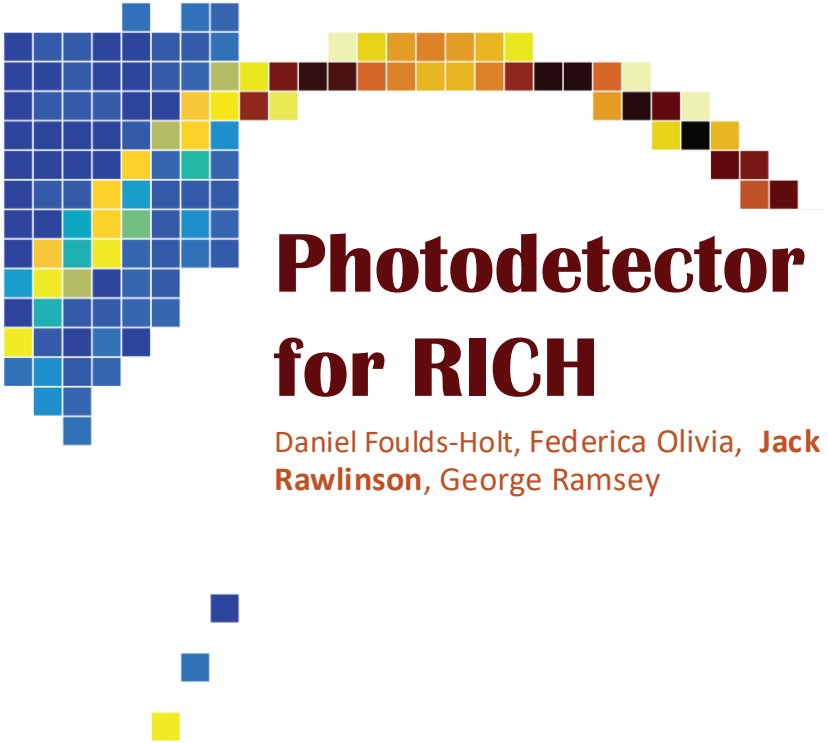




THE UNIVERSITY of EDINBURGH



Photodetector characterisation for RICH

Daniel Foulds-Holt, Federica Olivia, **Jack Rawlinson**, George Ramsey

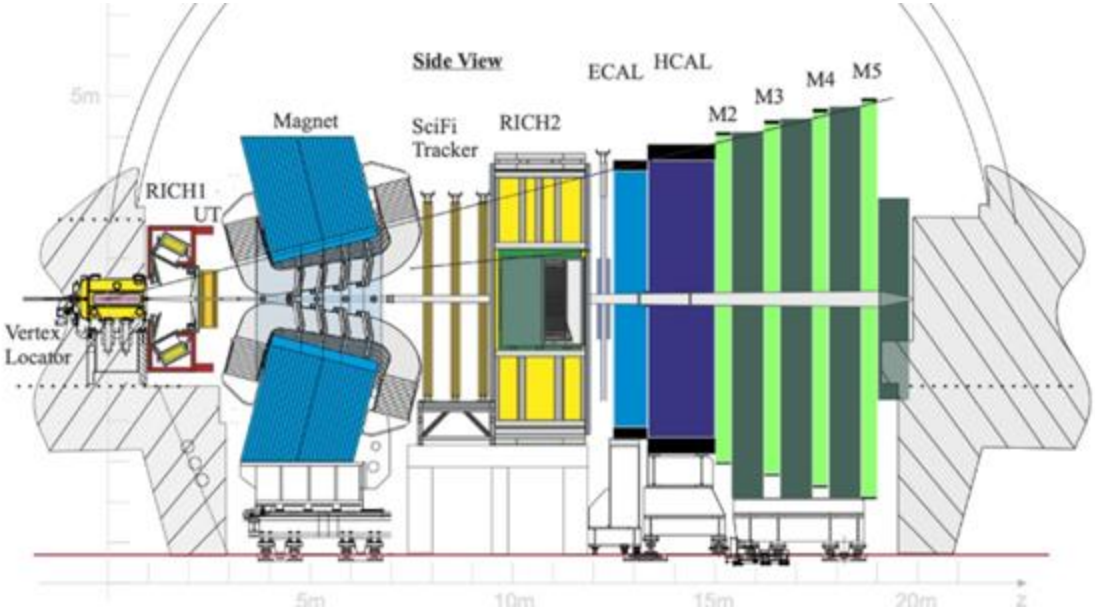


Outline

- Background
- Detectors
- Signal readout setup
- Lab Setup
- Test beam
- Bumps in the road

LHCb

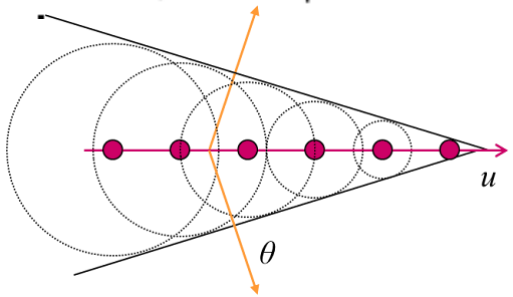
- Composite detector focussing on heavy quarks studies (beauty and charm) and investigating CP violation

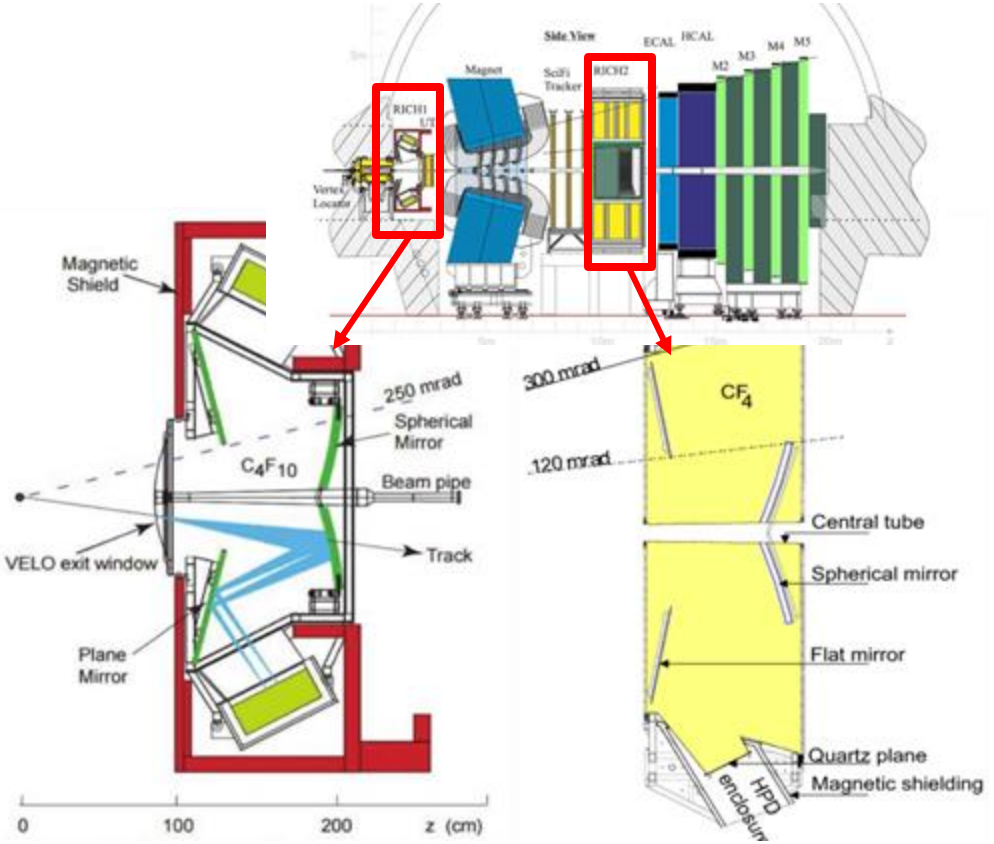


RICH - Ring Imaging Cherenkov Detectors

- Cherenkov Radiation:
  - Sonic boom-like effect caused when a particle goes faster than the speed of light in a medium
- Rings of single photons, angle of emission linked to speed of particle :

