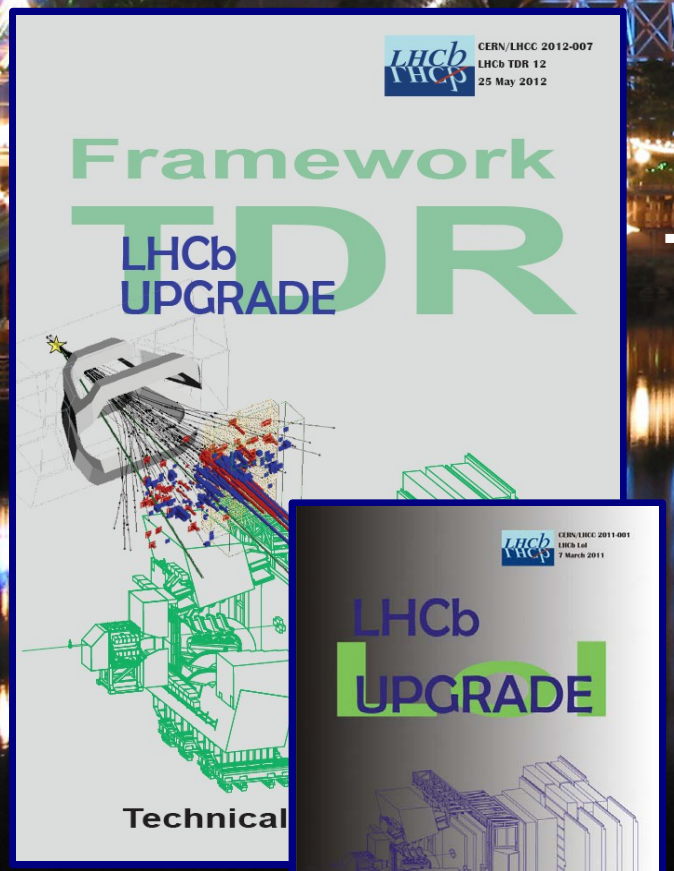
IEEE/NSS

29.10. - 03.11.2012

Anaheim



The LHCb detector upgrade

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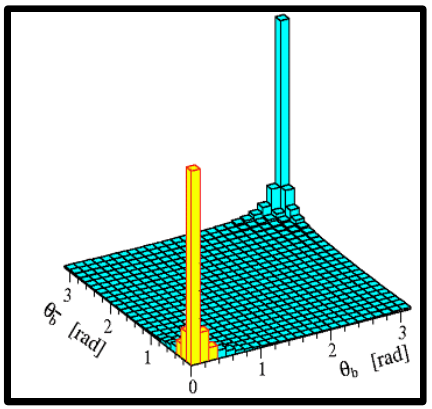
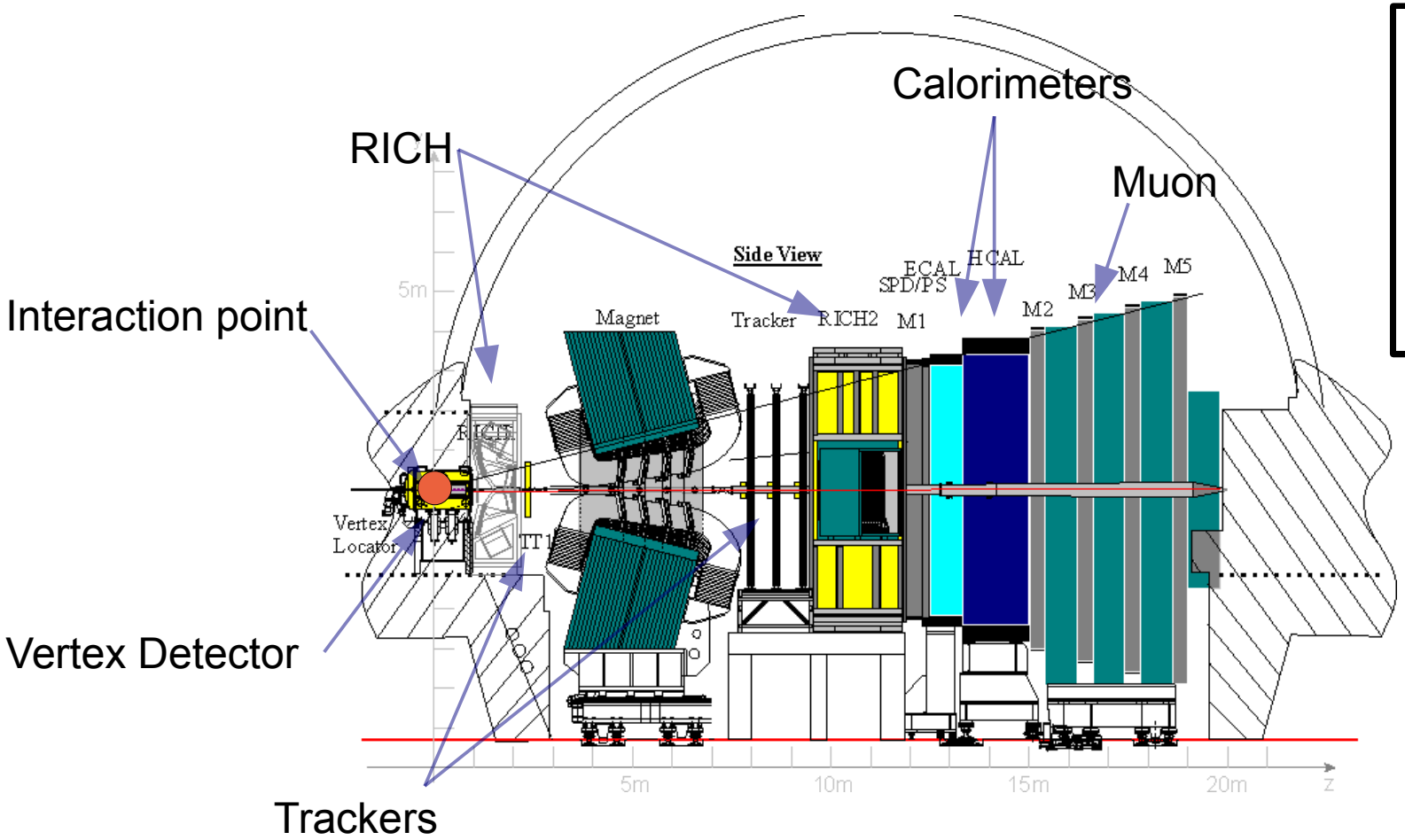
On behalf of the LHCb collaboration

