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SEMILEPTONIC CHARM DECAY*

Joseph M. Izen

University of Illinois at Urbana/Champaign
Urbana, Illinois 61801

Representing the MARK III Collaboration *at the*
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94309

ABSTRACT

Semileptonic branching ratios for $D^0 \to \pi^- e^+ \nu_e$, $K^- e^+ \nu_e$ and $K^- \mu^+ \nu_e$ are presented, leading to a measurement of V_{cd}/V_{cs}. Seven additional exclusive D^0 and D^+ semileptonic branching ratios and a first inclusive D_s^+ measurement are given.

1. ANALYSIS METHOD AND CUTS

Semileptonic decays are searched for using 3329 $D^0 \bar{D}^0$ decays tagged with $K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$, $\overline{K}^0\pi^+\pi^-$ and $K^-\pi^+\pi^0$ and 1777 D^+D^- decays tagged with $K^-\pi^+\pi^+$, $\overline{K}^0\pi^+$ and $\overline{K}^0\pi^+\pi^+\pi^-$ (Fig. 1). These are found in 9.56 pb^{-1} of $\psi(3770)$ data. Both TOF and shower information is used to identify leptons. The kinematic variable $U = E_{missing} - |\vec{P}_{missing}|$ is sensitive particle misidentification (Fig. 2). Redundant kinematic and TOF hadron identification is required. $M_{visible} < 1.7$ GeV rejects hadronic decays, and we require that there be no extra isolated photons in an event. U is sensitive to the presence of an undetected π^0 (Fig. 3); we require $|U| < 0.100$ GeV.

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2. CABIBBO-SUPPRESSED SEMILEPTONIC DECAYS AND V_{cd}

Semileptonic decays of charm mesons provide an excellent laboratory for studying the weak Kobayashi–Maskawa (KM) coupling of the charm quark to down and strange quarks because the interference effects and final state interactions present in hadronic decays are absent. An indirect measurement of the charm-down coupling has been obtained from neutrino induced charm production,[1] but it depends on an estimate of the relative abundance of produced charm species, the total semimuonic branching ratios of each species, and it assumes that phase space and form factors do not differ significantly between Cabibbo-favoured and Cabibbo-suppressed decays. We obtain it directly by measuring semileptonic branching ratios and using the relation:[2]

$$\frac{B(D^0 \to \pi^- e^+ \nu_e)}{B(D^0 \to K^- e^+ \nu_e)} = 1.86 \cdot |V_{cd}/V_{cs}|^2 \left[f_+^\pi(0)/f_+^K(0)\right]^2$$

Recent calculations for the ratio of form factors f_+^π/f_+^K at $q^2 = 0$ give values around 0.69/0.76.[3] Branching ratios may be found in Table I. Mark III's $\pi^- e^+ \nu$ events (Fig. 2b) constitute the first measurement of an exclusive Cabibbo-suppressed semileptonic decay, and they have a statistical significance of 3.4σ. By forming the ratio of branching ratios, we eliminate any systematic dependence on charm cross sections, efficiency and the number of tags, and we find:

$$|V_{cd}/V_{cs}|^2 \;=\; \left[f_+^K(0)/f_+^\pi(0)\right]^2 (0.051^{+0.039}_{-0.018} \pm 0.010)$$

3. MORE SEMILEPTONIC BRANCHING RATIOS

Exclusive semileptonic decays with more complex final states have been found as evidenced by the U distributions of Fig. 4. Table I lists individual branching ratios and averages which have been computed using lepton universality, isospin symmetry and Poisson statistics. E691[4] measurements have been included for comparison. There is good agreement between experiments. Inclusive semileptonic branching ratios[5] suggest that the list of D^+ decays is not complete. Mark III places the following 90% C.L. limits: $B(D^+ \to \rho^0 e^+ \nu_e) < 0.5\%$ and $B(D^+ \to K^- \pi^+ \pi^0 e^+ \nu_e) < 3.0\%$. The resonant ($K^*$) fraction of $K\pi e\nu$ decays is measured to be $0.68 \pm 0.18 \pm 0.20$ (Fig. 5).

