Development of Radiation Hard Detectors for LHCb at CERN

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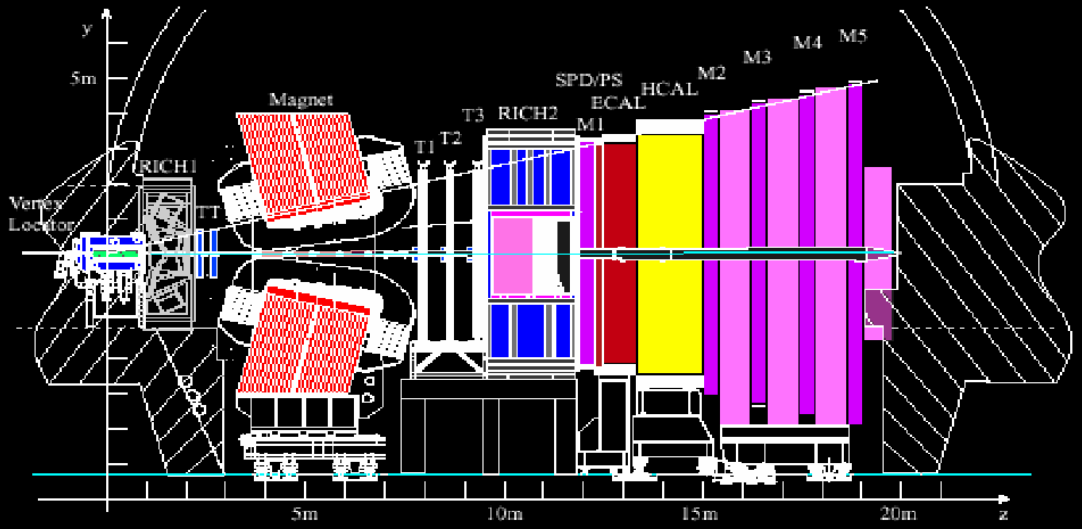
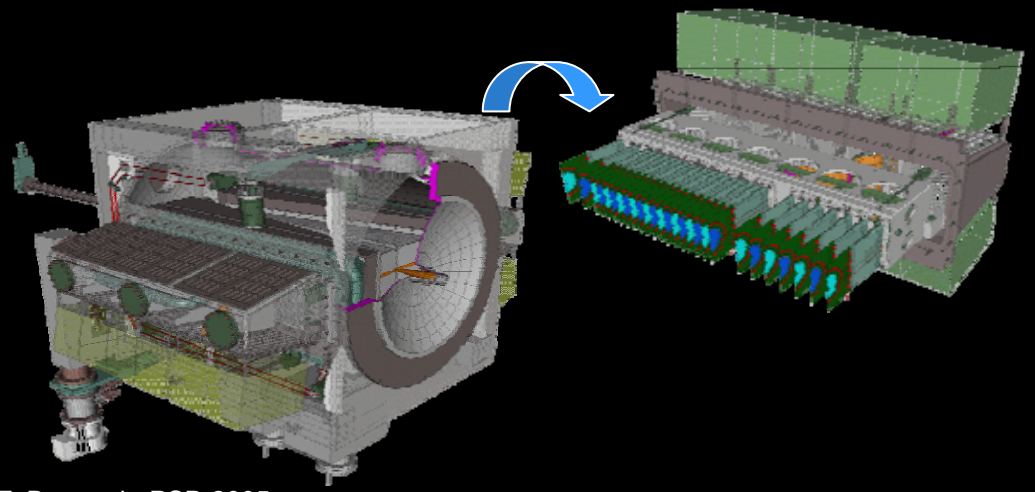
Introduction

- LHCb requirements
- existing detectors under construction
- progress on replacement technology

LHCb

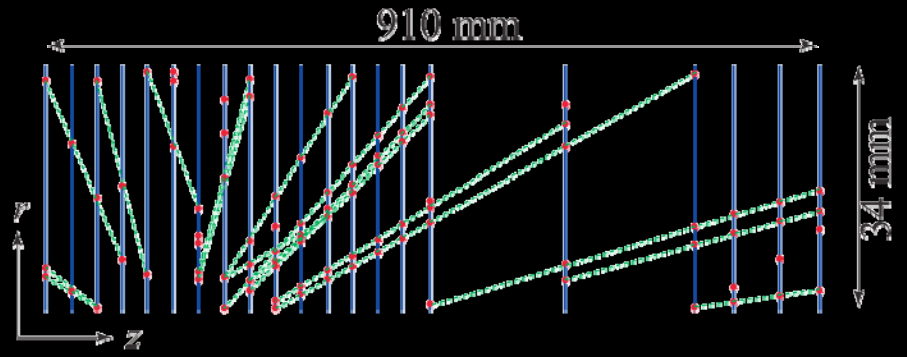
- specialized detector
- high quality tracking and vertexing
- vertex locator
- 2007

