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Measurements of flavour changing charged current decays at LHCb

on behalf of the LHCb collaboration

Biljana Mitreska

Moriond EW
16.03.2026

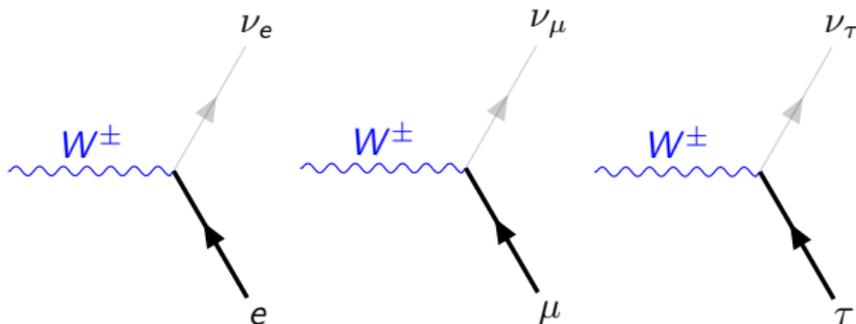
Outline

- 1 Introduction
- 2 $b \rightarrow cl\nu$ at LHCb
- 3 BF measurement of $\Lambda \rightarrow p\mu\nu$
- 4 **NEW** $B^0 \rightarrow D^*\mu\nu$ angular analysis: form factor measurement
- 5 Summary

Introduction

Semileptonic b-hadron decays provide powerful probes for testing the Standard Model(SM) and search for BSM effects

Lepton Flavour Universality (LFU) hypothesis: equal gauge bosons couplings to leptons

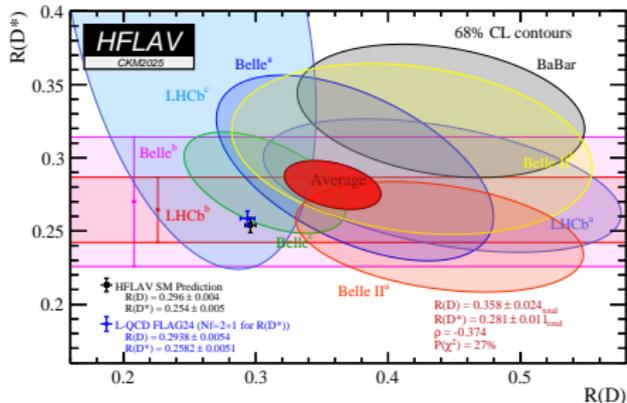


- Plethora of measurements that can be done:
 - CKM elements: V_{cb} , V_{ub}
 - Form factor measurements and angular observables
 - Lepton flavour universality tests: $\mathcal{R}(H_C) = \frac{\mathcal{B}(H_b \rightarrow H_c \tau \nu)}{\mathcal{B}(H_b \rightarrow H_c \mu \nu)}$

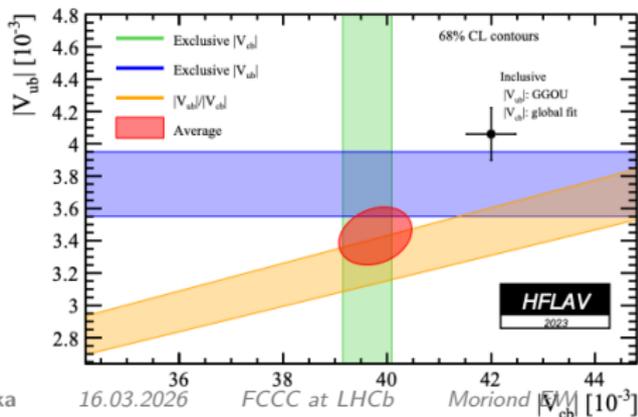
$b \rightarrow cl\nu$ transitions

Currently intriguing discrepancies exist:

- 3.8σ in $R(D^{(*)})$ measurements



- Inclusive vs exclusive V_{cb} and V_{ub}



► HFLAV

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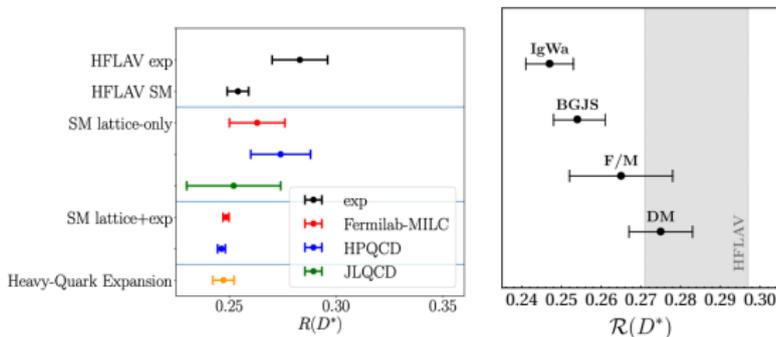
FCCC at LHCb

Moriond

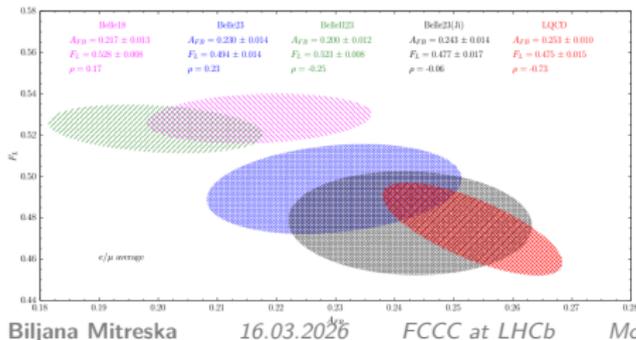
$|V_{cb}|$ [10⁻³]

$b \rightarrow cl\nu$ transitions

- Discrepancies when including lattice input
- Different form factor predictions shift variables of interest: how to solve this? ▶ talk by J.Harrison, ▶ talk by M.Blanke



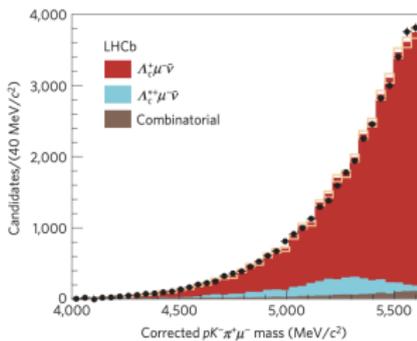
- Discrepancies when including lattice input in angular observables



