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SUSY PARTICLE PHYSICS SUMMARY*

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A review of the activity of the European Network "Physics at Colliders" in the area of SUSY particle physics is presented.

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1. Introduction

The electroweak precision tests carried out at LEP and SLC, together with the measurements of m_t and m_W at the Tevatron indicate that the Standard Model (SM) performs quite well when confronting with the experimental data [1]. At the moment there is no clear indication for new physics beyond the SM [2], however these results form a very stringent set of precise constraints on possible extensions of the SM.

The experimental data show a clear indication that mechanisms of electroweak symmetry breaking with a "light" Higgs are favored. Furthermore, any new physics of the non-decoupling type, *i.e.* effects that do not vanish as $\Lambda \to \infty$ where Λ is the new physics scale, is so constrained by the success of the SM fit that there is always the need of some "conspiracy" among different effects in order not to get in conflict with the precision tests. On the contrary, new physics of the decoupling type, *i.e.* effects that scale as m_z^2/Λ^2, can avoid naturally the precision test constraints and seem to be a more viable candidate for physics beyond the SM. Supersymmetric extensions of the SM belong to the latter category with the further distinguishing property of predicting one "light" Higgs boson state. The Minimal Supersymmetric Standard Model (MSSM), likewise similar models, has also the great virtue of being well defined and computable up to the Planck scale making it one of the most attractive extension of the SM.

The European Network "Physics at Colliders" in its four years of activity has contributed significantly to SUSY studies and in the following I am going to discuss just a small selection of the results that have been produced. Most of them can be grouped in five different areas that I indicate as: standardization, precision physics, m_h predictions, determination of SUSY parameters from LHC/LC analyses and CP-violation. For each area I present few results that can be taken as illustrative of the collaborations between the various nodes of the network.

2. Standardization

2.1. Snowmass points and slopes

Supersymmetry is not an exact symmetry of nature and therefore realistic models should contain SUSY breaking terms. In order not to spoil the good convergence of the theory, they are introduced through soft terms. Thus, the result of any calculation depends on several SUSY breaking parameters whose number in the MSSM can vary from more than one hundred if no particular SUSY breaking mechanism is assumed to four or five according to which SUSY breaking mechanism, like minimal supergravity (mSUGRA), gauge mediation (GMSB) or anomaly mediation (AMSB), is considered. Detailed scanning over a five- or four-dimensional parameter space is actually beyond the present capability, in particular when it comes to simulate experimental signature within the detectors. For this reason there has been inside the physics community an effort to select some benchmark scenarios, *i.e.* specific points in the MSSM parameter space, that can be taken as representative of different physical situations. It should be kept in mind that the parameter choices that are useful as benchmark scenarios actually depend on the purpose of the investigation. Thus, in case one is interested in setting exclusion limits on the SUSY parameter space from the non observation of SUSY signal it is useful to use a scenario which give rise to "conservative" bounds. As an example, the theoretical upper bound on the lightest CP-even Higgs boson mass, m_h, as a function of $\tan\beta$, the ratio of the two vacuum expectation values of the two Higgs fields, can be combined with the result from direct searches at LEP to constrain $\tan\beta$. To set a conservative exclusion bound on $\tan\beta$ the point in the MSSM parameter space should be chosen in such a way that the maximum value of m_h is obtained.

In the Snowmass Workshop on the Future of Particle Physics (2001), to which five nodes of the network contributed, the "Snowmass Points and Slopes" (SPS) were introduced [3]. This set of benchmark points and parameter lines in the MSSM parameter space was agreed upon by several groups that had made proposals for post-LEP benchmark scenarios as a standard to be used in experimental simulations for SUSY searches at the next generation of colliders. The SPS agreement selected ten benchmark points, from which six correspond to an mSUGRA scenario, one to an mSUGRA-like scenario with non-unified gaugino masses, two refer to the GMSB scenario and one is an AMSB scenario. Different scenarios correspond to different values of the SUSY breaking parameters and therefore give rise to different particle spectra and different phenomenology. As an example, the SPS1 scenario consists of two "typical" mSUGRA points defined by the same values of the gaugino and scalar masses and the trilinear coupling but differing by the value of $\tan\beta$, $\tan\beta = 10$ for the SPS1a point, $\tan\beta = 30$ for the SPS1b one. In this scenario the τ-rich neutralino and chargino decays are important for the collider phenomenology. Instead the point SPS4 is a mSUGRA scenario with large $\tan\beta$, ($\tan\beta = 50$), which enhances the couplings of the CP-odd A Higgs boson and of the heaviest CP-even one, H, to the down fermions as well as the Htb coupling resulting in large associated H boson production cross section. Attached to seven of the ten benchmark points are the model lines ("slopes"), i.e continuous sets of parameters depending on one dimensionful parameter, that are intended for more general analyses of typical SUSY signatures. As an example of model line we can consider the point (1a) defined by $m_0 = 100$ GeV, $m_{1/2} = 250$ GeV, $A_0 = -100$ GeV, $\tan\beta = 10$, $\mu > 0$. The points on the slope that pass through it are obtained varying $m_{1/2}$ while keeping the relations $m_0 = -A_0 = 0.4 m_{1/2}$.

