Electroweak Precision Measurements
Triple and Quartic Gauge Couplings
Contact Interactions

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based on collaboration with
U. Baur and (in principle) *many others . . . ???*

1. Introduction
2. Electroweak precision measurements
3. Triple and quartic gauge couplings
   $\rightarrow$ nothing yet... Friday! [*U. Baur '03*]
4. Contact interactions
   $\rightarrow$ nothing
5. Conclusions

1. Introduction

Electroweak precision observables (EWPO):

– the W boson mass M_W
– the effective leptonic mixing angle $\sin^2\theta_{\text{eff}}$

and in addition:

– the top quark mass m_t
– the Higgs boson mass m_h

Experimental errors:

	today	LHC	LC	GigaZ
$\delta\sin^2\theta_{\text{eff}}(\times 10^5)$	17	14-20	–	1.3
δM_W [MeV]	34	15	10	7
δm_t [GeV]	5.1	1-2	0.2	0.1
δm_h [MeV]	–	200	50	–

$\Rightarrow$ LC more capable than LHC
$\Rightarrow$ EWPO alone: no LHC/LC interplay

New situation with Supersymmetry
$\Rightarrow$ heavy mass scales only accessible with LHC

Higgs sector of the MSSM:

Physical states: $h^0, H^0, A^0, H^\pm$

Goldstones: $G^0, G^\pm$

Input parameters:

$$\tan\beta = \frac{v_2}{v_1}, \qquad M_A^2 = -m_{12}^2(\tan\beta + \cot\beta)$$

$\tilde{t}$ sector of the MSSM:

(scalar partner of the top quark)

Mass matrix for $\tilde{t}_L, \tilde{t}_R$:

$$M_{\tilde{t}}^2 = \begin{pmatrix} M_{\tilde{t}_L}^2 + m_t^2 + DT_{1t} & m_t X_t \\ m_t X_t & M_{\tilde{t}_R}^2 + m_t^2 + DT_{2t} \end{pmatrix}$$

$$\Downarrow \leftarrow \text{Diagonalization}, \theta_{\tilde{t}}$$

$$\begin{pmatrix} m_{\tilde{t}_1}^2 & 0 \\ 0 & m_{\tilde{t}_2}^2 \end{pmatrix}$$

$m_t X_t = m_t(A_t - \mu\cot\beta)$; large mixing possible

$\Rightarrow$ Physical parameters: $m_{\tilde{t}_1}$, $m_{\tilde{t}_2}$, $\theta_{\tilde{t}}$

Soft SUSY-breaking parameters: $M_{\tilde{t}_L}$, $M_{\tilde{t}_R}$, A_t

Interplay of different sectors:

m_h depends strongly on m_t and $\tilde{t}$ sector :

$$\Delta m_h^2 \sim \frac{m_t^4}{M_W^2 \sin^2\beta} \log\left(\frac{m_{\tilde{t}_1}^2 m_{\tilde{t}_2}^2}{m_t^4}\right)$$

$M_W, \sin^2\theta_{\text{eff}}$ depend on m_t and $\tilde{t}$ sector :

$$\begin{aligned}
\Delta M_W &\sim m_t^2 \\
&\sim \log(m_{\tilde{t}_1} m_{\tilde{t}_2}) \text{ (decoupling!)} \\
&\sim \log(m_h) \\
\Delta \sin^2\theta_{\text{eff}} &\sim m_t^2 \\
&\sim \log(m_{\tilde{t}_1} m_{\tilde{t}_2}) \text{ (decoupling!)} \\
&\sim \log(m_h)
\end{aligned}$$

$\Rightarrow$ especially δm_t^{exp} has to be under control

(LC measurement important)

$\Rightarrow$ $\tilde{t}$ sector has to be known ...

(LHC measurements important)

$\Rightarrow$ theory prediction of m_h has to be under control

(... a lot of work for theorists ...)

2. Electroweak precision measurements

SUSY offers many possibilities . . .

$\Rightarrow$ look at specific examples

adopted from:

[S.H., S. Kraml, W. Porod, G.W. '03]

[J. Erler, S.H., W. Hollik, G.W., P. Zerwas '00]

"Realistic scenarios"

$\Updownarrow$

realistic errors assumptions !

