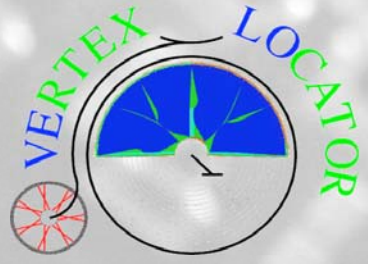
The LHCb VErtex LOcator

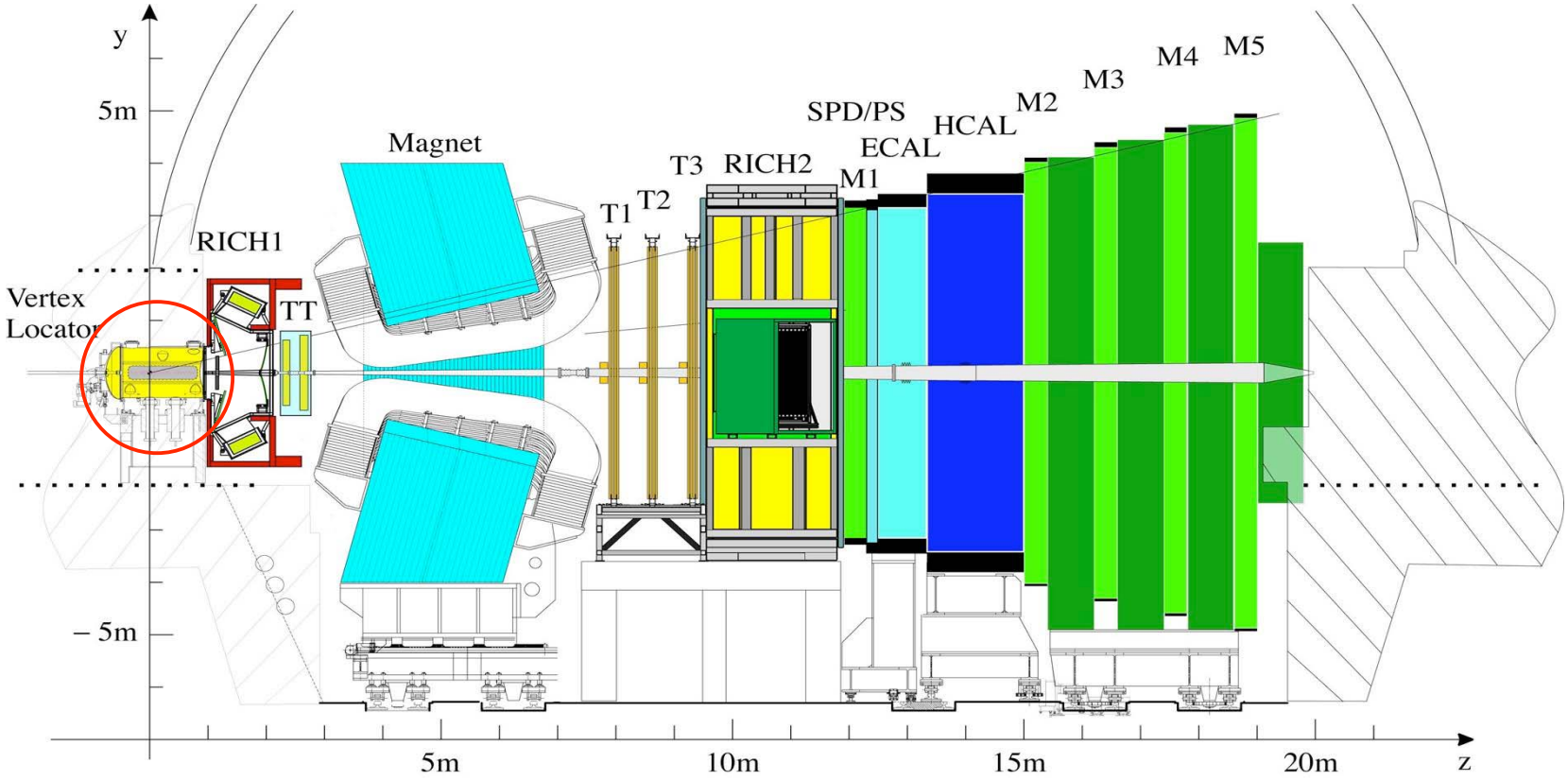
Olaf Behrendt

on behalf of the VELO group



EPS HEP 2007
Manchester, 20.07.07

Role of the VELO in LHCb



Reconstruction

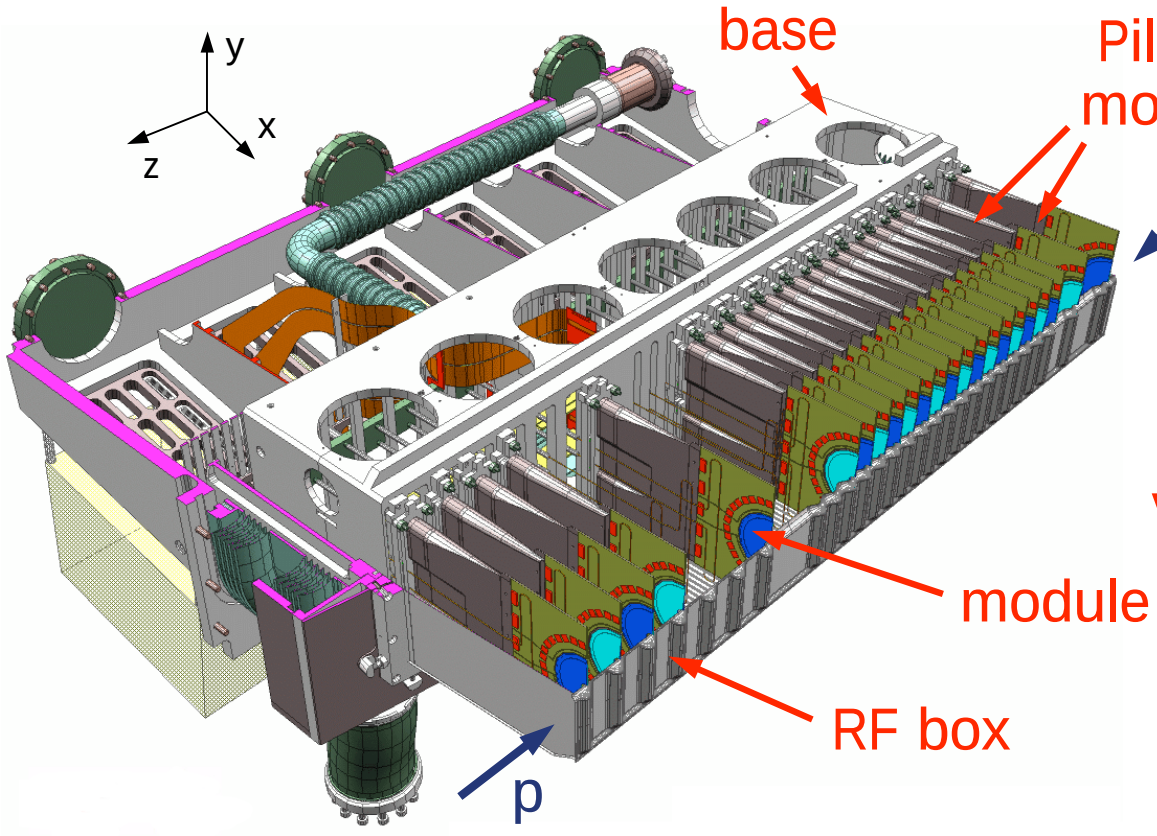
- precise tracking
- primary/secondary vertices [lifetime]

