teractions and uncertainties in the pion- and kaon-absorption processes.

[8]Except where otherwise stated we assume that D mesons are produced with a distribution in $Z \equiv E_D/E_H$ of the form $F(Z) = Ce^{-3Z}$, where E_D and E_H are the laboratory energies, respectively, of the D meson and the total hadronic system. We assume an equal mixture of the decays $D \to K\mu\nu$ and $D \to K^*\mu\nu$.

[9]Here $y_{\rm vis} = (E_{\mu 2} + E_H)/E_{\rm vis}$ and $x_{\rm vis} = (E_{\mu 1}/M_p)(1 - \cos\theta_{\mu 1})/y_{\rm vis}$, where $E_{\rm vis} = E_{\mu 1} + E_{\mu 2} + E_H$. For ν-induced dimuons $\mu 1$ is μ^- and $\mu 2$ is μ^+. Because of the undetected energy of neutrinos from charmed-particle decays, $x_{\rm vis} > x$ and $y_{\rm vis} < y$, where $x = q^2/2M_pE_H$ and $y = E_H/E_\nu$.

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[12]For example, for the $\bar{\nu}$ dimuon data well above the charm threshold, one has

$$\epsilon\frac{\sigma(\mu^+\mu^-)}{\sigma(\mu^+)} = \frac{b\sigma(\bar{\nu}\bar{s} \to \mu^+\bar{c})}{\sigma(\bar{\nu}u \to \mu^+d) + \sigma(\bar{\nu}\bar{d} \to \mu^+\bar{u}) + \sigma(\bar{\nu}\bar{s} \to \mu^+\bar{c})}$$

$$= b\bar{S}/(\tfrac{1}{3}U + \bar{D} + \bar{S})$$

and for the $\bar{\nu}$ single-muon data

$$\tfrac{1}{2}(1 - B^{\bar{\nu}}) = (\bar{S} + \bar{D})/(U + \bar{D} + \bar{S}),$$

where, as usual, $\bar{S} \equiv \int x\bar{s}(x)dx$ is the fractional momentum carried by the strange antiquarks, etc., $B^{\bar{\nu}} \equiv -\int xF_3(x)dx/\int F_2(x)dx$, ϵ is the correction for dimuon acceptance, and b is the branching ratio for $(\bar{c} \to \bar{\mu})$. Hence

$$\frac{\bar{S}}{U} = \frac{\sigma(\mu^+\mu^-)}{\sigma(\mu^+)}\frac{\epsilon}{b}\left(\frac{1}{3} + \frac{1 - B^{\bar{\nu}}}{1 + B^{\bar{\nu}}}\right)$$

and

$$\frac{\bar{D}}{U} = \frac{(1 - B^{\bar{\nu}})}{(1 + B^{\bar{\nu}})} - \frac{\bar{S}}{U}.$$

We use $b = 0.10$ [R. Brandelik *et al.*, Phys. Lett. 70B, 387 (1977); J. M. Feller *et al.*, Phys. Rev. Lett. 40, 274 (1978); W. Bacino *et al.*, Phys. Rev. Lett. 40, 671 (1978)], and for $E_{\bar{\nu}} > 80$ GeV we use $B^{\bar{\nu}} = 0.66 \pm 0.05$ [F. Bobisut, in Proceedings of the International Conference on Neutrino Physics and Neutrino Astrophysics, West Lafayette, April 1978 (to be published)], $\epsilon = 2.0$, and $\sigma(\mu^+\mu^-)/\sigma(\mu^+) = (0.70 \pm 0.25) \times 10^{-2}$ from Fig. 4(a). Similar calculations for the ν data and for the combined ν and $\bar{\nu}$ data yield S/D and $\bar{S}/D$.

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Direct Electron-Pair Production in $\pi^{\pm}p$ Interactions at 18 GeV/c

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With use of the Stanford Linear Accelerator Center hybrid facility 1-m bubble chamber fitted with tantalum plates, a measurement was made of direct unexplained e^+e^- pair production in 18-GeV/c $\pi^{\pm}p$ interactions. Limits are set in π^+p processes. In π^-p a signal is observed which cannot be caused by η, ω, or ρ decay, and for masses $> m_{\pi^0}$, $e^{\pm}/\pi^{\pm} = (0.87 \pm 0.25) \times 10^{-4}$. Some properties of the events are discussed.

