

SPheno

[Supersymmetry Phenomenology]

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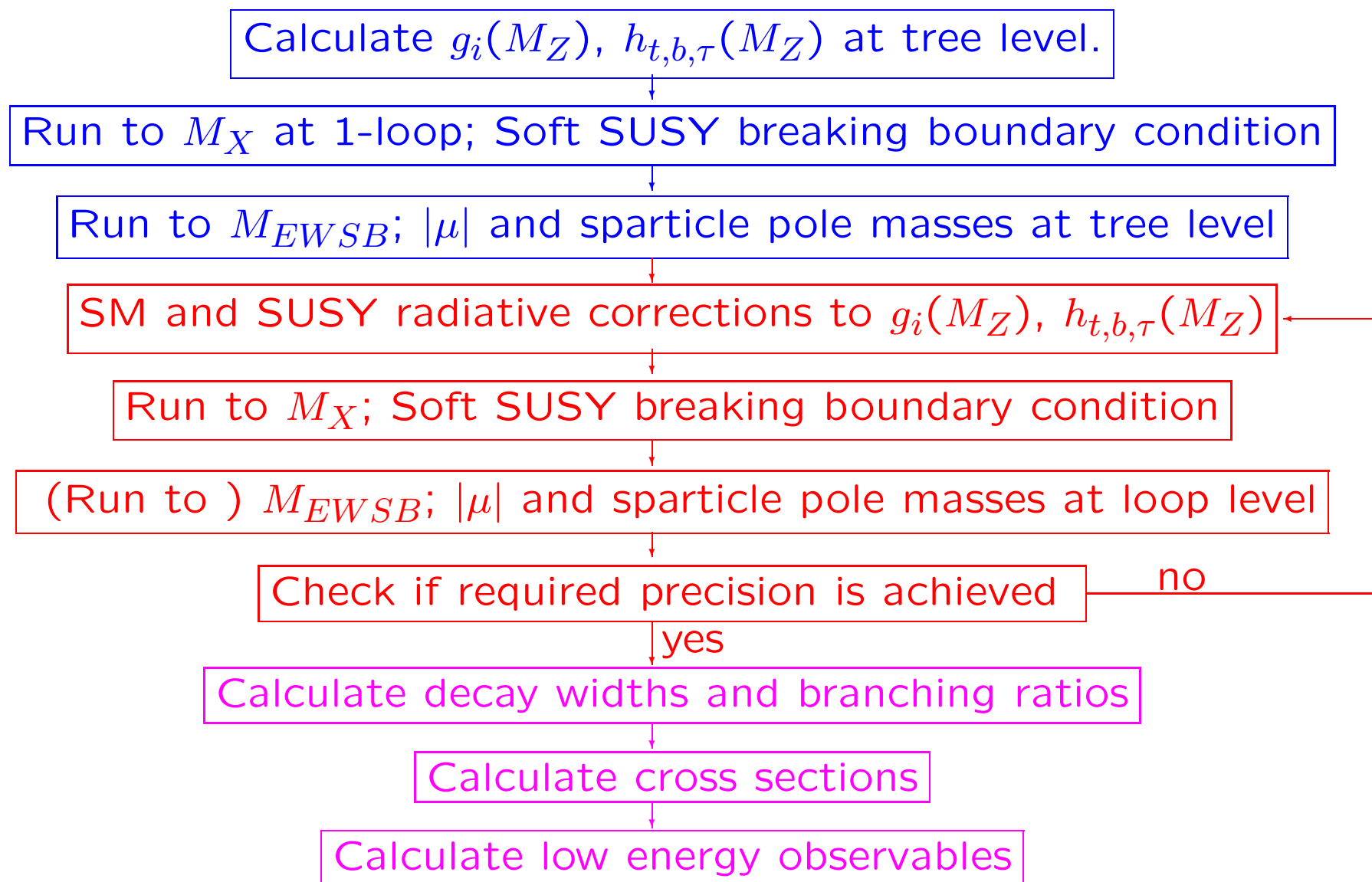
IFIC-CSIC Valencia

