Probing New Physics through FCNC transition.

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Outline

- Standard Model a little introduction.
- Limitations in the Standard Model(SM).
- How to address the limitations in SM?
- Theoretical tools in flavor sector.
- Role of B-meson decays beyond the Standard Model(NP).

A breif Introduction to Z' model.

$B \to K^{*}\ell^{+}\ell^{-}$

- Physical observables for rare semileptonic B decays.
- Summary and Conclusion.

Standard Model a little introduction

- Standard Model (SM) describes strong and electroweak interactions of elementary particles.

It is based upon the gauge group :

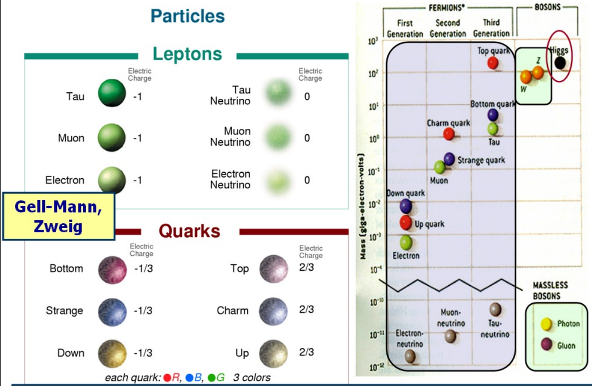
$$SU(3)_C \bigotimes SU(2)_L \bigotimes U(1)_Y.$$

- In the SM, the fermions are the building blocks of matter.

Matter fields (either quarks or leptons) exist in three families:

3 flavors of up-type

3 flavors of down-type



How Many Families (Generations) ? Mass Pattern ? Structure ?

- Because of gauge invariance the theory predicts all particles are massless.
- Within the SM, masses of all particles are generated by Spontaneous symmetry breaking (**Higgs mechanism**).

- After symmetry breaking the flavor and mass eigenstates are not identical but are related through the global unitary transformation

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = V_{\text{CKM}} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

$$V_{\text{CKM}} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

- Standard model of particle physics is one of the successful model.

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- In addition, during the last few years there are some mismatch between the SM predictions and experimental measurements are also found

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Many others.

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Flavor physics studies transitions between different flavors.

Tools for theoretical predictions in Flavor Physics

- The basic starting point for doing phenomenology in weak decays of hadrons is the weak effective Hamiltonian

$$H_{eff} = \frac{G_F}{\sqrt{2}} \sum_i V^i_{CKM} C_i(\mu) O_i$$

- The simplest and famous example is Fermi theory for β-decay

$$H^{\beta}_{eff} = \frac{G_F}{\sqrt{2}} V_{ud} \left[\bar{u}\gamma_\mu(1-\gamma_5)d \otimes \bar{e}\gamma^\mu(1-\gamma_5)\nu_e\right]$$

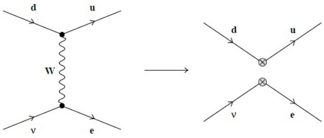

Figure: β-decay at quark level in the full and effective theories

- The explicit form of the operators are as follows
Current Current Operators

$$O_1 = (\bar{c}_\alpha b_\beta)_{V-A}(\bar{s}_\beta c_\alpha)_{V-A}$$
$$O_2 = (\bar{c} b)_{V-A}(\bar{s} c)_{V-A}$$

QCD-Penguins

$$O_3 = (\bar{s}b)_{V-A} \sum_{q=u,d,s,c,b} (\bar{q}q)_{V-A}$$

$$O_4 = (\bar{s}_\alpha b_\beta)_{V-A} \sum_{q=u,d,s,c,b} (\bar{q}_\beta q_\alpha)_{V-A}$$

$$O_5 = (\bar{s}b)_{V-A} \sum_{q=u,d,s,c,b} (\bar{q}q)_{V+A}$$

$$O_6 = (\bar{s}_\alpha b_\beta)_{V-A} \sum_{q=u,d,s,c,b} (\bar{q}_\beta q_\alpha)_{V+A}$$

Magnetic Penguins

$$O_{7\gamma} = \frac{e}{8\pi^2} m_b \bar{s}_\alpha \sigma^{\mu\nu}(1+\gamma^5) b_\alpha F_{\mu\nu}$$

$$O_{8G} = \frac{g}{8\pi^2} m_b \bar{s}_\alpha \sigma^{\mu\nu}(1+\gamma^5) T^a_{\alpha\beta} b_\beta G^a_{\mu\nu}$$

Electroweak penguins

$$
\begin{aligned}
O_7 &= \frac{3}{2}(\bar{s}b)_{V-A}\sum_{q=u,d,s,c,b} e_q\,(\bar{q}q)_{V+A} \\
O_8 &= \frac{3}{2}(\bar{s}_\alpha b_\beta)_{V-A}\sum_{q=u,d,s,c,b} (\bar{q}_\beta q_\alpha)_{V+A} \\
O_9 &= \frac{3}{2}(\bar{s}b)_{V-A}\sum_{q=u,d,s,c,b} e_q\,(\bar{q}q)_{V-A} \\
O_{10} &= \frac{3}{2}(\bar{s}_\alpha b_\beta)_{V-A}\sum_{q=u,d,s,c,b} (\bar{q}_\beta q_\alpha)_{V-A}
\end{aligned}
$$

