PARTICLE PHYSICS THEORY GROUP

M. Ciccolini, A. Denner, K.-P. O. Diener, J. Guasch Inglada[1], P. Häfliger[2], K. Junker[3], A. Kaiser[2], Ch. Meier[2], M. Mühlleitner, H. Pichl[4], R. Rosenfelder, M. Spira, R. Unterdorfer, J. Urban[5], M. Walser[2], L. Wieders[2]

[1] *now: Fac. de Fisica, U. Barcelona, Spain,* [2] *PhD student,* [3] *retired,* [4] *now: Helvetia Patria, St. Gallen, Switzerland,*
[5] *now: European Centre for Medium Range Weather Forecasts, Reading, UK*

Particle Physics seeks to identify the elementary constituents of nature and to discover the fundamental forces acting between these constituents. Ordinary matter and non-gravitational interactions are described by the *Standard Model* which comprises two kinds of matter particles (quarks and leptons), three fundamental forces (the strong, electromagnetic and weak interactions) and the Higgs sector as the origin of mass via spontaneous symmetry breaking. The Standard Model constitutes a quantum field theory valid down to microscopic distances of the order of 10^{-18} m. The only Standard Model particle that escaped detection so far is the *Higgs boson*. The search for it is one of the most important endeavours at present and future collider experiments.

Quarks and *leptons* are grouped into three families (see Fig. 1). The first family contains the electron and the electrically neutral electron-neutrino as leptons as well as the up- and down-quarks. The protons and neutrons are built-up by up- and down-quarks and form atomic nuclei as strong-interaction bound states. The second family involves the muon and muon-neutrino as leptons and the strange- and charm-quark. The tau lepton and tau-neutrino joined by the bottom- and top-quark belong to the third family. The fundamental forces are mediated by the exchange of gauge bosons which are observable as particles in collider experiments. The gauge boson of the electromagnetic interaction is the massless *photon*, while the massive *W- and Z-bosons* mediate the weak interaction with a very short range. Strong interactions are described by the exchange of *gluons* between the quarks as formulated in Quantum Chromodynamics (QCD).

The big success of the Standard Model in describing the experimental data relies crucially on precise calculations of quantum corrections to experimentally measured processes. The calculation of these corrections constitutes an important research direction of the Theory Group. In the future the Standard Model will be tested at the LHC, a proton–proton collider currently built at CERN and possibly at a future International Linear e^+e^- Collider (ILC). A major focus of the work of the Theory Group is the evaluation of precise predictions for various Higgs-boson production processes, which will be used at the LHC and the ILC to search for the Higgs boson and to study its properties. Other work concerned gauge-boson pair production processes which can be used to study the self-interaction of the electroweak gauge bosons.

The Standard Model has been tested with great accuracy at high energies where it can be treated perturbatively. At low energies, however, non-pertubative effects are dominant and lead to the confinement of quarks and gluons. Only colourless bound states of the basic degrees of freedom are experimentally observed as hadrons. The theoretical description of these effects is a challenging problem and can be attacked in different ways: either by numerical simulation of QCD (lattice gauge theory) or by employing Chiral Perturbation Theory in terms of the observed low-energy hadrons. The latter method is particularly suited for low-energy decay and scattering processes and has been used in the Theory Group to analyse the pion beta decay experiment at PSI. Moreover, the relativistic binding problem has been investigated with special variational methods.

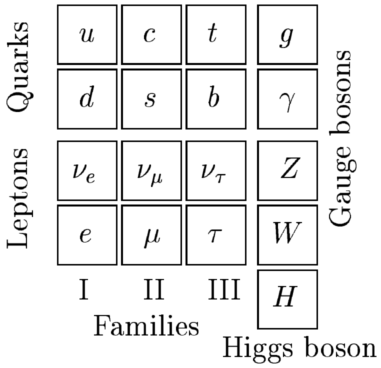

Figure 1: Particles of the Standard Model grouped into 3 families of quarks and leptons, the gauge bosons and the Higgs boson (see the text for more details).

Despite its success, the Standard Model leaves several questions unanswered and suffers from various theoretical problems. Part of the latter are deeply routed in the Higgs sector and can be solved by the introduction of *supersymmetry*, a symmetry connecting bosons and fermions. For all particles of the Standard Model, it predicts supersymmetric partners, which have not yet been observed so far. The Theory Group performed calculations of quantum corrections to the production and decay processes of supersymmetric Higgs bosons and sfermions (the supersymmetric partners of the standard fermions) at the Tevatron, a running proton–antiproton collider, the LHC and the ILC. It was also involved in the construction of a Fortran code for the decays of supersymmetric particles in the Minimal Supersymmetric Standard Model.

The following contributions give more details on specific projects of the Theory Group. For a more complete overview of our work in 2004 see the list of publications and conference contributions.

In August 2004 the Theory Group organized again the traditional Particle Physics Summer School in Zuoz. The school with the topic "*The Challenge of Supersymmetry*" was attended by 84 participants from 21 different countries. Internationally recognised experts gave both an introduction into the subject and detailed reports on the status of the field within theory and experiment. The lectures are available at http://ltpth.web.psi.ch/zuoz2004/ .

