CP violation asymmetry for semileptonic decay channel $B \rightarrow \pi\mu^+\mu^-$ in non-universal Z' model

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(BLV 2019), Madrid, Spain on 24th October, 2019

Overview of $B \to \pi\mu^+\mu^-$

- **Rare B meson decays induced by FCNC transition $b \to s(d)$ play one of the most important role in the flavor sector of Standard Model (SM).**

- **Although there exists a lot of precise results on $b \to sl^+l^-$ induced processes, there is lack of sufficient data for $b \to dl^+l^-$ induced decays.**

- **Semileptonic rare B meson decays are challenging because of small branching ratio $\mathcal{O}(10^{-6})$ for $b \to sl^+l^-$ and $\mathcal{O}(10^{-8})$ for $b \to dl^+l^-$ transition.**

- **The detection of decays having $b \to d$ quark level transition becomes more problematic for the purpose of large CP violation and small branching ratio.**

$B \to \pi \mu^+ \mu^-$ in SM

- **In the SM, the effective Hamiltonian for the transition $b \to dl^+l^-$ is expressed as**

$$H_{eff}$$

$$= -\frac{4G_F\alpha}{\sqrt{2}}V_{tb}V_{td}^*\left[\sum_{i=1}^{10}C_iO_i - \lambda_u\{C_1|O_1^u - O_1| + C_2|O_2^u - O_2|\}\right]$$

Using the form factors the decay matrix element for this transition can be written as

$$\mathcal{M}^{B\to\pi}$$

$$= \frac{G_F\alpha}{\sqrt{2}\pi}V_{tb}V_{td}^*\{A(p_B)_\mu(\bar{l}\gamma^\mu l) + B(p_B)_\mu(\bar{l}\gamma^\mu\gamma^5 l) + C(\bar{l}\gamma_5 l)\}$$

- **The expression of CP violating partial width asymmetry as** $A_{CP}(\hat{s}) = \dfrac{-2Im\lambda_u\Delta_\pi}{\Sigma_\pi + 2Im\lambda_u\Delta_\pi}.$

Contribution of Z' boson

The effective Hamiltonian in this Z' model can be written as

$$H_{eff}^{Z'} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{td}^* \left[\wedge_{db} C_9^{Z'} O_9 + \wedge_{db} C_{10}^{Z'} O_{10} \right]$$

$$\wedge_{db} = \frac{4\pi e^{-i\varphi_{db}}}{\alpha V_{tb} V_{td}^*}$$

Basically the contribution of Z' on the current operators, semileptonic electroweak penguin operators and QCD penguin operators remains same as that of the SM.

New Physics effect in the non-universal Z' model comes due to the modification of Wilson coefficients C_9 and C_{10}.

Modification of C_9^{eff} and C_{10}

$$C_9^{Z'} = |B_{db}| S_{LL}$$

$$C_{10}^{Z'} = |B_{db}| D_{LL}$$

$$S_{LL} = S_{ll}^L + S_{ll}^R \text{ and } D_{LL} = S_{ll}^R - S_{ll}^L$$

$$C_9^{NP} = \wedge_{db} C_9^{Z'}$$

$$C_{10}^{NP} = \wedge_{db} C_{10}^{Z'}$$

$$C_9^{Total} = C_9^{eff} + C_9^{NP}$$

$$C_{10}^{Total} = C_{10} + C_{10}^{NP}$$

Numerical analysis

✓ We have fixed the numerical values of the coupling parameter $|B_{db}|$ and the weak phase φ_{db}.

✓ These values are encapsulated in following table for two different scenarios S_1 and S_2.

