

Status of LHCb

RRB, 28th April 2021

- Collaboration Matters
- Selected Physics Results
- LHCb Upgrade I Construction Status
- LHCb Upgrade II Framework TDR
- Conclusions & Outlook



Chris Parkes
on behalf of the LHCb Collaboration

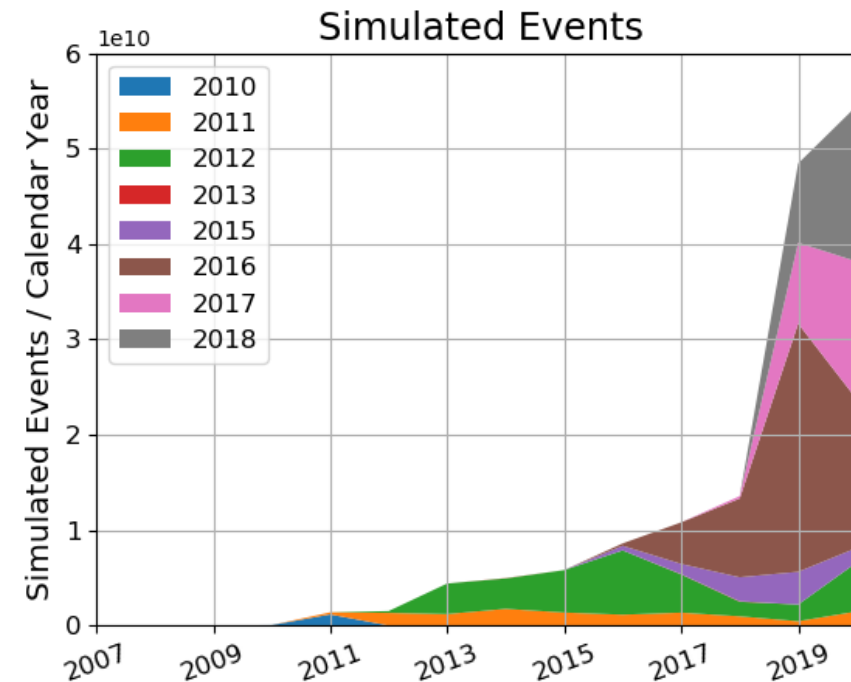
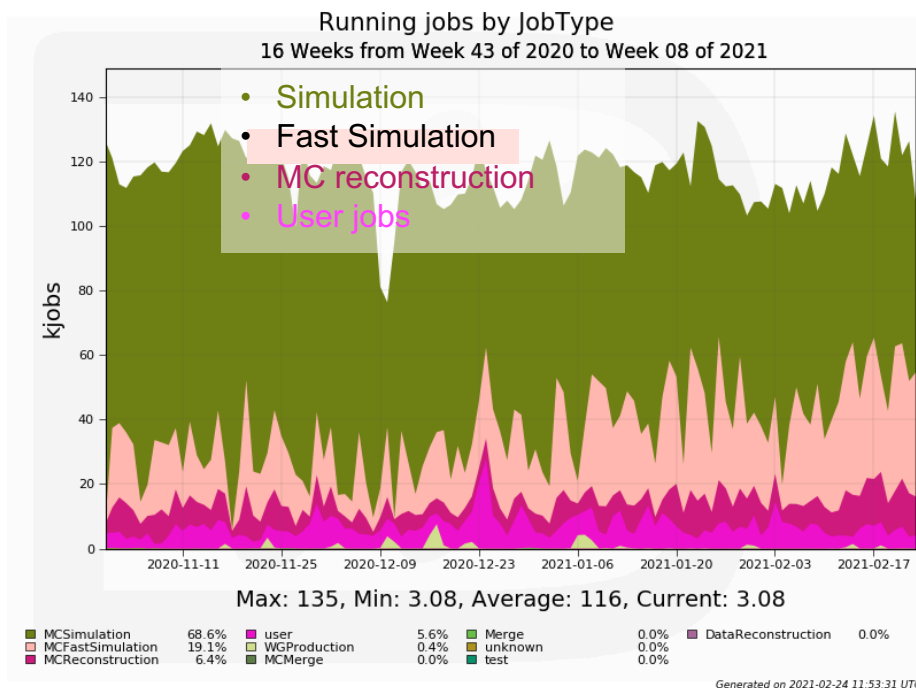


- The collaboration continues to grow and has updated its constitution to allow further opportunities to those working on software and detector development.
- Two new groups have joined
 - **Eötvös Loránd University, Budapest, Hungary** has joined as an associate member group. Our first group from Hungary and we welcome their representative to the RRB.
 - **Instituto de Microelectronica De Barcelona (CNM-IMB), Bellaterra, Spain,** has joined as a Technical Associate Group
- One associate group has left as a consequence of a retirement
 - Rostock, Germany, with the retired academic becoming emeritus member

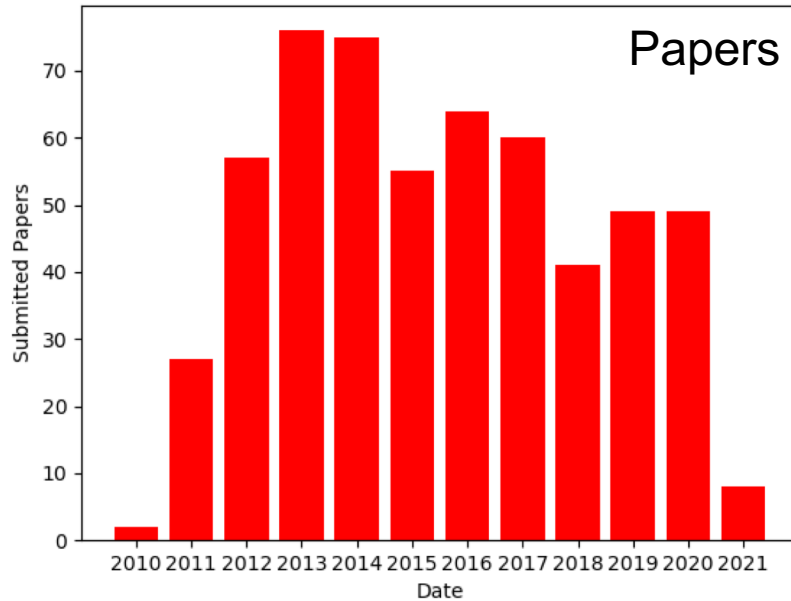
Operation: Computing



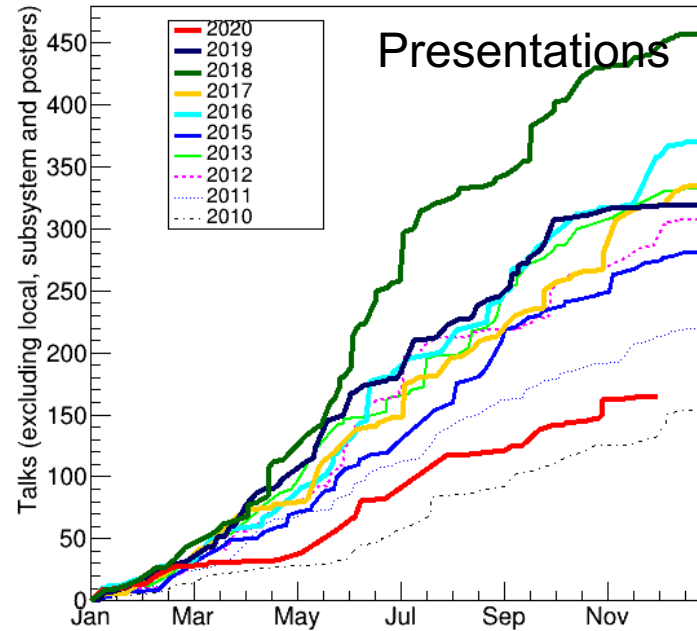
- Extensive use of fast simulation techniques has increased the number of events produced by a **factor of four** with only a **30% increase** in CPU resources



Physics Results: Publications and Presentations



Year of submission



- 563 Submitted papers
- 49 submitted papers 2020

In addition:

- 16 with the Editorial Board
- 40 in collaboration review

- Winter Conferences
 - A number of high-profile results were released

- Physics harvest continues apace
 - Despite strong focus on Upgrade preparation
 - Pandemic had major effect on number of talks

Selected Physics Results



- LHCb was originally designed for matter antimatter asymmetry measurements (CP Violation) and studying rare decays
 - of course it has achieved much more
- Report on recent highlights from the core programme and beyond.

