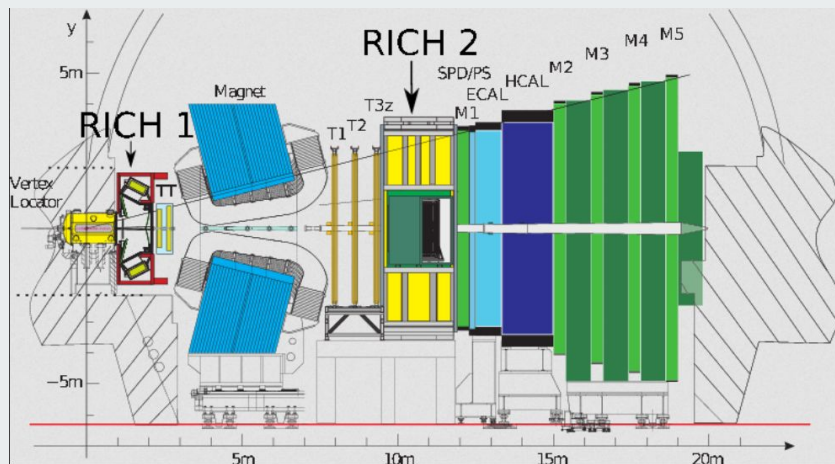


The upgrade and performance of the RICH detector

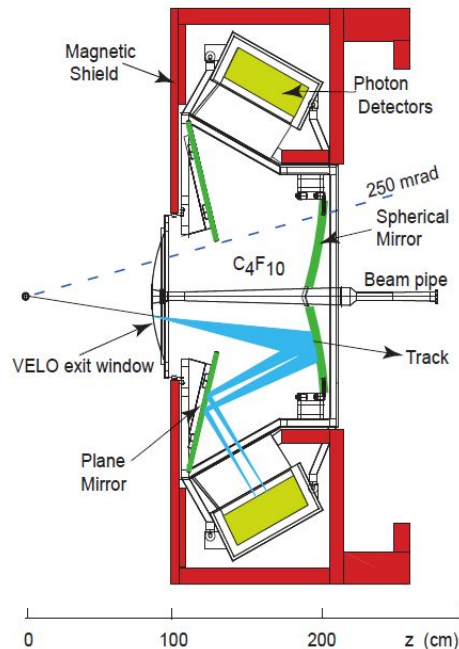
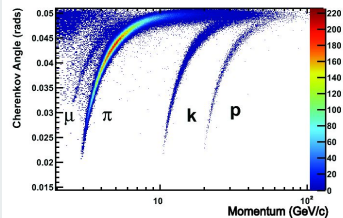
Edoardo Franzoso
on behalf of the LHCb Collaboration



RICH Physics

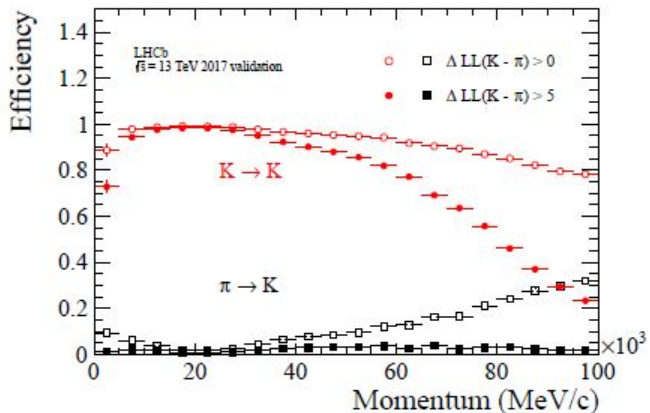
Hadron Particle Identification (PID)

- Cherenkov light reflected towards photodetectors
- ID hypothesis of a candidate particles is compared with the pion hypothesis
- DLL variables are obtained from RICHes information



