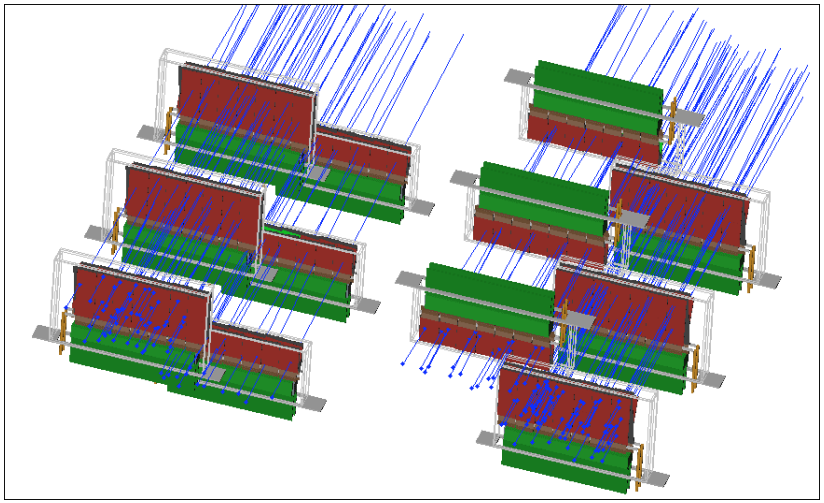
Performance of the LHCb Silicon Tracker with first data



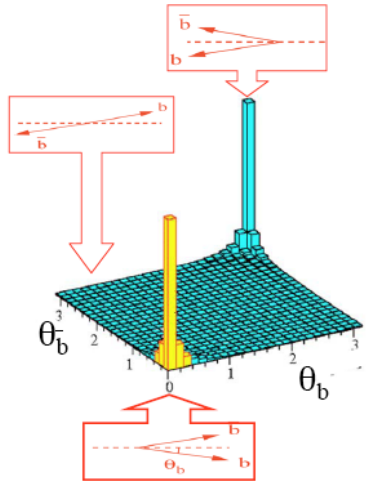
M. Needham
On behalf of the LHCb Silicon Tracker Group
11th ICATPP Conference, Como 5th - 9th October 2009

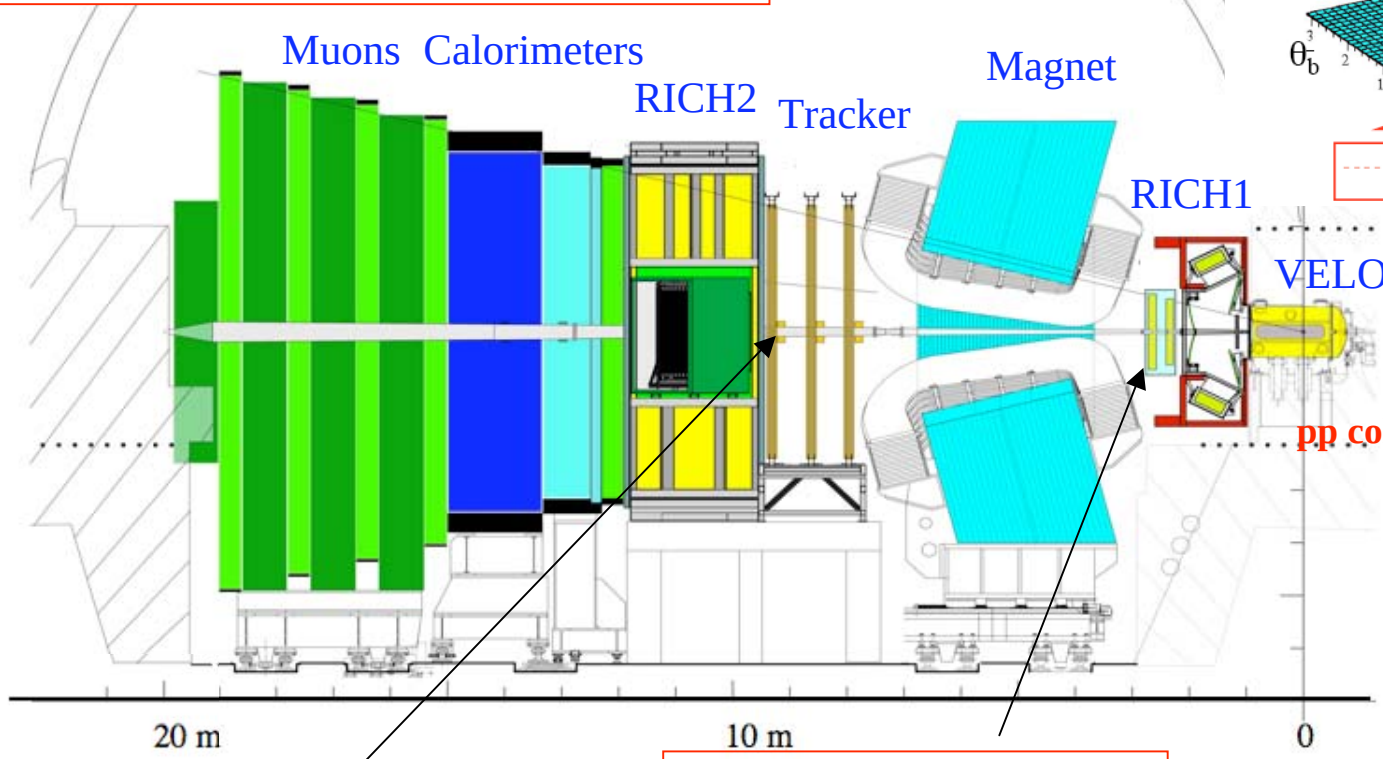
Outline

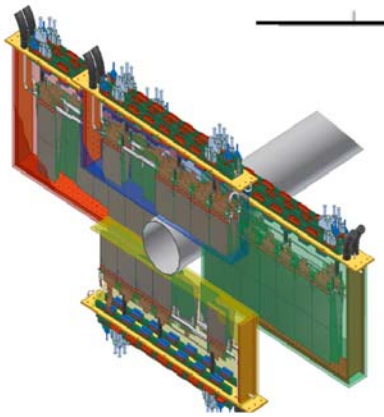
- The LHCb Silicon Tracker
- Commissioning and status
- Performance with first data (TED runs)
  - Time Alignment
  - Spatial Alignment
- Summary

LHCb

Dedicated b physics experiment at the LHC
Detector is a single forward arm spectrometer

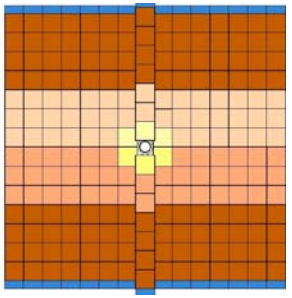






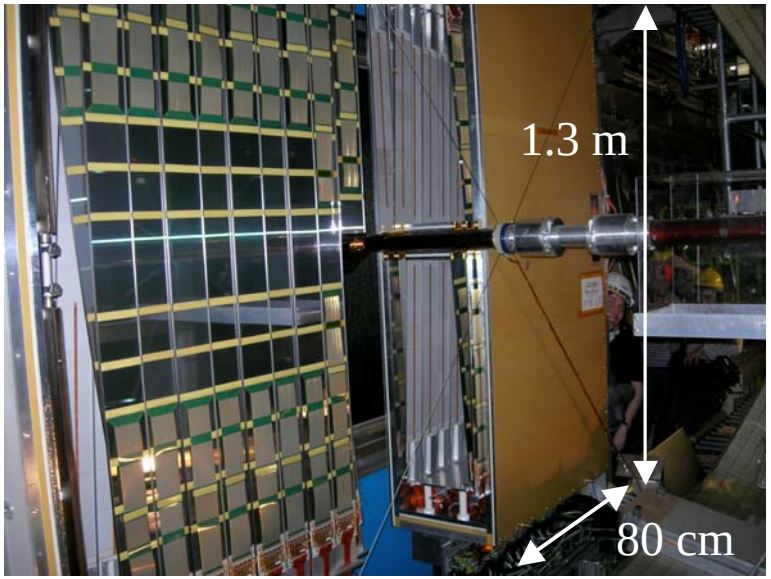
Inner Tracker (IT)

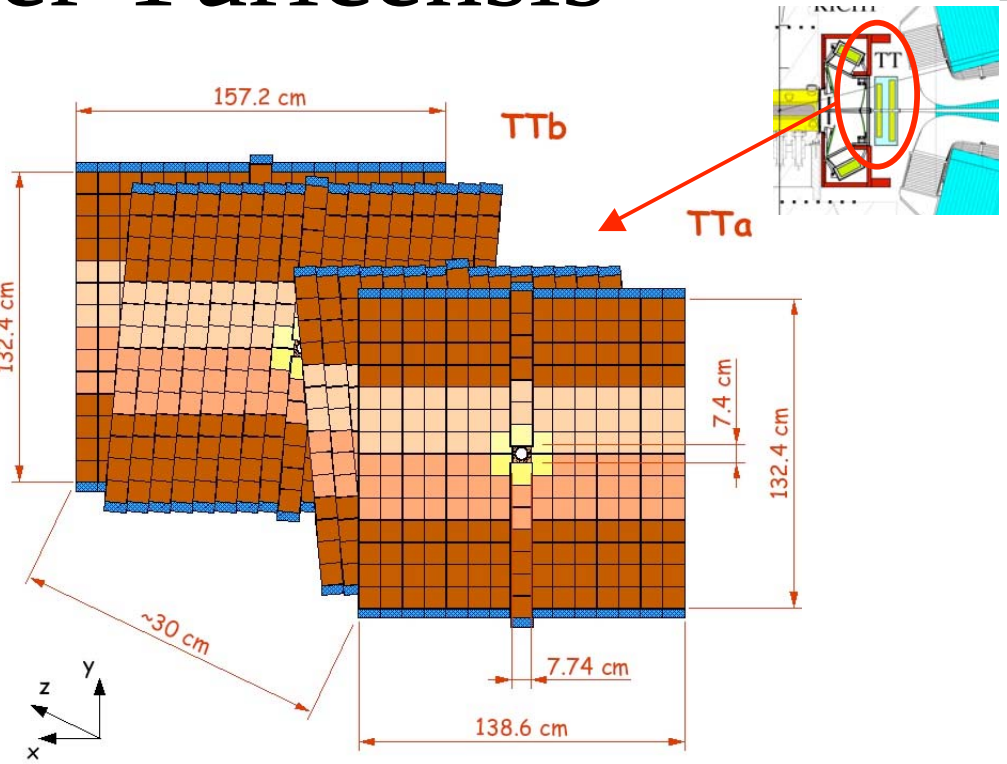
Tracker Turicensis (TT)

