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Mass suppression in octet baryon production

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There is a striking suppression of the cross section for production of octet baryons in e^+e^- annihilation, as the mass of the produced hadron increases. We present a simple parametrization for the fragmentation functions into octet baryons guided by two input models: the SU(3) flavor symmetry part is given by a quark-diquark model, and the baryon mass suppression part is inspired by the string model. We need only *eight* free parameters to describe the fragmentation functions for all octet baryons. These free parameters are determined by a fit to the experimental data of octet baryon production in e^+e^- annihilation. Then we apply the obtained fragmentation functions to predict the cross section of the octet baryon production in charged lepton deep inelastic scattering and find consistency with the available experimental data. Furthermore, baryon production in *pp* collisions is suggested to be an ideal domain to check the predicted mass suppression.

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I. INTRODUCTION

It is well known that there is an SU(3) flavor symmetry between the wave functions of the octet baryons. Very recent lattice QCD calculations also suggest that the Λ and proton quark structures can be related by an SU(3) transformation [1]. Unfortunately it is not possible to investigate the parton distributions of the octet hyperons by means of structure functions in deep inelastic scattering (DIS), since they cannot be used as a target due to their short lifetime. Also one obviously cannot produce a beam of charge-neutral hyperons such as Λ. Therefore there is no experimental information on the relation between the parton distributions of octet hyperons and those of the nucleon. However, it has been proposed that the quark fragmentation functions might be related to the corresponding quark distributions by a so called Gribov-Lipatov relation [2,3]. Therefore we can explore the relation between quark distributions of octet baryons by means of hyperon production from quark fragmentation. Actually great progress has been made along this direction recently [4,5].

A specific regularity in baryon production rates in e^+e^- annihilation has been recently noticed by Chliapnikov and Uvarov [6]. However, to our knowledge, there has not been a detailed investigation on the relation among the octet baryon fragmentation functions. The data show a striking suppression of the cross section as the mass of the produced hadron increases, which is puzzling since naive SU(3) would suggest that they should be comparable. For example, once an *s* quark is produced then one could think that the $\Sigma:\Lambda$ ratio would be $3:1$, since the *qq* pair is statistically three times more likely to be in an isospin $I=1$ state than in isospin $I=0$. Nevertheless the experimental data show just the opposite trend, with a lower cross section for Σ production (see Fig. 1). Apparently something in the fragmentation process makes it much easier for the *s* quark to pick up an isosinglet *qq* than an isotriplet.

In this paper we will not provide a detailed physical explanation of the suppression. Our, more modest, purpose is to give a consistent simple parametrization of all the fragmentation functions into octet baryons, with a rather small number of free parameters. Nevertheless, since the parametrizations that we obtain are inspired by well known input models, they can be considered as a first step into a physical understanding of these processes. For every octet baryon, there are 18 (unpolarized, longitudinally polarized and transversely polarized) quark/antiquark fragmentation functions. As a sensible parametrization of a fragmentation function usually needs at least 3 parameters, a lot of experimental data are needed in order to fix all of them. We plan to constrain the shape of fragmentation functions with the help of some models in order to reduce the number of free parameters. Models such as those using strings and shower algorithms [7] still involve many parameters, and therefore with these models it is difficult to obtain a clear relation among the fragmentation functions for various octet baryons. On the other hand, the diquark model given in Ref. [8] can provide us with SU(3) flavor symmetry relations for octet baryon fragmentation functions. An investigation of the spin structure of the diquark fragmentation functions can be found in previous publications [8–10]. It was found that the spin structure of the diquark model fragmentation functions for the Λ is supported by the available experimental data [9,10], which indicates that the diquark model works well in describing the fragmentation functions. In the present work, we will retain the flavor and spin structure of fragmentation functions as given by the diquark model and concentrate on

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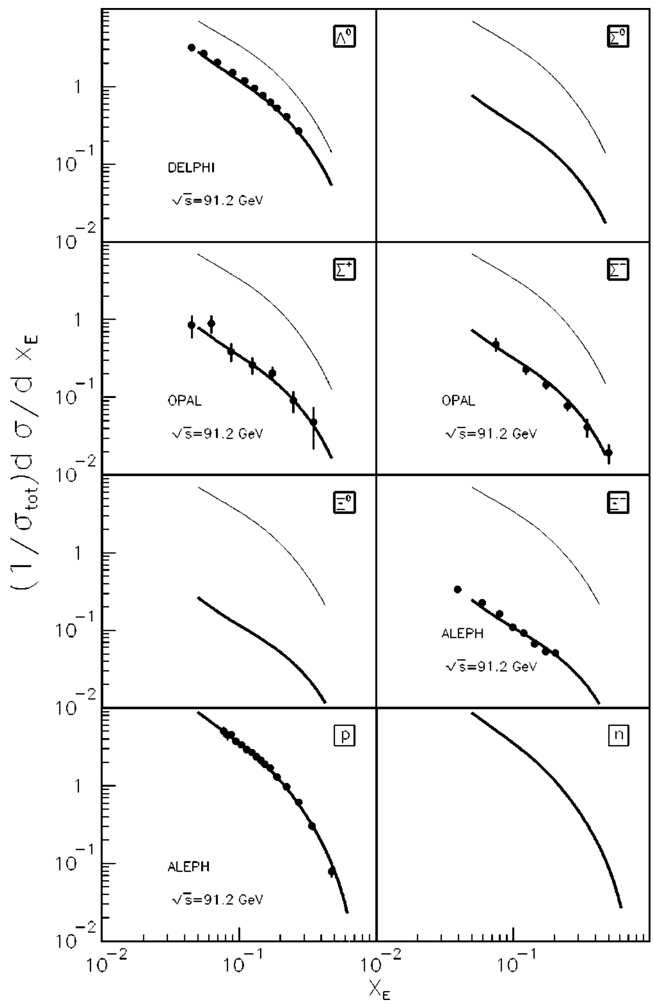

