VALIDITY OF STANDARD MODEL AT 90 GeV

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The interpretation of the recently observed "Z"$\to e^+e^-\gamma$ events has posed a challenge to the standard model. We propose a simple test which might shed light on the underlying dynamics.

1. The recently observed "Z" $\to e^+e^-\gamma$ events [1] raise questions of their origin. If not simply a statistical fluctuation, they at least imply a deviation from the perturbative standard model. In an attempt to salvage as much of the model as possible one is led to consider such things as excited electrons [2] or bound states of vector bosons [3]. In this note we shall discuss a simple test that may help in understanding the limits of validity of the model.

Our basic assumption is that fermions couple to the rest of the world solely through the currents of the standard model. This idea is similar to the views advocated by Gell-Mann [4] in the early sixties, which led to the current commutation hypothesis. Here we shall consider this assumption on a much more elementary level.

If the above assumption is true then the leptons couple through two distinct currents, the SU(2) and U(1) currents. Knowing the ratio of "Z" $\to e^+e^-\gamma$ to "Z" $\to \nu\bar{\nu}\gamma$ ought to be enough to determine the mixing of the currents. It should then be possible to compute the rate for "Z" $\to q\bar{q}\gamma$.

2. The decay process is depicted in fig. 1. We suppose the coupling to the final state fermions is through a neutral current J^μ, which is some combination of the familiar hypercharge U(1) and isospin SU(2) neutral currents

$$J^\mu = aj_1^\mu + bj_2^\mu\,. \tag{1}$$

The constants a, b are assumed to be real. With the usual isospin and hypercharge assignments these cur-

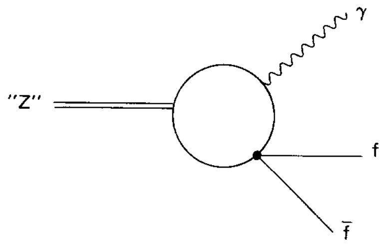

Fig. 1.

rents are

$$j_1^\mu = -\tfrac{1}{2}g_1(\bar{\nu}_L\gamma^\mu\nu_L + \bar{\ell}_L\gamma\ell_L + 2\bar{\ell}_R\gamma^\mu\ell_R)$$
$$+\tfrac{1}{6}g_1(\bar{u}_L\gamma^\mu u_L + \bar{d}_L\gamma^\mu d_L + 4\bar{u}_R\gamma^\mu u_R - 2\bar{d}_R\gamma^\mu d_R),$$
$$j_2^\mu = \tfrac{1}{2}g_2(\bar{\nu}_L\gamma^\mu\nu_L - \bar{\ell}_L\gamma^\mu\ell_L + \bar{u}_L\gamma^\mu u_L - \bar{d}_L\gamma^\mu d_L), \tag{2}$$

for each generation, colour sums on the quarks being implicit.

By the above (1), (2) we can extract the vector and axial couplings of each fermion to J^μ

$$\begin{aligned}
&g_V^{(\nu)} = -g_A^{(\nu)} = \tfrac{1}{4}g_2b(1-x),\\
&g_V^{(\ell)} = -\tfrac{1}{4}g_2b(1+3x),\quad g_A^{(\ell)} = \tfrac{1}{4}g_2b(1-x),\\
&g_V^{(u)} = \tfrac{1}{4}g_2b(1+\tfrac{5}{3}x),\quad g_A^{(u)} = -\tfrac{1}{4}g_2b(1-x),\\
&g_V^{(d)} = -\tfrac{1}{4}g_2b(1+\tfrac{1}{3}x),\quad g_A^{(d)} = \tfrac{1}{4}g_2b(1-x),
\end{aligned} \tag{3}$$

where the parameter $x = g_1a/g_2b = \tan\theta_W\, a/b$.

The partial widths for the decay of the initial state will be proportional to $g_V^2 + g_A^2$, and to the number of colours and/or generations in the final state. Of

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course, this is provided there are no strong interactions between the quarks and the blob, which should be the case for the proposals of refs. [2,3]. If these interactions were present there should have been a preponderance of hadronic events. As both fermions interact via the current the decay width may depend on the $\mathrm{f\bar{f}}$ invariant mass $\bar{m}$. We deduce that the partial widths should have the form

$$\begin{aligned}
\Gamma(\nu) &= (1-x)^2 G(\bar{m}) , \\
\Gamma(\ell) &= (1+2x+5x^2) G(\bar{m}) , \\
\Gamma(\mathrm{u}) &= 3(1+\tfrac{2}{3}x+\tfrac{17}{9}x^2) G(\bar{m}) , \\
\Gamma(\mathrm{d}) &= 3(1-\tfrac{2}{3}x+\tfrac{5}{9}x^2) G(\bar{m}) ,
\end{aligned} \tag{4}$$

for each generation, where the function G is unknown and may depend on the dynamics of the blob.

