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Report of Snowmass 2001 Working Group E2 : Electron-positron Colliders from the ϕ to the Z

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We report on the status and plans of experiments now running or proposed for electron-positron colliders at energies between the ϕ and the Z. The e^+e^- B and charm factories we considered were PEP-II/*BABAR*, KEKB/Belle, superKEK, Super*BABAR*, and CESR-c/CLEO-c. We reviewed the programs at the ϕ factory at Frascati and the proposed PEP-N facility at Stanford Linear Accelerator Center. We studied the prospects for B physics with a dedicated linear collider Z factory, associated with the TESLA high energy linear collider. In all cases, we compared the physics reach of these facilities with that of alternative experiments at hadron colliders or fixed target facilities.

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Introduction

In this report we review the status of ongoing and planned electron-positron collider facilities whose center of mass energies range from the mass of the ϕ meson to that of the Z Boson. In Section 1 and 2, we discuss the physics potential of two "low energy machines", the ϕ factory at Frascati and the proposed PEP-N storage ring at Stanford Linear Accelerator. Section 3 presents the physics potential of a proposed reorientation of the CESR machine and the CLEO detector, known as CLEO-c, which would focus on topics in charm physics and QCD. In section 4, we discuss the future evolution of the two asymmetric e^+e^- B-factory facilities, KEKB/Belle and PEP-II/*BABAR* to superKEK and Super*BABAR* and compare their B physics reach to that of existing and proposed hadron collider experiments. In section 5, we discuss the potential of a dedicated Z factory associated with a Linear Collider, in this case TESLA, for B physics studies and compare its strengths to those of e^+e^- and hadron collider experiments. In section 6, we present our conclusions. This report is a written version of the E2 Summary Talk given at the final plenary session of Snowmass [1].

I. ϕ FACTORIES

The ϕ factory, DAϕNE, at Frascati is a unique facility, in which electron and positron beams of energy 510 MeV collide [2]. There are no plans to build a similar facility elsewhere. While there are several aspects to its physics program, the E2 working group concentrated on the physics reach of the KLOE (KLOng Experiment) as compared to planned fixed target Kaon experiments, which will run at US facilities in the next several years.

A. Status of DAϕNE

DAϕNE consists of two independent storage rings, one for electrons of 510 MeV and one for positrons of 510 MeV. The beams intersect at an angle of 25 milliradians at two locations. The bunch length is 3 cm. The horizontal bunch size is 2 mm and the vertical size is 0.02 mm. The design luminosity is $5 \times 10^{32}\text{cm}^{-2}\text{s}^{-1}$.

It has been a great challenge to obtain reasonable luminosity. Recently, a luminosity of $2.5 \times 10^{31}\text{cm}^{-2}\text{s}^{-1}$ has been achieved. This is a significant improvement over a year ago and, while still far below the design, is sufficient to begin to do meaningful physics. Over the last few months sustained running at $1.3pb^{-1}$/day has been achieved. An integrated luminosity of $200pb^{-1}$ is expected by the end of calendar 2001.

B. The KLOE Experiment: Description, Goals, and Status

A main goal of KLOE is to study rare and CP violating decays of the K_L^o mesons which are produced in the decay $\phi \to K_L^o K_s^o$. A schematic of the KLOE detector is given in Fig. 1. It has a 5m diameter superconducting solenoid, which contains a drift chamber and a lead-scintillator electromagnetic calorimeter. There is also an endcap electromagnetic calorimeter. The drift chamber uses Helium gas to minimize multiple scattering and K_L^o regeneration. A CP violating K_L^o decay has a very clear signature in the detector, as shown in Fig. 2.

The physics program of KLOE is quite broad and is described in Table I. The table includes physics topics and the approximate luminosity required to make meaningful measurments for each topic. It can be seen that some measurements are already achievable with the current luminosity but the study of CP violation and rare kaon decays requires significant improvements.

TABLE I: Summary of KLOE Physics Program

Physics Topic	Integrated Luminosity (pb^{-1})
ϕ radiative decays ($f_o\gamma, a_o\gamma, \eta\gamma, \eta'\gamma$) Measurement of $\sigma(\pi\pi)$ (for $g-2$)	20-100
K semileptonic decays, $Kl4$, η/η' mixing, ...	1000
Tests of CP and CPT violation and measurement of rare K decays	5000

C. Comparison of Physics Reach of KLOE to Planned Fixed Target Experiments

The current status of measurements of "direct CP violation" through the quantity ϵ'/ϵ in Fixed Target Experiments at CERN(NA48) and Fermilab(KTeV) is shown in Fig. 3. At a ϕ factory, the double ratio and interferometric methods are complementary to the Fixed Target experiments. KLOE's goal of measuring ϵ'/ϵ to an accuracy of $\sim 2 \times 10^{-4}$, which requires 5000 pb^{-1}, will provide a measurement comparable to the other experiments. However, the ability to extract Standard Model CP parameters from this quantity is, at present, limited by theoretical uncertainties.

Another emphasis of future Fixed Target programs in the US is rare kaon decays, in particular, measurement of the branching fractions of

$$K^+ \to \pi^+\nu\bar{\nu} \quad (1)$$
$$K_L^o \to \pi^o\nu\bar{\nu}. \quad (2)$$

The first of these provides a measurement of V_{td} and the second is a direct indicator of the CKM parameter η. The branching fractions are very small, of order a few$\times 10^{-11}$. Very high kaon fluxes are needed and Fixed Target experiments that want to detect them must withstand formidable backgrounds and run at very high rates.

The ϕ factory has very desirable features for doing these measurements which avoid many of the problems of the Fixed Target experiments. However, even with 5000 pb^{-1}, only about 10^{10} $K_L K_s$ pairs will be produced so the Standard Model expectations cannot quite be reached. The branching fraction for the now observed decay $K^+ \to \pi^+\nu\bar{\nu}$ is already too low for KLOE to reach. However, if there is new physics, outside the Standard Model, in the decay $K_L^o \to \pi^o\nu\bar{\nu}$, which currently has a limit only of order 10^{-6}, this process could be within the range of the KLOE experiment. Thus, KLOE has a few year window to push the sensitivity of $K_L^o \to \pi^o\nu\bar{\nu}$ in the hope that new physics might be present there. If the Standard Model processes are the dominant ones, then

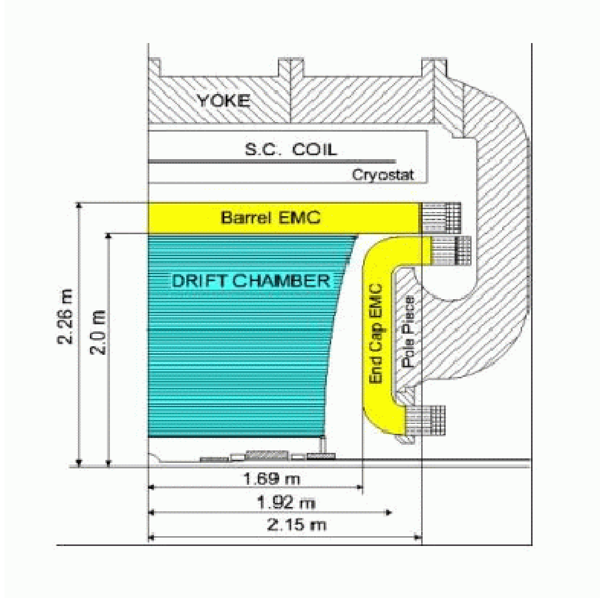

FIG. 1: A schematic of the KLOE detector

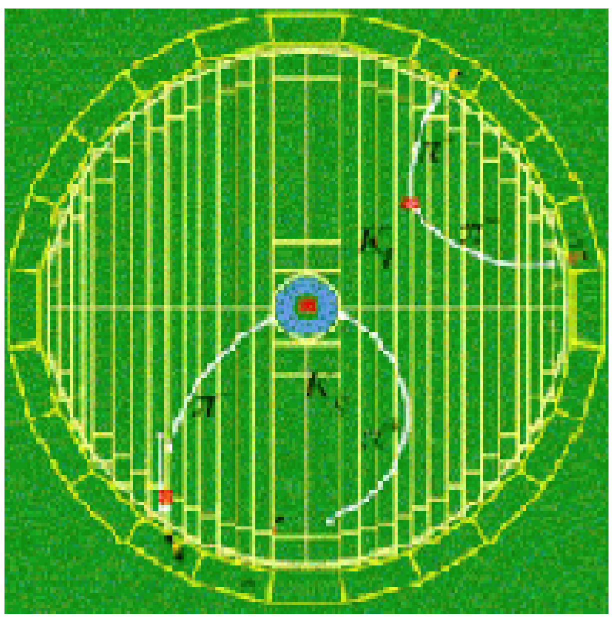

FIG. 2: A CP violating K_L^o decay as seen in KLOE

ultimately this decay will have to be observed in Fixed Target kaon experiments. See [3] for further details.

II. PEP-N

PEP-N is a proposed novel extension of PEP-II. The machine is an asymmetric collider consisting of the PEP-II Low Energy Ring (LER) (3.1 GeV) and a new electron storage ring (Very Low Energy Ring, VLER) of energy 100 MeV $< E_e <$ 800 MeV. The accessible center of mass (CM) energy is 1.2 GeV $< \sqrt{s} <$ 3.15 GeV. This machine would run simultaneously with PEP-II operation at the $\Upsilon(4S)$.

There is a rich variety of important physics measurements that are accessible at this collider. The most prominent are the high-precision measurement of the ratio, R [5][6], of the hadron total cross section to the muon pair cross section and the determination of nucleon form factors [7]. Other physics topics which can be studied at

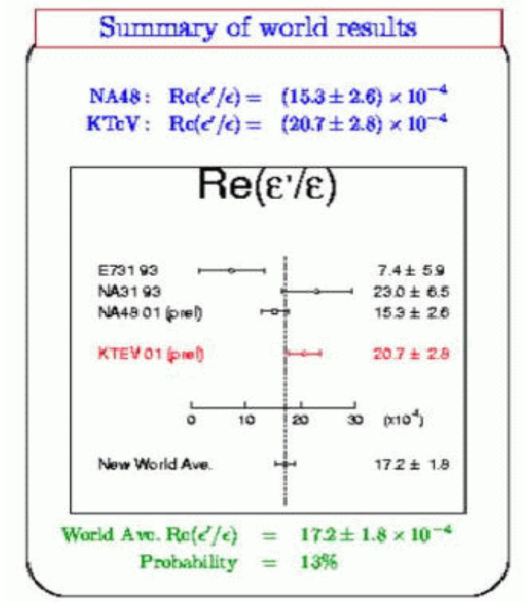

FIG. 3: World Results on $\frac{\epsilon'}{\epsilon}$

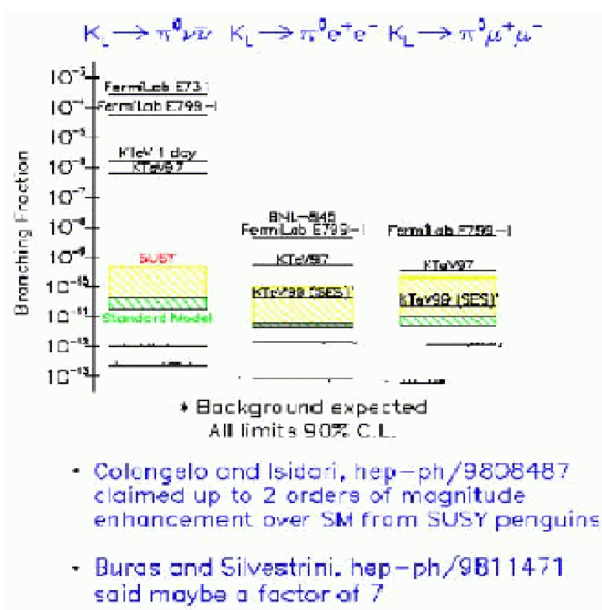

FIG. 4: Current and expected results on rare K decays. For each mode, the two lines corresponding to the greatest sensitivity are for the Kopio experiment ($K_L^o \to \pi^o \nu\bar{\nu}$) and the KAMI proposal (all three modes). Note KAMI is not approved.

PEP-N include meson form factors, vector meson spectroscopy, the search for non $q\overline{q}$ states and $\gamma\gamma^*$ interactions.

In our view the most important single measurement that PEP-N could contribute is the determination of R with greatly improved precision. In this report we will focus solely on the physics motivation and challenges of measuring R.

