

1. Introduction

Automatic calculation of amplitudes

-> important @ HE colliders

LHC,

TESLA, NLC, CLIC,

GLC (Global Linear Collider)

* many body final states

* possible many new particles

GRACE/SUSY (Minami-Tateya)

CompHEP (Moscow)

[hep-ph/0205020](#), [hep-ph/0111291](#), [hep-ph/0101232](#)

Feyn series (Germany)

[Nucl.Phys.Proc.Supp.29A:204-208,1992](#)

MADGRAPH/MADEVENT (US)

[JHEP 0302:027,2003](#)

The SPA Project

SUSY Parameter Determination

J. Kalinowski
Warsaw University

Montpellier, Nov. 14, 2003

Outline:

- Motivation
- The SPA Project
- Examples
- Summary and call for contributions

Call for contributions

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Coordinators SPA project (www-flc.desy.de/spa/)

1. Theoretical tools
 - masses & widths (sfermions, gauginos) W Holllik, J Guasch
 - chargino/neutralino production W Majorotto, A Bartl
 - slepton production A Freitas
 - squarks & gluino production M Spira
 - Susy Higgs G Weiglein
 - dark matter, high precision data A Djouadi, G Belanger
2. Experimental input
 - sparticle properties, LC H-U Martyn
 - squarks & gluino, LHC G Polesello
 - Susy Higgs K Desch
3. Extraction of LE param. evolution to HE J Kalinowski
 - chargino/neutralino sector A Freitas
 - slepton sector G Weiglein
 - Susy Higgs sector W Porod, G Blair
 - extrapolation to HE scales

Chairpersons
Coordination program codes
Physics advisor
J Kalinowski, H-U Martyn
W Kilian
P Zerwas

Join us!!

In Asia

We have

GRACE/SUSY ~

based on GRACE/SM

"IMPLEMENTATION OF THE NONLINEAR GAUGE INTO GRACE"

G. Belanger, F. Boudjema, J. Fujimoto, T. Ishikawa, T. Kaneko, K. Ka
V. Lafage , N. Nakazawa, Y. Shimizu

hep-ph/9907406

% tree level <- released already

"GRACE/SUSY AUTOMATIC GENERATION OF TREE AMPLITUDES
IN THE MINIMAL SUPERSYMMETRIC STANDARD MODEL"

KEK-CP-129, Aug 2002, **hep-ph/0208036**
Comput.Phys.Commun. 153 (2003) 106

<http://minami-home.kek.jp/>

% 1-loop level <- under checking!

2. Tree level system

MSSM

particle	variable name
photon	photon
$W^+(W^-)$	W-plus (W-minus)
Z	Z
gluon	gluon
$\nu_e(\bar{\nu}_e)$	nu-e (nu-e-bar)
$e^-(e^+)$	electron (positron)
$\nu_\mu(\bar{\nu}_\mu)$	nu-mu (nu-mu-bar)
$\mu^-(\mu^+)$	muon (anti-muon)
$\nu_\tau(\bar{\nu}_\tau)$	nu-tau (nu-tau-bar)
$\tau^-(\tau^+)$	tau (anti-tau)
$u(\bar{u})$	u (u-bar)
$d(\bar{d})$	d (d-bar)
$c(\bar{c})$	c (c-bar)
$s(\bar{s})$	s (s-bar)
$t(\bar{t})$	t (t-bar)
$b(\bar{b})$	b (b-bar)
h^0	Higgs1
H^0	Higgs2
A^0	Higgs3
$H^+(H^-)$	Higgs-plus (Higgs-minus)

