

# Lawrence Berkeley National Laboratory

## Recent Work

**Title**

PRODUCTION OF  $S=0$ ,  $I$  RESONANT STATES IN K-p INTERACTIONS AT 2.45 GeV/c

**Permalink**

<https://escholarship.org/uc/item/7p80c7f1>

**Author**

Tripp, Robert D.

**Publication Date**

1964-07-07

University of California

Ernest O. Lawrence  
Radiation Laboratory

PRODUCTION OF  $S = 0, -1$  RESONANT STATES  
IN  $K^- p$  INTERACTIONS AT 2.45 GeV/c

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*

Berkeley, California

## **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.

Paper submitted to the 1964 International Conference  
on High Energy Physics, Dubna, U. S. S. R.,  
August 5-15, 1964

UCRL-11424

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory  
Berkeley, California

AEC Contract No. W-7405-eng-48

PRODUCTION OF  $S=0, -1$  RESONANT STATES  
IN  $K^-p$  INTERACTIONS AT 2.45 GeV/c

Ronald R. Ross, Jerome H. Friedman, Daniel M. Siegel, Stanley Flatte,  
Luis W. Alvarez, Angela Barbaro-Galtieri, Janice Button-Shafer,  
Orin I. Dahl, Philippe Eberhard, William E. Humphrey,  
George R. Kalbfleisch, James S. Lindsey, Deane W. Merrill,  
Joseph J. Murray, Alan Rittenberg, Frank T. Shively,  
Gerald A. Smith, and Robert D. Tripp

July 7, 1964

# PRODUCTION OF $S=0, -1$ RESONANT STATES IN $K^-p$ INTERACTIONS AT 2.45 GeV/c\*

Ronald R. Ross, Jerome H. Friedman, Daniel M. Siegel, Stanley Flatte,  
Luis W. Alvarez, Angela Barbaro-Galtieri, Janice Button-Shafer,  
Orin I. Dahl, Philippe Eberhard, William E. Humphrey,  
George R. Kalbfleisch, James S. Lindsey, Deane W. Merrill,  
Joseph J. Murray, Alan Rittenberg, Frank T. Shively  
Gerald A. Smith, and Robert D. Tripp

(Presented by Ronald R. Ross)

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

July 7, 1964

## I. INTRODUCTION

About 70 000 pictures of 2.45-GeV/c  $K^-p$  interactions have been obtained in the present 72-inch hydrogen bubble-chamber experiment.<sup>1</sup> Approximately 24 000 events of all topologies except 1-, 2-, and 3-prong events have been measured, and 50% have been remeasured. We report here on a study of the production of known resonances in the reactions:

$$K^- + p \rightarrow \Lambda + \pi^+ + \pi^- \quad (1)$$

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

The cross section for production and number of events in reactions (1) and (2) are given in Table I.

## II. $Y_4^*(1385)$ AND $\rho$ PRODUCTION IN THE REACTION $K^-p \rightarrow \Lambda \pi^+ \pi^-$

To estimate the amount of resonance production, we have assumed no interference between production of  $Y_4^{*+}$ ,  $Y_4^{*-}$ ,  $\rho^0$ , or background. We constructed a likelihood function, assuming phase space for the nonresonant background and a matrix element proportional to  $[(M - M_0)^2 + (\Gamma/2)^2]^{-1}$  for each resonant process, independent of any alignment. Masses and widths used in calculation of the likelihood function are given in Table II. The fit corresponding to the maximum likelihood is shown in Fig. 1 as a solid curve over

\*Work done under the auspices of the U. S. Atomic Energy Commission.

histograms of the mass distribution of the events. We also show phase space, normalized to the total number of events, for comparison. The percentages of this final state contributed by each process are given in Table III. Even though interference may be important in further analysis of this final state, the mass distributions clearly do not give much information on this interference.

Figure 2 is a plot of the angular distribution in production of the three resonant states. We have defined a  $Y_1^*$  band as  $\Lambda\pi$  invariant mass between 1.335 and 1.435  $\text{GeV}/c^2$  and a  $\rho$  band as  $\pi^+\pi^-$  mass between 0.665 and 0.865  $\text{GeV}/c^2$  for selection of events to be included in angular distributions. For the  $Y_1^*$  production, Fig. 2 a and b, the solid histogram corresponds to the angular distribution of those  $Y_1^*$  events that are not also in the  $\rho$  band. The dotted histogram is an estimate of the angular distribution for all  $Y_1^*$ ; the contribution of events within the  $\rho$  band is estimated from  $Y_1^*$  events outside the  $\rho$  band that, upon a parity reversal of the  $Y_1^*$  in its center of mass, become events in the  $\rho$  band. This technique of treating the  $Y_1^*$ - $\rho$  overlap region is described in reference 2.

In Fig. 2 c, the solid histogram corresponds to all events in the  $\rho$  band. The dotted curve is an estimate of the angular distribution for  $\rho$  production arrived at by subtraction of background estimated by parity reversal of  $\Lambda\pi$  events. This procedure is equivalent to assuming phase space for the non- $Y_1^*$  events.

At this momentum the  $Y_1^{*+}$  and  $Y_1^{*-}$  angular distributions are markedly different from one another, and both distributions differ from previously reported angular distributions for the same states at lower momenta.<sup>3</sup> The  $\rho$  production angular distribution, after background subtraction is statistically very weak, and the forward peak is not statistically significant.

