含 W' 的电弱手征拉氏量

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工作的动机

含$W'^{\pm}, Z'$的电弱手征拉氏量

$W-W'$混合、费米子的混合

$$\Delta m_K,\ |\epsilon_K|,\ \Delta m_{B_d},\ \Delta m_{B_s}$$

工作的动机

- **LHC**开始运行！期待发现新的粒子，$\Rightarrow$超出标准模型的新物理！
- 我们关心新粒子是带电的矢量粒子的情形！
- 理论的幺正性要求它是自发破缺的非阿贝尔规范理论中的规范粒子.
- 最小的非阿贝尔规范对称性是$SU(2)$，产生规范粒子$W'^{\pm}, Z'$
- 构造含$W'^{\pm}, Z'$的电弱手征拉氏量，进行模型无关和相关的研究
- 为改善理论的幺正性，还得加上一个中性**Higgs**粒子h
- 期待研究的物理情形：最轻的新粒子是 h 和 $W'^{\pm}$

含$W'^{\pm}, Z'$的电弱手征拉氏量

- 粒子内容：♠ 标准模型中所有已被发现的粒子
  ♣ h, $W'^{\pm}, Z'$及其对应的三个**Goldstone**玻色子

- 对称性的实现方式： $SU(2)_1 \otimes SU(2)_2 \otimes U(1) \longrightarrow U(1)_{\rm em}$

- $W'^{\pm}, Z'$耦合夸克$q-\bar{q}$、轻子$l-\bar{l}$：
$$\begin{cases} \mathrm{LR}: \mathrm{Left-right\quad symmetric} \\ \mathrm{LP}: \mathrm{Leptophobic} \\ \mathrm{HP}: \mathrm{Hadrophobic} \\ \mathrm{FP}: \mathrm{Fermionphobic} \\ \mathrm{UN}: \mathrm{Ununified} \\ \mathrm{NU}: \mathrm{Non-universal} \end{cases}$$

- 不讨论**leptoquark**: W'将夸克耦合到轻子

不同的费米子表示安排

Fields/Models	LR	LP	HP	FP	UN	NU
$q_{\alpha L}=\begin{pmatrix} u_{\alpha L} \\ d_{\alpha L} \end{pmatrix}$	$(2,1,\frac{1}{6})$	$(2,1,\frac{1}{6})$	$(2,1,\frac{1}{6})$	$(2,1,\frac{1}{6})$	$(1,2,\frac{1}{6})$	$(2,1,\frac{1}{6})\delta_{\alpha\alpha_1}+(1,2,\frac{1}{6})\delta_{\alpha\alpha_2}$
$q_{\alpha R}=\begin{pmatrix} u_{\alpha R} \\ d_{\alpha R} \end{pmatrix}$	$(1,2,\frac{1}{6})$	$(1,2,\frac{1}{6})$	$(1,1,\frac{2}{3})$ $(1,1,-\frac{1}{3})$	$(1,1,\frac{2}{3})$ $(1,1,-\frac{1}{3})$	$(1,1,\frac{2}{3})$ $(1,1,-\frac{1}{3})$	$(1,1,\frac{2}{3})$ $(1,1,-\frac{1}{3})$
$l_{\alpha L}=\begin{pmatrix} \nu_{\alpha L} \\ e^-_{\alpha L} \end{pmatrix}$	$(2,1,-\frac{1}{2})$	$(2,1,-\frac{1}{2})$	$(2,1,-\frac{1}{2})$	$(2,1,-\frac{1}{2})$	$(2,1,-\frac{1}{2})$	$(2,1,-\frac{1}{2})\delta_{\alpha\alpha_1}+(1,2,-\frac{1}{2})\delta_{\alpha\alpha_2}$
$l_{\alpha R}=\begin{pmatrix} \nu_{\alpha R} \\ e^-_{\alpha R} \end{pmatrix}$	$(1,2,-\frac{1}{2})$	$(1,1,0)$ $(1,1,-1)$	$(1,2,-\frac{1}{2})$	$(1,1,0)$ $(1,1,-1)$	$(1,1,0)$ $(1,1,-1)$	$(1,1,0)$ $(1,1,-1)$

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$$\overline{W}_{i,\mu\nu} \equiv U_i^\dagger g_i W_{i,\mu\nu} U_i \qquad X_i^\mu \equiv U_i^\dagger (D^\mu U_i) \qquad D_\mu U_i = \partial_\mu U_i + i g_i \frac{\tau^a}{2} W_{i,\mu}^a U_i - i g U_i \frac{\tau_3}{2} B_\mu$$

$$\begin{aligned}\mathcal{L}_{\rm EWCL}^{\rm boson} = & -V(h) + \frac{1}{2}(\partial_\mu h)^2 - \frac{1}{4} f_1^2 {\rm tr}(X_{1,\mu} X_1^\mu) - \frac{1}{4} f_2^2 {\rm tr}(X_{2,\mu} X_2^\mu) + \frac{1}{2}\kappa f_1 f_2 {\rm tr}(X_1^\mu X_2^\mu) \\ & + \frac{1}{4}\beta_{1,1} f_1^2 [{\rm tr}(\tau^3 X_{1,\mu})]^2 + \frac{1}{4}\beta_{2,1} f_2^2 [{\rm tr}(\tau^3 X_{2,\mu})]^2 + \frac{1}{2}\tilde{\beta}_1 f_1 f_2 [{\rm tr}(\tau^3 X_{1,\mu})][{\rm tr}(\tau^3 X_2^\mu)] \\ & + \mathcal{L}_K + \mathcal{L}_1 + \mathcal{L}_{H1} + \mathcal{L}_2 + \mathcal{L}_{H2} + \mathcal{L}_C + O(p^6)\end{aligned}$$

$$\mathcal{L}_K = -\frac{1}{4} W_{1,\mu\nu}^a W_1^{\mu\nu,a} - \frac{1}{4} W_{2,\mu\nu}^a W_2^{\mu\nu,a} - \frac{1}{4} B_{\mu\nu} B^{\mu\nu}$$

$$\begin{aligned}\mathcal{L}_i = & \frac{1}{2}\alpha_{i,1} g B_{\mu\nu} {\rm tr}(\tau^3 \overline{W}_i^{\mu\nu}) + i\alpha_{i,2} g B_{\mu\nu} {\rm tr}(\tau^3 X_i^\mu X_i^\nu) + 2i\alpha_{i,3} {\rm tr}(\overline{W}_{i,\mu\nu} X_i^\mu X_i^\nu) + \alpha_{i,4} [{\rm tr}(X_{i,\mu} X_{i,\nu})]^2 \\ & + \alpha_{i,5} [{\rm tr}(X_{i,\mu}^2)]^2 + \alpha_{i,6} {\rm tr}(X_{i,\mu} X_{i,\nu}) {\rm tr}(\tau^3 X_i^\mu) {\rm tr}(\tau^3 X_i^\nu) + \alpha_{i,7} {\rm tr}(X_{i,\mu}^2) [{\rm tr}(\tau^3 X_{i,\nu})]^2 \\ & + \frac{1}{4}\alpha_{i,8} [{\rm tr}(\tau^3 \overline{W}_{i,\mu\nu})]^2 + i\alpha_{i,9} {\rm tr}(\tau^3 \overline{W}_{i,\mu\nu}) {\rm tr}(\tau^3 X_i^\mu X_i^\nu) + \frac{1}{2}\alpha_{i,10} [{\rm tr}(\tau^3 X_{i,\mu}) {\rm tr}(\tau^3 X_{i,\nu})]^2 \\ & + \alpha_{i,11} \epsilon^{\mu\nu\rho\lambda} {\rm tr}(\tau^3 X_{i,\mu}) {\rm tr}(X_{i,\nu} \overline{W}_{i,\rho\lambda}) + 2\alpha_{i,12} {\rm tr}(\tau^3 X_{i,\mu}) {\rm tr}(X_{i,\nu} \overline{W}_i^{\mu\nu}) \\ & + \frac{1}{4}\alpha_{i,13} g \epsilon^{\mu\nu\rho\sigma} B_{\mu\nu} {\rm tr}(\tau^3 \overline{W}_{i,\rho\sigma}) + \frac{1}{8}\alpha_{i,14} \epsilon^{\mu\nu\rho\sigma} {\rm tr}(\tau^3 \overline{W}_{i,\mu\nu}) {\rm tr}(\tau^3 \overline{W}_{i,\rho\sigma})\end{aligned}$$

$$\mathcal{L}_{Hi} =(\partial_\mu h)\{\bar\alpha_{Hi,1}\mathrm{tr}(\tau^3X_i^\mu)\mathrm{tr}(X_{i,\nu}^2)+\bar\alpha_{Hi,2}\mathrm{tr}(\tau^3X_i^\nu)\mathrm{tr}(X_i^\mu X_{i,\nu})+\bar\alpha_{Hi,3}\mathrm{tr}(\tau^3X_i^\nu)\mathrm{tr}(\tau^3X_i^\mu X_{i,\nu})$$
$$+\bar\alpha_{Hi,4}\mathrm{tr}(\tau^3X_i^\mu)[\mathrm{tr}(\tau^3X_{i,\nu})]^2+i\bar\alpha_{Hi,5}\mathrm{tr}(\tau^3X_{i,\nu})\mathrm{tr}(\tau^3\overline{W}_i^{\mu\nu})+ig\bar\alpha_{Hi,6}B^{\mu\nu}\mathrm{tr}(\tau^3X_{i,\nu})$$
$$+i\bar\alpha_{Hi,7}\mathrm{tr}(\tau^3\overline{W}_i^{\mu\nu}X_{i,\nu})+i\bar\alpha_{Hi,8}\mathrm{tr}(\overline{W}_i^{\mu\nu}X_{i,\nu})\}+(\partial_\mu h)(\partial_\nu h)[\bar\alpha_{Hi,9}\mathrm{tr}(\tau^3X_i^\mu)\mathrm{tr}(\tau^3X_i^\nu)$$
$$+\bar\alpha_{Hi,10}\mathrm{tr}(X_i^\mu X_i^\nu)]+(\partial_\mu h)^2\{\bar\alpha_{Hi,11}[\mathrm{tr}(\tau^3X_{i,\nu})]^2+\bar\alpha_{Hi,12}\mathrm{tr}(X_{i,\nu}^2)\}$$
$$+\bar\alpha_{Hi,13}(\partial_\mu h)^2(\partial_\nu h)\mathrm{tr}(\tau^3X_i^\nu)+\bar\alpha_{Hi,14}(\partial_\mu h)^4$$

$$f(\hat U_R,\hat U_L,D_\mu\hat U_R,D_\mu\hat U_L)q_\alpha=\begin{cases} f(U_2,U_1,D_\mu U_2,D_\mu U_1)q_\alpha & \textbf{LR,LP}\\ f(1,U_1,0,D_\mu U_1)q_\alpha & \textbf{HP,FP}\\ f(1,U_2,0,D_\mu U_2)q_\alpha & \textbf{UN}\\ f(1,U_1,0,D_\mu U_1)q_\alpha\delta_{\alpha\alpha_1}+f(1,U_2,0,D_\mu U_2)q_\alpha\delta_{\alpha\alpha_2} & \textbf{NU}\end{cases}$$

$$f(\hat U_R,\hat U_L,D_\mu\hat U_R,D_\mu\hat U_L)l_\alpha=\begin{cases} f(U_2,U_1,D_\mu U_2,D_\mu U_1)l_\alpha & \textbf{LR}\\ f(1,U_1,0,D_\mu U_1)l_\alpha & \textbf{LP}\\ f(U_2,U_1,D_\mu U_2,D_\mu U_1)l_\alpha & \textbf{HP}\\ f(1,U_1,0,D_\mu U_1)l_\alpha & \textbf{FP,UN}\\ f(1,U_1,0,D_\mu U_1)l_\alpha\delta_{\alpha\alpha_1}+f(1,U_2,0,D_\mu U_2)l_\alpha\delta_{\alpha\alpha_2} & \textbf{NU}\end{cases}$$

S-Z.Wang, F-J.Ge, Q.Wang, Phys. Lett. B662，375(2008)

$$\mathcal{L}_{\rm Y,lepton} = \bar{l}^I_{\alpha L}[\hat{U}_L(y^{\alpha\beta}+y_3^{\alpha\beta}\tau^3)\hat{U}_R^\dagger]l^I_{\beta R} + \frac{1}{2}[h_L^{\alpha\beta}\overline{l^{Ic}_{\alpha L}}\hat{U}_L^*(1+\tau^3)\hat{U}_L^\dagger l^I_{\beta L} + (L\to R)] + {\rm h.c.}$$

$$\mathcal{L}_{\rm Y,quark} = \bar{q}^I_{\alpha L}[\hat{U}_L(\tau^u y_u^{\alpha\beta} + \tau^d y_d^{\alpha\beta})\hat{U}_R^\dagger]q^I_{\beta R} + {\rm h.c.}$$

$$\begin{aligned}\mathcal{L}_{f-4} = i\sum_\alpha\Big\{&\bar{q}^I_{\alpha L}\not{D}q^I_{\alpha L} + \delta_{L,1,\alpha}\bar{q}^I_{\alpha L}\hat{U}_L(\not{D}\hat{U}_L)^\dagger q^I_{\alpha L} + \delta_{L,2,\alpha}\bar{q}^I_{\alpha R}\hat{U}_R\hat{U}_L^\dagger(\not{D}\hat{U}_L)\hat{U}_R^\dagger q^I_{\alpha R}\\
&+\delta_{L,3,\alpha}\bar{q}^I_{\alpha L}[(\not{D}\hat{U}_L)\tau^3\hat{U}_L^\dagger - \hat{U}_L\tau^3(\not{D}\hat{U}_L)^\dagger]q^I_{\alpha L} + \delta_{L,4,\alpha}\bar{q}^I_{\alpha L}\hat{U}_L\tau^3\hat{U}_L^\dagger(\not{D}\hat{U}_L)\tau^3\hat{U}_L^\dagger q^I_{\alpha L}\\
&+\delta_{L,5,\alpha}\bar{q}^I_{\alpha R}\hat{U}_R[\tau^3\hat{U}_L^\dagger(\not{D}\hat{U}_L)-(\not{D}\hat{U}_L)^\dagger\hat{U}_L\tau^3]\hat{U}_R^\dagger q^I_{\alpha R}+\delta_{L,6,\alpha}\bar{q}^I_{\alpha R}\hat{U}_R\tau^3\hat{U}_L^\dagger(\not{D}\hat{U}_L)\tau^3\hat{U}_R^\dagger q^I_{\alpha R}\\
&+\delta_{L,7,\alpha}[\bar{q}^I_{\alpha L}\hat{U}_L\tau^3\hat{U}_L^\dagger\not{D}q^I_{\alpha L} - (\bar{q}^I_{\alpha L}\not{D}^\dagger)\hat{U}_L\tau^3\hat{U}_L^\dagger q^I_{\alpha L}]\Big\} + q^I\to l^I,\delta\to\delta^l + L\leftrightarrow R\end{aligned}$$

$$D_\mu q_\alpha = \begin{cases}(\partial_\mu + ig_1\frac{\tau^a}{2}W^a_{1,\mu}P_L + ig_2\frac{\tau^a}{2}W^a_{2,\mu}P_R + \frac{i}{6}gB_\mu)q_\alpha & \textbf{LR, LP}\\
(\partial_\mu + ig_1\frac{\tau^a}{2}W^a_{1,\mu}P_L + ig\frac{\tau^3}{2}B_\mu P_R + \frac{i}{6}gB_\mu)q_\alpha & \textbf{HP, FP}\\
(\partial_\mu + ig_2\frac{\tau^a}{2}W^a_{2,\mu}P_L + ig\frac{\tau^3}{2}B_\mu P_R + \frac{i}{6}gB_\mu)q_\alpha & \textbf{UN}\\
(\partial_\mu + i\delta_{\alpha\alpha_1}g_1\frac{\tau^a}{2}W^a_{1,\mu}P_L + i\delta_{\alpha\alpha_2}g_2\frac{\tau^a}{2}W^a_{2,\mu}P_L + ig\frac{\tau^3}{2}B_\mu P_R + \frac{i}{6}gB_\mu)q_\alpha & \textbf{NU}\end{cases}$$

$$D_\mu l_\alpha = \begin{cases}(\partial_\mu + ig_1\frac{\tau^a}{2}W^a_{1,\mu}P_L + ig_2\frac{\tau^a}{2}W^a_{2,\mu}P_R - \frac{i}{2}gB_\mu)l_\alpha & \textbf{LR, HP}\\
(\partial_\mu + ig_1\frac{\tau^a}{2}W^a_{1,\mu}P_L + ig\frac{\tau^3}{2}B_\mu P_R - \frac{i}{2}gB_\mu)l_\alpha & \textbf{LP, FP, UN}\\
(\partial_\mu + i\delta_{\alpha\alpha_1}g_1\frac{\tau^a}{2}W^a_{1,\mu}P_L + i\delta_{\alpha\alpha_2}g_2\frac{\tau^a}{2}W^a_{2,\mu}P_L + ig\frac{\tau^3}{2}B_\mu P_R - \frac{i}{2}gB_\mu)l_\alpha & \textbf{NU}\end{cases}$$

