Distorsion of resolution for angular tracks in irradiated microstrip detectors

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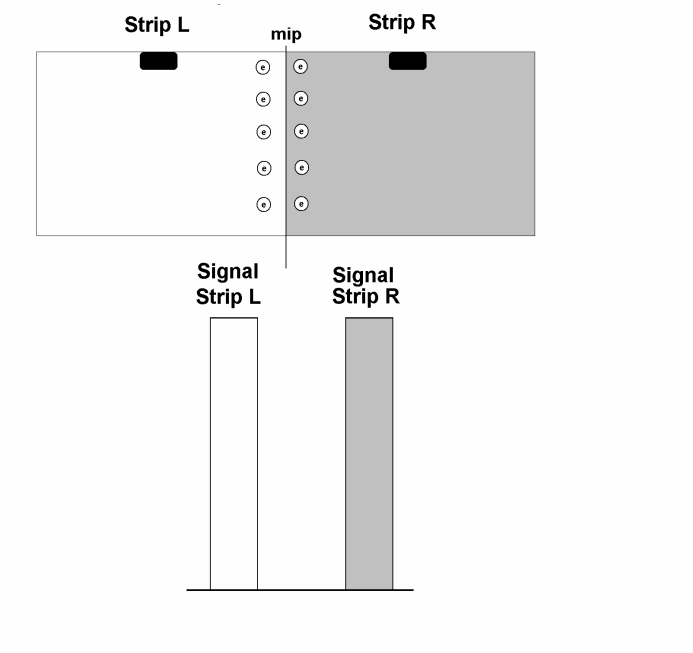
Purpose

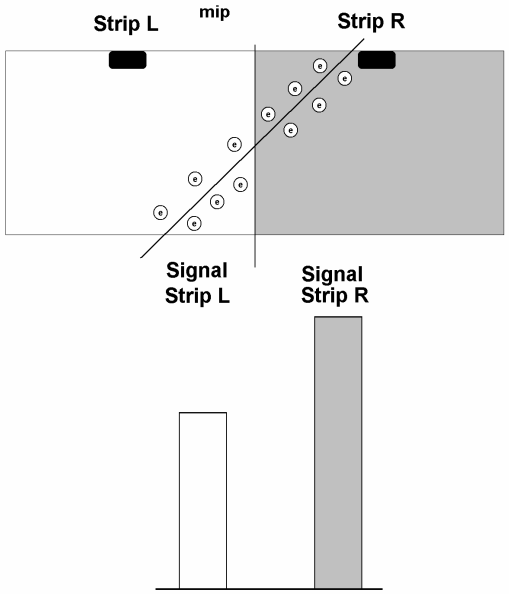
- Estimation of the shift in the reconstructed position for angular tracks in a typical LHCb VELO detector geometry

Why do we expect distortion of the resolution?

Case of normal impact in the midpoint between two strips: equal signal on both strips irrespectively of irradiation



Case of angular incidence where the mid-plane between the two strips is crossed at half the detector thickness: expected equal signal on both strips, but the collection time of the charge drifting towards strip L is larger due to distance and lower field. This introduces a distortion which varies with irradiation.



Programme

- ISE TCAD
  - DESSIS V7.5
  - Complete model of geometry (2D)
  - Complete model of processing
  - All semiconductor effects taken into account
  - Radiation effects parameterized by 4 Energy levels in band gap
  - Each iteration takes 16hours

