Physics options at High Luminosity LEP

The full exploitation of the physics potential at LEP would require three types of upgrade:

(1) An increase in energy up to $\sqrt{s}$ = 200 GeV (LEP 200) and even greater if it is possible in the future.

(2) An increase in luminosity (for instance by using more bunches with or without a Pretzel scheme).

(3) An increase in the sensitivity of the measurement of electroweak parameters by polarizing the beams.

(1) and (3) have been thoroughly studied(*),(**); (2) is presently under active consideration.

An increase in luminosity is first of all vital for (1) since, in the LEP 200 range, all interesting cross sections are at or below the picobarn level. Measurements of the W properties would then be better made.

The exploration of the Higgs sector up to M_Z — a must if one wants to validate or invalidate minimal SUSY — requires absolutely both energy and luminosity.

On the Z^0 a strong increase in luminosity (by an order of magnitude) would open three main avenues:

(a) much better accuracy of electroweak checks,

(b) access to rare modes of the Z,

(c) b^b physics, in particular a measurement of B_s^0 mixing, giving access to the phase of the KM matrix.

The two papers below illustrate two particular aspects of this vast programme:

- the search for manifestations of nearby compositeness, both in rare modes of the Z and in measurements at higher energy;
- the search for rare modes of the B decays in the Z^0 final states.

(*) Aachen Workshop on LEP 200, Report CERN 87–08.

(**) CERN Report on Polarization at LEP, CERN 88–06.

Suppressed and rare B –decay modes at LEP

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Studies of B decays are just beginning, but experiments at CESR and DESY are already setting upper limits on the branching ratios (BR) of several exclusive B decays. The amplitudes of such decays are related to the elements of the Cabibbo–Kobayashi–Maskawa matrix. In addition, it should be noted that the theoretical BR are often enhanced by orders of magnitude over those of the corresponding bare quark transitions. Thus, the study of exclusive decays can also teach us a great deal of how QCD works.

At present, only a few hundred $B_{u,d}$ events have been fully reconstructed. This will, of course, improve if CLEO II fulfills its potential. A threshold B factory has an excellent mass resolution of reconstructed channels (of a few megavolts), obtained with the help of beam constraints.

At LEP, whilst the mass resolution is worse (~ 40–50 MeV), a natural boost ensures the visibility of the B decay vertex and also guarantees that the decay products of the two b quarks are in opposite hemispheres, with no possible confusion. A High-Luminosity LEP (HLUM LEP) can thus become an ideal laboratory for the observation of strongly-suppressed $B_{u,d,s}$ meson decays.

Recent simulation studies explore the detectability of such decays, assuming apparata with the performance of the DELPHI [1] and ALEPH [2] detectors. In particular, the sensitivities to: (i) hadronic decays with large missing energy, and (ii) non-charm two-body decays, are investigated.

The first class includes $B \rightarrow \tau\nu$ in addition to $B \rightarrow M_{uq}\, \tau\nu$, where M_{uq} represents any pseudoscalar meson containing a u quark. The signal and most of the background channels were analyzed by means of a Monte Carlo simulation. In the study of ref. [2], a BR of 2×10^{-4} was found to be observable from the production of $5 \times 10^6\, Z^0$.

A more detailed study is under way [3], and in this report the preliminary results are summarized. An updated version of the Lund parton shower Monte Carlo (JETSET 7.2 PS [4]) is used for the generation of the initial state and the decays of unstable particles. The response of the detector has been simulated according to the performance of an "average" LEP apparatus, as determined in ref. [5]. In addition, a simulation of a RICH and a microvertex detector with the potential efficiencies of the DELPHI apparatus [6] have been included. This simulation keeps into account in a more realistic way the performance of the LEP detectors.

For the first class of rare decays, it comes out that BR of the order of 10^{-4} can be detectable with $10^7\, Z^0$. The background due to the processes $Z \rightarrow \tau^+\tau^-$ and $D_s \rightarrow \tau\nu$ has also been taken into account for this determination.

The second class includes decays like ($\pi^+\pi^-$, $K^\pm\, \pi^\mp$, K^+K^-), and $p\bar{p}$. After removing the background by exploiting standard energy and topology cuts, the Monte Carlo simulation of ref. [2] gives a visibility limit of 6×10^{-5} (assuming $5 \times 10^6\, Z^0$) for these branching ratios. In our preliminary study [3], a more realistic treatment of the detector effects worsens the previous result by a factor of two.

However, these two classes of processes do not exhaust the rare decays of the B mesons. For example, "precious rarity" processes are generated by the

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$b \to s\gamma$ transition, leading for instance to $B \to K^*\gamma$, $B_s \to \phi\gamma$. These transitions are forbidden at the tree level and are generated through loops involving heavy quarks. There is an extensive literature about the computation of such rates within the Standard Model (SM) [7] and beyond [8].

For large m_t, the dependence on the top quark mass of the expected decay amplitude is weak, and BR of 10^{-4} for $B \to K^*\gamma$ and $B_s \to \phi\gamma$ are predicted. Enhancements are possible in the framework of new physics [8].

The observability of the $B \to K^*\gamma$ decay at the HLUM LEP has recently been studied [9] by means of a detailed Monte Carlo simulation assuming an average LEP detector with realistic π/K identification. The $B \to K^*\gamma$ decay came out to be detectable with an efficiency $\cong 40\%$. With a selection efficiency of 70% for the $b\bar{b}$ sample, the observability at the 2σ level of a BR of 10^{-4} appears possible with 2×10^6 Z^0. For 10^8 Z^0, a potential limit of ~ 10^{-5} can be achieved for the BR, so that this decay mode could possibly be detected.

Other radiative $B \to \gamma + X$ decays, like the $B_s \to \gamma\phi$ mode, are now under investigation [3]. They seem to be detectable with similar efficiencies at the HLUM LEP.

In conclusion, from preliminary simulation studies based on realistic assumptions it comes out that LEP at high luminosity can provide important results on the detection of rare and suppressed B decay modes. These results can complement the physics output of B factories.

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Compositeness with Pretzel scheme at LEP

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Abstract

We study the improvements on compositeness limits which may come from the availability of an increase of LEP luminosity.

1. Introduction

Although there is no experimental result that conflicts with the Standard Model (SM), it leaves unanswered fundamental questions such as the unification of all forces including gravitation and the generation puzzle [1]. Concerning the second problem, i.e. the understanding of the number of generations, lepton and quark masses, a possibility is that quarks and leptons are composite. The main difficulty of such models is to reconcile the mass range of leptons and quarks, lying between a few megavolts and 100 GeV with the compositeness scale in the tera-electronvolt region. Since up to now there is no satisfactory model which reproduces the spectrum, we will perform a pure phenomenological analysis of possible manifestations at LEP.

The aim of the present paper is to study which improvements may come from an increase of LEP luminosity. Let us recall that two years ago a new option, known as Pretzel scheme, was proposed [2] for LEP consisting in an increase in luminosity at the Z peak by a factor of 10 leading to an exposure of 10^8 Z and possibly to a gain in luminosity of a factor of 2 at LEP 200 energy allowing to reach an integrated luminosity of 800 pb^{-1}.

We will divide our discussion into two parts. The first one deals with compositeness effects on the Z peak through rare decay modes and the second one away from the Z peak up to LEP 200 energy. We will not discuss the case of composite vector bosons which would manifest