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Particle identification with the fast COMPASS RICH-1 detector

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A R T I C L E I N F O

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A B S T R A C T

A new photon detection system for the COMPASS RICH-1 detector has been designed and installed. In the central region, the project is based on multi-anode photo-multiplier technology accompanied by charge sensitive, high resolution and dead-time free time digitization. In the outer area, only the readout electronics for the existing photon detectors has been replaced. Details on the detector upgrade and its performance are presented.

1. Introduction

The COmmon Muon and Proton Apparatus for Structure and Spectroscopy (COMPASS) is a fixed-target experiment set up at the M2 beam line of the CERN SPS accelerator complex [1]. It is built as a multi-purpose two stage spectrometer [2], optimized for the investigations of the gluon and quark structure of the nucleon and the spectroscopy of hadrons using the high intensity secondary muon and hadron beams. Good particle identification (PID) at high rates is an important prerequisite for most of the physics program of the experiment. Charged hadron identification up to about 50 GeV/c in a wide angular range of 180 mrad in vertical and 250 mrad in horizontal directions is performed by a Ring Imaging Cherenkov detector (RICH-1).

The RICH-1 detector is operated with C_4F_{10} as radiator gas at atmospheric pressure. The typical path length in the radiator is about 3 m. Image focusing is obtained by two spherical surfaces, formed by hexagonal and pentagonal mirror elements, resulting in a reflective surface of about 20 m^2. Images are collected on two sets of photon detectors, placed above and below the detector acceptance region. Until 2004, eight photon detectors, consisting of multi-wire proportional chambers (MWPC) with segmented CSI

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photo-cathodes, were used to cover an active area of 5.2 m^2. Aiming to withstand increased luminosities and trigger rates, an important upgrade of the RICH-1 photon detection system and its front-end electronics has been accomplished by spring 2006. This upgrade and the performance of present RICH-1 detector are described in the next paragraphs.

2. RICH-1 upgrade

After the upgrade, the photon detection system in RICH-1 uses two different techniques.

In the peripheral region, which accounts for 75% of the active surface, the photon detection is unchanged and MWPC with CSI photo-cathodes are being used. For this region, the front-end electronics, however, has been replaced by a new readout system based on the APV25-S1 chip [3]. The new readout allows for negligible dead-time, essential to operate at higher luminosities and significantly improves on time resolution.

In the central region, which accounts for 25% of the active surface, the level of uncorrelated and correlated background photons is very high and can reach rates up to 1 MHz per single channel. In this region, the MWPCs have been exchanged by multi-anode photo-multiplier tubes (MAPMT) with UV extended glass windows (Hamamatsu R7600-03-M16) coupled to individual lens telescopes (Fig. 1). The purpose of the lens telescope is to focus the Cherenkov photons to the MAPMT photo-cathodes, preserving the position information of the original ring image. The design of the lens telescope has been optimized to maximize the photon acceptance while minimizing the image distortions. The final design of the telescope includes a field lens followed by a concentrator lens, both made from fused silica covered by a single layer MgF_2 to give a surplus of 8.4% detectable photons [4].

The readout system [5] for the MAPMTs is based on the MAD4 preamplifier-discriminator [6] and the F1-TDC chip [7]. The system is designed and set up to exploit the high rate capabilities and the excellent time resolution of the central photon detection array. All sensitive front-end electronics is mounted in a compact way directly to the voltage dividers of the MAPMTs. This reduces significantly the electrical noise pick-up and obtains a very robust setup (Fig. 2).

The MAD4 amplifier-discriminator chip features a small noise level of less than 7 fC, resulting in a *signal-to-noise* ratio better 14 for single photon detection. The analog part has been further upgraded in 2009 with the CMAD chip [8] to allow operation up to rates of 5 MHz per channel.

The F1 time-to-digital converter (TDC) is used for time digitization. The F1 chip is a high resolution and dead-time free TDC, which can be operated at rates of 10 MHz per channel at 100 kHz trigger rates. In our application, the digitization bin width has been set to 108 ps. The time resolution of the entire MAPMT photon detection system, including the photo-multiplier, the analog and digital readout electronics, was determined to be $\sigma = 320$ ps in the final installation. This is negligible compared to the time uncertainty of about 1 ns due to different geometrical path lengths of the Cherenkov photons.

A system, based on ray tracing with photons from LEDs and photon detection by high resolution CCD cameras, has been installed permanently in the RICH-1 vessel for mirror alignment and for continuous online monitoring of the detector performance.

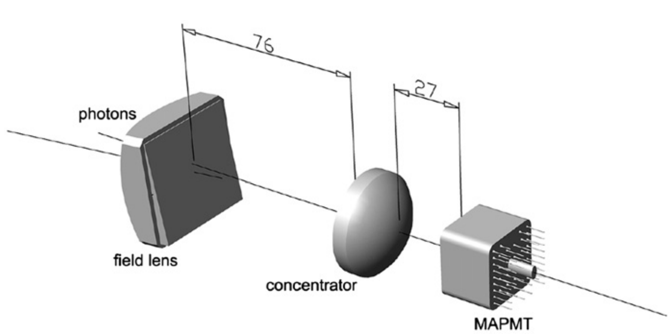

Fig. 1. Artistic view of the lens telescope (distances in mm).

