LOW ENERGY, HIGH LUMINOSITY
e^+e^- COLLIDING BEAM ACCELERATORS

P.M.Tuts
SUNY at Stony Brook
Stony Brook, NY 11794

S.W.Herb, P.LePage, S.-H.H.Tye
Cornell University
Ithaca, NY 14853

F.Pauss
Max-Plank Institute
D8000 Munich 40, West Germany

A.Seiden
University of California
Santa Cruz, California 95064

Summary

In this report we summarise the findings of the low energy-high luminosity lepton-lepton collider subgroup, and refer the reader to the individual reports, as indicated in the text, for greater detail. We conclude that 'upgraded' facilities are required to complete some of the charm studies, and the percent level spectroscopy of the Upsilon system. The harder subpercent level spectroscopy such as the η_b, rare B,D and τ decay searches require a new super high luminosity e^+e^- facility. Note that in keeping in the spirit of a summary report, we have left all the references to the individual reports.

Introduction

The low energy-high luminosity subgroup of the Lepton-Lepton Collider group has addressed the question of whether new e^+e^- accelerators with considerably increased luminosity are necessary to exploit the physics in the 3 to 10 GeV center of mass energy range. We have restricted ourselves to three possible scenarios which we believe are achievable:

1) Are the present accelerators (SPEAR, DORIS, CESR, etc.) capable of completing all the physics in the 3 to 10 GeV range?

2) Are upgraded versions of existing machines with increases of 5 to 10 in luminosity required?

3) Are new super high luminosity machines (x100 the present luminosities) required to adequately complete all the physics?

A summary of the present situation is described in Tables I and II where we have listed the typical number of particles produced in the charm and beauty system in one year of operation (10^7 sec).

Table I. Charm system particles produced in one year of operation.

Particle type	Present	Upgrade
J/ψ	$\sim 10^7$	$\sim 10^8$
ψ'	$\sim 10^7$	$\sim 10^8$
$D\bar{D}$	$\sim 10^5$	$\sim 10^6$

Table II. Beauty system particles produced in one year of operation.

Particle	Present	Upgrade	Super Luminosity
J/ψ	—	—	$\sim 6\times 10^8$
Υ	$\sim 2\times 10^6$	$\sim 2\times 10^7$	$\sim 2\times 10^8$
Υ'	$\sim 7\times 10^5$	$\sim 7\times 10^6$	$\sim 7\times 10^7$
Υ''	$\sim 4\times 10^5$	$\sim 4\times 10^6$	$\sim 4\times 10^7$
Υ'''	$\sim 10^5$	$\sim 10^6$	$\sim 10^7$
$\tau\bar{\tau}$	$\sim 10^5$	$\sim 10^6$	$\sim 10^7$

Although we have not considered particular accelerators, since that was not the purpose of this subgroup, we have used the examples of SPEAR (L $\sim 10^{30}$ $cm^{-2}sec^{-1}$) and CESR (L $\sim 10^{31}$ $cm^{-2}sec^{-1}$) as a starting point. The numbers in the 'Upgrade' and 'Super Luminosity' columns are motivated by the fact that the Chinese will be building a high luminosity e^+e^- accelerator in the charm energy range with a design luminosity of $\sim 10^{31}$ $cm^{-2}sec^{-1}$, and that if necessary, the present SPEAR machine could be upgraded by a factor of 5 to 10 in luminosity. We are similarly motivated in the beauty energy range by the proposed upgrade in the luminosity of CESR to $\sim 10^{32}$ $cm^{-2}sec^{-1}$ which could be achieved through multibunching, an improved linac gun, and μ-beta insertions. There also exists a preliminary design in a report by Tigner for a super high luminosity independent ring storage ring accelerator with a design luminosity of $\sim 10^{33}$ $cm^{-2}sec^{-1}$ in the Upsilon range. In addition, we point out that it would have a luminosity of $\sim 6\times 10^{31}$ $cm^{-2}sec^{-1}$ in the J/ψ range.

The Charm Region

In this section we will briefly review those topics in which greater luminosity would be necessary. For more details the reader is referred to Seiden's report. At present, ~20 Cabbibo suppressed D semi leptonic decays are expected in the present running program for SPEAR; sufficient to observe the signal. Similarly in the F studies (we assume that it will have been found by then) more luminosity would be essential in the observation of the Cabbibo suppressed semi-leptonic decays, since the F's are expected to be reduced by a factor of 5 to 10 on the D's. In fact this lower rate for F's requires at least the upgraded luminosity of Table I in order to achieve similar results to the D studies that are currently planned.

