September 20, 2014

SUSY_FLAVOR v2.5: a computational tool for FCNC and CP-violating processes in the MSSM

A. Crivellin[a], J. Rosiek[b], P. Chankowski[b], A. Dedes[c], S. Jäger[d], P. Tanedo[e]

[a] *Albert Einstein Center for Fundamental Physics, Institute for Theoretical Physics, University of Bern, CH-3012 Bern, Switzerland*

[b] *Institute of Theoretical Physics, University of Warsaw, 00-681 Warsaw, Poland*

[c] *Division of Theoretical Physics, University of Ioannina, GR 45110, Greece*

[d] *Department of Physics and Astronomy, University of Sussex, Brighton BN1 9QH, UK*

[e] *Institute for High Energy Phenomenology, Newman Laboratory of Elementary Particle Physics, Cornell University, Ithaca, NY 14853, USA*

Abstract

We present SUSY_FLAVOR version 2.5 — a Fortran 77 program that calculates low-energy flavor observables in the general R-parity conserving MSSM. For a set of MSSM parameters as input, the code gives predictions for:

1. Electric dipole moments of the leptons and the neutron.
2. Anomalous magnetic moments (i.e. $g-2$) of the leptons.
3. Radiative lepton decays ($\mu \to e\gamma$ and $\tau \to \mu\gamma, e\gamma$).
4. Rare Kaon decays ($K_L^0 \to \pi^0 \bar{\nu}\nu$ and $K^+ \to \pi^+ \bar{\nu}\nu$).
5. Leptonic B decays ($B_{s,d} \to l^+ l^-$, $B \to \tau\nu$, $B \to D\tau\nu$ and $B \to D^\star \tau\nu$).
6. Radiative B decays ($B \to \bar{X}_s \gamma$).
7. Rare decays of top quark to Higgs boson ($t \to ch, uh$).
8. $\Delta F = 2$ processes ($\bar{K}^0$–K^0, $\bar{D}$–D, $\bar{B}_d$–B_d and $\bar{B}_s$–B_s mixing).

SUSY_FLAVOR v2 performs the resummation of all chirally enhanced corrections, i.e. takes into account the effects enhanced by $\tan\beta$ and/or large trilinear soft mixing terms to all orders in perturbation theory. All calculations are done using exact diagonalization of the sfermion mass matrices. Comparing to previous versions, in SUSY_FLAVOR v2.5 parameter initialization in SLHA2 format has been significantly generalized and simplified, so that program accepts without modifications most of the output files produced by other codes calculating MSSM spectra and processes. In addition, the routine calculating branching ratios for rare decays of top quark to Higgs boson has been included. The program can be obtained from `http://www.fuw.edu.pl/susy_flavor`.

Contents

1 Introduction

Flavor physics was in the recent years one of the most active and fastest developing fields in the high energy physics. Numerous new experiments, spanning a wide energy range from neutrino mass measurements to hard proton scattering at LHC collider, helped to improve significantly the accuracy of various measurements related to flavor-observables. Almost all such experiments reported result which are in agreement with the Standard Model (SM) predictions, with a few exception where small observed deviations still require further confirmation (like e.g. $g-2$ muon magnetic moment anomaly [1, 2]).

The extensive set of measurements available for rare decays puts strong constraints on the flavor structure of physics beyond the Standard Model. In particular, it imposes stringent limits on the flavor- and CP- violating parameters of the Minimal Supersymmetric Standard Model (MSSM) [3], where the flavor changing neutral currents (FCNCs) originate, in addition to the CKM induced FCNCs, from the fact that one cannot (in general) simultaneously diagonalize the mass matrices of fermions and sfermions. Such a misalignment leads to FCNCs which can involve the strong coupling constant and which do not necessarily respect the hierarchy of the CKM matrix. Moreover, many of the MSSM parameters can take complex values and are potential sources of CP violation. Thus supersymmetric contributions to flavor and/or CP-violating processes can, in principle, exceed the SM predictions by orders of magnitude. The apparent absence of such big effects leads to the constraint that MSSM couplings which may generate FCNCs and CP violation are actually strongly suppressed. The difficulty to explain this suppression is known as the "SUSY flavor problem" and the "SUSY CP problem". Even if one assumes the so-called Minimal Flavor Violation (MFV) hypothesis [4] which requires that *all* FCNC effects originate from the Yukawa couplings of the superpotential, supersymmetric contributions to various flavor and CP-violating amplitudes can still be of comparable (or sometimes even much larger, like in the case of the electron and neutron EDMs or $B_s \to \mu^+\mu^-$) size as the corresponding SM contributions.

As the accuracy of the flavor experiments constantly improves, it is important to have an universal computational tool which helps to compare new data with the predictions of the MSSM. Developing such a tool is a non-trivial task requiring extensive and often tedious calculations. Numerous analyses have been published in the literature, but because of the complexity of the problem, they usually consider only a few rare decays simultaneously. Furthermore, many analyses done for general flavor violation in the MSSM use the mass insertion approximation for the soft terms (MIA) (see e.g. [5, 6]) which simplifies the calculations but does not produce correct results if flavor violation (and/or chirality violation) in the sfermion sector becomes large.

In a series of papers published since 1997 [6–16], many supersymmetric FCNC and CP-violating observables were analyzed within the setup of the most general R-parity conserving MSSM using exact diagonalization of the sfermion mass matrices. A FORTRAN computer programs based on the common set of Feynman rules of Ref. [17] were developed for each process (using also parts of code written for earlier papers on MSSM Higgs physics [18]) and, after collecting them together, published as `SUSY_FLAVOR` v1 [19, 20].

`SUSY_FLAVOR` v1 was able to calculate only the 1-loop supersymmetric virtual corrections, whereas, as widely discussed in the literature [13, 21–35], in the regime of large $\tan\beta$ or large trilinear A-terms so-called chirally enhanced corrections must be taken into account. Chiral enhancement is always related to fermion-Higgs couplings. Because these couplings have mass-dimension 4, the corresponding corrections do not vanish in the decoupling limit ($m_{\rm SUSY} \to \infty$) but rather converge to a constant. This in turn also means that the flavor-changing neutral Higgs couplings, which are induced by chirally-enhanced SUSY corrections, are still relevant for heavy SUSY particles. Thus, especially for observables which are sensitive to Higgs contributions (like for example $B_{s,d} \to \mu^+\mu^-$ or $B_{d,s}$ mixing), the consistent resummation and inclusion of chirally enhanced corrections to all orders of perturbation theory is very important.

In Ref. [36] such resummation was performed in the most general MSSM taking into account all possible sources of chiral enhancement; in the decoupling limit ($m_{\rm SUSY} \gg v_1, v_2$) analytical formulae has been given. Results of ref. [36] has been implemented in `SUSY_FLAVOR` v2.0. The consistent treatment of all chirally enhanced effects in the general MSSM (and the corresponding threshold corrections), including correct calculation of neutral Higgs penguins in such scenario, is a unique feature of `SUSY_FLAVOR` v2 not shared at the moment by other publicly available programs calculating rare decays in the supersymmetric models.

In `SUSY_FLAVOR` v2.5 the input and output routines for reading and writing files in SLHA2 [37] format have been significantly generalized and simplified, so that the program accepts most of the output files produced by other codes calculating MSSM spectra and processes. The output of `SUSY_FLAVOR` itself is now by default written to the file `susy_flavor.out` and, as described in more details in Section 7 and Appendix D, has a SLHA2-like block structure. `SUSY_FLAVOR` v2.5 allows also for easier comparison the relative importance of contributions from various MSSM sectors, providing new debug control variables which allow to separately switch on/off contributions from diagrams with gauge+Higgs bosons, gluinos, charginos and neutralinos circulating in loops (see Section 4.1). Also, new routines calculating rates of rare decays of top quark to Higgs boson in the MSSM, based on Ref. [38], has been added.

Several other programs allowing to analyze various aspects of the MSSM flavor phenomenology have been published. The most relevant to `SUSY_FLAVOR` are: `CPsuperH` [39], `SusyBSG` [40], `SPheno` [41], `SuperIso` [42] and `SUSEFLAV` [43]. `SusyBSG` is dedicated to high-precision predictions for $B \to X_s\gamma$ while `CPsuperH` and `SuperIso` calculate processes similar to the ones computed by `SUSY_FLAVOR`. However, these existing codes are restricted to the Minimal Flavor Violation scenario, whereas `SUSY_FLAVOR` can simultaneously calculate the set of rare decays listed in Table 1 without any (apart from the

R-parity conservation) restrictions on the choice of MSSM parameters. Other publicly available codes that are relevant to SUSY_FLAVOR (which can e.g. calculate the MSSM soft parameters used as input to SUSY_FLAVOR, or for the same set of input parameters calculate non-FCNC related observables) are FeynHiggs [44], SoftSUSY [45], SuSpect [46], MicrOMEGAs [47], DarkSUSY [48] and NMHDECAY [49].

In summary, the basic features of SUSY_FLAVOR v2.5 are:

- The program utilizes the most general R-parity conserving Lagrangian for the MSSM. In addition to the standard soft breaking terms, it can accommodate for additional non-holomorphic trilinear soft-SUSY breaking terms,

$$A_l'^{IJ} H_i^{2\star} L_i^I R^J + A_d'^{IJ} H_i^{2\star} Q_i^I D^J + A_u'^{IJ} H_i^{1\star} Q_i^I U^J + \text{H.c.} \,, \tag{1}$$

  that do not appear in the minimal supergravity scenario but are present in the most general softly broken supersymmetric effective Lagrangian [50]. These non-holomorphic terms can give rise to sizable effects in Higgs-fermion couplings.

- SUSY_FLAVOR can read and accept without modifications most of the SLHA2-compatible output files produced by other public libraries calculating various aspects of the MSSM phenomenology.

- There is no limit on the size of flavor violating parameters because the calculation does not rely on the MIA expansion. However, if the off-diagonal elements are larger than the diagonal ones, imaginary sfermion masses would be induced. Complex "mass insertions" of the form

$$\delta_{QXY}^{IJ} = \frac{(M_Q^2)_{XY}^{IJ}}{\sqrt{(M_Q^2)_{XX}^{II}(M_Q^2)_{YY}^{JJ}}} \,, \tag{2}$$

  (I, J denote quark flavors, X, Y denote superfield chirality, and Q indicates either the up or down quark superfield sector, similarly for slepton superfields) are taken as inputs, but they only serve to conveniently parametrize the sfermion mass matrices. SUSY_FLAVOR numerically calculates the exact tree-level spectrum and mixing matrices, which are later used in loop calculations.

- After calculating SUSY spectrum, SUSY_FLAVOR performs the resummation of the chirally enhanced corrections (following the systematic approach of ref. [36]), arising in the regime of large $\tan\beta$ and/or large trilinear soft sfermion mixing. The values of the Yukawa couplings and the CKM matrix elements of the superpotential are calculated (by taking into account the threshold corrections) and are then used for the calculations of the SUSY loop contributions to flavor observables. These chirally enhanced corrections also lead to flavor-changing neutral Higgs couplings and corrections to charged Higgs vertices which are implemented as well in the calculation of the amplitudes.

Observable	Experiment
$\Delta F = 0$	
$\frac{1}{2}(g-2)_e$	$(1159652188.4 \pm 4.3) \times 10^{-12}$ [51]
$\frac{1}{2}(g-2)_\mu$	$(11659208.7 \pm 8.7) \times 10^{-10}$ [2]
$\frac{1}{2}(g-2)_\tau$	$< 1.1 \times 10^{-3}$ [52]
$\lvert d_e\rvert$(ecm)	$< 1.6 \times 10^{-27}$ [53]
$\lvert d_\mu\rvert$(ecm)	$< 2.8 \times 10^{-19}$ [54]
$\lvert d_\tau\rvert$(ecm)	$< 1.1 \times 10^{-17}$ [55]
$\lvert d_n\rvert$(ecm)	$< 2.9 \times 10^{-26}$ [56]
$\Delta F = 1$	
$\mathrm{Br}(\mu \to e\gamma)$	$< 5.7 \times 10^{-13}$ [57]
$\mathrm{Br}(\tau \to e\gamma)$	$< 3.3 \times 10^{-8}$ [58]
$\mathrm{Br}(\tau \to \mu\gamma)$	$< 4.4 \times 10^{-8}$ [58]
$\mathrm{Br}(K_L \to \pi^0\nu\nu)$	$< 6.7 \times 10^{-8}$ [59]
$\mathrm{Br}(K^+ \to \pi^+\nu\nu)$	$17.3^{+11.5}_{-10.5} \times 10^{-11}$ [60]
$\mathrm{Br}(B_d \to ee)$	$< 1.13 \times 10^{-7}$ [61]
$\mathrm{Br}(B_d \to \mu\mu)$	$< 7.4 \times 10^{-10}$ [62]
$\mathrm{Br}(B_d \to \tau\tau)$	$< 4.1 \times 10^{-3}$ [64]
$\mathrm{Br}(B_d \to \mu e)$	$< 3.7 \times 10^{-9}$ [63]
$\mathrm{Br}(B_s \to ee)$	$< 7.0 \times 10^{-5}$ [65]
$\mathrm{Br}(B_s \to \mu\mu)$	$(2.9 \pm 0.7) \times 10^{-9}$ [66]
$\mathrm{Br}(B_s \to \tau\tau)$	$--$
$\mathrm{Br}(B_s \to \mu e)$	$< 1.4 \times 10^{-8}$ [63]
$\mathrm{Br}(B_s \to \tau e)$	$< 2.8 \times 10^{-5}$ [55]
$\mathrm{Br}(B_s \to \mu\tau)$	$< 2.2 \times 10^{-5}$ [55]
$\mathrm{Br}(B^+ \to \tau^+\nu)$	$(1.14 \pm 0.27) \times 10^{-4}$ [55]
$\mathrm{Br}(B \to D\tau\nu)/\mathrm{Br}(B \to Dl\nu)$	$(0.440 \pm 0.058 \pm 0.042)$ [67]
$\mathrm{Br}(B \to D^\star\tau\nu)/\mathrm{Br}(B \to D^\star l\nu)$	$(0.332 \pm 0.024 \pm 0.018)$ [67]
$\mathrm{Br}(B \to X_s\gamma)$	$(3.52 \pm 0.25) \times 10^{-4}$ [68]
$\mathrm{Br}(t \to ch, uh)$	$< 5.6 \times 10^{-3}$ [69]
$\Delta F = 2$	
$\lvert\epsilon_K\rvert$	$(2.229 \pm 0.010) \times 10^{-3}$ [55]
ΔM_K	$(5.292 \pm 0.009) \times 10^{-3}$ ps^{-1} [55]
ΔM_D	$(2.37^{+0.66}_{-0.71}) \times 10^{-2}$ ps^{-1} [55]
ΔM_{B_d}	(0.507 ± 0.005) ps^{-1} [68]
ΔM_{B_s}	(17.77 ± 0.12) ps^{-1} [70]

Table 1: List of observables calculated by `SUSY_FLAVOR` v2.5 and their measured values.

- As an intermediate step parton-level form factors for quark and lepton 2-, 3- and 4-point Green functions are calculated. They are later dressed in hadronic matrix elements (see Table 3 in Sec. 3) to obtain predictions for the physical quantities listed in Table 1. The set of Green's functions computed by SUSY_FLAVOR as intermediate "building blocks" is quite universal and can be used for a calculation of various processes not yet implemented in SUSY_FLAVOR.
- The full list of the processes which can be calculated by SUSY_FLAVOR v2.5 is given in Table 1.

This article is organized as follows. In Sec. 2 we discuss the conventions used for the MSSM parameters (a more explicit description can be found in the manual of SUSY_FLAVOR v1 [19]). Sec. 3 describes the internal structure of SUSY_FLAVOR, the most important steps of the calculations and the file structure of the library. In Sec. 4 we define the input parameters and present the initialization sequence for SUSY_FLAVOR. Sec. 5 discusses how the resummation of the chirally enhanced corrections to all orders of perturbation theory is performed. Routines for calculating the flavor and CP observables collected in Table 1 are described in Sec. 6. In Sec. 7 the output format for the quantities calculated by SUSY_FLAVOR is presented. We conclude in Sec. 8 with a summary of the presentation. Appendix A contains brief instructions on how to install and run the SUSY_FLAVOR package. In appendices B and C we provide templates for initializing SUSY_FLAVOR from within the program and using an external file in the SLHA2 format [37], respectively. Both of these templates produce the set of test results listed in Appendix D.

SUSY_FLAVOR can be downloaded from the following address[1]:

http://www.fuw.edu.pl/susy_flavor

2 Lagrangian and conventions

SUSY_FLAVOR is capable of calculating physical observables within the most general R-parity conserving MSSM, with one exception: currently it assumes massless neutrinos (and no right neutrino and right sneutrino fields in the Lagrangian [71]), so the PMNS mixing matrix does not appear in any lepton and slepton couplings. Neutrino flavor mixing and the PMNS matrix should be taken into account once new experiments are able to identify the flavor of the neutrinos produced in rare decays, but at present this is not experimentally feasible. Still, over 100 Lagrangian parameters are taken as input to SUSY_FLAVOR and can be initialized independently.

SUSY_FLAVOR has been in development since 1996, long before the Les Houches Accord [72] (SLHA), followed in 2008 by SLHA2 [37], for common MSSM conventions

[1] For an additional information, bug reports or any other questions related to the code please contact SUSY_FLAVOR maintainer at the address janusz.rosiek@fuw.edu.pl

was established. By the time SLHA2 became a commonly accepted standard, it was no longer feasible to change the internal SUSY_FLAVOR structure. Thus, its internal routines follow the conventions for the MSSM Lagrangian and Feynman rules given in the earlier paper [17]. However, by default SUSY_FLAVOR can be initialized with a SLHA2 compatible set of parameters, necessary translations are done in a way invisible for an user.

Actually, the choice of convention for the input parameters of SUSY_FLAVOR is a user-defined option. If required, parameters can be also initialized directly following the [17] conventions. The choice between SLHA2 and ref. [17] can be made by setting the relevant control variable, as described in Sec. 4.2. In Table 2 we summarize the (rather minor) differences between the conventions of the extended SLHA2 [37] and those of [17].

SLHA2 [37]	Ref. [17]
$\hat{T}_U$, $\hat{T}_D$, $\hat{T}_E$	$-A_u^T$, $+A_d^T$, $+A_l^T$
$\hat{m}^2_{\tilde{Q}}$, $\hat{m}^2_{\tilde{L}}$	m^2_Q, m^2_L
$\hat{m}^2_{\tilde{u}}$, $\hat{m}^2_{\tilde{d}}$, $\hat{m}^2_{\tilde{l}}$	$(m^2_U)^T$, $(m^2_D)^T$, $(m^2_E)^T$
$\mathcal{M}^2_{\tilde{u}}$, $\mathcal{M}^2_{\tilde{d}}$	$(\mathcal{M}^2_U)^T$, $(\mathcal{M}^2_D)^T$

Table 2: Comparison of SLHA2 [37] and Ref. [17] conventions.

One should note that in SUSY_FLAVOR one can also use non-standard trilinear scalar couplings, involving the complex conjugated Higgs fields (sometimes called "non-analytic" or "non-holomorphic" A-terms). In the notation of [17] they read as:

$$A_l^{\prime IJ} H_i^{2\star} L_i^I E^J + A_d^{\prime IJ} H_i^{2\star} Q_i^I D^J + A_u^{\prime IJ} H_i^{1\star} Q_i^I U^J + \text{h.c.} \tag{3}$$

Usually these couplings are not considered as they are not generated in standard SUSY breaking models. However, they are included in SUSY_FLAVOR and by default initialized to zero. Users may decide to set them to some non-trivial values in order to check their impact on rare decays phenomenology (loop corrections non-holomorphic A-terms may lead to large flavor-changing neutral Higgs couplings).

