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Flavour Les Houches Accord: Interfacing Flavour related Codes

F. Mahmoudi[1*], S. Heinemeyer[2†] , A. Arbey[3] , A. Bharucha[4],
T. Goto[4] , T. Hahn[5] , U. Haisch[6] , S. Kraml[7] , M. Muhlleitner[8],
, J. Reuter[9] , P. Skands[10] , P. Slavich[11]

[1]*Clermont Université, Université Blaise Pascal, CNRS/IN2P3, LPC, BP 10448, 63000 Clermont-Ferrand, France*

[2]*Instituto de Física de Cantabria (CSIC-UC), Santander, Spain*

[3]*Université de Lyon, France; Université Lyon 1, F-69622; CRAL, Observatoire de Lyon, F-69561 Saint-Genis-Laval; CNRS, UMR 5574; ENS de Lyon, France.*

Abstract

We present the Flavour Les Houches Accord (FLHA) which specifies a unique set of conventions for flavour related parameters and observables using the generic SUSY Les Houches Accord (SLHA) file structure. It defines the relevant SM masses, Wilson coefficients, form factors, decay tables, flavour observables, etc. The accord provides a universal and model independent interface between codes evaluating and/or using flavour related observables.

*email: mahmoudi@in2p3.fr
†email: Sven.Heinemeyer@cern.ch

1 Introduction

Advanced programs dedicated to the calculation of flavour related observables (Wilson coefficients, branching ratios, mixing amplitudes, renormalization group equation (RGE) running including flavour effects, etc.) have appeared [1,2], along with an increasing number of refined approaches in the literature. Flavour related observables are also implemented in many other non-dedicated public codes as additional checks for the models under investigation [3–8]. These quantities are subsequently often used by other codes, e.g. as constraints on the parameter space of the model under consideration [9–12].

At present, a small number of specialized interfaces exists between various codes. Such tailor-made interfaces are not easily generalized and are time-consuming to construct and test for each specific implementation. A universal interface would clearly be an advantage here. A similar problem appeared some time ago in the context of Supersymmetry (SUSY). The solution found is the SUSY Les Houches Accord (SLHA) [13, 14], which is nowadays frequently used to exchange information between SUSY related codes, such as soft SUSY-breaking parameters, particle masses and mixings, branching ratios etc. The SLHA is a robust solution, exchanging information between different codes via ASCII files for inputs and outputs. The detailed structure of these files is described in Refs. [13, 14].

The goal of this article is to exploit the existing organizational structure of the SLHA and use it to define an accord for the exchange of flavour related quantities, the "Flavour Les Houches Accord" (FLHA). Briefly stated, the purpose of this Accord is thus to present a set of generic definitions for an input/output file structure which provides a universal framework for interfacing flavour related calculation programs. Furthermore, such a standard format will allow the users to have a clear and well-structured result that can eventually be used for different purposes.

The structure is set up in such a way that the SLHA and the FLHA can be used together or independently. Obviously, some of the SLHA entries, such as the Standard Model (SM) measured values and CKM matrix elements are also needed for flavour observable calculations. Therefore, a FLHA file can indeed contain a SLHA block if necessary. For this reason and also for sake of clarity, the FLHA block names start with "`F`". Also, in order to avoid any confusion, the SLHA blocks are not modified and redefinition of SLHA blocks by means of FLHA is not allowed. If a block needs to be extended to include flavour requirements, a new "`F`" block is defined instead.

Note that different codes may have different implementations of how the FLHA input/output is *technically* achieved. The details of how to 'switch on' the FLHA input/output with a particular program should be described in the manual of that program and are not covered here. For the SLHA, libraries have been developed to permit an easy implementation of the input/output routines [15]. In principle these programs could be extended to include also the FLHA.

It should be noted that, while the SLHA was developed especially for the case of SUSY, the FLHA is, at least in principle, model independent. While it is possible to indicate the model used in a specific block, the general structure for the information exchange can be applied to any model.

2 Conventions

2.1 Standard Model Parameters

In general, the spectrum of the SM particles plays by definition a crucial role in flavour physics. Consequently, experimental measurements of masses and coupling constants at the electroweak scale enter. In the SLHA this block was defined as `SMINPUTS`. This block is borrowed from SLHA as it is.

It is also important to note that all presently available experimental determinations of, e.g., α_s and the running b mass are based on assuming the SM as the underlying theory, for natural reasons. When extending the field content of the SM to that of a New Physics Model (NPM), the *same* measured results would be obtained for *different* values of these quantities, due to the different underlying field content present in the NPM. However, since these values are not known, all parameters contained in the block `SMINPUTS` should be the 'ordinary' ones obtained from SM fits, i.e. with no NPM corrections included. Any flavour code itself is then assumed to convert these parameters into ones appropriate to an NPM framework.

2.2 CKM matrix

The CKM matrix structure is also taken from SLHA2 as it is, in blocks `VCKMIN` and `UPMNSIN`. The real and imaginary parts of the $\overline{\rm DR}$ CKM matrix can also be given in `VCKM` and `IMVCKM`, respectively. The format of the individual entries is the same as for the mixing matrices in the SLHA1. Analogous blocks are defined for the neutrino sector, called `UPMNS` and `IMUPMNS`.