The higher rate provided by the increased luminosity would also make possible a partial wave analysis of the expected gluonium spectrum from the J/ψ decays, where individual channels are expected to have branching ratios for $J/\psi \to \gamma X$ of $\sim 10^{-4}$ (see the report by Chanowitz). A partial wave analysis would allow the gluonium spectrum to be distingushed from the multi quark states. A sample of 10^7 J/ψ's, could be obtained in one year of present running. It is quite clear that the increased luminosity would greatly facilitate the collection of such a large sample of J/ψ events. If the standard model is correct, then D^0-$\bar{D}^0$ mixing is unobservable even at larger luminosities since at present only ~250 D^0 $\bar{D}^0$ reconstructed events (in $K\pi$ modes) are expected in the MkIII detector for a sample of $\sim 10^5$ D^0 $\bar{D}^0$ events produced.

The Upsilon Region

Before listing some of the topics covered in the individual contributions, we would like to emphasize that improving the accelerator luminosity is not the only way of improving the effective luminosity. In particular the present detector efficiencies are low (~20%) for photons or electrons, which is not unexpected in view of the high multiplicities of events in the Upsilon region (e.g. the $B\bar{B}$

multiplicity is ~24). Therefore when searching for dielectron or di-photon events, the combined efficiency falls to the percent level. Thus modest increases in detector efficiencies are reflected in substantial increases of 'effective' luminosity. Some detector improvements such as new calorimetric materials (BGO), better vertex detectors, etc. have been discussed in the Detector group at this workshop (see the report by Ruchti). We feel that both accelerator improvements and better detector efficiencies, including special purpose detectors which would require more dedicated interaction regions, could lead to substantial increases in 'effective' luminosity.

As has been stressed in other groups (see the report by LePage on how to determine α_s) at this workshop, the Υ system may provide one of the best testing grounds for QCD, the leading candidate for a theory of strong interactions. In particular the Υ has a richer spectrum than the J/ψ system (as shown in Figs 1 and 2). Also the non-pertubative and relativistic corrections are less important than in the J/ψ case.

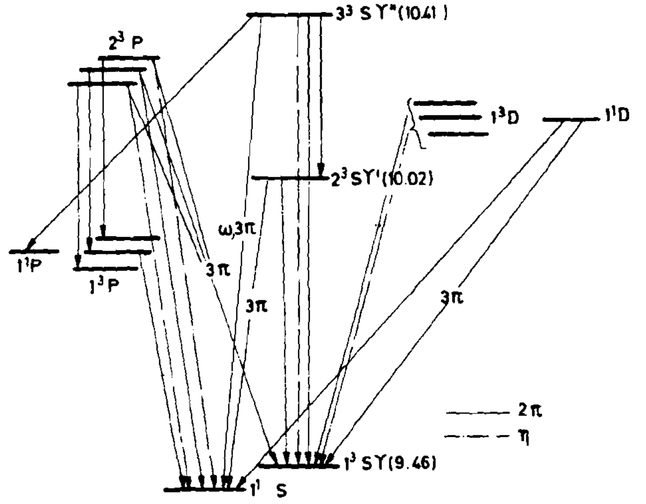

Fig. 1 Hadronic transitions for the Υ system.

It may even prove to be better than the $t\bar{t}$ system because the rates and widths of the $t\bar{t}$ system may prove experimentally unfavourable (see the report by Jackson, Olsen, Tye). We have summarised some of the important QCD tests (see LePage for details) that can be carried out in Table III. Unfortunately it appears that the theoretically most uncertain calculations are the easiest experimentally, including $BR(\Upsilon \to \mu^+\mu^-)$, $\Gamma_{ee}(\Upsilon)$, the center of gravity of the χ states and their splitting, etc. whereas the most theoretically secure calculations such as η_b physics are very difficult experimentally because of the very small branching ratios (see the report by Pauss and Tuts for a discussion).

Table III. Some important QCD tests and brief theoretical and experimental comments.

Measurement	Comment Theoretical	Experimental
$\Gamma(\Upsilon\to ggg)/\Gamma(\Upsilon\to\mu\mu)$	uncertain	easy
$\Gamma(\Upsilon\to\gamma gg)/\Gamma(\Upsilon\to ggg)$	OK	π^0 background
$\Gamma(\eta_b\to gg)/\Gamma(\eta_b\to\gamma\gamma)$	very good	impossible?
Υ-η_b splitting	good	hard

We find that no new accelerators are necessary to complete the easy spectroscopy of the Υ system, including the E1 transitions, and some of the hadronic cascades, however an upgraded accelerator will be necessary to do some of the 1% branching ratio spectroscopy such as $3^3S_1 \to \pi\pi + 1^1P_0$ where the singlet P state subsequently decays to $\gamma\eta_b$. The most difficult, although potentially the most interesting spectroscopy, are the M1 and hindered M1 transitions such as $\Upsilon'' \to \gamma\eta_b$ where the branching ratios are of the order of 10^{-4}. In order to observe these types of transitions, it is absolutely necessary to have the highest luminosity achievable, together with the necessary detector improvements in photon efficiency.

