Presented at the IPP International Summer School, McGill University, Montreal, Canada, June 21 - 26, 1976

OBSERVATION OF A NARROW STATE AT 1865 MeV/c^2 DECAYING INTO $K\pi$ AND $K\pi\pi\pi$ PRODUCED IN e^+e^- ANNIHILATION

G. Goldhaber

July 1976

Prepared for the U. S. Energy Research and Development Administration under Contract W-7405-ENG-48

Invited Talk at IPP International Summer School, McGill University, Montreal, Canada, June 21 - 26, 1976

LBL-4883

OBSERVATION OF A NARROW STATE AT 1865 MeV/c^2 DECAYING INTO $K\pi$ AND $K\pi\pi\pi$ PRODUCED IN e^+e^- ANNIHILATION*

G. Goldhaber**

Department of Physics and Lawrence Berkeley Laboratory
University of California, Berkeley, California 94720

ABSTRACT

We present evidence, from a study of multihadronic final states produced in e^+e^- annihilation at center-of-mass energies between 3.90 GeV and 4.60 GeV, for the production of a new neutral state with mass 1865 ± 15 MeV/c^2 and decay width less than 40 MeV/c^2 that decays to $K^\pm\pi^\mp$ and $K^\pm\pi^\mp\pi^\pm\pi^\mp$. The recoil mass spectrum for this state shows structure with peaks at ~ 2010 and ~ 2150 MeV/c^2. This suggests that the state at 1865 MeV/c^2 is produced only in association with systems of comparable or larger mass.

We have observed narrow peaks near 1.87 GeV/c^2 in the invariant mass spectra for neutral combinations of the charged particles $K^\pm\pi^\mp$ ($K\pi$) and $K^\pm\pi^\mp\pi^\pm\pi^\mp$ ($K3\pi$) produced in e^+e^- annihilation. The agreement in mass, width, and recoil mass spectrum for these peaks strongly suggests they represent different decay modes of the same object. The mass of this state is 1865 ± 15 MeV/c^2 and its decay width (FWHM) is less than 40 MeV/c^2 (90% confidence level). The state appears to be produced only in association with systems of comparable or higher mass.

This observation was the result of continuing efforts in the search for charmed mesons.[1,2,3] Our results are based on studies of multihadronic events recorded by the SLAC/LBL magnetic detector operating at the Stanford Linear

*Work supported by the United States Energy Research and Development Administration.

**Research Professor, Miller Institute for Basic Research in Science, University of California, Berkeley, California, 1975 - 76.

Accelerator Center colliding beam facility SPEAR. Descriptions of the detector and event selection procedures have been published.[4,5]

The present study differs from our earlier one[1] in two essential ways. In the first place, it is based on a hadron sample of $\sim 29{,}000$ events in the energy region $E_{c.m.} = 3.9 - 4.6$ GeV. This is the energy region above the ψ/J and ψ' in which the average value of the ratio $R = \sigma_{hadron}/\sigma_{\mu^+\mu^-}$ increases from a level of ~ 2.5 (excluding the ψ and ψ') to ~ 5, and in which we have observed considerable structure in σ_{hadron} as reported earlier.[6,7] It was in the course of the exploration of this detailed structure in σ_{hadron} that we accumulated much of the data for the analysis of the final states. Figure 1 shows these measurements of R together with the more recent preliminary data.[8]

Secondly, an important innovation used here was the application of time-of-flight (TOF) information to help identify hadrons. The TOF system includes 48 2.4 cm $\times$ 20 cm $\times$ 260 cm Pilot Y scintillation counters arranged in a cylindrical array immediately outside the tracking spark chambers at a radius of 1.5 m from the beam axis. Both ends of each counter are viewed by Amperex 56 DVP photomultiplier tubes (PM); anode signals from each PM are sent to separate TDC's, ADC's, and latches. Pulse height information is used to correct times given by the TDC's. The collision time is derived from a pickup electrode that senses the passage of the 0.2 ns long beam pulses; the period between successive collisions is 780 ns. Run-to-run calibrations of the TOF system are performed with Bhabha scattering ($e^+e^- \to e^+e^-$) events. The rms resolution of the TOF system is $\sigma_t = 0.4$ ns.

Particle Identification by TOF

Typical time difference between a π and a K in the $K\pi$ signal is only about 0.5 ns. We have used the following two techniques to extract the best possible information on particle identity. To apply these methods, tracks are required to have good timing information from both PM's, consistent with the extrapolated position of the track in the counter.

A. Direct Particle Identification by TOF

In this method we calculate two χ^2 values for each observed track. The first is related to the probability that the track is a $\pi,(\chi^2_\pi)$ and the second to the probability of the track being a $K,(\chi^2_K)$. Here χ^2_i is defined by:

$$\chi^2_i = (t_i - t_M)^2/\sigma^2_t$$

where $i = \pi$, K; t_i is time calculated for mass i from measured momentum; t_M is measured TOF. If the track satisfies the criteria $\chi^2_K < 3$, $\chi^2_K < \chi^2_\pi$ the track is called a K. If $\chi^2_\pi < \chi^2_K$ the track is called a π; the track is also called a π when no reliable TOF information is available as when, for example, more than one track hits the TOF counter. There are also a small number of nucleons and antinucleons which have been identified but these do not play a part in the present analysis.

B. The Weight Method

In the weight method each track is assigned a weight corresponding to its probability of being a π and a second weight corresponding to its probability of being a K. These are determined from the measured momentum and TOF assuming a Gaussian probability distribution with standard deviation 0.4 ns. Tracks with net (π plus K) probability less than 1% are rejected. (This eliminates most of the nucleons.) Then, the relative π-K probabilities are renormalized so that their sum is unity, and two-particle combinations are weighted by the joint probability that the particles satisfy the particular π or K hypothesis assigned to them. In this way, the total weight assigned to all $\pi\pi$, Kπ, and KK combinations equals the number of two-body combinations and no double-counting occurs.

To be more specific, we define

$$W_\pi \propto e^{-\chi_\pi^2/2}$$

and $$W_K \propto e^{-\chi_K^2/2}$$

with the normalizing condition

$$W_\pi + W_K = 1 \quad .$$

In the study of the two-body system for example each pair of particles with total charge zero gets entered into three graphs:

in $M(\pi^\pm\pi^\mp)$ we enter $W_{\pi_1} W_{\pi_2}$

in $M(K^\pm\pi^\mp)$ we enter $W_{K_1} W_{\pi_2}$ and $W_{\pi_1} W_{K_2}$

in $M(K^\pm K^\mp)$ we enter $W_{K_1} W_{K_2}$.

In our article submitted to Physical Review Letters[9] we showed the data in terms of Method B, the weight method. We will thus here first show the results obtained by use of Method A, followed by those obtained by Method B.

The $K^\pm\pi^\mp$ Distributions

To begin with, Figs. 2 and 3 show the $K^\pm\pi^\mp$ mass spectrum at the ψ and the ψ' respectively. Here no double counting occurs as each track has been assigned a definite mass and the corresponding $K\pi$ pair appears only once. A very striking feature of these histograms is a strong $K^*(890)$ signal in each. The data for the ψ is based on $\sim$ 150,000 hadronic events and for the ψ' on $\sim$ 350,000 hadronic events. In Fig. 4 is shown the $K^\pm\pi^\mp$ mass spectrum for the data under study here, the $\sim$ 29,000 hadronic event sample collected in the $E_{c.m.}$ interval 3.9 - 4.6 GeV. Here now aside from the $K^*(890)$ peak we observe a small second peak centered at $\sim$ 1865 MeV/c^2. Figures 5, 6 and 7 show these same three mass distributions in greater detail from 1500 MeV/c^2 to 2500 MeV/c^2.

The Recoil System Against $K^\pm\pi^\mp$

Figure 8 shows a scatter plot where we plot the mass of the $K\pi$ system versus the recoil mass against that system. Here a band centered on 1865 MeV is clearly visible. However one can note that the recoil mass does not occur at primarily 1865 MeV/c^2 but rather starts at about 2 GeV/c^2 and goes up to approximately 2.2 GeV/c^2 at least as far as a strong signal is concerned. We utilize the information learned from the appearance of the missing mass spectrum and make a cut on the recoil mass from 2 - 2.2 GeV. This gives rise to the next figure (Fig. 9) which now shows a very large signal centered at 1865 MeV/c^2.

The recoil system against the $K^{\pm}\pi^{\mp}$ peak is shown in more detail in the following three figures. In these figures, aside from the 29,000 hadronic events discussed in the text, ~ 6000 events from running in late May 1976 at $E_{c.m.}$ = 4.03 GeV were added. In Fig. 10 we show the recoil system as directly calculated for the mass band 1840 - 1900 MeV/c^2. In Fig. 11 the same data is shown only now calculated for a fixed mass -- namely 1865 MeV/c^2 -- of the $K^{\pm}\pi^{\mp}$ system. In this calculation we use the momentum of the $K^{\pm}\pi^{\mp}$ system as measured but replace the measured mass by the above fixed mass. In Fig. 12 the same data is shown again, with the "fixed mass" calculation, but only for $E_{c.m.}$ = 3.9 - 4.25 GeV, called "4.1 GeV," and in 10 MeV/c^2 mass intervals.

Background estimates are obtained by plotting smooth curves corresponding to the recoil spectra for $K\pi$ invariant mass combinations in bands on either side of the signal region. The normalizations of these curves are fixed by the areas of the respective control regions.

It is clear from Figs. 10 - 12 that there is structure in the recoil mass system with two prominent peaks at ~ 2010 MeV/c^2 and ~ 2150 MeV/c^2 respectively.

The $K\pi$ Mass Assignment

As shown by the top row of Fig. 13 a significant signal appears even when we simply consider invariant mass spectra for all possible neutral combinations of two charged particles assuming both π and K masses for the particles as was done in our previous search for the production of narrow peaks.[1] Through kinematic reflections, the signal appears near 1.74 GeV/c^2 for the $\pi^+\pi^-$ hypothesis (Fig. 13a), 1.87 GeV/c^2 in the case of $K^+\pi^-$ or $K^-\pi^+$ (Fig. 13b), and 1.98 GeV/c^2 for K^+K^- (Fig. 13c).

To establish the correct choice of final-state particles associated with these peaks, we use the TOF information as in Method B.

Invariant mass spectra weighted by the above procedure are presented in the second row of Fig. 13. We see that the $K\pi$ hypothesis (Fig. 13e) for the peak at the $K\pi$ mass 1.87 GeV/c^2 is clearly preferred over either $\pi^+\pi^-$ (Fig. 13d) or K^+K^- (Fig. 13f). The areas under the small peaks remaining in the $\pi^+\pi^-$ and K^+K^- channels are consistent with the entire signal being $K\pi$ and the resulting misidentification of true $K\pi$ events expected for our TOF system. From consideration of possible residual uncertainties in the TOF calibration, we estimate that the confidence level for this signal to arise only from $\pi^+\pi^-$ or K^+K^- is less than 1%. Assuming the entire signal in Fig. 13d,e,f to be in the $K\pi$ channel, we find a total of 110 ± 25 decays of the new state; the significance of the peak in Fig. 13e is greater than 5 standard deviations. No signal occurs in the corresponding doubly-charged channels.

The $K^\pm\pi^\mp\pi^+\pi^-$ Distribution

In our search for other decay modes we have obtained a clear signal in the final state $K^\pm\pi^\mp\pi^+\pi^-$. With four particles in the final state the $K^\pm$ momenta are such that there is no longer any serious difficulty in the K/π separation.

Evidence for the decay of the above state to neutral combinations of a charged K and three charged π's is presented in the third row of Fig. 13. Again, we employ the TOF weighting technique, Method B, discussed above; the hadron event sample is the same as that used for the $K\pi$ study. Four-body mass combinations are weighted by their joint π-K probabilities.

