SLAC-PUB-2056
December 1977
(E)

# Limits on the Production of Unpaired Electrons or Positrons in 18 GeV/c $\pi^{\pm}p$ Interactions*

J. Ballam, J. Bouchez,** T. Carroll, G. Chadwick,
V. Chaloupka, C. Field, D. Freytag, R. Lewis,‡ K. Moffeit, R. Stevens

Stanford Linear Accelerator Center
Stanford University, California 94305

H. Band, L. R. Fortney, T. Glanzman,
J. S. Loos,+ W. J. Robertson, W. D. Walker

Duke University
Durham, North Carolina 27706

P. A. Baker, P. J. Dornan, D. J. Gibbs,
G. Hall, A. P. White, T. S. Virdee

Imperial College
London, England

October 20, 1977

## Abstract

Using the SLAC Hybrid Facility 1 m. bubble chamber with tantalum plates, a search was made for single electrons or positrons produced directly in 18 GeV/c $\pi^{\pm}$ interactions. At 90% C.L. $R = e^{\pm}/\pi^{\pm} < 2.4 \times 10^{-5}$. In addition, a limit can be set on charmed particle pair or associated production channels in terms of their semielectronic decay branching ratios, namely, $\sigma \times (BR_1 + BR_2) < 2.4\ \mu b$ at 90% C.L.

(Submitted to Phys. Rev. Letters)

*Work supported by the Dept. of Energy and U.K.S.R.C.

The subject of lepton production in hadron collisions has absorbed considerable experimental and theoretical effort for some time.[1] Plausible descriptions of the production processes seem to be available now except in two kinematic domains - at very low lepton transverse momentum $p_T$ and at low c.m. energy.[1] The results to be described on the production of unpaired $e^{\pm}$ contribute new information in these areas.

At low $p_T$, strong $e^{\pm}$ signals have been observed at the I.S.R.[2] and in $\pi p$ and pp collisions at 10-24 GeV/c.[3] In the former case the $e/\pi$ ratio increased from $2 \times 10^{-4}$ to $5.5 \times 10^{-4}$ as $p_T$ decreased from 500 MeV/c to 200 MeV/c. The lower energy data gave a ratio increasing to $2 \times 10^{-4}$ as $p_T$ decreased to 500 MeV/c. The $e^-$ rate was reported to be comparable with the $e^+$ rate. (The term "electron" will be used to refer to $e^-$ or $e^+$ in what follows.) Muon production experiments[4] at larger $X_F$ do not report such a strong increase.

The experiments reporting the electron excess were unable to observe the interactions directly and hence could not say whether the production was by $e^+e^-$ pairs or otherwise. The experiment being described here had the advantage of observing all the charged tracks at the interaction vertex, and it has been possible to separate pair production from the apparent production of unpaired electrons.

The SLAC 1-m hydrogen bubble chamber was exposed to 18 GeV/c beams of $\pi^+$ and $\pi^-$. In the chamber were three tantalum plates, each 1.0 radiation lengths thick, perpendicular to the beam. A hole of $\sim 5$ cm$^2$ in each plate was provided to allow the non-interacting beam particles to leave the chamber without hitting the plates. Upstream and downstream of the bubble chamber were counters and proportional chambers of the SLAC Hybrid Facility.[5] Beam tracks entering the chamber, but failing to hit a small scintillator 5 m beyond the bubble chamber, triggered the proportional chamber read-in. The flux was restricted to 2-3 particles/pulse.

The proportional chamber data were then used by the on-line computer to flash bubble chamber lights unless the beam track was out of position or the interaction was clearly outside the fiducial volume. A study of interactions in the bubble chamber indicates that this triggering process introduced a bias only to the extent of eliminating 50% of the (most forward) elastic scatters.

Electrons were identified in the bubble chamber by a variety of techniques: (1) spiralling (by this means tracks are detectable down to $\lesssim 1$ MeV/c, (2) Bremsstrahlung in hydrogen, (3) high energy $\delta$-rays, (4) ionization (useful to $\sim$ 200 MeV/c) and (5) characteristically electromagnetic interactions in the plates. In addition, the test of proper charge balance could be applied to all interactions, thereby eliminating any remaining difficulties with $\delta$-rays near the interaction vertex or extremely asymmetric electron pairs. Hadrons could be distinguished from electrons by heavy ionization, interactions or decays in the hydrogen, or by characteristically non-electromagnetic behavior in the plates.

