



Flavour anomalies overview

On the intriguing set of discrepancies with the SM

Rafael Silva Coutinho

Syracuse University

Snowmass Community Summer Study workshop

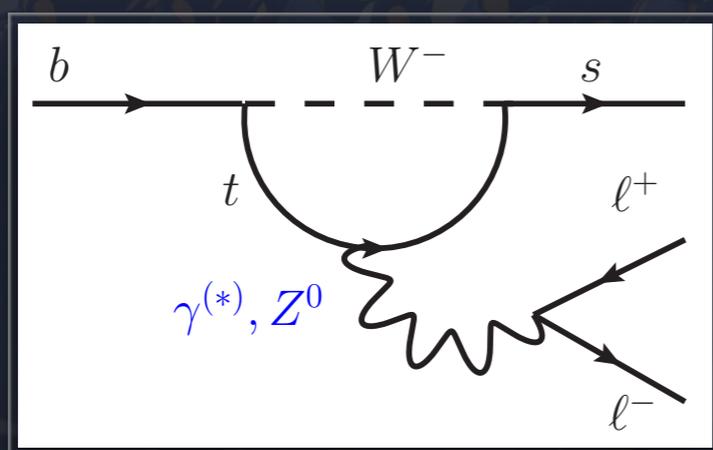
July 21st, 2022



OUTLINE

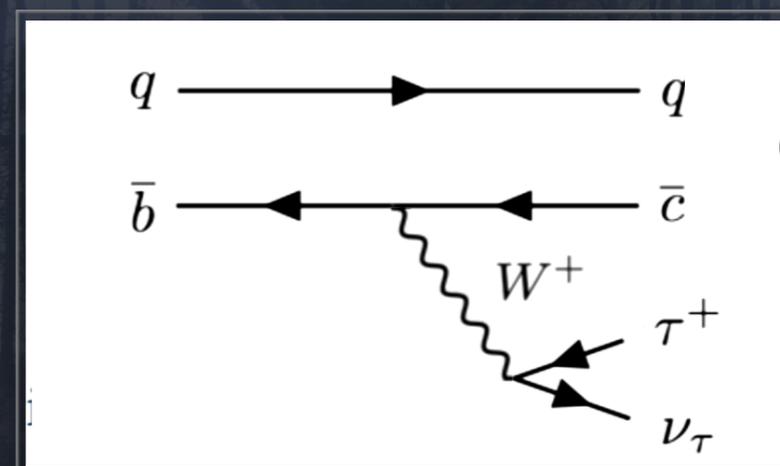
$$[b \rightarrow sl^+l^-]$$

- “RARE” DECAYS (DECAY RATE $< 10^{-6}$)
 - ▶ FORBIDDEN AT TREE-LEVEL, DOMINATED BY PENGUIN OR BOX SM DIAGRAM
 - ▶ HEAVY NP COULD BE SAME ORDER AS SM



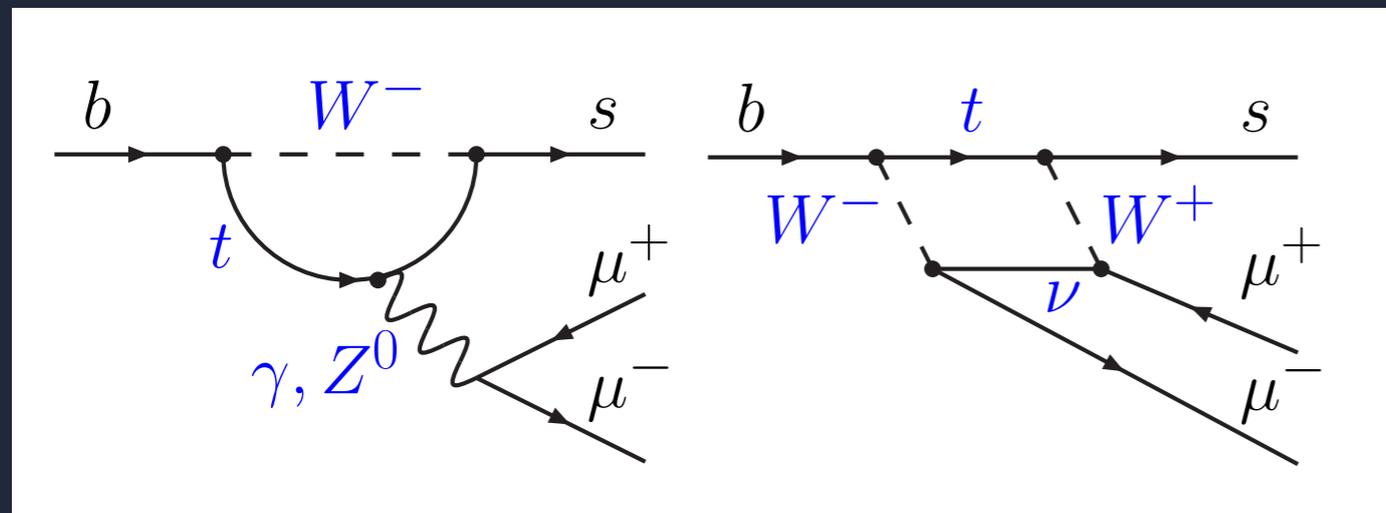
$$[b \rightarrow cl\nu_l]$$

- “SEMILEPTONIC” DECAYS (DECAY RATE $\sim 10\%$)
 - ▶ TREE-LEVEL TRANSITIONS
 - ▶ LEPTON UNIVERSALITY TESTS



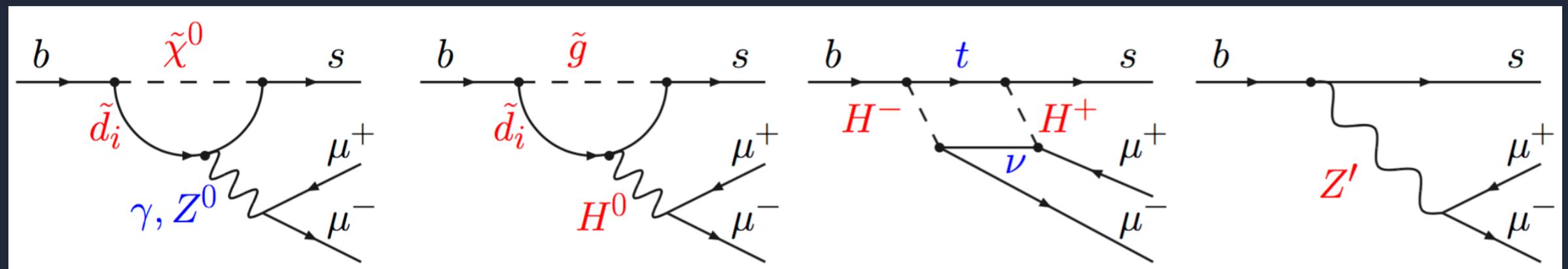
RARE DECAYS AS A PROBE OF NEW PHYSICS

FCNC: UNIQUE GLIMPSE TO HIGHER SCALE



[E.G. ENHANCEMENT/SUPPRESSION OF DECAY RATE, ANGULAR DISTRIBUTIONS AND NEW SOURCES OF ~~CP~~]

NEW PARTICLES CAN CONTRIBUTE AT LOOP AND/OR TREE LEVEL



RARE DECAYS AS A PROBE OF NEW PHYSICS

RARE B DECAYS ARE A MULTI-SCALE PROBLEM: $\Lambda_{\text{NP}}^2 \gg m_W \gg m_b > \Lambda_{\text{QCD}}$

FCNC EFFECTIVE HAMILTONIAN DESCRIBED AS OPE

WILSON COEFFICIENTS
("EFFECTIVE COUPLING")

$$\mathcal{H}_{\text{eff}} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_i C_i \mathcal{O}_i$$

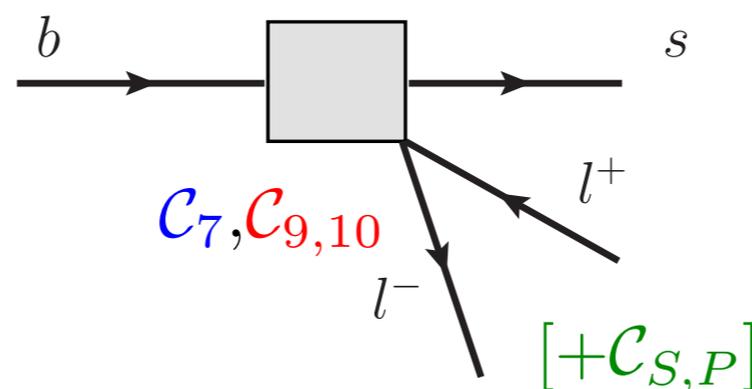
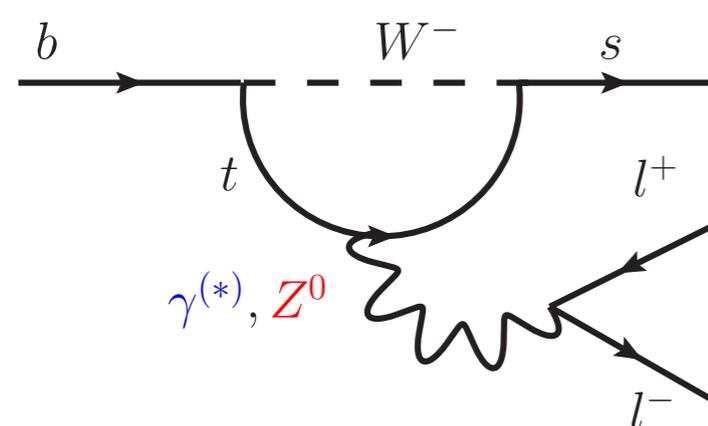
LOCAL OPERATOR

$i = 1, 2$	Tree
$i = 3 - 6, 8$	Gluon penguin
$i = 7$	Photon penguin
$i = 9, 10$	Electroweak penguin
$i = S$	Higgs (scalar) penguin
$i = P$	Pseudoscalar penguin

FLAVOUR-VIOLATING COUPLING

$$\Delta \mathcal{H}_{\text{NP}} = \frac{\kappa}{\Lambda_{\text{NP}}^2} \mathcal{O}_i$$

NP SCALE



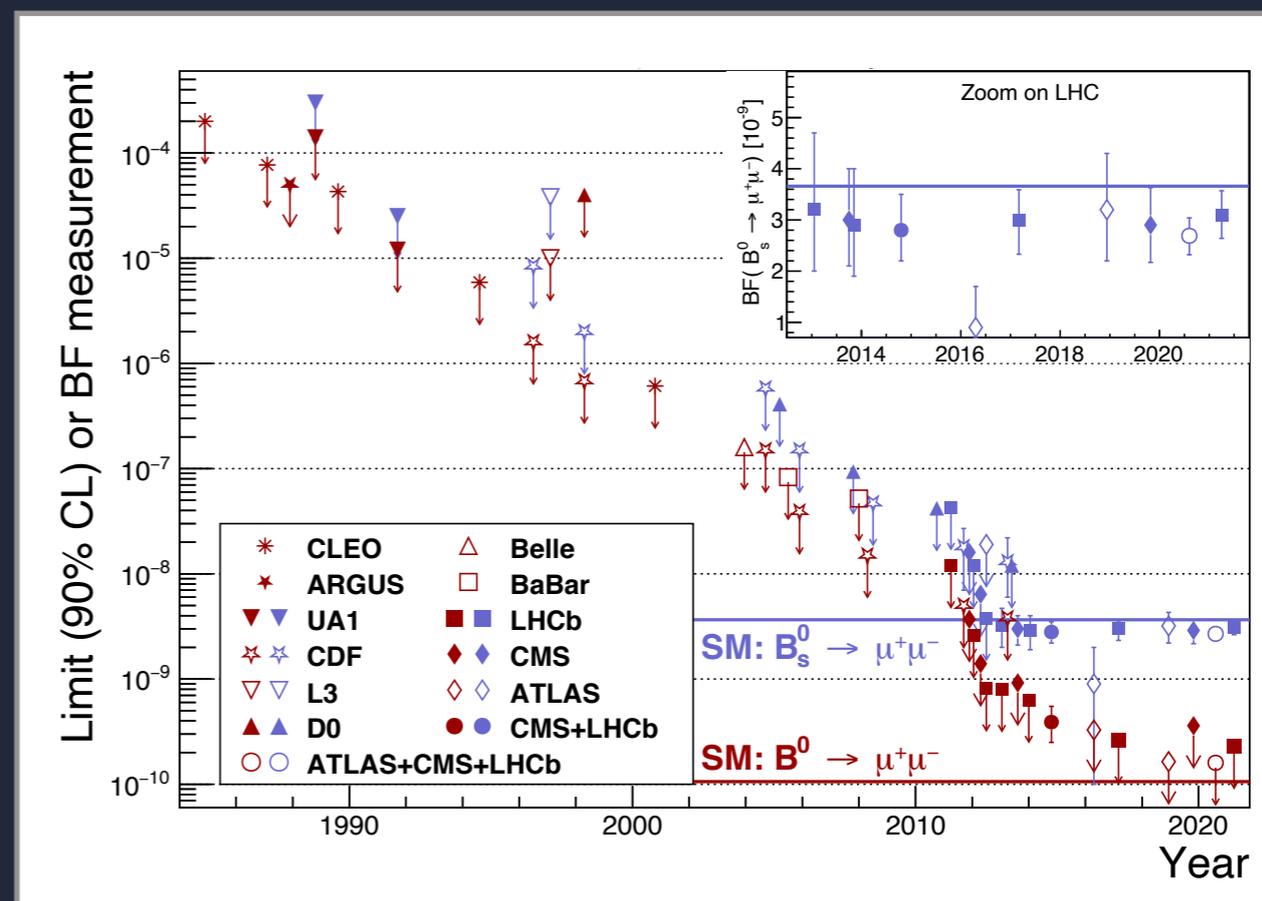
- $B_{(s)}^0 \rightarrow l^+ l^-$
[C_{10}, C_S, C_P]
- $b \rightarrow s l^+ l^-$
[C_7, C_9, C_{10}]

$$B_{(s)}^0 \rightarrow \mu^+ \mu^-$$



“The” very rare decay, FCNC and helicity suppressed in SM

A 30 years endeavour



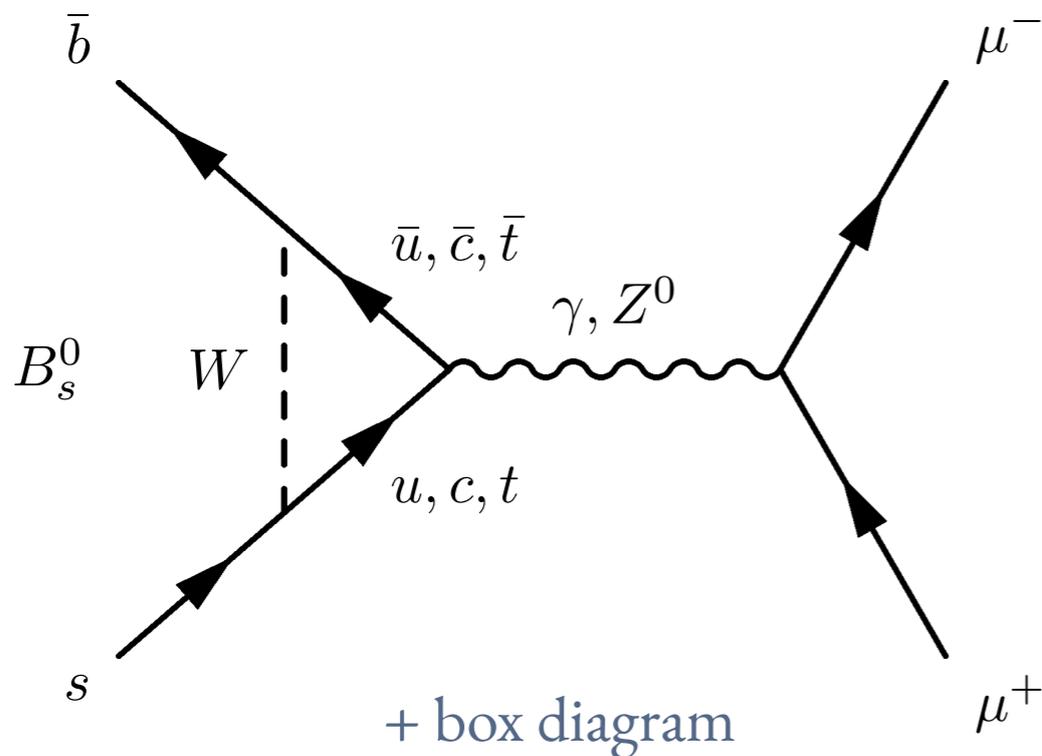
$B^0_{(s)} \rightarrow \mu^+\mu^-$ DECAYS

CLEAN THEORETICAL PREDICTIONS

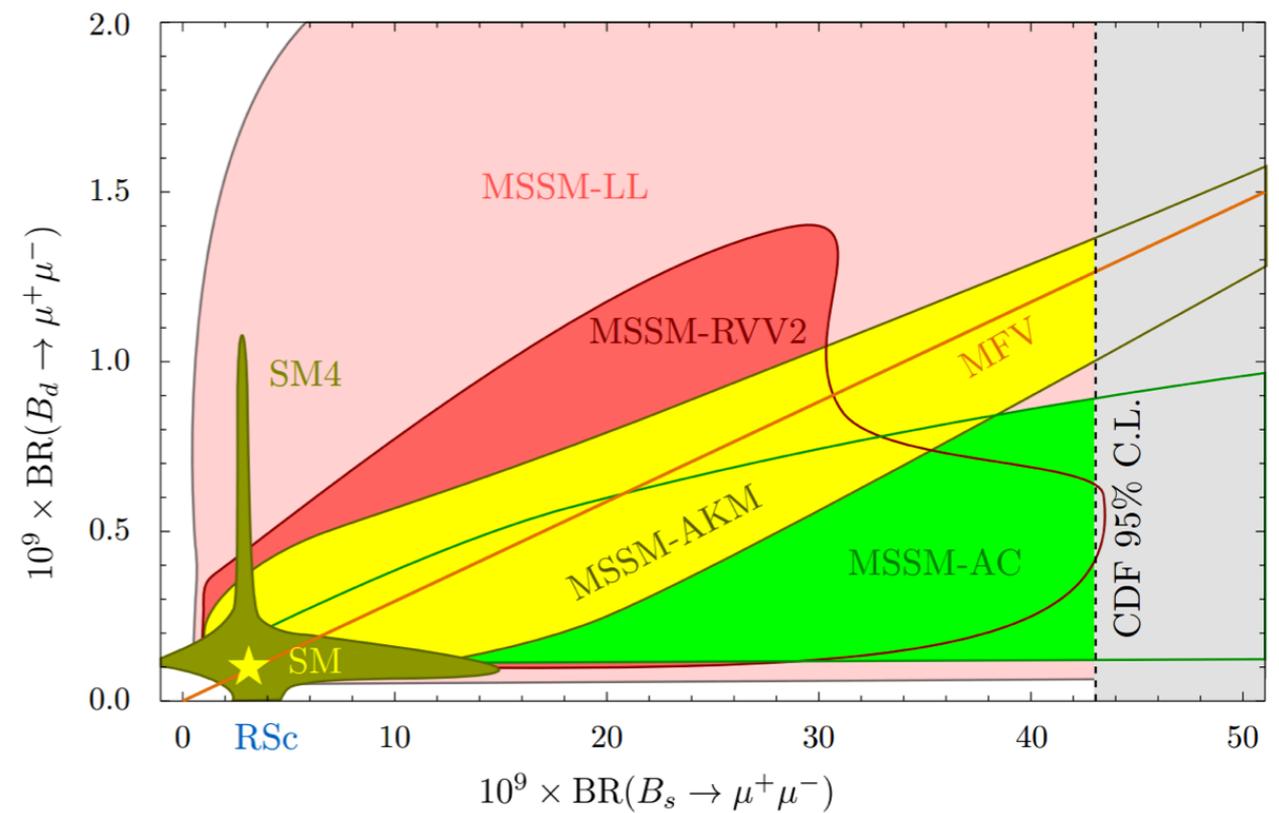
$$B(B_s^0 \rightarrow \mu^+\mu^-) = (3.66 \pm 0.14) \times 10^{-9}$$

$$B(B^0 \rightarrow \mu^+\mu^-) = (1.03 \pm 0.05) \times 10^{-10}$$

[JHEP 10 (2019) 232]



[Nuovo Cim.C 035N1 (2012) 249]



STRINGENT CONSTRAINTS ON
THE NEW PHYSICS PHASE SPACE

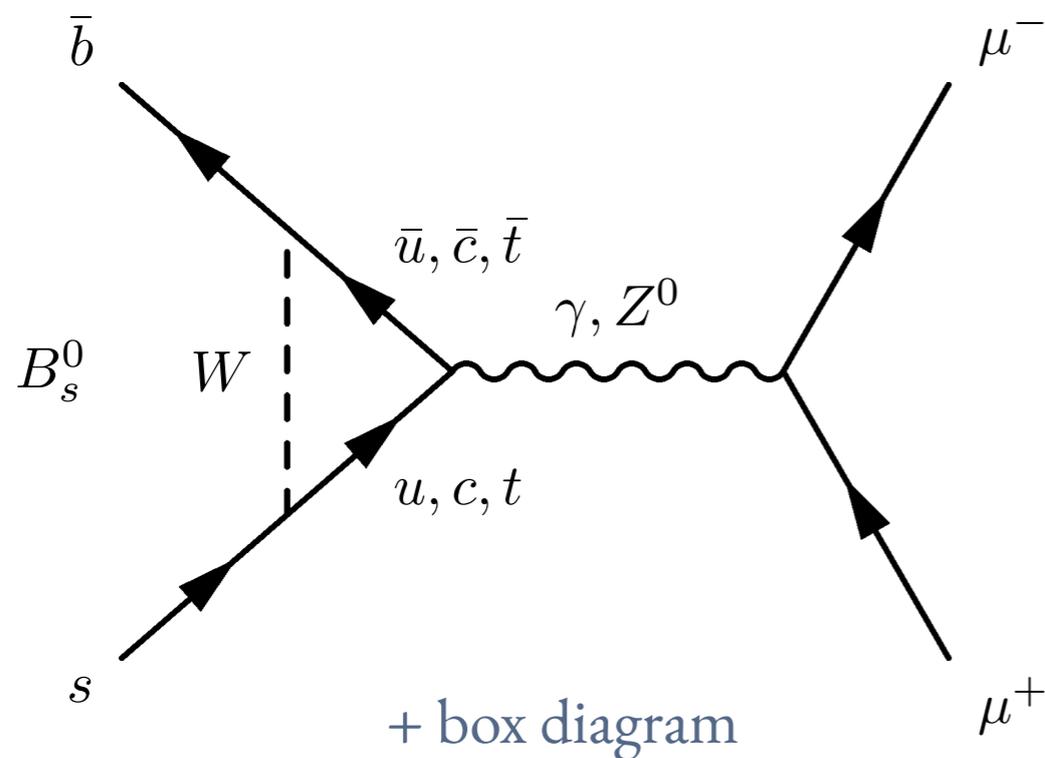
$B^0_{(s)} \rightarrow \mu^+\mu^-$ DECAYS

CLEAN THEORETICAL PREDICTIONS

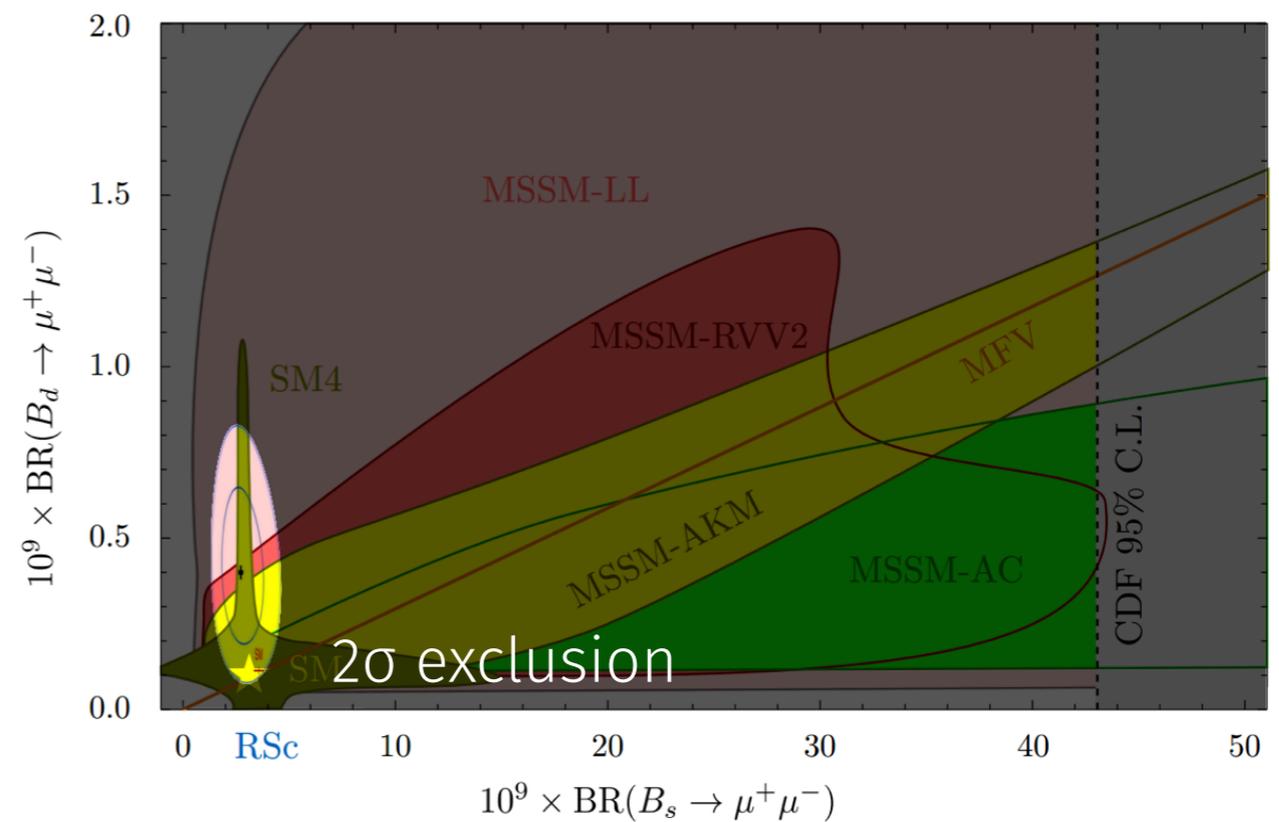
$$B(B_s^0 \rightarrow \mu^+\mu^-) = (3.66 \pm 0.14) \times 10^{-9}$$

$$B(B^0 \rightarrow \mu^+\mu^-) = (1.03 \pm 0.05) \times 10^{-10}$$

[JHEP 10 (2019) 232]



