The LHCb Vertex Locator

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Outline

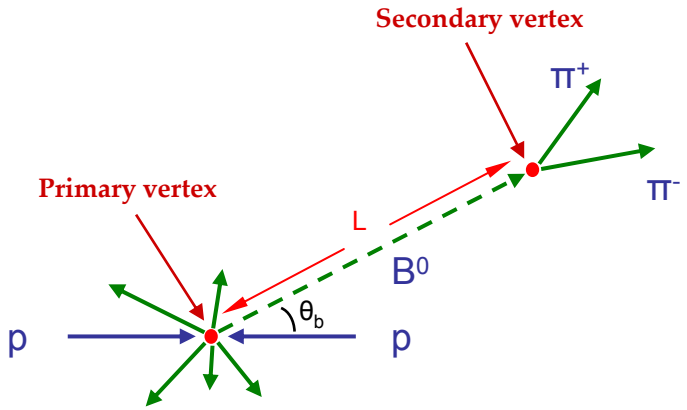
- LHCb and its Vertex Locator
- Radiation Environment
- Technology Choices
- Current Status
- Upgrade Possibilities

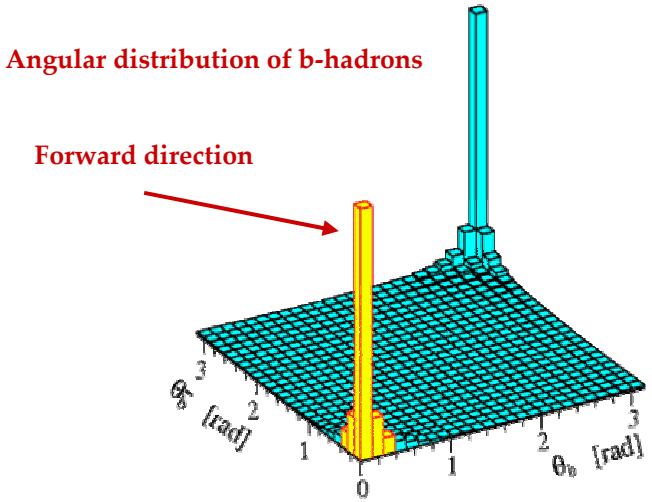
One of four experiments at **LHC**:

- @ CERN, Geneva
- Commissioned April 2007
- 14 TeV p-p collisions at 40 MHz

  → 25 ns read-out time

- Study the physics of **b**-flavoured hadrons (CP-violation)





Kinematical constraints → majority of b-hadrons produced in the direction close to the beam-line

Primary and secondary vertex resolution

→ Characteristic of b-hadrons

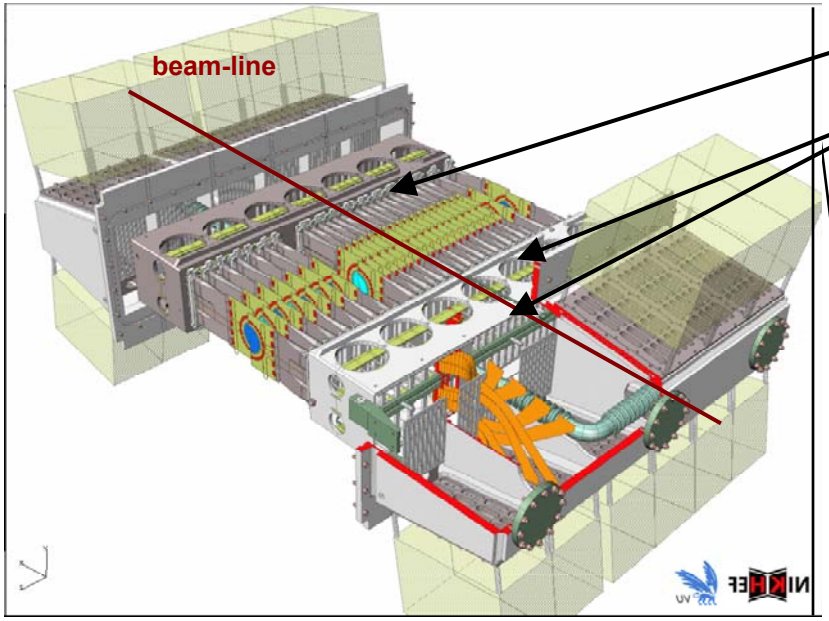
- Flight path in the order of mm
- Measured with precision of 100 μm