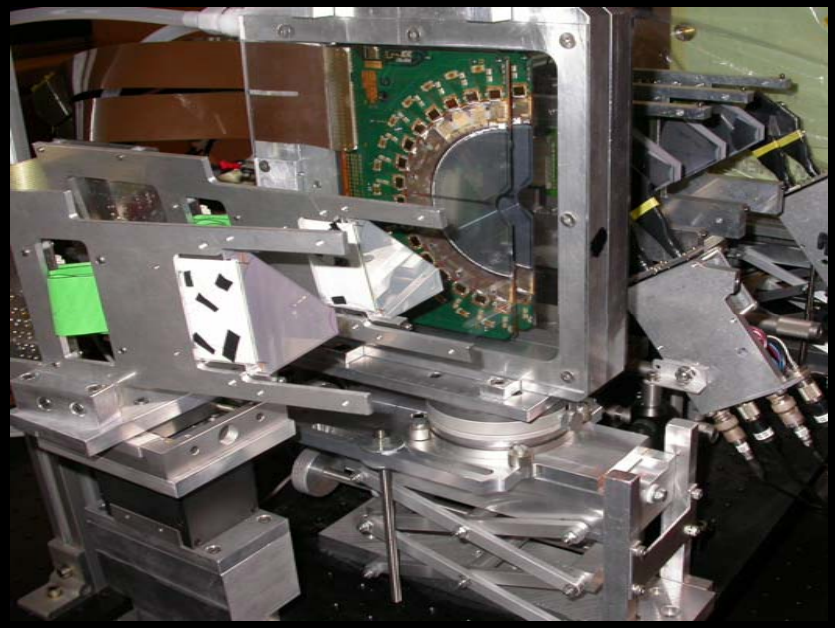




Vertex Locator

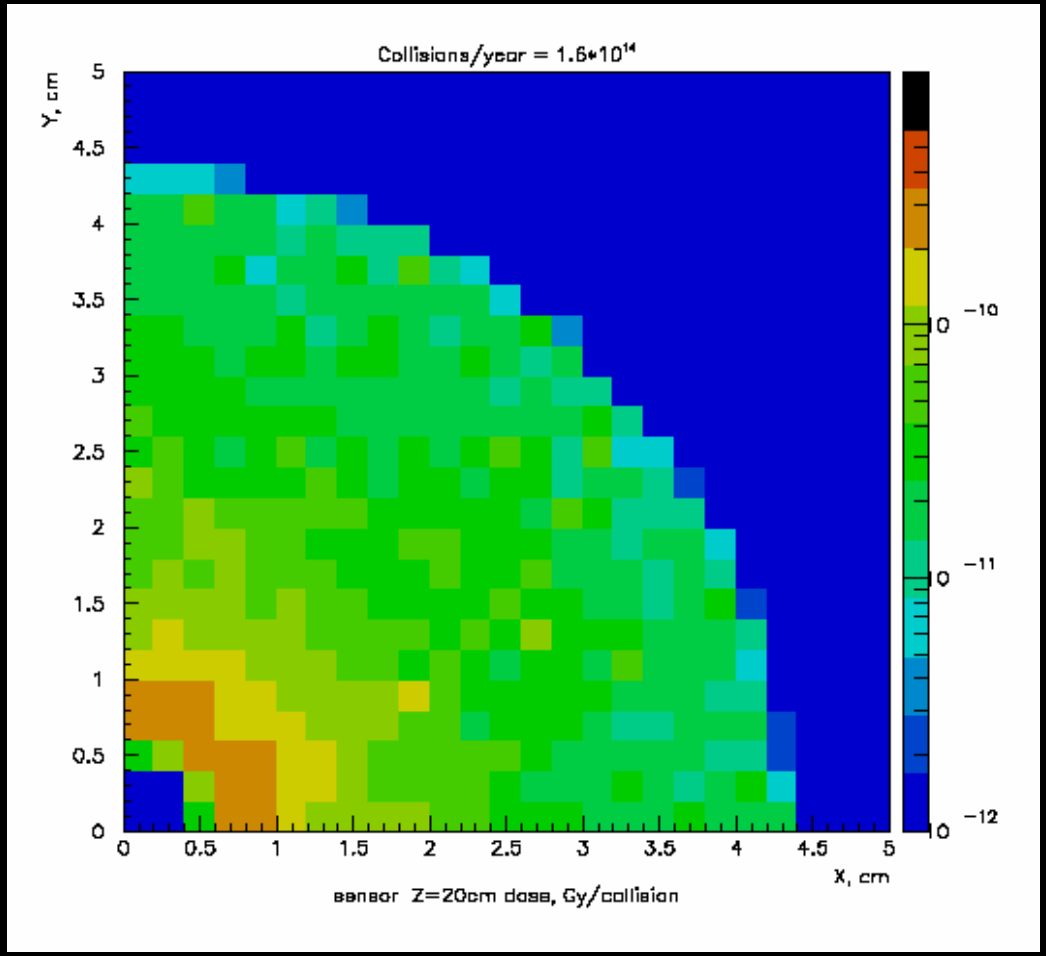
- vertex locator
- 8mm from LHC beam
- vacuum
- R&D started 1997





