Plan:

- Why we should the exact informations about Cabbibo-Kobayashi-Maskawa matrix ($V_{CKM}$)?

- $V_{CKM}$ – the only source of CP and flavour violation?

- Classification of SM extensions.

- CP and flavour violation in Standard Model and its extensions.

- Description of the experimental quantities in SM and its extensions.

- How to distinguish between models? Possibility of experimental excluding models.

- Bounds on new models following from present and future experimental data.

- The examples of the models - 2HDM(II) i MSSM.
The motivations for precise finding the Cabbibo-Kobayashi-Maskawa matrix elements ($V_{CKM}$)

- the $V_{CKM}$ matrix describes CP violation and flavour violation

- this is the only source of CP violation and flavour violation in Standard Model (SM)

- CP violation is necessary in bariogenesis theories

- in SM CP violation is too small to explain
  \[
  \frac{n_{\text{barion}}}{n_{\text{foton}}} \sim 10^{-9}
  \]
Cabbibo-Kobayashi-Maskawa ($V_{CKM}$) matrix

$$V_{CKM} = \begin{bmatrix}
V_{ud} & V_{us} & V_{ub} \\
V_{cd} & V_{cs} & V_{cb} \\
V_{td} & V_{ts} & V_{tb}
\end{bmatrix} \tag{1}$$

For 3 generations of quarks this matrix is parametrized by 3 angles and the phase $\delta$. In SM that phase is the only source of CP violation.

The $V_{CKM}$ elements are found experimentally. They are determined from the tree or loop level processes.

<table>
<thead>
<tr>
<th>$V_{ij}$</th>
<th>value</th>
<th>process</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>V_{us}</td>
<td>$</td>
</tr>
<tr>
<td>$</td>
<td>V_{cb}</td>
<td>$</td>
</tr>
<tr>
<td>$</td>
<td>V_{ub}</td>
<td>$</td>
</tr>
</tbody>
</table>

$|V_{td}|$ and $|V_{ts}|$ - are determined from the loop-level processes.
How we can classify the extensions of Standard Model with respect on sources CP violation:

1. $V_{CKM}$ matrix is the only one source of CP violation and flavour violation: then the enhancement of CP violated effects arrive by the new particles which give rise to the amplitudes of FCNC (flavour changing neutral current) processes.

Example: 2HDM or SUSY models

That effects are especially important in quark $b$ physic $B_{s,d}^0 \to \bar{B}_{s,d}^0$, rare decays $B$ mesons, because in vertices stand Yukawa constants of top or bottom (which is large for $\tan \beta \gg 1$).

Processes with $b$ quark are experimentally researched. (e.g. $B_s \to X_s \gamma$ /CLEO/, $B \to \Psi K_S$ /BELLE, BaBar/, $B \to l\bar{l}$ /CLEO/)
How we can classify ...(cont.)

2. New sources (except $V_{CKM}$ matrix) of CP and flavour violation – sfermion mass matrices

$u \rightarrow \tilde{U}_L, \tilde{U}_R$

\[
\mathcal{M}^2_D = \begin{bmatrix}
(\mathcal{M}^2_D)_{LL} & (\mathcal{M}^2_D)_{LR} \\
(\mathcal{M}^2_D)_{RL} & (\mathcal{M}^2_D)_{RR}
\end{bmatrix}, \quad (2)
\]

$(\mathcal{M}^2_D)_{XY} \quad X, Y = L, R \rightarrow 3 \times 3$ matrices.


\[\sim (\alpha_s)^2\]
Rare processes description by $H_{eff}$

We consider processes with $\Delta F = 2$, because we will use them to find some $V_{CKM}$ matrix elements – $V_{td}$ and $V_{ts}$ (neutral kaons mixing and neutral $B^0$ mesons mixing).

The examples of the theories above $M_W$ scale: Standard Model (SM), 2-Higgs Doublet Model (2HDM), Minimal Supersymmetric Standard Model (MSSM).