A. The Measurement of R

Testing the consistency of the Standard Model requires a variety of measurements for which radiative corrections play a crucial role. Two of the most important examples are (a) Higgs mass bounds from precision measurements at LEP and electroweak natural relations (i.e. the evolution of α to the Z pole), and (b) Interpretation of the

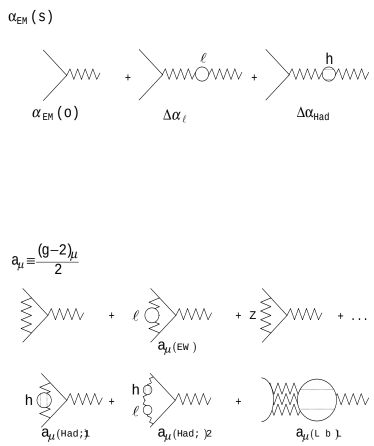

FIG. 5: Feynman diagrams for radiative corrections to α_{em} and $(g-2)_\mu$

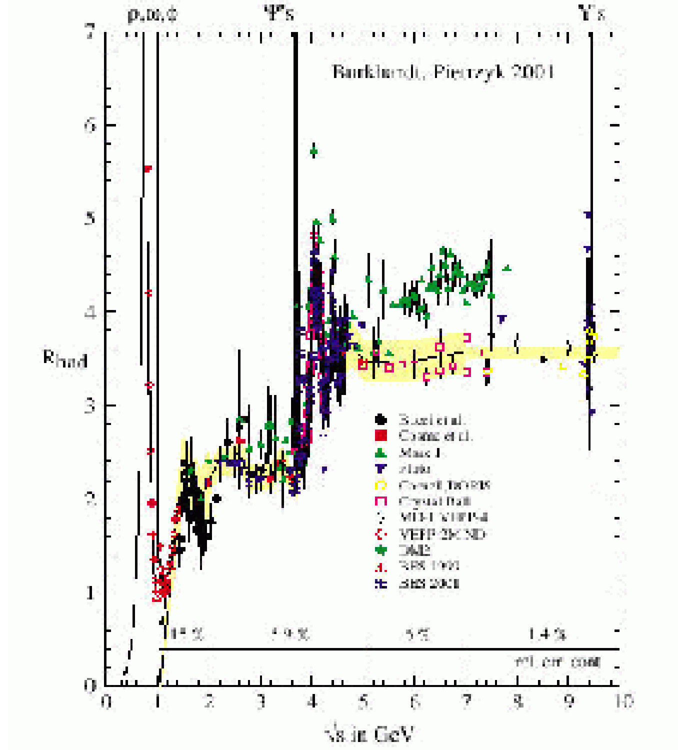

FIG. 6: R_{had} including resonances with the parameterization of Burkhardt and Pietrzyk.

BNL $g_\mu - 2$ experiment [8]. In addition, future higher precision experiments, such as Giga-Z, will depend on radiative corrections being precisely known.

The parameters of the electroweak model can be taken as G_F, $\alpha_{em}(0)$, M_Z, m_H and the fermion masses and mixings. In order to compute physical quantities we must include radiative corrections which renormalize charges, masses and magnetic moments as shown in Fig. 5. Although the electroweak radiative corrections are calculable, the hadronic radiative corrections are not. However the lowest-order hadronic radiative corrections can be obtained from $e^+e^- \to hadrons$ using dispersion relations and unitarity. The forward scattering amplitude for virtual photons interacting with the vacuum is related to the total cross section for that process by the Optical Theorem.

1. *The evolution of α to M_Z*

In leading order perturbation theory:

$$\begin{aligned}\Delta\alpha(s) &= \frac{\alpha}{3\pi}\sum_{m_f^2<<s} Q_f^2 N_{cf}\left(ln\frac{s}{m_f^2}-\frac{5}{3}\right)\\ &= \Delta\alpha_{leptons}(s) + \Delta\alpha_{hadrons}(s) \qquad (3)\end{aligned}$$

This expression is inadequate for the hadronic contribution, which can be obtained from the measurement of R. For $(2m_t)^2 >> s >> (2m_b)^2$ we have:

$$\Delta\alpha(s) = \Delta\alpha_{leptons}(s) + \Delta\alpha^{(5)}_{hadrons}(s) \qquad (4)$$

$$\Delta\alpha^{(5)}_{hadrons}(s) = -\frac{\alpha s}{3\pi}\int_{4m_\pi^2}^{\infty}\frac{R(s')}{s'(s'-s)}ds' \qquad (5)$$

Our current knowledge of R below 10 GeV is shown in Fig. 6. $\Delta\alpha(M_Z^2)$ is of particular importance for predicting the W mass and Z-pole asymmetries and has been calculated by many authors including Burkhardt and Pietrzyk (BP) [10]. BP find $\Delta\alpha^{(5)}_{hadrons}(M_Z^2) = 0.02761 \pm 0.00036$ (1.3%) corresponding to $1/\alpha(M_Z^2) = 128.936 \pm 0.046$ (0.037%). The largest contributions to the uncertainty in $\Delta\alpha^{(5)}_{hadrons}(s)$ are from the measured values of R in the regions 1.05< $\sqrt{s}$ <2.0 GeV and 2.0< $\sqrt{s}$ <5.0 GeV, each contributing about 0.8% as shown in Fig. 7 from Ref. [10]. The latter uncertainty decreased significantly after inclusion of the recent BES (inclusive) data [11], even though the measurements between 2 and 3 GeV have large errors and potentially significant systematic uncertainties. The uncertainties in the contributions from different intervals are systematics dominated. However BP combines the errors in quadrature. If one were to sum the systematic errors, the uncertainty would be 3%.

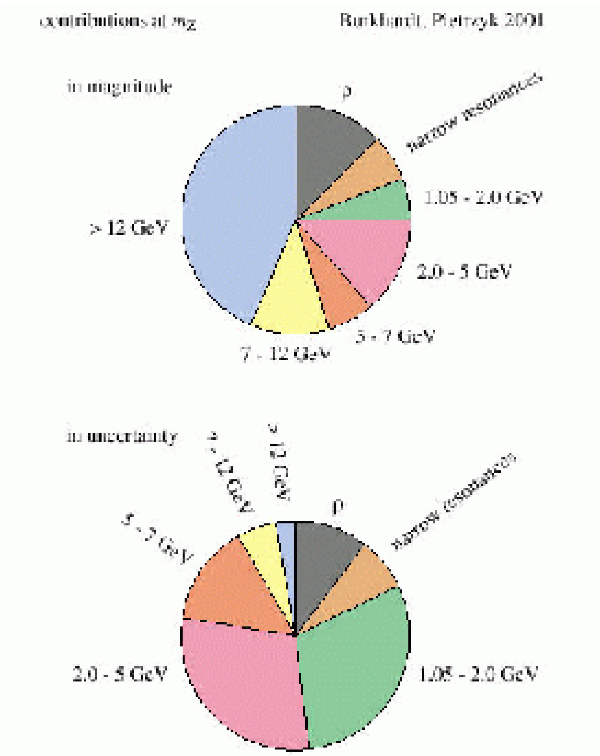

FIG. 7: Relative contributions to $\Delta\alpha^{(5)}_{had}(M_Z^2)$ in magnitude and uncertainty from Burkhardt and Pietrzyk.

As noted in [5], the consistency of R measurements between 3 and 4 GeV and between 5 and 8 GeV is poor. Absolute cross sections are difficult to measure and there may be significant systematic errors in the measurements beyond those estimated by the experiments.

$\Delta\alpha(M_Z^2)$ enters in electroweak physics via

$$\sin^2\Theta\cos^2\Theta = \frac{\pi\alpha}{\sqrt{2}G_F M_Z^2}\frac{1}{1-\Delta r} \tag{6}$$

where

$$\Delta r = \Delta\alpha(M_Z^2) - f(\sin^2\Theta)\delta\rho + \Delta r_{Higgs} + \Delta r_{other} \tag{7}$$

and

$$\delta\rho \simeq \frac{\sqrt{2}G_F}{16\pi^2}3m_t^2 \tag{8}$$

$$\Delta r_{Higgs} \simeq \frac{\sqrt{2}G_F M_W^2}{16\pi^2}\{c^H(\sin^2\Theta)(ln\frac{m_H^2}{M_W^2} - \frac{5}{6})\}; \quad m_H >> M_W \tag{9}$$

$c^H(\sin^2\Theta)$ and $f(\sin^2\Theta)$ are dependent on the definition of $\sin^2\Theta$, i.e. the renormalization method. In the on-shell scheme, for example, $C_W^H = 11/3$ and $f_W(\sin^2\Theta) = \cot^2\Theta_W \simeq 3.35$.

The resulting fractional theoretical uncertainty in M_W is $\sim 0.23\delta\Delta\alpha$. The contribution from the 0.0004 uncertainty in $\Delta\alpha^{(5)}_{hadrons}(s)$ is about 75 MeV, compared to the experimental uncertainty of 56 MeV. Measurements of the effective leptonic $\sin^2\theta_W$ and the predictions of the Standard Model with uncertainties due to $\Delta\alpha^{(5)}_{had}(M_Z^2)$ and m_t from the LEPWG [12] are shown in Fig. 8.

The effective weak mixing angle, can be determined from Z-pole asymmetry data, etc. without knowledge of the top and Higgs masses. The Standard Model prediction is given as a function of m_H with uncertainties due to $\Delta\alpha^{(5)}_{hadrons}$, m_t, and m_Z. The uncertainty in $sin^2\Theta^l_{eff}$ due to $\Delta\alpha^{(5)}_{hadrons}$ is $\sim sin^2\Theta^l_{eff}\Delta\alpha^{(5)}_{hadrons} \sim \pm 0.0001$, that due to m_t is also about 0.0001, and that due to $M_Z << 0.0001$, compared to the experimental error of 0.00017. The overall fit to m_H from all electroweak data, shown in Fig.9, yields an estimate of $\sim 100^{+57}_{-38}$GeV where the dominant contribution to the uncertainty, ~ 20 GeV, is from $\Delta\alpha^{(5)}_{had}$.

2. $(g-2)_\mu$

We now consider hadronic corrections to the muon magnetic moment. The Standard Model prediction for $a_\mu \equiv (g-2)_\mu/2$ is:

$$a_\mu(theory) = a_\mu(EW) + a_\mu(Had). \tag{10}$$

$a_\mu(EW) \equiv a_\mu(QED) + a_\mu(Weak)$ is calculable to a few parts in 10^{11}. The uncertainty in a_μ is dominated by that in $a_\mu(Had)$ which is usually broken up into the leading vacuum polarization contribution $a_\mu(Had;1)$ of order $(\frac{\alpha}{\pi})^2$, the higher order vacuum polarization contribution $a_\mu(Had;2)$ of order $(\frac{\alpha}{\pi})^3$, and the hadronic light-by-light contribution $a_\mu(LbL)$, also of order $(\frac{\alpha}{\pi})^3$. The first of these is related to R by a dispersion relation, and the second and third must be estimated.

$$a_\mu(Had;1) = (\frac{\alpha_{em}m_\mu}{3\pi})^2\int_{4m_\pi^2}^{\infty}\frac{ds}{s^2}K(s)R(s) \tag{11}$$

where

$$\begin{aligned} K(s) &= \frac{3s}{m_\mu^2}\{x^2(1-\frac{x^2}{2}) \\ &+ (1+x)^2(1+\frac{1}{x^2})\{ln(1+x) - x + \frac{x^2}{2}\} \\ &+ \frac{1+x}{1-x}x^2 lnx\} \end{aligned} \tag{12}$$

with

$$x = \frac{1-\beta}{1+\beta}, \beta = \sqrt{1-\frac{4m_\mu^2}{s}}. \tag{13}$$

Note the weighting of $R(s)$ is $1/s^2$, making the low energy regime more important than for $\alpha(s)$. Some recent analyses have used τ decay data to supplement e^+e^- data.

Here CVC is used to relate processes through the vector charged weak current to comparable processes through the isovector E.M. current assuming no second class weak currents, which implies that the contribution of the axial vector current to G+ decays is zero. Thus annihilation cross sections with $G = C(-1)^I = +1$ (G+, i.e. n_π even) are obtained from the rates of corresponding τ decays. While τ decay data is useful at the current level of accuracy, I-spin violation and effects such as initial and final state radiation must be understood if we are to rely on it at smaller experimental errors, as emphasized by Eidelman and Jegerlehner [13, 14]and by Melnikov [15]. PQCD is used at energies> 12 GeV by all authors because of the lack of data. The result of Davier and Hocker (DH) [16], who use QCD sum rule constraints at low energy as well as τ data, is $a_\mu(Had;1) = 6924(62) \times 10^{-11}$, giving the dominant uncertainty in a_μ. The more conservative result of Jegerlehner is 6987(111).

