LAPPDs for the LHCb RICH Upgrade II Activities in Edinburgh

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University of Edinburgh

LAPPD workshop
8 May 2024

Outline

LHCb RICH Upgrades and Edinburgh involvment

LAPPD work in Edinburgh

- **New custom** readout board
- **New** mechanics for the September test beam
- First Tests in the laboratory

Test Beam at CERN SPS

September 2023 and April/ May 2024

- Optics and simulation studies
- Setup Installation

Next steps and future plans

LHCb Upgrade Ib

Many advantage to add the timing information to the RICH detector in Upgrade Ib using current MAPMTs
See Steve and Dan's talks for more detail

LHCb Upgrade II

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

➡ Main technologies considered, R&D planned for each: improved MAPMTs, SiPMs, MCP based solutions

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

➡ 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 - see M.Fiorini's talk - RICH parallel session LHCb week

➡ Strong R&D on photon detectors neeeded

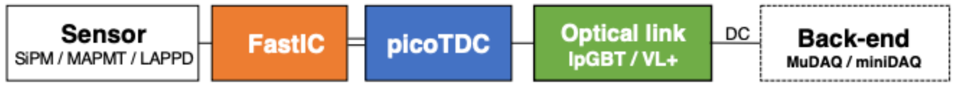
Involvement of the LHCb RICH Edinburgh group

➡ MCP based solution considered - LAPPD - test in the lab already presented in the LHCb UK upgrade meeting last year

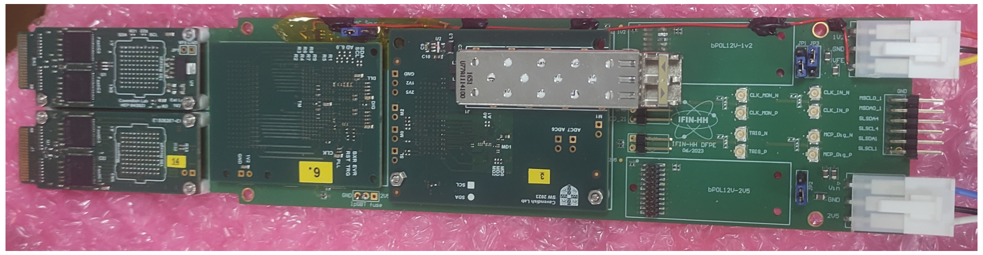
➡ Studies to allow the full integration with RICH fast electronics with Upgrade 2 sensors

➡ Participation in RICH test beams

2023 beam tests



See LHCb Upgrade II talk on LS3 RICH enhancement



LAPPD (INCOM US)

Micro Channel Plate photomultiplier,
Dimension 20 x 20 cm²

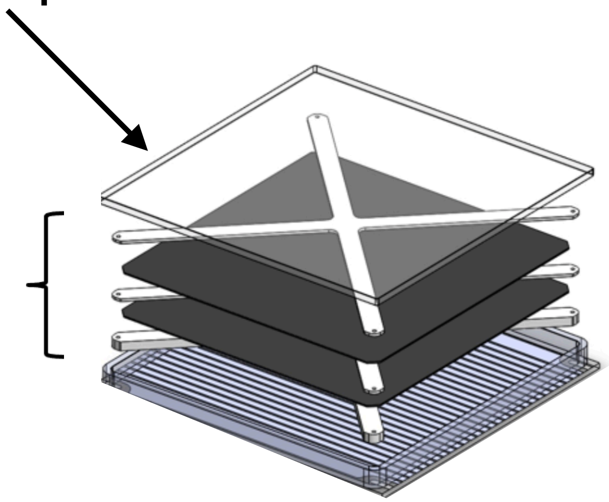
Advantages:

- 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*

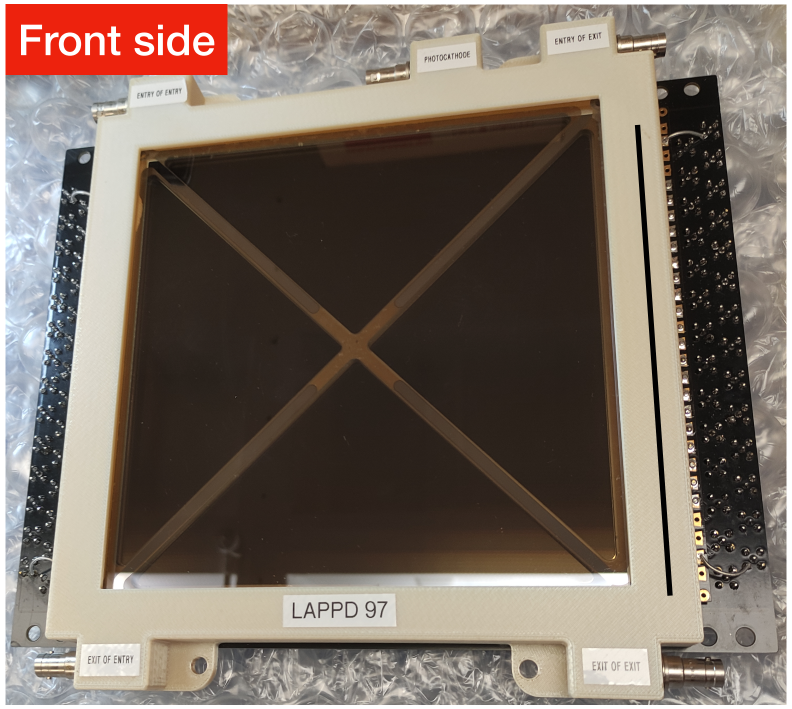
20 cm x 20 cm MCPs, spacers



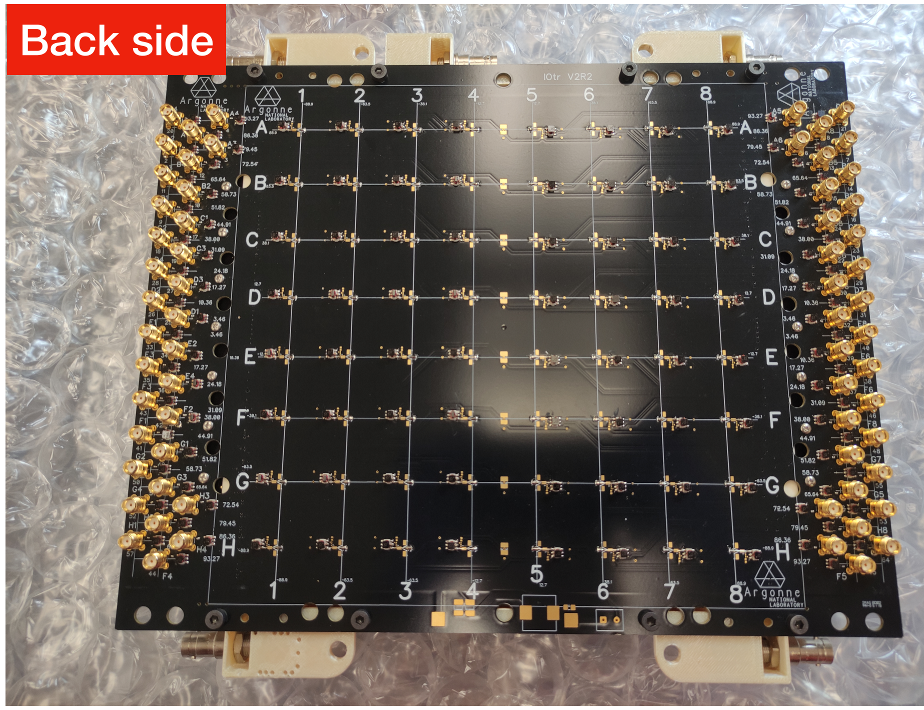
Gen II LAPPD 97 @ Edinburgh

- Gen II LAPPD, pixel readout
- Spectral response 160-650 nm
- 5 taps for independent voltage control of the photocathode and entry/exit of each MCP
- readout board used for testing so far as directly provided from INCOM, **pixel Pitch to pitch** distance **25 mm**, effective dimension 24 x 24 mm²

Front side



Back side



➡ Pixels too big, new custom readout board with 3mm pitch to pitch designed in Edinburgh to improve the spatial resolution

LHCb test facilities in Edinburgh

Different activities going on at the Edinburgh laboratory

➡**Test bench for fast photodetectors**

- Dark box
- Picosecond Laser for gain and timing studies of fast devices
- CAEN digitiser (DRS4 chip based) and fast oscilloscope (bandwidth 20GHz) available in the lab

Lab results from LAPPD 97 already presented during the last LAPPD workshop using PicoQuant laser, wavelength 470 nm, pulse width 70 ps, jitter<20 ps

➡**QE setup to be revived, work in progress**

- Dark box
- Monochromator
- Photodiode

➡**Quality ensurance test stations for spare MaPMTs**

- test the spare MaPMTs used in the Upgrade I LHCb, to better investigate the properties while the Run3 commissioning is ongoing

