PROCEEDINGS OF SCIENCE

CP violation summary

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In the two sessions devoted to CP violation, rich physics results have been reported by speakers from D0, CDF, LHCb, Belle, and BaBar. In addition, a useful phenomenological review has been given. There are a few measurements that show possible deviations from the standard model as well as those with significantly improved precisions. We briefly mention some highlights in this short summary.

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1. Mixing and semileptonic asymmetries

The D0 experiment has reported a result on the dilepton asymmetry defined by

$$A_{sl}^{b} \equiv \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}}$$

which is related to the wrong-sign single lepton asymmetries of B_d and B_s, $a_{sl}^{d,s}$, by

$$A_{sl}^{b} = (0.506 \pm 0.043) a_{sl}^{d} + (0.494 \pm 0.043) a_{sl}^{d} \,.$$

The contributions from B_d and B_s are roughly equal since B_s is produced less but its mixing is larger. After correcting for the asymmetries due to backgrounds and detector, it is measured to be

$$A_{sl}^{b} = 0.957 \pm 0.251_{\rm stat} \pm 0.146_{\rm sys}\% \,.$$

Fig.1(left) shows the result in the 2-dimensional space of a_{sl}^{s} vs a_{sl}^{d}. The deviation from SM is 3.2σ, while it is consistent with previous measurements. It is considered impossible that this deviation is reproduced by assumption of no tree-level new physics. At LHCb, there are large production asymmetries due to pp collision, the difference between a_{sl}^{s} and a_{sl}^{d}, however, can be measured with small systematics. The expected resolution with $1 fb^{-1}$ is shown in the figure as a yellow line.

Deviation from SM of the B_s mixing can be parametrized by

$$M_{12}^{\rm full} = C_{Bs} e^{2i\phi_{Bs}} M_{12}^{SM} \,.$$

Current result for B_s is shown in Fig.1(right). While the absolute value of M_{12} is consistent with SM, its phase is 3.2σ away from SM.

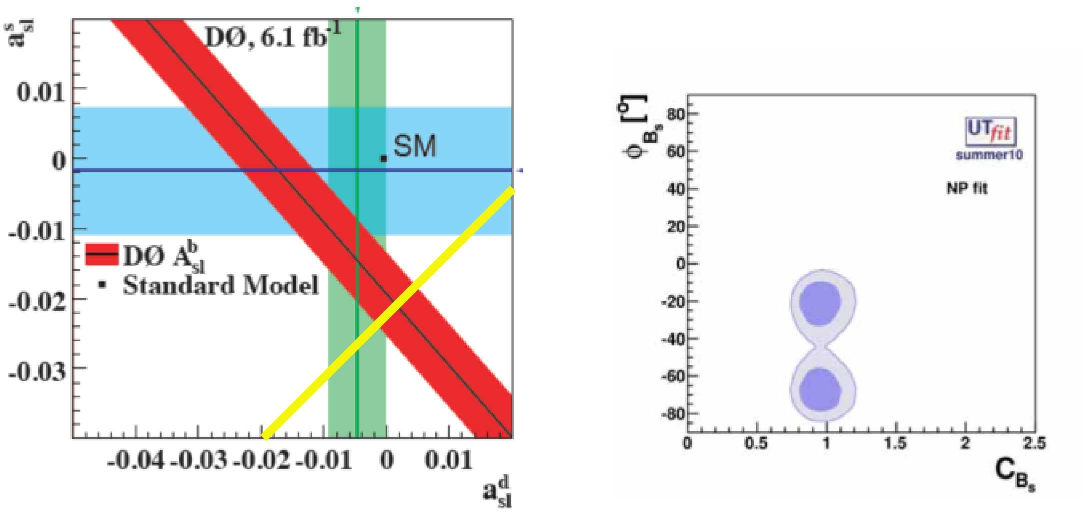

Figure 1: Left: Dilepton asymmetry measurement by D0. The blue band is a a_{sl}^{s} measurement by D0 and the green band is the measurement of a_{sl}^{d} by the B factories. Right: Deviations from the standard model of Bs mixing parameters.

