Is there a $10^{36}$ Collider in SLAC's future?

David Hitlin
SLAC BABAR Seminar
October 18, 2002
Is the a $10^{36}$ collider in SLAC's future?

- Is there discovery potential in the study of 10 to 50 ab$^{-1}$ data samples?
  - YES!
- Is there an interested community in the US and in other countries?
  - Potentially, yes
- Can we obtain funding for a $10^{36}$ collider and detector?
  - Not certain, but possible, given the appropriate circumstances
- Is there a time window for a $10^{36}$ machine?
  - Yes, there is a clear time window
    - It must take data on a time scale comparable to the LHC experiments (ATLAS, CMS, LHCb) and, potentially with BTeV
- That's quite a way off. What's the urgency?
  - The HEPAP-mandated P5 is being formed. It's first order of business will be BTeV (which has just had a Director's Review at Fermilab)
  - The committee will clearly evaluate BTeV in the context of other opportunities, which include $10^{36}$
    - We must have a formal document available for comparison
Dorfan and Sugawara have encouraged cooperation between BABARians and Bellies on future activities, since they believe that “there will be at most one new high luminosity B Factory”

- Both Directors agree that “high luminosity” means $10^{36}$
- Despite this statement at the Director level, Belle is preparing a proposal for an upgrade to $10^{35}$, costing 450 okuYen, and taking ten years
  - They have held three workshops in support of this effort, the last in August 2002 (attended by Uli Wienands, Thomas Hadig and DH)
  - The new effort replaces the previous $10^{35}$ EOI, which was rejected
- Until this scenario plays out, real cooperation is difficult
The Discovery Potential of Asymmetric $e^+e^- B$ Factories

- PEP-II/BaBar and KEK-B/Belle have provided the first evidence that the CKM phase is indeed the source of $CP$ violation in $B$ meson (and, by extension) $K$ meson weak decays.
- Since the matter-antimatter asymmetry of the universe cannot be accounted for by Standard Model $CP$ violation, we had a reasonable expectation that the Standard Model would fail this unique test.
- The Standard Model passed the test.
  - The unitarity triangle construction is self-consistent.
- Is there still discovery potential in pursuing $CP$ violation studies?
  - Or are we now just engaged in a series of refinements of the measurement precision?
- The clear answer is **YES!**, provided we have the means to study $B$ decays with appropriate precision.
- Achieving this precision requires a luminosity of $10^{36} \text{ cm}^{-2}\text{s}^{-1}$
Measurements by $\textit{BAbAR}$/Belle confirm the CKM ansatz

nb: SM predictions of $CP$-violating quantities in the quark sector are often more precise than predictions of $CP$-conserving quantities
**SUSY Scenarios**

- Assume that evidence for SUSY is found at the Tevatron, LHC or NLC
  - What will you actually know?
    - The masses of some of the SUSY partners: gluino, squark, ........
    - Perhaps the identity of the LSP

![Mass Diagram](image.png)
The New Physics Bible according to Nir

- **CP** violation is an excellent probe of new physics
  - The CKM mechanism has a single source of **CPV** and makes quantitative predictions
  - New sources of flavor and **CP** violation can induce large deviations from the Standard Model predictions, many of which are not obscured by hadronic uncertainties

- Henceforth in this discussion, I will use the supersymmetric SM as an example
  - The supersymmetric SM has 124 independent parameters, 44 of which are **CP**-violating
    - What are the constraints of existing measurements of **CPV** on SUSY model building?
    - What are the prospects that future **CPV** measurements will uncover deviations from the SM predictions?

- Having found that $A_{CP}$ in $B^0 \rightarrow J/\psi K_S^0$ agrees with CKM prediction, we are beyond the era of seeking alternatives to the CKM phase and must now search for new physics by finding loop corrections to the CKM picture
New *CP* Violating effects must be there

- *CP* effects in the flavor sector that are not accounted for by the CKM phase must exist
- If they do not exist, SUSY and other models constructed with the same motivation will be ruled out
- The required sensitivity can be reached
  - A real optimist might conclude that SUSY could be discovered through loop effects before there is explicit production of new particles at LHC
  - Even if this is not realistic, it will be important to study *CPV* in flavor physics at the scale of $10^{10}$ to $10^{11}$ $B$ decays
Constraints on SUSY from existing measurements

