NNLO SQCD corrections to the Neutralino pole masses in the MSSM

R. Schöfbeck (HEPHY, Vienna)

in collaboration with the Vienna SUSY group:
H. Eberl, W. Majerotto, K. Kovařík, Ch. Weber

ILC-ECFA, Valencia, 2006

Introduction

- Analysis of combined experimental results done by the LHC/LC Study Group calls for NNLO pole mass calculation to match experimental standards

  [G. Weiglein *et al.*, 2004]

Introduction

- Analysis of combined experimental results done by the LHC/LC Study Group calls for NNLO pole mass calculation to match experimental standards

  [G. Weiglein *et al.*, 2004]

ACCURACY FROM EXPERIMENT AT LHC + ILC

Particle	Mass	"LHC"	"ILC"	"LHC+ILC"
$\tilde{\chi}_1^0$	97.7	4.8	0.05	0.05
$\tilde{\chi}_2^0$	183.9	4.7	1.2	0.08
$\tilde{\chi}_1^\pm$	183.7		0.55	0.55
$\tilde{q}_R$	547.2	7 − 12	−	5 − 11
$\tilde{q}_L$	564.7	8.7	−	4.9
$\tilde{g}$	607.1	8.0	−	6.5

[SPA, J. A. Aguilar-Saavedra *et al.*, 2005], all numbers in GeV

Pole masses in mixing fermion systems

Neutralino mass matrix at tree level

$$Y = \begin{pmatrix} M_1 & 0 & -M_Z\cos\beta\sin\theta_W & M_Z\sin\beta\sin\theta_W \\ 0 & M_2 & M_Z\cos\beta\cos\theta_W & -M_Z\sin\beta\cos\theta_W \\ -M_Z\cos\beta\sin\theta_W & M_Z\cos\beta\cos\theta_W & 0 & -\mu \\ M_Z\sin\beta\sin\theta_W & -M_Z\sin\beta\cos\theta_W & -\mu & 0 \end{pmatrix}$$

$$M_D = N^* Y N^\dagger = \mathrm{diag}(m_{\tilde{\chi}^0_1}, m_{\tilde{\chi}^0_2}, m_{\tilde{\chi}^0_3}, m_{\tilde{\chi}^0_4})$$

Pole masses in mixing fermion systems

Neutralino mass matrix at tree level

$$Y = \begin{pmatrix} M_1 & 0 & -M_Z \cos\beta \sin\theta_W & M_Z \sin\beta \sin\theta_W \\ 0 & M_2 & M_Z \cos\beta \cos\theta_W & -M_Z \sin\beta \cos\theta_W \\ -M_Z \cos\beta \sin\theta_W & M_Z \cos\beta \cos\theta_W & 0 & -\mu \\ M_Z \sin\beta \sin\theta_W & -M_Z \sin\beta \cos\theta_W & -\mu & 0 \end{pmatrix}$$

$$M_D = N^* Y N^\dagger = \mathrm{diag}(m_{\tilde\chi^0_1}, m_{\tilde\chi^0_2}, m_{\tilde\chi^0_3}, m_{\tilde\chi^0_4})$$

renormalized 2-point function $\Gamma^{(2)\tilde\chi^0\tilde\chi^0}$

$$G^{(2)-1}_{\tilde\chi^0\tilde\chi^0} = -i\Gamma^{(2)\tilde\chi^0\tilde\chi^0} = -i \begin{pmatrix} -M_D + \hat\Sigma^{LL}_m(s) & \sigma \cdot k(1 + \hat\Sigma^R_k(s)) \\ \bar\sigma \cdot k(1 + \hat\Sigma^L_k(s)) & -M_D^\dagger + \hat\Sigma^{RR}_m(s) \end{pmatrix}$$

$$s = k^2$$

Pole masses in mixing fermion systems

Pole mass condition

$$0 = \det \left(s - \left(M_D - \hat{\Sigma}_m^{LL}(s) \right) \cdot \left(1 + \hat{\Sigma}_k^L(s) \right)^{-1} \cdot \left(M_D^\dagger - \hat{\Sigma}_m^{RR}(s) \right) \cdot \left(1 + \hat{\Sigma}_k^R(s) \right)^{-1} \right)$$

Pole masses in mixing fermion systems

Pole mass condition

$$0 = \det\left(s - \left(M_D - \hat{\Sigma}_m^{LL}(s)\right)\cdot\left(1+\hat{\Sigma}_k^{L}(s)\right)^{-1}\cdot\left(M_D^{\dagger} - \hat{\Sigma}_m^{RR}(s)\right)\cdot\left(1+\hat{\Sigma}_k^{R}(s)\right)^{-1}\right)$$

Iterative solution to order $\alpha\alpha_S$

$$\begin{aligned} s_{i,pole} &= m^2_{\tilde{\chi}^0_i} - \delta m^{2(1)}_{\tilde{\chi}^0_i} - \delta m^{2(2)}_{\tilde{\chi}^0_i} \\ \delta m^{2(1)}_{\tilde{\chi}^0_i} &= \hat{\Sigma}_m^{(1)LL}(m^2_{\tilde{\chi}^0_i}) + \hat{\Sigma}_m^{(1)RR}(m^2_{\tilde{\chi}^0_i}) + \hat{\Sigma}_k^{(1)L}(m^2_{\tilde{\chi}^0_i}) + \hat{\Sigma}_k^{(1)R}(m^2_{\tilde{\chi}^0_i}) \\ \delta m^{2(2)}_{\tilde{\chi}^0_i} &= \hat{\Sigma}_m^{(2)LL}(m^2_{\tilde{\chi}^0_i}) + \hat{\Sigma}_m^{(2)RR}(m^2_{\tilde{\chi}^0_i}) + \hat{\Sigma}_k^{(2)L}(m^2_{\tilde{\chi}^0_i}) + \hat{\Sigma}_k^{(2)R}(m^2_{\tilde{\chi}^0_i}) \end{aligned}$$

Technicalities of perturbative expansion

REGULARIZATION SCHEME: $\overline{DR}\,'$

Technicalities of perturbative expansion

Regularization scheme: $\overline{DR}\,'$

- dimensional reduction in $d = 4 - \epsilon$

Technicalities of perturbative expansion

Regularization scheme: $\overline{DR}\,'$

- dimensional reduction in $d = 4 - \epsilon$
- absorbing the ϵ-scalar mass parameter in the sfermion masses [S.P. Martin, 2001]

