\[ A_{LT} \text{ in the polarized Drell-Yan process} \]
\[ \text{at RHIC and HERA energies} \]

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\begin{abstract}
We present a leading order (LO) estimate for the longitudinal-transverse spin asymmetry \( A_{LT} \) in the nucleon-nucleon polarized Drell-Yan process at RHIC and HERA-\( \bar{N} \) energies in comparison with \( A_{LL} \) and \( A_{TT} \). \( A_{LT} \) receives contribution from \( g_1 \), the transversity distribution \( h_1 \), and the twist-3 distributions \( g_T \) and \( h_L \). For the twist-3 contribution we use the bag model prediction evolved to a high energy scale by the large-\( N_c \) evolution equation. We found that \( A_{LT} \) (normalized by the asymmetry in the parton level) is much smaller than the corresponding \( A_{TT} \). Twist-3 contribution given by the bag model also turned out to be negligible.
\end{abstract}

PACS numbers: 13.85.Qk, 13.88.+e, 12.39.Ba

[keywords: Drell-Yan, longitudinal-transverse spin asymmetry, chiral-odd distribution, twist-3 effect]
The nucleon-nucleon scattering provides us with a new opportunity to probe nucleon’s internal structure. In particular, polarized Drell-Yan lepton pair production opens a window toward new types of spin dependent parton distributions – chiral-odd distributions $h_1(x, \mu^2)$ and $h_L(x, \mu^2)$ which cannot be measured by the deep inelastic lepton-nucleon scatterings [1], [2], [3], [4]. There are three kinds of double spin asymmetries in the nucleon-nucleon polarized Drell-Yan process: They are $A_{LL}$ (collision between the longitudinally polarized nucleons), $A_{TT}$ (collision between the transversely polarized nucleons), and $A_{LT}$ (longitudinal versus transverse). The experimental data on these asymmetries will presumably be reported by RHIC at BNL and HERA-$\bar{N}$ at DESY. By now several reports are already available for the estimate of $A_{LT}$ in comparison with $A_{LL}$ and $A_{TT}$ at RHIC and HERA energies in the LO QCD. Our interest in $A_{LT}$ is amplified by the fact that it receives the twist-3 contribution as a leading contribution (although it is proportional to $1/Q$ with a hard momentum $Q$), giving a possibility of seeing quark-gluon correlation in hard processes [5].

We first recall the parton distributions relevant to these asymmetries. For the nucleon moving in the positive $\hat{e}_3$ direction, the parton distributions of the nucleon defined at a factorization scale $\mu^2$ are given by the following lightcone correlation functions in the nucleon ($z^2 = 0$, $z^+ = 0$, $\vec{z}_\perp = \vec{0}$):

$$P^+ \int \frac{dz^-}{2\pi} e^{ixP^-z} \langle PS|\tilde{\psi}(0)\gamma_{\mu}\psi(z)|\mu|PS\rangle = 2f_1(x, \mu^2)P_\mu, \quad (1)$$

$$P^+ \int \frac{dz^-}{2\pi} e^{ixP^-z} \langle PS|\tilde{\psi}(0)\gamma_{\mu}\gamma_5\psi(z)|\mu|PS\rangle = 2 \left[ g_1(x, \mu^2)P_\mu(S \cdot n) + g_T(x, \mu^2)S_{\perp\mu} \right], \quad (2)$$

$$P^+ \int \frac{dz^-}{2\pi} e^{ixP^-z} \langle PS|\tilde{\psi}(0)\sigma_{\mu\nu}i\gamma_5\psi(z)|\mu|PS\rangle = 2 \left[ h_1(x, \mu^2) (S_{\perp\mu}P_\nu - S_{\perp\nu}P_\mu) / M + h_L(x, \mu^2)M (P_\mu n_\nu - P_\nu n_\mu) (S \cdot n) \right], \quad (3)$$

where $|PS\rangle$ denotes the nucleon (mass $M$) state with the four momentum $P$ and the spin $S$ ($P^2 = M^2, S^2 = -M^2, P \cdot S = 0$), and a light-like vector $n$ with its only nonzero component $n^-$ is introduced by the relation $P \cdot n = 1$. $S^\mu$ is decomposed as $S^\mu = (S \cdot n)P^\mu - M^2 (S \cdot n)n^\mu + S^\mu_{\perp \nu}$ with $P \cdot S_{\perp \nu} = n \cdot S_{\perp \nu} = 0$. In (1)-(3), the gauge link operators which ensure gauge invariance are suppressed for simplicity. We remind that in the infinite momentum frame ($P^+ \rightarrow \infty$) the coefficients of $f_1$, $g_1$ and $h_1$ are of $O(P^+)$ (twist-2), those of $g_T$ reference [5].
and \( h_L \) are of \( O(1) \) (twist-3), and the \( O(1/P^+) \) contributions (twist-4) are ignored in the right hand side of (1)-(3). Note also that \( f \) the nucleon. A quark and an anti-quark distributions are related as