Present LHCb Detector





- Single-arm spectrometer designed to search new physics through measuring CP violation and rare decays of heavy flavor mesons.

- Recorded 1 fb^{-1}(2011), + 1.7 fb^{-1}(2012)
- Detector shows excellent performance
  - See talk R. Jacobsson (N17-2)

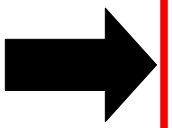
Physics Motivation for Upgrade

Two classes of measurements:

- Exploration:
  Focus on decay modes or observables a priori very sensitive to New Physics, but which have not been accessible to previous experiments.
- Precision studies:
  Measurement of known parameters with improved sensitivity, to allow for more precise comparisons with theory.

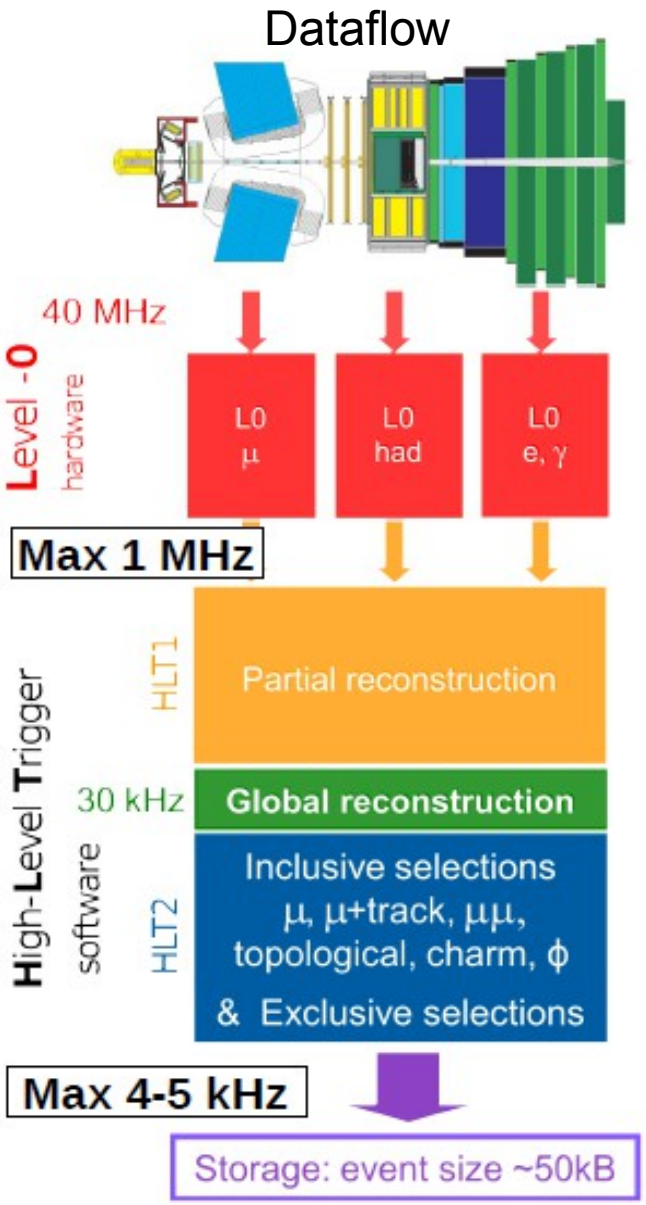
- As new exploration topics appear, existing studies migrate to precision studies.

<u>Present LHCb Detector</u>
collect ~7 fb^{-1} with L~4x$10^{32}$$cm^{-2}s^{-1}$
Readout at 1MHz
Exploration example:
Search for $B_s \rightarrow \mu^+\mu^-$ down to SM value (BR: 3x10^{-9})
Precision studies:
Measure CKM angle γ to 3-4°
to permit meaningful CKM tests



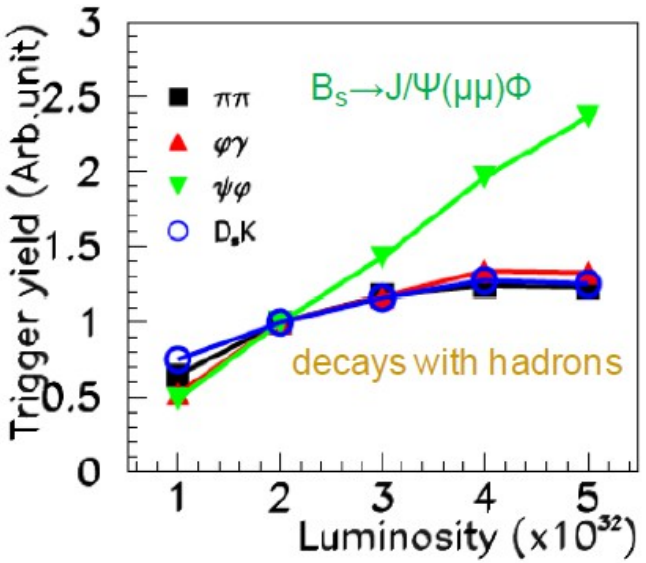
<u>Upgraded LHCb Detector</u>
collect > 50 fb^{-1} with L~1-2x$10^{33}$$cm^{-2}s^{-1}$
Readout at 40MHz
Precision studies:
Measure BR($B_s \rightarrow \mu^+\mu^-$) to precision of ~10% (assuming SM value)
Exploration example:
Search for $B^0 \rightarrow \mu^+\mu^-$
(BR: 1x10^{-10})

