Here we put the preprint numbers

Flavour Les Houches Accord: Interfacing Flavour related Codes

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.

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`.

NM: To be expanded?

2.3 Wilson coefficients

The Wilson coefficients are classified according to the transition type ΔF. The real and imaginary parts 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 [22]:

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

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

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

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.
  SH: no change according to our discussion? Continue at CERN!
- `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.
- `BLOCK FSHAPE`: Shape 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 F??MODSEL

SH: following Peter's suggestion

This block provides switches and options for the model selection. The entries in this block should consist of an index, possibly followed by a string, possibly followed by another index. The first index defines a minimal type of model, while the string can give more precise definitions (for non-SUSY models). The second index can define a special particle content of the model.

- `1` :
  - `-99` : Non-SUSY Model (`MODSEL` entry 2 must be present)
  - `-1` : SM
  - `0` : General MSSM
  - `1` : (m)SUGRA model
  - `2` : (m)GMSB model
  - `3` : (m)AMSB model
  - `4` : ...

An extended and updated list will be available at the FLHA web page.

- `2` : String specifying model name. Mandatory when `MODSEL`(1) = -99, ignored otherwise (but can of course still be used for information purposes for other `MODSEL`(1) values). The FLHA web site will provide a list of which ones have so far been oficially defined.

3 : (Default=0) Choice of particle content (ignored when MODSEL(1) = -99)

0 : MSSM (this corresponds to SLHA1).

1 : NMSSM (this corresponds to SLHA2).

PS: The latter point has to be agreed upon with the SLHA2 authors.

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. [21], 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. [21]. 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 extension of the SLHA `BLOCK MASS` which contained only pole masses. Here we specify additional information concerning the renormalization scheme as well as the scale at which the masses are given. 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 : ...

SH: Do we really need this block? Pole masses should go into BLOCK MASS, quark masses should be define in a unique way in SMINPUTS. What about 1S masses?

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 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.

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.

NM: We should provide the list of the main B parameters (similarly to the decay constants) and propose an implementation in the block.

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 and appendix C.

The entries in `BLOCK FWCOEF` should consist of, first the transition type (see Appendix C) followed by the transition sub-type number in the second place:

- `1` : $\Delta F = 1$
  - `1` : $b \leftrightarrow s$
  - `2` : $b \leftrightarrow d$
  - `3` : $s \leftrightarrow d$
  - `4` : $c \leftrightarrow u$
  - `5` : ...
- `2` : $\Delta F = 2$
  - `1` : $bb \leftrightarrow ss$
  - `2` : $bb \leftrightarrow dd$
  - `3` : $ss \leftrightarrow dd$
  - `4` : $cc \leftrightarrow uu$
  - `5` : $db \leftrightarrow cu$
  - `6` : ...
- `3` : leptonic
  - `1` : $\mu \leftrightarrow e$
  - `2` : $\tau \leftrightarrow \mu$
  - `3` : $\tau \leftrightarrow e$
  - `4` : ...

The next entries consist of the number of the Wilson coefficient followed by the order at which they are computed. For the Wilson coefficient numbers, the following convention is adopted:

- Wilson coefficients are given positive numbers when they correspond to the normal operators described in appendix C,
- Wilson coefficients are given negative numbers for the inverted chirality operators (C' or $\tilde{C}$ coefficients).

The fourth 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 (or `-1` can be used).

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

where the double precision number is 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. If the form factors depend on additional parameters (e.g. q^2 in $B \to K^* \mu^+ \mu^-$ process) this dependence is not described by the accord, but can be specified as a comment.

`BLOCK FSHAPE`

The block `BLOCK FSHAPE` contains the shape factors related to decays are given in a format identical to `BLOCK FFORM`. Again it is essential to describe the variable in the comment area.

NM: Do we want to define a "miscellaneous" block containing form factors, shape factors, etc, instead of defining separate blocks for each?

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...

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A The PDG Particle Numbering Scheme

Listed in the tables below are the PDG codes for the SM quarks and mesons. Codes for other particles may be found in [21].

Name	Code
d	1
u	2
s	3
c	4
b	5
t	6

Table 1: PDG codes for SM quarks.

Name	Code	Name	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 2: 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 3.

