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# Panel Discussion

## Models and Methods:

## Can Theory meet the B Physics Challenge?

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The target of B physics is short-distance physics associated with the electroweak scale and higher scales: CP violation, CKM elements and the search for new physics

Short-distance physics couples to quarks, but in experiments we encounter hadrons. Do we have to deal with non-perturbative QCD or even rely on QCD models?

Present situation:

- The B-factories measure $\sin 2\beta$ from $B \to J/\psi K_S$, with hadronic uncertainties from penguin pollution below 1%.
- The B-factories measure $\sin 2\beta$ from $B \to \phi K_S$ can probe the Standard Model with hadronic uncertainties from penguin pollution below a few %.
- Other measured observables involve QCD, which in many cases is understood for $m_b \to \infty$. The size of $1/m_b$ corrections is often unclear (as e.g. in QCD factorization).

Purity Classification:

| Rating: | uses: | example: |
|---|---|---|
| $*****$ | CP or isospin symmetry of QCD | $\gamma - 2\beta_s$ from $B_s \to D_s^\pm K^\mp$ |
| $****$ | CP or isospin symmetry of QCD plus $\mathcal{O}(\lambda^2)$-suppressed penguin | $\beta$ from $B \to J/\psi K_S$ |
| $***$ | operator product expansion | $\lvert V_{cb}\rvert$ from incl. decays |
| $**$ | four-quark matrix elements from unquenched lattice QCD | $B - \overline{B}$ mixing |
| $*$ | SU(3)$_F$ symmetry | $\gamma$ from $B_s \to K^+K^-$ and $B_d \to \pi^+\pi^-$ |

Not yet rated: QCD factorization/SCET

Other $*****$ and $****$ observables:

| Decay | quantity |
|---|---|
| $B^\pm \to K^\pm D^0$, CP study | $\gamma$ |
| $B_s \to \psi\phi, \psi\eta$, CP study | $\beta_s$ |
| $B \to \pi\pi$, CP study | $\alpha$ |
| $B_s \to \phi\phi, \phi\eta, \eta\eta$, CP study | $\beta_s$ |
| $B^0 \to \ell^+\ell^-$ and $B^+ \to \ell^+\nu_\ell$ | $\lvert V_{td}/V_{ub}\rvert$ |
| ... | |

Caveat: In the presence of new physics interference effects between the Standard Model (SM) amplitude and the new amplitude introduces hadronic uncertainties.

$\Rightarrow$ We can falsify the SM from clean observables, but we cannot necessarily determine the parameters of the new theory cleanly.

Example: $a_{CP}(B^0 \to \phi K_S)$.

Best strategy for analyzing hints of new physics: Study observables which are zero or very small in the Standard Model.

Example: You'll find $\Delta m_{B_s}$ off from the SM prediction by 10%. New Physics? Or did the lattice people compute $f_{B_s}^2 B_{B_s}$ incorrectly? Solution: Study $a_{CP}(B_s \;\longrightarrow\; \psi\phi)$, which can be enhanced by a factor of 3.

"(Near) zero predictions" of the SM include

- certain CP asymmetries,
- certain rare decays,
- FCNC's in the charm system

In particular I want to mention the CP asymmetry in flavor-specific decays (meaning $\overline{B} \not\rightarrow f$ and $B \not\rightarrow \overline{f}$):

$$a_{\rm fs} \;=\; \frac{\Gamma(\overline{B}(t) \rightarrow f) - \Gamma(B(t) \rightarrow \overline{f})}{\Gamma(\overline{B}(t) \rightarrow f) + \Gamma(B(t) \rightarrow \overline{f})} \;=\; -(5.0 \pm 1.1) \times 10^{-4},$$

e.g. $f = X\ell^-\overline{\nu_\ell}$.
$a_{\rm fs}$ is GIM suppressed in the SM and new physics can give an $\mathcal{O}(1)$ contribution.