In general, the parameter μ, the soft-SUSY breaking Higgs-mass term m^2_{12}, the gaugino mass parameters $M_{1,2,3}$, the soft sfermion mass matrices and the trilinear soft couplings may be complex. Global rephasing of all fermion fields of the theory and of one of the Higgs multiplets can render two of these parameters real [7]. We choose them to be the gluino mass M_3 and the Higgs mass term m^2_{12}. The latter choice keeps the Higgs vacuum expectation values (VEV) and, therefore, the parameter $\tan\beta$ real at tree level.

3 Structure of the code

Calculations in SUSY_FLAVOR take the following steps:

1. Parameter initialization. This is described in details in Sec. 4. Users can adjust the basic Standard Model parameters according to latest experimental data and initialize all (or the chosen subset of) supersymmetric soft masses and couplings and Higgs sector parameters. The supersymmetric input parameters for the `SUSY_FLAVOR` must be given at the SUSY scale and program offers no internal routines for evolving them to other scales. At this step also various QCD- and hadronic-related quantities, like e.g. hadronic matrix element values, can be adjusted.

2. Calculation of the physical masses and the mixing angles. After setting the input parameters, `SUSY_FLAVOR` calculates the eigenvalues of the mass matrices of all MSSM particles and their mixing matrices at tree level. Diagonalization is done numerically without any approximations.

3. Resummation of the chirally enhanced effects. In the regime of large $\tan\beta$ and/or large trilinear SUSY breaking terms, large chirally enhanced corrections to Yukawa couplings and CKM matrix elements arise. `SUSY_FLAVOR` v2 can perform resummation of these corrections to all orders of perturbation theory. After calculating threshold corrections, the Yukawa couplings and CKM elements of the superpotential (i.e. the "bare" parameters) are determined. Using these quantities the chirally enhanced effects are calculated and absorbed into effective Higgs-fermion and fermion-sfermion-gaugino(higgsino) vertices. Using these vertices in the calculation of flavor observables, all chirally enhanced corrections are automatically taken into account. The level of resummation (no resummation, approximate analytical resummation in the decoupling limit, iterative numerical resummation) is a user defined option.

4. Calculation of the Wilson coefficients at the SUSY scale. The one-loop Wilson coefficients of the effective operators required for a given process are calculated using the sfermion mixing matrices and the physical masses as input. Again, the formulae used in the code do not rely on any approximations, such as the MIA expansion. In the current version, `SUSY_FLAVOR` calculates Wilson coefficients generated by the diagrams listed in Table 3. All Wilson coefficients are calculated at the energy scale assumed to be the average mass of SUSY particles contributing to a given process or the top quark scale.

Box	Penguin	Self energy
$dddd$	$Z\bar{d}d$, $\gamma\bar{d}d$, $g\bar{d}d$	d-quark
$uuuu$	$H_i^0\bar{d}d$, $A_i^0\bar{d}d$	u-quark
$ddll$	$H_i^0\bar{u}u$, $A_i^0\bar{u}u$	charged lepton l
$dd\nu\nu$	$\gamma\bar{l}l$	

Table 3: One loop parton level diagrams implemented in `SUSY_FLAVOR`.

It is important to stress that routines of `SUSY_FLAVOR` calculating form factors accept fermion generation indices as input parameters. Thus in Table 3 d and u, l and ν denote quarks or leptons of *any* generation. Hence, the actual number of amplitudes which can be calculated using combinations of these form factors is much larger than used by the rare decay rates currently implemented fully in SUSY_FLAVOR, opening possibility for further developments of the library.

5. Strong corrections. In the final step SUSY_FLAVOR performs (when necessary) the QCD evolution of the Wilson coefficients from the high scale (SUSY or top quark mass scale) to the low energy scale appropriate for a given decay, calculates the relevant hadronic matrix elements, and returns predictions for physical quantities. The formulae for QCD and hadronic corrections are primarily based on calculations performed in the SM and supplemented, when necessary, with contributions from non-standard operators which usually are neglected in the SM, because they are suppressed by powers of the light quark Yukawa couplings. This part of SUSY_FLAVOR is based on analyses published by other authors, whereas points 1-4 are implemented using our own calculations. The accuracy of strong corrections differ from process to process, from negligible or small (leptonic EDM, "gold-plated" decay modes $K \to \pi\bar{\nu}\nu$ [80]) to order of magnitude uncertainties (unknown long distance contributions to Δm_K or Δm_D). Even in the case of large QCD uncertainties, the result of the calculation performed by SUSY_FLAVOR can be of some use. Flavor violation in the sfermion sector can lead to huge modifications of many observables, sometimes by several orders of magnitude, so that comparison with experimental data can help to constrain the soft flavor-violating terms even if the strong corrections are not very well known.

In Table 4 we list the files included in SUSY_FLAVOR library with a brief description of their content and purpose. Most of the 2-, 3- and 4-point Green functions are calculated for vanishing external momenta (exception are up-quark self energies and Higgs-up quark 3-point functions where Higgs boson and top quark masses are not small enough to be neglected). As mentioned before, by "u quark" and "d quark" we mean all generations of quarks. In addition to files listed in Table 4, the library contains the master driver files `susy_flavor_file.f` and `susy_flavor_prog.f` which illustrate the proper initialization sequence for SUSY_FLAVOR parameters and produce a sample of results for the implemented observables.

4 Parameter initialization in SUSY_FLAVOR

Apart from initialization routines used by SUSY_FLAVOR and their arguments we list here the FORTRAN common blocks storing the most important program data (other common blocks serve for the internal purposes and usually do not need to be accessed by users). As mentioned in the previous section, supersymmetric input parameters should be given at the SUSY scale (only for some SM parameters, like running quark masses, the input scale is user defined).

`b_fun.f`:	general 2-point loop functions
`bsg_nl.f`:	formulae for $\mathrm{Br}(B \to X_s\gamma)$, including QCD corrections
`cdm_q.f`:	u- and d-quark chromoelectric dipole moments
`cdm_g.f`:	gluon chromoelectric dipole moment
`c_fun.f`:	general 3-point loop functions
`c_fun_exp.f`:	3-point functions c_0, c_{11}, c_{12} expanded in external momenta
`cd_fun.f`:	3-, 4- and some 5-point loop functions at vanishing external momenta
`db_fun.f`:	derivatives of general 2-point loop functions
`dd_gamma.f`:	d quark-d quark-photon 1-loop triangle diagram
`ddg_fun.f`:	general gauge boson-fermion-fermion 1-loop triangle diagram
`dd_gluon.f`:	d quark-d quark-gluon 1-loop triangle diagram
`dd_ll.f`:	d quark-d quark-lepton-lepton 1-loop box diagram
`dd_mix.f`:	4-d quark 1-loop box diagram
`dd_vv.f`:	d quark-d quark-neutrino-neutrino 1-loop box diagram
`d_self0.f`:	full d-quark self-energy
`edm_q.f`:	u- and d-quark electric dipole moments
`eisch1.f`:	auxiliary numerical routine - hermitian matrix diagonalization
`l_self0_dlim.f`:	routines for the various decompositions of the lepton self energies
`ll_gamma.f`:	lepton-lepton-photon 1-loop triangle diagram
`mh_diag.f`:	diagonalization of tree level mass matrices, approximate 2-loop Higgs mass m_h
`mh_init.f`:	initialization of MSSM parameters
`phen_2l.f`:	formulae for $Br(\mu \to e\gamma)$, $\mathrm{Br}(\tau \to \mu\gamma, e\gamma)$, lepton $g-2$ anomaly and EDMs
`phen_2q.f`:	formulae for $Br(K_L^0 \to \pi^0\bar{\nu}\nu)$, $\mathrm{Br}(K^+ \to \pi^+\bar{\nu}\nu)$, $\mathrm{Br}(B_{s(d)} \to l^+l^-)$, $\mathrm{Br}(B \to \tau\nu, D\tau\nu)$, $\mathrm{Br}(t \to uh, ch)$, $\mathrm{Br}(t \to ug, cg)$ and neutron EDM
`phen_4q.f`:	formulae for the meson mixing observables: Δm_K, ϵ_K, Δm_D, $\Delta m_{B_{d(s)}}$
`qcd_fun.f`:	auxiliary QCD calculations - running α_s, running quark masses etc.
`q_self0_dlim.f`:	routines for the various decompositions of the u- and d-quark self energies
`rombint.f`:	auxiliary numerical routine - Romberg numerical integration
`sff_fun.f`:	general scalar-fermion-fermion 1-loop triangle diagram
`sflav_io.f`:	input/output routines for the SLHA2 data format
`sflav_main.f`:	main routine calculating all physical observables
`suu_vert.f`:	CP-even neutral Higgs boson-u quark-u quark 1-loop triangle diagram
`u_self0.f`:	u-quark self-energy
`uu_gluon.f`:	u quark-u quark-gluon 1-loop triangle diagram
`uu_mix.f`:	4-u quark 1-loop box diagram
`vegas.f`:	auxiliary numerical routine - Vegas Monte Carlo integration
`vf_def.f`:	definitions of fermion tree-level vertices
`vg_def.f`:	definitions of gauge boson tree-level vertices
`vh_def.f`:	definitions of Higgs boson tree-level vertices
`yuk_ren.f`:	chiral corrections to the Yukawa couplings and CKM matrix
`zdd_vert0.f`:	Z boson-d quark-d quark 1-loop triangle diagram

Table 4: List of files included in `SUSY_FLAVOR` library.

By default, SUSY_FLAVOR uses the following implicit type declaration in all routines:

```
implicit double precision (a-h,o-z)
```

so that all variables with names starting from `a` to `h` and from `o` to `z` are automatically defined as `double precision` and those with names starting from `i` to `n` are of `integer` type. In what follows we indicate variables that do not obey this rule. Such variables are always listed in explicit type statements inside the procedures. Complex parameters are declared in SUSY_FLAVOR as `double complex` type. Mass parameters are always given in GeV.

SUSY_FLAVOR provides two ways of initializing the input parameters. Firstly, they can be read from the file `susy_flavor.in`. The structure of this file follows the SLHA2 convention [37], with optional extensions which we describe in Sec. 4.2. Initializing parameters in the input file does not require a detailed knowledge of the program internal structure. This option, as it requires a disk file access for each parameter set may not be most efficient for scans over the MSSM parameter space. Therefore, SUSY_FLAVOR provides also a set of routines designed to initialize parameters defined in the program, which can be used to prepare programs that scan over large parameter sets. As described in Sec. 4.3, these routines require more care, as they should be initialized in proper order, i.e. first the gauge sector, then the fermion sector, Higgs sector, and at the end SUSY sectors (the initialization sequences for the gaugino, slepton and squark sectors are independent).

An examples of an initialization sequence for SUSY_FLAVOR, illustrating both options mentioned above, is presented Appendix B. The sample input file `susy_flavor.in` is given in Appendix C. Test output generated for parameters used in Appendices B and C is enclosed in Appendix D.

4.1 Variables controlling particle content

SUSY_FLAVOR v2.5 allows to separately switch contributions from various MSSM sectors on or off. Such a feature is useful to understand the relative size of their effects for each of the calculated processes. The relevant control variables can be set by the following FORTRAN statement at the beginning of the driver program:

```
call set_active_sector(ih,ic,in,ig),
```

where the variables `ih, ic, in` and `ig` can take values 0 or 1 and they control, respectively, the inclusion in the total result the diagrams with gauge and Higgs bosons, charginos, neutralinos and gluinos exchanged in the loops. Note that diagrams with Higgs and gauge bosons circulating in loops are always added together and currently cannot be disentangled, so setting `ih=1, ic=in=ig=0` does not reproduce the SM result. Also for $\Delta F = 2$ processes, where mixed box diagrams with both neutralino and gluino in the loop exist, such diagrams are included only if both `in=ig=1`.

Obviously, by default, if no call to `set_active_sector` is made, all control variables are assumed to be equal 1, so that all contributions are included.

4.2 Parameter initialization from the input file

The input parameters for `SUSY_FLAVOR` can be set by the editing appropriate entries of the file `susy_flavor.in` and subsequently calling the subroutine `sflav_input`, which reads the input file, stores the MSSM Lagrangian parameters in FORTRAN common blocks and calculates tree-level physical masses and mixing matrices. After calling `sflav_input`, all physical observable described in Sec. 6 can be calculated. The input file `susy_flavor.in` is written in the SLHA2 format, with some extensions which we list below.

The initialization proceeds as follows. Before reading the input file, all parameters are set to some initial values. In version 2.50 they are:

- basic SM parameters

$\alpha_{em}(M_Z) = 1/127.934$	$M_Z = 91.1876$ GeV	s_W^2(MSBar) $= 0.23116$
$\alpha_s(M_Z) = 0.1172$	$M_W = 80.398$ GeV	

- quark-related parameters

running quark masses	pole fermion masses	CKM parameters
$m_u(2\text{ GeV}) = 2.15$ MeV	$m_t = 173.5$ GeV	$\lambda = 0.2258$
$m_d(2\text{ GeV}) = 4.7$ MeV	$m_e = 0.5109989$ MeV	$A = 0.808$
$m_s(2\text{ GeV}) = 93.5$ MeV	$m_\mu = 105.658$ MeV	$\bar{\rho} = 0.177$
$m_c(m_c) = 1.275$ GeV	$m_\tau = 1.77684$ GeV	$\bar{\eta} = 0.36$
$m_b(m_b) = 4.18$ GeV		

- all MSSM mass parameters (μ, gaugino and sfermion masses, trilinear A terms) are set to 0. $\tan\beta$ and the CP-odd Higgs mass M_A, which we use as the input parameters for the Higgs sector, are also set to 0.

- hadronic-related parameters (QCD scales and effective coefficients, hadronic matrix elements etc.) are set to values described in Sections 6.1–6.12. Their compact list is given in `Block SFLAV_HADRON` in Appendix C.

Subsequently, the input Blocks are read from the file `susy_flavor.in` in the following order: `SOFTINP`, `SMINPUTS`, `VCKMIN`, `MINPAR` ($\tan\beta$ only, other entries ignored), `EXTPAR`, `IMEXTPAR`, `MSL2IN`, `IMMSL2IN`, `MSE2IN`, `IMMSE2IN`, `TEIN`, `IMTEIN`, `TEINH`, `IMTEINH`, `MSQ2IN`, `IMMSQ2IN`, `MSU2IN`, `IMMSU2IN`, `MSD2IN`, `IMMSD2IN`, `TUIN`, `IMTUIN`, `TUINH`, `IMTUINH`, `TDIN`, `IMTDIN`, `TDINH`, `IMTDINH`, `SFLAV_HADRON`.

In principle the presence of *any* Block is optional - if some Block is absent, the program falls back to default parameter values listed above. Obviously, at least flavor-diagonal SUSY mass parameters have to be defined, otherwise the vanishing default masses will cause the crash of the program. If a parameter is multiply defined in several Blocks (for example left slepton mass parameters in `Block EXTPAR` and later in `Blocks MSL2IN, IMMSL2IN`), the value from Block read as latest in the list above overwrites (without warning!) the values from preceding Blocks. Blocks do not need to be complete, i.e. to contain all entries described in SLHA2 specification - it is sufficient to define minimal set of parameters relevant for given problem, others would be filled with default values.

Comparing to standard SLHA2 conventions, `SUSY_FLAVOR` uses following extensions:

1. We define an optional `Block SOFTINP` defining choice of input conventions. If such block is not present, program assumes default values of control variables:

Variable value	Sfermion sector parametrization
`iconv` = 1	**default:** MSSM parameters defined in SLHA2 conventions.
`iconv` = 2	MSSM parameters defined in conventions of Ref. [17].
`input_type` = 1	off-diagonal soft terms are given as dimensionless mass insertions.
`input_type` = 2	**default:** sfermion soft terms given as absolute dimensionful values.
`ilev` = 0	no resummation of chirally enhanced corrections, all SUSY contributions are strictly taken at the 1-loop level.
`ilev` = 1	resummation of chirally enhanced corrections performed with the use of analytical formulae valid in the decoupling limit $M_{SUSY} \gg v_1, v_2$.
`ilev` = 2	**default:** resummation of chirally enhanced corrections performed using the numerical iterative solutions for bare Yukawa couplings and CKM matrix elements.

2. `SUSY_FLAVOR` uses two non-standard (comparing to SLHA2) entries of `Block SMINPUTS`. Entry 30 is used to define M_W and entry 31 to define s_W^2 in MSbar renormalization scheme.

3. Following the SLHA2 convention, full sfermion soft mass matrices can be defined in the `MSL2IN`, `MSE2IN`, `MSQ2IN`, `MSD2IN`, `MSU2IN` and `IMMSL2IN`, `IMMSE2IN`, `IMMSQ2IN`, `IMMSD2IN`, `IMMSU2IN` blocks. The `input_type` parameter in the `SOFTINP` block defines the dimension of the off-diagonal terms. If `input_type` = 1, the off-diagonal entries given in `susy_flavor.in` are assumed to be dimensionless mass insertions δ_X^{IJ} and the actual flavor violating sfermion soft mass terms are calculated as

$$(m_X^2)_{IJ} \;=\; (m_X^2)^\star_{JI} = \delta_X^{IJ}\sqrt{(m_X^2)_{II}(m_X^2)_{JJ}}\;, \tag{4}$$

where $X = L, E, Q, U, D$ and I, J enumerate superpartners of the mass-eigenstates quarks.

4. The blocks `TEIN, TDIN, TUIN` and `IMTEIN, IMTDIN, IMTUIN` define the full trilinear SUSY breaking terms. They are in general not hermitian and one is required to define all entries. Again the parameter `input_type` defines the format and dimension of the off-diagonal terms. If `input_type` = 1, then all relevant `susy_flavor.in` entries are treated as dimensionless numbers and expanded to the full trilinear SUSY breaking terms as:

$$A_l^{IJ} \;=\; \delta_{LLR}^{IJ}\left((m_L^2)_{II}(m_E^2)_{JJ}\right)^{\frac{1}{4}}\;,$$

$$
\begin{aligned}
A_d^{IJ} &= \delta_{DLR}^{IJ} \left((m_Q^2)_{II} (m_D^2)_{JJ} \right)^{\frac{1}{4}} , \\
A_u^{IJ} &= \delta_{ULR}^{IJ} \left((m_Q^2)_{II} (m_U^2)_{JJ} \right)^{\frac{1}{4}} .
\end{aligned} \tag{5}
$$

Note that the A-terms are normalized to the diagonal sfermion masses, not to the diagonal trilinear terms, and that in eq. (5) for simplicity we use $(m_Q^2)_{II}$ as the diagonal mass scale for both up and down left squark fields (related by the CKM rotation).

5. The "non-holomorphic" LR mixing terms of eq. (3) are not included in the SLHA2 specification of the MSSM parameters. They can be defined if necessary in blocks `TEINH, TDINH, TUINH` and `IMTEINH, IMTDINH, IMTUINH`. If such blocks are not present, all such terms are set to 0. As standard LR mixing terms, non-holomorphic ones are also not hermitian in general. Again depending on the value of `input_type` they can be given as dimensionful or dimensionless. In the second case (`input_type` = 1) the dimensionful non-holomorphic terms are calculated in a way analogous to eq. (5).

