Edinburgh PPE Seminar

# RICH Detectors for the LHCb: 2006 Test Beam Studies

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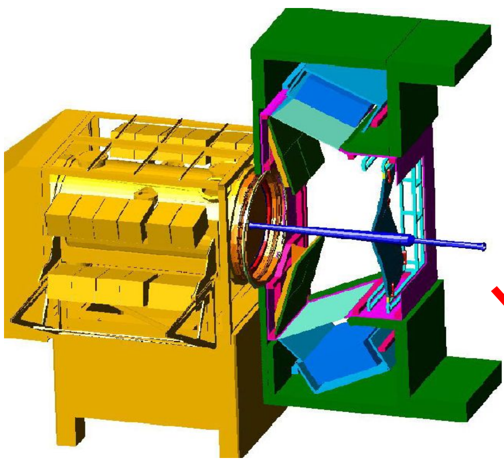
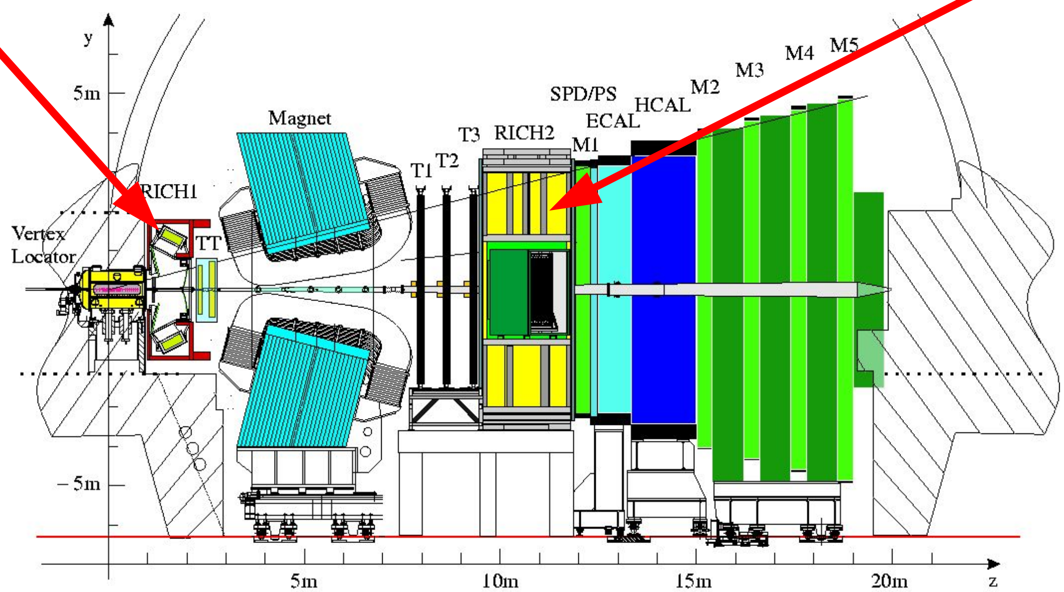
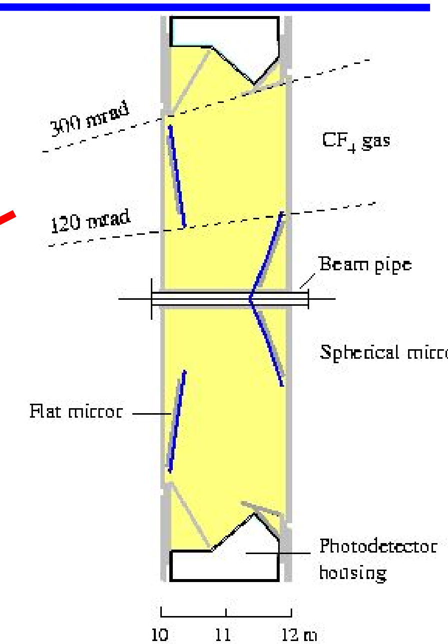
Thursday 24th August 2006

# RICH 1 & RICH 2 Detectors






RICH 1:

- $C_4F_{10}$ & Aerogel Radiators
- Identifies particles with momentum <60 GeV, which would otherwise be swept out of the detector acceptance by the magnet

RICH 2:

