CONSEQUENCES OF A LARGE TOP-QUARK CHIRAL WEAK-MOMENT

Charles A. Nelson

Department of Physics, State University of New York at Binghamton
Binghamton, N.Y. 13902

Abstract

This talk concerns some theoretical patterns of the helicity amplitudes for \( t \to W^+b \) decay. The patterns involve both the standard model’s decay helicity amplitudes, \( A_{SM}(\lambda_{W^+}, \lambda_b) \), and the amplitudes \( A_+(\lambda_{W^+}, \lambda_b) \) in the case of an additional \( t_R \to b_L \) tensorial coupling of relative strength \( \Lambda_+ = E_W/2 \sim 53\text{GeV} \). Such an additional electroweak coupling would arise if the observed top-quark has a large chiral weak-transition-moment. The \( A_+ \) amplitudes are interpreted as corresponding to the observed top-quark decays. Three \( tWb \)-transformations

\[ A_+ = M A_{SM}, \ldots, \]

are used in simple characterization of the values of \( \Lambda_+, m_W/m_t, \) and \( m_b/m_t \). Measurement of the sign of the \( \eta_L = \pm 0.46(SM/+\) helicity parameter, due to the large interference between the \( W \) longitudinal and transverse amplitudes, could exclude such a chiral weak-transition-moment in favor of the SM prediction.

---

1Electronic address: cnelson@binghamton.edu

Talk presented at “Les Rencontres de la Valle d’Aoste”, March 12, 2003.
1 Introduction

While the theoretical analysis discussed in this talk does involve the observed mass values of the top-quark, $W$ boson, and the $b$-quark, it is not a matter of any presently available empirical data disagreeing with a standard model (SM) prediction. Instead, the interest is because of some theoretical patterns of the helicity amplitudes for $t \rightarrow W^+b$ decay. The theoretical patterns involve both the standard model’s decay helicity amplitudes, $A_{SM}(\lambda_{W^+}, \lambda_b)$, and the amplitudes $A_+(\lambda_{W^+}, \lambda_b)$ in the case of an additional $t_R \rightarrow b_L$ tensorial coupling of relative strength $\Lambda_+ = E_W/2 \sim 53 GeV$. To focus the discussion, in this talk the $A_+$ amplitudes are interpreted as corresponding to the observed top-quark decays $t \rightarrow W^+b$ [1]. This identification hypothesis might be excluded by future theoretical analysis and/or empirical data; in (I), alternatives to this identification were considered [2]. Experimental tests and measurements in ongoing and forthcoming [1,3,4] top-quark decay experiments at hadron and $l^-l^+$ colliders should be able to significantly clarify matters. The explicit expressions for these amplitudes, and other details, are given in (I) and in a “hep-ph” preprint (II) [2].

Measurement of the sign of the $\eta_L \equiv \frac{1}{\Gamma} |A(-1, -\frac{1}{2})||A(0, -\frac{1}{2})| \cos \beta_L = \pm 0.46 (SM/+)$ helicity parameter[5], due to the large interference between the $W_{\text{Longitudinal}}$ and $W_{\text{Transverse}}$ amplitudes, could exclude such a large chiral weak-transition-moment in $t \rightarrow W^+b$ decay in favor of the SM prediction. On the other hand, measurement of the SM predicted fraction of final $W_{\text{Longitudinal}}$ versus final $W_{\text{Transverse}}$ bosons for this decay mode would not distinguish between the two cases. The definitive empirical test must establish the sign of $\cos(\beta_L)$ where $\beta_L$ is the relative phase of the two $\lambda_b = -1/2$ amplitudes, $A(0, -1/2)$ and $A(-1, -1/2)$, c.f. Table 1 below.
In the $t$-quark rest frame, the matrix element for $t \rightarrow W^+ b$ is

$$\langle \theta^t_1, \phi^t_1, \lambda_{W^+}, \lambda_b | \frac{1}{2}, \lambda_1 \rangle = D^{(1/2)*}_{\lambda t + \mu} (\phi^t_1, \theta^t_1, 0) A_i (\lambda_{W^+}, \lambda_b) \quad (1)$$