FIG. 1. The comparison of our fit results (thick solid curves) for the x_E dependence of the inclusive octet baryon production cross section $(1/\sigma_{tot})d\sigma/dx_E$ in e^+e^- annihilation and the experimental data [20–23]. The thin solid curves correspond to the results with the hyperon fragmentation functions deduced directly from the proton fragmentation functions by using SU(3) symmetry.

the relation between fragmentation functions of various octet baryons. We will emphasize the mass suppression effect in hyperon production.

The paper is organized as follows. In Sec. II, we briefly describe our ansatz of the fragmentation functions for all octet baryons based on the diquark model and the string model. Using only eight free parameters, we relate the fragmentation functions for all octet baryons to each other. The free parameters of the model are determined based on the experimental data on octet baryons production in e^+e^- annihilation, where the mass suppression effect in hyperon production is very important in order to understand the available experimental data. In Sec. III, we propose a possible cross check of the mass suppression via octet baryon production in charged lepton DIS. In Sec. IV, we give predictions for cross sections of baryon production in *pp* collisions with the obtained fragmentation functions for the octet baryons. Finally, we give a summary with our conclusions in Sec. V.

II. QUARK FRAGMENTATION FUNCTIONS FOR THE OCTET BARYONS

Recently, it was found that a simple diquark model can be used to describe quite accurately the octet baryon fragmentation functions [8–10]. The parameters of the model were determined by fitting the experimental data of octet baryon production in e^+e^- annihilation. In this work, we adopt an alternative approach and present a parametrization based on the spin and flavor structure predicted by the diquark model. We focus our attention on the relation between the fragmentation functions of various octet baryons.

In contrast to the nucleon parton distributions which are well determined by experimental data, we have much less information on fragmentation functions for the octet baryons. For this reason, we constrain the fragmentation functions with the help of some models in order to reduce the number of free parameters. In particular the diquark model [8] has a clear physical motivation and needs only a few parameters.

Within the framework of the diquark model [8], the unpolarized valence quark to proton fragmentation functions can be expressed as

$$D^p_{u_v}(z)=\frac{1}{2}a_S^{(u/p)}(z)+\frac{1}{6}a_V^{(u/p)}(z), \tag{1}$$

$$D^p_{d_v}(z)=\frac{1}{3}a_V^{(d/p)}(z), \tag{2}$$

where $a_D^{(q/p)}(z)$ ($D=S$ or V) is the probability of finding a quark q splitting into the proton p with longitudinal momentum fraction z and emitting a scalar (S) or axial vector (V) antidiquark. The form factors for scalar and axial vector diquark are customarily taken to have the same form

$$\phi(k^2)=N\frac{k^2-m_q^2}{(k^2-\Lambda_0^2)^2}, \tag{3}$$

with a normalization constant N and a mass parameter Λ_0. The value $\Lambda_0=500$ MeV is usually adopted in numerical calculations. In Eq. (3), m_q and k are the mass and the momentum of the fragmenting quark q, respectively. According to Ref. [8], in the quark-diquark model $a_D^{(q/p)}(z)$ can be expressed as

$$a_D^{(q/p)}(z)=\frac{N^2z^2(1-z)^3}{64\pi^2}\frac{[2(M_p+m_qz)^2+R^2(z)]}{R^6(z)} \tag{4}$$

with

$$R(z)=\sqrt{zm_D^2-z(1-z)\Lambda_0^2+(1-z)M_p^2}, \tag{5}$$

where M_p and m_D ($D=S$ or V) are the mass of the proton and diquark, respectively. We choose the values for the diquark masses to be $m_S=900$ MeV and $m_V=1100$ MeV, for scalar and axial vector diquark states, respectively. The quark masses are taken as $m_u=m_d=350$ MeV.

Similarly, the longitudinally and transversely polarized quark to proton fragmentation functions can be written as

$$\Delta D_{u_v}^{p}(z)=\frac{1}{2}\tilde{a}_S^{(u/p)}(z)-\frac{1}{18}\tilde{a}_V^{(u/p)}(z), \tag{6}$$

$$\Delta D_{d_v}^{p}(z)=-\frac{1}{9}\tilde{a}_V^{(d/p)}(z), \tag{7}$$

$$\delta D_{u_v}^{p}(z)=\frac{1}{2}\hat{a}_S^{(u/p)}(z)-\frac{1}{18}\hat{a}_V^{(u/p)}(z), \tag{8}$$

$$\delta D_{d_v}^{p}(z)=-\frac{1}{9}\hat{a}_V^{(d/p)}(z), \tag{9}$$

with

$$\tilde{a}_D^{(q/p)}(z)=\frac{N^2z^2(1-z)^3}{64\pi^2}\frac{[2(M_p+m_qz)^2-R^2(z)]}{R^6(z)}, \tag{10}$$