Semileptonic Operators

$$
\begin{aligned}
O_9 &= (\bar{s}b)_{V-A}\left(\bar{\ell}\ell\right)_V \qquad O_{10} = (\bar{s}b)_{V-A}\left(\bar{\ell}\ell\right)_A \\
O_{\nu\bar{\nu}} &= (\bar{s}b)_{V-A}(\bar{\nu}\nu)_{V-A} \qquad O_{\ell\bar{\ell}} = (\bar{s}b)_{V-A}\left(\bar{\ell}\ell\right)_{V-A}
\end{aligned}
$$

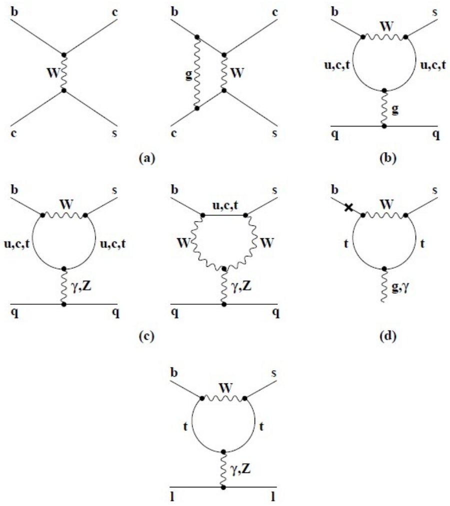

Figure: Tree and penguin diagrams of quark level operators

In flavor sector ideal laboratory system is Rare decays.

- The processes that are suitable for indirect searches of NP are those which are rare in SM and can be measured precisely.
- FCNC transitions will provide a suitable tool to investigate the physics within and beyond the SM.
- These transitions occurs at loop level through GIM mechanism in the SM and are also CKM suppressed.
- Rare B decays are mediated through flavor changing neutral current (FCNC) transitions.

Role of B-meson decays beyond the SM

Examples are B-meson decays.

Exploration of NP through various B meson decay modes are

Inclusive decay modes e.g $B \to X_{s,d}\ell^+\ell^-$

Exclusive decay modes e.g $B \to M\ell^+\ell^-$ (M =K, K_1 etc.)

Dedicated B- factories

BABAR

BELLE

LHCb

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- Rare decay modes involved observables which can distinguish between the various extensions of the SM.

branching ratio

single lepton polarization asymmetries

CP violation etc.

greatly influenced under different beyond the SM scenarios.

- Precise measurement of these observables will play an important role in the indirect searches of NP.

Models beyond the Standard Model

- New physics effects in rare decays arises in two different ways
  1. Through a new contribution to the Wilson coefficients (Class I).
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- Universal Extra Dimensions (Class I)
- Z' model (Class I)
- Supersymmetric Models (Class II)
- General Effective Hamiltonian (Class II)

Family of non-Universal Z' Model

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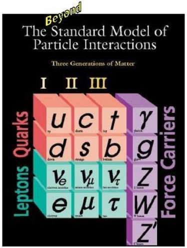
Additional $U(1)'$ gauge symmetries and associated gauge bosons, usually labeled Z', is an electrically-neutral spin-1 particle. Z' gauge bosons are one of the simplest and best motivated extensions of the standard model (SM).



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- The model is formulated in detail by Langacker and Plümacher.

Phys. Rev. D 62 (2000) 013006 [hep-ph/0001204]; P. Langacker, arXiv:0801.1345 [hep-ph].

Family of non-Universal Z' Model

- The effective Hamiltonian due to the Z' contribution can be written as

$$\mathcal{H}_{eff}^{Z'} = -\frac{2G_F}{\sqrt{2}}\bar{s}\gamma^{\mu}(1-\gamma^5)b \\ \times B_{sb}\left[\mathcal{S}_{\ell\ell}^{L}\bar{\ell}\gamma^{\mu}(1-\gamma^5)\ell - \mathcal{S}_{\ell\ell}^{R}\bar{\ell}\gamma^{\mu}(1+\gamma^5)\ell\right],$$

  with $P_{L,R} = (1 \pm \gamma_5)/2$, B_{sb} is the off diagonal left handed coupling of Z' boson with quarks and $\mathcal{S}_{\ell\ell}^{L}$ and $\mathcal{S}_{\ell\ell}^{R}$ represent the left and right handed couplings of Z' boson with leptons, respectively.

- It is to be noted that if a new weak phase ϕ_{sb} is introduced in the off-diagonal coupling B_{sb} then this coupling could be read as $B_{sb} = \mathcal{R}e(B_{sb})e^{-i\phi_{sb}}$.

- Therefore, one can also put the above equation in the following form

$$\mathcal{H}_{eff}^{Z'} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \left[\Lambda_{sb} C_9^{Z'} Q_9 + \Lambda_{sb} C_{10}^{Z'} Q_{10} \right].$$

$$\Lambda_{sb} = \frac{4\pi e^{-i\phi_{sb}}}{\alpha V_{ts}^* V_{tb}}$$

$$C_9^{Z'} = \mathcal{R}e(B_{sb}) S_{LL};\ C_{10}^{Z'} = \mathcal{R}e(B_{sb}) D_{LL}$$

$$S_{LL} = \mathcal{S}_{\ell\ell}^L + \mathcal{S}_{\ell\ell}^R;\ D_{LL} = \mathcal{S}_{\ell\ell}^L - \mathcal{S}_{\ell\ell}^R$$