Single spectrometer arm

→ 15-300 mrad acceptance

The LHCb Experiment - VELO

The Vertex Locator (VELO)

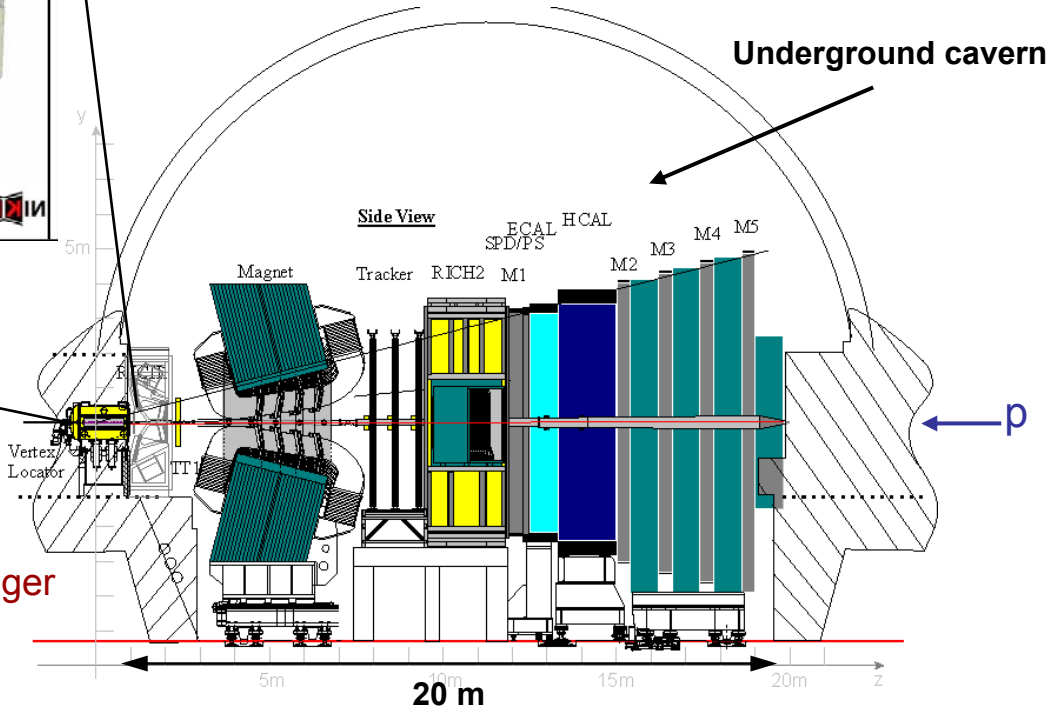


21 pairs of silicon micro-strip detector modules

Two retracting detector halves

First sensitive element: 8.2 mm from beam-line

Operated in vacuum: separated from LHC vacuum by a 250 μm Aluminum foil.



High spatial resolution (>4 μm)

