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ABSTRACT

In a preliminary analysis of 50 000 photographs of the 80-inch BNL hydrogen bubble chamber exposed to a 4.6-BeV/c K^+ meson beam, we have studied the reactions

$$K^+ + p \rightarrow K^0 \pi^+ p, \qquad (1)$$
$$K^+ p \rightarrow K^0 \pi^+ \pi^0 p, \qquad (2)$$

and

$$K^+ + p \rightarrow K^+ \pi^- \pi^+ p \, . \qquad (3)$$

In all these reactions $K^*(1400)$ production is observed. The distribution of the $K\pi$ scattering angle for $K^*(1400)$ shows characteristic features expected for an aligned 2^+ meson on a one-pion-exchange model. The $K^*(890)\,\pi$ enhancement at 1320 MeV, reported by Almeida et al., is observed in Reactions (2) and (3). We observe a definite mass enhancement for Reactions (2) and (3) in the $K^*\pi$ mass spectrum at 1320 MeV with a width at about 80 MeV. This corresponds to the results reported by Almeida et al. We have considered the data both as a bona fide resonance and a kinematical enhancement via the Deck mechanism. We find good agreement for various tests of the kinematic model, but cannot rule out the resonance interpretation.

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We report in this note the preliminary results we have obtained in studying the K^+p interactions at an incident momentum of 4.6 BeV/c.[1] This work was carried out in the Brookhaven National Laboratory 80-inch hydrogen bubble chamber exposed at the AGS.

$$K^+ + p \rightarrow K^0\pi^+p \quad 281 \text{ events} \quad (1)$$

$$\rightarrow K^0\pi^+p\pi^0 \quad 454 \text{ events} \quad (2)$$

$$\rightarrow K^+\pi^-p\pi^+ \quad 997 \text{ events.} \quad (3)$$

The above reactions have been identified in an analysis of about 50 000 pictures. In measuring we have employed both the conventional digitized measuring machine (Franckenstein) and the automatic measuring machine, the LRL Flying-Spot Digitizer. The computer program PACKAGE has been used for geometric reconstruction and kinematical fitting.

In all three reactions we observe the formation of $K^*(1400)$ in addition to $K^*(890)$. Figure 1 shows the Dalitz plot and projections for Reaction (1). In Figs. 2, 3, and 4 we show the triangle plots and mass distributions for Reactions (2) and (3). We note here that Reaction (2) can proceed via two channels to produce K^* resonances, i.e.,

$$K^+p \rightarrow K^{*+}p\pi^0, \quad (2a)$$

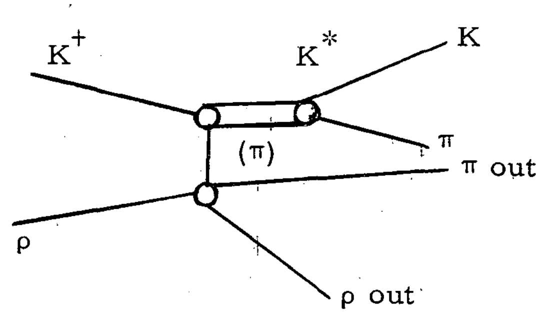
$$K^+p \rightarrow K^{*0}p\pi^+ . \quad (2b)$$

A comparison of these triangle plots indicates that double resonance formation $N^* + K^*(1400)$ is an important channel for $K^*(1400)$ production. The reduced number of events in the charged $K^*(1400)$ channel compared with that of the neutral K^{*0} is probably due to the reduced intensity of N^{*+}

*John Simon Guggenheim fellow, Deceased. This paper is the last one presented by Sulamith Goldhaber at an International Conference.

production compared with that of N^{*++}. In Fig. 5 we show the angular distribution in the $K\pi$ rest frame for events from Reactions (2b) and (3) with $K^+\pi^-$ mass in the K^* (1400) band, $1300 \leq M(K^+\pi^-) \leq 1500$ MeV and π^+p mass in the N^{*++} band, $1130 \leq M(p\pi^+) \leq 1320$ MeV. For comparison we also show the angular distribution of the K^{*0}(890) events produced in Reaction (3) with π^+p inside the N^{*++} band. The curves shown in the figure represent the least-square fits to the power-series expansion of the angular distributions where $I(\cos\alpha) = \sum_n A_n \cos^n\alpha$. The coefficients, normalized to $A_0 = 1$, are listed in Table I. The analysis of the $K\pi$ scattering angle in the K^*(1400) band shows the characteristic features of $Y_2^0(\cos\alpha)$ expected for an aligned $J^P = 2^+$ particle produced in a pion-exchange process, together with small interference with other partial waves.

We have also observed in this experiment an enhancement of events for which the $K^*\pi$ mass lies in the region of 1320 MeV. Almeida et al. have reported such an enhancement and referred to it as the K^{**}(1320).[2] We see this enhancement in channels (2a), (2b), and (3). The effect can be seen in the $K\pi\pi$ mass distribution for K^* selected events (see Fig. 6) as well as in the corresponding Dalitz plots (see Fig. 7). We have analyzed our data to see whether this enhancement can be the result of a kinematical effect. We find that when the $K^*\pi p$ event is considered as peripheral formation of K^* (see diagram), the behavior of the πp vertex is very reminiscent of diffraction scattering, similar to the A_1 effect,[3] namely, the entire K^{**} enhancement is associated with small πp scattering angles in the outgoing πp cm system. (See Fig. 8).



To make a more quantitative comparison, we divide the π^+p mass range into five intervals of 250 MeV each and compare the π^+p scattering angular distribution with the available elastic π^+p differential cross section data. Figure 9 shows the data of the events in the final state $K^{*0}\pi^+p$ plotted on semilog paper. The curves shown correspond to the elastic π^+p scattering data averaged over each mass interval, and normalized to the observed number of events.

For this interpretation we would further require a strong spin alignment of the $K^*(890)$ relative to the incident direction associated with the K^{**}. Figure 10 shows the $K\pi$ scattering angular distribution for events in the $K^*(1320)$ band. The presence of alignment is clearly observed. For comparison we show also the distribution for events in the $K^{*0}N^{*++}$ double-resonance channel, which is well known to be aligned. Figure 11 shows the Treiman-Yang angular distribution at the K^* vertex, which is consistent with isotropy within our statistical accuracy.

In summary, we conclude the following:

(a) $K^*(1400)$ production is observed. In the four-particle final state, $K^*(1400)$ is mainly produced with $N^*(1238)$ in the double resonance channel $K^*(1400)\ N^*(1238)$. The spin parity assignment $J^P = 2^+$ is favored.