Family of non-Universal Z' Model

- The FCNC transition originates from the quark level transition $b \to sl^+l^-$ and are based on the following operators

$$
\begin{aligned}
O_7 &= \frac{e^2}{16\pi^2} m_b \left(\bar{s}\sigma_{\mu\nu} P_R b\right) F^{\mu\nu}, \\
O_9 &= \frac{e^2}{16\pi^2} (\bar{s}\gamma_\mu P_L b)(\bar{l}\gamma^\mu l), \\
O_{10} &= \frac{e^2}{16\pi^2} (\bar{s}\gamma_\mu P_L b)(\bar{l}\gamma^\mu \gamma_5 l),
\end{aligned}
$$

In term of these operators and neglecting the mass of the s-quark, the effective Hamiltonian takes the form

$$
\begin{aligned}
\mathcal{H}_{eff}^{SM} &= -\frac{G_F \alpha}{\sqrt{2}\pi} V_{tb} V_{ts}^* \Big\{ C_9^{SM} (\bar{s}\gamma_\mu P_L b)(\bar{l}\gamma^\mu l) + C_{10}^{SM} (\bar{s}\gamma_\mu P_L b)(\bar{l}\gamma^\mu \gamma_5 l) \\
& -2 m_b C_7^{SM} (\bar{s} i \sigma_{\mu\nu} \frac{q^\nu}{q^2} P_R b)(\bar{l}\gamma^\mu l) \Big\}.
\end{aligned}
$$

Family of non-Universal Z' Model

- Thus, to include the Z' effects in the problem under consideration one has to make the following replacements in the Wilson coefficients C_9 and C_{10}, while, C_7 remains unchanged

$$
\begin{aligned}
C_9^{tot} &= C_9^{SM} + \Lambda_{sb} C_9^{Z'}, \\
C_{10}^{tot} &= C_{10}^{SM} + \Lambda_{sb} C_{10}^{Z'}.
\end{aligned}
$$

- The above effective Hamiltonian gives the following amplitude

$$
\begin{aligned}
\mathcal{M}(B \to M l^+ l^-) &= \frac{\alpha_{em} G_F}{2\sqrt{2}\pi} V_{tb}^* V_{ts} \Big[\langle M(k,\epsilon) | \bar{s} \gamma^\mu (1-\gamma^5) b | B(p) \rangle \\
&\times \left\{ C_9^{tot} (\bar{l} \gamma^\mu l) + C_{10}^{tot} (\bar{l} \gamma^\mu \gamma^5 l) \right\} \\
&- 2 C_7^{eff} m_b \langle M(k,\epsilon) | \bar{s} i \sigma_{\mu\nu} \frac{q^\nu}{s} (1+\gamma^5) b | B(p) \rangle (\bar{l} \gamma^\mu l) \Big]
\end{aligned}
$$

Among all the purely and semi leptonic FCNC processes, $B \to K^{*}\ell^{+}\ell^{-}$ decay has largest branching ratio which is of the order of 10^{-6}.

Among all the purely and semi leptonic FCNC processes, $B \to K^*\ell^+\ell^-$ decay has largest branching ratio which is of the order of 10^{-6}.

The matrix elements in the $B \to K^* l^+ l^-$ decay for above amplitude can be parameterized in terms of the form factors as follows

$$\langle K^*(k,\epsilon)|\bar{s}\gamma^\mu(1\pm\gamma^5)b|B(p)\rangle = \mp i q_\mu \frac{2m_{K^*}}{s}\epsilon^*\cdot q\Big[A_3(s) - A_0(s)\Big]$$
$$\pm i\epsilon^*_\mu(m_B + m_{K^*})A_1(s) \mp i(p+k)_\mu \epsilon^*\cdot q\frac{A_2(s)}{(m_B + m_{K^*})}$$
$$-\epsilon_{\mu\nu\lambda\sigma}p^\lambda q^\sigma \frac{2V(s)}{(m_B + m_{K^*})}$$

and

$$\langle K^*(k,\epsilon)|\bar{s}i\sigma_{\mu\nu}q^\nu(1\pm\gamma^5)b|B(p)\rangle = 2\epsilon_{\mu\nu\lambda\sigma}p^\lambda q^\sigma F_1(s)$$
$$\pm i\left\{\epsilon^*_\mu(m_B^2 - m_{K^*}^2) - (p+k)_\mu\epsilon^*\cdot q\right\}F_2(s)$$
$$\pm i\epsilon^*\cdot q\left\{q_\mu - \frac{(p+k)_\mu}{(m_B^2 - m_{K^*}^2)}\right\}F_3(s)$$

Single Lepton Polarization Asymmetries

The single lepton polarization asymmetries in the $B \to K^* l^+ l^-$ i.e. the asymmetries where only one of the final state lepton is polarized. For this purpose we first define the six orthogonal vectors belonging to the polarization of l^- and l^+ which we denote here by S_i and W_i respectively where $i =$L, N and T.

