TTP 94-4
March 1994

V-A TESTS THROUGH LEPTONS FROM POLARISED TOP QUARKS *

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Abstract

Angular-energy distributions are studied for charged leptons and neutrinos from the decays of polarised top quarks. A small admixture of V+A interactions is incorporated. The polarisation dependent part of the neutrino distribution which can be measured experimentally through the missing momentum is particularly sensitive towards deviations from the V-A structure. This result remains unaffected by QCD corrections which, however, cannot be neglected in a quantitative analysis.

*Work supported in part by BMFT under contract 056KA93P and by KBN under grant 2P30225206.

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The analysis of polarised quarks and their decays, in particular of top quarks, has recently attracted considerable attention. Studies at a linear electron-positron collider are particularly clean for precision tests [1, 2]. However, also hadronic [3, 4, 5] or $\gamma\gamma$ collisions [6] and subsequent spin analysis of top quarks might reveal new information. These studies will allow to determine the top quark coupling to the W and Z boson, confirming the predictions of the Standard Model or providing clues for physics beyond. For the top quark this latter possibility is particularly intriguing since it plays an exceptional role in the fermion mass spectrum. In this article we point out that neutrino momentum distributions are particularly sensitive towards violations of the V-A structure of the charged current. To perform such tests a sample of maximally polarised top quarks is required.

A number of mechanisms have been suggested that will lead to polarised top quarks. For $\gamma\gamma$ collisions with circular polarised photons this possibility has been discussed in [6]. Related studies may be performed in hadronic collisions which in this case, however, are based on the correlation between t and $\bar{t}$ decay products [4, 7, 5]. The most efficient and flexible reactions to produce polarised top quarks are electron-positron collisions. A small component of polarisation transverse to the production plane is induced by final state interactions which have been calculated in perturbative QCD [3, 5]. The longitudinal polarisation P_L is large. Its dependence on the production angle, beam energy and the top mass is discussed in [7, 8]. P_L varies strongly with the production angle, e.g. between nearly 0.6 for $\cos\vartheta = -1$ and -0.3 for $\cos\vartheta = 1$ at $\sqrt{s} = 500$ GeV. Averaging over the production angle leads therefore to a significant reduction of P_L with typical values of $\langle P_L \rangle$ around 0.2 [9]. QCD corrections change $\langle P_L \rangle$ by a relative amount of about 3% [9]. All these reactions lead to sizable polarisation and can be used to obtain information on the production mechanism. The most efficient analyser of top polarisation is the charged lepton direction (as seen from the top rest-frame) in semileptonic top decays $t \to Wb \to \ell^+\nu b$. The decay distribution factorises into an energy and an angular dependent part [10, 11]

$$\frac{\mathrm{d}N}{\mathrm{d}x_\ell \, \mathrm{d}\cos\theta_+} = \frac{\mathrm{d}N}{\mathrm{d}x_\ell} \left(1 + \cos\theta_+\right)/2 \qquad (1)$$

where θ_+ denotes the angle between the top spin and the lepton direction. This factorised form applies for arbitrary top mass below and above the threshold for decays into real W bosons. QCD corrections to this distribution are well under control [12] and will be included in the discussion below. The analysing power of the charged lepton direction is obviously maximal and hence far superior to the W direction [13] which suffers from the suppression factor $(m_t^2 - 2m_{\mathrm{w}}^2)/(m_t^2 + 2m_{\mathrm{w}}^2)$. However, two drawbacks of all these proposals are evident: production and decay are mixed in an intricate manner, and furthermore the degree of polarisation is relatively small and depends on the production angle. Top quark production with longitudinally polarised electron beams and close to threshold provides one important exception: the restricted phase space leads to an amplitude which is dominantly S-wave such that the electron (and positron) spin is directly transferred to the top quark. Close to threshold and with longitudinally polarised electrons one may deal with a highly polarised sample of top quarks *independent of the production dynamics*. Thus one may study the V-A structure of t decays under particularly convenient conditions: large event rates, well identified restframe of the top quark, and large degree of polarisation.

