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Flavour Les Houches Accord: Interfacing Flavour related Codes

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Abstract

We present the Flavour Les Houches Accord (FLHA) which specifies a 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, renormalisation group equation (RGE) running including flavour effects have recently been developed [1–4]. Flavour-related observables are also implemented by many other non-dedicated public codes to provide additional checks for the models under investigation [5–13]. The results are often subsequently used by other codes, e.g. as constraints on the parameter space of the model under consideration [14–17].

At present, a small number of specialised interfaces between the various codes exist. Such tailor-made interfaces are not easily generalised 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) [18, 19], 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. [18, 19]. While the first definitions, SLHA1 [18], concerned the simplest version of the MSSM, the SLHA2 [19] also included definitions for the case of complex parameters, R -parity violation, non-minimal flavour violation etc.

The goal of this article is to exploit the existing organisational 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 standardised format will provide the users with a clear and well-structured result that could eventually be used for other purposes. We stress that in cases of ambiguity in the precise definition of a given quantity, it is the responsibility of the authors of the specific program to document in detail the definition they use.

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 [20]. 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 choice of model in a specific block, the general structure used for the information exchange can be applied to any model.

2 Definitions of the interfaces

The FLHA input and output files are described in this section.

2.1 General structure

Following the general structure for the SLHA [18, 19] we assume the following:

- All quantities with dimensions of energy (mass) are 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. The first character of data lines should be 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 E16.8¹. 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 G.
- 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”.

¹E16.8: 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 fall-back solution by generalising the SLHA block MODSEL. This takes 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, such that FMODESEL is redundant and should in most cases be absent. In case it is present and there are conflicts, the most specific accord takes precedence, such that internal consistency of the accord with the smallest scope is guaranteed. In the case of MODSEL vs. FMODESEL, MODSEL would thus take precedence, however it would be prudent to issue warnings if both are present, especially if their contents differ. Also note that although there is the possibility to reuse more specific accords, one is not forced to do so. Thus, even for a SUSY model, an FLHA user who does not wish to deal with an entire SLHA spectrum could just 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. [18].

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 FDIPOLE: Prediction of electric and magnetic dipole moments.
- 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).

A string is as usual a sequence of ASCII characters. 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. It is defined as in the 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 that one only uses BLOCK MODSEL for SLHA models and 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 violation is completely neglected. 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 parameters specific to other models. It is advised that all such 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 universally recognised.

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. α_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 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 (with 5 active flavours).
- 6 : m_t , top quark pole mass.
- 7 : m_τ , tau 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 , and also the PDG parameterisation for the phase convention. For the output we use the SLHA2 blocks VCKM and IMVCKM which do not rely on any specific convention.

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 parameterisation, Eq. (13.30) of Ref. [21]. All the angles and phases should be given in radians. For the output we use BLOCK UPMNS and BLOCK IMUPMNS, exactly in the same way as in SLHA2.

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 renormalisation 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 renormalisation 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 : $\overline{\text{MS}}$
- 2 : $\overline{\text{DR}}$
- 3 : 1S
- 4 : kin
- 5 : ...

For the definition of $\overline{\text{DR}}$ scheme see [22, 23].

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

$$(1\text{x}, \text{I9}, 3\text{x}, 1\text{P}, \text{E16.8}, 0\text{P}, 3\text{x}, \text{'\#'}, 1\text{x}, \text{A}),$$

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 renormalisation scheme and scale are also specified to allow for large flexibility. The standard for each line in the block should correspond to the FORTRAN format

$$(1\text{x}, \text{I9}, 3\text{x}, \text{I2}, 3\text{x}, 1\text{P}, \text{E16.8}, 0\text{P}, 3\text{x}, \text{I2}, 3\text{x}, 1\text{P}, \text{E16.8}, 0\text{P}, 3\text{x}, \text{'\#'}, 1\text{x}, \text{A}),$$

where the first nine-digit integer should be the PDG code of a particle, the second integer the number associated with the decay constant, the double precision number the value of this decay constant, the following integer stands for the renormalisation scheme (see below) and finally the last double precision number indicates the renormalisation scale Q (0 in the case of renormalisation group invariant parameters). An additional comment could be given after #.

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 GeV^3

221 : η
 1 : f_η^q in GeV
 2 : f_η^s in GeV
 11 : h_η^q in GeV³
 12 : h_η^s in GeV³

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

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

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

Finally, the schemes are defined as follows:

0 : renormalisation group invariant (with renormalisation scale
 set to 0)
 1 : $\overline{\text{MS}}$
 2 : MOM
 3 : SMOM
 4 : ...

