Imperial College London

Photon Detectors for the LHCb RICH System

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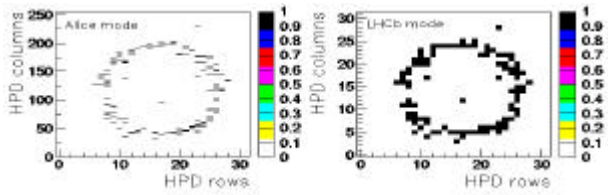
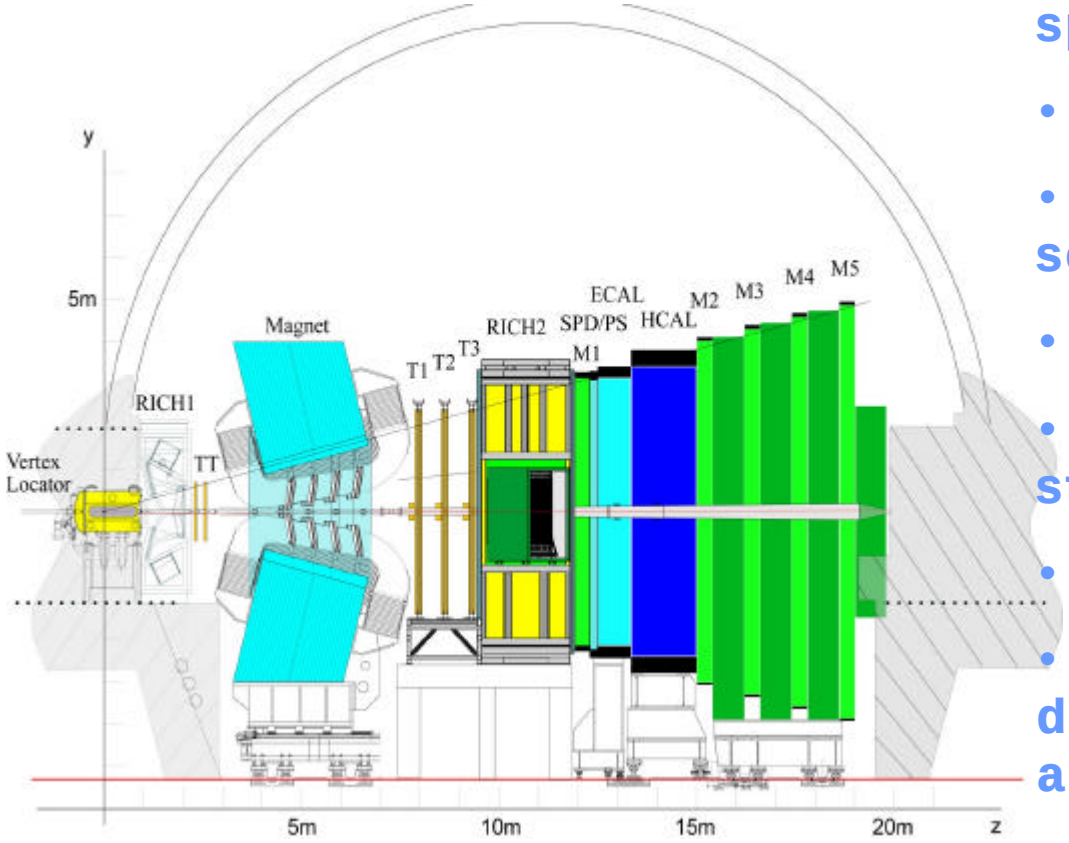
Overview



