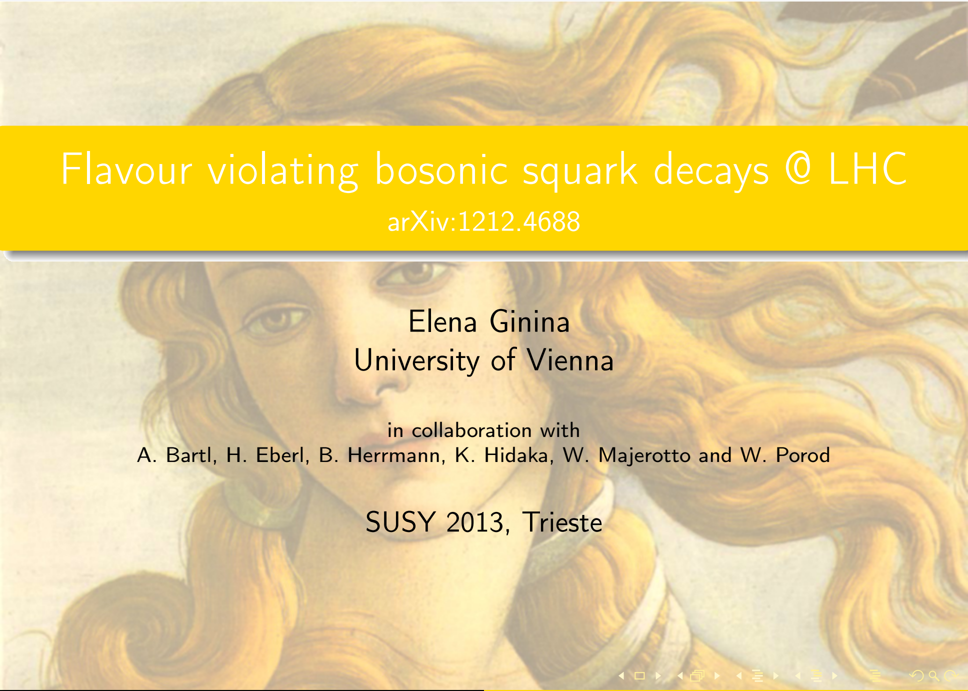

Flavour violating bosonic squark decays @ LHC

arXiv:1212.4688

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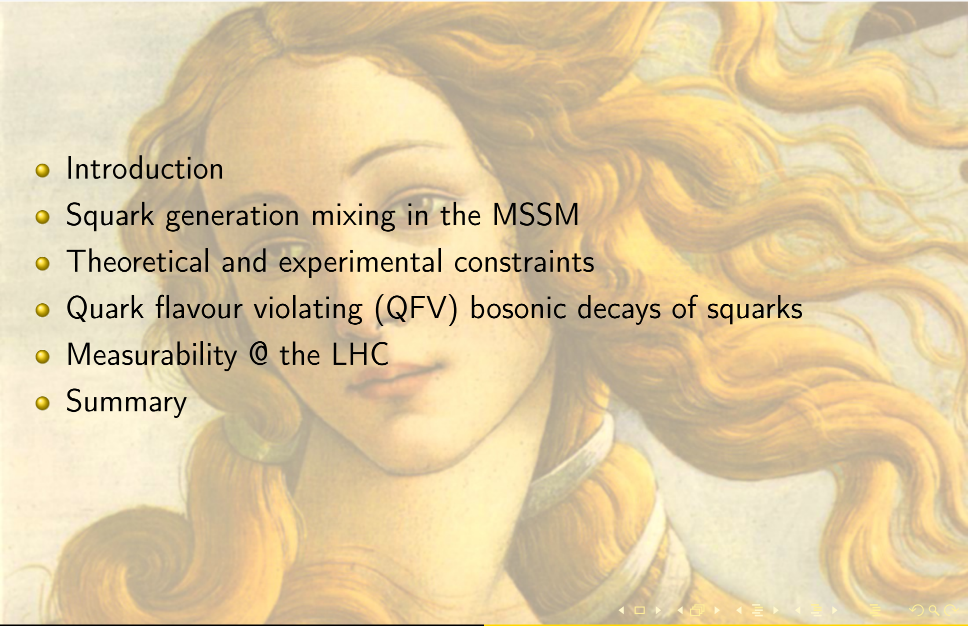
in collaboration with
A. Bartl, H. Eberl, B. Herrmann, K. Hidaka, W. Majerotto and W. Porod

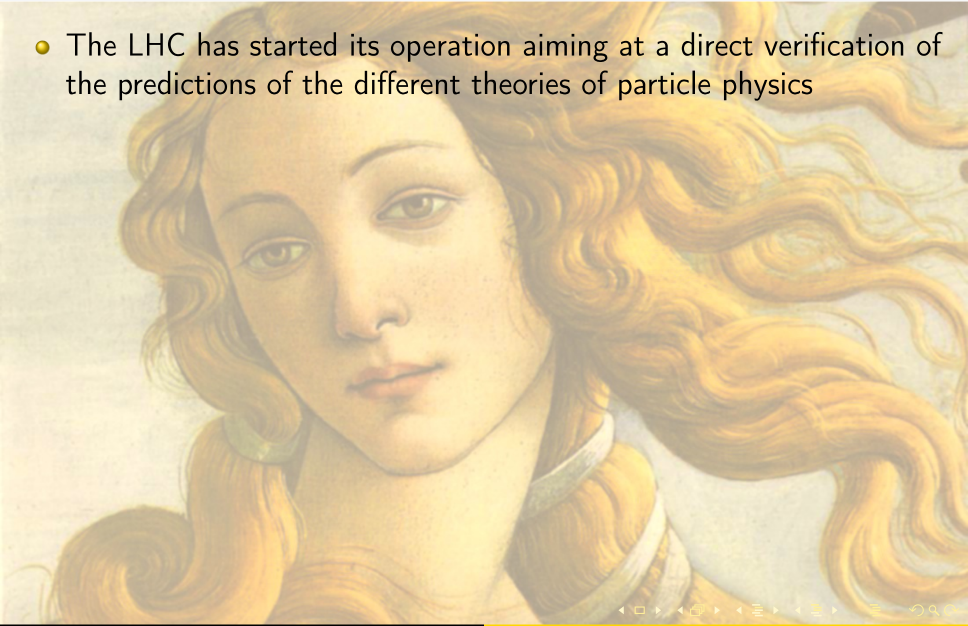
SUSY 2013, Trieste

Outline



- Introduction
- Squark generation mixing in the MSSM
- Theoretical and experimental constraints
- Quark flavour violating (QFV) bosonic decays of squarks
- Measurability @ the LHC
- Summary

Introduction



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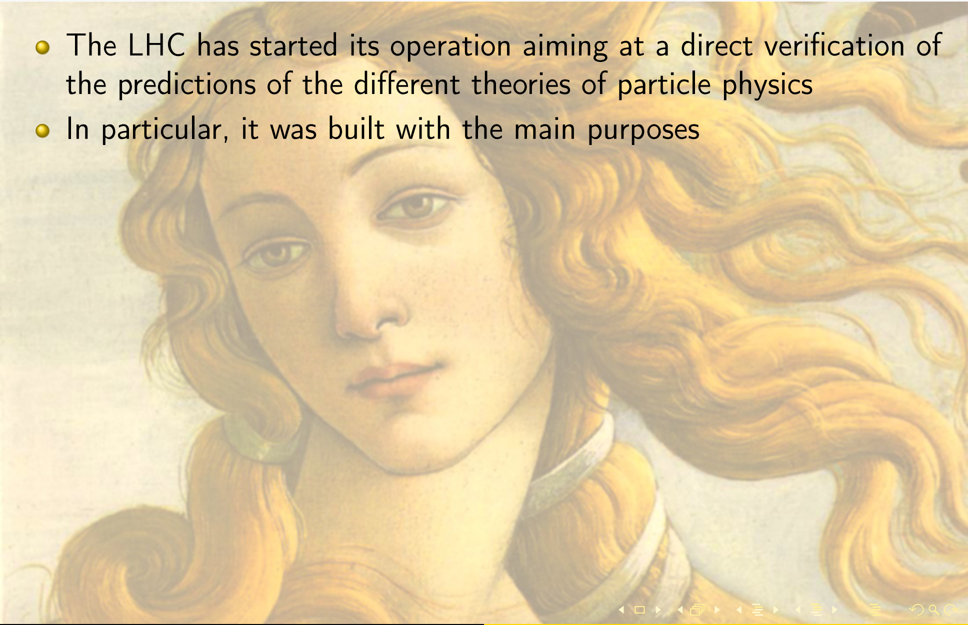

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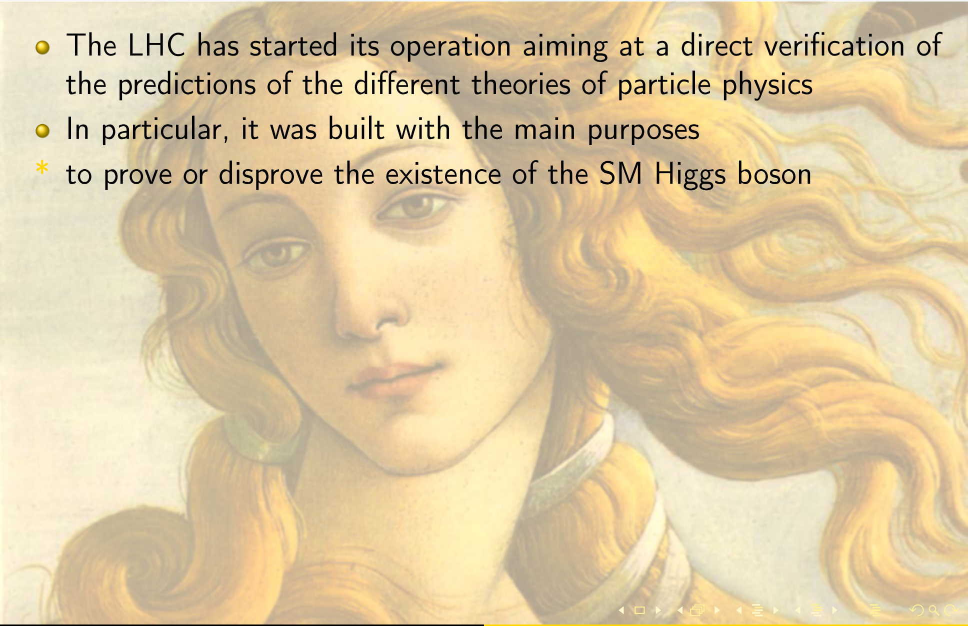

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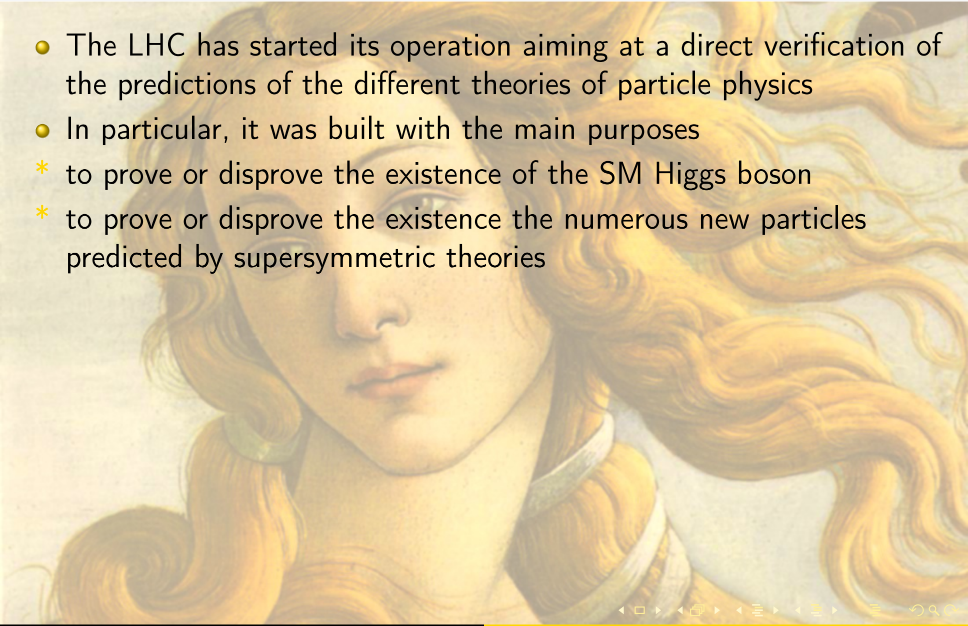