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 3: 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

C.1 $\Delta F = 1$

The relevant Wilson coefficients for $b \leftrightarrow s$ decays are given in the standard operator basis [16]. For the cases of other quark transitions one should make obvious replacements of the quark fields.

$$
\begin{aligned}
O_1 &= (\bar{s}\gamma_\mu T^a P_L c)(\bar{c}\gamma^\mu T_a P_L b)\ , \\
O_2 &= (\bar{s}\gamma_\mu P_L c)(\bar{c}\gamma^\mu P_L b)\ , \\
O_3 &= (\bar{s}\gamma_\mu P_L b)\sum_q (\bar{q}\gamma^\mu q)\ , \\
O_4 &= (\bar{s}\gamma_\mu T^a P_L b)\sum_q (\bar{q}\gamma^\mu T_a q)\ , \\
O_5 &= (\bar{s}\gamma_{\mu_1}\gamma_{\mu_2}\gamma_{\mu_3} P_L b)\sum_q (\bar{q}\gamma^{\mu_1}\gamma^{\mu_2}\gamma^{\mu_3} q)\ , \\
O_6 &= (\bar{s}\gamma_{\mu_1}\gamma_{\mu_2}\gamma_{\mu_3} T^a P_L b)\sum_q (\bar{q}\gamma^{\mu_1}\gamma^{\mu_2}\gamma^{\mu_3} T_a q)\ , \\
O_7 &= (O_\gamma) = \frac{e}{16\pi^2}\left[\bar{s}\sigma^{\mu\nu}(m_s P_L + m_b P_R) b\right] F_{\mu\nu}\ , \\
O_8 &= (O_g) = \frac{g}{16\pi^2}\left[\bar{s}\sigma^{\mu\nu}(m_s P_L + m_b P_R) T_a b\right] G^a_{\mu\nu}\ .
\end{aligned}
\tag{2}
$$

Here T^a $(a = 1 \ldots 8)$ denote the $SU(3)_C$ generators, and $P_{L,R} = \frac{1}{2}(1 \mp \gamma_5)$.

The relevant operators for $b \to s\ell\bar{\ell}$ decays are [17, 18]:

$$
\begin{aligned}
O_9 = (O_V) &= \frac{e^2}{16\pi^2}(\bar{s}\gamma_\mu P_L b)\,(\bar{\ell}\gamma^\mu \ell)\ , \\
O_{10} = (O_A) &= \frac{e^2}{16\pi^2}(\bar{s}\gamma_\mu P_L b)\,(\bar{\ell}\gamma^\mu\gamma_5 \ell)\ , \\
O_{83} = (O_S) &= \frac{e^2}{16\pi^2} m_b (\bar{s} P_R b)(\bar{\ell}\ell)\ , \\
O_{80} = (O_P) &= \frac{e^2}{16\pi^2} m_b (\bar{s} P_R b)(\bar{\ell}\gamma_5\ell)\ .
\end{aligned}
\tag{3}
$$

Note that the numbers "83" and "80" correspond respectively to the decimal ASCII code for "S" and "P".

NM: Here we use the standard operator basis which is used for $b \to s\gamma$ calculations. O_γ and O_g are called O_7 and O_8 respectively and are commonly used and numbered in this way in the literature. The question is how to write and to number the electroweak penguin operators in this basis (in Buras notations, i.e. traditional basis, they are called $O_{7\cdots 10\cdots}$).

(Goto): For the definitions of the operator basis and the Wilson coefficients, I would like to ask experts on QCD corrections (Uli Haisch?) to provide us with the "best" choice. My questions/comments are the following.

- How should we define the overall normalization of the Wilson coefficients? In the example given in Appendix D, we see $C_2^{(0)}(m_t?) = 1$. On the other hand, for example, $C_2^{c(0)} = -1$ is used in Ref. [17]. Furthermore, is it a good way to factor out CKM matrix elements even when New Physics contributions (which are independent of the CKM matrix in principle) are assumed to exist?

