Results and prospects of Y(5S) running at Belle.

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*LPHE seminar*

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Outline

- Introduction.
- Recent Belle measurements at Y(5S).
- Prospects of $B_s$ meson (and other) studies at Y(5S).
- My thoughts (speculations) about $Y(5S) \rightarrow Y(6S) \rightarrow \ldots$.
- Conclusion.
Resonance to continuum hadron production ratios are $\Upsilon(4S)/\text{Cont} \sim 1./3.5$ and $\Upsilon(5S)/\text{Cont} \sim 1./10$. 
### Running at Y(4S) and Y(5S)

**Asymmetric energy e\(^+\)e\(^-\) colliders (B Factories) running at Y(4S):**

- **1985:** CESR (CLEO,CUSB) \(\sim 0.1 \text{ pb}^{-1}\) at Y(5S)
- **2003:** CESR (CLEO III) \(\sim 0.42 \text{ fb}^{-1}\) at Y(5S)
- **2005:** Belle, KEKB \(\sim 1.86 \text{ fb}^{-1}\) at Y(5S)
- **2006, June 9-31:** Belle, KEKB \(\sim 21.7 \text{ fb}^{-1}\) at Y(5S)

\[ \text{e}^+ \text{e}^- \rightarrow Y(4S) \rightarrow B\overline{B}, \text{ where } B \text{ is } B^+ \text{ or } B^0 \text{ meson} \]

\[ \text{e}^+ \text{e}^- \rightarrow Y(5S) \rightarrow B\overline{B}, B^*\overline{B}, B^*\overline{B}^*, B\overline{B}\pi, B\overline{B}\pi\pi, B_s\overline{B}_s, B_s^*\overline{B}_s, B_s^*\overline{B}_s^* \]

**where**

- \(B^* \rightarrow B\gamma\) and \(B_s^* \rightarrow B_s\gamma\)

\[ M(Y(5S)) = 10865 \pm 8 \text{ MeV/c}^2 \text{ (PDG)} \]

\[ \Gamma(Y(5S)) = 110 \pm 13 \text{ MeV/c}^2 \text{ (PDG)} \]

- \(B_s\) rate is \(\sim 10-20\% \rightarrow\) high lumi e\(^+\)e\(^-\) collider at Y(5S) \(\rightarrow\) \(B_s\) factory.
First $Y(5S)$ runs at the KEKB $e^+e^-$ collider

Electron and positron beam energies were increased by 2.7% (same Lorentz boost $\beta\gamma = 0.425$) to move from $Y(4S)$ to $Y(5S)$. No modifications are required for Belle detector, trigger system or software to move from $Y(4S)$ to $Y(5S)$.

Integrated luminosity of $\sim 1.86 \text{ fb}^{-1}$ at 2005 and $\sim 21.6 \text{ fb}^{-1}$ at 2006 was taken by Belle detector at $Y(5S)$. The same luminosity per day was taken at $Y(5S)$ as it is at $Y(4S)$. Very smooth running
New 2006 runs at Y(5S) at Belle

Belle collected data at Y(5S): June 9-June 31, 2006 => 21.7 fb$^{-1}$

Exceeded 1.2 fb$^{-1}$/day for the first time at Y(4S).

Correction factor (1.056) is necessary for 5S run due to smaller Bhabha Cross section.

Off-resonance run 5S run ~22 fb$^{-1}$
Integrated luminosity

Belle + BaBar > 1 ab\(^{-1}\)

Integrated Luminosity (log)

- KEKB
- PEP-II
- World

Belle (10 Mar 08)
All: \(\sim 778 \text{ fb}^{-1}\)
Cont: \(\sim 68 \text{ fb}^{-1}\)
Y(5S): \(\sim 24 \text{ fb}^{-1}\)
Hadronic event classification

hadronic events at Y(5S)

Y(5S) events

b continuum

u,d,s,c continuum

bb events

B_s events

B^0, B^+ events

f_s = N(B_s^(*) B_s^(*)) / N(bb)