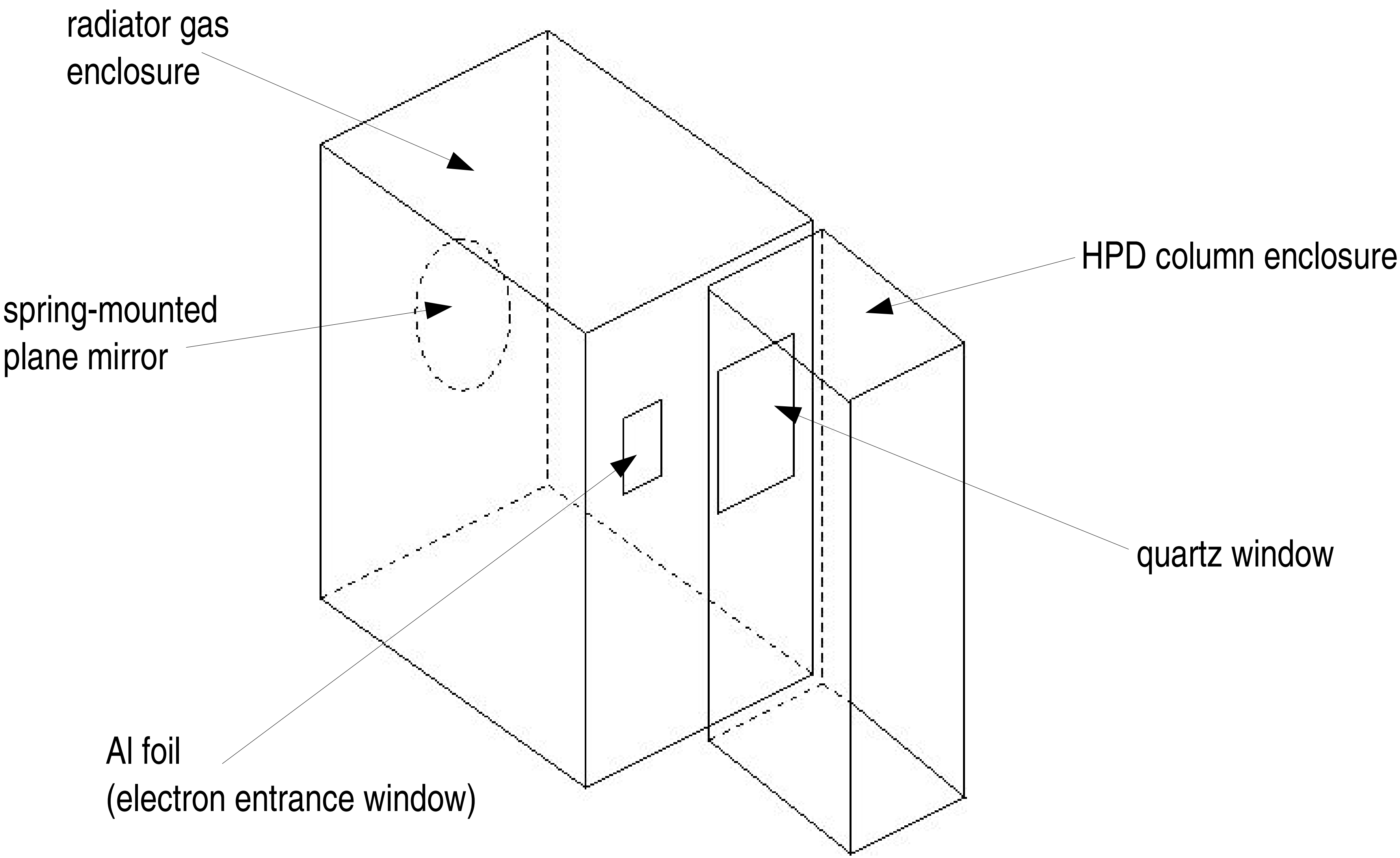
- $CF_4$ gas radiator
- Identifies higher momentum particles
- $\pi$-K separation up to 110 GeV

# Beam Test Facility (1)

# Beam Test Facility (2)

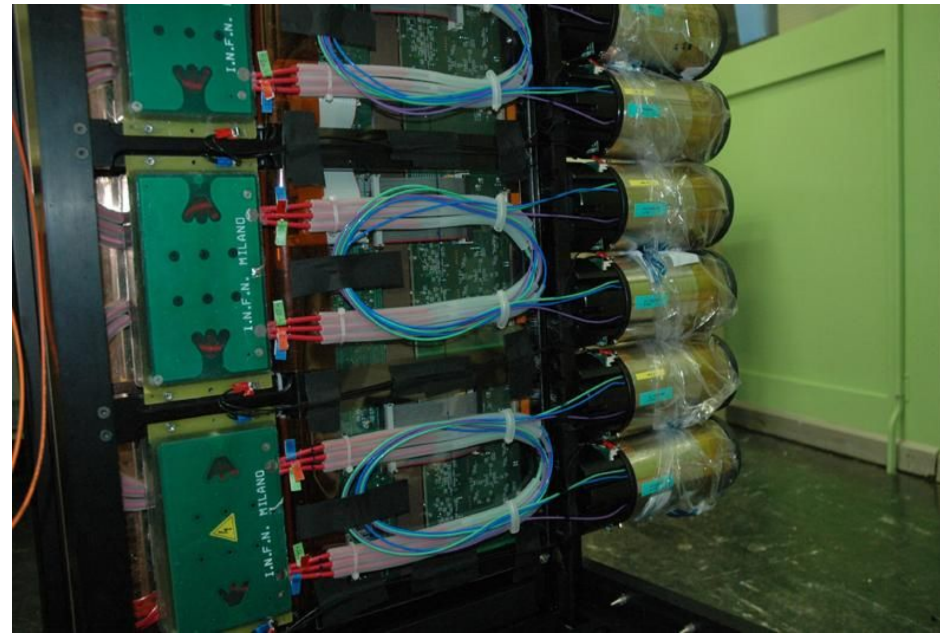
- Uses 500 MeV electrons from DA$\Phi$NE linac
  - 500 MeV is sufficiently high energy for saturation, i.e. the Cherenkov angle is at its maximum, with $\beta \longrightarrow 1$
- Beam has tunable multiplicity, but was used (for the most part) in single-electron mode
- Beam is asynchronous, meaning electrons arrive randomly wrt internal clock pulses, so timing scans are required to obtain peak efficiency
- Beam is available on average 20 minutes in every hour, in between injection of electrons/positrons into the DA$\Phi$NE collider.

