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RICH upgrade: Current status and future perspectives

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Summary. — The LHCb experiment is dedicated to precision measurements of CP violation and rare decays of B hadrons at the Large Hadron Collider (LHC) at CERN (Geneva). The second long shutdown of the LHC is currently scheduled to begin in 2018. During this period the LHCb experiment with all its sub-detectors will be upgraded in order to run at an instantaneous luminosity of $2 \times 10^{33}\,\text{cm}^{-2}\text{s}^{-1}$ and to read out data at a rate of 40 MHz into a flexible software-based trigger. The Ring Imaging CHerenkov (RICH) system will require new photon detectors and modifications of the optics of the upstream detector. Tests of the prototype of the smallest constituent of the new RICH system have been performed during testbeam sessions at the Test Beam Facility SPS North Area (CERN) in Autumn 2014.

1. – The LHCb experiment and its RICH detectors

The LHCb experiment is one of the four big experiments which is taking place at the Large Hadron Collider (LHC) at CERN (Geneva) [1]. The physics studies at LHCb are dedicated to probe New Physics in CP violation and rare decays of b and c quarks.

An excellent particle identification (PID) is fundamental in order to perform this kind of studies. The Ring Imaging Cherenkov (RICH) system of the LHCb experiment is able to identify charged hadrons over a momentum range of 1.5–100 GeV/c [2].

The RICH system is composed by two RICH detectors equipped with Hybrid Photon Detectors (HPD). The HPDs are custom-built photosensors that combine a silicon pixel detector with an integrated readout electronics with a maximum rate of 1 MHz.

At the end of Run II of the LHC the integrated luminosity recorded by the LHCb experiment will be $\sim$8 fb^{-1}.

2. – The LHCb and RICH upgrade

In order to expand the potential for discovery and study of new phenomena, an upgrade of the LHCb experiment is planned in 2018 during the second long shutdown of the LHC [3]. In order to collect 5 fb^{-1} per year, the goals of the upgrade are to run at an instantaneous luminosity of $2 \times 10^{33}\,\text{cm}^{-2}\text{s}^{-1}$, remove trigger limitations and readout the detectors at a maximum rate of 40 MHz.

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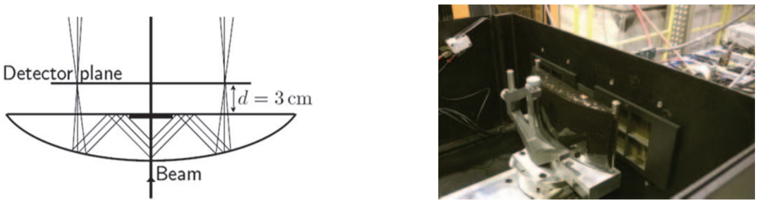

Fig. 1. – The left panel shows a scheme of the concept while the right panel shows a picture of the system.

In order to cope with the high luminosity environment and this new maximum readout rate, the RICH detectors will require new photo-sensors [4]. The requirements of these new photo-sensors are high spatial resolution, single photon detection, negligible dark current and cross-talk rates. Due to its characteristics the baseline photon detector for the upgraded RICH is the MaPMT combined with an external readout electronics featuring low deadtime, low power consumption and radiation tolerance. Moreover significant modifications of the optics and mechanics of the upstream RICH detector are necessary in order to reduce the peak occupancy.

3. – RICH testbeam

After a full characterization of the single components performed in laboratory, the first tests of the full opto-electronics chain have been performed in testbeam sessions at the Test Beam Facility SPS North Area at CERN during Autumn 2014. In order to test the system performances a beam consisting mainly of 10^6–10^7 pions and protons per spill with momentum of $180\,\mathrm{GeV}/c$ has been used. The beam has been directed through a light-tight experimental box containing a borosilicate plano-convex lens and the MaPMTs, together with their DAQ chain, housed in an aluminium structure. The lens had a double role, acting as a radiator in order to produce Cherenkov light and as focusing element. A picture of the system can be found in fig. 1.

4. – Conclusions

Using the data collected, several analysis have been performed in order to learn a lot on the MaPMTs and on the readout chain: threshold scans and cross-talk studies, the fit of the Cherenkov ring, the reconstruction of the Cherenkov angle, the eventual correlation between multiple tracks events and higher number of hits.

Most of the data are in good agreement with the expected values from simulations.

In July 2015 a new testbeam has been performed in order to test several ECs housed in a prototype of the mechanical structure and a new testbeam in Autumn 2015 is foreseen to test a new version of the readout electronics.

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