$D^0 - \bar{D}^0$ Mixing in Multi-Higgs Model

Yanzhi Meng
Oklahoma State University

Based on works with **K.S. Babu** (to appear)

Pheno 2007

Motivations

- Flavor Puzzles; Quark, Lepton Mixings
- SUSY Flavor Problem, $\frac{\Delta m^2_{\tilde{d}\tilde{s}}}{m^2_{ave}} \leq 10^{-3}$
- SUSY CP Problem, SUSY Phase $<10^{-2}$ From EDM

Flavor Symmetry may explain this puzzles, and flavor symmetry needs multi-Higgs model. In standard model there is no tree level flavor changing neutral current. In multi-Higgs model, tree level NCFC is available with arbitrary strength. But experiments show FCNC effects are small. So we need symmetry to constraint FCNC. Q_6 model is one of the models to make way. In this model two light flavors fall into a doublet representation. The heavy third flavor a singlet. From it the famous relation

$$\sin\theta_c = \sqrt{\frac{m_d}{m_s}} - e^{i\theta_q}\sqrt{\frac{m_u}{m_c}}$$

can be derived. And SUSY phase is also naturally small.

Q_6 Model

Q_6 (Babu and Kubo 2005) is a nonabelian group which has 12 elements. It is made of the products of the two generators.

$$\mathbf{A} = \begin{pmatrix} \cos\frac{\pi}{3} & \sin\frac{\pi}{3} \\ -\sin\frac{\pi}{3} & \cos\frac{\pi}{3} \end{pmatrix} \mathbf{B} = \begin{pmatrix} i & 0 \\ 0 & -i \end{pmatrix}$$

Representation are

$$2,\ 2',\ 1,\ 1',\ 1'',\ 1'''$$

$$1'\times 1' = 1,\ 1''\times 1'' = 1,\ 1'''\times 1''' = 1',\ 1''\times 1''' = 1,\ 1'\times 1''' = 1'',\ 1\times 1'' = 1'''$$

$$2\times 1' = 2,\ 2\times 1'' = 2',\ 2\times 1''' = 2',\ 2'\times 1' = 2',\ 2'\times 1'' = 2,\ 2'\times 1''' = 2$$

$$2\times 2 = 1 + 1' + 2',\ 2'\times 2' = 1 + 1' + 2',\ 2\times 2' = 1'' + 1''' + 2$$

Model Continues

The presentations of fermions and Higgs under Q_6

$$\psi = \begin{pmatrix} \psi_1 \\ \psi_2 \end{pmatrix} = 2, \quad \psi^c = \begin{pmatrix} -\psi_1^c \\ \psi_2^c \end{pmatrix} = 2', \quad \psi_3 = 1' \quad \psi_3^c = 1''',$$

$$H = \begin{pmatrix} H_1 \\ H_2 \end{pmatrix} = 2', \quad H_3 = 1'''$$

The Q_6 invariant Yukawa coupling is

$$L = a\psi_3 \psi_3^c H_3 + b\psi^T \tau_1 \psi_3^c H - b' \psi_3 \psi^{cT} i\tau_2 H + c\psi^T \tau_1 \psi^c H_3 + h.c.$$

and leads to the mass matrix

$$\mathbf{M} = \begin{pmatrix} 0 & c\langle H_3 \rangle & b\langle H_2 \rangle \\ -c\langle H_3 \rangle & 0 & b\langle H_1 \rangle \\ b'\langle H_2 \rangle & b'\langle H_1 \rangle & a\langle H_3 \rangle \end{pmatrix}$$

Model Continues

Since H_1 and H_2 are symmetric under Q_6, the mass matrix can be simplified by an overall $45°$ rotation in the Q_6 doublet into

$$\mathbf{M} = \begin{pmatrix} 0 & c\langle H_3\rangle & 0 \\ -c\langle H_3\rangle & 0 & b\langle H_1\rangle \\ 0 & b'\langle H_1\rangle & a\langle H_3\rangle \end{pmatrix}$$

Generally the mass matrices are complex. If CP is spontaneously broken. Using two parameters θ^u and θ^d the mass matrices of U-sector and D-sector can be realized. $\theta^q = \theta^d - \theta^u$ and the Yukawa coupling constants and are determined (Babu and Kubo 2005). $\theta^q = -1.15$.

