SUSY Spectrum Codes

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- ISAJET, SoftSUSY, SPheno, SUSPECT
  - main features
  - SM input
  - calculation of masses
  - comparison between programs

- Special codes for Higgsmasses:
  CPsuperH, FeynHiggs, NMHDECAY

Common overall features

ISAJET 7.74: H. Baer, F.E. Paige, S.D. Protopopescu, X. Tata
SoftSUSY 2.05: B. Allanach
SPheno 2.2.3: W.P.
SUSPECT 2.34: A. Djouadi, J.L Kneur, G. Moultaka

- all use $\overline{DR}$ scheme

- complete 2-loop SUSY RGEs

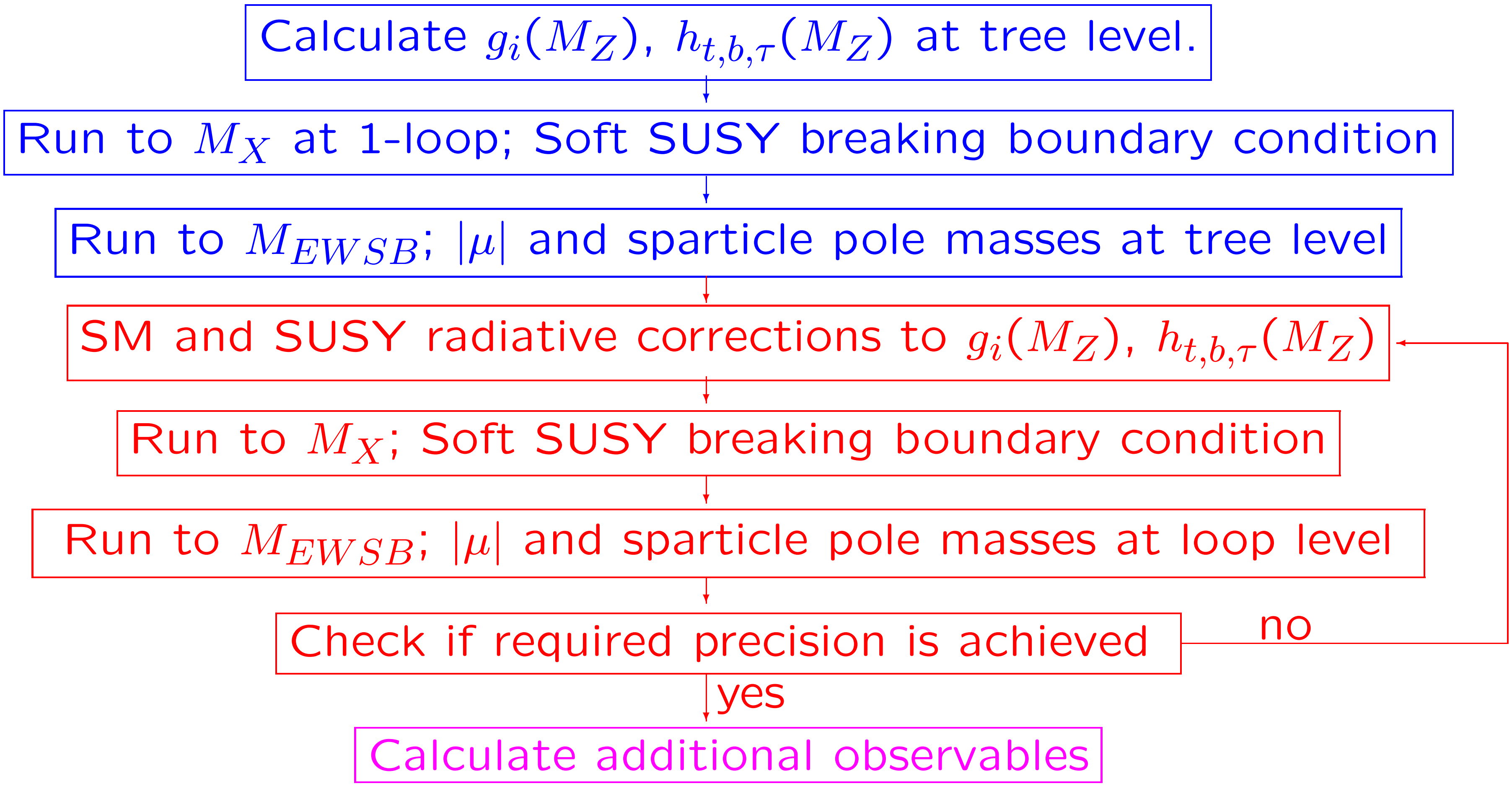
- SUSY threshold effects to gauge and Yukawa couplings

