

The LHCb Silicon Tracker Project

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Overview

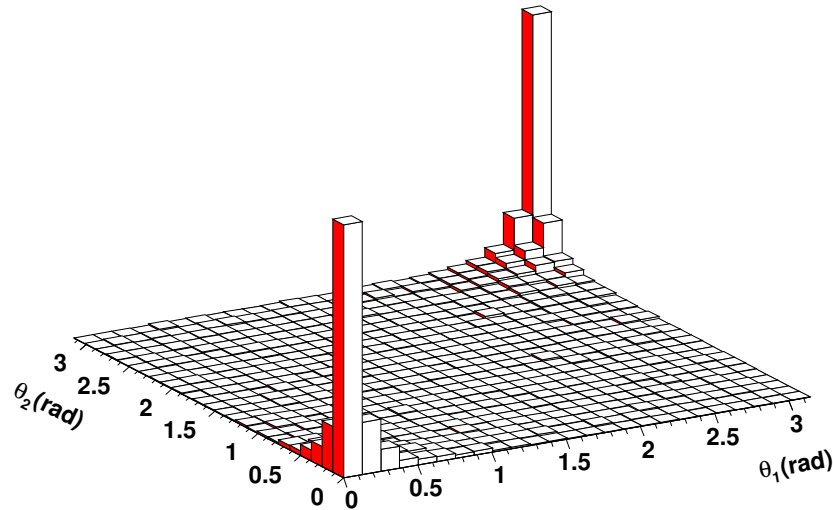
- Introduction
- LHCb Spectrometer
- Trigger Tracker
- Inner Tracker
- Readout Chip
- Testbeam Results
- Outlook