Current Trigger



- Hardware Trigger:
  - Calorimeter and Muon data and the full event data of up to 1 MHz of events is readout and sent to the HLT
- Software Trigger:
  - At the HLT more refined selections are made
  - Up to 4-5 kHz of events can be written to disk

- Problem with upgrade Luminosity:
  - At higher luminosity need to increase the hadron L0 E_T / p_T thresholds to stay within the allowed 1 MHz

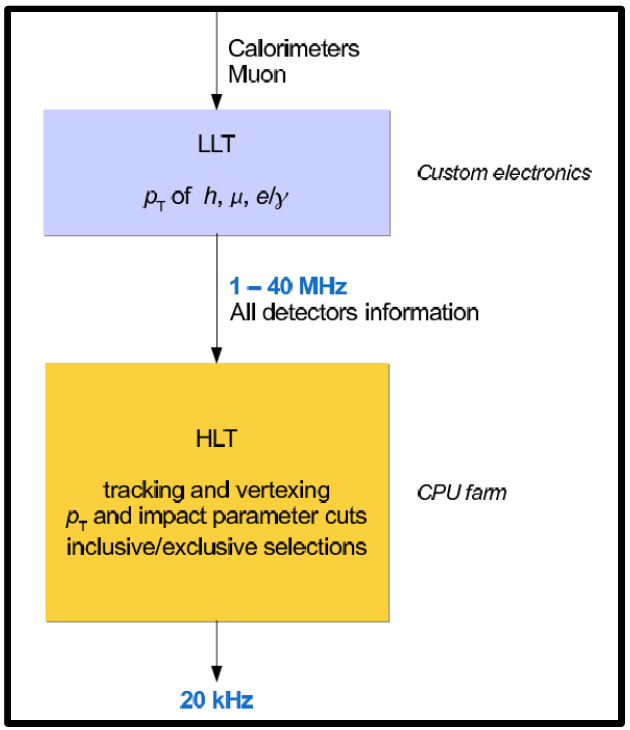


Final state with muons:
→ linear gain

Final state with hadrons:
→ saturation

Modifications for the Upgrade

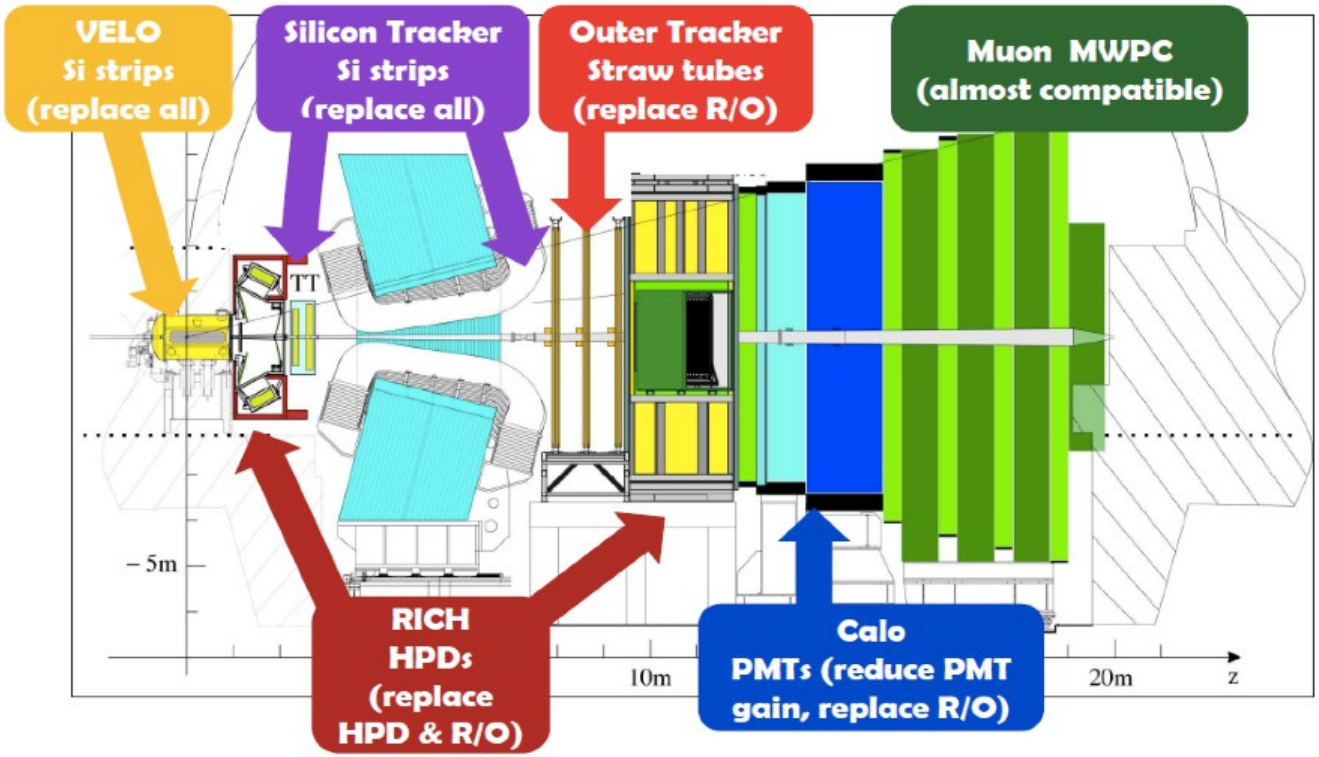
Trigger



20 kHz data taking (challenging)

