LAPPD for the Upgrade II of the LHCb RICH Activities in Edinburgh

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LAPPD workshop
20th April 2023

Outline

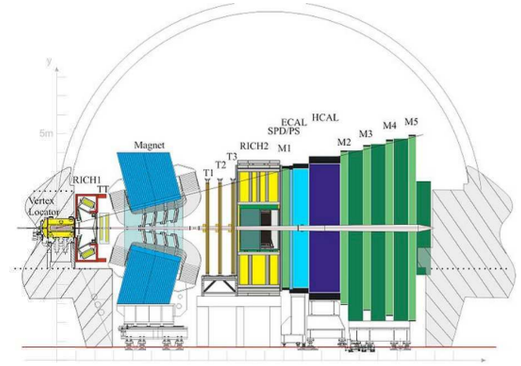
- LHCb RICH photodetectors Phase II Upgrade
- LAPPD Edinburgh setup
- Programmed LAPPD measurements @Edinburgh
- First gain, dark rate study and time resolution extraction
- Future plans in Edinburgh

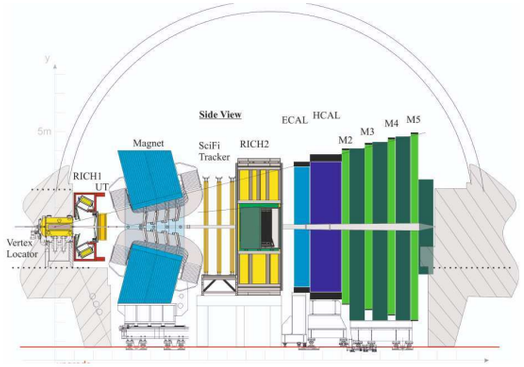
Possible candidates

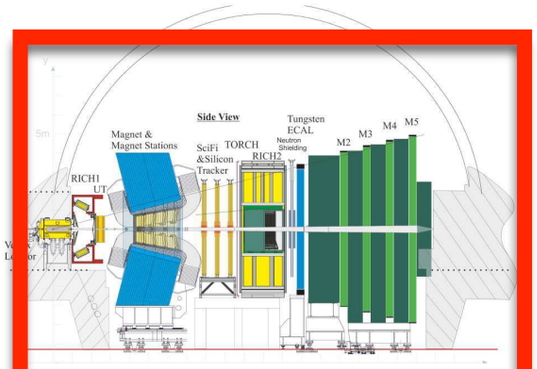
LAPPD Motivation

LAPPD features

Phase II Upgrade challenge

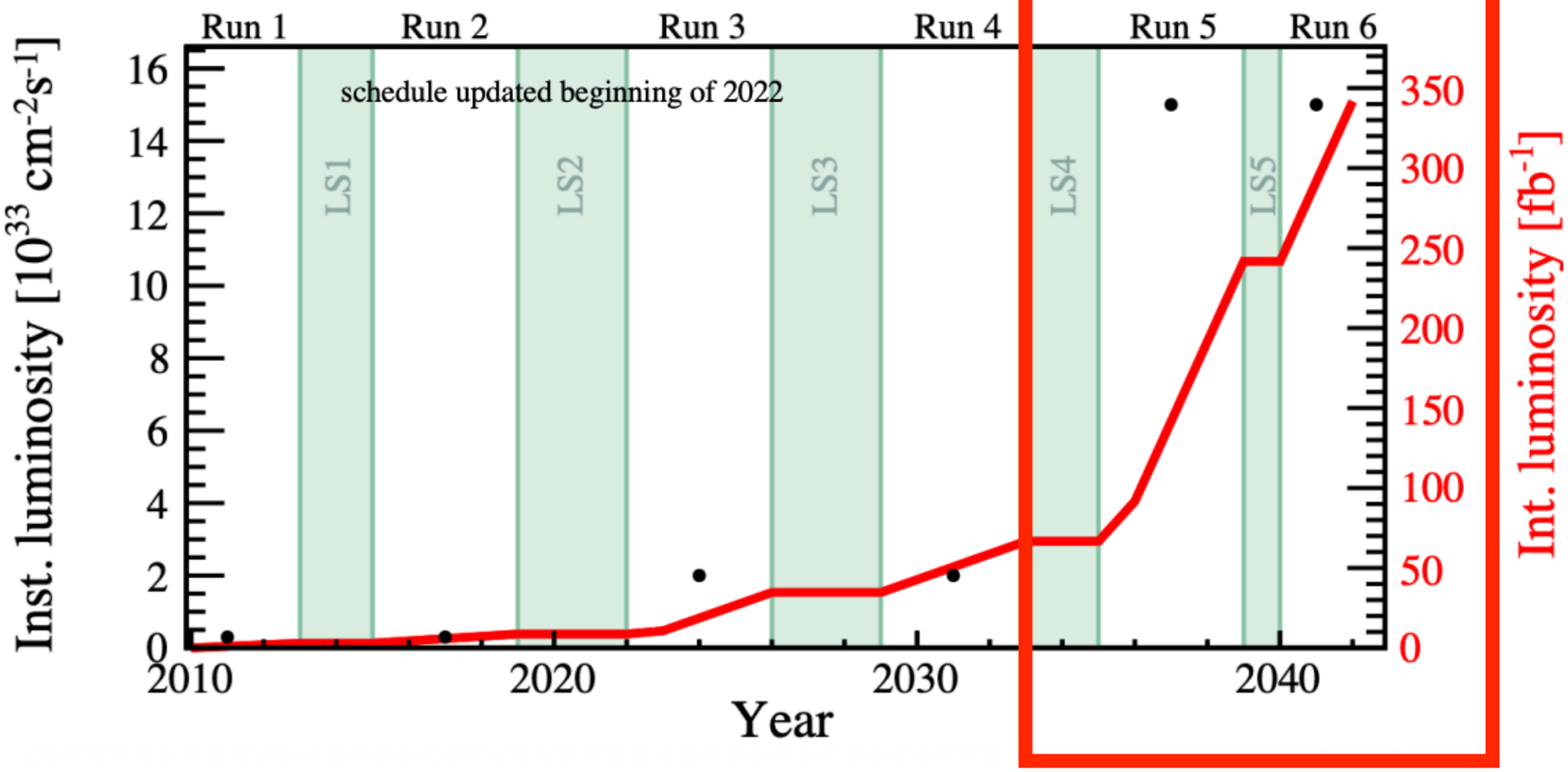






LHCb → **Upgrade I** → **Upgrade II** →

current



RICH CHALLENGE:

