Upstream Tracker upgrade for LHCb

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on behalf of the LHCb Upstream Tracker group

Vertex 2019; October 15, 2019; Lopud Island, Croatia
LHCb now upgrading during LHC long shutdown 2

Increase luminosity $\mathcal{L}$ from $4 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ to $2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

Means more interactions per crossing, while maintaining the same performance

To benefit from increase, need to remove hardware trigger: readout full detector, trigger in software

Subdetectors must cope with increased occupancy
Upgraded tracking

New tracking detectors

+ Upgraded electronics and trigger
Goals for upgraded tracking

- Full 40 MHz readout
- Track building in the software trigger
- Maintain efficiency and performance at higher pile-up
- Avoid “ghost” tracks (fake or mismatched track segments)
Upstream Tracker’s role

- UT measurements just before magnet key to upgrade strategy:
  - Speed up matching between upstream and downstream
  - Remove ghosts
Upstream Tracker design

Principles

- 4 plane silicon strip tracker
- No acceptance gaps
- Get close to beam with circular cutout
- Fine segmentation in inner region
- High efficiency essential
- Currently under construction for installation in 2020

512 strips
Type A

1024 strips
Type B

1024 strips
Type C

1024 strips
Type D
Upstream Tracker design
Implementation
The sensors

- Use four designs to cope with occupancy and radiation
- p-in-n for outer sensors, n-in-p for inner ones
- Produced by Hamamatsu
- All production sensors received, final QA finishing today
The sensors

Design features

- Embedded pitch adapters
- HV contact on top side
- Cutout around beam pipe

All features working well!
The SALT ASIC

Key features:

- 40 MHz readout
- Onboard ADC
- Common mode noise subtraction
- Zero suppression
SALT v3

- SALT has had a long revision history
- v3 series usable for detector
- Baseline oscillation most serious issue now under control
The module

- Four or eight ASICs mounted to hybrid circuit
  - Four ASIC hybrid in production
  - Eight ASIC hybrid to launch shortly

First module with production components
First test of nearly final module with real signal

SALT v3, prototype hybrid, production sensors

Unirradiated A sensor, doubly irradiated B sensor
Signal and noise
Type A sensor

- Good noise performance in harsh conditions
- Signal/noise $\approx 11$

Type A sensor
at Testbeam

Type A sensor
on bench at SU

$\Gamma_3 = 0.713 \pm 0.018$
$\mu_3 = 11.108 \pm 0.027$
$\sigma_3 = 1.354 \pm 0.031$
- ≈ 9% signal loss from irradiation
- Expect 0.01 % track inefficiency
Production hybrids

- First production hybrids now completed
- Final version has some optimization designed in conjunction with latest SALT
Module construction

- Final jigs being produced
- Full-time construction to begin now
The stave

- Foam support with CO\textsubscript{2} cooling tube sandwiched in carbon fiber
- All staves completed and waiting for instrumentation
Flex cables and mounting

- Flex cables in full production, being mounted on staves
Data readout through electronics located near stave ends
Slice test

- Stave with full complement of ASICs
- One production version sensor connected
- Cooling connected
- Installed since June
Slice test
Construction

Important test of mounting procedures
Able to achieve similar performance to bench tests while operating full stave.
Slice test
Conclusions

- System working well with full chain
- Gained invaluable experience:
  - Installation procedures
  - DAQ
  - Detector control
  - Powering under realistic conditions
  - Cooling
- Will lead naturally into full commissioning
Detector mechanics and outer infrastructure in final design and procurement
Construction outlook

- Instrumented staves to begin shipping to CERN shortly, up to 20 by the end of the year
  - Should ramp up from there
- Necessary components to begin installation to be available starting in January
- Full commissioning will follow during 2020
Conclusions

- Upstream Tracker upgrade is a key component of the LHCb upgrade strategy.
- Integrated systems tests in 2019 demonstrate that we can achieve our performance goals.
- All detector components either produced, in final production, or about to launch production.
- Installation set to begin in 2020.
Backup
Sensor QA

- Semi-automatic visual inspection
- Current and capacitance v. voltage measurements
SALT block diagram
Mounting mockup