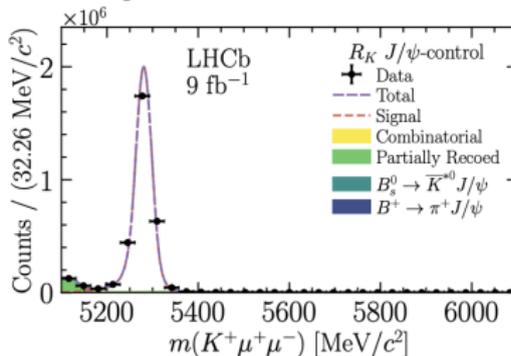
▶ PRD 111 (2025) 013005

$b \rightarrow cl\nu$ at LHCb: challenges

- Neutrinos not detected at LHCb: approximation needed to reconstruct the B momentum \rightarrow broad resolutions
- No mass peaks, harder to search for signatures



► Nature 11 (2015) 743-747



► PRD 108 (2023) 032002

- Heavily background polluted: precise modelling needed
- Different τ decay modes give rise to different background treatment: $\tau^- \rightarrow \mu^-\nu_\mu\nu_\tau$ and $\tau^- \rightarrow \pi^+\pi^-\pi^-\nu_\tau$

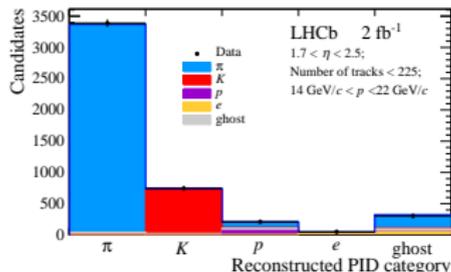
$b \rightarrow cl\nu$ LHCb: backgrounds

Usually modelled with simulation

- Semileptonic decays to heavier charmed hadrons
 $D^{**} \rightarrow D^{*+} \pi \pi$
- $B \rightarrow D^{*+} H_c X$

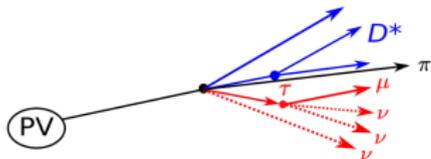
Data derived

- Misidentified hadrons (π, K, p)
- Combinatorial backgrounds



► PRL 134 (2025) 061801

- Use of charged and neutral isolation to reject backgrounds

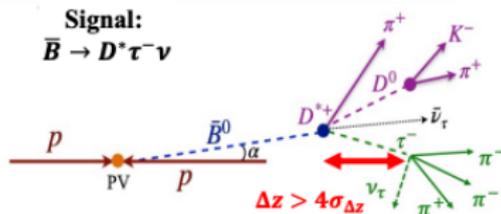


► arXiv:2302.02886

► PRL 120,121801

► PRL 128, 191803

- Residual prompt background rejected knowing the τ vertex



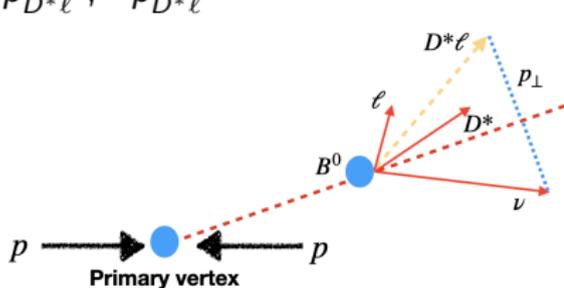
Neutrino reconstruction

Approximate B rest frame

$$p_z^B = \frac{m_B}{m_{D^*\ell}} p_z^Y \quad |p_B| = \frac{m_B}{m_{D^*\ell}} p_z^{D^*\ell} \sqrt{1 + \tan^2(\alpha_z)}$$

Quadratic equation

$$p_{D^*\ell}^\perp, p_{D^*\ell}^\parallel$$



$$a = \frac{p_{D^*\ell}^\parallel (m^2 - m_{D^*\ell}^2 - 2(p_{D^*\ell}^\perp)^2)}{2((p_{D^*\ell}^\perp)^2 - E_{vis}^2)}$$

$$r = \frac{E_{D^*\ell}^\parallel (m^2 - m_{D^*\ell}^2 - 2(p_{D^*\ell}^\perp)^2)}{4((p_{D^*\ell}^\perp)^2 - E_{vis}^2)^2} + \frac{(E_{D^*\ell} p_{D^*\ell}^\perp)^2}{(p_{D^*\ell}^\perp)^2 - E_{vis}^2}$$

$$p^+ = p_{D^*\ell}^\parallel - a + \sqrt{r}$$

$$p^- = p_{D^*\ell}^\parallel - a - \sqrt{r}$$

- Choose a random solution
- Linear regression algorithm: [arXiv:1611.08522v2](https://arxiv.org/abs/1611.08522v2)

Measurements of semileptonic decays at LHCb

$R(D^0)$ vs $R(D^*)$ Run I (2023)

$$R(D^*) = 0.281 \pm 0.018(\text{stat}) \pm 0.024(\text{syst})$$

$$R(D^0) = 0.441 \pm 0.060(\text{stat}) \pm 0.066(\text{syst})$$

▶ PRL 131 111802

$R(D^+)$ vs $R(D^{*+})$ Run II (2025)

$$R(D^{*+}) = 0.402 \pm 0.081(\text{stat}) \pm 0.085(\text{syst})$$

$$R(D^+) = 0.249 \pm 0.043(\text{stat})$$

▶ PRL 134 (2025) 061801

$R(J/\psi)$ Run I (2018)

$$0.71 \pm 0.17(\text{stat}) \pm 0.18(\text{syst})$$

▶ PRL 120 121801

$R(D^{*+})$ part Run II (2023)

$$0.247 \pm 0.015(\text{stat}) \pm 0.015(\text{syst}) \pm 0.012(\text{ext})$$

▶ PRD 108 012018

$R(\Lambda_c^+)$ Run I (2022)

$$0.242 \pm 0.026(\text{stat}) \pm 0.040(\text{syst}) \pm 0.059(\text{ext})$$

▶ PRL 128 191803

D^* polarisation (2024)

$$0.41 \pm 0.06(\text{stat}) \pm 0.03(\text{syst}) \pm 0.059(\text{ext})$$

▶ PRD 110 (2024) 092007

$R(D^{**})$ (2025)

$$0.13 \pm 0.03(\text{stat}) \pm 0.01(\text{syst}) \pm 0.03(\text{ext})$$

▶ PRL 135 (2025) 021802

BF measurement in $\Lambda \rightarrow p\mu\nu$ (2025)

$$1.462 \pm 0.016 \pm 0.100 \pm 0.011$$

▶ arXiv:2511.15681

Measurement of FFs with

$B^0 \rightarrow D^* \mu\nu$ (2026)