(b) A definite mass enhancement is observed in the $K^*\pi$ mass spectrum at 1320 MeV with a width of about 80 MeV. Although we find the data consistent with an interpretation as a kinematic enhancement via the Deck mechanism, we feel at present that the possibility of a bona fide resonance cannot be ruled out.

FOOTNOTES AND REFERENCES

1. This paper, which includes the data obtained since the Oxford Conference, was presented at the APS Meeting, New York, 1966, B. C. Shen, I. Butterworth, J. Dash, C. M. Fu, S. Goldhaber, G. Goldhaber, and G. H. Trilling, Bull. Am. Phys. Soc. 11, 77 (1966). Work was done under auspices of the U. S. Atomic Energy Commission.

2. S. P. Almeida, H. W. Atherton, T. A. Byer, P. J. Dornan, A. G. Ferson, J. H. Scharenguivel, D. A. Sendall, and B. A. Westwood, Phys. Letters 16, 184 (1965).

3. B. C. Shen, G. Goldhaber, S. Goldhaber, and J. A. Kadyk, Phys. Rev. Letters 15, 731 (1965).

Table I. Expansion coefficients of $I(\cos\alpha) = \sum A_n \cos^n\alpha$ normalized to $A_0 = 1$ for the K^{*0} decay in the double resonance channel $K^+ + p \to K^{*0} + N^{*++}$.

$K^*(890)$ with $\Delta^2(K^{*0}) \leq 25\ M_\pi^2$	$K^*(1400)$ with $\Delta^2(K^{*0}) \leq 50\ M_\pi^2$
$A_0 = 1.0$	$A_0 = 1.0$
$A_1 = 1.0 \pm 0.6$	$A_1 = 0.9 \pm 0.6$
$A_2 = 6.6 \pm 2.4$	$A_2 = -2.6 \pm 1.4$
	$A_3 = -1.3 \pm 1.2$
	$A_4 = 6.1 \pm 1.9$

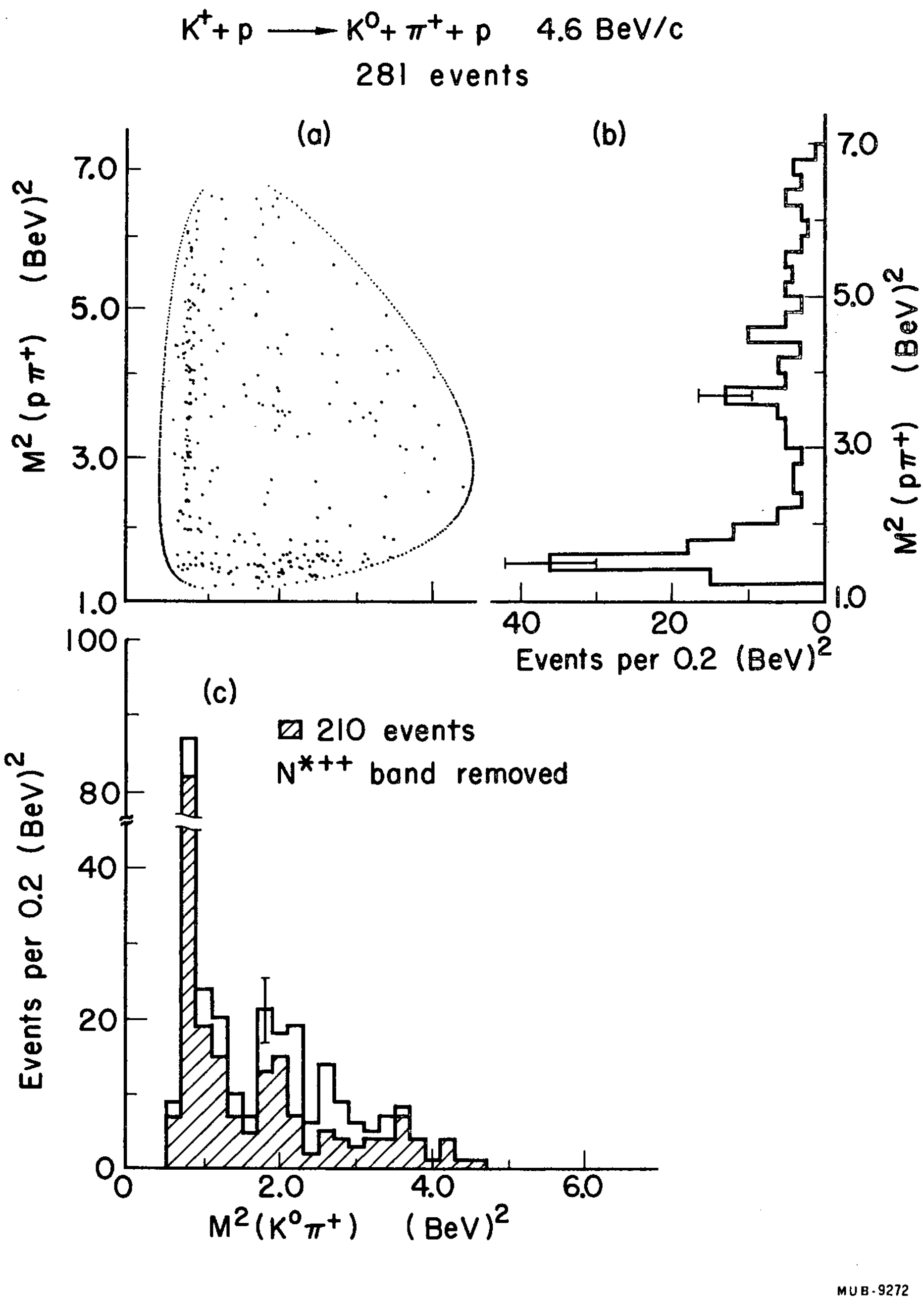


Fig. 1. (a) Dalitz plot for the reaction $K^+ + p \to K^0 + \pi^+ + p$.
(b) Projection in $M^2(\pi^+ p)$.
(c) Projection in $M^2(K^0\pi^+)$.