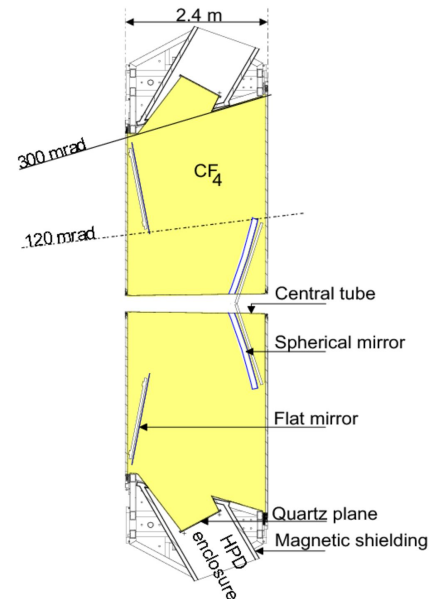
RICH 1

- P coverage up to 50 GeV
- $n = 1.0014$



RICH 2

- P coverage up to 100 GeV
- $n = 1.0005$



Upgrade and Motivation

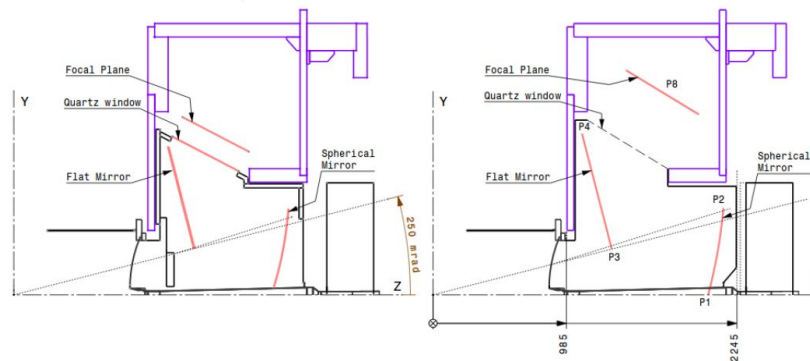
RUN	RUN I	RUN II	RUN III	RUN IV
Period	2010 - 12	2015 - 18	2021 - 23	2027-29
\mathcal{L}	$4 \cdot 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$		$2 \cdot 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$	
$\int \mathcal{L} dx$	3 fb^{-1}	9 fb^{-1}	25 fb^{-1}	50 fb^{-1}

LHCb RICH Upgrade

- Optical system redesigned
- Modified mechanics and cooling system
- New Front-End (FE) Electronics and DAQ system
 - HPDs replaced by MaPMTs
 - FE electronics to deal with 40 Mhz readout rate
 - CLARO8 ASIC
 - FPGA-based Digital Board
 - GigaBit Transceiver chip for data transmission

New detector requirements for RUN III

- fivefold luminosity increment
- Increased readout from 1 MHz to 40 MHz

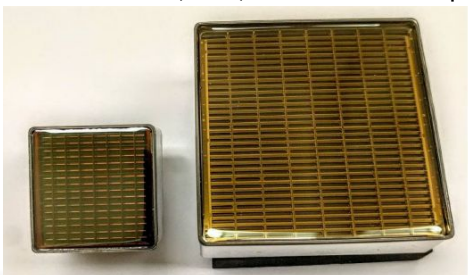


New Photomultipliers and Readout

To achieve the required readout rate, a new electronic (CLARO chip) has been developed and coupled with Multi-Anode PhotoMultiplier Tubes (MaPMTs), instead of the Hybrid Photon Detectors used for previous LHC runs

MaPMTs

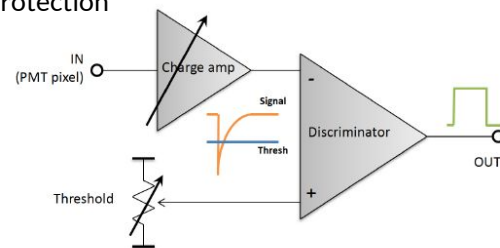
- R-type (1") and H-type(2")
- 64 pixels each
- High quantum efficiency (QE) super-bialkali photocathode
 - lower chromatic error
- Gain $\sim 2 \cdot 10^6$ at 1kV with 1:3 pixel gain spread for a single MaPMT
- Dark count rate (DCR) < 1 kHz for each pixel