▶ LHCb-CONF-2026-001

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BF measurement in $\Lambda \rightarrow p\mu\nu$
(2025) $1.462 \pm 0.016 \pm 0.100 \pm 0.011$

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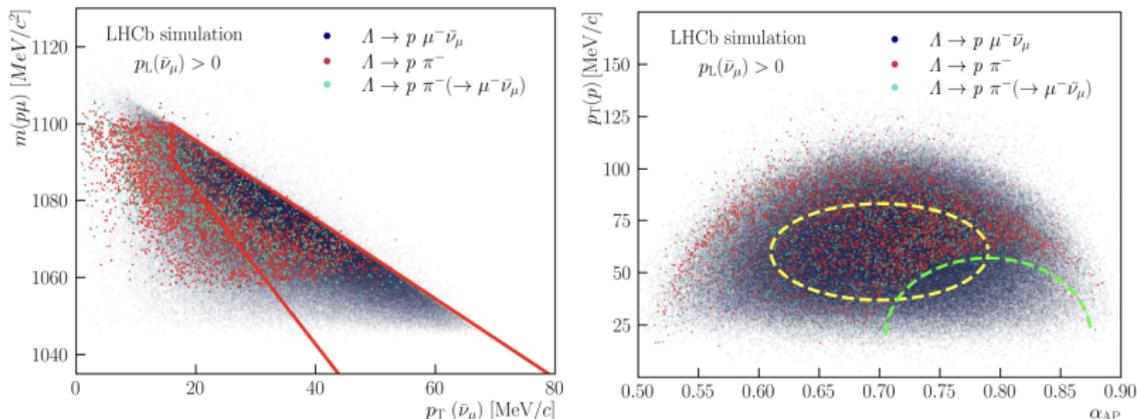
▶ LHCb-CONF-2026-001

BF measurement of $\Lambda \rightarrow p\mu\nu$

- The BF measurement provides a valuable input for the LFU test:

$$R^{\mu e} = \frac{BF(\Lambda \rightarrow p\mu\nu)}{BF(\Lambda \rightarrow p e \nu)} \quad (\text{electron mode measured precisely})$$

- $\Lambda \rightarrow p\pi$ used as normalisation channel to extract the BF
- Selection based on kinematic variables to account for the neutrino

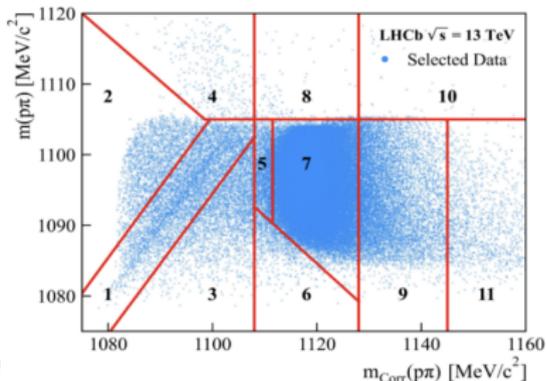
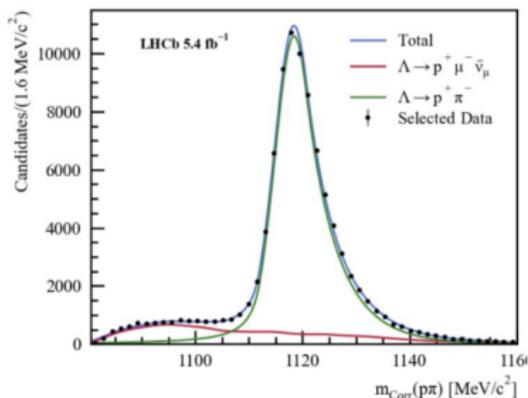


- 2D binned fit in $m(p\pi)$ and $m_{corr}(p\pi)$

BF measurement of $\Lambda \rightarrow p\mu\nu$

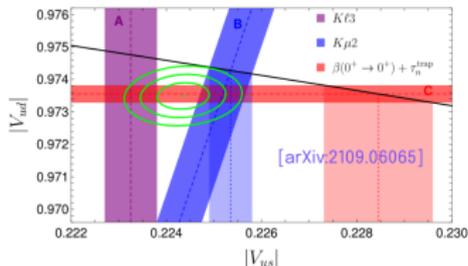
- World best BF measurement with total uncertainty of 6.9 %

$$\mathcal{B}(\Lambda \rightarrow p\mu^-\bar{\nu}_\mu) = (1.462 \pm 0.016 \text{ (stat)} \pm 0.100 \text{ (sys)} \pm 0.011 \text{ (norm)}) \times 10^{-4} = \mathbf{(1.46 \pm 0.10) \times 10^{-4}}$$

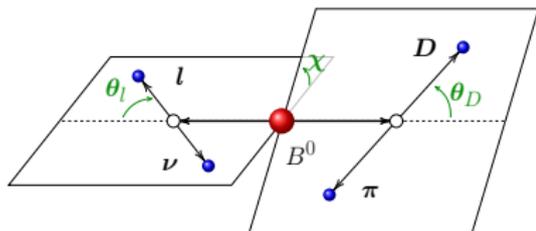


- V_{US} evaluated from the BF $\rightarrow 0.252 \pm 0.011$
- $R^{\mu/e} = 0.175 \pm 0.012$
 $\rightarrow 1.5 \sigma$ from SM prediction

▶ [arXiv:2511.15681](https://arxiv.org/abs/2511.15681)



NEW $B^0 \rightarrow D^* \mu \nu$ angular analysis



- θ_l angle between the direction of the lepton and the direction opposite the B meson in the virtual W rest frame

- θ_d angle between the direction of the D meson and the direction opposite the B meson in the D^* rest frame

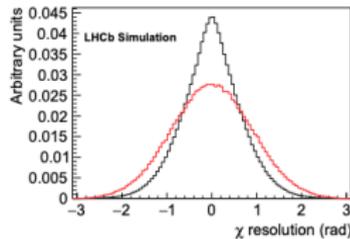
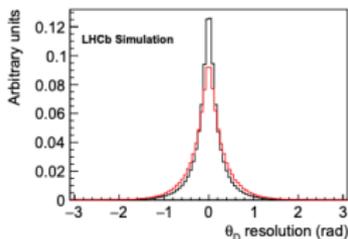
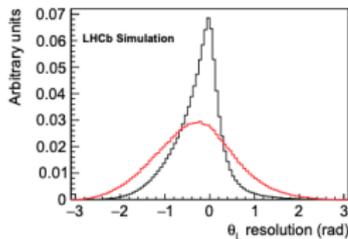
- χ angle between the plane by the D^* and the plane formed by the W decay, defined in the B rest frame

$$B^0 \rightarrow D^* \mu \nu$$

$$D^* \rightarrow D^0 \pi_s$$

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

- Better resolution in **muonic** decays than **tauonic** ($\tau \rightarrow \mu \nu \nu$): rest frame approximation [▶ arXiv:1808.08865](https://arxiv.org/abs/1808.08865)