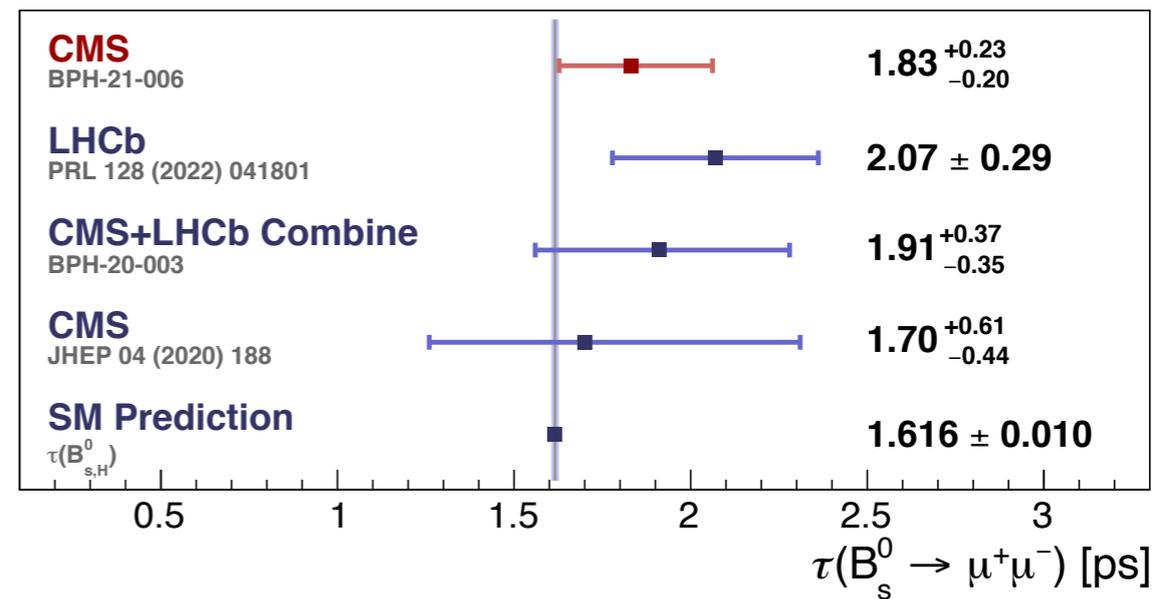
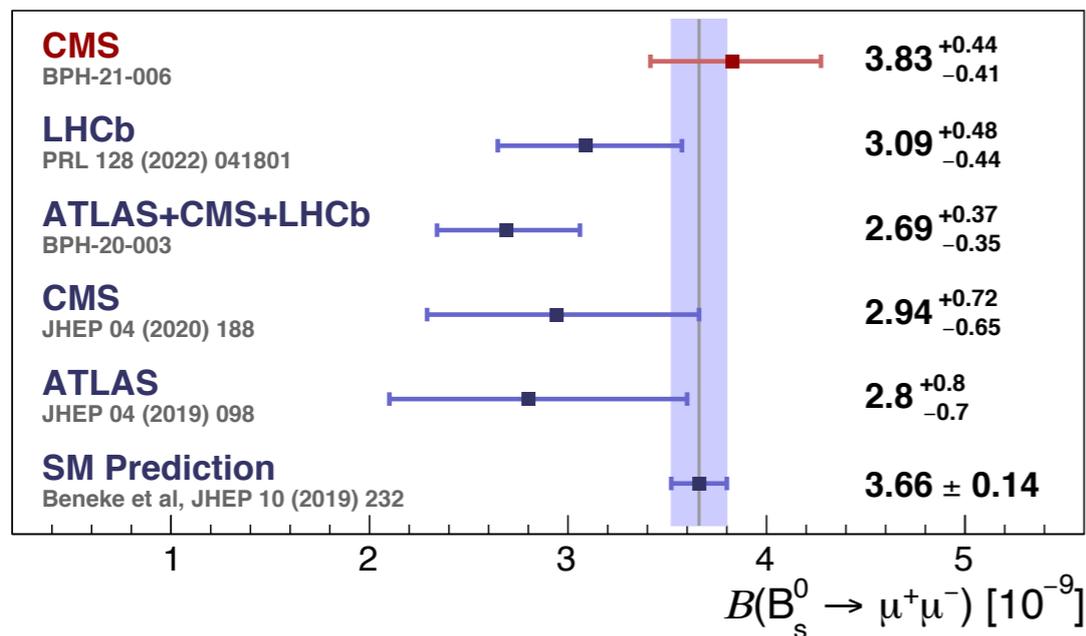
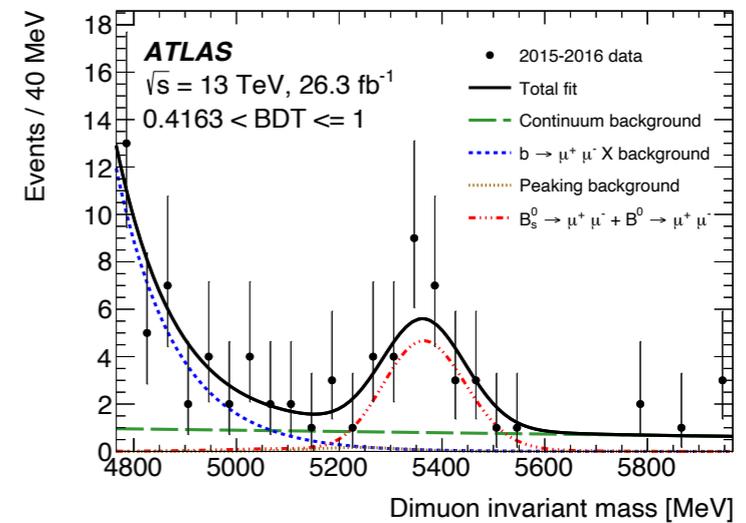
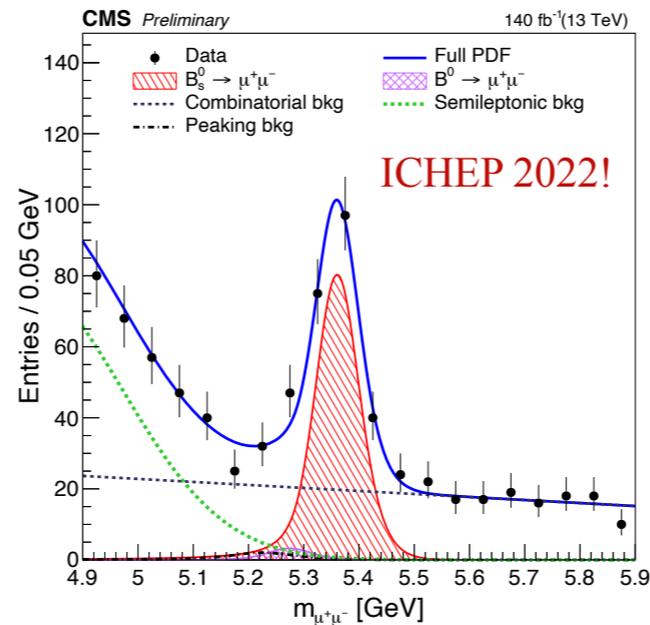
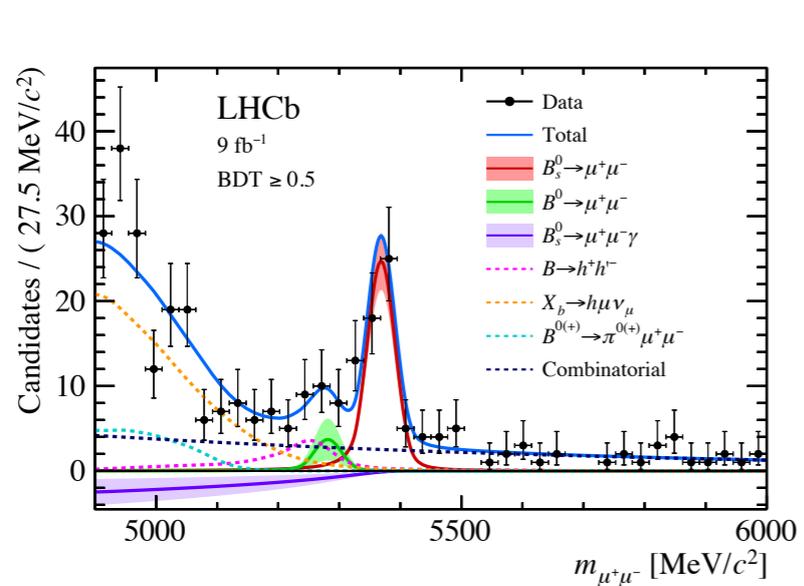
[Nuovo Cim.C 035N1 (2012) 249]



STRINGENT CONSTRAINTS ON
THE NEW PHYSICS PHASE SPACE

$B^0_{(s)} \rightarrow \mu^+\mu^-$ DECAYS

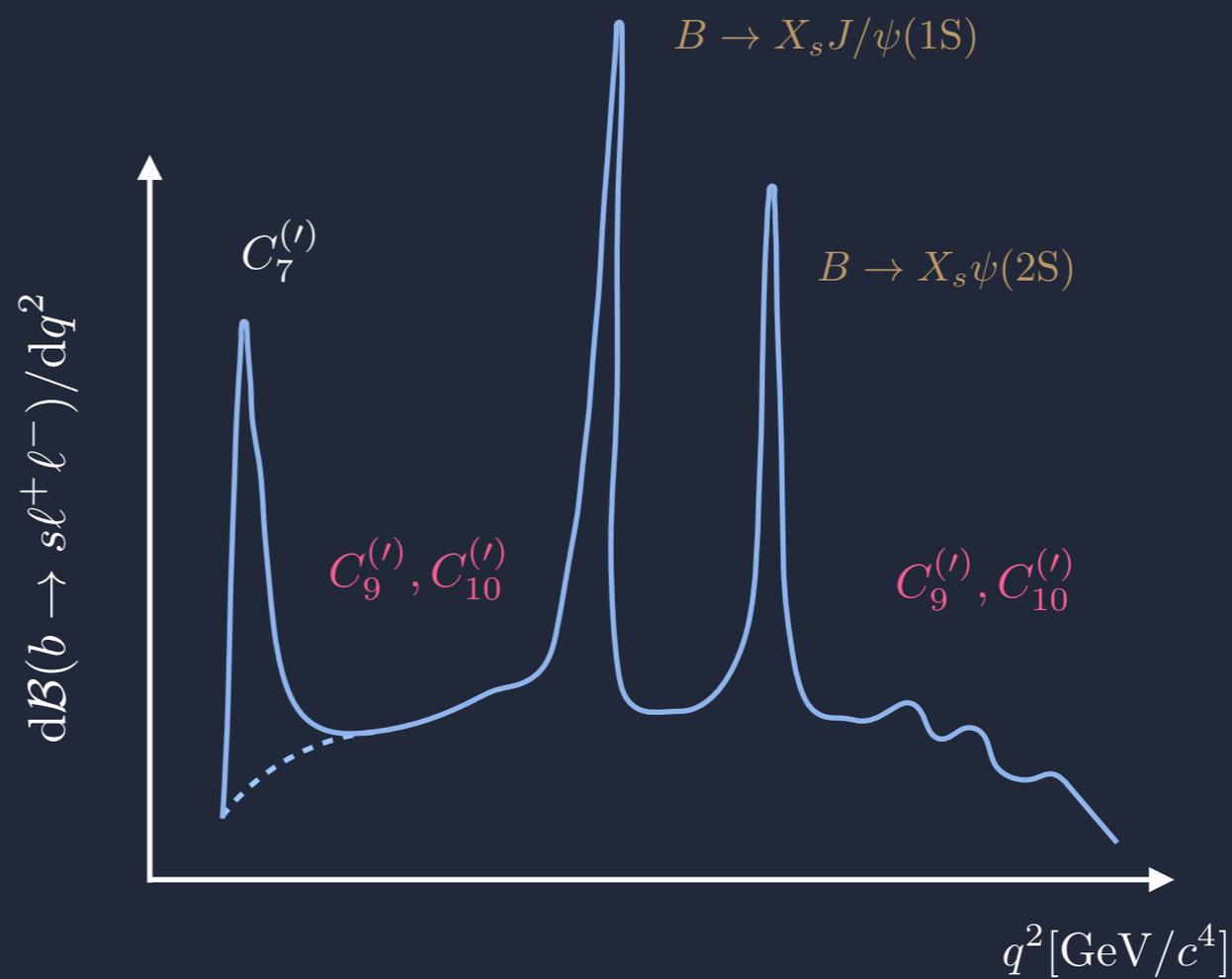
[PRL 128 (2022) 4, 041801, CMS-PAS-BPH-21-006, ATLAS-CONF-2020-049]



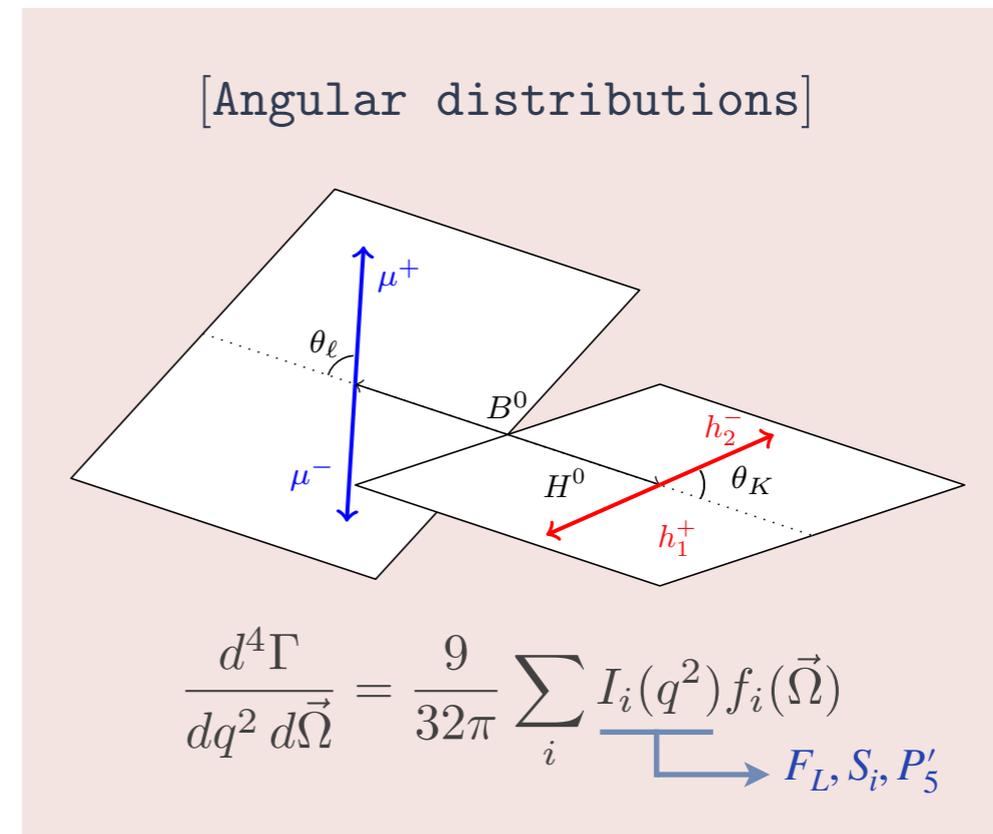
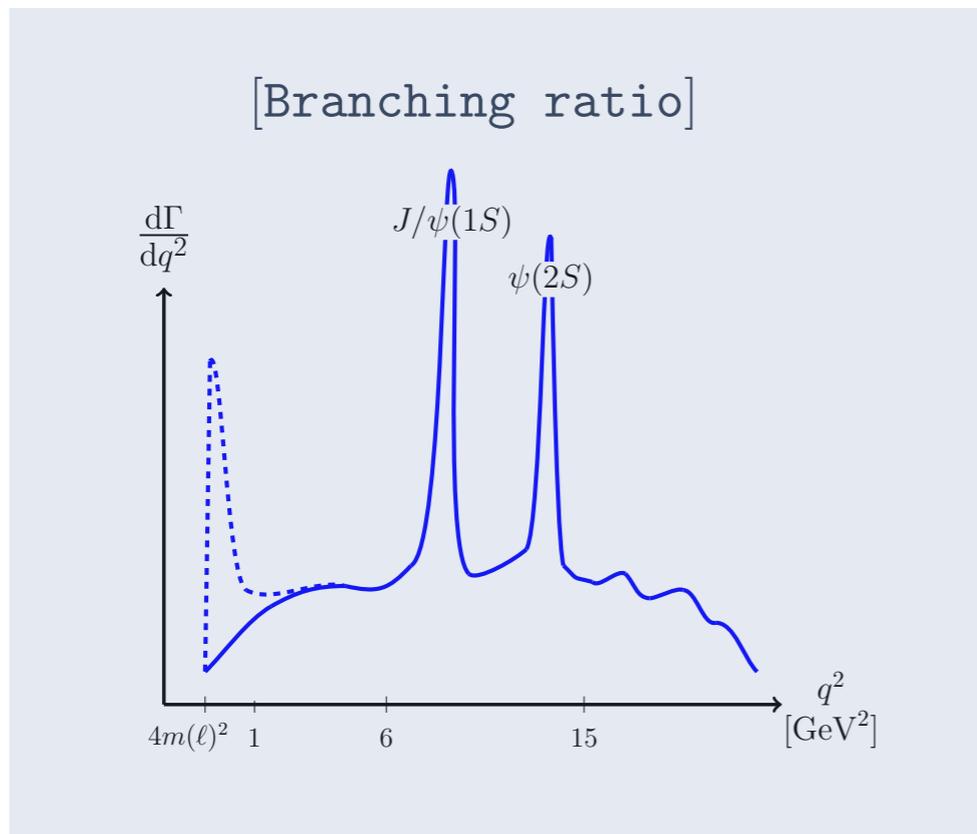
$$b \rightarrow s\mu^+\mu^-$$



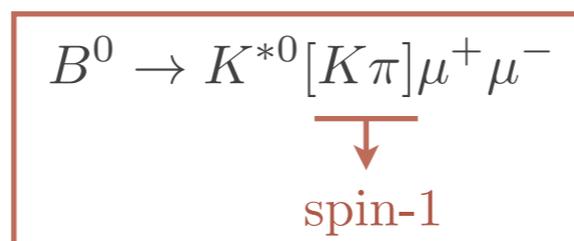
The branching ratio/angular “anomalies”



THE FLAVOUR ANOMALIES IN $b \rightarrow s \mu^+ \mu^-$



HIGHER THEORY
UNCERTAINTIES



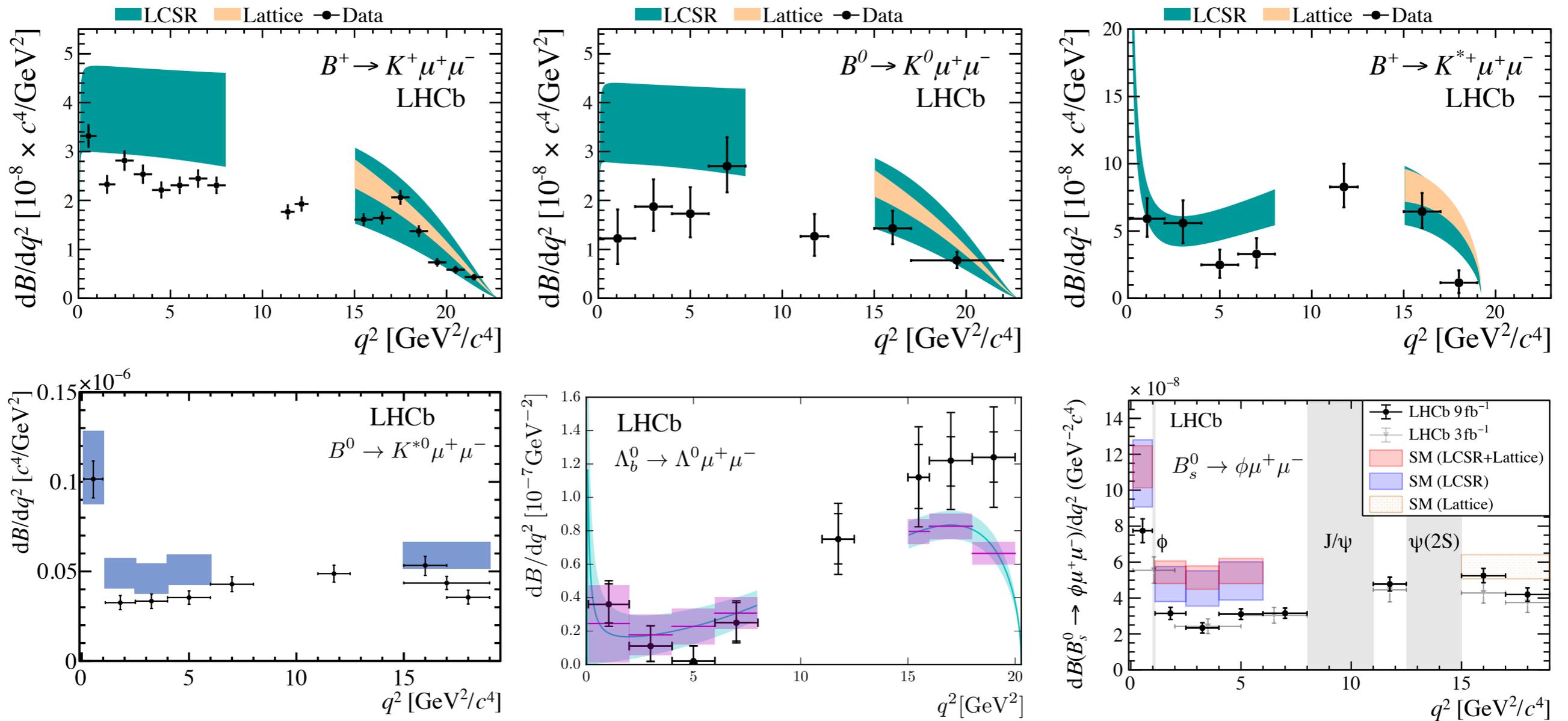
LOWER THEORY
UNCERTAINTIES

$$\mathcal{A}_\lambda^{(\ell) L,R} = \mathcal{N}_\lambda^{(\ell)} \left\{ (C_9^{(\ell)} \mp C_{10}^{(\ell)}) \mathcal{F}_\lambda(q^2) + \frac{2m_b M_B}{q^2} \left[C_7^{(\ell)} \mathcal{F}_\lambda^T(q^2) - 16\pi^2 \frac{M_B}{m_b} \mathcal{H}_\lambda(q^2) \right] \right\}$$

$b \rightarrow s\mu^+\mu^-$ DECAY RATES



[LHCb, JHEP 06 (2014) 133, 11 (2016) 047, 06 (2015) 115, PRL 127 (2021) 151801]



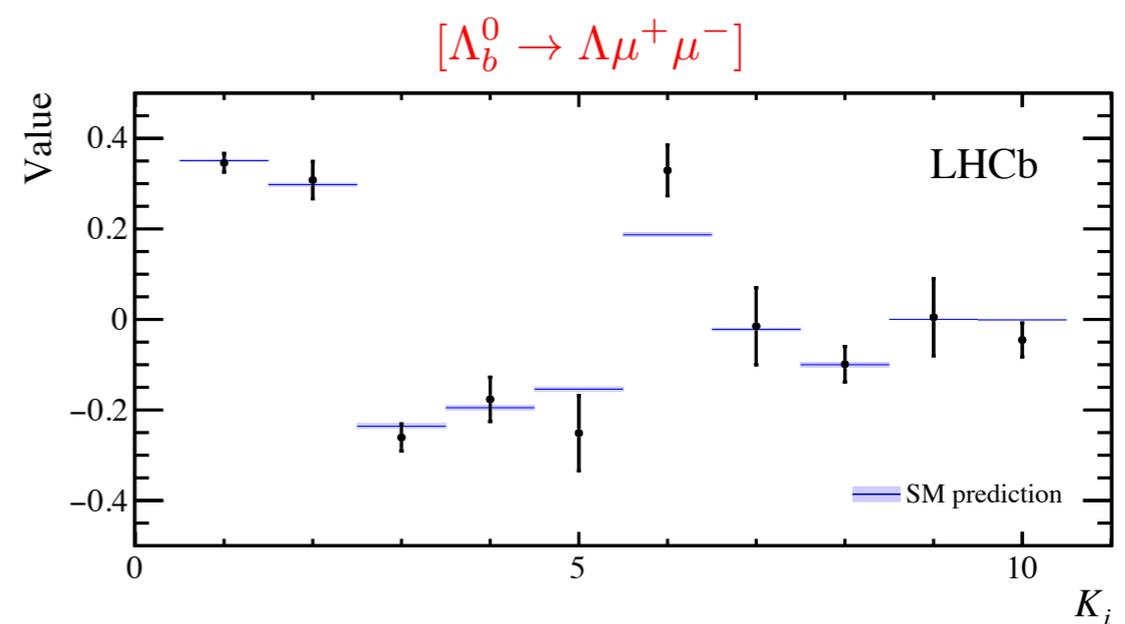
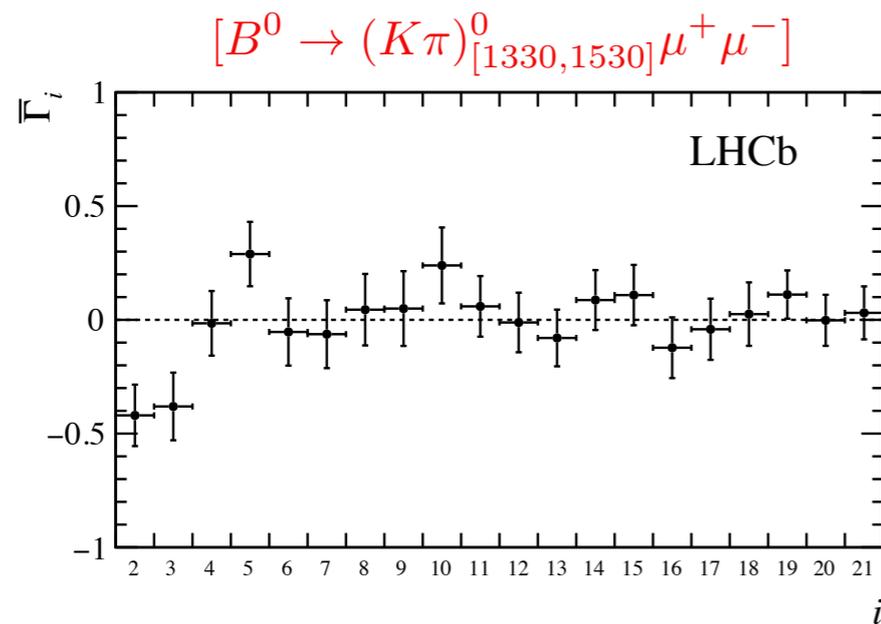
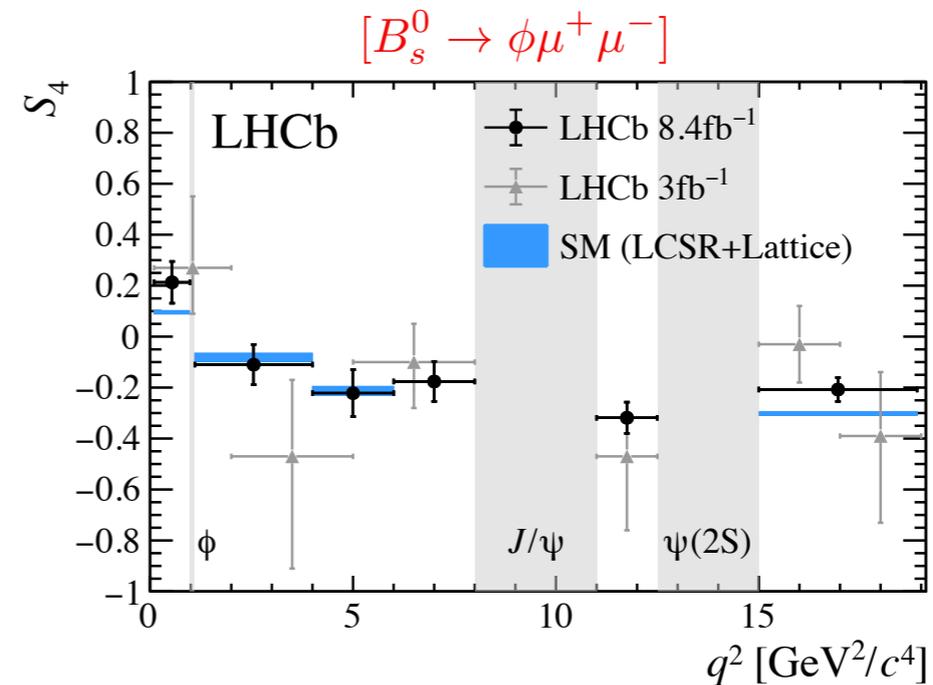
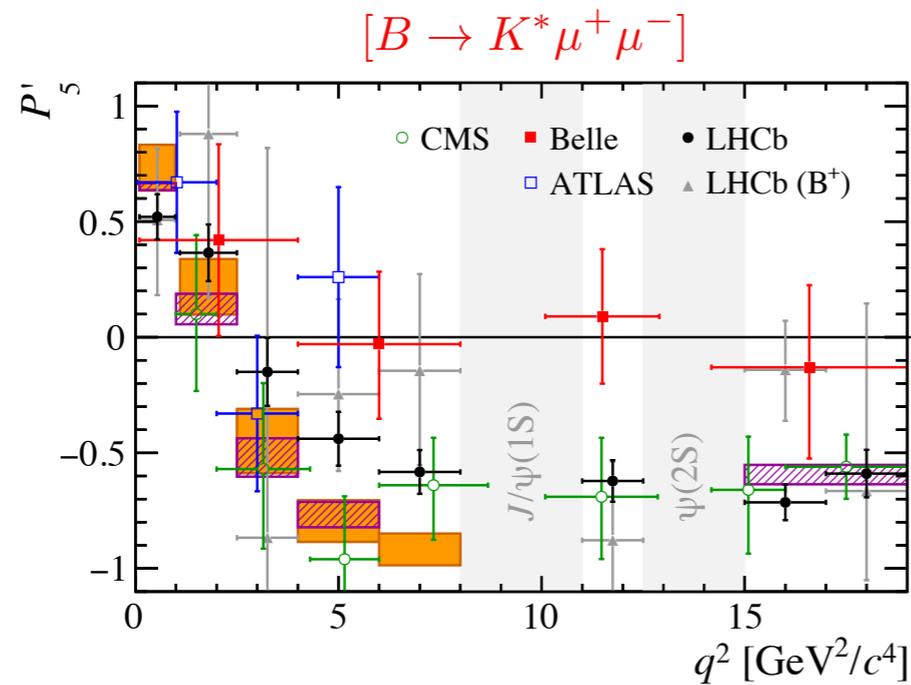
$b \rightarrow s\mu\mu$ DECAY RATES SYSTEMATICALLY BELOW THE SM PREDICTIONS