B_s^* B_s^* channel

B_s^* B_s

B_s B_s

N(bb events) = N(hadr, 5S) - N(udsc, 5S)

CLEO
PRL 54, 381 (1985)
Number of $bb$ events, number of $B_s$ events

Continuum event yield ($u\bar{u}, d\bar{d}, s\bar{s}, c\bar{c}$) is estimated using data taken below the Y(4S):

$$N_{\text{cont}}(5S) = N_{\text{cont}}(E=10.519) \times \frac{\mathcal{L}(5S)}{\mathcal{L}(\text{cont})} \times \left(\frac{E_{\text{cont}}}{E_{5S}}\right)^2 \times \left(\frac{\varepsilon_{5S}}{\varepsilon_{\text{cont}}}\right)^2$$

Y(5S) : Lumi = $1.857 \pm 0.001 \ (\text{stat}) \ fb^{-1}$

$N_{bb}(5S) = 561,000 \pm 3,000 \pm 29,000 \ \text{events}$

$N_{bb}(5S) / fb^{-1} = 302,000 \pm 15,000$

Cont (below 4S) : $3.670 \pm 0.001 \ (\text{stat}) \ fb^{-1}$

=> 5% uncertainty from luminosity ratio

CLEO: $N_{bb}(5S) / fb^{-1} = 310,000 \pm 52,000$

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How to determine $f_s = N(B_s^{(*)} B_s^{(*)}) / N(bb)$?

$$Bf (Y(5S) \rightarrow D_s X) / 2 = f_s \times Bf (B_s \rightarrow D_s X) + (1- f_s) \times Bf (B \rightarrow D_s X)$$

---

1. $Bf (B_s \rightarrow D_s X)$ can be predicted theoretically, tree diagrams, large.
2. $Bf (B \rightarrow D_s X)$ is well measured at the Y(4S).
Inclusive analyses: $Y(5S) \rightarrow D_s X, Y(5S) \rightarrow D^0 X$

After continuum subtraction and efficiency correction:

$Bf (Y(5S) \rightarrow D_s X) / 2 = (23.6 \pm 1.2 \pm 3.6) \%$

$Bf (Y(5S) \rightarrow D^0 X) / 2 = (53.8 \pm 2.0 \pm 3.4) \%$

$\Rightarrow f_s = \frac{N(B_s\,^*\,B_s\,^*)}{N(bb)} = (18.0 \pm 1.3 \pm 3.2) \%$

$L = 1.86 \text{ fb}^{-1}$

$N_{bb(5S)} = 561,000 \pm 3,000 \pm 29,000$ events

$\sigma(Y(5S)\rightarrow bb) = (0.302 \pm 0.015) \text{ nb}$ at $E=10869 \text{ MeV}$
Signature of fully reconstructed exclusive $B_s$ decays

$e^+ e^- \rightarrow Y(5S) \rightarrow B_s B_s, B_s^* B_s, B_s B_s^*$, where $B_s^* \rightarrow B_s \gamma$

Reconstruction: $B_s$ energy and momentum, photon from $B_s^*$ is not reconstructed.

Two variables calculated: $M_{bc} = \sqrt{E^*_{beam}^2 - P^*_{B_s}^2}$, $\Delta E = E^*_B - E^*_{beam}$

Figures (MC simulation) are shown for the decay mode $B_s \rightarrow D_s^- \pi^+$ with $D_s^- \rightarrow \phi \pi^-$. The signals for $B_s B_s, B_s^* B_s$ and $B_s^* B_s^*$ can be separated well.
Exclusive $B_s \rightarrow D_s^{(*)+} \pi^-/\rho^-$ and $B_s \rightarrow J/\psi \phi/\eta$ decays

Data at Y(5S), 1.86 fb$^{-1}$

$N(B_s^*B_s^*) / N(B_s^{(*)}B_s^{(*)}) = (93\pm 7_{9}\pm 1)\%$

Potential models predict $B_s^*B_s^*$ dominance over $B_s^*B_s$ and $B_sB_s$ channels, but not so strong.