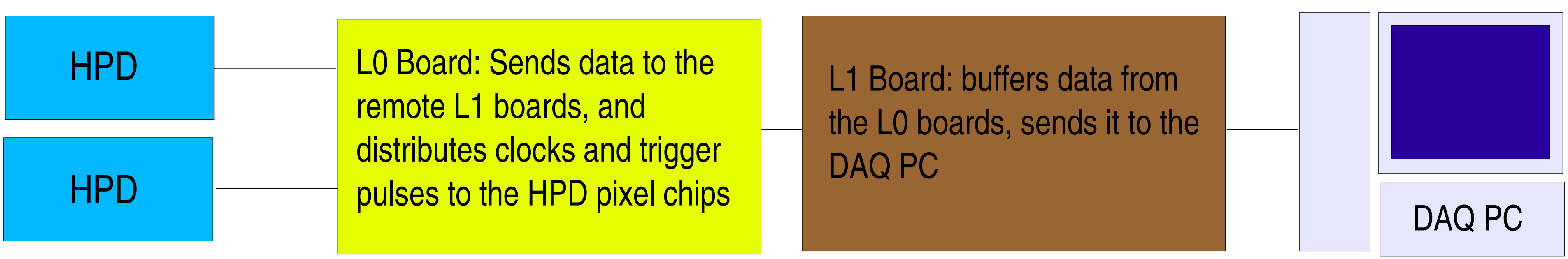
# The SSB


radiator gas
enclosure
HPD column enclosure
spring-mounted
plane mirror
quartz window
Al foil
(electron entrance window)

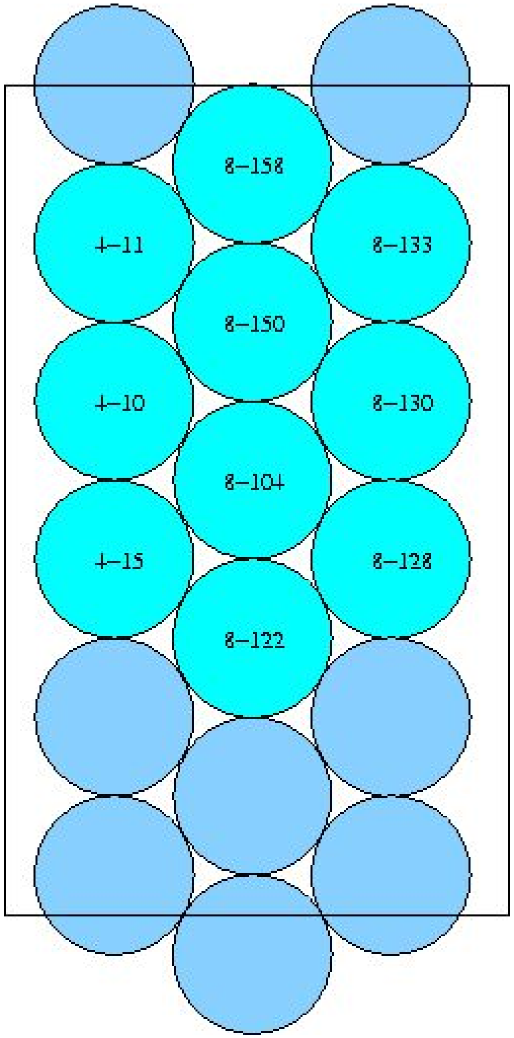
# HPD Column Layout (1)

- HPDs wrapped in kapton insulation and magnetic shielding material (mumetal/supra 36)
- 2 HPDs per Level 0 readout board
- High-Voltage distribution boards provide HPD Photo-cathode, Focus and Zoom voltages
- Low-Voltage distribution boards provide silicon bias voltage and various electronics voltages





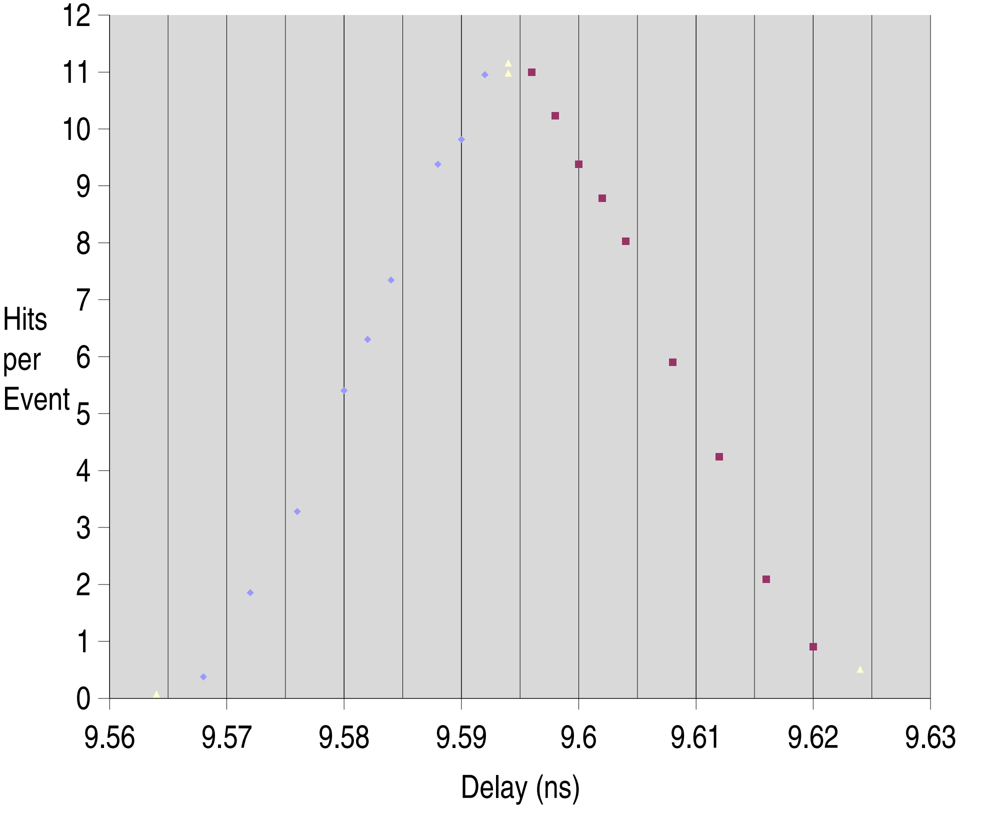
# HPD Column Layout (2)