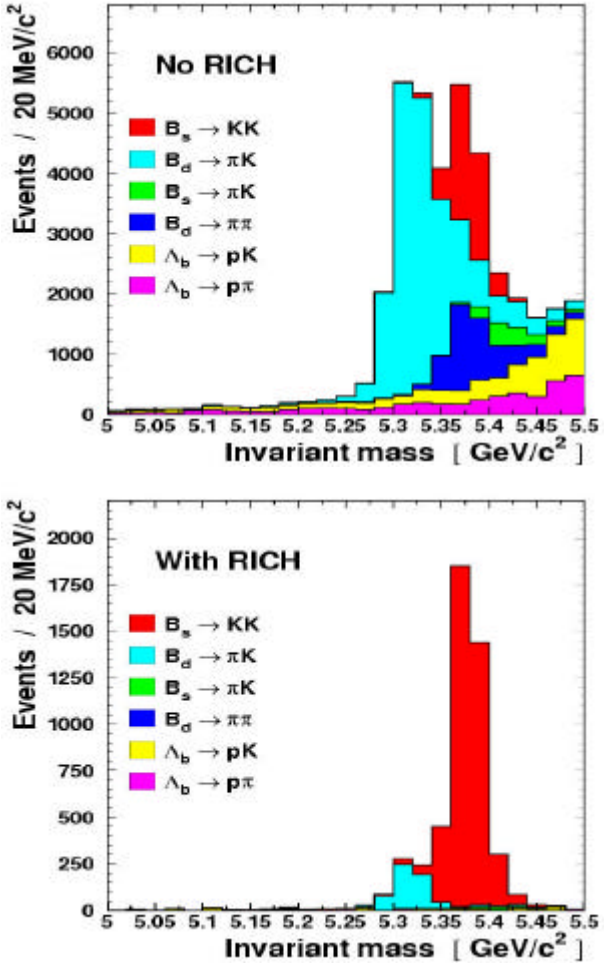
- The LHCb detector and its aims
- Ring Imaging Cherenkov (RICH) system
- Pixel hybrid photon detectors (HPDs)
- HPD characterisation tests
- Conclusions

The LHCb Detector

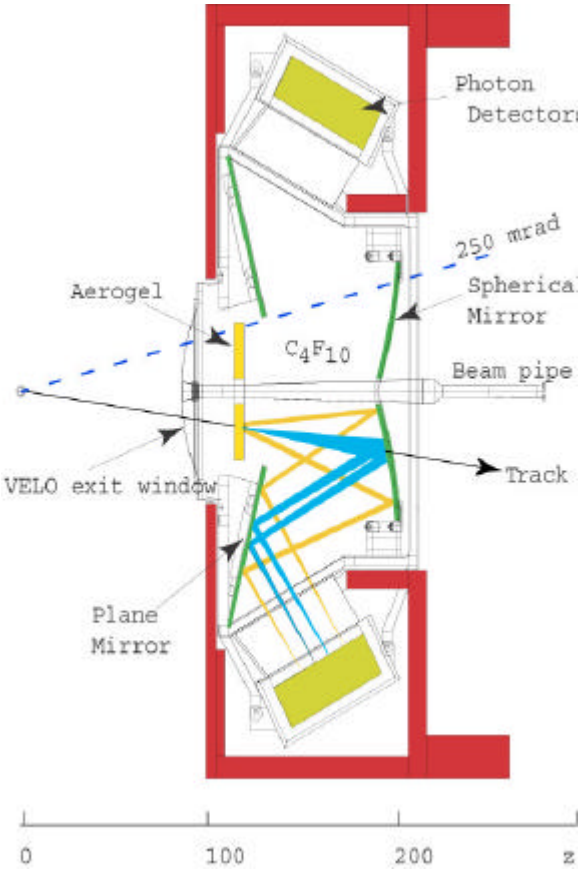


- Single arm forward spectrometer
- Silicon strip vertex detector
- Two RICH detectors for K/pi separation
- 4 Tm dipole magnet
- T1-T3 silicon/straw tracking stations
- M1-M5 muon chambers
- Calorimetry: scintillating pad detector, pre-shower, ECAL and HCAL
- Trigger and DAQ systems

