CP-odd phases @ NLC: a project outline

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A report on an idea & first results of a recent project in collaboration with:

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1. Introduction

- framework: MSSM with R-parity and without any assumptions about mechanism of SUSY breaking

- idea:

  · take low energy data as a set of constraints on parameter space

  · apply the resulting low-energy compatible points to set of high-energy experiments at NLC

  · study impact of non-vanishing phases on high-energy observables
  ($\rightarrow$CP-violation ?)

2. More details - 4 major steps

STEP 1:

constraints and parameters

- lower mass bounds: $m_{\tilde{e}}, m_{\tilde{\mu}}, m_{\tilde{\nu}}, m_{\tilde{\chi}_1^0}$

- cross-section for $\tilde{\chi}_1^- \tilde{\chi}_1^+$ from LEP2

- allowed range for $(d_e)_{SUSY}$
  $-7.9\text{ecm} < (d_e)_{SUSY} \cdot 10^{28} < 21.7\text{ecm}$

- allowed range for $(a_\mu)_{SUSY}$
  optimistic interpretation (e^+e^--data):
  $5.7 \cdot 10^{-10} < (a_\mu)_{SUSY} < 49.3 \cdot 10^{-10}$
  conservative interpretation (τ-decay-data):
  $-57.2 \cdot 10^{-10} < (a_\mu)_{SUSY} < 60.6 \cdot 10^{-10}$

- real parameters (without sflavor-mixing): $|\mu|$, $\tilde{m}_L$, $\tilde{m}_R$, $|M_1|$, M_2,$|A|$, $\tan\beta$

- phases: ϕ_μ, ϕ_1, ϕ_A ($\phi_2 = 0$ by convention)

STEP 2:

define high energy observables:
unpolarized, total cross-sections for

$$
\begin{aligned}
e^-e^- &\to \tilde{e}_i^-\tilde{e}_j^- \quad i,j = 1,2\ (\simeq R,L) \\
e^-e^+ &\to \tilde{e}_i^-\tilde{e}_j^+ \quad i,j = 1,2\ (\simeq R,L) \\
e^-e^+ &\to \tilde{\chi}_i^0\tilde{\chi}_j^0 \quad i,j = 1,\ldots,4 \\
e^-e^+ &\to \tilde{\chi}_i^-\tilde{\chi}_j^+ \quad i,j = 1,2
\end{aligned}
$$

problem: how to study CP phases at a LC ?

STEP 3:

Sensitivity of CP-even cross sections $S(\sigma_{f_i f_j})$

assume: real parameters to be fixed

idea:
compare size of deviation in counting rates of CP-violating (CPV) and CP-conserving (CPC) point to the statistical error in CP-conserving case:

$$S \propto \frac{|\Delta N_{CPV-CPC}|}{\delta N_{CPC}}$$

→ basically four significances corresponding to four CPC points relevant for collider physics

→ conservative estimate: take minimum of these four significances

→ definition of $S(\sigma_{f_i f_j})$

$$S(\sigma_{f_i f_j}) = \min \left\{ \frac{|\sigma^{CPV}_{f_i f_j} - \sigma^{CPC}_{f_i f_j}|}{\sqrt{\sigma^{CPC}_{f_i f_j}}} \right\} \sqrt{\mathcal{L}}$$

message of $S(\sigma_{f_i f_j})$:

- high $S(\sigma_{f_i f_j})$: impact of phases significant in this mode
- low $S(\sigma_{f_i f_j})$: this mode is not useful for constraining phases

STEP 4:

- $\underline{\text{next question}}$:
  how to disentangle kinematical from coupling effects ?