where $\mu = \lambda_{W^+} - \lambda_b$ in terms of the $W^+$ and $b$-quark helicities. Due to rotational invariance, there are four independent $A_i (\lambda_{W^+}, \lambda_b)$ amplitudes for the most general Lorentz coupling. We use the Jacob-Wick phase-convention for the amplitudes and use the subscript “$i$” to identify the amplitude’s associated coupling; in this paper $i = \text{SM}, (f_M + f_E)$ for only the additional $t_R \rightarrow b_L$ tensorial coupling, and (+) for $A_+ (\lambda_{W^+}, \lambda_b) = A_{SM}(\lambda_{W^+}, \lambda_b) + A_{f_M+f_E}(\lambda_{W^+}, \lambda_b)$ when $\Lambda_+ = E_W/2$. With respect to the latter case, the Lorentz coupling involving both the SM’s $(V - A)$ coupling and an additional $t_R \rightarrow b_L$ tensorial coupling of arbitrary relative strength $\Lambda_+$ is $W^{\ast}_{\mu} J^{\mu}_{bt} = W^{\ast}_{\mu} \bar{u}_b (p) \Gamma^\mu u_t (k)$ where $k_t = q_W + p_b$, and

$$\frac{1}{2} \Gamma^\mu = g_L \gamma^\mu P_L + \frac{g_{f_M+f_E}}{2 \Lambda_+} i \sigma^{\mu\nu} (k - p)_\nu P_R \quad (2)$$

Thus, for $\Lambda_+ = E_W/2$ in $g_L = g_{f_M+f_E} = 1$ units, which corresponds to the (+) amplitudes, the Lorentz structure of the effective coupling is very simple

$$\gamma^\mu P_L + i \sigma^{\mu\nu} v_\nu P_R \quad (3)$$

$$= P_R (\gamma^\mu + i \sigma^{\mu\nu} v_\nu) \quad (4)$$

where $P_{L,R} = \frac{1}{2} (1 \mp \gamma_5)$ and $v_\nu$ is the $W$-boson’s relativistic four-velocity.

The interest in these particular couplings arose as a by-product of a consideration [6] of future measurements of competing observables in $t \rightarrow W^+ b$ decay. In particular, we considered the SM’s the $g_{V-A}$ coupling values of helicity decay parameters versus those for “ $(V - A) + single additional Lorentz structures.” It was found that versus the SM’s dominant L-handed $b$-quark
amplitudes, there are two “dynamical phase-type ambiguities” produced respectively by an additional \((S + P)\) coupling and by an additional \(t_R \rightarrow b_L\) tensorial coupling, see the \(A(0, -\frac{1}{2})\) and \(A(-1, -\frac{1}{2})\) columns of Table 1. Such a dynamical-ambiguity produced physically by the additional Lorentz structure is to be contrasted to the mathematical forcing of a “phase-ambiguity” by simply changing by-hand the sign of one, or more, of the four helicity amplitudes \(A(\lambda_W, \lambda_b)\). By tuning the effective-mass-scale associated with the additional coupling constant, the additional \((S + P)\) coupling, \((f_M + f_E)\) coupling, has respectively changed the sign of the \(A(0, -\frac{1}{2}),\) \(A(-1, -\frac{1}{2})\) amplitude. In \(g_L = g_{S+P} = g_+ = 1\) units, the corresponding effective-mass scales are \(\Lambda_{S+P} \sim -35\text{GeV}, \Lambda_+ \sim 53\text{GeV}\). The numerical patterns shown in the table in the case of the additional \(\Lambda_{S+P}\) coupling are not surprising for the \((S + P)\) coupling because it only contributes to the \(W_{\text{Longitudinal}}\) amplitudes. However, associated with the additional \(t_R \rightarrow b_L\) tensorial coupling, labeled \((f_M + f_E)\) in this table, three interesting numerical puzzles arise at the 0.1\% level in the \((+\) amplitude versus the SM’s pure \((V - A)\) amplitudes.

The 1st puzzle is that the \(A_+(0, -1/2)\) amplitude has the same value as the \(A_{SM}(-1, -1/2)\) amplitude in the SM; see the corresponding two “220” entries in the top of Table 1. From the empirical t-quark and W-boson mass values, the mass ratio \(y = \frac{m_W}{m_t} = 0.461 \pm 0.014\). This can be compared with the puzzle’s associated mass relation

\[
1 - \sqrt{2y} - y^2 - \sqrt{2}y^3 = x^2(\frac{2}{1 - y^2} - \sqrt{2}y) - x^4(\frac{1 - 3y^2}{(1 - y^2)^2}) + \ldots
\]

\[
= 1.89x^2 - 0.748x^4 + \ldots
\]

which follows by setting \(A_+(0, -1/2) = A_{SM}(-1, -1/2)\) and then expanding in \(x^2 = (m_b/m_t)^2\) the \(A_+(0, -1/2)\) amplitude, with \(\Lambda_+ = E_W/2 = \frac{m_t}{4}[1 + y^2 - x^2]\) in \(g_L = g_+ = 1\) units. Since
empirically $x^2 \simeq 7 \cdot 10^{-4}$, there is only a 4th significant-figure correction from the finite b-quark mass to the only real-valued solution $y = 0.46006$ ($m_b = 0$) of this mass relation. The 0.1\% level of agreement of the two “220” entries of Table 1 is due to the present central value of $m_t$, and to the central value and 0.05\% precision of $m_W$. The error in the empirical value of the mass ratio $y$ is dominated by the current 3\% precision of $m_t$.