$b \rightarrow s\mu^+\mu^-$ ANGULAR ANALYSIS



[LHCb, PRL 125 (2020) 011802, 126 (2021) 161802, JHEP 11 (2021) 043, 12 (2016) 065, 09 (2018) 146]
 [Belle, PRL 118 (2017) 11, 111801, ATLAS, JHEP 10 (2018) 047, CMS, PLB 781 (2018) 517]



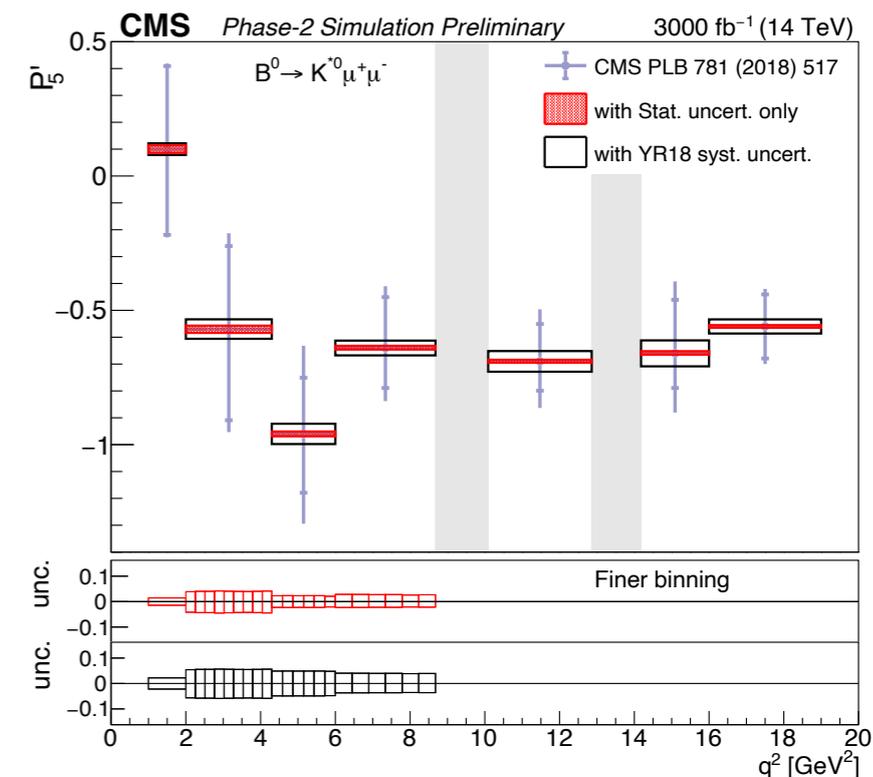
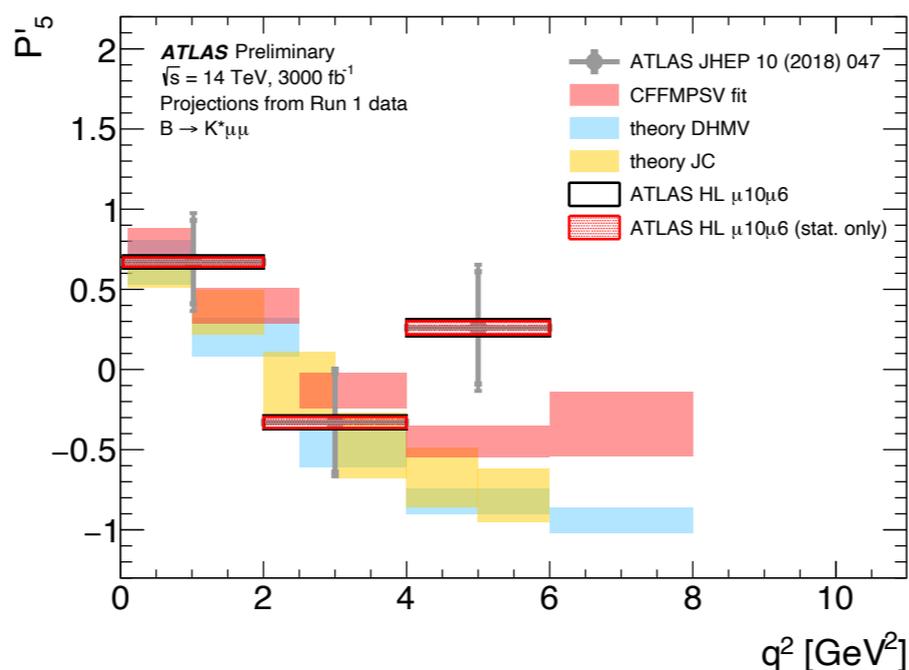
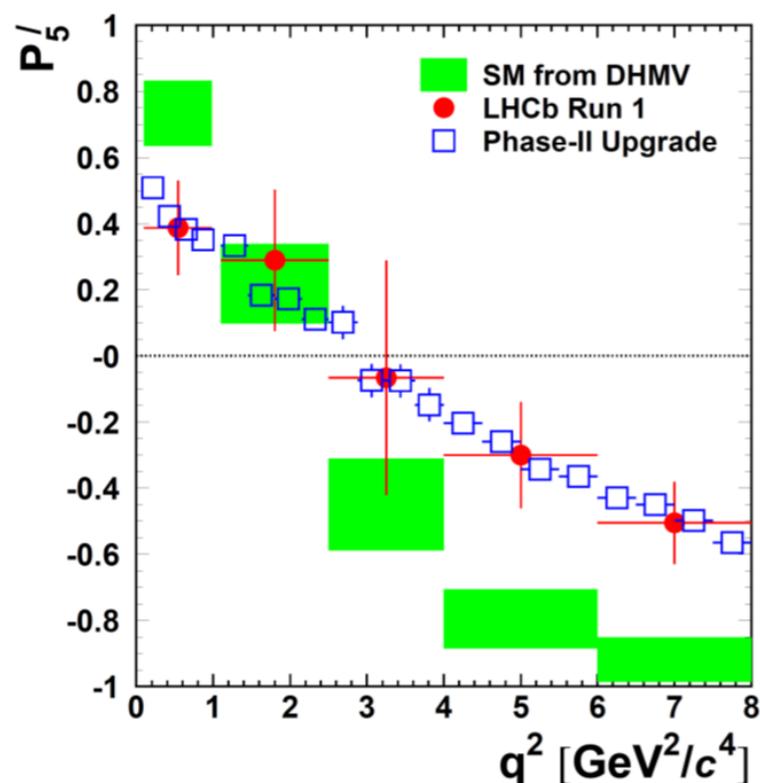
WHAT COMES “NEXT”?



[CERN-LHCC-2017-003, ATL-PHYS-PUB-2022-018 CMS PAS FTR-22-001]

MORE DATA, MORE CHANNELS, MORE OBSERVABLES (E.G. CP VIOLATION), NOVEL IDEAS ...

“PRECISION ERA”

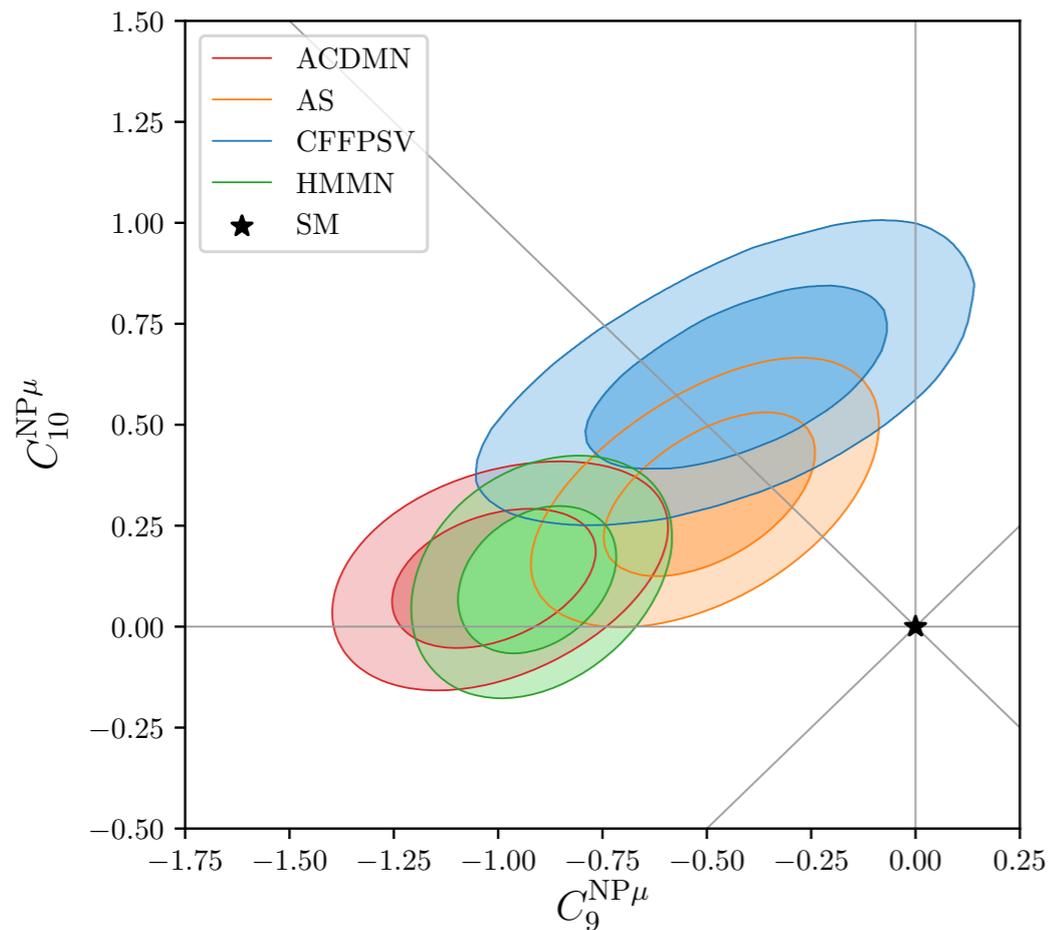


CRUCIAL INFORMATION FOR THE UNDERSTANDING OF THE CURRENT SM DEVIATIONS

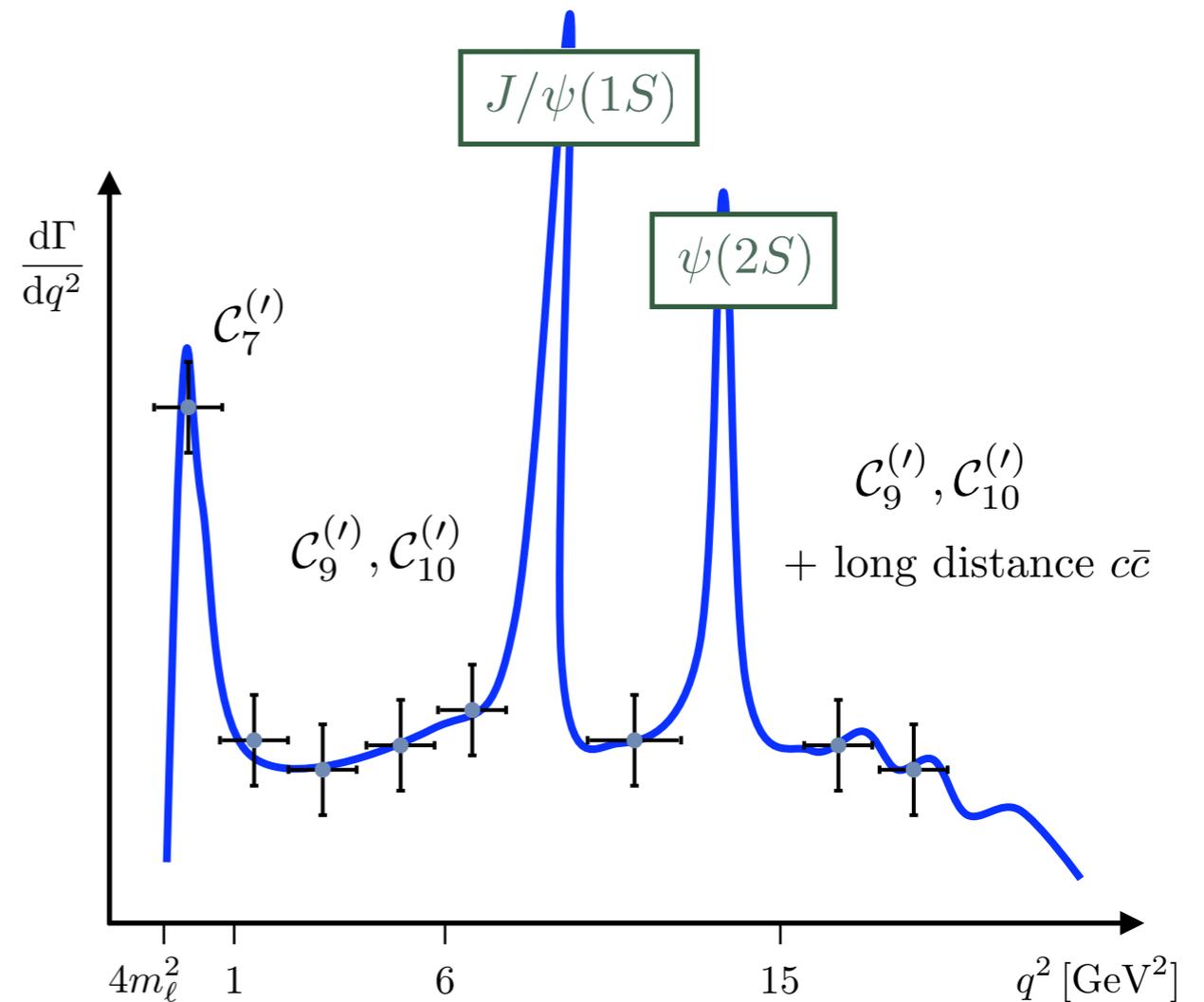
WHAT COMES “NEXT”?

“TODAY”

[FLAVOUR ANOMALIES WORKSHOP 2021 - SUMMARY]



TO “BIN” OR NOT TO “BIN”?



[Angular]: $A_{\text{FB}}, F_L, P'_5, \dots$
[Amplitude]: $C_9, C_{10}, \text{hadronic terms } \dots$

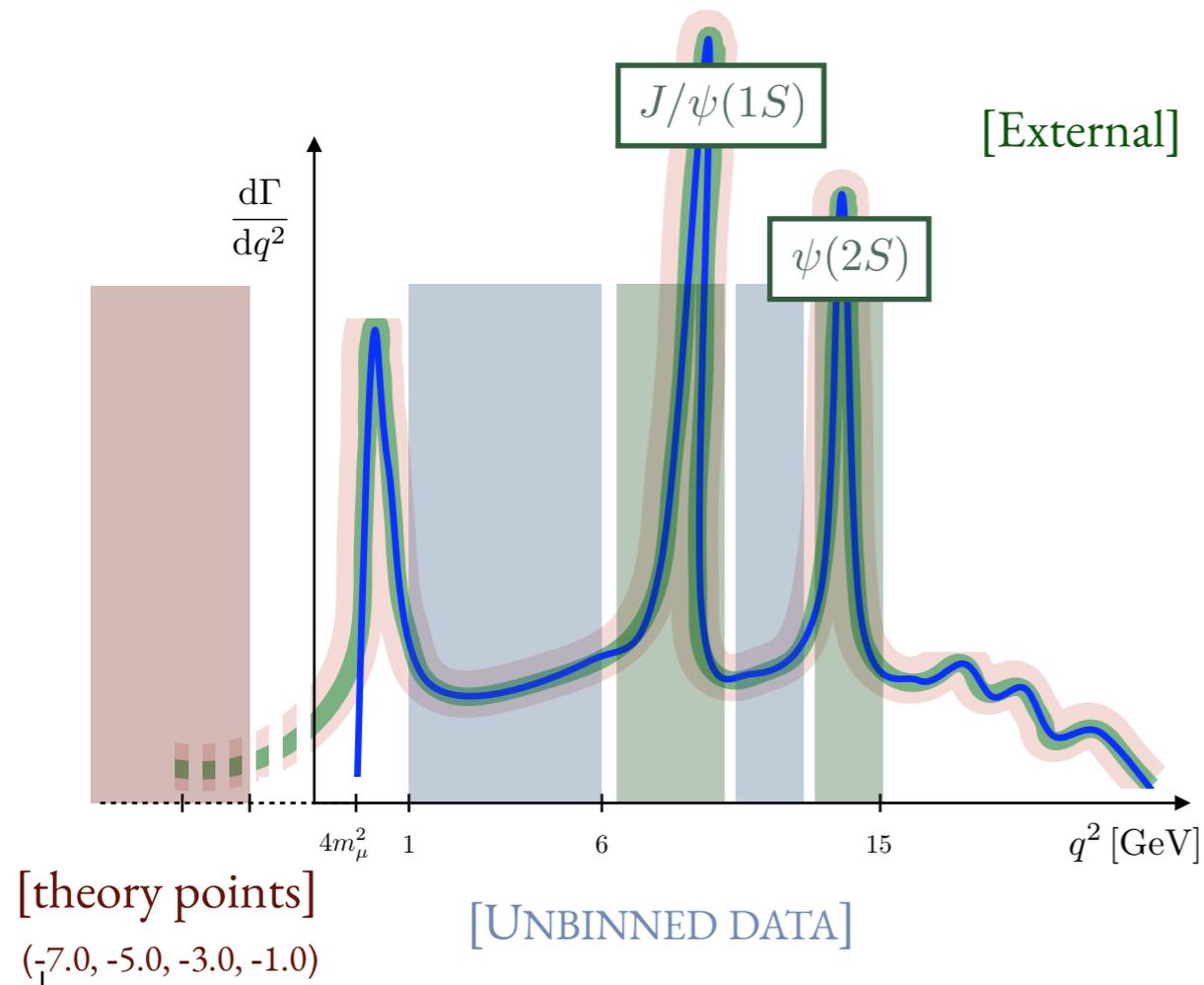
WHAT COMES “NEXT”?



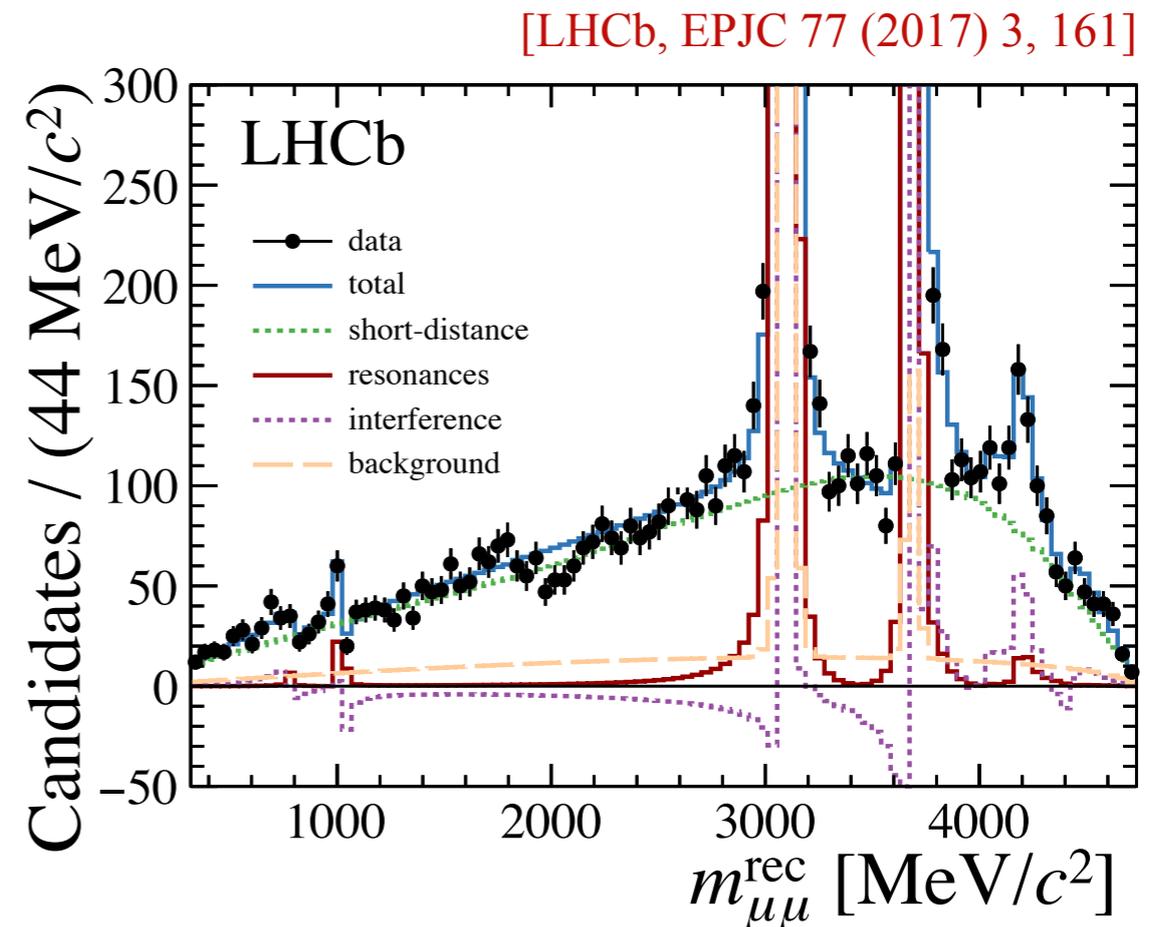
[EPJC 78 6 (2018) 451, JHEP 10 (2019) 236, EPJC 78 (2018) 453, EPJC 80 (2020) 12]

“UNBINNED” ANALYSES CAN SIGNIFICANTLY IMPROVE THE SENSITIVITY AND UNDERLYING UNDERSTANDING OF THE FIELD

WCs FITS THEORY-EXPERIMENTAL APPROACH



“ISOBAR-LIKE” WCs FITS



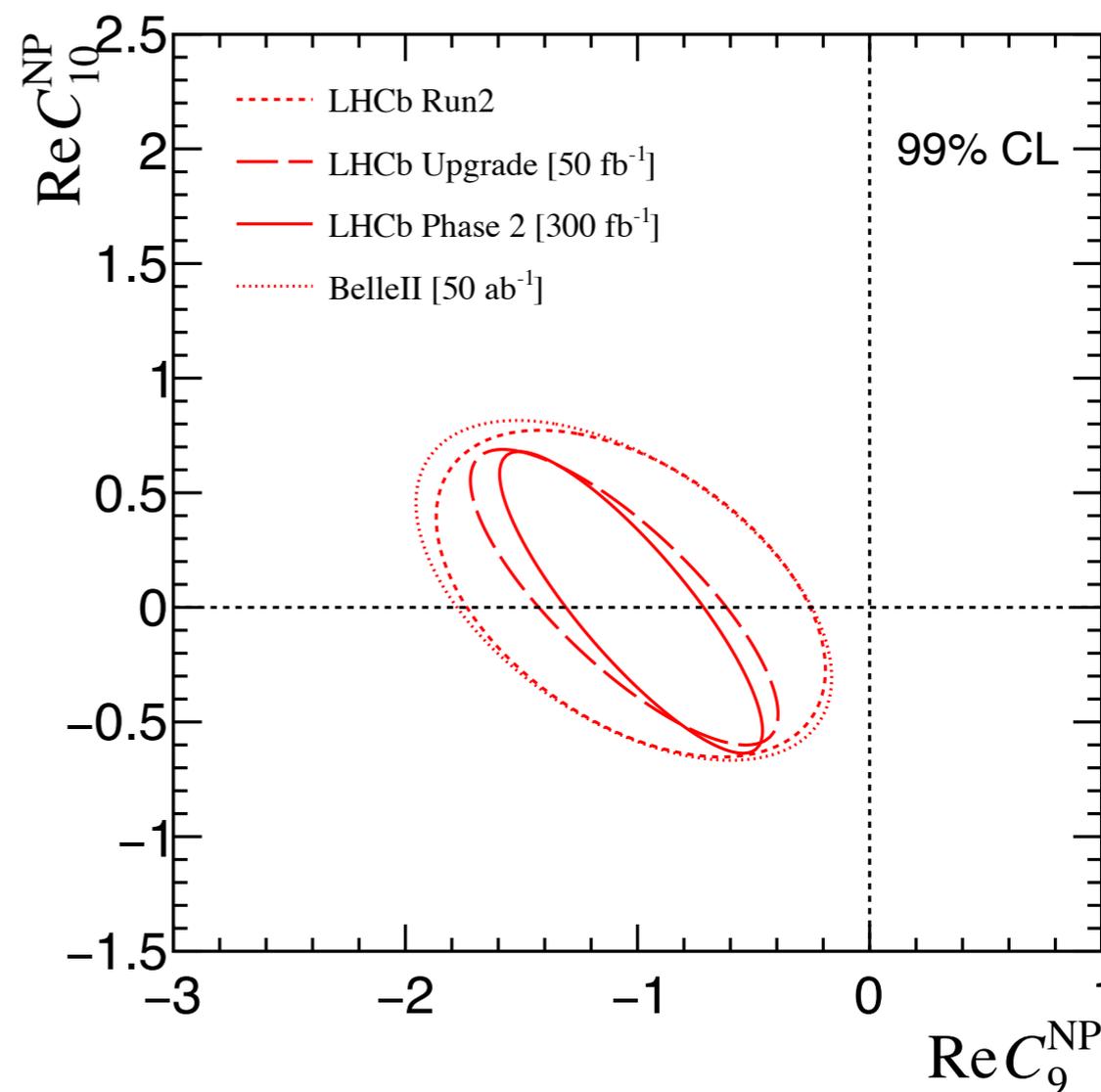
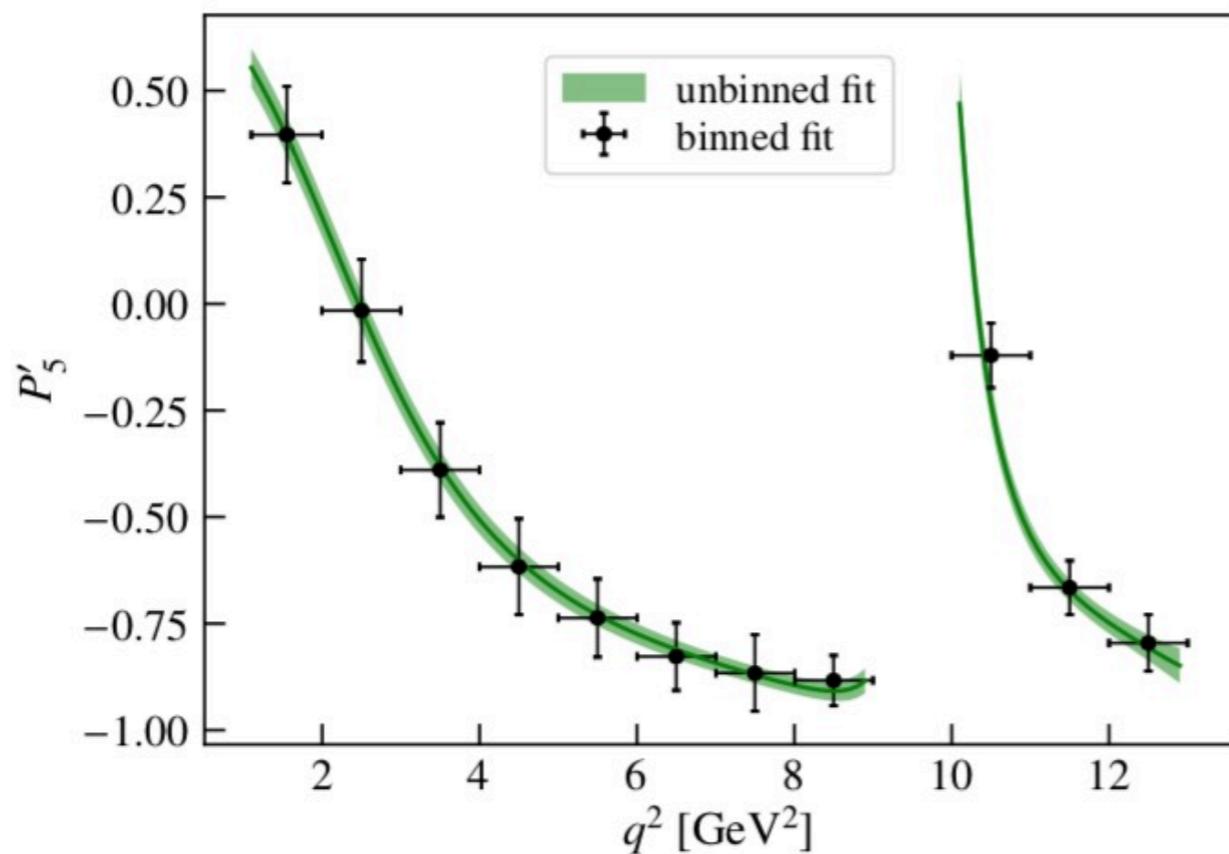
WHAT COMES “NEXT”?



