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PARITY-VIOLATING ASYMMETRIES IN DILEPTON PRODUCTION BY POLARIZED PROTONS*

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ABSTRACT

The parity-violating asymmetries arising from weak-electromagnetic interference in production of dileptons by polarized protons are investigated. The two separate terms in the asymmetry are calculated within the Weinberg-Salam model and the implications for experiment are discussed.

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I. Introduction

The Drell-Yan model[1] for production of high invariant mass lepton pairs in hadron-hadron collisions has become the standard with which continuum dilepton data is compared.[2] Basic features of the model such as the predicted scaling behavior of the cross section are in agreement with the results of experiments with proton beams. Other features such as the angular distribution of the pair and the ratio of π^+ to π^- induced cross sections are found to follow theoretical predictions as well. While the transverse momentum distribution of the dilepton pair and the absolute magnitude of the cross section point to possible higher order quantum chromodynamic (QCD) corrections to the model,[2] we shall use it as a lowest order mechanism in order to see what the size of weak-electromagnetic interference effects will be.

These effects arise in lowest order from interference between diagrams with a virtual photon, γ, and that with a neutral weak vector boson, Z^o. Such is the case for the asymmetry in the angular distribution of the lepton (or antilepton) with respect to the beam direction in dilepton production by hadrons.[3] This may arise from interference between the amplitude for $q\bar{q} \to \gamma \to \ell\bar{\ell}$ and for $q\bar{q} \to Z^o \to \ell\bar{\ell}$ with axial-vector coupling of the Z^o to both quarks and leptons. Such an asymmetry is completely analogous to that predicted in $e^-e^+ \to \mu^-\mu^+$, which is expected to be observed at PEP and PETRA. It has the disadvantage that an asymmetry of this type also occurs from higher order electromagnetic effects. These latter must be subtracted from the observed asymmetry to isolate the part due to weak-electromagnetic interference and thence permit extraction of Z^o couplings.

These last problems may be avoided by considering an explicitly parity-violating asymmetry which is forbidden to arise from electromagnetic effects in any order. In this paper we consider such asymmetries in dilepton production by polarized protons incident on nucleon targets. These are directly analogous to the asymmetry seen[4] in deep inelastic scattering of polarized electrons. Because of the large dilepton mass accessible in proton-nucleon collisions, however, one might expect asymmetries of order 10^{-2} or more, rather than those of order 10^{-4} measured[4] at SLAC in deep inelastic electron scattering.

In the next section, assuming the Drell-Yan mechanism, we calculate the form of the expected effects and show that there are two different cross section asymmetry terms. The relation of each to the quark distributions in a polarized proton and to the Z^o couplings to quarks and leptons is given. In Section III we use these formulae together with known quark-parton distributions and Z^o couplings in the Weinberg-Salam model to give numerical predictions of the asymmetries. We conclude in Section IV with a discussions of our results and their experimental implications.

II. Polarized Beam Asymmetries in Dilepton Production

It is most convenient in deriving the polarization asymmetry to work first at the quark level. We assume that the dileptons are generated via the Drell-Yan mechanism[1] of quark-antiquark annihilation through a virtual γ or Z^o. The vector or axial-vector nature of γ and Z^o couplings, together with neglect of quark masses, implies that right-handed and left-handed quarks annihilate with left-handed and right-handed antiquarks, respectively. Similarly, with neglect of lepton masses right-handed (left-handed) leptons are produced only with left-handed (right-handed) antileptons. The cross sections for $q\bar{q} \rightarrow \ell\bar{\ell}$ may then be labeled by just the initial quark and final lepton helicities, λ_q and λ_ℓ, respectively, the antiquark and antilepton helicities being implied.

The derivation then proceeds in a manner which is in direct analogy to that for the asymmetry in polarized electron scattering.[5] With cross sections $\sigma_{\lambda_q,\lambda_\ell}$ written in terms of couplings of the γ and Z^o to right-handed (left-handed) quarks and leptons, $Q_{R,q}$ and $Q_{R,\ell}$ ($Q_{L,q}$ and $Q_{L,\ell}$), and the rotation group d functions, we have:[6]

Right-handed quark, right-handed lepton,

$$\sigma_{RR} \propto \left| Q^{\gamma}_{R,q} \frac{1}{q^2} Q^{\gamma}_{R,\ell} + Q^{Z}_{R,q} \frac{1}{q^2 + M_Z^2} Q^{Z}_{R,\ell} \right|^2 |d^1_{1,1}(\theta)|^2 \quad ; \qquad (1a)$$

Right-handed quark, left-handed lepton,

$$\sigma_{RL} \propto \left| Q^{\gamma}_{R,q} \frac{1}{q^2} Q^{\gamma}_{L,\ell} + Q^{Z}_{R,q} \frac{1}{q^2 + M_Z^2} Q^{Z}_{L,\ell} \right|^2 |d^1_{1,-1}(\theta)|^2 \quad ; \qquad (1b)$$