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

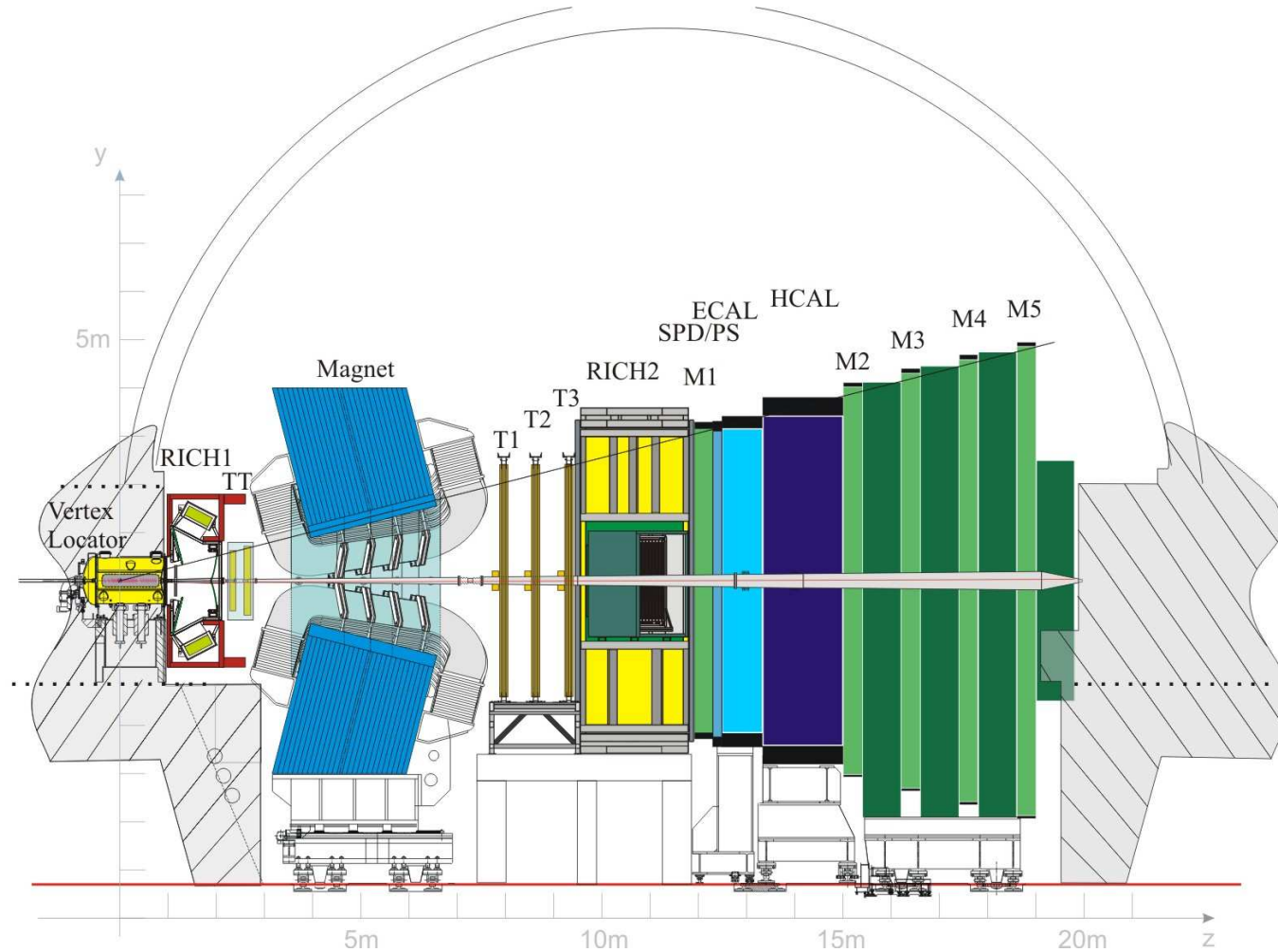
Introduction

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



- construct a forward-angle spectrometer

LHCb Spectrometer

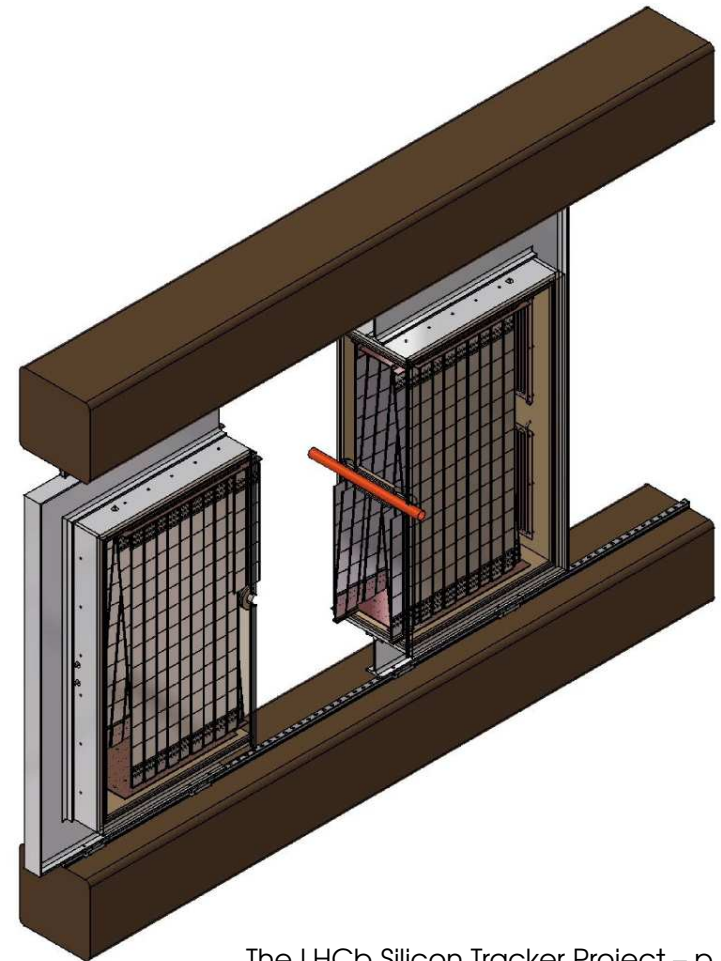


Requirements

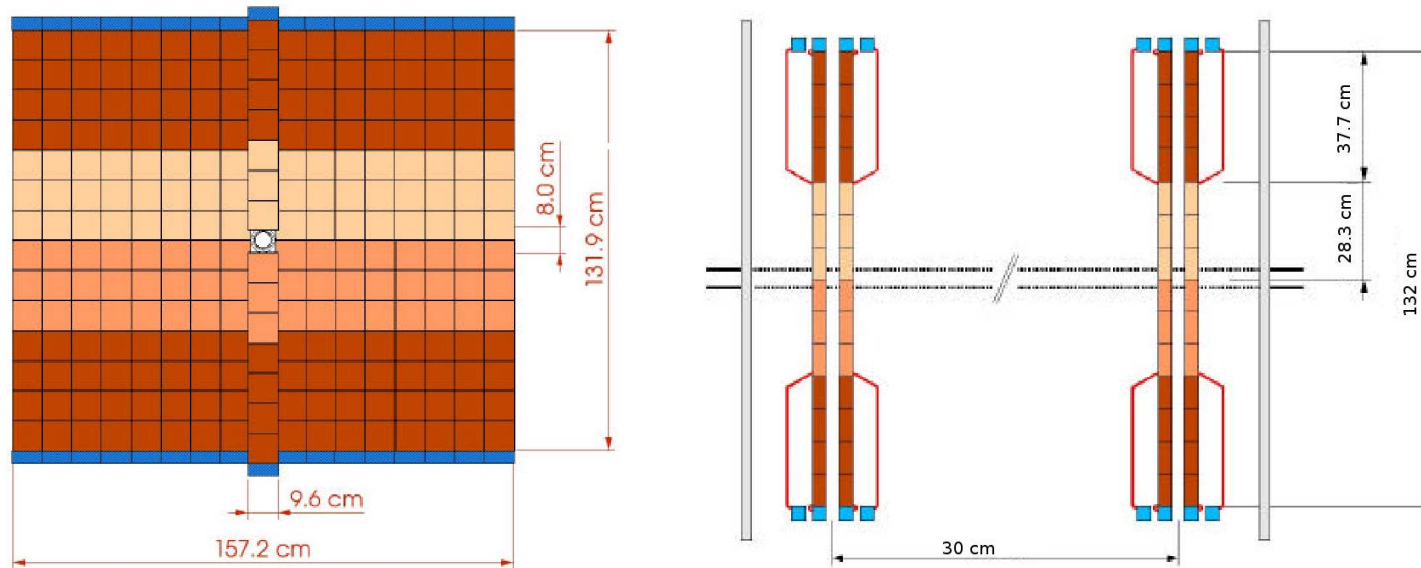
- 40 MHz interaction rate \rightarrow good event rejection needed.
- measure P_T in Trigger Tracker for use in L1 trigger.
- match granularity to particle density ($5 \times 10^5 \text{ cm}^{-2}\text{s}^{-1}$) around beam-pipe
- good ($\sim 100\%$) hit finding efficiency
- low ($\sim 1\%$) occupancy 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