particle	variable name
$\tilde{\chi}_1^0(\tilde{\chi}_1^-)$	chargino1 (anti-chargino1)
$\tilde{\chi}_2^0(\tilde{\chi}_2^-)$	chargino2 (anti-chargino2)
$\tilde{\chi}_1^0$	neutralino1
$\tilde{\chi}_2^0$	neutralino2
$\tilde{\chi}_3^0$	neutralino3
$\tilde{\chi}_4^0$	neutralino4
$\tilde{\nu}_e(\tilde{\nu}_e)$	smu-e (anti-smu-e)
$\tilde{\nu}_\mu(\tilde{\nu}_\mu)$	smu-mu (anti-smu-mu)
$\tilde{\nu}_\tau(\tilde{\nu}_\tau)$	smu-tau (anti-smu-tau)
$\tilde{e}_1^-(e_1^+)$	selectron1 (anti-selectron1)
$\tilde{e}_2^-(e_2^+)$	selectron2 (anti-selectron2)
$\tilde{\mu}_1^-(\mu_1^+)$	smuon1 (anti-smuon1)
$\tilde{\mu}_2^-(\mu_2^+)$	smuon2 (anti-smuon2)
$\tilde{\tau}_1^-(\tau_1^+)$	stau1 (anti-stau1)
$\tilde{\tau}_2^-(\tau_2^+)$	stau2 (anti-stau2)
$\tilde{u}_1(\tilde{u}_1)$	su1 (anti-su1)
$\tilde{u}_2(\tilde{u}_2)$	su2 (anti-su2)
$\tilde{d}_1(\tilde{d}_1)$	sd1 (anti-sd1)
$\tilde{d}_2(\tilde{d}_2)$	sd2 (anti-sd2)
$\tilde{c}_1(\tilde{c}_1)$	sc1 (anti-sc1)
$\tilde{c}_2(\tilde{c}_2)$	sc2 (anti-sc2)
$\tilde{s}_1(\tilde{s}_1)$	ss1 (anti-ss1)
$\tilde{s}_2(\tilde{s}_2)$	ss2 (anti-ss2)
$\tilde{t}_1(\tilde{t}_1)$	st1 (anti-st1)
$\tilde{t}_2(\tilde{t}_2)$	st2 (anti-st2)
$\tilde{b}_1(\tilde{b}_1)$	sb1 (anti-sb1)
$\tilde{b}_2(\tilde{b}_2)$	sb2 (anti-sb2)

gauge invariance check

```
ans1 = 0.139175455829902 covariant gauge
ans2 = 0.139175455829902 unitary gauge
ans1/ans2 - 1 = -2.220446049250313E-016
```