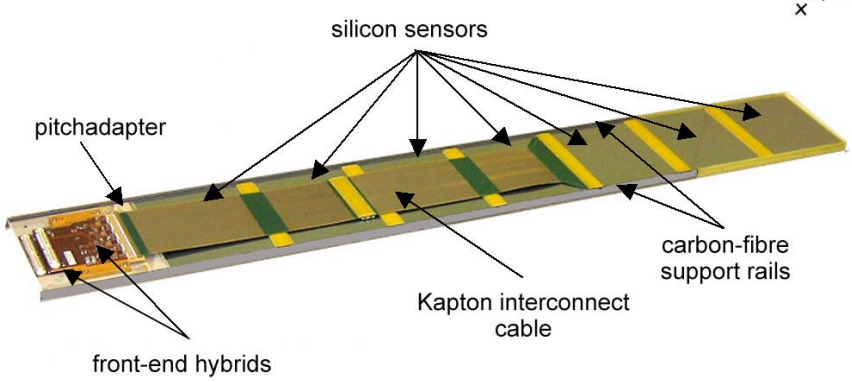


IT + TT
common project
Silicon Tracker

Tracker Turicensis

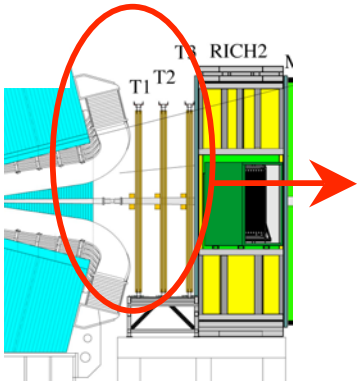


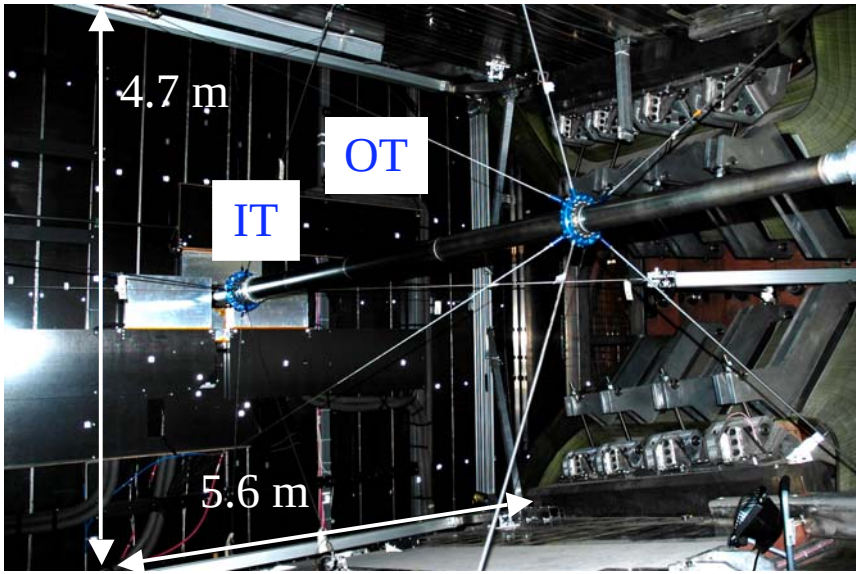


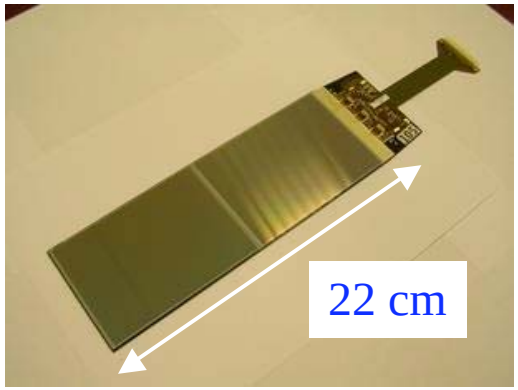


- Four planes of Silicon (0°, +5°, -5°, 0°)
- 500 μm thick, 7-sensor long ladders.
- Pitch 183 μm
- Strip lengths up to 37 cm, Capacitance 56 pF
- Area of 8.2 m^2 covered by Silicon
- 143 k strips

Inner Tracker



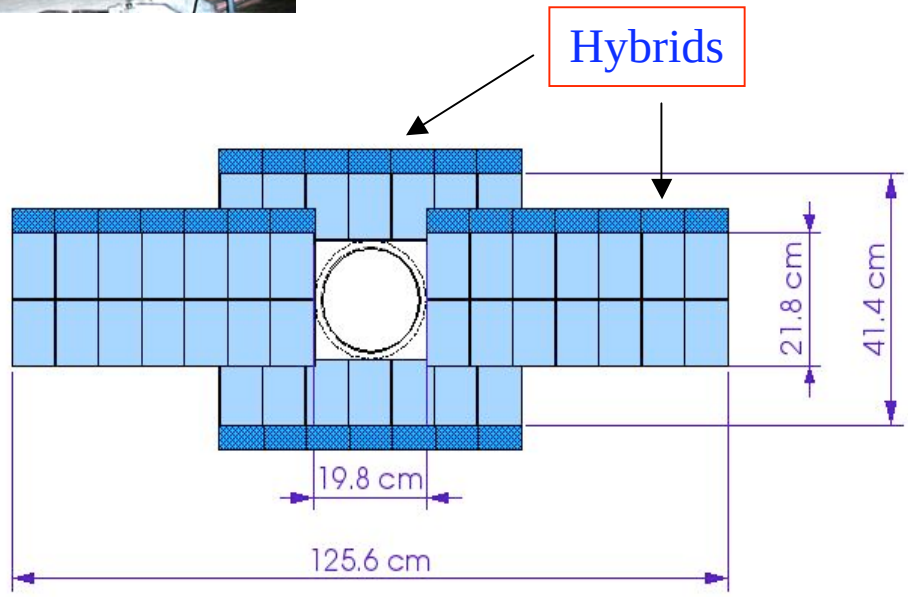




3 stations after the magnet

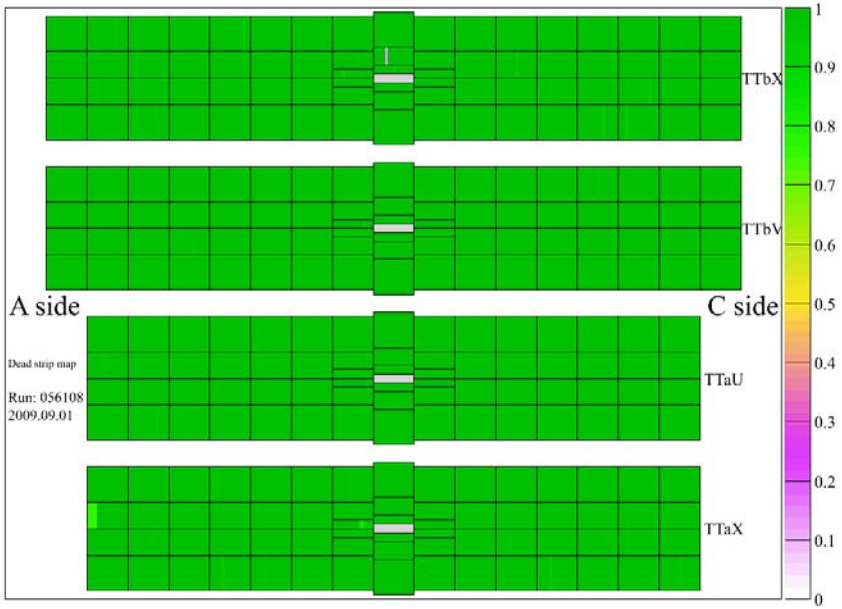
- Station consists of 4 boxes
- Box contains 4 layers (0°, 5°, -5°, 0°)
- Readout pitch 198 μm
- 320 μm, 1 sensor ladders
- 410 μm, 2 sensor ladders
- Area of 4 m^2 covered

336 ladders, 130 k readout strips

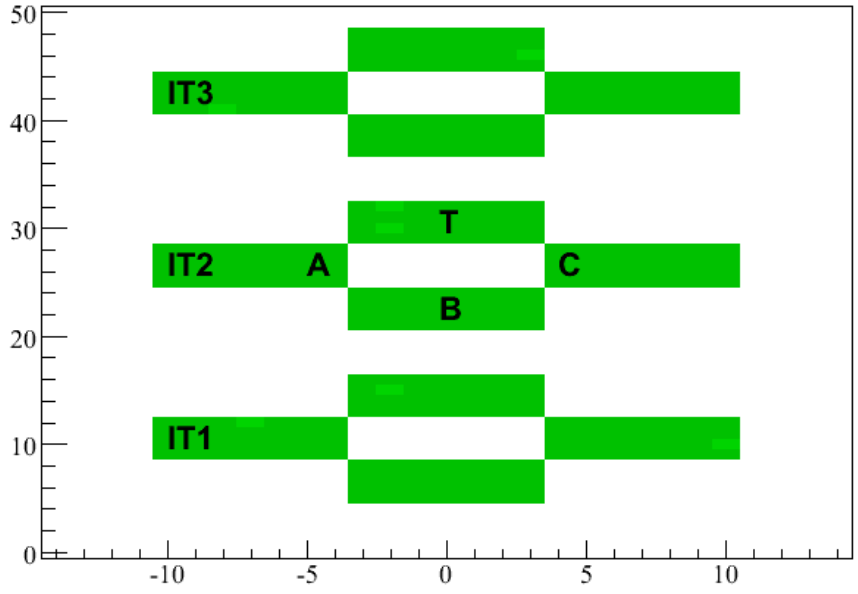


Status Summer 2009

Tracker Turicensis



Inner Tracker



- TT 99.7 % of channels functional
- IT 99.7 % of channels functional
- Noise cluster rate ~ 10^{-4} (with a S/N threshold of 4)