Model Parameters

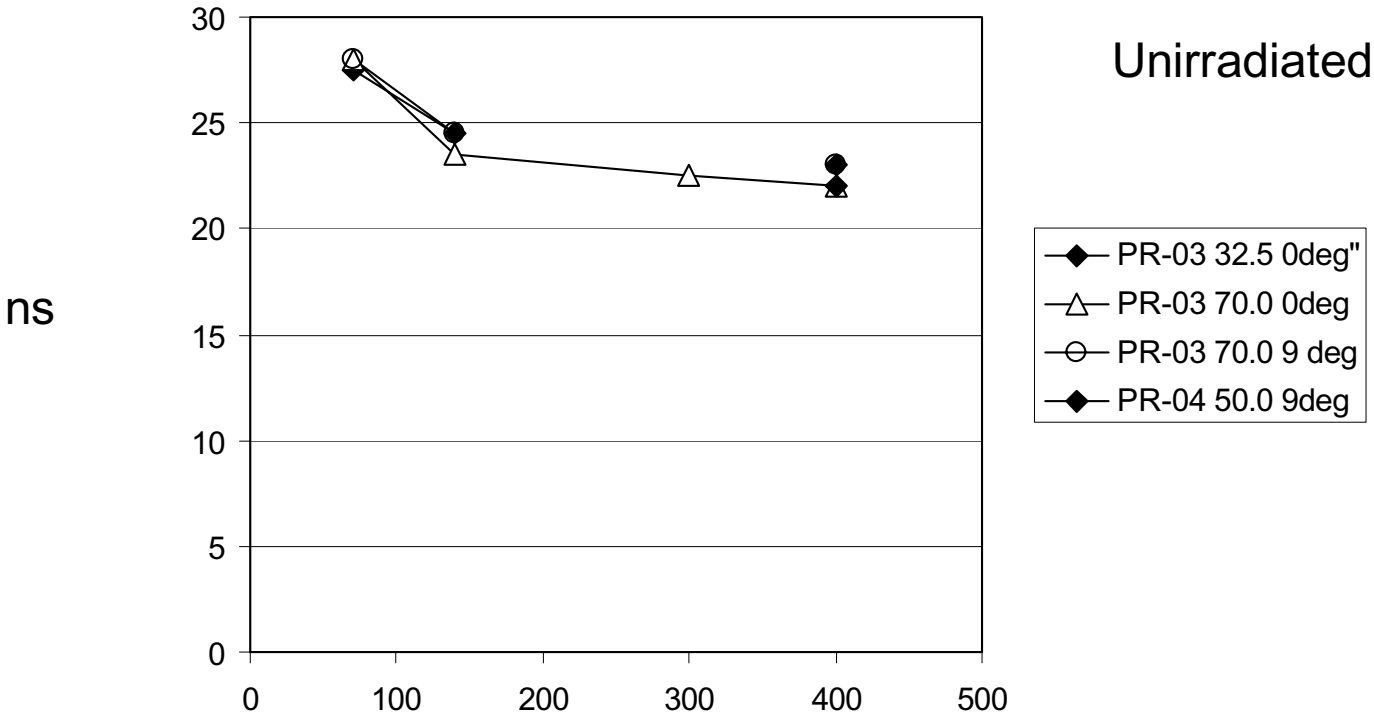
- Sensors
  - PR-03 at 295μm
    - Pitch 32.5 and 70μm
    - PR-03 geometry
  - PR-04 at 295μm
    - Pitch 50 μm
    - PR-04 geometry
- Track angles
  - 0 and 9°
- Bias Voltages
  - 70,140,300,400V
- Radiation
  - 0, 3×10^{14}, 3×10^{14}p/cm^2

Investigate

- Charge sharing
- Peak sampling time

Peaking Time

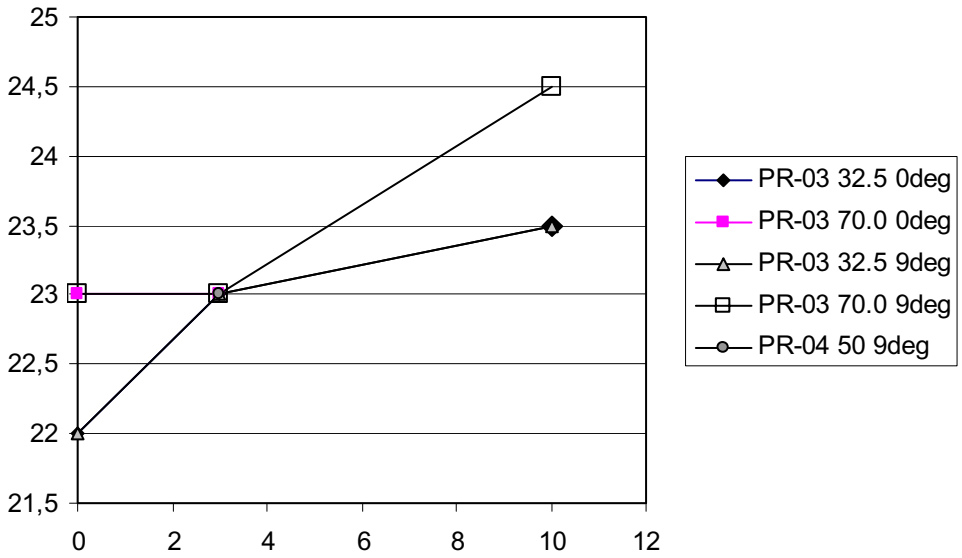
- Use Response function of Front End



Peaking time

Irradiated Detector (400V)

