Squark flavor constraints from $B \rightarrow K^{*}l^+l^-$

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work in preparation with
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Outline

a) improved $C_9 - C_{10}$ constraints from $B \rightarrow K^{*} l^+ l^-$ data [Bobeth, Hiller, van Dyk; '10,'11]

b) this work: implications for SUSY flavor

c) ... and (briefly) model-implications
   example: radiative flavor violation
$\Delta B=1$ Effective Hamiltonian

$$\mathcal{H}_{\text{eff}} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_i C_i(\mu) O_i(\mu) + \text{h.c.}$$

most important operators for $B \to K^* l^+ l^-$:

$$O_7 \sim m_b [\bar{s}_L \sigma_{\mu \nu} b_R] F^{\mu \nu} \quad O_{9(10)} \sim [\bar{s}_L \gamma_\mu b_L] [\bar{\ell} \gamma^\mu (\gamma_5) \ell]$$

$C_i = C_i^{\text{SM}} + C_i^{\text{NP}}$

- $|C_7|$: quite constrained by $b \to s \gamma$ data
- $C_9, C_{10}$: plenty of room for New Physics
B→K*ℓ+ℓ− at low K* recoil →
new C_9-C_{10} constraints

toy plot:
[taken from 1106.1547]

from
A_{FB} \sim \text{Re}\{C_9^* C_{10}\} at
low K* recoil

from
BR(B→K*ℓ+ℓ−)\sim
|C_9|^2 + |C_{10}|^2

➠ what are consequences for BSM models?
here: SUSY ➤ new constraints for squark FV?
$B \rightarrow K^* l^+ l^-$ at low $K^*$ recoil

new $C_9$-$C_{10}$ constraints

toy plot: [taken from 1106.1547]

from $A_{FB} \sim \text{Re}\{C_9^* C_{10}\}$ at low $K^*$ recoil

actual analysis: [Bobeth et al., JHEP 1007:098, 2010]

$A_{FB} \sim \text{Re}\{C_9^* C_{10}\}$ at low $K^*$ recoil

What are consequences for BSM models?

SM

Has for BSM models? Constraints for squark FV?

[taken from U. Egedes talk at PANIC 2011]
$B \rightarrow K^* l^+ l^-$ at low $K^*$ recoil $\rightarrow$ new $C_9$-$C_{10}$ constraints

**toilet plot:**
[taken from 1106.1547]

From $A_{FB} \sim \text{Re}\{C_9^* C_{10}\}$ at low $K^*$ recoil

From $\text{BR}(B \rightarrow K^* l^+ l^-) \sim |C_9|^2 + |C_{10}|^2$

$\Rightarrow$ what are consequences for BSM models? here: SUSY $\Rightarrow$ new constraints for squark FV?

**actual analysis:**
[Bobeth et. al., JHEP 1007:098, 2010]
**Squark mass matrices in SCKM basis**

\[
M_{\tilde{u}}^2 \equiv \begin{pmatrix}
\tilde{u}_L & \tilde{u}_R \\
\tilde{c}_L & \tilde{c}_R \\
\tilde{t}_L & \tilde{t}_R
\end{pmatrix}
\]

\[
\begin{array}{ccccc}
\tilde{u}_L & (\Delta_{12}^u)_{LL} & (\Delta_{13}^u)_{LL} & (\Delta_{13}^u)_{RR} & (\Delta_{13}^u)_{LR} \\
\tilde{c}_L & m_{\tilde{c}_L}^2 & m_{\tilde{c}_L}^2 & m_{\tilde{c}_R}^2 & m_{\tilde{c}_R}^2 \\
\tilde{t}_L & (\Delta_{23}^u)_{LL} & (\Delta_{23}^u)_{RR} & (\Delta_{23}^u)_{LR} & (\Delta_{23}^u)_{LR} \\
\tilde{t}_R & m_{\tilde{t}_L}^2 & m_{\tilde{t}_R}^2 & m_{\tilde{t}_R}^2 & m_{\tilde{t}_R}^2 \\
h.c. & & & & \\
\end{array}
\]

\[
(M_{\tilde{d}}^2 : \text{analogous...})
\]

we try to constrain \((\Delta_{23}^u)_{LR}\)

more precisely: the dimensionless parameter

\[
(\delta_{23}^u)_{LR} = \frac{(\Delta_{23}^u)_{LR}}{\frac{1}{6} \left(5m_{\tilde{q}}^2 + m_{\tilde{t}}^2\right)}
\]

other squark flavor parameters:

quite constraint by \(b \to s\gamma\) and/or subleading in \(C_9, C_{10}\)!
$C_{9,10}^{\text{NP}} \text{ from squark-chargino loops}$

example: $Z, \gamma$-penguin with higgsino + wino vertices:

\[
\begin{align*}
C_{9,10}^{\text{MI, } \tilde{c}} &= \frac{K_{cs}^*}{K_{ts}^*} \frac{1}{4 s_W^2} \frac{\lambda_t}{g_2} \left( (4 s_W^2 - 1) F^{Z-p.} + 4 s_W^2 \frac{m_W^2}{m_{\tilde{q}}^2} F^{\gamma-p.} - \frac{m_W^2}{m_{\tilde{q}}^2} F^{\text{box}} \right) \left( \delta_{23}^u \right)_{LR} \\
C_{10}^{\text{MI, } \tilde{c}} &= \frac{K_{cs}^*}{K_{ts}^*} \frac{1}{4 s_W^2} \frac{\lambda_t}{g_2} \left( F^{Z-p.} + \frac{m_W^2}{m_{\tilde{q}}^2} F^{\text{box}} \right) \left( \delta_{23}^u \right)_{LR}
\end{align*}
\]

[Cho et al.;’96 and Lunghi et al.;’99]
SUSY parameter scan

test each parameter point for

• $b \rightarrow s \gamma$ constraints
• $\rho$-parameter constraints
• Higgs-, chargino-, stop mass limits

⇒ maximal reach:

(1) for MFV-SUSY

• $|C_9^{\text{NP}}/C_9^{\text{SM}}| < 2\%$
• $|C_{10}^{\text{NP}}/C_{10}^{\text{SM}}| < 8\%$

(2) for $(\delta_{23}^{\text{u}})_{LR} \neq 0$

• $|C_9^{\text{NP}}/C_9^{\text{SM}}| < 8\%$
• $|C_{10}^{\text{NP}}/C_{10}^{\text{SM}}| < 82\%$

<table>
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<th>Parameter</th>
<th>Min.</th>
<th>Max.</th>
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<td>15</td>
<td>7</td>
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<tr>
<td>$m_{H^\pm}$</td>
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<td>\mu</td>
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<tr>
<td>$A_t$</td>
<td>-1000</td>
<td>1000</td>
<td>20</td>
</tr>
</tbody>
</table>
Improvement of \((\delta_{23}^u)_{LR}\) -constraints

\[\text{only } b \to s \gamma:\]

\[\text{including } B \to K^{*}l^+l^-:\]

\[\begin{align*}
A_t \text{ [GeV]} & \\
650 & 700 & 750 & 800 & 850 & 900 & 950 & 1000 \\
350 & 400 & 450 & 500 & 550 & 600 \\
\end{align*}\]

\[\begin{align*}
\begin{array}{ccccccc}
0.2 & 0.3 & 0.4 & 0.45 & 0.5 & 0.55 \\
0.24 & 0.27 & 0.29 & 0.32 & 0.35 & 0.37 & 0.4 \\
\end{array}\]

other SUSY parameters:

\[m_{\tilde{\nu}} = 100 \text{ GeV}, \ m_{H^\pm} = 400 \text{ GeV}, \ m_{\tilde{g}} = 1 \text{ TeV}, \ \tan \beta = 2, \]
\[M_2 = 100 \text{ GeV}, \ \mu = -1 \text{ TeV}, \ m_{\tilde{q}} = 1 \text{ TeV}\]
Implications for flavor-models?

constraints still mild

- only models with large \((\delta_{23}^u)_{LR} \sim A_{23}^u\) are affected

example: radiative flavor violation model of [Crivellin et al.;’11]

setup:

\[
(Y_q^{\text{tree}})_{ij} = \delta_i,3,3\delta_j,3\lambda_q \quad V_{CKM}^{\text{tree}} = 1_3
\]

\(\tilde{m}_Q^2, \tilde{m}_U^2, \tilde{m}_D^2\) : diag, 1.+2. el. degenerate

- quark mixing + masses generated from SUSY-loops with flavor-breaking A-terms

- to generate \(V_{cb}\) in up-sector need large \(A_{u23}^u\)

Our results allow to constrain this model

...but work still in progress
Conclusions

• New theoretical and experimental results regarding $B \to K^* l^+ l^-$ yielded improved constraints on $C_9/C_{10}$

• We find that $(\delta_{23}^u)_{LR}$ is the most sensitive SUSY flavor parameter

• Bounds are strengthened, but still only mild ... fortunately: good prospects from LHCb!

• can restrict models with large $A_{23}^u$