Cope with the instantaneous luminosity

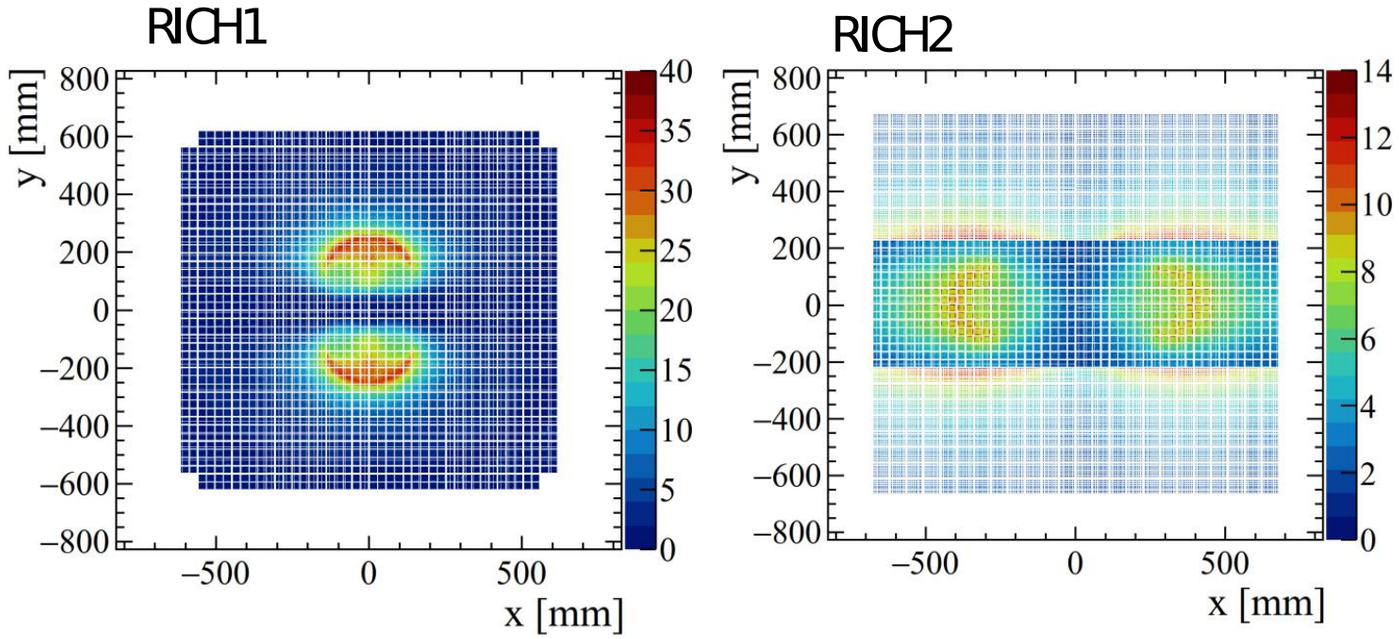
Be able to detect single photons in extremely high occupancy regions.

MAIN STRATEGY FOR DETECTOR R&D:

reduce the pixel size and add timing

RICH Upgrade II

Simulation Upgrade I

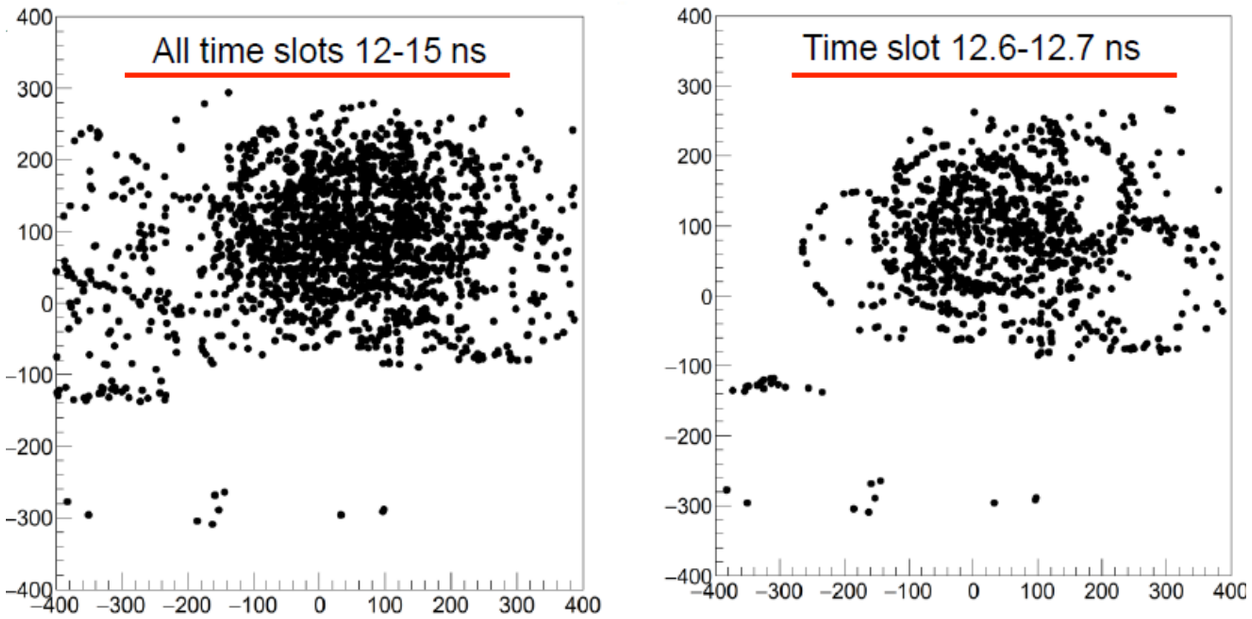


From simulation **peak occupancy** in Run3 conditions reaches **~35% in RICH1**

Occupancy in Run5 keeping same photon detectors and geometry **would reach 100%**

Possible solution

TIME READOUT on RICH detectors



Photon detectors for RICH Upgrade 2?

Main technologies considered, R&D planned for each

	SiPM and Solid-state PhD	MAPMT	HPD*	MCP based PhD**
Time res. [ps]	~ 100	~ 150	~ 100 ?	~ 30
Pixel size [mm]	~ 1	2.88	Down to ~100 μm	~ 1
Peak quantum efficiency	50 % at 400 nm	30 to 40 % at 350 nm	30 % at 400 nm	~ 30 % at 350 nm
Dark-count rate [Hz/mm^2]	$\mathcal{O}(10^5 - 10^7)$ at room T	< 1	$\mathcal{O}(1)$	$\mathcal{O}(1)$
Radiation hardness	Lattice defects	UV glass window	Si ASIC	UV glass window
Gain ageing (50% loss) [C/cm^2]	SPAD	~ 10^3	Si ASIC	$\mathcal{O}(10)$ ALD
Max anode current [μA/cm^2]	Quenched	~ 20		$\mathcal{O}(0.1)$
Bias voltage [V]	10-100	$\mathcal{O}(10^3)$	$\mathcal{O}(10^4)$	$\mathcal{O}(10^3)$
Robustness in B-field	Not affected	RICH 1 shielding (< 5 mT)	Poor, will depend on orientation	Micro-channel (< 2 T)

* Include Pixel-HPDs, Timepix-HPDs, A-HPDs,…

** Include MCP-PMT, Image Intensifiers, MCP-ASIC HPDs, LAAPD, …

LAPPD good candidate thanks to its very good time resolution

Latest table from RICH LS4 upgrade, C.D'Ambrosio, 6th Workshop on LHCb upgrade II

The Large Area Picosecond Photodetector

LAPPD (INCOM US)

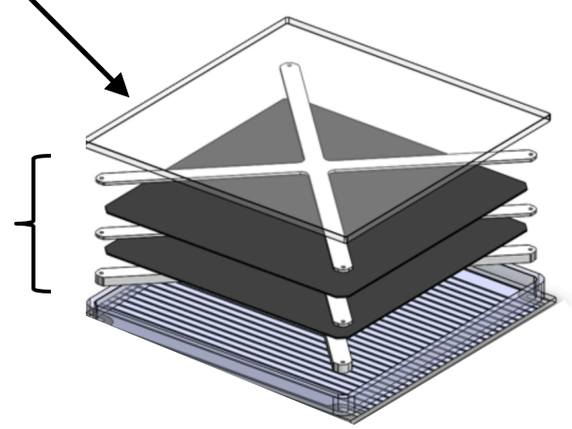
Micro Channel Plate photomultiplier,
Dimension 20 x 20 cm^2

