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OBSERVATION OF A DIRECT LOW-MASS e^+e^- CONTINUUM IN π^-p INTERACTIONS AT 16 GeV/c*

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ABSTRACT

The production of prompt electron-positron pairs in 16 GeV/c π^-p collisions has been measured using the LASS spectrometer at SLAC. An excess of events is observed above the estimated contribution of direct and Dalitz decays of known resonances in the kinematic range defined by $0.1 \leq x \leq 0.45$, $0 \leq p_T \leq 0.8$ GeV/c and $0.2 \leq M(e^+e^-) \leq 0.7$ GeV/c^2. The excess signal decreases slowly with increasing M, but exhibits very steep x and p_T^2 dependence.

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Direct lepton pair production has received considerable attention in recent years [1]. The observed pair mass spectrum consists of vector meson contributions superimposed on a continuum which decreases rapidly with increasing mass. At high mass, the continuum is well-understood in terms of the Drell-Yan mechanism [2]. At low mass the data from $\mu^+\mu^-$ experiments [3-6] indicate that the signal below ~1 GeV/c^2 is stronger than expected from vector meson decays alone, and is not compatible with the Drell-Yan description. There are also indications that the characteristics of the continuum depend on the kinematical range of observation. The inherently poor resolution of dimuon experiments has, however, made detailed study of the properties of the continuum difficult.

Low mass electron pair data are scarce and inconclusive. Two ISR experiments [7-8] have measured low mass e^+e^- pairs at large transverse momentum (p_T > 2 GeV/c); in each case the observed spectrum is consistent with the contributions resulting from Dalitz decays of η and ω mesons and semi-leptonic decays of charmed particles. Several bubble chamber groups [9-12] have seen indications of a low-mass continuum, but these experiments are limited by their low sensitivity.

In this letter we report the first results from an experiment measuring low mass e^+e^- pairs in π^-p collisions at 16 GeV/c using the LASS spectrometer at SLAC (fig. 1). Both the trigger and electron identification were provided by the multicell, atmospheric pressure, gas Čerenkov counter and a set of total absorption shower counters [13]. The individual electron tracks were required to have momentum in the range $0.75 \leq p_{LAB} \leq 5.0$ GeV/c and the corresponding combined Čerenkov and shower counter hadron rejection was measured to be better than

6.10^{-5} per track. With the configuration of fig. 1 and the above momentum requirements the experiment was sensitive to electron pairs emitted in the kinematical region defined by $0.10 \leq x \leq 0.45$ and $0 \leq p_T \leq 0.8$ GeV/c.

The flux of $\sim 10^9$ π^- incident on the liquid hydrogen target results in a sensitivity of 2.4 events/nb. The data were processed through the pattern recognition program requiring reconstruction of at least one track producing signals in both the Čerenkov and shower counters and also of another track firing an independent Čerenkov cell. No restrictions were made on the charge combination for such reconstructed pairs in order to obtain an unbiased estimate of background contributions to the final e^+e^- data sample.

The resulting sample is made up primarily of events involving a photon conversion or a Dalitz decay. Such events are eliminated by the requirement of a same or opposite sign electron pair of mass greater than 0.2 GeV/c^2 forming a good vertex with the beam track. The final data sample then contains 291 events in the mass interval $0.2 \leq M \leq 1.2$ GeV/c^2; of these approximately one third contain same sign electron pair combinations.

The same sign electron pair background consists of pairs of three types:

(i) pairs formed by electrons originating from different γ-conversions;

(ii) pairs containing an electron from a γ-conversion and a mis-identified hadron;

(iii) pairs containing two mis-identified hadrons.

Categories (i) and (ii) should contribute equally to the same and opposite sign pair samples since the probability of finding only one electron from a γ-conversion is charge symmetric.

This is not the case for category (iii) however; consequently a Monte Carlo program has been used [14] to estimate the dihadron background contribution to the direct e^+e^- sample obtained by subtracting same sign from opposite sign pairs. An estimated contribution of (6 ± 4) events has been obtained.