Effective description up to $M_W$ scale by effective Hamiltonian:

$$H_{eff} = \sum_i C_i Q_i^i. \quad (3)$$

It allow us to take into account QCD correction.

$C_i$ – Wilson coeffitiens calculated in 'full theory', $Q_i$ – local operators built on fermionic fields.
All possible (8) operators dimension 6, which give rise to $H_{\text{eff}}$ $\Delta F = 2$

\[
Q_{\text{VLL}}^{\text{VLL}} = (\bar{d}_J \gamma_\mu P_L d_I)(\bar{d}_J \gamma^\mu P_L d_I),
\]
\[
Q_1^{\text{LR}} = (\bar{d}_J \gamma_\mu P_L d_I)(\bar{d}_J \gamma^\mu P_R d_I),
\]
\[
Q_2^{\text{LR}} = (\bar{d}_J P_L d_I)(\bar{d}_J P_R d_I),
\]
\[
Q_1^{\text{SLL}} = (\bar{d}_J P_L d_I)(\bar{d}_J P_L d_I),
\]
\[
Q_2^{\text{SLL}} = (\bar{d}_J \sigma_{\mu\nu} P_L d_I)(\bar{d}_J \sigma^{\mu\nu} P_L d_I),
\]

$L \leftrightarrow R$, \hspace{1cm} (4)

$I, J$ - flavour indeces.
Connection of \( H_{eff} \) matrix elements with measurables quantities

\[
2\text{Im}\langle \bar{K}^0|H_{eff}|K^0\rangle \ M_{K^0} = \varepsilon_K, \tag{5}
\]
\[
2\text{Re}\langle \bar{B}^0|H_{eff}|B^0\rangle = \Delta M_{d,s}. \tag{6}
\]

Contribution to kaons mixing in 'full theory' (SM) and 'effective theory'.

\[
H_{eff} = C^{VLL} Q^{VLL}
\]
The matrix elements $Q^x$ between hadronic states (data from lattice calculations):

$$\langle \bar{K}^0 | Q^{LL} | K^0 \rangle = \frac{8}{3} M_{K^0}^2 f_K^2 \hat{B}_K,$$

$$\langle \bar{B}^0 | Q^{LL} | B^0 \rangle = \frac{8}{3} \hat{B}_{B_d} F_{B_d}^2 M_{B^0}^2 \quad (7)$$

$\hat{B}_K = 0.85 \pm 0.15,$

$\sqrt{\hat{B}_{B_d} F_{B_d}} = 230 \text{ MeV} \pm 40 \text{ MeV},$

$\sqrt{\hat{B}_{B_s} F_{B_s}} = 265 \text{ MeV} \pm 40 \text{ MeV}.$

Remark: still large uncertainties!
The classification of models with $V_{CKM}$ as the only source CP violation

One can classify such models on $H_{eff}$ level. It is convenient from phenomenological point of view.

1. The models 'similar to Standard Model’ (the MFV model– Minimal Flavour Violation).

$H_{eff}^{SM} = C^{VLL} Q^{VLL}$

In MFV we can factorize in $H_{eff}$ the elements of $V_{CKM}$. The contribution from $t i W^\pm$ to $H_{eff}$ one can write as:

$$H_{eff}^{\Delta F=2} = \frac{G_F M_W^2}{16\pi^2} \lambda_t^2 \sum_i \tilde{C}_i(\mu) Q_i$$  \hspace{1cm} (8)

where

$$\lambda_t = V_{ts} V_{td}^* \text{ dla } K^0 - \bar{K}^0$$

$$\lambda_t = V_{td} V_{tb}^* \text{ dla } B_d^0 - \bar{B}_d^0$$

$$\lambda_t = V_{ts} V_{tb}^* \text{ dla } B_s^0 - \bar{B}_s^0$$  \hspace{1cm} (9)

$\tilde{C}_i$ are real.
The classification of models ...(cont.)

2. GMFV model (Generalized Minimal Flavour Violation).
Possible contributions from all 8 operators with \( \Delta F = 2 \)

Because \( V_{CKM} \) is in models (1.,2.) the only source of CP and flavour violation, in \( H_{eff} \) one can factorize the \( V_{CKM} \) matrix elements from the Wilson coefficients like in Standard Model.