Technicalities of perturbative expansion

Regularization scheme: $\overline{DR}\,'$

- dimensional reduction in $d = 4 - \epsilon$
- absorbing the ϵ-scalar mass parameter in the sfermion masses [S.P. Martin, 2001]

Simplification: degenerate squarks for each family separately

Technicalities of perturbative expansion

Regularization scheme: $\overline{DR}\,'$

- dimensional reduction in $d = 4 - \epsilon$
- absorbing the ϵ-scalar mass parameter in the sfermion masses [S.P. Martin, 2001]

Simplification: degenerate squarks for each family separately

- trilinear breaking terms: $A_g^u = \mu \cot\beta$, $A_g^d = \mu \tan\beta$

Technicalities of perturbative expansion

Regularization scheme: $\overline{DR}\,'$

- dimensional reduction in $d = 4 - \epsilon$
- absorbing the ϵ-scalar mass parameter in the sfermion masses [S.P. Martin, 2001]

Simplification: degenerate squarks for each family separately

- trilinear breaking terms: $A_g^u = \mu \cot\beta$, $A_g^d = \mu \tan\beta$
- soft SUSY breaking masses $M^2_{\tilde{q},\tilde{u},\tilde{d}}$ are chosen such that
  the up-type sfermion mass matrix has degenerate eigenvalues $m^2_{\tilde{u},g}$.
  The down-type sfermion $m^2_{\tilde{d},g}$ masses then follow degenerate.

Technicalities of perturbative expansion

Regularization scheme: $\overline{DR}\,'$

- dimensional reduction in $d = 4 - \epsilon$
- absorbing the ϵ-scalar mass parameter in the sfermion masses [S.P. Martin, 2001]

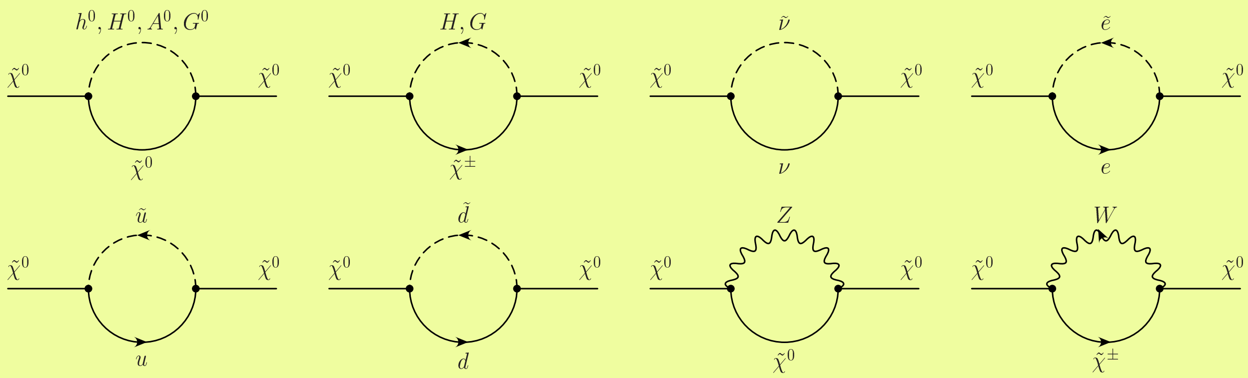
Simplification: degenerate squarks for each family separately

- trilinear breaking terms: $A_g^u = \mu \cot\beta$, $A_g^d = \mu \tan\beta$
- soft SUSY breaking masses $M^2_{\tilde{q},\tilde{u},\tilde{d}}$ are chosen such that
  the up-type sfermion mass matrix has degenerate eigenvalues $m^2_{\tilde{u},g}$.
  The down-type sfermion $m^2_{\tilde{d},g}$ masses then follow degenerate.