4. SEARCH FOR SEMILEPTONIC D_s^+ DECAYS

A similar analysis is performed on 6.3 pb^{-1} of $\sqrt{s} = 4.14$ GeV data containing $D_s \bar{D}_s^*$ events. 73 ± 10 D_s events are tagged by $\phi\pi^+$, $\bar{K}^{*0}K^+$ and $\bar{K}^0K^+$, and nine correct sign (three wrong sign) electrons are counted among the recoiling tracks (Fig. 6). Corrections are made for misidentified pions, and the charge symmetric background is subtracted to give $B(D_s^+ \to e^+X) = 0.09^{+0.09}_{-0.07} \pm 0.014$. The expectation from D lifetimes[6] and $B(D^0, D^+ \to e^+X)$[5] is 0.078 ± 0.010. Since the statistical significance of this signal is only 1.2σ, we can express it as the upper limit $B(D_s^+ \to e^+X) < 0.24$ @90% C.L.

REFERENCES

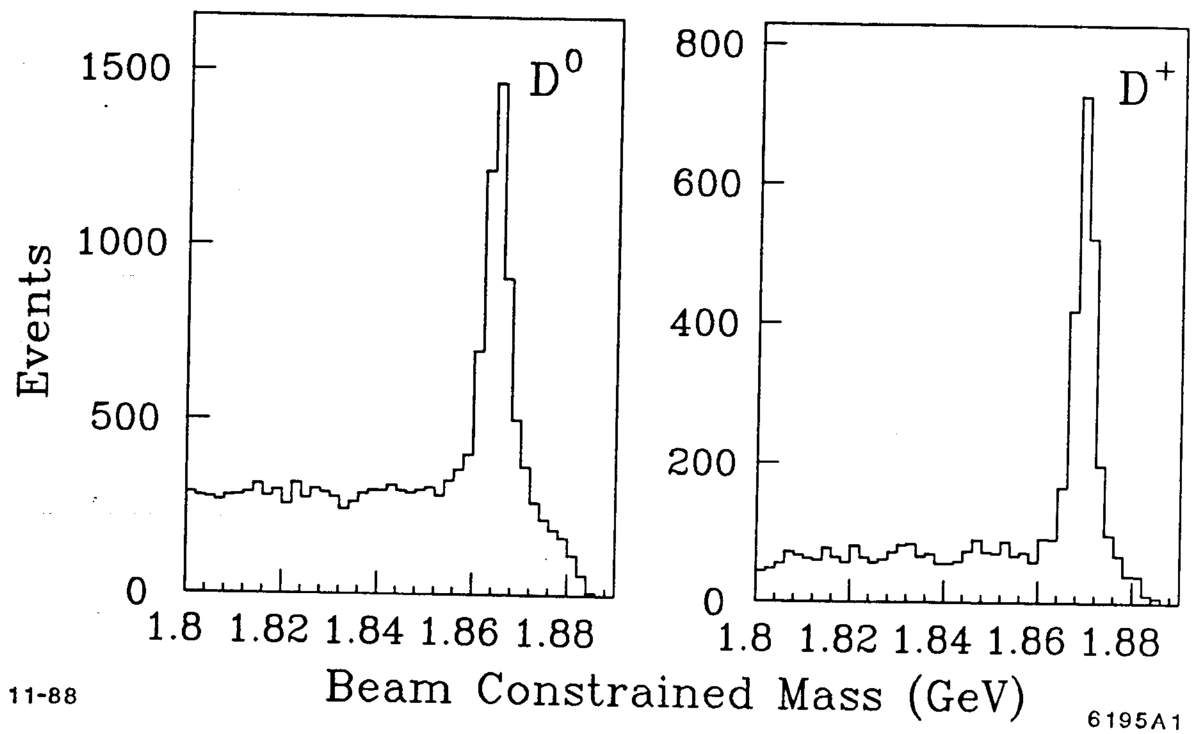
1. H. Abramowicz *et al.*, *Z. Phys. C* **15**, 19 (1982);
   K. Kleinknecht and B. Renk, *Z. Phys. C* **34**, 209 (1987).
2. The numerical value of 1.86 in this formula is:
   $\int[m^2_{D^*}/(m^2_{D^*} - t)]^2\,(E^2_\pi - m^2_\pi)^{3/2}\,dt \;/\; \int[m^2_{D_s^*}/(m^2_{D_s^*} - t)]^2\,(E^2_K - m^2_K)^{3/2}\,dt.$
3. See, for example: M. Wirbel *et al.*, *Z. Phys.* **C29**, 637 (1985);
   C. Dominguez and N. Paver, *Phys. Lett.* **207**, 499 (1988).
4. J.C. Anjos *et al.* "A Study of the Semileptonic Decay Mode $D^0 \to K^-e^+\nu_e$" and "An Experimental Study of the Semileptonic Decay $D^+ \to \overline{K^{*0}}e^+\nu_e$" submitted to the 24th Int. Conf. on High Energy Physics, Munich, West Germany, August 4–10, 1988.
5. R.M. Baltrusaitis *et al.*, *Phys. Rev. Lett.* **54**, 1976 (1985).
6. J.C. Anjos *et al. Phys. Rev.* **D37**, 2391 (1988).