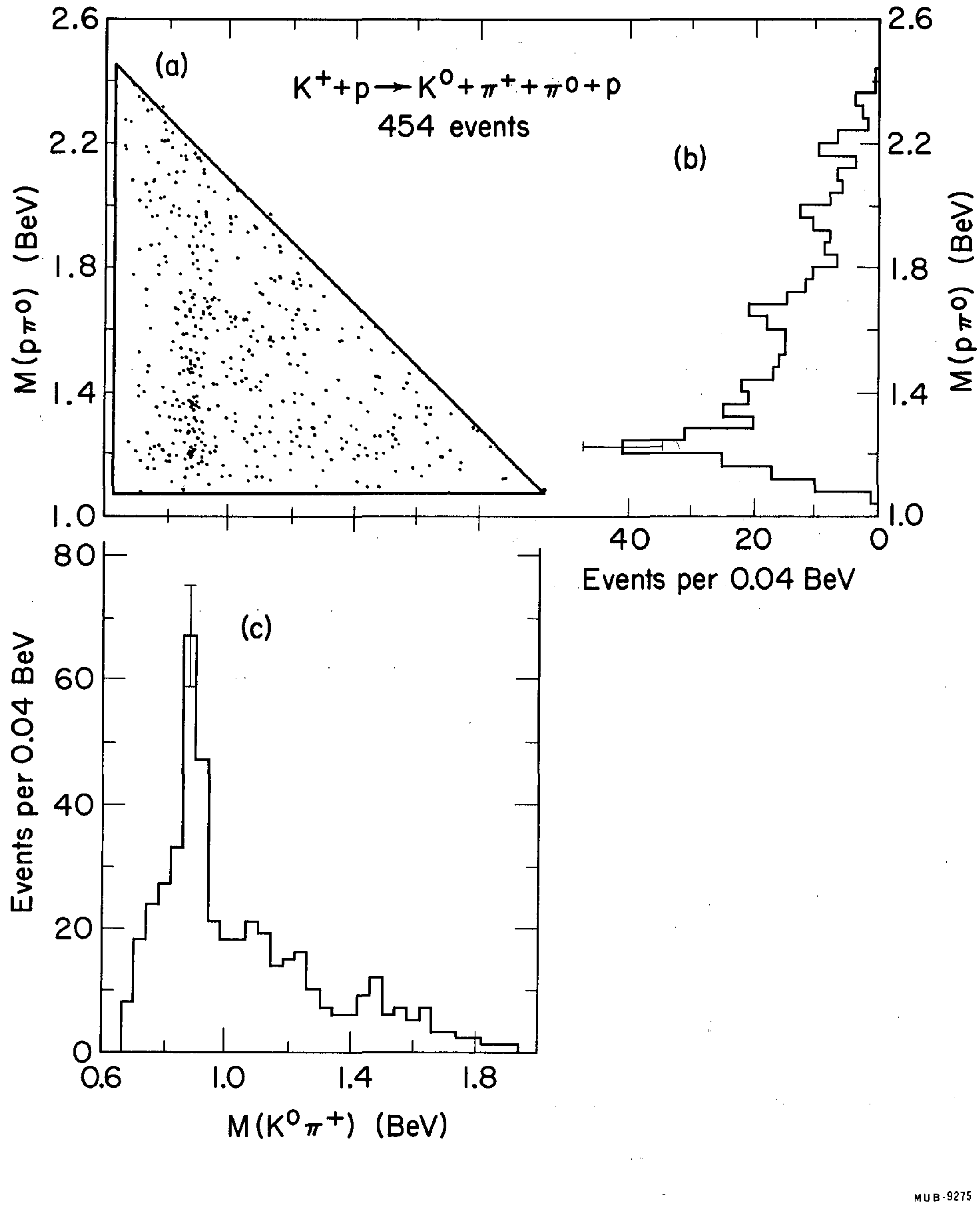


Fig. 2. Triangle plot of $M(p\pi^0)$ vs $M(K^0\pi^+)$ and mass projections for the reaction $K^+ + p \rightarrow K^0\pi^+\pi^0p$.