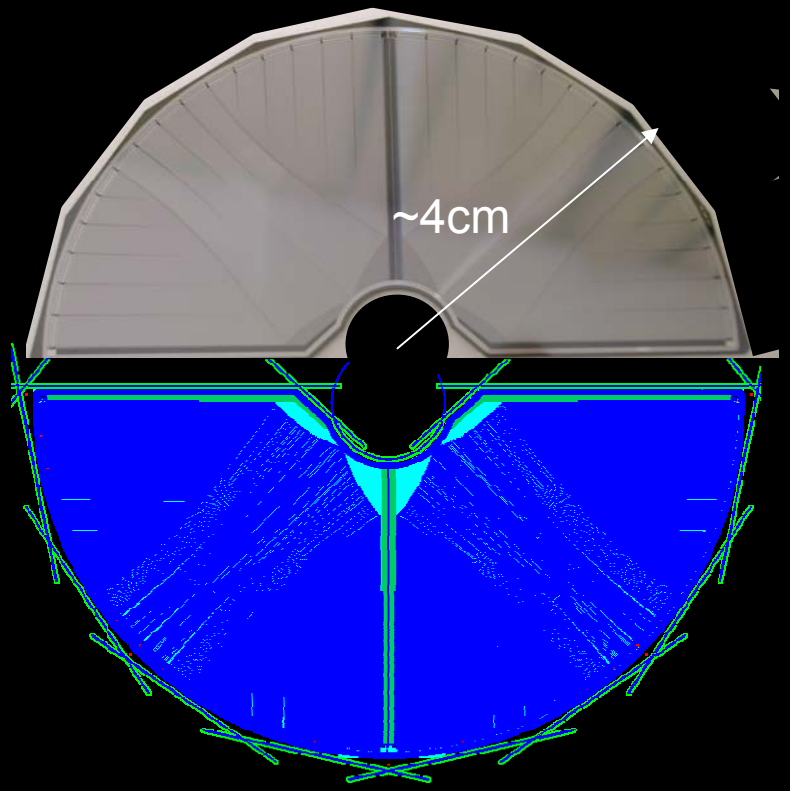
Radiation Levels

- maximum dose of ~10^{15}p/cm^2
- non uniform 1/r^2



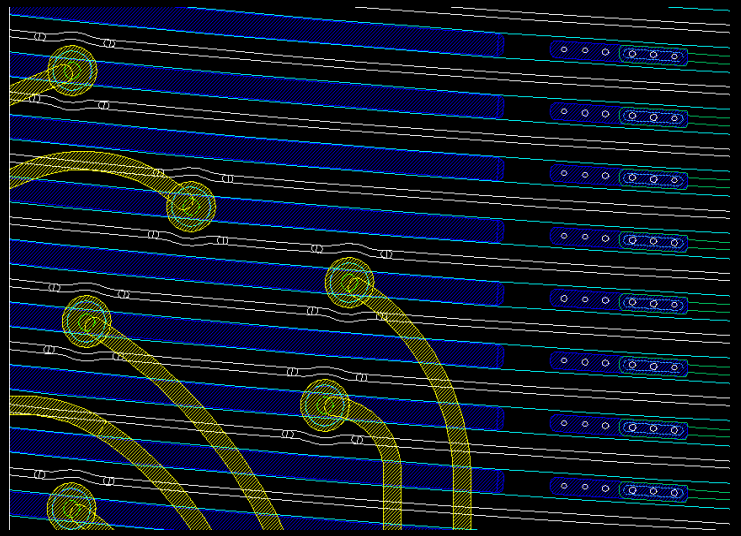
Silicon Sensor

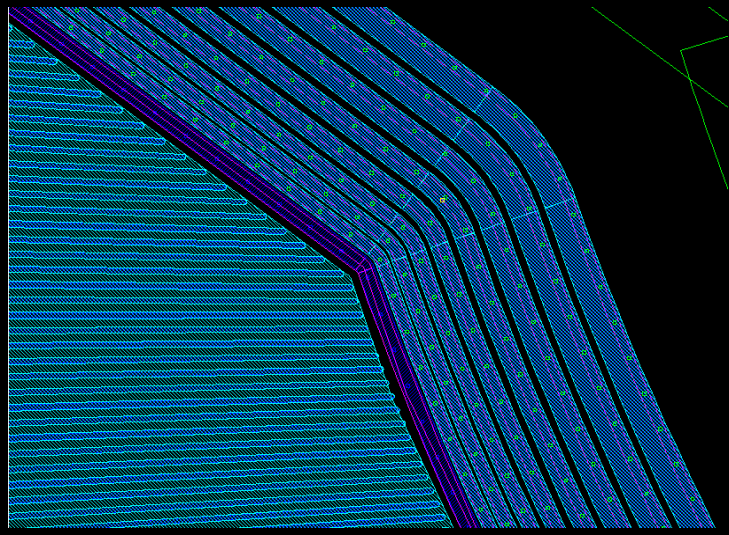
- highly segmented
- double metal layer
- 2048 strips/sensor
- Two designs
  - R-measuring
  - Phi-measuring



