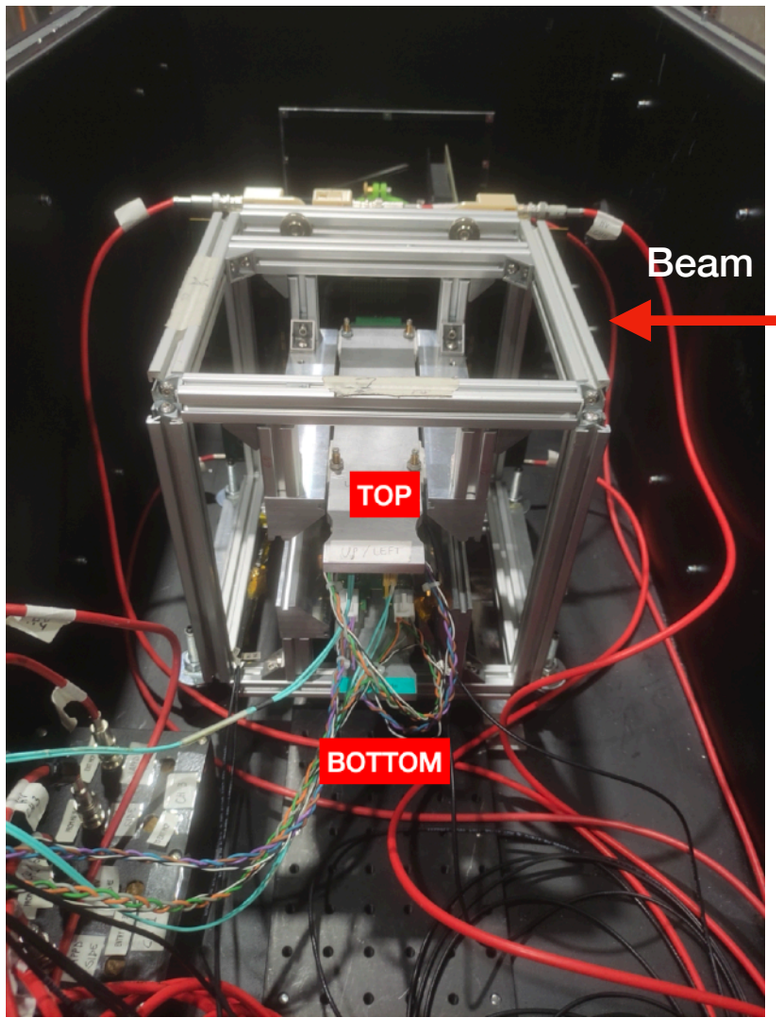
✓Improvements in the mechanics with respect to the 2023 Test Beam

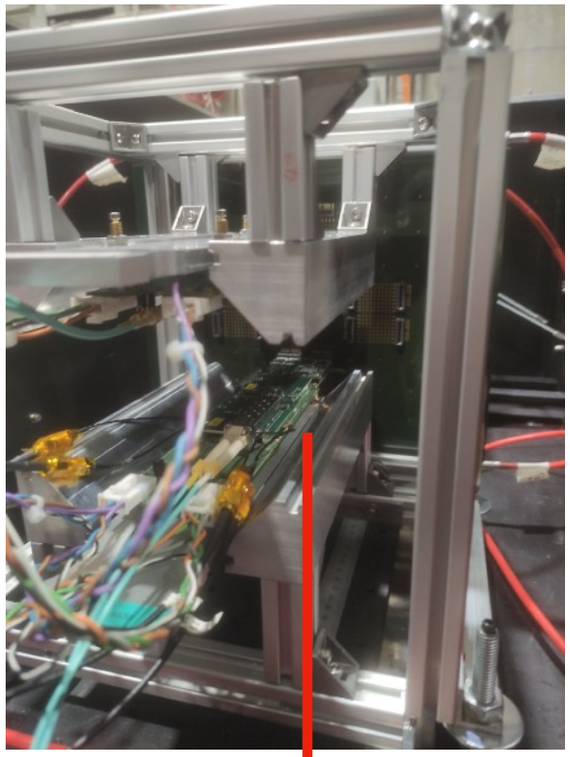
✓Two available readout boards to readout up to 128 channels at the time