The uncorrected e^+e^- mass spectrum after subtraction of the same sign background contains (107 ± 17) events and is shown in fig. 2 together with the estimated dihadron background contribution.

In the mass interval 0.72-0.80 GeV/c^2 of fig. 2 there are 11.8 ± 3.8 events with virtually no dihadron background. It is natural to associate this signal with the production of the ρ and ω resonances and their subsequent decay to e^+e^-.

In order to estimate the expected contribution from such a mechanism, Monte Carlo calculations were performed using the estimated ρ^o and ω production cross sections in π^-p interactions at 16 GeV/c [15]; these calculations took into account geometrical acceptance, as well as software and electron identification efficiencies. Using decay branching ratios from the Particle Data Tables [16], the spectrum of fig. 2 is expected to contain (7.5 ± 0.6) ρ^o events and (7.5 ± 2.0) ω events, ignoring possible interference effects. As indicated in fig. 2, such a contribution is completely consistent with the observed e^+e^- mass spectrum.

In the low-mass continuum region, i.e., $0.2 \leq M \leq 0.7$ GeV/c^2 the net e^+e^- sample consists of (92 ± 16) events, and contains ~ 1 $\rho \rightarrow e^+e^-$ event

in addition to the estimated (6 ± 4) events hadron-hadron contamination. The remaining major contribution from known sources is due to Dalitz decays of η and ω mesons. A similar Monte Carlo technique to that referred to above was used to estimate the contributions from these processes. The η production [15] was assumed to have the same x and p_T dependence as ω production, and the parent meson assumed to decay isotropically in its rest frame into a e^+e^- subsystem of mass M and the recoil particle; the subsystem M was then assumed to decay as $(1+\cos^2\theta)$ in its rest frame. The resulting η and ω contributions to the low mass continuum are estimated to be (15.3 ± 5.3) and (10.3 ± 1.6) events respectively, so that these sources account for only ~30% of the observed direct signal.

The M, x and p_T^2 distributions for the low-mass continuum are shown in fig. 3 together with the estimates of the corresponding η and ω Dalitz decay contributions. It is clear that the dynamical characteristics of the excess events are quite different from those of the η and ω spectra. The mass distribution (fig. 3a) is varying more slowly, whereas the x and p_T^2 distributions are much steeper for $x \leq 0.25$ and $p_T^2 \leq 0.1$ $(GeV/c)^2$ respectively.

In order to obtain differential cross sections, a Monte Carlo technique was used to estimate the overall pair acceptance at each point of the (x, p_T^2, M) phase space volume. Each pair was weighted by the inverse of its acceptance value, same sign pairs being given negative weight. The corrected cross section for the low-mass continuum is found in this way to be (955 ± 170) nb. The estimated (η,ω) contribution is (255 ± 60) nb, so that the excess corresponds to cross section of (700 ± 180) nb in the acceptance region of the experiment.

In figs. 4a-c are shown the acceptance corrected M, x and p_T^2 distributions of the continuum, and in figs. 4d-f, these distributions are reproduced after subtraction of the estimated η and ω contributions.

Describing the mass spectra by

$$\frac{d\sigma}{dM} = C_1 M^{-\alpha}$$

we find $\alpha = 1.77 \pm 0.64$ for fig. 4a and $\alpha = 0.94 \pm 0.89$ for fig. 4d. The removal of the estimated (η,ω) contribution thus results in a residual mass spectrum which is well described by an M^{-1} dependence.

Fits to the x distributions (figs. 4b and 4e) of the expression

$$\frac{d\sigma}{dx} = C_2(1-x)^{\beta}$$

yield $\beta = 7.46 \pm 1.72$ and $\beta = 9.78 \pm 2.64$ for the unsubtracted and subtracted distributions, respectively.

The p_T^2 distributions of figs. 4c and 4f are not well described by a single exponential function. Furthermore, for the unsubtracted data:

$$\langle p_T^2 \rangle = 0.137 \pm 0.034 \ (\mathrm{GeV/c})^2 \quad \text{for} \quad 0.10 \leq x \leq 0.20$$

$$\langle p_T^2 \rangle = 0.206 \pm 0.068 \ (\mathrm{GeV/c})^2 \quad \text{for} \quad 0.20 \leq x \leq 0.45$$

indicating that the p_T^2 distribution may exhibit some x dependence.