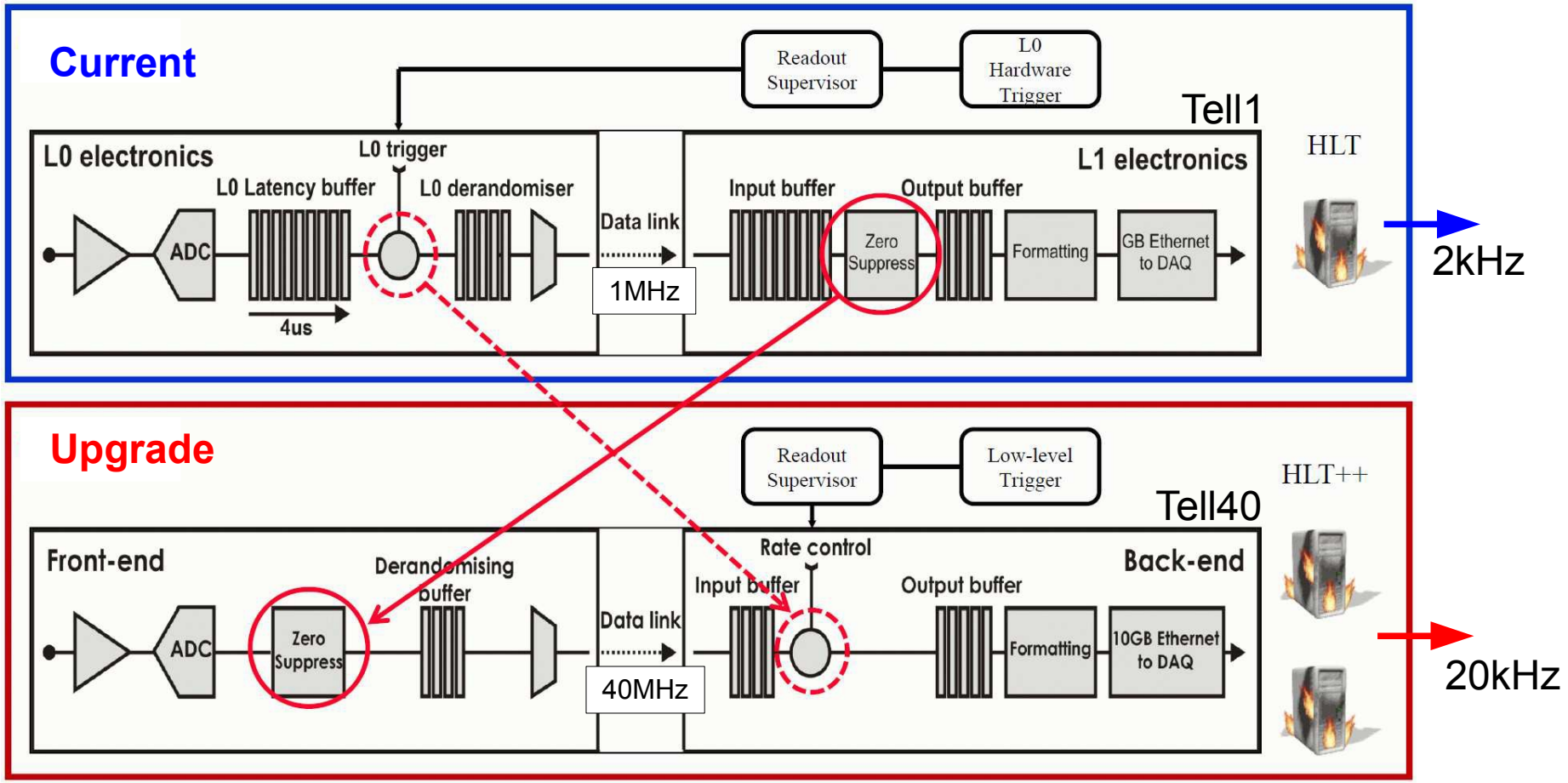
- Improvement in physics yields prevailing for hadronic channels, due to lower p_T, E_T cut

Detector



- 40 MHz readout needs the replacement of all Front-end electronics (except Muon)