- Public version 2.2.3
 - Calculation of Masses
 - Calculation of decays and cross sections
 - Low energy observables
 - Switches
- Comparison to other programs
- Future plans

Comput. Phys. Commun. 153 (2003) [hep-ph/0301101]

SPheno, version 2.2.3

- complete 2-loop SUSY RGEs
- complete 1-loop SUSY masses + 2-loop Higgs masses + μ at 2-loop
- all 2-body decays of SUSY and Higgs particles at tree-level, but running couplings
- all 3-body decay modes of $\tilde{\chi}_k^0$, $\tilde{\chi}_j^\pm$, $\tilde{g}$, $\tilde{t}_1$
- decays into gravitino in case of GMSB models
- production of SUSY particles in e^+e^- annihilation
- $b \rightarrow s\gamma$, Susy contributions to a_μ and ρ



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 $Q \leq 1$ TeV
different options concerning Higgs sector
 - $M_{H_d}^2 + M_{H_u}^2$
 - $\mu + m_{A^0}(\text{pole})$
 - $\mu + m_{A^0}(\text{running})$

SM Input*

- $\alpha, G_F, m_Z \Rightarrow g'^{\overline{DR}}(m_Z), g^{\overline{DR}}(m_Z), m_W, \sin^2 \theta_W, v_i$,
complete 1-loop formulas + leading 2-loop top-quark correction
- $\alpha_s^{\overline{MS}}(m_Z) \Rightarrow \alpha_s^{\overline{DR}}(m_Z)$, shift at 1-loop
- SM fermion masses
 - light quarks
 1. input: $m_{u,d,s}(2 \text{ GeV}), m_c(m_c), m_b(m_b)$
3-loop RGEs[†] including thresholds[†] to get $m_q^{\overline{MS}}(m_Z)$
 2. $O(\alpha_s^2) + O(\alpha)$ shift from $\overline{MS} \rightarrow \overline{DR}$
 3. shift due to SUSY particles,
in case of m_b resummation of $\tan \beta$ enhanced terms

* 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

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

- m_t pole mass $\Rightarrow m_t^{\overline{DR}}(m_Z)$ complete 1-loop SUSY loops + 2-loop α_s gluonic contribution
- $m_{e,\mu,\tau}$ pole masses; shift to $\overline{DR}$ masses at 1-loop, m_τ : resummation of $\tan\beta$ enhanced terms

