New physics in $b \rightarrow se^+e^-$: A model independent analysis

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Outline

- Lepton Flavor Universality and its violation in $b \to s\ell^+\ell^-$
- New Physics solutions in $b \to se^+e^-$
- Methods to discriminate the new physics scenarios
- Conclusions
The Standard Model

The SM becomes highly successful after the Higgs discovery in 2012.
⇒ All interactions are gauge interactions.
⇒ The gauge interactions are identical for three generations/ flavors.

Lepton Flavor Universality

New physics in $b \to s e^+ e^-$: A model independent analysis
Testing LFU through flavor ratios

\[ R_K = \frac{Br(B \rightarrow K\mu^+\mu^-)}{Br(B \rightarrow Ke^+e^-)} \quad R_{K^*} = \frac{Br(B \rightarrow K^*\mu^+\mu^-)}{Br(B \rightarrow K^*e^+e^-)} \]

- Theoretically clean and the SM expectations for these ratios are \( \sim 1 \)
- Present measurement of \( R_K \) in \([1.1 - 6.0] \) GeV\(^2\) is \( 0.846^{+0.042}_{-0.039} \) (stat.) \( +0.013 \) (syst.) by LHCb. [arXiv:2103.11769]
- The measured values of \( R_{K^*} \) are \( 0.660^{+0.110}_{-0.070} \) (stat.) \( \pm 0.024 \) (syst.) in \([0.045 - 1.1] \) GeV\(^2\) and \( 0.685^{+0.113}_{-0.069} \) (stat.) \( \pm 0.047 \) (syst.) in \([1.1 - 6.0] \) GeV\(^2\) bin. [arXiv:1705.05802, arXiv:1904.02440]
- Measured values are \( \sim 2.5 - 3.1\sigma \) lower than the SM prediction.

**Violation of LFU \( \implies \) Hint of new physics**

Additional measurements on the branching ratio of \( B_s \rightarrow \phi\mu^+\mu^- \) and the angular observables in \( B \rightarrow (K, K^*)\mu^+\mu^- \). [arXiv:1506.08777, arXiv:2003.04831]
Deviation at the level of \( 3 - 3.5\sigma \) in \( Br(B_s \rightarrow \phi\mu^+\mu^-) \) and \( P_5' \).
These are subject to significant hadronic uncertainties dominated by undermined power corrections. see e.g. \( T \) Hurth et al., arXiv:2006.04213
Effective Hamiltonian for $b \rightarrow s \ell^+ \ell^-$ process is given by

$$
H^\text{SM} = -\frac{4G_F}{\sqrt{2}\pi} V_{ts}^* V_{tb} \left[ \sum_{i=1}^{6} C_i(\mu) O_i(\mu) + C_7 \frac{e}{16\pi^2} [\bar{s}\sigma_{\mu\nu}(m_s P_L + m_b P_R)b] F^{\mu\nu} 
\right.
$$

$$
\left. + C_9 \frac{\alpha_{em}}{4\pi} (\bar{s}\gamma^\mu P_L b)(\bar{\ell}\gamma_\mu \ell) + C_{10} \frac{\alpha_{em}}{4\pi} (\bar{s}\gamma^\mu P_L b)(\bar{\ell}\gamma_\mu \gamma^5 \ell) \right],
$$

where $G_F$ is the Fermi constant, $V_{ts}$ and $V_{tb}$ are the Cabibbo-Kobayashi-Maskawa (CKM) matrix elements and $P_{L,R} = (1 \mp \gamma^5)/2$ are the projection operators. The effect of the operators $O_i, i = 1-6,8$ can be embedded in the redefined effective Wilson coefficients (WCs) as $C_7(\mu) \rightarrow C^\text{eff}_7(\mu, q^2)$ and $C_9(\mu) \rightarrow C^\text{eff}_9(\mu, q^2)$. 
New Physics only in \( b \to s\mu^+\mu^- \)

New Physics in the form of vector and axial vector

\[
\mathcal{H}_{\text{NP}} = -\frac{\alpha_{\text{em}} G_F}{\sqrt{2}\pi} V^*_{ts} V_{tb} \left[ C_{9}^{\text{NP}} (\bar{s}\gamma^\mu P_L b)(\bar{\mu}\gamma_\mu\mu) + C_{10}^{\text{NP}} (\bar{s}\gamma^\mu P_L b)(\bar{\mu}\gamma_\mu\gamma_5\mu) \\
+ C_9'^{\text{NP}} (\bar{s}\gamma^\mu P_R b)(\bar{\mu}\gamma_\mu\mu) + C_10'^{\text{NP}} (\bar{s}\gamma^\mu P_R b)(\bar{\mu}\gamma_\mu\gamma_5\mu) \right] + h.c.
\]

Several global fit analysis Alguer et al, arXiv:1903.09578; Alok et al, arXiv:1903.09617; Ciuchini et al, arXiv:1903.09632; Aebischer et al, arXiv:1903.10434; Kowalska et al, arXiv:1903.10932; Arbey et al, arXiv:1904.08399.....