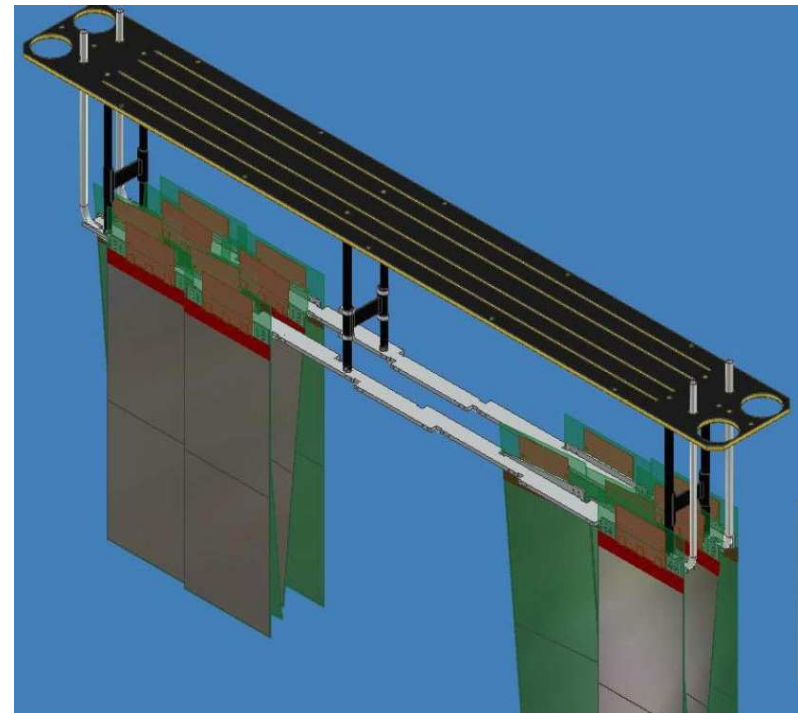
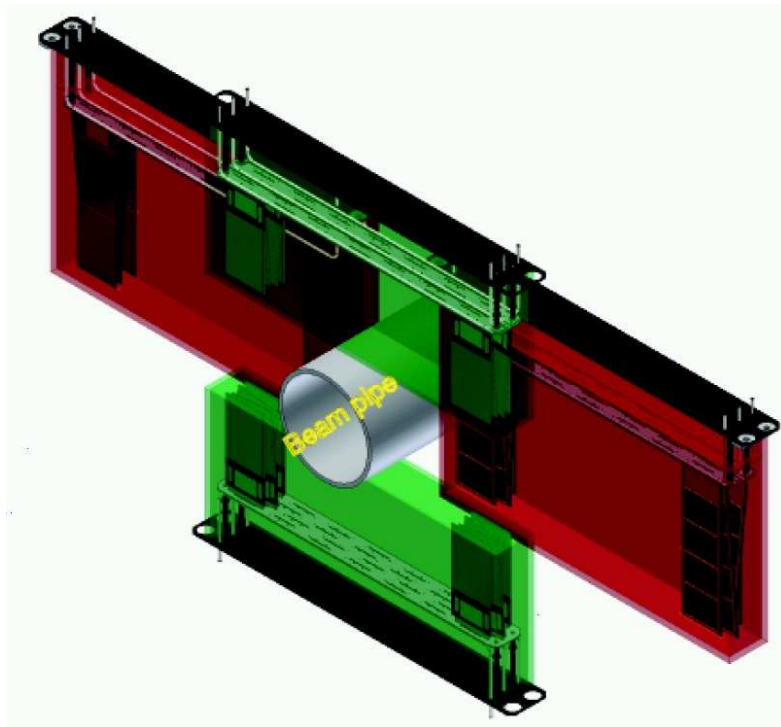
Trigger Tracker