This report is based on data taken with the Stanford Linear Accelerator Center (SLAC) 1-m bubble chamber hybrid facility in an investigation of direct e^+ or e^- production in 18-GeV/c π^+p and π^-p interactions. At similar energies, and also at the CERN intersecting storage-rings, experiments using single-particle spectrometers[1] have shown a low-p_T enhancement of hadronically produced e^+ and e^- which is not yet understood.[2] (In the text, "electron" will refer to e^+ or e^-.) An earlier result from this experiment[3] has indicated that unpaired electron production is not significant. Here we report measurements on pair production.

The bubble chamber was equipped with three tantalum plates, each 1.0 radiation lengths thick.

Approximately 90% of electrons could be identified by spiraling, ionization (for momenta $\lesssim 200$ MeV/c), bremsstrahlung, etc., in the hydrogen, or by showers in the plates, while hadrons were misidentified as electrons[3] at a level $<10^{-4}$. Backgrounds for events where both tracks are identified are consequently negligible. The remaining 10% of electrons have momentum $\gtrsim 200$ MeV/c and miss the plates, and so require a momentum-dependent geometrical-acceptance correction to the observations.

The technique contrasts with Ref. 1 in affording limited statistics but strong systematic advantages. Almost all charged tracks (and ~80% of γ rays) are detected in the bubble chamber, including electrons from asymmetric pairs with momentum >1 MeV/c. Possible backgrounds from δ rays or Compton scattering near the vertex are removed by requiring charge balance in the interaction.

Identification decisions were made by physicists after candidate events were found by scanners. The scanning efficiency for identifiable electron events was (94± 1)% after 66% of the film was scanned twice and 7% three times. Normalization was established by scanning random rolls for the number of pions produced in fiducial-volume interactions. The data correspond to 4.2×10^5 inelastically produced $\pi^\pm$ from π^+p and 5.2×10^5 from π^-p interactions. This count has been used to estimate e^+e^- pair production from known processes, and e/π production ratios after scanning and acceptance corrections.

Events with electrons fell into two categories: Cat. I, both tracks identified as electrons (3782 events); Cat. II, one track identified, but accompanied by unidentifiable tracks of opposite charge (893 events). A few cases with only one possible "electron" were treated elsewhere.[3] Where two pairs occurred in an event the combinations with highest pair masses were rejected. There were 133 unmeasurable pairs, mostly because of momenta <3 MeV/c. The background of photons converting near the primary vertex and taken to be Dalitz pairs was estimated at 214± 58 events.

Monte Carlo studies have been made on the identification acceptance and measurement resolution. Correlated $p_\parallel$ and p_T distributions of inclusive pion production[4] lead to good agreement with the observed Dalitz-pair spectra in pair mass, laboratory momentum, p_T, etc. The ratio between populations of Cat. II and Cat. I is 0.236 ± 0.01: The simulation gives 0.234 ± 0.007. With the use of the known inclusive cross sections for $\pi^\pm$ and π^0,[4] and ρ^0, ω^0, and η,[5] branching ratios,[6,7] and normalizing to the measured $\pi^\pm$ production, 4606 ± 393 pairs are expected in Cat. I and II, including the γ background. We observe 4675.

Checks have been made that measurement systematics on these events do not mask the signal of interest, ~50 events for $e/\pi \sim 10^{-4}$, which may be sought where the π^0 contribution is small, e.g., $m_{ee} \gtrsim m_{\pi^0}$. From the quality of fit of measurements to hypothetical trajectories, the reconstruction program estimated uncertainties in momentum and angle, and in invariant mass of each pair. (This procedure for uncertainties has been checked at fixed mass values with measurements of γ conversions in the hydrogen and K^0 and Λ decays.) The mass uncertainty distributions for the broad mass range of Dalitz pairs interpolate smoothly with m_{ee} between the distributions for γ, K, and Λ. In particular, at high pair masses there is no evidence for significant contamination by low-mass events with measurements distorted by electromagnetic or other processes, and this confirms the results of bremsstrahlung calculations. From the γ, K, and Λ measurements the average mass uncertainty was $\sigma_m = 7$ MeV/c^2. In Fig. 1 is shown the mass spectrum for Cat. I events and simulations with and without resolution functions. A broad range of (non-Gaussian) resolution parameters is satisfactory above ~20 MeV/c^2 and does not change the conclusions of the experiment.

