Upstream Tracker upgrade for LHCb

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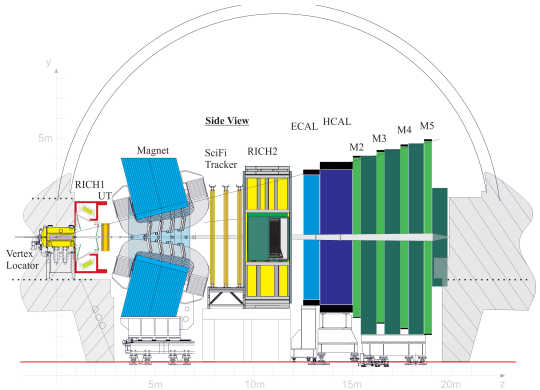
on behalf of the LHCb Upstream Tracker group

Vertex 2019; October 15, 2019; Lopud Island, Croatia

The LHCb upgrade

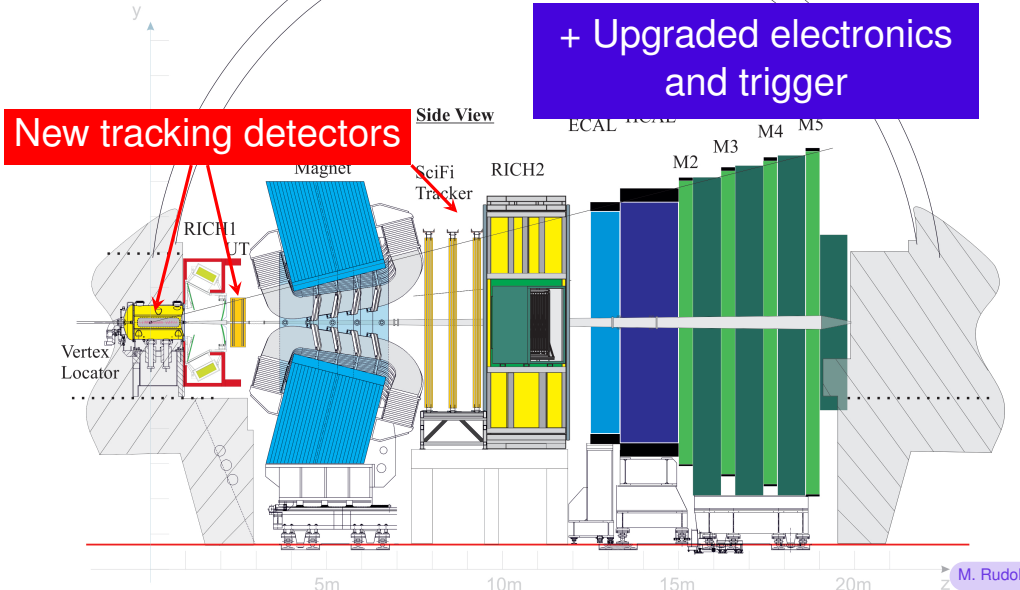
- LHCb now upgrading during LHC long shutdown 2
- Increase luminosity $\mathscr{L}$ from $4 \times 10^{32}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ to $2 \times 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$
- Means more interactions per crossing, while maintaining the same performance
- To benefit from increase, need to remove hardware trigger: readout full detector, trigger in software
- Subdetectors must cope with increased occupancy



