Performance Study of New Pixel Hybrid Photon Detector Prototypes for the LHCb RICH counters

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• Detector description
• Performance tests
• Summary
The 40 MHz LHCb Pixel HPD

- developed as photon detector for the LHCb RICH
  - high active-total area ratio (70%)
  - high time resolution (<25ns)

- 16x16mm² Si detector bump bonded to 40 MHz binary readout chip
- encapsulated in a vacuum envelope
- cross focusing, demagnifying (x5)
  - picture granularity: 2.5x2.5mm²

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Performance Tests

Real pixel size 62.5x500µm²:
1024 → 8192 pixels

• two 40 MHz HPD prototypes tested
  with 98.5% and 95.6% working bonds (out of 8192)
  (one 10 MHz HPD prototype with >99.9% working bonds)

each LHCb pixel subdivided into 8, ‘OR’ed together by readout chip

fast, pulsed LED used as light source & some test beam data

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Discrimination Threshold

Analogue front end consists of:
charge preamplifier, shaper and discriminator

- discriminating threshold can be adjusted
- threshold (~1700e⁻) and its spread (~250e⁻) within specifications
- 3 bit pixel adjustment to achieve lower and narrower threshold distribution
  ➢ efficiency improvement at 20kV: ~1%
Detector Bias & Tube High Voltage

- Performance vs. tube HV and detector bias studied
  - Detector has to be over-depleted to collect the charge efficiently
Detection Efficiency

- analogue back-pulse signal used for calibration
- (only accessible in prototype tests)
- 4 parameter fit to describe the spectrum
- to be compared with binary pixel data
Detection Efficiency Results

- corrections to the binary data:
  - **pixel clustering (charge sharing)**: adjacent fired pixels are clustered together, assumed to originate from only one p.e.
  - **pixel clustering over-correction**: account for probability to have adjacent hits (function of light intensity and light profile)
  - **missing bump bonds**

- **backpulse uncertainties not incl.**

- **stable photoelectron detection efficiency**: ~88%

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Dark Counts and Ion Feed Back

dark counts:
• thermal electron emission from photo cathode produces background signal
• average rate: $\sim 1\text{kHz/cm}^2$
  (depends on temperature and other experimental conditions)

ion feed back (=afterpulses in PMTs):
• ionized residual gas molecules hitting the cathode produce a cloud of photoelectrons
  ➢ delayed ($\sim 220\text{ns}$) signal on one or (usually) more pixels
• average rate: $<1\%$ (depends on tube vacuum)

background comparable to multialkali PMTs
High Occupancy and Aging

chip operated in **LHCb mode**: reduce 8192 channels to **1024** pulsed LED
pulsed and DC LED only DC(~1% occup.)

- **no efficiency loss** due to DC LED background signal
- **aging test**: simulate light exposure of 10 years LHC operation at 1% pixel occupancy: **no efficiency** (DE and QE) **loss** observed
Test-beam Measurements

• 10 GeV pions/electrons traversing through air
• Cherenkov rings focused on HPD
➢ all tests in agreement with LED results!

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Summary

Performance of two fully operational and functional 40MHz LHCb pixel HPDs studied:
• discriminating threshold (~1700e-) and its spread (~250e-) within specifications
• efficiency improvement with threshold adjustment demonstrated
• photoelectron detection efficiency stable (~88%) and above specification
• background due to dark counts and ion feed back small
• no performance degradation observed in operation with high pixel occupancy and after aging tests