3. Let $R_{\mathrm{e}\nu}$ be the electron–neutrino branching ratio for three generations

$$R_{\mathrm{e}\nu} = [\Gamma(\nu_\mathrm{e}) + \Gamma(\nu_\mu) + \Gamma(\nu_\tau)]/\Gamma(\mathrm{e}) ,$$

By (4) this can be expressed in terms of the parameter x as

$$R_{\mathrm{e}\nu} = 3(1-2x+x^2)/(1+2x+5x^2) , \tag{5}$$

from which we can solve for x. As (5) will give a quadratic equation for x we find two roots

$$x = \{3 + R_{\mathrm{e}\nu} \pm 2[R_{\mathrm{e}\nu}(6-R_{\mathrm{e}\nu})]^{1/2}\}/(3-5R_{\mathrm{e}\nu}), \tag{6}$$

with the special condition $x = \infty$ or $1/3$ when $R_{\mathrm{e}\nu} = 3/5$. Whatever the value of x we can then estimate the quark electron branching ratio. For three generations excluding the top quark this is

$$\begin{aligned}
R_{\mathrm{eq}} &= [3\Gamma(\mathrm{d}) + 2\Gamma(\mathrm{u})]/\Gamma(\mathrm{e}) \\
&= 3(5-\tfrac{2}{3}x+\tfrac{49}{9}x^2)/(1+2x+5x^2) ,
\end{aligned} \tag{7}$$

and if we include the top quark

$$R_{\mathrm{eq}} = (18+22x^2)/(1+2x+5x^2) . \tag{8}$$

A plot of R_{eq} against $R_{\mathrm{e}\nu}$ is shown in fig. 2. The solid (dotted) lines correspond to the two roots of (6), with the top quark exluded (included). If J^μ is proportional to the electromagnetic current then $x = 1$

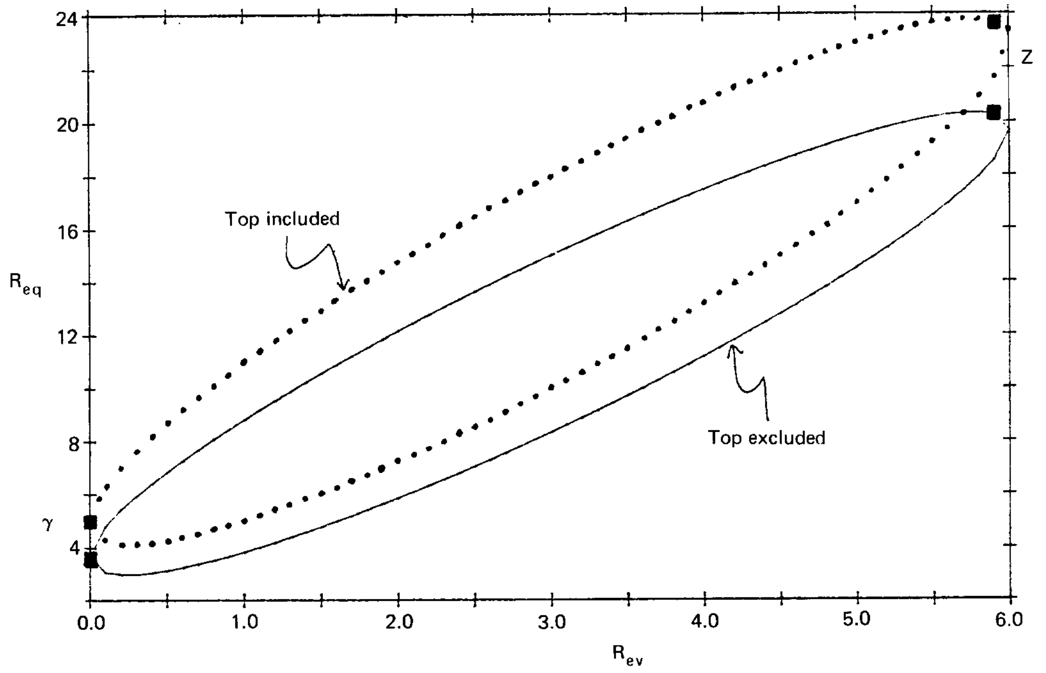

Fig. 2. Quark branching ratios.

and $R_{e\nu} = 0$, whereas if it is proportional to the usual weak neutral current then $x = -\tan^2\theta_w = -0.274$ and $R_{e\nu} = 5.9$. The corresponding values of R_{eq} are indicated in fig. 2. Should the $R_{e\nu}$ and R_{eq} be measured and agree with the results of our analysis then perhaps some credence ought to be afforded to our simple underlying assumptions.

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