



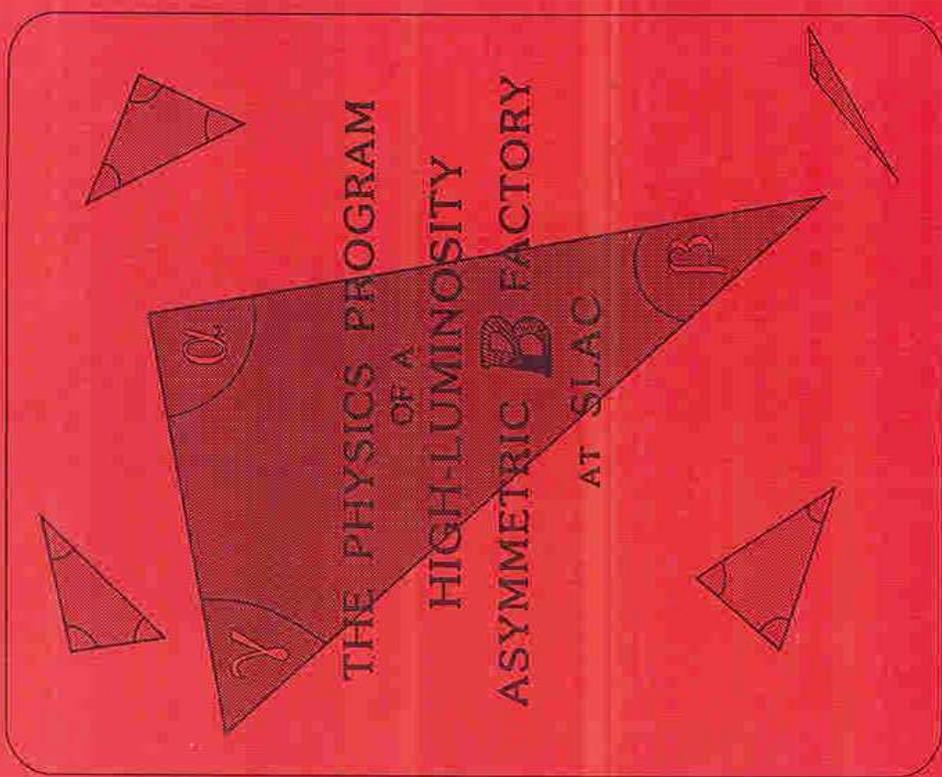
Why did we build it?