CLARO ASIC

8 channel amplifier/discriminator

- 0.35 μm AMS CMOS technology
- Recovery time < 25 ns
- Adjustable threshold and attenuation for each channel
- Triple modular redundancy protection
- Radiation- hard by design

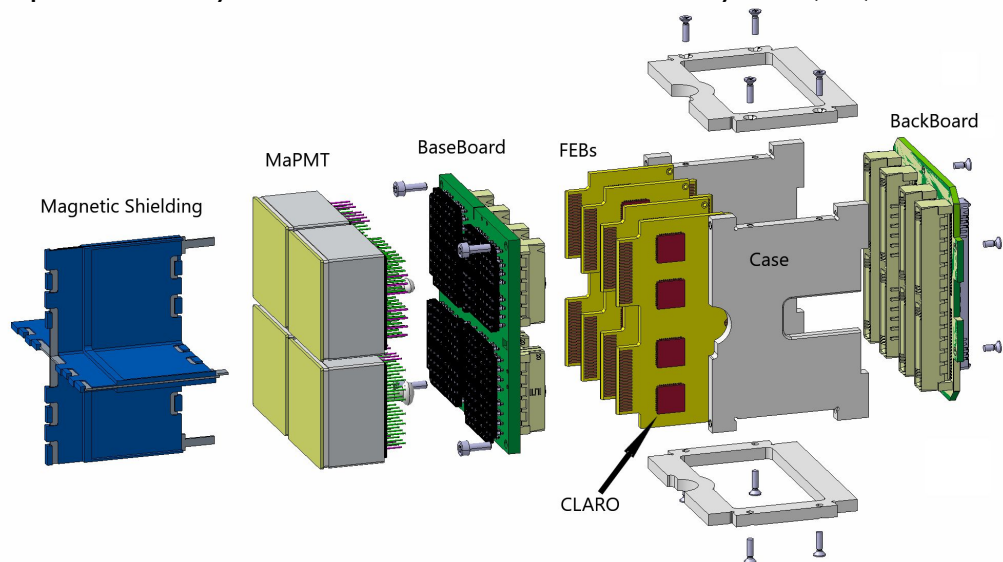
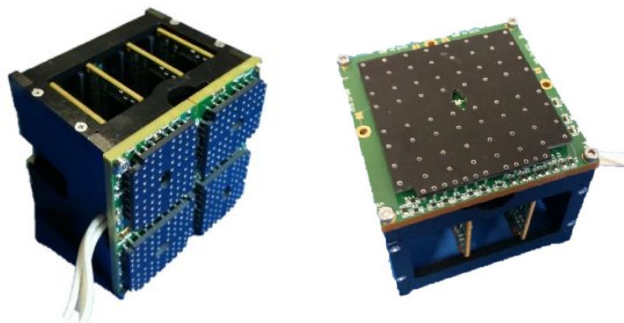


Elementary Cell

MaPMTs and readout electronics are coupled in a compact and fully functional unit called Elementary Cell (EC)

2 types of EC :

- R, hosting 4 MaPMTs of 1"
- H, hosting one 2" MaPMT



The BackBoard provides the interface between the EC and the FPGA based Digital Boards.