In summary the production of direct e^+e^- pairs has been measured in the region $0.10 \leq x \leq 0.45$, $p_T^2 \leq 0.64 \ (\mathrm{GeV/c})^2$ and $0.2 \leq M \leq 1.2 \ \mathrm{GeV/c^2}$. A low mass continuum in excess of the direct or Dalitz decays of known resonances is observed for $0.2 \leq M \leq 0.7 \ \mathrm{GeV/c^2}$. This continuum corresponds to a cross section of 700 ± 180 nb [17], and exhibits very steep x and p_T^2 distributions; the steepness of the low p_T^2 spike may be increasing with decreasing x.

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REFERENCES

[1] For reviews see e.g., L. Lederman, Phys. Rep. 26 (1976) 149; N. S. Craigie, Phys. Rep. 47 (1978) 1.

[2] S. D. Drell and T. M. Yan, Phys. Rev. Lett. 25 (1970) 316.

[3] K. J. Anderson et al., Phys. Rev. Lett. 37 (1976) 799.

[4] W. M. Morse et al., Phys. Rev. D18 (1978) 3145; D. M. Grannan et al., Phys. Rev. D18 (1978) 3150.

[5] J. Alspector et al., Phys. Lett. 81B (1979) 397.

[6] R. Cassell et al., SLAC-PUB-2408 (1979).

[7] A. Chilingarov et al., Nucl. Phys. B151 (1979) 29.

[8] J. H. Cobb et al., Phys. Lett. 78B (1978) 519.

[9] J. Ballam et al., Phys. Rev. Lett. 41 (1978) 1207.

[10] J. Guy et al., Phys. Lett. 66B (1977) 300.

[11] R. Barloutaud et al., SACLAY preprint DPhPE-80-06 (1980).

[12] G. Levman et al., Phys. Rev. D21 (1980) 1.

[13] For detailed description of the experimental apparatus see D. Blockus, Ph.D. Thesis, Johns Hopkins University (1980), and references therein.

[14] We are grateful to Dr. D. R. O. Morrison and the Aachen-Berlin-Bonn-CERN-Cracow-Heidelberg-Warsaw Collaboration for providing their 16 GeV $\pi^- p$ data, which were instrumental to these Monte Carlo studies.

[15] J. Bartke et al., Nucl. Phys. B107 (1976) 93 and Nucl. Phys. B118 (1977) 360.

[16] N. Barash-Schmidt et al., Particle Data Tables, Phys. Lett. 75B (1978) 1.

[17] Using the pion production data of ref. [14], it is found that, after subtracting known resonance contributions from the numerator, the $(e^+e^-/\pi^+\pi^-)$ ratio is $(4.7 \pm 1.2) \times 10^{-5}$ for the region of phase space accessible to our experiment. However the ratio exhibits strong x and p_T^2 dependence; consequently we reserve detailed discussion for a subsequent publication.

FIGURE CAPTIONS

1. The LASS spectrometer layout (plan-view).
2. The mass distribution of direct e^+e^- pairs. The estimated contributions of dihadron background and direct decays of ρ^o and ω mesons are shown as shaded areas.
3. The uncorrected distributions of mass, x and p_T^2 for the continuum. The estimated contributions of η and ω Dalitz decays are shown as shaded areas.
4. The acceptance corrected mass, x and p_T^2 distributions for the continuum: (a)-(c) before, (d)-(f) after subtraction of the η and ω Dalitz decay contributions. The curves correspond to the fits described in the text.

