Top Quark Decay $t \to ch$ in R-Parity Violating SUSY

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BUDAPEST

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Outline

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- 2 : Our results for $t \to ch$
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1 : Introduction: The importance of rare top decays

For the sake of this short talk:
"rare" $\equiv$ Flavor Changing Neutral Currents (FCNC)
In particular :
$t \to ch,\ cg,\ c\gamma,\ cZ$

Very good experience with FCNC :

- In K physics : The first appearance of charm in loops

- In B physics : The importance of $b \to s\gamma$

The top quark FCNC provide an excellent tool to investigate various Beyond the SM (BSM) scenarios :

- In the SM, top quark FCNC are beyond the reach of any conceivable experiment, with :
$10^{-11} \lesssim \mathrm{Br} \lesssim 10^{-14}$

- There are models BSM which exhibit large top FCNC (but always much smaller than the SM)

In the MSSM with R-parity conservation
$t \to ch$ could be greatly enhanced:

Kinematically this decay is allowed since $m_h \lesssim 135$ GeV.
The decay receives dominant contributions from FCNC SUSY QCD loops. For: $m_{\tilde{g}},\ m_{\tilde{q}} \lesssim 100$ GeV
$\mathrm{Br} \approx 10^{-5}$ can be reached, falling quickly for heavier sparticles in the loops

2 : Our results for $t \to ch$

R-parity conservation in SUSY is put in by hand.
Including R-parity violation ($\not{R}$) in the MSSM,
$t \to ch$ receives new contributions from loops with
$\not{R}$ interactions.

They can become significant since :

- There is only a single sparticle in the loop
- The relevant $\not{R}$ couplings involve weakly bounded 3rd-generation fermions

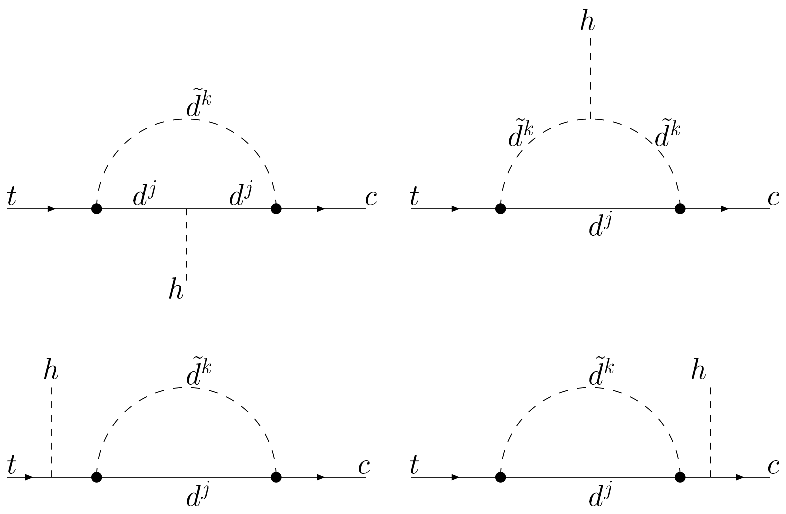
In principle, both $\not{L}$ and $\not{B}$ can co-exist, however in view of the bounds from proton decay, this seems very unlikely.

We therefore assume :

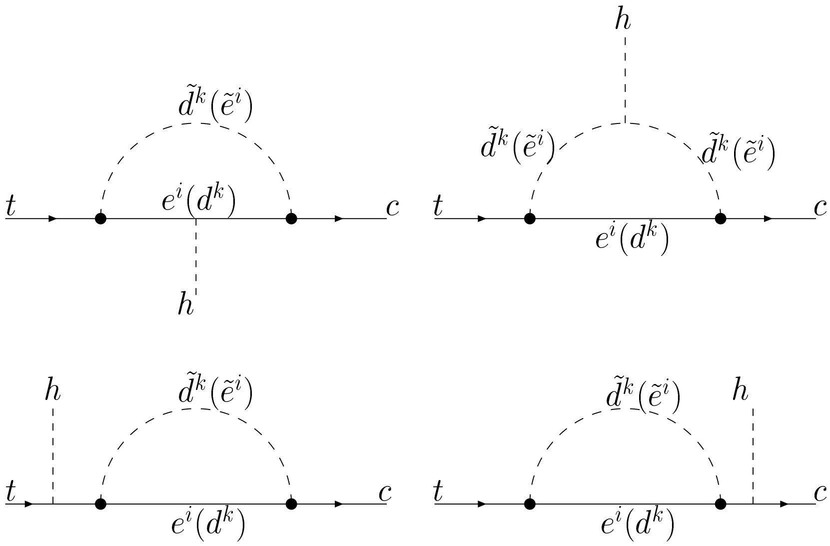
Either $\not{L}$ or $\not{B}$ contribute to $t \to ch$.