Left-handed quark, right-handed lepton,

$$\sigma_{LR} \propto \left| Q^{\gamma}_{L,q} \frac{1}{q^2} Q^{\gamma}_{R,\ell} + Q^{Z}_{L,q} \frac{1}{q^2 + M_Z^2} Q^{Z}_{R,\ell} \right|^2 |d^1_{-1,1}(\theta)|^2 \quad ; \qquad (1c)$$

Left-handed quark, left-handed lepton,

$$\sigma_{LL} \propto \left| Q^{\gamma}_{L,q} \frac{1}{q^2} Q^{\gamma}_{L,\ell} + Q^{Z}_{L,q} \frac{1}{q^2 + M_Z^2} Q^{Z}_{L,\ell} \right|^2 |d^1_{-1,-1}(\theta)|^2 . \qquad (1d)$$

The angle θ is that between the incoming quark and outgoing lepton in the $q\bar{q}$ (or $\ell\bar{\ell}$) center-of-mass system. The right- and left-handed couplings of the photon are equal and are just the charges 2e/3, -e/3, and -e/3 for the u,d, and s quarks, respectively. Similarly, $Q^{\gamma}_{R,\ell} = Q^{\gamma}_{L,\ell} = -e$ for the charged leptons.

If we form the parity-violating asymmetry from the difference of cross sections for initial quarks with positive and negative helicities (and summed over final lepton helicities), we have

$$A = \frac{\sigma_{RR} + \sigma_{RL} - \sigma_{LR} - \sigma_{LL}}{\sigma_{RR} + \sigma_{RL} + \sigma_{LR} + \sigma_{LL}} \quad . \tag{2}$$

Expanding to first order in q^2/M_Z^2, the γ-Z interference terms give the leading contribution to the numerator while the square of the photon amplitudes gives the leading contribution to the denominator:

$$\begin{aligned} A = -\frac{|q^2|}{2M_Z^2}\, Q^{\gamma}_q\, Q^{\gamma}_{\ell} \Bigg[& \left(Q^Z_{R,q}Q^Z_{R,\ell} + Q^Z_{R,q}Q^Z_{L,\ell} - Q^Z_{L,q}Q^Z_{R,\ell} - Q^Z_{L,q}Q^Z_{L,\ell}\right)(1+\cos^2\theta) \\ & + \left(Q^Z_{R,q}Q^Z_{R,\ell} - Q^Z_{R,q}Q^Z_{L,\ell} + Q^Z_{L,q}Q^Z_{R,\ell} - Q^Z_{L,q}Q^Z_{L,\ell}\right)(2\cos\theta)\Bigg] \\ & \times \left[\left(Q^{\gamma}_q Q^{\gamma}_{\ell}\right)^2 (1+\cos^2\theta)\right]^{-1} \end{aligned} \tag{3}$$

This formula takes on a somewhat neater appearance in terms of vector and axial-vector coupling constants,

$$\begin{aligned} Q^Z_R &= g_V + g_A \\ Q^Z_L &= g_V - g_A \quad , \end{aligned} \tag{4}$$

for both the Z^o couplings to quarks and leptons. The formula for the asymmetry then becomes

$$A = -\frac{2|q^2|}{M_Z^2} \cdot \frac{Q_q^\gamma Q_\ell^\gamma \left[g_{A,q}g_{V,\ell}(1+\cos^2\theta) + g_{V,q}g_{A,\ell}(2\cos\theta)\right]}{\left(Q_q^\gamma Q_\ell^\gamma\right)^2 (1+\cos^2\theta)} \tag{5}$$

Notice that there are two distinct terms which are coefficients of different angular factors. Averaging over center-of-mass angles just leaves a term proportional to $g_{A,q}g_{V,\ell}$.

The asymmetry to be observed in hadron-hadron collisions may now be obtained by folding the quark level cross sections and resulting asymmetry in Eq. (5) with the quark and antiquark distributions in the initial hadrons. We consider in particular collisions of longitudinally polarized protons with unpolarized nucleons. The probability of finding a quark of type i in the incident longitudinally polarized proton with spin parallel (antiparallel) to that of the proton and with momentum fraction x_1 is defined to be $f^+_{i/p}(x_1)$ $(f^-_{i/p}(x_1))$. Clearly $f^+_{i/p}(x_1) + f^-_{i/p}(x_1) = f_{i/p}(x_1)$, the probability of finding a quark of type i with any spin direction. A quark of type i in the proton annihilates with its corresponding anti-quark, $\bar{i}$, in the nucleon target, which occurs[7] with momentum fraction x_2 with probability $f_{\bar{i}/N}(x_2)$.

