Status of LHCb

RRB, 28th October 2020

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

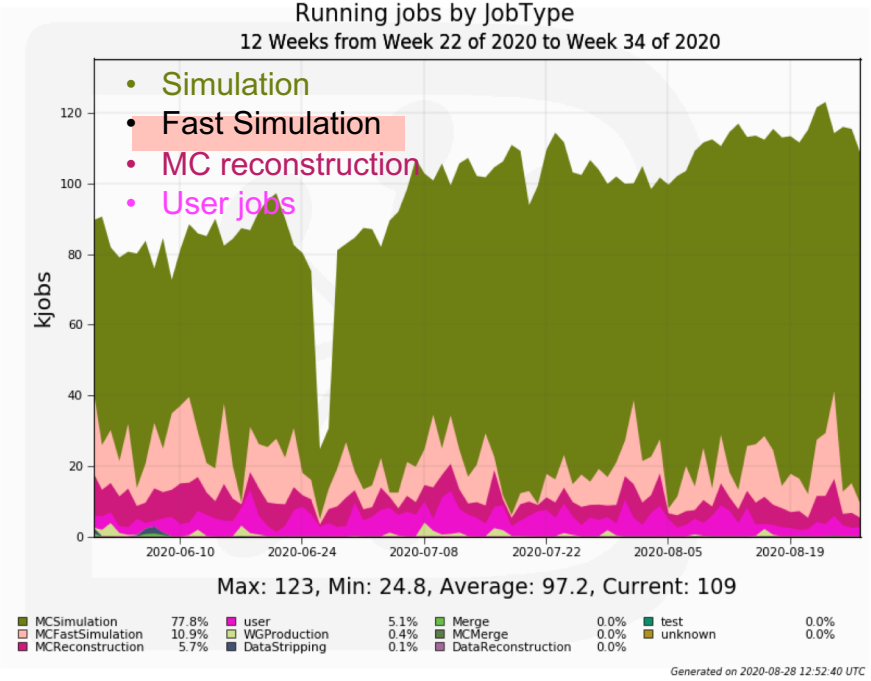
Chris Parkes
on behalf of the LHCb Collaboration

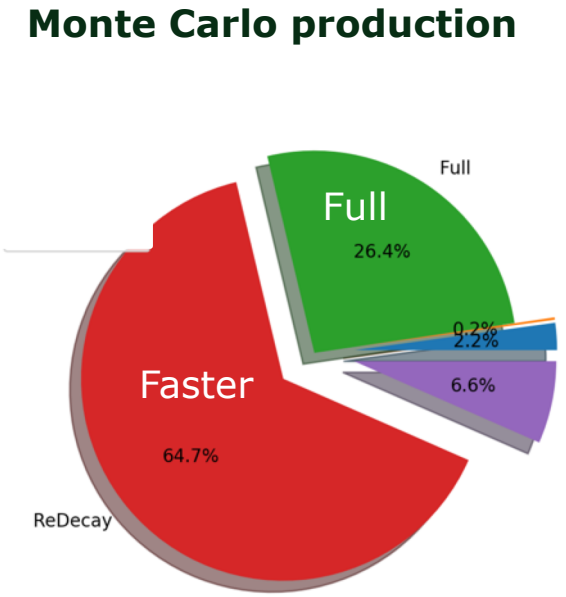
Collaboration Matters

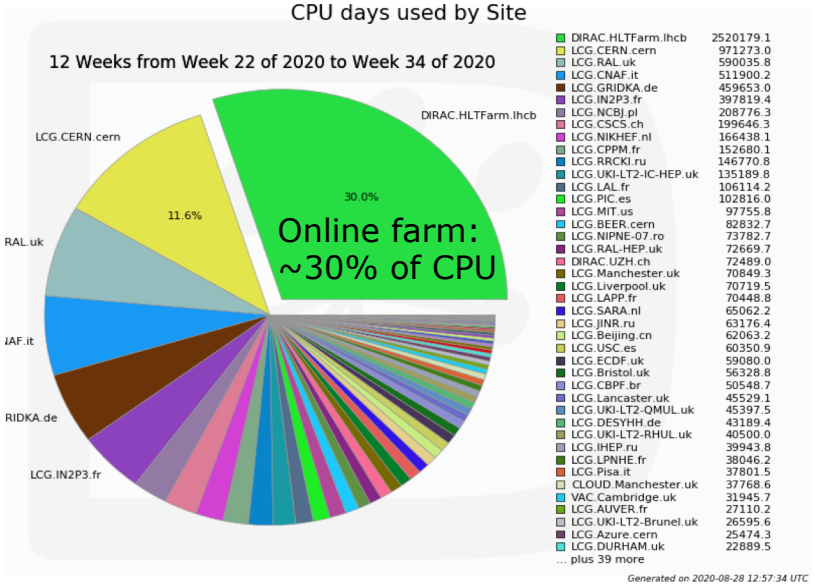
- The collaboration continues to grow and has updated its membership categories to allow further opportunities to those working on software and detector development.
- Three new groups have joined
  - Laboratoire Leprince-Ringuet, France has joined as a full member group
  - Hunan University, China has joined as an associate member group.
  - Karlsruhe Institute of Technology, Germany has joined as a Technical Associate Group
- One group has left as a consequence of difficult local circumstances
  - Constantine, Algeria, with the active embers joining other LHCb groups

Operation: Computing

- Simulation: 90% of the computing power
  - Online farm: 40% (30%) of Simulation events (CPU)
- 140M events per day







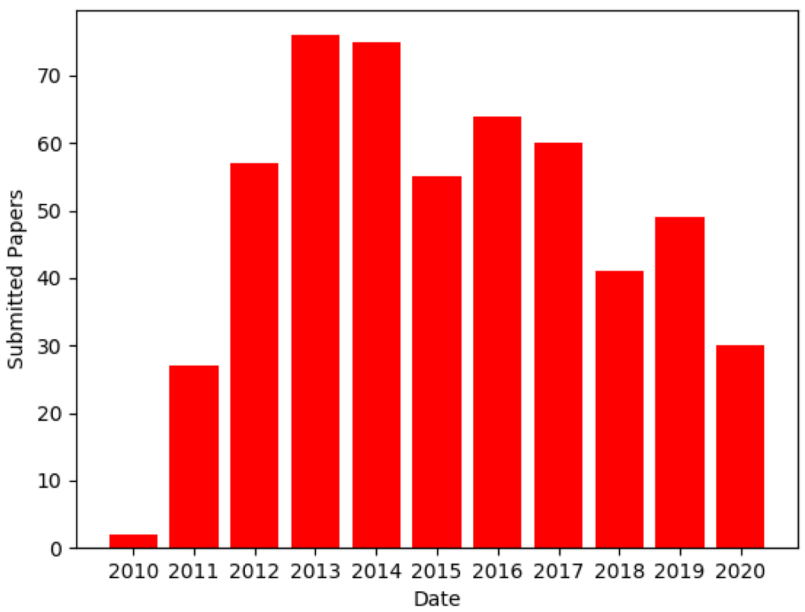
Operations: Run 1+ Run 2 Data Reprocessing

Data set		Status
pp Runs	2018	completed
	2011 and 2012	completed
	2015 and 2016	completed
	2017	completed
Ions Runs	2017 pNe	completed
	2018 PbPb	completed
	2018 PbNe	completed