Advantages:

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

LAPPD scheme

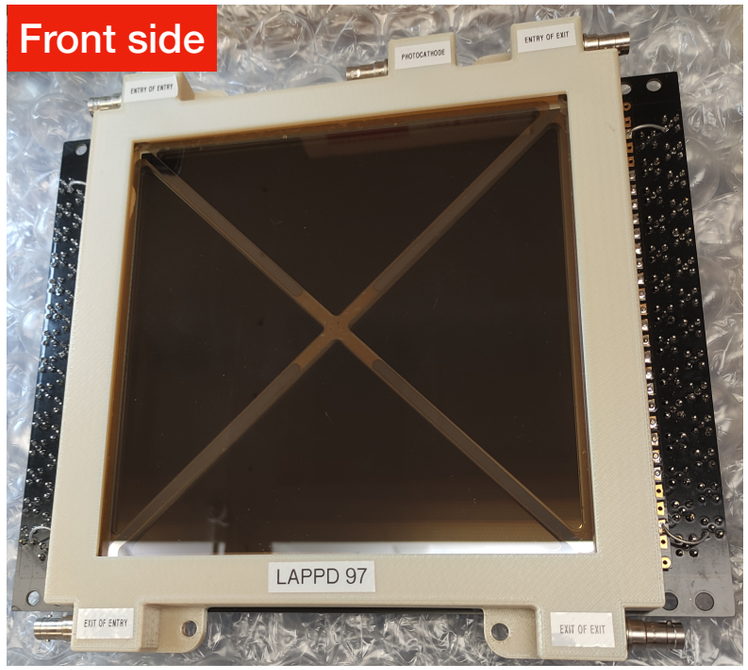
Fused silica window with **photocathode** *on inside surface*



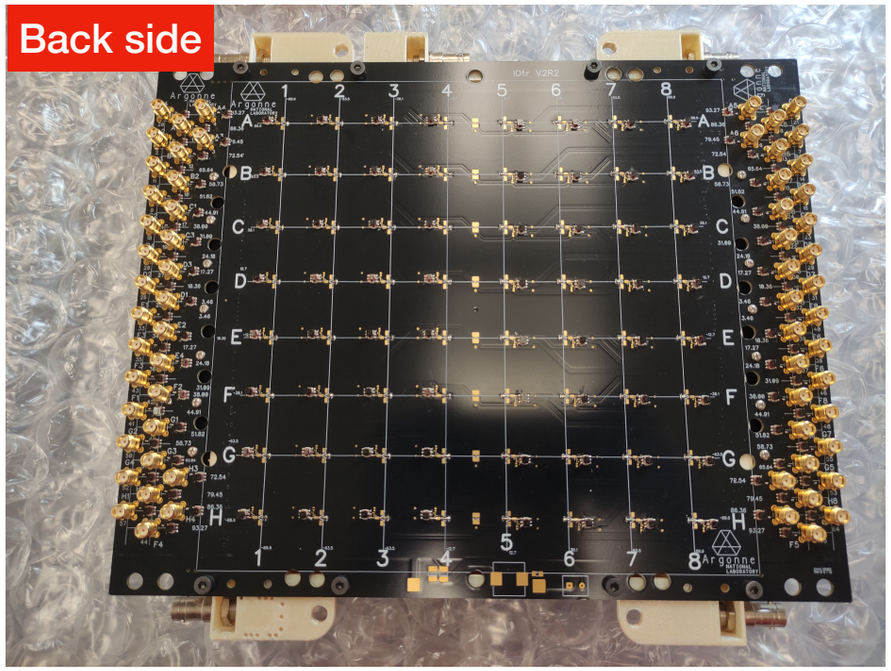
Gen II LAPPD 97 @ Edinburgh

- Gen II LAPPD, pixel readout
- 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 mm^2

Front side



Back side



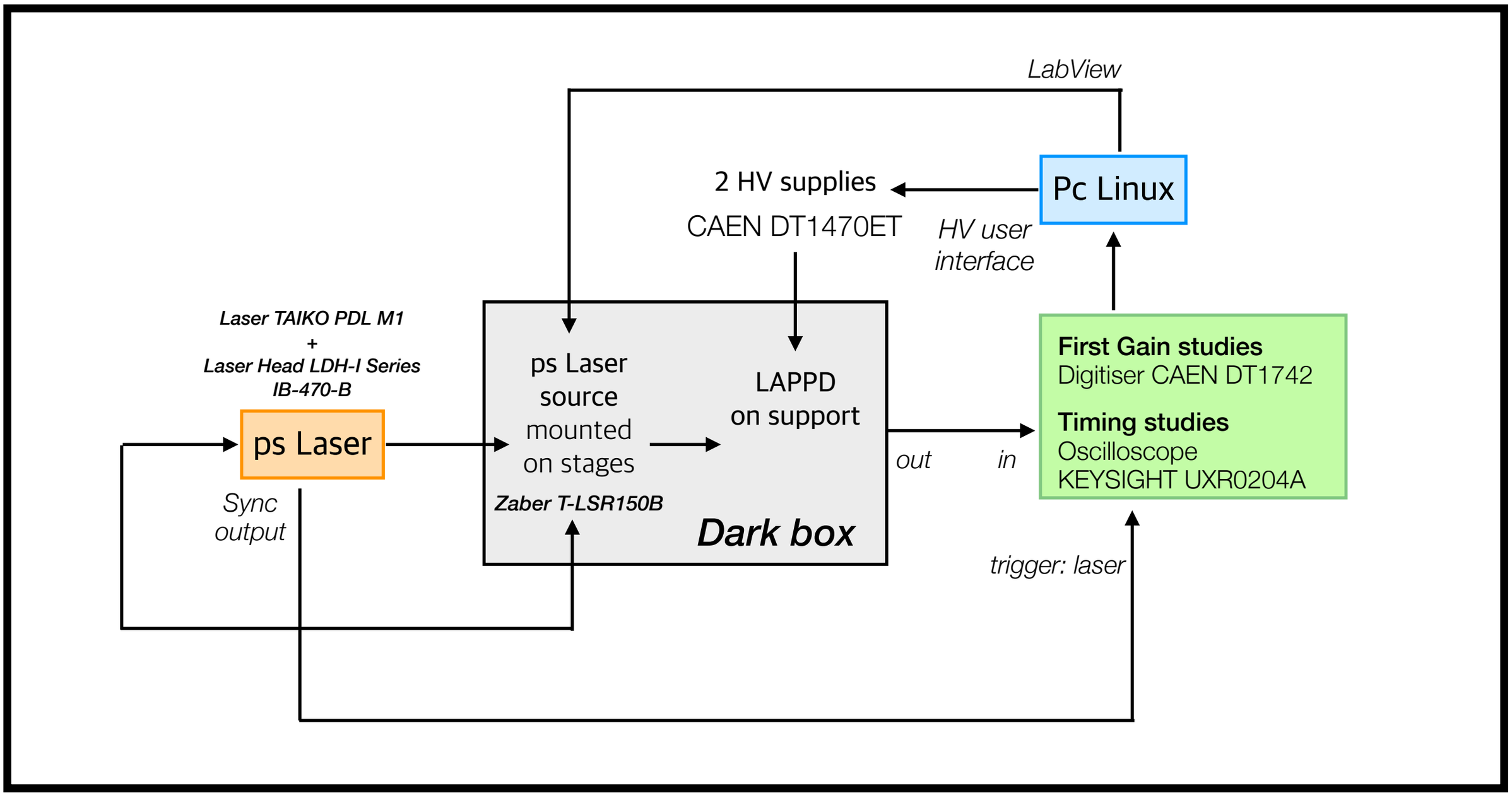
Programmed LAPPD measurements

The LAPPD97 is under test using a pico-second laser source at the Edinburgh laboratories