The 2nd and 3rd numerical puzzles are the occurrence of the same magnitudes of the two R-handed b-quark amplitudes $A_{New} = A_{gL=1}/\sqrt{\Gamma}$ for the SM and for the additional $t_R \rightarrow b_L$ tensorial coupling. This is shown in the $A \left(0, \frac{1}{2}\right)$ and $A \left(1, \frac{1}{2}\right)$ columns in the bottom half of Table 1. As explained below, for $\Lambda_+ = E_W/2$ the magnitudes of these two R-handed moduli are actually exactly equal and not merely numerically equal to the 0.1\% level.

We will next discuss different types of helicity amplitude relations involving both the standard model’s decay helicity amplitudes, $A_{SM}(\lambda_{W+}, \lambda_b)$, and the amplitudes $A_+(\lambda_{W+}, \lambda_b)$ in the case of an additional $t_R \rightarrow b_L$ tensorial coupling of relative strength $\Lambda_+$. These relations in some cases “explain” and in other cases analytically realize as theoretical patterns, these and other numerical puzzles of Table 1.

Helicity amplitude relations of types (i) and (ii) are exact ratio-relations holding for all $y = \frac{m_W}{m_t}$, $x = \frac{m_b}{m_t}$, and $\Lambda_+$ values. By the type (iii) ratio-relations holding for all $y = \frac{m_W}{m_t}$ and $x = \frac{m_b}{m_t}$ values, the tWb-transformation $A_+ = M \ A_{SM}$ where $M = v \ diag(1, -1, -1, 1)$ characterizes the mass scale $\Lambda_+ = E_W/2$. The parameter $v$ is the velocity of the $W$-boson in the $t$-quark rest frame. Somewhat similarly, the amplitude condition (iv), $A_+(0, -1/2) = aA_{SM}(-1, -1/2)$ with $a = 1 + O(v \neq y\sqrt{2}, x)$, and the amplitude condition (v), $A_+(0, -1/2) = -bA_{SM}(1, 1/2)$ with $b = v^{-8}$, determine respectively the scale of two additional 4x4 tWb-transformation matrices.
\( P \) and \( B \). Thereby, (iv) and (v) characterize the values of the mass ratios \( y = m_W/m_t \) and \( x = m_b/m_t \). \( O(v \neq y\sqrt{2}, x) \) denotes small corrections. It is not understood why the values are simple for the parameters \( a \) and \( b \).

## 2 Helicity amplitude relations

The first type of ratio-relations holds separately for \( i = (SM), (+); (i): \)

\[
\frac{A_i(0, 1/2)}{A_i(-1, -1/2)} = \frac{1}{2} \frac{A_i(1, 1/2)}{A_i(0, -1/2)} \tag{6}
\]

The second type of ratio-relations relates the amplitudes in the two cases (ii): Two sign-flip relations, note sign changes of amplitudes in Table 1,

\[
\frac{A_+ (0, 1/2)}{A_+ (-1, -1/2)} = \frac{A_{SM}(0, 1/2)}{A_{SM}(-1, -1/2)} \tag{7}
\]

\[
\frac{A_+ (0, 1/2)}{A_+ (-1, -1/2)} = \frac{1}{2} \frac{A_{SM}(1, 1/2)}{A_{SM}(0, -1/2)} \tag{8}
\]

and two non-sign-flip relations

\[
\frac{A_+ (1, 1/2)}{A_+ (0, -1/2)} = \frac{A_{SM}(1, 1/2)}{A_{SM}(0, -1/2)} \tag{9}
\]

\[
\frac{A_+ (1, 1/2)}{A_+ (0, -1/2)} = 2 \frac{A_{SM}(0, 1/2)}{A_{SM}(-1, -1/2)} \tag{10}
\]

