Impact of a non-universal Z' on the $B \to K^{(*)} l^+ l^-$ and $B \to K^{(*)} \nu\bar{\nu}$ processes

(based on Symmetry 13 (2021) 2, 191 and Phys.Rev.D 107 (2023) 11, 115033)

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Outline

Flavour anomalies

- $\sim 0.2\sigma$ in R_K [LHCb:2022zom]

$$R_K^{[1.1-6.0]} = \frac{BR(B \to K\mu^+\mu^-)}{BR(B \to Ke^+e^-)} = 0.949^{+0.042}_{-0.041}(stat.) \pm 0.022(syst.)$$

- $\sim 0.2\sigma$ in R_K^* [LHCb:2022zom]

$$R_K^{*[1.1-6.0]} = \frac{BR(B_0 \to K^*\mu^+\mu^-)}{BR(B_0 \to K^*e^+e^-)} = 1.027^{+0.072}_{-0.068} \pm 0.027$$

- $\sim 2.5\sigma$ in $P_5'^{[4-6.0]} = 0.439 \pm 0.111 \pm 0.036$ [Phys.Rev.Lett. 125 (2020) 1, 011802]
- The mass difference of the neutral $B_s - \bar{B}_s$ meson system

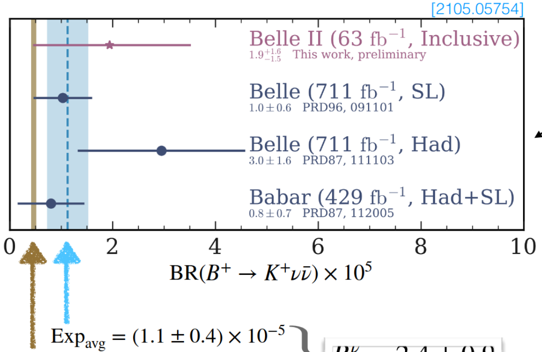
$$\Delta M_s^{exp} = (17.765 \pm 0.004)\ \text{ps}^{-1}, \qquad \text{[HFLAV, 2023]}$$
$$\Delta M_s^{SM} = (18.77 \pm 0.76)\ \text{ps}^{-1} \qquad \text{[Amhis:2019ckw]}$$

- $\sim 2.4\sigma$ in $BR(B_s \to \mu^+\mu^-)$

$$(B_s \to \mu^+\mu^-)^{Exp} = 3.45 \pm 0.29, \qquad \text{[HFLAV, 2023]}$$
$$(B_s \to \mu^+\mu^-)^{SM} = 3.68 \pm 0.14 \qquad \text{[JHEP 11 (2022) 099]}$$

$b \to s\nu\bar{\nu}$ decays

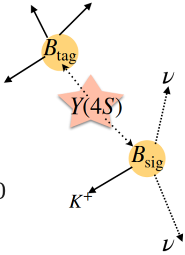
- $B \to K^{(*)}\nu\bar{\nu}$ theoretically much cleaner than $B \to K^* l^+ l^-$;
- Experimentally quite challenging due to two missing neutrinos — No signal has been observed so far;
- Inclusive tagging technique from Belle II has higher efficiency $\sim 4\%$

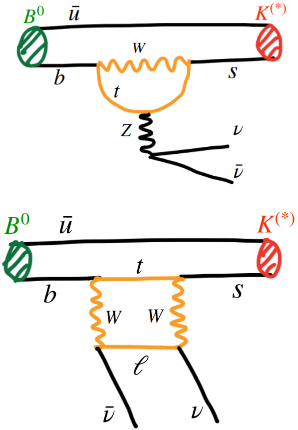


$\mathrm{Exp}_{avg} = (1.1 \pm 0.4) \times 10^{-5}$

$\mathrm{SM} = (4.6 \pm 0.5) \times 10^{-6}$

$$R_K^{\nu} = 2.4 \pm 0.9$$





$U\nu_R MSSM$ description

- $U(1)'$ extension of MSSM with gauge structure:

$$SU(3) \times SU(2) \times U(1) \times U(1)'$$

- MSSM chiral multiplets + singlet superfield S (allows one to break $U(1)'$ spontaneously and generate mass for the corresponding Z' boson);
- Three right-handed chiral superfields $\nu^c_{1,2,3}$;
- $Q' = a(B-L)_3 + b(L_2 - L_3) + c(L_1 - L_2)$ and made the substitutions $L_3 \to H_d$, $\nu^c_3 \to S$ ($a = 3$, $b = -2$, $c = -1$);
- Non-universal charges for ACCs:

field	Q'	field	Q'	field	Q'
$Q_{1,2}$	0	$U^c_{1,2}$	0	$D^c_{1,2}$	0
Q_3	$+1$	U^c_3	-1	D^c_3	-1
$L_{1,2}$	-1	$E^c_{1,2}$	$+1$	$\nu^c_{1,2}$	$+1$
L_3	0	E^c_3	$+1$	ν^c_3	0
H_d	-1	H_u	0	S	$+1$

- Superpotential:

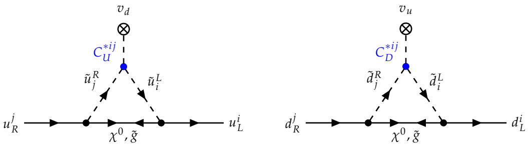
$$W = \sum_{i,j=1,2} Y_u^{ij} Q_i H_u U_j^c + Y_u^{33} Q_3 H_u U_3^c - (Q_3 H_d)(Y_d^{31} D_1^c + Y_d^{32} D_2^c)$$
$$+ \sum_{i,j=1,2} Y_\nu^{ij} L_i H_u \nu_j^c + M_3^\nu \nu_3^c \nu_3^c + Y_\nu^{33} L_3 H_u \nu_3^c$$
$$- (L_3 H_d)\left(Y_e^{31} E_1^c + Y_e^{32} E_2^c + Y_e^{33} E_c^3\right) + \lambda_s S H_u H_d \quad (1)$$

- The gauge field Z' couples to quarks and leptons as

$$\mathcal{L} \ni g_E Z'_\alpha \left[\bar{b}\gamma_\alpha b + \bar{t}\gamma_\alpha t\right]$$
$$- g_E Z'_\alpha \left[\sum_{i=1,2} \left([\bar{l}_{iL}\gamma_\alpha l_{iL} + \bar{\nu}_{iL}\gamma_\alpha \nu_{iL}] + \bar{\nu}_{iR}\gamma_\alpha \nu_{iR}\right) - \sum_{i=1,3} \bar{l}_{iR}\gamma_\alpha l_{iR}\right]. \quad (2)$$

- Non-holomorphic soft SUSY-breaking terms:

$$-\mathcal{L}^{nh}_{soft} = \sum_{i=1}^{2}\sum_{j=1}^{3} C_E^{ij} (H_u^* \tilde{l}_i)\tilde{E}_j^c + C_D^{33} H_u^* \tilde{q}_3 \tilde{d}_3^c + H_u^* \sum_{i,j=1,2} C_D^{ij} \tilde{q}_i \tilde{d}_j^c$$
$$+ H_d^* \left(\tilde{q}_1 C_U^{13} + \tilde{q}_2 C_U^{23}\right) \tilde{u}_3^c + H_d^* \left(\tilde{l}_1 C_\nu^{13} + \tilde{l}_2 C_\nu^{23}\right) \tilde{\nu}_3^c + \text{h.c.}. \quad (3)$$



- $U(3)_Q \times U(3)_L \times U(3)_D \times U(3)_U \times U(3)_E \times U(3)_\nu$, $U(1)'$ breaks this symmetry down to

$$U_{flavour} = \left[U(2)_{Q_{12}} \cdot U(1)_{Q_3}\right] \times \left[U(2)_{U_{12}} \cdot U(1)_{U_3}\right] \times \left[U(2)_{D_{12}} \cdot U(1)_{D_3}\right] \times \left[U(2)_{L_{12}} \cdot U(1)_{L_3}\right] \cdot \left[U(3)_E\right] \times \left[U(2)_{\nu_{12}} \cdot U(1)_{\nu_3}\right], \quad (4)$$

- Mass matrices breaks $U_{flavour}$ down to

$$U_{flavour} \to \begin{cases} U_B(1) \times U_L(1), & M_3^\nu = 0 \\ U_B(1), & M_3^\nu \neq 0 \end{cases} \quad (5)$$