We also assume :

Only trilinear terms in $\mathcal{W}_{\not{R}}$ survive.



Feynman diagrams of $t \to ch$ induced by $\not{B}$ SUSY interactions



Feynman diagrams of $t \to ch$ induced by $\not{L}$ SUSY interactions

For the sake of brevity, from now on we'll only look at $\not{B}$. The effective coupling :

$$V_{\text{tch}}^{\not{B}} = ie\frac{\lambda''_{2jk}\lambda''_{3jk}}{16\pi^2}\xi_c\left(F_L^{\not{B}}P_L + F_R^{\not{B}}P_R\right),$$

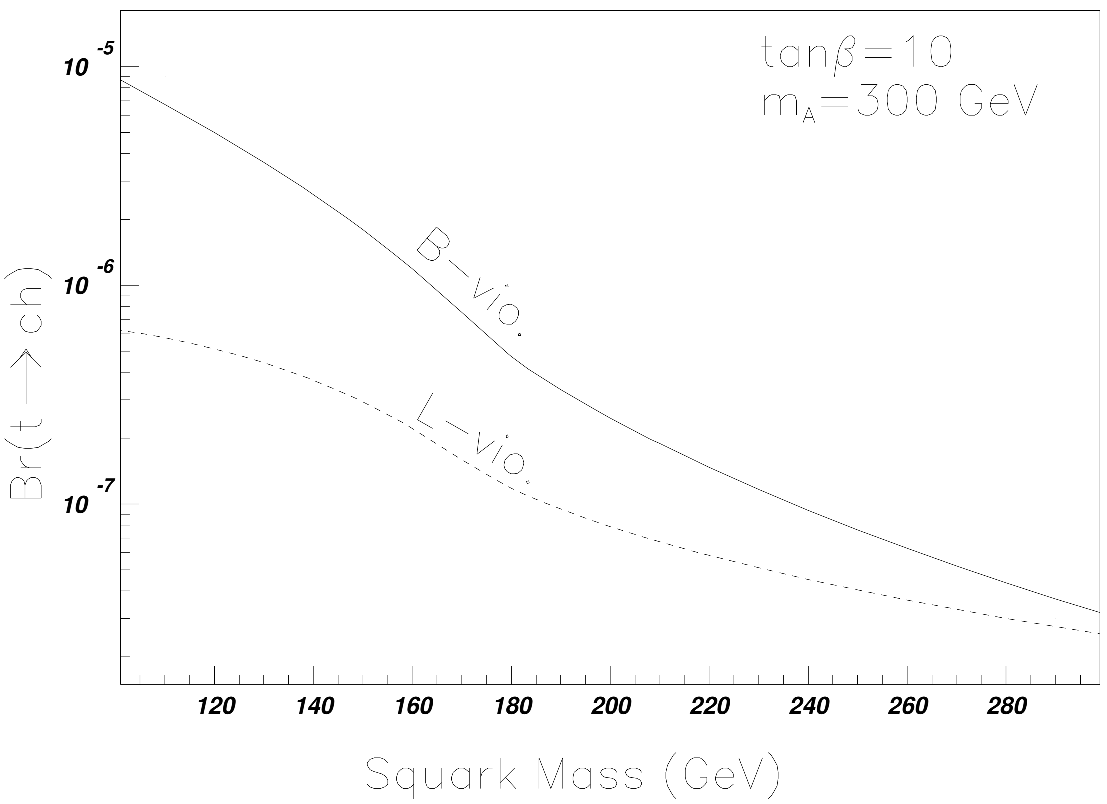
where $P_{R,L} = \frac{1}{2}(1 \pm \gamma_5)$, $\xi_c = 2$ & F are form factors calculated from the the diagrams.