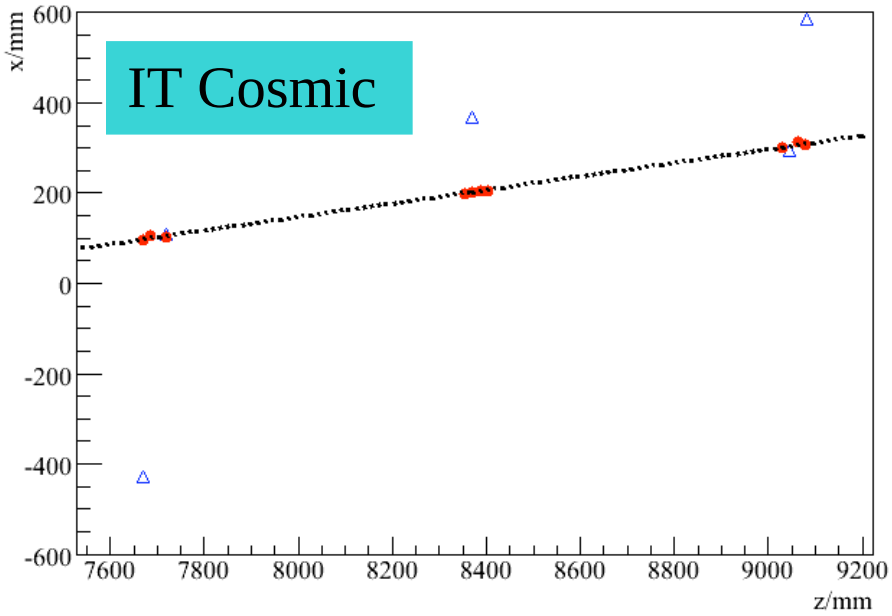
Commissioning Lessons

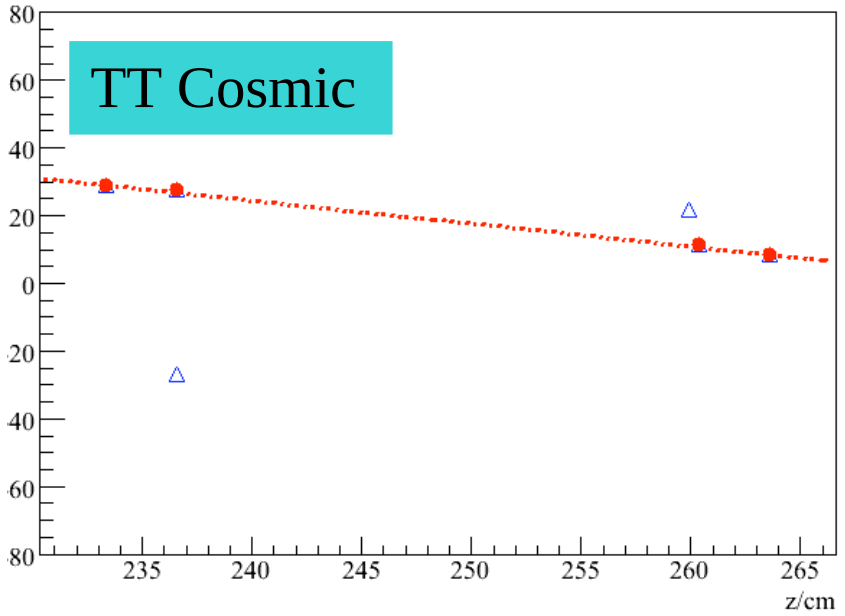
To achieve this status took a lot of work (before + after the winter shutdown)

- Oscillations in the LV power supplies:
  - Filter out with capacitors
- Failing voltage regulators:
  - Did not test with all different load scenarios
  - Replaced (~ 30 out of 1992)
- Low optical power readout links
  - Bad alignment between the diode and the optical fiber
  - Replaced in IT: 30 out of 1008 diodes , TT: 95 out of 1152
- Internal swaps in optical fiber bundle, bad connections, ….

Commissioning with Cosmics

Low rate of cosmics due to the forward geometry of LHCb





IT 2008 cosmic running

2.6 million calorimeter triggers

3 cosmics going through 3 IT boxes

~ 1000 through 1 IT box

First signals + coarse timing

TT 2009 cosmic running

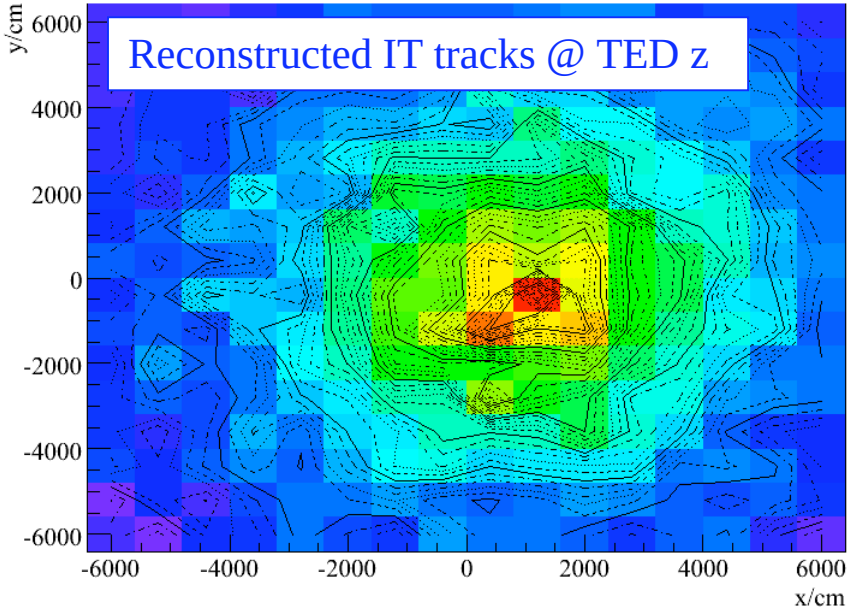
Few cosmics 2008 (trigger is far away)

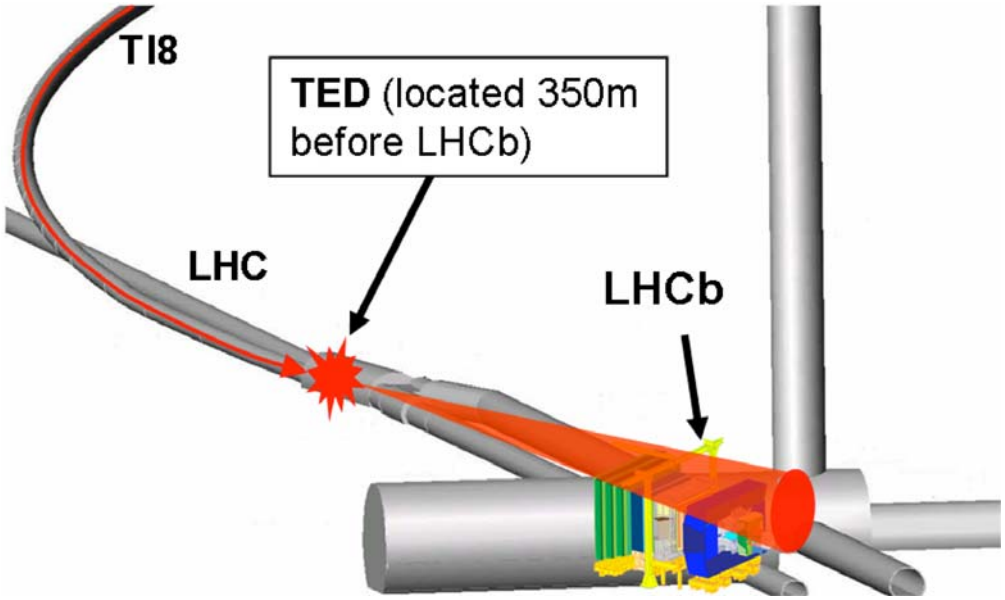
Scintillator trigger close to RICH1

First coincidences (TT/RICH)

Commissioning with Beam

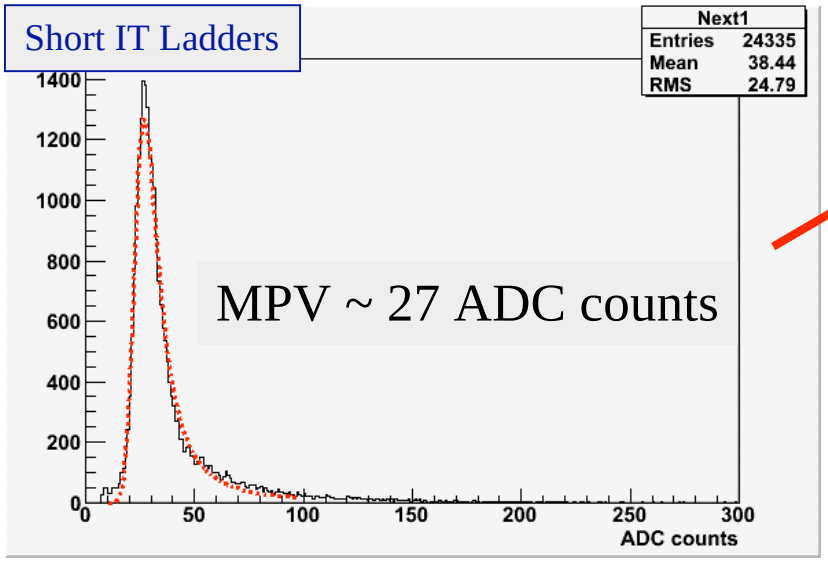
- 2- 5 $\times 10^9$ protons extracted from SPS and dumped on a tungsten beam-stopper (the 'TED') 350 m downstream of LHCb
- Spray of ~ 10 GeV muons in the detector, occupancies 10× that in normal running
- ~ 6 hours running September 2008, 72 hours running June 2009
- Wealth of data for time and spatial alignment and performance studies
  - e.g. 2009 run 50000 tracks in the IT