2.3 Wilson coefficients

The real and imaginary parts of the Wilson coefficients are given in `FWCOEF` and `IMFWCOEF`, respectively. The Wilson coefficients are to be given in the standard operator basis (see Appendix C). The different orders $C_i^{(k)}$ have to be given separately according to the following convention for the perturbative expansion [16]:

$$\begin{aligned} C_i(\mu) &= C_i^{(0)}(\mu) + \frac{\alpha_s(\mu)}{4\pi} C_{i,s}^{(1)}(\mu) + \left(\frac{\alpha_s(\mu)}{4\pi}\right)^2 C_{i,s}^{(2)}(\mu) \\ &\quad + \frac{\alpha(\mu)}{4\pi} C_{i,e}^{(1)}(\mu) + \frac{\alpha(\mu)}{4\pi}\frac{\alpha_s(\mu)}{4\pi} C_{i,es}^{(2)}(\mu) + \cdots . \end{aligned} \tag{1}$$

The couplings should therefore not be included in the Wilson coefficients.

3 Definitions of the Interfaces

In this section, the Flavour Les Houches Accord input and output files are described. We concentrate here on the technical structure only.

Following the general structure for the SLHA [13, 14] we assume the following:

- All quantities with dimensions of energy (mass) are implicitly understood to be in GeV (GeV/c^2).
- Particles are identified by their PDG particle codes. See appendix A for lists of these, relevant for flavour observables.
- The first character of every line is reserved for control and comment statements. Data lines should have the first character empty.
- In general, a formatted output should be used for write-out, to avoid "messy-looking" files, while a free format should be used on read-in, to avoid misalignment etc. leading to program crashes.
- Read-in should be performed in a case-insensitive way, again to increase stability.
- The general format for all real numbers is the FORTRAN format E16.8[1]. This large number of digits is used to avoid any possible numerical precision issue, and since it is no more difficult for, e.g., the spectrum calculator to write out such a number than a shorter version. For typed input, it merely means that at least 16 spaces are reserved for the number, but, e.g., the number `123.456` may be typed in "as is". See also the example file in appendix E.
- A "`#`" mark anywhere means that the rest of the line is intended as a comment and to be ignored by the reading program.
- Any input and output is divided into sections in the form of "blocks".
- To clearly identify the blocks of the FLHA, the first letter of the name of a block is an "`F`". There are two exceptions to this rule: blocks borrowed from the SLHA, which keep their original name, and blocks containing imaginary parts, which start with "`IMF`".
- A "`BLOCK Fxxxx`" (with the "`B`" being the first character on the line) marks the beginning of entries belonging to the block named "`Fxxxx`". For instance, "`BLOCK FMASS`" marks that all following lines until the next "`BLOCK`" statement contain mass values, to be read in a specific format, intrinsic to the `FMASS` block. The order of the blocks is arbitrary, except that input blocks should always come before output blocks.

[1] E16.8: a 16-character wide real number in scientific notation, whereof 8 digits are decimals, e.g., "`-0.12345678E+000`".

- Further definitions can be found in Sect. 3 of Ref. [13].

The following general structure for the FLHA file is proposed:

- `BLOCK FCINFO`: Information about the flavour code used to prepare the FLHA file.
- `BLOCK FMODSEL`: Information about the underlying model used for the calculations. This is the only place for "model dependent" information.
- `BLOCK SMINPUTS`: Measured values of SM parameters used for the calculations.
- `BLOCK VCKMIN`: Input parameters of the CKM matrix for the calculations.
- `BLOCK UPMNSIN`: Input parameters of the PMNS neutrino mixing matrix for the calculations.
- `BLOCK VCKM`: Real part of the CKM matrix elements.
- `BLOCK IMVCKM`: Imaginary part of the CKM matrix elements.
- `BLOCK UPMNS`: Real part of the PMNS matrix elements.
- `BLOCK IMUPMNS`: Imaginary part of the PMNS matrix elements.
- `BLOCK FMASS`: Masses of quarks, mesons, hadrons, etc.
- `BLOCK FLIFE`: Lifetime (in seconds) of flavour related mesons, hadrons, etc.
- `BLOCK FCONST`: Decay constants.
- `BLOCK FCONSTRATIO`: Ratios of decay constants.
- `BLOCK FBAG`: Bag parameters.
- `BLOCK FWCOEF`: Real part of the Wilson coefficients.
- `BLOCK IMFWCOEF`: Imaginary part of the Wilson coefficients.
- `BLOCK FOBS`: Prediction of flavour observables.
- `BLOCK FOBSERR`: Theory error on the prediction of flavour observables.
- `BLOCK FOBSSM`: SM prediction for flavour observables.
- `BLOCK FFORM`: Form Factors.

More details on each block are given in the following.

BLOCK FCINFO

Flavour code information, including the name and the version of the program:

- `1` : Name of the flavour calculator
- `2` : Version number of the flavour calculator

Optional warning or error messages can also be specified:

- `3` : If this entry is present, warning(s) were produced by the flavour calculator. The resulting file may still be used. The entry should contain a description of the problem (string).
- `4` : If this entry is present, error(s) were produced by the flavour calculator. The resulting file should not be used. The entry should contain a description of the problem (string).

This block is purely informative, and is similar to `BLOCK SPINFO` in the SLHA.

BLOCK MODSEL

This block provides switches and options for the model selection. The SLHA2 `BLOCK MODSEL` is extended to allow for more flexibility [**?**] and here we follow exactly this newly extended format.

- `1` : Choice of SUSY breaking model or indication of other model. By default, a minimal type of model will always be assumed. Possible values are:
  - `-1` : SM
  - `0` : General MSSM Simulation
  - `1` : (m)SUGRA model
  - `2` : (m)GMSB model
  - `3` : (m)AMSB model
  - `4` : ...
  - `31` : THDM
  - `99` : other model. This choice requires a string given in the entry `99`
- `3` : (Default=0) Choice of particle content, only used for SUSY models. The defined switches are:
  - `0` : MSSM
  - `1` : NMSSM
  - `2` : ...
- `4` : (Default=`0`) R-parity violation. Switches defined are:
  - `0` : R-parity conserved. This corresponds to the SLHA1.
  - `1` : R-parity violated.