- In order to obey the constraints from K decay:
  - Indirect CPV in $K \rightarrow \pi\pi$ and $K \rightarrow \pi\ell\nu_\ell$ decays: $|\varepsilon| = (2.28 \pm 0.02) \times 10^{-3}$
  - Direct CPV in $K \rightarrow \pi\pi$ decays: $\text{Re} |\varepsilon'/\varepsilon| = (1.66 \pm 0.16) \times 10^{-3}$
  - it is necessary to invoke one or more of the following:
    - Heavy squarks: $\tilde{m} \gg 100$ GeV
    - Universality: $\Delta m^2_{\tilde{s}\tilde{d}} \ll \tilde{m}^2$
    - Alignment: $\left|K_{12}^d\right| \ll 1$
    - Approximate CP: CPV phases are small
  - All viable models of SUSY-breaking use one or more of these mechanisms
  - Two other measurements:
    - $A_{CP}$ in $B^0 \rightarrow J/\psi K^0_S$ decay: $\text{Im} \chi_{\psi K} = 0.734 \pm 0.054$
    - Limits on EDM's (through $T$ violation and CPT)
      impose serious additional constraints
  - For example, $A_{CP}$ effectively kills Approximate CP models
  - EDM limits imply that the source of CPV beyond the Standard Model in models with minimal flavor violation is Yukawa couplings, which can be flavor dependent
Effects of SUSY breaking on CPV in flavor physics

- Specific models produce specific CPV patterns
- There are a variety of models of SUSY breaking on the market
- Many of these models generate specific, calculable CP-violating effects in hadronic and rare $B$ decays
- Other extensions (Technicolor, Little Higgs (?),.....) have the same sorts of effects, although they often have distinguishable patterns
- In order to exploit CP violation as a tool to search for physics beyond the Standard Model we must do two things:
  - Achieve the highest meaningful precision on CPV ($\alpha$, $\beta$, $\gamma$) measurements of the $B$ unitarity triangle
    - This requires several x 10 ab$^{-1}$ (1 ab$^{-1}$ = 1000 fb$^{-1}$)
  - Measure kinematic distributions and CP-violating (and sometimes CP-conserving) asymmetries in very rare decays, both inclusive and exclusive
    - These are decay modes such as $B^0 \rightarrow K\ell^+\ell^-$ where we have at present only a handful of events
**A possible scenario for improvement in the precision of CKM matrix elements**

<table>
<thead>
<tr>
<th>$V_{ij}$</th>
<th>Experimental Measurement</th>
<th>$\sigma$ Quantity</th>
<th>$\sigma$ 2001 stat/sys</th>
<th>$\sigma$ 2006 stat/sys</th>
<th>$\sigma$ 2011 stat/sys</th>
<th>Theoretical Quantity</th>
<th>$\sigma$ 2001 quenched</th>
<th>$\sigma$ 2-5 years unquenched</th>
<th>$\sigma$ 4-10 years unquenched</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{ub}$</td>
<td>$B(B \rightarrow \rho l\nu)$</td>
<td>$f_+(E_\pi)$</td>
<td>4.3%/8%</td>
<td>8.6%/2.4%</td>
<td>1.4%/2.4%</td>
<td>$\overline{\Lambda}$, $\lambda_1$, $\lambda_2^*$</td>
<td>15%</td>
<td>10-15%</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>$B(B \rightarrow ul\nu)$</td>
<td>$f_B$</td>
<td>3.4%/16%</td>
<td>4.0%/2.4%</td>
<td>2.8%/2.4%</td>
<td>24%</td>
<td>5%</td>
<td>see note</td>
<td>see note</td>
</tr>
<tr>
<td></td>
<td>$B(B \rightarrow \tau l\nu)$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{cb}$</td>
<td>$(F(1))$</td>
<td>$f_+(q^2)$</td>
<td>3.1%/4%</td>
<td>0.4%/2%</td>
<td>0.10%/1%</td>
<td>$\overline{\Lambda}$, $\lambda_1$, $\lambda_2^*$</td>
<td>2-4%</td>
<td>2-4%</td>
<td>1%</td>
</tr>
<tr>
<td></td>
<td>$B(B \rightarrow D l\nu)$</td>
<td></td>
<td>2.5%/2%</td>
<td>0.3%/1%</td>
<td>0.07/0.5%</td>
<td>5%</td>
<td>25%</td>
<td>15%</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>$B(B \rightarrow cl\nu)$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{us}$</td>
<td>$B(K \rightarrow \pi l\nu)$</td>
<td>$f_+(q^2)$</td>
<td>7.1%</td>
<td>1%</td>
<td>2%</td>
<td>$f_+(E_\pi)$</td>
<td>15%</td>
<td>10-15%</td>
<td>2-5%</td>
</tr>
<tr>
<td></td>
<td>$B(D \rightarrow \pi l\nu)$</td>
<td></td>
<td>0.4%</td>
<td>1%</td>
<td></td>
<td>$f_D$</td>
<td>15%</td>
<td>10%</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>$B(D \rightarrow l\nu)$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{cs}$</td>
<td>$B(D \rightarrow K l\nu)$</td>
<td>$f_+(E_K)$</td>
<td>0.4%</td>
<td>0.05%/0.2%</td>
<td></td>
<td>$f_D$</td>
<td>15%</td>
<td>10-15%</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>$B(D_s \rightarrow l\nu)$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{td}$</td>
<td>$\Delta m_d$</td>
<td>$f_{B_d}/\sqrt{B_{B_d}}$</td>
<td>1%/1%</td>
<td>0.2%/0.5%</td>
<td>0.05%/0.2%</td>
<td>$f_{B_s}/\sqrt{B_{B_s}}$</td>
<td>~20%</td>
<td>15%</td>
<td>5%</td>
</tr>
<tr>
<td>$V_{ts}$</td>
<td>$\Delta m_s$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† 50% of the error on $f_B/f_{D_s}$
* from experiment: $\lambda_2$ from $m_{B^*} - m_B$; $\overline{\Lambda}$ and $\lambda_1$ from moments of $B \rightarrow cl\nu$ and $B \rightarrow s\gamma$ spectra
‡ lattice measures $F(1) - 1$
♯ $\xi = \frac{f_{B_s}/\sqrt{B_s}}{f_{B_d}/\sqrt{B_d}}$ error divided by 1.5-2