$W - W'$混合

$$\tan 2\zeta = \frac{2\kappa x}{1-x^2} \qquad \begin{pmatrix} W_1^\pm \\ W_2^\pm \end{pmatrix} = \begin{pmatrix} \cos\zeta & -\sin\zeta \\ \sin\zeta & \cos\zeta \end{pmatrix} \begin{pmatrix} W^\pm \\ W'^\pm \end{pmatrix} \qquad x = \frac{f_1 g_1}{f_2 g_2}$$

$$\frac{M_W^2}{M_{W'}^2} = \frac{1+x^2-\sqrt{(1-x^2)^2+4\kappa^2x^2}}{1+x^2+\sqrt{(1-x^2)^2+4\kappa^2x^2}}$$

$$\kappa \sim 10^{-2}, \quad x \sim 10^{-1} \quad \Rightarrow \quad \zeta \sim 10^{-3}, \quad M_{W'} \sim 10 M_W$$

$$\mathcal{L}_{\rm EWCL}^{\rm boson} = -V(h) + \frac{1}{2}(\partial_\mu h)^2 - \frac{1}{4}f_1^2{\rm tr}(X_{1,\mu}X_1^\mu) - \frac{1}{4}f_2^2{\rm tr}(X_{2,\mu}X_2^\mu) + \frac{1}{2}\kappa f_1 f_2 {\rm tr}(X_1^\mu X_2^\mu)$$
$$+\frac{1}{4}\beta_{1,1}f_1^2[{\rm tr}(\tau^3 X_{1,\mu})]^2 + \frac{1}{4}\beta_{2,1}f_2^2[{\rm tr}(\tau^3 X_{2,\mu})]^2 + \frac{1}{2}\tilde{\beta}_1 f_1 f_2[{\rm tr}(\tau^3 X_{1,\mu})][{\rm tr}(\tau^3 X_2^\mu)]$$
$$+O(p^4)$$

$$\overline{W}_{i,\mu\nu} \equiv U_i^\dagger g_i W_{i,\mu\nu} U_i \qquad X_i^\mu \equiv U_i^\dagger (D^\mu U_i) \qquad D_\mu U_i = \partial_\mu U_i + i g_i \frac{\tau^a}{2} W_{i,\mu}^a U_i - i g U_i \frac{\tau_3}{2} B_\mu$$

轻子混合

$$\mathcal{L}_{\text{Y,lepton}}\big|_{\textbf{Unitary gauge}} = \mathcal{L}_{Me} + \mathcal{L}_{M\nu} \qquad \mathcal{L}_{Me} = \overline{e^{-I}}_{\alpha L}(y^{\alpha\beta} - y_3^{\alpha\beta})e^{-I}_{\beta R} + \overline{e^{-I}}_{\alpha R}(y^{\dagger\alpha\beta} - y_3^{\dagger\alpha\beta})e^{-I}_{\beta L}$$

$$e^-_{L,R} = \tilde{V}^e_{L,R}e^{-I}_{L,R} \qquad \mathcal{L}_{Me} = \overline{e^-}_L\mathbf{M}^{e\dagger}e^-_R + \overline{e^-}_R\mathbf{M}^e e^-_L \qquad \mathbf{M}^e = \tilde{V}^e_L(y - y_3)\tilde{V}^{e\dagger}_R$$

$$\mathcal{L}_{M\nu} = \overline{\nu^I}_{\alpha L}(y^{\alpha\beta} + y_3^{\alpha\beta})\nu^I_{\beta R} + h_L^{\alpha\beta}\overline{\nu^{Ic}_{\alpha L}}\nu^I_{\beta L} + h_R^{\alpha\beta}\overline{\nu^{Ic}_{\alpha R}}\nu^I_{\beta R} + \textbf{h.c.}$$

$$= \frac{1}{2}\begin{pmatrix} \overline{\nu^I_L} & \overline{\nu^{Ic}_R} \end{pmatrix}\begin{pmatrix} 2h_L & y + y_3 \\ (y + y_3)^T & 2h_R \end{pmatrix}\begin{pmatrix} \nu^{Ic}_L \\ \nu^I_R \end{pmatrix} + \textbf{h.c.}$$

$$\begin{pmatrix} V & R \\ S & U \end{pmatrix}^\dagger\begin{pmatrix} 2h_L & y + y_3 \\ (y + y_3)^T & 2h_R \end{pmatrix}\begin{pmatrix} V & R \\ S & U \end{pmatrix}^* = \begin{pmatrix} \hat{M}_\nu & 0 \\ 0 & \hat{M}_N \end{pmatrix}$$

$$\begin{pmatrix} V & R \\ S & U \end{pmatrix} = \begin{pmatrix} 1 - \frac{1}{8}(y + y_3)h_R^{-2}(y + y_3)^T & \frac{1}{2}(y + y_3)h_R^{-1} \\ -\frac{1}{2}h_R^{-1}(y + y_3)^T & 1 - \frac{1}{8}h_R^{-1}(y + y_3)^T(y + y_3)h_R^{-1} \end{pmatrix}$$

$$\begin{pmatrix} V & R \\ S & U \end{pmatrix}^\dagger\begin{pmatrix} 2h_L & y + y_3 \\ (y + y_3)^T & 2h_R \end{pmatrix}\begin{pmatrix} V & R \\ S & U \end{pmatrix}^*$$

$$= \begin{pmatrix} 2h_L - \frac{1}{2}(y + y_3)h_R^{-1}(y + y_3)^T + O(h_R^{-2}) & O(h_R^{-1}) \\ O(h_R^{-1}) & 2h_R + O(h_R^{-1}) \end{pmatrix}$$

夸克混合

$$\mathcal{L}_{\mathrm{Y,quark}}\Big|_{\textbf{Unitary gauge}} = \bar{q}^I_{\alpha L}(\tau^u y_u^{\alpha\beta} + \tau^d y_d^{\alpha\beta})q^I_{\beta R} + \text{h.c.}$$

$$u_{L,R} = V^u_{L,R} u^I_{L,R} \qquad d_{L,R} = V^d_{L,R} u^I_{L,R} \qquad V^u_L y^0_u V^{u\dagger}_R = M^u_{diag} \qquad V^d_L y^0_d V^{d\dagger}_R = M^d_{diag}$$

$$q_{\alpha L,R} = \begin{pmatrix} u_{\alpha L,R} \\ d_{\alpha L,R} \end{pmatrix} = [(V^u_{L,R})_{\alpha\beta}\tau^u + (V^d_{L,R})_{\alpha\beta}\tau^d]\begin{pmatrix} u^I_{\beta L,R} \\ d^I_{\beta L,R} \end{pmatrix}$$

$$V_L^{\mathrm{CKM}} = \begin{pmatrix} V_L^{ud} & V_L^{us} & V_L^{ub} \\ V_L^{cd} & V_L^{cs} & V_L^{cb} \\ V_L^{td} & V_L^{ts} & V_L^{tb} \end{pmatrix} = \begin{pmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta} \\ -s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta} & s_{23}c_{13} \\ s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta} & c_{23}c_{13} \end{pmatrix}$$

$$V_R^{\mathrm{CKM}} = \begin{pmatrix} \bar{V}_R^{ud}e^{2i\alpha_1} & \bar{V}_R^{us}e^{i(\alpha_1+\alpha_2+\beta_1)} & \bar{V}_R^{ub}e^{i(\alpha_1+\alpha_3+\beta_1+\beta_2)} \\ \bar{V}_R^{cd}e^{i(\alpha_1+\alpha_2-\beta_1)} & \bar{V}_R^{cs}e^{2i\alpha_2} & \bar{V}_R^{cb}e^{i(\alpha_2+\alpha_3+\beta_2)} \\ \bar{V}_R^{td}e^{i(\alpha_1+\alpha_3-\beta_1-\beta_2)} & \bar{V}_R^{ts}e^{i(\alpha_2+\alpha_3-\beta_2)} & \bar{V}_R^{tb}e^{2i\alpha_3} \end{pmatrix}$$

$$\begin{pmatrix} \bar{V}_R^{ud} & \bar{V}_R^{us} & \bar{V}_R^{ub} \\ \bar{V}_R^{cd} & \bar{V}_R^{cs} & \bar{V}_R^{cb} \\ \bar{V}_R^{td} & \bar{V}_R^{ts} & \bar{V}_R^{tb} \end{pmatrix} = \begin{pmatrix} \bar{c}_{12}\bar{c}_{13} & \bar{s}_{12}\bar{c}_{13} & \bar{s}_{13}e^{-i\bar{\delta}} \\ -\bar{s}_{12}\bar{c}_{23} - \bar{c}_{12}\bar{s}_{23}\bar{s}_{13}e^{i\bar{\delta}} & \bar{c}_{12}\bar{c}_{23} - \bar{s}_{12}\bar{s}_{23}\bar{s}_{13}e^{i\bar{\delta}} & \bar{s}_{23}\bar{c}_{13} \\ \bar{s}_{12}\bar{s}_{23} - \bar{c}_{12}\bar{c}_{23}\bar{s}_{13}e^{i\bar{\delta}} & -\bar{c}_{12}\bar{s}_{23} - \bar{s}_{12}\bar{c}_{23}\bar{s}_{13}e^{i\bar{\delta}} & \bar{c}_{23}\bar{c}_{13} \end{pmatrix}$$

pseudo-manifest left-right symmetric: $\bar{V}_R^{\alpha\beta} = (V_L^{\alpha\beta})^*$

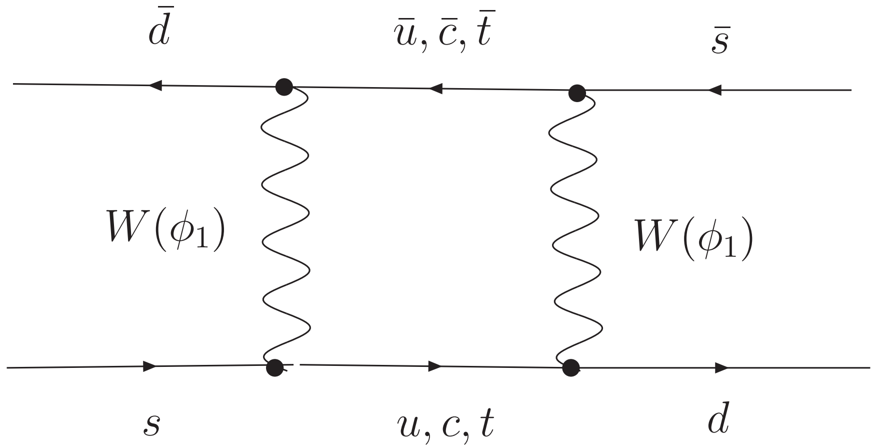
$\Delta m_K,\ |\epsilon_K|,\ \Delta m_{B_d},\ \Delta m_{B_s}$

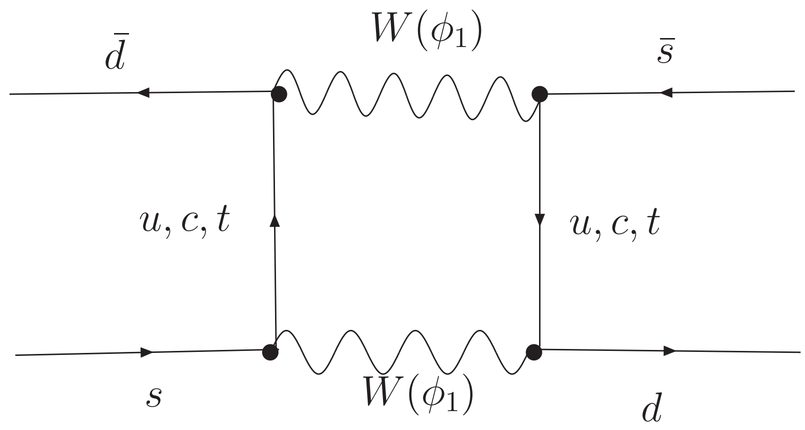
$$\Delta m_K = \Delta m_K^{WW} + \Delta m_K^{WW'} + \Delta m_K^h$$

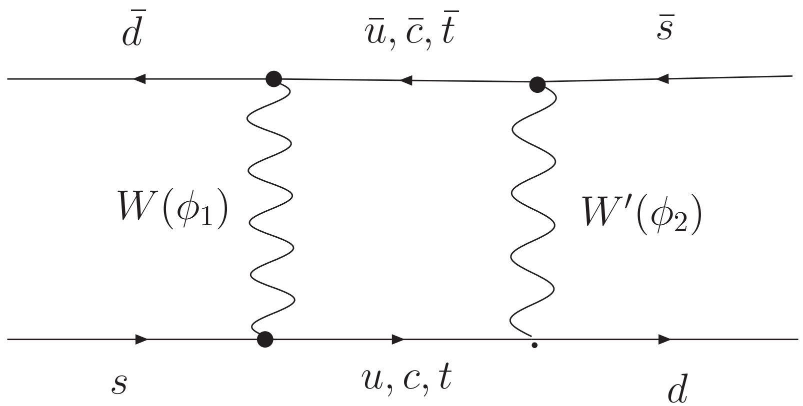
$$|\epsilon_K| = |\epsilon_K|^{WW} + |\epsilon_K|^{WW'} + |\epsilon_K|^h$$

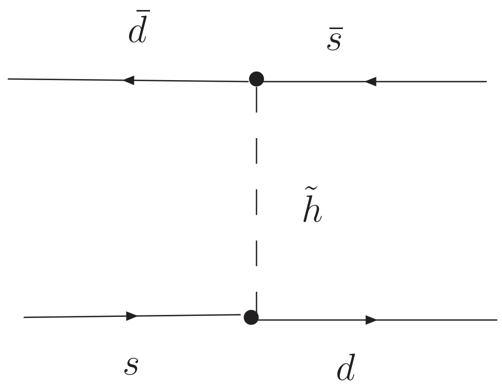
$$\Delta m_{B_d} = \Delta m_{B_d}^{WW} + \Delta m_{B_d}^{WW'} + \Delta m_{B_d}^h$$