4.3 Parameter initialization inside the program

`SUSY_FLAVOR` input parameters can be initialized directly inside the driver program using the set of routines described below. Before the proper initialization sequence, the user can set the `iconv` variable value to choose the input convention:

`common/sf_cont/eps,indx(3,3),iconv`

`iconv=1`	SLHA2 [37] input conventions
`iconv=2`	[17] input conventions

After choosing the input conventions, one should subsequently initialize the gauge, matter fermion, Higgs, SUSY fermion and sfermion sectors (exactly in this order), using the procedures described in detail in the following sections.

4.3.1 Gauge sector

As input, `SUSY_FLAVOR` takes the gauge boson masses (M_W, M_Z) and the gauge coupling constants (electromagnetic and strong) at the M_Z scale. They are initialized by:

Routine and arguments	Purpose and MSSM parameters
`vpar_update(zm,wm,alpha_em,st2)`	Sets electromagnetic sector parameters
`zm`	M_Z, Z boson mass
`wm`	M_W, W boson mass
`alpha_em`	$\alpha_{em}(M_Z)$, QED coupling at M_Z scale
`st2`	s_W^2 in MSBar scheme
`lam_fit(alpha_s)`	Sets $\alpha_s(M_Z)$ and Λ_{QCD} for 4-6 flavors at the NNLO level
`lam_fit_nlo(alpha_s)`	Sets $\alpha_s(M_Z)$ and Λ_{QCD} for 4-6 flavors at the NLO level
`alpha_s`	$\alpha_s(M_Z)$, strong coupling at M_Z scale

4.3.2 Matter fermion sector

SUSY_FLAVOR assumes that neutrinos are massless. The pole masses of the charged leptons are initialized in the file `sflav_io.f` in the routine `sflav_defaults` and can be adjusted changing the values given there. In the quark sector the most important input parameters are the running top and bottom masses at a given renormalization scale and the CKM angles and phase. They can be set by:

Routine and arguments	Purpose and MSSM parameters
`init_fermion_sector(alpha_s,tm,tsc,bm,bsc)`	Sets running top and bottom quark mass
`alpha_s`	$\alpha_s(M_Z)$, strong coupling at M_Z scale
`tm,tsc`	$m_t(\mu_t)$, running $\overline{\mathrm{MS}}$ top quark mass
`bm,bsc`	$m_b(\mu_b)$, running $\overline{\mathrm{MS}}$ bottom quark mass
`ckm_init(s12,s23,s13,delta)`	Option 1: initialization of the CKM matrix
`s12,s23,s13`	$\sin\theta_{12}, \sin\theta_{23}, \sin\theta_{13}$, sines of the CKM angles
`delta`	δ, the CKM phase in radians
`ckm_wolf(alam,a,rhobar,etabar)`	Option 2: initialization of the CKM matrix
`alam,a,rhobar,etabar`	Wolfenstein parameters $\lambda, A.\bar{\rho}, \bar{\eta}$

The light quark masses can be also adjusted by changing values which are set in the routine `sflav_defaults`.

4.3.3 Higgs sector

Following the common convention, we take the Higgs mixing parameter μ, the CP-odd Higgs boson mass M_A, and the ratio of vacuum expectation values $\tan\beta = v_2/v_1$ as the input parameters (in order to calculate values of Higgs mass terms in the Lagrangian, one needs to set also the μ parameter already here):

`subroutine init_higgs_sector(pm,tb,amu,ierr)`

Argument	MSSM parameters
`pm`	CP-odd Higgs mass M_A
`tb`	Ratio of Higgs VEVs, $\tan\beta = \frac{v_2}{v_1}$
`amu`	Higgs mixing parameter μ (complex)
`ierr`	output error code: $ierr \neq 0$ if Higgs sector initialization failed

4.3.4 Sfermion sector

SUSY_FLAVOR uses two subroutines to initialize sfermion parameters, `init_slepton_sector` and `init_squark_sector`. They accept as input diagonal masses and off-diagonal dimensionless mass insertions, expanded later to entries of the soft mass matrices as defined by eqs. (4), (5) (this is only a choice of parametrization and does not lead to any loss of generality). The sfermion initialization routines have the following arguments:

```
subroutine init_squark_sector(sql,squ,sqd,asu,asd,sqmi_l,sumi_r,sdmi_r,
           sumi_lr,sdmi_lr,sumi_lrp,sdmi_lrp,ierr)
```

Argument	MSSM parameters
`sql`	Array of the diagonal left-handed down-squark masses $(m_D^2)_{LL}^{II} = \mathtt{sql(I)}^2$, $I = 1\dots3$
`squ`	Array of the diagonal right-handed up-squark masses $(m_U^2)_{RR}^{II} = \mathtt{squ(I)}^2$, $I = 1\dots3$
`sqd`	Array of the diagonal right-handed down-squark masses $(m_D^2)_{RR}^{II} = \mathtt{sqd(I)}^2$, $I = 1\dots3$
`sqmi_l`	Array of the off-diagonal left-handed down squark mass insertions $(\delta_D)_{LL}^{12} = \mathtt{sqmi\_l(1)}$, $\delta_D{}_{LL}^{23} = \mathtt{sqmi\_l(2)}$, $(\delta_D)_{LL}^{13} = \mathtt{sqmi\_l(3)}$ (complex parameters); remaining down LL mass insertions are initialized via hermitian conjugation; up LL mass matrix obtained via $SU(2)$ relation
`sumi_r`	Array of the off-diagonal right-handed up-squark mass insertions $(\delta_U)_{RR}^{12} = \mathtt{sumi\_r(1)}$, $(\delta_U)_{RR}^{23} = \mathtt{sumi\_r(2)}$, $(\delta_U)_{RR}^{13} = \mathtt{sumi\_r(3)}$ (complex parameters); remaining up RR mass insertions are initialized via hermitian conjugation
`sdmi_r`	Array of the off-diagonal right-handed down-squark mass insertions $(\delta_D)_{RR}^{12} = \mathtt{sdmi\_r(1)}$, $(\delta_D)_{RR}^{23} = \mathtt{sdmi\_r(2)}$, $(\delta_D)_{RR}^{13} = \mathtt{sdmi\_r(3)}$ (complex parameters); remaining down RR mass insertions are initialized via hermitian conjugation
`sumi_lr`	Matrix with the standard (holomorphic) up-squark trilinear LR mass insertions $(\delta_U)_{LR}^{IJ} = \mathtt{sumi\_lr(I,J)}$, $I,J = 1\dots3$ (complex parameters)
`sdmi_lr`	Matrix with the standard (holomorphic) down-squark trilinear LR mass insertions $(\delta_D)_{LR}^{IJ} = \mathtt{sdmi\_lr(I,J)}$, $I,J = 1\dots3$ (complex parameters)
`sumi_lrp`	Matrix with the non-holomorphic up-squark trilinear LR mass insertions $(\delta'_U)_{LR}^{IJ} = \mathtt{sumi\_lrp(I,J)}$, $I,J = 1\dots3$ (complex parameters)
`sdmi_lrp`	Matrix with the non-holomorphic down-squark trilinear LR mass insertions $(\delta'_D)_{LR}^{IJ} = \mathtt{sdmi\_lrp(I,J)}$, $I,J = 1\dots3$ (complex parameters)
`ierr`	output error code: $ierr \neq 0$ if squark sector initialization failed (negative physical squark mass^2)

`subroutine init_slepton_sector(sll,slr,slmi_l,slmi_r,slmi_lr,slmi_lrp,ierr)`

Argument	MSSM parameters
`sll`	Array of the diagonal left-handed slepton masses $(m_L^2)_{LL}^{II} =$ `sll(I)`^{2}, $I = 1\dots 3$
`slr`	Array of the diagonal right-handed slepton masses $(m_L^2)_{RR}^{II}$=`slr(I)`^{2}, $I = 1\dots 3$
`slmi_l`	Array of the off-diagonal left-handed slepton mass insertions $(\delta_L)_{LL}^{12} =$ `slmi_l(1)`, $(\delta_L)_{LL}^{23} =$ `slmi_l(2)`, $(\delta_L)_{LL}^{13} =$ `slmi_l(3)` (complex parameters); remaining LL mass insertions are initialized via hermitian conjugation
`slmi_r`	Array of the off-diagonal right-handed slepton mass insertions $(\delta_L)_{RR}^{12} =$ `slmi_r(1)`, $(\delta_L)_{RR}^{23} =$ `slmi_r(2)`, $(\delta_L)_{RR}^{13} =$ `slmi_r(3)` (complex parameters); the remaining RR mass insertions are initialized via hermitian conjugation
`slmi_lr`	Matrix with the standard (holomorphic) slepton trilinear LR mass insertions $(\delta_L)_{LR}^{IJ} =$ `slmi_lr(I,J)`, $I, J = 1\dots 3$ (complex parameters)
`slmi_lrp`	Matrix with the non-holomorphic slepton trilinear LR mass insertions $(\delta'_L)_{LR}^{IJ} =$ `slmi_lrp(I,J)`, $I, J = 1\dots 3$ (complex parameters)
`ierr`	output error code: $ierr \neq 0$ if slepton sector initialization failed (negative physical slepton mass^2)

4.3.5 Supersymmetric fermion sector

Initialization is done by the routine `init_ino_sector`:

`subroutine init_ino_sector(gm1,gm2,gm3,amu,tb,ierr)`

Argument	MSSM parameters
`gm1,gm2`	$U(1), SU(2)$ gaugino masses (complex)
`gm3`	$SU(3)$ gaugino mass
`tb`	$\tan\beta = \frac{v_2}{v_1}$, the ratio of Higgs VEVs
`amu`	the Higgs mixing parameter μ (complex)
`ierr`	output warning code: $ierr \neq 0$ for chargino or neutralino lighter than $M_Z/2$

If one sets $M_1 = 0$ in the call to `init_ino_sector` then the GUT-derived relation $M_1 = \frac{5}{3}\tan^2\theta_W M_2$ is used for M_1.

4.4 Tree-level physical masses and mixing angles

After performing the full initialization sequence in `SUSY_FLAVOR`, all the MSSM Lagrangian parameters, physical tree-level particle masses (with the exception of the running quark masses), and mixing matrices are calculated and stored in common blocks. If necessary, they can be directly accessed and modified. Note, however, that after any modifications of the Lagrangian parameters, relevant procedures calculating physical masses and mixing angles have to called again. In Table 5 we list the important blocks storing MSSM parameters. Common blocks containing masses and mixing angles are listed in Table 6.

Common block and variables	Lagrangian parameters
`common/vpar/st,ct,st2,ct2,sct,sct2,e,e2,alpha,wm,wm2,zm,zm2,pi,sq2`	
`st,ct,st2,ct2,sct,sct2`	Weinberg angle functions, respectively s_W, c_W, s_W^2, c_W^2, $s_W c_W$, $s_W^2 c_W^2$
`e,e2,alpha`	electric charge powers at M_Z scale: e, e^2, α_{em}
`wm,wm2,zm,zm2`	gauge boson masses: M_W, M_W^2, M_Z, M_Z^2
`pi,sq2`	numerical constants, π and $\sqrt{2}$
`common/hpar/hm1,hm2,hm12,hmu`	
`hm1,hm2`	soft Higgs masses $m_{H_1}^2, m_{H_2}^2$
`hm12`	soft Higgs mixing parameter m_{12}^2
`hmu`	Higgs mixing parameter μ (complex)
`common/vev/v1,v2`	
`v1,v2`	Higgs vacuum expectation values v_1, v_2
`common/yukawa/yl(3),yu(3),yd(3)`	
`yl(3)`	charged lepton Yukawa couplings Y_e, Y_μ, Y_τ (complex)
`yu(3)`	Running $\overline{\text{MS}}$ up-quark Yukawa couplings at m_t scale: Y_u, Y_c, Y_t
`yd(3)`	Running $\overline{\text{MS}}$ down-quark Yukawa couplings at m_t scale: Y_u, Y_c, Y_t
`common/gmass/gm3,gm2,gm1`	
`gm1,gm2`	$U(1), SU(2)$ gaugino masses M_1, M_2 (complex)
`gm3`	$SU(3)$ gaugino mass M_3
`common/msoft/lms(3,3),rms(3,3),ums(3,3),dms(3,3),qms(3,3)`	
`lms(3,3),rms(3,3)`	hermitian slepton soft mass matrices m_L^2, m_E^2 (complex)
`ums(3,3),dms(3,3),qms(3,3)`	hermitian squark soft mass matrices m_U^2, m_D^2, m_Q^2 (complex)
`common/soft/ls(3,3),ks(3,3),ds(3,3),es(3,3),us(3,3),ws(3,3)`	
`ls(3,3),ds(3,3),us(3,3)`	trilinear soft SUSY breaking terms A_l, A_d, A_u (complex)
`ks(3,3),es(3,3),ws(3,3)`	trilinear "non-holomorphic" soft SUSY breaking terms A_l', A_d', A_u' (complex)

Table 5: Common blocks storing the MSSM Lagrangian parameters.

Common block and variables	Masses and mixing matrices
`common/fmass/em(3),um(3),dm(3)`	
`em(3)`	Charged lepton pole masses m_e, m_μ, m_τ
`um(3)`	Running $\overline{\rm MS}$ up-quark masses at the m_t scale: m_u, m_c, m_t
`dm(3)`	Running $\overline{\rm MS}$ down-quark masses at the m_t scale: m_u, m_c, m_t
`common/hmass/cm(2),rm(2),pm(2),zr(2,2),zh(2,2)`	
`rm(2)`	neutral CP-even Higgs masses $\mathtt{rm}(1) = M_H$, $\mathtt{rm}(2) = M_h$
`pm(2)`	neutral CP-odd Higgs mass `pm(1)` and Goldstone mass `pm(2)`
`cm(2)`	charged Higgs mass `cm(1)` and charged Goldstone mass `cm(2)`
`zr(2,2)`	CP-even Higgs mixing matrix Z_R
`zh(2,2)`	CP-odd and charged Higgs mixing matrix Z_H
`common/charg/fcm(2),zpos(2,2),zneg(2,2)`	
`fcm(2)`	chargino masses $M_{\chi_i^+}$, $i = 1, 2$
`zpos(2,2),zneg(2,2)`	chargino mixing matrices Z_+, Z_- (complex)
`common/neut/fnm(4),zn(4,4)`	
`fnm(4)`	neutralino masses $M_{\chi_i^0}$, $i = 1 \ldots 4$
`zn(4,4)`	neutralino mixing matrix Z_N (complex)
`common/slmass/vm(3),slm(6),zv(3,3),zl(6,6)`	
`vm(3)`	sneutrino masses $M_{\tilde\nu_I}, I = 1 \ldots 3$
`slm(6)`	charged slepton masses $M_{L_i}, i = 1 \ldots 6$
`zv(3,3)`	sneutrino mixing matrix $Z_{\tilde\nu}$ (complex)
`zl(6,6)`	charged slepton mixing matrix Z_L (complex)
`common/sqmass/sum(6),sdm(6),zu(6,6),zd(6,6)`	
`sum(6)`	up-squark masses $M_{U_i}, i = 1 \ldots 6$
`sdm(6)`	down-squark masses $M_{D_i}, i = 1 \ldots 6$
`zu(6,6)`	up-squark mixing matrix Z_U (complex)
`zd(6,6)`	down-squark mixing matrix Z_D (complex)

Table 6: Common blocks storing particle masses and mixing matrices.

5 Resummation of chirally enhanced corrections

The resummation of the chirally enhanced corrections, including the threshold corrections to Yukawa couplings and CKM matrix elements, is an important new feature added to SUSY_FLAVOR from version 2.0. Such corrections arise in the case of large values of $\tan\beta$ or large trilinear SUSY-breaking terms. They formally go beyond the 1-loop approximation, but should be included due to their numerical importance[2]. Implementation of the resummation in SUSY_FLAVOR follows the systematic approach of ref. [36] and takes into accounts all contributions involving sfermions and gauginos (gluino, chargino and neutralino exchanges). The level of resummation is a user selectable option and can be done using the following routine:

Routine:	`subroutine set_resummation_level(ilev,ierr)`	
Input:	`ilev=0`:	no resummation
	`ilev=1`:	analytical solution used for bare Yukawa couplings and the bare CKM matrix elements (i.e. parameters of the superpotential), valid in the "decoupling limit" $M_{SUSY} \gg v_1, v_2$
	`ilev=2`:	exact iterative numerical solution for the bare Yukawa couplings and the bare CKM matrix elements.
Output:	`ierr=0`:	resummation successful
	`ierr<0`:	exact resummation (`ilev=2`) requested but failed (no convergence), instead analytical resummation in the decoupling limit performed successfully
	`ierr>0`:	resummation failed (both for `ilev=1,2`), only 1-loop expressions will be used in calculations of the physical observables
Details of calculations:	Ref. [36]	

After call to `set_resummation_level` with `ilev`$\neq$ `0`, SUSY_FLAVOR calculates the values of bare Yukawa couplings and CKM matrix elements (i.e. the values of the MSSM Lagrangian parameters) and starts to use in loop calculations appropriately corrected effective Higgs boson and supersymmetric particle couplings, automatically taking into account resummation of enhanced higher order terms.

One should keep in mind that if the chirally enhanced corrections are very large relation between bare and effective physical fermion masses and CKM matrix elements involve a significant degree of fine-tuning and one might also encounter numerical instabilities using the program. Therefore, the routines performing the resummation should be used with care. One can reasonably assume that resummation works properly in the decoupling limit $v_1, v_2 \ll M_{SUSY}$ as long as the difference between the bare and physical quantities is at least not significantly larger than the physical values themselves. Setting the actual "safety condition" is left to the SUSY_FLAVOR users. To facilitate that,

[2]It is even possible that the light fermion masses and off-diagonal CKM elements are generated entirely by chirally-enhanced self-energies involving the trilinear A-terms [73]

the blocks SFLAV_CHIRAL_YUKAWA and SFLAV_CHIRAL_CKM in the SUSY_FLAVOR output file list the relative size of differences between the bare Yukawa couplings and CKM matrix elements of the superpotential and the (effective) physical quantities, calculated as

$$\delta X_{corr} = \left| \frac{X_{\text{bare}} - X_{\text{effective}}}{X_{\text{effective}}} \right| \tag{6}$$

One can use such output to define conditions rejecting points of the MSSM parameters space where the resummation effects are too large and calculations cannot be trusted. In our numerical experience, the stability of SUSY_FLAVOR results requires the relative size of the resummed loop corrections to be at most of order one for CKM elements and Yukawa couplings of 2nd and 3rd generation. Thus, if the chosen input respects 't Hooft's naturalness argument [30, 34], also the resummation of all chirally enhanced effects can be performed analytically in the decoupling limit and is stable numerically.

6 List of processes

In this section we list the set observables whose computation is implemented in SUSY_FLAVOR v2.5. QCD corrections and hadronic matrix elements are extracted mostly from various analyses done within the Standard Model. They are assumed to work reasonably well also in the MSSM since supersymmetric strong corrections from gluino and squarks are suppressed by large masses of these particles.

The values of the hadronic matrix elements are calculated using the lattice QCD techniques and thus carry significant theoretical uncertainties. Therefore, in SUSY_FLAVOR, hadronic matrix element estimates and other QCD related quantities are treated as external parameters. They are initialized to the default values listed below for each observable and can be directly modified by the users by changing the relevant variables in the common blocks where they are stored, or simpler, modifying entries of the Block SFLAV_HADRON in the file susy_flavor.in. Currently most of the hadronic (and related) input parameters used in SUSY_FLAVOR are taken from the Table 3 of Ref. [74].