The higher order hadronic vacuum polarization and hadronic light-by-light contribution to a_μ are comparable. However while the uncertainty in the former is several parts in 10^{11}, the uncertainty in the latter is much larger. The detailed calculations done by Hayakawa and Kinoshita [17] and by Bijkens, Pallante and Prades [18] give a negative a_μ^{LbL} [19]. Marciano and Roberts in their recent review [21] combine in quadrature the DH result for $a_\mu(Had;1) = 6924(62) \times 10^{-11}$ and $a_\mu(LbL) = -85(25) \times 10^{-11}$(the average of HK and BPP taking the average of the quoted uncertainties) for an overall result of $a_\mu^{SM} = 116591597(67) \times 10^{-11}$. This is to be compared with the BNL E821 [8] result of $116592020(160) \times 10^{-11}$. The discrepancy is $423(173) \times 10^{-11}$ [19]. Other authors regard the light-by-light calculation as model-dependent and less reliable [5]. BNL E821 ultimately anticipates an uncertainty of 40×10^{-11}. Clearly improved knowledge of $a_\mu(Had;1)$ and $a_\mu(LbL)$ are required to exploit high-precision measurements of $(g-2)_\mu$. The former will greatly benefit from better e^+e^- data below 3 GeV.

B. Experimental Requirements

Two methods can be used to measure R:

- **Inclusive approach:** hadronic events are defined inclusively by requiring a minimum number of particles in the detector. In order to measure the cross section $\sigma(e^+e^- \to hadrons)$ the acceptance is required. Due to the large number of contributing channels, a Monte Carlo simulation is used, leading to potentially large systematic errors and rendering this method unsuitable for a high-precision (1-2 %) measurement of R.
- **Exclusive approach**: the cross section of each individual channel contributing to R is measured. Events must be completely reconstructed with high efficiency, and acceptances for each channel must be well known. With this method an accuracy of 1-2 % in R can be reached, as shown by the recent VEPP-2M measurements.

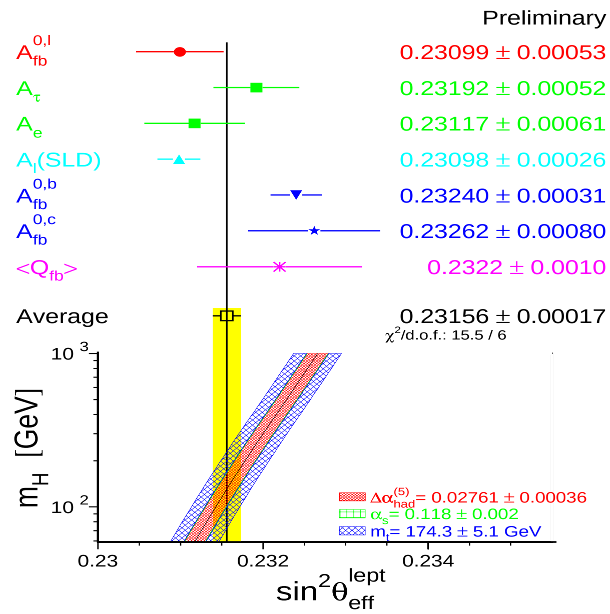

FIG. 8: Measurements of the effective leptonic $\sin^2\theta_W$ and the predictions of the Standard Model with uncertainties due to $\Delta\alpha^{(5)}_{had}(M_Z^2)$ and m_t.

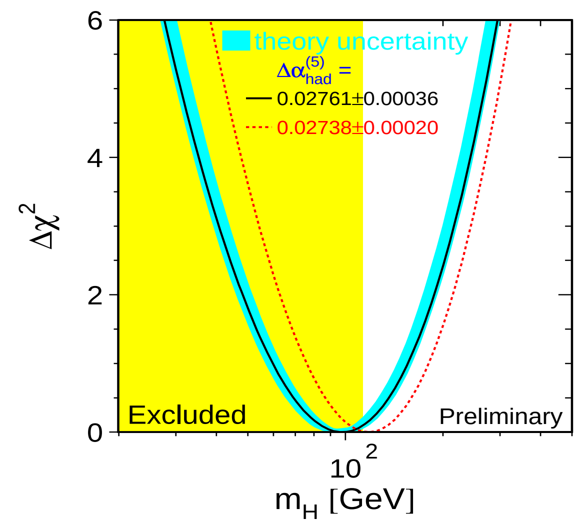

FIG. 9: Light Higgs mass prediction of precision electroweak data, with uncertainty due to hadronic corrections.

To measure R with a precision of the order of 2 % (or better), the PEP-N experiment is designed to use the exclusive method. The detector has a large acceptance and is able to measure the absolute position of charged and neutral particles. In addition, since $\sigma(e^+e^- \to n\overline{n})$ is a sizeable fraction of the total hadronic cross section

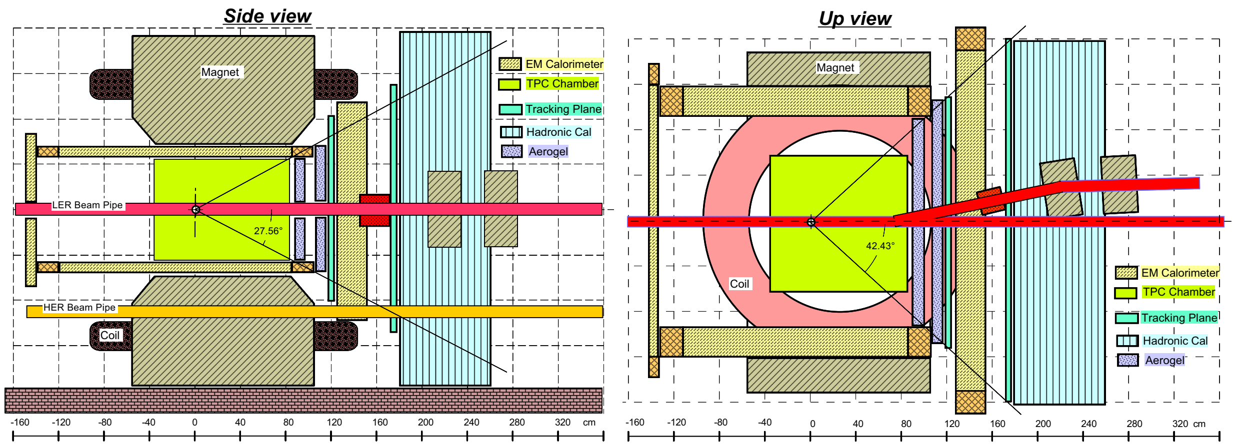

FIG. 10: PEP-N detector layout: side view (left) and top view (right).

(e.g. 2.5 % at $\sqrt{s} = 2$ GeV), $n\overline{n}$ detection capability is needed.

The proposed PEP-N detector must satisfy the following requirements:

- **Low mass tracking.** In the energy range of PEP-N multiple scattering contributes significantly to the momentum resolution ($\approx 2\%$);
- **Momentum measurement with good accuracy.** A high-precision measurement of R requires the ability to reconstruct efficiently every individual final state. This can be done by means of topological selections and kinematic fitting. The ability to identify each channel contributing to R depends crucially on a high-precision measurement of the momenta.
- **Electromagnetic (EM) calorimetry.** The EM calorimeter provides the direction and energy of photons with high precision and accuracy down to 100 MeV or below, and identifies Bhabhas used for the luminosity measurement.
- **Particle ID** is necessary for π/K separation; this feature is crucial to distinguish between and reconstruct efficiently final states containing pions and kaons.
- **Luminosity measurement** with an accuracy of the order of 1 % or better.
- $n\overline{n}$ **capability**

As PEP-N is an asymmetric machine, the CM is travelling at $0.6 < \beta_{CM} < 0.94$. In consequence, slow particles in the CM frame are boosted to momenta ranging from a few hundred MeV to 1-2 GeV, simplifying detection and reducing the angular coverage needed to obtain full acceptance. The asymmetric operation has the additional advantage of simplifying beam separation.

Another important feature of the PEP-N design is the magnet. The magnetic field required to perform beam separation with minimal interference with PEP-II operation is a weak dipole field ($B \approx 0.3\ T$). This field is also used by the experiment for the measurement of charged particle momenta. Therefore, the tracking system is housed inside the magnet gap which, as a consequence, has to be made big enough to give a suitable acceptance. Considerable effort has been expended to design a magnet with a sufficiently uniform field.

Assuming an average instantaneous luminosity of $5 \times 10^{30}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and a detection efficiency of 50 %, the expected hadronic event rate for the measurement of R is 10,000 events per day. A 1-2 day data taking period at each CM energy provides statistical accuracies better than 1 %. PEP-N plans to take data at intervals of 10 MeV. Several hundred days of data taking are required to cover the energy region between 1.2 GeV and 3.15 GeV.

Taking a maximum total cross section of 100 nb and maximum instantaneous luminosities of $10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, the event rate (excluding backgrounds) is 1 Hz. Backgrounds will increase this rate but should present no problem for the detector.

The proposed PEP-N detector layout is shown in fig. 10. The central detector is housed inside the magnet gap. It consists of a time projection chamber (TPC) using a slow He based gas providing $\sigma = 200 - 300\mu$m and dE/dx capability. It is proposed to use GEMs for the readout to eliminate the $E \times B$ term. The EM calorimeter modules are located outside the magnet. Energy resolution of a few percent down to 100 MeV and good time resolution can be achieved with a lead and scintillating fiber technology based on the KLOE design. Particle ID is achieved with two 10 cm thick KEDR style aerogel counters, which achieve 4σ π/K separation between 600 MeV/c and 1.5 GeV/c. The hadron calorimeter design was not chosen at the time of writing this report. A scintillator based calorimeter or an extension in depth of the EM calorimeter were under investigation. The dipole magnet and the central detector are not centered on the interaction point. They are shifted 25 cm in the forward direction to increase the path inside the magnetic field for particles produced in the forward direction.

The forward detector consists of two silicon aerogel counters for particle ID, additional tracking planes (drift chambers) as well as EM and hadronic calorimeter modules. Also shown in fig. 10 are the HER (High Energy Ring), LER and VLER beam pipes.

The proposed schedule for PEP-N is as follows. A proposal review is planned for summer of 2001. If approval is granted, then in 2003 the injector gun, linac, and transport lines would be installed. Also modifications to the PEP-II LER and HER would be made. The first injector beam test would be in October 2003. In summer 2004, the VLER ring, detector magnet, and detector would be installed. In October 2004, first VLER injected beam tests are foreseen. In January 2005, first collisions would occur.

C. Summary

The determination of R in this energy range is of particular importance and is timely. The statistical error achievable is negligible. However, there was no clear demonstration that the required systematic error of about 2% (dominated by knowledge of the acceptance) is achievable. Studies stimulated by the E2 group are ongoing to address this concern. In one approach, a CLEO-c 10^9 J/Ψ run would yield precision J/Ψ absolute branching ratios, which could be used by PEP-N in a calibration run at the J/Ψ for a precision determination of the acceptance. The PEP-N detector design appears to be sound. There is no new technology except for the GEM readout of the TPC. We conclude that the physics program of PEP-N is well defined, important and unique and the required number of events can be obtained in five years. However, control of systematic errors needs to be carefully evaluated before proceeding.

III. CHARM PHYSICS WITH CLEO-c

For many years, the CLEO experiment at the Cornell Electron Storage Ring, CESR, operating on the Υ(4S) resonance, has provided much of the world's information about the B_d and B_u mesons. At the same time, CLEO, using the copious continuum pair production at the Υ(4S) resonance has been a leader in the study of charm and τ physics. Now that the asymmetric B-factories have achieved high luminosity, CLEO is uniquely positioned to advance the knowledge of heavy flavor physics by carrying out several measurements near charm threshold, at center of mass energies in the 3.5-5.0 GeV region. These measurements address crucial topics which benefit from the high luminosity and experimental constraints which exist near threshold but have not been carried out at existing charm factories because the luminosity has been too low, or have been carried out previously with meager statistics. They include:

1. Charm decay constants f_D, f_{D_s};
2. Charm absolute branching fractions;
3. Semileptonic decay form factors;
4. Direct determination of V_{cd} & V_{cs};
5. QCD studies including:
   Charmonium and bottomonium spectroscopy;
   Glueball and exotic searches;
   Measurement of R between 3 and 5 GeV, via scans; and
   Measurement of R between 1 and 3 GeV, via ISR (Initial State Radiation).
6. Search for new physics via charm mixing, CP violation and rare decays; and
7. τ decay physics.