The LHCb RICH System

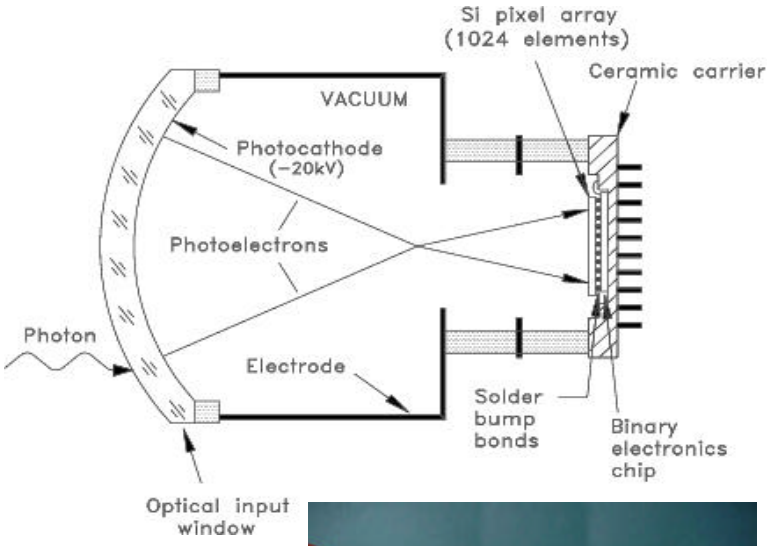


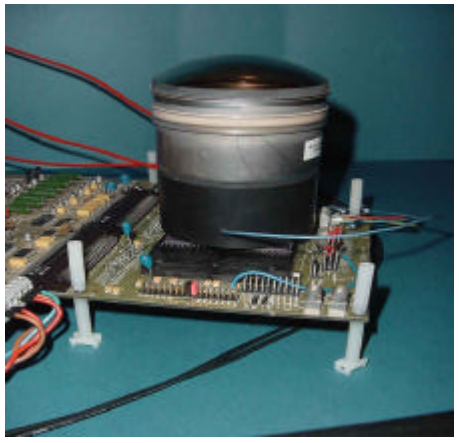
- **Hadron PID important for precise CP studies**
- **Need hadron PID over 1-150 GeV**
- **Use 3 different radiators; aerogel, C_4F_{10} and CF_4**
- **Correlation between particle momentum and angle**
- **RICH system split into two detectors**



RICH1 y-z plane

Pixel Hybrid Photon Detectors





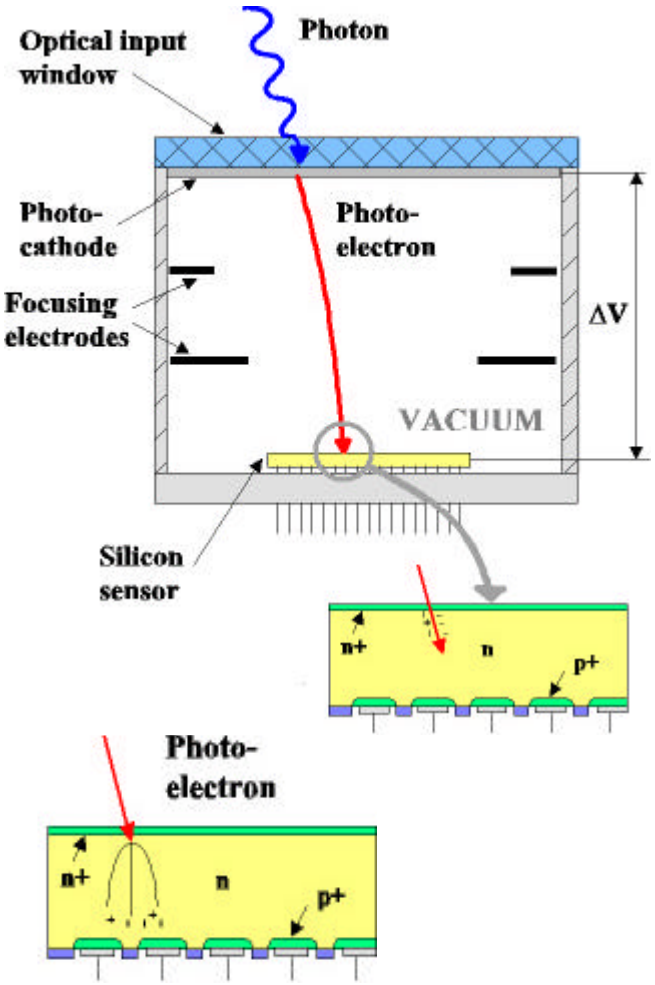
Developed in collaboration with industry to fulfil stringent LHCb requirements :

