

## Flavour Les Houches Accord: Interfacing Flavour related Codes

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### Abstract

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

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# 1 Introduction

In addition to the increasing number of refined approaches in the literature for calculating flavour-related observables, advanced programs dedicated to the calculation of such quantities, e.g. Wilson coefficients, branching ratios, mixing amplitudes, renormalization group equation (RGE) running including flavour effects have recently been developed [1–3]. Flavour-related observables are also implemented by many other non-dedicated public codes to provide additional checks for the models under investigation [4–9]. The results are often subsequently used by other codes, e.g. as constraints on the parameter space of the model under consideration [10–13].

At present, a small number of specialized interfaces between the various codes exist. 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. Some time ago a similar problem arose in the context of Supersymmetry (SUSY). The solution took the form of the SUSY Les Houches Accord (SLHA) [14, 15], which is nowadays frequently used to exchange information between SUSY related codes, such as values for the soft SUSY-breaking parameters, particle masses and mixings, branching ratios etc. The SLHA has proved to be a robust solution, allowing information to be exchanged between different codes via ASCII files. The detailed structure of these input and output files is described in Refs. [14, 15]. While the first definitions, SLHA1 [14], concerned the simplest version of the MSSM, the SLHA2 [15] also included definitions for the case of complex parameters,  $R$ -parity violation, non-minimal flavor violation etc.

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, which we refer to as the “Flavour Les Houches Accord” (FLHA). In brief, 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 programs. Furthermore, the standardized format will provide the users with a clear and well-structured result that could eventually be used for other 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 measured parameters in the Standard Model (SM) and the Cabibbo-Kobayashi-Maskawa (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 the sake of clarity, the new FLHA block names start with “F”. Also, in order to avoid any confusion, the SLHA blocks are not modified or redefined in the FLHA. Instead, if a block needs to be extended to meet the requirements of flavour physics, a new “F” block is defined.

Note that different codes may *technically* achieve the FLHA input/output in different ways. The details of how to ‘switch on’ the FLHA input/output for 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 [16]. In principle these programs could be extended to include the FLHA as well.

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 Definitions of the interfaces

In this section, the FLHA input and output files are described.

### 2.1 General structure

Following the general structure for the SLHA [14, 15] we assume the following:

- All quantities with dimensions of energy (mass) are implicitly understood to be in GeV ( $\text{GeV}/c^2$ ).
- 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 for 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<sup>1</sup>. The 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, this 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 F.
- A “#” mark anywhere means that the rest of the line is intended as a comment and should 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”.

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<sup>1</sup>E16.8: a 16-character wide real number in scientific notation, whereof 8 digits are decimals, e.g., “-0.12345678E+000”.

- 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 FLHA is designed to be compatible with SLHA (and with any future accords that follow the same general structure). For generic models, e.g., ones for which an accord does not yet exist, we provide a fallback solution by generalizing the SLHA block MODSEL in the form of a new FLHA-specific block, FMODESEL, with entries as described below. For models for which a more specific accord does exist, e.g., SLHA, a complete model of that type can be specified instead, in which case FMODESEL is redundant and should normally be absent. In case it is present and there are conflicts, the most specific accord takes precedence, so that internal inconsistency of the accord with the smallest scope is guaranteed. In the case of MODSEL vs. FMODESEL, MODSEL would thus take precedence, though it would be prudent to issue warnings if both are present, and especially if their contents differ. Note also that the possibility to reuse more specific accords should not be perceived as forcing one to use them. Thus, even for a SUSY model, an FLHA user who does not wish to deal with an entire SLHA spectrum could also use FMODESEL. In that case, the file would be treated just like any other FLHA file, i.e., without any reference to the SUSY-specific parts of the SLHA. The only difference from a practical perspective would be that SLHA-specific tools would then not be able to process the file correctly.
- The order of the blocks is arbitrary, although it is in general good practice to put FMODESEL or MODSEL near the beginning.

Further definitions can be found in section 3 of Ref. [14].

The following general structure for the FLHA file is proposed:

- BLOCK FCINFO: Information about the flavour code used to prepare the FLHA file.
- BLOCK FMODESEL: Basic information about the underlying model used for the calculations, for generic models. This is the only place where “model dependent” information can be found. In the case of SUSY models with complete SLHA spectra, the SLHA BLOCK MODSEL is used instead and overrides FMODESEL if both are present.
- BLOCK SMINPUTS: Measured values of SM parameters used for the calculations.
- BLOCK VCKMIN: Input parameters of the CKM matrix in the Wolfenstein parameterisation.
- BLOCK UPMNSIN: Input parameters of the PMNS neutrino mixing matrix in the PDG parameterisation.
- 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 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 FPARAM: process dependent variables and parameters.

More details on each block are given in the following.

## 2.2 Definition of the blocks

The FLHA input and output blocks are described 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, it means warnings 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, it means errors 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 is part of the SLHA. Its presence in an FLHA file signals that the file contains, in addition to the FLHA-specific blocks, a complete and self-consistent SLHA spectrum, for which MODSEL defines the switches and options used. We do not modify its definition, relative to SLHA2. For non-SLHA models, see instead BLOCK FMODESEL below. Note that, if the user does not wish to provide a complete set of SLHA blocks, MODSEL should not be used. Instead, see BLOCK FMODESEL below.

## BLOCK FMODESEL

In the case of non-SLHA models this block provides switches and options for model selection. It is similar to the SLHA2 BLOCK MODSEL, but extended to allow more flexibility. It is advised to use only BLOCK MODSEL for SLHA models and only BLOCK FMODESEL for non-SLHA models, to avoid double definitions.