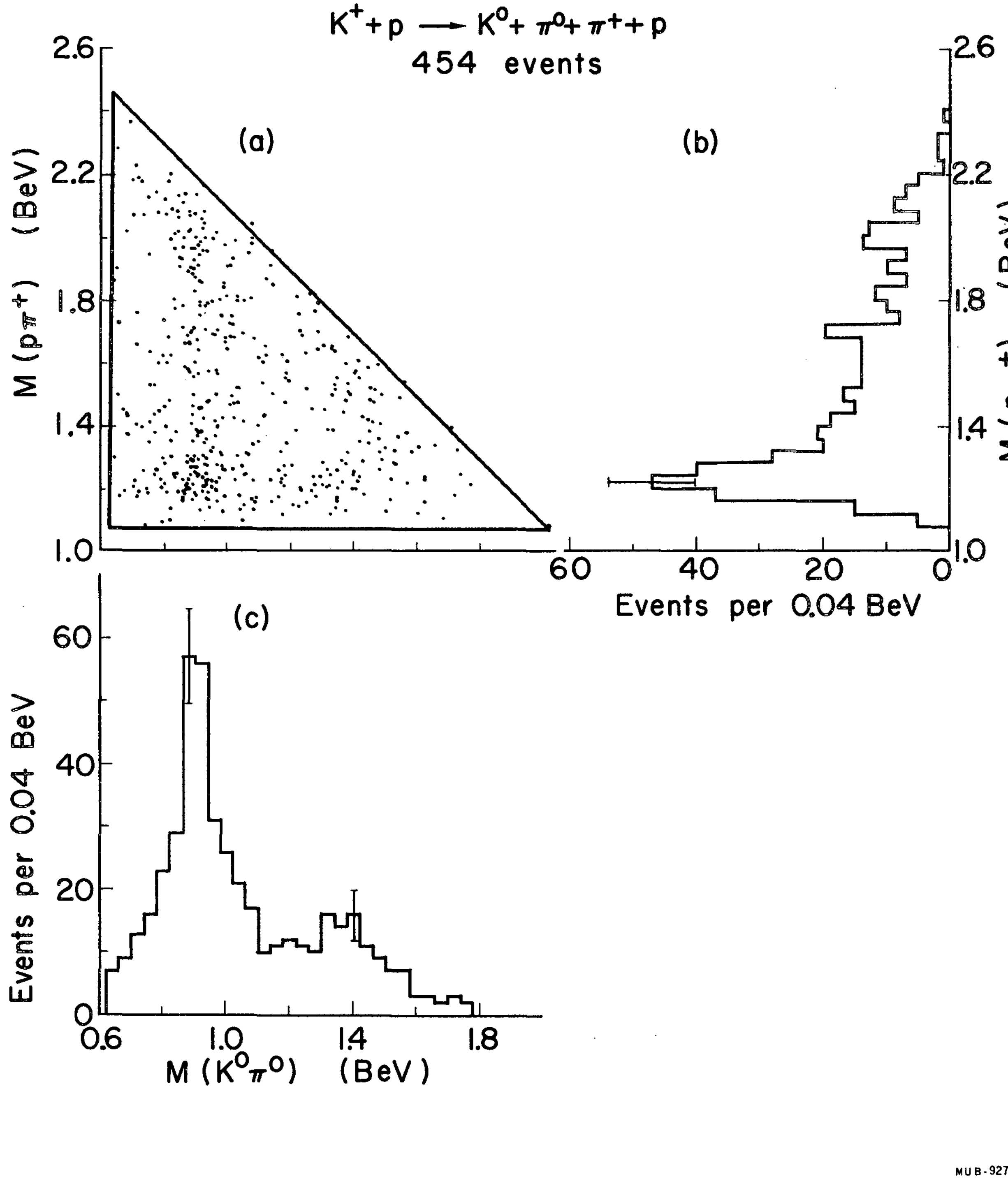


Fig. 3. Triangle plot of $M(p\pi^+)$ vs $M(K^0\pi^0)$ and corresponding mass projections for the reaction $K^+ + p \rightarrow K^0\pi^+\pi^0 + p$.

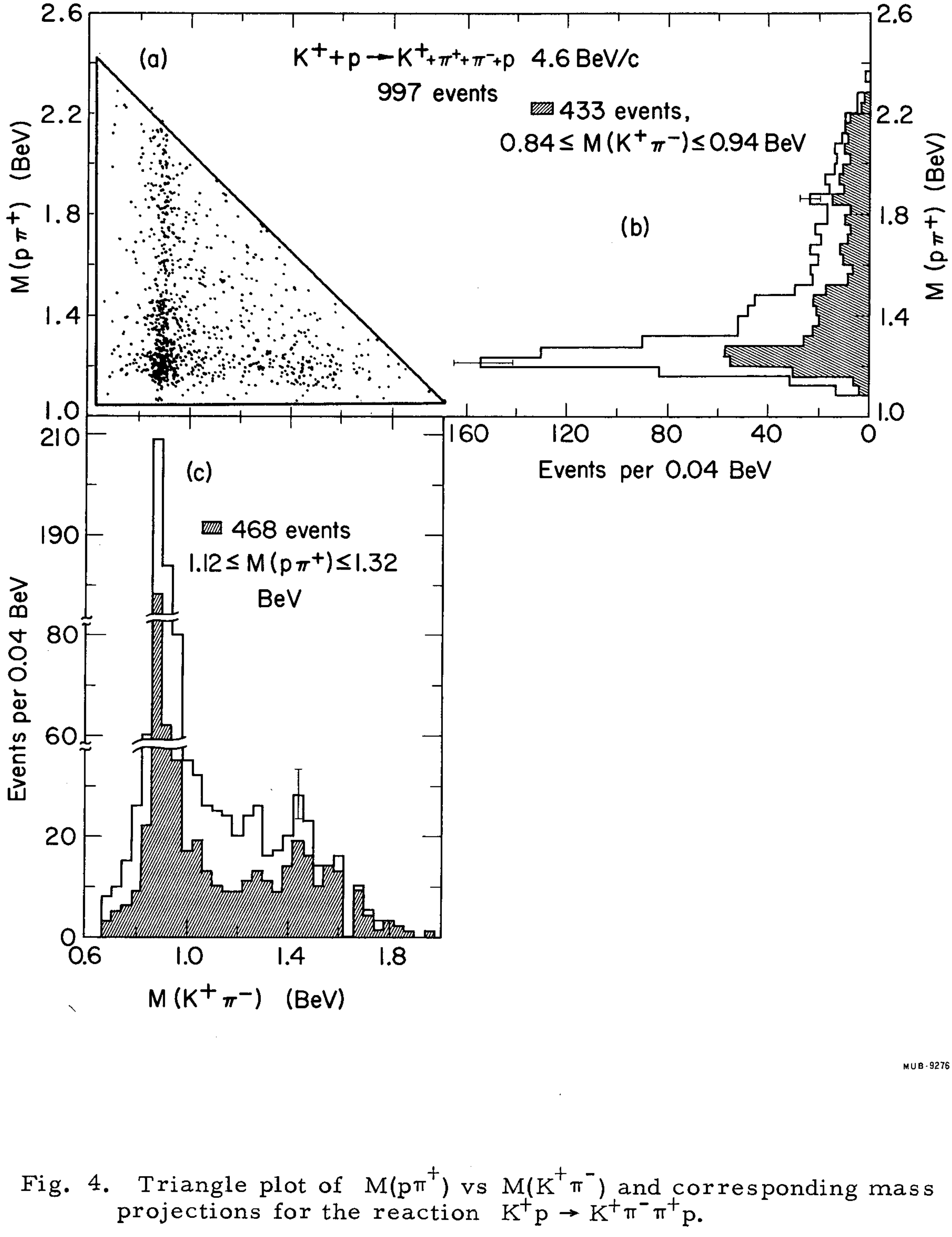


Fig. 4. Triangle plot of $M(p\pi^+)$ vs $M(K^+\pi^-)$ and corresponding mass projections for the reaction $K^+p \rightarrow K^+\pi^-\pi^+p$.

