Hybrid Photon Detectors for LHCb

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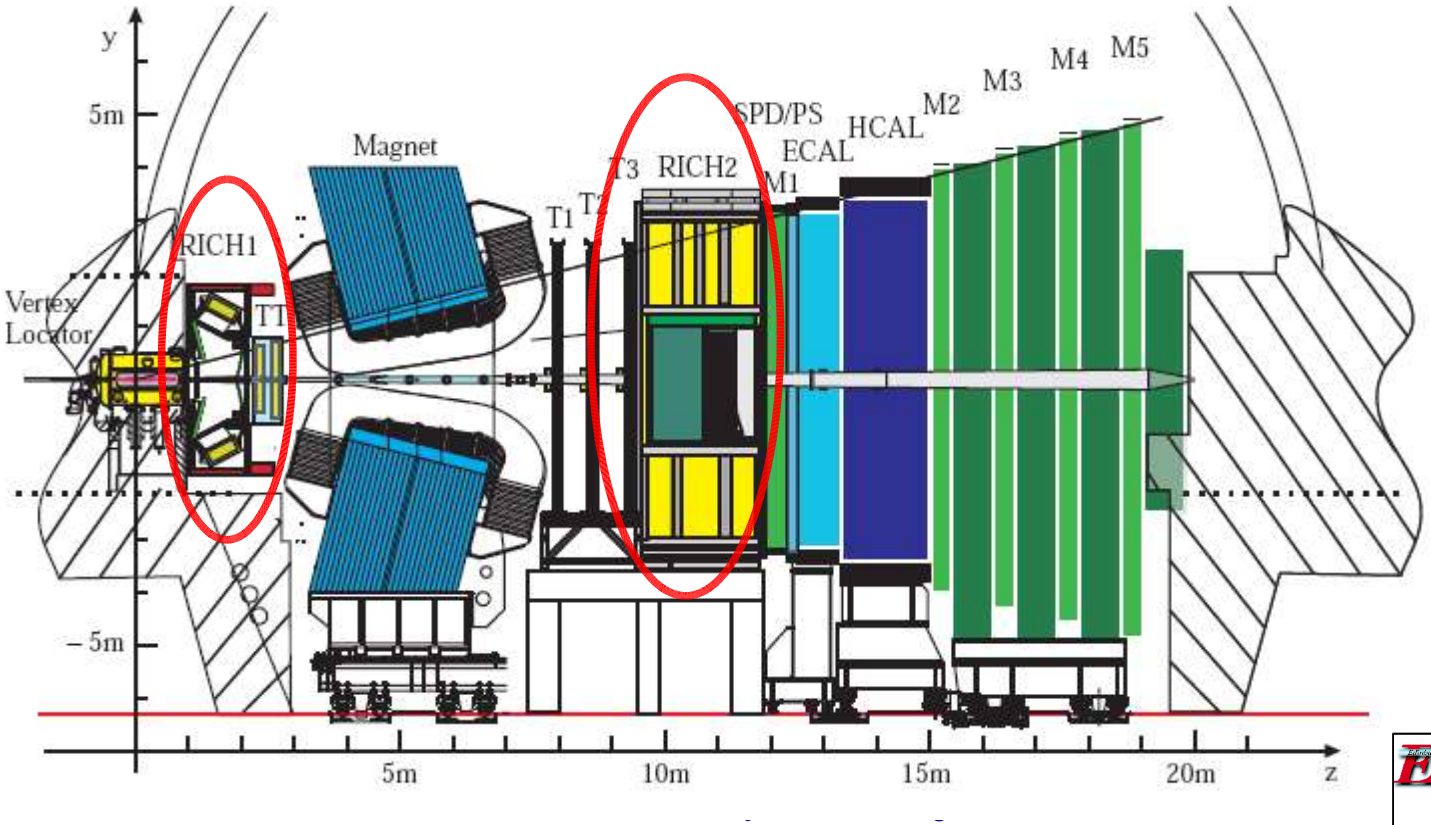
on behalf of the Edinburgh / Glasgow teams

The LHCb Experiment

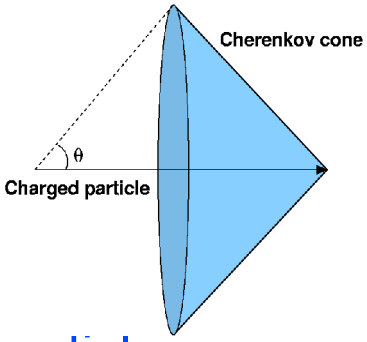
- One of the four experiments at the LHC
- p-p collisions at 14TeV centre-of-mass energy
- Single-arm spectrometer
- Aims to study Charge-Parity Violation ($\not{CP}$) in B-mesons



RICH detectors

- Two Ring Imaging Cherenkov detectors (RICH) enable charged particle ID
- Gives K/π separation needed for CP studies
- Cherenkov radiation:

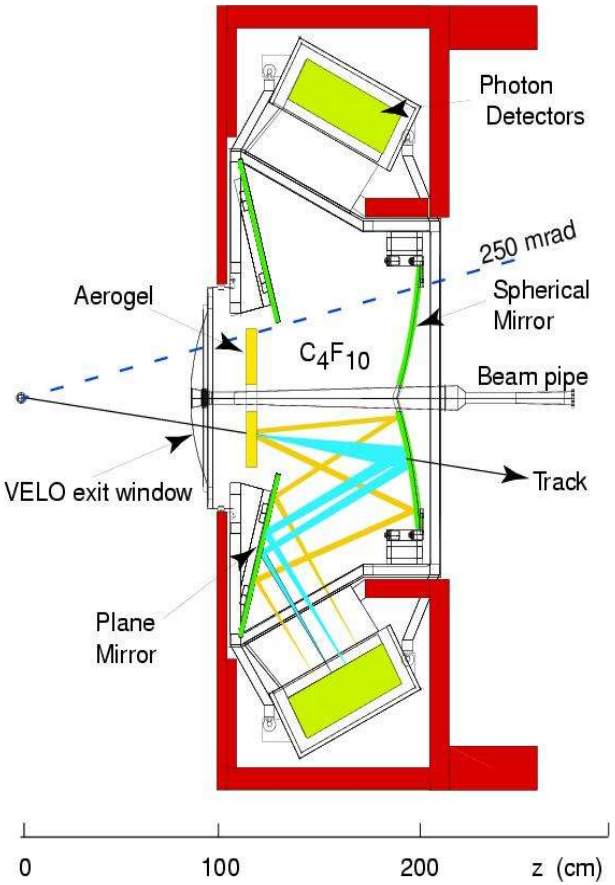
$\cos\theta = 1/(n\beta)$



- → angle dependent on velocity, combined with momentum gives particle mass
- Three radiators used:

RICH 1	C4F10/	n=1.0014/	Low-momentum particles
	Aerogel	n=1.03	
RICH 2	CF4	n=1.0005	High-momentum particles

→ wide momentum range (1-100 GeV/c)



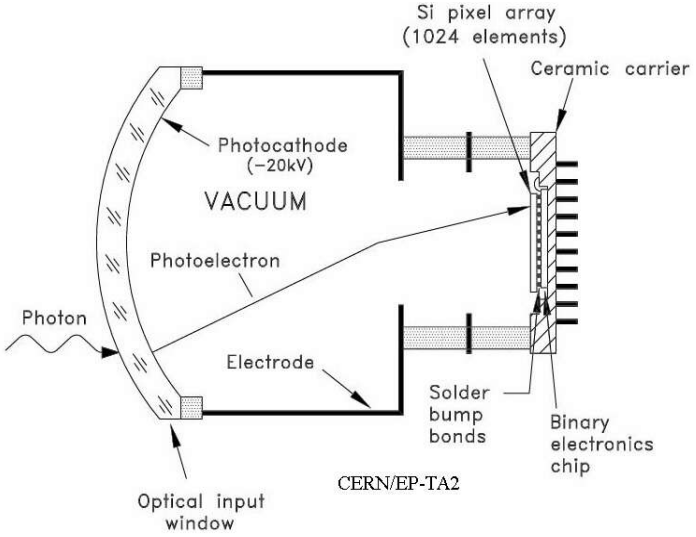
RICH 1

- Spherical mirrors focus light rings on arrays of light detectors (HPDs)

Hybrid Photon Detectors (HPDs):

- HPDs are sensitive light detectors : hybrid between silicon sensors and photomultiplers