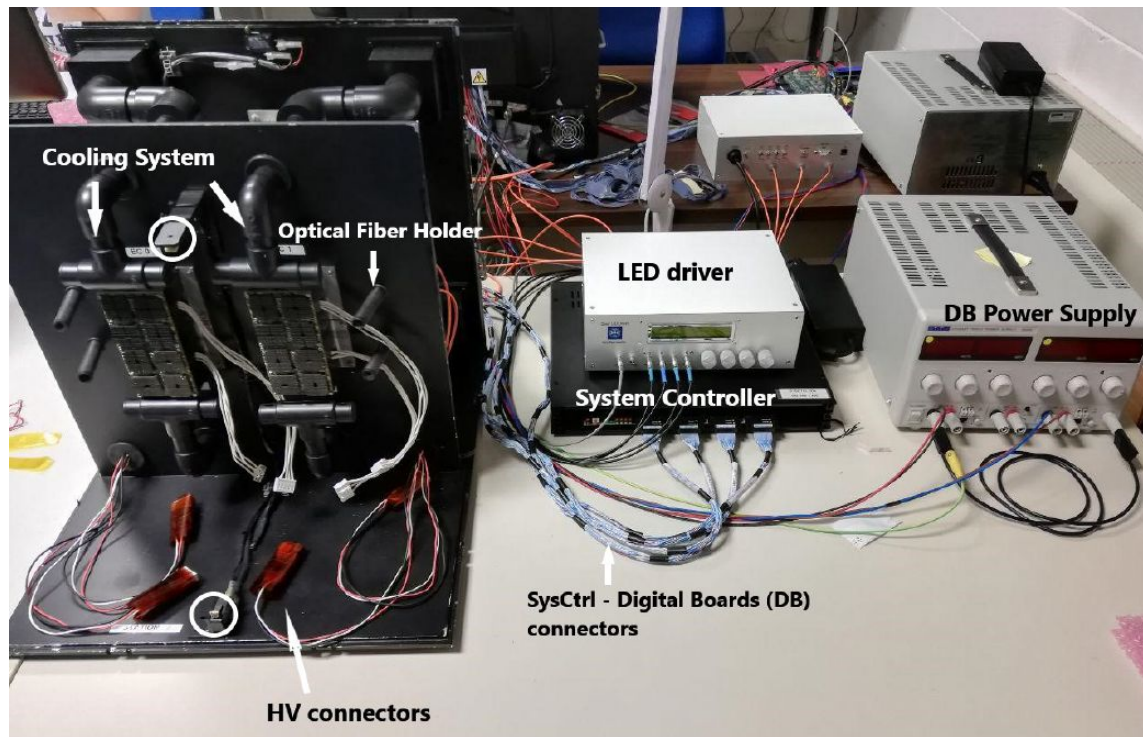
4 ECs coupled with 2 Digital Boards constitutes a Photon Detector Module, the basic element of a RICH column

Elementary Cell Quality Assurance (ECQA) (I)

Single components validation and
full EC quality assurance

ECQA test stations

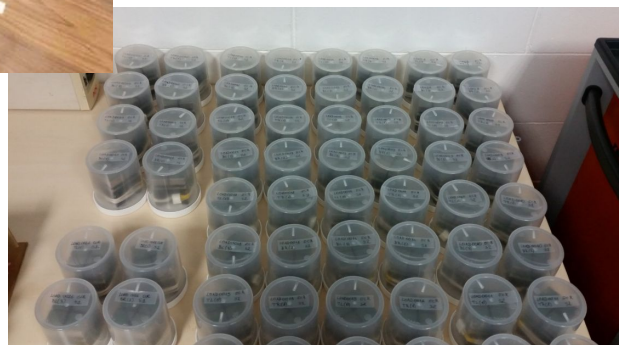
- NI LabVIEW control software
- Test protocol established for
EC acceptance/rejection



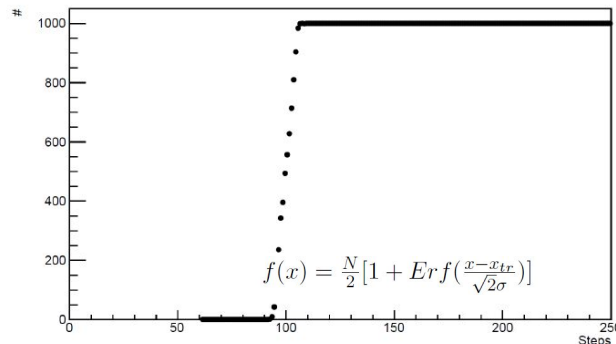
Elementary Cell Quality Assurance (ECQA) (II)