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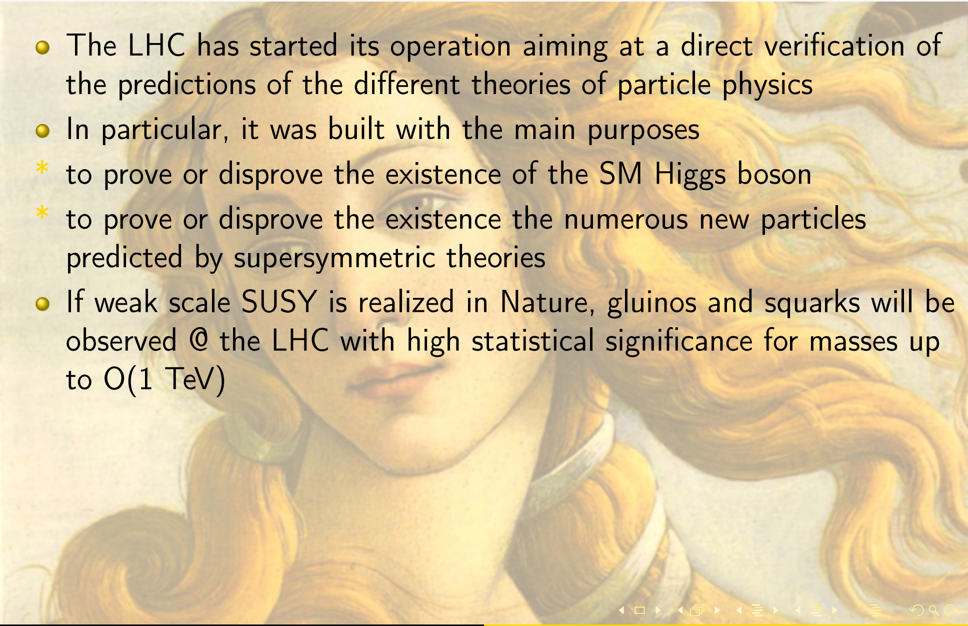

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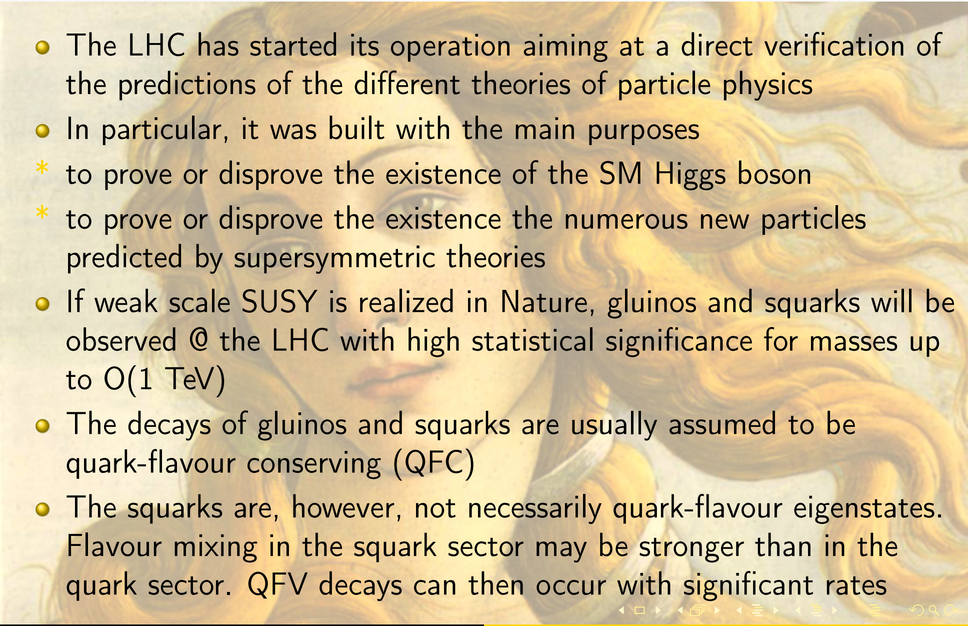

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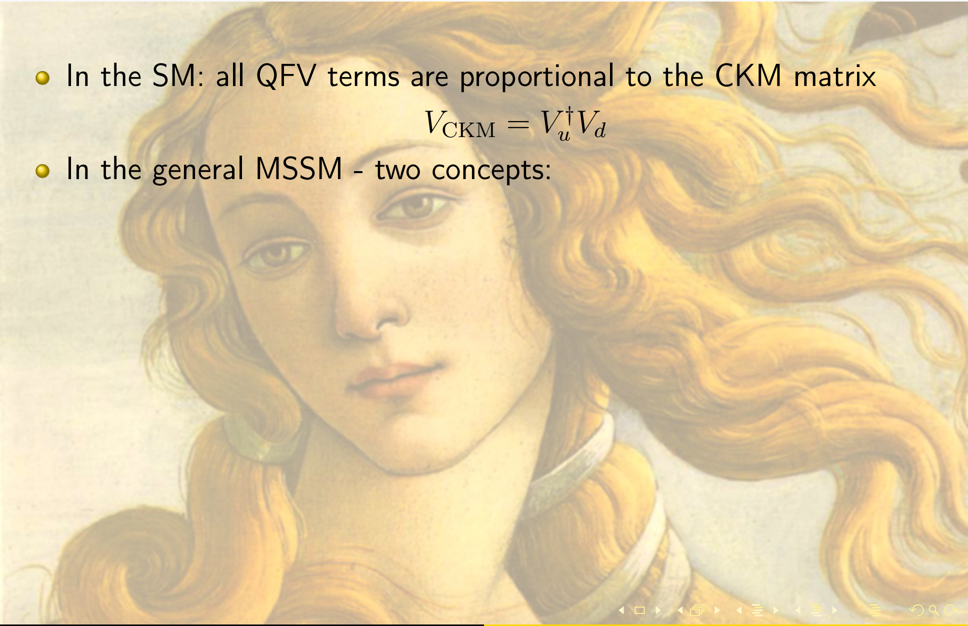
- The decays of gluinos and squarks are usually assumed to be quark-flavour conserving (QFC)
- The squarks are, however, not necessarily quark-flavour eigenstates. Flavour mixing in the squark sector may be stronger than in the quark sector. QFV decays can then occur with significant rates

QFV in the MSSM

- In the SM: all QFV terms are proportional to the CKM matrix

$$V_{\mathrm{CKM}} = V_u^\dagger V_d$$

QFV in the MSSM



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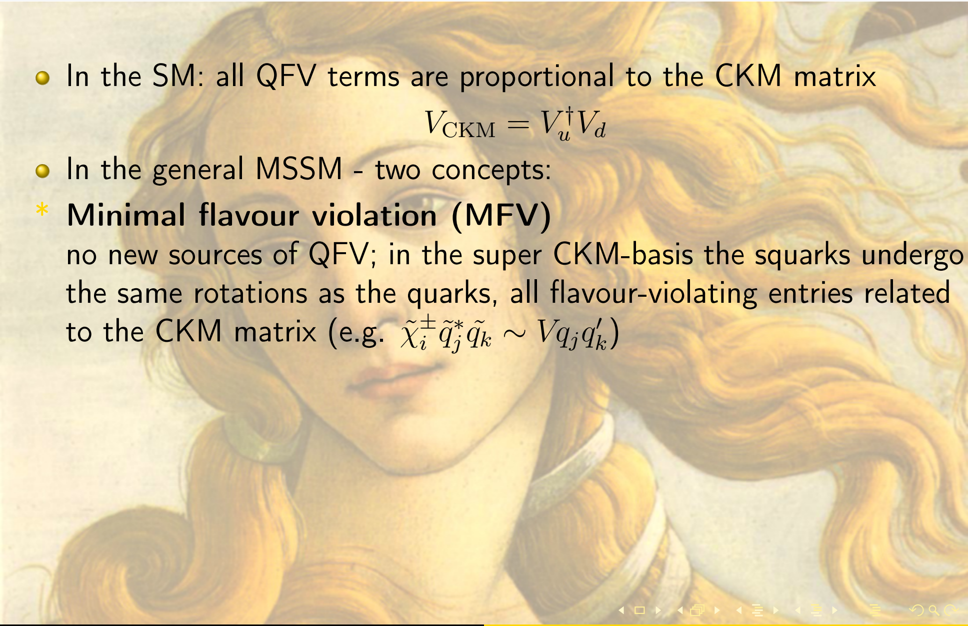

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* **Minimal flavour violation (MFV)**

no new sources of QFV; in the super CKM-basis the squarks undergo the same rotations as the quarks, all flavour-violating entries related to the CKM matrix (e.g. $\tilde{\chi}_i^\pm \tilde{q}_j^* \tilde{q}_k \sim V q_j q_k'$)

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- In the following we assume **NMFV**

NMFV in the MSSM

- The flavour-violating terms are contained in the mass matrices of the squarks at the electroweak scale

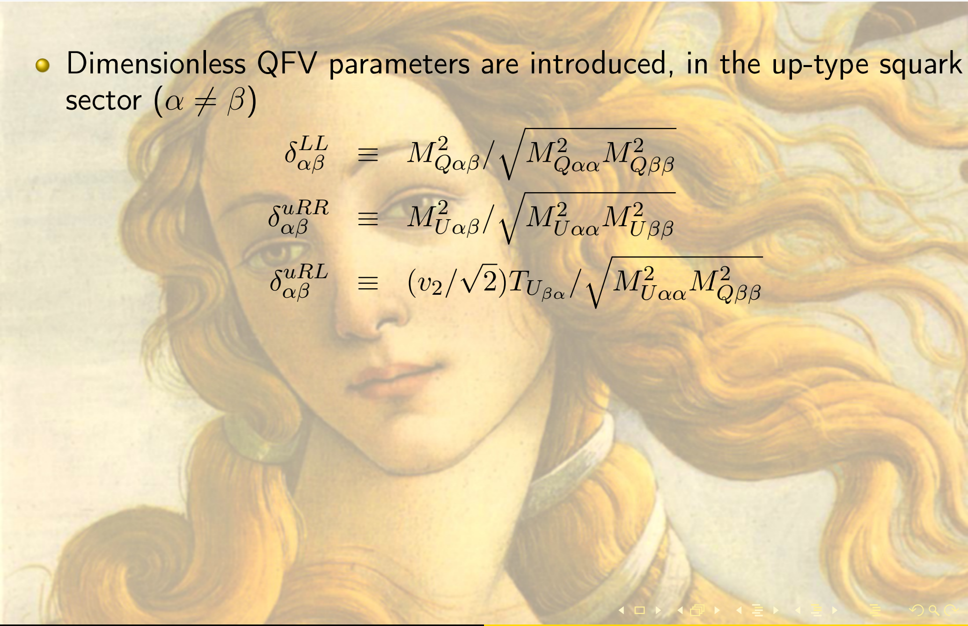
$$\mathcal{M}^2_{\tilde{q}} \;=\; \begin{pmatrix} \mathcal{M}^2_{\tilde{q}\,LL} & (\mathcal{M}^2_{\tilde{q}\,RL})^\dagger \\ \mathcal{M}^2_{\tilde{q}\,RL} & \mathcal{M}^2_{\tilde{q}\,RR} \end{pmatrix}, \; q = u, d.$$