2.2. Les Houches accord

Precise predictions within supersymmetric models heavily rely on programs that compute the SUSY mass and coupling spectrum which are often interfaced to specialized decay packages, relic density calculations and (parton-level) event generators. Some of these programs were developed inside the network, with four nodes contributing to this subject. Network's contributions include the two codes FeynHiggs [4] and SuSpect [5] that produce the SUSY spectrum and HDECAY [6], SDECAY [7] and PROSPINO [8] that compute the production and decay of SM and SUSY particles. In particular, the Fortran code SDECAY [7, 9] calculates the decay widths and branching ratios of all the supersymmetric particles in the MSSM including higher order effects. SDECAY includes, besides the usual two-body decays of fermions and gauginos and the three-body decays of charginos, neutralinos and gluinos, the three- and four-body decays of top squarks as well as the important loop-induced decay modes. The QCD corrections to the two-body decays involving strongly interacting particles and the dominant components of the electroweak corrections to all decay modes are also taken into account.

All the programs available "on the market" reflect the various philosophies their developers had chosen, so that very often interfacing different results can be quite a difficult task. To overcome this difficulty and set an efficient and well-defined way in which information is transferred between different programs, an agreement among the developers of the SUSY public codes has been reached to define standards not only for the structure of the input/output files of the codes but also regarding the conventions and notations the output results should be expressed. The Les Houches accord [10, 11] put forward an accord specifying a unique set of conventions for SUSY extensions of the SM together with generic file structures for: *(i)* SUSY model specifications and input parameters; *(ii)* EW and SUSY scale mass and coupling spectra and *(iii)* decay tables, to provide a universal interface between spectrum calculation programs, decay packages, and high energy physics event generators. This was a most needed tool that is enabling all experiments to probe SUSY in a more efficient self-consistent way and the theorists to translate their results into unique constraints on the underlying SUSY model, thereby avoiding previous drawbacks due different conventions, approximations, renormalization schemes, *etc.*

3. Precision physics

In order to treat the MSSM at the same level of accuracy as the SM, higher-order contributions have to be taken into account. Several nodes of the network have worked on this subject. In the following I will discuss few examples of the investigations carried out inside the network.

3.1. MSSM contribution to the ρ parameter

Ref. [12] reports the leading electroweak two-loop corrections to the ρ parameter in the MSSM, *i.e.* the $\mathcal{O}(\alpha_t^2)$, $\mathcal{O}(\alpha_t\alpha_b)$, $\mathcal{O}(\alpha_b^2)$ corrections involving the top and bottom Yukawa couplings. These contributions are of particular interest, since they involve corrections proportional to m_t^4 and bottom loop corrections enhanced by $\tan\beta$. They were studied in the limit of heavy squarks, that corresponds, due to the decoupling properties of the MSSM, to a situation in which besides the SM particles only the two Higgs doublets of the MSSM are active, *i.e.* a Two-Higgs-Doublet Model (THDM) with MSSM restrictions. In Fig. 1 the numerical effect of the $\mathcal{O}(\alpha_t^2)$ corrections on m_W is shown. The total (SM + SUSY particles) correction amounts up to -12 MeV while the specific SUSY part ranges from -3 MeV to zero when the decoupling regime is reached. Concerning the latter, in the physical situation considered, *i.e.* heavy squark masses, the onset of decoupling is governed by the value of M_A. The left side of Fig. 1 shows that in the case of small $\tan\beta$ the decoupling is very slow. In fact, the plot is drawn at fixed values of $\tan\beta$ while varying M_A from 50 GeV to 1000 GeV, showing that for $\tan\beta = 3$ the difference between the MSSM and the SM result (the long-dashed line) does not vanish. Indeed for $\tan\beta = 3$ the decoupling region is reached for $M_A \gtrsim 3$ TeV. On the contrary, the right side of Fig. 1 shows that for $\tan\beta \gtrsim 5$ a pseudoscalar Higgs mass of 300 GeV is already inside the decoupling region.