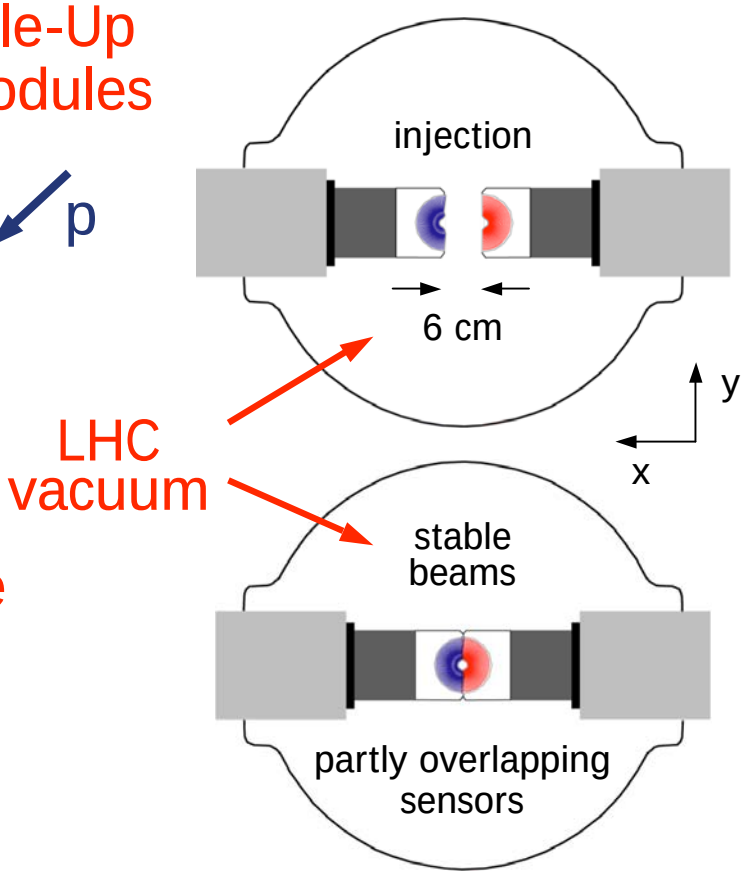
Trigger

- B-decay selection
- suppression of multiple interactions

- absolute luminosity measurement

Layout



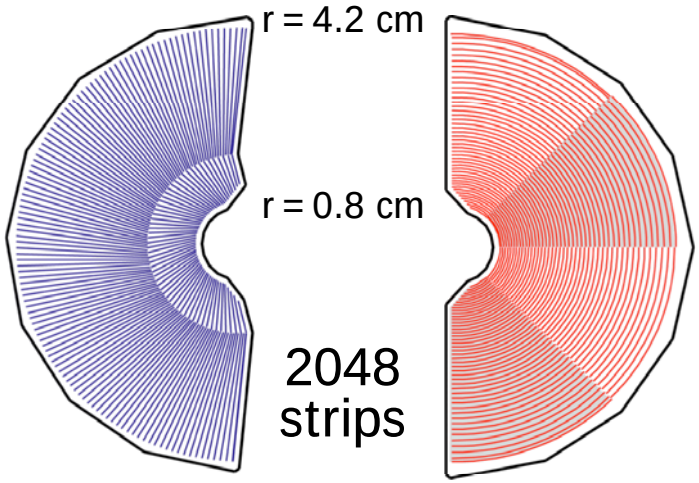


- 2 retractable detector halves
- 21 stations per half with an R and ϕ sensor
- 2 Pile-Up stations per half [trigger]