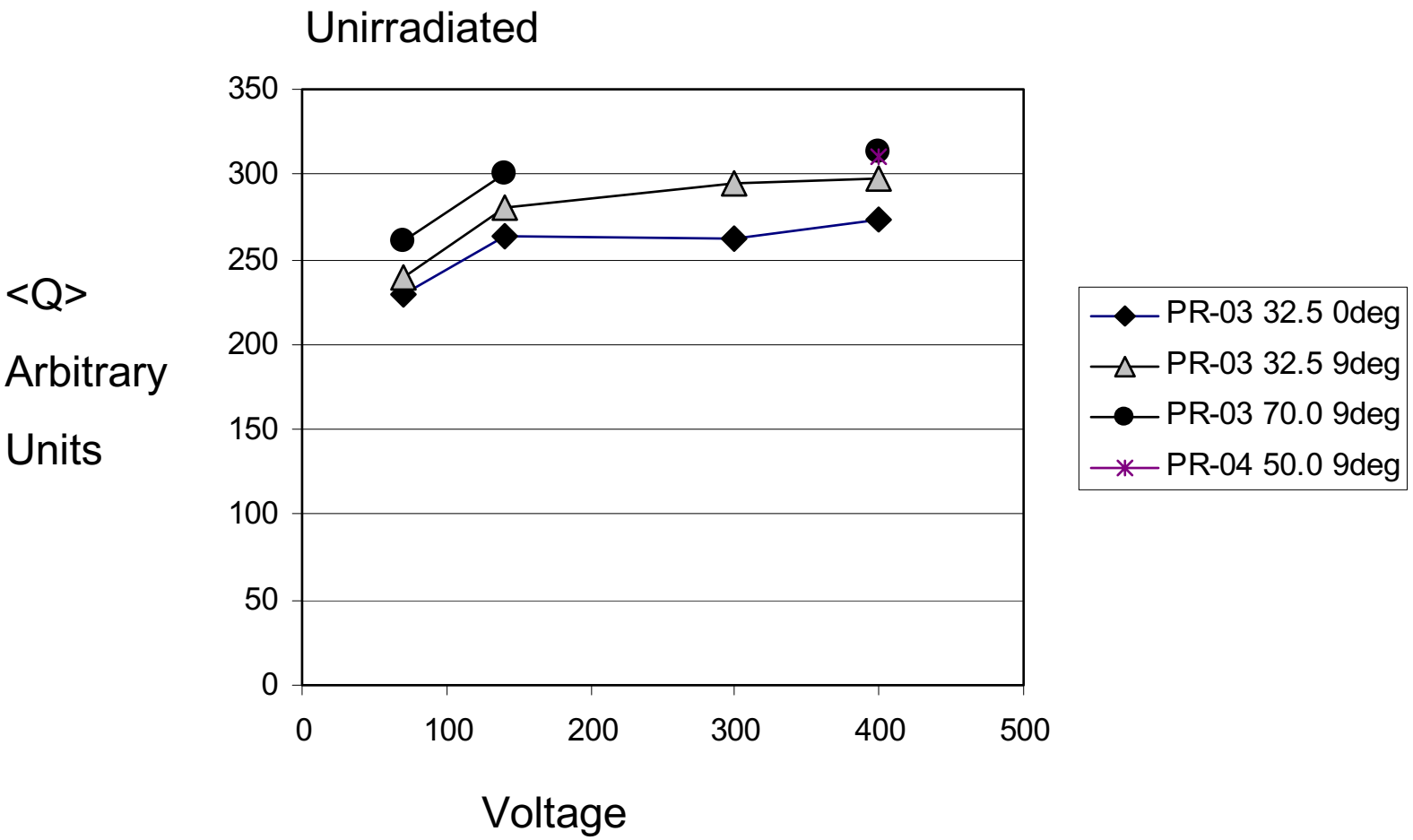
ns



Fluence (×10-14 p/cm2)