The experiment is sensitive to electrons at all momenta. The techniques (1) and (4) above are dominant at the lowest energies, but their efficiency falls off sharply above 200 MeV/c. The acceptance of the plates, on the other hand, rises steadily with momentum. At 500 MeV/c it is 55%, at 1 GeV/c it is 80% and by 2 GeV/c it reaches 90%. A Monte Carlo simulation of the experiment based on a correlated $x_F$ - $p_T$ distribution of pion production has proved useful in the analysis. It has been successfully tested against results of scanning a fraction of the data. Scanning and simulation both show that only 5% of pions can be identified by techniques 1-4 (whereas ∿60% of observed $e^{\pm}$ from Dalitz pairs are so identified). About 72% of pions hit the plates, however.

Within their ranges of applicability the identification methods are sufficiently unambiguous to separate $e^{\pm}$ from hadrons at a level better than 1 in $10^4$. Since pions are mostly identified by means of plate interactions, the potential background from this source is discussed here.

Calibration data were obtained for both electrons and pions. An electron beam of 1.57 GeV/c was directed at the plates, and the film used to determine properties of the interactions. Several characteristics were considered to be useful in the visual separation of electron and hadron tracks: (1) Electrons interact visibly before plate 3. (2) The observed transverse momentum of each track in the shower, including converting gamma rays, does not exceed 30 MeV/c in the film plane projection. No track with momentum > 10 MeV/c is produced at an angle beyond $90^{\circ}$. (3) For each event, the total visible shower energy, $E_{VIS}$, was evaluated behind each plate. At least one of these $E_{VIS}$ samples is greater than 7% of the energy of the incoming track. (4) Low energy identifiable electrons are produced in the shower. (5) No hadron signatures (heavy ionization, scatters, etc.) occur. These criteria are essentially energy independent[6] down to ∿ 300 MeV. From the scanning results they correspond to a loss of about 2% of electrons.

To test the criteria with pions, beams of 1.57 and 3.14 GeV/c were purified by lead curtains, R-F separation and a Cerenkov counter, and their electron contamination shown to be $< 5 \times 10^{-6}$ with the aid of a shower counter. Interactions of these beams with the plates gave a broad spectrum of values of $p_T$ and $E_{VIS}$. Seven cases in $1.16 \times 10^5$ pions at 1.57 GeV/c fell within the "electron" criteria. At 3.14 GeV/c there were 1.5 cases in $1.4 \times 10^5$ tracks (one event's error bar straddled the $p_T$ criterion).

The misidentification process has been simulated using $\pi^{\pm}p$, $\pi^{\pm}n$ tabulated cross sections for $\pi^o$ channels, allowing for intranuclear cascades, assuming that protons escaping the plate will be recognized by their ionization level in the hydrogen, and incorporating the 30 MeV/c visible transverse momentum criterion on the $\gamma$ which converts. The momentum dependence is controlled by relatively well known factors, the cross sections, and to a lesser extent by proton production kinematics. The model is compared with the calibration in Fig. 1a, where $\pi^+$ Ta and $\pi^-$ Ta results are shown separately. The agreement is quite good. The model has been used to interpolate and extrapolate the results of the calibration. For this purpose, the predicted rates from the model have been decreased by 11% to bring the average of $\pi^+$ and $\pi^-$ values to that of the 1.57 GeV/c calibration.

The film of the 18 GeV/c data has been scanned with the electron identification criteria set very wide, so including a broad spectrum of hadron showers among the candidates. A second scan was performed on 66% of the film. After measuring, events have been examined at the scanning table by physicists. At this stage the electron identification criteria enumerated above were applied, and the scanning efficiency for detecting identifiable electrons was shown to be $(96 \pm 1)\%$.

The normalization has been determined by scanning random rolls to count the number of pions produced in interactions within the fiducial volume. The data sample corresponds to $9.4 \times 10^5$ inelastically produced $\pi^{\pm}$ from $\pi^+$ and $\pi^-$ beams.

The reconstructed $e^{\pm}$ candidates were divided into three categories for events with: (A) a single $e^{\pm}$ candidate with all opposite charge tracks identified as hadrons: 22 candidates within the criteria; (B) candidates in pairs, $e^+e^-$: 2000 pairs analyzed to date from 55% of the data; (C) a single $e^{\pm}$ candidate with at least one unidentifiable track of opposite charge: 400 "pairs" from 55% of the data.

A detailed analysis of the pairs of category (B) will be the subject of a later report. We here discuss the category A events to determine whether they are real unpaired electrons or are consistent with background.

