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Comparison of the Yields of Inelastic Electron and Positron Scattering from Hydrogen and Deuterium at 15 (GeV/c)^2 *

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We have measured the ratio, Y^+/Y^-, of positron to electron inelastic scattering yields from hydrogen and deuterium at Q^2, the square of the four-momentum transfer, between 2.4 and 14.9 (GeV/c)^2. The ratios are consistent with $Y^+/Y^-=1$ to within errors of a few percent.

We report the results of a measurement of Y^+/Y^-, the ratio of the yield for inelastic positron scattering to that for inelastic electron scattering from hydrogen and deuterium,[1] which was carried out as part of a larger program of measurements of electron-proton and electron-deuteron scattering cross sections, using the Stanford Linear Accelerator Center (SLAC) spectrometer facility. This ratio is sensitive to the mechanism of the hadron-lepton interaction. For example, if in addition to the usually assumed one-photon exchange process there is also two-photon exchange, the interference between the two occurs with a different sign for electrons and positrons, and the ratio of the cross sections goes like $1+4\times \mathrm{Re}(A_2/A_1)$, where A_1 and A_2 are the amplitudes for one- and two-photon exchange, respectively. Also, the existence of a direct, nonelectromagnetic interaction between electrons and hadrons, as was suggested[2] to explain certain features of the early e^+e^- storage-ring results,[3] would lead, in some models, to a ratio appreciably different from unity.

Previously, measurements had been made for *elastic* scattering for Q^2 up to 5 (GeV/c)^2, and the ratios of cross sections were consistent with unity.[4] Some measurements have also been made for inelastic scattering using incident muons, but at lower Q^2, with similar results.[5]

To make the present measurements, positrons were produced by the electron beam in a radiator[6] one-third of the way down the SLAC linear accelerator and accelerated to a final energy of 13.9 GeV in the remaining two-thirds of the machine. In separate runs, a similar beam of electrons was also produced from the same radiator, as well as the usual electron beam accelerated directly from the electron gun. While the ordinary electron beam was of much higher intensity and thus yielded improved statistical accuracy, we took data with both types of electron beam to look for systematic effects due to differences in intensity and to possible differences in transverse phase space and energy spectrum. In fact, we found no significant differences in the data from the two types of electron beams; therefore, we averaged these yields to obtain the final results.

The beam passed through slits which limited the maximum momentum spread to less than 0.75%. The intensity of the beam was about 5×10^{11} electrons/pulse from the gun and 3 to 5% of this from the radiator. The transverse dimensions of the beams at the target were a few millimeters, and beam position and angle were maintained to about 1 mm and 0.1 mrad, respectively.

The total charge in the beam was measured in two independent current transformers which were calibrated using known amounts of charge. The charges measured by the two monitors always agreed to within 0.3%.

The beams scattered in a 7-in. liquid hydrogen or deuterium target, and the scattered particles were detected in the SLAC 20-GeV magnetic spectrometer at 15° and in the 1.6-GeV magnetic spectrometer at 50°, simultaneously but not in coincidence. Each spectrometer was equipped with detectors to measure the angle and momentum of the scattered particles (multiwire proportional chambers in the 20-GeV spectrometer and scintillator hodoscopes in the 1.6-GeV spectrometer) and a Cherenkov counter and a segmented total-absorption shower counter to separate electrons from hadrons. After we made cuts in the Cherenkov- and shower-counter pulse-height distributions, the pion subtraction in the final sample was always less than 2%.