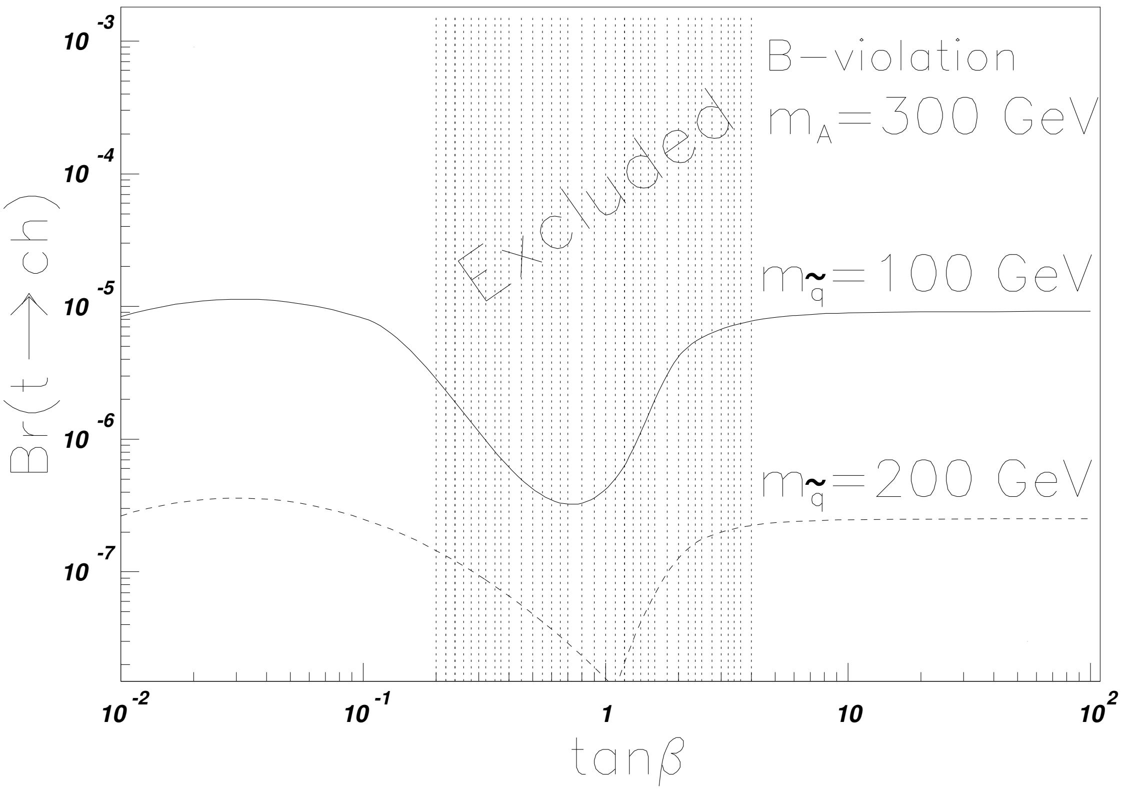
Again, for the sake of brevity we assume that $m_f \ll m_t$. Then :

$$\Gamma(t \to ch) = \frac{K^2(m_t^2 - m_h^2)^2}{32\pi m_t} \left| \frac{(C_{11} - C_{12})}{16\pi^2} \right|^2,$$

