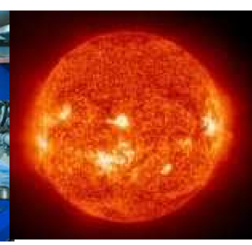
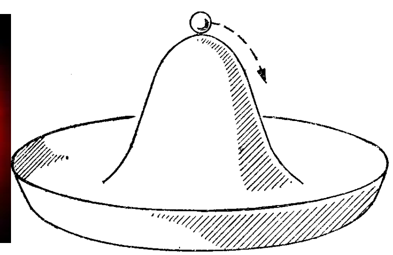
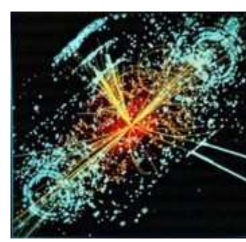
QFTHEP'2010

Alexey Sukachev [*]

[*]: M.V. Lomonosov Moscow State University (MSU),
D.V. Skobeltsyn Scientific Institute of Nuclear Research (SINP)

Alexey Sukachev and Mikhail Dubinin

Neutral mesons' mixings and rare decays in the framework of the MSSM (with an explicit CP-violation)


[*]: salex-82@yandex.ru

Model. 1-1. Feature points

- **Scalar sector** – MSSM Effective Potential:

$$U(\Phi_1,\Phi_2) = -\mu_1^2(\Phi_1^\dagger\Phi_1) - \mu_2^2(\Phi_2^\dagger\Phi_2) - \underline{\mu_{12}^2(\Phi_1^\dagger\Phi_2)} - \underline{\underline{\overset{*}{\mu}{}_{12}^2\,(\Phi_2^\dagger\Phi_1)}} +$$
$$+\lambda_1(\Phi_1^\dagger\Phi_1)^2 + \lambda_2(\Phi_2^\dagger\Phi_2)^2 + \lambda_3(\Phi_1^\dagger\Phi_1)(\Phi_2^\dagger\Phi_2) + \lambda_4(\Phi_1^\dagger\Phi_2)(\Phi_2^\dagger\Phi_1) +$$
$$+\underline{\frac{\lambda_5}{2}(\Phi_1^\dagger\Phi_2)(\Phi_1^\dagger\Phi_2)} + \underline{\underline{\frac{\overset{*}{\lambda}_5}{2}(\Phi_2^\dagger\Phi_1)(\Phi_2^\dagger\Phi_1)}} +$$
$$+\underline{\lambda_6(\Phi_1^\dagger\Phi_1)(\Phi_1^\dagger\Phi_2)} + \underline{\underline{\overset{*}{\lambda}_6\,(\Phi_1^\dagger\Phi_1)(\Phi_2^\dagger\Phi_1)}} + \underline{\lambda_7(\Phi_2^\dagger\Phi_2)(\Phi_1^\dagger\Phi_2)} + \underline{\underline{\overset{*}{\lambda}_7\,(\Phi_2^\dagger\Phi_2)(\Phi_2^\dagger\Phi_1)}}.$$

SM:

$m_h > 114\ GeV$

$e^+e^- \to ZH$

MSSM:

$m_{H^\pm} > 79.3\ GeV$

$e^+e^- \to H^+H^-$

- **Yukava sector** – THDM II (Two Higgs Doublet Model of the Second Type):

$$-L_Y^{II} = g_{ij}^{u\,1}\bar{Q}'_{i\,L}\tilde{\Phi}_1 u'_{j\,R} + g_{ij}^{d\,2}\bar{Q}'_{i\,L}\Phi_2 d'_{j\,R} + \text{lept. sec.} + \text{h.c.}$$

- **Radiative Corrections** [1]:

$A_{t,b}$ – **Universal trilinear couplings**

μ – **Higgsino mass (“Higgs mixing parameter”)**

SUSY breaking scale: M_{SUSY}

Universal phase: $\varphi = \arg(\mu A_{t,b})$

[1] – E. N. Akhmetzyanova, M. V. Dolgopolov, and M. N. Dubinin; Phys. Rev. D. 71, P. 075008 (2005).

Mass spectrum:

h, H, A $\longrightarrow$ h(1), h(2), h(3)

$$m_{H^\pm}^2 = m_W^2 + m_A^2 - \frac{v^2}{2}(\text{Re}\Delta\lambda_5 - \Delta\lambda_4)$$

Main Assumptions:

- **CPX scenario:**

$\mu = 2\,A_{t,b} = 4\,M_{SUSY}$ $\qquad$ $M_{\text{SUSY}} = 500$ ГэВ

- **Phase universality:**

$\varphi = \arg(\mu A_b) = \arg(\mu A_t)$

System. 2-1. K-mesons. Basic expressions

Mass splitting:

$$\Delta m_{LS}^{K} = B_K \cdot \Delta m_{LS}^{SD}(\eta_i) + \Delta m_{LS}^{LD}$$

Corrections and contributions:

1). Δm_{LS}^{SD} **- contributions from virtual exchanges at short distances (PT);**

2). η_i **- QCD (perturbative) corrections accounting for hard gluon exchanges;**

3). B_K**- QCD (non-perturbative) corrections accounting for intermediary hadron states at short distances;**

4).Δm_{LS}^{LD} **- hadron boundary states at long distances.**

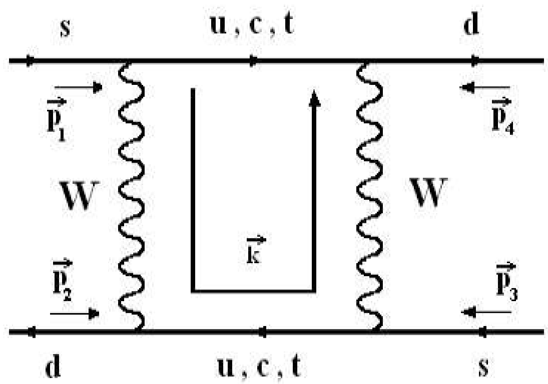
Normalization:

$$\Delta m_{LS}^{LD} = \Delta m_{LS}^{exp} - \Delta m_{LS}^{SD-WW}$$

Non-Direct CP-violation:

$$|\varepsilon_{K-exact}^{tot}| = \frac{1}{2\sqrt{2}} \frac{M_{LS}^{WW} + \sum_{i=1}^{i=2} M_{LS}^{HWi} + \sum_{j=1}^{j=7} M_{LS}^{HGj} + \sum_{k=1}^{k=4} M_{LS}^{HHk}}{N_{LS}^{WW} + \sum_{i=1}^{i=2} N_{LS}^{HWi} + \sum_{j=1}^{j=7} N_{LS}^{HGj} + \sum_{k=1}^{k=4} N_{LS}^{HHk}}$$

System. 2-2. K-mesons. SM.



1. GIM-mechanism [3], [4]:

$$\Delta m_{LS}^{WW} = \frac{G_F^2 f_K^2 m_K B_K}{6\pi^2} \mathrm{Re}\, A$$

$$|\varepsilon| = \frac{1}{2\sqrt{2}} \frac{\mathrm{Im}\, A}{\mathrm{Re}\, A}$$

$$A = \left[(V_{cd}^* V_{cs})^2 m_c^2 \eta_1 I(\xi_1) + (V_{td}^* V_{ts})^2 m_t^2 \eta_2 I(\xi_2) + \right.$$
$$\left. + \; 2\, V_{td}^* V_{cd}^* V_{ts} V_{cs} \eta_3 m_c m_t I(\xi_1, \xi_2, \xi_3) \right],$$

3. QCD-corrections [5]:

$B_K \approx 1.0,\ B_d \approx 1.4,\ B_s \approx 1.4$

$\eta_1 = 1.3\ (central\ value)$

$\eta_2 = 0.57\ ,\ \eta_2^B = 0.55$

$\eta_3 = 0.47$

2. Vysotsky-Inami-Lim Functions:

$$I(\xi) = \left\{ \frac{\xi^2 - 11\xi + 4}{4(\xi - 1)^2} - \frac{3\xi^2 \ln \xi}{2(1 - \xi)^3} \right\}$$

$$I(\xi_1, \xi_2, \xi_3) = \left(\frac{\xi_3}{\ln \xi_3} \quad \frac{1}{\ln \xi_3} \right) \left(\frac{\ln \xi_1}{(1 - \xi_1)^2 (1 - \xi_2)^2 (1 - \xi_3)} \right.$$
$$- \frac{\xi_1}{(1 - \xi_1)^2 (1 - \xi_2)^2} + \frac{(2 - \xi_2)\xi_2 \ln \xi_1 - (2 - \xi_1)\xi_1 \ln \xi_2}{(1 - \xi_1)^2 (1 - \xi_2)^2 (1 - \xi_3)} +$$
$$\left. + \frac{\xi_1^2 (1 - \xi_2) - \xi_2^2 (1 - \xi_1)}{(1 - \xi_1)^2 (1 - \xi_2)^2 (1 - \xi_3)} \right).$$

$$\xi_1 = \left(\frac{m_c}{m_W}\right)^2$$

$$\xi_2 = \left(\frac{m_t}{m_W}\right)^2$$

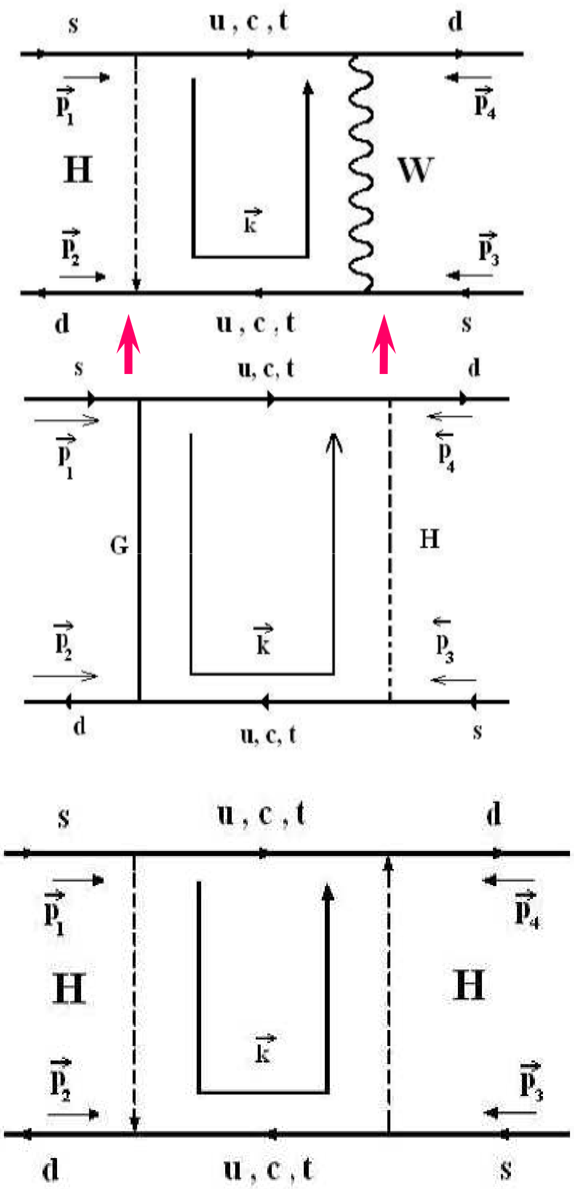
$$\xi_3 = \left(\frac{m_t}{m_c}\right)^2$$

[3] – S.L. Glashow, J. Iliopoulos, and L. Maiani, Phys. Rev. D 2, P. 1285 (1970);

[4] – J. Ellis, M.K. Gaillard, and D.V. Nanopoulos, Nucl. Phys. B 109, P 213 (1976);

[5] – S. Herrlich, and U. Nierste, Nucl. Phys. B 419, P 292 (1994).

