Determination of flavor asymmetry for $\Sigma^{\pm}$
by the Drell-Yan process

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Abstract

Flavor asymmetries for the valence and sea quarks of the $\Sigma^{\pm}$ can be obtained from Drell-Yan experiments using charged hyperon beams on proton and deuteron targets. A large, measurable difference in sea quark asymmetries is predicted between SU(3) and pseudoscalar meson models. The latter predict that in $\Sigma^+$, $\bar{u}/\bar{d} \leq 1/2$, whereas the former predict $\bar{u}/\bar{d} \approx 4/3$. Estimates of valence quark asymmetries based on quark models also show large deviations from SU(3) predictions, which should be measurable.

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Parton distributions contain a wealth of information concerning the non-perturbative structure of hadrons. While most attention has so far been paid to the distributions of the nucleon, through the Drell-Yan process one can also get information on the parton distributions of the hyperons. We shall be concerned with the predictions of the distributions for the \( \Sigma^\pm \) hyperons in various models, including: (1) a quark and meson model, (2) an SU(3) model and (3) a model involving the coupling of octets of mesons and baryons (without regard to mass). In particular, a comparison of \( \Sigma^\pm \) and proton structure functions can be used to differentiate between these models. We show that measurements of the Drell-Yan process for \( \Sigma^\pm \) scattering on protons and neutrons (in deuteron targets) allow one to extract information on the parton distributions of the \( \Sigma^\pm \) and that the expectations are quantitatively quite different for (1), (2) and (3), above. In particular, we find that measurements of the \( \bar{u}/\bar{d} \) ratio in the \( \Sigma^+ \) are very sensitive to the model chosen, and that a quark-diquark model of the hyperon predicts large SU(3) violations in the valence quark distributions.

One of the surprises in the structure of the proton is that the sea appears to have a flavor asymmetry, an excess of \( \bar{d} \) compared to \( \bar{u} \) [1–3]. Although the experimental results could imply some violation of isospin, this appears to be less likely, and we interpret them as an SU(2)\(_Q\) flavor asymmetry in the sea [4]. Thus, the \( \bar{d} \) excess in the proton is expected to be reflected in an excess of \( \bar{u} \) in the neutron; isospin symmetry would be broken if this were not the case. The evidence for flavor asymmetry in the proton sea is based on analyses of deep inelastic muon scattering [1,2] and Drell-Yan processes [3]. One explanation that has been offered is that the excess of \( \bar{d} \) over \( \bar{u} \) is due to the Pauli exclusion principle [3,7]. A more likely explanation, in our view, is that offered by Thomas and colleagues [8–12], Henley and Miller [13], and others [14–21], namely that the presence of a pion cloud surrounding a proton favors \( \bar{d} \) over \( \bar{u} \) because of the excess positive charge of the meson cloud.

It is interesting to apply these arguments to the strange baryons and to compare them with SU(3). Here we focus on the charged \( \Sigma^+ \) (\( \Sigma^- \)), composed of \( uus \) (\( dds \)) valence quarks. Thus the main difference from the \( p(n) \) case is the replacement of a valence \( d(u) \) quark by an
s quark. In the following, the quark distribution \( q(u, d, \text{or } s) \) without subscripts refers to the proton, and with a \( \Sigma \) subscript refers to the \( \Sigma^+ \). The \( x \)-dependence of these distributions is implied, but not shown explicitly. With neglect of mass effects or under SU(3),

\[
\bar{r} \equiv \frac{\bar{u}}{\bar{d}} = \frac{\bar{u}_\Sigma}{\bar{s}_\Sigma} = 0.51 \pm 0.04 \pm 0.05,
\]

where the experimental ratio \([3]\) is that obtained for the proton at \( x \approx 0.18 \).

The ratio \( \kappa \equiv 2\bar{s}/(\bar{d} + \bar{u}) \) is a measure of the strange quark content of the nucleon. It has been determined experimentally in neutrino-induced charm production \([22–24]\) to be in the range \( 0.373^{+0.048}_{-0.041} \pm 0.018 \leq \kappa \leq 0.57 \pm 0.09 \). The CTEQ \([25]\) determination of parton distributions from global QCD analyses of experimental data uses the value \( \kappa = 0.5 \), from which

\[
\bar{r}_\Sigma \equiv \frac{\bar{s}}{\bar{u} + \bar{d}} = \frac{\kappa}{2} = 0.25,
\]

so with \( \bar{d} \approx 2\bar{u} \) from Eq. 1,

\[
\frac{1}{\bar{r}_\Sigma} \equiv \frac{\bar{d}_\Sigma}{\bar{u}_\Sigma} = \frac{\bar{s}}{\bar{u}} \approx 0.75.
\]

We also find

\[
\frac{\bar{d}_\Sigma}{\bar{s}_\Sigma} = \frac{\bar{s}}{\bar{d}} \approx 0.38
\]

from the same analysis.

