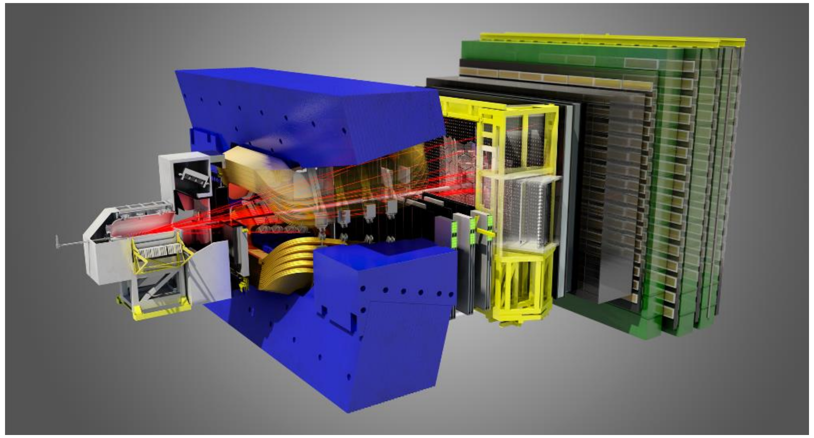
# LHCb RICH test beam campaigns for future upgrades

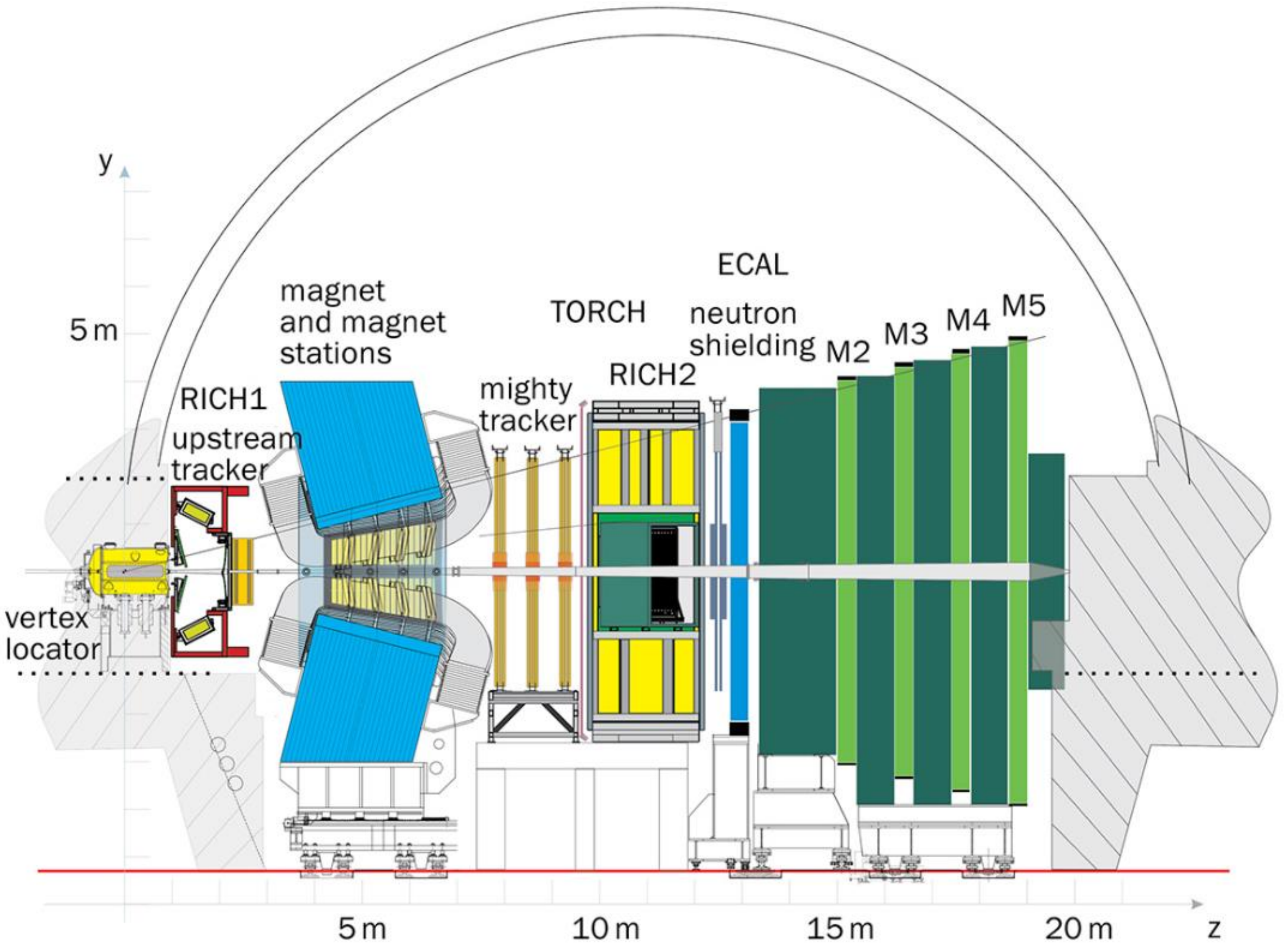

**Constantinos Vrahas**

**on behalf of LHCb RICH**

# Brief introduction to LHCb RICH

- LHCb allows us to probe matter-antimatter asymmetry in the early universe
- RICH measures the Cherenkov angle of photons emitted by charged particles → allows estimation of their mass
- Increased luminosity at LHCb due to Upgrades:
    1. **Increase in detector occupancy**
    2. **Better spatial and timing resolution needed to retain PID performance**
    3. **Higher electronic readout rate required**



