HUMAN RESOURCES AND MOBILITY (HRM) ACTIVITY

MARIE CURIE ACTIONS
Marie Curie Research Training Networks (RTN)

HEPTOOLS

Contents

1 NCSR-D: Athens/Thessaloniki/Patras/Sofia

Research expertise and proposed research: The team is composed by researchers from the theoretical high-energy physics groups of the NCSR 'Democritos' (NCSR-D), the Aristotle University of Thessaloniki (AUTH), University of Athens (UoA), the Technical University of Athens (NTUA), the University of Patras (UoP) and the INRNE, Sofia.

The team has considerable expertise covering a wide range of modern particle physics. It includes the development of novel techniques for scattering-amplitude computations based on the recursive Dyson-Schwinger equations; the study of higher-order corrections in multi-fermion production processes; the description of multi-parton process in hadron colliders; the development of automatic Monte-Carlo tools for arbitrary scattering processes; the study of supersymmetric interactions and particle production, namely neutralino one-loop processes, relevant for LHC physics and Dark matter searches; calculations of LSP relic abundances; CP violation in SUSY models and implications for cosmology and accelerator physics; the asymptotic properties of two-body amplitudes in the SM and in renormalizable SUSY models where the important property of helicity conservation has been discovered; the neutrino masses and mixing within the context of MSSM supplemented by a $U(1)$ anomalous family symmetry and additional Higgs singlet fields charged under this extra $U(1)$; the study of explicit lepton number violation arising in a wide class of supersymmetric models (R-parity violating models); Finite N=1 supersymmetric Grand Unified Theories (GUTs) and and finiteness constrained MSSM phenomenology; the study of phenomenological aspects of theories resulting from higher dimensional theories with smooth or fuzzy extra dimensional manifolds; GUTs inspired from branes; renormalisation group equation and gauge coupling unification.

The last years the group has been actively participating in several working groups and workshops set up to study LHC and ILC physics, developing strong collaborations with the teams of Durham, Nijmegen, Montpellier, Torino, Krakow, CERN and DESY-Zeuthen. It is a major aspect of the proposed network to further develop and strengthen these collaborations with emphasis to develop computational tools to study multi-loop contributions to processes that can be accessed experimentally with high accuracy.

The group will contribute in the following project tasks: the development of automated tools for multiparticle productions processes both at tree- and one-loop order, the numerical evaluation of one-loop multiparticle Feynman amplitudes, the development of event generator interfaces, the study of four- and six-fermion production processes including fermion-loop corrections, the study of Higgs physics at the LHC, the study of supersymmetric particle production at lepton and hadron colliders, the study of flavour violating processes in present and future experiments, the study of lepton-number violation effects within MSSM and finally, the astrophysical and cosmological implications of supersymmetric particles and interactions.

Training environment: NCSR-D has a well established tradition in training through research. Being the first place in Greece offering post-graduate courses (from early 70's), it is still now the only place that has a scholarship system, attracting every year more than 50 students. More specifically the Institute of Nuclear Physics takes responsibility for more than 15 PhD students. The PhD programme is running in collaboration with the Department of Physics in the National Technical University of Athens (NTUA). Moreover, several bilateral agreements with Universities over all Europe, enable students from Demokritos to follow training abroad and vice versa. AUTH, UoA, and UoP they also run regular graduate school and PhD programmes, offering high-level training to young researchers. Over the last few years, the experience of these institutions in training early stage researchers form all over Europe, within European projects, has been significantly improved. Finally the Corfu school offers excellent training at an international level. There are several instruments to be used in order to implement a training project: exchange and/or secondment of students, exchange of experienced researchers for courses and tutorials, transfer of knowledge activities through working groups, research visits and meetings, web-based exchange of information and material.

Key Scientific Staff and Individual Expertise

NCSR-D: C. G. Papadopoulos (team coordinator, 100%, faculty, electroweak and QCD calculations, multiparticle production, automated LO and NLO calculations), P. Draggiotis (100%, research associate, multiparticle production), E. N. Argyres (100%, faculty, multiparticle production), 1 EU post-doc (100%), 1 EU PhD student (25%), 1 PhD student (100%); **UoA**: A. B. Lahanas (50%, faculty, SUSY phenomenology-cosmology), V. C. Spanos (50%, research associate, SUSY phenomenology-cosmology), 2 PhD students (all 40%); **NTUA**: George Zoupanos (50%, faculty, Finite GUTs, Higher Dimensional Theories, Non-Commutative Higher Dimensional Theories), Nick Tracas (20%, faculty, SUSY phenomenology, RGE analysis), Pantelis Manousselis (50%, post-doc, Higher Dimensional Theories, Non-Commutative Higher Dimensional Theories), 3 PhD students (all 60%); **AUTH**: G. J. Gounaris (deputy team coordinator, 70%, SM and SUSY phenomenology), N. Vlachos (20%, SUSY phenomenology at zero and no-zero temperatures), J.E. Paschalis (20%, Quantum Gravity), 1 PhD Student(100%), 1 PhD Student (50%); **UoP**: S. Lola (50%, faculty, Beyond the SM phenomenology with emphasis on lepton flavour violation, R-violating supersymmetry and neutrino physics); **INRNE, Sofia**: E. Christova (50%, staff,CP violating phenomena in supersymmetric models)

Most significant recent publications

1) G. J. Gounaris and F. M. Renard, "About helicity conservation in gauge boson scattering at high energy," Phys. Rev. Lett. **94** (2005) 131601.

2) T. Gleisberg, F. Krauss, C. G. Papadopoulos, A. Schaelicke and S. Schumann, "Cross sections for multi-particle final states at a linear collider," Eur. Phys. J. C **34** (2004) 173

3) P. Aschieri, J. Madore, P. Manousselis and G. Zoupanos, "Dimensional reduction over fuzzy coset spaces," JHEP **0404** (2004) 034

2 IPPP: Durham/Cambridge/Edinburgh/Glasgow/Sheffield/Southampton

Research expertise and proposed research: The team consists of leading UK researchers in collider physics and related phenomenology from Durham, Cambridge, Edinburgh, Glasgow and Southampton. The Durham group is the largest in the UK; it includes the new UK Institute for Particle Physics Phenomenology (IPPP) .

The team has particular expertise in multiparticle and multi-loop calculations including the use of computer algebra, numerical simulation and large scale computing as well as the application to precision electroweak observables and the determination of the Higgs boson mass in the SM and SUSY, strong and electroweak radiative corrections, the determination of Higgs and superparticle cross sections and signals, and in studies of alternative physics signals at the LHC and the ILC. In the future the group will continue to study the physics at hadron colliders (Tevatron, LHC) and electron-positron linear colliders.

Training environment: The Durham, Cambridge, Edinburgh, Glasgow and Southampton groups are each active research centres based in universities which provide an excellent training environment for young researchers. The team faculty members are experienced in teaching and supervising students and post-docs and regularly give lecture courses on QCD, Standard Model, Supersymmetry and other Physics beyond the Standard Model. Young researchers will be actively involved in national or international collaborations entertained by team members, which will expose them to a variety of different approaches and styles of doing research and will help them to develop their own "research personality". They will also be given the opportunity to present the results of their research at conferences and workshops. The IPPP has excellent dedicated research facilities and hosts regular meetings and workshops in all areas covered by the scientific programme of the network. Typically, around 10 workshops per year are timetabled, offering the potential for young researchers to give talks, meet international experts, participate in topical research problems and help to establish their presence in the field. Members of the team have co-organised several international summer schools such as the Scottish Universities Summer School on LHC phenomenology in 2003, and the ICTP Summer School "Expecting LHC", which is going to take place at Trieste in September 2006.