- The 3×3 soft-breaking matrices can introduce flavour-violating (off-diagonal) terms, e.g. in the up-squark sector

$$\begin{aligned}
(\mathcal{M}^2_{\tilde{u}\,LL})_{\alpha\beta} &= M^2_{Q_u\alpha\beta} + \left[(\frac{1}{2} - \frac{2}{3}\sin^2\theta_W)\cos 2\beta\; m_Z^2 + m^2_{u_\alpha} \right] \delta_{\alpha\beta} \\
(\mathcal{M}^2_{\tilde{u}\,RR})_{\alpha\beta} &= M^2_{U\alpha\beta} + \left[(\frac{2}{3}\sin^2\theta_W)\cos 2\beta\; m_Z^2 + m^2_{u_\alpha} \right] \delta_{\alpha\beta} \\
(\mathcal{M}^2_{\tilde{u}\,RL})_{\alpha\beta} &= (v_2/\sqrt{2})\, T_{U\beta\alpha} - m_{U_\alpha}\mu^* \cot\beta\; \delta_{\alpha\beta}
\end{aligned}$$

- After diagonalization with a 6×6 rotation matrix $R^{\tilde{u}}$, the mass eigenstates are obtained $\tilde{u}_i = R^{\tilde{u}}_{i\alpha}\tilde{u}_{0\alpha}$, where $R^{\tilde{u}}\mathcal{M}^2_{\tilde{u}}R^{\tilde{u}\dagger} = \mathrm{diag}(m_{\tilde{u}_1}, ..., m_{\tilde{u}_6})$, with $m_{\tilde{u}_i} < m_{\tilde{u}_j}$ for $i < j$

NMFV in the MSSM



- Dimensionless QFV parameters are introduced, in the up-type squark sector ($\alpha \neq \beta$)

$$
\begin{aligned}
\delta^{LL}_{\alpha\beta} &\equiv M^2_{Q\alpha\beta} / \sqrt{M^2_{Q\alpha\alpha} M^2_{Q\beta\beta}} \\
\delta^{uRR}_{\alpha\beta} &\equiv M^2_{U\alpha\beta} / \sqrt{M^2_{U\alpha\alpha} M^2_{U\beta\beta}} \\
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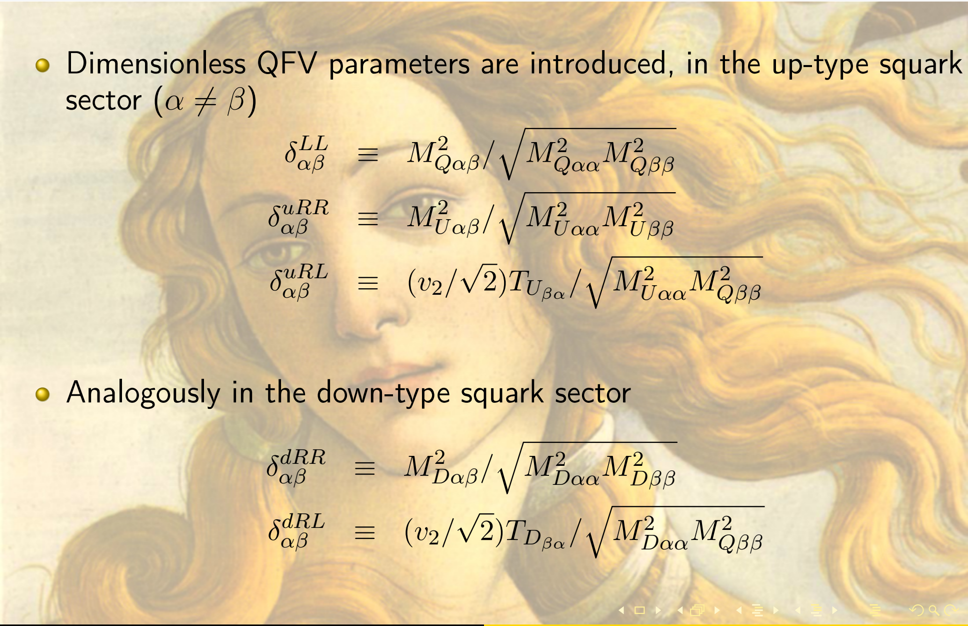

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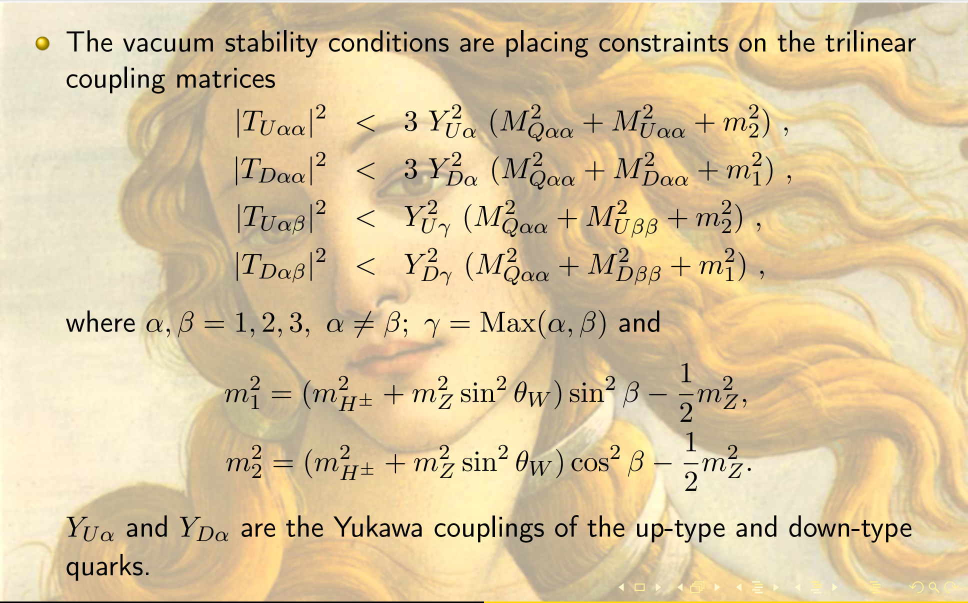
\delta^{uRL}_{\alpha\beta} &\equiv (v_2/\sqrt{2})T_{U\beta\alpha}/\sqrt{M^2_{U\alpha\alpha}M^2_{Q\beta\beta}}
\end{aligned}$$

- Analogously in the down-type squark sector

$$\begin{aligned}
\delta^{dRR}_{\alpha\beta} &\equiv M^2_{D\alpha\beta}/\sqrt{M^2_{D\alpha\alpha}M^2_{D\beta\beta}} \\
\delta^{dRL}_{\alpha\beta} &\equiv (v_2/\sqrt{2})T_{D\beta\alpha}/\sqrt{M^2_{D\alpha\alpha}M^2_{Q\beta\beta}}
\end{aligned}$$

Constraints on the MSSM parameters

Theoretical constraints



- The vacuum stability conditions are placing constraints on the trilinear coupling matrices

$$\begin{aligned}
|T_{U\alpha\alpha}|^2 &< 3\,Y_{U\alpha}^2\,(M_{Q\alpha\alpha}^2 + M_{U\alpha\alpha}^2 + m_2^2)\ ,\\
|T_{D\alpha\alpha}|^2 &< 3\,Y_{D\alpha}^2\,(M_{Q\alpha\alpha}^2 + M_{D\alpha\alpha}^2 + m_1^2)\ ,\\
|T_{U\alpha\beta}|^2 &< Y_{U\gamma}^2\,(M_{Q\alpha\alpha}^2 + M_{U\beta\beta}^2 + m_2^2)\ ,\\
|T_{D\alpha\beta}|^2 &< Y_{D\gamma}^2\,(M_{Q\alpha\alpha}^2 + M_{D\beta\beta}^2 + m_1^2)\ ,
\end{aligned}$$

where $\alpha, \beta = 1, 2, 3,\ \alpha \neq \beta;\ \gamma = \mathrm{Max}(\alpha, \beta)$ and

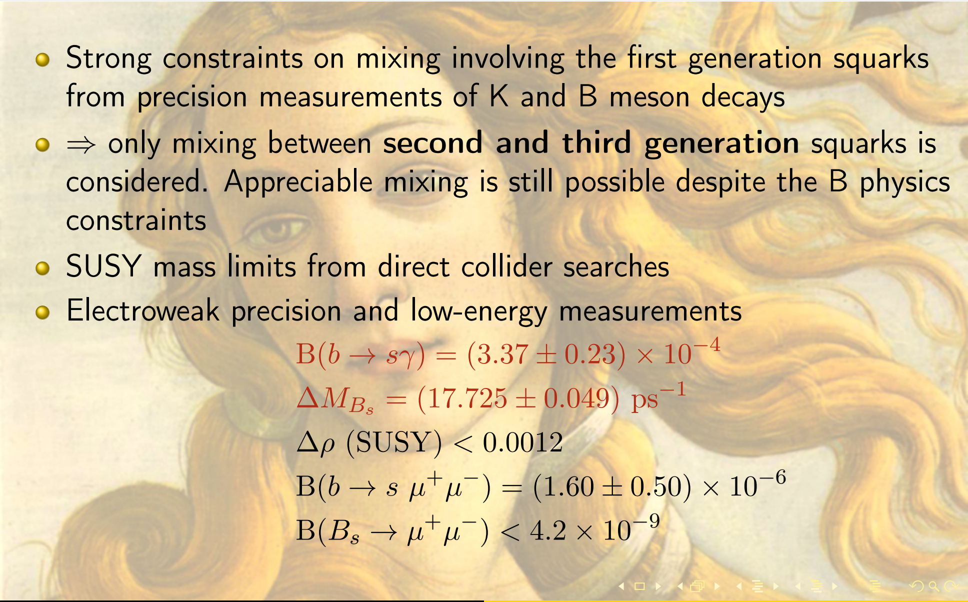
$$m_1^2 = (m_{H^\pm}^2 + m_Z^2 \sin^2\theta_W)\sin^2\beta - \frac{1}{2}m_Z^2,$$

$$m_2^2 = (m_{H^\pm}^2 + m_Z^2 \sin^2\theta_W)\cos^2\beta - \frac{1}{2}m_Z^2.$$

$Y_{U\alpha}$ and $Y_{D\alpha}$ are the Yukawa couplings of the up-type and down-type quarks.