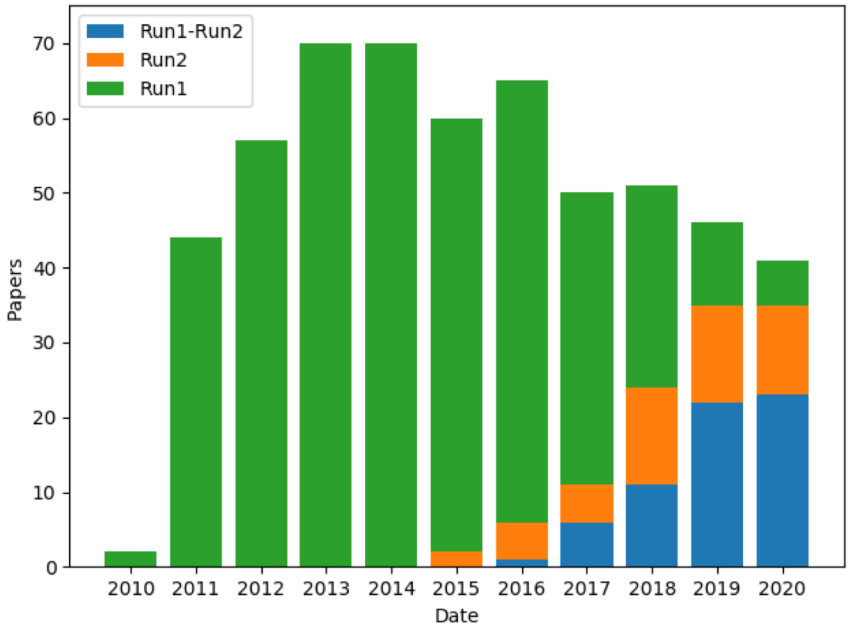
- Centrally run reconstruction and selection
  - sorting the data into streams
  - dedicated offline selection for each analysis

- **Full legacy data set has been produced**
- Huge amount of work, engaged our computing & operations teams for ~ 2 years

Physics Results: Publications and Presentations



Year of submission



Year of approval

- 536 Submitted papers
- 30 submitted papers 2020

In addition:

- 20 with the Editorial Board
- 33 in collaboration review

- Physics harvest continues apace
  - Despite strong focus up Upgrade preparation
  - Full Run1 & 2 analyses
- Joint LHCb/Theory workshop this week
  - A number of new results being released

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.

CP Violation: World best γ parameter

CP Violation: Discovery of new type

Rare decays: Flavour Anomalies

Discovery of exotic tetraquark particles

CP Violation: World best γ parameter

- The precision measurement of the γ parameter is one of the key aims of LHCb

CKM angle γ in $B^{\pm} \to DK^{\pm}$ and $B^{\pm} \to D\pi^{\pm}$, with $D \to K_s\pi\pi$ and $D \to K_sKK$

LHCb-PAPER-2020-019

2011 -2018: Preliminary

$\gamma = (69 \pm 5)^{\circ}$

σ(stat) ~ 5° σ(BESIII+CLEO) ~ 1°, σ(syst) ~1°

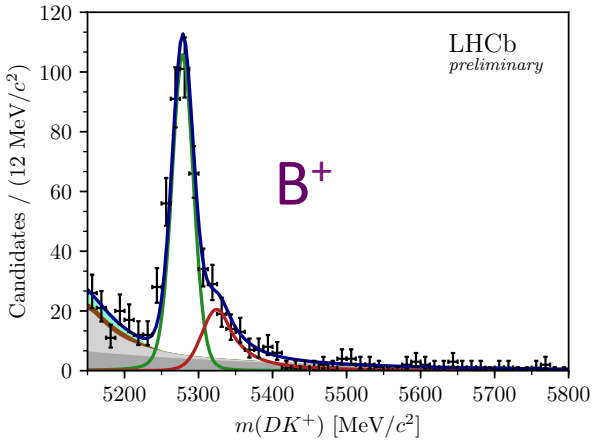
2011 -2016:

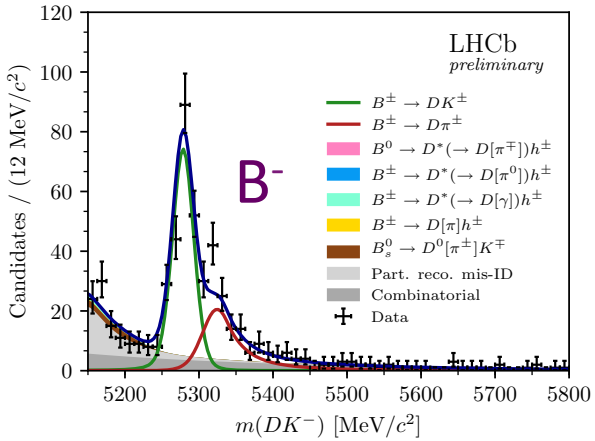
$\gamma = (80^{+10}_{-9})^{\circ}$

σ(stat) ~ 9° σ(CLEO) ~ 4°, σ(syst) ~3°

New inputs from BESIII on strong phases in D→Ksππ make a large difference

- Example bin 4 shown below and demonstrates a region of large asymmetry





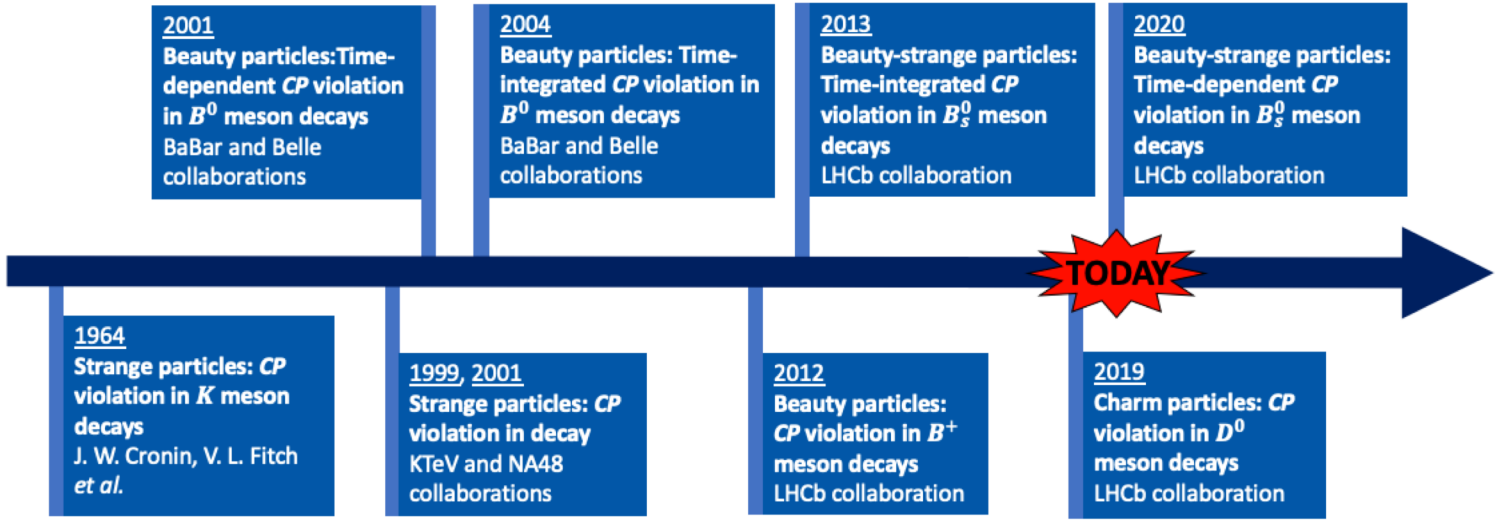
- Joint LHCb/BESIII workshops held to facilitate synergy