`5` : (Default=`0`) CP violation. Switches defined are:

- `0` : CP is conserved. No information even on the CKM phase is used.
- `1` : CP is violated, but only by the standard CKM phase. All other phases are assumed zero.
- `2` : CP is violated. Completely general CP phases allowed.

`6` : (Default=`0`) Flavour violation. Switches defined are:

- `0` : No flavour violation.
- `1` : Quark flavour is violated.
- `2` : Lepton flavour is violated.
- `3` : Lepton and quark flavour is violated.

`31` : defines the type of THDM, is used only if entry `1` is given as 31, otherwise it is ignored.

- `1` : type I
- `2` : type II
- `3` : type III
- `4` : type IV

`99` : a string that defines other models, is used only if entry `1` is given as 99, otherwise it is ignored.

BLOCK SMINPUTS

The block `BLOCK SMINPUTS` contains the measured SM parameters used for the flavour calculations. This block is strictly identical to the SLHA `BLOCK SMINPUTS` and is reproduced here for completeness. It should be noted that some programs have hard-coded defaults for various of these parameters, hence only a subset may sometimes be available as free inputs. The parameters are:

- `1` : $\alpha_{\rm em}^{-1}(m_Z)^{\overline{\rm MS}}$. Inverse electromagnetic coupling at the Z pole in the $\overline{\rm MS}$ scheme (with 5 active flavours).
- `2` : G_F. Fermi constant (in units of GeV^{-2}).
- `3` : $\alpha_s(m_Z)^{\overline{\rm MS}}$. Strong coupling at the Z pole in the $\overline{\rm MS}$ scheme (with 5 active flavours).
- `4` : m_Z, pole mass.
- `5` : $m_b(m_b)^{\overline{\rm MS}}$. b quark running mass in the $\overline{\rm MS}$ scheme.
- `6` : m_t, pole mass.
- `7` : m_τ, pole mass.

BLOCK VCKMIN

This block is strictly identical to the SLHA2 `BLOCK VCKMIN`. The parameters are:

`1` : λ.
`2` : A.
`3` : $\bar{\rho}$.
`4` : $\bar{\eta}$.

We use the PDG definition, Eq. (11.4) of Ref. [17], which is exact to all orders in λ.

BLOCK UPMNSIN

This block is strictly identical to the SLHA2 `BLOCK UPMNSIN`. The parameters are:

`1` : θ_{12}.
`2` : θ_{23}.
`3` : θ_{13}.
`4` : δ.
`5` : α_1.
`6` : α_2.

We use the PDG parametrization, Eq. (13.30) of Ref. [17]. All the angles and phases should be given in radians.

BLOCK FMASS

The block `BLOCK FMASS` contains the mass spectrum for the involved particles. It is an addition to the SLHA `BLOCK MASS` which contained only pole masses and to the SLHA `BLOCK SMINPUTS` which contains quark masses. If a mass is given in two blocks the block `FMASS` overrules the other blocks. In `FMASS` we specify additional information concerning the renormalization scheme as well as the scale at which the masses are given and thus allow for larger flexibility. The standard for each line in the block should correspond to the following FORTRAN format

`(1x,I9,3x,1P,E16.8,0P,3x,I2,3x,1P,E16.8,0P,3x,#',1x,A)`,

where the first nine digit integer should be the PDG code of a particle, followed by a double precision number for its mass. The next integer corresponds to the renormalization scheme, and finally the last double precision number points to the energy scale (0 if not relevant).

The schemes are defined as follows:

`0` : pole
`1` : $\overline{\rm MS}$
`2` : $\overline{\rm DR}$
`3` : 1S
`4` : kin

5 : ...

BLOCK FLIFE

The block BLOCK FLIFE contains the lifetimes of mesons and hadrons in seconds. The standard for each line in the block should correspond to the FORTRAN format

(1x,I9,3x,1P,E16.8,0P,3x,'#',1x,A),

where the first 9–digit integer should be the PDG code of a particle and the double precision number its lifetime.

BLOCK FCONST

The block BLOCK FCONST contains the decay constants in GeV. The standard for each line in the block should correspond to the FORTRAN format

(1x,I9,3x,I2,3x,1P,E16.8,0P,3x,'#',1x,A),

where the first nine digit integer should be the PDG code of a particle, the second integer the number of the decay constant, and the double precision number its decay constant.

The decay constants for the most commonly used mesons with several decay constants are defined as:

321 : K^+.
- 1 : f_K in GeV.
- 11 : h_K in GeV^3.

221 : η.
- 1 : f_η^q in GeV.
- 2 : f_η^s in GeV.
- 11 : h_η^q in GeV^3.
- 12 : h_η^s in GeV^3.

213 : $\rho(770)^+$.
- 1 : f_ρ in GeV.
- 11 : f_ρ^T in GeV.

223 : $\omega(782)$.
- 1 : f_ρ^q in GeV.
- 2 : f_ρ^s in GeV.
- 11 : $f_\rho^{T,q}$ in GeV.
- 12 : $f_\rho^{T,s}$ in GeV.

More details and definitions can be found in appendix D.

BLOCK FCONSTRATIO

The block `BLOCK FCONSTRATIO` contains the ratio of decay constants, which often have less uncertainties. The ratios are specified by the two PDG codes in the form f(code1)/f(code2). The standard for each line in the block should correspond to the FORTRAN format

```
(1x,I9,3x,I9,3x,I2,3x,1P,E16.8,0P,3x,'#',1x,A),
```

where the two nine digit integers should be the two PDG codes of particles, the third integer the number of the decay constant, which corresponds to the second index of the entry in `BLOCK FCONST`, and the double precision number the ratio of the decay constants.