B factory Symposium

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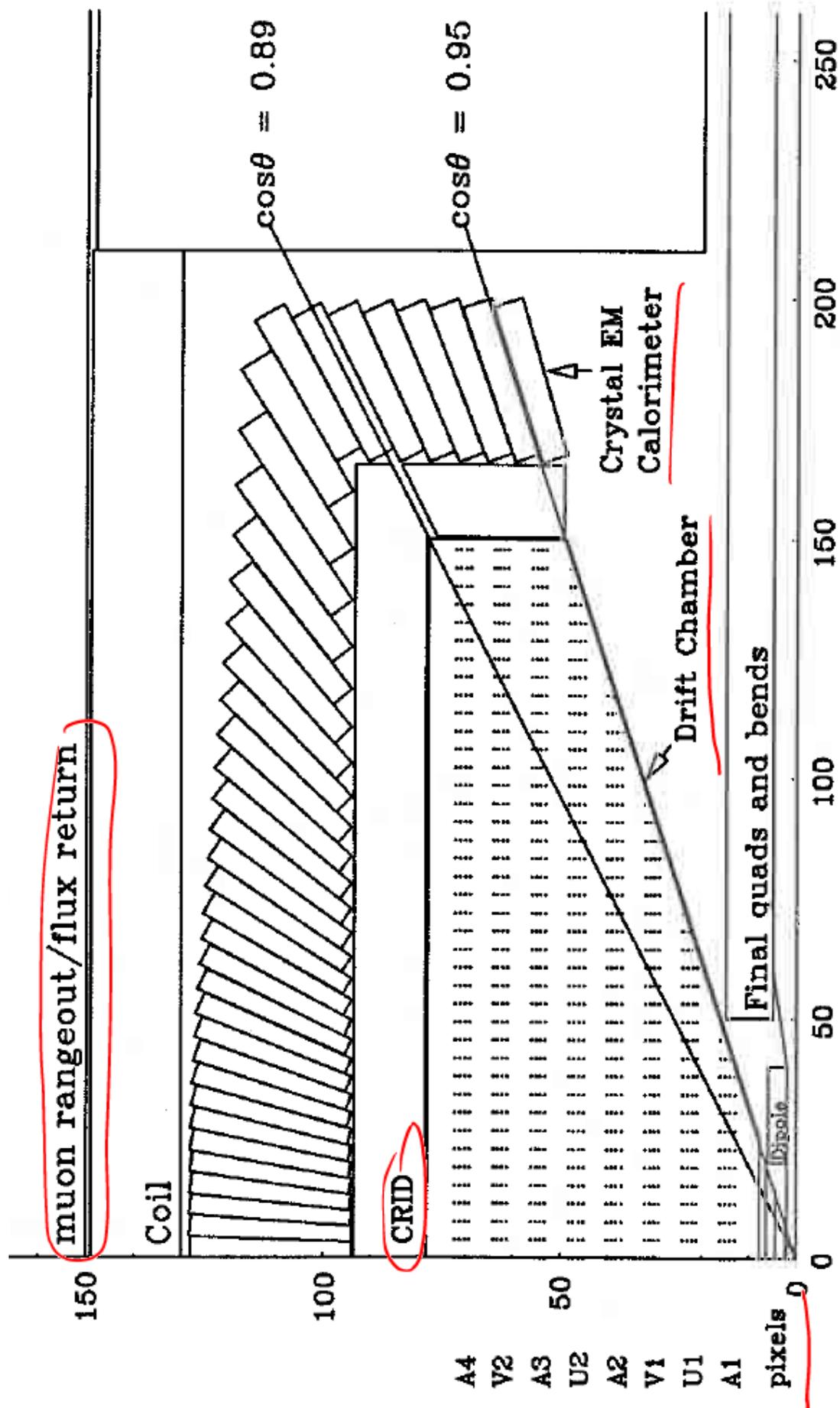
Who?

- U.C. Intercampus Institute for Research at Particle Accelerators
 - ◊ Alan Eisner
 - U.C. Irvine
 - ◊ Mark Mandelkern
 - U.C. Santa Barbara
 - ◊ Rollin Morrison, Michael Witherell
 - U.C. Santa Cruz
 - ◊ Patricia Burchat, Joel Kent
 - U.C. San Diego
 - ◊ Robin Erbacher, Wayne Vernon
 - California Institute of Technology
 - ◊ Gerald Eigen, David Hitlin, Frank Porter, Alan Weinstein, William Wisniewski
 - University of Colorado
 - ◊ Steven Wagner
 - Columbia University
 - ◊ Paolo Franzini, Michael Tuts
 - University of Indiana
 - ◊ Doris Averill, Arthur Snyder
 - Lawrence Berkeley Laboratory
 - ◊ Gerson Goldhaber, Piermaria Oddone, Natalie Roe, Michael Ronan, Martin Spahn
 - McGill University
 - ◊ David MacFarlane
 - Stanford Linear Accelerator Center
 - ◊ John Bartelt, Elliott Bloom, Fatin Bulos, Dieter Cords, Claudio Dib, Jonathan Dorfan, Isard Dunitz, Frederick Gilman, Gary Godfrey, Thomas Hyer, Garth Jensen, David Leith, Helmut Marsiske, Yosef Nir
 - SUNY Stony Brook
 - ◊ Juliet Lee-Franzini
- The Study was divided into Working Groups. The Working Group leaders were:
- CP Violation - John Bartelt
 - Other *B* Physics - Natalie Roe and Arthur Snyder
 - Υ Physics - Michael Tuts
 - τ Studies - Helmut Marsiske
 - Charm Studies - Michael Witherell
 - Detector Simulation - Alan Weinstein

The Study was coordinated by David Hitlin, who served as editor of this report.

Touches on pretty much everything

The plan of this Report is as follows: we will first investigate the present and projected future status of the determination of the “unitarity triangle” which summarizes the tests of consistency of the Standard Model. Next, the Monte Carlo tools used in the studies will be described, as will the parameters for the model detector employed. Subsequent chapters will then present the results of studies of experimental capabilities in B meson decay (CP violation; B_s mixing; and “conventional” B physics, such as searches for rare decays and measurements of $|V_{ub}|$), studies of the Υ system in unprecedented detail, charmed hadrons and τ decay.



