# LHCb Challenges for Run 2

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on behalf of LHCb

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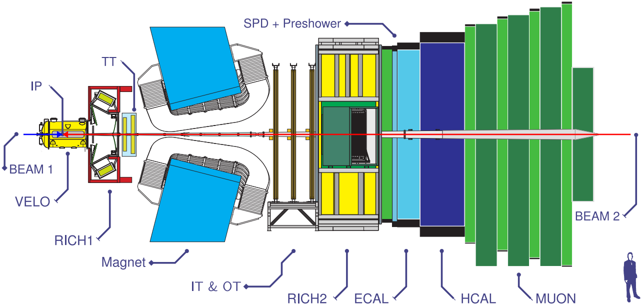
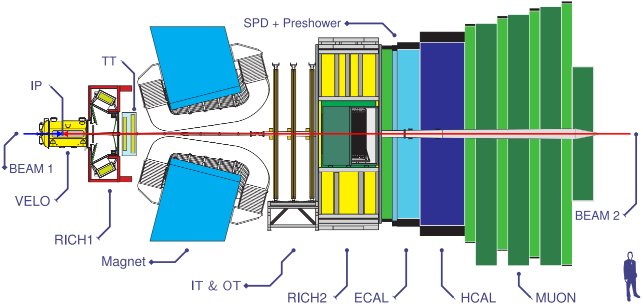
# The LHC Beauty Experiment




- Single arm spectrometer instrumented in the forward region: $2 < \eta < 5$.
- Precision experiment designed to detect decays of b- and c-hadrons for the study of *CP* violation and rare decays.

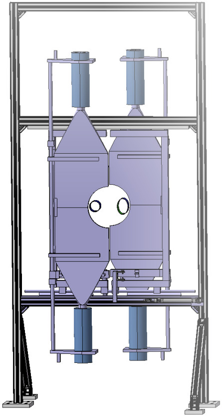
# The LHC Beauty Experiment




- Unique features:
  - vertex resolution (4$\mu$m single-hit resolution)
  - RICH provides excellent particle identification (Kaon ID efficiency: 95%)
  - high rate trigger (1MHz to software trigger)
  - momentum resolution ($\Delta p/p$: 0.4% @ 5 GeV/c, 0.6% @ 100 GeV/c)

# LHCb Physics at 13 TeV and beyond

- $b\bar{b}$ and $c\bar{c}$ cross-sections expected to increase $>60\%$ for LHC Run 2.
- LHCb will maintain its physics program with increased statistics.
- HeRSCheL - High Rapidity Shower Counters for LHCb
  - Scintillator planes with PMTs placed in tunnel either side of LHCb
  - Looks for showers at high rapidity
  - Improve performance of Central Exclusive Production studies



# Long Shutdown 1

- Long Shutdown 1 (2013/2014) has presented several opportunies in order to prepare for the challenging new run.
- Further enhance detector stability
- Perform repairs/replacements to problematic hardware
- Service aging electronics
- Consolidation of gas, cooling systems, and power supplies/racks
- Enhance the capability of the computing farm
- **Revise trigger strategy**

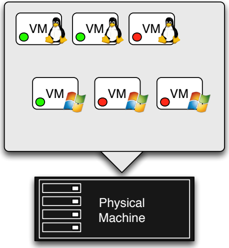
# Experiment-wide activities

- Beam pipe replacement
  - section 3 removed - local nano-porosity
  - Improved production process for vacuum tightness
  - Dismantled in May 2013, to be commissioned in Nov. 2014
- Power supply maintenance
- Extensive maintenance to cooling system
- Operations weeks
  - Regular detector check-out
  - Team of experts to problem solve
  - New hardware/software testing

- B-field measurement
- Creation of a new control room to become operational in 2015

