ℓ INFN, Sezione di Torino and University of Torino,
m INFN, Sezione di Trieste and University of Trieste,

Design and Status of COMPASS FAST-RICH

Abstract

P. Abbon [k], M. Alekseev [ℓ], H. Angerer [i], M. Apollonio [m], R. Birsa [m], P. Bordalo [h], F. Bradamante [m], A. Bressan [m], L. Busso [ℓ], M. Chiosso [ℓ], P. Ciliberti [m], M. L. Colantoni [a], S. Costa [ℓ], S. Dalla Torre [m], E. Delagnes [k], H. Deschamps [k], V. Diaz [m], N. Dibiase [ℓ], V. Duic [m], W. Eyrich [d], D. Faso [ℓ], A. Ferrero* [ℓ 1], M. Finger [j], M. Finger Jr [j], H. Fisher [e], S. Gerassimov [i], M. Giorgi [m], B. Gobbo [m], D. von Harrach [g], F. H. Heinsius [e], S. Horikawa [c], R. Joosten [b], B. Ketzer [i], K. Königsmann [e], I. Konorov [i], D. Kramer [f], F. Kunne [k], A. Lehmann [d], A. Maggiora [ℓ], A. Magnon [k], A. Martin [m], G. Menon [m], A. Mutter [g], O. Nähle [b], D. Neyret [k], P. Pagano [m], S. Panebianco [k], D. Panzieri [a], S. Paul [i], J. Polak [f], P. Rebourgeard [k], P. Schiavon [m], C. Schill [e], W. Schröder [d], L. Silva [h], M. Slunecka [j], F. Sozzi [m], L. Steiger [j], M. Sulc [f], F. Tessarotto [m], A. Teufel [d]

[a] *Dipartimento di Scienze e Tecnologie Avanzate, UPO and INFN - Torino, Italy*

[b] *Universität Bonn, Helmholtz-Institut für Strahlen- und Kernphysik, 53115 Bonn, Germany*

[c] *CERN, European Organization for Nuclear Research, Geneva, Switzerlan*

[d] *Universität Erlangen-Nürnberg, Physikalisches Institut, 91054 Erlangen, Germany*

[e] *Universität Freiburg, Physikalisches Institut, 79104 Freiburg, Germany*

[f] *Technical University of Liberec, Liberec, Czech Republic*

[g] *Universität Mainz, Institut für Kernphysik, 55099 Mainz, Germany*

[h] *LIP, Lisbon, Portugal*

[i] *Technische Universität München, Physik Department, 85748 Gerching, Germany*

[j] *Charles University, Prague, Czech Republic and JINR, Dubna, Russia*

[k] *CEA Saclay, DSM/DAPNIA, 91191 Gif-sur-Yvette, France*

[1] Ferrero Andrea,
e-mail: aferrero@to.infn.it,
Phone: +390116707411,
FAX: +39016707429,
Address: Via Pietro Giuria, 1 - 10125 -
Torino, ITALY

In the context of the upgrade of COMPASS RICH-1, we are developing a fast photodetection system for RICH counters, based on UV extended Multi-Anode Photo-Multiplier Tubes (MAPMT) and a custom, low dead-time electronic read-out system. Photons are concentrated on the MAPMT photocatode by an optical system that preserves the position information. The ratio between the collection and the photosensitive surfaces is ~7.5 in our design, larger than in previous applications. A new front-end electronics, based on a modified version of the MAD4 discriminator chip, is being realized to digitize the MAPMT signals. We report about the design of the photodetection system and of the associated electronic readout system, and on the preliminary test beam results.

Key words: COMPASS, RICH, multianode photomultiplier tubes, UV lenses
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1 Introduction

Particle identification at high rates and in high multiplicity environments is a crucial aspect of many modern and future high energy experiments. The upgrade of the detector RICH-1[1] of the COMPASS experiment[2] at CERN SPS requires, in the detector central region, photon detection technology and an associated electronic readout system that allow trigger rates in the 100 kHz range and single channel counting rates of several MHz. Such demanding requirements can be fulfilled by a Ring Image Cherenkov (RICH) detector, equipped with Multi Anode Photomultipliers (MAPMT) and fast, pipelined, low dead-time readout electronics. The ratio between the photon collection and photon detection surfaces is made larger than 7 by introducing a photon condensation optics. In order to keep the overall cost affordable, in our design this ratio is larger than similar implemented[3] or proposed[4] systems, where it was < 3. Outside RICH-1 central region, where the single channel counting rates are lower, an upgrade of the read-out system of the present photon detectors is foreseen[5].