$B^0 \rightarrow D^* \ell \nu$ angular analysis

- 5D templates (three angles, q^2 and m_{miss}^2)

Main background contributions:

- $B^0 \rightarrow D^* \tau \nu$ - using the same FF parameterisation as the signal
- $B \rightarrow D^{**} \mu \nu$ - modelled with the BLR FF parametrisation
 - ▶ PRD 97 075011 (2018)
- Semileptonic decays to heavier charmed hadrons
- MisID and combinatorial (data derived)
 - ▶ PID information is used to decompose the misID sample in 5 categories (pions, kaons, protons, electrons, ghosts)
- Combinatorial (same sign, $D^{*+} \mu^+$)
- D^* combinatorial (same sign, $D^0 \pi^+ \mu^+$)
- 80 % of the data is covered by the signal $B^0 \rightarrow D^* \mu \nu$,
 $B \rightarrow D^{**} \mu \nu$ contributes 10 %, rest of the backgrounds 10 %
- Fitting interface of RooFit/pyhf with HAMMER allows for likelihood dependent on WCs and FFs
 - ▶ RooFit-Hammer
 - ▶ pyhf-Hammer
- Goal: determine form factor parameters from data
- Separate fit for BGL, CLN and BLPR (form-factor parameters are floated in the fit)

$B \rightarrow D^* \mu \nu$ form factors

$$\frac{d\Gamma(B \rightarrow D^* \ell \nu)}{dq^2} = \frac{G_F^2 |V_{cb}^2| |\eta_{EW}|^2 |\vec{p}|^2 q^2}{96\pi^3 m_{B0}^2} \left(1 - \frac{m_\ell^2}{q^2}\right) \times \left[(|H_+|^2 + |H_-|^2 + |H_0|^2) \left(1 - \frac{m_\ell}{2q^2}\right) + \frac{3}{2} \frac{m_\ell^2}{q^2} |H_t|^2 \right]$$

- Helicity amplitudes (H_\pm , H_0 and H_t) can be parametrized in terms of functions of q^2 = form factors
- Most general approach is given by Boyd, Grinstein and Lebed (BGL)

Helicity amplitudes in **BGL** ▶ PRL 74 4603 (1995)

$$r = \frac{m_B}{m_{D^*}}$$

$$\omega(q^2) = \frac{m_B^2 + m_{D^*}^2 - q^2}{2m_{D^*}m_B}$$

$$H_\pm(\omega) = f(\omega) \mp m_B m_{D^*} \sqrt{\omega^2 - 1} g(\omega)$$

$$H_0(\omega) = \frac{F_1(\omega)}{\sqrt{q^2}}$$

$$H_t(\omega) = m_B \left(\frac{r\omega^2 - 1}{1 + r^2 - 2r\omega} F_2(\omega) \right)$$

$$f(z) = \frac{1}{P_{1^+}(z)\phi_f(z)} \sum_{n=0}^N b_n z^n$$

$$F_1(z) = \frac{1}{P_{1^+}(z)\phi_{F_1}(z)} \sum_{n=0}^N c_n z^n$$

$$g(z) = \frac{1}{P_{1^-}(z)\phi_g(z)} \sum_{n=0}^N a_n z^n$$

$$F_2(z) = \frac{1}{P_{0^-}(z)\phi_{F_2}(z)} \sum_{n=0}^N d_n z^n$$

- Fit parameters: a_i , b_i , c_i , d_i

$B \rightarrow D^* \mu\nu$ form factors

BLPR FF parametrization

- HQET parametrization for hadronic matrix elements
- Improved calculations by Bernlochner et al. [▶ PRD 95 \(2018\) 115008](#), using both the leading and $O(\Lambda_{QCD}/m_b)$ subleading Isgur-Wise function
- Parameters ρ^2 , $\chi_2(1)$, $\eta(1)$, $\eta'(1)$ and are floated
- $\chi'_3(1)$ is fixed from a prediction in [▶ PRD 95 \(2018\) 115008](#)

$B \rightarrow D^* \mu \nu$ form factors

- The parameterization derived by Caprini, Lellouch and Neubert (CLN) uses dispersion relations and reinforced unitarity bounds based on Heavy Quark Effective Theory (HQET) to reduce the number of free parameters

Helicity amplitudes in **CLN** ▶ Nucl. Phys. B 530 1 (1998)

$$H_{\pm}(\omega) = m_B \sqrt{r}(\omega + 1) h_{A_1}(\omega) \left[1 \mp \sqrt{\frac{\omega - 1}{\omega + 1}} R_1(\omega) \right]$$

$$H_0(\omega) = m_B \sqrt{r}(\omega + 1) \frac{1 - r}{\sqrt{q^2}} h_{A_1}(\omega) \left[1 + \frac{\omega - 1}{1 - r} (1 - R_2(\omega)) \right]$$

$$H_t = \frac{2 |\vec{p}^*|}{\sqrt{1 + r^2 - 2wr}} R_0(\omega) h_{A_1}(\omega) \frac{2\sqrt{m_B m_{D^*}}}{m_B + m_{D^*}}$$

$$h_{A_1}(\omega) = h_{A_1}(1) [1 - 8\rho_{D^*}^2 z(\omega) + (53\rho_{D^*}^2 - 15)z^2(\omega) - (231\rho_{D^*}^2 - 91)z^3(\omega)]$$

$$R_1(\omega) = R_1(1) - 0.12(\omega - 1) + 0.05(\omega - 1)^2$$

$$R_2(\omega) = R_2(1) + 0.11(\omega - 1) + 0.06(\omega - 1)^2$$

$$R_0(\omega) = R_0(1) - 0.11(\omega - 1) + 0.01(\omega - 1)^2$$

- Fit parameters: R_1 , R_2 , ρ^2
- R_0 is fixed from theory predictions to value of 1.15

