LHCb highlights

DISCRETE 2024
Ljubljana, 2-6 December 2024

Adam Szabelski

3rd December 2024

National Centre for Nuclear Research
On behalf of the LHCb collaboration

Outline

LHCb

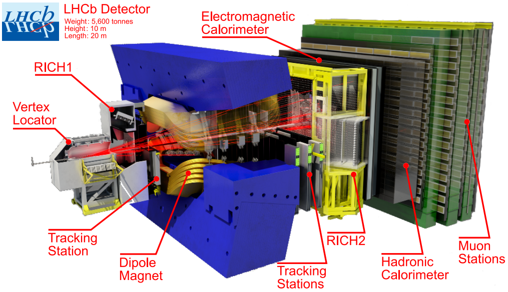
CKM parameters

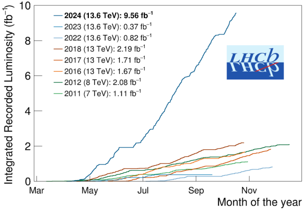
CPV

Summary

LHCb

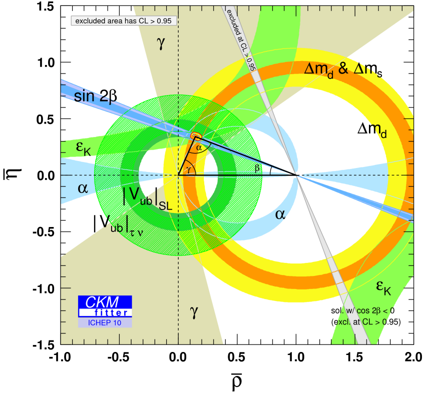
- Forward spectrometer
- Designed to measure heavy-flavour decays
- Run 1 and 2 - great success: an unprecedented sample of *b* and *c* decays
- The "old" data is still being analysed
- Undergone the upgrade I in 2019-2021
- First results from Run 3 coming soon



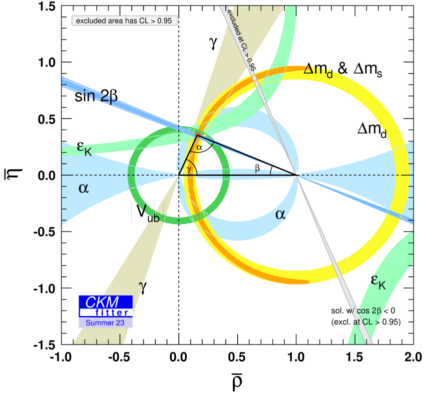


CKM parameters

2010



2023

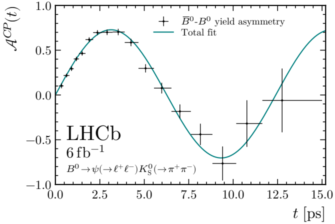


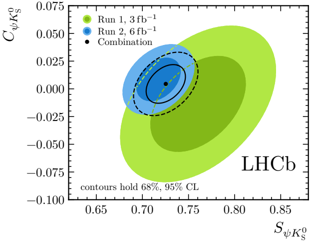
$\sin 2\beta$ from $B^0 \to \Psi(\to \ell^+\ell^-)K^0_S(\to \pi^+\pi^-)$