- Very naively, we can write the followoing 80 $b \to s$ four-quark operators:

$$
\begin{aligned}
\mathcal{O}^{q,1}_{VLL} &= (\bar{s}\gamma^\mu P_L b)(\bar{q}\gamma_\mu P_L q), && (4)\\
\mathcal{O}^{q,1}_{VLR} &= (\bar{s}\gamma^\mu P_L b)(\bar{q}\gamma_\mu P_R q), && (5)\\
\mathcal{O}^{q,1}_{SLL} &= (\bar{s} P_L b)(\bar{q} P_L q), && (6)\\
\mathcal{O}^{q,1}_{TLL} &= (\bar{s}\sigma^{\mu\nu} P_L b)(\bar{q}\sigma_{\mu\nu} P_L q), && (7)\\
\mathcal{O}^{q,8}_{VLL} &= (\bar{s}\gamma^\mu T^a P_L b)(\bar{q}\gamma_\mu T^a P_L q), && (8)\\
\mathcal{O}^{q,8}_{VLR} &= (\bar{s}\gamma^\mu T^a P_L b)(\bar{q}\gamma_\mu T^a P_R q), && (9)\\
\mathcal{O}^{q,8}_{SLL} &= (\bar{s} T^a P_L b)(\bar{q} T^a P_L q), && (10)\\
\mathcal{O}^{q,8}_{TLL} &= (\bar{s}\sigma^{\mu\nu} T^a P_L b)(\bar{q}\sigma_{\mu\nu} T^a P_L q), && (11)\\
& \qquad q = u,\ d,\ s,\ c,\ b, && (12)
\end{aligned}
$$

  and their mirror images ($P_L \Leftrightarrow P_R$). For $q = b$, $\mathcal{O}^{1,b}_{VLL}$ and $\mathcal{O}^{8,b}_{VLL}$ are equivalent (with Fierz rearrangement in four dimension). Also, among four operators $\mathcal{O}^{b,1}_{SLL}$, $\mathcal{O}^{b,8}_{SLL}$, $\mathcal{O}^{b,1}_{TLL}$ and $\mathcal{O}^{b,8}_{TLL}$, only two are linearly independent. Same relations apply for $q = s$

and mirror images. Therefore, we have 68 linearly independent four-quark operators for $b \to s$. In the SM, only six (tree and QCD penguins) or ten (+ electroweak penguins) combinations are relevant. However, for example, all of them may be generated by SUSY box diagrams, in principle. The numbering scheme for ten SM operators has to be defined anyway. Scheme for mirror images is ready (with minus sign). How about for remaining 24? Should we define a basis for them and assign numbers, or leave undefined?

- Signs of the dipole operators $O_{7(\gamma)}$ and $O_{8(g)}$ (or their coefficients) depend on the sign convention in the gauge covariant derivatives. Here, it is assumed that QCD and QED covariant derivatives are taken as $\partial_\mu + igT_aG^a_\mu$ and $\partial_\mu + ieQA^a_\mu$ for a quark with electric charge Q ($Q = +\frac{2}{3}$ for up-type and $-\frac{1}{3}$ for down-type), and that $g > 0$, $e > 0$, $F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$, $G^a_{\mu\nu} = \partial_\mu G^a_\nu - \partial_\nu G^a_\mu + \cdots$ and $\sigma^{\mu\nu} = \frac{i}{2}[\gamma^\mu, \gamma^\nu]$, I guess. Is this correct? In any case, we should show our convention explicitly.

- Semileptonic operators are, again naively,

$$\begin{aligned}
\mathcal{O}^\ell_{VLL} &= (\bar{s}\gamma^\mu P_L b)(\bar{\ell}\gamma_\mu P_L \ell), && (13)\\
\mathcal{O}^\ell_{VLR} &= (\bar{s}\gamma^\mu P_L b)(\bar{\ell}\gamma_\mu P_R \ell), && (14)\\
\mathcal{O}^\ell_{SLL} &= (\bar{s}P_L b)(\bar{\ell}P_L \ell), && (15)\\
\mathcal{O}^\ell_{SLR} &= (\bar{s}P_L b)(\bar{\ell}P_R \ell), && (16)\\
\mathcal{O}^\ell_{TLL} &= (\bar{s}\sigma^{\mu\nu} P_L b)(\bar{\ell}\sigma_{\mu\nu} P_L \ell), && (17)
\end{aligned}$$

  and their mirror images for charged leptons, and

$$\begin{aligned}
\mathcal{O}^\nu_{VLL} &= (\bar{s}\gamma^\mu P_L b)(\bar{\nu}\gamma_\mu P_L \nu), && (18)\\
\mathcal{O}^\nu_{VRL} &= (\bar{s}\gamma^\mu P_R b)(\bar{\nu}\gamma_\mu P_L \nu), && (19)
\end{aligned}$$

  for neutrinos. Operators listed in (3) are equivalent to $\mathcal{O}^\ell_{VLL}$, $\mathcal{O}^\ell_{VLR}$, $\mathcal{O}^\ell_{SLL}$ and $\mathcal{O}^\ell_{SLR}$. We should assign numbers for remaining ones. Also lepton flavors should be distinguished: The operators (coefficients) for $\ell = e$, μ and τ have to be given different numbers. How about neutrinos? Mass basis or flavor basis?

