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

Matthias Moritz

(on behalf of the LHCb Pixel Group)

- **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

Performance Tests

Real pixel size $62.5 \times 500 \mu\text{m}^2$:
 $1024 \rightarrow 8192$ pixels

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

- 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)

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

Discrimination Threshold

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

- discriminating threshold can be **adjusted**
- **threshold ($\sim 1700e^-$) and its spread ($\sim 250e^-$) within specifications**
- **3 bit pixel adjustment** to achieve lower and narrower threshold distribution
- **efficiency improvement at 20kV: $\sim 1\%$**

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%**

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!

Summary

Performance of two fully **operational and functional**
40MHz LHCb pixel HPDs studied:

- discriminating threshold ($\sim 1700e^-$) and its spread ($\sim 250e^-$) within specifications
- **efficiency improvement** with **threshold adjustment** demonstrated
- photoelectron **detection efficiency stable ($\sim 88\%$)** 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**