The third type of ratio-relations, follows by determining the effective mass scale, \( \Lambda_+ \), so that there is an exact equality for the ratio of left-handed amplitudes (iii):

\[
\frac{A_+(0, -1/2)}{A_+(-1, -1/2)} = -\frac{A_{SM}(0, -1/2)}{A_{SM}(-1, -1/2)} \tag{11}
\]

This was the tuning condition used to produce the dynamical phase-ambiguities of Table 1 [6]. Equivalently, \( \Lambda_+ = E_W/2 \) follows from each of:

\[
\frac{A_+(0, -1/2)}{A_+(-1, -1/2)} = -\frac{1}{2} \frac{A_{SM}(1, 1/2)}{A_{SM}(0, 1/2)} \tag{12}
\]
\[
\frac{A_+(0, 1/2)}{A_+(1, 1/2)} = -\frac{A_{SM}(0, 1/2)}{A_{SM}(1, 1/2)}, \quad (13)
\]
\[
\frac{A_+(0, 1/2)}{A_+(1, 1/2)} = -\frac{1}{2} \frac{A_{SM}(-1, -1/2)}{A_{SM}(0, -1/2)}. \quad (14)
\]

Alternatively, the value of \( \Lambda_+ \) can be characterized by postulating the existence of a tWb-transformation \( A_+ = M A_{SM} \) where \( M = v \text{ diag}(1, -1, -1, 1) \), with
\[
A_{SM} = [A_{SM}(0, -1/2), A_{SM}(-1, -1/2), A_{SM}(0, 1/2), A_{SM}(1, 1/2)] \text{ and analogously for } A_+.
\]

Assuming (iii), the fourth type of relation is the equality (iv):
\[
A_+(0, -1/2) = a A_{SM}(-1, -1/2), \quad (15)
\]
where \( a = 1+O(v \neq y\sqrt{2}, x) \). This is equivalent to the velocity formula \( v = a y \sqrt{2} \left( \frac{1}{1-(E_b-\gamma)/m_b} \right) \simeq ay\sqrt{2} \), for \( m_b = 0 \). For \( a = 1 \), (iv) leads to the mass relation discussed above, Eq.(5). However, for \( a = 1 \), (iv) also leads to \( \sqrt{2} = \gamma(1+v) = \sqrt{\frac{1+x}{1-x}} \) so \( v = 0.6506 \ldots \) without input of a specific value for \( m_b \). But by Lorentz invariance \( v \) must depend on \( m_b \). Accepting (iii) as exact, we interpret this to mean that \( a \neq 1 \). As shown in (II), the \( O(v \neq y\sqrt{2}, x) \) corrections in \( a \), required by Lorentz invariance, arise from \( v \neq y\sqrt{2} \) and \( x \neq 0 \).

Equivalently, for \( a \) arbitrary, (15) can be expressed postulating the existence of a second tWb-transformation \( A_+ = P A_{SM} \) where
\[
P \equiv v \begin{bmatrix}
0 & a/v & 0 & 0 \\
-v/a & 0 & 0 & 0 \\
0 & 0 & 0 & -v/2a \\
0 & 0 & 2a/v & 0
\end{bmatrix} \quad (16)
\]

The above two tWb-transformations do not relate the \( \lambda_b = -\frac{1}{2} \) amplitudes with the \( \lambda_b = \frac{1}{2} \).
amplitudes. From (i) thru (iv), in terms of a parameter $b$, the equality (v):

$$A_+(0, -1/2) = -bA_{SM}(1, 1/2),$$

(17)

is equivalent to $A_+ = B A_{SM}$

$$B \equiv \begin{bmatrix}
0 & 0 & 0 & -b \\
0 & 0 & 2b & 0 \\
0 & v^2/2b & 0 & 0 \\
-v^2/b & 0 & 0 & 0
\end{bmatrix}$$

(18)

The choice of $b = v^{-8} = 31.152$, gives

$$B \equiv v \begin{bmatrix}
0 & 0 & 0 & -v^{-9} \\
0 & 0 & 2v^{-9} & 0 \\
0 & v^9/2 & 0 & 0 \\
-v^9 & 0 & 0 & 0
\end{bmatrix}$$

(19)

and corresponds to the mass relation $m_b = \frac{m_t}{8} \left[1 - \frac{v^9}{\sqrt{2}}\right] = 4.407...GeV$ for $m_t = 174.3GeV$.

