



Status of LHCb: Dawn of new era

RRB, 27th April 2022

- Collaboration Matters
 - Ukrainian and Russian contributions
- Selected Physics Results
- LHCb Upgrade I Status
- Summary



Chris Parkes on behalf of the LHCb Collaboration

Collaboration News



B DECAYS TO CHARMONIUM

B DECAYS TO OPEN CHARM

CHARMLESS *b*-HADRON DECAYS

b-HADRONS AND QUARKONIA

CHARM PHYSICS

FLAVOUR TAGGING

LUMINOSITY

QCD, ELECTROWEAK AND EXOTICA

RARE DECAYS

SEMILEPTONIC B DECAYS

DETECTOR PERFORMANCE

IONS AND FIXED TARGET Lanzhou University, China, has joined. Detector Interests in Upstream Tracker for Upgrade I & II



- Innovative technology interests for Upgrade II is a driver in the interests of a number of groups that have recently joined.
- Eric Thomas (CERN) will take over as Technical Coordinator from 1st July
- Yasmine Amhis (IJC Lab, Paris) will take over as Physics Coordinator from 1st August

War against Ukraine



- LHCb is a collaboration of 20 countries with scientists and engineers all working together across geographical and political boundaries
- LHCb supports the statements of the CERN Council on the war in Ukraine: "CERN condemns, in the strongest terms, the military invasion of Ukraine by the Russian Federation. CERN wishes to express solidarity with our Ukrainian colleagues, their families and the entire Ukrainian people."



The LHCb Collaboration has: **15 members** from four institutes in Ukraine Key responsibilities: **Radiation Monitoring System, Plume luminometer**



Institute for Nuclear Research, Kyiv, Ukraine

Chris Parkes, LHCb RRB

Russian Contribution



- CERN Council will discuss the suspension of cooperation agreements at its June meeting and requested information for deliberations
- LHC Spokes proposed to council establishing a "shelter scheme" if cooperation agreements cancelled, ongoing discussions
- The LHCb Collaboration has:
- **148 members** from eleven institutes in Russia, ~ **10% collaboration**
- LHCb operations and technical coordination rely on a team of ~ 15 people in local CERN area
- Detectors: Calorimeter, Muon, SciFi Tracker, VELO
 - Leadership in Muon and Calorimeter
 - Muon chambers in construction in Russia for insertion during run 3
- Software: Offline data management, online monitoring
- Finances discussed in later presentation in this session

The three eras of LHCb



• Physics results

- Constructed !
 - Framework Technical Design Report



Celebrating LHCb Physics discoveries



Matter antimatter differences



Rare decays



New states of matter



- Charm CP Violation, time-integrated
- B_s CP Violation, time-integrated
- B_s CP Violation, time-dependent
- B[±] CP Violation

• B_s→µµ

- Tetraquarks
- Pentaquarks
- 55 hadrons discovered by LHCb

Physics Results: Publications and Presentations





611 Submitted papers

• 49 submitted papers 2021

In addition:

- 22 with the Editorial Board
- 50 in collaboration review

- Paper submission was paused after Russian invasion of Ukraine
- · Has now been restarted, with collaboration name only given
 - Holding position till after June CERN Council



- 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.

Probing anomalies with Baryons

Slow but Charm-ing Oscillations

Largest matter antimatter difference ever !

Understanding dark matter in space



Probing Semi-leptonic Anomalies with Baryons



- The other lepton flavour anomalies (outside $b \rightarrow sll$)
- Tension with theory in b \rightarrow clv decays, mainly from Babar/Belle
- $R(\Lambda_c^+)$ decays of baryon to tau lepton compared with muon
- New strategy: First observation of this channel and first test of ratios with semi-leptonic baryons

Slow but Charm-ing Oscillations

- Fascinating quantum mechanical effect that four particles in nature can turn into their own antiparticles
- D⁰ mesons (containing charm quark) are the slowest oscillations: takes 100 average lifetimes to oscillate !
- Parameter, y, is one of two that controls oscillation rate

