Status of LHCb

RRB, 27th October 2021

- Collaboration Matters
- Selected Physics Results
- LHCb Upgrade I Installation Status
- LHCb Upgrade II Framework TDR
- Summary

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on behalf of the LHCb Collaboration
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- Activities and hobbies:
  - I studied piano and practised martial arts
  - I love travelling and mountain hiking
Collaboration News

- Collaboration continues to expand
  1000th Author

- Growth – important signal of growing interest in field

- A number of recent groups have joined for
  - Technology for Upgrade II
  - activities outside the “core” flavour programme
Physics Results: Publications and Presentations

- A number of high-profile results were released
- Dedicated “Flavour Anomaly Workshop” 20th October
  – LHCb+ATLAS+CMS+Theory

Year of submission

CERN seminar last week:
In person meetings restarting

- 596 Submitted papers
- 41 submitted papers 2021

In addition:
- 7 with the Editorial Board
- 47 in collaboration review
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.

**Charming Tetraquark discovered**

**Charming Protons ?**

**Charming Mass Difference**

**Lepton Flavour Universality**
Charming Tetraquark Discovery: $T_{cc}^+$

- Exotic Hadron: four quarks
- Contains two charm quarks
  - $cc\bar{u}\bar{d}$
- First of its type
- Prediction: the equivalent state with beauty quarks might fly for ~ cm before decaying!
  - Weak force decay
Charming Protons?

- Proton = u u d quarks - % level charm component long debated
  - Gluon splitting gives charm – not *intrinsic* charm
- $Z$+jet fraction containing charm, forward region

- Incorporating into global analysis could reveal valence-like intrinsic charm
• D⁰ particle anti-particle oscillations
  – Frequency controlled by mass difference
  – \( m_1 - m_2 = 6.4 \times 10^{-6} \text{ eV} = 0.000000000000000000000000000000001 \text{ grams} \)

• Fascinating quantum mechanics – milestone in field
• Standard Model predicts identical electroweak couplings of $e, \mu$
  – Discussed in April meeting – $3.1\sigma$ deviation from Standard Model
  – Fits with hints from other previous results
• New results on diff. channels point in same direction
  – Limited statistical sensitivity ~ $2\sigma$ combined
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

*We need to pass the message:* «This is a new detector at the LHC»
Upgrade I: Major Progress - Tracking

Velo:
Modules nearing completion
Module mounting in halves underway

SciFi:
First half Installed
Final module mounted

UT:
Modules produced
Stave production advanced
Services advancing
Upgrade I: Major Progress - PID

**RICH2:**
Commissioning
Data taking in beam test

**RICH1:**
Mechanics completed
Optical system in place

**ECAL:**
Commissioning
All electronics installed

**Muon Commissioning:**
Installation completed early 2021

Beam-pipe mounted & baked-out

Chris Parkes, LHCb RRB
Upgrade I: Major Progress – Online / Trigger/ Offline

Online Commissioning
Throughput tests
GPUs Purchased

Trigger Performant
HLT2 evaluated with some selections

Offline Data Processing
Data Reduction & Preparation
Upgrade I: Schedule Overview

• Installation Critical-Path
  SciFi: on-track, full system readiness may extend into 2022
  VELO: 2nd half installation planned early 2022
  UT: advancing, contingency plans for later installation

• Online system & 3 detectors expect to take test collisions this week!
• Expect almost all systems to be fully installed by February 2022
• Early Measurements Plan in place – commission & first physics
• On budget & On schedule for physics in 2022
Upgrade I: Schedule Overview

- Installation Critical Path
  - Early Measurements Plan in place
  - Commission & first physics
  - On budget & On schedule for physics in 2022

Chris Parkes, LHCb RRB
Fully exploit LHC facility for Flavour physics & beyond

Following from Expression of Interest 2017, Physics Case 2018, European Strategy 2020

Enthusiastic support for physics from previous review

Now review detector options to deliver

Chris Parkes, LHCb RRB
Future major upgrade of the experiment, mainly for LS4 (~2030) with some preparatory work in LS3 (~2025)

Summary, Introduction, Tracking Detectors, Particle Identification, DAQ and online processing, simulation & offline computing, Infrastructure, Environment, Timeline, Detector Scenarios & Costs

Indicative (non-binding) detector interests of contributing countries, without financial details

Overall estimated costs of systems, with discussion of descope options
- Keen to involve FAs and RRB at early stage, please contact your national PIs if you would like further information
Upgrade II FTDR – New Technologies

• Synergies with future projects
• Innovative Technology:
  • precision timing, novel sensors,
  • heterogeneous computing

Upgrade II FTDR – Environment

• First TDR with dedicated section
  – Gas emissions (direct)
  – Power consumption (indirect)
  – Travel
Upgrade II FTDR – LHCC Review Process & beyond

• Scientific review underway
  – First meeting with review panel
    • LHCC referees + invited experts (Tracking, PID, Computing)
  – Expected to complete for March 2022
• MoU anticipated ~ 2025
  – ~3 year period for R&D, negotiating contributions and scope
  – Upgrade Resource Board in LHCb with national PIs
  – Regular updates in RRB
  – Individual discussions with FAs
  – Spring 2022 FA discussion with LHCC
Summary

- Upgrade I installation highly advanced
  - Strong progress made
  - Several systems commissioning
  - Schedule tight for others

- Major physics results
  - Observation of mass difference that controls charm particle anti-particle oscillations
  - Intriguing results in LFV continue

- Upgrade II Framework TDR Scientific Review (LHCC) started
Backup
• First LHCb W Mass – pathfinder 2016 data only

\[ m_W = 80354 \pm 23_{\text{stat}} \pm 10_{\text{exp}} \pm 17_{\text{theory}} \pm 9_{\text{PDF}} \text{ MeV}, \]

• Different systematic sensitivity than ATLAS/CMS due to forward rapidity