We measured Y^+/Y^- in a range of Q^2 between 2.4 and 14.9 $(\mathrm{GeV}/c)^2$. Most of the data are from hydrogen, but two points were taken with a deuterium target as well. The kinematics of the points and the ratios of the measured yields are listed in Table I. Figure 1 shows the ratios plotted versus Q^2 for the case in which the spectrometers were set to accept scattered beam particles. The errors given are based only on counting statistics. We estimate a systematic uncertainty of about ± 1% for the 15° points and ± 2% for the 50° points coming from effects of pulse-height cuts and counting rates, and an additional overall uncertainty in normalization of about ± 1% arising primarily from uncertainties in the energy and integrated flux of the beam. There is no evidence for a significant difference between

TABLE I. The ratios of the measured yields for the cases in which the spectrometers were set to accept particles with the same sign of charge as the beam, as well as the cases in which the spectrometers accepted particles with sign opposite from that of the beam. The sign attached to Y denotes the sign of the beam, and the signs in $e^\pm/e^\mp$ denote the sign of charge accepted by the spectrometer. W is the effective mass of the final hadronic system. The errors shown are based on counting statistics only. Other uncertainties are discussed in the text. The measurements at 15° were made with the 20-GeV spectrometer and those at 50° with the 1.6-GeV spectrometer. In the last column, Y denotes the actually observed (same sign) yield, and $d^2\sigma/d\Omega dE'$ denotes the yield that would have occurred if there were no radiative effects, no target walls, no charge-symmetric background, etc.

KINEMATICS AND TARGET					RATIOS OF MEASURED YIELDS, Y^+/Y^-		
	Target	Scattered Energy E' (GeV)	Q^2 $(\mathrm{GeV}/c)^2$	W (GeV/c^2)	Relative Sign of Spectrometer and Beam: Same (e^+/e^-)	Opposite (e^-/e^+)	$\dfrac{Y}{d^2\sigma/d\Omega dE'}$
15°	H_2	2.50	2.37	4.46	1.002 ± 0.025	1.05 ± 0.06	3.2
		3.00	2.84	4.30	0.993 ± 0.024	1.08 ± 0.09	1.8
		3.50	3.32	4.13	0.996 ± 0.026	1.28 ± 0.16	1.5
		4.00	3.79	3.96	0.978 ± 0.024		1.3
		5.50	5.21	3.38	1.023 ± 0.018		1.1
		7.50	7.11	2.40	1.011 ± 0.020		0.9
	D_2	5.50	5.21	3.38	1.003 ± 0.013		1.1
50°	H_2	1.00	9.91	3.90	0.973 ± 0.022	1.02 ± 0.04	2.7
		1.15	11.41	3.66	1.007 ± 0.027	1.13 ± 0.07	1.8
		1.50	14.88	3.04	1.032 ± 0.038		1.2
	D_2	1.50	14.88	3.04	0.926 ± 0.053		1.2

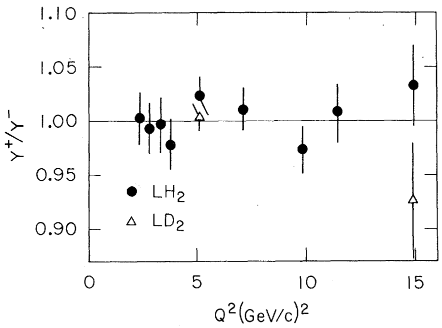

FIG. 1. Ratios of measured yields with the spectrometer set for the same sign as the incident beam plotted versus the square of the four-momentum transfer, Q^2. The errors shown are based on counting statistics only. Other uncertainties are discussed in the text.

electron and positron yields.

The quantity Y is not the usually reported inelastic cross section; it is the measured yield of electrons or positrons, and so includes contributions from the stainless-steel walls of the target cell, from various radiative processes some of which increase the yield and some of which deplete it, and from a variety of intermediate processes such as $\gamma \to e^+e^-$, $\pi^0 \to e^+e^-\gamma$, $\psi \to e^+e^-$, $K^\pm \to e^\pm\pi^0\nu$, etc., most of which give equal numbers of e^+ and e^-. The inelastic cross section is derived from the yield after subtracting or correcting for these other processes. As an indication of the size of these other contributions, we give in the last column in Table I the ratio of the measured yield to the derived cross section at the kinematic point defined by the beam and spectrometer. The ratio Y^+/Y^- given in Fig. 1 and Table I could deviate from unity if any of the processes mentioned above gave unequal numbers of e^+ and e^-.