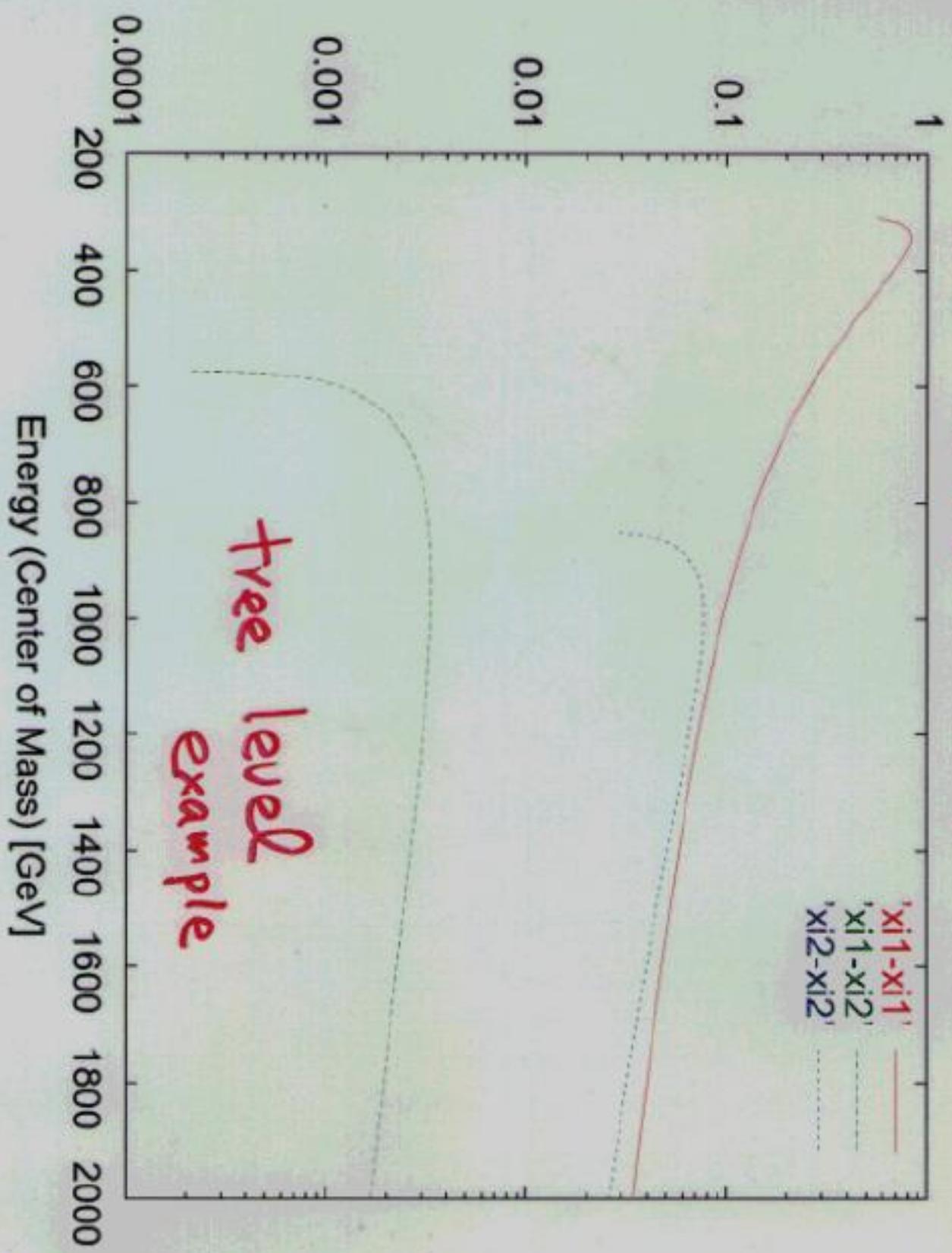
We have checked the gauge invariance with quadruple-precision

SUSY processes with up to 6 external particles

582,102 processes

$e^- e^+ \rightarrow \tilde{\chi}_i^+ \tilde{\chi}_j^-$ (tree level)

Cross Section [pb]



3. 1-loop level system

Renormalization scheme

gauge symmetric, on shell scheme

by M. Kuroda

SM part : conventional approach

Bohm, Hollik and Spiesberger, Fortschr. Phys. C34 (1986) 687

Higgs, Chargino and Neutralino sector : Dabelstein's approach

Dabelstein, Z. Phys. C67 (1995) 495

(wavefunction ren. const. ; only to the unmixed bare states)

Sfermion sector : Kyoto approach

Aoki et al., Prog. Theor. Phys. Suppl. 73 (1982) 1

(wavefunction ren. const. ; only to the mixed mass eigenstates)

Note GRACE/SM 1-loop : Kyoto approach

$$e^- e^+ \rightarrow \tilde{\chi}_i^+ \tilde{\chi}_i^-$$

Ref.

M.A. Diaz, S.F. King and A. Ross,
Nucl. Phys. B529 (1998) 23.

T. Blank and W. Hollik,
hep-ph/0011092.

W. Oller, H. Eberl, W. Majerotto
and C. Weber,
hep-ph/0304006.

We calculated 1-loop level
cross sections for

$\tilde{\chi}_1^+ \tilde{\chi}_1^-$ and $\tilde{\chi}_2^+ \tilde{\chi}_2^-$

pair productions
by GRACE/SUSY.