and

$$\hat{a}_D^{(q/p)}(z)=\frac{N^2z^2(1-z)^3}{32\pi^2}\frac{(M_p+m_qz)^2}{R^6(z)}, \tag{11}$$

for $D=S$ or V. Here we are not interested in the absolute magnitude of the fragmentation functions but in the flavor and spin structure of them, which is given by the diquark model. In order to extract the flavor and spin structure information, we introduce flavor structure ratios

$$F_V^{(u/d)}(z)=\frac{a_V^{(u/p)}(z)}{a_V^{(d/p)}(z)}, \tag{12}$$

$$F_M^{(u/d)}(z)=\frac{a_S^{(u/p)}(z)}{a_V^{(d/p)}(z)}, \tag{13}$$

and spin structure ratios

$$W_D^{(q/p)}(z)=\frac{\tilde{a}_D^{(q/p)}(z)}{a_D^{(q/p)}(z)}, \tag{14}$$

$$\hat{W}_D^{(q/p)}(z)=\frac{\hat{a}_D^{(q/p)}(z)}{a_D^{(q/p)}(z)}, \tag{15}$$

with $D=S$ or V. Then we can use the fragmentation function $D_{d_v}^{p}(z)$ to express all other unpolarized and polarized fragmentation functions for the proton as follows:

$$D_{u_v}^{p}(z)=\frac{1}{2}[F_V^{(u/d)}(z)+3F_M^{(u/d)}(z)]D_{d_v}^{p}(z), \tag{16}$$

$$\Delta D_{u_v}^{p}(z)=\frac{3}{2}\left[W_S^{(u/p)}(z)F_M^{(u/d)}(z)-\frac{1}{9}W_V^{(u/p)}(z)F_V^{(u/d)}(z)\right]D_{d_v}^{p}(z), \tag{17}$$

$$\Delta D_{d_v}^{p}(z)=-\frac{1}{3}W_V^{(d/p)}(z)D_{d_v}^{p}(z), \tag{18}$$

$$\delta D_{u_v}^{p}(z)=\frac{3}{2}\left[\hat{W}_S^{(u/p)}(z)F_M^{(u/d)}(z)-\frac{1}{9}\hat{W}_V^{(u/p)}(z)F_V^{(u/d)}(z)\right]D_{d_v}^{p}(z), \tag{19}$$

and

$$\delta D_{d_v}^{p}(z)=-\frac{1}{3}\hat{W}_V^{(d/p)}(z)D_{d_v}^{p}(z). \tag{20}$$

The spin structure of the quark-diquark fragmentation functions for the Λ has been studied before [9,10], and it is supported by the available experimental data on Λ production in various processes [11–16]. In this work, we retain the flavor and spin structure of the fragmentation functions suggested by the diquark model.

From the above analysis, we find out that the essential ingredient is to choose a suitable shape for the function $D_{d_v}^{p}(z)$ from which the other valence fragmentation functions can then be deduced. We could use the expression of $D_{d_v}^{p}(z)$ coming from the diquark approach and fix the parameters of the model by a fit to the experimental data as it was done in Ref. [10]. Another way is to use a commonly accepted parametrization form such as

$$D_{d_v}^{p}(z,Q_0^2)=N_v z^{\alpha_v}(1-z)^{\beta_v}, \tag{21}$$

with the exponents α_v and β_v at an initial scale Q_0^2. Previous work [9,10] indicates that compatible results can be obtained in both ways. In our present analysis, we adopt the latter approach, with the analytical expression (21) for $D_{d_v}^{p}(z)$, since this simple parametrization can be easily used later for other purposes. In addition, the diquark model fragmentation functions are easier to describe in the large z region where the valence quark contribution dominates. In the small z region, the sea contribution is difficult to include in the framework of the diquark model. Nevertheless, we also adopt a similar functional form

$$D_{q_s}^{p}(z,Q_0^2)=D_{\bar{q}}^{p}(z,Q_0^2)=N_s z^{\alpha_s}(1-z)^{\beta_s} \tag{22}$$

to parametrize fragmentation functions of the sea quark $D_{q_s}^{p}(z)$ and antiquark $D_{\bar{q}}^{p}(z)$ for $q=u,d,s$ at the initial scale Q_0^2. For simplicity, we take the same initial parametrization for the spin independent gluon and the sea quark fragmentation functions, and moreover we assume that ΔD_g^p, δD_g^p,

$\Delta D^p_{q_s(\bar{q})}$, and $\delta D^p_{q_s(\bar{q})}$ at the initial scale are zero and that they are only generated by QCD evolution.

Hence, the input unpolarized and polarized quark to proton fragmentation functions can be written as

$$D_q^{p[\mathrm{SU}(3)]}(z,Q_0^2)=D^p_{q_v}(z,Q_0^2)+D^p_{q_s}(z,Q_0^2), \tag{23}$$

$$\Delta D_q^{p[\mathrm{SU}(3)]}(z,Q_0^2)=\Delta D^p_{q_v}(z,Q_0^2), \tag{24}$$

and

$$\delta D_q^{p[\mathrm{SU}(3)]}(z,Q_0^2)=\delta D^p_{q_v}(z,Q_0^2). \tag{25}$$

Now we deduce the fragmentation functions $D_{q(g)}^{B[\mathrm{SU}(3)]}$ for all other octet baryons B by SU(3) symmetry at the initial scale Q_0^2. More specifically, we have

