Installation and operation of the LHCb Silicon Tracker detector

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on behalf of the Silicon Tracker collaboration

1st international conference on Technology and Instrumentation in Particle Physics, TIPP09
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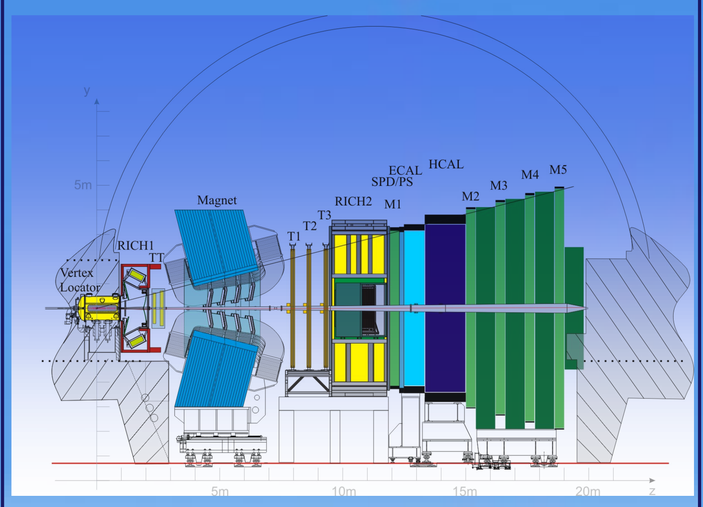
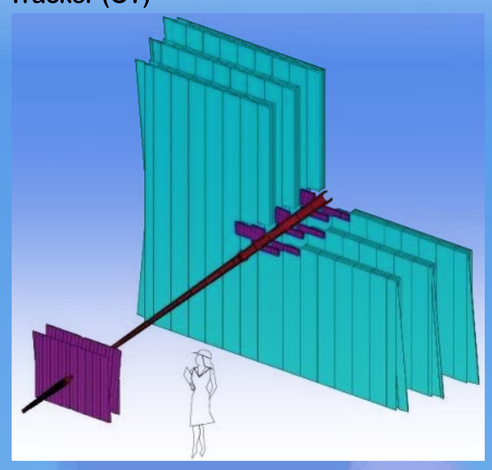
The LHCb experiment



- Single-arm forward spectrometer dedicated to B-physics
- Acceptance: 15-300(250) mrad
- pp@14 TeV, luminosity = $2 \cdot 10^{32}$ $cm^{-2}s^{-1}$
- 10^{12} $b\bar{b}$/year, full B spectrum

The Tracking detectors

The tracking system is formed by the Vertex detector (VELO), the Tracker Turicensis (TT) station and the Tracking stations (T1-T3) downstream the magnet which are split into and Inner Tracker (IT),close to the beam pipe, and an Outer Tracker (OT)



The Read-Out electronics

Beetle chip: charge integrators for high capacitance strips, rad-hard (>10Mrad) & 0.25 µm CMOS @ 40MHz :

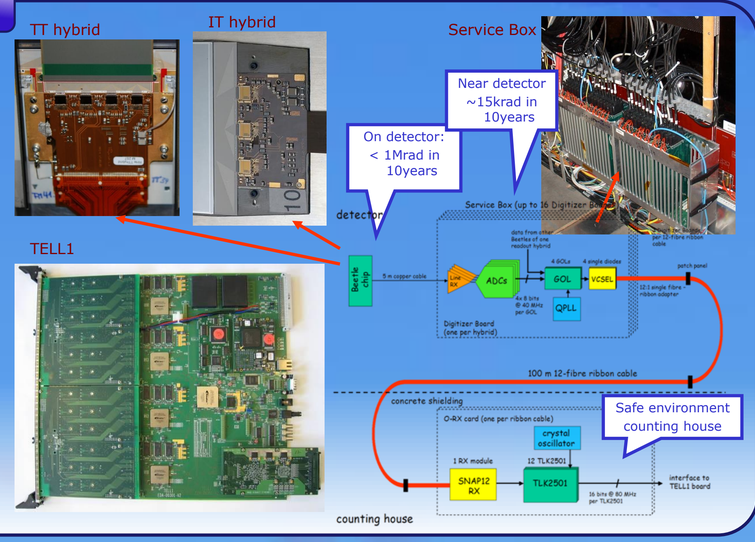
- 128 channels multiplexed onto 4 ports ➡ 1.1 MHz read-out
- Pipelined 160 bunch crossings

Read-out hybrid: 3(IT) or 4(TT) "Beetle" readout chips

Service Box: digitization, optical transmission and control electronics. Rad-tolerant (~Krads)