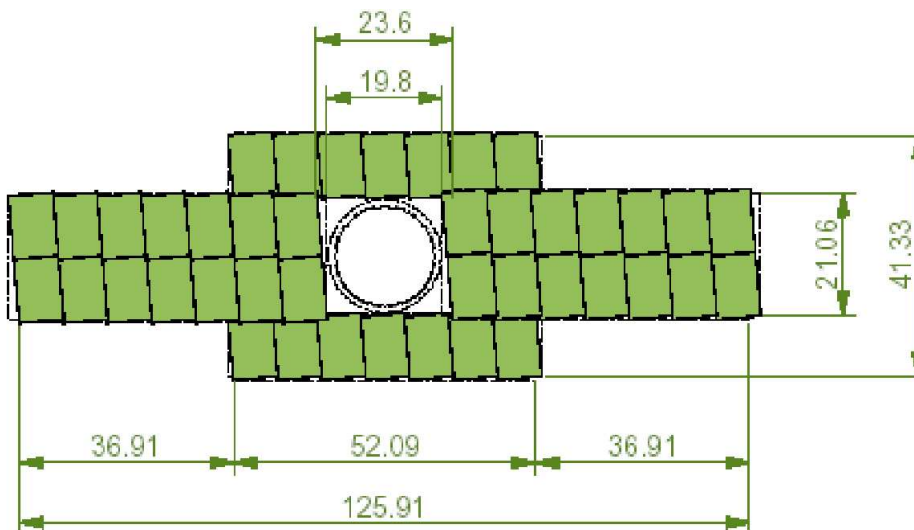
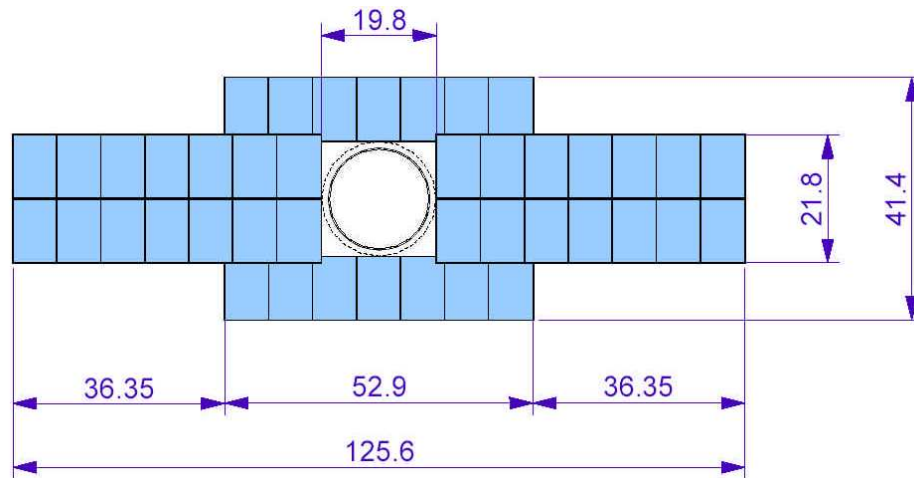
- two stations with each two planes in an $(0, 0')$ and $(-5^\circ, 5^\circ)$ stereo-angle configuration
- connect inner modules with flexible Kapton cable to read-out frontends

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° , $+5^\circ$, -5° , 0°)