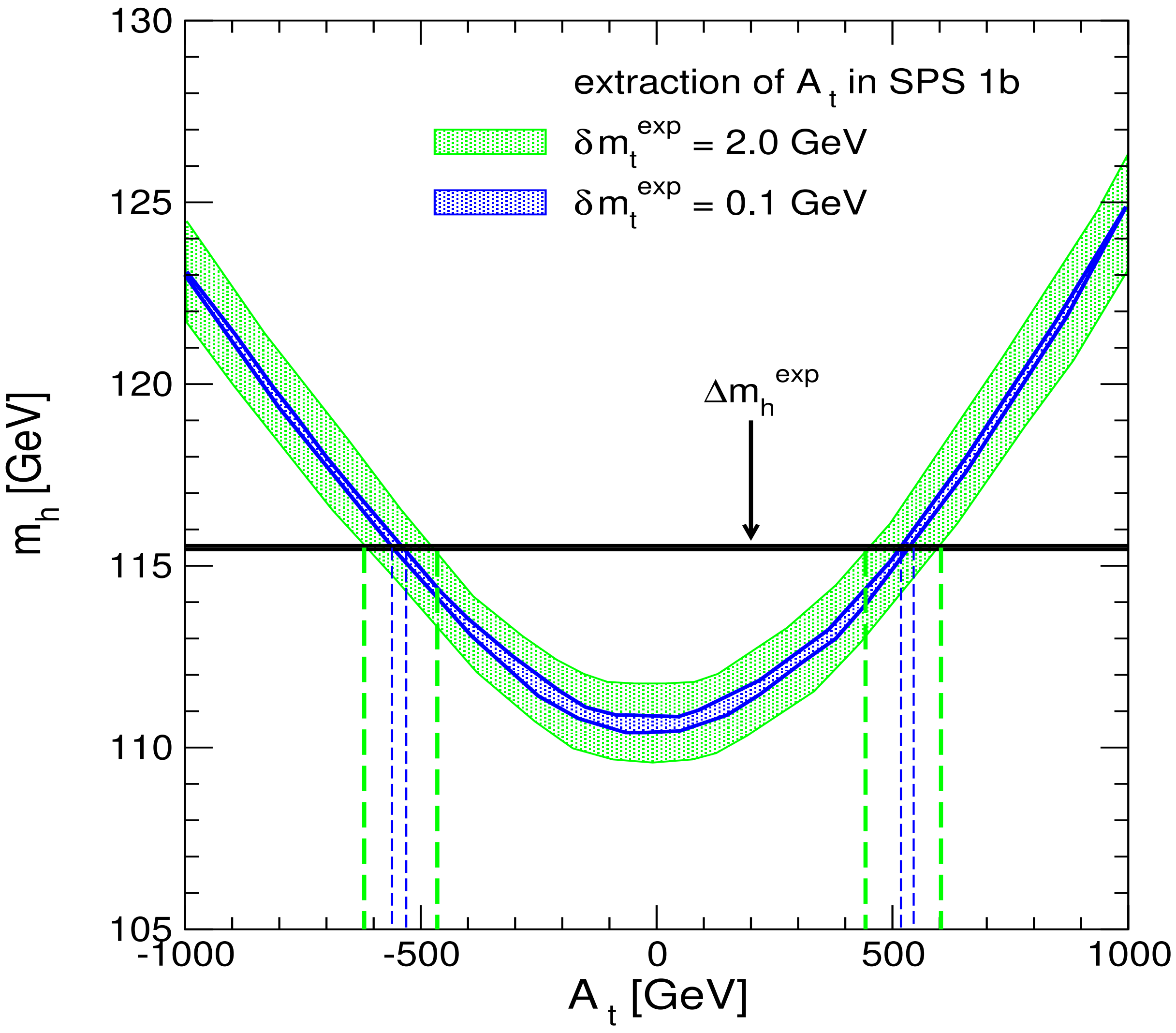
SUSY at LHC	:	$10 - 30\%$
SUSY at LC	:	$\sim 1\%$
m_t at LHC	:	$1 - 2$ GeV
m_t at LC	:	100 MeV
m_h at LC		
$M_W, \sin^2\theta_{\mathrm{eff}}$ at LC		

"Realistic" SUSY example I:

SPS1b:

LHC: $m_{\tilde{t}_1}, m_{\tilde{t}_2}, m_{\tilde{b}_1}, m_{\tilde{b}_2}$, $\tan\beta, M_A$
LC: m_h, m_t