As stated before the angular distribution of charged leptons is optimal for the analysis of the top polarisation. On the other hand exactly for this reason it is less suited to identify small admixtures of non-standard couplings, e.g. a small V+A amplitude. In the analysis of neutrino ($\equiv$ missing momentum) distributions the situation is reversed: neutrino distributions in top decays are sensitive to small V+A admixtures and less sensitive to top polarisation. This observation and the detailed analysis of charged lepton and neutrino distributions with a small admixture of V+A interaction is the key point of our paper. Two aspects will be considered. The strong sensitivity of the neutrino energy-angular distribution towards a V+A admixture will be demonstrated. In addition it will be shown that QCD corrections to the Standard Model distributions are well understood, such that any deviation can truly be attributed to a deviation from pure V-A coupling in the decay.

As stated before, the emphasis of this work will be on a discussion of polarised top quarks decays in their rest frame. Nevertheless, a brief comment is appropriate on relativistic top quarks produced far above threshold at a future linear collider. With increasing energy it will be more and more difficult to reconstruct the double differential energy-angular distributions for the leptons. For ultra-relativistic top quarks the situation will resemble the one for b quark semiloptonic decays at LEP energies. A difference which makes the studies at the Z^0 peak particularly interesting is the very high polarisation of b quarks, $P_L = \langle -0.94 \rangle$, which weakly depends on the production angle [1]. For top quarks the net polarisation will be smaller, as stated earlier, but evidently a lot may be gained when considering the asymmetry or the first Legendre moment rather than the average over the production angle. Moreover, the short lifetime in the top case helps to avoid depolarisation in hadronization which is a serious problem for the bottom quark. Thus the studies for ultra-relativistic top quarks are also worth consideration. In close analogy to b quarks at LEP one can study the charged lepton energy distribution (and its moments) in the laboratory frame. Formulae are given in [14] which relate this distribution to the double differential angular-energy distribution discussed in the present article. The neutrino distribution, which can be treated in the same way, has recently attracted considerable interest. It has been pointed out [15] that for b decays the neutrino distribution is highly sensitive to the polarisation of the parent quark and can be used in polarisation studies for Λ_b baryons in addition to the distribution of the charged lepton. In [16] it has been advocated that the ratio of the average energies of the charged lepton and the neutrino is particularly sensitive to b polarisation. In a recent preprint [17] a study has been proposed of the charged weak current and its space-time structure in b semileptonic decays through the neutrino distribution. Unlike for the top decay where the invariant mass of the lepton system is equal to m_{w}, the mass of W boson, for b decays one usually integrates over this variable. We think, however, that another difference is much more important. Neglecting the effects of W propagator the neutrino spectrum in the decays of a heavy quark with the weak isospin $I_3 = -1/2$ is the same as the spectrum of the charged lepton for $I_3 = 1/2$. Thus the results of the present article suggest that for polarised b quarks the distribution of the charged lepton should be more sensitive to V+A admixture. The detailed discussion will be given elsewhere.

Let us perform now a quantitative discussion of the sensitivity of different distributions to V+A admixtures. The tbW vertex is parametrised as follows:

$$g_V\,\gamma^\mu \;+\; g_A\,\gamma^\mu\gamma_5$$

with

$$g_V = (1+\kappa)/\sqrt{1+\kappa^2}\,, \qquad\qquad g_A = (-1+\kappa)/\sqrt{1+\kappa^2} \tag{2}$$

Hence $\kappa = 0$ corresponds to pure V-A and $\kappa = \infty$ to V+A. We consider only leptonic decays of W. The masses of all fermions in the final state are neglected. The error associated with the lepton masses is negligible at least for electrons and muons. The effects of non-vanishing b quark mass are of order $\kappa\epsilon$, where $\epsilon = m_b/m_t$, so they are $\sim 1\%$ for $\kappa = 0.3$ and $\epsilon = 0.03$. The following discussion refers to the rest frame of the decaying top quark.
Neglecting QCD corrections the differential decay rate is proportional to the following expression:

$$\mathrm{d}\Gamma \sim \frac{1}{1+\kappa^2}\,\Big(b\cdot\nu\; R_-\cdot\ell \;+\; \kappa^2\, b\cdot\ell\; R_+\cdot\nu\Big) \tag{3}$$

where

$$R_\pm \;=\; t \pm s$$

t, b, ℓ and ν are the scaled four-momenta of top, bottom, charged lepton and neutrino. The common scaling factor is m_t^{-1}, so

$$t^2 = 1 \qquad \text{and} \qquad y = (\ell+\nu)^2 = (m_{\mathrm{w}}/m_t)^2\ .$$