2. Hadronic final states - time-dependent

Using the final state $J/\Psi\phi$, D0 and CDF have measured the mixing phase $\phi_s(\sim -2\beta_s)$ of B_s. The decay angular distribution allows separation of CP even and CP odd components. By fitting the decay time as well as the angular distribution, D0 has obtained $\phi_s = -0.76^{+0.38}_{-0.36} \pm 0.02$, and the SM expectation (~ -0.04) is well within its 95% confidence interval. The value obtained by CDF, $\beta_s = (0.28, 0.52) \cup (1.08, 1.55)$ 68% confidence interval, is also consistent with SM within 1σ. These are based on $5 \sim 6$ fb^{-1} of luminosity and the statistical errors are expected to improve. The sensitivity on ϕ_s by LHCb will approach the SM value with $\sim$ 1fb^{-1} of luminosity.

As for $b \to sg$ time-dependent analyses, the naive world average of $\beta/\phi_1^{\text{eff}}$ for many $b \to sg$ modes is now consistent with the corresponding value of $b \to c\bar{c}s$ modes:

$$\beta/\phi_1^{\text{eff}} = 0.64 \pm 0.04 \; (b \to sg), \qquad 0.67 \pm 0.02 \; (b \to c\bar{c}s).$$

The possible deviation from SM that was reported earlier seems to have disappeared.

3. Hadronic final states - time-independent

Direct CP asymmetry A_f of a decay $B \to f$ is defined by

$$A_f \equiv \frac{\Gamma(\bar{B} \to \bar{f}) - \Gamma(B \to f)}{\Gamma(\bar{B} \to \bar{f}) - \Gamma(B \to f)}.$$

The so-called $K\pi$ puzzle is the discrepancy between A_f's of $B^+ \to K^+\pi^0$ and $B^0 \to K^+\pi^-$. Naive isospin argument indicates that the two asymmetries are the same.The measurements by Belle are

$$\begin{cases} A_{K^+\pi^-} = -0.094 \pm 0.018 \pm 0.008 \\ A_{K^+\pi^0} = 0.07 \pm 0.03 \pm 0.01 \end{cases}, \qquad A_{K^+\pi^0} - A_{K^+\pi^-} = 0.164 \pm 0.037.$$

This discrepancy could be due to a new physics such as a new bsZ interaction. However, it is also consistent with SM within hadronic uncertainty.

Measurements on the last of the three CP violating angles, ϕ_3/γ, are getting to be more precise. Up to now, the best measurements come from analyses of $B^+ \to DK^+$ (and its CP conjugate mode) followed by $D \to K_s\pi^+\pi^-$ where the interference in the Dalitz distribution make it possible to extract ϕ_3/γ and the strong phase separately. The latest results are

$$\begin{cases} \gamma = (68^{+15}_{-14} \pm 4 \pm 3)^\circ \quad \text{(BaBar)} \\ \phi_1 = (78^{+11}_{-12} \pm 4 \pm 9)^\circ \quad \text{(Belle)} \end{cases}$$

where the last errors are the systematic errors due to modeling of the 3-body D^0 decay. One way to avoid such model dependence is to use more than two 2-body final states of D decay in $B^+ \to DK^+$. This technique is called the Atwood-Dunietz-Soni (ADS) method, and the key mode is the highly suppressed mode $B^+ \to DK^+$ followed by $D \to K^-\pi^+$. The first evidence of this mode has been observed by Belle:

$$R_{ADS} \equiv \frac{N(B^+ \to (K^-\pi^+)_D K^+) + C.C.}{N(B^+ \to (K^+\pi^-)_D K^+) + C.C.} = 1.62 \pm 0.42^{+0.16}_{-0.19} \quad \text{(Belle)}.$$

When all relevant DK modes are combined, the ADS method is expected to lead to $\sigma_{\phi_3/\gamma}$ of less than 10° using the data currently available.