Minimal material

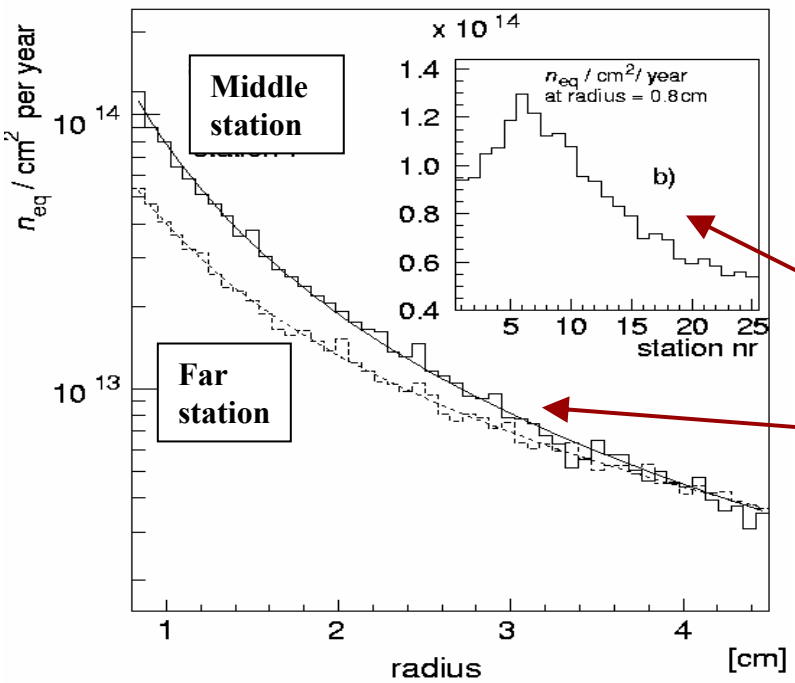
Radiation hardness

Secondary vertex identification used in the trigger
→ ***Fast*** track reconstruction (1 MHz rate)

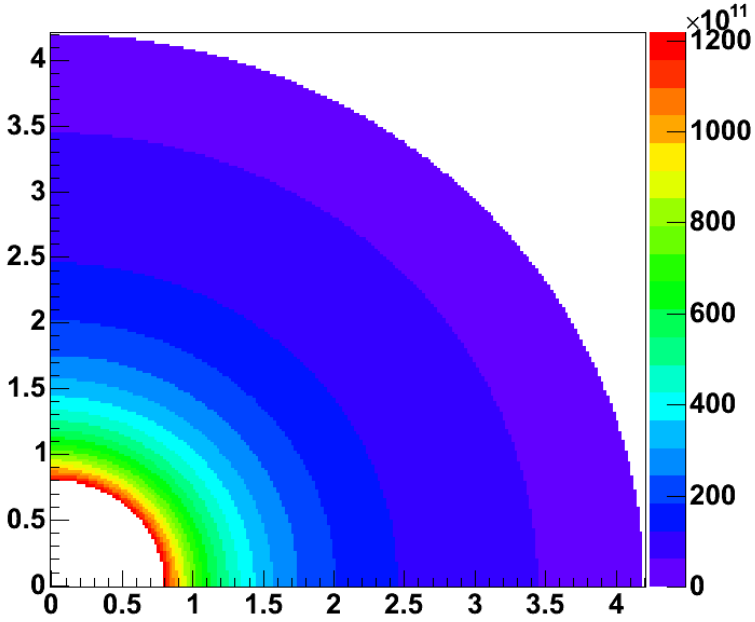
Radiation Environment

Non-uniform radiation environment:

- Peak value: 1.3 * 10^{14} n_{eq} cm^{-2} NIEL per year
- Decreases with increasing radius
- Depends on z (tracking station)



Particle flux for one year of operation tracking station 7
(1 MeV neutron/cm^2 NIEL equivalent)

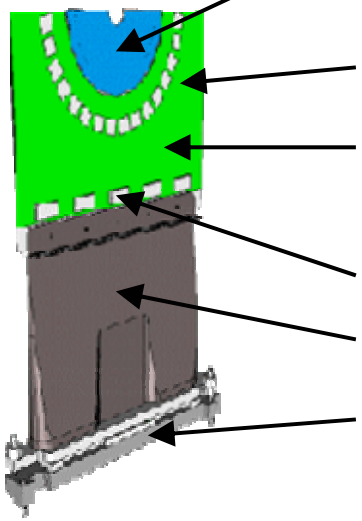


Fluence as a function of tracking station

Fluence as a function of radius

Goal: To operate two - three years with sufficient resolution and S/N

The Detector module



2 silicon types of sensors: R and Φ micro-strips

2 x 16 Read-out chips (“Beetle”):