More than 50 hadrons discovered

Oscillations: 3 Trillion Hz of Quantum Mechanics

Rare Decays: Key legacy measurement

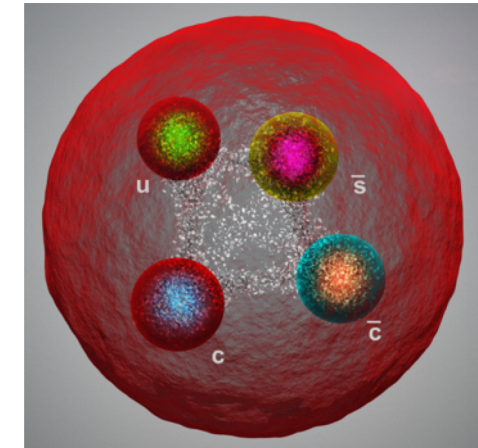
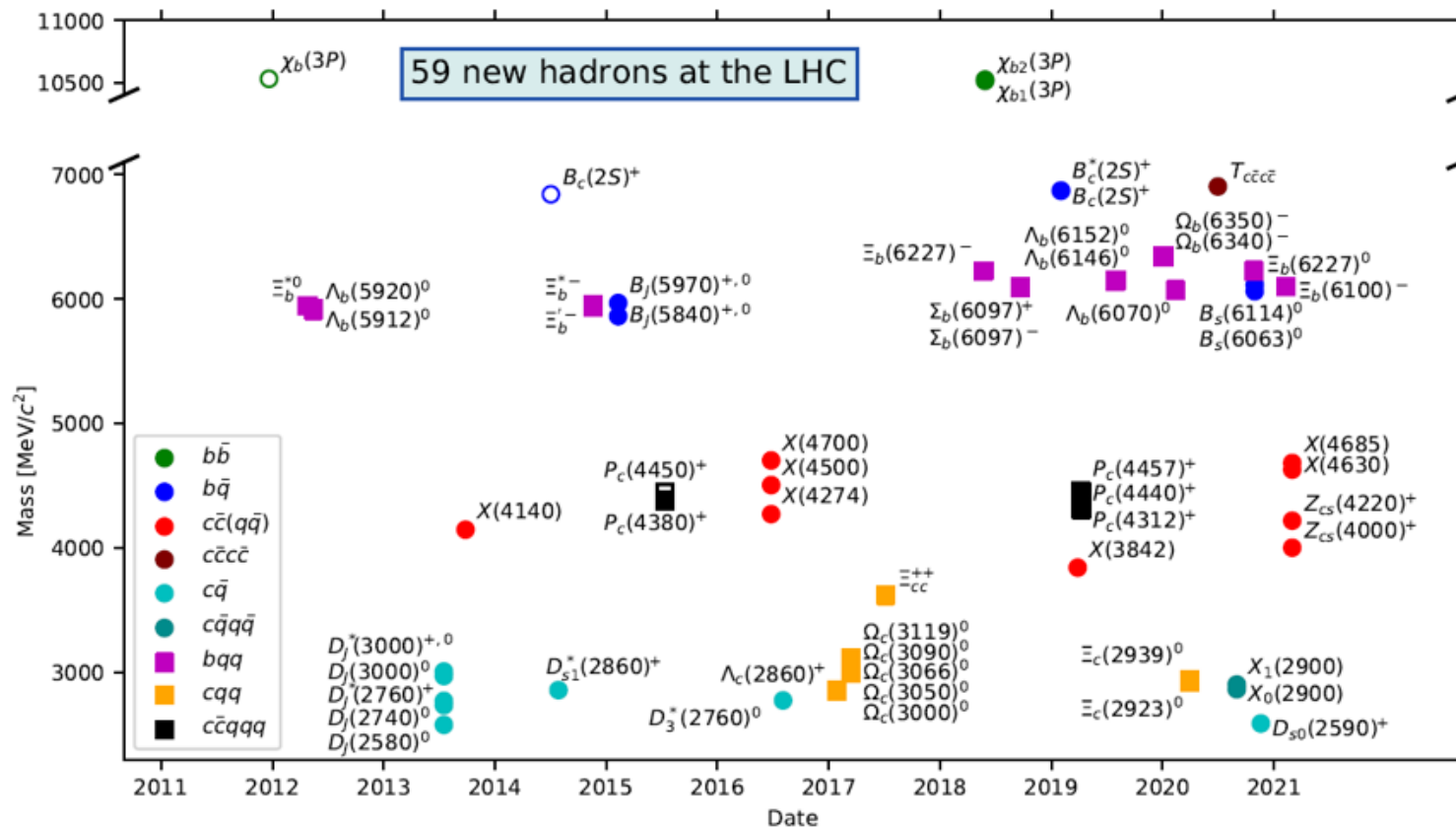
Rare decays: Lepton Flavour Universality

LHCb Recent Results: > 50 hadrons Discovered



LHCb-PAPER-2020-044

- Observation of two $c\bar{c}u\bar{s}$ tetraquarks and two $c\bar{c}s\bar{s}$ tetraquarks
 - $Z_{cs}(4000)^+$, $Z_{cs}(4220)^+$, $X(4630)$, $X(4685)$



