91. A Note on the Heavy Flavor Averaging Group

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The Heavy Flavor Averaging Group (HFLAV)* is an international collaboration of physicists from experiments measuring properties of heavy flavored particles, *i.e.*, hadrons containing b and c quarks, and τ leptons. HFLAV calculates for the HEP community world average values of quantities such as lifetimes, branching fractions, form factors, mixing parameters, and CP-violating asymmetries. Most parameters concern decays of B and D mesons, and many are related to elements of the Cabibbo-Kobayashi-Maskawa (CKM) quark mixing matrix [1,2].

HFLAV was originally formed in 2002 to continue the activities of the LEP Heavy Flavor Steering group. Since its inception a wide range of results have become available from increasingly larger data sets, and consequently HFLAV has expanded to include seven subgroups. These are as follows:

- b-hadron lifetimes and oscillations, including parameters of CP violation in b mixing;
- decay-time-dependent CP violation in B decays, and angles of the CKM Unitarity Triangle;
- semileptonic decays of b-hadrons ($B \to X\ell\nu$, $\ell = e, \mu, \tau$), including determinations of the CKM matrix elements $|V_{cb}|$ and $|V_{ub}|$;
- b-hadron decays to hadronic final states containing c-quarks (open charm and charmonium);
- (rarer) b-hadron decays to final states not containing c-quarks, including fully hadronic, semileptonic ($B \to X\ell\ell, X\nu\bar{\nu}$), leptonic, and radiative decays;
- c-hadron physics including branching fractions, CP- and T-violating asymmetries, D^0–$\bar{D}^0$ mixing, semileptonic decays, and properties of excited D states and charm baryons;
- τ-lepton physics including branching fractions, tests of lepton universality, determination of the CKM matrix element $|V_{us}|$, and searches for lepton flavor violation.

Each subgroup has one or two conveners and typically a half-dozen members representing experiments making measurements in that area. Most groups contain representatives from the Belle, BaBar, and LHCb experiments, while some groups contain representatives from the BESIII, CLEO(c), CDF, and DØ experiments. Members of HFLAV are appointed by their respective experimental collaborations. There are two co-leaders of HFLAV; these were originally appointed by the managements of the BaBar and Belle experiments and are now appointed by the managements of Belle/Belle II and LHCb.

The averaging procedures used by HFLAV are similar to those of the PDG [3]. When calculating world averages, common parameters used for different input measurements are adjusted (rescaled) to common values. The confidence level of the fit is provided to indicate the consistency of the measurements included in the average. However,

* The group was originally referred to as "HFAG." This acronym was changed to "HFLAV" in 2017.

unlike the PDG, in the case of obtaining a world average with a small confidence level (*i.e.*, a large χ^2 per degree of freedom), HFLAV does not usually scale the resulting uncertainty. Rather, the systematic uncertainties of the measurements are reviewed with experts from the experiments to understand the discrepancy. Unless inconsistencies among measurements are found, no correction is made to the calculated uncertainty. Close communication between representatives of the experiments and HFLAV members performing averages help ensure that measurement uncertainties, known correlations, and systematic effects are properly accounted for. If special treatment is needed to calculate an average, or if an approximation used in an average calculation might not be sufficiently accurate (*e.g.*, assuming Gaussian errors when the likelihood function is non-Gaussian), a note is included to describe this.

In general, HFLAV uses all publicly available results that have written documentation such as a journal publication, preprint, or conference note. These include preliminary results presented at conferences and workshops. However, preliminary results that remain unpublished for an extended period of time, or for which no publication is planned, are not included. A special subset of HFLAV averages are included in the PDG Listings; for these averages only measurements that are published or accepted for publication are used. The averages provided by HFLAV are listed by the PDG as "OUR EVALUATION" with a corresponding note.

All HFLAV averages and input measurements are documented in an approximately biennial preprint posted to the arXiv preprint server; the most recent version is Ref. 4. The latest results and plots are posted on an extensive set of webpages that are updated several times per year; these are available at

`http://www.slac.stanford.edu/xorg/hflav` .

References:

1. N. Cabibbo, Phys. Rev. Lett. **10**, 531 (1963).
2. M. Kobayashi and T. Maskawa, Prog. Theor. Phys. **49**, 652 (1973).
3. See Section 5 of the "Introduction" to this *Review*.
4. Y. Amhis *et al.* [HFLAV Group], `arXiv:1612.07233 [hep-ex]`.