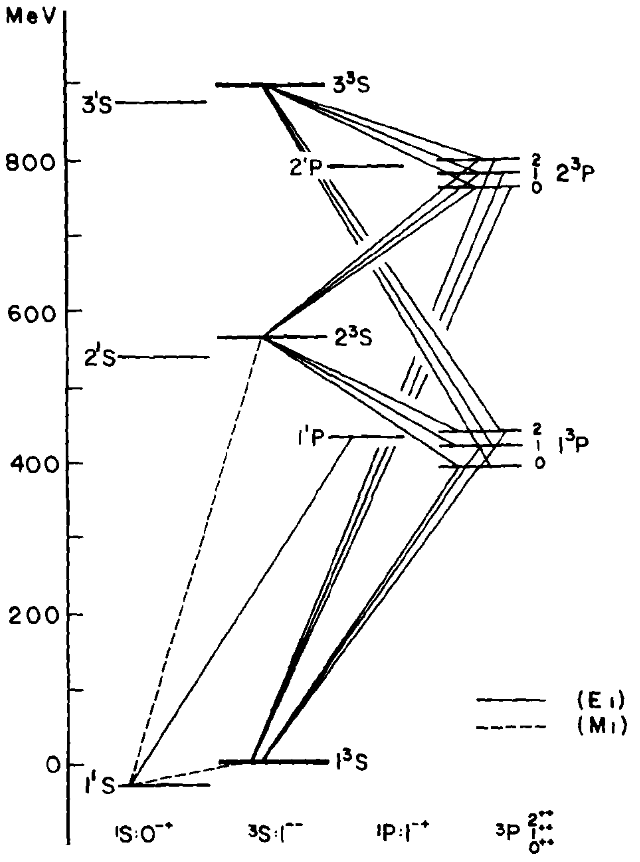

Fig. 2 Photon transitions for the Υ system.

Another interesting topic in spectroscopy is the question of gluonium spectroscopy for the many possible glueball states expected from the decay of the Υ, for which we refer the reader to the report by Tye on the Υ as a glueball factory. Although precise calculations of rates are not yet available, it is expected that the branching ratios to exclusive final states will be about $\sim 10^{-4}$ to 10^{-6}. Thus the first observations of glueball states may be made with the upgraded accelerators, but partial wave analyses would require the super luminosities.

In the area of B meson physics (see the report by Herb) it would appear that the present goal of B reconstruction can be achieved with the present luminosities via the low multiplicity B decays (e.g. $B \to K\pi$, $D\pi$, $D\pi\pi$, $D^*\pi$), which could yield a sample of ~20 reconstructed B's from a sample of $\sim 2\times10^5$ B or $\bar{B}$ events. Higher luminosities would be required in order to obtain a sample of a few thousand 'tagged' B events. The observation of B^0-$\bar{B}^0$ mixing is very dependent on the amount of mixing, which at present is not well constrained theoretically, and thus might be observable with an upgraded machine if there were more than ~10% of complete mixing. In any case the super luminosity accelerator would be able to observe mixing at the 5% level assuming that systematic uncertainties can be managed. The field of rare B decays is a very important topic in a super high luminosity machine.

In particular, the search for flavour changing neutral currents (e.g. $B\to K^{+}e^{+}e^{-}$) and tests of horizontal symmetries (e.g. $B^{-}\to K^{-}\mu^{+}\tau^{-}$) could be done at the 10^{-6} and 10^{-3} level respectively. The possibility of observing CP violation in the total lepton asymetry, with an accuracy of $\pm.002$ (for 1000 nb^{-1}), becomes feasable; sufficient to compare with the expected standard model upper limit of .005.

Finally we point out that concurrently to running on the resonances, one obtains a large sample of τ events, where one can search for rare τ decays such as $\tau\to\mu\gamma$, $e\gamma$, μee, etc. at the $\sim10^{-6}$ level. In addition, improvements on the upper limit of m_{τ} could be expected ($m_{\tau} < 100$ MeV). For more details see the contribution of Shrock.

In conclusion, we find that with the present accelerators and the probable upgrades, coupled with improved detectors, would allow a five year program to observe all of the E1 transitions, begin to observe the η_b, possibly detect $B^{o}-\bar{B}^{o}$ mixing and have a 10^{6} sample of produced τ events. However, to do a good job on M1 transitions, including the η_b physics, glueball spectroscopy, rare B,D,τ decays, 'tagged' B events, CP violation in $B^{o}-\bar{B}^{o}$ mixing and the production of other possible exotics, a new super high luminosity machine would be required.