Sensors

ϕ-sensor

- divided into short and long strip region
- pitch: 35 - 100 μm
- stereo angle



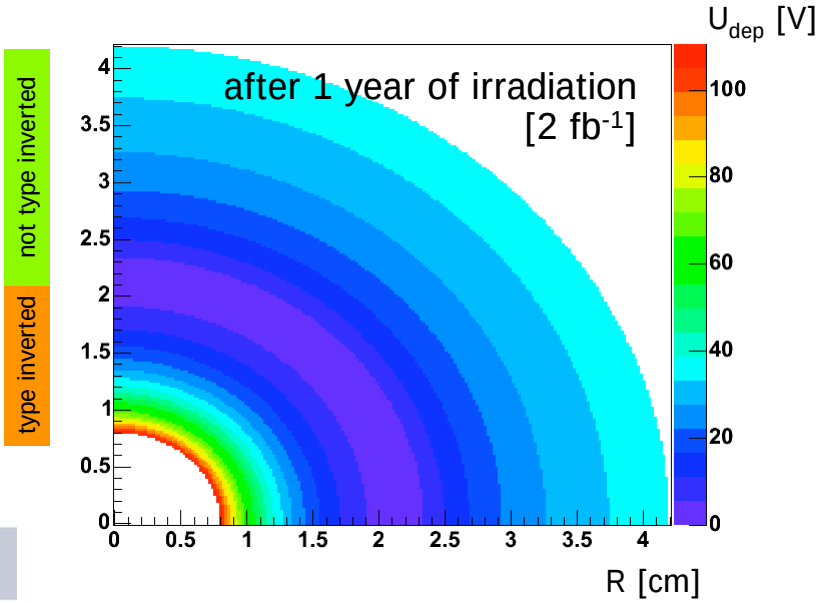
R-sensor

- divided into quadrants
- pitch: 40 - 100 μm

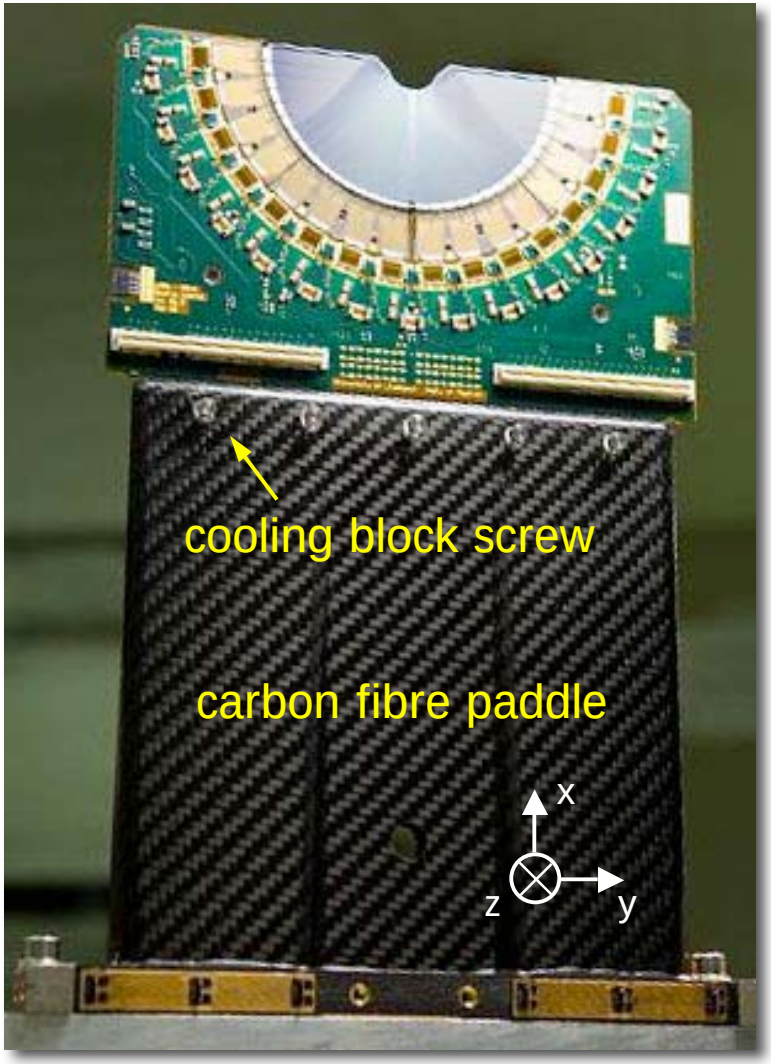
n^+ in n-bulk sensors [300 μm]

