# Search for new physics from $B \to K_2^*(\to K\pi)l^+l^-$ $B_s \to f_2^{'}(\to KK)l^+l^-$ decays

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**arXiv: 1012.2129, PRD83, 034034 (2011)**


中台世界

# outline

- Introduction
- $B \to K_2^*(\to K\pi)l^+l^-$ in SM
  - Angular distribution
  - BR, FBA, fL.

$$(B_s \to f_2^{'} l^+ l^-)$$

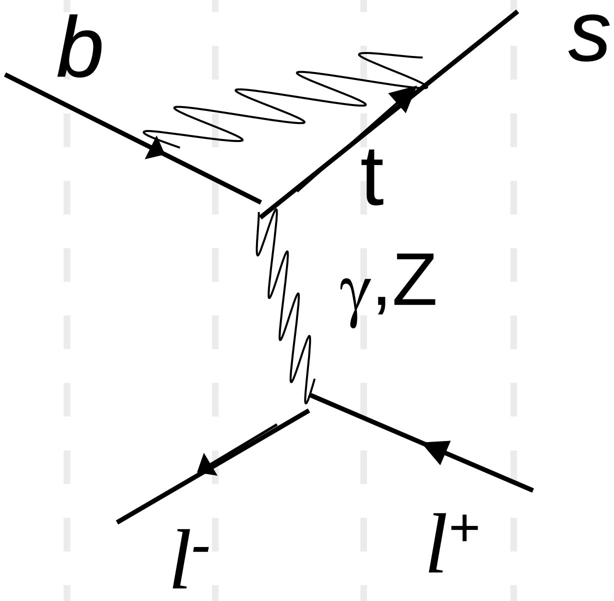
- Two New Physics scenarios
  - Brief introduction
  - Parameters obtained by fitting
  - Effect on the SM results
- Summary

# Flavor changing Electroweak penguin operators

$$O_7 = \frac{em_b}{8\pi^2}\bar{s}\sigma^{\mu\nu}(1+\gamma_5)bF_{\mu\nu} + \frac{em_s}{8\pi^2}\bar{s}\sigma^{\mu\nu}(1-\gamma_5)bF_{\mu\nu}$$

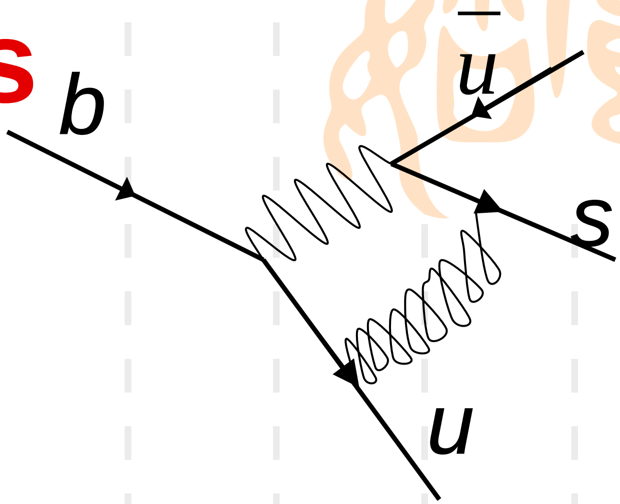
$$O_9 = \frac{\alpha_{em}}{2\pi}(\bar{l}\gamma_\mu l)(\bar{s}\gamma^\mu(1-\gamma_5)b),$$

$$O_{10} = \frac{\alpha_{em}}{2\pi}(\bar{l}\gamma_\mu\gamma_5 l)(\bar{s}\gamma^\mu(1-\gamma_5)b)$$




**No tree level flavor changing neutral current in SM**

# With QCD corrections from the four quark operators

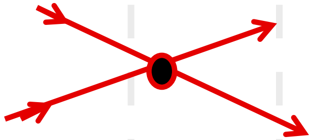



$$H_{eff} = \frac{G_F}{\sqrt{2}} V_{CKM} \sum_i C_i O_i$$

$$O_1 = \bar{u}\gamma^{\mu} L u \cdot \bar{s}\gamma_{\mu} L b \qquad O_2 = \bar{s}\gamma^{\mu} L u \cdot \bar{u}\gamma_{\mu} L b$$

$$O_3 = \bar{s}\gamma^{\mu} L b \cdot \sum_q \bar{q}\gamma_{\mu} L q \qquad O_4 = \bar{s}_{\alpha}\gamma^{\mu} L b_{\beta} \cdot \sum_q \bar{q}_{\beta}\gamma_{\mu} L q_{\alpha}$$

$$O_5 = \bar{s}\gamma^{\mu} L b \cdot \sum_q \bar{q}\gamma_{\mu} R q \qquad O_6 = \bar{s}_{\alpha}\gamma^{\mu} L b_{\beta} \cdot \sum_q \bar{q}_{\beta}\gamma_{\mu} R q_{\alpha}$$



# Introduction

- **Unlike $b \to s\gamma$ or $B \to K^*\gamma$, which have only limited physical observables**
- **$b \to s\, l^+l^-$, and especially $B \to K^*\, l^+l^-$, with a number of observables accessible (exp. also easier), provides a wealth of information of weak interactions, ranging from the forward-backward asymmetries, isospin asymmetries, and polarization fractions**