- There is another issue about the dipole and semileptonic operators. In Ref. [23], these operators are divided by $\frac{\alpha_s}{4\pi}$. Which normalization should we take?

I propose to use three-digit (and a minus sign) numbering system for the operators of this class in the blocks `F(IM)WCOEF`. Assignments looks like:

`1--99` : Four-quark operators.

`101` : "O_7" or "O_γ".

`102` : "O_8" or "O_g".

`21x` : Semileptonic operators for $\ell = e$.

`22x` : Semileptonic operators for $\ell = \mu$.

`23x` : Semileptonic operators for $\ell = \tau$.

`24x` : Semileptonic operators for $\ell = \nu_e$.

`25x` : Semileptonic operators for $\ell = \nu_\mu$.

`26x` : Semileptonic operators for $\ell = \nu_\tau$.

Last digit `x` in semileptonic operators stands for spinor structure.

C.2 $\Delta F = 2$

The vector, scalar and tensor operators relevant for $bb \leftrightarrow ss$ oscillations are [19, 20]:

$$
\begin{aligned}
O_1 &= (\bar{s}\gamma_\mu P_L b)(\bar{s}\gamma^\mu P_L b) \ , \\
O_2 &= (\bar{s}P_L b)(\bar{s}P_L b) \ , \\
O_3 &= (\bar{s}T^a P_L b)(\bar{s}T_a P_L b) \ , \\
O_4 &= (\bar{s}P_L b)(\bar{s}P_R b) \ , \\
O_5 &= (\bar{s}T^a P_L b)(\bar{s}T_a P_R b) \ , \\
O_6 &= (\bar{s}\gamma_\mu P_L b)(\bar{s}\gamma^\mu P_R b) \ , \\
O_7 &= (\bar{s}\sigma_{\mu\nu} P_L b)(\bar{s}\sigma^{\mu\nu} P_L b) \ .
\end{aligned}
\tag{20}
$$

For the cases of other mixings one should make obvious replacements of the quark fields.

To be completed?

Do we need to give also leptonic operators? How far do we want to go?

(Goto): There are two popular $\Delta F = 2$ operator bases. In Ref. [20, 24] where SUSY contributions are considered, the operator basis is taken as:

$$
\begin{aligned}
\mathcal{O}_1 &= (\bar{s}^\alpha \gamma_\mu P_L d^\alpha)(\bar{s}^\beta \gamma^\mu P_L d^\beta), && (21)\\
\mathcal{O}_2 &= (\bar{s}^\alpha P_L d^\alpha)(\bar{s}^\beta P_L d^\beta), && (22)\\
\mathcal{O}_3 &= (\bar{s}^\alpha P_L d^\beta)(\bar{s}^\beta P_L d^\alpha), && (23)\\
\mathcal{O}_4 &= (\bar{s}^\alpha P_L d^\alpha)(\bar{s}^\beta P_R d^\beta), && (24)\\
\mathcal{O}_5 &= (\bar{s}^\alpha P_L d^\alpha)(\bar{s}^\beta P_R d^\beta), && (25)
\end{aligned}
$$

and mirror images of $\mathcal{O}_{1,2,3}$. α and β are color indices. On the other hand, in Ref. [19, 25] where QCD corrections are calculated, a different basis is chosen:

$$
\begin{aligned}
Q_1^{\rm VLL} &= (\bar{s}^\alpha \gamma_\mu P_L d^\alpha)(\bar{s}^\beta \gamma^\mu P_L d^\beta), && (26)\\
Q_1^{\rm LR} &= (\bar{s}^\alpha \gamma_\mu P_L d^\alpha)(\bar{s}^\beta \gamma^\mu P_R d^\beta), && (27)\\
Q_2^{\rm LR} &= (\bar{s}^\alpha P_L d^\alpha)(\bar{s}^\beta P_R d^\beta), && (28)
\end{aligned}
$$