- HV and current trends — Check the HV and current absorption stability ✓
- Noise study and dark counts — dark counts study varying the HV — *First dark rate study performed*
- Laser source alignment procedure ✓
- Measurement of the gain — Measurement in SP condition; Gain VS HV applied study — *First gain study centring one pixel*
- Time resolution — **Preliminary results**
- Tests with customise pixellated board to dicrease the spatial resolution — **Current plan**
- Quantum efficiency study — **Future plan**

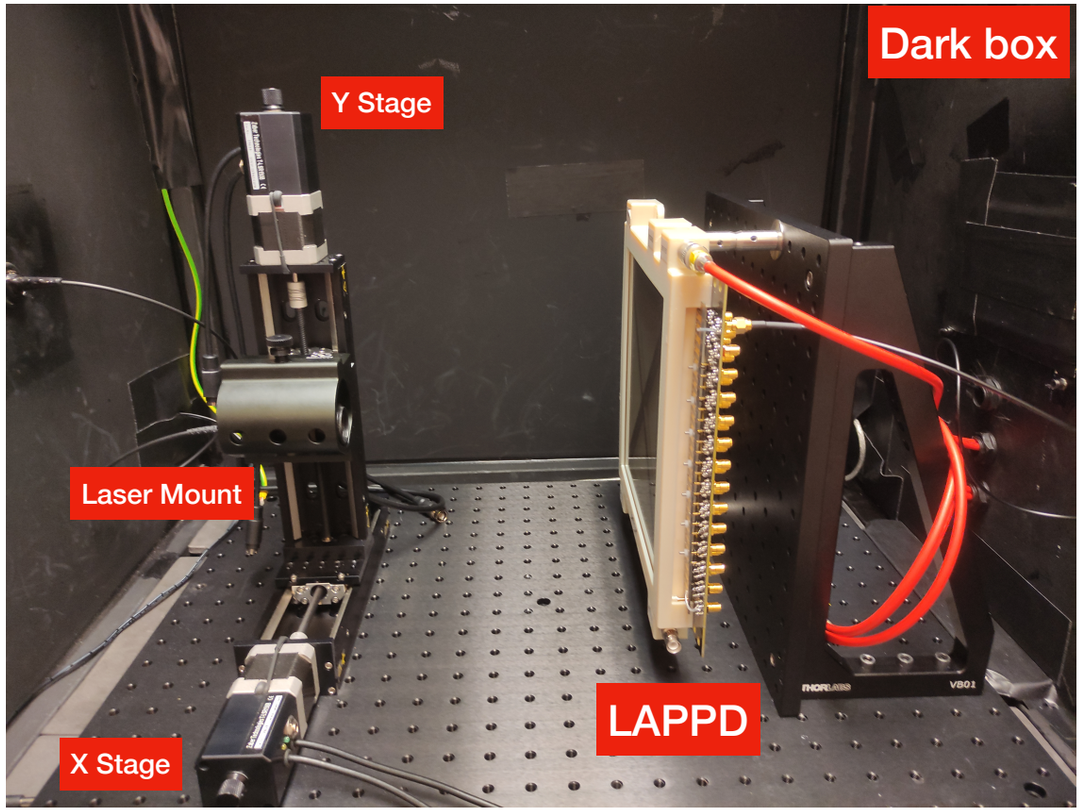
LAPPD setup layout

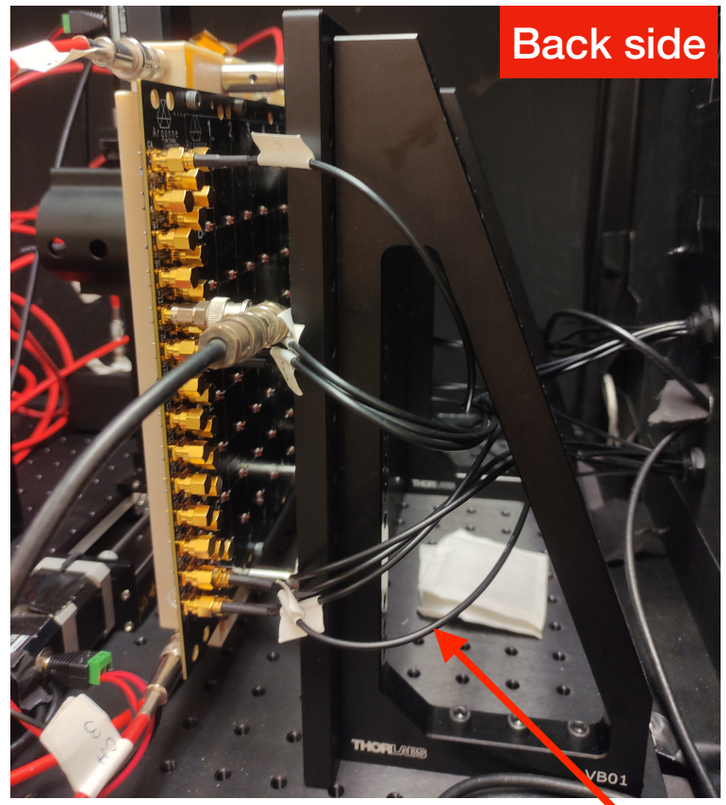
LAPPD test station@LHCb Edinburgh Laboratory