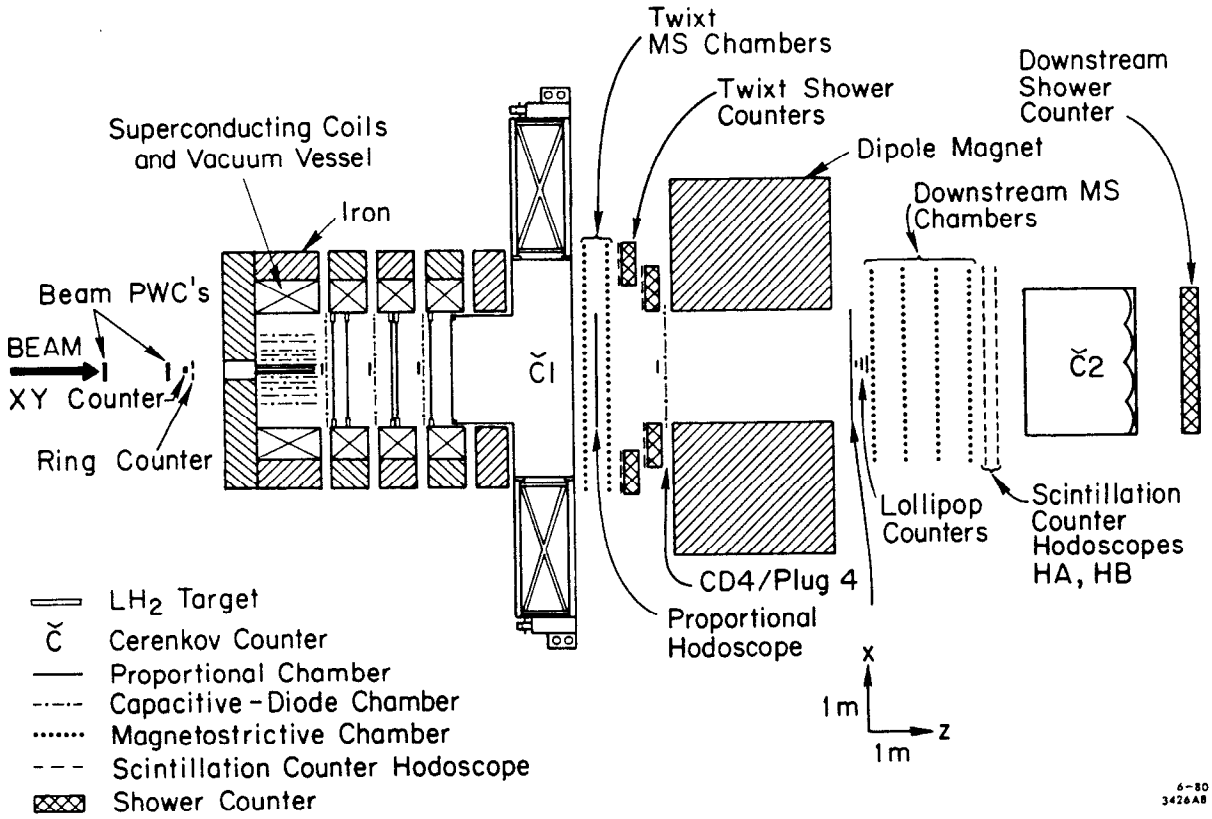
Twixt
MS Chambers
Twixt Shower
Counters
Downstream
Shower
Counter
Superconducting Coils
and Vacuum Vessel
Dipole Magnet
Iron
Downstream MS
Chambers
Beam PWC's
BEAM
XY Counter
Ring Counter
C̆1
C̆2
Lollipop
Counters
Scintillation
Counter
Hodoscopes
HA, HB
CD4/Plug 4
Proportional
Hodoscope
x
1m
z
1m
LH2 Target
C̆ Cerenkov Counter
Proportional Chamber
Capacitive-Diode Chamber
Magnetostrictive Chamber
Scintillation Counter Hodoscope
Shower Counter
6-80
3426A8