Proto Babar

Luminosity

worth noting that the lower backgrounds to B meson reconstruction at an asymmetric machine require less off-resonance running; fifteen percent should suffice.

Running on the $\Upsilon(4S)$ in an asymmetric configuration produces signal-to-background ratios which are superior to both $\Upsilon(4S)$ running in the symmetric case, due to the ability to reconstruct individual B -decay vertices, and to running above the $\Upsilon(4S)$, due to the larger fraction of the cross section which represents $B\bar{B}$ production

The first few years of running of the proposed asymmetric machine therefore nearly triple the total world sample, even with the initial luminosity assumptions. The ultimate sample represents a factor of thirty increase over the sample projected to exist at turn-on. This increase is important in itself, but the fact that the B mesons will be produced in motion at the $\Upsilon(4S)$ represents a new and most important feature.

As the separate decay vertices of B and D mesons are distinguishable, the combinatoric background under exclusive-mode peaks will be substantially reduced, pro-

Asymmetry

in some detail in Chapter 6. More importantly, the ability to measure the decay time between vertices in the decay of B^0 and \bar{B}^0 to CP eigenstates makes the search for CP violation viable. The energy asymmetry provides *unique capability* to study CP violation. The measurement of CP-violating asymmetries in decays to CP eigenstates is *not possible at a symmetric machine*, as the CP asymmetry integrates to zero. While other CP-violating effects can conceivably be

Importance for SLAC

1.1. THE ROLE OF A B FACTORY IN THE SLAC PHYSICS PROGRAM

In recent months, SLAC has been pondering new directions for its current program, seeking directions which are consistent both with its long-term goals and with the needs of a national program. It has been decided that SLAC will not serve as a major participant in the construction of an SSC detector but rather will maintain its role as the mainstay of the electron-positron arm of the national program. This provides crucial diversity to the national program, as a

The B factory will allow SLAC to maintain its leadership in the e^+e^- arm of the national program through the coming decade

Cost savings by using PEP

a peak luminosity of $10^{34} \text{ cm}^{-2} \text{ sec}^{-1}$, although the initial luminosity goal is 3×10^{33} . Basing the project on the PEP complex results in a considerable savings of money and time and takes advantage of the existing PEP infra-structure. The project as a whole benefits from the SLAC's managerial and technical expertise, its long experience in electron-positron storage rings and its existing relationship with the DOE. The enthusiastic participation of Lawrence Berkeley Laboratory and major university groups in the design and construction of the accelerator promises to bring a considerable amount

The B factory project would be actively supported by LBL and a variety of major university user groups



*International role
not yet foreseen*

Naïve approach to Unitarity Triangle

Quark sub-process (class)	Decay mode	Im λ
$\bar{b} \rightarrow \bar{c} + c\bar{s}, \bar{c} + c\bar{d}, \bar{s}$ (i)	$B_d \rightarrow \psi K_S, \chi K_S, \phi K_S, \eta_c K_S,$ $\omega K_S, \rho K_S, D^+ D^-, \bar{D}^0 D^0,$ $\psi K_L, \phi K_L, \rho K_L, \dots$	$-\sin(2\beta)$
$\bar{b} \rightarrow \bar{u} + u\bar{d}$ (ii)	$B_d \rightarrow \pi^+ \pi^-, \bar{p}p, \rho\pi^0,$ $\omega\pi^0, \pi^0\pi^0$	$-\sin(2\alpha)$
$\bar{b} \rightarrow \bar{u} + u\bar{d}$ (iii)	$B_s \rightarrow \rho K_S, \omega K_S,$ $\rho K_L, \omega K_L$	$-\sin(2\gamma)$
$\bar{b} \rightarrow \bar{c} + c\bar{s}, \bar{c} + c\bar{d}$	$B_s \rightarrow \psi\phi, \eta_c\phi, \psi K_S$	$2 \left \frac{V_{us} V_{ub}}{V_{ud} V_{cb}} \right \sin \gamma$

← Penguin's
assumed
small

\leftarrow
 $t \rightarrow \mu$ mass
 not yet
 known!