Defining the asymmetry in polarized proton + nucleon $\rightarrow \ell\bar{\ell}$ + ... collisions as the difference over the sum of cross section for proton helicity +1/2 and -1/2, we then find[8]

$$A(x_1,x_2,\theta) = -\frac{2|q^2|}{M_Z^2} \tag{6}$$

$$\times \frac{\sum_i Q_i^\gamma Q_\ell^\gamma \left[f^+_{i/p}(x_1) - f^-_{i/p}(x_1)\right] f_{\bar{i}/N}(x_2) \left[g_{A,i}g_{V,\ell} + g_{V,i}g_{A,\ell}\,\frac{2\cos\theta}{1+\cos^2\theta}\right] + i \leftrightarrow \bar{i}}{\sum_i \left(Q_i^\gamma Q_\ell^\gamma\right)^2 f_{i/p}(x_1)\, f_{\bar{i}/N}(x_2) + i \leftrightarrow \bar{i}}$$

The sum over i includes all types of quarks u,d,s,c,.... For all leptons $Q^{\gamma}_{\ell} = -e$. In terms of s, the square of the center-of-mass energy of the p-N system, we have the kinematic relation $|q^2| = x_1x_2s$. We then rewrite Eq. (6) as

$$A(x_1,x_2,\theta) = \frac{x_1x_2s}{2\pi\alpha M_Z^2} \tag{7}$$

$$\times \frac{\sum_i (Q^{\gamma}_i/e)\left[f^+_{i/p}(x_1) - f^-_{i/p}(x_1)\right] f_{\bar{i}/N}(x_2)\left[g_{A,i}g_{V,\ell} + g_{V,i}g_{A,\ell}\,\frac{2\cos\theta}{1+\cos^2\theta}\right] + i\leftrightarrow\bar{i}}{\sum_i \left(Q^{\gamma}_i/e\right)^2 f_{i/p}(x_1)\, f_{\bar{i}/N}(x_2) + i\leftrightarrow\bar{i}}$$

The numerator of Eq. (7) is composed of pieces containing $g_{A,i}g_{V,\ell}$ and $g_{V,i}g_{A,\ell}$ which have different angular properties. The asymmetry which survives integration over θ is

$$A_1(x_1,x_2) = \frac{x_1x_2s}{2\pi\alpha M_Z^2}\,\frac{\sum_i (Q^{\gamma}_i/e)\, g_{A,i}g_{V,\ell}\left[f^+_{i/p}(x_1) - f^-_{i/p}(x_1)\right] f_{\bar{i}/N}(x_2) + i\leftrightarrow\bar{i}}{\sum_i \left(Q^{\gamma}_i/e\right)^2 f_{i/p}(x_1)\, f_{\bar{i}/N}(x_2) + i\leftrightarrow\bar{i}} \tag{8}$$

Isolating the term which is odd in cos θ (by forming a forward-backward lepton angular asymmetry on top of the polarization asymmetry) gives the independent asymmetry:

$$A_2(x_1,x_2) = \frac{x_1x_2s}{2\pi\alpha M_Z^2}\,\frac{\sum_i (Q^{\gamma}_i/e)\, g_{V,i}g_{A,\ell}\left[f^+_{i/p}(x_1) - f^-_{i/p}(x_1)\right] f_{\bar{i}/N}(x_2) + i\leftrightarrow\bar{i}}{\sum_i \left(Q^{\gamma}_i/e\right)^2 f_{i/p}(x_1)\, f_{\bar{i}/N}(x_2) + i\leftrightarrow\bar{i}} \tag{9}$$

The decomposition

$$A(x_1,x_2,\theta) = A_1(x_1,x_2) + \frac{2\cos\theta}{1+\cos^2\theta}\,A_2(x_1,x_2) \quad , \tag{10}$$

into θ independent and θ dependent terms is in complete analogy to the situation[5] in polarized electron deep inelastic scattering where the asymmetry has y independent and y dependent terms. In fact, since the y variable is directly related to the angle of scattering in the electron-quark center-of-mass, it is more than just an analogy. There is, however, an important difference. Because in the present case the asymmetry is based on the difference of quark polarizations rather than lepton polarizations, the positions of $g_{A,q}g_{V,\ell}$ and $g_{V,q}g_{A,\ell}$ are flipped. The θ independent term here involves $g_{A,q}g_{V,\ell}$, while the y independent term in the asymmetry for deep inelastic polarized electron scattering involves $g_{V,q}g_{A,\ell}$, and vice versa for the θ and y dependent terms. This is of major importance for the predicted magnitude of A_1 relative to that of A_2 which is calculated in the next section.