In SM the contributions to \( \tilde{C}_i \) dla \( K^0 - \bar{K}^0 \), \( B_d^0 - \bar{B}_d^0 \) i \( B_s^0 - \bar{B}_s^0 \) are the same (they are given by one function common for all that processes), similar in MFV. This is no longer true in GMFV.
Wolfenstein parametrization

\[
V_{CKM} = \begin{bmatrix}
1 - \frac{\lambda^2}{2} & \lambda & A\lambda^3(\varrho - i\eta) \\
-\lambda & 1 - \frac{\lambda^2}{2} & A\lambda^2 \\
A\lambda^3(1 - \varrho - i\eta) & \lambda^2/2 & 1
\end{bmatrix}
\]  

(10)

Wolfenstein parameters: $\lambda$, $A$, $\varrho$, $\eta$, where $A$ and $\lambda$ are found from tree-level processes.

One of orthogonality relation

\[
V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0.
\]  

(11)

Unitarity triangle.
\[ R_b \equiv \left| \frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*} \right| = \sqrt{\bar{\theta}^2 + \bar{\eta}^2} = \left(1 - \frac{\lambda^2}{2}\right) \frac{1}{\lambda} \left| \frac{V_{ub}}{V_{cb}} \right| \quad (12) \]

\[ R_t \equiv \left| \frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*} \right| = \sqrt{(1 - \bar{\theta})^2 + \bar{\eta}^2} = \frac{1}{\lambda} \left| \frac{V_{td}}{V_{cb}} \right| \quad (13) \]

The formula for $\Delta M_{d,s}$ i $\varepsilon_K$ in Standard Model:

- masses differences of neutral mesons $B$:

\[ \Delta M_q = \frac{G_F^2 M_W^2}{6\pi^2} M_{B_q} \eta_B \hat{B}_{B_q} F_{B_q}^2 |V_{tq}|^2 S_0(x_t), \quad q = d, s \quad (14) \]

where $S_0(x_t)$ with $x_t = m_t^2/M_W^2$ is function deriving from diagram $(t, W^\pm)$ (in SM) $S_0(x_t) \approx 2.38 \pm 0.11$ for $\bar{m}_t(m_t) = (166 \pm 5)$ GeV.
\[ \Delta M_s/\Delta M_d \text{ and } \Delta M_d \]

- \[ \Delta M_d = (0.487 \pm 0.009)/ps \] - uncertainties, from \[ \sqrt{\hat{B}_{B_d}F_{B_d}} \]
- \[ \Delta M_s \geq 15.0/ps \ (\frac{\Delta M_s}{\Delta M_d} \geq 30) \]

\[ \xi = \frac{\sqrt{\hat{B}_{B_s}F_{B_s}}}{\sqrt{\hat{B}_{B_d}F_{B_d}}} = 1.15 \pm 0.06 \]
- we do not know \[ \Delta M_s \], just upper bound

\* \[ \varepsilon_K \] describing CP violating in the neutral kaon system:

\[ \bar{\eta} \left[ (1 - \bar{\varrho}) A^2 \eta_2 S_0(x_t) + P_c(\varepsilon) \right] A^2 \hat{B}_K = 0.204 \]  

(15)
\( \sin 2\beta \) measured in \( B^0_d(\bar{B}^0_d) \rightarrow \psi K_S \) decay

\( \sin 2\beta \) is found from measurement of the CP violated asymmetry \( (a_{\psi K_S}) \) in \( B^0_d(\bar{B}^0_d) \rightarrow \psi K_S \) decay.

Asymmetry:
\[
a_f = \frac{A(i \rightarrow f)-A(\bar{i} \rightarrow \bar{f})}{A(i \rightarrow f)+A(\bar{i} \rightarrow \bar{f})}.
\]

Why \( B^0_d(\bar{B}^0_d) \rightarrow \psi K_S \) measures the \( \sin 2\beta \)?