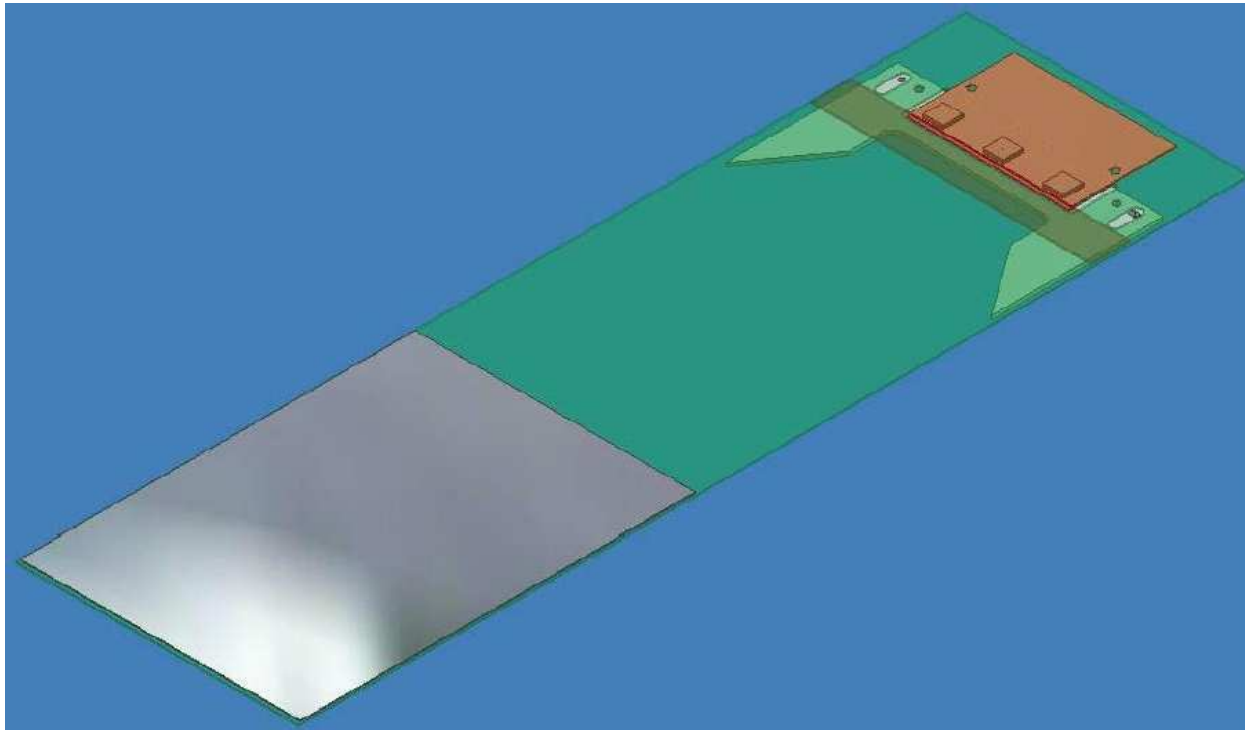
Inner Tracker



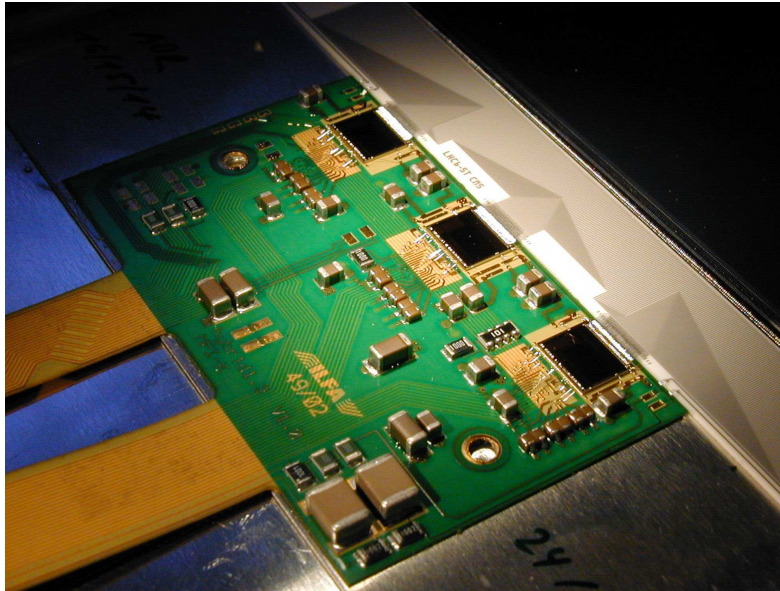
- $110 \times 78 \text{ mm}^2$ size sensors
- 1- and 2-sensor ladders
- $197 \mu\text{m}$ pitch
- operating temperature 5°C

Ladder Design

- 6'' wafers, n-bulk, p^+ -strips
- single-sided sensors
- dead-area of < 2 mm between sensors on multi-sensor ladder



Front-end



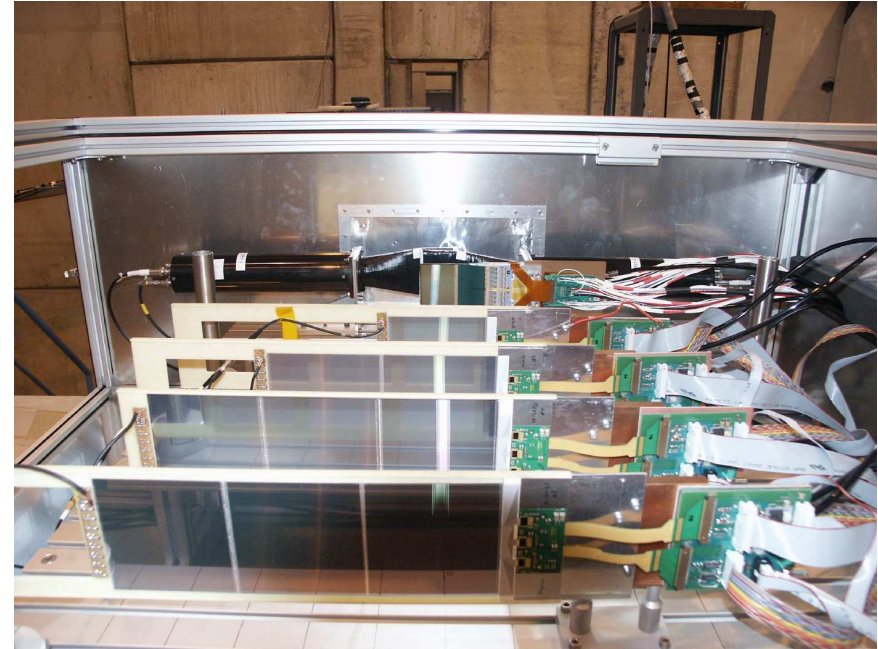
- Beetle chip developed by ASIC lab in Heidelberg
 - 128 channel charge integrator
 - sampling at 40 MHz
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- 25 ns shaping time
 - 0.25 μm CMOS technology
 - complete Beetle read-out in 900ns
 - three Beetle front-end chips per hybrid