- 1 : Choice of model. By default, a minimal type of model will always be assumed. Possible values are (note: when giving a complete SLHA spectrum, use BLOCK MODSEL instead. The options here are only intended to cover the cases when a complete SLHA spectrum is not provided.):
  - 1 : SM
  - 0 : General MSSM simulation
  - 1 : (m)SUGRA model
  - 2 : (m)GMSB model
  - 3 : (m)AMSB model
  - 4 : ...
  - 30 : General THDM
  - 31 : THDM type I
  - 32 : THDM type II
  - 33 : THDM type III
  - 34 : THDM type IV
  - 35 : ...
  - 99 : other model. This choice requires a string given in the entry 99
- 5 : (Default=0) CP violation. Switches defined are:
  - 0 : CP is conserved. No information 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.

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

The definition of the different Two-Higgs Doublet Model (THDM) types is given in Appendix B.

Private blocks can also be constructed by the user, for instance `BLOCK MYMODEL`, to contain specific parameters of other models. It is advised that all relevant model parameters are provided in this way. Due to the user-defined specific structure of these blocks it is not required that they are recognized universally.

## BLOCK SMINPUTS

In general, the spectrum of the SM particles plays a crucial role in flavour physics. Consequently, experimental measurements of masses and coupling constants at the electroweak scale are required. The block containing these quantities in the SLHA is `SMINPUTS`. We borrow this block from SLHA as it is, and reproduce it here for completeness.

It is also important to note that experimental results for all quantities available at present, e.g.  $\alpha_s$  or the running bottom quark mass, are clearly obtained based on the assumption that the SM is the underlying theory. Extending the field content of the SM to that of a New Physics (NP) Model means that the *same* measured results would be obtained for *different* values of these quantities. 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 NP corrections included. Any flavour code itself is then assumed to convert these parameters into ones appropriate to an NP framework.

It should be noted that some programs have hard-coded defaults for some of these parameters, hence only a subset may sometimes be available as free inputs. The parameters are:

1 :  $\alpha_{\text{em}}^{-1}(m_Z)^{\overline{\text{MS}}}$ , inverse electromagnetic coupling at the  $Z$  pole in the  $\overline{\text{MS}}$  scheme (with 5 active flavours).

2 :  $G_F$ , Fermi constant (in units of  $\text{GeV}^{-2}$ ).

3 :  $\alpha_s(m_Z)^{\overline{\text{MS}}}$ , strong coupling at the  $Z$  pole in the  $\overline{\text{MS}}$  scheme (with 5 active flavours).

4 :  $m_Z$ , pole mass.

5 :  $m_b(m_b)^{\overline{\text{MS}}}$ , bottom quark running mass in the  $\overline{\text{MS}}$  scheme.

6 :  $m_t$ , top-quark pole mass.

7 :  $m_\tau$ , tau pole mass.

## BLOCK VCKMIN

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

- 1 :  $\lambda$
- 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  $\lambda$ .

## BLOCK UPMNSIN

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

- 1 :  $\theta_{12}$
- 2 :  $\theta_{23}$
- 3 :  $\theta_{13}$
- 4 :  $\delta$
- 5 :  $\alpha_1$
- 6 :  $\alpha_2$

We use the PDG parameterisation, 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 particles involved, in addition to the SLHA BLOCK MASS which only contains 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 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 indicates the energy scale (0 if not relevant). An additional comment could be given after #.

The schemes are defined as follows:

- 0 : pole
- 1 :  $\overline{MS}$
- 2 :  $\overline{DR}$



3 : 1S  
 4 : kin  
 5 : ...

## BLOCK FLIFE

The block **BLOCK FLIFE** contains the lifetimes, in seconds, of mesons and hadrons. 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 nine-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 associated with the decay constant, and the double precision number the value of this decay constant.

The decay constants for the mesons that are used most often, which have several decay constants associated with them, are defined as:

321 :  $K^+$ .  
     1 :  $f_K$  in GeV.  
    11 :  $h_K$  in  $\text{GeV}^3$ .

221 :  $\eta$ .  
     1 :  $f_\eta^q$  in GeV.  
     2 :  $f_\eta^s$  in GeV.  
    11 :  $h_\eta^q$  in  $\text{GeV}^3$ .  
    12 :  $h_\eta^s$  in  $\text{GeV}^3$ .

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

223 :  $\omega(782)$ .

1 :  $f_\rho^q$  in GeV.

2 :  $f_\rho^s$  in GeV.

11 :  $f_\rho^{T,q}$  in GeV.

12 :  $f_\rho^{T,s}$  in GeV.

More details, and definitions for the decay constants ( $f$ ,  $h$ , etc.) can be found in Appendix D.

## BLOCK FCONSTRATIO

The block `BLOCK FCONSTRATIO` contains the ratios of decay constants, which often have less uncertainty than the decay constants themselves. 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,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 and fourth integers the numbers of the decay constants, which correspond 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 renormalization scheme as well as the scale at which the bag parameters are evaluated are also specified to allow for large flexibility. The standard for each line in the block should correspond to the FORTRAN format

`(1x,I9,3x,I2,3x,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, the second integer the number associated with the bag parameter, the double precision number the value of the bag parameter, the following integer stands for the renormalization scheme and finally the last double precision number indicates the energy scale  $Q$  (0 in the case of renormalization group invariant bag parameters). An additional comment could be given after `#`.

Bag parameters for  $B_d^0 - \bar{B}_d^0$  (and similarly for  $B_s^0 - \bar{B}_s^0$ ,  $K^0 - \bar{K}^0$  and  $D^0 - \bar{D}^0$ ) mixing are listed as:

511 :  $B_d^0$

1 :  $B_1(Q)$

2 :  $B_2(Q)$

3 :  $B_3(Q)$

4 :  $B_4(Q)$

5 :  $B_5(Q)$

The schemes are defined as follows:

- 0 : renormalization group invariant (with energy scale set to 0)
- 1 :  $\overline{\text{MS}}$
- 2 : MOM
- 3 : ...