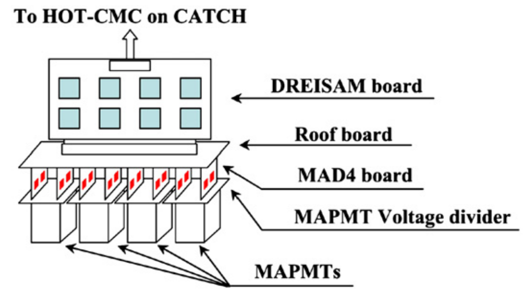

Fig. 2. Scheme of the MAPMT readout system. The MAD4 preamplifier-discriminators are mounted to the MAD4 board, whereas the F1-TDC chips are hosted by the DREISAM board. The roof board is the interface between the analog and the digital part and is used to distribute power and control signals.

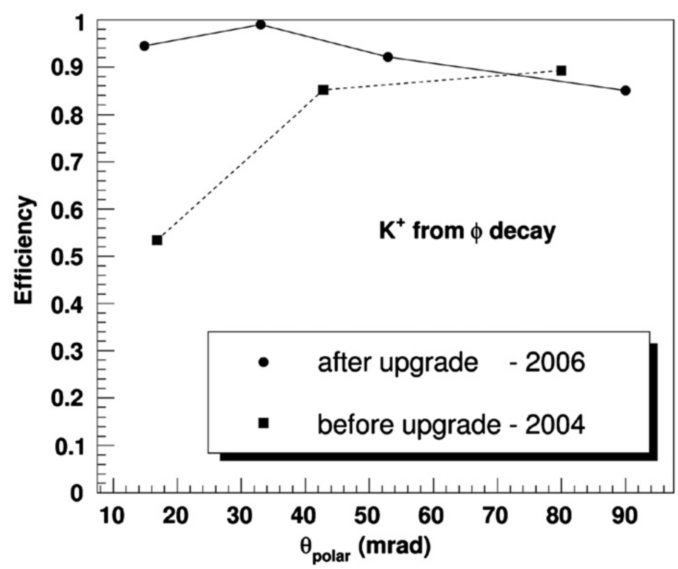

Fig. 3. PID efficiency versus polar angle.

3. System performance

RICH-1 has been fully characterized monitoring in operating conditions the number of detected photons, the angular resolution and the PID efficiency.

The number of photons at saturation in the peripheral region is around 14, unchanged by the upgrade, while it has increased to 56 in the central region. The ratio of signal photons to uncorrelated and correlated background photons in each ring is increased, because the number of clusters from background photons is reduced by 30%, mostly in the central part.

The resolution on the measured Cherenkov angle is evaluated with pions originating from K^0 decays. For single photon information it is about 2 mrad, and for the whole ring image it is less than 0.3 mrad.

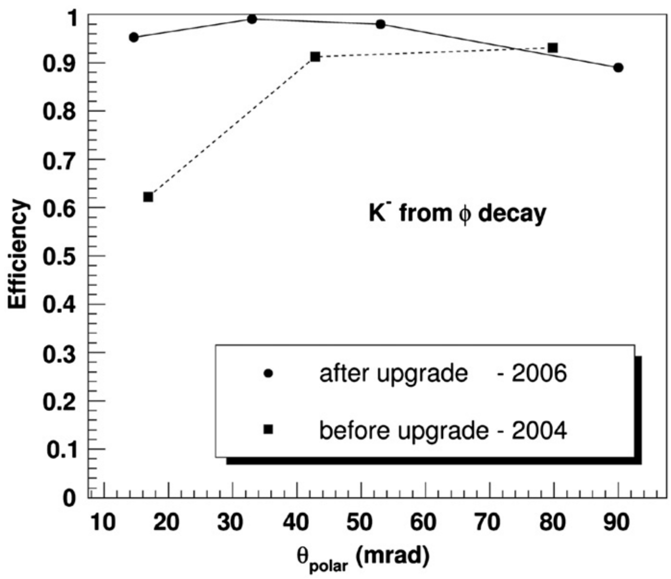

Fig. 4. PID efficiency versus polar angle.

In Figs. 3 and 4, the PID efficiency has been evaluated separately for K^+ and K^- particles originating from the decays of exclusively produced ϕ mesons [9]. This efficiency is found to be well above 90% at all polar angles, whereas it was limited to 60% in certain kinematical regions before the upgrade.

4. Conclusions

We have presented the upgrade of the RICH-1 detector of the COMPASS experiment at CERN. This upgrade became necessary to withstand the high rates anticipated for data taking from 2006 onwards. The upgraded detector and the new electronics entirely fulfill the expected performances and have been operated successfully since the data taking period in 2006.

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References

[1] The COMPASS Collaboration, Proposal, CERN/SPSLC/96-14, SPSLC/P297, 1996.
[2] P. Abbon, et al.COMPASS Collaboration, Nucl. Instr. and Meth. A 577 (2007) 455.
[3] M.J. French, et al., Nucl. Instr. and Meth. A 466 (2001) 359.
[4] P. Abbon, et al., Nucl. Instr. and Meth A, in press, doi:10.1016/j.nima.2010.02.069.
[5] P. Abbon, et al., Nucl. Instr. and Meth. A 587 (2008) 371.
[6] F. Gonnela, M. Pegoraro, CERN-LHCC-2001-034, 2001, p. 204.
[7] H. Fischer, et al., Nucl. Instr. and Meth. A 461 (2001) 507.
[8] O. Cobanoglu, et al., Proceedings of the PRIME 2007, IEEE, Ph.D., 2007, p. 105.
[9] F. Abbon, et al., Nucl. Instr. and Meth. A 595 (2008) 233.