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Constraining New Physics with Vertex Corrections

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Abstract

We discuss how new physics not encompassed within the STU oblique correction framework can be constrained from precision electroweak measurements via vertex corrections to Z–pole observables.

1. Limitations of the Oblique Correction Analysis

In constructing models beyond the Standard Model (SM) such as technicolor or supersymmetric theories, it is important to test their viability by looking for possible conflicts with currently available experimental data. A popular procedure has been the STU oblique correction analysis of Ref. [1]. However, the method can only be applied to theories which satisfy three conditions, namely (1) the electroweak gauge group is the standard $SU(2)_L \times U(1)_Y$, (2) vertex and box corrections from new physics are negligible, and (3) the scale of new physics is large compared to the electroweak scale. Furthermore, the oblique correction analysis requires (4) the model to be completely specified since any particle with electroweak gauge quantum numbers will show up in a vacuum polarization loop. Many theories of interest do not fall into this category. For instance, in the topcolor assisted technicolor model of Ref. [2], (1) the electroweak gauge group is $SU(2)_L \times U(1) \times U(1)$ resulting in an extra Z' boson, (2) there are potentially large corrections to the $Zf\bar{f}$ vertex for third generation fermions coming from Z' and coloron exchange, (3) the scale of new physics may be as low as a TeV, and (4) the technisector of the theory remains unspecified.

2. Vertex Corrections at the Z–pole

The solution to our predicament lies in the observation that a large number of electroweak observables have been measured accurately at LEP and SLD *on the Z–pole*, and that the majority of them are just *ratios of coupling constants* of the Z to quarks and leptons. This means that they are only sensitive to oblique corrections through the effective value of $\sin^2\theta_W$ *at that particular energy scale.* Therefore, one can use just one of the observables, $A_{\rm LR}$ say, to *fix* the value of $\sin^2\theta_W$, and use it to predict all the rest for the SM. Any deviations of the data from those predictions must be due to *vertex corrections* from new physics.

This method of comparing SM predictions to Z–pole electroweak observables solves all of the problems mentioned above since (1) mixing of the Z with extra gauge bosons can be treated as a vertex correction, (2) vertex corrections need not be small while box corrections are still naturally suppressed on the Z–pole, (3) the new physics scale need not be large since only observables at one scale are used in the analysis, and (4) the theory need not be specified completely since the method is blind to oblique corrections.

3. Applications

This method has been used successfully to constrain the size of possible vertex corrections to the $Zb\bar{b}$ vertex [3], and to constrain the topcolor assisted technicolor model mentioned above [4]. We have also applied the technique to constrain: an R–parity violating extension to the MSSM [5], Higgs masses in a general two Higgs doublet model [6], and the fundamental Planck scale of a model with large extra dimensions [7]. Details are provided in the respective references.

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