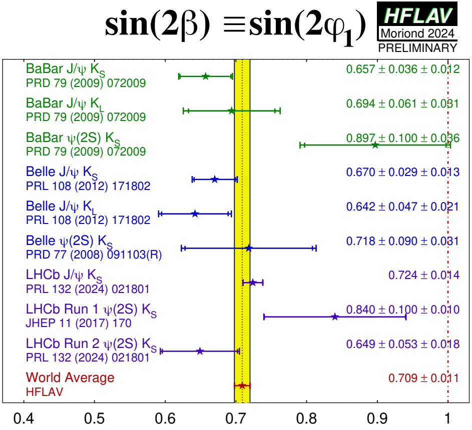
PRL132 (2024) 021801

Run 2: $S_{\Psi K^0_S} = 0.717 \pm 0.013(\text{stat}) \pm 0.008(\text{syst})$

$C_{\Psi K^0_S} = 0.008 \pm 0.012(\text{stat}) \pm 0.003(\text{syst})$





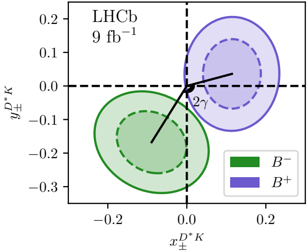


γ from $B \to D^* K$

JHEP12(2023)013

$$\gamma = (69^{+13}_{-14})^\circ$$

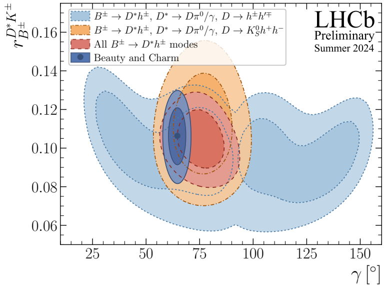
Run1 + Run2 $= 9fb^{-1}$



D^* is reconstructed through the decay chains $D^* \to D\pi^0/\gamma$; $D \to K^0_S\pi^+\pi^-/K^0_S K^+K^-$

Signal yields variation analysis across the D decay phase-space

Final states need to be accessible to both D^0 and $\overline{D}^0$ to have an interference



γ from $B \to DK^*$

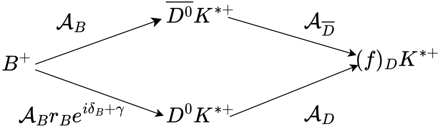
arXiv:2410.21115

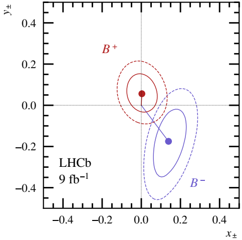
$$\gamma = (63 \pm 13)^\circ$$

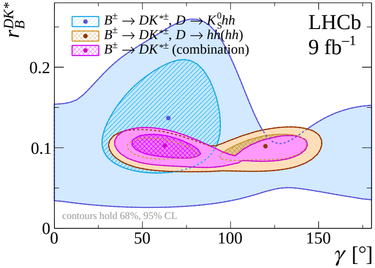
$B^\pm \to D^0 K^{*\pm}$

Using self-conjugate decays $D^0 \to K^0_S h^+ h^-$ and $K^{*\pm} \to K^0_S \pi^\pm$

Interference







CP in $B^0 \to D^0 K^{0*}$

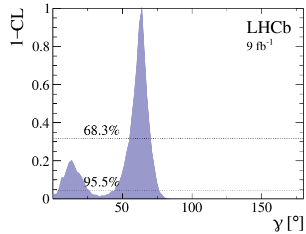
JHEP 05(2024) 025

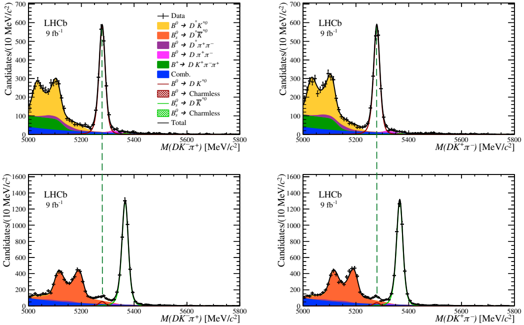
Interference between $B^0 \to D^0 K^{0*}$ and $B^0 \to \overline{D^0} K^{0*}$ enables to measure

$$\gamma = (63.2^{+6.9}_{-8.1})^\circ$$

$D^0 \to K^\mp \pi^\pm (\pi^+\pi^-)$, $D^0 \to \pi^+\pi^-(\pi^+\pi^-)$ and $D^0 \to K^+K^-$ final states