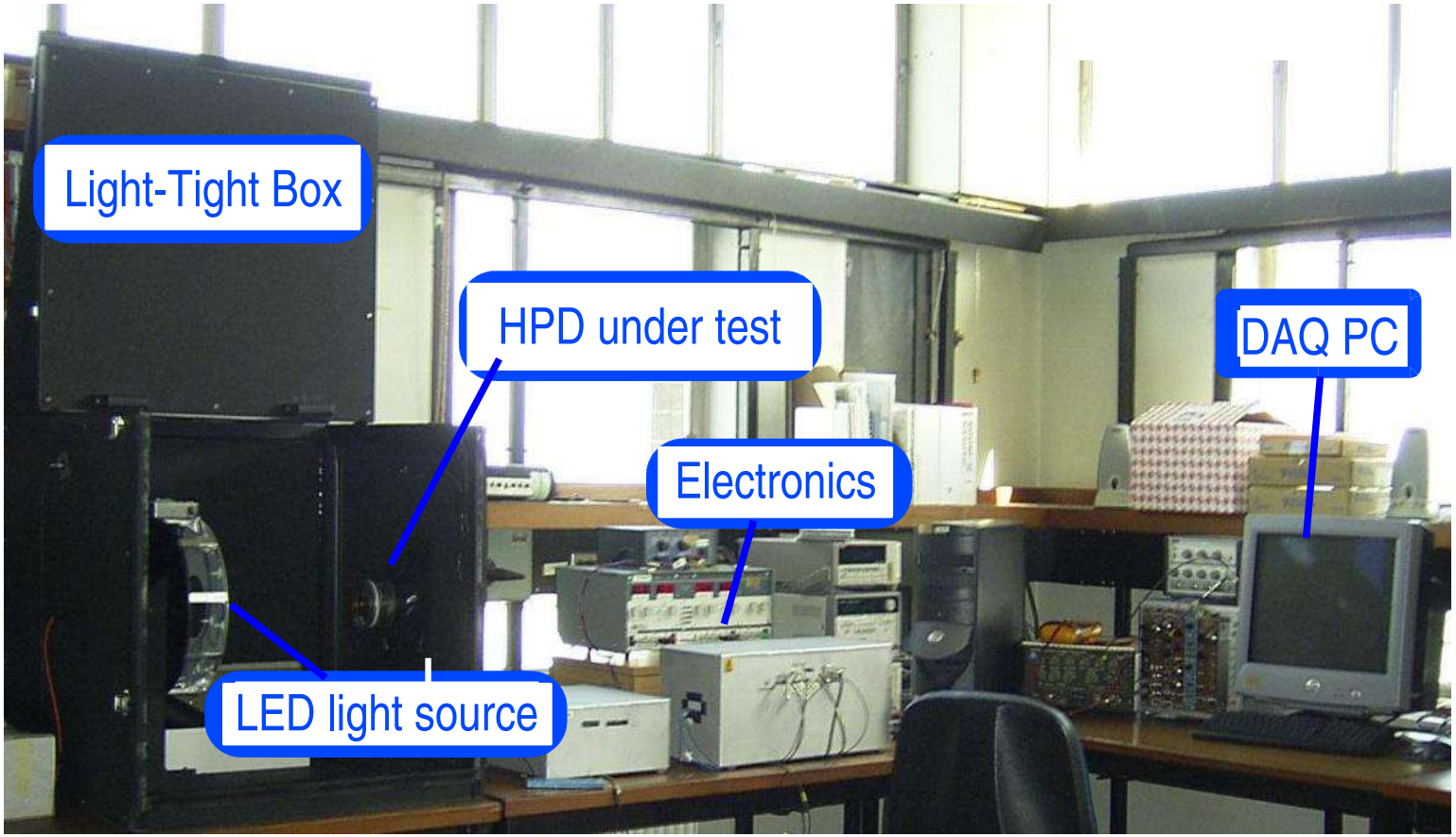
- Quartz window with multi-alkali photocathode
- Cherenkov light hitting photocathode releases photoelectrons.
- Accelerated by high voltages (~20kV) and focussed.
- Photoelectrons hit reverse biased silicon diode
- ~5000 e^- - hole pairs formed
- Anode separated into 8192 pixels
- Position of hits digitised by bump-bonded sensor chip



HPD Testing in Scotland

- ~550 HPDs needed for RICHs
- Being tested in Edinburgh and Glasgow:
  - 162 delivered
  - 136 tested
- HPDs delivered at ~30 per month
  - split evenly between each site
- Two full test chains at each site:
  - one for mandatory QA tests
  - other for further characterisation/redundancy
- We are testing 1 HPD per day at each site
- Extended tests for a sub-sample of HPDs
  - Quantum Efficiency

HPD Testing in Scotland:



Test station at Edinburgh, showing dark box and electronics

Test Procedure

- Leakage Current vs. Bias Voltage Scan– IV curve of anode
- Threshold Scan - Determines optimum working thresholds