ELECTROWEAK CORRECTIONS TO GAUGE-BOSON PRODUCTION AT THE LHC

E. Accomando[1]*, A. Denner*[2]*, A. Kaiser*[2]

University of Torino[1] – PSI[2]

The Standard Model of the Elementary Particle Physics forms a very successful basis for the theoretical description of the fundamental constituents of matter and their interactions. It has been subject to extensive precision tests in the past. While gauge-boson properties, such as masses and interactions with fermions have been measured with great accuracy at LEP and the Tevatron, vector-boson self interactions, and thus the non-abelian structure of the Standard Model, have not been tested with comparable precision. New physics occurring at energy scales much larger than those probed at forthcoming experiments could modify the structure of these interactions, which can be parametrized in terms of anomalous gauge-boson couplings.

Vector-boson pair production provides us with an ideal testing ground for the gauge-boson self interactions. Using these processes, the triple gauge-boson couplings have been measured at LEP and the Tevatron. However, the resulting precision was only moderate, mainly because of the modest energies reached by these colliders. The effects of anomalous gauge-boson couplings are strongly enhanced by increasing the invariant mass of the produced gauge-boson pairs. Therefore, a significant improvement in the bounds on anomalous gauge-boson couplings is expected from future colliders operating at high energies such as the Large Hadron Collider (LHC).

In the near future, the LHC will be the main source of vector-boson pairs with large invariant masses. The experiments ATLAS and CMS will collect thousands of events which allow for a detailed investigation of the triple gauge-boson couplings. The gauge bosons are detected via their decays into fermion pairs. In order to enable an adequate analysis of the data, theoretical predictions with an accuracy of the order of a few per cent are mandatory. This requires to take into account spin correlations and finite-width effects, i.e. to compute the full 4-fermion production process $\mathrm{pp} \to 4f$. In addition, full control of the QCD and electroweak corrections is needed. In the past years large efforts have gone into accurate calculations of hadronic vector-boson pair production. In particular, the $\mathcal{O}(\alpha_s)$ QCD corrections to massive gauge-boson pair production and decay have been extensively analysed by many authors (see Ref. [1] and references therein).

We have complemented these investigations with a calculation of the electroweak $\mathcal{O}(\alpha)$ radiative corrections to massive vector-boson pair production at the LHC [2]. We have considered WZ, ZZ, and $\mathrm{W}^+\mathrm{W}^-$ production where both gauge bosons decay into leptons. Because vector-boson pair production is dominated by the contributions involving two resonant gauge bosons, we have used the double-pole approximation for the virtual corrections. Moreover, at high energies electroweak corrections are dominated by logarithms of the ratio of the energy to the vector-boson mass scale. Therefore, we have evaluated the virtual radiative corrections in a high-energy approximation that takes into account only the corrections enhanced by large logarithms. To this end we used a generic prescription developed in our group [3]. The accuracy of our approach is at the level of some per cent and thus sufficient for the experiments at the LHC. The real corrections, on the other hand, have been calculated exactly, and phase-space integration has been performed with Monte Carlo techniques.

In the physically interesting region of large invariant masses of the vector-boson pair and large angles of the produced vector bosons, the electroweak corrections lower the predictions for WZ, ZZ, and WW production by 5–30%. Some illustrative results are shown in Figure 1. Our results underline that higher-order electroweak effects are appreciable compared with the expected experimental precision at the LHC.

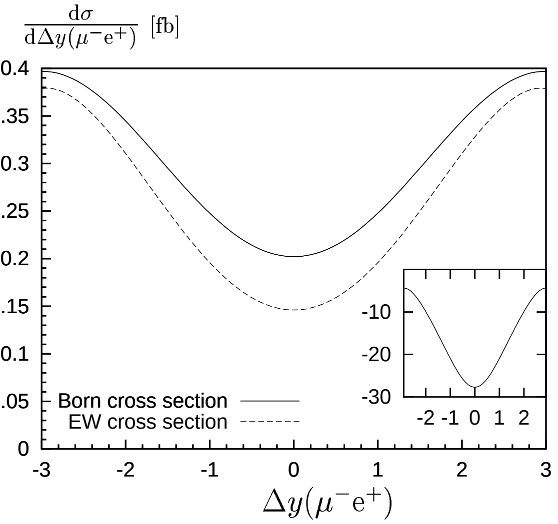

Figure 1: Cross section for $\mathrm{pp} \to \mathrm{W}^+\mathrm{W}^- \to \nu_\mathrm{e}\mathrm{e}^+\mu^-\bar{\nu}_\mu$ at the LHC energy of 14 TeV in lowest order and including the $\mathcal{O}(\alpha)$ electroweak corrections as a function of the rapidity difference $\Delta y(\mu^-\mathrm{e}^+)$ of the two charged leptons in the final state. The invariant mass of the $\mu^-\mathrm{e}^+$ pair is required to be above 500 GeV. The inset plot shows the relative electroweak radiative corrections.

REFERENCES

[1] S. Haywood *et al.*, hep-ph/0003275, in *Standard Model Physics (and more) at the LHC*, eds. G. Altarelli and M.L. Mangano, (CERN-2000-004, Genève, 2000) p. 117.

[2] E. Accomando, A. Denner and A. Kaiser, Nucl. Phys. **B 706**, 325 (2005), PSI-PR-04-08 [arXiv:hep-ph/0409247].

[3] A. Denner and S. Pozzorini, Eur. Phys. J. C **18**, 461 (2001), PSI-PR-00-15 and Eur. Phys. J. C **21**, 63 (2001), PSI-PR-01-06.

