System test of a Three-Column LHCb RICH-2 prototype detector

M. Adinolfi

University of Oxford

On behalf of the LHCb RICH group

The LHCb RICH Detectors

RICH-2

RICH-1

See Sajan Easo presentation

System Test aims

- Different elements of the LHCb RICH developed in lab over the last few years.
- Final prototypes ready, production about to start.
- Integration issues: need to verify all the elements will work in situ, in particular
 - Preproduction HPD
 - Readout electronics
 - Mechanics
 - Power distribution

Prototype detector built to test all elements, identify problems and develop solutions.

Hybrid Photon Detector

- $16 \times 16 \text{ mm}^2$ Si pixel detector
- Detector bump bonded to binary readout “pixel” chip.
- 256×32 pixel matrix ($62.5 \times 500 \mu\text{m}^2$)
- Granularity $2.5 \times 2.5 \text{ mm}^2$.

- Single photon sensitivity.
- 83% active area.
- Typical quantum efficiency at peak (270 nm) $\sim 23\%$.

See Naoko Kanaya presentation

Readout electronics

- The Pixel chip data is read-out on 32 parallel lines at 40 MHz.
- ZIF (Pentium 100) connector and 2 Kapton cables are used to transfer the data to the front-end (Level-0) electronics.
- An aluminum cup supports the HPD and is attached to an aluminum frame.
- The frame also supports the electronics.

L0 board:

Receives and distributes clocks and trigger from TTC.

Generates the control signals for the Pixel chip.

Provides the DC power levels for the Pixel chip.

Transmits the data to the counting room (100 m in LHCb) at 1.6 Gbit s⁻¹ using the GOL chip.

Controlled via JTAG.

Low Voltage Board:

Provides the DC power for the L0 board.

High Voltage Board:

Provides the 20 kV HV for the HPD.

Data Acquisition

Simplified version of the RICH Level-1 electronics.

The L1 receiver board receives the data from 4 HPD at 1.6 Gbit s^{-1} .

Data is stored on the board until the end of the spill when it is transferred to a PC.

Test beam setup

System tested at the CERN PS T9 site.

Beam of 10 GeV π^- and electrons.

N₂ radiator: optics such that the ring is contained in one HPD.

C₄F₁₀ radiator (same as RICH 1): one ring contained by up to 4 HPD.

Cherenkov beam counter used to select π^-/e

6 HPD used.

Test beam completed in the 2nd week of November.

Detector Housing

Mirror

Quartz window

Al foil

**RICH-2
support frame**

Al support frame

Cherenkov rings

Superimposition of over 30000 events.

N_2 used as radiator.

Beam Cherenkov counter used to select pions or electrons.

Small background as expected.

Ring radii in nitrogen

Rings diameters obtained slicing hits distribution on x and y axis, measured in pixels.

HPD	$\varnothing e (x)$	$\varnothing e (y)$	$\varnothing \pi (x)$	$\varnothing \pi (y)$
C0	15.72 ± 1.28	16.14 ± 1.1	13.33 ± 0.91	13.50 ± 0.67
C1	15.37 ± 1.47	15.72 ± 1.35	13.54 ± 0.97	13.86 ± 0.72
R0	14.68 ± 1.42	15.49 ± 1.39	12.67 ± 0.93	13.28 ± 0.69
R1	15.29 ± 1.42	16.21 ± 1.25	13.32 ± 0.95	13.79 ± 0.8
L0	15.99 ± 1.67	16.11 ± 1.32	13.87 ± 1.03	14.07 ± 0.64
L1	15.29 ± 1.47	15.37 ± 1.47	13.41 ± 0.97	13.49 ± 0.59

Expected values, pion: 13.9 ± 0.2
electron: 16.7 ± 0.2

Photoelectron yield in nitrogen

Thanks to small background the photoelectron yield can be estimated from the total number of hits in the HPD.

The distribution is well fitted as a Poisson.

Photoelectron yield tables

HPD	Yield	Exp. Yield	Ratio
C0	7.38 ± 0.02	6.24 ± 0.54	1.15
C1	8.60 ± 0.02	8.97 ± 0.77	0.96
R0	7.08 ± 0.02	7.11 ± 0.61	0.99
R1	8.20 ± 0.02	8.59 ± 0.74	0.95
L0	6.46 ± 0.02	9.10 ± 0.78	0.71
L1	8.08 ± 0.02	8.00 ± 0.69	1.01

**Very
Preliminary!**

Detector efficiency assumed 85% in the expected yield calculation.

Still under investigation:

- Detector threshold optimization.
- Timing uncertainties.
- Detector efficiency.
- Quartz window transmission.

Cherenkov rings in C_4F_{10}

To Do list

- The system test has shown that time synchronization between photo-detectors is critical and requires careful study.
- Study front-end electronics sensitivity to temperature changes.
- Cooling system has not yet been tested.
- Study magnetic shielding effects (see Mitel Patesh and Ann van Lysebetten presentations)
- Introduce final version of slow control and monitoring.

Conclusions

➤ A prototype of the LHCb RICH-2 detector has been built and tested in a test beam run. In the prototype the (almost) final versions of the following have been used:

- HPD
- Readout electronics
- Power distribution

➤ All the final version of the front-end read-out electronics components, pixel chip, L0, LV and HV boards have operated together for the first time.

➤ A close packed sample of 6 HPD at 20 kV has been used.

➤ The data of 6 HPD has been read at 40 MHz, and it has been transmitted to the off-detector electronics at 1.6 Gbit s⁻¹.

➤ Data analysis undergoing.

Extra slides

RICH-1

RICH-2

Support Frame

Beam Pipe envelope

Photodetector
magnetic shield

Flat mirrors

Spherical mirrors

Requirements for the LHCb RICH

- Strong correlation between track momentum and polar angle.
- Physics requires identification of both low and high momentum hadrons.
 - Upper limit: π in $B \rightarrow \pi\pi$ decay
 - Lower limit from tagging kaons.

2 different RICH detectors are used:

RICH-1: Low momentum (2-60 GeV/c) particles, 25-300 mrad acceptance, upstream of magnet.

RICH-2: High momentum (20-100 GeV/c) particles, 15-120 mrad acceptance, downstream of magnet.