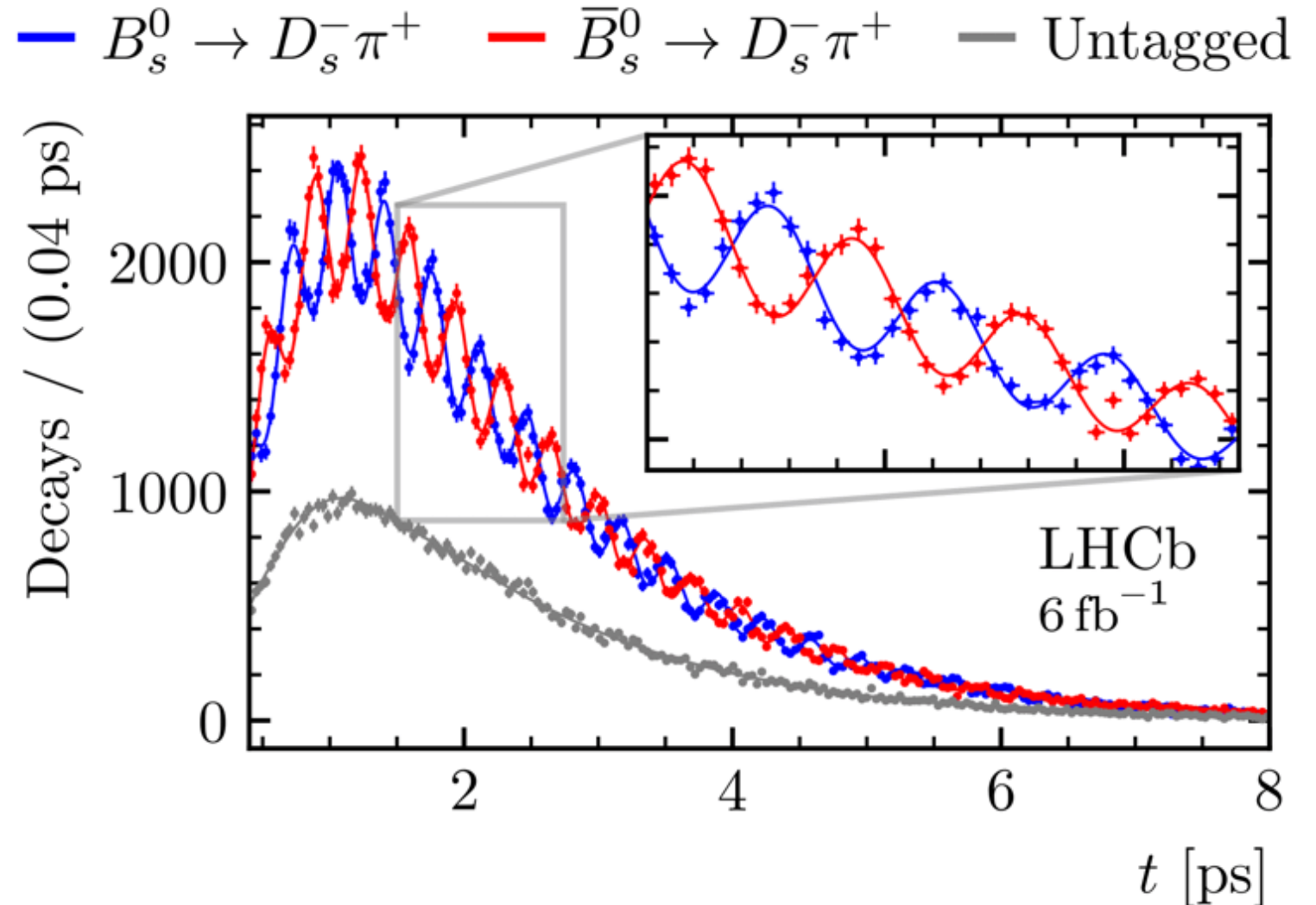
- For the 50th anniversary of hadron colliders the LHC has now discovered **more than 50 hadrons !**
- 52 discovered by LHCb

LHCb Recent Results: 3 Trillion Hz of Quantum Mechanics



LHCb-PAPER-2021-005

- Fascinating Quantum Mechanics
 - B_s particle anti-particle oscillations
- Clear oscillations - text book plot !
- Precision: 3×10^{-4} , Run 2 Legacy Δm_s



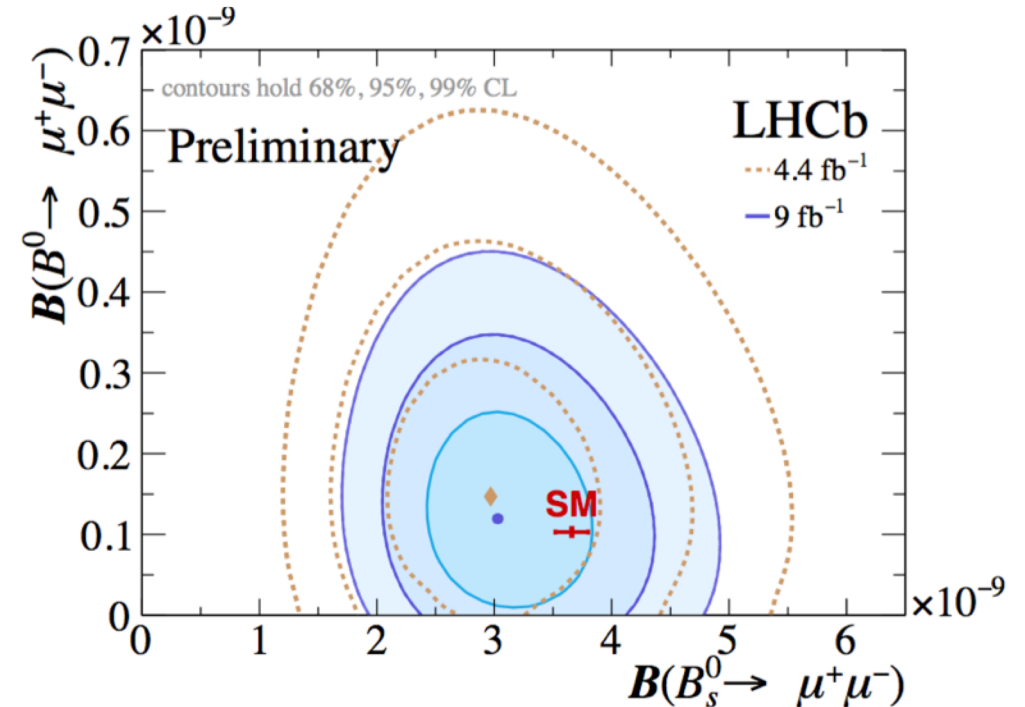
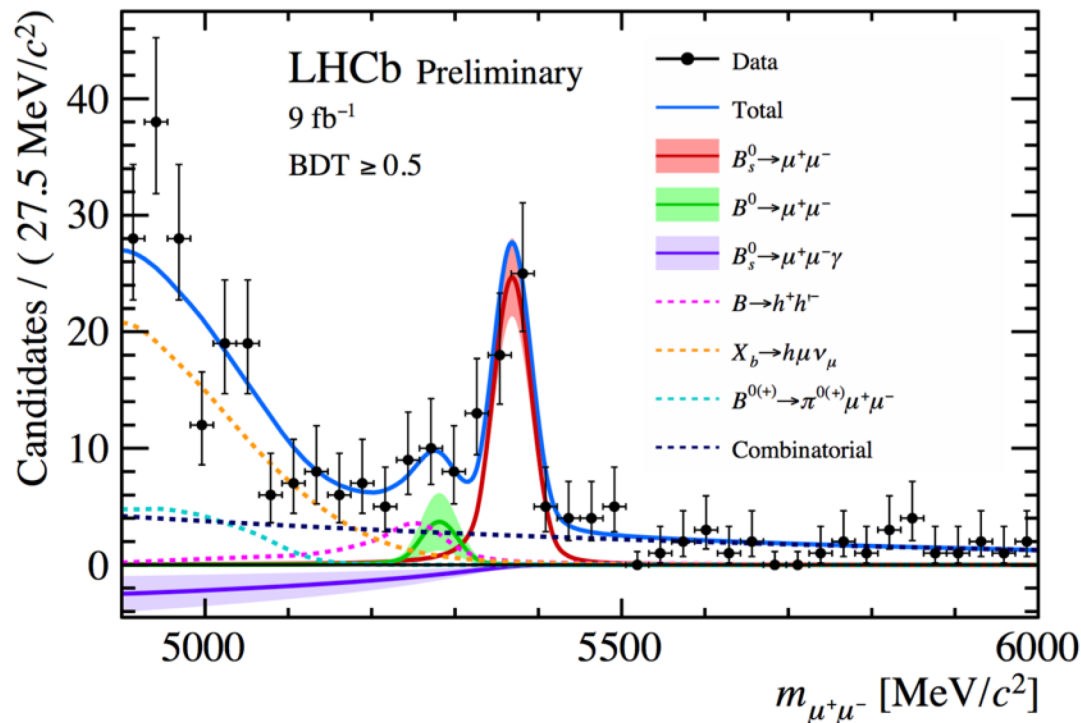
LHCb Recent Results: Key Legacy Measurement