\[
\tilde{f}(x) = x f(x),
\]

\[
\tilde{g}(x) = x g(x),
\]

\[
\tilde{h}(x) = x h(x).
\]

The above distribution functions \( g_{1,T} \) and \( h_{1,L} \) etc are defined for each quark and anti-quark flavor \( \psi = \psi^a (a = u, d, s, \bar{u}, \bar{d}, \bar{s}, ...) \) and have support \(-1 < x < 1\). They represent distributions of a quark (or anti-quark) carrying the momentum component \( k^+ = x P^+ \) in the nucleon. A quark and an anti-quark distributions are related as \( f_a^q(-x) = -f_1^q(x) \), \( g_{1,T}(-x) = g_1^{\bar{q}}(x) \), \( h_{1,L}(-x) = -h_1^{\bar{q}}(x) \). The three twist-2 distributions have a simple parton model interpretation, and they can be written as \( f_1(x) = q_+(x) + q_-(x) = q_1(x) + \bar{q}_1(x) \), \( g_1(x) = q_+(x) - q_-(x) \), and \( h_1(x) = q_1(x) - \bar{q}_1(x) \). Here \( q_+(x) \) (\( q_-(x) \)) represents a density of a quark with its helicity parallel (anti-parallel) to the nucleon spin in the longitudinally polarized nucleon. Likewise, \( q_1(x) \) (\( \bar{q}_1(x) \)) represents a density of a quark with its polarization parallel (anti-parallel) to the nucleon spin in the transversely polarized nucleon. Therefore \( h_1 \) is called transversity distribution [3]. For nonrelativistic quarks, \( h_1(x) = g_1(x) \). Nucleon models suggest \( h_1(x) \) is not so different from \( g_1(x) \) at a low energy scale [3, 19].

The twist-3 distributions \( g_T \) and \( h_L \) can be decomposed into the twist-2 contribution and the “purely twist-3” contribution:

\[
g_T(x, \mu^2) = \int_x^1 dy \frac{g_1(y, \mu^2)}{y} + \tilde{g}_T(x, \mu^2), \tag{4}
\]

\[
h_L(x, \mu^2) = 2x \int_x^1 dy \frac{h_1(y, \mu^2)}{y^2} + \tilde{h}_L(x, \mu^2). \tag{5}
\]

The purely twist-3 pieces \( \tilde{g}_T \) and \( \tilde{h}_L \) can be written as quark-gluon-quark correlator on the lightcone using QCD equation of motion [21, 3, 20]. In the following we call the first terms in (4) and (5) \( g_{WW}^T(x, \mu^2) \) and \( h_{WW}^L(x, \mu^2) \) (Wandzura-Wilczek parts) respectively.

With these definition for the parton distributions, we can write down the expression for the double spin asymmetries, \( A_{LL}, A_{TT} \) [1], \( A_{LT} \) [3], in the polarized Drell-Yan process. In LO QCD, there is some arbitrariness in choosing the factorization scale \( \mu^2 \) in each distribution. In this paper, we set \( \mu^2 = Q^2 \), the squared invariant mass of the lepton pairs, in calculating the asymmetries. By this choice the LO double asymmetries are given by

\[
A_{LL} = \frac{\sigma(\uparrow, \uparrow) - \sigma(\downarrow, \downarrow)}{\sigma(\uparrow, \uparrow) + \sigma(\downarrow, \downarrow)} = \frac{\Sigma_a e_a^2 g_1^a(x_1, Q^2) g_1^\bar{a}(x_2, Q^2)}{\Sigma_a e_a^2 f_1^a(x_1, Q^2) f_1^\bar{a}(x_2, Q^2)}, \tag{6}
\]