Upgraded tracking

+ Upgraded electronics and trigger

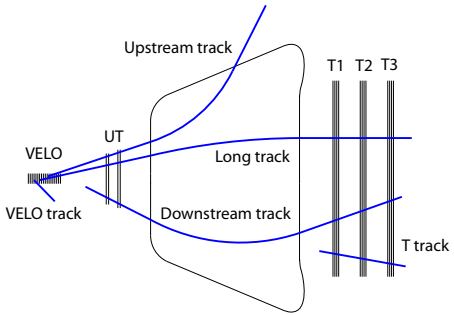
New tracking detectors

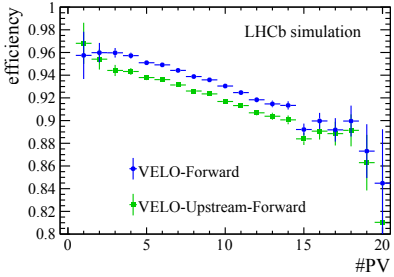


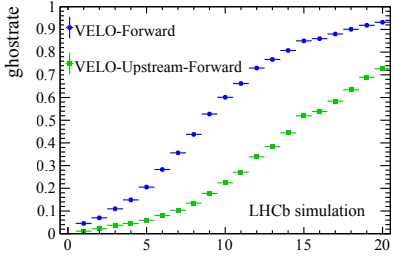
Goals for upgraded tracking

- 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





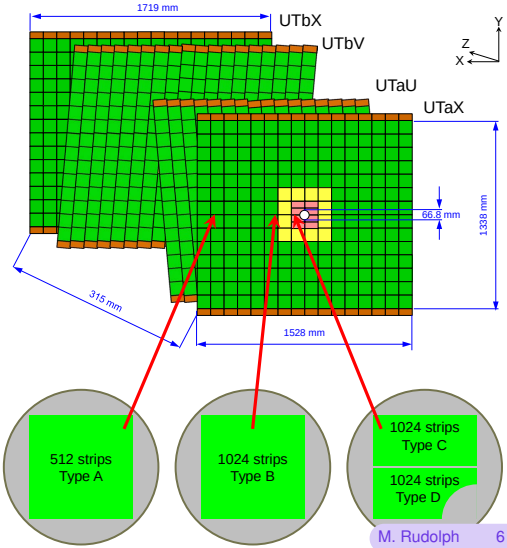


- UT measurements just before magnet key to upgrade strategy:
  - Speed up matching between upstream and downstream
  - Remove ghosts