BGL fit - BGL truncation estimate

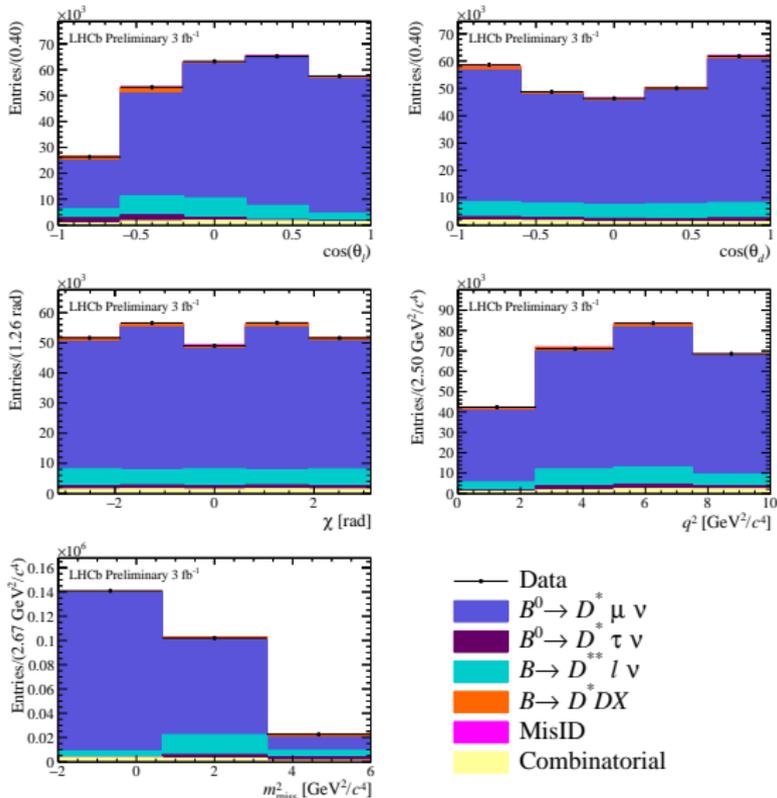
- Use the Bayesian Information Criterion (BIC) to choose between alternative models = choose the order of fitting parameters

$$\text{BIC} = \chi^2 + k \ln(n)$$

k is the number of model parameters
 n is the sample size (number of bins)

- Comparing models involves calculating BIC for each model
- Make all the combinations of fitting parameters: a_i , b_i (b_0 fixed), c_i and shared between $B^0 \rightarrow D^*_{\mu\nu}$ and $B^0 \rightarrow D^*_{\tau\nu}$
- The model with lowest BIC is considered as the nominal model measuring: a_0 , a_1 , b_1 , c_1 and c_2
- To estimate truncation systematic uncertainty one order higher is taken in the a , b and c series
- d_i parameters are fixed from prediction in [JHEP11 \(2017\) 061](#)

$B \rightarrow D^* \mu \nu$ angular analysis: fit projections



▸ LHCb-CONF-2026-001

Form factor results

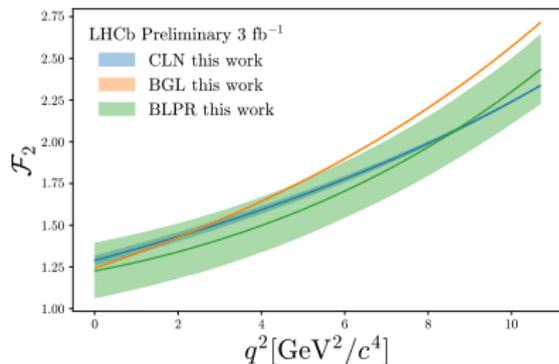
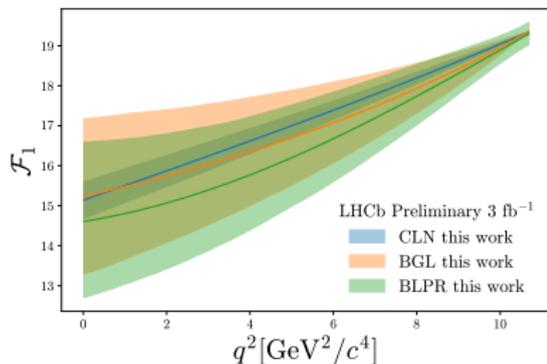
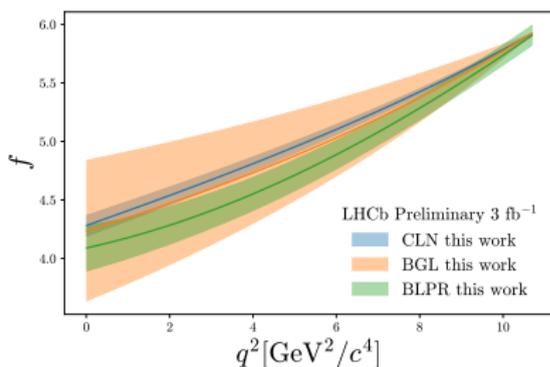
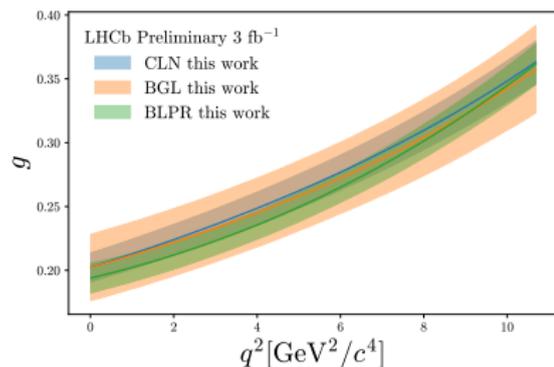
CLN parametrisation						
		Statistical correlations				
		R_1	R_2	ρ^2		
R_1	1.303 ± 0.032 (stat) ± 0.049 (syst)	R_1	1.000	0.66	$-\rho^2$	−0.61
R_2	0.859 ± 0.014 (stat) ± 0.031 (syst)	R_2		1.000		−0.77
ρ^2	1.211 ± 0.020 (stat) ± 0.030 (syst)	ρ^2				1.000

BGL parametrisation							
		Statistical correlations					
		a_0	a_1	b_1	c_1	c_2	
a_0	0.026 ± 0.001 (stat) ± 0.002 (syst)	a_0	1.000	−0.91	0.50	0.35	−0.27
a_1	$−0.039 \pm 0.022$ (stat) ± 0.031 (syst)	a_1		1.000	−0.56	−0.23	0.15
b_1	$−0.008 \pm 0.004$ (stat) ± 0.031 (syst)	b_1			1.000	0.58	−0.48
c_1	$−0.001 \pm 0.001$ (stat) ± 0.007 (syst)	c_1				1.000	−0.97
c_2	0.019 ± 0.026 (stat) ± 0.026 (syst)	c_2					1.000