- single p.e detected in range 200-600nm

- high readout speed of 25ns

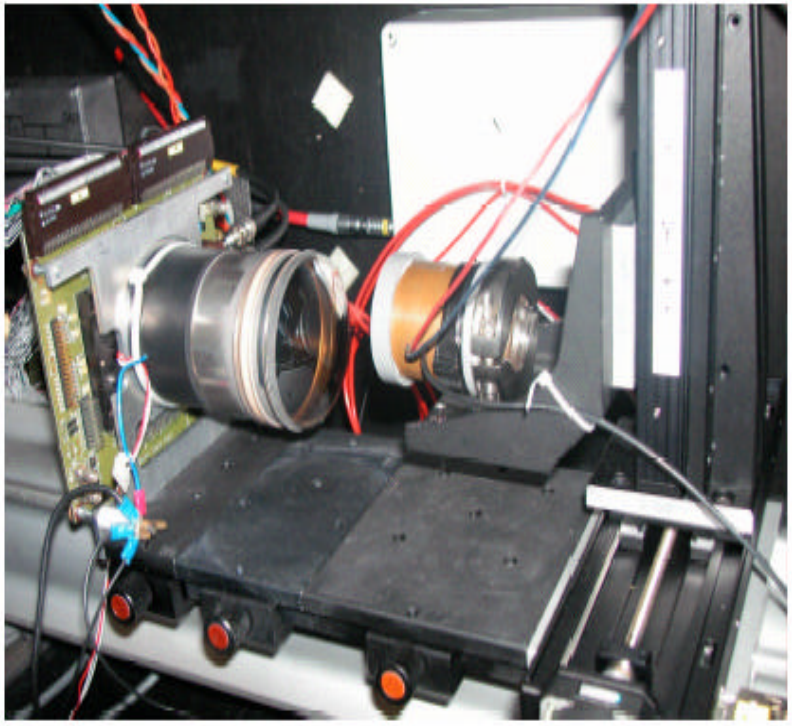
- spatial granularity of 2.5mm x 2.5mm at photocathode level

HPD Description



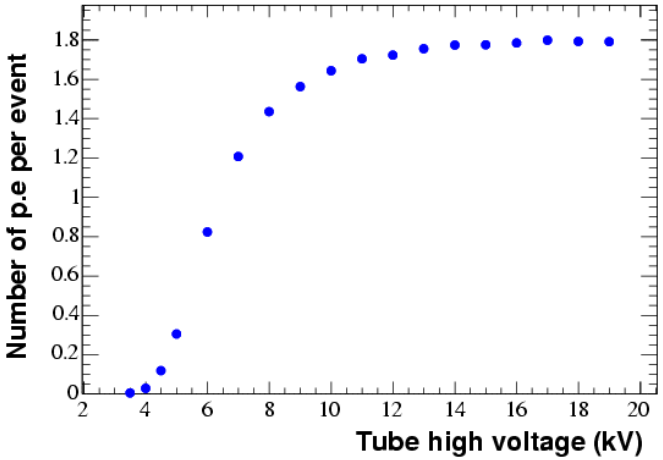
- Multi-alkali photocathode deposited on quartz window inside vacuum envelope
- Photoelectrons accelerated by -20kV onto back side of Si pixel anode
- Si anode array of 256x32 reverse biased p-n junctions
- Each pixel bump bonded to readout cell on binary front end chip
- Electrostatic cross focussing to image and accelerate p.e with demagnification factor ~5