Normalizations can be found in Appendix E.

## BLOCK FWCOEF Q= ...

The block `BLOCK FWCOEF Q= ...` contains the real part of the Wilson coefficients at the scale `Q`. The Wilson coefficients are calculated for the required set of operators. A list of the most relevant effective operators is given in Appendix C and we recommend the user to use the normalization as given in this appendix.

The coefficients  $C_{i,j}^{(k)}$  at order  $k$  in the perturbative expansion in  $\alpha(\mu)$  ( $j = e$ ) or  $\alpha_s(\mu)$  ( $j = s$ ), have to be specified individually. The following convention for the perturbative expansion is used:

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

Therefore the couplings should not be included in the Wilson coefficients.

The first two entries in `BLOCK FWCOEF` should consist of two integers defining the fermion structure of the operator and the operator structure itself. These two numbers do not describe the operator fully, including normalization etc., but together act as a unique identifier for any possible Wilson coefficient. Consequently, the user has to take care that a consistent normalization including prefactors etc. is used in specifying the Wilson Coefficients. 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 fermions are encoded by their PDG code in two-digit form, which is the same for 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 operator sub-structures are defined in Table 2. Correspondingly, the second integer number defining  $O_1$ , containing the operator structure  $\gamma_\mu T^a P_L \gamma^\mu T^a P_L$  is given by 6161.

A few more rules are needed for an unambiguous definition.

- If part of an operator appears without fermions (as it is possible, e.g., for  $F_{\mu\nu}$ ) it should appear right-most, so that the encoded fermions correspond to the left-most part of the operator.
- In the case of a possible ambiguity, for instance  $O_1 = (\bar{s}\gamma_\mu T^a P_L c)(\bar{c}\gamma^\mu T^a P_L b)$  corresponding to 03040405 6161 and  $O_1 = (\bar{c}\gamma_\mu T^a P_L b)(\bar{s}\gamma^\mu T^a P_L c)$  corresponding to

name	PDG code	two-digit number	name	PDG code	two-digit number
$d$	1	01	$e$	11	11
$u$	2	02	$\nu_e$	12	12
$s$	3	03	$\mu$	13	13
$c$	4	04	$\nu_\mu$	14	14
$b$	5	05	$\tau$	15	15
$t$	6	06	$\nu_\tau$	16	16
$\sum_q q$		07	$\sum_l l$		17
$\sum_q q Q_q$		08	$\sum_l l Q_l$		18

Table 1: PDG codes and two-digit number identifiers of quarks and leptons. The summations are over active fermions.

operator	number	operator	number	operator	number
1	30	$T^a$	50	$\delta_{ij}$	70
$P_L$	31	$P_L T^a$	51	$P_L \delta_{ij}$	71
$P_R$	32	$P_R T^a$	52	$P_R \delta_{ij}$	72
$\gamma^\mu$	33	$\gamma^\mu T^a$	53	$\gamma^\mu \delta_{ij}$	73
$\gamma_5$	34	$\gamma_5 T^a$	54	$\gamma_5 \delta_{ij}$	74
$\sigma^{\mu\nu}$	35	$\sigma^{\mu\nu} T^a$	55	$\sigma^{\mu\nu} \delta_{ij}$	75
$\gamma^\mu \gamma^\nu \gamma^\rho$	36	$\gamma^\mu \gamma^\nu \gamma^\rho T^a$	56	$\gamma^\mu \gamma^\nu \gamma^\rho \delta_{ij}$	76
$\gamma^\mu \gamma_5$	37	$\gamma^\mu \gamma_5 T^a$	57	$\gamma^\mu \gamma_5 \delta_{ij}$	77
$\gamma^\mu P_L$	41	$\gamma^\mu T^a P_L$	61	$\gamma^\mu \delta_{ij} P_L$	81
$\gamma^\mu P_R$	42	$\gamma^\mu T^a P_R$	62	$\gamma^\mu \delta_{ij} P_R$	82
$\sigma^{\mu\nu} P_L$	43	$\sigma^{\mu\nu} T^a P_L$	63	$\sigma^{\mu\nu} \delta_{ij} P_L$	83
$\sigma^{\mu\nu} P_R$	44	$\sigma^{\mu\nu} T^a P_R$	64	$\sigma^{\mu\nu} \delta_{ij} P_R$	84
$\gamma^\mu \gamma^\nu \gamma^\rho P_L$	45	$\gamma^\mu \gamma^\nu \gamma^\rho T^a P_L$	65	$\gamma^\mu \gamma^\nu \gamma^\rho \delta_{ij} P_L$	85
$\gamma^\mu \gamma^\nu \gamma^\rho P_R$	46	$\gamma^\mu \gamma^\nu \gamma^\rho T^a P_R$	66	$\gamma^\mu \gamma^\nu \gamma^\rho \delta_{ij} P_R$	86
$F_{\mu\nu}$	22	$G_{\mu\nu}^a$	21		

Table 2: Two-digit number definitions for the operators.  $T^a$  ( $a = 1 \dots 8$ ) denote the  $SU(3)_C$  generators,  $P_{L,R} = \frac{1}{2}(1 \mp \gamma_5)$ , and  $(T^a)_{ij}(T^a)_{kl} = \frac{1}{2}(\delta_{il}\delta_{kj} - 1/N_c \delta_{ij}\delta_{kl})$ , where  $i, j, k, l$  are colour indices.

04050304 6161, the “smaller” number, i.e. in this case 03040405 6161, should be used.