In most cases, QCD and hadronic corrections are known to a precision at the level of few percent to tens of percent, while variations of supersymmetric flavor and CP-violating parameters can change observables by orders-of-magnitude. Thus, as long as the MSSM parameters are not measured very precisely, the current implementation of strong corrections is sufficient for analyses performed in the framework of the general MSSM.

Although SUSY_FLAVOR is designed to calculate flavor-related observables, it is convenient to evaluate within one code also the CP-even Higgs mass m_h, often used as a constraint on the MSSM parameters. Therefore, in SUSY_FLAVOR v2.5 we added the routine calculating the approximate 2-loop estimate of the neutral CP-even Higgs mass m_h, based on Refs. [90,91]. For precise calculations of this mass other public SUSY generators should be used.

6.1 $g-2$ magnetic moment anomaly for leptons

Anomalous magnetic moment of leptons are defined as the coefficient $a_{l^I} \equiv (g_I - 2)/2$ in the effective Hamiltonian for the flavor-diagonal lepton-lepton-photon interaction:

$$\mathcal{H}_l = -\frac{e}{4m_{l^I}} a_I \bar{l}^I \sigma_{\mu\nu} l^I F^{\mu\nu} , \tag{7}$$

where $I = 1, 2, 3$ is the generation index of the lepton[3]. In `SUSY_FLAVOR` supersymmetric contribution to $(g-2)$ anomaly (to be added to the SM one) is calculated by the routine:

Routine:	`double precision function g_minus_2_susy(I)`
Input:	$I = 1, 2, 3$ for e, μ, τ respectively
Output:	SUSY contribution to $a_I = (g_I - 2)/2$ for the charged lepton specified by I
QCD related factors:	none, QCD corrections are small and not included
Details of calculations:	Performed by authors, unpublished

6.2 Electric Dipole Moments of charged leptons

Lepton EDMs are defined as another coefficient d_{l^I} in the effective Hamiltonian for the flavor-diagonal lepton-lepton-photon interaction:

$$\mathcal{H}_l = \frac{i d_{l^I}}{2} \bar{l}^I \sigma_{\mu\nu} \gamma_5 l^I F^{\mu\nu} , \tag{8}$$

where $I = 1, 2, 3$ is again the generation index of the lepton. In `SUSY_FLAVOR` lepton EDM is calculated by:

Routine:	`double precision function edm_l(I)`
Input:	$I = 1, 2, 3$ for e, μ, τ respectively
Output:	EDM for the charged lepton specified by I (in the units $e\ cm$)
QCD related factors:	none, QCD corrections are small and not included
Details of calculations:	Ref. [7] (note that EDM are defined there with opposite relative sign to `SUSY_FLAVOR` convention)

6.3 Neutron Electric Dipole Moment

The neutron EDM can be approximated by the sum of the electric dipole moments of the constituent quarks plus contributions from the chromoelectric dipole moments (CDM) of

[3]The measurement of the anomalous magnetic moment of the muon is used to determine α. In order to consider the possible effect of new physics one needs an independent determination of α [33] - e.g. one can use the measurements of the Rubidium atom [75].

quarks and gluons. The EDMs of the individual quarks are defined analogously to eq. (8). The CDM c_q of the quark q is defined as:

$$\mathcal{H}_c = -\frac{ic_q}{2}\bar{q}\sigma_{\mu\nu}\gamma_5 T^a q G^{\mu\nu a}. \tag{9}$$

The gluonic dipole moment c_g is defined as:

$$\mathcal{H}_g = -\frac{c_g}{6} f_{abc} G^a_{\mu\rho} G^{b\rho}_{\nu} G^c_{\lambda\sigma} \epsilon^{\mu\nu\lambda\sigma}. \tag{10}$$

The exact calculation of the neutron EDM requires knowledge of its hadronic wave function. `SUSY_FLAVOR` uses the formulae:

$$E_n = \eta_{ed} d_d + \eta_{eu} d_u + e(\eta_{cd} c_d + \eta_{cu} c_u) + \frac{e\eta_g \Lambda_X}{4\pi} c_g \tag{11}$$

where η_i and Λ_X are QCD correction factors [76] and the chiral symmetry breaking scale [77], respectively. Various models give significantly different factors η_i. Thus the `SUSY_FLAVOR` result should be treated as an order of magnitude estimate only. The calculations are performed by calling

Routine	`double precision function edm_n()`
Input	none
Output	neutron EDM
QCD related factors:	
`common/edm_qcd/eta_ed,eta_eu,eta_cd,eta_cu,eta_g,alamx`	
η_{ed}	`eta_ed` $= 0.79$
η_{eu}	`eta_eu` $= -0.2$
η_{cd}	`eta_cd` $= 0.59$
η_{cu}	`eta_cu` $= 0.3$
η_g	`eta_g` $= 3.4$
Λ_X	`alamx` $= 1.18$
Details of calculations:	Ref. [7]

6.4 $\mu \to e\gamma$ and $\tau \to e\gamma, \mu\gamma$ decay rates

The branching ratios for the flavor violating decays of a heavy lepton into a lighter lepton and photon are given by:

$$Br(l^J \to l^I\gamma) = \frac{48\pi^2 e^2 Br(l^J \to e\bar{\nu}\nu)}{m_{l^J}^2 G_F^2}\left(|C_L^{JI}|^2 + |C_R^{JI}|^2\right) , \tag{12}$$

where $C_{L,R}^{IJ}$ are the relevant Wilson coefficients calculated from the 1-loop lepton-photon triangle diagram with an on-shell photon. The branching ratios are calculated by

Routine:	`double precision function br_llg(J,I)`
Input:	$J, I = 1, 2, 3$ for e, μ, τ respectively
Output:	branching ratios for $\mu \to e\gamma$ decay ($J = 2, I = 1$) and $\tau \to e\gamma, \mu\gamma$ decays ($J = 3, I = 1, 2$)
QCD related factors:	none, QCD corrections are small and not included
Details of calculations:	Performed by authors, unpublished

6.5 $K_L^0 \to \pi^0 \bar{\nu}\nu$ and $K^+ \to \pi^+ \bar{\nu}\nu$ decay rates

The relevant part of the effective Hamiltonian generated by the top quark and SUSY particle exchanges can be written as

$$\mathcal{H}_{\text{eff}} = \frac{G_F}{\sqrt{2}} \frac{\alpha}{2\pi \sin^2 \theta_w} \sum_{l=e,\mu,\tau} \left[X_L (\bar{s}d)_{V-A} (\bar{\nu}_l \nu_l)_{V-A} + X_R (\bar{s}d)_{V+A} (\bar{\nu}_l \nu_l)_{V-A} \right]. \tag{13}$$

The branching ratios for the $K \to \pi\nu\bar{\nu}$ decays are then given by

$$Br(K^+ \to \pi^+ \bar{\nu}\nu) = \kappa_+ \left[\left(\frac{\Im\mathrm{m}(X_L + X_R)}{\lambda^5} \right)^2 + \left(\frac{\Re\mathrm{e}(K_{cs}^\star K_{cd})}{\lambda} P_c + \frac{\Re\mathrm{e}(X_L + X_R)}{\lambda^5} \right)^2 \right] \tag{14}$$

$$\mathrm{Br}(K_L^0 \to \pi^0 \bar{\nu}\nu) = \kappa_L \left(\frac{\Im\mathrm{m}(X_L + X_R)}{\lambda^5} \right)^2 \tag{15}$$

where κ [78], λ (the Wolfenstein parameters [79]), and the NLO charm quark contribution P_c [80–82] can be modified by SUSY_FLAVOR users (note that κ and P_c depend on V_{us}, m_c and α_s) The calculations of the branching ratios are performed by calling

Routine	`subroutine k_pivv(br_k0,br_kp)`
Input	none
Output	`br_k0` $= Br(K_L^0 \to \pi^0 \bar{\nu}\nu)$ `br_kp` $= Br(K^+ \to \pi^+ \bar{\nu}\nu)$
QCD related factors	

`common/kpivv/ak0,del_ak0,akp,del_akp,pc,del_pc,alam`

$\kappa_L \pm \Delta\kappa_L$	`ak0` $= 2.231 \cdot 10^{-10}$, `del_ak0` $= 0.013 \cdot 10^{-10}$
$\kappa_+ \pm \Delta\kappa_+$	`akp` $= 5.173 \cdot 10^{-11}$, `del_akp` $= 0.025 \cdot 10^{-11}$
$P_c \pm \Delta P_c$	`pc` $= 0.41$, `del_pc` $= 0.03$
λ	`alam` $= 0.225$
Details of calculations:	Ref. [14]

6.6 $B_d^0 \to l^{I+} l^{J-}$ and $B_s^0 \to l^{I+} l^{J-}$ decay rates

The general expression for these branching ratios are rather complicated and can be found in [15][4]. For most users it is sufficient to know that, in addition to the MSSM parameters,

[4]Note that only the 1-loop electroweak/SUSY contributions to $B_{d,s}^0 \to l^{I+} l^{J-}$ are implemented in SUSY_FLAVOR v2.5. Thus, in the limit of heavy SUSY masses SUSY_FLAVOR reproduces older SM 1-loop

the dilepton B decays depend on the B meson masses and the hadronic matrix elements of the down quark vector and scalar currents:

$$\langle 0|\bar{b}\gamma_\mu P_{L(R)} s|B_{s(d)}(p)\rangle \quad = \quad -(+)\frac{i}{2} p_\mu f_{B_{s(d)}} \,, \tag{16}$$

$$\langle 0|\bar{b} P_{L(R)} s|B_{s(d)}(p)\rangle \quad = \quad +(-)\frac{i}{2} \frac{M^2_{B_{s(d)}} f_{B_s}}{m_b + m_{s(d)}} \,, \tag{17}$$

where p_μ is the momentum of the decaying $B_{s(d)}$-meson of mass $M_{B_{s(d)}}$. The $B^0_d \to l^{I+} l^{J-}$ and $B^0_s \to l^{I+} l^{J-}$ decay branching ratios are calculated by:

Routine	`double precision function b_ll(K,L,I,J)`
Input	$I, J = 1, 2, 3$ - outgoing leptons generation indices K, L - generation indices of the valence quarks of the B^0 meson: setting $(K, L) = (3, 1), (1, 3), (3, 2)$ and $(2, 3)$ chooses respectively B^0_d, $\bar{B}^0_d$, B^0_s and $\bar{B}^0_s$ decay
Output	Branching ratios of the decay defined by K, L, I, J
QCD related factors	
`common/meson_data/dmk,amk,epsk,fk,dmd,amd,fd,amb(2),dmb(2),gam_b(2),fb(2)`	
M_{B_d}	`amb(1)` $= 5.2794$
M_{B_s}	`amb(2)` $= 5.368$
f_{B_d}	`fb(1)` $= 0.193$
f_{B_s}	`fb(2)` $= 0.232$
Details of calculations:	Ref. [15]

6.7 $B \to (D)\tau\nu$ decay rates

`SUSY_FLAVOR` calculates $Br(B \to \tau\nu)$ $Br(B \to D\tau\nu)$ and $Br(B \to D^\star\tau\nu)$ including the SM and the charged Higgs contribution. The chirally enhanced corrections to Yukawa couplings from SUSY sectors, which also affect the charged Higgs contribution, are included. The relevant part effective Hamiltonian reads as:

$$H^I_{eff} = \frac{4G_F V_{qb}}{\sqrt{2}} \left[(\bar{q}\gamma_\mu P_L b)(\bar{\tau}\gamma_\mu P_L \nu) + C^L_q (\bar{q} P_L b)(\bar{\tau} P_L \nu) + C^R_q (\bar{q} P_R b)(\bar{\tau} P_L \nu) \right] \,, \tag{18}$$

where $q = u$ for $B \to \tau\nu$ and $q = c$ for $B \to D(D^\star)\tau\nu$ decays. The New Physics $C^{L(R)}_q$ contributions come from the modification of the effective Yukawa couplings and read as

$$C^L_q \quad \approx \quad -\frac{\sqrt{2}}{4m^2_{H^+} G_F V_{qb}} \Gamma^{H^+RL}_{qb} \Gamma^{H^+LR\star}_{\nu\tau} \,, \tag{19}$$

$$C^R_q \quad \approx \quad -\frac{\sqrt{2}}{4m^2_{H^+} G_F V_{qb}} \Gamma^{H^+LR}_{qb} \Gamma^{H^+LR\star}_{\nu\tau} \,, \tag{20}$$

estimates for such decays, somewhat higher that the NLO result given recently for $B_s \to \mu^+\mu^-$ in [83] with $\Gamma_{qb}^{H^+LR}, \Gamma_{qb}^{H^+RL}, \Gamma_{\nu\tau}^{H^+LR}$ defined in eqs. (48), (50) of ref. [36].

The decay rates are given by [84]:

$$Br(B \to \tau\nu) = \frac{G_F^2 |V_{ub}|^2}{8\pi} m_\tau^2 m_B f_B^2 \tau_B \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 \left|1 + \frac{m_B^2}{m_b m_\tau}(C_u^R - C_u^L)\right|^2 \quad (21)$$

$$\frac{Br(B \to D\tau\nu)}{Br(B \to Dl\nu)} = R_D \left(1 + 1.5\ \mathrm{Re}(C_c^R + C_c^L) + 1.0 \left|C_c^R + C_c^L\right|^2\right) \quad (22)$$

$$\frac{Br(B \to D^\star\tau\nu)}{Br(B \to D^\star l\nu)} = R_{D^\star} \left(1 + 0.12\ \mathrm{Re}(C_c^R - C_c^L) + 0.05 \left|C_c^R - C_c^L\right|^2\right) \quad (23)$$

where R_D and $R_{D^\star}$ are the respective ratios calculated within the SM.

Branching ratios are calculated by:

Routine	`subroutine b_taunu(br_taunu,br_dtaunu,br_dstaunu)`
Input	none
Output	`br_taunu` $= Br(B^+ \to \tau^+\nu)$
	`br_dtaunu` $= \frac{Br(B\to D\tau\nu)}{Br(B\to Dl\nu)}$
	`br_dstaunu` $= \frac{Br(B\to D^\star\tau\nu)}{Br(B\to D^\star l\nu)}$
QCD related factors	
`common/meson_data/dmk,amk,epsk,fk,dmd,amd,fd,amb(2),dmb(2),gam_b(2),fb(2)`	
f_{B_d}	`fb(1)` $= 0.193$
`common/dtau_data/dmbp, rd, del_rd, rds, del_rds`	
M_{B+_u}	`dmbp` $= 5.27917$
$R_D \pm \Delta R_D$	`rd` $= 0.297$, `del_rd` $= 0.017$
$R_{D^\star} \pm \Delta R_{D^\star}$	`rds` $= 0.252$, `del_rds` $= 0.003$
Details of calculations:	Ref. [36, 84]

6.8 $B^0 \to X_s\gamma$ decay rate

Both the SUSY contributions and the QCD corrections to the calculation of the $B^0 \to X_s\gamma$ decay rate are quite complex. Their implementation in `SUSY_FLAVOR` is based on the SUSY loop calculations performed by the authors (not published in a general form) and on the QCD evolution published in [85]. There are no user-accessible QCD factors apart from the arguments of the `bxg_nl` routine.

Routine	`double precision function bxg_nl(del,amiu_b)`
Input	`del` - relative photon energy infrared cutoff scale, $E_\gamma \geq (1 - \mathtt{del})E_\gamma^{max}$, $0 < \mathtt{del} < 1$
	`amiu_b` - renormalization scale
Output	$Br(B \to X_s\gamma)$.
Details of calculations:	General SUSY diagrams unpublished, QCD corrections based on [85]

6.9 $t \to ch, uh$ decay rates

In SUSY_FLAVOR v2.5 rare decays of the top quark to a CP-even Higgs boson and lighter up-type quarks, $t \to ch, uh$, has also been included based on Ref. [38]. The expression for the relevant branching ratio is given by

$$Br(t \to qh) = \frac{m_t \left(1 - \frac{m_h^2}{m_t^2}\right)^2}{32\pi\Gamma_{t\to bW}} \left[1.018 \left(|C_L^{(h)}|^2 + |C_R^{(h)}|^2\right) + \frac{0.098 m_t^2}{v} \Re e \left(C_R^{(h)\star} C_R^{(g)} + C_L^{(h)\star} C_L^{(g)}\right)\right] \tag{24}$$

where q can be either c or u, m_t denotes the top quark pole mass, v is the SM Higgs vev, $C_{L,R}^{(h)}$ are form factors for the effective flavor violating Higgs-up quark coupling and $C_{L,R}^{(g)}$ are dipole type form factors for the effective flavor violating gluon-up quark vertex, all calculated at the scale $\mu = m_t$ (see Ref. [38] for more details).

Also decays to heavier CP-even Higgs boson, H, can be calculated using this routine, assuming that they are accessible kinematically. The branching ratios are calculated by

Routine:	`double precision function br_suu(k,I)`
Input:	$I = 1, 2$ for, respectively, u, c quark in the final state $k = 1, 2$ for, respectively, H, h Higgs boson in the final state
Output:	branching ratios for $t \to ch$ decay ($I = 2, k = 2$) or $t \to uh$ decay ($I = 1, k = 2$) or similar decays to H for $k = 1$.
QCD related factors:	none
Details of calculations:	Ref. [38]

6.10 $\bar{K}^0 K^0$ meson mixing parameters

SUSY_FLAVOR calculates two parameters measuring the amount of CP-violation in neutral K meson oscillations: ε_K and the $\bar{K}^0 - K^0$ mass difference ΔM_K.

$$\Delta M_K = 2\Re\mathrm{e}\langle \bar{K}^0 | H_{\mathrm{eff}}^{\Delta S=2} | K^0 \rangle \ , \tag{25}$$

$$\varepsilon_K = \frac{\exp(i\pi/4)}{\sqrt{2}\Delta M_K} \Im\mathrm{m}\langle \bar{K}^0 | H_{\mathrm{eff}}^{\Delta S=2} | K^0 \rangle \ . \tag{26}$$

QCD dependent corrections are known with reasonable accuracy for the ε_K parameter. The long distance contributions to ΔM_K are large and difficult to control. Thus the result given by SUSY_FLAVOR for ΔM_K should be treated as an order of magnitude estimate only.