The inclusive cross sections used for ρ, ω, and η simulations are 4.9± 0.22, 4.15± 1.0, and 1.55 ± 0.55 mb, respectively. The last two are scaled from semi-inclusive measurements by comparison with ρ production,[5] but are consistent with quark-model expectations for the production ratios.[8] To be conservative, we have arbitrarily increased the reported errors on σ_ω by a factor of 2 and on σ_η by a factor of 3. An inclusive result, $\sigma_\eta \lesssim 1$ mb, has also recently been reported.[9] The distributions of these mesons are taken to follow those of the ρ in $p_\parallel$ and p_T,[5] since there is rather strong evidence for a universality in this respect, but wide variations do not affect the conclusions of this work.

In Fig. 2 are shown the mass distributions above 130 MeV/c^2 for Cat. I events, with π^+p and π^-p treated separately. Not plotted are 3 events in the ρ-ω mass region where 3.6 are expected, and an event in π^-p at 1420 MeV/c^2. There is an unexplained excess of π^-p, but not of π^+p events.

In the π^-p data, neither the 1420-MeV/c^2 event nor 3 events (where 0.15 are expected) between

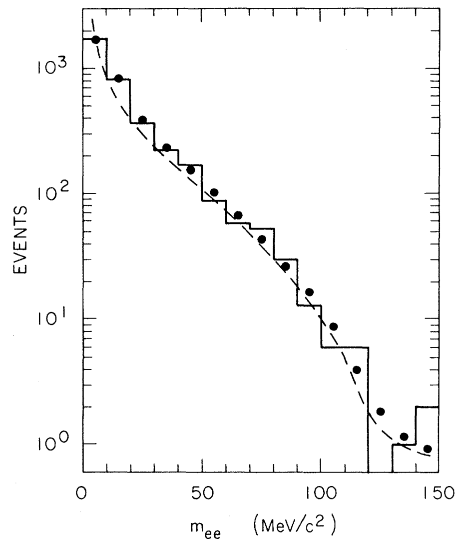

FIG. 1. Mass distribution of e^+e^- pairs from π^+p and π^-p, with both electrons identified. The dots represent the simulation, and dashes the simulation without the effects of resolution.

420 and 600 MeV/c^2 could be explained by unexpectedly large ρ, ω, or η contributions. For $m_\pi < m_{ee} < 600$ MeV/c^2 the *excess* is 16.1 ± 4.7 events, or $e^\pm/\pi^\pm = (0.87 \pm 0.25) \times 10^{-4}$, and is consistent with a parametrization $\exp(-m_{ee}/M)$, $M = 195 \pm 80$. In this mass range, $M = 100$ for the η and ω contribution. In the lower-mass interval $\frac{1}{2}m_\pi$ to m_π the excess is 7.0 ± 9.2 events.

Figure 3 shows the electron p_T distribution. It contrasts with results of Ref. 1, which gave e^+/π^- for $p_T > 500$ MeV/c in π^+p and pp interactions at 15 GeV/c. In π^+p, for $m_\pi < m_{ee} < 600$ MeV/c^2, the excess rate is $e^\pm/\pi^\pm < 3 \times 10^{-5}$ (90% confidence level). The significance of the difference between π^+p and π^-p is $\leq 2.7\sigma$ in any mass range. For tracks with $p_T > 500$ MeV/c and $m_{ee} > 100$ MeV/c^2,

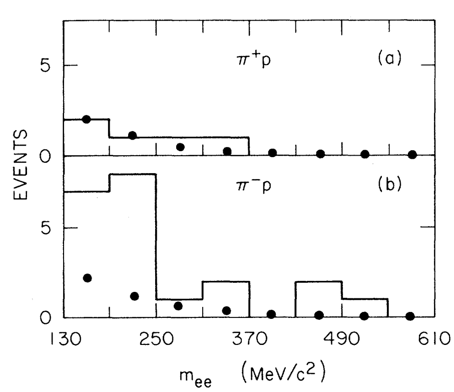

FIG. 2. Observed (lines) and expected (dots) events at higher masses: (a) π^+p; (b) π^-p.

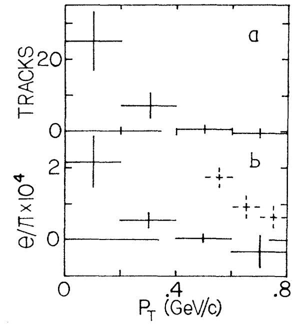

FIG. 3. Electron transverse-momentum distributions for π^-p events with $135 < m_{ee} < 600$ MeV/c^2: (a) Tracks in excess of expectations; (b) the corresponding $e^\pm/\pi^\pm$ ratio, with the excess from Ref. 1 (dashes).

we have $e^\pm/\pi^\pm < 3 \times 10^{-5}$ (π^-p) and $< 1 \times 10^{-5}$ (π^+p) at 90% confidence level.

