Fast photon-detection for COMPASS RICH-1

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A fast photon-detection system for the detector RICH-1 of the COMPASS Experiment at CERN SPS is in operation since the 2006 run. It is based on the use of Multi-Anode Photomultipliers (MAPMTs) coupled to individual fused silica lens telescopes and fast read-out electronics. It has been designed taking into account the high photon flux in the central region of the detector and the high rate requirements of the COMPASS Experiment. We present the photon-detection design and construction, together with its characterization and measured performances based on the data collected in 2006.

Keywords: particle identification; RICH; COMPASS; multi-anode photomultiplier.

1. Introduction

COMPASS is high luminosity experiment,[1] at CERN SPS, dedicated to hadron physics, with an extend research program both dedicated to the nucleon spin structure, collecting data with the muon beam, and to the hadron spectroscopy, using hadron beams. For both scientific programs, as for many other particle and nuclear experiments, a very efficient particle identification (PID) is mandatory. In the COMPASS spectrometer hadronic particle identification in the multi-decade GeV/c range is performed by RICH-1,[2] a large size RICH counter in operation since 2001.
During years 2001-2004 RICH-1 was fully instrumented with Multi-Wires Proportional Chambers (MWPCs) equipped with CsI photocathodes for single photon detection, operated at low gain, and thus read-out by long integration time amplificators, as imposed by the presence of CsI photocathodes. This results in a detection system with long memory, not adequate for extremely high rates. To overcome these limitations and to cope with the higher trigger rates, of up to 100 KHz, foreseen by the COMPASS experiment from 2006 on, an ambitious upgrade project has been developed and implemented during the SPS shut down period, between Autumn 2004 and Spring 2006. In particular, the central detection region, corresponding to 25% of the active surface, has been equipped with the new fast photon-detection system based on MAPMTs, while in the peripheral region the existing MWPCs with CsI photocathodes are unchanged, but read-out by a new electronic system based on APV preamplifiers and flash ADC chips.[3]
We focus here on the fast photon-detection system, presenting the detector design and construction, as well as its characterization and performances based on the 2006 data.

2. General description of the photon-detection system

Multi-anode photo-multiplier tubes (MAPMTs) by Hamamatsu, type R7600-03-M16, with 16 anode channels, have been chosen to detect single photons at high rates: they have bialkali photocathodes with 18x18 mm^2 active surface and UV extended glass window, to enlarge the range of the detectable Cherenkov light spectrum (200-700 nm). MAPMTs are coupled to individual telescopes of two lenses in order to increase the geometrical acceptance; image distortion is avoided by an accurate telescope design; lenses are made of fused silica to match the wavelength range of the PMT. A custom voltage-divider compact circuit, which also provides connections between MAPMT anodes and the read-out chain, has been realised; it is based on the standard circuit[4] proposed by Hamamatsu, which, as proved by laboratory test, ensures high efficiency in single photo-electron detection also at high rate: in fact no gain reduction has been observed up to rates larger than 5 MHz per anode.

3. The read-out electronics

The whole electronics system is arranged in a very compact setup, free from cable connections to minimise the electrical noise and to take into account the limited space in front of the RICH-1 detector. The small analog boards, each populated with two MAD4 preamplifier-discriminator chips,[5] are directly linked via a connector to the voltage divider boards. A deck board, the Roof board, provides services to eight MAD4 boards: power, threshold settings and input/output data transfer from and to the digital board; it also acts as a mechanical fixation of the other elements of the read-out system. The digital data from the Digital RICH ElectronIc Sampling (DREISAM) boards are transferred via optical links to the HOT-CMC receiver boards, explicitly developed for this project, mounted on the common read-out driver of the COMPASS experiment: the COMPASS Accumulate, Transfer and Control Hardware (CATCH).[6]

The main task of the front-end electronics is to amplify the signals from the MAPMTs, to discriminate them and send the differential LVDS signals to the digital board. Low noise level and good efficiency in single photo-electron detection are required. In Fig. 1 typical threshold curves for three