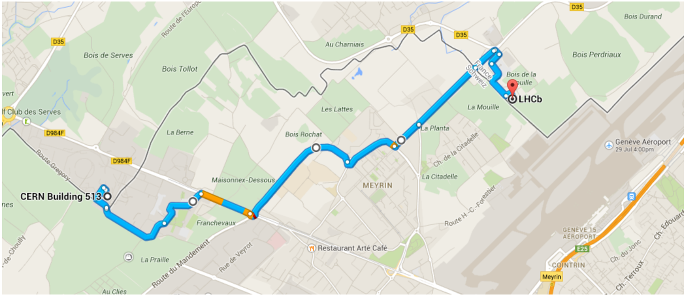
# Online

- Detector Control PCs moved to Virtual Machines
  - 2 years from concept to deployment
  - Failure recovery reduced from 4+ hours to 4 mins
  - Seamless and automatic
  - All control PCs can run in one of two chassis clones
- PVSS → WinCC - ECS software changed
- Operating systems updated. Most control PCs now running on Linux
- Hardware drivers now running on CCPCs

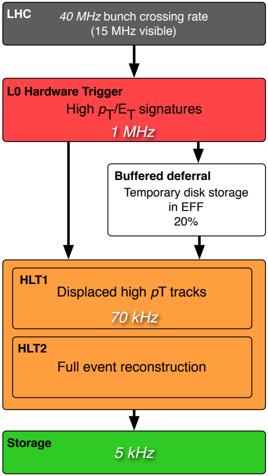



# Online

- Network redundancy with CERN IT and LHCb detector site
- Bandwidth to storage increased from 300 MB/s to 1 GB/s
- HLT Farm Upgrade
  - Farm will be doubled in CPU capacity. Many first and second generation servers will be replaced with state of the art.
  - Adding 3PB local storage across farm to accommodate new HLT scheme



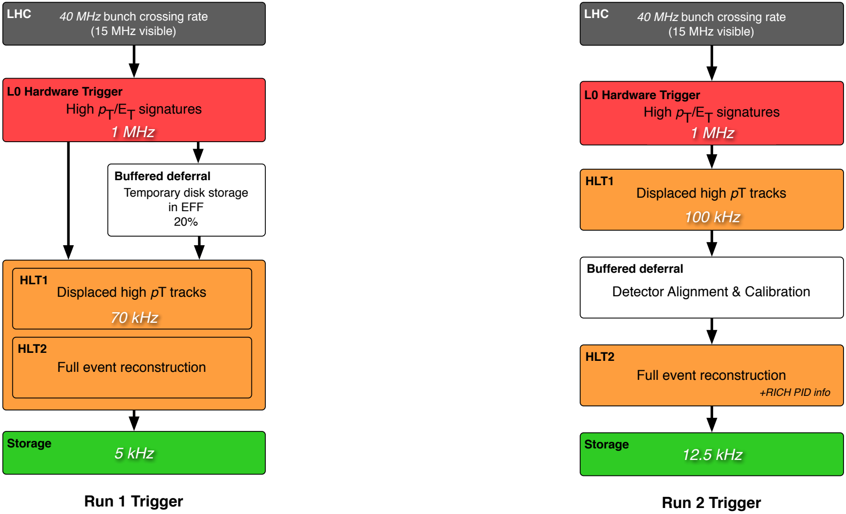
# Trigger




**Run 1 Trigger**

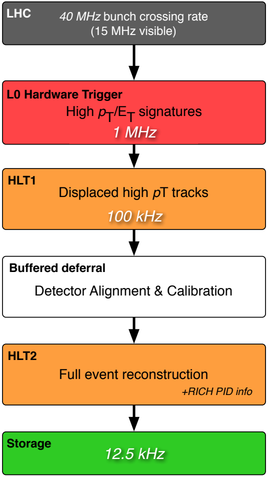
- L0 Hardware trigger - muon & calorimeters
  - High rate!
- High Level Trigger (HLT) - software
  - HLT1 - tracking
  - HLT2 - full reconstruction
  - much of the same algorithms running in trigger and offline
- Deferred trigger
  - buffers data for processing between fills
  - improved trigger efficiency

