UCRL-16370

University of California

Ernest O. Lawrence Radiation Laboratory

TWO-WEEK LOAN COPY

This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 5545

STUDY OF THE REACTION $K^+ + p \rightarrow K + N + \pi$
BETWEEN 0.86 AND 1.58 BeV/c

Berkeley, California

UCRL-16370 c.2

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

Lecture presented at the
Oxford International Conference
on Elementary Particles,
Oxford, England,
September 19-25, 1965,
M. G. Bowler

UCRL-16370

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

STUDY OF THE REACTION $K^+ + p \rightarrow K + N + \pi$ BETWEEN 0.86 AND 1.58 BeV/c

M. G. Bowler, R. W. Bland, J. L. Brown, G. Goldhaber,
J. A. Kadyk, V. Seeger, and G. H. Trilling

December 16, 1965

STUDY OF THE REACTION $K^+ + p \rightarrow K + N + \pi$ BETWEEN 0.86 AND 1.58 BeV/c

M. G. Bowler, R. W. Bland, J. L. Brown, G. Goldhaber,
J. A. Kadyk, V. Seeger, and G. H. Trilling

Lawrence Radiation Laboratory
University of California
Berkeley, California

December 16, 1965

The reaction $K^+ + p \rightarrow K + N + \pi$ has been studied at 0.86, 0.96, 1.20 and 1.58 BeV/c. At all these momenta this reaction is dominated by resonance formation, $N^*(1236)$ at the lower two momenta and both $N^*(1236)$ and $K^*(891)$ at the higher momenta. The N^* production is reasonably well described by the Stodolsky-Sakurai ρ exchange model. The K^* production does not fit any simple one-particle exchange model.

I. INTRODUCTION

We have made an exposure of the Lawrence Radiation Laboratory's 25-inch hydrogen bubble chamber to a separated K^+ beam of variable momentum for the purpose of studying the reactions

$$K^+ + p \rightarrow K^0 + p + \pi^+, \quad (1)$$

$$K^+ + p \rightarrow K^+ + p + \pi^0, \quad (2)$$

$$K^+ + p \rightarrow K^+ + n + \pi^+. \quad (3)$$

Previous studies of these reactions[1] at various momenta have shown that they are dominated by production of the quasi—two-particle final states

$$K^+ + p \rightarrow K + N^*(1236), \quad (4a)$$

$$K^+ + p \rightarrow K^*(891) + p. \quad (4b)$$

In this experiment we have examined in some detail the behavior of these production processes as a function of primary momentum over the range 0.86 to 1.58 BeV/c. We have completed our analysis at 0.96 BeV/c, and have preliminary results at 0.86, 1.20, and 1.58 BeV/c. Since Processes (4a) and (4b) both go most strongly through Reaction (1), we confine our discussion to this reaction, noting only that at 0.96 BeV/c, where Reactions (2) and (3) have also been studied, the N^* production via (4a) is consistent with the 9:2:1 ratio predicted by the Clebsch-Gordan coefficients, when N^* and nonresonant background have been properly separated.

The Dalitz plots for Reaction (1) corresponding to the four incident momenta under study are shown in Fig. 1. In interpreting the populations in terms of resonance formation, we have assumed that Reaction (1)

consists of an incoherent superposition of KN^*, K^*p, and "nonresonant phase space," and have further assumed the validity of the mass-conjugation procedure of Eberhard and Pripstein.[2] With these qualifications, it is straightforward to estimate from the Dalitz plot projections the proportions of channels (4a) and (4b), but it must be emphasized that the validity of these assumptions has not been demonstrated and is presently under study.

The cross sections for Reaction (1) are given in Table I, along with rough estimates of their apportionment into K^*, N^*, and phase-space nonresonant background. Although both 0.86 and 0.96 BeV/c are below the K^* production threshold, it appears from the Dalitz plots that there is a clear population increase in the region of high $K-\pi$ masses. Because of the difficulty of estimating accurately the amount of K^* involved, this enhancement has been included in Table I in the nonresonant background. We now consider K^* and N^* production in greater detail.

II. K^* PRODUCTION

As mentioned above, the enhancement of high $K-\pi$ masses evident at 0.86 and 0.96 BeV/c is suggestive of the production of a significant amount, namely $\approx 10\%$, of K^* production through the tail of the resonance. Since this K^* is completely buried under the N^*, very little can be said about the dynamics of production at these momenta. At 1.2 BeV/c the K^* still largely overlaps the N^*, but since the K^* production amounts to about 30% of the reaction it is feasible to subtract an appropriate amount of N^*, determined by mass conjugation, from the overlap region and investigate the remaining K^*. Because of this subtraction

procedure, the statistical errors associated with each histogram bin in the various figures are greater than those one would estimate from the number of events in each bin. The distributions of K-π mass and momentum transfer squared, $\Delta^2(K\pi)$, are shown in Fig. 2, and folded distributions of ϕ and $\cos\alpha$ are shown in Fig. 3 for two ranges of momentum transfer. Here α is the polar angle of the outgoing K in the $K\pi$ rest frame, measured with respect to the incoming K direction, and ϕ is the Treiman-Yang angle. It is clear that pion exchange plays at most a small role, but more detailed conclusions are premature until the validity of the method of background removal is further investigated.

At 1.58 BeV/c, the K^* band is well separated from the N^* band over a substantial region of the Dalitz plot, and a more dependable analysis can be carried out. The $K\pi$ mass and $\Delta^2(K\pi)$ distributions are shown in Fig. 4 and the ϕ and $\cos\alpha$ distributions shown in Fig. 5 for three regions of momentum transfer. It should be noted that the $\Delta^2(K\pi)$ distribution shows a sizable peak below ≈ 0.3 BeV^2 superimposed on a rather flat distribution. Furthermore the ϕ distribution corresponding to events in the peak is uniform, whereas for the higher values of $\Delta^2(K\pi)$ the Treiman-Yang distribution shows an increasingly strong $\sin^2\phi$ component. It thus seems reasonable to associate the peak in the $\Delta^2(K\pi)$ distribution with pion exchange and the remaining flat distribution with vector exchange. However, it should be noted that the $\cos\alpha$ distribution is almost independent of momentum transfer and largely characteristic of vector exchange. It thus appears that the behavior of the $\Delta^2(K\pi)$, $\cos\alpha$, and ϕ distributions are not easily interpreted in terms of any simple one-particle exchange, or incoherent superposition of one-particle-exchange

models. Just as is the case for the CERN 3-BeV/c data, the absorption effects appear to play an essential role in modifying the detailed features of K^* production.