# About $K_2^*(1430)$ and $f_2'(1525)$

$\Gamma =$ 100MeV , 73 MeV

→ K π , → K K

| $l$ | $s$ | $J$ | $^{2s+1}L_J$ | $J^{PC}$ | Meson |
|---|---|---|---|---|---|
| $l=0$ | $s=0$ | $J=0$ | $^1S_0$ | $0^{-+}$ | Pseudoscalar $(P)$ |
| | $s=1$ | $J=1$ | $^3S_1$ | $1^{--}$ | Vector $(V)$ |
| $l=1$ | $s=0$ | $J=1$ | $^1P_1$ | $1^{+-}$ | Axial-vector $(A(^1P_1))$ |
| | $s=1$ | $J=0$ | $^3P_0$ | $0^{++}$ | Scalar $(S)$ |
| | | $J=1$ | $^3P_1$ | $1^{++}$ | Axial-vector $(A(^3P_1))$ |
| | | $J=2$ | $^3P_2$ | $2^{++}$ | Tensor $(T)$ |

$$B \to K_2^* l^+ l^- (B_s \to f_2' l^+ l^-)$$

- 5 polarization states: Jz= -2, -1, 0, 1, 2
- 3 contribute to $\bar{B}^0 \to K_2^* l^+ l^-$, Jz=-1, 0, 1, because of angular momentum conservation
- Similar to K* mesons. $\bar{B}^0 \to K_2^* l^+ l^-$ formulism can be got by some substitution in $\bar{B}^0 \to K^* l^+ l^-$ formulism in pQCD approach.

# Form factors needed for the exclusive decays

- Definition similar to the B→K* case

$$\langle K_2^*(P_2,\epsilon)|\bar{s}\gamma^\mu b|\bar{B}(P_B)\rangle = -\frac{2V(q^2)}{m_B+m_{K_2^*}}\epsilon^{\mu\nu\rho\sigma}\epsilon^*_{T\nu}P_{B\rho}P_{2\sigma},$$

$$\langle K_2^*(P_2,\epsilon)|\bar{s}\gamma^\mu\gamma_5 b|\bar{B}(P_B)\rangle = 2im_{K_2^*}A_0(q^2)\frac{\epsilon_T^*\cdot q}{q^2}q^\mu + i(m_B+m_{K_2^*})A_1(q^2)\left[\epsilon^*_{T\mu} - \frac{\epsilon_T^*\cdot q}{q^2}q^\mu\right]$$
$$- iA_2(q^2)\frac{\epsilon_T^*\cdot q}{m_B+m_{K_2^*}}\left[P^\mu - \frac{m_B^2-m_{K_2^*}^2}{q^2}q^\mu\right],$$

$$\langle K_2^*(P_2,\epsilon)|\bar{s}\sigma^{\mu\nu}q_\nu b|\bar{B}(P_B)\rangle = -2iT_1(q^2)\epsilon^{\mu\nu\rho\sigma}\epsilon^*_{T\nu}P_{B\rho}P_{2\sigma},$$

$$\langle K_2^*(P_2,\epsilon)|\bar{s}\sigma^{\mu\nu}\gamma_5 q_\nu b|\bar{B}(P_B)\rangle = T_2(q^2)[(m_B^2-m_{K_2^*}^2)\epsilon^*_{T\mu} - \epsilon_T^*\cdot qP^\mu] + T_3(q^2)\epsilon_T^*\cdot q\left[q^\mu - \frac{q^2}{m_B^2-m_{K_2^*}^2}P^\mu\right]$$

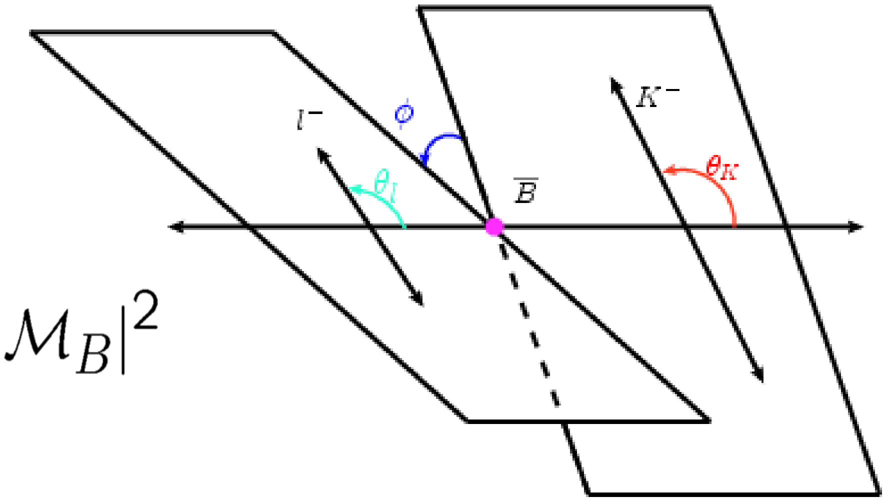
- Non-perturbative variables, difficult to calculate in QCD

