

## A NOTE ON HFAG ACTIVITIES

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The Heavy Flavor Averaging Group (HFAG) is an international collaboration of physicists from experiments measuring properties of heavy flavored particles. HFAG 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  $\tau$  leptons, and many are related to elements of the Cabibbo-Kobayashi-Maskawa (CKM) quark mixing matrix [1,2].

HFAG 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 HFAG 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 ( $B \rightarrow X\ell\nu$ ,  $\ell = e, \mu, \tau$ ), 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 ( $B \rightarrow X\ell\ell, X\nu\bar{\nu}$ ), 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;
- $\tau$ -lepton physics including lepton universality tests, 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 currently or recently making measurements in that area. Most groups contain representatives from the Belle, BaBar, and LHCb experiments, while some groups contain representatives or contacts from the BESIII, CLEO(c), CDF and DØ experiments. Members of HFAG are appointed by their respective experimental collaborations. There are two co-leaders of HFAG; these were originally appointed by the managements of the BaBar and Belle collaborations and are now appointed by the managements of Belle/Belle II and LHCb.

The averaging procedures used by HFAG are similar to those of the PDG [3], but there are some differences. When calculating world averages, common input parameters used in the different analyses are adjusted (rescaled) to common values. Close communication between representatives of the experiments and HFAG members performing averaging calculations help ensure that measurement uncertainties, known correlations, and systematic effects are properly accounted for. The confidence level of the fit is provided to indicate the consistency of the measurements included in the average. In the case of obtaining a world average with a small confidence level, *i.e.*, a large  $\chi^2$  per degree of freedom, HFAG does not usually scale the resulting uncertainty as the PDG does. Rather, the systematic uncertainties of each input measurement are reviewed with experts from the experiments to better understand the discrepancy. Unless inconsistencies between the measurements are found, no correction is made to the calculated uncertainty. If special treatment is necessary to calculate an average, or in case an approximation used in an average calculation might not be sufficiently accurate (*e.g.*, assuming Gaussian errors when the likelihood function indicates non-Gaussian behavior), a note is included to describe this treatment.

In general, HFAG 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 or 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 HFAG world averages are included in the PDG Listings. For these averages, the standard fitting procedures are performed but only input measurements that are published or accepted for publication are used. The averages provided by HFAG are listed by the PDG as “OUR EVALUATION” with a corresponding note.

All HFAG world averages and listings of all 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/hfag>.

**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.* [HFAG Collab.], [arXiv:1412.7515](https://arxiv.org/abs/1412.7515).