A_t unknown



⇒ extraction of A_t possible

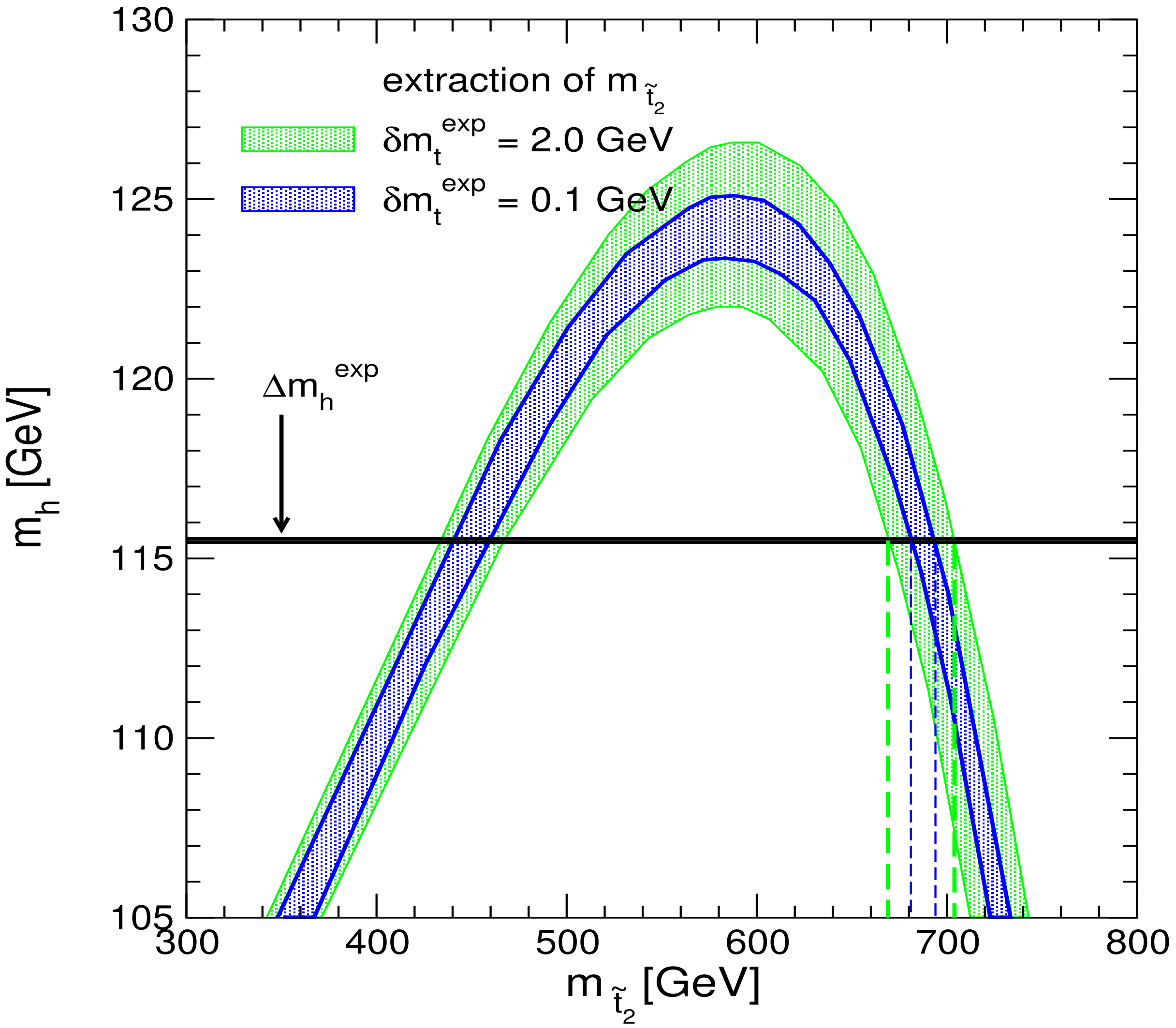
⇒ $\delta m_t = 0.1$ GeV gives improvement $\sim 3 - 4$

"Realistic" SUSY example II:

Light $\tilde{t}$ scenario (TESLA TDR):

LHC: $m_{\tilde{t}_2}$?, $m_{\tilde{b}_1}$, $m_{\tilde{b}_2}$
LC: $m_{\tilde{t}_1} = 180$ GeV, $\theta_{\tilde{t}}$, M_A, $\tan\beta$, m_h, m_t

$m_{\tilde{t}_2}$ unknown/known from LHC



$\Rightarrow$ extraction of $m_{\tilde{t}_2}$ possible
(prediction/consistency check)