$s = (0, \vec{s})$ is the spin four-vector of the decaying quark. $S = |\vec{s}| = 1$ corresponds to fully polarised and $S = 0$ to unpolarised top quarks. The following variables will be used:

$$\begin{aligned} x_\ell &= 2\,t\cdot\ell & \qquad S\cos\theta_+ &= -\,s\cdot\ell/t\cdot\ell \\ x_\nu &= 2\,t\cdot\nu & \qquad S\cos\theta_0 &= -\,s\cdot\nu/t\cdot\nu \end{aligned} \tag{4}$$

Thus, x_ℓ and x_ν are proportional to the energies of the respective leptons, θ_+ is the angle between $\vec{s}$ and the three-momentum of the charged lepton, and θ_0 is the analogous angle for the neutrino. Employing the Dalitz parametrization of the phase space and following the steps described in Appendix B of [12] and Appendix A.2 of [18] one derives the following formulae for the normalized double differential angular and energy distributions for the charged lepton and for the neutrino

$$\begin{aligned}\frac{\mathrm{d}N}{\mathrm{d}x_\ell\,\mathrm{d}\cos\theta_+} &= \frac{6}{(1+\kappa^2)\ \mathcal{F}_0(y)}\Big\{\mathrm{F}_0^+(x_\ell,y)\ +\ S\cos\theta_+\,\mathrm{J}_0^+(x_\ell,y) \\ &\quad +\kappa^2\ \Big[\mathrm{F}_0^-(x_\ell,y)\ -\ S\cos\theta_+\,\mathrm{J}_0^-(x_\ell,y)\Big]\Big\} \\ &\qquad\qquad (\,y\le x_\ell\le 1\,)\end{aligned} \tag{5}$$

$$\begin{aligned}\frac{\mathrm{d}N}{\mathrm{d}x_\nu\,\mathrm{d}\cos\theta_0} &= \frac{6}{(1+\kappa^2)\ \mathcal{F}_0(y)}\Big\{\mathrm{F}_0^-(x_\nu,y)\ +\ S\cos\theta_0\,\mathrm{J}_0^-(x_\nu,y) \\ &\quad +\kappa^2\ \Big[\mathrm{F}_0^+(x_\nu,y)\ -\ S\cos\theta_0\,\mathrm{J}_0^+(x_\nu,y)\Big]\Big\} \\ &\qquad\qquad (\,y\le x_\nu\le 1\,)\end{aligned} \tag{6}$$

where

$$\mathrm{F}_0^+(x,y) = x(1-x) \tag{7}$$
$$\mathrm{J}_0^+(x,y) = \mathrm{F}_0^+(x,y) \tag{8}$$
$$\mathrm{F}_0^-(x,y) = (x-y)(1-x+y) \tag{9}$$
$$\mathrm{J}_0^-(x,y) = (x-y)(1-x+y-2y/x) \tag{10}$$
$$\mathcal{F}_0(y) = 2(1-y)^2(1+2y) \tag{11}$$

These distributions can be easily integrated over the energies leading to the following angular distributions

$$\frac{\mathrm{d}N}{\mathrm{d}\cos\theta_+} = \frac{1}{2} + \frac{1}{2}S\cos\theta_+\left[1-\frac{\kappa^2}{1+\kappa^2}h(y)\right] \tag{12}$$

$$\frac{\mathrm{d}N}{\mathrm{d}\cos\theta_0} = \frac{1}{2} - S\cos\theta_0\,[\,1\ -\ h(y)\,]\left[1\ +\ \frac{\kappa^2}{1+\kappa^2}\,\frac{h(y)}{1-h(y)}\right] \tag{13}$$

where

$$h(y) = 2\ -\ \frac{12y(1-y+y\ln y)}{(1-y)^2(1+2y)} \tag{14}$$

For $m_{\mathrm{w}} = 80$ GeV and $m_t = 160$ GeV one obtains $y = 0.25$ and $h(0.25) = 0.566$. It is evident that the neutrino angular distribution is significantly more sensitive towards the admixture of V+A than the angular distribution of the charged lepton. One can also gain sensitivity by studying the double differential angular-energy distributions. A convenient method is to calculate moments of the distributions. The average energies provide the simplest example:

$$
\begin{aligned}
\frac{\mathrm{d}\langle x_\ell\rangle}{\mathrm{d}\cos\theta_+} &= \frac{1+2y+3y^2}{4(1+2y)}\left\{\left[1+\frac{\kappa^2}{1+\kappa^2}\frac{2y(1-y)}{1+2y+3y^2}\right]\right. \\
&\quad\left. + S\cos\theta_+\left[1-\frac{\kappa^2}{1+\kappa^2}\frac{2(1-3y+2y^2)}{1+2y+3y^2}\right]\right\} \qquad (15)\\
\frac{\mathrm{d}\langle x_\nu\rangle}{\mathrm{d}\cos\theta_0} &= \frac{1+4y+y^2}{4(1+2y)}\left[1-\frac{\kappa^2}{1+\kappa^2}\frac{2y(1-y)}{1+4y+y^2}\right] \\
&\quad + S\cos\theta_0\,\frac{1-8y+y^2}{4(1+2y)}\left[1-\frac{\kappa^2}{1+\kappa^2}\frac{2(1-3y+2y^2)}{1-8y+y^2}\right] \qquad (16)
\end{aligned}
$$

Hence the V-A form of the charged current in top decays can be tested by measuring these averages. Even without polarisation they are changed by an admixture of V+A, so, in principle at least, it is possible to see some effects although the 'signal/background' ratio is smaller. The best strategy, however, is to combine the results on both the charged lepton and the neutrino distributions for highly polarised top quarks. At this point it becomes necessary to include QCD corrections to the decay.

QCD corrections to the lepton spectra in decays of polarised quarks were calculated previously [1] [11, 12, 15, 18]. It is plausible that they reduce the V+A contribution to the total rate by the same factor as the well-known one for V-A contribution [20]. This implies that the ratio of V-A and V+A contributions should be $1 : \kappa^2$ also after inclusion of $\mathcal{O}(\alpha_s)$ corrections. This condition will be imposed on the QCD corrected normalized distributions given in the following. Anyway, the unknown corrections are small ($\sim \alpha_s\kappa^2$) and the errors related to our procedure should be even smaller. The normalized distributions including first order QCD corrections read:

$$
\begin{aligned}
\frac{\mathrm{d}N}{\mathrm{d}x_\ell\,\mathrm{d}\cos\theta_+} &= \frac{1}{2}\left[\,\mathrm{A}_\ell(x_\ell)\; + \;S\cos\theta_+\,\mathrm{B}_\ell(x_\ell)\,\right] \qquad (17)\\
\frac{\mathrm{d}N}{\mathrm{d}x_\nu\,\mathrm{d}\cos\theta_0} &= \frac{1}{2}\left[\,\mathrm{A}_\nu(x_\nu)\; + \;S\cos\theta_0\,\mathrm{B}_\nu(x_\nu)\,\right] \qquad (18)
\end{aligned}
$$

[1]The results of [11] are in conflict with earlier analytic calculations[19]. The QCD correction to the lifetime of t quark [20] follows from [11] and has been confirmed by other groups [21]. The result of [11] on the e^+ spectrum in charm decays has been also confirmed [22]. For e^- from b decays see [11], footnote on page 27. Adding this to the cross-checks performed in [11, 18] the controversy can be considered as solved in favor of our article [11] and the related subsequent articles.

$$
\begin{aligned}
\mathrm{A}_\ell(x) &= \frac{12}{1+\kappa^2}\left[\frac{\mathrm{F}_0^+(x,y)\,-\,a_s\,\mathrm{F}_1^+(x,y)}{\mathcal{F}_0(y)\,-\,a_s\,\mathcal{F}_1(y)}+\frac{\kappa^2\,\mathrm{F}_0^-(x,y)}{\mathcal{F}_0(y)}\right] && (19)\\
\mathrm{B}_\ell(x) &= \frac{12}{1+\kappa^2}\left[\frac{\mathrm{J}_0^+(x,y)\,-\,a_s\,\mathrm{J}_1^+(x,y)}{\mathcal{F}_0(y)\,-\,a_s\,\mathcal{F}_1(y)}-\frac{\kappa^2\,\mathrm{J}_0^-(x,y)}{\mathcal{F}_0(y)}\right] && (20)\\
\mathrm{A}_\nu(x) &= \frac{12}{1+\kappa^2}\left[\frac{\mathrm{F}_0^-(x,y)\,-\,a_s\,\mathrm{F}_1^-(x,y)}{\mathcal{F}_0(y)\,-\,a_s\,\mathcal{F}_1(y)}+\frac{\kappa^2\,\mathrm{F}_0^+(x,y)}{\mathcal{F}_0(y)}\right] && (21)\\
\mathrm{B}_\nu(x) &= \frac{12}{1+\kappa^2}\left[\frac{\mathrm{J}_0^-(x,y)\,-\,a_s\,\mathrm{J}_1^-(x,y)}{\mathcal{F}_0(y)\,-\,a_s\,\mathcal{F}_1(y)}-\frac{\kappa^2\,\mathrm{J}_0^+(x,y)}{\mathcal{F}_0(y)}\right] && (22)
\end{aligned}
$$