$$\begin{aligned} D_u^{p[\mathrm{SU}(3)]}&=D_d^{n[\mathrm{SU}(3)]}=D_u^{\Sigma^+[\mathrm{SU}(3)]}=D_d^{\Sigma^-[\mathrm{SU}(3)]}=D_s^{\Xi^-[\mathrm{SU}(3)]}=D_s^{\Xi^0[\mathrm{SU}(3)]}\\ &=\frac{2}{3}D_u^{\Lambda[\mathrm{SU}(3)]}+\frac{4}{3}D_s^{\Lambda[\mathrm{SU}(3)]}=2D_u^{\Sigma^0[\mathrm{SU}(3)]}=2D_d^{\Sigma^0[\mathrm{SU}(3)]};\\ D_d^{p[\mathrm{SU}(3)]}&=D_u^{n[\mathrm{SU}(3)]}=D_s^{\Sigma^+[\mathrm{SU}(3)]}=D_s^{\Sigma^-[\mathrm{SU}(3)]}=D_d^{\Xi^-[\mathrm{SU}(3)]}=D_u^{\Xi^0[\mathrm{SU}(3)]}\\ &=\frac{4}{3}D_u^{\Lambda[\mathrm{SU}(3)]}-\frac{1}{3}D_s^{\Lambda[\mathrm{SU}(3)]}=D_s^{\Sigma^0[\mathrm{SU}(3)]}, \end{aligned} \tag{26}$$

with similar relations for the polarized fragmentation functions. We assume that the sea quark fragmentation functions also have the above SU(3) relations. In principle the diquark model can also be used to partly reflect the SU(3) flavor symmetry breaking effect if the differences in the quark, antidiquark, and baryon masses are taken into account in the probabilities $a_D^{(q/B)}(z)$ [10] for a quark q fragmenting into the baryon B. However the SU(3) symmetry breaking effect due to this difference in quark, diquark and baryon masses in the diquark model is too weak to explain the experimentally measured values for the average hadronic multiplicities per hadronic e^+e^- annihilation event [17], where hyperon production is significantly suppressed as compared with proton production. Actually, we find that the cross sections for Λ, Σ, and Ξ baryons in e^+e^- annihilation would be overestimated by up to two orders of magnitude if we only considered this SU(3) symmetry breaking in the framework of the diquark model. We have to search for another possible source of the suppression effect in hyperon production. In Ref. [18], a description of the strangeness suppression effect was proposed by putting a suppression factor in the u, d, and sea quark fragmentation functions for baryons containing a valence s quark (and a further overall suppression factor for baryons containing two s quarks). In our present analysis, we will consider an alternative suppression mechanism due to the hyperon masses which is inspired by the string model [19]. For simplicity, we do not include SU(3) symmetry breaking caused by the difference in quark, diquark and baryon masses in the diquark model itself since this is small. We introduce an additional mass suppression factor for the SU(3) symmetric fragmentation functions of the diquark model. This overall mass suppression factor should not alter significantly the flavor and spin structure of the fragmentation functions as given by the diquark model. More specifically, we assume that the quark q to baryon B fragmentation function can be expressed as follows:

$$D_q^B(z)=D_q^{B[\mathrm{SU}(3)]}(z)(2J+1)\left\{1+\frac{|S|}{(2I+1)}\right\}\times\exp[-bM_B^2/z^c] \tag{27}$$

where S, I, J and M_B are the strangeness, isospin, spin and mass of the octet baryon B. The term within the curly brackets is a strangeness modification factor. The mass suppression factor is inspired by the string model [19], and $D_q^{B[SU(3)]}(z)$ is the SU(3) diquark model fragmentation functions for the octet baryon B.

To summarize, our model which describes the fragmentation functions of all the octet baryons involves a total of *eight* free parameters:

$$N_v,\alpha_v,\beta_v,N_s,\alpha_s,\beta_s,b,c. \tag{28}$$

For a fit to the experimental data, the fragmentation functions have to be evolved from the initial scale Q_0 to the scale of the experiments. We take the input scale $Q_0^2=1.0\ \mathrm{GeV}^2$ and the QCD scale parameter $\Lambda_{QCD}=0.3$ GeV, and determine the free parameters of the model by fitting the experimental data [20–23] on the differential cross sections

$$\frac{1}{\sigma_{tot}}\frac{d\sigma}{dx_E}=\frac{\sum_q \hat{C}_q[D_q^B(x_E,Q^2)+D_{\bar{q}}^B(x_E,Q^2)]}{\sum_q \hat{C}_q} \tag{29}$$

for semi-inclusive octet baryon production $e^+e^-\to B+X$, where σ_{tot} is the total cross section for the process and x_E

TABLE I. The parameters for the diquark model with the strangeness suppression.

