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Lepton Pair Production and the Modified Drell-Yan Mechanism
in High Energy Unpolarized and Polarized pp and $\bar{p}p$ Collisions

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Abstract

A modified Drell-Yan mechanism for the inclusive dilepton pair production in hadronic reactions is studied, and the significance of comparing high energy unpolarized and polarized pp and $\bar{p}p$ collisions is discussed. The required beams are currently in proposal at FNAL and CERN.

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$$f_1^S(x_1) = \frac{1}{2} \left(f_1^V(x_1) + f_1^S(x_1) \right)$$

where $f_1^S(x_1) = f_1^S(x_1, s)$ is the probability of a color, and is

$$f_1^S(x_1) = \begin{cases} 0 & \text{colorless sea quark} \\ 1 & \text{colored sea quark} \end{cases}$$

The factor (f_1^V/f_1^S) in the original model is a quark-antiquark pair to combine to form a lepton with mass Q and longitudinal momentum P . We further assume

$$f_1^S(x_1, s)/f_1^S(x_1) \xrightarrow{x_1 \rightarrow 1} 1$$

to make the original Drell-Yan model consistent with the data for massive lepton pairs. In this modified mechanism the lepton pairs need to become more massive in order to agree with the original Drell-Yan mechanism as the center of mass energy increases.

The strong interaction dynamics of high energy $\bar{p}p$ collision is very similar to pp collision, for example, their total cross section difference vanishes as the center of mass energy increases. It is then natural to use the same effective sea quark distributions in $\bar{p}p$ collision as in pp collision, and the factor $C_{\bar{p}p}$ becomes, with x_1 standing for $\bar{p}$ and x_2 for p ,

$$C_{\bar{p}p} = \sum_i e_i^2 \left\{ \left[\bar{f}_i^V(x_1) + \bar{g}_i^S(x_1, s) \right] \left[f_i^V(x_2) + g_i^S(x_2, s) \right] + \bar{g}_i^S(x_1, s) g_i^S(x_2, s) \right\}.$$

From particle-antiparticle symmetry $\bar{f}_i^V(x) = f_i^V(x)$, and $\bar{g}_i^S(x, s) = g_i^S(x, s)$ from the $SU(3)$ properties of the sea. The subtraction of pp from $\bar{p}p$ leads to the relation

$$\left(\frac{d\sigma}{dQ^2 d\Omega d\phi}\right)_{S_1 S_2} = \left(\frac{d\sigma}{dQ^2 d\Omega d\phi}\right)_{S_1 S_2}^{\text{pp}} \times \left(\frac{d\sigma}{dQ^2 d\Omega d\phi}\right)_{S_1 S_2}^{\text{pp}} \times \left(\frac{d\sigma}{dQ^2 d\Omega d\phi}\right)_{S_1 S_2}^{\text{pp}} \quad (2)$$

where $\left(\frac{d\sigma}{dQ^2 d\Omega d\phi}\right)_{S_1 S_2}^{\text{pp}}$ is defined in the original Drell-Yan mechanism of the lepton pair production in pp collisions. We must note the different application of Eq.(2) to the modified and in the original Drell-Yan mechanism. In the original Drell-Yan mechanism the dilepton mass region to apply Eq.(2) is for Q^2 as the region where the mechanism is applicable to pp collisions itself, and we already know that the original mechanism severely underestimates the dilepton yield for $Q^2 < 5 \text{ GeV}^2$. In this modified Drell-Yan mechanism the application to pp (or $\bar{p}p$) collision alone is not very meaningful, since the functions $f_1^S(x, e)$ are not known. However Eq.(2) is expected to hold for $Q^2 > 2(\text{GeV})^2$ where the first assumption of Drell and Yan is applicable, considering the exact Bjorken scaling observed in the deep inelastic lepton-nucleon scatterings and the behavior of e^+e^- annihilation into hadrons. Therefore Eq.(2) in the region $Q^2 > 2(\text{GeV})^2$ will provide a very important test of this modified Drell-Yan mechanism, since the density functions $f_1^V(x)$ are obtainable, in principle, from the deep inelastic lepton-nucleon scattering processes.