System. 2-3. K-mesons. MSSM. HW, HH и HG



$$\Delta m_{LS}^{appr-HW} = \frac{G_{\mathrm{F}} C_{\mathrm{H}} f_K^2 m_K B_K}{24\pi^2 m_W^2} \left(\frac{1}{2 \cdot \mathrm{tg}^2\beta} \mathrm{Re} C_1(G_{1j}^{HW}) - \mathrm{tg}^2\beta \cdot m_s m_d \mathrm{Re} C_2(G_{2j}^{HW}) \right)$$

$$C_i(G_{ij}^{HW}) = [(V_{cd}^* V_{cs})^2 m_c^2 \eta_4 G_{i1}^{HW}(\Lambda, m_c^2) + (V_{td}^* V_{ts})^2 m_t^2 \eta_5 G_{i1}^{HW}(\Lambda, m_t^2) + $$
$$+ 2\, V_{td}^* V_{cd}^* V_{ts} V_{cs} m_c m_t \eta_6 G_{i2}^{HW}(\Lambda, m_c^2, m_t^2)] \quad (i = 1, 2;\ j = 1, 2)\ .$$

$$\Delta m_{LS}^{appr-HH} = \frac{C_{\mathrm{H}}^2 f_K^2 m_K B_K}{384\pi^2 m_W^4} \left(\frac{m_s^2 m_d^2 \cdot \mathrm{tg}^4\beta}{4} \mathrm{Re}\ B_1 - \frac{m_s m_d}{2} \mathrm{Re}\ B_2(G_{2k}^{HH}) + \right.$$
$$\left. + \frac{1}{4 \cdot \mathrm{tg}^4\beta} \mathrm{Re}\ B_3(G_{3k}^{HH}) + \frac{5}{8} \cdot \frac{B_K^S}{B_K} \cdot m_s^2 \mathrm{Re}\ B_4(G_{4k}^{HH}) \right)$$

$$B_1 = [(V_{cd}^* V_{cs})^2 m_c^2 \eta_7 + (V_{td}^* V_{ts})^2 m_t^2 \eta_8 + 2\, V_{td}^* V_{cd}^* V_{ts} V_{cs} \frac{m_c^2 m_t^2}{m_t^2 - m_c^2} \ln\left(\frac{m_t^2}{m_c^2}\right) \eta_9]\ ,$$

$$B_l(G_{lk}^{HH}) = [(V_{cd}^* V_{cs})^2 m_c^4 \eta_7 G_{l1}^{HH}(\Lambda, m_c^2) + (V_{td}^* V_{ts})^2 m_t^4 \eta_8 G_{l1}^{HH}(\Lambda, m_t^2) + $$
$$+ 2\, V_{td}^* V_{cd}^* V_{ts} V_{cs} m_c^2 m_t^2 \eta_9 G_{l2}^{HH}(\Lambda, m_c^2, m_t^2)] \quad (l = 2, 3, 4;\ k = 1, 2).$$

FOUR-FERMION APPROXIMATION

System. 2-4. K-mesons. MSSM. HW, HH и HG

$$\Delta m_{LS}^{ex-HH} = \frac{C_H^2 f_K^2 m_K B_K}{384\pi^2 m_W^4} \cdot \left[\frac{\mathrm{tg}^4\beta\, m_s^2 m_d^2}{4 \cdot m_H^2} D_1(J_{11}^{HH}, J_{12}^{HH}) - \frac{m_s m_d}{2} \cdot D_2(J_{21,22}^{HH}) + \right.$$

$$\left. + \frac{m_H^2}{4 \cdot \mathrm{tg}^4\beta} \cdot D_3(J_{31}^{HH}, J_{32}^{HH}) + \frac{5}{8} \cdot \frac{B_K^S}{B_K} \cdot m_s^2 \cdot D_4(J_{41}^{HH}, J_{42}^{HH}) \right]$$

$$\Delta m_{LS}^{ex-HW} = \frac{G_F C_H f_K^2 m_K B_K m_H^2}{24\pi^2 \cdot m_W^3} \left[\frac{m_W}{2 \cdot \mathrm{tg}^2\beta} E_1(J_{1j}^{HW}) - \frac{\mathrm{tg}^2\beta\, m_s m_d}{m_W} E_2(J_{2j}^{HW}) \right]$$

$$\Delta m_{LS}^{ex-HG} = \frac{G_F C_H f_K^2 m_K B_K m_H^2}{96\pi^2 m_W^8} \left[m_d^2 m_s^2 \mathrm{tg}^2\beta \cdot F_1(J_{11}^{HG}, J_{12}^{HG}) + \right.$$

$$+ m_s m_d m_W^2 \cdot F_2(J_{21}^{HG}, J_{22}^{HG}) + \frac{m_W^4}{2 \cdot \mathrm{tg}^2\beta} \cdot F_3(J_{31}^{HG}, J_{32}^{HG}) -$$

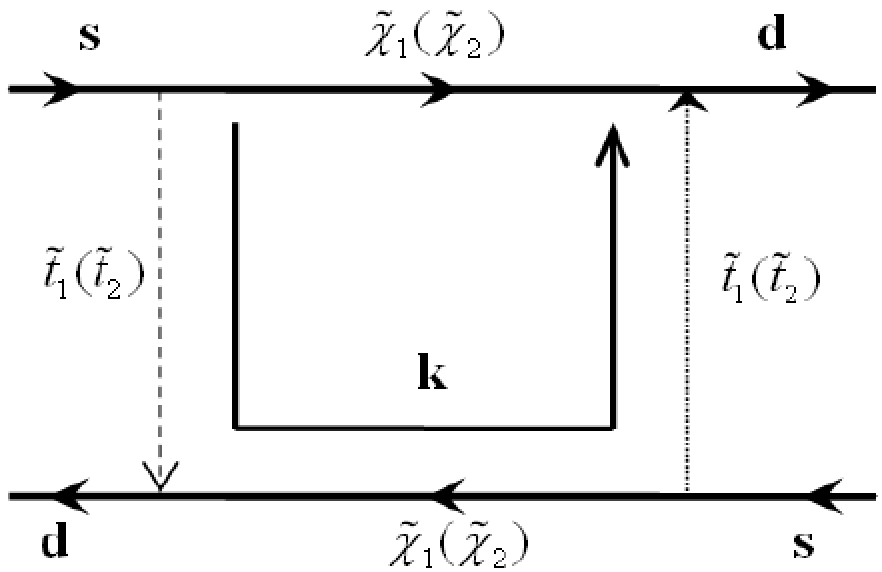
$$\left. - \frac{5}{4} \cdot \frac{B_K^S}{B_K} \cdot m_W^2 \cdot \left(m_s^2 + m_d^2 - \frac{m_s m_d}{\mathrm{tg}^2\beta} - m_s m_d\, \mathrm{tg}^2\beta \right) \cdot F_4(J_{41}^{HG}, J_{42}^{HG}) \right]$$

$$F_i(J_{ij}^{HG}) = \mathrm{Re}\left[(V_{cd}^* V_{cs})^2 m_c^4 \eta_4 J_{i1}^{HW}(\xi_1, \xi_4, \xi_6) + (V_{td}^* V_{ts})^2 m_t^4 \eta_5 J_{i1}^{HW}(\xi_2, \xi_5, \xi_6) + \right.$$

$$\left. + 2\, V_{td}^* V_{cd}^* V_{ts} V_{cs} m_c^2 m_t^2 \eta_6 J_{i2}^{HW}(\xi_1, \xi_2, \xi_3, \xi_4, \xi_5, \xi_6) \right] \quad (i = 1, 2, 3, 4;\ j = 1, 2).$$

EXACT RESULTS

System. 2-5. K-mesons. MSSM. SP impacts



$$\frac{\Delta m_{LS}^{HH}}{\Delta m_{LS}^{MSSM}} \approx \frac{\sin^4\beta \cdot m_{\tilde{\chi}1}^2}{\mathrm{tg}^4\beta \cdot m_H^2}.$$

$$\frac{\Delta m_{LS}^{WW}}{\Delta m_{LS}^{MSSM}} \approx \frac{\sin^4\beta \cdot m_{\tilde{\chi}1}^2 \cdot v^4 \cdot G_F^2}{m_t^2}.$$

$$tg\beta \approx 5, m_{H^\pm} \approx 150\,GeV$$
$$m_{\tilde{\chi}_1} \approx 5\,TeV$$

$$\frac{\Delta m_{LS}^{HH}}{\Delta m_{LS}^{MSSM}} \approx 2\,, \qquad \frac{\Delta m_{LS}^{WW}}{\Delta m_{LS}^{MSSM}} \approx 300$$

$$\Delta m_{LS}^{SUSY} = \frac{m_t^4 f_K^2 m_K B_K \cdot |Z_{p_{22}}|^4}{48\pi^2 v^4 \cdot m_{\tilde{\chi}1}^2 \cdot \sin^4\beta} \cdot \mathrm{Re}[(V_{td}^* V_{ts})^2 \cdot Q]$$

$$Q = (Z_{u_{63}}^* Z_{u_{33}})^2 \cdot J_{\tilde{t}_1,\tilde{t}_1}^{11} + (Z_{u_{66}}^* Z_{u_{36}})^2 \cdot J_{\tilde{t}_2,\tilde{t}_2}^{11} + 2 \cdot Z_{u_{63}}^* Z_{u_{33}} Z_{u_{66}}^* Z_{u_{36}} \cdot J_{\tilde{t}_1,\tilde{t}_2}^{12}$$

$$Z_{p_{22}} = 0.98$$

LEADING ORDER

System. 2-6. K-mesons. MSSM. Loop Integrals

$$\xi_1 = \left(\frac{m_c}{m_W}\right)^2, \xi_2 = \left(\frac{m_t}{m_W}\right)^2, \xi_3 = \left(\frac{m_t}{m_c}\right)^2,$$

$$\xi_4 = \left(\frac{m_c}{m_H}\right)^2, \xi_5 = \left(\frac{m_t}{m_H}\right)^2, \xi_6 = \left(\frac{m_H}{m_W}\right)^2.$$

$$J_{11}^{HH}(m_H^2, m_{c,t}^2) = \frac{1}{m_H^6} \cdot \left(\frac{1+\xi_{4,5}}{\xi_{4,5}(\xi_{4,5}-1)^2} - \frac{2}{(\xi_{4,5}-1)^3} \ln \xi_{4,5} \right)$$

$$J_{11}^{HH}(m_H^2, m_q^2) = \int \frac{d^4k \cdot k_\mu k_\nu}{(2\pi)^4 \cdot i\, k^4 \cdot (k^2 - m_H^2)^2 \cdot (k^2 - m_q^2)^2} = -\frac{g_{\mu\nu}}{64\pi^2} \int_0^{+\infty} \frac{dt}{(t+a)^2 (t+b)^2}$$

L'Hospital Rules

$$\lim_{\xi_5 \to 1} J_{11}^{HH}(\xi_5) = \frac{1}{m_H^6} \cdot \lim_{\xi_5 \to 1} \left(\frac{\xi_5^2 - 1 - 2\xi_5 \ln \xi_5}{\xi_5 \cdot (\xi_5 - 1)^3} \right) =$$

$$= \frac{1}{m_H^6} \cdot \lim_{\xi_5 \to 1} \left(\frac{2\xi - 2 - 2\ln\xi}{(\xi-1)^3 + 3\xi(\xi-1)^2} \right) = \frac{1}{m_H^6} \cdot \lim_{\xi_5 \to 1} \left(\frac{1}{3\xi(12\xi - 6)} \right) = \frac{1}{18 \cdot m_H^6}$$

Sample: integration results for –ctHW–

$$J_{12}^{HW}(m_{c,t,H,W}^2) = \frac{1}{m_W^2} \left[\frac{\xi_6^2 \ln\xi_6 (\xi_2 - \xi_1) + \xi_2^2 \ln\xi_2 (\xi_1 - \xi_6) + \xi_1^2 \ln\xi_1 (\xi_6 - \xi_2)}{(1-\xi_6)(\xi_1 - 1)(\xi_2 - \xi_6)(\xi_2 - 1)(\xi_1 - \xi_6)(\xi_1 - \xi_2)} + \right.$$

$$\left. + \frac{\xi_2^2 \xi_6^2 \ln\xi_5 (1 - \xi_1) + \xi_1^2 \xi_6^2 \ln\xi_4 (\xi_2 - 1) + \xi_1^2 \xi_2^2 \ln\xi_3 (\xi_6 - 1)}{(1-\xi_6)(\xi_1 - 1)(\xi_2 - \xi_6)(\xi_2 - 1)(\xi_1 - \xi_6)(\xi_1 - \xi_2)} \right].$$

EXACT RESULTS

System. 2-7. K-mesons. MSSM. Integrals

Elimination of singularities strictly depends on the sort of the certain propagator

Feynman propogator for a scalar particle:

$$D_F(x-y) \;=\; \int \frac{d^4k}{(2\pi)^4}\cdot\frac{i}{k^2-m^2+i\varepsilon}\cdot e^{-ik\cdot(x-y)}$$

Basic fermionic propagator:

$$\Pi_t^0 \;=\; \frac{i}{\hat{k}-m_t} \;=\; i\,\frac{\hat{k}+m_t}{k^2-m_t^2} \;\sim\; \frac{1}{k^2-m_t^2}$$

Summing over all sorts of single-particle irreducable insertions:

$$\Pi_t^{1'} \;=\; \frac{1}{\hat{k}-m_t-\Sigma(k)} \;\longrightarrow\; \Pi_t^{1'} \;\sim\; \frac{1}{k^2-m_t^2-M^2(k^2)}$$

$$\Sigma = A\left(k^2\right) \;+\; \hat{k}\,B\left(k^2\right)$$

Expressing the full width via an imaginary part of self-energy:

$$\Gamma \;=\; -\frac{Z}{m}\mathrm{Im}\,M^2(m^2)$$

Gauge-invariant:

$$\Pi_t^2 \;=\; i\,\frac{\hat{k}+m_t-i\frac{\Gamma_t}{2}}{k^2-m_t^2+im_t\Gamma_t-\frac{\Gamma_t^2}{4}}$$

Breit-Wigner propogator ~ Laurent Series first sum.:

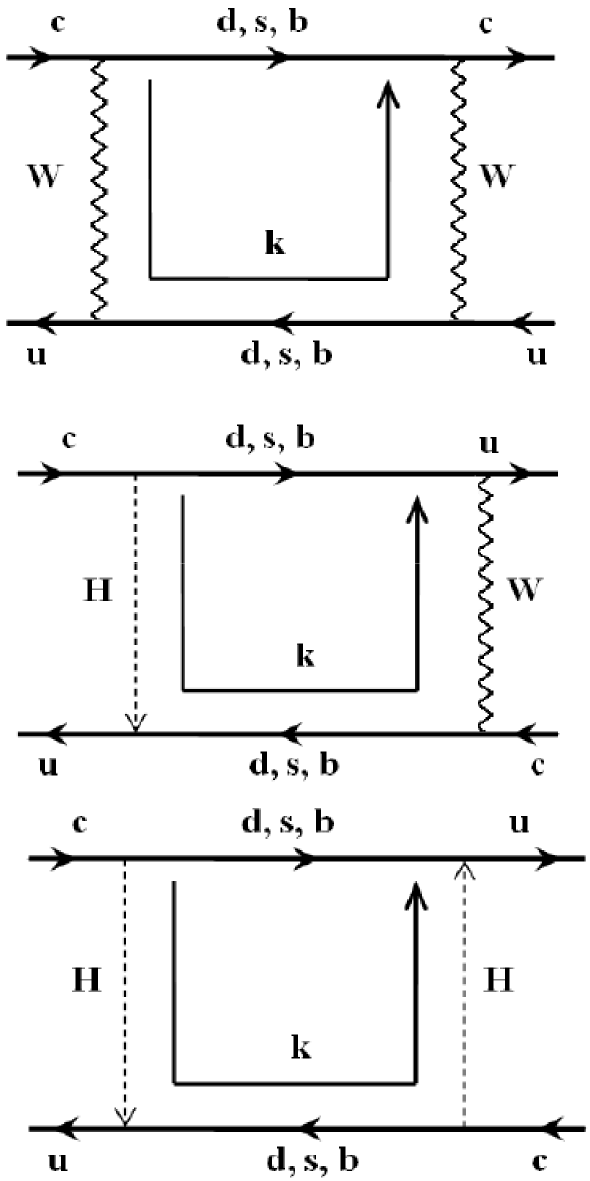
$$\Pi_t^1 \;=\; \frac{k^2-m_t^2}{(k^2-m_t^2)^2+m_t^2\Gamma_t^2}+i\,\frac{m_t\Gamma_t}{(k^2-m_t^2)^2+m_t^2\Gamma_t^2}$$

$$J_{11}^{HH}(m_H^2,m_t^2) \;=\; \int d'^4k\;(\Pi_H^0)^2\cdot(\Pi_t^1)^2 \;=\; \int\limits_0^{+\infty}\frac{dt\cdot[(t+a)^2-c^2]}{[(t+a)^2+c^2]^2\cdot(t+b)^2}$$

Sirlin A. Theoretical considerations concerning the Z_0 mass // Phys. Rev. Lett., 1991. **67**. P. 2127.

Nowakowski M., Pilaftsis A. On gauge invariance of Breit-Wigner propagators // Z. Phys., 1993. **C60**. P. 121.

System. 2-8. D-mesons. MSSM. HW and HH.



$$\underset{\sim\lambda}{V_{ud}^*V_{cd}} + \underset{\sim\lambda}{V_{us}^*V_{cs}} + \underset{\sim\lambda^5}{V_{ub}^*V_{cb}} \;=\; 0\,, \quad \longrightarrow \quad \frac{(V_{us}^*V_{cs})^2 m_s^2}{(V_{ub}^*V_{cb})^2 m_b^2} \sim \frac{\lambda^8 m_s^2}{m_b^2} \approx 600,$$

$$\Delta m_D^{HW} = \frac{C_H G_F f_D^2 B_D m_D m_u m_c}{48\pi^2 m_W^2 \mathrm{tg}^2\beta}(V_{us}^*V_{cs})^2 m_s^2 -$$

$$- \frac{C_H G_F f_D^2 B_D m_D \mathrm{tg}^2\beta}{24\pi^2 m_W^2}\left[(V_{us}^*V_{cs})^2 m_s^4\left(\ln\left(\frac{\Lambda+m_s^2}{m_s^2}\right) - \frac{\Lambda}{\Lambda+m_s^2}\right) +\right.$$

$$+ 2\cdot V_{us}^*V_{ub}^*V_{cs}V_{cb}m_s^2m_b^2\left(\frac{m_b^2}{m_b^2-m_s^2}\ln\left(\frac{\Lambda+m_b^2}{m_b^2}\right) - \frac{m_s^2}{m_b^2-m_s^2}\ln\left(\frac{\Lambda+m_s^2}{m_s^2}\right)\right) +$$

$$\left. + (V_{ub}^*V_{cb})^2 m_b^4\left(\ln\left(\frac{\Lambda+m_b^2}{m_b^2}\right) - \frac{\Lambda}{\Lambda+m_b^2}\right)\right].$$

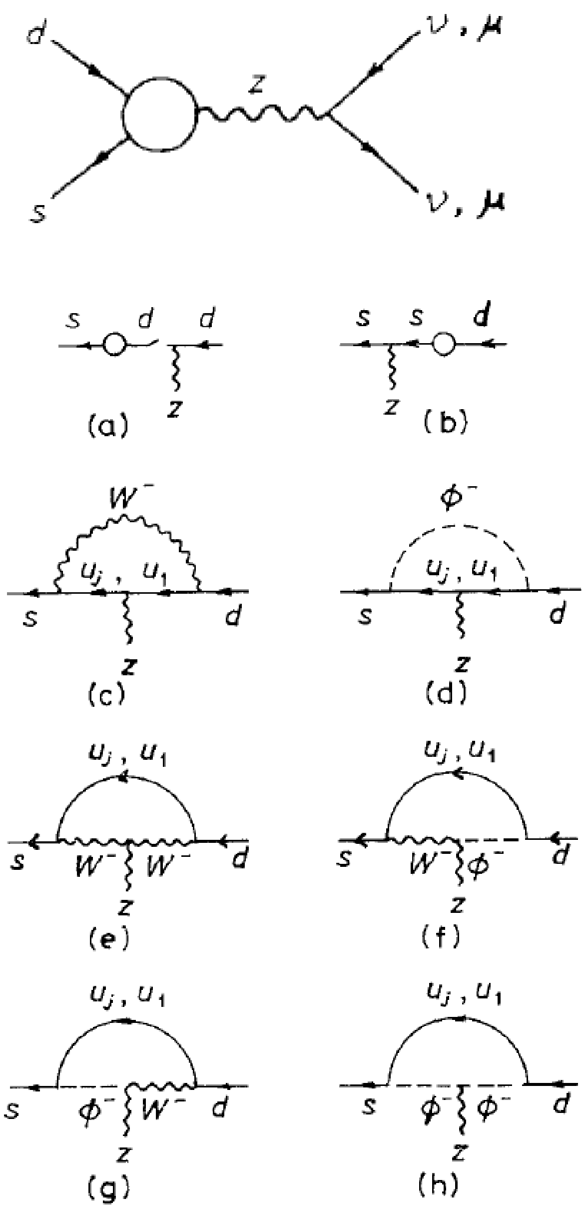
$$\Delta m_D^{HH-appr} = -\frac{5\, B_D^S\, L\cdot \mathrm{tg}^4\beta m_s^4}{32\, B_D}\,\cdot$$

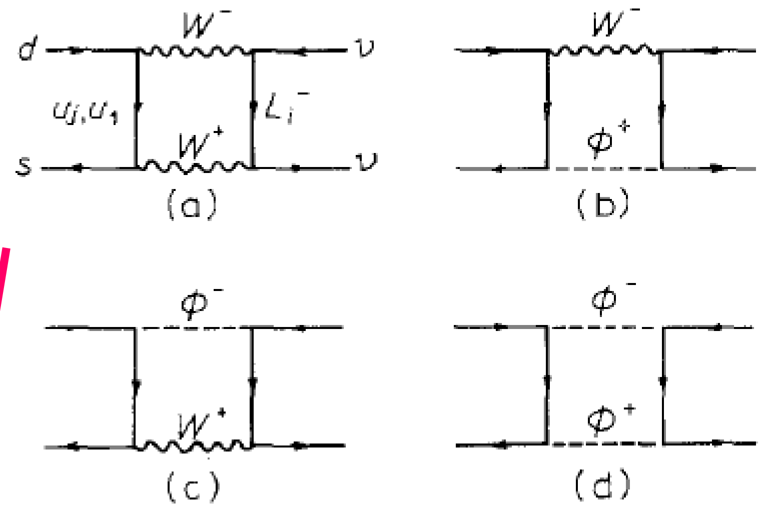
$$\cdot\,\mathrm{Re}\left[(V_{us}^*V_{cs})^2\left(\Lambda\cdot\frac{\Lambda+2m_s^2}{\Lambda+m_s^2} + 2m_s^2\ln\left(\frac{m_s^2}{\Lambda+m_s^2}\right)\right)\right]$$

$$L = \frac{C_H^2 f_D^2 B_D m_D}{384 m_W^4 \pi^2}$$

ONLY FOUR-FERMION APROXIMATION (!)

System. 2-9. Rare Decays. SM. K-mesons





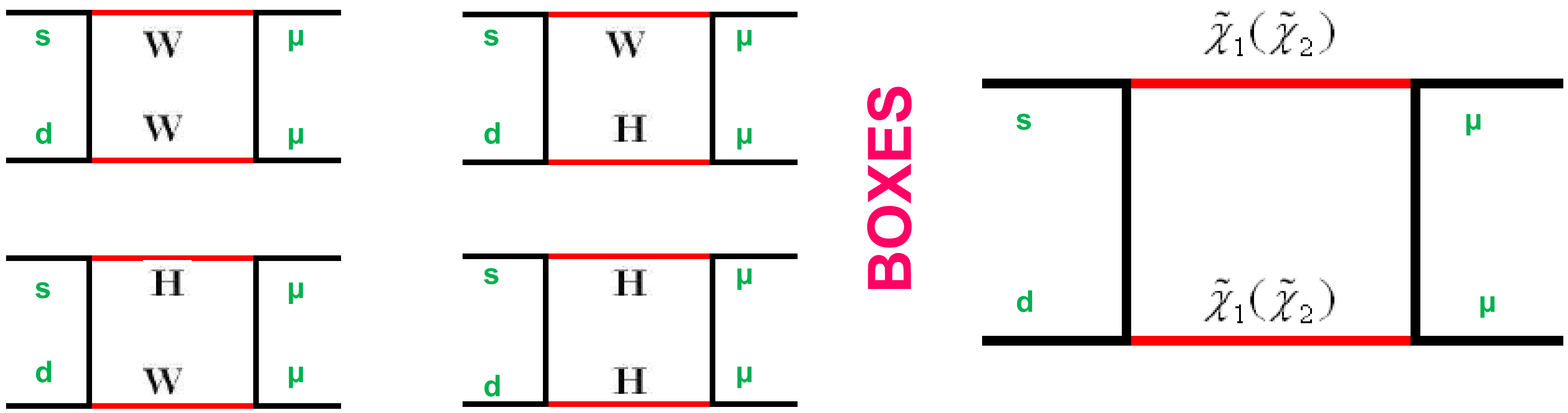
$$\bar{C}_{\square} = -\frac{3}{8}\frac{x_j}{(x_j-1)^2}\ln x_j - \frac{3}{8}\frac{1}{x_j-1} - c(x_j,\xi) - (x_j \to x_1)$$

$$\Gamma_Z \equiv \sum_{i=1}^{h} \Gamma^{(i)} = \frac{1}{4}x_j - \frac{3}{8}\frac{1}{x_j-1} + \frac{3}{8}\frac{2x_j^2-x_j}{(x_j-1)^2}\ln x_j + \gamma(x_j,\xi) - (x_j \to x_1)$$