- 1-loop SUSY masses
  2-loop Higgs masses + μ at 2-loop (except ISAJET)

- SUSY Les Houches Accord implemented (hep-ph/0311123)

Implemented Models

- mSUGRA, GMSB, AMSB, string inspired models
- at M_{GUT}: specification of all SUSY parameters is possible
- all MSSM parameters at a user given scale $Q \lesssim 1$ TeV
  different options concerning Higgs sector
  - $M_{H_d}^2 + M_{H_u}^2$
  - $\mu + m_{A^0}$(pole)
  - $\mu + m_{A^0}$(running)


Calculate $g_i(M_Z)$, $h_{t,b,\tau}(M_Z)$ at tree level.
Run to M_X at 1-loop; Soft SUSY breaking boundary condition
Run to M_{EWSB}; $|\mu|$ and sparticle pole masses at tree level
SM and SUSY radiative corrections to $g_i(M_Z)$, $h_{t,b,\tau}(M_Z)$
Run to M_X; Soft SUSY breaking boundary condition
Run to M_{EWSB}; $|\mu|$ and sparticle pole masses at loop level
Check if required precision is achieved
no
yes
Calculate additional observables

Calculation of gauge and Yukawa couplings*

I .. ISAJET, SO .. SoftSUSY, SP .. SPheno, SU .. SUSPECT

- α, G_F, $m_Z \Rightarrow g'^{\overline{DR}}(m_Z)$, $g^{\overline{DR}}(m_Z)$, m_W, $\sin^2\theta_W$, v_i,
  1-loop, leading 2-loop top-quark correction: SO, SP, SU
  hard coded values + 1-loop corrections: I

- $\alpha_s^{\overline{MS}}(m_Z) \Rightarrow \alpha_s^{\overline{DR}}(m_Z)$, shift at 1-loop: I, SO, SP, SU
  I: $\alpha_s^{\overline{MS}}(m_Z) = 0.1172$ hard-coded

- SM fermion masses

  – light quarks

* G.Degrassi et al., NPB351, 49 (1991); D. M. Pierce et al., Nucl. Phys. B **491** (1997) 3; L. V. Avdeev and M. Y. Kalmykov, Nucl. Phys. B **502** (1997) 419

1. input: $m_{u,d,s}$(2 GeV), $m_c(m_c)$: SO, SP
   $m_b(m_b)$: SO, SP, SU
   $m_b(m_b) = 4.214$ hard coded: I
   3-loop RGEs† including thresholds† to get $m_q^{\overline{MS}}(m_Z)$

2. O(α_s^2) + O(α) shift from $\overline{MS} \to \overline{DR}$: I, SO, SP, SU

3. shift due to SUSY particles,
   in case of m_b resummation of $\tan\beta$ enhanced terms:
   I, SO, SP, SU

- m_t pole mass $\Rightarrow m_t^{\overline{DR}}(m_Z)$:
  complete 1-loop SUSY loops + 2-loop α_s gluonic contribution: I, SO, SP, SU
  I: calculation at $Q = m_t$

- $m_{e,\mu}$ pole masses,1-loop shift to $\overline{DR}$ masses: SO, SP
  m_τ pole masses, 1-loop shift to $\overline{DR}$ mass: I, SO, SP, SU
  m_τ: resummation of $\tan\beta$ enhanced terms: SO, SP

