LHCb status report

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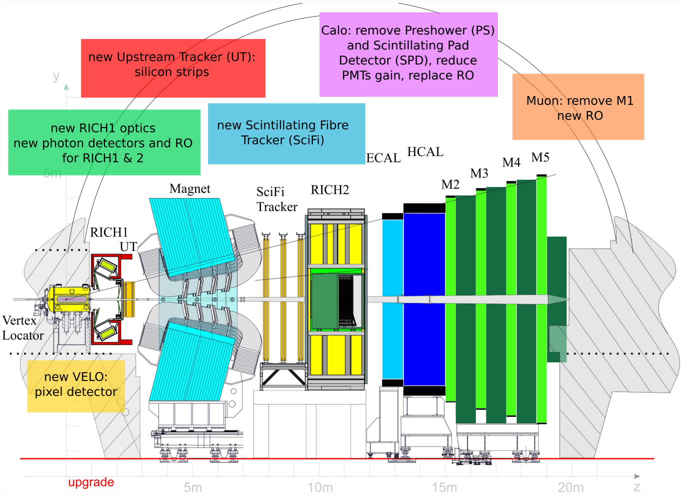
on behalf of the LHCb collaboration

141st LHCC Meeting - OPEN Session

Overview

- status of Upgrade I
  - installation
  - status of sub-system
  - all-software trigger (Real Time Analysis)
- Upgrade II studies
- status of Operations
- Physics results

LHCb Upgrade I



all front-end electronics read out @40MHz

$50\ \text{fb}^{-1}$
$2 \times 10^{33}\text{cm}^{-2}\text{s}^{-1}$

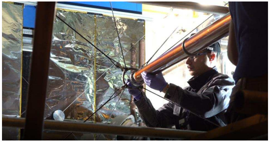
CERN-LHCC-2008-007
CERN-LHCC-2011-001
CERN-LHCC-2012-007
CERN-LHCC-2013-021
CERN-LHCC-2013-022
CERN-LHCC-2014-001
CERN-LHCC-2014-016
CERN-LHCC-2018-007
CERN-LHCC-2018-014
CERN-LHCC-2019-005

a new experiment: maintain current reconstruction performance in harsher environment!

LS2: the story so far

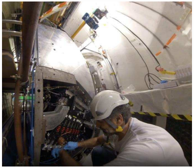
dismantle shielding wall

beam pipe removal

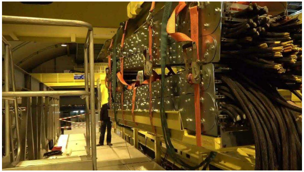


new data centre

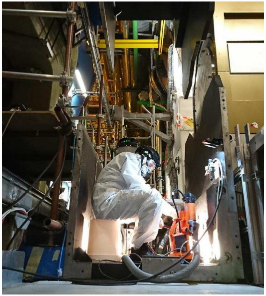
detectors removal



cables removal



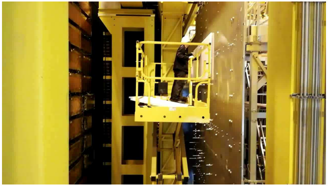
modifications



a monumental work carried out by the infrastructure team to prepare for the installation of new detectors

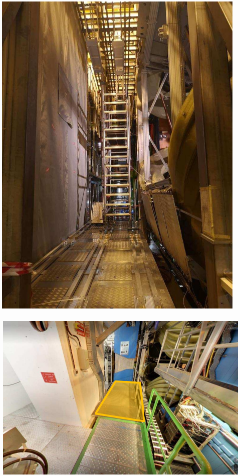
LS2: getting ready for detector installation

SciFi neutron shielding installation
on M1 wall

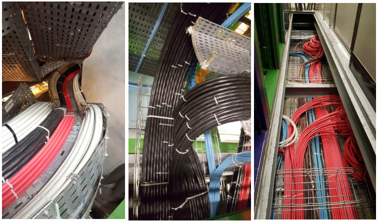


Cooling plants installation

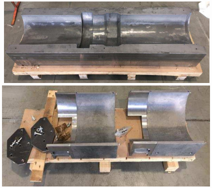
Platforms modifications



Cables installation



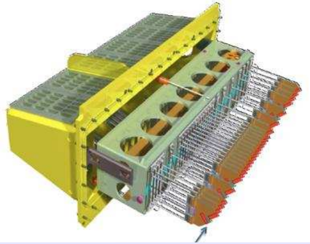
new HCAL beam shielding



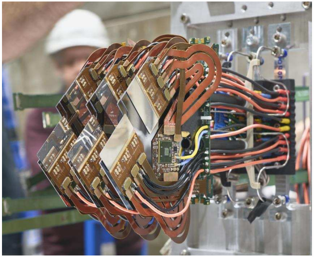
installation of services nearly completed: getting ready to install and test detectors!