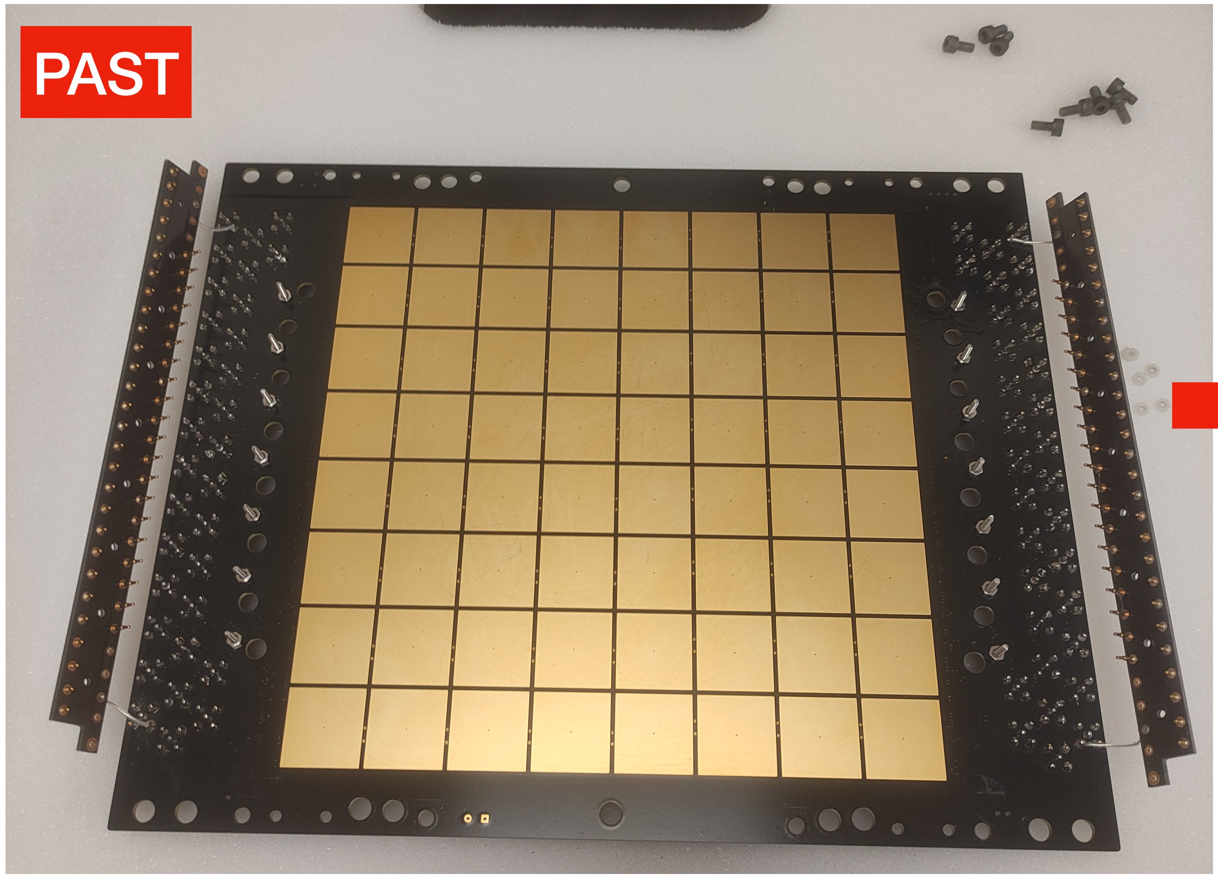
➡**Progress in readout board design, to couple the sensors with fast electronics**

- Custom readout board for MCP based detector (LAPPD)

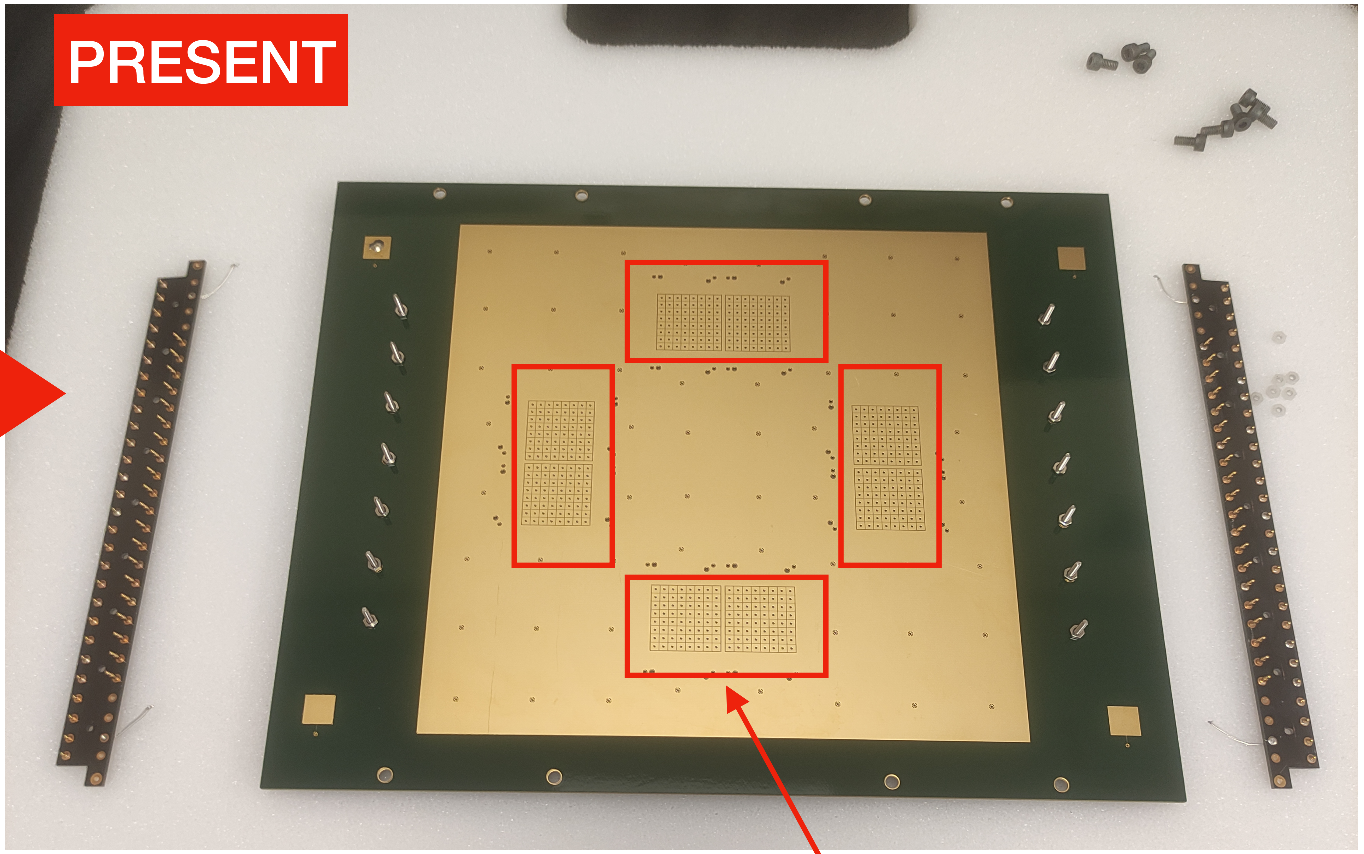
➡**The Edinburgh group is actively involved in RICH test beam campaigns**

Edinburgh custom readout board (P. Gheewalla)

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



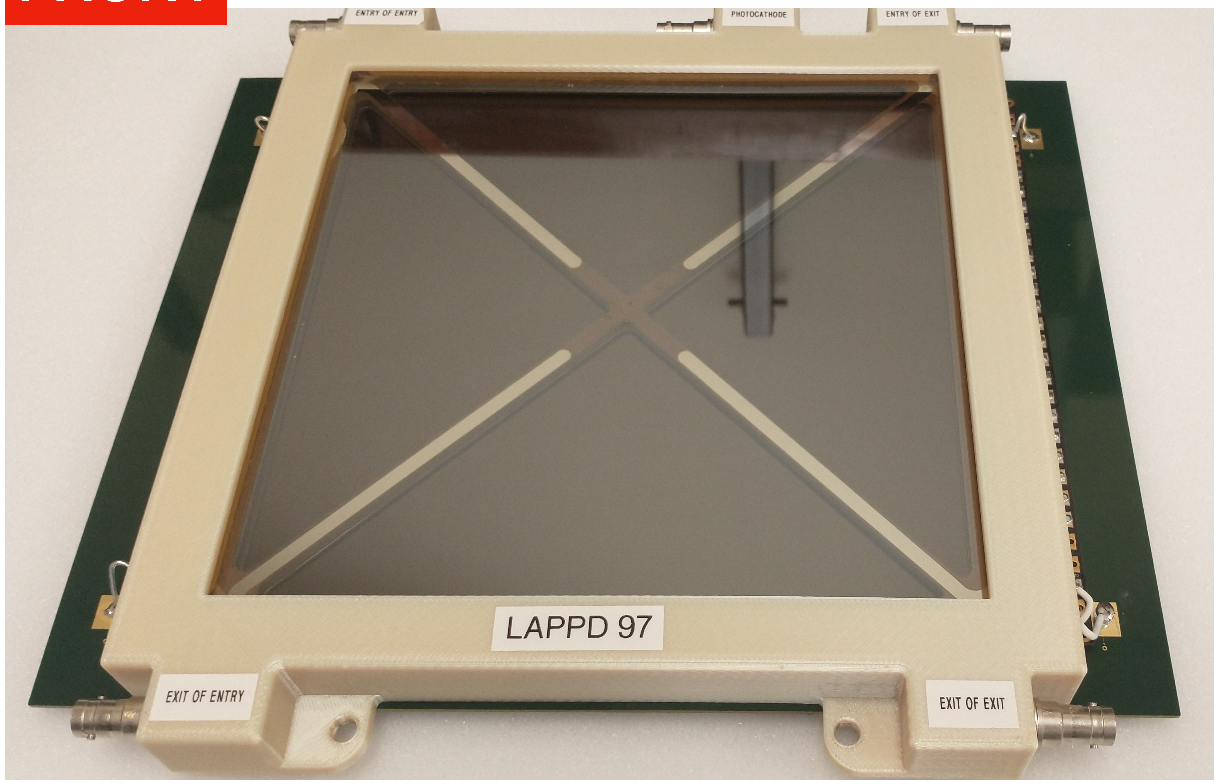
Custom readout board V0, 512 pixels
Pixel size:
3 mm pitch to pitch
(2.9 x 2.9 mm^2 active area, 0.1 mm dead gap)