Constraints on the MSSM parameters

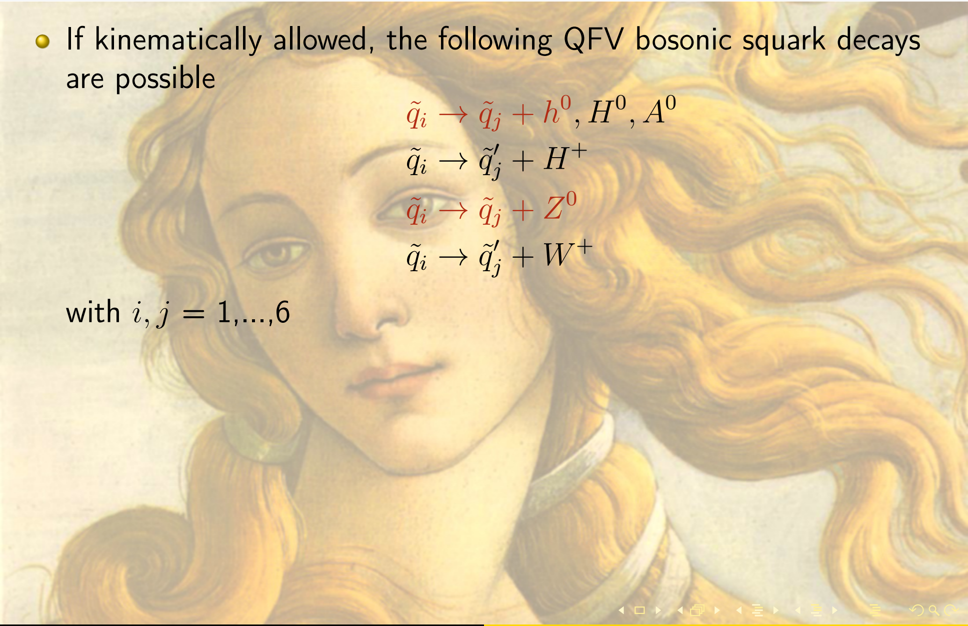
Experimental constraints



- Strong constraints on mixing involving the first generation squarks from precision measurements of K and B meson decays
- ⇒ only mixing between **second and third generation** squarks is considered. Appreciable mixing is still possible despite the B physics constraints
- SUSY mass limits from direct collider searches
- Electroweak precision and low-energy measurements

$$
\begin{aligned}
&\mathrm{B}(b \to s\gamma) = (3.37 \pm 0.23) \times 10^{-4} \\
&\Delta M_{B_s} = (17.725 \pm 0.049)\ \mathrm{ps}^{-1} \\
&\Delta\rho\ (\mathrm{SUSY}) < 0.0012 \\
&\mathrm{B}(b \to s\ \mu^+\mu^-) = (1.60 \pm 0.50) \times 10^{-6} \\
&\mathrm{B}(B_s \to \mu^+\mu^-) < 4.2 \times 10^{-9}
\end{aligned}
$$

QVF bosonic squark decays



- If kinematically allowed, the following QFV bosonic squark decays are possible

$$\tilde{q}_i \to \tilde{q}_j + h^0, H^0, A^0$$

$$\tilde{q}_i \to \tilde{q}'_j + H^+$$

$$\tilde{q}_i \to \tilde{q}_j + Z^0$$

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with i, j = 1,...,6

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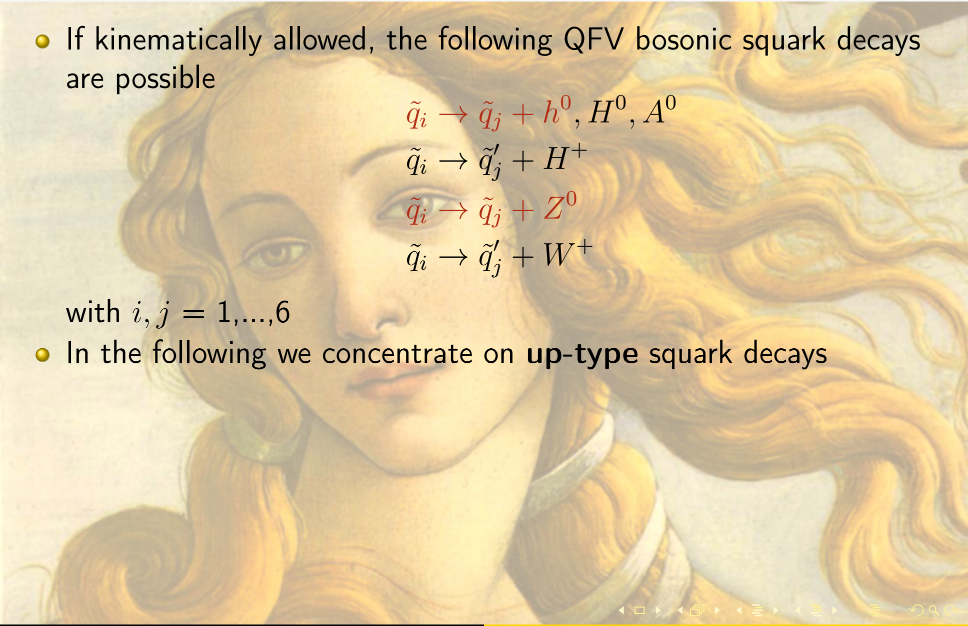

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- In the following we concentrate on **up-type** squark decays

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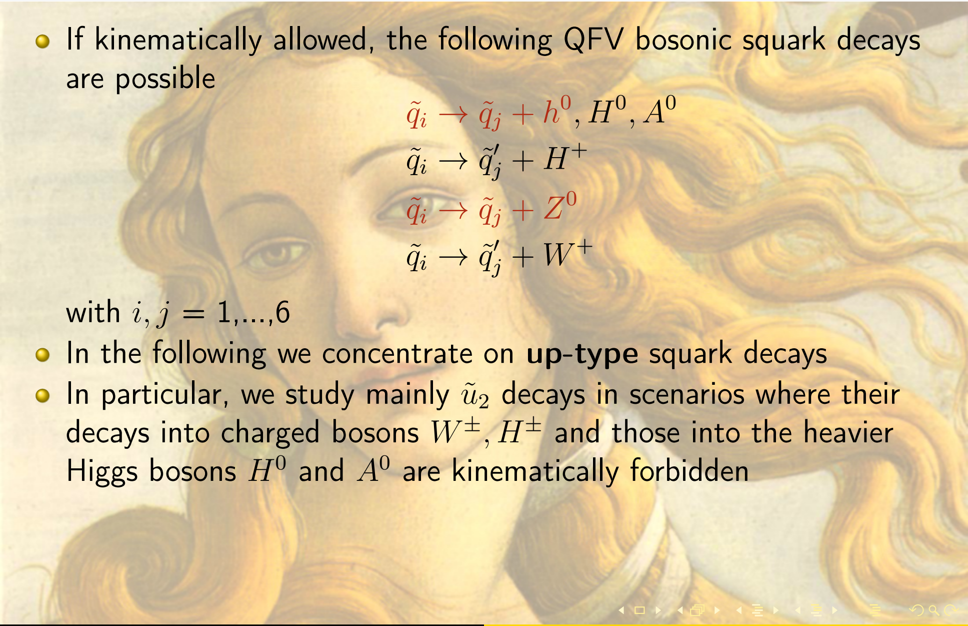

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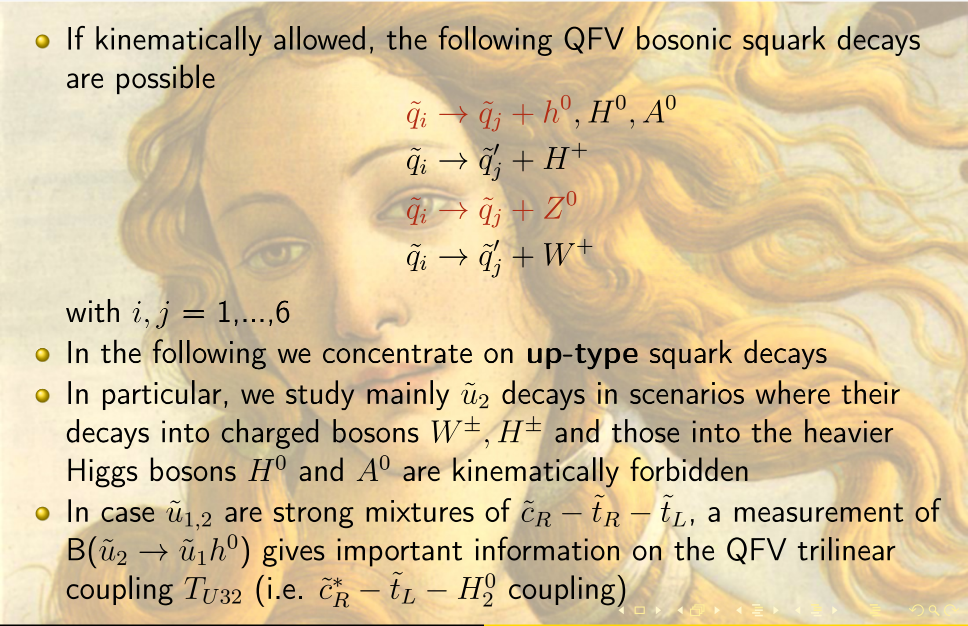

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- In particular, we study mainly $\tilde{u}_2$ decays in scenarios where their decays into charged bosons $W^\pm, H^\pm$ and those into the heavier Higgs bosons H^0 and A^0 are kinematically forbidden
- In case $\tilde{u}_{1,2}$ are strong mixtures of $\tilde{c}_R - \tilde{t}_R - \tilde{t}_L$, a measurement of B($\tilde{u}_2 \to \tilde{u}_1 h^0$) gives important information on the QFV trilinear coupling T_{U32} (i.e. $\tilde{c}^*_R - \tilde{t}_L - H^0_2$ coupling)

QVF bosonic squark decays

- In the super-CKM basis, the Lagrangian including the coupling of up-type squarks to h^0 contains the trilinear couplings $(T_U)_{ij}$ which are explicitly flavour-breaking terms that couple left-handed to right-handed squarks

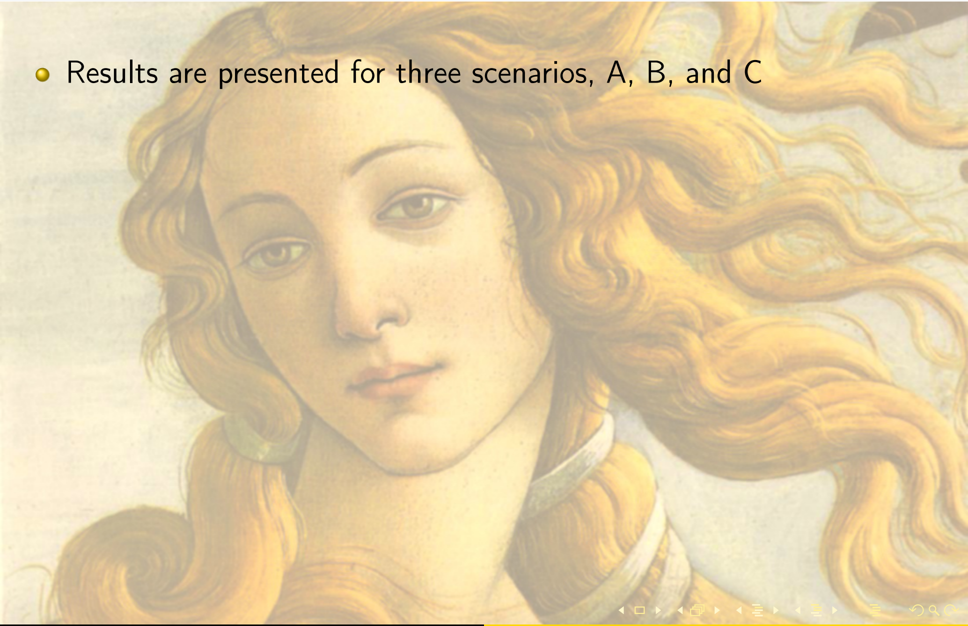
$$\mathcal{L} \ni -\frac{g_2}{2m_W} h^0 \Big[\tilde{u}^*_{iR} \tilde{u}_{jL} \Big(\mu^* \frac{\sin\alpha}{\sin\beta} m_{u,i} \delta_{ij} + \frac{\cos\alpha}{\sin\beta} \frac{v_2}{\sqrt{2}} (T_U)_{ji} \Big) + \text{h.c.} \Big]$$