$$S_L^\mu \equiv (0, \mathbf{e}_L^-) = \left(0, \frac{\mathbf{p}_-}{|\mathbf{p}_-|}\right) \qquad W_L^\mu \equiv (0, \mathbf{e}_L^+) = \left(0, \frac{\mathbf{p}_+}{|\mathbf{p}_+|}\right)$$

$$S_N^\mu \equiv (0, \mathbf{e}_N^-) = \left(0, \frac{\mathbf{k} \times \mathbf{p}_-}{|\mathbf{k} \times \mathbf{p}_-|}\right) \qquad W_N^\mu \equiv (0, \mathbf{e}_N^+) = \left(0, \frac{\mathbf{k} \times \mathbf{p}_+}{|\mathbf{k} \times \mathbf{p}_+|}\right)$$

$$S_T^\mu \equiv (0, \mathbf{e}_T^-) = (0, \mathbf{e}_N \times \mathbf{e}_L) \qquad W_T^\mu \equiv (0, \mathbf{e}_T^+) = (0, \mathbf{w}_N \times \mathbf{w}_L)$$

After the Lorentz boost operation the longitudinal four vectors read as

$$S_L^\mu = \left(\frac{|p_-|}{m_l}, \frac{E_l \mathbf{p}_-}{m_l|\mathbf{p}_-|}\right)$$
$$W_L^\mu = \left(\frac{|p_+|}{m_l}, -\frac{E_l \mathbf{p}_+}{m_l|\mathbf{p}_+|}\right)$$

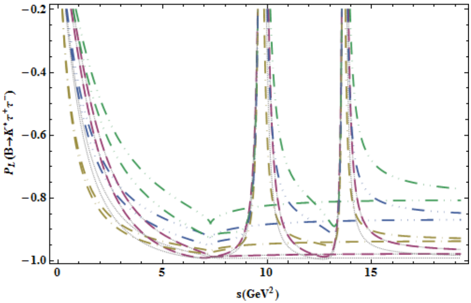
while the other two polarization vectors remain unchanged.
To achieve the polarization asymmetries one can use the spin projectors $\frac{1}{2}(1+\gamma_5 \not{S})$ and $\frac{1}{2}(1+\gamma_5 \not{W})$ for ℓ^- and ℓ^+, respectively. The single lepton polarization asymmetries formula which is given in

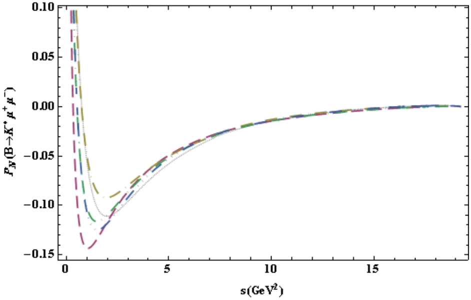
$$P_i^\pm = \frac{\frac{d\Gamma(\mathbf{S}^\pm=\mathbf{e}_i^\pm)}{ds} - \frac{d\Gamma(\mathbf{S}^\pm=-\mathbf{e}_i^\pm)}{ds}}{\frac{d\Gamma(\mathbf{S}^\pm=\mathbf{e}_i^\pm)}{ds} + \frac{d\Gamma(\mathbf{S}^\pm=-\mathbf{e}_i^\pm)}{ds}}$$

$m_B = 5.28$ GeV, $m_b = 4.28$ GeV, $m_\mu = 0.105$ GeV,
$m_\tau = 1.77$ GeV, $f_B = 0.25$ GeV, $\lvert V_{tb}V_{ts}^*\rvert = 45 \times 10^{-3}$,
$\alpha^{-1} = 137$, $G_F = 1.17 \times 10^{-5}$ GeV^{-2},
$\tau_B = 1.54 \times 10^{-12}$ sec, $m_{K^*} = 0.892$ GeV, $m_{K_2^*} = 1.43$ GeV.

- As for as the numerical values of the Z' couplings are concerned, there are several severe constraints from different inclusive and exclusive B decays.
- These numerical values of coupling parameters of Z' model are recollected in the following Table where $S1$ and $S2$ correspond to two different fittings values for $B_s - \bar{B}_s$ mixing data by the UTfit collaboration.

	$\mathcal{R}e(B_{sb}) \times 10^{-3}$	ϕ_{sb}	$S_{LL} \times 10^{-2}$	$D_{LL} \times 10^{-2}$
$S1$	1.09 ± 0.22	$-72^\circ \pm 7^\circ$	-2.8 ± 3.9	-6.7 ± 2.6
$S2$	2.20 ± 0.15	$-82^\circ \pm 4^\circ$	-1.2 ± 1.4	-2.5 ± 0.9