Test Beam

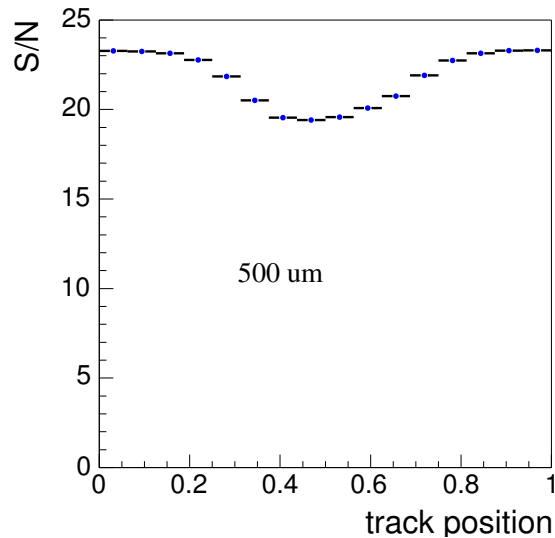
- study pulse shapes on different loads
- signal remainder
- tracking efficiency
- study signal-over-noise behaviour for
 - different substrate thicknesses
 - different ladder lengths (capacitive load)

Set-up at CERN's X7 testbeam facility

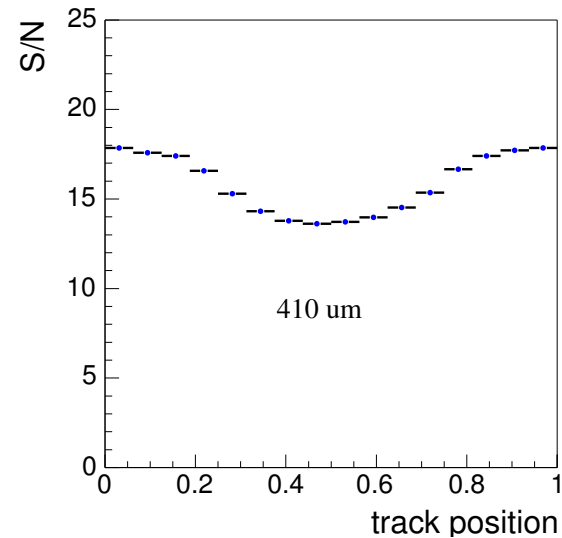
- use charged π beam
- tracking performed by HERA-b beam-telescope



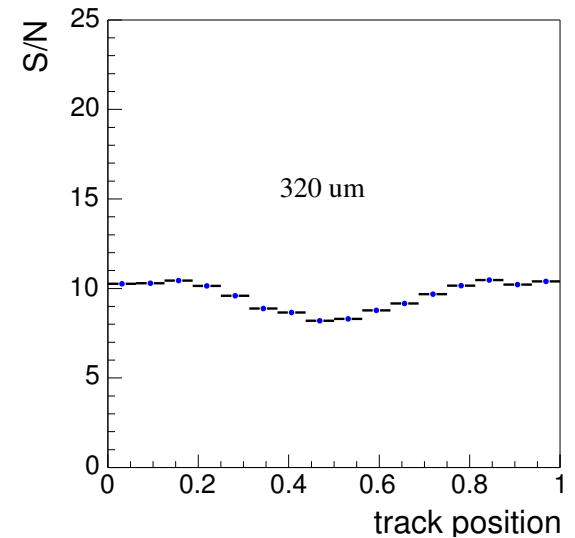
Test Beam



500 μm thick
180 μm pitch

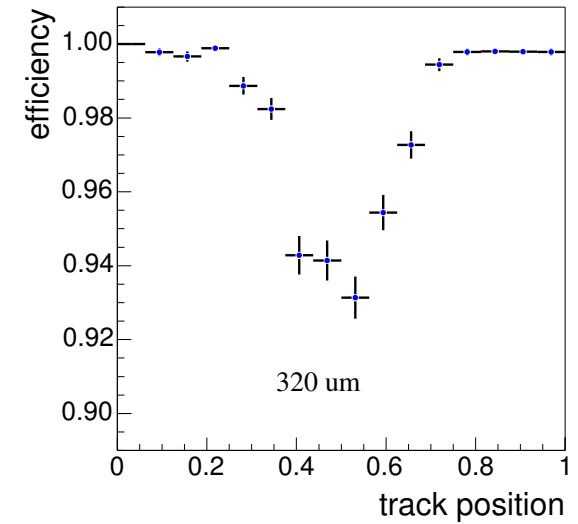
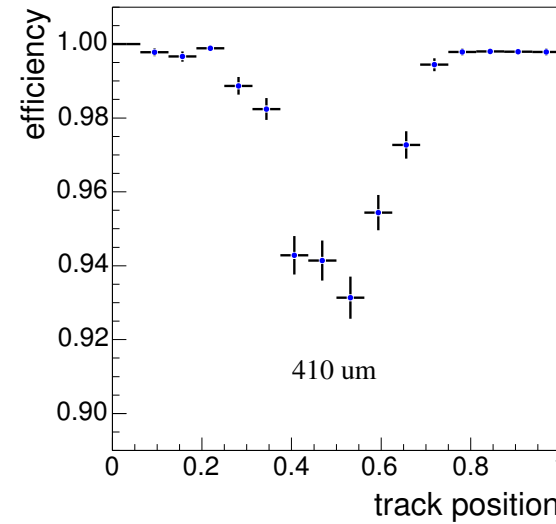
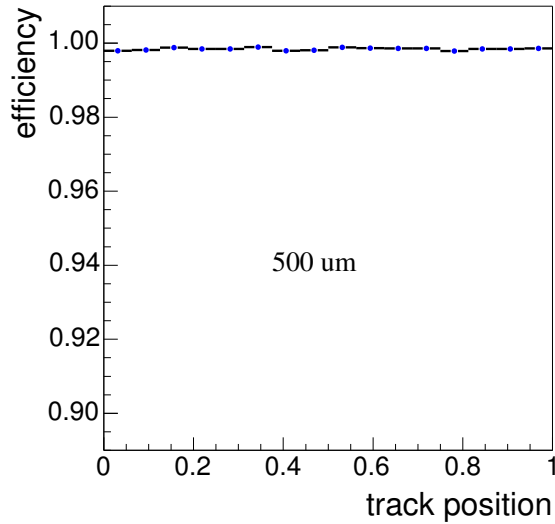