Apart from the MSSM parameters, the calculation of the $\bar{K}^0 K^0$ meson mixing requires knowledge of the meson masses and of the hadronic matrix elements of the following set of four-quark operators:

$$\begin{aligned} Q_1^{\mathrm{VLL}} &= (\bar{q}_\alpha^I \gamma_\mu P_L q_\alpha^J)(\bar{q}_\beta^I \gamma^\mu P_L q_\beta^J), \\ Q_1^{\mathrm{LR}} &= (\bar{q}_\alpha^I \gamma_\mu P_L q_\alpha^J)(\bar{q}_\beta^I \gamma^\mu P_R q_\beta^J), \end{aligned}$$

$$
\begin{aligned}
Q_2^{\rm LR} &= (\bar{q}^I_\alpha P_L q^J_\alpha)(\bar{q}^I_\beta P_R q^J_\beta), \\
Q_1^{\rm SLL} &= (\bar{q}^I_\alpha P_L q^J_\alpha)(\bar{q}^I_\beta P_L q^J_\beta), \\
Q_2^{\rm SLL} &= (\bar{q}^I_\alpha \sigma_{\mu\nu} P_L q^J_\alpha)(\bar{q}^i_\beta \sigma^{\mu\nu} P_L q^J_\beta)
\end{aligned} \tag{27}
$$

where α, β are color indices, for the $\bar{K}^0 K^0$ mixing one should choose flavor indices $I = 2$ and $J = 1$. The matrix elements can be written as:

$$
\begin{aligned}
\langle \bar{K}^0 | Q_1^{\rm VLL}(\mu) | K^0 \rangle &= \frac{1}{3} M_K F_K^2 B_1^{\rm VLL}(\mu), \\
\langle \bar{K}^0 | Q_1^{\rm LR}(\mu) | K^0 \rangle &= -\frac{1}{6} \left(\frac{M_K}{m_s(\mu) + m_d(\mu)} \right)^2 M_K F_K^2 B_1^{\rm LR}(\mu), \\
\langle \bar{K}^0 | Q_2^{\rm LR}(\mu) | K^0 \rangle &= \frac{1}{4} \left(\frac{M_K}{m_s(\mu) + m_d(\mu)} \right)^2 M_K F_K^2 B_2^{\rm LR}(\mu), \\
\langle \bar{K}^0 | Q_1^{\rm SLL}(\mu) | K^0 \rangle &= -\frac{5}{24} \left(\frac{M_K}{m_s(\mu) + m_d(\mu)} \right)^2 M_K F_K^2 B_1^{\rm SLL}(\mu), \\
\langle \bar{K}^0 | Q_2^{\rm SLL}(\mu) | K^0 \rangle &= -\frac{1}{2} \left(\frac{M_K}{m_s(\mu) + m_d(\mu)} \right)^2 M_K F_K^2 B_2^{\rm SLL}(\mu),
\end{aligned} \tag{28}
$$

where F_K is the K-meson decay constant. By default, `SUSY_FLAVOR` uses the B_i^X values at the scale $\mu = 2$ GeV given in [86] using the NDR renormalization scheme (quark masses at the scale 2 GeV are stored in `common/fmass_high/`).

In addition to the hadronic matrix elements, QCD corrections depend also on the "η" factors describing the evolution of the relevant Wilson coefficients from the high to low energy scale. These factors are automatically calculated at NLO by `SUSY_FLAVOR`. For the SM contribution to the Wilson coefficient of the $Q^{\rm VLL}$ operator a separate careful calculation of the evolution factors has been performed [87, 88]. Therefore `SUSY_FLAVOR` treats this contribution separately, setting $B^{\rm VLL}_{SM}$ and the η_{SM} factor to default values given in [89] (see [86] for a very detailed discussion of the structure of the QCD corrections in $\bar{B}^0 B^0$ and $\bar{K}^0 K^0$ systems, including their renormalization scheme dependence and calculations of the QCD qevolution factors implemented in `SUSY_FLAVOR`).

The kaon mass difference ΔM_K and the ε_K parameter measuring the amount of CP violation in $\bar{K}^0 K^0$ mixing are calculated by

Routine	`subroutine dd_kaon(eps_k,delta_mk)`
Input	none
Output	`eps_k` = ε_K parameter
	`delta_mk` = ΔM_K mass difference

QCD related factors:

`common/meson_data/dmk,amk,epsk,fk,dmd,amd,fd,amb(2),dmb(2),gam_b(2),fb(2)`

M_K	`amk` $= 0.497614$
Measured ΔM_K^{exp}	`dmk` $= 3.483 \cdot 10^{-15}$
Measured ε_K^{exp}	`epsk` $= 2.229 \cdot 10^{-3}$
f_K	`fk` $= 0.156$

`common/bx_4q/bk(5),bd(5),bb(2,5),amu_k,amu_d,amu_b`

$B_1^{\mathrm{VLL}}(\mu_K)$	`bk(1)` $= 0.61$
$B_1^{\mathrm{SLL}}(\mu_K)$	`bk(2)` $= 0.76$
$B_2^{\mathrm{SLL}}(\mu_K)$	`bk(3)` $= 0.51$
$B_1^{\mathrm{LR}}(\mu_K)$	`bk(4)` $= 0.96$
$B_2^{\mathrm{LR}}(\mu_K)$	`bk(5)` $= 1.30$
Renormalization scale μ_K	`amu_k` $= 2$

`common/sm_4q/eta_cc,eta_ct,eta_tt,eta_b,bk_sm,bd_sm,bb_sm(2)`

B_{SM}^{VLL}	`bk_sm` $= 0.724$
η_{cc}	`eta_cc` $= 1.86$
η_{ct}	`eta_ct` $= 0.496$
η_{tt}	`eta_tt` $= 0.577$
Details of calculations:	Ref. [13, 86]

6.11 $\bar{D}^0 D^0$ meson mass difference

Calculations of the mass difference Δm_D of the neutral D mesons have large theoretical uncertainties due to unknown long-distance strong corrections. Thus, as in the case of Δm_K, the `SUSY_FLAVOR` result for Δm_D should be treated as an order of magnitude estimate only.

The structure of strong corrections is analogous to those in the K meson system. However, in this case hadronic matrix elements and QCD evolution calculations available in the literature are much less refined. `SUSY_FLAVOR` uses the NLO evolution for the "η" factors and sets, by default, all the relevant hadronic matrix elements $B_i = 1$, i.e. it uses the "vacuum saturation" approximation (this can be changed easily when new results become available).

Routine	`subroutine uu_bmeson(delta_md)`
Input	none
Output	`delta_md` $= \Delta M_D$ mass difference

QCD related factors:

`common/meson_data/dmk,amk,epsk,fk,dmd,amd,fd,amb(2),dmb(2),gam_b(2),fb(2)`

M_D	`amd` $= 1.8645$
Measured ΔM_D^{exp}	`dmd` $= 4.61 \cdot 10^{-14}$
f_D	`fd` $= 0.2$

`common/bx_4q/bk(5),bd(5),bb(2,5),amu_k,amu_d,amu_b`

$B_1^{\rm VLL}(\mu_D)$	`bd(1)` $= 1$
$B_1^{\rm SLL}(\mu_D)$	`bd(2)` $= 1$
$B_2^{\rm SLL}(\mu_D)$	`bd(3)` $= 1$
$B_1^{\rm LR}(\mu_D)$	`bd(4)` $= 1$
$B_2^{\rm LR}(\mu_D)$	`bd(5)` $= 1$
Renormalization scale μ_D	`amu_d` $= 2$

`common/sm_4q/eta_cc,eta_ct,eta_tt,eta_b,bk_sm,bd_sm,bb_sm(2)`

$B_{SM}^{\rm VLL}$	`bd_sm` $= 1$
Details of calculations:	Performed by authors, unpublished

6.12 $\bar{B}_d^0 B_d^0$ and $\bar{B}_s^0 B_s^0$ meson mixing parameters

Mixing and CP violation phenomena are also observed in the neutral B meson systems. In particular, the mass differences in the $\bar{B}_d^0 B_d^0$ and $\bar{B}_s^0 B_s^0$ oscillations have been measured,

$$\Delta M_{B_{d(s)}} = 2 \left| \langle \bar{B}_{d(s)}^0 | H_{\rm eff}^{\Delta B=2} | B_{d(s)}^0 \rangle \right| \ . \tag{29}$$

The time-dependent CP asymmetry in $B_d \to J/\psi K_s$ decays, $a_{J/\psi K_s} = \sin 2\beta_{eff} \sin \Delta M_{B_d} t$, is also measured. It can be related to the argument of the $\Delta F = 2$ hadronic matrix element:

$$2\beta_{eff} = {\rm Arg} \left[\langle \bar{B}_d^0 | H_{\rm eff}^{\Delta B=2} | B_{d(s)}^0 \rangle \right] \ . \tag{30}$$

As experimental definitions of CP asymmetries are often convention-dependent, `SUSY_FLAVOR` gives as a more universal output directly real and imaginary parts of the $\Delta F = 2$ matrix element, which can be further used in various asymmetry calculations.

In addition to the MSSM parameters, theoretical calculations of Δm_{B_d} and Δm_{B_s} depend, as for K and D oscillations, on the relevant hadronic matrix elements and QCD evolution factors. The formulae for $\bar{B}^0 B^0$ mixing can be obtained by making the obvious replacements in the formulae presented in Sec. 6.10. Currently `SUSY_FLAVOR` uses the same set of B_i factors for both the B_d and B_s sectors, but it leaves the possibility to distinguish between them in future, if necessary. For this one needs to independently initialize the arrays `bb(1,i)` (B_d meson hadronic matrix elements) and `bb(2,i)` (B_s meson hadronic matrix elements) stored in `common/bx_4q/`.

The values of the B meson masses and coupling constants are the same as those listed in Sec. 6.6. $\Delta M_{B_{d(s)}}$ is calculated by:

Routine	`subroutine dd_bmeson(i,delta_mb,dmb_re,dmb_im)`
Input	$i = 1, 2$ - generation index of the lighter valence quark in the B^0 meson, i.e. $i = 2$ chooses B^0_s and $i = 1$ chooses B^0_d.
Output	`delta_mb` $= \Delta m_{B_d} (\Delta m_{B_s})$ for $i = 1(2)$
	`dmb_re` $= \mathrm{Re}[\langle \bar{B}^0_{d(s)} \vert H^{\Delta B=2}_{\mathrm{eff}} \vert B^0_{d(s)} \rangle]$ for $i = 1(2)$
	`dmb_im` $= \mathrm{Im}[\langle \bar{B}^0_{d(s)} \vert H^{\Delta B=2}_{\mathrm{eff}} \vert B^0_{d(s)} \rangle]$ for $i = 1(2)$

QCD related factors:

`common/meson_data/dmk,amk,epsk,fk,dmd,amd,fd,amb(2),dmb(2),gam_b(2),fb(2)`

Measured $\Delta M^{exp}_{B_d}$	`dmb(1)` $= 3.337 \cdot 10^{-13}$
Measured $\Delta M^{exp}_{B_s}$	`dmb(2)` $= 1.17 \cdot 10^{-11}$
Measured lifetime $\Gamma^{exp}_{B_d}$	`gam_b(1)` $= 1.519 \cdot 10^{-12}$
Measured lifetime $\Gamma^{exp}_{B_s}$	`gam_b(1)` $= 1.512 \cdot 10^{-12}$

`common/bx_4q/bk(5),bd(5),bb(2,5),amu_k,amu_d,amu_b`

$B^{\mathrm{VLL}}_1(\mu_B)$	`bb(1,1)` $=$ `bb(2,1)` $= 0.87$
$B^{\mathrm{SLL}}_1(\mu_B)$	`bb(1,2)` $=$ `bb(2,2)` $= 0.8$
$B^{\mathrm{SLL}}_2(\mu_B)$	`bb(1,3)` $=$ `bb(2,3)` $= 0.71$
$B^{\mathrm{LR}}_1(\mu_B)$	`bb(1,4)` $=$ `bb(2,4)` $= 1.71$
$B^{\mathrm{LR}}_2(\mu_B)$	`bb(1,5)` $=$ `bb(2,5)` $= 1.16$
Renormalization scale μ_B	`amu_b` $= 4.6$

`common/sm_4q/eta_cc,eta_ct,eta_tt,eta_b,bk_sm,bd_sm,bb_sm(2)`

$B^{\mathrm{VLL}}_{SMB_d}$	`bb_sm(1)` $= 1.22$
$B^{\mathrm{VLL}}_{SMB_s}$	`bb_sm(2)` $= 1.22$
η_b	`eta_b` $= 0.55$

Details of calculations: Ref. [13]

7 SUSY_FLAVOR output

Starting from v2.10, the SUSY_FLAVOR output is written to the file named `susy_flavor.out`. It has a "SLHA-like" structure, i.e. it is split into "data blocks". However, these blocks are SUSY_FLAVOR-specific and do not follow common SLHA2 standards. The output file of SUSY_FLAVOR v2.5 contains the data blocks listed in Table 7.

The first four blocks in `susy_flavor.out` are included for control and test purposes. The block `SFLAV_CONTROL` lists the state of control variables defining conventions used for input parameters, in particular the dimension of sfermion flavor violating parameters. The block `SFLAV_MASS` contains a full list of MSSM particle masses - mass eigenstates of sleptons, squarks, neutralinos and charginos, physical Higgs boson masses (as mentioned earlier the estimate of m_h is calculated using the approximate 2-loop formulae based on Refs. [90, 91]) and, for completeness, the pole lepton masses and running quark

Block name	Block content
SFLAV_CONTROL	SUSY_FLAVOR control variables and error code status
SFLAV_MASS	full mass spectrum of the MSSM particles after mass matrix diagonalization
SFLAV_CHIRAL_YUKAWA	Relative size of resummed chiral corrections to Yukawa couplings
SFLAV_CHIRAL_CKM	Relative size of resummed chiral corrections to CKM matrix
SFLAV_DELTA_F0	Observables related to $\Delta F = 0$ processes (EDM, $g-2$ anomaly)
SFLAV_DELTA_F1	Observables related to $\Delta F = 1$ processes ($l \to l'\gamma$, $K \to \pi\bar{\nu}\nu$, $B^+ \to \tau^+\nu$, $B \to D\tau\nu$, $B \to D^\star\tau\nu$, $B \to X_s\gamma$, $B_{d,s} \to l_i^+ l_j^-$, $t \to ch$, $t \to uh$)
SFLAV_DELTA_F2	Observables related to $\Delta F = 2$ processes (ϵ_K, Δm_K, Δm_D, Δm_{B_d}, Δm_{B_s})

Table 7: Block structure of susy_flavor.out file.

masses at m_t scale. The blocks SFLAV_CHIRAL_YUKAWA and SFLAV_CHIRAL_CKM show the relative difference of bare vs. physical Yukawa couplings and CKM matrix elements after resummation of chiral corrections. If they are too large, $\geq \mathcal{O}(1)$, the perturbative loop calculations may not be converging an the remaining program output cannot be considered to be fully reliable.

Finally, the entries of the blocks SFLAV_DELTA_F0, SFLAV_DELTA_F1 and SFLAV_DELTA_F2 contain the values of the flavor and CP-violating observables given in Table 1.

8 Summary and Outlook

We have presented SUSY_FLAVOR v2.5, a tool for calculating important flavor observables in the general R-parity conserving MSSM. Version 2 of SUSY_FLAVOR is capable of calculating:

- Electric dipole moments of the leptons and the neutron.
- Supersymmetric contributions to anomalous magnetic moments $g-2$ of leptons.
- Radiative lepton decays ($\mu \to e\gamma$ and $\tau \to \mu\gamma, e\gamma$).
- Rare Kaon decays ($K_L^0 \to \pi^0\bar{\nu}\nu$ and $K^+ \to \pi^+\bar{\nu}\nu$).
- Leptonic B decays ($B_{s,d} \to l^+l^-$, $B^+ \to \tau^+\nu$, $B \to D\tau\nu$ and $B \to D^\star\tau\nu$).
- Radiative B decays ($B \to \bar{X}_s\gamma$).
- Rare decays of the top quark to Higgs boson ($t \to ch, uh$).

- $\Delta F = 2$ processes ($\bar{K}^0$–K^0, $\bar{D}$–D, $\bar{B}_d$–B_d and $\bar{B}_s$–B_s mixing).

All implemented physical observables can be calculated simultaneously for a given set of MSSM input parameters. The calculation of the SUSY tree-level particle spectrum and flavor mixing matrices are performed exactly, so the code can be used for a completely general pattern of soft SUSY breaking terms (including complex phases), without restrictions on the size of the off-diagonal elements in the sfermion mass matrices. Program is written in FORTRAN 77 and runs fairly quickly; it is capable of producing a reasonably wide-range scan over the MSSM parameters within hours or days on a typical personal computer.

In code `SUSY_FLAVOR` v2 the resummation of chirally enhanced corrections (stemming from large values of $\tan\beta$ and/or large trilinear A-terms) has been implemented using the systematic method developed in [36]. Such corrections modify the effective couplings of supersymmetric particles and charged Higgs bosons and generate enhanced flavor-changing neutral Higgs couplings, the latter giving significant contributions to various amplitudes coming from Higgs-penguin type diagrams. Thus, `SUSY_FLAVOR` is valid for the whole parameter space of the general R-parity conserving MSSM, a unique feature currently not shared by other publicly available programs calculating FCNC and CP violation in SUSY models.

Starting from v2.5, `SUSY_FLAVOR` accepts automatically as input most of output files from other libraries calculating SUSY processes. Only the parameters relevant for given problem needs to be defined in the input file, others are initialized using the predefined default values.

Besides complete routines for calculating the physical observables, `SUSY_FLAVOR` v2 also provides an extensive library of parton-level Green's functions and Wilson coefficients of many effective quark and lepton operators (see Table 3). This set actually contains many more amplitudes than necessary to compute the quantities listed in Table 1. These intermediate building blocks can be used by `SUSY_FLAVOR` users to calculate observables related to additional processes, beyond those already fully implemented, by dressing appropriate combinations of available form factors in QCD corrections and hadronic matrix elements, without repeating tedious SUSY loop calculations. For instance, the form factors implemented in `SUSY_FLAVOR` for the analysis of $B \to X_s\gamma$ and $B_{d(s)} \to l^+l^-$ decays [6, 15] are sufficient to also calculate the $B \to Kl^+l^-$ decay rate.

The `SUSY_FLAVOR` library is an open project. We want to gradually add more features in future versions. In particular, we plan to:

- add more observables in the B-meson system, like the CP asymmetries in $B \to X_s\gamma$ decay, observables associated with $B \to Kl^+l^-$ decay and others.

- include more FCNC related quantities in the top sector, in particular $t \to q\gamma, qZ$ and qg decay rates.

- include the effects of massive neutrinos.

With the increasing accuracy of experimental data on flavor and CP violation in rare processes, it may eventually become possible to not only constrain the MSSM parameters, but also, if significant deviations from the SM predictions are found, to recover their actual values. For that multi-process analysis, such as the one performed by `SUSY_FLAVOR`, will be necessary. Therefore, we hope that `SUSY_FLAVOR` becomes an important tool that is useful not only to theorists working on MSSM but also to experimentalists fitting the MSSM onto current and forthcoming data from the Tevatron, LHC, and B-factories.

Acknowledgments

The authors thank A. Buras, T. Ewerth, L Hofer, M. Misiak, C. Savoy, Ł. Sławianowska, S. Pokorski, M. Paraskevas and K. Suxho for collaboration in performing theoretical calculations used in `SUSY_FLAVOR` and for helping to check and debug some of its sections. We would also like to thank W. Altmannshofer, J. Stockel, D. Straub, S. Frank, D. Guadagnoli, W. Porod, M. Wick, J. Berger and D. Ghosh for checking various parts of the `SUSY_FLAVOR` code and reporting bugs or inconsistencies.

This work has received funding from the EU Seventh Framework Programme under grant agreement PITN-GA-2009-237920 (2009-2013). A.C. is supported by the Swiss National Science Foundation. The Albert Einstein Center for Fundamental Physics is supported by the "Innovations- und Kooperationsprojekt C-13 of the Schweizerische Universitätskonferenz SUK/CRUS". The work by J.R. is supported in part by National Science Center under research grant DEC-2011/01/M/ST2/02466 (12.2011-12.2014). The A.D. research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: THALIS. Investing in the society of knowledge through the European Social Fund. S.J. was supported by the Science and Technology Facilities Council [grant number ST/H004661/1] and acknowledges support from the NExT institute and SEPnet. P.T. is supported by the Paul and Daisy Soros foundation and the U.S. National Science Foundation through grant PHY-0757868.