The amplitude of that process is composed on three amplitudes:

- \( B^0_d - \bar{B}^0_d \) mixing \( (\sim |V_{td}V_{tb}^*|^2) \),
- \( B^0_d(\bar{B}^0_d) \rightarrow \psi K_S \) decay, which is real, if we neglect any loop-diagram (double Cabbibo-suppressed),
- \( K^0 - \bar{K}^0 \) mixing, which is real.

\( \beta \) angle (exactly \( \sin 2\beta \)) is the phase of the amplitude \( B^0_d - \bar{B}^0_d \) mixing.
Why $B_d^0(\bar{B}_d^0) \rightarrow \psi K_S$ measures the $\sin 2\beta$?

Experimental results:

$$a_{\psi K_S} = \begin{cases} 
0.59 \pm 0.14 \pm 0.05 & \text{(BaBar)} \\
0.99 \pm 0.14 \pm 0.06 & \text{(Belle)} \\
0.79^{+0.41}_{-0.44} & \text{(CDF)} \\
0.84^{+0.82}_{-1.04} \pm 0.16 & \text{(ALEPH)}
\end{cases} \quad (16)$$

The grand average is

$$a_{\psi K_S} = 0.79 \pm 0.10 , \quad (17)$$

but in view of the fact that BaBar and Belle results are not fully consistent with each other we believe that a better description of the present situation is $a_{\psi K_S} = 0.80 \pm 0.20$. 

IFT UW
Unitarity triangle in GMFV i MFV models

There are 3 processes, in which we will determine $V_{CKM}$ elements – it is convenient to define separate function for each process:

$$F_{tt}^d = S_0(x_t)[1 + f_d] \quad \text{(for } \varepsilon_K),$$
$$F_{tt}^s = S_0(x_t)[1 + f_s] \quad \text{(for } \Delta M_d),$$
$$F_{tt}^\varepsilon = S_0(x_t)[1 + f_\varepsilon] \quad \text{(for } \Delta M_\varepsilon)$$

in SM: $f_d = f_s = f_\varepsilon = 0$, $F_{tt}^d = F_{tt}^s = F_{tt}^\varepsilon = S_0(x_t)$

In MFV is $F_{tt}^d = F_{tt}^s = F_{tt}^\varepsilon$.

The formula for $\varepsilon_K$ in GMFV:

$$\bar{\eta} \left[ (1 - \bar{\varrho}) A^2 \eta_2 F_{tt}^\varepsilon + P_c(\varepsilon) \right] A^2 \hat{B}_K = 0.204 \quad (19)$$

The formula for $\Delta M_q$ in GMFV:

$$\Delta M_q = \frac{G_F^2 M_W^2}{6\pi^2} M_{B_q} \eta_B \hat{B}_{B_q} F_{B_q}^2 |V_{tq}|^2 F_{tt}^q, \quad q = d, s \quad (20)$$
As in SM, we can determine $R_t$ in 2 ways: from $\Delta M_d$ and $\Delta M_d/\Delta M_s$:

$$R_t = 1.084 \frac{R_0}{A} \frac{1}{\sqrt{F_{tt}^d}}$$  \hspace{1cm} (21)$$

$$R_0 \equiv \sqrt{\frac{\Delta M_d}{0.487/\text{ps}}} \left[ \frac{230 \text{ MeV}}{\sqrt{\hat{B}_{B_d} F_{B_d}}} \right] \sqrt{\frac{0.55}{\eta_B}}$$

and

$$R_t = 0.819 \, \xi \sqrt{\frac{\Delta M_d}{0.487/\text{ps}}} \sqrt{\frac{15/\text{ps}}{\Delta M_s}} \sqrt{R_{sd}} ,$$  \hspace{1cm} (22)$$

$$R_{sd} = \frac{1 + f_s}{1 + f_d}$$  \hspace{1cm} (23)$$

In MFV $R_{sd} = 1$ ($R_t$ found from $\Delta M_d/\Delta M_s$ does not depend on parameters of model).
How to distinguish between GMFV and MFV models:
The question: how one can check experimentally, if MFV are still valid, or no?:

- if the experimentally value \( \sin 2\beta \) will be small (smaller than 0.42), then MFV models are excluded.
  In the MFV models there exists an absolute lower bound on \( \sin 2\beta \) that follows from the interplay of \( \Delta M_d \) and \( \varepsilon \) and depends mainly on \( V_{cb}, V_{ub} \) and the non-perturbative parameters \( \hat{B}_K, F_{B_d} \sqrt{\hat{B}_{B_d}} \) entering the analysis of the unitarity triangle. Lower bound on \( \sin 2\beta \) obtained by scanning independently all relevant input parameters reads \( (\sin 2\beta)_{\text{min}} = 0.42 \),

- if the experimentaly value \( \sin 2\beta \) will be above this bound, then we analize the correlations between \( \Delta M_d/\Delta M_s \), \( \sin 2\beta \) and another quantities like \( \varepsilon_K \) or \( \gamma \).
– 'strategy A': if we will know experimentally value for $\Delta M_d/\Delta M_s$, then for any $R_{sd}$ we know $R_t$ - so we can find $\sin 2\beta$ (and we can compare with experimental results):

$$R_t \sim \frac{1}{\sqrt{\Delta M_s/\Delta M_d}} \sqrt{R_{sd}}$$  \hspace{1cm} (24)

$R_t, R_b \to \sin 2\beta$

– 'strategy B': if we will know experimentally value for $\Delta M_d/\Delta M_s$ and $\sin 2\beta$, we can find the value of the $\gamma$ angle (from $B \to \pi K$)
Ranges of $(\bar{\rho}, \bar{\eta})$ allowed in $1\sigma$ for $\Delta M_s = (18.0 \pm 0.5)/ps$, three values of $a_{\psi K_S}$ and different values of $R_{sd}$ (marked in the figures). Black spots correspond to $R_{sd} = 1$. Dotted lines show the constraint from $\varepsilon_K$, for $1 + f_\varepsilon = 1$. 
The question: how one in concrete model find bounds on \( F_{tt}^{d,s,e} \) function?

- from fitting the formula (20) to the measured (in the near future) value of \( \Delta M_s \). This determines \( 1 + f_s \) (or \( F_{tt}^s \)):

\[
1 + f_s = 0.80 \left[ \frac{2.38}{S_0(x_t)} \right] \left( \frac{265 \text{ MeV}}{\sqrt{B_{Bs} F_{Bs}}} \right)^2 \left[ \frac{0.55}{\eta_B} \right] \left[ \frac{0.041}{|V_{ts}|} \right]^2 \left[ \frac{\Delta M_s}{15/\text{ps}} \right]
\]

scanning over uncertainties gives

\[
0.52 \left[ \frac{\Delta M_s}{15/\text{ps}} \right] < 1 + f_s < 1.29 \left[ \frac{\Delta M_s}{15/\text{ps}} \right] \quad (26)
\]

( at present this gives \( 1 + f_s > 0.52 \).)

next, there are bounds on \( R_t \) coming from unitarity of \( V_{CKM} \) matrix

\[
1 - R_b < R_t < 1 + R_b \quad (27)
\]
it gives $0.54 < R_t < 1.46$. This can be used to constrain either $1 + f_d$ or $R_{sd}$:

$$0.20 < 1 + f_d < 4.24$$

(28)

and

$$0.29 \left[ \frac{\Delta M_s}{15/ps} \right] < R_{sd} < 2.73 \left[ \frac{\Delta M_s}{15/ps} \right].$$

(29)

- from measurement of $\sin2\beta$ i $R_b$ we can get more stringent constraint on $R_{sd}$ (if we know $\sin2\beta$ i $R_b$, then we know $R_t$).
if we make use on experimental result on \( \varepsilon_K \), we can corelate \( F_{tt}^{\varepsilon} \) with \( F_{tt}^{d} \).

Allowed ranges of \( 1 + f_d \) and \( 1 + f_\varepsilon \).