FIGURE CAPTIONS

1. Beam constrained mass of D^0 and D^+ tags.
2. U distribution for $\pi^-e^+\nu_e$ events (shaded), $K^-\ell^+\nu_\ell$ events (histogram) where the K^- is intentionally interpreted as a π^-. Overlayed curves are Monte Carlo for these two classes of events.
3. Monte Carlo U distribution for $K^-e^+\nu_e$ and $K^-\pi^0e^+\nu_e$ events interpreted as $K^-e^+\nu_e$.
4. U distributions for additional D^0 and D^+ decays. Arrows mark the $|U| <$ 0.100 GeV cut. Overlayed curves are Monte Carlo shapes.
5. Invariant $K\pi$ mass from $D \to K\pi e\nu$ events. Fit is to K^* plus nonresonant S-wave.
6. Mass distribution of D_s tags (bold curve, left scale), wrong-sign electrons (solid, right scale) and right-sign electrons (light curve, right scale) plotted at the mass of its tag.

Table I. Preliminary Mark III Semileptonic Branching Ratios

Decay mode	Signal Events	Branching Ratio (%) Mark III	E691
$D^0 \to \pi^- e^+ \nu_e$	6	$0.40^{+0.30}_{-1.3} \pm 0.08$	
$D^0 \to K^- e^+ \nu_e$	51	$4.1 \pm 0.7 \pm 0.4$	
$D^0 \to K^- \mu^+ \nu_\mu$	50	$4.4 \pm 1.0 \pm 0.9$	
$D^0 \to K^- e^+ \nu_e$ (avg.)		$4.2 \pm 0.6 \pm 0.4$	$3.8 \pm 0.5 \pm 0.6$
$D^0 \to \overline{K}^0 \pi^+ e^- \nu_e$	9	$4.8^{+2.7}_{-1.3} \pm 0.5$	
$D^0 \to \overline{K}^0 \pi^+ \mu^- \nu_\mu$	6	$2.6^{+3.1}_{-1.4} \pm 1.0$	
$D^0 \to K^- \pi^0 e^- \nu_e$	5	$1.8^{+1.4}_{-0.6} \pm 0.2$	
$D^0 \to [K^- \pi^0 + \overline{K}^0 \pi^-] e^+ \nu_e$		$5.9^{+1.8}_{-1.4} \pm 0.9$	
D^0 Σ exclusive		$10.5 \pm 1.8 \pm 1.3$	
D^0 inclusive		$7.5 \pm 1.1 \pm 0.4$	
$D^+ \to \overline{K}^0 e^- \nu_e$	11	$5.4^{+2.4}_{-1.3} \pm 0.5$	
$D^+ \to \overline{K}^0 \mu^- \nu_\mu$	19	$10.0 \pm 3.1 \pm 1.7$	
$D^+ \to \overline{K}^0 e^+ \nu_e$ (avg.)		$7.1^{+1.8}_{-1.6} \pm 1.0$	
$D^+ \to K^- \pi^- e^- \nu_e$	12	$2.6^{+1.4}_{-0.8} \pm 0.3$	
$D^+ \to \overline{K}^0 \pi^0 e^- \nu_e$	3	$3.8^{+5.3}_{-1.7} \pm 0.6$	
$D^+ \to [K^- \pi^+ + \overline{K}^0 \pi^0] e^+ \nu_e$		$4.2^{+1.7}_{-1.4} \pm 0.6$	$4.95 \pm 0.5 \pm 1.1$
D^+ Σ exclusive		$11.3 \pm 2.3 \pm 1.6$	
D^+ inclusive		$17.0 \pm 1.9 \pm 0.7$	