⇒ A common conclusion: Three distinct NP solutions

\[(\text{arXiv:1903.09617})\]

| NP scenarios | Best fit value | pull = \( \sqrt{\chi^2_{\text{SM}} - \chi^2_{\text{min}}} \) |
|--------------|----------------|----------------------------------|
| (I) \( C_9^{\text{NP}} \) | \(-1.01 \pm 0.15\) | 6.9 |
| (II) \( C_9^{\text{NP}} = -C_{10}^{\text{NP}} \) | \(-0.49 \pm 0.07\) | 7.0 |
| (III) \( C_9^{\text{NP}} = -C_9'^{\text{NP}} \) | \(-1.03 \pm 0.15\) | 6.7 |

⇒ A possible methods to discriminate between these solutions are discussed in Alok et al, arXiv:2001.04395; Li et al, arXiv:2105.06768
New Physics only in $b \to se^+e^-$

The effective Hamiltonian in the presence of vector, axial-vector, scalar, pseudoscalar and tensor NP operators is given by

$$H_{\text{eff}}(b \to se^+e^-) = H_{SM} + H_{VA}^{NP} + H_{SP}^{NP} + H_{T}^{NP},$$

$$H_{VA}^{NP} = -\frac{\alpha_{\text{em}}G_F}{\sqrt{2}\pi} V_{ts}^* V_{tb} \left[ C_9^{NP,e} (\bar{s}\gamma_\mu P_L b) (\bar{e}\gamma_\mu e) + C_{10}^{NP,e} (\bar{s}\gamma_\mu P_L b) (\bar{e}\gamma_\mu \gamma_5 e) 
+ C_9'^{e} (\bar{s}\gamma_\mu P_R b) (\bar{e}\gamma_\mu e) + C_{10}'^{e} (\bar{s}\gamma_\mu P_R b) (\bar{e}\gamma_\mu \gamma_5 e) \right],$$

$$H_{SP}^{NP} = -\frac{\alpha_{\text{em}}G_F}{\sqrt{2}\pi} V_{ts}^* V_{tb} \left[ C_{SS}^{e} (\bar{s}b)(\bar{e}e) + C_{SP}^{e} (\bar{s}b)(\bar{e}\gamma_5 e) 
+ C_{PS}^{e} (\bar{s}\gamma_5 b) (\bar{e}e) + C_{PP}^{e} (\bar{s}\gamma_5 b) (\bar{e}\gamma_5 e) \right],$$

$$H_{T}^{NP} = -\frac{\alpha_{\text{em}}G_F}{\sqrt{2}\pi} V_{ts}^* V_{tb} \left[ C_{T}^{e} (\bar{s}\sigma^{\mu\nu} b) (\bar{e}\sigma_{\mu\nu} e) + C_{T5}^{e} (\bar{s}\sigma^{\mu\nu} b) (\bar{e}\sigma_{\mu\nu} \gamma_5 e) \right]$$
Constraints on (Pseudo)-scalar and Tensor operators

Scalar/pseudoscalar NP:

- The scalar NP operators ($\bar{s}b$) can lead to $B \rightarrow K$ but not to $B \rightarrow K^*$.
- The pseudo-scalar NP operator ($\bar{s}\gamma_5 b$) cannot lead to $B \rightarrow K$ transition.
- Hence scalar or pseudo-scalar NP cannot explain $R_K$ and $R_{K^*}$ simultaneously.
- In addition, a tight constraint comes from the upper limit of $Br(B_s \rightarrow e^+e^-) < 9.4 \times 10^{-9}$ (at C.L. 90%) [LHCb, arXiv:2003.03999]

\[ |C_{PS}^e|^2 + |C_{PP}^e|^2 \lesssim 0.01 \]

- However, the experimental measurement of $R_{K^*}^{low}$ and $R_{K^*}^{central}$ lead to

\[ 120 \lesssim |C_{PS}^e|^2 + |C_{PP}^e|^2 \lesssim 345, \quad 9 \lesssim |C_{PS}^e|^2 + |C_{PP}^e|^2 \lesssim 29, \]

- Hence, none of the scalar and pseudo-scalar NP operators can explain the $b \rightarrow se^+e^-$ data.