A Installation of the program

The installation and execution of SUSY_FLAVOR is very simple. On Unix or Linux systems, just follow these steps :

1. Download the latest version of the code from `http://www.fuw.edu.pl/susy_flavor` and unpack it.

2. Change directory into `susy_flavor`.

3. Edit `Makefile` and change `F77 = gfortran` and `FOPT = -O -fno-automatic -Wall` into your compiler name and options, respectively.

4. To use the `susy_flavor_file.f` driver, reading input data from `susy_flavor.in` file, type `make sfile` (or simply `make`). To use the `susy_flavor_prog.f` driver, where input data are initialized directly inside the FORTRAN code, type `make sprog`.

5. If everything goes through, the code output is written to the file `susy_flavor.out`.

6. To run the code from now on just type `./sfile` or `./sprog`.

The authors tested SUSY_FLAVOR on Linux machines. With few straightforward modifications the procedure describe above can be adapted to install program on other systems. A sample set of input parameters and corresponding SUSY_FLAVOR output are listed in the following appendices.

B Example of the SUSY_FLAVOR initialization sequence

Below we list the contents of `susy_flavor_file.f` and `susy_flavor_prog.f`, the driver files for the SUSY_FLAVOR library. They illustrate the correct initialization sequence for all relevant MSSM parameters (see Sec. 4) and how to perform calls to the routines calculating physical observables (Sec. 6).

Driver program `susy_flavor_file.f`, initializing MSSM parameters from the input file `susy_flavor.in` is compact and simple:

```
      program susy_flavor_file
      program susy_flavor_header
      implicit double precision (a-h,o-z)

c     choose MSSM sectors to include
      ih = 1                              ! Higgs + gauge diagrams included
      ic = 1                              ! chargino diagrams included
      in = 1                              ! neutralino diagrams included
      ig = 1                              ! gluino diagrams included
      call set_active_sector(ih,ic,in,ig) ! set control variables

      call sflav_input(ilev,ierr)         ! parameters read from susy_flavor.in
      if (ierr.ne.0) write(*,*) 'Error in parameter initialization!'
      call set_resummation_level(ilev,ierr)! resummation of chiral corrections
      if (ierr.ne.0) write(*,*)ierr,'Error in chiral corrections resummation!'
      call susy_flavor                    ! main routine calculating physical observables
      call sflav_output(ilev,ierr)        ! output written to susy_flavor.out
      end
```

Driver `susy_flavor_prog.f` is longer and more complicated as all parameters has to be specified inside the code. Using this diver, flavor violating entries of sfermion mass matrices has to be given as dimensionless mass insertions.

```
      program susy_flavor_prog
      implicit double precision (a-h,o-z)
      dimension sll(3),slr(3),amsq(3),amsu(3),amsd(3)
      double complex slmi_l(3),slmi_r(3),slmi_lr(3,3),slmi_lrp(3,3)
      double complex sqmi_l(3),sdmi_r(3),sumi_r(3)
      double complex sdmi_lr(3,3),sumi_lr(3,3)
      double complex sdmi_lrp(3,3),sumi_lrp(3,3)
      double complex amg,amgg,amue
      common/sf_cont/eps,indx(3,3),iconv

c     Input convention choice:
```

```
      iconv = 1                            ! SLHA2 input conventions
c     iconv = 2                            ! hep-ph/9511250 input conventions

c     fixes the treatment of enhanced chiral correction resummation
c     ilev = 0                             ! no resummation, SUSY corrections strictly 1-loop
c     ilev = 1                             ! resummation using the decoupling limit
      ilev = 2                             ! exact iterative solution, may not always converge

c     choose MSSM sectors to include
      ih = 1                               ! Higgs + gauge diagrams included
      ic = 1                               ! chargino diagrams included
      in = 1                               ! neutralino diagrams included
      ig = 1                               ! gluino diagrams included
      call set_active_sector(ih,ic,in,ig) ! set control variables

      call sflav_sm                        ! initialize auxiliary SM parameters

c     SM basic input initialization
      zm0 = 91.1876d0                      ! M_Z
      wm0 = 80.398d0                       ! M_W
      alpha_z = 1/127.934d0                ! alpha_em(M_Z)
      st2_new = 0.23116d0                  ! s_W^2(MSBar)
      call vpar_update(zm0,wm0,alpha_z,st2_new)

c     CKM matrix initialization
      alam = 0.2258d0                      ! lambda
      apar = 0.808d0                       ! A
      rhobar = 0.177d0                     ! rho bar
      etabar = 0.360d0                     ! eta bar
      call ckm_wolf(alam,apar,rhobar,etabar)

c     Fermion mass initialization, input: MSbar running quark masses
      alpha_s = 0.1172d0                   ! alpha_s(MZ)
      top_scale = 163.1d0
      top = 163.1d0                        ! m_t(top_scale)
      bot_scale = 4.18d0
      bot = 4.18d0                         ! m_b(bot_scale)
      call init_fermion_sector(alpha_s,top,top_scale,bot,bot_scale)

c     Higgs sector parameters
      pm = 200                             ! M_A
      tanbe = 4                            ! tan(beta)
      amue = (200.d0,100.d0)               ! mu
```

```
      call init_higgs_sector(pm,tanbe,amue,ierr)
      if (ierr.ne.0) stop 'negative tree level Higgs mass^2?'

c     Gaugino sector parameters. CAUTION: if M1 is set to 0 here then
c     program sets M1 and M2 GUT-related, i.e. M1 = 5/3 s_W^2/c_W^2*M2

      amgg = (200.d0,0.d0)                 ! M1 (bino mass)
      amg = (300.d0,0.d0)                  ! M2 (wino mass)
      amglu = 600                          ! M3 (gluino mass)
      call init_ino_sector(amgg,amg,amglu,amue,tanbe,ierr)
      if (ierr.ne.0) write(*,*) '-ino mass below M_Z/2?'

c     Slepton diagonal soft breaking parameters
      sll(1) = 300.d0                      ! left selectron mass scale
      sll(2) = 300.d0                      ! left smuon mass scale
      sll(3) = 300.d0                      ! left stau mass scale
      slr(1) = 300.d0                      ! right selectron mass scale
      slr(2) = 300.d0                      ! right smuon mass scale
      slr(3) = 300.d0                      ! right stau mass scale
c     Slepton LL and RR mass insertions (hermitian matrices)
c     slmi_x(1),slmi_x(2), slmi_x(3) are 12,23,31 entry respectively
      do i=1,3
         slmi_l(i) = dcmplx(0.d0,0.d0)     ! slepton LL mass insertion
         slmi_r(i) = dcmplx(0.d0,0.d0)     ! slepton RR mass insertion
      end do
      slmi_l(1) = (2.d-2,3.d-2)            ! example, non-vanishing LL 12 entry
c     Slepton LR mass insertions, non-hermitian in general
c     All entries dimensionless (normalized to diagonal masses)
      do i=1,3
        do j=1,3
c     holomorphic LR mixing terms
           slmi_lr(i,j) = (0.d0,0.d0)
c     non-holomorphic LR mixing terms
           slmi_lrp(i,j) = (0.d0,0.d0)
         end do
      end do
c     Example: diagonal entries normalized to Y_l as in SUGRA
      slmi_lr(1,1) = (1.d-4,0.d0)          ! A_e
      slmi_lr(2,2) = (1.0d-2,0.d0)         ! A_mu
      slmi_lr(3,3) = (1.0d-1,0.d0)         ! A_tau
      slmi_lr(2,3) = (2.d-2,1.d-2)         ! example, non-vanishing LR 23 entry
c     Calculate physical masses and mixing angles
      call init_slepton_sector(sll,slr,slmi_l,slmi_r,slmi_lr,slmi_lrp
```

```
     $      ,ierr)
      if (ierr.ne.0) stop 'negative tree level slepton mass^2?'

c     Squark diagonal soft breaking parameters
      amsq(1) = 500.d0                    ! left squark mass, 1st generation
      amsq(2) = 450.d0                    ! left squark mass, 2nd generation
      amsq(3) = 400.d0                    ! left squark mass, 3rd generation
      amsd(1) = 550.d0                    ! right down squark mass
      amsd(2) = 550.d0                    ! right strange squark mass
      amsd(3) = 300.d0                    ! right sbottom mass
      amsu(1) = 450.d0                    ! right up squark mass
      amsu(2) = 450.d0                    ! right charm squark mass
      amsu(3) = 200.d0                    ! right stop mass
c     Squark LL and RR mass insertions (hermitian matrices)
c     sqmi_l(1),sqmi_l(2), sqmi_l(3) are 12,23,31 entry respectively, etc.
      do i=1,3
         sqmi_l(i) = (0.d0,0.d0)          ! squark LL mass insertion
         sumi_r(i) = (0.d0,0.d0)          ! up-squark RR mass insertion
         sdmi_r(i) = (0.d0,0.d0)          ! down-squark RR mass insertion
      end do
      sqmi_l(2) = (-1.d-2,1.d-2)          ! example, non-vanishing LL 23 entry
c     Squark holomorphic LR mass insertions, non-hermitian in general
c     All entries dimensionless (normalized to masses)
      do i=1,3
         do j=1,3
c     holomorphic LR mixing terms
            sumi_lr(i,j) = (0.d0,0.d0)    ! up-squark
            sdmi_lr(i,j) = (0.d0,0.d0)    ! down-squark
c     non-holomorphic LR mixing terms
            sumi_lrp(i,j) = (0.d0,0.d0)   ! up-squark
            sdmi_lrp(i,j) = (0.d0,0.d0)   ! down-squark
         end do
      end do
c     Example: diagonal entries normalized to Y_d,Y_u as in SUGRA
      sumi_lr(1,1) = dcmplx(1.d-5,0.d0)
      sumi_lr(2,2) = dcmplx(4.d-3,0.d0)
      sumi_lr(3,3) = dcmplx(1.d0,0.d0)
      sdmi_lr(1,1) = dcmplx(-1.d-3,0.d0)
      sdmi_lr(2,2) = dcmplx(-2.d-2,0.d0)
      sdmi_lr(3,3) = dcmplx(-8.d-1,0.d0)
      sdmi_lr(2,3) = (1.d-2,-1.d-2)       ! example, non-vanishing down LR 23 entry
c     Calculate physical masses and mixing angles
      call init_squark_sector(amsq,amsu,amsd,sqmi_l,sumi_r,sdmi_r,
```

```
     $     sumi_lr,sdmi_lr,sumi_lrp,sdmi_lrp,ierr)
      if (ierr.ne.0) stop 'negative tree level squark mass^2?'

c     reset status of physical Higgs mass after parameter changes
      call reset_phys_data

c     Neutral CP-even Higgs masses with the 2-loop approximate formula
      call mhcorr_app2(ierr)
      if (ierr.ne.0) stop 'negative CP-even Higgs mass^2?'

c     !!! End of input section !!!

      call set_resummation_level(ilev,ierr)
      if (ierr.ne.0) write(*,*)ierr,'Error in chiral corrections resummation!'
      call susy_flavor                   ! main routine calculating physical observables
      call sflav_output(ilev,ierr)       ! output written to susy_flavor.out
      end
```

C Example of SUSY_FLAVOR input file

By default, the driver program susy_flavor_file.f reads input parameters from the file susy_flavor.in. Starting from v2.5, SUSY_FLAVOR should be able to directly read most of output files defining MSSM Lagrangian parameters produced by other public SUSY generators, simply after renaming them to susy_flavor.in. However, as there are already many of such programs and they do not always uniformly follow SLHA2 standards, some incompatibilities may eventually occur. In such case, please send a message to program maintainer, so the problem could be removed in next versions of SUSY_FLAVOR library.