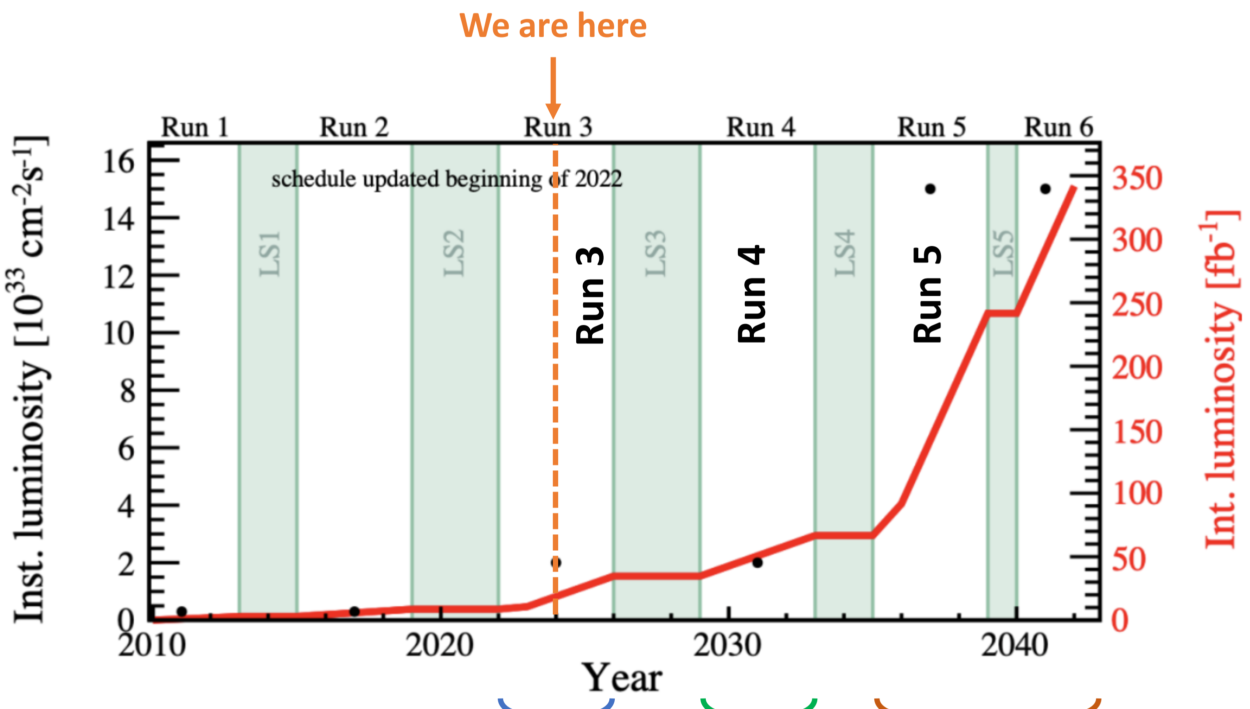
# LHCb Upgrades

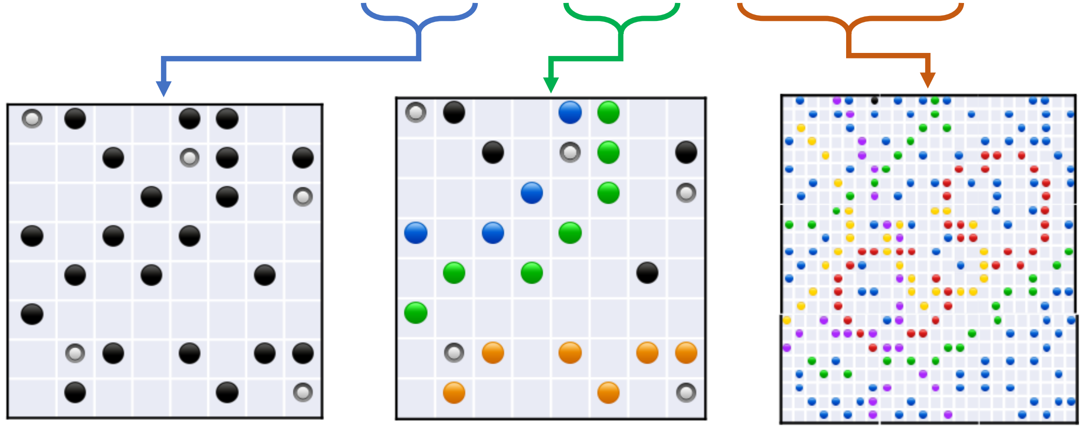
## LS3 Enhancement (2026-2028)

- Readout chain updated to provide the **timestamp of each Cherenkov photon** (FastRICH) → Easier to associate photons to tracks

## LHCb Upgrade II (2032+)

- Luminosity increase by factor of **7**
- Plan to reuse Run 4 electronics
- Upgrade to photodetectors with higher spatial and timing resolution → Technologies considered include **MaPMTs**, **SiPMs** and **MCPs**
- Requirements not yet met by any photodetector
→ Considerations for **updating detector geometry**
→ Additional **R&D on photodetectors** required