As can be seen in Fig. 13h, a clear signal is obtained in the $K3\pi$ system at a mass near 1.86 GeV/c^2. No corresponding signal is evident at this mass or the appropriate kinematically reflected mass for either the $\pi^+\pi^-\pi^+\pi^-$ or $K^+K^-\pi^+\pi^-$ systems. We estimate the number of $K3\pi$ decays in the 1.86 GeV/c^2 peak to be 124 ± 21, an effect of more than 5 standard deviations. Again, there is no signal in the corresponding doubly-charged channel.

In Fig. 14 is shown the $K3\pi$ distribution as obtained by Method A. The peak centered near 1865 is very clear. For this distribution it must be remembered that there are many kinematical reflections in the data. For example the simplest occurs when one of the pions in the $K^{\pm}\pi^{\mp}\pi^+\pi^-$ signal is replaced with another pion belonging to the recoil system. Depending on $E_{c.m.}$ and the details of the recoil system such a $K3\pi$ system can have a mass fairly close to 1865 MeV/c^2, say within 100 to 200 MeV/c^2. Thus without much more careful study, and Monte-Carlo calculations, we cannot make any statement about the presence or absence of additional structure in the $K3\pi$ system.

In Fig. 15 we show the recoil spectrum to the $K3\pi$ system (by Method A). Here we are dealing with much more background and the structure in the recoil system is not as clear.

In Fig. 16 we show the two recoil spectra by Method B in 40 MeV/c^2 bins.

Fitted Mass Values for the $K\pi$ and $K3\pi$ Systems

To determine the masses and widths of the peaks in the $K\pi$ and $K3\pi$ mass spectra, we have fitted the data given here with a Gaussian for the peak and linear and quadratic background terms under various conditions of bin size, event selection criteria, and kinematic cuts. Masses for the $K\pi$ signal center at 1870 MeV/c^2; those for the $K3\pi$ signal center at 1860 MeV/c^2. The spread in central mass values for the various fits is ± 5 MeV/c^2. Within the statistical errors of ± 3 to 4 MeV/c^2, the widths obtained by these fits agree with those expected from experimental resolution alone. From Monte-Carlo calculations we expect a rms mass resolution of 25 MeV/c^2 for the $K\pi$ system and 13 MeV/c^2 for the $K3\pi$ system.

In Figs. 17 and 18 we show an example of the fits for the $K\pi$ and $K3\pi$ systems respectively together with the corresponding Monte-Carlo calculations. In these particular examples we used a cut which requires the mass of the recoil system to be greater than 1800 MeV/c^2.

Systematic errors in momentum measurement are estimated to contribute a $\pm$ 10 MeV/c^2 uncertainty in the absolute mass determination, and can account for the 10 MeV/c^2 mass difference observed between the $K\pi$ and $K3\pi$ systems. Thus, both signals are consistent with being decays of the same state and, from our mass resolution, we deduce a 90% confidence level upper limit of 40 MeV/c^2 for the decay width of this state.

Evidence for Associated Production and Threshold Behavior

From Figs. 10 - 12 and 15, 16 we find no evidence for the production of recoil systems having masses less than or equal to 1.87 GeV/c^2 in either spectrum. The $K\pi$ data of Figs. 10 - 11 show a large signal for recoil masses in the range 1.96 GeV/c^2 to 2.20 GeV/c^2 with contributions up to 2.5 GeV/c^2. The $K3\pi$ recoil mass spectrum (Figs. 15, 16b) has more background, but appears to be consistent with the $K\pi$ spectrum. These spectra suggest that the $K\pi$ and $K3\pi$ systems are produced with thresholds occurring above 3.7 c.m. energy.

As a further test of this apparent threshold behavior, we have examined 150,000 multihadronic events collected at the ψ mass (Fig. 2; $E_{c.m.} = 3.1$ GeV) and 350,000 events at the ψ' mass (Fig. 3; $E_{c.m.} = 3.7$ GeV) for $K\pi$ and $K3\pi$ signals near 1.87 GeV/c^2. Because of the large cascade decay rate[10] of ψ' to ψ and the large second-order electromagnetic decay rate[11] of the ψ, the resonance events contain 72,000 examples of hadron production by a virtual photon of c.m. energy 3.1 GeV. From fits to invariant mass spectra (with the signal mass near 1.87 GeV/c^2 we find no $K\pi$ signal larger than 0.3 standard deviations and no $K3\pi$ signal larger than 1.2 standard deviations in this large sample of events. The upper limits (90% confidence level) are 60 events for the $K\pi$ signal and 200 events for the $K3\pi$ signal.

The threshold behavior noted above as well as the narrow widths argue against the interpretation of the structure in Fig. 13 as being a conventional K^*; e.g., the strange counterpart of the g(1680).

Estimates of $\sigma \cdot BR$

Preliminary Monte-Carlo calculations to estimate detection efficiencies for the two modes have been performed; present systematic uncertainties in these detection efficiencies could be as large as ±50%. Our estimate of the cross section times branching ratio $\sigma \cdot BR$ (errors quoted are statistical) averaged over our 3.9 GeV - 4.6 GeV c.m. energy data is 0.20 ± 0.05 nb for the $K\pi$ mode and 0.67 ± 0.11 nb for the $K3\pi$ mode. These are to be compared with the average total hadronic cross section σ_T in this energy region of 27 ± 3 nb. We have also searched for these signals in the events at higher c.m. energies. In our previous search for the production of narrow peaks[1] at 4.8 GeV, there was a small $K\pi$ signal at 1.87 GeV/c^2 corresponding to a $\sigma \cdot BR$ of 0.10 ± 0.07 nb. This signal set the upper limit quoted in the paper ($\sigma \cdot BR < 0.18$ nb for the $K\pi$ system of mass between 1.85 and 2.40 GeV/c^2) but lacked the statistical significance necessary to be considered a convincing peak. The value of σ_T at 4.8 GeV is 18 ± 2 nb. In the c.m. energy range 6.3 GeV to 7.8 GeV the $K\pi$ $\sigma \cdot BR$ is 0.04 ± 0.03 nb and the average σ_T is 10 ± 2 nb.

Summary and Conclusion

In summary, we have observed significant peaks in the invariant mass spectra of $K^{\pm}\pi^{\mp}$ and $K^{\pm}\pi^{\mp}\pi^{+}\pi^{-}$ that we associate with the decay of a state of mass 1865 ± 15 MeV/c^2 and width less than 40 MeV/c^2. The recoil mass spectra indicate that this state is produced in association with systems of comparable or larger mass.

We find it significant that the threshold energy for pair-producing this state lies in the small interval between the very narrow ψ' and the broader structures present in e^+e^- annihilation near 4 GeV. In addition, the narrow width of this state, its production in association with systems of even greater mass, and the fact that the decays we observe involve kaons form a pattern of observation that would be expected for a state possessing the proposed new quantum number charm.[12,13]

The results presented here are the work of the LBL-SLAC collaboration at SPEAR, whose members are: F. M. Pierre, G. S. Abrams, M. S. Alam, A. M. Boyarski, M. Breidenbach, W. C. Carithers, W. Chinowsky, S. C. Cooper, R. G. DeVoe, J. M. Dorfan, G. J. Feldman, C. E. Friedberg, D. Fryberger, G. Hanson, J. Jaros, A. D. Johnson, J. A. Kadyk, R. R. Larsen, D. Lüke, V. Lüth, H. L. Lynch, R. J. Madaras, C. C. Morehouse, H. K. Nguyen, J. M. Paterson, M. L. Perl, I. Peruzzi, M. Piccolo, T. P. Pun, P. Rapidis, B. Richter, B. Sadoulet, R. H. Schindler, R. F. Schwitters, J. Siegrist, W. Tanenbaum, G. H. Trilling, F. Vannucci, J. S. Whitaker, and J. E. Wiss.

We wish to thank the LBL and SLAC Computer Centers for their help in facilitating the data analysis.

REFERENCES

1. A. M. Boyarski et al., Phys. Rev. Letters 35, 196 (1975).
2. C. Osgood, Physics Today 29, 11 (April 1976).
3. L. Grossberger, The New Yorker, May 10, 1976, p. 32.
4. J.-E. Augustin et al., Phys. Rev. Letters 34, 233 (1975).
5. J.-E. Augustin et al., Phys. Rev. Letters 34, 764 (1975).
6. J. Siegrist et al., Phys. Rev. Letters 36, 700 (1976).
7. J.-E. Augustin et al., Phys. Rev. Letters 34, 764 (1975).
8. H. L. Lynch, presented at the International Conference on Production of

Particles with New Quantum Numbers, University of Wisconsin, Madison, WI, April 22-24, 1976.

9. G. Goldhaber, F. M. Pierre et al., Phys. Rev. Letters (in press).

10. G. S. Abrams et al., Phys. Rev. Letters 34, 1181 (1975).

11. A. M. Boyarski et al., Phys. Rev. Letters 34, 1357 (1975).

12. S. L. Glashow, J. Iliopoulos, and L. Maiani, Phys. Rev. D2, 1285 (1970). S. L. Glashow, Experimental Meson Spectroscopy, A.I.P. Conf. Proc. No. 21, Particles and Fields Subseries No. 8, p. 387 (1974). For more details, see also M. K. Gaillard, B. W. Lee, and J. L. Rosner, Rev. Mod. Phys. 47, 277 (1975); A. De Rujula, H. Georgi, and S. L. Glashow, Phys. Rev. D12, 147 (1975); M. B. Einhorn and C. Quigg, Phys. Rev. D12, 2015 (1975).

13. Other indications of possible charmed particle production have come from experiments involving neutrino interactions. See, for example: A. Benvenuti et al., Phys. Rev. Letters 34, 419 (1975); E. G. Cazzoli et al., Phys. Rev. Letters 34, 1125 (1975); J. Blietschau et al., Phys. Letters 60B, 207 (1976); J. von Krogh et al., Phys. Rev. Letters 36, 710 (1976); B. C. Barish et al., Phys. Rev. Letters 36, 939 (1976).