- We consider $\tilde{c} - \tilde{t}$ mixing $\Rightarrow$ the relative QFV parameters are:

$$\begin{aligned}
\delta^{LL}_{\alpha\beta} &\equiv M^2_{Q\alpha\beta} / \sqrt{M^2_{Q\alpha\alpha} M^2_{Q\beta\beta}} \\
\delta^{uRR}_{\alpha\beta} &\equiv M^2_{U\alpha\beta} / \sqrt{M^2_{U\alpha\alpha} M^2_{U\beta\beta}} \\
\delta^{uRL}_{\alpha\beta} &\equiv (v_2/\sqrt{2}) T_{U_{\beta\alpha}} / \sqrt{M^2_{U\alpha\alpha} M^2_{Q\beta\beta}} \\
\delta^{uLR}_{\alpha\beta} &= \delta^{uRL*}_{\beta\alpha}
\end{aligned}$$

for $\alpha, \beta = 2, 3,\ \alpha \neq \beta$

QVF bosonic squark decays



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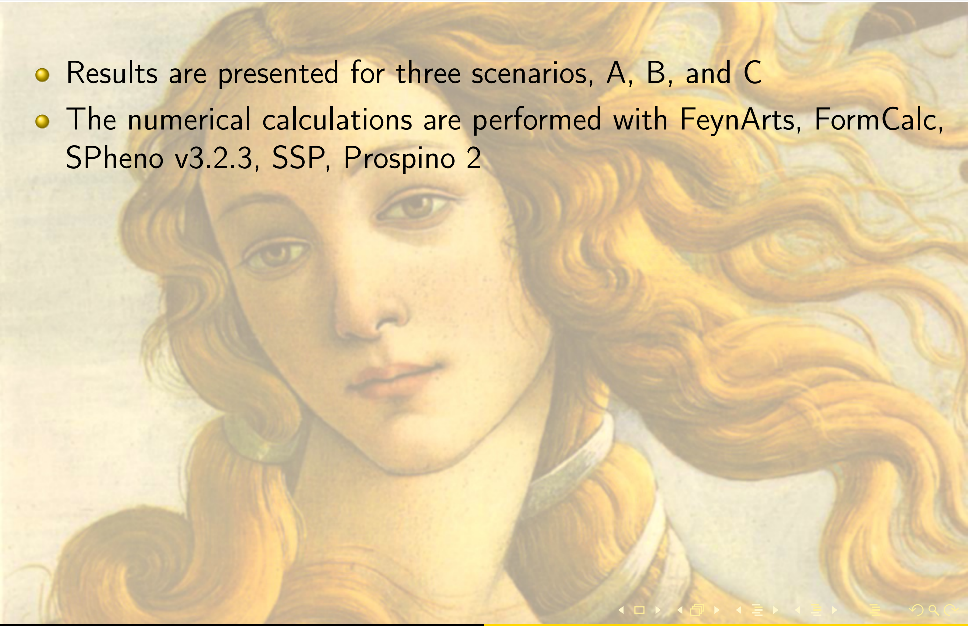

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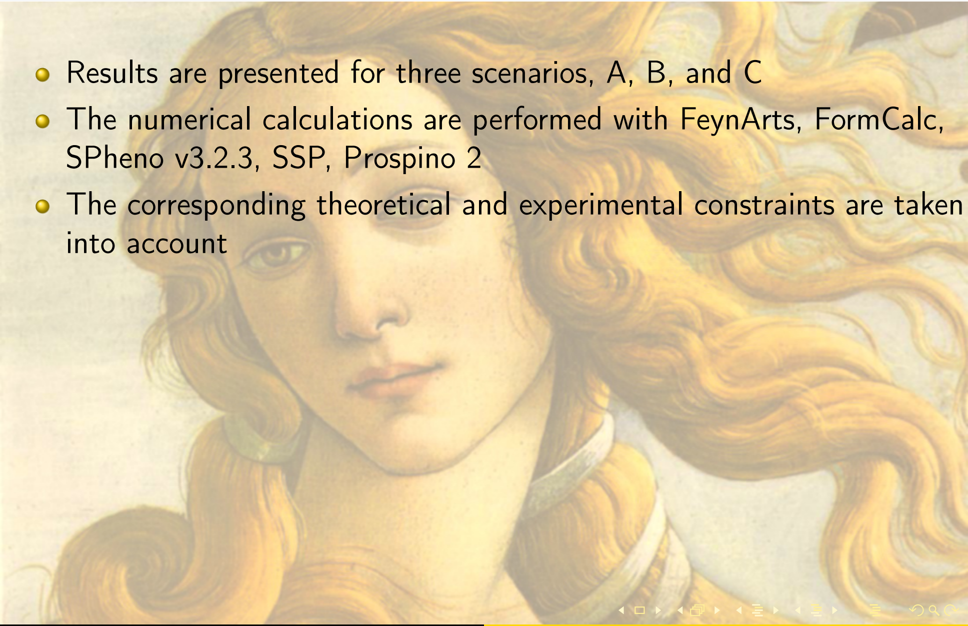

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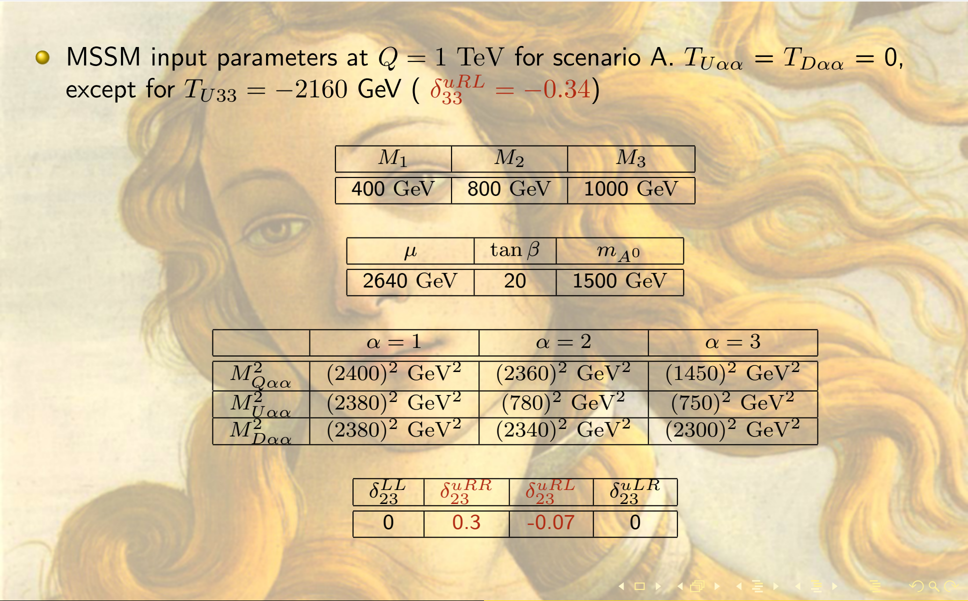
- M_3 is chosen so that the guino is within the reach of the LHC
- The gaugino masses M_1, M_2 and M_3 do not unify at the GUT scale, except for scenario B
- The lightest Higgs mass we obtain within the range of the Higgs signal at the LHC, $h^0 \approx 124 \text{ GeV}$, and, hence, it is SM-like

QVF bosonic squark decays

Scenario A



- MSSM input parameters at $Q = 1$ TeV for scenario A. $T_{U\alpha\alpha} = T_{D\alpha\alpha} = 0$, except for $T_{U33} = -2160$ GeV ($\delta^{uRL}_{33} = -0.34$)

M_1	M_2	M_3
400 GeV	800 GeV	1000 GeV

μ	$\tan\beta$	m_{A^0}
2640 GeV	20	1500 GeV

	$\alpha = 1$	$\alpha = 2$	$\alpha = 3$
$M^2_{Q\alpha\alpha}$	$(2400)^2$ GeV^2	$(2360)^2$ GeV^2	$(1450)^2$ GeV^2
$M^2_{U\alpha\alpha}$	$(2380)^2$ GeV^2	$(780)^2$ GeV^2	$(750)^2$ GeV^2
$M^2_{D\alpha\alpha}$	$(2380)^2$ GeV^2	$(2340)^2$ GeV^2	$(2300)^2$ GeV^2

δ^{LL}_{23}	δ^{uRR}_{23}	δ^{uRL}_{23}	δ^{uLR}_{23}
0	0.3	-0.07	0

QVF bosonic squark decays

Scenario A

- Physical masses in GeV of the particles in scenario A

$m_{\tilde{\chi}_1^0}$	$m_{\tilde{\chi}_2^0}$	$m_{\tilde{\chi}_3^0}$	$m_{\tilde{\chi}_4^0}$	$m_{\tilde{\chi}_1^+}$	$m_{\tilde{\chi}_2^+}$
397	824	2623	2625	825	2625

m_{h^0}	m_{H^0}	m_{A^0}	m_{H^+}
124.0	1496	1500	1510

$m_{\tilde{g}}$	$m_{\tilde{u}_1}$	$m_{\tilde{u}_2}$	$m_{\tilde{u}_3}$	$m_{\tilde{u}_4}$	$m_{\tilde{u}_5}$	$m_{\tilde{u}_6}$
1141	605	861	1477	2387	2401	2427

$m_{\tilde{d}_1}$	$m_{\tilde{d}_2}$	$m_{\tilde{d}_3}$	$m_{\tilde{d}_4}$	$m_{\tilde{d}_5}$	$m_{\tilde{d}_6}$
1433	2321	2364	2388	2404	2428

- Flavour decomposition of $\tilde{u}_1$ and $\tilde{u}_2$ in scenario A (shown are the squared coefficients)

	$\tilde{u}_L$	$\tilde{c}_L$	$\tilde{t}_L$	$\tilde{u}_R$	$\tilde{c}_R$	$\tilde{t}_R$
$\tilde{u}_1$	0	0	0.032	0	0.209	0.759
$\tilde{u}_2$	0	0	0.031	0	0.785	0.184

QVF bosonic squark decays

Scenario A

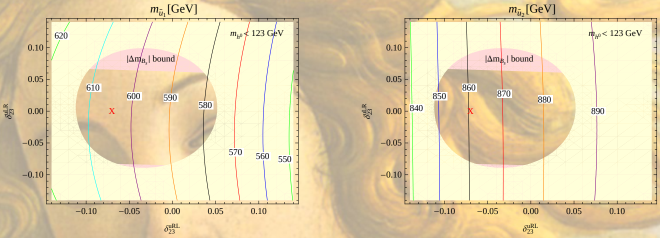
- Two-body decay branching ratios of $\tilde{u}_2$, $\tilde{u}_1$ and gluino in scenario A. The charge conjugated processes have the same branching ratios and are not shown explicitly

$B(\tilde{u}_2 \to \tilde{u}_1 h^0)$	0.47
$B(\tilde{u}_2 \to \tilde{u}_1 Z^0)$	0.01
$B(\tilde{u}_2 \to c\tilde{\chi}_1^0)$	0.43
$B(\tilde{u}_2 \to t\tilde{\chi}_1^0)$	0.09
$B(\tilde{u}_1 \to c\tilde{\chi}_1^0)$	0.36
$B(\tilde{u}_1 \to t\tilde{\chi}_1^0)$	0.64
$B(\tilde{g} \to \tilde{u}_2 \bar{c})$	0.12
$B(\tilde{g} \to \tilde{u}_2 \bar{t})$	0.01
$B(\tilde{g} \to \tilde{u}_1 \bar{c})$	0.09
$B(\tilde{g} \to \tilde{u}_1 \bar{t})$	0.27