Key Scientific Staff and Individual Expertise

IPPP, Durham: G. Weiglein (Team Leader, 50%, faculty; Higgs physics, SUSY, higher-order corrections, coordinator of the world-wide LHC / ILC Study Group), N. Glover (Deputy Team leader, 50%, faculty, Director of the IPPP; loop integrals, computer algebra, multi-particle production, LHC phenomenology), P. Ball (25%, faculty; flavour physics, effective field theories), A. Dedes (50%, faculty; SUSY phenomenology, flavour physics), C. Maxwell (100%, faculty; QCD, renormalisation group methods), A. Signer (100%, faculty; top physics, QCD, effective field theories, regularisation of SUSY theories), W.J. Stirling (10%, faculty; QCD, LHC phenomenology, parton distribution functions), O. Brein (100%, post-doc; Higgs and SUSY phenomenology at the LHC), G. Moortgat-Pick (100%, post-doc; LHC and ILC phenomenology, SUSY, spin and polarisation effects at colliders), T. Underwood (100%, post-doc; neutrino physics, CP-violation in the lepton sector, leptogenesis), R. Zwicky (50%, post-doc; flavour physics), 1 EU post-doc (50%), 1 EU graduate student (50%), 3 research students (100%). **Cambridge**: B. Allanach (20%, faculty; SUSY spectrum generation, renormalisation group equations, LHC phenomenology). **Edinburgh**: R. Ball (50%, faculty; small x QCD, LHC phenomenology), T. Binoth (50%, faculty; QCD higher-order corrections, LHC phenomenology, multi-loop and one-loop multi-leg methods), T. Plehn (50%, faculty; LHC phenomenology, SMADGRAPH event generator), D. Stöckinger (100%, faculty; renormalisation and regularisation of SUSY theories, electroweak higher-order calculations), A. Guffanti (100%, post-doc; QCD phenomenology, resummations), M. Rauch (100%, post-doc; higher-order effects at the LHC, computer algebra tools), 2 SUPA graduate students (100%), 1 research student (100%). **Glasgow**: J. Campbell (100%, faculty;

higher-order QCD calculations, simulation of SM backgrounds for new physics searches), D. Miller (50%, faculty; Higgs physics, non-minimal SUSY models, LHC phenomenology). **Sheffield**: L. Roszkowski (25%, faculty; SUSY phenomenology, flavour violation, rare heavy quark processes). **Southampton**: S. Moretti (40%, faculty; higher-order QCD and electroweak calculations, Monte Carlo implementation and simulations, Higgs physics in the SM and SUSY theories), D. Ross (25%, faculty; higher-order QCD and electroweak calculations, renormalisation and regularisation, computer algebra and numerical tools).

Most significant recent publications

1) MHV rules for Higgs plus multi-gluon amplitudes, L. J. Dixon, E. W. N. Glover and V. V. Khoze, JHEP **0412** (2004) 015 [hep-th/0411092];.

2) Physics interplay of the LHC and the ILC, G. Weiglein *et al.* [LHC/ILC Study Group Collaboration], hep-ph/0410364, accepted for publication in Phys. Rep., in press.

3) Complete two-loop electroweak fermionic corrections to $\sin^2\theta_{\rm eff}^{\rm lept}$ and indirect determination of the Higgs boson mass, M. Awramik, M. Czakon, A. Freitas and G. Weiglein, Phys. Rev. Lett. **93** (2004) 201805 [hep-ph/0407317].

3 UGR: Granada/Barcelona/Cataluña/Madrid/Valencia/Zaragoza

Research expertise and proposed research: The team is composed of researchers of six Spanish groups working on high energy physics from Granada, Barcelona, Madrid, Valencia and Zaragoza, joining a large fraction of the Spanish groups with expertise on physics at colliders. The team as a whole has experience in SM calculations and in extracting the phenomenological consequences of alternative theories, in particular on different aspects of supersymmetry near the electroweak scale. Thus, for instance, the Granada team has contributed, in collaboration with the Munich node, to the calculation of the supersymmetric contributions to the top form factors. The group at the University of Barcelona has calculated top decays and Higgs production at large colliders, and in collaboration with the Munich and PSI nodes they have worked out sfermion production and decay to one loop order. The Madrid group has concentrated on the effective-Lagrangian approach in supersymmetric theories. Whereas the Zaragoza member has participated together with the Durham and Munich nodes in the calculation of electroweak precision observables in the MSSM at two loops. The Valencia participant has contributed to the study of multiparticle collinear amplitudes at higher orders. Two other main objectives will be to continue the study of the phenomenological implications of extra dimensions and the neutrino physics at colliders and at neutrino factories. To learn about new physics beyond the SM, theoretical calculations must include the SM predictions to the available experimental precision, and then usually beyond the leading order. This type of calculations will also require the complementary expertise of other nodes within the network. All this variety of interests makes the training environment of this node very attractive.

Training environment: The members of the group belong to five Universities among the largest and best ranked ones in education and research in Spain, according to the Ministries of Education and Science, and to the largest Spanish Research Center. All university staff members have responsibilities in teaching in Physics and training of Ph D students. In particular, they collaborate in Programmes for training of Ph D students distinguished by the Spanish Administration by its quality. For example, it collaborates in Doctorate studies in Physics and Mathematics, Programme *FisyMat*, recognised by the Spanish Government by its quality. For further information see: http://www.ugr.es/ fisymat/ . Apart of these general aspects we are involved in the initiatives to further develop and improve the training of young researchers in high-energy physics in Spain. Our group (A. Bueno, F. Cornet) has organised the *Taller de Altas Energías* (TAE) in Granada, May 5-16 (2003) [http://www-ftae.ugr.es/TAE/TAE.htm]. TAE is a yearly workshop aimed at completing the education of young graduated students who are starting their research on experimental/theoretical high-energy physics. The program of the workshop combines courses delivered by international experts and individual work supervised by tutors. The TAE is a collaborative initiative of all the Spanish departments and groups working on high-energy physics. For up to date information see: http://benasque.ecm.ub.es/2005tae/2005tae.htm .

The EU early-stage researcher (24 months) will be recruited by the University of Barcelona, which will then act as a subcontractor, as will eventually do the other four institutions.

Key Scientific Staff and Individual Expertise

Universidad de Granada: F. del Aguila (Team leader, 100%, faculty, *Alternative new physics*), J.A. Aguilar-Saavedra (100%, post-doc, *Multiparticle production*) A. Bueno (100%, faculty, *Neutrino physics*), F. Cornet (50%, faculty, *Photon structure functions*), J.I. Illana (100%, faculty, *Flavour physics*), M. Pérez-Victoria (100%,faculty, *Alternative new physics*), V. Sanz (100%, post-doc, *Effective theories*), 2 research students: J. de Blas, J.L. Padilla (100%). **Universidad de Barcelona**: J. Solà (50%, faculty, *Top and Higgs physics*), J. Guasch (100%, faculty, *SUSY particle production*), S. Peñaranda (100%, post-doc, *Higgs physics*), 2 research students: S. Béjar, R. Sánchez (100%). **Universidad Politécnica de Cataluña**: Ll. Ametller (50%, faculty, *Multiparticle production*). **Universidad Autónoma de Madrid**: M.J. Herrero (100%, faculty, *Effective theories*), 1 research student: E. Arganda (100%). **IFIC-CSIC, Valencia**: G. Rodrigo (50%, faculty, *Multiparticle amplitudes*). **Universidad de Zaragoza**: S. Heinemeyer (100%, post-doc, *SUSY radiative corrections*).

Most significant recent publications

1) TESLA: The superconducting electron positron linear collider with an integrated X-ray laser laboratory. Technical design report. Part 6. Appendices. Chapter 1. Photon Collider at TESLA, ECFA/DESY Photon Collider Working Group (B. Badelek et al.), Int. J. Mod. Phys. **A19** (2004) 5097.
2) Recursive numerical calculus of one-loop tensor integrals, F. del Aguila and R. Pittau, JHEP **0407** (2004) 017.
3) Single top-quark production by direct supersymmetric flavour-changing neutral-current interactions at the LHC, J. Guasch, W. Hollik, S. Peñaranda and J. Solá, [arXiv:hep-ph/0601218].