III. N^* PRODUCTION

Stodolsky and Sakurai[3] have proposed a model for N^* production through ρ exchange with a magnetic-dipole transition at the $p\rho N^*$ vertex. The experimental consequences of this model are best expressed in terms of the distributions of the polar angle γ and azimuth δ of the outgoing pion with respect to the production-plane normal in the N^* rest frame. Specifically, $\cos\gamma$ is distributed according to $1+3\cos^2\gamma$, and δ is uniform. The experimental distributions of $\cos\gamma$ and δ for the four momenta under consideration are shown in Figs. 6, 7, 8, and 9 along with fits of the $p\pi^+$ mass distributions with resonance production and phase-space background in the ratios of Table I. For all momenta except 0.86 BeV/c, K^* background was removed by mass conjugation. To do this at 0.96 BeV/c, for which there is no well-defined K^* band, only half of the Dalitz plot corresponding to $\Theta_{\pi K} < 90°$ was taken, where $\Theta_{\pi K}$ is the angle between the outgoing π and K in the N^* rest frame. The δ distribution at 0.96 BeV/c was correspondingly folded. The deviation from uniformity of the 0.86 BeV/c δ distribution is probably associated with the high-mass K-π enhancement evident in the Dalitz plot, since there is a strong a priori correlation, essentially kinematic in origin, between K-π mass and δ. With this qualification it is clear that the $\cos\gamma$ and δ distributions fit the predictions of the Stodolsky-Sakurai model at all momenta under study.

The distributions of momentum transfer squared $\Delta^2(p\pi)$ to the N^* are shown in Fig. 10 with curves calculated from the Stodolsky-Sakurai model. There is good agreement between theory and experiment except at 1.58 BeV/c, where the experimental data show more forward collimation than the theory. This behavior is completely in contradiction with the use of form factors independent of primary momentum to interpret production angular distributions. Finally, note that the cross sections for the Stodolsky-Sakurai model are expected to be in the ratio 1:3.5:16:45 for the four momenta under consideration. The experimental ratios are 1:3:6:5. It is clear that the absorption effects responsible for the forward collimation above 1.2 BeV/c are simultaneously cutting off the cross sections.

In conclusion it may be said that the Stodolsky-Sakurai model provides a satisfactory representation of N^* decay angular distributions for all momenta under study. It also correctly gives energy dependence of the cross sections and the production angular distribution below 1.2 BeV/c, but clearly requires modification above this momentum to properly account for absorption effects.

This work was done under the auspices of the U. S. Atomic Energy Commission.

REFERENCES

1. B. Kehoe, Phys. Rev. Letters 11, 93 (15 July 1963);
G. B. Chadwick, D. J. Crennel, W. T. Davies, M. Derrick, J. H. Maloey, P. B. Jones, D. Radojicic, C. A. Wilkinson, A. Bettini, M. Cresti, S. Limertani, L. Perruzo and R. Santangelo, Phys. Letters 6, 309 (1963);
G. Goldhaber, Proceedings Athens Topical Conference on Recently Discovered Resonant Particles, Ed. B. A. Munir and L. J. Gallaher, April 26-27, 1963. (Ohio University, Athens, Ohio), p. 92;
M. Ferro-Luzzi, R. George, Y. Goldschmidt-Clermont, V. P. Henri, B. Jongejans, D. W. G. Leith, G. R. Lynch, F. Muller, and J.-M. Perreau, Nuovo Cimento 36, 1101 (1965).

2. Philippe Eberhard and Morris Pripstein, Phys. Rev. Letters 10, 351 (1963).

3. L. Stodolsky and J. J. Sakurai, Phys. Rev. Letters 11, 90 (1963);
J. D. Jackson and H. Pilkuhn, Nuovo Cimento 33, 189 (1964).
Our calculations have been modeled after those of Jackson and Pilkuhn, but their coupling constants have been chosen to be $G_1 = G_3 = \frac{mb+md}{2md} G_2$, corresponding to pure M1 coupling in the limit $t \to 0$, $mb \neq md$.

Table I. Cross sections for the reaction $K^+ + p \rightarrow K^0 + p + \pi^+$ at various incident momenta.

Incident K^+ momentum (BeV/c)	Number of events analyzed	Cross section (mb)	Percent due to $K^+ + p \rightarrow K^+ + N^*(1236)$	Percent due to $K^+ + p \rightarrow K^*(891) + p$	Percent due to nonresonant background
0.86	282	0.9 ± 0.2	$\approx 80\%$	—	$\approx 20\%$
0.96	1140	2.8 ± 0.5	$\approx 80\%$	—	$\approx 20\%$
1.20	2446	5.2 ± 0.9	$\approx 65\%$	$\approx 29\%$	$\approx 6\%$
1.58	706	4.8 ± 0.5	$\approx 54\%$	$\approx 40\%$	$\approx 6\%$

FIGURE CAPTIONS

Fig. 1. Dalitz plots for the reaction $K^+ + p \rightarrow K^0 + p + \pi^+$ at 860, 960, 1200, and 1580 MeV/c incident laboratory momentum.

Fig. 2. Distributions of $K^0\pi^+$ invariant mass squared and squared momentum transfer to the $K\pi$ system at 1200 MeV/c incident momentum. The lower distributions include only events in the K^* band shown above. Since these distributions involve significant background subtractions, the statistical errors are somewhat larger than implied by the numbers of events in the histograms. The same qualification applies to most of the other distributions given here.

Fig. 3. Distributions of ϕ and $\cos\alpha$ for two regions of momentum transfer.

Fig. 4. Distributions of $K^0\pi^+$ invariant mass squared and squared momentum transfer to the $K\pi$ system at 1580 MeV/c momentum.

Fig. 5. Distributions of ϕ and $\cos\alpha$ for three regions of momentum transfer.

Fig. 6. Distributions of $p\pi^+$ mass squared and pion-decay angles in the $p\pi^+$ center of mass at incident momentum of 860 MeV/c.

Fig. 7. Same as Fig. 6 but at 960 MeV/c.

Fig. 8. Same as Fig. 6 but at 1200 MeV/c.

Fig. 9. Same as Fig. 6 but at 1580 MeV/c.