- $$N_{tot}^{quark} = 14_{Re} + 14_{Im}, \quad N_{tot}^{lepton} = 16_{Re} + 16_{Im} + (1_{Re} + 1_{Im})_{M_3^\nu \neq 0}, \quad (6)$$

$$N_{broken}^{quark} = 3_{angles} + (12-1)_{phases}, \quad N_{broken}^{lepton} = 5_{angles} + 14_{phases} - (1_{phases})_{M_3^\nu = 0} \quad (7)$$

Therefore

$$N_{phys}^{quark} = 11_{Re} + 3_{Im}, \quad N_{phys}^{lepton} = 11_{Re} + 3_{Im} + (1_{Re})_{M_3^\nu \neq 0}. \quad (8)$$

In the quark sector: 6 quark masses, 3 CKM angles and 1 CKM phase + $(\alpha_{13}, \alpha_{23})$, (ϕ_{13}, ϕ_{23}). In the lepton sector: $(M_3^\nu = 0)$: 6 lepton masses, 3 CKM angles and 3 angles and 1 CP-violating phase in PMNS + (β_{13}, β_{23}), (χ_{13}, χ_{23}).

- The mixing-matrices elements for quarks $V_{L(R),3q}$ are defined as

$$V_{L,3q} = \left\{-s^d_{13}e^{-i\phi_{13}}, -c^d_{13}s^d_{23}e^{-i\phi_{23}}, c^d_{13}c^d_{23}\right\},$$
$$V_{R,3q} = \frac{\left\{-m_b m_s s^d_{13}e^{-i\phi_{13}}, -m_b m_d c^d_{13}s^d_{23}e^{-i\phi_{23}}, m_s m_d c^d_{13}c^d_{23}\right\}}{\sqrt{m_d^2(m_b^2 s_{23}^2 + m_s^2 c_{23}^2)c_{13}^2 + m_b^2 m_s^2 s_{13}^2}}, \tag{9}$$

while for leptons one can write

$$V_{L,3l} = \left\{-s^e_{13}e^{i\chi_{13}}, -c^e_{13}s^e_{23}e^{i\chi_{23}}, c^e_{13}c^e_{23}\right\}, \qquad V_{R,3l} = 1, \tag{10}$$
$$V_{L,3\nu} = \left\{\tilde{U}_{l1}, \tilde{U}_{l2}, \tilde{U}_{l3}\right\}, \quad V_{R,3\nu} = \frac{\left\{m_{\nu_1}\tilde{U}_{l1}, m_{\nu_2}\tilde{U}_{l2}, m_{\nu_3}\tilde{U}_{l3}\right\}}{\sqrt{m_{\nu_3}^2|\tilde{U}_{l3}|^2 + m_{\nu_2}^2|\tilde{U}_{l2}|^2 + m_{\nu_1}^2|\tilde{U}_{l1}|^2}}. \tag{11}$$

For convenience, we introduce the following shorthand notation

$$\tilde{U}_{li} \equiv c^e_{13}(U_{\tau i}c^e_{23} - U_{\mu i}s^e_{23}e^{-i\chi_{23}}) - U_{ei}s^e_{13}e^{-i\chi_{13}}, \qquad i = \{1, 2, 3\}, \tag{12}$$

with $U_{l_{ij}}$ being the matrix elements of the PMNS matrix.