The third entry specifies the order of the perturbative expansion in Eq. (1). 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  $C_i^{(0)}$ , e.g.:

$$00 : C_i^{(0)}(Q)$$

$$01 : C_{i,s}^{(1)}(Q)$$

$$02 : C_{i,s}^{(2)}(Q)$$

- 10 :  $C_{i,e}^{(1)}(Q)$
- 11 :  $C_{i,es}^{(2)}(Q)$
- 99 : total

The Wilson coefficients can be provided either via separate New Physics 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 : NP
- 2 : SM+NP

The New Physics model is the model specified in the `BLOCK FMODEL`.

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 that of 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 observable, the value of the observable, the energy dependence  $q$  for the observable (0 if not relevant), 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,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 double precision number the energy scale  $q$ , the next integer 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 a comment.

For more specific conventions for each observable, the user is encouraged to refer to the manual of the flavour calculator.

### BLOCK FOBSERR

The block `BLOCK FOBSERR` contains the theoretical error for flavour observables, with a similar structure to that of `BLOCK FOBS`, but with the double precision number for the value of the observable replaced by two double precision numbers for the minus and plus uncertainties.

In a similar way, for every block `Fname`, a corresponding block containing the errors, `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`. These SM values may be helpful as a reference for comparison.

### BLOCK FPARAM

The block `BLOCK FPARAM` contains process dependent variables, such as form factors, shape functions etc., for a specific decay. The decay should be defined as in `BLOCK FOBS`, but with the type of the observable replaced by a user defined number for the parameter. Here it is essential to describe the variable as a comment.

## 3 Conclusion

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

As the number of flavour related codes keeps growing, the connection between results from flavour physics and high  $p_T$  physics is becoming more relevant to the disentangling of the underlying physics model. Using the lessons learnt from the SLHA, we hope the FLHA will prove useful for studies related to flavour physics.

## **Acknowledgements**

We thank the organizers of the Les Houches workshop 2009, where this work was started, for their hospitality and support. This work was supported in part by the European Community's Marie Curie Research Training Networks under contracts MRTN-CT-2006-035505 'Tools and Precision Calculations for Physics Discoveries at Colliders', and MRTN-CT-2006-035606 'MCnet'. The work of S.H. was partially supported by CICYT (grant FPA 2007-66387). 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
$\pi^0$	111	$D^+$	411
$\pi^+$	211	$D^0$	421
$\rho(770)^0$	113	$D_s^+$	431
$\rho(770)^+$	213	$D_s^{*+}$	433
$\eta$	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 charged Higgs boson couplings to fermions for the four types of the Two-Higgs Doublet Model (THDM) can be expressed as

$$\begin{aligned}
 H^+ D \bar{U} &: \frac{-g}{2\sqrt{2}m_W} V_{UD} [\lambda^U m_U (1 - \gamma^5) - \lambda^D m_D (1 + \gamma^5)] \\
 H^+ \ell^- \bar{\nu}_\ell &: \frac{g}{2\sqrt{2}m_W} \lambda^\ell m_\ell (1 + \gamma^5),
 \end{aligned} \tag{3}$$

where  $U$ ,  $D$  and  $\ell$  stand, respectively, for the up-type quarks, the down-type quarks and the leptons. The conventions used for the different THDM types, corresponding to different Yukawa couplings, are given in Table 4.

The notation and meaning of the different types of model 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.



Type	$\lambda^U$	$\lambda^D$	$\lambda^\ell$
I	$\cot \beta$	$\cot \beta$	$\cot \beta$
II	$\cot \beta$	$-\tan \beta$	$-\tan \beta$
III	$\cot \beta$	$-\tan \beta$	$\cot \beta$
IV	$\cot \beta$	$\cot \beta$	$-\tan \beta$

Table 4: Charged Higgs Yukawa coupling coefficients  $\lambda^f$  in the  $Z_2$ -symmetric types of the THDM.

## C Effective Operators

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

### C.1 Effective operators for $b \rightarrow s$ transition

Effective operators relevant to the  $b \rightarrow s$  transition are

$$\begin{aligned}
O_1 &= O(03040405\ 6161) = (\bar{s}\gamma_\mu T^a P_L c)(\bar{c}\gamma^\mu T^a P_L b), \\
O_2 &= O(03040405\ 4141) = (\bar{s}\gamma_\mu P_L c)(\bar{c}\gamma^\mu P_L b), \\
O_3 &= O(03050707\ 4133) = (\bar{s}\gamma_\mu P_L b) \sum_q (\bar{q}\gamma^\mu q), \\
O_4 &= O(03050707\ 6153) = (\bar{s}\gamma_\mu T^a P_L b) \sum_q (\bar{q}\gamma^\mu T^a q), \\
O_5 &= O(03050707\ 4536) = (\bar{s}\gamma_{\mu_1}\gamma_{\mu_2}\gamma_{\mu_3} P_L b) \sum_q (\bar{q}\gamma^{\mu_1}\gamma^{\mu_2}\gamma^{\mu_3} q), \\
O_6 &= O(03050707\ 6556) = (\bar{s}\gamma_{\mu_1}\gamma_{\mu_2}\gamma_{\mu_3} T^a P_L b) \sum_q (\bar{q}\gamma^{\mu_1}\gamma^{\mu_2}\gamma^{\mu_3} T^a q), \\
O_7 &= O(0305\ 4422) = \frac{e}{16\pi^2} [\bar{s}\sigma^{\mu\nu} (m_b P_R) b] F_{\mu\nu}, \\
O_8 &= O(0305\ 6421) = \frac{g}{16\pi^2} [\bar{s}\sigma^{\mu\nu} (m_b P_R) T^a b] G_{\mu\nu}^a.
\end{aligned} \tag{4}$$