Conclusions:
1. Belle can take $\sim$30 fb$^{-1}$ per month.
2. Number of produced $B_s$ at Y(5S) is $\sim$10$^5$/fb$^{-1}$.
3. $B_s^*B_s^*$ channel dominates over all $B_s^{(*)}B_s^{(*)}$.
4. Backgrounds in exclusive modes are not large.
Number of $B_S$ in dataset

- $bb$ continuum included
- hadronic events at $Y(5S)$
  - $bb$ events
    - $B_S$ events
      - $B_{Ss}^* B_{Ss}^*$ channel
        - $f(B_{Ss}^* B_{Ss}^*) = (93 \pm 7 \pm 1)\%$
        - $N_{ev} = 94,000 \pm 7,000 \pm 20,000$
      - $f_{s} = (18.0 \pm 1.3 \pm 3.2 )\%$
      - $N_{ev} = 101,000 \pm 7,000 \pm 19,000$
    - $N_{ev} = 561,000 \pm 3,000 \pm 29,000$
    - $Lumi = 1.857 \text{ fb}^{-1}$

$\sim 10^5 B_S$ mesons per $1 \text{ fb}^{-1}$ at $Y(5S)$

Biggest uncertainty comes from $f_s$ systematics. How to improve it (3 times)?
How to measure $f_s$ with 5% uncertainty?

*I spent a lot of time thinking about that. It could be:

1. CLEO method, from $B_f(Y(5S)\rightarrow D_s X)$, with better statistics.

2. Using same-sign lepton-lepton sample, maybe with $z$-distance measurement between profile-lepton vertices.

3. $J/\psi$ vertex $xy$-distance from profile.

4. $B_f(B\rightarrow D^+\pi^-)$, $B_f(B\rightarrow D^0\pi^-)$, $B_f(B\rightarrow D^{*0}\pi^-)$ measurements.

5. Number of slow photons from $B_s*$ decays.

No one of these methods is perfect.
First observation of $B_s \rightarrow \phi \gamma$ and new upper limit for $B_s \rightarrow \gamma \gamma$.

- $Bf(B_s \rightarrow \phi \gamma) = (5.7^{+1.8+1.2}_{-1.5-1.1}) \times 10^{-5}$
- $Bf(B_s \rightarrow \gamma \gamma) < 8.7 \times 10^{-6}$ (90% CL)

First measurement of $Y(5S) \rightarrow Y(nS) \pi^+ \pi^-$ decays (21.7 fb$^{-1}$).
Is the $\Upsilon(10860)$ purely $\Upsilon(5S)$?

-> look for: $\mu^+\mu^-h^+h^-$

$e^+e^- \rightarrow \Upsilon(1S)\pi^+\pi^-X$

$e^+e^- \rightarrow \Upsilon(2S)\pi^+\pi^-X$

arXiv:0710.2577[hep-ex]
(accepted PRL)

Study motivated by observation of $\Upsilon(4230) \rightarrow J/\Psi\pi^+\pi^-$-signal (analogous?).
Is the \( \Upsilon(10860) \) purely \( \Upsilon(5S)? \)

4 modes seen: \( \Upsilon(5S) \rightarrow \Upsilon(nS) \) \( h^+h^- \)