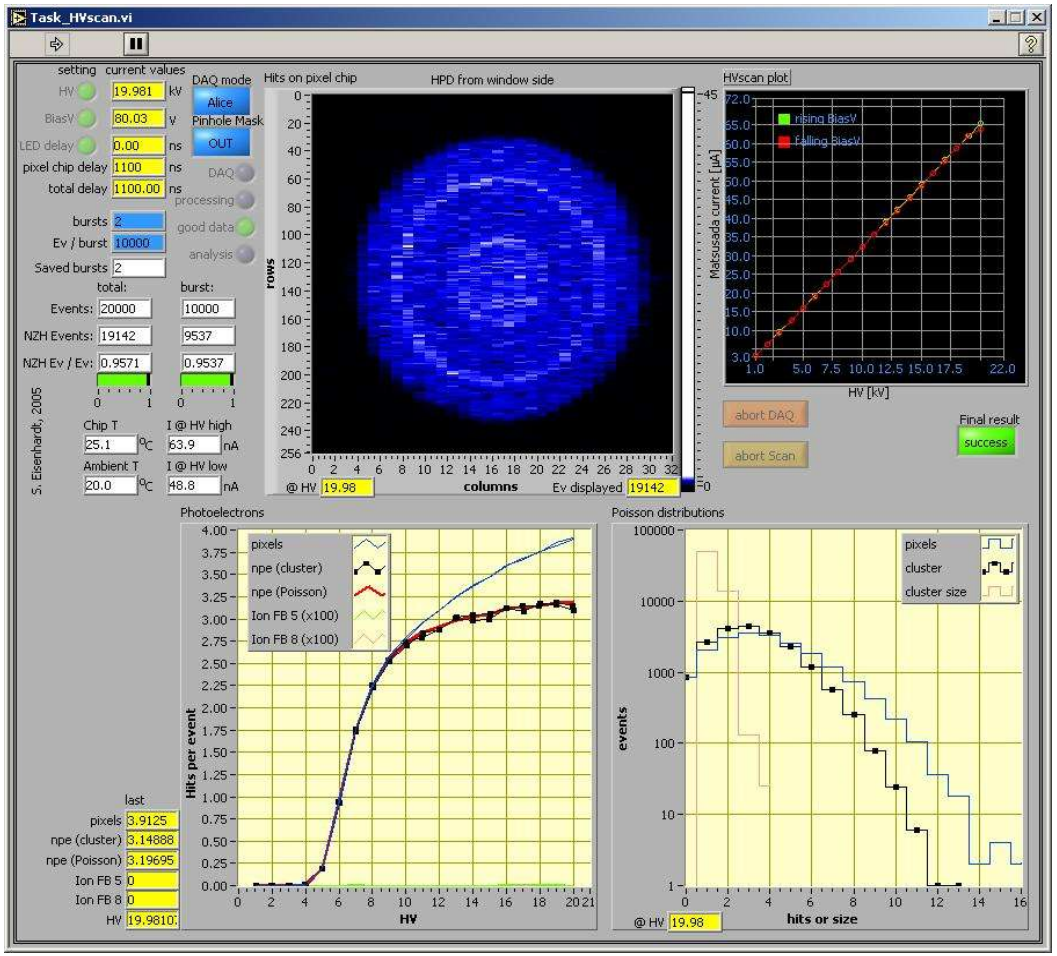
TESTS CHIP FUCTIONALITY

- High Voltage Ramp-Up – Slowly ramps voltage to 20kV
- Strobe Scan - Finds optimum timing of LED wrt DAQ trigger
- Ion Feedback Rate Scan – Measures ion feedback
- Bias Voltage Scan - Photoelectron response as bias voltage on anode varied
- High Voltage Scan -Photoelectron response to Voltage ramp-up and ramp-down
- Long LED Run - 200 k triggers
- Dark Count – 5 million triggers
- Distortion Map – tests focussing of HPD

TESTS TUBE FUNCTIONALITY

Automated Testing

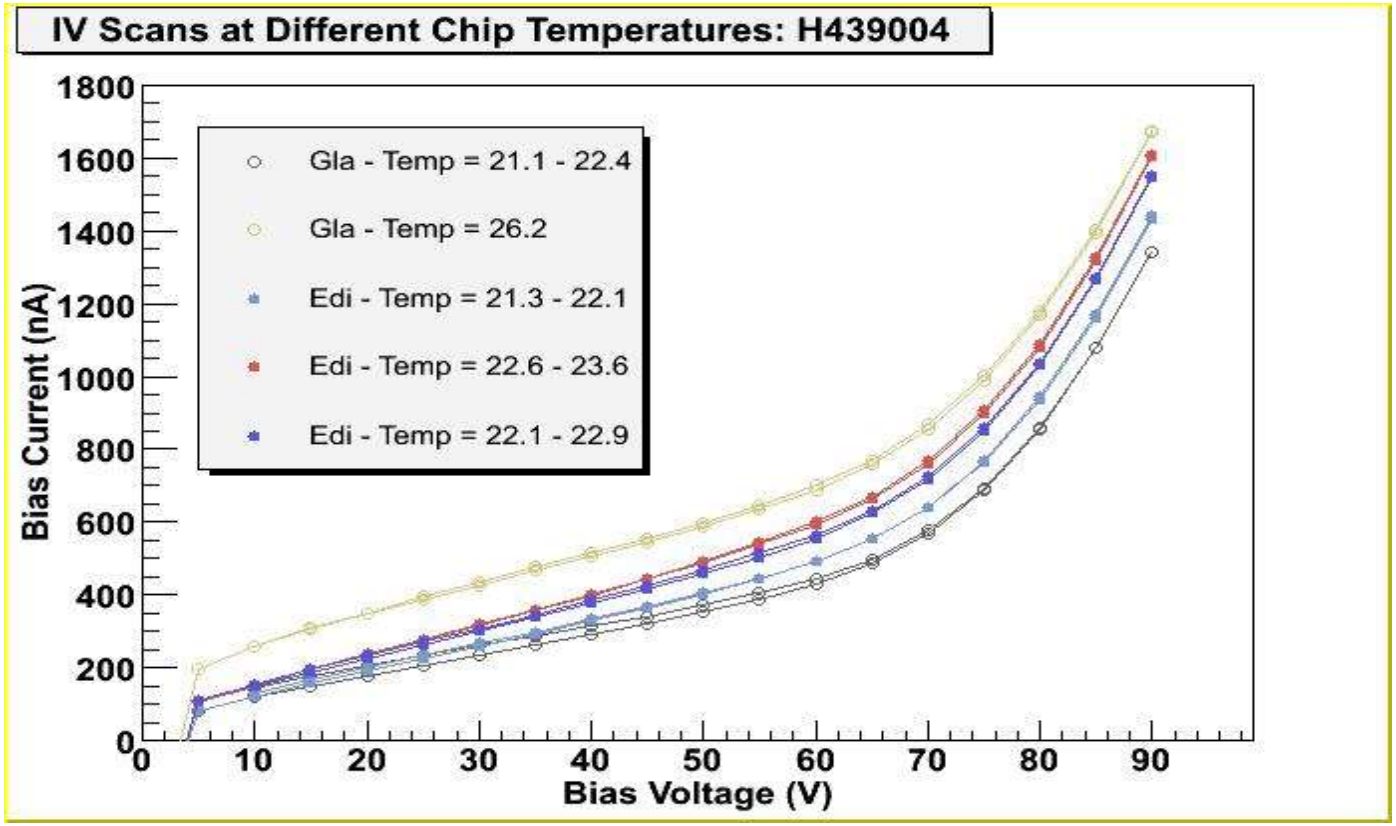
- Labview software written to:
  - automate testing of HPDs
  - record results at each step of testing
- Online analysis (eg clustering algorithm)