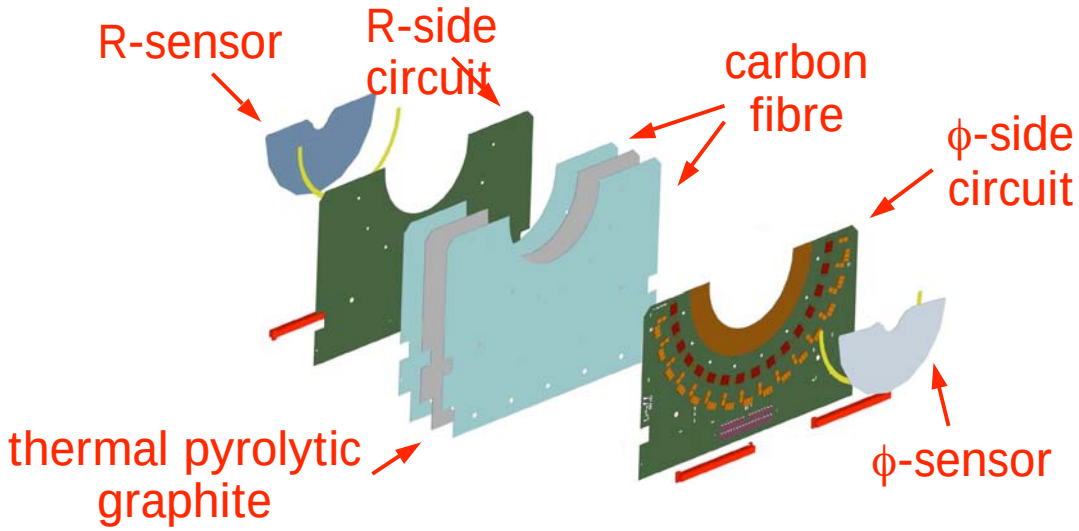
- inherently radiation tolerant
- strip isolation via p-spray
- expected radiation dose:
  - $1.3 \cdot 10^{14}$ n_{eq}/cm^2/year at r = 0.8 cm
  - $5 \cdot 10^{12}$ n_{eq}/cm^2/year at r = 4.2 cm

after 3-4 years [~8 fb^{-1}]: run partially depleted



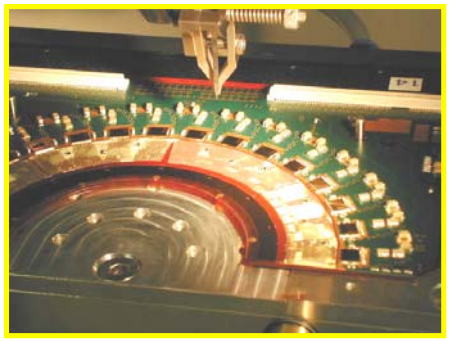
Modules

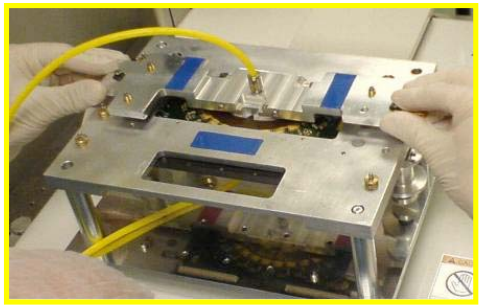


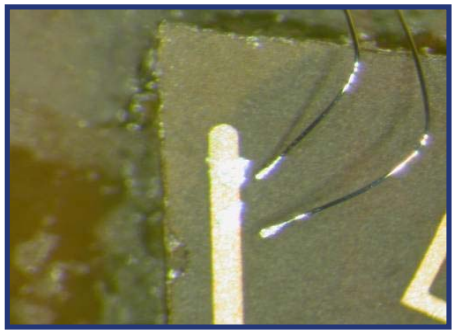


- double-sided hybrid to balance stresses due to “bi-metallic” effects
- typical non-planarities: 250 μm
- sensor-sensor accuracy: < 10 μm
- analogue front-end read-out: 2 x 16 Beetle chips
- cooling: 2-phase CO_2 [silicon @ -7° C]

Module Production







HV return line problem
[jig pushing bonds at feet]