### C.2 Effective operators for neutral meson mixings

Effective operators for  $B_d^0 - \bar{B}_d^0$  mixing are

$$\begin{aligned}
O(01050105\ 4141) &= (\bar{d}\gamma_\mu P_L b)(\bar{d}\gamma^\mu P_L b), \\
O(01050105\ 3131) &= (\bar{d} P_L b)(\bar{d} P_L b), \\
O(01050105\ 7171) &= (\bar{d}_i P_L b^j)(\bar{d}_j P_L b^i),
\end{aligned}$$

$$\begin{aligned}
O(01050105\ 3132) &= (\bar{d}P_L b)(\bar{d}P_R b), \\
O(01050105\ 7172) &= (\bar{d}_i P_L b^j)(\bar{d}_j P_R b^i),
\end{aligned} \tag{5}$$

and those with opposite chiralities. Operators for  $B_s^0 - \bar{B}_s^0$ ,  $K^0 - \bar{K}^0$  and  $D^0 - \bar{D}^0$  mixings are defined in the same way.

### C.3 Effective operators for lepton flavor violations

The effective operators for  $\Delta LF = 1$  lepton flavor violating processes are as follows,

- $\mu \rightarrow e$  transitions ( $\mu \rightarrow e\gamma$ ,  $\mu \rightarrow eee$  and  $\mu - e$  conversion in a muonic atom):

$$\begin{aligned}
O(1311\ 4322) &= m_\mu(\bar{\mu}\sigma^{\mu\nu}P_L e)F_{\mu\nu}, \\
O(13111111\ 3131) &= (\bar{\mu}P_L e)(\bar{e}P_L e), \\
O(13111111\ 4141) &= (\bar{\mu}\gamma_\mu P_L e)(\bar{e}\gamma^\mu P_L e), \\
O(13111111\ 4142) &= (\bar{\mu}\gamma_\mu P_L e)(\bar{e}\gamma^\mu P_R e), \\
O(13110101\ 3131) &= (\bar{\mu}P_L e)(\bar{d}P_L d), \\
O(13110101\ 3132) &= (\bar{\mu}P_L e)(\bar{d}P_R d), \\
O(13110101\ 4141) &= (\bar{\mu}\gamma_\mu P_L e)(\bar{d}\gamma^\mu P_L d), \\
O(13110101\ 4142) &= (\bar{\mu}\gamma_\mu P_L e)(\bar{d}\gamma^\mu P_R d), \\
O(13110101\ 4343) &= (\bar{\mu}\sigma^{\mu\nu}P_L e)(\bar{d}\sigma_{\mu\nu}P_L d), \\
O(13110202\ 3131) &= (\bar{\mu}P_L e)(\bar{u}P_L u), \\
O(13110202\ 3132) &= (\bar{\mu}P_L e)(\bar{u}P_R u), \\
O(13110202\ 4141) &= (\bar{\mu}\gamma_\mu P_L e)(\bar{u}\gamma^\mu P_L u), \\
O(13110202\ 4142) &= (\bar{\mu}\gamma_\mu P_L e)(\bar{u}\gamma^\mu P_R u), \\
O(13110202\ 4343) &= (\bar{\mu}\sigma^{\mu\nu}P_L e)(\bar{u}\sigma_{\mu\nu}P_L u), \\
O(13110303\ 3131) &= (\bar{\mu}P_L e)(\bar{s}P_L s), \\
O(13110303\ 3132) &= (\bar{\mu}P_L e)(\bar{s}P_R s), \\
O(13110303\ 4141) &= (\bar{\mu}\gamma_\mu P_L e)(\bar{s}\gamma^\mu P_L s), \\
O(13110303\ 4142) &= (\bar{\mu}\gamma_\mu P_L e)(\bar{s}\gamma^\mu P_R s),
\end{aligned}$$

$$O(13110303\ 4343) = (\bar{\mu}\sigma^{\mu\nu}P_L e)(\bar{s}\sigma_{\mu\nu}P_L s). \quad (6)$$

We also define operators with opposite chiralities by replacing  $P_L$  and  $P_R$  with each other in (6).

- $\tau \rightarrow \mu$  transitions ( $\tau \rightarrow \mu \gamma$ ,  $\tau \rightarrow \mu \mu \mu$ ,  $\tau \rightarrow \mu e^+ e^-$  and  $\tau \rightarrow \mu$  hadrons):

$$O(1513\ 4322) = m_\tau(\bar{\tau}\sigma^{\mu\nu}P_L\mu)F_{\mu\nu},$$

$$O(15131313\ 3131) = (\bar{\tau}P_L\mu)(\bar{\mu}P_L\mu),$$

$$O(15131313\ 4141) = (\bar{\tau}\gamma_\mu P_L\mu)(\bar{\mu}\gamma^\mu P_L\mu),$$

$$O(15131313\ 4142) = (\bar{\tau}\gamma_\mu P_L\mu)(\bar{\mu}\gamma^\mu P_R\mu),$$

$$O(15131111\ 3131) = (\bar{\tau}P_L\mu)(\bar{e}P_L e),$$

$$O(15131111\ 3132) = (\bar{\tau}P_L\mu)(\bar{e}P_R e),$$

$$O(15131111\ 4141) = (\bar{\tau}\gamma_\mu P_L\mu)(\bar{e}\gamma^\mu P_L e),$$

$$O(15131111\ 4142) = (\bar{\tau}\gamma_\mu P_L\mu)(\bar{e}\gamma^\mu P_R e),$$

$$O(15131111\ 4343) = (\bar{\tau}\sigma^{\mu\nu}P_L\mu)(\bar{e}\sigma_{\mu\nu}P_L e),$$