High Voltage Scan

Leakage Current vs Bias Voltage Scans

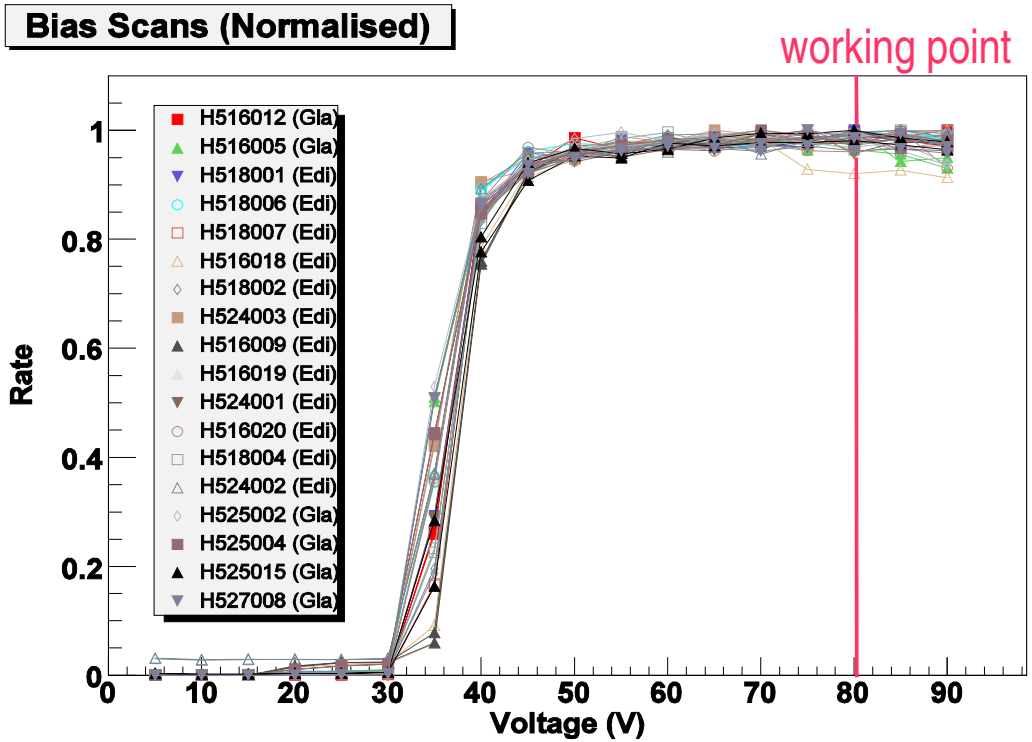
- Characteristic IV curve of anode



- Current needed to deplete sensor is dependent on temperature

Bias Voltage Scan:

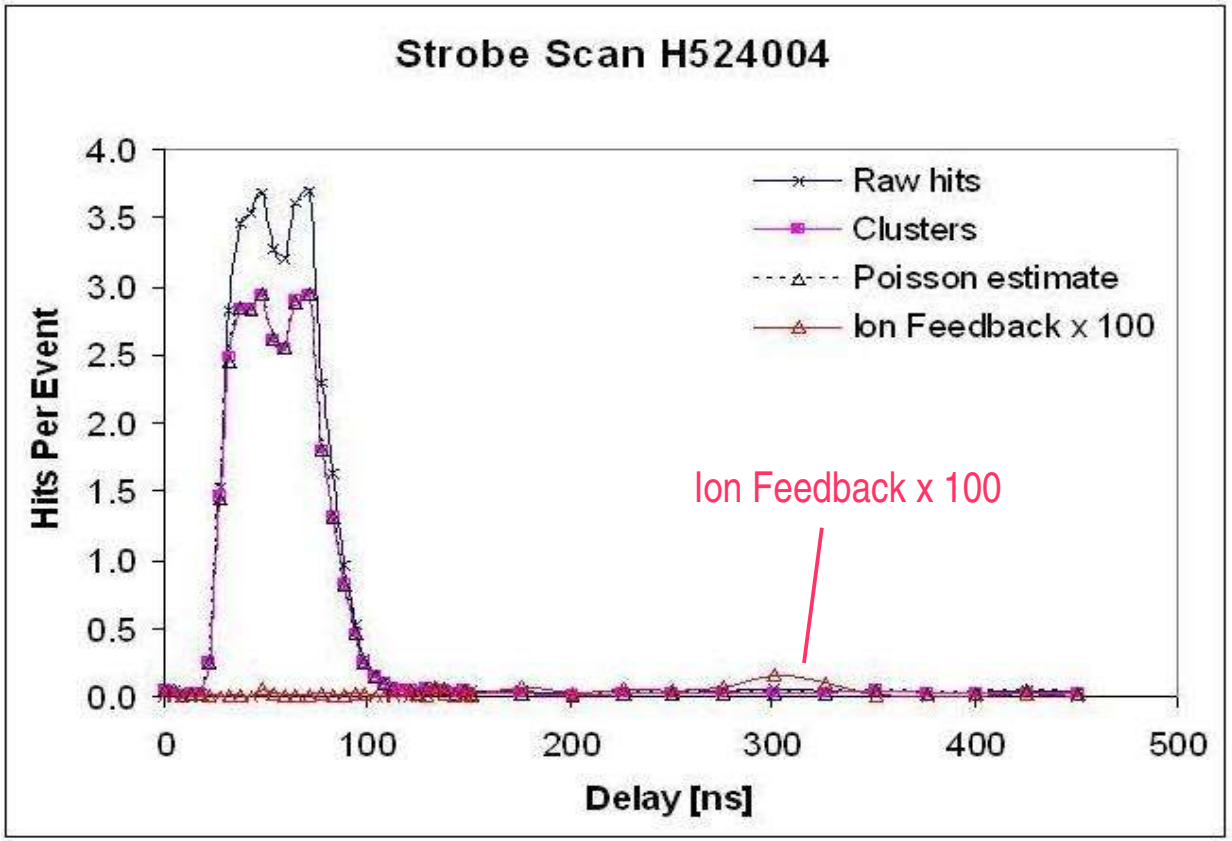
- PE response to LED light as bias voltage on anode varied



- Excellent agreement between Glasgow and Edinburgh
- Maximum response always in same range
- Same “turn on” for depletion

Ion Feedback

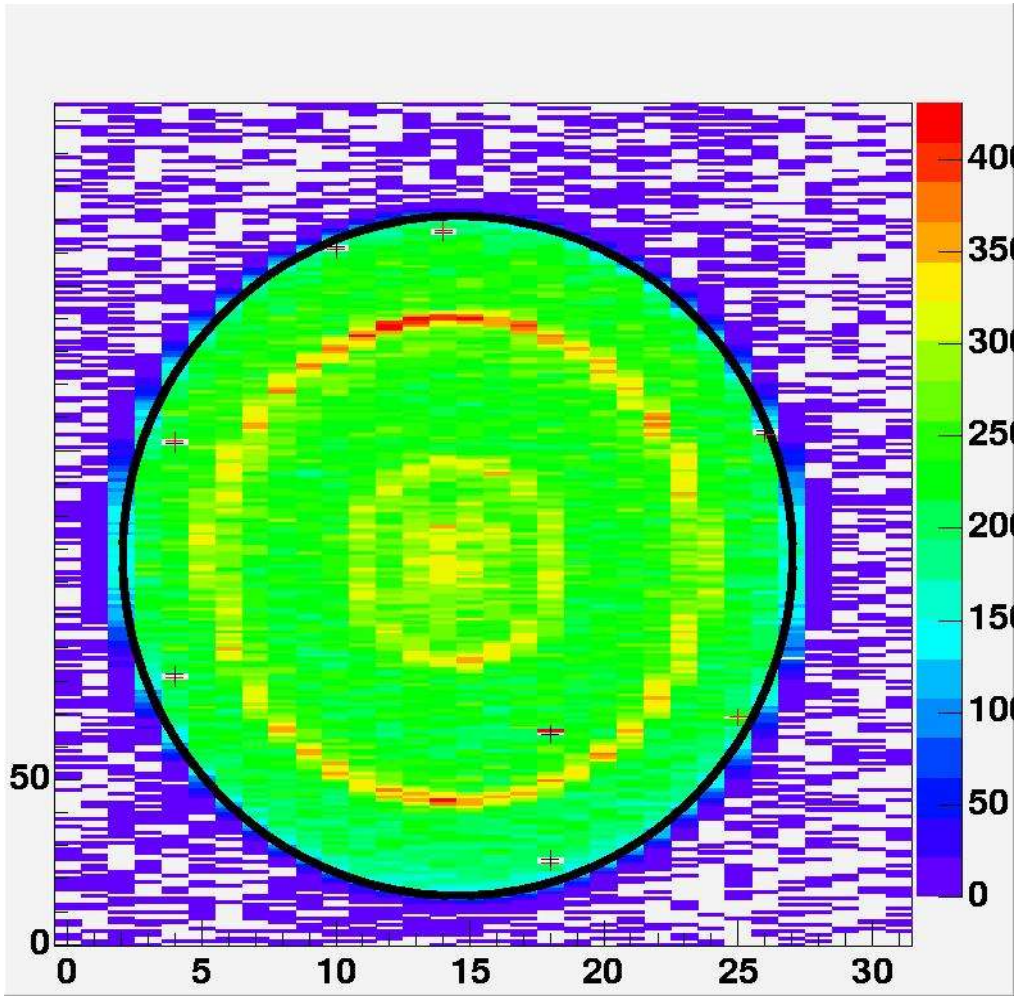
- Profile of Ion Feedback gives measure of vacuum quality