LHCb-PAPER-2021-007

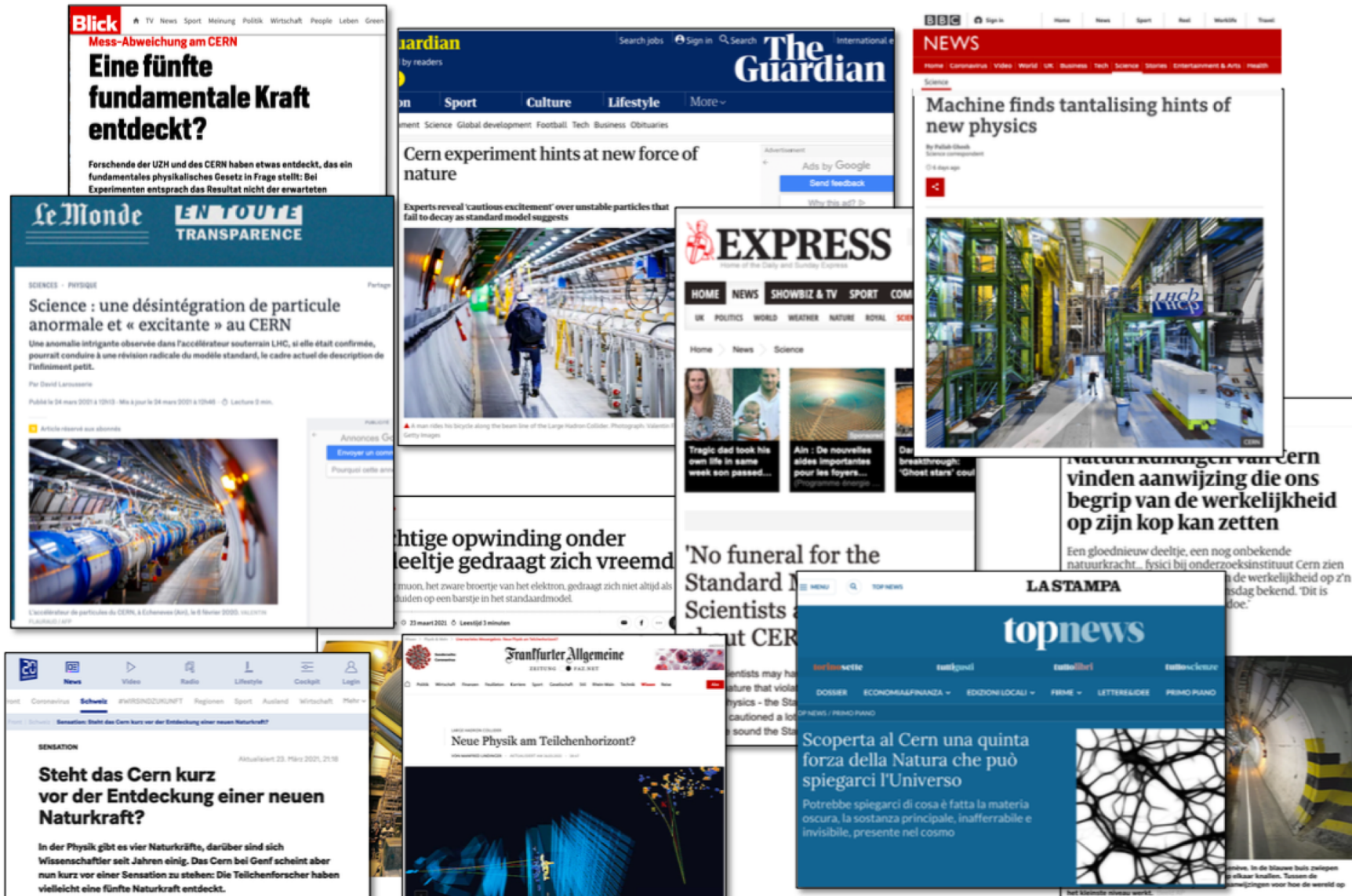
$B_s \rightarrow \mu^+ \mu^-$

- New results with full data set
 - Best single expt measurement
 - A key process to constrain new physics, for example extended Higgs sectors
 -and including models related to the next slide...
- $\mathcal{B}(B_s^0 \rightarrow \mu^+ \mu^-) = (3.09^{+0.46+0.15}_{-0.43-0.11}) \times 10^{-9} \quad (10.8\sigma)$



LHCb Recent Results – Lepton Flavour Universality

Media coverage



LHCb Recent Results – Lepton Flavour Universality



LHCb-PAPER-2021-004

- Standard Model predicts identical electroweak couplings of e, μ
 - Intriguing hints from LHCb in recent years at 2.1-2.5 σ level of deviations from SM in $b \rightarrow s l^+ l^-$ ratios, also in angular distributions and branching fractions.

$$R_K(1.1 < q^2 < 6.0 \text{ GeV}^2/c^4) = 0.846^{+0.042}_{-0.039} {}^{+0.013}_{-0.012},$$

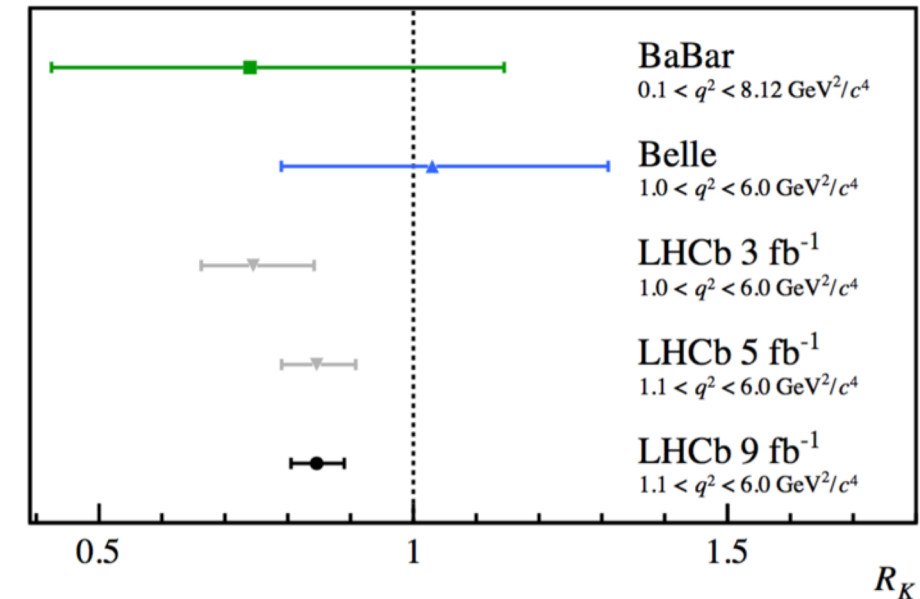
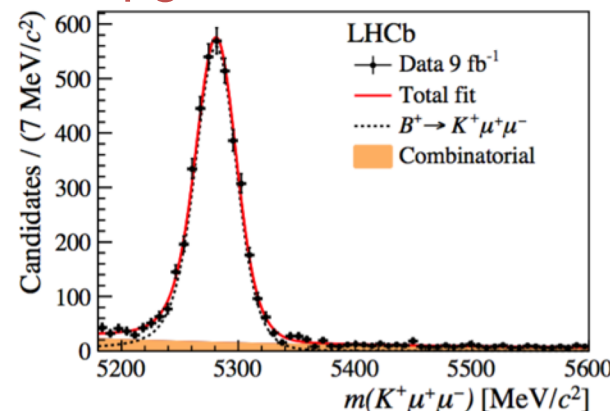
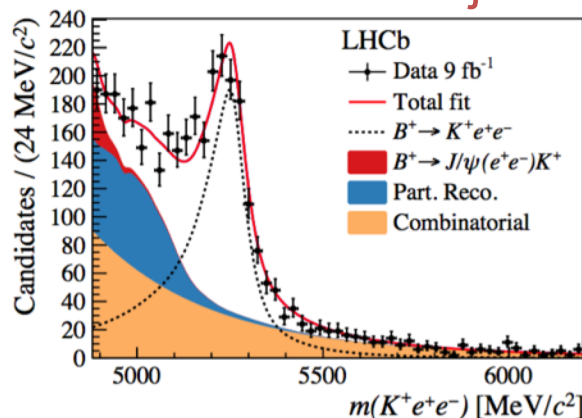
Rare B decay process:
 $B \rightarrow K \mu^+ \mu^-$, $B \rightarrow K e^+ e^-$,

