Improved Near Beam Particle Tracking with Radiation Hard Si Detectors at LHCb

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Overview

- LHCb VErtex LOcator introduction
- Track impact parameter resolution
- Varying VELO guard ring widths
- Baseline guard ring simulation
- Simulations of new guard ring designs

RD50 Objectives

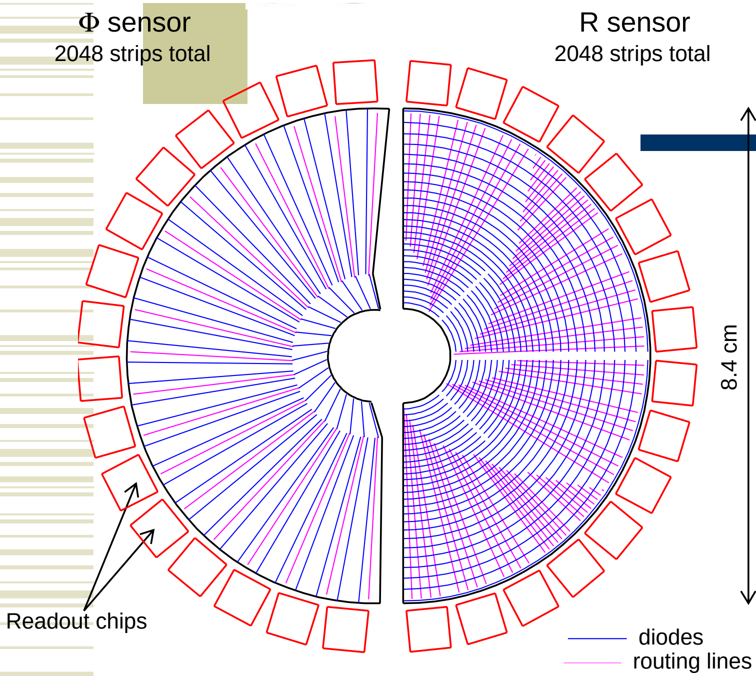
- Increased particle tracking accuracy requires the active silicon of the detector closer to the beam line