Fig. 10. Distributions of squared momentum transfer to the $p\pi^+$ system. The curves represent M1 ρ-exchange N^* production.

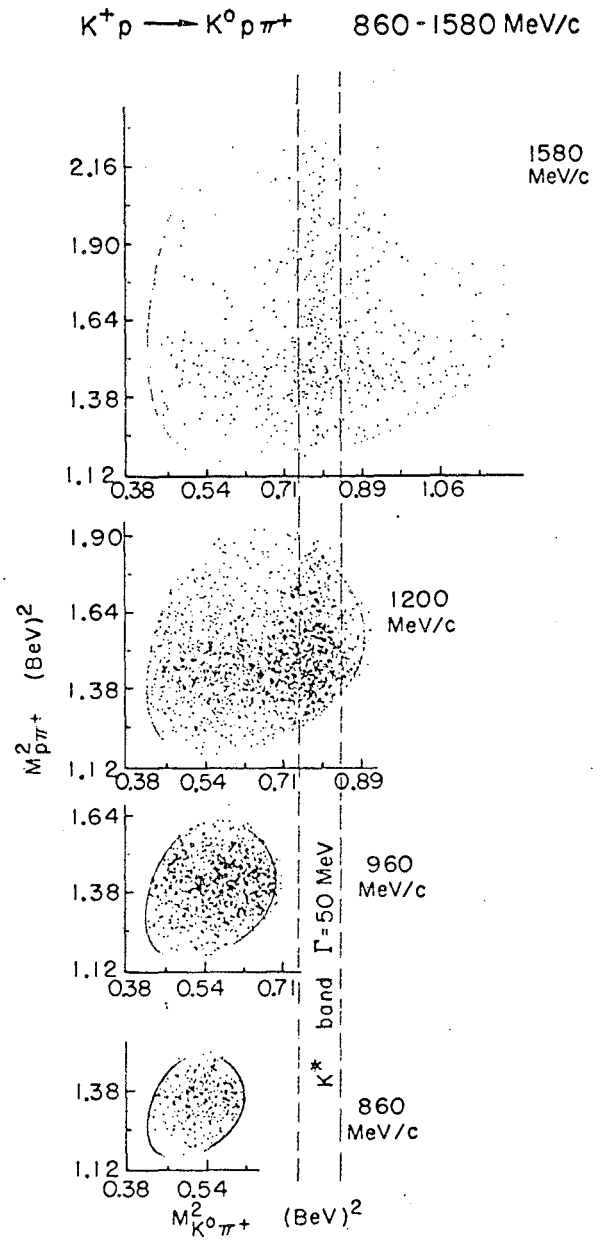


Fig. 1

MUB-7862

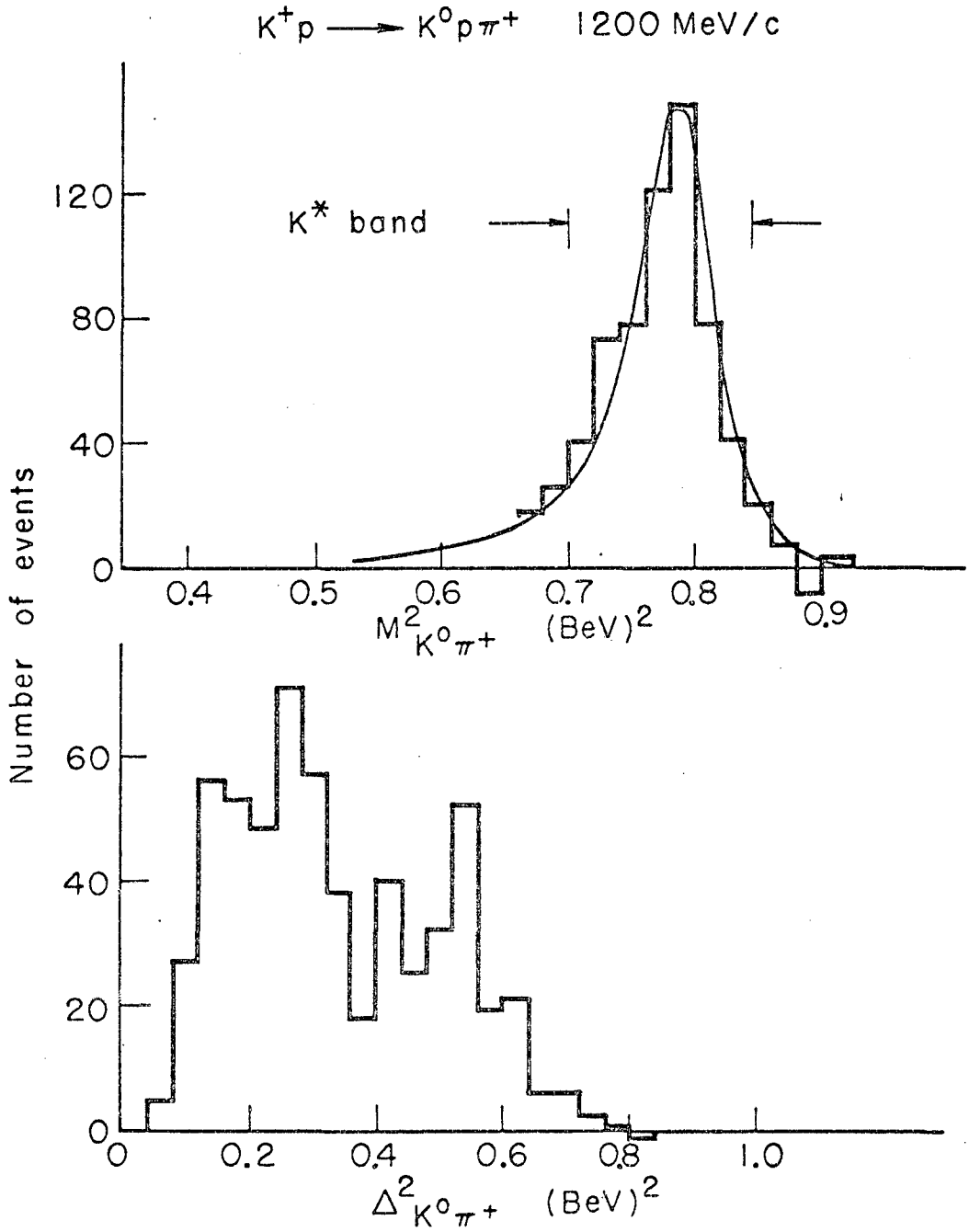


Fig. 2