WORLDLINE VARIATIONAL APPROXIMATION: A NEW APPROACH TO THE RELATIVISTIC BINDING PROBLEM

K. Barro-Bergflödt [1], *R. Rosenfelder* [2], *M. Stingl* [3]

ETH Zürich[1] – PSI[2] – Universität Münster[3]

Traditionally the relativistic bound-state problem is treated within the framework of the Bethe-Salpeter equation [1]. Although formally exact this equation must be approximated in various ways. The most common one is the ladder approximation which nearly has become synonymous with *the* Bethe-Salpeter equation although it has numerous deficiencies.
Over the years three-dimensional reductions, spectator approximations, light front methods and other variants [2] have been investigated and often used. In hadronic physics where the perturbative methods of bound-state QED are of little value there is an urgent need for methods which also work at strong coupling. Lattice QCD is considered as the prime method to obtain gauge-invariant results from first principles, albeit with enormous numerical efforts and problems of its own. Therefore we have looked at this more than 50-year-old problem from the perspective of the particle representation of field theory which has very attractive features [3].

Instead of solving a Schrödinger-like equation (which is not available in relativistic field theory) we determine the lowest bound-state pole of the density-density correlator

$$\Pi(q^2) \sim \int d^4x\, e^{iq\cdot x} \left\langle 0 \left| \mathcal{T}\left(\Phi^\dagger(x)\Phi(x)\,\Phi^\dagger(0)\Phi(0)\right)\right| 0 \right\rangle$$

as a function of the external variable q^2. We do that in the context of the scalar Wick-Cutkosky model where two equal-mass "nucleons" (described by the field Φ) interact via the exchange of "mesons" (χ) with a cubic interaction $g\Phi^2\chi$. This is done by employing the worldline representation for the correlator together with a variational approximation as in Feynman's treatment of the polaron. Unlike traditional methods based on the Bethe-Salpeter equation, self-energy and vertex corrections are (approximately) included as are crossed diagrams (see Fig. 1). Only diagrams with internal nucleon loops are neglected.

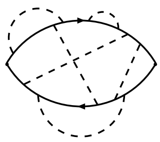

Figure 1: Typical diagram for the correlator $\Pi(q^2)$ included approximately in the worldline variational approximation. Solid lines refer to nucleons, dashed ones to mesons.

We have derived and solved numerically the variational equations [4]. Indeed a pole of the correlator at $q_0^2 < 4M^2$ was found *below* the threshold given by the physical (renormalized) mass M of the nucleon. The resulting binding energy $\epsilon = \sqrt{q_0^2} - 2M$ is shown in Fig. 2 as function of the dimensionless coupling constant $\alpha = g^2/(4\pi M^2)$ and compared with various other approaches. Inclusion of self-energy and vertex corrections is seen to give more binding.

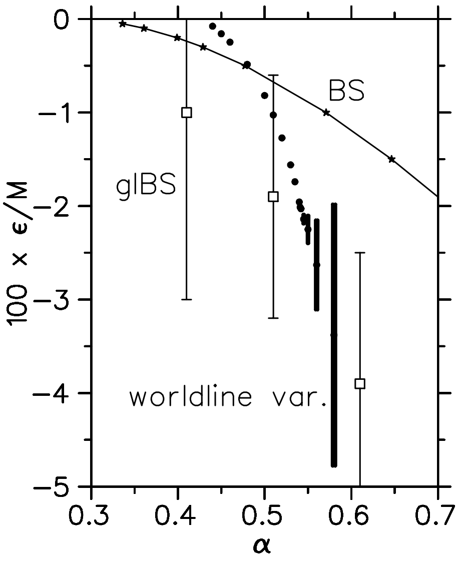

Figure 2: The binding energy ϵ/M of the two-body bound state for nucleon mass $M = 0.939$ GeV and meson mass $m = 0.14$ GeV as a function of the coupling constant α in the worldline variational approach. The length of the thick bars gives the width of the bound state above the critical coupling. Also shown are results from the ladder Bethe-Salpeter (BS) equation and from Monte-Carlo calculations (with errors) in the "generalized ladder approximation" which includes crossed diagrams.

Due to the well-known (non-perturbative) instability of the Wick-Cutkosky model, solutions of the variational equations only exist below a critical coupling [3]. Our numerical results and analytical methods show that for the bound case the critical coupling is *smaller* than for the single-nucleon case indicating an induced instability due to the presence of the second particle. The width of the bound state above the critical coupling can be estimated and is also shown in Fig. 2. Extension of this approach to more realistic strong-coupling (gauge) theories seems to be possible.

REFERENCES

[1] E. E. Salpeter and H. A. Bethe, Phys. Rev. **84**, 1232 (1951).

[2] A. Weber, arXiv:hep-ph/0308280.

[3] R. Rosenfelder and A. W. Schreiber, Phys. Rev. D **53**, 3337 and 3354 (1996).

[4] K. Barro-Bergflödt, R. Rosenfelder and M. Stingl, PSI-PR-04-04, [arXiv:hep-ph/0403304].