Test Protocol

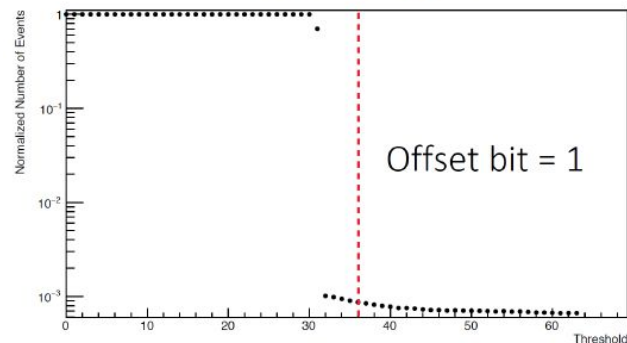
- S-curve
- Threshold Scan
- DCR
- Afterpulses



feb 0 chip 2 ch 7

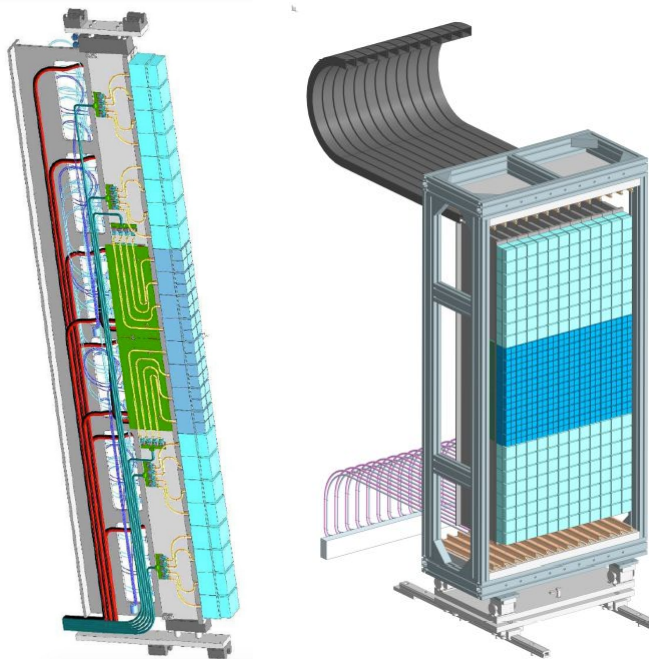


ThresholdScan_FEB1_CHIP_6_CH_5



The Photon Detector Module (PDM)

The PDM is the logic unit which allows to interface the EC with the LHCb readout architecture



A PDM is made by 4 ECs.

PDMs are grouped in columns.

More columns constitutes a
RICH planes

Columns Commissioning at CERN



RICH planes are organized in columns

RICH2 columns first commissioning is completed.

A lot of work has been done and is ongoing for mechanics, optics, commissioning, software.

RICH1 commissioning ongoing



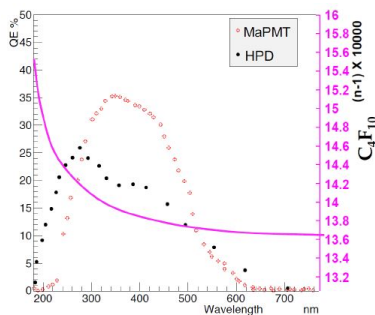
pictures by Silvia Gambetta



Upgrade Performances

Overall an improvement in the Cherenkov rings resolution (mrad) is expected

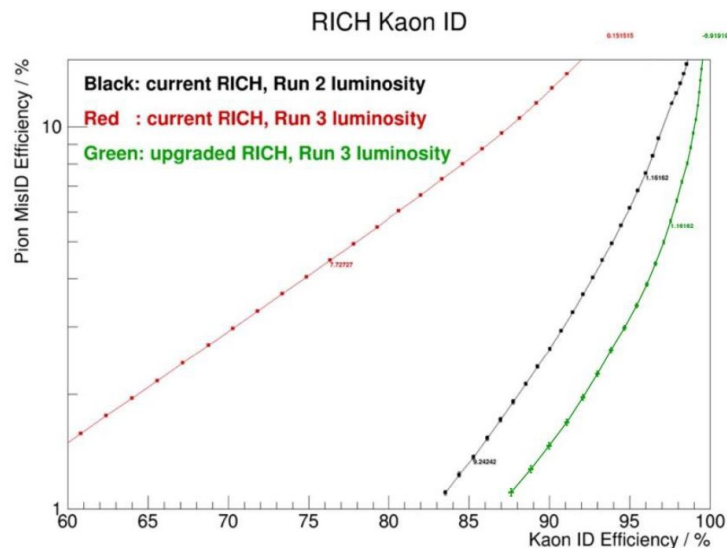
- QE peaks at higher wavelength
- No Point Spread Function
- New optics (lower emission point error)