The CLEO detector can carry out this program with only minimal modifications. The CLEO-c project is described at length in [25]. It was also described in several talks at this workshop: [26] - [34]. Theoretical issues in charm physics were covered in talks [35] - [38]. A very modest upgrade to the storage ring, described elsewhere in these proceedings, is required to achieve the required luminosity. Below, we summarize the advantages of running at charm threshold, the minor modifications required to optimize the detector, examples of key analyses, a description of the proposed run plan, and a summary of the physics impact of the program.

A. Advantages of running at charm threshold

The B-factories, running on the Υ(4S) will have produced 500 million charm pairs from the underlying continuum by 2005. However, there are significant advantages of running at charm threshold:

1. Charm events produced at threshold are extremely clean;
2. Double tag events, which are key to making absolute branching fraction measurements, are pristine;
3. Signal/Background is optimum at threshold;
4. Neutrino reconstruction is clean; and
5. Quantum coherence aids D mixing and CP violation studies

These advantages are dramatically illustrated in Figure 11, which shows a picture of a simulated and fully reconstructed $\psi(3770) \to D\bar{D}$ event.

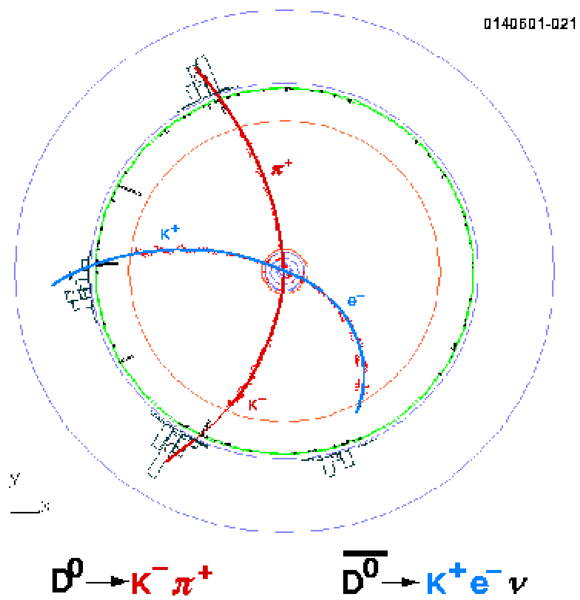

FIG. 11: A doubly tagged event at the $\psi(3770)$

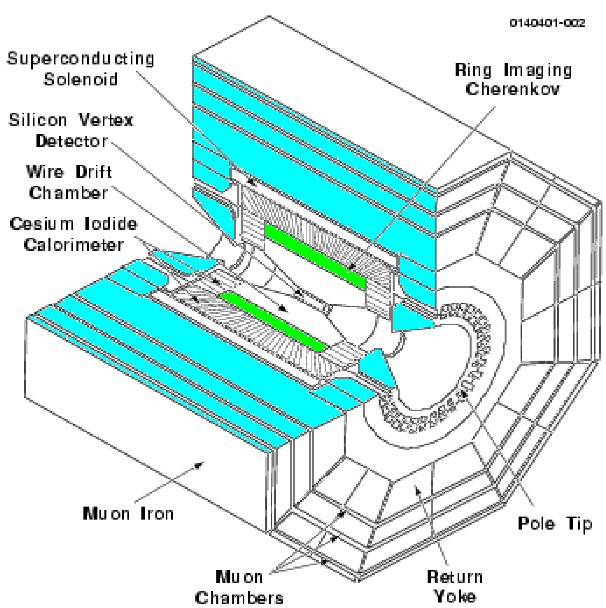

FIG. 12: The CLEO III detector

B. The CLEO-III Detector : Performance, Modifications and issues

The CLEO III detector, shown in Figure 12, consists of a new silicon tracker, a new drift chamber, and a Ring Imaging Cherenkov Counter (RICH), together with the CLEO II/II.V magnet, electromagnetic calorimeter and muon chambers. The upgraded detector was installed and commissioned during the fall of 1999 and spring of 2000. Subsequently, operation has been very reliable (see below for a caveat) and a very high quality data set has been obtained. To give an idea of the power of the CLEO III detector, Figure 13 (left plot) shows the beam constrained mass for the Cabibbo allowed decay $B \to D\pi$ and the Cabibbo suppressed decay $B \to DK$ with and without RICH information. The latter decay was extremely difficult to observe in CLEO II/II.V, which did not have a RICH detector. In the right plot of Figure 13, the penguin dominated decay $B \to K\pi$ and the tree dominated decay $B \to \pi\pi$ are shown. Both of these modes are observed in CLEO III with branching ratios consistent with those found in CLEO II/II.V. and are also in agreement with recent Belle and *BABAR* results. Figure 13 is a demonstration that CLEO III performs very well indeed.

Unfortunately, there is one detector subsystem that is not performing well. The CLEO III silicon detector, Si3, has experienced an unexpected loss of efficiency which is increasing with time. The cause of the inefficiency is unknown. The situation is under constant evaluation but it is likely that Si3 will be replaced with a wire vertex chamber for CLEO-c. We note that if one was to design a charm factory detector from scratch the tracking would be entirely gas based to ensure that the detector material was kept to a minimum. CLEO-c simulations indicate that a simple six layer stereo tracker inserted into the CLEO III drift chamber as a silicon replacement would provide a system with superior momentum resolution to the current CLEO III tracking system. The CLEO collaboration therefore proposes to build such a device for CLEO-c at a cost of order \$100,000.

Due to machine issues, CLEO also plans to lower the solenoid field strength to 1 T from 1.5 T. The other parts of the detector do not require modification. The dE/dx and Ring Imaging Cerenkov counters are expected to work well over the CLEO-c momentum range. The electromagnetic calorimeter works well and has fewer photons to deal with at 3-5 GeV than at 10 GeV. Triggers will work as before. Minor upgrades may be required of the Data Acquisition system to handle peak data transfer rates. CESR conversion to CESR-c requires 18 m of wiggler magnets at a cost of $\sim$ \$4M and is discussed elsewhere. The conclusion is that, with the addition of the replacement wire chamber, CLEO is expected to work well in the 3-5 GeV energy range at the expected rates.

C. Examples of analyses with CLEO-c

The main targets for the CKM physics program at CLEO-c are absolute branching ratio measurements of hadronic, leptonic, and semileptonic decays. The first of these provides an absolute scale for all charm and hence all beauty decays. The second measures decay constants and the third measures form factors and, in combination with theory, allows the determination of V_{cd} and V_{cs}.

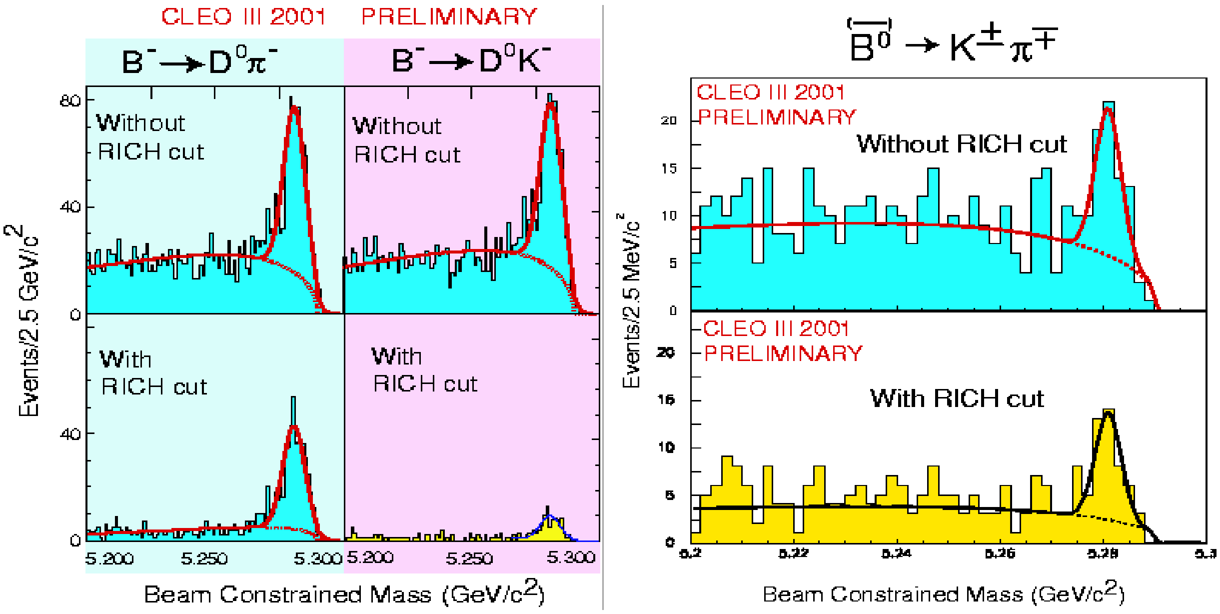

FIG. 13: (Left) Beam constrained mass for the Cabibbo allowed decay $B \to D\pi$ and the Cabibbo suppressed decay $B \to DK$ with and without RICH information. The latter decay was extremely difficult to observe in CLEO II/II.V, which did not have a RICH detector. (Right) The penguin dominated decay $B \to K\pi$. This mode is observed in CLEO III with a branching ratios consistent with that found in CLEO II/II.V.

1. *Absolute branching ratios*

The key idea is to reconstruct a D meson in as many hadronic modes as possible. This, then, constitutes the tag. Figure 14 shows tags in the mode $D \to K\pi$. Note the y axis is a log scale. Tag modes are very clean. The signal to background ratio is $\sim 5000/1$ for the example shown. Since $\psi(3770) \to D\bar{D}$, reconstruction of a second D meson in a tagged event to a final state X, corrected by the efficiency which is very well known, and divided by the number of D tags , also very well known, is a measure of the absolute branching ratio $Br(D \to X)$. Figure 15 shows the $K^-\pi^+\pi^+$ signal from doubly tagged events. It is essentially background free. The simplicity of $\psi(3770) \to D\bar{D}$ events combined with the absence of background allows the determination of absolute branching ratios with extremely small systematic errors. This is a key advantage of running at threshold.

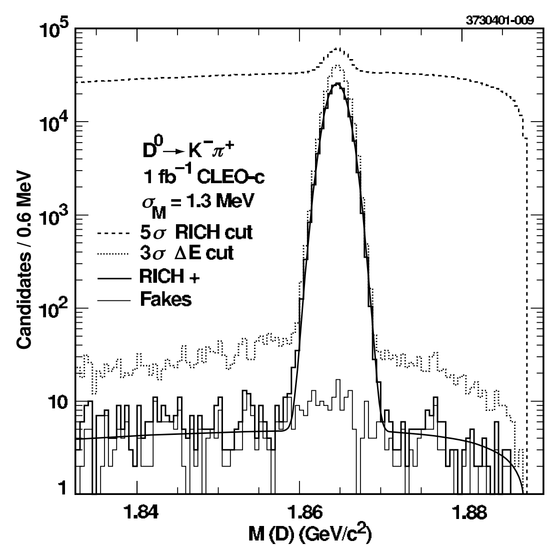

FIG. 14: $K\pi$ invariant mass in $\psi(3770) \to D\bar{D}$ events, showing a strikingly clean signal for $D \to K\pi$. The y axis is logarithmic. The S/N $\sim 5000/1$.

2. *Leptonic decay $D_s \to \mu\nu$*

This is a crucial measurement because it provides information which can be used to extract the weak decay constant, f_{D_s}. The constraints provided by running at threshold are critical to extracting the signal.

The analysis procedure is as follows:

1. Fully reconstruct one D_s;
2. Require one additional charged track and no additional photons;
3. Compute the missing mass squared (MM2), which peaks at zero for a decay where only a neutrino is unobserved.

The missing mass resolution, which is of order $\sim M_{\pi^0}$, is good enough to reject the backgrounds to this process as shown in Fig. 16. There is no need to identify muons, which helps reduce the systematic error. One can inspect

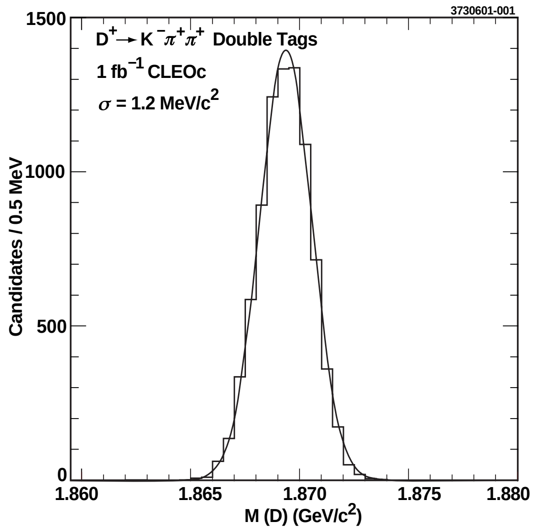

FIG. 15: $K\pi\pi$ invariant mass in $\psi(3770) \to D\bar{D}$ events, where the other D in the event has already been reconstructed. A clean signal for $D \to K\pi\pi$ is observed and the absolute branching ratio $Br(D \to K\pi\pi)$ is measured by counting events in the peak.

the single prong to make sure it is not an electron. This provides a check of the background level since the leptonic decay to an electron is severely helicity-suppressed and no signal is expected in this mode.