→ IBM rad-hard deep sub-micron process

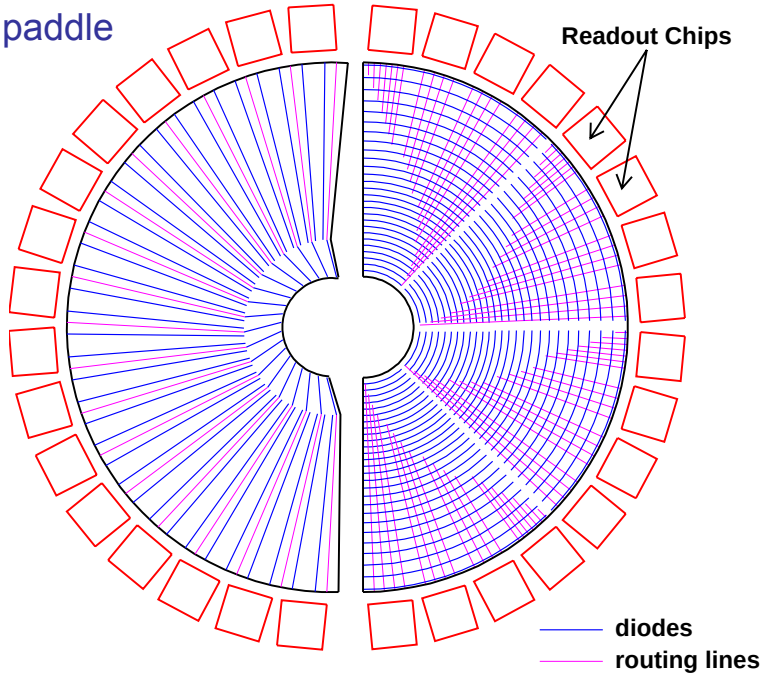
TPG substrate with carbon fibre frame

→ Kapton flex circuit laminated on each side

Contact for CO_2 cooling

Low-mass, high rigidity carbon fibre paddle

Precision aluminium base plate



Silicon micro-strip sensor:

- R and Φ strips: for computational efficiency and occupancy
- Pitch: 40-102 μm for R and 36-97 μm for Φ
- Read-out chips out of acceptance
- Double metal for routing lines
- Silicon operating temperature: -5 °C

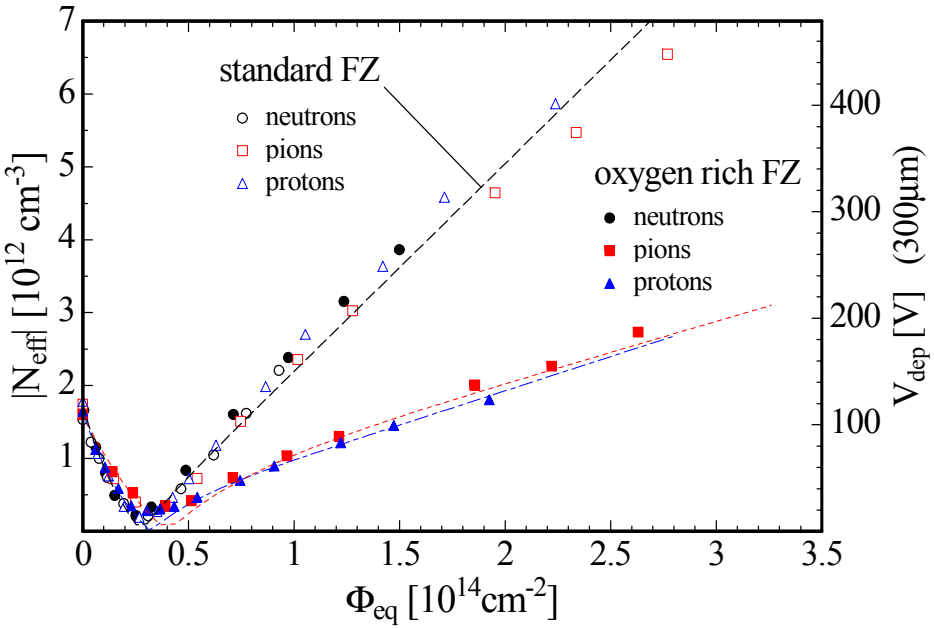
Technology choices (1)