LAPPD Board configurations

2 carrier boards, 128 readout channels in total

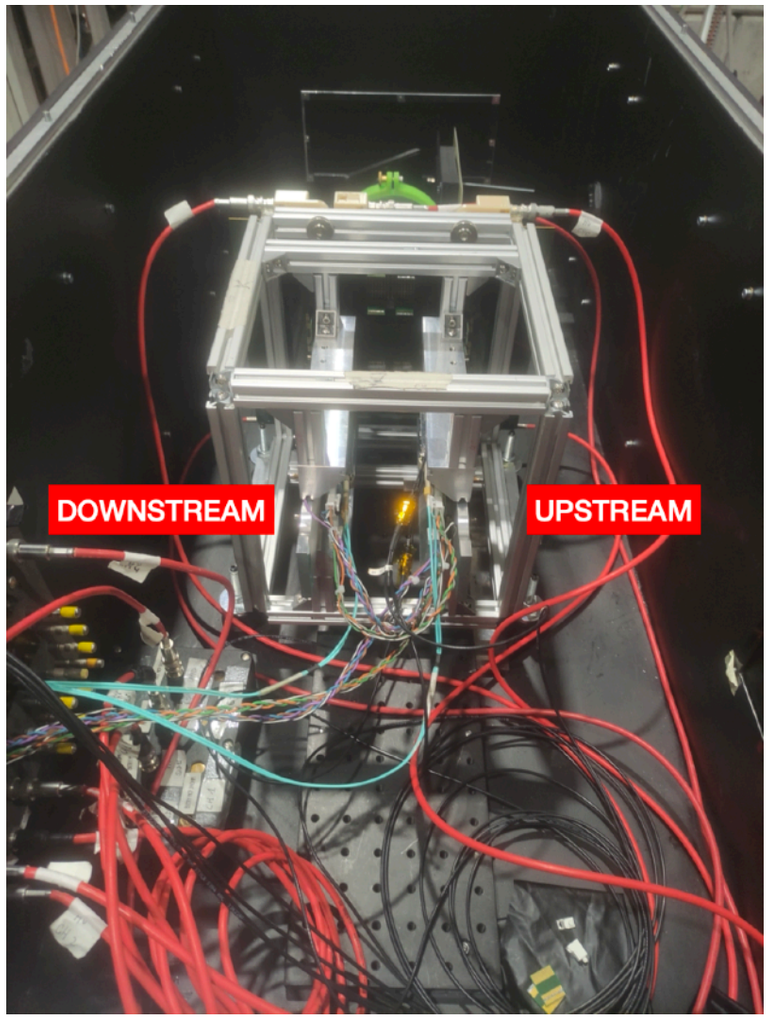
Initial configuration to spot misalignments:
Boards at Top (with time reference) and Bottom