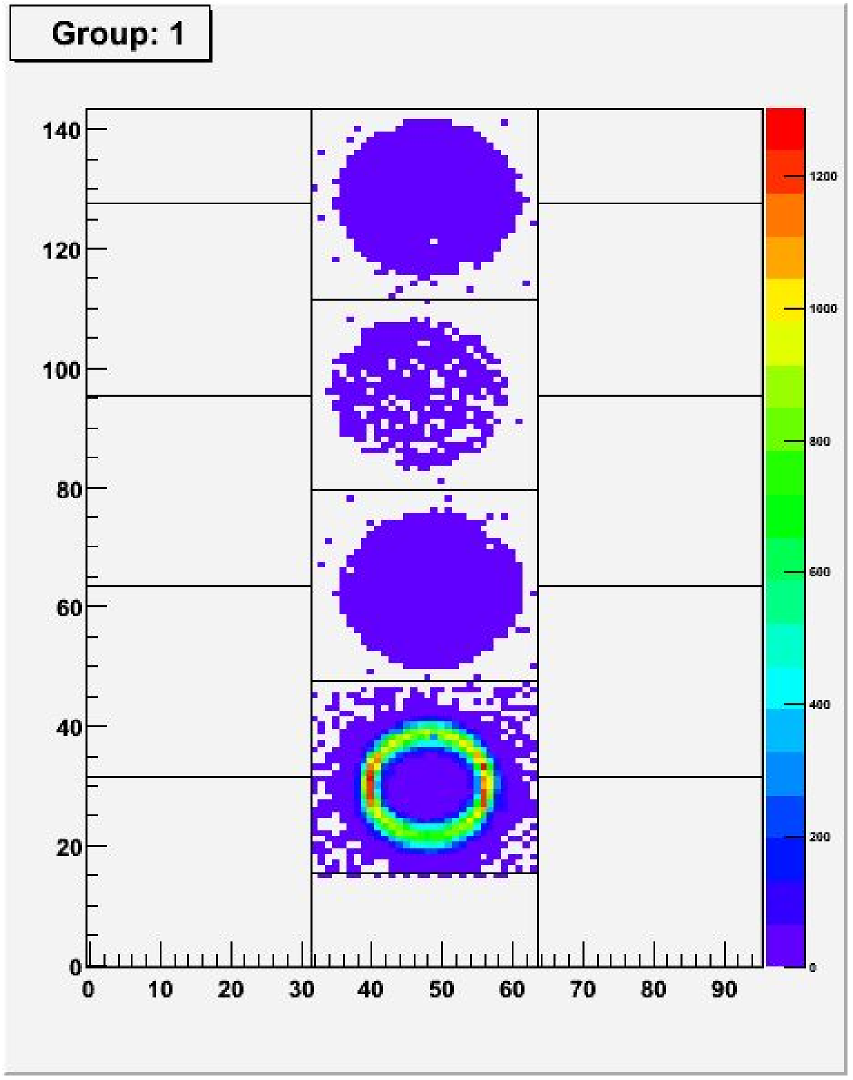

- In total, 36 HPDs mounted (12 on each of 3 columns)
- Not all of these HPDs (only 18) can be illuminated, due to the size of the quartz window
- Of these 18, only 10 can have a Cherenkov ring positioned on them, due to limitations of the mirror
- For these 10 HPDs, timing scans, dark count and LED runs, as well as Cherenkov runs with both $N_2$ and $C_4F_{10}$ radiators