LAPPD Edinburgh setup

LAPPD in place inside the dark box

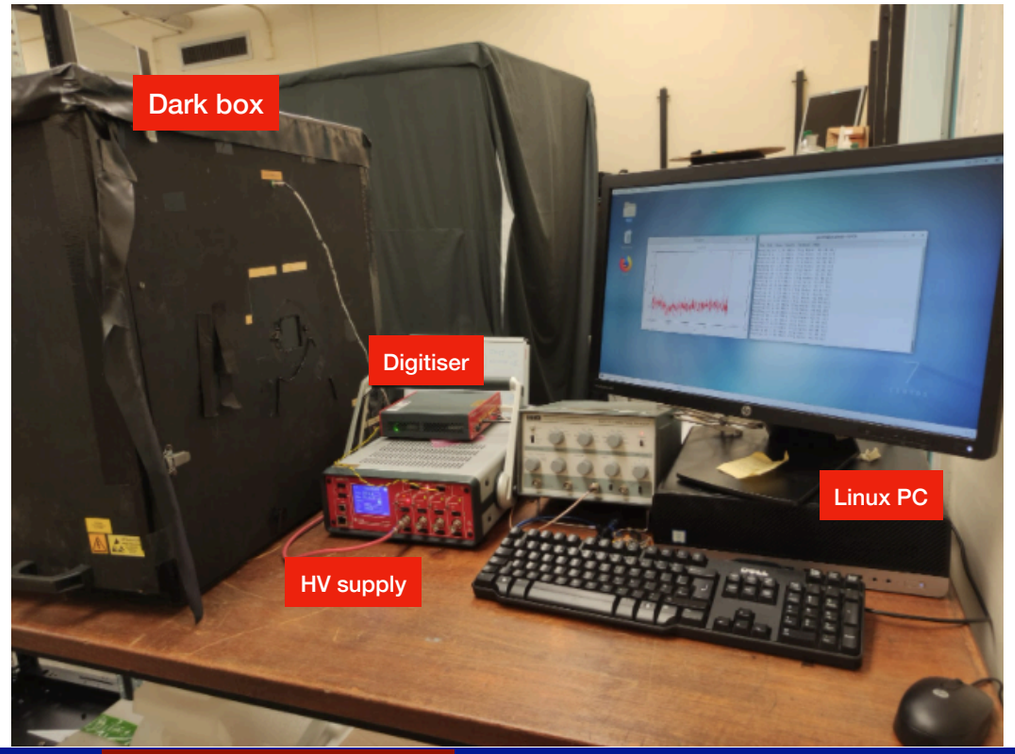




Cables SMA-MCX to the digitiser

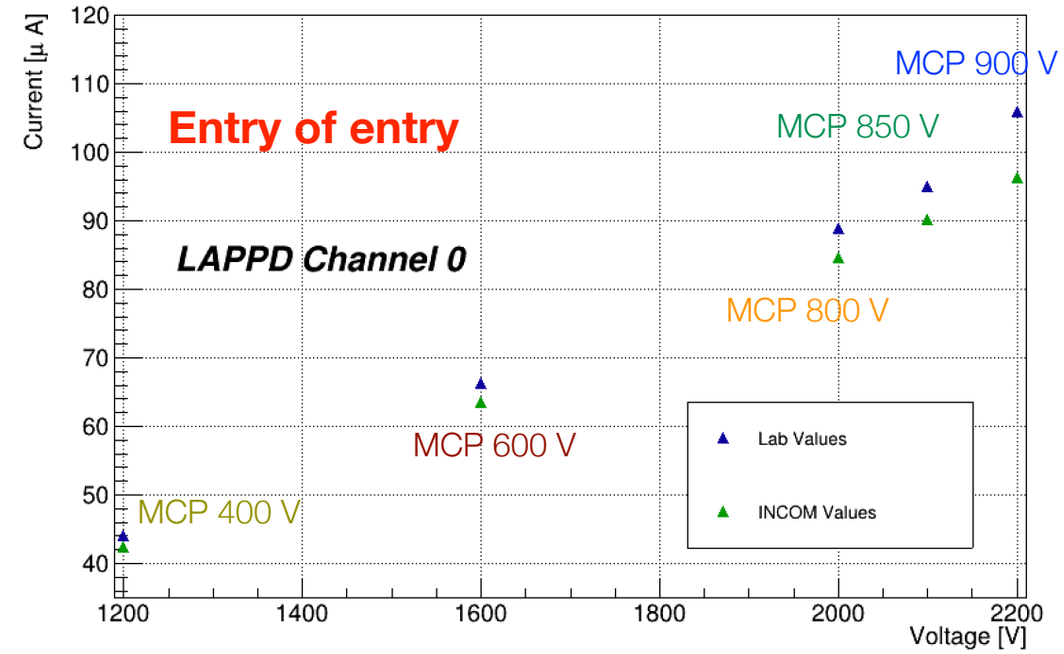
Alternatively SMA-3.5 mm input oscilloscope