D0
D+
Events
1500
1000
500
0
800
600
400
200
0
1.8 1.82 1.84 1.86 1.88
1.8 1.82 1.84 1.86 1.88
Beam Constrained Mass (GeV)
11-88
6195A1

Fig. 1

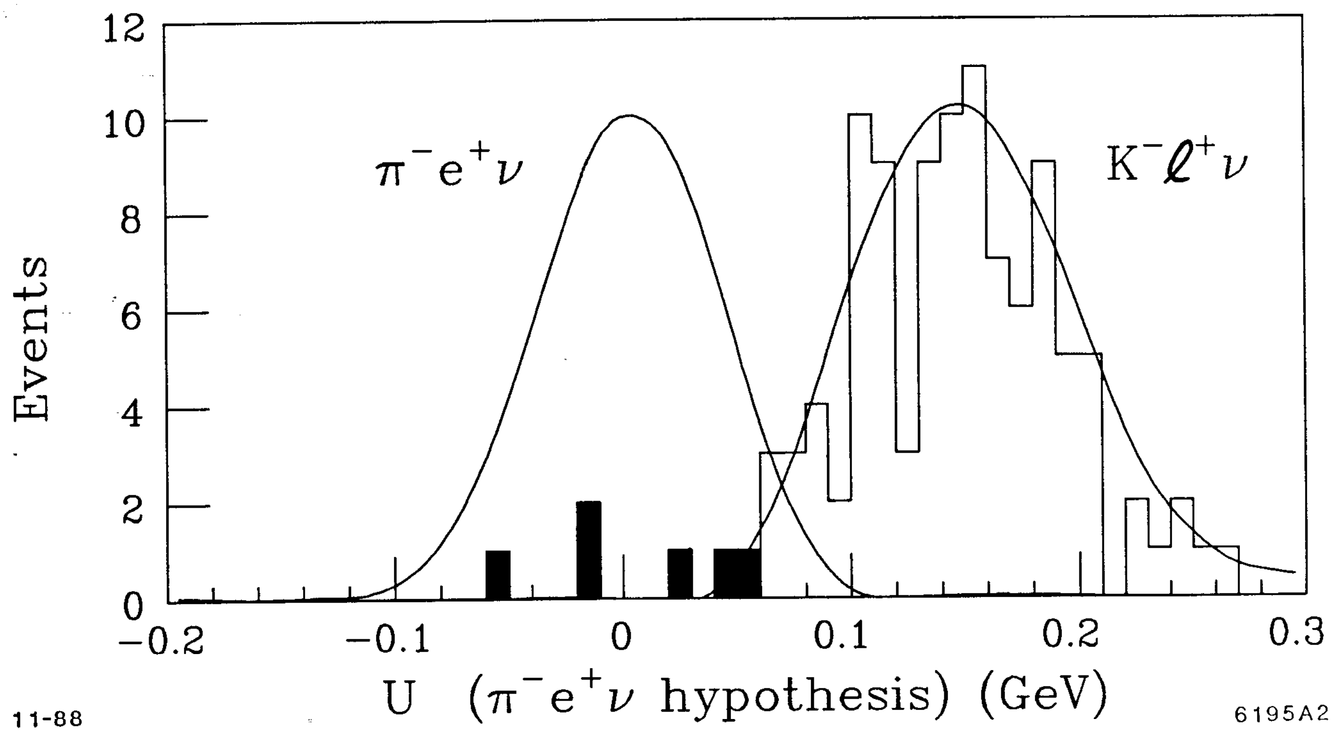

12
10
8
6
4
2
0
Events
$\pi^- e^+ \nu$
$K^- \ell^+ \nu$
−0.2
−0.1
0
0.1
0.2
0.3
U ($\pi^- e^+ \nu$ hypothesis) (GeV)
11-88
6195A2