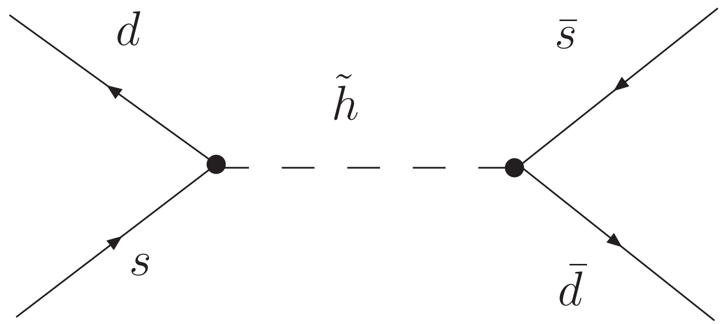
$$\Delta m_{B_s} = \Delta m_{B_s}^{WW} + \Delta m_{B_s}^{WW'} + \Delta m_{B_s}^h$$


$\bar{d}$
$\bar{u}, \bar{c}, \bar{t}$
$\bar{s}$
$W(\phi_1)$
$W(\phi_1)$
s
u, c, t
d


$\bar{d}$
$W(\phi_1)$
$\bar{s}$
u, c, t
u, c, t
s
$W(\phi_1)$
d


$\bar{d}$
$\bar{u}, \bar{c}, \bar{t}$
$\bar{s}$
$W(\phi_1)$
$W'(\phi_2)$
s
u, c, t
d


$\bar{d}$
$\bar{s}$
$\tilde{h}$
s
d


d
$\tilde{h}$
$\bar{s}$
s
$\bar{d}$

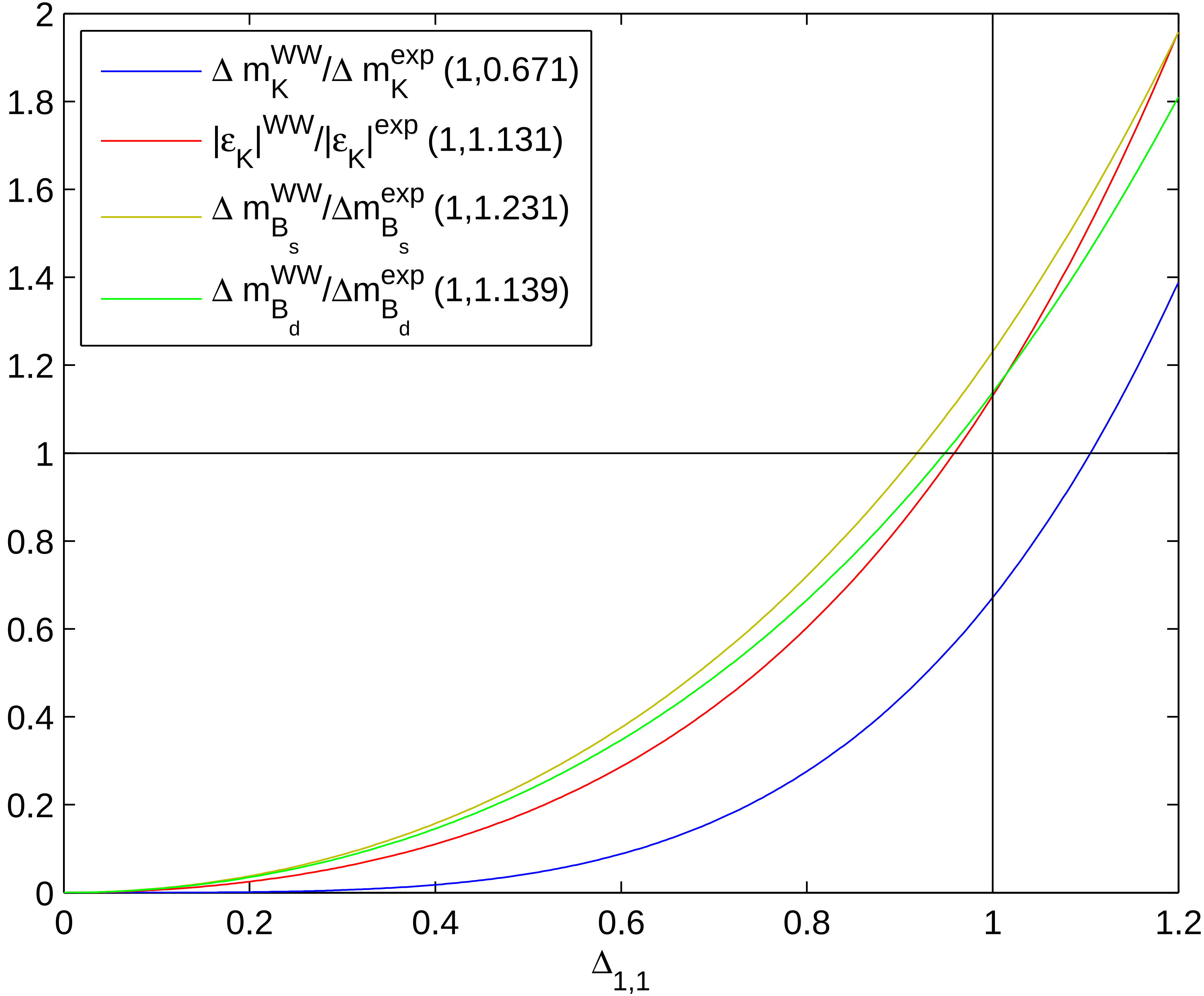
$\Delta m_K,\ |\epsilon_K|,\ \Delta m_{B_d},\ \Delta m_{B_s}$

$$U_{1,2} = \exp(\frac{ig_{1,2}}{\sqrt{2}M_{1,2}}\phi_{1,2}) \qquad \phi_{1,2} = \begin{pmatrix} \frac{\phi^0_{1,2}}{\sqrt{2}} & \phi^+_{1,2} \\ \phi^-_{1,2} & -\frac{\phi^0_{1,2}}{\sqrt{2}} \end{pmatrix} \qquad M_{1,2} = \frac{1}{2}f_{1,2}g_{1,2}$$

$$\mathcal{L}_{f-4}\Big|_{\textbf{Unitary gauge}} = \sum_\alpha \bar{q}^I_\alpha[i\not{\partial} - (\ \Delta_{1,1,\alpha}g_1\frac{\tau^{a'}}{2}\not{W}^{a'}_1 + \Delta_{1,2,\alpha}\frac{\tau^{a'}}{2}g_2\not{W}^{a'}_2 + \Delta^3_{1,1,\alpha}g_1\not{W}^3_1$$
$$+\Delta^3_{1,2,\alpha}g_2\not{W}^3_2 + \Delta_{1,\alpha}g\not{B}\ )P_L - (\ \Delta_{2,1,\alpha}g_1\frac{\tau^{a'}}{2}\not{W}^{a'}_1 + \Delta_{2,2,\alpha}\frac{\tau^{a'}}{2}g_2\not{W}^{a'}_2$$
$$+\Delta^3_{2,1,\alpha}g_1\not{W}^3_1 + \Delta^3_{2,2,\alpha}g_2\not{W}^3_2 + \Delta_{2,\alpha}g\not{B}\ )P_R]q^I_\alpha + q^I \to l^I, \delta \to \delta^l, \Delta \to \Delta^l\ ,$$

$$u_{L,R} = V^u_{L,R}u^I_{L,R} \qquad d_{L,R} = V^d_{L,R}u^I_{L,R} \qquad V^u_L y^0_u V^{u\dagger}_R = M^u_{diag} \qquad V^d_L y^0_d V^{d\dagger}_R = M^d_{diag}$$

$$\Delta_{1,1,\alpha} = 1 - \delta_{L,1,\alpha} - \delta_{L,4,\alpha} \quad \textbf{LR,LP,HP,FP} \qquad \Delta_{2,1,\alpha} = \begin{cases} 1 - \delta_{R,1,\alpha} - \delta_{R,4,\alpha} & \textbf{LR,LP} \\ \delta_{L,2,\alpha} - \delta_{L,6,\alpha} & \textbf{HP,FP} \end{cases}$$

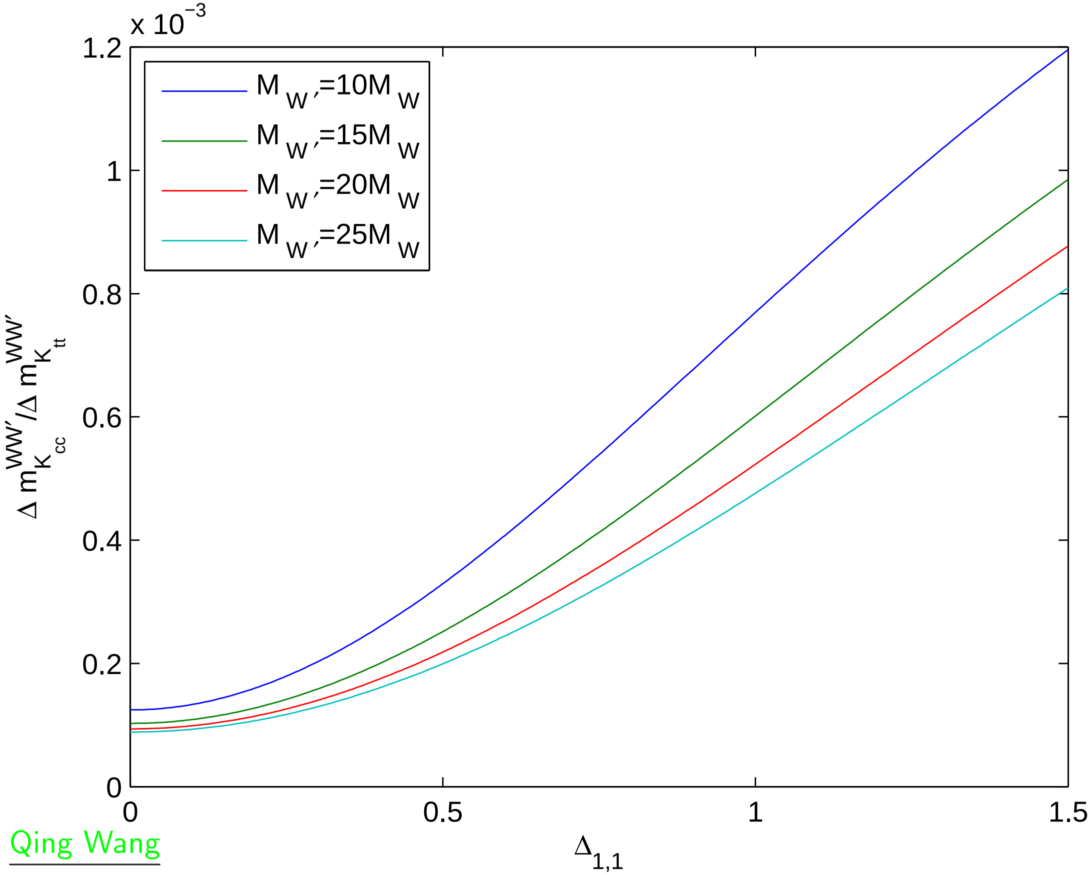

$\Delta m_K^{WW}/\Delta m_K^{exp}$ (1,0.671)
$|\varepsilon_K|^{WW}/|\varepsilon_K|^{exp}$ (1,1.131)
$\Delta m_{B_s}^{WW}/\Delta m_{B_s}^{exp}$ (1,1.231)
$\Delta m_{B_d}^{WW}/\Delta m_{B_d}^{exp}$ (1,1.139)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
$\Delta_{1,1}$

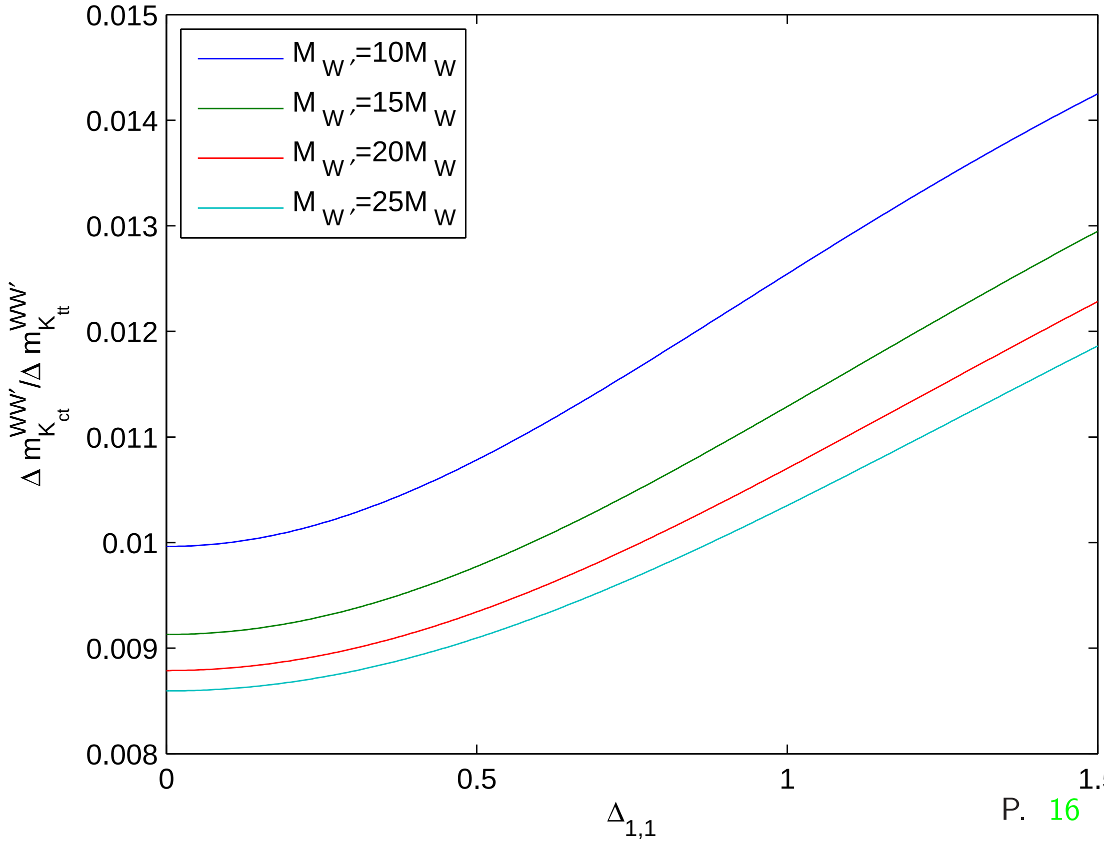
$$\Delta m_K^{WW'} = \Delta_{2,1}^2 \frac{g_2^2}{g_1^2} \Delta m_{K_{tt}}^{WW'} \left[\mathrm{Re}(\lambda_t^{LR}\lambda_t^{RL}) + \mathrm{Re}(\lambda_c^{LR}\lambda_c^{RL}) \underbrace{\frac{\Delta m_{K_{cc}}^{WW'}}{\Delta m_{K_{tt}}^{WW'}}}_{10^{-3}} + \mathrm{Re}(\lambda_c^{LR}\lambda_t^{RL} + \lambda_t^{LR}\lambda_c^{RL}) \underbrace{\frac{\Delta m_{K_{ct}}^{WW'}}{\Delta m_{K_{tt}}^{WW'}}}_{10^{-2}} \right]$$

$$\lambda_x^{LR}(K)\lambda_x^{RL}(K) = |V_L^{xs} V_L^{xd*} \bar{V}_R^{xs} \bar{V}_R^{xd*}| e^{-i(\alpha_1 - \alpha_2 - \beta_1 - \phi_{xs} - \bar{\phi}_{xs} + \phi_{xd} + \bar{\phi}_{xd})} \qquad x = c, t$$