Tensor NP:

- Tensor NP operator is constrained by inclusive $Br(B \rightarrow X_s e^+e^-)$ and radiative $b \rightarrow s\gamma$. Hiller and Schmaltz, PRD90(2014),054014
- Only tensor NP can not accommodate the recent data on $b \rightarrow s\ell^+\ell^-$ transition.
(Axial)-Vector New Physics

\[ \chi^2(C_i) = \sum_{\text{all obs.}} \frac{(O^{\text{th}}(C_i) - O^{\exp})^2}{\sigma_{\text{exp}}^2 + \sigma_{\text{th}}^2}. \]

Measurements included into fit:

- \( R_K, R_K^{\text{low}} \) and \( R_K^{\text{central}} \) by LHCb and \( R_K^{*} \) by the Belle collaboration in \( 0.045 < q^2 < 1.1 \text{ GeV}^2, 1.1 < q^2 < 6.0 \text{ GeV}^2 \) and \( 15.0 < q^2 < 19.0 \text{ GeV}^2 \) bins for both \( B^0 \) and \( B^+ \) decay modes,

- \( Br(B_s \to e^+e^-) < 9.4 \times 10^{-9} \) at 90% C.L. by the LHCb,

- The differential branching fraction of \( B \to K^*e^+e^- \)

- \( K^* \) longitudinal polarization fraction by LHCb

- \( Br(B \to X_s e^+e^-) \) by the BaBar cn. in both \( 1.0 < q^2 < 6.0 \text{ GeV}^2 \) and \( 14.2 < q^2 < 25.0 \text{ GeV}^2 \) bins

- \( P_4' \) and \( P_5' \) in \( B \to K^*e^+e^- \) decay by the Belle cn in \( 1.0 < q^2 < 6.0 \text{ GeV}^2 \) and \( 14.18 < q^2 < 19.0 \text{ GeV}^2 \) bins

Fitting Methodology:

- We use CERN minimization code Minuit library to minimize the \( \chi^2 \).

- We use Flavio package to calculate the theoretical expressions of the observables.

- We perform the minimization in two ways: (A) one NP operator at a time and (B) two similar NP operators at a time.
# Allowed NP solutions in form of (Axial)-Vector

| Solution | Wilson Coefficient(s) | Best fit value(s) | pull | $R_K$ | $R_{K^*}^{low}$ | $R_{K^*}^{central}$ |
|----------|------------------------|-------------------|------|------|---------------|-------------------|
| Expt. 1σ range | | | | | | |
| I | $(C_9^{NP,e}, C_9′,e)$ | $(-3.61, -4.76)$ | 3.1 | $0.867 \pm 0.050$ | $0.757 \pm 0.007$ | $0.625 \pm 0.024$ |
| II | $(C_9^{NP,e}, C_9′,e)$ | $(-3.52, 4.29)$ | 3.4 | $0.832 \pm 0.001$ | $0.798 \pm 0.028$ | $0.707 \pm 0.090$ |
| III | $(C_{10}^{NP,e}, C_{10}′,e)$ | $(3.64, 5.33)$ | 3.0 | $0.860 \pm 0.015$ | $0.788 \pm 0.014$ | $0.645 \pm 0.015$ |

## 2D Scenarios

**Solution-I and II**

- $C_9^{9′}$
- $C_9^{e}$

**Solution-III**

- $C_{10}^{9′}$
- $C_{10}^{e}$
Angular distribution in $B \rightarrow K^* (\rightarrow K\pi) e^+ e^-$

How to distinguish these solutions? $\implies$ Angular observables

$$d^4 \Gamma \over dq^2 \, d \cos \theta_e \, d \cos \theta_K \, d\phi = \frac{9}{32\pi} I(q^2, \theta_e, \theta_K, \phi),$$

where [Altmannshofer et al JHEP 01 (2009),019]

$$I(q^2, \theta_e, \theta_K, \phi) = l_1^s \sin^2 \theta_K + l_1^c \cos^2 \theta_K + (l_2^s \sin^2 \theta_K + l_2^c \cos^2 \theta_K) \cos 2\theta_e + l_3 \sin^2 \theta_K \sin^2 \theta_e \cos 2\phi + l_4 \sin 2\theta_K \sin 2\theta_e \cos \phi + l_5 \sin 2\theta_K \sin \theta_e \cos \phi + (l_6^s \sin^2 \theta_K + l_6^c \cos^2 \theta_K) \cos \theta_e + l_7 \sin 2\theta_K \sin \theta_e \sin \phi + l_8 \sin 2\theta_K \sin 2\theta_e \sin \phi + l_9 \sin^2 \theta_K \sin^2 \theta_e \sin 2\phi.$$
Angular observables

