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Characterisation and compensation of magnetic distortions for the pixel Hybrid Photon Detectors of the LHCb RICH

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Abstract

The LHCb experiment at LHC, optimised for the study of CP violation, has two RICH detectors to provide particle identification in the momentum range ~2–100 GeV/c. The stringent requirements on the photon detectors are met by the custom-made pixel Hybrid Photon Detector.

The photon detectors need to operate in the fringe field of the LHCb dipole magnet which will produce distortions of the image detected on the pixel chip which is encapsulated inside the HPD. This paper reports on the experimental characterisation of the image distortions caused by an external magnetic flux density. These measurements allow for the development of a parameterisation of the effects and a compensation algorithm, which are also presented.

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Keywords: Hybrid Photon Detector; Magnetic distortions; S-distortion correction

1. Introduction

The LHCb experiment [1] at the LHC, dedicated to the study of CP violation, has two RICH detectors to provide particle identification over a wide momentum range (~ 2–100 GeV/c). Three different radiator materials are used (aerogel and the fluorocarbon gases C_4F_{10} and CF_4). To detect the Cherenkov photons produced by charged particles in these materials with a high granularity ($2.5 \times 2.5\,mm^2$) over a large active area ($2.8\,m^2$), a high efficiency position sensitive single photon detector is needed. The adopted solution for the LHCb RICH detectors is the pixel Hybrid Photon Detector (HPD) [2]. The HPD (see Fig. 1) is a vacuum photon detector with a pixelated silicon

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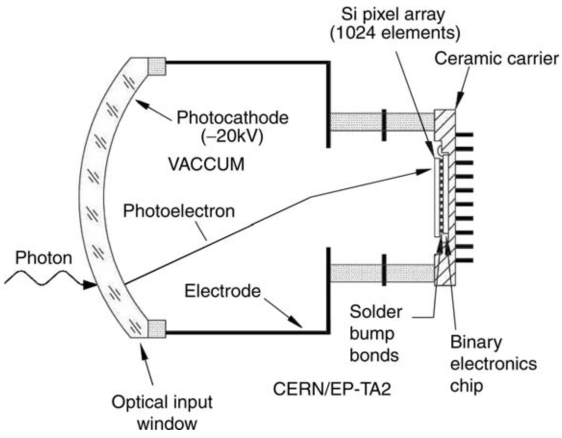

Fig. 1. A schematic of the HPD.

detector anode assembly. The tube has a quartz entrance window with a multialkali photocathode. Photoelectrons emitted from the photocathode are accelerated onto the anode assembly by a 20 kV cross-focussing electron optics. The demagnification factor is 5.

Both RICH detectors are situated in proximity of the LHCb dipole magnet, hence the 484 photon detectors need to operate in its fringe field. The HPD electron optics is sensitive to magnetic flux densities, in the same way as most image intensifiers [3]. The Lorentz force due to a field $\mathbf{B}_{\parallel}$ parallel to the tube axis changes the electron trajectories causing them to rotate around the tube axis. This effect is visible as a significant S-distortion and magnification of the anode image. A transverse magnetic flux density $\mathbf{B}_{\perp}$ with respect to the tube axis, causes a lateral shift of the electronic image.

Hence the HPDs are enclosed in primary magnetic shielding boxes designed to limit the field density flux to 2.5 mT and 1.0 mT in RICH1 and RICH2, respectively. The direction of the magnetic flux density at the RICH1 photon detector plane (mainly longitudinal) is different from the direction in RICH2 (mainly transverse) [4]. This is a direct consequence of the placement and orientation of the photon detector planes within the RICH detectors. The field value varies across the HPD plane, hence the field experienced by each HPD will be different. The magnetic flux

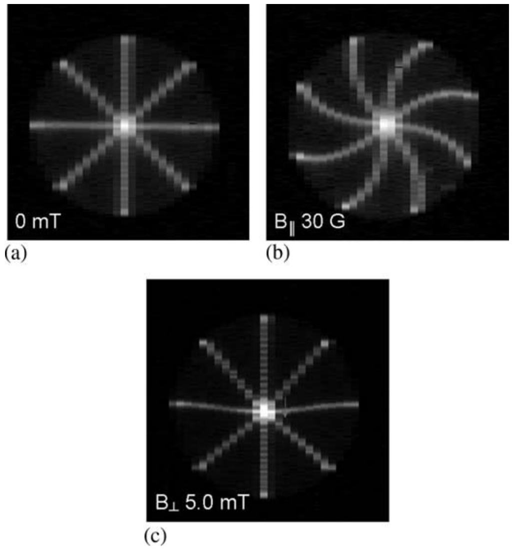

Fig. 2. (a) Image of the double cross with $B = 0\,\mathrm{mT}$. (b) Same light pattern with a 3.0 mT axial field. (c) With a transverse field of 5.0 mT applied.

density level inside the shielding boxes would still induce excessive distortions and even signal losses. Therefore, a local magnetic secondary shield of a high permeability alloy (MuMetal[1]) surrounds every HPD.

The results from detailed experimental characterisation are presented in this paper and are used in the development of a parameterisation procedure for distortion correction.

2. The experimental set-up

The measurements consisted of recording the photoelectron hit position on the anode when photons were shone on known locations on the photocathode while various magnetic flux densities were applied. The set-up used a DC LED to produce a double cross pattern (see Fig. 2(a)) and a digital projector for a programmable static light pattern (see Fig. 3(a)). The measurement of the spot centre and its error are determined from either a double gaussian fit or a weighted mean of the light intensity distribution. The magnetic flux

[1]Hereafter referred to as mumetal.