Impact of SUSY CP Phases on Stop and Sbottom Decays in the MSSM

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Introduction

Two-body decays of stops and sbottoms
- $\rightarrow$ dependence on φ_{A_t} and φ_{A_b}
- $\rightarrow$ determination of φ_{A_t} and φ_{A_b}

Conclusion and outlook

Introduction

MSSM with complex parameters

General MSSM:
complex parameters in Higgs potential and soft SUSY breaking terms

$\rightarrow$ physical phases of the parameters

A_f : trilinear couplings of sfermions
μ : Higgs-higgsino mass parameter
M_1 : U(1) gaugino mass parameter
$m_{\tilde{g}}$: gluino mass

$\rightarrow$ introduction of CP violation

$\Rightarrow$ constraints from EDM of
electron, neutron, Hg, Tl
φ_μ: one loop contributions, strong constraints
[Barger et al. '01]

$\varphi_{A_{t,b}}$: two loop contributions, weaker constraints
[Chang et al. '99, Pilaftsis '02]

Effects of φ_{A_t} and φ_{A_b} on two-body decays of stops and sbottoms

$\longleftrightarrow$

Possible determination of φ_{A_t} and φ_{A_b}

Mixing of stops and sbottoms

$$\mathcal{L}_M^{\tilde{q}} = -(\tilde{q}_L^*, \tilde{q}_R^*) \begin{pmatrix} M^2_{\tilde{q}_{LL}} & M^2_{\tilde{q}_{LR}} \\ M^2_{\tilde{q}_{RL}} & M^2_{\tilde{q}_{RR}} \end{pmatrix} \begin{pmatrix} \tilde{q}_L \\ \tilde{q}_R \end{pmatrix}$$

with

$$\begin{aligned} M^2_{\tilde{q}_{LL}} &= M^2_{\tilde{Q}} + (T_q^3 - Q_q \sin^2\theta_W)\cos 2\beta\, m_Z^2 + m_q^2, \\ M^2_{\tilde{q}_{RR}} &= M^2_{\tilde{Q}'} + Q_q \sin^2\theta_W \cos 2\beta\, m_Z^2 + m_q^2, \\ M^2_{\tilde{q}_{RL}} &= (M^2_{\tilde{q}_{LR}})^* = m_q \left(A_q - \mu^* (\tan\beta)^{-2T_q^3} \right), \end{aligned}$$

$M_{\tilde{Q}'} = M_{\tilde{D}}$ $(M_{\tilde{U}})$ for $q = b$ (t),

$M_{\tilde{Q}}$, $M_{\tilde{D}}$, $M_{\tilde{U}}$: squark mass parameters

$\tan\beta = \dfrac{v_2}{v_1}$: ratio of Higgs vevs

→ phase in squark sector:

$$\varphi_{\tilde{q}} = \arg\left[M^2_{\tilde{q}_{RL}}\right] = \arg\left[A_q - \mu^* (\tan\beta)^{-2T_q^3}\right]$$

→ mass eigenstates:

$$\begin{aligned} \tilde{q}_1 &= e^{i\varphi_{\tilde{q}}} \cos\theta_{\tilde{q}}\, \tilde{q}_L + \sin\theta_{\tilde{q}}\, \tilde{q}_R \\ \tilde{q}_2 &= -\sin\theta_{\tilde{q}}\, \tilde{q}_L + e^{-i\varphi_{\tilde{q}}} \cos\theta_{\tilde{q}}\, \tilde{q}_R \end{aligned}$$

with squark mixing angle $\theta_{\tilde{q}}$

→ φ_{A_q}, φ_μ influence $\varphi_{\tilde{q}}$ and $\theta_{\tilde{q}}$

Two-body decays of squarks

Decays of light stops and sbottoms

$\tilde{t}_1 \to \tilde{\chi}_i^+ b$	$\tilde{b}_1 \to \tilde{\chi}_i^- t$	fermionic decays
$\tilde{t}_1 \to \tilde{\chi}_i^0 t$	$\tilde{b}_1 \to \tilde{\chi}_i^0 b$	
$\tilde{t}_1 \to \tilde{b}_1 H^+$	$\tilde{b}_1 \to \tilde{t}_1 H^-$	bosonic decays
$\tilde{t}_1 \to \tilde{b}_1 W^+$	$\tilde{b}_1 \to \tilde{t}_1 W^-$	

Decays of heavy stops and sbottoms

$\tilde{t}_2 \to \tilde{\chi}_i^+ b$	$\tilde{b}_2 \to \tilde{\chi}_i^- t$	fermionic decays
$\tilde{t}_2 \to \tilde{\chi}_i^0 t$	$\tilde{b}_2 \to \tilde{\chi}_i^0 b$	
$\tilde{t}_2 \to \tilde{b}_i H^+$	$\tilde{b}_2 \to \tilde{t}_i H^-$	bosonic decays
$\tilde{t}_2 \to \tilde{b}_i W^+$	$\tilde{b}_2 \to \tilde{t}_i W^-$	
$\tilde{t}_2 \to \tilde{t}_1 H_i$	$\tilde{b}_2 \to \tilde{b}_1 H_i$	
$\tilde{t}_2 \to \tilde{t}_1 Z$	$\tilde{b}_2 \to \tilde{b}_1 Z$	