HIGGS RADIATION OFF HEAVY QUARKS AT ELECTRON-POSITRON COLLIDERS

P. Häfliger[1,2], *M. Spira*[2]

ETH Zürich[1] – PSI[2]

The Higgs mechanism is a cornerstone of the Standard Model (SM) and its supersymmetric extensions. In the minimal supersymmetric extension of the SM (MSSM) two isospin Higgs doublets have to be introduced in order to generate masses of up- and down-type fermions. After electroweak symmetry-breaking 3 of the 8 degrees of freedom are absorbed by the Z and W gauge bosons, leading to the existence of five elementary Higgs particles. These consist of two CP-even neutral (scalar) particles h, H, one CP-odd neutral (pseudoscalar) particle A and two charged particles $H^\pm$. At leading order the MSSM Higgs sector is fixed by two independent input parameters which are usually chosen to be the pseudoscalar Higgs mass M_A and $\mathrm{tg}\beta = v_2/v_1$, the ratio of the two vacuum expectation values. The one-loop and dominant two-loop corrections modify all Higgs masses and couplings significantly.

An important property of the bottom-Yukawa couplings is their enhancement for large values of $\mathrm{tg}\beta$, while the top-Yukawa couplings are suppressed for large $\mathrm{tg}\beta$. This implies that Higgs radiation off bottom quarks plays a significant role at linear e^+e^- colliders in the large $\mathrm{tg}\beta$ regime, while Higgs radiation off top quarks is relevant for small and moderate values of $\mathrm{tg}\beta$. Both processes allow a measurement of the parameter $\mathrm{tg}\beta$. For reliable analyses the production cross sections have to be known beyond leading order in perturbation theory, since the theoretical uncertainties at leading order are significantly larger than the expected experimental accuracies. In the past the pure QCD corrections to MSSM Higgs radiation off heavy quarks have been determined [1].

Since the MSSM also contains the superpartners to all SM particles which couple with the same strengths to matter, the virtual effects of squark- and gluino-exchange contributions have to be added for a full calculation of strong radiative corrections. In the case of Higgs radiation off top quarks they turn out to be of similar magnitude as the pure QCD corrections, but of opposite sign [2]. The corrections modify the shape of the Higgs energy distributions slightly.

Higgs radiation off bottom quarks on the other hand is plagued by large SUSY-QCD corrections for large values of $\mathrm{tg}\beta$, which, however, can be resummed [3]. We demonstrate in Fig. 1 that the residual corrections after resummation (shown by the grey curves) are of moderate size and cancel the pure QCD corrections to a large extent, thus leaving total corrections of $\mathcal{O}(10\%)$.

The residual theoretical QCD uncertainties are reduced to a level which allows an accurate measurement of the Yukawa couplings in these processes and thus an extraction of $\mathrm{tg}\beta$. The overall theoretical uncertainties, however, are dominated by the unknown SUSY-electroweak corrections.

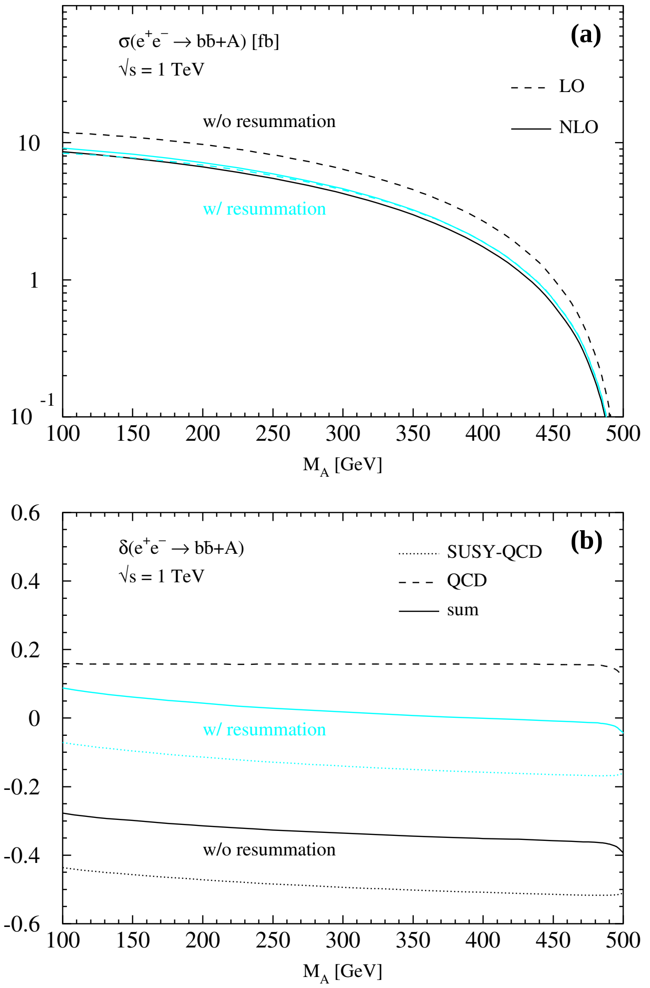

Figure 1: *(a) Production cross sections of pseudoscalar Higgs radiation off bottom quarks in e^+e^- collisions with (grey curves) and without (black curves) resummation. The LO cross section is depicted by the dashed line and the full QCD- and SUSY-QCD corrected cross section by the full line; (b) Relative QCD, SUSY-QCD and total corrections to pseudoscalar Higgs radiation off bottom quarks with (grey lines) and without (black lines) resummation. The pure QCD corrections are indistinguishable in both cases.*

REFERENCES

[1] S. Dittmaier, M. Krämer, Y. Liao, M. Spira and P. M. Zerwas, Phys. Lett. **B 478**, 247 (2000).

[2] P. Häfliger and M. Spira, hep-ph/0501164.