Stabilities for parameters

At Energy (center of mass) = 1900GeV

CUV (UV constant) dependence

CUV	1-loop (pb)
0	-0.1913091178482273
100	-0.1913091178449565

λ (photon mass) dependence

λ (GeV)	1-loop + soft γ (pb)
1.0e-20	-7.433338646007673e-02
1.0e-23	-7.433338646189581e-02

k_C (critical photon energy) dependence

k_C (GeV)	1-loop + soft γ + hard γ (pb)
1.0e-01	0.1374e-02 (+-0.000345e-02)
1.0e-03	0.1368e-02 (+-0.000473e-02)

for $e^- e^+ \rightarrow \tilde{\chi}_2^+ \tilde{\chi}_2^-$

with Input Parameters: $m_{\tilde{\chi}_1^+} = 150 \text{ GeV}$

$m_{\tilde{\chi}_2^+} = 420 \text{ GeV}$

$m_{\tilde{\chi}_1^0} = 75 \text{ GeV}$

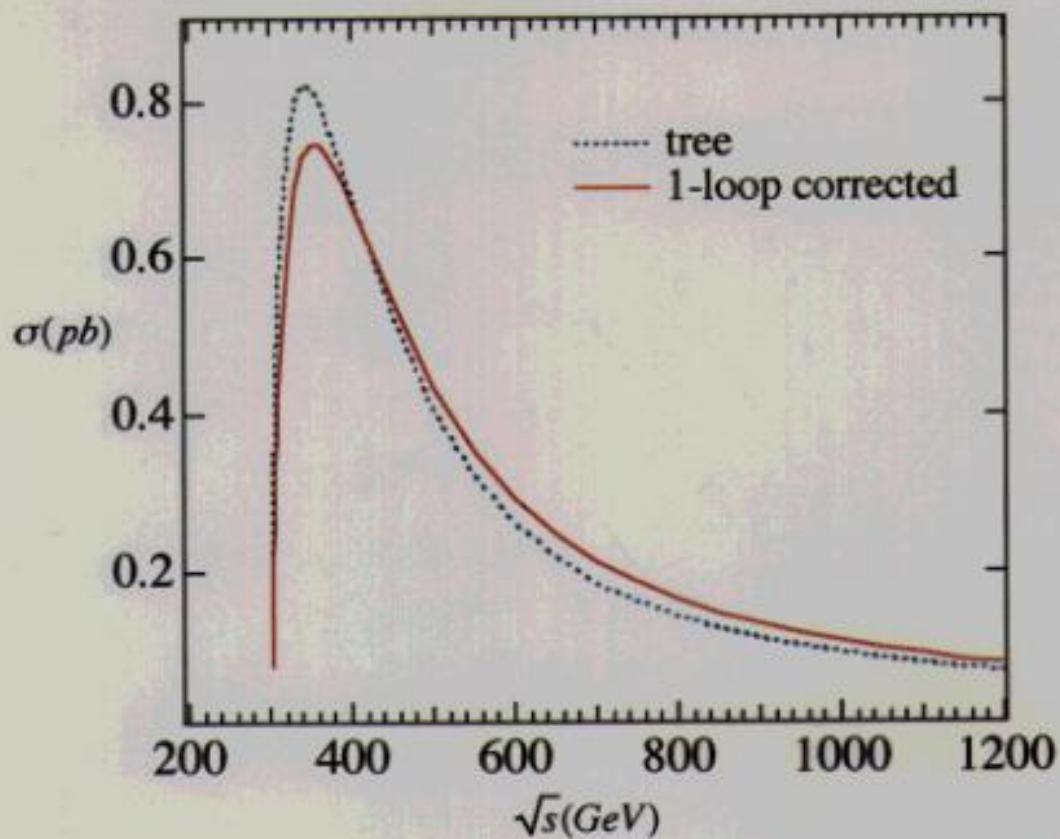
$\tan\beta = 5$

$A_f = M_h = 500 \text{ GeV}$

$m_{\tilde{\nu}} = 500 \text{ GeV}$

$m_{A^0} = 150 \text{ GeV}$

$e^-e^+ \rightarrow \tilde{\chi}_1^+\tilde{\chi}_1^-$



$$m_{\tilde{\chi}_1^0} = 150\text{GeV}$$

$$m_{\tilde{\chi}_1^\pm} = 420\text{GeV}$$

$$m_{\tilde{Z}_1^0} = 75\text{GeV}$$

$$\tan \beta = 5$$

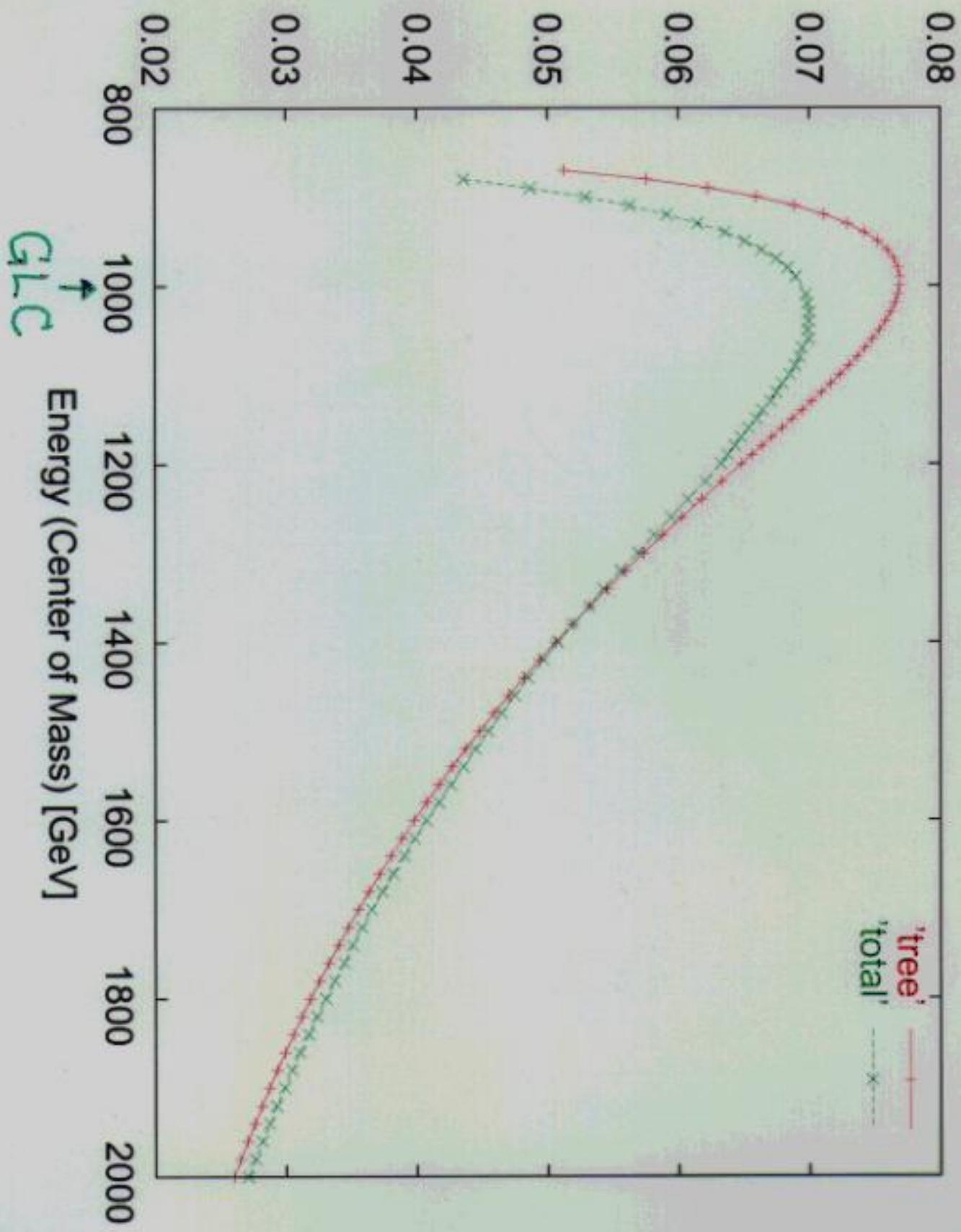
$$A_f = M_F = 500\text{GeV}$$

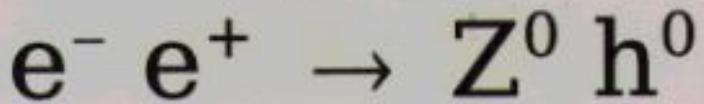
$$m_{\tilde{\nu}} = 500\text{GeV}$$

$$m_{A^0} = 150\text{GeV}$$

$e^- e^+ \rightarrow \tilde{\chi}_2^+ \tilde{\chi}_2^-$

Cross Section [pb]





Ref.