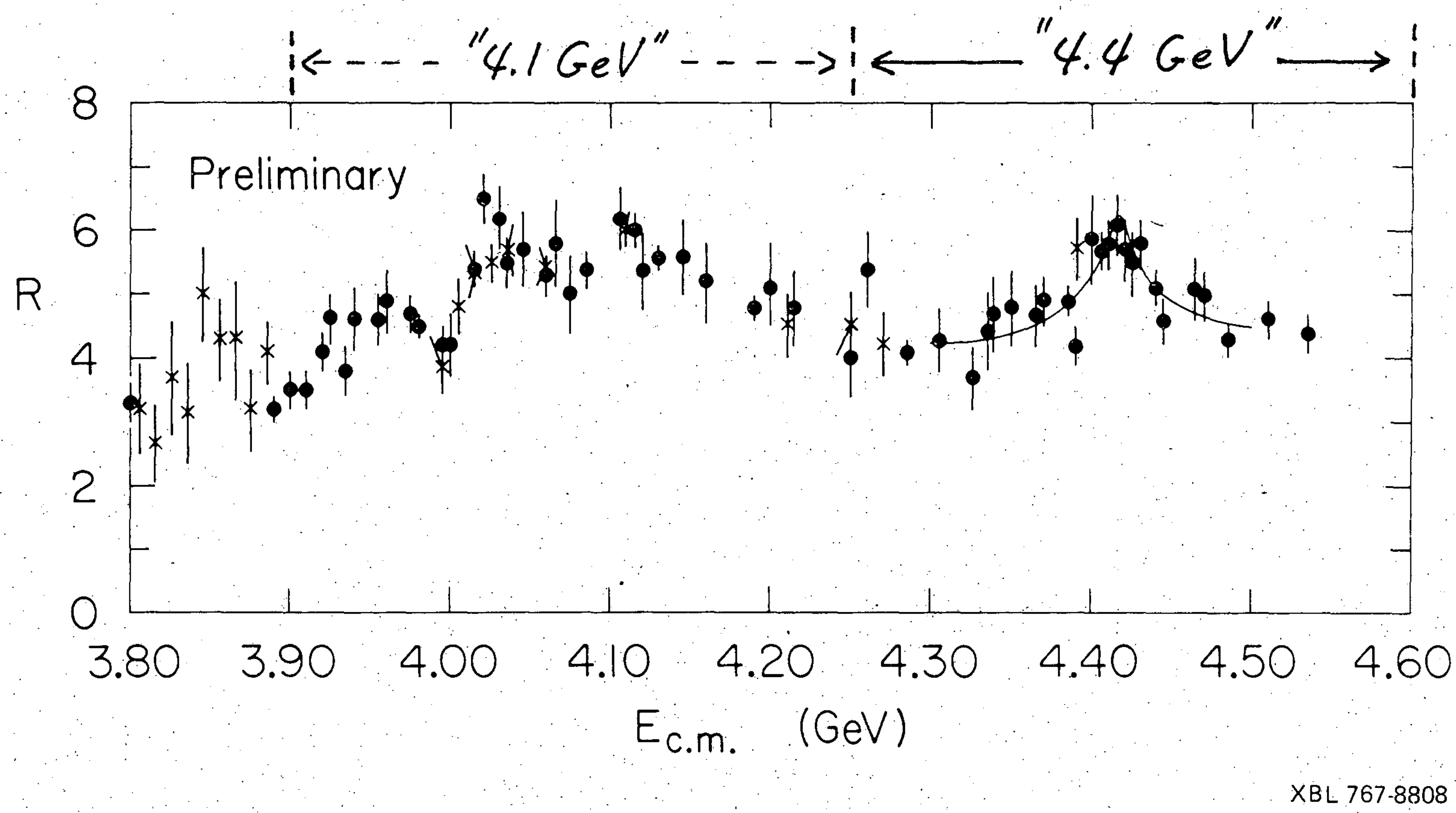

"4.1 GeV"
"4.4 GeV"
Preliminary
R
8
6
4
2
0
3.80
3.90
4.00
4.10
4.20
4.30
4.40
4.50
4.60
Ec.m. (GeV)
XBL 767-8808

Fig. 1

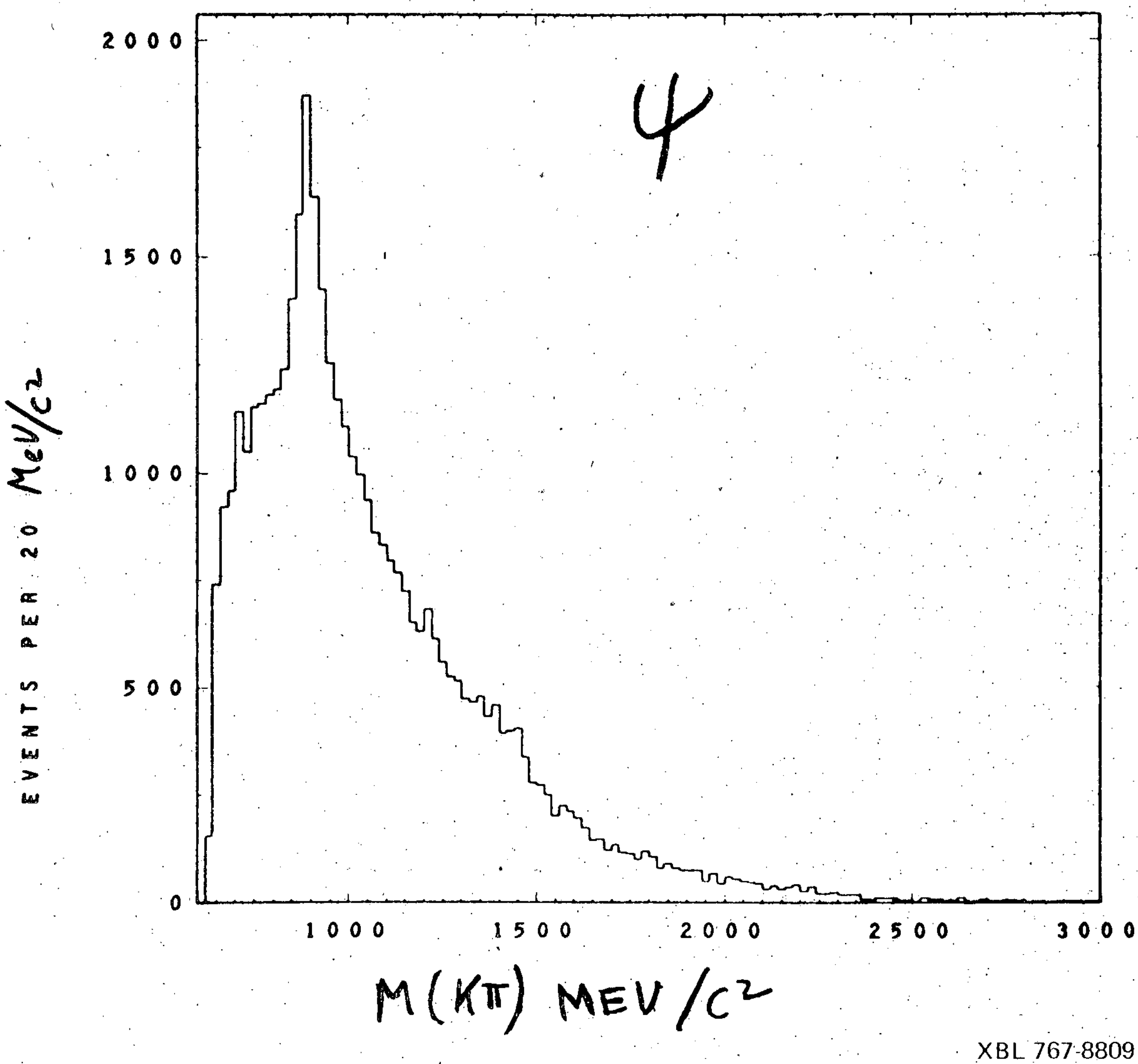
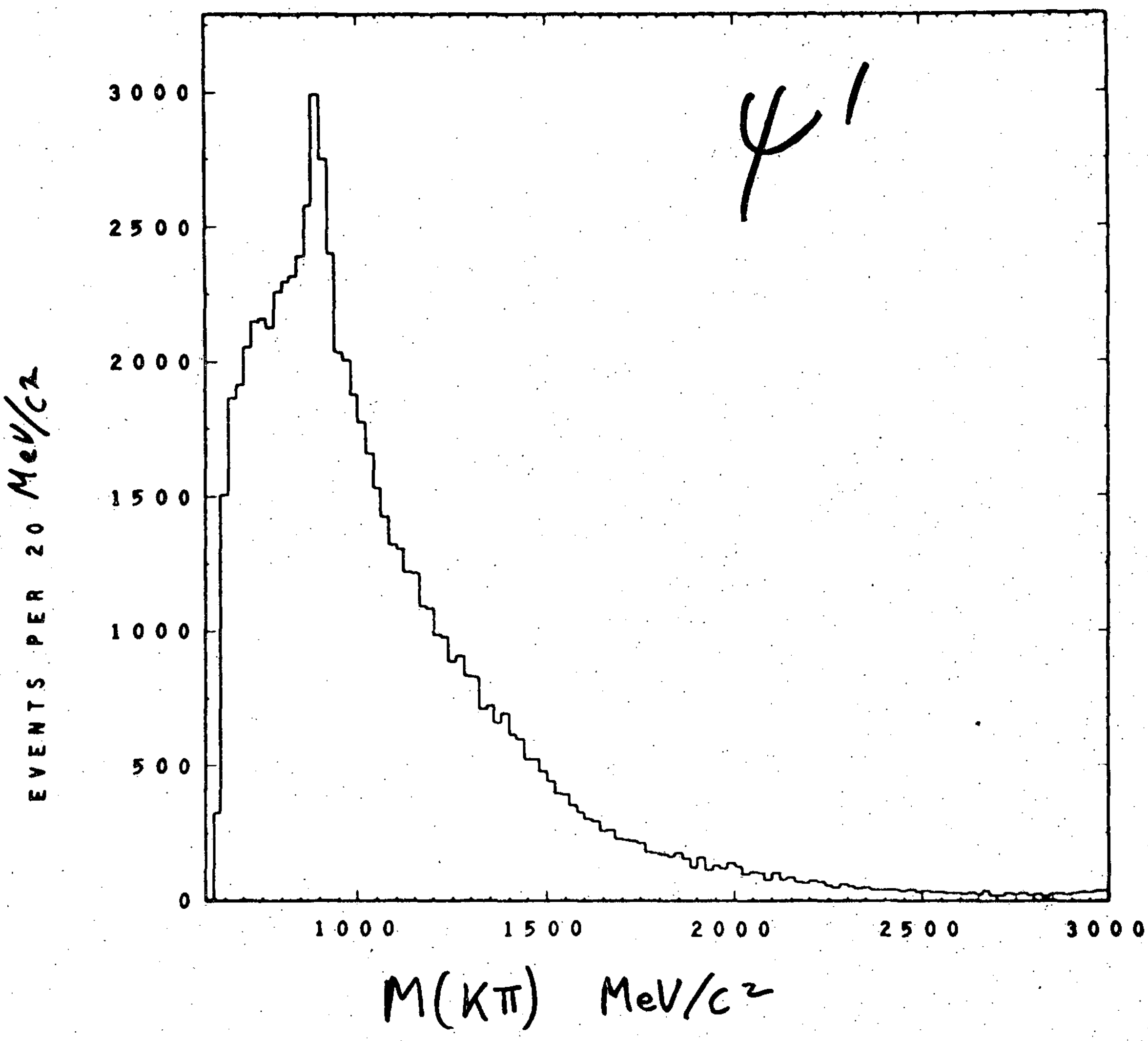

2000
1500
1000
500
0
EVENTS PER 20 MeV/c²
ψ
1000
1500
2000
2500
3000
M(Kπ) MEV/c²
XBL 767-8809