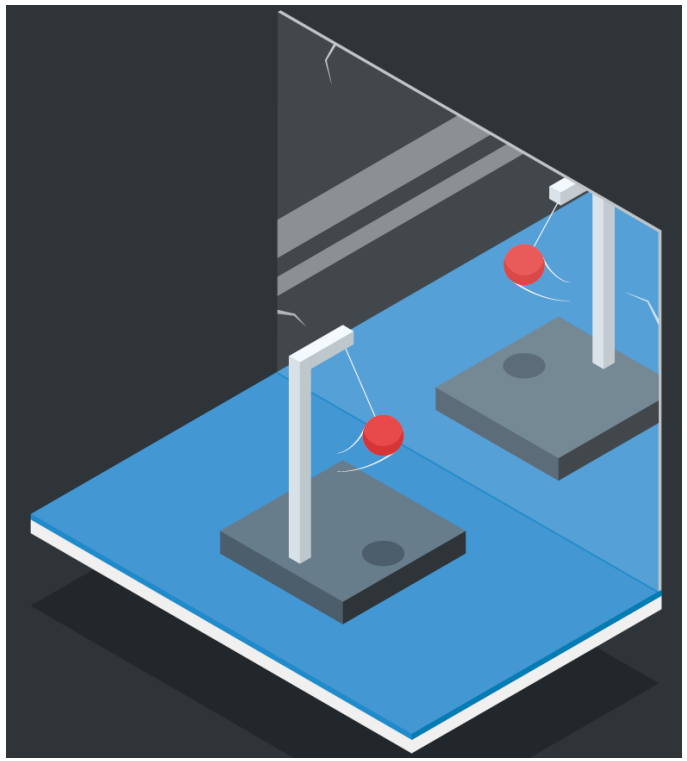
CP Violation: Discovery of new type

- New since submission of RRB paperwork

LHCb-PAPER-2020-029

Observation of Time-dependent CP Violation in B^0_s





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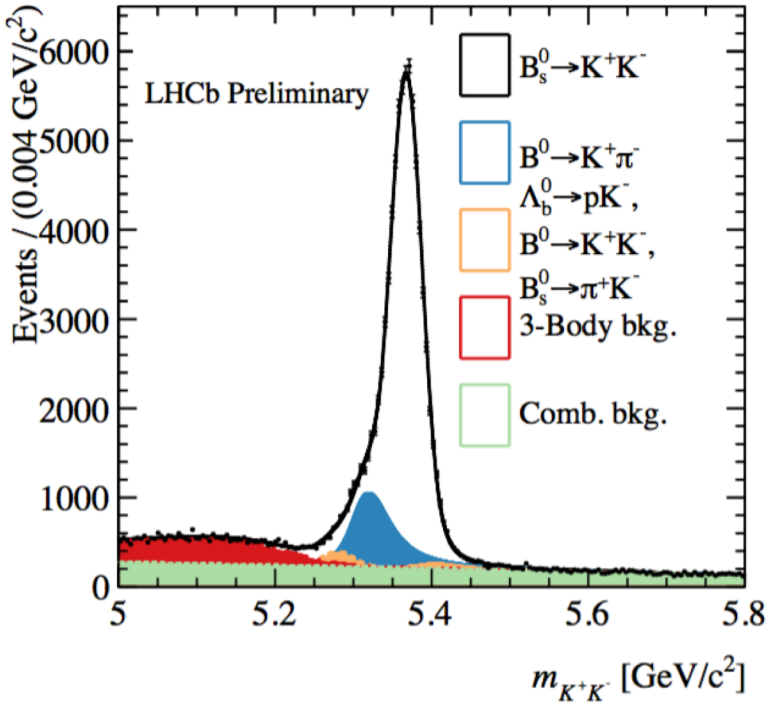
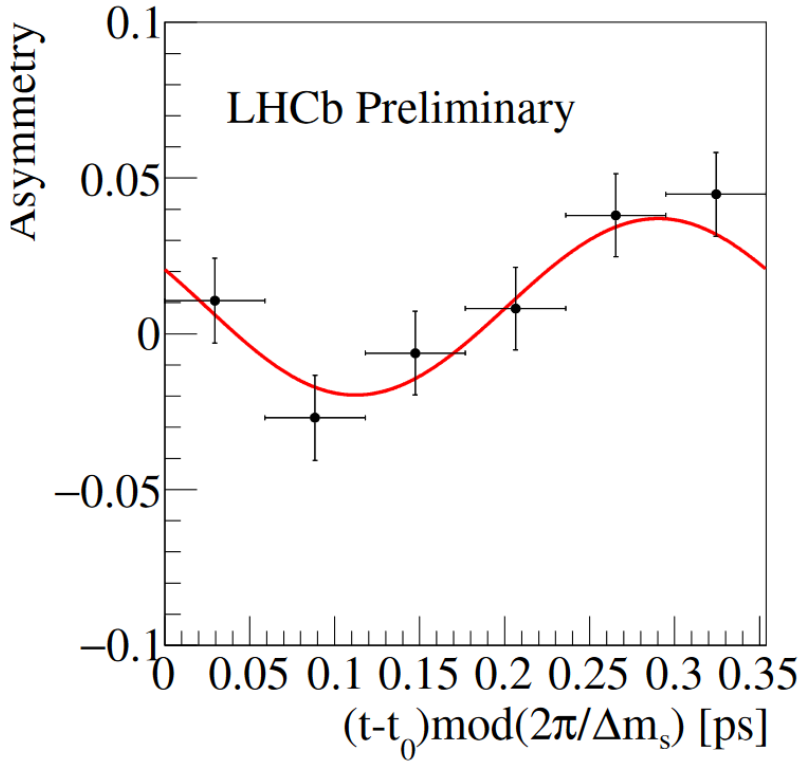




- $B^0_s \to K^+K^-$, CPV Observation (>5σ)
- Powered by key attributes of LHCb experiment
  - Time resolution – VELO
  - Particle Identification π/K - RICH