# Form factors calculated in pQCD to leading order of $1/m_b$

| $F$ | $F(0)$ | $a$ | $b$ |
|---|---|---|---|
| $V^{BK_2^*}$ | $0.21^{+0.04+0.05}_{-0.04-0.03}$ | $1.73^{+0.02+0.05}_{-0.02-0.03}$ | $0.66^{+0.04+0.07}_{-0.05-0.01}$ |
| $A_0^{BK_2^*}$ | $0.18^{+0.04+0.04}_{-0.03-0.03}$ | $1.70^{+0.00+0.05}_{-0.02-0.07}$ | $0.64^{+0.00+0.04}_{-0.06-0.10}$ |
| $A_1^{BK_2^*}$ | $0.13^{+0.03+0.03}_{-0.02-0.02}$ | $0.78^{+0.01+0.05}_{-0.01-0.04}$ | $-0.11^{+0.02+0.04}_{-0.03-0.02}$ |
| $A_2^{BK_2^*}$ | $0.08^{+0.02+0.02}_{-0.02-0.01}$ | $\cdots$ | $\cdots$ |
| $T_1^{BK_2^*}$ | $0.17^{+0.04+0.04}_{-0.03-0.03}$ | $1.73^{+0.00+0.05}_{-0.03-0.07}$ | $0.69^{+0.00+0.05}_{-0.08-0.11}$ |
| $T_2^{BK_2^*}$ | $0.17^{+0.03+0.04}_{-0.03-0.03}$ | $0.79^{+0.00+0.02}_{-0.04-0.09}$ | $-0.06^{+0.00+0.00}_{-0.10-0.16}$ |
| $T_3^{BK_2^*}$ | $0.14^{+0.03+0.03}_{-0.03-0.02}$ | $1.61^{+0.01+0.09}_{-0.00-0.04}$ | $0.52^{+0.05+0.15}_{-0.01-0.01}$ |
| $V^{B_sf_2'}$ | $0.20^{+0.04+0.05}_{-0.03-0.03}$ | $1.75^{+0.02+0.05}_{-0.00-0.03}$ | $0.69^{+0.05+0.08}_{-0.01-0.01}$ |
| $A_0^{B_sf_2'}$ | $0.16^{+0.03+0.03}_{-0.02-0.02}$ | $1.69^{+0.00+0.04}_{-0.01-0.03}$ | $0.64^{+0.00+0.01}_{-0.04-0.02}$ |
| $A_1^{B_sf_2'}$ | $0.12^{+0.02+0.03}_{-0.02-0.02}$ | $0.80^{+0.02+0.07}_{-0.00-0.03}$ | $-0.11^{+0.05+0.09}_{-0.00-0.00}$ |
| $A_2^{B_sf_2'}$ | $0.09^{+0.02+0.02}_{-0.01-0.01}$ | $\cdots$ | $\cdots$ |
| $T_1^{B_sf_2'}$ | $0.16^{+0.03+0.04}_{-0.03-0.02}$ | $1.75^{+0.01+0.05}_{-0.00-0.05}$ | $0.71^{+0.03+0.06}_{-0.01-0.08}$ |
| $T_2^{B_sf_2'}$ | $0.16^{+0.03+0.04}_{-0.03-0.02}$ | $0.82^{+0.00+0.04}_{-0.04-0.06}$ | $-0.08^{+0.00+0.03}_{-0.09-0.08}$ |
| $T_3^{B_sf_2'}$ | $0.13^{+0.03+0.03}_{-0.02-0.02}$ | $1.64^{+0.02+0.06}_{-0.00-0.06}$ | $0.57^{+0.04+0.05}_{-0.01-0.09}$ |

W. Wang, PRD83,014008

Branching ratios are proportional to form factors, have large uncertainties, but Angular distribution is not




**Partial decay width**

$$\frac{d^4\Gamma}{dq^2 d\cos\theta_K d\cos\theta_l d\phi} = \frac{3}{8}|\mathcal{M}_B|^2$$

$|\mathcal{M}_B|^2$ is decomposed into 11 terms

$$\begin{aligned} |\mathcal{M}_B|^2 = \; & [I_1^c C^2 + 2I_1^s S^2 + (I_2^c C^2 + 2I_2^s S^2)\cos(2\theta_l) \\ & +2I_3 S^2 \sin^2\theta_l \cos(2\phi) + 2\sqrt{2} I_4 CS \sin(2\theta_l)\cos\phi \\ & +2\sqrt{2} I_5 CS \sin(\theta_l)\cos\phi + 2I_6 S^2 \cos\theta_l \\ & +2\sqrt{2} I_7 CS \sin(\theta_l)\sin\phi + 2\sqrt{2} I_8 CS \sin(2\theta_l)\sin\phi \\ & +2I_9 S^2 \sin^2\theta_l \sin(2\phi)] \end{aligned}$$

# Angular distribution

$$I_7 = \sqrt{2}\beta_l[\mathrm{Im}(A_{L0}A^*_{L||}) - \mathrm{Im}(A_{R0}A^*_{R||})]$$

$$I_8 = \frac{1}{\sqrt{2}}\beta_l^2[\mathrm{Im}(A_{L0}A^*_{L\perp}) + \mathrm{Im}(A_{R0}A^*_{R\perp})]$$

$$I_9 = \beta_l^2[\mathrm{Im}(A_{L||}A^*_{L\perp}) + \mathrm{Im}(A_{R||}A^*_{R\perp})]$$

- $A_{Ri} = A_{Li}|_{C_{10}\to -C_{10}}$
- Up to one-loop matrix element and resonances taken out, only $C_9^{\mathrm{eff}}$ contributes an imaginary part.

