THE ISOLINES OF ELECTROWEAK RADIATIVE CORRECTIONS AND THE CONFIDENCE LEVELS FOR THE MASSES OF THE TOP AND HIGGS

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ABSTRACT

The most sensitive "gluon-free" electroweak corrections are compared with corresponding experimental data; the results of this comparison are combined to find the confidence levels of bounds on the top and the higgs masses.

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The measurements of the $W$ mass $[1,2]$ and the LEP measurements of the $Z$-mass and leptonic $Z$-couplings give $[3]-[5]$

\begin{align}
(m_W/m_Z)_{\text{exp}} & = 0.8797(29) \tag{1} \\
(g_L^W)_{\text{exp}} & = -0.4999(9) \tag{2} \\
(g_L^Z) & = 1 - 4 \sin^2 \theta_{\text{eff}} = 0.0728(28) \tag{3}
\end{align}

These numbers allow the extraction of experimental values of three theoretical functions: $V_m$, $V_A$, and $V_R$, where $m$, $A$, and $R$ refer to $m_\tau$, $m_Z$, $g_A$, and the ratio $g_V/g_A$, respectively:

\begin{align}
V_m^{\text{exp}} & = [0.8797(29) - c(32\pi(s^2 - s^4)3/3c^2 = 1.78 \pm 1.78 \tag{4} \\
V_A^{\text{exp}} & = [0.4999(9) - 0.56s^2]3/3c = -0.15 \pm 1.38 \tag{5} \\
V_R^{\text{exp}} & = [0.0728(28) - (1 - 4s^2)]4s^2/3c = -0.73 \pm 0.81 \tag{6}
\end{align}

where $\bar{\alpha} = \alpha(m_Z) = 1/128.87(12)$, $s \equiv \sin \theta$, $c \equiv \cos \theta$, $4s^2 = 4\pi \alpha/\sqrt{2}G_F m_Z^2$, and hence $s^2 = 0.2312(3), (1 - 4s^2) = 0.0753(12), c = 0.8768(19)$.

The one-loop explicit analytical expressions of $V_m$, $V_A$, $V_R$ as functions of the top and higgs masses, $m_t$ and $m_H$, as well as their corresponding graphs and numerical tables, were presented in ref. [6] and with gluonic corrections in ref. [7].

In this paper we first compare isolines of the functions $V_m$, $V_A$ and $V_R$ projected on the $m_t$, $m_H$ plane (Fig. 1). An isoline on such a map corresponds to a given value of $V$. The mean experimental values of $V$'s are shown by solid lines. Lower 1$\sigma$ isolines for $V_m$ and $V_R$ and upper 1$\sigma$ for $V_A$ are shown in Fig. 1 by dashed lines.

As is evident from Fig. 1 the mean isoline of $V_A$ "prefers" surprisingly low values of $m_t$. In fact this isoline is situated mainly in the region of $m_t$ excluded by CDF and D0 data (to the left of the vertical dashed line at $m_t = 108$ GeV) [8].

For the higgs masses larger than their lower experimental LEP bound, the isolines of different $V$'s cross at such small angles that it is practically impossible to extract a single value of $m_H$, where they cross. Note that isolines $V_A$, $V_R$, $V_R$ tend to cross at very low values of $m_H$, which are excluded by LEP data (below the horizontal dashed line at $m_H = 60$ GeV); the horizontal dashed line at $m_H = 700$ GeV indicates the upper theoretical bound for an elementary higgs.

Our second aim is to determine the confidence level of various values of $m_t$ and $m_H$ using the isolines of $\chi^2$. The errors in $g_V/g_A$ and $g_A$ are not absolutely independent. But the correlation is so tiny that one can neglect this subtlety and consider the whole set of experimental inputs(1)--(3) as statistically independent. Therefore

$$
\chi^2(m_t, m_H) = \sum \left( \frac{V(m_t, m_H) - \bar{V}_i}{\sigma_i} \right)^2
$$

where $i = m, A, R; \bar{V}_i$ is the central experimental value of $V_i$ and $\sigma_i$ is its 1$\sigma$ uncertainty as given by Eqs. (1)–(6).
The isolines of $\chi^2$ are presented in Fig. 2. Solid lines correspond to expressions for $V_i$ from Ref. [7], which take into account gluonic corrections. (They have been calculated by us only for values of $m_t$ larger than 90 GeV). Dashed isolines correspond to purely electroweak expressions for $V_i$'s from Ref. [6]. We use them in order to demonstrate the role of gluonic corrections.

The results of Fig. 2 are in qualitative agreement with previous $\chi^2$ fits [9]–[15] of electroweak data. The main difference between our analysis and those of refs. [9]–[15] is that instead of relying on a global computer fit of all electroweak data we use only the subset of the most accurate and "gluon-free" experimental data and easily trace the importance of a possible change of each of them.

In particular, the minimum of $\chi^2$ at $m_t \simeq 10$ GeV in Fig. 2 is connected with the low crossing of $V_{ts}, V_{sb}, V_{td}$ mentioned above. It is evident from Fig. 1 that, in order to get a higher crossing, the mean value of $V_{tb}$, and hence of the leptonic width of the $Z$ boson, $\Gamma_{L}$, has to increase if the data on $\sin \beta/\sin \alpha$ are correct and if there is no New Physics.

The increased experimental accuracy of $\sin \beta/\sin \alpha$ calls for two final remarks.

First, the Born approximation based on $\bar{\alpha}$, which is the natural coupling constant for electroweak processes (see Ref. [16]), continues to describe experimental data with remarkable accuracy. The electroweak radiative corrections have been, in fact, observed experimentally. They turned out to be small as a result of cancellation between two large contributions: one from the top, the other from the rest of the virtual particles (see Ref. [6], Figs. 1, 3 and 5). It looks like a "top conspiracy".

The second remark refers to the uncertainty $1\pm 0.0012\pm 1$ of $1-4s^2$, which is determined by the uncertainty of $\bar{\alpha}$ [see definitions after Eq. (6)]. The experimental uncertainty in $1-4\sin^2 \theta_{w}$ is getting closer and closer to that in $1-4s^2$ so that the latter may become the bottleneck in further precision tests of electroweak corrections. As values $\bar{s} \bar{\alpha}$ and $\alpha$ are connected by a dispersion relation, the uncertainty in $\bar{\alpha}$ is determined by the uncertainty in the hadronic contribution to the dispersion integral. Therefore precision measurements of the cross-section $\bar{s}e^+e^- \rightarrow$ hadrons at low energies are becoming mandatory (see the remark by J. Haissinsky after the talk by L. Rolandi [1]).

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REFERENCES


FIGURE CAPTIONS

Fig. 1 - Isolines of $V_{ts}, V_{tb}, V_{td}$ on the plane $m_t, m_H$. Mean experimental values are shown by solid lines. The upper (for $V_{tb}$) and lower (for $V_{ts}, V_{td}$) $1\sigma$ limits are shown by dashed lines.

Fig. 2 - Isolines for $\chi^2$. Numbers indicate the values of $\Delta\chi^2 = \chi^2 - \chi^2_{min}$.