VErtex LOcator

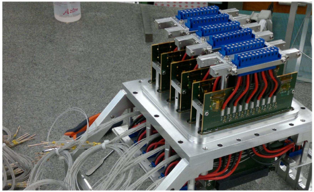
RF foil treatment: etching to 150μm, torlon internal coating, NEG outer coating preparation



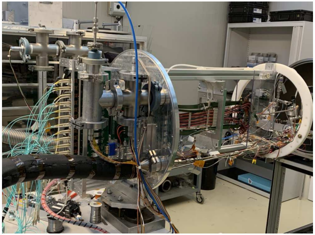
module production delayed due to assembly problem, resumed now



Vacuum Feed Through being assembled



VELO module test setup



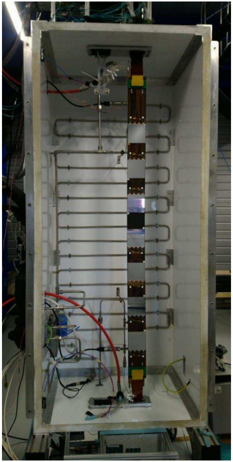
preparation @P8 for RF foil installation

Upstream Tracker

staves construction chain: mechanical support, cooling pipes, flex cables

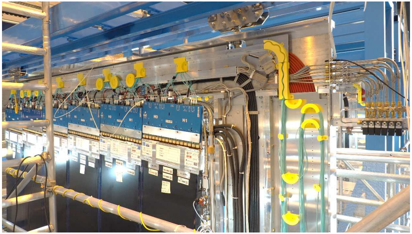
wire-bonded modules mounted on staves

stave installation in assembly hall at CERN



mass production of staves ongoing ⇒ soon shipments to CERN for assembly
installation delayed due know issues with ASIC, tight schedule

SciFi



fibre mats modules (2.5 m) assembled with SiPM coldbox, readout electronics, mechanics

$\Rightarrow$ C-frames to be assembled in LHCb

C-frames in the assembly hall

transport and integration test in the cavern performed in preparation for installation

RICH

new interface for quartz window developed and installed

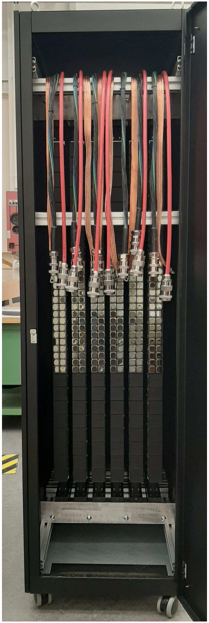
more work on the gas enclosure before installation

spherical mirrors and mechanical frame at CERN

production and qualification of Photon Detectors completed

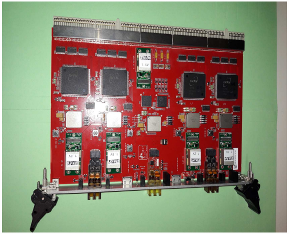
production and testing of electronics almost finished

RICH2 fully assembled, half commissioned and ready for installation

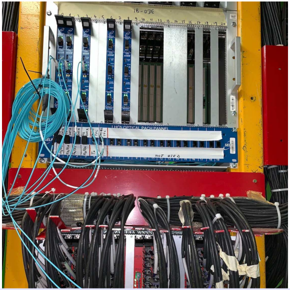


CALO & Muon

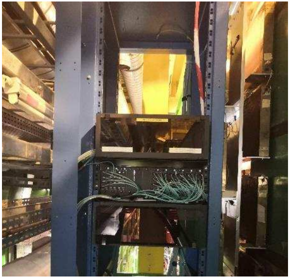
production of nODE boards completed



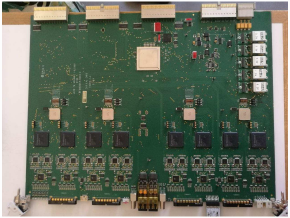
commissioning ongoing at CERN: population of M4 and M5



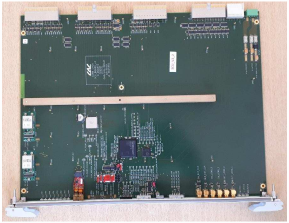
installation of patch panels for both ECAL and HCAL



FEB and control boards under production and test



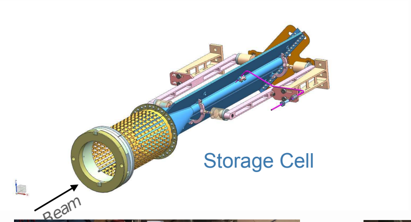
optical links installed

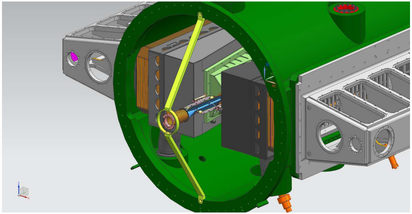


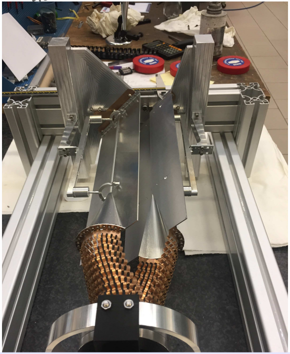
SMOG 2

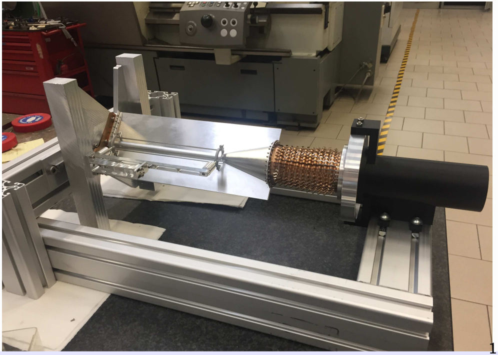
new fixed target system (SMOG): significant increase of the luminosity for fixed-target collisions