For the model of quarks surrounded by light pseudoscalar mesons, the \( \Sigma^+ \) has an excess of \( \bar{d} \) over \( \bar{u} \) (and the opposite for the \( \Sigma^- \)) in contradistinction to the SU(3) prediction. If we neglect higher masses, then the \( \Sigma^+(uus) \) will have components \( \Lambda^0(uds)\pi^+(ud\bar{d}) \), \( \Sigma^0(uus)\pi^0(1/\sqrt{2}[dd - uu]) \), or \( p(uud)\bar{K}^0(d\bar{s}) \); similarly a \( \Sigma^-(dds) \) can be \( \Lambda^0(uds)\pi^-(d\bar{u}) \), \( \Sigma^0(uus)\pi^-(d\bar{u}) \), \( \Sigma^-(dds)\pi^0(1/\sqrt{2}[dd - uu]) \), or \( n(udd)\bar{K}^- (\bar{u}s) \). Thus there is a clear enhancement of \( \bar{d} \) for \( \Sigma^+ \) and \( \bar{u} \) for \( \Sigma^- \) and we expect \( \bar{r}_\Sigma \leq 0.5 \).

We also consider an SU(3) model in which a baryon is composed of octets of baryons and mesons. We use the SU(3) isoscalar factors and representation matrices given by the Particle Data Group \([26]\). For \( 8_1 \rightarrow 8 \otimes 8 \)
\[ N \to \frac{g_1}{\sqrt{20}} [3N\pi - N\eta - 3\Sigma K - \Lambda K], \]  

(5)

and for \(8_2 \to 8 \otimes 8\)

\[ N \to \frac{g_2}{\sqrt{12}} [\sqrt{3}N\pi + \sqrt{3}N\eta + \sqrt{3}\Sigma K - \sqrt{3}\Lambda K]. \]  

(6)

The standard \(D\) and \(F\) couplings are related to \(g_1\) and \(g_2\) by

\[ D = \frac{\sqrt{30}}{40} g_1 \text{ and } F = \frac{\sqrt{6}}{24} g_2, \]

so

\[ p \to \sqrt{8}D \left[ \left( 1 + \alpha \right) \pi^0 + \sqrt{3} \left( \alpha - \frac{1}{3} \right) \eta \right] - \sqrt{2}(1 + \alpha)n\pi^0 + \sqrt{2}(\alpha - 1)\Sigma^0 K^0 + (1 - \alpha)\Sigma^0 K^0 - \sqrt{3} \left( \alpha + \frac{1}{3} \right) \Lambda K^0, \]  

(7)

\[ p \to \sqrt{8}D \left[ \left( 1 + \alpha \right) \frac{u\bar{u} - d\bar{d}}{\sqrt{2}} + \sqrt{3} \left( \alpha - \frac{1}{3} \right) \frac{u\bar{u} + d\bar{d} - 2s\bar{s}}{\sqrt{6}} \right] - \sqrt{2}(1 + \alpha)nu\bar{d} + \sqrt{2}(\alpha - 1)\Sigma^+ d\bar{s} + (1 - \alpha)\Sigma^0 u\bar{s} - \sqrt{3} \left( \alpha + \frac{1}{3} \right) \Lambda u\bar{s}, \]  

(8)

with \(\alpha \equiv F/D\), and which leads to relative probabilities, averaged over \(x\),

\[ \bar{u} \approx \frac{2}{9} \left[ 9\alpha^2 + 6\alpha + 1 \right], \]  

(9)

\[ \bar{d} \approx \frac{2}{9} \left[ 9\alpha^2 + 18\alpha + 13 \right], \]  

(10)

\[ \bar{s} \approx \frac{4}{9} \left[ 18\alpha^2 - 12\alpha + 8 \right]. \]  

(11)