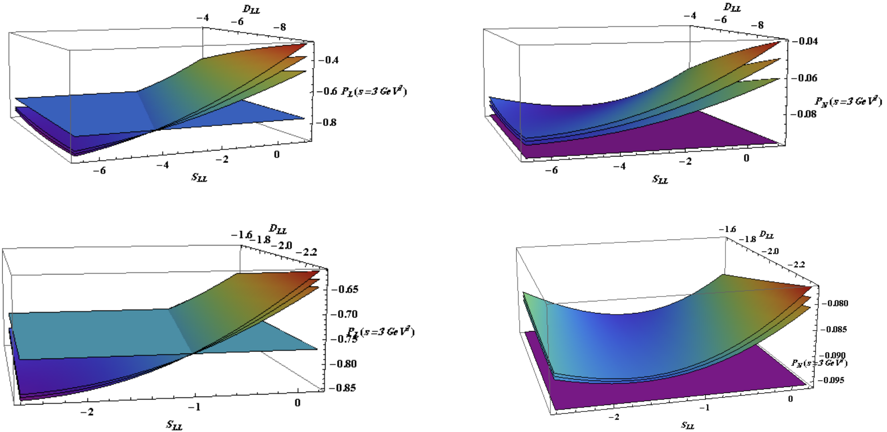




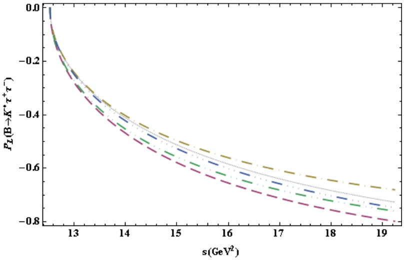
Longitudinal Polarization

Normal Polarization

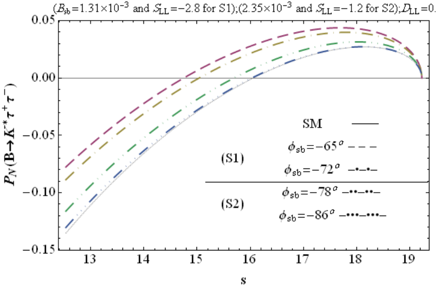
We have also plotted 3-dimensional graphs of P_L and P_N at $s = 3\text{GeV}^2$ (which is well below the resonance region) against the D_{LL} and S_{LL}.

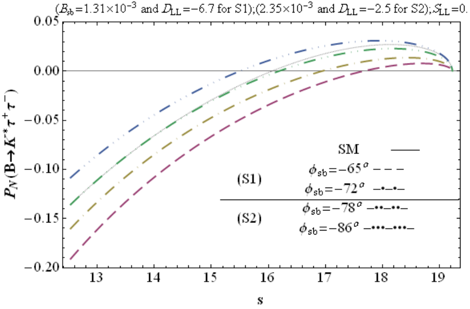


Flat curves correspond to the SM values of P_L and P_N.



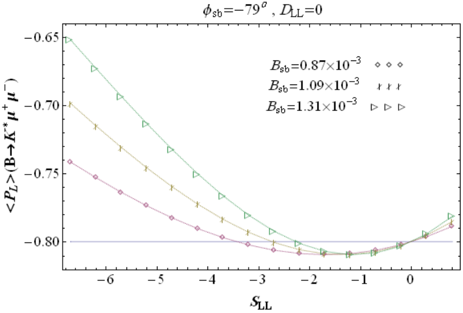
- The P_L of $B \to K^*\tau^+\tau^-$ is portrayed against s.
- P_N as a function of s for $S1$ and $S2$ with different values of Z' parameters in the following graphs.

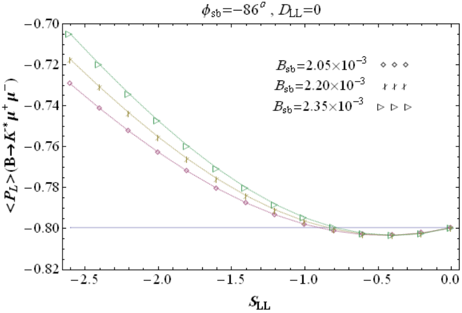


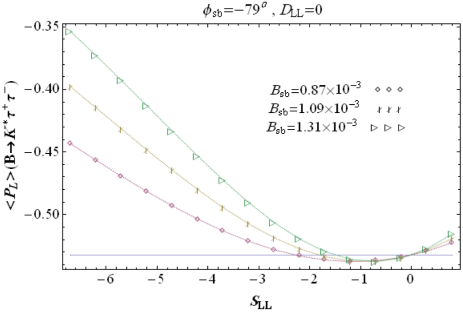


The average values of asymmetries are also very important tool to probe new physics and can be obtained by the following formula

$$\langle P_i \rangle = \frac{\int_{4m_l^2}^{(m_B^2 - m_{k^*}^2)} P_i \frac{d\Gamma}{ds} ds}{\int_{4m_l^2}^{(m_B^2 - m_{k^*}^2)} \frac{d\Gamma}{ds} ds}$$







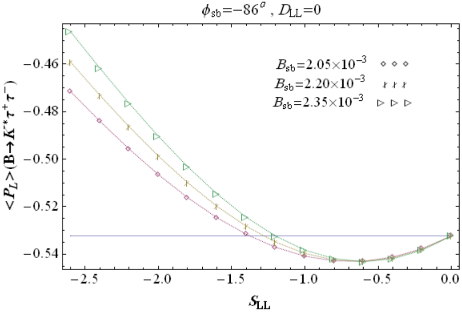
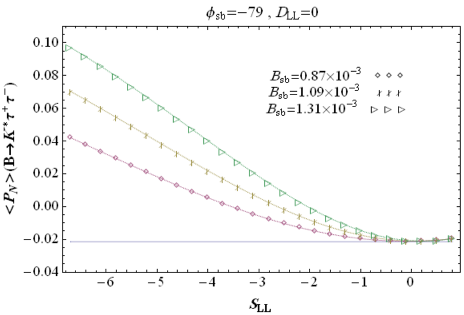