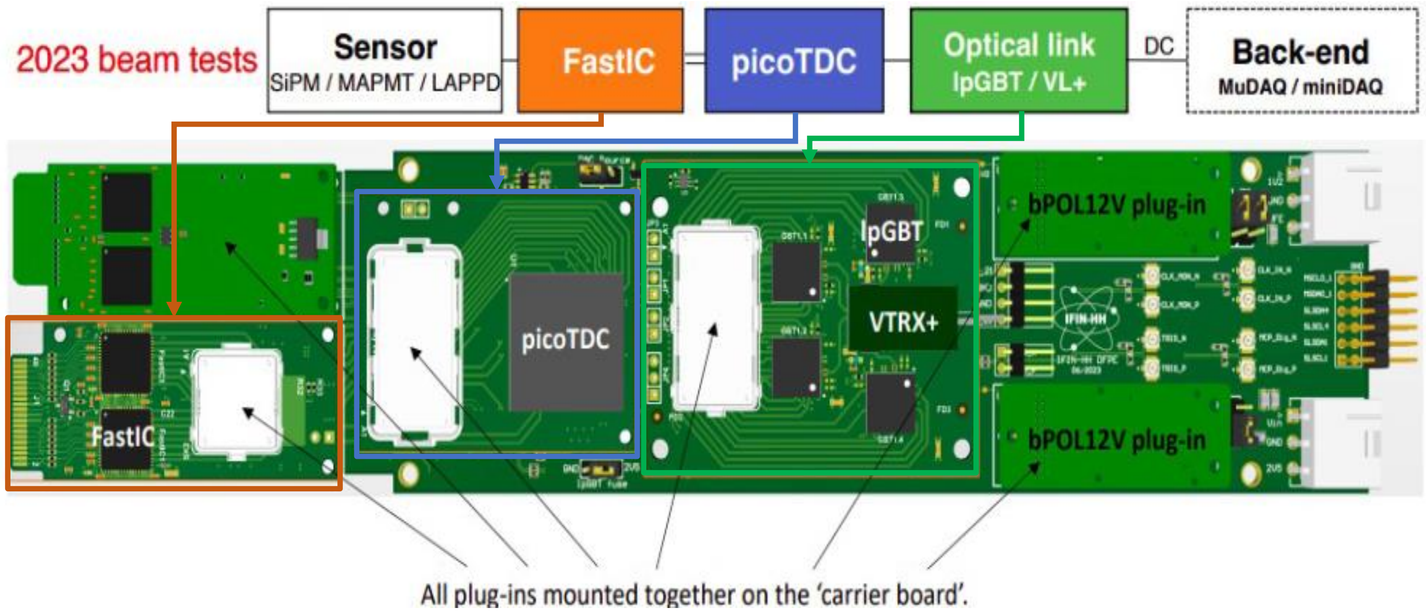


# Overview on RICH TB electronics

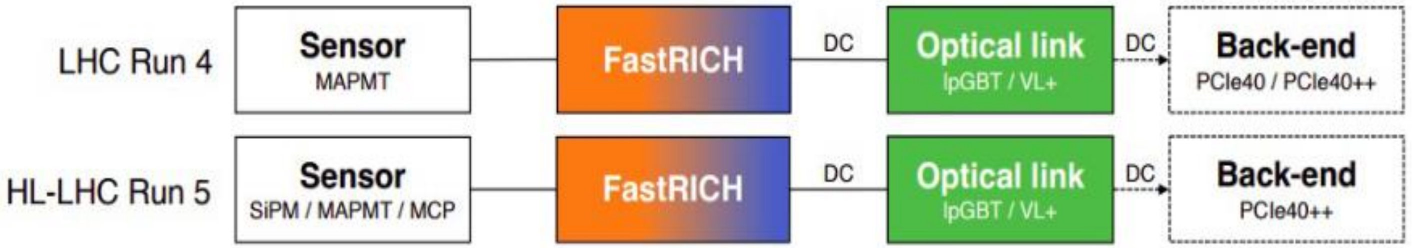
## 2023 electronics chain:

- **FastIC** plugins obtain analog signal from sensors
- Analog signal digitized in **picoTDC** plugin → sent to back-end via **lpGBT** optical link
- Simultaneous measurements with up to **7** boards with **64** channels per board




## Run 4/5 electronics:

- FastIC and TDC functionality combined in **FastRICH** plugin

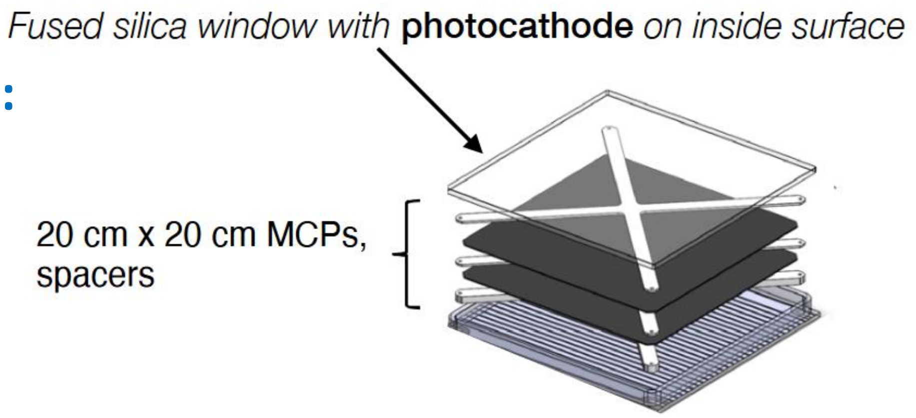


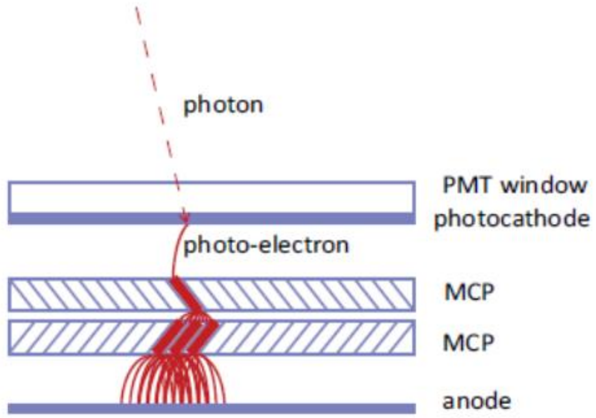

**See Steve's LHCb UK Birmingham and RAL talks for more info:**
https://indico.cern.ch/event/1283997/contributions/5484547/attachments/2685530/4659260/LHCbUK-Birmingham-20230717.pdf
https://indico.cern.ch/event/1332271/contributions/5707357/attachments/2776969/4839997/LHCbUK-20240108.pdf