Then

\[ \bar{r} \equiv \frac{\bar{u}}{\bar{d}} = \frac{\bar{u}_{\Sigma}}{\bar{s}_{\Sigma}} = \frac{1 + 6F/D + 9(F/D)^2}{13 + 18F/D + 9(F/D)^2}, \]  

(12)

and

\[ \bar{r}_s = \frac{\bar{s}}{\bar{u} + \bar{d}} = \frac{\bar{d}_{\Sigma}}{\bar{u}_{\Sigma} + \bar{s}_{\Sigma}} = \frac{8 - 12F/D + 18(F/D)^2}{7 + 12F/D + 9(F/D)^2}. \]  

(13)

With \(\alpha = 0.6\), consistent with a recent analysis [27], we obtain for the proton

\[ \bar{r} = .29, \quad \bar{r}_s = .42 \]  

(14)

which differ significantly from the experimental result (\(\bar{r} = .51\)) and parameter (\(\bar{r}_s = \kappa/2 = .25\)). We also show in Table I the prediction of this model, \(\bar{r}_{\Sigma} = 0.54\), which, like the meson cloud model, disagrees with the SU(3) expectation of 4/3.
Deviations from SU(3) predictions are also expected for the valence quark distributions in $\Sigma^+$ ($\Sigma^-$). On the basis of SU(3) symmetry we expect

\[ r_\Sigma \equiv \frac{s_\Sigma}{u_\Sigma} \approx \frac{d}{u} \approx 0.57(1 - x). \] (15)

The functional form is taken from a fit by CDHS [28], and agrees with the latest parton distribution analysis of CTEQ [25] within 20%, which is adequate for our calculations.

We find that for $x \geq 0.2$, quark models predict valence quark flavor asymmetries in the $\Sigma^+$ that are greater than the SU(3) result, e.g. by a factor of 3.4 at $x = 0.7$. Our approach to estimating valence quark distributions in the $\Sigma^+$ is based on a quark-diquark model initiated at Adelaide [7,29] which has led to the study of charge symmetry violation in the nucleon [30]. It was found that the dominant contribution to the structure function $q(x)$ in the valence region comes from a state in which the two spectator quarks are in their ground states. The effective mass of this diquark state will deviate from $\frac{3}{4}$ of the nucleon mass (in the MIT bag model, $\frac{2}{3}$ in the constituent quark model) because of the hyperfine interaction. The mass difference between the two spin states of the diquark leads to spin and flavor dependence of $q(x)$ [31]. Let $x_q$ represent the most probable momentum fraction carried by the quark $q$, and $x_{qq}$ represent the most probable momentum fraction carried by the diquark. Then the peak in $q(x)$ can be estimated from

\[ x_q + x_{qq} = 1, \quad x_q = 1 - x_{qq} \approx 1 - \frac{m_{qq}}{m_B}. \] (16)

in which $m_{qq}$ and $m_B$ are the diquark and baryon masses, respectively. For the nucleon, the $N - \Delta$ splitting leads to $m_{qq} = 650$ MeV in the spin singlet state, and $m_{qq} = 850$ MeV in the spin triplet. Then in the proton, $d(x)$ peaks at $x_d \approx 0.10$, whereas $u(x)$ peaks at $x_u \approx 0.31$ – at the scale appropriate to the model. After QCD evolution, these estimates are in reasonable agreement with recent parton distribution analyses [27].

These same arguments may be applied to the $\Sigma^+$. In this case the diquark $uu$ must be in a spin triplet, so from the $\Lambda - \Sigma$ splitting, $m_{uu} \approx 850$ MeV, and $s_\Sigma(x)$ peaks at $x_s \approx 0.28$. This is close to the value found for $u(x)$ in the proton, so we set $s_\Sigma(x) \approx u(x)/2$ (the factor
of 2 comes from normalization). To estimate the $u_{\Sigma}$ distribution we note that the $su$ diquark mass is increased by $\approx 180$ MeV because of $m_s$, and with the hyperfine splitting, $m_{su} \approx 900$ MeV in the singlet, leading to a peak $x_u(S = 0) \approx 0.24$ - i.e., a "harder" distribution, like that of $u(x)$ in the proton - and $m_{su} \approx 1050$ MeV in the triplet, leading to $x_u(S = 1) \approx 0.10$ - a "softer" distribution like $d(x)$ in the proton. Since the singlet and triplet diquark states are equally probable, we approximate $u_{\Sigma}(x) \approx d(x) + u(x)/2$. Then

$$r_{\Sigma} \equiv \frac{s_{\Sigma}}{u_{\Sigma}} \approx \frac{u}{2(d + u/2)} \approx \frac{1}{1 + 2d/u} = \frac{1}{1 + 1.14(1 - x)}. \quad (17)$$