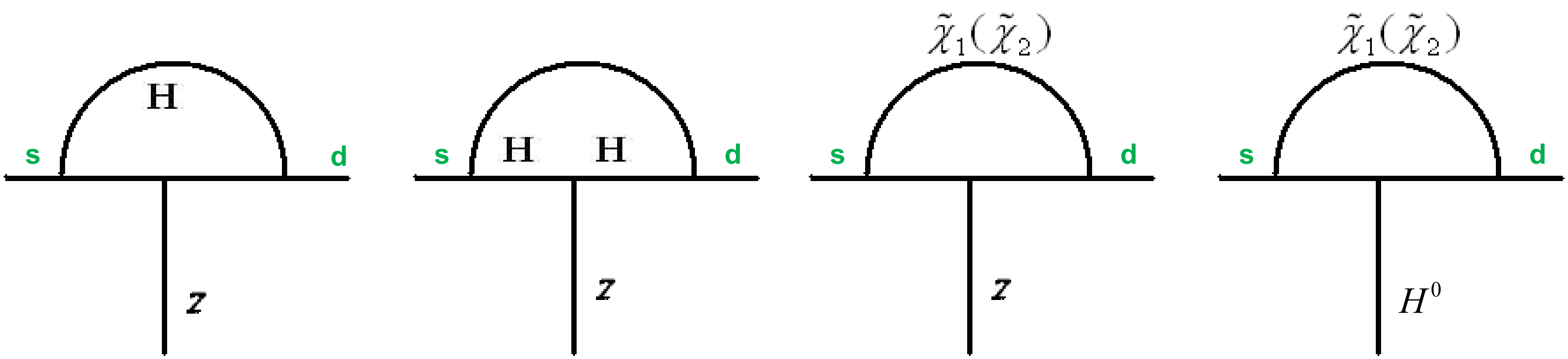
$$\bar{C} = \bar{C}(x_j, x_1=0) = \frac{3}{4}\left(\frac{x_j}{x_j-1}\right)^2 \ln x_j + \frac{1}{4}x_j - \frac{3}{4}\frac{x_j}{x_j-1}$$

$$\mathcal{L}_{\text{eff}} = \frac{G_F}{\sqrt{2}}\{\varkappa[4\,\bar{s}_L\gamma_\mu d_L(\tilde{C}\mu_L\gamma^\mu\mu_L - \sum_{i=1}^{N}\tilde{D}_i\nu_{Li}\gamma^\mu\nu_{Li}) + \tilde{E}(\bar{s}_L\gamma_\mu d_L)^2] + (\alpha/4\pi)[\tilde{H}_1\,\bar{s}_L\gamma_\mu d_L + \tilde{H}_2\Box^{-1}\partial^\nu(m_s\bar{s}_L\sigma_{\mu\nu}d_L + m_d\bar{s}_R\sigma_{\mu\nu}d_R)]\mu\gamma^\mu\mu\} + \text{h.c.}$$

System. 2-9. Rare Decays. MSSM. K-mesons



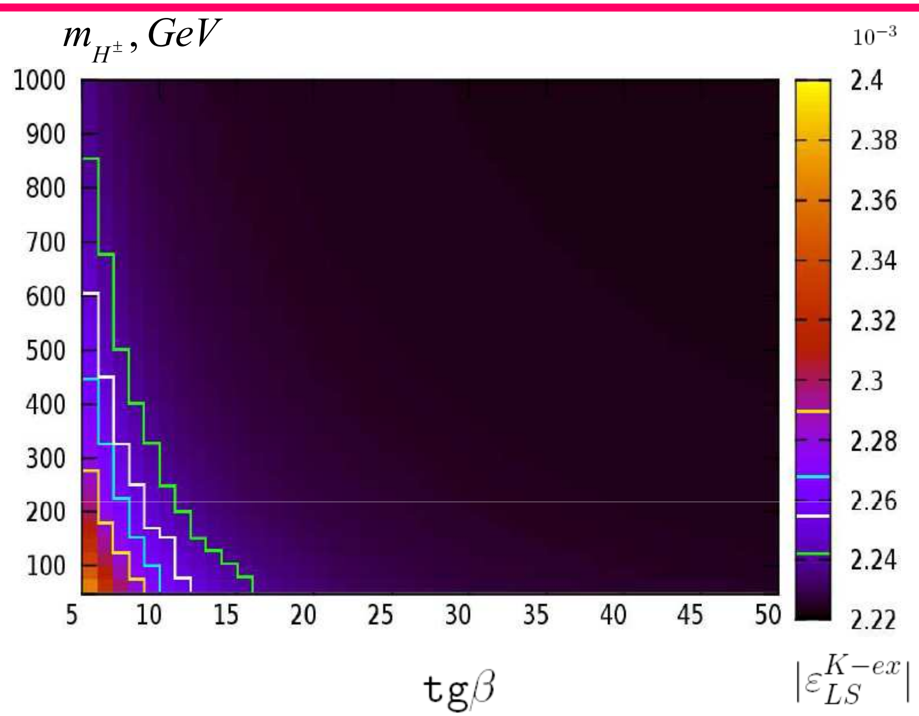
BOXES

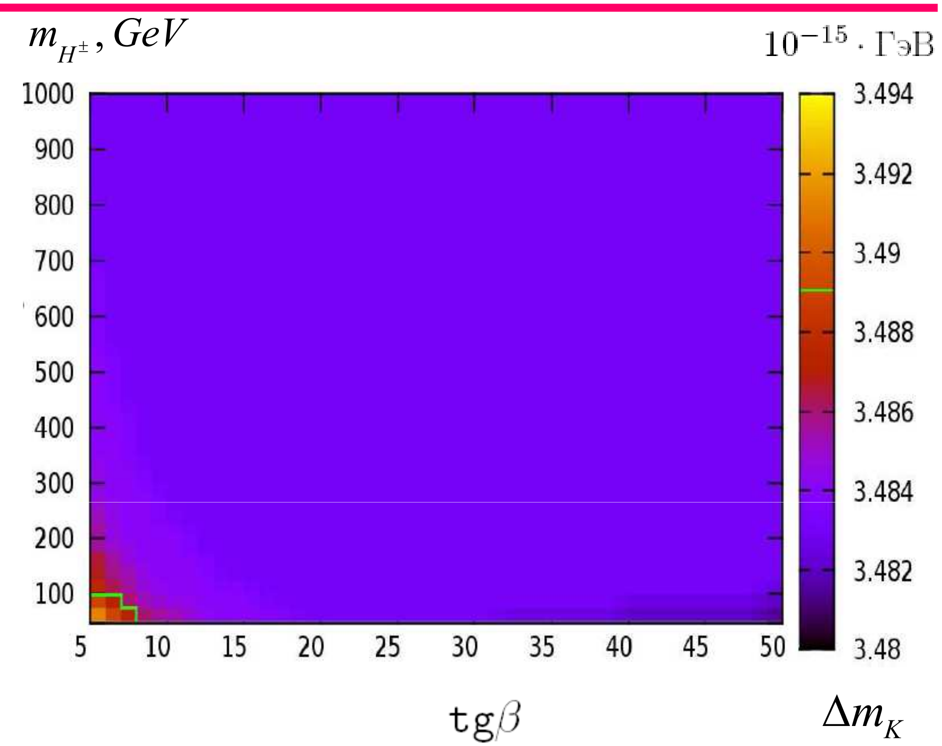


PENGUINS

Numerical Results. K-mesons

EXACT RESULTS



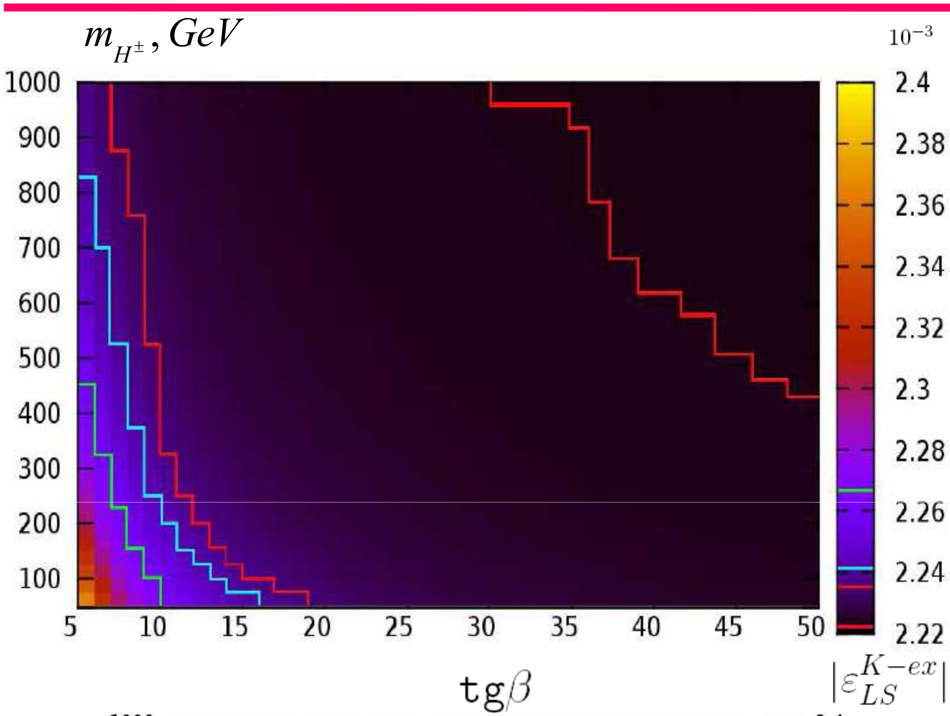


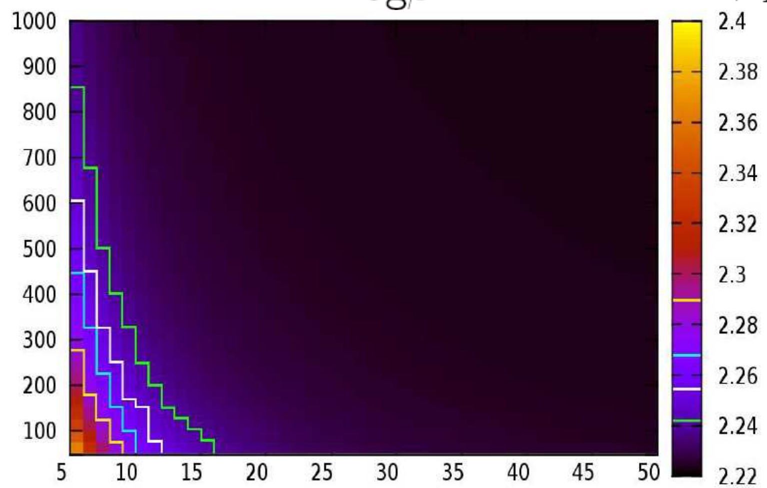
$m_{H^\pm}$(ГэВ) / tgβ	5	10	15	20
50	*2.399*	*2.266*	*2.242*	2.233
75	*2.379*	*2.261*	2.239	2.232
100	*2.362*	*2.257*	2.237	2.231
125	*2.346*	*2.253*	2.236	2.230
150	*2.334*	*2.250*	2.234	2.229
175	*2.323*	*2.247*	2.233	2.228
200	*2.313*	*2.245*	2.232	2.228

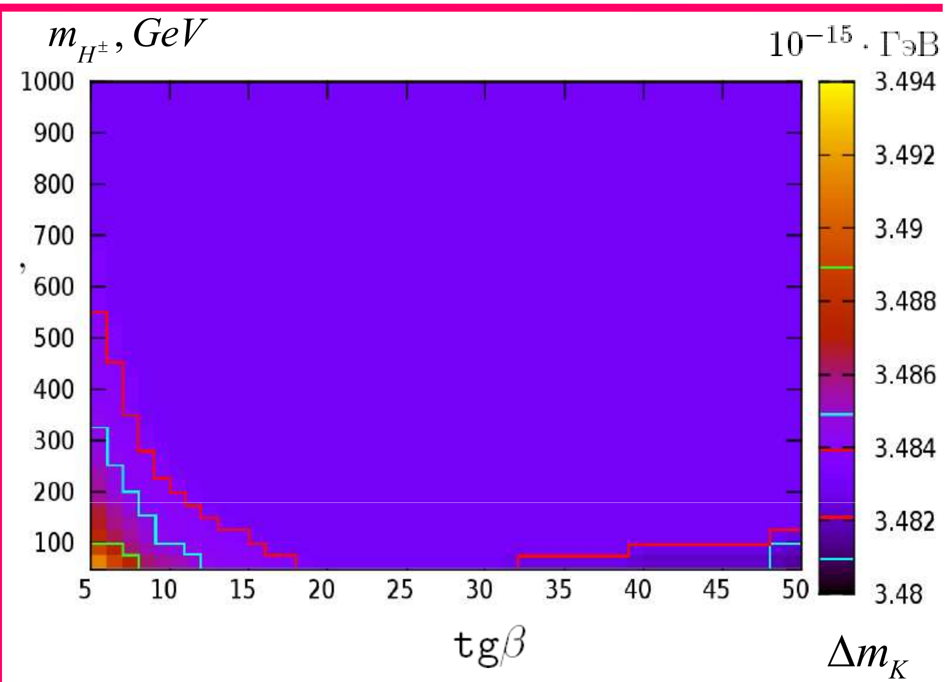
$m_{H^\pm}$(ГэВ) / tgβ	5	10	15	20
50	*3.494*	3.486	3.484	3.483
75	*3.491*	3.485	3.484	3.483
100	3.489	3.484	3.484	3.483
125	3.488	3.484	3.483	3.483
150	3.487	3.484	3.483	3.483
175	3.487	3.484	3.483	3.483
200	3.486	3.484	3.483	3.483