- V.Low ion feedback (<<1%) : Excellent Vacuum

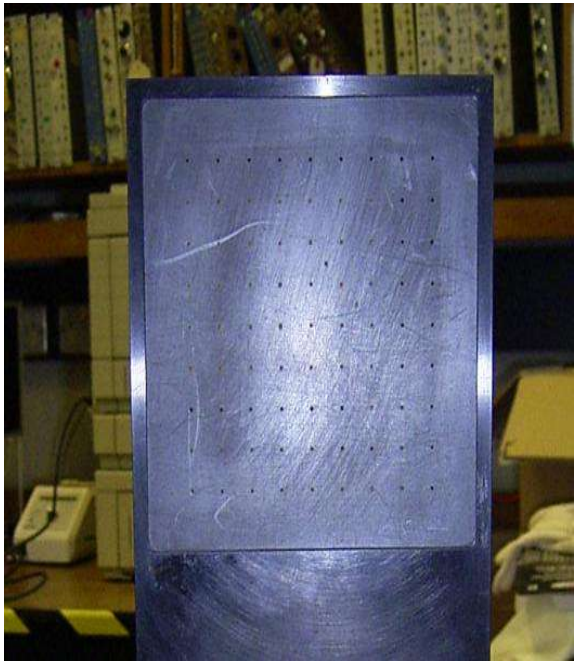
Long LED Run

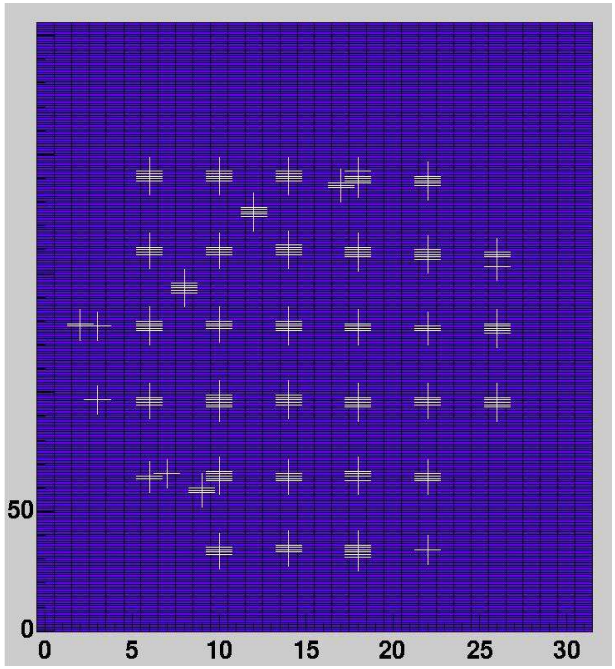
- Photoelectron response to LED light
- 200k triggers
- Analysis shows:
  - Number of dead pixels at chip level
  - Position of photocathode image on pixel chip (centre x,y, radius)

