STUDIES FOR A FAST RICH

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The present and next generation of HEP experiments requires RICH detectors able to stand high beam intensities and trigger rates and to handle complex, crowded events: fast RICHes are needed. In the context of the future requirements of the enlarged luminosity of the COMPASS experiment, we are building a fast RICH detection system, with photon detection based on multianode photomultipliers and a system of lenses to collect the light from a much larger surface and to guide it to the PMT photocathode, preserving the position information. Albeit this approach is not new, we exploit a surface ratio of the order of 7, thus keeping the costs of the photon detection system reasonable, and we emphasize the fast response of the detectors and the associated electronics. We report about test beam results and laboratory studies of the multianode PMT performances.

1. Introduction

The COMPASS experiment[1], at CERN SPS, is a high luminosity experiment dedicated to hadron physics, with a full research programme including studies about nucleon spin structure and charm spectroscopy. As for many modern HEP experiments, particle identification in COMPASS is a fundamental requirement; for this purpose, RICH-1[2] detector is operating in the experiment since 2001. The detection technique relies on MWPCs with CsI photocatodes, and the read-out system is based on the front end chip Gassiplex[3]. The long memory time of this detection system ($\sim 3\mu$s) causes the presence of high pad occupancy due to background photons from uncorrelated particles. Due to the muons of the beam halo, the background is very large in the detector central regions causing a sensitive reduction in the RICH performances for forward particle trajectories. For the second phase of COMPASS data taking, planned to start in 2006, high beam intensity (up to 10^8/sec) and trigger rates (up to a maximum of 100 kHz) as well as complex events are foreseen: this calls for an upgrade of the RICH detector. The RICH-1 Upgrade consists of two complementary projects: in the external part of the detector, the present MWPCs will be read by a read-out electronics with APV-based architecture[4], allowing to reduce the detector dead time; for the central part, a system based on Multi Anode Photo Multiplier Tubes (MAPMT)[5,6], lenses and a reduced dead time read-out system will result in an important increase in the number of detected photons and in a reduction of the background from uncorrelated events. In the following, we will describe test beam and laboratory studies related to the up-grade of the central region.

2. Description of the photodetection system

The use of MAPMT matrices as photon detectors for RICH applications has been already proposed (HeraB, studies for LHCb): respect to these approaches, we increase significantly the ratio between the surface of the entrance lens and the MAPMT photocathode surface. The MAPMT chosen is the R7600-03-M16 by Hamamatsu, characterized by a bialkali photocathode with 18×18 mm^2 active surface, 16 pixels and an UV extended glass entrance window to increase the range of the detectable Cherenkov light spectrum (200-600 nm). MAPMTs are coupled to a two lens system that allows to increase the geometrical acceptance and to minimize image distorsions; lenses are made of fused silica in order to match the wavelength range of the PMT. Home made resistive dividers are mounted on MAPMTs; the small front-end boards equipped with the MAD4 amplifier/discriminator chip[7], which are used to amplify and digitize the MAPMT signals, are directly linked via a connector to the resistive divider boards. Power and threshold are distributed via a deck PCB. F1 TDC chips[8] arranged in digital boards, provide time resolution better than 130 ps.

3. Test beam results

The principle of the photon detection system proposed for a fast RICH has been validated with two test beams at CERN SPS, T11 beam line, during 2003 and 2004. In the 2004 test, the Cherenkov photon source is a fused silica radiator placed on the axis of a UV paraboloidal mirror whose aim is modify the photon trajectories, so to decrease the opening angle. The amount of detectable photons is controlled with a cylindric aluminium screen. The detection system is formed by 8 MAPMTs, each coupled with a single thick fused silica lens. A typical threshold curve[5,6] exhibits a long plateau; the peak at low threshold values includes both electronics noise and signal generated by the cross-talk from adjacent MAPMT pixels. The plateau indicates a wide range for non critical threshold setting, allowing a rejection of cross-talk signal without affecting PMT efficiency. The long plateau has been observed also at the level of single MAPMT channel.

4. Laboratory studies on MAPMT performances

RICH-1 detector is located in the residual field region of one of the COMPASS spectrometer magnets. The maximum value of the magnetic field B in the region where the MAPMTs will sit is ∼200 Gauss. Figure 1 shows the efficiency of single photoelectron detection for different values of the longitudinal magnetic field B, normalized to the efficiency measured at B=0; the different sets of points correspond to a group of 4 external pixels

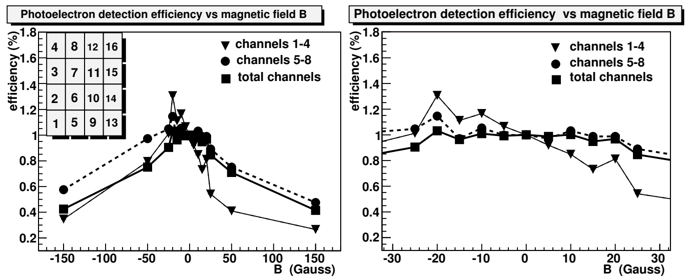

Figure 1. Efficiency of single photoelectron detection versus longitudinal magnetic field B, normalised to the efficiency measured at B=0; different sets of points correspond to a group of 4 external pixels (1-4), 4 internal pixels (5-8) and the totality of the 16 pixels of a MAPMT. At right magnification of the low B values region.

(1-4), 4 internal pixels (5-8) and the totality of the 16 pixels of a MAPMT. The plot at left shows a photoelectron efficiency reduction at high B values, while for values lower than 20 Gauss (plot at right), there is no efficiency reduction for the sets of 16 pixels and 4 internal pixels. For the external pixels, we can observe increased efficiency or reduced efficiency, according to the field sign; the behaviour is opposite for the corresponding group of 4 pixels at the opposite MAPMT edge. Globally, at low magnetic field, there is no efficiency reduction, while the photoelectron collection is partially moved from a pixel to the adjacent one. All the data points have been obtained producing threshold curves in the different field conditions.

A soft iron shielding to house PMTs has been validated: inside the box, B value is below 10 Gauss even for an external field around 200 Gauss.

The maximum photoelectron rate per MAPMT channel foreseen at COMPASS during the 2006 run is $\sim$2 MHz. We have studied the MAPMT response at high rate to validate the design of the voltage divider. The effect of high photoelectron rates on gain has been studied monitoring the dependence of the anodic signal amplitude on the amount of photons per channel, operating the MAPMT at different HV values (Fig. 2). The high photoelectron rate is generated with a Halogen lamp and it is controlled applying calibrated neutral filters. No amplitude reduction is observed up to 950 V and photoelectron rates as large as at least 5 MHz per channel. For RICH application, the MAPMTs will be operated between 850 V and 900 V, HV values that guarantee maximum photoelectron collection efficiency.

5. Conclusions

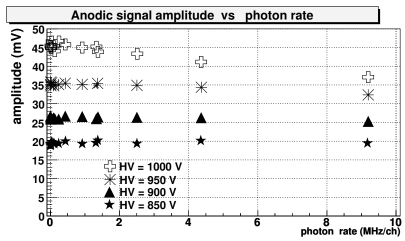

Figure 2. Anodic signal amplitude vs photoelectron rate per channel, at different HV.

Test beams and laboratory studies have confirmed the validity of a fast system for photon detection based on UV extended MAPMT, read by MAD4 front end chip and coupled with quartz lenses. Applications for large RICH detectors are promising.

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