SMOG system ready to be installed together with VELO RF foil



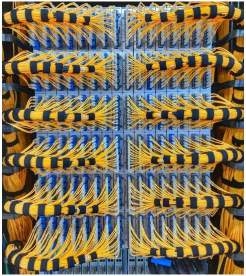




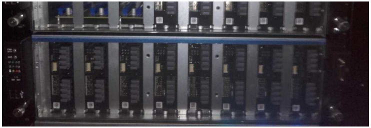


Online

new data centre constructed, commissioned and connected to cavern via long distance fibres, old farm moved



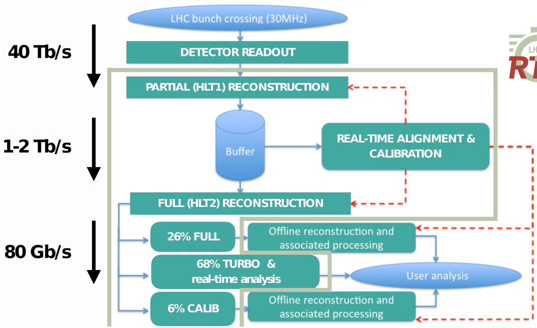
long distance fibres light transmission tested and quality assured: only 45 out of 19008 fibres ∼0.25% damaged during installation



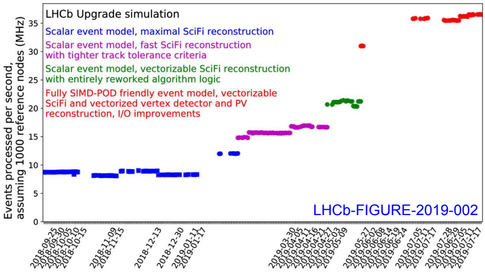
- PCIe40 cards production well advanced
- quality control ongoing
- getting ready for detector installation and commissioning at P8

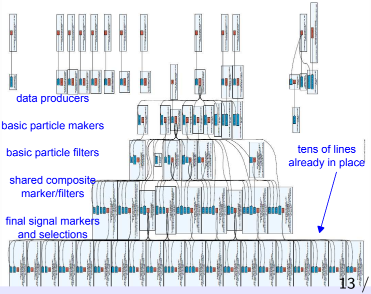
Real Time Analysis

aim to process 30 MHz of non-empty bunch crossings at 2×10^{33}

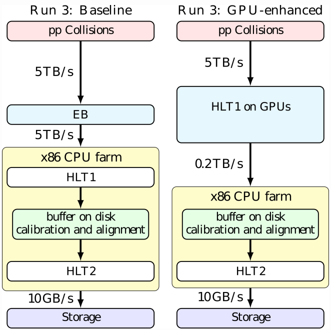


- software-only trigger
- Full HLT2 reconstruction: no further offline processing needed
- HLT1 performance achieved
- focus on HLT2 selection preparation
- full reconstruction and selection framework in preparation

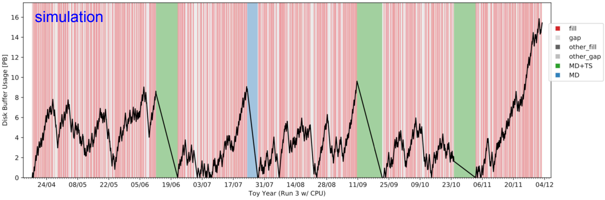




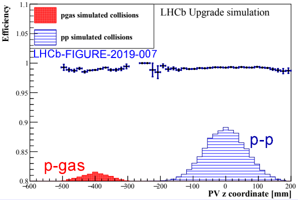
Real Time Analysis



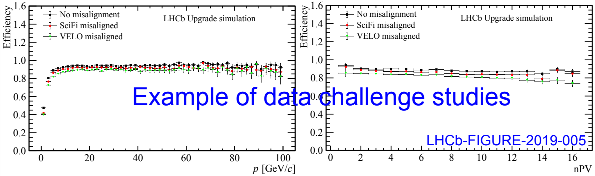
baseline option: HLT1 on CPU
option under study: HLT1 on GPU
review process in plan to arrive at decision on CPU vs GPU within Q1 2020



studies of VELO tracking efficiency with SMOG 2 collisions with displaced primary vertex



