Fast photon detection for COMPASS RICH-1

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The new photon detection system for COMPASS RICH-1 has been designed to cope with the demanding requests of operation at high beam intensity and at high trigger rates. The detection technique in the central region of RICH-1 has been changed with a system based on multianode photomultipliers coupled to individual fused silica lens telescopes and to a fast, almost dead time free readout system based on the MAD-4 amplifier-discriminator and the F1 TDC-chip.

The new photon detection system design and construction are described, as well as its first response in the experiment.

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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. It includes the study of the nucleon spin structure with measurements of $\frac{\Delta G}{G}$, of the polarised flavour separated quark density distributions and of the nucleon spin transverse function and charm spectroscopy. The experiment requires hadronic identification in the multi-10 GeV/c range, up to now performed by RICH-1 [3], a large size RICH with gas radiator in operation at COMPASS since 2001 in its original version.

There are three major components forming RICH-1. The photon detection system based on 8 Multi Wire Proportional Chambers (MWPC) with CsI photocathode and with a total surface of 5.3 m^2. They have good quantum efficiency in the far ultraviolet region (below 200 nm). The chamber volume is closed by fused silica plates with 50% photon transmission at 165 nm. Each photocathode is segmented in 8×8 mm^2 pads. The second element of RICH-1 is the mirror wall consistent in 116 pentagonal and hexagonal pieces that form two spherical surfaces with a reflectance better than 80% in the ultraviolet region of interest (165-200 nm). The last fundamental component is the radiator gas and the radiator gas system. C_4F_{10} has been chosen as radiator material for its low chromaticity and its transparency in the deep UV domain. The gas system ensures the continuous gas circulation in a closed loop. The gas is constantly filtered for optimal transparency, which is monitored with a dedicated set-up for UV light transmission measurement.

The basic parameters characterising the detector performances are the mean number of detected photons: 14 per ionising particle at saturation, the single photon resolution of the measured Cherenkov angle: 1.2 mrad at saturation, the global resolution of the measured Cherenkov angle: 0.6 mrad at saturation, a Particle IDentification (PID) efficiency larger than 95% for Cherenkov angles larger than 30 mrad and a 2σ π-K separation value 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 (presently 40 MHz and expected to increase up to 100 MHz) and trigger rates (presently 20 kHz, goal: 100 kHz) 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 Multi Anode Photo Multiplier Tubes (MAPMT) [4], discussed in this paper. In the peripheral regions, the photon detectors are unchanged; they are read-out by a new system [5], based on the chip APV [6], with negligible dead-time and a time resolution improved by one order of magnitude.

2 The photon detection system for the RICH-1 upgrade

The project is based on the use of 576 MAPMTs, Hamamatsu R7600-03-M16, 16 channels, with UV extended glass window (see Fig. 1), coupled to individual fused silica lens telescopes (see Fig. 2). 612 MAPMTs have been submitted to a complete quality control protocol: a two-hour procedure including visual inspection, measurements of the dark current and measurements of the gain at 5 different applied voltages. The most critical parameter is the dark current level, which has caused a rejection rate at 1-2% level. The telescope allows enlarging the effective active surface by a factor seven. The dead zones are almost completely eliminated (the remaining dead surfaces are only 2%). The system cost is reduced by limiting the number of MAPMTs required. The telescope is designed so to have large angular acceptance ($\pm$ 9.5^0) and to minimise the image distortion [7].

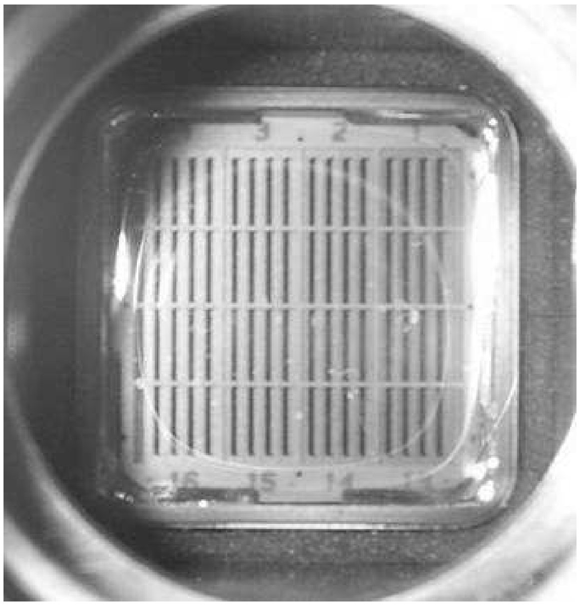

Fig. 1. Frontal view of the MAPMT; the 16 pixels (4 $\times$ 4 mm^2) are clearly visible.