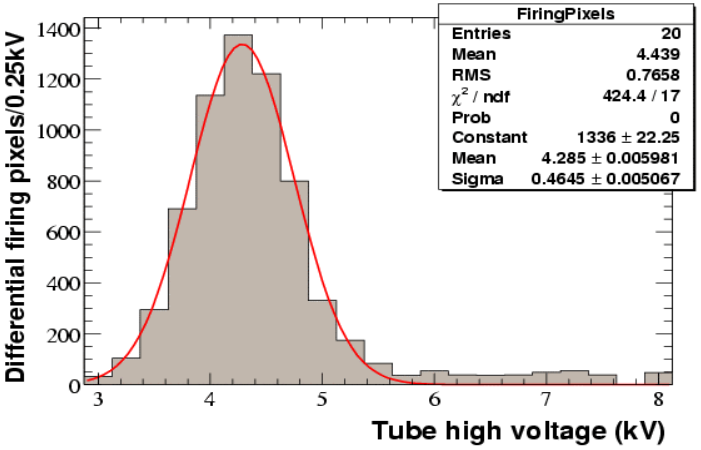
Experimental Arrangement



- Tests carried out in light tight box using fast pulsed LED
- Photoelectron response investigated as function of silicon detector bias and tube high voltage
- Estimation of single p.e detection efficiency
- Ion feedback and dark current rates investigated

Tube High Voltage Scan





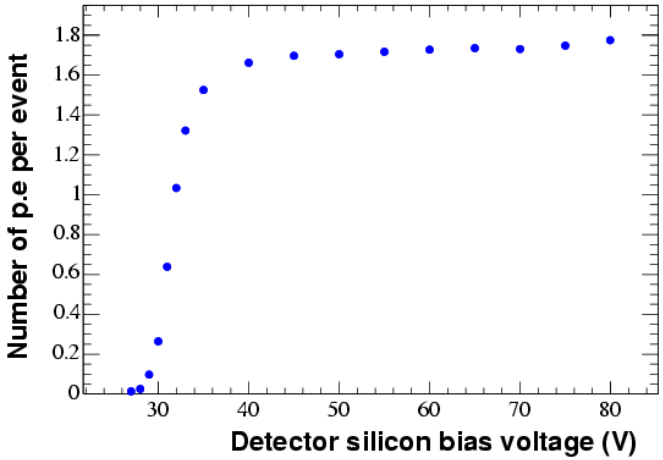
- Increase in HV results in increase of charge deposited in Si
- Plateau not reached due to back scattered p.e
- Differential number of firing pixels plot reflects chip discriminator level :

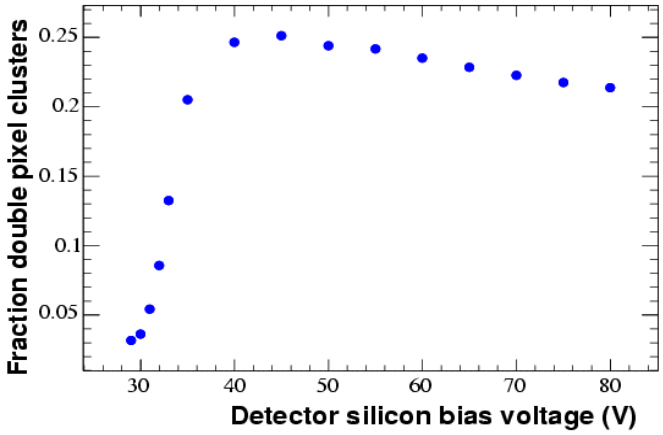
- Average threshold 4.3kV / 3.6eV ~ 1200 e-