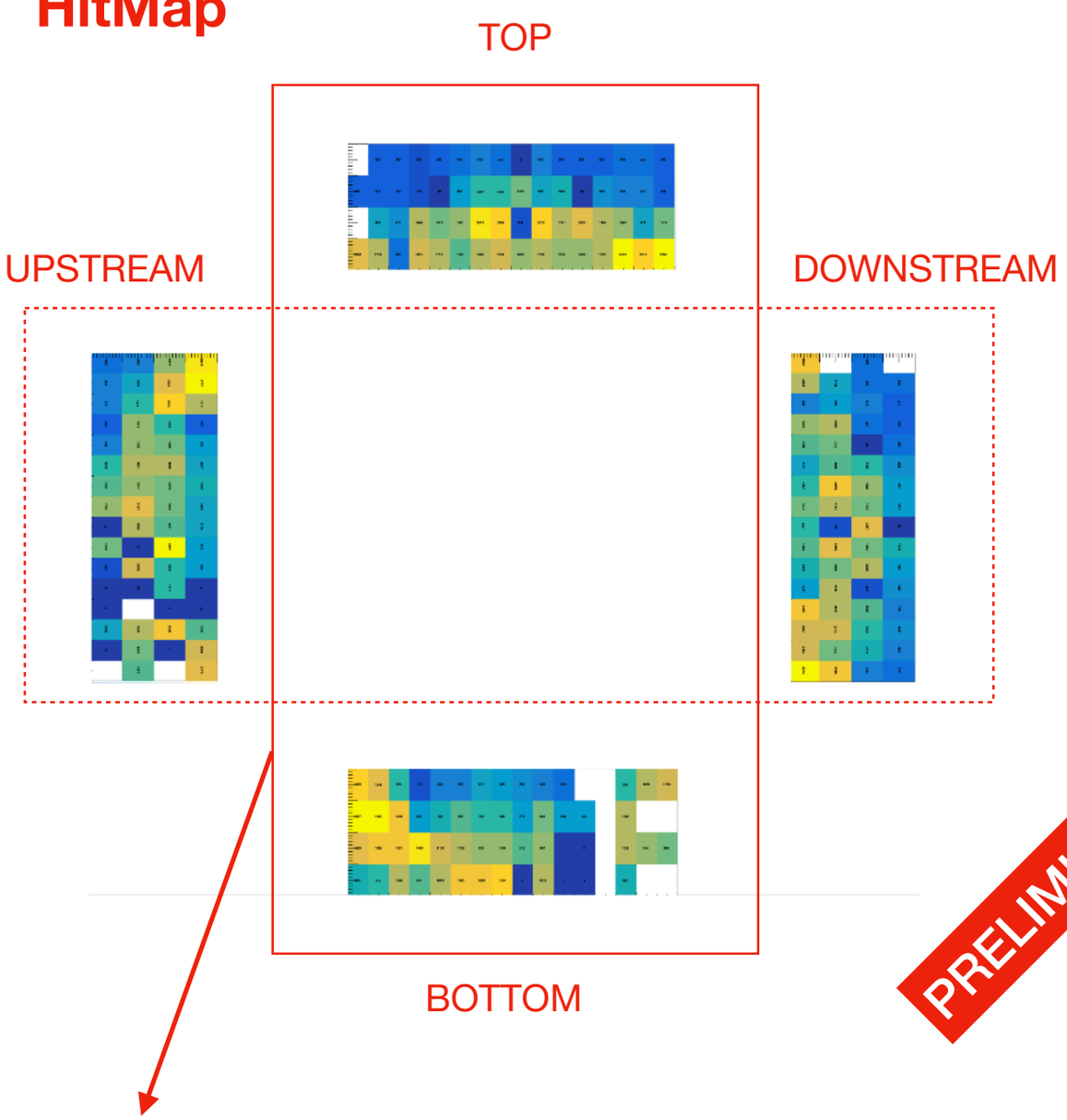
Board with time reference

Board swapped (Upstream and Downstream) in some runs to reproduce the whole ring

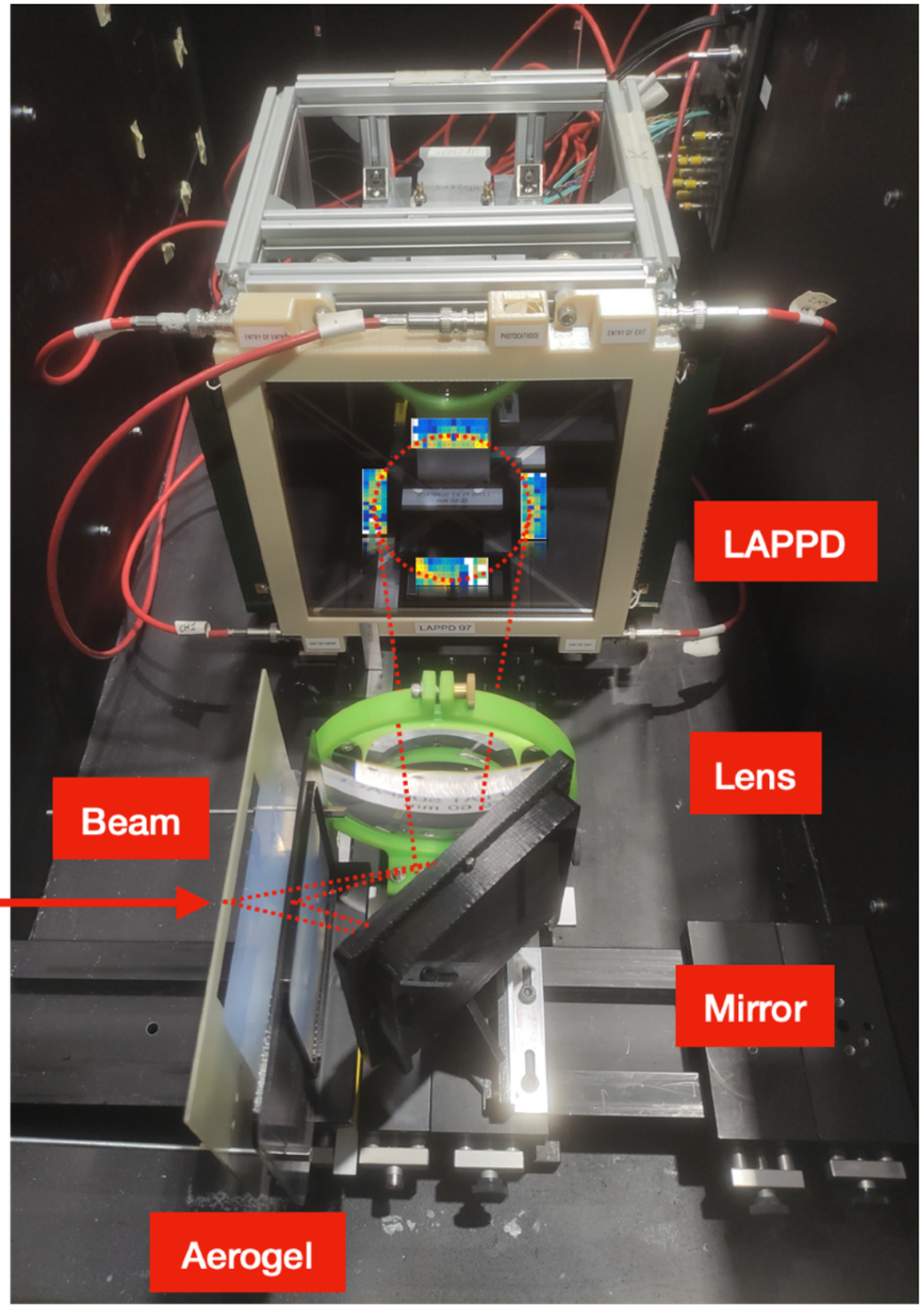


Full Rings observed with the LAPPD

HitMap



PRELIMINARY



Board swapped in one access, same beam configuration
TOP/BOTTOM -> UPSTREAM/DOWNSTREAM