TELL1 real time processing boards

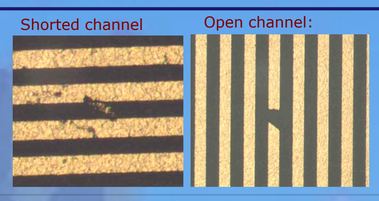
- 2128 Gbit optical channels
- ~337 Gbyte input , ~6.4 Gbyte output to the DAQ network

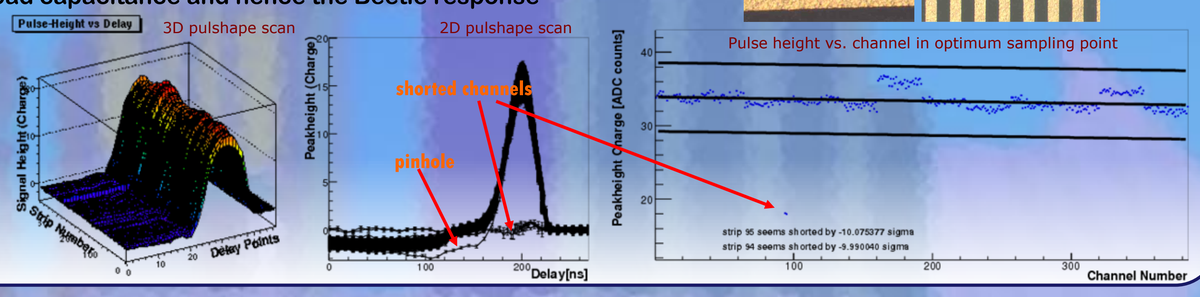


Sensors testing

Internal Beetle calibration pulses reliable to detect common defects (broken, short, pinhole) in final modules:

- Shorted/broken channels (typically on pitch adapter) change load capacitance and hence the Beetle response





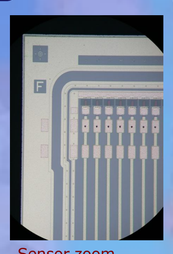
The LHCb Silicon Tracker design and assembly

Inner Tracker + Tracker Turicensis

- Spatial resolution requirements ~60 µm ➡ pitch ~200 µm
- 270k silicon readout channels and ~12 m^2 of silicon sensors
- Liquid C_6F_{14} cooling system ➡ operation at ~5°C
- Lightweight foam for thermal insulation + Al foil for electrical shielding

Silicon Sensors:

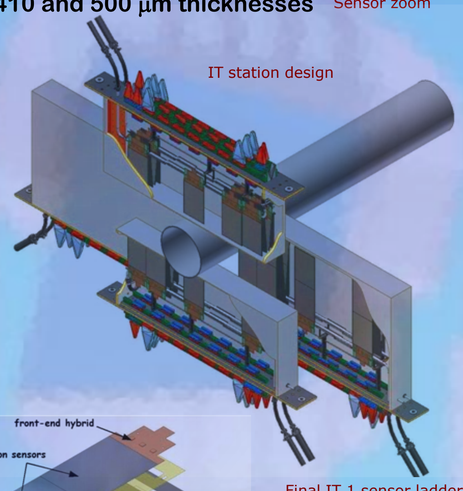
- p-n silicon micro-strip sensors (HPK)
- 1-4 sensors bonded together ➡ up to 37 cm long strips
- 183 µm and 198 µm pitch, w/p=0.25,
- 320, 410 and 500 µm thicknesses

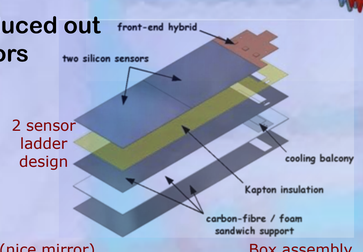

Sensor zoom

Inner Tracker:

Provides granularity in the high multiplicity region around the beam pipe - 1.3% of sensitive area (4.3 m^2 and ~130K channels) 20% of tracks

- 3 stations with 4 boxes, 4 layers per box (2 with ±5° stereo angle) ➡ 336 modules
- Modules: 1, 2 sensor-ladders (11 and 22 cm) with 384 AC coupled strips
- Hybrid with 3 "Beetle" read-out chips
- Cooling "balcony" for mounting and positioning of the module on the supporting cooling rod which is connected to the liquid cooling system
- Thermally conductive Carbon Fibre (CF) support produced out of high thermal conductive fiber used to cool the sensors


IT station design

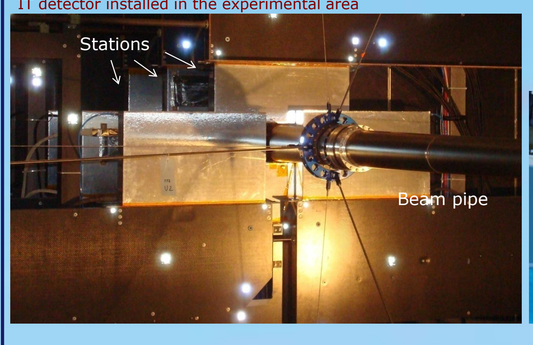


Final IT 1 sensor ladder

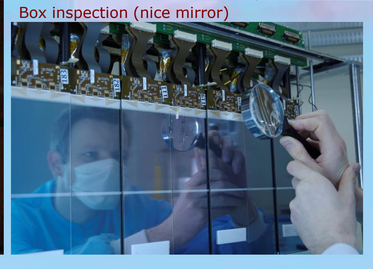
Installation:

- ~98% of the Inner Tracker is fully functioning

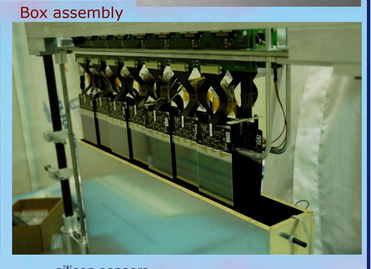
IT detector installed in the experimental area



Box inspection (nice mirror)



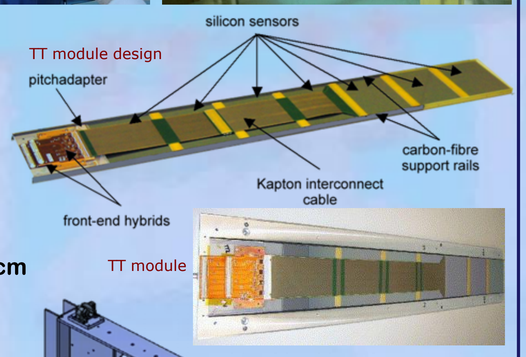
Box assembly



TT-station:

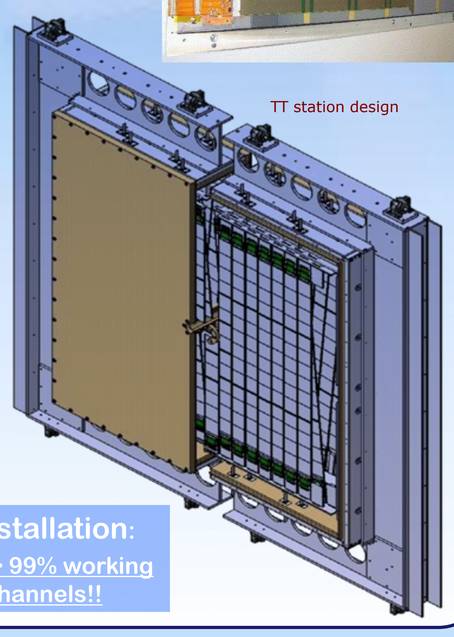
Provides high resolution information of the momentum of charged particles. Active area: 8.14 m^2 and ~140k channels

- 4 layers in a single detector box volume (2 with ±5° stereo angle) ➡ 280 modules
- Modules: 1, 2, 3 and 4 sensor sectors
- Sensors: 9.63(w) x 9.43(l) cm, 512 AC coupled strips. Inner sensors connected via Kapton interconnect cable (up to 55 cm long)
- High load capacitance: 3 sensor + flex ➡ 57 pF
- Hybrid with 4 "Beetle" readout-chips
- Support and readout hybrids outside of the acceptance

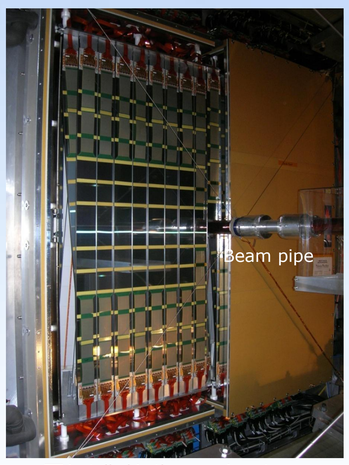


TT module

TT station design




TT station installation



TT installed in the experiment

Installation:

- > 99% working channels!!

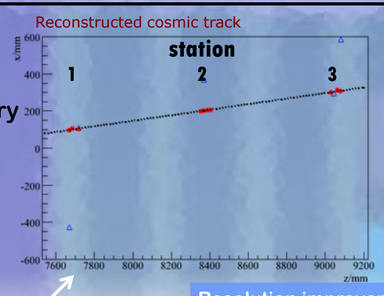
Detectors Commissioning

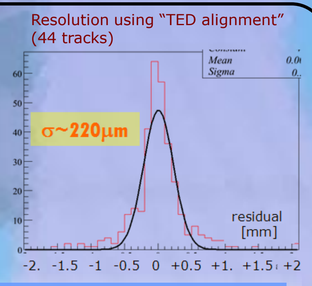
COSMIC EVENTS

They are very rare as LHCb geometry is "not very favorable" . Used for coarse time alignment:

- From 1.1 million cosmic (special stand alone tracking with very tight noise cuts)
- 44 track candidates that cross two stations
- Found 2 track candidates that cross all three stations

Reconstructed cosmic track with 10/12 hits!