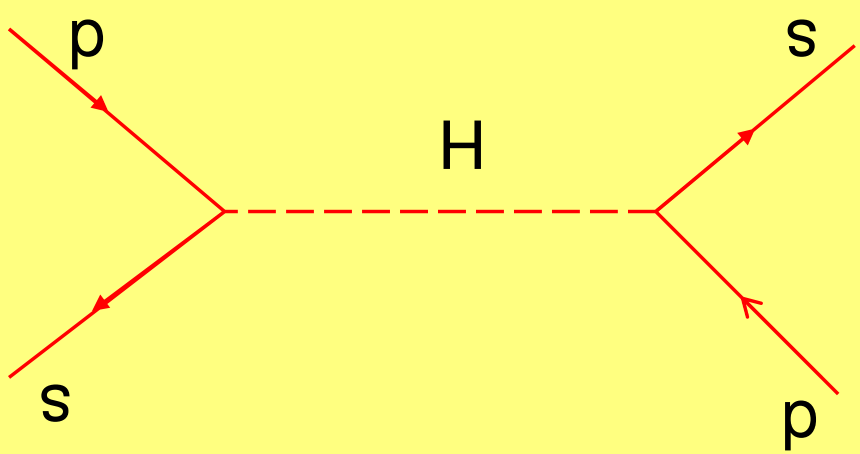

Figure 1: An example of FCNC through neutral Higgs

Phenomenology

In this model, H_1 and H_2 are symmetric. We define $\tan\gamma_u = \frac{<H_1^u>}{<H_3^u>}$, $\tan\gamma_d = \frac{<H_1^d>}{<H_3^d>}$. Another unknown parameter is $\tan\beta = \frac{H^u}{H^d}$. They are not determined by the model. We fit them with experimental data. The data we are choosing are $K^0 - \bar{K}^0$ mixing, $B_d^0 - \bar{B}_d^0$ mixing, $B_s^0 - \bar{B}_s^0$ mixing and the new data $D^0 - \bar{D}^0$(Nir, Ball) mixing. The below fit assumes $\tan\beta = 2.0$.

$K^0 - \bar{K^0}$ Mixing

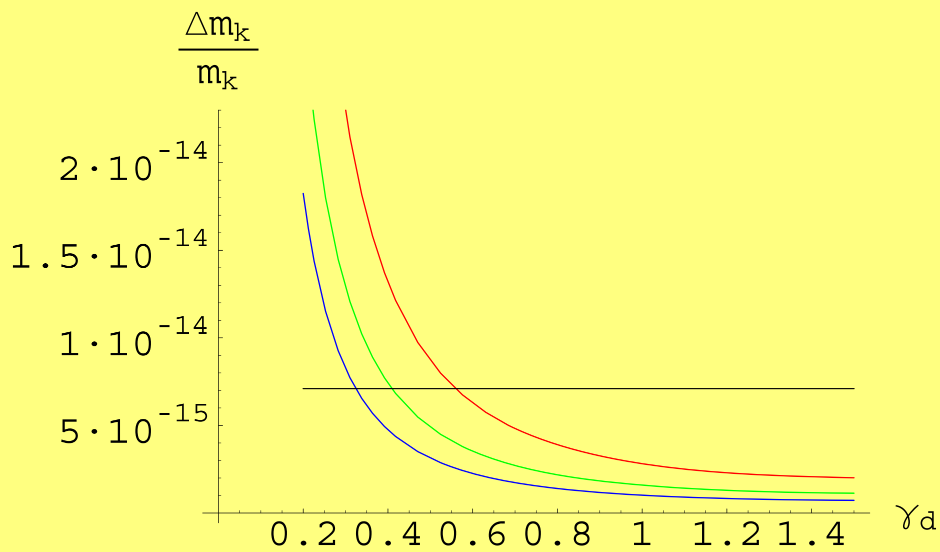

Figure 2: The fit with $K^0 - \bar{K^0}$ mixing. The red line corresponds to $M_{h_d} = 1500GeV$, green $M_{h_d} = 2000GeV$, blue $M_{h_d} = 2500GeV$. The black line is the experimental value 7.1×10^{-15}.

$B_d^0 - \bar{B}_d^0$ Mixing

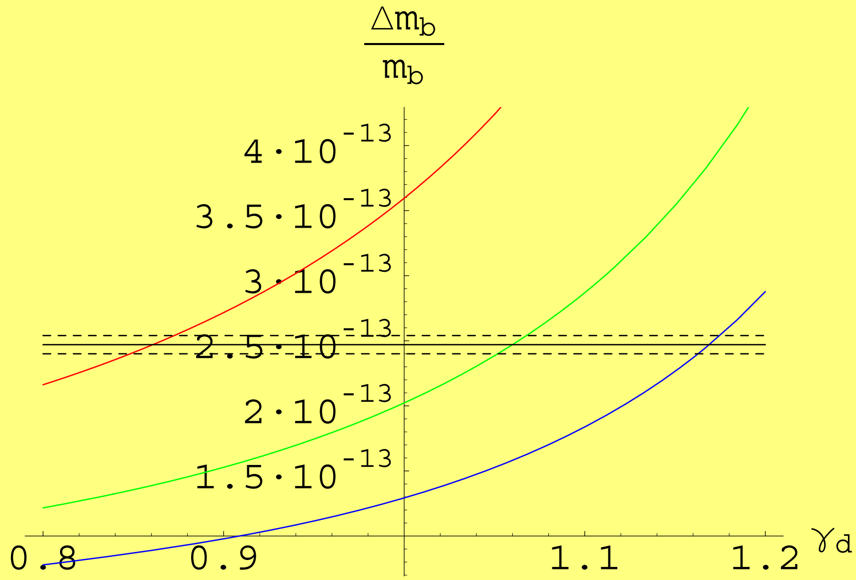

Figure 3: The fit with $B_d^0 - \bar{B}_d^0$ mixing. The red line corresponds to $M_{h_d} = 1500GeV$, green $M_{h_d} = 2000GeV$, blue $M_{h_d} = 2500GeV$. The black line and the dash lines are the experimental value $2.47 \pm 0.07 \times 10^{-13}$.