receive and validate components

hybrid assembly

wire bonding on the hybrid

glue sensors on hybrid

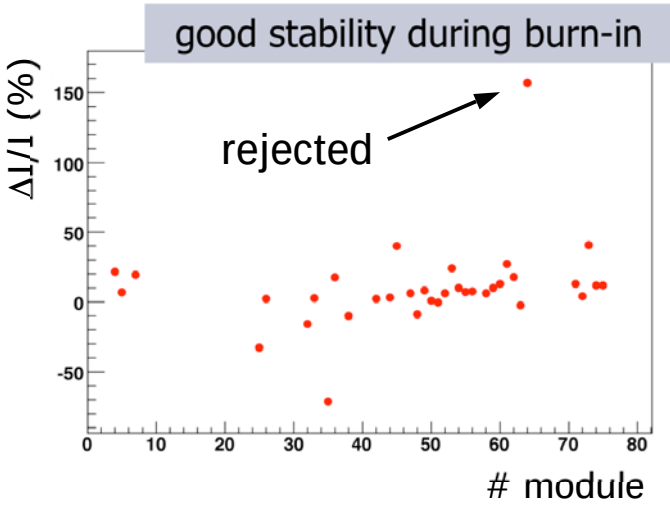
wire bonding of sensors to hybrid

glue to carbon-fibre paddle

module metrology

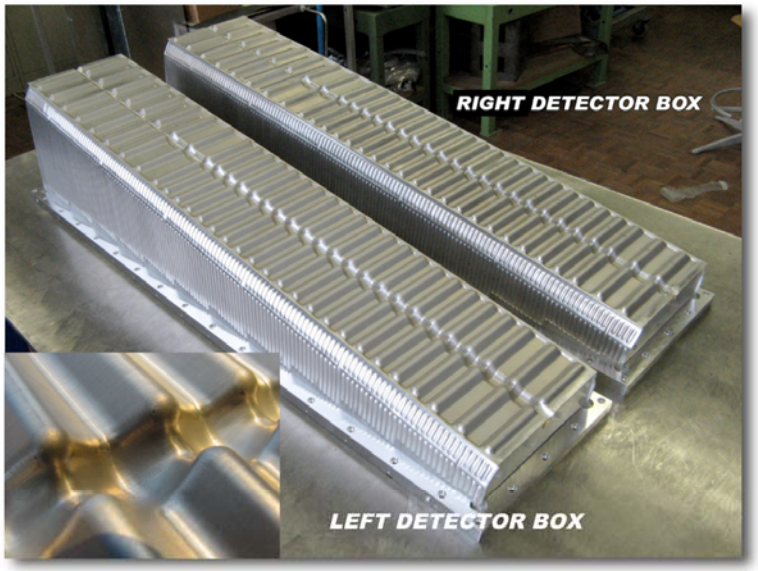
visual re-inspection

module burn-in
- electrical test in vacuum
- thermal stress
- electronics burn-in



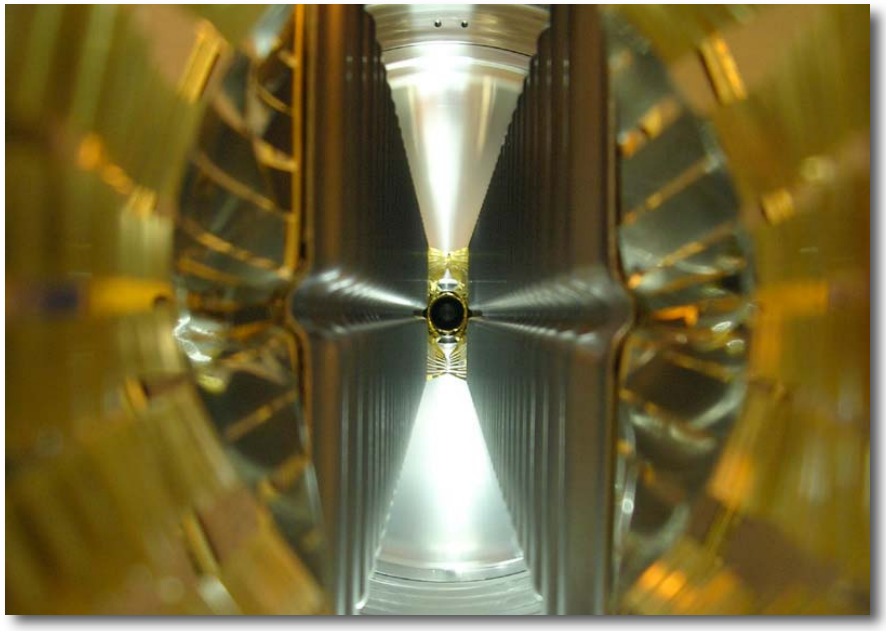
Fully Assembled VELO Half

Vacuum System



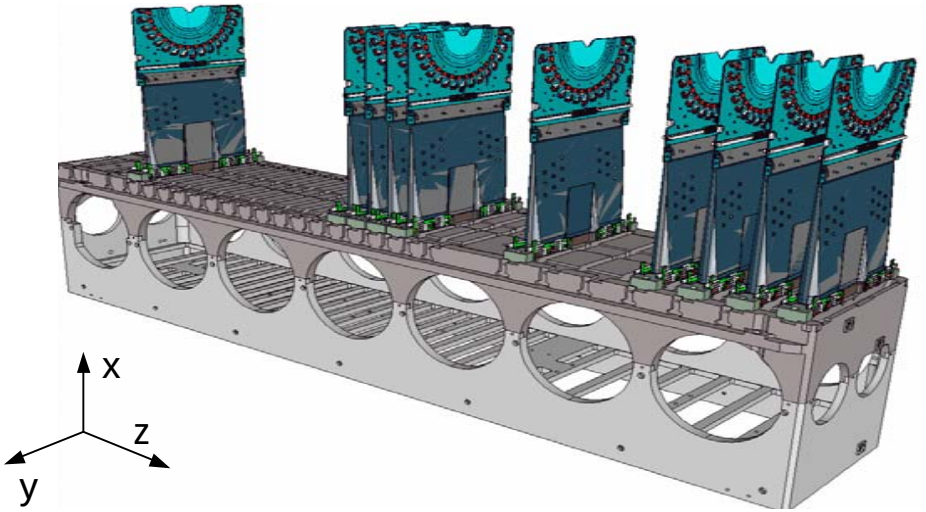
- silicon detectors operated in vacuum
- RF shield of 300 μm Al [3% Mg]
  - constitutes beampipe in VELO region
  - shape allows for overlapping sensors [alignment]