Readout Electronics

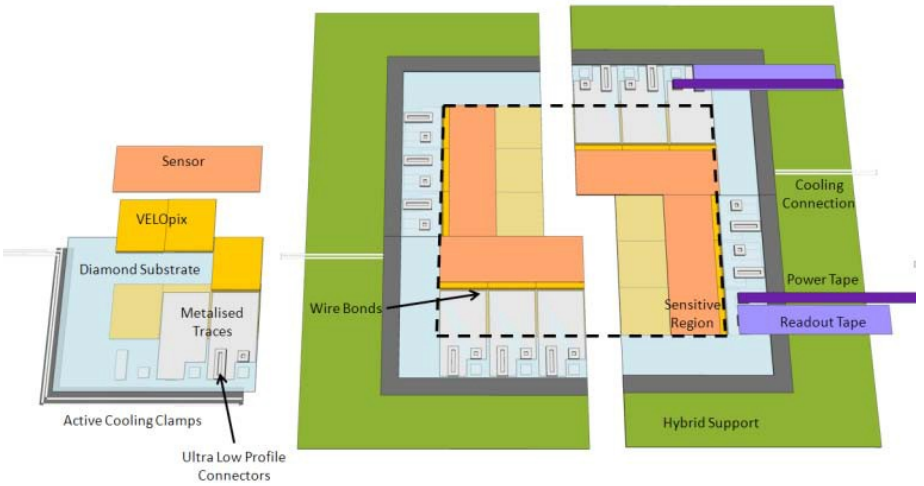


- Migration to a trigger-free readout at the bunch crossing rate of 40 MHz
  - Readout at 40 MHz instead of 1 MHz
  - Compression in the Front-ends
  - 10 Gbits/s to the farm
  - Event selection in the farm

Vertex Detector

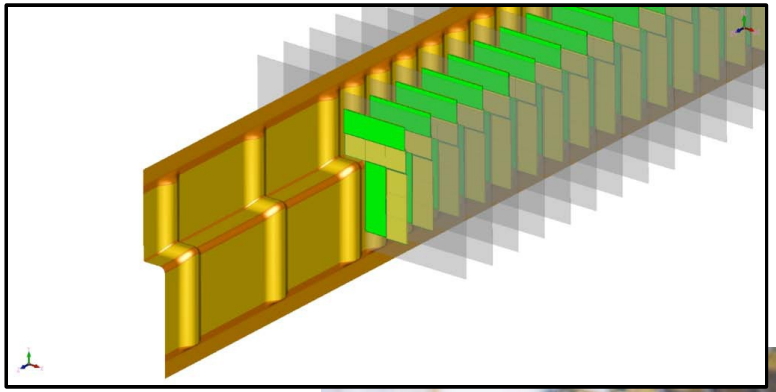
- Requirements: segmentation, data rate, radiation hardness, material Budget

- Two options to replace current detector:
  - Pixels: “VELOPIX” chip with 55x55 µm pixels
  - Strips: Proven design, reduced strip pitch (~30 µm)

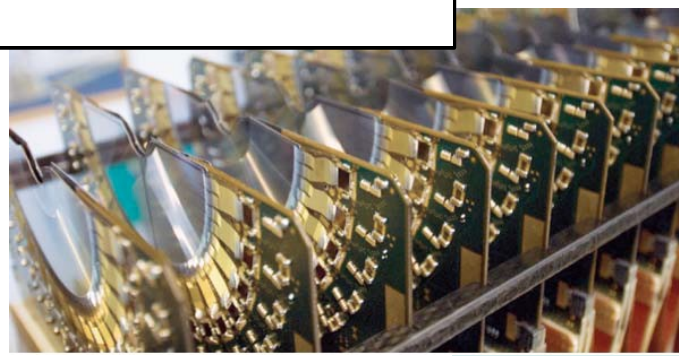


- R&D programme:
  - Module layout and mechanics
  - Sensor material: planar or 3D Si, diamond cooling substrate
  - Front-end electronics

New



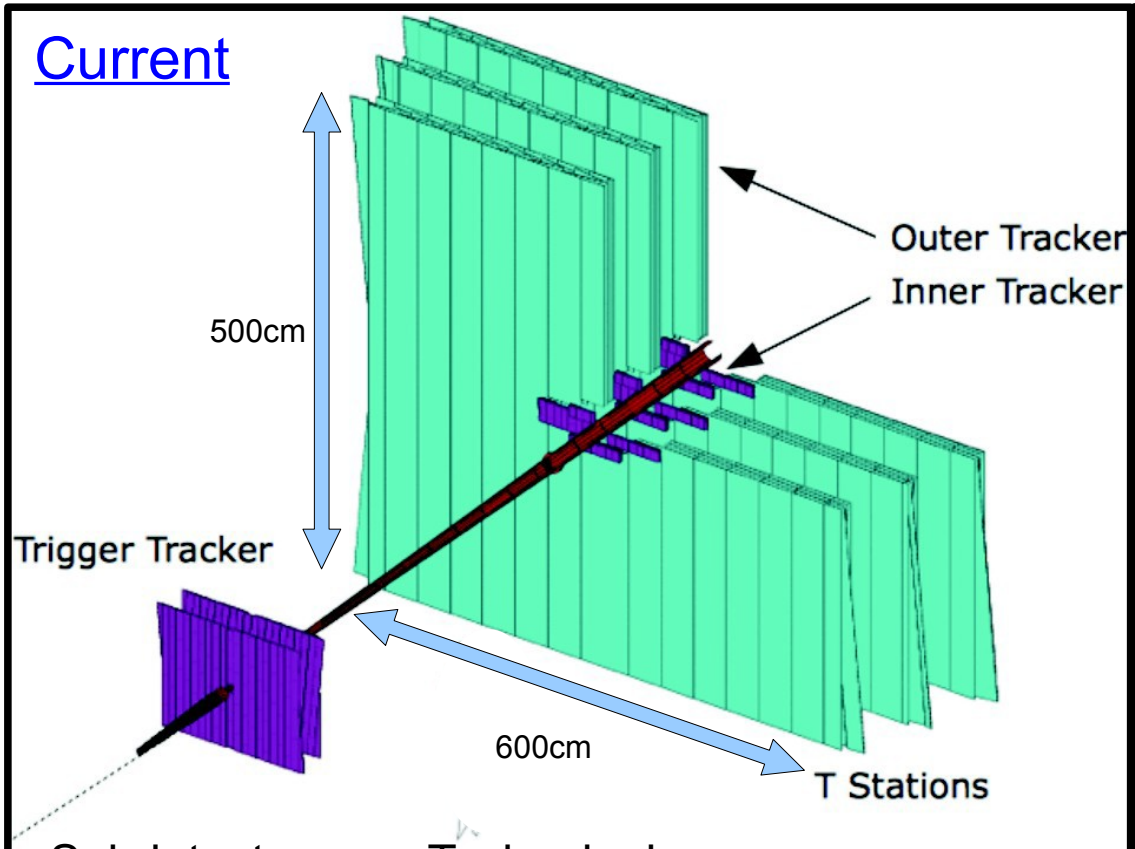
Old



More details see talk
by Álvaro Dosil Suárez
The LHCb VELO Upgrade (N24-2)

