dashed lines. These distributions are relevant to the behavior of the charmed-quark fragmentation function.

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[5] The sum of the $\bar{\nu}_\mu$, ν_e, and $\bar{\nu}_e$ fluxes is calculated to be less than 5% of the total beam.

[6] The quoted errors include both the statistical and our estimate of the systematic errors.

[7] We have investigated the narrow structure at 1660 MeV. Using the procedures defined above but with the width constrained to our resolution, we find its significance to be ≤ 2.5 standard deviations.

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[11] The measured energy consists of three parts, $E_{\text{meas}} = E_{\mu^-} + E_{D^0} + E_{\text{other hadrons}}$. The hadronic energy used in the calculation of z has been corrected for neutral particles, which were not measured in this sample, and charged tracks that interact and are too short for a measurement of their energy, by the formula $E_{\text{hadronic}} = E_{D^0} + (E_{\text{other hadrons}}/0.75)$. The distributions of Fig. 3 are not sensitive to the details of this correction.

Residual Proton Production in Deep-Inelastic Electron Scattering

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We have measured residual proton yields from deep-inelastic electron scattering as a function of the fractional longitudinal momentum, z_p $(=p_l/p_{l\max})$, imparted to the proton. We find a peaked distribution in z_p centered near $z_p = -0.25$.

The distribution of the nucleonic component in hadron-proton collisions has been studied extensively for both residual protons[1,2] and neutrons.[3] Briefly, one finds a peak in the yield corresponding to collisions with small momentum transfer to the target proton ($z_p \simeq -1$); these are commonly called diffractive collisions.[1] There is also a substantial yield of protons and neutrons corresponding to more highly inelastic collisions.[2,3] This yield is broadly distributed in z $(-p_l/p_{l\max}$ in the center-of-mass system) but clearly separated from the diffractive component by a minimum in the cross section. The yield of antiprotons[2] has also been measured; except for small z_p ($|z_p| \lesssim 0.2$) it is well below the proton yield. This difference in yield must represent the excess baryonic charge of the initial state and therefore the residual proton; we suppose that the antiprotons are a measure of those protons produced as baryon-antibaryon pairs. The corresponding measurement in inelastic lepton-nucleon scattering has been studied less extensively; it is known that there is a diffractive component[4] and that the nucleon yield falls with z for $z > -0.2$.[5] This paper reports on more accurate measurements of this recoil-proton distribution in inelastic electron scattering. We believe the measurement of this residual proton yield is important; the momentum distribution of these recoil protons reveals the "history" of the meson-emission process. We cite two opposite predictions from the current literature: (1) In a model which envisages the struck proton as composed of a leading fast parton, a slow target-fragmentation region, and a string of partons of intermediate rapidity in between[6] one would expect the residual proton to exhibit the rapidity of the target fragmentation region and thus $z_p < -0.3$. (2) A semiclassical fireball model[7] would have meson emission occurring equally forward and back; the average momentum of the residual proton would then be zero in the center-of-mass system, i.e., $\bar{z}_p = 0$.

The experiment was performed in a 20.5-GeV electron beam at Stanford Linear Accelerator Center. The apparatus is described elsewhere.[8] In addition to a high-pressure Cherenkov counter, proton identification was made through time-of-flight (TOF) measurements between the electron shower counter and hadron counters at the rear of the apparatus and approximately 6 m from the target. To optimize accuracy, in each event the TOF was corrected for the light TOF in the scintillators by knowing the striking point of the charged particle. Furthermore, each scintillator pair was corrected for any systematic deviation from zero by the measured location of the TOF distribution peak, using high-momentum particles ($p_{\text{lab}} > 8$ GeV/c). To check the method we can compare the measured yields of protons (see Fig. 2) and antiprotons against the measurement made using the Cherenkov counter[8] where these overlap ($z_p \sim 0.1$ to 0.3). In this range the TOF method gives $\bar{p}/\pi^- = 0.046 \pm 0.008$ whereas the Cherenkov counter gives 0.036 ± 0.013—a satisfactory agreement.

