The Pixel Hybrid Photon Detectors of the LHCb RICH

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Outline

- LHCb detector
- RICH detectors structure
- HPDs working principle and characteristics
- First results from commissioning runs
- Current issues and future plans
LHCb will investigate the properties of the b quark and the CPV-related Physics. Detector has a single-arm structure with good particle identification capabilities provided by 2 RICH detectors.
**RICH1:**
Radiator $C_4F_{10}$ (85 cm) and Aerogel (5 cm)
Momentum between 1 and 60 GeV/c
Acceptance: 25 – 300 mrad
**RICH2:**
Radiator CF$_4$ (180 cm)  
Momentum range: between 17 and 100 GeV/c  
Acceptance: 10 – 120 mrad

*For a general description of RICH detectors see D. Perego’s poster at this conference*
Characteristics of HPD focal planes

- 484 HPDs (Hybrid Photon Detector): 196 for RICH1 and 288 for RICH2
- ~3.3 m² total surface
- Granularity: 2.5 x 2.5 mm² (almost 0.5 million pixels)
- Active area coverage >65 %
- Single-photon sensitivity between 200-600 nm
- Magnetic fringe field <25 G
- Read-out:
  - Compatible with LHC 40MHz bunch crossing frequency
  - 10% occupancy (worst case)
A RICH2 column

On-detector

Off-detector

HPDs are mounted on columns together with readout electronics, power distribution & active cooling
HPD: The Hybrid Photon Detector

-20 kV
-19.7 kV
-16.4 kV

Peak eff. >30% @ 270 nm

LHCbPIX1
HPD characteristics

- HPDs developed in close collaboration with industry (Photonis-DEP lead partner)
- Quartz window with S20 photocathode
- Cross focusing optics:
  - 20 kV operating voltage
  - Demagnification of ~5
  - Point Spread Function 200 µm at the chip level
- Encapsulated binary electronics readout chip
- Two possible readout configuration:
  - 256x32 basic pixels (0.0625x0.5 mm² each)
  - 32x32 pixels (0.5x0.5 mm² each) OR-ing 8 basic pixels at the digital level (no increase of noise)
The solid state electronics

Silicon sensor made by Canberra

Expected signal: $5000 \, e^- @ 20kV$ (2000 $e^-$ worst case in case of charge sharing)

Threshold: 970 $e^-$

Noise: 130 $e^-$
System tests in a test beam

The very good noise performance of HPDs are shown in this image obtained during a test run using a 80 GeV/c charged particle beam at CERN SPS. $C_4F_{10} \sim 1m$. radiator length.

Pixel map of a $C_4F_{10}$ ring focused on 4 HPDs integrated over $\sim 50k$ events

Photon Yield
Sensitivity to magnetic fields

Axial  Transverse

Coils  HPD
(shielded with $\mu$-metal)

LED & collimator used to produce pattern of light on HPD
Effects of magnetic field on pixel position can be quickly spotted using a commercial projector illuminating the focal plane with a fixed point pattern.

After filtering and pattern recognition we may compute the center of mass of each spot of light and then calculate how much a point has been rotated by the stray field on the RICH2 focal plane (1 HPD shown)

Pattern seen by one of the RICH2 HPDs
The net rotation effect due to stray magnetic field can be clearly seen here where the rotation angle $<\Delta \theta>$ is plotted against HPD number.
And when you have a beamer at your disposal you may use it to project on the focal plan whatever you want...

Single photon accumulated image taken shining from a projector (the same used for the magnetic distortion) on the C-side of RICH2. The light level over the whole surface is ~100 photoelectrons per event.
RICH1 Detector Time alignment

Fine time alignment of Level 0 trigger required, in order to maximize photon collection efficiency:

• Use 100ps pulsed laser
• Delay of readout varied in steps of 1ns with respect to laser pulse

Data acquired while scanning the trigger delay
And finally you get (preliminary) DATA!
(only one beam injected)

Rich2  A-side
C-side
Rich1  Upper and lower box

Run number 32490   50 events accumulated
(only Rich1 time aligned) – Tracks not directed from interaction point.
Conclusions

• LHCb RICH System is working and we started acquiring first data.
• We have to complete alignment and calibrate it, but we already have seen photons from tracks and we are confident the RICH detectors will give beautiful physics results.

• HPDs present many nice features and for sure they will be much used in future detectors.
Spare Slides
**Ion Feedback Rate (IFB)**

Vacuum inside HPDs must be very good (in fact much better than a standard photomultiplier), otherwise gas trapped inside will get ionized by photoelectrons and then ions will be accelerated toward photocathode.

When ions hit photocathode they free many electrons and you end up with a nasty big cluster on the pixel detector.

IFB is generally very low (<1%). In a few tubes (<10%) it’s higher. Work is in progress to understand why it happens.