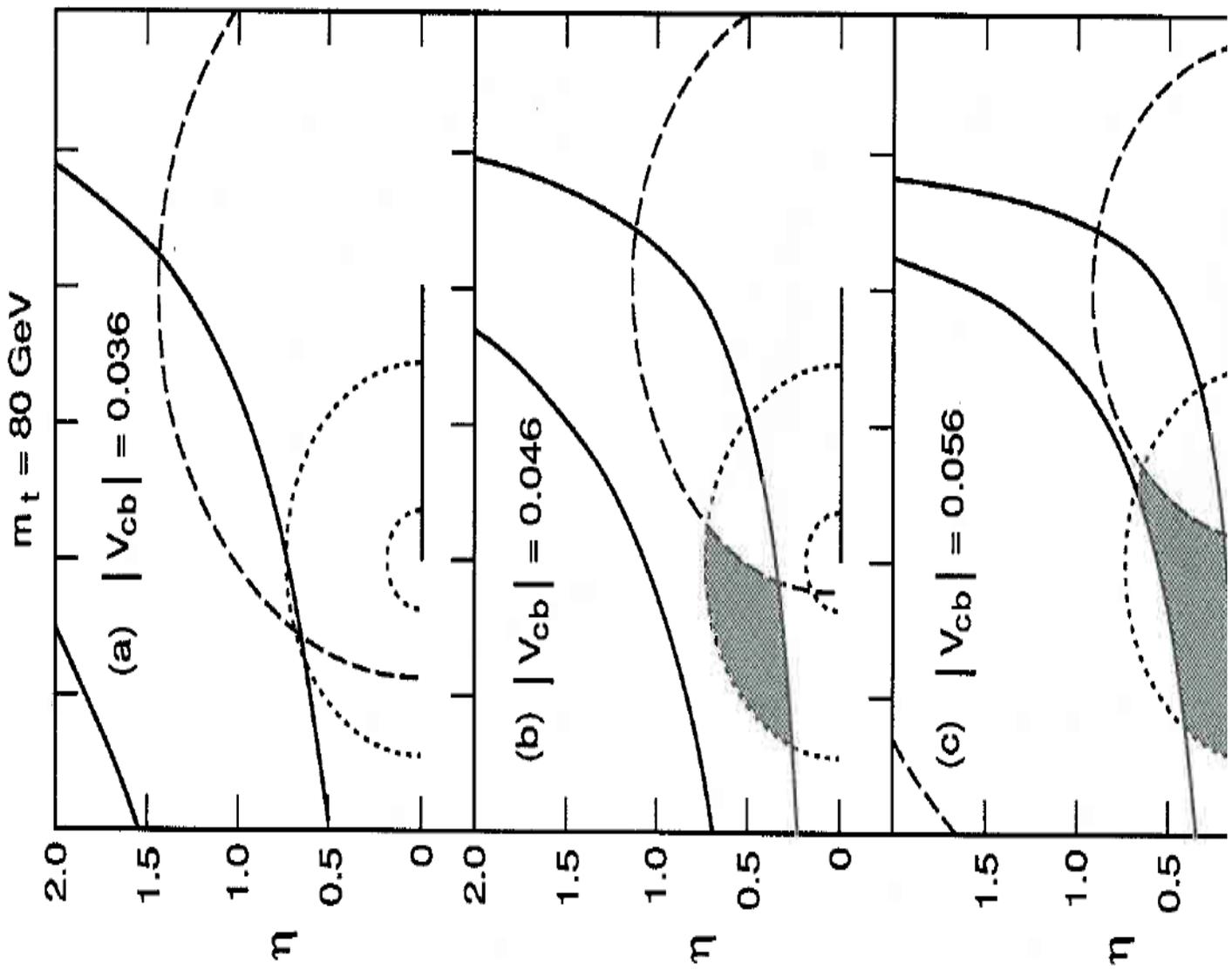


Figure 2.2 Constraints from $|V_{ub}/V_{cb}|$ (dotted circles), x_d (dashed circles), and ϵ (solid hyperbo-