III. Numerical Results

We now proceed to numerical evaluation of the asymmetries given in Eqs. (8) and (9) within the context of the Weinberg-Salam model[9] for weak and electromagnetic interactions. With the standard assignment of right-handed quarks and leptons to singlets and left-handed quarks and leptons to doublets of weak isospin, the couplings of the Z^o are given by

$$g_{V,\ell} = \frac{e}{4\sin\theta_W \cos\theta_W}\left(-1 + 4\sin^2\theta_W\right) ,$$

$$g_{A,\ell} = \frac{e}{4\sin\theta_W \cos\theta_W} ,$$

$$g_{V,i} = \frac{e}{4\sin\theta_W \cos\theta_W}\left(2T_{3,i} - 4\frac{Q_i}{e}\sin^2\theta_W\right) ,$$

$$g_{A,i} = \frac{e}{4\sin\theta_W \cos\theta_W}\left(-2T_{3,i}\right) . \tag{11}$$

The third component of weak isospin, $T_{3,i}$, is +1/2 for $i = u, c, \ldots$ and $-1/2$ for $i = d, s, \ldots$. The mass of the neutral weak boson is related to $G_F = 1.02 \times 10^{-5}/M_N^2$ by

$$\frac{1}{M_Z^2} = \frac{\sqrt{2}\, G_F \sin^2\theta_W \cos^2\theta_W}{\pi\alpha} \quad . \tag{12}$$

We may now rewrite the general Eqs. (8) and (9) in the specific case of the Weinberg-Salam model:

$$A_1(x_1,x_2) = \frac{x_1 x_2\, s\, G_F}{4\sqrt{2}\ \pi\alpha} \tag{13}$$

$$\times \frac{\sum_i \left(Q_i^\gamma/e\right)\left(-2T_{3,i}\right)\left(-1+4\sin^2\theta_W\right)\left[f^+_{i/p}(x_1) - f^-_{i/p}(x_1)\right] f_{\bar{i}/N}(x_2) + i \leftrightarrow \bar{i}}{\sum_i \left(Q_i^\gamma/e\right)^2 f_{i/p}(x_1)\ f_{\bar{i}/N}(x_2) + i \leftrightarrow \bar{i}}$$

and

$$A_2(x_1,x_2) = \frac{x_1 x_2\, s\, G_F}{4\sqrt{2}\ \pi\alpha} \tag{14}$$

$$\times \frac{\sum_i \left(Q_i^\gamma/e\right)\left(2T_{3,i} - 4\,\frac{Q_i^\gamma}{e}\sin^2\theta_W\right)\left[f^+_{i/p}(x_1) - f^-_{i/p}(x_1)\right] f_{\bar{i}/N}(x_2) + i \leftrightarrow \bar{i}}{\sum_i \left(Q_i^\gamma/e\right)^2 f_{i/p}(x_1)\ f_{\bar{i}/N}(x_2) + i \leftrightarrow \bar{i}}$$

The only quantities remaining unspecified are the quark distributions, and in particular the correlation between the spin direction of the proton and its quark partons, which is contained in the functions $f^+_{i/p}(x_1)$ and $f^-_{i/p}(x_1)$. Here we make the additional assumption that to a good approximation only the valence quarks in the nucleon correlate their spins with the overall nucleon spin direction. The "ocean" is assumed unpolarized. Numerical results are presented here for two cases. First, the SU(6) wave function for the proton gives

$$\frac{f^{+}_{u/p}(x)}{f^{+}_{u/p}(x) + f^{-}_{u/p}(x)} = \frac{5}{6}$$

$$\frac{f^{+}_{d/p}(x)}{f^{+}_{d/p}(x) + f^{-}_{d/p}(x)} = \frac{1}{3} \quad . \tag{15}$$

Second, the x dependent form[10]

$$\frac{f^{+}_{u/p}(x)}{f^{+}_{u/p}(x) + f^{-}_{u/p}(x)} = \frac{1}{2}\left(1 + x^{0.39}\right)$$

$$\frac{f^{+}_{d/p}(x)}{f^{+}_{d/p}(x) + f^{-}_{d/p}(x)} = \frac{1}{2}\left(1 - \frac{1}{3}x^{0.23}\right) \quad , \tag{16}$$

will be used. In the latter case, the u quark spin is completely aligned with that of the proton at $x = 1$, while both the u and d quarks are completely uncorrelated at $x = 0$. Both sets of polarized quark distributions yield spin dependent structure functions which are in adequate agreement with the polarized electron-polarized proton deep inelastic scattering experiments.[11] Of course the second set is somewhat better in this regard, having been fit in part to these data. For the unpolarized quark parton distributions themselves we use the parametrization of Field and Feynman,[12] but with the "ocean" as modified by Berger.[13] This gives a good description of the muon pair production data in 400 GeV pN collisions.

