CERN Summer Student Programme 2019
Summer Student Project Report

High rate tests of the photon detection system for the LHCb RICH Upgrade

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1 Introduction

The Large Hadron Collider beauty (LHCb) experiment studies CP violation through high precision measurements and searches New Physics. It looks for rare decays of beauty and charm hadrons. One of key systems from LHCb detector which helps scientists identify hadrons, particularly, kaons and pions is the Ring Imaging Cherenkov (RICH) system. The RICH system consists of two detectors, RICH 1 and RICH 2. [5]

LHCb is currently being upgraded since 2018 during the second long shutdown (LS2) of the Large Hadron Collider (LHC) at CERN. In the LHCb Upgrade, the readout rate is up to 40 MHz, the inelastic collision rate is 30 MHz and, at the central area of RICH 1, we expect the occupancy to be at 25 percent [1]. Therefore, we have to test the photon detection system response and performance at such high rate and high occupancy.

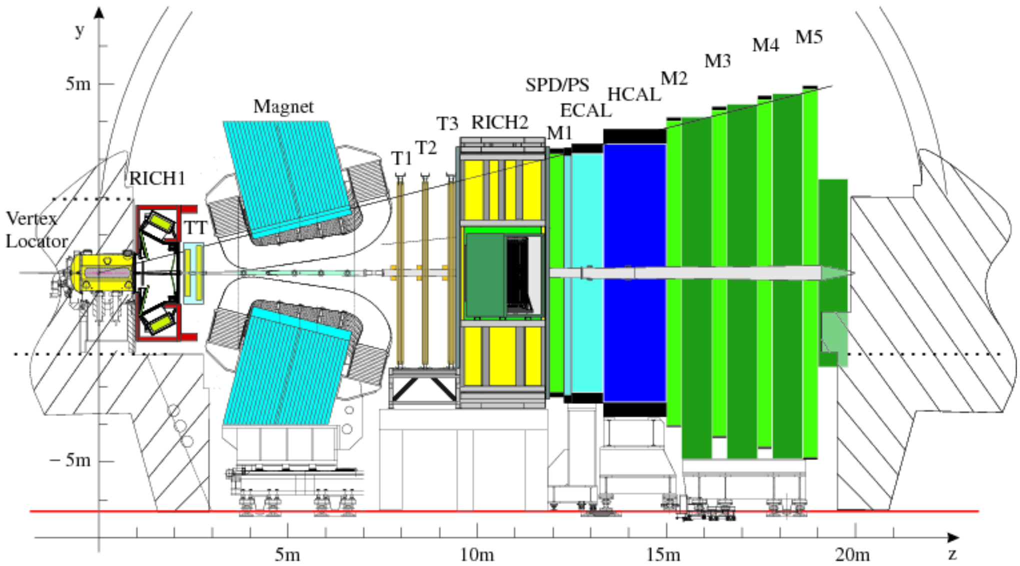


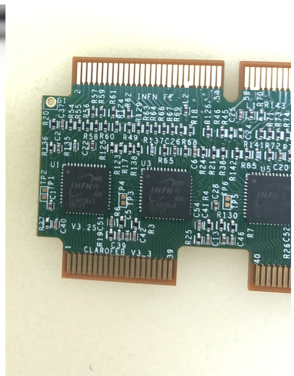
Figure 1: LHCb Detector layout [5]

2 Setup

The photon detection system consists of Multi-Anode Photomultiplier tubes (MaPMTs) and readout electronics. In this measurement, we use a pulsed laser and test the system at 100 kHz, 1 MHz, 10 MHz, 20 MHz, which are the rates of the laser illumination. 16 MaPMTs, 4 Elementary Cells and 2 PDMDBs have been utilized. The data readout is performed using a MiniDAQ2. The PDMDB, a digital board, provides the configuration and data interface between the Elementary Cell and MiniDAQ2.

The type of MaPMT is R13742: 1×1 inch, 64 Anodes (pixels), wide effective area, high speed response [4]. The main part of readout electronics is the CLARO chip. The CLARO is an application specific integrated circuit (ASIC) used for fast photon counting with pixelated photodetectors and providing signal shaping, amplification, discrimination and digitization [2].