N_v	α_v	β_v	N_s	α_s	β_s	b (GeV^{-2})	c
161.602	1.450	4.313	121.292	−0.251	8.161	3.394	0.241

$=2E_B/\sqrt{s}$. Here s is the total center-of-mass (c.m.) energy squared, and E_B the energy of the produced proton in the e^+e^- c.m. frame. In Eq. (29), $\hat{C}_q$ reads

$$\hat{C}_q = e_q^2 - 2\chi_1 v_e v_q e_q + \chi_2 (a_e^2 + v_e^2)(a_q^2 + v_q^2), \tag{30}$$

with

$$\chi_1 = \frac{1}{16\sin^2\theta_W \cos^2\theta_W} \frac{s(s-M_Z^2)}{(s-M_Z^2)^2 + M_Z^2\Gamma_Z^2}, \tag{31}$$

$$\chi_2 = \frac{1}{256\sin^4\theta_W \cos^4\theta_W} \frac{s^2}{(s-M_Z^2)^2 + M_Z^2\Gamma_Z^2}, \tag{32}$$

$$a_e = -1, \tag{33}$$

$$v_e = -1 + 4\sin^2\theta_W, \tag{34}$$

$$a_q = 2T_{3q}, \tag{35}$$

and

$$v_q = 2T_{3q} - 4e_q \sin^2\theta_W, \tag{36}$$

where $T_{3q}=1/2$ for u, while $T_{3q}=-1/2$ for d, s quarks, e_q is the charge of the quark in units of the proton charge, θ is the angle between the outgoing quark and the incoming electron, θ_W is the Weinberg angle, and M_Z and Γ_Z are the mass and width of Z^0.

We perform a leading order (LO) analysis since the results in Refs. [24,25] show that the leading order fit is of similar quality as the next-to-leading order fit. Also, the LO analysis should be enough in order to outline the qualitative feature of mass suppression in baryon production. In addition, we only use $z>0.1$ data samples because understanding the very low-z region data needs further modifications to the evolution of the fragmentation functions [24,25]. However, we find that some of the data in the low-z region can still be described by our fragmentation functions. With the above mentioned cut, we have a total of 157 experimental data points [20–23]. Eight free parameters of our initial parametrizations are determined by performing a fit to the experimental data. The total χ^2 value of the fit is 192.362, which corresponds to χ^2/point=1.225. The values of the parameters of our model are given in Table I.

In Fig. 1, we give the fit results (thick solid curves) as compared with the experimental data. In order to provide a clear comparison between the experimental data and the fit curves, only part of the data are shown in the figure and a similar fit quality is obtained for other data points. We also present the results for the cross sections for hyperon production with the hyperon fragmentation functions deduced directly from the proton fragmentation functions by means of the SU(3) flavor symmetry relation (see the thin solid curves in Fig. 1). By comparing the thick and thin curves, one can find that the mass suppression effect in the cross section of hyperon production is significant. In addition, we also show in Fig. 2 the fit results for Λ production at various center of mass energies, which indicates that the QCD evolution behavior of the fragmentation functions is reasonable.

III. OCTET BARYON PRODUCTION IN CHARGED LEPTON DIS

A. Unpolarized case

In the above section, we showed a strong mass suppression effect in hyperon production. This is an extra SU(3)

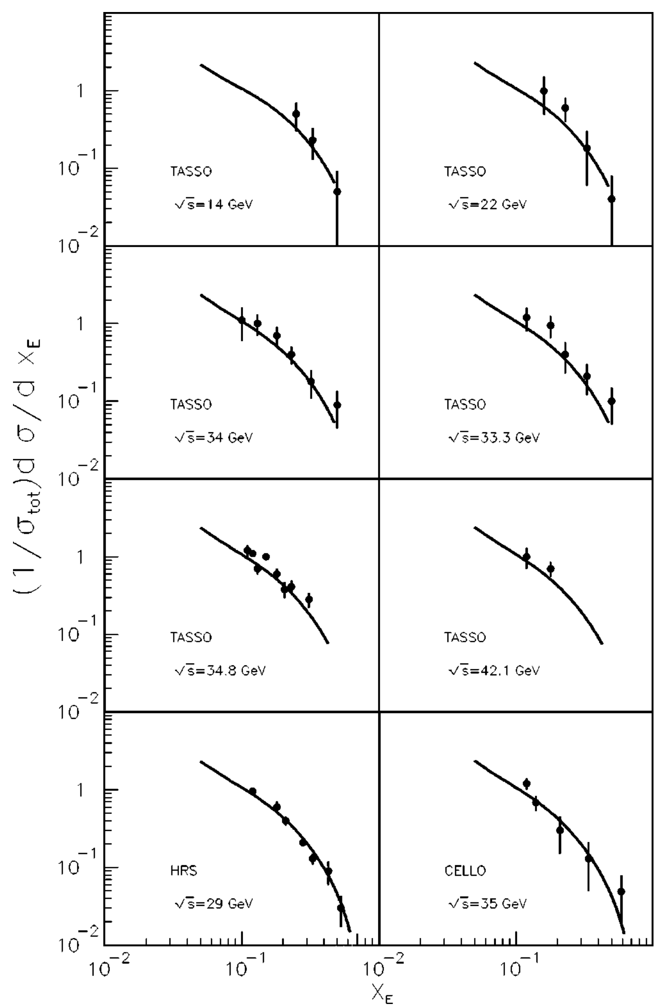

FIG. 2. The comparison of our fit results for the x_E dependence of the inclusive Λ production cross section $(1/\sigma_{tot})d\sigma/dx_E$ in e^+e^- annihilation and the experimental data [23,24].

symmetry breaking distinct from that due to the quark and diquark mass differences in the diquark model fragmentation functions, and is effectively described by a mass suppression factor in the octet baryon fragmentation functions. We need a cross check of this mass suppression effect from a different process. Thus we apply the obtained fragmentation functions to calculate the cross sections of octet baryon production in charged lepton DIS.