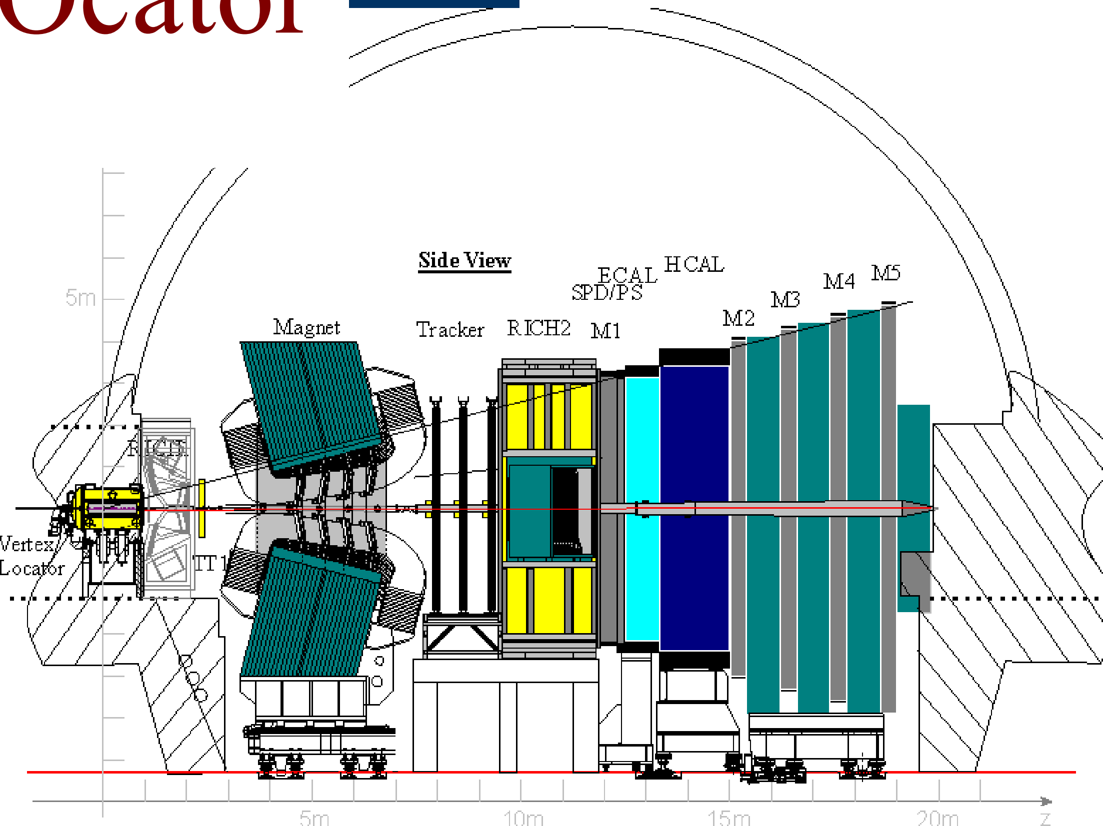
  → Detector geometry alterations

- Higher radiation environment, avoid repeat replacements

  → More radiation hard materials [Cz, …]

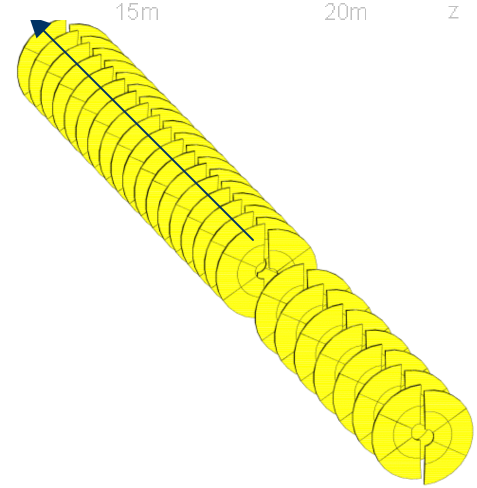
LHCb VErtex LOcator Stations





- 21 oxygenated silicon sensors.
- Silicon detectors start 7mm from beam axis but 1mm of guard ring structure