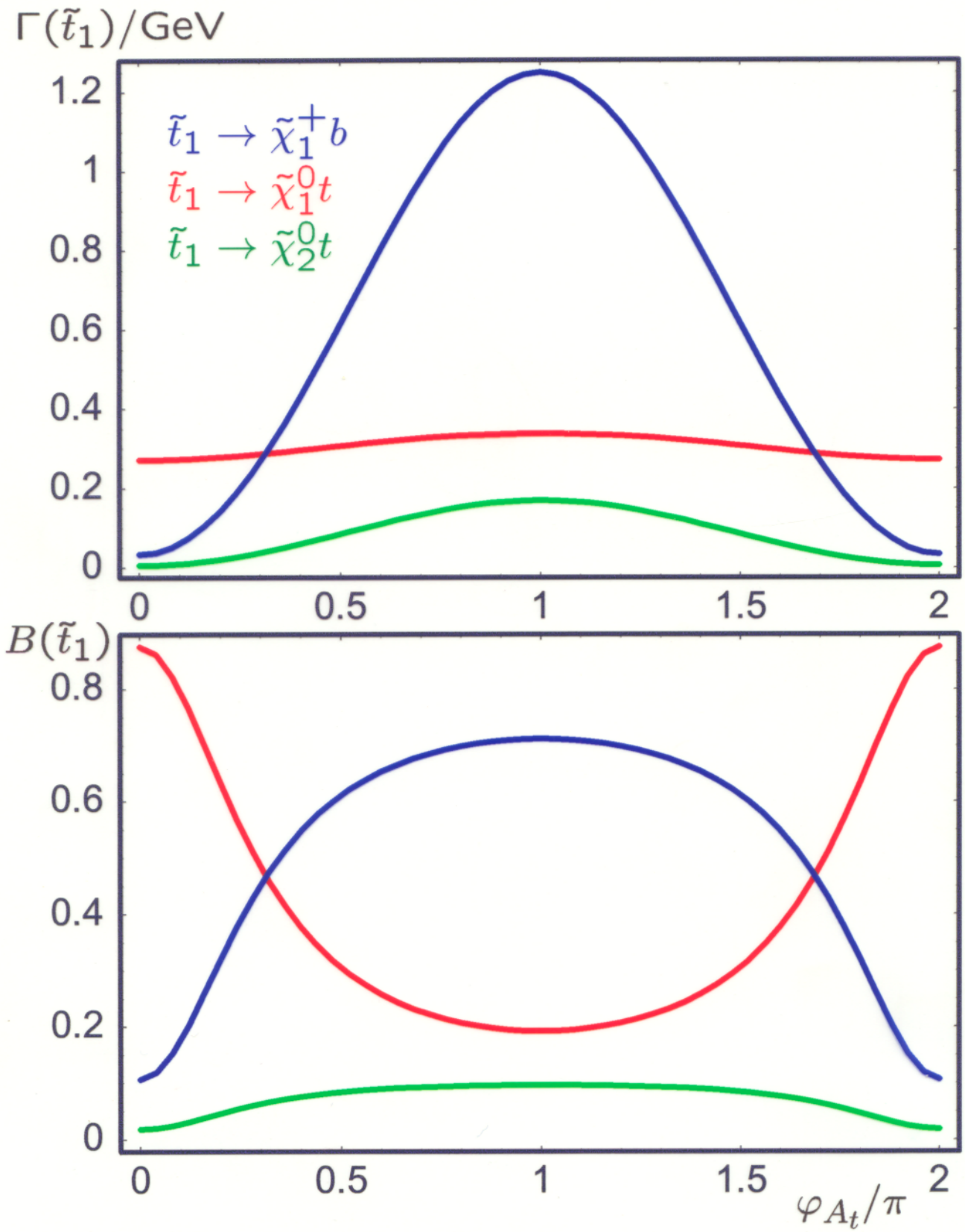
In numerical analysis:

use of running quark masses
$m_t^{\mathrm{RUN}} = 150$ GeV, $m_b^{\mathrm{RUN}} = 3$ GeV
in $\tilde{t}$, $\tilde{b}$ couplings

Widths and branching ratios of $\tilde{t}_1$

in SPS 1a inspired scenario:

$M_Q > M_U$, $m_{\tilde{t}_1} = 379$ GeV, $m_{\tilde{t}_2} = 575$ GeV, $m_{\tilde{b}_1} = 492$ GeV,
$|A_t| = 466$, $|A_b| = 759$ GeV, $\varphi_{A_b} = 0$, $|\mu| = 352$ GeV, $\varphi_\mu = 0$,
$M_2 = 193$ GeV, $\varphi_{M_1} = 0$, $\tan\beta = 10$, $m_{H^+} = 402$ GeV



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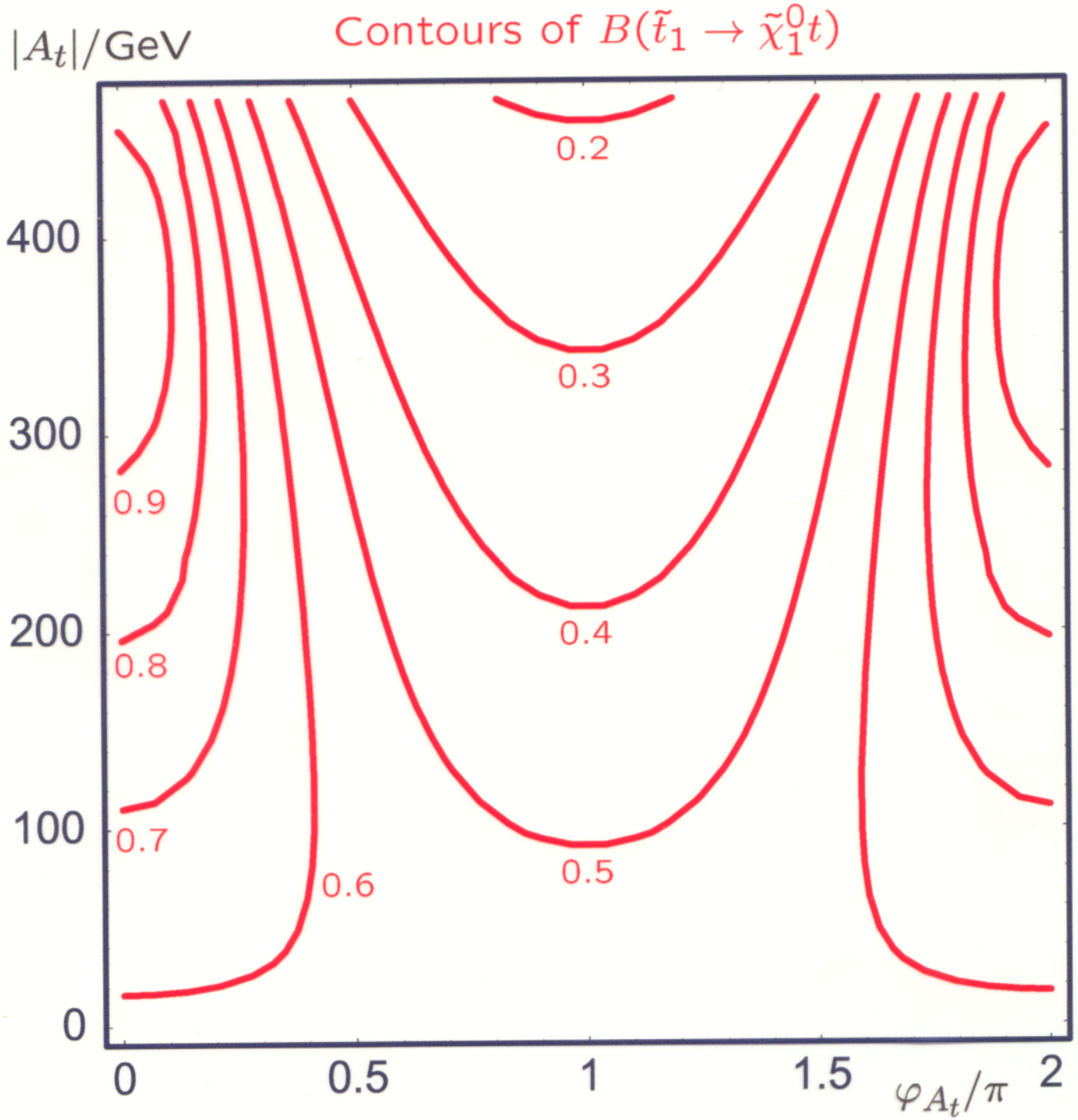