Source	HPD - RICH 1	MaPMT - RICH 1	HPD - RICH 2	MaPMT - RICH 2
Chromatic	0.84	0.58	0.48	0.31
Pixel	0.60	0.44	0.19	0.19
Emission point	0.76	0.37	0.27	0.27
Total	1.70	0.78	0.65	0.45

Simulation of RICH performance is constantly updated with experimental input

Excellent PID performance of the RICH is maintained



Time Gate

DOI:10.17863/CAM.45822

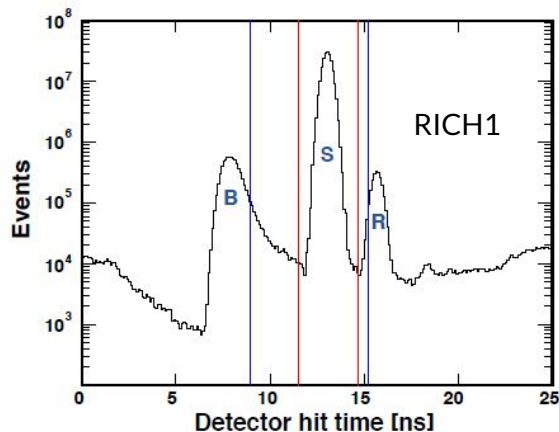
Gating signal observed by RICH in the 25 ns bunch crossing interval

Signal from a pp collision fits within a time window of 50 ps for RICH1 and 500 ps in RICH2

Time gate has been studied during particle beam test at the CERN SPS

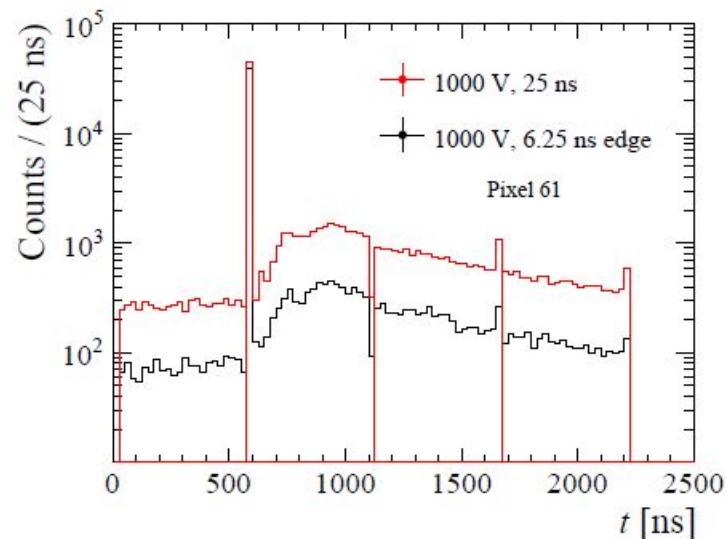
From simulation

- B: background from tracks and photons travelling directly to the detector planes
- S: Cherenkov signal
 - red band → 3.125 ns
 - blue band → 6.250 ns
- R: background due to additional reflections



During tests, when a 6.25 ns gate is applied, the continuous background is suppressed by a factor of 3-4