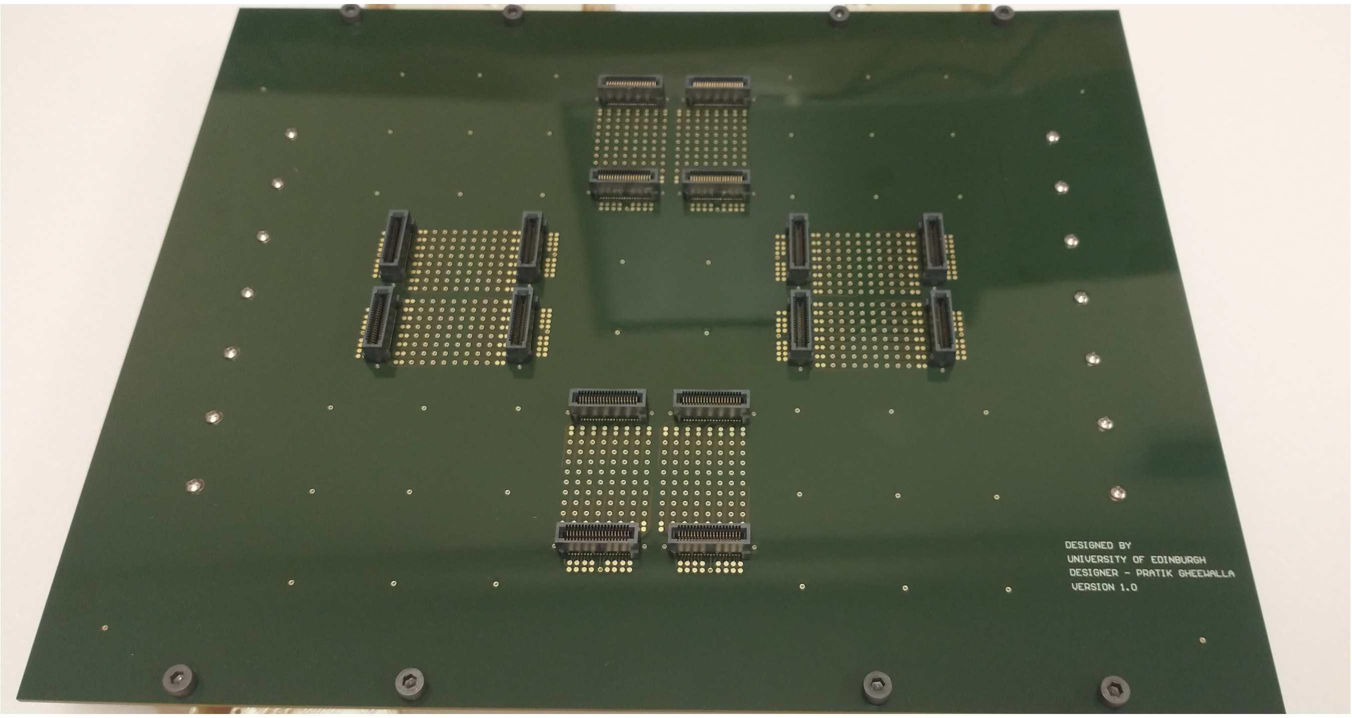
Active area
to match the Cherenkov ring
For the Sepetember test beam