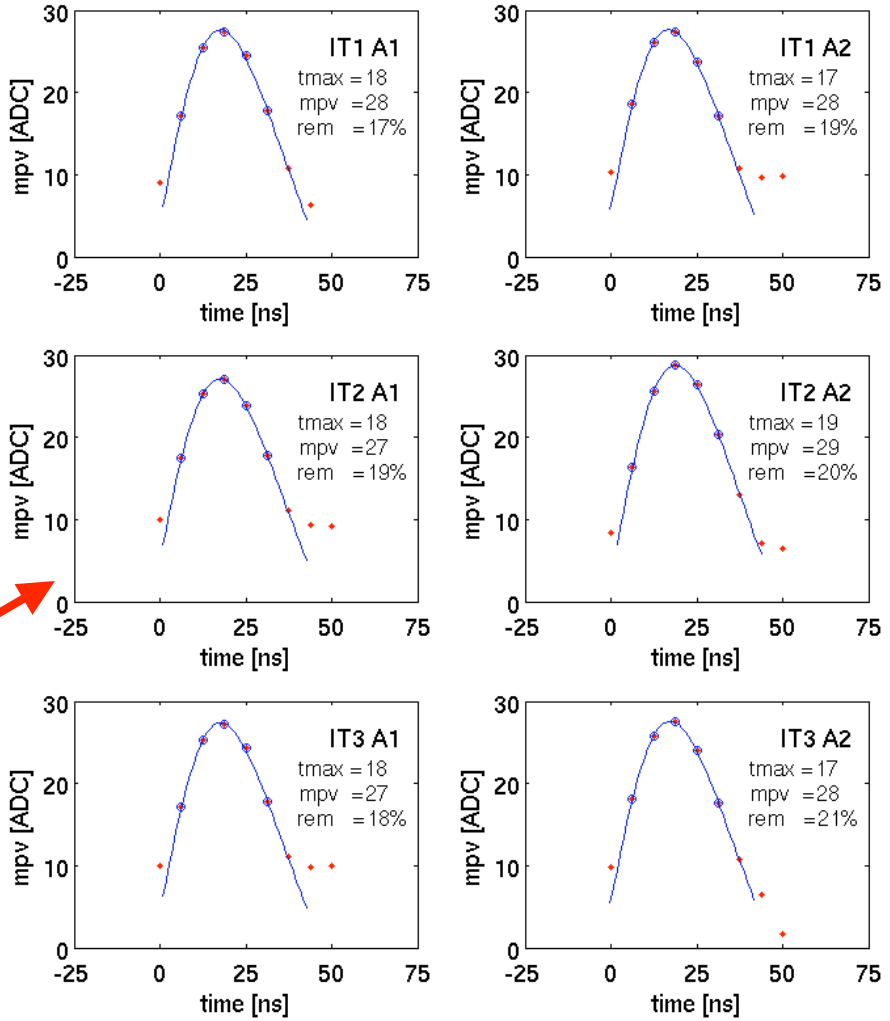




IT Time Alignment

- Different cable lengths for different detector parts
- Time of flight different per station
- Time delay scans (collected charge vs sampling time)



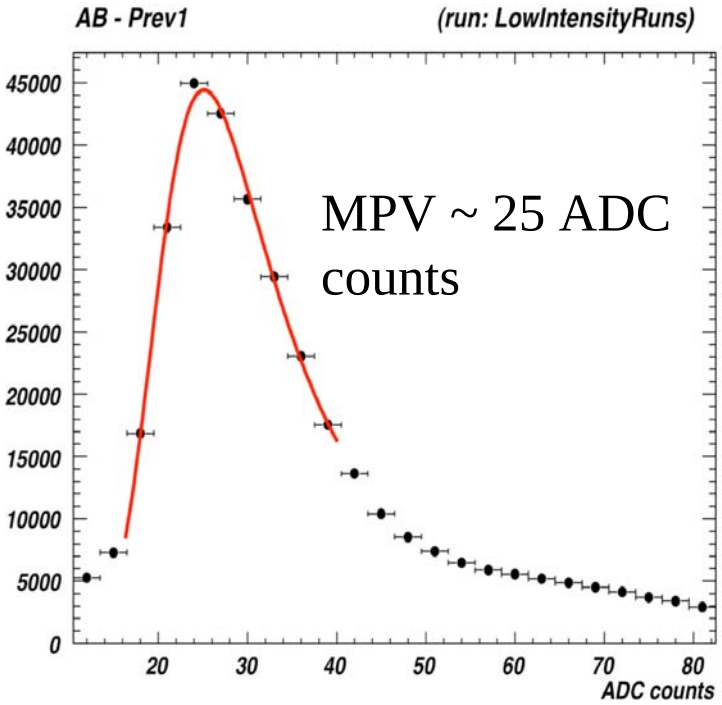


Scanning sampling time →

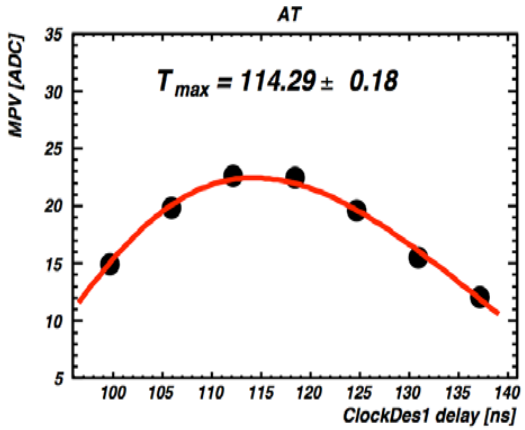
Detector internally time aligned with accuracy better 1 ns

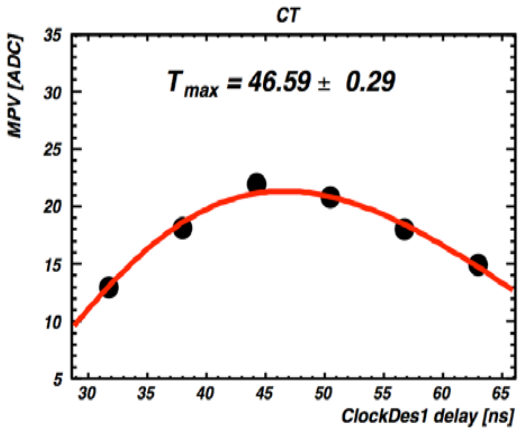
TT Time Alignment

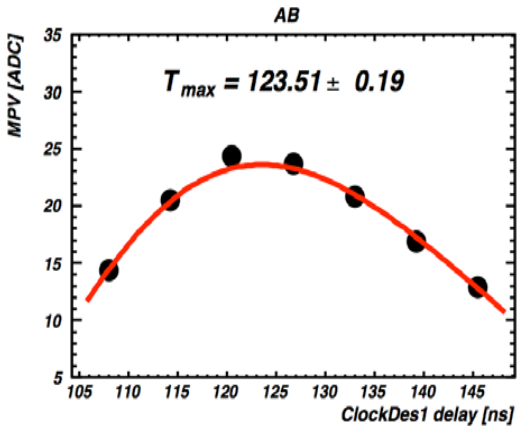
Adjust timing delays of four quadrants of TT
Plot signal versus sampling time

