technische universität dortmund

FSP LHCb
Erforschung von Universum und Materie

Bundesministerium für Bildung und Forschung

# Bachelorseminar: Detektorsysteme und Hardwareprojekte


**Nils Breer**


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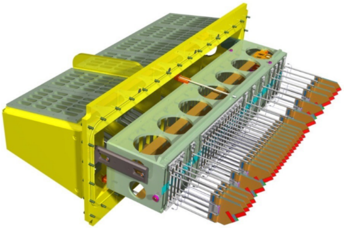
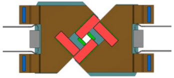
TU Dortmund

# Vertex Locator (VELO)

- 30 µm spatial hit resolution for 1 GeV transverse momentum
- primary vertex finding efficiency ≈90%
- 52 modules, 4 hybrid pixel sensors, arranged in 2 halves with 26 modules each
- can be opened and closed depending on beam quality
- VELO tank seperated from beam vacuum by RF foil
- clos to beam pipe (5.1 mm) →best possible vertex resolution



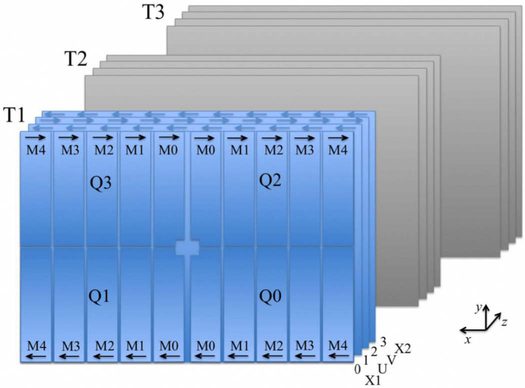


# Upstream Tracker (UT)

- 4 tracking planes upstream of the magnet
- used for matching VELO to the SciFi by reducing ghost rate
- arranged in $X - U - V - X$ stereo pattern
- improves momentum resolution for low $p_T$ tracks
- U and V rotated ±5 degrees →achieve 2D spatial resolution while suppressing ghost hits
- momentum measurements: integrated B-field = 4 Tm between UT and SciFi

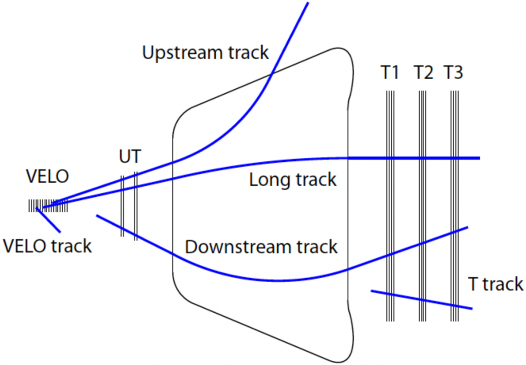
# Scintillating Fibre Tracker (SciFi)

- last element of the tracking system
- 3 stations, 4 layes per station, 10 (12) Modules per layer
- made out of scintillating fibre mats
- spatial mass resolution of 100 µm
- covering an area of 360 $m^2$
- $X1 - U - V - X2$ layer pattern with $U - V$ stereo angles repeating for every station



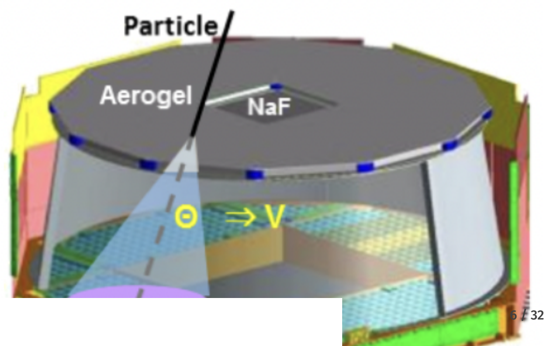
# Tracktypes

- VELO tracks only inside VELO
- Long Tracks: extended VELO Tracks matches hits in UT and SciFi
- Upstream Tracks: Tracks that leave the Detector after passing the UT
- Tracks without hits in the VELO
    - Downstream Tracks: Hits in UT and SciFi for long lived particles like Lambda and $K_s$
    - TTracks: only Hits in SciFi, here the seeding algorithm is used
    - TTracks found by seeding can also be found as long tracks by