For the collision between two polarized protons, one with the spin $S_1=S$ and the other $S_2=\pm S$, Eq.(1) is replaced by

$$\left(\frac{d\sigma}{dQ^2 d\Omega d\phi}\right)_{S_1 S_2}^{\text{pp}} = \left(\frac{1}{3}\right)^2 \int dx_1 dx_2 \delta(Q^2 - x_1 x_2 s) \delta\left(P - \frac{\sqrt{s}}{2}(x_1 - x_2)\right) \times \sum_{\lambda_1=\pm S_1} \sum_{\lambda_2=\pm S_2} c_{pp}(\lambda_1, \lambda_2; S_1, S_2) \left(\frac{d\hat{\sigma}}{dQ^2 d\Omega d\phi}\right)_{\lambda_1 \lambda_2} \quad (3)$$

$$f_1^V(x, S; S) = \frac{1}{2} \left(f_1^V(x, S; S) + f_1^V(x, -S; S) \right) = f_1^V(x), \quad (6)$$

Substituting Eqs. (1), (3), and (5) into the relation (6), we obtain the relation (6) for the valence quark distributions $f_1^V(x)$, or vice versa. If we assume that the valence quark distributions $f_1^V(x)$ are known, then we can get the distributions for the modified distributions $f_1^V(x, S; S)$ to be valid. Substituting these valence quark distributions into Eqs. (1), (3), and (5), the effective sea quark distributions can be determined, and the strong interaction operators derived from the parton picture for quarks and gluons during hadronic interactions. Especially the sea quark distributions obtained from Eqs. (1) and (5) should be the same, and this will serve as a self-consistency check of the approach.

So far we have not discussed the detailed quark-parton models⁽¹²⁻¹⁵⁾ which predict the spin distributions of the valence quarks. We will only consider a very simple model here as an illustration. There exist the constraints $f_1^V(x, S; S) + f_1^V(x, -S; S) = f_1^V(x)$, where i stands for u or d quarks, and from $SU(3)$ symmetry $\int dx f_u^V(x) = 2 \int dx f_d^V(x) = 2$. We assume that the spin of the proton is simply the sum of the spin of the valence quarks. This leads to the constraint

$$\int dx \{f_u^V(x, S; S) - f_u^V(x, -S; S)\} + \int dx \{f_d^V(x, S; S) - f_d^V(x, -S; S)\} = 1. \quad (7)$$

The relation $f_1^V(x, S; S) = a_1 f_1^V(x)$ is further introduced to complete this simple quark model. Substituting these relations into Eq. (7), and with the help of the constraints we obtain the relation $a_d = 2(1 - a_u)$.

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References

1. E. W. Greife and T.-s. Yeh, *Phys. Rev. Lett.* 29, 216 (1970).
2. R. F. Styer, *Phys. Rev. Lett.* 23, 1448 (1969).
3. J. D. Bjorken, *Phys. Rev.* 179, 1547 (1969).
4. S. Jafarizadeh, D. Harnett and S. J. Lee, *Phys. Rev. Lett.* 33, 112 (1974).
5. G. E. Brown, *Nucl. Phys.* 271, 437 (1974).
6. J. L. Gunion, *Phys. Rev.* 140, 242 (1974).
7. H. P. Paar and E. A. Paschos, *Phys. Rev.* D10, 1502 (1974).
8. D. C. How et al., *Phys. Rev. Lett.* 37, 1374 (1976).
9. J. W. Cronin, Lecture at International School of Subnuclear Physics, Erice (1976).
10. P. V. Landshoff and J. C. Polkinghorne, *Nucl. Phys.* E33, 221 (1971).
11. J. D. Bjorken and H. Weisberg, *Phys. Rev.* D13, 1405 (1976).
12. J. Kuti and V. F. Weisskopf, *Phys. Rev.* D4, 3418 (1971).
13. F. Close, *Nucl. Phys.* E30, 269 (1974).
14. G. Domokos, S. Kovesi-Domokos, and E. Schonberg, *Phys. Rev.* D3, 1191 (1971).
15. S. D. Drell and T. G. Lee, *Phys. Rev.* D5, 1733 (1972).