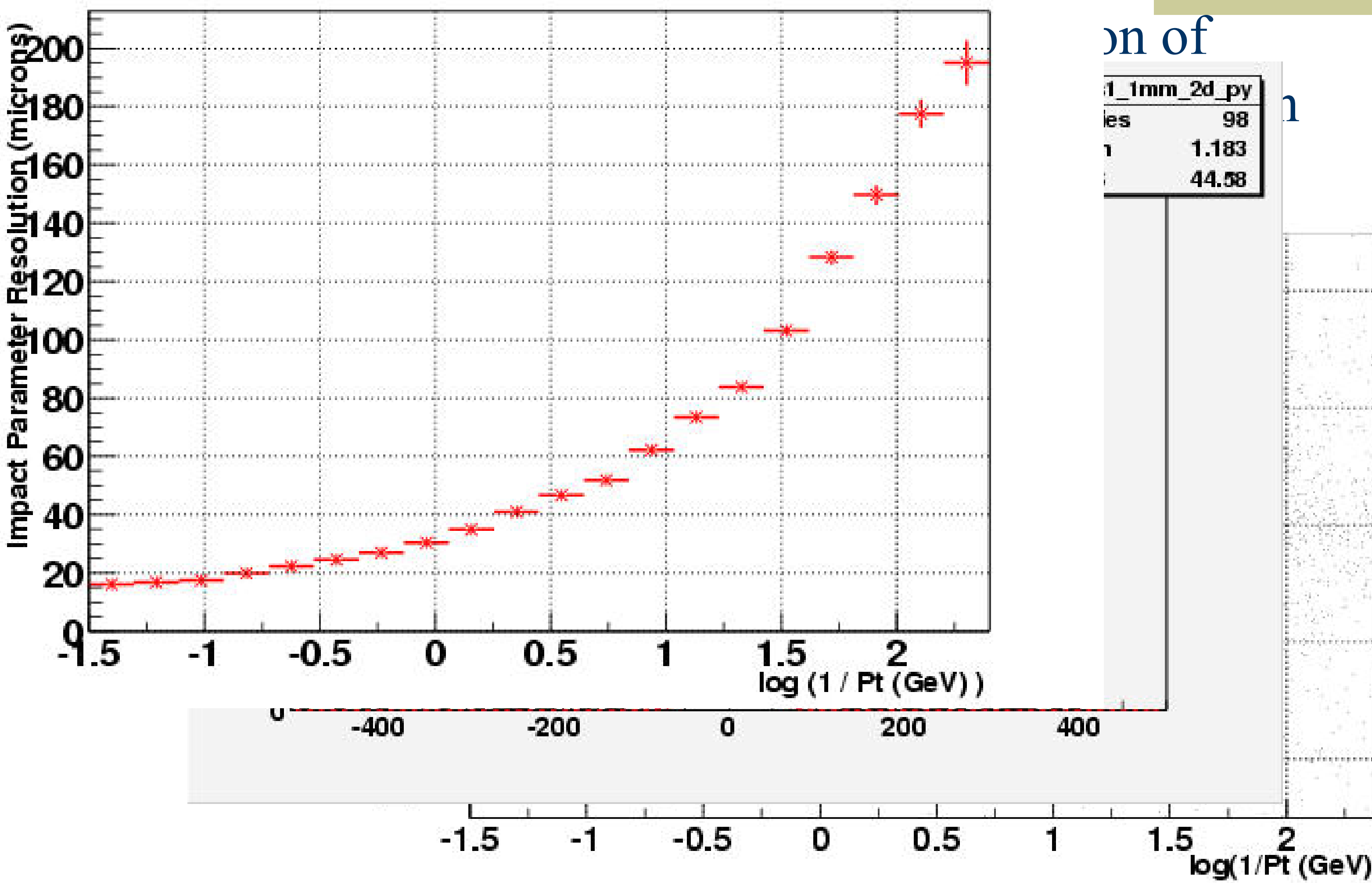
➡ silicon detection begins at 8mn



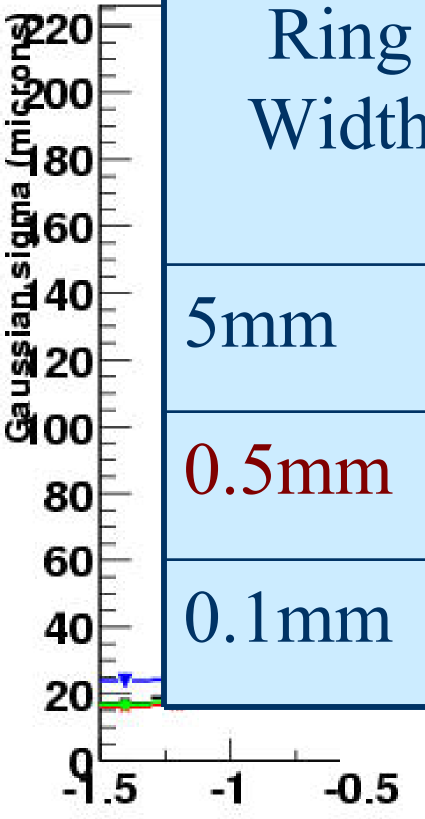
Impact Parameter Resolution

- on of

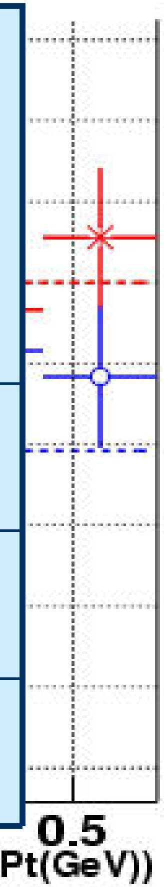
n



Effect on IP resolution