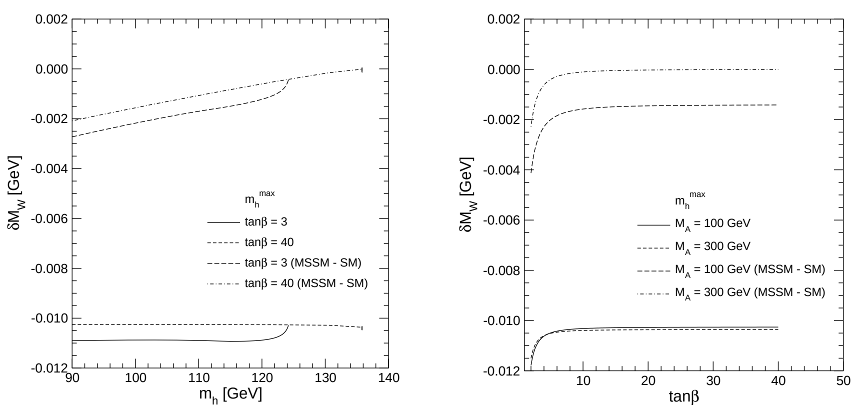

Fig. 1. The absolute $\mathcal{O}(\alpha_t^2)$ MSSM contribution and the effective change in δm_W is shown for $M_{\rm SUSY} = 1000$ GeV in the $m_h^{\rm max}$ scenario. The other parameters are $\mu = 200$ GeV $A_b = A_t$. m_h is obtained in the left (right) plot from varying M_A from 50 GeV to 1000 GeV, while keeping $\tan\beta$ fixed at $\tan\beta = 3, 40$ (from varying $\tan\beta$ from 2 to 40, while keeping M_A fixed at $M_A = 100, 300$ GeV). The figure is taken from Ref. [12].

A similar analysis can be performed also for the effective electroweak angle showing that the total correction to $\sin^2\theta_{\rm eff}$ amounts up to $+6\times10^{-5}$ while the SUSY part ranges between $+3\times10^{-5}$ for small $\tan\beta$ and small M_A and approximately zero for large $\tan\beta$ and large M_A.

3.2. MSSM contributions to $(g-2)_\mu$

The anomalous magnetic moment of the muon $(g-2)_\mu$ is one of the most precisely measured and calculated quantities in physics. Presently, the world average experimental value, $a_\mu = 116592080(6)\times10^{-10}$ [13], is not in perfect agreement with the SM prediction. The latter depends on two quantities, the hadron light-by-light (l.b.l.) contribution and the hadronic vacuum polarization part, of which we have several evaluations that differ both in the central value and in the error. The comparison of the SM results with the experimental value gives a discrepancy $(6 \lesssim a_\mu^{\rm exp} - a_\mu^{\rm SM} \lesssim 24)\times10^{-10}$, employing for the l.b.l. the value $a_\mu(\text{l.b.l.}) = 14(3)\times10^{-10}$ [14], that corresponds to a difference between 0.7 and 2.8 standard deviations. Somewhat higher discrepancies are obtained if $a_\mu(\text{l.b.l.}) = 8(4)\times10^{-10}$ [15] is used, the number of standard deviations spanning the range [1.2–3.2].

Supersymmetric effects could naturally explain the observed deviation. In fact the SUSY one-loop contribution is approximately given by [16]

$$a_\mu^{\rm SUSY,1l} \simeq 13\times10^{-10}\left(\frac{100\rm GeV}{M_{\rm SUSY}}\right)^2 \tan\beta\,{\rm sign}(\mu)\,, \tag{1}$$

where $M_{\rm SUSY}$ represents the typical common mass scale of the supersymmetric particles, so that for $\mu>0$ supersymmetric effects can easily account for the deviation but also exceed it. Thus the $(g-2)_\mu$ measurement places strong constraint on the SUSY parameter space [17].