The use of UV extended glass for the MAPMT windows allowing photon detection in the spectral range 200-600 nm, and fused silica lenses allows incrementing the number of detected photons, in particular collecting and converting photons with wavelengths in the range between 300 and 200 nm (see Fig. 3). The MAPMT is housed in a soft iron shielding box (see Fig. 4) to ensure the correct MAPMT behaviour in the experimental environment: the magnetic fringe field due to the first analysing magnet of the COMPASS spectrometer located upstream of RICH-1, is up to 200 G in the PMT region.

The MAPMT signals are read-out employing a sensitive FE chip, the 4-channel amplifier-discriminator MAD4 [8], originally designed for gaseous detectors, and a high resolution F1 TDC [9] (see Fig.5). Two MAD4 are mounted on a MAD Board and thus 2 boards are needed to read-out a 16-channel MAPMT. A Roof Board distributes the power to 8 MAD Board, controls the MAD4 threshold settings and

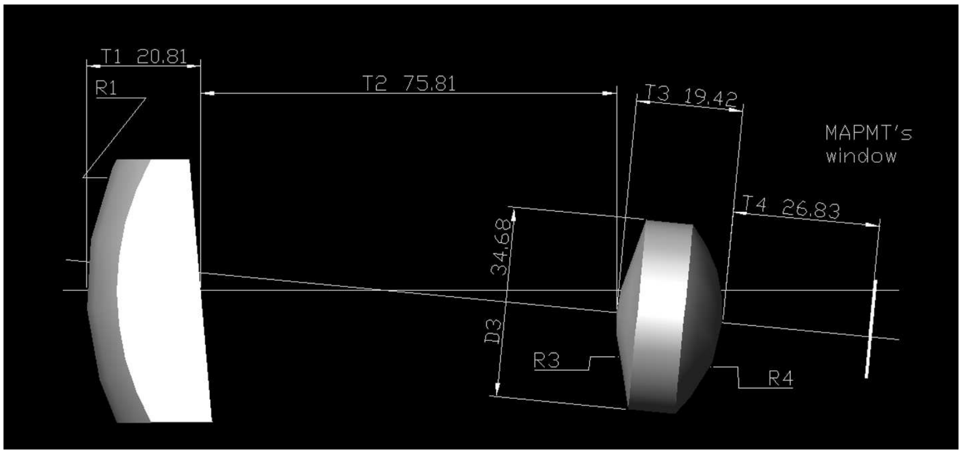

Fig. 2. The principle of the optical arrangement used for the photon detection system: the MAPMT is coupled to a telescope of fused silica lenses.

convoy the data to the DREISAM boards housing the TDC chips. The reduced data are transferred from the DREISAM board to the COMPASS data acquisition system via an optical link. All the read-out system components are shown in Fig. 5. A more complete view of the new RICH-1 photodetection system is presented in Fig. 6.

The efficiency of single photoelectron detection of the MAPMT coupled to the MAD4 chip is ~95% and the residual channel cross-talk is negligible. [4]. Due to the low noise characteristics of the MAD4 chip and the accurate coupling between the MAPMT anodes and the front-end chip, the noise level is reduced and the threshold setting for high efficiency and good cross-talk rejection is non critical.

Laboratory tests show that there is no MAPMT gain reduction at single photoelectron rate as high as 5 MHz per channel.

The front-end chip MAD4 can operate up to ~1 MHz per channel. An upgraded version of the chip, CMAD, in CMOS technology, designed to match the specific features of the 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 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 has an effective pixel size of 12×12 mm^2, a mean number of detected photons of more than 60 per particle at saturation and a resolution on the measured Cherenkov angle better 0.4 mrad at saturation. The $2\sigma\pi$-K separation limit is expected above 50 GeV/c and efficient particle identification will be possible for Cherenkov angles larger than 20 mrad.