All of the single electron candidates, category (A), are identified by their plate interactions. A distribution of their shower properties in terms of $p_T$ and $E_{VIS}$ normalized to the initial track energy $E_o$, merges smoothly at the $p_T$ = 30 MeV/c and $E_{VIS}/E_o$ = 7% criterion contours with that of the rejected candidates. It is similar to that obtained in the $\pi^{\pm}$ calibration film but quite different from the electron distribution. The number of events with showers originating in the second plate is compatible with a hadronic, rather than an electromagnetic, origin.

If the events were real electrons with a pion-like production distribution, approximately two extra events would have been expected in the momentum range where ionization and spiralling would have identified them. No such events were found. The category (C) events are formed of a low mass Dalitz pair distribution with a small contribution from pion misidentification. Unpaired electron events are lost into this category at a rate < 25% (90% C.L.) of the category (A) events.

There are no surprises in the $X_F$, $p_T$ or event multiplicity distributions of the 22 events, as compared with those expected with a pion misidentification scenario. There were no identifiable strange particles associated with the events, but in one case an additional low mass Dalitz pair was found. Both statements are consistent with a misidentification origin.

A momentum distribution of the candidate tracks is shown in Fig. 1b, agreeing with the spectrum expected from the model discussed above. (Above 3 GeV/c there are two events where 0.6 are expected.) Further, a comparison between the model and the data in the different charge sign categories (Table 1) shows excellent agreement.

If the 22 events in category (A) were all directly produced electrons, they would correspond to a ratio of $e/\pi = (4.3 \pm 0.9) \times 10^{-5}$. The evidence strongly favors the conclusion, however, that the events are caused by pion interactions in the plates at a rate consistent with calculations. Consequently, the expected background is used as a subtraction from the observed 22 events. Notwithstanding the good agreement, the statistical error on the direct calibration of the plates is quite large. For the uncertainty in the background subtraction we therefore use the fractional uncertainty in the 1.57 GeV/c calibration data, that is on the 7 events observed there.

We express the results as a 90% C.L. limit on single electron production relative to inelastic pion production, $R = e^{\pm}/\pi^{\pm} < 2.4 \times 10^{-5}$. The result is also given in Fig. 2 as a function of a lower limit on the transverse momentum accepted in the data, to facilitate comparison with other experiments. Because of low pion statistics the limit on the ratio is weak beyond $\sim$ 700 MeV/c.

Some information can be obtained from these numbers on the production of pairs of charmed particles, since semielectronic decays could be detected. The acceptance of the apparatus is not reduced for distributions broad in $p_T$

such as would be anticipated for such decays. The D semielectronic branching ratios are <15%.[7] If this is true also for other charmed particles then in general only a small correction is needed for losses into the $e^+e^-$ category B. The detection probability then depends on the sum of the semielectronic branching ratios of the charmed particles, and one obtains a 90% C.L. limit for any charm production channel cross section $\sigma$: $\sigma \times (B.R._1 + B.R._2) < 2.4\ \mu b$. In the case of charmed meson pair production, the semielectronic branching ratio $(9.4 \pm 1.4)\%$ is indicated by $e^+e^-$ storage ring experiments,[7] and we obtain $\sigma < 13\ \mu b$, 90% C.L.

We wish to thank the SLAC accelerator and bubble chamber staff for their efficient operation of the equipment and all the scanners for their efforts in searching the film.

** Now at CEN Saclay, Gif-sur-Yvette, France.

‡ Now at Michigan State University, East Lansing, MI 48823.

+ Now at Argonne National Lab., Argonne, IL 60439.

References

1. L. M. Lederman, Physics Reports 26C, 151, 1976 and references cited therein.

2. L. Baum et al., Phys. Letters <u>60B</u>, 485 (1976).

3. E. W. Beier et al., Phys. Rev. Letters <u>37</u>, 1117 (1976).

4. J. G. Branson et al., Phys. Rev. Letters <u>38</u>, 457 (1977).

5. J. Ballam and R. D. Watt, SLAC-PUB-1954, (1977) (to be published in Ann. Rev. Nucl. Sci.).

6. H. Messel and D. F. Crawford, <u>Electron-Photon Shower Distribution Function</u>, Pergamon Press, London, 1970; T. Kitagaki et al., Tohoku Report TUHEL-76/3, (1976) (unpublished).

