Averaging Methodology

Method
- We focus on the problem of combining measurements obtained with different assumptions about external (nuisance) parameters and the correlation of systematic uncertainties across them.

- We define the $\chi^2$ statistic for the average, where we consider cases that the parameter of interest is not measured directly, but as a quantity that is a function of (multiple) observables.

$$\chi^2(p) = \sum_i N \left( \frac{f_i(p) - \bar{x}_i}{\sigma_i} \right)^2 + \sum_i \frac{\left( f_i(p) - \bar{x}_i \right)^2}{\Delta x_i^2}$$

Treatment of correlated systematic uncertainties
- Knowledge of external (nuisance) parameters often improve after publication, and can be easily incorporated when the unconstrained Likelihoods are provided.
- If they are not provided, we adjust the central values and correlated systematic uncertainties linearly for each measurement and each external parameter and combine the adjusted measurements.

Semileptonic $b \rightarrow c/u/\ell\nu$ Decays

Combined extraction of $|V_{ub}|$ and $|V_{cb}|$
- Includes measured ratios of $|V_{ub}|/|V_{cb}|$ and $\sigma$.

$|V_{ub}| = 0.175 \pm 0.017$ in the Standard Model.

$|V_{cb}| = (39.10 \pm 0.50) \times 10^{-3}$

CP violation.

3. no weak phases in D decays and
2. assuming

- Combined $\chi^2$ extraction of $|V_{ub}|$ and $|V_{cb}|$

$|V_{ub}| = (3.51 \pm 0.12) \times 10^{-3}$

$|V_{cb}| = (39.10 \pm 0.50) \times 10^{-3}$

Charm CP Violation and Oscillations

$D^0-\bar{D}^0$ mixing and CP Violation
- Combined $\chi^2$ fit of 61 observables, extracting 10 parameters of interest.

- Different fit scenarios studied: 1. assuming CP conservation, 2. no weak phases in D decays, 3. no weak phases in D decays and including theory parameters, 4. allowing full CP violation.

- Conclusions:
  - $x = y = 0$ (no-mixing) excluded at >1.5σ.
  - $x_0$ positive $\rightarrow$ CP-even state short-lived
  - $x_0$ positive $\rightarrow$ CP-even state heavier
  - No evidence for $\phi_0 \neq 0$.

Interplay between direct and indirect CP violation
- CP asymmetry measurements in $D^0$ decays have contributions from direct and indirect CP.

- The contribution of indirect CP depends on the decay-time distribution of the data.

- We perform a $\chi^2$ fit to disentangle both contributions.

$\Delta x_{CP} = (0.010 \pm 0.012) \%$

- No-CP violation hypothesis rejected with 5.4σ.

Charm Decays

$|V_{ub}|$ and $|V_{cb}|$
- Obtained from leptonic $D^+ \rightarrow \mu^+\nu$ and $D^+ \rightarrow \tau^-\nu$ decays.

- Lattice QCD calculations for the decay constants have improved, reducing the theoretical uncertainty <15%.

$|V_{ul}| = 0.2181 \pm 0.0049 \pm 0.0007$

$|V_{ul}| = 0.9839 \pm 0.0115 \pm 0.0020$

-charm matrix elements agree with the indirect determinations via the unitarity constraint.

And More!

- The HFLAV report is over 500 pages long and provides much more detail and many more results than presented on this poster. Our other covered topics include:
  - $b$-hadron production fractions,
  - lifetimes and mixing parameters of $b$ hadrons,
  - decays of $b$-hadrons into open or hidden charm hadrons, and into charmless final states,
  - $c$ charm decays,
  - tau lepton properties.

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