# Trigger


LHC
40 MHz bunch crossing rate
(15 MHz visible)
L0 Hardware Trigger
High $p_T$/$E_T$ signatures
1 MHz
Buffered deferral
Temporary disk storage
in EFF
20%
HLT1
Displaced high $p$T tracks
70 kHz
HLT2
Full event reconstruction
Storage
5 kHz
Run 1 Trigger
LHC
40 MHz bunch crossing rate
(15 MHz visible)
L0 Hardware Trigger
High $p_T$/$E_T$ signatures
1 MHz
HLT1
Displaced high $p$T tracks
100 kHz
Buffered deferral
Detector Alignment & Calibration
HLT2
Full event reconstruction
+RICH PID info
Storage
12.5 kHz
Run 2 Trigger

# Trigger

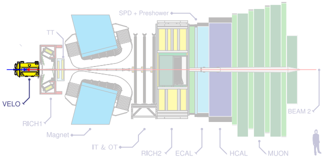
- New trigger strategy based on the experiences of Run 1
- All HLT 2 processing will be deferred
- Calibration and alignment will be performed per-fill and in some cases per-run
- Can use PID in trigger
- HLT processing much closer to Offline
- $\times 2$ farm CPU capacity allows much greater flexibility
- 5 kHz $\rightarrow$ 12.5 kHz
  - Exceeding grid quota - need to reduce data/event size




**Run 2 Trigger**

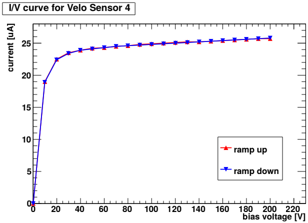
# Vertex Locator

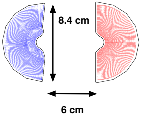
- Primary tracking and vertexing detector
- R and $\Phi$ strip sensors using $n^{+}$-in-n silicon
- 300 $\mu$m thick Al foil separates modules from LHC vacuum
- Retractable halves - Si 7 mm from beam
- Detector performed extremely well in Run 1
- Radiation damage not enough to impact physics in Run 2
  - unnecessary to replace with spare



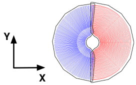

# Vertex Locator

- New automatic calibration per fill
- Radiation monitoring scans optimised
- ECS and monitoring software overhaul
- Studies of HV trips at $\sim$300 V, believed understood. (Run 1 operating voltage: 150 V)
- New HLT strategy - VELO alignment performed per fill
  - Moveable detector - closes every fill




VELO Open



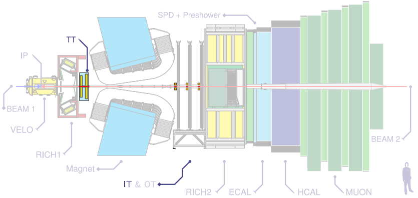

**VELO Closed**
*Stable Beams*

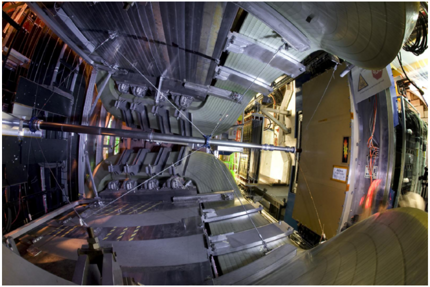
Maximum variation of 2 half alignment

| | x ($\mu$m) | y ($\mu$m) |
|---|---|---|
| Run 1 | $\pm 9$ | $\pm 6$ |
| calculated per fill | $\pm 3$ | $\pm 1$ |

# Silicon Tracker

- Two sets of silicon trackers
  - one upstream of magnet (TT) and one downstream (IT)
  - TT has 1 station of 4 detection layers
  - IT has 3 stations of 4 detection layers
- $p^{+}$-in-n silicon with long strips
- Improved resolution in magnet bending plane



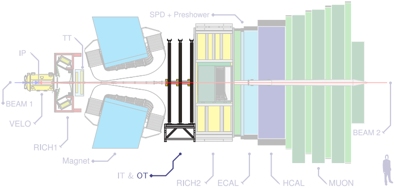
# Silicon Tracker

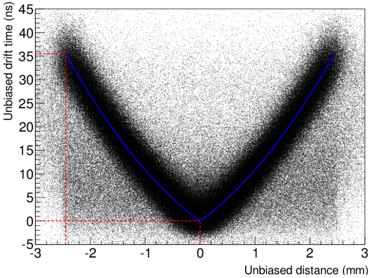
- Cooling
  - Degradation in performance of cooling system during Run 1
  - Lubricant mixing with coolant
  - Recirculated every 2-3 weeks in 2012
  - No temperature increase seen in detector (due to vigilant experts)
  - New chiller installed for Run 2
- Alignment
  - Inner Tracker too low on frame
    - New mechanics installed
    - Adjusted to nominal position
    - BCAM monitoring system installed
  - New HLT strategy - tracker alignment will be performed fill-by-fill