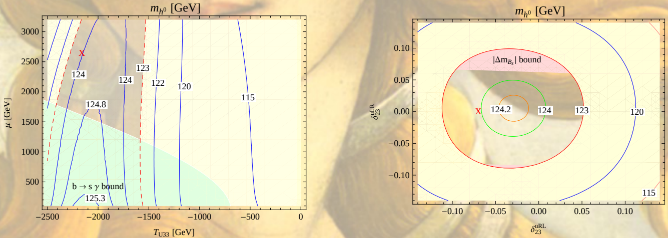
QVF bosonic squark decays

Numerical results, Scenario A

- Dependence of the masses of $\tilde{u}_1$ and $\tilde{u}_2$ on δ_{23}^{uRL} and δ_{23}^{uLR}



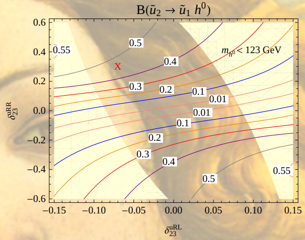
- m_{h^0}, as a function of T_{U33} and μ and as a function of δ_{23}^{uRL} and δ_{23}^{uLR}



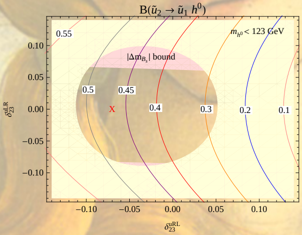
QVF bosonic squark decays

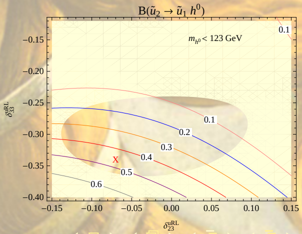
Numerical results, Scenario A

- $B(\tilde{u}_2 \to \tilde{u}_1 h^0)$ as a function of δ_{23}^{uRL} and δ_{23}^{uRR}



- $B(\tilde{u}_2 \to \tilde{u}_1 h^0)$ as a function of δ_{23}^{uRL} and δ_{23}^{uLR} and as a function of δ_{23}^{uRL} and δ_{33}^{uRL}

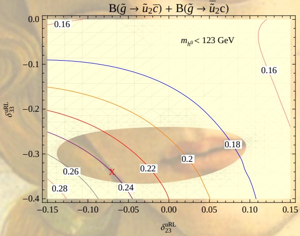




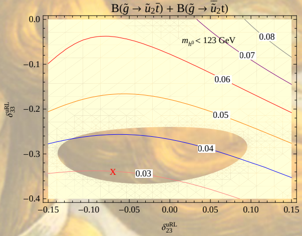
QVF bosonic squark decays

Numerical results, Scenario A

- Branching ratios of $\tilde{g} \to \tilde{u}_2 \bar{c} + c.c.$ and $\tilde{g} \to \tilde{u}_2 \bar{t} + c.c.$ as functions of δ_{23}^{uRL} and δ_{33}^{uRL}



$B(\tilde{g} \to \tilde{u}_2 \bar{c}) + B(\tilde{g} \to \bar{\tilde{u}}_2 c)$



$B(\tilde{g} \to \tilde{u}_2 \bar{t}) + B(\tilde{g} \to \bar{\tilde{u}}_2 t)$

QVF bosonic squark decays

Scenario B

- Scenario B: GUT-inspired, $M_1 \approx 0.5\ M_2$, $M_3/M_2 = g_3^2/g_2^2$, where g_2 and g_3 are the SU(2) and SU(3) gauge coupling constants, respectively

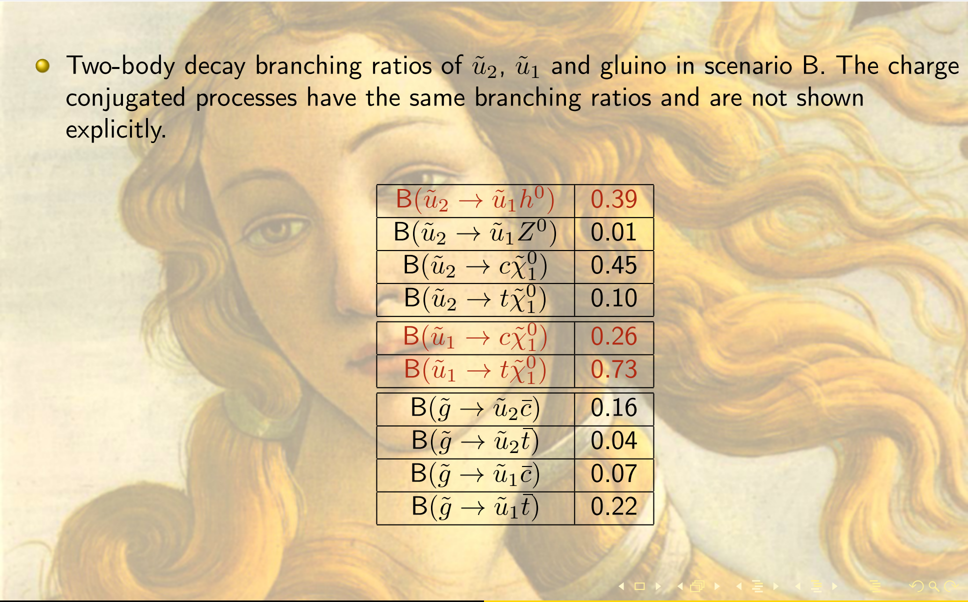
- Only M_1, M_2 and M_3 are replaced with respect to scenario A, $M_1 = 250\ \mathrm{GeV}$, $M_2 = 500\ \mathrm{GeV}$ and $M_3 = 1500\ \mathrm{GeV}$

- Large $m_{\tilde{g}} = 1626\ \mathrm{GeV} \Longrightarrow$ small production cross section

- The dependences of the QFV parameters are similar to those in scenario A

QVF bosonic squark decays

Scenario B



- Two-body decay branching ratios of $\tilde{u}_2$, $\tilde{u}_1$ and gluino in scenario B. The charge conjugated processes have the same branching ratios and are not shown explicitly.

B$(\tilde{u}_2 \to \tilde{u}_1 h^0)$	0.39
B$(\tilde{u}_2 \to \tilde{u}_1 Z^0)$	0.01
B$(\tilde{u}_2 \to c\tilde{\chi}_1^0)$	0.45
B$(\tilde{u}_2 \to t\tilde{\chi}_1^0)$	0.10
B$(\tilde{u}_1 \to c\tilde{\chi}_1^0)$	0.26
B$(\tilde{u}_1 \to t\tilde{\chi}_1^0)$	0.73
B$(\tilde{g} \to \tilde{u}_2 \bar{c})$	0.16
B$(\tilde{g} \to \tilde{u}_2 \bar{t})$	0.04
B$(\tilde{g} \to \tilde{u}_1 \bar{c})$	0.07
B$(\tilde{g} \to \tilde{u}_1 \bar{t})$	0.22

QVF bosonic squark decays

Scenario C

- Scenario C, comparable branching ratios of $\tilde{u}_2 \to \tilde{u}_1 h^0$ and $\tilde{u}_2 \to \tilde{u}_1 Z^0$. Parameters changed with respect to scenario A:

$$M^2_{U22} = (650\ \mathrm{GeV})^2, \quad M^2_{U33} = (1600\ \mathrm{GeV})^2, \quad M^2_{Q33} = (780\ \mathrm{GeV})^2,$$
$$\delta^{uLL}_{23} = 0, \quad \delta^{uRR}_{23} = 0, \quad \delta^{uRL}_{23} = -0.17, \quad \delta^{uRL}_{33} = -0.3$$

- Physical masses in GeV of the particles in scenario C

$m_{\tilde{\chi}^0_1}$	$m_{\tilde{\chi}^0_2}$	$m_{\tilde{\chi}^0_3}$	$m_{\tilde{\chi}^0_4}$	$m_{\tilde{\chi}^+_1}$	$m_{\tilde{\chi}^+_2}$
398	819	2623	2625	819	2625

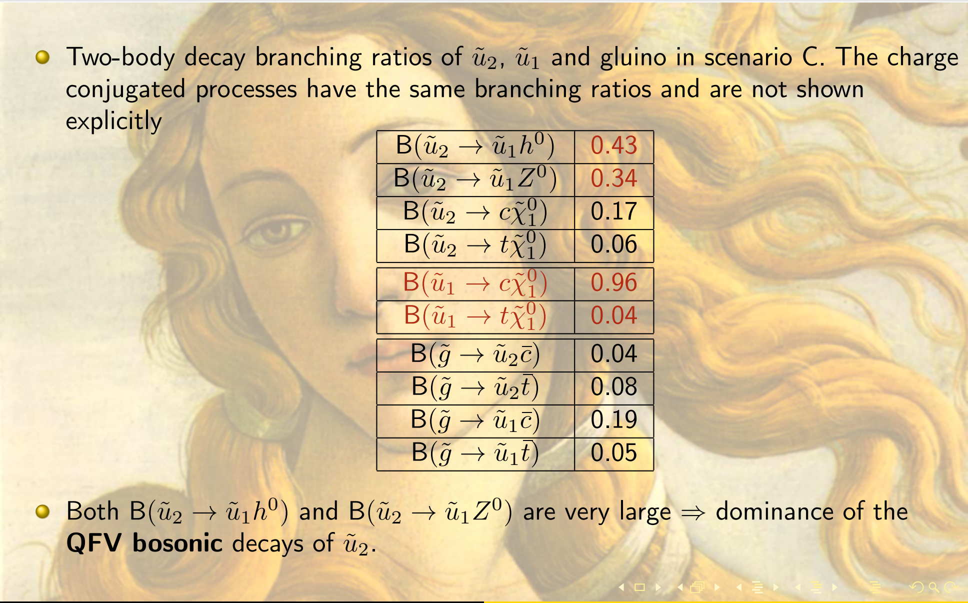
m_{h^0}	m_{H^0}	m_{A^0}	m_{H^+}
123.7	1497	1500	1537

$m_{\tilde{g}}$	$m_{\tilde{u}_1}$	$m_{\tilde{u}_2}$	$m_{\tilde{u}_3}$	$m_{\tilde{u}_4}$	$m_{\tilde{u}_5}$	$m_{\tilde{u}_6}$
1134	651	800	1580	2387	2401	2427

$m_{\tilde{d}_1}$	$m_{\tilde{d}_2}$	$m_{\tilde{d}_3}$	$m_{\tilde{d}_4}$	$m_{\tilde{d}_5}$	$m_{\tilde{d}_6}$
807	2321	2363	2388	2404	2428

QVF bosonic squark decays

Scenario C



- Two-body decay branching ratios of $\tilde{u}_2$, $\tilde{u}_1$ and gluino in scenario C. The charge conjugated processes have the same branching ratios and are not shown explicitly

B$(\tilde{u}_2 \to \tilde{u}_1 h^0)$	0.43
B$(\tilde{u}_2 \to \tilde{u}_1 Z^0)$	0.34
B$(\tilde{u}_2 \to c\tilde{\chi}_1^0)$	0.17
B$(\tilde{u}_2 \to t\tilde{\chi}_1^0)$	0.06
B$(\tilde{u}_1 \to c\tilde{\chi}_1^0)$	0.96
B$(\tilde{u}_1 \to t\tilde{\chi}_1^0)$	0.04
B$(\tilde{g} \to \tilde{u}_2 \bar{c})$	0.04
B$(\tilde{g} \to \tilde{u}_2 \bar{t})$	0.08
B$(\tilde{g} \to \tilde{u}_1 \bar{c})$	0.19
B$(\tilde{g} \to \tilde{u}_1 \bar{t})$	0.05

- Both B$(\tilde{u}_2 \to \tilde{u}_1 h^0)$ and B$(\tilde{u}_2 \to \tilde{u}_1 Z^0)$ are very large ⇒ dominance of the **QFV bosonic** decays of $\tilde{u}_2$.