† K.G.Chetyrkin et al., hep-ph/0004189

GUT output	Isajet 7.72	Isajet 7.73	SPheno 2.2.4
$M_G \times 10^{16}$ GeV	2.28	2.28	2.46
$g_1(M_G) = g_2(M_G)$	0.715	0.715	0.721
$g_3(M_G)$	0.706	0.706	0.707
$h_t(M_G)$	0.505	0.516	0.527
$h_b(M_G)$	0.049	0.047	0.051
$h_\tau(M_G)$	0.068	0.068	0.068

$\overline{DR}$ GUT scale gauge and Yukawa couplings for SPS1a.

SUSY/Higgs Masses*

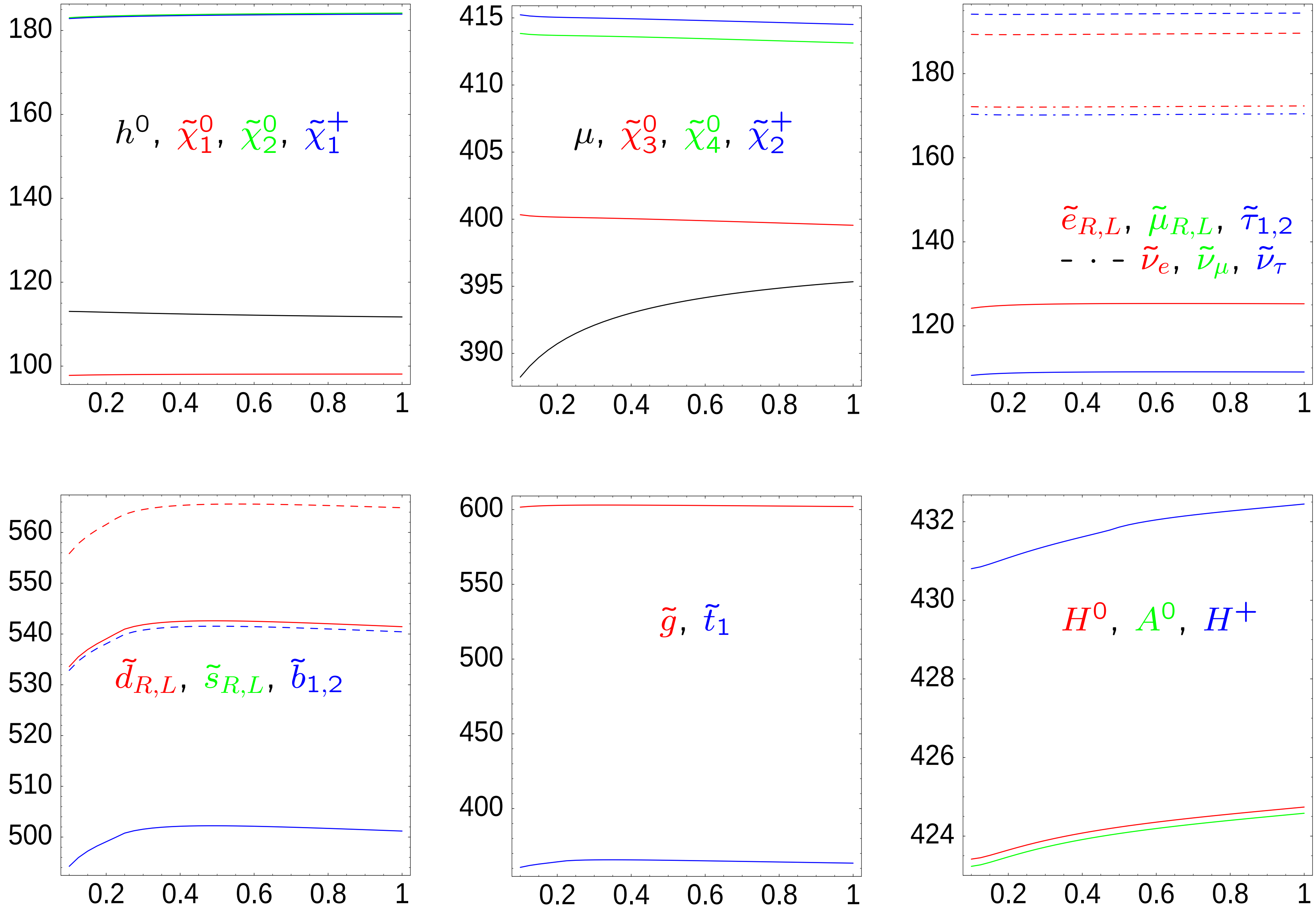
- All masses are calculated [default, can be changed by user]
  $Q = \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}}$: SP
  $Q = \sqrt{m_{\tilde{t}_R} m_{\tilde{t}_L}}$: SO, SU
  $Q = \sqrt{m_{\tilde{t}_R} m_{\tilde{t}_L}}$: I, all particles which mix, otherwise $\tilde{m}(\tilde{m})$