- varying guard ring widths



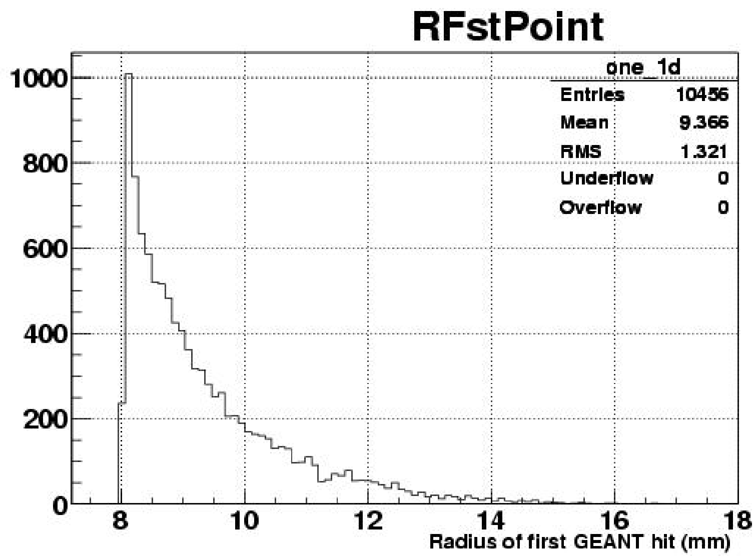
Guard Ring Width	Increase in flux (%) to sensitive silicon	Improvement of the IP resolution w.r.t baseline (%)
5mm	-44	-38.1±0.9
0.5mm	+14.1	+5.8 ±0.7
0.1mm	+27.7	+10.0 ± 0.7