4 IFJ PAN: Cracow/Katowice/Warsaw

Research expertise and proposed research: The team is composed by researches of Polish groups from the Henryk Niewodniczanski Institute of Nuclear Physics, affiliated to the Polish Academy of Sciences (IFJ PAN); Inst. of Phys. Univ. of Silesia in Katowice and the Physics Department of Warsaw University. All three represent the most important Institutions in Poland in the field. Main areas of activities of the key scientific staff of the Cracow team (IFJ-PAN + JU) are the most precise theoretical calculation, with precision 0.06%, of the luminosity at LEP1 in the form of the Monte Carlo simulators, essential for all precision measurement at LEP1; theoretical calculation of the W–pair production at LEP2 with precision 0.4%; construction of the first and most comprehensive tau-lepton decay simulation library; first QCD calculation of the top quark lifetime and QCD calculations for semileptonic decays of unpolarised and polarised heavy quarks; connecting the see-saw mechanism and bi-maximal neutrino mixing and finally phenomenology of the Higgs search with LHC experiments. The scientific staff of the Katowice team is since years involved in calculation of full electroweak corrections to the two heavy bosons production in e+e- interaction; neutrino physics; calculations of all two loop bosonic corrections to muon lifetimes in the SM. The key researchers of the Warsaw team are active in the field of development of theoretical tools to investigate properties of the Higgs boson and to discriminate the SM Higgs boson from supersymmetric Higgses; development of algorithms for a model-independent reconstruction of fundamental supersymmetry parameters from experimental measurements; search for Higgs particles in SM and the Two-Higgs-Doublet models, and studying their CP-properties, QCD effects and photon processes, anomalous top-quark couplings and phenomenological implications of extra dimensions. The presented variety of the research topics within our team will be maintained and will lead to a very fruitful and intensive participation of the group in the proposed milestones.

Training environment: All teams have large expertise in the training of research students as the respective Scientific Councils have authorities to confer the degrees of PhD, habilitation and Professorships in Physics. Yearly about 10-25 students participate to that program in each of the involved Institutes. The training will be based on the close collaboration between young researcher and staff member involved, while stressing the guidance role of the first one and innovativeness and independence of the latest one. Whenever possible, young researches will be actively involved in a variety of collaborations (both theoretical and experimental) supervised by team members. Typically around 10 or more conferences or workshops together are organised per year by those three Institutes, including topical conferences of Ephiphany, Zakopane, Kazimierz and Ustron, giving young researchers the opportunity to give talks, meet international experts and generally establish their presence in the field.

University of Silesia will act as a subcontractor. The EU early-stage researcher (12 months) will be recruited by the University of Silesia.

Key Scientific Staff and Individual Expertise

IFJ-PAN + JU: E. Richter-Was (Team leader, 50%, staff; Monte Carlo techniques, LHC signals and backgrounds for new physics, realistic simulations for detectors and QCD), S. Jadach (Deputy team leader, 30%, staff; Monte Carlo techniques, parton showers, electroweak effects,realistic observables at LHC and ILC), M. Jezabek (50%, staff; top quark production and decay), W. Placzek (50%, staff; Monte Carlo techniques, parton showers, electroweak effects, realistic observables at LHC and ILC), M. Skrzypek (20%, staff; Monte Carlo techniques, parton showers, electroweak effects, realistic observables at LHC and ILC), Z. Was (50%, staff; Monte Carlo techniques, parton showers, electroweak effects, realistic observables at LHC and ILC, CP sensitive observables at LHC and ILC), K. Golec-Biernat (50 %, staff; parton showers, phenomenology of structure functions), M. Awramik (50%, post-doc; two loop calculations in SM and QCD), M. Worek (50%, post-doc; spin amplitudes for multi particle final states, Monte Carlo techniques), P. Urban (50%, post-doc; phenomenology of b-flavour), R. Matyszkiewicz (50%, post-doc; spin amplitudes for multi particle final states, Monte Carlo techniques), 2 research students) (50%); Thomas Gajdosik (Fisikos Instituts Vilnius, 50% staff; CP phenomena in supersymmetry); **Univ. of Silesia**: M. Zralek (50%, staff; electroweak corrections), H. Czyz (30%, staff; Monte Carlo simulations, hadronic physics), K. Kolodziej (40%, staff; electroweak corrections, spin amplitudes for multi particle final states), J. Gluza (50%, staff; two loop calculations in SM and QCD); **Univ. of Warsaw**: J. Kalinowski (40%, staff; CP-sensitive observables, Higgs boson signatures at LHC and ILC, signatures of supersymmetry at LHC and ILC), M. Krawczyk (50%, staff; CP-sensitive observables, Higgs boson signatures at LHC and ILC, QCD effects and photon processes at LHC and ILC), B. Grzadkowski (40%, staff; CP-sensitive observables, Higgs boson signatures at LHC and ILC, Extra dimension signatures at LHC and ILC), J. Rosiek (40%, staff; signatures of supersymmetry at LHC and ILC, non-minimal supersymmetry).

Most significant recent publications

1) F. Gianotti, E. Richter-Was, M. Mangano *et al.*, “Physics potential and experimental challenges of the LHC luminosity upgrade,” Eur. Phys. J. C **39**, 293 (2005).

2) J. A. Aguilar-Saavedra, J. Kalinowski *et al.*, Supersymmetry parameter analysis: SPA convention and project,” hep-ph/0511344, submitted to Eur. Phys. J. C.

3) J. Gluza, A. Hoefer, S. Jadach and F. Jegerlehner, “Measuring the FSR-inclusive pi+ pi- cross section,” Eur. Phys. J. C **28**, 261 (2003)

5 IST: Lisbon

Research expertise and proposed research: The Lisbon group belongs to IST - Instituto Superior Técnico, one of the leading portuguese institutions in Science and Technology. The Group includes the majority of physicists working in Portugal in the topics of this project and has expertise in some of the hottest subjects in Theoretical Particle Physics. These include the study of CP violation in both hadronic and leptonics sectors, Supersymmetric extensions of the Standard Model (in particular with R parity violation), Neutrino Physics (including lepton flavour violation, baryogenesis through leptogenesis, etc.). We have also been working on model building (e. g. extended gauge groups, models with extra dimensions, models with discrete symmetries). We are particularly interested in the phenomenological implications testable at the next Colliders such as the LHC and possibly the ILC. This is a very active field and has been the subject of intense investigation by many different groups. In the last few years the Lisbon group has established very fruitful collaborations with several of the nodes belonging to the proposed network. Examples are Granada, Durham, Vienna, Japan and we expect to successfully extend these collaborations, in the future, to some of the other nodes. The Group intends to contribute actively to the project with special emphasis on the following milestones: study of standard and non-standard top interactions, study of semileptonic and radiative B decays, Higgs production and identification at the LHC, new sources of CP violation in extended Higgs sector,study of SUSY particle production at the LHC, CP violating effects in SUSY particle production and decays, study of flavour violation effects in the MSSM, impact of SUSY particles on the determination of the CKM mixing matrix, constraints from precision B and K physics on the SUSY spectrum, study of CP violation in the leptonic sector and leptogenesis, study of neutrino physics in SUSY and other extensions of the SM, study of quantum effects of Kaluza-Klein towers.

Training environment: In the past fifteen years, our group has trained a considerable number of graduate students and postdoctoral fellows. In our group, there is a tradition of collaboration among students, postdocs and more senior permanent members. This has led to a large number of publications written in several different joint collaborations. The vast majority of the young people trained within the group have been able to find research positions after finishing their training with the Lisbon group, i.e., postdoctoral positions abroad or tenure track positions either abroad or in Portugal. Several of these already have permanent positions.

Our university in Lisbon adopted the 3+2 Bologna format with the offer of regular graduate courses in the second two year block in field theory, theory of unification and other important subjects. Furthermore, we have a long experience in organizing International Schools, Workshops and Advanced Graduate Minicourses for our sudents and postdocs. We organize an International Autumn School, almost every year, alternating with other groups and several of these have been on subjects related to this Project. We have also organized NATO and EC funded Schools and Workshops. Our Schools have had strong international participation both by lecturers and students. We invite leading scientists to give sets of lectures on important subjects (mini-courses). Apart from that, we have a lively programme of regular seminars. We are looking forward to starting training graduate students in collaboration with other nodes.