Design

- complex
- highly automated
- Simulated ISE-TCAD



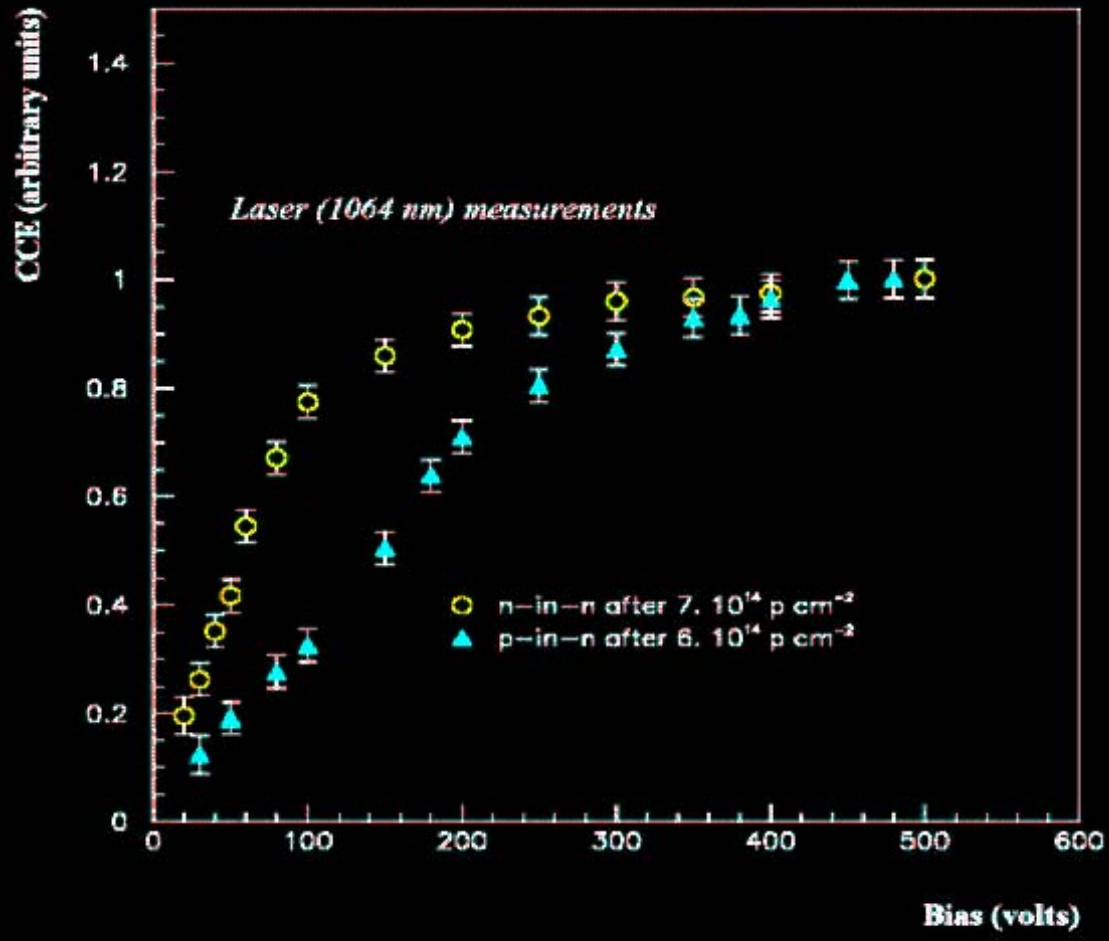


Fabrication

- earliest n^+n prototype Hamamatsu Photonics
  - n^+n not available since ~2000
- later n^+n and p^+n designs Micron Semiconductor

Technology Choice (2001)