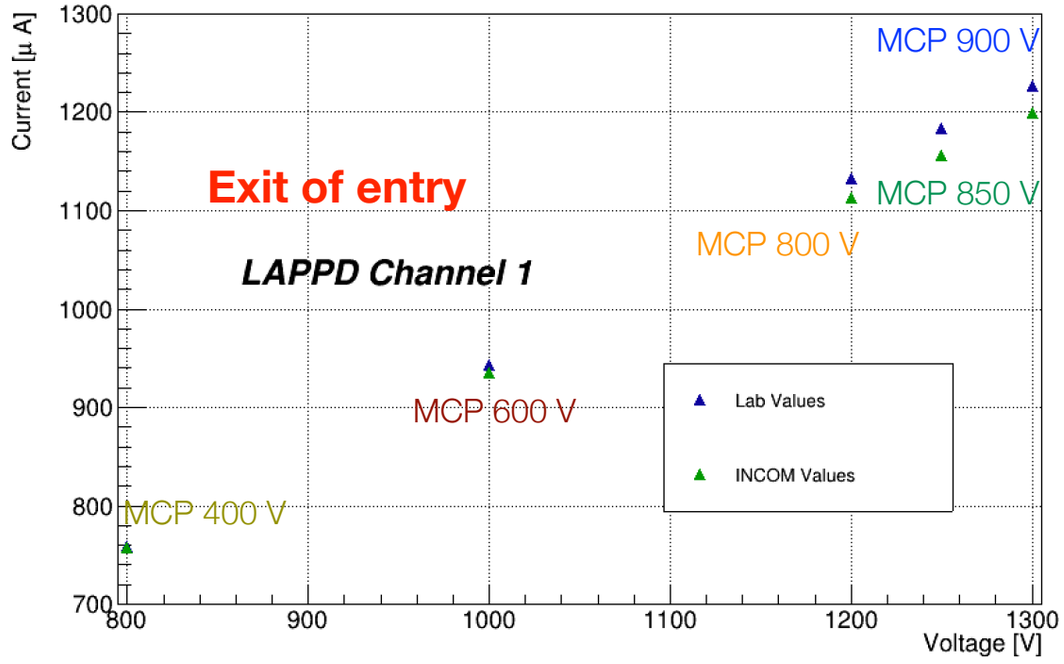
DAQ chain



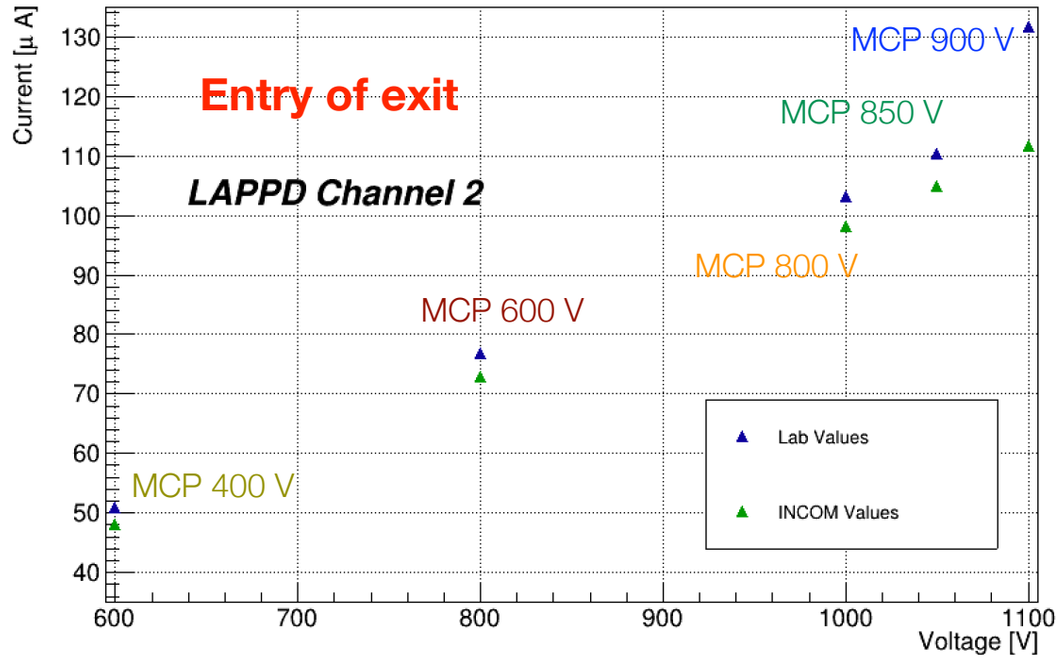
First Current & Voltage comparison

ENTRY MCP





EXIT MCP



Exit of exit

LAPPD Channel 3

HV [V]	I [μA]	I [μA] from INCOM
200	346.2	352.25
200	320.2	327.25
200	293.8	302.10
200	286.8	295.40
200	274.5	288.65

Difference between entry and exit of each MCP

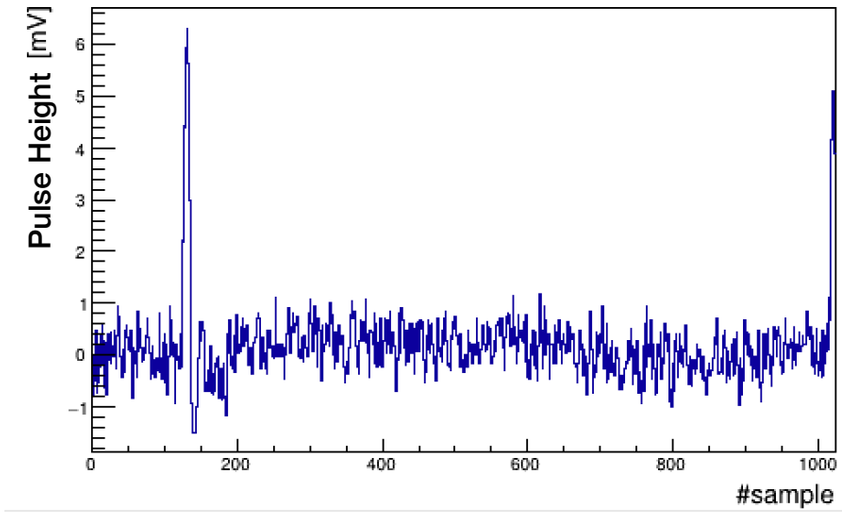
MCP 400 V MCP 800 V MCP 900 V
MCP 600 V MCP 850 V

✓ Trend of the current in agreement with the reference ones

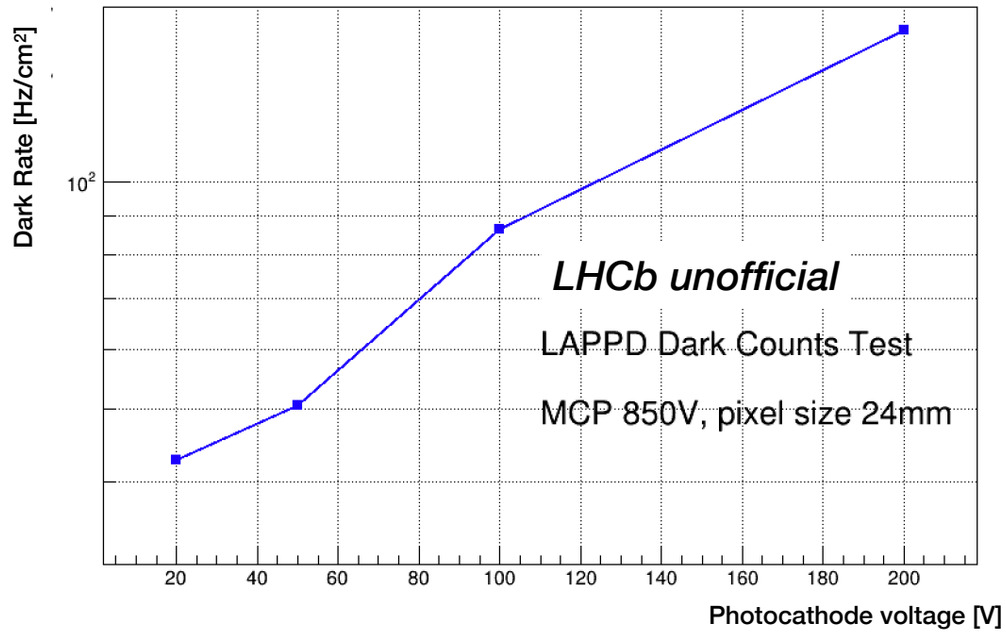
Measurements at Edinburgh with the digitiser CAEN DT1742

