The LHCb Silicon Tracker Project

Johan Blouw, for the Silicon Tracker Group

Max Planck Institute for Nuclear Physics
Overview

- Introduction
- LHCb Spectrometer
- Trigger Tracker
- Inner Tracker
- Readout Chip
- Testbeam Results
- Outlook
Introduction

- study CP violation and rare B meson decays with very high precision
- provide understanding of quark flavour physics in Standard Model
- reveal signs of physics beyond Standard Model
- at LHCb: $10^{12} \ b\bar{b}$ pairs per year
Introduction

- At LHC, $b\bar{b}$ pairs produced at forward and backward angles

- construct a forward-angle spectrometer
LHCb Spectrometer
Requirements

- 40 MHz interaction rate → good event rejection needed.
- measure $P_T$ in Trigger Tracker for use in L1 trigger.
- match granularity to particle density $(5 \times 10^5 \, \text{cm}^{-2}\text{s}^{-1})$ around beam-pipe
- good ($\sim 100\%$) hit finding efficiency
- low ($\sim 1\%$) occupancy for pattern recognition
- excellent $\delta p/p \approx 0.4\%$ resolution for reconstruction of $B_s$ mass
Trigger Tracker

- 28.3 and 37.7 cm long modules per ladder
- cover full acceptance with silicon (total of 8.3 m²)
- located in fringe-field in front of dipole magnet
- operated at 5° Celcius
two stations with each two planes in an \((0, 0')\) and \((-5^\circ, 5^\circ)\) stereo-angle configuration

connect inner modules with flexible Kapton cable to read-out frontends
Inner Tracker

- located in proximity of beampipe behind magnet
- 1.3% area, but 20% of tracks
- three stations, four boxes of four layers each around beampipe (0°, +5°, −5°, 0°)
Inner Tracker

- 110 × 78 mm² size sensors
- 1- and 2-sensor ladders
- 197 μm pitch
- Operating temperature 5°C
Ladder Design

- 6” wavers, n-bulk, $p^+$-strips
- single-sided sensors
- dead-area of $< 2$ mm between sensors on multi-sensor ladder
Front-end

- Beetle chip developed by ASIC lab in Heidelberg
- 128 channel charge integrator
- Sampling at 40 MHz
- 25 ns shaping time
- 0.25 μm CMOS technology
- Complete Beetle read-out in 900 ns
- Three Beetle front-end chips per hybrid
Test Beam

- study pulse shapes on different loads
- signal remainder
- tracking efficiency
- study signal-over-noise behaviour for
- different substrate thicknesses
- different ladder lengths (capacitive load)

Set-up at CERN’s X7 testbeam facility
- use charged $\pi$ beam
- tracking performed by HERA-b beam-telescope
Test Beam

500 μm thick
180 μm pitch

410 μm thick
228 μm pitch

320 μm thick
198 μm pitch
Test Beam

- signal drop in between two strips due to charge loss
- impact on efficiency for S/N < 10
- signal drop largest for thinner substrates
Test Beam

- signal remainder after 25 ns < 50% of peaking time
- mirror charges arrive quicker
- Beetle tuned to accommodate various load capacitances
Impact on Physics

- thicker substrates → reconstruction efficiency loss
- test the impact of thicker substrate with Monte Carlo
- for instance $B_s \rightarrow D_s K$ and $D_s \rightarrow K^+ K^- \pi$: 

\[
\mu_1 = -0.136, \sigma_1 = 1.15 \\
\mu_2 = -0.133, \sigma_2 = 1.15
\]
Conclusions

- minimal substrate thickness: 410 $\mu$m for multisensor ladder
- no adverse effect on tracking and physics performance
- large pitch: 200 $\mu$m
- long strips: 10 – 30 cm
- fast read-out: $O(25 \text{ ns})$
- signal remainder $< 50\%$, 25ns after peak
- $\sim 300,000$ readout channels