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Fast photon detection for COMPASS RICH-1

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Abstract

A fast photon detection system has been built and assembled for the upgrade of COMPASS RICH-1. The system is based on multianode photomultipliers coupled to fused silica lenses to collect the light from a larger surface and to guide it to the photocathode, preserving the position information. The emphasis is on the fast response and high rate capability of the detectors and the associated electronics. The photon detection system is now ready and it will be employed in the 2006 COMPASS data taking. We report about the system design and construction.

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Keywords: COMPASS; RICH; Multianode photomultiplier tubes; UV lenses; Photon detection

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1. Introduction

The COMPASS experiment [1,2] at CERN SPS is a high luminosity experiment dedicated to hadron physics with a rich research programme, including the study of the nucleon spin structure and charm spectroscopy. The experiment requires hadron identification in the multi-10 GeV/c range, presently performed by RICH-1 [3], a large size RICH with gas radiator in operation at COMPASS since 2001. The basic parameters characterising the detector performances are the mean number of detected photons: 14 per particle at saturation, the single photon resolution on the measured Cherenkov angle: 1.2 mrad at saturation, the global resolution on the measured Cherenkov angle: 0.6 mrad at saturation, a PID efficiency larger than 95% for Cherenkov angles larger than 30 mrad and a 2-sigma $\pi-K$ separation at 43 GeV/c. The single photon and global resolution do not scale, due to the large uncorrelated background present in the COMPASS environment. Moreover, in future experiment operation, increased beam intensity and trigger rates are foreseen. To overcome these challenges, an upgrade of the RICH-1 photon detection system has been implemented. The central photon detection area (25% of the surface) is instrumented with a new fast detection system based on MAPMTs [4], discussed in this paper. In the peripheral regions, the photon detectors, namely MWPCs with CsI photocathode, are unchanged; they are read out by a new system [5], based on the chip APV, with negligible dead-time and increased time resolution.

2. The project and the constructions

The project is based on the use of 576 MAPMTs, Hamammatsu R7600-03-M16, 16 channels, UV extended window glass, coupled to individual fused silica telescopes, read out via sensitive FE chips, MAD4 [6], originally designed for gaseous detectors, and high resolution F1 TDCs [7] (see Fig. 1 for a sketch of the project principle).

The single photoelectron detection efficiency of the MAPMT coupled to the MAD4 chip is ~95% [4]. No MAPMT gain reduction is observed up to single photoelectron rate of at least 5 MHz per channel. Six hundred and twelve MAPMTs have been submitted to a complete quality control protocol: a 2 h procedure including visual inspection, measurements of dark current and measurements of gain at five different applied voltages. The most critical parameter is the dark current, causing a rejection rate in the order of 1–2%.

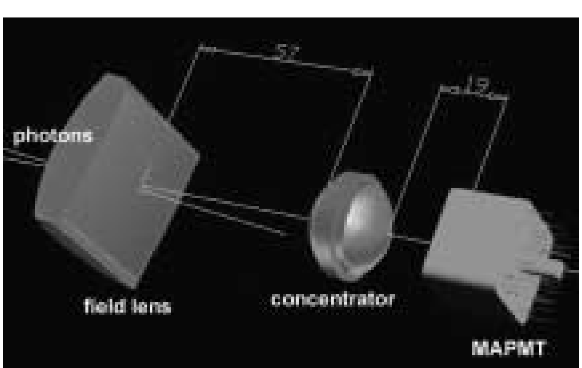
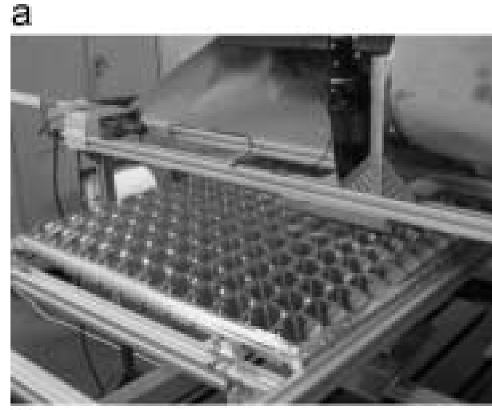


Fig. 1. Optical arrangement of the MAPMT and the fused silica lens telescope.

The fused silica lens telescope has been designed minimising the image distortion and optimising the angular acceptance and the manufacturing parameters. The resulting telescopes are formed by two lenses, are 11.5 cm long and have an angular acceptance of $\pm 9.5^\circ$. The spot size rms is ~1 mm, taking into account the chromatic effects and the angular acceptance. Each lens and each complete telescope has been controlled employing the Hartmann method by a custom setup and analysis code (see Fig. 2(a)). The image displacement introduced by optics imperfections is below 50 μm for 70% of the telescopes, below 100 μm for 20% and below 150 μm for the remaining 10%.

The front-end chip MAD4, essential for good efficiency, is characterised also by small noise level (5−7 fC, compared to a typical mean signal at FE input of 500 fC) and can operate up to ~1 MHz per cannel. An upgraded version of the chip, CMAD, in CMOS technology, designed to match the specific features of MAPMT read-out, will be available in 2007: it will guarantee full efficiency up to 5 MHz per channel input rates. The digital cards housing the F1 TDCs

a



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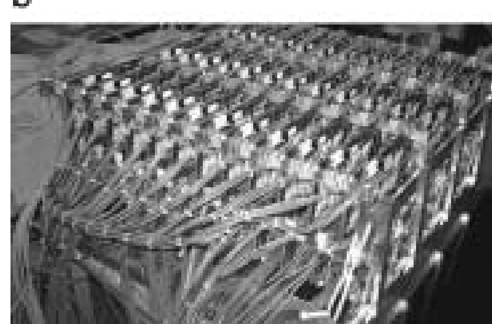

Fig. 2. Fast photon detection system: (a) a panel of field lenses during the control of the optical alignment by Hartmann test; (b) a complete panel of 144 MAPMTs equipped with the read-out electronics.

can stably operate up to 10 MHz per channel input rate and 100 kHz trigger rate. The 120 ps time resolution guarantees negligible background level from uncorrelated physical events.

The new detection system will have an effective space resolution of 5 mm, a mean number of detected photons of 40 per particle at saturation, a single photon resolution on the measured Cherenkov angle of 2.4 mrad at saturation, a global resolution on the measured Cherenkov angle of 0.4 mrad at saturation. 2-sigma $\pi-K$ separation is expected at 50 GeV/c and efficient particle identification will be possible for Cherenkov angles larger than 20 mrad. The project was fully designed and implemented (see Fig. 2b) in the period November 2005–May 2006 and will contribute to the 2006 COMPASS data taking.

3. Conclusions

A fast photon detection system for the upgrade of COMPASS RICH-1 has been designed and implemented on the time scale of one year and a half and it is ready for the COMPASS 2006 data taking. It will enlarge RICH-1 PID range both at high momenta and near to the threshold.

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