BLOCK FBAG

The block `BLOCK FBAG` contains the Bag parameters. The standard for each line in the block should correspond to the FORTRAN format

```
(1x,I9,3x,I2,3x,1P,E16.8,0P,3x,'#',1x,A),
```

where the first nine digit integer should be the PDG code of a particle, the second integer the number of the Bag parameter, and the double precision number its Bag parameter.

So far no normalization etc. has been defined, which at this stage has to be taken care of by the user. An unambiguous definition will be given elsewhere.

BLOCK FWCOEF Q= ...

The block `BLOCK FWCOEF Q= ...` contains the real part of the Wilson coefficients at the scale `Q`, respecting the conventions given in section 2.3.

The entries in `BLOCK FWCOEF` should consist of two integers defining the fermion structure of the operator and the operator structure itself. These two numbers correspond to a unique identifier for any possible Wilson coefficient. The most relevant examples are listed in appendix C. As an example, for the operator O_1,

$$O_1 = (\bar{s}\gamma_\mu T^a P_L c)(\bar{c}\gamma^\mu T_a P_L b) \tag{2}$$

the definition of the two numbers is given as follows. The appearing fermions are encoded by a two-digit number originating from their PDG code, where no difference is made between particles and antiparticles, as given in Table 1.

Correspondingly, the first integer number defining O_1, containing the fermions $\bar{s}c\bar{c}b$ is given by 03040405.
The various operators are defined in Table 2.

Here T^a $(a = 1 \dots 8)$ denote the $SU(3)_C$ generators, and $P_{L,R} = \frac{1}{2}(1 \mp \gamma_5)$. Correspondingly, the second integer number defining O_1, containing the operators $\gamma_\mu T^a P_L \, \gamma^\mu T_a P_L$ is given by 4141.

name	PDG code	two-digit number	name	PDG code	two-digit number
d	1	01	e	11	11
u	2	02	ν_e	12	12
s	3	03	μ	13	13
c	4	04	ν_μ	14	14
b	5	05	τ	15	15
t	6	06	ν_τ	16	16
$\sum_q$		07	$\sum_l$		17

Table 1: PDG codes and two-digit number identifications of quarks and leptons.

operator	two-digit number	operator	two-digit number
P_L	01	$P_L T_a$	11
P_R	02	$P_R T_a$	12
γ^μ	03	$\gamma^\mu T_a$	13
$\sigma^{\mu\nu}$	04	$\sigma^{\mu\nu} T_a$	14
$\gamma^\mu\gamma^\nu\gamma^\rho$	05	$\gamma^\mu\gamma^\nu\gamma^\rho T_a$	15
$\gamma^\mu P_L$	31	$\gamma^\mu T_a P_L$	41
$\gamma^\mu P_R$	32	$\gamma^\mu T_a R_R$	42
$\sigma^{\mu\nu} P_L$	33	$\sigma^{\mu\nu} T_a P_L$	43
$\sigma^{\mu\nu} P_R$	34	$\sigma^{\mu\nu} T_a P_R$	44
$\gamma^\mu\gamma^\nu\gamma^\rho P_L$	35	$\gamma^\mu\gamma^\nu\gamma^\rho T_a P_L$	45
$\gamma^\mu\gamma^\nu\gamma^\rho P_R$	36	$\gamma^\mu\gamma^\nu\gamma^\rho T_a P_R$	46
$F_{\mu\nu}$	22	$G^a_{\mu\nu}$	21

Table 2: Two-digit number definitions for the operators.

The third index corresponds to each term in (1):

`0` : $C_i^{(0)}(\mu)$
`1` : $C_{i,s}^{(1)}(\mu)$
`2` : $C_{i,s}^{(2)}(\mu)$
`10` : $C_{i,e}^{(1)}(\mu)$
`11` : $C_{i,es}^{(2)}(\mu)$
`99` : total

The information about the order is given by a two-digit number xy, where x indicates $\mathcal{O}(\alpha^x)$ and y indicates $\mathcal{O}(\alpha_s^y)$, and 0 indicates $C_i^{(0)}$.

The Wilson coefficients can be provided either separately for the new physics contributions and SM contributions, or as a total contribution of both new physics and SM, depending on the code generating them. To avoid any confusion, the fourth entry must

specify whether the given Wilson coefficients correspond to the SM contributions, new physics contributions or to the sum of them, using the following definitions:

`0` : SM

`1` : NPM

`2` : SM+NPM

The new Physics model is the model specified in the `BLOCK FMODSEL`.
The standard for each line in the block should thus correspond to the FORTRAN format

`(1x,I8,1x,I4,3x,I2,3x,I1,3x,1P,E16.8,0P,3x,'#',1x,A)`,

where the eight digit integer specifies the fermion content, the four digit integer the operator structure, the two digit integer the order at which the Wilson coefficients are calculated followed by the one digit integer specifying the model, and finally the double precision number gives the real part of the Wilson coefficient.

Note that there can be several such blocks for different scales `Q`.

BLOCK IMFWCOEF Q= ...

The block `BLOCK IMFWCOEF` contains the imaginary part of the Wilson coefficients at the scale `Q`. The structure is exactly the same as for the `BLOCK FWCOEF`.

BLOCK FOBS

The block `BLOCK FOBS` contains the flavour observables. The structure of this block is based on the decay table in SLHA format. The decay is defined by the PDG number of the parent, the type of the observable, the value of the observable, the number of daughters and PDG IDs of the daughters.
The types of the observables are defined as follows:

`1` : Branching ratio

`2` : Ratio of the branching ratio to the SM value

`3` : Asymmetry – CP

`4` : Asymmetry – isospin

`5` : Asymmetry – forward-backward

`6` : Asymmetry – lepton-flavour

`7` : Mixing

`8` : ...