BLPR parametrisation							
		Statistical correlations					
		$\bar{\rho}_*^2$	$\chi_2(1)$	$\chi_2'(1)$	$\eta(1)$	$\eta(1)'$	
$\bar{\rho}_*^2$	1.28 ± 0.03 (stat) ± 0.04 (syst)	$\bar{\rho}_*^2$	1.000	−0.28	−0.68	−0.27	0.83
$\chi_2(1)$	$−0.11 \pm 0.12$ (stat) ± 0.29 (syst)	$\chi_2(1)$		1.000	0.11	−0.68	−0.33
$\chi_2'(1)$	0.38 ± 0.18 (stat) ± 0.20 (syst)	$\chi_2'(1)$			1.000	0.32	−0.85
$\eta(1)$	0.43 ± 0.14 (stat) ± 0.36 (syst)	$\eta(1)$				1.000	−0.38
$\eta(1)'$	$−0.52 \pm 0.52$ (stat) ± 0.47 (syst)	$\eta(1)'$					1.000

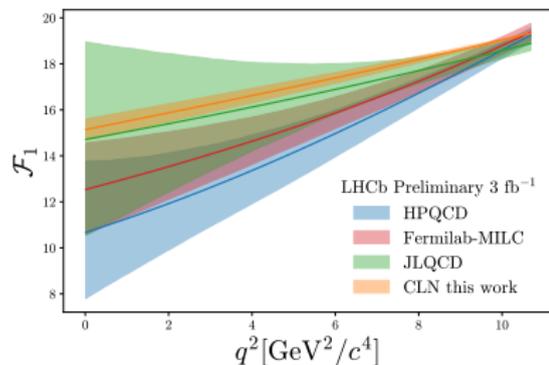
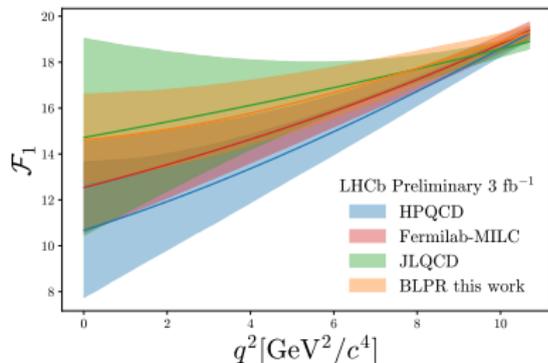
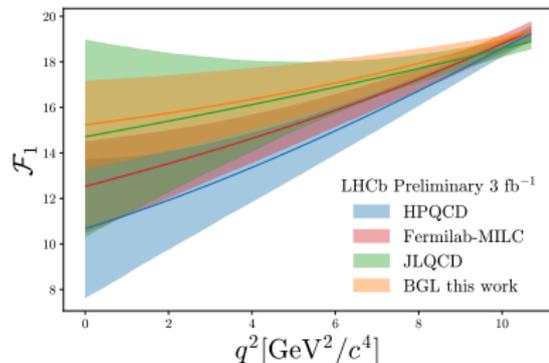
Largest systematic uncertainties: template statistics, simulation corrections and BGL truncation

Form factor results



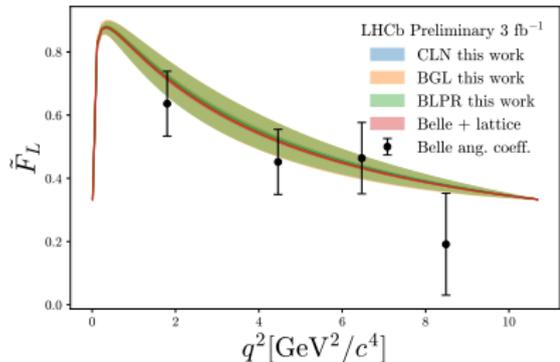
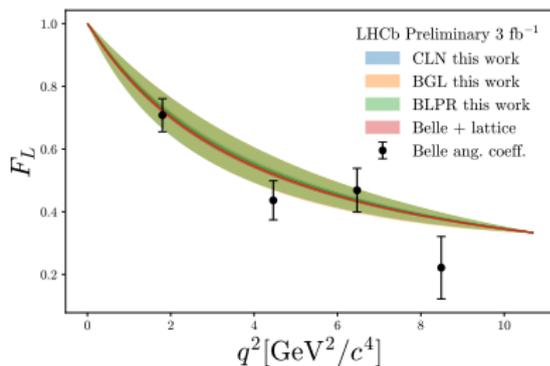
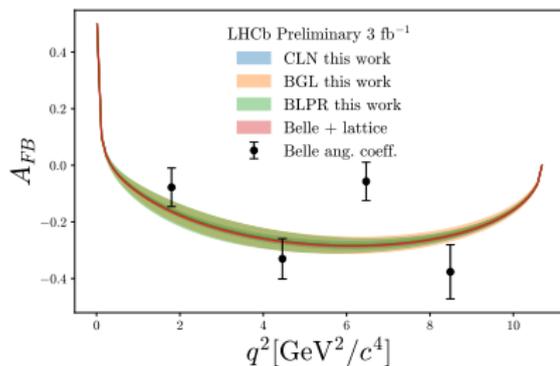
Form factor results from this work compatible among each other

Form factor results: comparison with lattice



- Compatible results with lattice determinations achieving improved precision
- Best precision achieved in CLN
- Only \mathcal{F}_1 shown (others in backup)
- We will provide full correlations for further use in the paper

FF results: angular observables



- In agreement with:
 - Belle angular coefficient measurement (black markers)
▶ PRL 133 (2024) 131801
 - BLPR prediction containing lattice and Belle data
▶ PRD 95 (2018) 115008

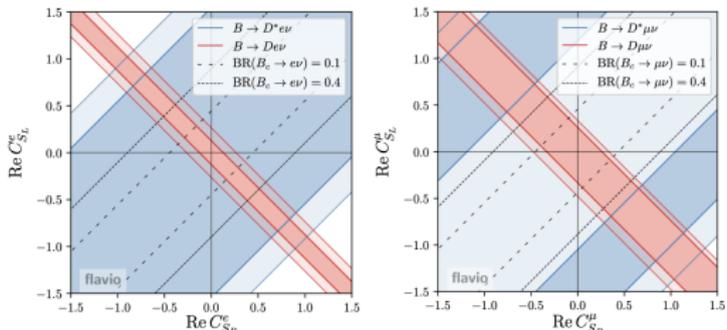
$B^0 \rightarrow D^{*\mu\nu}$ angular analysis: WCs + FFs