Upstream Tracker design

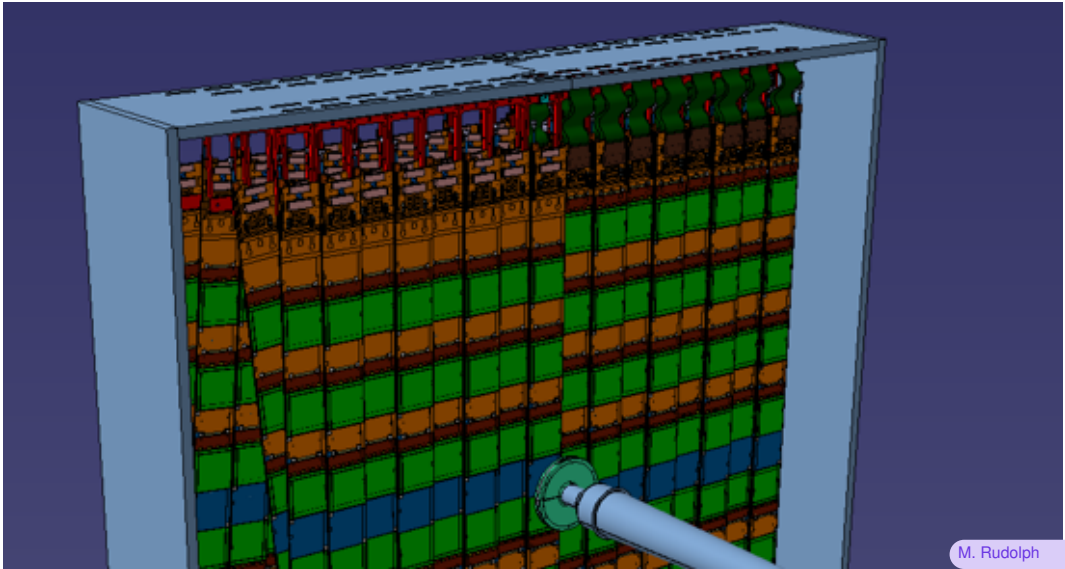
Principles

- 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



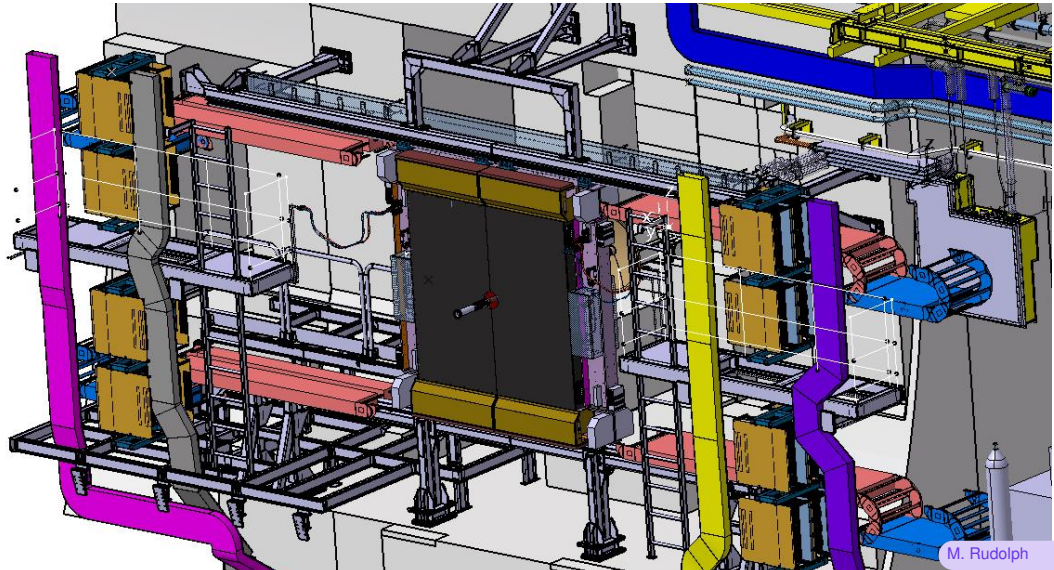
Upstream Tracker design

Implementation



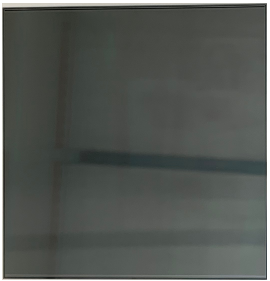
Upstream Tracker design

The full context



The sensors

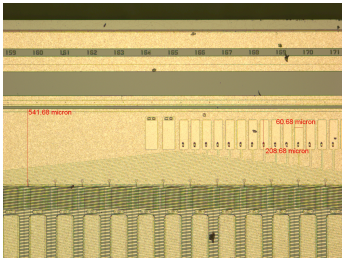
- Use four designs to cope with occupancy and radiation
- p-in-n for outer sensors, n-in-p for inner ones
- Produced by Hamamatsu
- All production sensors received, final QA finishing today

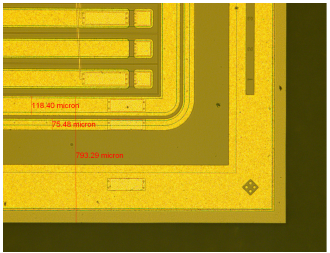
The sensors

Design features

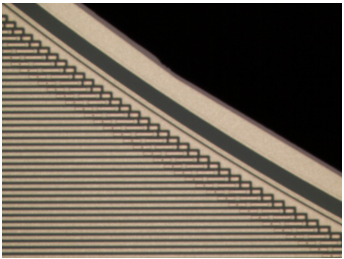
Embedded pitch adapters



HV contact on top side



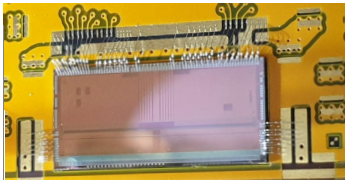
Cutout around beam pipe

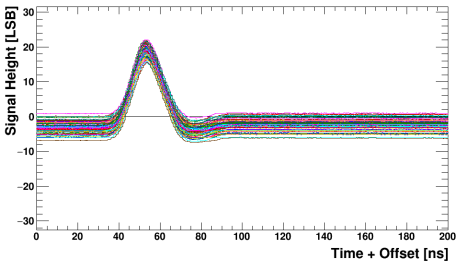


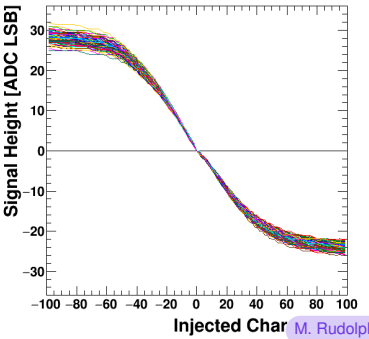
- All features working well!

