Probing CP violation through stop and sbottom decays

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Reference

The results I present in this talk are obtained in collaboration with:

Alfred Bartl
Ekaterina Christova
Karl Hohenwarter-Sodek

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Triple product correlations in top squark decays
Phys.Rev. D70 (2004) 095007 [hep-ph/0409060]

CP asymmetries in scalar bottom quark decays
JHEP 11 (2006) 076 [hep-ph/0610234]

Motivation

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- LHC: $\widetilde{g} \to \widetilde{t}_i t,\ \widetilde{b}_i b$

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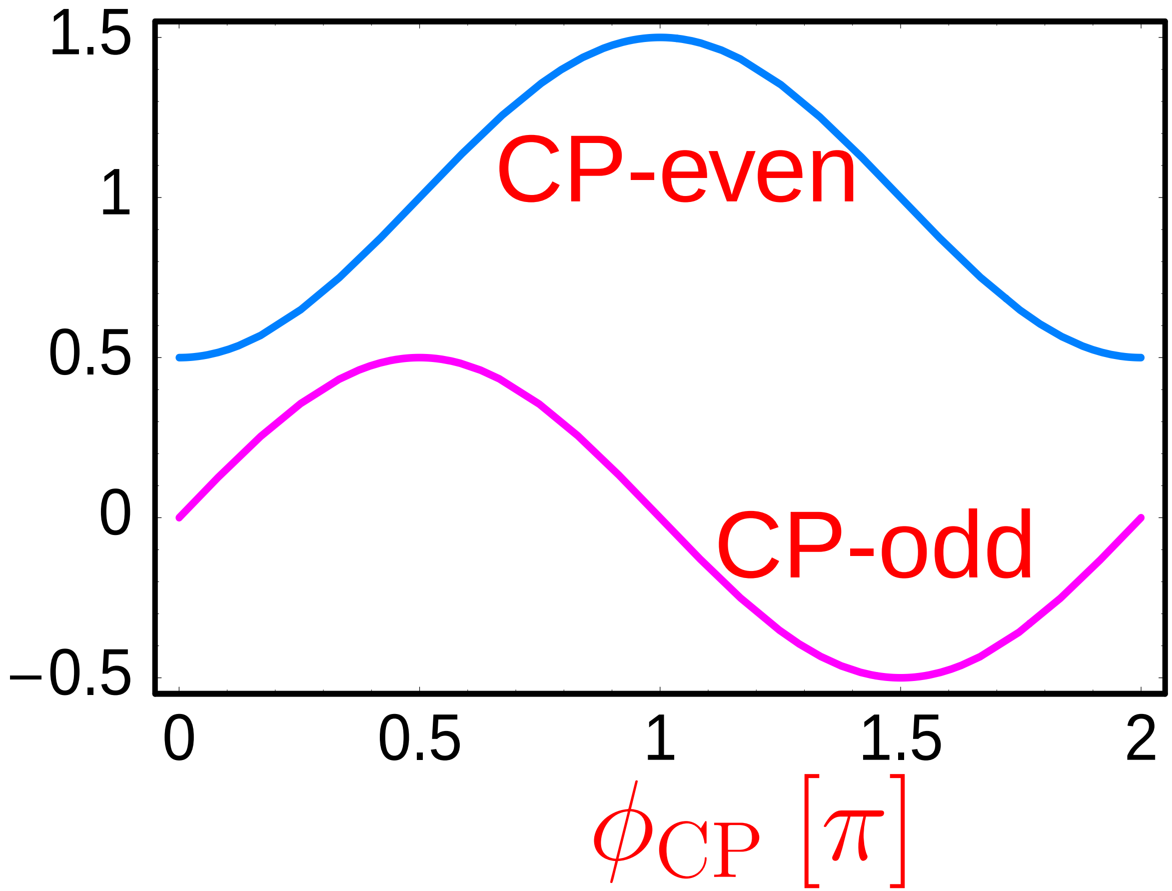
- Proposition of suitable CP sensitive observables
  - Proofs that CP is violated in the stop (sbottom) system
  - Determination of the model parameters
    Minimal Supersymmteric Standard Model (MSSM)

CP-even versus CP-odd observables

CP-even: masses, cross sections,...