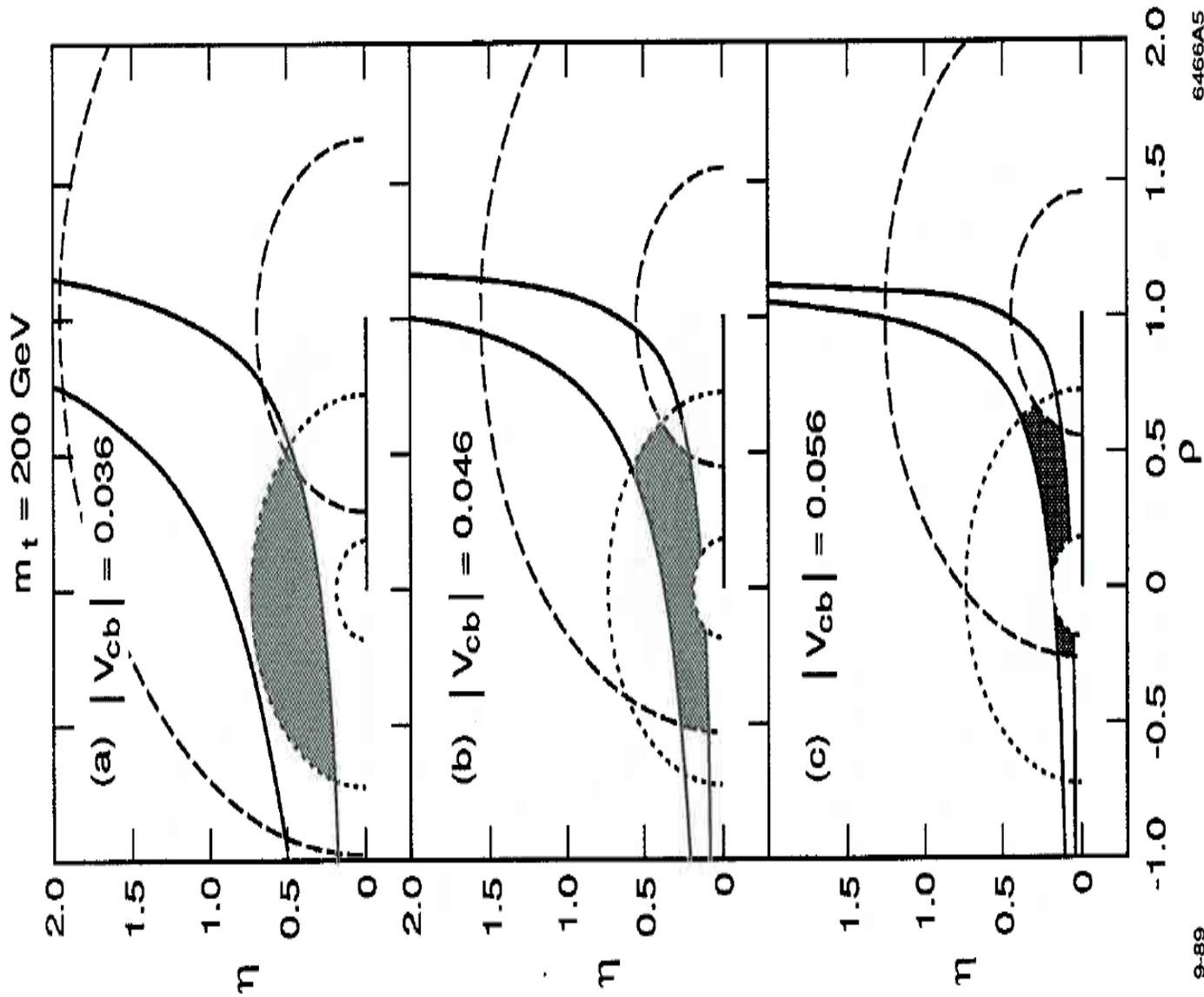


Figure 2.5 Constraints from $|V_{ub}/V_{cb}|$ (dotted circles), x_a (dashed circles), and ϵ (solid hyperbolas) on the rescaled unitarity triangle for $m_t = 200 \text{ GeV}$. The shaded region is that allowed for the vertex $A(\rho, \eta)$. (a) $|V_{cb}| = 0.036$, (b) $|V_{cb}| = 0.046$, (c) $|V_{cb}| = 0.056$.

Need for vertex detector

The vertex detector is a critical element in the design of the experiment for the asymmetric B factory. The vertex detector must meet the requirements imposed by the physics and the environment, if we are to realize the benefits of an asymmetric machine. Since no experiment operating in the Υ region has experience with such a device, we cannot extrapolate from present performance.