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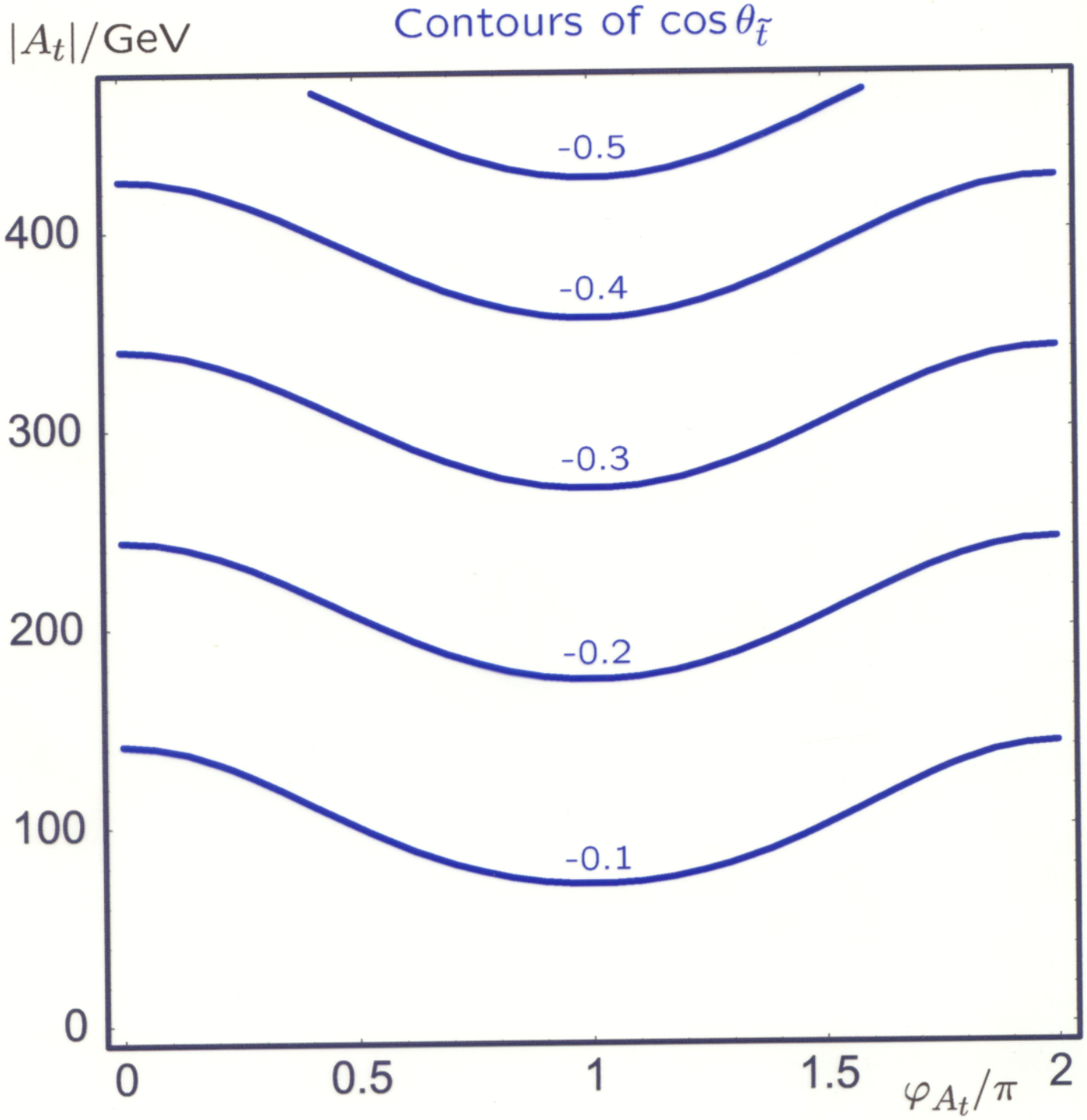


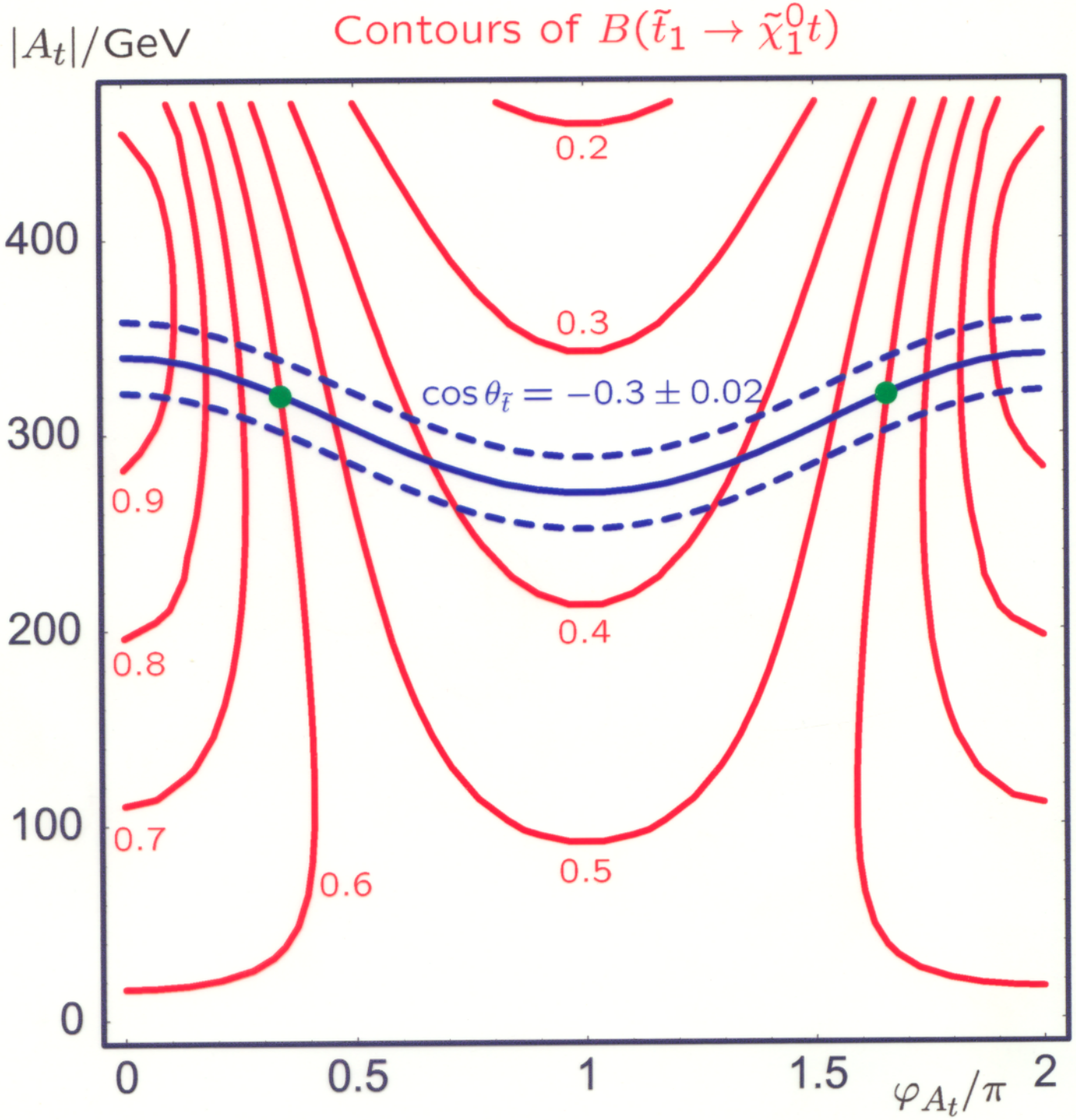
Production at linear collider with polarized beams