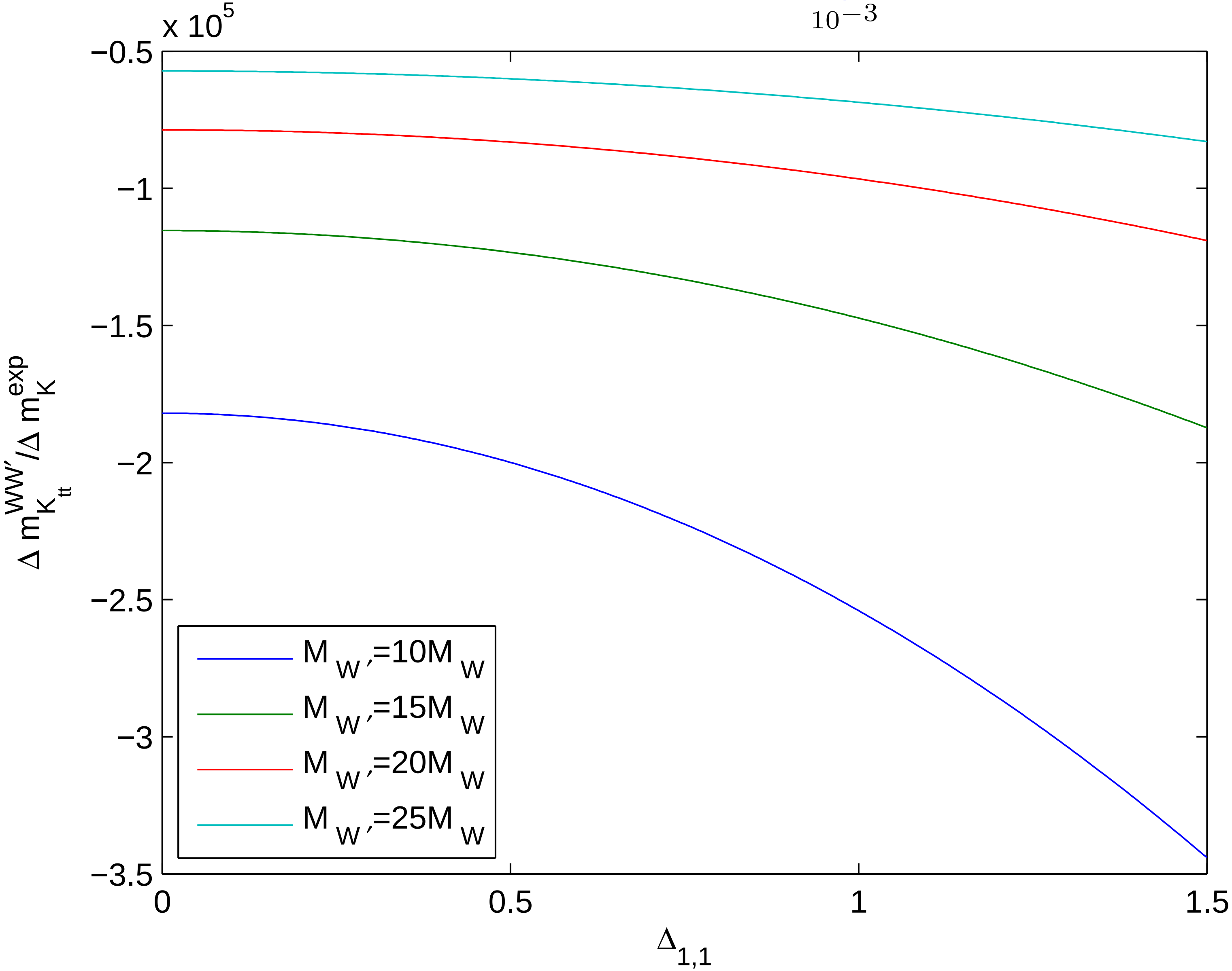
$$\lambda_c^{LR}(K)\lambda_t^{RL}(K) = |V_L^{cs} \bar{V}_R^{cd*} \bar{V}_R^{ts} V_L^{td*}| e^{-i(\alpha_1 - \alpha_3 - \beta_1 + \beta_2 - \phi_{cs} + \bar{\phi}_{cd} - \bar{\phi}_{ts} + \phi_{td})} \qquad \arg(V_L^{\alpha\beta}) = \phi_{\alpha\beta}$$

$$\lambda_t^{LR}(K)\lambda_c^{RL}(K) = |V_L^{ts} \bar{V}_R^{td*} \bar{V}_R^{cs} V_L^{cd*}| e^{-i(\alpha_1 - 2\alpha_2 + \alpha_3 - \beta_1 - \beta_2 - \phi_{ts} + \bar{\phi}_{td} - \bar{\phi}_{cs} + \phi_{cd})} \qquad \arg(\bar{V}_R^{\alpha\beta}) = \bar{\phi}_{\alpha\beta}$$





$$\Delta m_K^{WW'} = \Delta_{2,1}^2 \frac{g_2^2}{g_1^2} \Delta m_{K_{tt}}^{WW'} \left[\mathrm{Re}(\lambda_t^{LR}\lambda_t^{RL}) + \mathrm{Re}(\lambda_c^{LR}\lambda_c^{RL}) \underbrace{\frac{\Delta m_{K_{cc}}^{WW'}}{\Delta m_{K_{tt}}^{WW'}}}_{10^{-3}} + \mathrm{Re}(\lambda_c^{LR}\lambda_t^{RL} + \lambda_t^{LR}\lambda_c^{RL}) \underbrace{\frac{\Delta m_{K_{ct}}^{WW'}}{\Delta m_{K_{tt}}^{WW'}}}_{10^{-2}} \right]$$

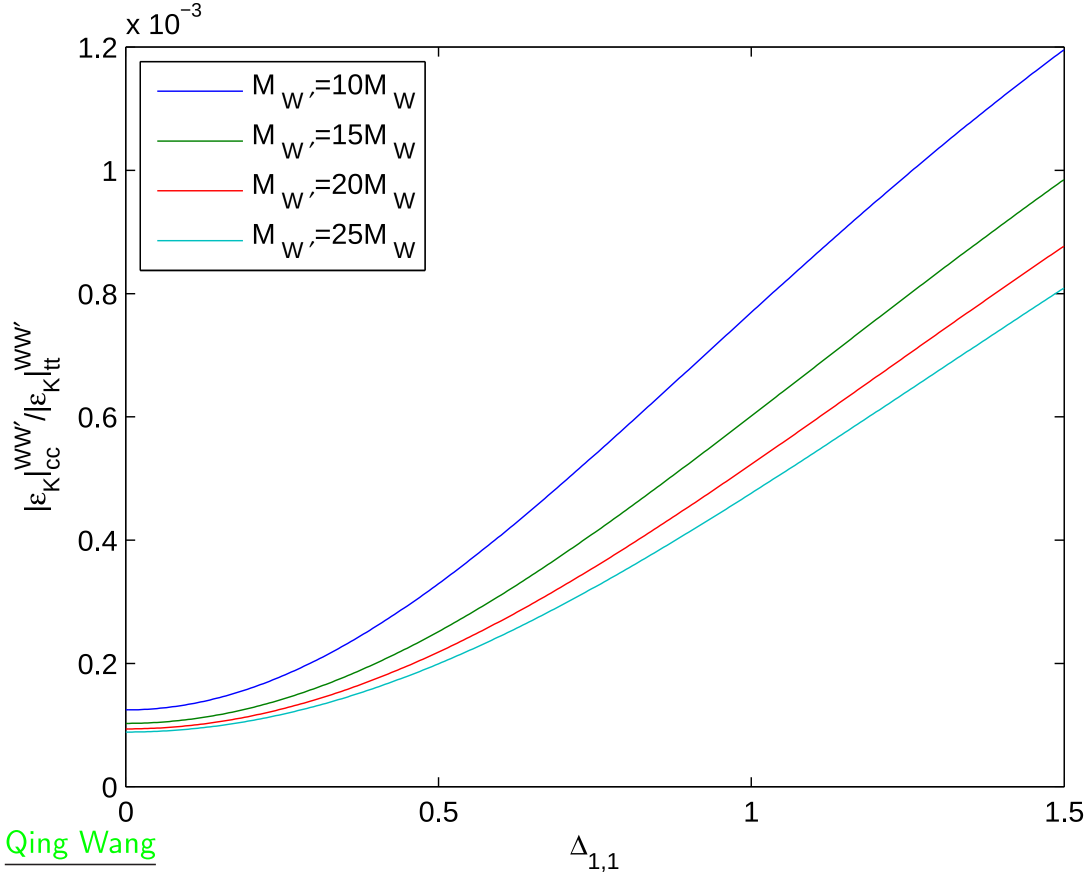


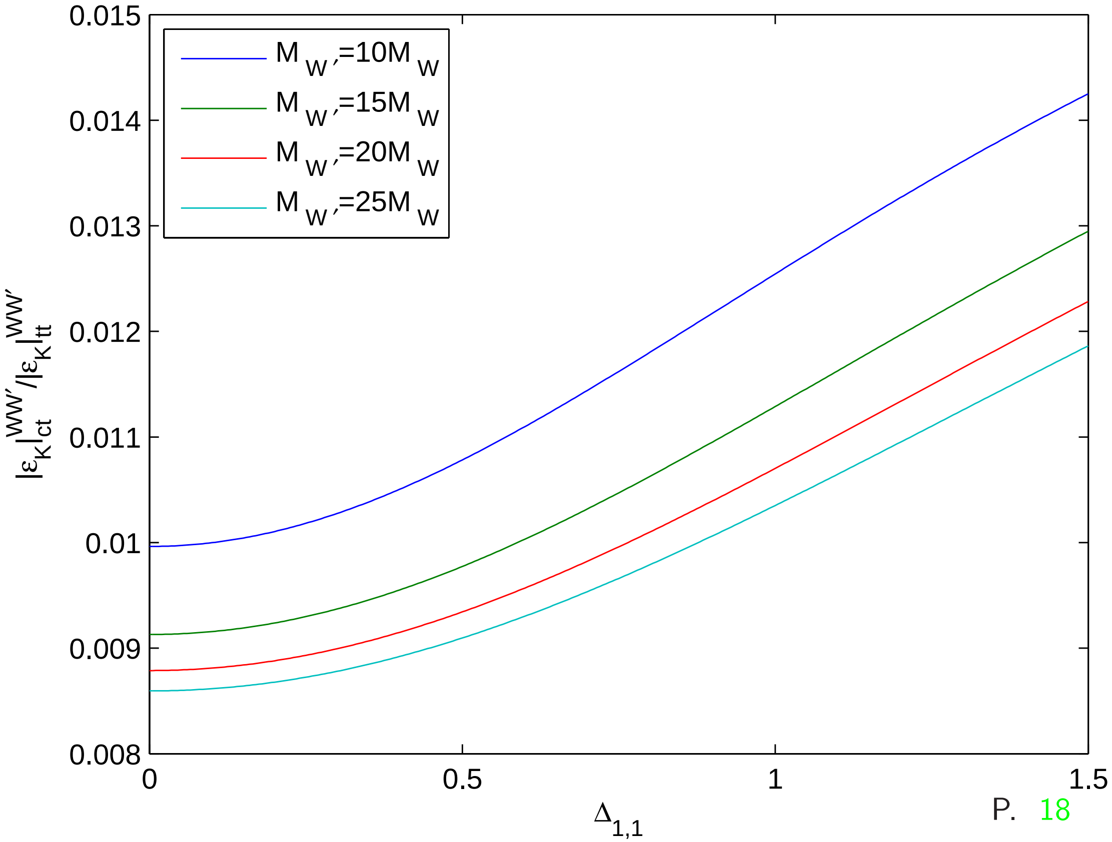
$$|\epsilon_K|^{WW'} = \Delta_{2,1}^2 \frac{g_2^2}{g_1^2} |\epsilon_K|_{tt}^{WW'} \left| \mathrm{Im}(\lambda_t^{LR}\lambda_t^{RL}) + \mathrm{Im}(\lambda_c^{LR}\lambda_c^{RL}) \underbrace{\frac{|\epsilon_K|_{cc}^{WW'}}{|\epsilon_K|_{tt}^{WW'}}}_{10^{-3}} + \mathrm{Im}(\lambda_c^{LR}\lambda_t^{RL} + \lambda_t^{LR}\lambda_c^{RL}) \underbrace{\frac{|\epsilon_K|_{ct}^{WW'}}{|\epsilon_K|_{tt}^{WW'}}}_{10^{-2}} \right|$$

$$\lambda_x^{LR}(K)\lambda_x^{RL}(K) = |V_L^{xs}V_L^{xd*}\bar{V}_R^{xs}\bar{V}_R^{xd*}|e^{-i(\alpha_1-\alpha_2-\beta_1-\phi_{xs}-\bar{\phi}_{xs}+\phi_{xd}+\bar{\phi}_{xd})} \qquad x = c, t$$

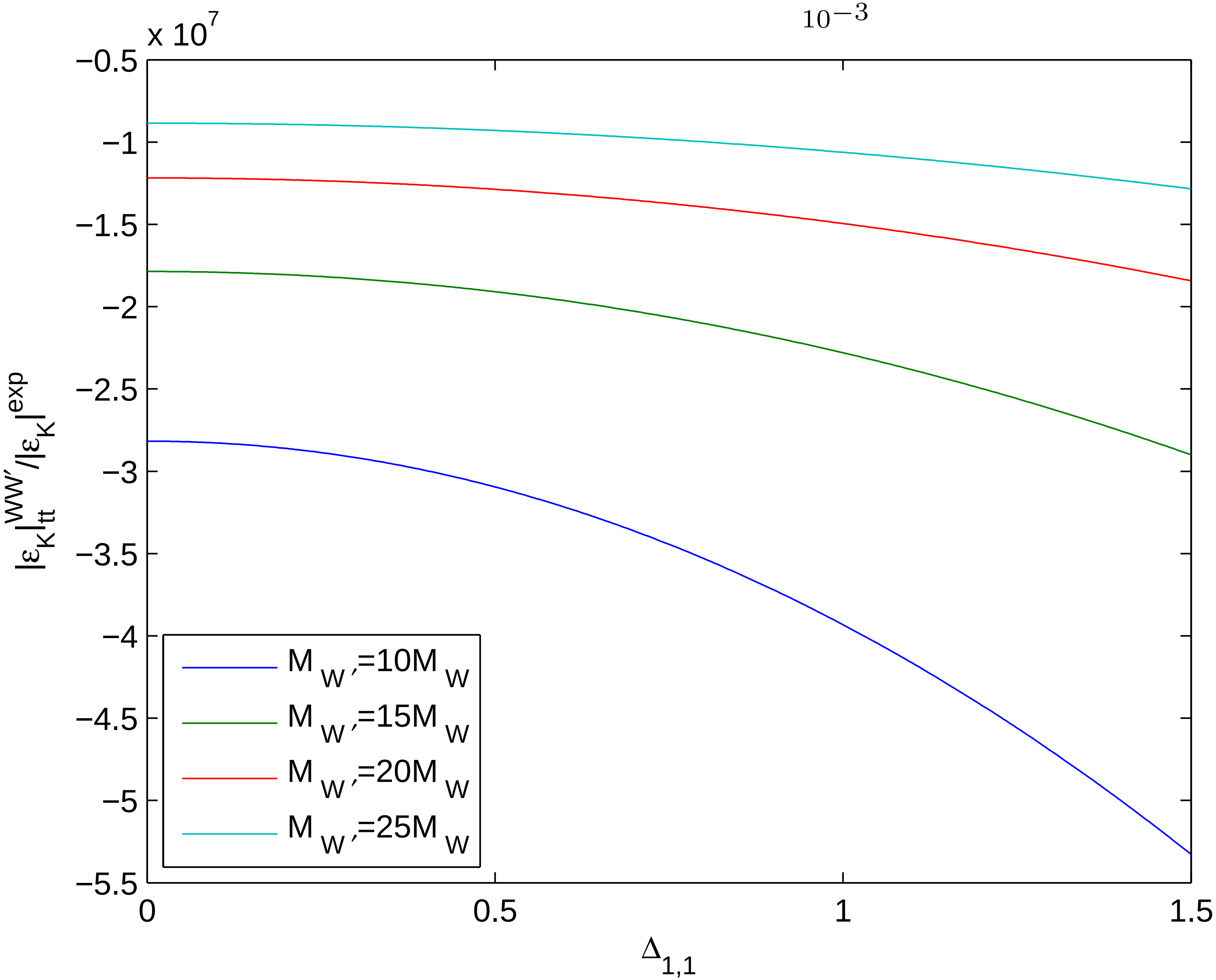
$$\lambda_c^{LR}(K)\lambda_t^{RL}(K) = |V_L^{cs}\bar{V}_R^{cd*}\bar{V}_R^{ts}V_L^{td*}|e^{-i(\alpha_1-\alpha_3-\beta_1+\beta_2-\phi_{cs}+\bar{\phi}_{cd}-\bar{\phi}_{ts}+\phi_{td})} \qquad \arg(V_L^{\alpha\beta}) = \phi_{\alpha\beta}$$