Eigen, Kronfeld, Mackenzie
Isolating the penguin contribution to $\sin 2\alpha$ using $B^0 \rightarrow \pi^0 \pi^0$

Current precision on $A_{CP}(B^0 \rightarrow \pi^+ \pi^-)$ yields

$$\sin 2\alpha_{\text{eff}} = 0.02 \pm 0.34 \pm 0.05$$

with $2\alpha_{\text{eff}} = 2\alpha + 2\delta$

Isolating the $2\delta$ contribution due to penguin pollution requires measurement of tagged $B^0 \rightarrow \pi^0 \pi^0$ and $\bar{B}^0 \rightarrow \pi^0 \pi^0$ decay branching fractions, which can only be done at a $B$ Factory.
Isolating the penguin contribution to $\sin 2\alpha$ using $B^0 \rightarrow \pi^0 \pi^0$

With 10 ab$^{-1}$, the Gronau-Wyler construction can place a stringent limit on penguin amplitudes.

$$\cos \phi = \frac{\text{Br}(\pi^+ \pi^0) + \frac{1}{2} \text{Br}(\pi^+ \pi^-) - \text{Br}(\pi^0 \pi^0)}{\sqrt{2 \text{Br}(\pi^+ \pi^-) \text{Br}(\pi^+ \pi^0)}}$$

... but there is a 4-fold ambiguity!

Toy MC, assuming:
- $\text{BR}(B^- \rightarrow \pi^- \pi^0) = 4.1 \times 10^{-6}$
- $\text{BR}(B^0 \rightarrow \pi^+ \pi^-) = \text{BR}(B^0 \rightarrow \pi^+ \pi^-)$
- $\text{BR}(B^0 (\overline{B}^0) \rightarrow \pi^0 \pi^0) = 4.7 \times 10^{-6}$
- $\text{BR}(B^0 (\overline{B}^0) \rightarrow \pi^0 \pi^0) = 0.5 (1.5) \times 10^{-6}$

With 10 ab$^{-1}$, the Gronau-Wyler construction can place a stringent limit on penguin amplitudes.
Measuring $\gamma$ with $B^+ \rightarrow D_{CP}^0 K^+$

\[
\sqrt{2} A(B^+ \rightarrow D_0^0 K^+) = A(B^- \rightarrow D^0 K^-) + A(B^- \rightarrow \bar{D}^0 K^-)
\]

- Estimate experimental uncertainty on $f^-_+, ..., f^+_-$ using existing measurements (+ use additional $D^0$ modes)
- Toy MC with different luminosities, experimental resolutions, true “r”