LAPPD assembly

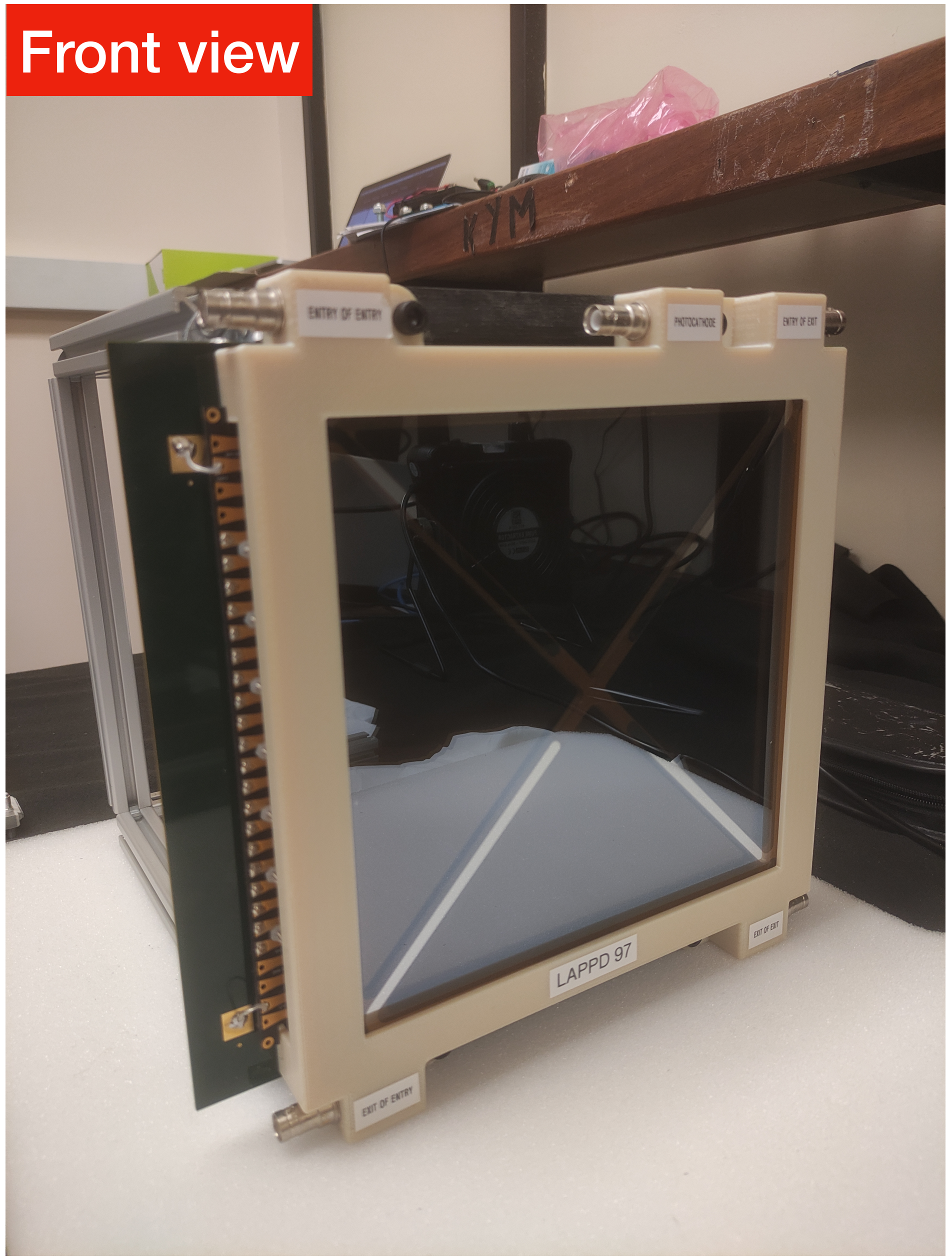
FRONT

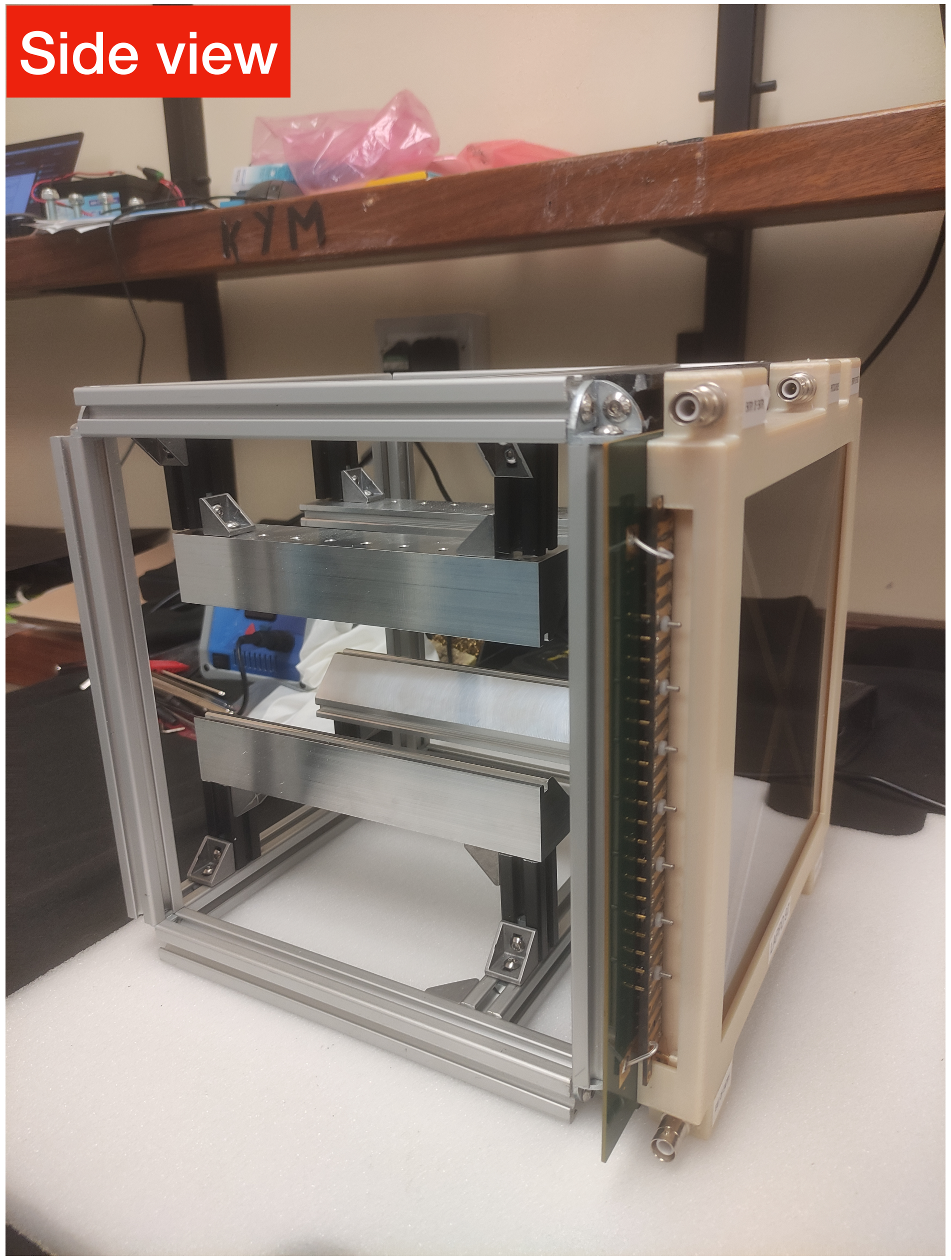


BACK

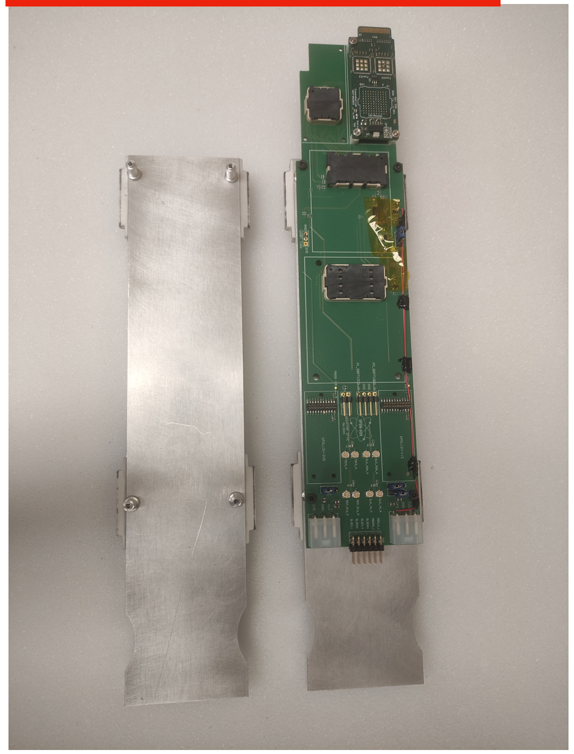


LAPPD mechanics - I (O.Shea)