Count and compare,
expect same
numbers of decays

$$R_H \equiv \frac{\int_{q_{\min}^2}^{q_{\max}^2} \frac{d\mathcal{B}(B \rightarrow H \mu^+ \mu^-)}{dq^2} dq^2}{\int_{q_{\min}^2}^{q_{\max}^2} \frac{d\mathcal{B}(B \rightarrow H e^+ e^-)}{dq^2} dq^2}.$$

- 3.1 σ deviation from Standard Model

- Additional measurements with existing data set will provide further information, then data from the current major LHCb Upgrade for Run 3

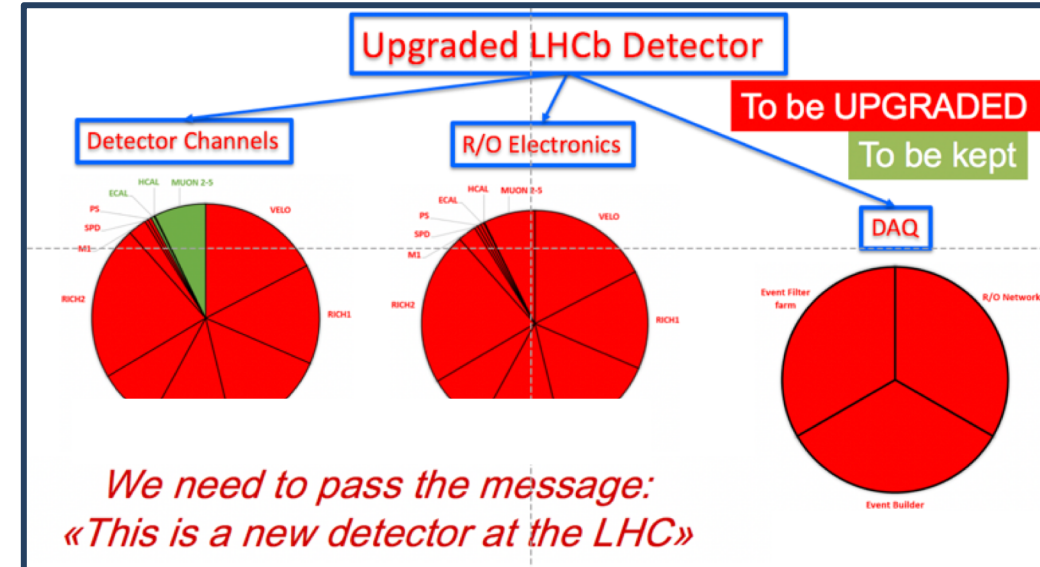
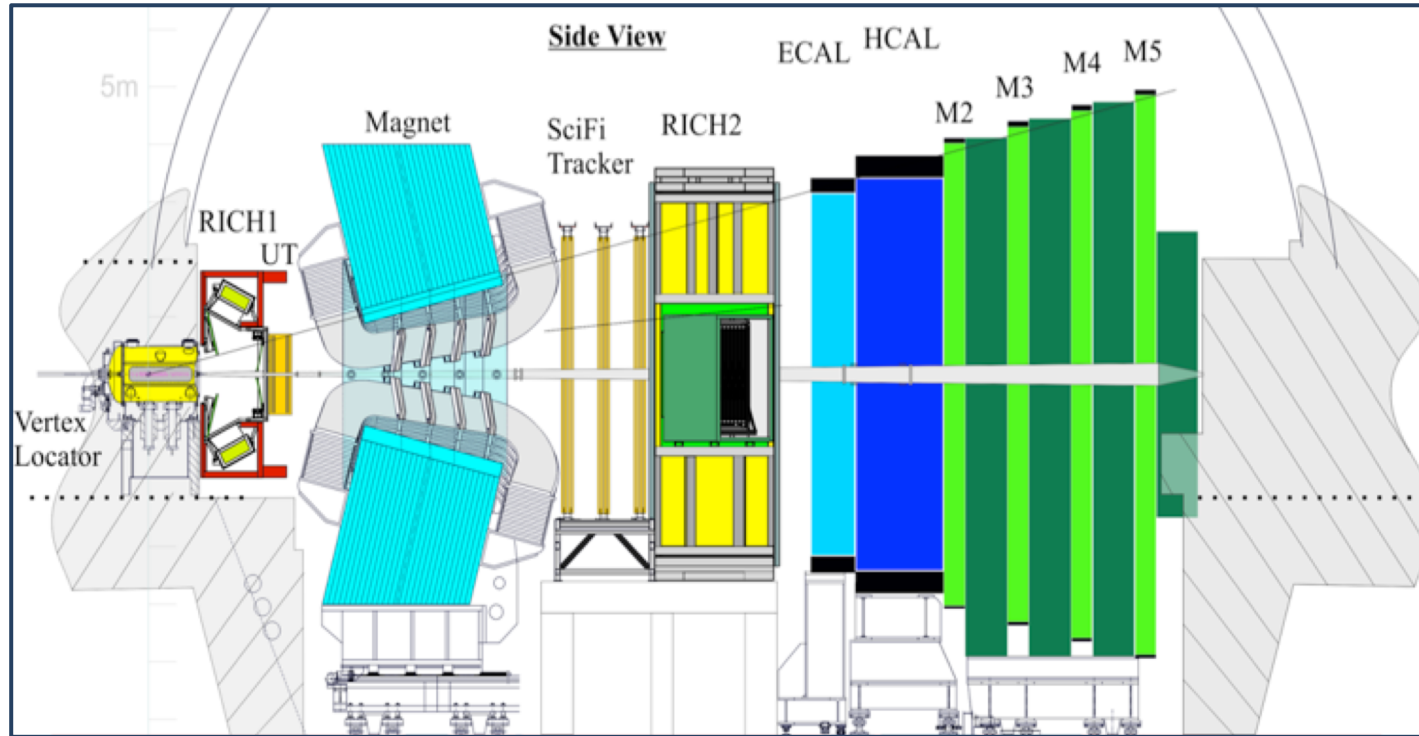


