KEKB/Belle Status

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$L_{\text{peak}} = 1.627 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
Crossing 22mrad

Crab cavity

Beam-beam simulation

Crab

non-Crab

SC Crab cavity
Crab installation rescheduled to Summer shutdown. KEKB has resumed and will run through June.

Belle physics updates this summer will be based on 560 fb\(^{-1}\) at hand.

\[ \text{Acp}(B^0 \rightarrow \phi K_S, \eta' K_S) \text{ update this summer.} \]
Spring 2006
Belle physics updates
Evidence for the purely leptonic decay $B \rightarrow \tau \nu_{\tau}$

This result.

hep-ex/0604018
\( \text{B}\rightarrow \tau\nu \) and B Meson Decay Constant \( f_B \)

- Leptonic decay proceeding through W boson annihilation in the Standard Model

- Decay rate simply related to B meson decay constant \( f_B \)

\[
\mathcal{B}(B \rightarrow \tau\nu) = \frac{G_F^2 m_B}{8\pi} m_B^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B
\]

Helicity suppressed by light lepton mass: \( \tau\nu \) is favored over \( e\nu \) and \( \mu\nu \)

- Clean experimental method of measuring B meson decay constant \( f_B \)
- Physics beyond the SM could enhance the branching fraction through the introduction of a charged Higgs boson
B decays with missing neutrinos lack the kinematic constraints which are used to separate signal events from backgrounds ($M_{bc}$ and $\Delta E$).

Reconstruct the decay of the non-signal B (tagging), then look for the signal decay in whatever is left over.

**Tagging side:**
- Fully reconstruct hadronic modes

**Signal side:**
- Reconstruct particles from $\tau$ decay

$B^\pm : 680K$ (57% pure)
$B^0 : 412K$ (52% pure)
Belle

Signal shape: Gauss + exponential
Background shape: second-order polynomial

<table>
<thead>
<tr>
<th></th>
<th>$N_{\text{obs}}$</th>
<th>$N_{S}$</th>
<th>$N_{b}$</th>
<th>$\Sigma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu^{-}\bar{\nu}<em>{\mu}\nu</em>{\tau}$</td>
<td>13</td>
<td>$5.4^{+3.2}_{-2.2}$</td>
<td>$9.1^{+0.2}_{-0.1}$</td>
<td>$2.3\sigma$</td>
</tr>
<tr>
<td>$e^{-}\bar{\nu}<em>{e}\nu</em>{\tau}$</td>
<td>12</td>
<td>$3.9^{+3.5}_{-2.5}$</td>
<td>$9.2^{+0.2}_{-0.2}$</td>
<td>$1.5\sigma$</td>
</tr>
<tr>
<td>$\pi^{-}\nu_{\tau}$</td>
<td>9</td>
<td>$3.4^{+2.6}_{-1.6}$</td>
<td>$4.0^{+0.2}_{-0.1}$</td>
<td>$1.9\sigma$</td>
</tr>
<tr>
<td>$\pi^{-}\pi^{0}\nu_{\tau}$</td>
<td>11</td>
<td>$6.2^{+3.9}_{-2.7}$</td>
<td>$4.2^{+0.3}_{-0.3}$</td>
<td>$2.6\sigma$</td>
</tr>
<tr>
<td>$\pi^{-}\pi^{+}\pi^{-}\nu_{\tau}$</td>
<td>9</td>
<td>$3.1^{+3.1}_{-2.6}$</td>
<td>$3.7^{+0.3}_{-0.2}$</td>
<td>$1.2\sigma$</td>
</tr>
<tr>
<td>Combined</td>
<td>54</td>
<td>$21.2^{+6.7}_{-5.7}$</td>
<td>$30.2^{+0.5}_{-0.4}$</td>
<td>$4.2\sigma$</td>
</tr>
</tbody>
</table>

$\Sigma$: Significance with systematics

Background yield is consistent with the expectation from the MC simulation

Observe $21.2^{+6.7}_{-5.7}$ events with a significance of $4.2\sigma$
**B → τν Branching Fraction**

- Branching fractions are calculated by
  \[ B = \frac{N_S}{2 \cdot \varepsilon_{\text{sel}} \cdot \varepsilon_{\text{tag}} \cdot N_{B\bar{B}}} \]

- All τ decay modes combined
  \[ B(B \rightarrow \tau \nu) = (1.06^{+0.34}_{-0.28} \text{(stat)} + 0.18 \text{(syst)}) \times 10^{-4} \]

- SM: \( B(B \rightarrow \tau \nu) = (1.59 \pm 0.40) \times 10^{-4} \)

Result is consistent with SM prediction within error
**f_B Extraction**

- Product of B meson decay constant $f_B$ and CKM matrix element $|V_{ub}|$

$$f_B \cdot |V_{ub}| = (7.73^{+1.24}_{-1.02} \text{(stat)}^{+0.66}_{-0.58} \text{(syst)}) \times 10^{-4} \text{ GeV}$$

| $G_F$ | $1.16639 \times 10^{-5}$ GeV$^{-2}$ |
| $\tau_B$ | $(1.643 \pm 0.010) \times 10^{-12}$ s |
| $m_B$ | 5.279 GeV |
| $m_\tau$ | 1.77699 GeV |

