Super B factories.

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Current and future $B$ Factories

- Two $B$ Factories (PEP-II at SLAC, KEK-B at KEK) have been in operation since 1999
  - These high luminosity asymmetric energy $e^+e^-$ colliders have made the first measurements of $CP$-violating asymmetries in $B$ meson decays
- $CPV$ measurements provide unique new tests of the quark sector of the Standard Model
  - The Standard Model seems to have passed the most straightforward of these tests, but there are hints of failure in more subtle areas tests
    - These seem to occur in places predicted by supersymmetric extensions of the Standard Model
- A Super $B$ Factory with $>50$ times current luminosity is needed to provide definitive answers on New Physics beyond the Standard Model effects in the heavy flavor sector
Success of B Factories

- About 300 papers in the last 5 years from BABAR & Belle on:
  - B Physics;
  - Charm Physics;
  - Charmonium Physics;
  - $\gamma\gamma$ and $\tau$ Physics.

- Many new analyses and ideas in progress.
Success of B Factories

First precise test of CKM picture for CPV.

- $\sin 2\beta = +0.726 \pm 0.037$ is now a precise measurement (~5%).
- The other angles are becoming interesting.
  - $\alpha$ from $S_{\rho\rho}$ and $\rho\pi$ Dalitz
  - $2\beta + \gamma$ from $B \rightarrow D(*)\pi$
  - $\gamma$ from $B \rightarrow DK$ (w/ $D$ Dalitz)
+ side measurements too.
  - $|V_{cb}|$, $|V_{ub}|$, $\Delta m_d$

Paradigm change: look for Alternatives to CKM
Corrections by NP
Need far precise tests

~300fb$^{-1}$(KEKB)
~250fb$^{-1}$(PEP-II)
**sin2β from charmonium modes (b → ccs)**

- BABAR: $\sin^2 \beta = +0.722 \pm 0.040 \pm 0.023$
- $|\lambda| = +0.950 \pm 0.031 \pm 0.013$

**HFAG**

- $\sin^2 \beta(\text{WA}) = +0.726 \pm 0.037$
- $|\lambda|(\text{WA}) = +0.969 \pm 0.028$

- $227\text{M } B\bar{B}$
- $152\text{M } B\bar{B}$

**cos2β**:
- BaBar: $+2.72 \pm 0.27$
- Belle: $-0.56 \pm 0.86 \pm 0.11$

(convention not the same)

Not yet very useful.

- Belle:

\[
A = \frac{|\lambda|^2 - 1}{|\lambda|^2 + 1}
\]

**all modes**
Summary of $CP$ asymmetries in $b \rightarrow cc(s,d)$ decays

Measurements of both the $S$ and $C$ parameters are consistent with Unitarity Triangle constraints.
Summary of constraints on $\alpha$

**BABAR & Belle combined**

Mirror solutions disfavored

From combined $\pi\pi$, $\rho\pi$, $\rho\rho$ results:

$$\alpha = \left[ 100^{+12}_{-11} \right]^\circ$$

CKM indirect constraint fit:

$$\alpha = 98 \pm 16^\circ$$
Combined GLW and ADS constraint on $\gamma$

**BABAR & Belle combined**

From combined GLW and ADS fit:

$\gamma = \left[ 51^{+20}_{-34}\right]^{\circ}$

CKM indirect constraint fit:

$\gamma = \left[ 58^{+8}_{-7}\right]^{\circ}$
Sides of the UT: V_{cb} and V_{ub}

|V_{cb}|_{excl} = (41.4 \pm 1.0_{\text{exp}} \pm 1.8_{\text{theo}}) \times 10^{-3}

|V_{ub}| = (4.70 \pm 0.44) \times 10^{-3}

excl. |V_{ub}| also in progress. |V_{td}/V_{ts}| from b \to d\gamma in the near future?
**DCPV in B⁰ → K⁺π⁻**

First observation from BaBar & Belle

![BABAR logo]

![BELLE logo]

- Evidence for DCPV (4.2σ)
  
  \[ \mathcal{A} = -0.133 \pm 0.030 \pm 0.009 \]

- Evidence for DCPV (3.9σ)
  
  \[ \mathcal{A} = -0.101 \pm 0.025 \pm 0.005 \]

\[ n_{K\pi} = 1606 \pm 51 \]

\[ A_{K\pi} = -0.133 \pm 0.030 \pm 0.009 \]

\[ n(B^0 \to K^+\pi^-) = 910 \]

\[ n(\bar{B}^0 \to K^-\pi^+) = 696 \]

**HFAG**

\[ \mathcal{A}(WA) = -0.109 \pm 0.019 \]
$B^0 ightarrow \phi K^0$ signals

$227M \ BB$

$275M \ B\bar{B}$

Plots for all signal events

$N_{\text{sig}} = 139 \pm 14$

purity = 0.63

$\phi K_S$: $\phi \rightarrow K^+K^-$

$K_S \rightarrow \pi^+\pi^-$

$N_{\text{sig}} = 114 \pm 12$

$\phi K_S$: $\phi \rightarrow K^+K^-$

$K_S \rightarrow \pi^+\pi^-, \pi^0\pi^0$
Search for New Physics.