Upgrade I: Reminder



- All sub-detectors read out at 40 MHz for a **fully software trigger**

with new data centre



- Pixel detector **VELO** with silicon microchannel cooling 5mm from LHC beam
- New **RICH** mechanics, optics and photodetectors
- New silicon strip upstream tracker **UT** detector
- New **SciFi** tracker with 11,000 km of scintillating fibres
- New electronics for **muon** and **calorimeter** systems

Major project
being installed
currently for
operation in Run 3

Upgrade I & pandemic



- All finding ways to live & work with the ongoing pandemic
 - Minimising risk while ensuring progress is made
- CERN is assisting in facilitating travel and local arrangements for high priority projects such as ours
- We thank all the participating institutes and agencies for their support in these difficult circumstances



Installation work on the LHCb SciFi Tracker at LHCb

Morale is high and we have no change to the schedule

LHCb Upgrade I: Tracking [VELO, UT, SciFi]



VELO module
At half assembly site

VELO

Microchannel plates: main production complete

VELO Modules: first half completed

Half Assembly: expected start 15th May

Travel & quarantine delays to problem solving and components

SciFi

Four assembled C-frames completed, installation expected from May 4th

Cable chains nearing completion

Travel of significant part of team resumed despite restrictions



UT stave at LHCb

UT

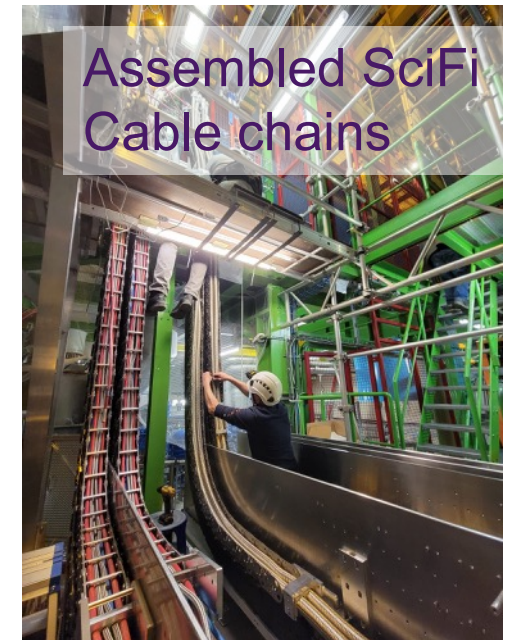
Hybrids: 4-chip complete, 8-chip verified

Modules: main type production nearly complete

Staves: 40% produced

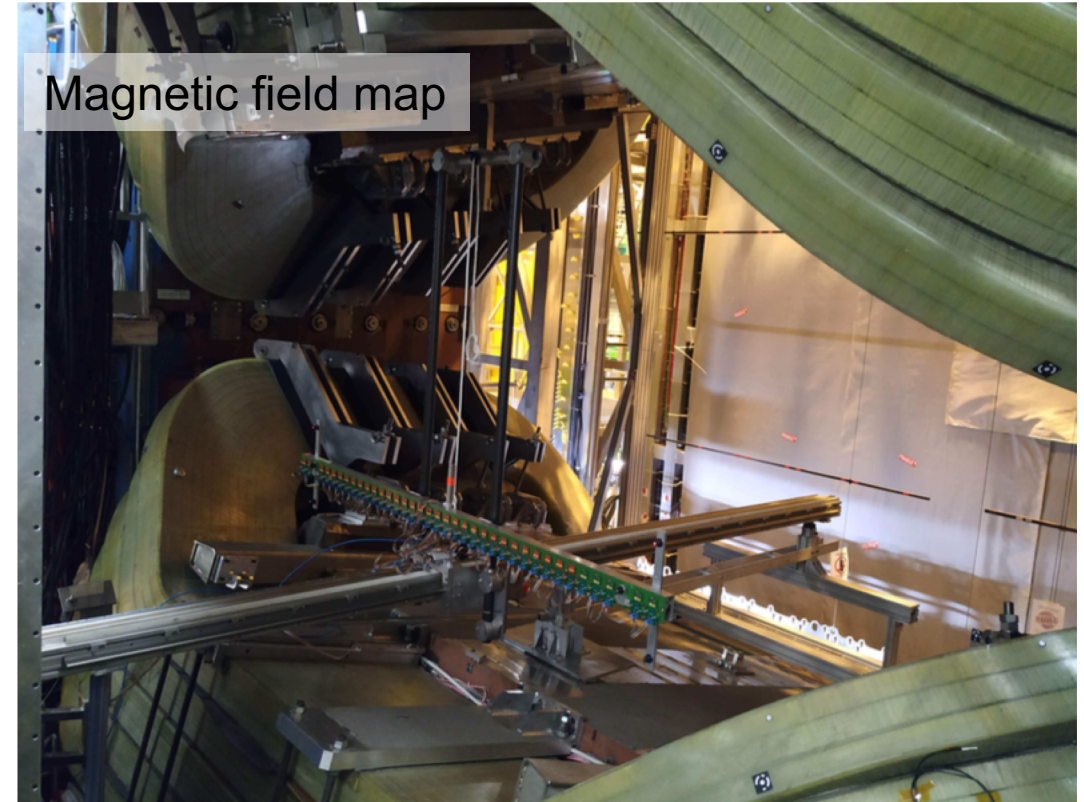
Assembly: clean room ready, being prepared

Travel restrictions affecting assembly



Assembled SciFi
Cable chains

- General infrastructure is completed
- LHCb Dipole Magnet repaired, tested & field map produced
- Technical team able to support detector teams, as travel restrictions have reduced personnel at CERN
 - Expanded technical support team to support this work
 - e.g. completion of clean-room for UT, SciFi near detector services installation



Excellent progress on detector services and infrastructure

LHCb Upgrade I: Particle Identification [RICH, CALO, Muons]

RICH

RICH1 Gas enclosure installed
and leak tested

Upper quartz window installed

Exit window installed

RICH2 photodetector arrays
installed, first new sensors

Key expert travel allowed &
excellent progress



CALO

Front-end board production in progress

Work on HV, calibration, monitoring

Maintenance of movement system completed

Issues at production companies but acceptable

Muons

All electronic boards installed

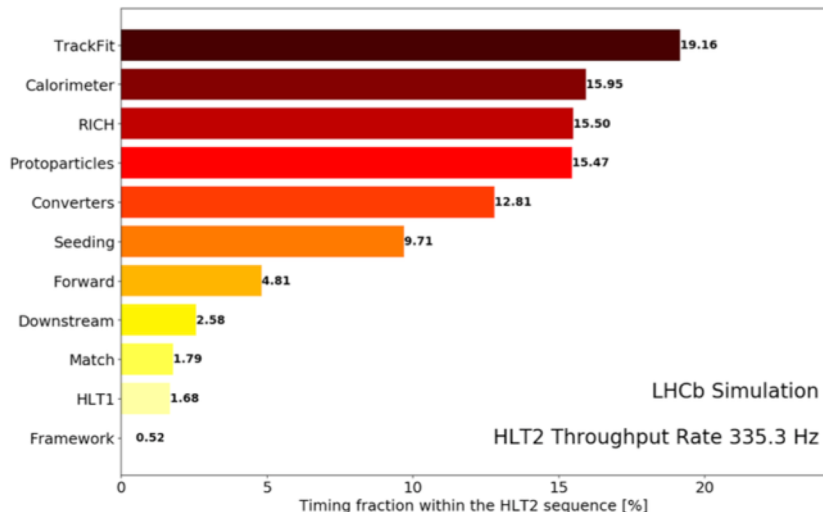
Commissioning progressing well

Excellent progress made





- Installation of Event builder PC servers & their FPGA DAQ (PCIe40) cards completed
- Commissioning of Muon and RICH systems underway
 - Event reconstruction in trigger achieved in single GPU card
 - Full reconstruction in trigger achieved 300Hz / node milestone
 - Data Processing and Analysis new work package on analysis preservation and open-data