<table>
<thead>
<tr>
<th>Process</th>
<th>( \sigma ) (pb)</th>
<th>( B ) (%)</th>
<th>( \Gamma ) (MeV)</th>
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<tbody>
<tr>
<td>( \Upsilon(1S)\pi^+\pi^- )</td>
<td>1.61 ± 0.10 ± 0.12</td>
<td>0.53 ± 0.03 ± 0.05</td>
<td>0.59 ± 0.04 ± 0.09</td>
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<tr>
<td>( \Upsilon(2S)\pi^+\pi^- )</td>
<td>2.35 ± 0.19 ± 0.32</td>
<td>0.78 ± 0.06 ± 0.11</td>
<td>0.85 ± 0.07 ± 0.16</td>
</tr>
<tr>
<td>( \Upsilon(3S)\pi^+\pi^- )</td>
<td>1.44 ± 0.55 ± 0.19</td>
<td>0.48 ± 0.18 ± 0.07</td>
<td>0.52 ± 0.20 ± 0.10</td>
</tr>
<tr>
<td>( \Upsilon(1S)K^+K^- )</td>
<td>0.185 ± 0.048 ± 0.028</td>
<td>0.061 ± 0.016 ± 0.010</td>
<td>0.067 ± 0.017 ± 0.013</td>
</tr>
</tbody>
</table>

Expectation: \( \Upsilon(5S) \) width comparable to \( \Upsilon(2S/3S/4S) \)

Conclusion: not pure \( \Upsilon(5S)? \) Energy scan: 12/07.
New Belle results with 23.6 fb$^{-1}$

- First observation of $B_s \rightarrow \phi \gamma$ and new upper limit for $B_s \rightarrow \gamma \gamma$.

  $Bf(B_s \rightarrow \phi \gamma) = (5.7 \pm 1.8\pm 1.2) \times 10^{-5}$

  $Bf(B_s \rightarrow \gamma \gamma) < 8.7 \times 10^{-6}$ (90% CL)  

  Jean Wicht

- First measurement of $Y(5S) \rightarrow Y(nS) \pi^+ \pi^- \text{ decays} (21.7 \text{ fb}^{-1})$.

- First measurement of $B_s \rightarrow X^+ \ell^- \nu$ decay.
Motivation, feasibility of $B_s$ lifetime measurement.

PDG 2007: $Bf( B^0 \rightarrow X^+ l^- \bar{\nu} ) = (10.33 \pm 0.28)\%$

Semileptonic decays have no hadronic corrections.

Theory predicts about 12%. It is not yet understood by theory. Some recent models predict better (dis)agreement. Calculation problems? Exotics? Maybe semilep. $B_s$ decays can shed some light.

$\tau(B^0) > \tau(B_s) - 2.9\sigma$ difference (in contrast with theory).

$B_s$ and $D_s$ lifetimes can be measured using $D_s$ vertex, lepton track and beam profile.

This analysis requires much more work ... .
First measurement of $B_s \rightarrow X^+\ell^−\nu$ decay

Electron: $Bf(B_s \rightarrow X^+e^−\nu) = (10.9 \pm 1.0 \pm 0.9)\%$

Muon: $Bf(B_s \rightarrow X^+\mu^−\nu) = (9.2 \pm 1.0 \pm 0.8)\%$

Combined fit (electron+muon): $Bf(B_s \rightarrow X^+\ell^−\nu) = (10.2 \pm 0.8 \pm 0.9)\%$

Assuming similar decay widths and $\tau(B_s)/\tau(B^0)=1.00\pm0.01$ (theory: exp.diff.~2.3σ) it can be compared to PDG 2007: $Bf(B^0 \rightarrow X^+\ell^−\nu) = (10.33 \pm 0.28)\%$
New Belle results with 23.6 fb$^{-1}$

- First observation of $B_s \rightarrow \phi \gamma$ and new upper limit for $B_s \rightarrow \gamma \gamma$.

\[ Bf (B_s \rightarrow \phi \gamma) = (5.7 \pm 1.8 \pm 1.2) \times 10^{-5} \]

\[ Bf (B_s \rightarrow \gamma \gamma) < 8.7 \times 10^{-6} \text{ (90% CL)} \]

- First measurement of $Y(5S) \rightarrow Y(nS) \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- \text{ decays (21.7 fb}^{-1})$.

- First measurement of $B_s \rightarrow X^+ \ell^- \nu \text{ decay}$.