In the valence quark region, this ratio is considerably in excess of that predicted by SU(3), as can be seen in Fig. 1, in which we plot the ratio $R$

$$R = \frac{(r_{\Sigma})_{th}}{(r_{\Sigma})_{SU(3)}} \approx \frac{1}{[1 + 1.14(1 - x)]0.57(1 - x)} \quad (18)$$

There are a number of ways that these arguments and models can be tested for $\Sigma$ hyperons. The most practical to us appears to be in terms of the Drell-Yan cross sections for $\Sigma^\pm p$ and $\Sigma^\pm n$ (i.e. $d$) - e.g., in the inclusive reactions $\Sigma^\pm p \rightarrow l^+l^-X$, where $l^\pm$ are muons or electrons and $X$ is unmeasured. Beams of $\Sigma^\pm$ appear to be adequate for this purpose, but $\pi$ contamination will lead to problems which need to be overcome.

We first consider the determination of sea quark flavor asymmetry for $\Sigma^\pm$. We find that extracting the ratio $\tilde{r}_{\Sigma}(x) \equiv \tilde{u}_{\Sigma}(x)/\tilde{d}_{\Sigma}(x)$ for the $\Sigma^+$ depends on the known ratios $r(x) \equiv u(x)/d(x)$ and $\tilde{r}(x) \equiv \tilde{u}/\tilde{d}$ in the proton. The former is well-determined, and the recent determination of the latter has been discussed above. Ratios involving $\bar{s}$ in the $\Sigma^\pm$ cannot be tested easily because they involve second order annihilations ($\bar{s}_{\Sigma}$ on $s$), terms which we neglect because the present accuracy of Drell-Yan measurements is insufficient to be sensitive to them.

Drell-Yan cross-sections are proportional to the products $q(x)\bar{q}(x')$, weighted by the product of the quark charges, and summed over contributions from beam and target. We neglect sea-quark - sea-quark collisions, which would contribute below the likely level of accuracy of the experiment. We assume isospin reflection (charge) symmetry: $u(x) = d_n(x)$,
\( u(x) = \bar{d}_n(x), \ u_{\Sigma^+}(x) = d_{\Sigma^-}(x), \ \bar{u}_{\Sigma^+}(x) = \bar{d}_{\Sigma^-}(x), \) and \( s_{\Sigma^+}(x) = s_{\Sigma^-}(x) \). In the following equations, \( q(x) \) represents valence quarks and \( \bar{q}(x) \) represents sea quarks. The valence quark normalizations are: \( \int u(x) \, dx = 2 \) and \( \int d(x) \, dx = 1 \).

Consider the Drell-Yan process for \( \Sigma N \). Let \( \sigma(\Sigma N) \) represent the cross-section for inclusive dilepton production

\[
\sigma(\Sigma N) \equiv \frac{d^2\sigma(\Sigma N \rightarrow l^+l^-X)}{d\sqrt{\tau}dy} = \frac{8\pi\alpha^2}{9\sqrt{\tau}} K(x_N, x_S) \sum_i e_i^2 \{q_i(x)\bar{q}_i(x_N) + [\Sigma \leftrightarrow N]\} \tag{19}
\]

with \( M \) the mass of the dilepton pair and \( \sqrt{\tau} = M/\sqrt{s} \). The factor \( K(x_N, x_S) \) accounts for higher-order QCD corrections. If the c.m. rapidity \( y \approx 0 \), then \( x_N \approx x_S \approx x \), and

\[
\sigma(\Sigma^+ p) \approx \frac{8\pi\alpha^2}{9\sqrt{\tau}} K(x) \left\{ \frac{4}{9} [u(x)\bar{u}_{\Sigma^+}(x) + u_{\Sigma^+}(x)\bar{u}(x)] + \frac{1}{9} [d(x)d_{\Sigma^+}(x) + s_{\Sigma^+}(x)s(x)] \right\}. \tag{20}
\]