gauge: $R_{\xi=1}$

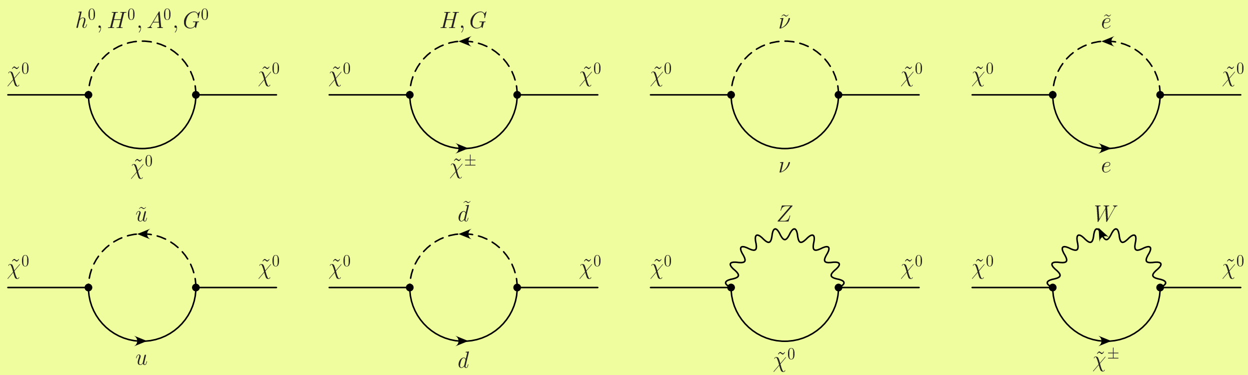
The Diagrams

One loop diagrams



The Diagrams

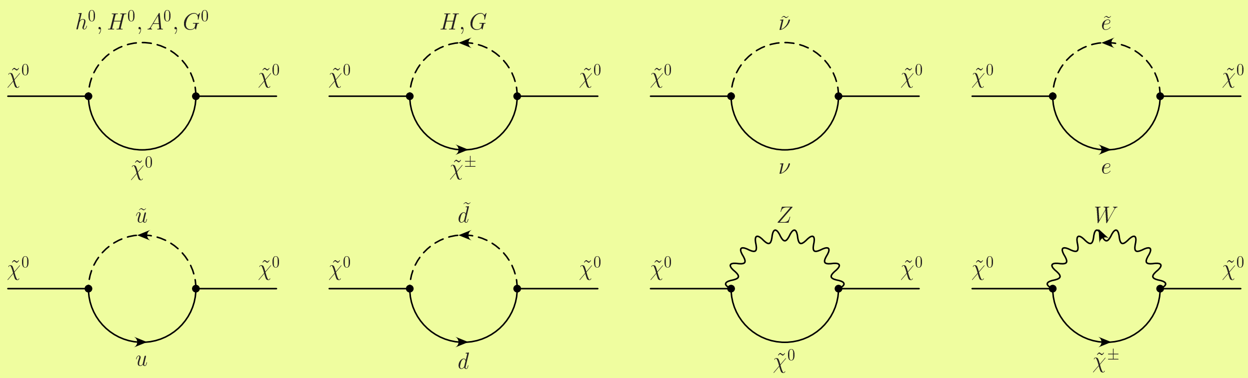
One loop diagrams



- use two-loop methods for evaluation of one-loop self-energies

The Diagrams

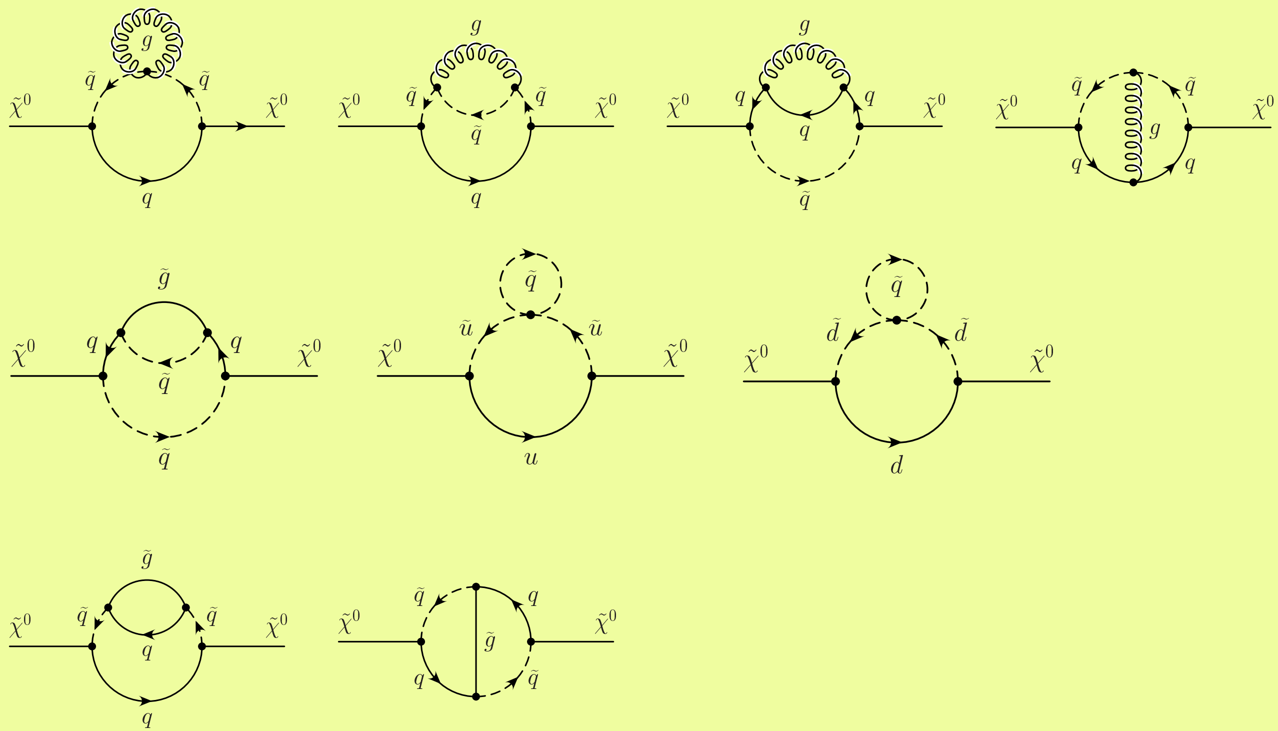
One loop diagrams



- use two-loop methods for evaluation of one-loop self-energies
- compare analytic result to previous one-loop calculations [W. Öller '03, T. Fritzsche '04]

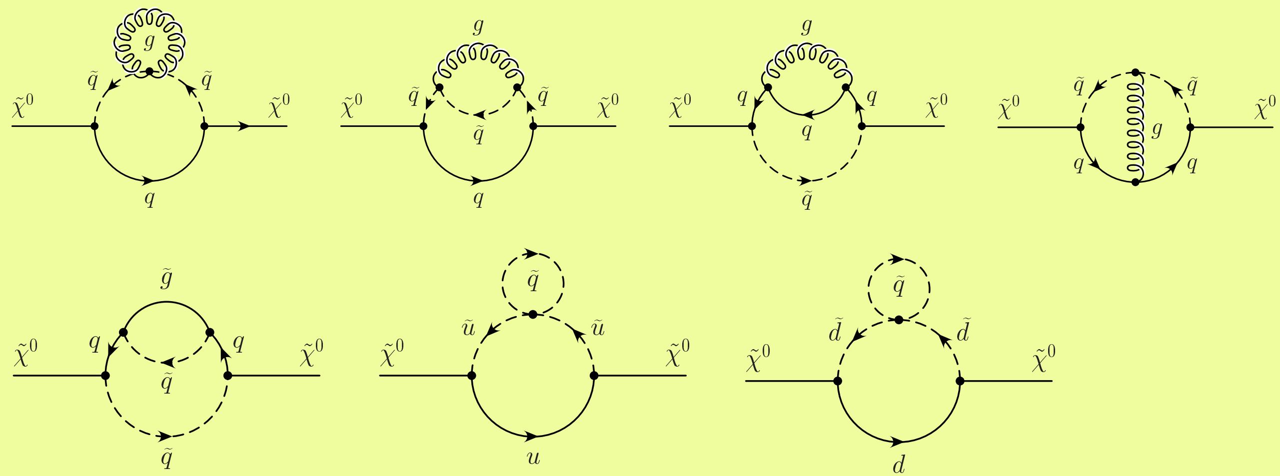
The Diagrams

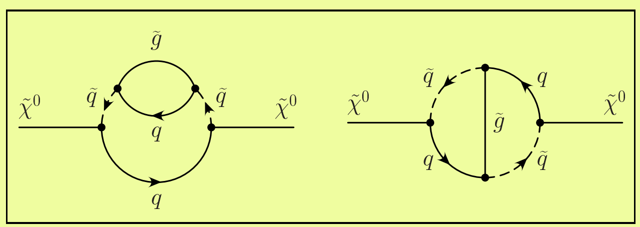
Two loop diagrams



The Diagrams

Two loop diagrams





degenerate squarks simplify
tensor reduction

The Calculation

Tensor reduction

The Calculation

Tensor reduction

- aim: reduce complicated two-loop integral to a small set of basis integrals

The Calculation

Tensor reduction

- aim: reduce complicated two-loop integral to a small set of basis integrals
- O.V. Tarasov gave a complete set of recurrence relations
  involving the space time dimension as a recursion variable [O.V. Tarasov, '97]