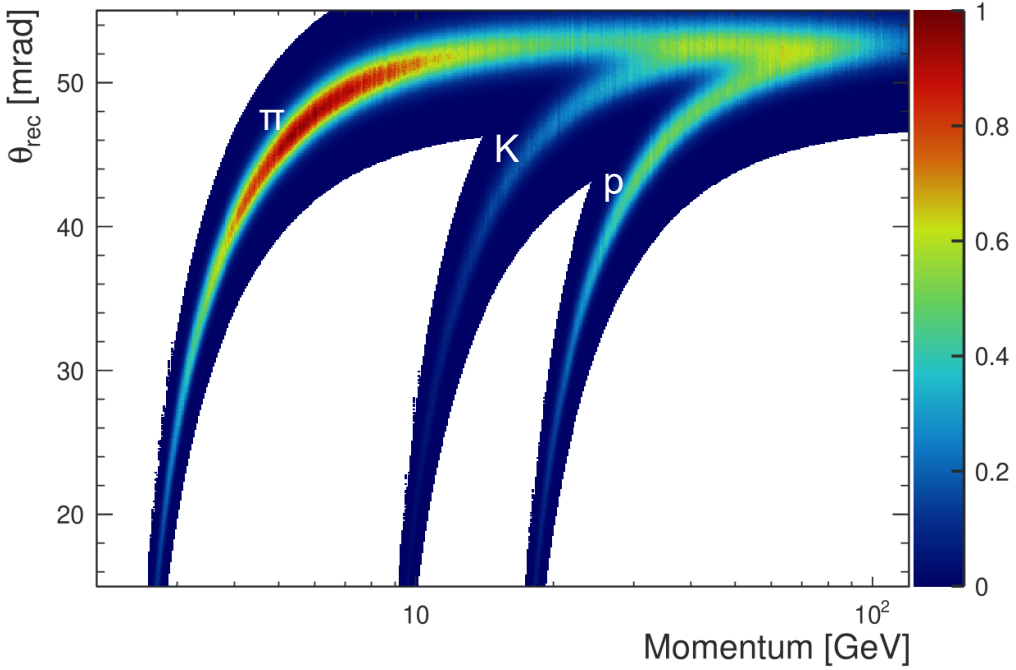
$$cos(\theta_c) = \frac{1}{n\beta}$$





RICH for PID

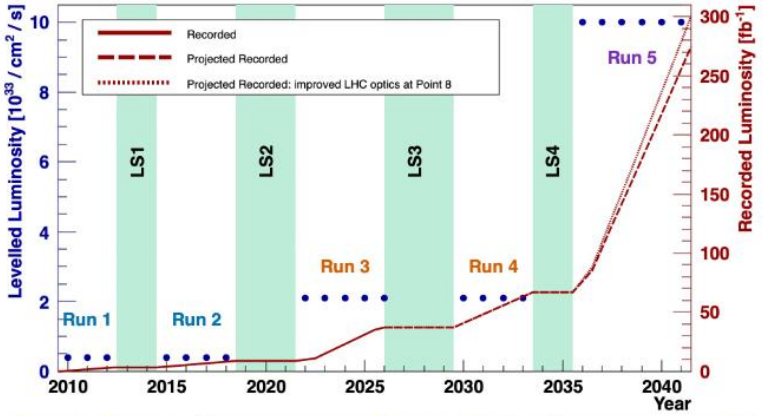
- Particle identification possible via plots of cherenkov angle vs momentum of incoming particle

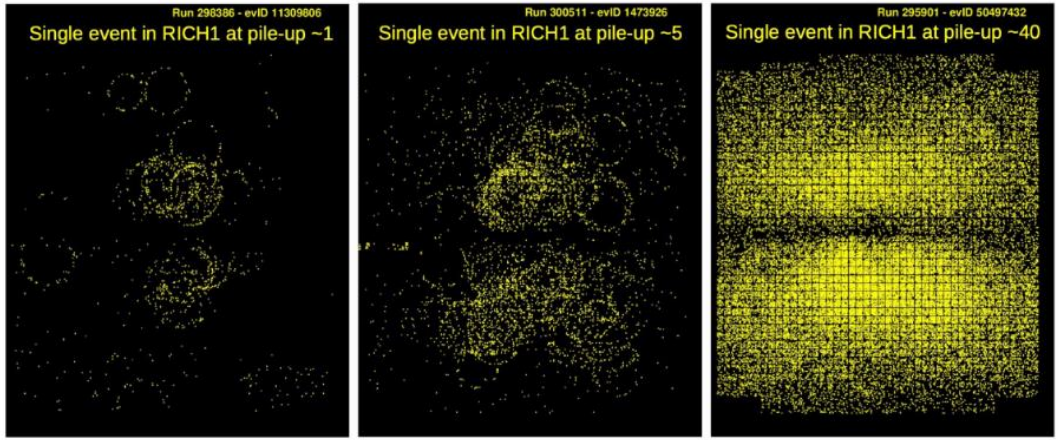


Real data analysed in Edinburgh courtesy of Michael

Hi-Lumi pressures

- LHC Hi-Lumi upgrade will lead to frequencies of >40MHZ
- This will oversaturate current RICH detectors
- Need to find new detectors with good time resolution (<100ps)



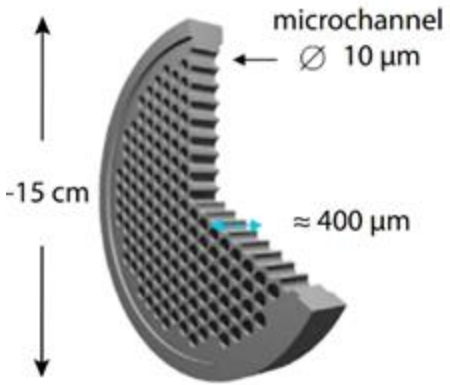


LS3 TDR, the LHCb framework TDR and Upgrade II scoping document

Detectors

Micro-Channel Plates

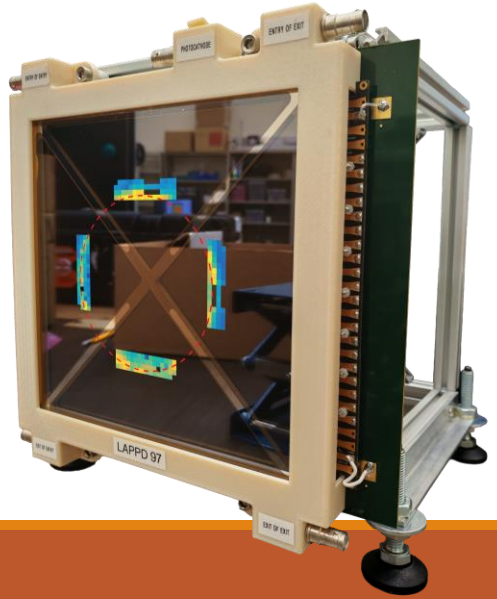
- Electron multipliers
- Microscopic tubes with large Voltage across it
- Act as one continuous dynode
- Electrons are accelerated and produce subsequent electrons
- Gain impacted largely on length-to-diameter ratio (α usually ~ 50)
- Larger α also leads to longer travel time for electrons so must be balanced with gain



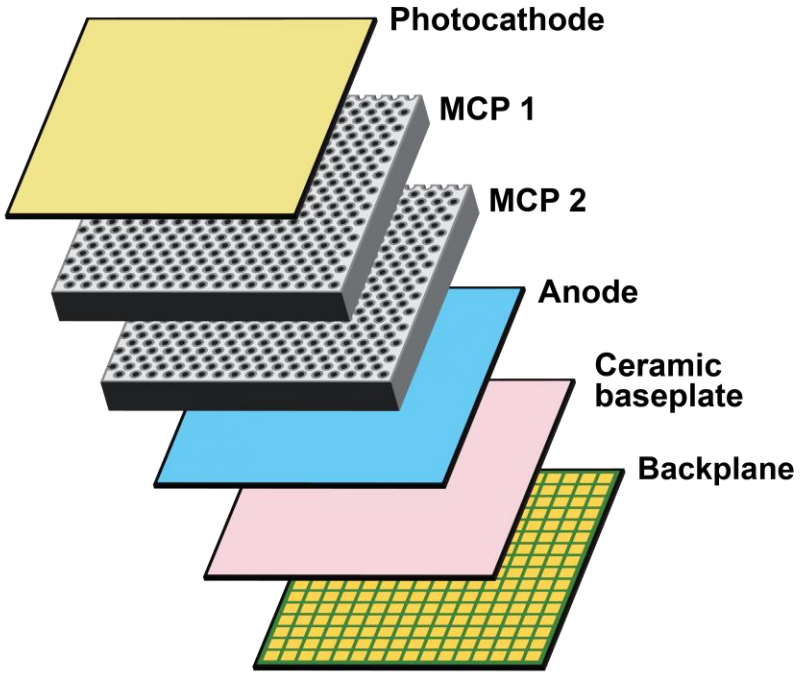


LAPPD - Large Area Picosecond Photodetector

- Photocathode to produce electrons when light is incident
- 2 MCPs to cause electron avalanche and multiplication
- 3x3 mm^2 pixelated anode