MUB-7831

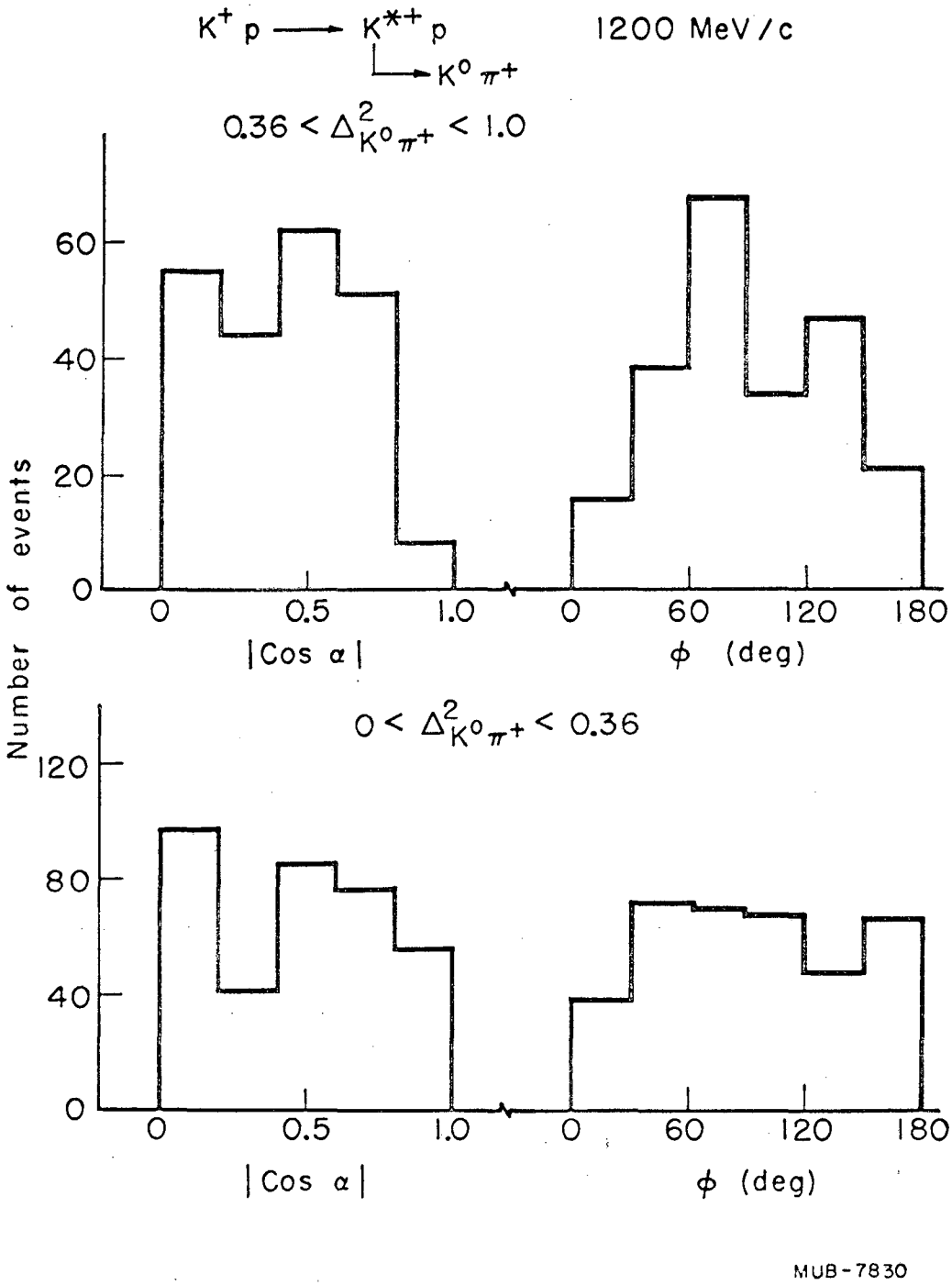

K+ p → K*+ p
K0 π+
1200 MeV/c
0.36 < Δ²K0π+ < 1.0
Number of events
60
40
20
0
0
0.5
1.0
|Cos α|
0
60
120
180
ϕ (deg)
0 < Δ²K0π+ < 0.36
120
80
40
0
0
0.5
1.0
|Cos α|
0
60
120
180
ϕ (deg)
MUB-7830

