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Strategy for the 1995 LEP Energy Scan

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Abstract

We propose a procedure to measure the Z^0 line shape and take full advantage of the superb performance of the CERN e^+e^- Collider LEP. A precise determination of the total cross section at 5 energies is needed for a model-independent analysis of the data and for a precision test of the QED initial state radiation from the fully inclusive hadronic channel.

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Motivated by the presentations given by T. Camporesi [1] and L. Rolandi [2] at the 1995 Italian LEP Workshop held in Genova last April, we shall discuss in this Letter a strategy for the 1995 LEP energy scan. Indeed, there seems to be the possibility that the 1995 scan be performed at precisely the same energies explored in the past: peak and ± 2 GeV off-peak. (The 1991 data do not add very much given their lower statistical significance.) We shall point out that this decision, would not, in our opinion, exploit to the fullest the experimental potentialities of the last Z^0 Lep run.

The theoretical foundation for a model-independent analysis of the Z-line shape, as first proposed by Borrelli et al. in [3], and motivated only by the general requirements of unitarity and renormalizability of an underlying quantum field theory, is based on a description of the total cross sections for the process $e^+e^- \to f\bar{f} + ...$ [4] in terms of (at least) 4 free parameters. Namely one has to introduce the Z mass M, its total decay decay width Γ, the peak cross section $\sigma^{(f)}_{peak} = \frac{12\pi}{M^2}\frac{\Gamma_e \Gamma_f}{\Gamma^2}$ in the given channel and the parameter $R^{(f)}$ controlling the interference of the Z-resonance with the non resonating background. In this case, this minimal parametrization introduced in [3] guarantees that the analysis of the experimental data is model-independent (to a high degree of accuracy) so that they can be interpreted consistently within a wide class of theoretical framework beyond the standard model minimal structure (e.g. super-symmetry, additional Z', technicolor and so on). We stress that, apart from the potential effects of new physics, the requirement of model-independence has a deep theoretical meaning. In fact, only in this case, one can quote unambiguously the Z mass, its total and partial decay rates without specifying that these are the values of the parameters within the assumptions of the minimal standard model(i.e with three fermion generations, one Higgs doublet, and so on).

Since the Z-line shape is dominated by the $e^+e^- \to hadrons$ data we shall mainly concentrate on the hadronic channel. Within the consistent approach of [3], the values of the total cross section (at least) at 5 energies have to be measured to fully constrain the 4 free parameters $M, \Gamma, \sigma^{(h)}_{peak}, R^{(h)}$ and check the quality of the fit. At the present, with only 3 energies explored at high statistics, the hadronic interference parameter $R^{(h)}$ has been fixed at its standard model value. With the 1995 scan, we could really perform a model-independent analysis provided the off-peak data are collected at *different* energies (e.g. at the peak and at ± 3 GeV off-peak). We understand that the choice of running at ≈ 2 GeV off peak is the result of an optimization which takes into account both the counting rate and the analyzing power toward the determination of the Z^0 width. We believe however, that, with a small degradation in the analyzing power, using different and eventually asymmetric energy settings to compensate the overall event yield to first order, one could gain a better understanding of the resonance parameters as a whole. We stress that, independently of the interest in determining $R^{(h)}$ from the precise LEP data and comparing its experimental value with the various theoretical predictions, when $R^{(h)}$ is constrained at its standard model value the actual error on the Z-mass is underestimated since M and $R^{(h)}$ are strongly correlated in the fit [3]. Furthermore,to the present level of accuracy, the additional uncertainty induced by the presence of an extra free parameter in the hadronic peak cross section and in the total width should not be neglected. Finally, this additional uncertainty from the interference parameters will propagate through all channels and in the various observables and *has to be taken into account* for a meaningful extimate of the ϵ-parameters [5] accounting for potential new physics effects beyond the minimal standard model.

Quite independently of the above discussion a high statistics determination of the cross sections at 5 energies is needed for a precision test of the pure QED effects around the Z resonance. At the present, in the fully inclusive hadronic channel, the theoretical predictions for initial state soft-photon and hard-photon radiation are believed to be under control at the level of 0.2-0.3%. A check of this statement requires to investigate the quality of the χ^2 by comparing the theoretical cross-section with the experimental data. Since there are (at least) three free parameters $M, \Gamma, \sigma^{(h)}_{peak}$ such a test would not be possible if only three cross section measurements (even with *infinite* precision) at three different energies were available.

As a final remark we stress that in the more delicate case of the forward-backward asymmetries, their pole values at $\sqrt{s} = M$ are determined from a fit with an energy dependent formulae. It is quite conceivable that by measuring the asymmetries at two new energies the fit would become considerably more precise and potential sources of systematic error could be identified.

In conclusion: an alternative procedure of energy scanning for the Z^0 pole is suggested, to take full advantage of the superb performance of the CERN e^+e^- Collider LEP. A precise determination of the total cross sections at 5 energies would be extremely beneficial for a model-independent analysis of the data and for a precision test of the QED initial state radiation from the fully inclusive hadronic channel.

References

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