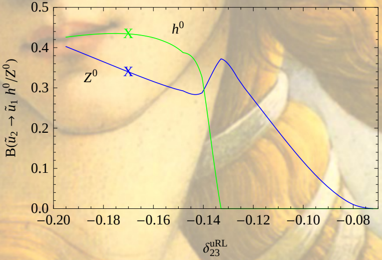
QVF bosonic squark decays

Numerical results, Scenario C

- Flavour decomposition of $\tilde{u}_1$ and $\tilde{u}_2$ in scenario C. Shown are the squared coefficients

	$\tilde{u}_L$	$\tilde{c}_L$	$\tilde{t}_L$	$\tilde{u}_R$	$\tilde{c}_R$	$\tilde{t}_R$
$\tilde{u}_1$	0	0	0.242	0	0.745	0.012
$\tilde{u}_2$	0	0	0.713	0	0.255	0.032

- δ_{23}^{uRL} dependence of the branching ratios B$(\tilde{u}_2 \to \tilde{u}_1 h^0)$ and B$(\tilde{u}_2 \to \tilde{u}_1 Z^0)$



QVF bosonic squark decays

Characteristic final states

- We discuss some characteristic final states from the bosonic QFV decays of $\tilde{u}_2$ to be expected @ LHC, $\sqrt{s} = 14$ TeV
- Lighter squarks can be produced directly, $pp \to \tilde{u}_1 \bar{\tilde{u}}_1 X$, $pp \to \tilde{u}_2 \bar{\tilde{u}}_2 X$, or via gluino production, $pp \to \tilde{g}\tilde{g}X$, where at least one of the gluino decays into $\tilde{u}_1$ or $\tilde{u}_2$, $\tilde{g} \to \tilde{u}_{1,2}\ c;\ \tilde{u}_{1,2}\ t$
- The relevant for our study decays are:

$$
\begin{aligned}
&\tilde{u}_1 \to c/t\ \tilde{\chi}^0_1, \\
&\tilde{u}_2 \to c/t\ \tilde{\chi}^0_1, \\
&\tilde{u}_2 \to \tilde{u}_1\ h^0/Z^0 \to c/t\ \tilde{\chi}^0_1\ h^0/Z^0, \\
&\tilde{g} \to \tilde{u}_1\ \bar{c}/\bar{t} \to c/t\ \tilde{\chi}^0_1\ \bar{c}/\bar{t}\ (\text{and } c.c.), \\
&\tilde{g} \to \tilde{u}_2\ \bar{c}/\bar{t} \to c/t\ \tilde{\chi}^0_1\ \bar{c}/\bar{t}\ (\text{and } c.c.), \\
&\tilde{g} \to \tilde{u}_2\ \bar{c}/\bar{t} \to \tilde{u}_1\ h^0/Z^0\ \bar{c}/\bar{t} \to \\
&\qquad\qquad\qquad \to c/t\ \tilde{\chi}^0_1\ h^0/Z^0\ \bar{c}/\bar{t}\ (\text{and } c.c.).
\end{aligned}
$$

QVF bosonic squark decays
Characteristic final states

- Possible final states containing at least one Higgs boson h^0 expected from the decays of $\tilde{u}_2$ into h^0 and Z^0

processes	final states containing h^0
$pp \to \tilde{u}_2\tilde{u}_2X$ $pp \to \tilde{u}_2\bar{\tilde{u}}_2X$	$2j + h^0 + E_T^{\text{miss}} + X$ (1.5 fb)
	$j + t + h^0 + E_T^{\text{miss}} + X$ (2.8 fb)
	$2t + h^0 + E_T^{\text{miss}} + X$
	$2j + 2h^0 + E_T^{\text{miss}} + X$
	$j + t + 2h^0 + E_T^{\text{miss}} + X$ (1 fb)
	$2t + 2h^0 + E_T^{\text{miss}} + X$
	$2j + h^0 + Z^0 + E_T^{\text{miss}} + X$
	$j + t + h^0 + Z^0 + E_T^{\text{miss}} + X$
	$2t + h^0 + Z^0 + E_T^{\text{miss}} + X$

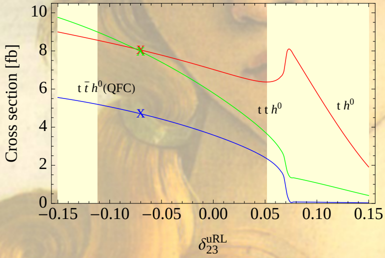
processes	final states containing h^0
$pp \to \tilde{g}\tilde{g}X$	$4j + h^0 + E_T^{\text{miss}} + X$ (2 fb)
	$3j + t + h^0 + E_T^{\text{miss}} + X$ (8 fb)
	$2j + 2t + h^0 + E_T^{\text{miss}} + X$ (13 fb)
	$4j + 2h^0 + E_T^{\text{miss}} + X$
	$3j + t + 2h^0 + E_T^{\text{miss}} + X$
	$2j + 2t + 2h^0 + E_T^{\text{miss}} + X$
	$4j + h^0 + Z^0 + E_T^{\text{miss}} + X$
	$3j + t + h^0 + Z^0 + E_T^{\text{miss}} + X$
	$2j + 2t + h^0 + Z^0 + E_T^{\text{miss}} + X$

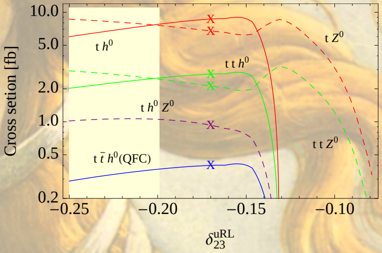
- Some of these final states are explicitly QFV, some look like QFC, and others can stem from both QFC and QFV decays
  - * Note, that e.g. final states tt(or $\overline{tt}$)jj from gluino pair production, such as tt (or $\overline{tt}$)$jjh^0E_T^{\text{miss}}X$ can practically not be produced in the QFC MSSM (nor in the SM)
- For scenario A, the production cross section for $pp \to \tilde{g}\tilde{g}X$ is 148 fb, including SUSY-QCD corrections (Prospino 2) and the cross section for $pp \to \tilde{u}_1\bar{\tilde{u}}_1X$ is at tree-level 10 fb (FA/ FC)

QVF bosonic squark decays

Characteristic final states

- Summing up the cross sections for all final states with at least one h^0 in scenario A one gets 28 fb, 16 fb of which come from pure QFV states
- $\Longrightarrow$ one could expect about 1600 of such events assuming an integrated luminosity of 100 fb^{-1} at LHC (14 TeV)
- Cross sections for $pp \to \tilde{g}\tilde{g}X \to 3j + t + h^0 + E_T^{\mathrm{miss}} + X$ and $pp \to \tilde{g}\tilde{g}X \to 2j + 2t + h^0 + E_T^{\mathrm{miss}} + X$ in scenario A and in scenario C as functions of δ_{23}^{uRL}





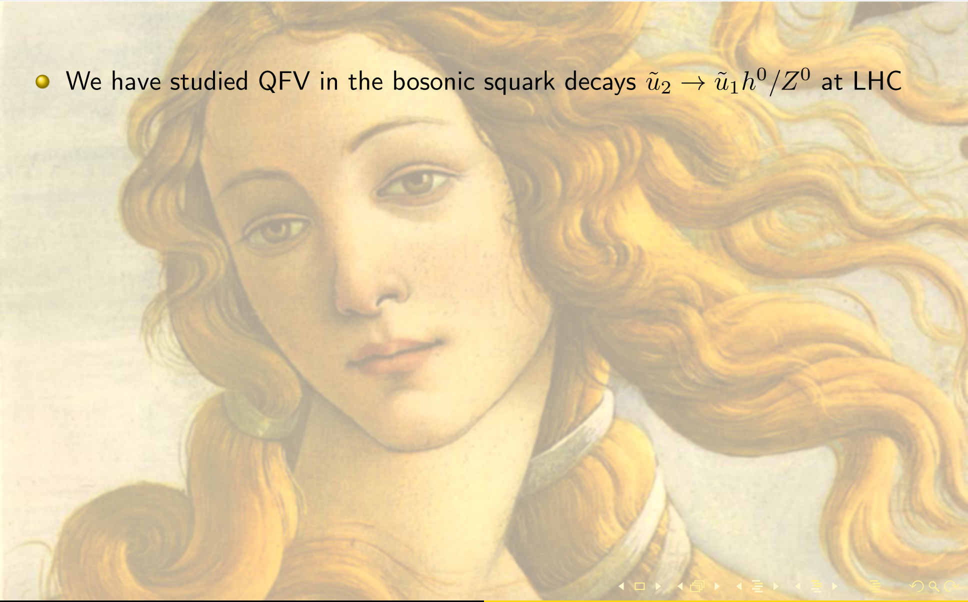
QVF bosonic squark decays

Mesurability

- An important background is h^0 production in association with top quarks, $pp \to t\bar{t}h^0X$, where h^0 is radiated off from top or anti-top. The cross section at $\sqrt{s} = 14$ TeV is ≈ 400 fb. No missing energy in the final state
- Higgs production processes $pp \to Z^0Z^0h^0$; $W^+W^-h^0$ will constitute a background to the $h^0 + jets + E_T^{\text{miss}}$. No top in the final state
- Single h^0 production from gluon-gluon fusion as well as $pp \to b\bar{b}h^0X$ also do not contain a top quark in the final state
- In the scenarios considered the charginos and neutralinos are relatively heavy and the $\tilde{u}_{1,2}$ fermionic decays are suppressed, except those into $\tilde{\chi}_1^0$. If this is not the case the QFV signals will be less pronounced
- Most interesting final states are $j + t + h^0 + E_T^{\text{miss}} + X$ from $\tilde{u}_2\bar{\tilde{u}}_2$ production and $3j + t + h^0 + E_T^{\text{miss}} + X$ from $\tilde{g}\tilde{g}$ production. To extract these events, the identification of the t-quark and the h^0 by their decay products needed - requires Monte Carlo simulations. This is, however, beyond the scope of this study.