$\rightarrow$ introduce : kinematical fixed significances

$$\bar{S}(\sigma_{f_i f_j}) = \min \left\{ \frac{|\sigma^{\overline{CPV}}_{f_i f_j} - \sigma^{CPC}_{f_i f_j}|}{\sqrt{\sigma^{CPC}_{f_i f_j}}} \right\} \sqrt{\mathcal{L}}$$

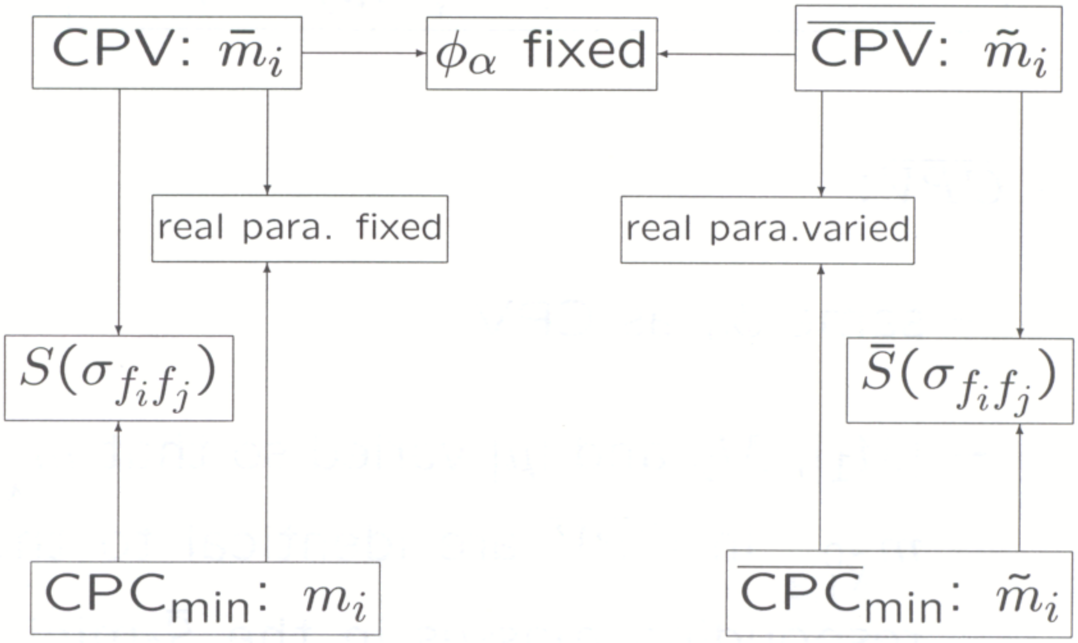
- $\overline{CPV}$:
  - same ϕ_α as CPV
  - $|M_1|$, M_2 and $|\mu|$ varied so that $m_{\tilde{\chi}^-_1}$ and $m_{\tilde{\chi}^0_{1,3}}$ in $\overline{CPV}$ are identical to the corresponding masses in the $\bar{S}$-minimizing CPC point

$\rightarrow$ – smaller or removed kinematical effects

– coupling effects more dominant

- problem with selectron modes: kinematical and coupling effects interfere in neutralino functions

- schematic



4. Preliminary results

performed two random scans for both a_μ-bounds:

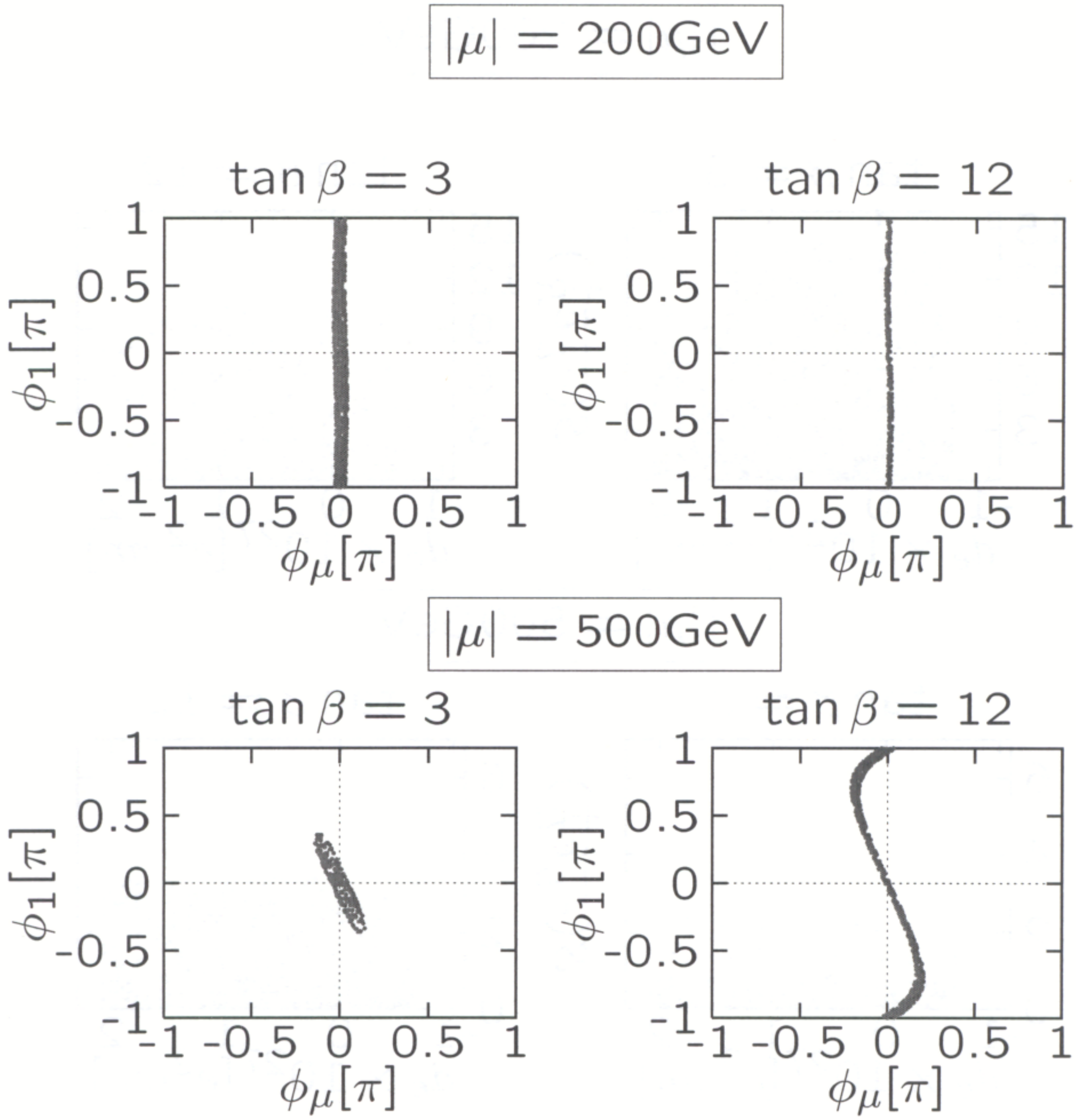
A: $(\phi_\mu,\ \phi_1,\ \phi_A) \in (0, 2\pi)$ and $|\mu| = 200\text{GeV}$

B: $(\phi_\mu,\ \phi_1,\ \phi_A) \in (0, 2\pi)$ and $|\mu| = 500\text{GeV}$

- $\tan\beta$=3, 12
- M_2=2$|M_1|$=200 GeV
- $\tilde{m}_L$=235 GeV, $\tilde{m}_R$=180 GeV, $|A|$=500GeV

a few examples presented here:

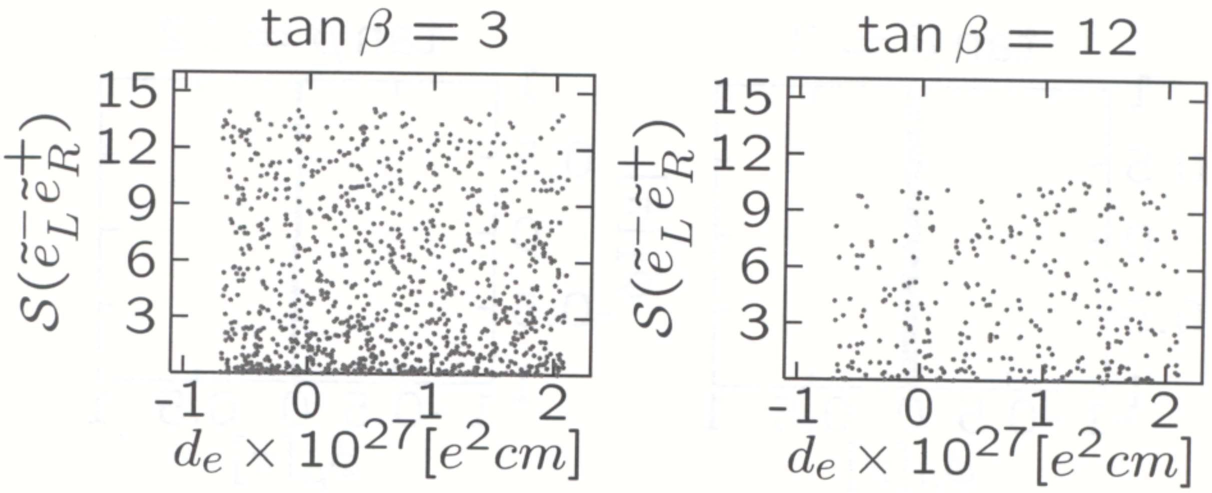
- only optimistic a_μ-bound
- only $S(\sigma_{f_i f_j})$
- selected cross sections: $\tilde{e}_L^- \tilde{e}_R^+$ and $\tilde{\chi}_1^0 \tilde{\chi}_2^0$



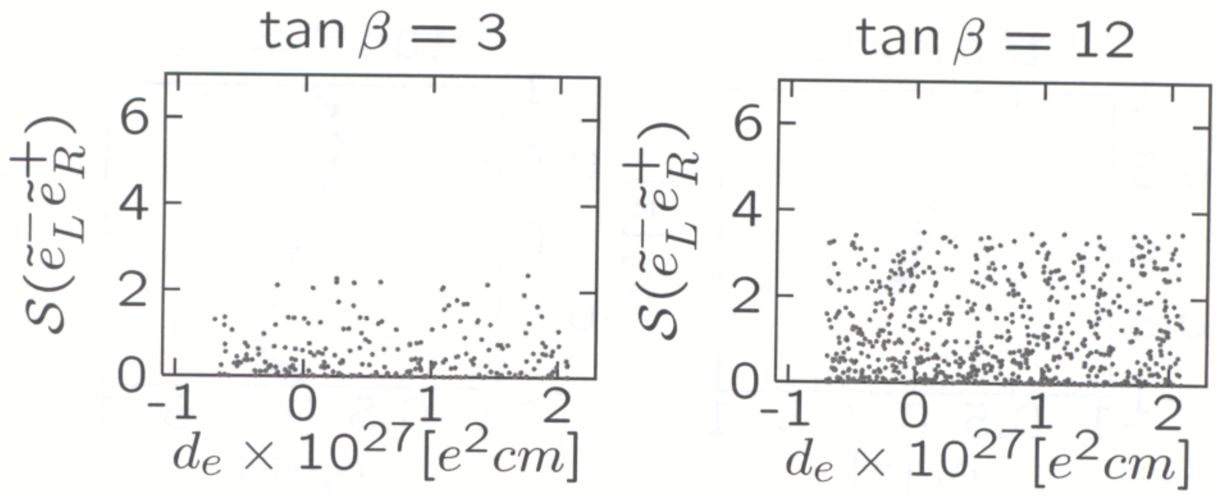
known fact: in general MSSM cancellations may occur and phases can be sizeable