# Large Area Picosecond Photo-Detector (LAPPD)

## 20x20cm MCP photomultiplier by INCOM:

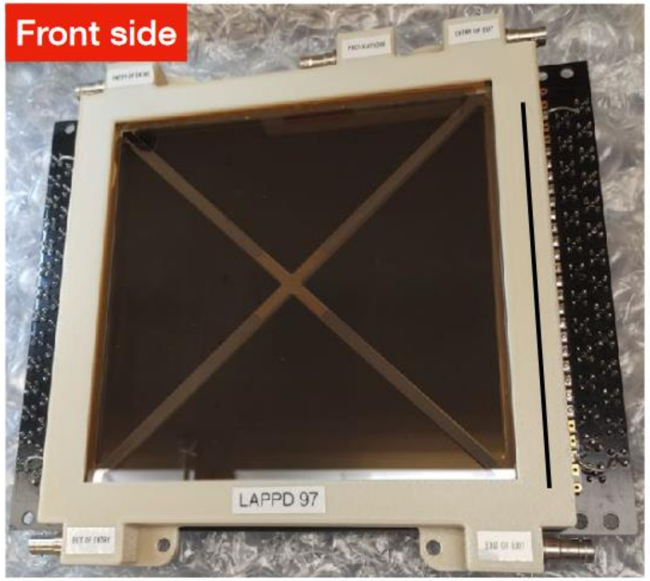
- Photos hitting the photocathode release photoelectrons
- Electric field causes photoelectric amplification between plates
- Electrons arriving on anode induce signal on back-plane

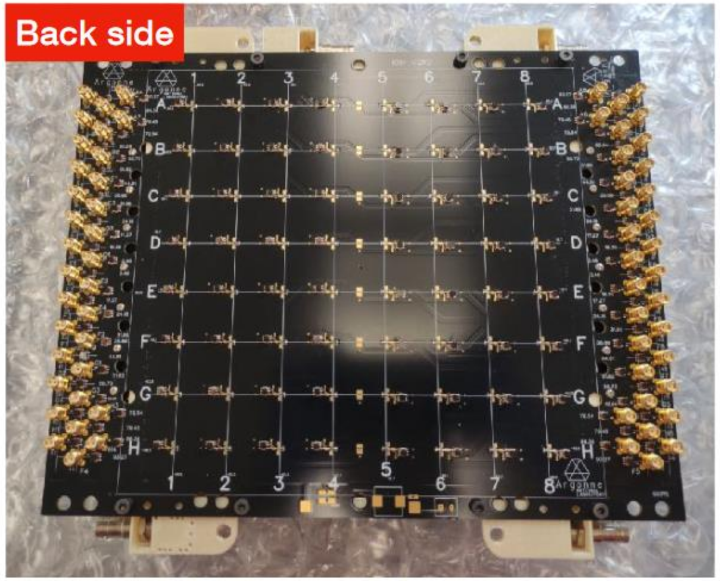



## Properties:

- Time resolution lower than **60ps**
- High gain ($\sim 10^7$)
- Capable of imaging single photons