where

$$a_s = \frac{2\alpha_s}{3\pi}\ ,$$

$$
\begin{aligned}
\mathcal{F}_1(y) &= \mathcal{F}_0(y)\,\left[\tfrac{2}{3}\pi^2+4\mathrm{Li}_2(y)+2\ln y\ln(1-y)\right]-(1-y)(5+9y-6y^2)\\
&\quad +4y(1-y-2y^2)\ln y+2(1-y)^2(5+4y)\ln(1-y) && (23)
\end{aligned}
$$

as first derived in [20], and [11, 12, 18]

$$
\begin{aligned}
\mathrm{F}_1^+(x,y) &= \mathrm{F}_0^+(x,y)\,\Phi_0+x\Phi_1-(3+2x+y)\Phi_{2\diamond 3}+5(1-x)\Phi_4+(-2xy\\
&\quad +9x-4x^2-2y-y^2)\Phi_5+y(4-4x-y+y/x)/2 && (24)
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{F}_1^-(x,y) &= \mathrm{F}_0^-(x,y)\,\Phi_0+(-2xy+x+y+y^2)\Phi_1+(-5+2x-3y)\Phi_{2\diamond 3}\\
&\quad +(5+4xy-5x+3y-5y^2-2y^2/x)\Phi_4+(6xy+9x-4x^2\\
&\quad -11y-2y^2+2y^2/x)\Phi_5+y(2+3x-3y-2y/x)/2 && (25)
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{J}_1^+(x,y) &= \mathrm{J}_0^+(x,y)\,\Phi_0-x\Phi_1+(5-2x-y-2y/x-2/x)\Phi_{2\diamond 3}+(-3+x\\
&\quad +2/x)\Phi_4+(-2xy+3x-4x^2+6y-y^2-2y^2/x)\Phi_5\\
&\quad +(2-2x^2+2y-3y^2-2y/x+3y^2/x)/2 && (26)
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{J}_1^-(x,y) &= \mathrm{J}_0^-(x,y)\,\Phi_0+(-2xy-x-5y+y^2-2y^2/x)\Phi_1+(3+10x+y\\
&\quad +10y/x-2/x)\Phi_{2\diamond 3}+(-3+12xy+x-7y-y^2-12y/x\\
&\quad +8y^2/x+2/x)\Phi_4+(6xy-9x-4x^2-y-2y^2+10y^2/x)\Phi_5\\
&\quad +(2-5xy-2x^2+2y+7y^2-2y/x-2y^2/x)/2 && (27)
\end{aligned}
$$

where

$$
\begin{aligned}
\Phi_0 &= \tfrac{\pi^2}{3}+2\mathrm{Li}_2(x)+2\mathrm{Li}_2(y/x)+\ln^2\left(\tfrac{1-y/x}{1-x}\right)\\
\Phi_1 &= \tfrac{\pi^2}{6}+\mathrm{Li}_2(y)-\mathrm{Li}_2(x)-\mathrm{Li}_2(y/x)\\
\Phi_{2\diamond 3} &= \tfrac{1}{2}(1-y)\ln(1-y)\\
\Phi_4 &= \tfrac{1}{2}\ln(1-x)\\
\Phi_5 &= \tfrac{1}{2}\ln(1-y/x) && (28)
\end{aligned}
$$

It is worth mentioning that in [18] formulae are also given for the QCD corrections to V-A heavy quark decays for non-zero mass of the quark produced in the decay which are only slightly more complicated than those in the massless approximation. Thus it is easy to generalize the present discussion to non-zero ϵ. As stated before, terms $\sim \kappa\epsilon$ appear for $\epsilon \neq 0$. The corresponding QCD corrections of $\mathcal{O}(\alpha_s \kappa\epsilon)$ are unknown but small, and can be safely neglected. Anyhow, in the present article we stick to the massless approximation for the sake of simplicity of the presentation.