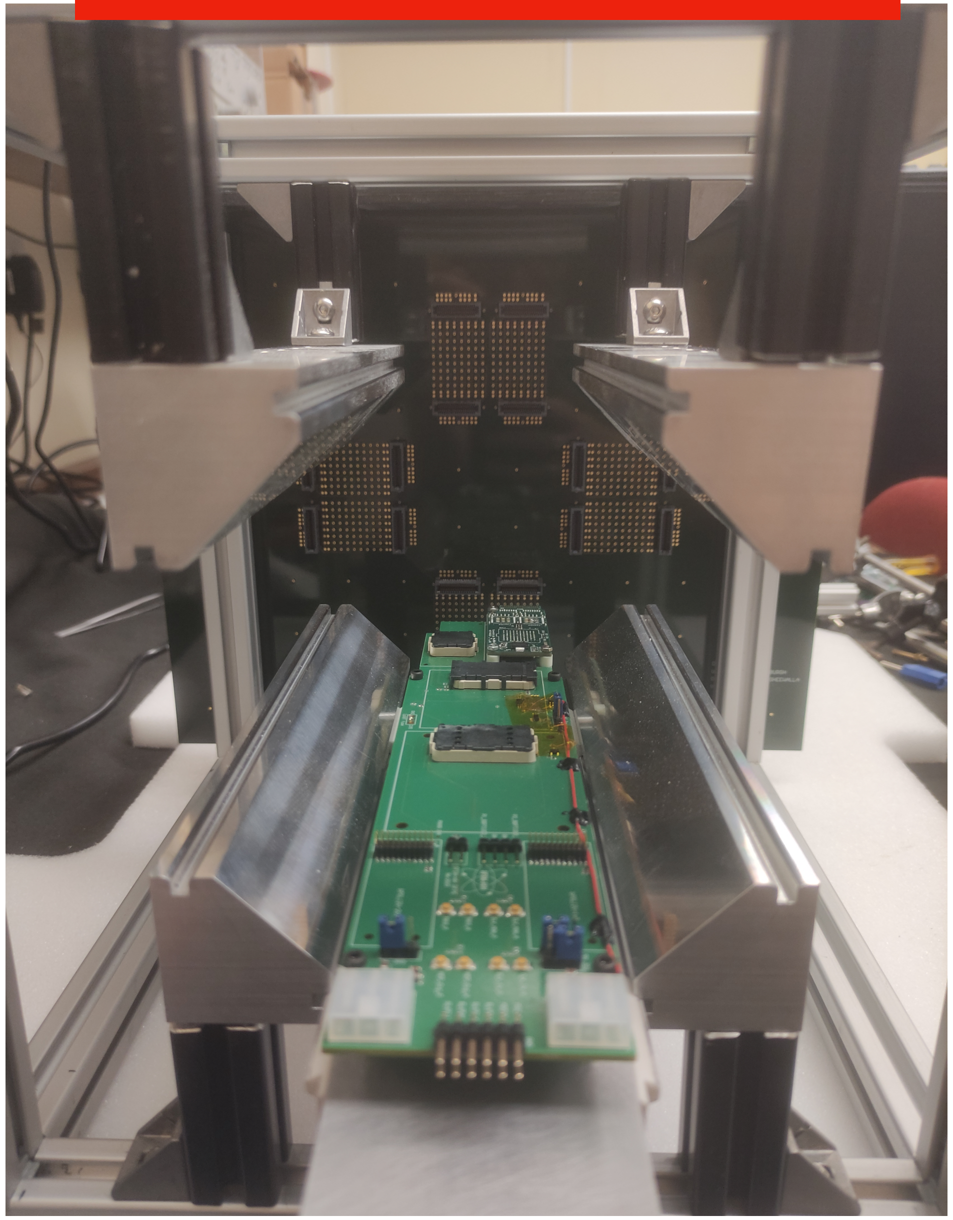


Motherboard supports

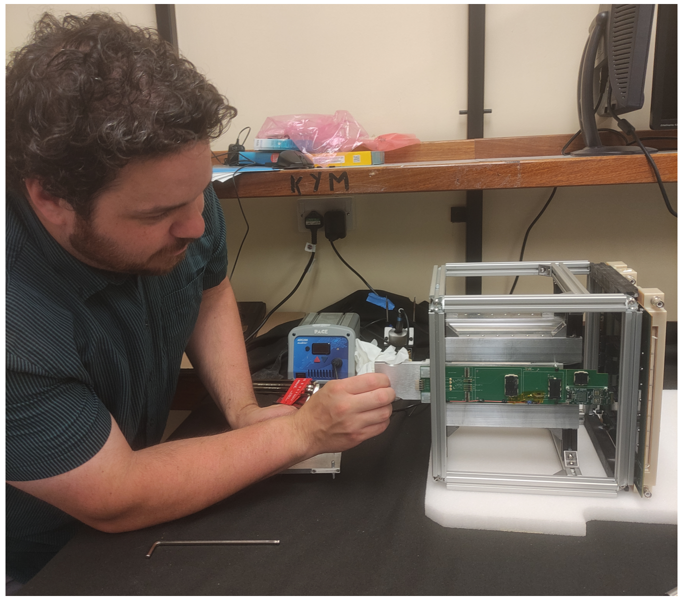


Up to 8 mother boards can be connected in parallel ✓

Slides to insert motherboards



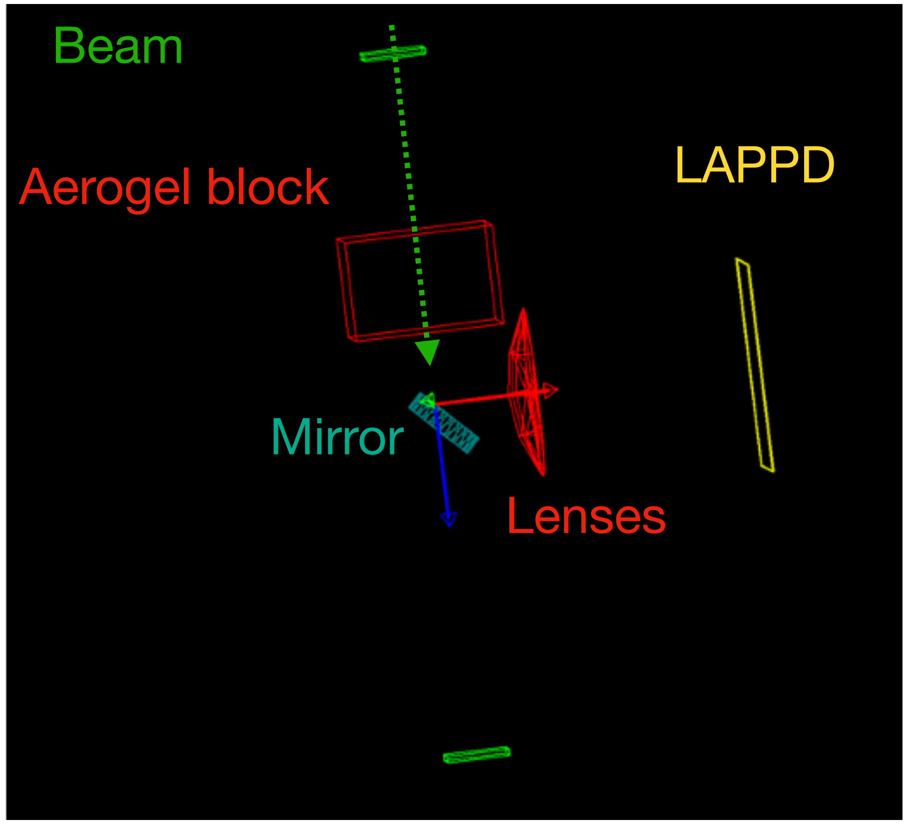
✓ Stress tests performed in the lab with the dummy board in Edinburgh



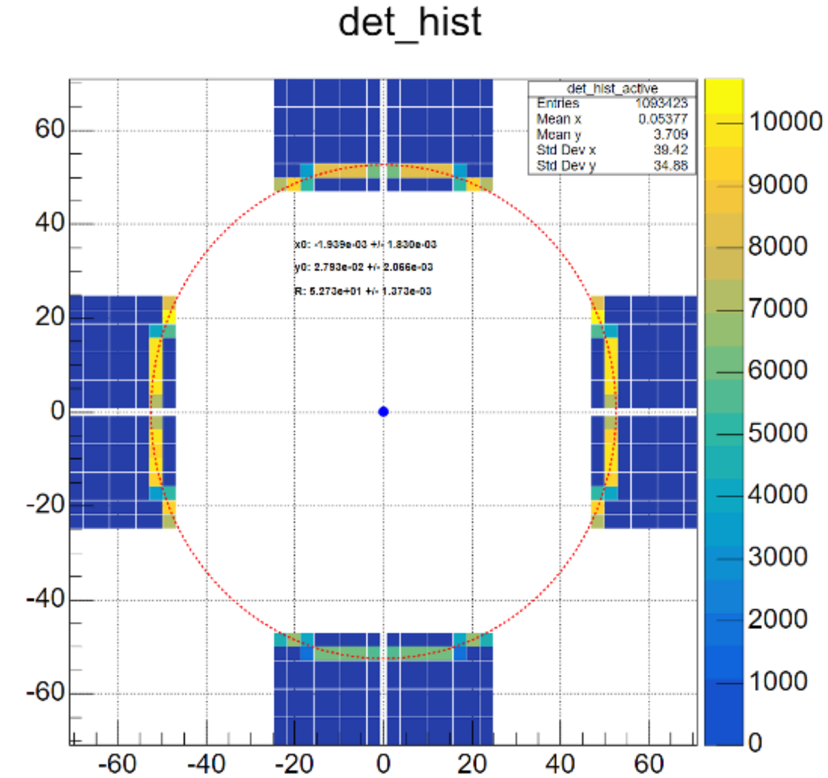
Simulation (Kiev group)

Test beam simulation studies in collaboration with KNU and Ljubljana

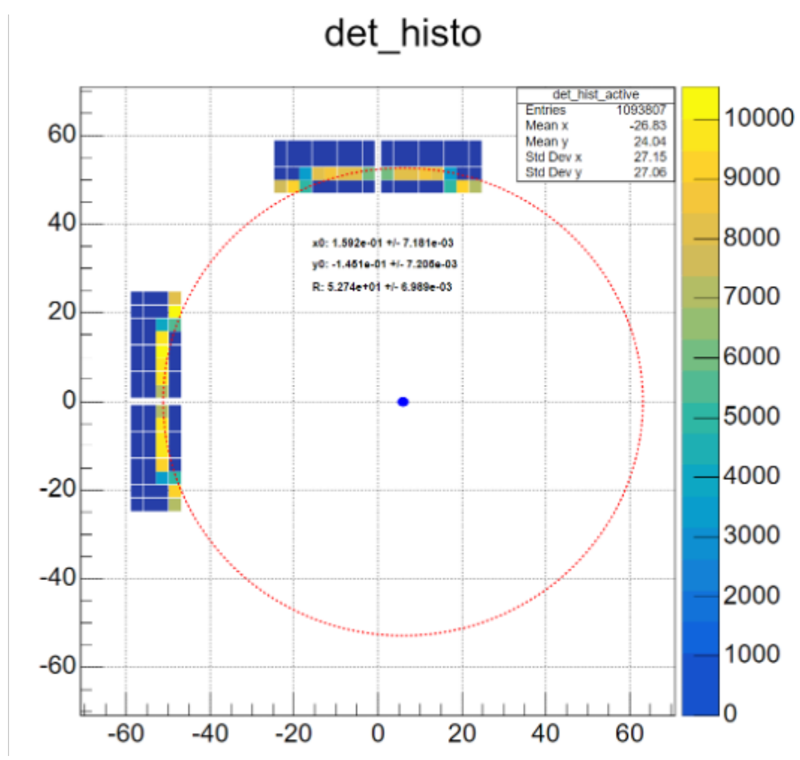
Thanks to the Ljubjana group for the simulation framework