Without higher order QCD corrections

$I_7 = 0$, $I_8$ and $I_9$ is tiny

**They could be chosen as the window to observe those effects that can change the behavior of the Wilson coefficients, such as NP effects.**

# BRs, fL

With the recent pQCD results for $\bar{B}^0 \to K_2^*$ form factors

Branching ratios:

$$\mathcal{BR}(B \to K_2^* \mu^+ \mu^-) = (2.5^{+1.6}_{-1.1}) \times 10^{-7},$$
$$\mathcal{BR}(B \to K_2^* \tau^+ \tau^-) = (9.6^{+6.2}_{-4.5}) \times 10^{-10}.$$

Longitudinal Polarization fractions:

$$f_L \equiv \frac{\Gamma_0}{\Gamma} = \frac{\int dq^2 \frac{d\Gamma_0}{dq^2}}{\int dq^2 \frac{d\Gamma}{dq^2}}$$

$$f_L(B \to K_2^* \mu^+ \mu^-) = (66.6 \pm 0.4)\%,$$
$$f_L(B \to K_2^* \tau^+ \tau^-) = (57.2 \pm 0.7)\%$$

# Estimate BRs from exp.

- Experimentally, we have

$$\mathcal{B}(\bar{B}^0 \to K_2^*\gamma) = (12.4 \pm 2.4) \times 10^{-6},$$

$$\mathcal{B}(\bar{B}^0 \to K^*\gamma) = (43.3 \pm 1.5) \times 10^{-6}.$$

$$B(\overline{B}^0 \to K^* l^+ l^-) = (1.09 \pm 0.12) \times 10^{-6}$$

- Assume $R = B(K_2^*)/B(K^*)$ is the same for radiative and semi-leptonic decays, we have

$$\mathcal{B}_{\exp}(B^0 \to K_2^{*0} l^+ l^-) = (3.1 \pm 0.7) \times 10^{-7}$$

Compare with KC Yang, **PRD79:114008,2009**

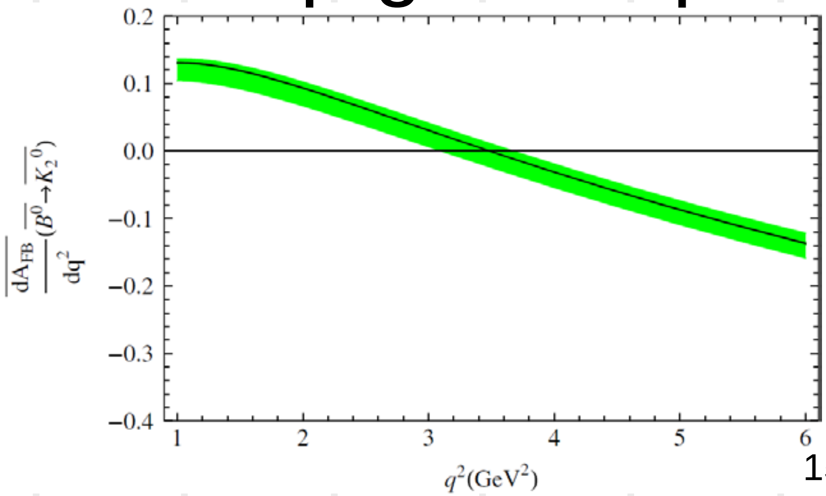
$$\mathcal{B}(B^0 \to K_2^{*0}(1430)\mu^+\mu^-) = (3.5^{+1.1+0.7}_{-1.0-0.6}) \times 10^{-7}$$

## D. Forward-backward asymmetry

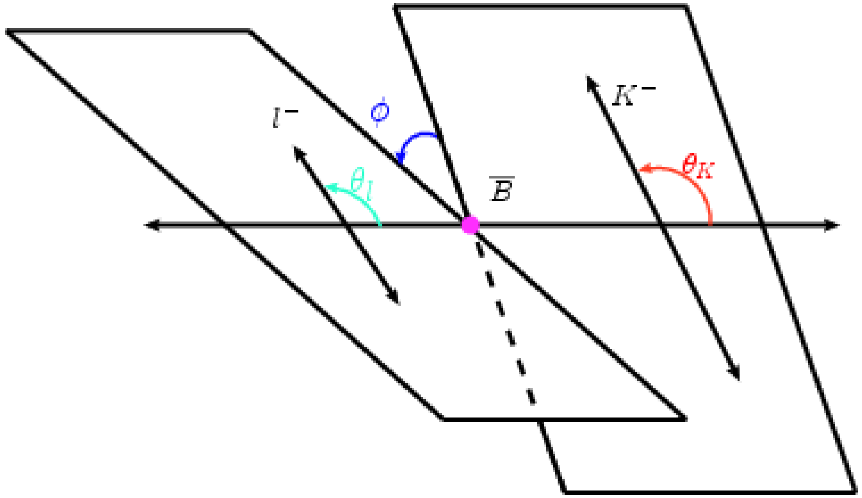
The differential forward-backward asymmetry of $\bar{B} \to \bar{K}_2^* l^+ l^-$ is defined by

$$\frac{dA_{FB}}{dq^2} = \left[\int_0^1 - \int_{-1}^0\right] d\cos\theta_l \frac{d^2\Gamma}{dq^2 d\cos\theta_l} = \frac{3}{4} I_6$$