- \( \Delta M_d, \varepsilon \) and \( R_b \) allow the region delimited by the dashed lines.
- Regions between the solid lines are allowed by \( \Delta M_d, \varepsilon \) and \( \sin 2\beta = 0.4 \) (panel a) and \( \sin 2\beta = 0.8 \) (panel b).
- Dotted regions are allowed by \( \Delta M_d, \varepsilon \) and \( R_b \) for \( \sin 2\beta = 0.4 \) and 0.8 in panels a) and b), respectively.
The examples of GMFV models

1. 2HDM(II) with large $\tan \beta$

Tree-level coupling of charged Higgs scalar $(H_k^+ \equiv (H^+, G^+))$ to quarks:

$$L_{\text{int}} = H_k^+ \bar{u}_A V_{AI} (a_L^{AIk} P_L + a_R^{AIk} P_R) d_I + \text{H.c.} \quad (30)$$

where

$$a_L^{AIk} = \frac{e}{\sqrt{2} s_W} \frac{m_{u_A}}{M_W} \times \begin{cases} \cot \beta & \text{for } k = 1 \\ 1 & \text{for } k = 2 \end{cases} \quad (31)$$

$$a_R^{AIk} = \frac{e}{\sqrt{2} s_W} \frac{m_{d_I}}{M_W} \times \begin{cases} \tan \beta & \text{for } k = 1 \\ -1 & \text{for } k = 2 \end{cases} \quad (32)$$
Box diagrams in extended Higgs sector

**dominant contributions to Wilson coefficients:**
diagram with $W^\pm H^\pm$:

$$
\delta^{(+)C_{2}^{LR}} \sim -\frac{8 m_d m_{dJ}}{3 m_t^2} \tan^2 \beta
$$

diagram with $H^\pm H^\mp$:

$$
\delta^{(+)C_{2}^{LR}} \sim -\frac{4 m_d m_{dJ}}{3 M_W^2} \tan^2 \beta
$$

(33)

It is clear that for large $\tan \beta$ the biggest contribution appears in $\delta^{(+)C_{2}^{LR}}$. It is of the opposite sign than the contribution of the $tW^\pm$ box diagram and can be significant only for the $B_s^0 - B_s^0$ (similar contributions to $\delta^{(+)C_{2}^{LR}}$ for $B_d^0 - B_d^0$ and $\bar{K}^0 - K^0$ transitions are suppressed by factors $m_d/m_s$ and $m_d/m_b$, respectively.)
$1 + f_s$ in the 2HDM(II): a) as a function of $\tan \beta$ for $M_{H^+} = (\text{from below})$ 150, 250, 300 and 350 GeV and b) as a function of $M_{H^+}$ for $\tan \beta = (\text{from above})$ 40, 60, 80 and 100.

The computation of the $b \rightarrow s\gamma$ rate together with the experimental result for this process
$BR(B \rightarrow X_s\gamma) = (3.03 \pm 0.40 \pm 0.26) \times 10^{-4}$ set the bound $M_{H^+} \gtrsim 350 \text{ GeV}$. This means that in the 2HDM(II) for the still allowed range of charged Higgs boson masses the decrease of $1 + f_s$ can be very small. Consequently, the SM analysis of the unitarity triangle based on $\varepsilon$, $\Delta M_d$ and $\Delta M_s$ is practically unchanged in the 2HDM(II) for large $\tan \beta \lesssim 50$. 
2. MSSM with large $\tan \beta$, heavy sparticles and light Higgs sector

- in the limit of heavy sparticles (which is practically realized already for $M_{\text{sparticles}} \gtrsim 500$ GeV) the one loop diagrams involving charginos and stops are negligible.
- one loop diagrams with charged Higgs and top quark can give large ($\sim \tan^2 \beta$) contributions (the bound on $M_{H^+}$ from $b \rightarrow s\gamma$ is much weaker)
- two loop corrections, deriving from one loop corrections to down quarks with neutral Higgs couplings (double penguin diagram), can be very large ($\sim \tan^4 \beta$)
One-loop correction to the $\bar{b}b$-neutral Higgs vertex in MSSM (contribution charginos and stops in loop), proportional to $\tan \beta^2$. Such kind of effects does not vanish with very heavy sparticles.