The standard for each line in the block should correspond to the FORTRAN format

`(1x,I9,3x,I2,3x,1P,E16.8,0P,3x,I1,3x,I9,3x,I9,3x,...,3x,'#',1x,A)`,

where the first nine digit integer should be the PDG code of the parent decaying particle, the second integer the type of the observable, the double precision number the value of the observable, the next interger the number of daughters, and the following nine digit integers the PDG codes of the daughters. It is strongly advised to give the descriptive name of the observable as comment.

BLOCK FOBSERR

The block BLOCK FOBSERR contains the theoretical error for flavour observables, with the structure similar to BLOCK FOBS where the double precision number for the value of the observable is replaced by two double precision numbers for the minus and plus uncertainties (which is particularly helpful for asymmetric errors).

In a similar way, for every block, a corresponding error block with the name BLOCK FnameERR can be defined.

BLOCK FOBSSM

The block BLOCK FOBSSM contains the SM values of the flavour observables in the same format as in BLOCK FOBS. The given SM values may be very helpful as a comparison reference.

BLOCK FFORM

The block BLOCK FFORM contains the form factors related to decays are given by defining the decay as in BLOCK FOBS, but replacing the type of the observable by the number of the form factor. It is essential here to describe the variable in the comment area. The dependence on q^2 can be specified as a comment. A more unambigous definition will be given elsewhere.

4 Conclusion

The interplay of collider and flavour physics is entering a new era with the start up of the LHC and in the future more and more programs will be interfaced in order to exploit a maximum amount of information from both collider and flavour data. In this direction, an accord will play a crucial role. The present accord specifies a unique set of conventions in ASCII file format for most commonly investigated flavour related observables and provides a universal framework for interfacing different programs.

The number of flavour related codes is growing constantly, while the connection between results from flavour physics and high p_T physics becomes more relevant to disentangle the underlying physics model. Using the lessons learnt from the SLHA, we hope the FLHA will prove useful for flavour physics related studies.

Acknowledgements

The work of S.H. was partially supported by CICYT (grant FPA 2007–66387). Work supported in part by the European Community's Marie-Curie Research Training Network under contract MRTN-CT-2006-035505 'Tools and Precision Calculations for Physics Discoveries at Colliders'. The work of T.G. is supported in part by the Grant-in-Aid for Science Research, Japan Society for the Promotion of Science, No. 20244037.

A The PDG Particle Numbering Scheme

Listed in the tables below are the PDG codes for the SM baryons and mesons. Codes for other particles may be found in [17].

Name	PDG code	Name	PDG code
π^0	111	D^+	411
π^+	211	D^0	421
$\rho(770)^0$	113	D_s^+	431
$\rho(770)^+$	213	D_s^{*+}	433
η	221	B^0	511
$\eta'(958)$	331	B^+	521
$\omega(782)$	223	B^{*0}	513
$\phi(1020)$	333	B^{*+}	523
K_L^0	130	B_s^0	531
K_S^0	310	B_s^{*0}	533
K^0	311	B_c^+	541
K^+	321	B_c^{*+}	543
$K^{*0}(892)$	313	$J/\psi(1S)$	443
$K^{*+}(892)$	323	$\Upsilon(1S)$	553
$\eta_c(1S)$	441	$\eta_b(1S)$	551

Table 3: PDG codes for most commonly considered mesons.

B Two-Higgs Doublet Model

The conventions used for the different Two-Higgs Doublet Model (2HDM) types, corresponding to different charged Higgs Yukawa couplings are given in Table 4.

Type	λ^U	λ^D	λ^L
I	$-\tan\beta$	$-\tan\beta$	$-\tan\beta$
II	$\cot\beta$	$-\tan\beta$	$-\tan\beta$
III	$-\tan\beta$	$-\tan\beta$	$\cot\beta$
IV	$\cot\beta$	$-\tan\beta$	$\cot\beta$

Table 4: Charged Higgs Yukawa coupling coefficients λ^f in the Z_2-symmetric types of the 2HDM. The superscripts U, D and L stand, respectively, for the up-type quarks, the down-type quarks and the leptons.

The notation and meaning of the different types vary in the literature. Sometimes type Y (III) and type X (IV) are used. In supersymmetry, type III usually refers to the general model encountered when the Z_2 symmetry of the tree-level type II model is broken by higher order corrections.

C Effective Operators

Here we give a list of the most relevant effective operators together with their unique two number identifier.

$$
\begin{aligned}
O_1 &= (\bar{s}\gamma_\mu T^a P_L c)(\bar{c}\gamma^\mu T_a P_L b) && : 03040405\ 4141,\\
O_2 &= (\bar{s}\gamma_\mu P_L c)(\bar{c}\gamma^\mu P_L b) && : 03040405\ 3131,\\
O_3 &= (\bar{s}\gamma_\mu P_L b)\sum_q(\bar{q}\gamma^\mu q) && : 03050707\ 3103,\\
O_4 &= (\bar{s}\gamma_\mu T^a P_L b)\sum_q(\bar{q}\gamma^\mu T_a q) && : 03050707\ 4113,\\
O_5 &= (\bar{s}\gamma_{\mu_1}\gamma_{\mu_2}\gamma_{\mu_3} P_L b)\sum_q(\bar{q}\gamma^{\mu_1}\gamma^{\mu_2}\gamma^{\mu_3} q) && : 03050707\ 3505, \qquad (3)\\
O_6 &= (\bar{s}\gamma_{\mu_1}\gamma_{\mu_2}\gamma_{\mu_3} T^a P_L b)\sum_q(\bar{q}\gamma^{\mu_1}\gamma^{\mu_2}\gamma^{\mu_3} T_a q) && : 03050707\ 4515,\\
O_7 &= (O_\gamma) = \frac{e}{16\pi^2}\,[\bar{s}\sigma^{\mu\nu}(m_b P_R)b]\,F_{\mu\nu} && : 03050000\ 3422,\\
O_8 &= (O_g) = \frac{g}{16\pi^2}\,[\bar{s}\sigma^{\mu\nu}(m_b P_R)T_a b]\,G^a_{\mu\nu} && : 03050000\ 4421.
\end{aligned}
$$