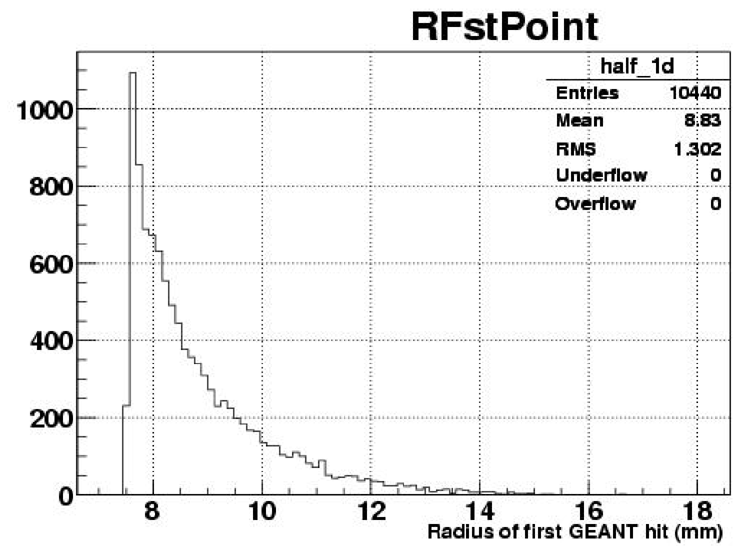


Circles=0.5mm

Crosses=0.1mm

Sensitive silicon radius reduction
- sensitive radius 8.0 mm → 7.5 mm

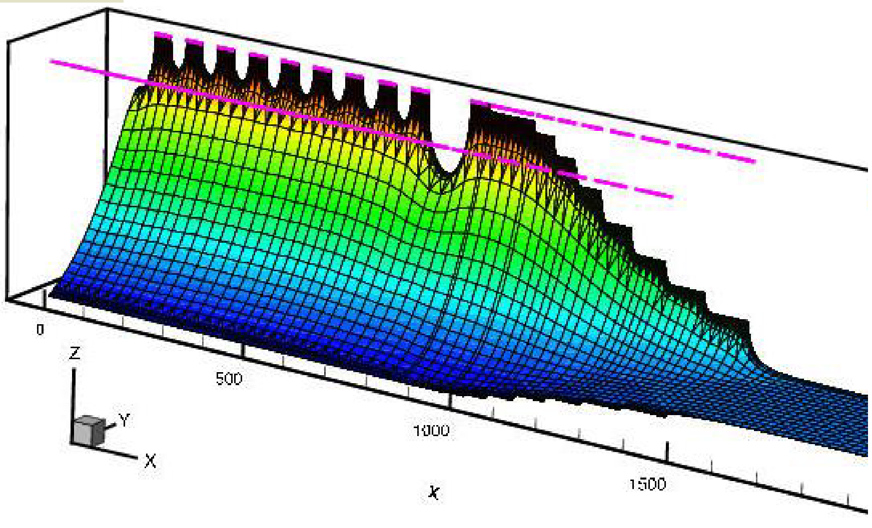


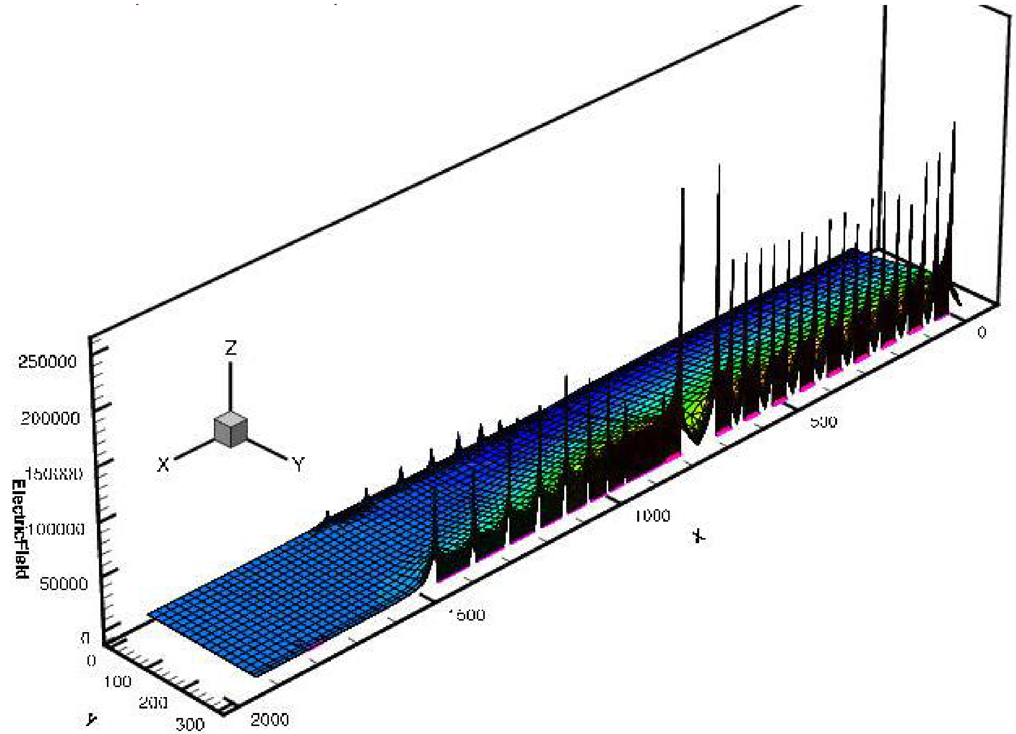


- Radiation lengths transversed before first measured hit
- Mean radius of first GEANT hit in sensitive silicon reduced from 9.4 mm to 8.8 mm
- Distance over which the track is extrapolated is reduced by 3.8%