Fig. 3

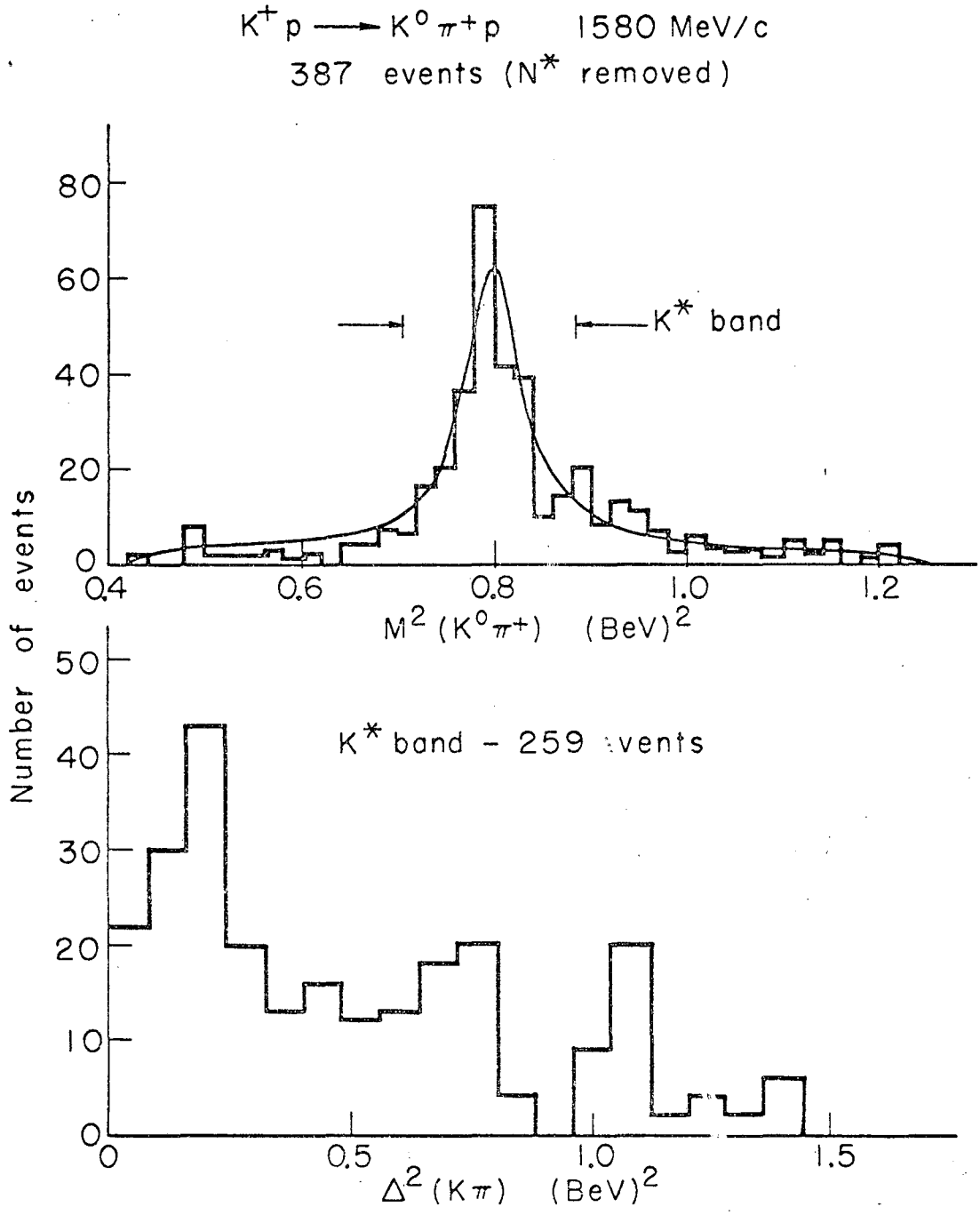


Fig. 4

MUB-7826

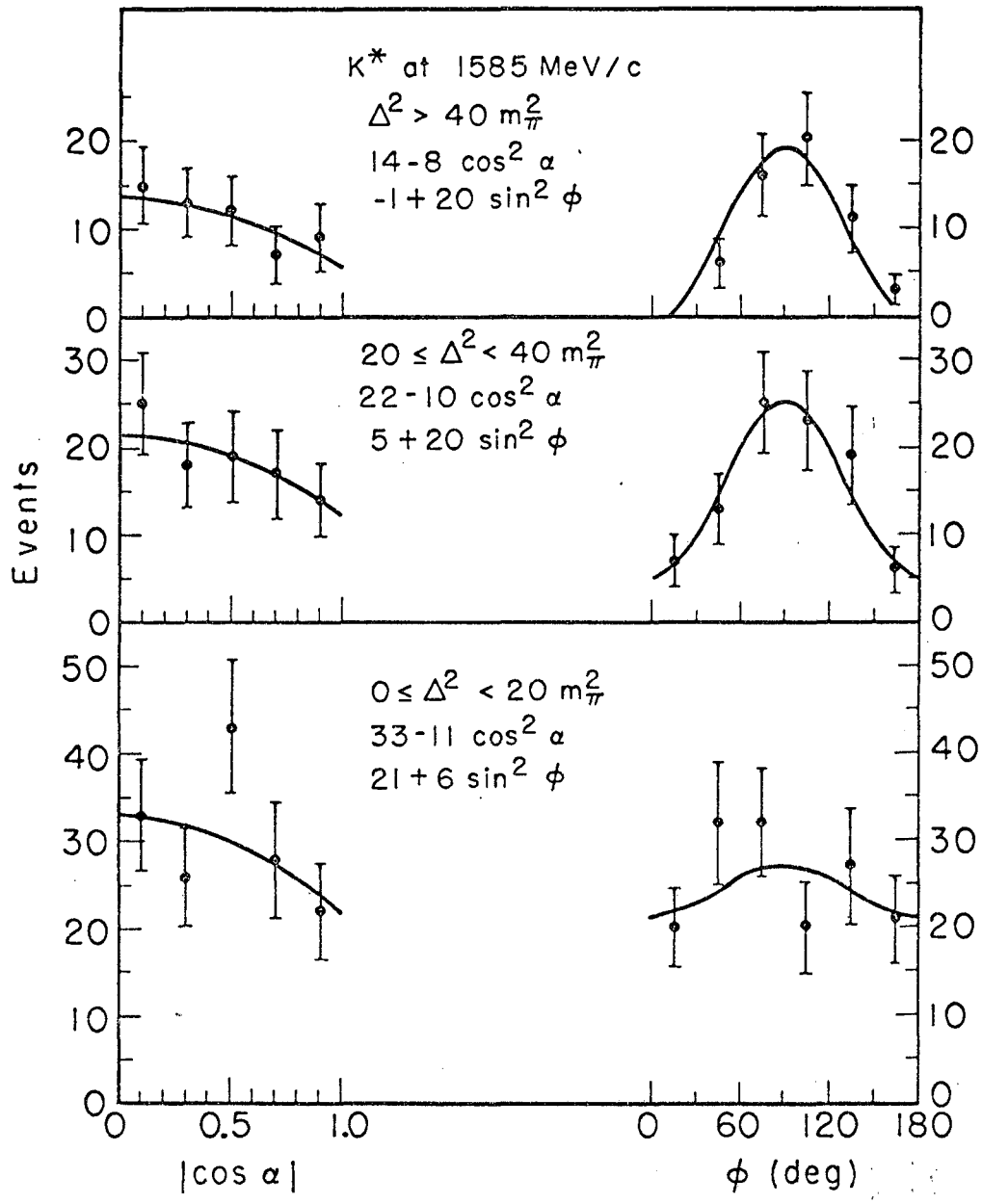


Fig. 5