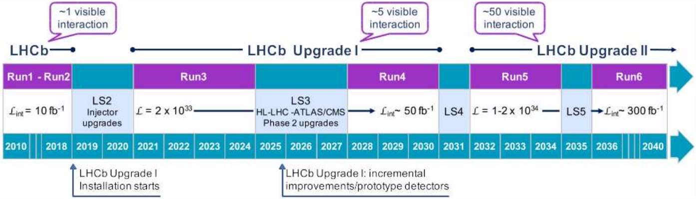
data challenges used to validate reconstruction algorithms, alignment, ecc... on simulation samples



LHCb Upgrade II

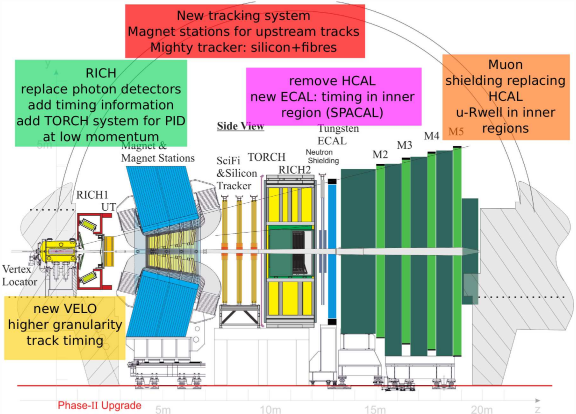
Green light to proceed to Framework TDR from LHCC and CERN research board: "The recommendation to prepare a framework TDR for the LHCb Upgrade-II was endorsed, noting that LHCb is expected to run throughout the HL-LHC era"

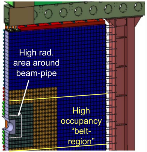
- install new detector for the beginning of Run 5
- operate at $\mathscr{L} \sim 1.5 \times 10^{34} \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- mean number of interactions per bunch crossing: $\mu \sim 45$
- collect more than 300 fb^{-1}
- improve even more LHCb precision (even after first upgrade many measurements still limited by statistics)
- fully exploit HL-LHC

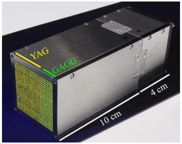


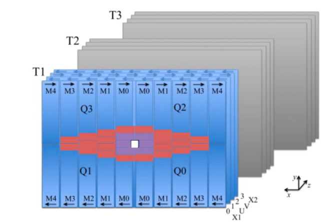
LHCb Upgrade II

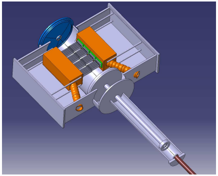
a sample of proposed ideas for Upgrade II

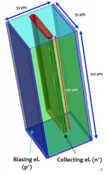












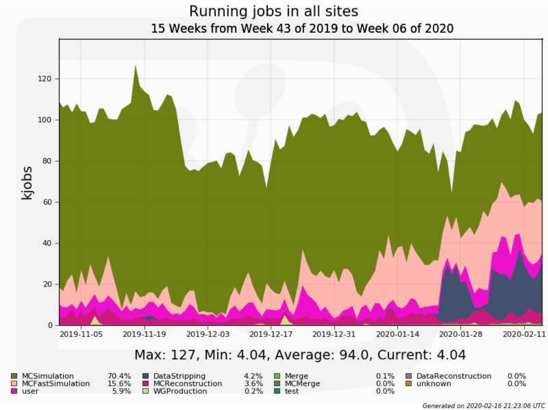
extremely challenging projects

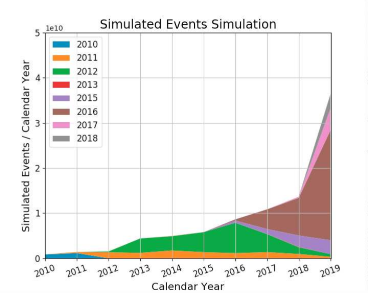
lots of R&D projects ongoing

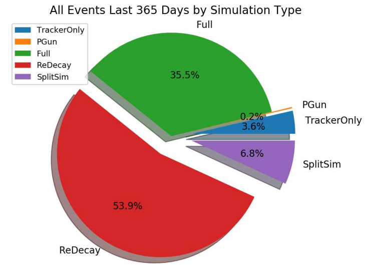
adding timing is the key to cope with the pile-up!

Operations

- smooth operations
- computing resources mostly devoted to MC
- stripping of 2016 data ongoing
- Factor $\sim$4 increase in number of events produced in 2019 wrt previous years while CPU work increased only by 20% per year
- joint effort of computing, simulation and RTA preparing the resources for upgrade