- Measurement of $B_s \rightarrow D_s^+ \pi^- \text{ and } B_s \rightarrow D_s^+ K^- \text{ decays}$.

\[ Bf (B_s \rightarrow D_s^+ \pi^-) = (3.31 \pm 0.31 \pm 0.67) \times 10^{-3} \]

\[ Bf (B_s \rightarrow D_s^+ \pi^-) = (2.2 \pm 1.1 \pm 0.5) \times 10^{-4} \]

R = 0.066 $\pm$ 0.015

Jean Wicht

R. Louvot, T. Aushev, J. Wicht
Why it is interesting?

1. $Bf (B_s \rightarrow D_s^+ \pi^-) = (3.31^{+0.31+0.67}_{-0.30-0.64}) \times 10^{-3}$
   
   PDG: $Bf (B \rightarrow D^+ \pi^-) = (2.68 \pm 0.13) \times 10^{-3}$
   
   W-exchange diagram? Difference is not yet significant.

2. $M(B_s^*) = 5417.4 \pm 0.4 \pm 1.0$ MeV/$c^2$
   
   PDG: $M(B_s) = 5366.1 \pm 0.6$ MeV/$c^2$
   
   $\Delta(B_s^0) = 51.3 \pm 1.2$ MeV/$c^2$ \hspace{1cm} $\Delta(B^0) = 45.78 \pm 0.35$ MeV/$c^2$
   
   Very unexpected difference

3. $N(B_s^*B_s^*) / N(B_s^*(*)B_s^*(*)) = (90 \pm 3.7_{3.9} \pm 0.2)\%$ \hspace{1cm} very unexpected

4. Flat B direction angular distribution $\rightarrow$ has to be explained.
1. K. Sayeed, A. Schwartz: $B_s \to J/\psi \phi$ and $B_s \to J/\psi K_s$ decays.

   Important for future CP studies.

2. J.-H. Chen: Search for $B_s \to K^+ K^-$ decay.

   CP eigenstate, can be used in future for $\Delta \Gamma_s/\Gamma_s$ measurement.

Analysis started:

1. S. Esen: Measurement $B_s \to D_s^{(*)} D_s^{(*)}$

   Mostly CP eigenstates, important for indirect $\Delta \Gamma_s/\Gamma_s$ measurement.
\[ \Delta \Gamma_s / \Gamma_s \text{ measurement from } Bf (B_s \rightarrow D_s^{(*)} D_s^{(*)}) \]

\[ M_{Bs} = (M_H + M_L)/2 \quad \Gamma_s = (\Gamma_H + \Gamma_L)/2 \]
\[ \Delta m_s = M_H - M_L \quad \Delta \Gamma = \Gamma_L - \Gamma_H > 0 \text{ in SM} \]

\[ i \frac{d}{dt} \begin{pmatrix} \frac{B_s}{B_s} \\ \frac{B_s}{B_s} \end{pmatrix} = \left( M - i/2 \Gamma \right) \begin{pmatrix} \frac{B_s}{B_s} \\ \frac{B_s}{B_s} \end{pmatrix} \quad \text{ - Schrödinger equation} \]

Matrices \( M \) and \( G \) are \( t \)-dependent, Hermitian 2x2 matrices

Assuming CPT: \( M_{11} = M_{22} \quad \Gamma_{11} = \Gamma_{22} \)

\[ | B_{H,L}(t) > = \exp ( - (i M_{H,L} + \Gamma_{H,L}/2) t ) \quad | B_{H,L} > \]

SM: \( \beta_s = \text{arg}(-V_{ts} V_{tb}^*/V_{cs} V_{cb}^*) = O(\lambda^2) \) - no CP-violation in mixing