$$Q_1^{\rm SLL} = (\bar{s}^\alpha P_L d^\alpha)(\bar{s}^\beta P_L d^\beta), \tag{29}$$
$$Q_2^{\rm SLL} = (\bar{s}^\alpha \sigma_{\mu\nu} P_L d^\alpha)(\bar{s}^\beta \sigma^{\mu\nu} P_L d^\beta), \tag{30}$$

where $\sigma^{\mu\nu} = \frac{1}{2}[\gamma^\mu, \gamma^\nu]$ (so we may have to put minus sign to $Q_2^{\rm SLL}$ if we take a definition $\sigma^{\mu\nu} = \frac{i}{2}[\gamma^\mu, \gamma^\nu]$). In either case, the way of color contraction and appearance of γ_5 (or $P_{L,R}$) look "traditional"-like rather than "standard" ones in $\Delta F = 1$ case. Which should we take, or something else?

In addition, there is an issue of normalization. In Refs. [19, 20], Wilson coefficients are defined as

- Ref. [20]:
$$\mathcal{H}_{\rm eff}^{\Delta F=2} = \sum C_i \mathcal{O}_i, \tag{31}$$
- Ref. [19]:
$$\mathcal{H}_{\rm eff}^{\Delta B=2} = \frac{G_F^2 M_W^2}{16\pi^2} (V_{tb}^* V_{ts})^2 \sum C_i Q_i. \tag{32}$$

This normalization should be defined in a consistent way with $\Delta F = 1$ operators.

C.3 $\Delta LF = 1$

(Goto): In Ref. [26], the following basis is used for $\tau \to \mu$ dipole and four-lepton operators:

$$\mathcal{L}(\tau^+ \to \mu^+\mu^+\mu^-) = -\frac{4G_F}{\sqrt{2}} \left[m_\tau \left(A_R \bar{\tau} \sigma^{\mu\nu} P_L \mu + A_L \bar{\tau} \sigma^{\mu\nu} P_R \mu \right) F_{\mu\nu} + \sum_{i=1}^{6} g_i \mathcal{O}_i(\tau^+ \to \mu^+\mu^+\mu^-) \right], \tag{33}$$

$$\mathcal{L}(\tau^+ \to \mu^+e^+e^-) = -\frac{4G_F}{\sqrt{2}} \left[m_\tau \left(A_R \bar{\tau} \sigma^{\mu\nu} P_L \mu + A_L \bar{\tau} \sigma^{\mu\nu} P_R \mu \right) F_{\mu\nu} + \sum_{i=1}^{10} \lambda_i \mathcal{O}_i(\tau^+ \to \mu^+e^+e^-) \right], \tag{34}$$

where

$$\mathcal{O}_1(\tau^+ \to \mu^+\mu^+\mu^-) = (\bar{\tau} P_L \mu)(\bar{\mu} P_L \mu), \tag{35}$$
$$\mathcal{O}_2(\tau^+ \to \mu^+\mu^+\mu^-) = (\bar{\tau} P_R \mu)(\bar{\mu} P_R \mu), \tag{36}$$
$$\mathcal{O}_3(\tau^+ \to \mu^+\mu^+\mu^-) = (\bar{\tau} \gamma^\mu P_R \mu)(\bar{\mu} \gamma_\mu P_R \mu), \tag{37}$$
$$\mathcal{O}_4(\tau^+ \to \mu^+\mu^+\mu^-) = (\bar{\tau} \gamma^\mu P_L \mu)(\bar{\mu} \gamma_\mu P_L \mu), \tag{38}$$
$$\mathcal{O}_5(\tau^+ \to \mu^+\mu^+\mu^-) = (\bar{\tau} \gamma^\mu P_R \mu)(\bar{\mu} \gamma_\mu P_L \mu), \tag{39}$$
$$\mathcal{O}_6(\tau^+ \to \mu^+\mu^+\mu^-) = (\bar{\tau} \gamma^\mu P_L \mu)(\bar{\mu} \gamma_\mu P_R \mu), \tag{40}$$

$$\mathcal{O}_1(\tau^+ \to \mu^+e^+e^-) = (\bar{\tau} P_L \mu)(\bar{e} P_L e), \tag{41}$$
$$\mathcal{O}_2(\tau^+ \to \mu^+e^+e^-) = (\bar{\tau} P_L \mu)(\bar{e} P_R e), \tag{42}$$