CP averaged angular observables:[Descotes-Genon et al JHEP 01 (2013), 048]

\[ S_{i}^{(a)}(q^2) = \frac{I_{i}^{(a)}(q^2) + \bar{I}_{i}^{(a)}(q^2)}{d(\Gamma + \bar{\Gamma})/dq^2}. \]

\[ A_{FB} = \frac{3}{8} (2S_{6}^{\bar{g}} + S_{6}^{c}) , \quad F_{L} = -S_{2}^{c}. \]

\[ P_{1} = \frac{2S_{3}}{1 - F_{L}} , \quad P_{2} = \frac{S_{6}^{s}}{2(1 - F_{L})} , \quad P_{3} = \frac{-S_{9}}{1 - F_{L}} , \]

\[ P'_{4} = \frac{2S_{4}}{\sqrt{F_{L}(1 - F_{L})}} , \quad P'_{5} = \frac{S_{5}}{\sqrt{F_{L}(1 - F_{L})}} , \quad P'_{6} = \frac{-S_{7}}{\sqrt{F_{L}(1 - F_{L})}} , \quad P'_{8} = \frac{-2S_{8}}{\sqrt{F_{L}(1 - F_{L})}} . \]
In low $q^2$ region, the SM prediction of $A_{FB}(q^2)$ has a zero crossing at $\sim 3.5 \text{ GeV}^2$. For the NP solutions, the predictions are negative throughout the low $q^2$ range. However, the $A_{FB}(q^2)$ curve is almost the same for S-I and S-II whereas for S-III, it is markedly different. Therefore an accurate measurement of $q^2$ distribution of $A_{FB}$ can discriminate between S-III and the remaining two NP solutions.

In high $q^2$ region, the SM prediction of $A_{FB}$ is $0.368 \pm 0.018$ whereas the predictions for the three solutions are almost zero.
Distinguishing power of $F_L$

The S-I and S-II scenarios can marginally suppress the value of $F_L$ in low $q^2$ region compared to the SM whereas for S-III, the predicted value is consistent with the SM. In high $q^2$ region, $F_L$ for all three scenarios are close to the SM value. Hence $F_L$ cannot discriminate between the allowed V/A solutions.
The observable $P_1$ in the low $q^2$ region can discriminate between all three NP solutions, particularly S-I and S-II. The sign of $P_1$ is opposite for these scenarios. Hence an accurate measurement of $P_1$ can distinguish between S-I and S-II solutions. In fact, measurement of $P_1$ with an absolute uncertainty of 0.05 can confirm or rule out S-I and S-II solutions by more than 4$\sigma$. 
Conclusions

- Assuming new physics in $b \rightarrow se^+e^-$ transition, we identify the allowed solutions which can explain the deviations in $R_K/R_{K^*}$ measurements.

- We show that none of the (pseudo)-scalar or tensor new physics can explain the $b \rightarrow se^+e^-$ data.

- Only three vector/axial-vector new physics solutions (2D fit) can explain the present measurement of $R_K/R_{K^*}$ within $1\sigma$.

- The $A_{FB}$ and $F_L$ in $(B \rightarrow K^* e^+e^-)$ decay have poor ability to discriminate between three new physics solutions.

- In order to discriminate three solutions uniquely, $P_1(B \rightarrow K^* e^+e^-)$ is the most suitable angular observable. If it is measured with a 5% accuracy, $P_1$ can distinguish all three solutions.

Thank You!