Tracker Upgrade:

Current



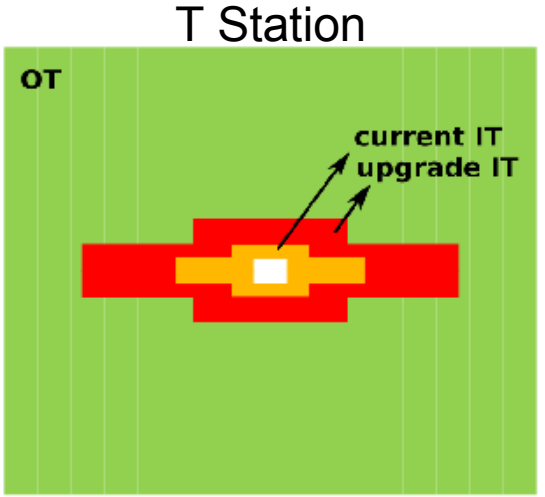
Subdetector	Technologie
TT	Microstrip silicon detector
IT	Silicon strip detector
OT	Straw tube detector

Problem for upgrade: OT occupancy too high!

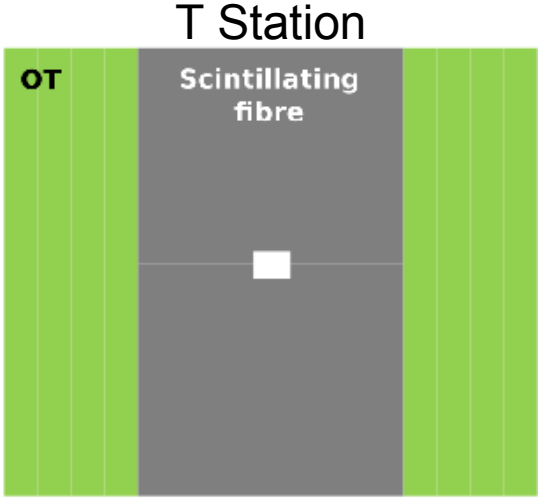
Upgrade

- Two options:

1. Bigger IT



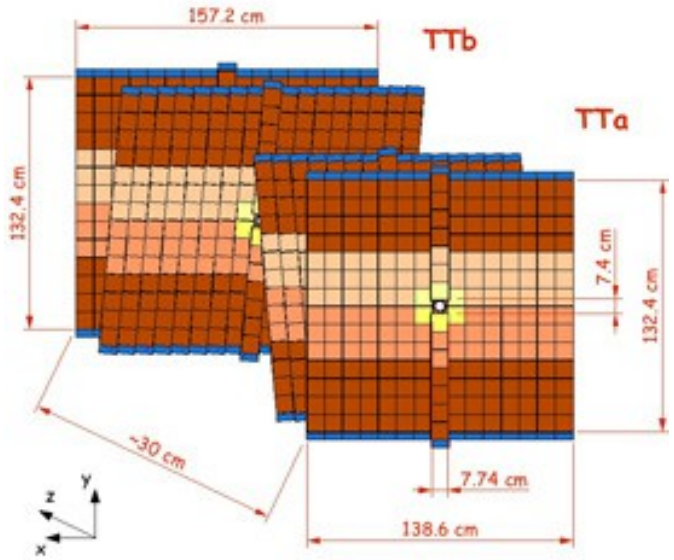
2. CT
Fiber tracker



Tracker Modifications: TT/IT

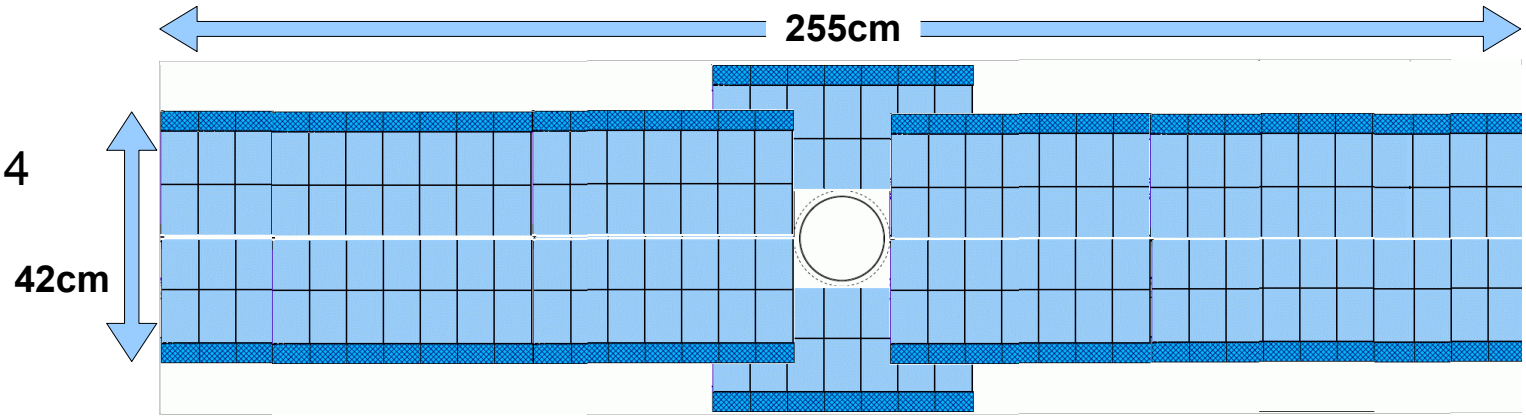
TT:

- Must be replaced as the FE electronics are "integrated" with detector.
- For optimal operation in upgrade environment consider smaller inner radius and better vertical segmentation.