[JHEP 10 (2019) 236]

“UNBINNED” ANALYSES CAN SIGNIFICANTLY IMPROVE THE SENSITIVITY AND UNDERLYING UNDERSTANDING OF THE FIELD

CURRENT STATISTICS

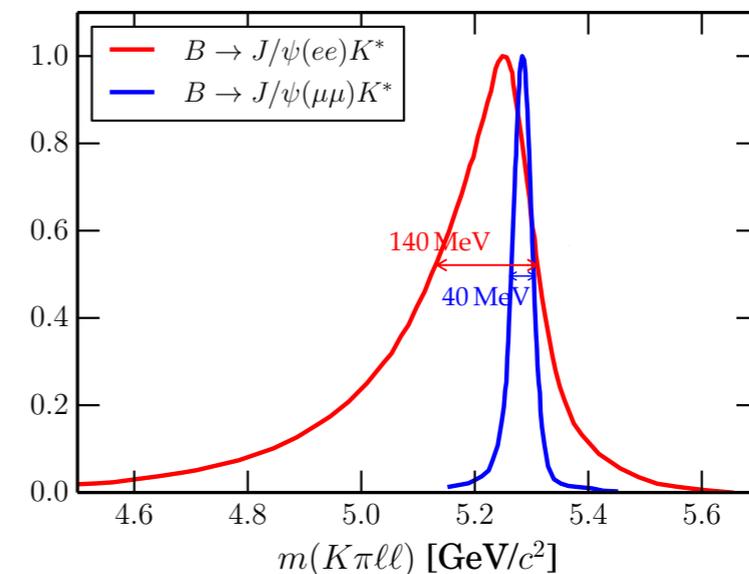
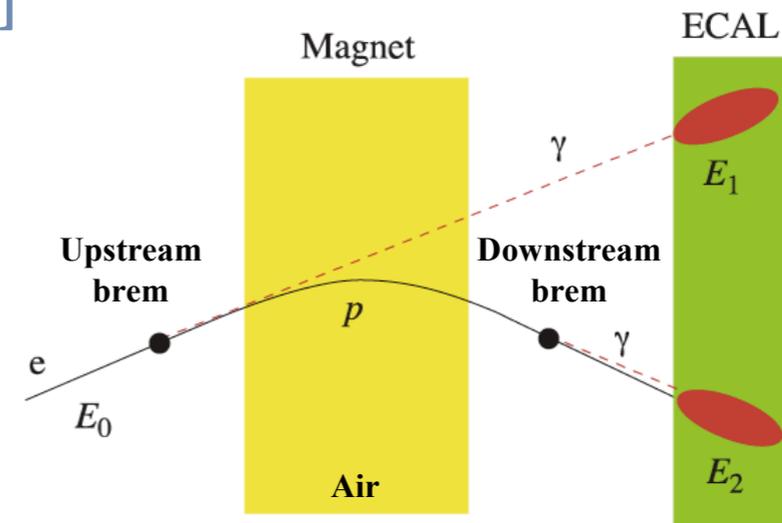
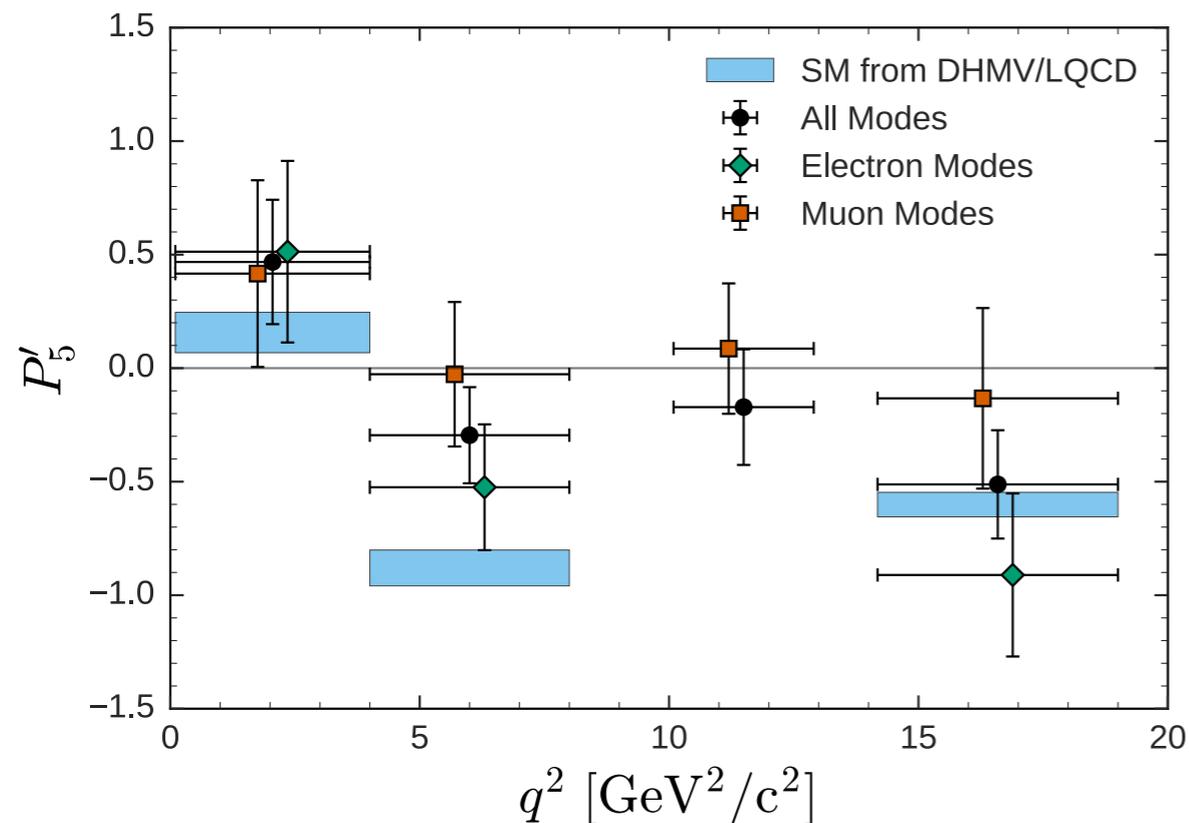


WHAT ABOUT OTHER LEPTONS?



SIMILAR RATE BETWEEN LEPTONS IN BELLE II

[Belle, PRL 118 (2017) 11, 111801]



CHALLENGING ANALYSIS FOR LHCb

SENSITIVITY FOR P'_5 AT ~ 0.12 IN 1.1-7.0 GEV q^2

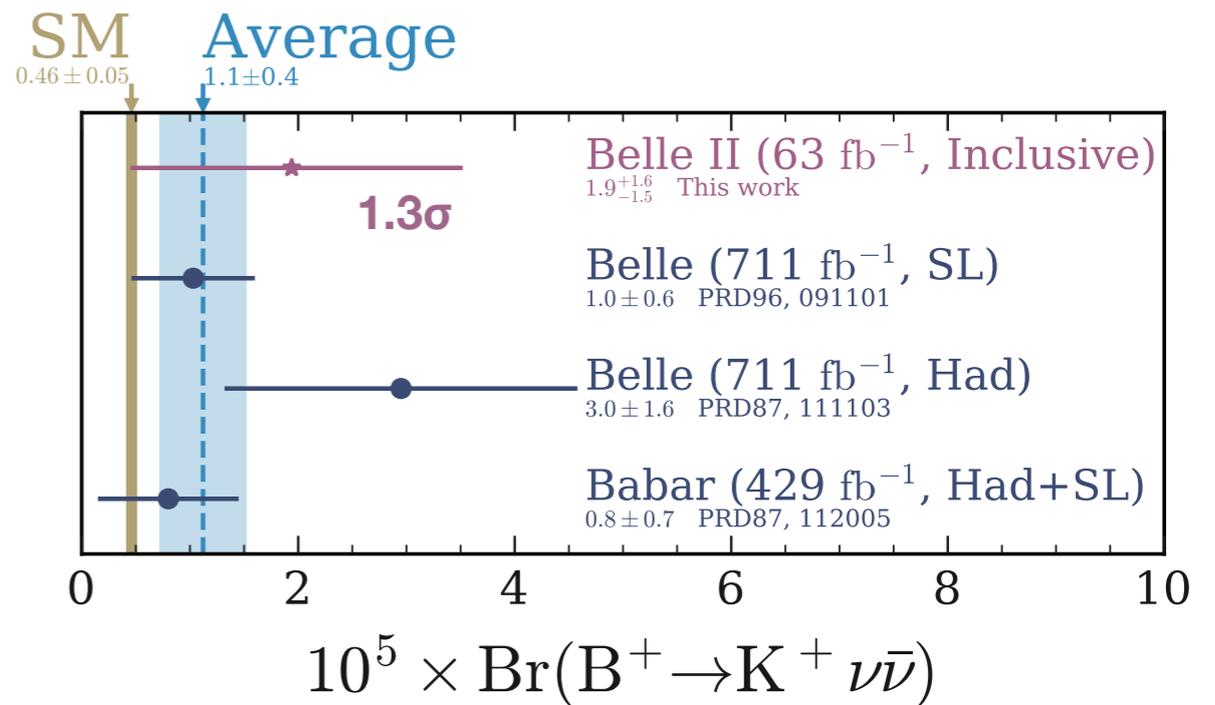
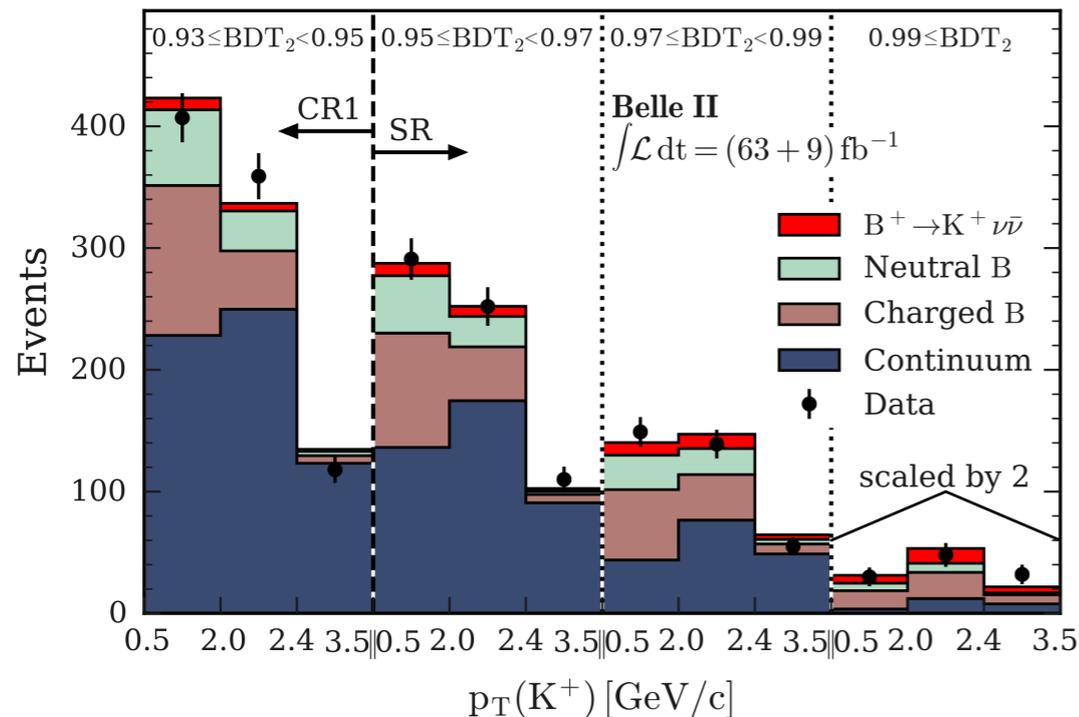
WHAT ABOUT OTHER LEPTONS?

$$[B \rightarrow K^{(*)}\nu\nu]$$

[Belle II, PRL 127 (2021) 18, 181802]

BELLE II HAS A UNIQUE PHYSICS REACH TO STUDY FINAL STATES WITH MISSING ENERGY

SET A COMPETITIVE LIMIT WITH ONLY 63 fb⁻¹!



Decay	1 ab ⁻¹	5 ab ⁻¹	10 ab ⁻¹	50 ab ⁻¹
$B^+ \rightarrow K^+ \nu\bar{\nu}$	0.55 (0.37)	0.28 (0.19)	0.21 (0.14)	0.11 (0.08)
$B^0 \rightarrow K_S^0 \nu\bar{\nu}$	2.06 (1.37)	1.31 (0.87)	1.05 (0.70)	0.59 (0.40)
$B^+ \rightarrow K^{*+} \nu\bar{\nu}$	2.04 (1.45)	1.06 (0.75)	0.83 (0.59)	0.53 (0.38)
$B^0 \rightarrow K^{*0} \nu\bar{\nu}$	1.08 (0.72)	0.60 (0.40)	0.49 (0.33)	0.34 (0.23)

EXCITING PHYSICS RANGE TO
BE EXPLORED!

SOON?

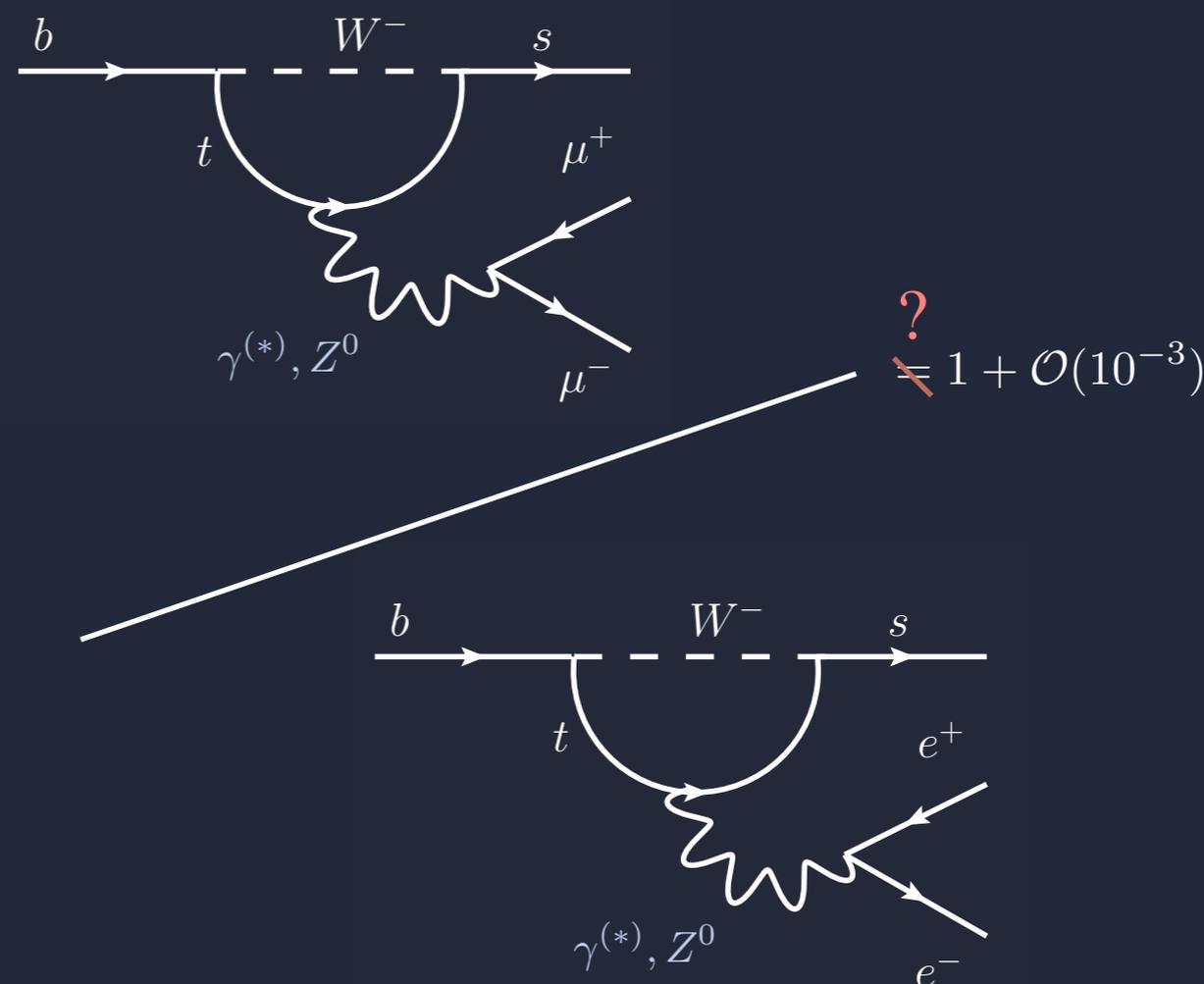
Lepton Flavour Universality



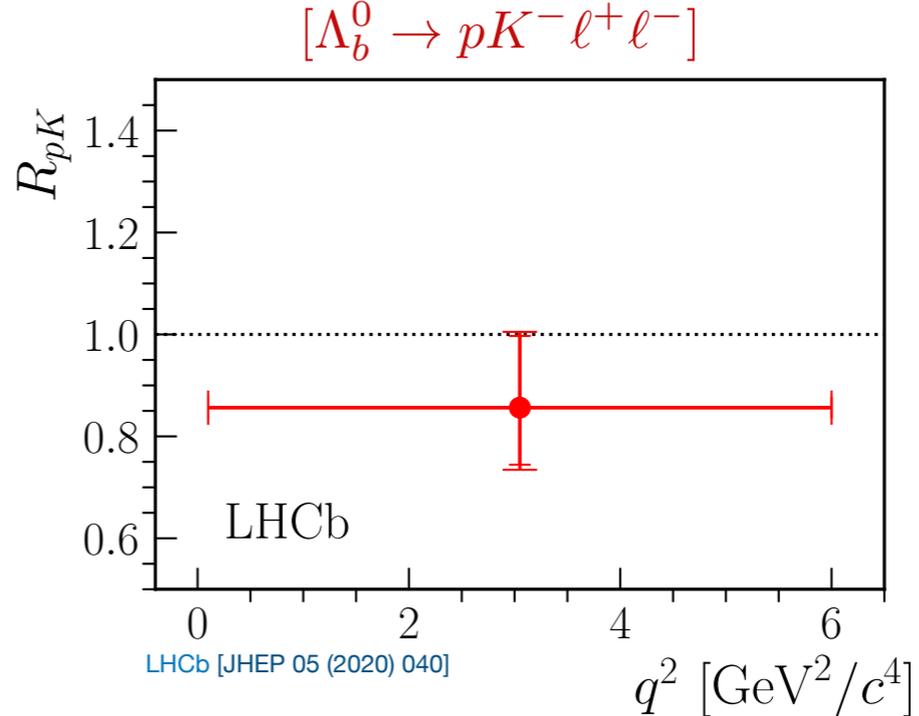
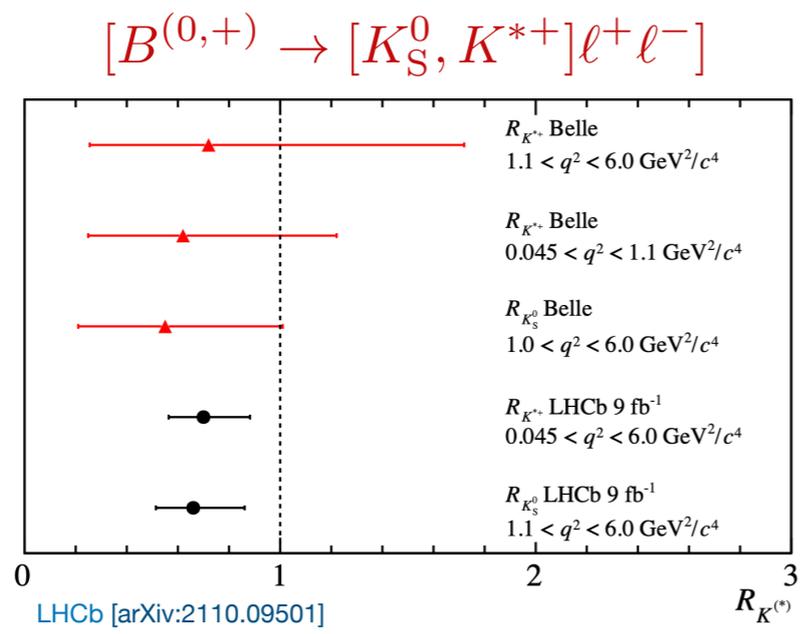
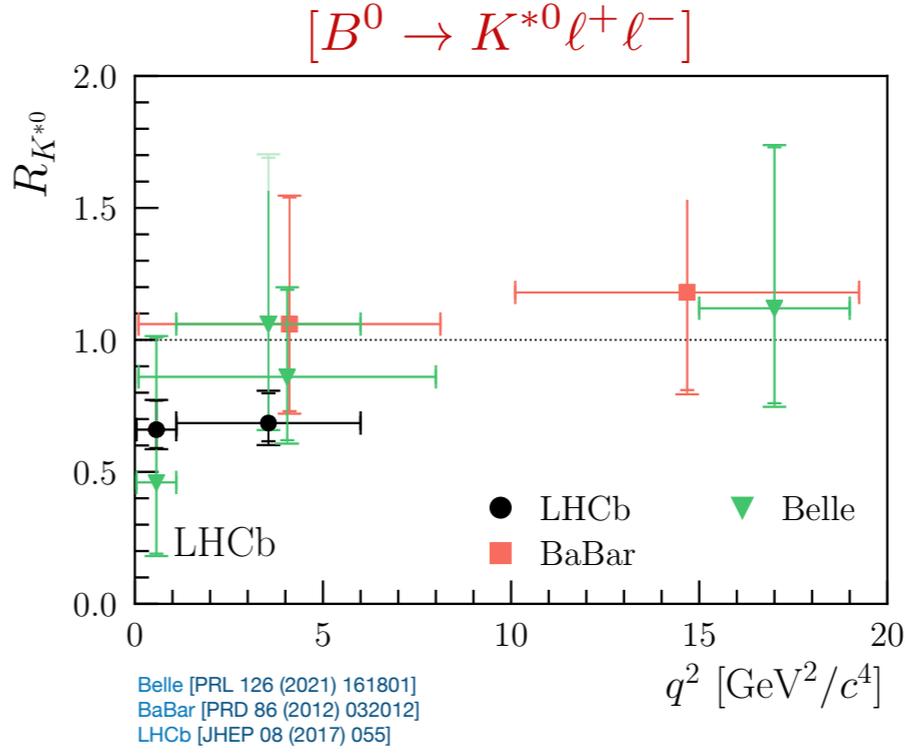
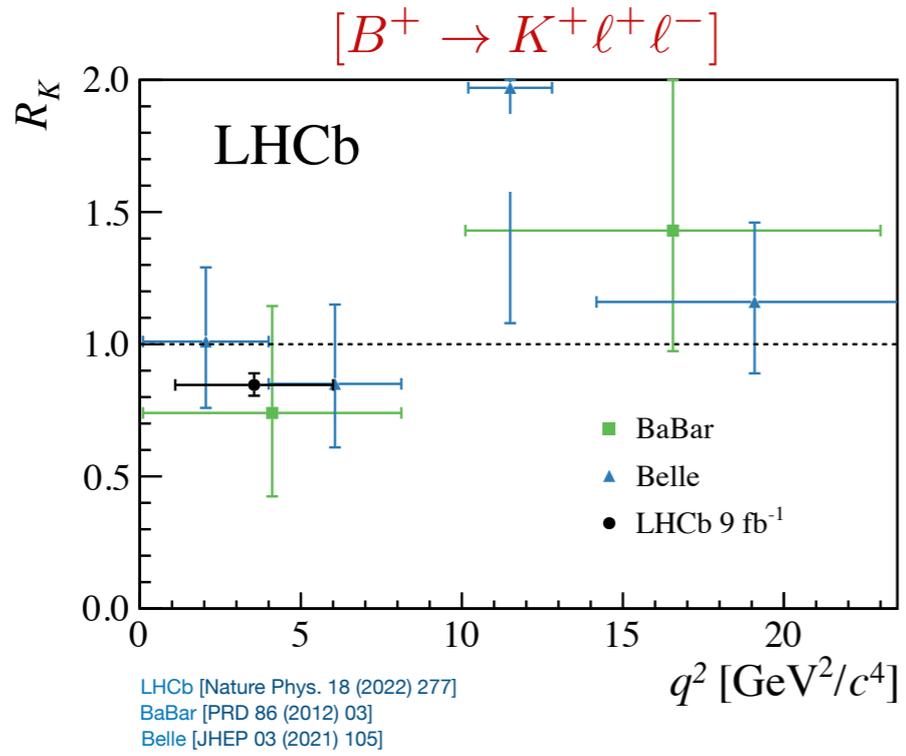
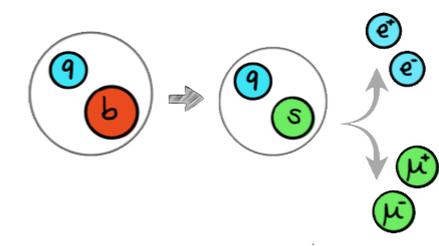
+



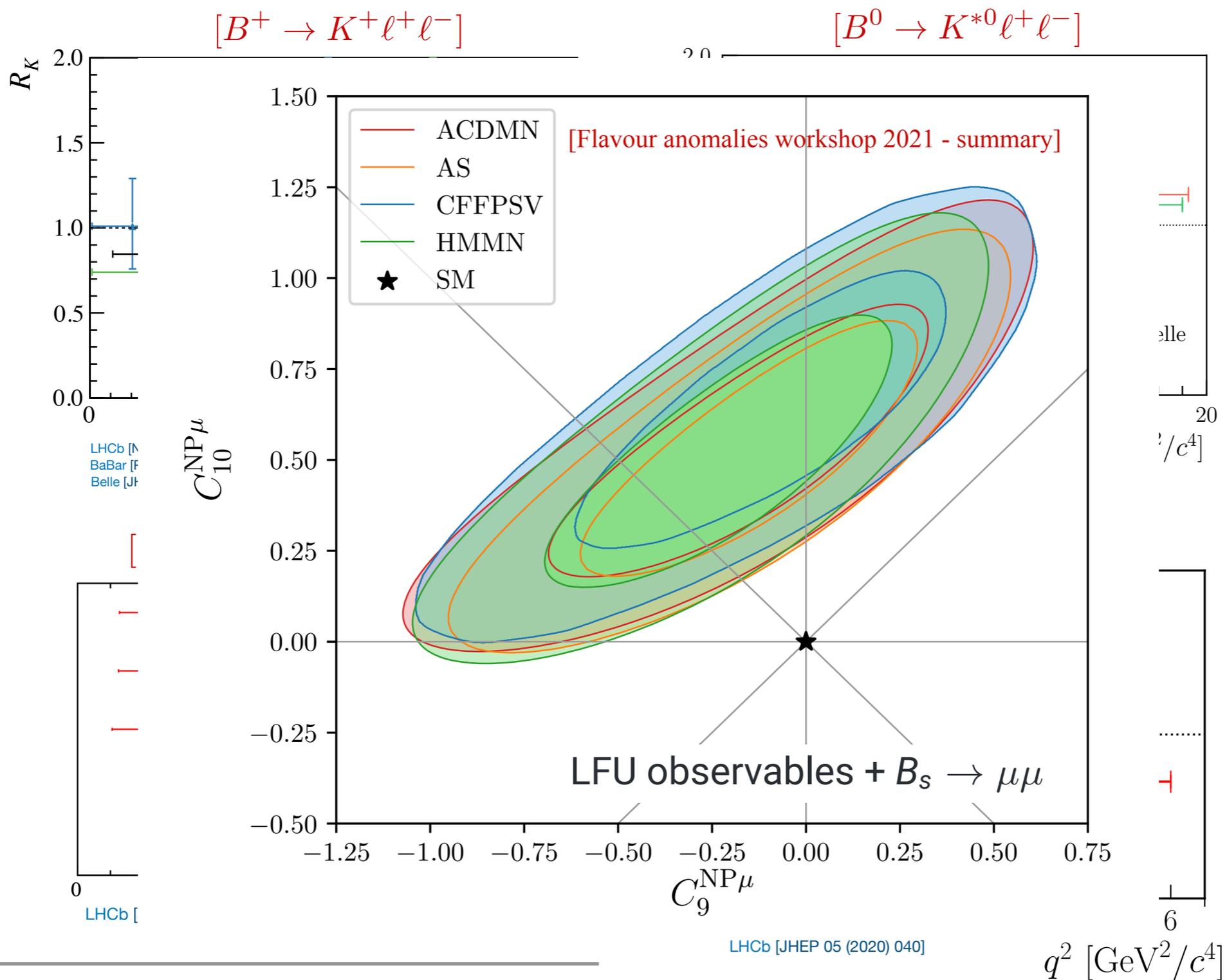
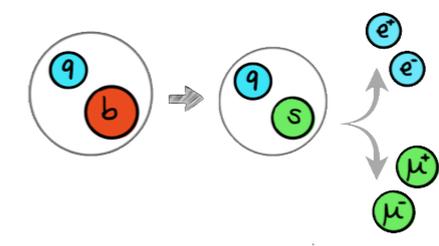
The “third” anomalies: from $b \rightarrow s ll$ to $b \rightarrow cl\nu$