Table 3.4: Numerical values of $\langle P_L\rangle$ in Z' model for scenario-I

ϕ_{sb} in Degree	Decay Channel	$\langle P_L\rangle$ at $D_{LL}=0$				$\langle P_L\rangle$ at $S_{LL}=0$			
		S_{LL} −6.7		S_{LL} 1.1		D_{LL} −9.3		D_{LL} −4.1	
		$B_{sb}=0.87$	1.31	0.87	1.31	0.87	1.31	0.87	1.31
-65°	$B\to K^*\mu^+\mu^-$	-0.785	-0.715	-0.774	-0.757	-0.597	-0.485	-0.731	-0.679
	$B\to K^*\tau^+\tau^-$	-0.423	-0.347	-0.526	-0.519	-0.515	-0.476	-0.538	-0.532
-79°	$B\to K^*\mu^+\mu^-$	-0.741	-0.651	-0.782	-0.772	-0.573	-0.442	-0.728	-0.669
	$B\to K^*\tau^+\tau^-$	-0.443	-0.354	-0.517	-0.506	-0.454	-0.394	-0.509	-0.490



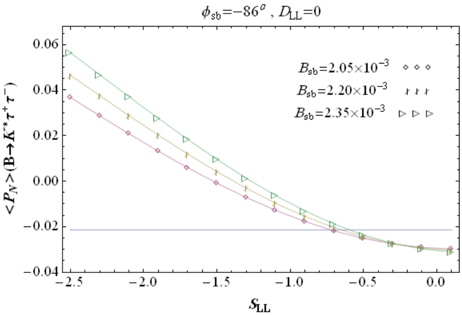
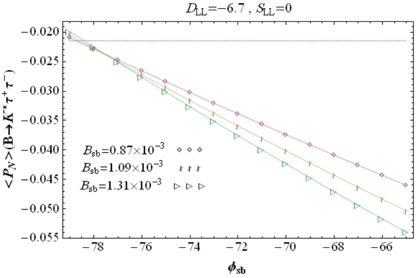
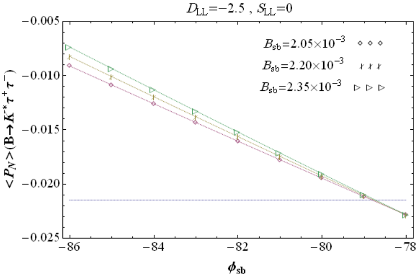
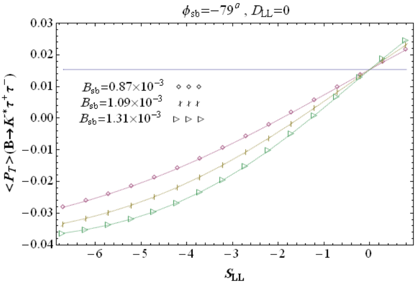


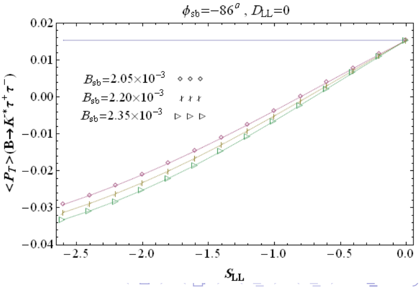
TABLE V: Numerical values of $\langle P_L \rangle$ in Z' model for scenario-II

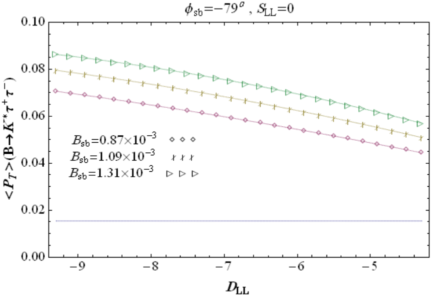
		$\langle P_L \rangle$ at $D_{LL} = 0$				$\langle P_L \rangle$ at $S_{LL} = 0$			
ϕ_{sb} in Degree	Decay Channel	S_{LL} −2.6		S_{LL} 0.2		D_{LL} −2.34		D_{LL} −1.6	
		$B_{sb} = 2.05$	2.35	2.05	2.35	2.05	2.35	2.05	2.35
−78°	$B \to K^*\mu^+\mu^-$	-0.795	-0.780	-0.790	-0.788	-0.696	-0.675	-0.539	-0.537
	$B \to K^*\tau^+\tau^-$	-0.437	-0.451	-0.531	-0.531	-0.535	-0.532	-0.539	-0.537
−86°	$B \to K^*\mu^+\mu^-$	-0.754	-0.733	-0.793	-0.792	-0.689	-0.665	-0.736	-0.722
	$B \to K^*\tau^+\tau^-$	-0.458	-0.434	-0.527	-0.526	-0.496	-0.488	-0.511	-0.507

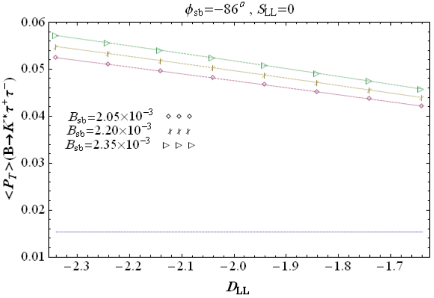

$D_{LL}=-6.7$, $S_{LL}=0$
$B_{sb}=0.87\times10^{-3}$
$B_{sb}=1.09\times10^{-3}$
$B_{sb}=1.31\times10^{-3}$
$<P_N>(B\to K^*\tau^+\tau^-)$
ϕ_{sb}


$D_{LL}=-2.5$, $S_{LL}=0$
$B_{sb}=2.05\times10^{-3}$
$B_{sb}=2.20\times10^{-3}$
$B_{sb}=2.35\times10^{-3}$
$<P_N>(B\to K^*\tau^+\tau^-)$
ϕ_{sb}