To leading order, the cross section for the process

$$l+p\rightarrow B+X \tag{37}$$

can be expressed as

$$\frac{1}{\sigma_{tot}}\frac{\mathrm{d}\sigma}{\mathrm{d}z\mathrm{d}x}=\frac{\sum e_q^2 q(x)D_q^B(z)+(q\rightarrow\overline{q})}{\sum e_q^2}, \tag{38}$$

where $q(x)$ is the quark distribution in the target nucleon. By inserting the fragmentation functions for the octet baryons into the above cross section, and using the CTEQ5 [26] quark distributions in the target nucleon, we get the numerical results shown in Fig. 3, where the x-integrated cross sections $(1/\sigma_{tot})\mathrm{d}\sigma/\mathrm{d}z$ for baryon (thick solid curves) and antibaryon (thick dashed curves) production are compared with the available experimental data. In the calculation we have taken $Q^2=50\ \mathrm{GeV}^2$ and the x integration range [0.02, 0.4].

We find that the theoretical predictions are compatible with the available experimental data. In Fig. 3, we also show the calculated results with the hyperon fragmentation functions deduced directly from the proton fragmentation functions by using the SU(3) symmetry (thin curves). The experimental data are taken from Refs. [27–29]. The data points with full circles, triangles and squares are for particle production measured by the E665, EMC and H1 Collaborations, respectively; open circles and triangles indicate the data for antiparticle production measured by the E665 Collaboration and European Muon Collaboration (EMC), respectively. The mass suppression effect in hyperon production, especially in Σ and Ξ production, is evident. Therefore, the hyperon production in charged DIS is an ideal place to check the proposed mass suppression effect.

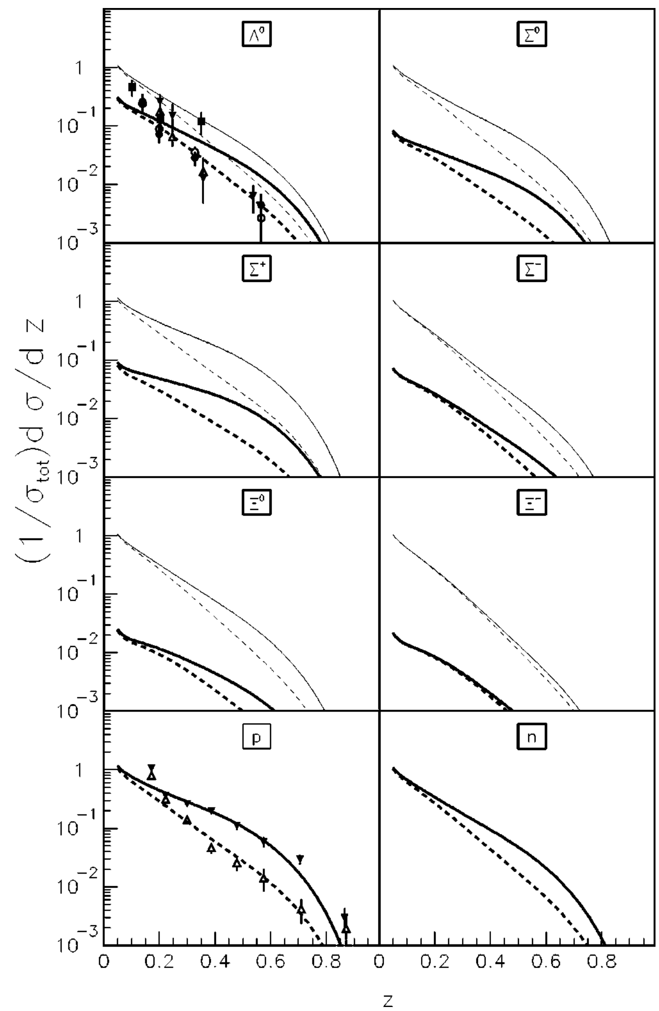

FIG. 3. The cross sections for baryons (thick solid curves) and antibaryons (thick dashed curves) production in charged lepton DIS, obtained with our fragmentation functions. The results with the hyperon fragmentation functions deduced directly from the proton fragmentation functions by using the SU(3) symmetry are also shown for hyperons (thin solid curves) and antihyperons (thin dashed curves) production. The experimental data are taken from Refs. [27–29]. The original SIDIS data in terms of x_F have been converted to the variable z by using the method of Ref. [24].

B. Polarized case

Recently experimental data on the spin transfer to Λ in charged lepton DIS have become available. The spin transfer is a good observable to check the helicity structure of the fragmentation functions for a baryon. In longitudinally polarized charged lepton DIS on an unpolarized proton target, the produced baryon polarization along its own momentum axis is given in the quark parton model by

$$P_B(x,y,z)=P_b D(y)A_B(x,z), \tag{39}$$

where P_b is the polarization of the charged lepton beam, $D(y)$ with $y=\nu/E$ is the longitudinal depolarization factor of the virtual photon with respect to the parent lepton, and

$$A_B(x,z)=\frac{\sum_q e_q^2[q(x,Q^2)\Delta D_q^B(z,Q^2)+(q\rightarrow\overline{q})]}{\sum_q e_q^2[q(x,Q^2)D_q^B(z,Q^2)+(q\rightarrow\overline{q})]}, \tag{40}$$

is the longitudinal spin transfer to the baryon B.

In order to check the spin structure of the obtained fragmentation functions, we calculate the x-integrated spin transfer to octet baryons in charged lepton DIS. The numerical results are shown in Fig. 4. Our theoretical predictions are consistent with the available experimental data on Λ production.