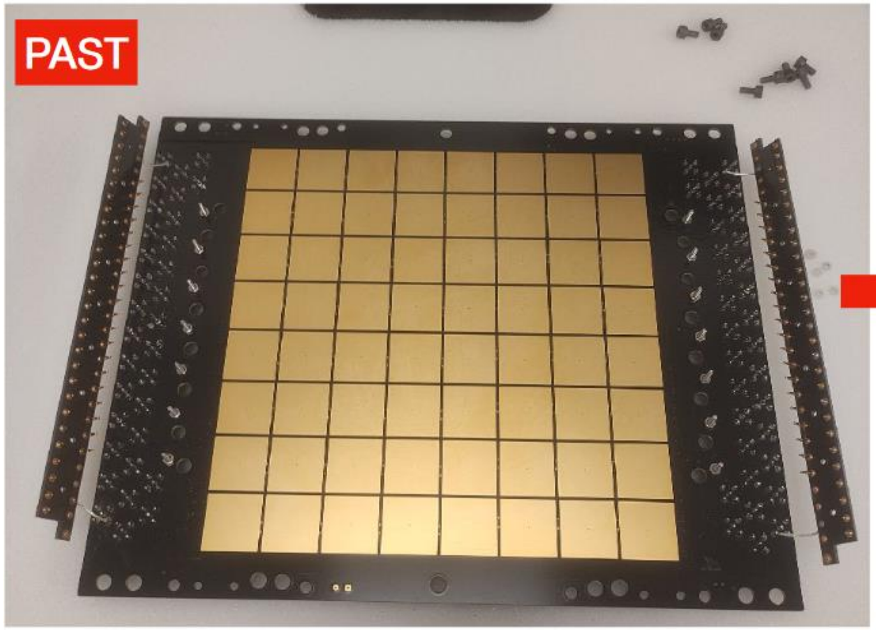
# Changes to LAPPD for use in the RICH

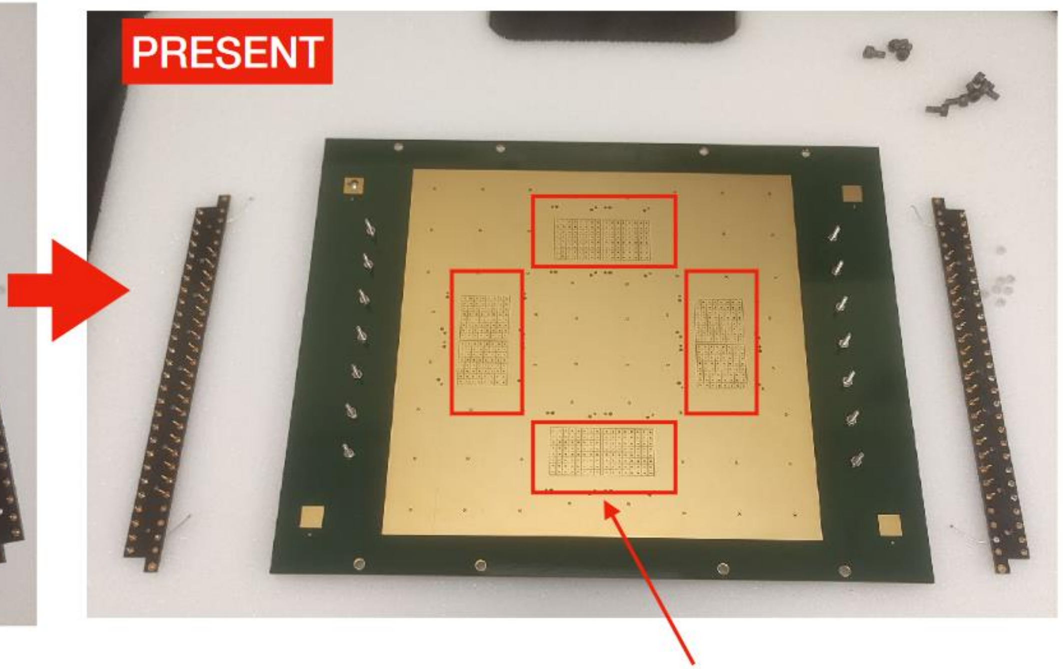
## INCOM readout board:

- **64** pixels, **25mm** pitch to pitch
- **24x24mm** active area, **1mm** dead gap
- Good for testing, not suitable for resolving rings

## Custom readout board:

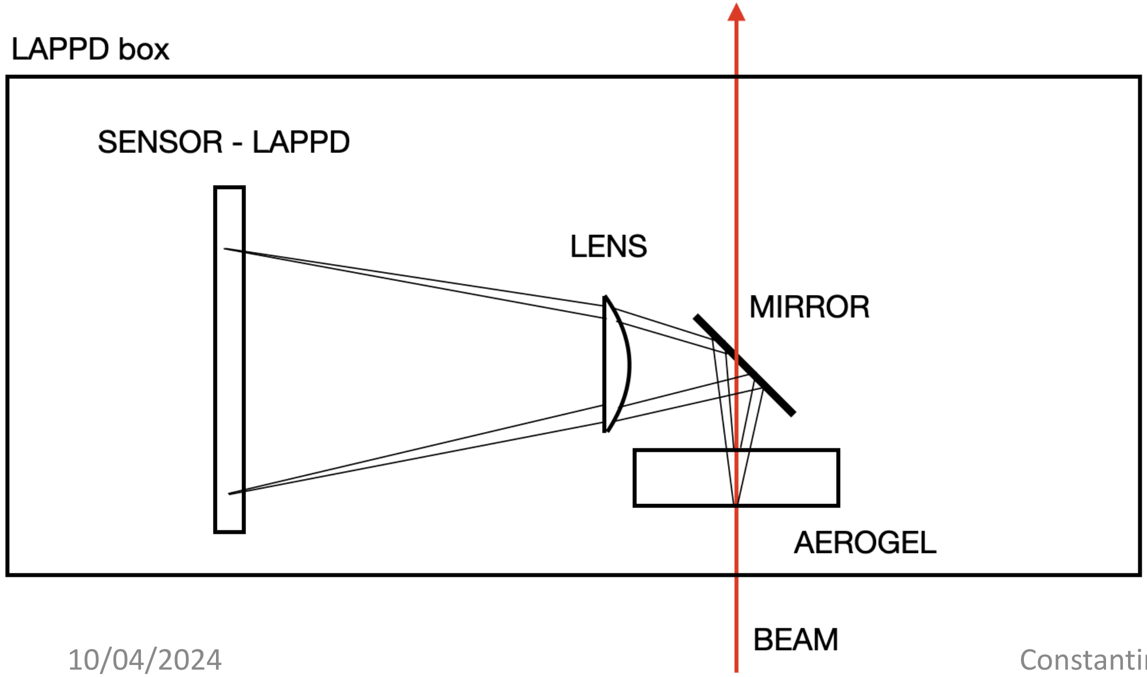
- **512** pixels **3mm** pitch to pitch
- **2.9x2.9mm** active area, **0.1mm** dead gap
- Better utilization of active area for use in the testbeam