Fig. 1

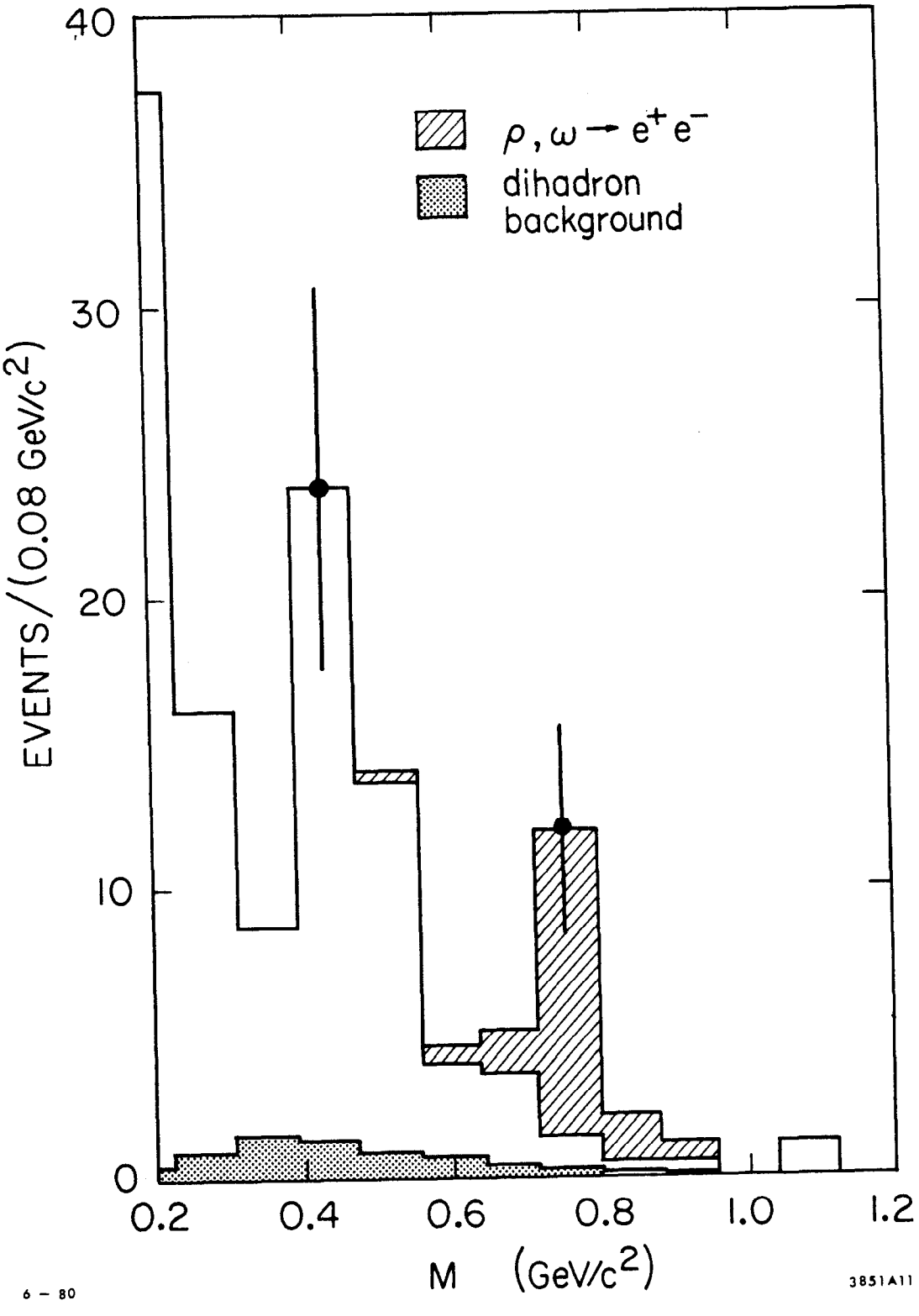
40
30
20
10
0
EVENTS/(0.08 GeV/c²)
ρ, ω → e⁺e⁻
dihadron background
0.2
0.4
0.6
0.8
1.0
1.2
M (GeV/c²)
6 - 80
3851A11