To illustrate the sensitivity of the method we show a distribution of the square of the hadron mass calculated from the electron-hadron TOF difference in Fig. 1. When the hadron momentum is below 1.5 GeV/c the proton peak is unambiguously separable from the π-K peak. At higher momenta we calculate the proton (or antiproton) contribution to the total hadron yield by counting the number of hadrons with TOF greater than the average TOF for protons (T_p) of the measured momentum; this must include half the protons. We measure the meson contribution to this signal by counting the hadrons with TOF $< -T_p$. The dif-

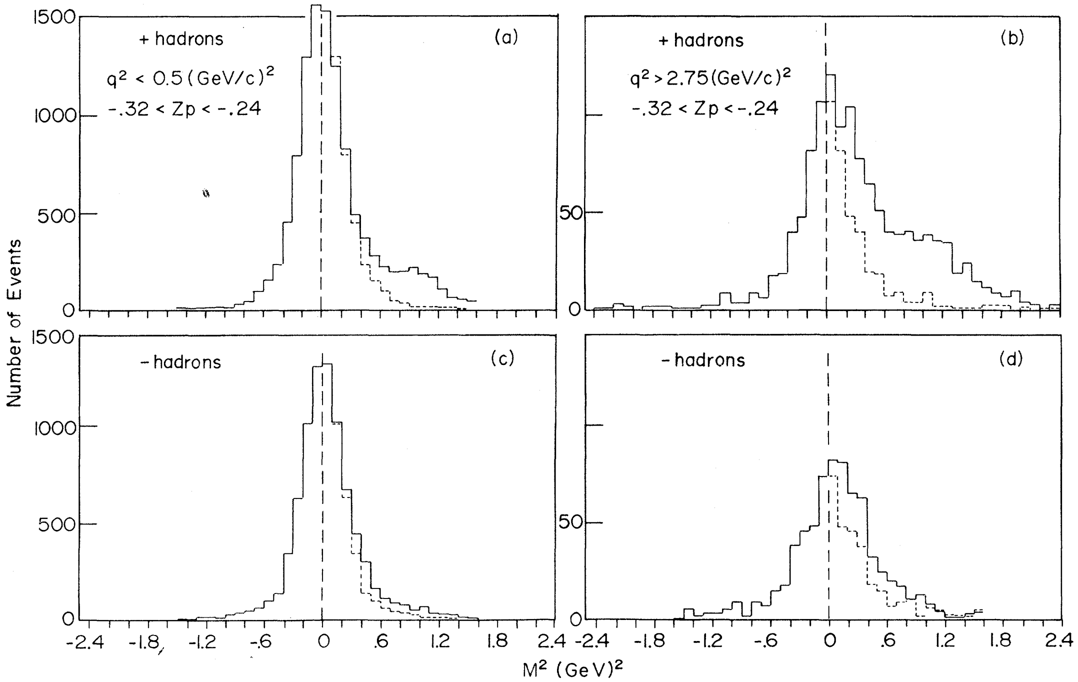

FIG. 1. An illustration of various distributions of the square of the missing mass calculated from the hadron TOF for the z_p bin, -0.32 to 0.24 and for (a) and (c) low-q^2 and (b) and (d) high-q^2 bins. There is a clear proton signal which increases with q^2 relative to the π^+ signal. The dotted lines are a reflection of negative m^2 data about $m^2 = 0$ and are intended merely to guide the eye.

ference in these numbers multiplied by 2 and divided by the remaining hadrons at all TOF gives the proton to $(\pi + K)$ ratio. The K contribution toward a net proton-production signal is small since its TOF is close to that of the π and its contribution is small where measured[8] and is further reduced by decay in flight. We concentrate on a second number, the difference between proton and antiproton yields, i.e., the yield obtained from this analysis for negatives is subtracted from the positives. We measure thereby the net baryonic yield, i.e., we exclude the proton yield due to nucleon-antinucleon production. This subtraction is not large; the average antiproton yield is about 20% that of the proton.

Our apparatus is not efficient for the detection of low-momentum (< 1.5 GeV/c) and therefore large-production-angle hadrons. To calculate absolute yields of protons at low momentum we do not rely on our Monte Carlo efficiencies but we use our measured $p/(\pi + K)$ ratio and an exponential extrapolation of our $\pi + K$ measured cross sections to small $|z_\pi|$; this is modeled after other experiments where the full z_π distribution could be measured.[9,10] Figure 2 shows our measured proton-antiproton to $(K^+ + \pi^+)$ ratio and the calculated net baryonic yield as a function of z_p, dN/dz. It is interesting to note that dN/dz occurs as a "bump" with a maximum near $z \simeq -0.2$. The "bump" appears to move to higher z with higher s; we obtain $\bar{z} = -0.123 \pm 0.012$ and -0.184 ± 0.013 for the high- and low-s data, respectively. The second value is an upper limit since the low-s distribution appears to continue beyond $z < -0.5$.