CP-odd: rate asymmetries, T-odd asymmetries,...



CP sensitive observables

If kinematically accessible: two-body decays dominate

$$\tilde{t}_i \longrightarrow \tilde{\chi}^0_k t \qquad (k = 1, \ldots, 4)$$

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Which CP sensitive observables?

Amplitude squared (rest system):

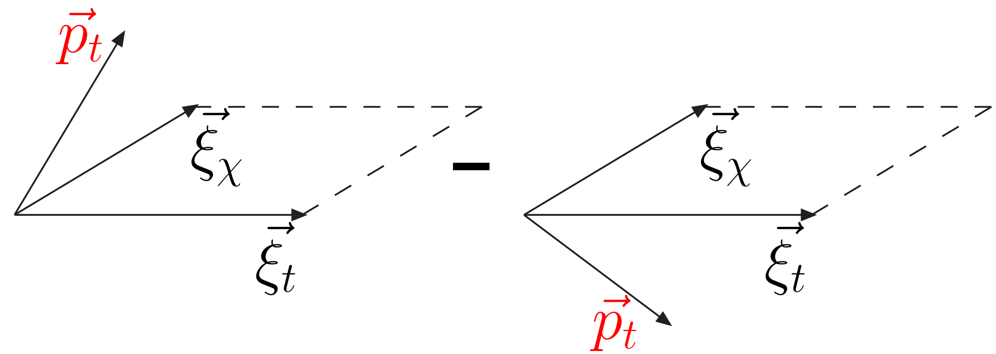
$$|A|^2 \supset m_{\widetilde{q}}\, \Im m(L^* R)\ \vec{p}_t \cdot (\vec{\xi}_\chi \times\ \vec{\xi}_t) + (|L|^2 + |R|^2)(p_t \cdot p_\chi) + \ldots$$

$$[A = \bar{u}(p_t, \xi_t)\ (L\ P_L + R\ P_R)\ v(p_\chi, \xi_\chi)]$$

Triple product: $\vec{p}_t \cdot (\vec{\xi}_\chi \times\ \vec{\xi}_t)$

CP sensitive observables

$$N_+ - N_- \quad =$$



N_+ is number of events where $\vec{p}_t \cdot (\vec{\xi}_\chi \times \vec{\xi}_t) > 0$

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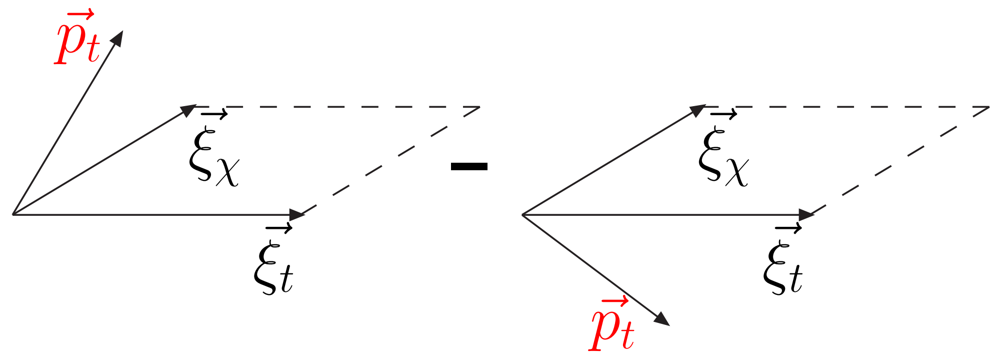

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T-odd asymmetry A_T:

$$A_T = \frac{N_+ - N_-}{N_+ + N_-}$$

$$A_T \propto \Im m(L^* R)$$

CP violation in stop decays

T-odd asymmetries in $\tilde{t}_1 \to \tilde{\chi}^0_2 t$

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Polarization vectors ξ_χ, ξ_t expressed in momenta of the decay products [S. Kawasaki, T. Shirafuji, and S.Y. Tsai, Prog. Theor. Phys. 49, 1656 (1973)]

$\Rightarrow$ eight different T-odd asymmetries can be constructed

Numerical examples $\widetilde{t}_1 \to \widetilde{\chi}^0_2 t$

Phases in the game: $\phi_\mu = \phi_{M_1} = 0$ (determined in other processes), $\phi_{A_t} \neq 0$