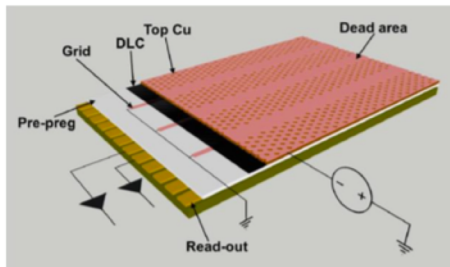


LHCb Upgrade II: R&D Progress

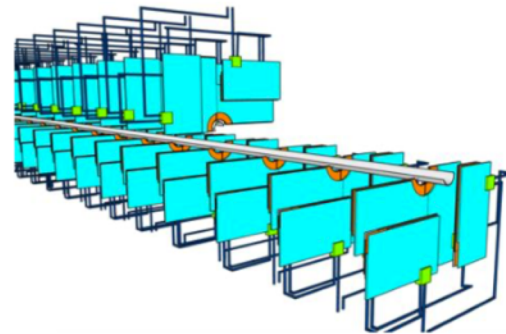


- Future **major** upgrade of the experiment, mainly for LS4 (~2030)
 - with some preparatory work in LS3 (~2025)
- Innovative Technology: precision timing, novel sensors, heterogeneous computing

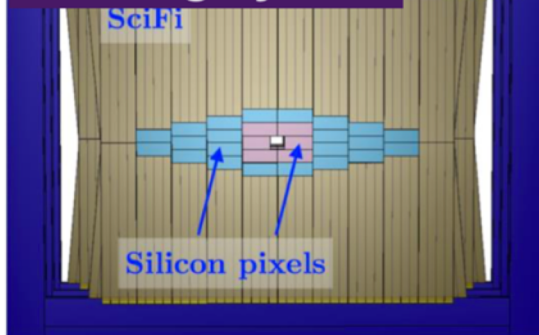
Muon system



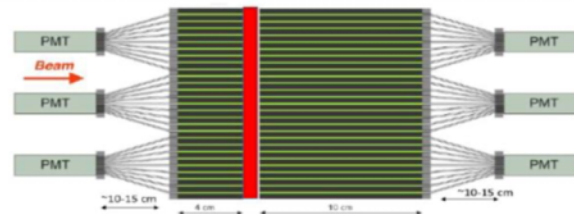
Vertex Detector (VELO)



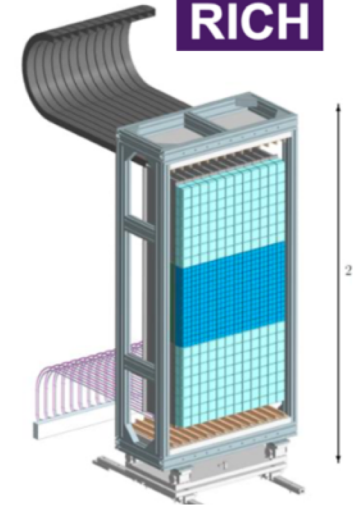
Tracking System



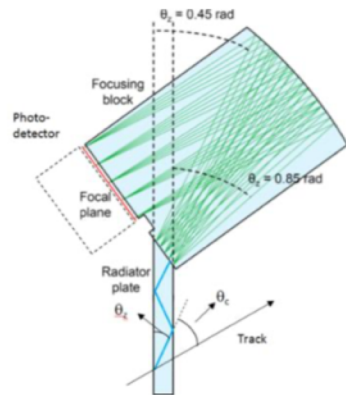
Electromagnetic Calorimetry



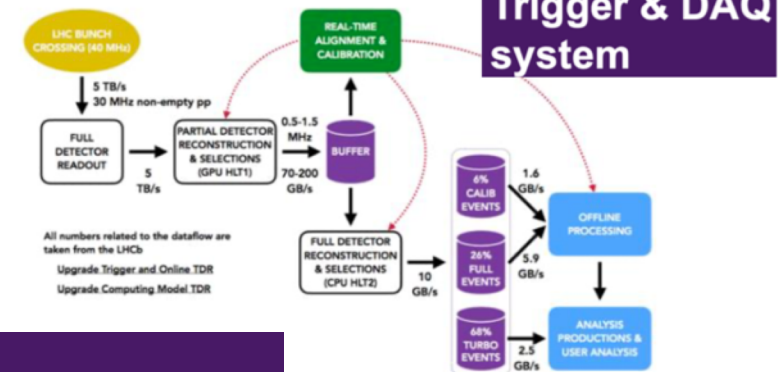
RICH



TORCH ToF

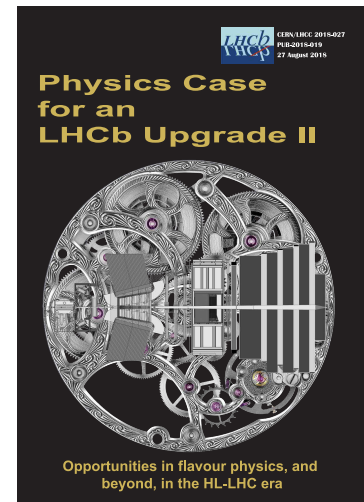
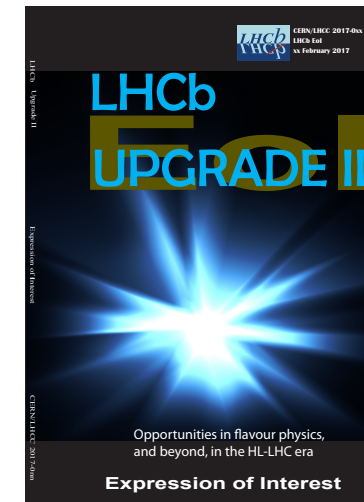


Trigger & DAQ system



LHCb Upgrade II : Framework TDR

- Five years of research on concept
 - **Fully exploit LHC facility for flavour physics & beyond**
 - Expression of interest (2017), Physics Case (2018)
 - Strong support in European Strategy (2020)
- Framework Technical Design Report
 - Options, not decisions, to achieve physics programme
 - Drafting phase, baseline description nearly in place
 - Initial cost ranges, indicative interests of countries
 - **Hope to be able to discuss draft with you in our October meeting**