(Goto): Let me first decompose the effective Lagrangian as follows (btw, we have to decide which should be used: Lagrangian or Hamiltonian).

$$\mathcal{L}_{\text{eff}} = A\sum_{ijkl,xy} V_{ijkl}C_{ijkl,xy}P_{ijkl,xy}O_{ijkl,xy}. \qquad (4)$$

- i,j,k,l are two-digit numbers listed in Table 1 and x,y are those in Table 2.
- $O_{ijkl,xy}$ is the operator which is constructed from the elements in Tables 1 and 2 only: $O_{03050000,3422} = (\bar{s}\sigma^{\mu\nu}P_R b)F_{\mu\nu}$, for example.
- $P_{ijkl,xy}$ is an operator dependent prefactor like $em_b/(4\pi)^2$.
- V_{ijkl} is the CKM matrix factor which should be independent of the Dirac/color structure of the operator.

- A is an overall factor such as $4G_F/\sqrt{2}$, which should be common to all the Wilson coefficients in a single input/output file.
- $C_{ijkl,xy}$ is the Wilson coefficient whose value is given in the block (IM)FWCOEF.

I suggest to make additional blocks for $P_{ijkl,xy}$, V_{ijkl} and A for flexibility. Coefficients in several references can be encoded in the following way.

- Ref. [19] ($b \to s\gamma$): $A = -4G_F/\sqrt{2}$.

$ijkl$	xy	V	P	C
03040405	4141	$-V_{ts}^*V_{tb}$	1	C_1
	1111		1	C_2
03050707	3103	$-V_{ts}^*V_{tb}$	1	C_3
	4113		1	C_4
	3505		1	C_5
	4515		1	C_6
03050000	3422	$-V_{ts}^*V_{tb}$	$\frac{em_b}{16\pi^2}$	C_7
	4421		$\frac{g_s m_b}{16\pi^2}$	C_8

- Ref. [20] ($b \to sl^+l^-$): $A = 4G_F/\sqrt{2}$.

$ijkl$	xy	V	P	C
03020205	4141	$V_{us}^*V_{ub}$	1	C_1^c
	1111		1	C_2^c
03040405	4141	$V_{cs}^*V_{cb}$	1	C_1^c
	1111		1	C_2^c
03050707	3103	$V_{ts}^*V_{tb}$	1	$C_3^t - C_3^c$
	4113		1	$C_4^t - C_4^c$
	3505		1	$C_5^t - C_5^c$
	4515		1	$C_6^t - C_6^c$
03050000	3422	$V_{ts}^*V_{tb}$	$\frac{em_b}{g_s^2}$	$C_7^t - C_7^c$
	4421		$\frac{m_b}{g_s}$	$C_8^t - C_8^c$
03051717	3103	$V_{ts}^*V_{tb}$	$\frac{e^2}{g_s^2}$	$C_9^t - C_9^c$
	31??		$\frac{e^2}{g_s^2}$	$C_{10}^t - C_{10}^c$

The "??" in the last entry should be the index number for $\gamma^\mu\gamma_5$, which is not defined in Table 2.

- Ref. [21] ($\mu \to eee$): $A = -4G_F/\sqrt{2}$.

$ijkl$	xy	V	P	C
13111111	0101	1	1	g_1
	0202		1	g_2
	3232		1	g_3
	3131		1	g_4
	3231		1	g_5
	3132		1	g_6
13110000	3322	1	m_μ	A_R
	3422		m_μ	A_L

- Ref. [22] ($K - \bar{K}$ mixing): $A = -1$.

$ijkl$	xy	V	P	C
01030103	3131	1	1	C_1
	3232		1	$\bar{C}_1$
	0101		1	$C_2 + \frac{1}{3}C_3$
	1111		1	$2C_3$
	0202		1	$\bar{C}_2 + \frac{1}{3}\bar{C}_3$
	1212		1	$2\bar{C}_3$
	0102		1	$C_4 + \frac{1}{3}C_5$
	1112		1	$2C_5$

Here, I have used the identity $(\bar{d}^\alpha P_L s_\beta)(\bar{d}^\beta P_L s_\alpha) = 2(\bar{d} P_L T^a s)(\bar{d} P_L T^a s) + \frac{1}{3}(\bar{d}^\alpha P_L s_\alpha)(\bar{d}^\beta P_L s_\beta)$, although I do not know if this conversion is valid for the higher order terms. If the color contraction like $(\bar{d}^\alpha P_L s_\beta)(\bar{d}^\beta P_L s_\alpha)$ is allowed as Uli suggested, the encoding will be more straightforward.