$$\lambda_t^{LR}(K)\lambda_c^{RL}(K) = |V_L^{ts}\bar{V}_R^{td*}\bar{V}_R^{cs}V_L^{cd*}|e^{-i(\alpha_1-2\alpha_2+\alpha_3-\beta_1-\beta_2-\phi_{ts}+\bar{\phi}_{td}-\bar{\phi}_{cs}+\phi_{cd})} \qquad \arg(\bar{V}_R^{\alpha\beta}) = \bar{\phi}_{\alpha\beta}$$





$$|\epsilon_K|^{WW'} = \Delta^2_{2,1}\frac{g_2^2}{g_1^2}|\epsilon_K|^{WW'}_{tt}\left|\mathrm{Im}(\lambda_t^{LR}\lambda_t^{RL}) + \mathrm{Im}(\lambda_c^{LR}\lambda_c^{RL})\underbrace{\frac{|\epsilon_K|^{WW'}_{cc}}{|\epsilon_K|^{WW'}_{tt}}}_{10^{-3}} + \mathrm{Im}(\lambda_c^{LR}\lambda_t^{RL} + \lambda_t^{LR}\lambda_c^{RL})\underbrace{\frac{|\epsilon_K|^{WW'}_{ct}}{|\epsilon_K|^{WW'}_{tt}}}_{10^{-2}}\right|$$



pseudo-manifest left-right symmetric case

$$\bar{V}_R^{\alpha\beta} = (V_L^{\alpha\beta})^* \qquad \Rightarrow \qquad \phi_{\alpha\beta} + \bar{\phi}_{\alpha\beta} = 0$$

$$\lambda_c^{LR}(K)\lambda_c^{RL}(K) = |V_L^{cs}V_L^{cd}|^2 e^{-i(\alpha_1-\alpha_2-\beta_1)} \qquad \lambda_t^{LR}(K)\lambda_t^{RL}(K) = |V_L^{ts}V_L^{td}|^2 e^{-i(\alpha_1-\alpha_2-\beta_1)}$$

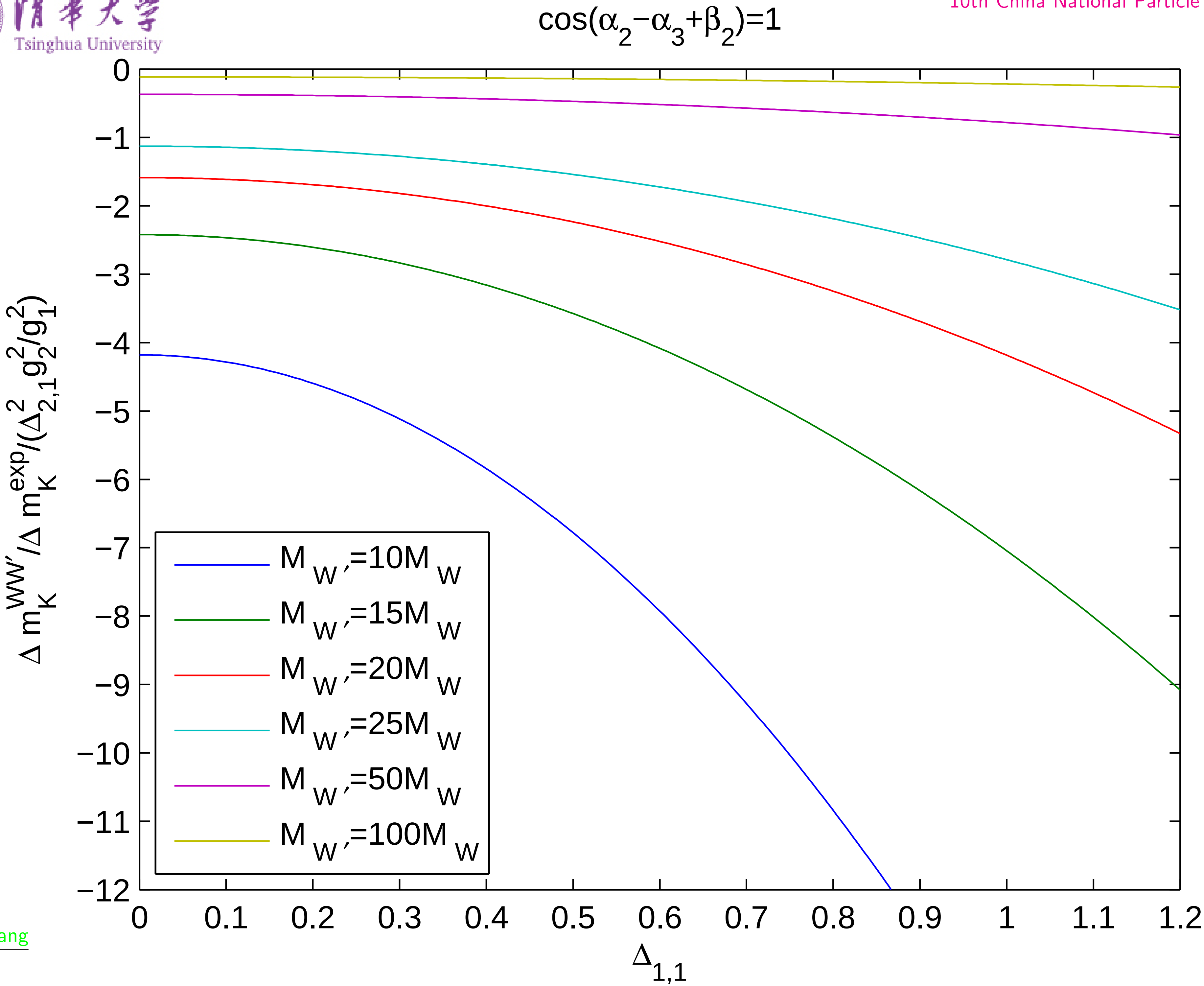
$$\lambda_c^{LR}(K)\lambda_t^{RL}(K) + \lambda_t^{LR}(K)\lambda_c^{RL}(K) = 2|V_L^{cs}V_L^{cd}V_L^{ts}V_L^{td}|[\cos(\alpha_1-\alpha_2-\beta_1)\cos(\alpha_2-\alpha_3+\beta_2) - i\sin(\alpha_1-\alpha_2-\beta_1)\cos(\alpha_2-\alpha_3+\beta_2)]$$

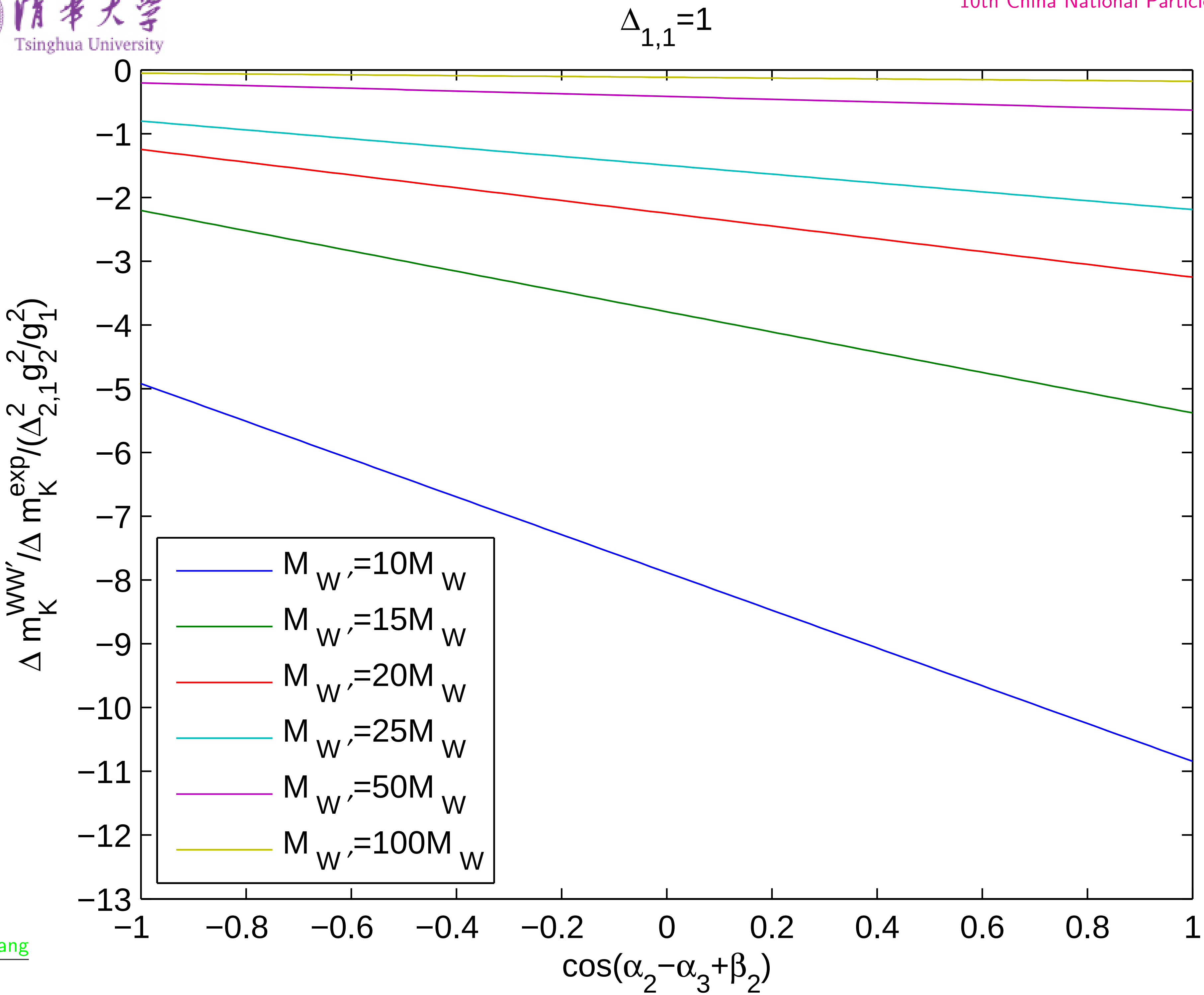
$$\alpha_1-\alpha_2-\beta_1=0 \Rightarrow \mathrm{Im}[\lambda_c^{LR}(K)\lambda_c^{RL}(K)]=\mathrm{Im}[\lambda_t^{LR}(K)\lambda_t^{RL}(K)]=\mathrm{Im}[\lambda_c^{LR}(K)\lambda_t^{RL}(K)+\lambda_t^{LR}(K)\lambda_c^{RL}(K)]=0$$

cc、tt和ct圈分别无CP破坏！

$$|\epsilon_K|^{WW'} = 0$$

$$\frac{\Delta m_K^{WW'}}{\Delta m_K^{\exp}} = \Delta_{2,1}^2 \frac{g_2^2}{g_1^2} \underbrace{\frac{\Delta m_{K_{tt}}^{WW'}}{\Delta m_K^{\exp}}}_{10^5} \left[\mathrm{Re}(\underbrace{\lambda_t^{LR}\lambda_t^{RL}}_{5.9\times10^{-6}}) + \mathrm{Re}(\underbrace{\lambda_c^{LR}\lambda_c^{RL}}_{0.049}) \underbrace{\frac{\Delta m_{K_{cc}}^{WW'}}{\Delta m_{K_{tt}}^{WW'}}}_{10^{-3}} + \mathrm{Re}(\underbrace{\lambda_c^{LR}\lambda_t^{RL}+\lambda_t^{LR}\lambda_c^{RL}}_{0.0011\times\cos(\alpha_2-\alpha_3+\beta_2)}) \underbrace{\frac{\Delta m_{K_{ct}}^{WW'}}{\Delta m_{K_{tt}}^{WW'}}}_{10^{-2}}\right]$$


cos(α2−α3+β2)=1
Δ m_K^WW'/Δ m_K^exp/(Δ_{2,1}^2 g_2^2/g_1^2)
Δ_{1,1}
M_W'=10M_W
M_W'=15M_W
M_W'=20M_W
M_W'=25M_W
M_W'=50M_W
M_W'=100M_W
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−12
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2

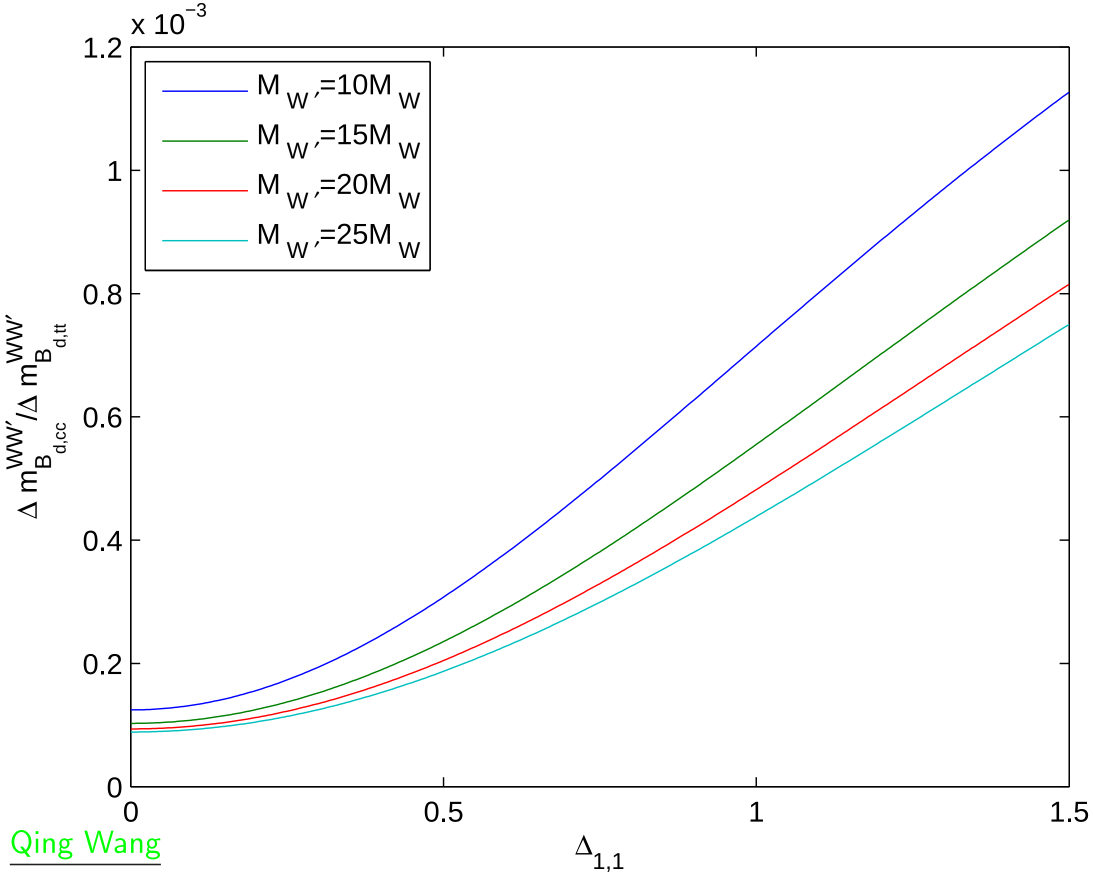

Δ1,1=1
Δ m_K^WW'/Δ m_K^exp/(Δ²2,1 g²2/g²1)
cos(α2−α3+β2)
M W'=10M W
M W'=15M W
M W'=20M W
M W'=25M W
M W'=50M W
M W'=100M W
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−12
−13
−1
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1