The SALT ASIC

- Key features:
  - 40 MHz readout
  - Onboard ADC
  - Common mode noise subtraction
  - Zero suppression

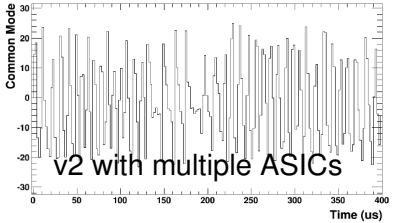


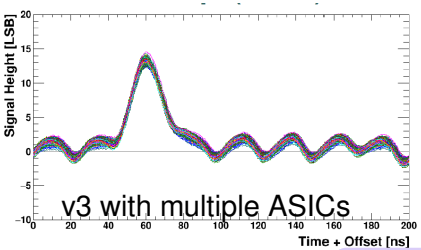




SALT v3

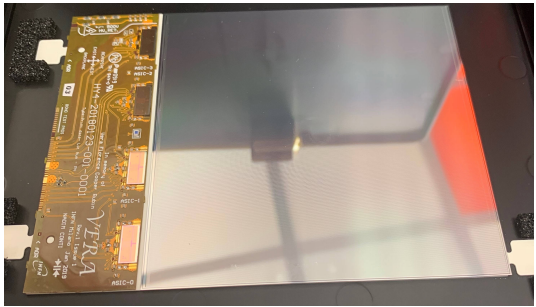
- SALT has had a long revision history
- v3 series usable for detector
- Baseline oscillation most serious issue now under control





The module

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

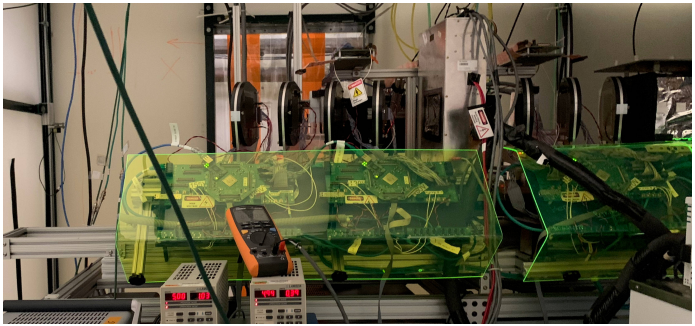


First module with production components

Testbeam at Fermilab

March 2019

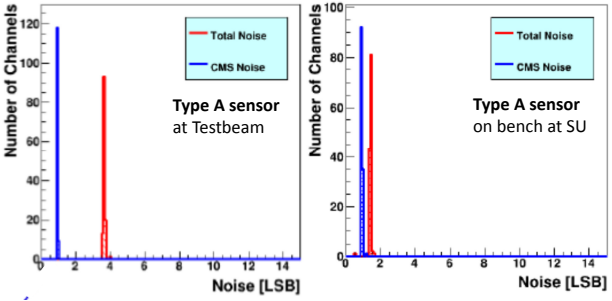
- First test of nearly final module with real signal
- SALT v3, prototype hybrid, production sensors
- Unirradiated A sensor, doubly irradiated B sensor