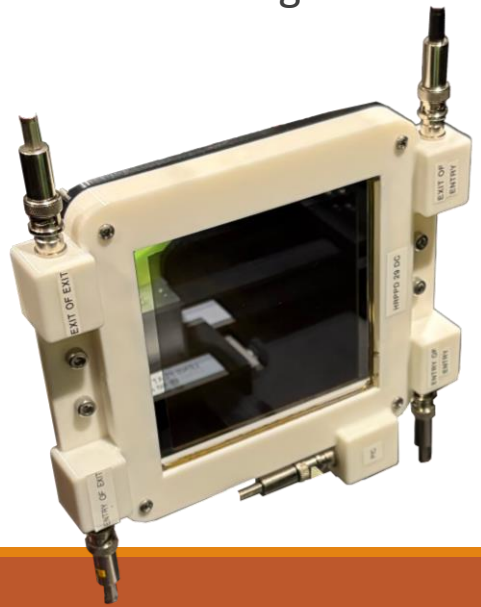


- Capacitively coupled baseplate
- 2 backplanes:
  - INCOM standard
  - Edinburgh Custom

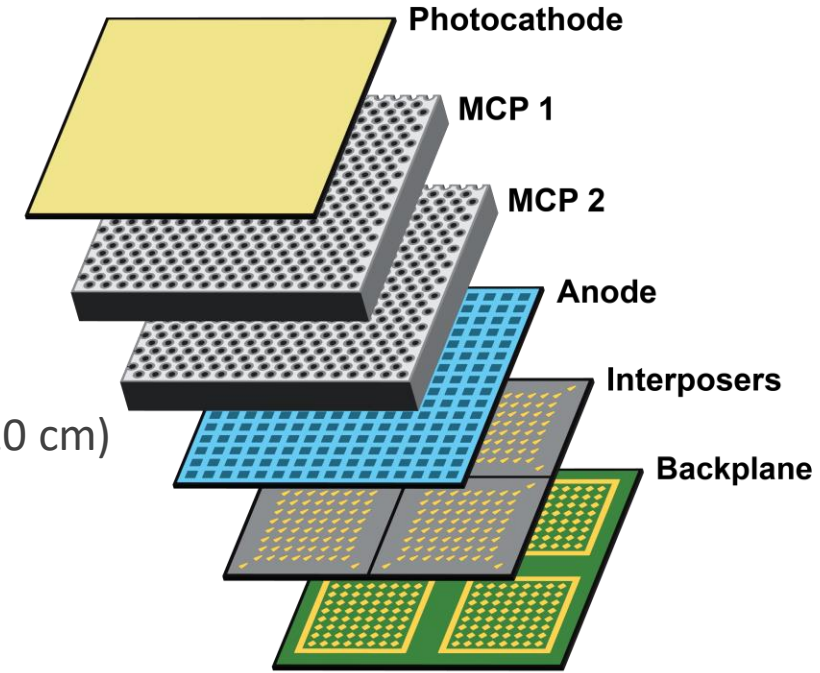


HRPPD – High-Rate Picosecond Photodetector

- Main differences:
  - Directly coupled interposers to backplane
  - Different backplane Backplane
  - Smaller MCP pores (20μm -> 10μm) -> larger α

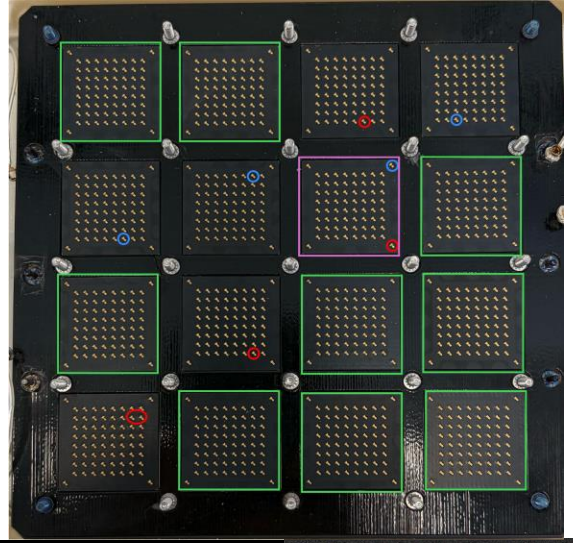


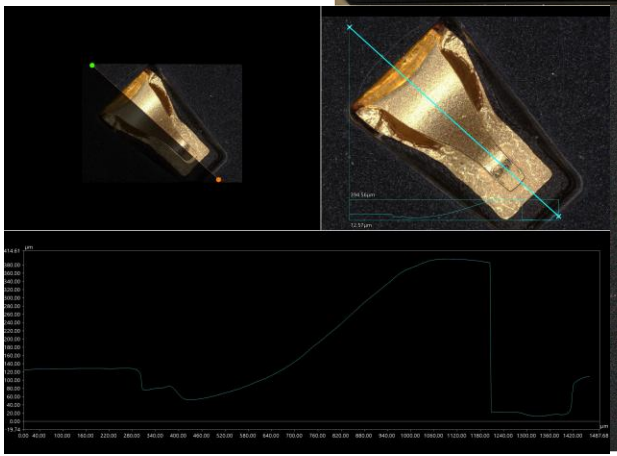
  - Smaller (20x20cm -> 10x10 cm)



HRPPD – Interposer check

- Using microscope in clean room (5202) inspected interposers on HRPPD
- Found several bent interposers but impact was negligible thanks to size of backplane pads