MUB-7468

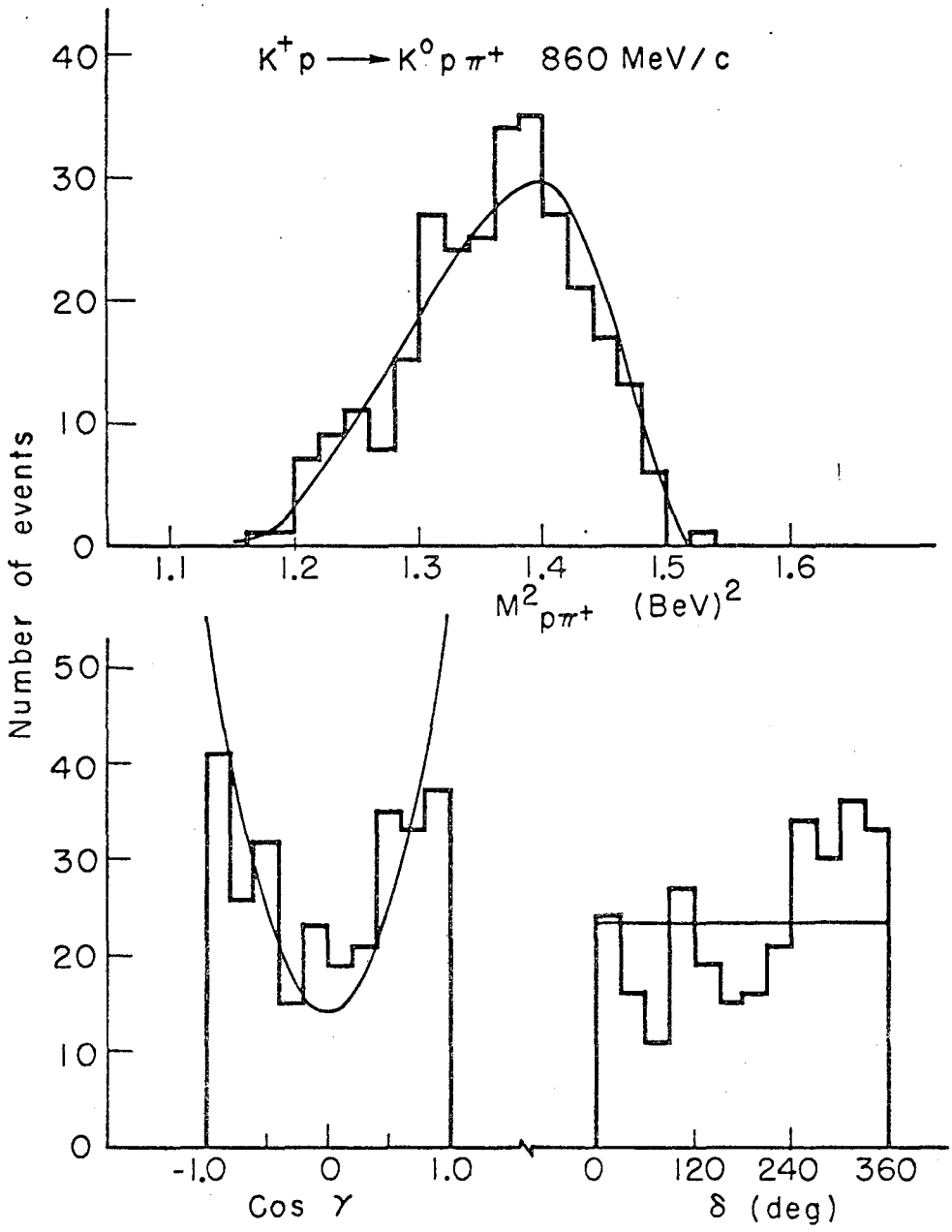


Fig. 6

MUB-7828

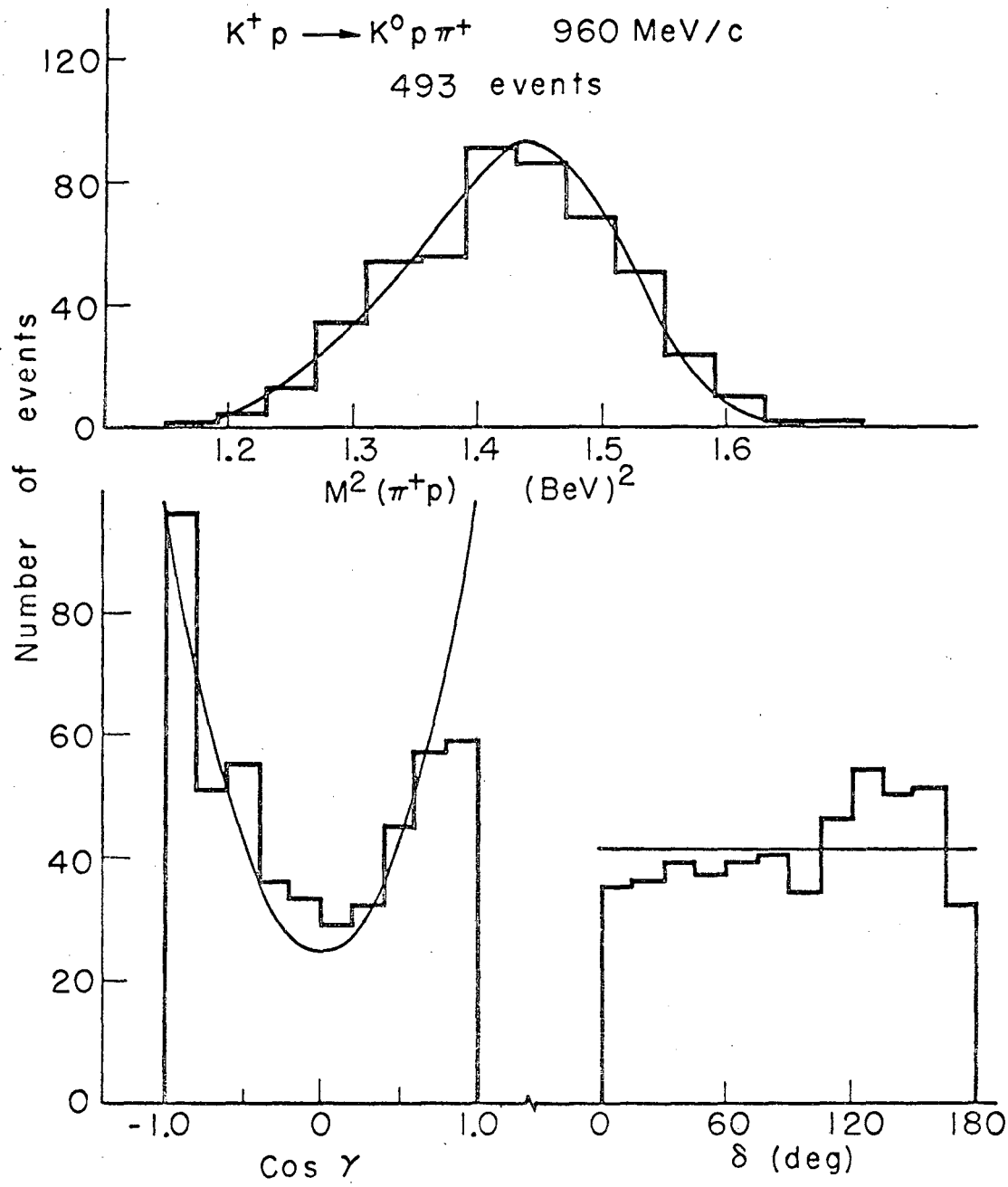


Fig. 7