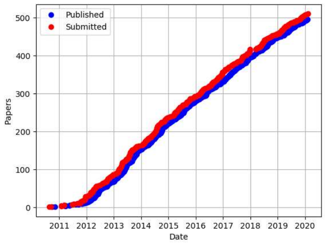


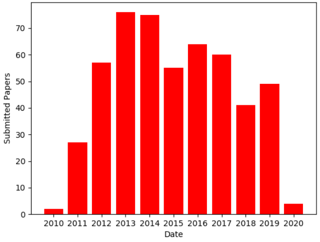


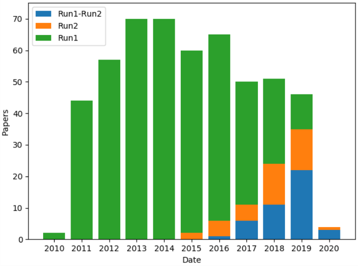


LHCb publications

Last year LHCb reached 500 publications! Celebration at the December LHCb week







9 new papers submitted since the last LHCC session

Since the previous session

Submitted

- PAPER-2019-028: Search for CP violation and observation of P violation in $\Lambda_b^0 \to p\pi^-\pi^+\pi^-$ decays
- PAPER-2019-036: Measurement of CP violation in $B^0 \to D^{*\pm}D^{\mp}$ decays
- PAPER-2019-038: Strong constraints on the $K_S^0 \to \mu^+\mu^-$ branching fraction
- PAPER-2019-039: Isospin amplitudes in $\Lambda_b^0 \to J/\psi\Lambda(\Sigma^0)$ and $\Xi_b^0 \to J/\psi\Xi^0(\Lambda)$ decays
- PAPER-2019-040: Test of lepton universality with $\Lambda_b^0 \to pK^-\ell^+\ell^-$ decays
- PAPER-2019-041: Measurement of $|V_{cb}|$ with $B_s^0 \to D_s^{(*)-}\mu^+\nu_\mu$ decays
- PAPER-2019-042: First observation of excited Ω_b^- states
- PAPER-2019-044: Measurement of CP observables in $B^\pm \to DK^\pm$ and $B^\pm \to D\pi^\pm$ with $D \to K_S^0K\pi$ decays
- PAPER-2019-045: Observation of a new baryon state in the $\Lambda_b^0\pi^+\pi^-$ mass spectrum

Preliminary

- PAPER-2019-046: Measurement of the shape of the $B_s^0 \to D_s^*\mu\nu_\mu$ differential distribution

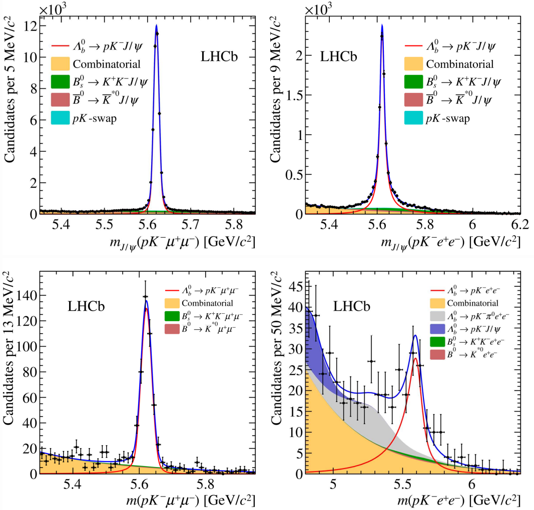
Test of lepton universality with $\Lambda_b^0 \to pK^-\ell^+\ell^-$ decays

LHCb-PAPER-2019-040, arXiv:1912.08139, submitted to JHEP

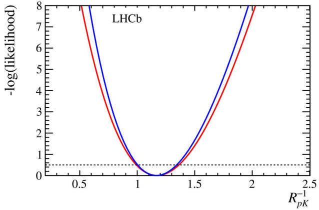
Run1+2016 (Run2) dataset: $\sim 4.7\ \mathrm{fb}^{-1}$

aim to test lepton flavour universality by measuring ratio of branching fractions:

$$R_{pK}^{-1} = \frac{\mathcal{B}(\Lambda_b^0 \to pK^-e^+e^-)}{\mathcal{B}(\Lambda_b^0 \to pK^-J/\psi(\to e^+e^-))} \Bigg/ \frac{\mathcal{B}(\Lambda_b^0 \to pK^-\mu^+\mu^-)}{\mathcal{B}(\Lambda_b^0 \to pK^-J/\psi(\to \mu^+\mu^-))}$$



- dilepton mass-squared range: $0.1 < q^2 < 6\ \mathrm{GeV}^2$
- $\Lambda_b^0 \to pK^-e^+e^-$ never observed before, efficiency and mass fit blind
- $r_{J/\psi}^{-1}$ central value blind, should be compatible with 1

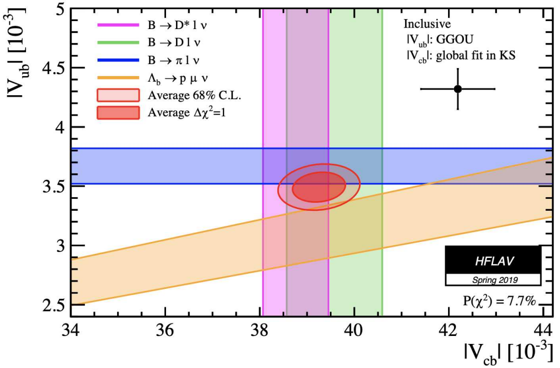


$$r_{J/\psi}^{-1} = 0.96 \pm 0.05$$

$$R_{pK}^{-1} = 1.17^{+0.18}_{-0.16} \pm 0.07$$

$|V_{cb}|$ and $B_s^0 \to D_s^{(*)}$ form factors using B_s^0 semileptonic decays