We present the design of a fast photon detection system fulfilling the mentioned requirements (section 2), the most relevant test beam result obtained with a prototype setup (section 3), and the design of the optical system (section 4).

2 The photon detection system and the associated read-out electronics

The system is based on the MAPMT R7600-03-M16 by Hamamatsu[2], characterized by a bialkali photocathode with 18×18 mm^2 active surface and 16 pixels. They have extended UV glass entrance window

[2] Hamamatsu, PHOTONICS K.K., 314-5, Shimokanzo, Toyooka-village, Iwata-gun, Shizuoka-ken, 438-0193, Japan

to increase the range of detectable Cherenkov photons (200-600 nm). The MAPMTs have been equipped with thin home made resistive divider boards. The careful design of the internal PCB ground layers and the application of an external black varnish ensure light tightness on the back side of the device. The MAD4 discriminator chip[6] is used to digitize the photomultiplier signal. A modified version of this chip (CMAD) is being developed; the main goals are the ability to provide individual threshold settings for each channel and single channel rate capabilities up to 5 MHz. To minimize the noise at the input stage, the preamplifier/discriminators are housed on small PCB boards directly connected to the resistive dividers. The hit time measurement and data transmission are performed by a digital readout board based on the F1 TDC chips[7], providing a time resolution better than 130 ps. The hit information is formatted by the TDC chips into 24-bits data words, and transmitted out through a 400 Mb/s fast serial connection. A deck board connects one TDC board to 64 discriminator channels (4 MAPMT), and provides the distribution of the supply and threshold voltages to the discriminator boards. The arrangement described here avoids the use of cables up to the data transmission out of the TDC boards, resulting in a compact read-out system.

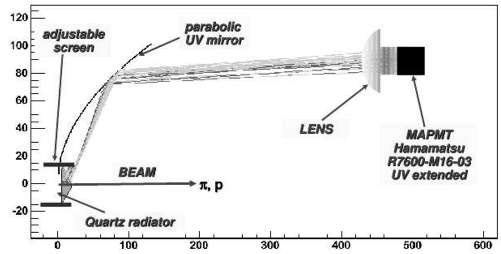

Fig. 1. Schematic view of the 2004 test beam setup.

3 Testbeam results

The proposed design has been studied and validated in two test beam exercises at the T11 beam line of the CERN PS accelerator facility, during years 2003 and 2004. In the following, the setup of the 2004 test beam will be described, and the most relevant results will be discussed.

The setup is schematically shown in Fig. 1. A far Cherenckov photon source is simulated by placing a fused silica radiator, shaped as a truncated cone, in the focus of a UV parabolic mirror. The angle of the cone surface is such that, at saturation, the Cherenkov photons produced by particles flying parallel to the cone axis are not deflected at the exit of the radiator piece. The angle at which the photons are reflected by the mirror can be varied by adjusting the relative position of the radiator and the mirror itself. A movable aluminium tube surrounding the radiator allowed to precisely tune the amount of Cherenkov photons reaching the MAPMTs. The Cherenkov photons are concentrated onto the MAPMT sensitive surface using single, thick fused silica lenses (an arrangement