QVF bosonic squark decays

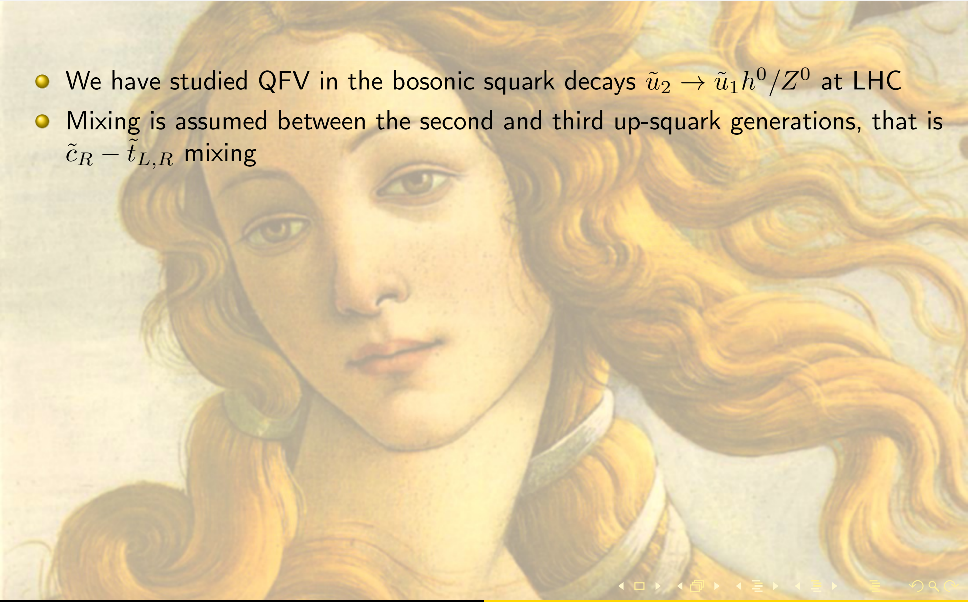
Summary



- We have studied QFV in the bosonic squark decays $\tilde{u}_2 \to \tilde{u}_1 h^0/Z^0$ at LHC

QVF bosonic squark decays

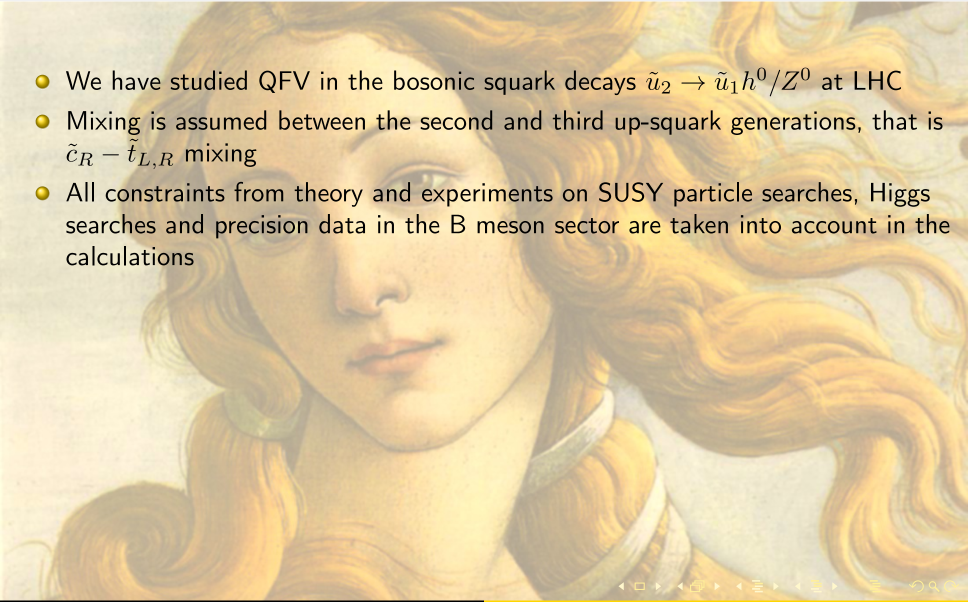
Summary



- We have studied QFV in the bosonic squark decays $\tilde{u}_2 \to \tilde{u}_1 h^0/Z^0$ at LHC
- Mixing is assumed between the second and third up-squark generations, that is $\tilde{c}_R - \tilde{t}_{L,R}$ mixing

QVF bosonic squark decays

Summary



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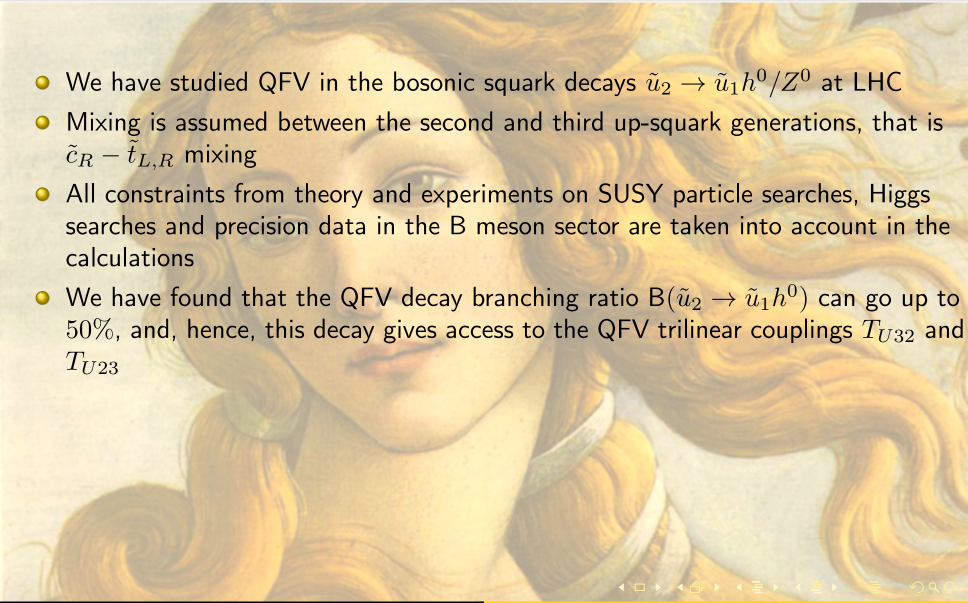
- All constraints from theory and experiments on SUSY particle searches, Higgs searches and precision data in the B meson sector are taken into account in the calculations

QVF bosonic squark decays

Summary



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- We have found that the QFV decay branching ratio B$(\tilde{u}_2 \to \tilde{u}_1 h^0)$ can go up to 50%, and, hence, this decay gives access to the QFV trilinear couplings T_{U32} and T_{U23}

QVF bosonic squark decays

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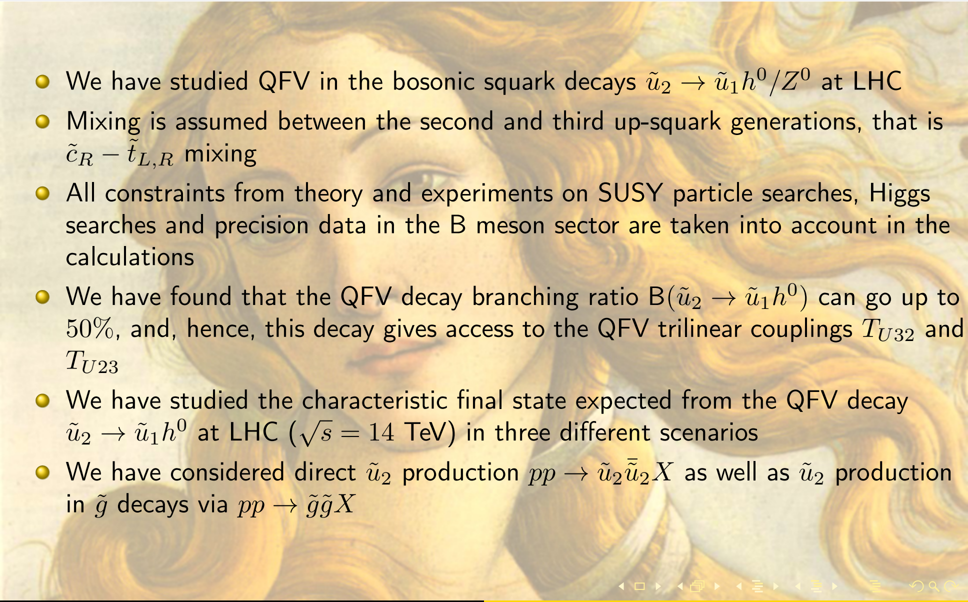
QVF bosonic squark decays

Summary



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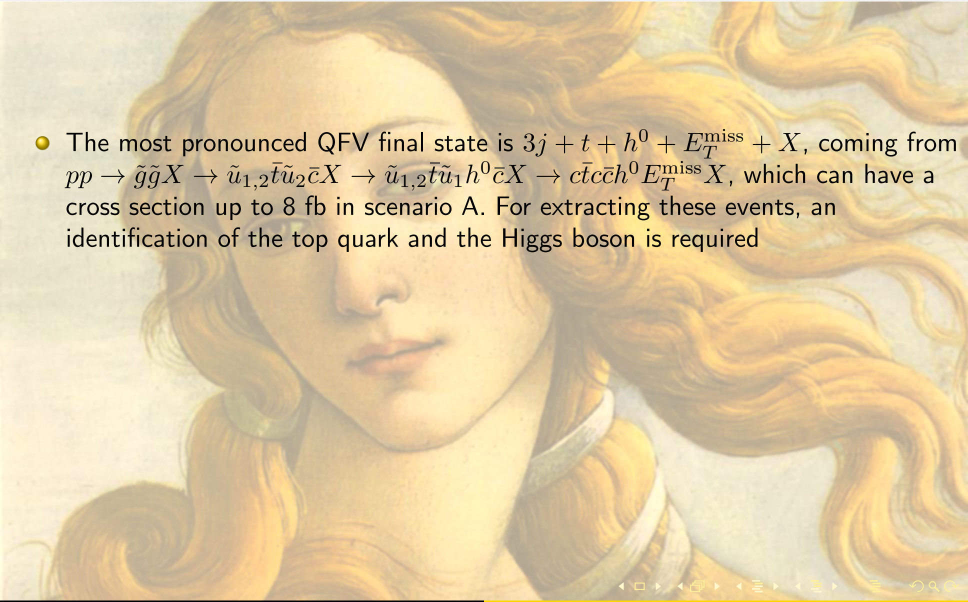
- We have studied the characteristic final state expected from the QFV decay $\tilde{u}_2 \to \tilde{u}_1 h^0$ at LHC ($\sqrt{s} = 14$ TeV) in three different scenarios
- We have considered direct $\tilde{u}_2$ production $pp \to \tilde{u}_2 \bar{\tilde{u}}_2 X$ as well as $\tilde{u}_2$ production in $\tilde{g}$ decays via $pp \to \tilde{g}\tilde{g}X$

QVF bosonic squark decays

Summary



- The most pronounced QFV final state is $3j + t + h^0 + E_T^{\text{miss}} + X$, coming from $pp \to \tilde{g}\tilde{g}X \to \tilde{u}_{1,2}\bar{t}\tilde{u}_2\bar{c}X \to \tilde{u}_{1,2}\bar{t}\tilde{u}_1 h^0\bar{c}X \to c\bar{t}c\bar{c}h^0 E_T^{\text{miss}} X$, which can have a cross section up to 8 fb in scenario A. For extracting these events, an identification of the top quark and the Higgs boson is required

QVF bosonic squark decays
Summary

- The most pronounced QFV final state is $3j + t + h^0 + E_T^{\mathrm{miss}} + X$, coming from $pp \to \tilde{g}\tilde{g}X \to \tilde{u}_{1,2}\bar{t}\tilde{u}_2\bar{c}X \to \tilde{u}_{1,2}\bar{t}\tilde{u}_1 h^0\bar{c}X \to c\bar{t}c\bar{c}h^0 E_T^{\mathrm{miss}}X$, which can have a cross section up to 8 fb in scenario A. For extracting these events, an identification of the top quark and the Higgs boson is required
- Our analyses suggest that for a complete determination of the parameters of the squark mass matrices in the MSSM it would be necessary to study both the fermionic and the bosonic QFC and QFV decays of squarks. This can also have an influence on the squark and gluino searches at LHC.

Thank you for your attention!!! :)