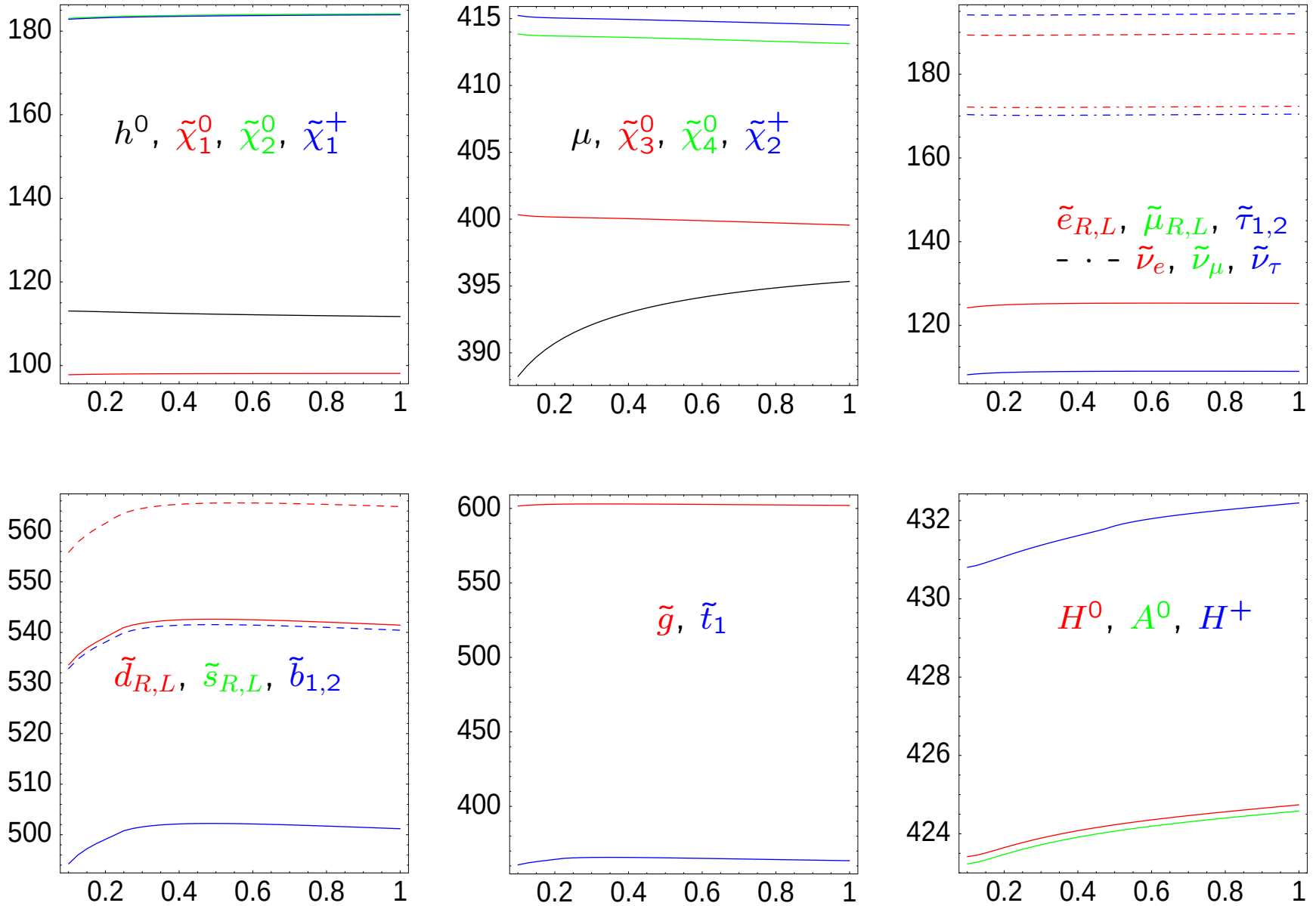
The obtained gauge and Yukawa couplings serve as input for RGEs

SUSY/Higgs Masses*

- All masses are calculated at $Q = \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}}$ [default, can be changed by user]
 - SUSY masses at 1-loop, complete formulas without approximations, include left-right mixing for all sfermions
 - μ + neutral Higgs bosons:
 - complete 1-loop formulas without approximations
 - + 2-loop corrections $\alpha_s(\alpha_t + \alpha_b) + \alpha_t^2 + (\alpha_b + \alpha_\tau)^2$
- $m_{H^\pm}$ at 1-loop