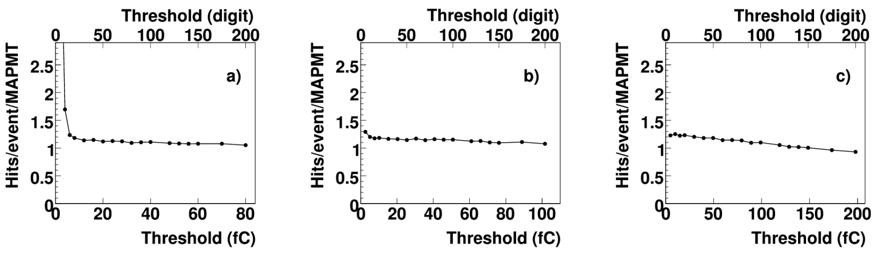

Fig. 1. Threshold curves for three different DAC resolutions: a) 0.40 fC/digit; b) 0.50 fC/digit; c) 0.99 fC/digit; Signals are generated by single photo-electrons

different DAC resolutions are shown. In the second plot, corresponding to the currently used DAC resolution of 0.5 fC/digit, there is a wide range of threshold settings, outside the noise and crosstalk region, and with negligible photo-electron losses. A small electronic noise, in the range of 5-7 fC, has been measured in laboratory; it has to be compared with typical photo-electron signals of 500 fC.
The DREISAM board hosts eight F1 TDC chips[7] for the read-out of four MAPMTs. The F1-TDC is a high-resolution dead-time free TDC chip, that can provide time measurement with different resolution modes: normal, high and latch mode. For our application a normal resolution mode with a digitisation bin width of 108.7 ps has been chosen. In the selected mode the F1 chip can operate at input data rates of up to 10 MHz per channel and trigger rates of up to 100 kHz. The time resolution of the complete readout-chain, including MAPMT, has been measured in laboratory to be about 290 ps.[8]

4. Performances in the real environment

The new fast photo-detection system has been successfully commissioned at the beginning of the 2006 data taking. In this section we present its performances and preliminary characterization based on the 2006 data.
In Fig. 2, left, the time spectrum obtained during the data taking for a

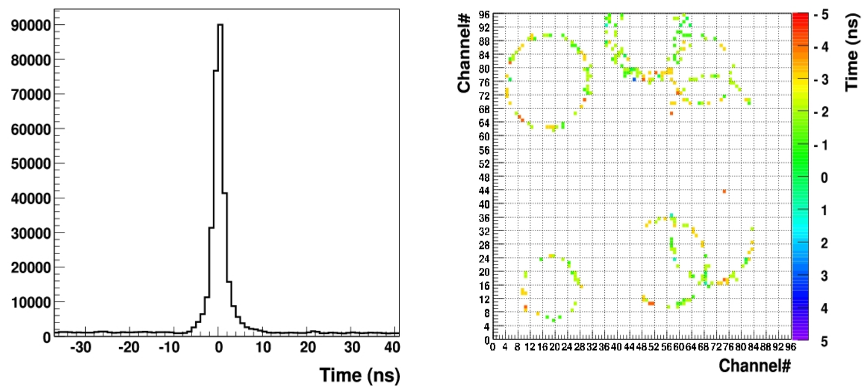

Fig. 2. Left: Physics signal and background, in real environment; Right: Hadron Cherenkov rings from the online single event display.

whole quarter of the MAPMT detector system is shown. The visible peak is due to Cherenkov photons generated in the radiator gas by particles scattered in the triggered physics event. The standard deviation of about 1 ns has been confirmed in a Monte Carlo simulation and it is due to the different geometrical path lengths of the photons. The background below the peak is determined by uncorrelated Cherenkov photons mainly generated by beam halo muons. Thanks to the very good time resolution of the whole read-out system, an excellent background suppression can be obtained, applying an offline cut of a few ns around the signal peak. The excellent time resolution can also benefit to the correct assignment of hits to rings, as it can be nicely seen in the online event display shown in Fig. 2, right, where multiple hadron Cherenkov rings detected in a single physics event are shown. It is possible to appreciate a time resolution of the order of 1 ns within a single Cherenkov ring. The average number of detected photons per ring at saturation is about 56 and the angle resolution obtained is about 0.3 mrad.

5. Conclusions

A fast photon-detection system has been designed and successfully implemented, as a part of a global upgrade project of the COMPASS RICH-1, between November 2004 and May 2006, during the SPS shut down period. The system has been operated during 2006 data taking period: its performances entirely fulfill the expectations.

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