Numerical examples $\tilde{t}_1 \to \tilde{\chi}_2^0 t$

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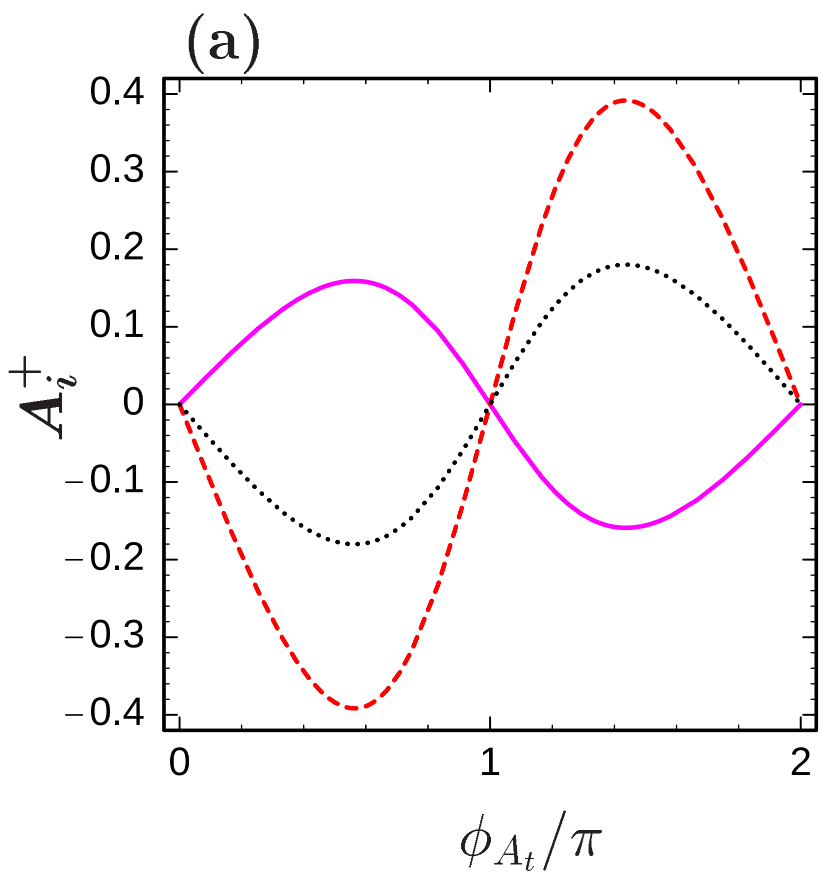
A_T based on $\vec{p}_b \cdot (\vec{p}_t \times \vec{p}_{\ell_1})$, $\vec{p}_l \cdot (\vec{p}_b \times \vec{p}_{\ell_1})$, $\vec{p}_c \cdot (\vec{p}_t \times \vec{p}_{\ell_1})$



$m_{\tilde{t}_1} = 400$ GeV

$m_{\tilde{\chi}_2^0} = 174$ GeV

Necessary number of stops

Required number of stops to probe the T-odd asymmetries:

$$N_{\tilde{t}_1} > \frac{\sigma^2}{(A_T)^2 BR(W \to f) BR(\tilde{t}_1 \to \tilde{\chi}^0_2 t) BR(\tilde{\chi}^0_2 \to \tilde{\ell}_R \ell)}$$

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Example ($\sigma = 3$): $m_{\tilde{t}_1} = 400$ GeV, $m_{\tilde{\chi}^0_2} = 153$ GeV, $B(\widetilde{t}_1 \to \widetilde{\chi}^0_2 t) = 22$%

A_T	value $[\%]$	$N_{\tilde{t}_1} \cdot 10^{-3}$
A_1^+	-11.5	4.5
A_2^+	28.3	1.6
A_3^+	13.8	6.8

($\phi_{A_t} = \frac{\pi}{2}$)

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T-odd asymmetries in $\tilde{b}_1 \rightarrow \tilde{\chi}_1^- t$