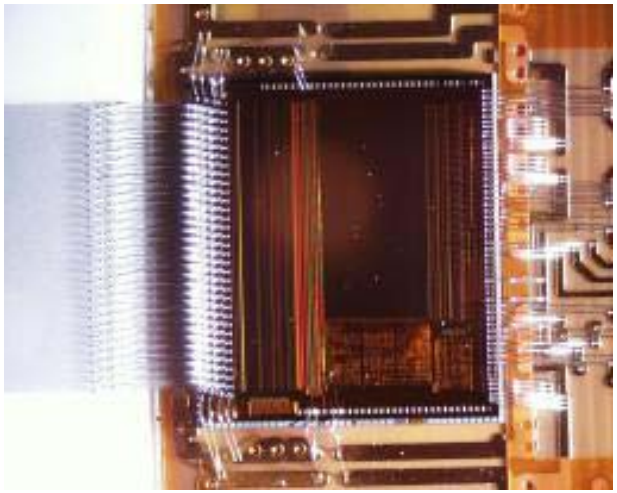
Diffusion Oxygenated Float Zone Silicon (DOFZ) is shown to be more resistant to charged particle radiation.

VELO will use thin (200-300 μm) DOFZ sensors produced by MICRON

Depletion voltage vs. particle fluence, 1 MeV NIEL equivalent.

From ROSE collaboration (NIM A 466 pp 308-326)

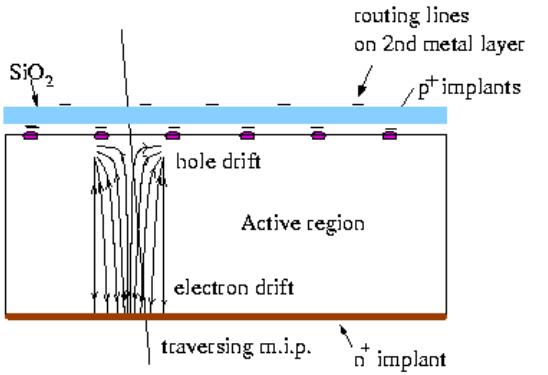


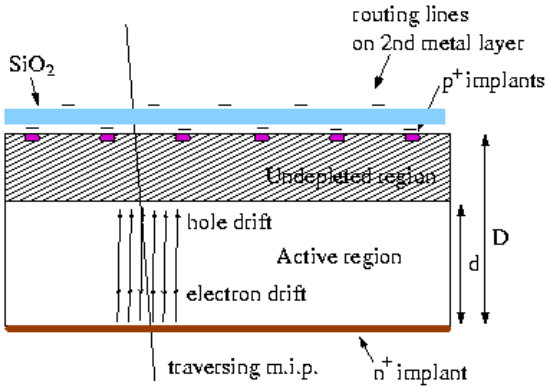


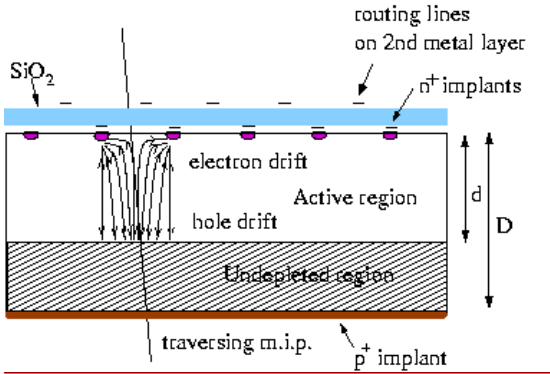
Beetle 1.3 front-end chip

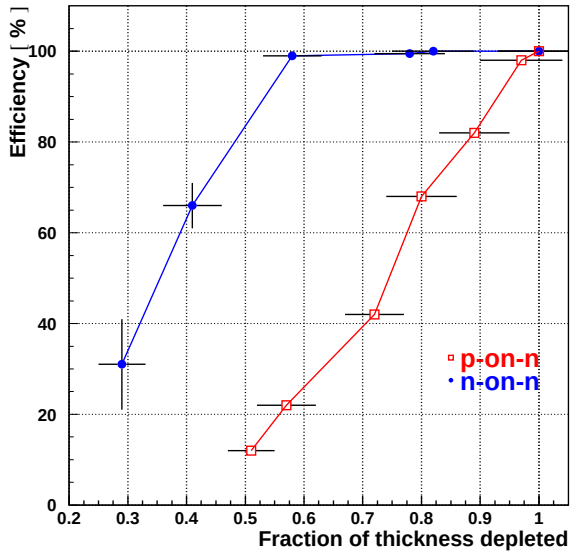
- IBM 0.25 μm CMOS process
- Rad-hard design rules
- Qualified > 30 MRad