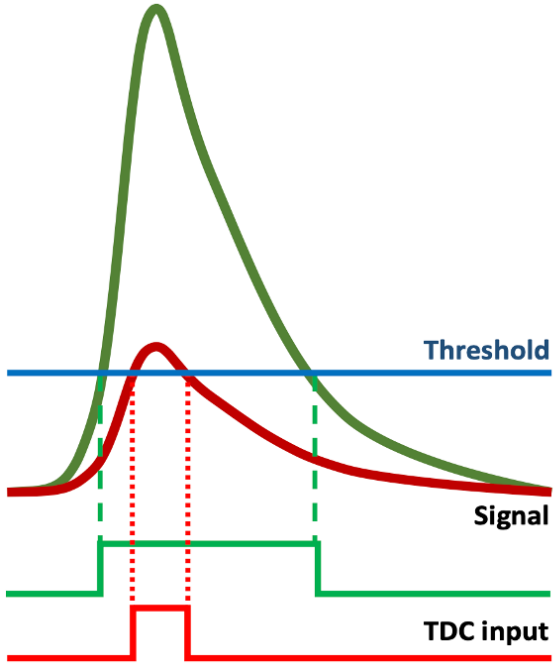




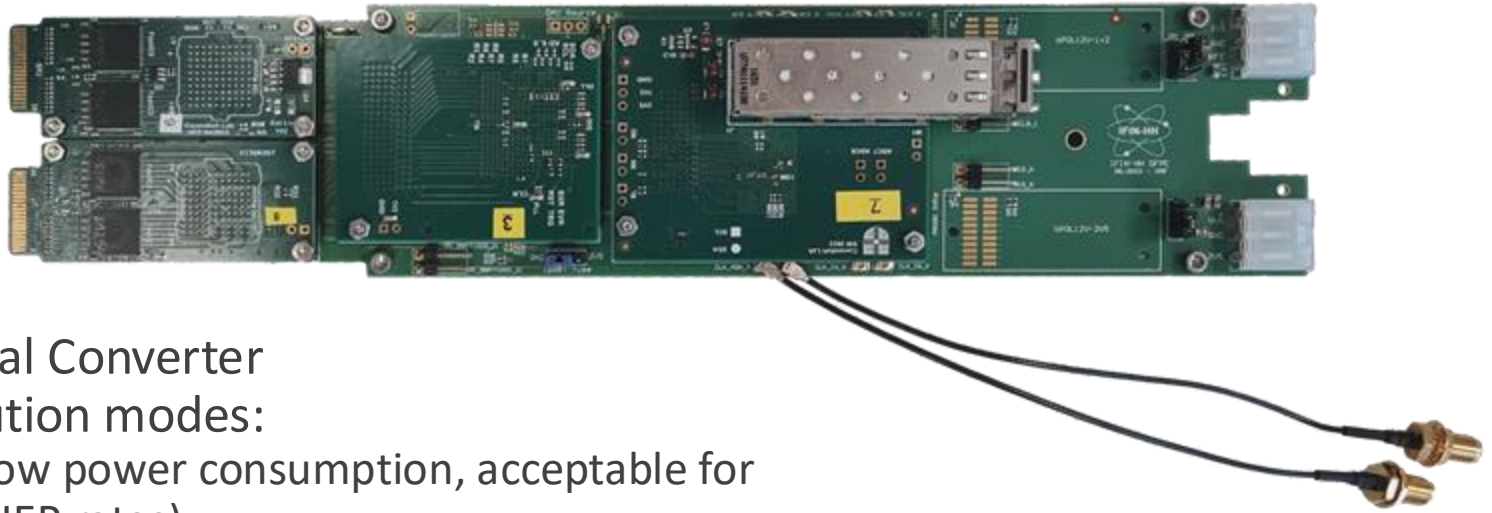
Signal Readout Setup

FastIC

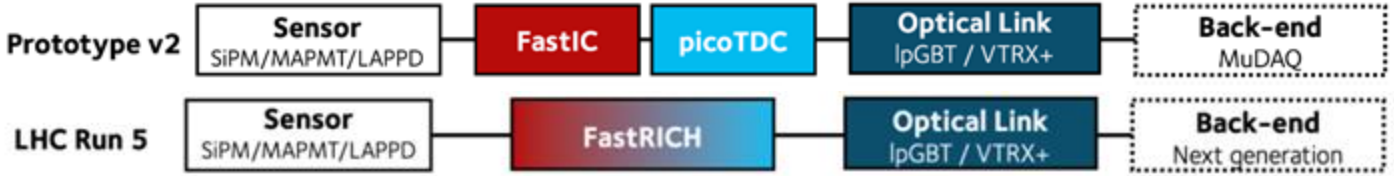
- Front-end ASIC to return energy and timing information from an input signal
- Energy can be found using ToT



PicoTDC



- Time to Digital Converter
- 2 time resolution modes:
  - 12.2ps (Low power consumption, acceptable for modern HEP rates)
  - 3.05ps (More accurate for assessing new detector technologies)

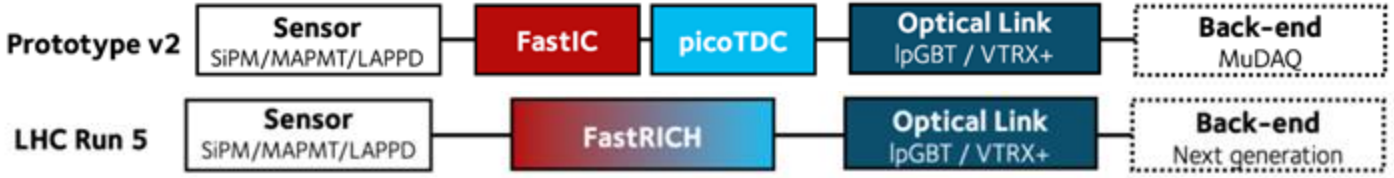


FastRICH

- Combines functionality of PicoTDC and FastIC
- 2 time binnings :
  - 24.4 ps
  - 97.64 ps
- Tests still ongoing



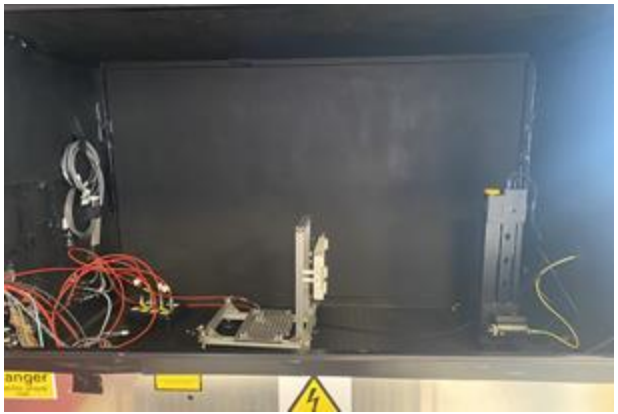


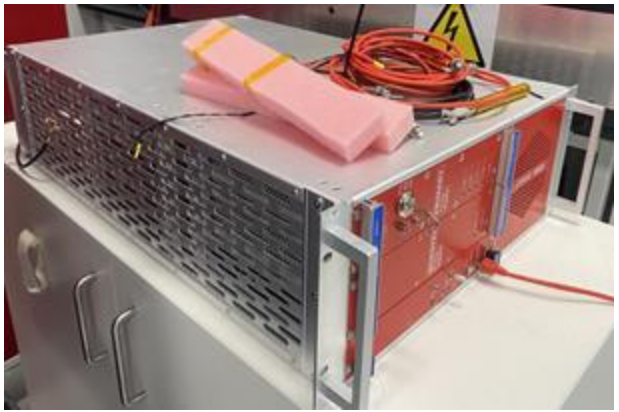


Lab setups

Laser setup

- Laser setup inside of dark box
- Can readout data through 2 means:
  - Oscilloscope – 4 readouts + 7ps resolution
  - MuDAQ (PicoTDC + FastIC setup) - 64 readouts + 3.05ps resolution
- Laser position is controlled via transition stages through ECROC
- Detector bias set by cean HV Crate using ECROC







ECROC integration

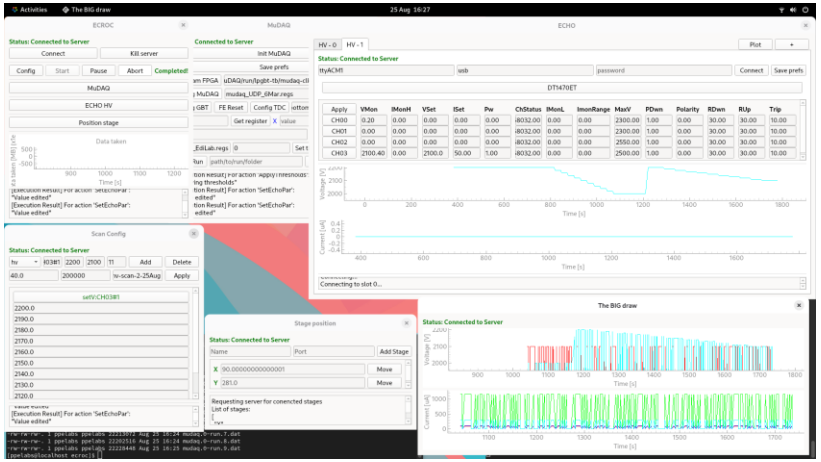
- ECROC allowed for centralised control of setup:
  - Laser position stage
  - MuDAQ readout
  - HV power supply



Position stage



MuDAQ



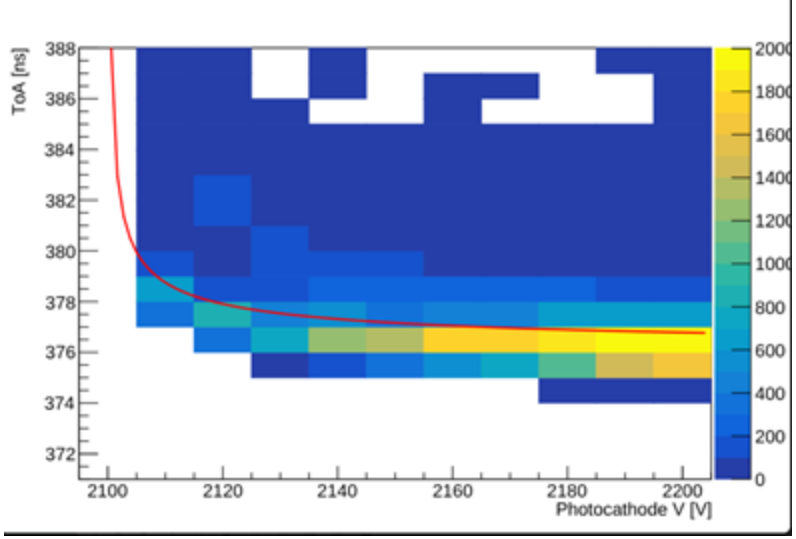
Example of ECROC in use.