Fig. 2



XBL 767-8810

Fig. 3

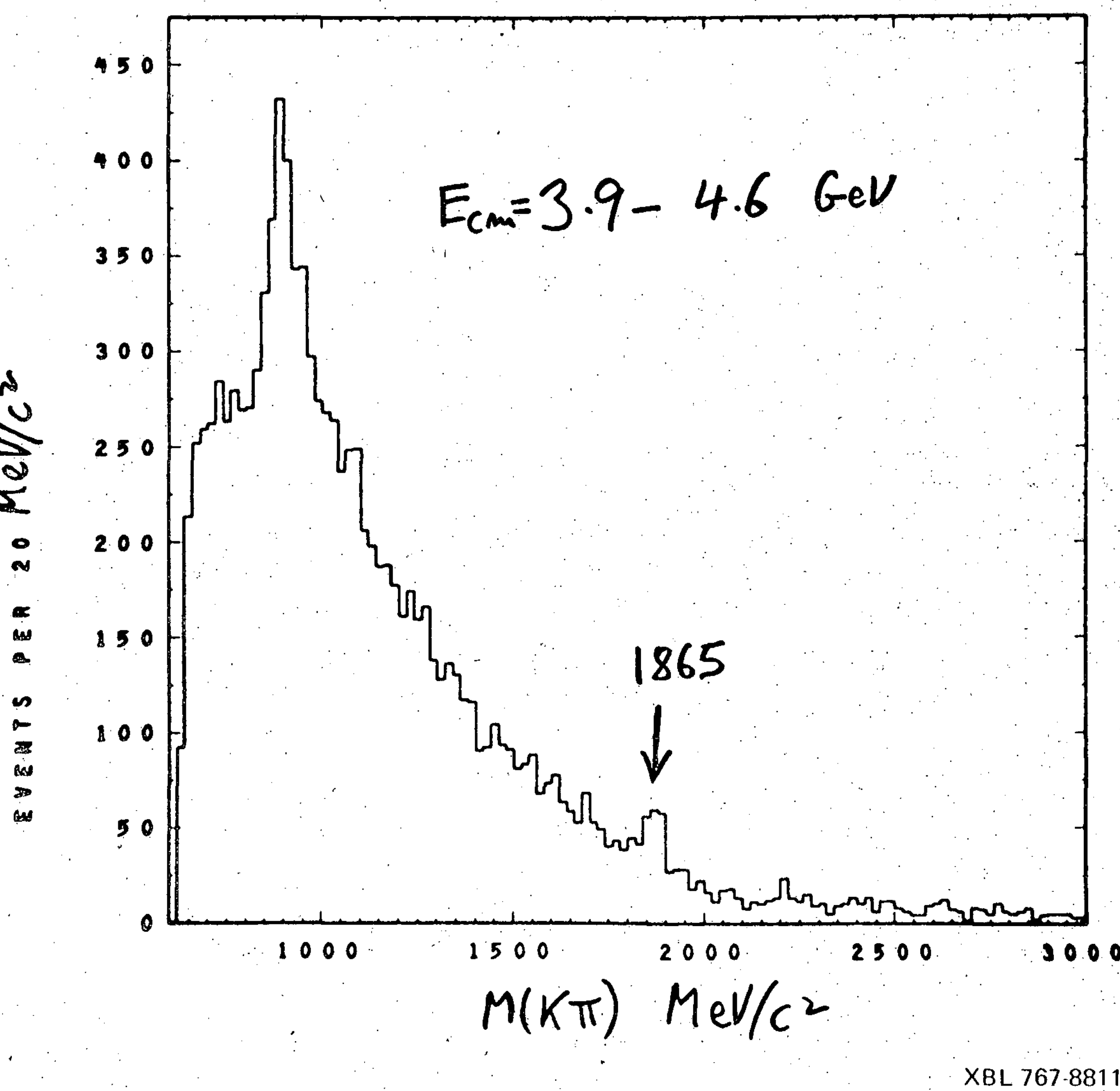

E_{cm}=3.9 – 4.6 GeV
1865
EVENTS PER 20 MeV/c²
M(Kπ) MeV/c²
0
50
100
150
200
250
300
350
400
450
1000
1500
2000
2500
3000
XBL 767-8811

Fig. 4

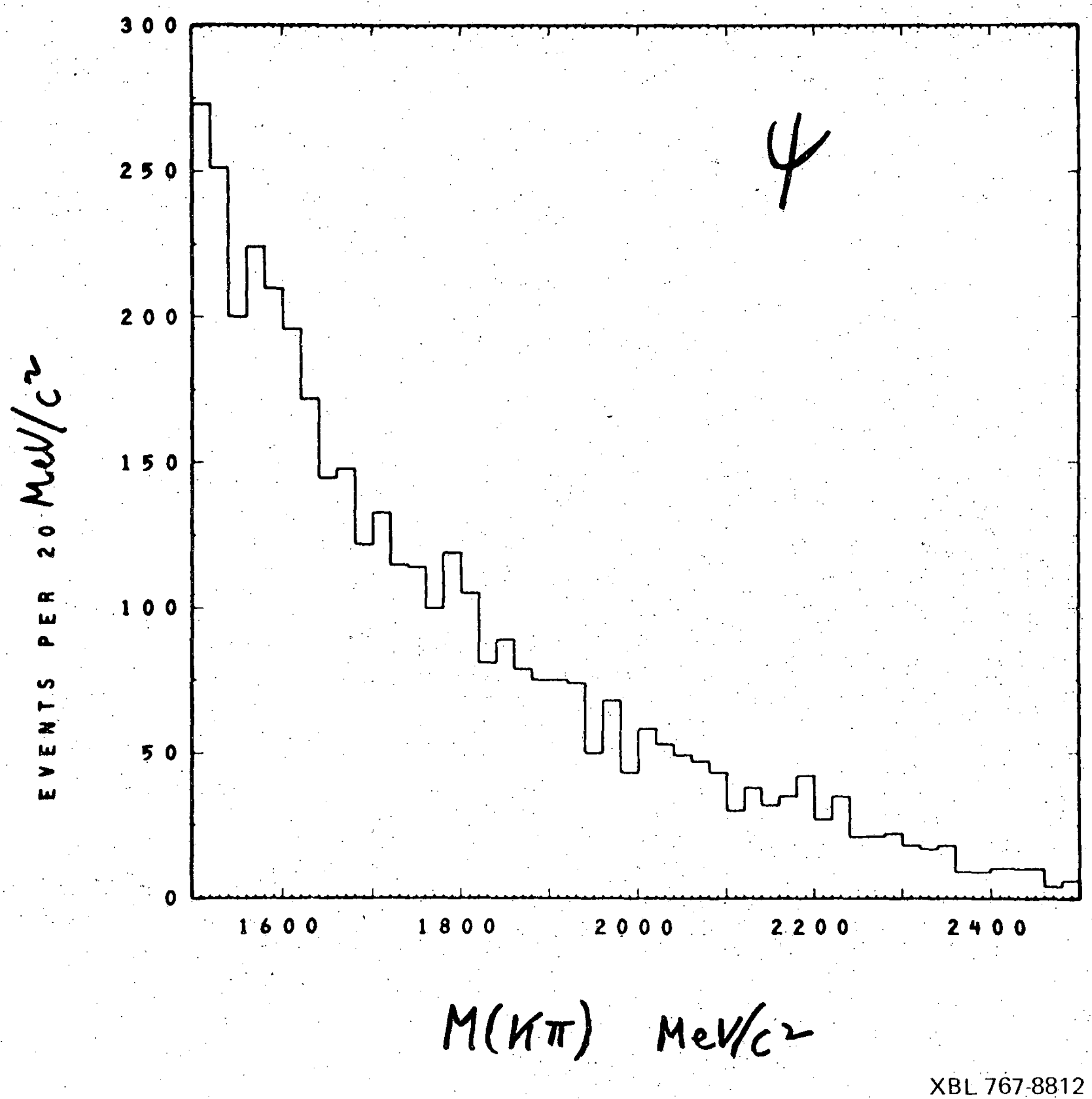
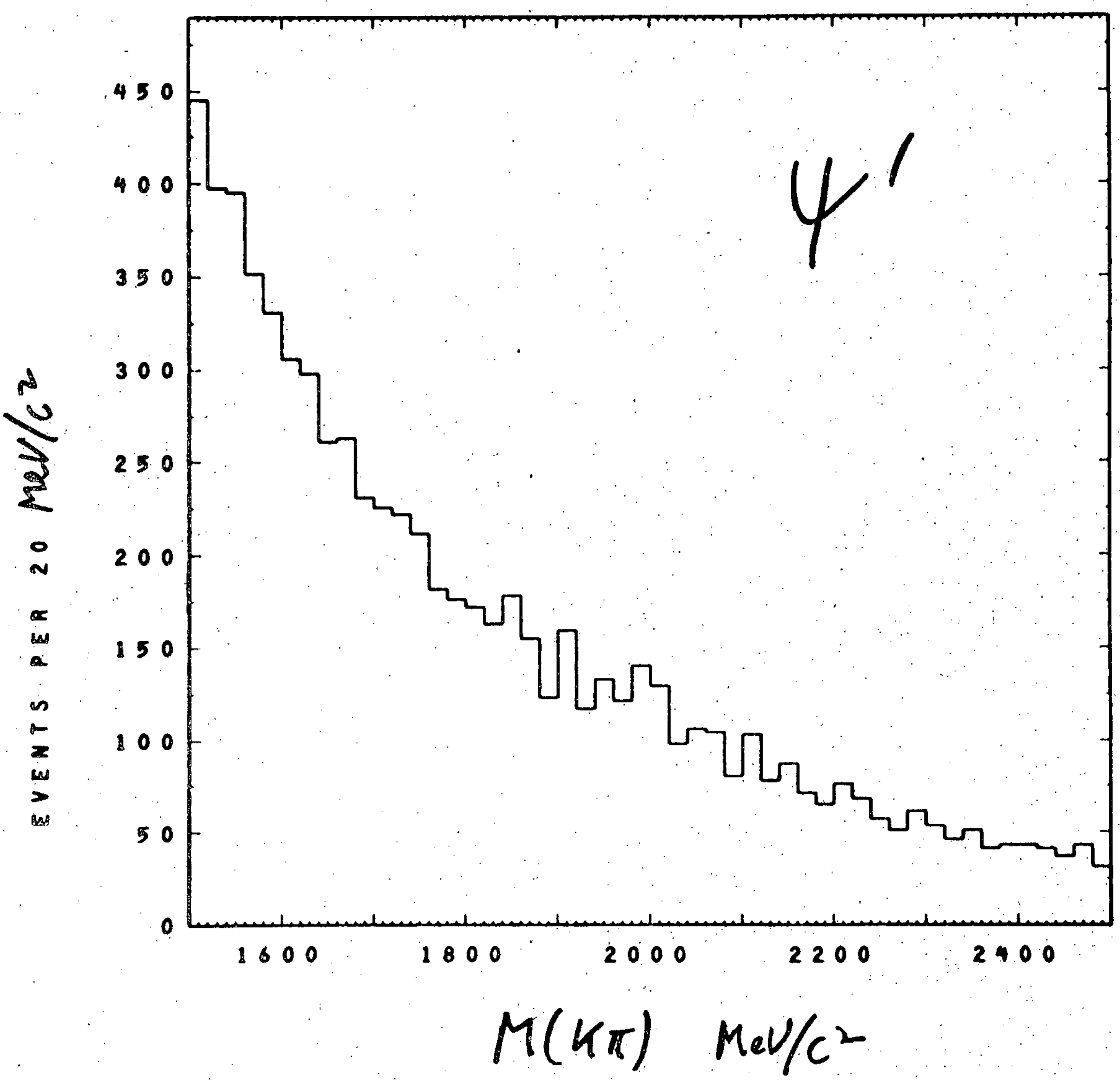
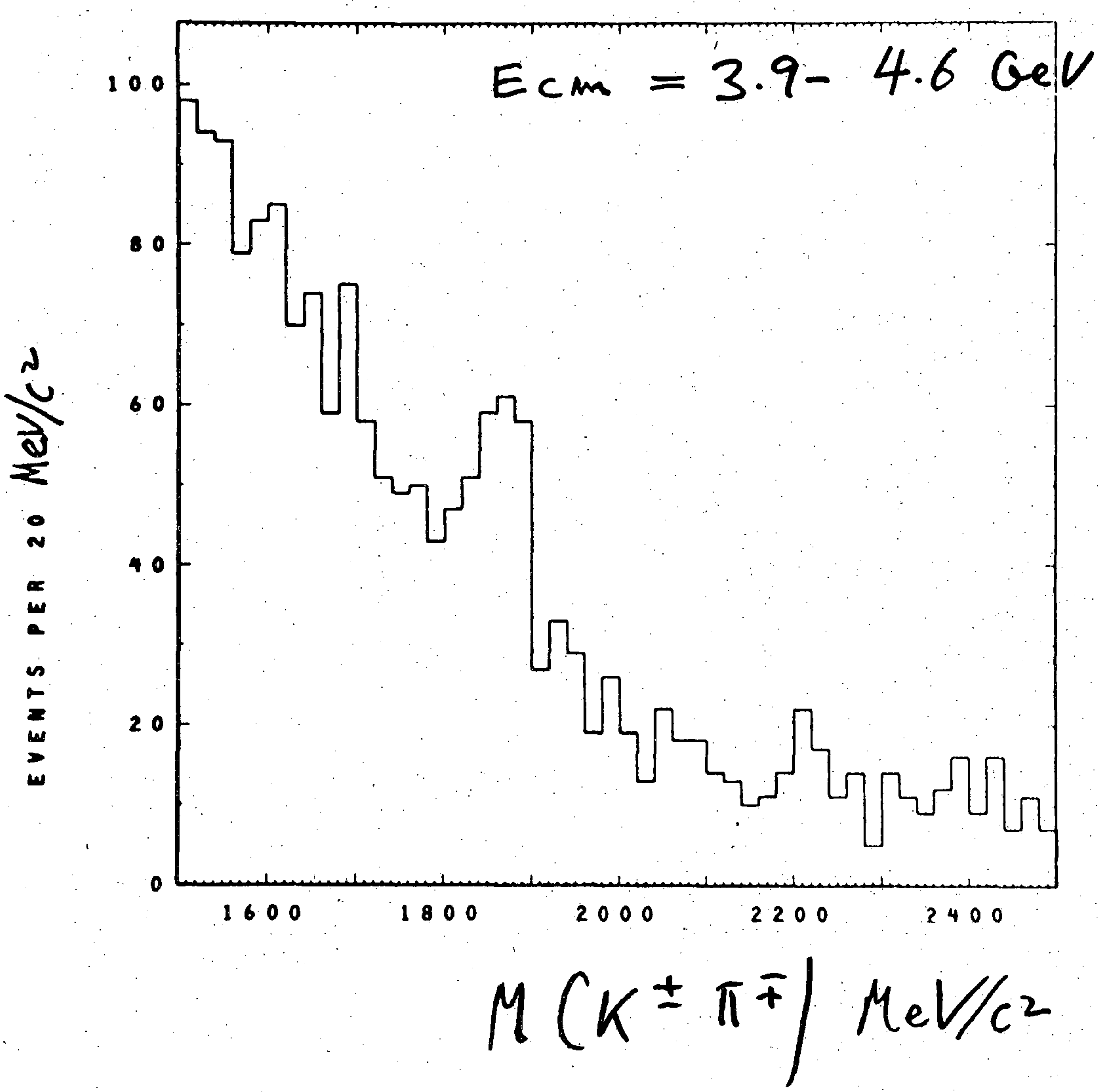