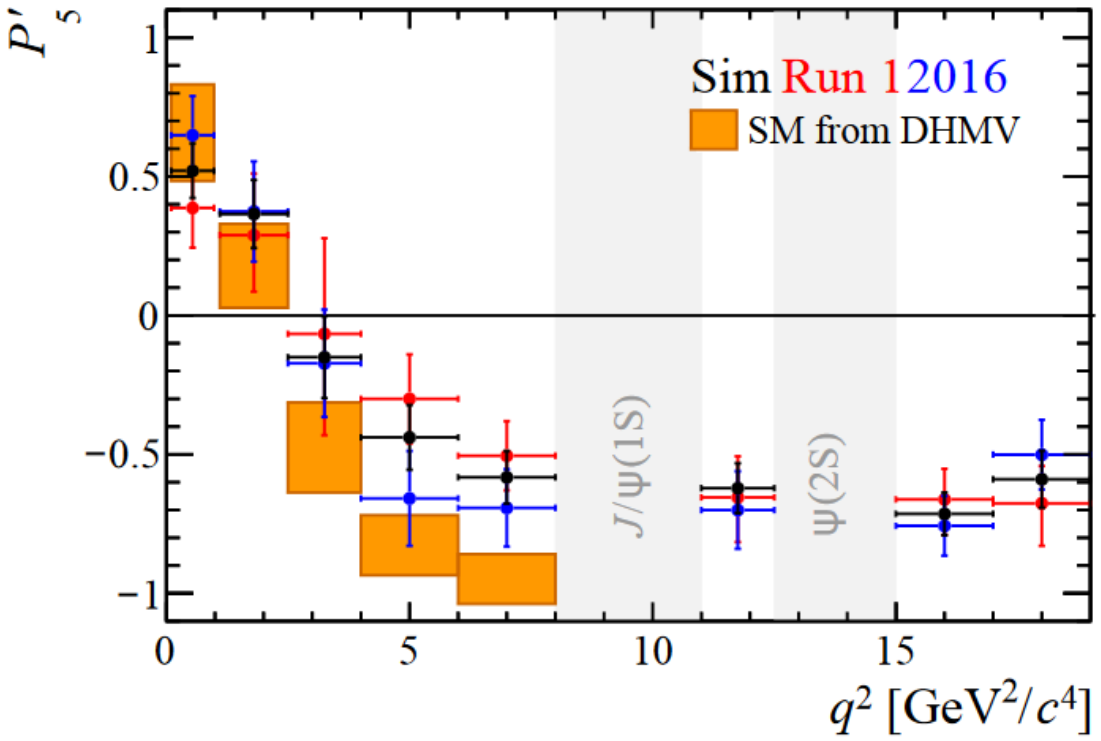
Rare Decays: Flavour Anomalies

- Over past years a series of results have hinted at discrepancies from the Standard Model, understanding this is a high priority

$B^0 \to K^* \mu^+ \mu^-$

LHCb-PAPER-2020-002

- Analysis of angular distributions – minimizing theory uncertainties
- Global fit tension to Standard Model increases from 3.0 to 3.3σ
- Lively discussion on whether it can be explained by uncertainties in the current theory and how it could be explained in new physics



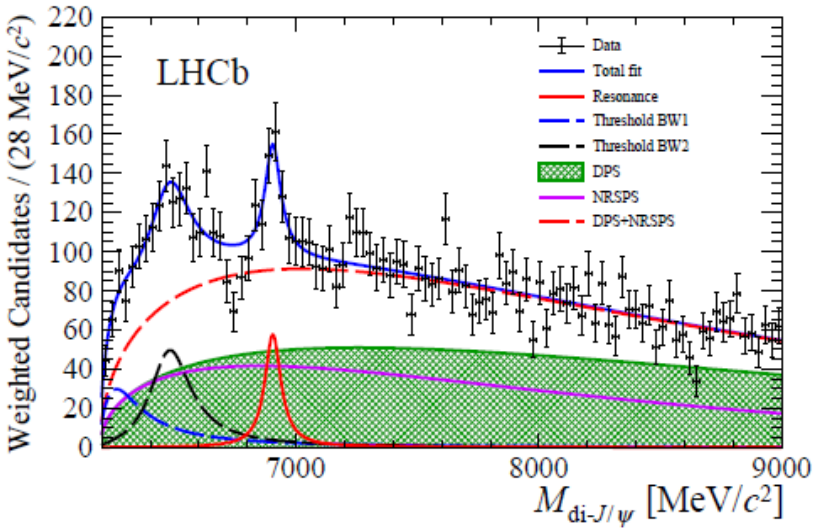
Discovery of exotic tetraquark particles – Two new types !

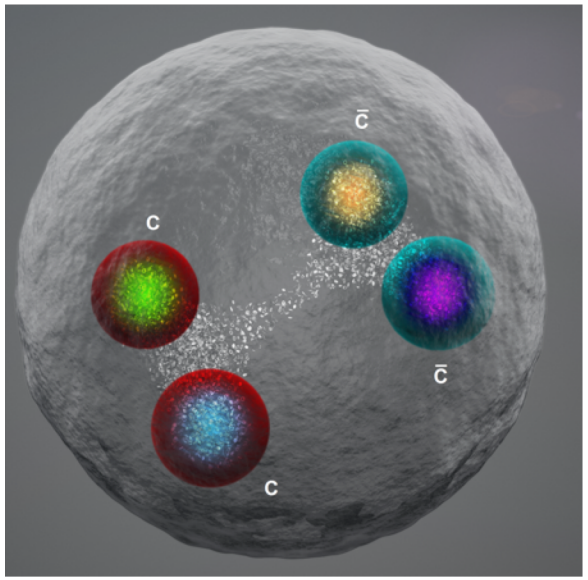
- LHCb had a wealth of results in exotic hadrons in recent years
  - Not composed of two or three quarks as is conventional

Exotic Hadrons: X(6900) cccc Tetraquark

LHCb-PAPER-2020-011

- Structures in J/ψ-pair mass spectrum (J/ψ→μμ)
- X(6900) resonance
- First fully heavy-quark tetraquarks !

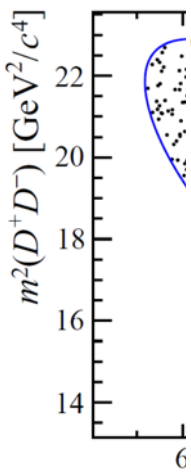


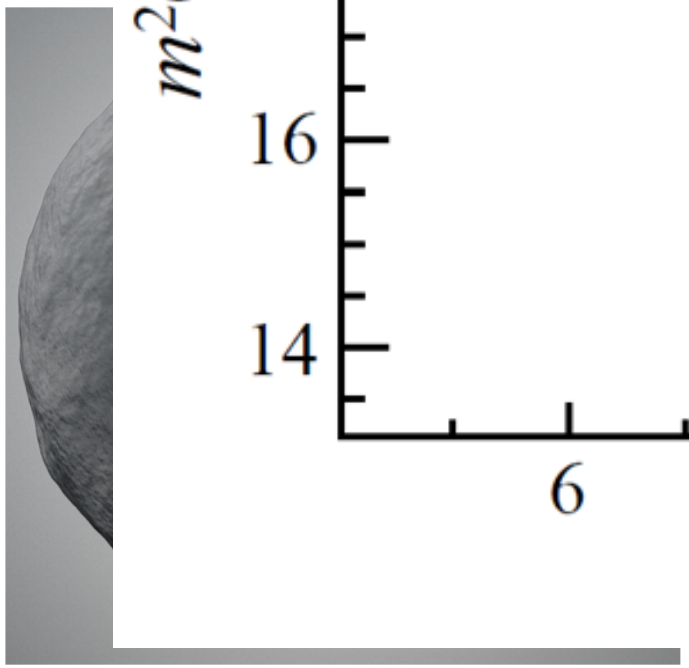


Theoretical interpretations include di-quark (cc) and anti-di-quark (cc) systems attracting each other.