→ determination of $\cos\theta_{\tilde{t}}$ possible
with $\Delta(\cos\theta_{\tilde{t}}) \approx 0.02$

[Bartl, Eberl, Kraml, Majerotto, Porod '00]

[Boos, Martyn, Moortgat-Pick, Sachwitz, Sherstnev, Zerwas '03]

SPS 1a inspired scenario

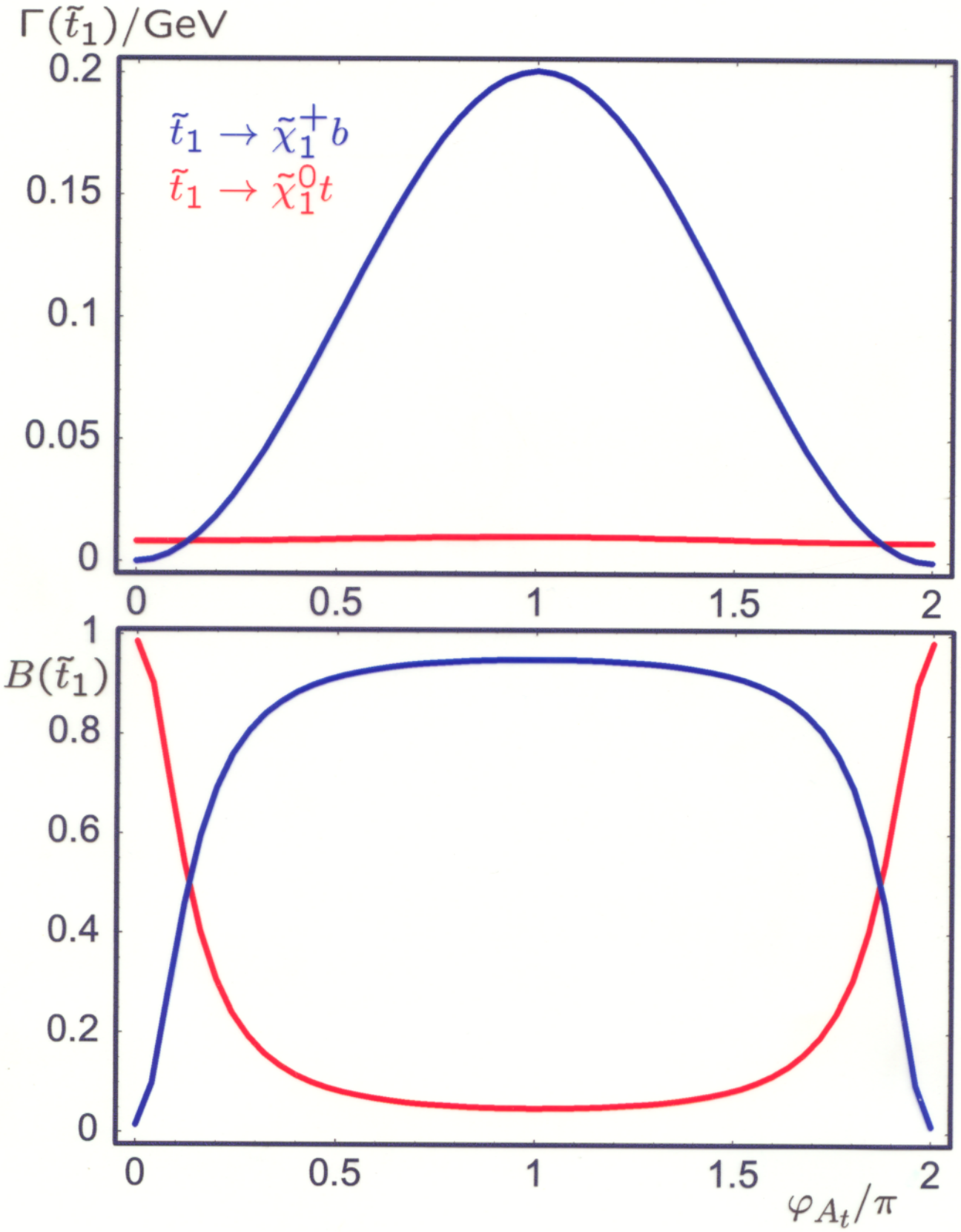


Example: $B = 0.6$ and $|\cos\theta_{\tilde{t}}| = 0.3$ measured

$\to \Delta(B) = 0.1 \Rightarrow \Delta(\varphi_{A_t}) = 0.1\pi,\ \Delta(|A_t|) = 20$ GeV
$\Delta(B) = 0.05 \Rightarrow \Delta(\varphi_{A_t}) = 0.05\pi, \Delta(|A_t|) = 20$ GeV

$\to$ ambiguity in $\varphi_{A_t} \to$ sign of $\mathrm{Im}(A_t)$

$M_Q > M_U$, $m_{\tilde{t}_1} = 240$ GeV, $m_{\tilde{t}_2} = 700$ GeV, $m_{\tilde{b}_1} = 400$ GeV,
$|A_t| = 600$, $|A_b| = 600$ GeV, $\varphi_{A_b} = 0$, $|\mu| = 400$ GeV, $\varphi_\mu = 0$,
$M_2 = 135$ GeV, $\varphi_{M_1} = 0$, $\tan\beta = 6$, $m_{H^+} = 400$ GeV