[3] M. Carena, D. Garcia, U. Nierste and C. E. M. Wagner, Nucl. Phys. **B 577**, 88 (2000); J. Guasch, P. Häfliger and M. Spira, Phys. Rev. **D 68**, 115001 (2003).

SDECAY - A FORTRAN CODE FOR SUSY PARTICLE DECAYS IN THE MSSM

A. Djouadi[1], *Y. Mambrini*[2], *M. Mühlleitner*[3]

LPT Orsay[1] – DESY[2] – PSI[3]

The search for supersymmetric (SUSY) particles is a major goal at present and future colliders. Their properties are expected to be determined with an accuracy of a few per cent at the LHC and at the per cent level and below at future e^+e^- linear colliders. To match the expected experimental accuracy, programs are needed for the calculation of the SUSY particle spectrum, of the production cross sections and of the SUSY particle decay widths and branching ratios with high precision. The Fortran code `SDECAY` [1] deals with the decays of SUSY particles in the Minimal Supersymmetric Standard Model (MSSM) and includes the most important higher-order effects. Up to the user's choice, the mass spectrum and soft SUSY breaking parameters are obtained from the renormalization group evolution program `SuSpect` [2] or from an input file in the SUSY Les Houches Accord (SLHA) format [3]. `SDECAY` then evaluates the various couplings of the SUSY particles and MSSM Higgs bosons and calculates the decay widths and branching ratios.

The tree-level and QCD corrected two-body decays: The following tree-level two-body sfermion ($\tilde f$), squark ($\tilde q$), gluino ($\tilde g$) and chargino/neutralino ($\tilde\chi$) decays have been implemented in the program

$$\begin{array}{lll} \tilde f_i & \rightarrow & \tilde\chi_j f, \qquad \tilde\chi_j : \text{chargino, neutralino} \\ \tilde f_i & \rightarrow & \tilde f_j V, \qquad V : W, Z \\ \tilde f_i & \rightarrow & \tilde f_j \Phi, \qquad \Phi : h, H, A, H^\pm \\ \tilde q_i & \rightarrow & \tilde g\, q, \qquad \tilde g \rightarrow \tilde q_i q, \\ \tilde\chi_i & \rightarrow & \tilde\chi_j V, \quad \tilde\chi_i \rightarrow \tilde\chi_j \Phi \quad \text{and} \quad \tilde\chi_i \rightarrow \tilde f_j f\,. \end{array}$$

For gauge mediated SUSY breaking models, the included decays into the lightest SUSY particle, the gravitino ($\tilde G$), are

$$\tilde\chi_1^0 \rightarrow \tilde G\gamma, \tilde G Z, \tilde G\phi \;\; (\phi = h, H, A) \quad \text{and} \quad \tilde\tau_1 \rightarrow \tilde G\tau\,.$$

A new feature compared to many existing decay programs, is the inclusion of the SUSY-QCD corrections to the decays

$$\begin{array}{lll} \tilde q_i & \rightarrow & \tilde\chi_j q, \quad \tilde q_i \rightarrow \tilde q_j V, \quad \tilde q_i \rightarrow \tilde q_j \Phi, \quad \tilde q_i \rightarrow \tilde g q \\ \tilde g & \rightarrow & \tilde q_i q, \quad \tilde\chi_i \rightarrow \tilde q_j q\,. \end{array}$$

To account for the bulk of the electroweak (EW) corrections the running parameters at the scale of the EW symmetry breaking are taken for the gauge and third generation Yukawa couplings, the soft SUSY-breaking parameters and third-generation sfermion mixing angles . Finally, `SDECAY` also evaluates the top quark decays in the MSSM:

$$t \rightarrow bW^+, \quad t \rightarrow bH^+ \quad \text{and} \quad t \rightarrow \tilde t_1 \tilde\chi_1^0\,.$$

The loop-induced and the multibody decays: If the 2-body decays are closed, multibody decays will be dominant. The implemented gaugino, gluino, stop and sbottom three-body decays [1] are

$$\begin{array}{lll} \tilde\chi_i & \rightarrow & \tilde\chi_j f\bar f, \qquad \tilde\chi_i \rightarrow \tilde g q\bar q \\ \tilde g & \rightarrow & \tilde\chi_i q\bar q, \qquad \tilde g \rightarrow \tilde t_1 \bar b W^-, \quad \tilde g \rightarrow \tilde t_1 \bar b H^- \\ \tilde t_i & \rightarrow & bW^+\tilde\chi_1^0, \quad \tilde t_i \rightarrow bH^+\tilde\chi_1^0 \\ \tilde t_i & \rightarrow & bl^+\tilde\nu_l, \quad \tilde t_i \rightarrow b\tilde l^+\nu_l, \quad \tilde t_i \rightarrow \tilde b_j f\bar f, \quad \tilde t_2 \rightarrow \tilde t_1 f\bar f \\ \tilde b_i & \rightarrow & tl^-\tilde\nu_l^*, \quad \tilde b_i \rightarrow t\tilde l^-\bar\nu_l, \quad \tilde b_i \rightarrow \tilde t_j f\bar f, \quad \tilde b_2 \rightarrow \tilde b_1 f\bar f\,. \end{array}$$