(a) MaPMT



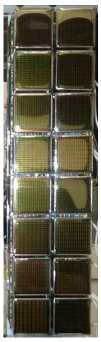
(b) CLARO chips

Figure 2: Facilities

We test the MaPMT and CLARO chain response and performance in conditions comparable to what expected in LHCb RICH Upgrade. The SIN (Signal Induced Noise) is the delayed noise signal in the MaPMT, not easily removable with cutting techniques and it has same signature as Cherenkov photon. It can manifest as the pileup effect on the affected pixels at high rate.

2.1 Old Setup

We use a plastic bar to diffuse the laser light onto the MaPMTs in order to obtain a roughly uniform illumination.



(a) MaPMT column

(b) Plastic bar for laser

Figure 3: Old Setup

2.1.1 The result from the old setup at low intensity of the laser

The occupancy for the central pixel, shown in Figure 4, is almost constant as we expect but the value is around 0.5% which means that the MaPMT has low occupancy compared to the 25% at which we would like to perform the test.

Furthermore, we expect pileup effect to appear in some pixels, because of SIN. In Figure 5 for example, at an edge pixel, the occupancy increases from about 0.5% to 9.5% due to pileup effect while the rate becomes greater.

Some MaPMTs show a larger pileup effect, as shown in Figure 6, for example; there are three rows of pixels with significant pileup.

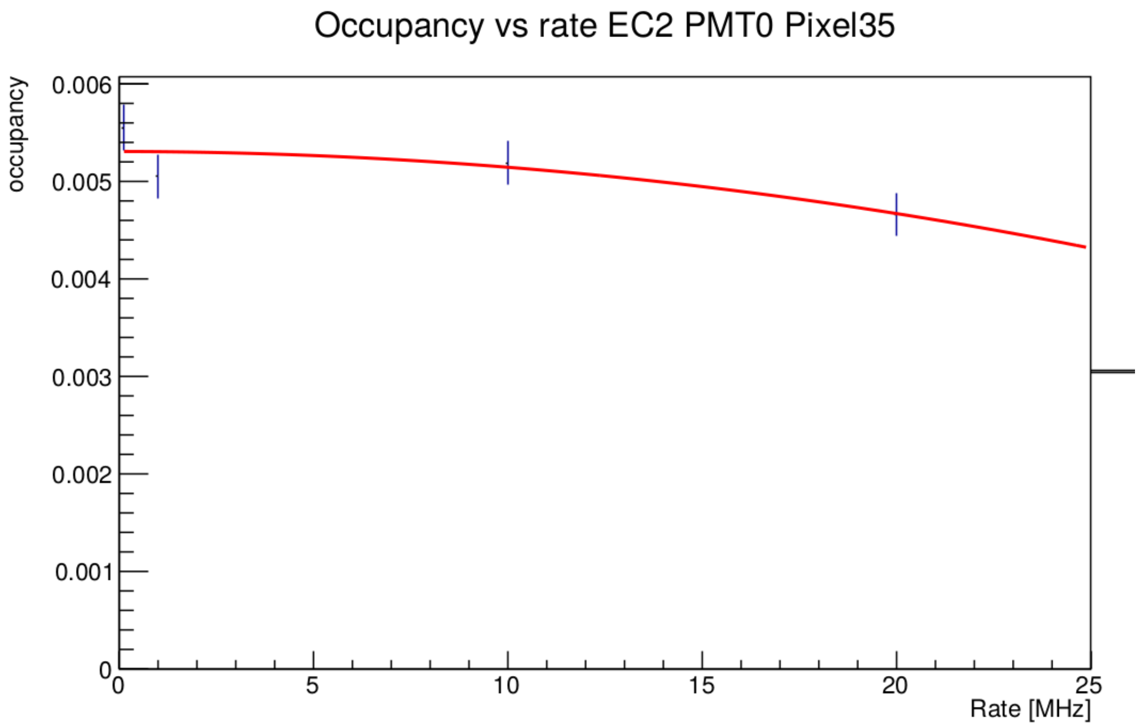


Figure 4: The result at the central pixel of one MaPMT [3]