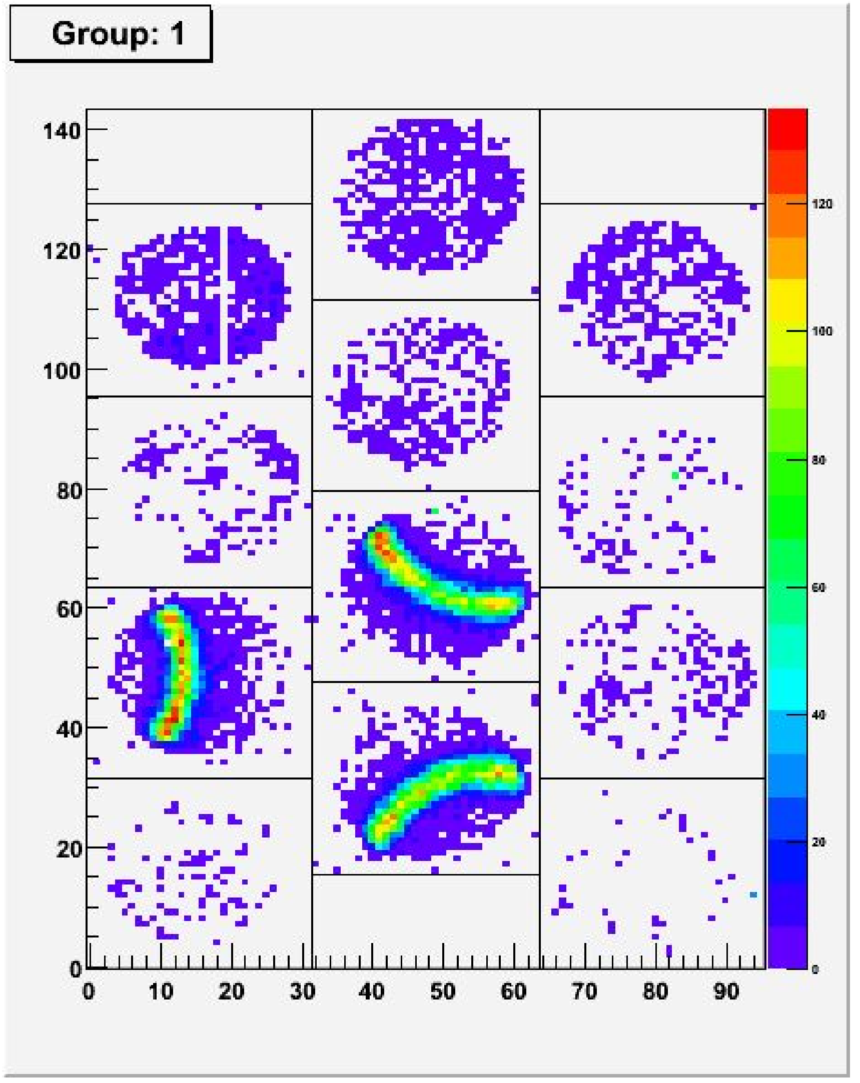
# Timing Scans

- Asynchronous beam means timing scans are required to obtain maximum efficiency
- Delay of the beam trigger pulse is varied with respect to the L0 clock pulses
- The convolution of two 'top-hat' distributions produces the timing 'triangle' seen on the plot to the right
- Timing scans were performed on each HPD accessible with the SSB mirror – peak timing varies from HPD to HPD
- 2 HPDs on the same L0 board are tied to have the same timing, so for runs when more than one HPD on the same board is used ($C_4F_{10}$ runs), the average peak time of the two was used



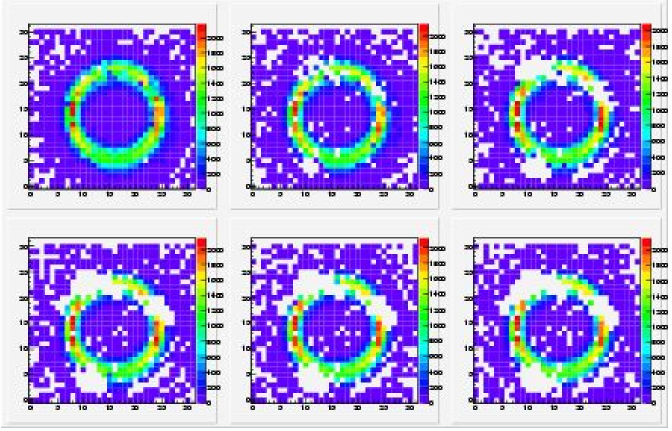
# Cherenkov Rings

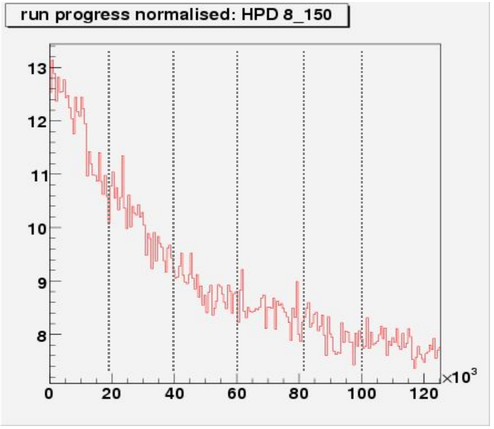


# Dying Pixel Problem

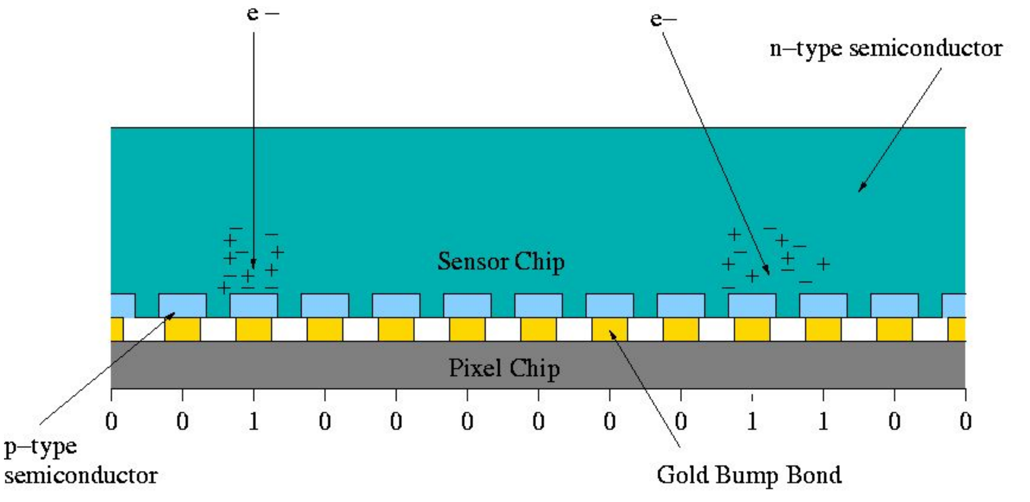
- It was noticed that as runs progressed, pixels around the ring would turn themselves off, and become unresponsive to either light or test pulse charge injection
- This problem was only apparent in LHCb mode, where 8 pixels are ORed to form an LHCb 'super-pixel', and not in ALICE mode, where each pixel is read out individually
- The pixels came back to life once a L0 reset signal was sent, so for the duration of the test beam a L0 reset signal was sent after every 500-trigger data burst
- The problem was later isolated at CERN, and a single logic block, the delay line busy logic used in the 8-fold ORing, was found to be the cause. The problem has now been fixed