IT option:

- IT light and large (Silicon strips)
- Area rises by factor 4



Tracker Modifications: OT/CT

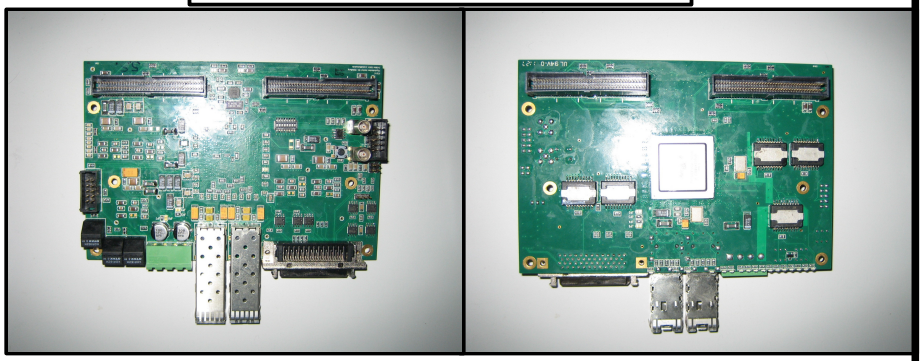
OT:

- Occupancy for Inner OT modules too high!
- Need new Front-end electronics for 40MHz readout.
  - FPGA based TDC under investigation.
    (main problem: Radiation hardness)

- Bigger IT option : Build shorter OT modules near beam pipe

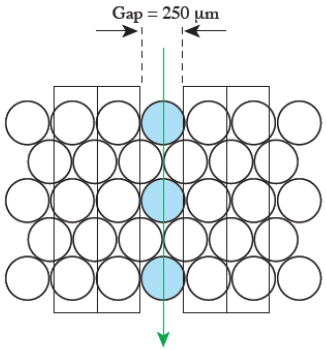
- CT option : Remove inner OT modules

New FE electronics prototype



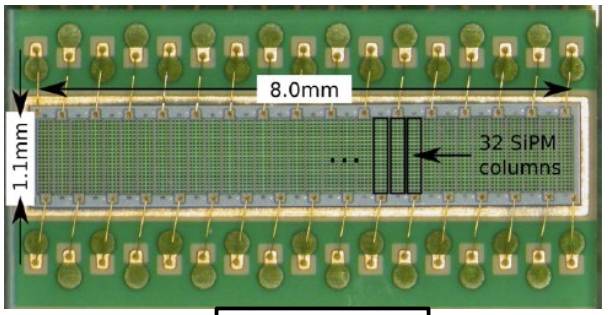
CT option:

- Fiber Tracker
- Scintillating fiber Modules in the middle of the Tracker
  Using SiPM arrays for readout
  - 5 fiber layers in each module
  - 250µm fibers



- New Front-end electronics in development

- Active R&D ongoing:
  - Investigation of radiation hardness



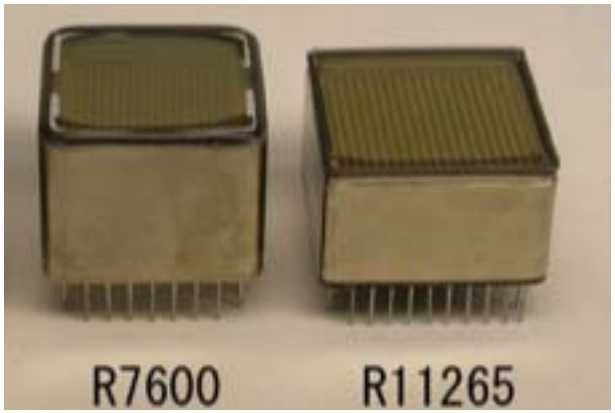
SiPM array

RICH / PID

- Needed for clean reconstruction of hadronic decay modes. (K/π separation)

