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The fast readout system for the MAPMTs of COMPASS RICH-1

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ABSTRACT

A fast readout system for the upgrade of the COMPASS RICH detector has been developed and successfully used for data taking in 2006 and 2007. The new readout system for the multi-anode PMTs in the central part of the photon detector of the RICH is based on the high-sensitivity MAD4 preamplifier-discriminator and the dead-time free F1-TDC chip characterized by high-resolution. The readout electronics has been designed taking into account the high photon flux in the central part of the detector and the requirement to run at high trigger rates of up to 100 kHz with negligible dead-time. The system is designed as a very compact setup and is mounted directly behind the multi-anode photomultipliers. The data are digitized on the front-end boards and transferred via optical links to the readout system. The readout electronics system is described in detail together with its measured performances.

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1. Introduction

The COMPASS experiment is a fixed target experiment at CERN. Its physics program is focused on the investigation of the internal

structure of the nucleon using muon and hadron beams. The main experimental challenge is the need to cope with high luminosity, resulting in high beam intensities and large trigger rates. The setup of the COMPASS spectrometer is described in Ref. [1].

Charged hadron identification is obtained using a large ring imaging Cherenkov detector, the COMPASS RICH-1 [2]. The RICH detector uses C₄F₁₀ as radiator gas inside a 5 × 6 m² wide and 3 m deep vessel. The produced Cherenkov photons are reflected on a 20 m² mirror wall onto two sets of photon detectors, an upper and a lower one.

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Until 2004, the photon detectors used were eight multi-wire proportional chambers (MWPCs) with cesium iodide (CsI) photocathodes covering an active surface of about 5.2 m². Limitations to the RICH-1 performance at high rates were related to the photon detector nature. Due to the presence of CsI photocathodes, the MWPCs could not be operated at high gain, thus requiring a long integration time of about 0.5 μ s of the front-end electronics, a modified version of the GASSIPLEX chip.

This limited the performance of the photon detection in the central part of the detector in two ways: In the COMPASS experimental environment a large flux of halo muons accounts for about 10–20% of the total beam flux. At high beam intensities of up to 10⁸ muons per second, the halo muons create a considerable background of Cherenkov photons. These photons create an uncorrelated background on the photon detectors, which reduces the particle identification efficiency and purity, especially for particles in the very forward direction. Since also the base-line restoration of the GASSIPLEX output takes about 3.5 μ s, a large dead-time is created at high trigger rates.

2. RICH-1 upgrade

Therefore a new and fast photon detection system was developed and installed between autumn 2004 and spring 2006 in order to be able to distinguish by time information between photons from physics events and background, and to be able to run at higher trigger rates of up to 100 kHz. The upgrade of the COMPASS RICH-1 is two-fold: In the central part of the photon detectors ($\frac{1}{4}$ of the surface), the MWPCs have been replaced by 576 Multi-Anode Photomultipliers (MAPMTs) [3] with new fast readout electronics, which will be discussed in this contribution. In the outer part, the existing MWPCs have been equipped with a faster readout electronics based on the APV preamplifier with sampling ADCs [4].

3. Fast readout electronics for the MAPMTs

The MAPMTs used for a fast photon detection in the central part of the photon detectors are 16-channel MAPMTs H7600-03-M16 from Hamamatsu [5]. The readout system [6] for the MAPMTs is based on the MAD4 preamplifier-discriminator [7] and the dead-time free F1-TDC characterized by a very good time resolution [8]. The electronics system is mounted in a very compact setup as close as possible to the photomultipliers (Fig. 1). This minimizes the electrical noise and takes into account the limited space in front of the RICH detector.

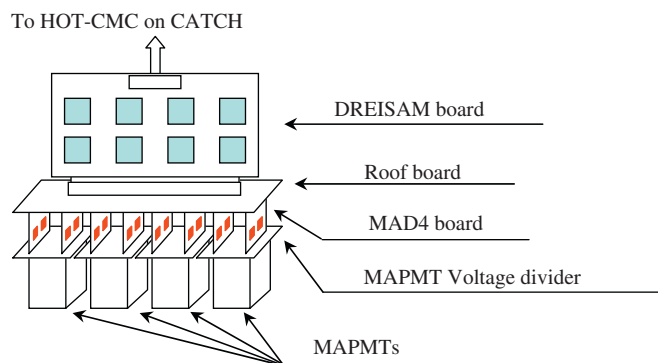


Fig. 1. Scheme of the readout system.