Resolution improvement in the reconstruction:

- Using nominal geometry: σ = 310 µm
- Using survey geometry: σ = 270 µm
- Using the "TED data alignment": σ = 220 µm

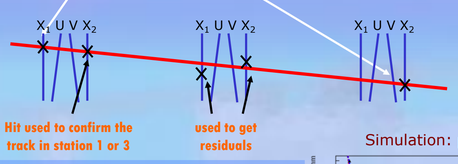
"TED" EVENTS

The only "beam" induced particles seen so far. LHC beam directed on a beam dump in the transfer line 300 m "behind" LHCb with a high density of particles.

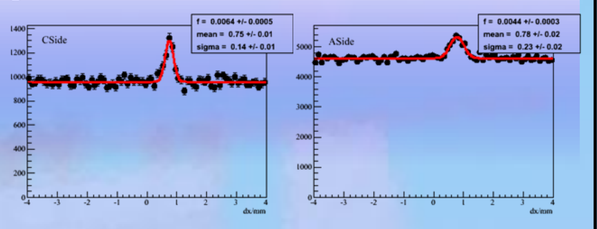
- ~ 4000 clusters in the Inner Tracker per event (~20x more than in nominal physics events)
- Used for fine time alignment between boxes in the IT and for spatial alignment (beyond survey, that is believed to have about 500 µm accuracy) for IT and TT

IT Spatial Alignment

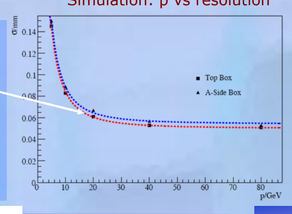
- The "Track density" is too high for standard track finding
- Used method: track candidates in expected direction from hits in first and last layer, a third hit confirms the track and final calculation of hit residuals in middle box



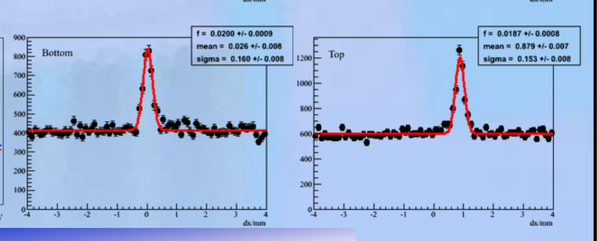
Updated relative box alignment from survey



Simulation: p vs resolution



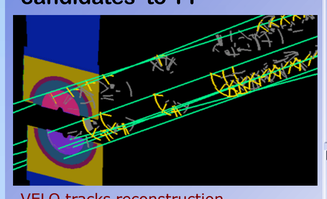
- This method with simulated TED events w/o misalignment shows a resolution of 60 µm assuming 20 GeV/c particles
- A 100 µm misalignment ➡ σ = 150 µm
- Conclusion: ladder misalignments still remain

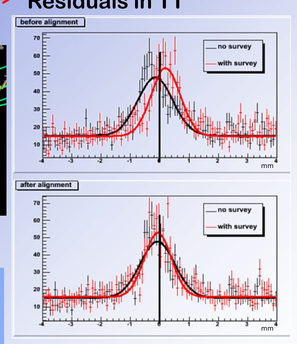


TT Spatial Alignment

- TT-Station has only 4 layers (x,u,v,x) → no stand alone tracking is possible
- Track candidates from the VELO are extrapolated to the TT ➡ hit residuals TT-layers:

Extrapolate VELO track candidates to TT → Residuals in TT


VELO tracks reconstruction



Expected resolution of extrapolation: 300 µm

Hit residuals observed in TT:

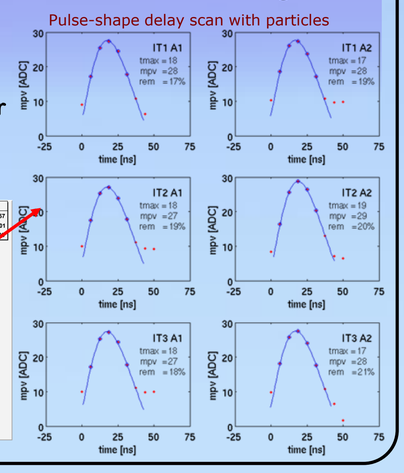
- Before alignment and survey: 600 µm
- After alignment and survey: 450 µm

IT Time Alignment

Performed configuring the delay of the LHC clock and trigger in the frontend electronics. Motivations:

- Cable lengths for different parts of the detector differ
- Different stations have different time of flight of particles
- Need to adjust timing delays of individual detector elements

Pulse-shape delay scan with particles



Landau charge distribution