Key Scientific Staff and Individual Expertise
Faculty: M. N. Rebelo 80% (Team leader), Flavour Physics, CP violation; G. C. Branco 80% (Deputy team leader) Flavour Physics, CP violation; L. Lavoura 50%, Flavour Physics, CP violation; P. A. Parada 40%, Flavour Physics, CP violation; João Pulido 50%, Neutrino Physics; J. C. Romão 40%, SUSY, Neutrino Physics; João P. Silva 40%, CP violation, B Decays; J. I. Silva-Marcos 80%, Flavour Physics, CP violation; **Post-doctoral fellows:** Bhag C. Chauhan 50%, Neutrino Physics; David Emmanuel-Costa 50%, Flavour Physics, CP violation; R. Gonzalez Felipe 50%, Leptonic CP violation; Gregory Moreau 50%, Neutrino Physics, Extra Dimensions; Miguel Nebot 50%, Flavour Physics, CP Violation; Marco Picariello 50%, Neutrino Physics; Pavel Fileviez Perez 50%, GUTs, SUSY, Flavor Physics; EU post-doc 50%; **PhD Students:** EU student 25% , two local students, 75% each.
Most significant recent publications:
1) G. C. Branco, M. N. Rebelo and J. I. Silva-Marcos, "CP-odd invariants in models with several Higgs doublets," Phys. Lett. B **614** (2005) 187 [hep-ph/0502118].
2) J. A. Aguilar-Saavedra, F. J. Botella, G. C. Branco and M. Nebot, "The size of chi = arg(-V(ts) V(tb)* V(cs)* V(cb)) and physics beyond the standard model," Nucl. Phys. B **706** (2005) 204 [hep-ph/0406151].
3) G. C. Branco, R. Gonzalez Felipe, F. R. Joaquim and M. N. Rebelo, "Leptogenesis, CP violation and neutrino data: What can we learn?," Nucl. Phys. B **640** (2002) 202 [hep-ph/0202030].

6 U-PSUD: Orsay/Montpellier/Annecy

Research expertise and proposed research: The Orsay, Montpellier and Annecy groups are interested in aspects of Higgs boson and supersymmetric particle searches at high-energy colliders and in astroparticle experiments. The research topics include electroweak and QCD radiative corrections to Higgs boson production and decays in the SM and in the MSSM; new techniques for perturbative QCD and twistor methods; models of supersymmetry breaking other than the minimal SUGRA model (anomaly and gauge mediated SUSY-breaking models, the next–to–minimal SUSY extension of the SM, etc.) and their implication for searches of Higgs particles and supersymmetric particles at the Tevatron, LHC and future e^+e^- colliders; exploring models of extra dimensions and Z' bosons at the LHC; the study of the Higgs boson couplings including the self-couplings; constraints on supersymmetric models from cosmological considerations and impact on collider physics; direct/indirect searches for supersymmetric Dark Matter.

The Orsay, Montpellier and Annecy groups are actively developing tools for collider physics and astroparticle physics. In particular, we are developing codes for calculating the spectrum of superparticles and Higgs bosons in the MSSM (the Fortran code Suspect) and for their decay modes (the fortran codes SDECAY and HDECAY and NMHDECAY for the decays of suspersymmetric particles and Higgs bosons). We have developed a code for the calculation of the relic density of dark matter in Supersymmetry as well as various collider constraints on supersymmetric models (the code micrOMEGAs); it is to be extented to include the direct/indirect detection of supersymmetric Dark Matter. Finally, with the GRACE collaboration in KEK, the Annecy group is developing a system for automatic calculations of tree-level and one-loop processes in the SM and in the MSSM.

We are involved in several working groups: the Euro-GDR Supersymmetry network (A. Djouadi was convenor of the MSSM group; J.L. Kneur and G. Moultaka are convenors of, respectively, the SUSY at colliders and Dar Matter groups); the ECFA workshop for e^+e^- colliders (G. Belanger is convenor of the SUSY group and A. Djouadi was convenor of the Higgs group and is now a convenor of the cosmology group); the Les Houches Workshop for Physics at TeV Colliders (G. Belanger and F. Boudjema are in the organising comitee, A. Djouadi was convenor of the Higgs group).
Training environment: The tenure staff at Orsay, Montpellier and Annecy who are involved in the project have a good experience in supervising PhD studends and postdocs. The Les Houches workshop attracts many PhD students and postdocs who have the opportunity to discuss with many specialists in the field.
Key Scientific Staff and Individual Expertise
Orsay: A. Djouadi (Team leader, 60%, staff): SUSY, SM/MSSM Higgs and Dark Matter phenomenology, radiative corrections; E. Dudas (50%, staff): model building, SUSY and extra dimensions; U. Ellwanger (50%, staff): model building, extended SUSY models; Y. Mambrini (50%, staff): phenomenology of SUSY Dark Matter; D. Kosower (50%, staff, SPhT/CEA, Saclay): new techniques for perturbative QCD, twistors; 1 EU post-doc (50%), 1 EU PhD student (50%), 1 post-doc (50%), 1 PhD student (50%); **Montpellier:** J.L. Kneur (50%, staff): SUSY and Higgs phenomenology, MSSM spectrum calculation; G. Moultaka (30%, staff): Dark matter and SUSY phenomenology; C. Hugonie (50%, staff): phenomenology of extended SUSY models; **Annecy:** G. Bélanger (Deputy Team leader, 50%, staff): SUSY and DM phenomenology, radiative corrections; F. Boudjema (50%, staff): Higgs

and DM matter searches, radiative corrections, automatic calculations; M. Mühlleitner (50%, staff): Higgs phenomenology, radiative corrections; P. Slavich (50%, staff): SUSY and Higgs, radiative corrections.

Most significant recent publications

1) Precise determination of the neutral Higgs boson masses in the MSSM, B.C. Allanach, A. Djouadi, J.L. Kneur, W. Porod and P. Slavich, JHEP 0409:044,2004

2) Electroweak corrections to Higgs production through ZZ fusion at the linear collider, F. Boudjema, J. Fujimoto, T. Ishikawa, T. Kaneko, K. Kato, Y. Kurihara, Y. Shimizu and Y. Yasui, Phys.Lett.B600:65-76,2004

3) NMHDECAY: A fortran code for the Higgs masses, couplings and decay widths in thE NMSSM. By U. Ellwanger, J.F. Gunion and C. Hugonie, JHEP 0502:066,2005.

7 MPG: Munich/Karlsruhe/Würzburg

Research expertise and proposed research: The MPG node includes scientists, besides from the Max-Planck-Institut für Physik (MPI) in Munich, from the Universities at Karlsruhe and Würzburg. The team leader had until May 2002 a chair at Karlsruhe University. Members of the node have been actively involved in LHC and Linear Collider Workshops as conveners; in particular W. Hollik and S. Dittmaier are the conveners of the European LoopVerein of the ECFA Linear Collider Workshop, which is the study group for developing tools for precision calculations, with links to the US LoopVerein (US node).

The MPI node has considerable and longstanding expertise in the calculation of radiative corrections to precision observables and application to precision tests of the Standard Model and beyond, and in development of calculational techniques, for both cases of multi-loop problems and many-particle processes including also Monte-Carlo generators, with applications to processes at electron-positron and hadron colliders. In order to facilitate these calculations in practice and to open new fields for the application, algebraic computer programs have been developed and are planned to be further upgraded and extended to more general models, in particular the program package Feynarts/FormCalc for automatizing loop calculations in the SM and MSSM. Among the tools for high-energy colliders being developed is the code for precision calculations in the MSSM Higgs sector, FeynHiggs, which is to be extended for comprising also CP-violation in the MSSM.

Fields of expertise and future research are: production and decay processes of SM particles at hadron and electron-positron colliders, including higher-order electroweak and QCD contributions; calculation of precision observables in the SM and in the MSSM and precision tests of the MSSM; radiative corrections in the Higgs sector of the MSSM with production and decay of non-standard Higgs bosons; production and decays of supersymmetric particles; higher-order electroweak radiative corrections beyond one loop; calculations of cross sections for 4-fermion final states in electron-positron annihilation and Monte Carlo generators to one-loop order; calculations of cross sections in electron-positron annihilation up to 6 fermion final states and Monte Carlo generators, improved by radiative corrections; renormalization of the MSSM; one-loop calculations for susy-particle masses, production, and decay processes; predictions from non-commutative space-time models.