The Calculation

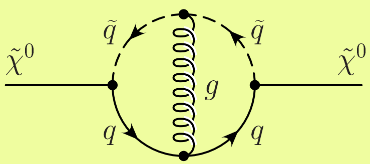
Tensor reduction

- aim: reduce complicated two-loop integral to a small set of basis integrals
- O.V. Tarasov gave a complete set of recurrence relations
  involving the space time dimension as a recursion variable [O.V. Tarasov, '97]
- succesful implementation into the Mathematica package Tarcer
  away from kinematic thresholds [R. Mertig, R. Scharf, '98]

The Calculation

<u>Tensor reduction</u>

- aim: reduce complicated two-loop integral to a small set of basis integrals
- O.V. Tarasov gave a complete set of recurrence relations involving the space time dimension as a recursion variable [O.V. Tarasov, '97]
- succesful implementation into the Mathematica package Tarcer away from kinematic thresholds [R. Mertig, R. Scharf, '98]



$$\xrightarrow{\bar{M}\bar{M}} \frac{m_q^2\, p\cdot(q_1+q_2)}{s(q_1^2-m_{\tilde{q}}^2)(q_2^2-m_{\tilde{q}}^2)((p+q_1)^2-m_q^2)((p+q_2)^2-m_q^2)(q_2-q_1)^2}$$

$$= \frac{m_q^2\left((m_q^2-m_{\tilde{q}}^2-s)M(m_q,m_q,m_{\tilde{q}},m_{\tilde{q}},0)-U(m_q,m_{\tilde{q}},0,m_{\tilde{q}})+U(m_{\tilde{q}},m_q,0,m_{\tilde{q}})\right)}{s}$$

The Calculation

Evaluating basis integrals

The Calculation

Evaluating basis integrals

- aim: evaluate scalar basis integrals for a set of arbitrary masses and external momentum

The Calculation

Evaluating basis integrals

- aim: evaluate scalar basis integrals for a set of arbitrary masses and external momentum
- any two-point two-loop integral with definite mass dimensions n satisfies a scaling equation of the form

$$\left(s\frac{\mathrm{d}}{\mathrm{d}s}+\alpha_i\frac{\mathrm{d}}{\mathrm{d}\alpha_i}+Q^2\frac{\mathrm{d}}{\mathrm{d}Q^2}-\frac{n}{2}\right)I(s,\alpha_i,Q)=0$$

The Calculation

Evaluating basis integrals

- aim: evaluate scalar basis integrals for a set of arbitrary masses and external momentum
- any two-point two-loop integral with definite mass dimensions n satisfies a scaling equation of the form

$$\left(s\frac{\mathrm{d}}{\mathrm{d}s} + \alpha_i\frac{\mathrm{d}}{\mathrm{d}\alpha_i} + Q^2\frac{\mathrm{d}}{\mathrm{d}Q^2} - \frac{n}{2}\right) I(s,\alpha_i,Q) = 0$$

- get complete set of basis integrals at a given s by Runge-Kutta integration in the complex plane starting from $s = 0$ [S.P. Martin, '03]

The Calculation

Evaluating basis integrals

- aim: evaluate scalar basis integrals for a set of arbitrary masses and external momentum
- any two-point two-loop integral with definite mass dimensions n satisfies a scaling equation of the form

$$\left(s\frac{\mathrm{d}}{\mathrm{d}s} + \alpha_i\frac{\mathrm{d}}{\mathrm{d}\alpha_i} + Q^2\frac{\mathrm{d}}{\mathrm{d}Q^2} - \frac{n}{2}\right) I(s, \alpha_i, Q) = 0$$

- get complete set of basis integrals at a given s by Runge-Kutta integration in the complex plane starting from $s = 0$ [S.P. Martin, '03]
- realized in TSIL [S.P. Martin and D.G. Robertson, '05]

The Calculation

Evaluation and Simplification of Amplitudes

The Calculation

Evaluation and Simplification of Amplitudes

- FeynArts 3.2 for generation of the amplitudes (36 diagrams)

  [J.Küblbeck, T. Hahn, et. al, '90]

The Calculation

Evaluation and Simplification of Amplitudes

- FeynArts 3.2 for generation of the amplitudes (36 diagrams)

  [J.Küblbeck, T. Hahn, et. al, '90]
- conversion to FeynCalc 4.0.2 and evaluation of color and Dirac traces

The Calculation

Evaluation and Simplification of Amplitudes

- FeynArts 3.2 for generation of the amplitudes (36 diagrams)
  [J.Küblbeck, T. Hahn, et. al, '90]
- conversion to FeynCalc 4.0.2 and evaluation of color and Dirac traces
- tensor reduction using Tarcer

The Calculation

Evaluation and Simplification of Amplitudes

- FeynArts 3.2 for generation of the amplitudes (36 diagrams)

  [J.Küblbeck, T. Hahn, et. al, '90]
- conversion to FeynCalc 4.0.2 and evaluation of color and Dirac traces
- tensor reduction using Tarcer
- Taylor expansion of Tarcer basis integrals in $d-4$ to TSIL basis integrals

The Calculation

Evaluation and Simplification of Amplitudes

- FeynArts 3.2 for generation of the amplitudes (36 diagrams)
  [J.Küblbeck, T. Hahn, et. al, '90]
- conversion to FeynCalc 4.0.2 and evaluation of color and Dirac traces
- tensor reduction using Tarcer
- Taylor expansion of Tarcer basis integrals in $d-4$ to TSIL basis integrals

Numerical Evaluation

The Calculation

Evaluation and Simplification of Amplitudes

- FeynArts 3.2 for generation of the amplitudes (36 diagrams)
  [J.Küblbeck, T. Hahn, et. al, '90]
- conversion to FeynCalc 4.0.2 and evaluation of color and Dirac traces
- tensor reduction using Tarcer
- Taylor expansion of Tarcer basis integrals in $d-4$ to TSIL basis integrals

Numerical Evaluation

- Creating Fortran code calling TSIL basis integrals and
  using some FormCalc subroutines for calculating the SUSY spectra