Digitisation rate up to 5GS/s, bandwidth 500MHz

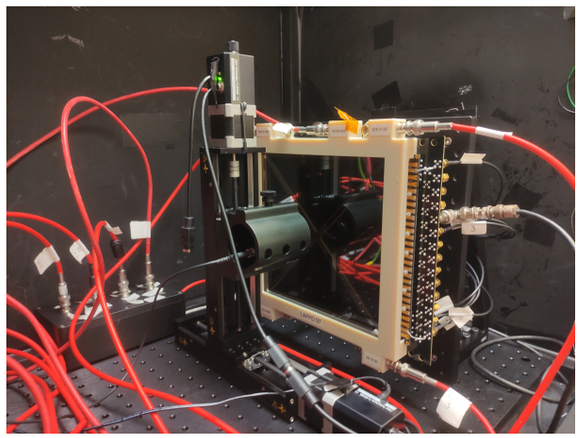
Dark counts



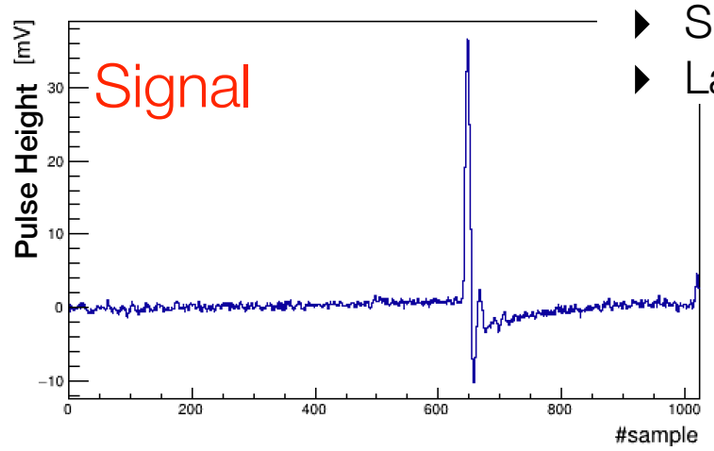
200 ns



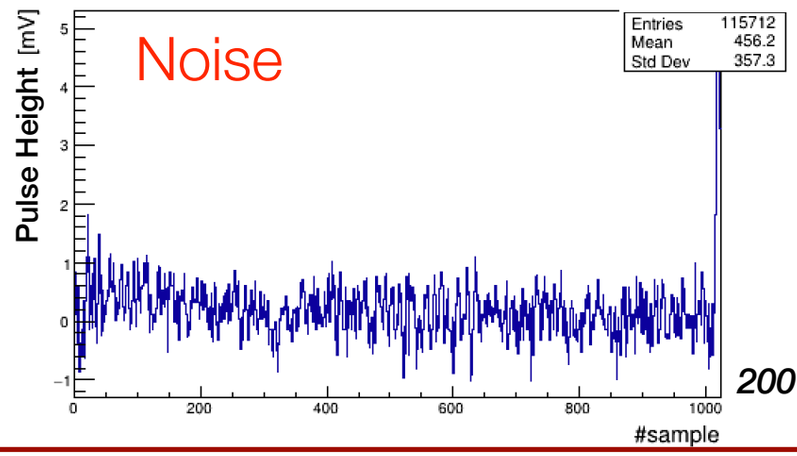
Tests with laser



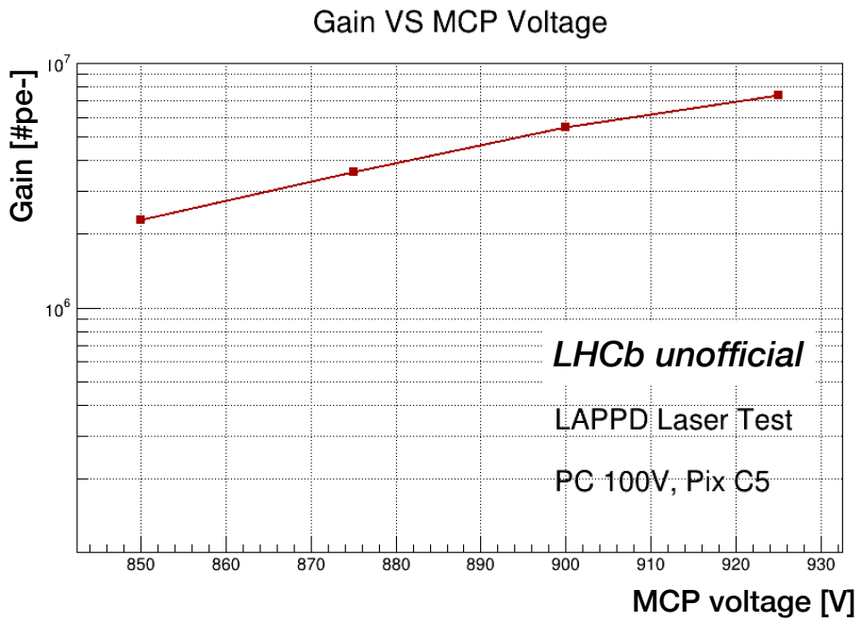
- Single photoelectron condition
- Laser frequency 5kHz



200 ns



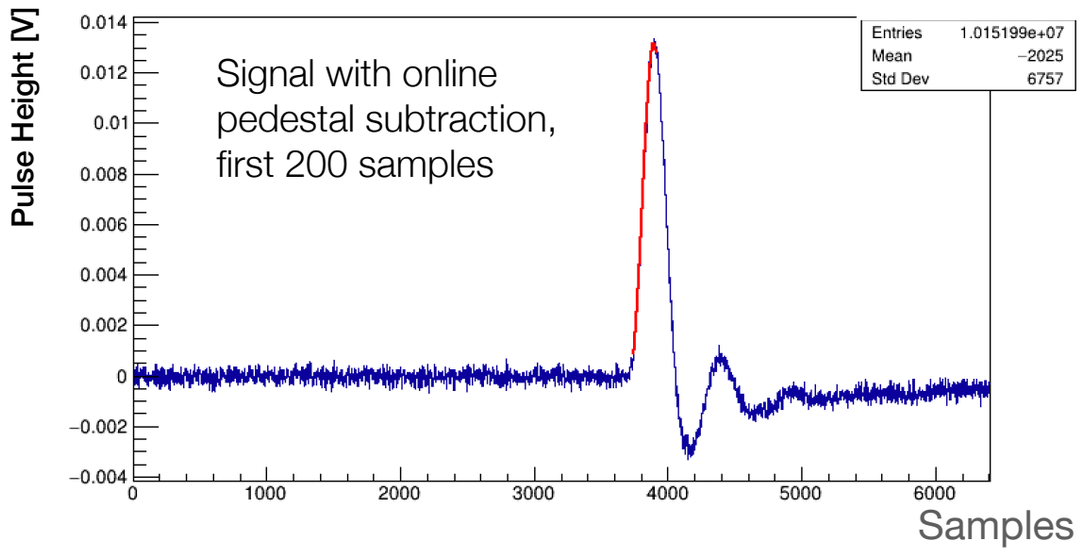
200 ns



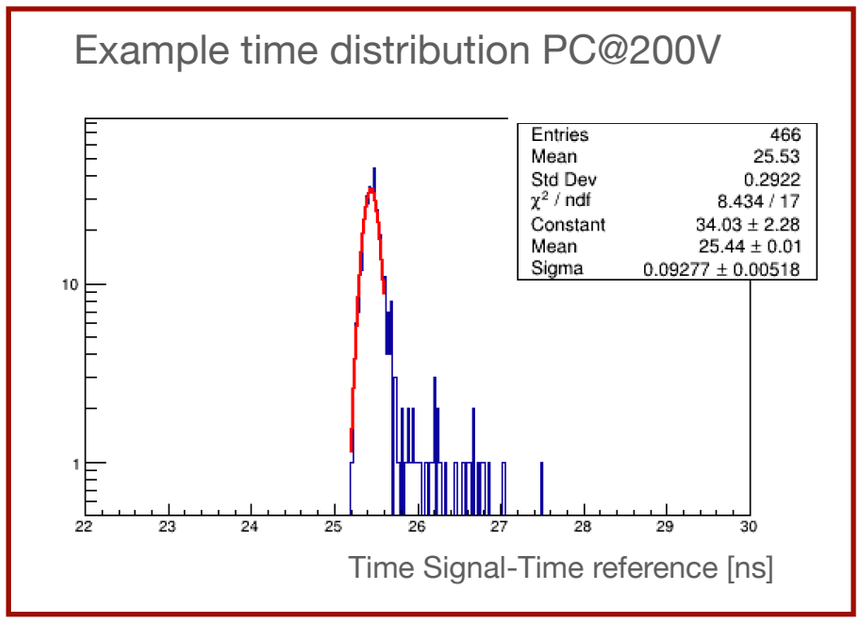
Time resolution with fast oscilloscope KEYSIGHT UXR0204A