MUB-7823

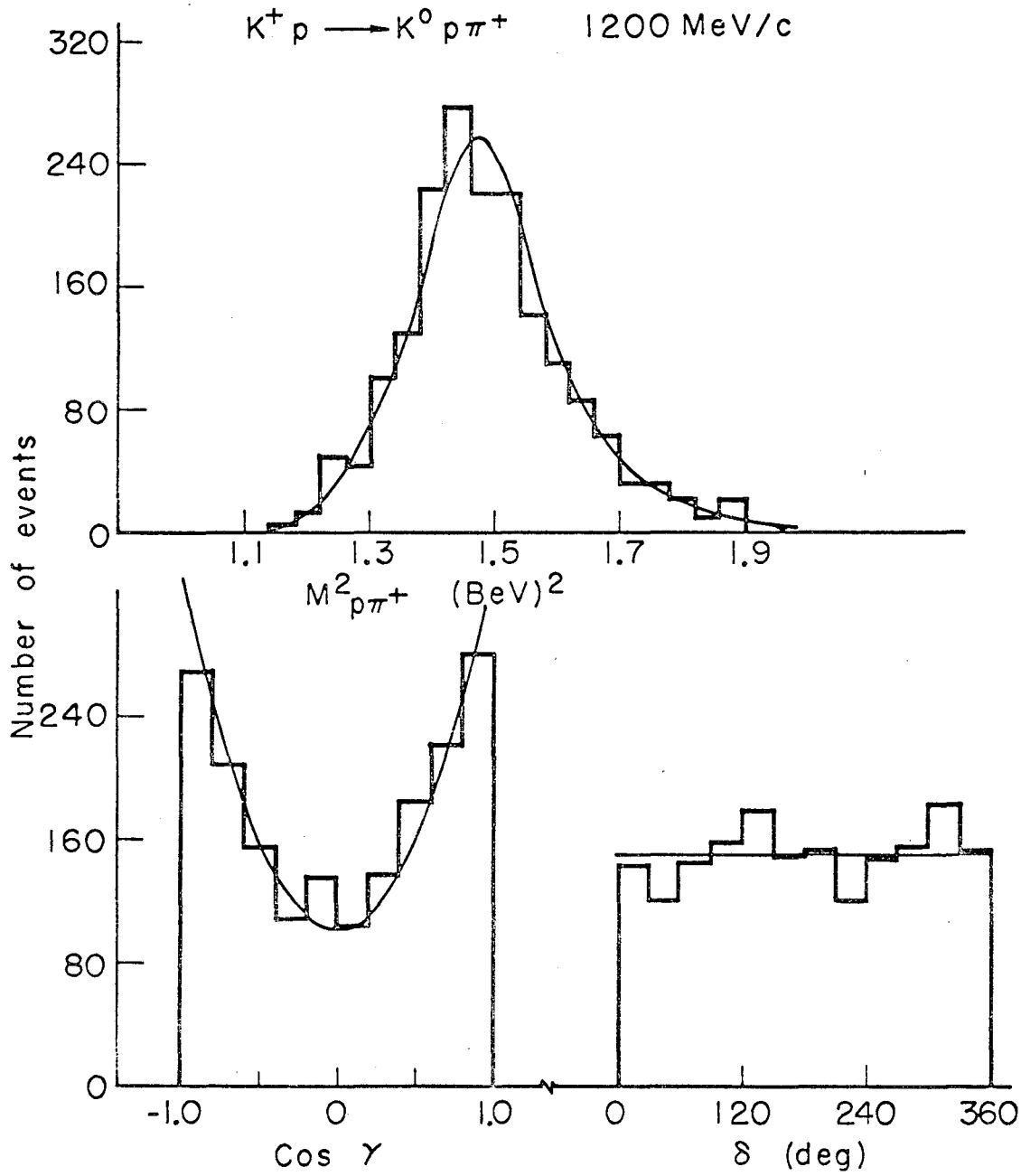


Fig 8

MUB-7832

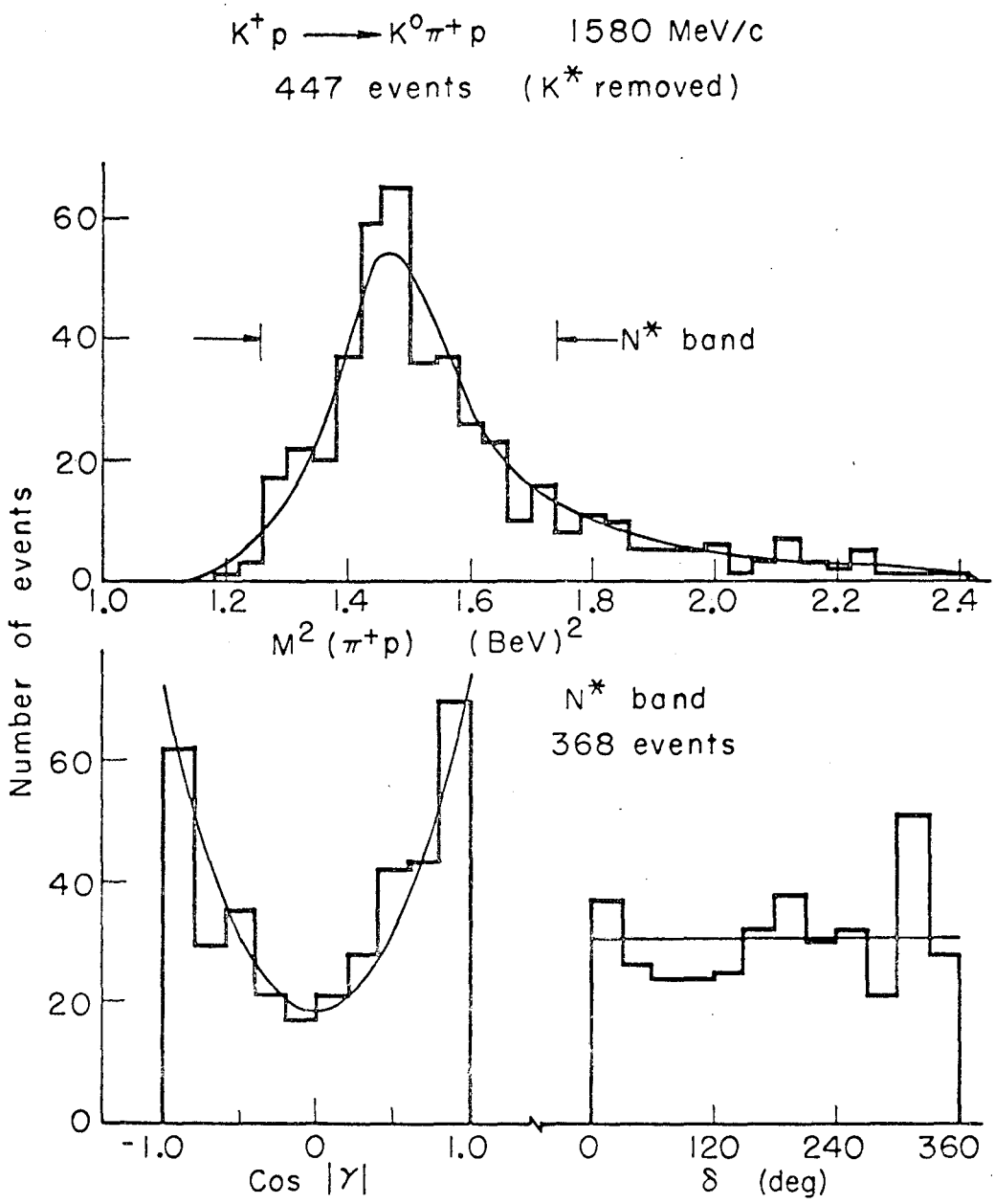