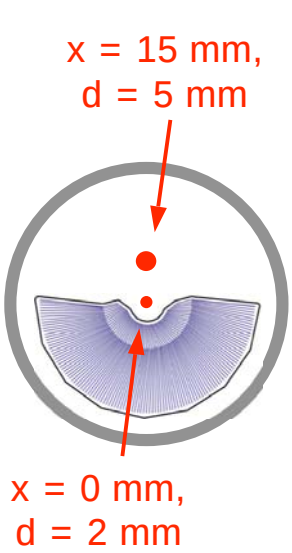
- avoid deformations:
  $\Delta P = P_{beam} - P_{detector} < 10$ mbar
- control system: $\Delta P < 5$ mbar
- beam vacuum after bakeout:
  $P_{beam} = 3.5 \cdot 10^{-10}$ mbar
  [requirement: 10^{-8} mbar]
- expected VELO vacuum:
  $P_{detector} < 10^{-4}$ mbar

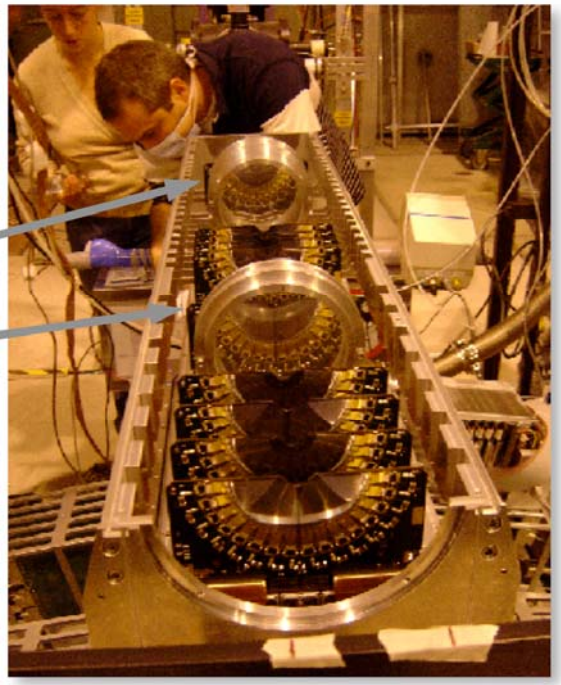


This is what the LHC beams see ...

Testbeam







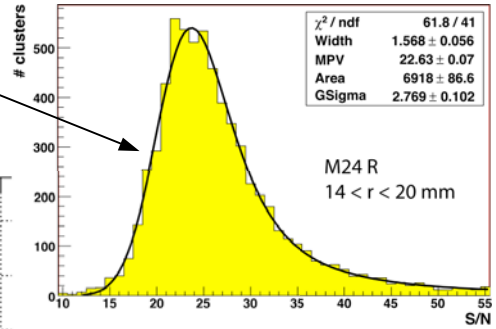
November 2006

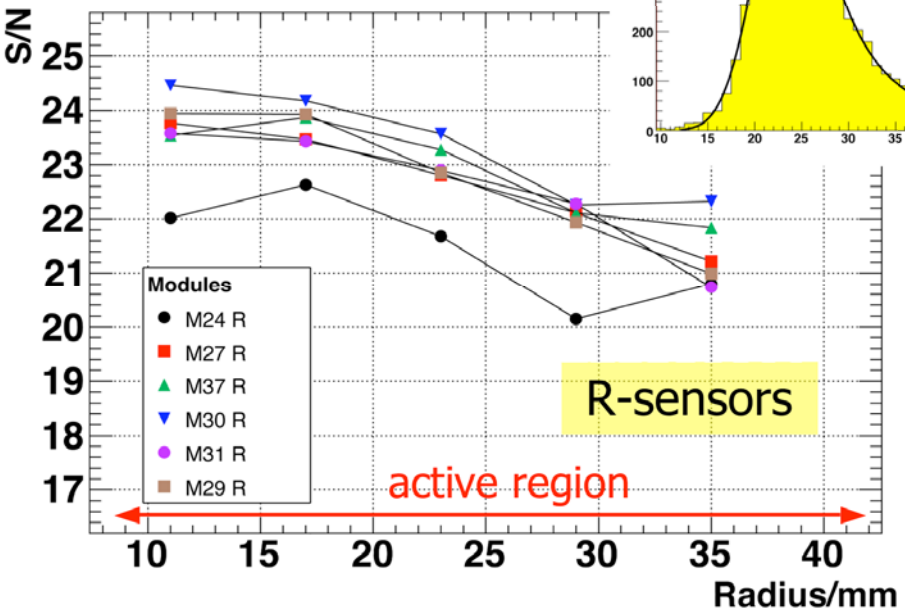
- 10 modules
- 180 GeV π beam
- small scale CO_2 cooling system
- 6 modules readout simultaneously
  [full readout chain with final electronics boards]
- software: DAQ, ECS, tracking, vertexing, online monitoring

- data for 0, 4 and 8 degrees
- interaction data
  - 4 layers with 2 Pb targets [300 μm]
  - test vertex reconstruction
  - emulate open and closed VELO
- > 50 million events to disk