3. *Semileptonic decay* $D \to \pi\ell\nu$

The analysis procedure is as follows:

1. Fully reconstruct one D;
2. Select events with one additional electron and one hadronic track;
3. Calculate the variable $U = E_{miss} - P_{miss}$, which peaks at zero for semileptonic decays.

Using the above procedure results in the right-hand plot of Figure 16. With CLEO-c, for the first time it will become possible to make absolute branching ratio and absolute form factor measurements of every charm meson semileptonic pseudoscalar to pseudoscalar and pseudoscalar to vector transition. This will be a lattice calibration data set without equal. Figure 17 graphically shows the improvement in absolute semileptonic branching ratios that CLEO-c will make.

D. Run Plan

CLEO-c must run at various center of mass energies in order to achieve its physics goals. The "run plan" currently used to calculate the physics reach is given below. Note that item 1 is prior to machine conversion and the remaining items are post machine conversion.

1. 2002: Υ's – 1-2 fb^{-1} each at $\Upsilon(1S), \Upsilon(2S), \Upsilon(3S)$ Spectroscopy, electromagnetic transition matrix elements, the leptonic width. Γ_{ee}, and searches for the yet to be discovered h_b, η_b with 10-20 times the existing world's data sample.
2. 2003: $\psi(3770)$ – 3 fb^{-1}
   30 million events, 6 million tagged D decays (310 times MARK III).
3. 2004: 4100 MeV – 3 fb^{-1}
   1.5 million $D_s D_s$ events, 0.3 million tagged D_s decays (480 times MARK III, 130 times BES).
4. 2005: J/ψ – 1 fb^{-1}
   1 Billion J/ψ decays (170 times MARK III, 20 times BES II).

E. Physics Reach of CLEO-c

Several talks to the E2 working group addressed the competition CLEO-c will face from BESII/III [39], *BABAR* [40], and experiments at hadron machines [41],[42]. Tables II, III , and IV, and Figures 17 and 18 summarize the CLEO-c measurements of charm weak decays, and compare the precision obtainable with CLEO-c to the expected precision at *BABAR*, which expects to have recorded 500 million charm pairs by 2005. CLEO-c clearly achieves far greater precision for many measurements. The reason for this is the ability to measure absolute branching ratios by tagging and the absence of background at threshold. In those topics where CLEO-c is not dominant, it remains comparable or complementary to the *B*-factories.

Also shown in Table IV is a summary of the data set size for CLEO-c and BES II at the J/ψ and ψ', and the precision with which R, the ratio of the e^+e^- annihilation cross section into hadrons to μ pairs, can be measured. Since the CLEO-c data sets are over an order of magnitude larger, the precision with which R is measured is a factor of three higher. In addition, the CLEO detector is vastly superior to the BES II detector. Taken together, the CLEO-c datasets at the J/ψ and ψ' will be qualitatively and quantitatively superior to any previous dataset in the charmonium sector thereby providing discovery potential for glueballs and exotics without equal.

F. CLEO-c and Future Competition

BES/BEPC is currently proposing to upgrade the machine and detector [39]. In response to the CESR-c/CLEO-c proposal, the design goal for the machine, BEPC II, was recently changed from a peak luminosity of $5 \times 10^{31}\text{cm}^{-2}\text{s}^{-1}$ to a two ring machine with a

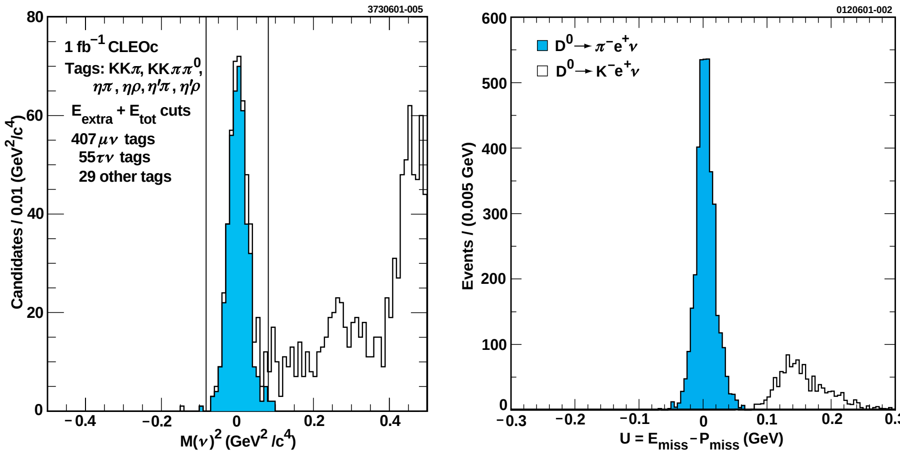

FIG. 16: (Left) Missing mass for D_sD_s tagged pairs produced at $\sqrt{s}$ = 4100 MeV. Events due to the decay $D_s \to \mu\nu$ are shaded. (Right) The difference between the missing energy and missing momentum in $\psi(3770)$ tagged events for the Cabibbo suppressed decay $D \to \pi\ell\nu$ (shaded). The unshaded histogram arises from the ten times more copiously produced Cabibbo allowed transition $D \to K\ell\nu$, where the K is outside the fiducial volume of the RICH.

TABLE II: Summary of CLEO-c charm decay measurements.

Topic	Reaction	Energy (MeV)	L (fb^{-1})	current sensitivity	CLEO-c sensitivity
Decay constant					
f_D	$D^+ \to \mu^+\nu$	3770	3	UL	2.3%
f_{D_s}	$D_s^+ \to \mu^+\nu$	4140	3	14%	1.9%
f_{D_s}	$D_s^+ \to \mu^+\nu$	4140	3	33%	1.6%
Absolute Branching Fractions					
	$Br(D^0 \to K\pi)$	3770	3	2.4%	0.6%
	$Br(D^+ \to K\pi\pi)$	3770	3	7.2%	0.7%
	$Br(D_s^+ \to \phi\pi)$	4140	3	25%	1.9%
	$Br(\Lambda_c \to pK\pi)$	4600	1	26%	4%

TABLE III: Summary of direct CKM reach with CLEO-c

Topic	Reaction	Energy (MeV)	L (fb^{-1})	current sensitivity	CLEO-c sensitivity
V_{cs}	$D^0 \to K\ell^+\nu$	3770	3	16%	1.6%
V_{cd}	$D^0 \to \pi\ell^+\nu$	3770	3	7%	1.7%

peak luminosity in excess of 10^{33}cm^{-2}s^{-1}. A completely new detector, BES III, would be built possibly around an electromagnetic calorimeter made of BGO crystals from the L3 experiment. The detector design is evolving and is the subject of a planned workshop in Beijing in October 2001. As now envisaged BEPCII/BESIII would come on line around 2006 and would accumulate a data sample one order of magnitude larger than CLEO-c. The physics program of BES III is identical to CLEO-c. For BES III to make a significant impact it is absolutely essential that the detector be as good as the CLEO-c detector. If that can be achieved, the significantly larger luminosity of BEPCII over CESR-c is likely to be a considerable advantage for new physics reach. For CKM physics, theory will have to sharpen for the larger statistics of BES III to be used to full advantage.

A program is underway at TJNAL to systematically explore the light mesons with masses up to 2.5 GeV/c^2 using photoproduction with the high quality low emittance CW photon beams available there. The program will be capable of exploring both light meson states and searching for exotic states in this mass region. A new detector is proposed along with an upgrade of CEBAF to 12 GeV. The target date for completion of construction is 2006. The goals of HALL-D and CLEO-c have some overlap but there is also complementarity. CLEO-c is focusing on glue rich states and vector hybrids both light and heavy. Hall-D is focused on states with exotic quantum numbers.

There is a proposal from the GSI accelerator in Germany for a High Energy Storage Ring (HESR) for antiprotons. One part of the program of this facility will be a search for gluonic excitations, glueballs and hybrids in the charmonium sector. This interesting facilty was

TABLE IV: Comparison of CLEO-c reach to *BABAR* and BES

Quantity	CLEO-c	*BABAR*	Quantity	CLEO-c	BES-II
f_D	2.3%	10-20%	$\#J/\psi$	10^9	5×10^7
f_{D_s}	1.7%	5-10%	ψ'	10^8	3.9×10^6
$Br(D^0 \to K\pi)$	0.7%	2-3%	4.14 GeV	$1\,fb^{-1}$	$23\,pb^{-1}$
$Br(D^+ \to K\pi\pi)$	1.9%	3-5%	3-5 R Scan	2%	6.6%
$Br(D_s^+ \to \phi\pi)$	1.3%	5-10%			

TABLE V: Current knowledge of CKM matrix elements (row one). Knowledge of CKM matrix elements after CLEO-c (row two). See the text for further details.

V_{cd}	V_{cs}	V_{cb}	V_{ub}	V_{td}	V_{ts}
7%	16%	5%	25%	36%	39%
1.7%	1.6%	3%	5%	5%	5%

not discussed in the E2 group as GSI was not represented. However, charmonium studies are likely to be complementary to CLEO-c.

G. CLEO-c Physics Impact

CLEO-c will provide crucial validation of Lattice QCD, which will be able to calculate many quantities with claimed accuracies of 1-2%. The CLEO-c decay constant and semileptonic data will provide a "golden", and timely test while CLEO-c QCD and charmonium data will provide additional benchmarks.

CLEO-c will provide, in a timely fashion, dramatically improved knowledge of absolute charm branching fractions, which are now contributing significant errors to measurements involving b's. CLEO-c will significantly improve knowledge of those CKM matrix elements which are now not very well known. In particular, V_{cd} and V_{cs} will be determined directly by CLEO-c data and LQCD, or other theoretical techniques. V_{cb}, V_{ub}, V_{td} and V_{ts} will be determined with enormously improved precision using B-factory data and lattice gauge results once the CLEO-c program of lattice validation is complete. Table V gives a summary of the situation. CLEO-c data alone will also allow new tests of the unitarity of the CKM matrix. The unitarity of the second row of the CKM matrix will be probed at the 3% level, which is comparable to our current knowledge of the first row. CLEO-c data will also test unitarity by measuring the ratio of the long sides of the squashed cu triangle to 1.3%.

Finally the potential to observe new forms of matter, glueballs, hybrids, etc in J/ψ decays, and new physics through sensitivity to charm mixing, CP violation, and rare decays provides a discovery component to the program.

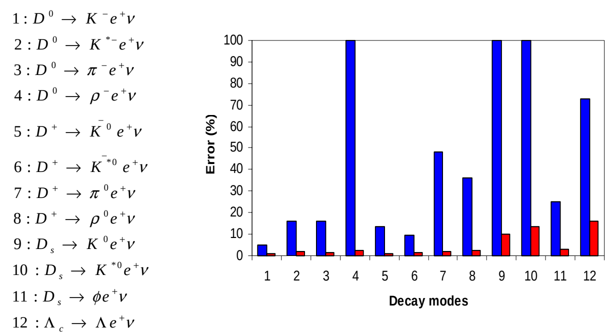

FIG. 17: Absolute branching ratio current precision from the PDG (left entry) and precision attainable at CLEO-c (right entry) for twelve semileptonic charm decays.

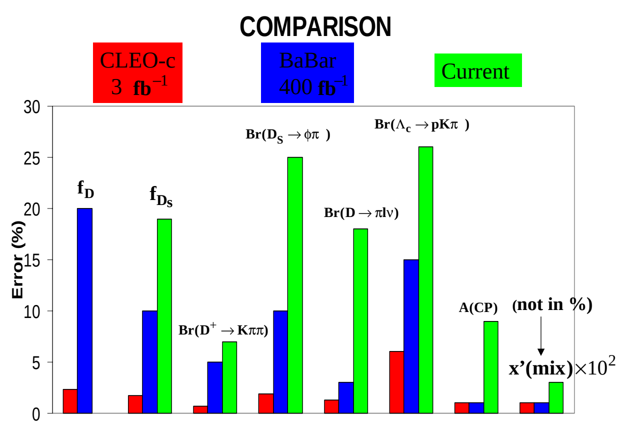

FIG. 18: Comparison of CLEO-c (left) *BABAR* (center) and PDG2001 (right) for eight physics quantities indicated in the key.