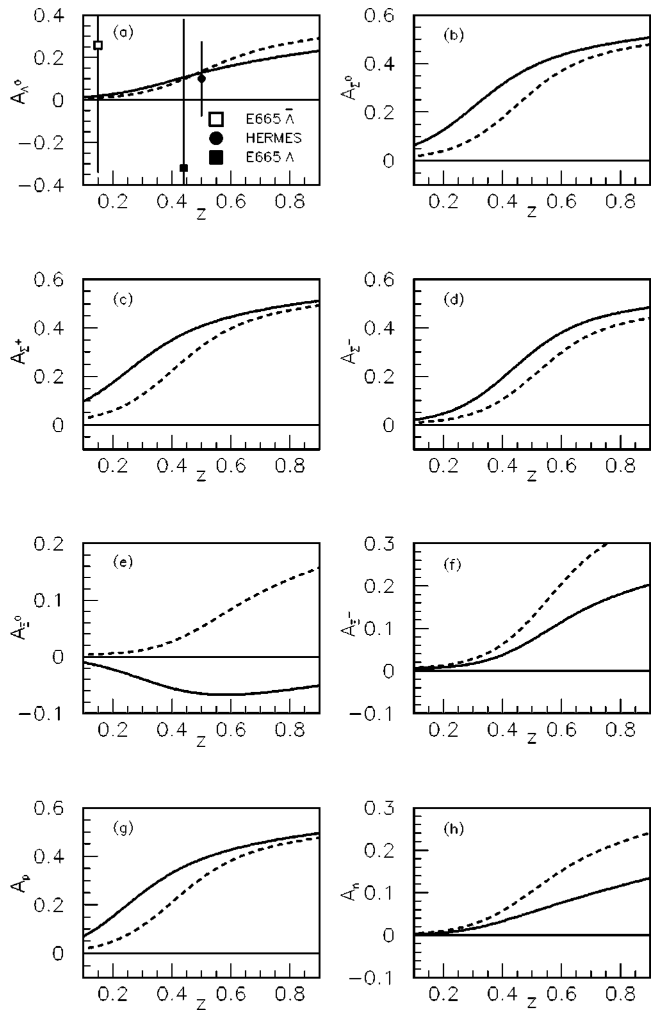

FIG. 4. The spin transfer to baryons (solid curves) and antibaryons (dashed curves) production in charged lepton DIS obtained with our fragmentation functions. The experimental data are taken from Refs. [14,15].

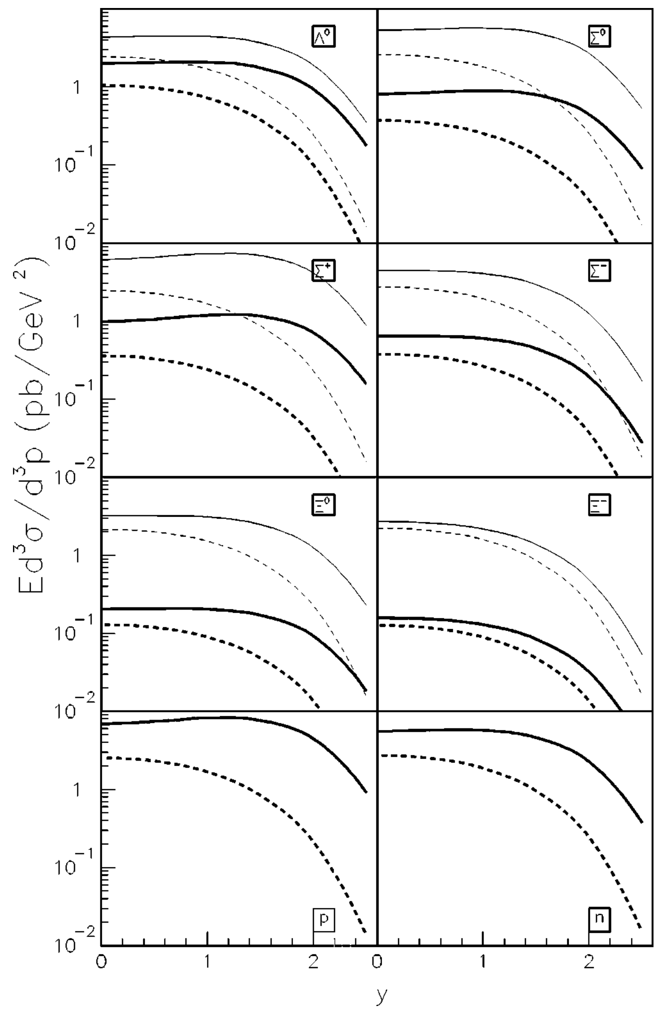

FIG. 5. The cross sections for baryons (thick solid curves) and antibaryons (thick dashed curves) production in pp collisions are predicted at $\sqrt{s}=500$ GeV and $p_T=15$ GeV/c. The results with the hyperon fragmentation functions deduced directly from the proton fragmentation functions by using the SU(3) symmetry relation are also shown for hyperons (thin solid curves) and antihyperons (thin dashed curves) production.

IV. OCTET BARYON PRODUCTION IN *pp* COLLISIONS

In the near future, new experimental data will become available on hadron production in *pp* collisions at BNL Relativistic Heavy Ion Collider (RHIC) [30]. Therefore, it is interesting to predict the cross sections for octet baryon production in *pp* collisions in order to have a further check of the mass suppression effect in octet hyperon production.