Simulation studies for the LAPPD setup

Framework developed by the Ljubljana group and adapted by the Kyiv Ukraine group to emulate the LAPPD response

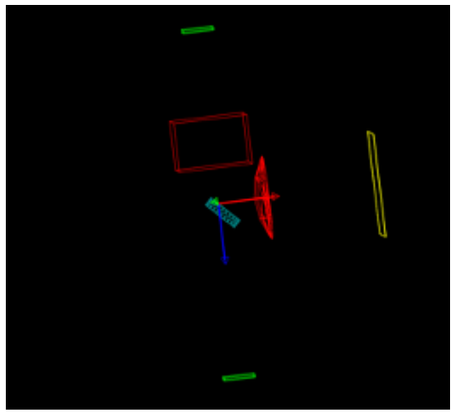
Tune the simulation

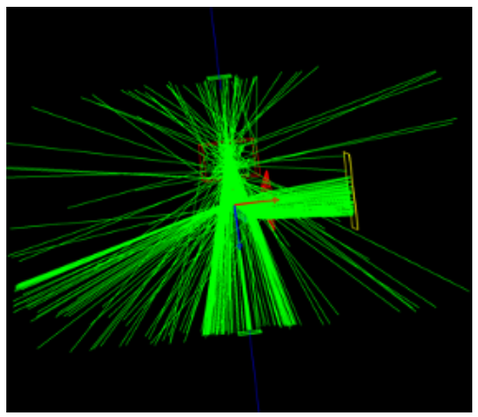
Realistic QE, from previous INCOM measurements

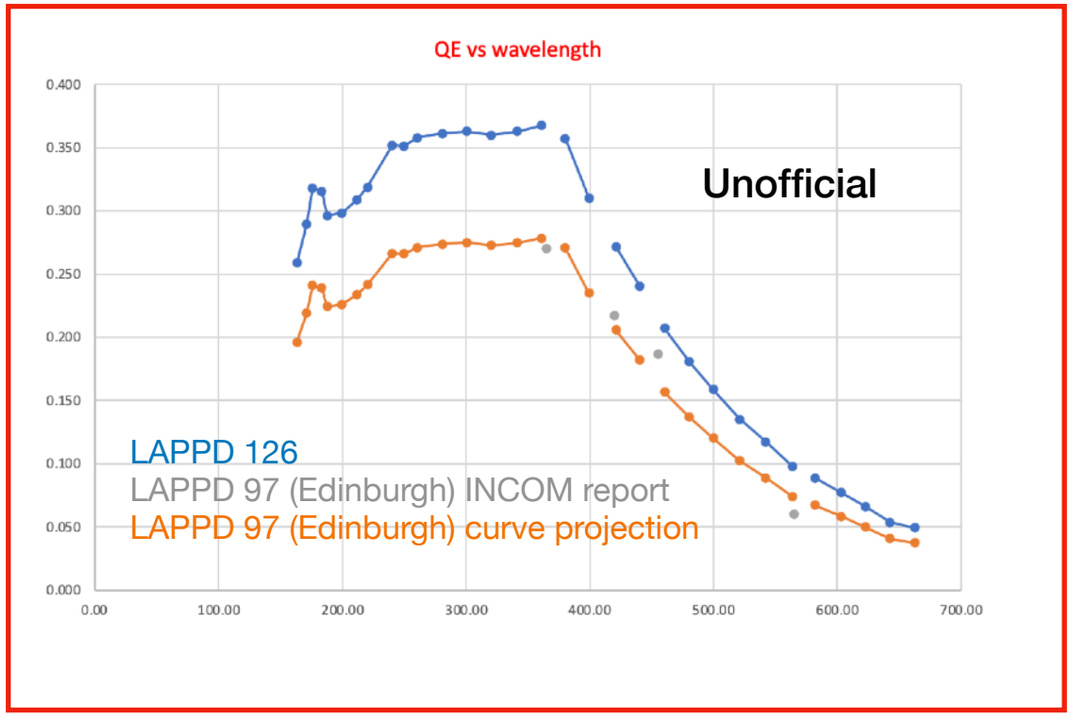
Inserting the footprint of the signal to have a realistic hit map