Before examining the predicted asymmetries in detail, let us discuss the expected sign of the effect. In the limit where $\sin^2\theta_W$ is very small, only left-handed leptons and quarks interact with the Z^o. For $u\bar{u} \to \ell\bar{\ell}$

the product of quark and lepton couplings is negative for both the photon and Z^o. However for dilepton masses less than M_Z, the photon and Z^o propagators are of opposite sign, so the amplitudes for the intermediate γ and Z^o interfere destructively (the same holds for $d\bar{d} \to \ell\bar{\ell}$) and decrease the cross section from what it would be from photon exchange alone. Consequently the asymmetry, defined as right-handed minus left-handed quark cross sections divided by their sum, is positive for all values of $\cos\theta$. The known value of $\sin^2\theta_W$ is small enough that this positive sign holds for A_1 and A_2 calculated below.

In Fig. 1 the predictions for $A_1(x_1,x_2)$ and $A_2(x_1,x_2)$ are shown for scattering of polarized protons on unpolarized protons with SU(6) spin wave functions for the valence quarks in the proton. The variables $x = x_1 - x_2$, the fractional momentum of the lepton pair along the polarized proton beam direction, and $\tau = |q^2|/s = x_1x_2$ have been used. A value of $\sin^2\theta_W = 0.225$, representative of the results of recent experiments,[14] is employed in all graphs. An s value of 1000 GeV^2 has been chosen, with the asymmetries at other energies obtainable by scaling linearly in s.

The most obvious difference between the results for A_1 and A_2 is that the former is roughly an order of magnitude smaller. This is a consequence of the value of $\sin^2\theta_W$: for $\sin^2\theta_W = 1/4$ there is an exact vanishing of $g_{V,\ell}$ and hence of A_1. The experimental value of $\sin^2\theta_W$ is close enough to 0.25 to severely suppress A_1.

For a given value of $\tau = x_1x_2$ the values of $x = x_1 - x_2$ lie between τ-1 and 1-τ. For negative values of x ($x_2 > x_1$) the dominant process is annihilation of valence quarks in the target with "ocean" antiquarks in the polarized proton. Since these antiquarks are unpolarized by assumption, the asymmetries are very small for $x < 0$.

At the opposite extreme, when x is near the maximum value of $1-\tau$, x_1 is near 1. In this regime, the cross section is dominated by valence u quarks in the polarized proton annihilating with antiquarks in the target. Since these u quarks are mostly aligned with the proton's spin, a maximum of the asymmetry is found.

In Figs. 2 and 3 we show A_1 and A_2 for proton and neutron targets using the x dependent polarized quark distributions of Eq. (16). The results for proton targets are quite similar to those in Fig. 1, but are somewhat larger in magnitude, especially near $x = 1$. Using a neutron target (Fig. 3) rather than a proton target makes little difference in the asymmetries.

IV. Discussion

As shown in Section II, the structure of the expression for the parity-violating asymmetry for polarized proton production of lepton pairs is very similar to that for the asymmetry in polarized electron deep inelastic scattering. The asymmetry A_1, being independent of θ, is the analogue of the y independent term in the deep inelastic asymmetry. A_2, which has a coefficient $2\cos\theta/(1+\cos^2\theta)$, is correspondingly the analogue of the coefficient of $[1-(1-y)^2]/[1+(1-y)^2]$ in deep inelastic scattering.

Numerically, A_2 is at the hoped for 10^{-2} level in the Weinberg-Salam model for $|q^2| = 200\ \mathrm{GeV}^2$ ($\tau = |q^2|/s = 0.2$ at $s = 1000\ \mathrm{GeV}^2$). However, because of the value of the weak mixing angle θ_W, A_1 is much smaller than A_2. Note that $|A_1| << |A_2|$ is the reverse of the case in polarized electron deep inelastic scattering where the y independent term in the asymmetry (and analogue of A_1) is the dominant term. This comes about because A_1 involves the vector coupling of the Z^o to leptons times the axial coupling to quarks, whereas its deep inelastic analogue involves axial coupling to leptons times vector coupling to quarks. The experimental value of $\sin^2\theta_W \approx 0.225$ makes $g_{V,\ell}$, which is proportional to $(1-4\sin^2\theta_W)$, especially small.

Unfortunately, this situation makes the already difficult experimental measurement of these asymmetries doubly so. The asymmetry A_2 has a coefficient $2\cos\theta/(1+\cos^2\theta)$, and must be separated from the isotropic but much smaller asymmetry A_1 by measuring an angular distribution on top of the difference of beam polarizations required for isolating a parity-violating effect.

Added to this is the question of whether the lowest order $q\bar{q} \rightarrow \ell\bar{\ell}$ diagram is to be trusted quantitatively as the mechanism for dilepton production in hadron collisions. The size of the experimental $\langle p_\perp \rangle$ values for the produced dileptons points toward higher order QCD effects being important,[2] e.g., $q\bar{q} \rightarrow \text{gluon} + \ell\bar{\ell}$ and $\text{gluon} + q \rightarrow \ell\bar{\ell} + q$. The disagreement between the predicted Drell-Yan total cross section and that observed may also indicate quantitative problems for the lowest order model.[2] Thus, while measurement of a parity-violating asymmetry in dilepton production with polarized proton beams is of interest as another check of basic ideas on weak and electromagnetic interactions, the extraction therefrom of couplings of the Z^o to quarks and leptons has quantitative uncertainties which correspond to those in the detailed theoretical understanding of dilepton production.