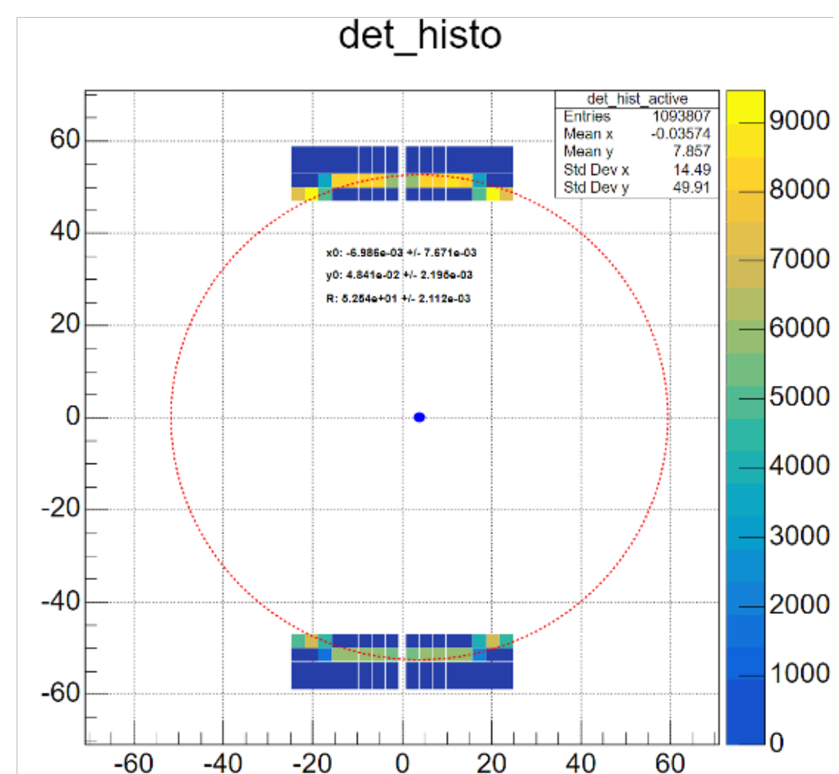


Implementation of the new LAPPD geometry



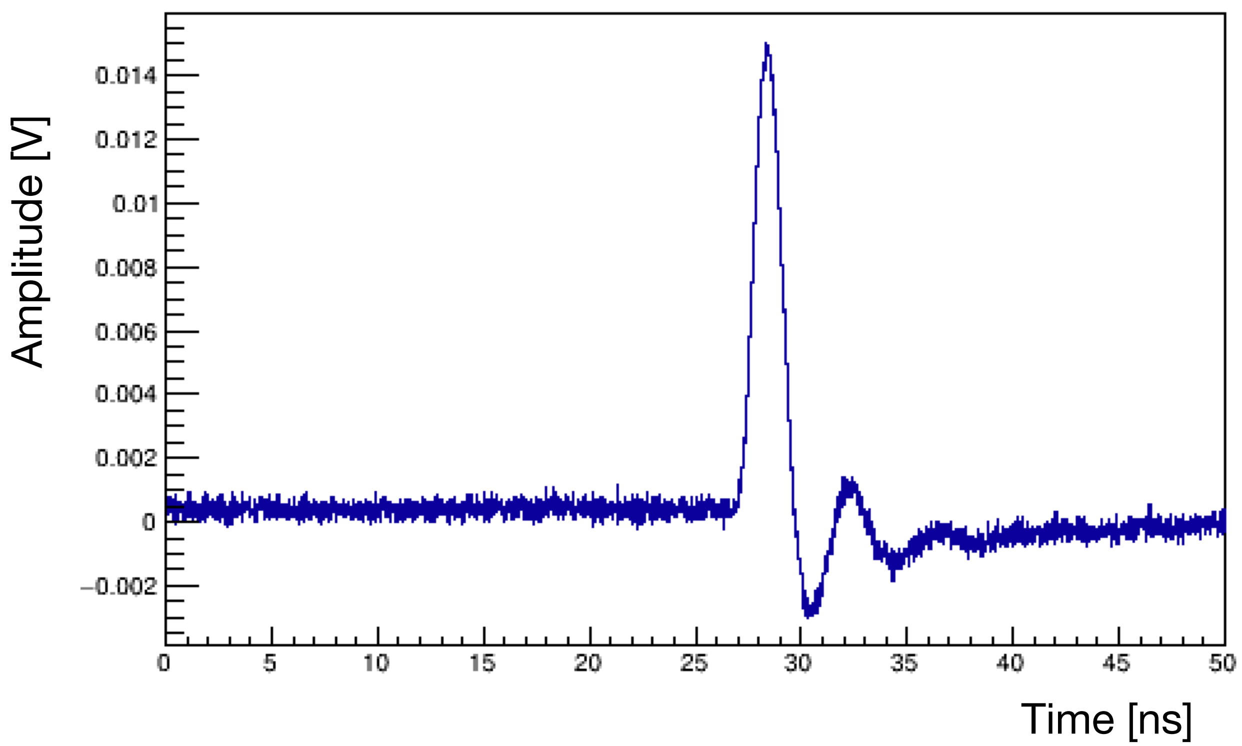
➡work in progress to insert in the simulation the exact final distances used in the test beam