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Extra Slides
# 1D and 2D Fit results

| Wilson Coefficient(s) | Best fit value(s) | $\chi^2_{\text{min}}$ | pull |
|-----------------------|-------------------|------------------------|------|
| $C_i = 0$ (SM)        | $-$               | 27.42                  |      |
| 1D Scenarios          |                   |                        |      |
| $C_{9}^{\text{NP,e}}$ | $0.91 \pm 0.28$   | 15.21                  | 3.5  |
| $C_{10}^{\text{NP,e}}$ | $-0.86 \pm 0.25$  | 12.60                  | 3.8  |
| $C_{9}^{\text{e}}$    | $0.24 \pm 0.24$   | 26.40                  | 1.0  |
| $C_{10}^{\text{e}}$   | $-0.17 \pm 0.21$  | 26.70                  | 0.8  |
| 2D Scenarios          |                   |                        |      |
| $(C_{9}^{\text{NP,e}}$, $C_{10}^{\text{NP,e}}$) | $(-1.03, -1.42)$ | 11.57                  | 3.9  |
| $(C_{9}^{\text{NP,e}}$, $C_{9}^{\text{e}}$) | $(-3.61, -4.76)$ | 17.65                  | 3.1  |
|                        | $(-3.52, 4.29)$   | 15.71                  | 3.4  |
|                        | $(1.21, -0.54)$   | 12.83                  | 3.8  |
| $(C_{9}^{\text{NP,e}}$, $C_{9}^{\text{e}}$) | $(1.21, 0.69)$   | 12.39                  | 3.9  |
| $(C_{9}^{\text{e}}$, $C_{10}^{\text{NP,e}}$) | $(-0.50, -1.03)$ | 11.30                  | 4.0  |
| $(C_{9}^{\text{e}}$, $C_{10}^{\text{e}}$) | $(2.05, 2.33)$   | 10.41                  | 4.1  |
|                        | $(-2.63, -1.86)$  | 12.71                  | 3.8  |
| $(C_{10}^{\text{NP,e}}$, $C_{10}^{\text{e}}$) | $(3.64, 5.33)$   | 18.50                  | 3.0  |
|                        | $(-1.04, 0.38)$   | 11.14                  | 4.0  |
|                        | $(4.56, -5.24)$   | 16.58                  | 3.3  |

**Table:** The best fit values of NP WCs in $b \to se^+e^-$ transition for 1D and 2D scenarios. The value of $\chi^2_{\text{SM}}$ is 27.42.
### Good fit scenarios

| Wilson Coefficient(s) | Best fit value(s) | pull  | $R_K$             | $R_K^{\text{low}}$ | $R_K^{\text{central}}$ |
|-----------------------|-------------------|-------|-------------------|--------------------|------------------------|
| Expt. 1σ range        |                   |       | [0.784, 0.908]    | [0.547, 0.773]     | [0.563, 0.807]         |
| **1D Scenarios**      |                   |       |                   |                    |                        |
| $C^\text{NP,}^e_9$    | 0.91 ± 0.28       | 3.5   | 0.806 ± 0.001     | 0.883 ± 0.008      | 0.832 ± 0.009          |
| $C^\text{NP,}^e_{10}$ | −0.86 ± 0.25      | 3.8   | 0.805 ± 0.005     | 0.855 ± 0.007      | 0.778 ± 0.012          |
| **2D Scenarios**      |                   |       |                   |                    |                        |
| $(C^\text{NP,}^e_9, C^\text{NP,}^e_{10})$ | (−1.03, −1.42)  | 3.9   | 0.825 ± 0.011     | 0.832 ± 0.007      | 0.745 ± 0.026          |
| $(C^\text{NP,}^e_9, C^\text{NP,}^e_{10})$ | (−3.61, −4.76)  | 3.1   | 0.867 ± 0.050     | 0.757 ± 0.007      | 0.625 ± 0.024          |
| $(C^\text{NP,}^e_9, C^\text{NP,}^e_{10})$ | (−3.52, 4.29)   | 3.4   | 0.832 ± 0.001     | 0.798 ± 0.028      | 0.707 ± 0.090          |
| $(C^\text{NP,}^e_9, C^\text{NP,}^e_{10})$ | (1.21, −0.54)   | 3.8   | 0.853 ± 0.001     | 0.825 ± 0.018      | 0.701 ± 0.012          |
| $(C^\text{NP,}^e_9, C^\text{NP,}^e_{10})$ | (1.21, 0.69)    | 3.9   | 0.855 ± 0.004     | 0.819 ± 0.016      | 0.691 ± 0.011          |
| $(C^\text{NP,}^e_9, C^\text{NP,}^e_{10})$ | (−0.50, −1.03)  | 4.0   | 0.844 ± 0.007     | 0.812 ± 0.012      | 0.690 ± 0.009          |
| $(C^\text{NP,}^e_9, C^\text{NP,}^e_{10})$ | (2.05, 2.33)    | 4.1   | 0.845 ± 0.010     | 0.808 ± 0.014      | 0.683 ± 0.029          |
| $(C^\text{NP,}^e_9, C^\text{NP,}^e_{10})$ | (−2.63, −1.86)  | 3.8   | 0.856 ± 0.020     | 0.808 ± 0.015      | 0.684 ± 0.010          |
| $(C^\text{NP,}^e_9, C^\text{NP,}^e_{10})$ | (3.64, 5.33)    | 3.0   | 0.860 ± 0.015     | 0.788 ± 0.014      | 0.645 ± 0.015          |
| $(C^\text{NP,}^e_9, C^\text{NP,}^e_{10})$ | (−1.04, 0.38)   | 4.0   | 0.846 ± 0.004     | 0.809 ± 0.013      | 0.686 ± 0.014          |
| $(C^\text{NP,}^e_9, C^\text{NP,}^e_{10})$ | (4.56, −5.24)   | 3.3   | 0.842 ± 0.004     | 0.809 ± 0.015      | 0.685 ± 0.019          |