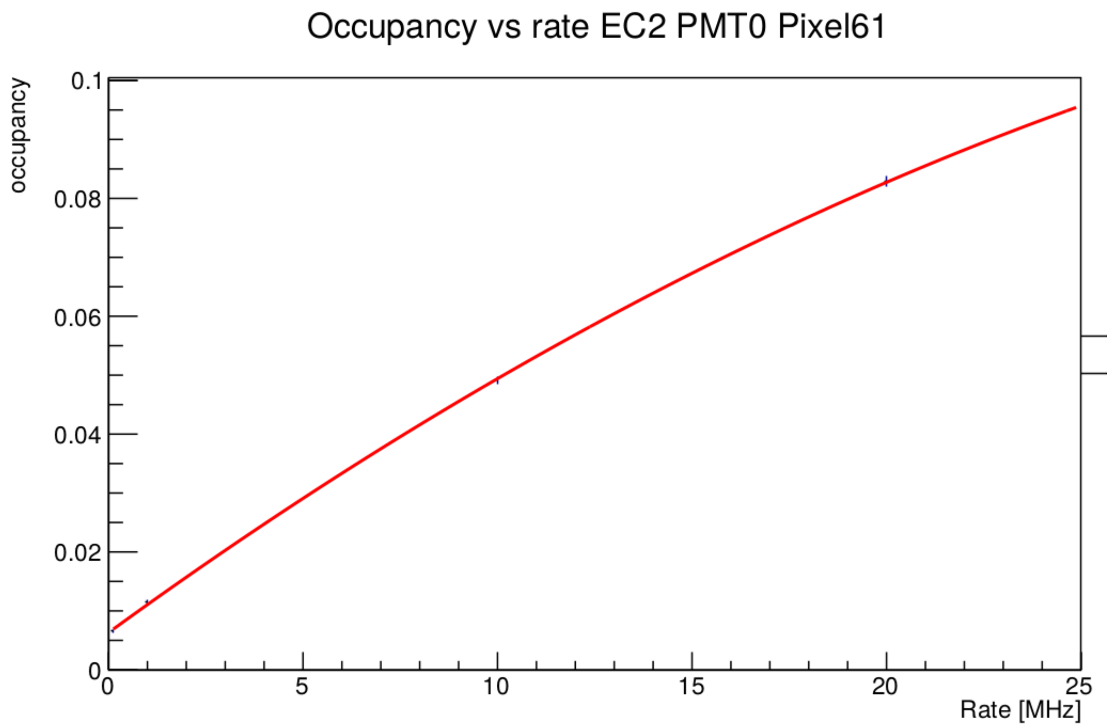


Figure 5: The result at the edge pixel of one MaPMT [3]

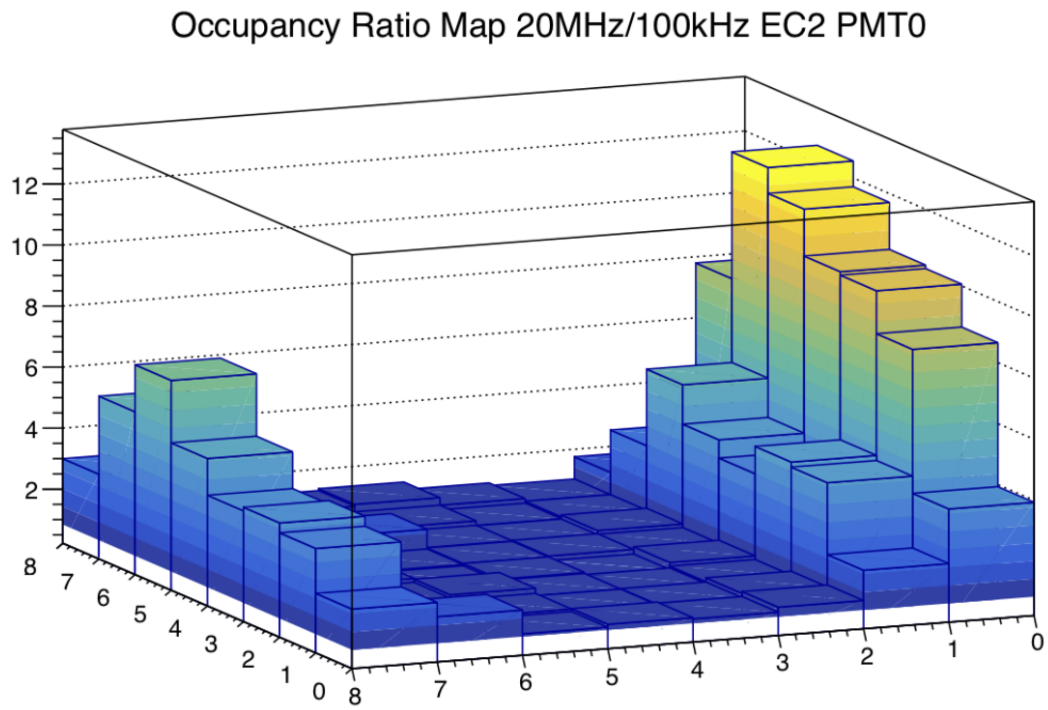


Figure 6: Pileup at some rows of pixel on a bad MaPMT [3]

2.1.2 The result from the old setup at high intensity of the laser

With high intensity, the occupancy of the central pixel goes down while increasing the rate of the illumination (shown in Figure 7). It means that the intensity of the laser decreases. Hence, the laser is not stable at high intensity.