$\Rightarrow$ $\delta m_t = 0.1$ GeV gives improvement ~ 3

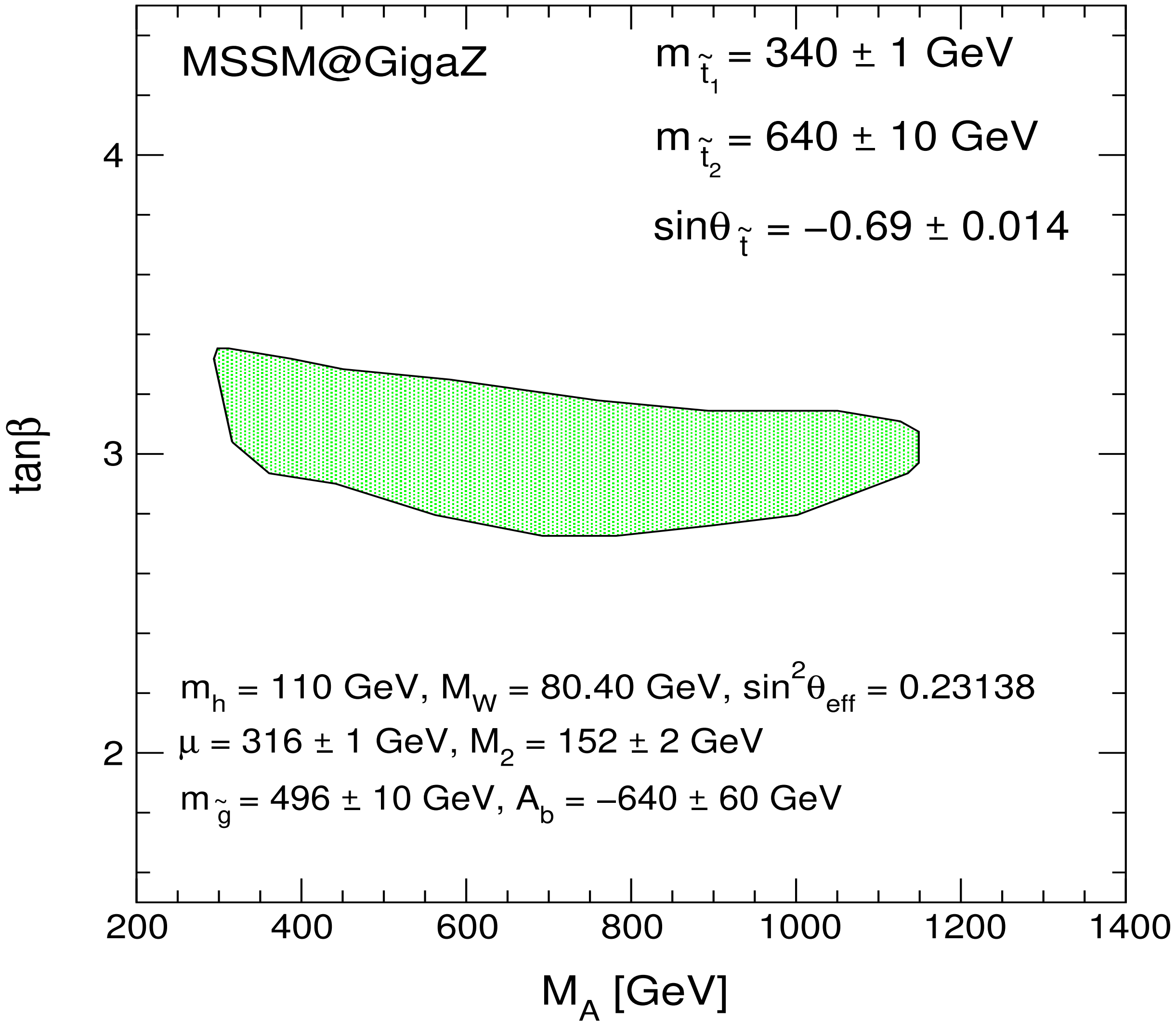
“Realistic” SUSY/Higgs example III:

TESLA TDR:

LHC: $m_{\tilde{t}_2}$, $m_{\tilde{b}_1}$, $m_{\tilde{b}_2}$

LC: $m_{\tilde{t}_1}$, $\theta_{\tilde{t}}$, m_t, m_h, M_W, $\sin^2\theta_{\rm eff}$

M_A, $\tan\beta$ unknown



$\Rightarrow$ extraction of M_A, $\tan\beta$ possible

$\Rightarrow$ δM_W, $\delta\sin^2\theta_{\rm eff}$ at GigaZ crucial

5. Conclusions

- EWPO: M_W, $\sin^2\theta_{\text{eff}}$, m_t, m_h

  $\Rightarrow$ strong interplay

  $\Rightarrow$ especially within SUSY

  $\Rightarrow$ δm_t^{exp} has to be under control
  (LC measurement important)

  $\Rightarrow$ $\tilde{t}$ sector has to be known ...
  (LHC measurements important)

  $\Rightarrow$ theory pred. of m_h has to be under control

- 3 "realistic" scenarios:

  Scenario I:
  δm_t from LC triples precision for A_t

  Scenario II:
  δm_t from LC triples precision for $m_{\tilde{t}_2}$

  Scenario III:
  δM_W, $\delta\sin^2\theta_{\text{eff}}$, δm_h from LC
  $m_{\tilde{t}_1}$, $m_{\tilde{t}_2}$, ... from LHC/LC
  $\Rightarrow$ extraction of M_A and $\tan\beta$ possible

- Triple/quartic gauge couplings: to be done

- Contact interactions: any volunteers?