Training environment: The tenure staff at MPI involved in the project are experienced in teaching and supervising graduate and undergraduate students as well as postdocs. There are close contacts to the two big Universities in Munich with activities in HEP phenomenology, Munich University (LMU) and Technical University (TUM); students are usually linked to either LMU or TUM. A Graduate School for Particle Physics by the Deutsche Forschungsgemeinschaft (DFG) and an International Max Planck Research School by the Max-Planck-Gesellschaft (MPG), for the three institutions LMU, TUM, and MPI, are established, involving a regular PhD study course with a three-years program, with regular classes and seminars on topics in theoretical and experimental particle physics. Moreover, there is close contact also with students and researchers of other groups at MPI, e.g. experimental particle physics for LHC, astroparticle and neutrino physics.

At Karlsruhe and Würzburg, the staff has longstanding teaching and supervising experience. At both Karlsruhe and Würzbug Universities, DFG Graduate Schools on Particle Physics and Astroparticle Physics are established; at Würzburg also a new Elite Study Course has been approved recently with close links to the MPI.

Key Scientific Staff and Individual Expertise

MPI: W. Hollik (100%, team leader, precision calculations in the SM and supersymmetric extensions), T. Hahn (100%, staff, computer algebra and numerical tools), S. Dittmaier (100%, staff, electroweak and QCD radiative corrections), J. Wess (50%, staff, non-commutative space-time), A. Hoang (50%, staff, top physics, higher-order corrections), S. Pozzorini (100%, post-doc, electroweak higher-order corrections), 1 EU post-doc (50%), 2 research students (100%), 1 EU research student (50%). **Karlsruhe**: J.H. Kühn (40%, staff, multi-loop calculations), D. Zeppenfeld, (100%, staff, Higgs physics), K. Chetyrkin (50%, staff, multi-loop calculations), Anna Kulesza

(50%, post-doc, electroweak radiative corrections), Alexander Penin (50%, post-doc, multi-loop calculations), 2 research students (50%). **Würzburg**: M. Böhm (100%, staff, electroweak radiative corrections), H. Fraas (100%, staff, supersymmetry phenomenology), T. Ohl (100%, staff, Monte Carlo generators), M. Czakon (100%, staff, multi-loop calculations), 2 research students (100%).

Most significant recent publications

1) Electroweak precision observables in the minimal supersymmetric standard model. S. Heinemeyer, W. Hollik, G. Weiglein, hep-ph/0412214, accepted for publication in Physics Reports, in press.

2) Higgs-mass dependence of the effective electroweak mixing angle $\sin^2\theta_{\rm eff}$ at the two-loop level. W. Hollik, U. Meier, S. Uccirati, Phys. Lett. B **632** (2006) 680 [hep-ph/0509302].

3) Two-loop electroweak logarithms in four-fermion processes at high energy. B. Jantzen, J.H. Kühn, A.A. Penin, V.A. Smirnov, Nucl. Phys. B **731** (2005) 188 [hep-ph/0509157]

8 RU: Nijmegen/NIKHEF/Leiden/Louvain-la-Neuve

Research expertise and proposed research: Nijmegen University will be an associated contractor with team members from Nijmegen and external team members from the NIKHEF, Amsterdam; from the university of Leiden; and from the university of Louvain (Belgium). The particular expertise of the team members falls broadly in the field of precision phenomenology at high-energy colliders.

(1) Higher-order corrections: Members of the team have played a major role in the phenomenology of SppS, LEP1, LEP2, Tevatron, LHC and (future) linear collider physics. This includes event generators for radiative corrections at LEP1 and LEP2 processes (Z-mediated and W^+W^--mediated final states, respectively). As an example we mention the EXCALIBUR code for LEP2 physics, which in its updated form NEXTCALIBUR has played an important role in the analysis of the LEP2 data. As an accompanying result, team members have, in collaboration with other subscribers to this proposal, obtained seminal results in implementing the subtle effects of running boson widths in realistic Monte Carlo approaches using the fermion-loop scheme. This has, more recently, led to the more generally applicable effective-Lagrangian approach for including such effects in more general processes. Another field of expertise is the effect of "large logarithms" at future linear colliders, where the mass of the W and Z bosons become, in effect, small enough to warrant a careful resummation to all orders of the most important perturbative corrections. This involves a subtle and difficult treatment of the resummation for different boson polarization.

Also, one external team member is one of the world's acknowledged leaders in the field of QCD higher-order corrections. He is the author of FORM, the foremost computer algebra program for performing such calculations in particle physics. The latest achievement in this field is the computation of the splitting functions and coefficient functions in deep-inelastic scattering (DIS) at third order of massless perturbative QCD. Currently he is involved in the automatic computation of processes at the one loop level for the LHC collider.

Another achievement in the field of QCD has been the recent finishing of a complete tree-level Monte Carlo generator for multijet final states at hadron colliders, where the number of jets produced (up to 8 jets has been achieved) calls for a fast and efficient evaluation of literally tens of millions of Feynman diagrams per generated event.

Further team expertise lies in providing more accurate predictions of heavy quark, jets and Higgs boson production characteristics at one-loop order, recently also in the context of NLO event generation interfaced with parton showers (MC@NLO), as well as in the development and application of all-order resummation techniques for cross sections involving near-threshold particle production.

(2) Numerical methods: The group plays a leading role in the study of algorithms for efficient phase space sampling of complicated cross sections. In the past this has led to "optimal" algorithms such as RAMBO (for uniform phase space sampling) and SARGE (for sampling according to QCD antenna structures). This also entails the study of so-called discrepancy measures as probes of the (non)uniformity of actually generated samples vis-a-vis the idealised one. Currently, studies of the computational complexity of the so-called ALPHA algorithm of Caravaglios and Moretti are under way, with the aim of improving the efficiency, and obtaining benchmark properties of future applications of this algorithm to include loop diagrams.

Training environment: The Nijmegen group is part of the Institute for Mathematics, Astrophysics and Particle Physics of Nijmegen University, and of the Dutch Research School of Theoretical Physics. As a part of the Physics department of Nijmegen University, the group organizes graduate as well as post-graduate training in the research field. The group contains 3 PhD students and a number of graduate students.

The Research School organizes yearly schools attracting PhD students from all over the Netherlands and bordering countries. In addition, the group members collaborate in the Graduate School in Physics at Colliders organized by the Torino group. At both previous occasions of this school the group members have lectured.

NIKHEF, the Dutch national institute for high-energy physics, is an active research center. It provides an excellent training environment for young researchers, and offers in addition a wide range of topical graduate courses and colloquia.

Key Scientific Staff and Individual Expertise

University of Nijmegen: R. Kleiss (dept. chair, staff, electroweak and QCD Monte Carlos, multiparticle production, 100%), W. Beenakker (staff,electroweak precision calculations, 100%), A.Lazopoulos (PhD student, 50%), **NIKHEF**: J. Vermaseren (staff, computer algebra, QCD precision calculations, 50%), E. Laenen (staff, QCD precision calculations and Monte Carlo, 100%), P. Motylinski (PhD student, 100%), **University of Leiden**: W. van Neerven (staff, electroweak and QCD precision calculations, 50%), **University of Louvain-la-Neuve**: F. Maltoni (staff. QCD and electroweak precision calculations, neutrino physics, 100%)

Most significant recent publications:

1) S. Moch, J. A. M. Vermaseren and A. Vogt, "The three-loop splitting functions in QCD: The non-singlet case," Nucl. Phys. B **688** (2004) 101 [hep-ph/0403192].

2) P. D. Draggiotis, R. H. P. Kleiss, A. Lazopoulos and C. G. Papadopoulos, "Diagrammatic proof of the BCFW recursion relation for gluon amplitudes in QCD," in press, hep-ph/0511288.

3) E. Laenen and L. Magnea, "Threshold resummation for electroweak annihilation from DIS data," Phys. Lett. B **632** (2006) 270 [hep-ph/0508284].

9 INFN: Roma/Padova/Milano

Research expertise and proposed research: The members of the INFN team belong to the Theory Groups of several institutions located in different cities: in Rome, to the Universities, Università di Roma "La Sapienza" and Università di Roma Tre, and to the INFN Sections, Sezione di Roma and Sezione di Roma III; in Padua, to the Università di Padova and to the INFN, Sezione di Padova; in Milan, to the Università di Milano and to the INFN, Sezione di Milano. All the scientists of the team are associated with the National INFN Theory Group ("Gruppo IV"). The INFN team presents an internationally recognized expertise in the fields of precision calculations in the Standard Model, Higgs and flavour physics and phenomenological implications of new physics beyond the SM, in particular in the supersymmetric (SUSY) extensions of the SM.