Table. 1. Numerical values of B_{db} and φ_{db}

Scenarios	$B_{db} \times 10^{-3}$	φ_{db} in Degree
S_1	0.16 ± 0.08	-33 ± 45
S_2	0.12 ± 0.03	-23 ± 21

✓ The maximum values of the coupling parameter and the weak phase angle as

- $B_{db} = 0.24 \times 10^{-3}$ and $\varphi_{db} = 12°$
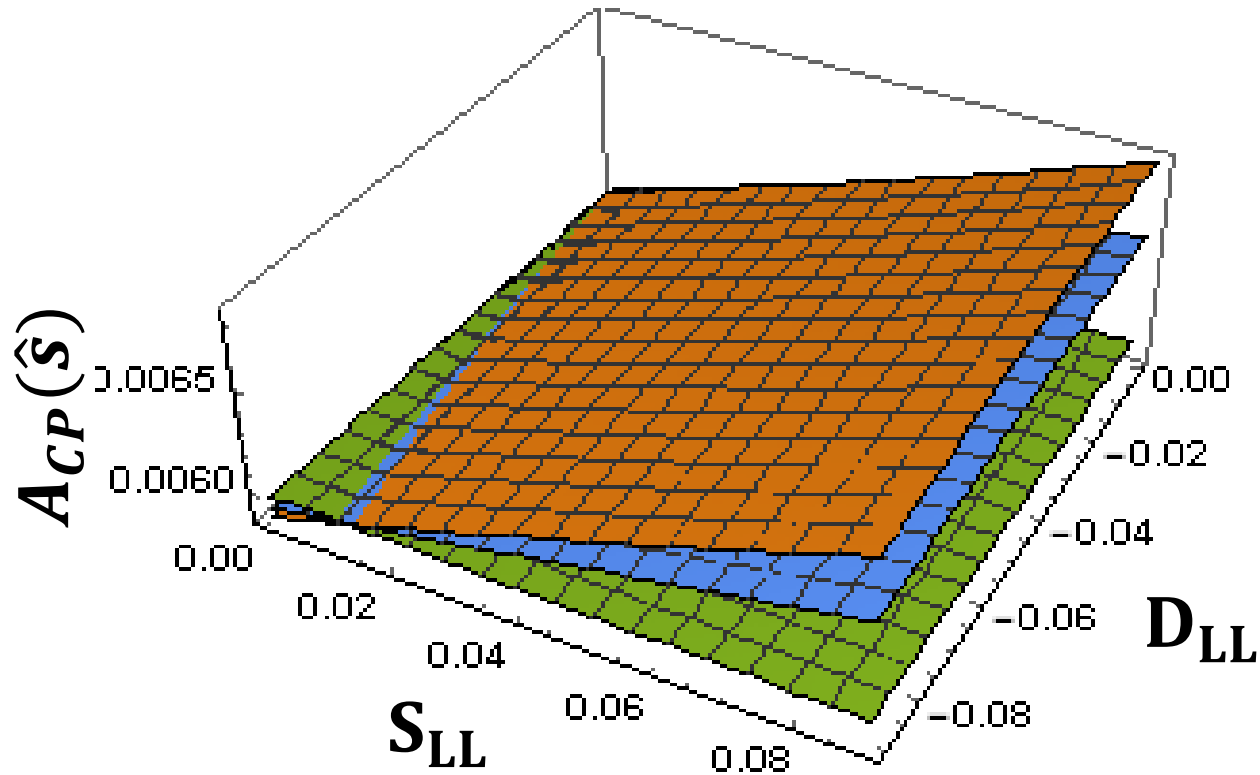- $B_{db} = 0.15 \times 10^{-3}$ and $\varphi_{db} = -2°$

Graphical representation

Fig. 1. The dependence of CP partial width asymmetry on coupling parameters S_{LL} and D_{LL} for $B \to \pi \mu^+ \mu^-$ decay

Conclusion
Phys. Rev. D 99, 013005 (2019)

Table 1. CP symmetry in SM and different NP scenarios

Decay mode	ACP_{SM}	$ACP_{Z'}$	
$B \to \pi\mu^+\mu^-$	0.0059	S_1	0.0062
		S_2	0.0061

✓The significant enhancements of CP asymmetry for $B \to \pi\mu^+\mu^-$ in non-universal Z' model gives a signal for NP beyond the SM.

✓The measurements of this kinematic observable will provide a good hunting ground to determine the precise values of coupling parameters of Z' boson with leptons as well as quarks.

References

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thank you