- SUSY masses at 1-loop, without approximations: I, SO, SP
  SUSY masses at 1-loop, some approximations: SU

- μ + neutral Higgs bosons:
  complete 1-loop formulas without approximations
  + 2-loop corrections $\alpha_s(\alpha_t + \alpha_b) + \alpha_t^2 + (\alpha_b + \alpha_\tau)^2$
  m_{H^+} at 1-loop: SO, SP, SU
  1-loop effective potential due to 3rd generation sfermions: I

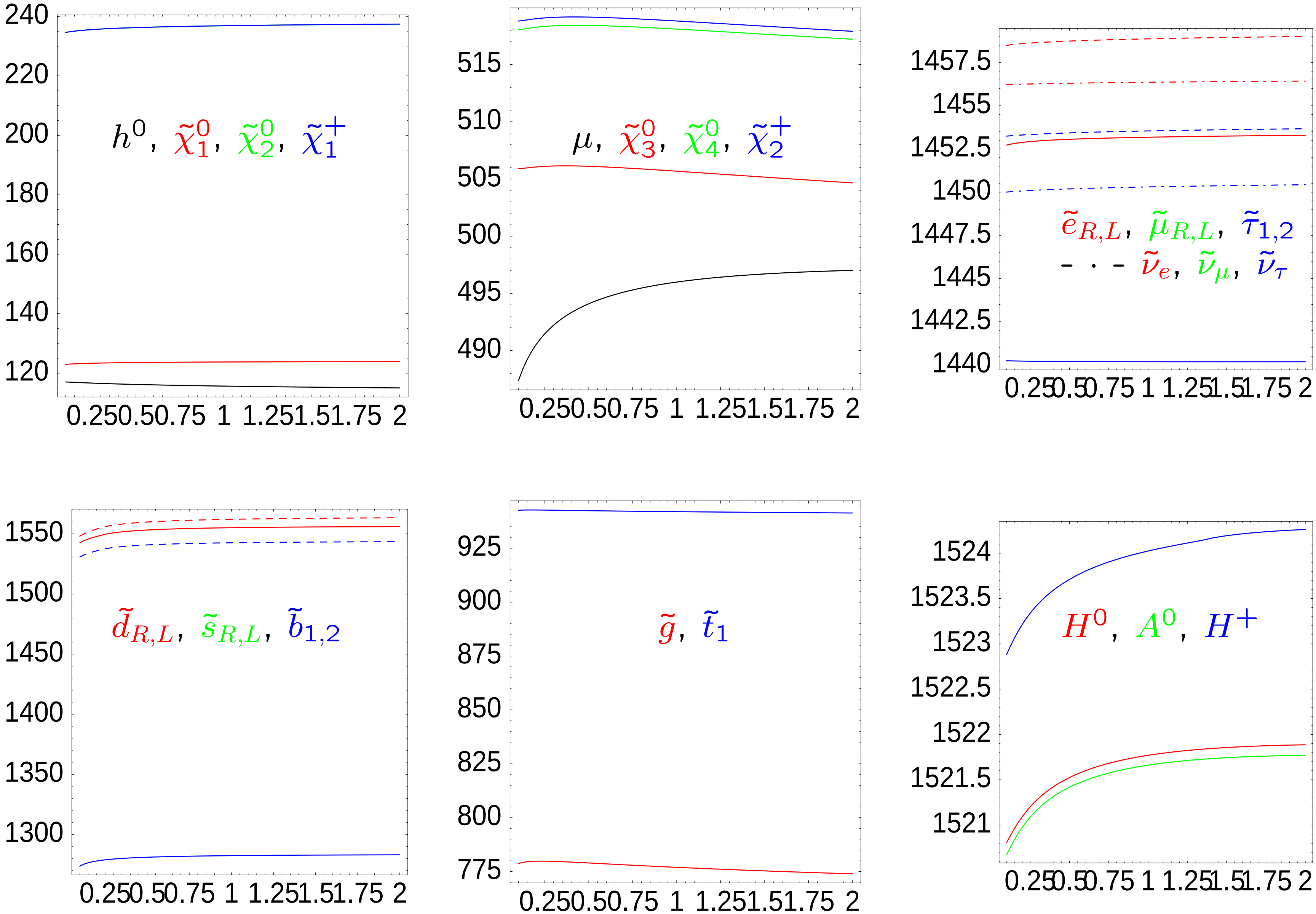
* D. M. Pierce et al., Nucl. Phys. B **491** (1997) 3; P.Slavich et al., Nucl. Phys. B **611** (2001) 403; Nucl. Phys. B **631** (2002) 195; Nucl. Phys. B **643** (2002) 79; Nucl. Phys. B **657** (2003) 333.