Digitisation rate up to 128 GS/s, bandwidth 20GHz

Time signal: Gaussian mean

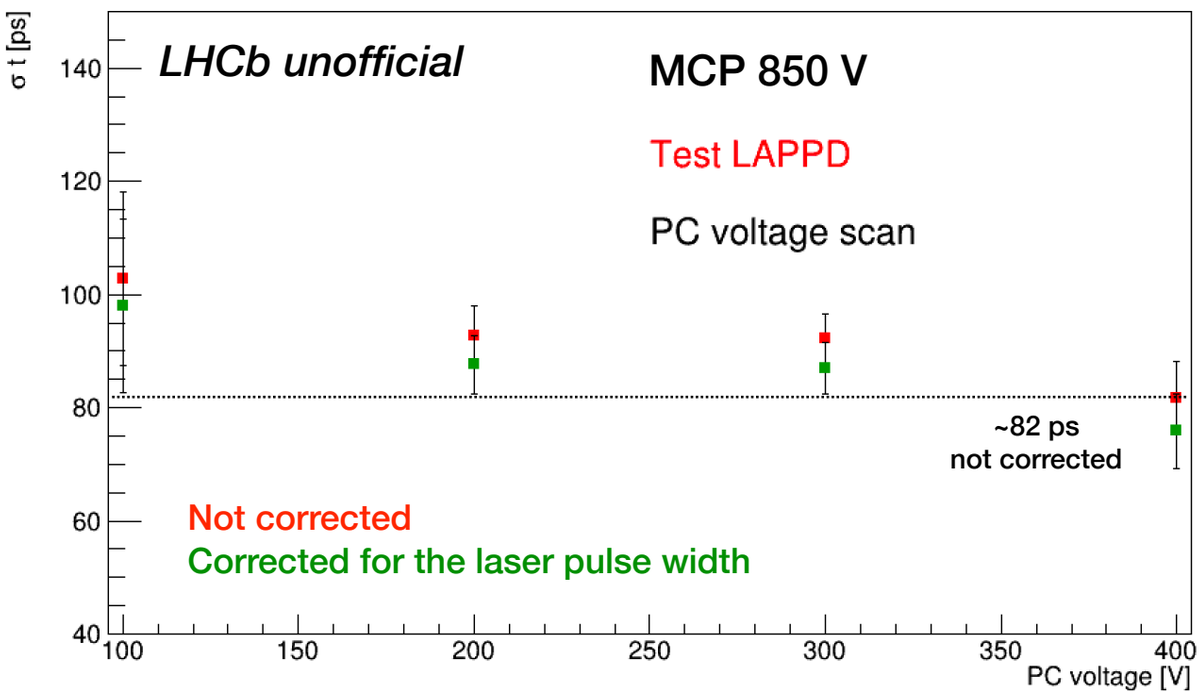


Extracted from Gaussian fit to the time difference Signal-Laser trigger



- Single photoelectron condition
- Laser frequency 5kHz

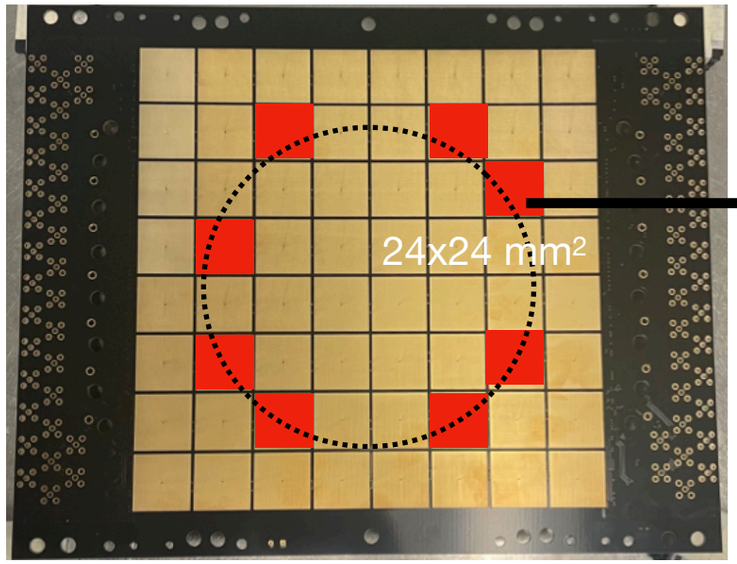
Work in progress



LAPPD plans

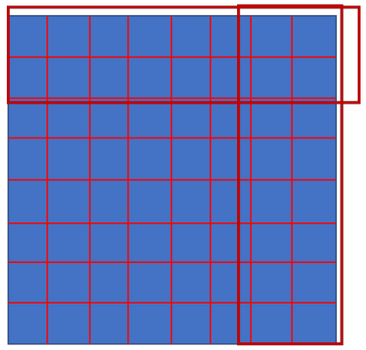
Custom pixelated readout board **design in progress**, in order to improve the spatial resolution

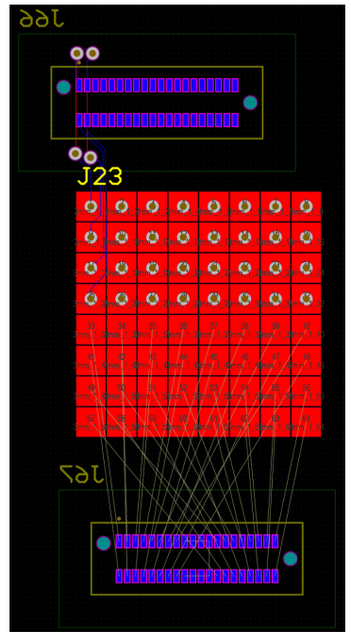
Current board



New board

- 8x8 pixels with pitch 3 mm

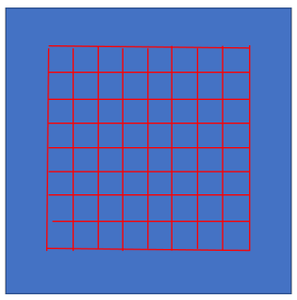




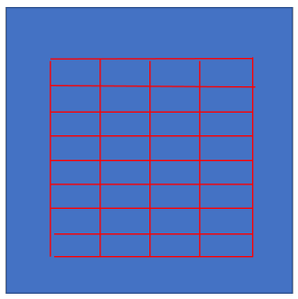
Preliminary

Some other ideas for the pixel size and patterns

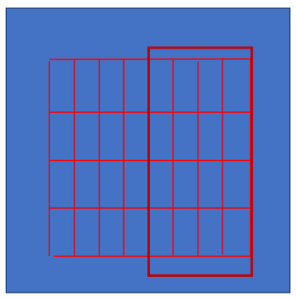
- 8x8 pixels with pitch 2 mm



- 8x4 pixels with pitch 2x4 mm



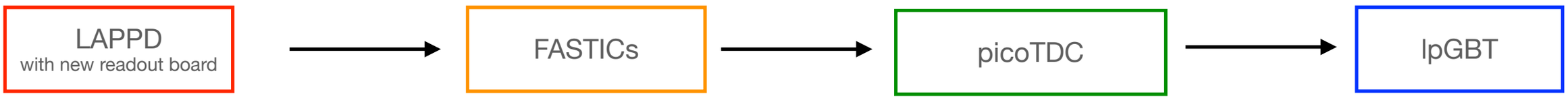
- 4x8 pixels with pitch 4x2 mm



Work in progress

Plans for September/October 2023

- Test beam with the LAPPD 97 at the SPS (CERN), coupled to the RICH fast electronics



Conclusions

- The LHCb RICH collaboration is actively working within the R&D programme for the LHCb RICH Phase II Upgrade
- LAPPD 97 is in under test in Edinburgh
- First promising results have been extracted, compared with the performance directly provided by INCOM
- Tests to achieve the ultimate time resolution of the LAPPD are in progress
- In parallel, the design of the custom board is ongoing
- LAPPD will be tested in the RICH test beam campaign in autumn, coupled to the RICH fast electronics