Category II events (one track identified, with unidentified opposite-charge tracks) have an additional background, evaluated in conjunction with Ref. 3, caused by pions interacting in the plates and simulating electrons at a rate of $\sim 0.5 \times 10^{-4}$. Allowing for this, we find excellent agreement in both π^+p and π^-p between data in Cat. I and Cat. II. In particular, in π^-p for $m_\pi < m_{ee} < 600$, the 14 events observed in Cat. II compare with 14.6 ± 3.3 expected from the number in Cat. I and our identification acceptance. The excess over "known" processes is 5.2 ± 4.7 events.

Since the background from "known" sources is only ~25% of the 21 π^-p Cat. I events with $m_\pi < m_{ee} < 600$ (but ~65% of Cat. II events), we have examined some of their properties. The distribution of charged-hadron multiplicities is similar to that of 18-GeV/c πp interactions in general. The distribution of charge transferred to the backward hemisphere follows the "universal curve,"[10] with a mean value of -0.89 ± 0.2. The angular distribution of the electron about the direction of the massive virtual "photon" resembles that of photon interactions, $1 + a\cos^2\theta$, with $a = 1.4_{-0.4}^{+3.4}$. The pairs are clustered near x_F $(= p_\parallel^{\text{c.m.}}/p_{\max}^{\text{c.m.}}) = 0$. Only two pairs exceed $x_F = 0.25$, and this precludes useful comparison with dimuon experiments for which $x_F \gtrsim 0.35$.[9]

Finally, in Fig. 4 is given the multiplicity distribution of observed γ conversions accompanying these events. The probability of detecting a γ ray is ~80% which badly distorts the distribution at high γ multiplicities. As a comparison we indicate the distribution obtained by scanning interactions without e^+e^- pairs, and [Fig. 4(b)] from events with low-mass Dalitz pairs. The

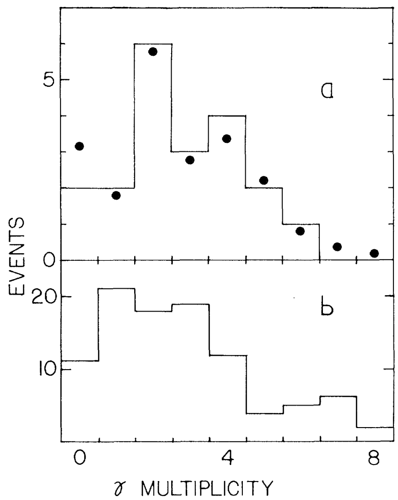

FIG. 4. γ-ray multiplicity distributions: (a) Events in π^-p with $135 < m_{ee} < 600$ MeV/c^2 and (dots) events with no associated e^+e^- pair plotted at $\frac{1}{5}$ scale; (b) with an associated low-mass Dalitz pair.

differences suggest that the excess high-mass pairs occur in interactions with an even number of free γ rays, unlike π^0 or η Dalitz pairs.

In summary, there is eveidence of direct, unexplained production of e^+e^- pairs in π^-p interactions, with a broad mass spectrum and a steep p_T dependence. The data from π^+p indicate a smaller effect, if any, and neither set is consistent with the p_T distribution reported in Ref. 1 for π^+p and pp interactions.[11]

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Nonrenormalizable Quantum Field Models in Four-Dimensional Space-Time

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The construction of no-cutoff Euclidean Green's functions for nonrenormalizable interactions $\mathcal{L}_I(\varphi) = \lambda\int d\delta(\epsilon)\!:\!\exp\epsilon\varphi\!:$ in four-dimensional space-time is carried out. It is shown that all axioms for the generating functional of the Euclidean Green's function are satisfied except perhaps SO(4) invariance.

In this work I consider a class of nonrenormalizable quantum field theories in four-dimensional space-time with the interaction Lagrangian given by the formula

$$\mathcal{L}_I^{\Lambda,\kappa}(\varphi) = \lambda\int_\Lambda\int_R :\exp\epsilon\varphi_\kappa:(x)d^4x\,d\sigma(\epsilon). \qquad (1)$$

Here : : means a normal ordering with respect to a covariance c_κ, i.e.,

$$:\exp\epsilon\varphi_\kappa:(x) = \exp[-\tfrac{1}{2}\epsilon^2 C_\kappa(x,x)]_{\exp\epsilon\,\varphi(x)}, \qquad (2)$$

and $\sigma(\epsilon)$ is a finite positive measure with a sup-