If one does not distinguish the (+) versus SM indices, respectively of the rows and columns, these three tWb-transformation matrices have some simple properties, for details see (II): The anticommuting 4x4 matrices $M, P$ with $a$ arbitrary, and $Q$ satisfy the closed algebra $[\overline{M}, P] = 2\overline{Q}$, $[\overline{M}, Q] = 2\overline{P}$, $[P, Q] = 2\overline{M}$. The bar denotes removal of the overall “$v$” factor, $M = v\overline{M}$,.... Note that $Q$ is not a tWb-transformation; $Q$ is obtained from the first listed commutator.

Including the B matrix with both $a$ and $b$ arbitrary, the “commutator + anticommutator” algebra closes with 3 additional matrices $C, H, G$ obtained by $\{\overline{M}, \overline{B}\} = -2\overline{C}$, $[\overline{P}, \overline{B}] = 2\overline{P}$, and $\{\overline{P}, \overline{C}\} = -2\overline{C}$. This has generated an additional tWb transformation $G \equiv v\overline{C}$; but $C \equiv v\overline{C}$ and $H \equiv v\overline{H}$ are not tWb transformations.
3 Discussion

The elements of the three logically-successive tWb transformations are constrained by the exact helicity amplitude ratio-relations (i) and (ii). Thereby, the type (iii) ratio-relation fixes $\Lambda_+ = E_W/2$ and the overall scale of the tWb-transformation matrix $M$. Somewhat similarly, the amplitude condition (iv) with $a = 1 + O(v \neq y\sqrt{2}, x)$ and the amplitude condition (v) with $b = v^{-8}$ determine respectively the scale of the tWb-transformation matrices $P$ and $B$ and characterize the values of $m_W/m_t$ and $m_b/m_t$. The overall scale can be set here by $m_t$ or $m_W$. From the perspective of further “unification”, $m_W$ is more appropriate since its value is fixed in the SM.

The additional $t_R \rightarrow b_L$ tensorial coupling violates the conventional gauge invariance transformations of the SM and traditionally in electroweak studies such anomalous couplings have been best considered as “induced” or “effective”. The $f_E$ component corresponds to a “second class current” [7]. $f_E$ has a distinctively different reality structure, and time-reversal invariance property versus the first class $V, A, f_M$ [8].

In the present context, supersymmetry could provide a more general and useful off-shell theoretical framework in which to consider these theoretical patterns of the helicity amplitudes for $t \rightarrow W^+b$ decay. Form factor effects would naturally occur. In the extant MSSM literature, see more complete references in (II), sizable “one-loop-level” reductions in the $t \rightarrow W^+b$ partial decay width have been reported: From SM Higgs and additional MSSM’s Higgs’s there is a small $\leq 2\%$ correction. However, from SUSY electroweak corrections, there is in [9] an up to 10% reduction, depending on $\tan(\beta)$. From QCD including some two-loop-level corrections and SUSY QCD corrections in the summary of [10] a 25% reduction is reported. It is to be emphasized that, firstly, the $(+)$ partial width considered in the present paper constitutes a very large, net 56% reduction.
versus the Born-level SM value and that, secondly, these cited SUSY calculations have been for the partial width, so other couplings instead of an additional effective $t_R \rightarrow b_L$ tensorial coupling, might be predominantly responsible for these reported reductions.

4 Experimental Tests/Measurements

Empirically, important tests of the physical relevance of the theoretical patterns to the observed top-quark decays are:

(a) Measurement of the sign of the $\eta_L \equiv \frac{1}{2} |A(1, -\frac{1}{2})||A(0, -\frac{1}{2})| \cos \beta_L = \pm 0.46(\text{SM}/+) \text{ helicity parameter}$ via determination of stage-two spin-correlation observables [5] for the $t\bar{t} \rightarrow t\bar{t} + jets$ channel. These values for $\eta_L$ are essentially the maximal possible deviations since $|\eta_L| = 0.5$ is the kinematic limit. The differences from $|\eta_L| = 0.5$ are due to $m_b \neq 0$.

(b) Measurement of the closely associated $\eta_L' \equiv \frac{1}{2} |A(1, -\frac{1}{2})||A(0, -\frac{1}{2})| \sin \beta_L \text{ helicity parameter}$. This would provide useful complementary information, since in the absence of $TFS$-violation, $\eta_L' = 0$ [6]. $TFS$-violation can occur due to intrinsic time-reversal violation and/or large $W^+b$ final-state interactions. It is very important to exclude sizable $TFS$-violation and/or $CP$-violation in top-quark decays.