SPS1a', $m_0 = 70$ GeV, $m_{1/2} = 250$ GeV, $A_0 = -70$ GeV, $\tan\beta = 10$, sign(μ)=+



Scale dependence of masses as a function of renormalization scale Q [TeV].

SPS2, $m_0 = 1450$ GeV, $m_{1/2} = 300$ GeV, $A_0 = 0$, $\tan\beta = 10$, sign(μ)=+



Scale dependence of masses as a function of renormalization scale Q [TeV].

Comparison of SUSY spectrum generators: mass spectra, relic densities, etc

Updated on 27 Feb 06 to Isajet7.74 and Softsusy2.0.5

On this website you can compare the mass spectra of four public SUSY codes, Isajet7.74, Softsusy2.0.5, Spheno2.2.3 and Suspect2.3.4, together with the resulting relic densities as computed by micrOMEGAs1.3.

Please note:

- Isajet has mb(mb)=4.214 alpha_s(MZ)=0.1172 hard-coded in the program so any change of mb(mb) and alpha_s below will NOT apply to Isajet.
- The improvements in Isajet7.74 are based on hep-ph/0511123.

NEW: you can now also download the corresponding SLHA spectrum files!

mSUGRA input:	**m_0**	100	GeV
	m_1/2	250	GeV
	A_0	-100	GeV
	tan beta	10	(ca 1.6 - 50)
	sign(mu)	+1	
SM input:	**m_t**	175	GeV (onshell value)
	m_b(mb)	4.214	GeV (MSbar)
	alpha_s(MZ)	0.1172	(MSbar)

submit reset

If you are using this tool in a publication please cite

- G. Belanger, S. Kraml, A. Pukhov, hep-ph/0502079
- B.C. Allanach, S. Kraml, W. Porod, JHEP03(2003)016 [hep-ph/0302102]
- and the URL http://cern.ch/kraml/comparison/

Thank you.

-S.Kraml- last update: 27 Feb 2006.

Your input was

```
m0         = 100
m12        = 250
A0         = -100
tan(be)    = 10
sgn(mu)    = 1
mt         = 175
mb         = 4.214
alphas(MZ)  = 0.1172
```

Running programs ... please be patient ...