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We consider the decay chains

$$\begin{aligned} \widetilde{\chi}_1^- &\to \ell_1^- \bar{\widetilde{\nu}} &\to \ell_1^- \bar{\nu}\, \widetilde{\chi}_1^0 \\ \widetilde{\chi}_1^- &\to \widetilde{\ell}_n^- \bar{\nu} &\to \ell_2^- \bar{\nu}\, \widetilde{\chi}_1^0 \\ \widetilde{\chi}_1^- &\to W^- \widetilde{\chi}_1^0 &\to \ell_3^- \bar{\nu}\, \widetilde{\chi}_1^0 \end{aligned}$$

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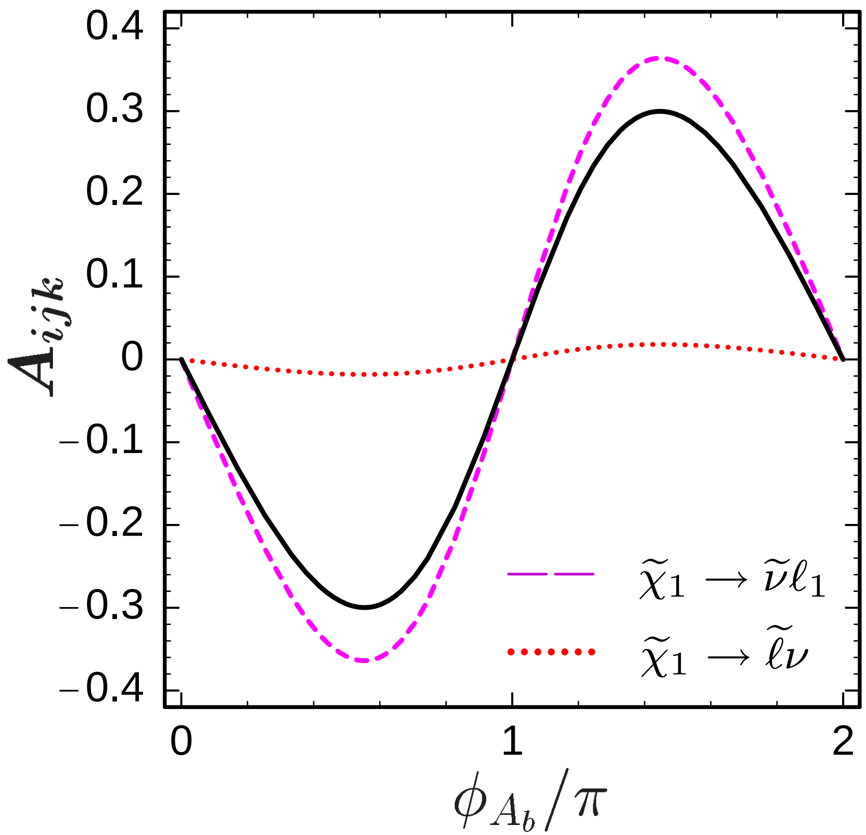
The polarization vector ξ_χ is different in the three different decay chains, i.e. ℓ_i have different angular (energy) distributions

$\Rightarrow$ twelve different T-odd asymmetries that are based on $\vec{p}_t \cdot (\vec{\xi}_\chi \times \vec{\xi}_t)$ can be constructed

Numerical examples $\widetilde{b}_1 \to \widetilde{\chi}_1^- t$

A_T based on $\vec{p}_c \cdot (\vec{p}_t \times \vec{p}_{\ell_i})$ phases: $\phi_\mu = 0$, $\phi_{A_b} \neq 0$



$m_{\tilde{b}_1} = 320$ GeV
$m_{\tilde{\chi}_1^-} = 108$ GeV

Required number of sbottoms to probe A_T at 3σ:
$N_{\tilde{b}_1} = 5.5 \times 10^3$

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- The influence of CP violation already arises at tree-level $\Rightarrow$ T-odd asymmetries can be in the tens of percent range
- Order 10^3 produced stops (sbottoms) are necessary to probe the asymmetries at 3σ $\Rightarrow$ can be provided at LHC and ILC. For example, at the ILC the production rates of stops and sbottoms can be of the order 10^4
- Their measurements may allow us to determine the CP phases ϕ_{A_t} and ϕ_{A_b} $\Rightarrow$ testing the underlying theory