$$\mathcal{O}_3(\tau^+ \to \mu^+e^+e^-) = (\bar{\tau}P_R\mu)(\bar{e}P_Le), \quad (43)$$
$$\mathcal{O}_4(\tau^+ \to \mu^+e^+e^-) = (\bar{\tau}P_R\mu)(\bar{e}P_Re), \quad (44)$$
$$\mathcal{O}_5(\tau^+ \to \mu^+e^+e^-) = (\bar{\tau}\gamma^\mu P_L\mu)(\bar{e}\gamma_\mu P_Le), \quad (45)$$
$$\mathcal{O}_6(\tau^+ \to \mu^+e^+e^-) = (\bar{\tau}\gamma^\mu P_L\mu)(\bar{e}\gamma_\mu P_Re), \quad (46)$$
$$\mathcal{O}_7(\tau^+ \to \mu^+e^+e^-) = (\bar{\tau}\gamma^\mu P_R\mu)(\bar{e}\gamma_\mu P_Le), \quad (47)$$
$$\mathcal{O}_8(\tau^+ \to \mu^+e^+e^-) = (\bar{\tau}\gamma^\mu P_R\mu)(\bar{e}\gamma_\mu P_Re), \quad (48)$$
$$\mathcal{O}_9(\tau^+ \to \mu^+e^+e^-) = (\bar{\tau}\sigma^{\mu\nu} P_L\mu)(\bar{e}\sigma_{\mu\nu}e), \quad (49)$$
$$\mathcal{O}_{10}(\tau^+ \to \mu^+e^+e^-) = (\bar{\tau}\sigma^{\mu\nu} P_R\mu)(\bar{e}\sigma_{\mu\nu}e). \quad (50)$$

We can adopt above basis as

`1` : $(\bar{\tau}\gamma^\mu P_L\mu)(\bar{\mu}\gamma_\mu P_L\mu)$,
`2` : $(\bar{\tau}\gamma^\mu P_L\mu)(\bar{\mu}\gamma_\mu P_R\mu)$,
`3` : $(\bar{\tau}P_L\mu)(\bar{\mu}P_L\mu)$,
`4` : $(\bar{\tau}\gamma^\mu P_L\mu)(\bar{e}\gamma_\mu P_Le)$,
`5` : $(\bar{\tau}\gamma^\mu P_L\mu)(\bar{e}\gamma_\mu P_Re)$,
`6` : $(\bar{\tau}P_L\mu)(\bar{e}P_Le)$,
`7` : $(\bar{\tau}P_L\mu)(\bar{e}P_Re)$,
`8` : $(\bar{\tau}\sigma^{\mu\nu}P_L\mu)(\bar{e}\sigma_{\mu\nu}e)$,
`101` : $m_\tau\bar{\tau}\sigma^{\mu\nu}P_L\mu F_{\mu\nu}$.

Since the QED gauge covariant derivative is taken as $\partial_\mu - ieQA^a_\mu$ with $Q = -1$ for the electron in Ref. [26], the sign of the dipole term may have to be flipped, in accordance with the conventions in the quark sector. It is also defined that $\sigma^{\mu\nu} = \frac{i}{2}[\gamma^\mu, \gamma^\nu]$ in Ref. [26]. More generally, if we need slots for operators like $(\bar{\tau}\gamma^\mu P_L\mu)(\bar{\tau}\gamma_\mu P_L\tau)$, numbers < 100 can be used for four-lepton operators in a similar way to the $\Delta F = 1$ four-quark operators.

For semihadronic operators relevant for $\tau^+ \to \mu^+\pi^0$ etc., the operator basis may be analogously defined as:

`2q4` : $(\bar{\tau}\gamma^\mu P_L\mu)(\bar{q}\gamma_\mu P_Lq)$,
`2q5` : $(\bar{\tau}\gamma^\mu P_L\mu)(\bar{q}\gamma_\mu P_Rq)$,
`2q6` : $(\bar{\tau}P_L\mu)(\bar{q}P_Lq)$,
`2q7` : $(\bar{\tau}P_L\mu)(\bar{q}P_Rq)$,
`2q8` : $(\bar{\tau}\sigma^{\mu\nu}P_L\mu)(\bar{q}\sigma_{\mu\nu}q)$,

where `q=1,2,3` for $q = u, d, s$, respectively. However, a different basis is used in Ref. [27]...