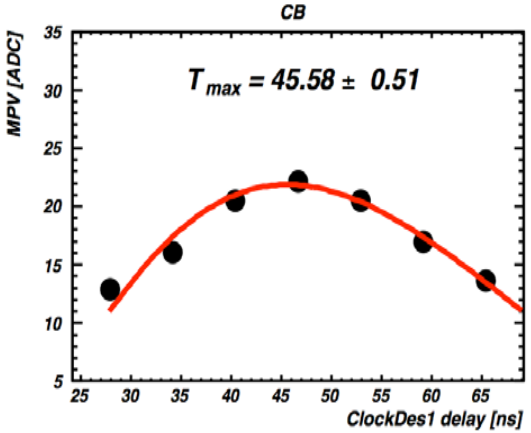


MPV ~ 25 ADC counts









Scanning sampling time →

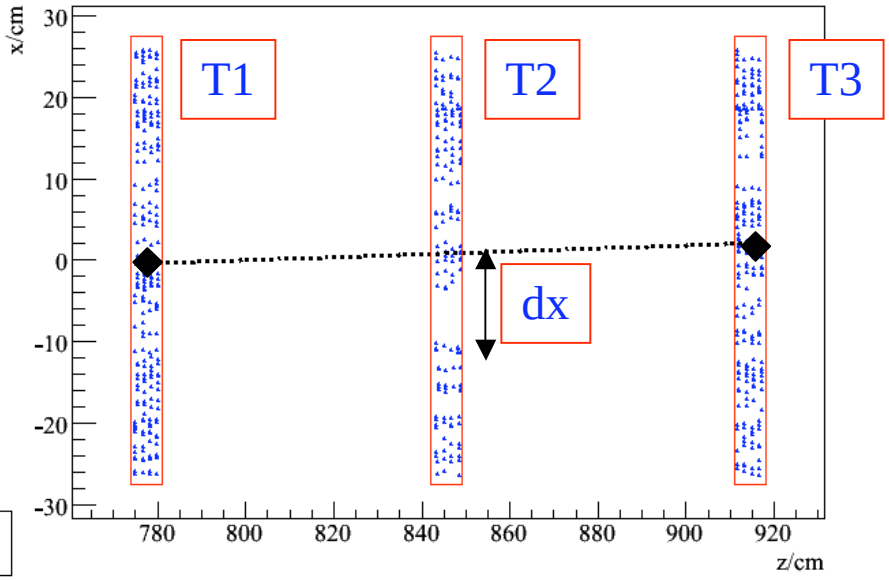
IT Spatial Alignment

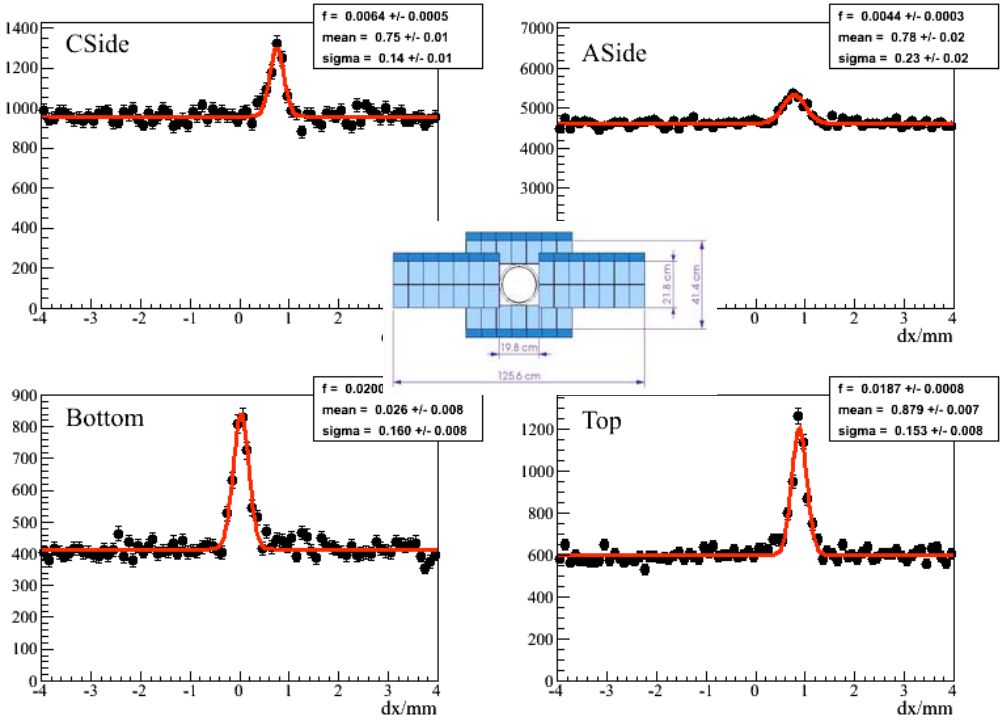
First Step:

Validate survey using histogramming method

Adjust box + layer positions in x

Boxes adjusted by 700 μm
(consistent with survey precision)