Our data cover a range of the square of the hadron center-of-mass, s, and total hadron energy, ν, lost by the electron to the hadronic system from $s = 7$ to 31 GeV^2. We also measure the four momentum, q^2, imparted to the nucleon by the electron in each event; these measurements cover a range in q^2 from 0.25 to 10.0 (GeV/c)^2. In Fig. 3 we have plotted the total proton-antiproton yield within our z limits as a function of x $(=q^2/2M\nu)$; the yield increases with x. It is natural, though not necessary, to associate the proton yields we measure as a phenomenon related to striking valence quarks. A simple expectation from any model of deeply inelastic collisions is that the residual nucleons would be a proton half the time and neutron the other half. If all this yield is not measured in the z_p range covered here presumably some protons occur at $z_p < -0.5$

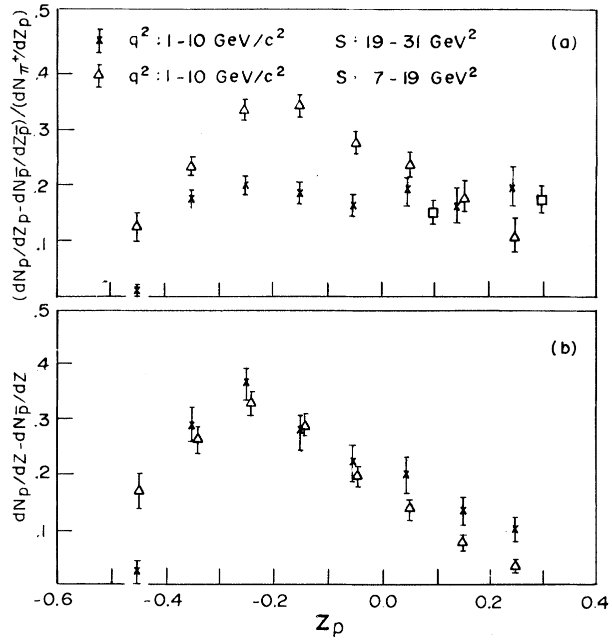

FIG. 2. The measured proton-antiproton to $\pi^+ + K^+$ yield is shown in (a). The absolute proton-antiproton yield derived as described in the text, is shown in (b) as a function of z_p. Two points as measured with the Cherenkov counter are included (squares) in (a) to illustrate that our method for proton separation by TOF methods gives satisfactory results.

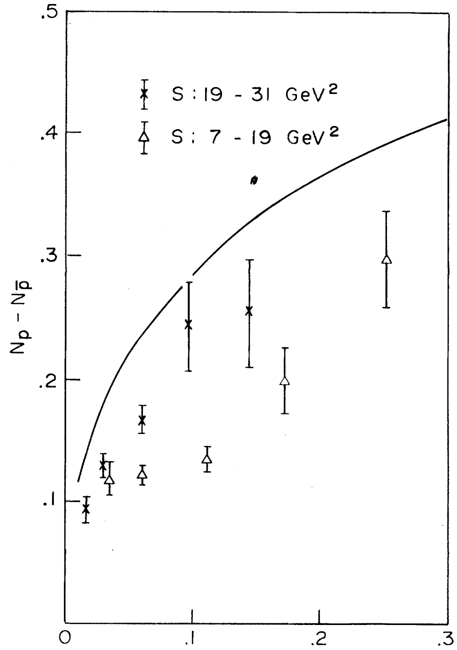

FIG. 3. We show the total proton-antiproton yield for $-0.5 < z_p < +0.3$ as a function of x for two s bins. The solid line indicates an expected yield using arguments described in the text.

which is not covered by our apparatus. In Fig. 3 we have plotted the ratio of valence quarks to vacuum plus valence quarks as given by a quark model[11] normalized to $\frac{1}{2}$ as $x \to 1.0$. Our data points are less than, but exhibit the x dependence compatible with, the above simple description. One should keep in mind the following circumstances. The low-s points (7–19 GeV^2) do not include the full proton yield (see Fig. 2). In some events the ultimate baryon is strange (Λ or Σ) and results in fewer protons detected; the proton from Λ or Σ decay has an additional transverse momentum which tends to throw it out of our angular acceptance. Indeed the Λ^0 yield has been measured in an electroproduction experiment and shows the same peaking as our proton experiment at $z \sim -0.2$.[12]

A plot of dN/dz [9] or the π structure function[10] from lepton-scattering experiments shows a net momentum imbalance with respect to $z=0$; these distributions tend to peak at a small but positive z ($z \sim +0.05$). Our result is qualitatively consistent with the requirement that the residual nucleon have an average negative-z component in the center-of-mass system to balance this average positive momentum component for the mesons.

In conclusion we find that the residual proton distribution after a deep-inelastic electron collision at high q^2 tends to gather in a peaked distribution at small negative z (-0.2 to -0.1) which value seems to increase with s. This result is in disagreement with those models that would expect the recoil proton to appear in the target—fragmentation region,[6] i.e., $z_p < -0.3$. It is consonant with a model where π's tend to be emitted symmetrically forward and backward.[7, 13]

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