Simulations

- baselir

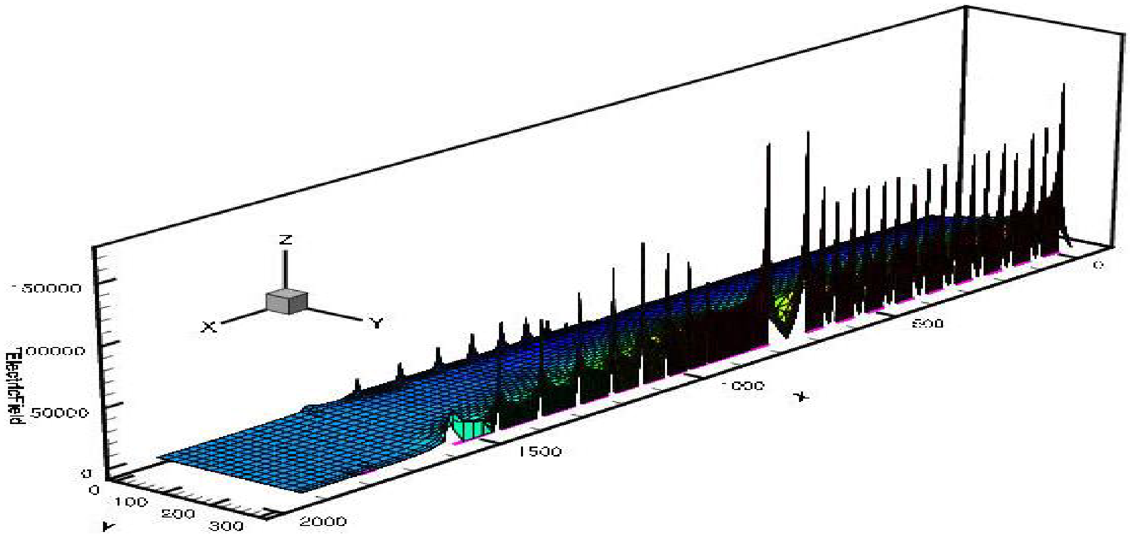


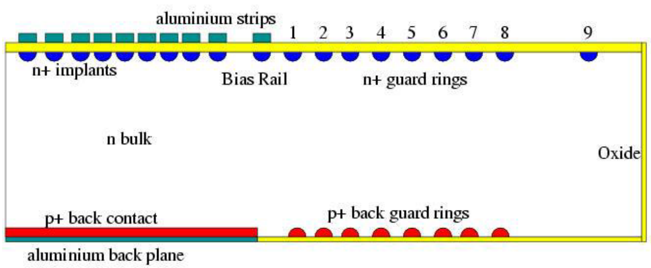


- 9 n^+ guard ring implants on front. Back guard rings included.
- Introduced fluence dependent interface and bulk traps for all simulations*. Radiation damage simulated ~ $3\times10^{14} n/cm^2$

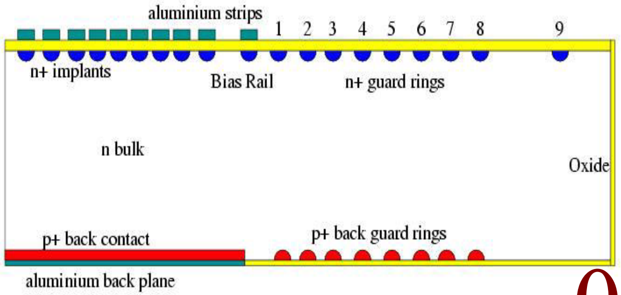
* from S.Biagi of the University of Liverpool – Many thanks!