-Threshold spread 0.46kV / 3.6eV ~ 130 e-

- Pixels that first fire at high HV correspond to back scattered p.e

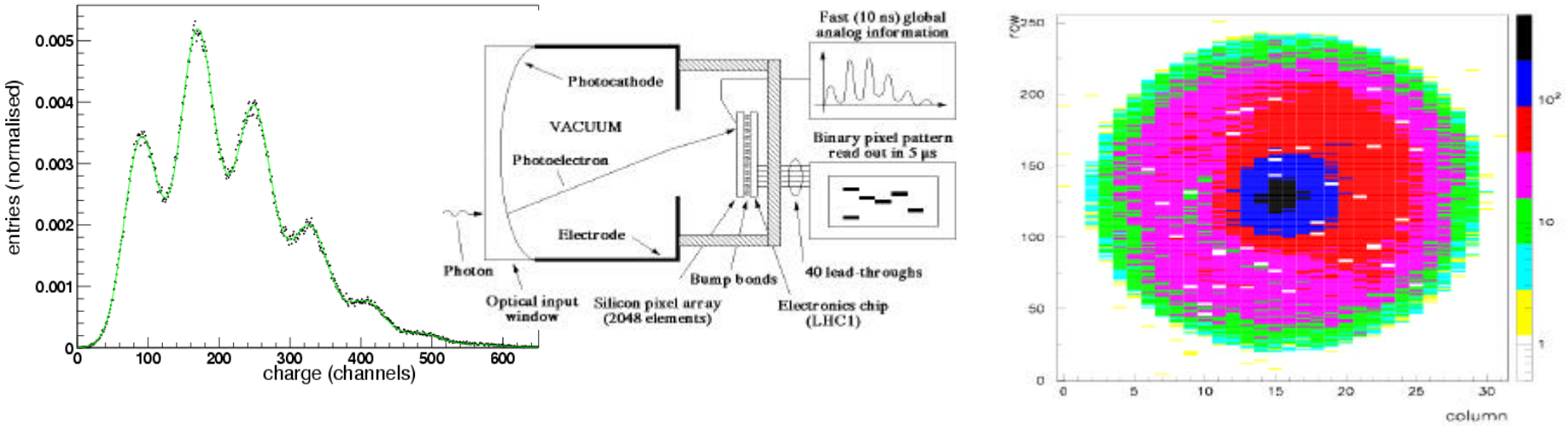
Silicon Detector Bias Scan





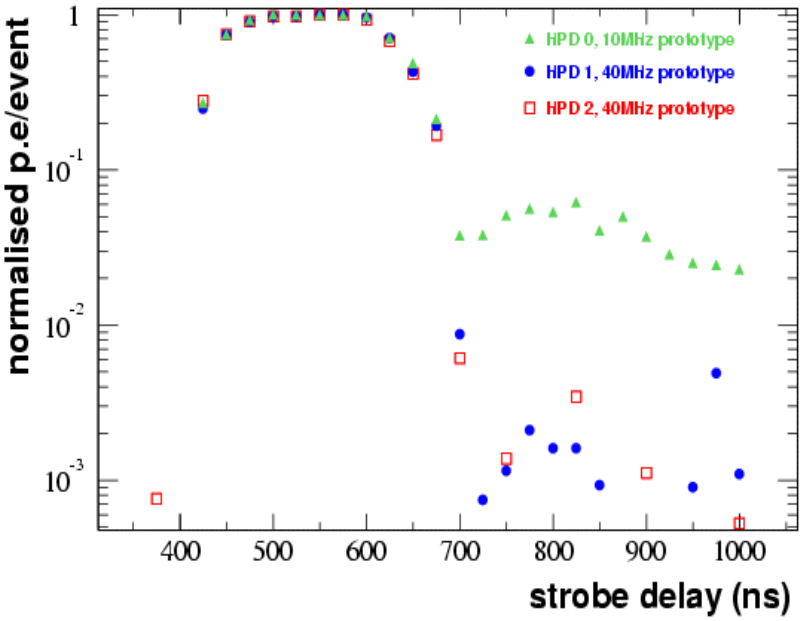
- Below 30V bias p.e stopped within first few microns of Si
- Increasing bias voltage increases charge collection efficiency
- No plateau reached due to charge sharing
- Over depleting silicon reduces fraction of double pixel clusters due to decrease in charge sharing probability