$$O(15130101\ 3131) = (\bar{\tau}P_L\mu)(\bar{d}P_L d),$$

$$O(15130101\ 3132) = (\bar{\tau}P_L\mu)(\bar{d}P_R d),$$

$$O(15130101\ 4141) = (\bar{\tau}\gamma_\mu P_L\mu)(\bar{d}\gamma^\mu P_L d),$$

$$O(15130101\ 4142) = (\bar{\tau}\gamma_\mu P_L\mu)(\bar{d}\gamma^\mu P_R d),$$

$$O(15130101\ 4343) = (\bar{\tau}\sigma^{\mu\nu}P_L\mu)(\bar{d}\sigma_{\mu\nu}P_L d),$$

$$O(15130202\ 3131) = (\bar{\tau}P_L\mu)(\bar{u}P_L u),$$

$$O(15130202\ 3132) = (\bar{\tau}P_L\mu)(\bar{u}P_R u),$$

$$O(15130202\ 4141) = (\bar{\tau}\gamma_\mu P_L\mu)(\bar{u}\gamma^\mu P_L u),$$

$$O(15130202\ 4142) = (\bar{\tau}\gamma_\mu P_L\mu)(\bar{u}\gamma^\mu P_R u),$$

$$O(15130202\ 4343) = (\bar{\tau}\sigma^{\mu\nu}P_L\mu)(\bar{u}\sigma_{\mu\nu}P_L u),$$

$$O(15130303\ 3131) = (\bar{\tau}P_L\mu)(\bar{s}P_L s),$$

$$O(15130303\ 3132) = (\bar{\tau}P_L\mu)(\bar{s}P_R s),$$

$$O(15130303\ 4141) = (\bar{\tau}\gamma_\mu P_L\mu)(\bar{s}\gamma^\mu P_L s),$$

$$\begin{aligned}
O(15130303\ 4142) &= (\bar{\tau}\gamma_\mu P_L \mu)(\bar{s}\gamma^\mu P_R s), \\
O(15130303\ 4343) &= (\bar{\tau}\sigma^{\mu\nu} P_L \mu)(\bar{s}\sigma_{\mu\nu} P_L s).
\end{aligned} \tag{7}$$

Operators with opposite chiralities are also defined.

- We define operators for  $\tau \rightarrow e$  transitions by replacing the muon (code 13) and the electron (code 11) fields with each other in (7).

Effective operators for  $\Delta LF > 1$  leptonic tau decay  $\tau^+ \rightarrow \mu^- e^+ e^+$  are

$$\begin{aligned}
O(15111311\ 3131) &= (\bar{\tau}P_L e)(\bar{\mu}P_L e), \\
O(15111311\ 4141) &= (\bar{\tau}\gamma_\mu P_L e)(\bar{\mu}\gamma^\mu P_L e), \\
O(15111311\ 4142) &= (\bar{\tau}\gamma_\mu P_L e)(\bar{\mu}\gamma^\mu P_R e),
\end{aligned} \tag{8}$$

and those with opposite chiralities. Operators for  $\tau^+ \rightarrow e^- \mu^+ \mu^+$  are defined by replacing the muon and electron fields.

For the processes in which both lepton and quark flavours are violated, such as  $\tau \rightarrow \mu K$ ,  $B^0 \rightarrow \mu \bar{e}$  and so on, relevant operators are as follows,

$$\begin{aligned}
O(03011513\ 3131) &= (\bar{s}P_L d)(\bar{\tau}P_L \mu), \\
O(03011513\ 3132) &= (\bar{s}P_L d)(\bar{\tau}P_R \mu), \\
O(03011513\ 4141) &= (\bar{s}\gamma_\mu P_L d)(\bar{\tau}\gamma^\mu P_L \mu), \\
O(03011513\ 4142) &= (\bar{s}\gamma_\mu P_L d)(\bar{\tau}\gamma^\mu P_R \mu), \\
O(03011513\ 4342) &= (\bar{s}\sigma^{\mu\nu} P_L d)(\bar{\tau}\sigma_{\mu\nu} P_L \mu).
\end{aligned} \tag{9}$$

Definitions of operators with opposite chiralities and/or different quark/lepton flavor combinations are straightforward.

## D Decay constants

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

$$\langle 0 | \bar{q}\gamma^\mu \gamma_5 Q | P(p) \rangle = -i f_P p^\mu, \tag{10}$$

for  $q \neq Q$  quark contents ( $P = \pi^\pm, K, D, B$ ). For  $\pi^0, \eta$  and  $\eta'$ , we define:

$$\frac{1}{\sqrt{2}} \langle 0 | \bar{u}\gamma^\mu \gamma_5 u - \bar{d}\gamma^\mu \gamma_5 d | \pi^0(p) \rangle = -i f_\pi p^\mu, \tag{11}$$

$$\frac{1}{\sqrt{2}} \langle 0 | \bar{u}\gamma^\mu \gamma_5 u + \bar{d}\gamma^\mu \gamma_5 d | \eta^{(\prime)}(p) \rangle = -i f_{\eta^{(\prime)}}^q p^\mu, \tag{12}$$

$$\langle 0 | \bar{s}\gamma^\mu \gamma_5 s | \eta^{(\prime)}(p) \rangle = -i f_{\eta^{(\prime)}}^s p^\mu, \tag{13}$$

assuming isospin symmetry. Other possible choice for  $\eta$  and  $\eta'$  may be:

$$\frac{1}{\sqrt{6}}\langle 0|\bar{u}\gamma^\mu\gamma_5u + \bar{d}\gamma^\mu\gamma_5d - 2\bar{s}\gamma^\mu\gamma_5s|\eta^{(\prime)}(p)\rangle = -if_{\eta^{(\prime)}}^8p^\mu, \quad (14)$$

$$\frac{1}{\sqrt{3}}\langle 0|\bar{u}\gamma^\mu\gamma_5u + \bar{d}\gamma^\mu\gamma_5d + \bar{s}\gamma^\mu\gamma_5s|\eta^{(\prime)}(p)\rangle = -if_{\eta^{(\prime)}}^1p^\mu, \quad (15)$$