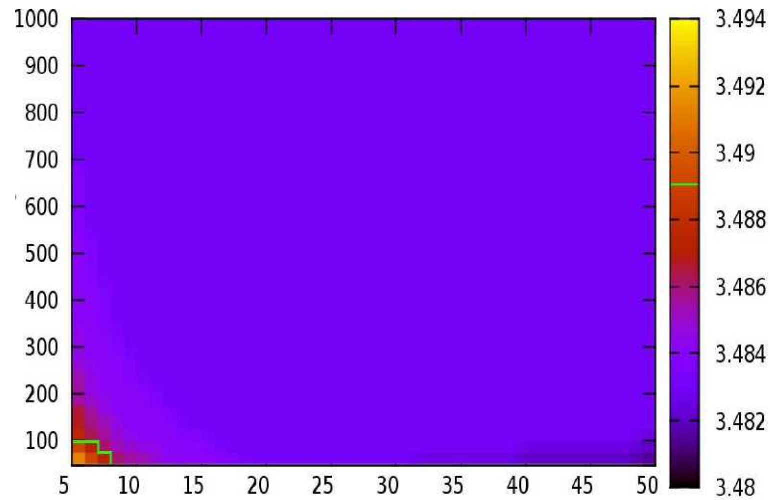
Numerical Results. K-mesons

EXACT RESULTS (THE FUTURE IS YET TO COME)

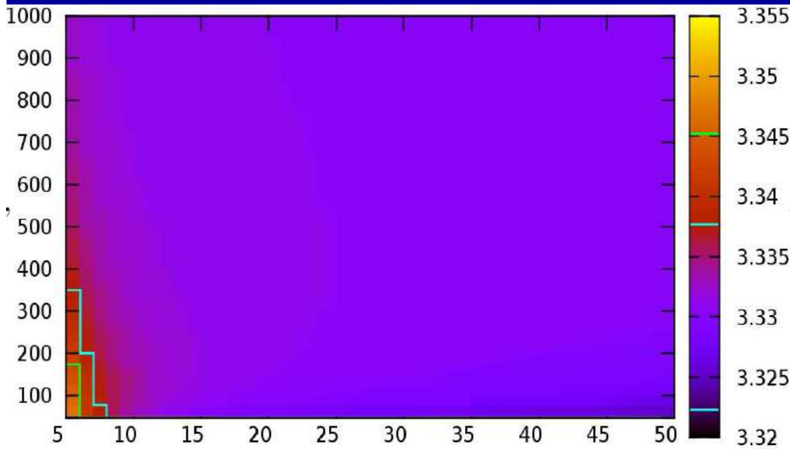








Numerical Results. B-mesons



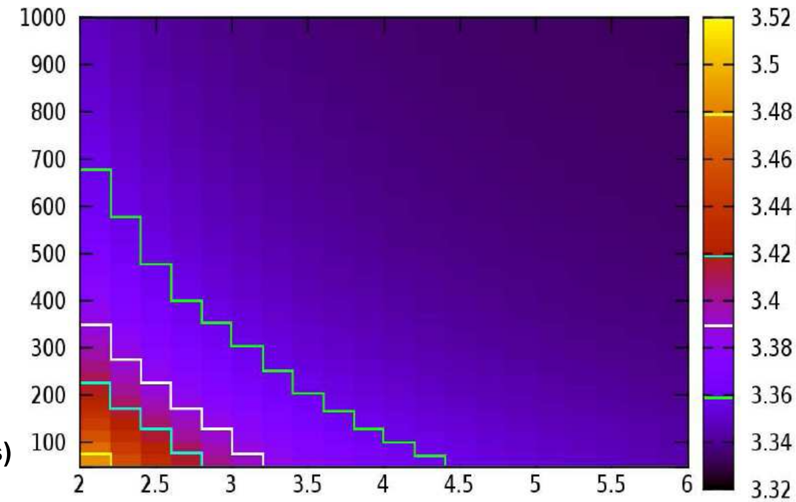
$$\Delta m_{LS}^{B_d(exp)} = (3.33 \pm 0.03) \cdot 10^{-13}\ \text{ГэВ}$$

$$B_d$$

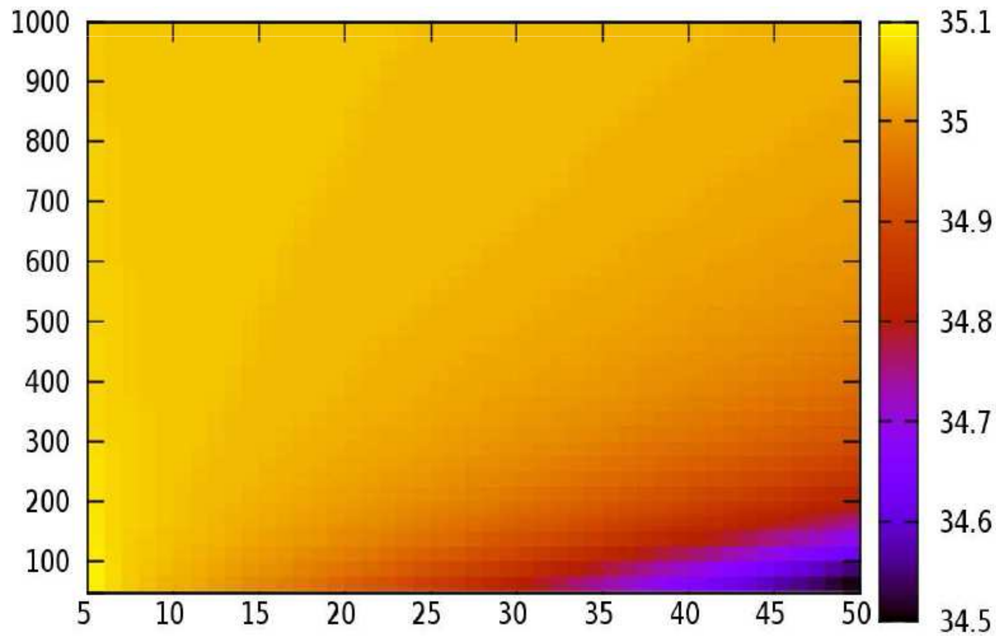
$$\Delta m_{B_d}$$

$$(\text{в}\, 10^{-13}\ GeV)$$

(Standard designations)



$m_{H^\pm}, GeV$



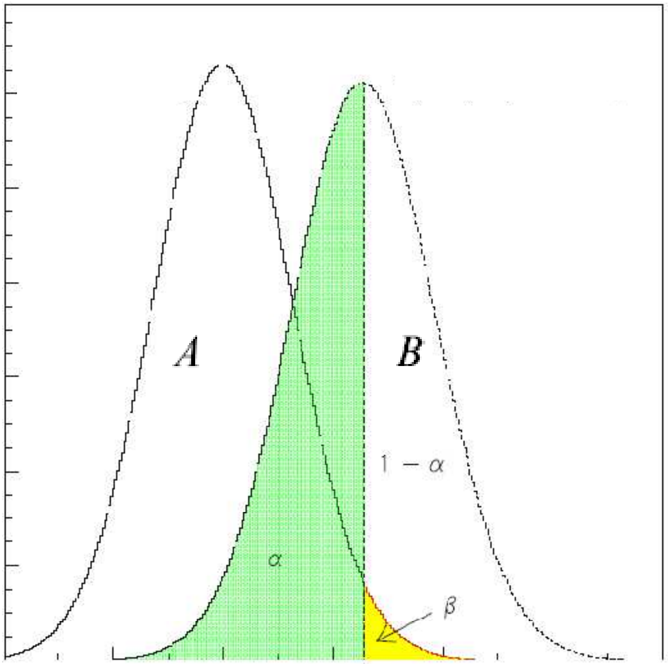
$\mathrm{tg}\beta$

$$\frac{\Delta m^0_{B_s}}{\Delta m^0_{B_d}}$$

$$\frac{\Delta m^{exp}_{B_s}}{\Delta m^{exp}_{B_d}} = 35.05$$

EXACT RESULTS

Numerical results. Estimates



ESTIMATE SAMPLE (K-Mesons)

Error of measurements: $\pm 0.006 \cdot 10^{-15}\,GeV$

Confidence level: $> 1.05\,\sigma$

Distinguishability: $> 86\%$

Boundaries: $\Delta m_{LS}^{appr-K} > 3.492 \cdot 10^{-15}\,GeV$

$tg\beta < 6 \quad u \quad m_{H^{\pm}} > 225\,GeV$

FOUR-FERMION APPROXIMATION

The statistical approach has been used [6].

1. Hypotheses

H_0 : *new physics is present in Nature*

H_1 : *new physics is absent in Nature*

2. Errors

$$\alpha = P(reject\ \mathrm{H}_0 | \mathrm{H}_0\ is\ true)$$

$$\beta = P(accept\ \mathrm{H}_0 | \mathrm{H}_0\ is\ false)$$

3. Functions

$f_0(n) = f(n; \mu_s + \mu_b),$

$f_1(n) = f(n; \mu_b).$

[6] – S.I. Bityukov and N.V. Krasnikov, Nucl. Instr. And Meth., A 534, P 152 (2004)

4. Universal method of error estimation:

$$\tilde{\kappa} = \frac{A \bigcap B}{A \bigcup B} = \frac{\hat{\alpha} + \hat{\beta}}{2 - (\hat{\alpha} + \hat{\beta})}$$ Uncertainty (Geometrical)

$$\tilde{\kappa} = \frac{\hat{\kappa}}{1 - \hat{\kappa}}$$ Uncertainty (arithmetical)

5. Estimators:

$\kappa = 1 - \tilde{k}$ Distinguishability (in %)

$\zeta = 1 - \hat{k}$ Confidence level (in σ)

Numerical results. Estimations

Theoretical boundaries for exact results

Excluded regions:

1. K-mesons:

$\kappa > 86\%$

$\zeta > 1.05\,\sigma$

$m_{H^\pm} < 100\,\text{ГэВ}$ $5 < \text{tg}\beta < 15$	$m_{H^\pm} < 325\,\text{ГэВ}$ $5 < \text{tg}\beta < 10$
$\text{tg}\beta < 5$	???

2. D-mesons (?):

3. B(d)-mesons:

4. B(s)-mesons:

$\text{tg}\beta < 2$ $\kappa > 97.5\%$ $\zeta > 2\,\sigma$	$m_{H^\pm} < 100\ \text{ГэВ}$ $\text{tg}\beta > 40$

5. COMBINED FIT (SOFT): $\zeta > 1.05\,\sigma$ $\kappa > 86\%$

$\text{tg}\beta < 5$	$m_{H^\pm} < 325\,\text{ГэВ}$ $5 < \text{tg}\beta < 10$	$m_{H^\pm} < 150\ \text{ГэВ}$ $\text{tg}\beta > 30$

Conclusions

- **It's shown that HW-, HH- and HG- contributions are tiny in comparison with those of the SM in the largest region of the MSSM parameter plane as they also decrease with the increase of** $\tan\beta$ **and** $m_{H^\pm}$ **for K-mesons and B-mesons as well.**

- **An entire set of Vysotsky-Inami-Lim analogue functions is obtained. VIL analogues are shown to have common limits with the results of four-fermion low-energy approximation, where it's meant that one fixes a cutoff constant during loop integration while using the latter.**

- **An estimation of possible constraints of the MSSM parameters space has been performed with the use of Bityukov-Krasnikov statistical approach. A region of low** $\tan\beta \sim 5-10$ **is found, where roots of the PBSM can be discovered with distuingishability** $\kappa > 86\%$ **and confidence level** $\zeta > 1.05\sigma$ **at modest** $m_{H^\pm} < 325\ GeV$ **Excluded regions are found with somewhat stricter bounds on κ and ζ. It's shown for the first time (based on** B_s^0 **–mesons studies) that considerable deviations from the SM do exist in the region of large** $\mathrm{tg}\beta > 40$ **and low values of the charged Higgs mass** $m_{H^\pm} < 150\ GeV$ **.**

Prospects

1. Mass splitting and non-direct CP-violation effects in neutral mesons due to chargino-stop exchanges can be large on the outskirts of the MSSM parameter plane.

2. Evaluation of penguin and box diagrams with charged higgs and charginos for direct CP-violation quantities and asymmetries.

3. Box and penguin diagrams for rare decays in B-, K- and D-meson systems with scalar bosons and superpartners.

4. Finite temperature effects and corresponding constraints for the MSSM parameters space (based on “CP Violation Evidence and Phase Transition in Extended Higgs Sector” by Mikhail Dolgopolov, Elsa Rykova and Mikhail Dubinin).

Thanks for Your Attention!

BACKUP SLIDES

Highlights - R

1. Model and motivation: what are the main boundary conditions for MSSM basic parameters?

2. System: evaluation of main mixing parameters for various neutral meson systems ($K^0, D^0, B^0_{d,s}$) -> direct applications to purely leptonic rare decays.

3. Numerical results: full-fledged comparison of evaluated observables with experimental data -> bounding MSSM parameter space.