- ECS and monitoring software overhaul
- 25 ns running: spillover effects to be studied

# Outer Tracker

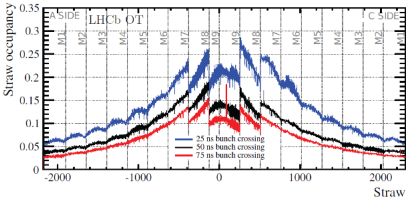
- Straw tube tracker downstream of magnet
- 3 stations surrounding inner silicon tracker
- 4 detection layers per station
- <50 ns drift time



# Outer Tracker

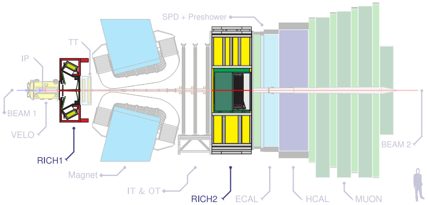
- Aging
  - Discovered during Q.A. just prior to Run 1.
  - Build-up of an insulating layer causing a decrease in gain -30%
  - cause by sealant glue (minor change at manufacturing)
  - Adding some $O_2$ to the straw tube gas mixture acts as a cleaning agent
  - No significant degradation seen in Run 1

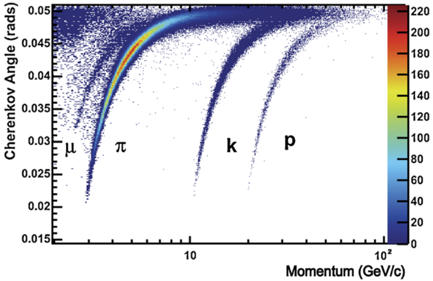



- 25 ns running/spillover
  - Maximum drift time 50 ns
  - Occupancy 5-25% (significant fraction from secondaries)
  - Spillover increase - under study

# RICH

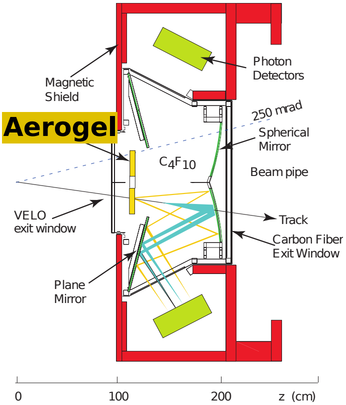
- Ring Imaging CHerenkov detector
- Excellent separation of K, $\pi$, p
- Hybrid Photon Detectors
  - can detect individual photons



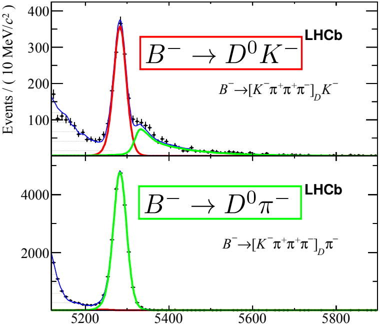
# RICH1 - Aerogel Removal

- Difficult to integrate into new HLT - aerogel produces large rings, making ring finding very CPU-heavy
- Harsher environment than design
  - higher instantaneous luminosity
  - higher photon multiplicity
- Slightly lower aerogel performance
  - resolution MC $\sim 4.5\mathrm{mrad}$
  - reconstructed $\sim 5.0\mathrm{mrad}$
- Improved gas performance due to extra gas length (but lose protons-pion separation)
- Efficiency determination more accurate - same RICH algorithms online/offline