- The forward backward asymmetry varies from positive to negative as $q^2$ grows up
- The 0-cross point is sensitive to new physics



# Forward and Backward Asymmetry




$$\frac{dA_{FB}}{dq^2} = \left[\int_0^1 - \int_{-1}^0\right] d\cos\theta_l \frac{d^2\Gamma}{dq^2 d\cos\theta_l}$$

**The zero-crossing point $s_0$ of FBAs is determined by the equation**

$$C_9 A_1(s_0)V(s_0) + C_{7L}\frac{m_b(m_B + m_{K_2^*})}{s_0}A_1(s_0)T_1(s_0)$$
$$+C_{7L}\frac{m_b(m_B - m_{K_2^*})}{s_0}T_2(s_0)V(s_0) = 0$$

$$s_0(B \to K_2^*\mu^+\mu^-) = (3.49 \pm 0.04)\,\mathrm{GeV}^2$$

Smaller uncertainty

# Similarly for $B_s \rightarrow f_2' \, l^+ l^-$

$$\mathcal{B}(B_s \to f_2' \mu^+ \mu^-) = (1.8^{+1.1}_{-0.7}) \times 10^{-7},$$

$$f_L(B_s \to f_2' \mu^+ \mu^-) = (63.2 \pm 0.7)\%,$$

$$s_0(B_s \to f_2' \mu^+ \mu^-) = (3.53 \pm 0.03)\ \mathrm{GeV}^2$$

$$\mathcal{B}(B_s \to f_2' \tau^+ \tau^-) = (5.8^{+3.7}_{-2.1}) \times 10^{-10},$$

$$f_L(B_s \to f_2' \tau^+ \tau^-) = (53.9 \pm 0.4)\%.$$

# NP scenario: Vector-like quark model (VQM)

Expanding SM including a $SU(2)_L$ singlet down type quark, Yukawa sector of SM is modified to

$$\mathcal{L}_Y = \bar{Q}_L Y_D H d_R + h_D \bar{Q}_L H D_R + m_D \bar{D}_L D_R + h.c.$$

This modification brings FCNC for the mass eigenstates at tree level.

The interaction for b-s-Z in VQM is

$$\mathcal{L}_{b\to s} = \frac{g c_L^s \lambda_{sb}}{\cos\theta_W} \bar{s}\gamma^\mu P_L b Z_\mu + h.c.,$$

free parameter

$$\lambda_{sb} = |\lambda_{sb}| \exp(i\theta_s)$$

with which the effective Hamiltonian for $b \to s l^+ l^-$ is given as

$$\mathcal{H}^Z_{b\to s l^+ l^-} = \frac{2G_F}{\sqrt{2}} \lambda_{sb} c_L^s (\bar{s}b)_{V-A} \left[ c_L^\ell (\bar{\ell}\ell)_{V-A} + c_R^\ell (\bar{\ell}\ell)_{V+A} \right]$$

# NP scenario: Vector-like quark model (VQM)

The VQM effects can be absorbed into the Wilson coefficients $C_9$ and $C_{10}$

$$C_9^{\mathrm{VLQ}} = C_9^{\mathrm{SM}} - \frac{4\pi}{\alpha_{\mathrm{em}}} \frac{\lambda_{sb} c_L^s (c_L^\ell + c_R^\ell)}{V_{ts}^* V_{tb}},$$

$$C_{10}^{\mathrm{VLQ}} = C_{10}^{\mathrm{SM}} + \frac{4\pi}{\alpha_{\mathrm{em}}} \frac{\lambda_{sb} c_L^s (c_L^\ell - c_R^\ell)}{V_{ts}^* V_{tb}}.$$

Lepton section in VQM is the same as in SM.

# NP scenario: Family non-universal Z′ model

**Expand SM by simply including an additional U(1)′ symmetry. The current is**

$$J^{\mu}_{Z'} = g' \sum_i \bar{\psi}_i \gamma^{\mu} [\epsilon_i^{\psi_L} P_L + \epsilon_i^{\psi_R} P_R] \psi_i \,,$$

**which couples to a family non-universal Z′ boson. After rotating to the mass eigen basis, FCNC appears at tree level in both LH and RH section.**

**Interaction for b-s-Z′ is given as**

$$\mathcal{L}^{Z'}_{\text{FCNC}} = -g'(B^L_{sb}\bar{s}_L\gamma_\mu b_L + B^R_{sb}\bar{s}_R\gamma_\mu b_R)Z'^{\mu} + \text{h.c.}$$

The effective Hamiltonian for $b \to s l^+ l^-$ is given as

$$\mathcal{H}^{Z'}_{\text{eff}} = \frac{8G_F}{\sqrt{2}}(\rho^L_{sb}\bar{s}_L\gamma_\mu b_L + \rho^R_{sb}\bar{s}_R\gamma_\mu b_R)(\rho^L_{ll}\bar{\ell}_L\gamma^\mu\ell_L + \rho^R_{ll}\bar{\ell}_R\gamma^\mu\ell_R)$$

# NP scenario: Family non-universal Z' model

Different from VQM, the couplings in both the quark and lepton section are free parameters.

Too many free parameters. So we set $\rho_{sb}^{R} = 0$ in our analysis to reduce freedoms.