Members of the team have significantly contributed to the subject of precision calculations, in particular to the topics of determination of electroweak parameters from two-loop observables, resummation of high-energy logarithms in hadronic processes and studies of radiative B decays. The subject of discovery physics has been extensively investigated by participants of the team, with particular attention to the areas of Higgs discovery, neutrino physics, flavour and supersymmetric phenomenology. Team members have studied the two-loop electroweak corrections to the Higgs production cross section via the gluon fusion process. The issue of lepton number violation, in particular neutrino masses and oscillations and lepton flavour violation processes, has been also investigated by participants of the team. One interesting result in this area has been the proposal of a model for lepton masses based on the flavour symmetry group $A_4 \times U(1)$ that reproduce the so-called tri-bimaximal lepton mixing scheme and is in excellent agreement with the current experimental data on neutrino oscillations. In the area of flavour and supersymmetric phenomenology members of team have produced very systematic and thorough analyses of the unitarity triangle in the SM and in models beyond it. This program has been conducted in strict contact with physics experimentalists giving rise to a collaboration called "UTfit Collaboration". Other contributions in this area include the analysis of Flavour Changing Neutral Current and CP violation constraints on low-energy supersymmetry and the individuation of the most promising processes where to look for indirect SUSY signals in leptonic and hadronic physics.

The future research of the members of the team will focus on the acquirement of all of the project objectives, with particular attention to the areas of precision calculations and discovery physics.

Staff scientists with a commitment less than 50% are experts in scientific fields, like, for example, astroparticle physics and cosmology, close to the ones investigated by the present proposal. They have long standing collaborations with other members of team and can play an important role in establishing the project objectives in the area of discovery physics.

Training environment: The various groups of the team operate within large Physics Departments that offer both undergraduate and graduate programs. The staff member of the team participate to the teaching and training activity of the Departments supervising students and offering courses both at basic and advanced level. We paid a special attention to the training of post-docs who are encouraged to take care of journal club activities and to present the results of their research at international meetings.

Key Scientific Staff and Individual Expertise

Rome: G. Degrassi (100%, Team leader, staff, higher order corrections in the electroweak theory), M. Ciuchini (50%, staff, flavour physics), E. Franco (100%, staff, flavour physics), M. Greco (80%, staff, resummation of high-energy logarithms in hadronic processes), V. Lubicz (50%, staff, flavour physics and QCD on the lattice), B. Mele (80%, staff, production and decays of supersymmetric particles and phenomenology of theories with extra dimensions), L. Silvestrini (40%, staff, flavour physics), 1 EU post-doc (50%), 1 PhD student (100%); **Padua:** M. Passera (100%, Deputy Team leader, staff, precision electroweak physics), A. Brignole (40%, staff, lepton flavour violation processes in supersymmetric models), F. Feruglio (40%, staff, neutrino physics), A. Masiero (10%, staff, astroparticle physics and flavour physics), 1 EU student (50%), 1 PhD student (100%); **Milan:** S. Forte (100%, staff, resummation of high-energy logarithms in hadronic processes), A. Vicini (100%, staff, higher order corrections in the electroweak theory).

Most significant recent publications

1) U. Aglietti, R. Bonciani, G. Degrassi and A. Vicini, "Two-loop light fermion contribution to Higgs production and decays," Phys. Lett. B **595** (2004) 432.
2) M. Bona *et al.* [UTfit Collaboration], "The 2004 UTfit collaboration report on the status of the unitarity triangle in the standard model," JHEP **0507** (2005) 028.
3) G. Altarelli and F. Feruglio, "Tri-bimaximal neutrino mixing from discrete symmetry in extra dimensions," Nucl. Phys. B **720** (2005) 64.

10 UTDFT: Torino

Research expertise and proposed research: Torino University will be an Associate Contractor with team members from Torino INFN and external team members from the University of Bologna and Bologna INFN. The members of our unit have particular expertise in the area of precision tests of the Standard Model and beyond for the new hadron (LHC) and electron – positron colliders (ILC). They are also expert in the construction of realistic event generators and semi-analytical Monte Carlo for collider physics.

LHC Tevatron and ILC physics. The first version of the MC event generator `PHASE` for six fermion final states at LHC has been released. It has been employed (within CMS), to analyze boson boson fusion processes at LHC. PHASE will be extended to cover all six parton final states at $O(\alpha_{\rm em}^6 + \alpha_{\rm s}^2\,\alpha_{\rm em}^4)$ and possible alternative EWSB scenarios. Top, Higgs and boson boson scattering physics will be studied in detail. The code `ALPGEN` (see http://mlm.home.cern.ch/m/mlm/www/alpgen) is the result of a collaboration Torino, INFN and CERN. Scope is creating, upgrading and maintaining an event generator as a fundamental tool to perform realistic SM studies of final states with many jets, gauge bosons, photons and Higgs particles. `ALPGEN` is already successfully used at TEVATRON, being the official program of CDF and DO at FERMILAB, and it is foreseen to be one of the main tools to perform the analysis of the very intricate signatures expected at LHC.

Electroweak radiative effects on four-fermion physics at the LHC. One-loop logarithmic EW corrections have been implemented in a Monte Carlo and computed for several processes. The inclusion of the EW radiative effects will be extended at the ILC.

QCD-Electroweak: Evaluation of cross-section at NNLO in α_s for e^+e^- collisions, applications and extensions to LHC. One-loop amplitudes for Higgs production (+ multi -jets) in hadronic collisions. Implementation of $pp \to HW(Z)$ in MC(at)NLO; implementation of $pp \to qqWW \to qqH$. Distributions in gluon fusion and Vector Boson Fusion in Higgs production. We plan to extend soft gluon resummation techniques in order to improve SM predictions for the Higgs production cross section, and in order to estimate power-suppressed effects which affect, for example, the determination of the jet energy scale at hadron colliders.

Multi-loop: Automatic generation and evaluation of multi-loop Feynman diagrams in the multi-scale scenario with a built-in test of the whole set of WST identities (the `Graphshot` code in FORM). Efficient evaluation of tensor integrals. Fast and efficient numerical evaluation of one-loop multi-leg (up to six) diagrams. Fast and efficient numerical evaluation of two-loop two- and three-point functions including infrared configurations (the Fortran 95 code `Loopback`). Complete two-loop renormalization of the standard model; very accurate predictions for physical observables: running of $\alpha_{\rm em}$, complex poles for W, Z, H bosons and for the top quark, $H \to \gamma\gamma(gg)$. Numerical solution of differential equations satisfied by master integrals related to a Feynman graph. On-shell form factors of the electron for arbitrary momentum transfer and finite electron mass, at two loops in QED. Harmonic

Polylogarithms. Analytic continuation of two-loop four-point functions with one off-shell external leg and internal massless propagators from the Euclidean region of space-like $1 \to 3$ decay to Minkowskian regions relevant to all $1 \to 3$ and $2 \to 2$ reactions with one space-like or time-like off-shell external leg. Two-loop master integrals and unrenormalized matrix elements for hadronic vector-boson-plus-jet production and deep inelastic two-plus-one-jet production.

NLO SUSY effects in radiative and rare B decays: Impact of SUSY particles on the determination of the CKM mixing matrix. Constraints from precision B and K physics on the SUSY spectrum. For what concerns the bottom quark, the experimental results at the B factories has entered a new phase of precision measurements, that will continue at the LHC. Precision calculations in semileptonic and radiative decays have become necessary. We will study strong and electroweak corrections to these processes and their impact on the determination of the CKM matrix elements and the quark masses.

Training environment: The group in Torino is part of the Department of Theoretical Physics with team members from INFN and external team members from the University of Bologna. Since 2001 the University of Torino has organised a new teaching structure, ISASUT (International School of Advanced Studies of the University of Torino). ISASUT is an advanced doctorate research institute that organises courses and promotes research and training activities aimed at integrating various disciplines.