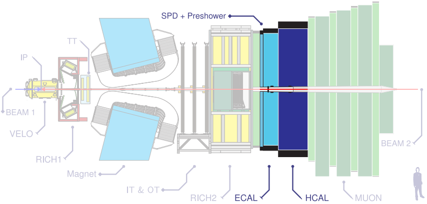
# RICH

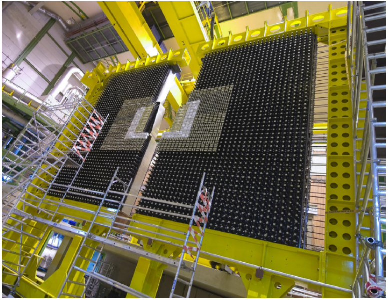
- New per-run HLT calibration
  - gas refractive-index calibration
  - HPDs calibrated for drift
  - mirror alignment
  - PID information in HLT 2
- Hybrid Photon Detectors
  - Aging problems seen in Run 1 due to vacuum degradation
    - Failure rate ∼3% per year
    - New HPDs have getter strips to take care of outgassing
  - Some HV-induced light background inside HPD boxes
    - Changed flushing gas from $N_2$ to $CO_2$ has mitigated the effect



# Calorimeters

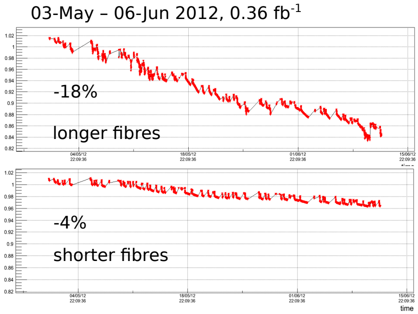
- SPD/PS, ECAL, HCAL
- Sampling calorimeters - Interleaved scintillator and absorber
- SPD/PS cells read out via multi-anode pixel photomultiplier (MaPMT)
- ECAL/HCAL cells read out via single anode PMT
- Regular HV calibration needed
- Very stable performance
- Part of the L0 trigger



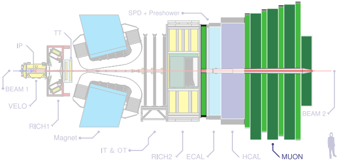
# Calorimeters

- Replacement of fibres for ECAL LED monitoring system
  - Aging due to radiation damage
  - problem not seen in detector fibres (oriented perpendicular to beam)
  - replaced with quartz fibres
- Automatic calibration fill-by-fill for new HLT scheme
  - regular gain adjustments - done in inter-fill gaps in Run 1
  - New method based on occupancy rather than LED system
  - to be commissioned with initial Run 2 data



# Muon

- Five stations of drift chambers interleaved with iron absorbers
- MultiWire Projection Chambers (MWPC)
- Exception - inner region of M1 - triple GEM
- First station (M1) situated upstream of the calorimeters
    - Improve $p_{\mathrm{T}}$ measurement at L0 trigger

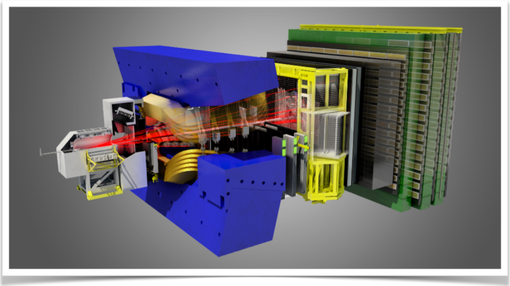



# Muon

- Improvement to MWPC grounding to reduce noise and increase stability
- Reconditioning of MWPC to prevent discharges
- HV channel doubling
  - improves redundancy
  - fewer gas-gaps removed in case of trip
- Malter effect currents
  - self-sustaining current produced by rad-induced insulation layer producing a high field
  - reversed by flipping HV polarity
  - $O_2$ used as a cleaning agent
- Shielding added behind last muon station (30 t of iron) - significant reduction in back-splash particles
- Automatic alignment fill-by-fill for new HLT scheme

# Final Remarks

- Very successful Run 1 for LHCb
- Lots of work ongoing during LS1
- Significant changes with respect to the LHCb trigger
- Implications for alignment and calibration of subdetectors
- Looking forward to Run 2 at 13 TeV !



# Q&A