The Calculation

Evaluation and Simplification of Amplitudes

- FeynArts 3.2 for generation of the amplitudes (36 diagrams)
  [J.Küblbeck, T. Hahn, et. al, '90]
- conversion to FeynCalc 4.0.2 and evaluation of color and Dirac traces
- tensor reduction using Tarcer
- Taylor expansion of Tarcer basis integrals in $d-4$ to TSIL basis integrals

Numerical Evaluation

- Creating Fortran code calling TSIL basis integrals and using some FormCalc subroutines for calculating the SUSY spectra
- hit Return

The Calculation

Some more technical issues

- tensor reduction formulas can become extremly complicated, up to $\sim 1\mathrm{MB}$ per diagram $\longrightarrow$ code made reusable

The Calculation

Some more technical issues

- tensor reduction formulas can become extremly complicated, up to $\sim 1\mathrm{MB}$ per diagram $\longrightarrow$ code made reusable
- save all intermediate results

The Calculation

Some more technical issues

- tensor reduction formulas can become extremly complicated,
  up to $\sim 1\mathrm{MB}$ per diagram $\rightarrow$ code made reusable
- save all intermediate results
- when large mass hierarchies are involved TSIL can become instable

The Calculation

Some more technical issues

- tensor reduction formulas can become extremly complicated, up to $\sim 1\mathrm{MB}$ per diagram $\longrightarrow$ code made reusable
- save all intermediate results
- when large mass hierarchies are involved TSIL can become instable
  - mostly, putting $m_q^{g=1,2} = 0$ cures the instabilities without any noticable change in the regions where the integral is well-behaved

The Calculation

Some more technical issues

- tensor reduction formulas can become extremly complicated,
  up to $\sim 1\mathrm{MB}$ per diagram $\rightarrow$ code made reusable
- save all intermediate results
- when large mass hierarchies are involved TSIL can become instable
  - mostly, putting $m_q^{g=1,2} = 0$ cures the instabilities without any noticable change in the regions where the integral is well-behaved
  - sometimes it is necessary to invoke the non-basis (V-topology) integral provided by TSIL to make things stable

The Calculation

Some more technical issues

- tensor reduction formulas can become extremly complicated, up to $\sim 1\mathrm{MB}$ per diagram $\longrightarrow$ code made reusable
- save all intermediate results
- when large mass hierarchies are involved TSIL can become instable
  - mostly, putting $m_q^{g=1,2} = 0$ cures the instabilities without any noticable change in the regions where the integral is well-behaved
  - sometimes it is necessary to invoke the non-basis (V-topology) integral provided by TSIL to make things stable
- when the masses are highly degenerate TARCER can fail to converge

The Calculation

<u>Some more technical issues</u>

- tensor reduction formulas can become extremly complicated,
  up to $\sim 1\mathrm{MB}$ per diagram $\longrightarrow$ code made reusable
- save all intermediate results
- when large mass hierarchies are involved TSIL can become instable
  - mostly, putting $m_q^{g=1,2} = 0$ cures the instabilities without any noticable change in the regions where the integral is well-behaved
  - sometimes it is necessary to invoke the non-basis (V-topology) integral provided by TSIL to make things stable
- when the masses are highly degenerate TARCER can fail to converge
  - this is because multiple zeros in kinematical prefactors in the recursion can block the usual path of recursion

The Calculation

Some more technical issues

- tensor reduction formulas can become extremly complicated, up to $\sim 1\mathrm{MB}$ per diagram $\longrightarrow$ code made reusable
- save all intermediate results
- when large mass hierarchies are involved TSIL can become instable
  - mostly, putting $m_q^{g=1,2} = 0$ cures the instabilities without any noticable change in the regions where the integral is well-behaved
  - sometimes it is necessary to invoke the non-basis (V-topology) integral provided by TSIL to make things stable
- when the masses are highly degenerate TARCER can fail to converge
  - this is because multiple zeros in kinematical prefactors in the recursion can block the usual path of recursion
  - a small in-house routine provides the necessary results at these special configurations

Checking the Result

Analytic Checks

Checking the Result

Analytic Checks

- gauge parameter independence in general R_ξ gauges

Checking the Result

Analytic Checks

- gauge parameter independence in general R_ξ gauges
- explicit cancellation of m_ϵ contributions in $\overline{DR}\,'$

Checking the Result

Analytic Checks

- gauge parameter independence in general R_ξ gauges
- explicit cancellation of m_ϵ contributions in $\overline{DR}\,'$
- IR finiteness by extraction of the IR divergent parts in each diagram

Checking the Result

Analytic Checks

- gauge parameter independence in general R_ξ gauges
- explicit cancellation of m_ϵ contributions in $\overline{DR}\,'$
- IR finiteness by extraction of the IR divergent parts in each diagram
- highly non-trivial: RGE check (UV finiteness) on $\mathrm{tr}(Y^\dagger Y) = \mathrm{tr}(M_D^\dagger M_D)$

Checking the Result

Analytic Checks

- gauge parameter independence in general R_ξ gauges
- explicit cancellation of m_ϵ contributions in $\overline{DR}\,'$
- IR finiteness by extraction of the IR divergent parts in each diagram
- highly non-trivial: RGE check (UV finiteness) on $\mathrm{tr}(Y^\dagger Y) = \mathrm{tr}(M_D^\dagger M_D)$

Checks on the Numerics

- RGE check of mass shifts $\delta m_{\tilde{\chi}_i^0}$ against SPHENO [W. Porod, '03]

Checking the Result

Analytic Checks

- gauge parameter independence in general R_ξ gauges
- explicit cancellation of m_ϵ contributions in $\overline{DR}\,'$
- IR finiteness by extraction of the IR divergent parts in each diagram
- highly non-trivial: RGE check (UV finiteness) on $\mathrm{tr}(Y^\dagger Y) = \mathrm{tr}(M_D^\dagger M_D)$