# Charge Sharing

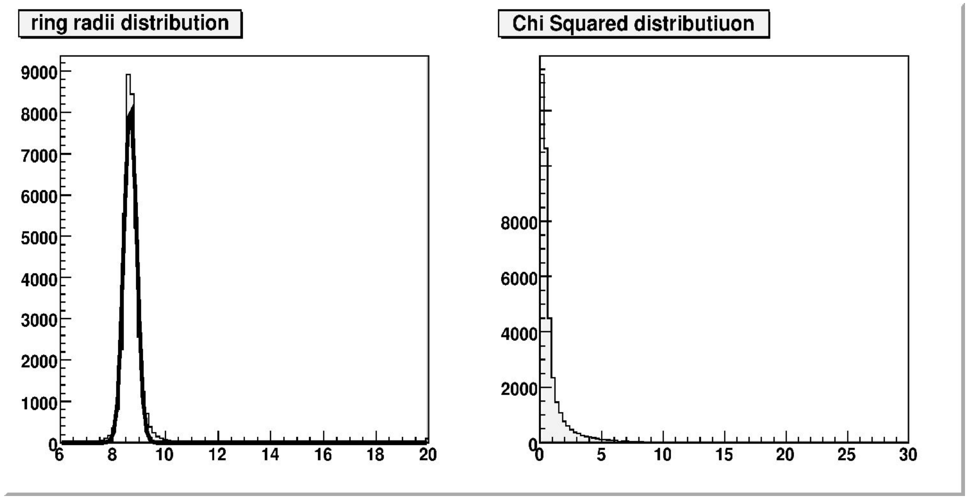
- Each photo-electron incident on the sensor chip produces ~5000 electron/hole pairs
- These charge carriers spread due to diffusion effects as they move through the silicon of the sensor chip
- Photo-electrons in the HPD have a point-spread function with $\sigma$=157 $\mu$m
- Some photo-electrons will cause sufficient charge to be deposited in two pixels to satisfy the threshold conditions
- This is the origin of Charge Sharing

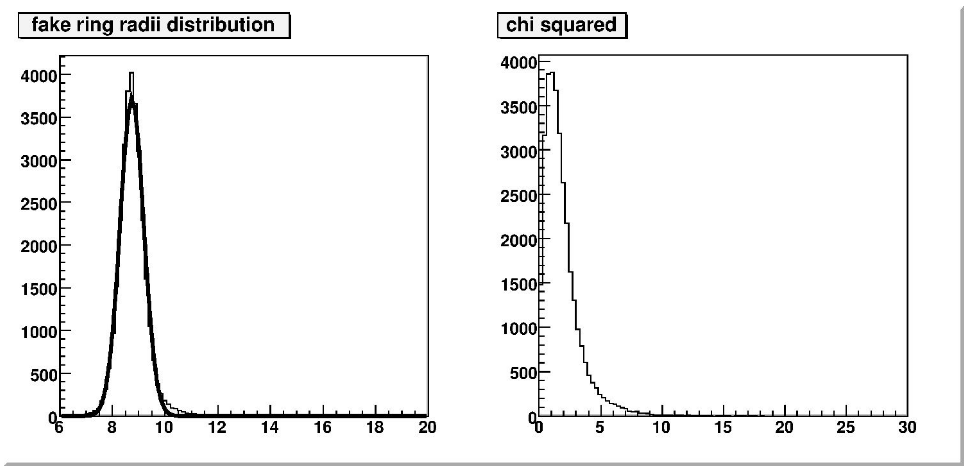


# Fake Events

- In order to quantify the effect that charge sharing has, a data sample free of charge sharing is required, this is the motivation for creating 'fake event' samples
- In the data, hits on adjacent pixels in the same event can be caused by 2 photo-electrons (genuine, 'geometric' adjacents) or 1 photo-electron (charge sharing) – The former must be kept and the latter removed
- To achieve this, 'fake' events are constructed by recombining hits from the real data events – To create a fake event, hits are taken randomly from real events, only one hit taken from any real event, until the fake event comprises the correct number of hits
- As no two hits are from the same event, and therefore cannot have occurred simultaneously, there are no hits which could be classified as charge sharing in the fake events
- As each real event should be a Cherenkov ring, with approximately the same Cherenkov angle and ring centre, sampling from these should be equivalent to the production of a new Cherenkov ring

# Comparing Real and Fake Events




- The average ring radius for the real and fake events is in good agreement
- The fake ring radius distribution is broader than for the real rings radius – This is because the real distribution is being sampled from multiple times to create the fake events
- The rings are fitted using $\chi^2$ minimisation implemented using the TMinuit class in Root
- The $\chi^2$ distribution for the fake event radii is also broadened compared to the real events for the same reason