IV. e^+e^- B-FACTORIES AND THEIR PLANS FOR THE FUTURE

The two asymmetric B-factories, PEP-II and KEKB, have achieved reliable operation at high luminosities of a few $10^{33}\text{cm}^{-2}\text{s}^{-1}$ in a remarkably short period of time after their startup. These luminosities have enabled their experiments, *BABAR* and Belle, respectively, to observe CP violation in the decays of the B^o meson. Operational experience with both machines has now led to plans for incremental upgrades which eventually are ex-

TABLE VI: Predicted Evolution of Luminosity and Number of Produced B's in Asymmetric B Factories

	KEKB 2001	KEKB 2005	PEPII 2001	PEPII 2005	super KEKB >2007	Super *BABAR* $>$ 200X
$L\times10^{33}$	4.1	10	3	10	100	1000
B's/10^7s	8.2×10^7	2×10^8	6×10^7	2×10^8	2×10^9	2×10^{10}

pected to produce luminosities of $10^{35}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. For the purposes of this report, we will refer to these as "super B-factories", with a lower case 's'. While this is happening, hadron collider experiments at the Tevatron, CDF and D0, will begin to produce B physics results that will compete with, and in some cases exceed, the sensitivity of the e^+e^- B-factories. Dedicated experiments at the Tevatron and the LHC, BTeV, and LHCb, and the two large general purpose experiments at the LHC, CMS and ATLAS, will begin to contribute at very high levels of sensitivity to the study of *CP* violation and rare decays in the B system, starting around 2007. The SLAC group has proposed a response to this, which we refer to as the "Super B-factory", which has a luminosity goal of $10^{36}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. We write this with an uppercase 'S' to emphasize that it is aiming at a factor of 10 higher luminosity than superKEK. This requires a new machine and a very significant upgrade of the *BABAR* detector. KEK seems, at present, to have no plans to pursue B physics after the dedicated hadron collider B experiments appear on the scene. We present the plans for the two phases of B-factory upgrade, emphasizing physics reach, and compare their reach to the physics reach of the hadron collider experiments that will be coming on in the same period. This part of the report is based on the following set of talks to the E2 working group [43] - [64], much lively discussion and much work during the summer study, especially by the E2 subgroup on Super B-factories organized by David Hitlin [65]. The projected evolution of luminosity in these machines is shown in Table VI.

In addition to these two circular machines, there are proposals to construct multi-hundred GeV center of mass energy e^+e^- Linear Colliders. This has raised the prospect of further running on the Z-pole, where: the b-quark cross section is very high, ∼7nb; where all species of B mesons and baryons are produced; there is significant boost for time-dependent studies; and the events are quite clean allowing flavor tagging to be done efficiently. While most of the time the machine will operate at a center of mass energy well above the Z-pole, it is possible to invent a scheme where continuous Z-pole running is possible. Such a scheme is proposed for TESLA at DESY where there is a second beam for a Free Electron Laser. Pulses can be stolen from that to form a so-called Giga-Z machine. The physics reach of this machine is explored, some areas in which it can do unique studies are described, and its sensitivities are compared with those of the circular e^+e^- machines and the hadron colliders.

A. KEKB/Belle Upgrade plans

KEK plans for call for an upgrade to $10^{35}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, which corresponds to 10^9 B pairs per year. Towards the end of this period, which they see as extending to around 2007/8, they expect to be overtaken by competition from hadron collliders. However, they believe that they will have significant advantages with respect to hadron colliders in terms of

- π^o and γ detection efficiency, and
- smaller backgrounds.

They look to techniques such as greater reliance on vertex separation cuts and full reconstruction tagging to reduce backgrounds below what they are today. With the improved backgrounds obtained with a detachment cut of about 2σ, they believe it will be possible to study decays with branching fractions at the level of 5×10^{-7}. Examples of decays that would then be accessible are $B^-\to K^{*o}K^-$ and decays such as $B^+\to D^+K_s$ and $B^+\to D^oK^+$, which can be used to measure the CKM angle γ. In full reconstruction tagging, as many B's as possible are fully reconstructed and then one studies the remnants, which must all be from the other B. This technique helps especially with states containing neutrinos, such as

$$b \to ul\nu \quad (14)$$
$$B \to \mu\nu \quad (15)$$
$$b \to s\nu\bar{\nu} \quad (16)$$

The technique relies on the detector's hermeticity.

The conclusion is that there are many significant physics studies they can do with approximately 5 years of running at a luminosity of 10^{35}. The machine upgrade is an extrapolation of the current KEK configuration. It was discussed in section M2 [55].

Operation at 10^{35} has implications for the detector and the IR. The rates from collisions will be significantly higher which will lead to larger occupancy. Trigger rates and rates through the data acquisition system will be higher. There will be more synchrotron radiation, which will have to be removed by masking. There may be larger vacuum pressure resulting in higher background rates from Touschek scattering. There may need to be a larger crossing angle which may make it harder to shield backgrounds efficiently. The final quads may be moved closer to the IP to reduce β^*. And finally, the background at injection might be significantly worse.

It is planned to use a 1 cm radius beampipe. Particle backgrounds will be controlled by massive masks around the inner vertex detectors, on the upstream beampipes and at other "weak spots". Nevertheless, the first few layers of the silicon vertex detector will have high occupancy and will be replaced by pixel detectors. Beampipe heating due especially to Higher Order Modes (HOM) requires that the beam pipe be water cooled. The Central

Drift Chamber is undergoing a modification in 2002 to replace the two inner layers with a small cell chamber. It is expected to be able to handle superKEK rates. The CsI(Tl) calorimeter is slow and something may need to be done to it. The RPCs in the muon system already suffer from inefficiency due to local deadtime and will probably need to be replaced with wire chambers. The data acquisition system will also have to be upgraded.

The upgrade to 10^{35} is believed to be feasible from a machine point of view. The detector will need several upgrades but these appear feasible as well. The physics case is based on the cleanliness of the signals and the ability to study modes that are very hard to measure in hadron colliders – modes which include π^o's and ν's. After several years of running at 10^{35}, the B physics program at KEK will probably end. A further push in luminosity would require a new machine configuration and a new detector and is not in their current plans.

B. PEP-II/*BABAR* Upgrade Plans: Super B Factory and Super*BABAR*

PEP-II and *BABAR* expect to achieve an integrated luminosity of 500 fb^{-1} (0.5 ab^{-1}) by around 2005. With that, they expect to achieve the following errors on the unitarity angles β and α:

$$\sin 2\beta \approx 0.04 \quad (17)$$
$$\sin 2\alpha \approx 0.14 \quad (18)$$

For details of these estimates and a discussion of the prospects and complications in the measurement of α and γ see [65]. Although the combined *BABAR* and Belle integrated luminosity will be about 1 ab^{-1} at this point and PEP-II will be delivering about 0.2 ab^{-1}/year, a new generation of hadron collider experiments will be positioned to dominate the study of CP violation and rare and Standard Model forbidden processes in B decays. A recent study has outlined a possible path for achieving a luminosity of 10^{36}cm^{-2}s^{-1} in e^+e^- collisions. This corresponds to 10 ab^{-1}/year and requires a new machine configuration and a very substantial upgrade of the *BABAR* detector, which involves complete replacement or major revision of many components. The goal is to be competitive with the next generation hadron collider experiments, at least in the area of B_d and B_u physics. Because of the experimental constraints of threshold production and the low backgrounds in e^+e^- physics, certain measurements could be made with this facility that might not be possible to do at hadron colliders.

Details of the new machine can be found in the M2 summary elsewhere in these proceedings. The machine could be located either in the PEP tunnel, where it would replace PEP-II, or in the tunnel for the SLC arcs. If located in the PEP tunnel, PEP-II operation would have to stop for about 1 year while the new machine components were installed.

1. *Physics Case for 10* ab^{-1}*/yr* e^+e^- *Facility*

There are a variety of interesting topics which can be addressed at such a facility. These include both precision tests of the consistency of the Standard Model predictions and discovery of, or sorting out of, new phenomena beyond the Standard Model. A list of interesting processes are:

- Improvement in CP asymmetry measurements
  - $\sigma(\sin 2\beta) \approx 0.01$ for $J/\psi\, K_s$
  - $\sin 2\beta$ will be measured with good precision in many modes which provides an important consistency check
  - $\sin 2\alpha(A_{CP})$ and $\sin\gamma$ can be measured
- Measurement of some particularly challenging two and three body branching fractions, for example $B^o \to \pi^o\pi^o$
- Measurement of f_B to useful precision to check lattice predictions
- Interesting sensitivity to rare B, D, and τ decays, such as $\tau \to \mu\gamma$
- High precision measurements of semileptonic decay distributions, especially the precision measurement of V_{ub}.

These topics were studied in the context of a high luminosity next generation e^+e^- B Factory at the "Beyond 10^{34} Workshop" [66] in Michigan during June 2000, at the follow-up session at the Fourth International Conference on B physics and CP Violation in Ise Shima, Japan in February 2001 [67] and were the focus of an E2 subgroup at Snowmass [65].

2. *Experimental Considerations*

Both the rates from the beam collisions and from backgrounds will be much higher than present. In particular, the overall loss rates will be about 1000 times the present rates. The beam lifetime will be only around 10 minutes so the machine will be filled continuously during the store. At a luminosity of 10^{36}cm^{-2}s^{-1}, there are

- 50 kHz of Bhabha scatters,
- $\sim$7 kHz of other physics events, and
- $O(\sim$10kHz) of triggerable machine associated background in the detector acceptance.

3. Detector Issues

Most of the *BABAR* subsystems will have to undergo some modification or replacement to handle the much higher rates of the new machine. To carry out the program, the overall performance, in terms of resolution, efficiency, and background rejection, must be similar to that of *BABAR*. The detector must retain its high degree of hermeticity as well. Table VII summarizes the problems that affect current *BABAR* detectors at these high luminosities and indicate possible solutions. One concept for the replacement detector, a very compact detector based on a high field solenoid, is shown in Fig. 19. The solenoid has a radius of about 0.75m and a field of 3 Tesla. The central vertex detector consists of two layers of pixel detector and a three layer silicon strip detector. The central drift chamber is replaced by a 4 layer silicon strip tracker, which is much more compact. The combination of the high field and the high precision tracking permit the detector to achieve momentum resolution comparable to *BABAR*. The expensive electromagnetic crystal calorimeter has a small radius, which lowers the cost.

In addition to detector modifications, a faster and more selective trigger and a higher speed, higher capacity Data Acquisition system must be implemented. While difficult compared to the existing *BABAR* experiment, the triggering and data acquisition problem is far less of a challenge than must be met at the Tevatron or LHC so this is not considered an insurmountable task. Data analysis will benefit from the projected continued drop in cost of computing cycles and data storage.

There are substantial uncertainties in the detector requirements due to the difficulty in estimating the various backgrounds. It is clearly important to implement a realistic machine lattice and IR design to provide predictions for the very large backgrounds that will exist at Super*BABAR*, especially backgrounds due to continuous injection. These studies were foreseen, but had not been performed at the time of Snowmass.

There are many questions about the cost and availability of suitable detector technologies which will need to be studied before the detector design can be finalized. We give four examples. (1) To maintain the vertex resolution of *BABAR* and withstand the radiation environment, pixels with a material budget of 0.3% X_o per layer are proposed. Traditional pixel detectors which consist of a silicon pixel array bump-bonded to a readout chip are at least 1.0% X_o. To obtain less material, monolithic pixel detectors are suggested. This technology has never been used in a particle physics experiment. (2) As a drift chamber cannot cope with the large rates and large accumulated charge, a silicon microstrip tracker has been proposed. At these low energies track parameter resolution is dominated by multiple Coulomb scattering. Silicon microstrip technology is well tested but is usually used at this energy for vertexing, not tracking. Realistic simulations need to be performed to establish if momentum resolution as good as *BABAR* can be achieved with the large amount of material present in the silicon tracker. If not, we suggest a TPC, possibly readout with a Gas Electron Multiplier, or MICROMEGAS, be explored as an alternative to the silicon tracker (3) There is no established crystal technology to replace the Csi(Tl). There are some candidate materials (see the Super*BABAR* document for details) but the most attractive have not been used in a calorimeter previously. (4) There is no known technology for the light sensor for the SuperDIRC.

TABLE VII: Modifications to the *BABAR* detector for Super*BABAR*.