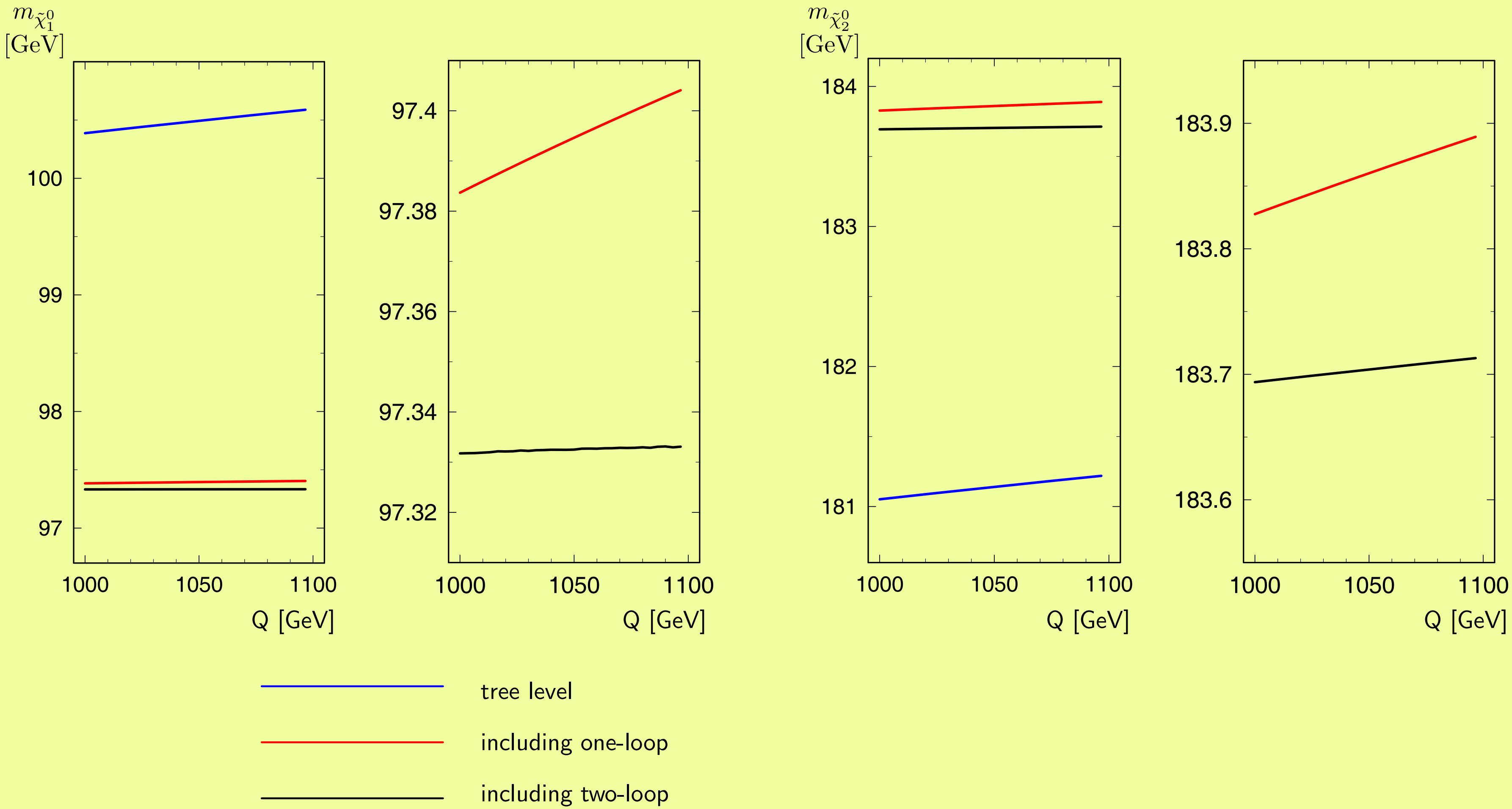
Checks on the Numerics

- RGE check of mass shifts $\delta m_{\tilde{\chi}_i^0}$ against SPHENO [W. Porod, '03]

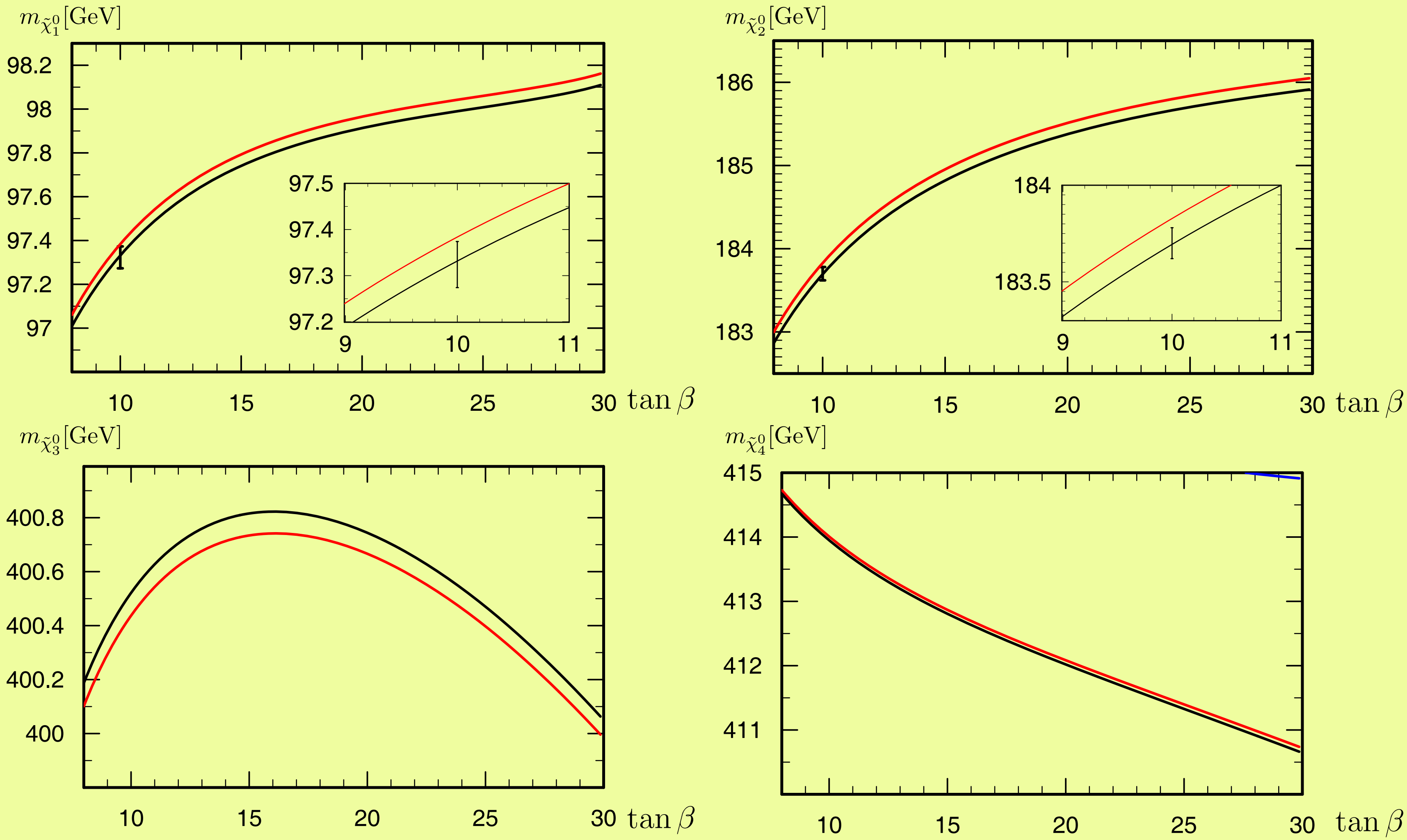
Check on the whole strategy

- SQCD corrections to the gluino pole mass agree with known result [S.P. Martin, '05]