Small increase in peaking time

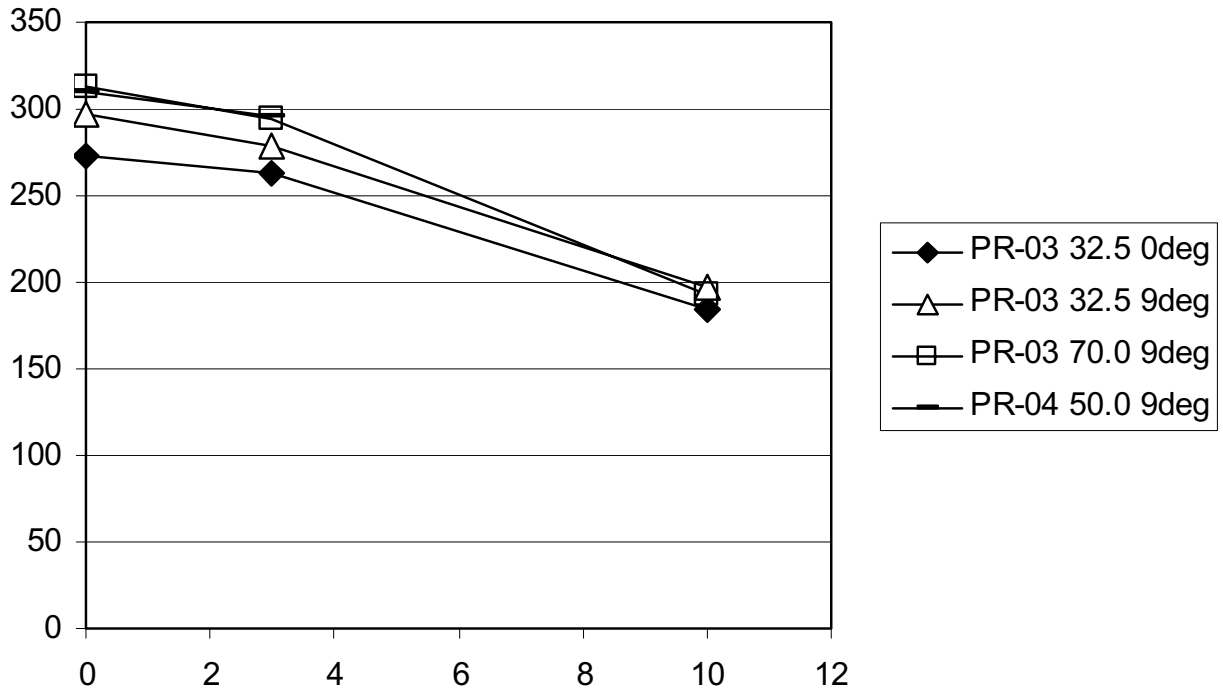
Charge Collection



Charge Collection

Irradiated Detector (400V)

<Q>
Arbitrary
Units



Fluence (×10-14 p/cm2)

Drop in total charge collected (lose approx 30%)