- ac coupled
- n^+n
- p^+n
- oxygenation



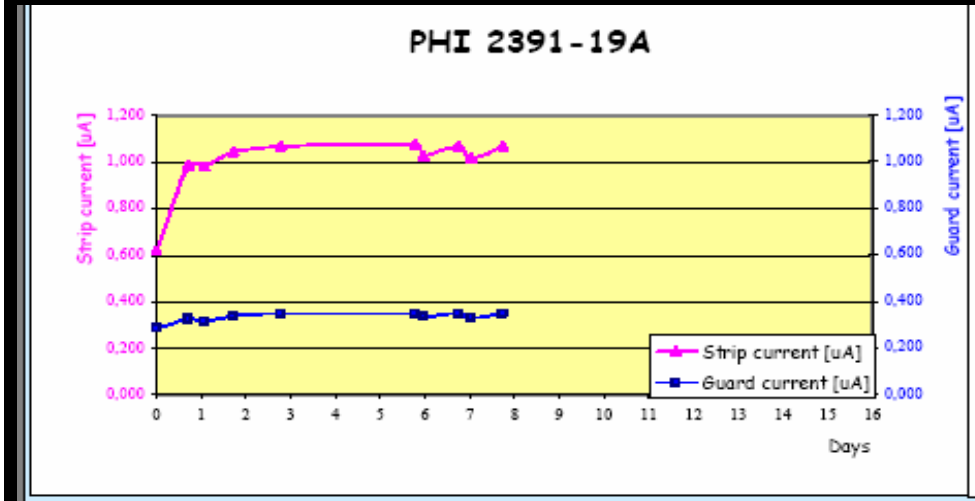
LHCb 2007

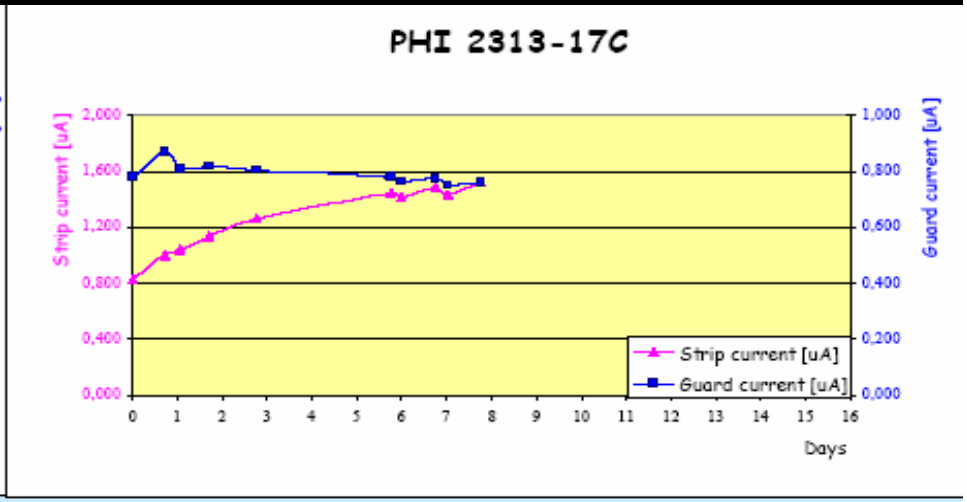
- read out segmented n-side
- signal being formed mainly by electron carriers collected on the high electric field side
- reduced charge collection time results in less trapping and higher signals

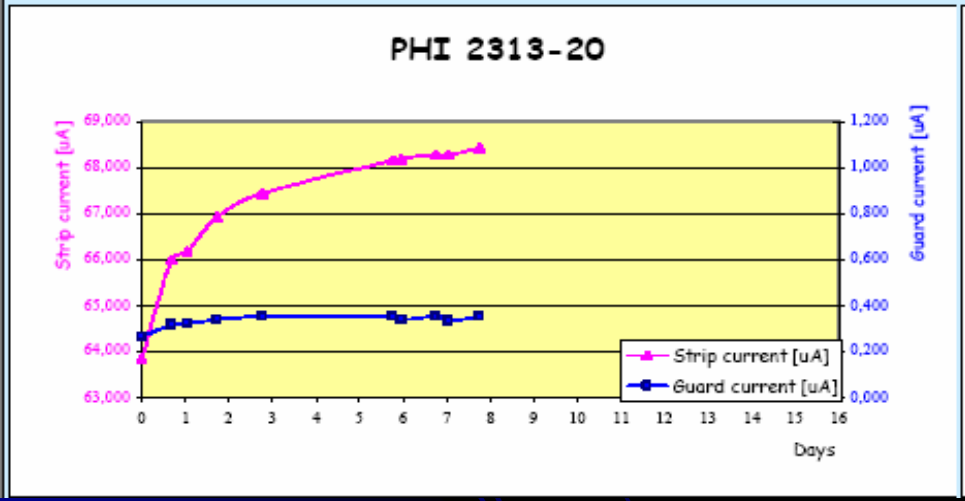
Vacuum performance

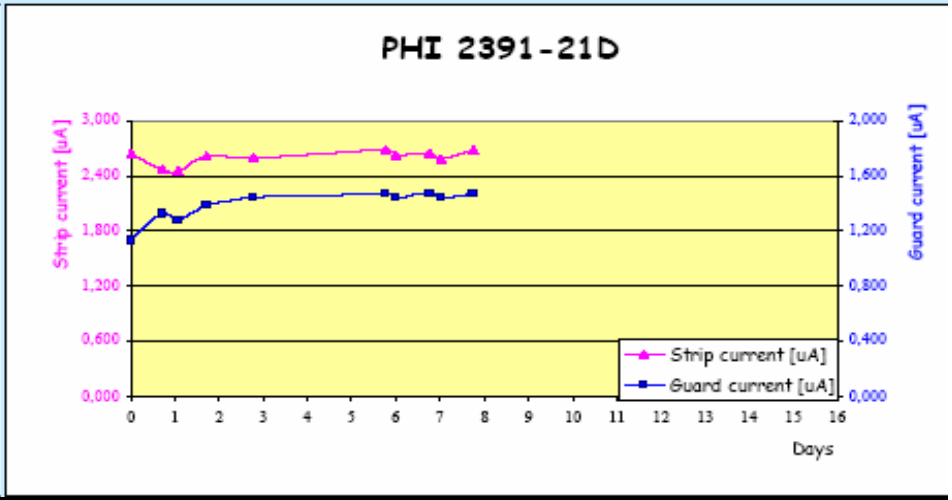
- new data available
- stability of currents (up to 21 days) under high vacuum