BSM: \( \phi_s = \text{arg} (-M_{12}/\Gamma_{12}) \quad 2\theta_s = \phi_s \quad \Delta \Gamma_s = 2 |\Gamma_{12}| \cos 2\theta_s \)
\( \Delta \Gamma_s / \Gamma_s \) measurement from \( Bf(B_s \rightarrow D_s^{(*)} D_s^{(*)}) \) (first proposed by Y. Grossman)

\[
\Delta \Gamma_s = 2 \mid \Gamma_{12} \mid \cos \phi_s \\
\Delta \Gamma_s^{SM} = \Delta \Gamma_{CP}^s = 2 \mid \Gamma_{12} \mid
\]

Since \( \Delta \Gamma_{CP}^s \) is unaffected by NP, NP effects will decrease \( \Delta \Gamma_s \).

\[
\Delta \Gamma_{CP}^s = \Sigma \Gamma(CP=+) - \Sigma \Gamma(CP=-)
\]

\( B_s \rightarrow D_s^{(*)} + D_s^{(*)} \) decays have \( CP \)-even final states with largest \( BF \)'s of \( \sim (1-3)\% \) each, saturating \( \Delta \Gamma_s / \Gamma_s \).

\[
\frac{\Delta \Gamma_{CP}^s}{\Gamma_s} \approx \frac{Bf(B_s \rightarrow D_s^{(*)} + D_s^{(*)})}{1 - Bf(B_s \rightarrow D_s^{(*)} + D_s^{(*)}) / 2}
\]

To prove this formula experimentally: a) Contribution of \( B_s \rightarrow D_s^{(*)} D_s^{(*)} n\pi \) is small. b) Most of \( B_s \rightarrow D_s^+ D_s^- \) and \( B_s \rightarrow D_s^{**} D_s^{*-} \) states are \( CP \)-even.

Assuming corrections are small (\( \sim 5-7\% \)), \( Bf \) measurement will provide information about \( \Delta \Gamma_{CP}^s \) or \( \mid \Gamma_{12} \mid \).
**Expected with 25 fb⁻¹ at Y(5S):**

\[
\begin{align*}
\text{Eff}(B_s \rightarrow D_s^+ D_s^-) & \sim 2 \times 10^{-4} \quad N \sim 10^7 \times 2 \times 10^{-4} \times 10^{-2} \sim 5 \text{ ev} \\
\text{Eff}(B_s \rightarrow D_s^{++} D_s^-) & \sim 1 \times 10^{-4} \quad N \sim 10^7 \times 10^{-4} \times 2 \times 10^{-2} \sim 5+5 \text{ ev} \\
\text{Eff}(B_s \rightarrow D_s^{++} D_s^{*-}) & \sim 5 \times 10^{-5} \quad N \sim 10^7 \times 5 \times 10^{-5} \times 3 \times 10^{-2} \sim 4 \text{ ev}
\end{align*}
\]

=> Accuracy of \( Bf(B_s \rightarrow D_s^{(*)+} D_s^{(*)-}) \) has to be \( \sim 25\% \).

\[
\frac{\Delta \Gamma_{\text{CP}}^S}{\Gamma_s} \approx \frac{\text{Bf}(B_s \rightarrow D_s^{(*)+} D_s^{(*)-})}{1 - \text{Bf}(B_s \rightarrow D_s^{(*)+} D_s^{(*)-}) / 2} \leq \frac{\Delta \Gamma_s}{\Gamma_s}
\]

\( \Delta \Gamma_s/\Gamma_s \) lifetime difference can be measured directly with high accuracy at Y(5S) and also at Tevatron and LHC experiments.
Further physics program with 23 fb$^{-1}$

1. $B_s \rightarrow D_s^+ \rho^-, B_s \rightarrow D_s^+ a_1^-$,
   
   $B_s \rightarrow D_s^{*+} \pi^-, B_s \rightarrow D_s^{*+} \rho^-, B_s \rightarrow D_s^{*+} a_1^-.$
   
   BF's should be compared with $B^0$ partners to test SU(3).

2. $B_s \rightarrow J/\psi \eta, J/\psi \eta', J/\psi \omega, J/\psi f_0(980), \ldots, B_s \rightarrow J/\psi K^+ K^-.$

   What is fraction of $s\bar{s}$ component in different mesons?