The mixing of the third-generation sfermions and the final-state fermion masses have been taken into account [1, 4]. Loop-induced decays of the lightest stop, the next-to-lightest neutralino and gluino might become important and have been included:

$$\tilde\chi_2^0 \rightarrow \tilde\chi_1^0\gamma, \qquad \tilde g \rightarrow \tilde\chi_1^0 g \qquad \text{and} \qquad \tilde t_1 \rightarrow \tilde\chi_1^0 c\,.$$

If the 3-body decays are kinematically forbidden, the following $\tilde t_1$ 4-body decay can compete with the loop-induced $\tilde t_1$ decay and has been implemented:

$$\tilde t_1 \quad \rightarrow \quad b\tilde\chi_1^0 f\bar f\,.$$

Structure of SDECAY: Besides the `SuSpect` files, the program `SDECAY` is composed of 3 files: (i) `sdecay.in`, where the user can choose various options, such as e.g. whether or not to include the QCD corrections to 2-body decays, the multibody and/or loop decays, as well as the scale for the running couplings and also, where to take the spectrum from, i.e. from `SuSpect` or any input file in the SLHA format; (ii) `sdecay.f` is the main body of the code. It evaluates the various couplings and calculates the decay widths and branching ratios; (iii) `sdecay.out`, which gives as output the branching ratios and total widths. In addition, the whole SUSY spectrum, mixing matrices and further parameters used for the calculation of the couplings and decay widths are written out. The necessary files and the makefile for the compilation can be found at the `SDECAY` homepage:

http://people.web.psi.ch/muehlleitner/SDECAY/.

In summary, the Fortran code `SDECAY` calculates all SUSY particle 2-body tree-level and QCD corrected decays, 3-body and loop-decays as well as $\tilde t_1$ 4-body and top-decays. The program is rather fast, flexible and maintained regularly to include upgrades and newest theoretical developments as well as experimental needs.

REFERENCES

[1] M. Mühlleitner, A. Djouadi and Y. Mambrini, arXiv:hep-ph/0311167 (and references therein).

[2] A. Djouadi, J.-L. Kneur and G. Moultaka, arXiv:hep-ph/0211331.

[3] P. Skands et al., JHEP **0407**, 036 (2004), [arXiv:hep-ph/0311123].

[4] A. Djouadi, Y. Mambrini and M. Mühlleitner, Eur. Phys. J. **C 20**, 563 (2001), [arXiv:hep-ph/0104115].

PUBLICATIONS

S. Bejar, F. Dilme, J. Guasch and J. Sola,
Higgs boson flavor changing neutral decays into bottom quarks in supersymmetry
JHEP **040**, 018 (2004).

V. Cirigliano, H. Neufeld and H. Pichl,
K_{e3} *decays and CKM unitarity*
Eur. Phys. J. **C 35**, 53 (2004).

A. Denner, S. Dittmaier, M. Roth and M. M. Weber,
Radiative corrections to Higgs-boson production in association with top quark pairs at e^+e^- *colliders*
Nucl. Phys. **B 680**, 85 (2004).

A. Denner, E. Kraus and M. Roth,
Physical renormalization condition for the quark mixing matrix
Phys. Rev. **D 70**, 033002 (2004).

K. P. O. Diener,
Electron to muon conversion in low-energy electron nucleus scattering
Nucl. Phys. B **697**, 387 (2004).

K. P. O. Diener, S. Dittmaier and W. Hollik,
Electroweak radiative corrections to deep-inelastic neutrino scattering: Implications for NuTeV ?
Phys. Rev. D **69**, 073005 (2004).

S. Dittmaier, M. Krämer and M. Spira,
Higgs radiation off bottom quarks at the Tevatron and the LHC
Phys. Rev. D **70**, 074010 (2004).

R. Rosenfelder and A. W. Schreiber,
An Abraham-Lorentz-like equation for the electron from the worldline variational approach to QED
Eur. Phys. J. **C 37**, 161 (2004).

P. Skands *et al.*, J. Guasch, M. Mühlleitner, M. Spira,
SUSY Les HOUCHES accord: Interfacing SUSY spectrum calculators, decay packages and event generators
JHEP **0407**, 036 (2004).

CONTRIBUTIONS TO CONFERENCES AND WORKSHOPS

B. C. Allanach *et al.*, J. Guasch, M. Mühlleitner, M. Spira,
Beyond the Standard Model working group: summary Report
3rd Les Houches Workshop: 'Physics at TeV Colliders', Les Houches, France, 26 May - 6 June 2003
arXiv:hep-ph/0402295.

K. A. Assamagan, J. Guasch, S. Moretti and S. Penaranda,
Distinguishing Higgs models in $H^+ \to \tau^+\nu/t\bar{b}$ *at large* $\tan\beta$
Conference on Physics at LHC, Vienna (Austria), 13-17 July 2004
arXiv:hep-ph/0409189.

K. A. Assamagan *et al.* , M. Spira, J. Guasch,
The Higgs working group: summary report
3rd Les Houches Workshop: 'Physics at TeV Colliders', Les Houches (France), 26 May - 6 June 2003
arXiv:hep-ph/0406152.

J. Campbell *et al.*, M. Spira,
Higgs-boson production in association with bottom quarks
3rd Les Houches Workshop: 'Physics at TeV Colliders', Les Houches (France), 26 May - 6 June 2003
arXiv:hep-ph/0405302.

A. Bay *et al.*, M. Spira,
Particle physics in Switzerland: Status and outlook of research and education
CHIPP (Swiss Institute of Particle Physics) report, May 2004.