In order to fully exploit the high precision of the $(g-2)_\mu$ experiment within SUSY, there has been in the recent years some effort, to which also the network contributed, to compute supersymmetric two-loop effects. The status of the knowledge of the two-loop SUSY contributions to $(g-2)_\mu$ can be summarize as follows: *(i)* Leading logarithms (L.L.) effects are known in general [18], *i.e.* all terms of the form $\log(m_\mu/M_{\rm SUSY})$ are under control. *(ii)* There were two estimates of the effects of closed fermion/sfermion loops inserted into a one-loop THDM diagram [19,20] reporting huge contributions up to $\mathcal{O}(20\times10^{-10})$ for large $\tan\beta$ and μ and the trilinear coupling of the order of several TeV. In these analyses, however, other experimental constraints on the MSSM parameter space were neglected. In the network's joint work of Ref. [21] it was shown that once the constraints from m_h, $\delta\rho$ and b decays are taken into account the contribution of these diagrams reduces to $a_\mu^{\tilde f,2l} \simeq 2.5\times10^{-10}$. *(iii)* The Higgs scalar sector contribution, *i.e.* the THDM part, was worked out in another network's publication, *i.e.* Ref. [22]. It was shown that the L.L. piece is an excellent approximation of the full bosonic result. *(iv)* In the same paper [22] the contribution of the chargino and neutralino loop inserted into a THDM one-loop diagram was also evaluated. These corrections can be described by the approximate relation

$$a_\mu^{\chi,2l} \sim 11 \times 10^{-10} \left(\frac{100\text{GeV}}{M_{\text{SUSY}}}\right)^2 \left(\frac{\tan\beta}{50}\right) \text{sign}(\mu) \qquad (2)$$

and can amount up to 10×10^{-10}, which is almost 2σ of the current experimental uncertainty. It is interesting to note that because the chargino/neutralino sector may very well be lighter than the slepton sector of the second generation, in particular in the light of FCNC and CP-violating constraints which are more easily satisfied for heavy 1st and 2nd generation sfermions, one can envisage a situation in which the one-loop SUSY contribution is suppressed by heavy slepton masses while the two-loop one can still be significant. In Fig. 2 the chargino/neutralino two-loop contributions are compared with the supersymmetric one-loop one, $a_\mu^{\text{SUSY},11}$ at fixed high smuon and sneutrino masses, $M_{\tilde{l}} = 1$ TeV and for a large $\tan\beta$ value, $\tan\beta = 50$. The figure shows that for $M_{\text{SUSY}} \lesssim 400$ GeV the two-loop contributions can be important significantly modifying the supersymmetric one-loop effects and thus also the bounds on the supersymmetric parameters.

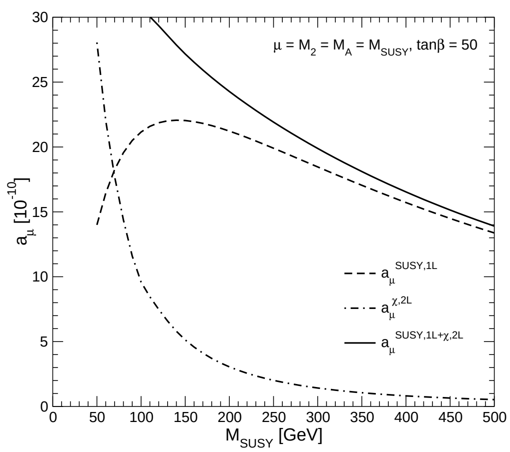

Fig. 2. Comparison of the supersymmetric one-loop result, $a_\mu^{\text{SUSY},11}$, (dashed) with the two-loop chargino/neutralino contributions, $a_\mu^{\chi,2l}$ and the sum (full line). The sfermion mass parameters are set to 1 TeV. The figure is taken from Ref. [22].

3.3. One-loop corrections to production and decays of sparticles

In the previous subsections we have seen that a major effort has been put into the computation of virtual SUSY effects in observables that involve only SM external particle. However, several nodes of the network have also contributed to the studies of direct production of SUSY particles where a detailed knowledge of higher-order effects is also needed.

For the calculation of radiative corrections to masses, production cross sections, decay rates *etc.* of particles (sfermions, charginos, neutralinos) which are mixtures of states, a proper renormalization of the mixing matrices is required. Two different definitions of a renormalized *on–shell* mixing angle were proposed inside the network [23, 24] and later applied to the one-loop calculation of several processes.