D Decay constants

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

$$\langle 0|\bar{q}\gamma^\mu\gamma_5 Q|P(p)\rangle = -if_P p^\mu, \quad (51)$$

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. [28], where "left" is written as "$1+\gamma_5$". For π^0, η and η', I prefer to define

$$\begin{aligned}
\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma^\mu\gamma_5 u - \bar{d}\gamma^\mu\gamma_5 d|\pi^0(p)\rangle &= -if_\pi p^\mu, &(52)\\
\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma^\mu\gamma_5 u + \bar{d}\gamma^\mu\gamma_5 d|\eta^{(\prime)}(p)\rangle &= -if^q_{\eta^{(\prime)}} p^\mu, &(53)\\
\langle 0|\bar{s}\gamma^\mu\gamma_5 s|\eta^{(\prime)}(p)\rangle &= -if^s_{\eta^{(\prime)}} p^\mu, &(54)
\end{aligned}$$

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

$$\begin{aligned}
\frac{1}{\sqrt{6}}\langle 0|\bar{u}\gamma^\mu\gamma_5 u + \bar{d}\gamma^\mu\gamma_5 d - 2\bar{s}\gamma^\mu\gamma_5 s|\eta^{(\prime)}(p)\rangle &= -if^8_{\eta^{(\prime)}} p^\mu, &(55)\\
\frac{1}{\sqrt{3}}\langle 0|\bar{u}\gamma^\mu\gamma_5 u + \bar{d}\gamma^\mu\gamma_5 d + \bar{s}\gamma^\mu\gamma_5 s|\eta^{(\prime)}(p)\rangle &= -if^1_{\eta^{(\prime)}} p^\mu, &(56)
\end{aligned}$$

Also, the following matrix elements are defined:

$$\begin{aligned}
(m_q + m_Q)\langle 0|\bar{q}\gamma_5 Q|P(p)\rangle &= ih_P, &(57)\\
(m_u + m_d)\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma_5 u - \bar{d}\gamma_5 d|\pi^0(p)\rangle &= ih_\pi, &(58)\\
(m_u + m_d)\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma_5 u + \bar{d}\gamma_5 d|\eta^{(\prime)}(p)\rangle &= ih^q_{\eta^{(\prime)}}, &(59)\\
2m_s\langle 0|\bar{s}\gamma_5 s|\eta^{(\prime)}(p)\rangle &= ih^s_{\eta^{(\prime)}}. &(60)
\end{aligned}$$

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.

$$\begin{aligned}
\langle 0|\bar{q}\gamma^\mu Q|V(p)\rangle &= m_V f_V \epsilon^\mu, &(61)\\
\langle 0|\bar{q}\sigma^{\mu\nu} Q|V(p)\rangle &= if_V^T(p^\nu\epsilon^\mu - p^\mu\epsilon^\nu), &(62)
\end{aligned}$$

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

$$\begin{aligned}
\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma^\mu u - \bar{d}\gamma^\mu d|\rho^0(p)\rangle &= m_\rho f_\rho \epsilon^\mu, &(63)\\
\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma^\mu u + \bar{d}\gamma^\mu d|\omega(p)\rangle &= m_\omega f_\omega \epsilon^\mu, &(64)\\
\langle 0|\bar{s}\gamma^\mu s|\phi(p)\rangle &= m_\phi f_\phi \epsilon^\mu. &(65)
\end{aligned}$$

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

$$\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma^\mu u + \bar{d}\gamma^\mu d|\omega(\phi)(p)\rangle = m_{\omega(\phi)} f^q_{\omega(\phi)} \epsilon^\mu, \quad (66)$$

$$\langle 0|\bar{s}\gamma^\mu s|\omega(\phi)(p)\rangle = m_{\omega(\phi)} f^s_{\omega(\phi)} \epsilon^\mu, \quad (67)$$

or

$$\frac{1}{\sqrt{6}}\langle 0|\bar{u}\gamma^\mu u + \bar{d}\gamma^\mu d - 2\bar{s}\gamma^\mu s|\omega(\phi)(p)\rangle = m_{\omega(\phi)} f^8_{\omega(\phi)} \epsilon^\mu, \quad (68)$$

$$\frac{1}{\sqrt{3}}\langle 0|\bar{u}\gamma^\mu u + \bar{d}\gamma^\mu d + \bar{s}\gamma^\mu s|\omega(\phi)(p)\rangle = m_{\omega(\phi)} f^1_{\omega(\phi)} \epsilon^\mu. \quad (69)$$

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_emˆ(-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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