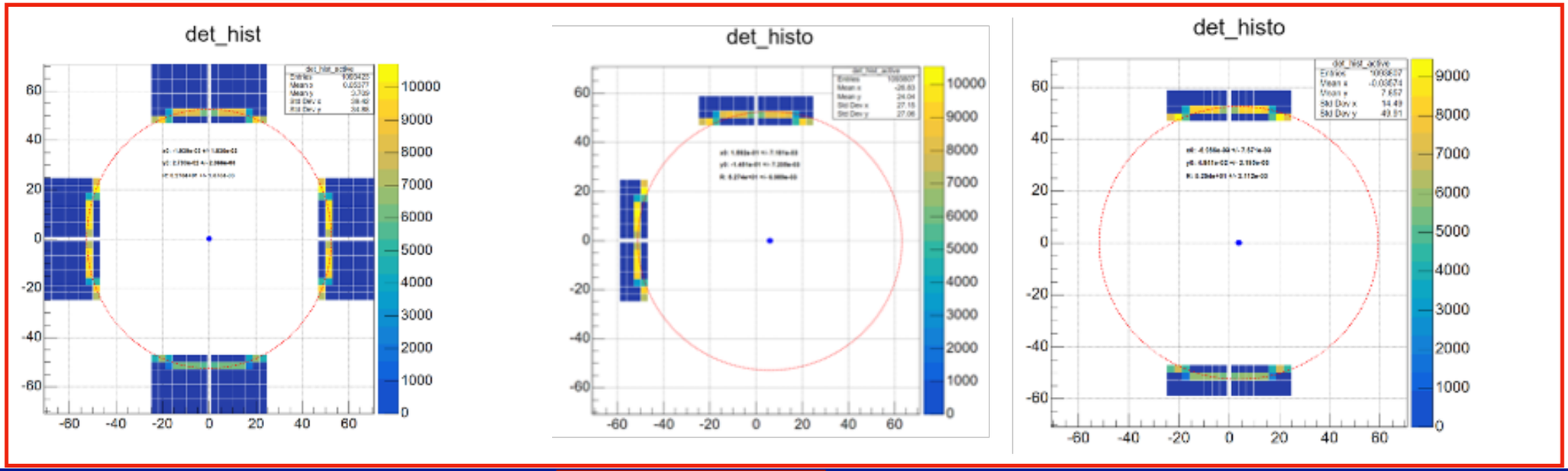
Double check of the distances, optics..

Test with additional arogel blocks: only one aerogel block used in September and Spring test beams









TB Spring 24 - Dataset acquired and analysis I

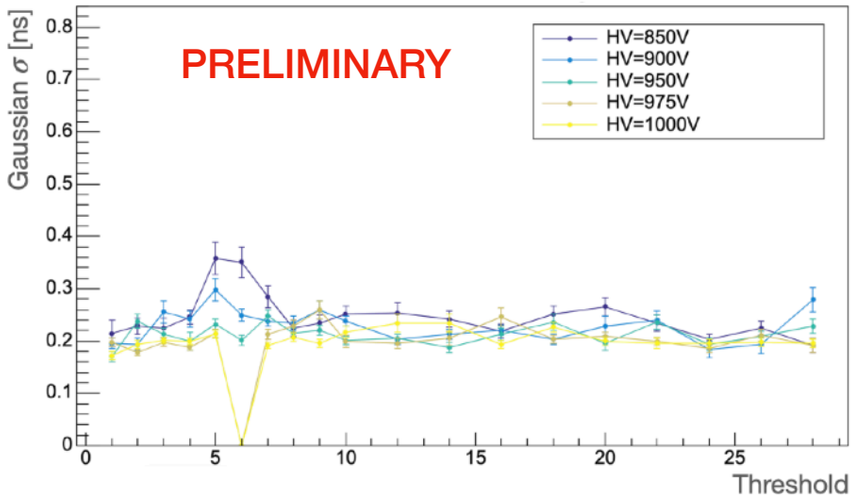
Successfull test beam campaign, millions of events acquired at different theresholds and HV for each sensor, in order to study the time resolution trend:

ECR, ECH voltage (850-1000) V
LAPPD - MCP kept at 850 V, photocathode voltage varied in the range (+100, +400) V relative to the entry of the first MCP
SiPMs - (55-60)V

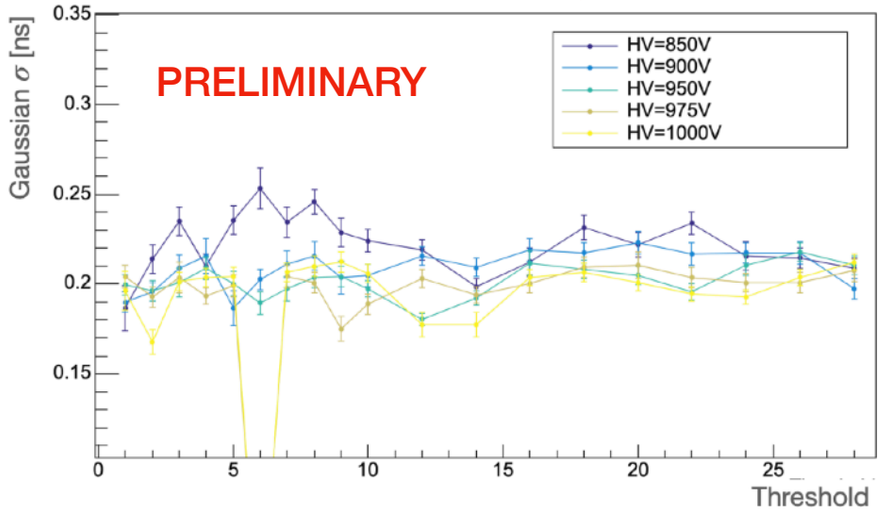
First plots extracted selecting the most populated bin in ToT, and studying the sigma of the Gaussian fit to the ToA distribution, to be independent from time walk correction