Refs. [23,25] present the computation of the full one-loop electroweak corrections to the partial decay widths of squarks and sleptons into charginos and neutralinos for all particle species in the context of the general MSSM $\Gamma(\tilde{f} \rightarrow f'\chi^{0,\pm})$. This computation includes the computation of the one-loop correction to the SUSY particle masses. The electroweak corrections are combined with the QCD corrections to provide precise predictions for the decay branching ratios of squarks and sleptons. The corrections show the interesting property of being non-decoupling, that is, the radiative corrections grow logarithmically with the heaviest mass of the model. This opens the possibility of studying the properties of SUSY particles that are too heavy to be produced at the colliders, by means of their virtual effects. The non-decoupling effects have a physical meaning in terms of the breaking of SUSY, and admit a simple explanation in terms of renormalization group equations. Since SUSY is (softly) broken, and these observables probe the SUSY relations, they feel the scale of the SUSY breaking. As a consequence, one expects radiative induced deviations of the SUSY coupling relations. Electroweak corrections as large as 5% can easily be obtained in certain regions of the parameter space. These corrections are comparable to the corrections of the strong sector. Therefore both kinds of effects must be taken into account on the same footing. The size of the corrections requires their inclusion for the determination of the SUSY parameters at the percent level, to be performed at a high energy e^+e^- linear collider.

The renormalization procedure developed in Ref. [24] has been applied to the calculation of full one-loop corrections to the masses and mass parameters of charginos and neutralinos [26], to neutral Higgs boson decays into neutralinos [27], to $A \rightarrow \tilde{f}_1\bar{\tilde{f}}_2$ [28], to $H, A \rightarrow \tilde{\chi}_i^+\tilde{\chi}_j^-$ [29], to $e^+e^- \rightarrow \tilde{\chi}_i^0\tilde{\chi}_j^0$ [30] and to $e^+e^- \rightarrow \tilde{f}_i\,\bar{\tilde{f}}_j$ [31]. Quite generally, it has been shown that the inclusion of full one-loop corrections is necessary for the comparison with future precision experiments.

3.4. Sudakow logarithms in SUSY

It has been shown [32] working at the one-loop level in the 't Hooft gauge that the Sudakov electroweak logarithms do exist also for the genuine SUSY virtual effects, and that they are only produced by SUSY vertices (not by SUSY boxes). At an e^+e^- collider with c.m. energy around 1 TeV a Sudakow expansion can be used to extract information on SUSY parameters in a scenario in which light SUSY has been discovered, *i.e.* all the sparticle masses lie below approximately 350 GeV. As an example, in Ref. [33] a method to extract information about $\tan\beta$ from the reaction $e^+e^- \to H^+H^-$ has been proposed. In fact, it is shown that the complete one-loop calculation can be satisfactorily reproduced by a Sudakov expansion, so that the difference between the one-loop and the Born result can be written as:

$$\Delta(q^2) = \frac{\sigma^{\mathrm{B}+1l} - \sigma^{\mathrm{B}}}{\sigma^{\mathrm{B}}} = c_2 \log^2 q^2 + c_1 \log q^2 + c_0\,, \tag{3}$$

where q^2 is the c.m. energy of the reaction. The coefficient c_2 is due to only SM contributions while c_1 depends upon SM parameters and $\tan\beta$. Concerning c_0, it has a complicated structure and depends on many SUSY parameters, however it has the characteristic to be practically q^2-independent. Thus a measurement of the slope of the cross-section is going to give information on $\tan\beta$ assuming known the SM part. It should be stressed that this method would be particularly effective for large values (40, 50) of $\tan\beta$. A similar analysis can be performed for chargino and neutralino production [34]. For final chargino and neutralino pairs the logarithmic terms contain $\tan\beta$, M_1, M_2, μ, thus a combined measurement of the slopes in energy of the production cross sections of charginos, neutralinos and charged Higgses would allow the identification of these parameters.