LFU IN $b \rightarrow s l^+ l^-$ [TODAY]



LFU IN $b \rightarrow s l^+ l^-$ [TODAY]



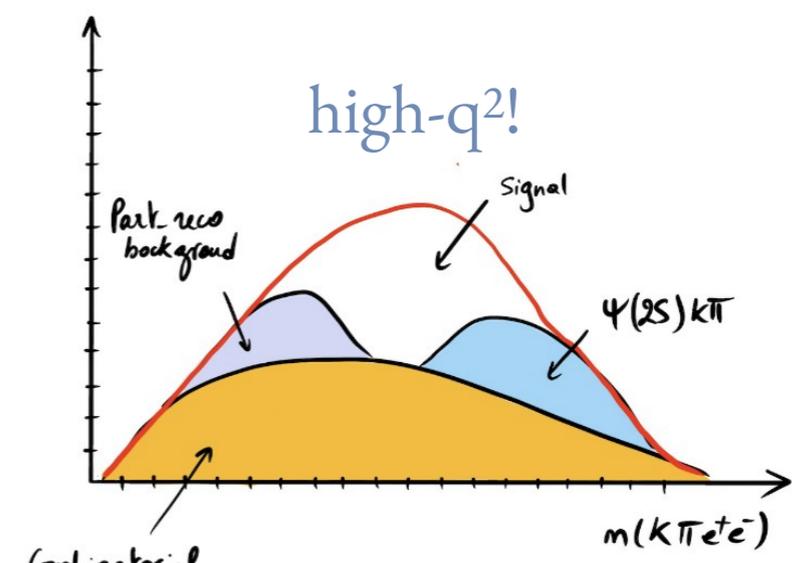


LFU IN $b \rightarrow s l^+ l^-$ [NEXT]

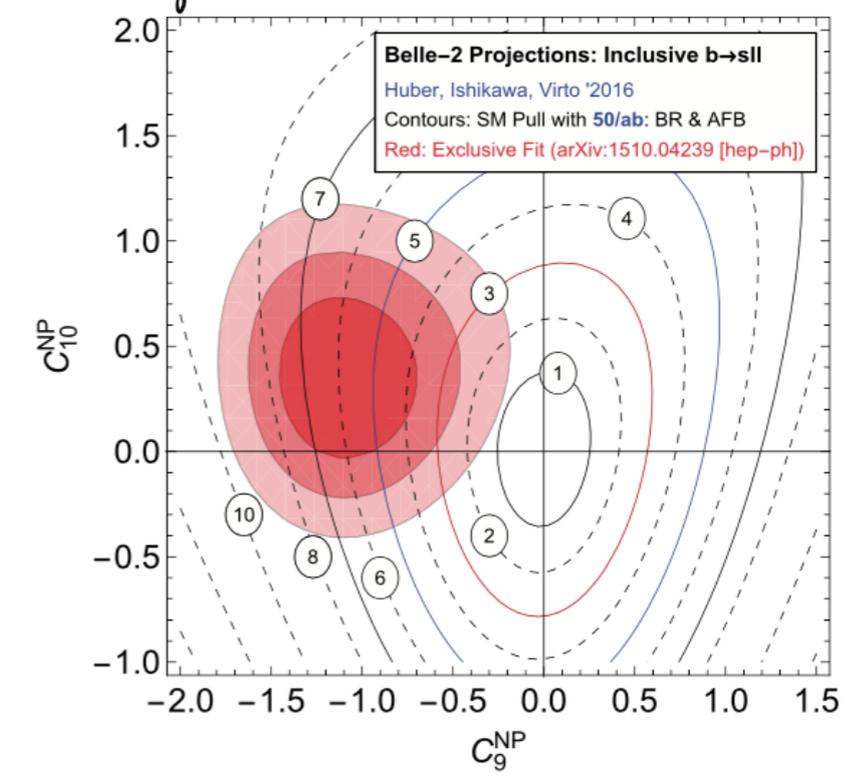
[LHCb, arXiv:1808.08865, Belle II physics book]

MORE DATA, MORE CHANNELS, MORE OBSERVABLES, NOVEL IDEAS ...

R_X precision	9 fb^{-1}	23 fb^{-1}	50 fb^{-1}
R_K	0.043	0.025	0.017
R_{K^*0}	0.052	0.031	0.020
R_ϕ	0.130	0.076	0.050
R_{pK}	0.105	0.061	0.041
R_π	0.302	0.176	0.117



Observables	Belle 0.71 ab^{-1}	Belle II 5 ab^{-1}	Belle II 50 ab^{-1}
R_K ($[1.0, 6.0] \text{ GeV}^2$)	28%	11%	3.6%
R_K ($> 14.4 \text{ GeV}^2$)	30%	12%	3.6%
R_{K^*} ($[1.0, 6.0] \text{ GeV}^2$)	26%	10%	3.2%
R_{K^*} ($> 14.4 \text{ GeV}^2$)	24%	9.2%	2.8%
R_{X_S} ($[1.0, 6.0] \text{ GeV}^2$)	32%	12%	4.0%
R_{X_S} ($> 14.4 \text{ GeV}^2$)	28%	11%	3.4%

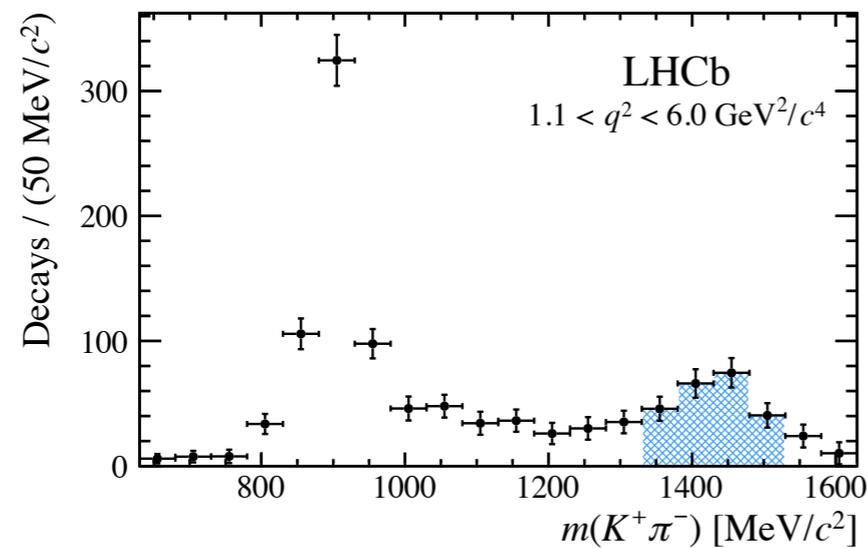


LFU IN $b \rightarrow s l^+ l^-$ [NEXT]

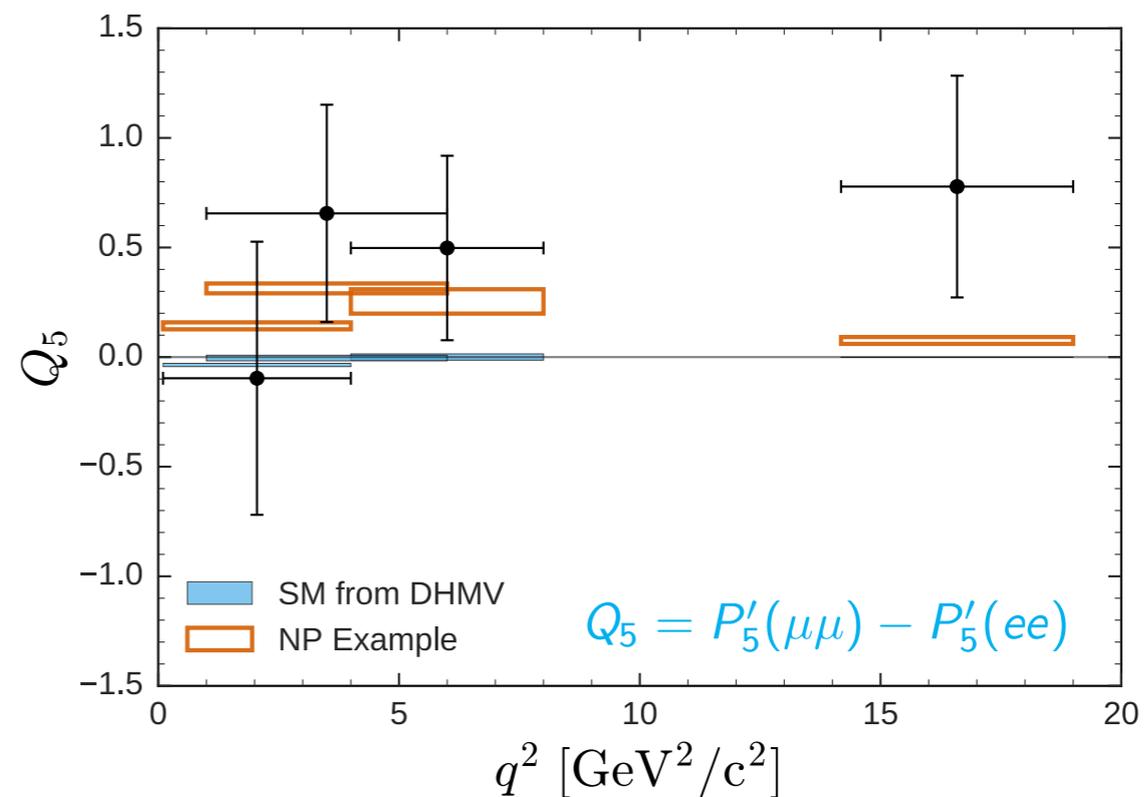


MORE DATA, MORE CHANNELS, MORE OBSERVABLES, NOVEL IDEAS ...

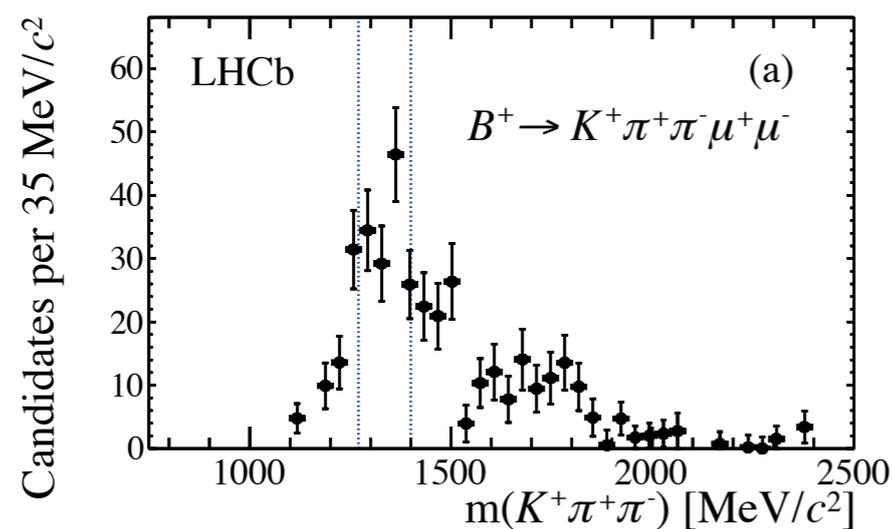
[LHCb, JHEP 12 (2016) 065]



[Belle, PRL 118 (2017) no.11, 111801]



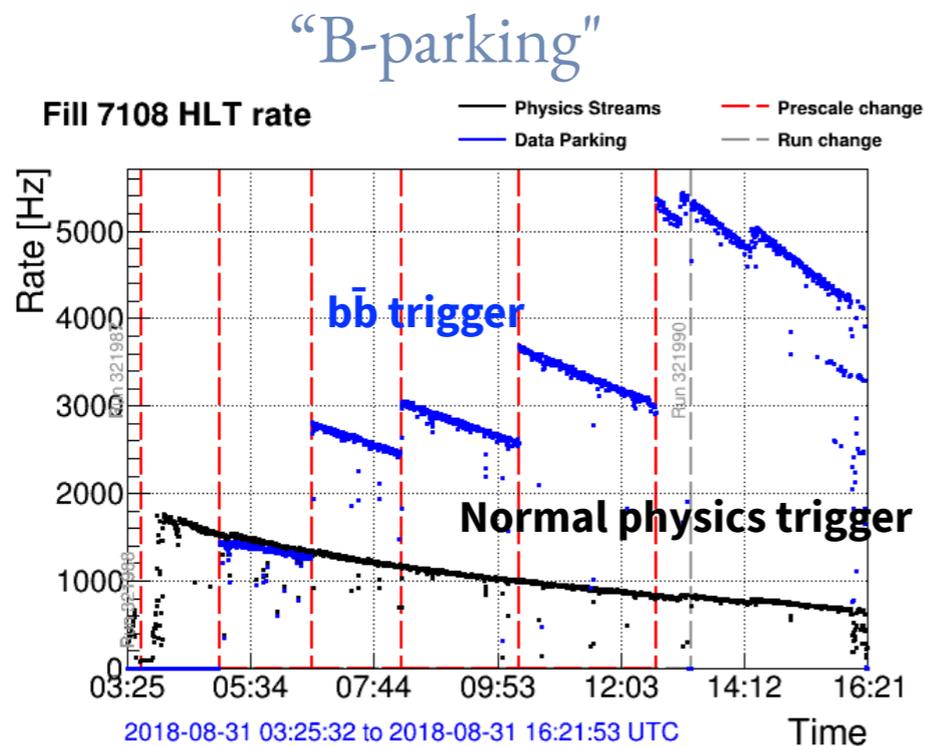
[LHCb, JHEP 1410 (2014) 064]



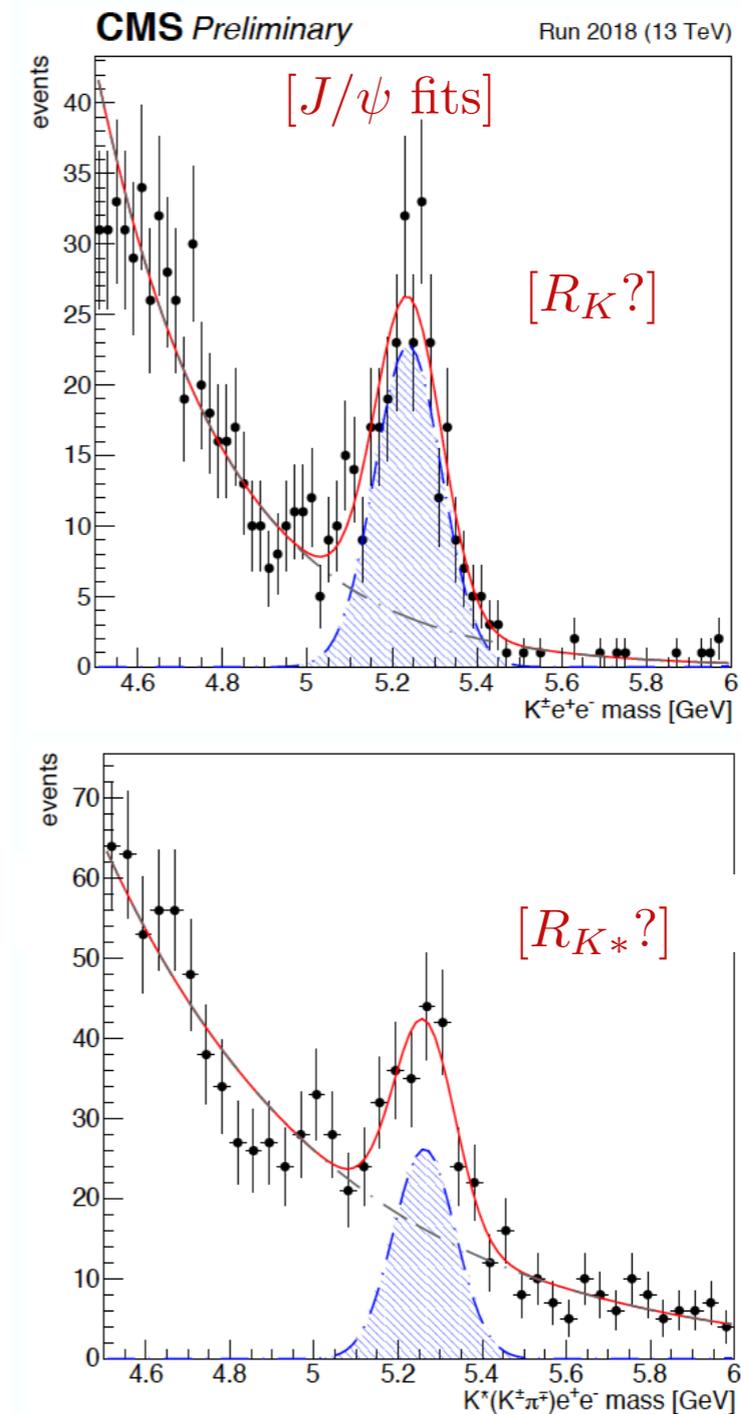
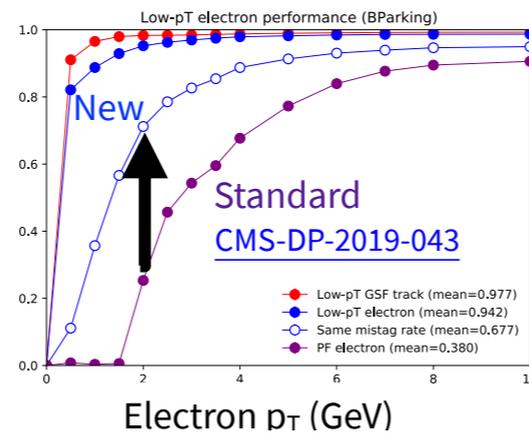
FIRST STEPS TOWARDS AN EXPERIMENTAL
CONNECTION BETWEEN LFU AND
ANGULAR ANOMALIES

LFU IN $b \rightarrow s l^+ l^-$ [LHC]

SEVERAL ACTIVITIES TOWARDS B-PHYSICS



Mode	N_{2018}
B_d^0	4.0×10^9
B^\pm	4.0×10^9
B_s	1.2×10^9
b baryons	1.2×10^9
B_c	1.0×10^7
Total	1.0×10^{10}



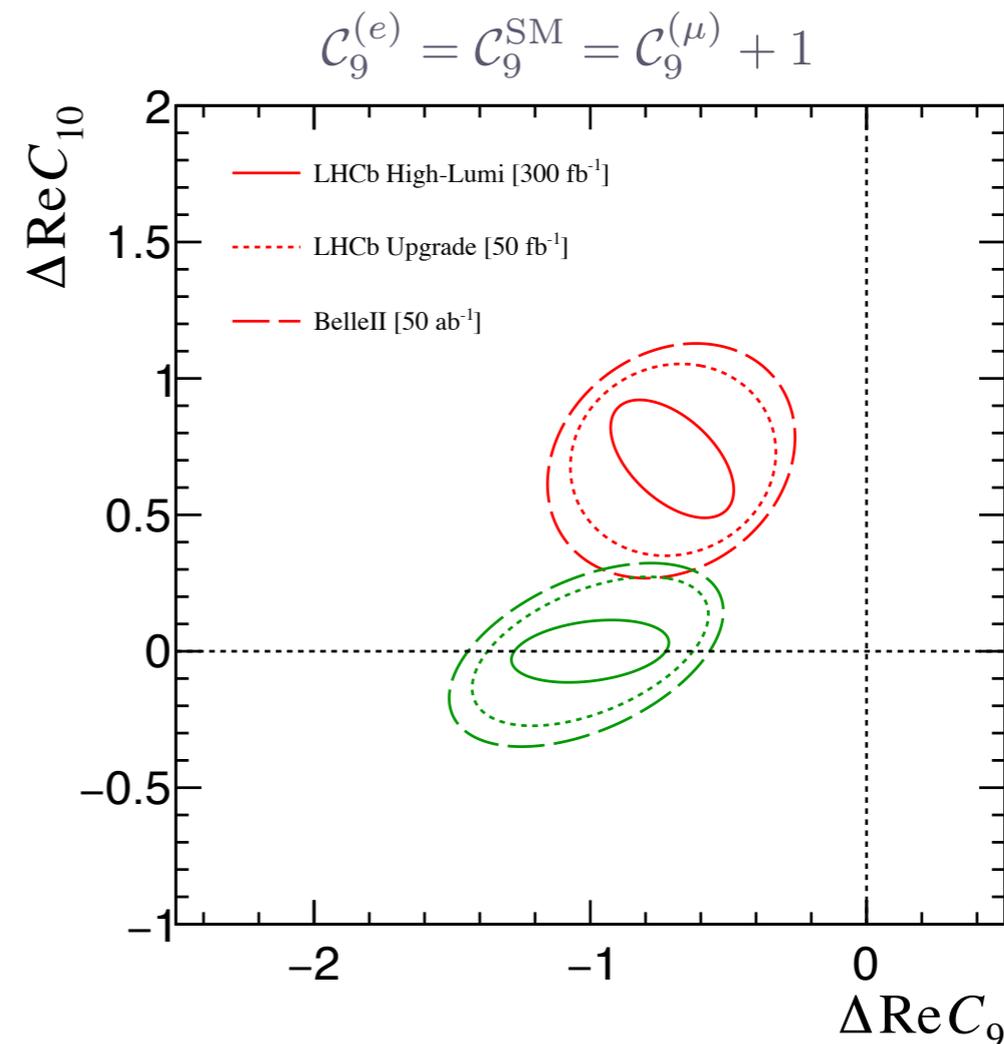
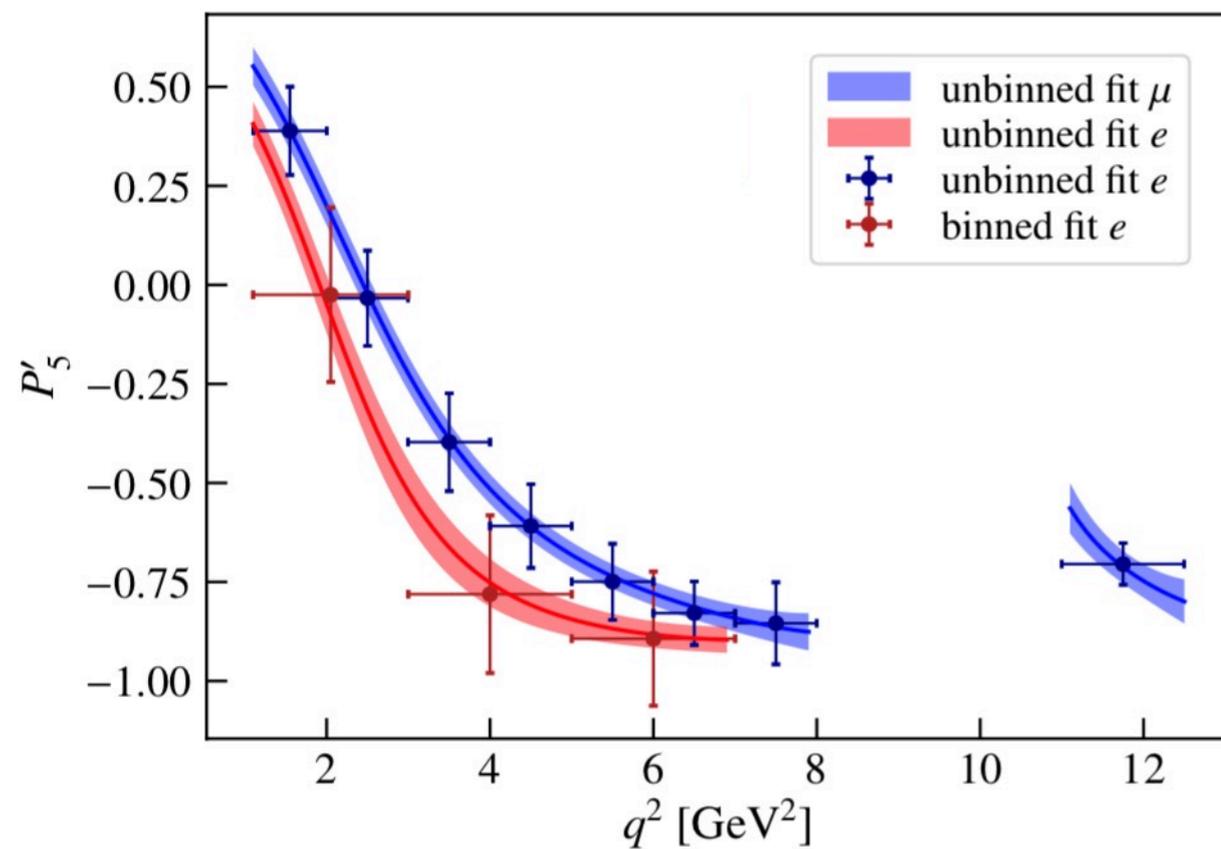
LFU IN $b \rightarrow s l^+ l^-$ [NEXT]

[PRD 99 (2019) 013007, arXiv:2203.06827]

TO “BIN” OR NOT TO “BIN” (LFU)?