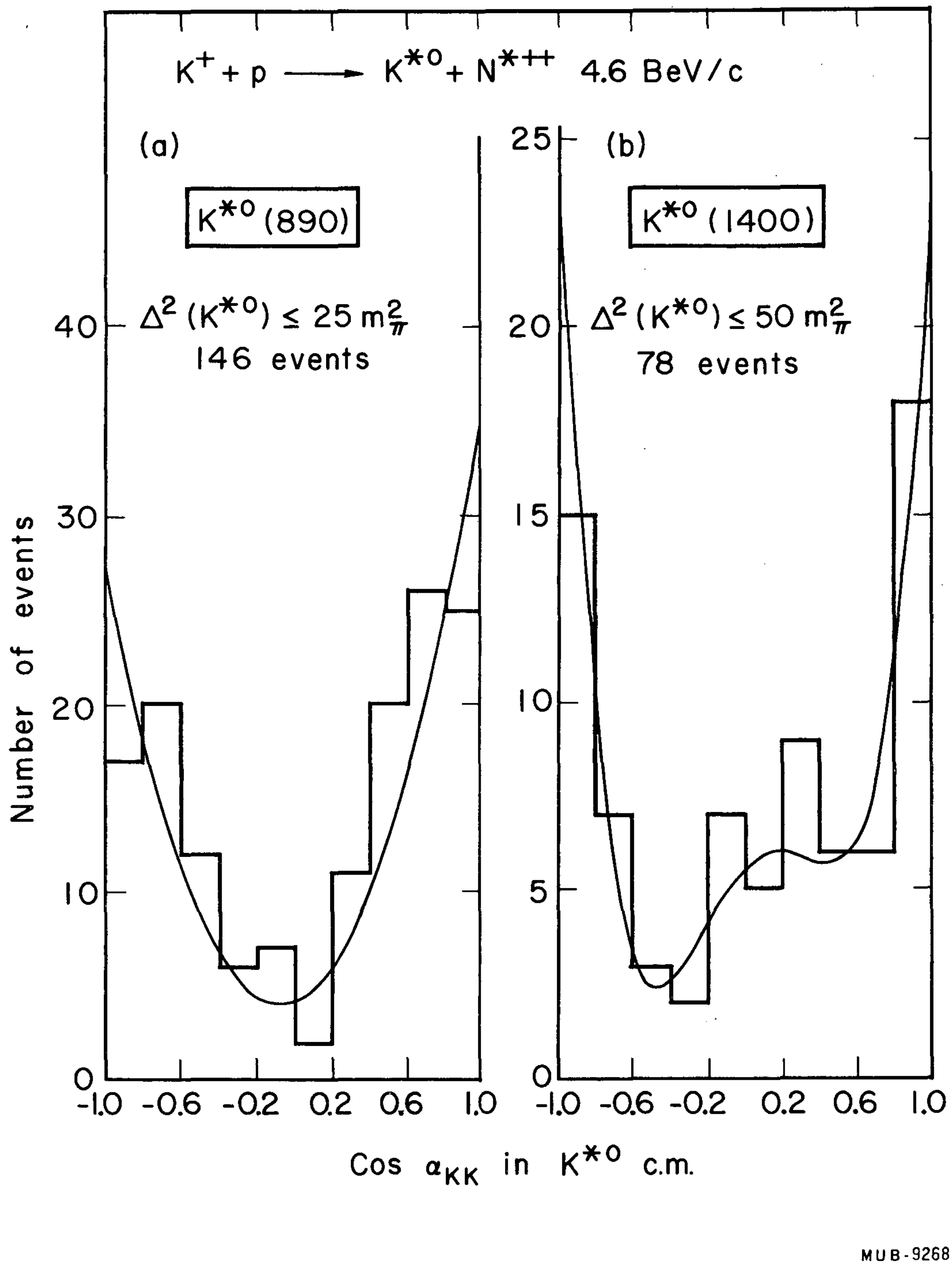


Fig. 5. Kπ scattering angular distribution in the Kπ rest frame for (a) K^{*0} (890) events with $\Delta^2(K^{*0}) \leqslant 25\ M_\pi^2$ in the double resonance channel of $K^{*0}(890)\ N^{*++}(1238)$, (b) K^* (1400) events with $\Delta^2(K^{*0}) \leqslant 50\ M_\pi^2$ in the double resonance channel of $K^{*0}(1400)\ N^{*++}(1238)$. The curves are the least-square fits to the power-series expansion $I(\cos\alpha) = \sum_n A_n \cos^n\alpha$.

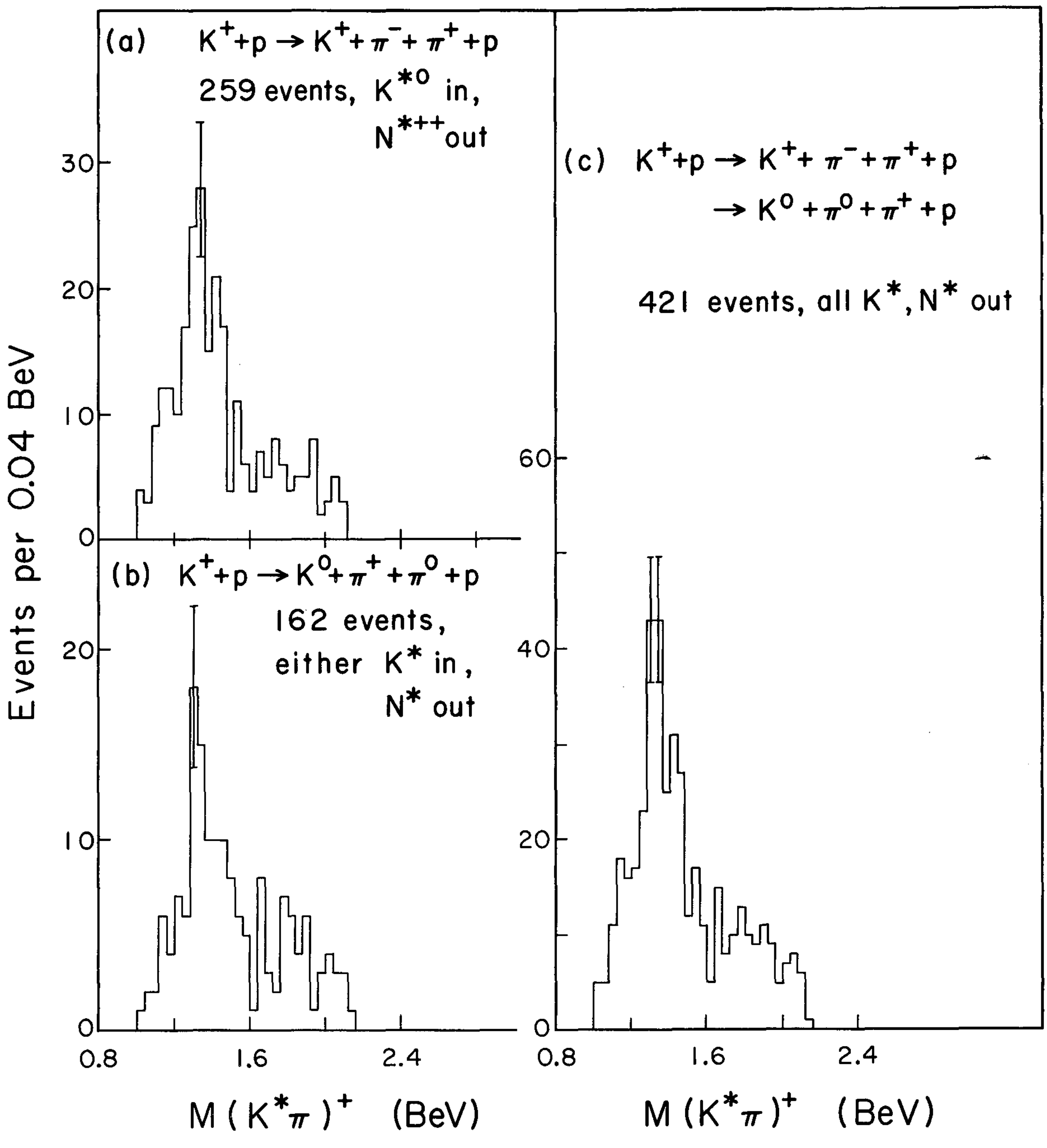


Fig. 6. M(K*π) mass distributions for Reactions (2) and (3) with N*(1238) events removed.