$\phi_{sb}=-79^o$, $D_{LL}=0$
$B_{sb}=0.87\times10^{-3}$
$B_{sb}=1.09\times10^{-3}$
$B_{sb}=1.31\times10^{-3}$
$<P_T>(B\to K^*\tau^+\tau^-)$
S_{LL}


$\phi_{sb}=-86^o$, $D_{LL}=0$
$B_{sb}=2.05\times10^{-3}$
$B_{sb}=2.20\times10^{-3}$
$B_{sb}=2.35\times10^{-3}$
$<P_T>(B\to K^*\tau^+\tau^-)$
S_{LL}





CP Violation

- *C* is for *charge* and *P* is for *parity*; so *CP* violation means you measure something happening with some particles, and then you measure the analogous thing happening when you switch particles with antiparticles and take the mirror image. (Parity reverses directions in space.)
- CP is a pretty good symmetry in nature, but not a perfect one. Cronin and Fitch won the Nobel Prize in 1980 for discovering CP violation experimentally.

In the context of CP asymmetry, it is important to emphasis here:

The FCNC transitions are proportional to three CKM matrix elements, namely, $V_{tb}V_{ts}^*$, $V_{cb}V_{cs}^*$ and $V_{ub}V_{us}^*$ but due to the unitarity condition and neglecting $V_{ub}V_{us}^*$ in comparison of $V_{cb}V_{cs}^*$ and $V_{tb}V_{ts}^*$, the CP asymmetry is highly suppressed in the SM.

- The normalized CP violation asymmetries can be defined through the difference of the differential decay rates of particle and antiparticle decay modes as follows

$$\mathcal{A}_{CP}(\mathbf{S}^{\pm} = \mathbf{e}_i^{\pm}) = \frac{\frac{d\Gamma(\mathbf{S}^-)}{ds} - \frac{d\bar{\Gamma}(\mathbf{S}^+)}{ds}}{\frac{d\Gamma}{ds} + \frac{\bar{\Gamma}}{ds}}$$

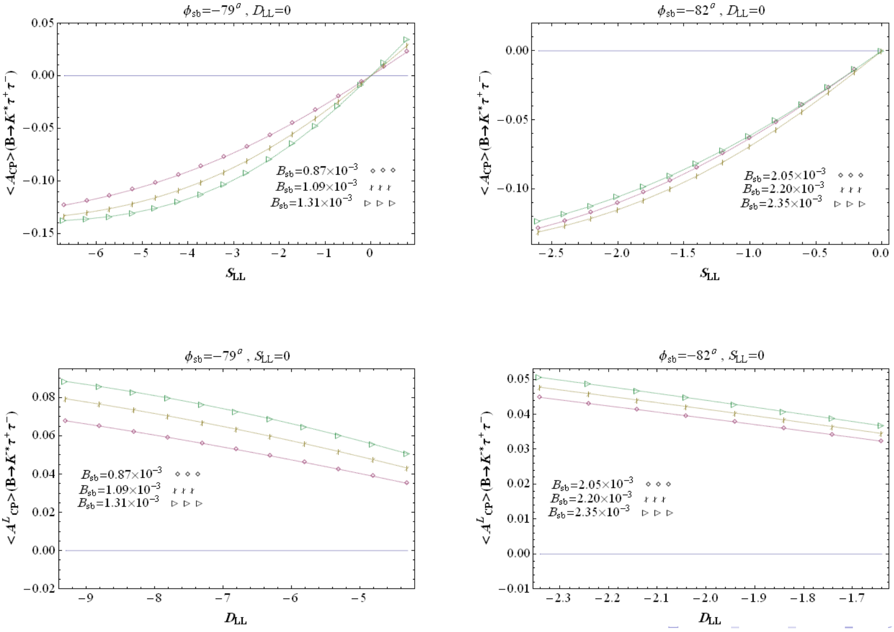
where

$$\frac{d\Gamma}{ds} = \frac{d\Gamma(B \to K^* \ell^+ \ell^- (\mathbf{S}^-))}{ds}$$

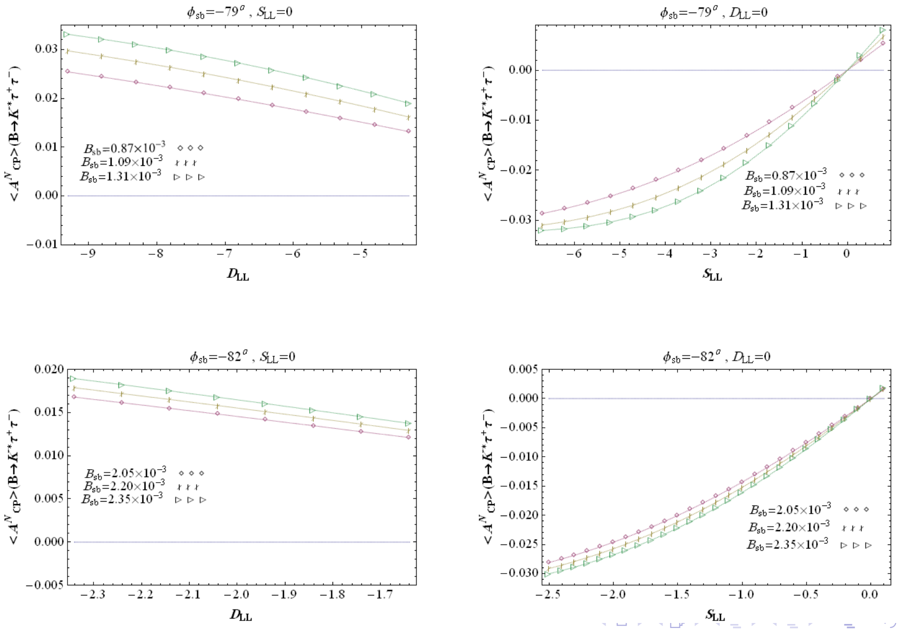
$$\frac{d\bar{\Gamma}}{ds} = \frac{d\bar{\Gamma}(B \to K^* \ell^+ (\mathbf{S}^+))\ell^-}{ds}$$