\[
A_{TT} = \frac{\sigma(\uparrow, \uparrow) - \sigma(\downarrow, \downarrow)}{\sigma(\uparrow, \uparrow) + \sigma(\downarrow, \downarrow)} = \frac{\Sigma_a e_a^2 h_1^a(x_1, Q^2) h_1^{\bar{a}}(x_2, Q^2)}{\Sigma_a e_a^2 f_1^a(x_1, Q^2) f_1^{\bar{a}}(x_2, Q^2)}. \tag{7}
\]
\[ A_{LT} = \frac{\sigma(+, \uparrow) - \sigma(+, \downarrow)}{\sigma(+, \uparrow) + \sigma(+, \downarrow)} = a_{LT} \frac{\sum_a e_a^2 [g_1(x_1, Q^2)x_2 g_0^q(x_2, Q^2) + x_1 h_L^q(x_1, Q^2)h_1^q(x_2, Q^2)]}{\sum_a e_a^2 f_1(x_1, Q^2)f_0^q(x_2, Q^2)}, \]

where \( \sigma(S_1, S_2) \) represents the Drell-Yan cross section with the two nucleon’s spin \( S_1 \) and \( S_2 \), \( e_a \) represent the electric charge of the quark-flavor \( a \) and the summation is over all quark and anti-quark flavors: \( a = u, d, s, \bar{u}, \bar{d}, \bar{s} \), ignoring heavy quark contents \( (c, b, \cdots) \) in the nucleon. The variables \( x_1 \) and \( x_2 \) refer to the momentum fractions of the partons coming from the two nucleons “1” and “2”, respectively. In \( A_{LT} \), the nucleon “1” is longitudinally polarized and the nucleon “2” is transversely polarized. In (8), \( a_{TT} \) and \( a_{LT} \) represent the asymmetries in the parton level defined as

\[ a_{TT} = \frac{\sin^2\theta \cos 2\phi}{1 + \cos^2\theta}, \]

\[ a_{LT} = \frac{M^2 \sin 2\theta \cos \phi}{Q^2 (1 + \cos^2\theta)}, \]

where \( \theta \) is the polar angle of the virtual photon in the center of mass system with respect to the beam direction and \( \phi \) represents its azimuthal angle with respect to the transverse spin.

We note that \( A_{LL} \) and \( A_{TT} \) receive contribution only from the twist-2 distributions, while \( A_{LT} \) is proportional to the twist-3 distributions and hence \( a_{LT} \) is suppressed by a factor \( 1/Q^2 \).

So far there has been much accumulation of experimental data on \( f_1 \) and \( g_1 \), and they have been parametrized in the NLO level in the literature. (\([13, 14, 15]\) for \( f_1 \) and \([17, 16, 18]\) for \( g_1 \)). Although these distributions can explain available experimental data, there still remains some uncertainties in the parametrizations especially for \( g_1 \). For future references, we use for \( g_1 \) the LO parametrization (standard scenario) by Glučk-Reya-Stratmann-Vogelsang (GRSV) \([16]\) and the LO model-A of Gehrmann and Stirling (GS) \([17]\) for our estimate. In both cases, we consistently use the LO parametrization for \( f_1 \) by Glučk-Reya-Vogt \([13]\). For \( h_1, g_T \) and \( h_L \) no experimental data is available up to now and we have to rely on some theoretical postulates. Here we assume \( h_1(x, \mu^2) = g_1(x, \mu^2) \) at a low energy scale \( (\mu^2 = 0.23 \text{ GeV}^2 \text{ for GRSV} \text{ and } \mu^2 = 1 \text{ GeV}^2 \text{ for GS}) \) as has been suggested by some low energy nucleon models \([1, 19]\) and has been used for the estimate of \( A_{TT} \) \([4]\). This assumption also fixes \( g_T^{WW} \) and \( h_L^{WW} \). For the purely twist-3 parts \( \tilde{g}_T \) and \( \tilde{h}_L \) we employ the bag model results at a low energy scale. In particular, we set the strangeness contributions to the purely twist-3 contributions equal to zero. By these boundary conditions for \( h_1, g_T \) and \( h_L \) at a low energy side and applying the relevant \( \mu^2 \) evolution to them, we can estimate \( A_{LT} \).

For the LO prediction of the asymmetries, we need LO \( \mu^2 \) evolution for each distribution. The twist-2 distributions obey simple DGLAP equation. The complete LO \( \mu^2 \) evolution of
the twist-3 distributions has been derived by several different approaches for $\tilde{g}_T$ and for $\tilde{h}_L$ \cite{22}. It has been also proved that at large $N_c$ their $\mu^2$-dependence can be described by a simple DGLAP evolution equation similarly for the twist-2 distributions and the correction due to the finite value of $N_c$ is of $O(1/N_c^2) \sim 10\%$ level \cite{23,20}. Since the complete evolution equations of $\tilde{g}_T$ and $\tilde{h}_L$ are quite complicated and not practically usefull, we apply the large-$N_c$ evolution to the bag model results \cite{24,25}.