Pairs of hits in T1 x, T3 x [define] line

Require to point to TED

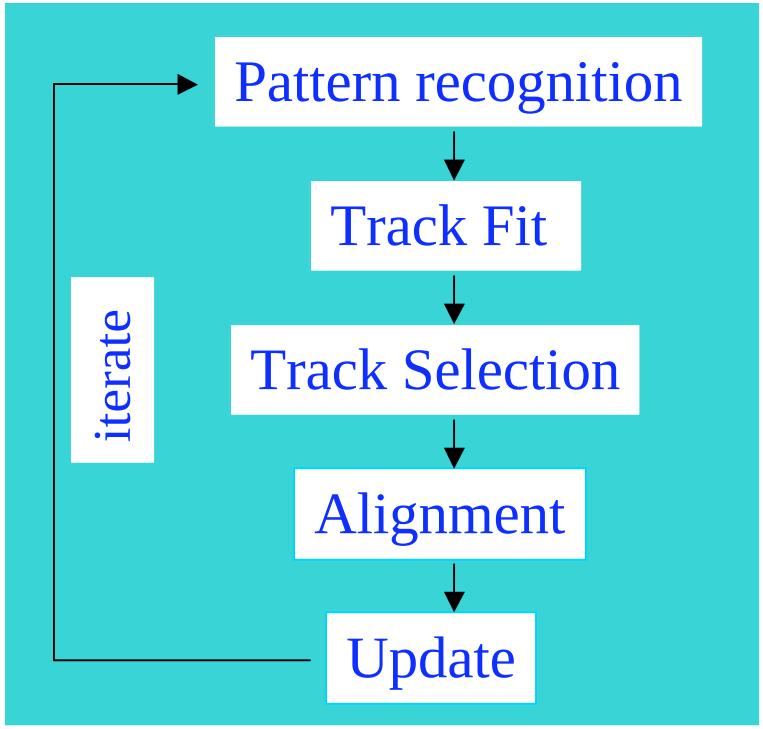
Interpolate to hits in T2

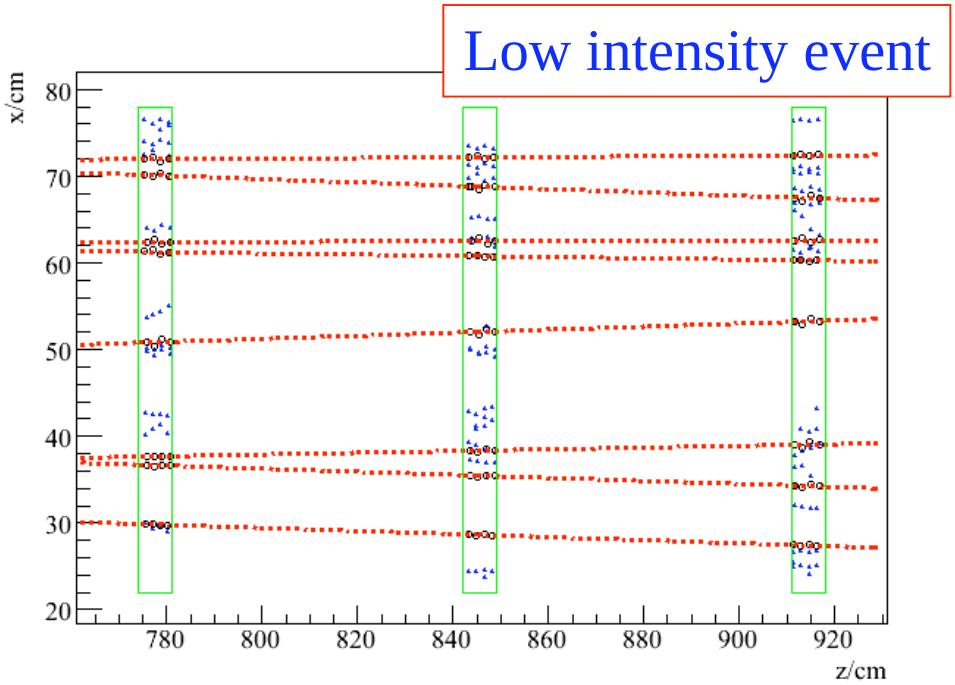
Calculate distance to hits +histogram

Box survey verified good to 700 μm

Layer survey verified good to 140 μm

IT Spatial Alignment

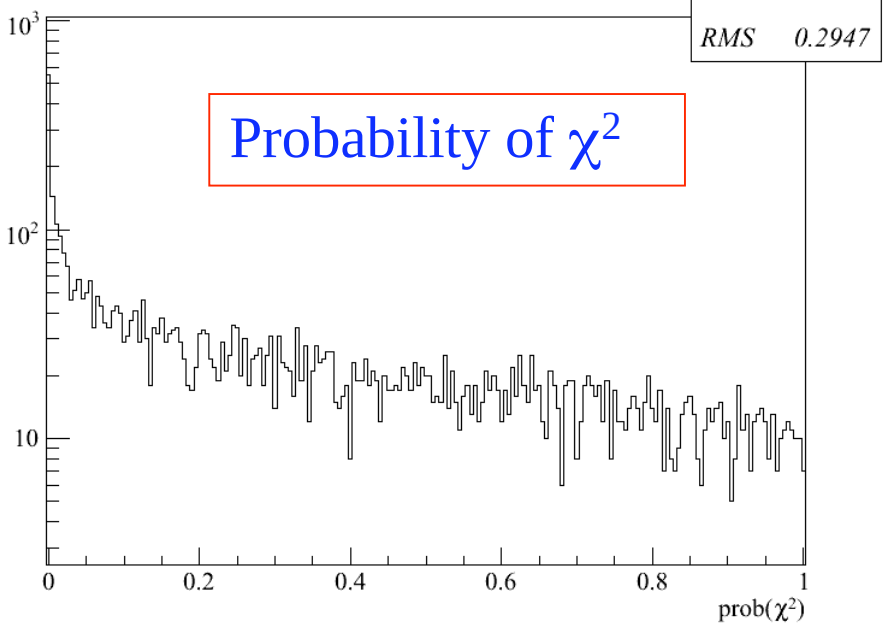


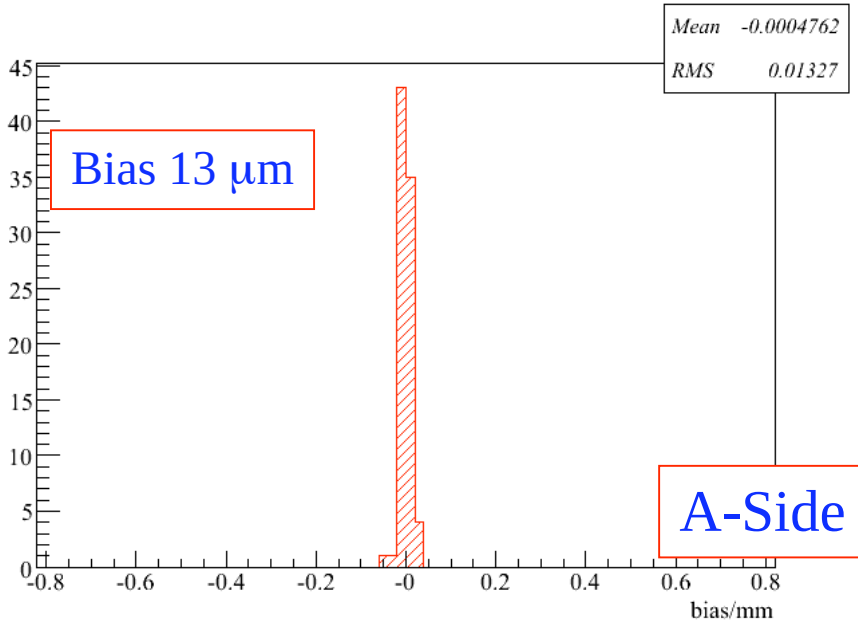


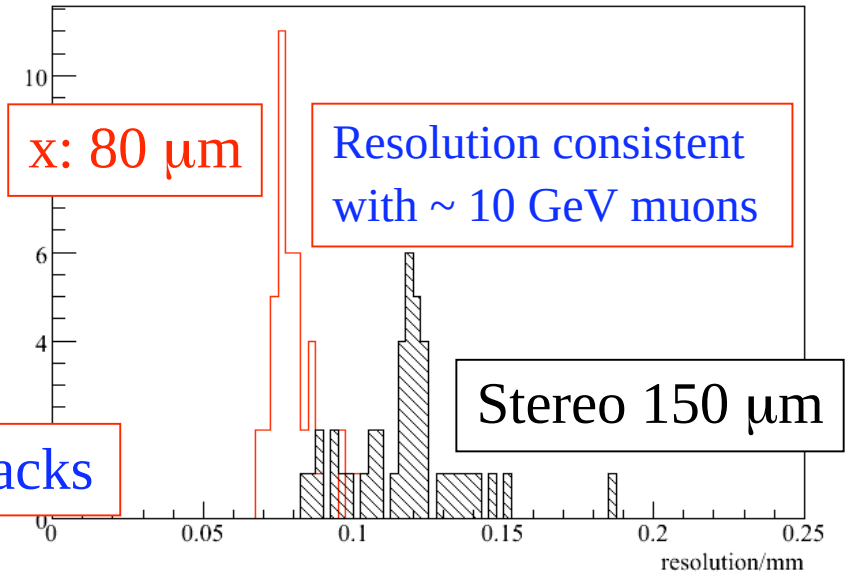
- Use TED events with lowest occupancy + select isolated tracks (16 k total)
- IT alignment with closed form Kalman Filter Method (NIM A600: 471-477, 2009)
- Alignment of Boxes (TxTyRz), Layers (TxRz), Ladders (Tx)
- Repeat pattern recognition at each step/iteration
  - Evolving pattern recognition and χ^2 cuts with iteration

IT Spatial Alignment

- Independent data sample for validation
- Study unbiased residuals per ladder
- Mean of distribution (bias)
- σ of distribution (resolution)

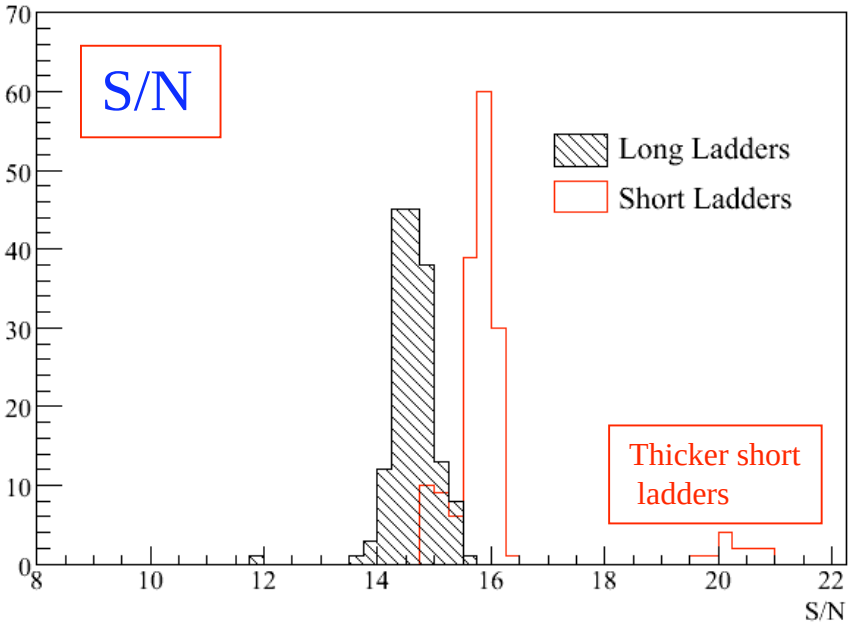


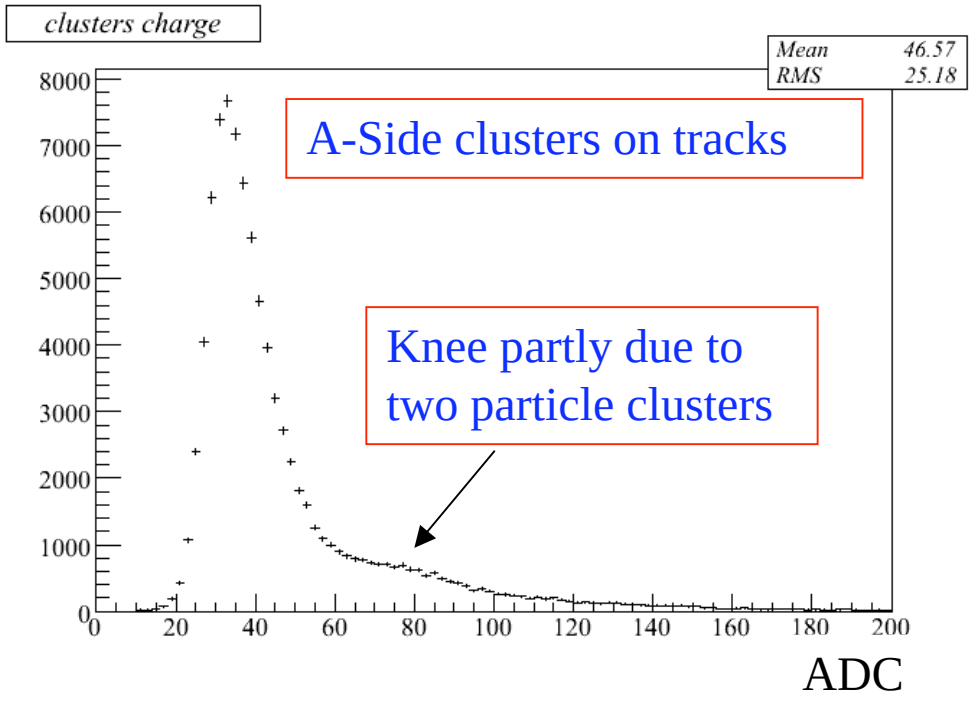




IT S/N

Detailed studies of charge deposition made. Landau fit per ladder to extract S/N

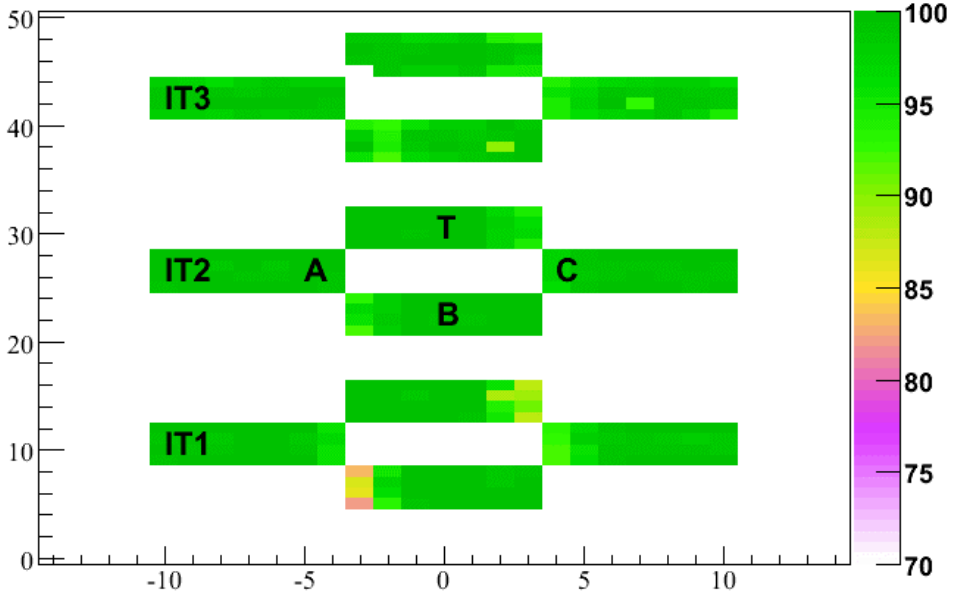


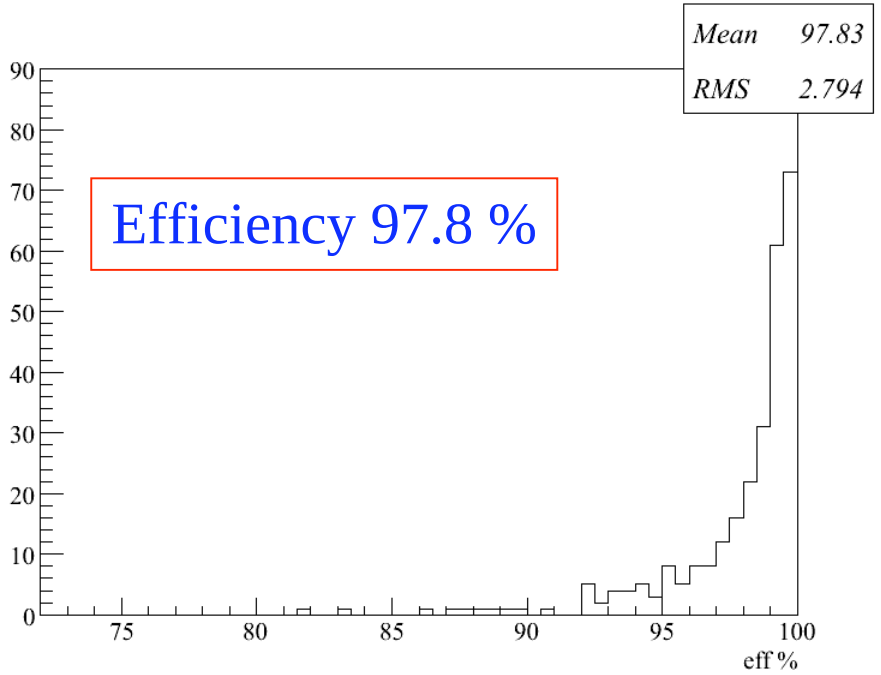


S/N long ladders ~ 14.5
S/N Short ladders ~ 15.5
Consistent with testbeam expectations at 5 % level