- Using $|V_{ub}| = (4.38 \pm 0.33) \times 10^{-3}$ from HFAG

$$f_B = 0.176^{+0.028}_{-0.023} \text{(stat)}^{+0.020}_{-0.018} \text{(syst)} \text{ GeV}$$

$$f_B = 0.216 \pm 0.022 \text{ GeV (HPQCD)}$$

Purely leptonic D decay by CLEO

$D^+ \rightarrow \mu^+ \nu_\mu$ and $f_{D^+}$

$$\Gamma (D^+ \rightarrow l^+ \nu) = \frac{G_F^2}{8\pi} f_{D}^2 \cdot m_l^2 \cdot M_{D'} \left( 1 - \frac{m_l^2}{M_{D'}^2} \right)^2 |V_{cd}|^2$$

$Br(D^+ \rightarrow \mu^+ \nu_\mu) = (4.40 \pm 0.66^{+0.09}_{-0.12}) \times 10^{-4}$
Constraints on Physics Parameters

- Constraint on Charged Higgs

\[ \mathcal{B}(B \rightarrow \tau \nu) / \mathcal{B}(B \rightarrow \tau \nu)_{SM} = r_H \]

\[ r_H = (1 - \frac{m_B^2}{m_H^2} \tan^2 \beta)^2 \quad \Rightarrow \quad r_H = 0.67^{+0.29}_{-0.26} \]

\[ \mathcal{B}(B \rightarrow \tau \nu) = (1.06^{+0.34}_{-0.28} \text{(stat)}^{+0.18}_{-0.16} \text{(syst)}) \times 10^{-4} \]

SM: \[ \mathcal{B}(B \rightarrow \tau \nu) = (1.59 \pm 0.40) \times 10^{-4} \]

- 95.5% C.L. exclusion boundaries
b → dγ

- CKM-suppressed counterpart of $b → sγ$, suppressed by $|V_{td}/V_{ts}|^2 ≈ 0.04$.
  - But additional annihilation diagram!
- Even more sensitive to new physics!
- Within SM: extract value for $|V_{td}/V_{ts}|^2$.
  - The B factories’ $\Delta m_s$!
  - But only exclusive measurements are possible ⇒ hadronic uncertainties.
- Huge backgrounds as for $b → sγ$, in addition substantial backgrounds from $b → sγ$ itself!
- The big news of 2005 (first observation)!
Belle: \( b \to d \gamma \)

First observation in 2005!  
(386M \( \bar{B}B \))

Measurement finalized and submitted for publication

- Very sophisticated background suppression necessary:
  - \( \pi^0 \) and \( \eta \) rejection, \( K^*\gamma \) veto, \( \rho/\omega \) helicity
  - Vertex displacement from other \( B \)
  - Flavor-tag algorithm (continuum is flavorless)
- Combine variables with event-shape Fisher in likelihood ratio, apply flavor-tag quality dependent cut.

Fit for signal, \( K^*\gamma \) contamination, continuum, other \( B \) bgr.

\[
\bar{B}[B \to (\rho/\omega)\gamma] = \frac{1}{2} \left\{ B(B^+ \to \rho^+\gamma) \right. \\
+ \frac{\tau_{B^0}}{\tau_{B^+}} \left[ B(B^0 \to \rho^0\gamma) + B(B^0 \to \omega\gamma) \right] \right\}
\]

Combined fit, assuming isospin:

\[
\bar{B}[B^0 \to [\rho,\omega]\gamma] = 1.32 \pm 0.34 \pm 0.10 \pm 0.31 - 0.09 \ (5.1\sigma)
\]

\[
\bar{B}[B \to (\rho,\omega)\gamma] = 0.56 \pm 0.34 \pm 0.05 \pm 0.27 - 0.10 \ (2.3\sigma)
\]

\[
\bar{B}[B^+ \to \rho^+\gamma] = 0.55 \pm 0.42 \pm 0.09 \pm 0.36 - 0.08 \ (1.6\sigma)
\]
$b \to d\gamma$: extraction of $|V_{td}/V_{ts}|$

$$\frac{\overline{B}[B \to (\rho/\omega)\gamma]}{\mathcal{B}(B \to K^*\gamma)} = \left| \frac{V_{td}}{V_{ts}} \right|^2 \left( \frac{1 - m_\rho^2/M_B^2}{1 - m_{K^*}^2/M_B^2} \right)^3 \zeta^2[1+\Delta R]$$

Form factor ratio:
$$\zeta^2 \approx 0.85 \pm 0.1$$

Different dynamics (weak annihilation diagram)
$$\Delta R \approx 0.1 \pm 0.1$$

$|V_{td}/V_{ts}| = 0.199^{+0.026}_{-0.025}$ (exp.) $+0.018^{+0.015}_{-0.015}$ (theor.)