Simulations
- altered baseline structure

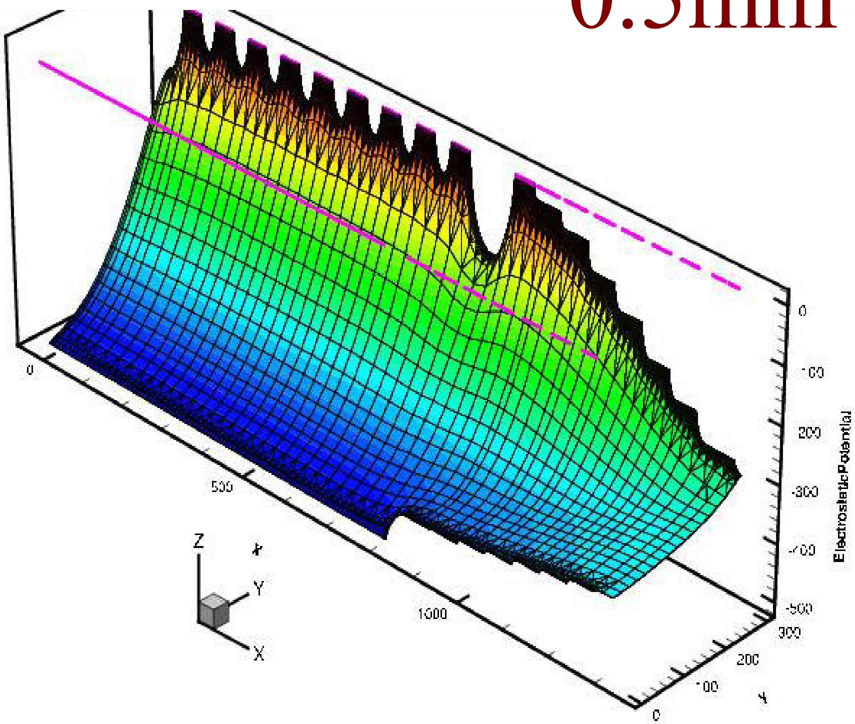


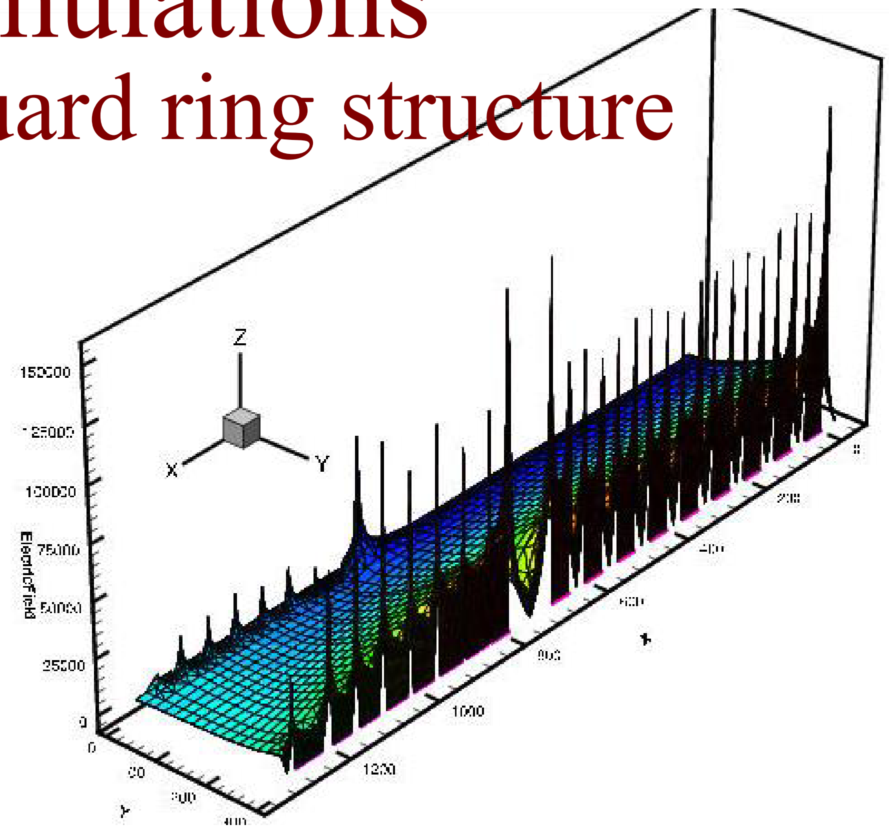


- Extra guard ring between 8th and 9th guard ring of baseline design.
- Same simulation conditions
  500 V reverse bias, 3x10^{14}n/cm^{2} fluence, fixed oxide charge.
- Maximum electric field strength is 170 kV/cm [baseline 250 kV/cm]
- Test structures currently being fabricated