7. R. Brandelik et al., DASP Collaboration, DESY Report 77/41, July 1977; W. Bacino et al., SLAC-PUB 2030, October 1977; J. M. Feller et al., SLAC-PUB-2028, October 1977.

| | $\pi^+ p$ predicted background | $\pi^+ p$ observed events | $\pi^- p$ predicted background | $\pi^- p$ observed events |
|---|---|---|---|---|
| $e^+$ | 8.0 | 6 | 5.7 | 5 |
| $e^-$ | 3.6 | 2 | 9.2 | 9 |

Table 1: Charge sign distribution of observed $e^{\pm}$ candidates compared with predictions based on the calibration data and the pion misidentification model.

## Figure Captions

1\. a. Results of the $\pi^+p$ and $\pi^-p$ calibration exposures in terms of apparent electrons per pion. Expectations from the model described in the text are shown as smooth curves.

b. Momentum distribution of electron candidates. The smooth curve is the expectation from the model as described in the text.

2\. 90% C.L. upper limit on the ratio $e^{\pm}/\pi^{\pm}$ as a function of the lower limit in $p_T$ accepted in the data.

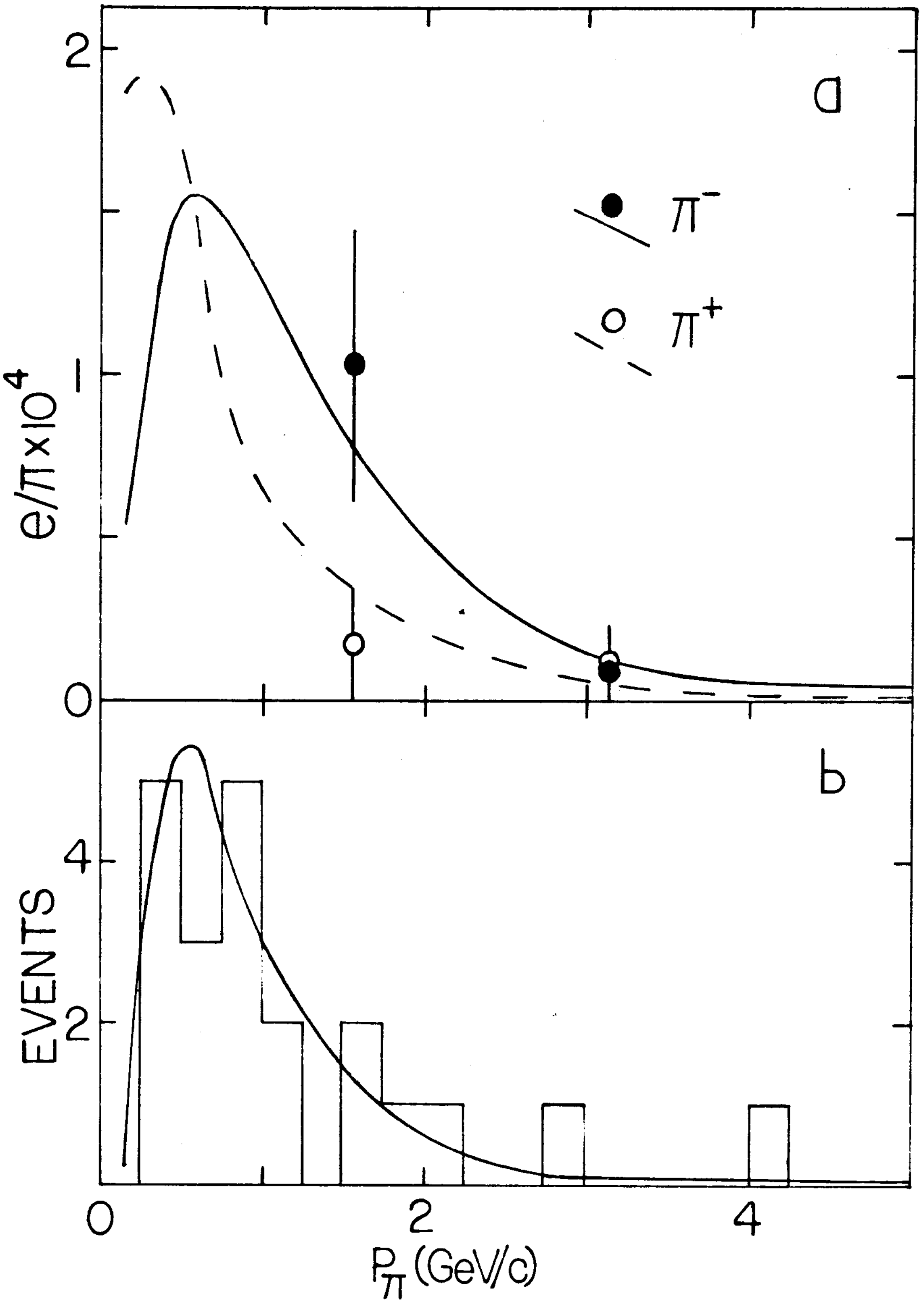

Fig. 1

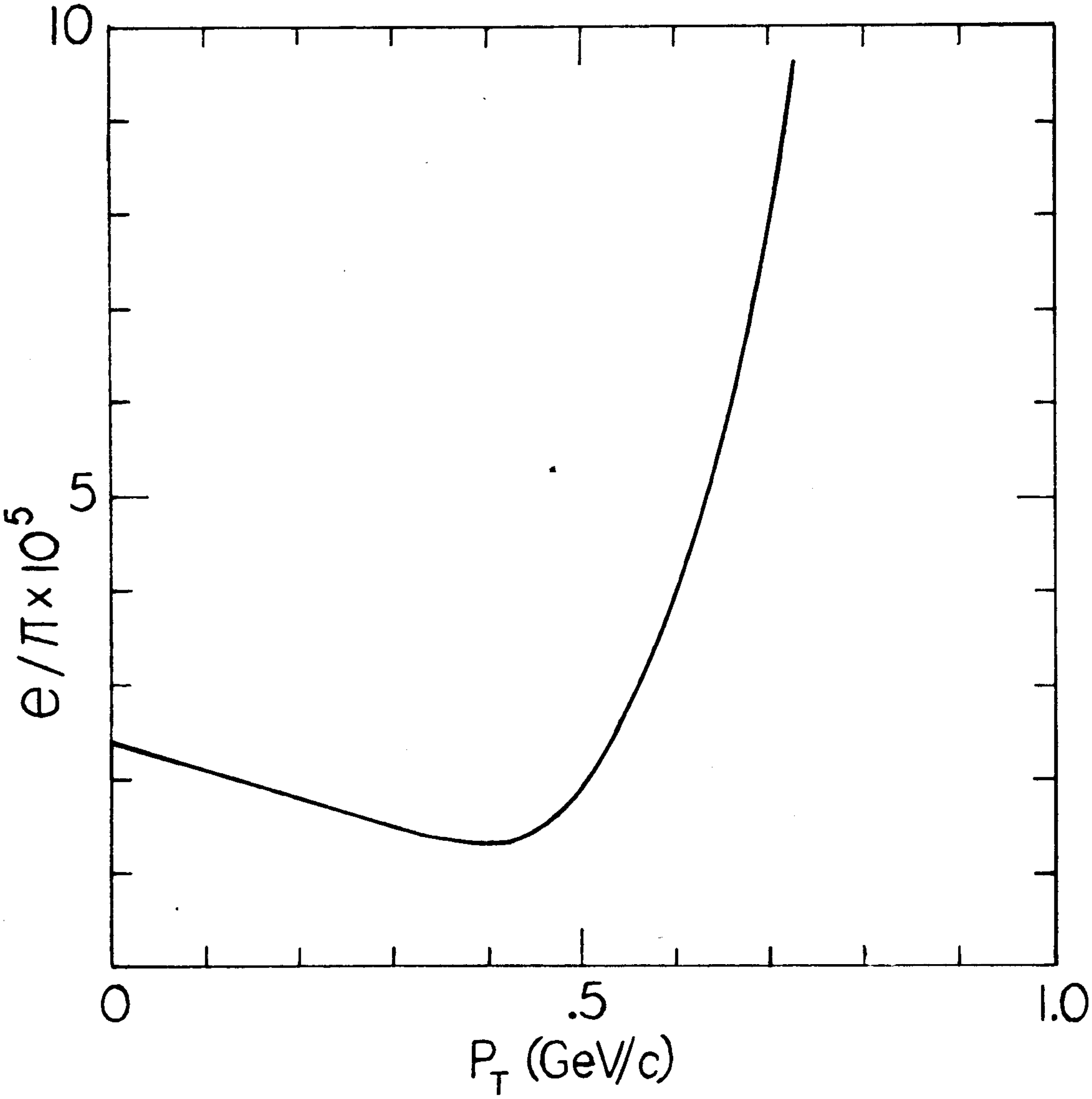


Fig. 2