- CP asymmetries in the decays of neutral B mesons into final CP eigenstates $f$ exhibit a time-dependent behavior:

$$A_f(t) = S_f \sin(\Delta m t) - C_f \cos(\Delta m t)$$

- The standard Model predicts that for most of the decays that proceed via $b \to q\bar{q}s$:

  - $\eta_f = \pm 1$, $C_f = 0$

where $\eta_f = \pm 1$

New physics may appear through:
- $S_f$ would be different from each other and from $S_{\psi K}$
- $C_f$ would be different from each other and from zero
**Anomalous CPV hints new physics?**

### sin2β comparison – average of BABAR and Belle

<table>
<thead>
<tr>
<th>Decay Mode</th>
<th>BABAR 04</th>
<th>Belle 04</th>
<th>Average (charmonium - all exps.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( c\bar{c} K^0 )</td>
<td>0.722 ± 0.040 ± 0.023</td>
<td>0.728 ± 0.066 ± 0.023</td>
<td>0.726 ± 0.037</td>
</tr>
<tr>
<td>( \phi K^0 )</td>
<td>BABAR 04 0.50 ± 0.25 ± 0.04</td>
<td>Belle 04 0.06 ± 0.33 ± 0.09</td>
<td></td>
</tr>
<tr>
<td>( \eta K^0 )</td>
<td>BABAR 04 0.30 ± 0.14 ± 0.02</td>
<td>Belle 04 0.65 ± 0.18 ± 0.04</td>
<td></td>
</tr>
<tr>
<td>( f^0 K^0 )</td>
<td>BABAR 04 0.95 ± 0.33 ± 0.10</td>
<td>Belle 04 -0.47 ± 0.41 ± 0.08</td>
<td></td>
</tr>
<tr>
<td>( \pi^0 K^0 )</td>
<td>BABAR 04 0.35 ± 0.33 ± 0.04</td>
<td>Belle 04 0.30 ± 0.53 ± 0.11</td>
<td></td>
</tr>
<tr>
<td>( a_0 K^0 )</td>
<td>BABAR 04 0.50 ± 0.23 ± 0.02</td>
<td>Belle 04 0.75 ± 0.64 ± 0.14</td>
<td></td>
</tr>
<tr>
<td>( K^0 K^0 )</td>
<td>BABAR 04 0.55 ± 0.22 ± 0.12</td>
<td>Belle 04 0.49 ± 0.18 ± 0.14</td>
<td></td>
</tr>
<tr>
<td>( K^0 K^0 )</td>
<td>BABAR 05 0.49 ± 0.18 ± 0.04</td>
<td>Belle 04 0.49 ± 0.18 ± 0.04</td>
<td></td>
</tr>
<tr>
<td>( K^0 K^0 )</td>
<td>BABAR 05 0.71 ± 0.36 ± 0.04</td>
<td>Belle 04 -1.26 ± 0.68 ± 0.18</td>
<td></td>
</tr>
</tbody>
</table>

Average (s-penguin) 0.43 ± 0.07

**Tree decay**

- **B** → \( \psi K_S \)
- **B** → \( J/\psi W \)
- **B** → \( c\bar{c} \)
- **B** → \( d\bar{d} \)

**Ave. CPV**

- \( 0.726 ± 0.037 \)
- \( 0.41 ± 0.07 \)

**3.8σ deviation observed**

**equal if only SM**

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**HFAG**

Moriond 2005
Roadmap of B Physics

- Discovery of CPV in B decays
- Study of NP effect in B and τ decays
- Precise test of SM and search for NP
- Identification of SUSY breaking mechanism
- Anomalous CPV in $b \rightarrow s\bar{s}s$

Yes!!

sin2β, CPV in $B \rightarrow \pi\pi$, $\gamma$, $V_{ub}$, $V_{cb}$, $b \rightarrow s\gamma$, $b \rightarrow sll$, new states etc.

Now 400 fb⁻¹

NP discovered at LHC(2010?)

if NP=SUSY

Integrated luminosity

time or
Projections for Super B Factory

Luminosity expectations:
Super B Factory
5-7x10^{35} cm^{-2}s^{-1}

5\sigma discovery region if non-SM physics is effect of 0.15

Projections are statistical errors only; but systematic errors at few percent level
Charm physics at a Super B factory.

- A super B factory will produce copious amounts of charm particles.
- With 10 ab\(^{-1}\) a total of 13 billion c\(\bar{c}\) pairs will be produced.
- This will allow to study many items related to charm physics:
  1. \(D^0\ \bar{D}^0\) mixing;
  2. Search for Rare Decays;
  3. Time-dependent Dalitz plot analyses
Charm Spectroscopy. **BaBar:** discovery of new Ds states.