- The gauge field Z' couples to quarks and leptons as

$$\Delta\mathcal{L}_{Z'} = g_E J^\alpha Z'_\alpha, \tag{13}$$

$$\begin{aligned} J^\alpha \supset & \sum_{q,q'=1,3} \Big[V_{R,3q}V^*_{R,3q'}(\overline{\mathcal{D}}_{qR}\gamma_\alpha\mathcal{D}_{q'R}) + V_{L,3q}V^*_{L,3q'}(\overline{\mathcal{D}}_{qL}\gamma_\alpha\mathcal{D}_{q'L})\Big] \\ & - \sum_{l,l'=1,3} \Big[\delta_{ll'}(\overline{\mathcal{E}}_l\gamma_\alpha\mathcal{E}_{l'} + \overline{\mathcal{N}}_l\gamma_\alpha\mathcal{N}_{l'}) - V^*_{L,3l}V_{L,3l'}(\overline{\mathcal{E}}_{lL}\gamma_\alpha\mathcal{E}_{l'L})\Big] \\ & + \sum_{\nu\nu'=1,3} \Big[V^*_{L,3\nu}V_{L,3\nu'}(\overline{\mathcal{N}}_{\nu L}\gamma_\alpha\mathcal{N}_{\nu' L}) + V^*_{R,3\nu}V_{R,3\nu'}(\overline{\mathcal{N}}_{\nu R}\gamma_\alpha\mathcal{N}_{\nu' R})\Big]. \end{aligned} \tag{14}$$

- We can introduce the following notation

$$\begin{aligned} g_L^{qq'} \equiv V_{L,3q}V^*_{L,3q'}, \qquad g_R^{qq'} \equiv V_{R,3q}V^*_{R,3q'}, \\ g_L^{ll'} \equiv V_{L,3l}V^*_{L,3l'} - \delta_{ll'}, \qquad g_R^{ll'} \equiv 1, \\ g_L^{\nu\nu'} \equiv V_{L,3\nu}V^*_{L,3\nu'} - \delta_{\nu\nu'}, \qquad g_R^{\nu\nu'} \equiv V_{R,3\nu}V^*_{R,3\nu'} - \delta_{\nu\nu'}, \end{aligned} \tag{15}$$

where $g^{ll'}_{L(R)}$ are the left-handed (right-handed) couplings of the Z' boson to leptons, $g^{\nu\nu'}_{L(R)}$ to neutrinos and $g^{qq'}_{L(R)}$ to quarks.

Effective Electroweak Hamiltonian for $b \to s$ FCNCs

The effective four-fermion Hamiltonian after integrating out the heavy Z'

$$\mathcal{H}_{eff}^{Z'} = \frac{g_E^2}{2M_{Z'}^2} J_\alpha J^\alpha \supset \frac{g_E^2}{M_{Z'}^2} g_L^{bs} (\bar{s}\gamma^\alpha P_L b)[\bar{l}\gamma_\alpha (g_L^{ll'} P_L + g_R^{ll'} P_R) l']$$
$$+ \frac{g_E^2}{M_{Z'}^2} g_R^{bs} (\bar{s}\gamma^\alpha P_R b)[\bar{l}\gamma_\alpha (g_L^{ll'} P_L + g_R^{ll'} P_R) l]$$
$$+ \frac{g_E^2}{2M_{Z'}^2} (g_{L(R)}^{bs})^2 (\bar{s}\gamma^\alpha P_{L(R)} b)(\bar{s}\gamma^\alpha P_{L(R)} b)$$
$$+ \frac{g_E^2}{M_{Z'}^2} (g_L^{bs})(g_R^{bs}) (\bar{s}\gamma^\alpha P_L b)(\bar{s}\gamma^\alpha P_R b)$$
$$+ \frac{g_E^2}{M_{Z'}^2} g_L^{bs} (\bar{s}\gamma^\alpha P_L b)[\bar{\nu}\gamma_\alpha (g_L^{\nu\nu'} P_L + g_R^{\nu\nu'} P_R) \nu']$$
$$+ \frac{g_E^2}{M_{Z'}^2} g_R^{bs} (\bar{s}\gamma^\alpha P_R b)[\bar{\nu}\gamma_\alpha (g_L^{\nu\nu'} P_L + g_R^{\nu\nu'} P_R) \nu'] + \text{h.c.} \quad (16)$$

where G_F – Fermi constant, $V_{tb}V_{ts}^*$ – CKM matrix element,
$C_i(\mu)$ – Wilson coefficients, $O_i(\mu)$ – Four-fermion operators for $b \to s$ transition