Below we provide an example input file defining a set of parameters equivalent to those given in the driver file presented in Appendix B.

```
# Example input of SUSY_FLAVOR in Les Houches-like format
#
Block MODSEL                          # Select model
    1    0                            # General MSSM
    3    0                            # MSSM particle content
    4    0                            # R-parity conserving MSSM
    5    2                            # CP violated
    6    3                            # Lepton and quark flavor violated
Block SOFTINP                         # Choose convention for the soft terms
#
# Block SOFTINP is optional - standard SLHA2 used if it is missing,
# i.e.  convention=1, input_type=2, ilev=2.  Otherwise:
#
# convention = 1(2):  input parameters in SLHA2(hep-ph/9511250) conventions
# input_type = 1:
# sfermion off-diagonal terms given as dimensionless mass insertions
# LR diagonal terms given as dimensionless parameters
# input_type = 2:
# sfermion soft terms given as absolute values (default)
# ilev = 0
# no resummation of chirally enhanced corrections
# ilev = 1
# analytical resummation of chirally enhanced corrections
# in the limit v1,v2 << M_SUSY
# ilev = 2 (default)
# numerical iterative resummation of chirally enhanced corrections
# See comment in Blocks MSXIN2, TXIN below
    1    1                            # iconv (conventions, SLHA2 or hep-ph/9511250)
    2    2                            # input_type (dimension of soft mass entries)
    3    2                            # ilev (level of chiral corrections resummation)
Block SMINPUTS                        # Standard Model inputs
```

```
    1    1.279340000e+02              # alpha^(-1) SM MSbar(MZ)
    3    1.172000000e-01              # alpha_s(MZ) SM MSbar
    4    9.118760000e+01              # MZ(pole)
    5    4.180000000e+00              # mb(mb) SM MSbar
    6    1.735000000e+02              # mtop(pole)
    7    1.77684000000e+00            # mtau(pole)
    11   5.10998900000e-04            # me(pole)
    13   1.056580000e-01              # mmu(pole)
    21   4.700000000e-03              # md(2 GeV) MSbar
    22   2.100000000e-03              # mu(2 GeV) MSbar
    23   9.340000000e-02              # ms(2 GeV) MSbar
    24   1.279000000e+00              # mc(mc) MSbar
    30   8.039800000e+01              # MW (pole), not a standard SLHA2 entry !!!
    31   2.31160000000e-01            # sW^2 (MSBar), not a standard SLHA2 entry !!!
Block VCKMIN                          # CKM matrix
    1    2.258000000e-01              # lambda
    2    8.080000000e-01              # A
    3    1.770000000e-01              # rho bar
    4    3.600000000e-01              # eta bar
Block EXTPAR                          # non-minimal input parameters, real part
    0    -1.000000000e+00             # input at EW scale only, cannot be modified!!!
    1    2.000000000e+02              # Re(m1), U(1) gaugino mass
    2    3.000000000e+02              # Re(m2), SU(2) gaugino mass
    3    6.000000000e+02              # m3, SU(3) gaugino mass
    23   2.000000000e+02              # Re(mu)
    25   4.000000000e+00              # tan(beta)
    26   2.000000000e+02              # MA
Block IMEXTPAR                        # non-minimal input parameters, imaginary part
    1    0.000000000e+00              # Im(m1), U(1) gaugino mass
    2    0.000000000e+00              # Im(m2), SU(2) gaugino mass
    23   1.000000000e+02              # Im(mu)
# if abs(m1) = 0 SUSY_FLAVOR uses m1=5/3 s_W^2/c_W^2 m2
#
# Soft sfermion mass matrices
#
# Off-diagonal entries may be given as absolute entries or as
# dimensionless mass insertions - then real off-diagonal entries of
# SLHA2 blocks are calculated by SUSY_FLAVOR as
# M^2(I,J) = (mass insertion)(I,J) sqrt(M^2(I,I) M^2(J,J))
# (see comments at the top of subroutine sflav_input)
#
# Below we give an example of dimensionful off-diagonal entries
#
```

```
Block MSL2IN                       # left soft slepton mass matrix, real part
    1 1  9.000000000e+04           # Left slepton diagonal mass^2, 1st generation
    2 2  9.000000000e+04           # Left slepton diagonal mass^2, 2nd generation
    3 3  9.000000000e+04           # Left slepton diagonal mass^2, 3rd generation
    1 2  1.800000000e-02           # Left slepton mass insertion 12
    2 3  0.000000000e+00           # Left slepton mass insertion 23
    1 3  0.000000000e+00           # Left slepton mass insertion 13
Block IMMSL2IN                     # Left soft slepton mass matrix, imaginary part
    1 2  2.700000000e+03           # Left slepton mass insertion 12
    2 3  0.000000000e+00           # Left slepton mass insertion 23
    1 3  0.000000000e+00           # Left slepton mass insertion 13
Block MSE2IN                       # right soft slepton mass matrix, real part
    1 1  9.000000000e+04           # Right selectron diagonal mass^2
    2 2  9.000000000e+04           # Right smuon diagonal mass^2
    3 3  9.000000000e+04           # Right stau diagonal mass^2
    1 2  0.000000000e+00           # right slepton mass insertion 12
    2 3  0.000000000e+00           # right slepton mass insertion 23
    1 3  0.000000000e+00           # right slepton mass insertion 13
Block IMMSE2IN                     # right soft slepton mass matrix, imaginary part
    1 2  0.000000000e+00           # right slepton mass insertion 12
    2 3  0.000000000e+00           # right slepton mass insertion 23
    1 3  0.000000000e+00           # right slepton mass insertion 13
Block MSQ2IN                       # Left soft squark mass matrix, real part
    1 1  2.500000000e+05           # Left squark diagonal mass^2, 1st generation
    2 2  2.025000000e+05           # Left squark diagonal mass^2, 2nd generation
    3 3  1.600000000e+05           # Left squark diagonal mass^2, 3rd generation
    1 2  0.000000000e+00           # Left squark mass insertion 12
    2 3  -1.800000000e+03          # Left squark mass insertion 23
    1 3  0.000000000e+00           # Left squark mass insertion 13
Block IMMSQ2IN                     # Left soft squark mass matrix, imaginary part
    1 2  0.000000000e+00           # Left squark mass insertion 12
    2 3  1.800000000e+03           # Left squark mass insertion 23
    1 3  0.000000000e+00           # Left squark mass insertion 13
Block MSU2IN                       # Right soft up-squark mass matrix, real part
    1 1  2.025000000e+05           # Right u-squark diagonal mass^2
    2 2  2.025000000e+05           # Right c-squark diagonal mass^2
    3 3  4.000000000e+04           # Right stop diagonal mass^2
    1 2  0.000000000e+00           # Right up-squark mass insertion 12
    2 3  0.000000000e+00           # Right up-squark mass insertion 23
    1 3  0.000000000e+00           # Right up-squark mass insertion 13
Block IMMSU2IN                     # Right soft up-squark mass matrix, imaginary part
    1 2  0.000000000e+00           # Right up-squark mass insertion 12
    2 3  0.000000000e+00           # Right up-squark mass insertion 23
```

```
    1 3  0.000000000e+00              # Right up-squark mass insertion 13
Block MSD2IN                          # Right soft down-squark mass matrix, real part
    1 1  3.025000000e+05              # Right d-squark diagonal mass^2
    2 2  3.025000000e+05              # Right s-squark diagonal mass^2
    3 3  9.000000000e+04              # Right sbottom diagonal mass^2
    1 2  0.000000000e+00              # Right down-squark mass insertion 12
    2 3  0.000000000e+00              # Right down-squark mass insertion 23
    1 3  0.000000000e+00              # Right down-squark mass insertion 13
Block IMMSD2IN                        # Right soft down-squark mass matrix, imaginary part
    1 2  0.000000000e+00              # Right down-squark mass insertion 12
    2 3  0.000000000e+00              # Right down-squark mass insertion 23
    1 3  0.000000000e+00              # Right down-squark mass insertion 13
#
# Soft sfermion trilinear mixing matrices
#
# LR mixing parameters can be given as absolute entries or as
# dimensionless diagonal A-terms and dimensionless off-diagonal mass
# insertions - see comments at the top of subroutine sflav_input
#
# In the second case the dimensionful entries of LR blocks
# are calculated by SUSY_FLAVOR as
# TL(I,J) = AL(I,J) (ML^2(I,I)*ME^2(J,J))**(1/4)
# TU(I,J) = AU(I,J) (MQ^2(I,I)*MU^2(J,J))**(1/4)
# TD(I,J) = AD(I,J) (MQ^2(I,I)*MD^2(J,J))**(1/4)
#
# Below we give an example of dimensionful ``A terms''.
#
Block TEIN                            # slepton trilinear mixing, real part
    1 1  3.000000000e-02              # Diagonal AL term, 1st generation
    2 2  3.000000000e-00              # Diagonal AL term, 2nd generation
    3 3  3.000000000e+01              # Diagonal AL term, 3rd generation
    1 2  0.000000000e+00              # Slepton LR mass insertion 12
    2 1  0.000000000e+00              # Slepton LR mass insertion 21
    2 3  2.000000000e-02              # Slepton LR mass insertion 23
    3 2  0.000000000e+00              # Slepton LR mass insertion 32
    1 3  0.000000000e+00              # Slepton LR mass insertion 13
    3 1  0.000000000e+00              # Slepton LR mass insertion 31
Block IMTEIN                          # slepton trilinear mixing, imaginary part
    1 1  0.000000000e+00              # Diagonal AL term, 1st generation
    2 2  0.000000000e+00              # Diagonal AL term, 2nd generation
    3 3  0.000000000e+00              # Diagonal AL term, 3rd generation
    1 2  0.000000000e+00              # Slepton LR mass insertion 12
    2 1  0.000000000e+00              # Slepton LR mass insertion 21
```

```
    2 3  1.000000000e-02            # Slepton LR mass insertion 23
    3 2  0.000000000e+00            # Slepton LR mass insertion 32
    1 3  0.000000000e+00            # Slepton LR mass insertion 13
    3 1  0.000000000e+00            # Slepton LR mass insertion 31
Block TUIN                          # up-squark trilinear mixing, real part
    1 1  4.743000000e-03            # Diagonal AU term, 1st generation
    2 2  1.800000000e-00            # Diagonal AU term, 2nd generation
    3 3  2.828000000e+02            # Diagonal AU term, 3rd generation
    1 2  0.000000000e+00            # Up-squark LR mass insertion 12
    2 1  0.000000000e+00            # Up-squark LR mass insertion 21
    2 3  0.000000000e+00            # Up-squark LR mass insertion 23
    3 2  0.000000000e+00            # Up-squark LR mass insertion 32
    1 3  0.000000000e+00            # Up-squark LR mass insertion 13
    3 1  0.000000000e+00            # Up-squark LR mass insertion 31
Block IMTUIN                        # up-squark trilinear mixing, imaginary part
    1 1  0.000000000e+00            # Diagonal AU term, 1st generation
    2 2  0.000000000e+00            # Diagonal AU term, 2nd generation
    3 3  0.000000000e+00            # Diagonal AU term, 3rd generation
    1 2  0.000000000e+00            # Up-squark LR mass insertion 12
    2 1  0.000000000e+00            # Up-squark LR mass insertion 21
    2 3  0.000000000e+00            # Up-squark LR mass insertion 23
    3 2  0.000000000e+00            # Up-squark LR mass insertion 32
    1 3  0.000000000e+00            # Up-squark LR mass insertion 13
    3 1  0.000000000e+00            # Up-squark LR mass insertion 31
Block TDIN                          # down-squark trilinear mixing, real part
    1 1  -5.244000000e-02           # Diagonal AD term, 1st generation
    2 2  -9.950000000e-01           # Diagonal AD term, 2nd generation
    3 3  -2.771000000e+01           # Diagonal AD term, 3rd generation
    1 2  0.000000000e+00            # Down-squark LR mass insertion 12
    2 1  0.000000000e+00            # Down-squark LR mass insertion 21
    2 3  1.000000000e-02            # Down-squark LR mass insertion 23
    3 2  0.000000000e+00            # Down-squark LR mass insertion 32
    1 3  0.000000000e+00            # Down-squark LR mass insertion 13
    3 1  0.000000000e+00            # Down-squark LR mass insertion 31
Block IMTDIN                        # down-squark trilinear mixing, imaginary part
    1 1  0.000000000e+00            # Diagonal AD term, 1st generation
    2 2  0.000000000e+00            # Diagonal AD term, 2nd generation
    3 3  0.000000000e+00            # Diagonal AD term, 3rd generation
    1 2  0.000000000e+00            # Down-squark LR mass insertion 12
    2 1  0.000000000e+00            # Down-squark LR mass insertion 21
    2 3  -3.674000000e+00           # Down-squark LR mass insertion 23
    3 2  0.000000000e+00            # Down-squark LR mass insertion 32
    1 3  0.000000000e+00            # Down-squark LR mass insertion 13
```

```
    3 1  0.000000000e+00             # Down-squark LR mass insertion 31
#
# ''Non-holomorphic'' soft sfermion trilinear mixing matrices (optional)
# Such couplings are not SLHA2-standard and set to 0 if not explicitly
# defined in the input file
#
# again LR mixing parameters can be given as absolute entries or as
# dimensionless diagonal A-terms and dimensionless off-diagonal mass insertions
#
Block TEINH                          # slepton trilinear mixing, real part
    1 1  0.000000000e-00             # Diagonal ALNH term, 1st generation
    2 2  0.000000000e-00             # Diagonal ALNH term, 2nd generation
    3 3  0.000000000e-00             # Diagonal ALNH term, 3rd generation
    1 2  0.000000000e+00             # Slepton LRNH mass insertion 12
    2 1  0.000000000e+00             # Slepton LRNH mass insertion 21
    2 3  0.000000000e-00             # Slepton LRNH mass insertion 23
    3 2  0.000000000e+00             # Slepton LRNH mass insertion 32
    1 3  0.000000000e+00             # Slepton LRNH mass insertion 13
    3 1  0.000000000e+00             # Slepton LRNH mass insertion 31
Block IMTEINH                        # slepton trilinear mixing, imaginary part
    1 1  0.000000000e+00             # Diagonal ALNH term, 1st generation
    2 2  0.000000000e+00             # Diagonal ALNH term, 2nd generation
    3 3  0.000000000e+00             # Diagonal ALNH term, 3rd generation
    1 2  0.000000000e+00             # Slepton LRNH mass insertion 12
    2 1  0.000000000e+00             # Slepton LRNH mass insertion 21
    2 3  0.000000000e-00             # Slepton LRNH mass insertion 23
    3 2  0.000000000e+00             # Slepton LRNH mass insertion 32
    1 3  0.000000000e+00             # Slepton LRNH mass insertion 13
    3 1  0.000000000e+00             # Slepton LRNH mass insertion 31
Block TUINH                          # up-squark trilinear mixing, real part
    1 1  0.000000000e-00             # Diagonal AUNH term, 1st generation
    2 2  0.000000000e-00             # Diagonal AUNH term, 2nd generation
    3 3  0.000000000e+00             # Diagonal AUNH term, 3rd generation
    1 2  0.000000000e+00             # Up-squark LRNH mass insertion 12
    2 1  0.000000000e+00             # Up-squark LRNH mass insertion 21
    2 3  0.000000000e-00             # Up-squark LRNH mass insertion 23
    3 2  0.000000000e+00             # Up-squark LRNH mass insertion 32
    1 3  0.000000000e+00             # Up-squark LRNH mass insertion 13
    3 1  0.000000000e+00             # Up-squark LRNH mass insertion 31
Block IMTUINH                        # up-squark trilinear mixing, imaginary part
    1 1  0.000000000e+00             # Diagonal AUNH term, 1st generation
    2 2  0.000000000e+00             # Diagonal AUNH term, 2nd generation
    3 3  0.000000000e+00             # Diagonal AUNH term, 3rd generation
```

```
    1 2  0.000000000e+00              # Up-squark LRNH mass insertion 12
    2 1  0.000000000e+00              # Up-squark LRNH mass insertion 21
    2 3  0.000000000e-00              # Up-squark LRNH mass insertion 23
    3 2  0.000000000e+00              # Up-squark LRNH mass insertion 32
    1 3  0.000000000e+00              # Up-squark LRNH mass insertion 13
    3 1  0.000000000e+00              # Up-squark LRNH mass insertion 31
Block TDINH                           # down-squark trilinear mixing, real part
    1 1  0.000000000e-00              # Diagonal ADNH term, 1st generation
    2 2  0.000000000e-00              # Diagonal ADNH term, 2nd generation
    3 3  0.000000000e-00              # Diagonal ADNH term, 3rd generation
    1 2  0.000000000e+00              # Down-squark LRNH mass insertion 12
    2 1  0.000000000e+00              # Down-squark LRNH mass insertion 21
    2 3  0.000000000e+00              # Down-squark LRNH mass insertion 23
    3 2  0.000000000e+00              # Down-squark LRNH mass insertion 32
    1 3  0.000000000e+00              # Down-squark LRNH mass insertion 13
    3 1  0.000000000e+00              # Down-squark LRNH mass insertion 31
Block IMTDINH                         # down-squark trilinear mixing, imaginary part
    1 1  0.000000000e+00              # Diagonal ADNH term, 1st generation
    2 2  0.000000000e+00              # Diagonal ADNH term, 2nd generation
    3 3  0.000000000e+00              # Diagonal ADNH term, 3rd generation
    1 2  0.000000000e+00              # Down-squark LRNH mass insertion 12
    2 1  0.000000000e+00              # Down-squark LRNH mass insertion 21
    2 3  0.000000000e+00              # Down-squark LRNH mass insertion 23
    3 2  0.000000000e+00              # Down-squark LRNH mass insertion 32
    1 3  0.000000000e+00              # Down-squark LRNH mass insertion 13
    3 1  0.000000000e+00              # Down-squark LRNH mass insertion 31
Block SFLAV_HADRON                    # hadronic and QCD-related input
    1    0.1561e0                     # f_K
    2    0.2e0                        # f_D
    3    0.193e0                      # f_B_d
    4    0.232e0                      # f_B_s
    5    0.724e0                      # B_K for SM contribution to KKbar
    6    1.86e0                       # eta_cc in KK mixing (SM)
    7    0.496e0                      # eta_ct in KK mixing (SM)
    8    0.577e0                      # eta_tt in KK mixing (SM)
    9    2.e0                         # scale for B_K (non-SM)
    10   0.61e0                       # B_K for VLL (non-SM)
    11   0.76e0                       # B_K for SLL1
    12   0.51e0                       # B_K for SLL2
    13   0.96e0                       # B_K for LR1
    14   1.30e0                       # B_K for LR2
    15   1.e0                         # B_D for SM contribution
    16   2.e0                         # scale for B_D (non-SM)
```

```
17   1.e0                       # B_D for VLL
18   1.e0                       # B_D for SLL1
19   1.e0                       # B_D for SLL2
20   1.e0                       # B_D for LR1
21   1.e0                       # B_D for LR2
22   1.22e0                     # B_Bd for SM contribution
23   4.6e0                      # scale for B_B (non-SM, both Bd and Bs)
24   0.87e0                     # B_Bd for VLL (non-SM)
25   0.8e0                      # B_Bd for SLL1
26   0.71e0                     # B_Bd for SLL2
27   1.71e0                     # B_Bd for LR1
28   1.16e0                     # B_Bd for LR2
29   1.22e0                     # B_Bs for SM contribution
30   0.55e0                     # eta_b for BsBs (SM)
31   0.87e0                     # B_Bs for VLL (non-SM)
32   0.8e0                      # B_Bs for SLL1
33   0.71e0                     # B_Bs for SLL2
34   1.71e0                     # B_Bs for LR1
35   1.16e0                     # B_Bs for LR2
36   1.519e-12                  # Bd lifetime (experimental value)
37   1.512e-12                  # Bs lifetime (experimental value)
38   5.27958e0                  # Bd mass (experimental value)
39   5.36677e0                  # Bs mass (experimental value)
40   3.337e-13                  # Delta Bd (experimental value)
41   1.17e-11                   # Delta Bs (experimental value)
42   0.497614e0                 # K0 mass (experimental value)
43   3.483e-15                  # Delta mK (experimental value)
44   2.229e-3                   # eps_K (experimental value)
45   1.8645e0                   # D0 mass (experimental value)
46   1.56e-14                   # Delta mD (experimental value)
47   2.231e-10                  # parameter kappa in K^0->pi^0vv calculations
48   5.173e-11                  # parameter kappa in K^+->pi^+vv calculations
49   0.41e0                     # parameter P_c in K->pivv calculations
50   0.013e-10                  # error of kappa0
51   0.024e-11                  # error of kappa+
52   0.03e0                     # error of P_c
53   0.79e0                     # neutron EDM_d QCD coefficient
54   -0.2e0                     # neutron EDM_u QCD coefficient
55   0.59e0                     # neutron CDM_d QCD coefficient
56   0.3e0                      # neutron CDM_u QCD coefficient
57   3.4e0                      # neutron CDM_g QCD coefficient
58   1.18e0                     # neutron EDM chiral symmetry breaking scale
59   1.5e0                      # pole c quark mass (in B->X_s gamma and t->cH)
```

```
60   0.1872e0                  # Br(tau->evv)
61   5.27917e0                 # M_B+
62   0.297e0                   # Br(B->D tau nu)/Br(B->D l nu) in SM
63   0.017e0                   # error of Br(B->D tau nu)/Br(B->D l nu) in SM
64   0.252e0                   # Br(B->D* tau nu)/Br(B->D* l nu) in SM
65   0.003e0                   # error of Br(B->D* tau nu)/Br(B->D* l nu) in SM
```

D Example of SUSY_FLAVOR output

The parameters defined inside the driver program in Appendix B and in the input file listed in Appendix C should produce almost identical output, up to minor differences on distant decimal digits coming from finite accuracy of numerical computations.

We enclose content of the susy_flavor.out output file here, so that SUSY_FLAVOR users can check that the program gives the same result on their own computers and compilers.

```
#
#            ***************************
#            * SUSY_FLAVOR 2.50 output *
#            ***************************
#
BLOCK SFLAV_CONTROL
    1        2                    # resummation level of chiral corrections
    2        0                    # error code (0 if all calculations were correct)
BLOCK SFLAV_MASS                  # Mass Spectrum
#   code     mass                 # particle
    24       8.039800000E+01      # W+
    25       9.700316978E+01      # h (simple 2-loop approximation only)
    35       2.061912209E+02      # H (simple 2-loop approximation only)
    36       2.000000000E+02      # A
    37       2.155547225E+02      # H+
    41       5.109989000E-04      # e (pole)
    42       1.056580000E-01      # mu (pole)
    43       1.776840000E+00      # tau (pole)
    44       2.608286100E-03      # md(mt) (running)
    45       5.183274930E-02      # ms(mt) (running)
    46       2.744876788E+00      # mb(mt) (running)
    47       1.165404427E-03      # mu(mt) (running)
    48       6.081579020E-01      # mc(mt) (running)
    49       1.630910000E+02      # mt(mt) (running)
    1000021  6.000000000E+02      # ~g
    1000022  1.609162276E+02      # ~chi_10
    1000023  2.232344115E+02      # ~chi_20
    1000025  2.283407379E+02      # ~chi_30
    1000035  3.446204135E+02      # ~chi_40
    1000024  1.879079878E+02      # ~chi_1+
    1000037  3.427487004E+02      # ~chi_2+
# sfermion mass eigenstates
    101      3.006758739E+02      # ~d(1)
    102      4.038884306E+02      # ~d(2)
    103      4.536071034E+02      # ~d(3)
```

```
    104      5.030960409E+02      # ~d(4)
    105      5.505085911E+02      # ~d(5)
    106      5.505109533E+02      # ~d(6)
    111      2.322291420E+02      # ~u(1)
    112      4.406135873E+02      # ~u(2)
    113      4.486873688E+02      # ~u(3)
    114      4.487396867E+02      # ~u(4)
    115      4.498531834E+02      # ~u(5)
    116      4.974625553E+02      # ~u(6)
    121      2.978728202E+02      # ~l(1)
    122      3.017183129E+02      # ~l(2)
    123      3.028111419E+02      # ~l(3)
    124      3.028119935E+02      # ~l(4)
    125      3.043692532E+02      # ~l(5)
    126      3.085762706E+02      # ~l(6)
    131      2.882497056E+02      # ~nu(1)
    132      2.938268860E+02      # ~nu(2)
    133      2.992956484E+02      # ~nu(3)
BLOCK SFLAV_CHIRAL_YUKAWA         # Chiral corrections size to Yukawa couplings
    1        9.250781508E-03      # correction to Y_e
    2        7.871358686E-03      # correction to Y_mu
    3        7.355398855E-03      # correction to Y_tau
    4        2.825581825E-02      # correction to Y_d
    5        2.875084532E-02      # correction to Y_s
    6        4.067136212E-02      # correction to Y_b
    7        1.478999649E-02      # correction to Y_u
    8        1.118390358E-02      # correction to Y_c
    9        8.435040750E-03      # correction to Y_t
BLOCK SFLAV_CHIRAL_CKM            # Chiral corrections size to CKM matrix
    1 1      3.660227820E-05      # correction to V_11
    1 2      6.792764515E-04      # correction to V_12
    1 3      3.087095532E-03      # correction to V_13
    2 1      6.871751836E-04      # correction to V_21
    2 2      3.415695240E-05      # correction to V_22
    2 3      5.961443433E-03      # correction to V_23
    3 1      5.998183639E-03      # correction to V_31
    3 2      5.944557565E-03      # correction to V_32
    3 3      7.838728907E-06      # correction to V_33
BLOCK SFLAV_DELTA_F0              # Delta F = 0 processes
    1        -1.496831513E-25     # EDM_e
    2        -3.083776497E-23     # EDM_mu
    3        -5.176903910E-22     # EDM_tau
    4        2.759938107E-25      # neutron EDM
```

```
    5         9.398319525E-15       # (g-2)_e/2, SUSY contribution
    6         4.843853089E-10       # (g-2)_mu/2, SUSY contribution
    7         1.458383883E-07       # (g-2)_tau/2, SUSY contribution
BLOCK SFLAV_DELTA_F1                # Delta F = 1 processes
    1         2.343751393E-08       # Br(mu-> e gamma)
    2         3.014685213E-20       # Br(tau-> e gamma)
    3         3.472210147E-09       # Br(tau-> mu gamma)
    4         2.797259621E-11       # Br(K0 -> pi0 nu nu)
    5         7.705350370E-11       # Br(K+ -> pi+ nu nu)
    6         8.768756807E-05       # BR(B -> tau nu)
    7         2.962481261E-01       # BR(B -> D tau nu)/BR(B -> D l nu)
    8         2.519503431E-01       # BR(B -> D* tau nu)/BR(B -> D* l nu)
    9         6.933649703E-04       # BR(B -> X_s gamma)
    10        6.246862414E-12       # BR(t -> u h)
    11        1.945309468E-10       # BR(t -> c h)
    12        2.686141823E-15       # BR(B_d -> e e)
    13        1.147486285E-10       # BR(B_d -> mu mu)
    14        2.402190900E-08       # BR(B_d -> tau tau)
    15        8.309954374E-22       # BR(B_d -> mu e)
    16        6.024806941E-34       # BR(B_d -> tau e)
    17        6.589103387E-24       # BR(B_d -> tau mu)
    18        8.986707552E-14       # BR(B_s -> e e)
    19        3.839108868E-09       # BR(B_s -> mu mu)
    20        8.143373208E-07       # BR(B_s -> tau tau)
    21        5.851883404E-20       # BR(B_s -> mu e)
    22        2.300098073E-28       # BR(B_s -> tau e)
    23        4.505919262E-23       # BR(B_s -> tau mu)
BLOCK SFLAV_DELTA_F2                # Delta F = 2 processes
    1         2.271797243E-03       # epsilon_K
    2         2.324836393E-15       # Delta m_K (GeV)
    3         1.792385187E-15       # Delta m_D (GeV)
    4         3.520066391E-13       # Delta m_Bd (GeV)
    5         1.195408141E-13       # Re(H_eff_Bd)
    6         -1.291787996E-13      # Im(H_eff_Bd)
    7         1.214313594E-11       # Delta m_Bs (GeV)
    8         6.067828156E-12       # Re(H_eff_Bs)
    9         2.130706402E-13       # Im(H_eff_Bs)
```

References

[1] T. Teubner, K. Hagiwara, R. Liao, A. D. Martin and D. Nomura, arXiv:1001.5401 [hep-ph].