Photoelectron Detection Efficiency



- Analog back pulse signal used to calibrate pixel binary data
- Fit analog data to estimate average number of p.e reaching detector
- Back pulse measurement only possible in lab tests
- Corrections to binary data to account for charge sharing
- Photoelectron detection efficiency ~ **88 %**

Ion Feedback Rate



- Ionisation of residual gas traces originating from :

- non perfect evacuation process

- migration of gases through entrance window

- material desorption in tube structure

- Ion feedback signal recorded after primary pulse according to ion transit time (typically 220 ns)

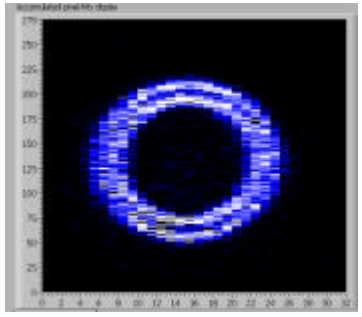
- **Ion feedback rate < 0.5 %**

Dark Current Rate

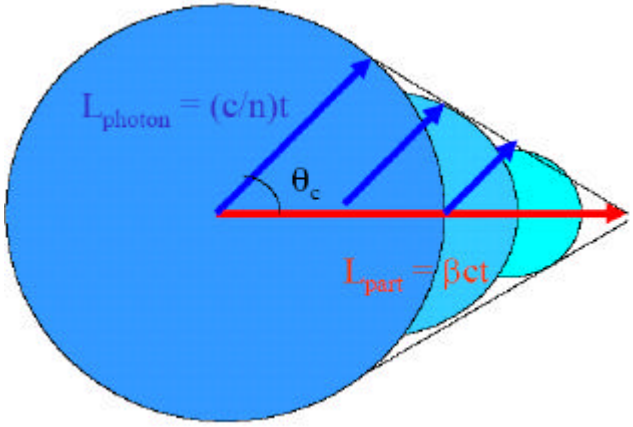
- Current that flows when a voltage is applied to a tube in total darkness
- Main source is photocathode thermal emission
- **Dark current rate ~ 1 kHz/cm^2 at 25^{o}C**
- Typical multi alkali photocathode dark current rate ~ 10 kHz/cm^2 at 25^{o}C

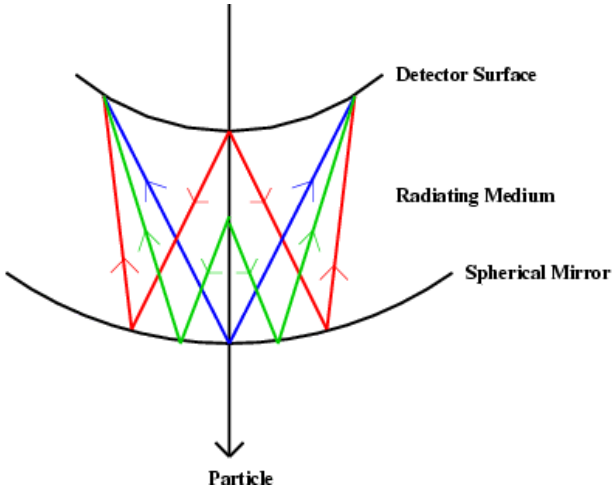
Conclusions

- **Proven HPD fulfils LHCb design specifications**
  - **Discriminating threshold ~ 1200 e-**
  - **Threshold spread ~ 130 e-**
  - **Single photoelectron detection efficiency ~ 88 %**
  - **Ion feedback and dark current background small**
- **HPD performance also verified in test beam environment**