BABAR Detector	Super*BABAR* Detector	Reason for change
Silicon Strips	Silicon Pixels	Occupancy
Drift Chamber	Silicon Tracker or TPC	accumulated charge
DIRC	super DIRC	Remove water standoff box due to high background Cerenkov light and replace with new optics
ECAL CsI(Tl)	new rad hard,	CsI(Tl) has a long decay
IFR(RPCs)	crystal scintillators	time and is not rad hard Occupancy

4. Comparison with Hadron Collider Experiments

Since the goal of the Super *B*-Factory and Super*BABAR* upgrades are to enable the e^+e^- machine to compete with future hadron collider experiments, it is important to make a realistic evaluation of the sensitivities of all these experiments over a wide range of final states. Such projections are, of course, somewhat uncertain. The sensitivities of future hadron collider experiments have been determined from detailed and sophisticated simulations of signals and backgrounds. As these simulations are an approximation to reality, the performance of LHCb and BTeV may be somewhat better or somewhat worse than the simulations predict. Projections for Super*BABAR* are, at this point, mainly done by scaling from *BABAR* experience assuming that the new detector, which still has many open R&D issues, will achieve the same efficiency that *BABAR* now achieves even though the luminosity will be a factor of 300 higher. More realistic studies need to be performed before a full comparsiion between Super*BABAR* and the hadron collider experiments is made.

For both the hadron collider experiments and Super*BABAR*, we assume the machine can achieve the desired luminosity, which is reasonably assured for the hadron colliders but less certain for the Super *B*-Factory, where design has just begun and there are many technology and accelerator issues.

With these caveats, Table VIII compares the rate of tagged $B^o \to \pi^+\pi^-$ obtained in one year from

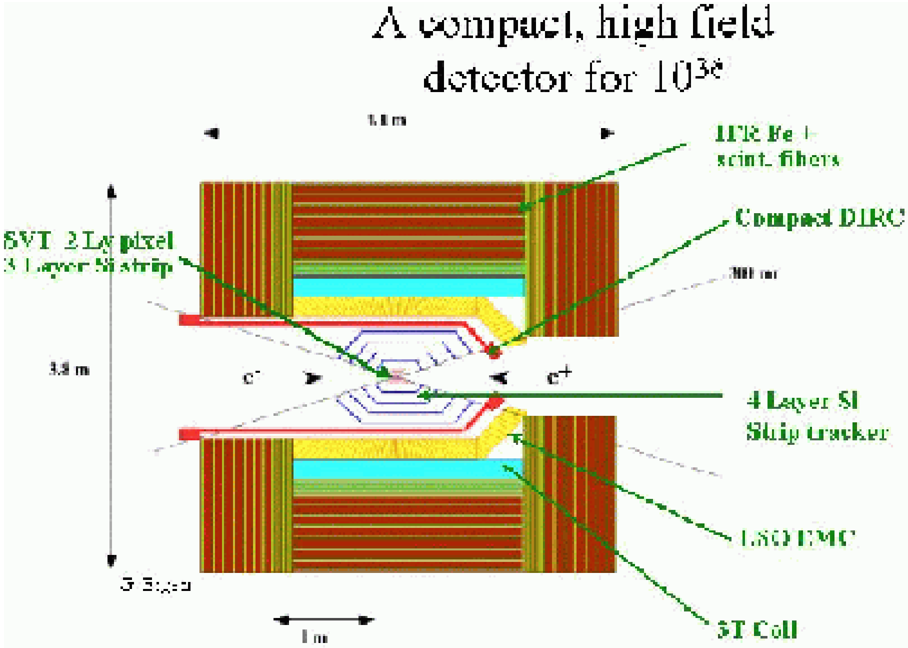

FIG. 19: Schematic of a Compact Detector Design for Super*BABAR*

TABLE VIII: Comparison of the number of tagged $B^o \to \pi^+\pi^-$ in Super*BABAR* and BTeV

	$L(\mathrm{cm}^{-2}\mathrm{s}^{-1})$	σ	$B^o/10^7$s	ϵ	S/B	ϵD^2	tagged
e^+e^-	10^{36}	1.1 nb	1.1×10^{10}	0.3	0.7	0.3	3600
BTeV	2×10^{32}	100μb	1.5×10^{11}	0.037	3.0	0.1	2370

TABLE IX: Comparison of the number of tagged $B^+ \to D^oK^+, D^o \to K^+\pi^-$ with in Super*BABAR* and BTeV (product of all branching factions taken as B=1.7 $\times$ 10^{-7})

	$L(\mathrm{cm}^{-2}\mathrm{s}^{-1})$	σ	$B^o/10^7$s	ϵ	S/B	tagged
e^+e^-	10^{36}	1.1 nb	1.1×10^{10}	0.5		600
BTeV	2×10^{32}	100μb	1.5×10^{11}	0.014	1.0	300

Super*BABAR* and BTeV. Table IX shows the number of tagged $B^+ \to D^oK^+, D^o \to K^+\pi^-$ in the two experiments. A comparison of BTeV, LHCb, *BABAR* and Belle in 2005, and the e^+e^- machines at 10^{35} and 10^{36} is given in Table X for several states of importance to the study of *CP* violation in B decays. Finally, Table XI shows a comparison of CDF/D0, BTeV/LHCb, ATLAS/CMS, *BABAR*/Belle, and e^+e^- machines at 10^{35} and 10^{36} for "rare decays" of the B mesons.

It is clear that the 10^{36} e^+e^- machine can compete with the hadron collider experiments on many interesting *CP* violating decays and on rare decays of B_d and B_u. It should do better on decays involving τ's and missing ν's since the hermeticity and energy constraints provided by running at threshold permit one to establish the neutrino's presence in the event by demonstrating a recoil mass consistent with zero. While $B^o \to \pi^o\pi^o$ may be barely detectable in several years of operation at the 10^{36} e^+e^- machine, none of the hadron experiments have yet claimed to be able to observe this state.

The tables are designed to compare the e^+e^- machines with the hadron machines in the areas where the former are strong. To have a complete picture, one needs to remember that the e^+e^- machine can do only very limited B_s physics compared to the hadron collider experiments. In particular, the proper time resolution, σ_τ of 900 fs, compared to better than 40 fs for BTeV, and LHCb, precludes the study of time dependent effects in B_s decays. This is a strength of the hadron collider experiments. The e^+e^- experiments also do not have high enough energy to study b-baryons or B_c mesons.

V. GIGA-Z MACHINES

The LEP experiments, running on the Z, were able to make many important B physics measurements even though the luminosity was only $\sim 10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. SLD, by exploiting the ability to polarize the electron beam at a linear collider, was able to make significant measurements at an even lower luminosity. As plans develop to build a high energy, high luminosity e^+e^- linear collider, it is worth considering whether competitive B physics at the Z can be carried out at these facilities [68][69].

The reasons why the Z-pole is a good place to study B physics are:

TABLE X: Comparison of *CP* Reach of Hadron Collider Experiments and Super*BABAR*. The last column is a prediction of which kind of facility will make the dominant contribution to each physics measurement.

	BTeV 10^7s	LHCb 10^7s	*BABAR* Belle (2005)	10^{35} 10^7s	10^{36} 10^7s	
$\sin 2\beta$	0.011	0.02	0.037	0.026	0.008	Equal
$\sin 2\alpha$	0.05	0.05	0.14	0.1	0.032	Equal
$\gamma\,[B_s(D_sK)]$	$\sim 7^o$					Had
$\gamma\,[B(DK)]$	$\sim 2^o$		$\sim 20^o$		1-2.5^o	Equal
$\sin 2\chi$	0.023	0.04	-	-	-	Had
BR($B \to \pi^o\pi^o$)	-	-	∼20%	14 %	6%	e^+e^-
V_{ub}	-	-	∼2.3%	∼1% (sys)	∼1% (sys)	e^+e^-

TABLE XI: Comparison of Reach of Hadron Collider Experiments and Super*BABAR*for Rare Decays of B_u and B_d Mesons. Entries are either branching fraction sensitivities, if they have negative exponents, or signal yields. An $\star$ indicates that the entry below is claimed to be the best measurement. The numbers in parentheses in column 1 are the branching fractions used in the calculations.

	Hadronic Exp			B-Factory		
Decay Mode (Br Ratio)	CDF /D0 ($2fb^{-1}$)	BTeV /LHCb 10^7s	ATLAS /CMS (1 year)	*BABAR* /Belle ($0.5ab^{-1}$)	10^{35} ($1ab^{-1}$)	10^{36} ($10ab^{-1}$)
$B \to X_s\gamma$					$\star$	$\star$
(3.29±0.21±)0.21)$\times 10^{-4}$				11K	22K	220K
with B tags				1.7K	3.4K	34K
$B \to K^*\gamma$						$\star$
(3-8)$\times 10^{-5}$	170/-	27K/24K		6K	12K	120K
$\delta\,(A_{CP})$		0.01		0.02	0.01	<0.01
$B \to X_s\nu\bar{\nu}$						$\star$
(4.1±0.9)$\times 10^{-5}$				8	16	160
$B \to K^*\nu\bar{\nu}$						$\star$
(5×10^{-6})				1.5	3	30
$B \to X_s\mu^+\mu^-$		$\star$				
(6.0±1.5)$\times 10^{-6}$		7.2K/-		300	600	6K
$B \to X_se^+e^-$		$\star$				
(6.0±1.5)$\times 10^{-6}$		7.2K/-		350	700	7K
$B \to K^*\mu^+\mu^-$		$\star$	$\star$			$\star$
(2±1 $\times 10^{-6}$)	61/60-150	4.4K/4.5K	665/4.2K	120	240	2.5K
$B \to K^*e^+e^-$				150	300	3K
(2±1 $\times 10^{-6}$)						
$B_d^o \to \tau^+\tau^-$					$\star$	$\star$
(10^{-7})				$<10^{-5}$	$<2\times 10^{-6}$	$<10^{-6}$
$B \to \mu^+\mu^-$		$\star$	$\star$			
B_s (10^{-9})	5/1.5-6	10/11	9/7			
B_d (8×10^{-11})	0/0	2/2	0.7/20	$<10^{-8}$	$<5\times 10^{-9}$	$<10^{-9}$
$B_d^o \to e^+e^-$					$\star$	$\star$
(10^{-14})				$<10^{-8}$	$<5\times 10^{-9}$	$<10^{-9}$
$B \to \tau\nu$						$\star$
(5×10^{-5})				17	34	350
$B \to \mu\nu$						$\star$
(1.6×10^{-7})				8	16	150
$B^o \to \gamma\gamma$						$\star$
(10^{-8})				0.4	0.8	8

- The cross section for producing states containing b-quarks is large, ~ 6.6nb;
- The signal to background is very favorable, $\sim 25\%$;
- All species of b-hadrons are produced, including B_s and Λ_b;
- The B's have a large boost so that time-evolution studies are possible;
- Due to the high boost, the two b-hadrons are well separated and separated from the interaction vertex; and
- The beams can be polarized. This leads to a correlation between b-direction, and the B hadron direction, with respect to the e^- direction, which constitutes a highly efficient flavor tag. Electron polarizations of >80% are achievable and it is expected that positron polarizations of ~60% can be obtained.

Even though the attainable b yield is low compared to the hadron colliders or Super*BABAR*, these features permit the extraction of clean, tagged samples with very high efficiency, since all B's are triggered and reconstructed and tagging is very efficient. The high efficiency partially offsets the low produced rates.

Typical design luminosities for an e^+e^- linear collider designed to run at 500 GeV center of mass energy are 2-3$\times 10^{34}$. As part of the program of electroweak physics studies that can be done at these machines, there will be some running at the Z, in order to make better measurements of electroweak parameters and to make rigorous tests of the consistency of the Standard Model. It seems to be currently accepted that a run that produces 10^9 Z's is what is required. At that level of statistics, some measurements are already limited by the understanding of how to make theory corrections while others are limited by the experimental systematic errors, for example in measuring the polarization or the center of mass energy.

Even with the lower luminosity, say 5×10^{33}, expected at the Z, it would take only 50 days to accumulate 10^9 Z's with polarization of 0.8 for electrons and 0.6 for positrons. This provides a sample of $\sim 4\times 10^8$ b-hadrons for studies.

There are plans for a dedicated Z facility associated with the high energy collider. Based on the remarks on electroweak physics, B physics would have to provide the justification for this. The objective would be to achieve 10^{10} Z's, corresponding to $\sim 4\times 10^9$ B-hadrons. Table XII compares the $\sin 2\beta$ reach for this facility with the B-factories and the hadron collider experiments. It is clear that even 10^{10} Z's, which takes 3-5 years to obtain, is barely competitive with one year of data from BTeV/LHCb or Super*BABAR*.