Along with the ratios of yields for "same sign" running, we show in Table I some ratios of yields with the spectrometer set to accept particles with the opposite sign of charge from that of the incident beam (e.g., e^+ beam, e^- detected). Measurements of this kind are customarily made in inelastic electron scattering experiments to subtract background contributions from charge-symmetric reactions. The five measured ratios are all greater than unity (which corresponds to more e^- detected than e^+), and based on statistics alone the weighted average is 1.06 ± 0.03. Since the opposite-sign yields are smaller than the same-sign yields, the pion corrections are larger for the opposite-sign yields, and we estimate systematic uncertainties in the opposite-sign ratios associated with pion subtraction of 0.02 to 0.04. Although the opposite-sign ratios suggest a relative excess of e^-, we cannot conclude, considering the uncertainties involved, that the opposite-sign ratios differ significantly from unity, nor have we been able to identify a mechanism for generating excess e^- at the level of sensitivity of the present experiment. However, we note that a value of this ratio of 1.06 would cause Y^+/Y^- (same sign) to change by less than 0.024 under the conditions of this experiment.

Another contribution that does give a different yield for positrons compared with electrons is the elastic radiative tail which is smaller for e^+p than for e^-p [7]; however, under the conditions of our experiment this effect would cause Y^+/Y^- to deviate from unity by less than 0.006.

Our present inelastic radiative correction procedures treat electron and positron scattering identically,[8] so that their application would not change the ratios. In fact, interference effects in inelastic radiative processes, which could give rise to a difference between electron and positron yields, are intimately connected to the effect of any two-photon exchange interaction, and any perturbation theory calculation of these effects must include both types of terms to cancel out certain infrared divergences. Some calculations have been reported[9] which predict an asymmetry on the order of 1 or 2% for the range of our data, coming from the noninfrared part of the two-photon exchange term. However, these calculations do not attempt to account for all sources of asymmetry, and in any event, the effects that they predict are of the same order as our experimental errors.

Since there are several processes which might in principle lead to measured ratios different from unity, we cannot place limits on anything but the sum of all such effects as measured in this experiment. Of course it is not impossible that several large effects happen to cancel everywhere to lead to our null result. In any event, it is important to note that the usual analysis procedures for inelastic eN scattering, which neglect two-photon effects and radiation from the hadrons, have been tested within the present experimental uncertainties, in a significant kinematic range. Our results could also be used to constrain models of a direct hadron-lepton interaction leading to differences between electron and positron yields.

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Weak Decay Modes of Charmed Mesons*

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A simple dynamical model is used to calculate the partial rates for various decay modes of charmed pseudoscalar and vector mesons. Our results together with the presently available data lend support to the hypothesis that the lowest-lying charmed particles are vector mesons. It is suggested that the multiparticle state $K^-\pi^+\pi^-\pi^+$ should be produced fairly copiously in charmed-vector-meson decays, which could offer a fruitful way of identifying charm.

If charmed hadrons exist, the analysis of various experimental results and the eventual identification of such particles would be greatly facilitated if estimates can be made for the relative importance of various decay modes of the lowest lying of these particles. Detailed information of this nature cannot be obtained from free-quark models, which provide[1] estimates for the inclusive decay rates, or by using symmetry or current-algebra arguments which essentially give sum rules.

In this paper we undertake a detailed study of the weak decays of the lowest-lying charmed mesons on the basis of a simple dynamical model. The model we use is a generalization of the vector-meson-dominance model suggested by Sakurai[2] to describe the nonleptonic decay of ordinary hadrons. The weak Hamiltonian responsible for charmed-particle decays can be written as

$$H_w = (G_F/\sqrt{2})[(\cos\theta_c\, J_{\mu 3}{}^4 - \sin\theta_c\, J_{\mu 2}{}^4)l_\mu + \text{H.c.}] + H_w{}^{\text{N.L.}}, \tag{1}$$

where l_μ is the usual weak leptonic current and $J_{\mu\beta}{}^\alpha = V_{\mu\beta}{}^\alpha + A_{\mu\beta}{}^\alpha$ is the hadronic $V-A$ current which in