- The CP conjugated differential decay width can be written as

$$\frac{d\bar{\Gamma}(\mathbf{S}^{\pm})}{ds} = \frac{1}{2}\left(\frac{d\bar{\Gamma}}{ds}\right)\left[1 + (P_L \mathbf{e}_L^{\pm} + P_N \mathbf{e}_N^{\pm} + P_T \mathbf{e}_T^{\pm}) \cdot \mathbf{S}^{\pm}\right]$$



$\phi_{sb}=-79^o$, $D_{LL}=0$
$<A_{CP}>(B\to K^*\tau^+\tau^-)$
S_{LL}
$B_{sb}=0.87\times10^{-3}$
$B_{sb}=1.09\times10^{-3}$
$B_{sb}=1.31\times10^{-3}$
$\phi_{sb}=-82^o$, $D_{LL}=0$
$<A_{CP}>(B\to K^*\tau^+\tau^-)$
S_{LL}
$B_{sb}=2.05\times10^{-3}$
$B_{sb}=2.20\times10^{-3}$
$B_{sb}=2.35\times10^{-3}$
$\phi_{sb}=-79^o$, $S_{LL}=0$
$<A^L_{CP}>(B\to K^*\tau^+\tau^-)$
D_{LL}
$B_{sb}=0.87\times10^{-3}$
$B_{sb}=1.09\times10^{-3}$
$B_{sb}=1.31\times10^{-3}$
$\phi_{sb}=-82^o$, $S_{LL}=0$
$<A^L_{CP}>(B\to K^*\tau^+\tau^-)$
D_{LL}
$B_{sb}=2.05\times10^{-3}$
$B_{sb}=2.20\times10^{-3}$
$B_{sb}=2.35\times10^{-3}$



$\phi_{sb}=-79^o$, $S_{LL}=0$
$<A^N_{CP}>(B\to K^*\tau^+\tau^-)$
D_{LL}
$B_{sb}=0.87\times10^{-3}$
$B_{sb}=1.09\times10^{-3}$
$B_{sb}=1.31\times10^{-3}$
$\phi_{sb}=-79^o$, $D_{LL}=0$
$<A^N_{CP}>(B\to K^*\tau^+\tau^-)$
S_{LL}
$B_{sb}=0.87\times10^{-3}$
$B_{sb}=1.09\times10^{-3}$
$B_{sb}=1.31\times10^{-3}$
$\phi_{sb}=-82^o$, $S_{LL}=0$
$<A^N_{CP}>(B\to K^*\tau^+\tau^-)$
D_{LL}
$B_{sb}=2.05\times10^{-3}$
$B_{sb}=2.20\times10^{-3}$
$B_{sb}=2.35\times10^{-3}$
$\phi_{sb}=-82^o$, $D_{LL}=0$
$<A^N_{CP}>(B\to K^*\tau^+\tau^-)$
S_{LL}
$B_{sb}=2.05\times10^{-3}$
$B_{sb}=2.20\times10^{-3}$
$B_{sb}=2.35\times10^{-3}$

Summary and Conclusion

- We have analyzed the influence of non-universal Z' model to the $B \to K^* \ell^+ \ell^-$ decay. For this purpose we have calculated CP violation and single lepton polarization asymmetries.
- It is found that in the presence of Z' the CP violation asymmetries $\mathcal{A}_{CP}$, $\mathcal{A}_{CP}^{L}$ and $\mathcal{A}_{CP}^{N}$ are considerably enhanced for the case when tauons are the final state leptons, While, for the case of muons CP asymmetries remain suppresed.
- Similarly, the values of P_i and $\langle P_i \rangle$ significantly deviate from their SM values where one can fix the parameters of Z' model.
- Therefore, the precise measurements of these asymmetries may help to yield the accurate values of new weak phase ϕ_{sb} and Z' coupling with the fermions.

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THANK YOU!

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Family of non-Universal Z' Model

- The current in this model can be given as follows in a proper gauge basis

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

where i represents the family index, ψ represents the families of up or down type quarks or charged or neutral leptons and $\epsilon_i^{L,R}$ are diagonal couplings of Z' boson with fermions.

- After rotating from the flavor basis to the physical basis the non-universal Z'-couplings $\epsilon_i^{L,R}$ become non-diagonal, one can write explicitly,

$$B^{\psi_L} = V_{\psi_L} \epsilon^{\psi_L} V^{\dagger}_{\psi_L}, B^{\psi_R} = V_{\psi_R} \epsilon^{\psi_R} V^{\dagger}_{\psi_R}$$

- These non diagonal couplings in the fermion mass of Z' boson may lead to FCNCs at tree level.
- Further these couplings might contains CP-violating phase, which is beyond that of SM.