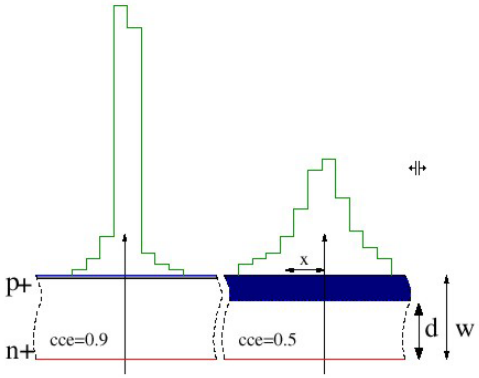
Technology choices (2)

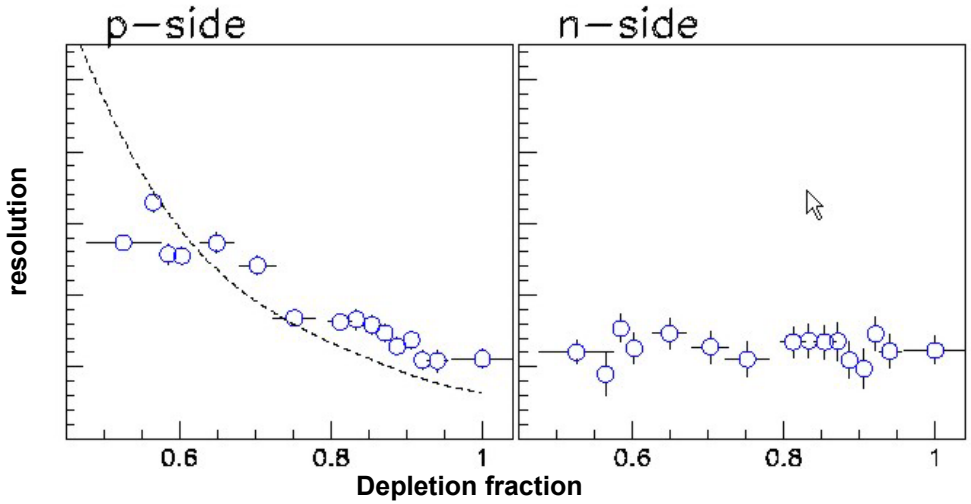




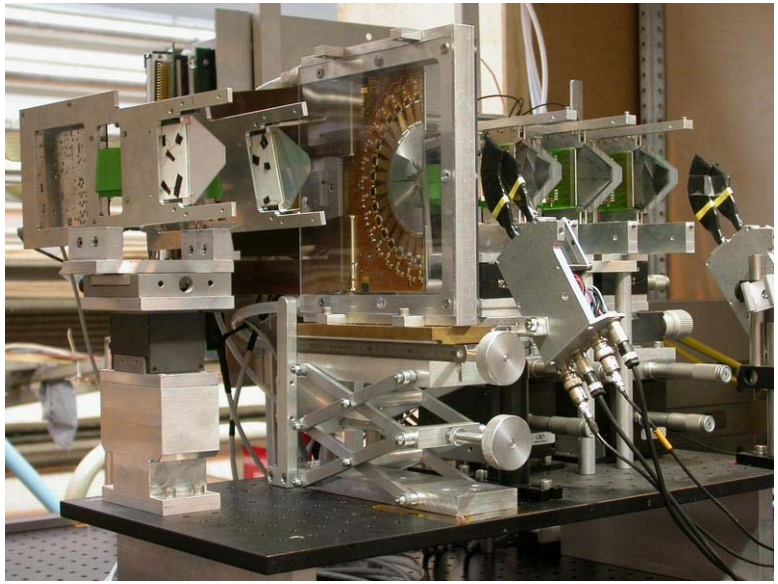








Current Status



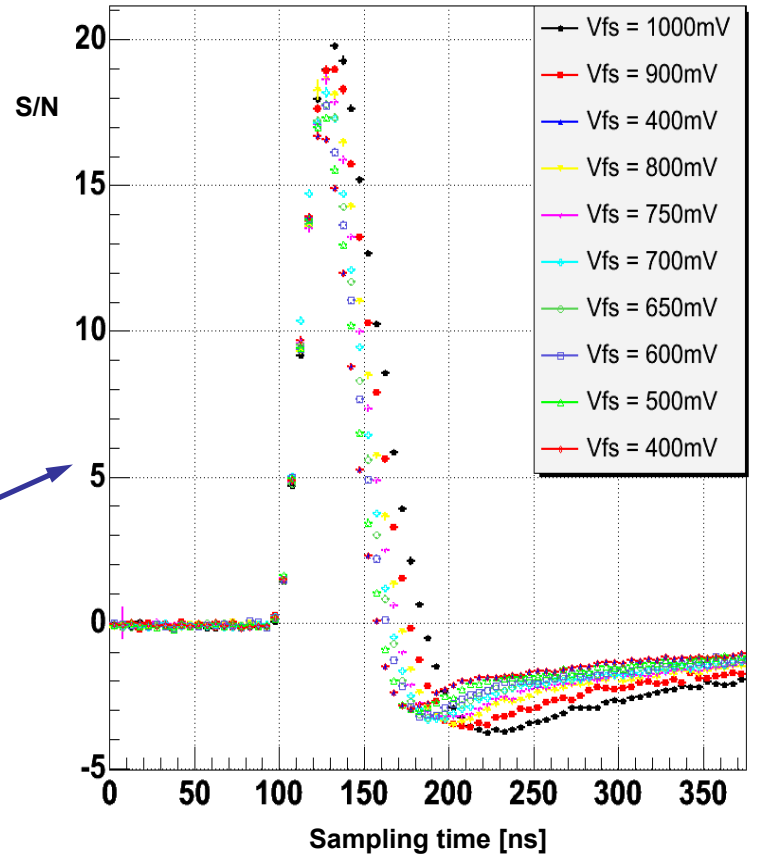
Final stage of R/D

- Evaluation of a final prototype in beam-test (June 04)