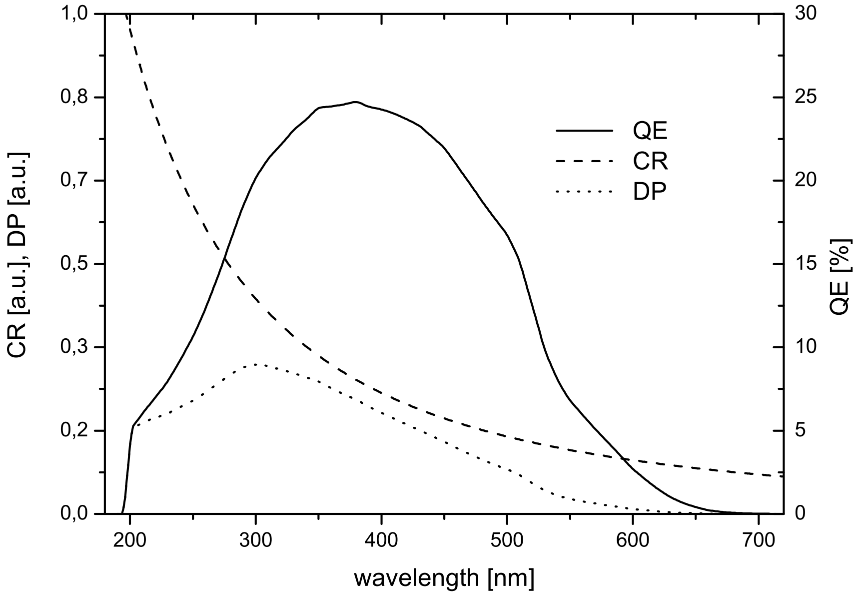

Fig. 3. Detected photons (DP) plotted versus the photon wavelength (arbitrary normalisation). The MAPMT effective QE and the spectrum of the generated photons (CR) are also shown.

Figure 7 shows one of the first images from the on line event display using the information provided by the new photon detection system. The image quality is clearly apparent.

3 Conclusions

The upgrade of the central part of the COMPASS RICH-1 photon detection system has been designed, implemented and installed in a year and a half period. The system has been ready for the 2006 COMPASS run started in July 2006. Ring images have been immediately available on the on-line event display offering the first feedback about the successful implementation of the upgrade and the good quality of the photon detection system.

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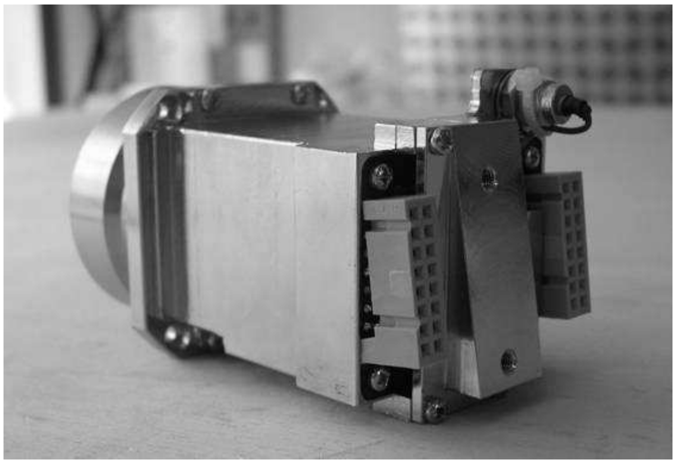

Fig. 4. Rear side of the MAPMT shielding: the two connectors for the front-end read-out cards are also visible.