Wilson coefficients induced by the Z' exchange

$$H_{eff} = \sum C_i O_i + \text{h.c.} \tag{17}$$

$$C_9^{ll'} = \mathcal{N} \frac{g_E^2}{M_{Z'}^2} g_L^{bs} [g_R + g_L]^{ll'} \qquad C_9'^{ll'} = \mathcal{N} \frac{g_E^2}{M_{Z'}^2} g_R^{bs} [g_R + g_L]^{ll'}, \tag{18}$$

$$C_{10}^{ll'} = \mathcal{N} \frac{g_E^2}{M_{Z'}^2} g_L^{bs} [g_R - g_L]^{ll'} \qquad C_{10}'^{ll'} = \mathcal{N} \frac{g_E^2}{M_{Z'}^2} g_R^{bs} [g_R - g_L]^{ll'}, \tag{19}$$

$$C_L^{\nu\nu'} = \mathcal{N} \frac{g_E^2}{M_{Z'}^2} g_L^{bs} [g_L]^{\nu\nu'} \qquad C_L'^{\nu\nu'} = \mathcal{N} \frac{g_E^2}{M_{Z'}^2} g_L^{bs} [g_R]^{\nu\nu'}, \tag{20}$$

$$C_R^{\nu\nu'} = \mathcal{N} \frac{g_E^2}{M_{Z'}^2} g_R^{bs} [g_L]^{\nu\nu'} \qquad C_R'^{\nu\nu'} = \mathcal{N} \frac{g_E^2}{M_{Z'}^2} g_R^{bs} [g_R]^{\nu\nu'}, \tag{21}$$

$$C_{LL(RR)}^{bs} = -\frac{1}{4\sqrt{2} G_F (V_{tb} V_{ts}^*)^2} \frac{g_E^2}{M_{Z'}^2} (g_{L(R)}^{bs})^2 \qquad C_{LR}^{bs} = -\frac{1}{2\sqrt{2} G_F (V_{tb} V_{ts}^*)^2} \frac{g_E^2}{M_{Z'}^2} (g_L^{bs})(g_R^{bs}), \tag{22}$$

where the overall factor is given by $\mathcal{N} = -\frac{\pi}{\sqrt{2} G_F \alpha_e V_{tb} V_{ts}^*}$.

Phenomenological model analysis

- Fit performed using python `flavio` package;
- Observable list:
  FIT$_1$: $B_s - \bar{B}_s$; $B_s \to \mu^+\mu^-$; $R_K(B^+ \to Kll)$, $R_{K^*}(B^0 \to K^*ll)$; $B^+ \to K\nu\nu$; $B \to X_s\mu^+\mu^-$; $B \to X_s e^+e^-$; $B^{0,+} \to K^{(*)}\mu^+\mu^-$; $B^0 \to K^* e^+e^-$; $B_s \to \phi\mu^+\mu^-$; $B_0 \to K^{*0}e^+e^-$; $B_s^0 \to \phi\mu^+\mu^-$.
  FIT$_2$: FIT$_1$ + CP-asymmetries $A_{i=3,4,5,6s,7,8,9}$, and A_{CP} for $B^{0,+} \to K^*\mu^+\mu^-$.

CP-conserving

$$\alpha_{13} = (2.0 \pm 4)\cdot 10^{-3}, \qquad \alpha_{23} = -0.207 \pm 0.022,$$
$$\beta_{13} = 0.61 \pm 0.10, \;\; \beta_{23} = 0 \pm 0.5,$$
$$M_{Z'}/g_E = 16.1 \pm 0.6\text{TeV},$$
$$\phi_{13} = \phi_{23} = \chi_{13} = \chi_{23} = 0,$$

CP-violating

$$\alpha_{13} = (8 \pm 2)\cdot 10^{-3}, \alpha_{23} = 0.34 \pm 0.08,$$
$$\beta_{13} = 0.76 \pm 0.17, \beta_{23} = 0.0 \pm 0.3,$$
$$M_{Z'}/g_E = 18.4 \pm 1.7\text{TeV},$$
$$\phi_{13} = \text{unconstrained}, \phi_{23} = -0.65 \pm 0.24,$$
$$\chi_{13} = \chi_{23} = 0..$$