WCs fit with BLPR

- Plan to report several configurations:
 - Fitting one NP operator at a time (vector, scalar or tensor)
 - Fit combination of real only parts (scalar, vector or tensor)
 - Reparameterise the multi WC case into

$$C_V^I = C_{V_R}^I + C_{V_L}^I, \quad C_A^I = C_{V_R}^I - C_{V_L}^I, \quad C_P^I = C_{S_R}^I - C_{S_L}^I, \quad C_T^I,$$

- Fix one imaginary part since the overall phase is not observable



► Eur. Phys. J. C (2021) 81:984

► arXiv:1801.01112

Summary and prospects

- Still a 3.8σ tension with the SM predictions of LFU ratios
- First measurement from LHCb on form factor parameters using $B^0 \rightarrow D^* \mu \nu$
- LHCb has an ongoing effort in angular analyses in each of the channels measuring: angular coefficients, CP observables, Wilson coefficients and CKM parameters with various channels:
 $B_{(s)} \rightarrow D^{(*)} \ell \nu$, $\Lambda_b \rightarrow \Lambda_c \mu \nu$, $B \rightarrow \pi \pi \mu \nu$, $B \rightarrow K \mu \nu$
- LFU ratios in progress: $R(D_{(s)}^{(*)})$, $R(J/\psi)$, $R(\Lambda_c)$

Experiment	LHCb	Belle II	LHCb	Belle II
Assumed data sample	50 fb^{-1}	10 ab^{-1}	300 fb^{-1}	50 ab^{-1}
Semileptonic B decays				
$ V_{ub} $	2%	1.5%	1%	1.2%
$ V_{cb} $	—	1.0%	—	1.0%
$R(D)$, $R(D^*)$	4.4%, 3.2%	3.0%, 1.8%	3.5%, 3.0%	1.4%, 1.0%

▶ [arXiv:2503.24346](https://arxiv.org/abs/2503.24346)

- LHCb collected lot of data in Run 3: analyses started exploiting this

Thank you!

BACKUP

Form factor results: angular observables

From the results we can calculate standard angular observables:

- Forward-backward asymmetry:

$$A_{FB}(q^2) = \frac{\int_0^1 \frac{d^2\Gamma}{dq^2 d\cos\theta_\ell} d\cos\theta_\ell - \int_{-1}^0 \frac{d^2\Gamma}{dq^2 d\cos\theta_\ell} d\cos\theta_\ell}{\frac{d\Gamma}{dq^2}} =$$

$$\frac{3}{2} \frac{(J_{6c} - 2J_{6s})}{3J_{1c} - J_{2c} + 2(3J_{1s} - J_{2s})}$$

- Longitudinal polarisation of D^*

$$F_L^{D^*}(q^2) = \frac{d\Gamma_L/dq^2}{d\Gamma/dq^2} = \frac{3J_{1c} - J_{2c}}{3J_{1c} - J_{2c} + 2(3J_{1s} - J_{2s})}$$

- Transverse polarisation of the lepton

$$\tilde{F}_L(q^2) = \frac{\frac{d\Gamma(\lambda=+1/2)}{dq^2} - \frac{d\Gamma(\lambda=-1/2)}{dq^2}}{\frac{d\Gamma}{dq^2}} = \frac{J_{1c} - 3J_{2c} + 2(J_{1s} - 3J_{2s})}{3J_{1c} - J_{2c} + 2(3J_{1s} - J_{2s})}$$

Form factor results

Largest systematic uncertainties: template statistics, simulation corrections and BGL truncation

Systematic source	CLN			BGL					BLPR				
	R_1	R_2	ρ^2	a_0	a_1	b_1	c_1	c_2	ρ_2^2	$\chi_2(1)$	$\chi_4(1)$	$\eta(1)$	$\eta(1)'$
Simulation sample size	0.013	0.012	0.016	<0.001	0.019	0.004	0.001	0.022	0.024	0.087	0.15	0.10	0.42
Simulation corrections	0.047	0.029	0.018	0.002	0.010	0.030	0.004	0.005	0.025	0.27	0.15	0.34	0.18
BGL truncation	-	-	-	<0.001	0.017	0.006	<0.001	0.004	-	-	-	-	-
Fixed d_i parameters	-	-	-	<0.001	0.005	<0.001	<0.001	0.009	-	-	-	-	-
Fixed b_0 parameter	-	-	-	<0.001	0.003	<0.001	<0.001	0.004	-	-	-	-	-
Fixed R_0 parameter	0.001	0.001	0.003	-	-	-	-	-	-	-	-	-	-
Fixed χ_1^2 parameter	-	-	-	-	-	-	-	-	<0.001	0.034	0.016	0.018	0.090
MisID model	0.004	0.001	0.001	<0.001	0.016	<0.001	<0.001	0.010	0.001	0.018	0.003	0.032	0.005
Physics bkg. model	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002	0.002	0.006
Coulomb correction	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.002	0.005	0.006
Total systematic	0.049	0.031	0.030	0.002	0.031	0.031	0.007	0.026	0.04	0.29	0.21	0.36	0.47
Stat. uncertainty	0.032	0.014	0.020	0.001	0.022	0.004	0.001	0.026	0.03	0.12	0.18	0.14	0.52

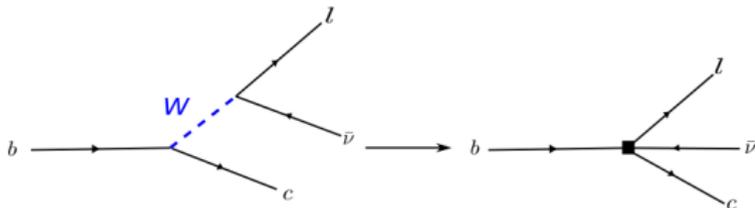
New Physics

- We can use operators with unknown coupling constants and write them in an effective Hamiltonian

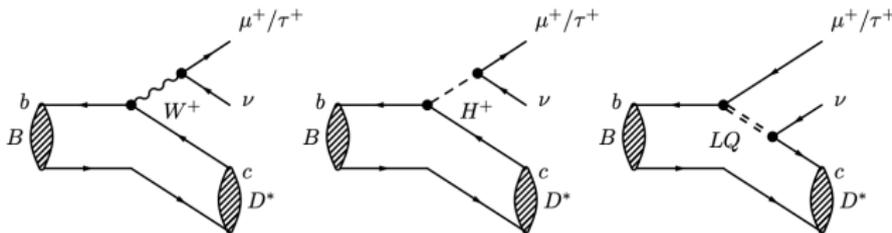
$$H_{\text{eff}} = \frac{G_F}{\sqrt{2}} V_{cb} \sum C_i O_i$$

$$C_i = C_i^{\text{SM}} + C_i^{\text{NP}}$$

- C_i^{NP} are the Wilson coefficients that describe the New Physics effects
- O_i are effective operators that can be a vector, scalar or tensor type