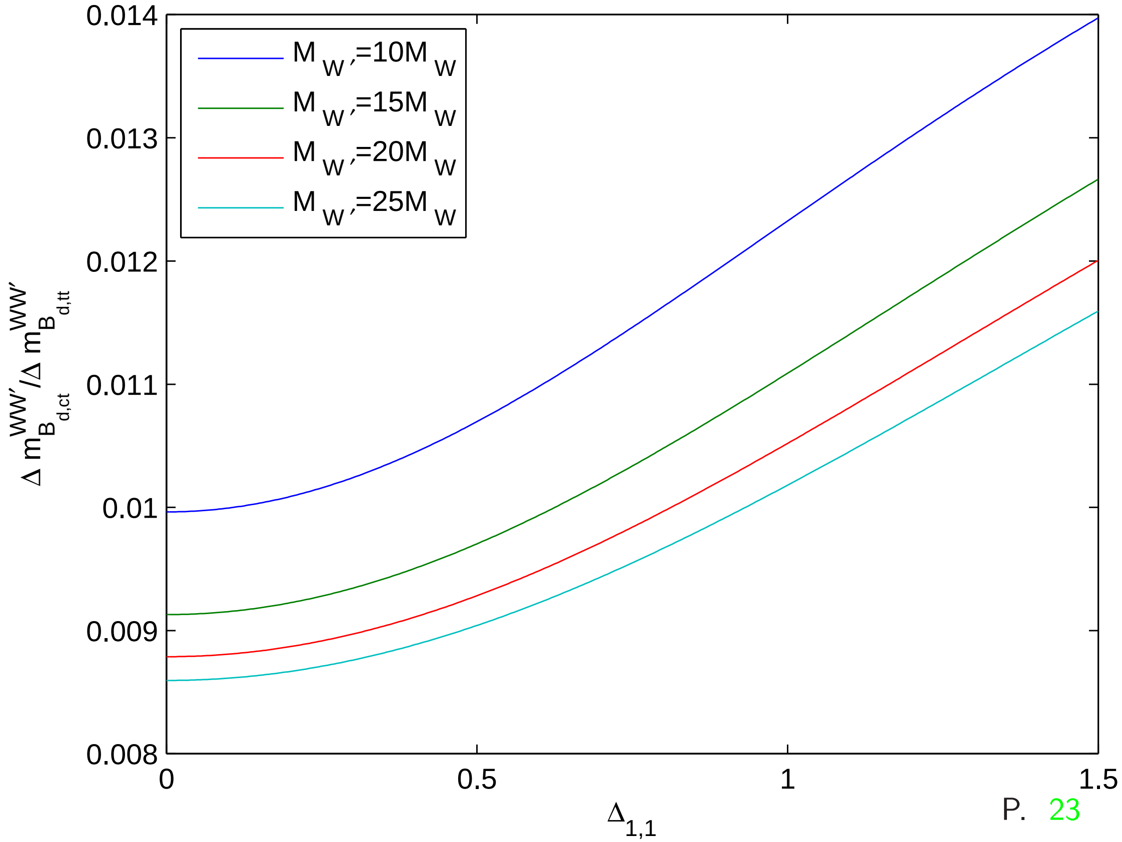
$$\Delta m_{B_d}^{WW'} = \Delta_{2,1}^2 \frac{g_2^2}{g_1^2} \Delta m_{B_d tt}^{WW'} \left| \lambda_t^{LR}\lambda_t^{RL} + \lambda_c^{LR}\lambda_c^{RL} \underbrace{\frac{\Delta m_{B_d cc}^{WW'}}{\Delta m_{B_d tt}^{WW'}}}_{10^{-3}} + (\lambda_c^{LR}\lambda_t^{RL} + \lambda_t^{LR}\lambda_c^{RL}) \underbrace{\frac{\Delta m_{B_d ct}^{WW'}}{\Delta m_{B_d tt}^{WW'}}}_{10^{-2}} \right|$$

$$\lambda_x^{LR}(B_d)\lambda_x^{RL}(B_d) = |V_L^{xb}V_L^{xd*}\bar{V}_R^{xb}\bar{V}_R^{xd*}|e^{-i(\alpha_1-\alpha_3-\beta_1-\beta_2-\phi_{xb}-\bar{\phi}_{xb}+\phi_{xd}+\bar{\phi}_{xd})} \qquad x = c, t$$

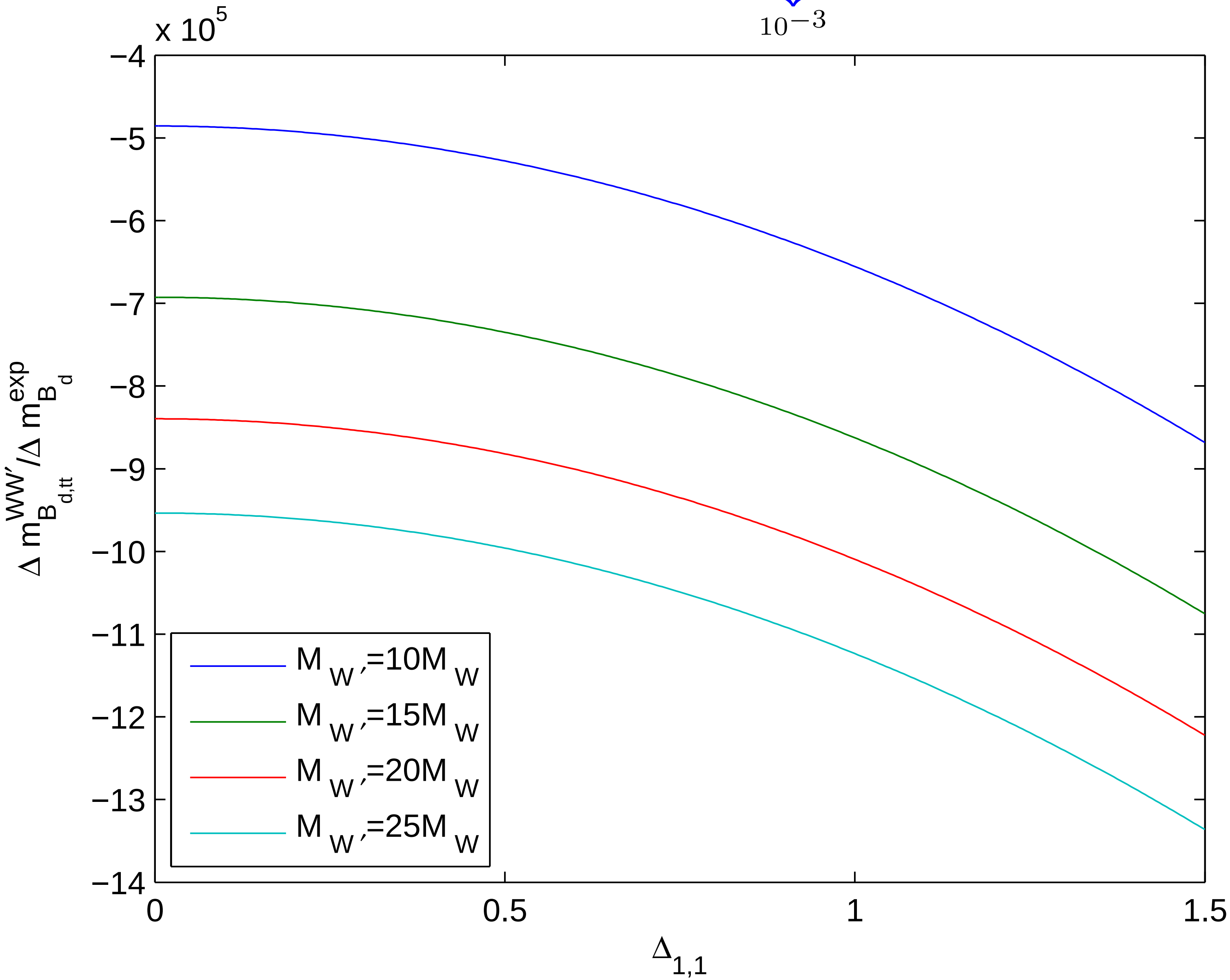
$$\lambda_c^{LR}(B_d)\lambda_t^{RL}(B_d) = |V_L^{cb}\bar{V}_R^{cd*}\bar{V}_R^{tb}V_L^{td*}|e^{-i(\alpha_1+\alpha_2-2\alpha_3-\beta_1-\phi_{cb}+\bar{\phi}_{cd}-\bar{\phi}_{tb}+\phi_{td})} \qquad \arg(V_L^{\alpha\beta}) = \phi_{\alpha\beta}$$

$$\lambda_t^{LR}(B_d)\lambda_c^{RL}(B_d) = |V_L^{tb}\bar{V}_R^{td*}\bar{V}_R^{cb}V_L^{cd*}|e^{-i(\alpha_1-\alpha_2-\beta_1-2\beta_2-\phi_{tb}+\bar{\phi}_{td}-\bar{\phi}_{cb}+\phi_{cd})} \qquad \arg(\bar{V}_R^{\alpha\beta}) = \bar{\phi}_{\alpha\beta}$$





$$\Delta m_{B_d}^{WW'} = \Delta_{2,1}^2 \frac{g_2^2}{g_1^2} \Delta m_{B_d tt}^{WW'} \left| \lambda_t^{LR}\lambda_t^{RL} + \lambda_c^{LR}\lambda_c^{RL} \underbrace{\frac{\Delta m_{B_d cc}^{WW'}}{\Delta m_{B_d tt}^{WW'}}}_{10^{-3}} + (\lambda_c^{LR}\lambda_t^{RL} + \lambda_t^{LR}\lambda_c^{RL}) \underbrace{\frac{\Delta m_{B_d ct}^{WW'}}{\Delta m_{B_d tt}^{WW'}}}_{10^{-2}} \right|$$

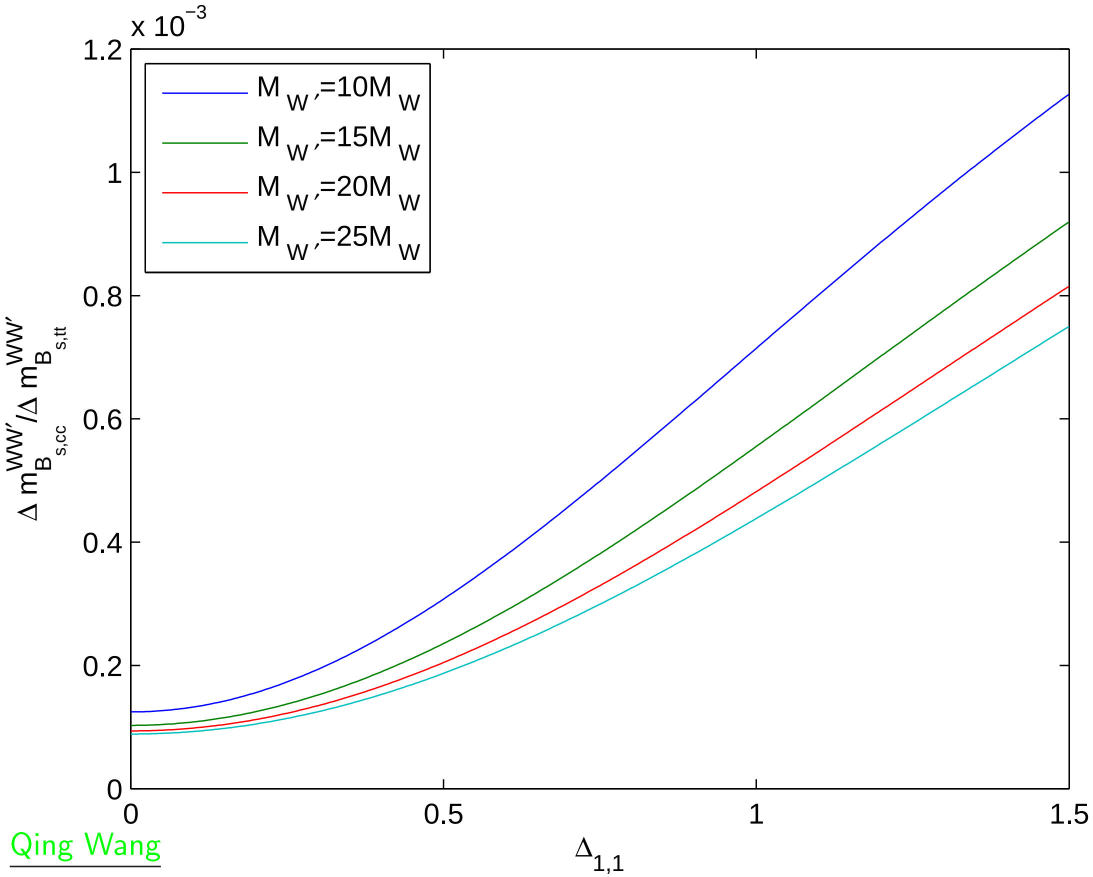


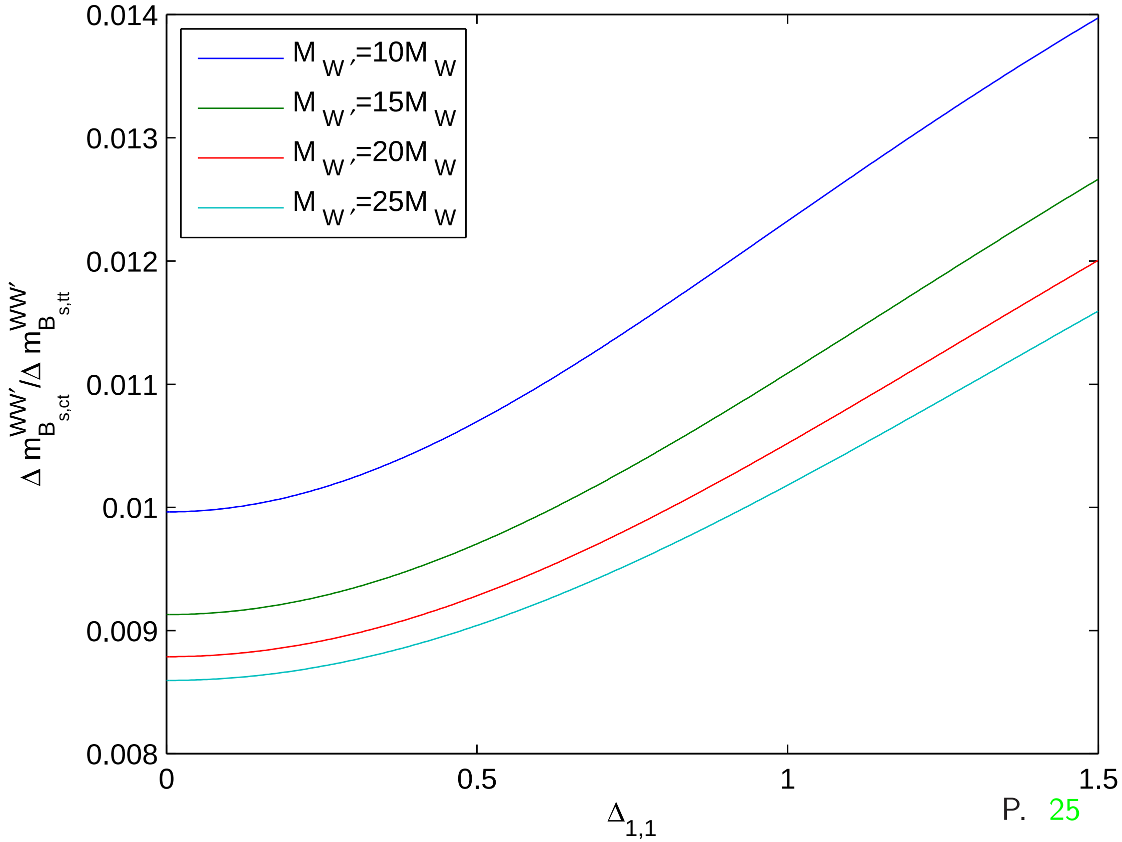
$$\Delta m_{B_s}^{WW'} = \Delta_{2,1}^2 \frac{g_2^2}{g_1^2} \Delta m_{B_s tt}^{WW'} \left| \lambda_t^{LR}\lambda_t^{RL} + \lambda_c^{LR}\lambda_c^{RL} \underbrace{\frac{\Delta m_{B_s cc}^{WW'}}{\Delta m_{B_s tt}^{WW'}}}_{10^{-3}} + (\lambda_c^{LR}\lambda_t^{RL} + \lambda_t^{LR}\lambda_c^{RL}) \underbrace{\frac{\Delta m_{B_s ct}^{WW'}}{\Delta m_{B_s tt}^{WW'}}}_{10^{-2}} \right|$$