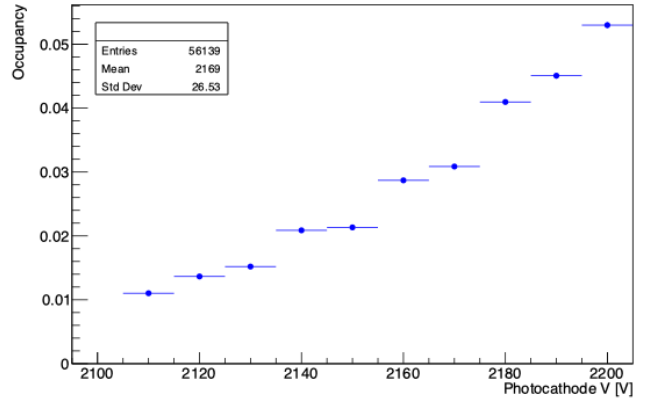


HV

Laser setup results

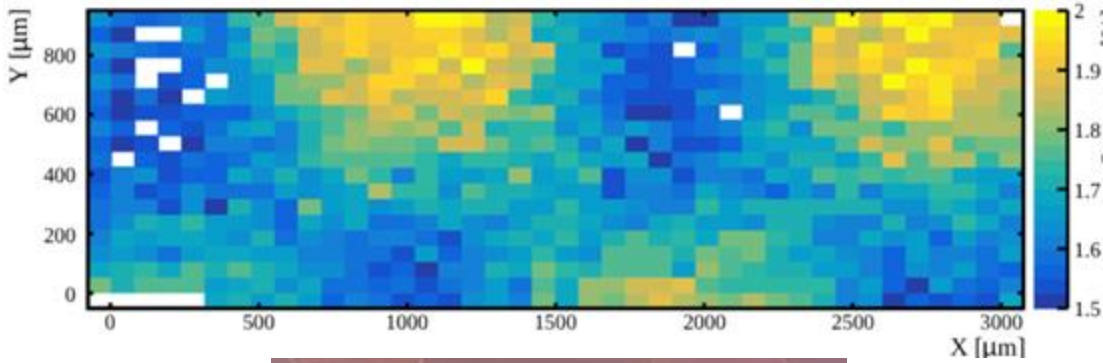
- With MuDAQ Investigated ToA vs PC voltage:
  - Electron transit time matched expected values (Physics works in the detector!)
- Investigation of occupancy showed increase with PC voltage – shows more photon signals being over threshold

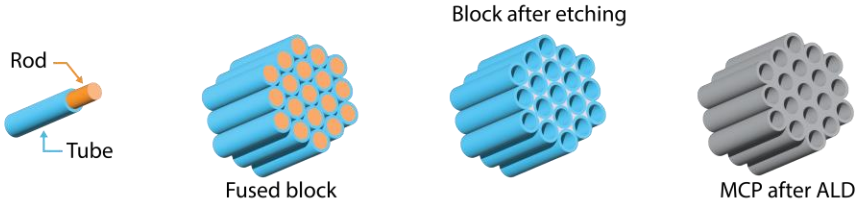


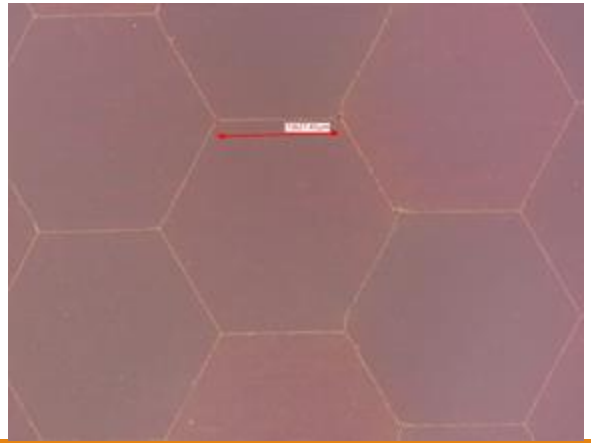


Laser setup results - Occupancy studies

- Hyper fine scan over LAPPD investigating occupancy of pores
- See less potent regions causing circular patterns around high occupancy
- Under microscope see this is actually due to the hexagonal design pattern from INCOMs design of MCPs

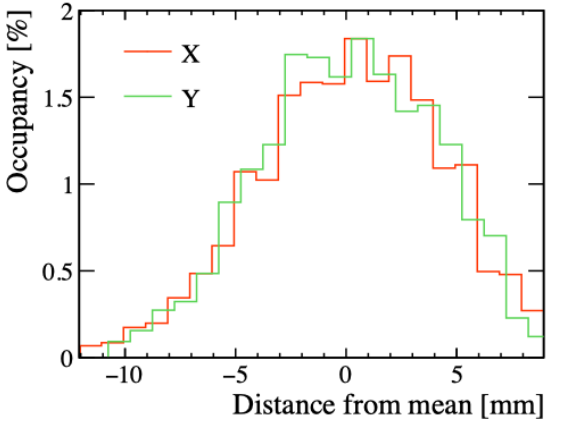


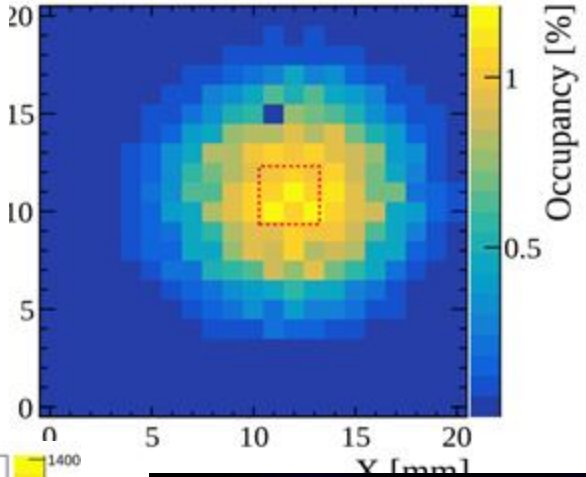


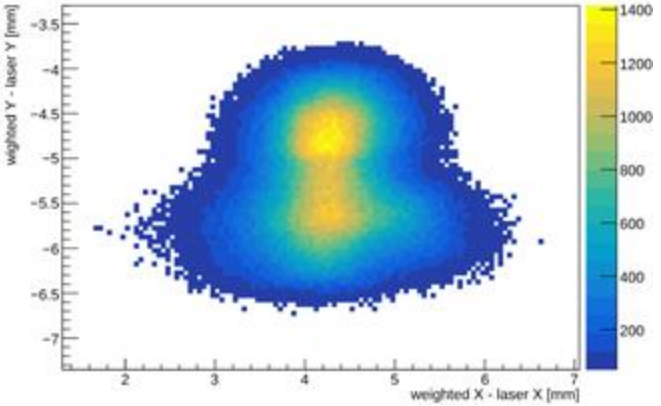


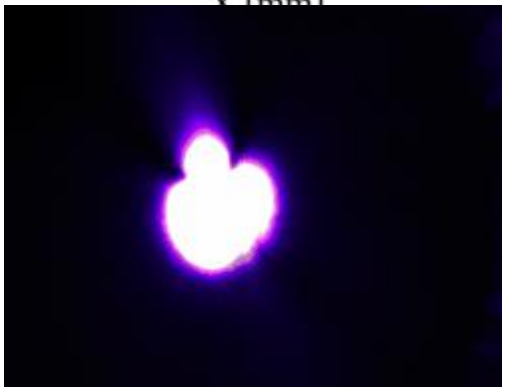
Laser setup results - Occupancy studies

- Focused laser on one section of LAPPD and collected occupancy across whole of the detector
- Shows spread of charge sharing and laser width
- Can fit the spread in x and y respecitvely using gaussian convolved with top hat function
- When weighting pixels and removing true laser position we gain increased spatial resolution allowing us to recreate laser shape!