Parameter	Value
$A_{K\pi}$	$0.031 \pm 0.017 \pm 0.015$
$R^+_{\pi K}$	$0.069 \pm 0.013 \pm 0.005$
$R^-_{\pi K}$	$0.093 \pm 0.013 \pm 0.005$
$A_{K\pi\pi\pi}$	$-0.012 \pm 0.018 \pm 0.016$
$R^+_{\pi K\pi\pi}$	$0.060 \pm 0.014 \pm 0.006$
$R^-_{\pi K\pi\pi}$	$0.038 \pm 0.014 \pm 0.006$
R^{KK}_{CP}	$0.811 \pm 0.057 \pm 0.017$
A^{KK}_{CP}	$-0.047 \pm 0.063 \pm 0.015$
$R^{\pi\pi}_{CP}$	$1.104 \pm 0.111 \pm 0.026$
$A^{\pi\pi}_{CP}$	$-0.034 \pm 0.094 \pm 0.016$
$R^{4\pi}_{CP}$	$0.882 \pm 0.086 \pm 0.033$
$A^{4\pi}_{CP}$	$0.021 \pm 0.087 \pm 0.016$





Search for CP violation in $D^+ \to K^- K^+ \pi^+$

arXiv:2409.01414

D^+ 135M D_s 181M

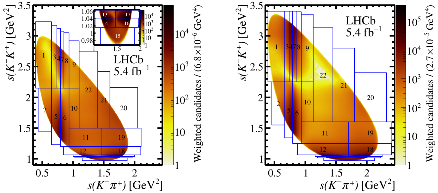
Significance $S_{\Delta_{CP}} = \frac{\Delta A_{CP}}{\sigma_{\Delta A_{CP}}}$

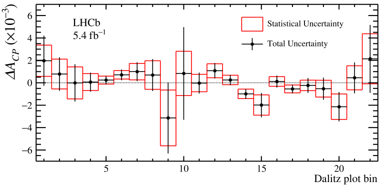
test statistics $\chi^2 = \sum_i^{N_{bins}} (S^i_{\Delta_{CP}})^2$

In the phase-space region dominated by $D^+ \to \phi \pi^+$ and $\phi \to \overline{K}^{0*} K^+$:

$A^{\phi\pi^+}_{CP|S} = (0.95 \pm 0.43\text{stat} \pm 0.26\text{syst}) \times 10^{-3}$

$A^{\overline{K}^{0*}K^+}_{CP|S} = (-0.26 \pm 0.56\text{stat} \pm 0.18\text{syst}) \times 10^{-3}$





The most sensitive search performed through the phase-space of a multi-body decay

No evidence of CP violation

For more CPV in charm $\Longrightarrow$ Luca Balzani's talk tomorrow

Evidence for direct CP-violation in baryons

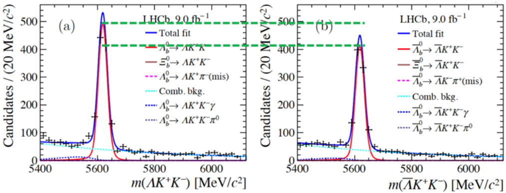
arXiv:2411.15441

$\Lambda_b/\Xi_b \to \Lambda h h^{(\prime)}$

6 final states (π, K)

Run 1 and 2

BF search/measurement



Measurement of CP asymmetries, evidence of direct CP-violation in $\Lambda_b^0 \to \Lambda K^+ K^-$ (3.1σ):

$$\Delta A_{CP}(\Lambda_b^0 \to \Lambda K^+ K^-) = 0.083 \pm 0.023 \pm 0.016$$

$$\Delta A_{CP}(\Lambda_b^0 \to \Lambda \pi^+ \pi^-) = -0.013 \pm 0.053 \pm 0.018$$

$$\Delta A_{CP}(\Lambda_b^0 \to \Lambda K^+ \pi^-) = -0.118 \pm 0.045 \pm 0.021$$

$$\Delta A_{CP}(\Xi_b^0 \to \Lambda K^- \pi^+) = 0.27 \pm 0.12 \pm 0.05$$

Beauty to charmonium

arXiv:2411.12178

Evidence for direct CPV

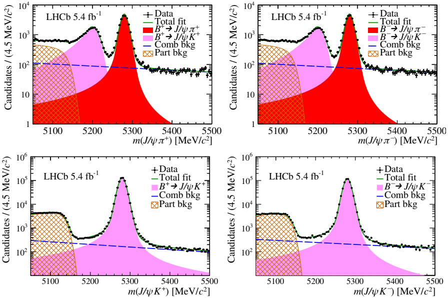
$$\Delta A_{CP} = A_{CP}(B^+ \to J/\Psi\pi^+) - A_{CP}(B^+ \to J/\Psi K^+)$$