Then by charge symmetry

\[
\sigma(\Sigma^- n) \approx \frac{8\pi\alpha^2}{9\sqrt{\tau}} K(x) \left\{ \frac{1}{9} [u(x)\bar{u}_{\Sigma^-}(x) + u_{\Sigma^-}(x)\bar{u}(x)] + \frac{4}{9} [d(x)d_{\Sigma^-}(x) + s_{\Sigma^-}(x)s(x)] \right\}. \tag{21}
\]

We also find

\[
\sigma(\Sigma^+ n) \approx \frac{8\pi\alpha^2}{9\sqrt{\tau}} K(x) \left\{ \frac{4}{9} [d(x)\bar{u}_{\Sigma^+}(x) + u_{\Sigma^+}(x)d(x)] + \frac{1}{9} [u(x)d_{\Sigma^+}(x) + s_{\Sigma^+}(x)s(x)] \right\}, \tag{22}
\]

and again by charge symmetry

\[
\sigma(\Sigma^- p) \approx \frac{8\pi\alpha^2}{9\sqrt{\tau}} K(x) \left\{ \frac{1}{9} [d(x)\bar{u}_{\Sigma^-}(x) + u_{\Sigma^-}(x)d(x)] + \frac{4}{9} [u(x)d_{\Sigma^-}(x) + s_{\Sigma^-}(x)s(x)] \right\}. \tag{23}
\]

As we note below, if \( K(x) \) is known, and all four cross sections are measured, \( \bar{u}_{\Sigma}, d_{\Sigma}, u_{\Sigma}, \) and \( s_{\Sigma} \) can be determined. The uncertainties in \( K(x) \) can be factored out by taking ratios of cross sections; two independent ratios can be constructed. We first define a ratio \( R'(x) \) determined from the Drell-Yan cross-sections so as to eliminate all unknowns except for \( \bar{r}_{\Sigma}(x) \)

\[
R'(x) \equiv \frac{\sigma(\Sigma^+ p) - \sigma(\Sigma^- n) + \bar{r}(x)[\sigma(\Sigma^- p) - \sigma(\Sigma^+ n)]}{\sigma(\Sigma^+ p) - \sigma(\Sigma^- n) + 4[\sigma(\Sigma^- p) - \sigma(\Sigma^+ n)]}, \tag{24}
\]

and use Eq. 20 - Eq. 23 to write \( R'(x) \) in terms of the ratios \( \bar{r}_{\Sigma}(x), r(x) \) and \( \bar{r}(x) \):
\[ R'(x) = \frac{\bar{r}_\Sigma(x)[r(x) - \bar{r}(x)] - [1 - \bar{r}(x)r(x)]}{5[r(x) - 1]} . \]  

(25)

Thus for \( r(x) \approx 2 \) and \( \bar{r}(x) \approx 0.5, \) \( R'(x) \approx 0.3 \bar{r}_\Sigma(x). \)

If \( K(x) \) is known, \( \bar{d}_\Sigma(x) \) can be determined directly from the cross sections:

\[ \bar{d}_\Sigma(x) = \frac{27\sqrt{\tau}}{40\pi\alpha^2 K(x)} \frac{\sigma(\Sigma^+p) - \sigma(\Sigma^+n) + 4[\sigma(\Sigma^-p) - \sigma(\Sigma^-n)]}{[u(x) - d(x)]}, \]  

(26)

and \( s_\Sigma(x) \) can be determined from the cross sections and \( \bar{s}(x) \):

\[ s_\Sigma(x) = \frac{27\sqrt{\tau}}{8\pi\alpha^2 K(x)} \frac{\sigma(\Sigma^+n) - 4\sigma(\Sigma^-p) - r(x)[\sigma(\Sigma^+p) - 4\sigma(\Sigma^-n)]}{\bar{s}(x)[r(x) - 1]} , \]  

(27)

(Recall that, because of the higher mass of the strange quark, we expect \( s_\Sigma(x) \) to peak at a larger \( x \) than \( d(x) \) – c.f., Eq. 11.)

Quark models with a meson cloud predict the sea quark distributions \( \bar{q}(x) \); they also predict that the difference \( D \equiv x[\bar{d}(x) - \bar{u}(x)] \) peaks at \( x \approx 0.1 \) \[14\ 20\]. On the basis of meson cloud models\[1\], the distributions of sea quarks in the \( \Sigma^\pm \) may differ somewhat from those in the nucleon due to the presence of kaons; this may shift the maximum of \( D \) to somewhat smaller values of \( x \). Nevertheless, the region \( 0 \leq x \leq 0.2 \) should be a good one in which to determine \( \bar{r}_\Sigma \).