# Initial Results

| Run # | Total Adjacents (fake) | # Hits(fake) | ratio(A) | Total Adjacents | # Hits | Ratio (B) | B-A |
|---|---|---|---|---|---|---|---|
| 6031 | 679 | 6198 | .109551 | 28223 | 152005 | .185672 | .076120 |
| 6037 | 7947 | 66681 | .119179 | 298122 | 1640098 | .181771 | .062591 |
| 6091 | 1368 | 14292 | .095718 | 53904 | 327524 | .164580 | .068862 |
| 6014 | 2228 | 21585 | .103220 | 66786 | 413443 | .161536 | .058316 |
| 6065 | 2137 | 19108 | .111838 | 88082 | 476899 | .184697 | .072859 |

| HPD | hpe | real adjacents | fake adjacents | Charge Sharing |
|---|---|---|---|---|
| 153 | 8.07 | 5.41 | 3.49 | 1.92 |
| 152 | 6.76 | 7.41 | 3.29 | 4.12 |
| 131 | 9.77 | 6.54 | 4.97 | 3.23 |
| 125 | 5.85 | 5.43 | 2.63 | 2.8 |
| 130 | 5.59 | 5.82 | 2.66 | 3.16 |
| 81 | 2.49 | 5.22 | 1.09 | 4.13 |

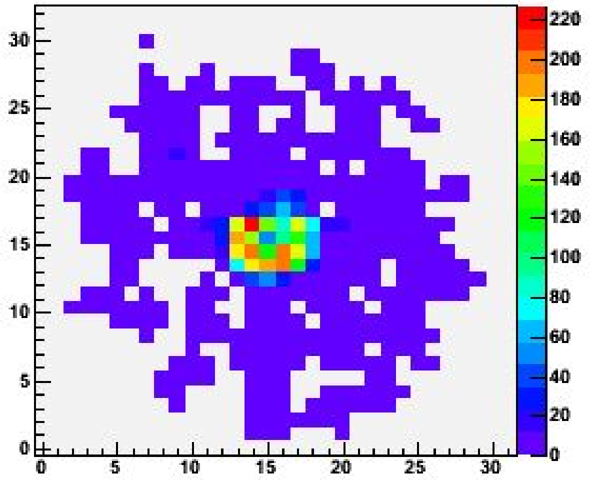
- These tables show the initial results obtained from comparing the amount of adjacent pixels hits found in the real and fake events for $N_2$ runs (left) and LED runs (right)
- The average estimated charge sharing from the $N_2$ runs is 6.77% compared to 3.23% for the LED runs – This is a significant variation
- The  runs have a higher occupancy than the LED runs, but there does not seems to be a general trend in charge sharing with increasing occupancy – the number of adjacents in the fake events scales linearly as expected, but this does not seem to the case for the real events

# PDTF Dark Count Runs

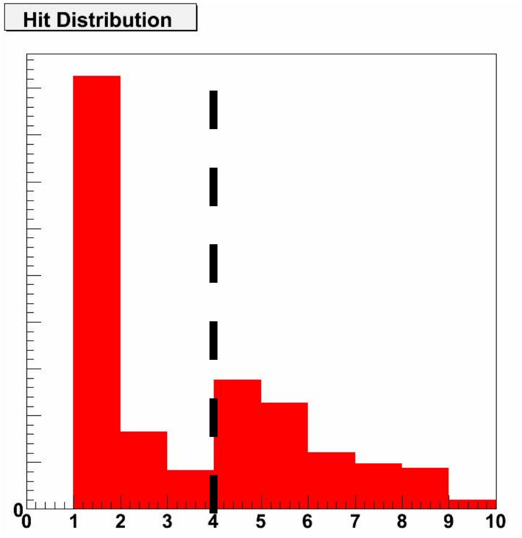
- PDTF 5M trigger Dark Count runs provide a low occupancy (low enough that the probability of geometric adjacents can be neglected, and all adjacents considered as charge sharing) high statistics data set

- Looking at the distribution of #adjacents per event, two regimes become apparent – a second peak can be seen at 4 adjacents per event – given the low occupancy of these runs, the events with >3 adjacents are likely to contain large clusters rather than multiple individual adjacents, and so these events are removed from the sample

- Looking at the hits that are removed by applying that cut, they are strongly clustered in the centre, consistent with ion feedback effects




- With this cut applied, the estimated charge sharing from the PDTF dark count runs is on average ~3.5%, similar to the result obtained from the LED runs

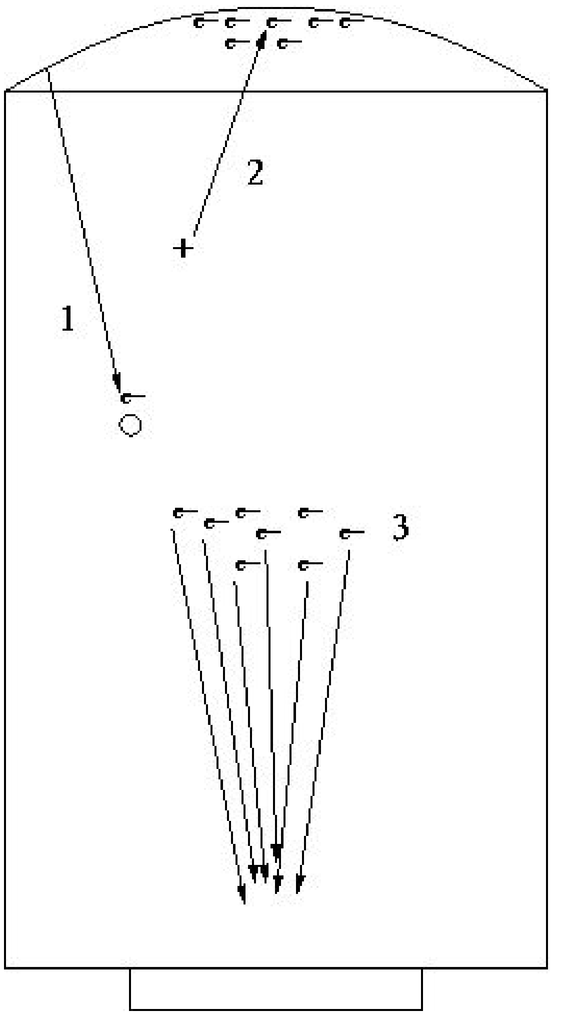


# Ion Feedback

1: Photo-electron strikes residual gas atom in HPD vacuum

2 : Positive ion drawn back towards centre of photo-cathode by accelerating potential, produces several photo-electrons