The double spin asymmetries are the functions of the square of the center-of-mass energy $s = (P_1 + P_2)^2$ ($P_1$ and $P_2$ are the four momenta of the two nucleons), the squared invariant mass of the lepton pair $Q^2 = (x_1 P_1 + x_2 P_2)^2 = x_1 x_2 s$ ($M^2 \ll Q^2$) and the Feynman’s variables $x_F = \frac{2p_T}{\sqrt{s}} = x_1 - x_2$. Using these variables, momentum fractions of each quark and antiquark in (6)-(8) can be written as

$$x_1 = \frac{1}{2} \left( x_F + \sqrt{x_F^2 + \frac{4Q^2}{s}} \right), \quad x_2 = \frac{1}{2} \left( -x_F + \sqrt{x_F^2 + \frac{4Q^2}{s}} \right). \quad (11)$$

Since the twist-3 effect is one of our main interest, we showed in Fig. 1 $g_T(x, \mu^2)$ and $h_L(x, \mu^2)$ for the $u$-quark at $\mu^2 = 1$ GeV$^2$. Figure 1(a) shows $g_T^{WW}(x, \mu^2)$ with two parametrizatons for $g_1$ (GRSV and GS) and the bag model prediction for $\tilde{g}_T(x, \mu^2)$ obtained by assuming the bag scale is $\mu^2_{bag} = 0.081$ and 0.25 GeV$^2$ \cite{24,25}. Although the $u$-quark distribution for $\tilde{g}_T$ contains flavor-singlet contribution which mixes with the gluon distribution, we ignored the mixing and applied the large-$N_c$ $\mu^2$ evolution, since the $\mu^2$ evolution for the singlet part can not be described by a simple evolution equation. The correction due to the mixing is expected to be at most of order of 10\%, which is irrelevant in the present rough estimate of $A_{LT}$ as we will see later. Likewise, Fig. 1(b) shows $h_L^{WW}(x, \mu^2)$ at $\mu^2 = 1$ GeV$^2$. Because of chiral-odd nature of $h_L$, $\tilde{h}_L$ does not mix with the gluon distribution and the large-$N_c$ evolution is more reliable than for $\tilde{g}_T$. One sees from Fig. 1, the GRSV and GS distributions give rise to different twist-2 contributions $g_T^{WW}$ and $h_L^{WW}$ at $x < 0.2$. It has been shown in \cite{24,25} that at high $\mu^2$ the bag model gives small $\tilde{g}_T$ and $\tilde{h}_L$, and $g_T$ and $h_L$ are dominated by $g_T^{WW}$ and $h_L^{WW}$. Figure 1 reflects this tendency already at $\mu^2 = 1$ GeV$^2$.

Figure 2 shows the three asymmetries normalized by the asymmetries in the parton level, $$\tilde{A}_{LL} = -A_{LL}, \quad \tilde{A}_{TT} = -A_{TT}/a_{TT}, \quad \tilde{A}_{LT} = -A_{LT}/a_{LT}$$ using the GRSV distribution for the twist-2 distributions. They are plotted as a function of $x_F$ for fixed values of $Q = \sqrt{Q^2}$ ($= 8, 10$ GeV) and $\sqrt{s}$ ($= 50, 200$ GeV), which are within or close to the planned RHIC and HERA-$\vec{N}$ kinematics. ($50$ GeV $< \sqrt{s} < 500$ GeV for RHIC, and $\sqrt{s} = 39.2$ GeV for