Isajet 7.74 ... Warning: Higgs mass(es) below LEP limit.
SoftSusy 2.0.5 ... Warning: Higgs mass(es) below LEP limit.
SPheno 2.2.3 ... Warning: Higgs mass(es) below LEP limit.
Suspect 2.3.4 ... Warning: Higgs mass(es) below LEP limit.

done.

Download SLHA file of Isajet, Softsusy, Spheno, Suspect, or all four as SHLAspectra.tar.

Sparticle	Isajet	Softsusy	Spheno	Suspect	(max-min)	diff[%]
nt_1	97.38	97.07	97.11	97.24	0.31	0.32
nt_2	180.39	181.11	180.72	180.80	0.72	0.40
nt_3	358.44	361.93	364.95	363.67	6.50	1.80
nt_4	378.78	380.13	382.16	382.44	3.66	0.96
ch_1	180.31	181.69	180.32	180.21	1.48	0.82
ch_2	377.76	378.33	383.25	382.67	5.49	1.44
gluino	608.73	604.84	604.33	606.97	4.40	0.73
h0	110.74	110.86	111.01	110.93	0.27	0.24
H0	399.57	398.30	400.02	400.00	1.72	0.43
A0	396.68	397.92	399.64	399.62	2.96	0.74
H+	407.10	406.26	407.93	407.93	1.68	0.41
snu_e	185.46	185.09	186.23	184.94	1.29	0.69
snu_mu	185.46	185.09	186.23	184.94	1.28	0.69
snu_tau	183.37	184.54	185.31	184.05	1.94	1.05
sel_L	203.31	202.76	202.43	200.85	2.46	1.22
sel_R	142.49	144.07	144.09	142.83	1.60	1.12
smu_L	203.31	202.76	202.45	200.85	2.46	1.22
smu_R	142.49	144.06	144.05	142.83	1.58	1.10
stau_1	134.65	134.52	134.44	133.17	1.48	1.10
stau_2	205.86	206.69	206.43	204.98	1.70	0.83
su_L	564.80	558.23	565.10	563.15	6.87	1.22
su_R	548.43	546.29	548.02	546.79	2.14	0.39
sd_L	570.79	565.58	570.51	568.65	5.22	0.92

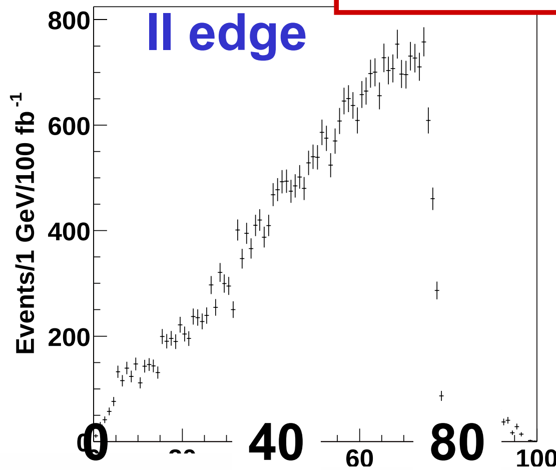
Left squark cascade decay

fast sim.