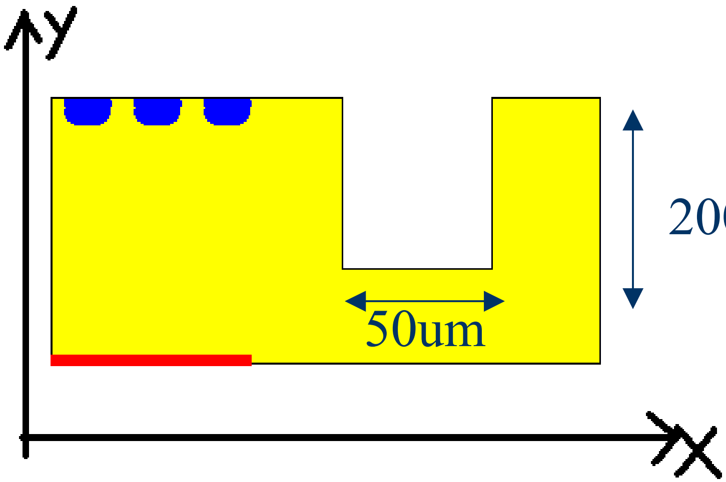
Simulations
0.5mm guard ring structure

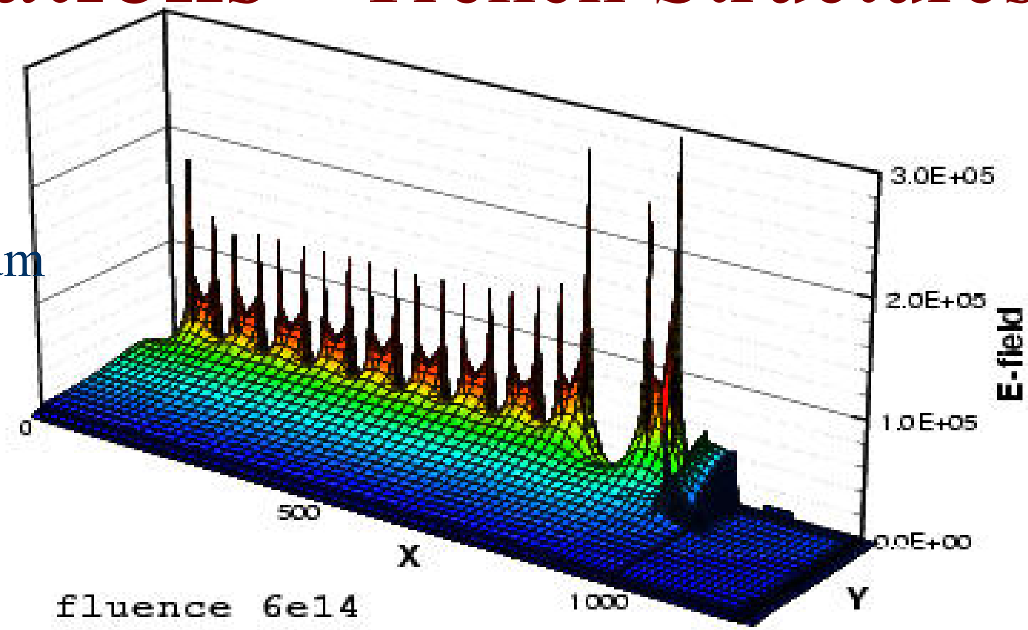




- Reduced baseline guard ring from 1mm to 0.5mm
  - Sensitive silicon now begins 7.5mm from beam axis
- Maximum electric field strength is 152 kV/cm [baseline 250 kV/cm]
- Test structures currently being fabricated

Simulations - Trench Structures





- Reduced baseline guard ring from 1mm to 365 microns

  ➡ Sensitive silicon now begins 7.365mm from beam axis
- Simulated up to 6×10^{14} n/cm^2, 500 V reverse bias & p-stops.
- Maximum electric field strength reduced by 13%
- Approximately 7% increase in impact parameter resolution
- 18% increase in flux per year received by the sensitive silicon (not the guard ring silicon)

Conclusions I

- Reducing radius of sensitive Si in VELO sensors
  - Improves impact parameter resolution
  - Increases radiation flux to the active silicon
- Full baseline guard ring simulation
  - Maximum electric field well below breakdown field
- Amended baseline simulation
  - Further reduced the maximum electric field
- 500 micron design
  - 6% improvement to Impact parameter resolution
  - Additionally, reduced the maximum electric field

Conclusions II

- Trench guard ring structures
  - 7 % improvement in IP resolution
  - Decrease Efield strength by 13 %

- Guard Ring Width Impact on d0 Performances and Structure Simulations. *A Gouldwell*, C Parkes, M Rahman, R Bates, M Wemyss, G Murphy, P Turner and S Biagi. LHCb Note, LHCb-2003-034.