300
250
200
150
100
50
0
EVENTS PER 20 MeV/c²
ψ
1600
1800
2000
2200
2400
M(Kπ) MeV/c²
XBL 767-8812

Fig. 5



XBL 767-8813

Fig. 6



XBL 767-8814

Fig. 7

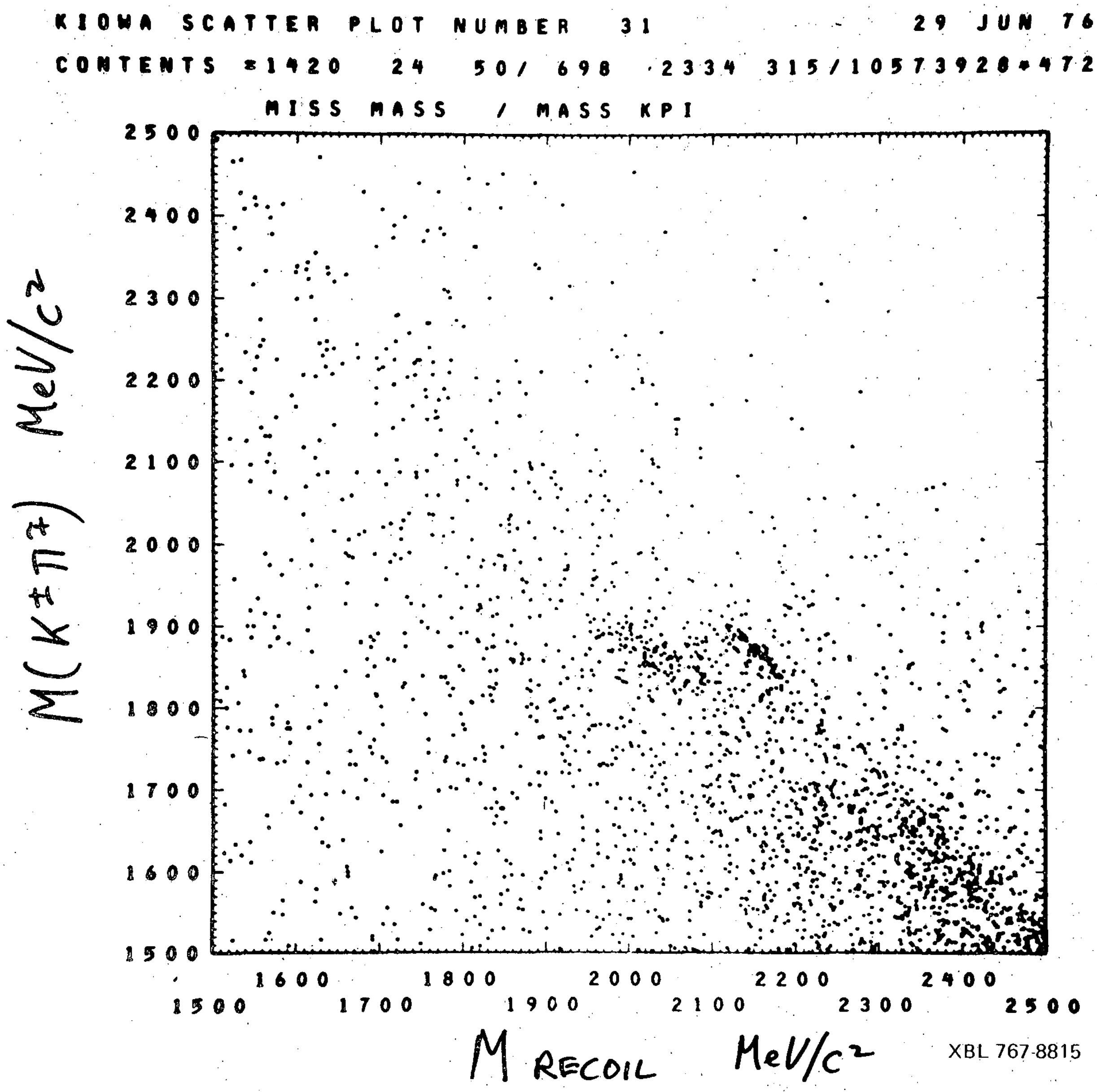

KIOWA SCATTER PLOT NUMBER 31
29 JUN 76
CONTENTS =1420 24 50/ 698 2334 315/10573928*472
MISS MASS / MASS KPI
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1600 1800 2000 2200 2400
1500 1700 1900 2100 2300 2500
M(K∓π±) MeV/c²
M RECOIL MeV/c²
XBL 767-8815

Fig. 8

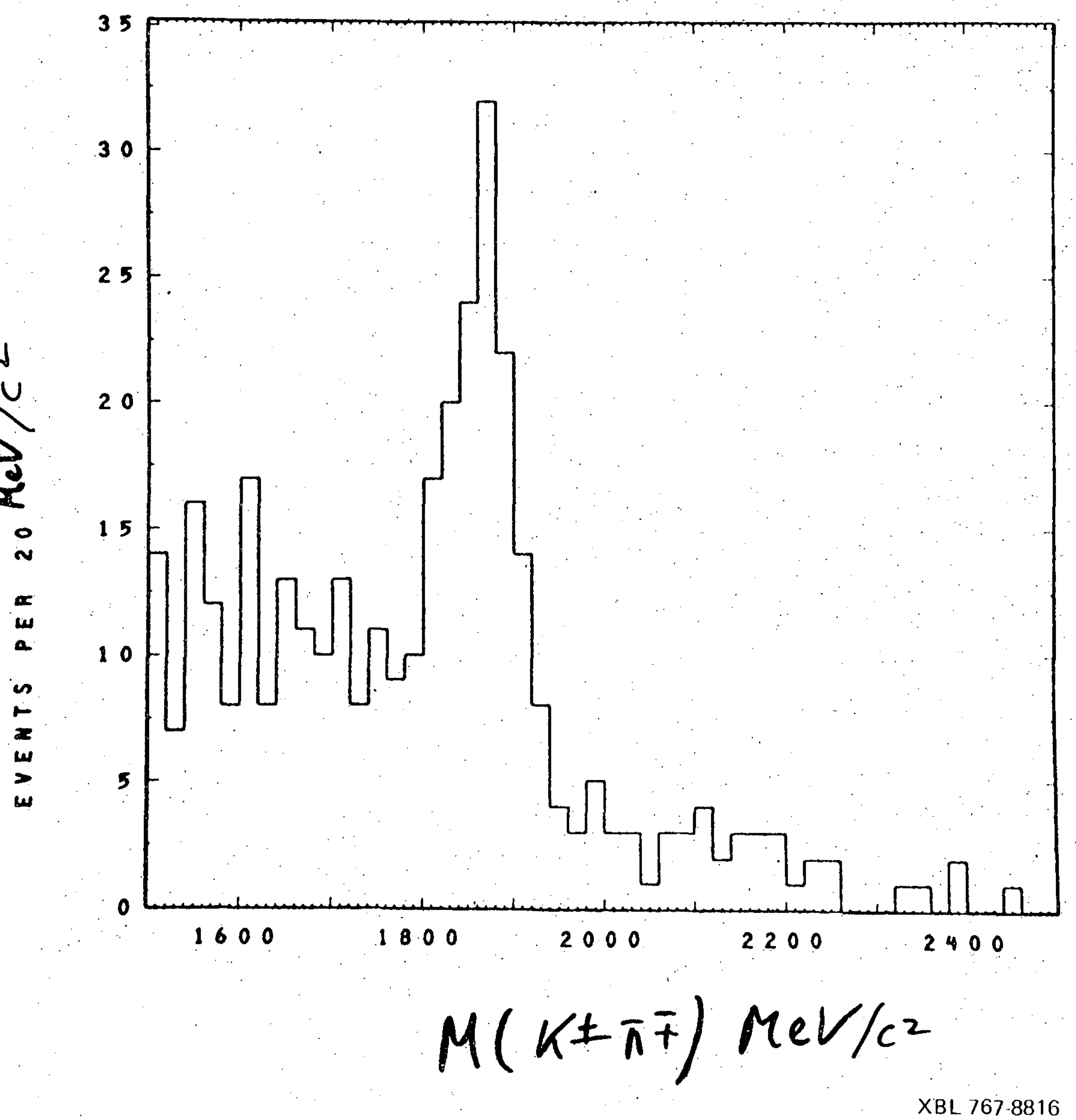

35
30
25
20
15
10
5
0
EVENTS PER 20 MeV/c²
1600
1800
2000
2200
2400
M(K± π∓) MeV/c²
XBL 767-8816