Measure:

\[
\frac{\Gamma(B^- \rightarrow D_0^+ K^-)}{\Gamma(B^- \rightarrow D_0^- K^-)} = f^- - (\gamma, \Delta \delta, r)
\]

\[
\frac{\Gamma(B^- \rightarrow D_0^- K^-)}{\Gamma(B^- \rightarrow D_0^+ K^-)} = f^-
\]

\[
\frac{\Gamma(B^+ \rightarrow D_0^+ K^-)}{\Gamma(B^- \rightarrow D_0^- K^-)} = f^+_-
\]

\[
\frac{\Gamma(B^+ \rightarrow D_0^- K^-)}{\Gamma(B^- \rightarrow D_0^+ K^-)} = f^+_+
\]

\[
r \equiv \frac{A(B^- \rightarrow \bar{D}_0^0 K^-)}{A(B^- \rightarrow D_0^0 K^-)} = O(0.1)
\]

- Crucially depends on $r$ (breaks down for $r < 0.1$?)
- 8-fold ambiguity spoils the extraction of $\gamma$
- But $A_{CP} = 2r \sin \Delta \delta \sin \gamma$ is accessible:

<table>
<thead>
<tr>
<th>$r$</th>
<th>$\sin^2 \gamma$</th>
<th>$\gamma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>$0.71 \pm 0.14$</td>
<td>$(58.5 \pm 7.4)\degree$</td>
</tr>
<tr>
<td>0.2</td>
<td>$0.70 \pm 0.26$</td>
<td>$(59.0 \pm 11.2)\degree$</td>
</tr>
<tr>
<td>0.1</td>
<td>unreliable</td>
<td>unreliable</td>
</tr>
</tbody>
</table>

$\sigma(A_{CP}) \sim 0.03$ with $2 \text{ ab}^{-1}$
**γ determination**

- **Gronau-Wyler, Atwood, Dunietz and Soni method:**
  
  Comparison of BR's for $B \rightarrow DK$ modes can allow extraction of $\gamma$

- There is an 8-fold ambiguity

- With sufficient luminosity, it is possible to resolve the ambiguity:
  
  with $10 \text{ ab}^{-1}$, it appears that a precision of $\Delta \gamma \lesssim 1^\circ - 2.5^\circ$ can be achieved

Study was done with 600 fb$^{-1}$, scaled to 10 ab$^{-1}$
Statistics and systematics

- Many important CPV measurements will remain statistics limited
- Certain measurements, such as $A_{CP}$ in $B^0 \to J/\psi K^0_S$ will be systematics limited at the ~1% level
- Other measurements, such as the extraction of $\sin 2\alpha$ or $V_{ub}$ will be limited by theory
- Many of the most interesting measurements will be limited by statistics and backgrounds
  - This leads to the question of whether an upgraded detector can do better than a $\sqrt{n}$ extrapolation would indicate
    - Does improved momentum resolution and improved particle ID lead to a better measurement of $S_{\pi\pi}$?
    - Does improved photon energy and angular resolution lead to a better measurement of tagged $B^0 \to \pi^0\pi^0$?
    - Does longitudinal segmentation in the EMC lead to better $\pi/e$ separation and thus better tagging?
It is important to measure with the right yardstick

- A comparison from the Snowmass E2 summary:

<table>
<thead>
<tr>
<th></th>
<th>BTeV $10^7$ s</th>
<th>LHCb $10^7$ s</th>
<th>BABAR Belle (2005)</th>
<th>$10^{35}$ $10^7$ s</th>
<th>$10^{36}$ $10^7$ s</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sin 2\beta$</td>
<td>0.011</td>
<td>0.02</td>
<td>0.037</td>
<td>0.026</td>
<td>0.008</td>
</tr>
<tr>
<td>$\sin 2\alpha$</td>
<td>0.05</td>
<td>0.05</td>
<td>0.1</td>
<td>0.1</td>
<td>0.032</td>
</tr>
<tr>
<td>$\gamma [B_s (D_s K)]$</td>
<td>$\sim 7^\circ$</td>
<td>$\sim 2^\circ$</td>
<td>$\sim 20^\circ$</td>
<td>-</td>
<td>$1-2.5^\circ$</td>
</tr>
<tr>
<td>$\gamma [B (D K)]$</td>
<td>$\sim 2^\circ$</td>
<td>$\sim 20^\circ$</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\sin 2\chi$</td>
<td>0.023</td>
<td>0.04</td>
<td>-</td>
<td>14%</td>
<td>6%</td>
</tr>
<tr>
<td>$\text{BR}(B \to \pi^0 \pi^0)$</td>
<td>-</td>
<td>-</td>
<td>$\sim 2.3%$</td>
<td>$\sim 1%$ (sys)</td>
<td>$\sim 1%$ (sys)</td>
</tr>
<tr>
<td>$V_{ub}$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- This is not the optimum strategy for finding new physics through the unitarity triangle construction
CKM Fitter Group Prophecy for 2010