410 μm thick
228 μm pitch



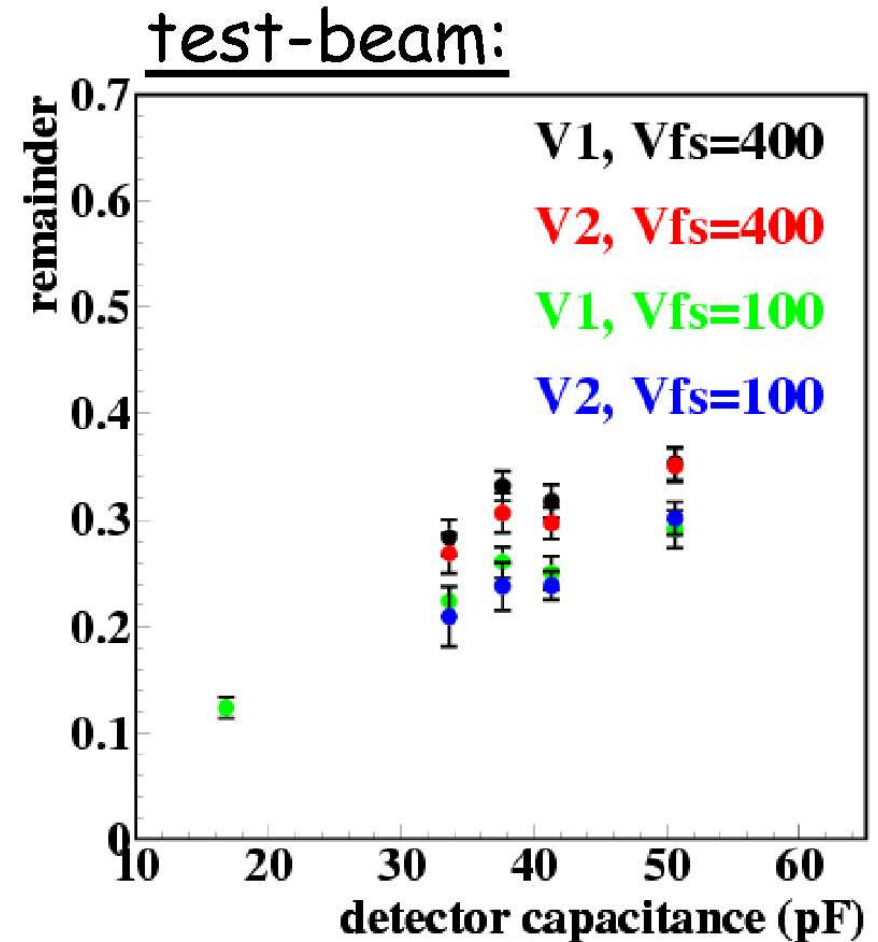
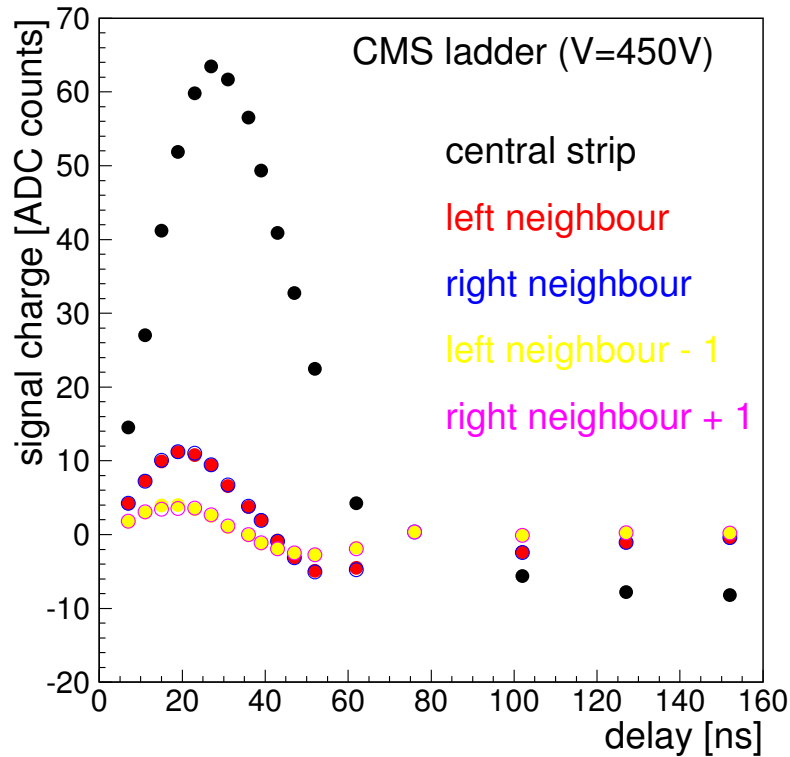
320 μm thick
198 μm pitch