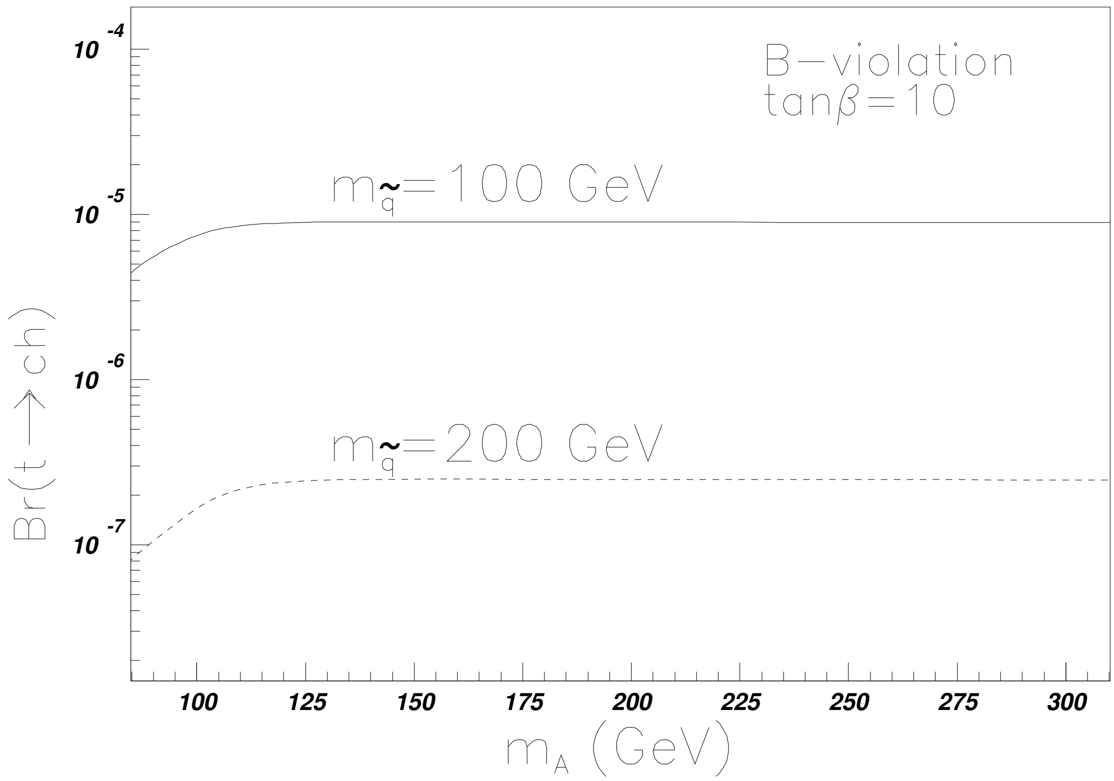
where

$$K = e\xi_c Y \lambda''_{2jk} \lambda''_{3jk}, \quad Y = -\frac{1}{3} m_Z \tan\theta_W \sin(\alpha + \beta)$$





B−violation
m_A=300 GeV
Excluded
$m_{\tilde{q}}$=100 GeV
$m_{\tilde{q}}$=200 GeV
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
$Br(t \to ch)$
10^{-2}
10^{-1}
1
10
10^{2}
$\tan\beta$



B−violation
tanβ=10
m~q=100 GeV
m~q=200 GeV
Br(t→ch)
10^-4
10^-5
10^-6
10^-7
100
125
150
175
200
225
250
275
300
m_A (GeV)

Some comments

- λ'' used here can be $\mathcal{O}(1)$ or even larger, since right now for some, perturbativity was assumed up to $M_U = 2 \times 10^{16}$ GeV

- Always $\not{L} < \not{R}$ since the couplings are better restricted

- It is unlikely that $t \to cH,\ cA$ will be substantial, even if kinematically allowed

3 : Observability

It depends on the machine, its $\mathcal{L}$, on efficiency and background, polarization of leptonic beam(s), ...

Typical background in hadron machines :

The signal is $gg,\ q\bar{q} \to t\bar{t} \to W^+ bh\bar{q}$

fighting against $t\bar{t}$ followed by

$t \to W^+ b \to l\nu j,\ \bar{t} \to W\bar{b} \to jj\bar{b}$

when one the jets is mis–identified as b

Then :

at 95% CL, and with m_h = 120 GeV the following limits can be achieved

At Tevatron II $\mathcal{L} = 20\text{fb}^{-1}$ 5.2×10^{-3}

At LHC with $10 \lesssim \mathcal{L} \lesssim 100\text{fb}^{-1}$ the limits will be between 1.4×10^{-4} to 4.5×10^{-5}.

And in LC :

Slightly better, down to limit of 10^{-5} for $\sqrt{s} = 500$ GeV + $\mathcal{L} = 500\text{fb}^{-1}$

BUT, many assumptions like : $g(hbb) = g^{\text{SM}}(hbb)$ and not taking experimentalists' ingenuity into account

NOTE, the above numbers are far away from the SM $\text{Br}(t \to ch) = 3.5 \times 10^{-14}$

4 : Summary and conclusions

The Higgs, and probably the top, hold the key to the secret of masses and couplings. So reaching for an increase in sensitivity to smaller $\mathrm{Br}(t \to ch)$ might be rewarding