The RICH Principle

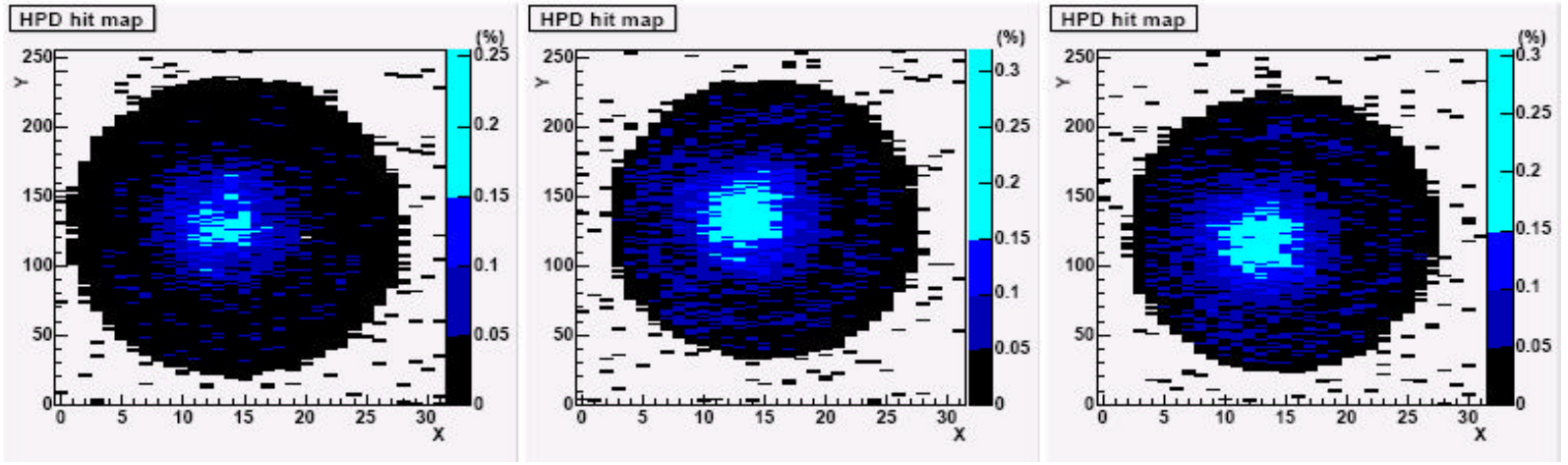


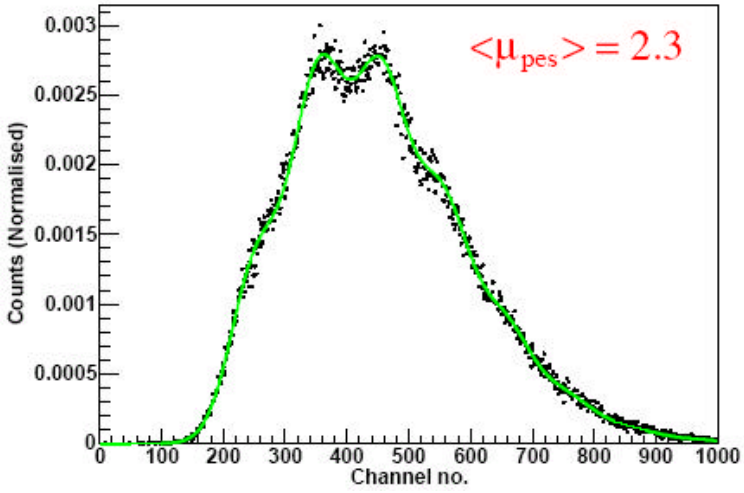


- If a charged particle traverses a medium, at a velocity greater than speed of light in that medium then Cherenkov light is emitted
- Opening angle of emission cone is

  cos ? = 1 / ßn
- RICH detectors measure angle of emission of the radiation using spherical mirror system
- Photon detectors placed at the focal length to detect Cherenkov radiation rings
- All photons emitted at same angle are focussed onto a point

Latest Prototype Results





Detection efficiency ~ 87%

Dark current rate ~ 0.3 kHz/cm²

Fraction of non-operational pixels < 0.1%

Performed by Naoko Kanaya