SIMULTANEOUS UNBINNED ANALYSIS OF $B^0 \rightarrow K^{*0} \mu^+ \mu^-$ AND $B^0 \rightarrow K^{*0} e^+ e^-$

[PROJECTION CURRENT LHCb STATISTICS (ONLY)]



LFU IN $b \rightarrow c l \nu$ [TODAY]

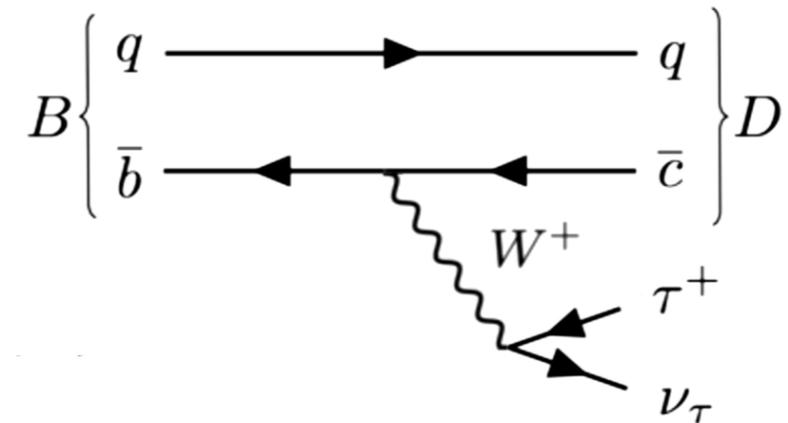
$$R(\mathcal{H}_c) = \frac{\mathcal{B}(\mathcal{H}_b \rightarrow \mathcal{H}_c \tau \nu_\tau)}{\mathcal{B}(\mathcal{H}_b \rightarrow \mathcal{H}_c \mu \nu_\mu)}$$

$\mathcal{H}_b = B^0, B_{(c)}^+, \Lambda_b^0, B_s^0 \dots$

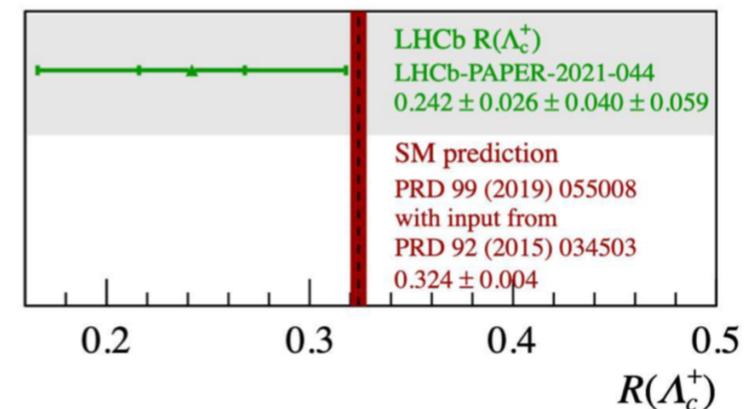
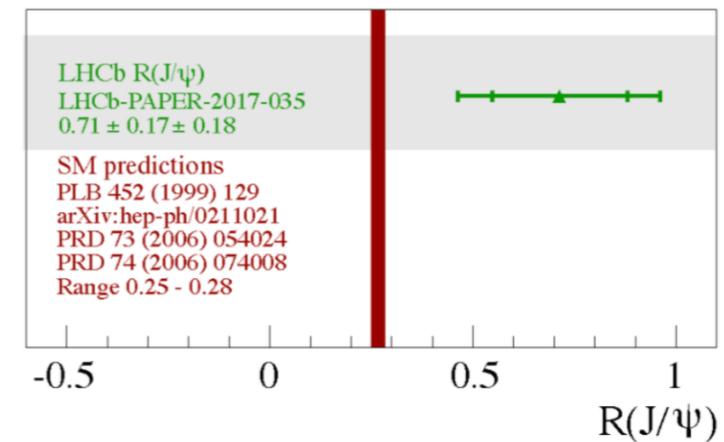
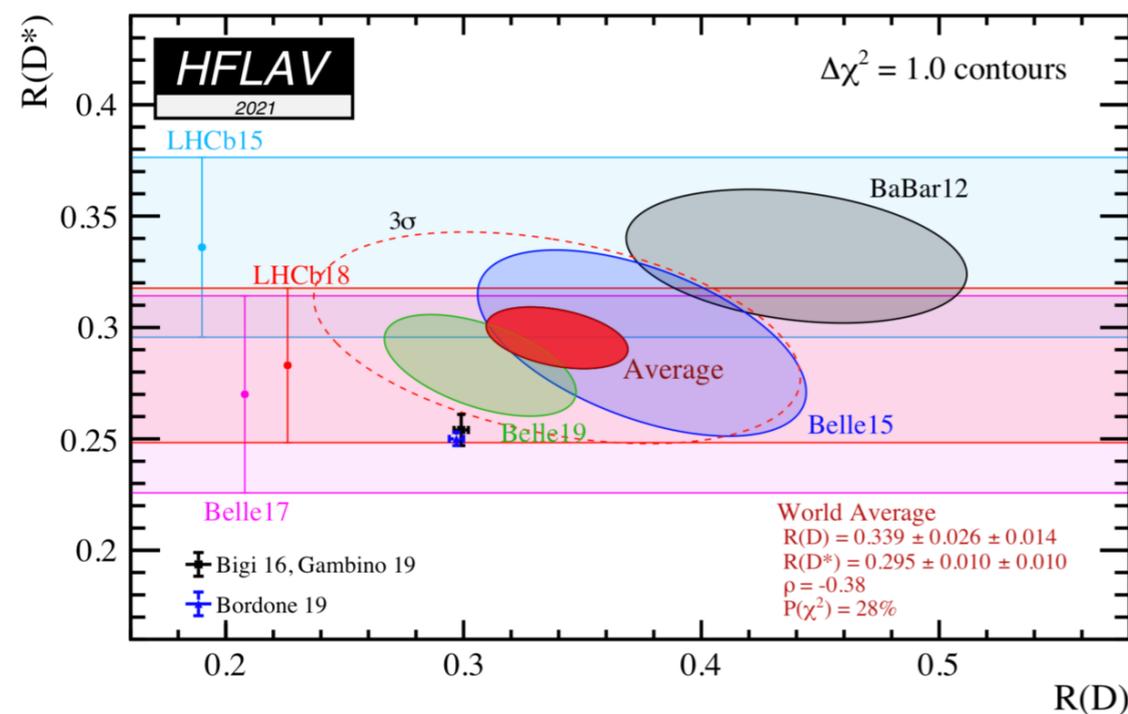
$\ell' = e/\mu$ (B-factories)

$\mathcal{H}_c = D^*, D^0, D^+, D_s, \Lambda_c^{(*)}, J/\psi \dots$

$\ell' = \mu$ (LHCb)



MEASUREMENTS FROM THE B-FACTORIES AND LHCb AT THE $> 3\sigma$ WRT THE SM

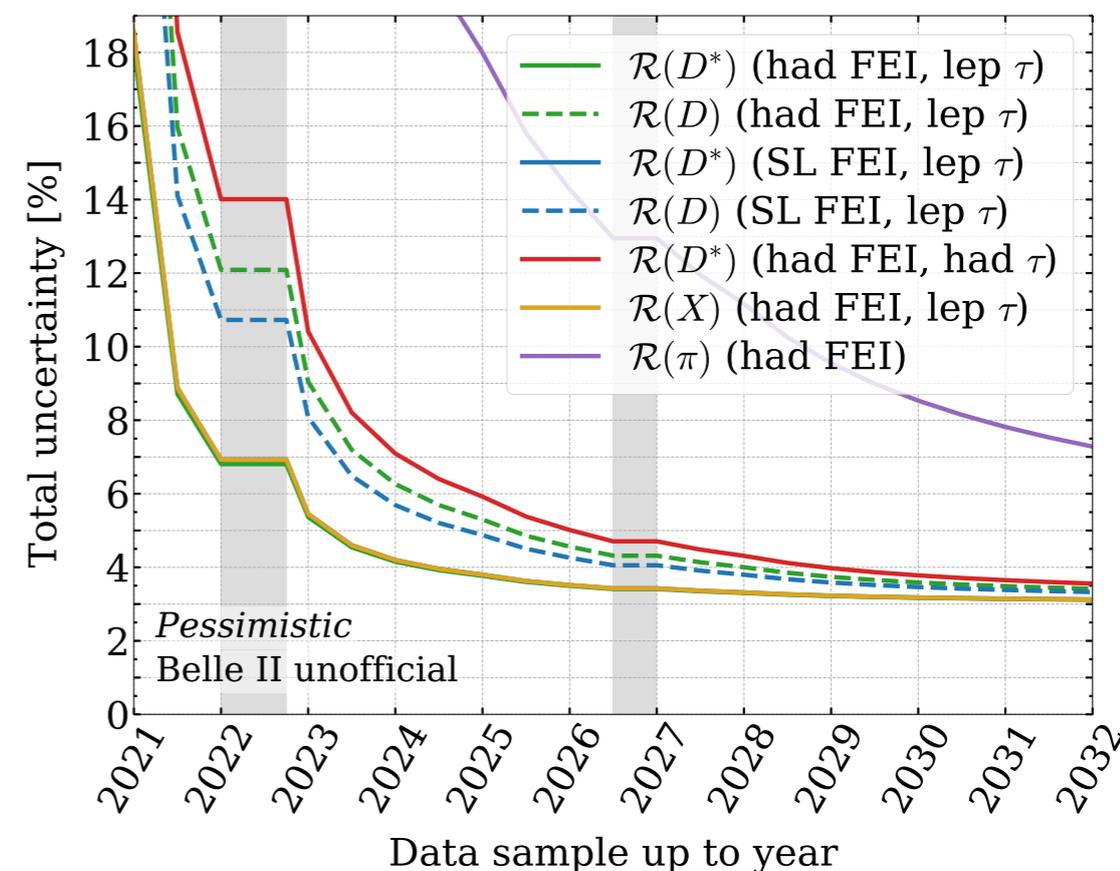
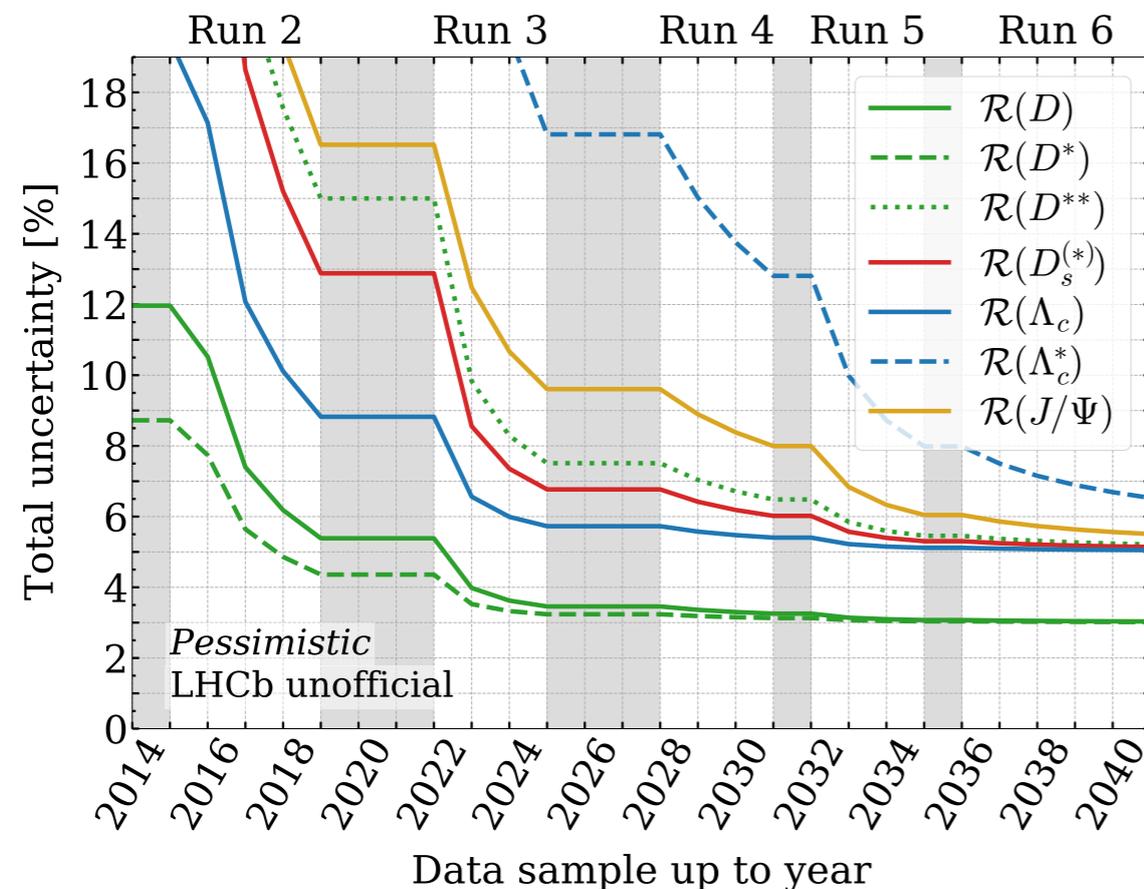


LFU IN $b \rightarrow c\ell\nu$ [NEXT]



[*Rev.Mod.Phys.* 94 (2022) 1, 015003]

EXCITING PROSPECTS IN THE LFU FOR BOTH EXPERIMENTS!



CAN OTHER LHC EXPERIMENTS ALSO CONTRIBUTE TO THIS PICTURE?

LFU IN $b \rightarrow c l \nu$ [NEXT]

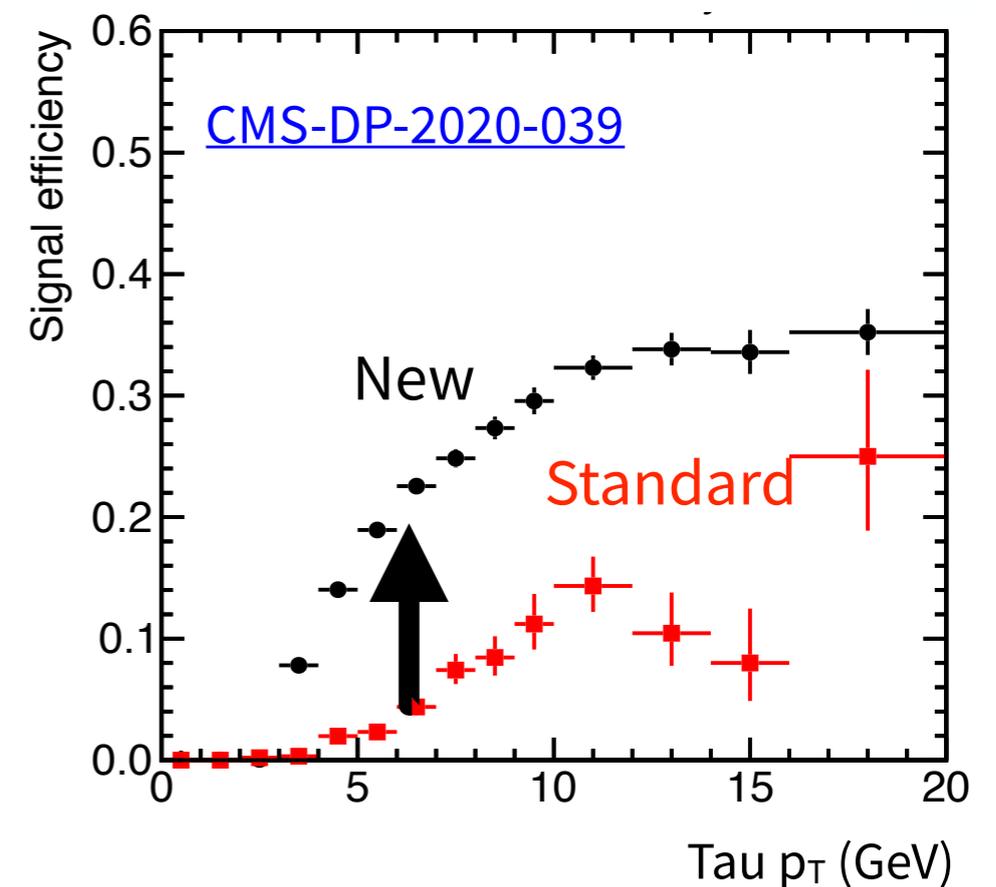


HISTORICALLY B -PHYSICS IN CMS IS POSSIBLE USING DIMUON TRIGGER (LOW RATE)

- ONGOING ANALYSIS OF $R(J/\psi)$ BOTH MUONIC AND HADRONIC TAU DECAYS
- “B-PARKED” DATA ALSO ALLOWED SINGLE MUON TRIGGER, *E.G.* $R(D^*)$

ATLAS IS ALSO WORKING ON SEMILEPTONIC B DECAYS WITH RUN 2 DATA AND PREPARING DEVOTED TRIGGER LINES FOR RUN 3

NEW LOW- p_T TAU RECONSTRUCTION
ALGORITHM DEDICATED TO
HADRONIC $\tau \rightarrow \pi\pi\pi\nu$ DECAY

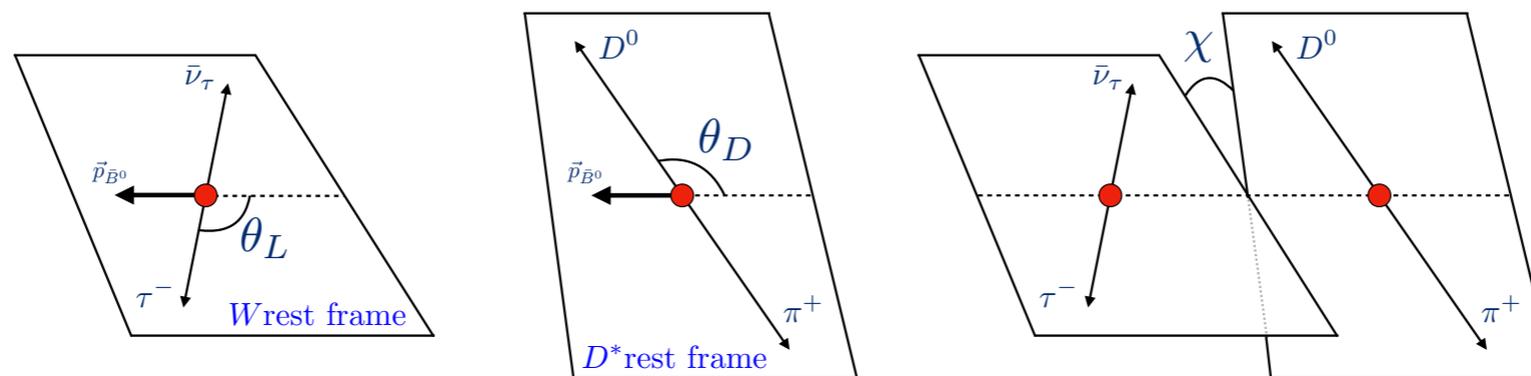


LFU IN $b \rightarrow cl\nu$ [NEXT]



[JHEP 11 (2019) 133]

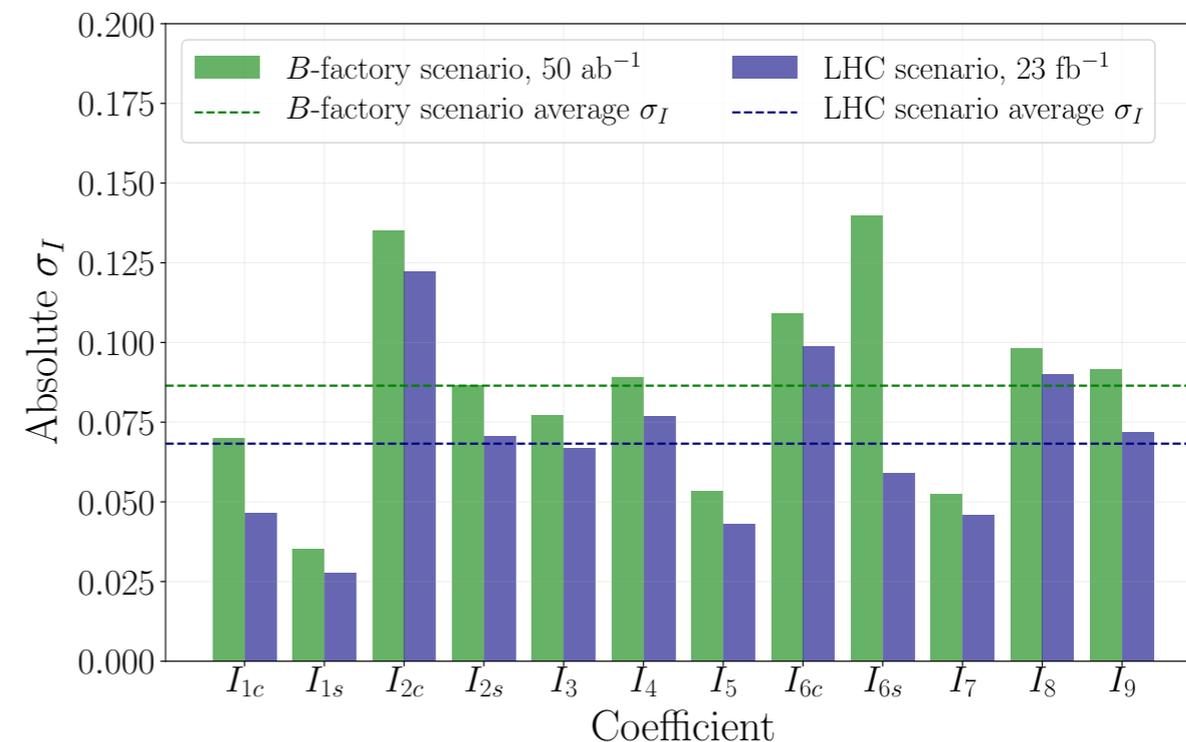
WITH ENOUGH DATA ONE CAN MEASURE ALL THE ANGULAR COEFFICIENTS



SIMILAR “METHODOLOGY” AS IN $b \rightarrow sl^+l^-$

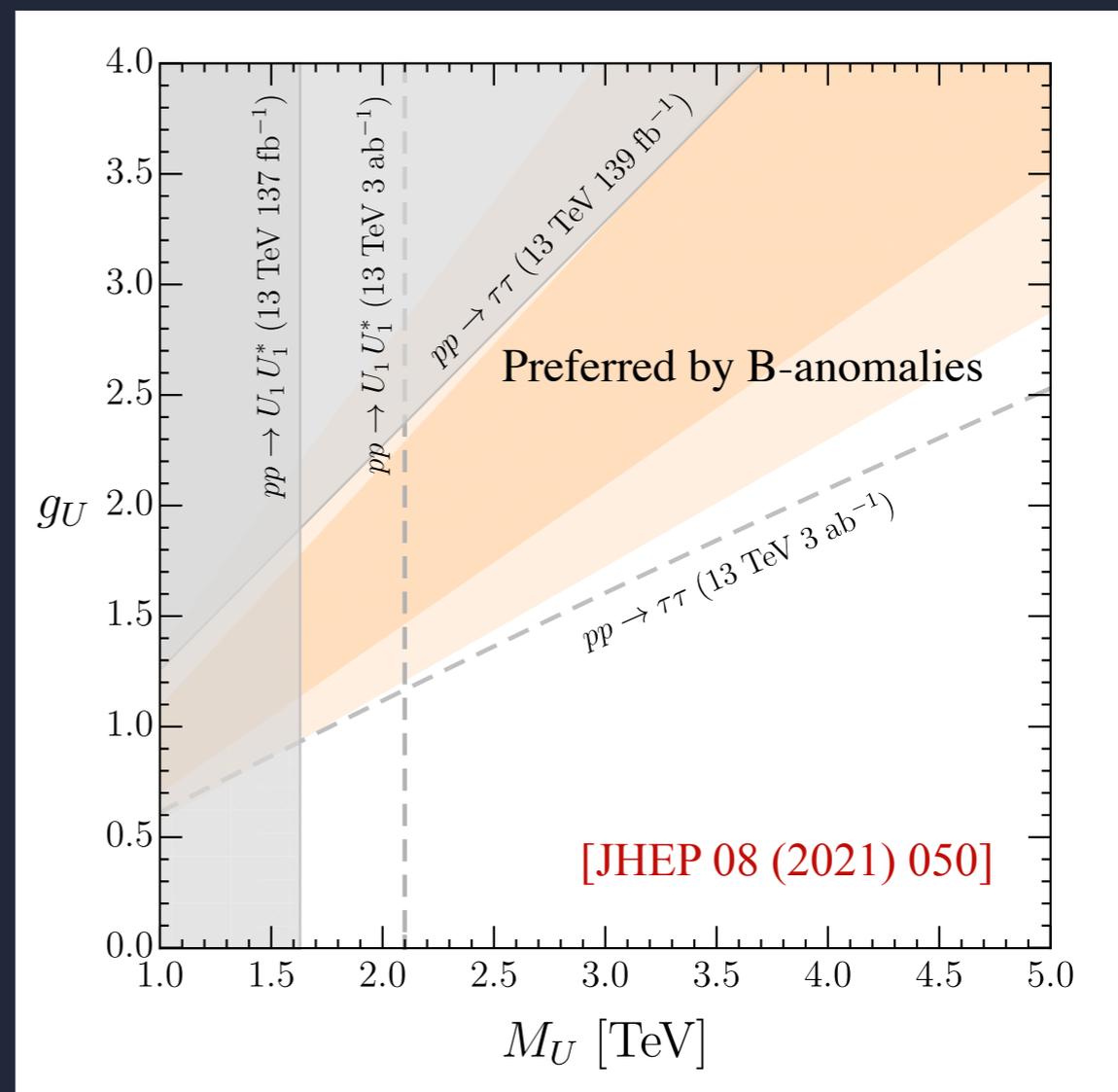
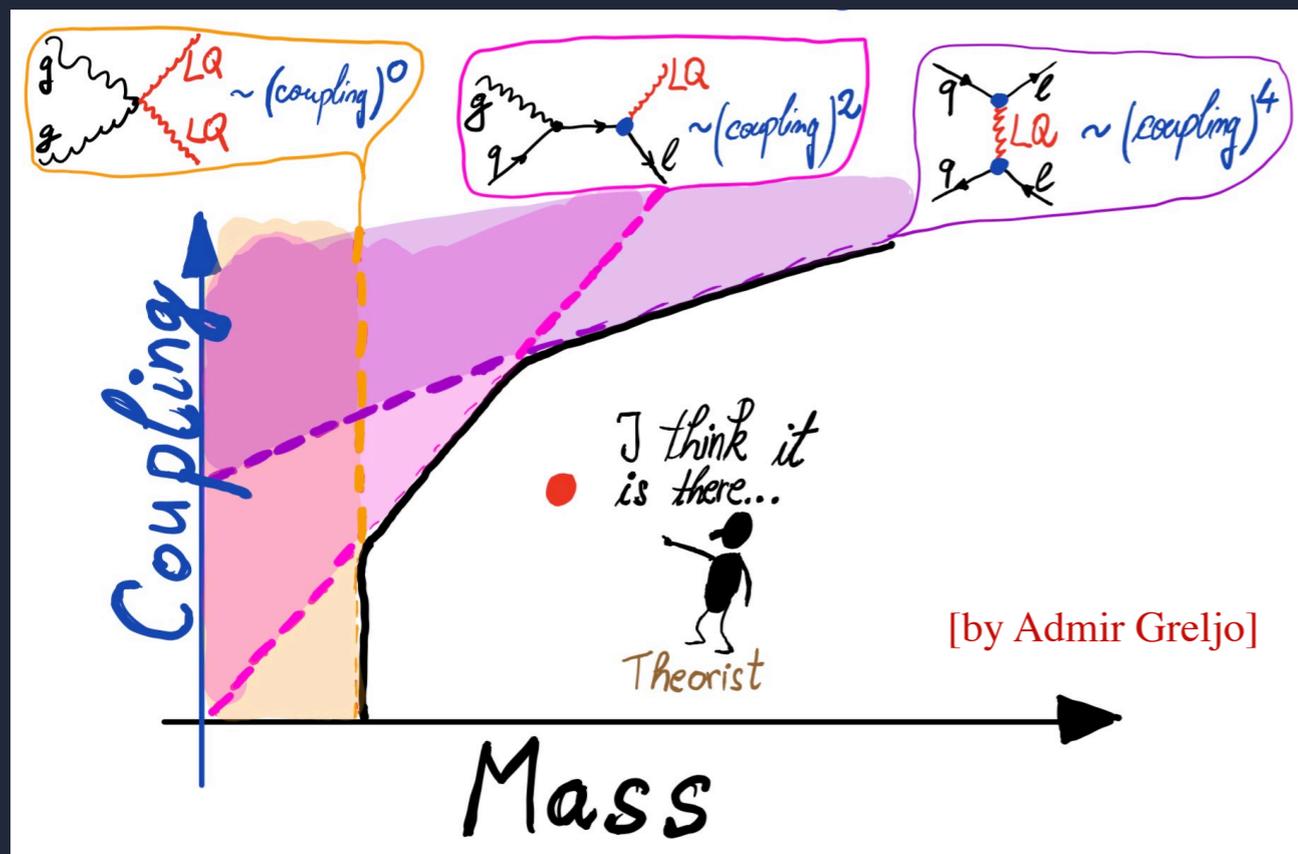
$$\frac{d^4\Gamma}{dq^2 d(\cos\theta_D) d(\cos\theta_L) d\chi} \propto I_{1c} \cos^2\theta_D + I_{1s} \sin^2\theta_D + \dots$$

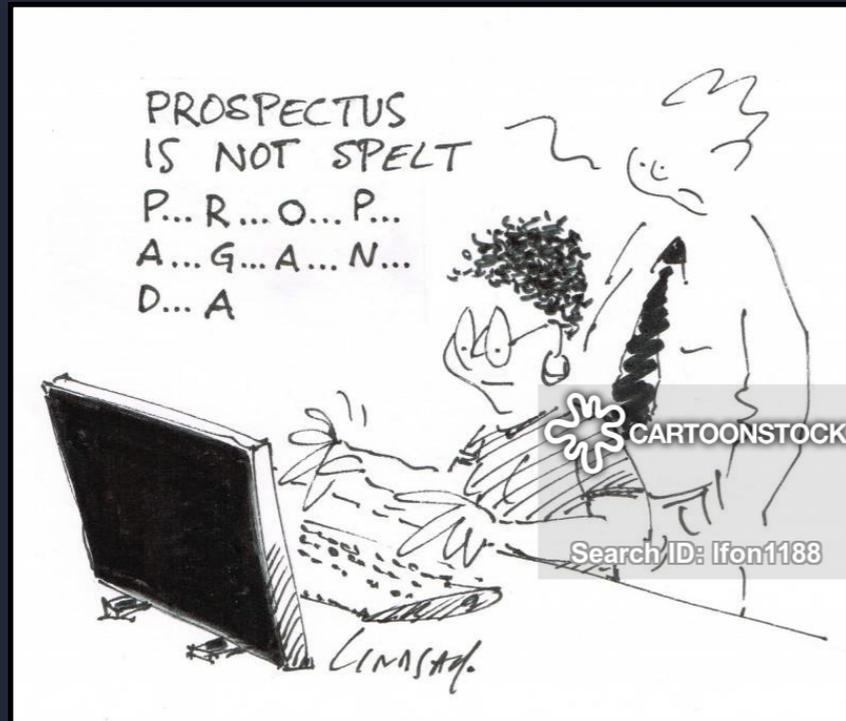
NATURALLY THE WC FITS IS THE NEXT STEP!