4. Analogue front-end electronics

The analogue front-end board amplifies the signal from the photomultiplier, discriminates it and sends it as a differential signal to the digital board. Each front-end card is equipped with two MAD4 chips with four channels each. The MAD4 chip features a charge-sensitive preamplifier with fixed gain (3.35 mV/fC), a shaper and a discriminator with digitally adjustable threshold. To match the amplitude of the MAPMT signal to the input stage of the MAD4 chip, a resistive voltage divider attenuates the signal by a factor of 2.4. The binning of the threshold setting was chosen to be 0.5 fC/digit. The measured noise level is < 7 fC (Fig. 2), while typical MAPMT signals have amplitudes between 100 and 1000 fC (Fig. 3) [5]. The signal peak at lower amplitudes originates from photoelectrons which are missing one amplification stage in the MAPMT. Since the signal fraction of this peak is significant, a

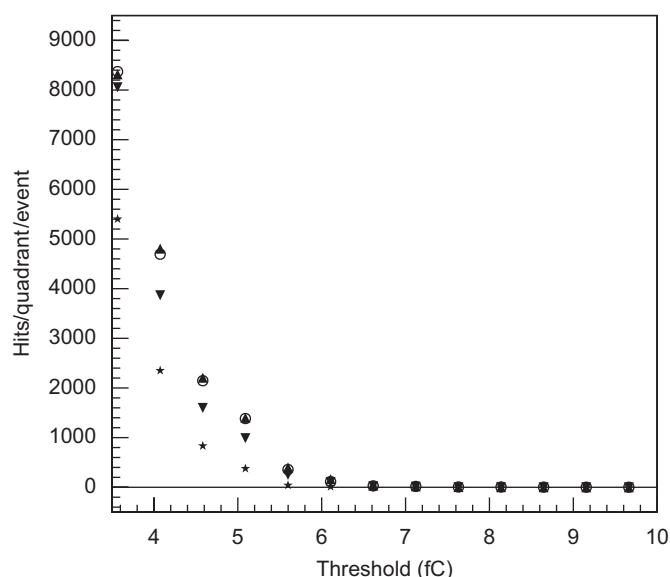


Fig. 2. Noise rate as a function of the threshold setting for one quadrant of the detector with 144 MAPMTs.

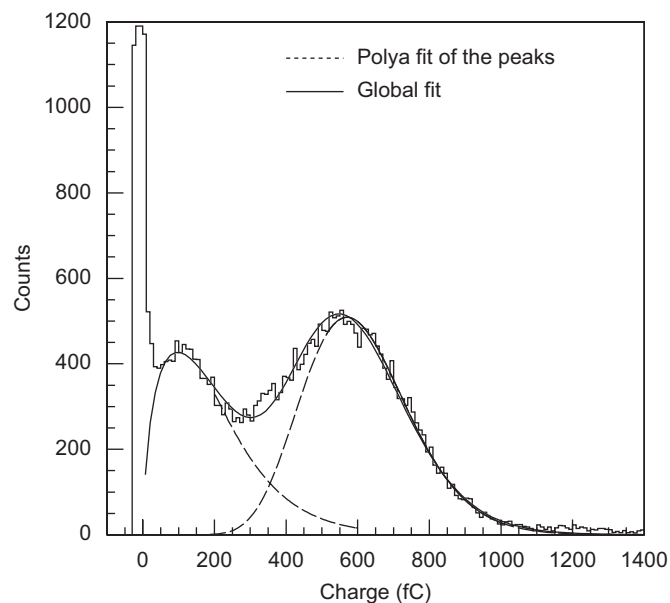


Fig. 3. Amplitude spectrum of the MAPMT for single photons at 900 V operating voltage, measured with an ADC.