Fig. 2

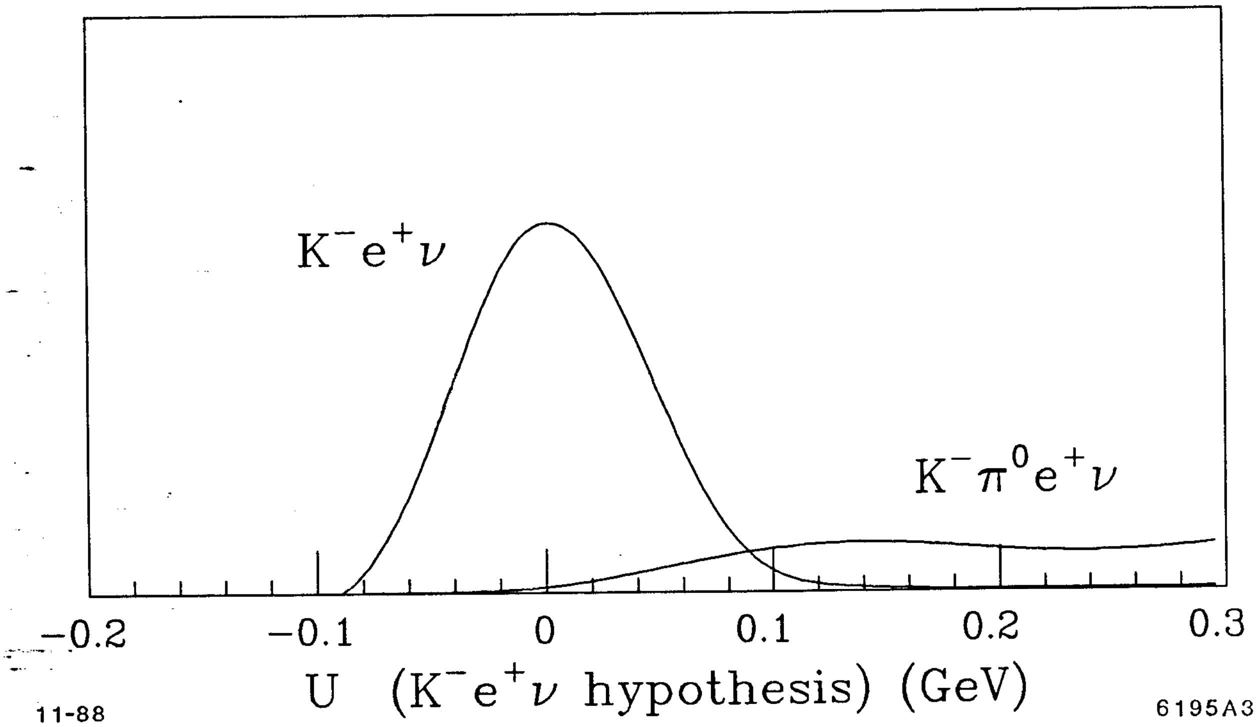
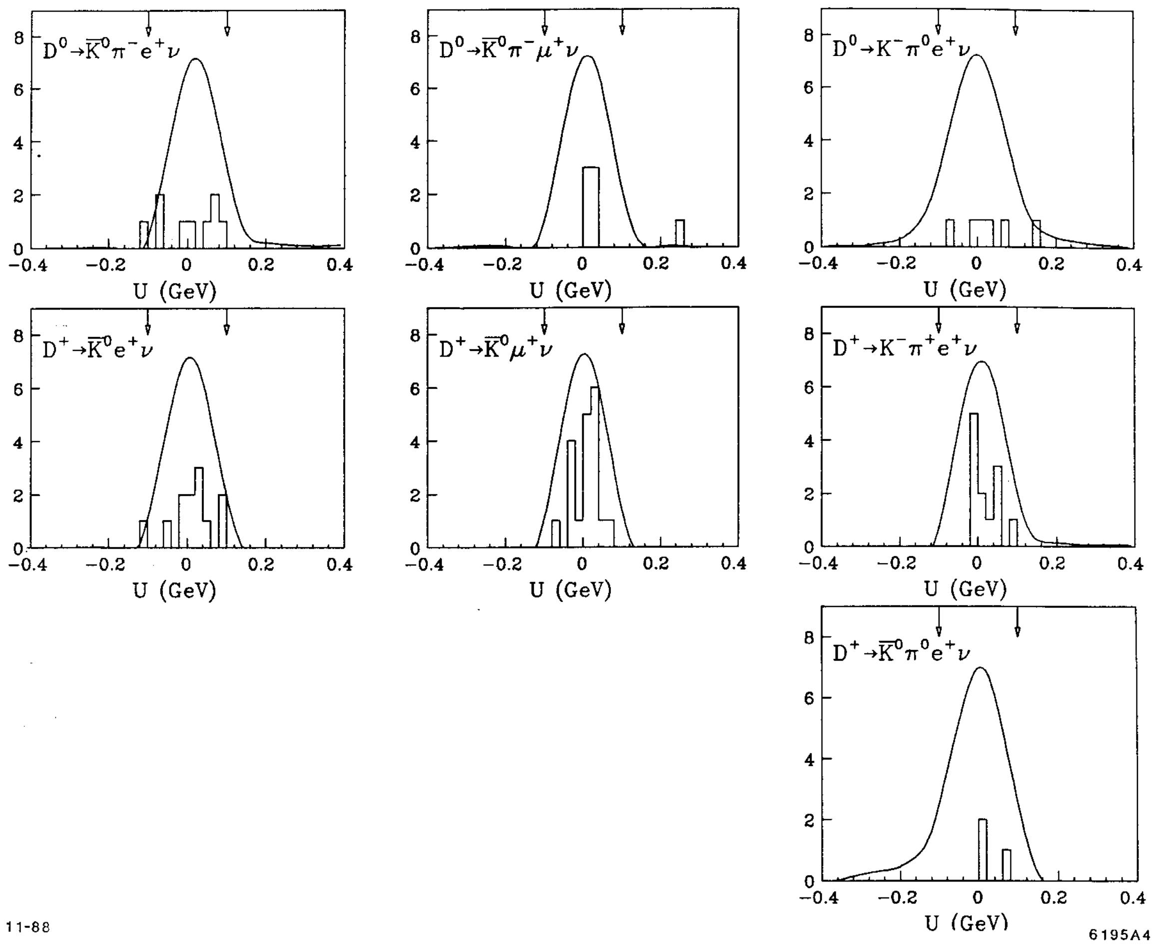


Fig. 3



$D^0 \to \overline{K}^0 \pi^- e^+ \nu$
$D^0 \to \overline{K}^0 \pi^- \mu^+ \nu$
$D^0 \to K^- \pi^0 e^+ \nu$
$D^+ \to \overline{K}^0 e^+ \nu$
$D^+ \to \overline{K}^0 \mu^+ \nu$
$D^+ \to K^- \pi^+ e^+ \nu$
$D^+ \to \overline{K}^0 \pi^0 e^+ \nu$
U (GeV)
11-88
6195A4