- Irradiation and sub-sequent measurements in the fall

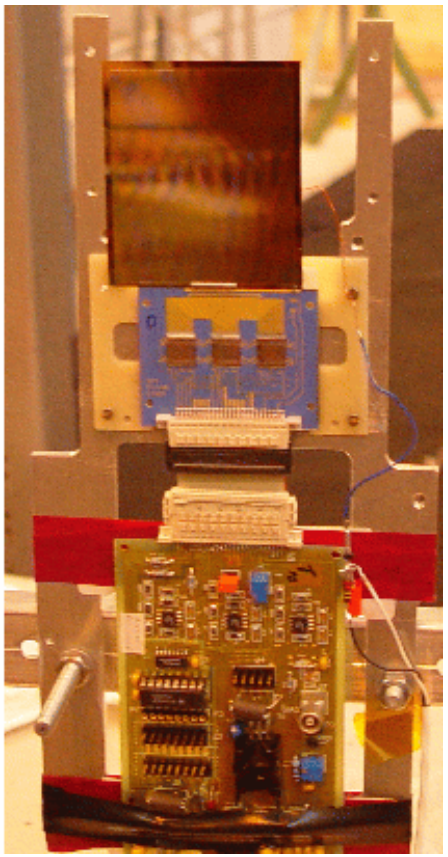
- Verify sensor design
- Confirm radiation hardness
- Finalise the detector *system*

Example:

Optimisation of front-end chip settings



VELO upgrade scenarios (1)