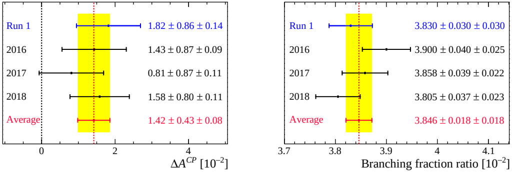
Run 1 + Run 2

$\Delta A_{CP} = 1.42 \pm 0.43 \pm 0.08) \times 10^{-2}$

$R_{\pi/K} = \frac{\mathcal{B}(B^+ \to J/\Psi\pi^+)}{\mathcal{B}(B^+ \to J/\Psi K^+)}$

$= (3.846 \pm 0.018 \pm 0.018) \times 10^{-2}$





Summary

LHCb remains an important player in the game in

- CKM parameters
- CP violation in beauty and charm

Didn't fit in this talk

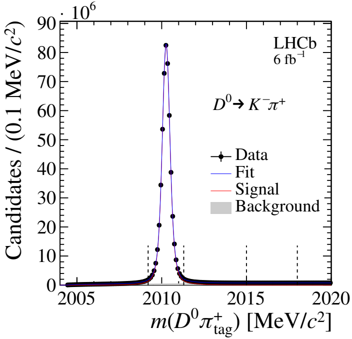
- Lepton Flavour universality
- Hadron spectroscopy
- SMOG program
- Heavy Ion program
- Search for CPT violation

THANK YOU & STAY TUNED

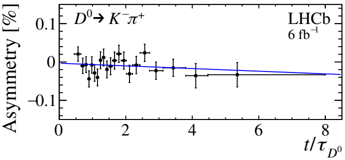
BACKUP

CPT violation search in $D^0 \to K^- \pi^+$

Phys.Rev.D 104 (2021) 7, 072010



In the search for time-dependent CP asymmetry in $D^0 \to \pi^+ \pi^-$ and $D^0 \to K^+ K^-$ $D^0 \to K^- \pi^+$ was used as a control channel.
Sample of 519×10^6 D^0 candidates from $D^{*+} \to D^0 \pi_s^+$



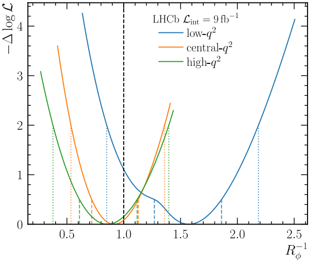
from the slope new limits on CPTV have been extracted (outside of LHCb)
Phys.Rev.D 110 (2024) 5

Flavour universality test with $B_s \to \phi\ell\ell$

arXiv:2410.13748

$$R_\phi = \left(\frac{\mathcal{B}(B_s \to \phi\mu\mu)}{\mathcal{B}(B_s \to \phi J/\Psi(\to \mu\mu))}\right) \Big/ \left(\frac{\mathcal{B}(B_s \to \phi ee)}{\mathcal{B}(B_s \to \phi J/\Psi(\to ee))}\right)$$

q^2 [GeV$^2/c^4$]	R_ϕ^{-1}	$\mathrm{d}\mathcal{B}(B_s^0 \to \phi e^+e^-)/\mathrm{d}q^2$ [10^{-7} GeV$^{-2}c^4$]
$0.1 < q^2 < 1.1$	$1.57\,^{+0.28}_{-0.25} \pm 0.05$	$1.38\,^{+0.25}_{-0.22} \pm 0.04 \pm 0.19 \pm 0.06$
$1.1 < q^2 < 6.0$	$0.91\,^{+0.20}_{-0.19} \pm 0.05$	$0.26 \pm 0.06 \pm 0.01 \pm 0.01 \pm 0.01$
$15.0 < q^2 < 19.0$	$0.85\,^{+0.24}_{-0.23} \pm 0.10$	$0.39 \pm 0.11 \pm 0.04 \pm 0.02 \pm 0.02$



results consistent with the SM