k	$\mathcal{A}_k^{(\ell)}$	$\mathcal{B}_k^{(\ell)}$	$\mathcal{A}_k^{(\nu)}$	$\mathcal{B}_k^{(\nu)}$
-1	2.008	2.005	1.593	-0.707
	.981	.940	1.023	1.166
0	1.000	.998	1.000	-0.452
	1.000	.949	1.000	1.110
1	.559	.558	.683	-0.322
	1.021	.960	.984	1.068
2	.345	.344	.500	-0.249
	1.043	.973	.973	1.037
3	.230	.230	.385	-0.203
	1.064	.989	.965	1.015

Table 1: Moments of the coefficient functions defining the angular-energy distributions for the charged leptons and for the neutrinos for $y = 0.25$ and $\alpha_s = 0.11$: the upper entries denote the moments for $\kappa^2 = 0$ and the lower ones are the ratios between the moments for $\kappa^2 = 0.1$ and $\kappa^2 = 0$.

In Table 1 the following moments are given

$$\mathcal{A}_k^{(\ell)} = \int_y^1 \mathrm{d}y\, x^k\, \mathrm{A}_\ell(x,y) \ , \qquad \mathcal{B}_k^{(\ell)} = \int_y^1 \mathrm{d}y\, x^k\, \mathrm{B}_\ell(x,y) \tag{29}$$

$$\mathcal{A}_k^{(\nu)} = \int_y^1 \mathrm{d}y\, x^k\, \mathrm{A}_\nu(x,y) \ , \qquad \mathcal{B}_k^{(\nu)} = \int_y^1 \mathrm{d}y\, x^k\, \mathrm{B}_\nu(x,y) \tag{30}$$

for integer k between -1 and 3, $y = 0.25$ and $\alpha_s(m_t) = 0.11$. The upper entries in the table denote the values of the moments for $\kappa^2 = 0$ and the lower ones the ratios of the moments evaluated for $\kappa^2 = 0.1$ to those for $\kappa^2 = 0$. From the comparison of the moments it is again evident that the moments $\mathcal{B}_k^{(\nu)}$ which govern the angular dependence of the neutrino spectrum are particularly sensitive towards a V+A admixture. The effect is most pronounced for the moment $k = -1$ which enhaces the lower energy part of the spectrum and where the relative change amounts to 17% for $\kappa^2 = 0.1$.

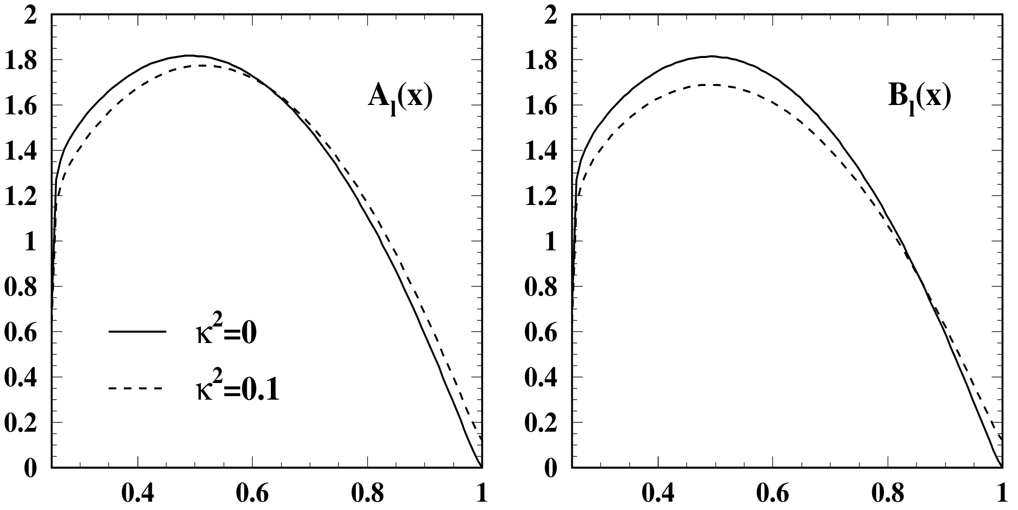

Figure 1: The coefficient functions a) $\mathrm{A}_\ell(x)$ and b) $\mathrm{B}_\ell(x)$ defining the charged lepton angular-energy distribution for $y = 0.25$ and $\alpha_s(m_t) = 0.11$: $\kappa^2 = 0$ – solid lines and $\kappa^2 = 0.1$ – dashed lines.