The Torino group has typically 4 research students (2 theo. and 2 exp.) that are partly financed by MIUR (Ministero dell'Universita' e della Ricerca Scientifica e Tecnologica) and partly by ISASUT under a special program for foreigner students. The students have an advisor at Torino and spend part of their time in partner institutions.

The Torino group will continue organizing the *Graduate School in Physics at Colliders* with the third edition in 2007. Members of the Torino group are in the organizing committee of the program 'Advancing Collider Physics: from Twistors to Monte Carlos' that will take place in the Autumn 2007 (10 weeks) at the Galileo Institute in Florence.

Key Scientific Staff and Individual Expertise

Torino University: G. Passarino (Team leader, 100%, faculty, multi-loop, LHC, ILC), E. Accomando (50%, post-doc, LHC Monte Carlo), E. Maina (100%, faculty, EWSB, LHC Monte Carlo), Lorenzo Magnea (100%, faculty, QCD resummation), E. Migliore (50%, faculty, CMS (experimental)), R. Pittau (100%, faculty, electroweak, LHC Monte Carlo), S. Uccirati (50%, post-doc, EW multi-loop), C. Sturm (25%, post-doc, QCD multi-loop), EU post-doc (50%), 2 (th.) research students (100%), 2 (exp.) research students (50%), 1 EU research student (50%); **Torino INFN:** A. Ballestrero (Deputy Team leader, 100%, staff, EWSB, LHC Monte Carlo), V. Del Duca (100%, staff, QCD, NNLO, twistors), P. Gambino (100%, staff, B physics, NLO SUSY), C. Mariotti (50%, staff, CMS (experimental) VV-fusion); **Bologna University:** E. Remiddi (50%, faculty, analytical multi-loop), **Bologna INFN:** M.Caffo (50%, staff, analytical multi-loop).

Most significant recent publications

1) A. Ferroglia, M. Passera, G. Passarino and S. Uccirati, All-purpose numerical evaluation of one-loop multi-leg Feynman diagrams, Nucl. Phys. B **650** (2003) 162.
2) L. W. Garland, T. Gehrmann, E. W. Glover, A. Koukoutsakis and E. Remiddi, Two-loop QCD helicity amplitudes for $e^+e^- \to$ 3jets, Nucl. Phys. B **642** (2002) 227.
3) Z. Bern, V. Del Duca, L. J. Dixon and D. A. Kosower, All non-maximally-helicity-violating one-loop seven-gluon amplitudes in N = 4 super-Yang-Mills theory, Phys. Rev. D **71** (2005) 045006.

11 HEPHY: Wien/Zagreb

Research expertise and proposed research: All contributing people of the Institute for High Energy Physics (HEPHY) of the ÖAW and the Theoretical Physics Division at the University of Vienna (except Walter Grimus) form the so called "Vienna SUSY Group", which has a long-lasting experience in the phenomenology of SUperSYmmetry going back to the 1980's. The group was actively involved in various international workshops on physics at LHC, LEP, HERA, in the recent ECFA-DESY Linear Collider Workshops, as well as in the world wide SPA (SUSY Parameter Analysis) project. A. Bartl and W. Majerotto were convenors of the working group on supersymmetry. Werner Porod developed the computing tool SPheno for the calculation of properties of SUSY particles. The Vienna SUSY Group will contribute to the attainments of the tasks of this project: We want to calculate the full (electroweak and QCD) one-loop corrections to the production of SUSY particles in e^+e^- collisions and also to their decays widths, which are important for the evaluation of LHC experiments. A particular topic will again concern the decays of Higgs bosons into supersymmetric particles, including all (one-loop) corrections. By taking complex SUSY parameters we want to explore CP violating effects in supersymmetric particle reactions at LHC and a future linear collider. By assuming the mass matrices of sleptons non-flavour diagonal, interesting signatures of lepton flavour violation will be studied at future particle colliders. Walter Grimus studies models for neutrino masses and mixing with emphasis on family symmetries. He investigates connections between symmetry groups and features following thereof like maximal atmospheric neutrino mixing, small mixing angle θ_{13}, specific neutrino mass spectra, etc. To test the models he considers, apart from results of neutrino oscillation experiments, predictions for neutrinoless double-beta decay, flavour-changing neutral interactions, properties of non-SM particles appearing in the models and leptogenesis.

The group of Josip Trampetić, belonging to the Theoretical Physics Division at the Rudjer Boskovic Institute (IRB) in Zagreb, has experience in electroweak interactions in heavy-quark physics, neutrino physics, soliton physics, as well as in perturbative QCD calculations beyond the leading order. Recently, they concentrated more on the space-time structure at extremely short distances. They have focused on noncommutative space-time and have learned how to handle it in the framework of deformation quantization. They already investigated phenomenological consequences of a number of noncommutative QFT model they constructed. They will continue along this line. Furthermore, the team members are highly experienced in the state of art scientific tools for complex computations.
Training environment: Staff members of HEPHY and faculty members of the University of Vienna are experienced in teaching and supervising students and post-docs. By concentrating its research on special topics of SUSY, this group is very compact having a strong cooperative spirit. Hence, it offers an excellent training environment for young researchers. The IRB theorists supervise graduate and post-graduate students from the neighbouring University (PMF Zagreb), and organize schools and workshops (Adriatic Meetings and LHC Days-Split), thus offering an environment where students can interact with world-wide recognized theoretical and experimental physicists.
Key Scientific Staff and Individual Expertise
(keywords: I $\sim$ SUSY phenomenology, II $\sim$ radiative corrections in SUSY, III $\sim$ CP-violation in SUSY, IV $\sim$ lepton flavour violation, V $\sim$ R-parity violation in SUSY, VI $\sim$ ν-physics, VII $\sim$ noncommutative QFT)

HEPHY Vienna: H. Eberl (80%, node coordinator, staff, I-III), K. Kovařík (80%, post-doc, I,II), W. Majerotto (50%, director of institute, I-IV), C. Weber (80%, post-doc, I,II), 2 graduate students (100%, I-III), 1 EU post-doc (50%), 1 EU graduate student (25%), **University Vienna:** A. Bartl (50%, faculty, I,III,IV), W. Grimus (50%, staff, IV,VI), T. Kernreiter (50%, post-doc, I,III,IV), W. Porod (50%, at present at IFIC Valencia, I,III-V), 1 graduate student (100%,I,III), **IRB Zagreb:** J. Trampetić (100%, team leader,VII), G. Duplančić (50%, staff,VII), B. Melić (50%, deputy team leader,VII), B. Nizić (50%, staff,VII), K. Passek-Kumerički (50%, staff,VII), 1 graduate student (100%,VII)
Most significant recent publications
1) The Standard Model on Non-Commutative Space-Time: Electroweak Currents and Higgs Sector, B. Melić, K. Passek-Kumerički, J. Trampetić, P. Schupp, M. Wohlgenannt, hep-ph/0502249, EPJ C42, 483 (2005).
2) Precise predictions for chargino and neutralino pair production in e^+e^- annihilation, W. Öller, H. Eberl, W. Majerotto, hep-ph/0504109, Phys. Rev. D71, 115002 (2005).
3) A model realizing the Harrison-Perkins-Scott lepton mixing matrix, W. Grimus, L. Lavoura, hep-ph/0509239, JHEP 01 (2006) 018

12 PSI: Paul Scherrer Institut/Zurich/ETH

Research expertise and proposed research: The PSI team consists of scientists from PSI and the nearby universities in Zurich. It includes practically all leading theorists working on colliders physics in Swiss universities and research centers.

The PSI group has considerable experience in precision calculations for electroweak observables. This includes both QCD corrections and electroweak corrections within the Standard Model and extensions thereof. In the past years, in particular, the electroweak radiative corrections to Higgs-production processes, such as $e^+e^- \to \nu\bar{\nu}H, t\bar{t}H$, and to 4-fermion production in electron-positron annihilation have been calculated and implemented into Monte Carlo generators. These calculations belong to the most involved one-loop calculations in the electroweak Standard Model that have been performed so far and required the improvement of existing and the development of new calculational techniques. Moreover, QCD corrections to the production of Higgs bosons and supersymmetric particles at hadron colliders that are relevant for experiments at Tevatron and LHC have been evaluated. A further important research topic was the investigation of leading-logarithmic electroweak corrections at high energies, and their evaluation for gauge-boson pair production processes at the LHC. The current research interests of the groups at the ETH and the University of Zurich overlap with the programme carried out at PSI. In particular, research at the University involves the development of new techniques for higher-order corrections in quantum field theory and their application to QCD processes at present and future colliders.