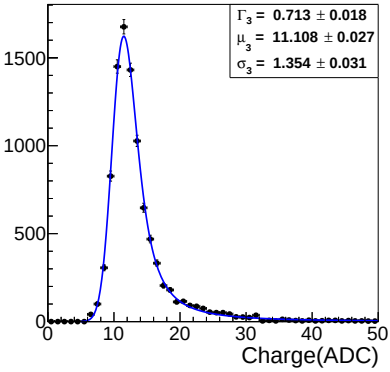


Signal and noise

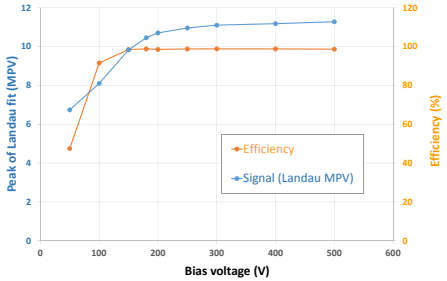
Type A sensor

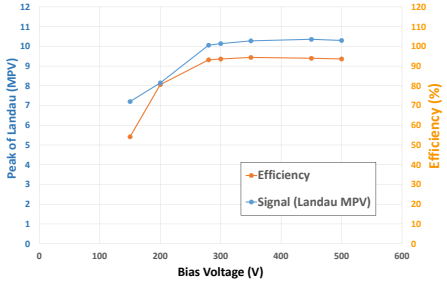
- Good noise performance in harsh conditions
- Signal/noise ≈ 11





Efficiency

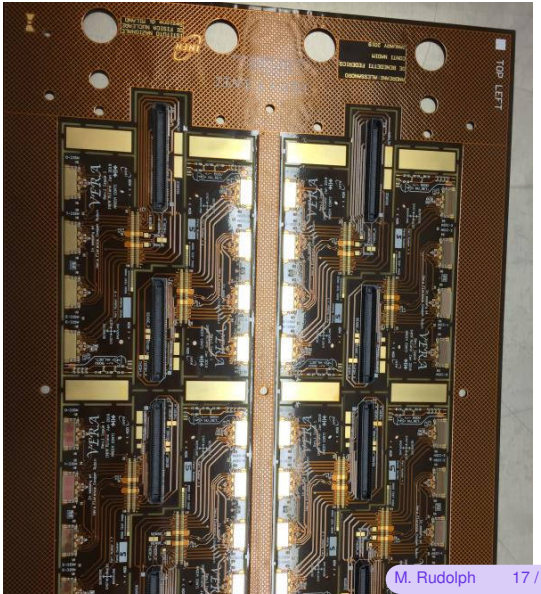




- $\approx$ 9% signal loss from irradiation
- Expect 0.01 % track inefficiency

Production hybrids

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



Module construction

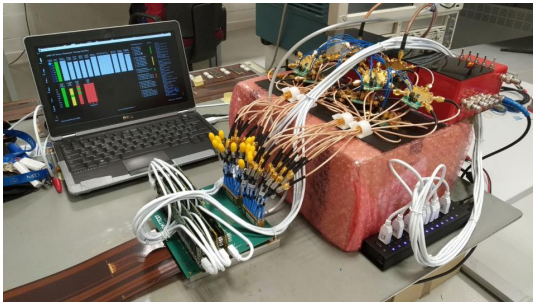
- Final jigs being produced
- Full-time construction to begin now

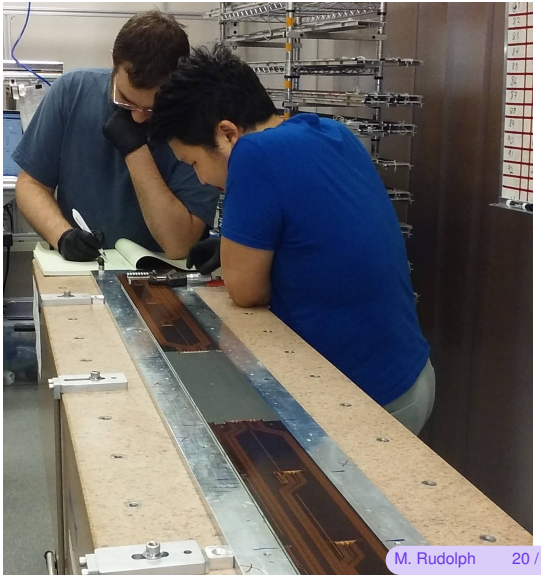
The stave

- Foam support with CO_2 cooling tube sandwiched in carbon fiber
- All staves completed and waiting for instrumentation