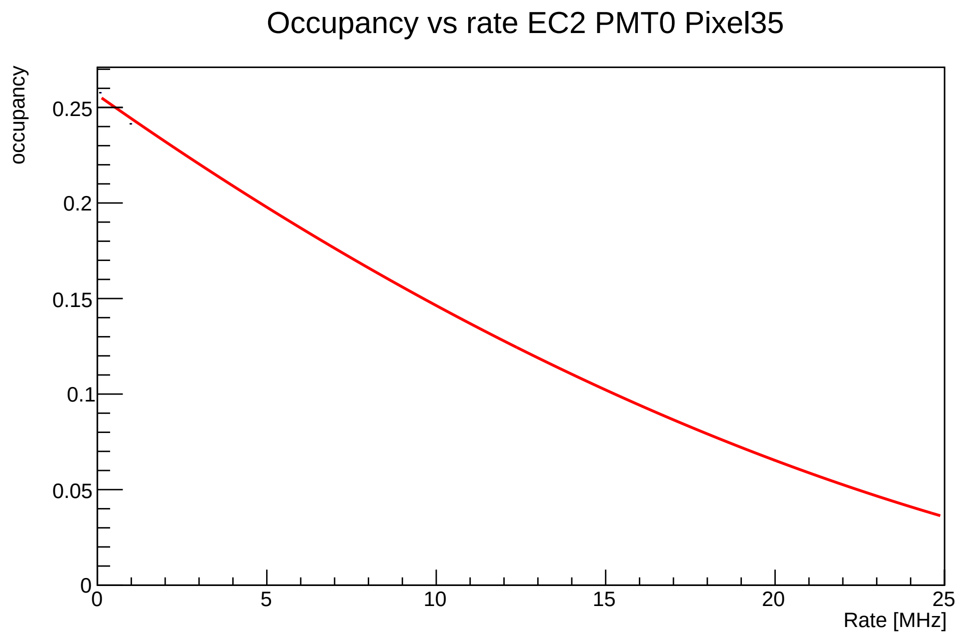
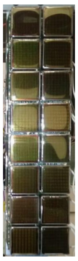


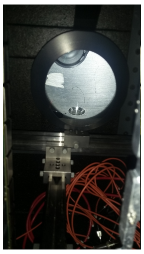
Figure 7: The result at the central pixel of one MaPMT

2.2 New Setup

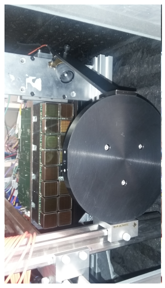
We cannot reach high occupancy at high rate using the old setup. Therefore, we need a new setup that can achieve high rate and high occupancy at lower intensity.



(a) MaPMT column



(b) Parabolic mirror



(c) Laser shines into MaPMTs

Figure 8: New Setup

In the new setup, we use a parabolic mirror instead of the plastic bar, so we can test higher occupancy while keeping lower laser intensity. The laser is more stable when increasing the illumination rate. Figure 9 and 10 show some results from the new setup.