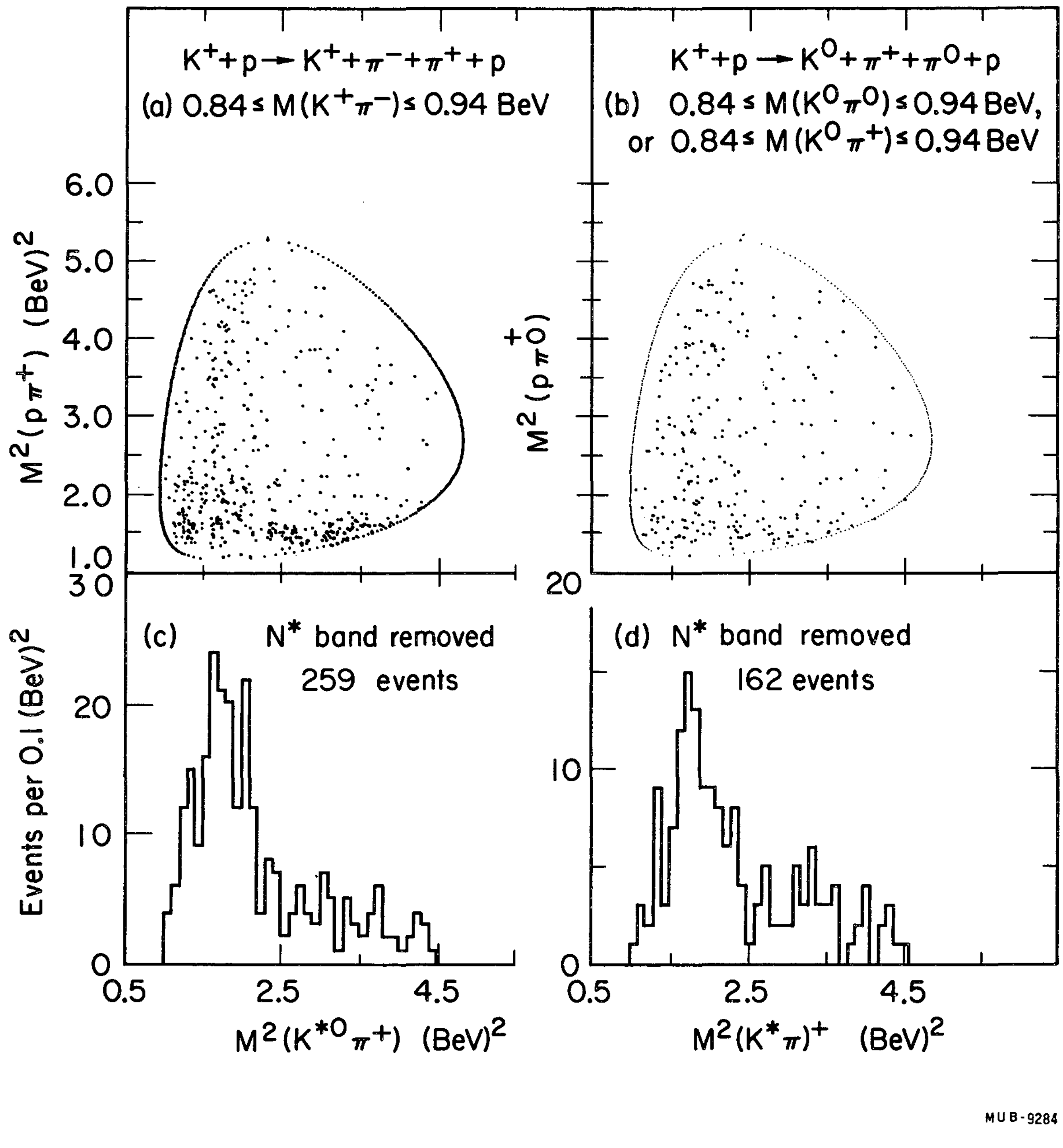


Fig. 7. Dalitz plots of M(pπ) vs M(K*π) for K*πp events and $M^2(K^*\pi)$ projections for (a) Reaction (3), (b) Reaction (2).