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HERA-$N$. Figure 3 shows the same quantities but with the GS distributions for the twist-2 distributions. In Figs. 2 and 3, $\tilde{A}_{LL}$ and $\tilde{A}_{TT}$ are symmetric with respect to $x_F = 0$, while $\tilde{A}_{LT}$ is not symmetric as is obvious from the kinematics. In general all these asymmetries are larger for larger $Q^2/s$. One sees from these figures that even for $\tilde{A}_{LL}$ and $\tilde{A}_{TT}$ the GRSV and GS parton distributions give completely different results. (See also [4].) Their $x_F$-dependence is mostly opposite. Comparing the curves with $\sqrt{s} = 50$ GeV and 200 GeV in Fig. 2, the relative magnitude of $\tilde{A}_{LL}$ and $\tilde{A}_{TT}$ is reversed. The GS distribution for $g_1$ gives negative $\tilde{A}_{LL}$ in some range of $x_F$ at $\sqrt{s} = 50$ GeV. $\tilde{A}_{LT}$ with only the twist-2 contributions in $g_T$ and $h_L$ are shown by solid lines in Figs. 2 and 3. They are typically 5 to 10 times smaller than $\tilde{A}_{LL}$ and $\tilde{A}_{TT}$ except when $\tilde{A}_{LL}$ changes sign in Fig. 3. $\tilde{A}_{LT}$ with complete $g_T$ and $h_L$ is shown by the short dash-dot ($\mu_{bag}^2 = 0.25$ GeV$^2$) and the dotted ($\mu_{bag}^2 = 0.081$ GeV$^2$) lines in these figures. Since large $|x_F|$ corresponds to small $x_1$ or $x_2$ (see [1]), and the bag model prediction for the distribution function becomes unreliable in the small-$x$ region, we only plotted these lines for the region $x_1, x_2 > 0.07$ [26]. As can be seen from Figs. 2 and 3, the purely twist-3 contribution brings only tiny correction to $\tilde{A}_{LT}$. Larger value of the bag scale $\mu_{bag}^2$ would not make it appreciably larger.

Figures 4 and 5 show the $Q^2$ dependence of the asymmetries at $x_1 = x_2 = Q/\sqrt{s}$ ($x_F = 0$) with $\sqrt{s} = 50, 200$ GeV, using two distributions. These figures also show the features noted above.

The reason for the smallness of $\tilde{A}_{LT}$ is the presence of the factors $x_1$ or $x_2$ in (8). In the kinematic range considered either $x_1$ or $x_2$ (or both) take very small values. If it were not for those factors, $\tilde{A}_{LT}$ would be comparable to $\tilde{A}_{LL}$ and $\tilde{A}_{TT}$. We remind in passing that what is measured experimentaly is $A_{LT}$ itself which receives the suppression factor $M/Q$ from $a_{LT}$.

Several comments are in order here. Our estimate of $A_{LT}$ is based on the assumption $h_1^q(x, \mu^2) = g_1^q(x, \mu^2)$ at low $\mu^2$. There are several model independent constraints among LO twist-2 parton distributions: $f_1^q(x, \mu^2) \geq |g_1^q(x, \mu^2)|$, $f_1^q(x, \mu^2) \geq |h_1^q(x, \mu^2)|$ and the Soffer’s inequality $f_1^q(x, \mu^2) + g_1^q(x, \mu^2) \geq 2|h_1^q(x, \mu^2)|$ [27]. Since the first inequality is satisfied by the GRSV and GS distributions at $\mu^2 > 1$ GeV$^2$, the second one is also satisfied by our input for $h_1^q$ and its $\mu^2$ evolution. On the other hand, our input assumption $h_1^q(x, \mu^2) = g_1^q(x, \mu^2)$ at low $\mu^2$ may violate the Soffer’s inequality even at relatively high $\mu^2$ for some quark or anti-quark flavors for which $g_1^q(x, \mu^2) \approx -f_1^q(x, \mu^2)$ at low $\mu^2$. For the case of the GRSV distribution, our assumption violates the inequality for the $\bar{u}, d, s$ and $\bar{s}$ distributions even at $\mu^2 > 1$ GeV$^2$ in the large $x$ region. For the case of GS distribution, we found that the $d$ quark distribution violates the inequality at $x > 0.5$ around $\mu^2 = 4$ GeV$^2$. This may be ascribed
not only to our exact setting of \( h_1(x, \mu^2) = g_1(x, \mu^2) \) at low \( \mu^2 \) but also to the uncertainty in \( g_1(x, \mu^2) \), in particular, the poor knowledge on sea distributions at \( x > 0.1 \). However, the violation occurs only in the region where the absolute magnitude of the distribution functions is extremely small. We thus expect that the effect of the violation to the asymmetries is not so serious numerically. Especially, we believe that the relative magnitude between \( A_{LT} \) and \( A_{TT} \) is relatively immune to this constraint.