Cluster Profile Example

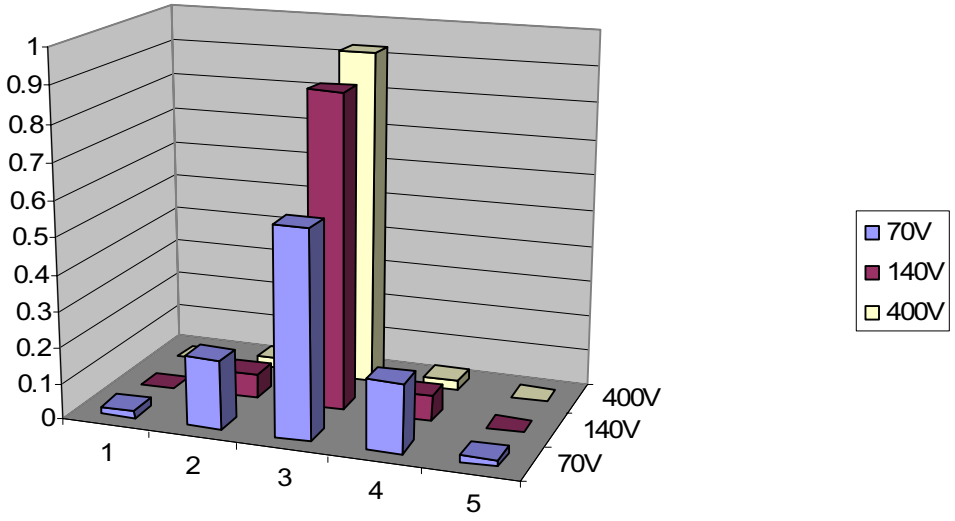
PR-03 32.5µm 0deg

Unirradiated

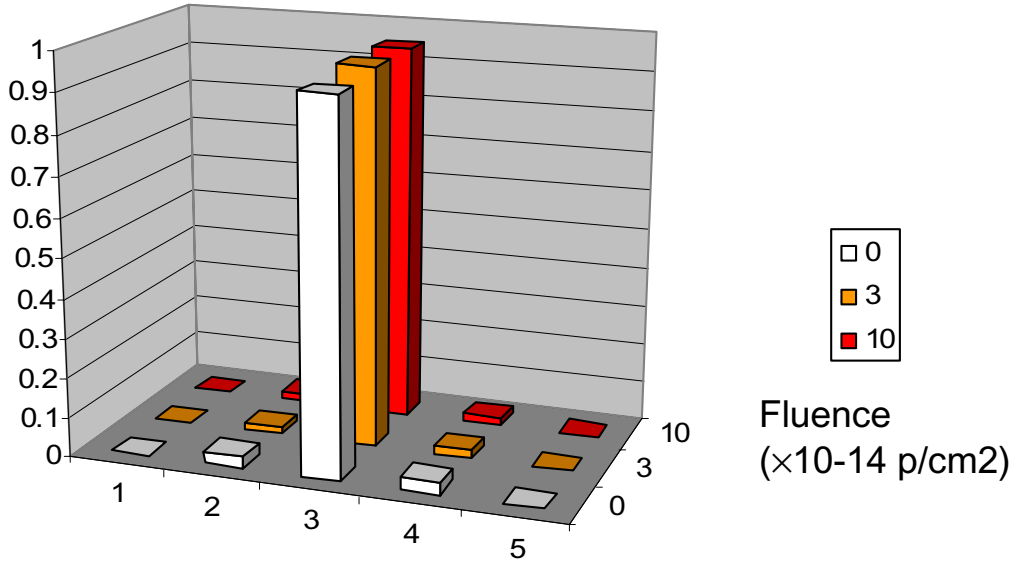
Normal incidence over middle

Strip

Cluster Shape v Voltage



PR-03 32.5µm 0deg
Normal incidence over middle
Strip at 400V
Cluster Shape v Fluence