D Decay constants

The decay constant f_P of a pseudoscalar meson P can be defined as:

$$\langle 0|\bar{q}\gamma^\mu\gamma_5 Q|P(p)\rangle = -if_P p^\mu, \tag{5}$$

for $q \neq Q$ quark contents ($P = \pi^\pm$, K, D, B), therefore f_π is about 130MeV and not 92MeV. The minus sign comes from the difference of the conventions for γ_5 used here and the textbook Ref. [18], where "left" is written as "$1 + \gamma_5$". For π^0, η and η', we define:

$$\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma^\mu\gamma_5 u - \bar{d}\gamma^\mu\gamma_5 d|\pi^0(p)\rangle = -if_\pi p^\mu, \tag{6}$$

$$\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma^\mu\gamma_5 u + \bar{d}\gamma^\mu\gamma_5 d|\eta^{(\prime)}(p)\rangle = -if^q_{\eta^{(\prime)}} p^\mu, \tag{7}$$

$$\langle 0|\bar{s}\gamma^\mu\gamma_5 s|\eta^{(\prime)}(p)\rangle = -if^s_{\eta^{(\prime)}} p^\mu, \tag{8}$$

assuming isospin symmetry. Other possible choice for η and η' may be:

$$\frac{1}{\sqrt{6}}\langle 0|\bar{u}\gamma^\mu\gamma_5 u + \bar{d}\gamma^\mu\gamma_5 d - 2\bar{s}\gamma^\mu\gamma_5 s|\eta^{(\prime)}(p)\rangle = -if^8_{\eta^{(\prime)}}p^\mu, \tag{9}$$

$$\frac{1}{\sqrt{3}}\langle 0|\bar{u}\gamma^\mu\gamma_5 u + \bar{d}\gamma^\mu\gamma_5 d + \bar{s}\gamma^\mu\gamma_5 s|\eta^{(\prime)}(p)\rangle = -if^1_{\eta^{(\prime)}}p^\mu, \tag{10}$$

Also, the following matrix elements are defined:

$$(m_q + m_Q)\langle 0|\bar{q}\gamma_5 Q|P(p)\rangle = ih_P, \tag{11}$$

$$(m_u + m_d)\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma_5 u - \bar{d}\gamma_5 d|\pi^0(p)\rangle = ih_\pi, \tag{12}$$

$$(m_u + m_d)\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma_5 u + \bar{d}\gamma_5 d|\eta^{(\prime)}(p)\rangle = ih^q_{\eta^{(\prime)}}, \tag{13}$$

$$2m_s\langle 0|\bar{s}\gamma_5 s|\eta^{(\prime)}(p)\rangle = ih^s_{\eta^{(\prime)}}. \tag{14}$$

h's may be unnecessary except for η and η' since they can be written in terms of other quantities as $h_\pi = m_\pi^2 f_\pi$ etc. $h^{q,s}_{\eta^{(\prime)}}$ do not satisfy relations of this kind due to the contributions of anomaly terms.

Decay constants of a vector meson V, whose quark content is $\bar{q}Q$ (such as $\rho^\pm$ and K^*), are defined by the following matrix elements.

$$\langle 0|\bar{q}\gamma^\mu Q|V(p)\rangle = m_V f_V \epsilon^\mu, \tag{15}$$

$$\langle 0|\bar{q}\sigma^{\mu\nu} Q|V(p)\rangle = if^T_V(p^\nu\epsilon^\mu - p^\mu\epsilon^\nu), \tag{16}$$

where ϵ^μ is the polarization vector of V. $f_{\rho,\omega,\phi}$ in the "ideal mixing" limit are defined as:

$$\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma^\mu u - \bar{d}\gamma^\mu d|\rho^0(p)\rangle = m_\rho f_\rho \epsilon^\mu, \tag{17}$$

$$\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma^\mu u + \bar{d}\gamma^\mu d|\omega(p)\rangle = m_\omega f_\omega \epsilon^\mu, \tag{18}$$

$$\langle 0|\bar{s}\gamma^\mu s|\phi(p)\rangle = m_\phi f_\phi \epsilon^\mu. \tag{19}$$

$f^T_{\rho,\omega,\phi}$ are also defined with the same flavor combinations. It is possible to define decay constants of ω and ϕ as

$$\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma^\mu u + \bar{d}\gamma^\mu d|\omega(\phi)(p)\rangle = m_{\omega(\phi)} f^q_{\omega(\phi)}\epsilon^\mu, \tag{20}$$

$$\langle 0|\bar{s}\gamma^\mu s|\omega(\phi)(p)\rangle = m_{\omega(\phi)} f^s_{\omega(\phi)}\epsilon^\mu, \tag{21}$$

or

$$\frac{1}{\sqrt{6}}\langle 0|\bar{u}\gamma^\mu u + \bar{d}\gamma^\mu d - 2\bar{s}\gamma^\mu s|\omega(\phi)(p)\rangle = m_{\omega(\phi)} f^8_{\omega(\phi)}\epsilon^\mu, \tag{22}$$

$$\frac{1}{\sqrt{3}}\langle 0|\bar{u}\gamma^\mu u + \bar{d}\gamma^\mu d + \bar{s}\gamma^\mu s|\omega(\phi)(p)\rangle = m_{\omega(\phi)} f^1_{\omega(\phi)}\epsilon^\mu. \tag{23}$$