In leading order of perturbative QCD, the differential cross section for the $pp\to BX$ process can be schematically written in a factorized form as [31]

$$E\frac{d^3\sigma}{d^3p}=\sum_{abcd}\int_{\bar{x}_a}^{1}dx_a\int_{\bar{x}_b}^{1}dx_b f_a^{\tilde{A}}(x_a,Q^2)f_b^{\tilde{B}}(x_b,Q^2)\times D_c^B(z,Q^2)\frac{1}{\pi z}\frac{d\hat{\sigma}}{d\hat{t}}(ab\to cd), \tag{41}$$

with

$$\bar{x}_a=\frac{x_T e^{y}}{2-x_T e^{-y}},\quad \bar{x}_b=\frac{x_a x_T e^{-y}}{2x_a-x_T e^{y}},$$

$$z=\frac{x_T}{2x_b}e^{-y}+\frac{x_T}{2x_a}e^{y}, \tag{42}$$

where $x_T=2p_T/\sqrt{s}$, $\sqrt{s}$ is the center of mass energy of the *pp* collision; p_T, E and y are the transverse momentum, energy and rapidity of the produced baryon B; $f_a^{\tilde{A}}(x_a,Q^2)$ and $f_b^{\tilde{B}}(x_b,Q^2)$ are the unpolarized distribution functions of partons a and b in the protons $\tilde{A}$ and $\tilde{B}$ at the scale $Q^2=p_T^2$; $D_c^B(z,Q^2)$ is the fragmentation function which we have obtained in Sec. II; $d\hat{\sigma}/d\hat{t}$ is the differential cross section for the subprocess $a+b\to c+d$, and $\hat{t}=-x_a p_T\sqrt{s}e^{-y}/z$ is the Mandelstam variable at the parton level.

By charge-conjugation invariance, the $e^+e^- \to BX$ cross section for baryon production should be equal to that for the corresponding antibaryon production process. Therefore, only the combinations $D_q^B + D_q^{\bar{B}}$ can be determined, and the same holds for the antiquark fragmentation functions. However, in *pp* collisions we can observe differences in the cross sections for baryon and antibaryon production. Therefore in this case we also predict the cross sections for antibaryon $\bar{B}$ production, whose quark fragmentation functions can be obtained according to the matter-antimatter symmetry $D_{q,\bar{q}}^B(z) = D_{\bar{q},q}^{\bar{B}}(z)$.

By adopting the LO set of unpolarized parton distributions of Ref. [32], we present in Fig. 5 the cross sections for octet baryons (thick solid curves) and antibaryons (thick dashed curves) produced in *pp* collisions. These results are calculated at $\sqrt{s} = 500$ GeV and $p_T = 15$ GeV/c. As a comparison, we also calculate the cross sections with the hyperon fragmentation functions deduced directly from the proton fragmentation functions by using the SU(3) symmetry relation (thin curves). By comparing the thick and thin curves, one can find that the mass suppression effect in hyperon production from *pp* collisions is also significant. Therefore, the cross sections for the octet hyperon production in *pp* collisions should be another ideal domain where the mass suppression effect can be checked. Although some experiments for baryon production in *pp* collisions have been done [33], the available data were taken in the low-p_T region. We need some data at high-p_T in order to check our partonic framework predictions. This may be realized by RHIC-BNL [30,31,34] in the near future.

V. SUMMARY

Based on the quark diquark model, the fragmentation functions for all octet baryons are related by the SU(3) relation. Nevertheless the hadronic multiplicities measurements in electron-positron annihilation indicate a strong suppression in octet hyperon production as compared with proton production, which cannot be explained by the SU(3) symmetry breaking within the diquark model framework. Inspired by the phenomenology of the string model, we proposed an overall mass suppression factor for both unpolarized and polarized octet baryon fragmentation functions, retaining the flavor and spin structure of the fragmentation functions given by the diquark model. We found that the diquark model with the mass suppression factor can be used to describe quite accurately the fragmentation functions for all octet baryons with *eight* free parameters. The parameters were determined by a fit to the available experimental data on the octet baryon production in electron-positron annihilation. We used eight parameters; three for the unpolarized valence down quark to proton fragmentation function $D_{d_v}^p(z)$ [see Eq. (21)], while all other unpolarized and polarized valence quark fragmentation functions for the proton follow from the diquark model [Eqs. (16)–(20)]; three parameters for the sea quark fragmentation functions [Eq. (22)]; and finally two more for the suppression factor [Eq. (27)]. In addition, the diquark model plays an important role in relating fragmentation functions for all octet baryons to each other [see Eq. (26)].

The mass suppression factor leads to an enormous simplification in our analysis and plays an important role in our understanding of the experimental data on the unpolarized hyperon production in e^+e^- annihilation. This mechanism needs to be further checked. The octet baryon fragmentation functions, determined from the $e^+e^- \to BX$ process, can be used to predict inclusive single baryon production cross sections in other processes, like *pp*, $p\bar{p}$, *ep*, νp, μp and γp scattering. With the obtained fragmentation functions, we calculated the cross section for octet baryon production in charged lepton DIS, and our predictions are compatible with the available experimental data. Furthermore, we predicted cross sections for octet baryon production in *pp* collisions. We investigated the mass suppression effect of hyperon production in charged lepton DIS and *pp* collisions, and found that these two processes are ideal places for checking the proposed mass suppression effect when further experimental data become available.

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