Exo

LHCb-PAPER-2020-024
020-025





$m(D^-K^+)$ [GeV/c^2]

T+)

cles

th two

0) → D+ D−

30) → D+ D−

30) → D+ D−

0) → D+ D−

0) → D+ D−

5) → D+ D−

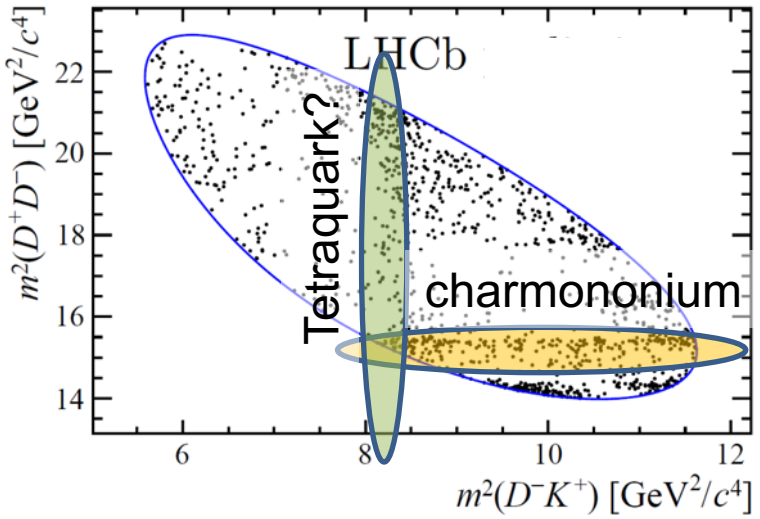
00) → D−K+

00) → D−K+

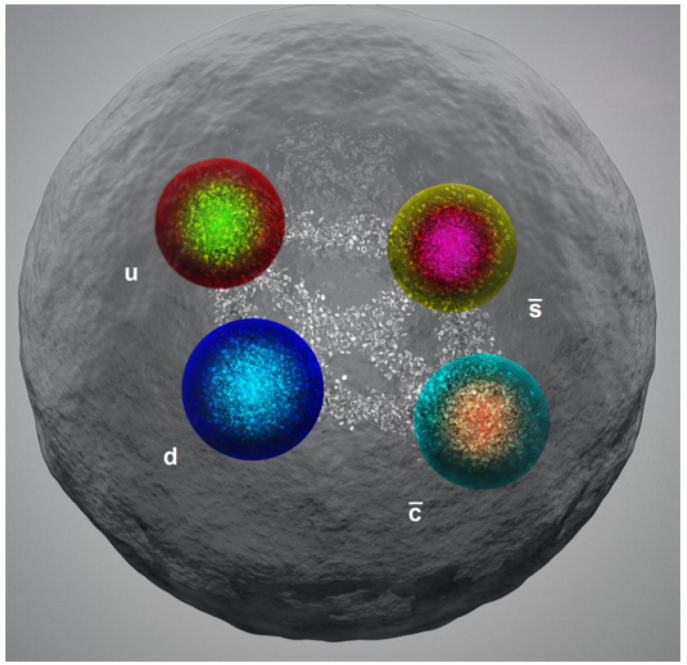
sonant

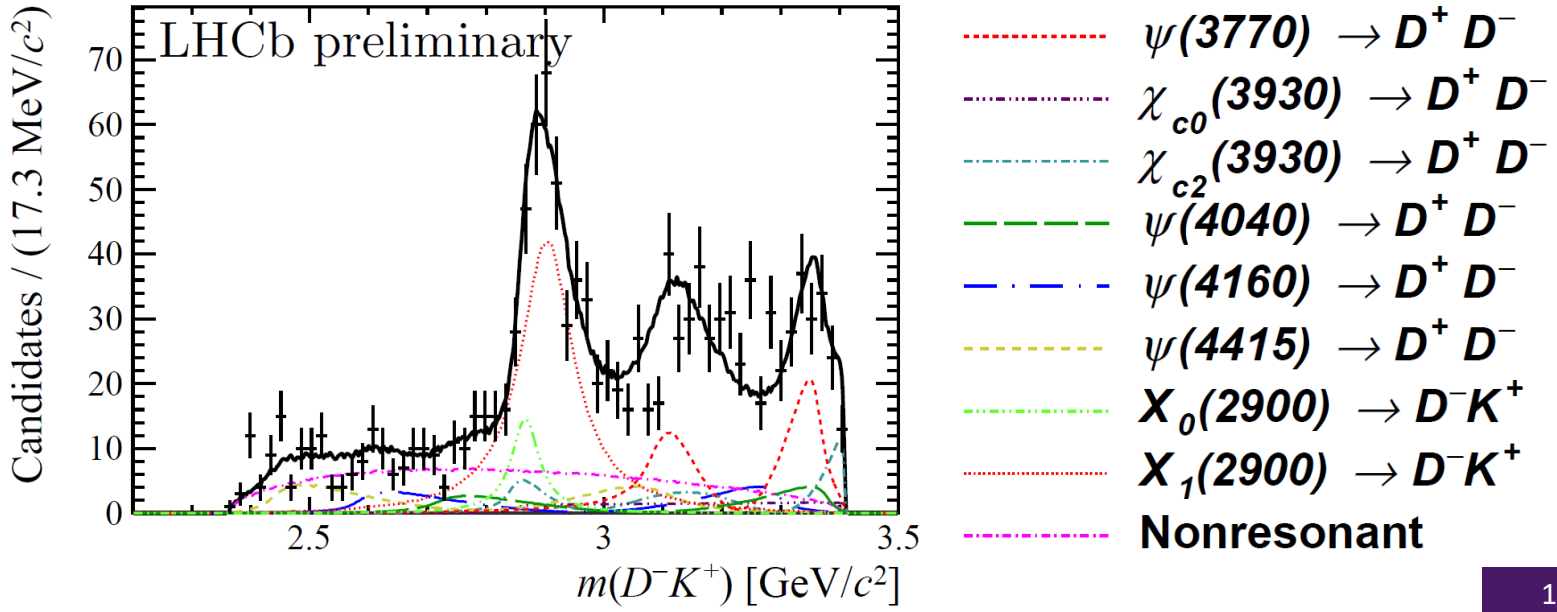
Exotic Hadrons: $X_{0,1}(2900)$ $\underline{c}d\underline{u}\underline{s}$ Tetraquark?