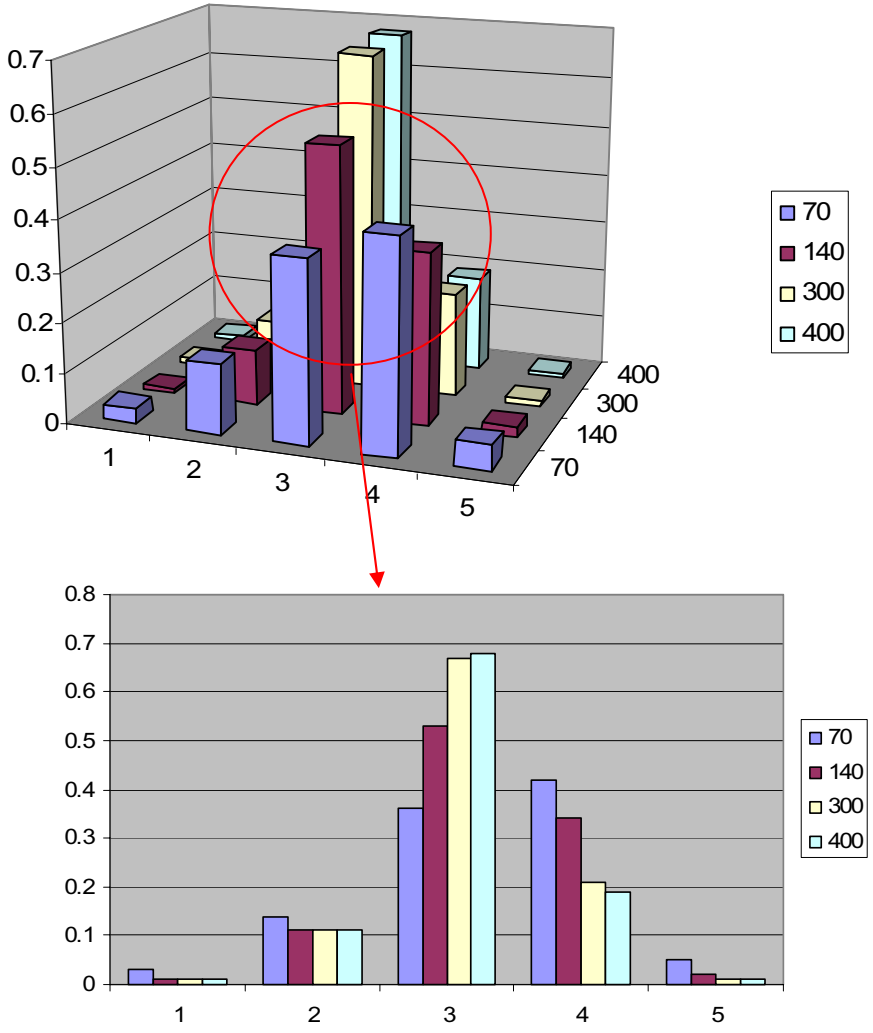
Cluster Profile Example

PR-03 32.5µm 0deg

Unirradiated

9° incidence over middle Strip

Cluster Shape v Voltage



Note change of cluster "mode" strip

Cluster Profile Example

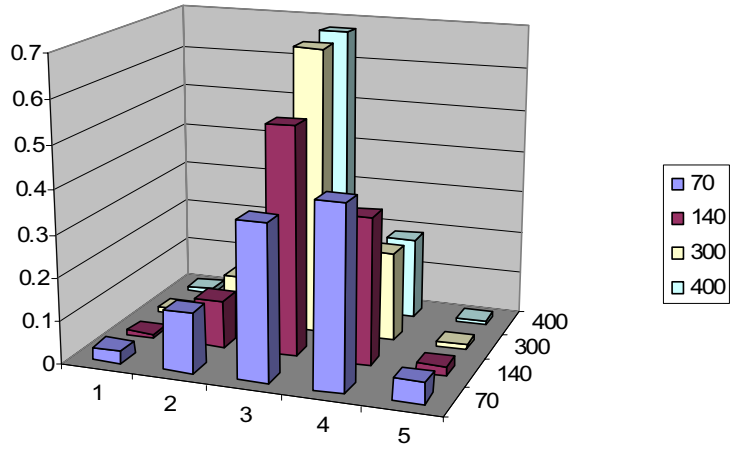
PR-03 32.5µm

Unirradiated

9° incidence over middle

Strip

Cluster Shape v Voltage



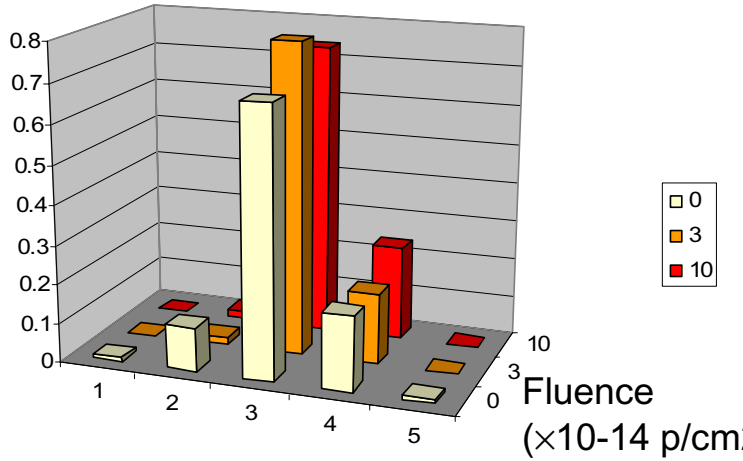
PR-03 32.5µm

Irradiated 400V

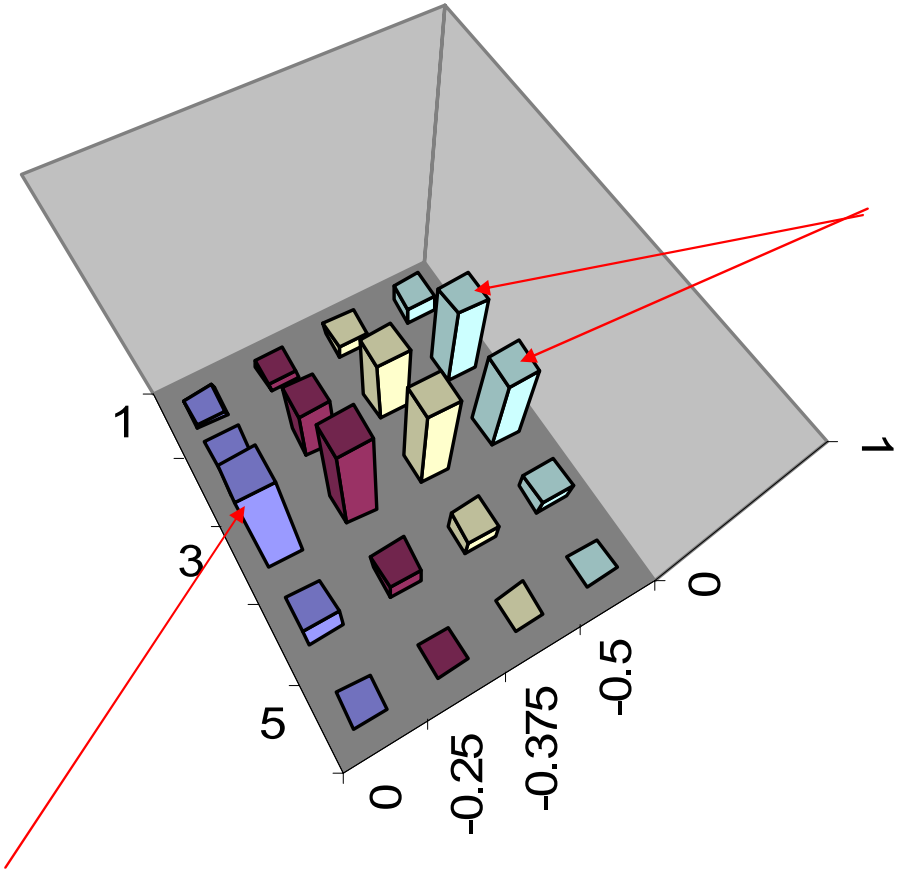
9° incidence over middle

Strip

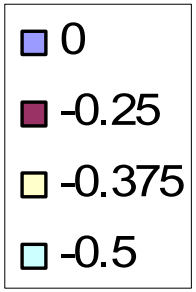
Cluster Shape v Fluence



Cluster Profiles Example



Midway between 2 and 3 (0°)