S. Y. Choi, J. Kalinowski, J. S. Lee, M. M. Mühlleitner, M. Spira and P. M. Zerwas,
$\tau\tau$ fusion to SUSY Higgs bosons at a photon collider: measuring $\tan\beta$
International Conference on Linear Colliders (LCWS 04), Paris (France), 19-24 April 2004
arXiv:hep-ph/0407048.

CLIC Physics Working Group (E. Accomando *et al.*, M. Mühlleitner, M. Spira),
Physics at the CLIC multi-TeV linear collider
CERN report CERN-2004-005, [arXiv:hep-ph/0412251].

G. Degrassi *et al.*, J. Guasch, M. Mühlleitner, M. Spira,
SUSY particle physics summary
Final Meeting of the Network 'Particle Physics Phenomenology at High Energy Colliders', Montpellier (France), 26-27 September, 2004
Acta Phys. Polon. **B 35**, 2711 (2004).

A. Denner, S. Dittmaier, M. Roth and M. M. Weber,
Electroweak corrections to $e^+e^- \to f\bar{f}H$
7th DESY Workshop on Elementary Particle Theory: 'Loops and Legs in Quantum Field Theory', Zinnowitz (Germany), 25-30 April 2004
Nucl. Phys. Proc. Suppl. **135**, 88 (2004).

A. Denner, S. Dittmaier, M. Roth and M. M. Weber,
Electroweak corrections to $e^+e^- \to \nu\bar{\nu}H$ and $e^+e^- \to t\bar{t}H$
International Europhysics Conference on High-Energy Physics (HEP 2003), Aachen (Germany), 17-23 July 2003
Eur. Phys. J. **C 33**, S635 (2004).

K. P. O. Diener, S. Dittmaier and W. Hollik,
Electroweak radiative corrections to deep-inelastic neutrino scattering
7th DESY Workshop on Elementary Particle Theory: 'Loops and Legs in Quantum Field Theory', Zinnowitz (Germany), 25-30 April 2004
Nucl. Phys. Proc. Suppl. **135**, 183 (2004).

K. P. O. Diener,
New predictions for electroweak $\mathcal{O}(\alpha)$ corrections to neutrino nucleon scattering
International Europhysics Conference on High-Energy Physics (HEP 2003), Aachen (Germany), 17-23 July 2003
Eur. Phys. J. C **33**, S662 (2004), [arXiv:hep-ph/0311122].

E. W. N. Glover *et al.*, J. Guasch,
Top quark physics at colliders
Final Meeting of the Network 'Particle Physics Phenomenology at High Energy Colliders', Montpellier (France), 26-27 September, 2004
Acta Phys. Polon. **B 35**, 2671 (2004), [arXiv:hep-ph/0410110].

W. Hollik *et al.*, A. Denner, K. P. O. Diener,
Electroweak physics
Final Meeting of the Network 'Particle Physics Phenomenology at High Energy Colliders', Montpellier (France), 26-27 September, 2004
Acta Phys. Polon. **B 35**, 2553 (2004).

R. Kinnunen, S. Lehti, F. Moortgat, A. Nikitenko and M. Spira,
Measurement of the H/A $\to \tau\tau$ cross section and possible constraints on $\tan\beta$
CMS-NOTE-2004-027.

M. Mühlleitner,
SDECAY: A Fortran code for SUSY particle decays in the MSSM
International Conference on Linear Colliders (LCWS 04), Paris (France), 19-24 April 2004
arXiv:hep-ph/0409200.

M. Mühlleitner,
SDECAY: A Fortran code for the calculation of the supersymmetric particle decays
Final Meeting of the Network 'Particle Physics Phenomenology at High Energy Colliders', Montpellier (France), 26-27 September, 2004
Acta Phys. Polon. **B 35**, 2753 (2004).

M. Mühlleitner,
Linear collider prospects on electroweak physics
32nd International Conference on High-Energy Physics (ICHEP 04), Beijing (China), 16-22 August 2004
arXiv:hep-ph/0411059.

ORGANIZATION OF WORKSHOPS

A. Denner and M. Spira,
16^{th} *Zuoz Particle Physics Summer School: "The Challenge of Supersymmetry"*
Zuoz/Engadin (Switzerland), 15 - 21 August 2004, http://ltpth.web.psi.ch/zuoz2004/

INVITED TALKS

A. Denner,
Electroweak radiative corrections to $e^+e^- \to \nu\bar{\nu}H$ *and* $t\bar{t}H$
Theorieseminar, DESY Zeuthen (Germany), 24 June 2004.

A. Denner,
Electroweak physics review
Final Meeting of the Network 'Particle Physics Phenomenology at High Energy Colliders', Montpellier (France), 26 September, 2004

A. Denner,
Präzisionstests der elektroschwachen Wechselwirkung bei hohen Energien
Theoriekolloquium, Universität Mainz (Germany), 18 November 2004.

K. P. O. Diener,
The NuTeV result for $\sin^2\theta_W$ *– a reanalysis of the electroweak radiative corrections*
Seminar, CERN, Geneva (Switzerland), 29 January 2004.

K. P. O. Diener,
The NuTeV $\sin^2\theta_W$ *anomaly*
Seminar, LBL, Berkeley (USA), 31 March 2004.

K. P. O. Diener,
Electroweak radiative corrections to deep-inelastic neutrino scattering
Seminar, Kavli Institute for Theoretical Physics, UCSB, Santa Barbara (USA), 3 April 2004.