[2] G. W. Bennett *et al.* [Muon G-2 Collaboration], Phys. Rev. D **73** (2006) 072003 [hep-ex/0602035].

[3] For reviews, see for example, H. P. Nilles, Phys. Rept. **110**, 1 (1984). H. E. Haber and G. L. Kane, Phys. Rept. **117**, 75 (1985). S. P. Martin, arXiv:hep-ph/9709356. S. Weinberg, "The quantum theory of fields. Vol. 3: Supersymmetry," *Cambridge, UK: Univ. Pr. (2000) 419 p*

[4] G. D'Ambrosio, G. F. Giudice, G. Isidori and A. Strumia, Nucl. Phys. B **645** (2002) 155 [arXiv:hep-ph/0207036].

[5] L. J. Hall, V. A. Kostelecky and S. Raby, Nucl. Phys. B **267** (1986) 415.

[6] M. Misiak, S. Pokorski and J. Rosiek, *"Supersymmetry and the FCNC effects"* Adv. Ser. Direct. High Energy Phys. **15** (1998) 795 [arXiv:hep-ph/9703442].

[7] S. Pokorski, J. Rosiek and C. A. Savoy, Nucl. Phys. B **570** (2000) 81 [arXiv:hep-ph/9906206].

[8] J. Rosiek, Acta Phys. Polon. B **30** (1999) 3379.

[9] A. Buras, P. Chankowski, J. Rosiek and L. Slawianowska, Nucl. Phys. B **619** (2001) 434 [arXiv:hep-ph/0107048].

[10] J. Rosiek, arXiv:hep-ph/0108226.

[11] A. Buras, P. Chankowski, J. Rosiek and L. Slawianowska, Phys. Lett. B **546** (2002) 96 [arXiv:hep-ph/0207241].

[12] P. Chankowski and J. Rosiek, Acta Phys. Polon. B **33** (2002) 2329 [arXiv:hep-ph/0207242].

[13] A. Buras, P. Chankowski, J. Rosiek and L. Slawianowska, Nucl. Phys. B **659** (2003) 3 [arXiv:hep-ph/0210145].

[14] A. Buras, T. Ewerth, S. Jager and J. Rosiek, Nucl. Phys. B **714** (2005) 103 [arXiv:hep-ph/0408142].

[15] A. Dedes, J. Rosiek and P. Tanedo, Phys. Rev. D **79** (2009) 055006 [arXiv:0812.4320 [hep-ph]].

[16] J. Rosiek, arXiv:0911.3339 [hep-ph].

[17] J. Rosiek, Phys. Rev. D **41** (1990) 3464; *erratum* arXiv:hep-ph/9511250.

[18] P. Chankowski, S. Pokorski and J. Rosiek, Phys. Lett. B **274** (1992) 191; P. Chankowski, S. Pokorski and J. Rosiek, Phys. Lett. B **281** (1992) 100; P. Chankowski, S. Pokorski and J. Rosiek, Phys. Lett. B **286** (1992) 307; P. Chankowski, S. Pokorski and J. Rosiek, Nucl. Phys. B **423** (1994) 437; P. Chankowski, S. Pokorski and J. Rosiek, Nucl. Phys. B **423** (1994) 497; P. Chankowski *et al.*, Nucl. Phys. B **417** (1994) 101; J. Rosiek and A. Sopczak, Phys. Lett. B **341** (1995) 419; P. Chankowski *et al*, Nucl. Phys. Proc. Suppl. **37B** (1994) 232; V. Driesen, W. Hollik and J. Rosiek, Z. Phys. C **71** (1996) 259; A. Djouadi, V. Driesen, W. Hollik and J. Rosiek, Nucl. Phys. B **491** (1997) 68; J. Rosiek, Acta Phys. Polon. B **27** (1996) 3855; S. Heinemeyer, W. Hollik, J. Rosiek and G. Weiglein, Eur. Phys. J. C **19** (2001) 535.

[19] J. Rosiek, P. Chankowski, A. Dedes, S. Jager and P. Tanedo, Comput. Phys. Commun. **181** (2010) 2180 [arXiv:1003.4260 [hep-ph]].

[20] J. Rosiek, arXiv:1212.0032 [hep-ph]; A. Crivellin and J. Rosiek, PoS EPS **-HEP2013**, 081 (2013) [arXiv:1308.6299 [hep-ph]].

[21] L. J. Hall, R. Rattazzi and U. Sarid, Phys. Rev. D **50** (1994) 7048 [hep-ph/9306309].

[22] M. S. Carena, M. Olechowski, S. Pokorski and C. E. M. Wagner, Nucl. Phys. B **426** (1994) 269 [hep-ph/9402253].

[23] C. Hamzaoui, M. Pospelov and M. Toharia, Phys. Rev. D **59** (1999) 095005 [hep-ph/9807350].

[24] M. S. Carena, D. Garcia, U. Nierste and C. E. M. Wagner, Nucl. Phys. B **577** (2000) 88 [hep-ph/9912516].

[25] K. S. Babu and C. F. Kolda, Phys. Rev. Lett. **84** (2000) 228 [hep-ph/9909476].

[26] G. Isidori and A. Retico, JHEP **0111** (2001) 001 [hep-ph/0110121].

[27] G. Isidori and A. Retico, JHEP **0209** (2002) 063 [hep-ph/0208159].

[28] A. Dedes and A. Pilaftsis, Phys. Rev. D **67** (2003) 015012 [arXiv:hep-ph/0209306].

[29] J. Foster, K. I. Okumura and L. Roszkowski, JHEP **0508** (2005) 094.

[30] A. Crivellin and U. Nierste, Phys. Rev. D **79** (2009) 035018 [arXiv:0810.1613 [hep-ph]].

[31] L. Hofer, U. Nierste and D. Scherer, JHEP **0910** (2009) 081 [arXiv:0907.5408 [hep-ph]].

[32] A. Crivellin and U. Nierste, Phys. Rev. D **81** (2010) 095007 [arXiv:0908.4404 [hep-ph]].

[33] J. Girrbach, S. Mertens, U. Nierste and S. Wiesenfeldt, JHEP **1005** (2010) 026 [arXiv:0910.2663 [hep-ph]].

[34] A. Crivellin and J. Girrbach, Phys. Rev. D **81** (2010) 076001 [arXiv:1002.0227 [hep-ph]].

[35] A. Crivellin, Phys. Rev. D **83** (2011) 056001 [arXiv:1012.4840 [hep-ph]].

[36] A. Crivellin, L. Hofer and J. Rosiek, JHEP **1107** (2011) 017 [arXiv:1103.4272 [hep-ph]].

[37] B. Allanach *et al.*, Comput. Phys. Commun. **180** (2009) 8 [arXiv:0801.0045 [hep-ph]].

[38] A. Dedes, M. Paraskevas, J. Rosiek, K. Suxho and K. Tamvakis, arXiv:1409.6546 [hep-ph].

[39] J. S. Lee, M. Carena, J. Ellis, A. Pilaftsis and C. E. M. Wagner, Comput. Phys. Commun. **180** (2009) 312 [arXiv:0712.2360 [hep-ph]].

[40] G. Degrassi, P. Gambino and P. Slavich, Comput. Phys. Commun. **179**, 759 (2008) [arXiv:0712.3265 [hep-ph]].

[41] W. Porod, Comput. Phys. Commun. **153**, 275 (2003) [arXiv:hep-ph/0301101].

[42] F. Mahmoudi, Comput. Phys. Commun. **180**, 1579 (2009) [arXiv:0808.3144 [hep-ph]].

[43] D. Chowdhury, R. Garani, S. K. Vempati, arXiv:1109.3551 [hep-ph].

[44] S. Heinemeyer, W. Hollik and G. Weiglein, Comput. Phys. Commun. **124**, 76 (2000) [arXiv:hep-ph/9812320].

[45] B. C. Allanach, Comput. Phys. Commun. **143**, 305 (2002) [arXiv:hep-ph/0104145].

[46] A. Djouadi, J. L. Kneur and G. Moultaka, Comput. Phys. Commun. **176**, 426 (2007) [arXiv:hep-ph/0211331].

[47] G. Belanger, F. Boudjema, A. Pukhov and A. Semenov, Comput. Phys. Commun. **177**, 894 (2007).

[48] P. Gondolo, J. Edsjo, P. Ullio, L. Bergstrom, M. Schelke and E. A. Baltz, JCAP **0407** (2004) 008 [arXiv:astro-ph/0406204].

[49] U. Ellwanger and C. Hugonie, Comput. Phys. Commun. **175** (2006) 290 [arXiv:hep-ph/0508022].

[50] L. J. Hall and L. Randall, Phys. Rev. Lett. **65** (1990) 2939.

[51] R. S. Van Dyck, P. B. Schwinberg and H. G. Dehmelt, Phys. Rev. Lett. **59** (1987) 26.

[52] A. Heister *et al.* [ALEPH Collaboration], Eur. Phys. J. C **30** (2003) 291 [hep-ex/0209066].

[53] B. C. Regan, E. D. Commins, C. J. Schmidt and D. DeMille, Phys. Rev. Lett. **88**, 071805 (2002).

[54] R. McNabb [Muon g-2 Collaboration], arXiv:hep-ex/0407008.

[55] K. A. Olive *et al.* [Particle Data Group Collaboration], Chin. Phys. C **38** (2014) 090001.

[56] C. A. Baker *et al.*, Phys. Rev. Lett. **97**, 131801 (2006) [arXiv:hep-ex/0602020].

[57] J. Adam *et al.* [MEG Collaboration], Phys. Rev. Lett. **110** (2013) 201801 [arXiv:1303.0754 [hep-ex]].

[58] B. Aubert *et al.* [BABAR Collaboration], Phys. Rev. Lett. **104** (2010) 021802 [arXiv:0908.2381 [hep-ex]].

[59] J. K. Ahn *et al.* [E391a Collaboration], Phys. Rev. Lett. **100**, 201802 (2008) [arXiv:0712.4164 [hep-ex]].

[60] A. V. Artamonov *et al.* [E949 Collaboration], Phys. Rev. Lett. **101**, 191802 (2008) [arXiv:0808.2459 [hep-ex]].

[61] B. Aubert *et al.* [BaBar Collaboration], Phys. Rev. D **77** (2008) 032007 [arXiv:0712.1516 [hep-ex]].

[62] R. Aaij *et al.* [LHCb Collaboration], Phys. Rev. Lett. **111** (2013) 101805 [arXiv:1307.5024 [hep-ex]].

[63] R. Aaij *et al.* [LHCb Collaboration], Phys. Rev. Lett. **111** (2013) 14, 141801 [arXiv:1307.4889 [hep-ex]].

[64] B. Aubert *et al.* [BABAR Collaboration], Phys. Rev. Lett. **96** (2006) 241802 [arXiv:hep-ex/0511015].

[65] M. Acciarri *et al.* [L3 Collaboration], Phys. Lett. B **391** (1997) 474.

[66] RAaij *et al.* [LHCb Collaboration], Phys. Rev. Lett. **110** (2013) 021801 [arXiv:1211.2674 [hep-ex]]. S. Chatrchyan *et al.* [CMS Collaboration], Phys. Rev. Lett. **111** (2013) 101804 [arXiv:1307.5025 [hep-ex]]. CMS and LHCb Collaborations [CMS and LHCb Collaboration], CMS-PAS-BPH-13-007.

[67] J. P. Lees *et al.* [BaBar Collaboration], Phys. Rev. Lett. **109** (2012) 101802 [arXiv:1205.5442 [hep-ex]].

[68] E. Barberio *et al.* [Heavy Flavor Averaging Group], arXiv:0808.1297 [hep-ex].

[69] CMS-PAS-HIG-13-034, "Combined $t \to cH$ limit from multi-lepton and di-photon analyses.

[70] A. Abulencia *et al.* [CDF Collaboration], Phys. Rev. Lett. **97** (2006) 242003 [arXiv:hep-ex/0609040].

[71] A. Dedes, H. Haber and J. Rosiek, JHEP **0711** (2007) 059 [arXiv:0707.3718 [hep-ph]].

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

[73] A. B. Lahanas and D. Wyler, Phys. Lett. B **122** (1983) 258. F. Borzumati, G. R. Farrar, N. Polonsky and S. D. Thomas, Nucl. Phys. B **555** (1999) 53. A. Crivellin, J. Girrbach and U. Nierste, Phys. Rev. D **83** (2011) 055009. A. Crivellin, L. Hofer, U. Nierste and D. Scherer, Phys. Rev. D **84** (2011) 035030.

[74] W. Altmannshofer, A. Buras, S. Gori, P. Paradisi and D. M. Straub, Nucl. Phys. B **830** (2010) 17 [arXiv:0909.1333 [hep-ph]].

[75] M. Cadoret, E. de Mirandes, P. Clade, S. Guellati-Khelifa, C. Schwob, F. Nez, L. Julien and F. Biraben, Phys. Rev. Lett. **101** (2008) 230801 [arXiv:0810.3152 [physics.atom-ph]].

[76] K. Fuyuto, J. Hisano, N. Nagata and K. Tsumura, arXiv:1308.6493 [hep-ph].

[77] A. Manohar, H. Georgi, *Nucl. Phys.* **B234** (1984) 189.

[78] F. Mescia and C. Smith, Phys. Rev. D **76** (2007) 034017 [arXiv:0705.2025 [hep-ph]].

[79] L. Wolfenstein, *Phys. Rev. Lett.* **51** (1983) 1945.

[80] G. Buchalla and A. Buras, Nucl. Phys. **B548** (1999) 309.

[81] G. Buchalla and A. Buras, Nucl. Phys. **B412** (1994) 106.

[82] A. Buras, M. Gorbahn, U. Haisch and U. Nierste, Phys. Rev. Lett. **95** (2005) 261805 [arXiv:hep-ph/0508165]; J. Brod and M. Gorbahn, Phys. Rev. D **78** (2008) 034006 [arXiv:0805.4119 [hep-ph]]; G. Isidori, F. Mescia and C. Smith, Nucl. Phys. B **718** (2005) 319 [arXiv:hep-ph/0503107].

[83] A. Buras, J. Girrbach, D. Guadagnoli and G. Isidori, Eur. Phys. J. C **72** (2012) 2172 [arXiv:1208.0934 [hep-ph]].

[84] A. Crivellin, C. Greub and A. Kokulu, Phys. Rev. D **86** (2012) 054014 [arXiv:1206.2634 [hep-ph]]. U. Nierste, S. Trine and S. Westhoff, Phys. Rev. D **78** (2008) 015006 [arXiv:0801.4938 [hep-ph]].

[85] Konstantin Chetyrkin, Mikolaj Misiak, Manfred Munz, Phys.Lett. **B400** (1997) 206-219; Erratum-ibid. **B425** (1998) 414 [arXiv:hep-ph/9612313].

[86] A. Buras, S. Jager and J. Urban, Nucl. Phys. B **605** (2001) 600.

[87] A. Buras, M. Jamin and P. Weisz, *Nucl. Phys.* **B347** (1990) 491; J. Urban, F. Krauss, U. Jentschura and G. Soff, *Nucl. Phys.* **B523** (1998) 40.

[88] S. Herrlich and U. Nierste, *Nucl. Phys.* **B419** (1994) 292; S. Herrlich and U. Nierste, *Phys. Rev.* **D52** (1995) 6505; *Phys. Rev.* **D476** (1996) 27.

[89] J. Brod and M. Gorbahn, Phys. Rev. D **82**, 094026 (2010) [arXiv:1007.0684 [hep-ph]]; Phys. Rev. Lett. **108** (2012) 121801 [arXiv:1108.2036 [hep-ph]].

[90] S. Heinemeyer, W. Hollik amd G. Weiglein, Phys.Lett. **B455** (1999) 179-191 [hep-ph/9903404]

[91] Howard E. Haber, Ralf Hempfling and Andre H. Hoang, Z.Phys. **C75** (1997) 539-554 [hep-ph/9609331] ”

PROGRAM SUMMARY

Manuscript Title: SUSY_FLAVOR v2.5: a computational tool for FCNC and CP-violating processes in the MSSM
Authors: A. Crivellin, J. Rosiek, P. Chankowski, A. Dedes, S. Jäger, P. Tanedo
Program Title: SUSY_FLAVOR v2.5
Journal Reference:
Catalogue identifier:
Licensing provisions: None
Programming language: Fortran 77
Operating system: Any, tested on Linux
Keywords: Supersymmetry, K physics, B physics, rare decays, CP-violation
PACS: 12.60.Jv, 13.20.He
Classification: 11.6 Phenomenological and Empirical Models and Theories
Nature of problem:
Predicting CP-violating observables, meson mixing parameters and branching ratios for set of rare processes in the general R-parity conserving MSSM.
Solution method:
We use standard quantum theoretical methods to calculate Wilson coefficients in MSSM and at one loop including QCD corrections at higher orders when this is necessary and possible.
Restrictions:
The results apply only to the case of MSSM with R-parity conservation.
Unusual features:
Running time:
For single parameter set below 1s in `double precision` on a personal computer
References:

[1] J. Rosiek, P. Chankowski, A. Dedes, S. Jager and P. Tanedo, Comput. Phys. Commun. **181** (2010) 2180 [arXiv:1003.4260 [hep-ph]].

[2] M. Misiak, S. Pokorski and J. Rosiek, *"Supersymmetry and the FCNC effects"* Adv. Ser. Direct. High Energy Phys. **15** (1998) 795 [arXiv:hep-ph/9703442].

[3] S. Pokorski, J. Rosiek and C. A. Savoy, Nucl. Phys. B **570** (2000) 81 [arXiv:hep-ph/9906206].

[4] A. Buras, P. Chankowski, J. Rosiek and L. Slawianowska, Nucl. Phys. B **659** (2003) 3 [arXiv:hep-ph/0210145].

[5] A. Buras, T. Ewerth, S. Jager and J. Rosiek, Nucl. Phys. B **714** (2005) 103 [arXiv:hep-ph/0408142].

[6] A. Dedes, J. Rosiek and P. Tanedo, Phys. Rev. D **79** (2009) 055 [arXiv:0812.4320 [hep-ph]].

[7] A. Crivellin, L. Hofer and J. Rosiek, JHEP **1107** (2011) 017 [arXiv:1103.4272 [hep-ph]].

[8] A. Dedes, M. Paraskevas, J. Rosiek, K. Suxho, K. Tamvakis [arXiv:1409.6546 [hep-ph]].