\[ \Delta m_s \quad \text{and} \quad \Delta m_d \]

\[ \gamma \]

\[ \gamma^0 \]

\[ \pi^+ \]

\[ \pi^0 \]

\[ \sin 2\beta \]

\[ \beta \]

\[ B \varepsilon_k B \]

\[ B V_{ub}/V_{cb} B \]
Many $CP$ asymmetries can be changed by SUSY

<table>
<thead>
<tr>
<th>Incl.</th>
<th>Excl.</th>
<th>$\phi_{\text{SM}}^D$</th>
<th>$\tau_{\text{SM}}$</th>
<th>$\phi_{\text{SUSY}}^D$</th>
<th>$\tau_{250}$</th>
<th>$\tau_{500}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b \to c\bar{c}s$</td>
<td>$B \to J/\psi K_S$</td>
<td>0</td>
<td>–</td>
<td>$\phi_{23}$</td>
<td>0.03 – 0.1</td>
<td>0.008 – 0.04</td>
</tr>
<tr>
<td>$b \to s\bar{s}s$</td>
<td>$B \to \phi K_S$</td>
<td>0</td>
<td>–</td>
<td>$\phi_{23}$</td>
<td>0.4 – 0.7</td>
<td>0.09 – 0.2</td>
</tr>
<tr>
<td>$b \to u\bar{u}s$</td>
<td>$B \to \pi^0 K_S$</td>
<td>Tree $\gamma$</td>
<td>0.009 – 0.08</td>
<td>$\phi_{23}$</td>
<td>0.4 – 0.7</td>
<td>0.09 – 0.2</td>
</tr>
<tr>
<td>$b \to d\bar{d}s$</td>
<td>$B \to \pi^0 K_S$</td>
<td>Penguin 0</td>
<td>0</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>$b \to c\bar{c}d$</td>
<td>$B \to D_{CP}^0 \pi^0$</td>
<td>0.02</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>$b \to u\bar{c}d$</td>
<td>$B \to D^+ D^-$</td>
<td>Tree $\gamma$</td>
<td>0.03 – 0.3</td>
<td>$\phi_{13}$</td>
<td>0.007 – 0.02</td>
<td>0.002 – 0.006</td>
</tr>
<tr>
<td>$b \to c\bar{c}d$</td>
<td>$B \to J/\psi \pi^0$</td>
<td>Penguin $\beta$</td>
<td>0.04 – 0.3</td>
<td>$\phi_{13}$</td>
<td>0.007 – 0.03</td>
<td>0.002 – 0.008</td>
</tr>
<tr>
<td></td>
<td>$B \to \phi \pi^0$</td>
<td>Penguin $\beta$</td>
<td>–</td>
<td>0.06 – 0.1</td>
<td>0.01 – 0.03</td>
<td></td>
</tr>
<tr>
<td>$b \to s\bar{s}d$</td>
<td>$B \to K^0 \bar{K}^0$</td>
<td>$u$-Penguin $\gamma$</td>
<td>0 – 0.07</td>
<td>$\phi_{13}$</td>
<td>0.08 – 0.2</td>
<td>0.02 – 0.06</td>
</tr>
<tr>
<td>$b \to u\bar{u}d$</td>
<td>$B \to \pi^+ \pi^-$</td>
<td>Tree $\gamma$</td>
<td>0.09 – 0.9</td>
<td>$\phi_{13}$</td>
<td>0.02 – 0.8</td>
<td>0.005 – 0.2</td>
</tr>
<tr>
<td>$b \to d\bar{d}d$</td>
<td>$B \to \pi^0 \pi^0$</td>
<td>Penguin $\beta$</td>
<td>0.6 – 6</td>
<td>$\phi_{13}$</td>
<td>0.06 – 0.4</td>
<td>0.02 – 0.1</td>
</tr>
<tr>
<td></td>
<td>$B \to K^+ K^-$</td>
<td>Tree $\gamma$</td>
<td>0.2 – 0.4</td>
<td>$\phi_{13}$</td>
<td>0.04 – 0.1</td>
<td>0.01 – 0.03</td>
</tr>
<tr>
<td>$b\bar{d} \to q\bar{q}$</td>
<td>$B \to D^0 \bar{D}^0$</td>
<td>Penguin $\beta$</td>
<td>only $\beta$</td>
<td>0.01 – 0.03</td>
<td>0.003 – 0.006</td>
<td></td>
</tr>
</tbody>
</table>