   Quark model: $\psi(\eta) = (u\bar{u}+d\bar{d}-s\bar{s})/\sqrt{3}$ \quad $\psi(\eta') = (u\bar{u}+d\bar{d}+2s\bar{s})/\sqrt{6}$

   $B(B_s^0 \rightarrow J/\psi \eta) = 1/3 \ B(B_s^0 \rightarrow J/\psi \phi)$

   $B(B_s^0 \rightarrow J/\psi \eta') = 2/3 \ B(B_s^0 \rightarrow J/\psi \phi)$

   Mixed channels? Enhanced branching fractions?
3. $B_S \rightarrow D_{sJ}^+ \pi^-$ (4 states).

Interesting physics issues, critical test of $D_{sJ}$ nature. Inclusive $D_{sJ}$ production study?

4. $B_S \rightarrow D^0 K^0(*)$.

Statistically significant signals are expected with BF's predicted at [C-K.Chua, W-S.Hou, hep-ph/0712.1882].

$$\text{Bf}(B_S \rightarrow D^0 K^0) \sim 8 \times 10^{-4} \Rightarrow \sim 20 \text{ signal events should be seen with } 23.6 \text{ fb}^{-1} \text{ at } Y(5S).$$

**Color-suppressed**

\[ \bar{B}_s^0 \rightarrow D^0 K^0 \]
Which diagram, color-suppressed or FSI, is dominant in $B^0 \rightarrow D^0 \pi^0$ decay? Decay mode $B_s \rightarrow D^0 K^{(*)0}$ has no FSI diagram. If the ratio $Bf(B_s \rightarrow D^0 K^{(*)0})/Bf(B_s \rightarrow D^+_s \pi^-) \sim 0.1$, then color-suppressed diagram dominates. If the ratio is significantly smaller, then FSI diagram dominates.
5. \( B_s \rightarrow D_s^+ l^- \nu \), \( B_s \rightarrow D_s^{*-} l^- \nu \) (\( B_s \rightarrow K^+ l^- \nu ? \)).

Important SU(3) test. CDF obtained large \( D_{sJ} \) semileptonic BF ( ? ).

6. \( B_s \) decays with baryons (with \( \Lambda^0 \) baryons).

Largest \( B^0 \) baryonic Bf’s are \( \sim 10^{-3} \). Is it similar in \( B_s \) decays?

7. \( B_s \) lifetime measurement.

Different samples can be used: fully reconstructed events, CP-fixed modes, two lepton events, \( D_s^+ \) lep\(^+ \) events … .

Good accuracy is expected (5-10%). Important measurement.
Feasibility of $B_s$ lifetime measurement with same-sign leptons

Lifetime can be measured using two fast same sign lepton tracks and beam profile. To remove secondary $D$ meson semileptonic decays: $P(\ell) > 1.4$ GeV.

$Y(5S) : \frac{B_s(\ell^+) B_s(\ell^+) / B_s(\ell^+) B_s(\ell^-)}{B_s(\ell^+)} = 100\%$

$Y(4S) : \frac{B(\ell^+) B(\ell^+) / B(\ell^+)}{B(\ell^-)} \sim 10\%$

$\Delta z = \beta \gamma c \Delta t$

$Z_{\text{beam}} \sim 3$ mm; $\Delta z \sim 0.1-0.2$ mm.
There are several topics, where $Y(5)$ running has advantages comparing with CDF and D0:
1) **Model independent** branching fraction measurements.
2) Measurement of decay modes with $\gamma$, $\pi^0$ and $\eta$ in final state ($D_s^+\rho^-$).
3) No trigger problems for multiparticle final states (like $D_s^+D_s^-$).
4) Inclusive branching fraction measurements (semileptonic $B_s$).
5) Partial reconstruction ($B_f(D_s^+l^-\nu)$ using “missing- mass” method).