S. Heinemeyer, W. Hollik, J. Rosiek
and G. Weiglein,
Eur. Phys. J. C19 (2001) 535.

We calculated 1-loop level cross sections with Higgs-mass shift in 1-loop level by GRACE/SUSY.

$$\delta^{\text{ELWK}} = \delta^{\text{ELWK}_{\text{FULL}}} - \delta^{\text{QED}_{\text{V+S}}}$$

$\delta^{\text{QED}_{\text{V+S}}}$: photon form factor

CUV check:

CUV	$(1 + \delta^{\text{ELWK}}) \times \sigma^{\text{Born}} (\text{pb})$
0	5.878371130 <u>045570</u> E-02
100	5.878371130 <u>992130</u> E-02

1 CP-even Higgs masses in one-loop order

$$\begin{aligned} M_Z &= 91.187, & M_W &= 80.35, & m_t &= 175, \\ M_A &= 300, & \mu &= -100, & M_2 &= 400, \\ \bar{m}_{\tilde{f}_L} &= \bar{m}_{\tilde{f}_R} = m_{sf} = 500, & \theta_f &= 0, & \text{for all sfermions.} \end{aligned} \quad (1.1)$$

The value of M_1 is computed from the unification relation;

$$M_1 = \frac{5}{3} \tan^2 \theta_W M_2. \quad (1.2)$$

In Z.Phys.67(1995)495 by A. Dabelstein, M_W is computed from

$$G_\mu = \frac{\pi \alpha}{\sqrt{2} s_W^2 M_W^2} \cdot \frac{1}{1 - \Delta r_{\text{MSSM}}}, \quad (1.3)$$

$\tan \beta$	m_{h^0}	M_{h^0}		m_{H^0}	M_{H^0}	
		tree	1-loop		Dabelstein	tree
0.5	53.11506	93.1		93.2	309.0208	352.4
2.0	53.11506	83.8		84.0	309.0208	312.3
5.0	83.55589	106.0		106.2	302.2143	302.9
10.0	89.20395	110.5		110.8	300.5955	300.8
30.0	90.96377	112.9		113.7	300.0677	300.1

Table 1. The tree mass and the full one-loop mass of h^0 and H^0 are compared with those given by Dabelstein. The input values are given in (1.1).

For completeness, we have also compared the Higgs mass given in Table 2 of ref.[?], in which