Ciuchini, Franco, Martinelli, Masiero, & Silvestrini
Other Standard Model extensions also change **CPV**

<table>
<thead>
<tr>
<th>Mode</th>
<th>( B_d \to )</th>
<th>SM angle (( \phi_0 ))</th>
<th>( \delta \phi_{SM} )</th>
<th>( \delta \phi_A )</th>
<th>( \delta \phi_B )</th>
<th>( \delta \phi_C )</th>
<th>( BR )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( b \to c \bar{c}s )</td>
<td>( J/\psi K^0 )</td>
<td>( \beta )</td>
<td>0</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>( 7 \times 10^{-4} )</td>
</tr>
<tr>
<td>( b \to c \bar{c}d )</td>
<td>( D^+ D^- )</td>
<td>( \beta )</td>
<td>0.1</td>
<td>0.2</td>
<td>0.6</td>
<td>0.6</td>
<td>( 4 \times 10^{-4} )</td>
</tr>
<tr>
<td>( b \to c \bar{u}d )</td>
<td>( D_{CP}^0 \pi^0 )</td>
<td>( \beta )</td>
<td>0.05</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
<td>( 10^{-5} )</td>
</tr>
<tr>
<td>( b \to s \bar{s}s )</td>
<td>( \phi K^0 )</td>
<td>( \beta )</td>
<td>0.04</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>( 10^{-5} )</td>
</tr>
<tr>
<td>( b \to u \bar{u}d )</td>
<td>( \pi^+ \pi^- )</td>
<td>( \beta + \gamma )</td>
<td>0.4</td>
<td>0.4</td>
<td>1</td>
<td>0</td>
<td>( 10^{-5} )</td>
</tr>
<tr>
<td>( b \to u \bar{c}s )</td>
<td>( D_{CP}^0 K^0 )</td>
<td>( \gamma )</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>( 10^{-6} )</td>
</tr>
<tr>
<td>( b \to d \bar{s}s )</td>
<td>( K_S^0 K_S^0 )</td>
<td>( 0 )</td>
<td>0.3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>( 10^{-6} )</td>
</tr>
</tbody>
</table>

Grossman and Worah
Extrapolated statistical errors on $CP$ asymmetries

10 to 50 ab$^{-1}$ are required for a meaningful comparison.
**CPV in exclusive radiative decays**

![Graph depicting CPV in exclusive radiative decays](image)

- SM central values
- EMFV central values
- SM at 68% C.L.
- EMFV at 68% C.L.
- MFV at 68% C.L., $C_7^8 > 0$

Ali and Lunghi
Probe of SUSY in $B^0 \rightarrow K^* \ell^+ \ell^-$ and $B^0 \rightarrow \rho \ell \nu$

$$R_i(s) = \frac{d\Gamma_{H_i}^{B \rightarrow K^* \ell^+ \ell^-}}{d\Gamma_{H_i}^{B \rightarrow \rho \ell \nu}} / ds$$

($i = 0, -1, +1$)

![Graphs showing comparison between SM and SUGRA for $R_0(s)/ds$ vs. $s$ (GeV$^2$)](image)

Ali and Safir
Kinematic distributions and $CP$ asymmetries in rare decays

$\Delta m(s)$

$\frac{d\bar{A}_{FB}(\beta \rightarrow K^0 \mu^+ \mu^-)}{ds}$

$\rightarrow$ Bauer, Stech & Wirbel
$\rightarrow$ Ball and Braun
$\rightarrow$ Melihov, Nikitin and Simula

$\rightarrow$ SM, $\ldots$ $\rightarrow$ SUGRA with $\pm C_7$,
$\rightarrow$ MIA with suppressed Br, $\rightarrow$ MIA with enhanced Br

Burdman
MSSM: \( CP \) asymmetry in \( b \to s \gamma \) may or may not be measurable

Bartl, Gajdosik, Lunghi, Masiero, Porod, Stremnitzer and Vives, hep:ph/0103324

- No EDM constraint
- Obey EDM constraint
### At $10^{36}$, $e^+e^-$ is fully competitive in rare decays