Z' also only affects $C_9$ and $C_{10}$ phenomenally:

$$C_9^{Z'} = C_9 - \frac{4\pi}{\alpha_{em}} \frac{\rho_{sb}^{L}(\rho_{ll}^{L} + \rho_{ll}^{R})}{V_{tb}V_{ts}^{*}}, \quad C_{10}^{Z'} = C_{10} + \frac{4\pi}{\alpha_{em}} \frac{\rho_{sb}^{L}(\rho_{ll}^{L} - \rho_{ll}^{R})}{V_{tb}V_{ts}^{*}}$$

# Constrain the model parameters by exp.

## Data used for fitting

| $b \to c l \bar{\nu}$ | $b \to s l^+ l^-$ | $\overline{B}^0 \to K^* l^+ l^-$ | |
|---|---|---|---|
| $(10.58 \pm 0.15) \times 10^{-2}$ | $(3.66^{+0.76}_{-0.77}) \times 10^{-6}$ | $(1.09^{+0.12}_{-0.11}) \times 10^{-6}$ | |

| $q^2(\mathrm{GeV}^2)$ | $\mathcal{B}(10^{-7})$ | $F_L$ | $-A_{FB}$ |
|---|---|---|---|
| $[0, 2]$ | $1.46 \pm 0.41$ | $0.29 \pm 0.21$ | $0.47 \pm 0.32$ |
| $[2, 4.3]$ | $0.86 \pm 0.32$ | $0.71 \pm 0.25$ | $0.11 \pm 0.37$ |
| $[4.3, 8.68]$ | $1.37 \pm 0.61$ | $0.64 \pm 0.25$ | $0.45 \pm 0.26$ |
| $[10.09, 12.86]$ | $2.24 \pm 0.48$ | $0.17 \pm 0.17$ | $0.43 \pm 0.20$ |
| $[14.18, 16]$ | $1.05 \pm 0.30$ | $-0.15 \pm 0.28$ | $0.70 \pm 0.24$ |
| $> 16$ | $2.04 \pm 0.31$ | $0.12 \pm 0.15$ | $0.66 \pm 0.16$ |
| $[1, 6]$ | $1.49 \pm 0.47$ | $0.67 \pm 0.24$ | $0.26 \pm 0.31$ |

Heavy Flavor Averaging Group, arXiv:1010.1589;
Particle Data Group, J. Phys. G 37,075021.

## Definition of $\chi^2$

$$\chi_i^2 = \frac{(B_i^{the} - B_i^{exp})^2}{(B_i^{err})^2}$$

# Constrain the VQM parameters

$$\mathrm{Re}\lambda_{sb} = (0.07 \pm 0.04) \times 10^{-3}$$
$$\mathrm{Im}\lambda_{sb} = (0.09 \pm 0.23) \times 10^{-3}$$

⟹

$|\lambda_{sb}| < 0.3 \times 10^{-3}$

Phase less constrained

Constrains on the Wilson coefficients

with $\chi^2/d.o.f. = 2.4$

$$|\Delta C_9| = |C_9 - C_9^{SM}| < 0.2$$
$$|\Delta C_{10}| = |C_{10} - C_{10}^{SM}| < 2.8$$

# Constrain the Z′ model parameters

Assume $\Delta C_9, \ \Delta C_{10}$ as real

$$\Delta C_9 = 0.88 \pm 0.75, \quad \Delta C_{10} = 0.01 \pm 0.69$$

with $\chi^2/d.o.f. = 2.3$

Both $\Delta C_9$ and $\Delta C_{10}$ are complex numbers.

$$\Delta C_9 = (-0.81 \pm 1.22) + (3.05 \pm 0.92)i$$
$$\Delta C_{10} = (1.00 \pm 1.28) + (-3.16 \pm 0.94)i$$

with $\chi^2/d.o.f. = 2.4$

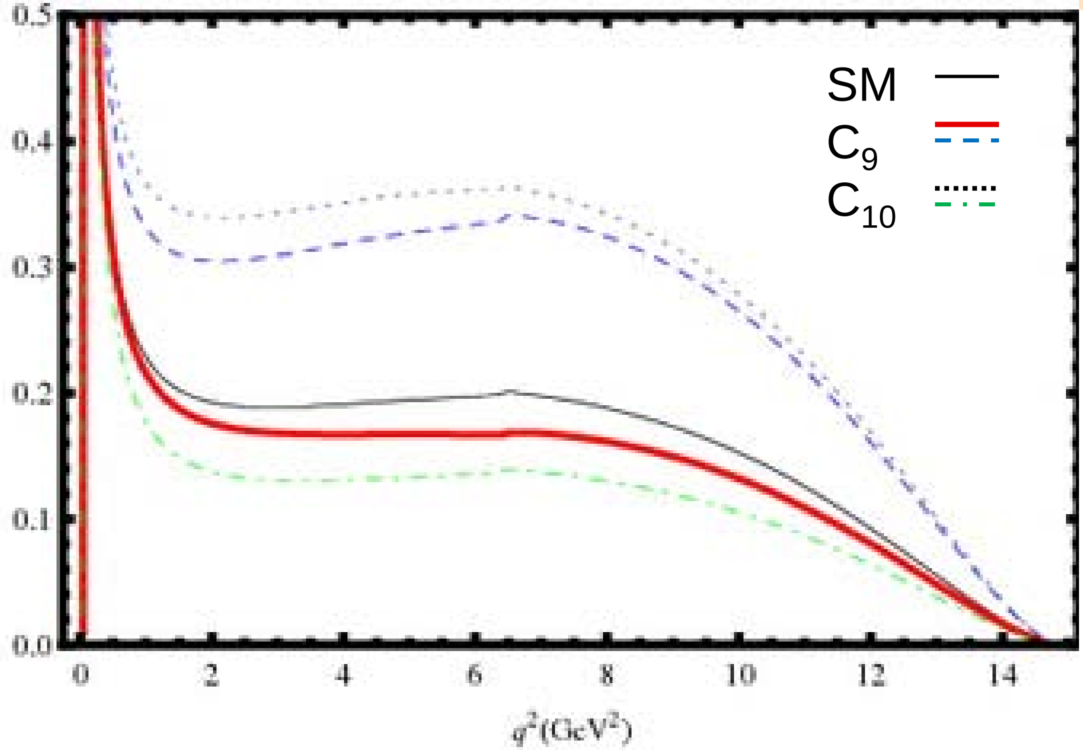
$\mathrm{Im}[C_{10}]$ has little effect on $\chi^2$