Belle

$|V_{td}/V_{ts}| < 0.19$

A non-trivial constraint for the unitarity triangle!

In comparison with "new-physics-free" tree-only UT:
\[
\frac{\Delta m_s}{\Delta m_d} = \frac{m_{B_s}}{m_{B_d}} \xi^2 \left| \frac{V_{ts}}{V_{td}} \right|^2
\]

\[\Delta m_s = 17.33^{+0.42}_{-0.21} \pm 0.07 \text{ (ps}^{-1}\text{)}\]

- **inputs:**
  - \(m(B^0)/m(B_s) = 0.9830\) (PDG 2006)
  - \(\xi = 1.21^{+0.47}_{-0.35}\) (M. Okamoto, hep-lat/0510113)
  - \(\Delta m_d = 0.507 \pm 0.005\) (PDG 2006)

\[|V_{td}| / |V_{ts}| = 0.208^{+0.008}_{-0.007} \text{ (stat + syst)}\]

- compare to Belle \(b \rightarrow s\gamma\) (hep-ex/0506079):
  \[|V_{td}| / |V_{ts}| = 0.199^{+0.026}_{-0.025} \text{ (stat)} +^{0.018}_{-0.015} \text{ (syst)}\]
Belle: $A_{FB}(q^2)$ for $B \rightarrow K^* \ell^+ \ell^-$

- Measurement based on $114 \pm 13 \ B \rightarrow K^* \ell^+ \ell^-$ decays (44% pure)
  - $K^* \rightarrow K^+ \pi^-, K_\Sigma \pi^+, K^+ \pi^0$.
- Analysis in terms of leading-order coefficients $A_7$, $A_9$, $A_{10}$
  - $(C_7 = A_7 +$ higher-order terms, etc.)
- Maximum-likelihood fit to normalized double-differential decay width,
  $(1/\Gamma) \frac{d^2\Gamma}{ds \cos\theta}$, using 8 event categories (signal, 3 cross-feeds, 4 backgrounds, of which dilepton dominant).
- Fix $A_7 = -0.330$ (SM value), fit for $A_9/A_7$ and $A_{10}/A_7$.
  - Repeat fit also for $A_7 = +0.330$, gives worse fit.
- Null test with $B \rightarrow K \ell^+ \ell^-$.

Fit result ($A_7$ fixed):

- $A_9/A_7 = -15.3 \pm 3.4 \pm 1.1$ (SM value)
- $A_{10}/A_7 = 10.3 \pm 5.2 \pm 3.5$

95% C.L. ($A_7$ free):

- $-1401 < A_9A_{10}/A_7^2 < -26.4$

SM:

- $A_9A_{10}/A_7^2 = -158.1$
B Factory Running at Y(5S)

- Provide the possibility to study Bs decays
  \[ e^+e^- \rightarrow Y(5S) \rightarrow B\bar{B}, B^{*}\bar{B}, B^{*}\bar{B}^{*}, BB\pi, BB\pi\pi, B_sB_s, B_s\bar{B}_s, B_s\bar{B}_s, B_s\bar{B}_s \]
  - e^+e^- collider has advantages over hadronic machines
  - CLEO has observed Bs signals from 0.42fb^{-1} Y(5S) data
    \[ [PRL96 022002(2006)] \]

- Y(5S) Engineering Run performed at KEKB/Belle
  - Achieved high luminosity as Y(4S) run
    \[ L_{\text{peak}} = 13.9/\text{nb/sec} \]
  - \[ L_{\text{int}} = 1.86 \text{ fb}^{-1} \] has been taken during 3 days runs (June 21-23, 2005)

\[ e^+ \text{ and } e^- \text{ beam energies were increased by 2.7\%} \]
(same Lorentz boost \( \beta \gamma = 0.425 \)) to move from Y(4S) to Y(5S)

No modifications for Belle detector, trigger system or software
Reconstructed $B_s$ Candidates

- $B_s$ signals are identified with $M_{bc}$ and $\Delta E$

\[ B_s \rightarrow D_s^{+} \pi^- \]
9 events in $B_s^* B_s^*$

\[ B_s \rightarrow D_s^{**} \pi^- \]
4 events in $B_s^* B_s^*$

\[ B_s \rightarrow D_s^{(*)+} \rho^- \]
7 events in $B_s^* B_s^*$

\[ B_s \rightarrow J/\psi \phi/\eta \]
3 events in $B_s^* B_s^*$

Clear $B_s$ signals seen in $B_s^* B_s^*$ region

$B_s B_s$, $B_s^* B_s$, $B_s^* B_s^*$ signals can be separated well

$0.08 < \Delta E < 0.02$ MeV

$M (B_s) = 5370 \pm 1 \pm 3$ MeV/c$^2$

Will run at $Y(5s)$ for 50fb$^{-1}$ (~one month running)
B factory physics goes on strong at KEK.