4. Future prospects and conclusions

Model. R-1. Details

$$\text{h, H, A} \xrightarrow[\|a_{ij}^{CP}\|]{\textbf{CP}} \text{h(1), h(2), h(3)}$$

$$m_{H^\pm}^2 = m_W^2 + m_A^2 - \frac{v^2}{2}(\mathrm{Re}\Delta\lambda_5 - \Delta\lambda_4)\,, m_A = m_A(\varphi = 0)$$ [2]

$$\Delta\lambda_4 = -\frac{3\,g_2^2}{32\pi^2}\,(h_t^2 + h_b^2)\ \ln\left(\frac{M_{\rm SUSY}^2}{m_{\rm top}^2}\right) + \frac{3}{8\pi^2}\,h_t^2 h_b^2\left[\ln\left(\frac{M_{\rm SUSY}^2}{m_{\rm top}^2}\right) + \frac{1}{2}X_{tb}\right] -$$
$$- \frac{3}{96\pi^2}\,\frac{|\mu|^2}{M_{\rm SUSY}^2}\left[h_t^4\left(3 - \frac{|A_t|^2}{M_{\rm SUSY}^2}\right) + h_b^4\left(3 - \frac{|A_b|^2}{M_{\rm SUSY}^2}\right)\right] +$$
$$+ \frac{3g_2^2\,[h_b^2(|\mu|^2 - |A_b|^2) + h_t^2(|\mu|^2 - |A_t|^2)]}{64\pi^2 M_{\rm SUSY}^2} + \frac{3g_2^4}{64\pi^2}\ \ln\left(\frac{M_{\rm SUSY}^2}{m_{\rm top}^2}\right),$$

$$\Delta\lambda_5 = \frac{3}{96\,\pi^2}\left(h_t^4\left(\frac{\mu A_t}{M_{\rm SUSY}^2}\right)^2 + h_b^4\left(\frac{\mu A_b}{M_{\rm SUSY}^2}\right)^2\right)$$

$$X_{tb} \equiv \frac{|A_t|^2 + |A_b|^2 + 2\mathrm{Re}(A_b^* A_t)}{2M_{\rm SUSY}^2} - \frac{|\mu|^2}{M_{\rm SUSY}^2} - \frac{||\mu|^2 - A_b^* A_t|^2}{6M_{\rm SUSY}^4}$$

Model. R-2. Details

Main Assumptions:

- **CPX scenario[2]:** $\mu = 2\,A_{t,b} = 4\,M_{SUSY}$, $M_{SUSY} = 500\ \mathrm{GeV}$
- **Phase universality:** $\varphi = \arg(\mu A_b) = \arg(\mu A_t)$

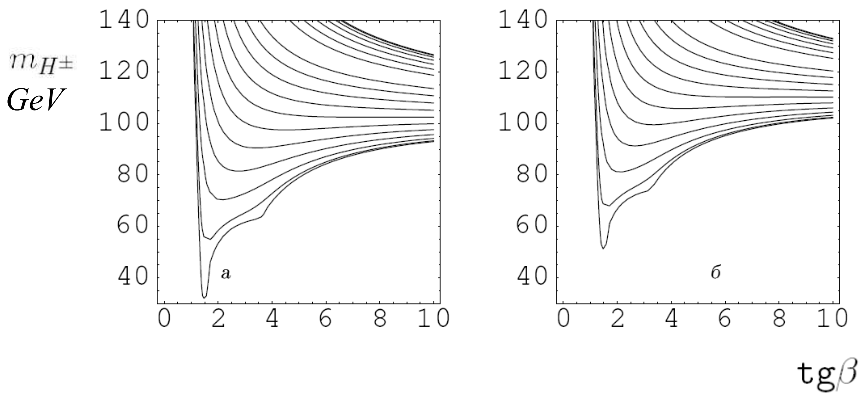
LEP2 limits

SM: $m_h > 114\ GeV$

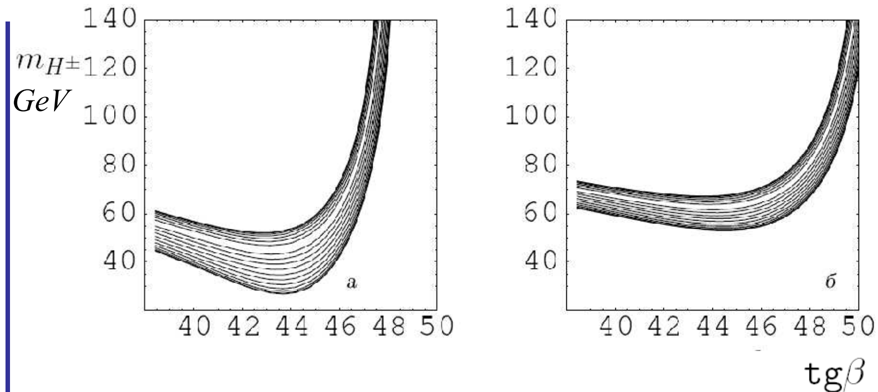
$e^+e^- \to ZH$

MSSM: $m_{H^\pm} > 79.3\ GeV$

$e^+e^- \to H^+H^-$



Pl. 1: Charged Higgs under the certain assumptions: (a) $m_{h_1} > 0$, (b) $m_{h_1} = 40\ GeV$ as a function of $tg\,\beta = v_2 / v_1$. φ varies from zero (the lowest outline) to 180 degrees (the highest outline) with 10 degree increment with each selected outline. CPX scenario is used. Below the certain outline the lightest neutral Higgs possesses either a negative mass or one, which is lower than 40 GeV.



Pl. 2: Charged Higgs Boson in the model with: $m_{h_1} \sim 50\ GeV$ at large values of $tg\,\beta$.

(a) $A_{t,b} = 890\ \mathrm{GeV}$, $\mu = 2000\ \mathrm{GeV}$

(b) $A_{t,b} = 890\ \mathrm{GeV}$, $\mu = 1900\ \mathrm{GeV}$

[2] – M. Carena et. al., Nucl. Phys., B 659, P. 145 (2003);

System. R-1. Neutral K-mesons

$$CP|K^0>=|\tilde{K}^0>,$$
$$CP|\tilde{K}^0>=|K^0>$$

1). Mass splitting

$$\Delta m = m_1 - m_2 = <K|H|\tilde{K}> + <\tilde{K}|H|K>$$

CP eigenstates

$$K_1^0 = \frac{K^0+\tilde{K}^0}{\sqrt{2}}, \quad CP|K_1^0>=+|K_1^0>,$$
$$K_2^0 = \frac{K^0-\tilde{K}^0}{\sqrt{2}}, \quad CP|K_2^0>=-|K_2^0>$$

$$\eta_{00} \equiv \frac{<\pi^0\pi^0|H|K_L>}{<\pi^0\pi^0|H|K_S>}, \quad \eta_{+-} \equiv \frac{<\pi^+\pi^-|H|K_L>}{<\pi^+\pi^-|H|K_S>}$$

$$\eta_{00} = \varepsilon_K - 2\varepsilon'_K$$
$$\eta_{+-} = \varepsilon_K + \varepsilon'_K$$

Cronin, Fitch – 1964 – CP-violation

2). CP violation

$$\left.\begin{array}{l}|K^0>\\|\tilde{K}^0>\end{array}\right\} \Rightarrow \left\{\begin{array}{l}|K_1^0>\\|K_2^0>\end{array}\right\} \Rightarrow \left\{\begin{array}{l}|K_S^0>\\|K_L^0>\end{array}\right\}$$

$$K_L^0 = \frac{1}{\sqrt{1+|\varepsilon|^2}}(K_2^0+\varepsilon K_1^0),$$
$$K_s^0 = \frac{1}{\sqrt{1+|\varepsilon|^2}}(K_1^0+\varepsilon K_2^0)$$

System. R-2. K-mesons. QCD Corrections

1). Perturbative

$$\eta_2 = \eta_5 = \eta_8 = [\alpha_s(m_c)]^{2/9}\left(\frac{\alpha_s(m_b)}{\alpha_s(m_c)}\right)^{6/25}\left(\frac{\alpha_s(m_W)}{\alpha_s(m_c)}\right)^{6/23} = 0.57$$

$$\eta_6 = \eta_9 = [\alpha_s(m_c)]^{2/9}\left(\frac{\alpha_s(m_b)}{\alpha_s(m_c)}\right)^{30/25}\left(\frac{\alpha_s(m_W)}{\alpha_s(m_c)}\right)^{30/23} = 0.2$$

$$\eta_7 = [\alpha_s(m_c)]^{2/9}\left(\frac{\alpha_s(m_b)}{\alpha_s(m_c)}\right)^{54/25}\left(\frac{\alpha_s(m_W)}{\alpha_s(m_c)}\right)^{54/23} = 0.07 \qquad \eta_4 = 0.2$$

2). Non-perturbative

$$B_{B_d} \approx B_{B_s} = 1.4 \pm 0.05$$

$$B_K = B'_K(\mu)[\alpha_s^{(3)}(\mu)]^{-2/9}\left[1 + \frac{\alpha_s^{(3)}(\mu)}{4\pi}J_3\right]$$

$$B_K = \left(1 - \frac{f_\pi^2 m_\pi^2 m_s m_0^2}{32\pi^2 m_K^2 f_K^4 (m_u + m_d)}\right)[\alpha_s(s_0)]^{-2/9} \longrightarrow B_K = 1.0 \pm 0.1$$

3). Long-distance contributions: $D_K = \dfrac{\Delta m_{LS}^{K-LD}}{\Delta m_{LS}^{K-exp}} = 0.25 \pm 0.15$

System. R-3. K-mesons. QCD corrections

References

1. Perturbative QCD Corrections:

Высоцкий М.И. Переход $K^0 \to \bar{K}^0$ в Стандартной $SU(3) \otimes SU(2) \otimes U(1)$-схеме. // ЯФ 1980. **31**, №1-4. С. 1535.

Herrlich S., Nierste U. Enhancement of the $K_L - K_S$ mass difference by short distance QCD corrections beyond leading logarithms // Nucl. Phys., 1994. **B419**, N 2. P. 292.

Gabrielli E., Giudice G.F. Supersymmetric corrections to ε'/ε at the leading order in QCD and QED // Nucl.Phys., 1995. **B433**. P. 3.

2. Non-Perturbative QCD Corrections:

Chetyrkin K.G., Kataev A.L., Krasulin A.B., Pivovarov A.A. Calculation of the $K^0 - \overline{K^0}$ mixing paramterer via the QCD sum rules at finite energies // Phys. Lett., 1986. **B174**. P. 104.

Mannel T., Pecjak B.D., Pivovarov A.A Analyzing $B_s - \overline{B_s}$ mixing: Non-perturbative corrections to bag parameters from sum rules // E-print, 2007. hep-ph/0703244. PP. 31.

Nikitin N., Melikhov D. Nonfactorizable effects in the $B - \bar{B}$ mixing // Phys. Lett., 2000. **B494**. P. 229.

3. Long-Distance Contributions:

Cea P., Nardulli G. An estimate of the long distance dispersive contributions to the $K(L) - K(S)$ mass difference // Phys. Lett., 1985. **B152**. P. 251.

Hill C.T. Large distance effects in CP violation and the $K_0 - \bar{K}_0$ mass matrix // Phys. Lett., 1980. **B97**. P. 275.