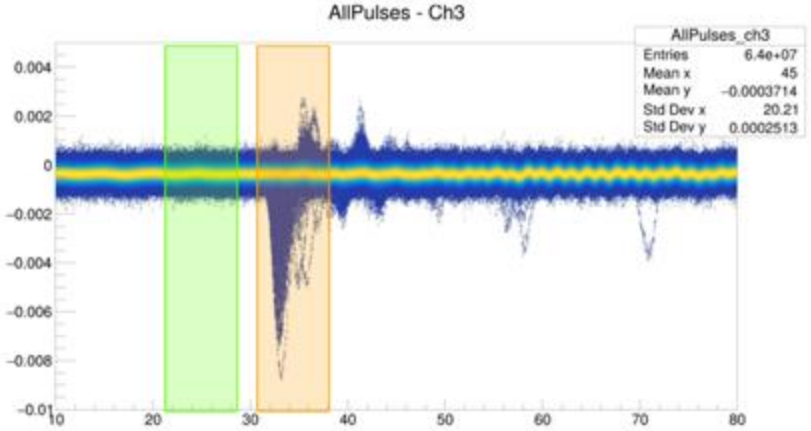


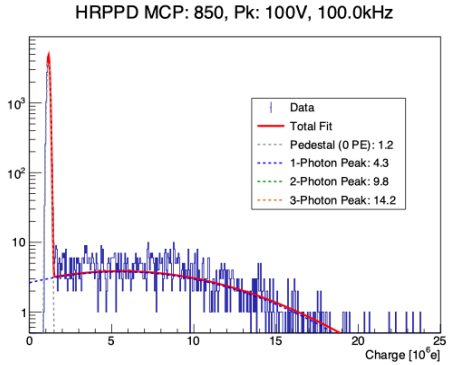


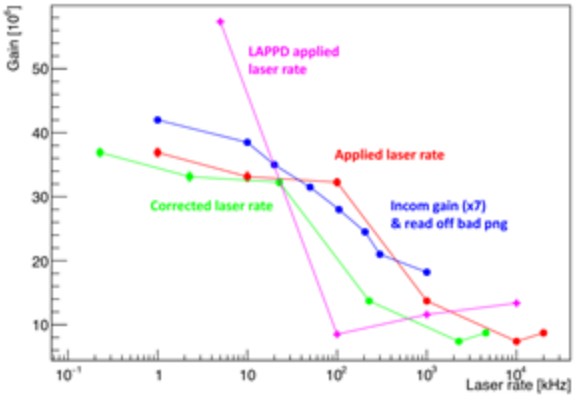


Laser setup results – Gain measurement

- Known weakness of MCPs - lower gain at higher rates
- HL-LHC will increase luminosity to ~ 40MHZ
- Need to understand if detectors can keep up consistent signal hits at these high rates

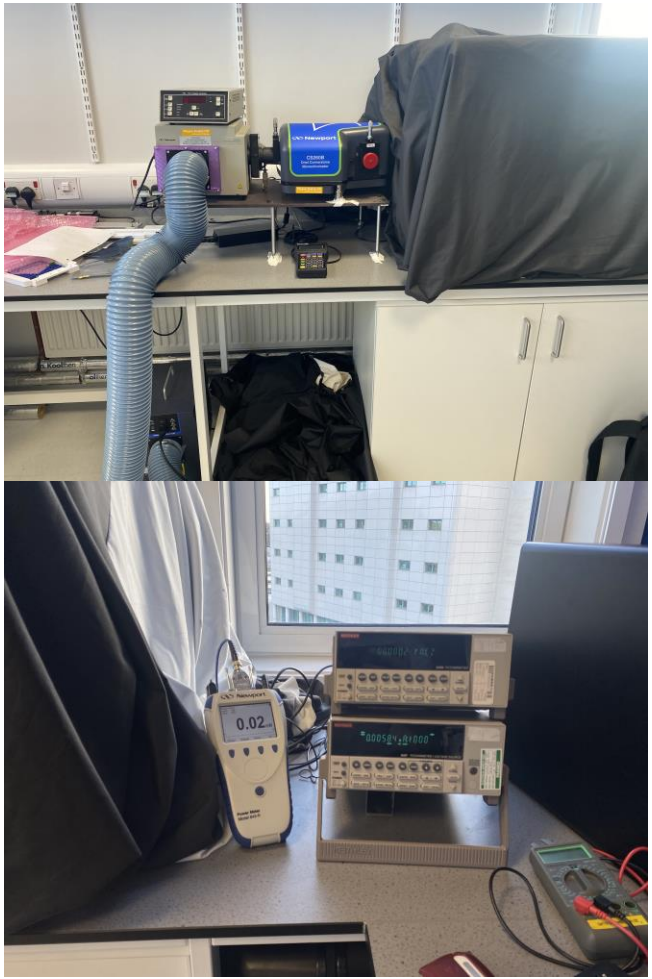






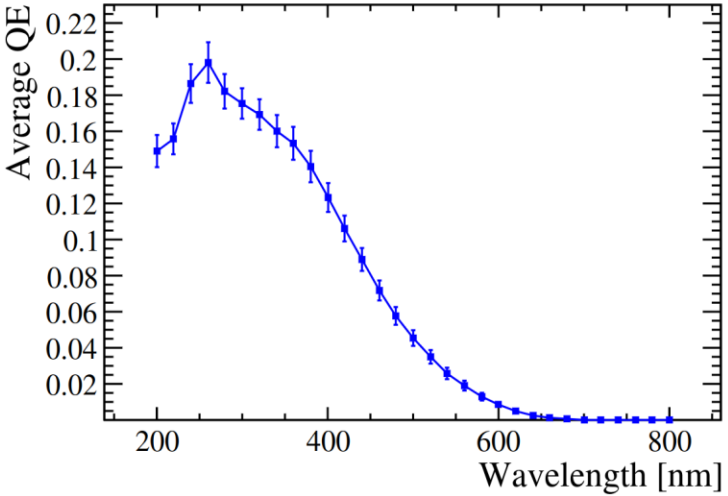
QE setup

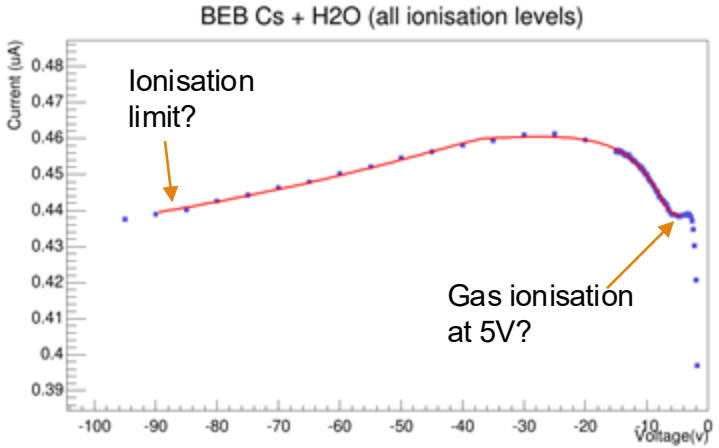
- Xenon lamp for production of continuous light at wide range of wavelengths
- Ozone extractor to remove hazardous byproduct
- Monochromator to select desired wavelengths and control light intensity
- Kiethly picoammeter and voltage source for collecting readings and biasing detector
- Power meter for power measurements



QE Results

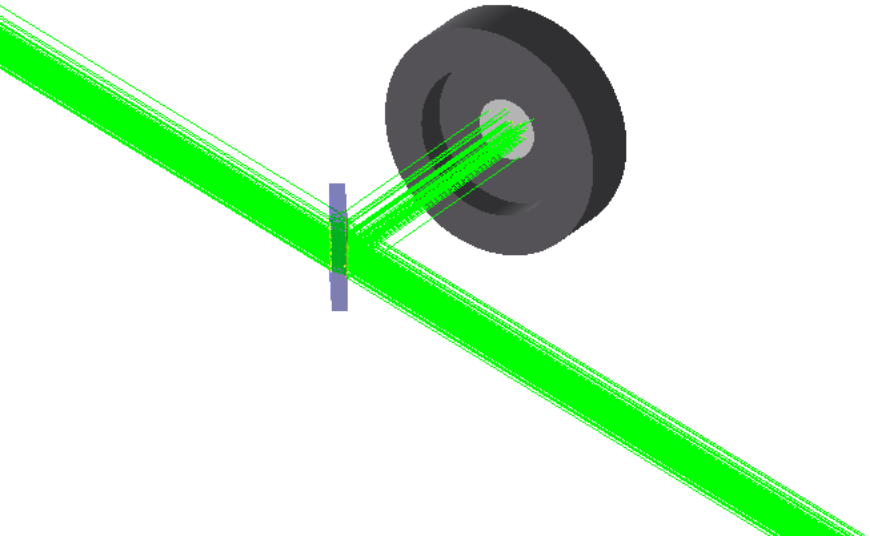
- See expected QE relation for multi-alkali PC
- Collect IV scans of the detector
- See weird behaviour at low voltages, potentially linked to gas ionisation inside the vacuum
- Fitting Binary Encounter Bethe (BEB)models to the data seems in good agreement but need more investigation into what gasses can appear in detector as well as expanding the BEB model