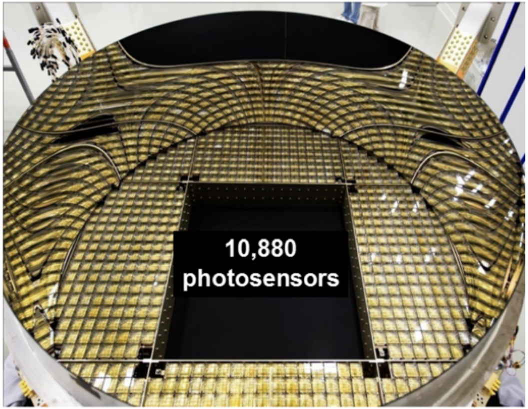
# Ring Immaging Cherenkov Detector (RICH)

- particle identification used to distinguish particles because track reco can only tell sign of particle change and momentum
- at interaction point: ring imiging cherenkov detector 1 and 2
- both detector volumes filled with flourcarbon gas →HE particles generate cherenkov radiation
- emitted light is caught by Photomultipliers
- →reconstruct speed →reconstruct mass →determine particle ID



# RICH Detector

- fbegf



## LumiTracker

- lumitracker purpose: provide measurement of luminosity by operating independently from the rest of the LHCb experiment
- →measures luminosity by reconstructing and counting tracks and also measures the luminous region by extending these tracks to the interaction point. Reconstruction in real-time needed!

# TimePix4 Telescope

- a
- b
- c

# Beam Conditions Monitor (BCM)

- original: 2009 →2018
- not a detector taking physics data, but as safety measure
- situated in 2 stations upstream of magnet
- fast particle flux measurement system
- 2 rings with 8 diamond sensors at 2 z-positions around
- BCM-U is upstream of the VELO
- BCM-D is downsteam of of TT (previous →now UT)

# BCM

- 200 V bias voltage
- current through diamonds is read out by current-to-frequency converter (CFC) cards [these were originally designed for LHC beam loss monitor]
- CFC cards integration time = 40 micro seconds
- CFC cards measurement range = (2.5 pico Amp (pA), 1 milli Amp (mA))
- →this is adequate for BCM diamonds since they show dark current in pico Amp range and dump threshold in micro Amp range
- digitized signal sent through redundant optical fibres with rate of 125kHz to TELL1 readout board

# BCM

- firmware of TELL1 board applies ”beam dump” logic to determine wether measured flux values are in problematic ranges
- TELL1 board located in D3 rack behind shielding wall in cavern where are UI is located
- Purpose of UI:
    - when conditions are met TELL1 can request beam dump
    - can inhibit injection of further bunches
    - post-mortem trigger: request a snapshot of systems current data
    - possible to send signal to VELO to open and move into safe position

# BCM

- during last months of LHC run 2 problems with BCM emerged
- multiple diamonds showed excessive currents during normal LHC conditions
- maybe radiation damage

# BCM upgrade

- 2019 →present
- all subdetectors getting a new readout hardware
- TELL1 FPGA readout board is getting deprecated
- new LHCb wide used readout boards used -> PCIe40 (BCM40 is the variant for BCM called)
- this board will be implemented in the new data center above ground with CIBU stauing in the cavern it will need an extra component:
- MIBAD board: machine interface and beam abort decision board
- featuring Intel Arriva FPGA will be placed in the same rack as TELL1 was previously

# BCM40 boards

- handles low level parts of BCM system:
  - receiving the read-out data
  - implementing beam-dump logic
  - interfacing to the machine
- this data is tunneled to BCM40 at surface center
- Using BCM40 as interface to MIBAD board -> computer system housing BCM40 runs monitoring alowing observation and control of the whole system from the LHCb control room
- →sensitive components are placed so close to damaging beams that it needs to be continuously monitored →BCM used for that

# MIBAD boards

- d
- e
- f

# Diamond Fundamentals

- bethe bloch for energy deposition
- crystalline carbon
- 2 displaced fcc lattices
- 43 eV needed to remove an atom from the lattice
- high mechanical hardness
- band gap of 5.47 eV indicates isulator but can be semiconductor as well
- large band gap →low number of charge carriers →low dark current
- large band gap + high displcement threshold →very radiation hard
- CCE picture on page 30

# Diamonds and BCM

- radiation damage →sensors failed →replacement of whole system
- to avoid said damage in the future:
- →characterization of diamond sensors with charge collection efficiency

# Field Programmable Gate Arrays: FPGA

- integrated digital circuits
- feature high number of reconfigurable logic blocks
- output depends on input (logic based)
- use look up table
- page 12 L Funke masterthesis: diagramm of FPGA

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