Fig. 9

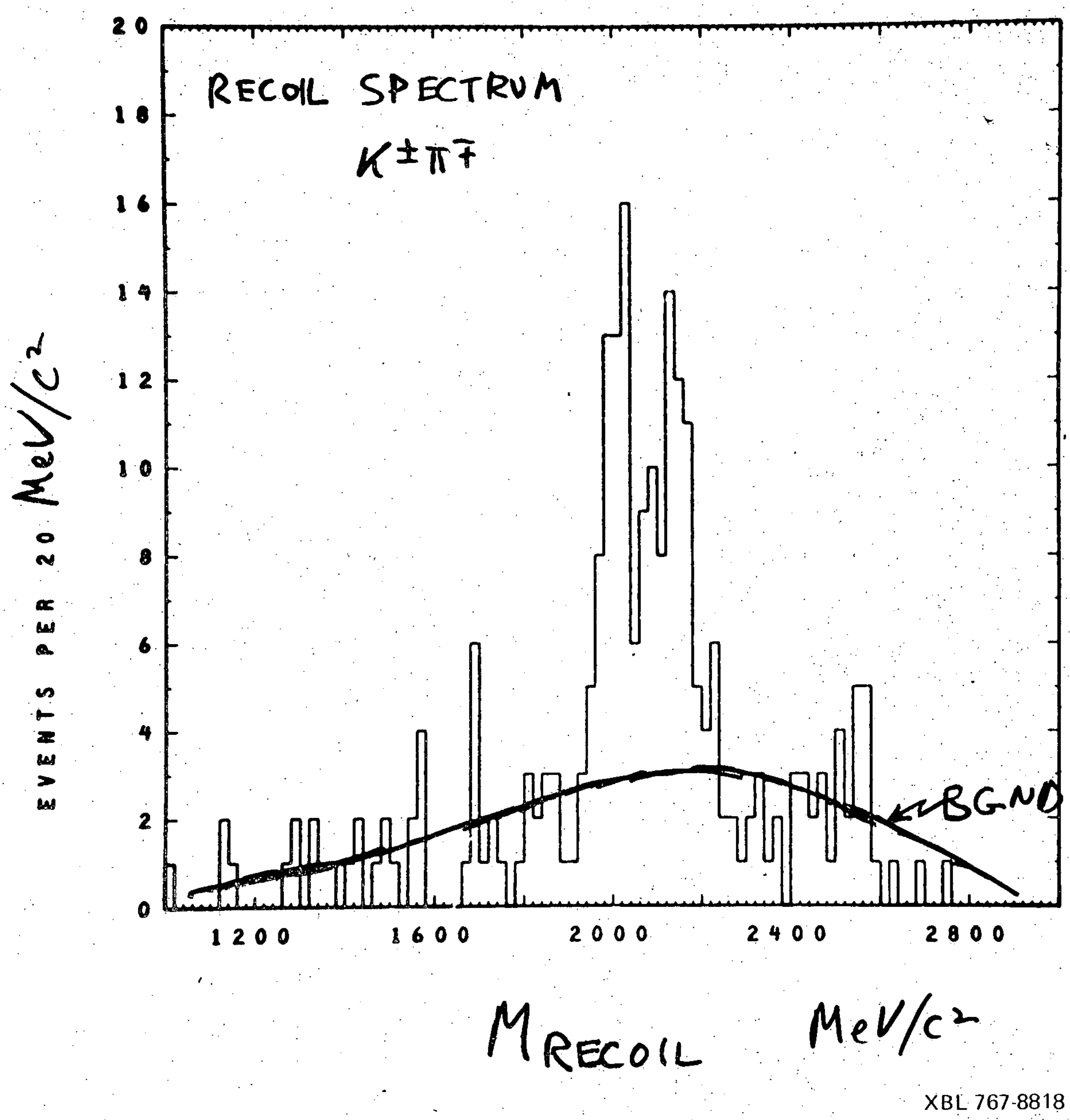
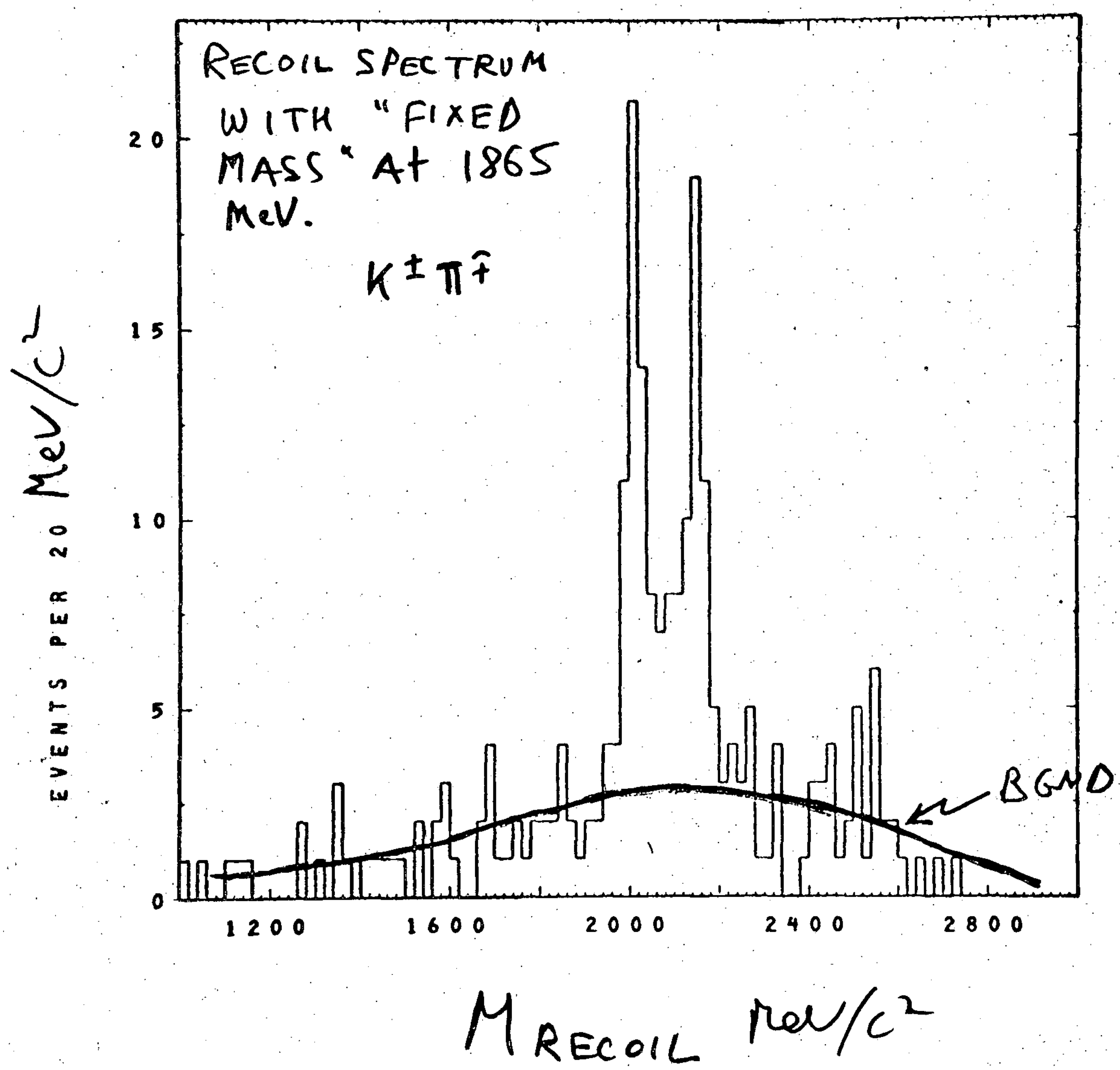
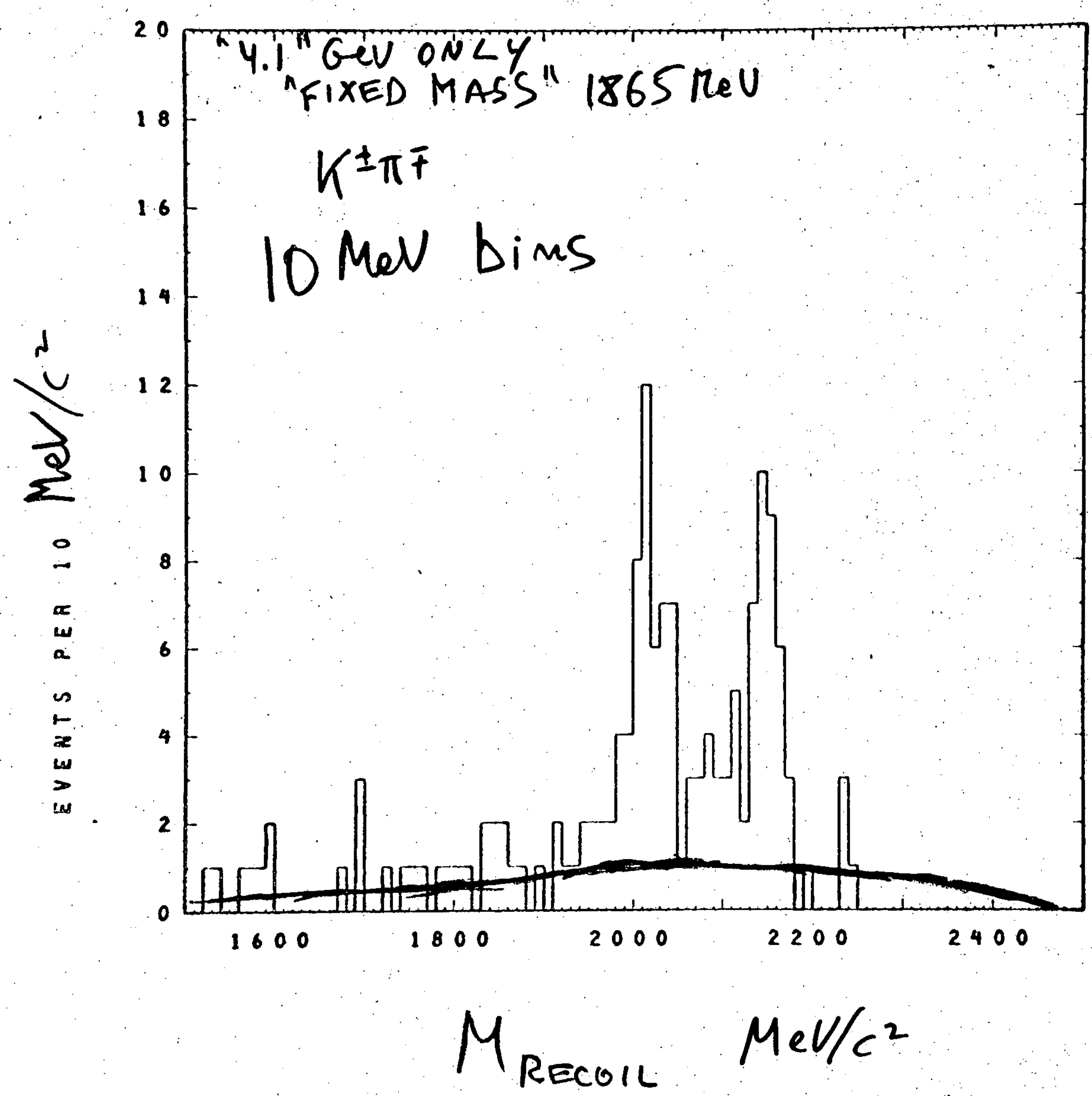

RECOIL SPECTRUM
K±π∓
EVENTS PER 20 MeV/c²
0
2
4
6
8
10
12
14
16
18
20
1200
1600
2000
2400
2800
BGND
M RECOIL MeV/c²
XBL 767-8818