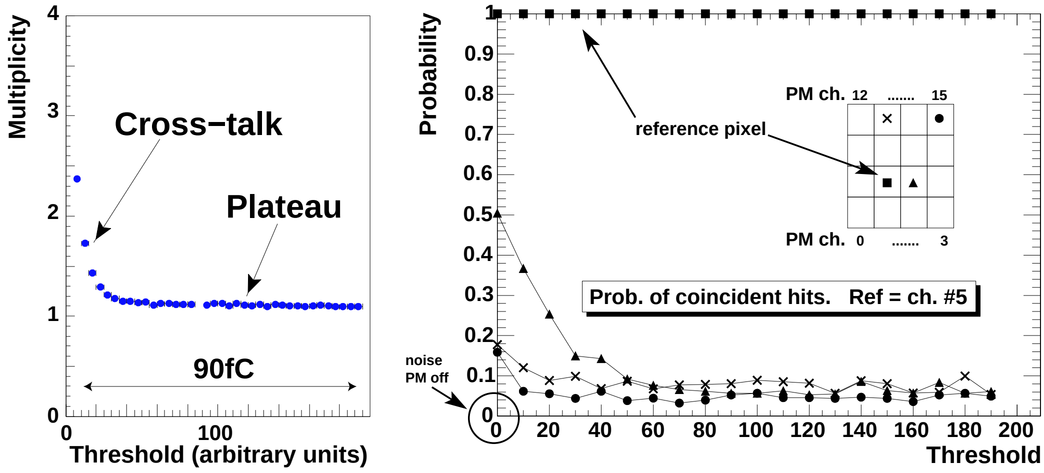

Fig. 2. Results from the 2004 test beam. The left picture shows the measured hit multiplicity for one of the MAPMTs at nominal HV, as a function of the applied electronics threshold. The horizontal scale is in arbitrary units, relative to the measured electronics noise. The right plot shows the measured cross-talk as a function of the discriminators thershold (arbitrary units) for some of the MAPMT pixels, when one of the central pixels is taken as reference.

substantially different from the final design of the optical system discussed in section 4). An aluminium panel, placed at about 50 cm from the radiator, provides the mechanical fixation for the lenses and the MAPMT. Eight lens and MAPMT blocks are mounted in a circular pattern, so that they intercept the reflected Cherenkov photons. The ring image produced by the Cherenkov photons is clearly visible as an enhancement in the counting rate by the corresponding MAPMT pixels. The typical hit multiplicity distributions of the MAPMTs are accurately reproduced by our MonteCarlo simulations of the test beam setup, while absolute rate estimations are accurate at 10% level. The threshold curves at nominal high voltage (see Fig. 2-left) clearly show the presence of a wide range of threshold values for which the electronics noise and the cross talk are rejected, without losses of the single photoelectron efficiency. The probability for each pixel to be fired in combination with a reference one (see Fig. 2-right) has been measured in order to estimate the overall cross-talk of the photon detection system. The highest cross-talk probability is indeed associated to the pixels sorrounding the reference one.

4 Optics design

The main design parameters of the optical system to transport the photons are:

- ratio of the photon collection/photon detection surfaces larger than 7;
- angular acceptance of ±200 mrad;
- transmitted wavelength range from 200 nm to 600 nm;
- RMS spot size matching the photocathode pixel size, to reduce the

cross-talk between channels;
- limited geometrical distorsion, again tuned on pixel size.

These design prescriptions can be fulfilled by the optical design shown in Fig.3. It is based on a fused silica lenses system with two elements. The second element has one aspherical surface to reduce image distorsion and aberration.

5 Conclusions

We have presented the design of a FAST RICH detector based on the MAPMT R7600-03-M16 by Hamamatsu and equipped with a fast, low dead-time readout electronics. A two-lens optical system is introduced to reduce the number of MAPMTs installed; the design ratio between the photon collection and photon detection surfaces is larger than 7. The proposed system will equip the central region of the upgraded COMPASS RICH-1 detector. Perspectives for application to other large area RICH detectors look promising.

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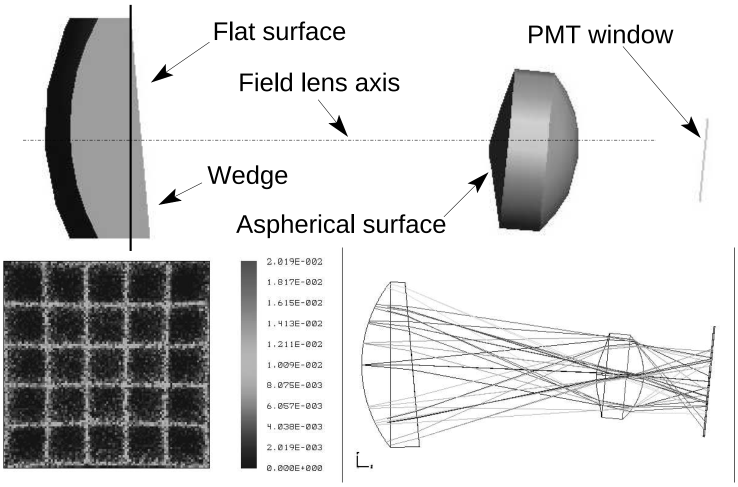

Fig. 3. Schematic view of the optics used to condense the Cherenkov photons on the MAPMT sensitive surface. The design comprises one aspherical element to reduce image distorsion and aberration. The bottom pictures show the simulated response of the optics to incident rays with angles of $\pm 8.3°$ maximum.