Testbeam Results

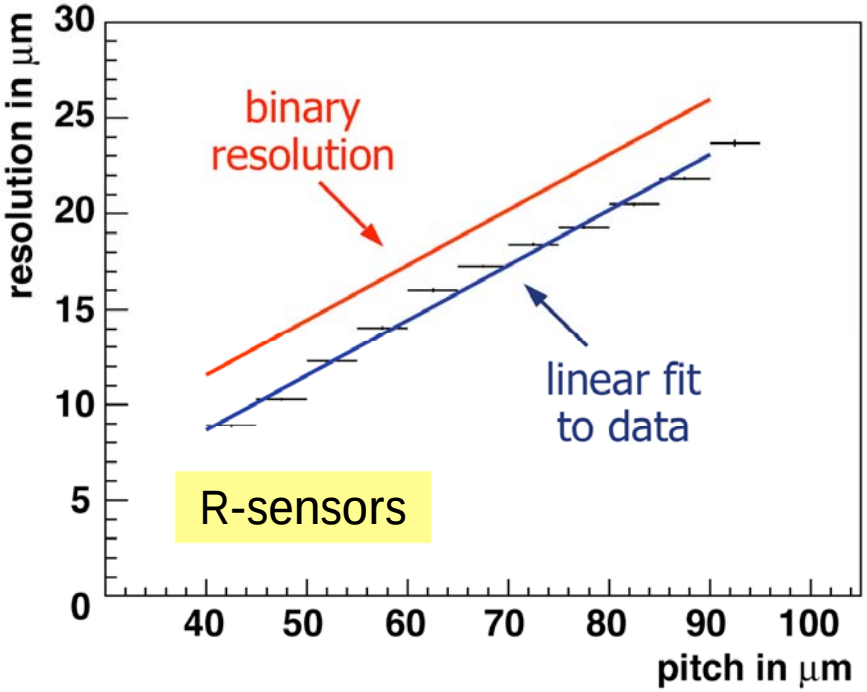
Landau ⊗ Gaussian





R-sensors

- S/N: 20 - 24
  [decreases with r due to increasing strip length]
- resolution: 10 - 25 μm
  [pitch: 40 - 100 μm]

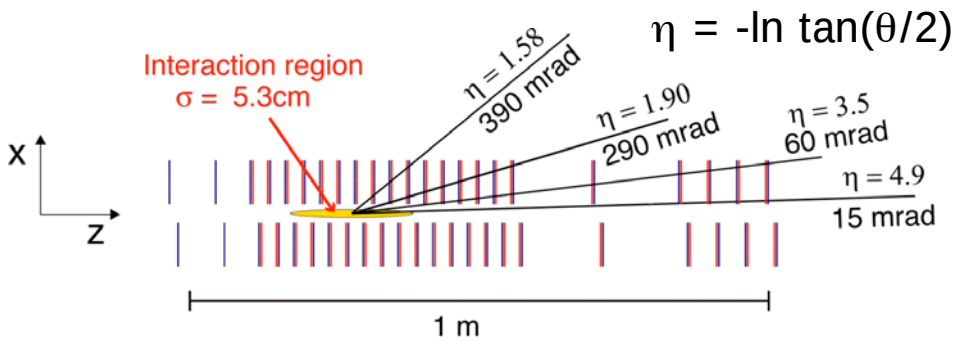


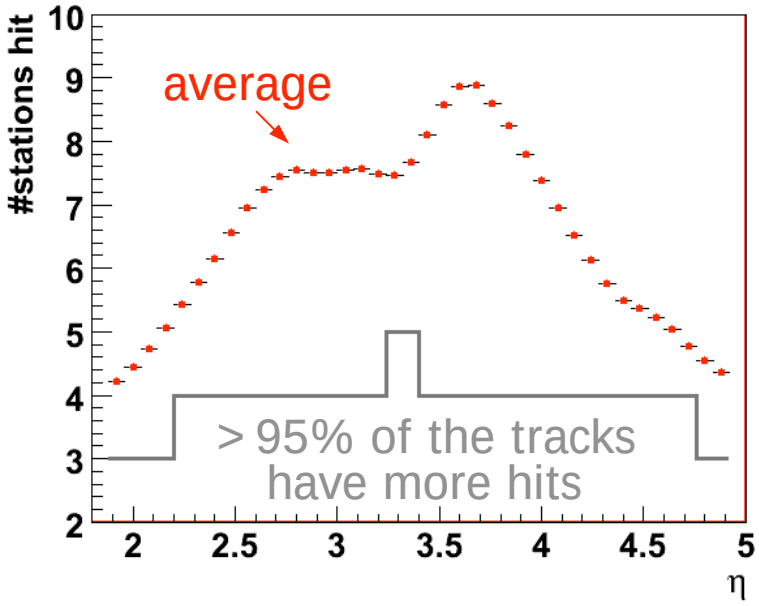
ϕ-sensors

- S/N: 24 - 29
- resolution: 9 - 20 μm [pitch: 35 - 100 μm]