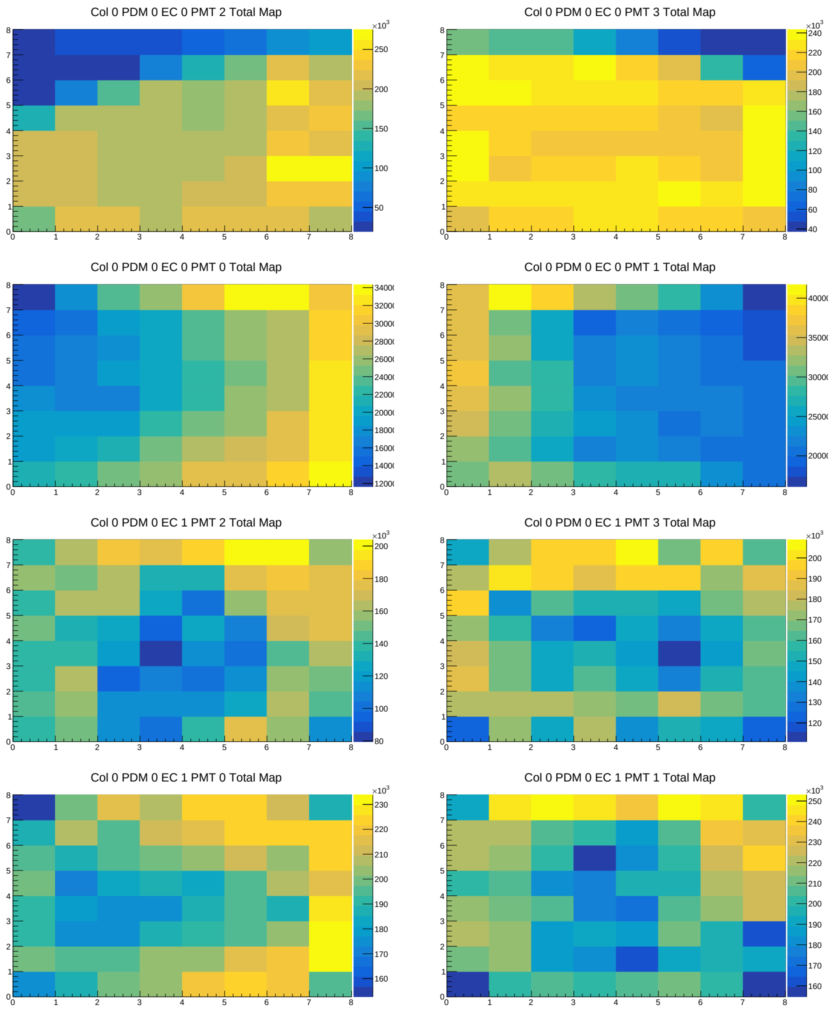


Figure 9: Hit maps of MaPMTs

Figure 9 shows some MaPMTs from the PDM; we can see that the illumination is less uniform. However, it is fine for one Elementary Cell.

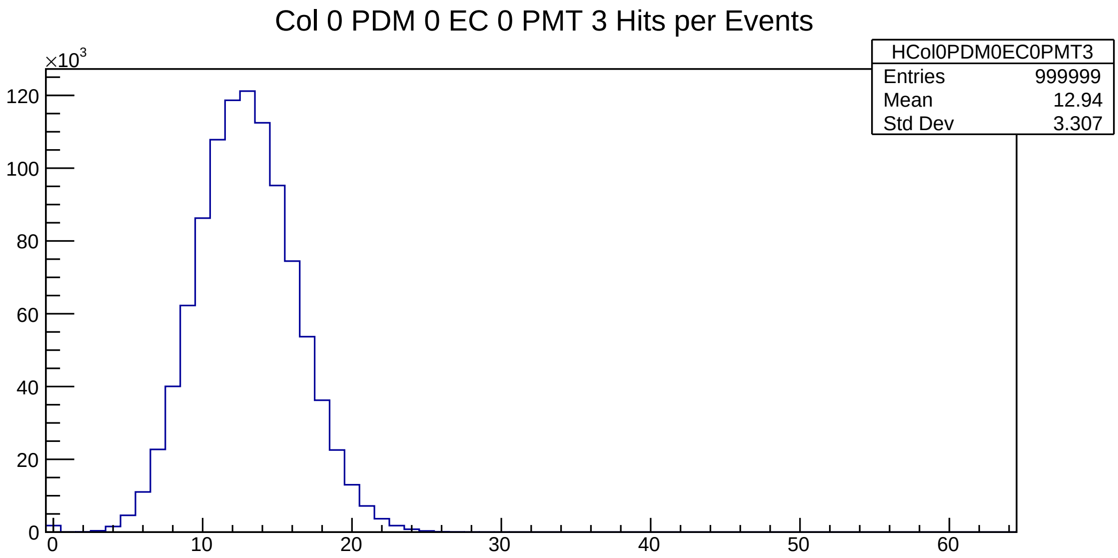


Figure 10: Hits per event distribution of a MaPMT

In Figure 10, the hits per event distribution of a typical MaPMT has an average of 12.94, corresponding to 20% occupancy, close to LHCb RICH Upgrade conditions.