Vacuum tests (new)









LHCb 2010

- detectors have an expected lifetime of approx 3 years for nominal operation
- Sensors have adequate performance (S/N, resolution etc)
- to extend lifetime we need new generation of sensors

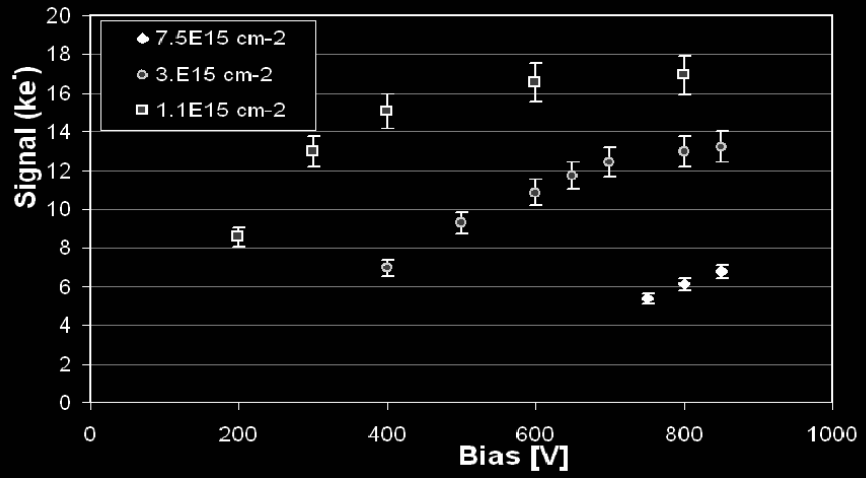
P-bulk for LHCb?

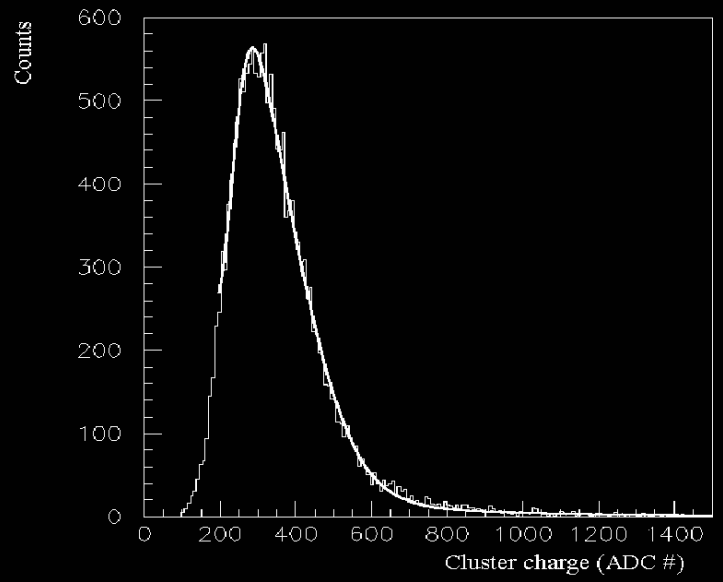
- RD-50
- miniature strip detectors
  - G.Casse et al.

- ac coupled, 80 mm strip pitch with p-spray isolation, made by CNM
- irradiated to 1.1, 3.5 and 7.5 10^{15}p/cm^2
- charge Collection Efficiency (CCE) studies with signal induced by β from a Ru(106) source
- read-out with SCT128A analogue electronics while kept in a freezer at T< -20°C.

P-bulk performance

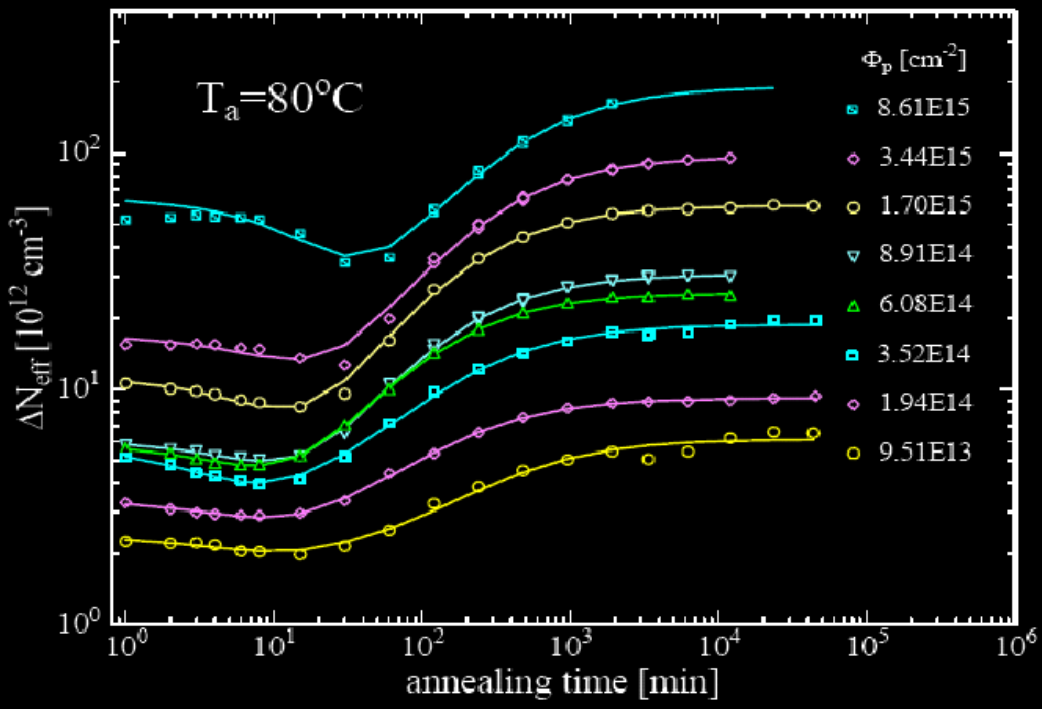
- V_{FD} after 7.5×10^{15} p/cm^2 ~2800V
- V_{bias} = 900V gives 12000e (no trapping)
- See ~7000e, charge loss ~ 40%,