expected resolution improvements: cross-talk and η corrections

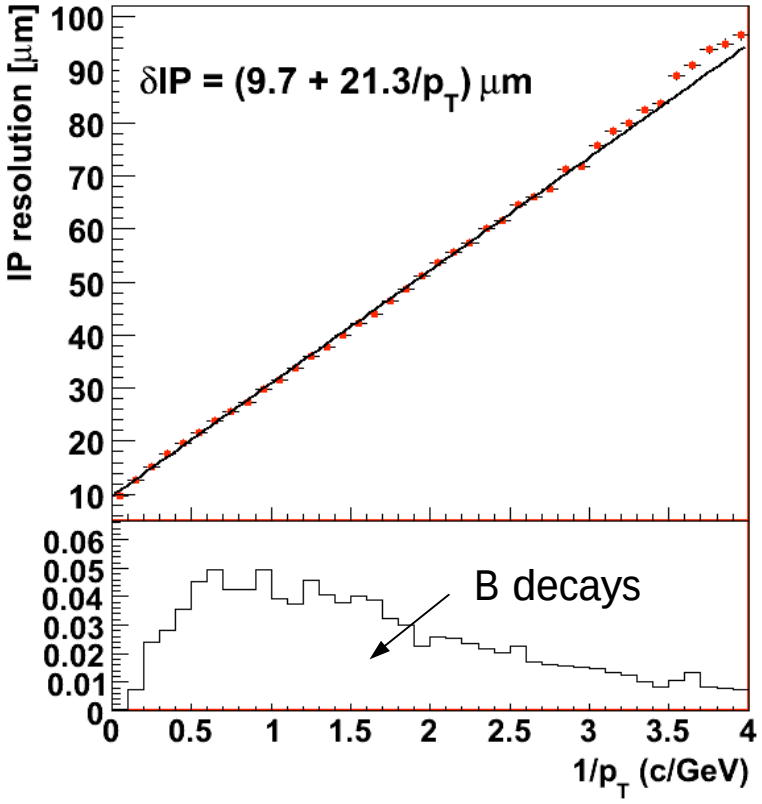
Expected Tracking Performance





reconstructed track - hits in 3 stations

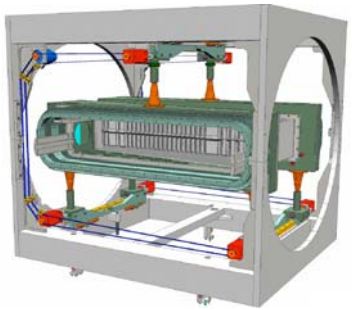
LHCb acceptance: $1.9 < \eta < 4.9$



For typical B decay modes:

- secondary vertex resolution:
  - x,y: ~10 μm, z: ~100 μm
- Proper time res.: ~40 fs
- B Mass res.: ~15 MeV

Status



positioning system

- module production and burn-in: completed March 2007
- module assembly on detector halves: completed March 2007
- checkout/metrology of detector halves: ongoing
- vacuum/detector positioning system: installed
- cooling system: commissioning
- Electronic boards/cables: commissioning

- installation of first VELO half in the pit: Q4 2007

CO_2 cooling system

readout electronics

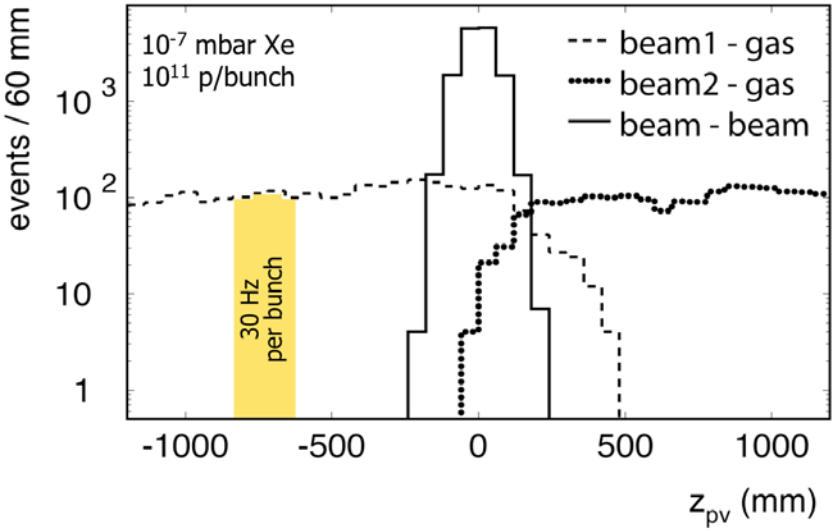
Summary

- VErtex LOcator is small but complex detector
- precision tracking very close to the interaction region
- vital role for the online event selection
- radiation tolerant design
- results from the testbeam in November 2006
  - S/N: 24-29 (ϕ), 20-24 (R)
  - resolution: 9-20 μm (ϕ), 10-25 μm (R)
- on schedule for first data in 2008

Luminosity Measurement

Method:

- injection of a tiny bit of gas into VELO region
- reconstruction of beam-gas interaction vertices
  - beam angles, profiles & relative positions
  - calculate luminosity
- simultaneous reconstruction of beam-beam interaction vertices
  - calibrate ‘reference’ cross-section



$$L = f\, N_1\, N_2\, 2c\, \cos^2(\phi/2) \int_{4-\text{fold}} \rho_1(\mathbf{x},t)\, \rho_2(\mathbf{x},t)\, d^3x\, dt$$

machine LHCb

- expected beam size: $\sigma_x \approx \sigma_y \approx 70\ \mu m$
- expected vertex resolution: $\sigma_{pv} \approx 30\ \mu m$

expected accuracy: ~1%

test setup for gas injection