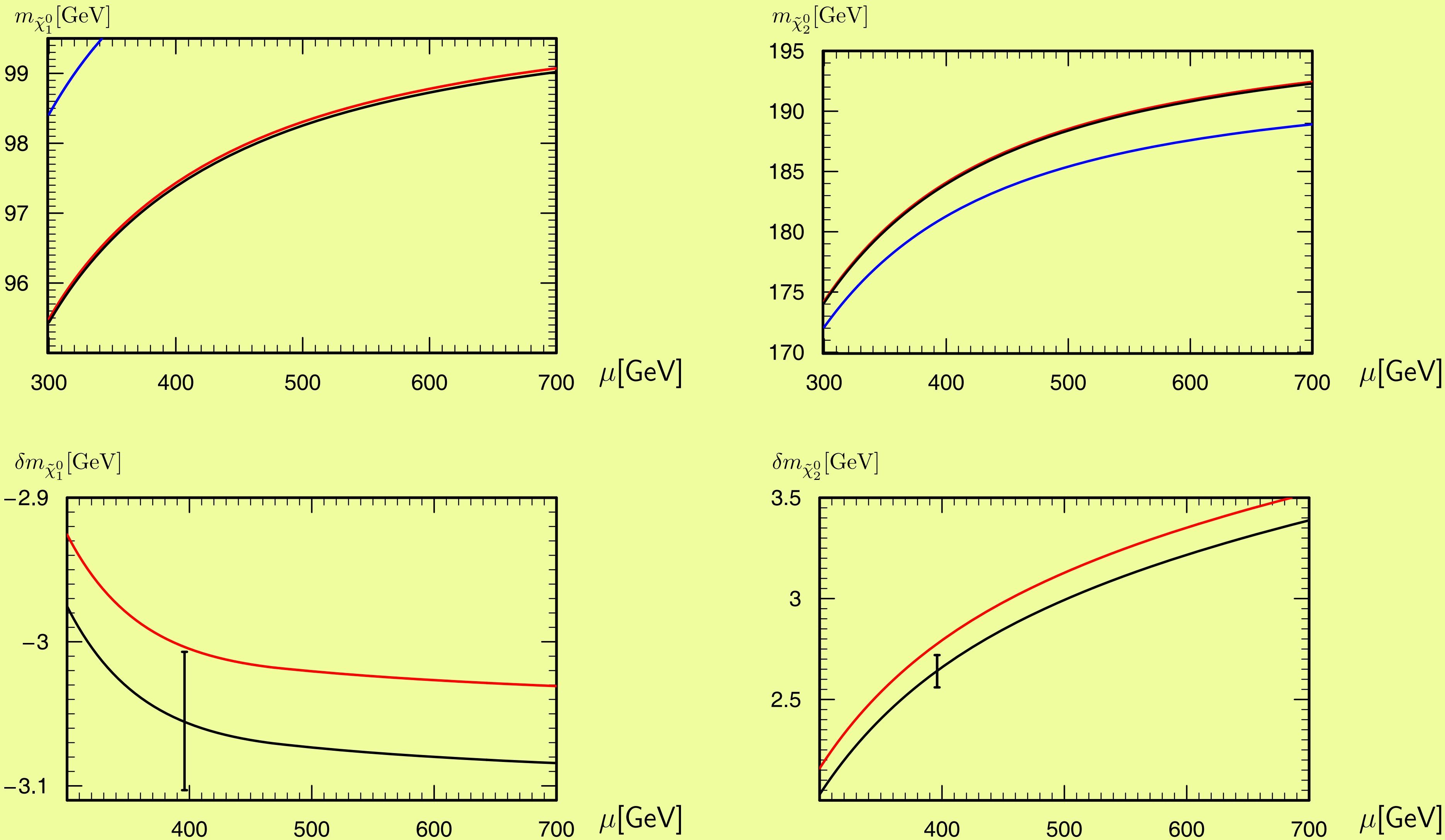
Renormalization scale dependence



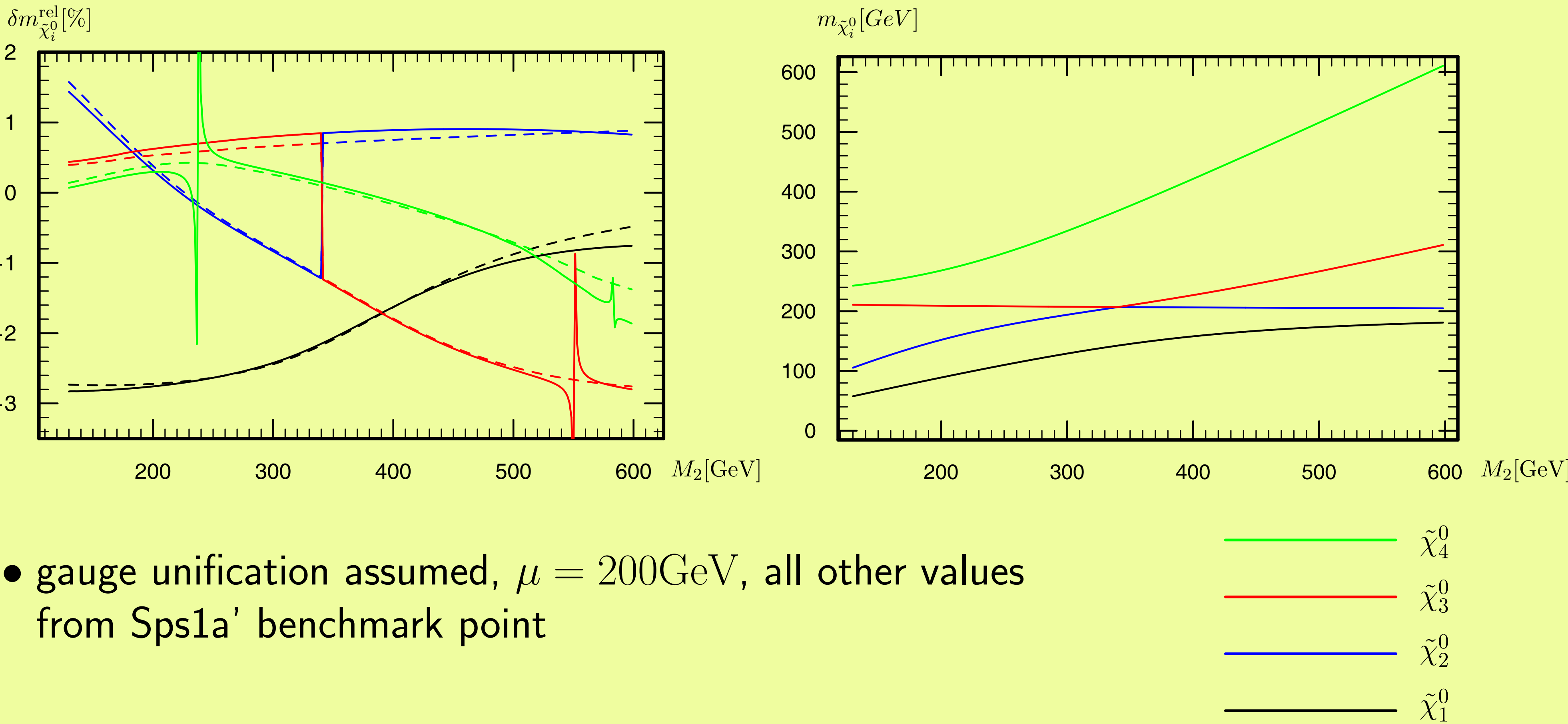
Example: dependence on $\tan\beta$



Example: dependence on μ



Example: dependence on gaugino mass parameters



- gauge unification assumed, $\mu = 200\mathrm{GeV}$, all other values from Sps1a' benchmark point

The next few steps

CONCERNING THIS CALCULATION

- include squark mixing

The next few steps

CONCERNING THIS CALCULATION

- include squark mixing
- include αy_t contributions

The next few steps

<u>CONCERNING THIS CALCULATION</u>

- include squark mixing
- include αy_t contributions
- full two-loop calculation is 2044 diagrams compared to 36 diagrams for NNLO SQCD
  - way faster analytic tools needed (at least very useful)
  - more efficient code needed (roughly 1sec/pp for this calculation now)

The next few steps

CONCERNING THIS CALCULATION

- include squark mixing
- include αy_t contributions
- full two-loop calculation is 2044 diagrams compared to 36 diagrams for NNLO SQCD
  - way faster analytic tools needed (at least very useful)
  - more efficient code needed (roughly 1sec/pp for this calculation now)

COMING UP NEXT

- NNLO SQCD corrections for charginos

The next few steps

CONCERNING THIS CALCULATION

- include squark mixing
- include αy_t contributions
- full two-loop calculation is 2044 diagrams compared to 36 diagrams for NNLO SQCD
  - way faster analytic tools needed (at least very useful)
  - more efficient code needed (roughly 1sec/pp for this calculation now)

COMING UP NEXT

- NNLO SQCD corrections for charginos
- two-loop gluino pole mass including massive vector bosons

The next few steps

CONCERNING THIS CALCULATION

- include squark mixing
- include αy_t contributions
- full two-loop calculation is 2044 diagrams compared to 36 diagrams for NNLO SQCD
  - way faster analytic tools needed (at least very useful)
  - more efficient code needed (roughly 1sec/pp for this calculation now)

COMING UP NEXT

- NNLO SQCD corrections for charginos
- two-loop gluino pole mass including massive vector bosons
- ...

Conclusion

MOTIVATION:

Conclusion

MOTIVATION:

- high precision experiments demand pole mass calculations in the Neutralino sector to two-loop order [LHC/LC Study Group]

Conclusion

MOTIVATION:

- high precision experiments demand pole mass calculations in the Neutralino sector to two-loop order [LHC/LC Study Group]