Fig. 10



XBL 767-8819

Fig. 11



XBL 767-8820

Fig. 12

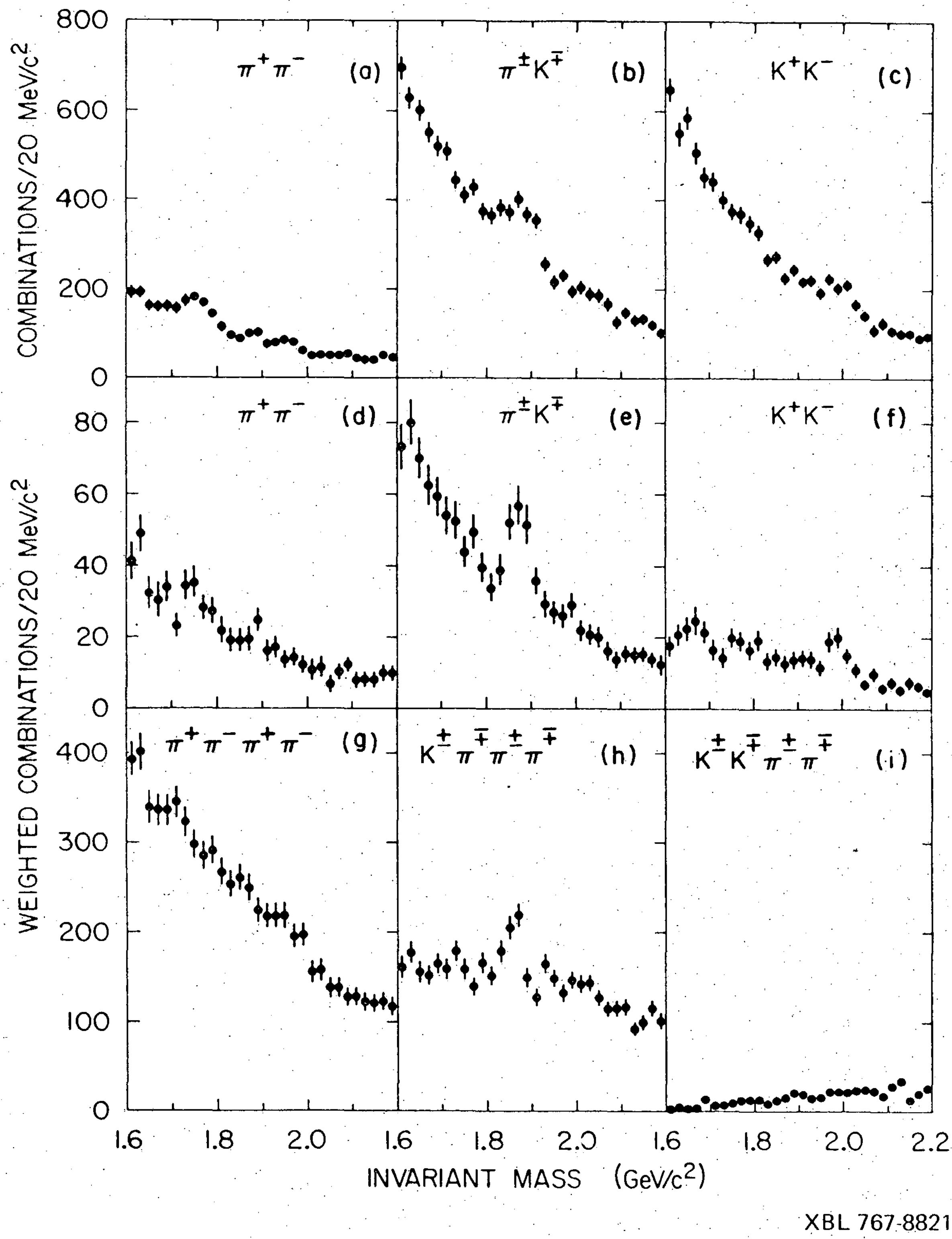
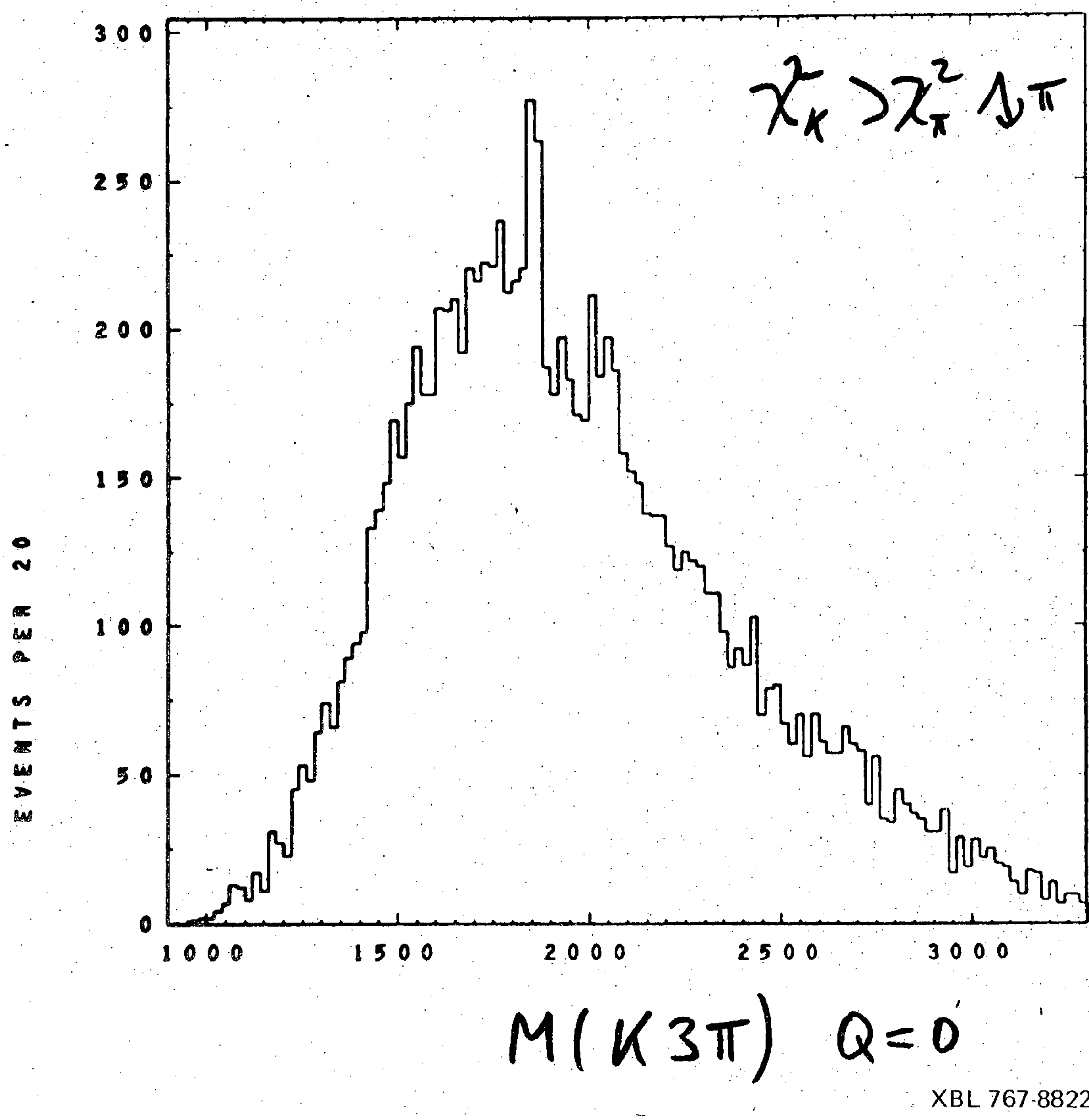
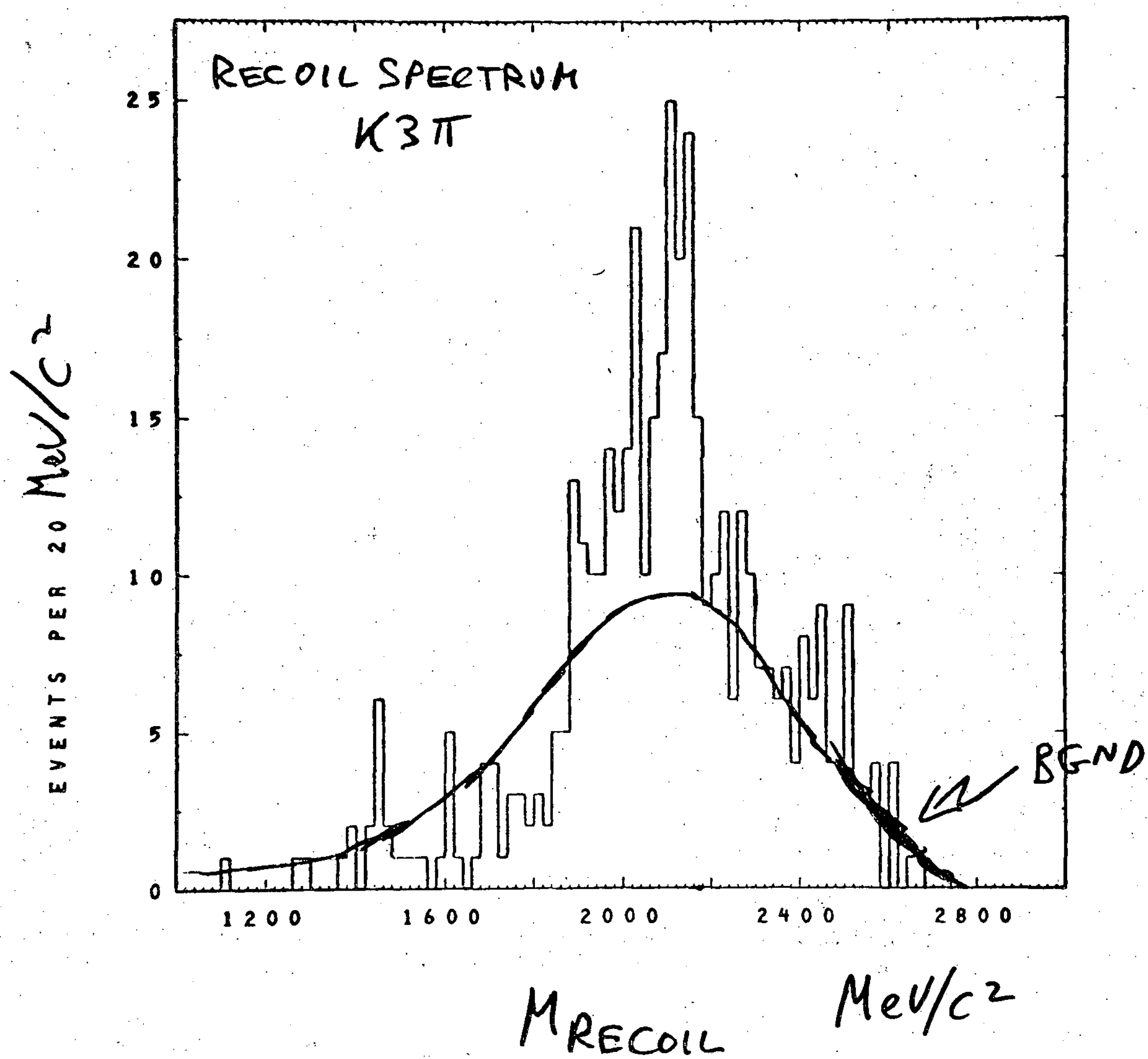

COMBINATIONS/20 MeV/c²
WEIGHTED COMBINATIONS/20 MeV/c²
π⁺π⁻ (a)
π±K∓ (b)
K⁺K⁻ (c)
π⁺π⁻ (d)
π±K∓ (e)
K⁺K⁻ (f)
π⁺π⁻π⁺π⁻ (g)
K±π∓π±π∓ (h)
K±K∓π±π∓ (i)
800
600
400
200
0
80
60
40
20
0
400
300
200
100
0
1.6
1.8
2.0
1.6
1.8
2.0
1.6
1.8
2.0
2.2
INVARIANT MASS (GeV/c²)
XBL 767-8821