Annealing Problem

- reverse annealing
- CV measurements
  - VFD>12000V
  - 7 years equivalent annealing time at 20°C.
  - Fluence 8.6 ×10^{15} p/cm^2



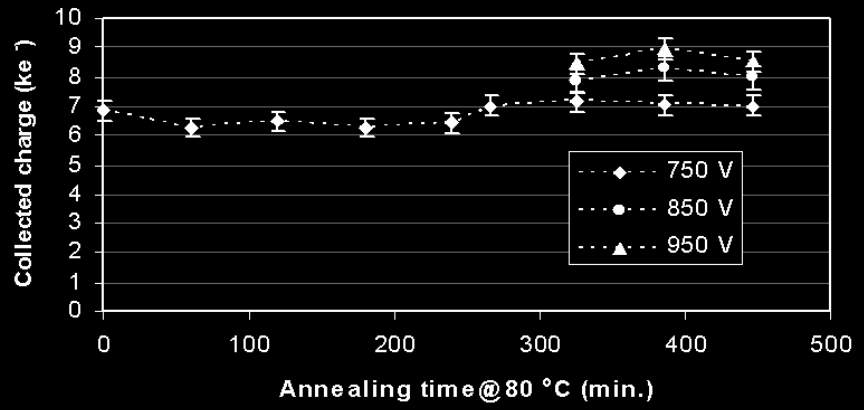
fit parameters to the various data points here agree with the RD48 predictions-Hamburg model (E. Fretwurst at the 4th RD50 workshop, CERN 5th-7th May 2004)

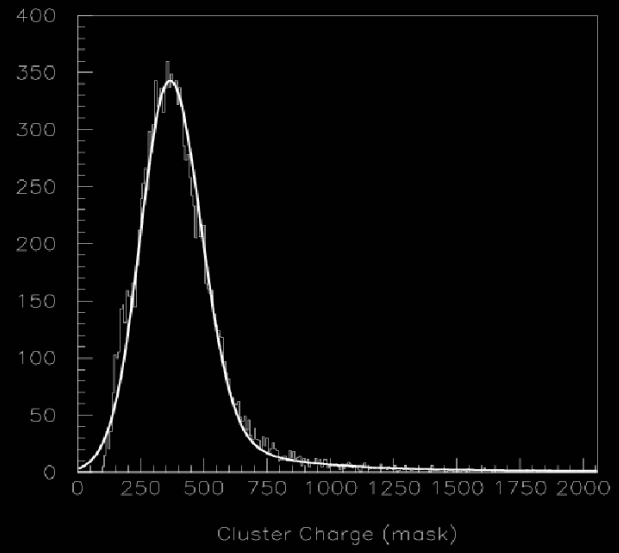
CCE studies

- 80μm pitch mini-detectors from CNM
- LHC-speed (40MHz) analogue electronics

P-Bulk Annealing

- doses up to 7.5× 10^{15} p/cm^2
- 80°C





Annealing Data

- ratio of the signal measured at room temperature to the pre-annealed value

Bias	~1 y	~ 3 y	~ 4.5y
300 V	0.9	0.93	0.72
500 V	1.02	1.0	1.07
800 V	0.98	0.98	0.93