Fortunately, as the physics studies in this report clearly demonstrate, a vertex detector typical of those now in use is quite adequate for our purposes. The most interesting events

The Golden Mode!

5.4. MEASURING $\sin 2\beta$ WITH $B \rightarrow J/\psi K_S^0$

In order to measure CP violation, we must identify events in which one B meson decays to a CP eigenstate (such as $J/\psi K_S^0$) and the other decays to a final state which identifies the B meson as a B^0 or \bar{B}^0 . The latter B will be referred to as the tagging B . The relative decay position of the two B 's must be measured to observe a CP-violating effect. In this section we explain in detail our methods, using the determination of $\sin 2\beta$ as an example.

Optimism - pi pi penguins small

5.5. MEASURING $\sin 2\alpha$ WITH $B \rightarrow \pi^+ \pi^-$

With a sample of 300 fb^{-1} , a good measurement of $\sin 2\alpha$ seems possible.

The position of the B decay to a CP eigenstate is measured with the $\pi^+ \pi^-$ vertex; the remaining tracks in the event identify the position of the tagging B decay.

no theory uncertainty
assumed

Other B Physics

What other advantages does an asymmetric collider offer compared to a symmetric machine? Perhaps the foremost is that it allows the CP violation study to be done at the $\Upsilon(4S)$, where the cross section is maximized for all the other B_d and B_u physics one wants to do. For a symmetric B factory running off the $\Upsilon(4S)$, all the other physics studies will suffer from the reduced cross section. Also, on the $\Upsilon(4S)$ the continuum cross section is only a factor of three larger than the $B\bar{B}$ cross section and, as we shall show, the vertex information at an asymmetric collider can be used to suppress a very large fraction of this background. Above the $\Upsilon(4S)$ the

Further topics

2-5 done, 1 and 6 a bit optimistic

1. B_s mixing.
2. Exclusive $b \rightarrow c$ hadronic decays.
3. Exclusive $b \rightarrow c$ semi-leptonic decays.
4. Exclusive $b \rightarrow u$ decays.
5. Penguin diagrams.
6. Annihilation diagrams.

Optimism ? on 5s running

Conclusions on Measuring $\sin 2\gamma$ Using $B_s \rightarrow \rho^0 K_S^0$

A large data sample above the B, \bar{B} , threshold and an optimistically large branching fraction for $B_s \rightarrow \rho^0 K_S^0$ are needed to measure $\sin 2\gamma$.

Upsilon system

We believe that the rich physics potential of the Υ system will remain largely untapped after 1990, until such time as a high luminosity B factory is available, together with a very high quality electromagnetic calorimeter. Thus, in this report, we discuss the unique Υ physics opportunities available at an asymmetric B factory. The physics topics include:

1. the possible discovery of the pseudoscalar and pseudovector states and the measurement of the hyperfine structure of the $b\bar{b}$ system from the measurement of transitions from the $\Upsilon(3S)$ and $\Upsilon(2S)$ states to the singlet S states, $\Upsilon(n^1S_0)$, otherwise known as the η_b states, and to the lowest singlet P state, $\Upsilon(1^1P_1)$, the h_b
2. the discovery and measurement of the $\Upsilon(1D)$ states via radiative transitions,
3. detailed studies of the known triplet P states (the χ_b 's),
4. detailed studies of hadronic transitions between Υ states,
5. high statistics studies of radiative Υ decays, including searches for light neutral Higgs,
6. high precision physics measurements such as a comparison of the $B_{\mu\mu}$ to $B_{\tau\tau}$ rate, which is sensitive to the

New particle searches

Radiative Υ Decays and Search for New Particles

A B factory is an excellent laboratory in which to search for new particles, rare transitions, and measure α_s , because of the vast ($\approx 10^8$) data sample of $\Upsilon(1S)$ events one could obtain there. In the following sections, we discuss some of the Υ radiative decay physics that can be done.

Tau physics

The B factory promises to produce by far the largest obtainable τ sample

We present a representative selection of τ measurements at a *B* factory. Our discussion is based primarily on a sample of 3×10^7 τ pairs, although in some cases we quote results for the full data sample. In our calculations we use the fol-

Charm Physics

It is relatively easy to identify a number of topics in charm physics which remain very interesting, but which are beyond the reach of present experiment:

- 1) $D^0 - \bar{D}^0$ Mixing, and Doubly Cabibbo-Suppressed Decays;
- 2) CP violation;
- 3) Semileptonic decays;
- 4) D_s and Λ_c decays;
- 5) the pseudoscalar decay constant, f_D ;
- 6) rare and forbidden leptonic decays;
- 7) meson spectroscopy; and
- 8) baryon spectroscopy and decays.