$$\lambda_x^{LR}(B_s)\lambda_x^{RL}(B_s) = |V_L^{xb}V_L^{xs*}\bar{V}_R^{xb}\bar{V}_R^{xs*}| e^{-i(\alpha_2-\alpha_3-\beta_2-\phi_{xb}-\bar{\phi}_{xb}+\phi_{xs}+\bar{\phi}_{xs})} \qquad x = c, t$$

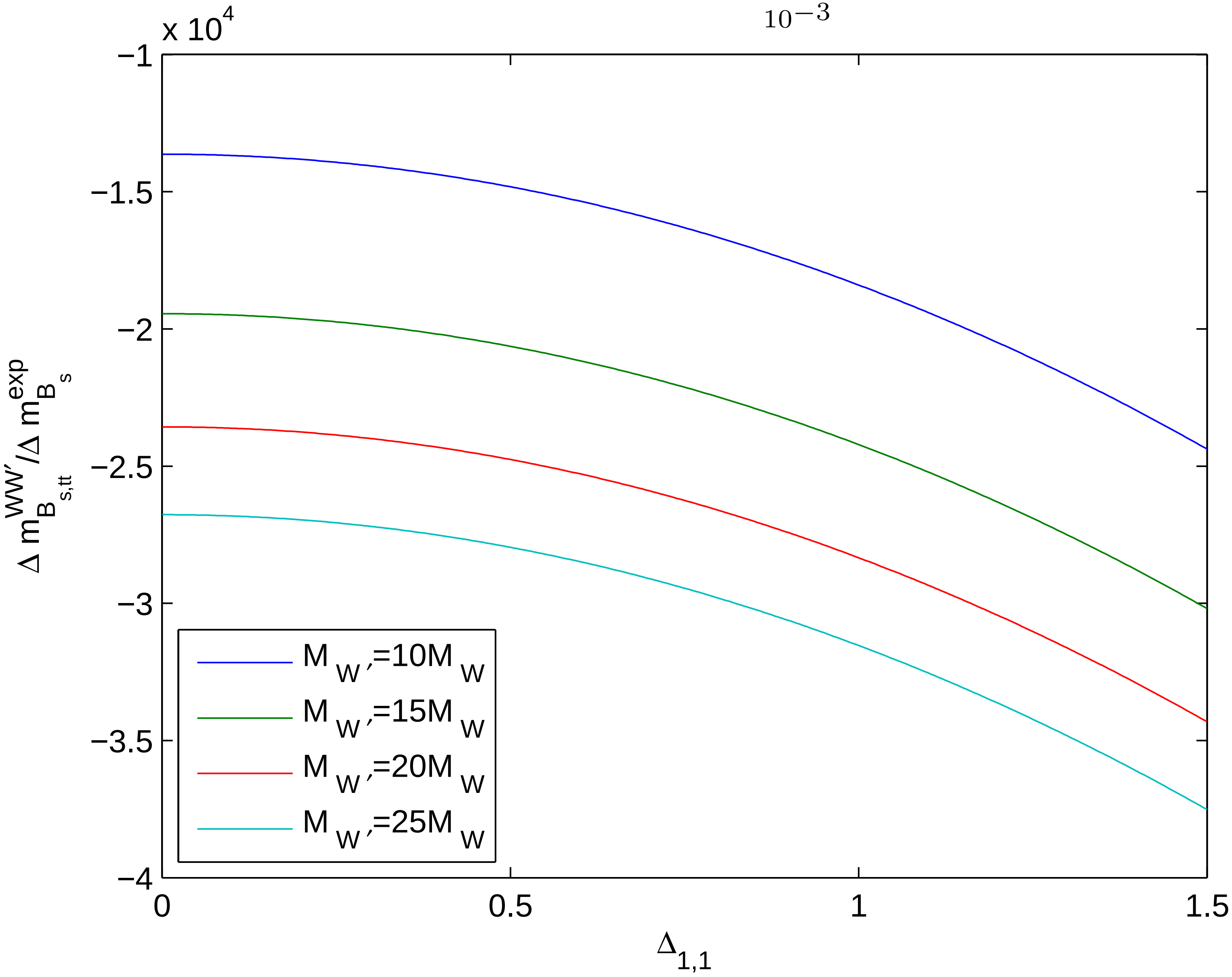
$$\lambda_c^{LR}(B_s)\lambda_t^{RL}(B_s) = |V_L^{cb}\bar{V}_R^{cs*}\bar{V}_R^{tb}V_L^{ts*}| e^{-i(2\alpha_2-2\alpha_3-\phi_{cb}+\bar{\phi}_{cs}-\bar{\phi}_{tb}+\phi_{ts})} \qquad \arg(V_L^{\alpha\beta}) = \phi_{\alpha\beta}$$

$$\lambda_t^{LR}(B_s)\lambda_c^{RL}(B_s) = |V_L^{tb}\bar{V}_R^{ts*}\bar{V}_R^{cb}V_L^{cs*}| e^{-i(-2\beta_2-\phi_{tb}+\bar{\phi}_{ts}-\bar{\phi}_{cb}+\phi_{cs})} \qquad \arg(\bar{V}_R^{\alpha\beta}) = \bar{\phi}_{\alpha\beta}$$





$$\Delta m_{B_s}^{WW'} = \Delta_{2,1}^2 \frac{g_2^2}{g_1^2} \Delta m_{B_s tt}^{WW'} \left| \lambda_t^{LR}\lambda_t^{RL} + \lambda_c^{LR}\lambda_c^{RL} \underbrace{\frac{\Delta m_{B_s cc}^{WW'}}{\Delta m_{B_s tt}^{WW'}}}_{10^{-3}} + (\lambda_c^{LR}\lambda_t^{RL} + \lambda_t^{LR}\lambda_c^{RL}) \underbrace{\frac{\Delta m_{B_s ct}^{WW'}}{\Delta m_{B_s tt}^{WW'}}}_{10^{-2}} \right|$$



$\Delta m_K,\ |\epsilon_K|,\ \Delta m_{B_d},\ \Delta m_{B_s}$

$$\mathcal{L}_{\mathrm{Y,quark}}\Big|_{\textbf{Unitary gauge}} = \bar{q}^I_{\alpha L}(\tau^u y_u^{\alpha\beta} + \tau^d y_d^{\alpha\beta})q^I_{\beta R} + \mathrm{h.c.} \quad y_i = y_i^0 + y_i^1\tilde{h} + \cdots \quad \tilde{y}_i = V_L^i y_i^1 V_R^{i\dagger} \quad i = u, d$$

$$\Delta m_K^h \ll \Delta m_K^{\mathrm{exp}} \quad \Rightarrow \quad \mathrm{Re}[(\tilde{y}_d^{ds} + \tilde{y}_d^{\dagger ds})^2 - 11.4(\tilde{y}_d^{ds} - \tilde{y}_d^{\dagger ds})^2] \ll 6.45\times 10^{-7}\left(\frac{m_h}{1\mathrm{TeV}}\right)^2$$

$$|\epsilon_K|^h \ll |\epsilon_K|^{\mathrm{exp}} \quad \Rightarrow \quad \mathrm{Im}[(\tilde{y}_d^{ds} + \tilde{y}_d^{\dagger ds})^2 - 11.4(\tilde{y}_d^{ds} - \tilde{y}_d^{\dagger ds})^2]$$
$$\ll 0.0065\times \mathrm{Re}[(\tilde{y}_d^{ds} + \tilde{y}_d^{\dagger ds})^2 - 11.4(\tilde{y}_d^{ds} - \tilde{y}_d^{\dagger ds})^2]$$

$$\Delta m_{B_d}^h \ll \Delta m_{B_d}^{\mathrm{exp}} \quad \Rightarrow \quad [(\tilde{y}_d^{db} + \tilde{y}_d^{\dagger db})^2 - 11.4(\tilde{y}_d^{db} - \tilde{y}_d^{\dagger db})^2] \ll 1.74\times 10^{-6}\left(\frac{m_h}{1\mathrm{TeV}}\right)^2$$

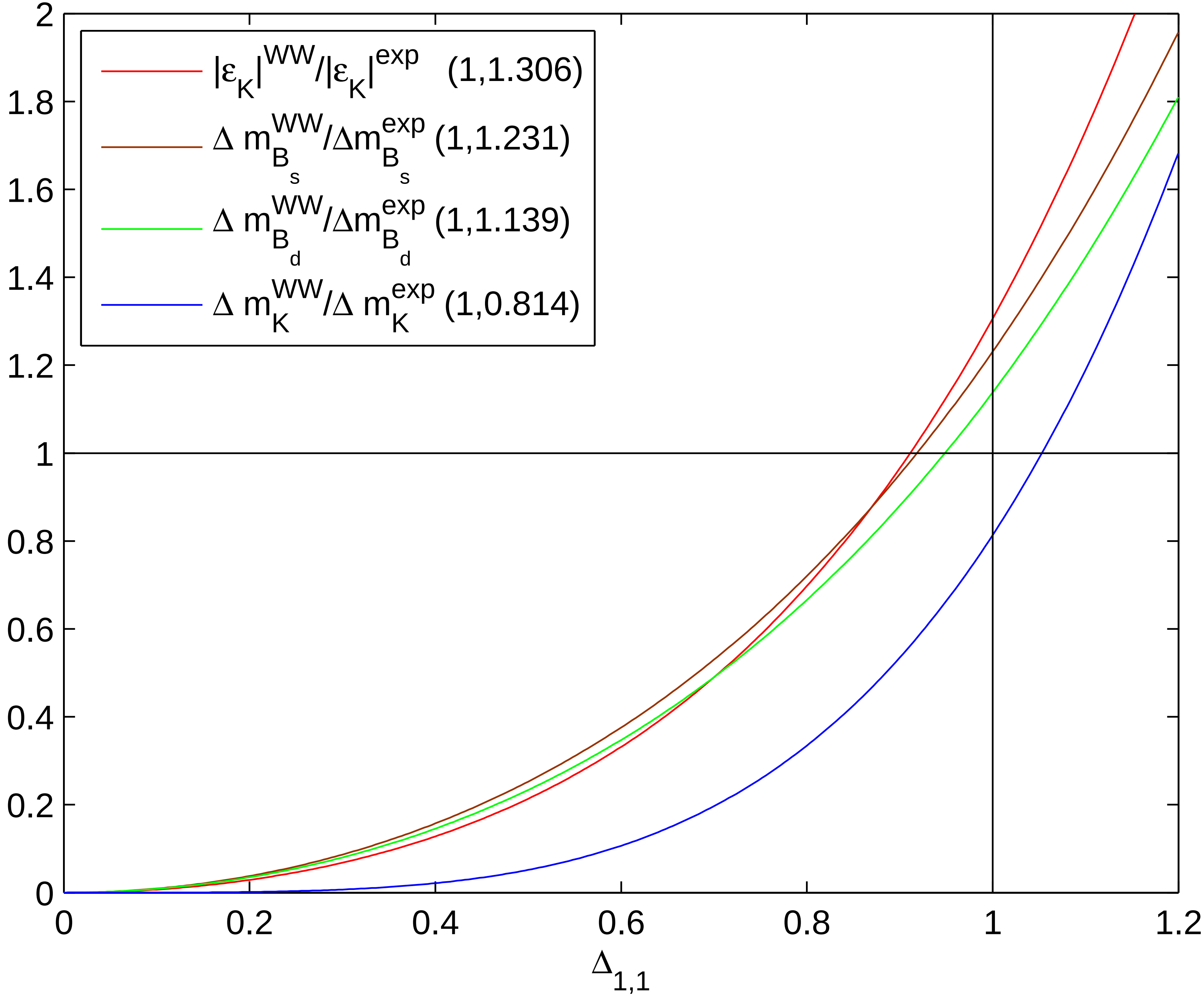
$$\Delta m_{B_s}^h \ll \Delta m_{B_s}^{\mathrm{exp}} \quad \Rightarrow \quad [(\tilde{y}_d^{sb} + \tilde{y}_d^{\dagger sb})^2 - 11.4(\tilde{y}_d^{sb} - \tilde{y}_d^{\dagger sb})^2] \ll 6.10\times 10^{-5}\left(\frac{m_h}{1\mathrm{TeV}}\right)^2$$