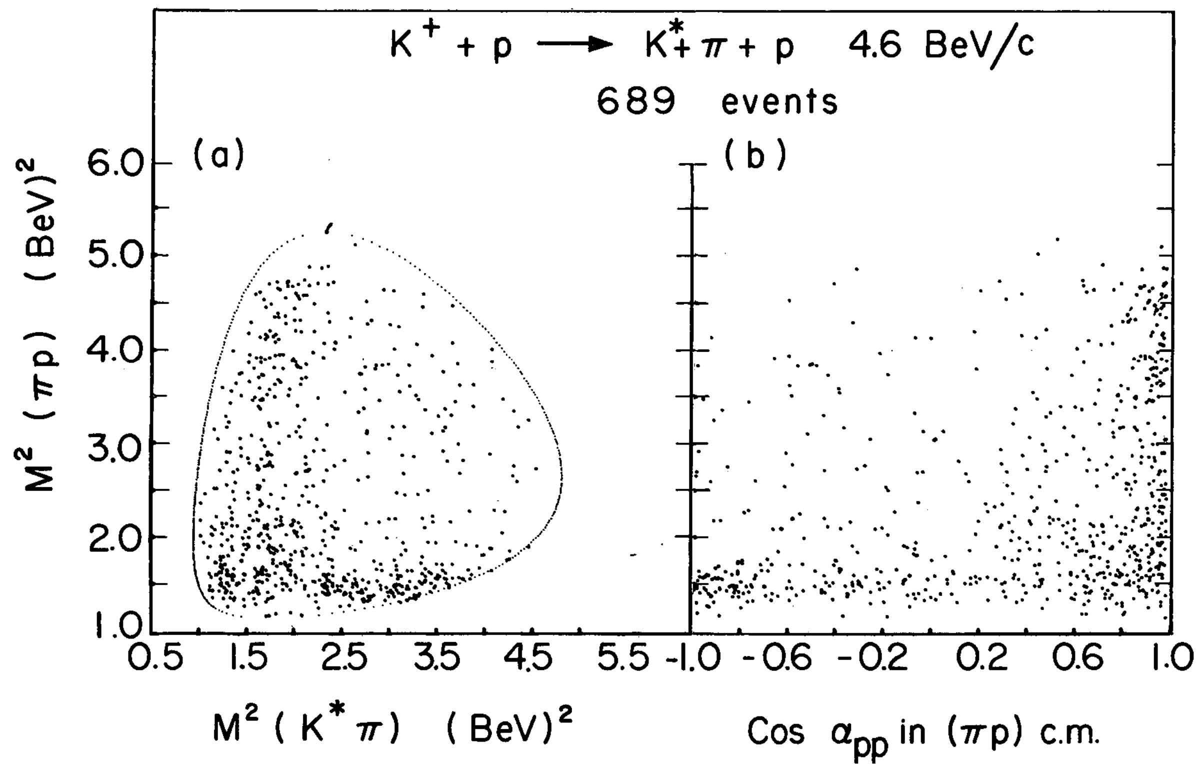


Fig. 8. (a) Dalitz plot of $K^*\pi p$ events from Reactions (2) and (3). (b) Scatter plot of $M^2(\pi p)$ vs cos α_{pp}, where α_{pp} is the πp scattering angle in the rest frame.

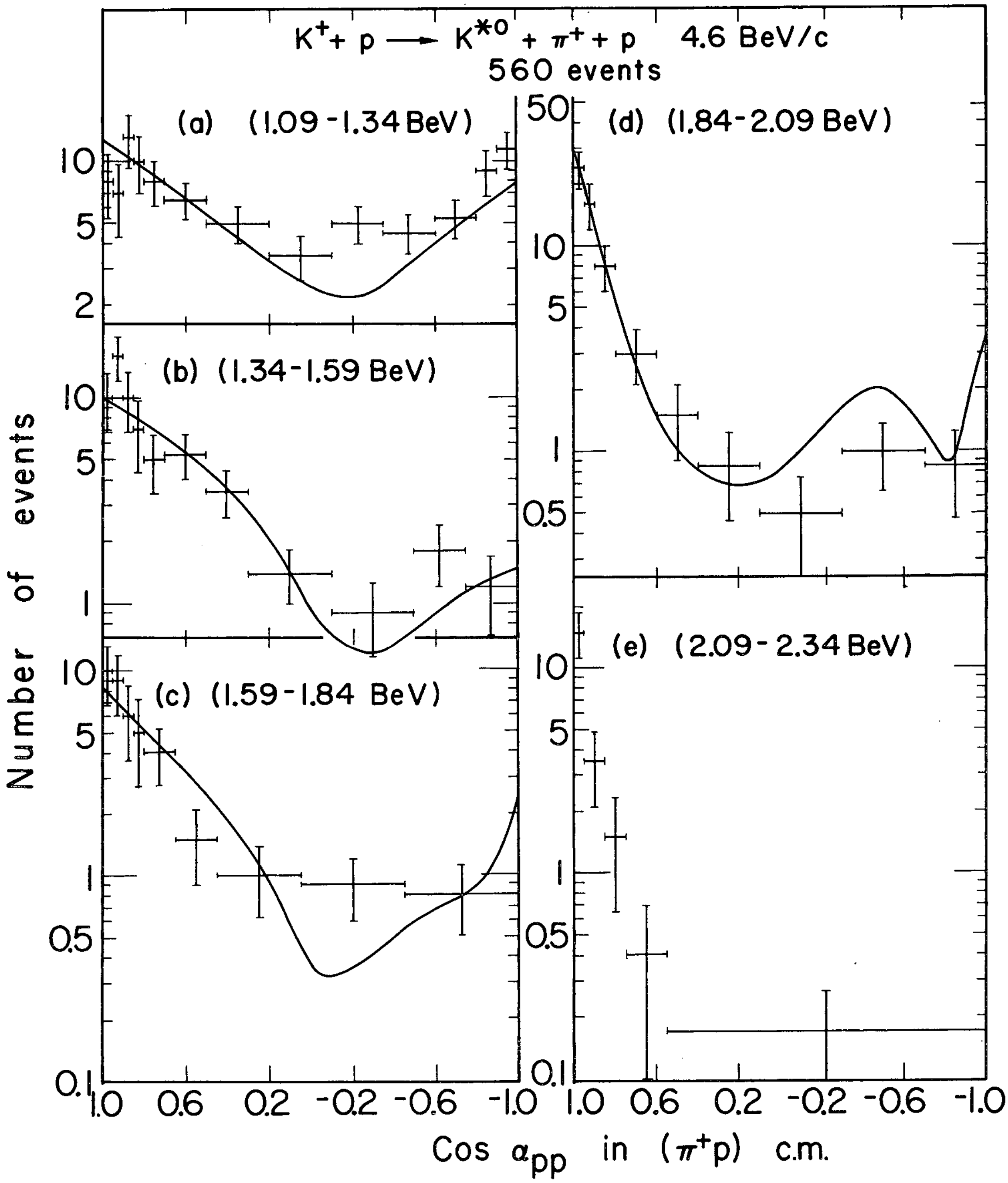


Fig. 9. Cos α_{pp} distributions for various intervals of $M(\pi^+p)$ for events in the final state $K^{*0}\pi^+p$. The curves correspond to the elastic π^+p differential cross-section data averaged over the mass interval.