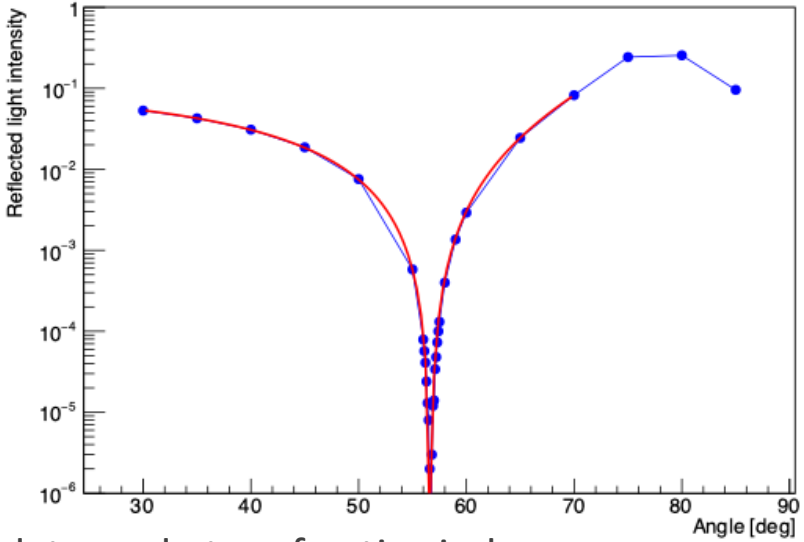




Possible RI measurement

- Rotate a reflective material (e.g. Aerogel)
- Locate brewseters angle via dip in reflected light intensity





- Relate angle to refractive index:

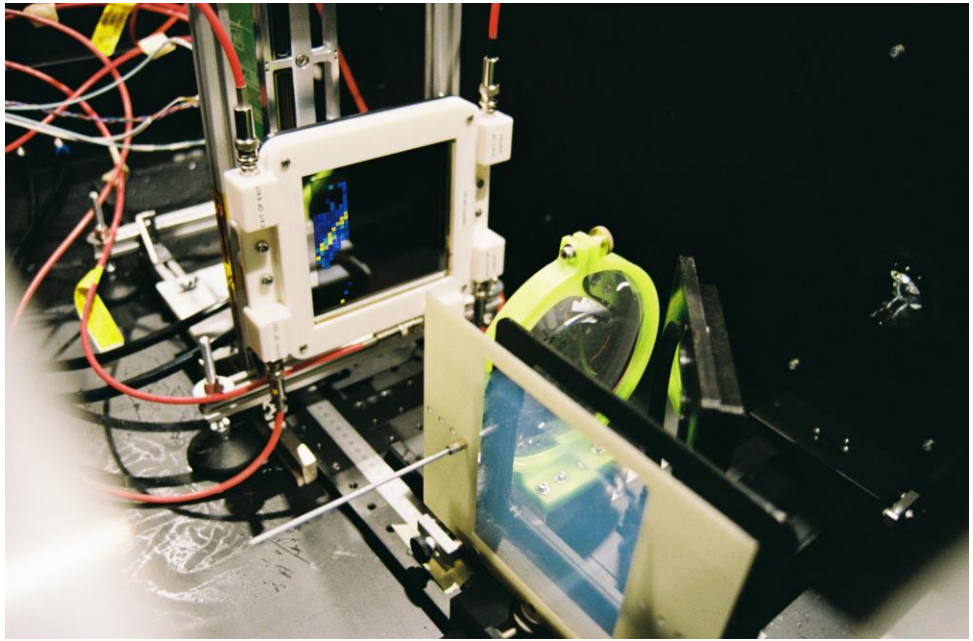
$$\theta_b = arctan(\frac{n_1}{n_2})$$

- Waiting on grant for rotation stages + other equipment so only simulated data for now

Test beam

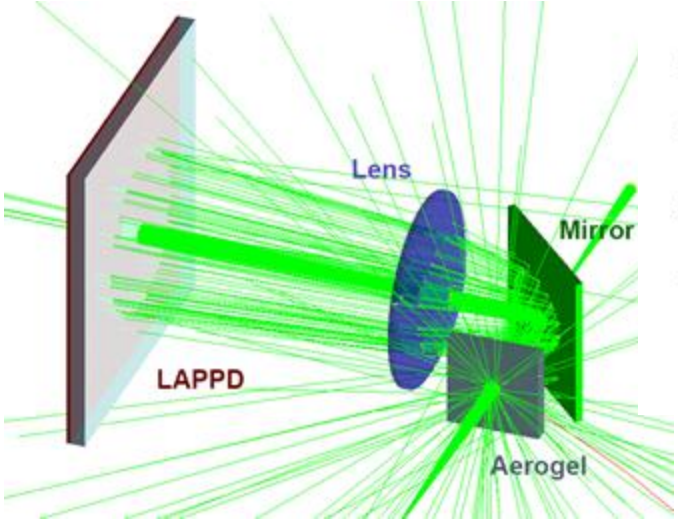
Test beam setup

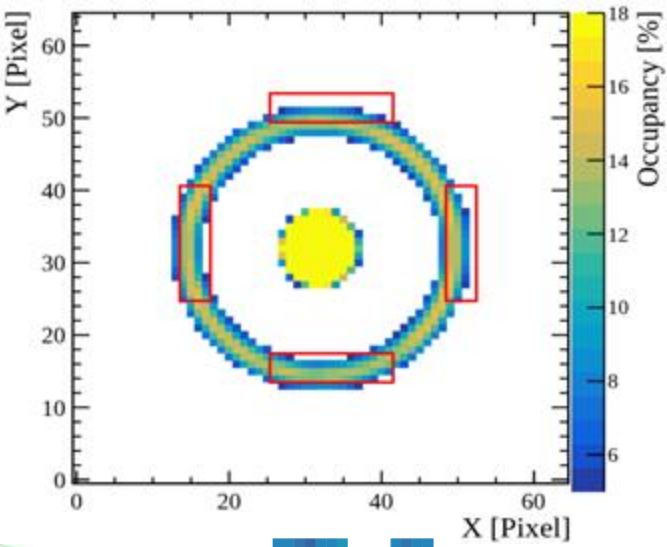
- HRPPD taken to test beam during summer at SPS CERN
- Test beam setup:
  - Aerogel to create Cherenkov radiation
  - Mirror to reflect towards detector
  - Lens for focusing light
  - HRPPD
- Got results proving FastRICH's ability to couple to HRPPD + experience working with FastRICH itself
- Results not ready to be shown publicly

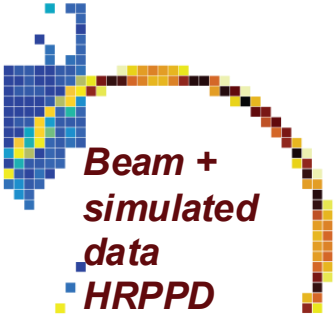


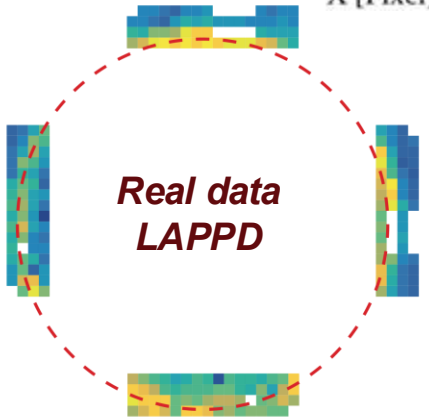
Geant4 simulations

- Simulated Cherenkov radiation to obtain ring information via Geant4
- Overlaid testbeam data and simulated ring position and saw good agreement!!