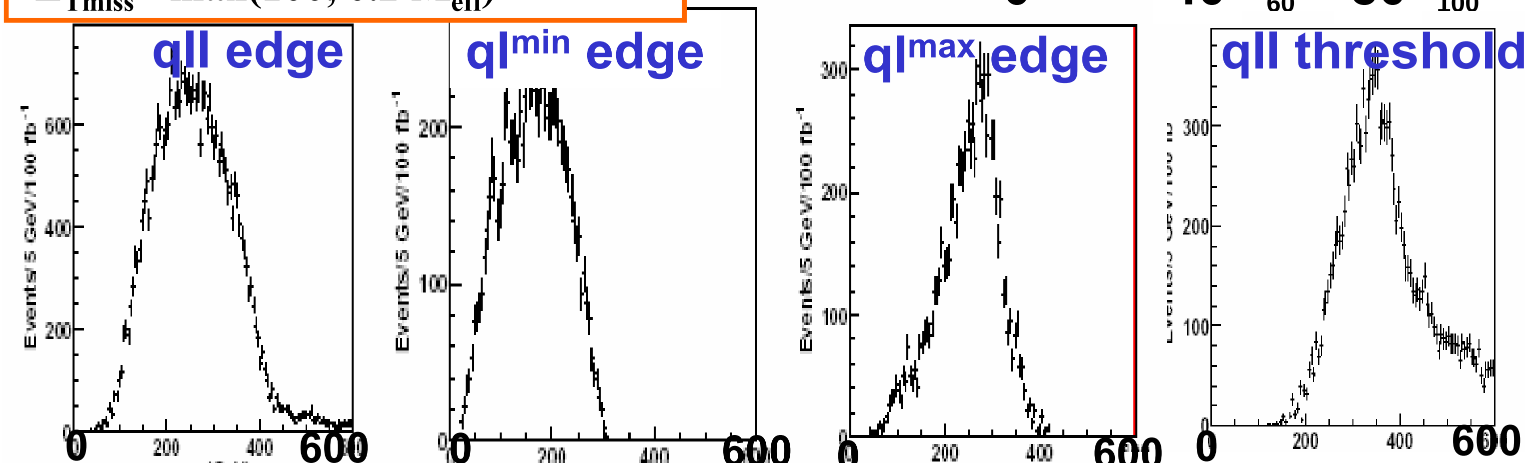
$L=100\ \mathrm{fb}^{-1}$

SPS1a (bulk region)
m_0= 100 GeV,
$m_{1/2}$= 250 GeV,
A_0= -100 GeV,
tan(β)=10 , μ>0

$$\tilde{q}_L \rightarrow \tilde{\chi}_2^0\, q \rightarrow \tilde{l}_R\, l\, q \rightarrow llq\, \tilde{\chi}_1^0$$



2 SFOS lep., p_T>20, 10 GeV
≥ 4 jets, p_T>150,100,50,50 GeV
M_{eff} > 600 GeV
E_{Tmiss} >max(100, 0.2 M_{eff})



Gjelsten, Lytken, Miller, Osland, Polesello,ATL-PHYS-2004-007

L=**100 fb^{-1}**

Fit results

Edge	Nominal Value	Fit Value	Syst. Error Energy Scale	Statistical Error
$m(ll)^{\rm edge}$	77.077	77.024	0.08	0.05
$m(qll)^{\rm edge}$	431.1	431.3	4.3	2.4
$m(ql)^{\rm edge}_{\rm min}$	302.1	300.8	3.0	1.5
$m(ql)^{\rm edge}_{\rm max}$	380.3	379.4	3.8	1.8
$m(qll)^{\rm thres}$	203.0	204.6	2.0	2.8

Mass reconstruction

5 endpoints measurements, 4 unknown masses

$$\chi^2 = \sum \chi_j^2 = \sum \left[\frac{E_j^{\rm theory}(\vec{m}) - E_j^{\rm exp}}{\sigma_j^{\rm exp}} \right]^2$$

$$E_j^i = E_j^{\rm nom} + a_j^i \sigma_j^{\rm fit} + b^i \sigma_j^{Escale}$$

$m(\chi_1^0) =$ 96 GeV
$m(l_R) =$ 143 GeV
$m(\chi_2^0) =$ 177 GeV
$m(q_L) =$ 540 GeV

$\Delta m(\chi_1^0) = 4.8$ GeV, $\Delta m(\chi_2^0) = 4.7$ GeV,
$\Delta m(l_R) = 4.8$ GeV, $\Delta m(q_L) = 8.7$ GeV

