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Production of 500 Pixel Hybrid Photon Detectors for the RICH counters of LHCb

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Talk layout

- ◆ The LHCb experiment, the RICH1 and RICH2 detectors and their photon detector requirements
- ◆ The pixel Hybrid Photon Detector
- ◆ Production flow-chart
- ◆ Pre-series tubes and test beam results
- ◆ Local magnetic shielding, distortions and calibrations
- ◆ Conclusions

The LHCb experiment

- ◆ Single-arm spectrometer for precision measurements of CP violation in B-meson system
- ◆ Search for signals of 'New Physics' beyond Standard Model
- ◆ Particle identification over momentum range $\sim 2\text{-}100\text{ GeV}/c$, using 2 Ring Imaging CHerenkov (RICH) detectors with silica aerogel and 2 fluorocarbon gas radiators

The RICH1 detector

The RICH2 detector

Horizontal X-section

Al superstructure

Magnetic shield box

HPD plane:
9 columns,
16 tubes each

RICH photon detector requirements

- ◆ Good sensitivity over the wavelength range 200nm to 600nm (aerogel response and scattering, and chromatic dispersion in gases)
- ◆ Large detection area of 2.6m² with active area fraction of ~65%
- ◆ Position-sensitive with fine granularity of 2.5mm x 2.5mm (optimum of pixel vs chromatic vs emission point errors)
- ◆ Single photon sensitivity $\Rightarrow$ good signal-to-noise ratio*
- ◆ Fast response for LHC bunch-crossing rate of 40MHz*
- ◆ Radiation tolerant (3krad per year)*

* see talk of K. Wyllie

Pixel-HPD description

Anode

Main features (already presented during previous Beane Conferences:

Close collaboration with industry

Quartz window with thin S20 photo-cathode:

- Typical $\int QE dE > 0.7eV$

Cross-focussing optics (tetrode structure):

- De-magnification by ~ 5
- Active diameter 75mm

$\Rightarrow$ 484 tubes for overall RICH system

- 20 kV operating voltage ($\sim 5000 e^-$ [eq. Si])

32x32 pixel sensor array (500 μm x500 μm each)

Encapsulated binary electronics readout chip

<http://www.cern.ch/~gys/LHCb/PixelHPDs.htm>

HPD flow chart: anode part

Completed anode part

HPD flow chart: HPD tube part (DEP)

Completed HPD tube + QA

Production rate of 30 HPD's per month over production period of ~18 months

Thorough HPD testing

LHCb quality assurance:

2 photon detector test facilities

1 HPD per work day per facility over production period of ~18 months

HPD pre-series (9 tubes): performance results

Item	Specification	Results
Pixel response	>95%	>99%
Min. threshold Noise	<2000e- <250e-	Typ. 1200e- Typ. 160e-
Leakage current	Typ. 1uA @ 80V bias	< 1uA
Dark count rate	Max. 5kHz/cm ²	0.03-3kHz/cm ²
Ion feedback rate	Max. 10 ⁻² rel. to signal	<10 ⁻³
P.e. detection efficiency	Typ. 85%	79-89%
Quantum efficiency	See next picture	Generally well above specs

HPD pre-series: QE curves

Typical and minimum QE
specs based on HPD
prototype results

Test beam with a prototype RICH

HPD column mechanics

6 HPD's on 3 columns

Beam

Mirror

Thin Al foil

HPD housing

Radiator vessel

Beam Pipe

Cherenkov rings in N₂ focussed on each HPD

3500

0

Light yields agree
to within 10% of
expectations

Cherenkov rings in C_4F_{10} radiator

DAQ display showing hits on anode planes (pixel chips)
Single event
Aggregate events

Very clean rings

Local magnetic shielding

To avoid image loss and minimize distortions, *local shielding* of HPD's required to reduce B field below 10G (1mT) inside HPD volume

Mu-metal shield grounded and insulated with $\sim 250\mu\text{m}$ -thick Kapton foil

RICH 1

Simulated magnetic field inside a Mu-metal array enclosed in RICH1 shielding box

Magnetic distortions

Test pattern measurements with locally-shielded HPD

$B=0$

$B_{\parallel} 30 \text{ G (3mT axial)}$

$B_{\perp} 50 \text{ G (5mT transverse)}$

Magnetic field not uniform and varying from tube to tube

⇒ with test pattern, reconstruct pixel hit - photon hit position correspondence for each HPD

Distortion correction must not degrade pixel size error

Parameterization, test pattern and protocol

Non uniform radial dilatation: 2nd order polynomial fit.

Non uniform rotation (S-distortion): 3rd order polynomial fit, ($a_1=0$)

Radius on photo-cathode

B field calibration protocol:

- Projection of a static pattern on the detectors plane in the experiment (proposals for RICH1 and RICH2)
- Combined approach: *parameterization, sampling and filling of a look-up table*
- Additional use of data for monitoring

Conclusions

- ◆ Production of 500 pixel-HPD's on-going
- ◆ HPD pre-series performance good
- ◆ Test beam confirm HPD lab tests
- ◆ Magnetic distortions and calibrations: protocol exists and tested;
Mu-metal insulation concept and implementation OK;
- ◆ Electronic aspects: see talk of K. Wyllie