1 Introduction

This document describes the process and conclusions of the review of the LHCb Ring Imaging Cherenkov detector (RICH), designed to identify charged particles in the LHCb detector. The RICH system consists of two detectors, RICH1 covering the angular range $25 < \theta < 300$ mrad and providing $K/\pi$ separation over the momentum range $1 < p < 50$ GeV/$c$, and RICH2 covering the angular range $15 < \theta < 120$ mrad and providing $K/\pi$ separation over the momentum range $15 < p < 150$ GeV/$c$.

Examples of B decay modes where particle identification is necessary include $B_d^0 \rightarrow \pi^+\pi^-$, $B_s^0 \rightarrow D_s^+K^\pm$, $B_d^0 \rightarrow D^0 K^{*-} \rightarrow (K^+\pi^-)(K^+\pi^-)$. Good $K/\pi$ separation also enhances the efficiency for B tagging via kaon decay modes and the RICH counters can be used in conjunction with the calorimeter and muon detection systems for positive identification of electrons and muons.

The TDR was received on 7 September 2000 (CERN/LHCC 2000-037). On 2 October, the LHCb referees discussed the document with the collaboration. The open presentation was given to the LHCC session on 4 October. Following the LHCC meeting the LHCb group received a number of questions. The response to these questions and the discussion of milestones took place in the referees’ meeting on 27 November. The referees were D. Cassel, Y. Karyotakis, A. Rostovtsev, and H. Schellman.

2 Detector Technology

The LHCb RICH system consists of 2 detectors, one (RICH1) mounted before the analyzing dipole magnet and the other (RICH2) mounted after the tracking system and in front of the electromagnetic calorimeter. The RICH1 system uses silica aerogel ($n \sim 1.03$) and $C_4F_{10}$ gas as radiators while the RICH2 uses $CF_4$ gas. Cherenkov photons in both detectors are reflected by mirrors onto active sensor planes with areas of several square meters. Prototype readout electronics for Level-0 (on-detector) multiplexing and Level-1 (off-detector) signal processing are under development.

The photodetector of choice is a pixel HPD (hybrid photodiode) built in cooperation with DCP, which incorporates a modified version of the pixel readout chip developed in collaboration with ALICE. Conventional Multi Anode PMT’s are also being considered as a backup technology. Each of the 430 HPD photodetectors is
83 mm in diameter and has 1024 pixels with digital readout. The prototype pixel chip was not available at the time that the TDR was submitted. At the time of this review, prototype chips with full functionality had become available for testing. The preliminary test results were promising but some essential specifications were not met. The most serious deficiency is that the maximum rate of the chip is apparently 20 MHz instead of the required 40 MHz. The currently available chip will be encapsulated in prototype HPDs in order to validate bump bonding and the encapsulation technique using the the final HPD tube design. This will occur in parallel with further chip testing and correction of the chip design if that proves to be necessary.

The detector layout has been optimized using a full simulation of LHC events with backgrounds, including particles passing through the photodetectors themselves. Test beam data were used to set many of the parameters in this simulation. The average number of photoelectrons detected per ring ranges from 6.6 for low momentum particles traversing the aerogel to 33 for higher momentum particles which traverse the C$_4$F$_{10}$ in RICH1. The average number of photoelectrons/ring in RICH2 is expected to be 18. The kaon identification efficiency predicted by these simulations ranges between 70% at low momenta to 95% above 10 GeV/c with purities ranging from 40% at the lowest momenta to 85-100% at momenta above 10 GeV/c.

3 Comments

The LHCC finds the detector technology adopted for the RICH adequate to achieve the physics goals stated in the Technical Proposal, and congratulates the LHCb collaboration for the quality of work presented in the TDR.

Although there are no major concerns, the LHCC notes that:

- The development of the HPD is a critical item that requires milestones on the project leading to the technical choice between the HPD and Multi Anode PMT options.

- LHCb should keep the LHCC informed of progress toward this technical decision.

The LHCC recommends that LHCb follows the established practice of conducting an independent reviews of the engineering designs.

A list of agreed milestones to monitor and regulate the progress of the project is appended.
## RICH Milestones

<table>
<thead>
<tr>
<th>Mechanics and Optics</th>
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<tbody>
<tr>
<td>finish optimizing engineering design</td>
<td>Mar 2002</td>
</tr>
<tr>
<td>10% of mirrors produced</td>
<td>Sep 2002</td>
</tr>
<tr>
<td>50% of mirrors produced</td>
<td>Jan 2003</td>
</tr>
<tr>
<td>finish mirror production</td>
<td>Jun 2003</td>
</tr>
<tr>
<td>begin RICH1 assembly in IP8</td>
<td>Jan 2004</td>
</tr>
<tr>
<td>begin RICH2 installation in IP8</td>
<td>Jul 2004</td>
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<table>
<thead>
<tr>
<th>Photodetectors</th>
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<tbody>
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<td>finish prototype HPD</td>
<td>Jun 2000</td>
</tr>
<tr>
<td>technical choice</td>
<td>Sep 2001</td>
</tr>
<tr>
<td>production readiness review</td>
<td>Nov 2001</td>
</tr>
<tr>
<td>place photodetector order</td>
<td>Mar 2002</td>
</tr>
<tr>
<td>10% of detectors produced</td>
<td>Dec 2002</td>
</tr>
<tr>
<td>50% of detectors produced</td>
<td>Jun 2003</td>
</tr>
<tr>
<td>finish detector production</td>
<td>Feb 2004</td>
</tr>
<tr>
<td>finish detector testing</td>
<td>Mar 2004</td>
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<table>
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<tr>
<th>Readout Electronics</th>
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<tr>
<td>finish prototype chain tests</td>
<td>May 2002</td>
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<tr>
<td>10% of Level-0 units produced</td>
<td>Jul 2002</td>
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<tr>
<td>50% of Level-0 units produced</td>
<td>Mar 2003</td>
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<tr>
<td>finish Level-0 unit production</td>
<td>Dec 2003</td>
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<tr>
<td>30% of Level-1 units produced</td>
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</tr>
<tr>
<td>60% of Level-1 units produced</td>
<td>Jun 2003</td>
</tr>
<tr>
<td>finish Level-1 unit production</td>
<td>Dec 2003</td>
</tr>
<tr>
<td>finish production and testing</td>
<td>Jan 2004</td>
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</table>

<table>
<thead>
<tr>
<th>RICH Detectors</th>
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<tbody>
<tr>
<td>ready for commissioning with beam</td>
<td>Jul 2005</td>
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