E Example

NM, SH: not updated yet
An example of a FLHA file is provided below.

```
Block FCINFO  # Program information
         1   SUPERISO   # flavor calculator
         2   2.8_beta   # version number
Block FMODSEL # Model selection
         2    1    0   # Supersymmetry general MSSM
Block SMINPUTS  # Standard Model inputs
         1   1.27839951e+02   # alpha_em^(-1)
         2   1.16570000e-05   # G_Fermi
         3   1.17200002e-01   # alpha_s(M_Z)
         4   9.11699982e+01   # m_Z(pole)
         5   4.19999981e+00   # m_b(m_b)
         6   1.72399994e+02   # m_top(pole)
         7   1.77699995e+00   # m_tau(pole)
        24   1.27000000e+00   # m_c(m_c)
Block FMASS  # Mass spectrum in GeV
#PDG code    mass           scheme  scale   particle
         3   1.05000000e-01    1   2.00000000e+00   # s
         5   4.68000000e+00    3   0                # b
       211   1.39600000e-01    0   0                # pi+
       313   8.91700000e-01    0   0                # K*
       321   4.93700000e-01    0   0                # K+
       421   1.86484000e+00    0   0                # D0
       431   1.96849000e+00    0   0                # D_s+
       521   5.27950000e+00    0   0                # B+
       531   5.36630000e+00    0   0                # B_s
Block FLIFE  # Lifetime in sec
#PDG code    lifetime         particle
       211   2.60330000e-08   # pi+
       321   1.23800000e-08   # K+
       431   5.00000000e-13   # D_s+
       521   1.63800000e-12   # B+
       531   1.42500000e-12   # B_s
Block FCONST  # Decay constant in GeV
#PDG code  number decay constant   particle
       431    1   2.41000000e-01   # D_s+
       521    1   2.00000000e-01   # B+
       531    1   2.45000000e-01   # B_s
Block FCONSTRATIO  # Ratio of decay constant
#PDG code1       code2   ratio            comment
       321         211   1.18900000e+00   # f_K/f_pi
Block FBAG  # Bag parameters
#PDG code  number B-parameter      particle
       511    1   1.26709794e+00   # B_d
       531    1   1.23000000e+00   # B_s
Block FFORM  # Form Factors in GeV
# ParentPDG number value           NDA       ID1         ID2          ID3 ...   comment
       521    1   4.60000000e-01   3         421         -15          16   # Delta(w) in B+->D0 tau nu
```

```
       521    2   1.02600000e+00   3         421         -15          16   # G(1) in B+->D0 tau nu
       521    3   1.17000000e+00   3         421         -15          16   # rho^2 in B+->D0 tau nu
       521    1   3.10000000e-01   2         313          22   # T1(B->K*)
Block FSHAPE  # Shape factors
# ParentPDG number value           NDA         ID1        ID2 ID3 ...   comment
         5    1   5.80000000e-01   2           3          22   # C (b->s gamma)
Block FWCOEF Q= 1.60846e+02  M= 2
#Effective Wilson coefficients in the standard basis
# type sub  nb  order  real part
  1    1    2   0   1.00000000e+00
  1    1    7   0  -1.82057567e-01
  1    1    8   0  -1.06651571e-01
  1    1    1   1   2.33177662e+01
  1    1    4   1   5.29677461e-01
  1    1    7   1   1.35373179e-01
  1    1    8   1  -6.94496405e-01
  1    1    1   2   3.08498153e+02
  1    1    2   2   4.91587899e+01
  1    1    3   2  -7.01872509e+00
  1    1    4   2   1.25624440e+01
  1    1    5   2   8.76122785e-01
  1    1    6   2   1.64273022e+00
  1    1    7   2   7.05439463e-01
  1    1    8   2  -4.65529650e+00
Block FWCOEF Q= 2.34384e+00 M= 2
#Effective Wilson coefficients in the standard basis
# type sub  nb  order  real part
  1    1    1   0  -8.47809531e-01
  1    1    2   0   1.06562816e+00
  1    1    3   0  -1.34214747e-02
  1    1    4   0  -1.29110603e-01
  1    1    5   0   1.36343067e-03
  1    1    6   0   2.88022278e-03
  1    1    7   0  -3.73787589e-01
  1    1    8   0  -1.80398551e-01
  1    1    1   1   1.52422776e+01
  1    1    2   1  -2.13433897e+00
  1    1    3   1   9.52880033e-02
  1    1    4   1  -4.81776851e-01
  1    1    5   1  -2.10727176e-02
  1    1    6   1  -1.22929476e-02
  1    1    7   1   2.14544819e+00
  1    1    8   1  -5.16870265e-01
  1    1    7   2   1.98785400e+01
Block FOBS  # Flavor observables
# ParentPDG type value      NDA         ID1        ID2  ID3 ...   comment
         5    1   2.97350499e-04   2           3           22   # BR(b->s gamma)
       521    4   8.25882011e-02   2         313           22   # Delta0(B->K* gamma)
       531    1   3.46978963e-09   2          13          -13   # BR(B_s->mu+ mu-)
       521    1   1.09699841e-04   2         -15           16   # BR(B_u->tau nu)
       521    2   9.96640362e-01   2         -15           16   # R(B_u->tau nu)
       431    1   4.81251996e-02   2         -15           16   # BR(D_s->tau nu)
       431    1   4.96947301e-03   2         -13           14   # BR(D_s->mu nu)
```

```
       521    1   6.96556180e-03   3         421         -15   16 # BR(B+->D0 tau nu)
       521   11   2.97261612e-01   3         421         -15   16 # BR(B+->D0 tau nu)/BR(B+-> D0 e nu)
       321   11   6.45414388e-01   2         -13          14   # BR(K->mu nu)/BR(pi->mu nu)
       321   12   9.99985822e-01   2         -13          14   # R_l23
Block FOBSERR  # Theoretical error for flavor observables at 68% C.L.
# ParentPDG type -ERR              +ERR                      NDA         ID1        ID2 ID3 ... comment
         5    1   0.30000000e-04   0.30000000e-04            2           3          22 # BR(b->s gamma)
Block FOBSSM  # SM prediction for flavor observables
# ParentPDG type value      NDA         ID1        ID2  ID3 ...   comment
         5    1   2.97350499e-04   2           3          22   # BR(b->s gamma)
```

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