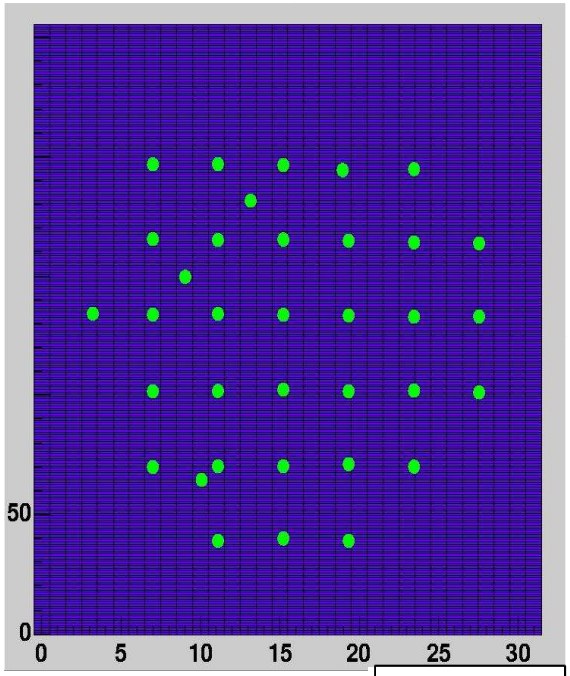


Pinhole Mask: Distortion

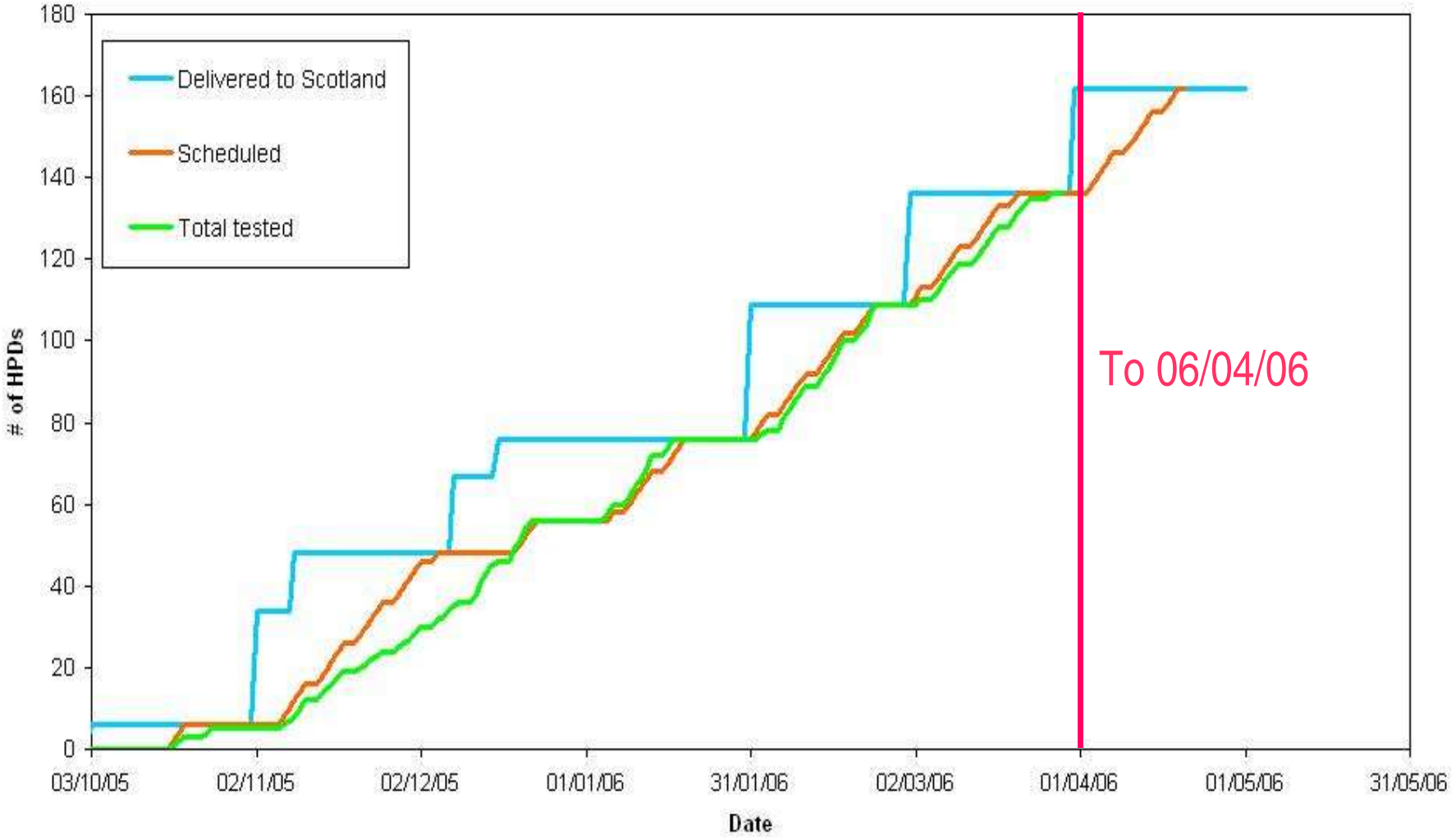
- Pinhole mask with irregular pattern
- Comparison with reference file
  - -Tests electrostatic focussing of HPD
  - - Refines demagnification / positioning







Progress


Delivered to Scotland
Scheduled
Total tested
To 06/04/06
# of HPDs
Date
0
20
40
60
80
100
120
140
160
180
03/10/05
02/11/05
02/12/05
01/01/06
31/01/06
02/03/06
01/04/06
01/05/06
31/05/06

Conclusions:

- Testing at Edinburgh and Glasgow is continuing at 1-a-day rate
  - Excellent agreement between sites
- HPDs meet requirements for LHCb RICH
- HPDs have pass rate > 95%