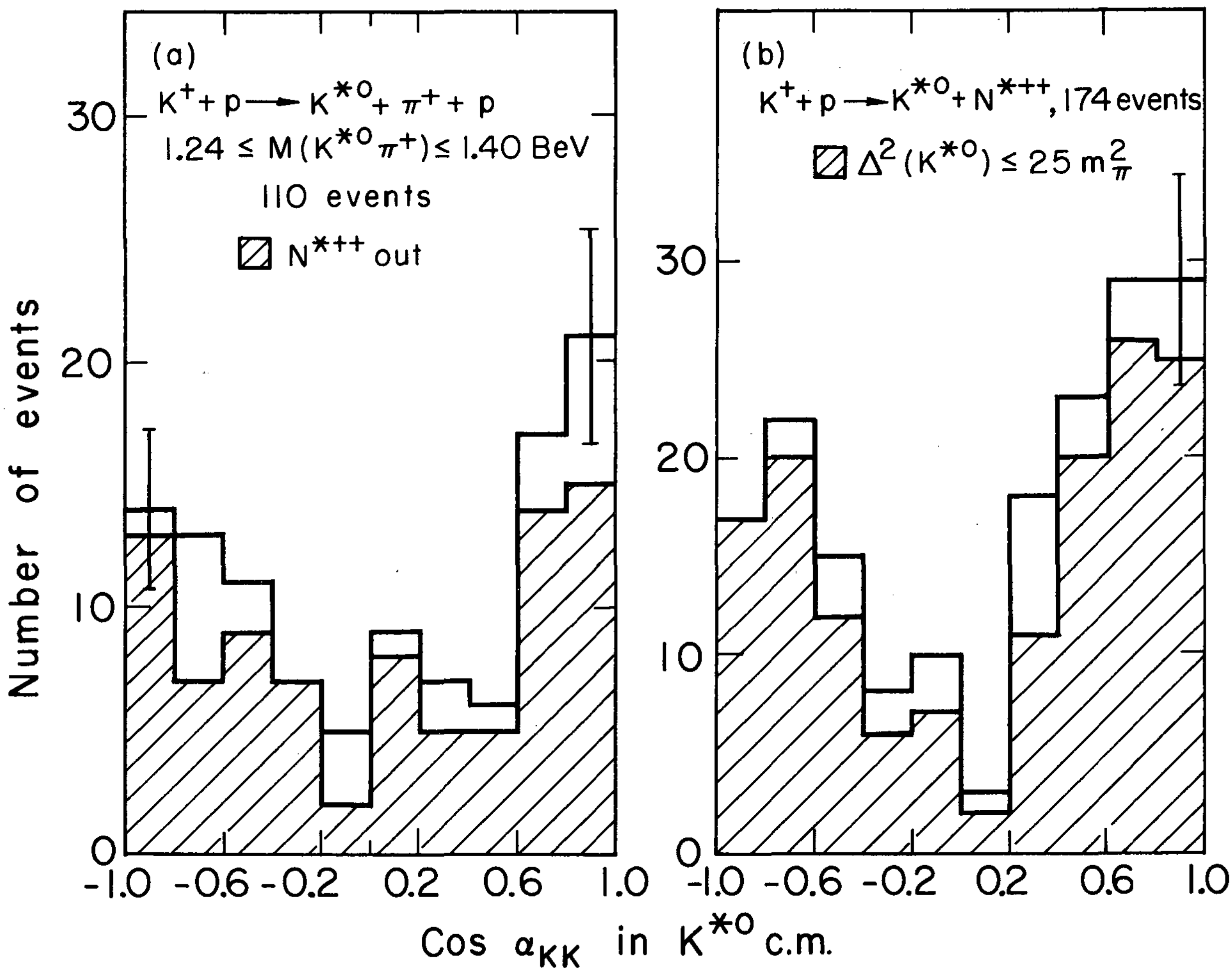


Fig. 10. Kπ scattering angular distributions in the Kπ rest frame for K^* event in (a) $K^{**}(1320)$ band, and (b) the double resonance channel K^*N^*.

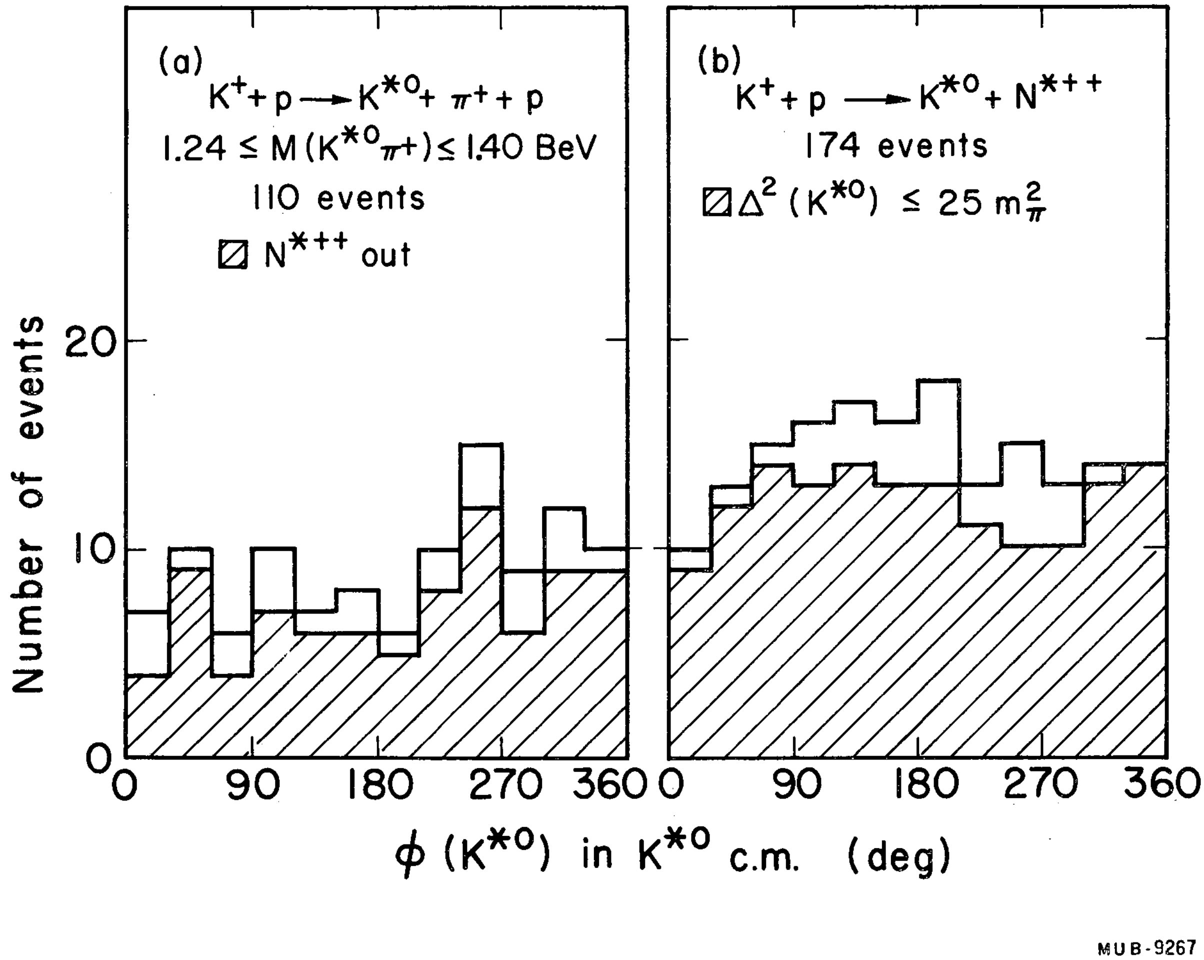


Fig. 11. Treiman-Yang angular distribution in the $K\pi$ rest frame for K^* events in the $K^{**}(1320)$ band, and (b) the double resonance channel K^*N^*.