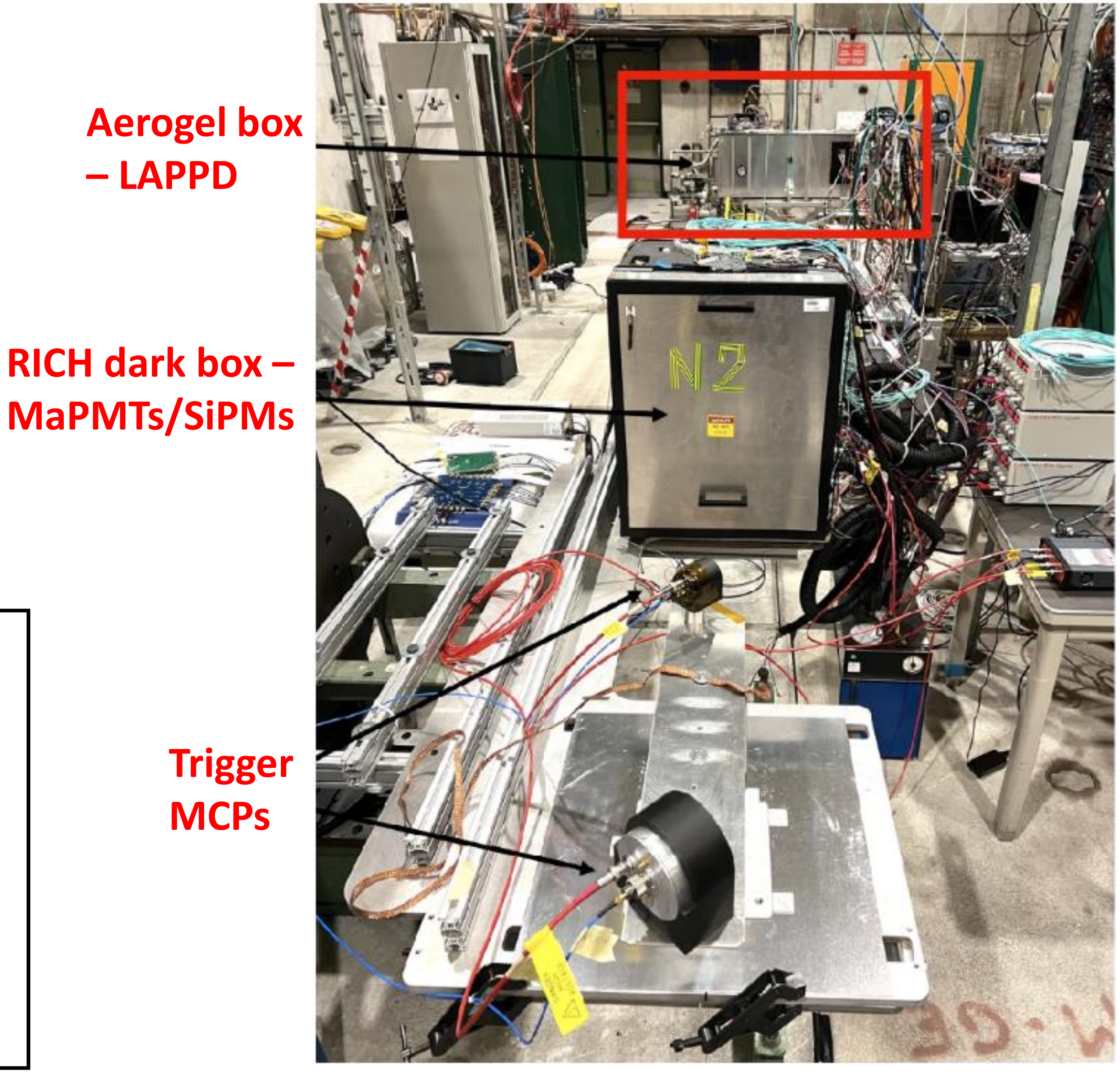


# Testbeam setup

- Used in September, retained for the April testbeam
- Aerogel box is upstream, **LAPPD** off-beam, optics redirect Cherenkov photons to the sensor
- RICH dark box in beam line, **MaPMTs** and **SiPMs** out of beam path
- Two MCPs downstream provide **trigger** and used as **time reference** for both setups