(c) Measurement of the partial width for $t \rightarrow W^+b$, e.g. by single top-quark production at a hadron collider [11]. The $v^2$ factor which differs their associated partial widths corresponds to the SM’s $\Gamma_{SM} = 1.55 GeV$, versus $\Gamma_+ = 0.66 GeV$ and a longer-lived (+) top-quark if this mode is dominant.

Acknowledgments:

We thank experimental and theoretical physicists for discussions, and the Fermilab Theory
Group for a visit during the summer of 2002. This work was partially supported by U.S. Dept. of Energy Contract No. DE-FG 02-86ER40291.

References

[1] CDF collaboration, T. Affolder, et.al., Phys.Rev.Lett. 84, 216(2000); DØ collaboration, B. Abbott, et.al., Phys.Rev.Lett. 85, 256(2000).

[2] C.A. Nelson, Phys. Rev. D65, 074033 (2002); hep-ph/0304198.

[3] ATLAS Technical Proposal, CERN/LHCC/94-43, LHCC/P2 (1994); CMS Technical Design Report, CERN-LHCC- 97-32; CMS-TDR-3 (1997).

[4] Pro. of APS/DPF/DPB Summer Study, Snowmass-2001-E3020, eConf C010630; Tesla Tech. Design Report, DESY 2001-011, http://tesla.desy.de/ ; Japanese Linear Collider Group, JLC-I, KEK-Report 92-16(1992); Linear Collider Physics Resource Book, American Linear Collider Working Group, SLAC-R-570, http://www.slac.stanford.edu/grp/th/LCBook/.

[5] C.A. Nelson, B.T. Kress, M. Lopes, and T.P. McCauley, Phys. Rev. D56, 5928(1997).

[6] C.A. Nelson, p. 369 in “Physics at Extreme Energies,” eds. Nguyen van Hieu and Jean Tran Thanh Van, The Gioi Publishers, Vietnam 2001; C.A. Nelson and L.J. Adler, Jr., Eur. Phys. J. C17, 399(2000); and C.A. Nelson and A.M. Cohen, Eur. Phys. J. C8, 393(1999).

[7] S. Weinberg, Phys. Rev. 112,1375(1958).

[8] N. Cabbibo, Phys. Rev. Lett. 12, 137(1964); c.f. C.A. Nelson, Phys. Lett. B355, 561(1995).
[9] D. Garcia, W. Hollik, R.A. Jimenez, J. Sola, Nucl. Phys. 427, 53(1994).

[10] A. Dabelstein, W. Hollik, C. Junger, R.A. Jimenez, J. Sola, Nucl. Phys., B454, 75(1995).

[11] S. Willenbrock and D. A. Dicus, Phys. Rev. D34, 155(1986); C.-P. Yuan, ibid. D41, 42 (1990); R.K. Ellis and S. Parke, ibid. D46, 3785(1992); G. Bordes and B. van Eijk, Z. Phys. C57, 81(1993); and T. Stelzer, Z. Sullivan, and S. Willenbrock, Phys. Rev. D56, 5919(1997).

Table Captions

Table 1: Numerical values of the helicity amplitudes $A(\lambda_{W^+}, \lambda_b)$ for the standard model and for the two dynamical phase-type ambiguities (with respect to the SM’s dominant $\lambda_b = -\frac{1}{2}$ amplitudes). The values are listed first in $g_L = g_{f_M+f_E} = 1$ units, and second as $A_{new} = A_{g_L=1}/\sqrt{\Gamma}$ where $\Gamma$ is the partial width for $t \to W^+b$. [ $m_t = 175GeV$, $m_W = 80.35GeV$, $m_b = 4.5GeV$ ].

|                         | $A(0, -\frac{1}{2})$ | $A(-1, -\frac{1}{2})$ | $A(0, \frac{1}{2})$ | $A(1, \frac{1}{2})$ |
|-------------------------|-----------------------|------------------------|---------------------|---------------------|
| $A_{g_L=1}$ in $g_L = 1$ units |                       |                        |                     |                     |
| $V - A$                 | 338                   | 220                    | -2.33               | -7.16               |
| $S + P$                 | -338                  | 220                    | -24.4               | -7.16               |
| $f_M + f_E$             | 220                   | -143                   | 1.52                | -4.67               |
| $A_{new} = A_{g_L=1}/\sqrt{\Gamma}$ |                       |                        |                     |                     |
| $V - A$                 | 0.84                  | 0.54                   | -0.0058             | -0.018              |
| $S + P$                 | -0.84                 | 0.54                   | -0.060              | -0.018              |
| $f_M + f_E$             | 0.84                  | -0.54                  | 0.0058              | -0.018              |