imposing model(s) for SUSY breaking $\rightarrow$ constraints get more severe

$|\mu| = 200\text{GeV}$



$|\mu| = 500\text{GeV}$

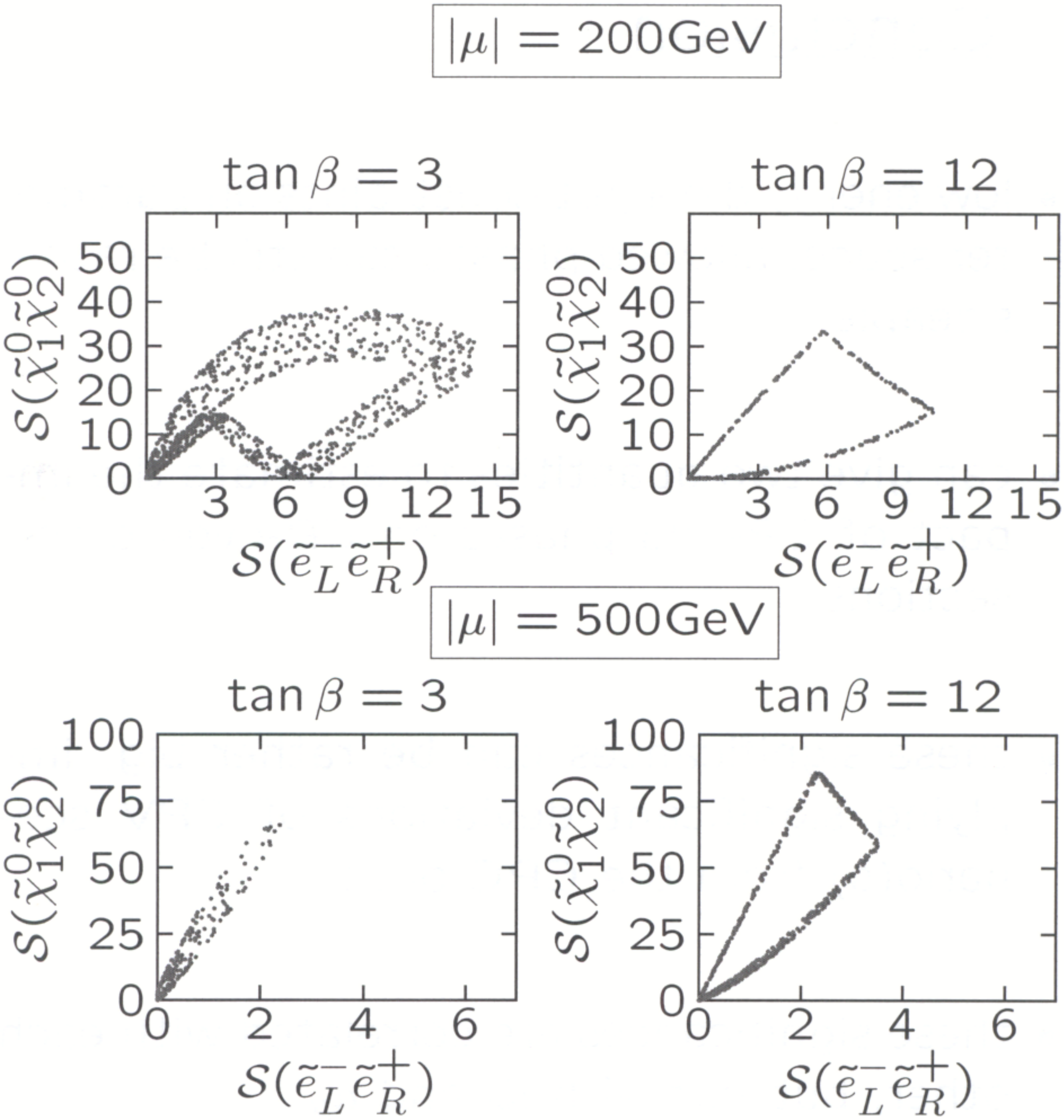


expected: $d_e = d_e(\phi_\mu, \phi_1, \phi_A) \Leftrightarrow S = S(\phi_\mu, \phi_1)$

different scales for S

$\leftrightarrow$ changes in neutralino mixing due to $|\mu|$

$\leftrightarrow$ available ϕ_1-range and available CPC points



smeared triangles (ϕ_μ) from ϕ_1-dependence of each S, as extrema of S_1 and S_2 do not coincident

more complicated patterns possible

5. Conclusion

- low energy data put constraints on parameter space, allowed phases can still be rather sizeable

- can give two quantities to estimate the impact of CP-odd phases on CP-even cross-sections

- these significances can be rather big, implying significant deviations of CPV scenario(s) from the CPC ones

- these significances are correlated with each other, but *not* with d_e and a_μ

- significances dominantly due to coupling effects