Fig. 2

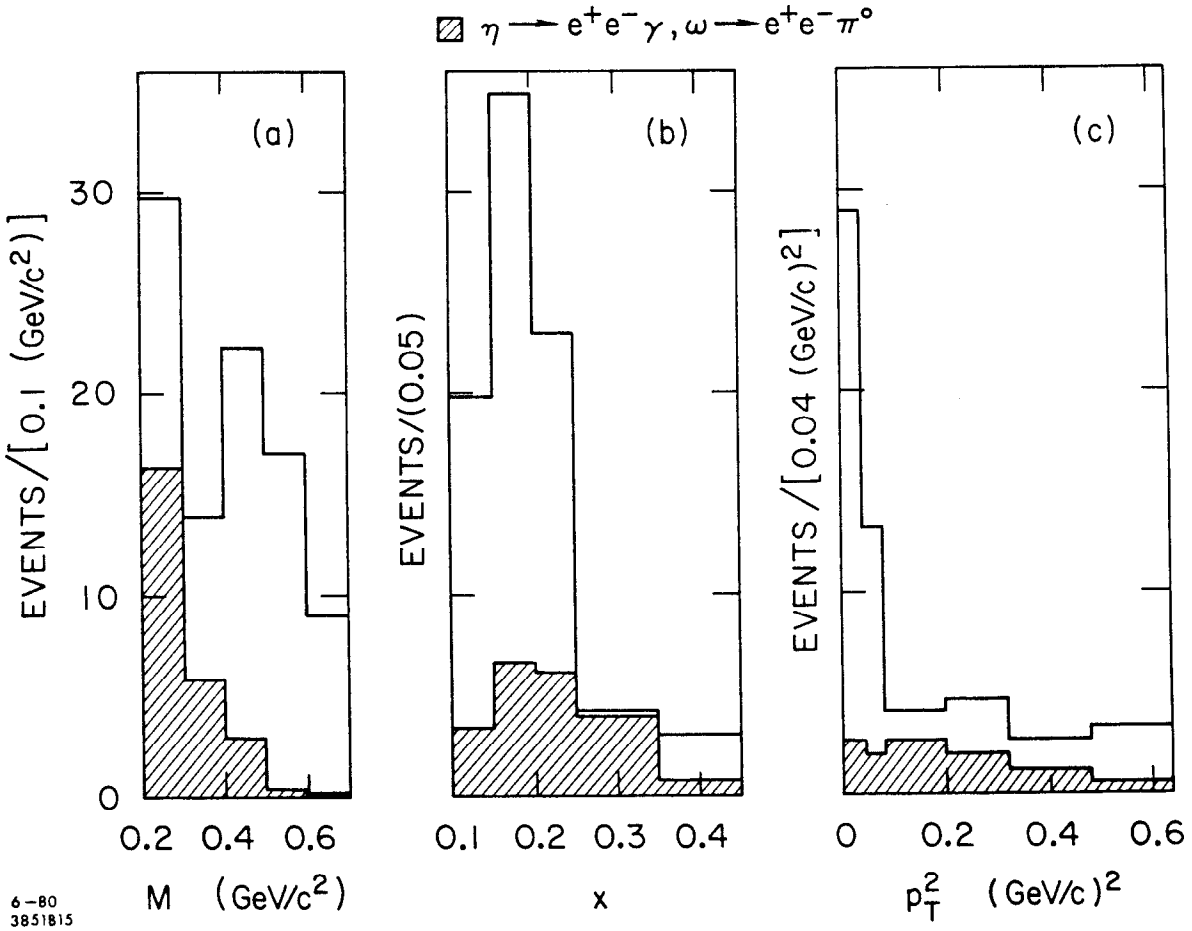
▨ η → e+e−γ, ω → e+e−π°
(a)
(b)
(c)
EVENTS/[0.1 (GeV/c²)]
EVENTS/(0.05)
EVENTS/[0.04 (GeV/c)²]
30
20
10
0
0.2 0.4 0.6
M (GeV/c²)
0.1 0.2 0.3 0.4
x
0 0.2 0.4 0.6
p²T (GeV/c)²
6-80
3851B15