Time gate applied by FPGA adapted to sample the CLARO signal at 320 MHz

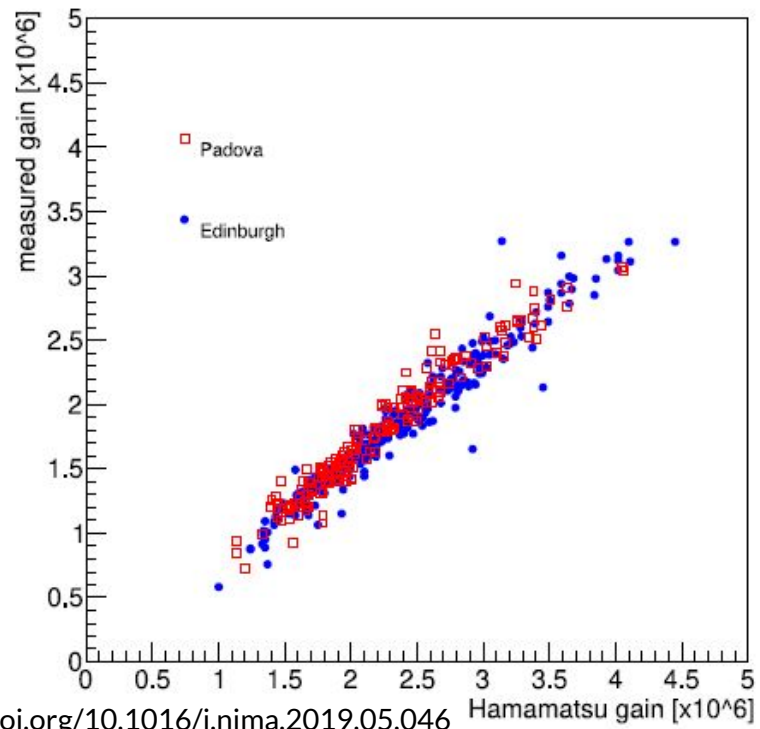
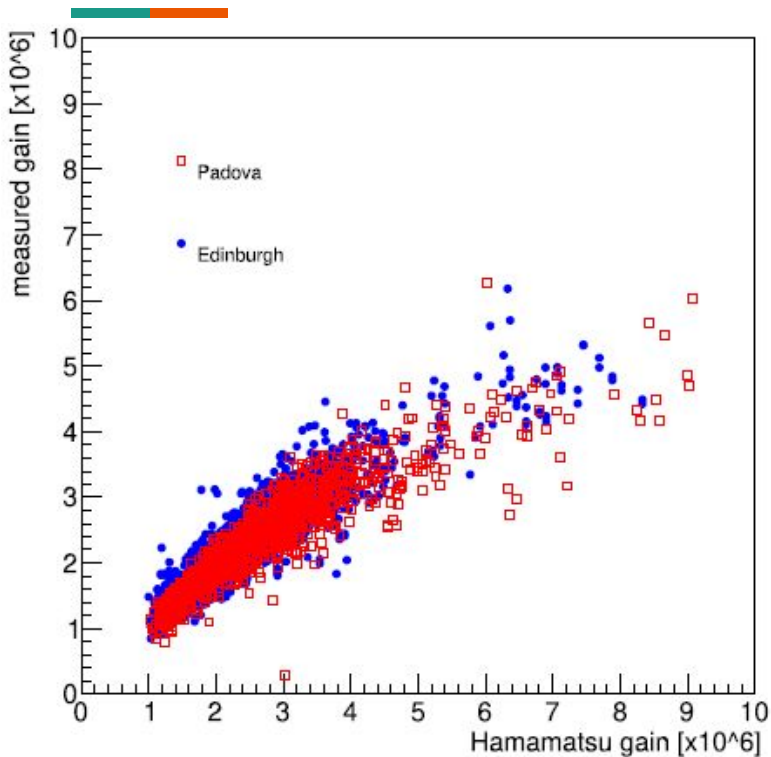


A short horizontal bar with a teal left half and an orange right half.

Conclusions

- LHCb will increase luminosity to $2 \cdot 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
- readout at 40 MHz bunch crossing rate
- RICH1 mechanics and optics modified
- RICH Photodetectors and Readout replaced
 - MaPMTs instead of HPDs
 - CLARO chip for fast readout
 - FPGA based Digital Board
- Quality Assurance successfully validated components
- Columns commissioning ongoing
 - RICH2 columns commissioned
 - Starting RICH1 commissioning

Photon Detector Quality Assurance (PDQA)



<https://doi.org/10.1016/j.nima.2019.05.046>