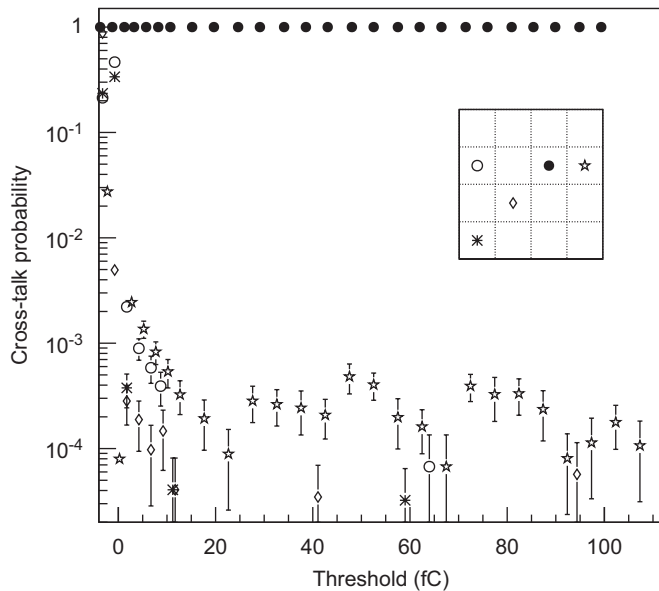


Fig. 4. Cross-talk level as a function of the threshold setting, obtained by illuminating in single photon mode a single pixel (black dot) with a focused laser beam.

threshold setting below this peak is essential for achieving high efficiency. A typical threshold setting of about 40 fC is chosen. For this threshold, the excellent signal-to-noise ratio allows to obtain a very high efficiency, preserving a negligible level of cross-talk (Fig. 4).

The MAD4 chip can operate at input rates up to 1 MHz per channel. An upgraded version of the MAD4 chip is under development, capable of input rates up to 5 MHz, the CMAD.

5. Digital front-end electronics

The digital part of the new RICH-1 front-end electronics consists of the DREISAM front-end board, which is equipped with eight F1-TDC chips to read out four MAPMTs (Fig. 5). The board was designed in a very compact way. The data are digitized on the DREISAM board and are sent out via optical links to the HOT-CMC board, a small mezzanine card on the CATCH, the common readout-driver board of the COMPASS experiment. The F1 chips on the digital boards have a digitization bin-width of 108.3 ps and can operate at input data rates of up to 10 MHz per channel. The readout of the data can be performed at trigger rates up to 100 kHz.

6. System performances

The time resolution of the complete system consisting of MAPMT, MAD4 board and DREISAM board has been determined by illuminating the MAPMT photocathode with optical pulses of width less than 50 ps from a pulsed laser system. The laser intensity was attenuated by optical filters to obtain single photon signals on the MAPMT. The time resolution of the complete system was determined to be $\sigma = 320$ ps.

The upgraded photon detection system of the COMPASS RICH-1 has been stably operated during the beam-time in 2006 and 2007. In Fig. 6 the time spectrum of the detected Cherenkov photons is shown. The central peak of the physics signal has a standard deviation of about 1 ns. The background below the peak

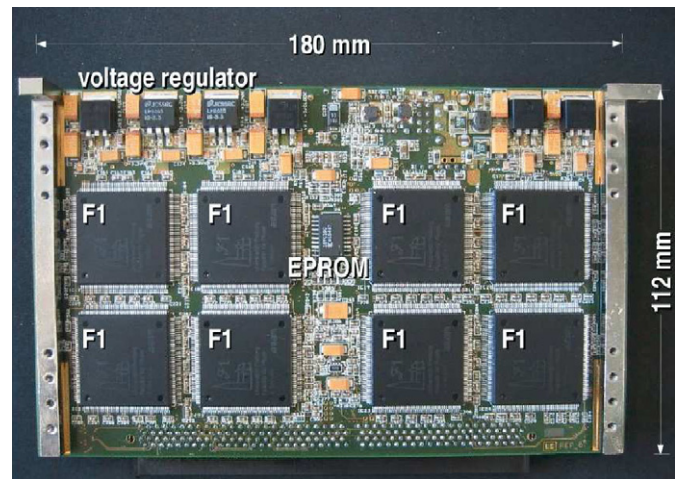


Fig. 5. Front side of the DREISAM card with eight F1-TDC chips.