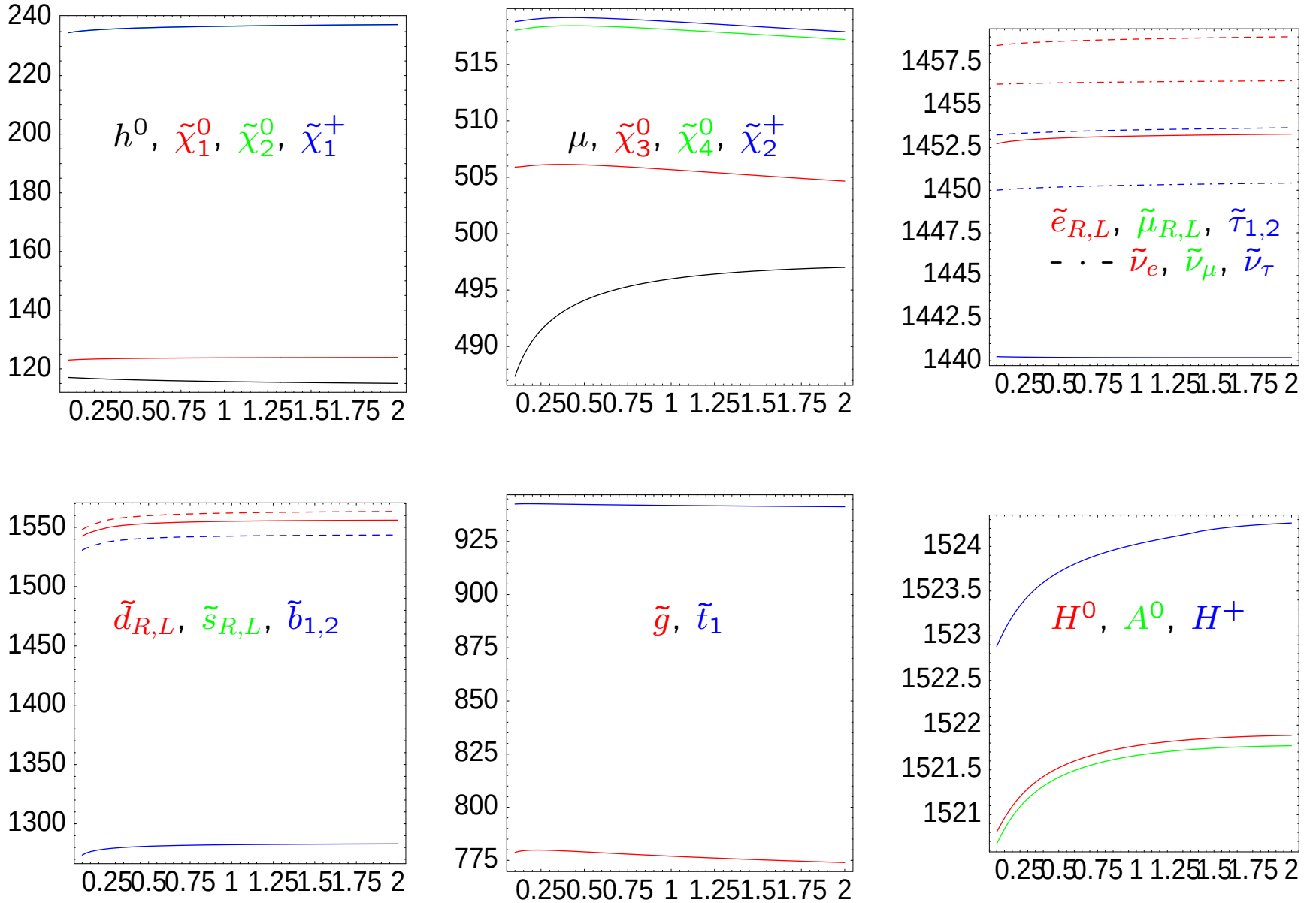
* D. M. Pierce et al., Nucl. Phys. B **491** (1997) 3; P. Slavich et al., Nucl. Phys. B **611** (2001) 403; Nucl. Phys. B **631** (2002) 195; Nucl. Phys. B **643** (2002) 79; Nucl. Phys. B **657** (2003) 333.

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



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

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



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

Decays and Cross sections

- Decays:
 - all SUSY + Higgs 2-body decays [except $H \rightarrow \gamma\gamma$],
 - all 3-body decays of $\tilde{\chi}_k^0$, $\tilde{\chi}_j^\pm$, $\tilde{g}$, $\tilde{t}_1$
 - lowest order but running couplings [default at $Q = m_{decay}$]
- production of SUSY and Higgs particles in e^+e^- annihilation,
 - all $2 \rightarrow 2$ process
 - tree level except $\tilde{q}$ production, running couplings
 - longitudinal polarisation of e^- and e^+ ,
 - ISR via convolution with γ spectrum [E.A. Kuraev and V.S. Fadin Sov. J. Nucl. Phys. **41**, 466 (1985)]

Low Energy Observables

- SUSY contribution to a_μ , complete 1-loop formulas
- SUSY contribution to ρ , complete 1-loop formulas
- $b \rightarrow s\gamma$, SM QCD corrections included + lowest order formulas for SUSY but with running couplings and running masses at M_Z