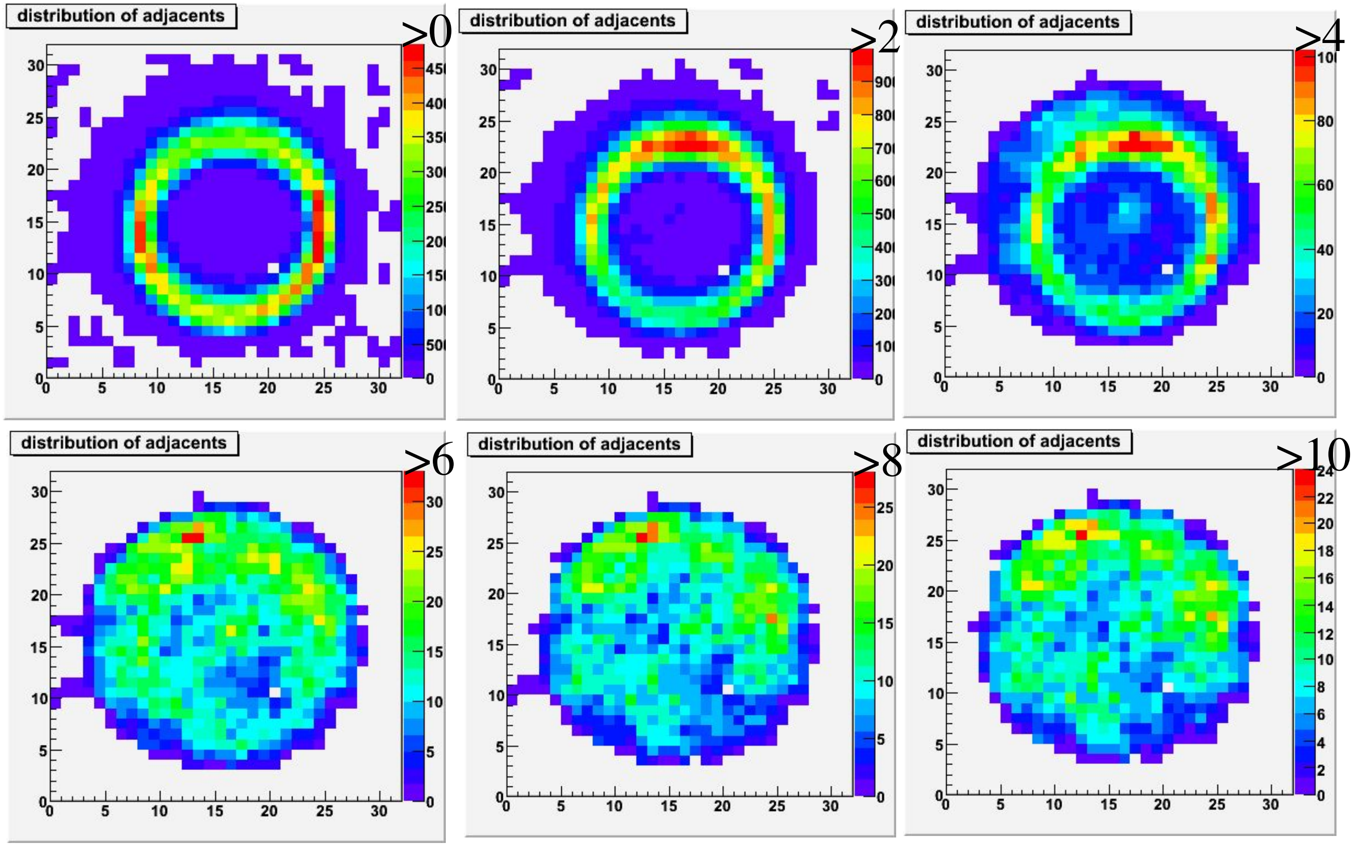
3: Photo-electrons drawn towards centre of sensor chip by focus field, cause centralised cluster of hits




As well as ion feedback, clusters are present due to effects such as micro-discharges, where dielectric breakdown of the air causes flashes of light. Also, errors in reading in the data from the L1 boards if the read/write pointers get out of step, etc, can cause clusters of hits

# Clustering

- The distribution of #adjacents per event for the N2 runs does not display a secondary peak like the PDTF DC runs
- Plotting only clusters of greater than a given size, it becomes clear that as cluster size increases, the distribution of clusters no longer follows the distribution of hits
- Clearly, these larger clusters are not due to charge sharing, and so should be removed from the sample



# Results

- Removing clusters >5 from N2 runs reduced charge sharing estimate by ~1.6%
- However, LED runs also reduced by ~1.04% by applying the same criteria
- Still a large discrepancy between the two results, and now results from PDTF DC runs are less in line with LED run results
- What could be the explanation?
- Is there some contribution to the events that has not yet been considered, let alone quantified?

## SUGGESTIONS PLEASE!