The authors of [10] calculated \( A_{TT} \) from a different point of view. They determined the input \( h_1 \) so that it saturates the Soffer’s inequality at a low energy scale, taking advantage of the fact that the inequality is maintained at higher \( \mu^2 \) by the QCD evolution, and claimed that they estimated the upper bound of \( A_{TT} \). However, they assumed the inequality for each valence and sea distributions. On the other hand, the Soffer’s inequality is an inequality for each quark and anti-quark flavor [28]. This does not necessarily leads to the inequality for the valence distributions. (The assumption in [10] is a sufficient condition to guarantee the inequality for each quark and anti-quark flavor.) Therefore the authors of [10] imposed a stronger constraint on \( h_1 \) than required by the Soffer’s inequality and their estimate of \( A_{TT} \) can not be taken as the upper bound of \( A_{TT} \) solely due to the Soffer’s inequality. Numerically, their estimate on \( A_{TT} \) is of the same order as those in Figs. 2 and 4 (also the one in [7]).

To summarize, we presented a first estimate of the longitudinal-transverse spin asymmetry \( A_{LT} \) for the polarized Drell-Yan process at RHIC and HERA-\( \vec{N} \) energies in comparison with \( A_{LL} \) and \( A_{TT} \). \( A_{LT} \) normalized by the asymmetry in the parton level turned out to be approximately five to ten times smaller than the corresponding \( A_{TT} \), although the prediction on its absolute magnitude suffers from the uncertainty of the distributions, in particular, of \( h_1 \) as was the case for \( A_{TT} \). The purely twist-3 contribution to \( g_T \) and \( h_L \) was modeled by the bag model, and it turned out its effect on \( A_{LT} \) is negligible compared with the Wandzura-Wilczek contribution to \( g_T \) and \( h_L \).

Acknowledgement

We thank N. Saito for useful discussions on the RHIC kinematics and T. Gehrmann for providing us with the Fortran code of their parton distribution.

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Figure 1: (a) $g_{WW}^{u}(x,\mu^2)$ obtained from the GRSV distribution (solid line) and the GS distribution (dashed line) at $\mu^2=1$ GeV$^2$, and $\tilde{g}_{T}(x,\mu^2)$ obtained from the bag model calculation at $\mu^2=1$ GeV$^2$ assuming the bag scale is $\mu^2_{bag}=0.081$ GeV$^2$ (long dash-dot line) and $\mu^2_{bag}=0.25$ GeV$^2$ (short dash-dot line). (b) $h_{L}^{WW}(x,\mu^2)$ and $\tilde{h}_{L}(x,\mu^2)$ at $\mu^2=1$ GeV$^2$. The meaning of the lines is the same as (a).
Figure 2: Double spin asymmetries, $\tilde{A}_{LL}$, $\tilde{A}_{TT}$, $\tilde{A}_{LT}$, for the polarized Drell-Yan using the GRSV parton distribution and the bag model at $Q = 8, 10$ GeV and $\sqrt{s} = 50, 200$ GeV. The solid line denotes $\tilde{A}_{LT}$ with only the Wandzura-Wilczek contributions in $g_T$ and $h_L$. The short dash-dot line denotes $\tilde{A}_{LT}$ with the bag scale $\mu_{bag}^2 = 0.25$ GeV$^2$, and the dotted line denotes $\tilde{A}_{LT}$ with the bag scale $\mu_{bag}^2 = 0.081$ GeV$^2$. The long dashed line corresponds to $\tilde{A}_{LL}$, and the long dash-dot line corresponds to $\tilde{A}_{TT}$.
Figure 3: Double spin asymmetries, $\tilde{A}_{LL}$, $\tilde{A}_{TT}$, $\tilde{A}_{LT}$, for the polarized Drell-Yan using the GS parton distribution and the bag model at $Q = 8$, 10 GeV and $\sqrt{s} = 50$, 200 GeV. The meaning of the lines is the same as Fig. 2.
Figure 4: The $Q^2$ dependence of the asymmetries, $\tilde{A}_{LL}$, $\tilde{A}_{TT}$, $\tilde{A}_{LT}$, at $x_F = 0$ in the polarized Drell-Yan at $\sqrt{s} = 50$ GeV (a) and 200 GeV (b) using the GRSV parton distribution and the bag model. The meaning of the lines is the same as Figs. 2.
Figure 5: The $Q^2$ dependence of the asymmetries, $\tilde{A}_{LL}$, $\tilde{A}_{TT}$, $\tilde{A}_{LT}$, at $x_F = 0$ in the polarized Drell-Yan at $\sqrt{s} = 50$ GeV (a) and 200 GeV (b) using the GS parton distribution and the bag model. The meaning of the lines is the same as Figs. 2.