Centred on strip 3 (0°)

Cluster Profiles

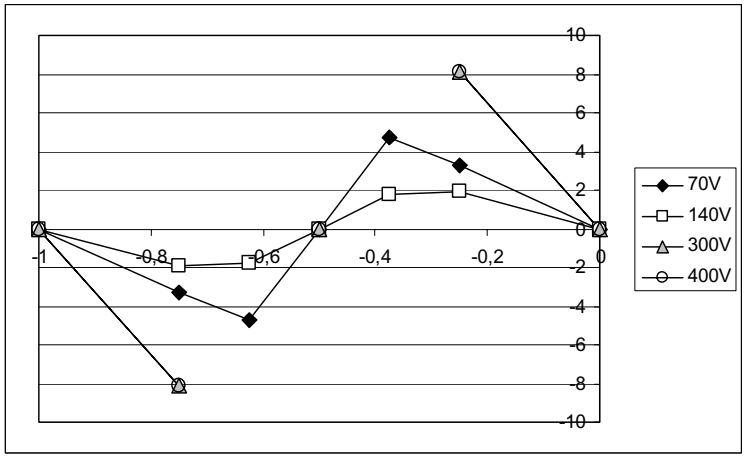
- Lot of information
  - PR-03 32.5: 0°,9°
  - PR-03 70.0: 0°,9°
  - PR-04 50.0: 9°
- Function of Voltage and Fluence!

Simplified Analyses

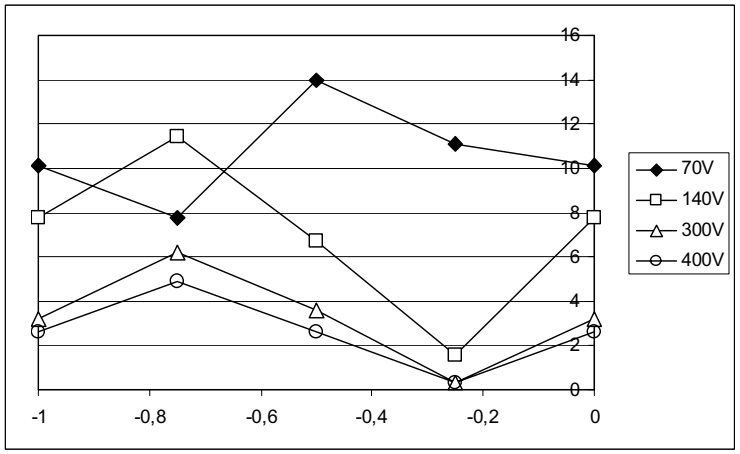
- Data available for more realistic cluster analysis of data…
- Remove hit strips that are less than 0.1 MIP (S/N should be better than this!)
- Look at cluster centroids as a function of entry point and angle into the detector
  - BUT NOT just an artefact of clustering
  - Mobility of e and h and sampling time

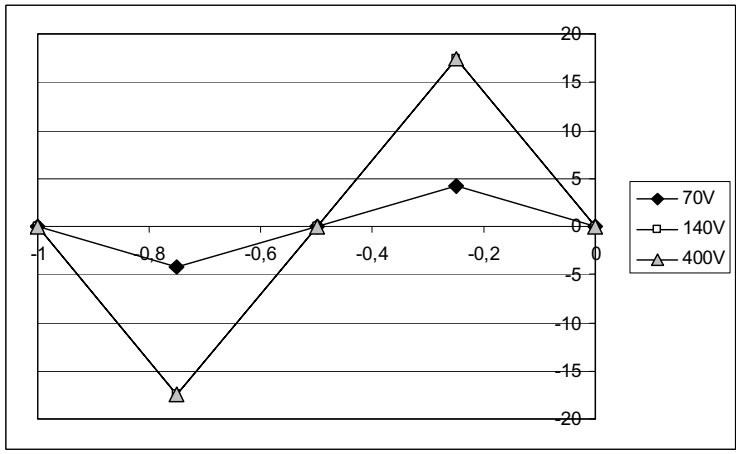
“Shift Errors”