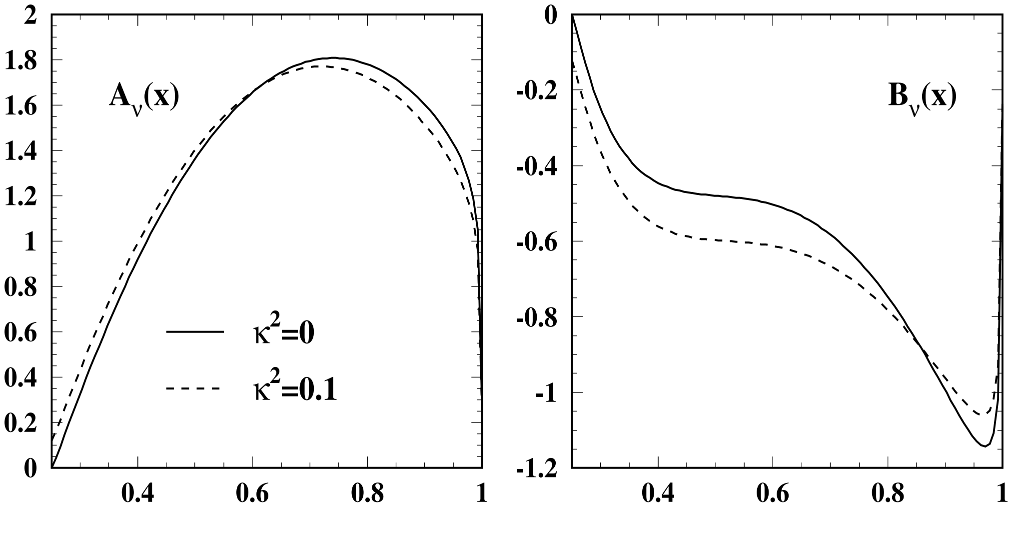

Figure 2: The coefficient functions a) $\mathrm{A}_\nu(x)$ and b) $\mathrm{B}_\nu(x)$ defining the neutrino angular-energy distribution for $y = 0.25$ and $\alpha_s(m_t) = 0.11$: $\kappa^2 = 0$ – solid lines and $\kappa^2 = 0.1$ – dashed lines.

The same conclusions follow from Figs.1 and 2 where the coefficient functions defined in eqs. (19)-(22) are shown as solid lines for $\kappa = 0$ and as dashed lines for $\kappa = 0.1$. In Figs.1a and 2a the functions $\mathrm{A}_\ell(x)$ and $\mathrm{A}_\nu(x)$ are plotted for $y = 0.25$, $\alpha_s(m_t) = 0.11$ and the functions $\mathrm{B}_\ell(x)$ and $\mathrm{B}_\nu(x)$ are shown in Figs.1b and 2b, respectively.

α_s	κ^2	$\mathrm{A}_\ell(0.5)$	$\mathrm{B}_\ell(0.5)$	$\mathrm{A}_\nu(0.7)$	$\mathrm{B}_\nu(0.7)$
0.11	0	1.816	1.812	1.794	-0.583
0.11	0.1	1.772	1.688	1.767	-0.666
0	0	1.778	1.778	1.760	-0.526
0	0.1	1.737	1.657	1.736	-0.614

Table 2: Comparison of the coefficient functions with and without QCD corrections and V+A admixture for $y = 0.25$

The effect of QCD corrections is illustrated by the comparison of the coefficient functions $\mathrm{A}_\ell(0.5)$, $\mathrm{B}_\ell(0.5)$, $\mathrm{A}_\nu(0.7)$ and $\mathrm{B}_\nu(0.7)$ which are given in Table 2. The effect of QCD correction can mimic a small admicture of V+A interaction. Therefore, inclusion of the radiative QCD correction to the decay distributions is necessary for a quantitative study.

We conclude that the angular-energy distribution of neutrinos from the polarised top quark decay will allow for a particularly sensitive test of the V-A structure of the charged current.

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