- semileptonic B decays used to constrain the CKM matrix element $|V_{cb}|$
- long lasting discrepancy between exclusive and inclusive measurements: arXiv:1909.12524
- requires form-factor modelling
- measurements carried out by B-factories only using B^0 and B^+ decays
- B_s^0 decays allow for lower theoretical uncertainty from lattice QCD



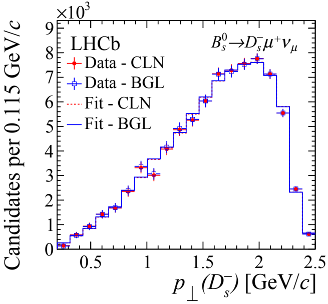
more details at the CERN seminar: https://indico.cern.ch/event/868248/

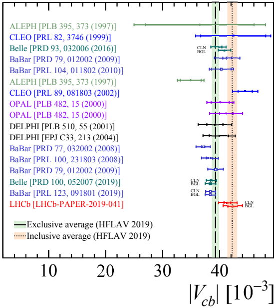
Measurement of $|V_{cb}|$ with $B_s^0 \to D_s^{(*)-}\mu^+\nu_\mu$ decays

LHCb-PAPER-2019-041, arXiv:2001.03225, submitted to PRD

- use $B_s^0 \to D_s^{(*)-}\mu^+\nu_\mu$ decays from Run1 data to measure $|V_{cb}|$ and form-factor functions
- do not reconstruct photon from $D_s^{*-} \to D_s^-\gamma$
- decays parametrised with two form-factor models: CLN (Caprini-Lellouch-Neubert) and BGL (Boyd-Grinstein-Lebed)
- $B^0 \to D^-\mu^+\nu_\mu$ decays used as normalisation channel
- no significant difference found for $|V_{cb}|$ determined in the two parametrisations
- first determination of $|V_{cb}|$ from exclusive decays at a hadron collider and the first using B_s^0 decays

$$|V_{cb}|_{\rm CLN} = (41.4 \pm 0.6({\rm stat}) \pm 0.9({\rm syst}) \pm 1.2({\rm ext})) \times 10^{-3}$$
$$|V_{cb}|_{\rm BGL} = (42.3 \pm 0.8({\rm stat}) \pm 0.9({\rm syst}) \pm 1.2({\rm ext})) \times 10^{-3}$$

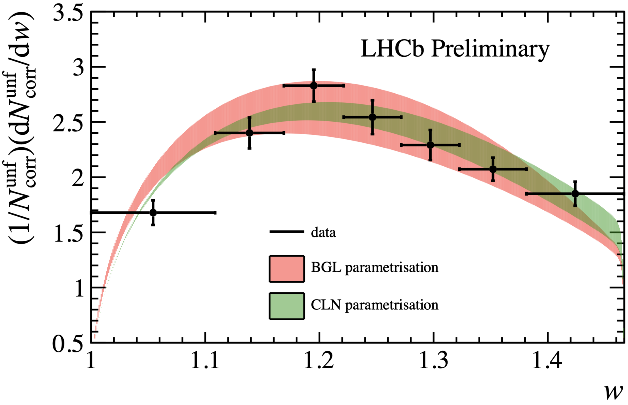




Measurement of the shape of the $B_s^0 \to D_s^* \mu\nu_\mu$ differential distribution

- $B_s^0 \to D_s^{*-} \mu^+ \nu_\mu$ decays from 2016 (Run2) data
- fully reconstruct $D_s^{*-} \to D_s^- \gamma$ decays
- extract the differential decay rate as a function of the dilepton momentum transfer squared
- confirms the trend observed that the parametrisation is not responsible for inclusive vs exclusive differences in $|V_{cb}|$

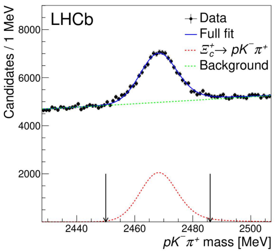
LHCb-PAPER-2019-046, in preparation

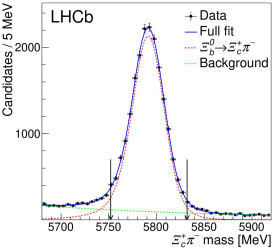


First observation of excited Ω_b^- states

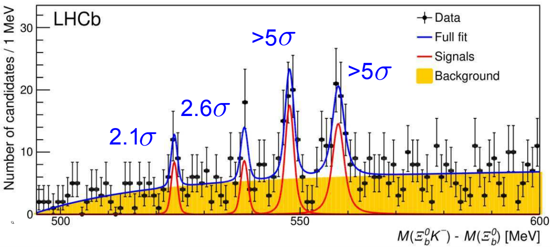
LHCb-PAPER-2019-042, arXiv:2001.00851, submitted to PRL