$B_s^0 - \bar{B}_s^0$ Mixing

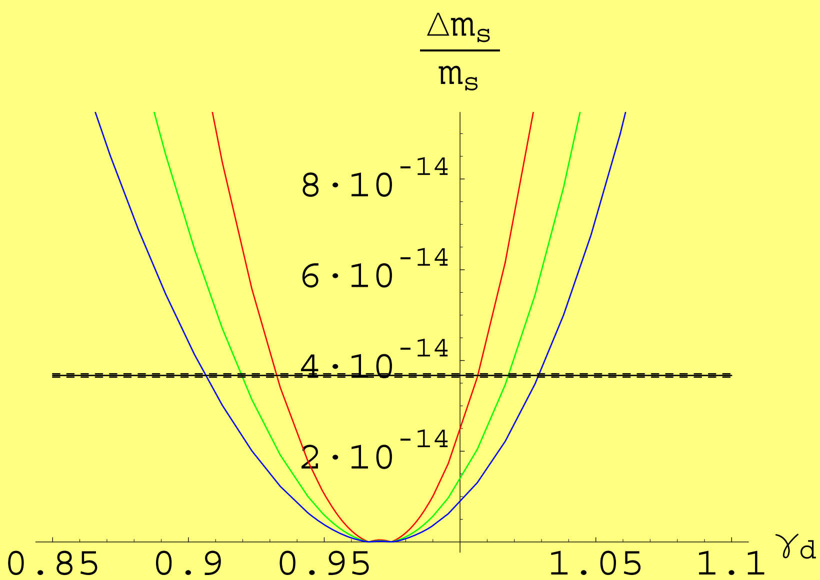

Figure 4: The fit with $B_s^0 - \bar{B}_s^0$ mixing. The red line corresponds to $M_{h_d} = 1500GeV$, green $M_{h_d} = 2000GeV$, blue $M_{h_d} = 2500GeV$. The black line and the dash lines are the experimental value $3.67 \pm 0.076 \times 10^{-13}$.

$D^0 - \bar{D}^0$ Mixing

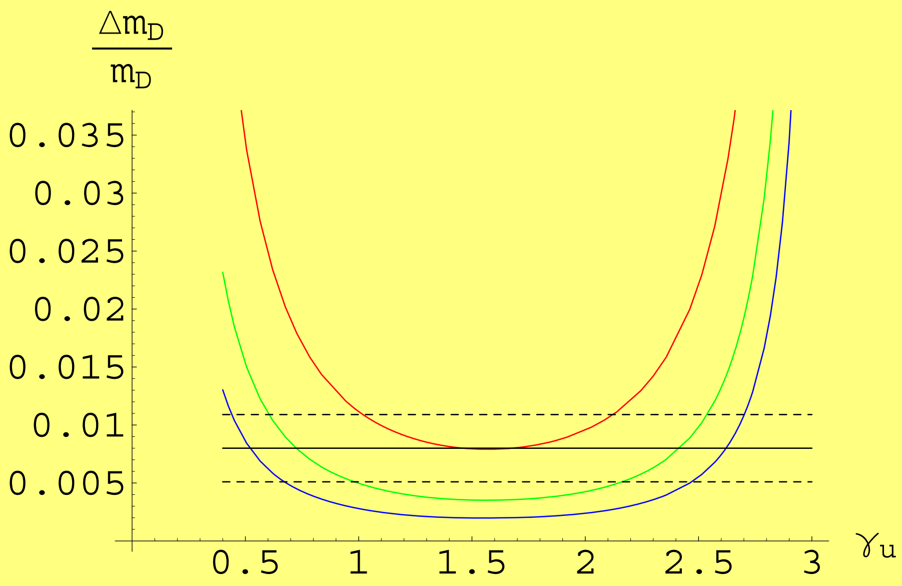

Figure 5: The fit with $D^0 - \bar{D}^0$ mixing. The red line corresponds to $M_{h_d} = 1000GeV$, green $M_{h_d} = 1500GeV$, blue $M_{h_d} = 2000GeV$. The black line and the dash lines are the experimental value $0.8 \pm 0.29 \times 10^{-2}$.

We also calculated the CP violation in $D^0 - \bar{D}^0$ system. Because the absorptive part is created through loops, it is suppressed. The result is $CP_D \sim 10^{-17}$. We didn't take account in the mixing of Higgs. The mixing can increase the CP violation effect.

Conclusions

- The FCNC effect is calculated in a multi-Higgs model. Under reasonable Higgs mass, the neutral meson mixing is close to experimental value.
- CP violation effect is small without Higgs mixing.
- Higgs masses and the values of $\frac{<H_1>}{<H_2>}$ need more experiments to determine.

References

[1] Babu, K. S. and Jisuke Kubo 2005. Phys. Rev. D 71, 056006. hep-ph/0411226

[2] Yosef Nir hep-ph/0703235

[3] Patricia Ball hep-ph/0703245