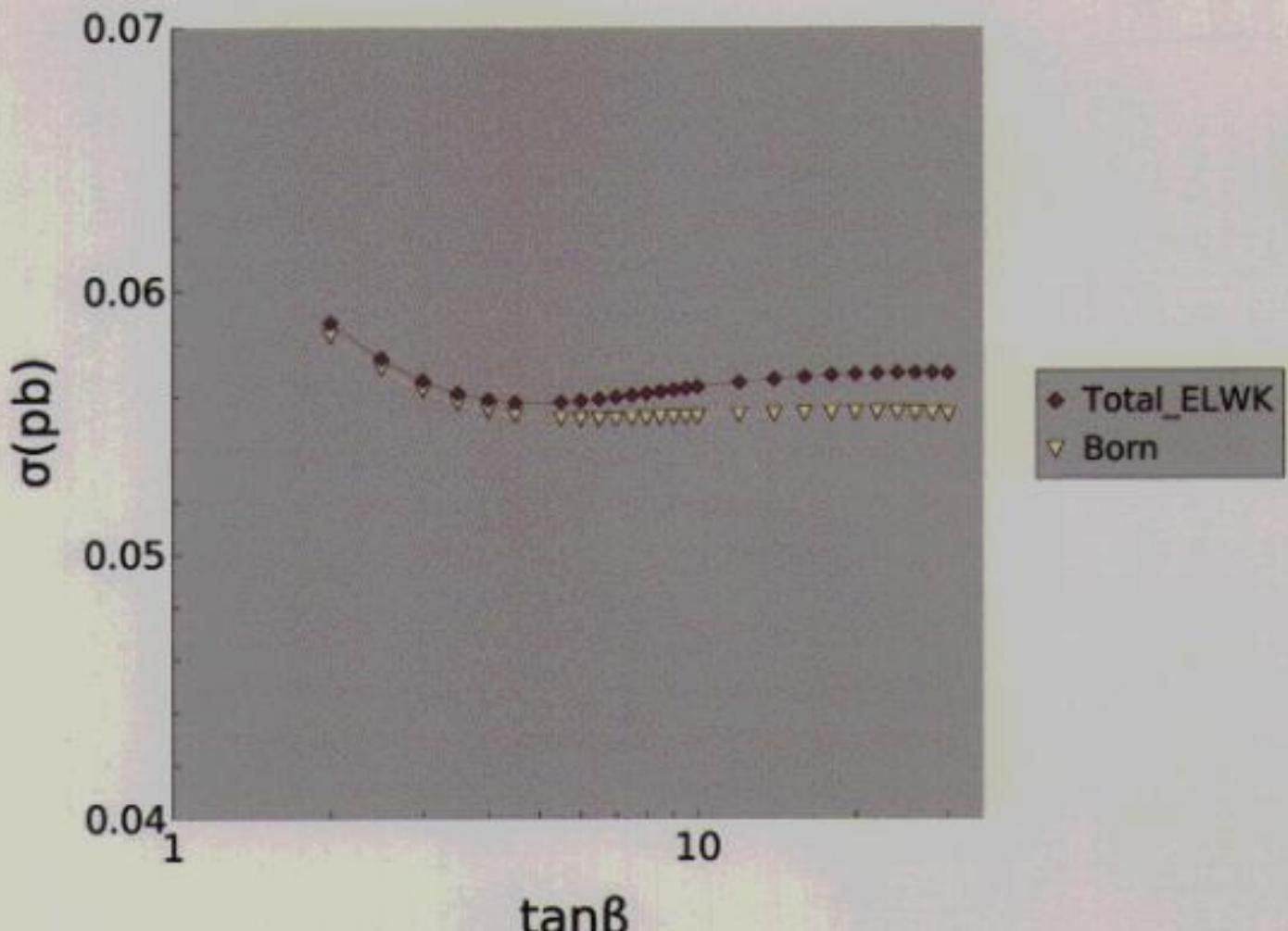
$$M_A = 200, \quad m_t = 150, \quad (1.4)$$

are used instead of the values given in (1.1).

$\tan \beta$	m_{h^0}	M_{h^0}		m_{H^0}	M_{H^0}	
		tree	1-loop		Dabelstein	tree
0.5	51.18954	79.0		79.2	213.7632	243.8
2.0	51.18954	69.2		69.5	213.7632	216.7
5.0	82.65397	95.5		95.7	203.6747	204.4
10.0	88.93069	101.2		101.5	201.0134	201.3
30.0	90.93177	103.6		104.2	200.1162	200.2