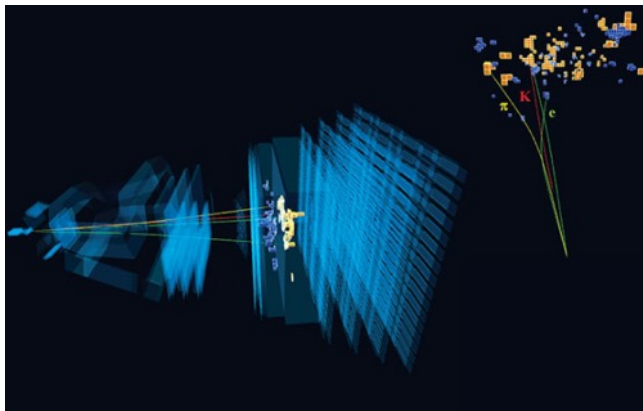


Conclusions & Outlook

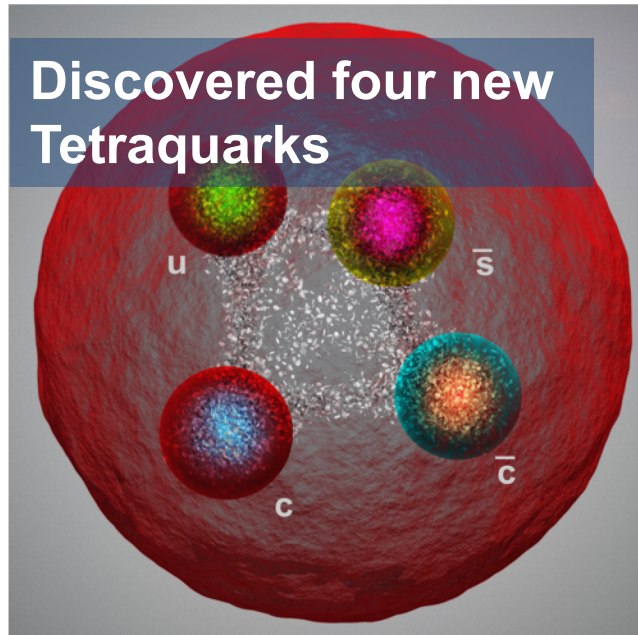


- Major scientific results have been delivered
- Significant progress made on Upgrade I
 - Advanced production → installation → commissioning
 - Despite pandemic schedule maintained (closure February 2022)
- Upgrade II Framework TDR in drafting phase

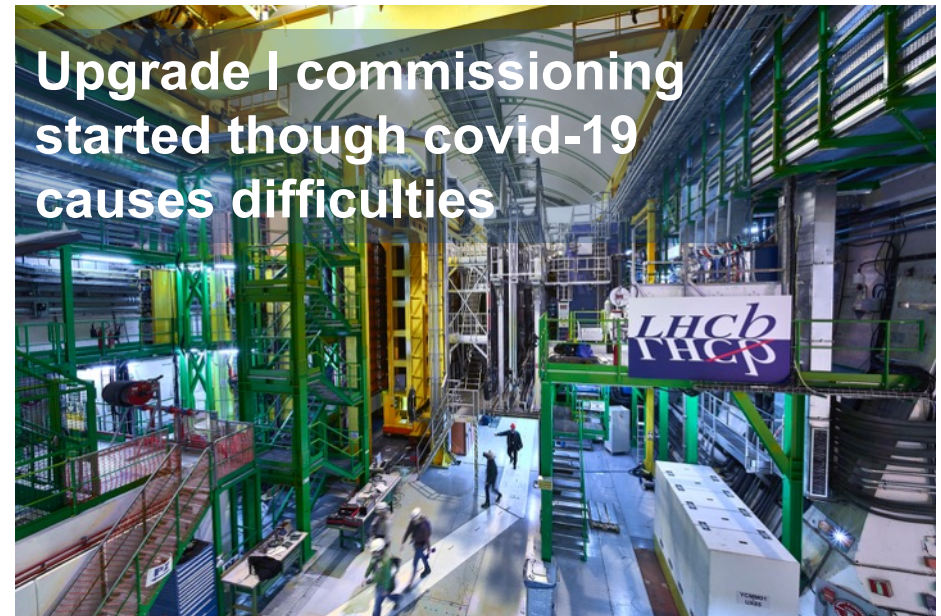
Intriguing “evidence”
of deviation from
fundamental theory



Discovered four new
Tetraquarks



Upgrade I commissioning
started though covid-19
causes difficulties

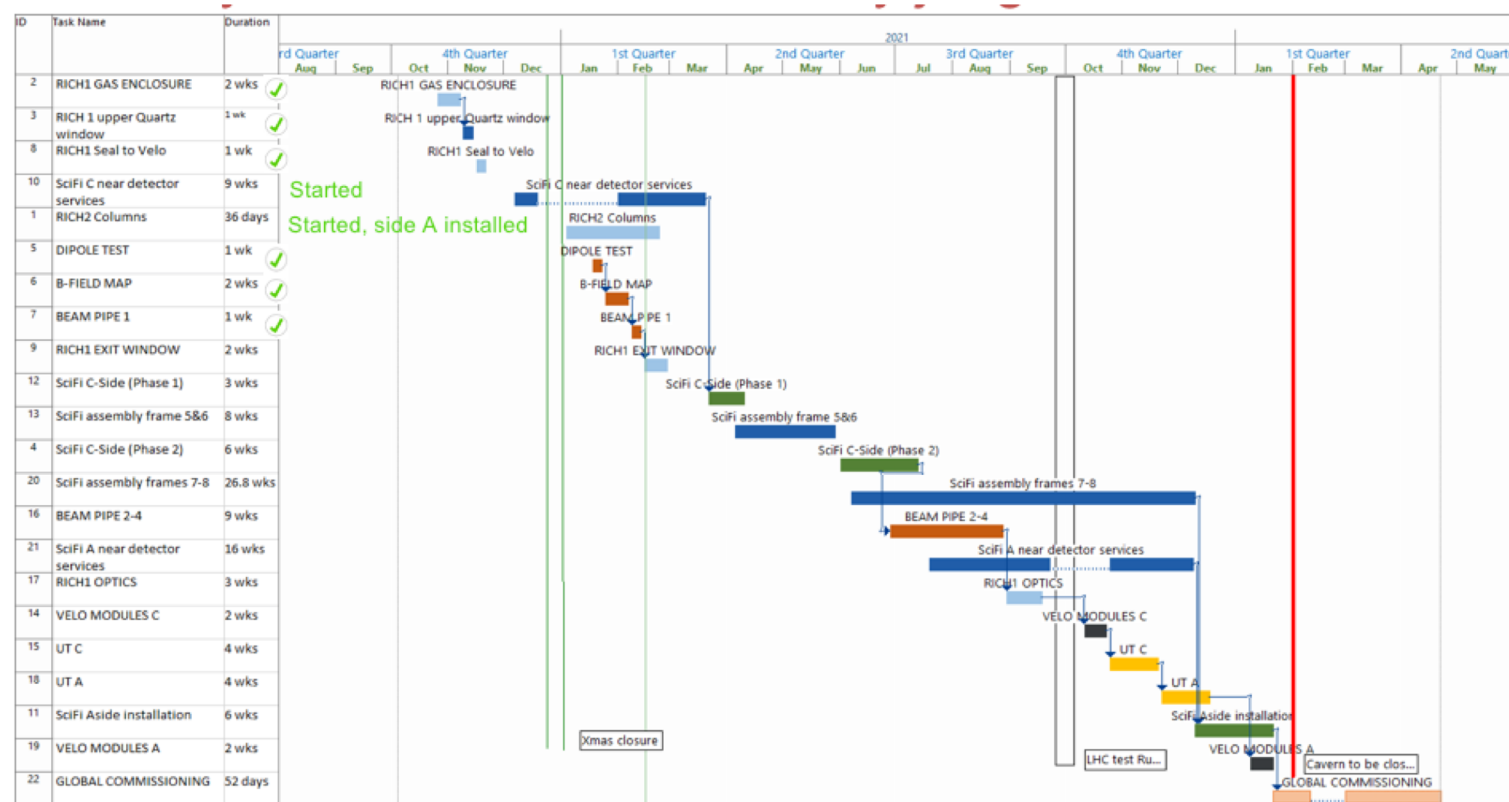


Backup

Schedule – top level key detector components



- Schedule tight but compatible with February 2022 cavern closure



- In this schedule

– Beam-pipe insertion compatible with an LHC beam test in Sept/Oct. 2021

- SciFi, VELO and UT are the projects that drive the critical path