Run1&2 dataset: $\sim 9\ \mathrm{fb}^{-1}$





- much interest in LHCb's recent observation of five new resonances decaying to $\Xi_c^+ K^-$ (LHCb-PAPER-2017-002)
- search for excited Ω_b^- states can help understanding of these states
- four narrow peaks observed for the first time
- simultaneous unbinned Maximum Likelihood fit to Right Sign and Wrong Sign distributions



	δM_{peak} [MeV]	Mass [MeV]	Width [MeV]
$\Omega_b(6316)^-$	$523.74 \pm 0.31 \pm 0.07$	$6315.64 \pm 0.31 \pm 0.07 \pm 0.50$	< 2.8 (4.2)
$\Omega_b(6330)^-$	$538.40 \pm 0.28 \pm 0.07$	$6330.30 \pm 0.28 \pm 0.07 \pm 0.50$	< 3.1 (4.7)
$\Omega_b(6340)^-$	$547.81 \pm 0.26 \pm 0.05$	$6339.71 \pm 0.26 \pm 0.05 \pm 0.50$	< 1.5 (1.8)
$\Omega_b(6350)^-$	$557.98 \pm 0.35 \pm 0.05$	$6349.88 \pm 0.35 \pm 0.05 \pm 0.50$	< 2.8 (3.2)
			$1.4^{+1.0}_{-0.8} \pm 0.1$

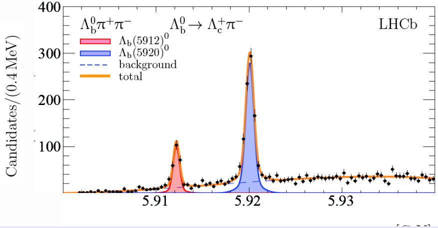
Observation of a new baryon state in the $\Lambda_b^0\pi^+\pi^-$ mass spectrum

LHCb-PAPER-2019-045, arXiv:2002.05112, submitted to JHEP

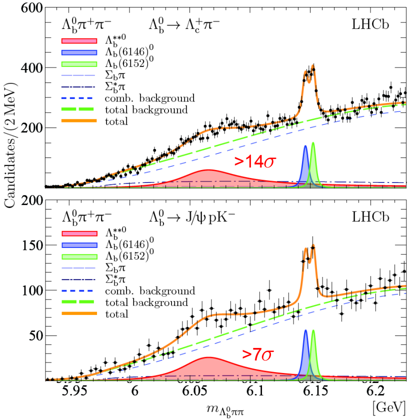
Run1&2 dataset: $\sim 9\ \text{fb}^{-1}$

- $\Lambda_b(6146)$ and $\Lambda_b(6152)$ from LHCb-PAPER-2019-025
- $m_{\Lambda_b^{**0}} = 6072.3 \pm 2.9 \pm 0.6 \pm 0.2$ MeV
- $\Gamma_{\Lambda_b^{**0}} = 72 \pm 11 \pm 2$ MeV

- $m_{\Lambda(5912)^0} = 5912.21 \pm 0.03 \pm 0.01 \pm 0.21$ MeV
- $m_{\Lambda(5920)^0} = 5920.11 \pm 0.02 \pm 0.01 \pm 0.21$ MeV
- $\Lambda_b(5912)$ and $\Lambda_b(5920)$ from LHCb-PAPER-2012-012



observation of new baryon Λ_b^{**0}, consistent with the first radial excitation of the Λ_b^0 baryon, the $\Lambda_b(2S)^0$, in two different channels



see also recent CMS result: arXiv:2001.06533

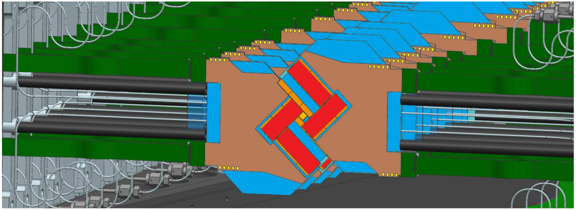
Conclusions

- Upgrade I:
  - good progress for different sub-systems
  - few issues encountered but generally under control
  - new schedule for LS2: no major changes to the LHCb schedule but allows to recover the contingency lost
  - installation of new detectors ongoing
  - software progressing in parallel to be ready to operate in new conditions
- Upgrade II:
  - several R&D activities ongoing
  - preparation for framework TDR
- Physics:
  - Run1&2 data analysis progressing: new results being published
  - many more in the pipeline

THANK YOU FOR YOUR ATTENTION!