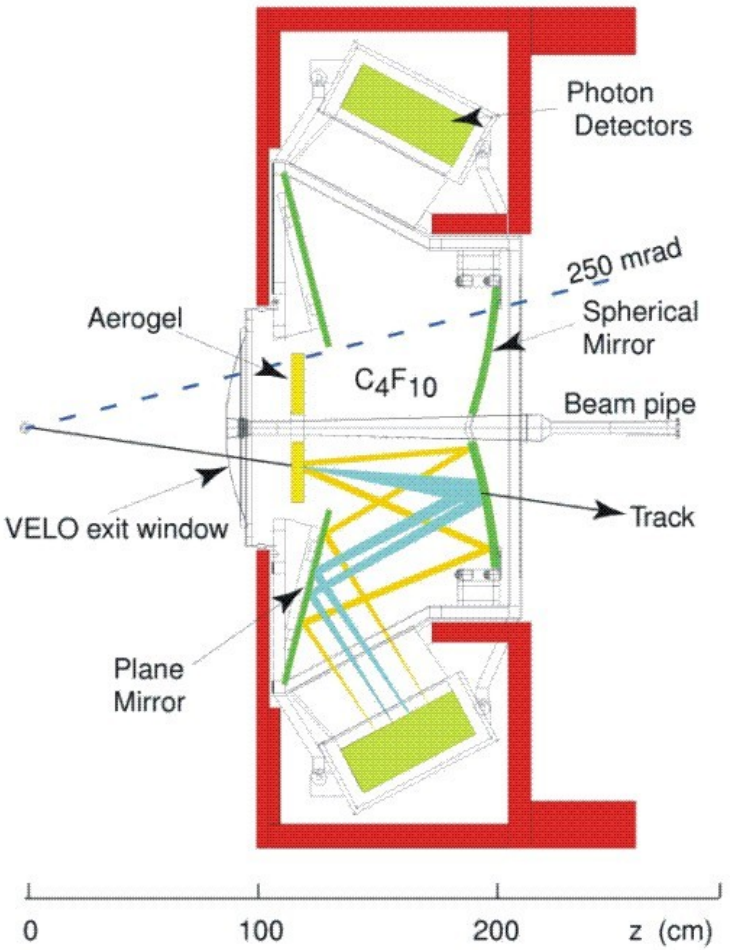
- RICHes on both sides of the magnet remain.
- Remove aerogel (due to occupancy)
- New photo-detectors needed to allow installation of readout at 40MHz.
- Multi anode PMT as baseline solution. New readout chip needed.

- Exploring the possibility of combining RICH1&2 in a single mechanical envelope



MaPMTs (Hamamatsu)

RICH 1

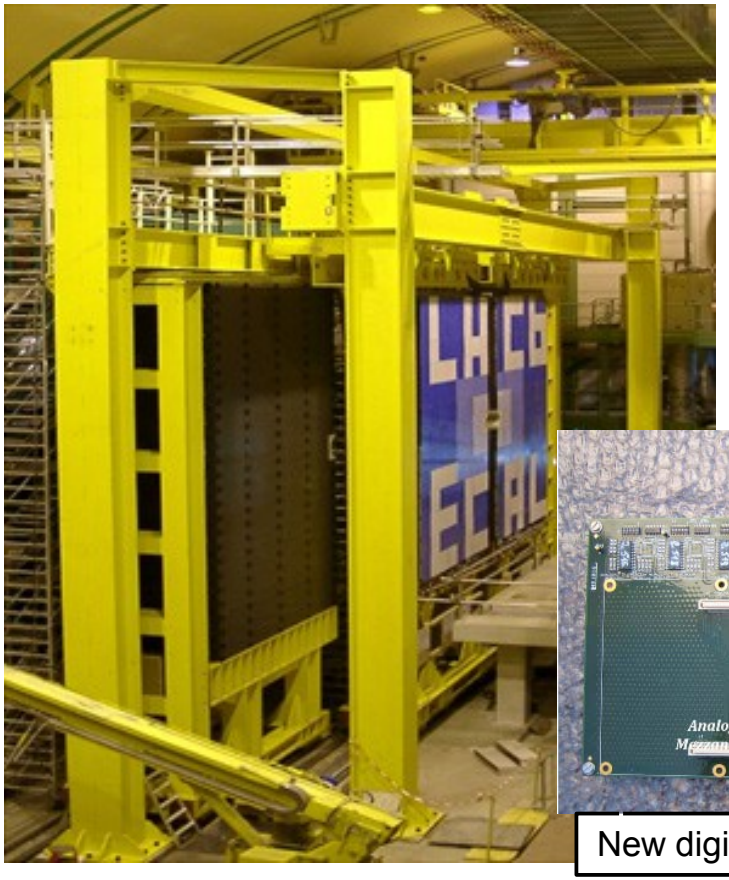


Calorimeters & Muon

Calorimeters:

- ECAL and HCAL changes
  - Keep all modules & PMTs
  - Reduce the PMTs gain by a factor 5
  - New FE electronics to compensate for lower gain and to allow 40 MHz readout

- PS and SPD will be removed
  - e / γ/ hadron separation in HLT with the whole detector info (tracker)



New digital electronics prototype

Muon:

- Muon detectors are already read out at 40MHz in current L0 trigger
  Front-end electronics can be kept
  Remove detector M1
  Performance at higher occupancy: $L=1x10^{33}cm^{-2}s^{-1}$ acceptable
  $L=2x10^{33}cm^{-2}s^{-1}$ under investigation

Schedule

- 2012: LHCb data taking @ 8 TeV
- 2013-2014: 1st LHC long shutdown:
  LHCb maintenance
  Submission of LHCb subsystems TDRs to LHCC
  LS1: Installation of fibers and cables
- 2015-2017: LHCb data taking @ 13-14 TeV and 25ns bunch spacing
  New hardware construction
- 2018/2019: 2nd LHC long shutdown:
  Installation and commissioning of the upgraded detector
- after 2019: LHCb data taking @ 14 TeV with $L=1\text{-}2\times10^{33}cm^{-2}s^{-1}$

Summary

- Main aspects of the LHCb Upgrade:
  - Change readout of entire detector to 40MHz with fully software-based trigger and replace some of the major detector components.
  - LHCb upgrade independent of the LHC luminosity upgrade.
- LHCb has a firm plan to upgrade the detector by 2018
  - Exploring the full potential of flavour physics at LHC will reduce experimental uncertainties down to theoretical uncertainties. (50 fb^{-1} needed)
- The LHCb Upgrade is taking shape
  - The LOI submitted in March 2011 was well received by LHCC
  - The Framework TDR, released in May 2012, provides updated physics performance, schedule and cost estimates
  - Subdetector R&D is in progress, TDRs will follow in 2013