Fig. 3

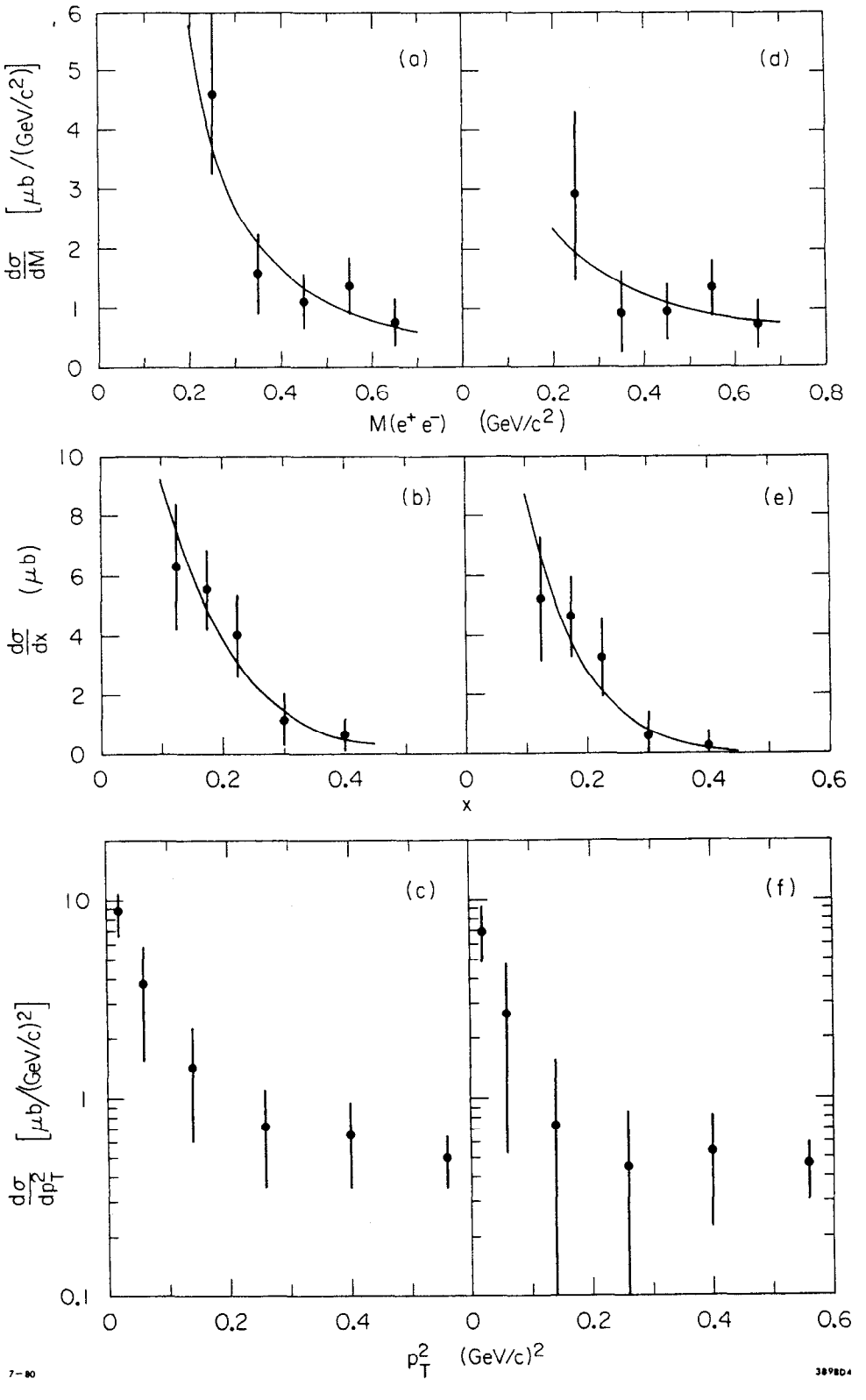
(a)
(d)
(b)
(e)
(c)
(f)
$\frac{d\sigma}{dM}$ [μb/(GeV/c^2)]
$\frac{d\sigma}{dx}$ (μb)
$\frac{d\sigma}{dp_T^2}$ [μb/(GeV/c)^2]
M(e$^+$e$^-$) (GeV/c^2)
x
p_T^2 (GeV/c)^2
7-80
3898D4

Fig. 4