We believe that the measurement of \( R' \) should be possible to within \( \approx 20\% \) and this is sufficient to establish the preponderance of \( \bar{d} \) over \( \bar{u} \) in the \( \Sigma^+ \), as predicted by the octet and meson cloud models. From Eq. 25, an error, \( e \), in the measurement of \( R' \) leads to an error of approximately \( 3e \) in \( \bar{r}_\Sigma \). If \( \bar{r}_\Sigma \) were found to be \( \leq 0.5 \), together with the known value of \( \bar{r} \approx 0.51 \), this measurement would help to reinforce the necessity to include pseudoscalar mesons in quark models of baryons.

To measure valence quark asymmetries we consider the Drell-Yan process for \( \Sigma^+ \) and \( \Sigma^- \) on isoscalar targets – with cross sections \( \sigma_+ \) and \( \sigma_- \), respectively. We fix \( x_\Sigma \) to be above 0.3 so that valence quarks in the hyperons dominate. Then from Eq. 19 - Eq. 23, with \( x \equiv x_\Sigma \) and \( x' \equiv x_N \),

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1We are undertaking a calculation of the \( \Sigma^\pm \) sea quark distributions.
\[\sigma_+ \equiv \sigma(\Sigma^+ A) \approx \frac{8\pi\alpha^2 A}{9\sqrt{7}} K(x, x') \left\{ \frac{4}{9}u_\Sigma(x)\bar{u}(x') + \bar{d}(x') \right\} + \frac{2}{9} |s_\Sigma(x)\bar{s}(x')|, \] (28)

and

\[\sigma_- \equiv \sigma(\Sigma^- A) \approx \frac{8\pi\alpha^2 A}{9\sqrt{7}} K(x, x') \left\{ \frac{1}{9}u_\Sigma(x)\bar{u}(x') + \bar{d}(x') \right\} + \frac{2}{9} |s_\Sigma(x)\bar{s}(x')|. \] (29)

We approximate \( K(x, x') \) by an average \( \bar{K} \), and integrate over \( x' \) in the nucleons, so that

\[\int dx' \sigma_+(x', x) = \frac{8\pi\alpha^2 A}{9\sqrt{7}} \bar{K} \left\{ \frac{4}{9}u_\Sigma(x)\bar{u} + \bar{d} \right\} + \frac{2}{9} |s_\Sigma(x)\bar{s}|, \] (30)

and similarly for \( \sigma_- \), with \( \bar{q} = \int dx' \bar{q}(x') \). Then

\[R_v(x) \equiv \frac{\int dx' \sigma_-(x', x)}{\int dx' \sigma_+(x', x)} = \frac{u_\Sigma(x)(\bar{d} + \bar{u}) + 2s_\Sigma(x)\bar{s}}{4u_\Sigma(x)(\bar{d} + \bar{u}) + 2s_\Sigma(x)\bar{s}} = \frac{1 + \kappa r_\Sigma}{4 + \kappa r_\Sigma}. \] (31)

We again use the CTEQ [25] value, \( \kappa = 0.5 \), and evaluate \( R_v \) for both the SU(3) prediction for \( r_\Sigma \) (Eq. 13) and for our quark model (Eq. 17). In Fig. 2 we plot the ratio \( D \)

\[D(x) \equiv \frac{R_v(\text{quark model})}{R_v(\text{SU}(3))}. \] (32)

We note that the predicted asymmetry exceeds the SU(3) prediction by about 10% at \( x = 0.5 \), increasing to 20% at \( x = 0.75 \). An accuracy of \( \approx 5\% \) should be possible for these integrated cross sections. Thus these measurements will test the SU(3) violations in the valence quark distributions of \( \Sigma^\pm \) predicted by quark models.

In summary, there are substantial differences expected between the valence and sea parton distributions associated with several models of hyperon structure. We have seen that Drell-Yan experiments based on existing hyperon beams should be capable of testing these ideas. The substantial violations of SU(3) flavor symmetry in the valence distributions are probably the easiest to test as they require only an isoscalar target and a semi-integrated cross-section. However, the enormous interest in the underlying cause of the flavor asymmetry of the proton sea should also make the tests of sea quark distributions an important priority as well.

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REFERENCES

[1] P. Amaudruz et al., Phys. Rev. Lett. 66 (1991) 2712.