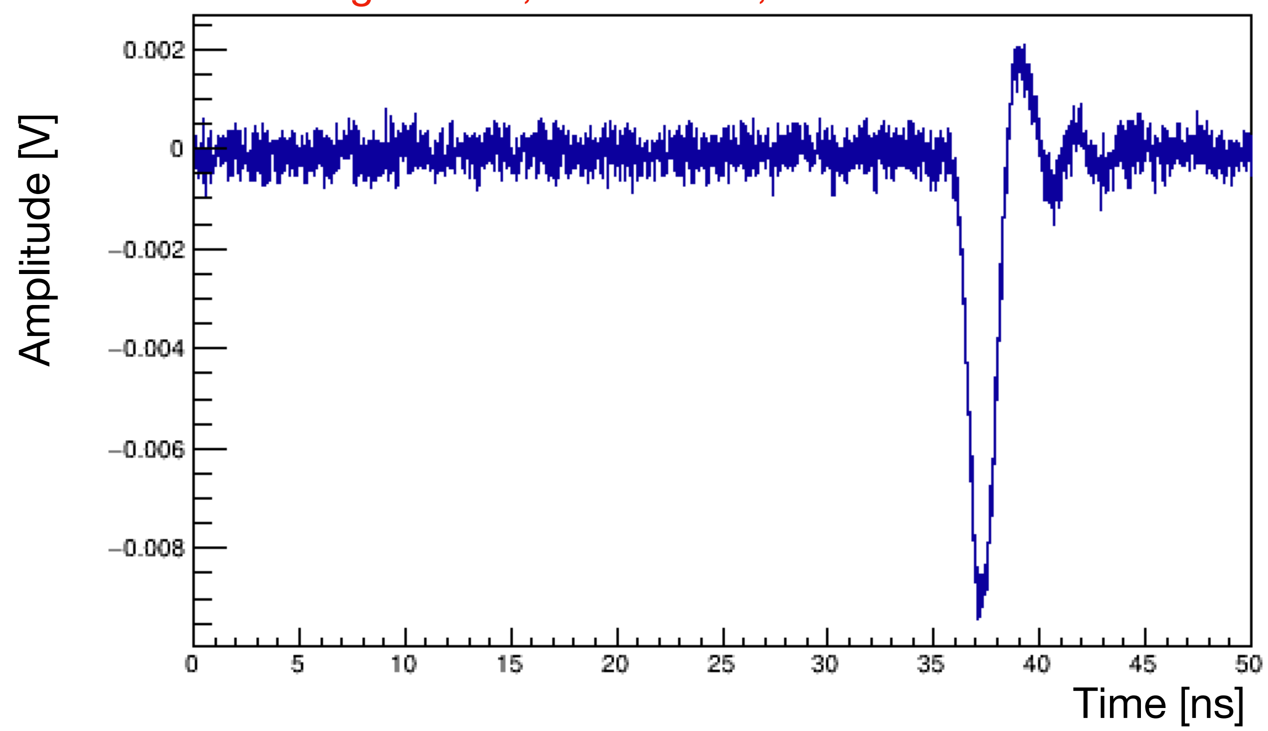


Signals - INCOM and Edinburgh boards comparison

INCOM board, MCP 850 V, PC 100 V



Edinburgh board, MCP 850 V, PC 100 V



RISING TIME

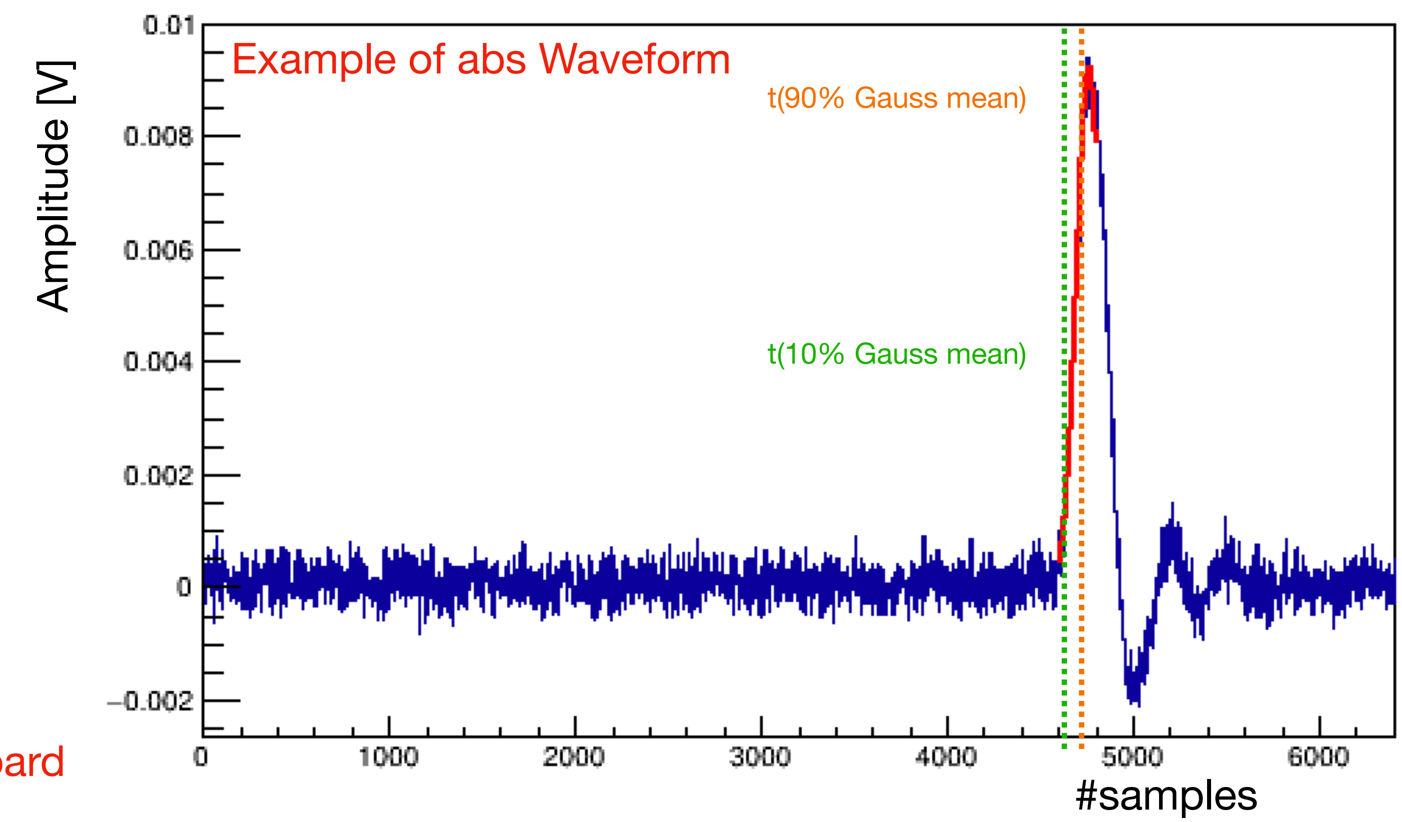
Acquired with oscilloscope

Digitisation rate 128 GS/s
Bandwidth 20GHz, 50Ω Termination

In both cases

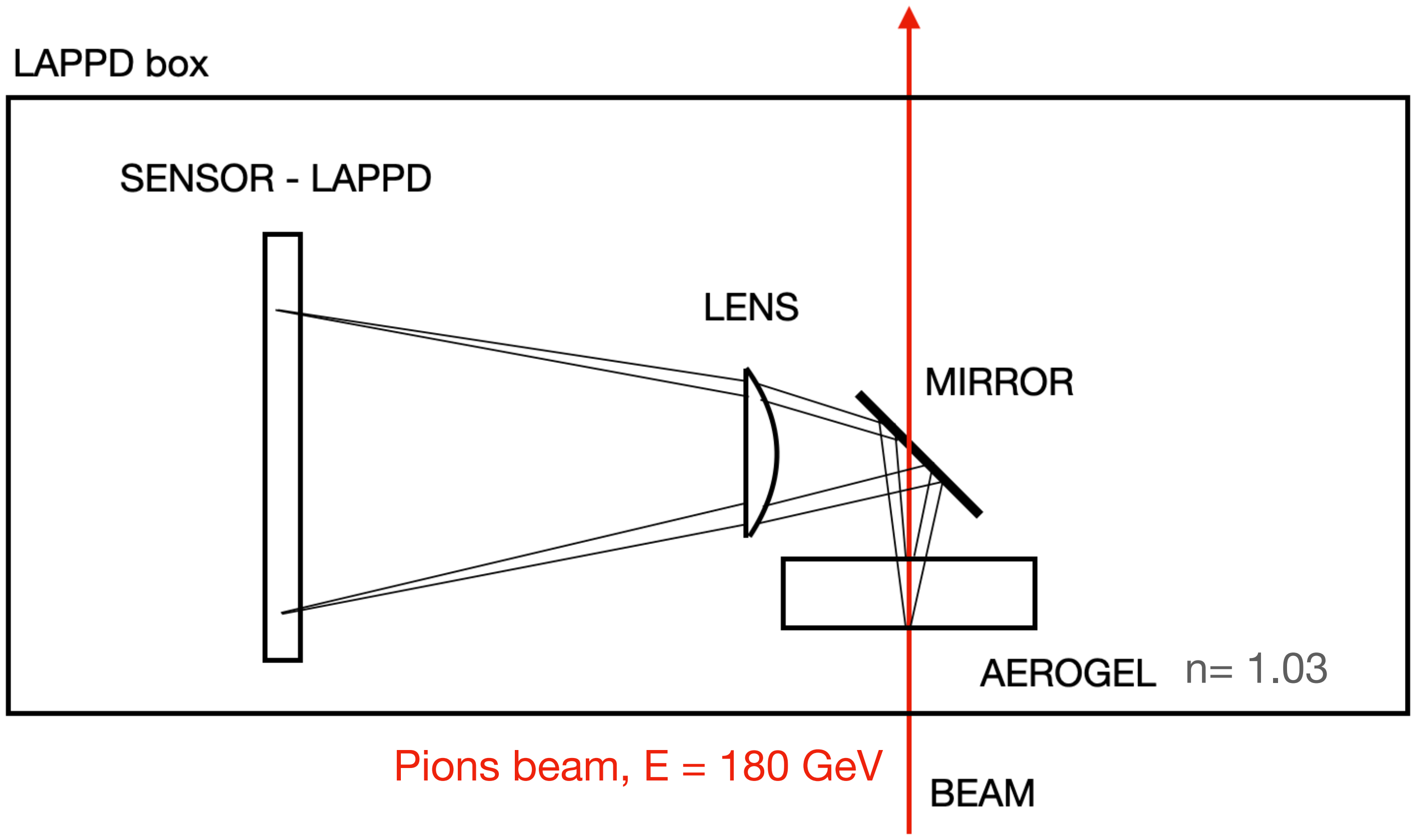
Rising time extracted performing a Gaussian fit to the waveform

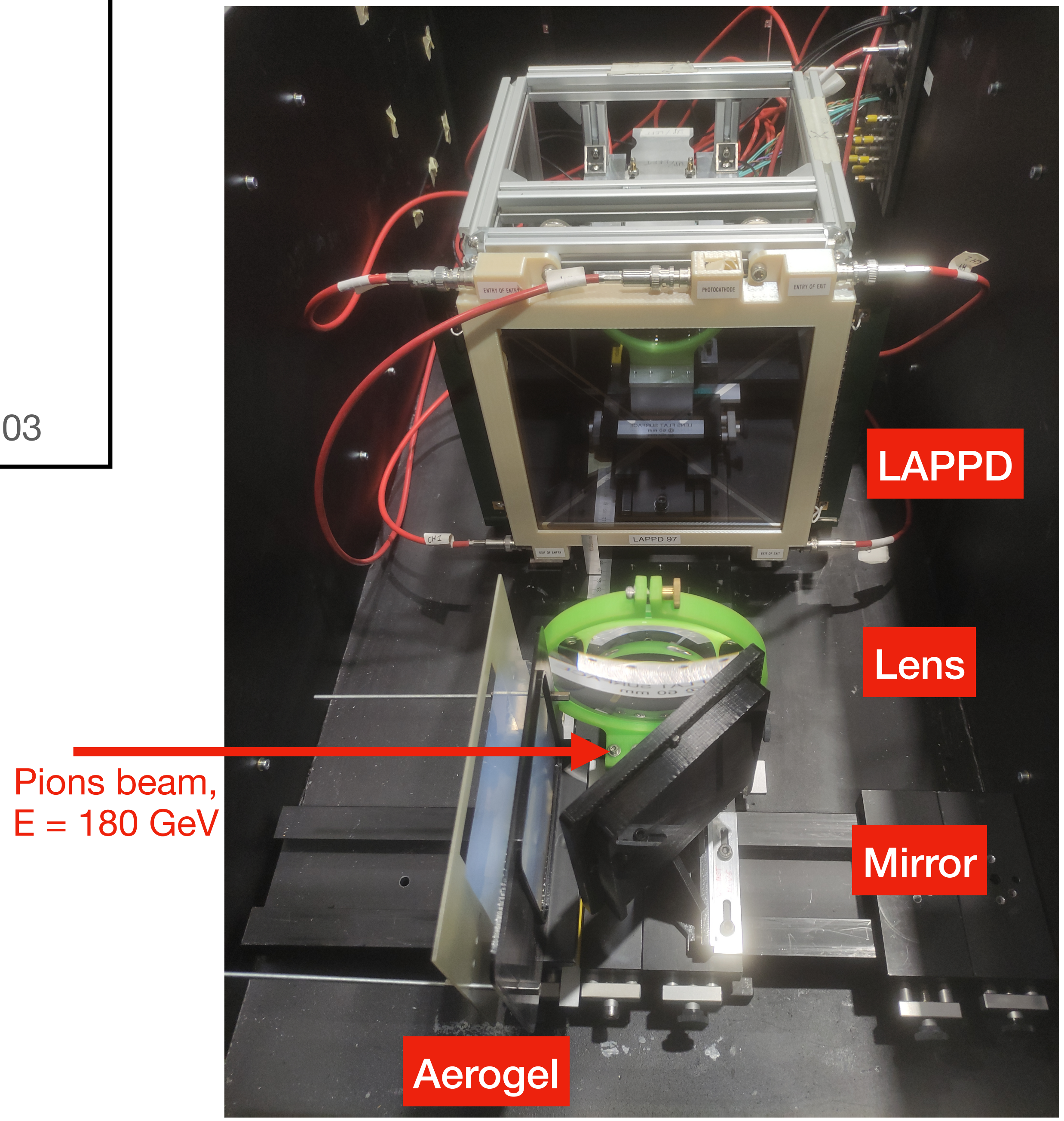
t(90% Gauss mean) - t (10% Gauss Mean) ~ 700-800 ps



Study in progress with the new custom board

The Edinburgh group participated to the LHCb RICH test beams in September 2023 and April/May 2024 with the **LAPPD 97**