LHCb-PAPER-2020-024
LHCb-PAPER-2020-025



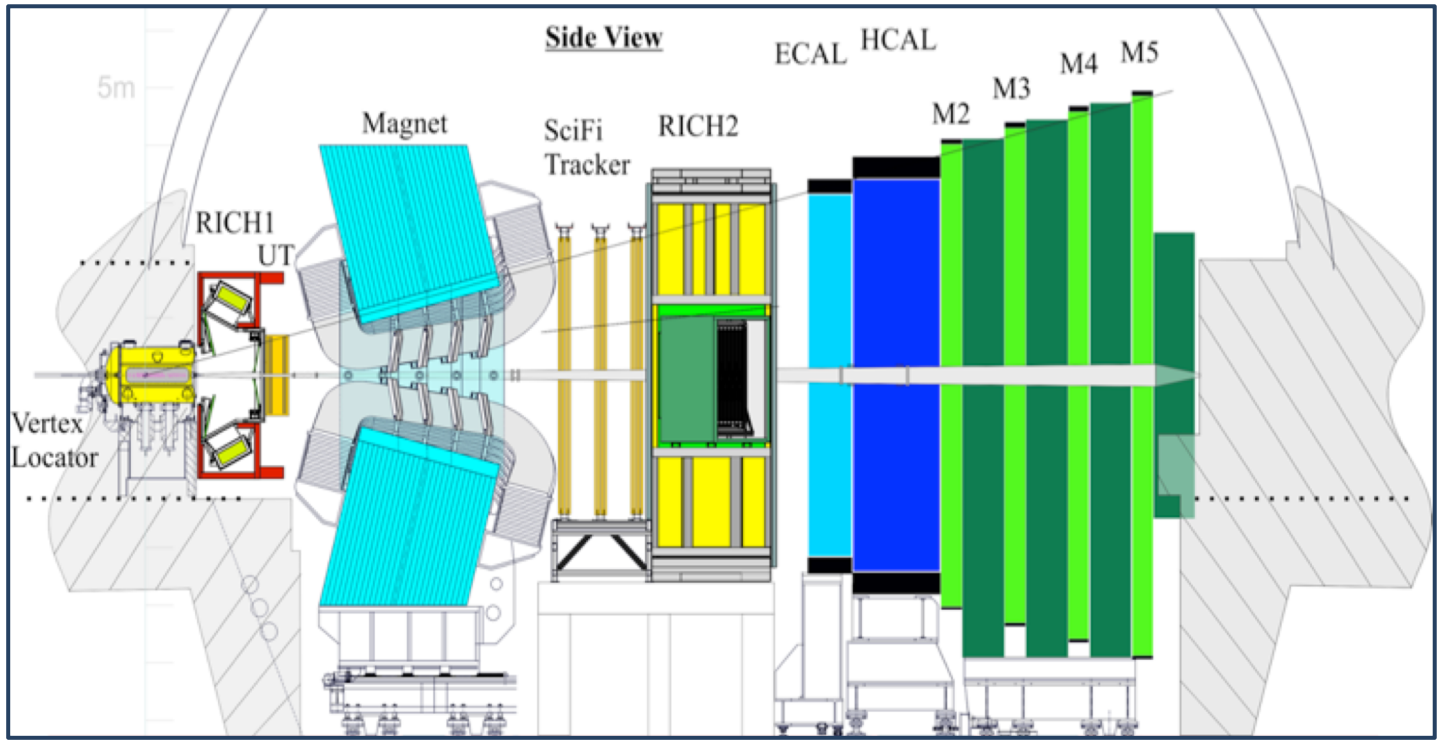
- Analysis of $B \to D^+D^-K^+$ (with $D^+ \to K^-\pi^+\pi^+$)
- Fit with expectations from known particles
- Prominent D^-K^+ structure, modelled with two tetraquarks
- First open-flavour exotic hadrons

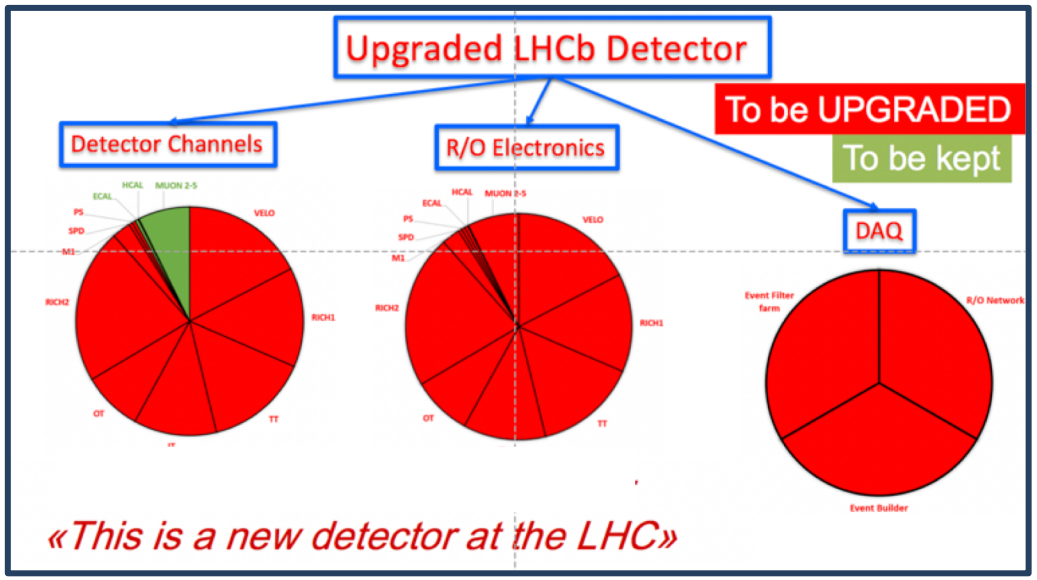




Upgrade I: Reminder

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



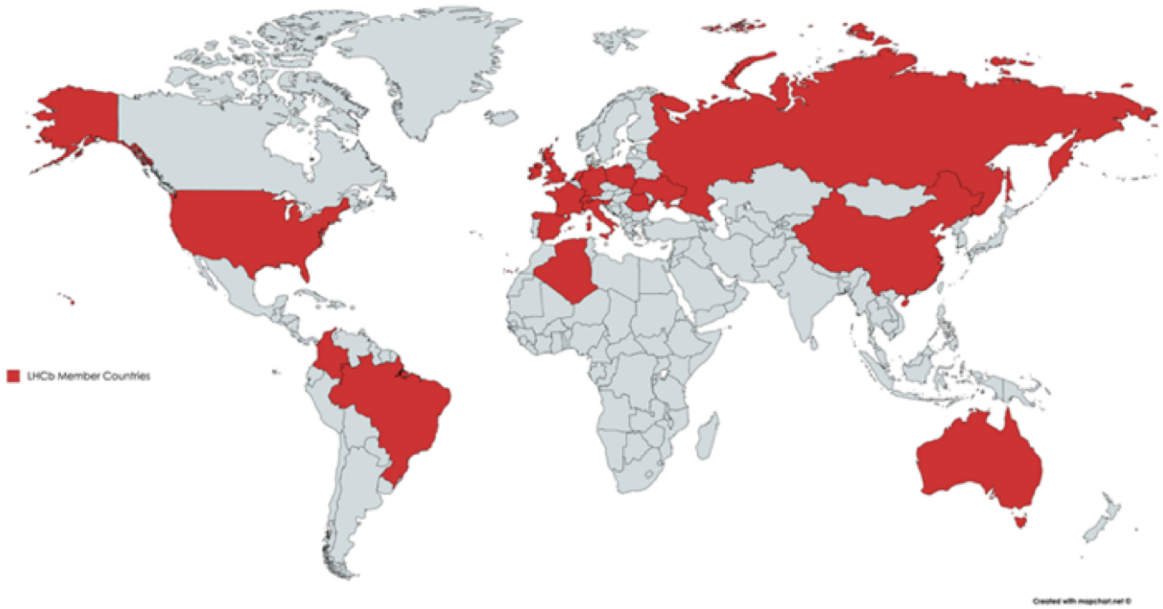


- Pixel detector VELO with silicon microchannel cooling 5mm from LHC beam
- New RICH mechanics, optics and photodetectors
- New silicon strip upstream tracker UT detector
- New SciFi tracker with 11,000 km of scintillating fibres
- New electronics for muon and calorimeter systems

Major project being installed currently for operation in Run 3

Upgrade I: Impact of Covid-19

1400 members in 18 countries



- We strongly value our spirit of international collaboration across borders
- Physics results, software development continued apace
- But activities requiring physical contact and travel delayed

Upgrade I construction:

- **Freeze in progress** of many critical path items in March-June 2020
- **Strong progress** in all critical path items July-September 2020
- **Delays** in several critical path items September-….