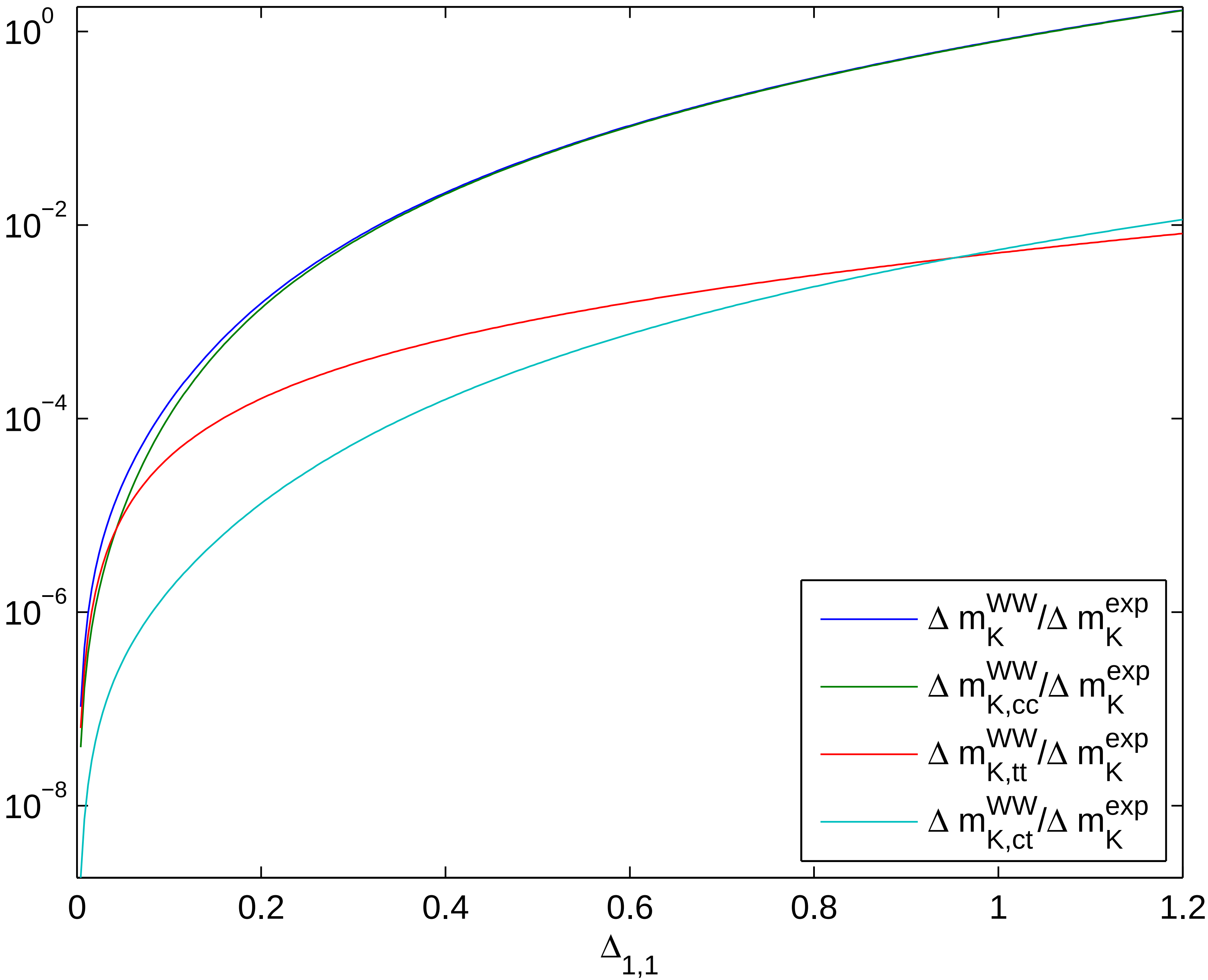
小　结

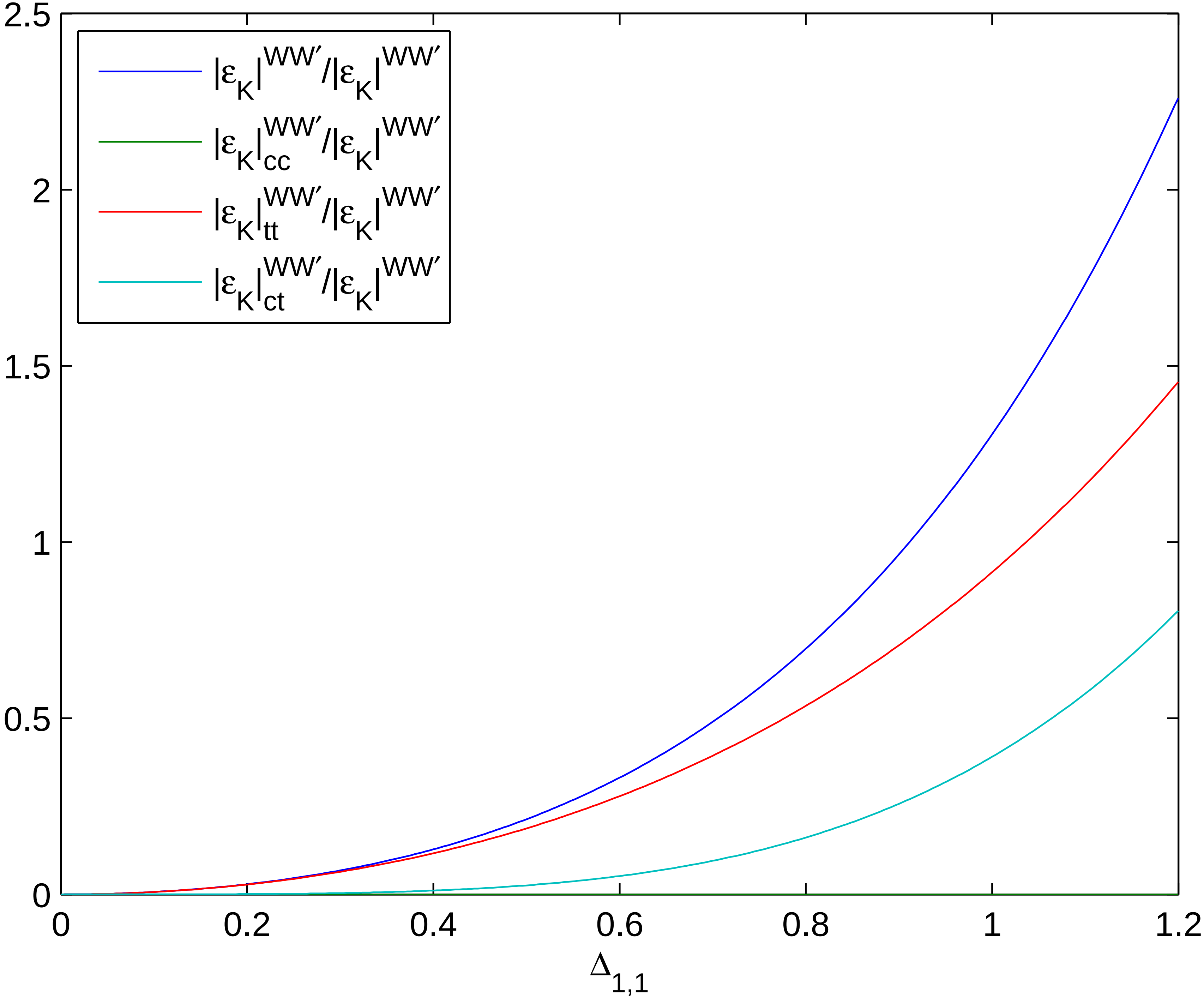
- 构造了含$W'^{\pm}, Z'$的电弱手征拉氏量！
- $W-W'$混合是普适的，小的混合并不限制W'一定很重！
- 轻子的混合与在标准模型中加入右手中微子的情形相同。
- 夸克的混合涉及右手的CKM矩阵。
- 为保证W'对Δm_K，$|\epsilon_K|$，Δm_{B_d}，Δm_{B_s}贡献不与实验冲突
  - $M_{W'}\gg M_W$;　$g_2\ll g_1$;　$\Delta_{2,1}\ll 1$;　特别选择右手CKM矩阵元
  - W'的额外贡献与W和Higgs的贡献相互抵消
- 没单独讨论Z'：Y.Zhang, S-Z.Wang, Q.Wang, JHEP03（2008）047

Thanks!

Backup


$|\epsilon_K|^{WW}/|\epsilon_K|^{exp}$ (1,1.306)
$\Delta m_{B_s}^{WW}/\Delta m_{B_s}^{exp}$ (1,1.231)
$\Delta m_{B_d}^{WW}/\Delta m_{B_d}^{exp}$ (1,1.139)
$\Delta m_K^{WW}/\Delta m_K^{exp}$ (1,0.814)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
0.2
0.4
0.6
0.8
1
1.2
$\Delta_{1,1}$


10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
0
0.2
0.4
0.6
0.8
1
1.2
$\Delta_{1,1}$
$\Delta m_K^{WW}/\Delta m_K^{exp}$
$\Delta m_{K,cc}^{WW}/\Delta m_K^{exp}$
$\Delta m_{K,tt}^{WW}/\Delta m_K^{exp}$
$\Delta m_{K,ct}^{WW}/\Delta m_K^{exp}$


$|\varepsilon_K|^{WW'}/|\varepsilon_K|^{WW'}$
$|\varepsilon_K|^{WW'}_{cc}/|\varepsilon_K|^{WW'}$
$|\varepsilon_K|^{WW'}_{tt}/|\varepsilon_K|^{WW'}$
$|\varepsilon_K|^{WW'}_{ct}/|\varepsilon_K|^{WW'}$
2.5
2
1.5
1
0.5
0
0.2
0.4
0.6
0.8
1.2
$\Delta_{1,1}$

$$\mathcal{L}_{\rm CC}|_{\rm quark}=-\frac{1}{\sqrt{2}}\bar{q}_\alpha(\tau^+\not{W}_1^++\tau^-\not{W}_1^-)[(g_L+\Delta_{\rm C\it L})P_L+\Delta_{\rm C\it R}P_R]q_\alpha$$

$$\mathcal{L}_{\rm NC}|_{\rm quark}=-\frac{1}{2}\bar{q}_\alpha\not{Z}\{T_{3L}[\frac{g_L}{\cos\theta_W}(1-\gamma_5)+\Delta_{{\rm N}VT}+\Delta_{{\rm N}AT}\gamma_5]+Q(\frac{2g_L\sin^2\theta_W}{\cos\theta_W}+\Delta_{{\rm N}VQ}+\Delta_{{\rm N}AQ}\gamma_5)\}q_\alpha$$

$$\mathcal{L}_{\rm EM}|_{\rm quark}=-\frac{1}{2}\bar{q}_\alpha\not{A}[Q(2e+\Delta_{{\rm E}VQ}+\Delta_{{\rm E}AQ}\gamma_5)+T_{3L}(\Delta_{{\rm E}VT}+\Delta_{{\rm E}AT}\gamma_5)]q_\alpha$$

$$\Delta_{{\rm C}L}=g_1[\cos\zeta(1-\delta_{L,1}-\delta_{L,4})-1]+g_2\sin\zeta(\delta_{R,2}-\delta_{R,6})\ ,$$

$$\Delta_{{\rm C}R}=g_1\cos\zeta(\delta_{L,2}-\delta_{L,6})+g_2\sin\zeta(1-\delta_{R,1}-\delta_{R,4})$$

$$\Delta_{{\rm N}VT}=-\frac{g_1}{\cos\theta_W}+g_1x_1[1-\delta_{L,1}+\delta_{L,4}+\delta_{L,2}+\delta_{L,6}-\frac{2}{Y}(\delta_{L,3}+\delta_{L,7}+\delta_{L,5})]+g_Ry_1[1-\delta_{R,1}$$
$$+\delta_{R,4}+\delta_{R,2}+\delta_{R,6}-\frac{2}{Y}(\delta_{R,3}+\delta_{R,7}+\delta_{R,5})]+gv_1[-2+\delta_{L,1}+\delta_{R,1}-\delta_{R,2}-\delta_{L,2}-\delta_{L,4}$$
$$-\delta_{R,4}-\delta_{R,6}-\delta_{L,6}+2Y\delta_{L,7}+2Y\delta_{R,7}+\frac{2}{Y}(\delta_{L,3}+\delta_{R,5}+\delta_{R,3}+\delta_{L,5})]\ ,$$

$$\Delta_{{\rm N}AT}=\frac{g_1}{\cos\theta_W}-g_1x_1[1-\delta_{L,1}+\delta_{L,4}-\delta_{L,2}-\delta_{L,6}-\frac{2}{Y}(\delta_{L,3}+\delta_{L,7}-\delta_{L,5})]-g_2y_1[1-\delta_{R,1}$$
$$+\delta_{R,4}-\delta_{R,2}-\delta_{R,6}+\frac{2}{Y}(\delta_{R,3}+\delta_{R,7}-\delta_{R,5})]+gv_1[\delta_{L,1}-\delta_{R,1}-\delta_{R,2}+\delta_{L,2}-\delta_{L,4}+\delta_{R,4}$$
$$-\delta_{R,6}+\delta_{L,6}+2Y\delta_{L,7}-2Y\delta_{R,7})+\frac{2}{Y}(-\delta_{L,3}-\delta_{R,5}+\delta_{R,3}+\delta_{L,5})]\ ,$$

$$\Delta_{\mathrm{N}VQ} = \frac{2g_1\sin^2\theta_W}{\cos\theta_W} + \frac{2}{Y}[g_1x_1(\delta_{L,3}+\delta_{L,7}+\delta_{L,5}) + g_2y_1(\delta_{R,3}+\delta_{R,7}+\delta_{R,5}) + gv_1(Y-\delta_{L,3} -\delta_{R,5}-\delta_{R,3}-\delta_{L,5})]\ ,$$

$$\Delta_{\mathrm{N}AQ} = -\frac{2}{Y}[g_1x_1(\delta_{L,3}+\delta_{L,7}-\delta_{L,5}) - g_2y_1(\delta_{R,3}+\delta_{R,7}-\delta_{R,5}) + gv_1(-\delta_{L,3}-\delta_{R,5}+\delta_{R,3}+\delta_{L,5})]\ ,$$

$$\Delta_{\mathrm{E}VQ} = -2e+\frac{2}{Y}[g_1x_3(\delta_{L,3}+\delta_{L,7}+\delta_{L,5})+g_2y_3(\delta_{R,3}+\delta_{R,7}+\delta_{R,5})+gv_3(Y-\delta_{L,3}-\delta_{R,5}-\delta_{R,3}-\delta_{L,5})]\ ,$$

$$\Delta_{\mathrm{E}AQ} = -\frac{2}{Y}[g_1x_3(\delta_{L,3}+\delta_{L,7}-\delta_{L,5}) - g_2y_3(\delta_{R,3}+\delta_{R,7}-\delta_{R,5}) + gv_3(-\delta_{L,3}-\delta_{R,5}+\delta_{R,3}+\delta_{L,5})]$$

$$\Delta_{\mathrm{E}VT} = g_1x_3[1-\delta_{L,1}+\delta_{L,4}+\delta_{L,2}+\delta_{L,6}-\frac{2}{Y}(\delta_{L,3}+\delta_{L,7}+\delta_{L,5})] + g_2y_3[1-\delta_{R,1}+\delta_{R,4}+\delta_{R,2} +\delta_{R,6}-\frac{2}{Y}((\delta_{R,3}+\delta_{R,7}+\delta_{R,5}))] + gv_3[-2+\delta_{L,1}+\delta_{R,1}-\delta_{R,2}-\delta_{L,2}-\delta_{L,4}-\delta_{R,4}-\delta_{R,6} -\delta_{L,6}+2Y\delta_{L,7}+2Y\delta_{R,7}+\frac{2}{Y}(\delta_{L,3}+\delta_{R,5}+\delta_{R,3}+\delta_{L,5})]$$

$$\Delta_{\mathrm{E}AT} = -g_1x_3[1-\delta_{L,1}+\delta_{L,4}-\delta_{L,2}-\delta_{L,6}-\frac{2}{Y}(\delta_{L,3}+\delta_{L,7}-\delta_{L,5})] - g_2y_3[1-\delta_{R,1}+\delta_{R,4}-\delta_{R,2} -\delta_{R,6}+\frac{2}{Y}((\delta_{R,3}+\delta_{R,7}-\delta_{R,5}))] + gv_3[\delta_{L,1}-\delta_{R,1}-\delta_{R,2}+\delta_{L,2}-\delta_{L,4}+\delta_{R,4}-\delta_{R,6} +\delta_{L,6}+2Y\delta_{L,7}-2Y\delta_{R,7})+\frac{2}{Y}(-\delta_{L,3}-\delta_{R,5}+\delta_{R,3}+\delta_{L,5})]\ .$$