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,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`, the double precision number the ratio of the decay constants and the following integer stands for the renormalisation scheme and finally the last double precision number indicates the renormalisation scale Q in the same way as in `BLOCK FCONST`.

BLOCK FBAG

The block **BLOCK FBAG** contains the bag parameters. The renormalisation 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 renormalisation scheme and finally the last double precision number indicates the renormalisation scale Q (0 in the case of renormalisation 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 in the same way as in **BLOCK FCONST** and the Bag parameter definitions and normalisations 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 normalisation as given in that appendix (the detailed information about the scheme and the normalisation of the effective interactions has to be provided in the program manual, and a short comment can be given in the FLHA file).

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

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:

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

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

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

The first two entries on each line in `BLOCK FWCDEF` 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 normalisation etc. , but together act as a unique identifier for any possible Wilson coefficient. Consequently, the user has to take care that a consistent normalisation including prefactors etc. is used in specifying the Wilson coefficients. The most relevant operators are listed in Appendix C. As an example, for the operator O_1 ,

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

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 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 $\mathcal{O}(\alpha^y)$, and 0 indicates $C_i^{(0)}$, e.g.:

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

operator	number	operator	number	operator	number
1	30	T^a	50	δ_{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
γ^μ	33	$\gamma^\mu T^a$	53	$\gamma^\mu \delta_{ij}$	73
γ_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.

- 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 FMODESEL`.

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.

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 predictions for 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. More details and definitions regarding the meson mixing are provided in Appendix F.

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 FDIPOLE

The block **BLOCK FDIPOLE** contains the predictions for the electric and magnetic dipole moments. The standard for each line in the block should correspond to the FORTRAN format

```
(1x,I10,3x,I1,3x,I1,3x,1P,E16.8,0P,3x,'#',1x,A),
```

where the first ten-digit integer should be the PDG code of a particle, the second integer the type (electric or magnetic), the next integer the model (SM, NP or SM+NP, as in **FWCOEF**) and finally the last double precision number the value of the moment. The electric dipole moments must be given in e.cm unit.

The PDG codes for the nuclei follows the PDG particle numbering scheme [21]: “Nuclear codes are given as 10-digit numbers $\pm 10LZZZAAAI$. For a (hyper)nucleus consisting of n_p protons, n_n neutrons and n_Λ Λ ’s, $A = n_p + n_n + n_\Lambda$ gives the total baryon number, $Z = n_p$ the total charge and $L = n_\Lambda$ the total number of strange quarks. I gives the isomer level, with $I = 0$ corresponding to the ground state (...). To avoid ambiguities, nuclear codes should not be applied to a single hadron, like p , n or Λ^0 , where quark-contents-based codes already exist.” As an example, the PDG code of the deuteron is 1000010020.

The types of the moments are defined as follows:

- 1 : electric
- 2 : magnetic

The electric and magnetic moments can be given for the SM only, the New Physics (NP) only or the total contributions of both SM and NP, using the following definitions:

- 0 : SM
- 1 : NP
- 2 : SM+NP

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 set of conventions in ASCII file format for the most commonly investigated flavour-related observables and provides a universal framework for interfacing different programs.

The presented accord will be further developed according to the user feedbacks and special needs of specific codes. Some discussions in this direction were held during Les Houches 2011 workshop [24], which led to a few clarifications and additions (included in the current manuscript).

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.

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A The PDG Particle Numbering Scheme

Listed in the table below are the PDG codes for some important SM mesons. Codes for other particles may be found in [21].

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

Table 3: PDG codes for most commonly considered mesons.

B Two-Higgs Doublet Model

The charged Higgs boson couplings to fermions for the Two-Higgs Doublet Model (THDM) can be expressed as

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

where U , D and ℓ stand, respectively, for the up-type quarks, the down-type quarks and the leptons. The conventions used for the four types of Z_2 -symmetric 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	λ^U	λ^D	λ^ℓ
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 λ^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 flavour violations

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

- $\mu \rightarrow e$ transitions ($\mu \rightarrow e \gamma$, $\mu \rightarrow e e e$ 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,

$$\begin{aligned}
O(03011513 \ 3131) &= (\bar{s} P_L d)(\bar{\tau} P_L \mu) , \\
O(03011513 \ 3132) &= (\bar{s} P_L d)(\bar{\tau} P_R \mu) , \\
O(03011513 \ 4141) &= (\bar{s}\gamma_\mu P_L d)(\bar{\tau}\gamma^\mu P_L \mu) , \\
O(03011513 \ 4142) &= (\bar{s}\gamma_\mu P_L d)(\bar{\tau}\gamma^\mu P_R \mu) , \\
O(03011513 \ 4343) &= (\bar{s}\sigma^{\mu\nu} P_L d)(\bar{\tau}\sigma_{\mu\nu} P_L \mu) .
\end{aligned} \tag{9}$$