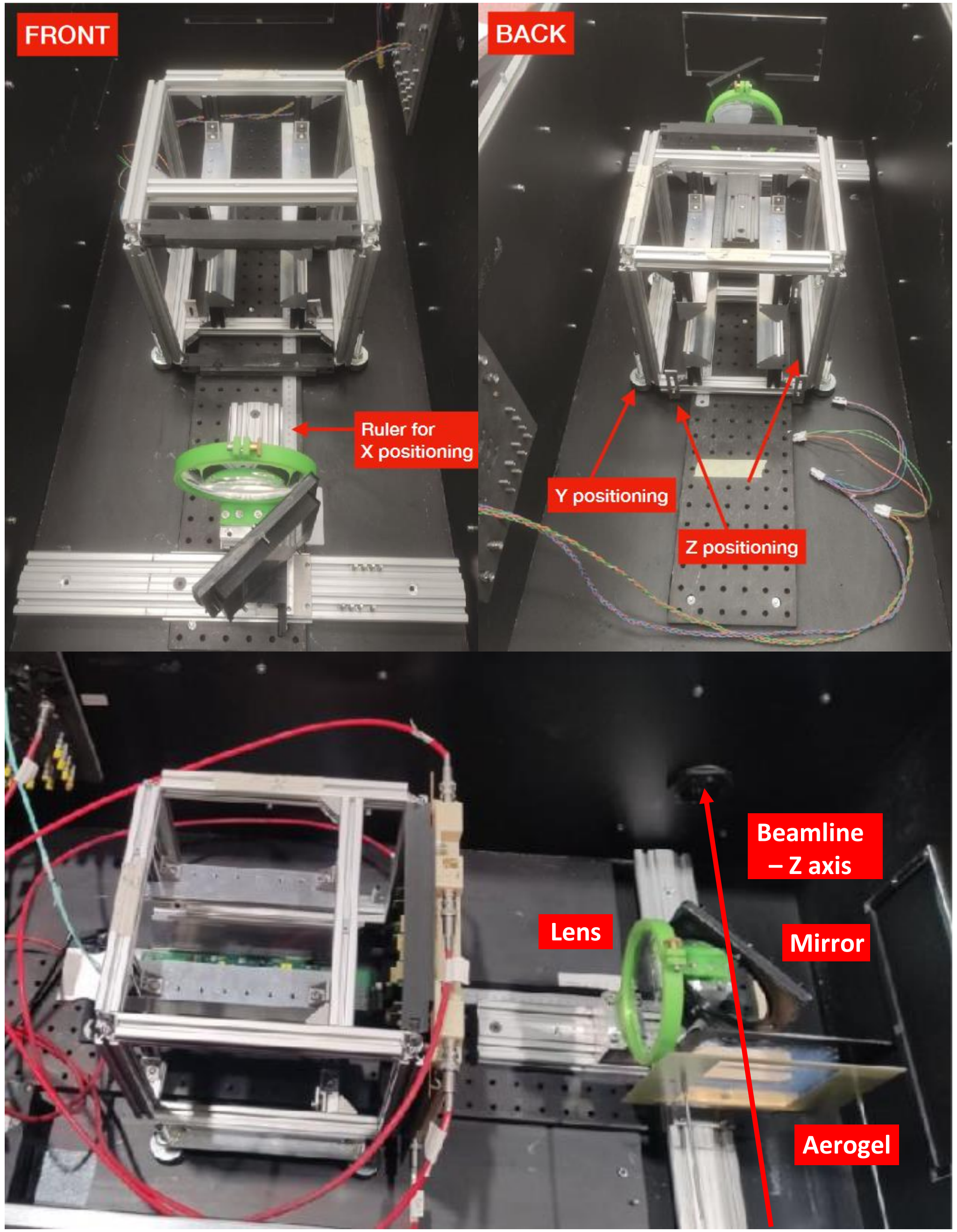
# LAPPD setup

## Components:

- LAPPD mechanical frame + electronics
- $45^{o}$ mirror
- Borosilicate lens
- 2cm aerogel block

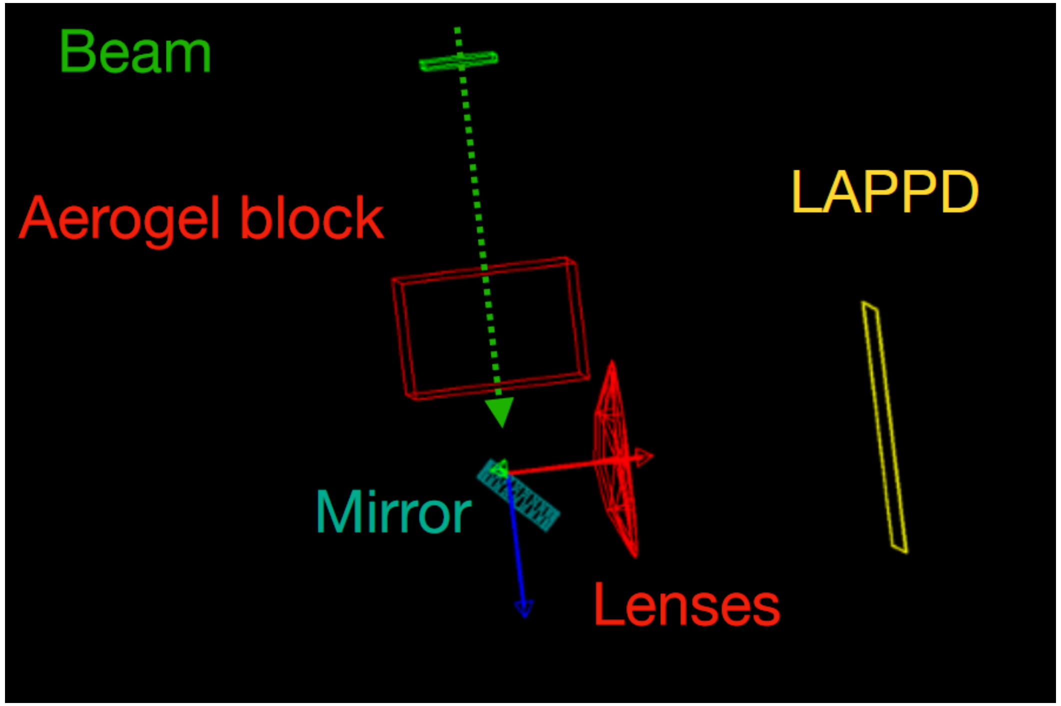
## Mechanics:

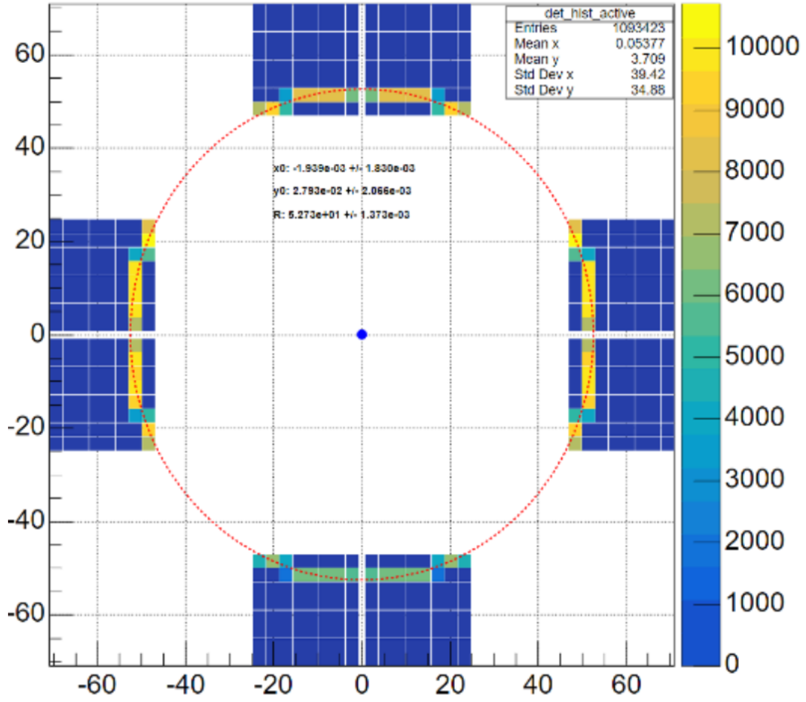
- Mechanical frame allows adjustment of the **Y** and **Z** position of the LAPPD
- Rails allow adjustment of distance between mirror and lens/aerogel and the **X** position of LAPPD
- Up to **8** readout boards (**512 channels**) can be connected to LAPPD using this setup



# Optics simulation

- Testbeam optic simulation was developed in collaboration with the Ljubljana and Kiev groups and adapted for use on the LAPPD optics
- Gives distances required between components to obtain a focused ring
- Shows expected occupancy of LAPPD sensitive area depending on simulation conditions
- Results were used for precise alignment of the LAPPD to the beam and give insight on requirements for ring-fitting