There are also disadvantages:
1) We have to choose between running at $Y(4S)$ or $Y(5S)$.
2) **Number of $B_s$** is smaller than in Fermilab experiments.
3) Vertex resolution is not good enough to measure $B_s$ mixing (???).
Realistic value of 200 fb\(^{-1}\)
Optimistic value of 2000 fb\(^{-1}\)

**Only big deals:**

1. \(\Delta \Gamma_s / \Gamma_s\) measurement

   Decay modes \(D_s^{(*)}D_s^{(*)}, K^+K^-, \phi\phi, \phi\gamma, J/\psi \eta(\phi)\)

   \(\sim 500\) CP-fixed events with 200 fb\(^{-1}\) \(\Rightarrow\) 5-10\% accuracy in \(\Gamma_s\).

2. Measurement of \(B_s \rightarrow \gamma\gamma\) decay

   It also requires about 1000 fb\(^{-1}\) to measure.

3. \(B_s\) mixing measurement
It is often postulated, that $B_s$ mixing cannot me measured at the $Y(5S)$. Have anybody checked it? Is it correct or not?

**Can we measure $B_s$ mixing? Let’s check it.**

Distance between max and min of oscillation function:
$$\Delta z = \pi \Delta m_s \beta \gamma c = 22.5 \mu m \text{ with } \beta \gamma = 0.425$$

Can we increase $\beta \gamma$ at $Y(5S)$ runs by 50%? Probably yes.

Then we need to get single vertex resolution of $\sim 20 \mu m$.

Is is planned resolution for fast ($0^\circ$ dip angle) tracks (next slide).

$\Rightarrow$ with high statistics we can select high vertex resolution events.

Yes, we can.
Impact Parameter resolution

Calculated by TRACKERR

Occupancy effects.
Degradation of intrinsic resolution is included.
Efficiency loss is NOT included

Beampipe radius is important
Competitive performance as the current SVD
What else can be done at Super B Factory?

PDG (Z→bb, pp at $S^{1/2} = 1.8$ TeV)

<table>
<thead>
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<th>b hadron fraction(%)</th>
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<tbody>
<tr>
<td>$B^+$, $B^0$</td>
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<tr>
<td>$B_s$</td>
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<tr>
<td>b baryons</td>
</tr>
</tbody>
</table>

Rates at $e^+e^-$ continuum should be similar, baryon production is large.

$M(\Lambda_b) = (5624 \pm 9)$ MeV/c²

$M(\Lambda_b) \times 2 = (11248 \pm 18)$ MeV/c² $\Rightarrow$ 6.3 % up from $\Upsilon(4S)$ CME.

Can Super B factory CM energy range be increased?

$M(\bar{B}_c) = (6286 \pm 5)$ MeV/c²

$e^+e^- \rightarrow \Upsilon(6S,7S) \rightarrow B_s\bar{B}_s, \Lambda_b\bar{\Lambda}_b, B_c\bar{B}_c, \Xi_b\bar{\Xi}_b \ldots$ ?
Conclusions

- $B_s$ decays with branching fractions down to $10^{-6}$ can be measured with statistics of $\sim 100$ fb$^{-1}$ at $e^+e^-$ colliders running at Y(5S).

- Many important SM tests can be done with statistics of the order of 1000 fb$^{-1}$.

- $B_s$ studies at $e^+e^-$ colliders running at Y(5S) have some advantages comparing with hadron-hadron colliders. These colliders are in some sense complementary.

- It is important to have more flexibility in beam energies.
Background slides
Belle Detector

SC solenoid 1.5T
EM calorimeter (CsI(Tl))
TOF counter

8GeV $e^-$

3.5GeV $e^+$

Central drift chamber He(50%) + C$_2$H$_6$(50%)

Cherenkov detector $n=1.015$~$1.030$

Si vertex detector

$\mu$ / $K_L$ detector
dz resolution

SuperB
SVD3mod
SVD3

For $\pi$
0.2GeV
0.5GeV
1.0GeV
2.0GeV

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