Definitions of operators with opposite chiralities and/or different quark/lepton flavour 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 π^0, η and η' , we define:

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

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

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

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

$$\frac{1}{\sqrt{6}}\langle 0|\bar{u}\gamma^\mu\gamma_5 u + \bar{d}\gamma^\mu\gamma_5 d - 2\bar{s}\gamma^\mu\gamma_5 s|\eta^{(\prime)}(p)\rangle = -if_{\eta^{(\prime)}}^8 p^\mu, \quad (14)$$

$$\frac{1}{\sqrt{3}}\langle 0|\bar{u}\gamma^\mu\gamma_5 u + \bar{d}\gamma^\mu\gamma_5 d + \bar{s}\gamma^\mu\gamma_5 s|\eta^{(\prime)}(p)\rangle = -if_{\eta^{(\prime)}}^1 p^\mu. \quad (15)$$

In addition, the following matrix elements are defined:

$$(m_q + m_Q)\langle 0|\bar{q}\gamma_5 Q|P(p)\rangle = ih_P, \quad (16)$$

$$(m_u + m_d)\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma_5 u - \bar{d}\gamma_5 d|\pi^0(p)\rangle = ih_\pi, \quad (17)$$

$$(m_u + m_d)\frac{1}{\sqrt{2}}\langle 0|\bar{u}\gamma_5 u + \bar{d}\gamma_5 d|\eta^{(\prime)}(p)\rangle = ih_{\eta^{(\prime)}}^q, \quad (18)$$

$$2m_s\langle 0|\bar{s}\gamma_5 s|\eta^{(\prime)}(p)\rangle = ih_{\eta^{(\prime)}}^s. \quad (19)$$

The parameters h_P may be unnecessary except for η and η' 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 ρ^\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 ϵ^μ 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 flavour combinations. It is possible to define decay constants of ω and ϕ as

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

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

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 renormalisation group invariant bag parameter, \hat{B}_B , can also be defined in function of B_1 . 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 Meson mixings

Meson mixing is assigned observable type 7 in BLOCK FOBS. In the FLHA, we assume the standard definition for the meson mixings. The oscillation frequency of Q_q^0 and \bar{Q}_q^0 mixing is characterised by the mass difference of the heavy and light mass eigenstates [25]:

$$\Delta M_q \equiv M_H^q - M_L^q = 2\text{Re} \sqrt{(M_{12}^q - \frac{i}{2}\Gamma_{12}^q)(M_{12}^{q*} - \frac{i}{2}\Gamma_{12}^{q*})}, \tag{30}$$

where M_{12} and Γ_{12} are the transition matrix elements from virtual and physical intermediate states respectively. For the kaon systems this gives:

$$\Delta M_K = 2\text{Re} M_{12}. \tag{31}$$

In the case of $\Delta B = 2$ transitions since $|\Gamma_{12}| \ll |M_{12}|$, one can write:

$$\langle B_q^0 | \mathcal{H}_{\text{eff}}^{\Delta B=2} | \bar{B}_q^0 \rangle = 2M_{B_q} M_{12}^q, \tag{32}$$

where M_{B_q} is the mass of B_q meson and

$$\Delta M_q = 2|M_{12}^q|. \tag{33}$$

The quantity given in the block is ΔM_q and the units are fixed to 1/ps. We use the PDG number of the oscillating mesons for the parent and the flipped sign for the daughter.² The number of daughters is fixed to 1. For example, the $B_s - \bar{B}_s$ oscillation frequency is given as:

² Exceptions to this rule are possible, for instance, in the case of $K - \bar{K}$ mixing, where the states K_{long} and K_{short} with their PDG numbers 130 and 310, respectively, can be used.

Block FOBS # Flavour observables

# ParentPDG	type	value	q	NDA	ID1	ID2	ID3	...	comment
531	7	1.9e01	0	1	-531	# Delta M_s			

Similarly, the corresponding SM values and the errors can be given in BLOCK FOBSSM and BLOCK FOBSERR, respectively. Note that the matrix elements (which are not physical observables) cannot be given in this block. Such quantities can be expressed in terms of Wilson coefficients, decay constants, bag parameters, etc. which are defined in the FLHA, or they can be given in a user defined block.