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6. Our metric is such that q^2 is negative for the time-like virtual γ and Z^o four-momenta of relevance here; $\alpha = e^2/4\pi \approx 1/137$.
7. Since a quark with given helicity only annihilates with an antiquark of the opposite helicity, the proper antiquark actually occurs in the unpolarized target with probability $\frac{1}{2} f_{\bar{i}/N}(x_2)$. The factor of one-half cancels out in the ratio of cross sections that forms the asymmetry.
8. Although we have analyzed the asymmetry at the quark level by labeling in terms of the initial quark, the same formulae hold using the initial antiquark with appropriate changes in γ and Z^o couplings. Thus the terms in Eq. (6) and thereafter involving antiquarks in place of quarks and vice versa $(i \leftrightarrow \bar{i})$ have the same form.

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FIGURE CAPTIONS

1. The parity-violating asymmetries $A_1(x_1,x_2)$ and $A_2(x_1,x_2)$ for production of dileptons by longitudinally polarized protons on a proton target using the SU(6) spin wave function for the valence quarks in the proton. The center-of-mass energy squared is $s = 1000\ \mathrm{GeV}^2$, and $\sin^2\theta_W = 0.225$.

2. Same as Fig. 1, but with x dependent polarized quark distributions.

3. Same as Fig. 1, but with x dependent polarized quark distributions and a neutron target.

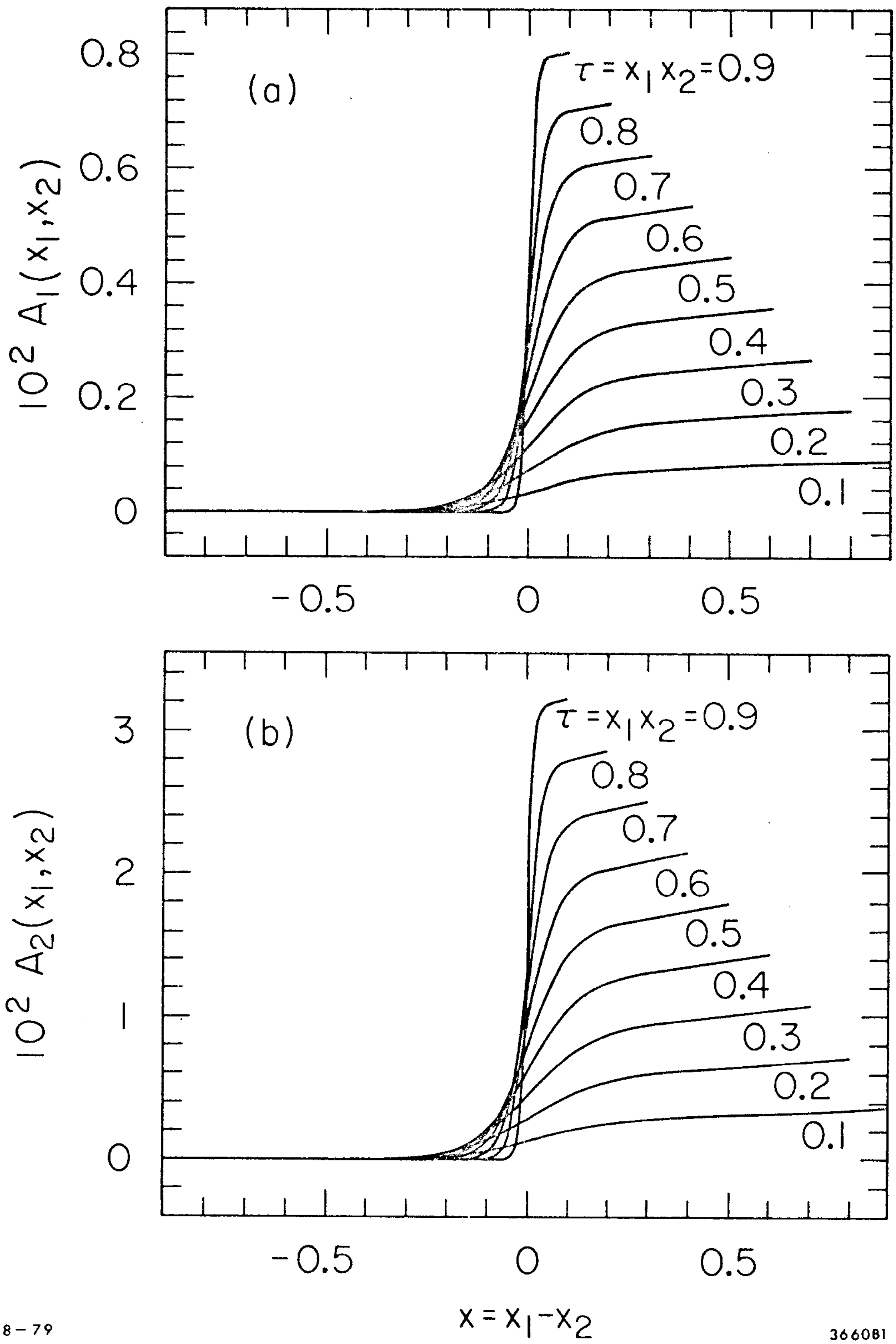
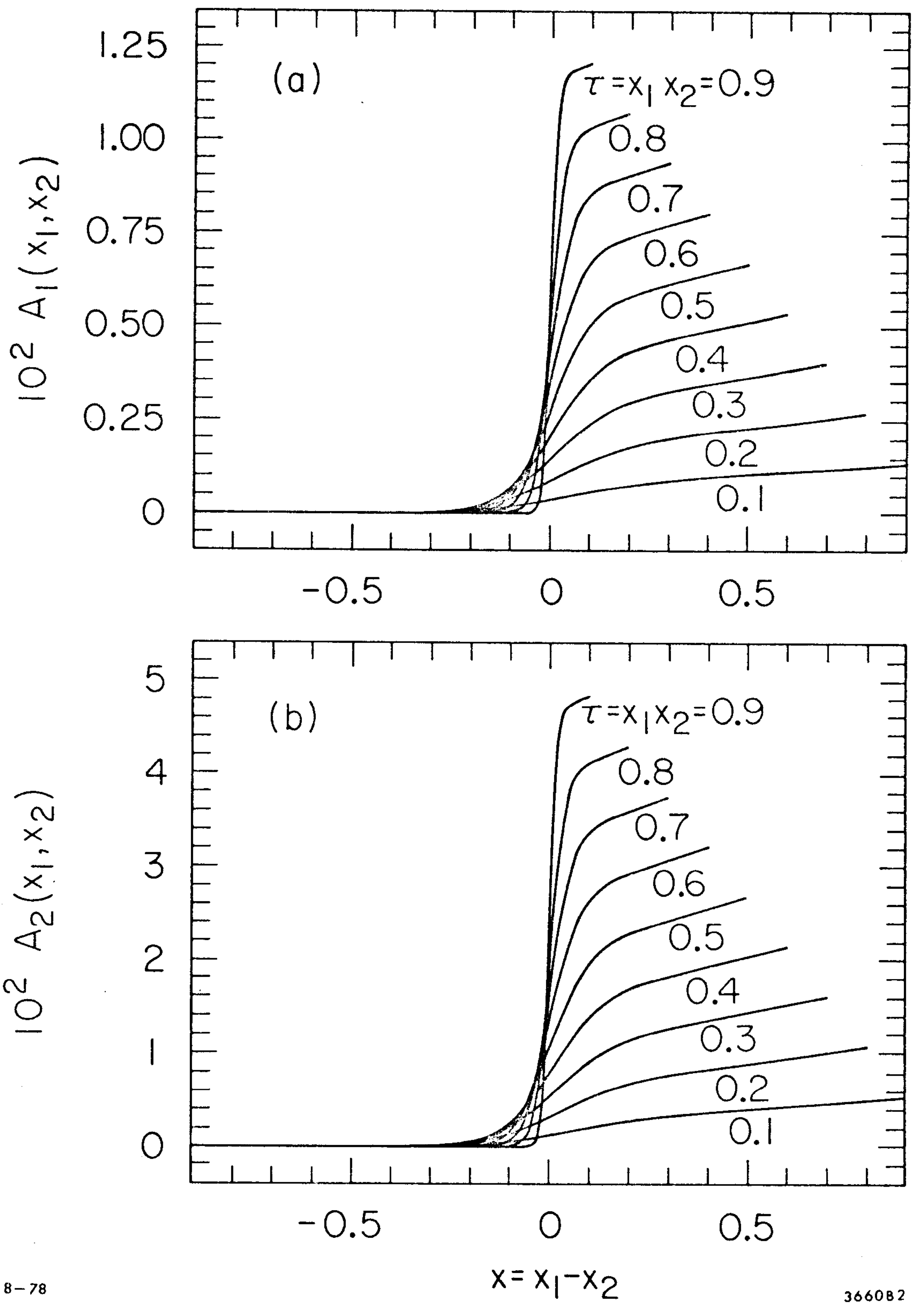
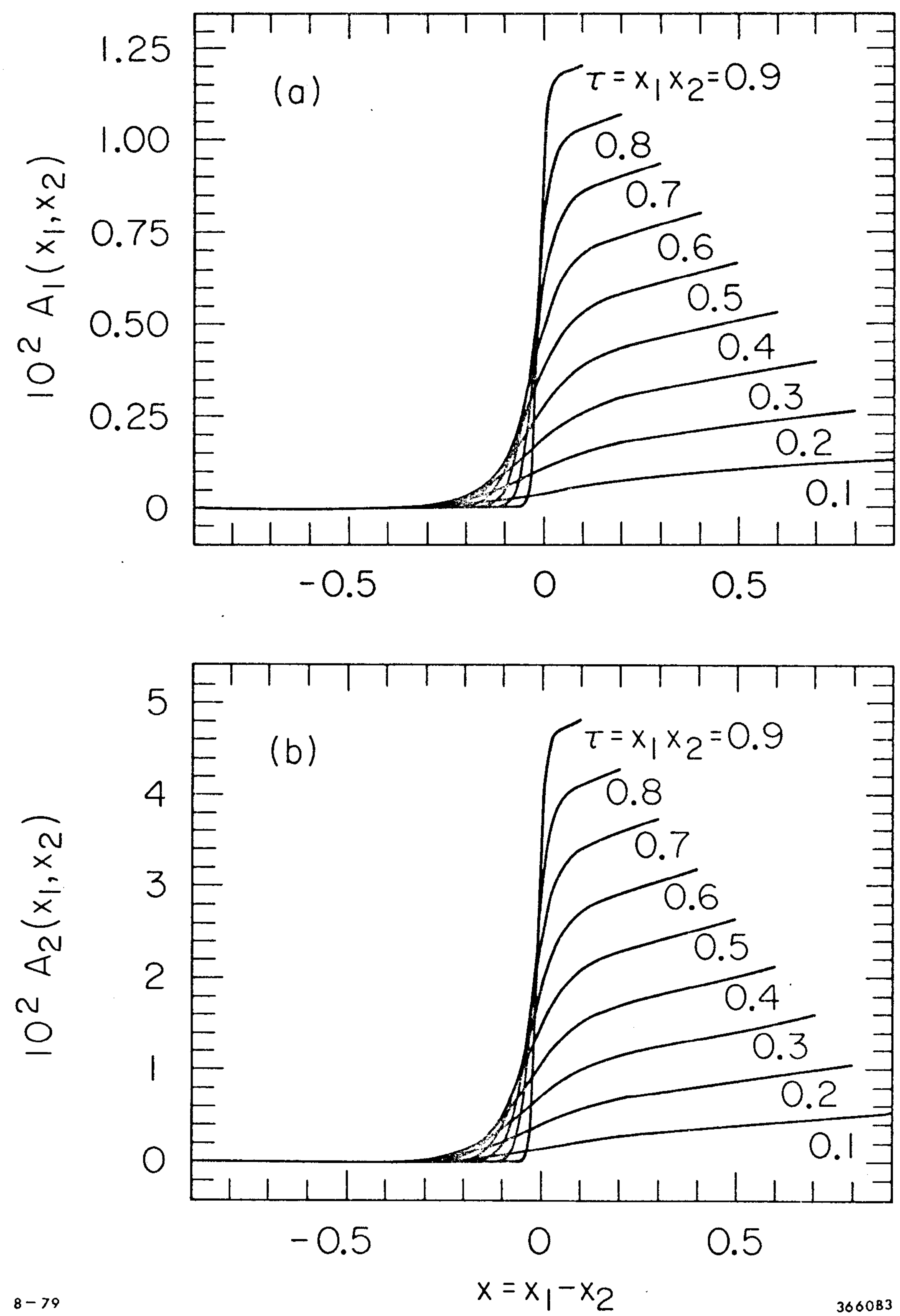