This, however, is not the entire story. There are several classes of studies that take advantage of the unique characteristics of b-quark production at the Z. These include:

TABLE XII: Comparison of the $\sin 2\beta$ reach with 10^9 and 10^{10} Z's

	e^+e^-(2005)	BTeV/LHCb 10^7s	10^9 Z	10^{10} Z (3-5 yrs)
$\delta\sin 2\beta$	0.037	0.014/0.02	0.04	0.013

- States that are polarized, especially b-baryons;
- Searches for direct CP asymmetries in rare decays, such as $b\to s\gamma$ and $b\to sl^+l^-$;
- Measurements involving inclusive final states;
- "Missing Energy" modes, such as $b\to s\nu\bar{\nu}$ and $B\to\tau\nu$; and
- Rare $Z\to b\bar{s}+\bar{b}s$ which are expected to be too small to observe in the Standard Model.

These classes of decays might reveal new physics.

Polarization studies are a case in point. The b quarks are strongly polarized. It is a prediction of HQET, confirmed by experiment, that the polarization survives the hadronization process. OPAL has measured

$$P_{\Lambda_b} \;=\; -0.56^{+0.20}_{-0.13}\pm 0.09 \qquad (19)$$

Thus, the Giga-Z facility can be viewed as a high luminosity, $\sim 10^8$/year source of polarized Λ_b's. A study of the angular correlation in $\Lambda_b\to\Lambda\gamma$ [70] between the photon direction and the spin of the Λ_b is sensitive to spin-flip effects due to New Physics beyond the Standard Model. In particular, enlarged spin-flip contributions can be sizeable in L-R symmetric models or SUSY models with flavor non-universal breaking. The hadronic rare decay $\Lambda_b\to\Lambda\phi$ also is a probe of New Physics, although it is theoretically less clean. Table XIII gives a list of potentially interesting decays modes. There are many other interesting topics in b-baryon physics that can be explored.

The case for a dedicated Giga-Z facility at the Z in a future e^+e^- linear collider is just beginning to be discussed and needs much more development followed by a careful assessment of the contributions it can make to the picture of rare B decays and CP violation.

VI. CONCLUSION

ϕ Factories have a broad program with many unique and desirable features, but, in the area of rare kaon decays, they are unlikely to have sufficient flux to challenge the dedicated Fixed Target experiments.

The PEP-N physics program is well-defined, unique and timely. This is especially true of the measurement of

TABLE XIII: Interesting b-baryon decay modes which can be studied at the Z.

Semileptonic:
$\Lambda_b \to \Lambda_c l \nu_l$
$\Lambda_b \to p l \nu_l$
rare:
radiative:
$\Lambda_b \to \Lambda\gamma$
semileptonic:
$\Lambda_b \to \Lambda l^+ l^-$
$\Lambda_b \to \Lambda\nu\bar{\nu}$
hadronic:
$\Lambda_b \to \Lambda\phi$
$\Lambda_b \to n D_2^{*o}$
inclusive:
$\Lambda_b \to X_s\gamma$

R. However, there was no clear demonstration at Snowmass that the required systematic error per point (about 2%) could be achieved. Control of systematic errors needs to be carefully evaluated before proceeding with PEP-N.

CESR-c/CLEO-c promises a 400-fold increase in D meson data at threshold. The data would provide a crucial and timely validation of lattice QCD, HQET, ChPTHH and other theoretical techniques which are central to progress in flavor physics in this decade, and in the case of lattice QCD, also a key to addressing strong coupling that may be a feature of the physics beyond the Standard Model that we expect to be discovered at the LHC. CLEO-c also promises (a) A factor 4-12 improvement in key hadronic branching ratios which will set the absolute scale for beauty and charm quark physics. (b) A significant improvement, $(\times 5-10)$ in CKM matrix element precision in the charm sector, and $(\times 2-8)$ in the beauty sector in conjunction with data obtained at experiments with a B physics capability at e^+e^- B-factories and hadron colliders. (c) CLEO-c has discovery potential, since the experiment is sensitive to new physics through D mixing, D CP violation and rare decays of D mesons and the τ lepton, and in the search for new forms of matter, including glueballs and hybrids. Finally a flexible accelerator, an experienced collaboration and a high quality detector are already in place, making the well-defined three year physics program very attractive.

BES/BEPC is currently proposing to upgrade the machine and detector. BEPC II would be a two ring machine with a peak luminosity in excess of 10^{33}cm^{-2}s^{-1}. A completely new detector, BES III, would be built. BEPCII/BESIII would come on line around 2006 and would accumulate a data sample one order of magnitude larger than CLEO-c. The physics program of BES III is identical to CLEO-c. For BES III to make a significant impact it is absolutely essential that the detector be as good as the CLEO-c detector. If that can be achieved, the significantly larger luminosity of BEPCII over CESR-c is likely to be a considerable advantage for new physics reach. For CKM physics, theory will have to sharpen for the larger statistics of BES III to be used to full advantage. Hall D at TJNAL, coming on-line in 2006, and CLEO-c have some overlap but there is also complementarity. CLEO-c is focusing on glue rich states and vector hybrids both light and heavy. Hall-D is focused on states with exotic quantum numbers. There is also a proposal from the GSI accelerator in Germany for a High Energy Storage Ring (HESR) for antiprotons. The charmonium studies this machine will allow are likely to be complementary to CLEO-c.

The two asymmetric B-factories, PEP-II and KEKB, have achieved reliable operation at high luminosities of a few 10^{33}cm^{-2}s^{-1} in a remarkably short time. Both machines have plans for incremental upgrades which eventually are expected to produce luminosities of 10^{35}cm^{-2}s^{-1}, which corresponds to 10^9 B pairs per year. These asymmetric super B-factories have significant advantages with respect to hadron colliders in terms of π^o detection efficiency, ν reconstruction and generally smaller backgrounds. In this report, as an example of what can be achieved by a long run at 10^{35}cm^{-2}s^{-1}, we discussed only the super KEKB/Belle upgrade. The PEP-II analog has identical physics reach. (For PEP, we concentrated Super*BABAR* with a design luminosity of 10^{36}cm^{-2}s^{-1}.) The high statistics of a 10^{35}cm^{-2}s^{-1} super B-factory allows significant numbers of B mesons to be tagged by full reconstruction, and this permits many significant physics studies to be performed especially involving final states with a neutrino such as semileptonic $b \to u$ transitions to determine V_{ub}, leptonic decays and electroweak penguins. The KEKB machine upgrade is believed to be feasible. Operation at 10^{35} will produce significantly higher background rates in Belle which will lead to larger occupancy. Accordingly, the detector will need several upgrades which we judge to be feasible. After several years of running at 10^{35}, the B physics program at KEK will probably end. A clear consensus was reached in the E2 group that an e^+e^- B-factory operating at 10^{35} would not be competitive with experiments at hadron colliders specifically LHCb/BTeV/ATLAS/CMS coming on-line around 2007. This view is also held by the proponents of the KEKB/Belle upgrade.

The Super B-factory is a new continuous injection e^+e^- collider that would operate in the PEP-II tunnel or the SLC arcs at a luminosity of 10^{36}cm^{-2}s^{-1}, a factor 300 more than PEP-II achieves today. It has been proposed specifically to be complementary to the hadron collider B experiments as a precision probe of the consistency of the flavor changing sector of the Standard Model and in searches for New Physics. Occupancy and machine backgrounds will probably require the replacement of the entire *BABAR* detector. The detector design is challenging, raising many difficult R&D issues. Assuming detector efficiency could be maintained at such a high luminosity, we estimate that Super*BABAR* would be complementary to LHCb/BTeV for rare decays of B_d and B_u mesons, superior for decays with ν's, and competitive for decays with a π^o,or γ. It accuracy would be comparable for the angles α, β and γ but not χ. Compared to hadron collider experiments, the B_s program would be limited by the complications of operating at the $\Upsilon(5S)$, and because of much poorer proper time resolution. There would be no Λ_b or B_c physics.

The sensitivities of future hadron collider experiments have been determined from detailed and sophisticated simulations of signals and backgrounds. As these simulations are an approximation to reality the expected performance of LHCb and BTeV may be somewhat better or somewhat worse than the simulations predict. Projections for Super*BABAR* are at this point mainly done by scaling from *BABAR* experience assuming that the new detector, which still has many open R&D issues, will achieve the same efficiency that *BABAR* now achieves even though the luminosity will be a factor of 300 higher. More realistic studies need to be performed before a full comparison between Super*BABAR* and the hadron collider experiments is made. It is also important to quickly implement a realistic machine lattice and IR design to provide predictions of the very large machine backgrounds that will exist at Super*BABAR*, especially background due to continuous injection. If backgrounds prove tractable, and detector simulations support the simple scaling from *BABAR* experience, an R&D program on the machine and detector should be initiated.

The case for a dedicated Giga-Z facility at a future e^+e^- linear collider is just beginning to be discussed and needs much more development followed by a careful assessment of the contributions it can make to our understanding of rare B decays and CP violation.

In conclusion, e^+e^- colliders at low energy have played an important role in the development of our understanding of flavor physics, non-peturbative QCD and radiative corrections. Today the Fixed Target hadron experiments appear to be the best way to address key measurements in kaon physics involving rare decays. Electron positron colliders have a unique role in the measuremnt of R, and are complementary to hadron colliders as a probes of non-peturbative QCD, and charm and beauty flavor physics. The physics is more important than the method used. It would be prudent to carefully evaluate the merits of both hadron colliders and e^+e^- colliders for each application at each stage in our quest, only ruling out one approach when it clearly fails. In these areas, competition, complementarity, and even some redundancy have proven to important to ultimate progress.

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[42] "Experimental Prospects for CP violation in charm with BTeV", D. Kaplan, talk to the E2 Working Group.
[43] "B physics with an asymmetric 10^{36} e^+e^- collider", D. Hitlin, talk to the E2 Working Group.
[44] "High luminosity B Factories : Overview - KEK-B version", H. Yamamoto, talk to the E2 Working Group.
[45] "Unitarity angles and CP Asymmetries (theory)", Y. Okada, talk to the E2 Working Group.
"CP Violation Reach at Very High Luminosity B Factories", A. Soffer, talk to the E2 Working Group.
[46] "Unitarity Angles and CP Asymmetries, at Existing and Planned Hadronic Facilities", S. Stone, talk to the E2 Working Group.
[47] "Precision Determination of Vub: theory", M. Luke, talk to the E2 Working Group.
[48] "Precision Determination of Vub at an e^+e^- B Factory", J. Lee, talk to the E2 Working Group and these proceedings.
[49] "Rare B Decays: A Theoretical Overview", G. Burdman, talk to the E2 Working Group.
[50] "Prospects for Rare B Decays at High Luminosity B Factories", N. Katayama, talk to the E2 Working Group.
[51] "Rare B Decays at Existing and Planned Factories ATLAS/BTeV/CDF/CMS/D0/LHCb A Survey of What's Been Done So Far", R. Kutschke, talk to the E2 Working Group.
[52] "$\Upsilon(5S)$ Super High Luminosity B Factory Experimental Reach", Sibylle Petrak, talk to the E2 Working Group.
[53] "B_s Physics at Hadronic Colliders", P. Kasper, talk to the E2 Working Group.
[54] "New Physics with Rare B Meson Decays", A. Gritsan, talk to the E2 Working Group.
[55] "Luminosity of $10^{35}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ at KEKB", Y. Ohnishi, talk to the M2 Working Group.
[56] "An e^+e^- Collider in a VLHC tunnel", T. Sen, talk to the E2 Working Group.
[57] "Detectors at High Luminosity e^+e^- Storage Rings", G. Eigen, talk to the E2 Working Group and these proceedings.
[58] "Physics Prospects at BTeV", P. Kasper, talk to the E2 Working Group.
[59] "e^+e^- Factories", F-J. Decker talk to the E2 Working Group.
[60] "10^{36} e^+e^- $\Upsilon(4S) - \Upsilon(5S)$ Collider Subgroup Report", D. Hitlin, talk to the E2 Working Group.
[61] "CP Asymmetry", A. Roodman, talk to the E2 Working Group.
[62] "CP Violation Reach at Very High Luminosity B Factories", A. Soffer, talk to the E2 Working Group.
[63] "Rare B Decays and New Physics at a 10^{36} B-Factory", P. Kim, talk to the E2 Working Group.
[64] "Machine Backgrounds Issues for Calorimetry at an Atto B Factory", S. Robertson, talk to the E2 Working Group.
[65] "SuperBaBar" these proceedings.
[66] "Beyond 10^{34} Physics at a Second Generation e^+e^- B Factory" http://www.physics.purdue.edu/10E34/
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[68] "Theoretical review of B physics at Giga-Z", G. Hiller, talk to the E2 Working Group.
[69] "B-physics at a linear collider", K. Moenig, talk to the E2 Working Group.
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