- combining existing software packages and some computational effort it was possible to calculate the leading NNLO corrections (SQCD)

Conclusion

MOTIVATION:

- high precision experiments demand pole mass calculations in the Neutralino sector to two-loop order [LHC/LC Study Group]
- combining existing software packages and some computational effort it was possible to calculate the leading NNLO corrections (SQCD)
- auto-generated code:
  FEYNARTS→FEYNCALC→TARCER
  FORTRAN, TSIL, LOOPTOOLS

Conclusion

MOTIVATION:

- high precision experiments demand pole mass calculations in the Neutralino sector to two-loop order [LHC/LC Study Group]
- combining existing software packages and some computational effort it was possible to calculate the leading NNLO corrections (SQCD)
- auto-generated code:
  FEYNARTS→FEYNCALC→TARCER
  FORTRAN, TSIL, LOOPTOOLS

RESULTS:

Conclusion

MOTIVATION:

- high precision experiments demand pole mass calculations in the Neutralino sector to two-loop order [LHC/LC Study Group]
- combining existing software packages and some computational effort it was possible to calculate the leading NNLO corrections (SQCD)
- auto-generated code:
  FEYNARTS→FEYNCALC→TARCER
  FORTRAN, TSIL, LOOPTOOLS

RESULTS:

- the remaining renormalization scale dependence is greatly improved

Conclusion

MOTIVATION:

- high precision experiments demand pole mass calculations in the Neutralino sector to two-loop order [LHC/LC Study Group]
- combining existing software packages and some computational effort it was possible to calculate the leading NNLO corrections (SQCD)
- auto-generated code:
  FEYNARTS→FEYNCALC→TARCER
  FORTRAN, TSIL, LOOPTOOLS

RESULTS:

- the remaining renormalization scale dependence is greatly improved
- at the SPS1a' benchmark point the NNLO must be included

Conclusion

MOTIVATION:

- high precision experiments demand pole mass calculations in the Neutralino sector to two-loop order [LHC/LC Study Group]
- combining existing software packages and some computational effort it was possible to calculate the leading NNLO corrections (SQCD)
- auto-generated code:
  FEYNARTS→FEYNCALC→TARCER
  FORTRAN, TSIL, LOOPTOOLS

RESULTS:

- the remaining renormalization scale dependence is greatly improved
- at the SPS1a' benchmark point the NNLO must be included
- many checks have been successful though it is clear that further (Yukawa) corrections are needed

Thank you for your attention