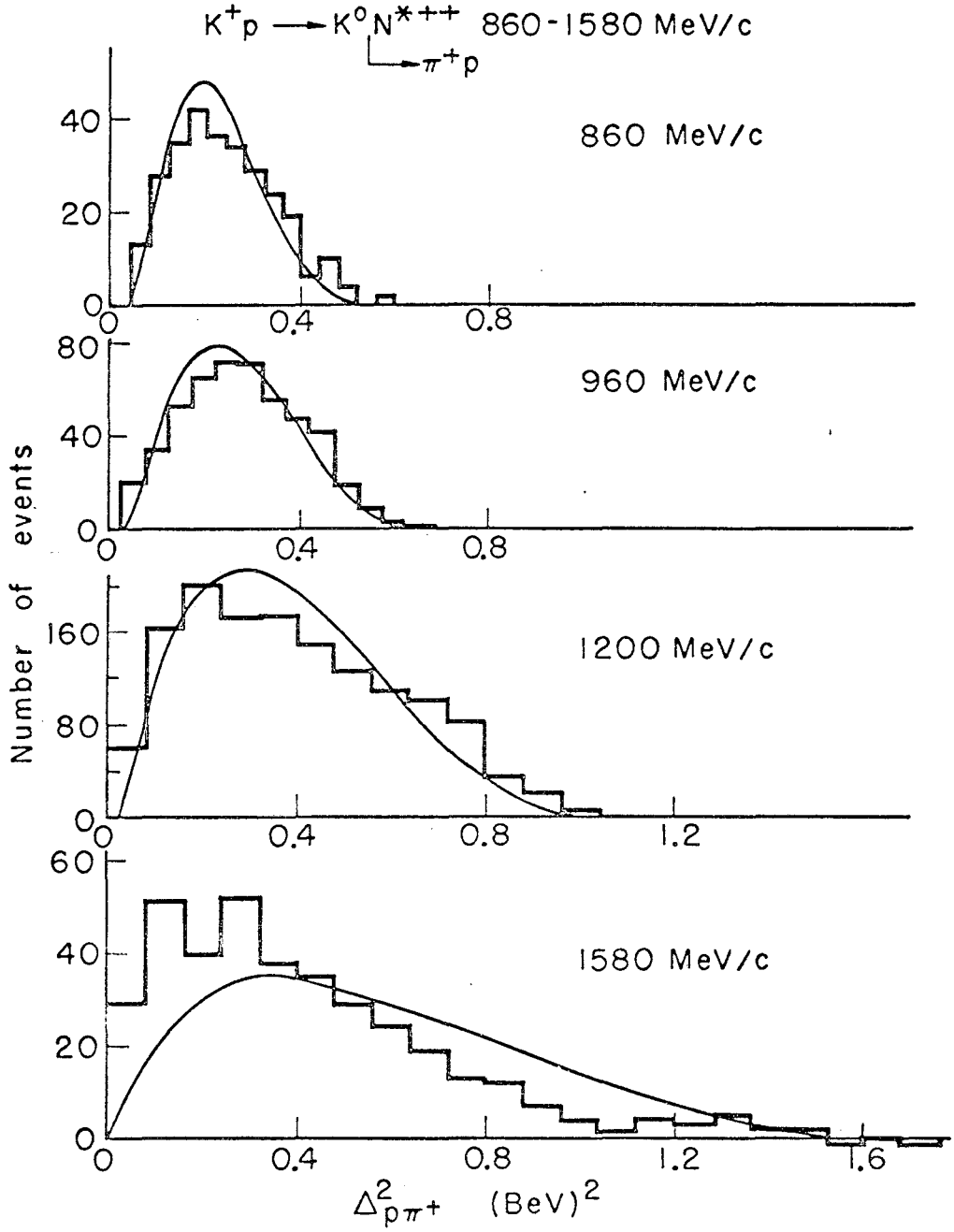


Fig 9

MUB-7824



MUB-7829

Fig. 10

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.