In the future the group will continue to study the physics at hadron colliders (Tevatron, LHC) and electron-positron linear colliders. One central focus will be the evaluation of QCD corrections for the production of Higgs bosons and supersymmetric particles at hadron colliders. Furthermore, electroweak corrections to important processes at the LHC, in particular Higgs-production, will be calculated. A particular interest of the group at the university of Zurich are the QCD two-loop corrections to benchmark processes (jet production and heavy quark pair production) at the LHC. As far as electron-positron physics is concerned, we are planning to complete the calculation of the full electroweak one-loop corrections to four-fermion production processes and to evaluate the leading corrections to six-fermion production processes. Furthermore our group will continue the study of leading-logarithmic electroweak corrections and try to develop methods for their resummation. All these enterprises require the development of new calculational techniques and tools.

Training environment: The Paul Scherrer Institut is an active research center which provides an excellent training environment for young researchers. It offers excellent computing and library facilities. The staff members at PSI and the faculty members at the universities in Zurich are experienced in teaching and supervising students and post-docs. Six post-docs at PSI and at Zurich contribute to the training of the students. Graduate students at PSI typically have an advisor at PSI and one at a ETH or University of Zürich and spend part of their time in both institutes thus profiting from the training opportunities in both places.

The PSI group is closely connected to the University of Zürich and ETH Zürich. A. Denner and M. Spira are regularly lecturing there on QCD, Standard Model, and Physics beyond the Standard Model. The universities in Zürich offer many specialized lectures also on topics in collider physics. The PSI group organizes every two years a particle physics summer school for graduate students in Zuoz, Engadin.

Key Scientific Staff and Individual Expertise

PSI: A. Denner (Team leader, 100%, staff; electroweak precision calculations), M. Spira (Deputy Team leader, 100%, staff; QCD corrections to Higgs and SUSY processes), M. Ciccolini (100%, post-doc; electroweak precision calculations), B. Jantzen (100%, post-doc; leading electroweak logarithms), H. Rzehak (100%, post-doc, supersymmetric corrections), 1 EU post-doc (50%), 1 EU graduate student (50%), 5 research students (100%). **University of Zürich**: T. Gehrmann (60%, faculty; higher order QCD), D. Wyler (30%, faculty; supersymmetry and heavy flavours), A. Freitas (100%, post-doc; higher-order electroweak corrections), A. Ferroglia (60%, post-doc; multi-loop calculations in QCD and electroweak theory), 1 research student (100%). **ETH Zürich**: Z. Kunszt (20%, faculty; QCD corrections), A. Gehrmann-De Ridder (30%, post-doc; collider physics, perturbative QCD), A. Daleo (20%, post-doc; QCD corrections).

Most significant recent publications

1) Electroweak corrections to charged-current $e^+e^- \to 4$ fermion processes: technical details and further results, A. Denner, S. Dittmaier, M. Roth, L. H. Wieders, Nucl. Phys. B **724** (2005) 247.
2) NLO QCD corrections to $t\bar{t}H$ production in hadron collisions, W. Beenakker, S. Dittmaier, M. Krämer, B. Plümper, M. Spira, P. M. Zerwas, Nucl. Phys. B **653** (2003) 151.
3) Antenna subtraction at NNLO, A. Gehrmann-De Ridder, T. Gehrmann, E.W.N. Glover. JHEP **0509** (2005) 056.

13 DESY: Zeuthen/Aachen/Dresden/Freiburg/Hamburg

Research expertise and proposed research: DESY will be an Associate Contractor with team members both at Hamburg and Zeuthen, and also from Technical University Dresden and Universities of Aachen and Freiburg.

The team members have particular expertise in precision perturbative calculations in the Standard Model and in supersymmetric theories for physics at LEP, Tevatron, LHC, ILC.

Both the DESY, Aachen and Freiburg teams are expert in complete one- and two-loop calculations and contributed much to the theoretical preparations for the Higgs searches performed at Fermilab and planned at LHC and LC. The DESY team was engaged in the electroweak precision predictions for LEP physics at the Z peak and above. It continues studies for ILC physics as well as QCD precision calculations for HERA and LHC physics: Precise determination of structure functions and of the strong coupling constant. The Dresden group has considerable expertise in the fields of development of full event generators and automatic evaluation of multi-particle cross sections at the tree-level including leading higher order corrections as well.

In the present network we will continue these lines of research but with significantly pronounced use of tools to be created allowing the automated solution of a large part of the calculations. For this, software tools like C++, FORM, MATHEMATICA, MAPLE, QGRAPH, DIANA, etc. have to be combined and supplemented by own programs with a new quality. New technologies in calculating one- and two-loop corrections will be developed and applied to collider physics. The automatization of perturbative calculations and of the creation of Monte Carlo generators for specific processes will be done. There is also special expertise for a further study of the nature of electroweak symmetry breaking, the nature of the Higgs. The team members are actively participating in the ongoing HERA, LHC, and ILC workshops as well as in the corresponding theoretical conferences. They have permanent collaborations with several other theory groups and experimental collaborations.

The team members are experienced in most advanced scientific tools for complicated calculations, using highly developed computer tools, but they are also very experienced in the cooperation with experimentalists in phenomenological applications.

Training environment: DESY is a major research and accelerator centre, with the ep collider HERA and proposing a linear e^+e^- collider, and with an ongoing participation at LHC. The local team takes active part in the corresponding physics programs. The team members are collaborating with Hamburg University and with Humboldt-University at Berlin. Dresden Technical University has a long tradition in nuclear physics and started a specialized research program in elementary particle physics after German reunification. Universities at Aachen and Freiburg are among the universities in Germany with a long tradition in theoretical and experimental elementary particle physics and with present participations at LHC and in the ILC project.

All tenure researchers have a lively tradition in educating young researchers and perform successful guest programs. Many of them give basic and specialized university courses for students. Diploma and PhD students take active parts in the research programs. The DESY team is participating in two Graduate Schools for the education of PhD students, is running the bi-annual topical conference 'Loops and Legs in Gauge Theories' and the bi-annual 'School on Computer Algebra and Particle Physics' (CAPP).

Key Scientific Staff and Individual Expertise

DESY: T. Riemann (Team leader, staff, 100%; Standard Model precision calculations), J. Blümlein (staff, 100%; QCD, multi-loop corrections), S. Moch (staff, 100%; multi-loop corrections, computer algebra), W. Kilian (staff, 100%; little Higgs and susy physics), P. Zerwas (staff, 100%; susy physics at LHC and ILC), Post-doc (post-doc, 100%), S. Actis (post-doc, 100%; electroweak higher order corrections), J. Reuter (post-doc, 100%; susy physics at LHC and ILC and MC generators), EU postdoc (50%). **Univ. Aachen**: M. Krämer (staff, 100%; Higgs and SUSY physics at LHC and NLO QCD Monte Carlo), A. Mück (post-doc, 100%; extensions of the SM and ILC). **Tech. Univ. Dresden**: F. Krauss (staff, 50%; NLO QCD Monte Carlo), 2 PhD students (100%). **Univ. Freiburg**: J. van der Bij (Deputy Team leader, staff, 60%; Higgs search at LHC and higher order corrections), A. Lorca (post-doc, 100%; electroweak higher order corrections), B. Tausk (post-doc, 100%; multiloop corrections, mathematical physics), EU PhD student (50%).

Most significant recent publications

1) M. Czakon, J. Gluza, T. Riemann, Master integrals for massive two-loop Bhabha scattering in QED, Phys. Rev. D71 (2005) 073009

2) J. Aguilar-Saavedra et al., Supersymmetry parameter analysis: SPA convention and project, hep-ph/0511344, subm. to EPJC.

3) G. Blair, W. Porod, P. Zerwas, The reconstruction of supersymmetric theories at high-energy scales, Eur. Phys. J. C27 (2003) 263.