Switches

Fully supports SLHA interface

in addition: *Block SPhenoInput*

- 1 : setting the error level
- 2 : if value=1 then the spectrum will be calculated according to the SPA conventions (see <http://spa.desy.de/spa>)
- 11 : if value=1 (0) then (no) branching ratios are calculated
- 12 : only branching ratios larger than value are written out
- 21 : if value=1 (0) then (no) cross sections are calculated
- 22 : cms energy for e^+e^- annihilation
has to be given before entries 23-26
- 23 : value gives degree of polarisation for e^- beam
- 24 : value gives degree of polarisation for e^+ beam
- 25 : if set 1 then ISR corrections will be included, default is 0
- 26 : only cross sections larger than value (in fb) are written out

31 : a fixed value for the GUT scale is used if value is larger than 0
 32 : if 0 then $g_3(m_{GUT})$ can differ from $g_1(m_{GUT}) = g_2(m_{GUT})$;
 if 1 $\Rightarrow g_1(m_{GUT}) = g_2(m_{GUT}) = g_3(m_{GUT})$ is enforced
 33 : fixing renormalization scale Q_{EWSB}
 41 : sets value of Z-boson width
 42 : sets value of W-boson width
 51 : sets value of electron mass
 52 : sets value of muon mass
 61 : sets scale of running masses for light quarks (u, d, s)
 62 : sets value of u-quark mass
 63 : sets value of c-quark mass $m_c(m_c)$
 64 : sets value of d-quark mass
 65 : sets value of s-quark mass

Comparison with other programs

Masses:

- SoftSusy, SUSPECT, same structure as SPheno;
main differences due to
 - several approximations for calculation of gauge and Yukawa couplings as well as SUSY masses
 - scale $\sqrt{m_{\tilde{t}_R} m_{\tilde{t}_L}}$
- ISAJET: different strategy: decoupling of SUSY parameters at different scales

Decays: excellent agreement with ISAJET and SDECAY

SPheno, development version, I

Model extensions

- NMSSM
- R-parity breaking, bilinear and trilinear couplings

in both cases: masses, decays and cross sections at electroweak scale, no RGE running

all calculations are checked, user interface under construction

update of manual is missing

SPheno, development version, II

Generation mixing and all complex phases are included in:

- complete 2-loop SUSY RGEs (including ν_R), several tests passed
- complete 1-loop SUSY masses, several tests passed
- all 2-body decays of SUSY and Higgs particles at tree-level, several tests passed
- all 3-body decay modes of $\tilde{\chi}_k^0$, $\tilde{\chi}_j^\pm$, $\tilde{g}$, $\tilde{t}_1$, several tests passed
- production of SUSY particles in e^+e^- annihilation, several tests passed

- Higgs masses
 - real parameters: complete 1-loop formulas + 2-loop part implemented assuming that there is no generation mixing.
 - complex parameters interface to FeynHiggs and CPSuperH; still machine and compiler dependent
- Low energy observables, several tests passed
 1. electric and magnetic moments of leptons: $a_i, d_i, [i = e, \mu, \tau]$
 2. rare lepton decays: $\mu \rightarrow e\gamma, \tau \rightarrow e\gamma, \tau \rightarrow \mu\gamma$
 3. $b \rightarrow q\gamma, A_{CP}(b \rightarrow q\gamma) [q = d, s]$
 4. $B_q^0 \rightarrow \mu^+\mu^- [q = d, s]$
 5. $\Delta M_{B_q^0} (q = d, s)$
 6. $b \rightarrow q\nu\nu, b \rightarrow ql^+l^-, [q = s, d], s \rightarrow d\nu\nu, s \rightarrow dl^+l^-$

Calculational part finished, however user Interface and documentation still missing

Summary + Outlook

- Masses: precision tool for precision physics
- Decays and cross sections: good estimates
- extensions to
 - NMSSM
 - R-parity violation
 - MSSM including the effects of CP-violation and generation mixing

user interface + documentation on the way

- inclusion of 2-loop masses for $\tilde{q}$ (S. Martin) and $\tilde{g}$ (Y. Yamada)
- 3-loop MSSM RGEs (Jack & Jones), RGEs for NMSSM and R-parity violation