System. R-4. K-mesons. MSSM. Loop Integrals

$$I_{21}^{k_\mu k_\nu} = \int \frac{d^4k \cdot k^\mu k^\nu}{i \cdot (2\pi)^4 \cdot k^2 (k^2 - m_q^2)^2} = \frac{g_{\mu\nu}}{64\pi^2} \cdot \left[\ln \left(\frac{\Lambda + m_q^2}{m_q^2} \right) - \frac{\Lambda}{\Lambda + m_q^2} \right]$$

$$I_{22}^{k_\mu k_\nu} = \frac{g_{\mu\nu}}{64\pi^2} \cdot \left[\frac{1}{m_{q2}^2 - m_{q1}^2} \left(m_{q2}^2 \ln \left(\frac{\Lambda + m_{q2}^2}{m_{q2}^2} \right) - m_{q1}^2 \ln \left(\frac{\Lambda + m_{q1}^2}{m_{q1}^2} \right) \right) \right]$$

$$I_{31}^{k_\mu k_\nu} = \int \frac{d^4k \cdot k^\mu k^\nu}{i \cdot (2\pi)^4 \cdot (k^2 - m_q^2)^2} = -\frac{g_{\mu\nu}}{64\pi^2} \cdot \left[\Lambda \cdot \frac{\Lambda + 2m_q^2}{\Lambda + m_q^2} + 2m_q^2 \ln \left(\frac{m_q^2}{\Lambda + m_q^2} \right) \right]$$

$$I_{32}^{k_\mu k_\nu} = -\frac{g_{\mu\nu}}{64\pi^2} \cdot \left[\Lambda + \frac{m_{q2}^2 + m_{q1}^2}{2} \ln \left(\frac{m_{q1}^2 m_{q2}^2}{\Lambda^2 + (m_{q2}^2 + m_{q1}^2) \cdot \Lambda + m_{q1}^2 m_{q2}^2} \right) + \right.$$

$$\left. + \frac{m_{q2}^4 + m_{q1}^4}{2 \cdot (m_{q2}^2 - m_{q1}^2)} \cdot \ln \left(\frac{m_{q2}^2 (\Lambda + m_{q1}^2)}{m_{q1}^2 (\Lambda + m_{q2}^2)} \right) \right],$$

Basic Integrals

FOUR-FERMION APPROXIMATION

$$I_{11'}^{k_\mu k_\nu}(m_{q_i}^2) = I_{31}^{k_\mu k_\nu}(m_{q_i}^2), \quad I_{12'}^{k_\mu k_\nu}(m_{q_i}^2, m_{q_j}^2) = I_{32}^{k_\mu k_\nu}(m_{q_i}^2, m_{q_j}^2)$$

$$I_{21'}(m_{q_i}^2) = I_{41}(m_{q_i}^2), \quad I_{22'}(m_{q_i}^2, m_{q_j}^2) = I_{42}(m_{q_i}^2, m_{q_j}^2)$$

$$C_{\mathrm{H}} = \frac{4\sqrt{2} m_W^2}{v^2 m_{H^\pm}^2} \approx 5.98 \times 10^{-7} \times m_{H^\pm}^{-2}$$

$$|\varepsilon_{K-appr}^{tot}| = \frac{1}{2\sqrt{2}} \frac{V_{LS}^{WW} + V_{LS}^{HW1} - V_{LS}^{HW2} + V_{LS}^{HH1} - V_{LS}^{HH2} + V_{LS}^{HH3} - V_{LS}^{HH4}}{W_{LS}^{WW} + W_{LS}^{HW1} - W_{LS}^{HW2} + W_{LS}^{HH1} - W_{LS}^{HH2} + W_{LS}^{HH3} - W_{LS}^{HH4}},$$

System. R-5. K-mesons. MSSM. Integrals

$$J_{11}^{HH}(m_H^2, m_q^2) = \int \frac{d^4k \cdot k_\mu k_\nu}{(2\pi)^4 \cdot i\, k^4 \cdot (k^2 - m_H^2)^2 \cdot (k^2 - m_q^2)^2} = -\frac{g_{\mu\nu}}{64\pi^2} \int_0^{+\infty} \frac{dt}{(t+a)^2(t+b)^2}$$

asymptotics

$$J_{11}^{HH}(m_H^2, m_q^2) \sim \frac{1}{k^8}$$

$$\int \frac{dx}{R^2} = \frac{b+2cx}{\Delta R} + \frac{2c}{\Delta}\int \frac{dx}{R}$$

$$R = a + bx + cx^2, \ \Delta = 4ac - b^2$$

$$\int \frac{dx}{R} = \frac{1}{\sqrt{-\Delta}} \ln\left(\frac{b+2cx-\sqrt{-\Delta}}{b+2cx+\sqrt{-\Delta}}\right), \ \Delta < 0$$

$$J_{11}^{HH} = \left(\frac{m_H^2 + m_q^2}{m_H^2 m_q^2 (m_q^2 - m_H^2)^2} + \frac{2}{(m_q^2 - m_H^2)^3} \ln\left(\frac{m_H^2}{m_q^2}\right)\right)$$

Dimensional variables

$$J_{11}^{HH}(m_H^2, m_{c,t}^2) = \frac{1}{m_H^6} \cdot \left(\frac{1+\xi_{4,5}}{\xi_{4,5}(\xi_{4,5}-1)^2} - \frac{2}{(\xi_{4,5}-1)^3} \ln \xi_{4,5}\right)$$

Dimentionless variables

EXACT RESULTS

System. R-6. K-mesons. MSSM. Integrals

$$\xi = \frac{m_{c,t}^2}{m_W^2}$$

Loop integrand's singularities – SM

$$I(\xi) = \left\{\frac{\xi^2 - 11\xi + 4}{4(\xi-1)^2} - \frac{3\xi^2 \ln\xi}{2(1-\xi)^3}\right\}$$

$$m_t \longrightarrow m_{W^\pm} \longleftrightarrow \xi \longrightarrow 1$$

$$\lim_{\xi\to1} I(\xi) = \lim_{\xi\to1}\left(\frac{\xi^3 - 12\xi^2 + 6\xi^2\ln\xi + 15\xi - 4}{4\cdot(\xi-1)^3}\right) =$$

$$= \lim_{\xi\to1}\left(\frac{3\xi^2 - 18\xi + 12\xi\ln\xi + 15}{12\cdot(\xi-1)^2}\right) = \lim_{\xi\to1}\left(\frac{6\xi - 6 + 12\ln\xi}{24\cdot(\xi-1)}\right) =$$

$$= \lim_{\xi\to1}\left(\frac{6+\frac{12}{\xi}}{24}\right) = \frac{3}{4}$$

Loop integrand's singularities – MSSM

$$\xi_5 = \frac{m_t^2}{m_H^2} \qquad J_{11}^{HH}(m_H^2, m_t^2) = \frac{1}{m_H^6}\cdot\left(\frac{1+\xi_5}{\xi_5(\xi_5-1)^2} - \frac{2}{(\xi_5-1)^3}\ln\xi_5\right) \qquad \xi_5 \longrightarrow 1$$

L'Hospital Rules

$$\lim_{\xi_5\to1} J_{11}^{HH}(\xi_5) = \frac{1}{m_H^6}\cdot\lim_{\xi_5\to1}\left(\frac{\xi_5^2 - 1 - 2\xi_5\ln\xi_5}{\xi_5\cdot(\xi_5-1)^3}\right) =$$

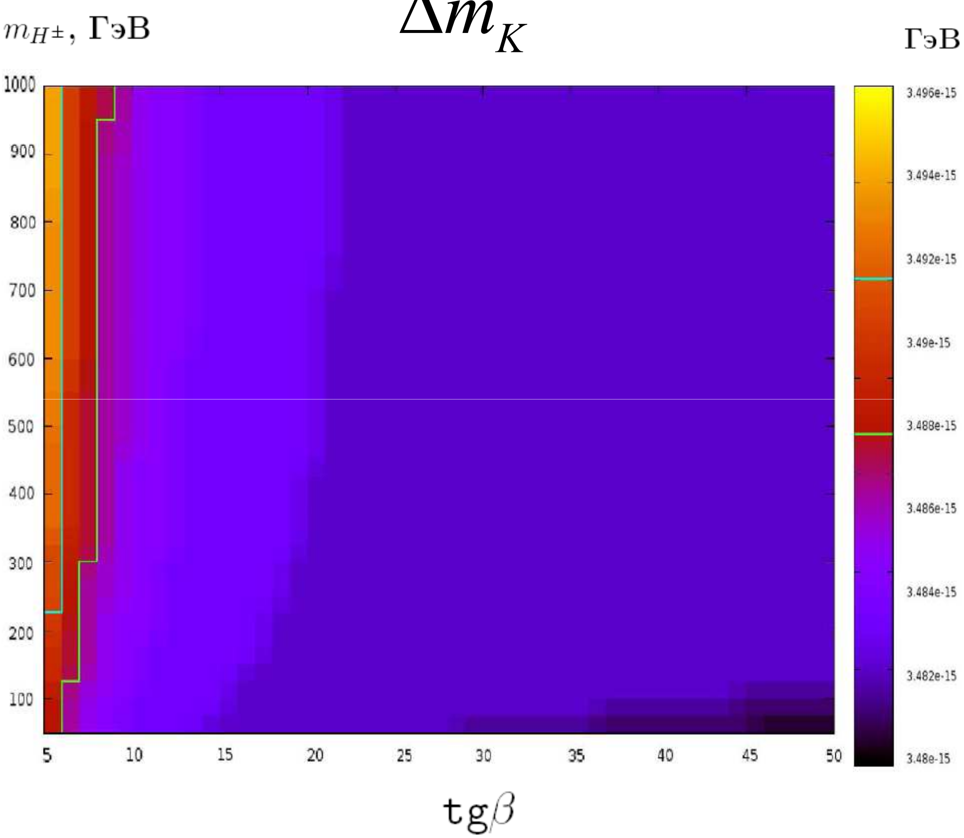
$$= \frac{1}{m_H^6}\cdot\lim_{\xi_5\to1}\left(\frac{2\xi - 2 - 2\ln\xi}{(\xi-1)^3 + 3\xi(\xi-1)^2}\right) = \frac{1}{m_H^6}\cdot\lim_{\xi_5\to1}\left(\frac{1}{3\xi(12\xi-6)}\right) = \frac{1}{18\cdot m_H^6}$$