In addition, the following matrix elements are defined:

$$(m_q + m_Q)\langle 0|\bar{q}\gamma_5Q|P(p)\rangle = ih_P, \quad (16)$$

$$(m_u + m_d)\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma_5u - \bar{d}\gamma_5d|\pi^0(p)\rangle = ih_\pi, \quad (17)$$

$$(m_u + m_d)\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma_5u + \bar{d}\gamma_5d|\eta^{(\prime)}(p)\rangle = ih_{\eta^{(\prime)}}^q, \quad (18)$$

$$2m_s\langle 0|\bar{s}\gamma_5s|\eta^{(\prime)}(p)\rangle = ih_{\eta^{(\prime)}}^s. \quad (19)$$

The parameters  $h_P$  may be unnecessary except for  $\eta$  and  $\eta'$  since they can be written in terms of other quantities such as  $h_\pi = m_\pi^2 f_\pi$  etc.  $h_{\eta^{(\prime)}}^{q,s}$  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,

$$\langle 0|\bar{q}\gamma^\mu Q|V(p)\rangle = m_V f_V \epsilon^\mu, \quad (20)$$

$$\langle 0|\bar{q}\sigma^{\mu\nu} Q|V(p)\rangle = if_V^T(p^\nu \epsilon^\mu - p^\mu \epsilon^\nu), \quad (21)$$

where  $\epsilon^\mu$  is the polarisation vector of  $V$ .  $f_{\rho,\omega,\phi}$  in the ‘‘ideal mixing’’ limit are defined as:

$$\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma^\mu u - \bar{d}\gamma^\mu d|\rho^0(p)\rangle = m_\rho f_\rho \epsilon^\mu, \quad (22)$$

$$\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma^\mu u + \bar{d}\gamma^\mu d|\omega(p)\rangle = m_\omega f_\omega \epsilon^\mu, \quad (23)$$

$$\langle 0|\bar{s}\gamma^\mu s|\phi(p)\rangle = m_\phi f_\phi \epsilon^\mu. \quad (24)$$

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

$$\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma^\mu u + \bar{d}\gamma^\mu d|\omega(\phi)(p)\rangle = m_{\omega(\phi)} f_{\omega(\phi)}^q \epsilon^\mu, \quad (25)$$

$$\langle 0|\bar{s}\gamma^\mu s|\omega(\phi)(p)\rangle = m_{\omega(\phi)} f_{\omega(\phi)}^s \epsilon^\mu, \quad (26)$$

or

$$\frac{1}{\sqrt{6}}\langle 0|\bar{u}\gamma^\mu u + \bar{d}\gamma^\mu d - 2\bar{s}\gamma^\mu s|\omega(\phi)(p)\rangle = m_{\omega(\phi)} f_{\omega(\phi)}^8 \epsilon^\mu, \quad (27)$$

$$\frac{1}{\sqrt{3}}\langle 0|\bar{u}\gamma^\mu u + \bar{d}\gamma^\mu d + \bar{s}\gamma^\mu s|\omega(\phi)(p)\rangle = m_{\omega(\phi)} f_{\omega(\phi)}^1 \epsilon^\mu. \quad (28)$$

## E Bag parameters

We define the bag parameters  $B_{1,2,3,4,5}$  for  $B_d^0 - \bar{B}_d^0$  mixing matrix elements as follows,

$$\begin{aligned}
\langle B_d^0 | (\bar{d}\gamma_\mu P_L b) (\bar{d}\gamma^\mu P_L b) | \bar{B}_d^0 \rangle &= \frac{2}{3} m_{B_d^0}^2 f_{B_d^0}^2 B_1, \\
\langle B_d^0 | (\bar{d} P_L b) (\bar{d} P_L b) | \bar{B}_d^0 \rangle &= -\frac{5}{12} m_{B_d^0}^2 f_{B_d^0}^2 \left( \frac{m_{B_d^0}}{m_b + m_d} \right)^2 B_2, \\
\langle B_d^0 | (\bar{d}_i P_L b^j) (\bar{d}_j P_L b^i) | \bar{B}_d^0 \rangle &= \frac{1}{12} m_{B_d^0}^2 f_{B_d^0}^2 \left( \frac{m_{B_d^0}}{m_b + m_d} \right)^2 B_3, \\
\langle B_d^0 | (\bar{d} P_L b) (\bar{d} P_R b) | \bar{B}_d^0 \rangle &= \frac{1}{2} m_{B_d^0}^2 f_{B_d^0}^2 \left( \frac{m_{B_d^0}}{m_b + m_d} \right)^2 B_4, \\
\langle B_d^0 | (\bar{d}_i P_L b^j) (\bar{d}_j P_R b^i) | \bar{B}_d^0 \rangle &= \frac{1}{6} m_{B_d^0}^2 f_{B_d^0}^2 \left( \frac{m_{B_d^0}}{m_b + m_d} \right)^2 B_5.
\end{aligned} \tag{29}$$

The renormalization group invariant bag parameter,  $\hat{B}_B$ , can also be defined in function of  $B_1$ .

As for the renormalization scheme for the four-quark operators, quark masses and  $B_i$ , we take the  $\overline{\text{MS}}$  scheme. Bag parameters for  $B_s^0 - \bar{B}_s^0$ ,  $K^0 - \bar{K}^0$  and  $D^0 - \bar{D}^0$  mixings are defined in the same way.