IT Efficiency

- Use tracks to measure ladder efficiency
- Measured efficiency 97.8 %
- Inefficiencies dominated by modules close to detectors edge (alignment/acceptance problems) + known problem modules



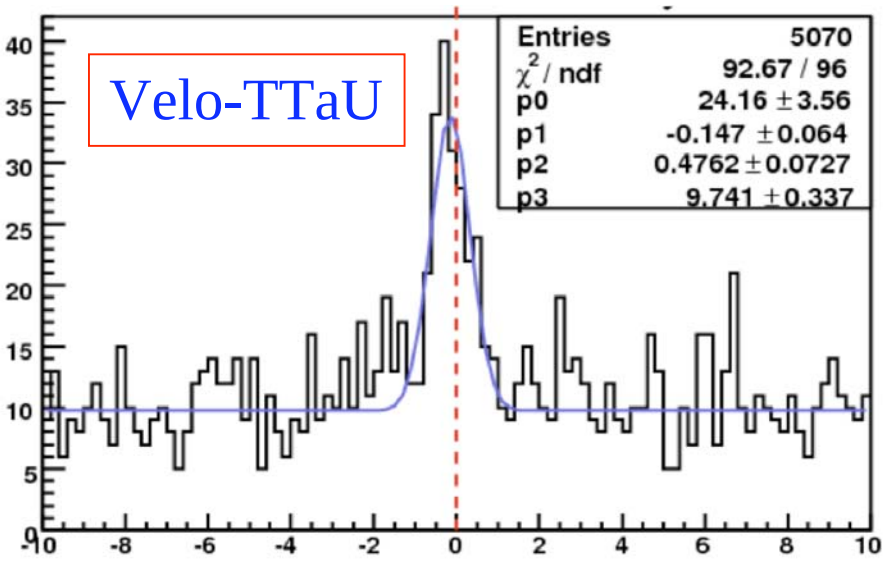


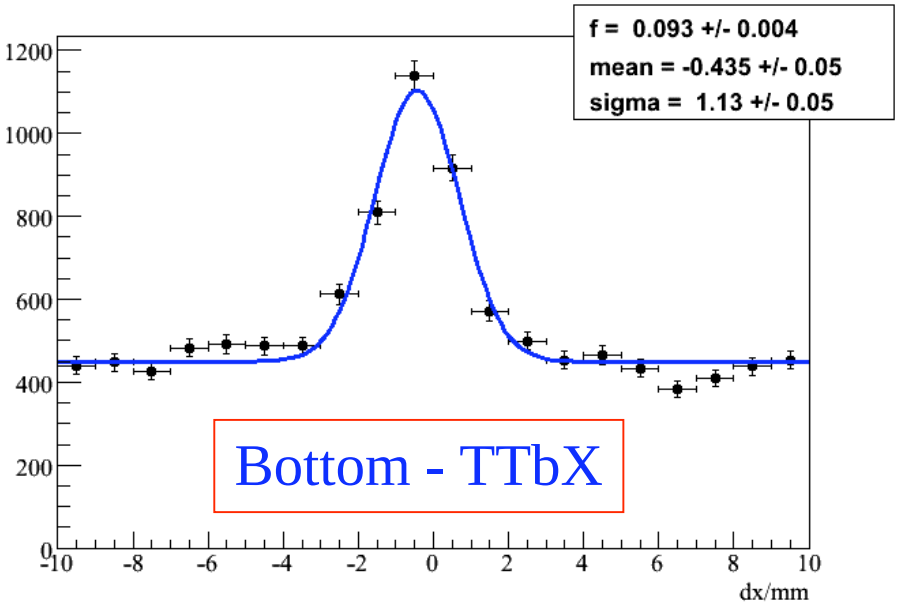
Efficiency 97.8 %

TT Spatial Alignment

TT only has four layers

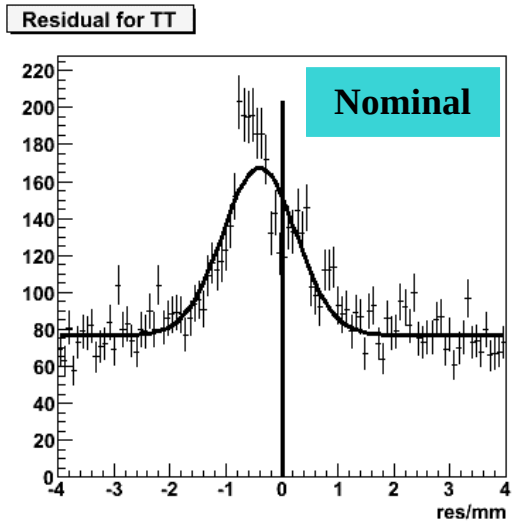
- Standalone tracking not possible
- Alignment needs seeds from either Vertex Locator or IT
- Residual distributions show clear correlations with Velo/IT tracks



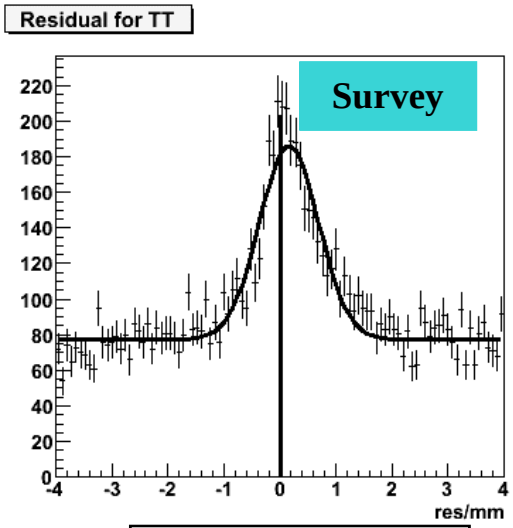


TT Spatial Alignment

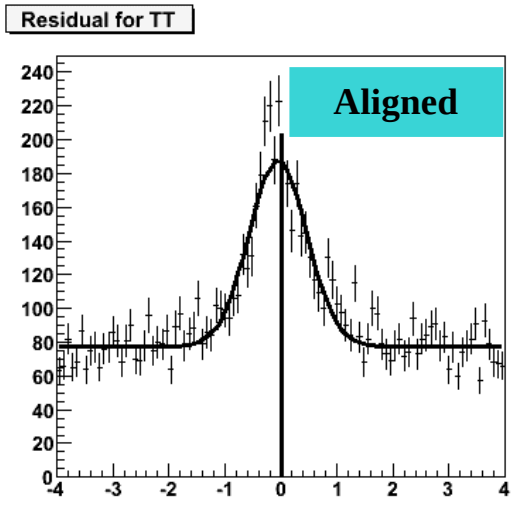
Residuals of TT hits to extrapolated VELO tracks



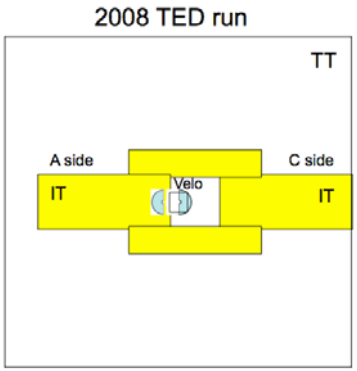
Mean: -0.404 mm
Width: 0.655 mm



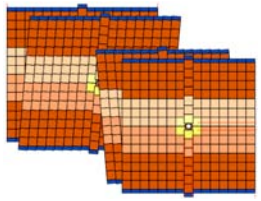
Mean: 0.162 mm
Width: 0.526 mm



Mean: -0.053 mm
Width: 0.519 mm



Full station alignment only
(limited overlap Velo-TT)



Summary

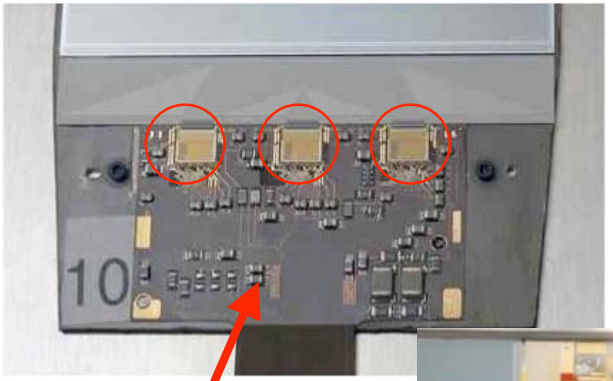
LHCb Silicon Tracker is commissioned and fully operational

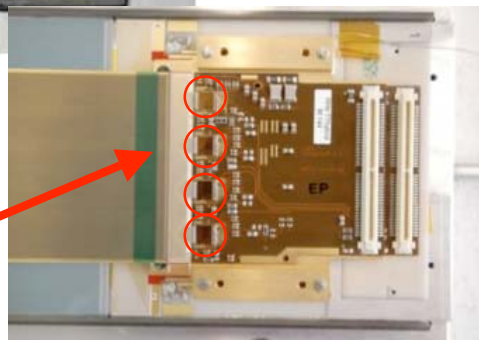
- ~99.7 % detector channels in IT + TT functional
- TED running has allowed first studies of detector performance
  - Internal time alignment with 1 ns accuracy
  - IT ladders internally aligned with a precision of 15 microns
  - IT efficiency measured to be ~ 98 % with tracks
  - S/N in line with expectations from testbeam