A “flavourful” path to NP?

On the interplay between direct and indirect searches





SUMMARY

- VERY RICH PHYSICS PROGRAMME WITH INTERESTING DISCOVERY POTENTIAL IN THE NEAR FUTURE

- INTRIGUING SET OF ANOMALIES IN B DECAYS

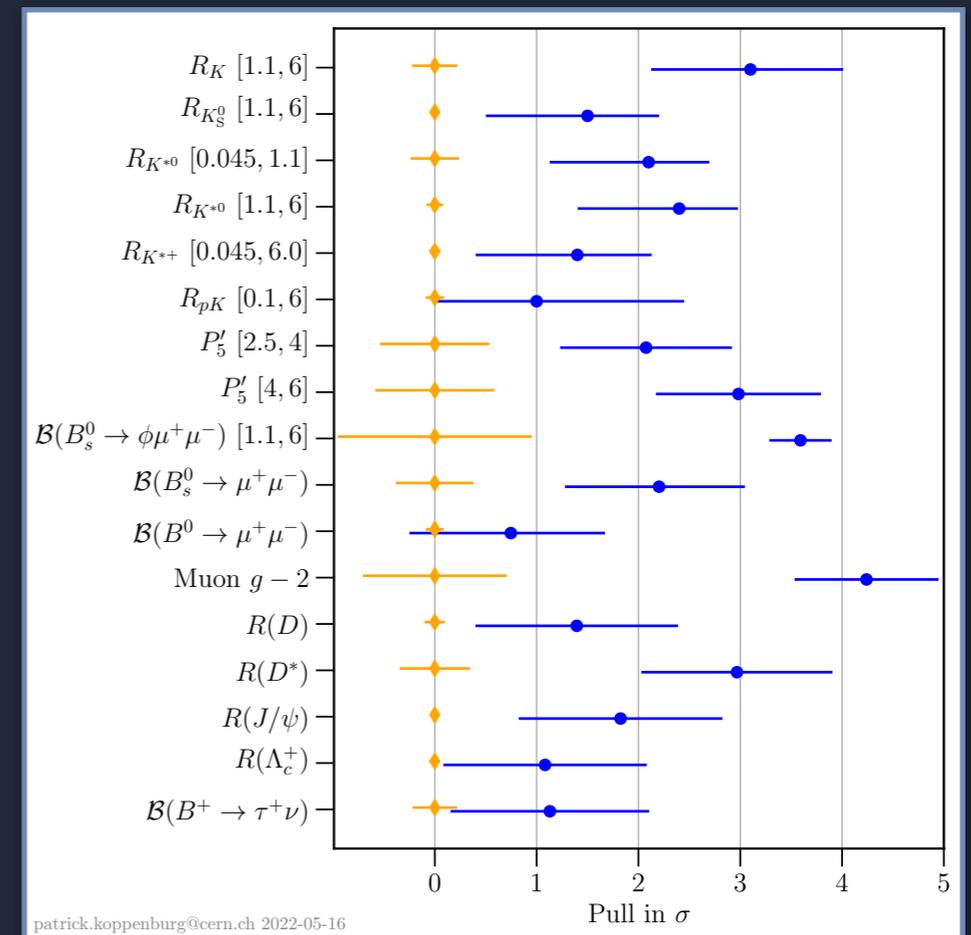
I.E. DECAY RATES, ANGULAR ANALYSIS, LFU ANALYSES

WHAT COMES NEXT?

- MORE DATA, CHANNELS, OBSERVABLES, IDEAS
- FULL UNDERSTANDING WILL REQUIRE A COMBINED EFFORT OF DIFFERENT EXPERIMENTS

- **A PRECISION FLAVOUR PHYSICS ERA AHEAD OF US!**

[A “COMPASS” TO THE LHC SEARCHES?]



Prospects for $B^0_{(s)} \rightarrow \mu^+\mu^-$

[LHCb-PUB-2018-009, ATL-PHYS-PUB-2018-005, CMS PAS FTR-14-013/-015]

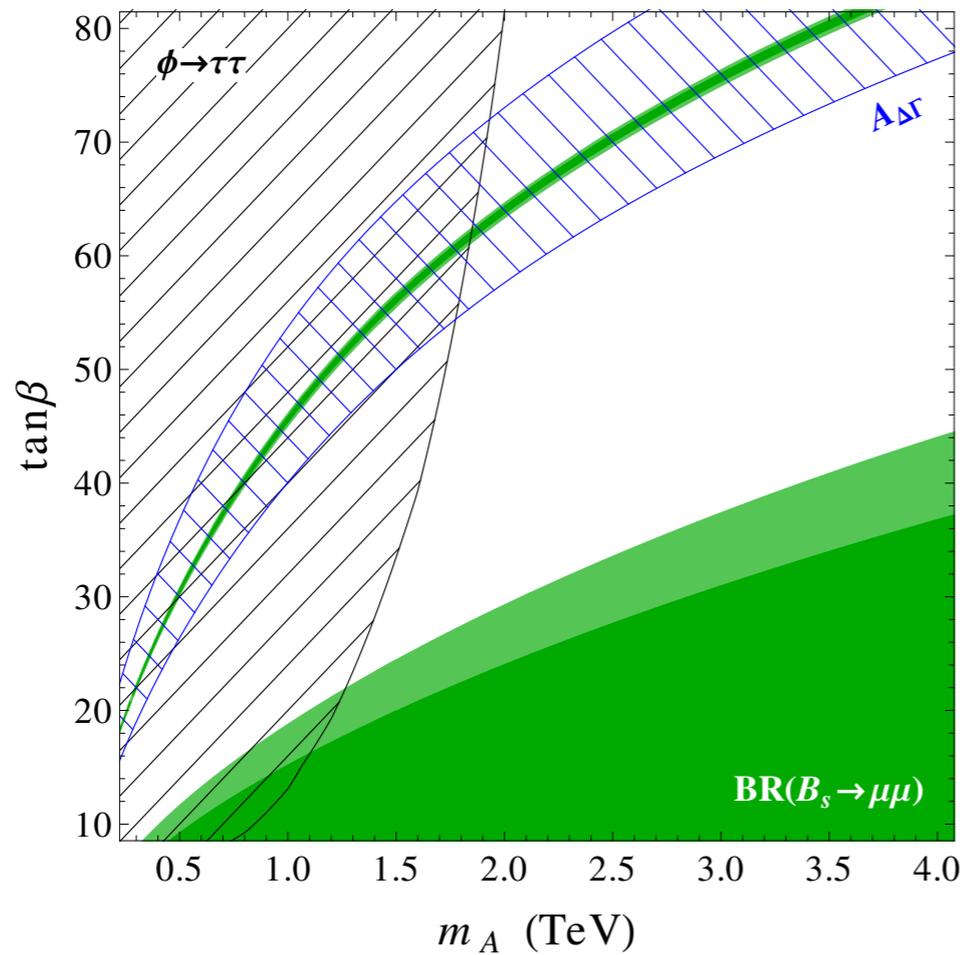
Large Hadron Collider (LHC)													HL-LHC					
Run 1		LS1		Run 2				LS2		Run 3			LS3		Run 4 - 5...			
7 TeV — 8 TeV		13 TeV										13/14 TeV						
2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	...2038		
		current		9fb ⁻¹				23fb ⁻¹			300fb ⁻¹							
LHCb	$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-)$	$\pm 0.6^{+0.3}_{-0.2} \times 10^{-9}$		$+0.46^{+0.15}_{-0.43} \times 10^{-9}$				$\pm 0.30 \times 10^{-9}$			$\pm 0.16 \times 10^{-9}$							
	$\frac{\mathcal{B}(B^0 \rightarrow \mu^+\mu^-)}{\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-)}$	90 %		70 %				34 %			10 %							
	$\tau_{\mu^+\mu^-}$ (ps)	$\pm 0.44 \pm 0.05$		$\pm 0.29 \pm 0.03$				± 0.16			± 0.04							
		150fb ⁻¹				300fb ⁻¹			3000fb ⁻¹									
CMS	$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-)$	$+0.7_{-0.6} \pm 0.2 \times 10^{-9}$						$\pm (0.43 - 0.46) \times 10^{-9}$			$\pm (0.39) \times 10^{-9}$							
	$\frac{\mathcal{B}(B^0 \rightarrow \mu^+\mu^-)}{\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-)}$							50 %			21 %							
	$\tau_{\mu^+\mu^-}$ (ps)	$+0.61_{-0.44}$						± 0.15			± 0.05							
ATLAS	$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-)$	$+0.8_{-0.7} \times 10^{-9}$		$\pm 0.83 \times 10^{-9}$				$\pm (0.46 - 0.55) \times 10^{-9}$										
	$\mathcal{B}(B^0 \rightarrow \mu^+\mu^-)$	$< 2.1 \times 10^{-10}$		$\pm 1.43 \times 10^{-10}$				$\pm (0.28 - 0.54) \times 10^{-10}$										

Prospects for $B^0_{(s)} \rightarrow \mu^+\mu^-$

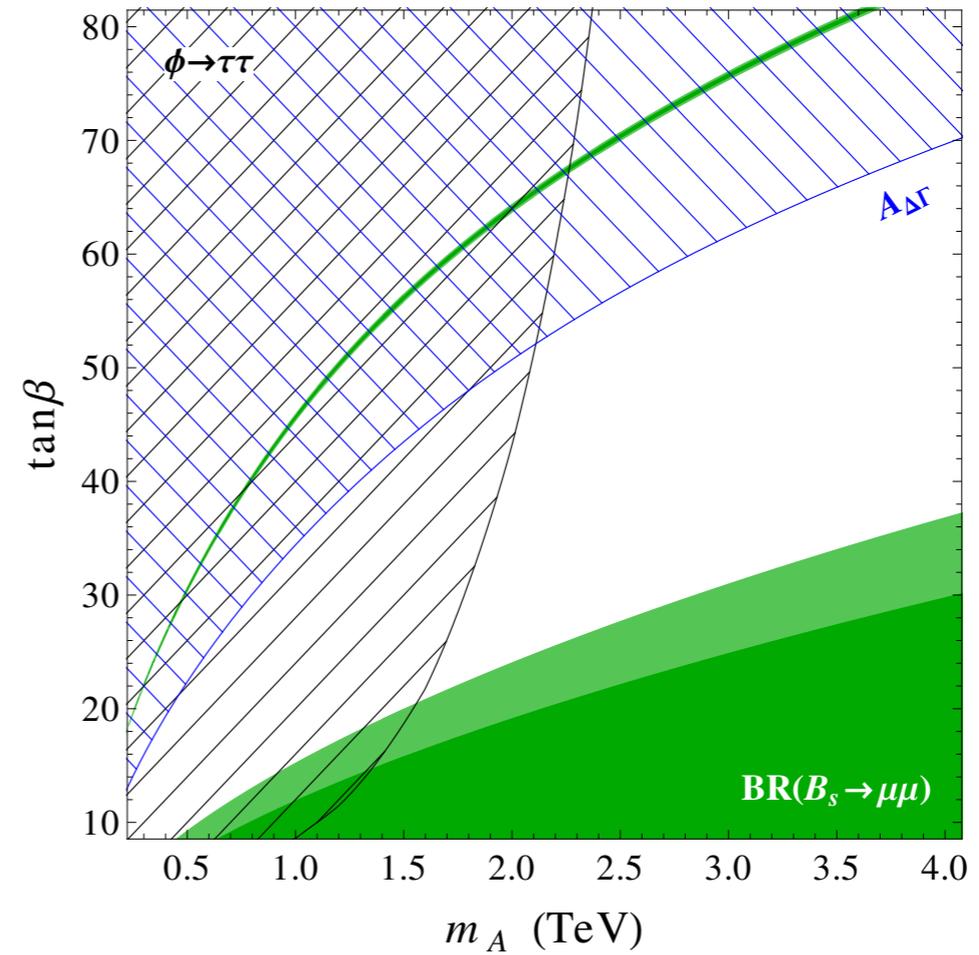
[JHEP 05 (2017) 076]



LHCb Run 4 projection

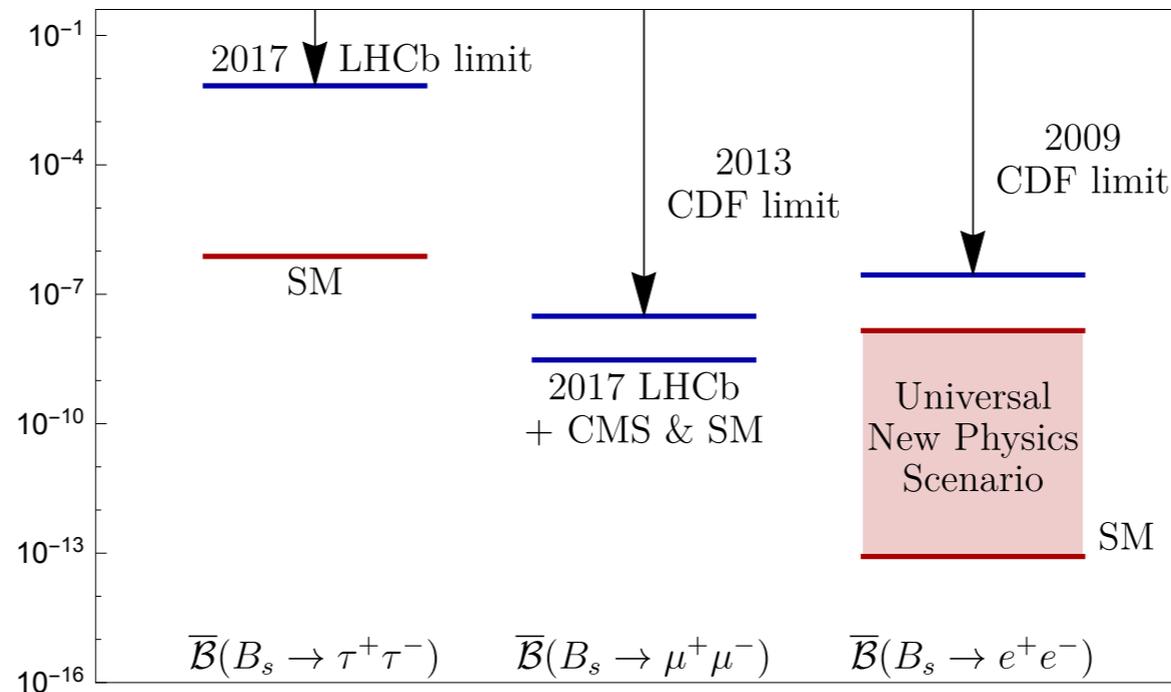


LHCb Run 5 projection

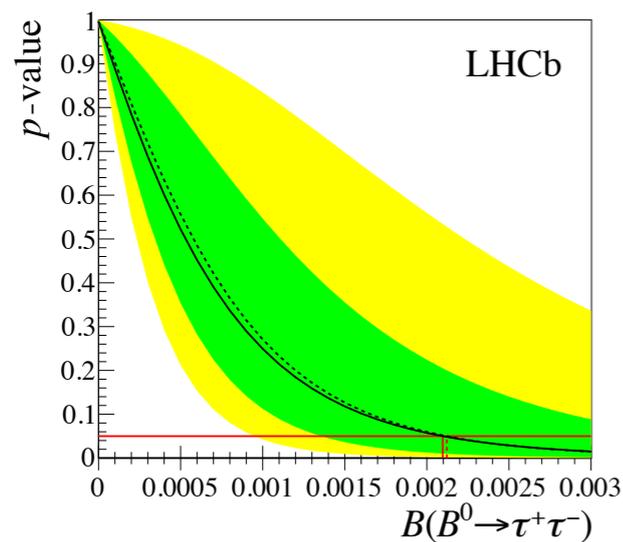


Prospects for $B^0_{(s)} \rightarrow l^+l^-$

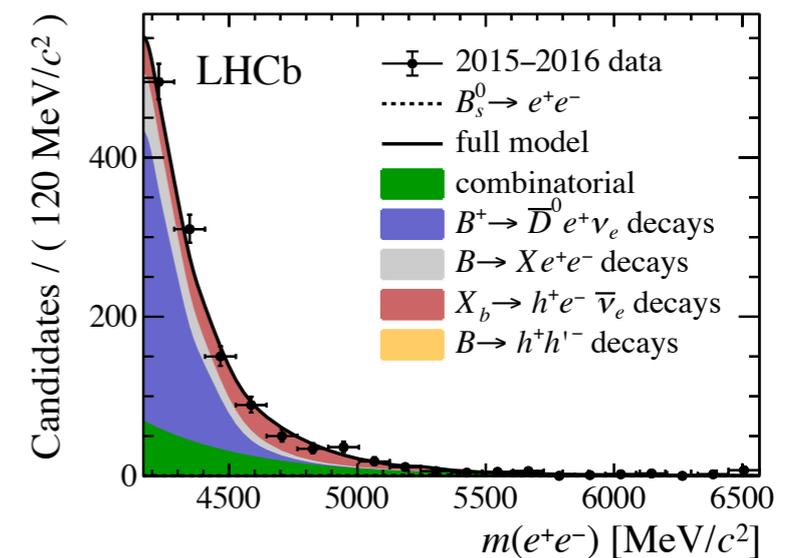
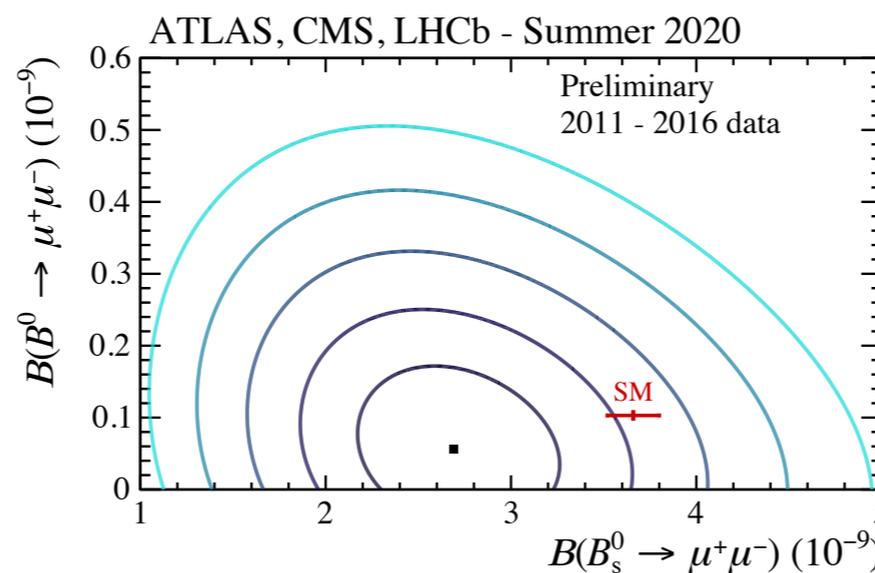
[JHEP 05 (2017) 156]



[PRL 118 (2017) 251802]



[PRL 124 (2020) 211802]

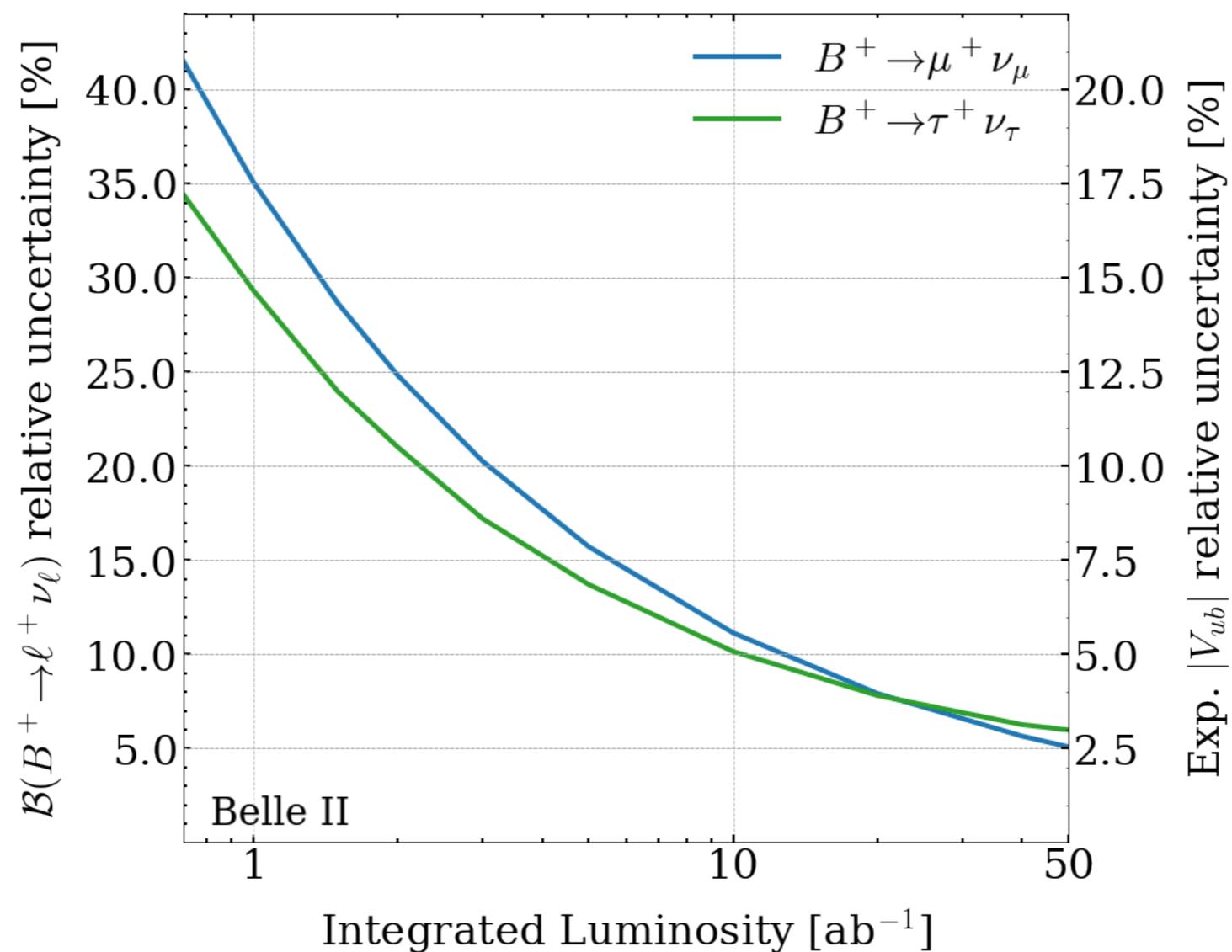


Prospects for $B^+ \rightarrow l\nu$



[JHEP 05 (2017) 156]

Unique opportunity for the Belle II experiment (with missing energy)



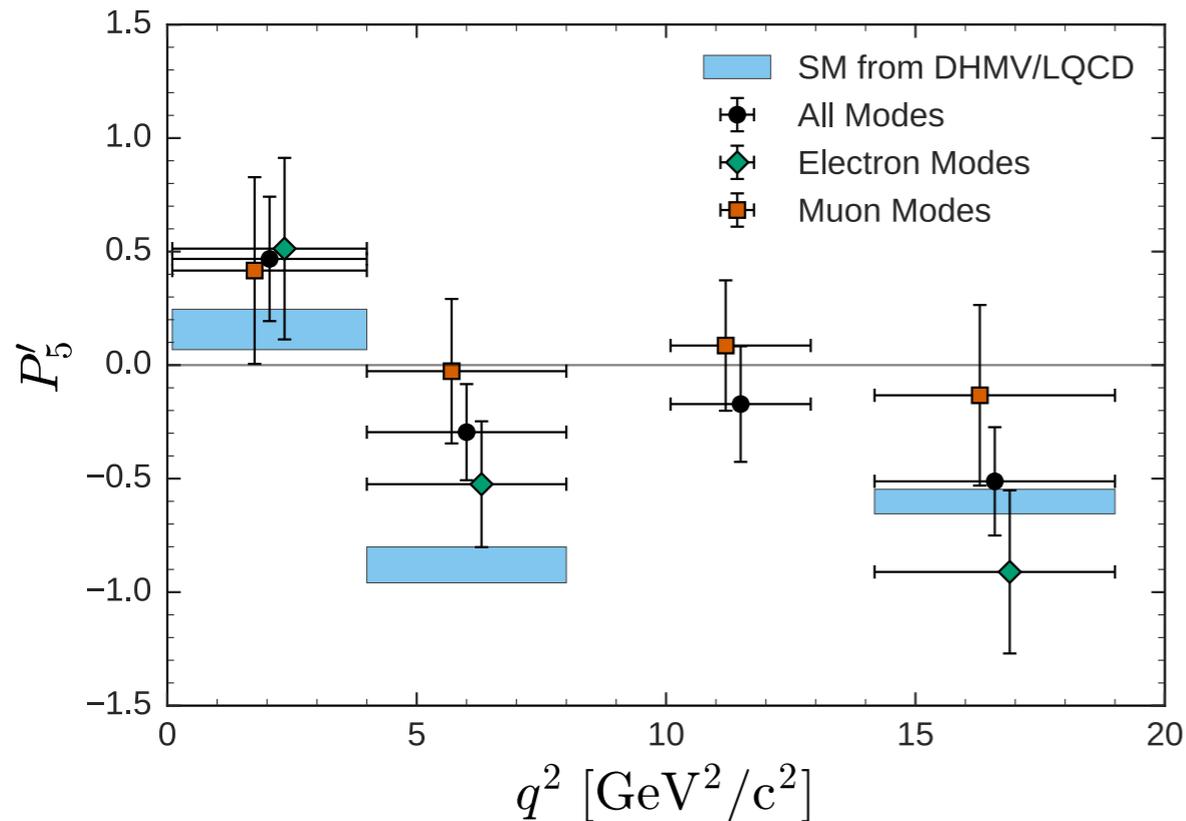
What about other leptons? [$B^0 \rightarrow K^{*0}e^+e^-$]



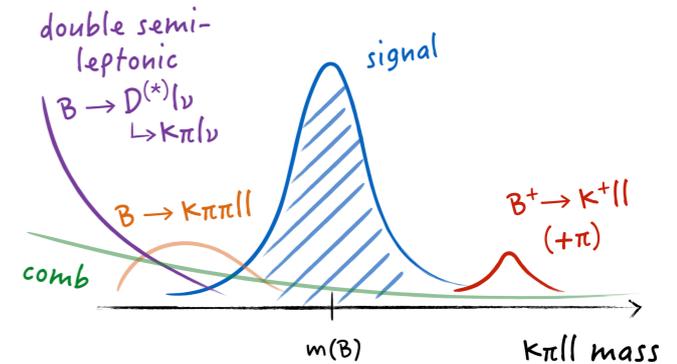
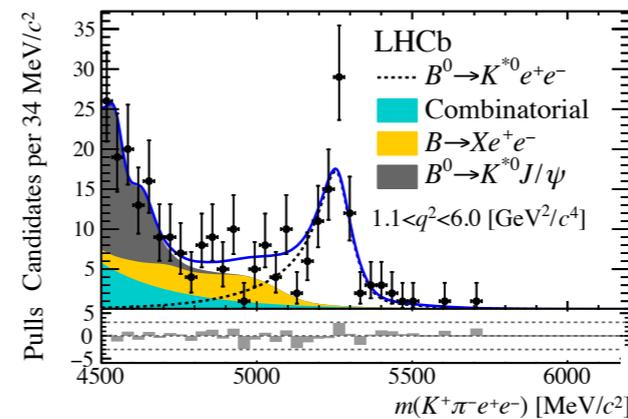
Challenging analysis for LHCb