Combining the above results $|\Delta C_9| < 3, \quad |\Delta C_{10}| < 3$

# New Physics effects in observables

In the NP effects, we choose $\Delta C_9 = 3e^{i\pi/4, i3\pi/4}$ and $\Delta C_{10} = 3e^{i\pi/4, i3\pi/4}$ as the reference points.

$$\frac{dBr}{dq^2}$$



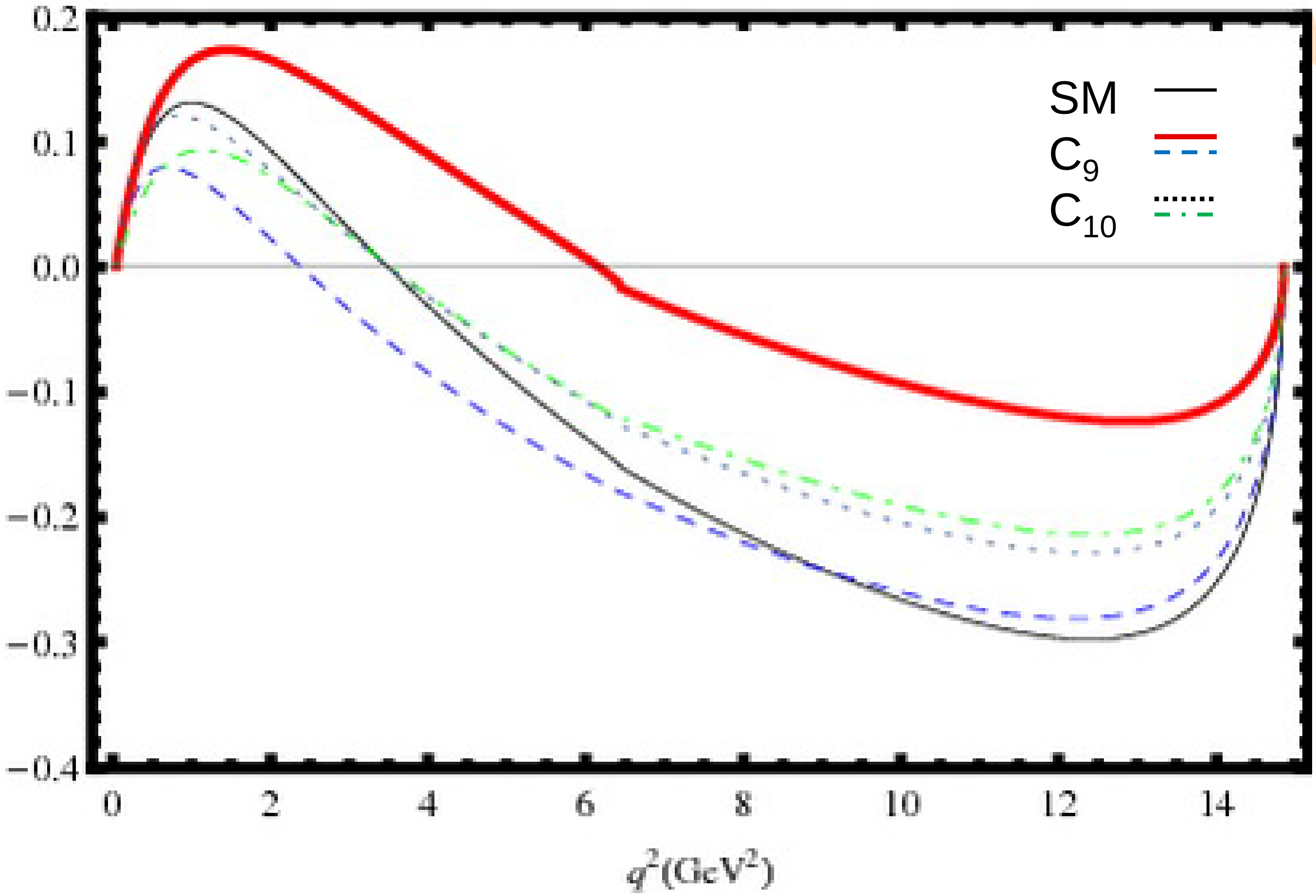

Br ($10^{-7}$) may be enhanced, however, large uncertainties

In this parameter space, $\mathcal{B}(B_s \to \mu^+\mu^-)$ is consistent with the recent measurement. $\mathcal{B}(B_s \to \mu^+\mu^-) < 5.1 \times 10^{-8}$

D0 collaboration, PLB 693,539.