For sure many challenges ahead, but we are looking forward to colliding beams

Backup

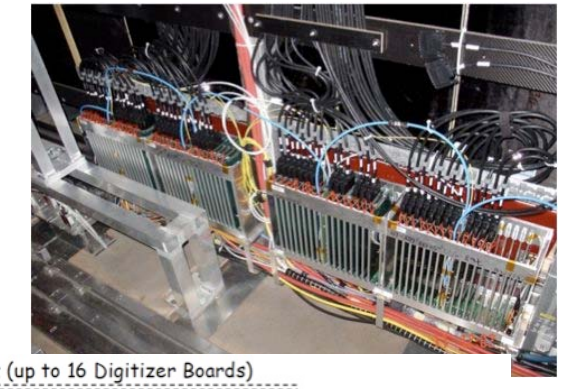
Readout Electronics

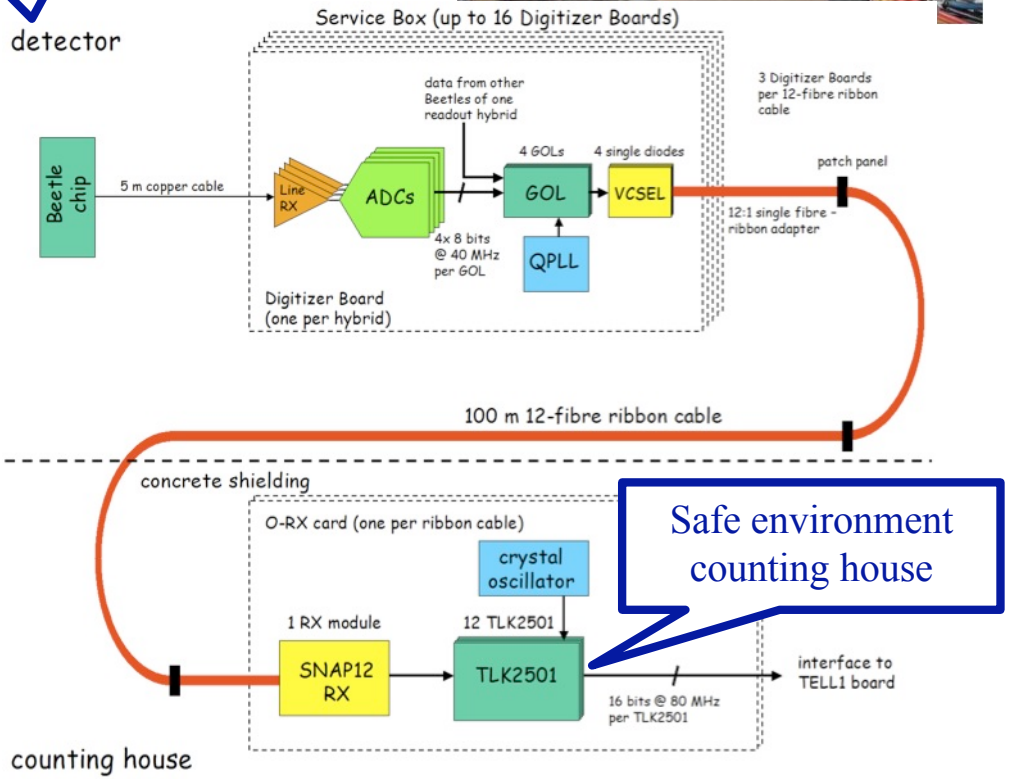




near detector
~ 15krad in 10 yrs

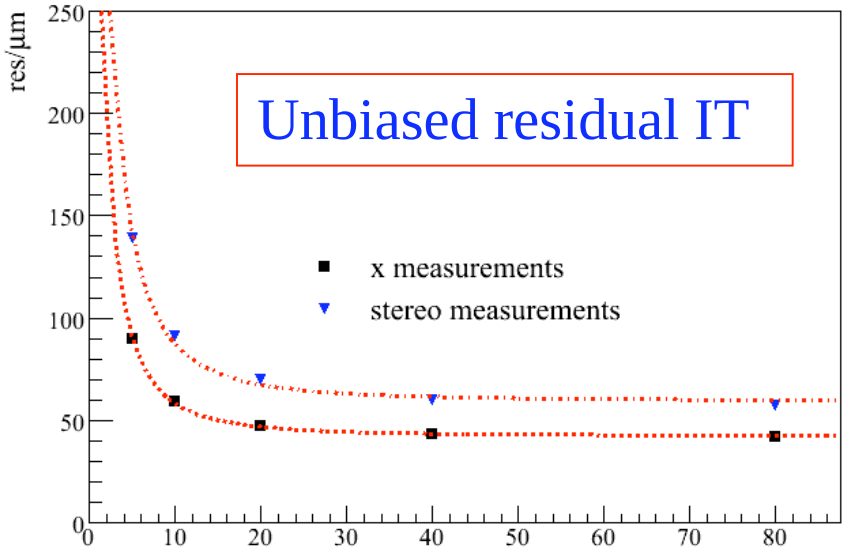
near detector
< 1 Mrad in 10yrs

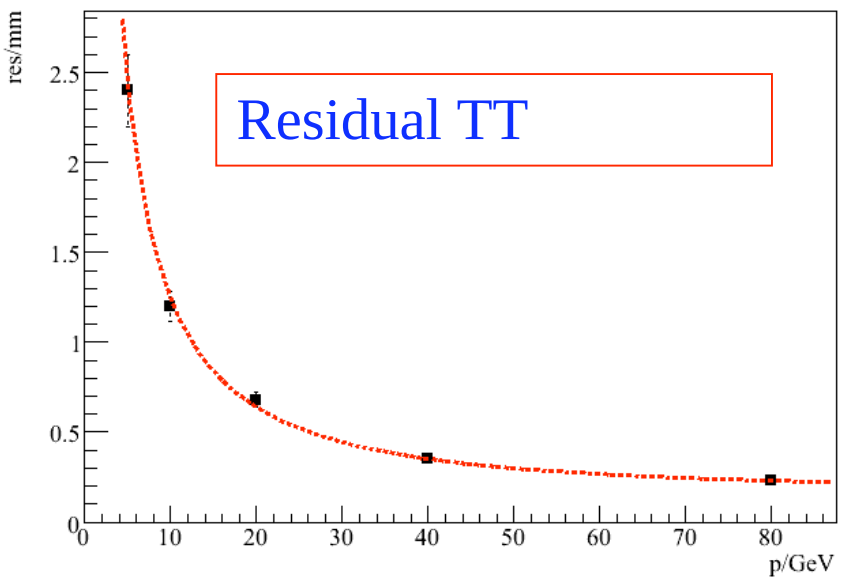


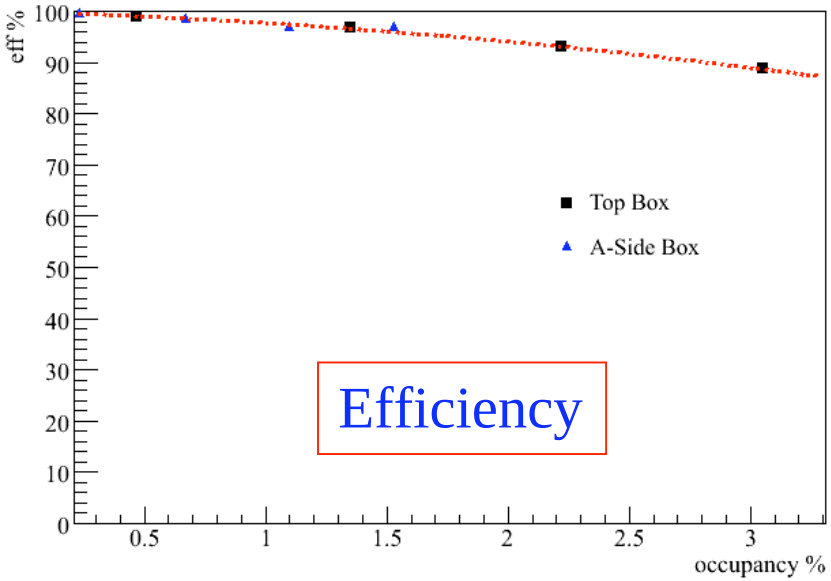


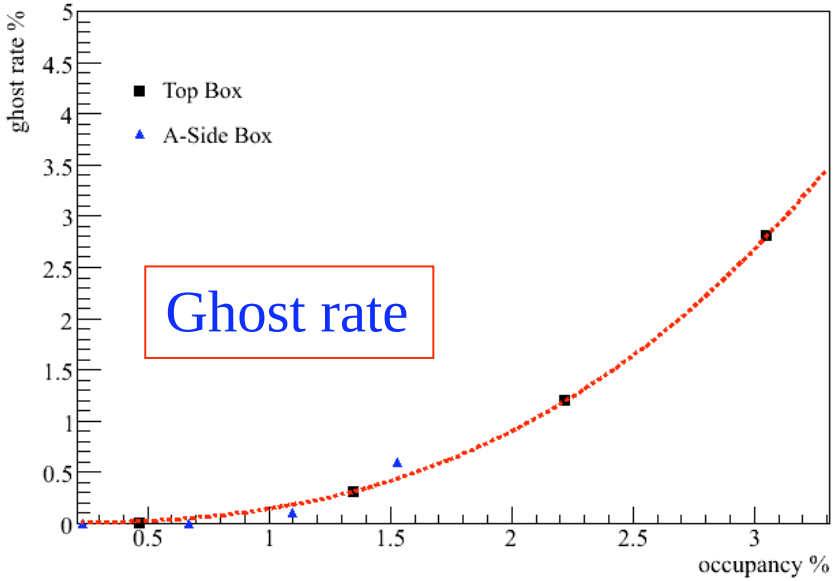
- 3 (4) Beetle readout chips IT(TT)
- rad hard 0.25 µm CMOS
- 40MHz, 128 channels
- multiplexed onto 4 ports
  - 36 cycles to read 1 event
  - 1.1 MHz readout
- Pipelined 160 bunch crossing

MC Studies


Unbiased residual IT
res/µm
x measurements
stereo measurements


Residual TT
res/mm
p/GeV


Efficiency
eff %
Top Box
A-Side Box
occupancy %


Ghost rate
ghost rate %
Top Box
A-Side Box
occupancy %