K. P. O. Diener,
The NuTeV result for $\sin^2\theta_W$ *– a reanalysis of the electroweak radiative corrections*
Seminar, Caltec, Pasadena (USA), 6 April 2004.

K. P. O. Diener,
New results for $\mathcal{O}(\alpha)$ corrections to neutrino-nucleon scattering - implications for NuTeV?
XII International Workshop on Deep Inelastic Scattering (DIS04), Štrbské Pleso (Slovakia), 15 April 2004.

K. P. O. Diener,
The NuTeV $\sin^2\theta_W$ *anomaly*
Seminar, RWTH Aachen (Germany), 5 May 2004.

M. Mühlleitner,
Higgs physics at e^+e^- linear colliders
Journée "Physique au-delà du Modèle Standard", Laboratoire de Physique Théorique, Université Paris-Sud XI, 10 May 2004.

M. Mühlleitner,
Higgs physics at e^+e^- linear colliders
Special theory seminar, DESY Hamburg (Germany), 21 July 2004.

M. Mühlleitner,
Linear Collider prospects on electroweak physics, including gauge couplings, top, Higgs
32nd International Conference on High Energy Physics, Beijing (China), 16-22 August 2004.

M. Mühlleitner,
Various aspects of Higgs physics at future colliders
Theory seminar, DESY Hamburg (Germany), 30 August 2004.

M. Mühlleitner,
La physique des bosons de Higgs et la supersymétrie auprès des futurs collisionneurs pp et e^+e^-
Seminar, Laboratoire d'Annecy-Le-Vieux de Physique Théorique (France), 25 October 2004.

H. Pichl,
K_{e3} decays and CKM unitarity
3rd Euridice Collaboration Meeting, Wien (Austria), 12-14 February 2004.

H. Pichl,
K_{e3} decays and radiative corrections
NA48 Kaon Mini Workshop, CERN, Geneva (Switzerland), 5 May 2004.

H. Pichl,
K_{e3} decays, radiative corrections and CKM unitarity
4th KLOE Workshop, Karlsruhe (Germany), 31 May - 3 June 2004.

M. Spira,
RS graviton production in PYTHIA and status of PROSPINO
CMS-Meeting, CERN, Geneva (Switzerland), 17 March 2004.

M. Spira,
NLO results on $b\bar{b}$ + Higgs production at hadron colliders
DIS04 conference, Štrbské Pleso (Slovakia), 14-18 April 2004.

M. Spira,
Working Group E: Theory Part (Convenor)
DIS04 conference, Štrbské Pleso (Slovakia), 14-18 April 2004.

M. Spira,
Higgs bosons @ LHC
Workshop 'Journeé Physique Atlas France', La Londe les Maures (France), 3-5 May 2004.

M. Spira,
SUSY-QCD corrections to $t\bar{t}/b\bar{b}$ + Higgs production
ECFA Study of Physics and Detectors for a Linear Collider, Durham (UK), 1-4 September 2004.

M. Spira,
Electroweak and Alternatives Working Group: Summary Report (Convenor)
ECFA Study of Physics and Detectors for a Linear Collider, Durham (UK), 1-4 September 2004.

M. Spira,
Pair production of leptoquarks at the LHC
ATLAS-Meeting, CERN, Geneva (Switzerland), 3 November 2004.

M. Spira,
Production of Higgs and SUSY particles at the LHC
Workshop 'Physics in the LHC Era', Kyoto (Japan), 13-15 December 2004.

M. Spira,
Search for Higgs bosons at future colliders
Seminar, KEK, Tsukuba (Japan), 16 December 2004.

ADDITIONAL PREPRINTS (not published in 2004)

E. Accomando, A. Denner and A. Kaiser,
Logarithmic electroweak corrections to gauge-boson pair production at the LHC
Nucl. Phys. **B 706**, 325 (2005) [arXiv:hep-ph/0409247].

K. Barro-Bergflödt, R. Rosenfelder and M. Stingl,
Worldline variational approximation: A new approach to the relativistic binding problem
arXiv:hep-ph/0403304 .

S. D. Bass, *The spin structure of the proton*
arXiv:hep-ph/0411005.

S. Y. Choi, J. Kalinowski, J. S. Lee, M. M. Mühlleitner, M. Spira and P. M. Zerwas,
Determining $\tan\beta$ *in* $\tau\tau$ *fusion to SUSY Higgs bosons at a photon collider*
Phys. Lett. **B 606**, 164 (2005), [arXiv:hep-ph/0404119].

CLIC Physics Working Group, M. Mühlleitner, M. Spira *et al.*,
Physics at the CLIC multi-TeV linear collider
arXiv:hep-ph/0412251.

A. Denner and S. Pozzorini,
An algorithm for the high-energy expansion of multi-loop diagrams to next-to-leading logarithmic accuracy
arXiv:hep-ph/0408068.

P. Häfliger and M. Spira,
Associated Higgs boson production with heavy quarks in e^+e^- *collisions: SUSY–QCD corrections*
arXiv:hep-ph/0501164.

M. Krämer, T. Plehn, M. Spira and P. M. Zerwas,
Pair production of scalar leptoquarks at the LHC
arXiv:hep-ph/0411038.

LHC/LC Study Group, J. Guasch, M. Mühlleitner, M. Spira *et al.*,
Physics interplay of the LHC and the ILC
arXiv:hep-ph/0410364.