Expertise needed at CERN in 2021 for installation/commissioning

LHCb Upgrade I: Infrastructure

- All long distance cable are installed, copper and fibre
- New cooling plants and pipes are installed, commissioning.
- Shielding wall back in place.
- Repair of magnet supports will complete next week
- Data Centre is operational.
- Event builder cabling is ongoing.

Excellent progress on detector services and infrastructure

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

VELO

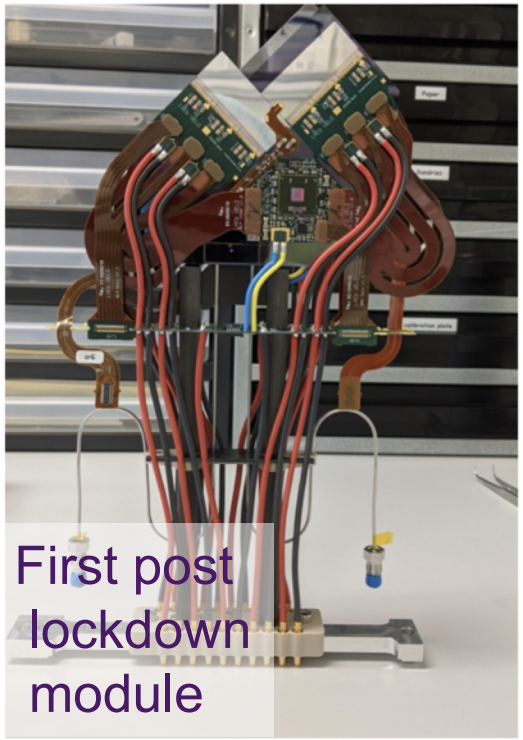
Microchannel plates: proceeding well

VELO Modules: production ongoing

Mechanics & Assembly: advancing

SMOG cell installed

Travel & quarantine delays



First post lockdown module

First UT production stave

UT

Instrumented staves: production advancing

Near detector electronics production complete

4-chip hybrids very advanced

Detector box produced

Assembly: clean room being installed now

long contractor delay from travel restrictions

SciFi

Readout Board completed

Cold-bar production completed during lockdown

Three assembled C-frames completed

C frame assembly currently suspended by travel restrictions

Assembled SciFi C-Frame

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

RICH

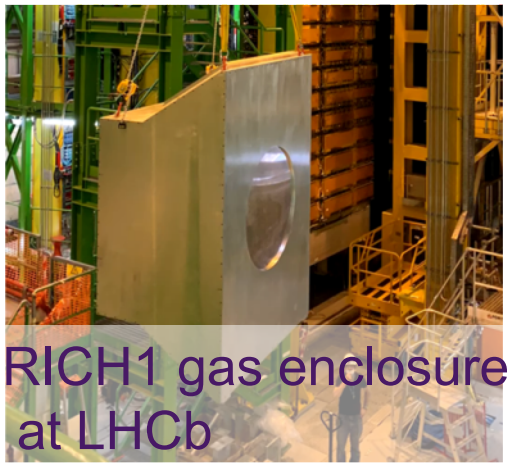
RICH2 photodetector arrays finished and commissioned

Full QA of digital board complete

RICH1 Gas enclosure arrived at CERN 20th October

Pandemic has caused delays but lab access and key expert travel allowed excellent progress

RICH2 photodetector array


RICH1 gas enclosure at LHCb


Muon commissioning rack

CALO

Front-end board final production about to start

Control board production nearing completion

Delays at production companies but acceptable

Muons

All electronic boards completed

Installation progressing well

HCAL beam plug installaled

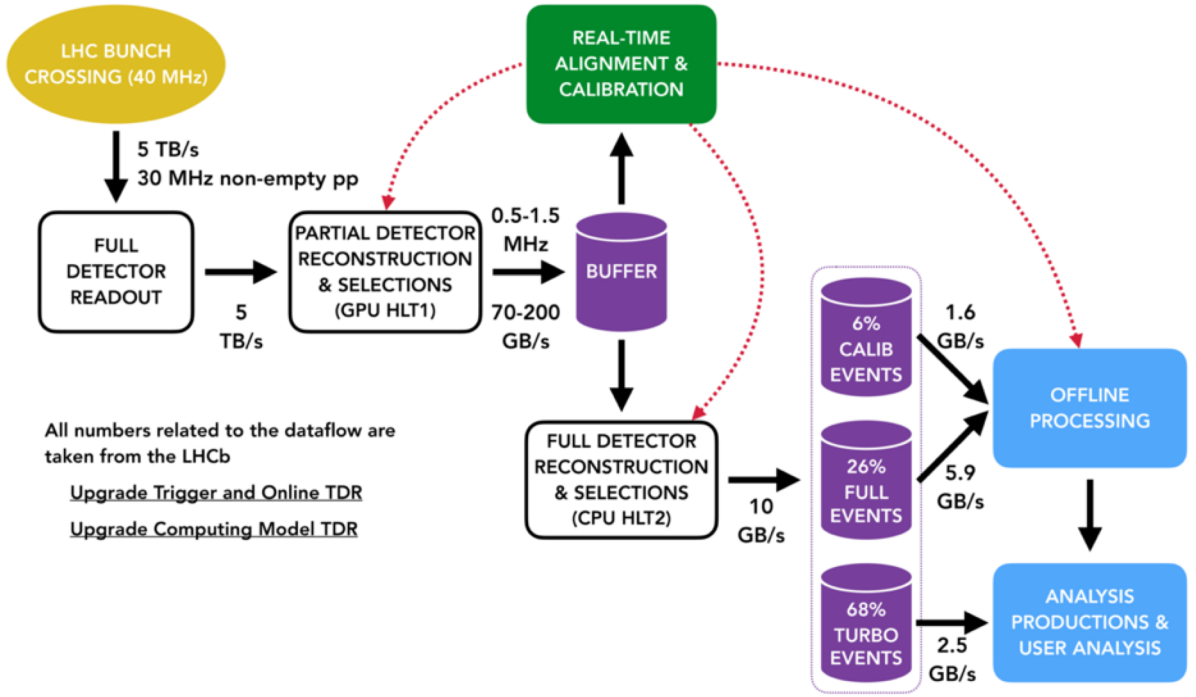
No major concerns


CALO Front-end board Test bench

LHCb Upgrade I: Computing, Online & Trigger

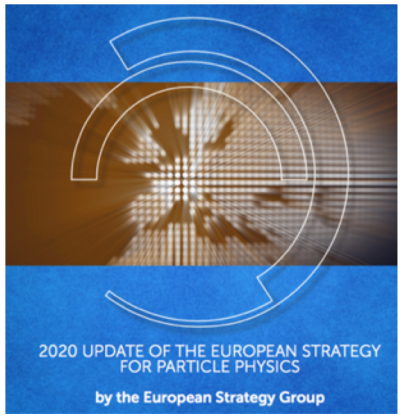
- FPGA DAQ (PCIe40) cards completed
- Event builder PC servers delivered
- Graphical Processing Units (GPUs) co-processors adopted for HLT1
  - Cost benefits, skill development for future