Similar rate for muons and electrons in Belle II

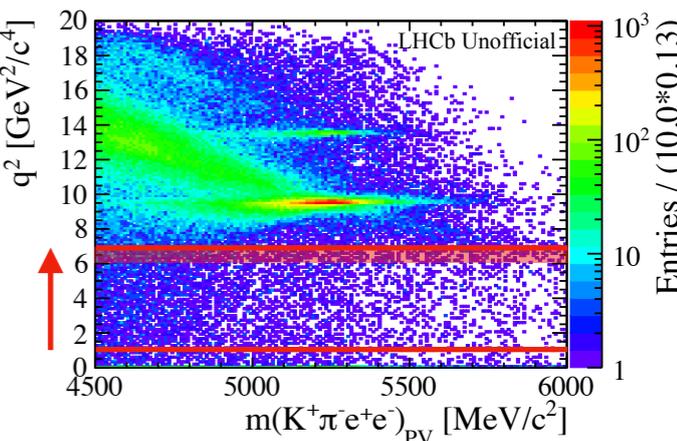
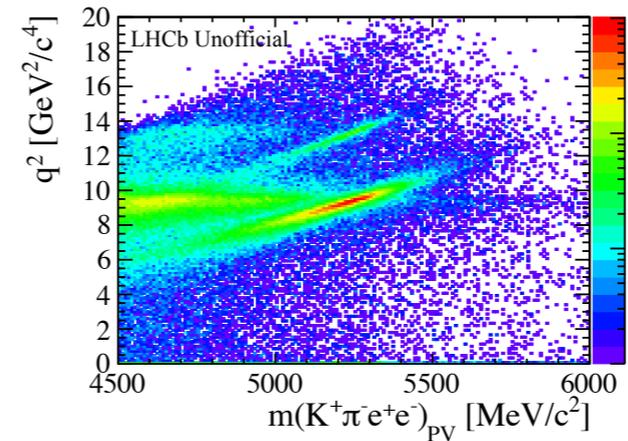
[Belle, PRL 118 (2017) 11, 111801]



[LHCb, JHEP 08 (2017) 055]



[LHCb, CERN-THESIS-2018-074]



Interesting complementary to LHC results

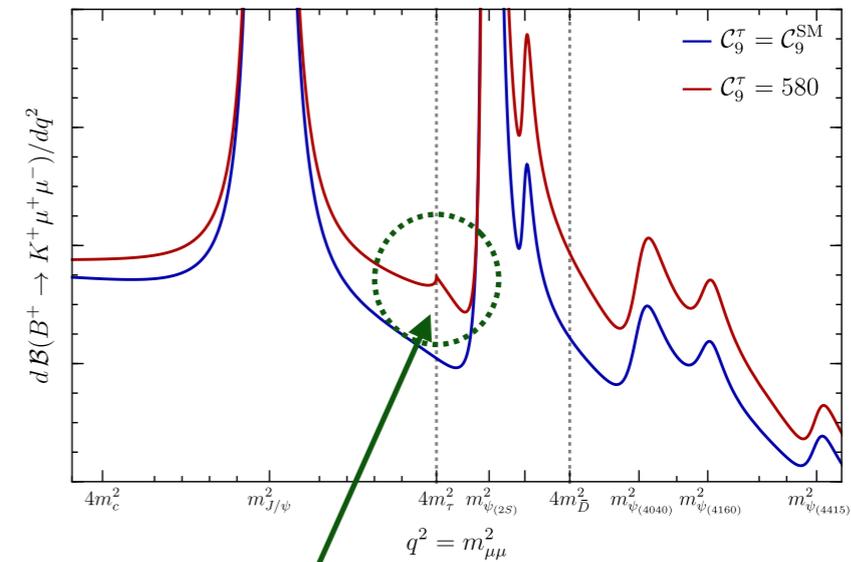
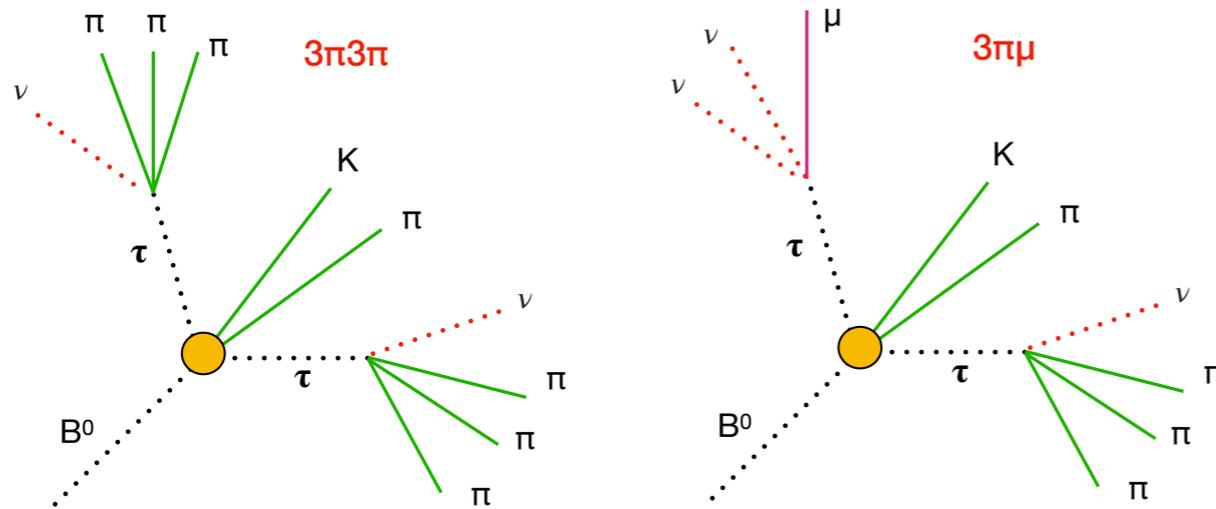
Current sensitivity for P'_5 at ~ 0.12 in $1.1-7.0 \text{ GeV } q^2$

What about other leptons? [$B^0 \rightarrow K^{*0} \tau^+ \tau^-$]



[JHEP 05 (2017) 156, EPJC 80 (2020) 12]

Experimentally extremely challenging, in particular for LHCb



Imprints of $B^0 \rightarrow K^{*0} \tau^+ \tau^-$

Belle II will offer unprecedented sensitivity to this mode

$\mathcal{B}(B^0 \rightarrow K^{*0} \tau \tau)$ (had tag)		
ab ⁻¹	"Baseline" scenario	"Improved" scenario
1	$< 3.2 \times 10^{-3}$	$< 1.2 \times 10^{-3}$
5	$< 2.0 \times 10^{-3}$	$< 6.8 \times 10^{-4}$
10	$< 1.8 \times 10^{-3}$	$< 6.5 \times 10^{-4}$
50	$< 1.6 \times 10^{-3}$	$< 5.3 \times 10^{-4}$

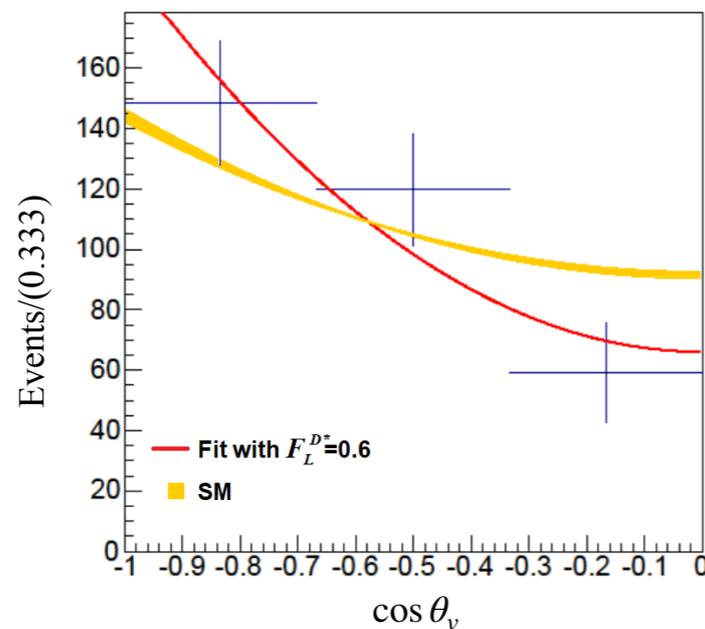
LFU in $b \rightarrow c l \nu$ [next]



Production polarisation of charm mesons, with non-zero spin, produced from $X_b \rightarrow X_c \tau \nu$ decays

$$f_L^{D^*} = \frac{\Gamma(D_L^*)}{\Gamma(D_L^*) + \Gamma(D_T^*)} \approx 45\% \text{ in SM}$$

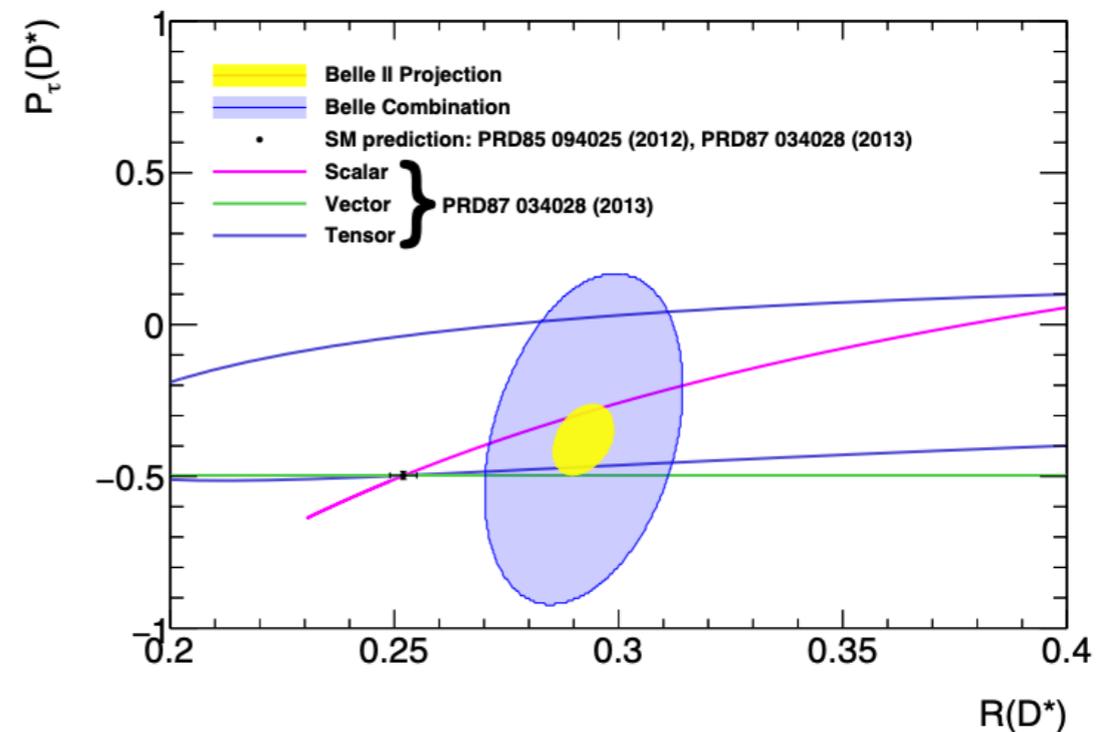
[PRD 79 (2009) 1, 015003]



New channels, e.g. $\Lambda_b \rightarrow \Lambda_c \tau \nu$ and $B \rightarrow D^{**} \tau \nu$

τ lepton polarisation can probe effects of NP

$$P^\tau = \frac{\Gamma^{\lambda_\tau = +1/2} - \Gamma^{\lambda_\tau = -1/2}}{\Gamma^{\lambda_\tau = +1/2} + \Gamma^{\lambda_\tau = -1/2}}$$



Current plans at LHCb with hadronic three-prong τ decays

LFV analyses [today]

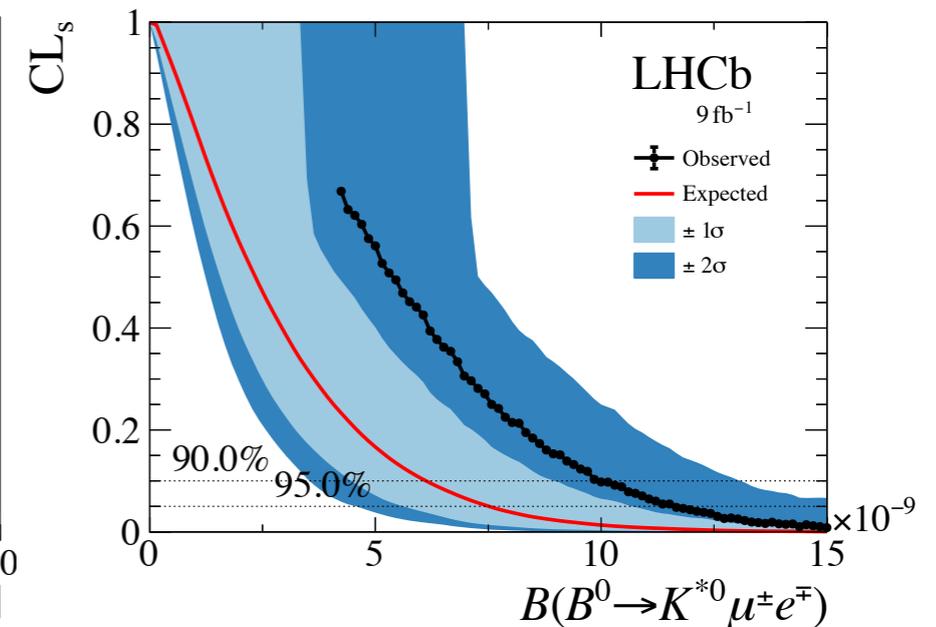
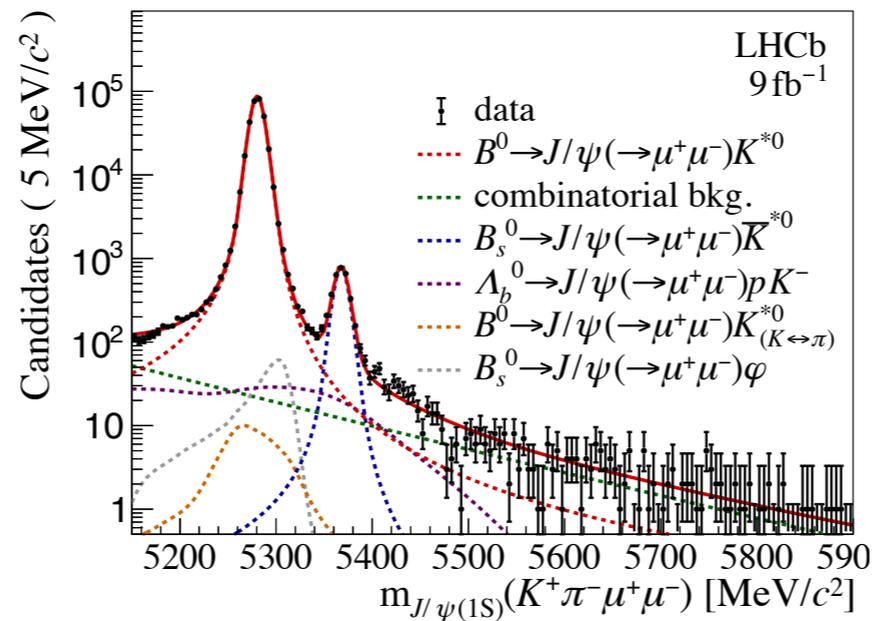
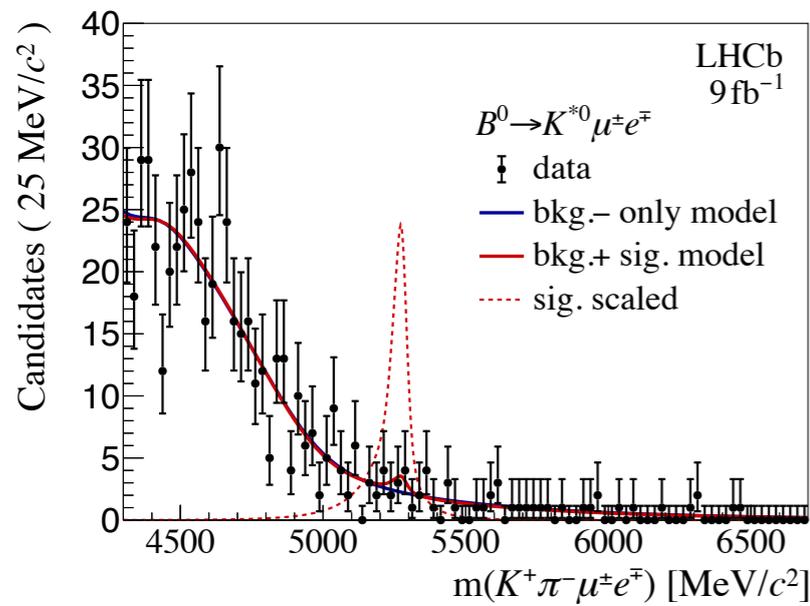


[Preliminary - LHCb-PAPER-2022-008]

Lepton flavour is not protected by any fundamental symmetry in the SM

Many models explaining LFU breaking naturally predict the LFV

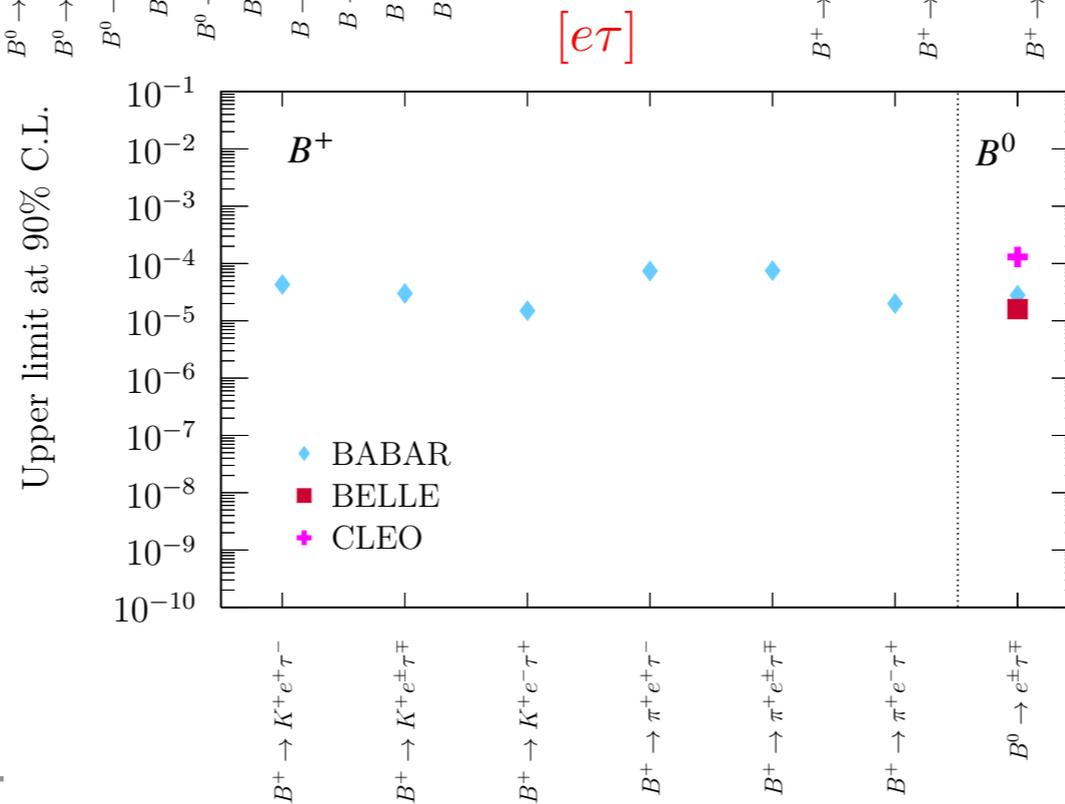
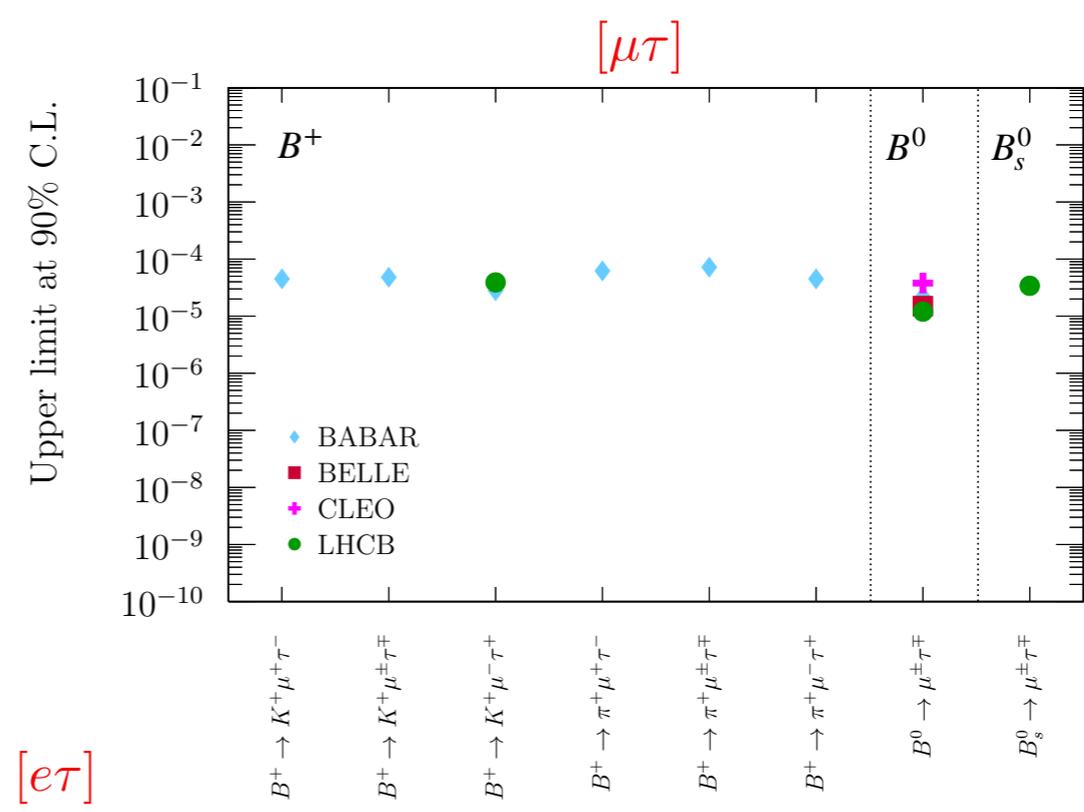
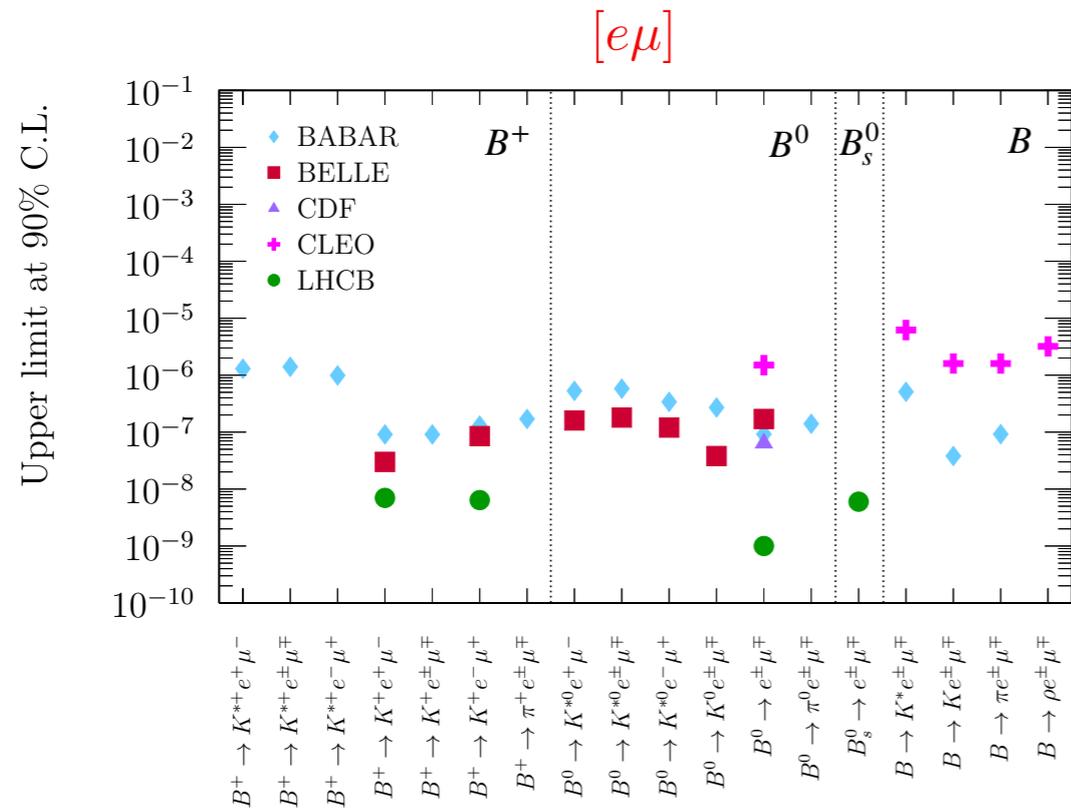
Recent search performed at LHCb



$$\mathcal{B}(B^0 \rightarrow K^{*0} \mu^\pm e^\mp) < 9.9 (11.6) \times 10^{-9}$$

Two orders of magnitude than previous searches

LFV analyses [today]



Significant improvements foreseen for the next decade

Decay	Limit @ 90% C.L.	Luminosity	Reference	Upgrade I	Upgrade II
$B^0 \rightarrow e \mu$	1.0×10^{-9}	3 fb^{-1} (Run1)	<i>JHEP 03 (2018) 078</i>	$\sim 2 \times 10^{-10}$	$\sim 9 \times 10^{-11}$
$B_s \rightarrow e \mu$	5.4×10^{-9}			$\sim 8 \times 10^{-10}$	$\sim 3 \times 10^{-10}$
$B^+ \rightarrow K^+ e^+ \mu^-$	7.0×10^{-9}	3 fb^{-1} (Run1)	<i>Phys. Rev. Lett. 123 (2019) 241802</i>	$\sim 4 \times 10^{-10}$	$\sim 7 \times 10^{-11}$
$B^+ \rightarrow K^+ e^- \mu^+$	6.4×10^{-9}			$\sim 4 \times 10^{-10}$	$\sim 6 \times 10^{-11}$
$B^0 \rightarrow K^{*0} \mu^\pm e$	9.9×10^{-9}	9 fb^{-1} (Run1+2)	<i>LHCb-PAPER-2022-008 (preliminary)</i>	$\sim 4 \times 10^{-9}$	$\sim 2 \times 10^{-9}$
$B^0 \rightarrow K^{*0} \mu^- e^+$	6.7×10^{-9}			$\sim 3 \times 10^{-9}$	$\sim 1 \times 10^{-9}$
$B^0 \rightarrow K^{*0} \mu^+ e^-$	5.7×10^{-9}			$\sim 4 \times 10^{-9}$	$\sim 1 \times 10^{-9}$
$B_s \rightarrow \phi \mu^\pm e$	1.6×10^{-8}			$\sim 4 \times 10^{-9}$	$\sim 4 \times 10^{-9}$
$B^0 \rightarrow \tau \mu$	1.2×10^{-5}	3 fb^{-1} (Run1)	<i>Phys. Rev. Lett. 123 (2019) 211801</i>	$\sim 3 \times 10^{-6}$	$\sim 1 \times 10^{-6}$
$B_s \rightarrow \tau \mu$	3.4×10^{-5}			$\sim 8 \times 10^{-6}$	$\sim 3 \times 10^{-6}$
$B^+ \rightarrow K^+ \tau \mu$	3.9×10^{-5}	9 fb^{-1} (Run1+2)	<i>JHEP 06 (2020) 129</i>	$\sim 1 \times 10^{-5}$	$\sim 5 \times 10^{-6}$
				$\sim 3 \times 10^{-9}$	$\sim 1 \times 10^{-9}$

Also: $BR(\tau \rightarrow \mu \mu \mu) < 4.6 \times 10^{-8}$ at 90% C.L. with 3 fb^{-1} (Run1) [*JHEP 02 (2015) 121*]

LFV analyses [next]



[LHCb, arXiv:1808.08865, The Belle II Physics Book]

Reaching an interesting range for BSM physics