[2] M. Arneodo et al., Phys. Rev. D 50 (1994) R1.

[3] A. Baldit et al., Phys. Lett. B 332 (1994) 244.

[4] S. Forte, Phys. Rev. D 47 (1993) 1842.

[5] R.P. Feynman and R.D. Field, Phys. Rev. D 15 (1977) 2590.

[6] A.I. Signal and A.W. Thomas, Phys. Lett. B 221 (1988) 481.

[7] A.I. Signal and A.W. Thomas, Phys. Rev. D 40 (1989) 2832.

[8] A.W. Thomas, Phys. Lett. 126B (1983) 97.

[9] M. Ericson and A.W. Thomas, Phys. Lett. 148B (1984) 191.

[10] A.W. Thomas, Prog. Theor. Phys. [Suppl.] 91 (1987) 204.

[11] W. Melnitchouk, A.W. Thomas, and A.I. Signal, Z. Phys. A 340 (1991) 85.

[12] A.I. Signal, A.W. Schreiber, and A.W. Thomas, Mod. Phys. Lett. A 6 (1991) 271.

[13] E.M. Henley and G.A. Miller, Phys. Lett. B 251 (1990) 453.

[14] E. Eichten, I. Hinchliffe, and C. Quigg, Phys. Rev. D 45 (1992) 2269.

[15] S. Kumano, Phys. Rev. D 43 (1991) 59.

[16] S. Kumano and J.T. Londergan, Phys. Rev. D 44 (1991) 717.

[17] W-Y. P. Hwang, J. Speth, and G.E. Brown, Z. Phys. A 339 (1991) 383.

[18] A. Szczurek and J. Speth, Nucl. Phys. A555 (1993) 249.

[19] A. Szczurek, J. Speth, and G.T. Garvey, Nucl. Phys. A570 (1994) 765.

[20] A. Szczurek, M. Ericson, H. Holtmann, and J. Speth, Nucl. Phys. A596 (1996) 397.
[21] H. Holtmann, N.N. Nikolaev, J. Speth, and A. Szczurek, Z. Phys. A 353 (1996) 411.

[22] H. Abromowicz et al., Z. Phys. C 15 (1982) 19.

[23] C. Foudas et al., Phys. Rev. Lett. 64 (1990) 1207; M.H. Shaevitz, Nucl. Phys. B (Proc. Suppl.) 19 (1991) 270; S.A. Rabinowitz et al., Phys. Rev. Lett. 70 (1993) 134; A.O. Bazarko et al., Z. Phys. C 65 (1995) 189.

[24] B. Strongin et al., Phys. Rev. D 43 (1991) 2778.

[25] H.L. Lai et al., Phys. Rev. D 51 (1995) 4763; CTEQ -604, hep-ph/9606399 (1996).

[26] R. M. Barnett et al., Phys. Rev. D54 (1996) 173.

[27] P. G. Ratcliffe, Phys. Lett. B365 (1996) 383.

[28] F. Eisele, J. de Physique C3 (Suppl) (1982) C3.

[29] A.W. Schreiber, A.W. Thomas, and J.T. Londergan, Phys. Rev. D 42 (1990) 2226.

[30] E. Sather, Phys. Lett. B274 (1992) 433;
    E. Rodionov, A. W. Thomas and J. T. Londergan, Mod. Phys. Lett. A9 (1994) 1799.

[31] F.E. Close and A.W. Thomas, Phys. Lett. B 212 (1988) 227.
TABLE I. Sea quark asymmetries

|                  | meson cloud | SU(3) | octets | experiment |
|------------------|-------------|-------|--------|------------|
| $\tilde{r} \equiv \frac{\bar{u}}{\bar{d}}$ | theory ref  |       | 0.29   | 0.51       |
| $\tilde{r}_s \equiv \frac{\bar{s}}{\bar{u} + \bar{d}}$ |             |       | 0.42   | $\kappa = 0.25$ |
| $\tilde{r}_\Sigma \equiv \frac{\bar{u}_\Sigma}{\bar{d}_\Sigma}$ | $\leq 0.5$  | $4/3$ |        | 0.54       |
FIGURES

FIG. 1. Plot of the ratio $R$, Eq. 18, as a function of $x$. We also show $r_\Sigma$, as obtained from the quark model, Eq. 17, and as found from SU(3), Eq. 15.

FIG. 2. Plot of $D$, Eq. 32, as a function of $x$. 
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