(a)
$\tau = x_1 x_2 = 0.9$
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
$10^2 A_1(x_1, x_2)$
0.8
0.6
0.4
0.2
0
-0.5
0
0.5
(b)
$\tau = x_1 x_2 = 0.9$
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
$10^2 A_2(x_1, x_2)$
3
2
1
0
-0.5
0
0.5
$x = x_1 - x_2$
8-79
366081

Fig. 1



(a)
$\tau = x_1 x_2 = 0.9$
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
$10^2\ A_1(x_1, x_2)$
1.25
1.00
0.75
0.50
0.25
0
−0.5
0
0.5
(b)
$\tau = x_1 x_2 = 0.9$
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
$10^2\ A_2(x_1, x_2)$
5
4
3
2
1
0
−0.5
0
0.5
$x = x_1 - x_2$
8–78
3660B2

Fig. 2



(a)
$\tau = x_1 x_2 = 0.9$
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1.25
1.00
0.75
0.50
0.25
0
$10^2 A_1(x_1, x_2)$
-0.5
0
0.5
(b)
$\tau = x_1 x_2 = 0.9$
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
5
4
3
2
1
0
$10^2 A_2(x_1, x_2)$
-0.5
0
0.5
$x = x_1 - x_2$
8-79
3660B3

Fig. 3