Fig. 13



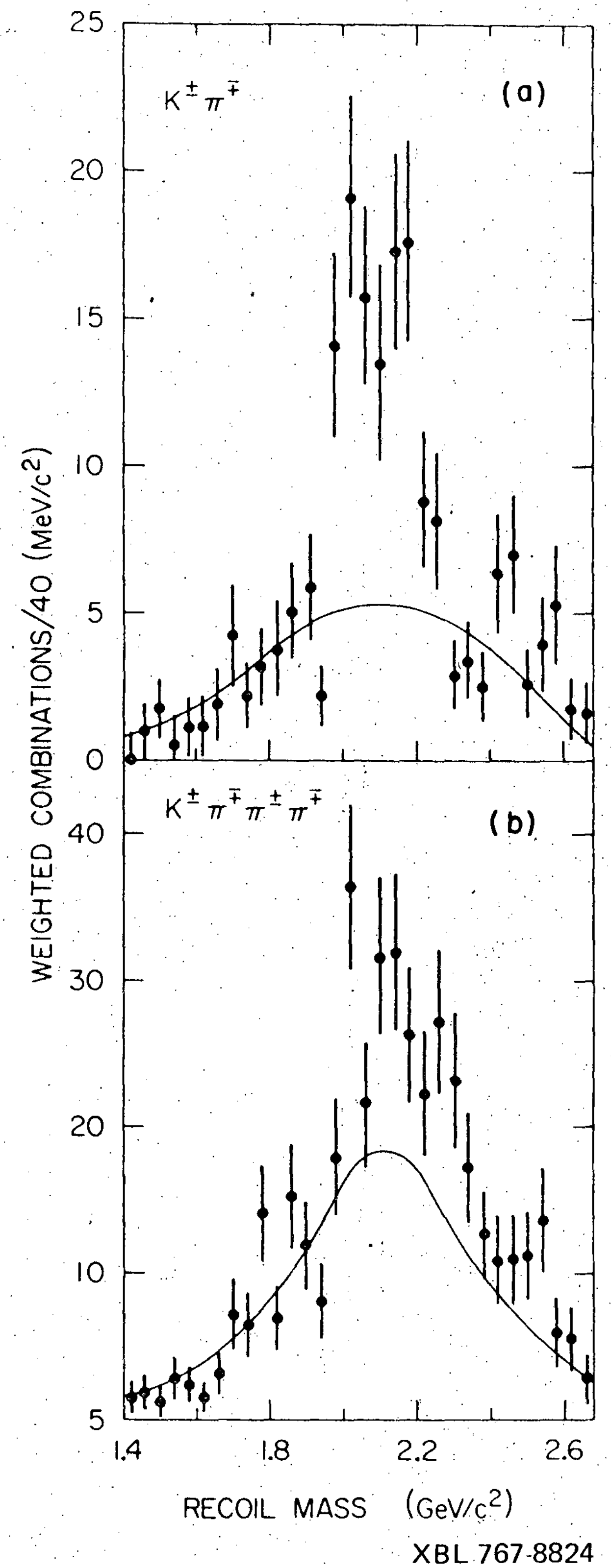
300
250
200
150
100
50
0
EVENTS PER 20
1000
1500
2000
2500
3000
$\chi^2_K > \chi^2_\pi + \pi$
M(K3π) Q=0
XBL 767-8822

Fig. 14



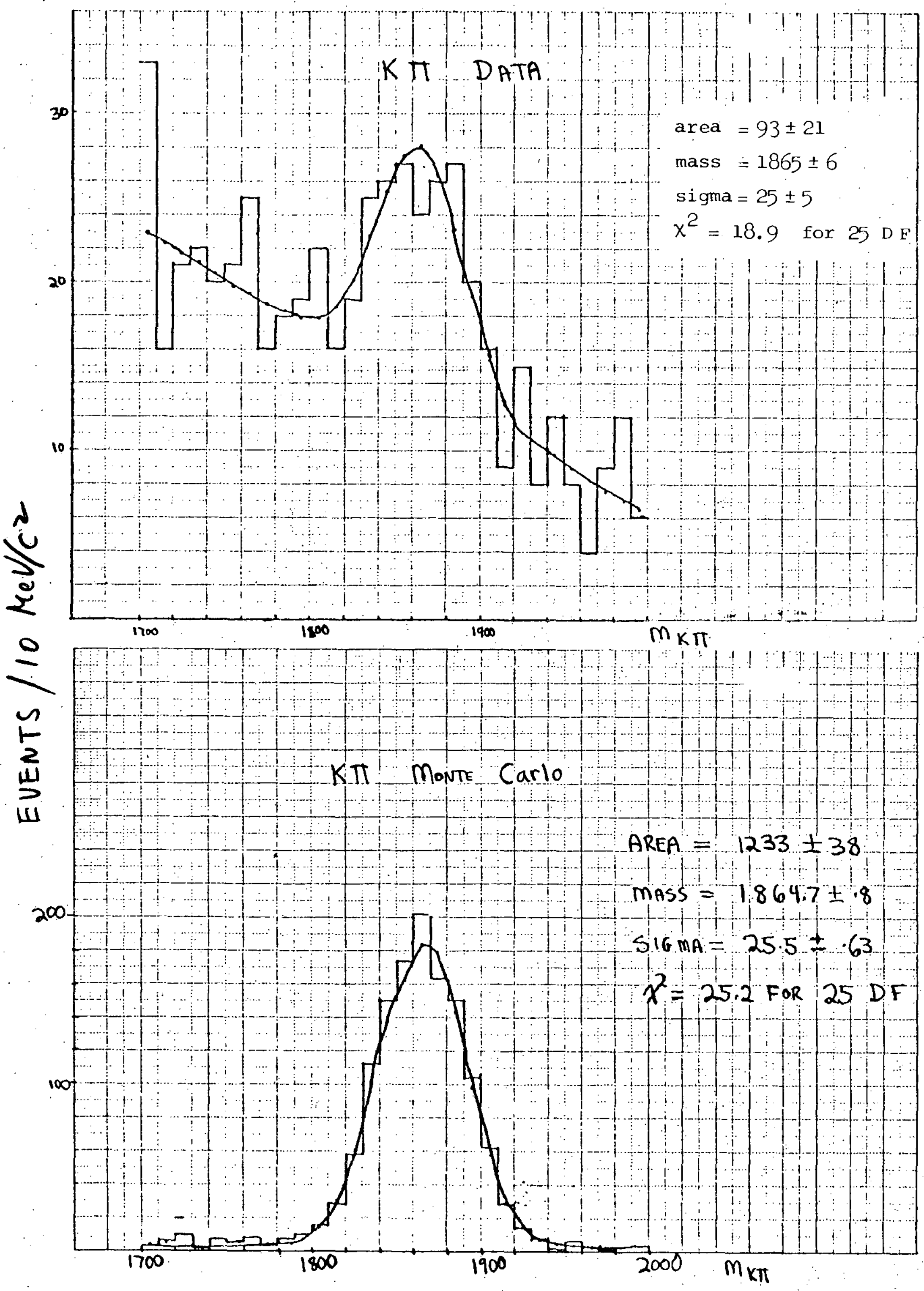
XBL 767-8823

Fig. 15



25
20
15
10
5
0
$K^{\pm}\pi^{\mp}$
(a)
40
30
20
10
5
$K^{\pm}\pi^{\mp}\pi^{\pm}\pi^{\mp}$
(b)
WEIGHTED COMBINATIONS/40 (MeV/c²)
1.4
1.8
2.2
2.6
RECOIL MASS (GeV/c²)
XBL 767-8824

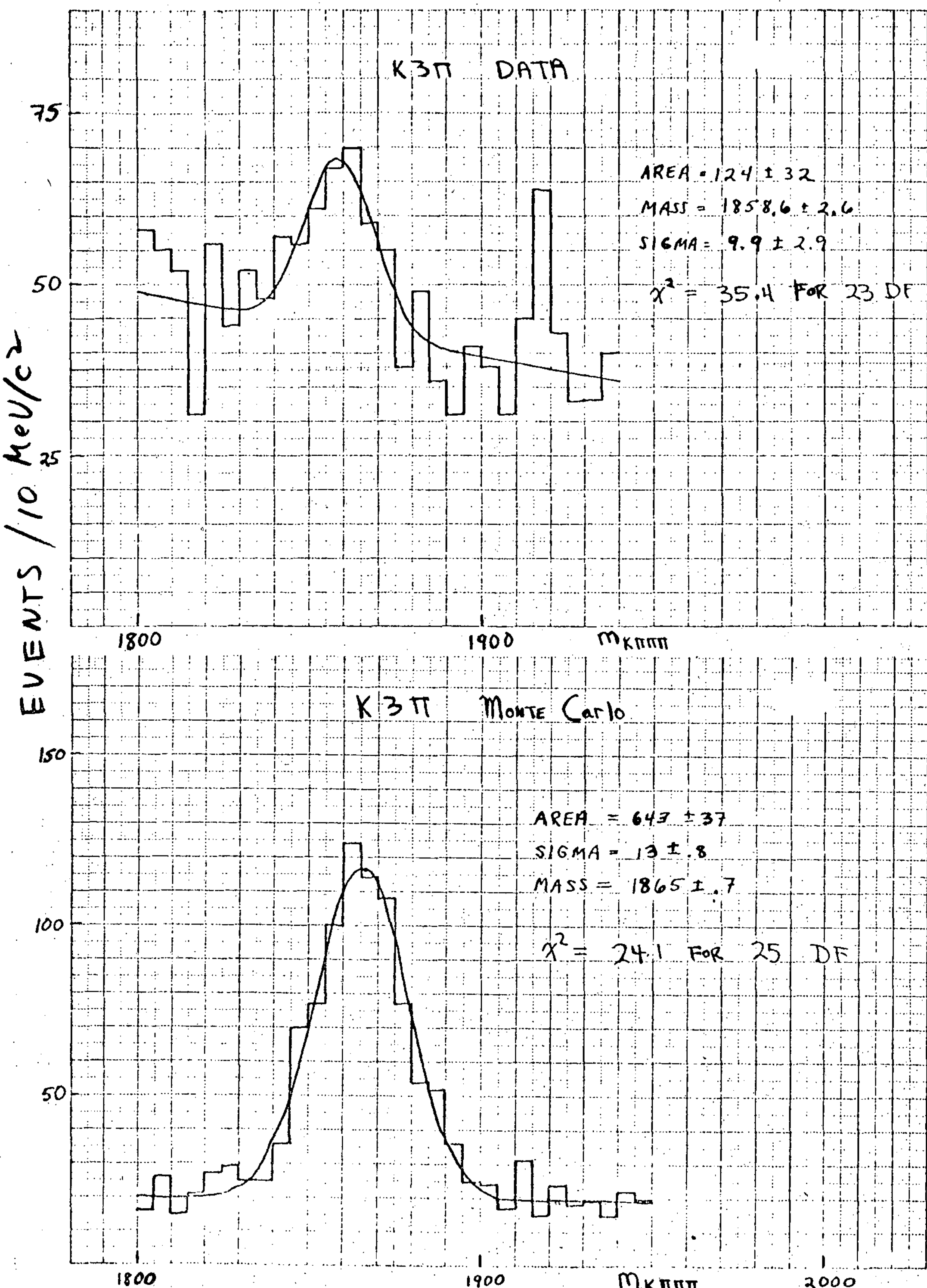
Fig. 16



XBL 767-8817

Fig. 17

0 0 0 0 4 5 0 2 7 0 2



XBL 767-8825

Fig. 18

TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720