G FLHA sample file

The following is an example of a generic FLHA file. For simplicity, we have chosen a SUSY model, but instead of giving the complete SLHA spectrum, we here present it as a generic FLHA model. Therefore we use FMODESEL to specify the model switches rather than using MODSEL, which would necessitate repeating the complete SLHA spectrum. For examples of the latter, see the SLHA manuals [18, 19]. 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    3.2              # 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    1.27934000e+02   # alpha_em^(-1)
  2    1.16637000e-05   # G_Fermi
  3    1.18400000e-01   # alpha_s(M_Z)
  4    9.11876000e+01   # m_{Z}(pole)
  5    4.19000000e+00   # m_{b}(m_{b})
  6    1.72900000e+02   # m_{top}(pole)
  7    1.77700000e+00   # m_{tau}(pole)
Block MINPAR # SUSY breaking input parameters
  1    8.00000000E+02   # m_0
  2    5.00000000E+02   # m_{1/2}
  3    2.00000000E+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    4.68474767e+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	1.86960000e+00	0	0		# D0
431	1.96847000e+00	0	0		# D_s+
521	5.27917000e+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	scheme	scale	particle
431	1	2.48000000e-01	0	0	# D_s+
521	1	1.92800000e-01	0	0	# B+
531	1	2.38800000e-01	0	0	# B_s

Block FCONSTRATIO # Ratio of decay constants

#PDG_code1	code2	nb1	nb2	ratio	scheme	scale	comment
321	211	1	1	1.19300000e+00	0	0	# 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	1.03000000e+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	2.68000000e-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	-1.53496321e-01	# C7^0
0305 6421	00	2	-9.51462419e-02	# C8^0
03040405 6161	01	2	2.33177662e+01	# C1^1
03040405 4141	01	2	0.00000000e+00	# C2^1
03050707 6153	01	2	5.29858390e-01	# C4^1
0305 4422	01	2	-4.27127914e-01	# C7^1
0305 6421	01	2	-1.06024128e+00	# C8^1
03040405 6161	02	2	3.08457152e+02	# C1^2
03040405 4141	02	2	4.91587899e+01	# C2^2
03050707 4133	02	2	-6.99555993e+00	# C3^2
03050707 6153	02	2	1.25585165e+01	# C4^2
03050707 4536	02	2	8.73907482e-01	# C5^2
03050707 6556	02	2	1.63857653e+00	# C6^2
0305 4422	02	2	8.40063580e-01	# C7^2
0305 6421	02	2	-4.61747635e+00	# C8^2

```

Block FDIPOLE # Electric and Magnetic dipole moments
# PDG_code type M value comment
13 2 1 5.00716589e-10 # 1/2 (g-2)_mu

Block FOBS # Flavour observables
# ParentPDG type value q NDA ID1 ID2 ID3 ... comment
5 1 2.83249483e-04 0 2 3 22 # BR(b->s gamma)
521 4 8.78354299e-02 0 2 313 22 # Delta0(B->K* gamma)
531 1 3.44359657e-09 0 2 13 -13 # BR(B_s->mu+ mu-)
521 1 9.89829667e-05 0 2 -15 16 # BR(B_u->tau nu)
521 2 9.81528344e-01 0 2 -15 16 # R(B_u->tau nu)
431 1 5.10125129e-02 0 2 -15 16 # BR(D_s->tau nu)
431 1 5.23481907e-03 0 2 -13 14 # BR(D_s->mu nu)
521 1 6.71755629e-03 0 3 421 -15 16 # BR(B->D0 tau nu)
521 11 2.96312243e-01 0 3 421 -15 16 # BR(B->D0 tau nu)/
BR(B->D0 e nu)
321 11 6.34141764e-01 0 2 -13 14 # BR(K->mu nu)/
BR(pi->mu nu)
321 12 9.99918554e-01 0 2 -13 14 # R_123

Block FOBSSM # SM predictions for flavour observables
# ParentPDG type value q NDA ID1 ID2 ID3 ... comment
5 1 3.10589604e-04 0 2 3 22 # BR(b->s gamma)
521 4 8.33856375e-02 0 2 313 22 # Delta0(B->K* gamma)
531 1 3.30981324e-09 0 2 13 -13 # BR(B_s->mu+ mu-)
521 1 1.00845755e-04 0 2 -15 16 # BR(B_u->tau nu)
521 2 1.00000000e+00 0 2 -15 16 # R(B_u->tau nu)
431 1 5.10235109e-02 0 2 -15 16 # BR(D_s->tau nu)
431 1 5.23594766e-03 0 2 -13 14 # BR(D_s->mu nu)
521 1 6.74263430e-03 0 3 421 -15 16 # BR(B->D0 tau nu)
521 11 2.97418437e-01 0 3 421 -15 16 # BR(B->D0 tau nu)/
BR(B->D0 e nu)
321 11 6.34245073e-01 0 2 -13 14 # BR(K->mu nu)/
BR(pi->mu nu)
321 12 1.00000000e+00 0 2 -13 14 # R_123

```

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