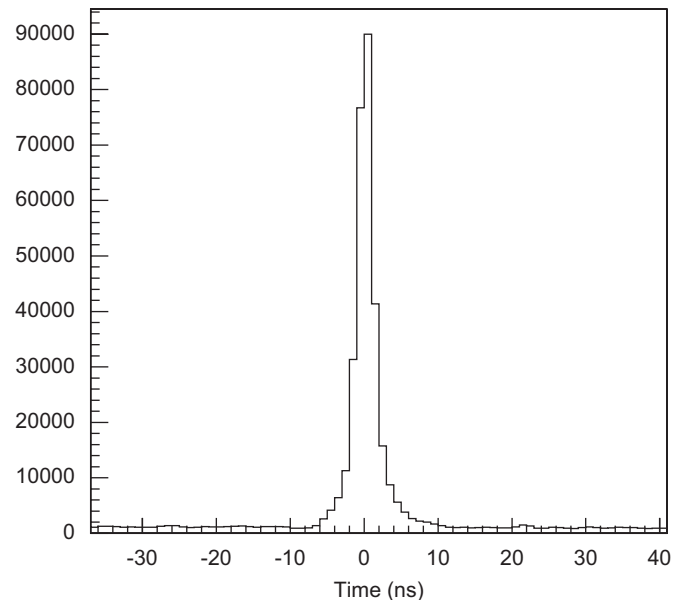


Fig. 6. Physics signal and background from 2006 data.

is created by uncorrelated Cherenkov photons mainly from muon-beam halo particles. The observed width of the central peak is determined by the different geometrical path length of the photons in a Cherenkov ring traveling from the mirrors to the photon detection system. This has been confirmed by a Monte Carlo simulation of the detector setup. By applying a suitable offline time-cut of ± 5 ns around the signal peak, an excellent background suppression is achieved. Cherenkov rings from a physics event are shown in Fig. 7.

7. Conclusions

A fast front-end electronics for the readout of the MAPMTs of the COMPASS RICH-1 was designed and successfully installed in 2006. The new electronics has an excellent time resolution for Cherenkov photons of less than 1 ns and thus allows a very good background suppression of photons originating from halo muons. Its high hit capability allows a dead-time free data taking at

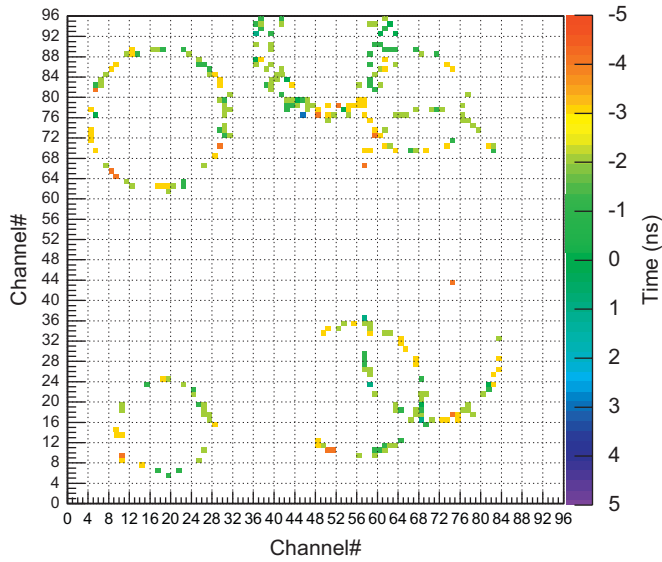


Fig. 7. Online display of Cherenkov rings from a physics event.

trigger rates of up to 100 kHz. The upgraded detector and the new electronics entirely fulfill the expected performances and have been operated successfully since the data taking period in 2006.

With the upgraded detector, the number of detected Cherenkov photons for saturated rings has increased from 14 before to 56 after the upgrade. The resolution of the Cherenkov angle has improved from 0.6 to 0.3 mrad [9].

Acknowledgments

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