Gjelsten, Lytken, Miller, Osland, Polesello, ATL-PHYS-2004-007

Mass differences

$$\tilde{u}_L \to q\tilde{\chi}^0_2 \to ql^+\tilde{l}_R \to ql^+l^-\tilde{\chi}^0_1$$

	I	SO	SP	SU	max.-min.	[%]
$m_{\tilde{\chi}^0_2} - m_{\tilde{\chi}^0_1}$	83.01	84.04	83.61	83.56	1.03	1.2 %
$m_{\tilde{l}_R} - m_{\tilde{\chi}^0_1}$	45.11	47.00	46.98	45.59	1.89	4.2 %
$m_{\tilde{\chi}^0_2} - m_{\tilde{l}_R}$	37.90	37.04	36.63	37.97	1.34	3.7 %
$m_{\tilde{u}_L} - m_{\tilde{\chi}^0_2}$	384.4	377.1	384.4	382.4	7.3	1.9 %

I .. Isajet 7.74

SO .. SoftSUSY 2.05

SP .. SPheno 2.2.4

SU .. SUSPECT 2.34

Missing steps in the multi-scale approach

- SUSY particles are only decoupled in RGEs for gauge and Yukawa couplings but not in RGEs for soft SUSY breaking parameters

- integrating out particles
  $\Rightarrow$ induce non-renormalizble terms in Lagrangian

Integrating out $\tilde{t}_L$ yields for example effective operators of the form

$$c_1 \frac{g A_t Y_t}{m^2_{\tilde{t}_L}} \bar{t} P_R \tilde{W}_3 H^0_u \tilde{t}_R \,, \; c_2 \frac{-g \mu Y_t}{m^2_{\tilde{t}_L}} \bar{t} P_R \tilde{W}_3 H^0_d \tilde{t}_R$$

$$c_3 \frac{|A_t Y_t|^2}{m^2_{\tilde{t}_L}} H^0_u H^{0*}_u \tilde{t}_R \tilde{t}^*_R \,, \; c_4 \frac{|\mu Y_t|^2}{m^2_{\tilde{t}_L}} H^0_d H^{0*}_d \tilde{t}_R \tilde{t}^*_R \,, \; c_5 \frac{-A_t \mu Y_t^2}{m^2_{\tilde{t}_L}} H^0_d H^{0*}_u \tilde{t}_R \tilde{t}^*_R + h.c.$$

$$\cos\theta_{\tilde{t}} = \frac{-m_t(A_t - \mu \cot\beta)}{\sqrt{(m^2_{\tilde{t}_L} - m^2_{\tilde{t}_1})^2 + m_t^2 (A_t - \mu \cot\beta)^2}} \simeq \frac{-m_t(A_t - \mu \cot\beta)}{m^2_{\tilde{t}_L}}$$

Higgs mass programs

- FeynHiggs: S. Heinemeyer, T. Hahn, W. Hollik, and G. Weiglein
  on-shell scheme, various ways to treat Y_b, 2-loop, includes CP-phases

- CPsuperH: J.S. Lee, A. Pilaftsis, M. Carena, S.Y. Choi,
  M. Drees, J. Ellis, C.E.M. Wagner
  2-loop RGE improved effective potential, includes CP phases

- NMHDECAY: U. Ellwanger, C. Hugonie and J. Gunion
  NMSSM Higgs spetrum, effective potential, leading 2-loop terms

Links

- ISAJET: `http://www.hep.fsu.edu/~isajet`
- SoftSUSY: `http://allanach.home.cern.ch/allanach/softsusy.html`
- SPheno: `http://ific.uv.es/~porod/SPheno.html`
- SUSPECT: `http://www.lpta.univ-montp2.fr/users/kneur/Suspect`
- Sabine Kraml's comparision page: `http://kraml.home.cern.ch/kraml/comparison`
- FeynHiggs: `http://www.feynhiggs.de/`
- CPsuperH: `http://www.hep.man.ac.uk/u/jslee/CPsuperH.html`
- NMHDECAY: `http://www.th.u-psud.fr/NMHDECAY/nmhdecay.html`