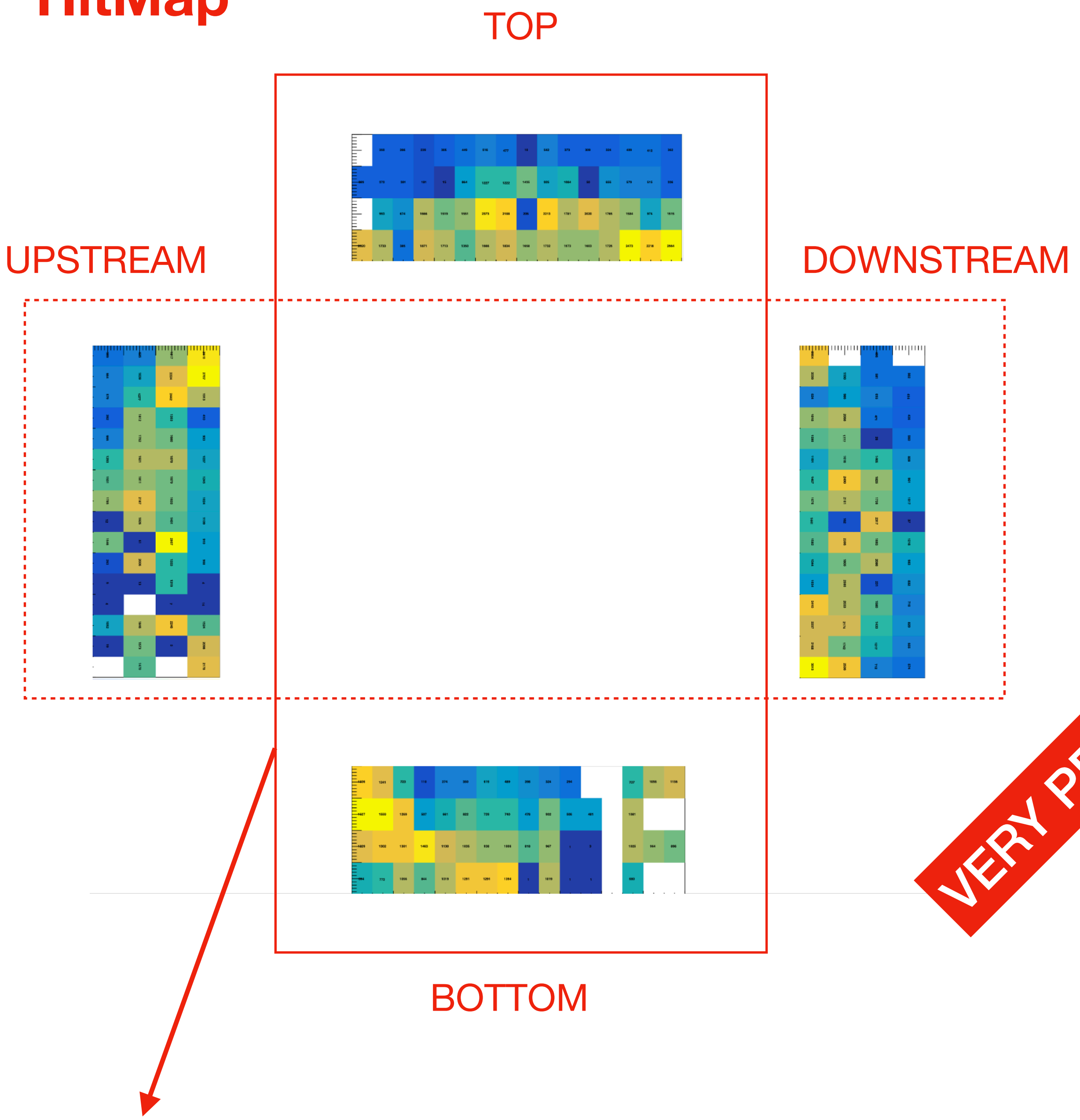


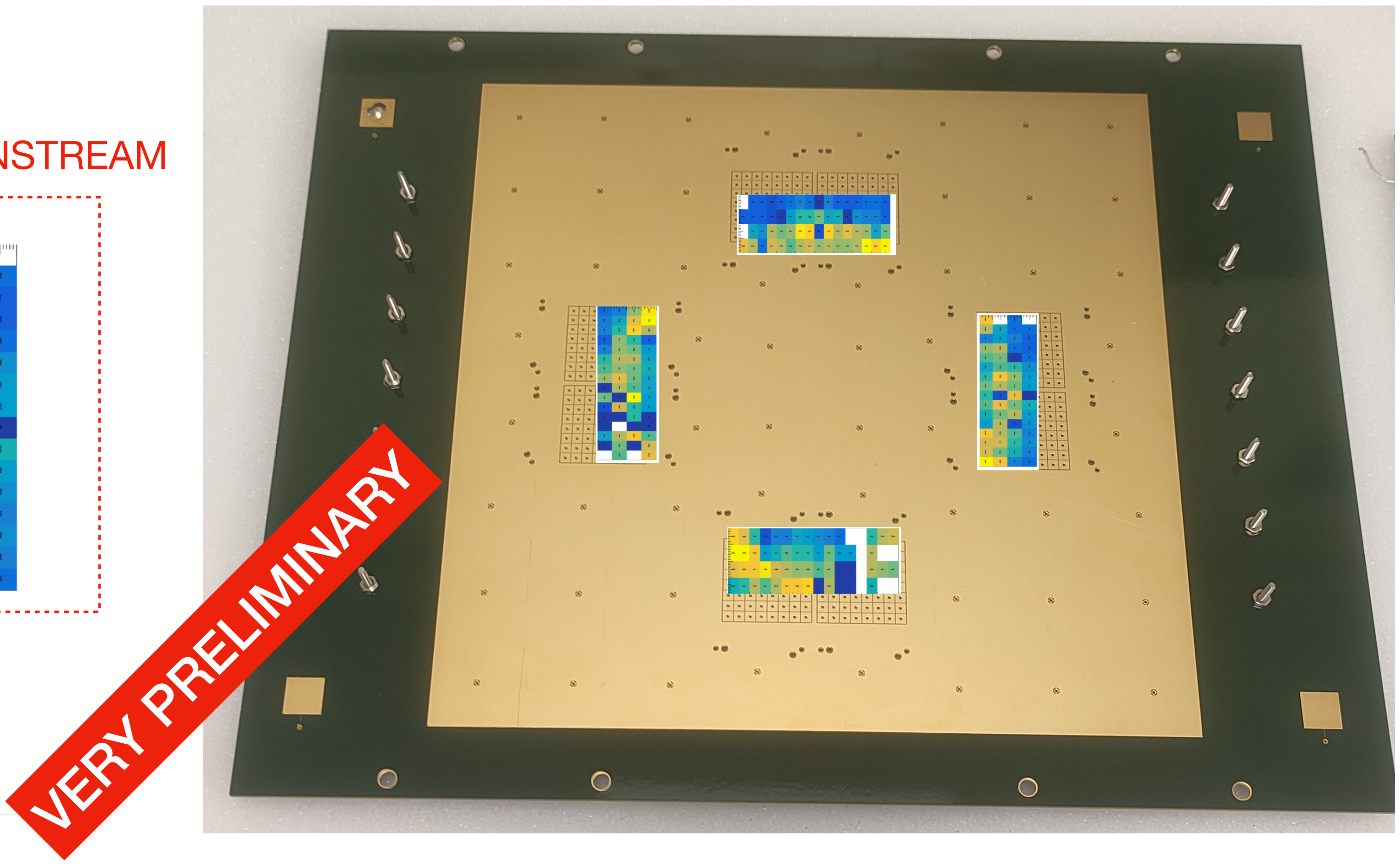


✓Two available readout boards to readout up to 128 channels at the time

Very first rings observed

HitMap



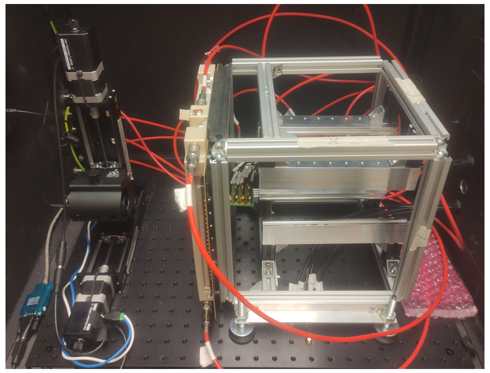


Board swapped in one access, same beam configuration
TOP/BOTTOM -> UPSTREAM/DOWNSTREAM

- Data acquired for different HV working point and pedestals
- Analysis will be conducted to extract the best time resolution

Ongoing work in the lab

Ongoing tests with the LAPPD Edinburgh backplane in the lab
Study of the footprint spread - ongoing tests using CAEN digitiser (DRS4 chip)/Oscilloscope readout



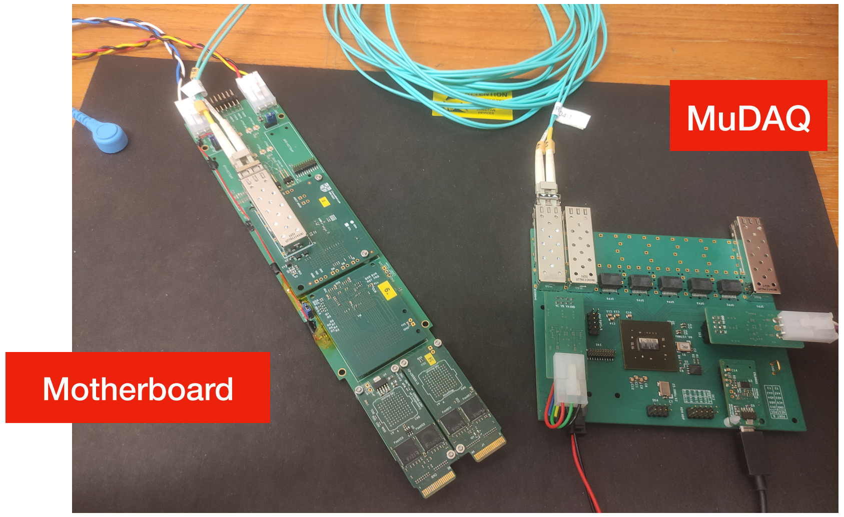
Improve time resolution measurements
New laser purchased to improve time resolution measurements
Custom picosecond laser, Pilas wavelength 405 nm, pulse width 25 ps, jitter<2ps
(Laser in use Taiko PicoQuant, Pulse width (FWHM) 70 ps, jitter <20 ps)

Next steps

Tests in the laboratory using multi-channels fast readout used in the last RICH test beam campaign

up to 64 channels readout using a single motherboard, MuDAQ available in Edinburgh

Characterise the existing electronics in the lab



Investigating the limitation of MCPs, in particular the high rate capability.
Interested in High Rate Photodetector (HRPPD) directly coupled pixellated anode, with better time resolution and spatial footprint.