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 and publishes [1] 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 [2], [3].

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. Consequently, HFLAV has expanded to include eight subgroups:

- 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;
- CP- and T-violating asymmetries of D mesons and D^0–$\bar{D}^0$ mixing;
- c-hadron decays (hadronic, semileptonic, leptonic), properties of excited D states and charm baryons and determination of $|V_{cs}|$ and $|V_{cd}|$;
- τ-lepton physics including branching fractions, tests of lepton universality, determination of $|V_{us}|$, and searches for lepton flavor violation.

Each subgroup has one or two conveners and typically a half-dozen members representing experiments that conduct measurements in that area. Most groups contain representatives from the Belle II and LHCb experiments, and some groups have representatives from the ATLAS, BABAR, Belle, BESIII and CMS experiments. Members of HFLAV are appointed by their respective experimental collaborations. HFLAV has two co-leaders, who are appointed by the managements of Belle II and LHCb.

The averaging procedures used by HFLAV are similar to those of the PDG [4]. When sufficient information is available in publications when calculating world averages, common parameters used for different input measurements are adjusted (rescaled) to common values. The p-value of the fit is provided to indicate the consistency of the measurements included in the average. However, unlike the PDG, when obtaining a world average with a low p-value (*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 who perform averages helps ensure that measurement uncertainties, known correlations, and systematic effects are properly accounted for. If a 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 uncertainties when the likelihood function is non-Gaussian), a note is included in the HFLAV publication and online documentation 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 journal paper or preprint; the most recent version is Ref. [1]. The latest results and plots are posted on an extensive set of webpages that are updated several times per year; these are available at

`https://hflav.web.cern.ch`.

References:

1. Y. Amhis *et al.* (Heavy Flavor Averaging Group), Eur. Phys. J. C **81**, 226 (2021), [arXiv:1909.12524], updated results, plots available at `https://hflav.web.cern.ch/`.
2. N. Cabibbo, Phys. Rev. Lett. **10**, 531 (1963).
3. M. Kobayashi and T. Maskawa, Prog. Theor. Phys. **49**, 652 (1973).
4. See Section 5 of the "Introduction" to this *Review*.