Of these eight topics of current interest, all but f_D can be studied with great sensitivity at an asymmetric B factory.

Charmed baryon production

Studies of charmed baryons are already dominated by CLEO and ARGUS. More states will be seen at the asymmetric B factory. Lifetimes for all those states which decay weakly can be measured

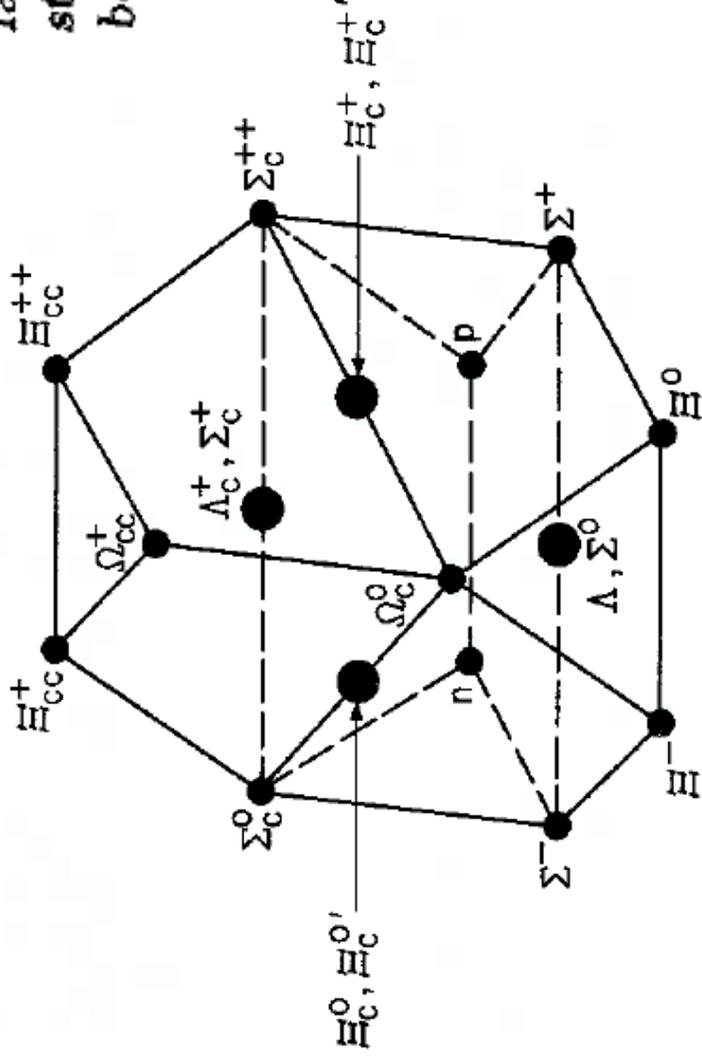


Figure 9.10 The $1/2^+$ baryon 20 plot. There should be 9 states which have a single c valence quark. Four of these states decay weakly.

Conclusion – Worth doing!

This report illustrates the richness of the physics program of a high-luminosity, asymmetric energy storage ring facility running at the $\Upsilon(4S)$ and the other Υ resonances. The combination of this novel machine, having a peak luminosity in excess of $10^{33} \text{ cm}^{-2}\text{sec}^{-1}$, and a new high quality detector will provide a wealth of data in the area of bottom, charm and τ physics. Much of this physics will not be accessible at any other facility currently available or planned for the future. We propose constructing the facility at SLAC, allowing us to capitalize on the existing PEP complex, thereby reducing the construction time and the cost. We envision a physics program commencing in late 1995, providing a large, international community of particle physicists with at least ten years of exciting and important physics opportunities.

And can be done!

companion document, *A Feasibility Study for a Asymmetric B Factory Based on PEP*, provides the basis for a credible design of such a machine. What remains is to move forward with this exciting project.

So we did it!

Or at least you all did it, and more!

I have greatly enjoyed watching and being an “honorary member” of this collaboration.

Thank you!