4. m_h predictions

The MSSM has a definite prediction, that is going to be tested at LHC, namely the existence of a light Higgs boson. The MSSM prediction at the classical level, $m_h < m_Z$, is significantly modified by quantum corrections that can raise this bound by 30–50 GeV. A recent analysis [35] reports $m_h \lesssim 150$ GeV as the most conservative upper bound on the lighter Higgs boson mass in the general MSSM. The subject of quantum correction to the CP-even Higgs boson mass matrix will be reviewed by Slavich in his contribution [36] and it will not be discussed here. Instead, I would like to emphasize that inside the network two computer codes for calculating Higgs mass spectrum were developed, *i.e.* FeynHiggs [4] and SuSpect [5]. These codes were designed with different philosophy, for example FeynHiggs employs an hybrid $\overline{\rm MS}$/OS renormalization while SuSpect uses $\overline{\rm DR}$ parameters that can be assigned either at the weak scale or at the GUT scale in which case they can be evolved down to the weak scale using the renormalization group equations. The important point is that both codes include all the "known" corrections to the CP-even Higgs boson mass matrix up to two-loop, namely strong and third-generation Yukawa corrections in the effective potential approximation. It should be said that recently there were calculations that went beyond this approximation [37]. However the way these results are presented, using a different set of input parameters from the usual one employed in the programs, makes them not easy to be understood and implemented in the various codes. This is a typical example of the importance of standardization when talking about SUSY results.

5. Determination of SUSY parameters from LHC/LC analyses

A significant network's activity has focused on studying the phenomenology of supersymmetric models at future experimental facilities and the determination of SUSY parameters. Among the various results I recall: the calculation of slepton production near threshold and in the e^+e^- continuum including higher order corrections [38]; the analysis of the chargino/neutralino system in the MSSM and beyond [39]; the neutralino pair production at a $\gamma\gamma$ collider [40] and the neutralino-neutralino annihilation to photon and gluon [41].

The production of MSSM Higgs bosons at a $\gamma\gamma$ collider has been studied in detail. MSSM Higgs bosons can be produced as s-channel resonances in $\gamma\gamma$ collisions which can be obtained with high luminosity at a linear e^+e^- colliders by means of Compton-backscattered laser light. The laser spectrum of the relevant helicities for Higgs boson production is strongly peaked at about 80% of the original e^+e^- c.m. energy. It has been shown that these Higgs resonances can easily be extracted in the $b\bar{b}$ final states which constitute the dominant decay channel of the heavy MSSM Higgs bosons for moderate and large values of $\tan\beta$ [42]. This study included the full NLO QCD corrections to the signal and background processes as well as the interference and in addition the resummation of large logarithms due to soft gluon radiation. In this way the large wedge in which the LHC can only discover the light scalar Higgs particle can be covered at this collider. Moreover, the maximal Higgs boson mass reachable at a $\gamma\gamma$ collider is significantly larger than in the e^+e^- mode. A crucial part of the analysis is a strong cut on configurations containing only two bottom jets in the final state. Final states containing chargino pairs look promising, too, if this decay mode of the heavy Higgs bosons is kinematically possible [42]. Another MSSM Higgs boson production mechanism at $\gamma\gamma$ collider is that in association with $\tau^+\tau^-$

pairs. This process has been shown to be dominated by the part which is covered by the equivalent-particle approximation, *i.e.* photon splittings into tau pairs, $\gamma \to \tau^+\tau^-$, followed by the fusion process of two taus to the Higgs bosons, $\tau^+\tau^- \to \phi$. After imposing appropriate cuts on the tau energies and angles as well as the invariant $b\bar{b}$ mass in order to reconstruct the Higgs mass due to $\phi \to b\bar{b}$ decays, the background processes can be suppressed significantly. The $\tau\tau$ fusion process allows an accurate determination of the SUSY parameter $\tan\beta$ in the range $\tan\beta \gtrsim 10$ [43].

A method to determine $\tan\beta$ at a linear collider (LC) via the analysis of the polarization of the final state products in sfermion decays has also been studied [44]. The method is based on the determination of the left–right entry of the sfermion mass matrix via a combined set of measurements of the sfermion physical masses, from the end-points spectra in decay distributions and threshold scans, and their mixing angle, from the production cross sections. Then, the measurement of the polarization of the outgoing fermion produced in the sfermion decay is crucial to disentangle in the left–right entry the value of the trilinear coupling from $\tan\beta$. Because the method uses the knowledge of the left–right entry of the sfermion mass matrix, it is clearly effective for third generation sfermions, therefore requiring the measurement of the tau polarization in stau decays or of the top polarization in stop/sbottom decays.

In general, the exploitation of polarization effects in production processes offers unique possibilities to test model assumptions and to prove the quantum numbers of the new particles [45]. It turned out that a LC with both beams polarized is essential for such purposes.