32.5 pitch, 0° Incidence

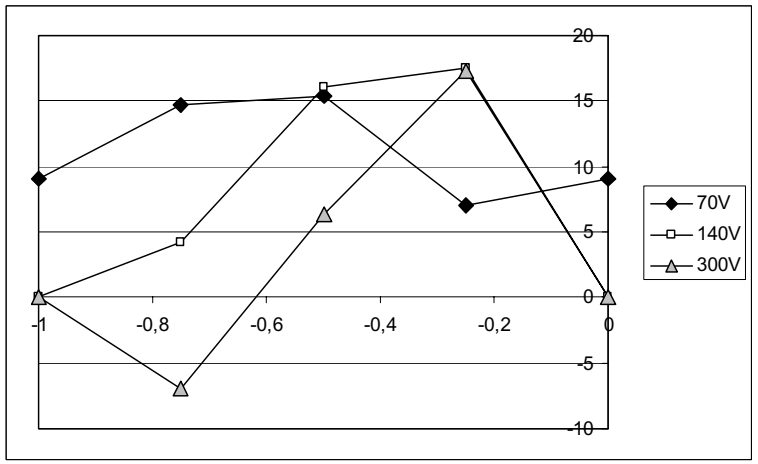


32.5 pitch, 9° Incidence





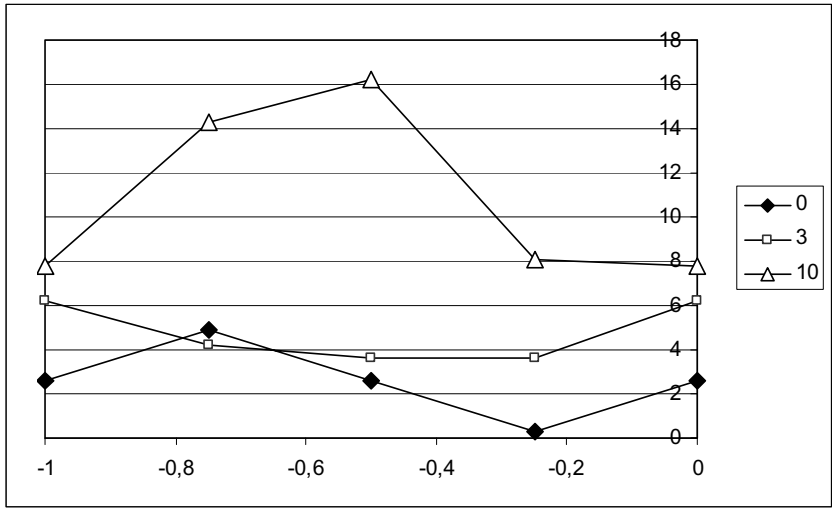
70.0 pitch, 0° Incidence



70.0 pitch, 9° Incidence

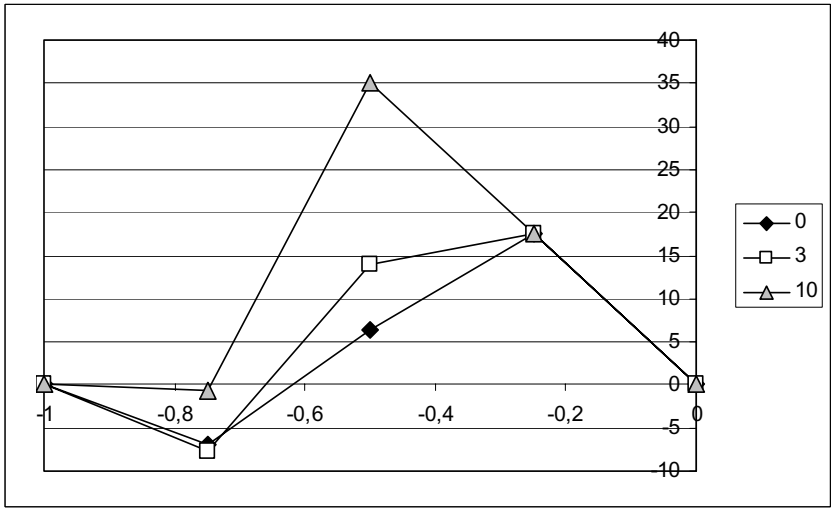
Shift Error with Radiation

32.5 pitch, 9° Incidence



Fluence
(×10-14 p/cm2)

70 pitch, 9° Incidence



Fluence
(×10-14 p/cm2)

Inclined tracks have more problems

As detector degrades effects appear to get larger

Summary

- Low voltages (even if above depletion, up to 140V): diffusion gives some charge sharing
- AT high voltage (300, 400V) there is almost no diffusion: the η function is determined by geometric overlap
- Asymmetric charge sharing is found for hits at angles different from 0^o
- The asymmetry depends on radiation: large at high doses and low electric field (low bias)
- At high fields asymmetry is small and almost radiation independent
- The charge at high fields is though contained to 1 strip for larger pitches (worsening resolution). The number of 1 strip hits is reduced with thicker detector (300 μm) (geometric overlap)