1.1×10^{15} p cm^{-2}

Bias	~1 y	~ 2.5 y	~ 6.5y
500 V	0.98	0.9	0.87
800 V	0.98	0.94	0.88

3.5×10^{15} p cm^{-2}

Bias	~1 y	~ 2.5 y	~ 6.7y
750 V	0.93	0.93	1.01

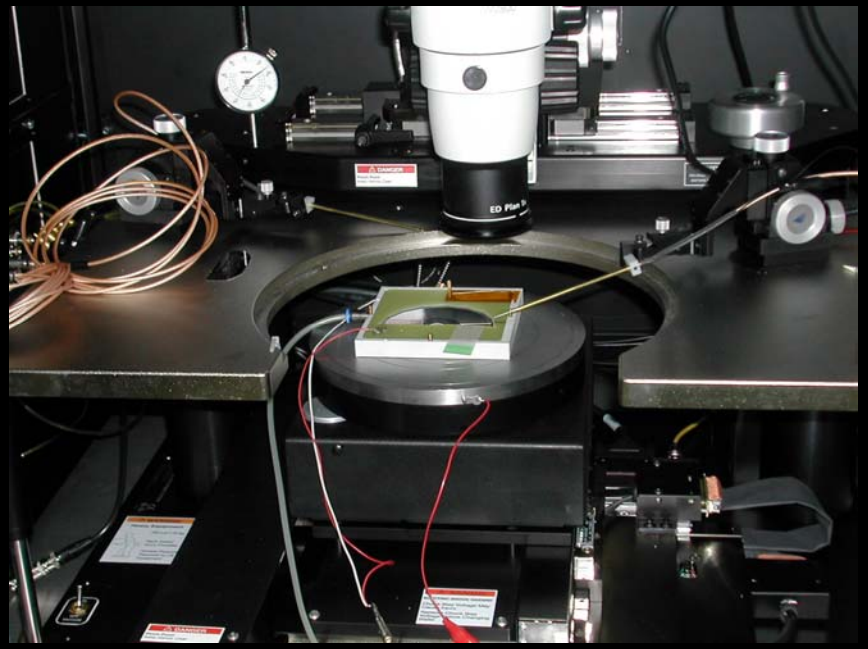
7.5×10^{15} p cm^{-2}

Comment

- if the predictions for V_{FD} changes of n-type silicon are valid for p-type, CCE measurements are in “sharp disagreement” with the CV measurements
- resolve discrepancy
- good news – but operation of Si still requires *may* require cooling to avoid thermal runaway

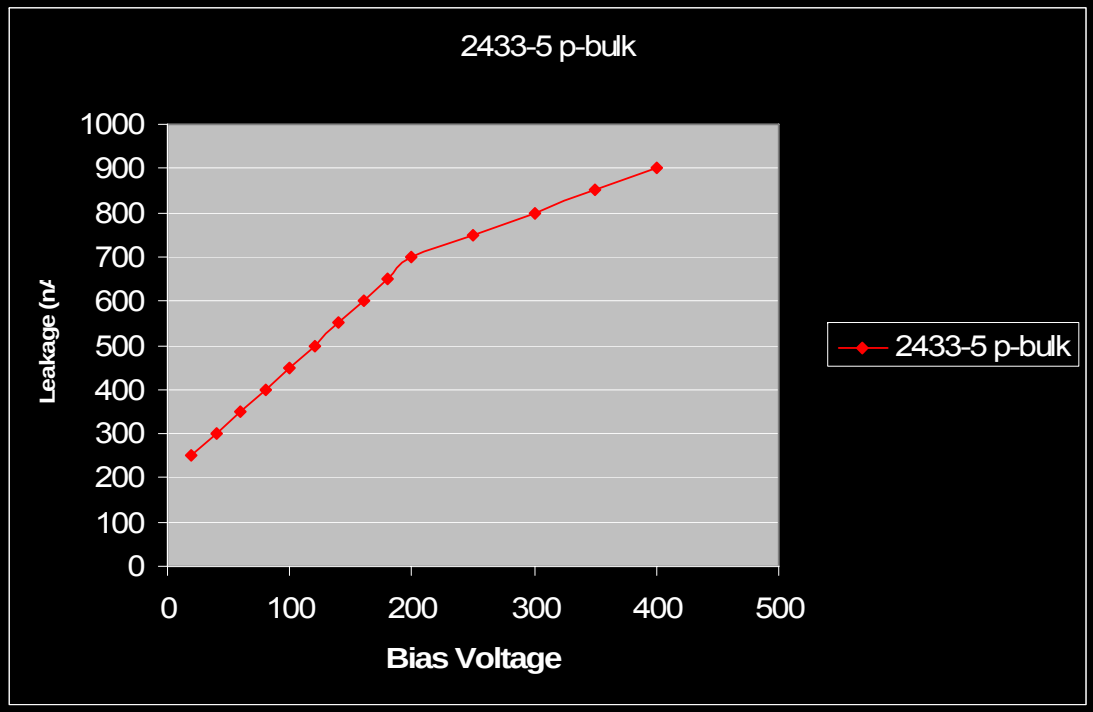
Progress for LHCb

- full size p-bulk detectors being fabricated by Micron Semiconductor
- existing n^+n maskset



Preliminary Data

- 6 wafers
- 3 detectors (after metal 1 tested)
- <1μA leakage current
- Completion ~ 1month



Courtesy Micron Semiconductor

Summary

- n^+n detectors have been developed and are being constructed for LHCb by Liverpool University
- next generation could benefit from higher radiation tolerance
- possible technolgy are p-bulk oxygenated sensors
- full size detectors being fabricated
- initial data look promising