<table>
<thead>
<tr>
<th>Decay Mode</th>
<th>Branching Fractions</th>
<th>Hadron Collider Experiments</th>
<th>$e^+e^-$ B Factories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CDF D0</td>
<td>ATLAS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2 fb$^{-1}$)</td>
<td>(1 Year)</td>
</tr>
<tr>
<td>$B \rightarrow X_s \gamma$</td>
<td>$(3.3 \pm 0.3) \times 10^{-4}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B \rightarrow K^* \gamma$</td>
<td>$5 \times 10^{-5}$</td>
<td>170</td>
<td>11K</td>
</tr>
<tr>
<td>$B \rightarrow \rho(\omega) \gamma$</td>
<td>$2 \times 10^{-6}$</td>
<td>25K</td>
<td>220K</td>
</tr>
<tr>
<td>$B \rightarrow X_s \mu^+ \mu^-$</td>
<td>$(6.0 \pm 1.5) \times 10^{-6}$</td>
<td>3.6K</td>
<td>1.7K (B Tagged)</td>
</tr>
<tr>
<td>$B \rightarrow K^* \mu^+ \mu^-$</td>
<td>$(2 \pm 1) \times 10^{-6}$</td>
<td>50-150</td>
<td>34K (B Tagged)</td>
</tr>
<tr>
<td>$B \rightarrow X_s \nu \bar{\nu}$</td>
<td>$(4.1 \pm 0.9) \times 10^{-5}$</td>
<td>1K</td>
<td></td>
</tr>
<tr>
<td>$B \rightarrow K^* \nu \bar{\nu}$</td>
<td>$5 \times 10^{-6}$</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>$B^0_d \rightarrow \tau^+ \tau^-$</td>
<td>$10^{-7}$</td>
<td>5/1.5-6</td>
<td>17</td>
</tr>
<tr>
<td>$B^0_s \rightarrow \mu^+ \mu^-$</td>
<td>$10^{-9}$</td>
<td>5/11</td>
<td>350</td>
</tr>
<tr>
<td>$B^0_d \rightarrow \mu^+ \mu^-$</td>
<td>$8 \times 10^{-11}$</td>
<td>0/0</td>
<td>8</td>
</tr>
<tr>
<td>$B \rightarrow \tau \nu$</td>
<td>$5 \times 10^{-5}$</td>
<td>1/2</td>
<td>150</td>
</tr>
<tr>
<td>$B \rightarrow \mu \nu$</td>
<td>$1.6 \times 10^{-7}$</td>
<td>0.7/20</td>
<td></td>
</tr>
<tr>
<td>$B^0 \rightarrow \gamma \gamma$</td>
<td>$10^{-8}$</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

* Two arm BTeV

---

*Two arm BTeV*
Limits on new physics have a sensitivity exceeding 10 TeV

\[ B(B^0 \rightarrow l^+ l^-) < 5 \times 10^{-9} \]

Figure 1: The 90\% CL limits on coupling versus leptoquark mass.

Figure 2: The 90\% CL limits on coupling versus slepton mass.

S. Yang
### A possible parameter set

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam particle</td>
<td>$e^+$</td>
<td>$e^-$</td>
</tr>
<tr>
<td>Beam energy (GeV)</td>
<td>8.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Circumference (m)</td>
<td>2200</td>
<td></td>
</tr>
<tr>
<td>Number of bunches</td>
<td>7000</td>
<td></td>
</tr>
<tr>
<td>Bunch length (mm)</td>
<td>1.75</td>
<td></td>
</tr>
<tr>
<td>Beam lifetime (min)</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Beam current (A)</td>
<td>10.3</td>
<td>23.5</td>
</tr>
<tr>
<td>Beta * (x/y) (mm)</td>
<td>150/1.5</td>
<td></td>
</tr>
<tr>
<td>Emittances (x/y) (πnm)</td>
<td>44/0.44</td>
<td></td>
</tr>
<tr>
<td>IP beam sizes (µm x/y)</td>
<td>81/0.8</td>
<td></td>
</tr>
<tr>
<td>Beam-beam tune shifts</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>RF Frequency (MHz)</td>
<td>952</td>
<td></td>
</tr>
<tr>
<td>Luminosity (cm$^{-2}$/s$^{-1}$)</td>
<td>$10^{36}$</td>
<td></td>
</tr>
<tr>
<td>Wall plug power (MW)</td>
<td>$\approx$ 110</td>
<td></td>
</tr>
</tbody>
</table>

- Many difficult issues: site power, RF system, bunch length, beam stability, seamless vacuum system, HOM heating, IR design, continuous injection, $e^-$ cloud &/or ions, beam lifetime...