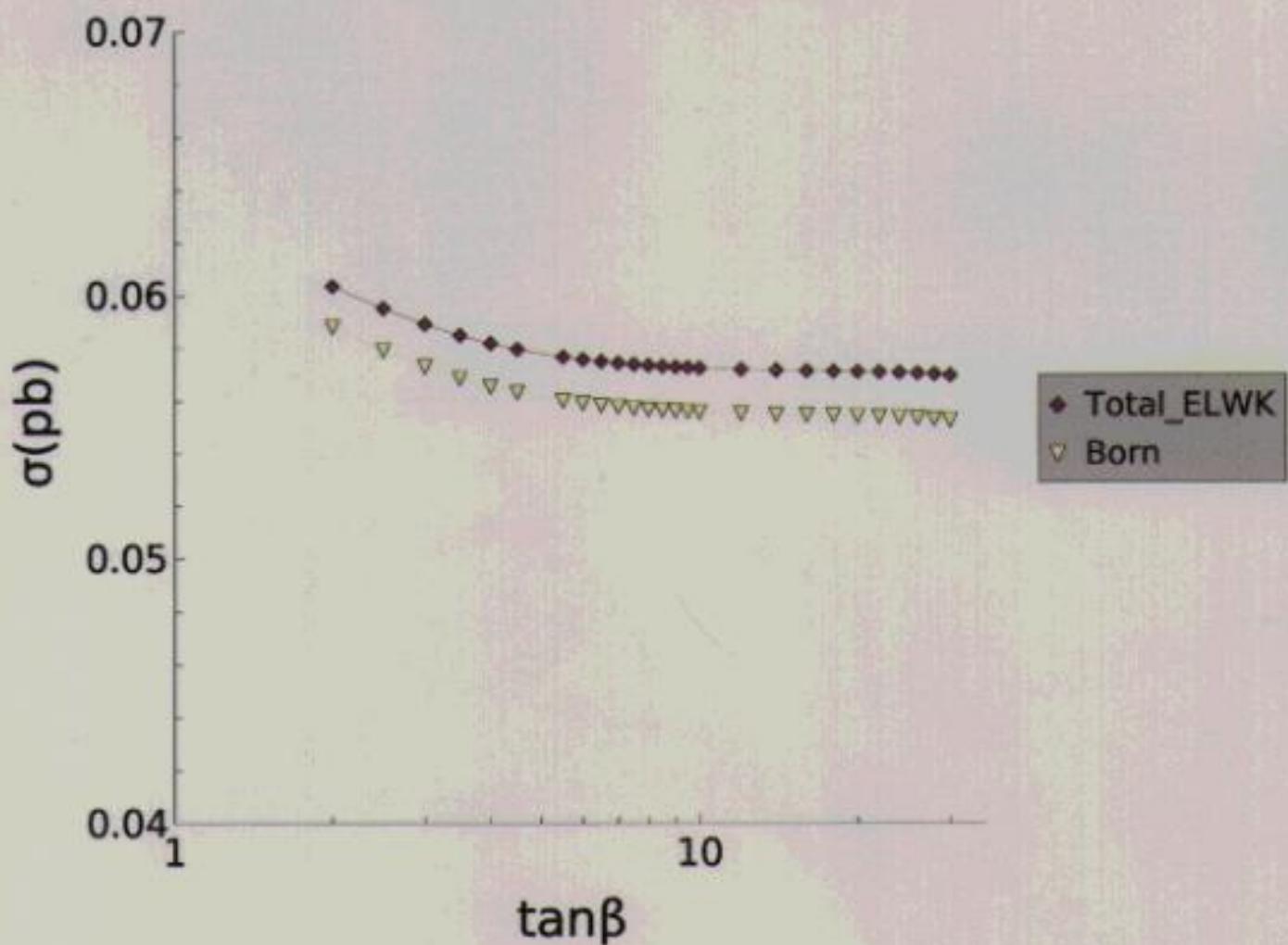
Table 2. The tree mass and the full one-loop mass of h^0 and H^0 are compared with those given by Dabelstein for the values of the input parameters given in (1.4).

$e^- e^+ \rightarrow Z0 h0$



$M(A0)=150\text{GeV}$

$e^- e^+ \rightarrow Z_0 h_0$



$M(A0)=350\text{GeV}$

4. Outlook

@Check with Non-linear gauge
in MSSM

$$\begin{aligned}F_{W^\pm} &= (\partial_\mu \pm ie\tilde{\alpha}A_\mu \pm igc_W\tilde{\beta}Z_\mu)W^{\pm\mu} \\&\quad \pm i\xi_W \frac{g}{2}(v + \tilde{\delta}_H H^0 + \tilde{\delta}_h h^0 \pm i\tilde{\kappa}G^0)G^\pm \\F_Z &= \partial_\mu Z^\mu + \xi_Z \frac{g_Z}{2}(v + \tilde{\varepsilon}_H H^0 + \tilde{\varepsilon}_h h^0)G^0 \\F_\gamma &= \partial_\mu A^\mu\end{aligned}$$

@Check for Renormalization

Sfermions

Neutralinos