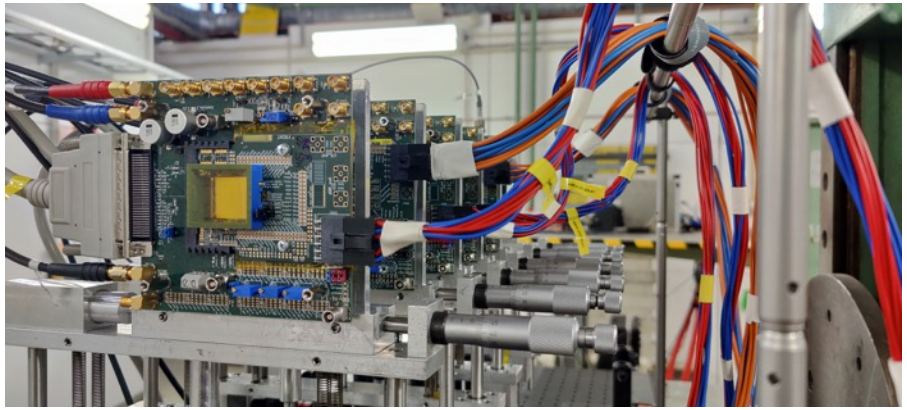
- Second level of trigger (CPU based) making good progress
  - Full reconstruction working, first selections in place
- Data Processing and Analysis (DPA) Project formed
  - Offline physics software



LHCb Upgrade II

- Future major upgrade of the experiment, mainly for LS4 (~2030)
  - with some preparatory work in LS3 (~2025)
- Strong support in European Strategy for Particle Physics 2020
- Framework Technical Design Report
  - Agreed submission in 2021 with LHCC
  - Initial cost ranges, indicative interests of countries
- Significant R&D Ongoing



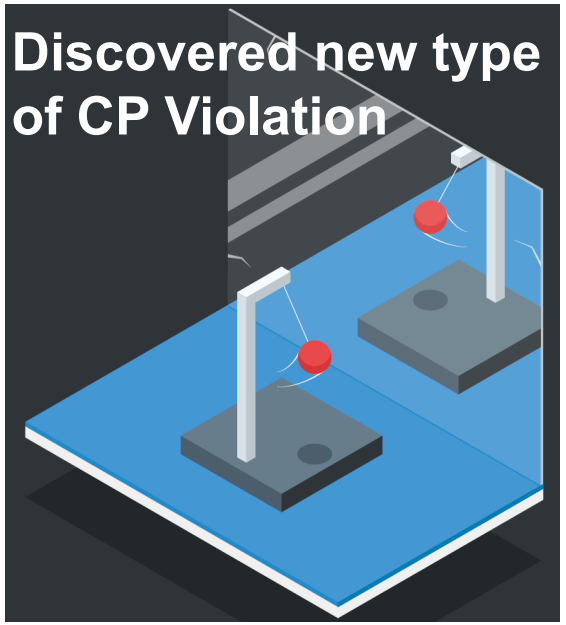


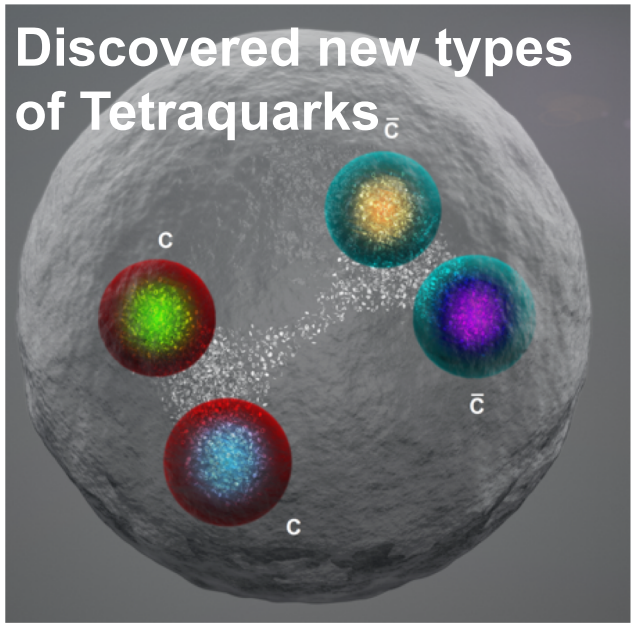
e.g.

- New HVCMOS Chip under test at DESY testbeam this week
- ECAL prototypes in testbeam in two weeks

Conclusions & Outlook

- A wealth of important scientific results have been delivered
- Significant progress has been made on the Upgrade I
  - Disruption from covid-19 has been inevitable
  - Compatible with LHC Schedule of cavern closure February 2022
- Planning for Upgrade II Framework TDR in place

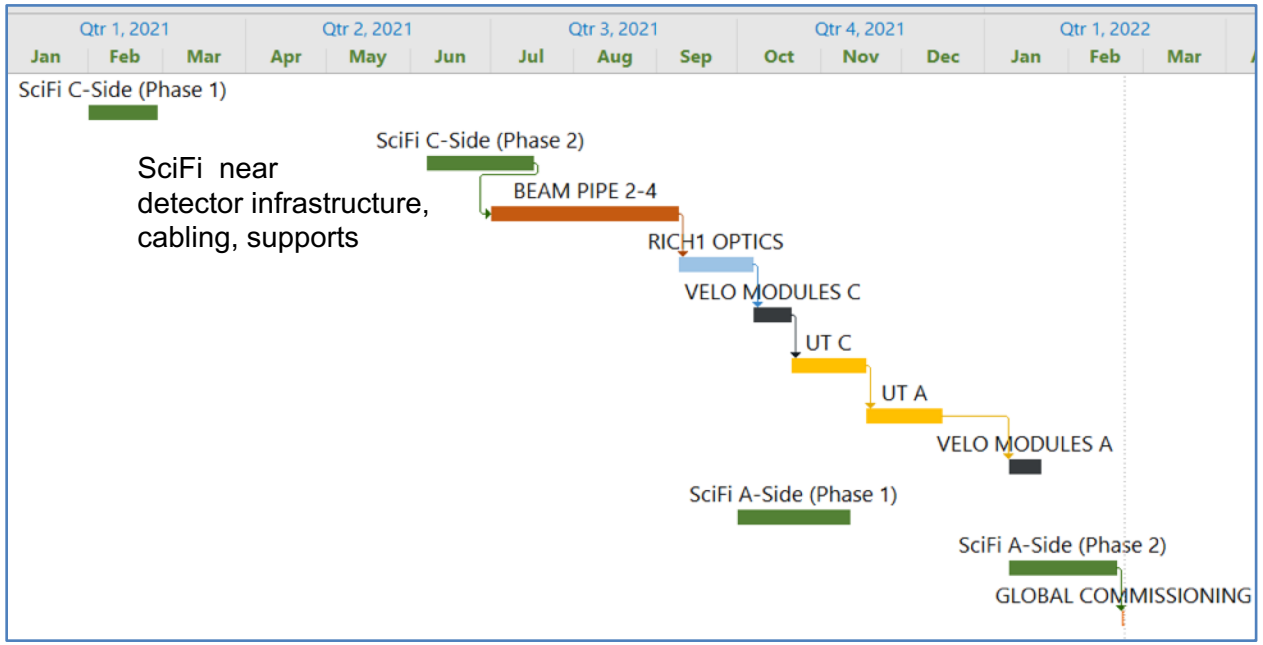




Backup

Schedule – top level key detector components

- Latest possible schedule compatible with February 2022 cavern closure



  - this is **not the aim**

  - this is the planning based on unblocking travel from institutes only by March 1st 2021

- In this schedule
  - Beam-pipe insertion compatible with an LHC beam test in Sept/Oct. 2021 but with limited contingency
- SciFi, VELO and UT are the projects that drive the critical path