Detector: physics rates! machine backgrounds!!
Total beam power is minimum at equal $e^+, e^-$ beam energy
Original studies of energy asymmetry have been updated

\[ B^0 \rightarrow \pi^+ \pi^- \quad \text{high } p \text{ lepton tag} \]

- \( \times \) \( \text{tau}(B^0) = 1.16 \text{ psec} \)
- \( \diamond \) \( \text{tau}(B^0) = 1.548 \text{ psec} \)
A possible luminosity scenario

- Time scales for the acquisition of data samples must be comparable
  - Hadronic - 2008-2010
  - $e^+e^-$ ????

Scenario for PEP-II/BABAR

⇒

Super PEP-II/

SuperBABAR

presented to the HEPAP SubPanel in 2001
The $10^{36}$ environment

- At Snowmass 2001, a "strawman design" was developed as an existence proof that a $10^{36}$ detector could be built at all
  - Main concerns
    - Radiation dose
    - Machine-related backgrounds
      - synchrotron radiation
      - particle backgrounds, due primarily to continuous injection
    - Physics backgrounds - hadronic split-offs, .....
Is there an upgrade path from \textit{BABAR} to \textit{SuperBABAR}?

- If it were feasible to modify the existing \textit{BABAR} detector for use at a $10^{36}$ machine, there would be substantial savings in time, money and effort.
  - We did not undertake such a study at Snowmass.
- Upgrading the existing detector is beneficial in:
  - Reducing costs by reuse of detector components and existing IR infrastructure.
  - Use of existing software as a basis for new programs.
  - Packaging an attractive proposal for funding agencies.
- It is likely that the energy asymmetry will be reduced from 9 on 3.1 GeV to perhaps 8 on 3.5 GeV to save on accelerator power.
A potential upgrade path from *BaBar* to *SuperBaBar*

1. Flux return and IFR upgraded à la MINOS
2. Remove SVT, DCH, EMC, DIRC
3. New EMC – liquid Xe
4. New tracker – Two inner pixel layers
   Seven(?) thin double-sided Si-strip arch layers
5. New DIRC(s) with compact readout
How do we proceed?

- In London the Exec Board agreed to set up a $10^{36}$ Task Force
  - Some progress has been made since then, but it is slow and painful
  - **Goals**
    - Participation by an international group interested in investigating the case for $10^{36}$ and studying detector options
    - Work on the $10^{36}$ Task Force is unlikely to be a full-time activity
    - Some people must be interested enough to provide the drive and continuity needed for a successful effort
    - There will be a core group that will seek out effort from the Collaboration for specific investigations
  - Produce a report that makes the case, if there is one, and can serve as the basis for an LOI
  - Build the physics case
  - Demonstrate that the crucial measurements can in fact be done in the challenging $10^{36}$ environment
- There will be weekly meetings, a hypernews group and a Web page
The MSSM (Minimal Symbolic Straw Man) Upgrade Detector

- The design you have seen several times is the sole product of my fevered imagination
  - It is certainly possible to improve upon this attempt
  - This should be among the first orders of business, as we need a stable reference baseline to instantiate in PRAVDA

- Steps in the process
  - Define a set of desirable, yet practical, design requirements on resolution, rate capability, misidentification probability, ...........
  - Survey available technologies, estimate their degree of readiness, cost, required additional R&D, etc.
  - Synthesize an optimized MSSM and put it into PRAVDA
    - We need the flexibility to
      - Vary parameters within a detector subsystem
      - Swap technologies for a given subsystem
      - Use TRACKERR for vertex/tracking studies and parameterized descriptions for PID, EMC and IFR
Conclusions

- Detailed studies of $CP$ violation in $B$ meson decay (and $D$ and $\tau$ decay) with samples of 10-50 ab$^{-1}$ are likely to show effects due to new physics such as SUSY.
- Detailed studies of physics backgrounds and limiting systematic errors remain to be done, but $\sqrt{n}$ estimates of physics capabilities are promising.
- Volunteers for the $10^{36}$ Task Force are urgently needed.
- If we get down to work, there can be a $10^{36}$ collider in SLAC's future.
DILBERT, PUT TOGETHER A TEAM TO DECIDE WHO’LL BE ON THE STRATEGY COUNCIL.

YOU WANT ME TO FORM A COMMITTEE TO CREATE A COMMITTEE THAT WILL PRODUCE A DOCUMENT THAT WILL BE IGNORED?

NO, IT’S A TEAM TO CREATE A COUNCIL. CAN I BE ON THE TEAM THAT IGNORES THE DOCUMENT?