Fig. 4

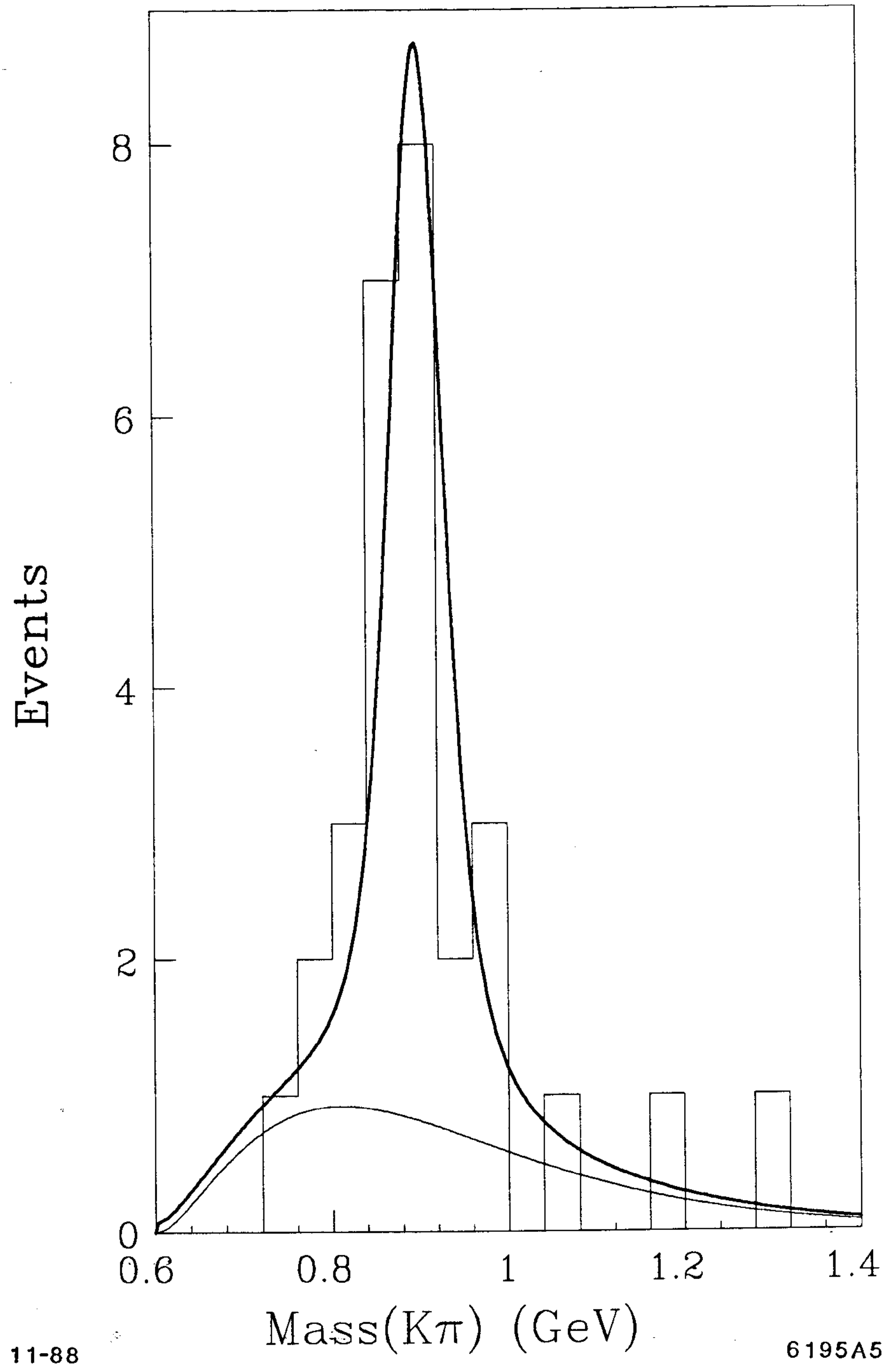


Fig. 5

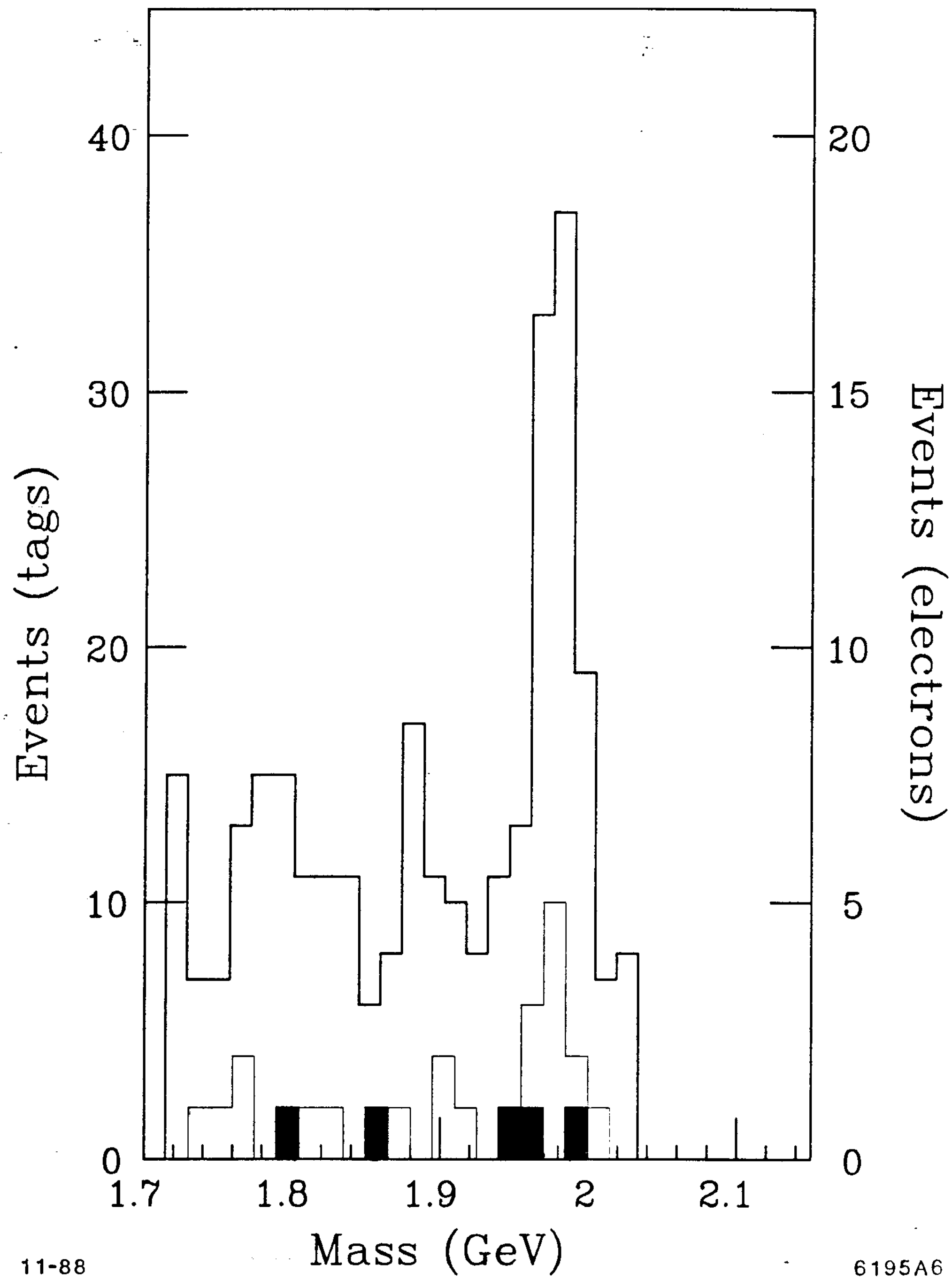

Events (tags)
Events (electrons)
0
10
20
30
40
5
15
1.7
1.8
1.9
2
2.1
Mass (GeV)
11-88
6195A6

Fig. 6