Status of LHCb: Start of Upgrade I & Run 3

RRB, 26th October 2022

- Collaboration Matters
- Selected Physics Results
- LHCb Upgrade I Status
- Summary

Chris Parkes
on behalf of the LHCb Collaboration

Start of Run 3 13.6 TeV collisions 5th July 2022
Welcome to

• **CONARE, Costa Rica.** Consortium of five universities joined as a single full member group. Interests include GPUs and SiPMs, long-lived particle searches.

• **Eric Thomas** (CERN) took over as Technical Coordinator from 1\textsuperscript{st} July

• **Yasmine Amhis** (IJC Lab, Paris) took over as Physics Coordinator from 1\textsuperscript{st} August

• **Francisco Polci** (LPNHE, Paris) took over as Operations Coordinator from 1\textsuperscript{st} September
The three eras of LHCb

- Physics results
- Commissioning
- R&D underway
Physics Results: Publications

- 636 Submitted papers
- 32 submitted papers 2022

In addition:
- 22 with the Editorial Board
- 54 in collaboration review

- Following Russian invasion of Ukraine discussions on authorship continue
- Paper submission to preprint server with collaboration name only given
- Collaboration reviews & approval unaffected
Selected Physics Results

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

**Tetraquarks & Pentaquark**

**Charm matter-antimatter difference**

**Rare Charm: D → μμ**

**Lepton Flavour Universality: R(D,D*)**
Pentaquark & Tetraquarks

- Discovery of new states continues
- First strange pentaquark $P^\Lambda_{\psi\phi}(4338)^0$ $c\bar{c}sud$
  - Confirms pentaquarks in different decay to LHCb 2015 discovery
- Tetraquark isospin partners $T^{a}_{c\bar{s}0}(2900)^{++} c\bar{s}ud\bar{d}$
  - First doubly charged tetraquark
  - Start to build up multiplets

or or…. understand nature of states
First evidence Charm CP Violation in specific decay

- Direct CP Discovery 2019
- $\Delta A_{\text{CP}}$ difference $K\bar{K}, \pi\pi$
- Cancel systematics
  - Production, detection asymmetries

Upper end of SM prediction – separate into individual symmetries
  - Control channels to correct asymmetries
  - 3.8$\sigma$ asymmetry evidence in $K\bar{K}$
Rare Charm: $D \rightarrow \mu\mu$

- Rare decays to two muons are important measurements to search for new physics
  - Experimentally clean and rare in SM
  - Flavour changing neutral currents
    - look for difference in observed rate from prediction
- Full Run1&2 analysis of $D \rightarrow \mu\mu$
  \[ \mathcal{B}(D^0 \rightarrow \mu^+\mu^-) < 2.94 (3.25) \times 10^{-9} \text{ at } 90 \text{ (95)}\% \text{ CL} \]
  - World’s most stringent limit
Lepton Flavour Universality: $R(D,D^*)$

- Tension with theory in $b \rightarrow c l v$ decays, mainly from Babar/Belle
- Challenging analysis: missing neutrinos, large backgrounds
- First combined $R(D), R(D^*)$ at hadron collider
  - Much anticipated result, pathfinder result with Run 1 data
- Excellent agreement with world average, 1.9$\sigma$ from standard model
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

We need to pass the message: «This is a new detector at the LHC»

Major project installed for operation in Run 3
Upgrade I Completion: VELO

• Installation completed shortly after last meeting as expected
  – In shadow of LHC machine RF issue
Upgrade I Completion: Upstream Tracker

- Silicon planes before magnet (UT), not essential for early physics operation
- First half fully assembled
- Second side assembly underway
- On schedule for installation in year end technical stop

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Commissioning
Commissioning – VELO Closing

- Detector retracted by 3cm while LHC injecting beams
- VELO approaches LHC beam to 3mm
  – LHC beam with energy of TGV train passes through pencil sized hole!
- For the safety of LHC & VELO detailed closing procedure required
- Fully closed Friday 21st October

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Commissioning – Status & Next steps

- All subsystems of all detectors in excellent state
  - Sensors, Cooling, HV, LV, DAQ, monitoring, safety systems....
- Fully software trigger with GPU first level
  - 25MHz stable operation, trigger on CALO activity
- Strong progress despite reduced LHC beam time this year
Collisions have begun, and we start to understand the performance of what we have built

Innovative 40MHz readout detectors with first-of-kind real-time analysis trigger, pathfinder for other large science projects

Huge thanks to all of you for your support
Upgrade II: Ultimate Flavour Physics

• Full exploitation in HL-LHC era for flavour physics and beyond

• R&D underway

• Dedicated session tomorrow
Summary

• Largest CERN particle physics detector project since LHC completion
  – Despite pandemic being completed on-budget and in time for Run 3
  – Commissioning proceeding well
    • All subsystems working
    • VELO Closing milestone

• Significant physics results
  – Pentaquark & Tetraquark discoveries
  – Lepton Flavour Universality $R(D, D^*)$