Flex cables and mounting

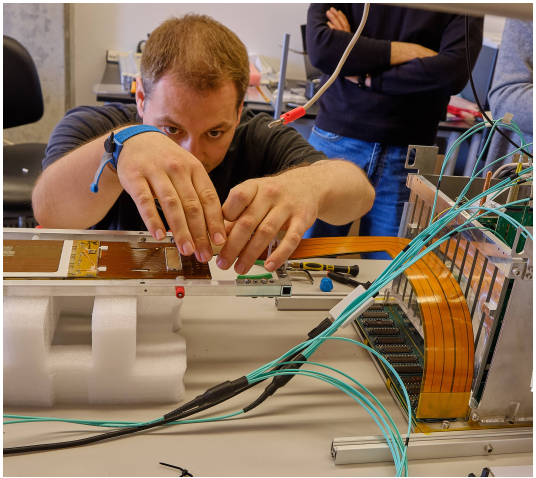
- Flex cables in full production, being mounted on staves

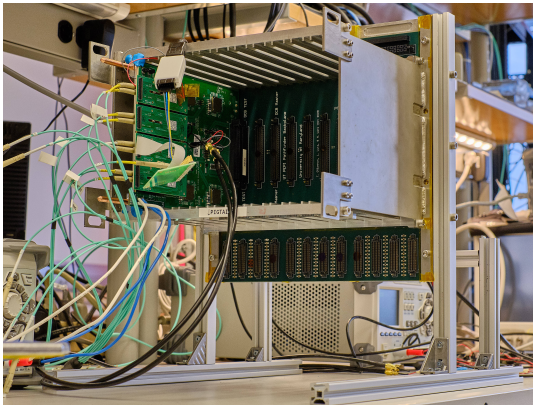




Near electronics

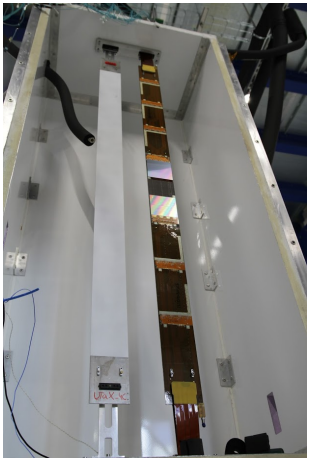
- Data readout through electronics located near stave ends





Slice test

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



Slice test

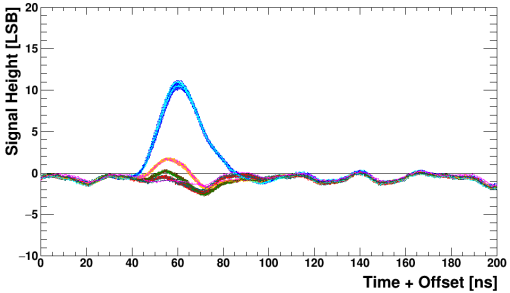
Construction

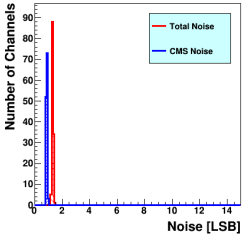
- Important test of mounting procedures

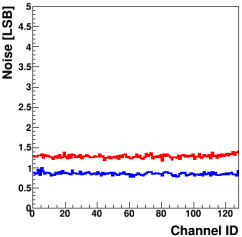
Slice test

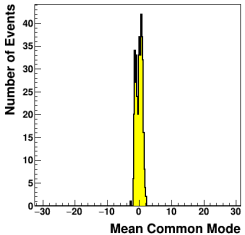
Operations

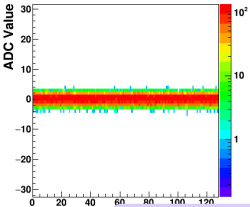
- Able to achieve similar performance to bench tests while operating full stave