F.Borgato

2-inches MaPMT, ECH



1-inch MaPMT, ECR



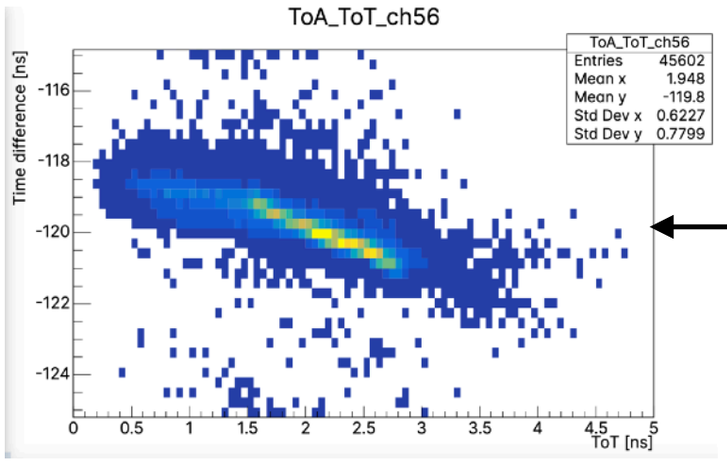
Work in progress! Regular meeting on Test Beam Analysis on Friday afternoon

TB Spring 24 - Dataset acquired and analysis II

Coupling of the fast electronics with the Upgrade II sensors is under investigation , at different thresholds

LAPPD

PRELIMINARY

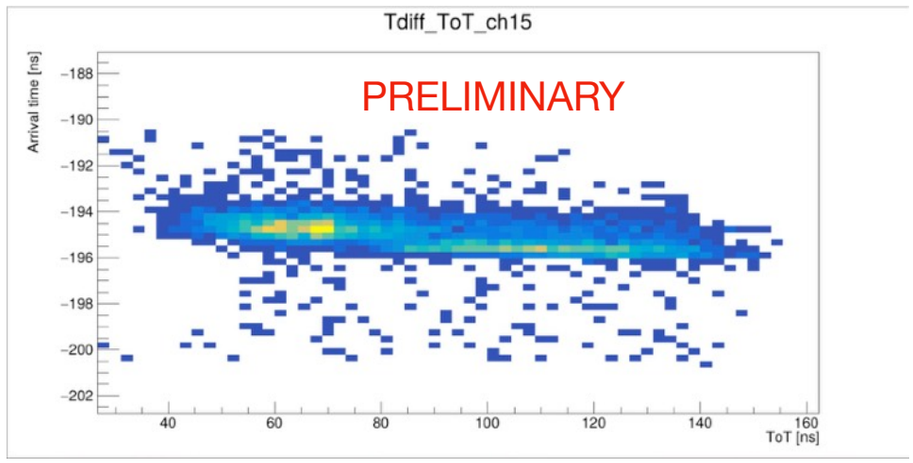


Clear correlation between ToA and ToT, time walk correction needed, studies in ptogress

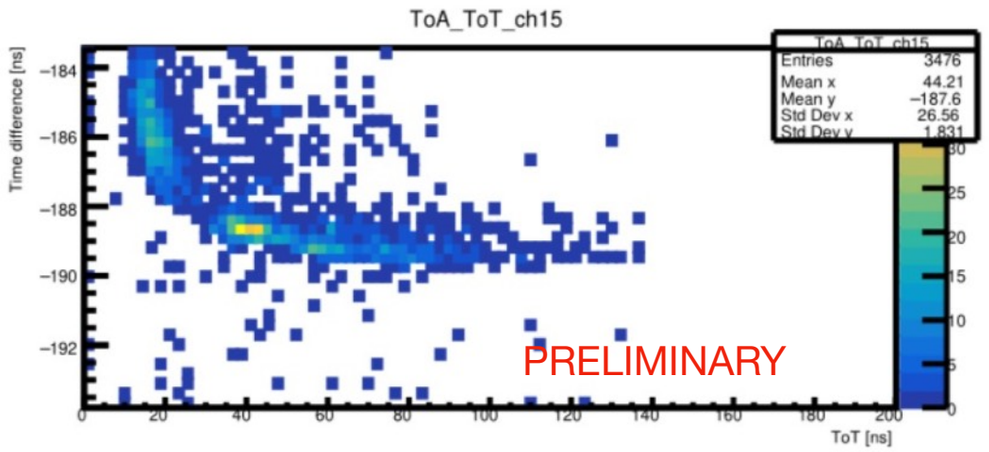
Master student in Edinburgh (Y.Wu) is working on time walk correction for his project

First preliminary results are really preliminary

SiPMs



S.Ghizzo



For the SiPMs also the behaviour of the dark counts is also under study (talk by **L.Malentacca** during the last TB meeting)

Summary and next steps

Successfull test beam campaign in Spring 2024!

And … NOW?