Candidates / (0.08 MeV/c²)

 $10 \vdash^{\times 10^6}$

8

LHCb

 $6 \, \text{fb}^{-1}$

140

 $D^0 \rightarrow K^- \pi^+$



• 100 million decays analysed

Data

Signal

— Fit

150

 $\Delta m \,({\rm MeV}/c^2)$

155

— Background

 Four times better than world average

 which was already dominated by LHCb

145



Largest matter antimatter difference ever

LHCb ГНСр

- CP Violation discovered in three different
 - B^{\pm} 3-body decays
 - $B^{\pm} \rightarrow K^{\pm}K^{+}K^{-}$, $B^{\pm} \rightarrow \pi^{\pm}\pi^{+}\pi^{-}$ and $B^{\pm} \rightarrow \pi^{\pm}K^{+}K^{-}$
- Matter & antimatter like mirror images ?
- Largest CP asymmetry ever observed
 - 75% in selected phase space region
 - 7 times more B⁻ contribution than B⁺
- In different phase space regions flips between more B⁺ or more B⁻
- Understanding relationships between different decays





Understanding Dark Matter in Space

- *LHCb* ГНСр
- Astrophysics tells us that dark matter exists
 LHCb-PAPER-2021-031/032
- Space based experiments try to detect it by measuring anti-protons
 - need to know how many anti-protons to expect from standard physics
 - protons collide with He in space and can produce anti-protons
- LHCb has unique programme measuring protons with gas



- Ratio of *detached* to *prompt* anti-protons
- Predictions
 have underestimated this ratio





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 installed for operation in Run 3

Upgrade I



- Being completed on-budget and *near* schedule
- Data taken in pilot beam test
 - RICH2, CALO, Muons, luminometer
 - Innovative trigger system with GPUs
- completed installation in first months of 2022:
 - RICH1, Scintillating Fibre main tracker, firsthalf of VELO, luminometer
- Second-half of VELO expected to be installed in next weeks, with minimal effect on LHC schedule
- Silicon planes before magnet (UT) later in year, not essential for early physics operation
 - Services in cavern completed
 - First stave mounted





Upgrade I: VELO





- Pixel detector 5mm from LHC beam with innovative microchannel cooling
- Testing of first-half disrupted by omicron wave in December '21
- First-half Installed March '21
- Cooling leak delayed second-half
- Transport to CERN imminent
- Installation planned ~ 12th May

Upgrade I: VELO



Chris Parkes, LHCb RRB

Upgrade I: RICH1



- Unique particle identification system
- Installation successfully completed
 - Optical system October '21
 - Photon detector columns December '21 and, after omicron wave, February '22
 - Photon detectors commissioned





Upgrade I: Scintillating Fibre Tracker



- Cost-effective large scale tracker based on 11,000 km of scintillating fibres
- Installation successfully completed
 - Frames 9-12 installed in January and February '22
 - All electronics and services connected



Upgrade I: A new Era





- Next month collisions begin, 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



Kick-off meeting 2016



Framework TDR TODAY



R&D MoU & TDRs Schedule

Phase	LS2	Run 3		LS3	Run 4	LS4	Run 5 & 6
Project Approval Stages	FTDR		MoU				
Detectors		LS3 TDR	LS4 TDR				
Online, Trigger, Computing							
LS3 Infrastructure							
LS3 Detector Construction				Installation			
LS4 Detector Construction						Installation	
VELO							
UT							
MT							
Magnet Stations							
RICH							
TORCH							
ECAL							
Muons							
Online & Trigger							

- Full exploitation in HL-LHC era for flavour physics and beyond
- Arguably the highest likelihood of a further paradigm shifting discovery at the LHC is in flavour physics
- Dedicated presentation in today's session

Summary



• Possible effects from war against Ukraine

- Largest CERN particle physics detector project since LHC completion
 - Despite pandemic, is being completed on-budget and *near* schedule
- Significant physics results
 - World best measurements on charm oscillations
 - 75% matter anti-matter asymmetry