EXACT RESULTS

Numerical Results. R-1. K-mesons

FOUR-FERMION APPROXIMATION

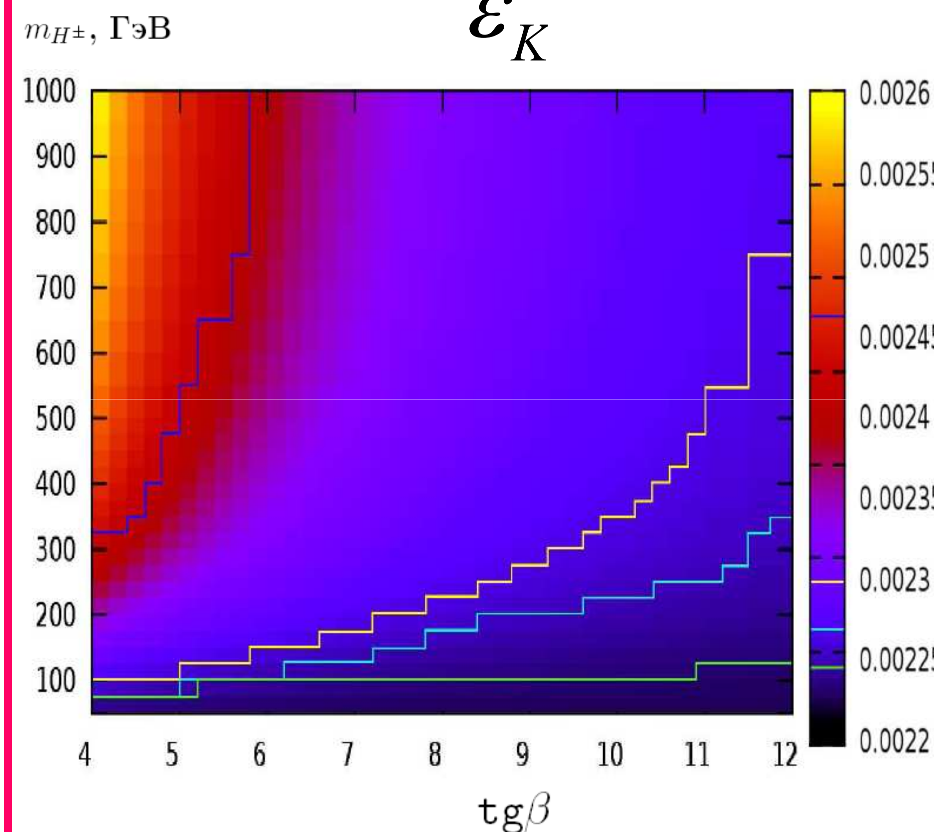
Δm_K



$$\Delta m_{LS}^{exp} = (3.483 \pm 0.006) \cdot 10^{-15}\ \text{ГэВ}$$

Mass Splitting

ε_K

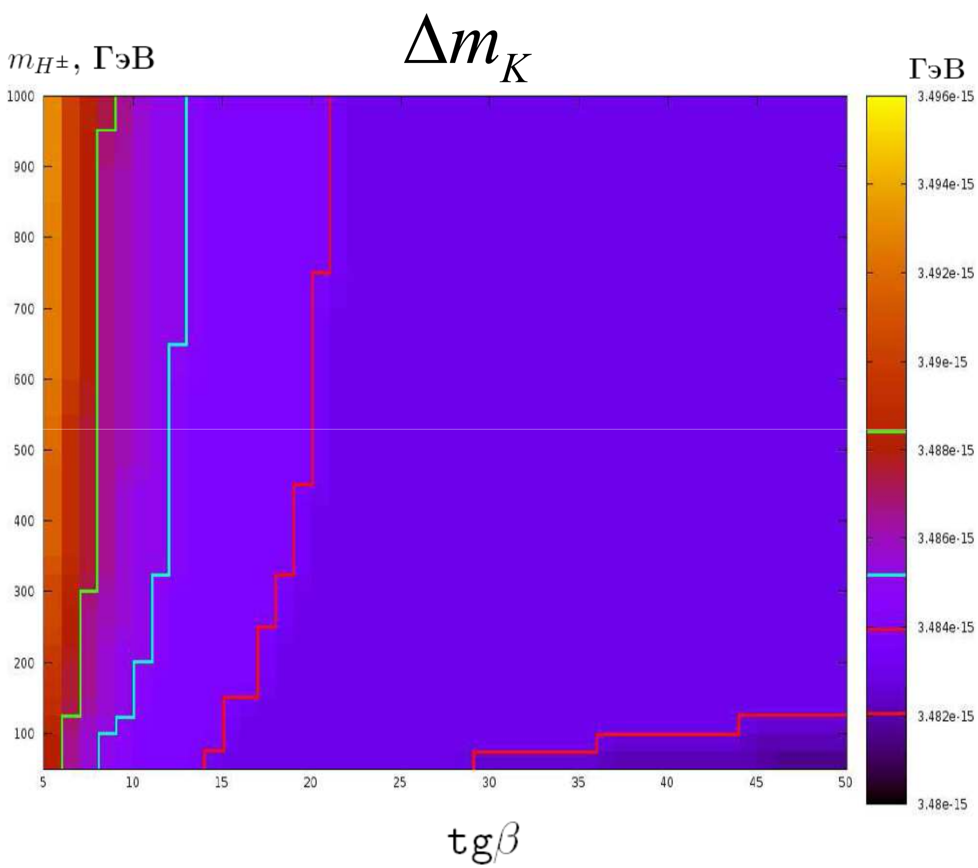


$$|\varepsilon_{LS}^{exp}| = (2.229 \pm 0.012) \cdot 10^{-3}$$

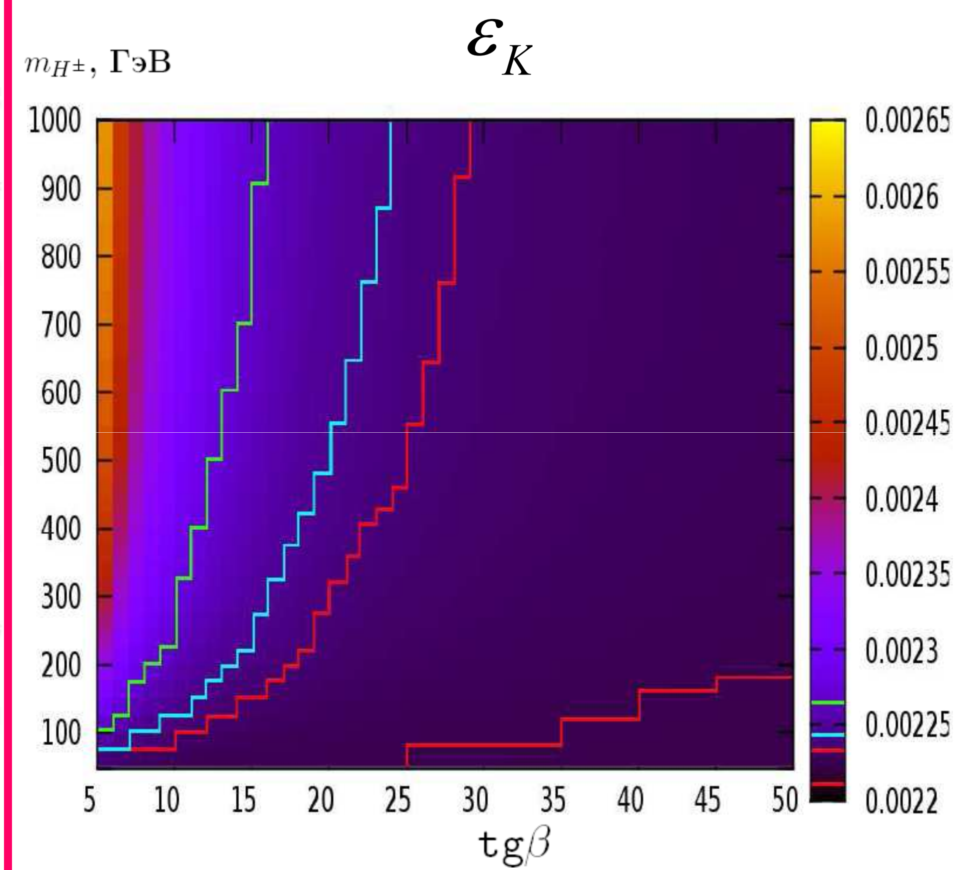
CP-Violation

Numerical Results. R-2. K-mesons

FOUR-FERMION APPROXIMATION (FUTURE IS YET TO COME)



Mass Splitting



CP-Violation

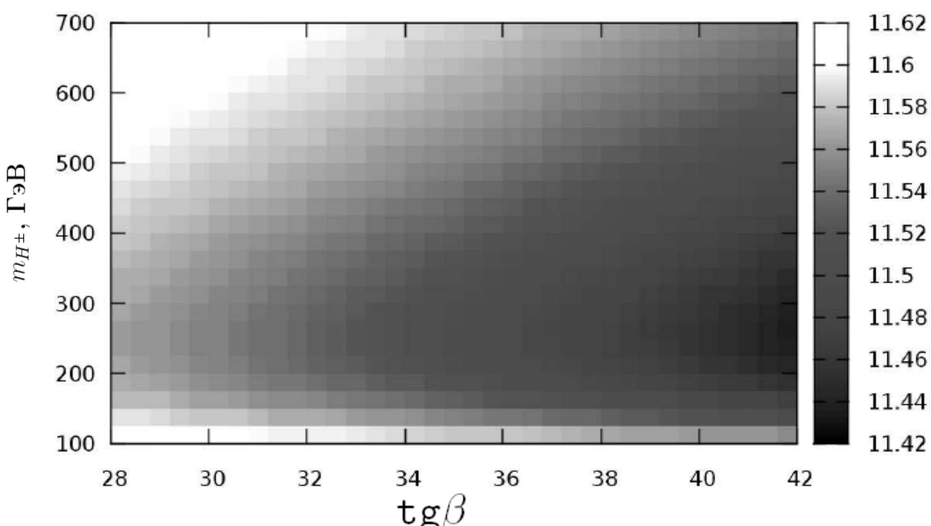
Numerical Results. R-3. B-mesons

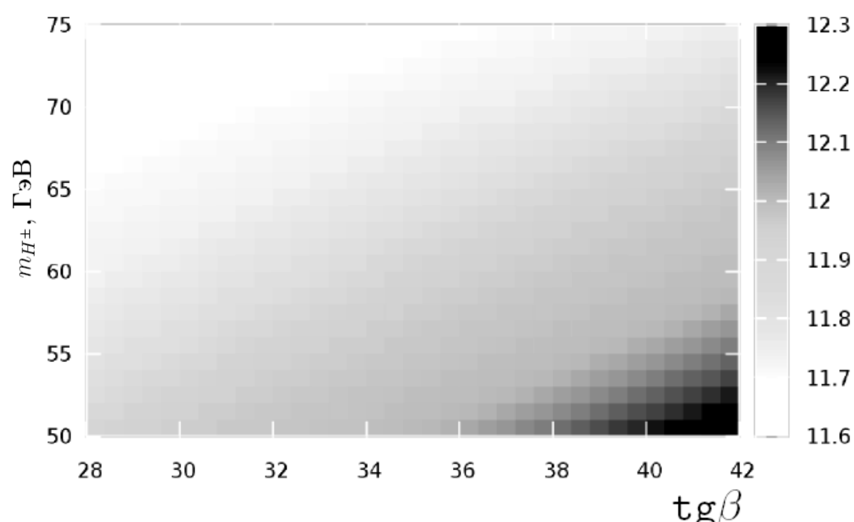
$m_{H^\pm}$(ГэВ) / tgβ	5	10	20	30	40
50	3.330	3.330	3.330	3.330	3.330
75	3.331	3.331	3.330	3.330	3.330
100	3.333	3.331	3.330	3.330	3.329
150	3.342	3.333	3.331	3.330	3.329
200	3.354	3.336	3.332	3.330	3.329
300	*3.379*	3.343	3.333	3.331	3.330
400	**3.401**	3.348	3.335	3.332	3.330
500	**3.416**	3.352	3.336	3.332	3.331

$\Delta m_{LS-appr}^{B_d(tot)}$ (*в* 10^{-13} *ГэВ*)

$m_{H^\pm}$(ГэВ) / tgβ	5	10	20	30	40
50	11.67	11.67	11.71	*11.88*	**12.36**
75	11.68	11.67	11.66	11.67	11.74
100	11.69	11.67	11.65	11.62	11.60
150	11.72	11.67	11.63	*11.57*	*11.49*
200	*11.77*	11.69	11.62	*11.55*	*11.45*
300	*11.88*	11.71	11.63	*11.55*	*11.44*
400	**11.98**	11.74	11.64	*11.56*	*11.47*
500	**12.06**	*11.76*	11.65	*11.58*	*11.50*

$\Delta m_{LS}^{B_s(exp)} = (11.4^{+0.2}_{-0.1}) \cdot 10^{-12}$ ГэВ $\qquad \Delta m_{LS}^{B_s(tot)}$

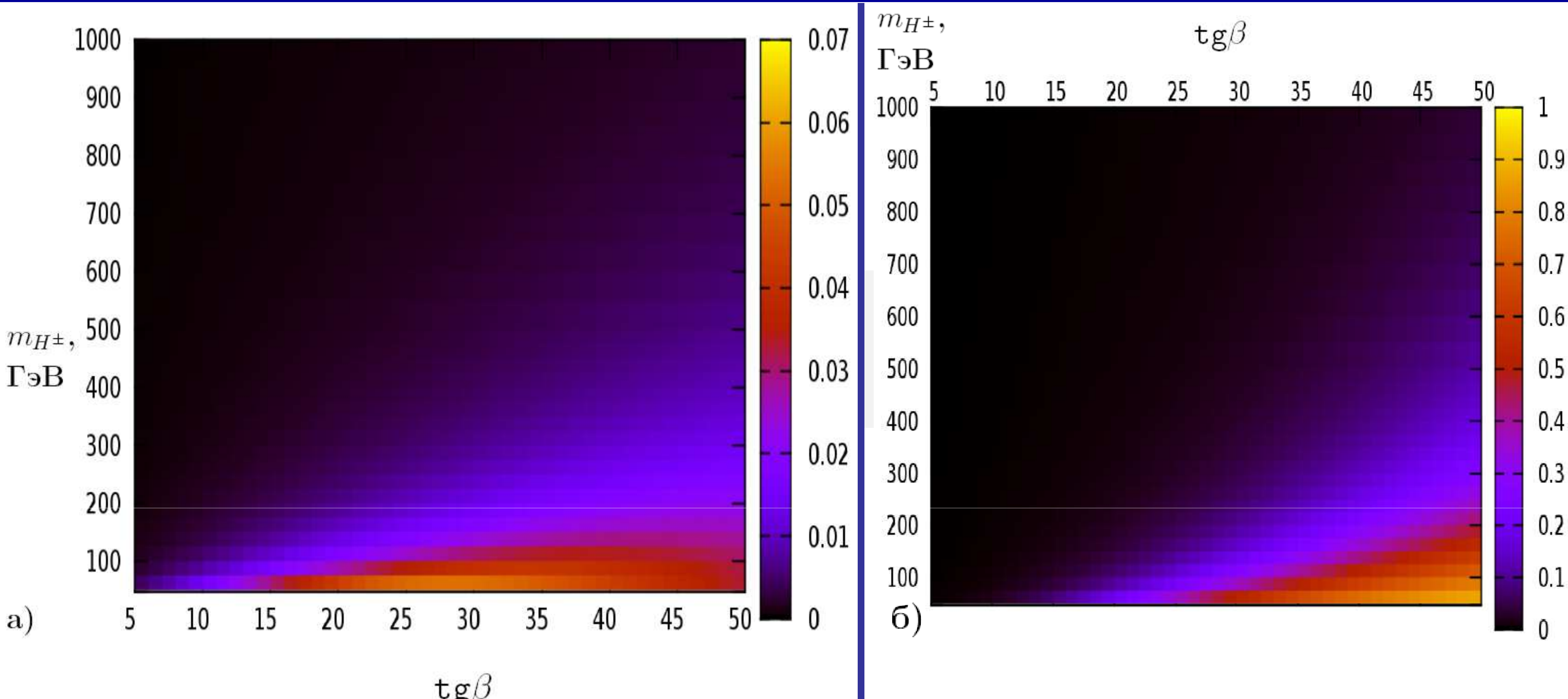




Δm_{B_s} (*в* 10^{-12} *ГэВ*)

FOUR-FERMION APPROXIMATION

Numerical results. R-4. D-mesons



Отношения $\frac{|\Delta m_{LS}^{D-HW}|}{|\Delta m_{LS}^{D}|}$ (а) и $\frac{|\Delta m_{LS}^{D-HH}|}{|\Delta m_{LS}^{D}|}$ (б) вкладов HW- и HH-диаграмм соответственно к величине суммарного расщепления в зависимости от массы заряженного бозона Хиггса ($m_{H^\pm}$) и отношения вакуумных средних скалярных дублетов модели (tgβ).

ONLY FOUR-FERMION APPROXIMATION