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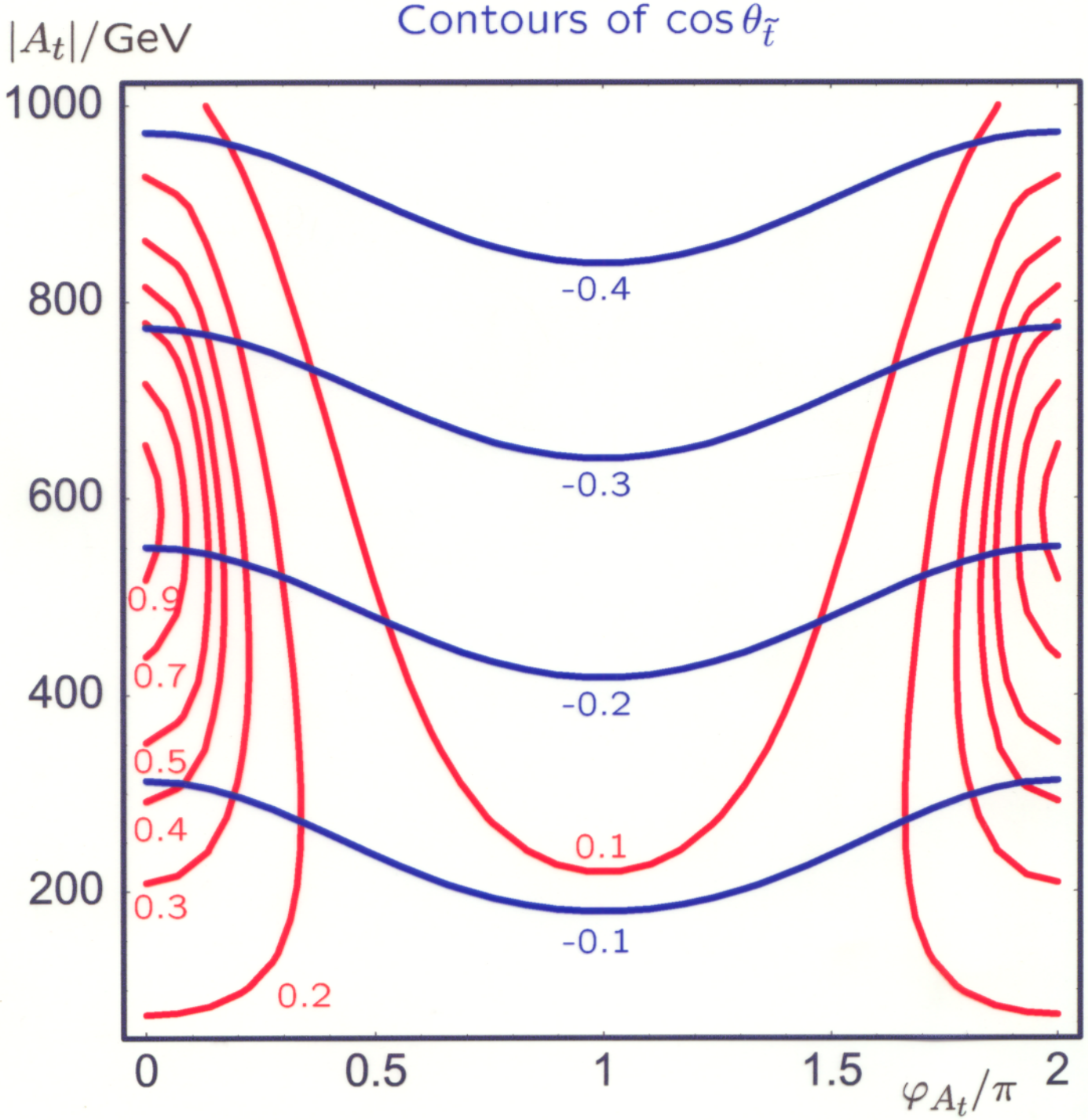
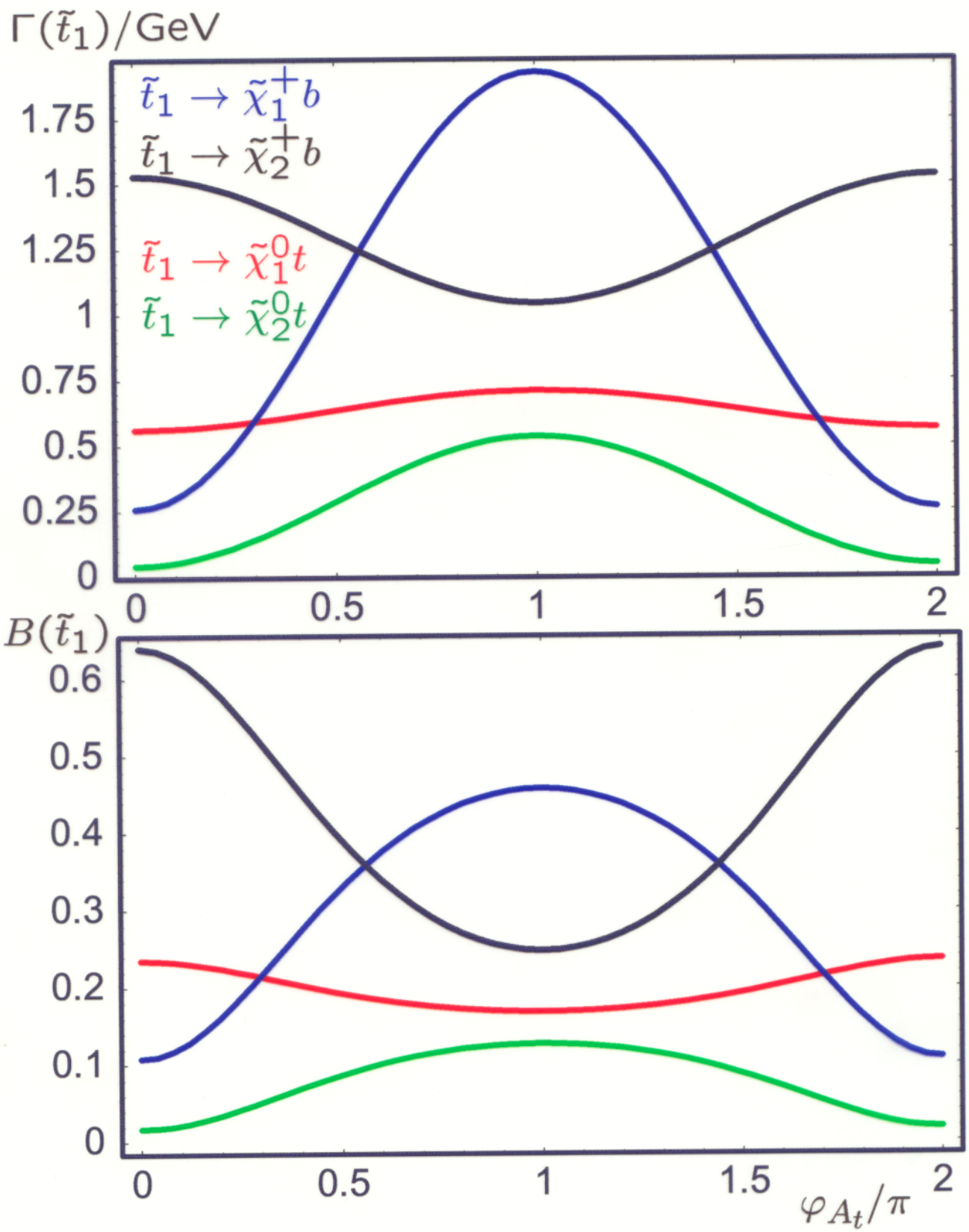
Contours of $B(\tilde{t}_1 \to \tilde{\chi}_1^0 t)$

Contours of $\cos\theta_{\tilde{t}}$



SPS 4 inspired scenario:

$M_Q > M_U$, $m_{\tilde{t}_1} = 531$ GeV, $m_{\tilde{t}_2} = 696$ GeV, $m_{\tilde{b}_1} = 607$ GeV,
$|A_t| = 499$, $|A_b| = 6430$ GeV, $\varphi_{A_b} = 0$, $|\mu| = 377$ GeV, $\varphi_\mu = 0$,
$M_2 = 233$ GeV, $\varphi_{M_1} = 0$, $\tan\beta = 50$, $m_{H^+} = 416$ GeV