Predictions for several $b \to s$ observables

Obs	SM	Exp	FIT 1	FIT 2
$R_K(B^+)^{[1.1,6.0]}$	1 ± 0.01	$0.949^{+0.042}_{-0.041} \pm 0.022$	0.894 ± 0.011	0.897 ± 0.012
$R_K^*(B^0)^{[1.1,6.0]}$	1 ± 0.01	$1.027^{+0.072}_{-0.068} \pm 0.027$	0.955 ± 0.025	0.923 ± 0.032
$P_5'^{[4,6]}$	-0.757 ± 0.077	$-0.439 \pm 0.111 \pm 0.036$	-0.53 ± 0.13	-0.56 ± 0.13
ΔM_{B_s}, ps^{-1}	18.77 ± 0.76	17.765 ± 0.004	17.74 ± 2.45	17.27 ± 1.19
$\mathcal{B}(B_s \to \mu\mu) \cdot 10^{-9}$	3.68 ± 0.14	3.45 ± 0.29[1]	3.69 ± 0.23	3.68 ± 0.22
$\mathcal{B}(B^+ \to K^+ \nu\bar{\nu}) \times 10^{-6}$	4.6 ± 0.5	$11 \pm 4, < 19$	5.38 ± 0.38	5.22 ± 0.34
$\mathcal{B}(B^0 \to K^0 \nu\bar{\nu}) \times 10^{-6}$	4.1 ± 0.5	< 26	4.99 ± 0.31	4.83 ± 0.32
$\mathcal{B}(B^0 \to K^{0*} \nu\bar{\nu}) \times 10^{-6}$	9.6 ± 0.9	< 18	10.10 ± 1.46	10.30 ± 1.36
$\mathcal{B}(B^+ \to K^{+*} \nu\bar{\nu}) \times 10^{-6}$	9.6 ± 0.9	< 61	10.90 ± 1.33	11.10 ± 0.96
$F_L^{B^0 \to K^* \nu\bar{\nu}}$	0.47 ± 0.03	-	0.479 ± 0.05	0.484 ± 0.06
$R_K^{\nu\bar{\nu}}$	1	2.4 ± 0.9	1.14 ± 0.028	1.10 ± 0.024
$R_{K^*}^{\nu\bar{\nu}}$	1	< 1.9	1.07 ± 0.024	1.08 ± 0.022

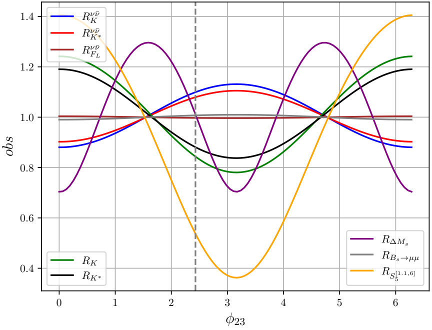
[1] January 2023 HFLAV average that takes into account recent results of LHCb [Phys.Rev.Lett. 128 (2022) 4, 041801] and CMS [Phys.Lett.B 842 (2023) 137955]

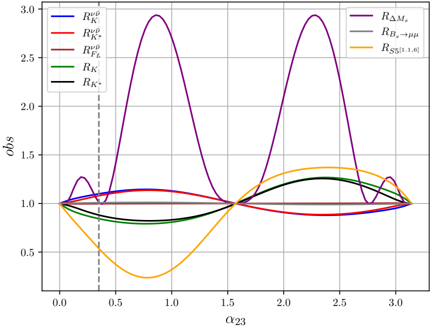
Prediction of certain angular CP asymmetries in $B^0 \to K^* \mu^+ \mu^-$ and $B^+ \to K^+ \mu^+ \mu^-$ in the central- and high-q^2 region

	$A_7^{[1.1,6]}(\%)$	$A_8^{[1.1,6]}(\%)$	$A_9^{[1.1,6]}(\%)$	$A_{CP}^{[1.1,6]}(K^*)(\%)$	$A_{CP}^{[1.1,6]}(K)(\%)$
EXP	$-4.5^{+5.0}_{-5.0} \pm 0.6$	$-4.7^{+5.8}_{-5.7} \pm 0.8$	$-3.3^{+4.0}_{-4.2} \pm 0.4$	-9.4 ± 4.7	0.4 ± 2.8
FIT_1	0.24 ± 0.11	0.03 ± 0.04	0.02 ± 0.01	0.05 ± 0.09	0.09 ± 0.09
FIT_2	0.32 ± 0.13	$\mathbf{-2.40 \pm 1.26}$	-0.24 ± 0.14	0.10 ± 0.68	-0.26 ± 0.78