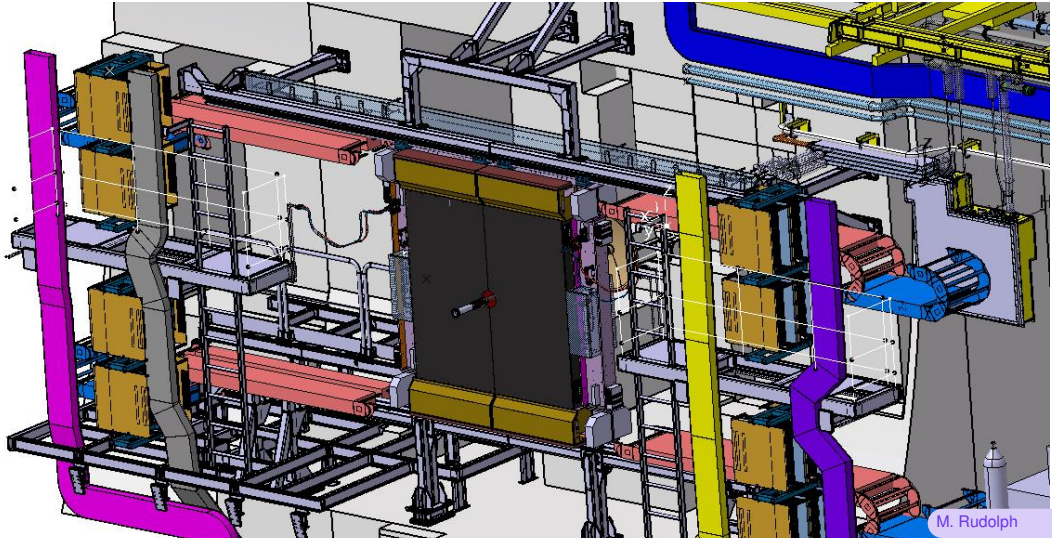
Slice test

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

Infrastructure

- 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

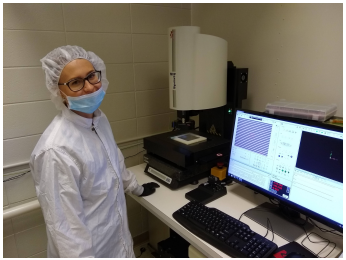
Conclusions

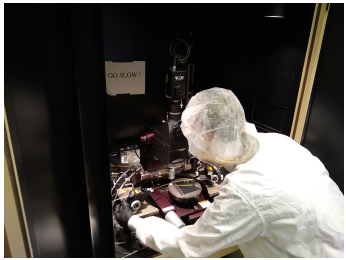
- Upstream Tracker upgrade is a key component of the LHCb upgrade strategy
- Integrated systems tests in 2019 demonstrate that we can achieve our performance goals
- All detector components either produced, in final production, or about to launch production
- Installation set to begin in 2020

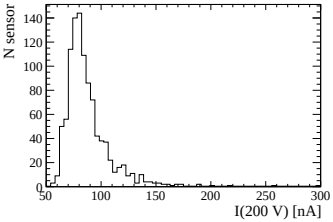
Backup

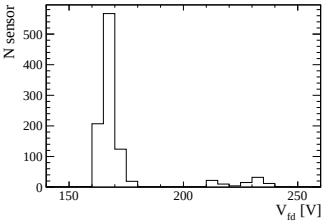
Sensor QA

- Semi-automatic visual inspection
- Current and capacitance v. voltage measurements

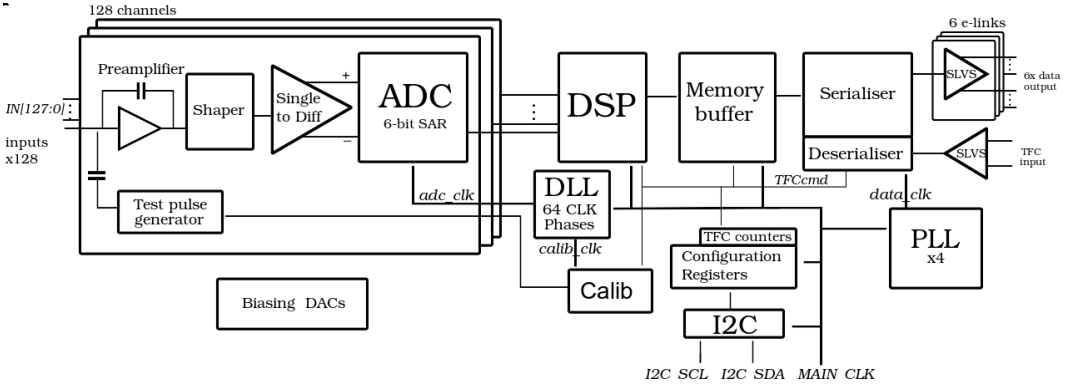








SALT block diagram



Mounting mockup