A rather new territory of phenomenological studies explored in the network are combined analyses at LHC and LC. To reconstruct the fundamental theory at high (GUT) scale it is very important to feed back the results of experiments carried out at LC into the ones obtained at LHC and vice versa. Indeed, the accuracies in measurements of cascade decays at LHC and in threshold production as well as decays of supersymmetric particles at LC complement and augment each other *mutually* so that a high-precision picture of the supersymmetric parameters at the electroweak scale can be drawn. Such a comprehensive and precise picture is necessary in order to carry out the evolution of the supersymmetric parameters to high scales, driven by perturbative loop effects that involve the entire supersymmetric particle spectrum [46, 47].

6. CP violation

This subject will be mainly reviewed by S. Hesselbach in his contribution. I just recall few contributions.

We had several papers on the construction of CP-sensitive observables in SUSY particle reactions. In particular, the production and decay of charginos and neutralinos in e^+e^- collisions in the MSSM with complex parameters was studied including the full spin correlations between production and decay and employing the technique of triple product correlations to define appropriate T-odd asymmetries. These asymmetries were proposed for sfermion decay [48], neutralino production and decay [49, 50], chargino production [51]. In particular, in Ref. [50] the CP asymmetry involving the transverse polarization of the τ lepton in the decay of the neutralino into τ and $\tilde{\tau}$ was studied. This asymmetry is sensitive to the phase of the trilinear coupling parameter A_τ, which is difficult to determine in another way. In the related paper [52] a CP-sensitive asymmetry in three-body $\widetilde{t}_1$ decay was also proposed.

The phase dependence of CP-even observables was also investigated. In the MSSM with complex parameters also the CP-even observables like SUSY particle masses, decay branching ratios, production cross sections *etc.* may appreciably depend on the phases of the complex SUSY parameters involved. The impact of CP phases on the searches and decays of stop and sbottom was analyzed; in particular how information on the complex SUSY parameters μ, M_1, A_t and A_b from measurements of the branching ratios of fermionic and bosonic decays of $\widetilde{t}_{1,2}$ and $\widetilde{b}_{1,2}$ can be extracted [53]. It was shown that $\mathrm{Re}(A_t)$ and $\mathrm{Im}(A_t)$ can be determined with an accuracy of a few percent, whereas for $\mathrm{Re}(A_b)$ and $\mathrm{Im}(A_b)$ the accuracy will only be of the order of 50%. An an analogous analysis for the $\widetilde{\tau}_i$ and $\widetilde{\nu}_\tau$ was also carried out [54]. Finally, CP sensitive forward–backward asymmetries in chargino production with transversely polarized e^+ and e^- beams was also studied [55].

SUSY can also induce CP violating effects in low-energy observables. The behavior of several CP-even and CP-odd low-energy observables in the general flavor blind MSSM with complex parameters was investigated in Ref. [56]. The observables considered were the electric dipole moment of the electron, the anomalous magnetic moment of the muon, the branching ratio and CP asymmetry of $b \to s + \gamma$, and the SUSY corrections to the unitarity triangle. In this model the CP asymmetry of $b \to s + \gamma$ is at most a few percent, once the restrictions from the electric dipole moment are taken into account. Also the SUSY corrections to the unitarity triangle turn out to be small.

A related subject to CP violation is Lepton Flavor Violation (LFV). Concerning it I recall the studies of LFV signals at e^+e^- collisions within the MSSM, allowing for the most general flavor structure in the mass matrices. In this situation large signals can be expected despite the strong constraints from rare decays [57]. In this general framework the effects of phases on the lepton dipole moments and rare lepton decays were also investigated [58]. Furthermore, LFV decays of neutral Higgs bosons were also studied. Indeed the effective LFV Higgs coupling to the second and third lepton generations can induce the decays (h, H, $A \to \mu\tau$) at non-negligible rate for large $\tan\beta$ and sizeable smuon-stau mixing [59].

7. Conclusions

I summarize the activity of the European Network "Physics at Colliders" in the area of SUSY particle physics through few numbers. In the four years of activity of the network I counted more than 70 joint papers, *i.e.* papers in which at least two authors belonged to different nodes, and even more produced by a single node. Five computer codes (FeynHiggs, SuSpect, HDECAY, SDECAY, PROSPINO) for computing MSSM particle spectrum, production and decay were developed and are maintained by people of the network. Eleven out of the thirteen nodes had joint publications. We had 3 network's post-docs that worked mainly in the SUSY particle area.

I think that these numbers show distinctly the amount of activity and interconnection the network had.

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