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

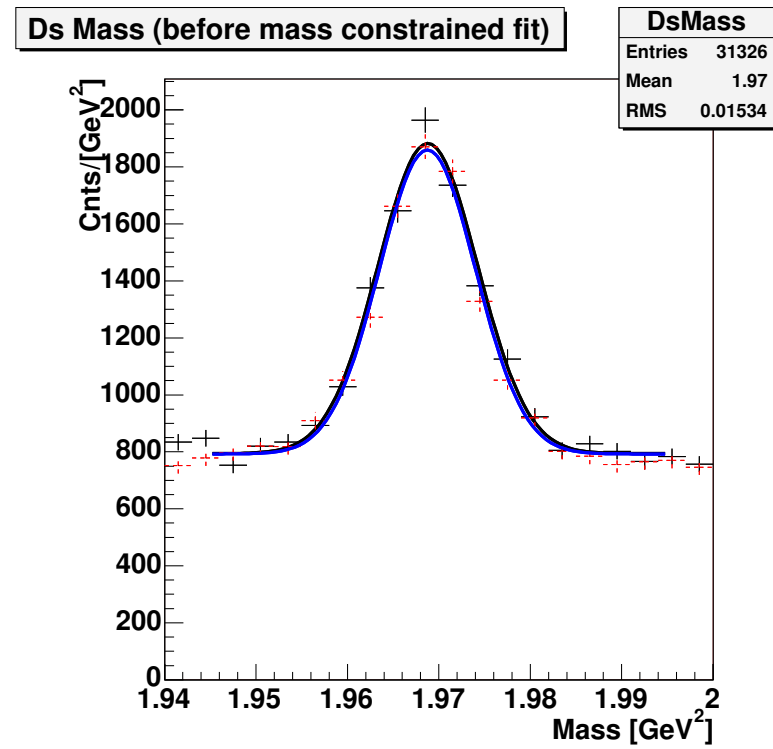
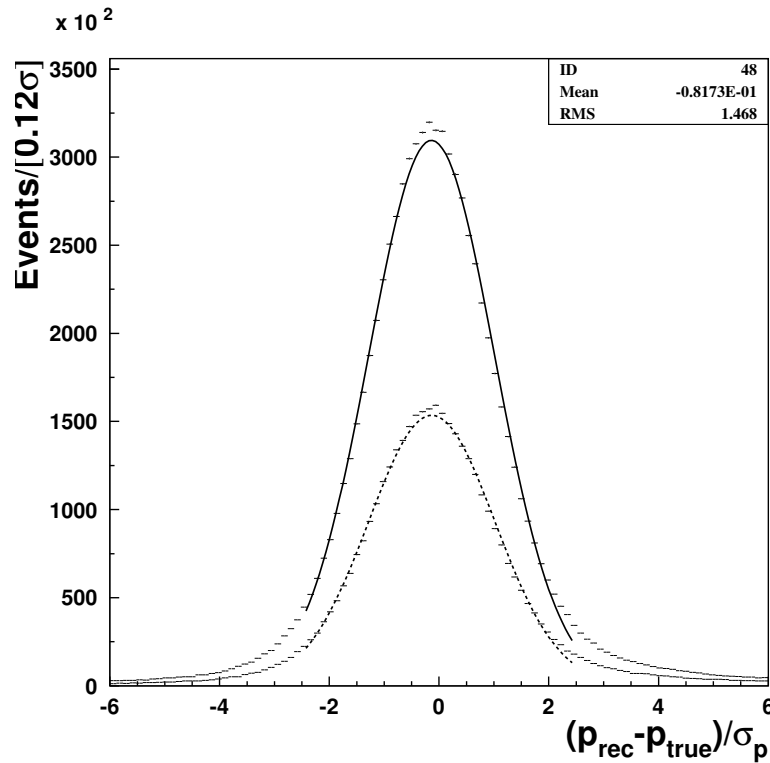
Test Beam



- signal remainder after 25 ns $< 50\%$ of peaking time
- mirror charges arrive quicker
- Beetle tuned to accomodate various load capacitances

Impact on Physics

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