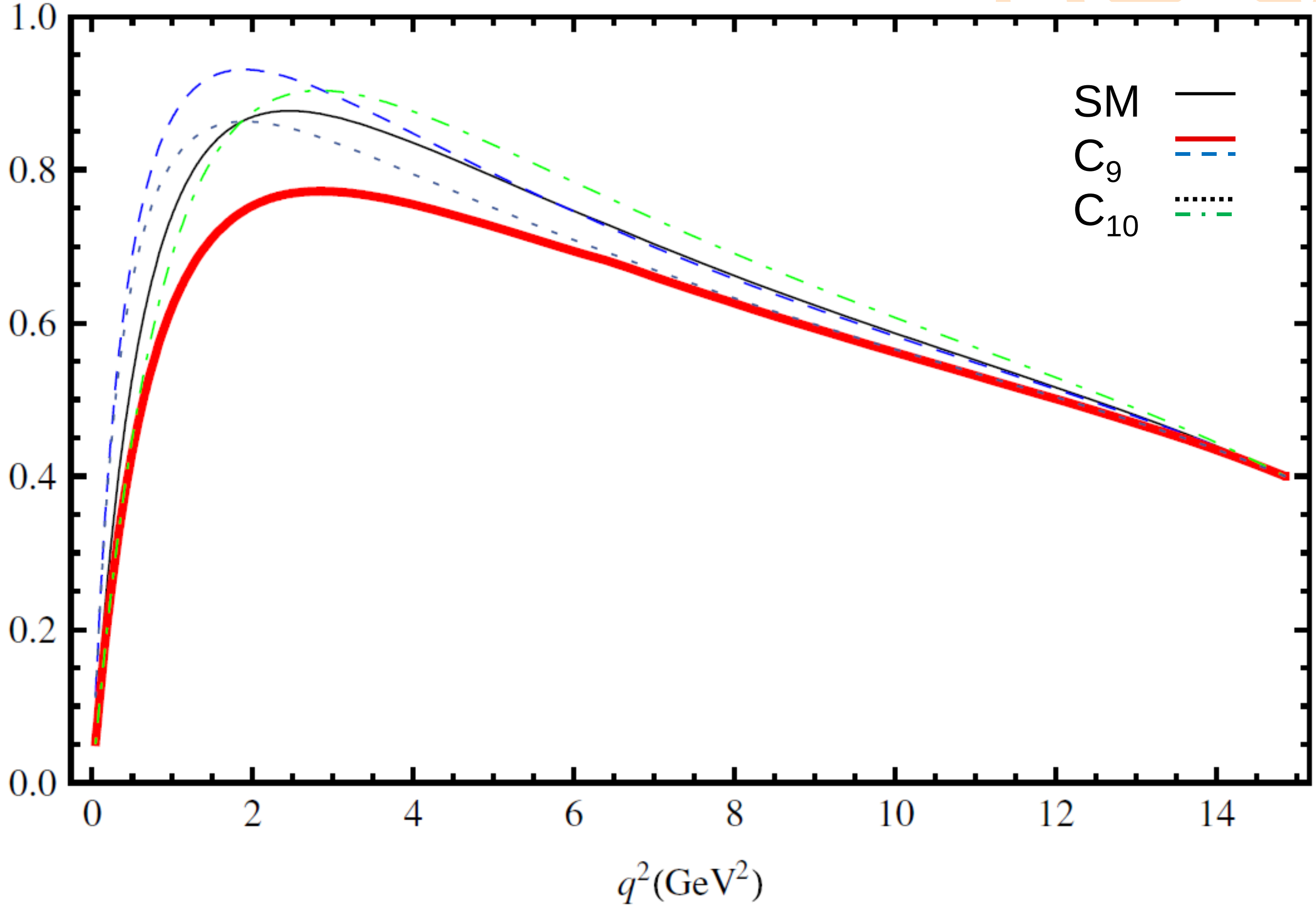
# New Physics effects in observable $\frac{d\overline{A_{FB}}}{dq^2}$

Zero-crossing point of AFB may be changed significantly in new physics model.



# Polarization fraction $f_L$

some changes of Polarization fraction $f_L$ in new physics model.



# Summary

- $\bar{B}^0 \to K_2^*(\to K\pi)l^+l^-$ is investigated in SM.
  - $\mathcal{B}(B \to K_2^*\mu^+\mu^-) = (2.5^{+1.6}_{-1.1}) \times 10^{-7}$
  - expected to be observed in future Exp.

  FBA, polarization fractions, etc, are investigated, with small uncertainties.

- Two NP scenarios (VQM, Z′ model) are investigated.

  Parameter space constrained with data of $\bar{B}^0 \to K^* l^+ l^-$ and $b \to s l^+ l^-$ .

Zero-crossing point of FBA can be changed dramatically, which are sensitive to NP effects

# Thank you