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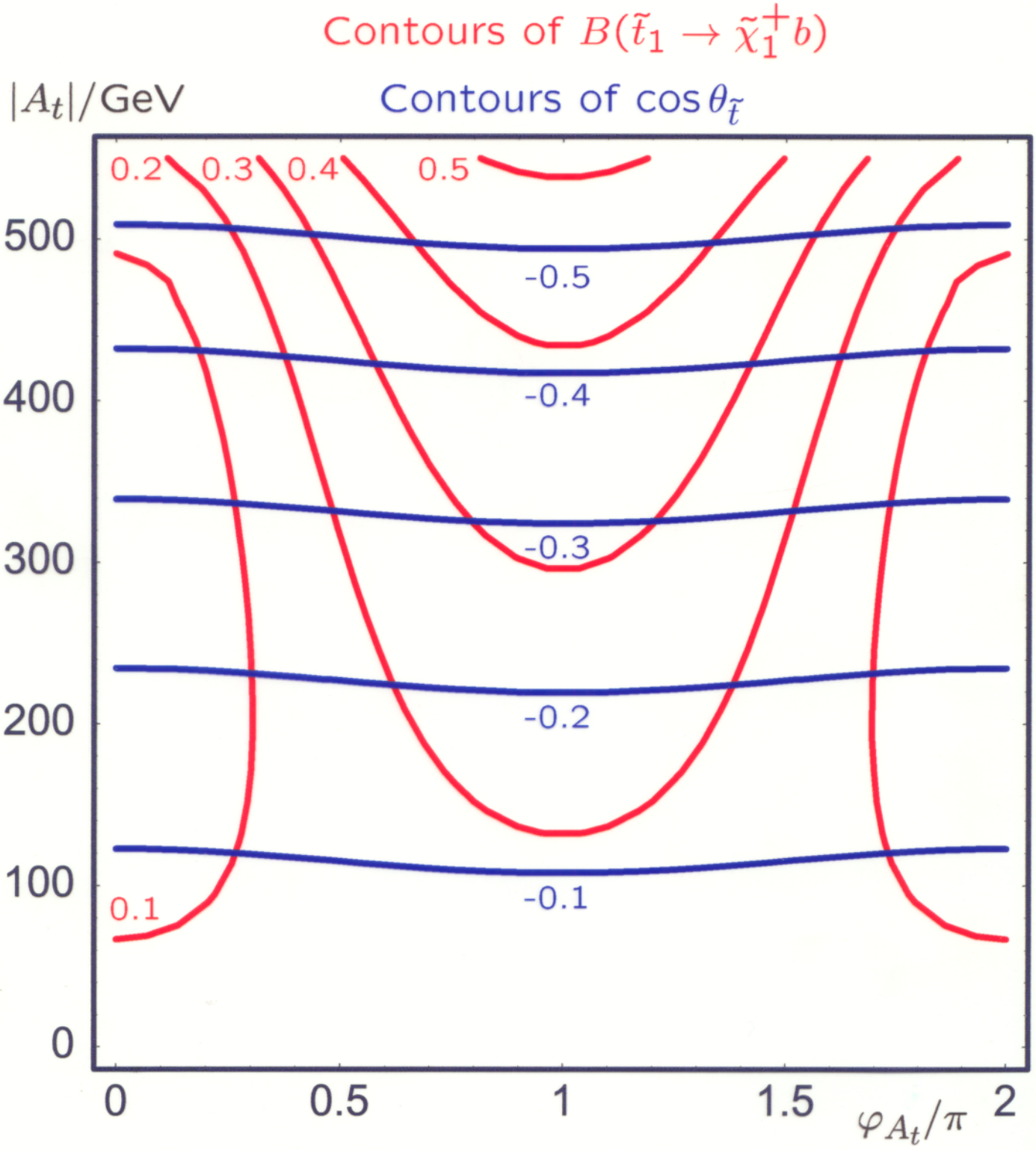
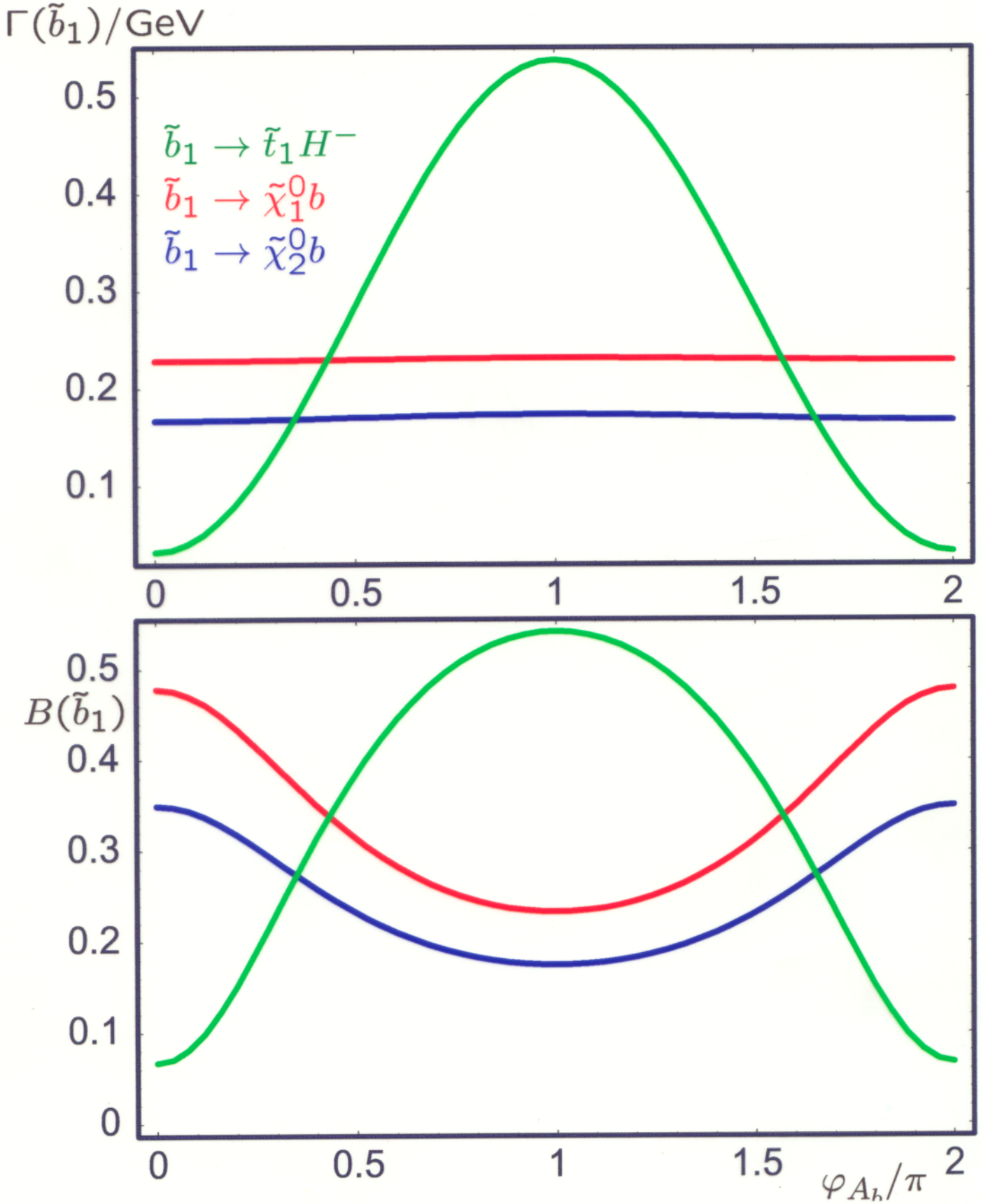