3 On Going

We perform tests at five different laser intensities with four different rates of illumination at different high voltage (HV) values. Table 1 shows the results at 1000 V high voltage. The highest occupancy of the whole test that we can reach is 27%, greater than 25% which we expect in the central region of RICH 1. The occupancy at 900 V is lower than the one at 1000 V (shown in Table 2) and the highest occupancy is 23.6%.

Table 1: The results at HV = 1000 V

The rate (MHz)	Initial parameter $\propto$ Intensity	Highest Occupancy
0.1	7.5	8.0%
1.0	7.5	8.3%
10.0	7.5	8.0%
20.0	7.5	7.9%
0.1	8.0	12.0%
1.0	8.0	12.0%
10.0	8.0	11.7%
20.0	8.0	11.3%
0.1	8.6	21.3%
1.0	8.6	21.2%
10.0	8.6	20.2%
20.0	8.6	19.0%
0.1	8.7	23.9%
1.0	8.7	23.7%
10.0	8.7	22.4%
20.0	8.7	21.0%
0.1	8.8	27.0%
1.0	8.8	26.9%
10.0	8.8	25.2%
20.0	8.8	23.5%

Table 2: The results at HV = 900 V

The rate (MHz)	Initial parameter $\propto$ Intensity	Highest Occupancy
0.1	7.5	7.3%
1.0	7.5	7.2%
10.0	7.5	7.0%
20.0	7.5	6.8%
0.1	8.0	10.6%
1.0	8.0	10.5%
10.0	8.0	10.2%
20.0	8.0	9.7%
0.1	8.6	18.7%
1.0	8.6	18.5%
10.0	8.6	17.6%
20.0	8.6	16.6%
0.1	8.7	21.0%
1.0	8.7	20.8%
10.0	8.7	19.7%
20.0	8.7	18.4%
0.1	8.8	23.6%
1.0	8.8	23.5%
10.0	8.8	22.1%
20.0	8.8	20.5%

4 Conclusion

In my project, we tested the photon detection system at high rate and high occupancy using a pulsed laser with a plastic bar (old setup). However, with the old setup, we cannot reach high occupancy because of the stability of laser at high intensity. Therefore, we prepared a new setup using a parabolic mirror instead of the plastic bar to illuminate MaPMTs. We can achieve high occupancy and high rate close to the LHCb RICH conditions.

The plan for the future is to setup a new triggering system of the laser and test at 40 MHz as well, to perform the same studies at low occupancy on a RICH column.

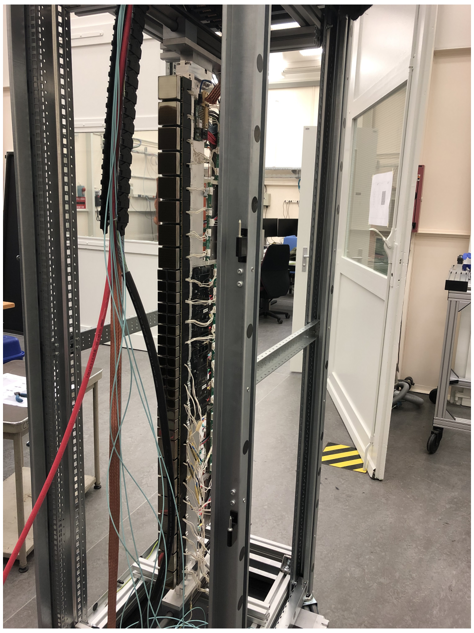


Figure 11: RICH column

Acknowledgements

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References

[1] M. K. Baszczyk et al. "Test of the photon detection system for the LHCb RICH Upgrade in a charged particle beam". In: *JINST* 12.01 (2017), P01012. DOI: 10.1088/1748-0221/12/01/P01012. arXiv: 1610.02879 [physics.ins-det].

[2] M.P. Blago and F. Keizer. "High rate tests of the photon detection system for the LHCb RICH Upgrade". In: *Nucl. Instrum. Methods Phys. Res., A* 876.arXiv:1801.02623 (Jan. 2018). Submitted to Nuclear Instruments and Methods in Physics Research A, 101–103. 3 p. DOI: 10.1016/j.nima.2017.02.014. URL: https://cds.cern.ch/record/2294156.

[3] Antonino Sergi Giovanni Cavallero Silvia Gambetta. *High-rate, SIN, pile-up*. Presentation. LHCb RICH, 2018.

[4] HAMAMATSU PHOTONICS K. K. *Photomultiplier tubes Basics and Applications*. third edition. Japan.

[5] "LHCb PID Upgrade Technical Design Report". In: (2013).