System Test of a Prototype
LHCb RICH Detector

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(on behalf of the LHCb RICH Group)
Experimental Goals

- **Precision Measurements of CP Violation in b decays**
- **Large Samples of b decays at LHC**
  - $N_{bb} = 10^{12}$ / year with Luminosity $2 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$ for $\pi \times 10^7 \text{s}$
  - b production predominately at small polar angle

- LHCb optimized as single forward arm spectrometer

- **Many pure hadronic final states**
  - Particle identification ($\pi/K$) essential
- **Employ two RICH detectors**
  - Integration of photon detector
  - Readout electronics
  - Mechanics, power, cooling, insulation

Example decays
LHCb Experiment

• Dedicated B physics Experiment at the LHC
  – See talk by W. Witzeling at these proceedings

• Acceptance :
  – 15-300mrad (bending)
  – 15-250mrad (non-bending)

• Particle ID
  – RICH detectors
  – Calorimeters
  – Muon Detectors

Aerogel and C$_4$F$_{10}$

RICH1
Z ~ 1.0-2.2 m

RICH2
Z ~ 9.5-11.9 m

CF$_4$

Calorimeters
Z ~ 12.5-15.0 m

Muon System
Z ~ 15.0-20.0 m
Photon Detector: The LHCb Pixel HPD

Require:
- Cover total area ~ 2.8 m²
- Single photon sensitivity
- Granularity ~ 2.5mm x 2.5mm
- Visible and near-UV sensitivity
- 25ns time resolution

Solution: The LHCb Pixel Hybrid Photon Detector

Electron optics: Cross-focussed, demagnification ~ 5

Anode: 16×16mm² Si pixel detector, bump-bonded to 40MHz binary readout chip

Pixel cell: 62.5µm x 500µm: 256 x 32 matrix

Effective pixel size at photocathode: 2.5mm x 2.5mm: 1024 channels
HPD developed in close collaboration with industry
Extensive programme of lab measurements → device is well understood
Now have first pre-production HPD – will produce ~550!

Integration Issues:

- Need to ensure that the HPD and other elements of the RICH detector will work in situ i.e. test:
  - Complete readout electronics chain
  - Mechanics
  - Power
  - Cooling, insulation ….

One single HPD
One HPD column
One RICH detector

Require a test system in which can put these elements together
The Prototype RICH Detector

- A prototype detector has been constructed to test solutions to these integration issues

- Beam tests at CERN-PS T9 facility: 10 GeV negative pions and electrons

  - **Phase 1** [COMPLETED – ONE WEEK AGO!]
    - Single column, with one pre-production HPD
    - \( \text{N}_2 \) radiator- optics such that electron ring encompassed on single HPD
    - Ensure on- and off-detector electronics operate correctly together
    - First check of final mechanics and mounting issues

  - **Phase 2**: [Early November]
    - Equip 3 columns with 10 HPDs
    - \( \text{C}_4\text{F}_{10} \) radiator – rings should cover up to 4 HPDs

- Detector large enough to allow future testing integration issues without beam
Test beam Set-up

- Beam Pipe
- Radiator vessel
- Detector Housing
- Column Mechanics
- Quartz Window
- Mirror
- Thin Al foil
- Test beam Set-up
**RICH Readout Electronics**

1. **Pixel chip, encapsulated in HPD**
   - Binary data multiplexed out at 40 MHz

2. **Level-0 Board**
   - Drives the pixel chip
   - Distributes clocks, triggers via TTC
     - Controls DC power levels for pixel chip
     - Gbit optical links (in LHCb 100 m to counting room)
     - Controlled using JTAG interface

   - During the first phase of the test beam pixel chip and L0 board were able to drive out the data at the full LHCb speed of 40 MHz
   - 1.6Gbit optical link also used successfully
3. Data Acquisition

- Writes the L0 data to disk
  - Data from the L0 1.6 Gbit optical link is received by a custom receiver
  - Triggered L0 events were transferred to receiver card immediately, buffered there until the end of the PS spill
  - Then copied to PC through PCI interface
Cooling Scheme

- Complete column of HPDs will output 220W
- Use cooling plates attached to HPD aluminum column to remove this heat
- Thermal mat between copper skin and electronics components
- Cooling system: closed circuit circulation of water/ $\text{C}_6\text{F}_{14}$

![Image showing cooling scheme with labels for Aluminum honeycomb, Copper pipes, Copper skin, $\text{C}_6\text{F}_{14}$ in, and $\text{C}_6\text{F}_{14}$ out]
Observation of Cherenkov Rings

- Plot integrated over many evts
- Use beam Cherenkov counter in trigger to select $\pi/e^-$
- As expected, background small
- $r/o$ problem observe double hits in a vertical configuration on left hand side
- Working on fixing this problem for the next iteration of the $r/o$ boards
- The double hits are always in the same vertical configuration
- Apply offline correction
Electrons: observe 4.0 ± 0.6 mm
expect 4.2 ± 0.1 mm

Pions: observe 3.3 ± 0.52 mm
expect 3.5 ± 0.05 mm
Photoelectron Yields

Electrons:
- Observe: 12.6 ± 0.1 photoelectrons
- Expect: 12.1 ± 1.1 photoelectrons

Pions:
- Observe: 9.1 ± 0.1 photoelectrons
- Expect: 7.9 ± 0.8 photoelectrons
Conclusions

• A prototype LHCb RICH detector has been constructed and used to test integration issues

• First phase :
  – Successfully integrated pre-production HPD together with other RICH elements
  – First meeting of readout electronics chain on-detector: binary chip and L0 board together and operated at 40 MHz, 1.6Gbit r/o through optical fibres
  – Final mechanics and HPD Mounting scheme used successfully
  – Electron and pion Cherenkov rings observed- radii and photoelectron yields in line with expectations

• Second Phase :
  – Three columns with up to 10 HPDs
  – C$_4$F$_{10}$ radiator – rings should cover up to 4 HPDs
  – Will be possible to check cooling, insulation schemes
RICH System Overview

**RICH1:**
- 5cm aerogel $n = 1.03$, 2-11 GeV
- $4 \, m^3 \; C_4 F_{10} \; n = 1.0014$, 10-60 GeV

**RICH2:**
- $100 \, m^3 \; CF_4 \; n = 1.0005$, 17-100 GeV