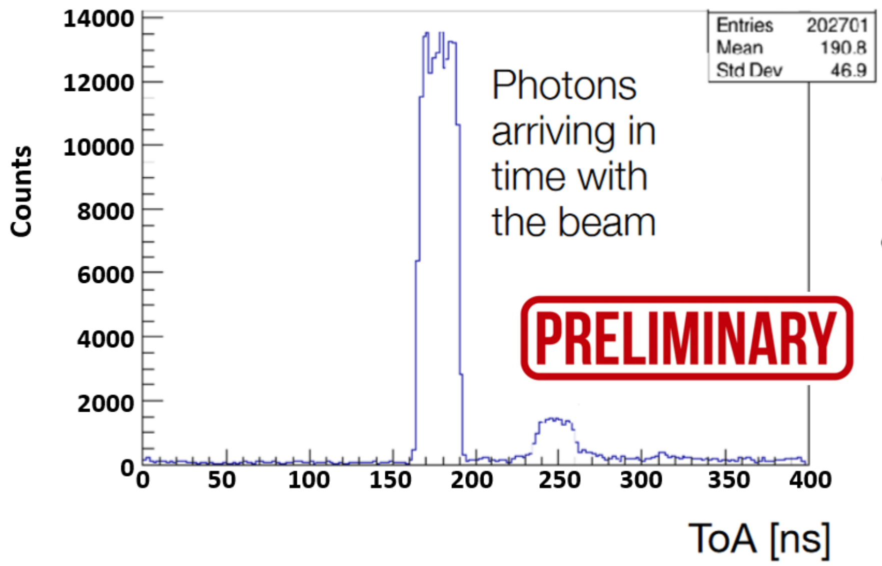
# Observations from September 2023 testbeam

- Time over Threshold (**ToT**) and Time of Arrival (**ToA**) information obtained from picoTDC in 2023 testbeam
- In-time photons in ToA → Cherenkov photons from beam
- ToT decreases further from pedestal as expected

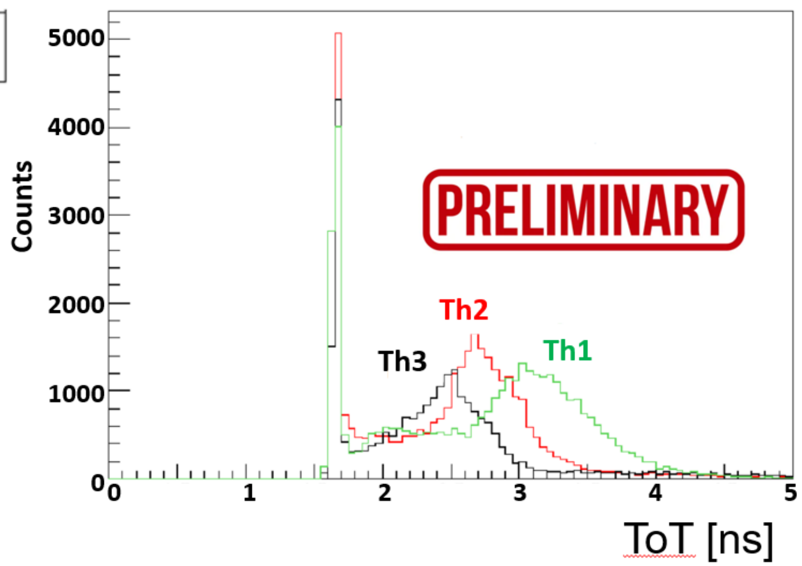
## Under investigation:

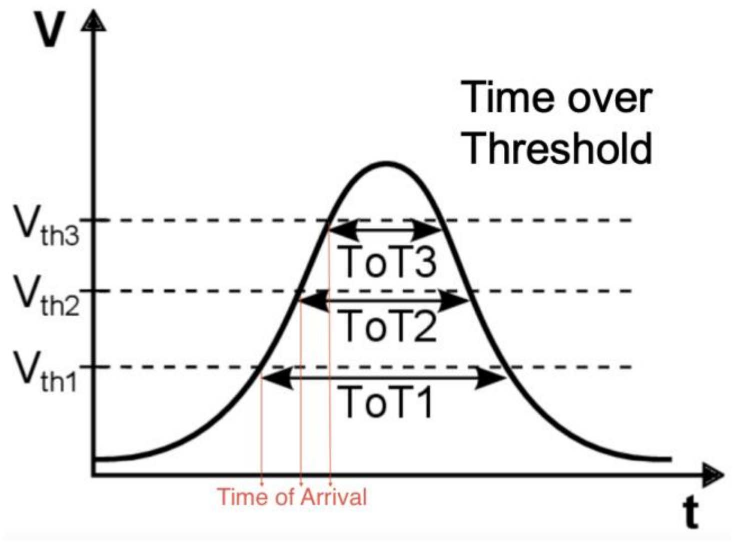
- Approx **10%** of data is shifted in ToA → scattered/reflected Cherenkov photons?
- Sharp peak around **1.5ns** ToT independent of pedestal

**Time-of-Arrival distribution**




**Time-over-Threshold distribution**



# Plans for upcoming testbeams

## Preparations for testbeam April 2024:

- Improved mechanics and simulation for optical alignment of the LAPPD in aerogel box
- Detailed threshold analysis and automated scans for investigating ToT distribution
- Collecting more statistics → characterizations of different sensors using fast electronics chain

## Plans for future testbeams:

- Implementation of FastRICH chip incorporating FastIC and TDC functionality in a single chip → changes in electronics chain and firmware
- New back-end → simultaneous DAQ using more than 7 carrier boards → possibility to test large number of channels and accurately reconstruct Cherenkov rings