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The NuTeV Anomaly, Neutrino Mixing, and a Heavy Higgs

Tatsu Takeuchi
IPPAP, Physics Department, Virginia Tech, Blacksburg, VA 24061, U.S.A.
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The NuTeV experiment [1] has measured the ratios of neutral to charged current events in muon (anti)neutrino – nucleon scattering:

$$R_\nu = \frac{\sigma(\nu_\mu N \to \nu_\mu X)}{\sigma(\nu_\mu N \to \mu^- X)} = g_L^2 + r g_R^2 ,$$
$$R_{\bar\nu} = \frac{\sigma(\bar\nu_\mu N \to \bar\nu_\mu X)}{\sigma(\bar\nu_\mu N \to \mu^+ X)} = g_L^2 + \frac{g_R^2}{r} , \qquad (1)$$

where

$$r = \frac{\sigma(\bar\nu_\mu N \to \mu^+ X)}{\sigma(\nu_\mu N \to \mu^- X)} \sim \frac{1}{2} , \qquad (2)$$

and has determined the parameters g_L^2 and g_R^2 to be

$$g_L^2 = 0.3005 \pm 0.0014 ,$$
$$g_R^2 = 0.0310 \pm 0.0011 . \qquad (3)$$

The Standard Model (SM) predictions based on a fit to LEP/SLD data are cited as $[g_L^2]_{\rm SM} = 0.3042$ and $[g_R^2]_{\rm SM} = 0.0301$ in Ref. [1] and we see a 2.6σ disagreement in g_L^2. In terms of the ratios R_ν and $R_{\bar\nu}$, this means that the neutral current events are not as numerous as the SM predicts when compared to the charged current events. On the LEP/SLD side, the measured invisible width is also known to be 2σ below the SM prediction. Both these facts seem to suggest that the $Z\nu\nu$ coupling is somehow suppressed.

Suppression of the $Z\nu\nu$ coupling can be arranged in a variety of models by mixing the neutrino with a heavy gauge singlet state as discussed in Ref. [3]. For the sake of simplicity, consider the case where all three generations of light neutrinos mix with a universal angle with such states. In such theories, if the $Z\nu\nu$ couplings are suppressed by a universal factor of $(1-\varepsilon)$, then the $W\ell\nu$ couplings are also suppressed by a factor of $(1-\varepsilon/2)$. Then the numerators of R_ν and $R_{\bar\nu}$ will be suppressed over their denominators, so such a mixing could in principle explain the NuTeV anomaly.

However, one must recall that one of the inputs used in calculating the SM predictions is the Fermi constant G_F which is extracted from the muon decay constant G_μ. The suppression of the $W\ell\nu$ couplings would lead to the correction

$$G_F = G_\mu(1+\varepsilon) , \qquad (4)$$

which will affect all SM predictions. The authors of Ref. [3] conclude that ε cannot be chosen to explain the NuTeV data without destroying the excellent agreement between LEP/SLD and the SM.

But what if we include oblique corrections from new physics [4] to compensate for the shift in G_F? Note that the Fermi constant always appears multiplied by the ρ-parameter in neutral current amplitudes so a shift in G_F should be absorbable into the T-parameter.

In Ref. [5], we perform a global fit to the NuTeV and LEP/SLD data to determine what values of ε, S, and T are preferred. Using $m_H = 115\,\text{GeV}$, $m_t = 174.3\,\text{GeV}$ as the reference SM, we obtain excellent agreement between theory and experiment at

$$S = -0.05 \pm 0.10 ,$$
$$T = -0.40 \pm 0.16 ,$$
$$\varepsilon = 0.0028 \pm 0.0010 . \qquad (5)$$

What kind of 'new physics' is compatible with these values of S and T? It turns out that the simplest solution is the SM itself with a larger Higgs mass. Thus neutrino mixing together with a heavy Higgs will reconcile the LEP/SLD and NuTeV results.

Details of this analysis will be presented in Ref. [5].

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