## F FLHA sample file

The following example shows how a generic FLHA file could look. For simplicity, we have chosen a SUSY model, but instead of giving the complete SLHA spectrum, we here present it only as a generic FLHA model, i.e., using FMODESEL to specify the model switches rather than MODSEL, which would necessitate repeating a complete SLHA spectrum. For examples of the latter, see the SLHA manuals [14, 15]. Some lines in the blocks FOBS and FOBSMS are broken for better readability.

```

# SuperIso output in Flavour Les Houches Accord format
Block FCINFO # Program information
  1 SUPERISO # flavour calculator
  2 2.8 # version number
Block FMODESEL # Model selection
  1 1 # Minimal supergravity (mSUGRA, CMSSM) model
  6 1 # Quark flavour is violated
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)
Block MINPAR # SUSY breaking input parameters
1      1.00000000E+03 # m_0
2      5.00000000E+02 # m_{1/2}
3      1.00000000E+01 # tan(beta)
4      1.00000000E+00 # sign(mu)
5      -5.00000000E+02 # A_0
Block FMASS # Mass spectrum in GeV
#PDG_code mass          scheme scale          particle
3      1.04000000e-01  1    2.00000000e+00 # s (MSbar)
5      4.68767577e+00  3    0              # b (1S)
211   1.39600000e-01  0    0              # pi+
313   8.91700000e-01  0    0              # K*
321   4.93700000e-01  0    0              # K+
421   1.86962000e+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  1.92800000e-01 # B+
531   1  2.38800000e-01 # B_s
Block FCONSTRATIO # Ratio of decay constants
#PDG_code1 code2 nb1 nb2 ratio          comment
321   211  1  1  1.18900000e+00 # f_K/f_pi
Block FPARAM # Process dependent parameters
# ParentPDG number value          NDA ID1 ID2 ID3 ... comment
5     1  5.80000000e-01  2    3  22          # C in b->s gamma
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 in B->K* gamma
Block FWCOEF Q= 1.60846e+02 # Wilson coefficients at scale Q
#id          order M value          comment
03040405 6161  00  2  0.00000000e+00 # C1^0
03040405 4141  00  2  1.00000000e+00 # C2^0
0305 4422  00  2 -1.82057564e-01 # C7^0
0305 6421  00  2 -1.06651568e-01 # C8^0

```

```

03040405 6161 01 2 2.33177662e+01 # C1^1
03040405 4141 01 2 0.00000000e+00 # C2^1
03050707 6153 01 2 5.29677461e-01 # C4^1
    0305 4422 01 2 1.35373179e-01 # C7^1
    0305 6421 01 2 -6.94496405e-01 # C8^1
03040405 6161 02 2 3.08498153e+02 # C1^2
03040405 4141 02 2 4.91587899e+01 # C2^2
03050707 4133 02 2 -7.01872509e+00 # C3^2
03050707 6153 02 2 1.25624440e+01 # C4^2
03050707 4536 02 2 8.76122785e-01 # C5^2
03050707 6556 02 2 1.64273022e+00 # C6^2
    0305 4422 02 2 7.05439463e-01 # C7^2
    0305 6421 02 2 -4.65529650e+00 # C8^2

```

Block FOBS # Flavour observables

#	ParentPDG	type	value	q	NDA	ID1	ID2	ID3	...	comment
5	1	1	2.95061156e-04	0	2	3	22			# BR(b->s gamma)
521	4	1	8.35442304e-02	0	2	313	22			# Delta0(B->K* gamma)
531	1	1	3.24270419e-09	0	2	13	-13			# BR(B_s->mu+ mu-)
521	1	1	1.00400993e-04	0	2	-15	16			# BR(B_u->tau nu)
521	2	1	9.96640362e-01	0	2	-15	16			# R(B_u->tau nu)
431	1	1	4.81249536e-02	0	2	-15	16			# BR(D_s->tau nu)
431	1	1	4.96944761e-03	0	2	-13	14			# BR(D_s->mu nu)
521	1	1	6.89944090e-03	0	3	421	-15	16		# BR(B->D0 tau nu)
521	11	1	2.97284656e-01	0	3	421	-15	16		# BR(B->D0 tau nu)/ BR(B->D0 e nu)
321	11	1	6.43078116e-01	0	2	-13	14			# BR(K->mu nu)/ BR(pi->mu nu)
321	12	1	9.99985344e-01	0	2	-13	14			# R_l23

Block FOBSSM # SM predictions for flavour observables

#	ParentPDG	type	value	q	NDA	ID1	ID2	ID3	...	comment
5	1	1	3.04263066e-04	0	2	3	22			# BR(b->s gamma)
521	4	1	8.28999878e-02	0	2	313	22			# Delta0(B->K* gamma)
531	1	1	3.21303763e-09	0	2	13	-13			# BR(B_s->mu+ mu-)
521	1	1	1.00846830e-04	0	2	-15	16			# BR(B_u->tau nu)
521	2	1	1.00000000e+00	0	2	-15	16			# R(B_u->tau nu)
431	1	1	4.82243559e-02	0	2	-15	16			# BR(D_s->tau nu)
431	1	1	4.97534286e-03	0	2	-13	14			# BR(D_s->mu nu)
521	1	1	6.91312984e-03	0	3	421	-15	16		# BR(B->D0 tau nu)
521	11	1	2.97532370e-01	0	3	421	-15	16		# BR(B->D0 tau nu)/ BR(B->D0 e nu)
321	11	1	6.43096966e-01	0	2	-13	14			# BR(K->mu nu)/ BR(pi->mu nu)
321	12	1	1.00000000e+00	0	2	-13	14			# R_l23



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