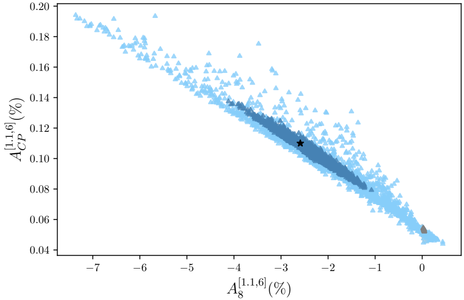
	$A_7^{[15,19]}(\%)$	$A_8^{[15,19]}(\%)$	$A_9^{[15,19]}(\%)$	$A_{CP}^{[15,19]}(K^*)(\%)$	$A_{CP}^{[15,19]}(K)(\%)$
EXP	$-4.0^{+4.5}_{-4.4} \pm 0.6$	$2.5^{+4.8}_{-4.7} \pm 0.3$	$6.1^{+4.3}_{-4.4} \pm 0.2$	-7.4 ± 4.4	-0.5 ± 3.0
FIT_1	0.011 ± 0.08	-0.01 ± 0.02	-0.03 ± 0.02	-0.10 ± 0.05	-0.21 ± 0.11
FIT_2	0.014 ± 0.08	-0.44 ± 0.24	-0.69 ± 0.20	-1.18 ± 0.44	$\mathbf{-2.99 \pm 1.24}$

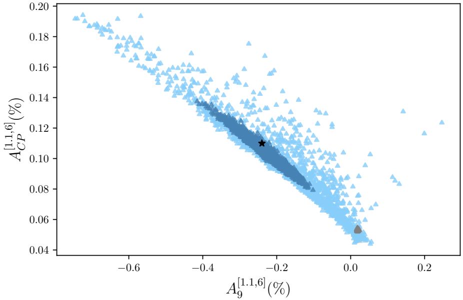
Angle and phase dependence for several $b \to s$ observables





Dependencies between A_{CP} in $B^0 \to K^*\mu^+\mu^-$ and A_8, A_9 in the central-q^2 region





Future prospects

- A_i, S_i and A_{CP} measurements for $B^0 \to K^*\mu^+\mu^-$ decay:
  - $3fb^{-1}$ [JHEP 02 (2016) 104]: $\sim 4-6\%$
  - $4.7fb^{-1}$ [Phys.Rev.Lett. 125 (2020) 1, 011802]: $\sim 2-4\%$
  - $50fb^{-1}$ [LHCb:2022ine]: $\sim 1-1.5\%$
  - $300fb^{-1}$ [LHCb:2022ine]: $\sim 0.4-0.6\%$

  Thus, the enhancements in A_8 and $A_{CP}(K)$ predicted by FIT_2 can be tested experimentally.
- Dineutrino modes [Belle-II:2022cgf] $50ab^{-1}$: $R_K^{\nu\bar{\nu}}$ 0.08 and $R_{K^*}^{\nu\bar{\nu}}$ 0.23. Obviously, this is not enough to favour or exclude our benchmark points. Nevertheless, some scenarios lying in the vicinity of the FIT_2, predict $R_K^{\nu\bar{\nu}} \sim 1.3-1.35$, and, thus, can be probed by future Belle II measurements.

Results

- Sizeable CP violation in $B^0 \to K^* \mu^+ \mu^-$ observables, for example, in $A_8^{[1.1,6]}$, $A_{CP}^{[15,19]}(K)$ and $A_{CP}^{[15,19]}(K^*)$, is predicted;
- Have found that $A_{CP}(K^{(*)})$ can be enhanced only in high-q^2 region up to $\sim -8\%$ for K-mode and up to $\sim -4\%$ for K^*-mode;
- Have observed that the triple product A_7, A_8, A_9 asymmetries are more prominent to the new CP violating phase, and can attain a few percent in the central- and high-q^2;
- Estimated future prospects of A_i, S_i and A_{CP} measurements for $B^0 \to K^* \mu^+ \mu^-$ decay and for dineutrino modes.

Thank you for your attention!