Identical diagrams give rise to $B \rightarrow \bar{\ell} \ell$ amplitude, so very strong effects which was expected in that process can be partially limited by neutral $B$ meson mixing.
The contributions of diagrams (from previous figure) to Wilson coefficients:

\[
\delta^{(0)} C_1^{SLL} = -\frac{\alpha_{EM}}{4\pi s_W^2} \frac{m_t^4}{M_W^4} m_{d_j} X_{tC}^2 \tan^4 \beta \mathcal{F}_-
\]

\[
\delta^{(0)} C_1^{SRR} = -\frac{\alpha_{EM}}{4\pi s_W^2} \frac{m_t^4}{M_W^4} m_{d_i} X_{tC}^2 \tan^4 \beta \mathcal{F}_- \quad (34)
\]

\[
\delta^{(0)} C_2^{LR} = -\frac{\alpha_{EM}}{2\pi s_W^2} \frac{m_t^4}{M_W^4} m_{d_j} m_{d_i} X_{tC}^2 \tan^4 \beta \mathcal{F}_+ .
\]

where \( X_{tC} = \sum_{j=1}^{2} Z_{2j}^2 Z_{2j}^2 A_t \frac{m_{C_j}}{m_{C_j}} H_2(x_{t/C_j}^{1}, x_{t/C_j}^{2}) \),

\( x_{i}^{t/C_j} = \frac{M_{t_i}^2}{m_{C_j}^2}, \quad i = 1, 2, j = 1, 2, \)

\[
\mathcal{F}_+ \equiv \left[ \frac{\cos^2 \bar{\alpha}}{M_H^2} + \frac{\sin^2 \bar{\alpha}}{M_h^2} + \frac{\sin^2 \beta}{M_A^2} \right] \quad (35)
\]
$1 + f_s$ in the MSSM as a function of the mixing angle of the top squarks for different lighter chargino masses and compositions ($r \equiv M_2/\mu$). Solid, dashed, dotted and dot-dashed lines correspond to stop masses (in GeV) (500,650), (500,850), (700,850) and (700,1000), respectively.
$1 + f_s$ in the MSSM for lighter chargino mass 750 GeV, $r \equiv M_2/\mu = -0.5$ and stop masses (in GeV) (500,850), (700,1000), (500,850) and (600,1100) (solid, dashed, dotted and dot-dashed lines, respectively) as a function of a) $\tan \beta$ and b) $M_{H^+}$. In panel a) solid and dashed (dotted and dot-dashed) lines correspond to $M_{H^+} = 200$ (600) GeV, and in panel a) solid and dashed (dotted and dot-dashed) lines correspond to $\tan \beta = 50$ (35).
Conclusions:

- Classification of SM extensions.

- Analysis of the role of new dimension six four-fermion $|\Delta F| = 2$ operators in models with minimal flavour violation (MFV and GMFV).

- Formulae for the mass differences $\Delta M_s$, $\Delta M_d$ and the CP violation parameter $\varepsilon$ (parametrization by three real functions $F^s_{tt}$, $F^d_{tt}$ and $F^\varepsilon_{tt}$, respectively).

- We have proposed a few simple strategies involving the ratio $\Delta M_s/\Delta M_d$, $\sin 2\beta$ and the angle $\gamma$ that allow to search for the effects of the new operators.

- The present experimental and theoretical uncertainties allow for sizable contributions of new operators to $\Delta M_{s,d}$ and $\varepsilon$.

- As an example we have analyzed the role of new operators in the MSSM with large
\[ \tan \bar{\beta} = v_2 / v_1 \] in the limit of heavy sparticles, investigating in particular the impact of the extended Higgs sector on the unitarity triangle. The largest effects of new contributions for large \( \tan \bar{\beta} \) are seen in \( \Delta M_s \).