Widths and branching ratios of $\tilde{b}_1$

$M_{\tilde{Q}} > M_{\tilde{D}}$, $m_{\tilde{b}_1} = 350$ GeV, $m_{\tilde{b}_2} = 700$ GeV, $m_{\tilde{t}_1} = 170$ GeV, $|A_t| = |A_b| = 600$ GeV, $\varphi_{A_t} = 0$, $|\mu| = 300$ GeV, $\varphi_\mu = 0$, $M_2 = 200$ GeV, $\varphi_{M_1} = 0$, $\tan\beta = 30$, $m_{H^+} = 150$ GeV



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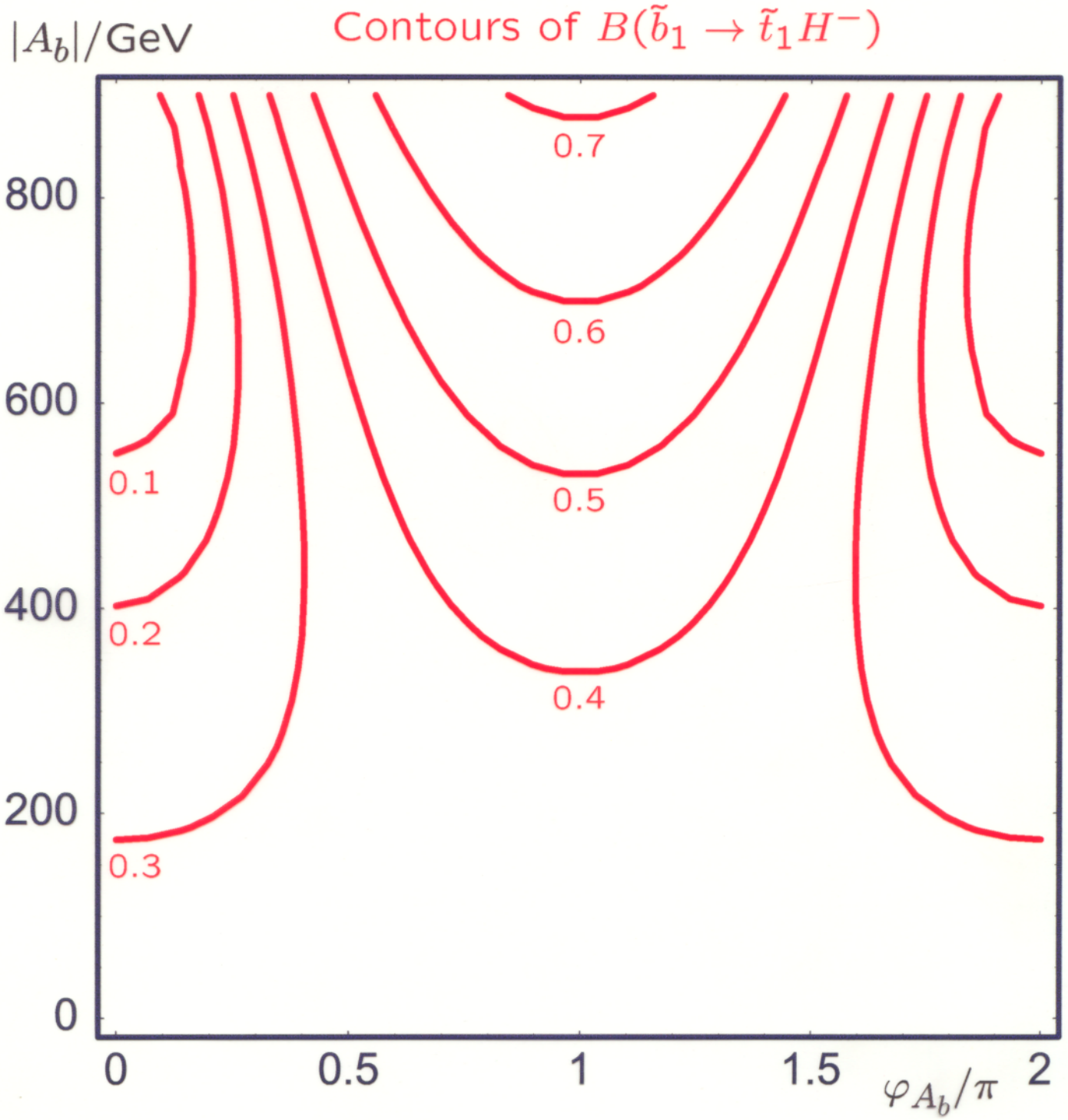

But: $\cos\theta_{\tilde{b}}$ nearly independent of φ_{A_b}, $|A_b|$

Widths and branching ratios of $\tilde{t}_2$

in SPS 1a inspired scenario:

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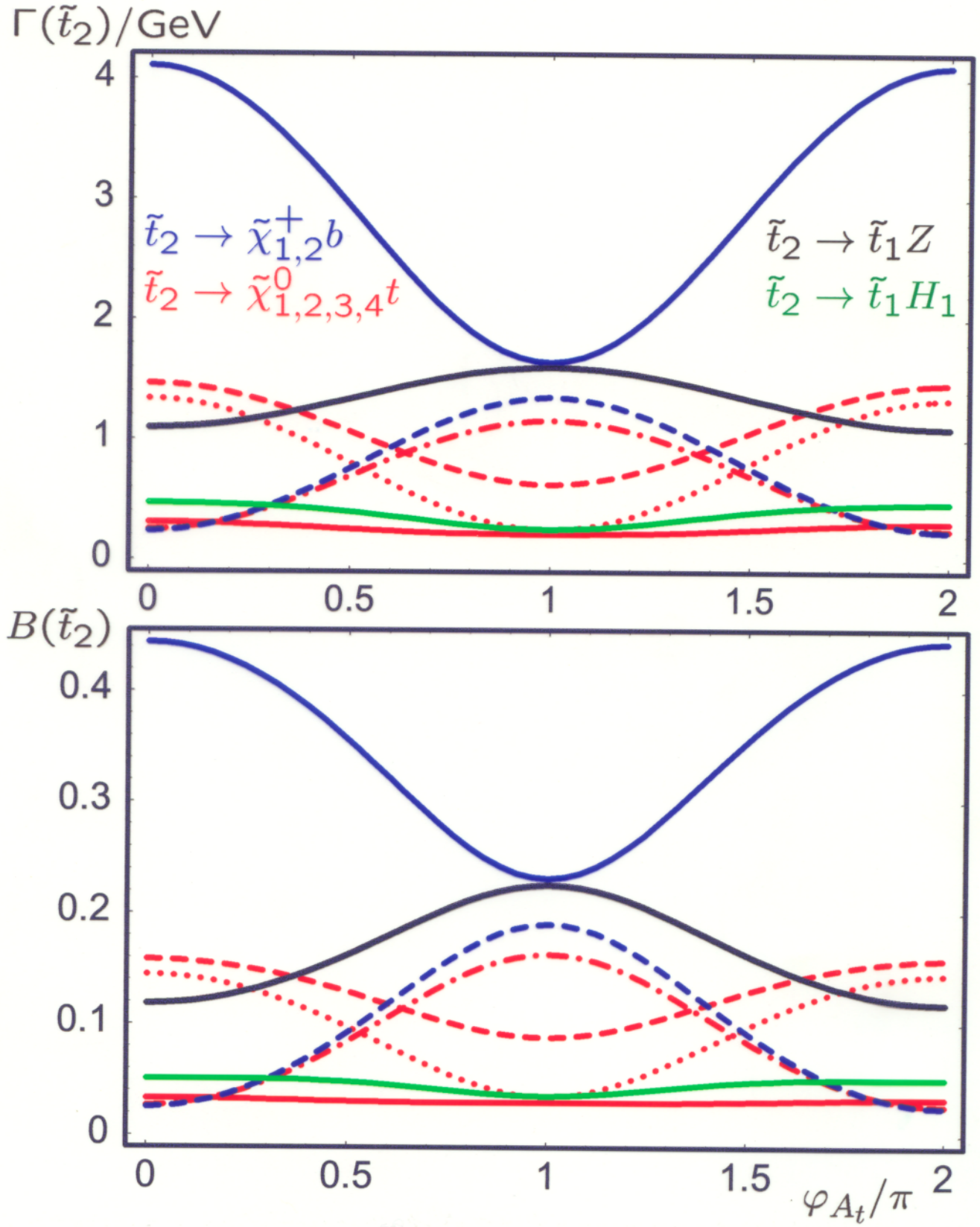

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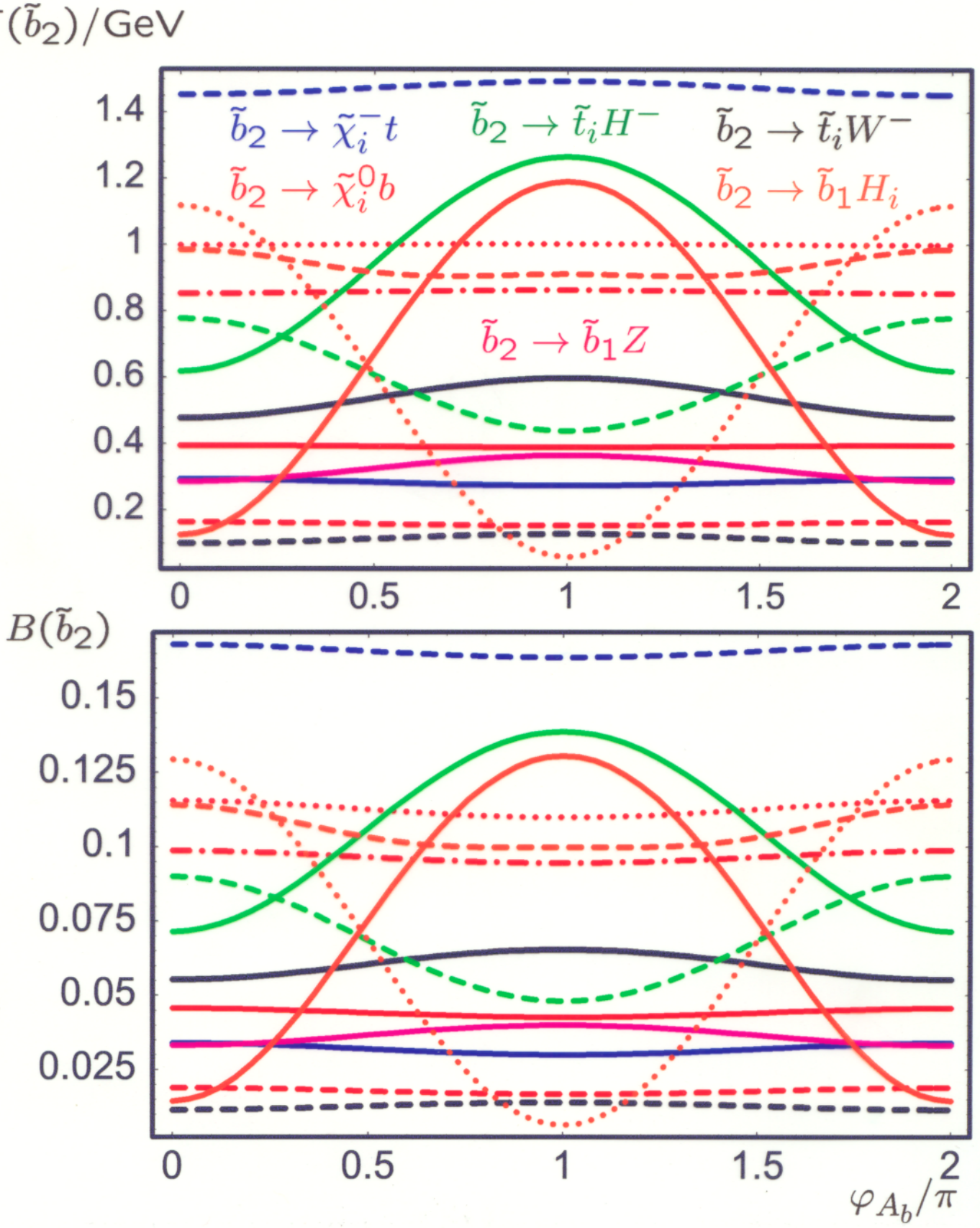

Conclusion and outlook

→ stop decays

→ $M^2_{\tilde{t}_{RL}} = m_t\,(A_t - \mu^*/\tan\beta)$

→ large mixing

→ $\varphi_{\tilde{t}} \sim \varphi_{A_t}$

→ pronounced φ_{A_t} dependence of BR

→ knowledge of $\cos\theta_{\tilde{t}}$: possibility to fix φ_{A_t}, $|A_t|$

→ sbottom decays

→ $M^2_{\tilde{b}_{RL}} = m_b\,(A_b - \mu^* \times \tan\beta)$

→ smaller mixing

→ φ_{A_b} dependence of BR smaller

→ reasonable φ_{A_b} dependence of decays into Higgs channels

Outlook

→ Parameter determination

→ Discussion of three-body decays of stops

→ Full SUSY QCD corrections