Cz detector in the beam-line

VELO Silicon foreseen to last ~ 3 years

→ LHC will operate ~ 10 years

→ Performance upgrade

Many different upgrade scenarios under discussion

→ n-on-p, 3D, Cz silicon, strixels, pixels …

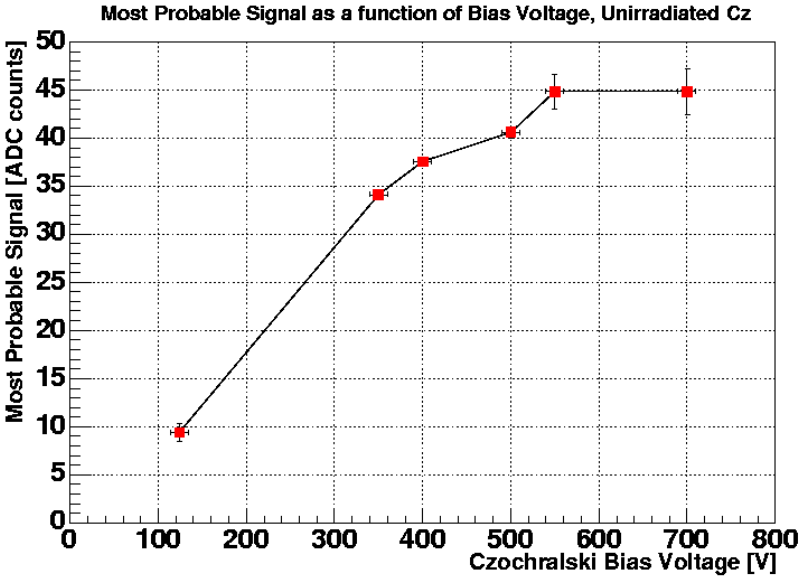
One option: Magnetic Czochralski (Cz) silicon

- Alternative to float-zone silicon - widely available in industry
- Naturally high oxygen levels: ~10^{18} cm^{-3} (Cf. DOFZ ~10^{17} cm^{-3})
- Expected to be radiation hard

First beam-test of a large micro-strip Cz sensor with 40 MHz read-out

- 380 µm sensor, parallel 50 µm strips
- p-on-n
- Measured before and after irradiation

VELO upgrade scenarios (2)



Results:

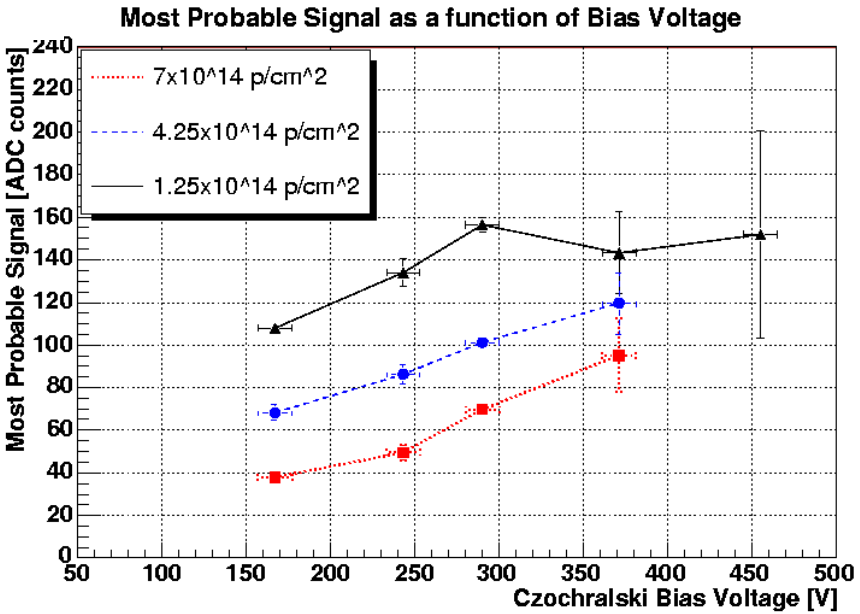
- S/N before irradiation: 23.5 ± 2.5 for 380 μm
- S/N after irradiation: 11 for 380 μm

→ Corresponding to two years of VELO operation

→ Under-depleted

→ Low statistics

We aim to continue investigating this track as a possibility for a VELO upgrade



Summary

LHCb Vertex Locator

- Exciting application of rad-hard silicon sensors
- Technology choices (DOFZ and n-on-n)
- Final R/D phase – commissioned April 2007
- Vision of one upgrade track