**Table:** The predictions of $R_K$, $R_K^{\text{low}}$ and $R_K^{\text{central}}$ for the good fit scenarios obtained in previous slide.
Predictions for angular observables

| Observable | $q^2$ bin | SM       | S-I       | S-II      | S-III     |
|------------|-----------|----------|-----------|-----------|-----------|
| $P_1$      | [1.1, 6]  | $-0.113 \pm 0.032$ | $0.507 \pm 0.064$ | $-0.627 \pm 0.035$ | $-0.291 \pm 0.034$ |
|            | [15, 19]  | $-0.623 \pm 0.044$ | $-0.602 \pm 0.042$ | $-0.609 \pm 0.040$ | $-0.700 \pm 0.037$ |
| $P_2$      | [1.1, 6]  | $0.023 \pm 0.090$  | $-0.263 \pm 0.020$ | $-0.267 \pm 0.021$ | $-0.046 \pm 0.030$ |
|            | [15, 19]  | $0.372 \pm 0.013$  | $-0.005 \pm 0.004$ | $0.002 \pm 0.004$  | $0.027 \pm 0.004$  |
| $P_3$      | [1.1, 6]  | $0.003 \pm 0.008$  | $0.018 \pm 0.036$  | $-0.017 \pm 0.032$ | $0.002 \pm 0.006$  |
|            | [15, 19]  | $-0.000 \pm 0.000$ | $-0.045 \pm 0.004$ | $0.045 \pm 0.004$  | $0.000 \pm 0.000$  |
| $P_4'$     | [1.1, 6]  | $-0.352 \pm 0.038$ | $-0.256 \pm 0.033$ | $-0.605 \pm 0.011$ | $-0.447 \pm 0.027$ |
|            | [15, 19]  | $-0.635 \pm 0.008$ | $-0.631 \pm 0.008$ | $-0.632 \pm 0.008$ | $-0.650 \pm 0.008$ |
| $P_5'$     | [1.1, 6]  | $-0.440 \pm 0.106$ | $0.336 \pm 0.060$  | $0.358 \pm 0.045$  | $0.487 \pm 0.079$  |
|            | [15, 19]  | $-0.593 \pm 0.036$ | $-0.001 \pm 0.005$ | $-0.014 \pm 0.006$ | $-0.032 \pm 0.005$ |
| $P_6'$     | [1.1, 6]  | $-0.046 \pm 0.102$ | $-0.025 \pm 0.053$ | $-0.028 \pm 0.066$ | $-0.042 \pm 0.093$ |
|            | [15, 19]  | $-0.002 \pm 0.001$ | $-0.002 \pm 0.001$ | $-0.002 \pm 0.001$ | $-0.002 \pm 0.001$ |
| $P_8'$     | [1.1, 6]  | $-0.015 \pm 0.035$ | $-0.006 \pm 0.032$ | $0.012 \pm 0.027$  | $-0.009 \pm 0.023$ |
|            | [15, 19]  | $0.001 \pm 0.000$  | $0.036 \pm 0.002$  | $-0.036 \pm 0.003$ | $0.000 \pm 0.000$  |

**Table:** Average values of $P_{1,2,3}$ and $P'_{4,5,6,8}$ in $B \rightarrow K^* e^+ e^-$ decay for the three allowed V/A NP solutions as well as for the SM.
$P_1(q^2)$ and $P_2(q^2)$

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$P_3(q^2)$ and $P_4(q^2)$

$$P_3(B_0^{0} \to K^{*0}e^+e^-)$$

$$P_4(B_0^{0} \to K^{*0}e^+e^-)$$
$P_5'(q^2)$ and $P_6'(q^2)$
$P_8(q^2)$

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