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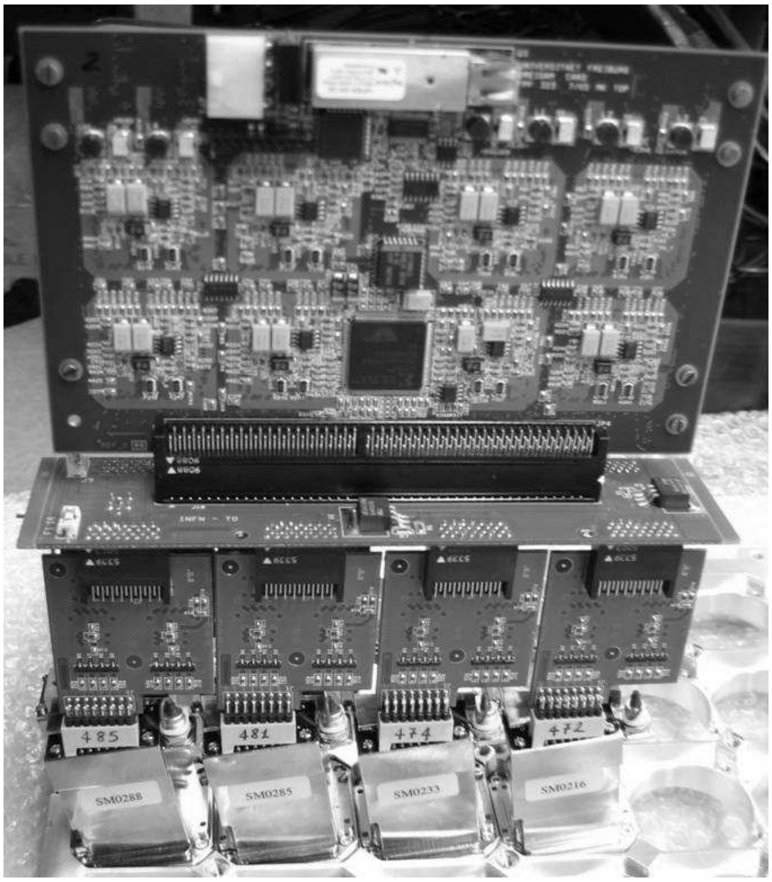

Fig. 5. The read-out components of the MAPMT based photon detection system. The MAD board, the Roof board and the DREISAM board are visible.

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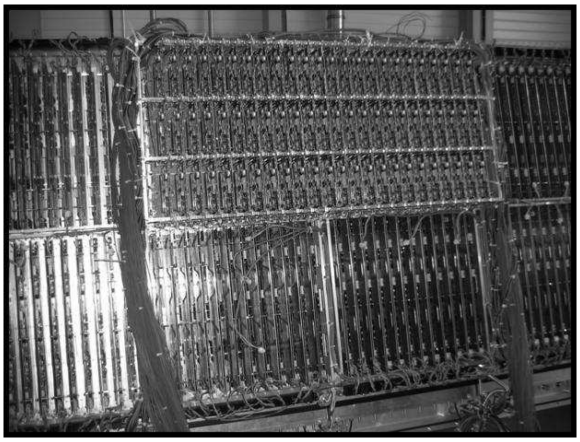

Fig. 6. Half of the COMPASS RICH-1 photon detection system (the bottom detector set) seen from the rear side: the components of the read-out system are visible. The two upper central panels are equipped with MAPMT and fused silica lenses.

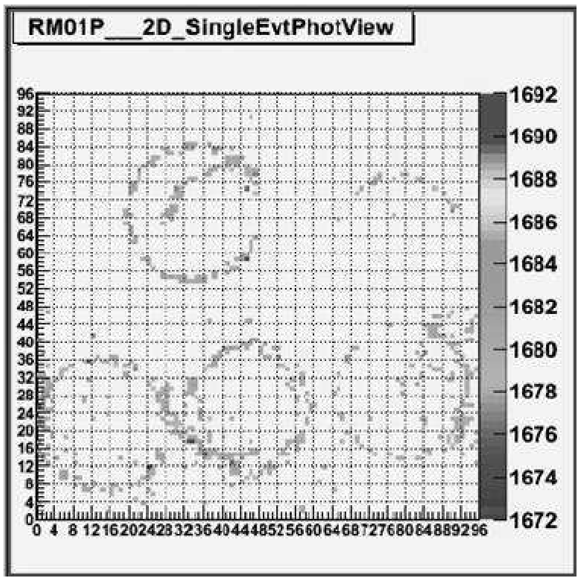

Fig. 7. The image produced by the central upgraded photon detection system of COMPASS RICH-1 as provided by the on line event display. Only hits collected in a 10 ns time window are shown.