Analysis of the dataset

- Lots of dataset to play with.. Millions of triggered events acquired to study the behaviour of all the sensors in the test beam setup and to extract the ultimate time resolution

Master student projects also ongoing

Lots of fun work in the lab ahead in Edinburgh!

- Tests in the lab with oscilloscope to better characterise the sensor using a new fast picosecond laser
- New setup with multichannel electronics
- Preparation for the next test beam… (Nothing comes for free!)

RICH Test Beam group at Conferences this year

- Talk from Constantinos during the BTTB12 workshop
- Poster contributions on test beam at the Pisa Meeting 2024

➡ Test Beam Paper on 2022 data ready, in circulation soon

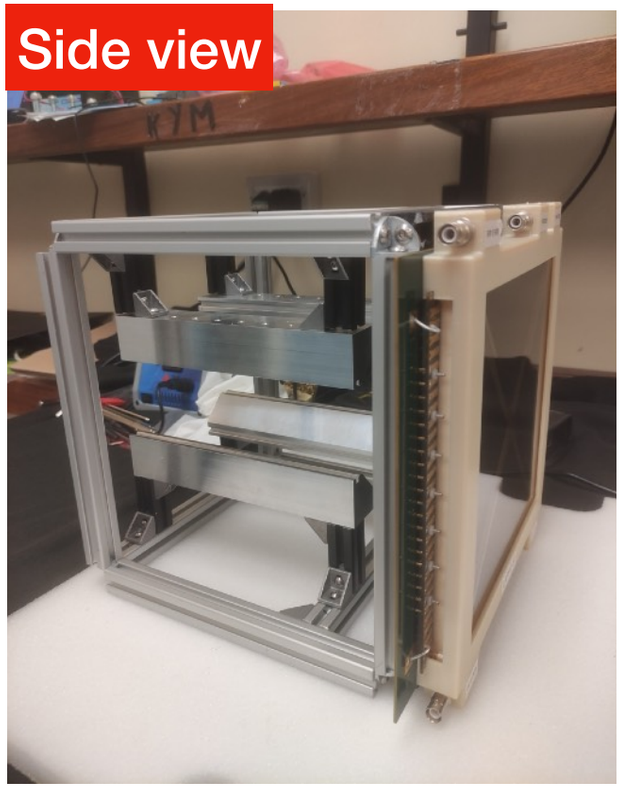
BACKUP

LAPPD mechanics for the test beam with fast electronics

O.Shea

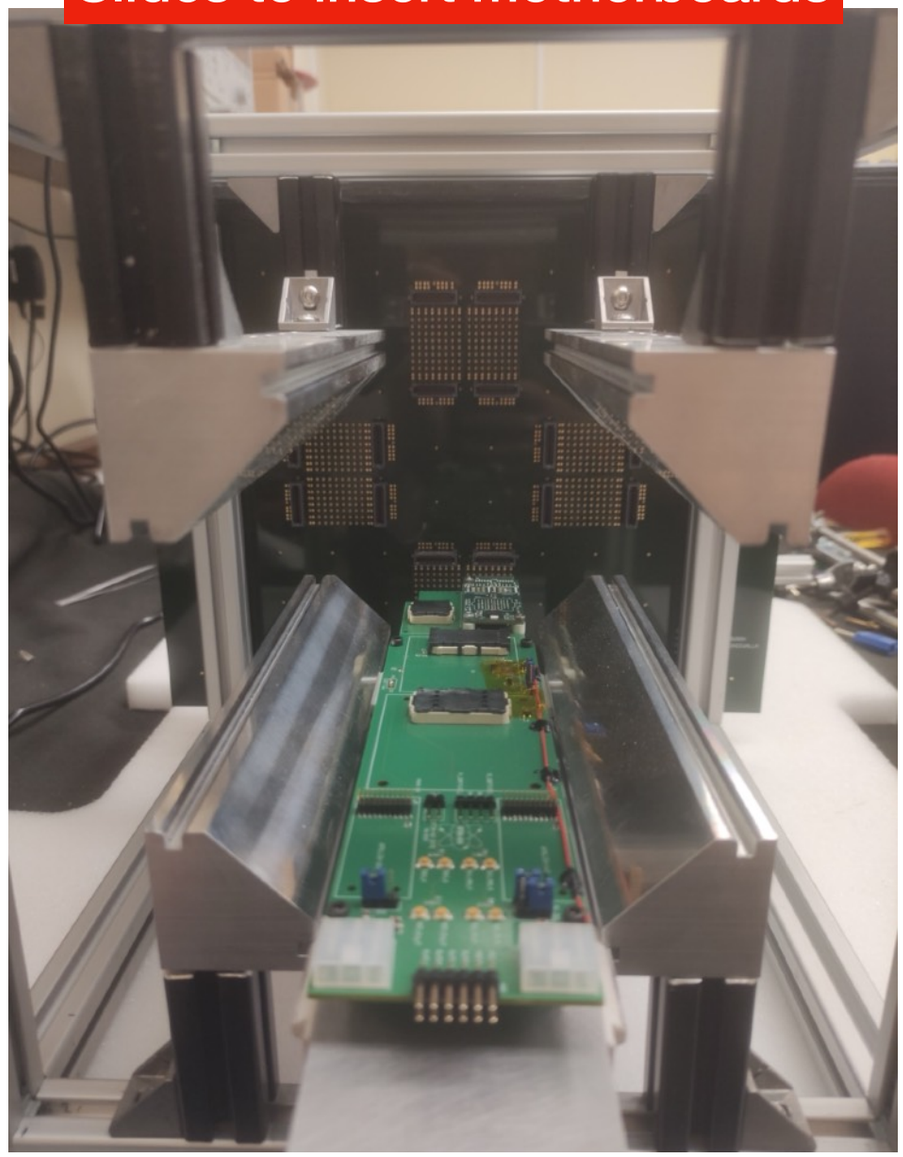
Front view

Side view



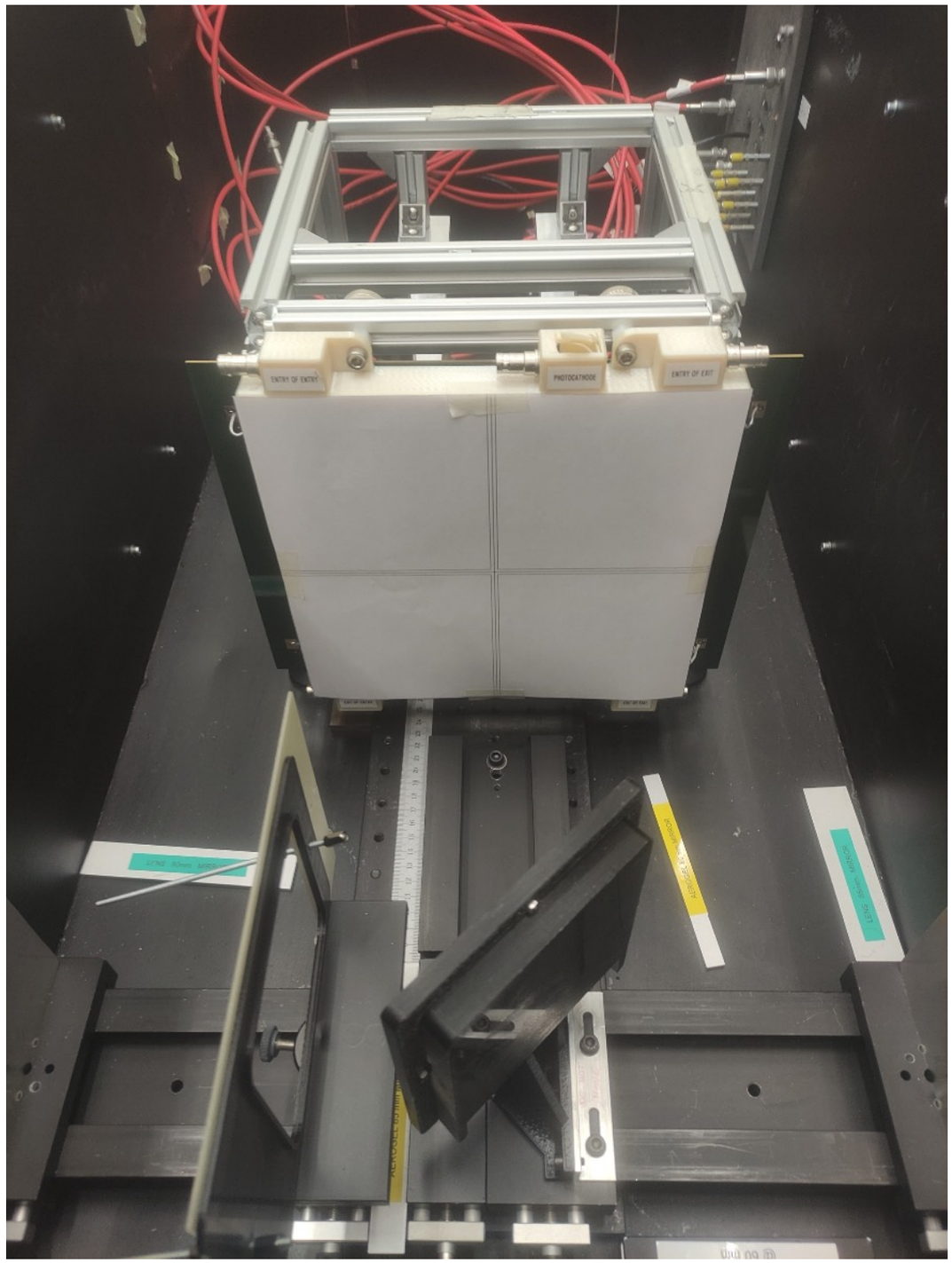
Up to 8 mother boards can be connected in parallel ✓

Slides to insert motherboards



Motherboard supports

Mechanics and alignment in the ComLAB



Improvements to the mechanics by Didier for the LAPPD box setup and to the LAPPD mechanics, to
allow the prefect connection of different boards at the same time