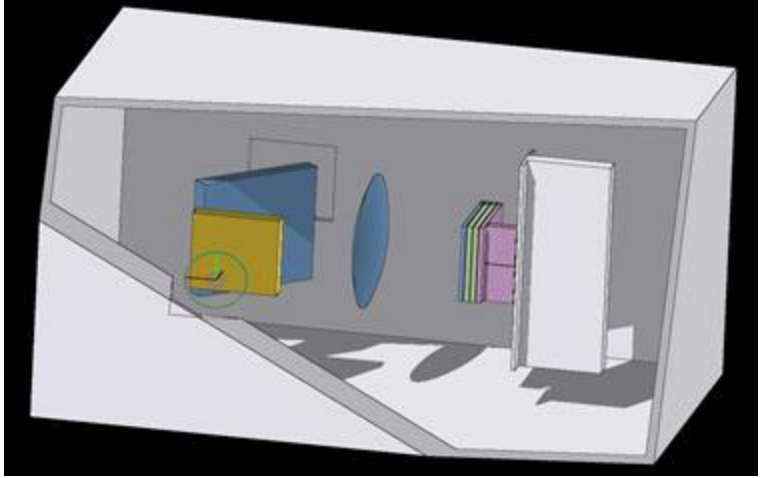


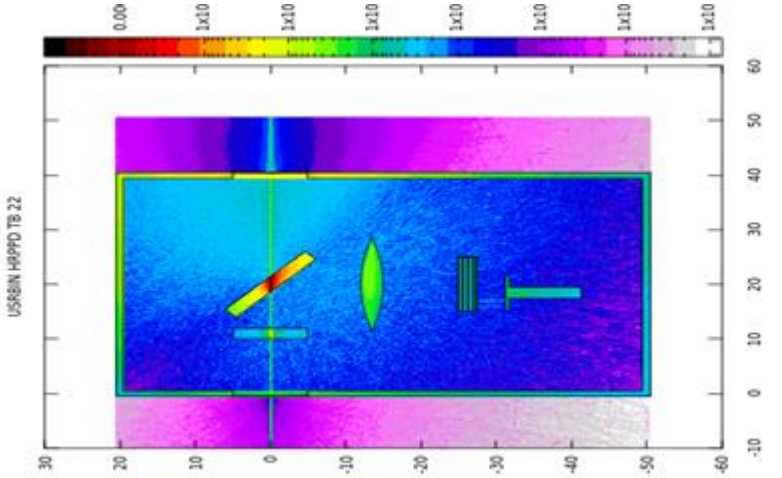




FLUKA simulations

- Rebuilt Geometry using FLAIR to obtain information on radiation doses of the equipment
- Confirmed that HRPPD was safe from radiation damage given the setup geometry

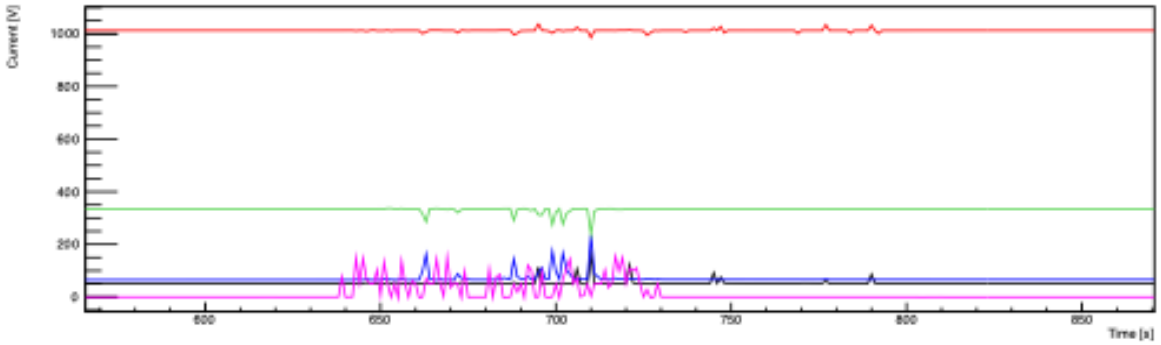


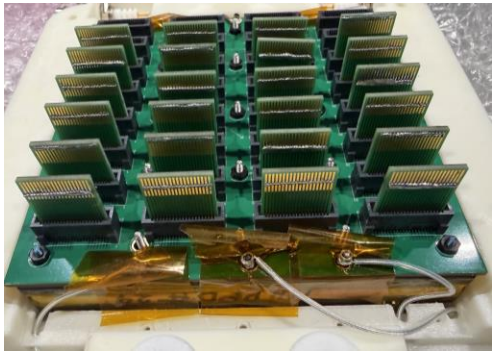


Bumps in the road

HRPPD issues

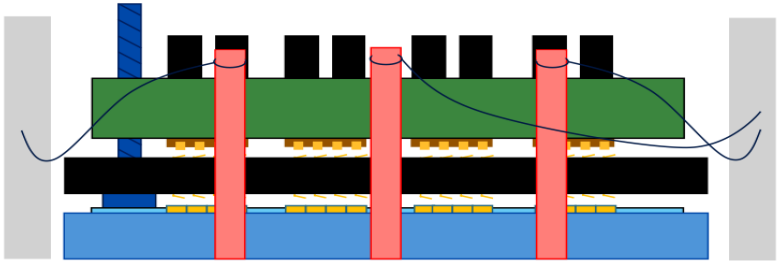
- During test beam saw significant instability of PC
- Talks with INCOM revealed issue was due high humidity allowing PC HV arcing to readout electronics ground

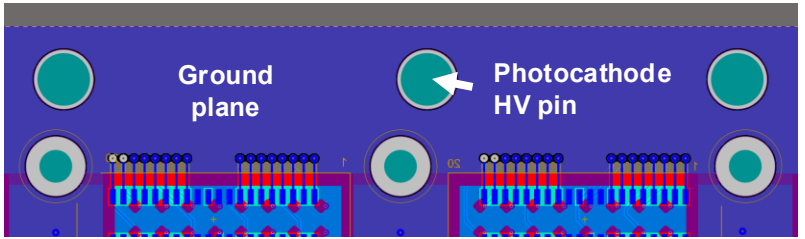




Kapton insulation of HV pin

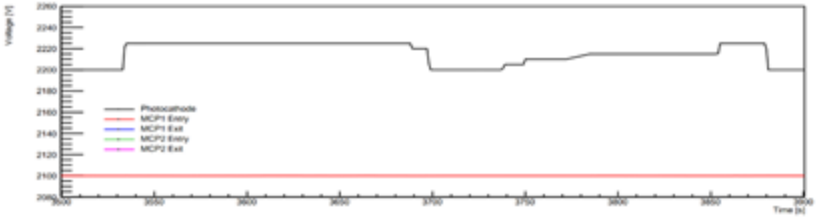
- Issue solved via adding Kapton tape around pins to insulate against humid air

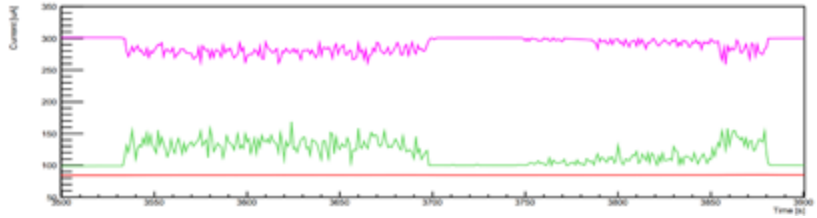


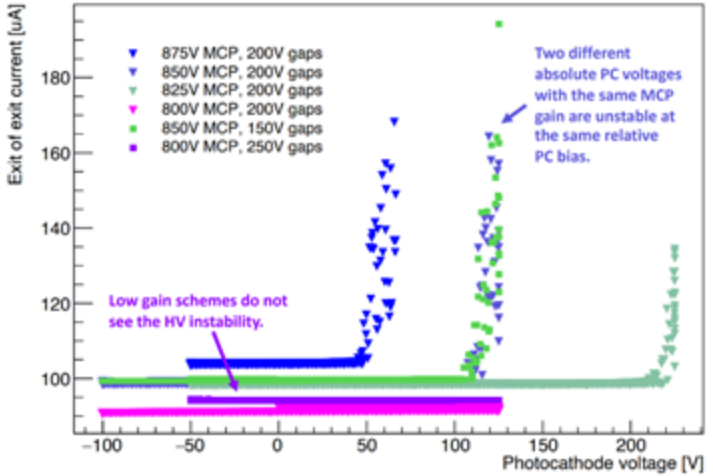


LAPPD issues

- Power outage in lab on 5th Oct
- Seeing weird current instabilities when PC Voltage is too high, after investigations seems to be linked to MCP voltages/gain across detector
- Believe exit MCP may be receiving too many electrons to amplify or has too large amplification across it for some reason







Any Questions?