Any discrepancy could be a clear sign of New Physics (NP)



HAMMER

- Tool that weights a MC sample from the generation amplitude to a new desired one [▶ Hammer](#) [▶ arXiv:2002.00020v2](#)

Theoretical approach

The decay rate ($B \rightarrow Xl\nu_l$):

$$\frac{d\Gamma}{dq^2} = \frac{G_F^2}{(2\pi)^3} V_{ij}^2 \frac{(q^2 - m_l^2)^2 p_X}{12m_B^2 q^2} (H_+^2(q^2) + H_-^2(q^2) + H_0^2(q^2)(1 + \frac{m_l^2}{2q^2}) + \frac{3}{2} \frac{m_l^2}{2q^2} H_s^2(q^2))$$

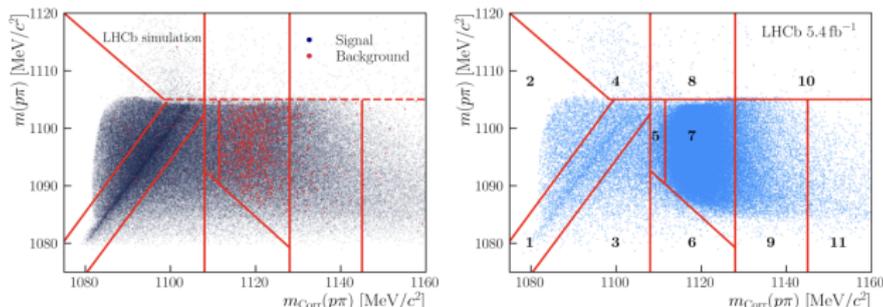
where $H_i(q^2)$ are the helicity amplitudes.

Reweighting to New Physics scenarios, e.g. by adding extra scalar, vector or tensor couplings can be done with the weight vector for each event calculated as:

$$\omega_i = \frac{\Gamma_{old}}{\Gamma_{new}} \frac{d^n \Gamma_{new} / dx}{d^n \Gamma_{old} / dx}$$

where Γ_{old} is the decay rate for the model implemented in simulation and Γ_{new} is the the decay rate for updated model

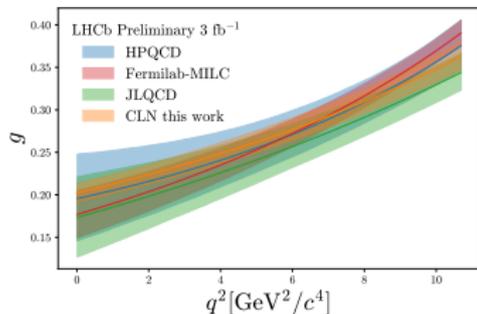
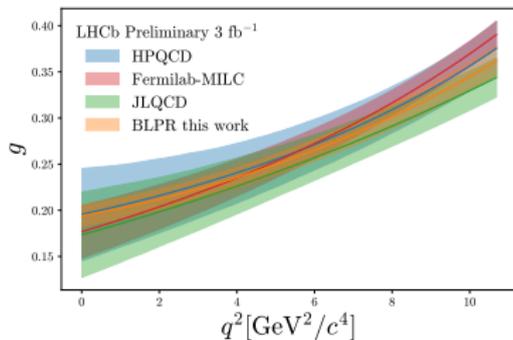
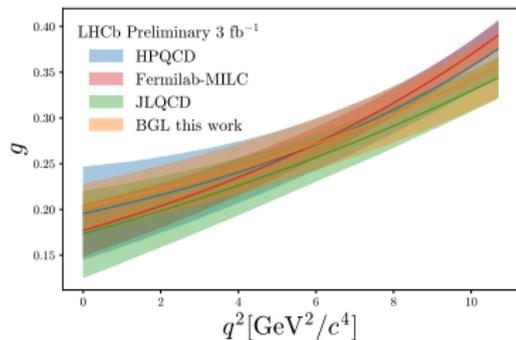
BF measurement of $\Lambda \rightarrow p\mu\nu$



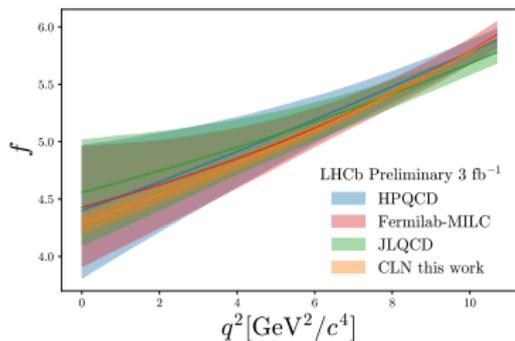
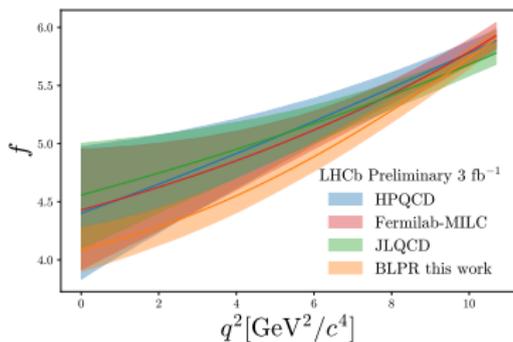
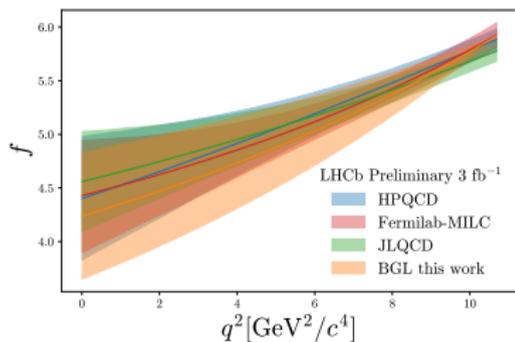
Systematic uncertainties

Source	Relative Uncertainty [%]
$\mathcal{B}(\Lambda \rightarrow p\pi^-)$	0.8
Correction PID efficiencies	3.5
Binning PID signal correction	1.6
Binning PID norm. correction	1.0
Correction tracking efficiencies	1.6
Intrinsic tracking uncertainty	1.8
$\Lambda \rightarrow p\mu^- \bar{\nu}_\mu$ yield (fit binning)	3.9
Correction trigger efficiencies	3.0
Simulation truth matching	0.7
Total	6.8

FF results: comparison with lattice



FF results: comparison with lattice



FF results: comparison with lattice