Extra slides

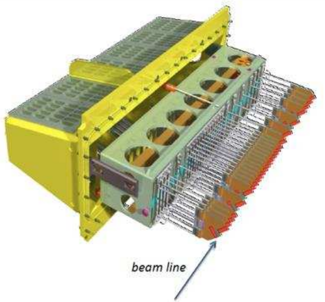
VELO Upgrade

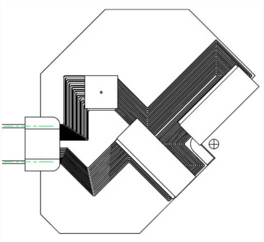


- hybrid pixel sensors, higher granularity (55μm pixel size)
- first sensor closer to the beam: 5.1mm
- reduced thickness for RF foil
- microchannel two-phase CO_2 cooling system (sensors at -20°C against radiation damage)
- improved IP resolution
- DAQ capable of handling $\sim$40 Tb/s

intense testbeam campaign to validate sensors and radiation tolerance

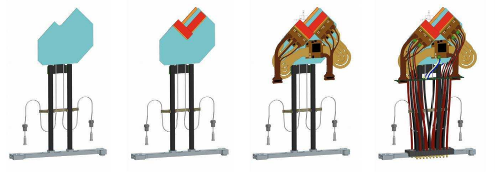
- charge collection
- charge collection efficiency
- spatial resolution





[LHCB-TDR-013]

VELO modules

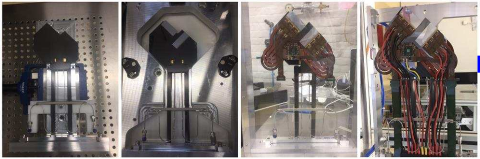


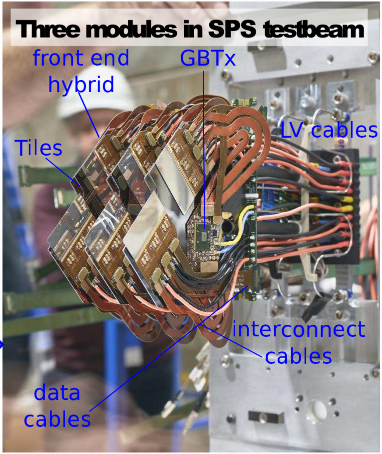
Mechanical Construction

Precision tile placement to 10 µm

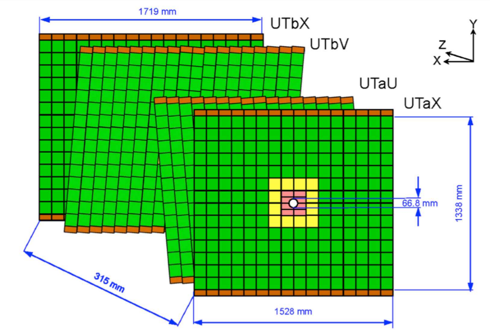
Flex circuit placement

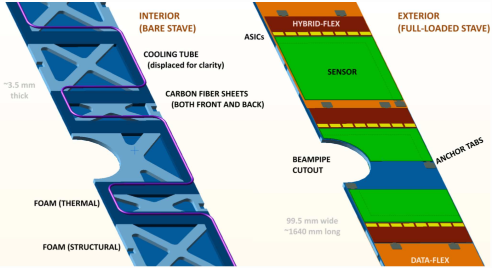
wire bonding and HV/LV/data cable attachment





Upstream Tracker

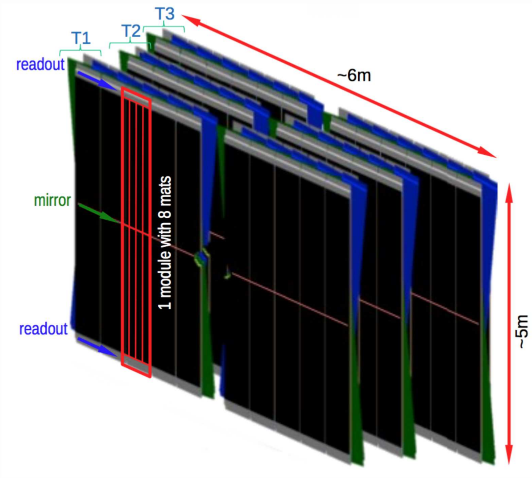


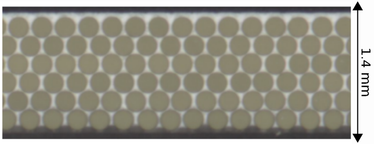


[LHCB-TDR-015]

- Reconstruct particles decaying after the VELO
- Reconstruct low-momentum tracks deflected out of the T-acceptance
- 4 planes of silicon strip as for TT
- Finer segmentation: from 183μm$\times$10cm to 95μm$\times$4.9cm, 95μm$\times$9.7cm, 190μm$\times$9.7cm
- Better coverage, no gaps
- Lower material budget
- Higher radiation hardness
- Front-end in the active area, close to sensors: better signal to noise ratio
- intense campaign of testbeams to validate the custom developed front-end chip

SciFi





- Scintillating fibres mats transport signal outside the the acceptance volume
- 2.5m long fibres with diameter of 250μm
- Each mat composed by 6 layers of fibres
- Signal readout by SiPMs at $-40°$C
- Homogeneous coverage with high granularity
- Spatial efficiency better than 70μm
- Single hit efficiency $> 99\%$

[LHCB-TDR-015]