- Potential models not always work!
Belle: Discovery of new charmonium states: $\eta_c(2S)$, X(3872), Y(3920)
Not all of them have a clear place in the $c\bar{c}$ scheme.
Where are charmonium hybrids?
Spectroscopy at a super B-factory

Key point for spectroscopy is:

Exclusive or quasi-exclusive reactions

- At a super B-factory, new charm and charmonium states can be discovered in:
  - B decays,
  - $e^+ e^- \rightarrow (cc)(cc)$
  - $J^{PC}=1^{--}$ states can be studied using ISR $e^+ e^- \rightarrow \gamma cc$
  - $J^C=even^+$ states can be studied in $\gamma\gamma$ collisions

A Super B factory is also a $\tau$ charm factory
Proposals for Super B-factories:
SLAC Super B-factory

- Defining physics case for Super B Factory
  - Primarily New Physics sensitivity in CP violation & rare decays
  - Capability for precision SM measurements as benchmark for New Physics

SLAC Workshop, May 8-10, 2003
BABAR Roadmap Study: Jan – July 04

Output:

The Discovery Potential of a Super B Factory
(SLAC-R-709, December, 2004)
Detector Upgrades

- Replace inner layers of present SVT with segmented strips, should be viable to about $5 \times 10^{35}$
- Develop thin pixels and replace inner SVT at an appropriate time to go higher in luminosity
- Not at all clear that DRC will work at these luminosities, upgrades needed.
- Replace EMC with either radiation hard crystals or liquid xenon
- Replace IFR forward endcap
- Replace DCH with all silicon tracker
Possible Timeline for Super B Program

Super-B Program

R&D, Design, Proposals and Approvals

Construction of upgrades to \( L = 5-7 \times 10^{35} \)

Super B Operation

\[ \int L dt \sim 10 \text{ ab}^{-1}/\text{yr} \]


Construction

LOI CDR P5

Installation

Commission

Planned PEP-II Program

\[
\int L dt = 140 \text{ fb}^{-1} \quad \int L dt = 500 \text{ fb}^{-1}
\]

(June 30, 2003) (End 2006)

\[ \int L dt \sim 1-2 \text{ ab}^{-1} \]

(PEP-II ultimate)

**Budgetary backdrop in US.**
- US domestic discretionary budget is under enormous pressure for the next few years.

**Priorities for US program.**
- Focus is on accelerator and non-accelerator based neutrino, dark matter, & dark energy experiments.
- After an initial interest, Ideas for Super PEP-II/BABAR do not fit in SLAC plans at present.
- Reflects changes underway to SLAC’s scientific mission, which is broadening in a big way into light science: sad for a Nobel factory.

**Still some possibility?**
- The US National Academy of Sciences (Board on Physics and Astronomy) study on Elementary Particle Physics in the 21st Century is underway, with a report expected in late 2005 or early 2006.
- Charge: “Identify, articulate, and prioritize the scientific questions and opportunities that define elementary-particle physics.
- Recommend a **15-year implementation plan** with realistic, ordered priorities to realize these opportunities”
KEK Super B-Facory

- 6 workshops to discuss physics, detector and accelerator issues.
  - 2001, Aug: 1st workshop at KEK
  - 2002, Jan (KEK)
  - 2002, Aug (Shonan)
  - 2003, Feb (KEK)
  - 2003, Sep (Shuzenji)
  - 2004, Nov (KEK)


- Belle/BaBar joint workshops:
  - February 14-16, 2002, TRIUMF
  - 2004, Jan (Hawaii)
  - 2005, April (Hawaii)
KEKB Upgrade Scenario

Projection of KEKB Luminosity

\[ L_{\text{peak}} = 1.4 \times 10^{34} \text{cm}^{-2}\text{s}^{-1} \]
\[ L_{\text{tot}} = 330 \text{fb}^{-1} \] (Nov.30, 2004)

~10^{10} BB/year !!
& similar number of \( \tau^+\tau^- \)

Major upgrade of KEKB & Belle detector
(>1yr shutdown)

Crab cavities

\[ L_{\text{peak}} \text{ (cm}^{-2}\text{s}^{-1}) \quad 1.4 \times 10^{34} \]
\[ L_{\text{int}} \quad 330 \text{ fb}^{-1} \]
\[ 5 \times 10^{34} \quad \sim 1 \text{ ab}^{-1} \]
\[ 5 \times 10^{35} \quad \sim 10 \text{ ab}^{-1} \]
Future.

• Members of PEP-II & BABAR communities are starting to discuss future options.
• Super KEKB is a possibility for a core part of PEP-II/BABAR, depending on the strength of the physics case & competitiveness with other physics opportunities.
• New participants could lead to expansion of scope for the Super B project and/or a more aggressive timescale

or

A Super B Factory in Europe?