### III. $Y_1^*$ , $\rho$ AND $\omega$ PRODUCTION IN THE REACTION $K^-p \rightarrow \Lambda \pi^+ \pi^0 \pi^-$

The effective-mass plots of this final state show significant evidence for the production of  $Y_1^*$ ,  $\rho$ , and  $\omega$ . Other resonant production occurs, but the rate of production is significantly lower than it is for these resonances. Again assuming (unjustifiably) noninterference of various resonant states and background, we have constructed a likelihood function similar to the one described in Section II for the eleven processes:

$$K^-p \rightarrow \Lambda \omega$$

$$Y_1^{*+} \rho^-$$

$$Y_1^{*0} \rho^0$$

$$Y_1^{*-} \rho^+$$

$$Y_1^{*+} \pi^0 \pi^-$$

$$Y_1^{*0} \pi^+ \pi^-$$

$$Y_1^{*-} \pi^+ \pi^0$$

$$\Lambda \pi^- \rho^+$$

$$\Lambda \pi^0 \rho^0$$

$$\Lambda \pi^+ \rho^-$$

$$\Lambda \pi^+ \pi^0 \pi^-$$

The masses and widths used in calculating the likelihood function are given in Table III. Table IV gives the maximum likelihood solution for percentages of the final state contributed by each process. Figure 3 contains mass plots for the two particle masses and the  $3\pi$  system. Monte Carlo events were generated for each process. The solid curves of Fig. 3 are obtained from the Monte Carlo events by weighting each event in proportion to the appropriate percentage in Table III. Phase space normalized to the total number of events is shown as a dashed line in Fig. 3.

The  $\pi$ - $\pi$  mass distributions deviate from the Monte Carlo representation of the fit at low  $\pi$ - $\pi$  mass, because the  $\omega$  - Monte Carlo events ( $\sim 300$ ) do not take account of the decay matrix element which sharpens the distribution of  $\pi$ - $\pi$  masses in the  $\omega$  decay.

The resonant production cross sections for  $Y_1^*$  and  $\omega$  are about two times those reported by Bertanza et al. at this conference two years ago for  $K^-$  interactions at 2.24 GeV/c.<sup>4</sup> Their numbers were preliminary and based on 247  $\Lambda\pi^+\pi^0\pi^-$  events; so there is no real discrepancy.

Figure 4 gives the angular distribution in production of the  $Y_1^*\rho$  and  $\Lambda\omega$  events. If an event happened to fall in the overlap region of two  $Y_1^*\rho$  charge combinations, it is not included in the angular distribution. There is no  $Y_1^*\rho$  -  $\Lambda\omega$  overlap. The  $\Lambda\omega$  angular distribution is given with the  $Y_1^*$  events removed (solid curve) and with them included (dotted curve).

The  $Y_1^*\rho$  and  $\Lambda\omega$  angular distributions indicate that all kinematically allowed momentum transfers are involved in the production processes. The  $Y_1^{*+}\rho^-$  events show a peaking at low momentum transfer, which may be due to the presence of an additional peripheral process. There is no significant change in the  $\Lambda\omega$  angular distribution from that reported at 2.24 GeV/c by Bertanza et al.<sup>4</sup>

#### IV. CONCLUSION

We have determined the production cross section for the processes given in Tables III and V and angular distributions for the most copiously produced pseudo-two-body final states. It will be interesting to continue this procedure throughout the 2.0- to 2.8-GeV/c  $K^-$  momentum range for many final states and try to relate the production cross sections by means of SU3 for different processes. For instance, the  $Y_1^*\rho$  production should be related to the  $\Xi^*(1530) K^*(888)$  production, since in each case we have a



member of the well-known baryon decuplet and a member of the well-known vector-meson octet. At 2.45 GeV/c, the beam is below threshold for this production; however, at 2.6 and 2.7 GeV/c  $\Xi^* K^*$  production occurs.<sup>5</sup>

Table I. Cross sections and numbers of events for

 $K^-p \rightarrow \Lambda \pi^+ \pi^-$  and  $K^-p \rightarrow \Lambda \pi^+ \pi^0 \pi^-$ .

Reaction	Number of events	Cross section <sup>a</sup> (mb)
$K^-p \rightarrow \Lambda \pi^+ \pi^-$	576	$0.44 \pm 0.03$
$K^-p \rightarrow \Lambda \pi^+ \pi^0 \pi^-$	1508	$1.14 \pm 0.06$

a. Corrected for neutral  $\Lambda$  decay.

Table II. Masses and widths used in likelihood  
calculations for  $K^- p \rightarrow \Lambda \pi^+ \pi^-$ .

Resonance	Mass (GeV)	Width, $\Gamma$ (GeV)
$Y_1^{*+}$	1.385	0.05
$Y_1^{*-}$	1.385	0.05
$\rho^0$	0.765	0.12

Table III. Maximum-likelihood solution for final-state contributions for each process for  $K^- p \rightarrow \Lambda \pi^+ \pi^-$ .

Reaction	Percent
$K^- p \rightarrow \Lambda \rho^0$	$21.8 \pm 3.7$
$K^- p \rightarrow Y^{*+} \pi^-$	$19.1 \pm 2.3$
$K^- p \rightarrow Y^{*-} \pi^+$	$8.7 \pm 1.9$
"Phase space"	$50.4 \pm 4.1$

Table IV. Masses and widths used in likelihood  
calculations for  $K^- p \rightarrow \Lambda \pi^+ \pi^0 \pi^-$ .

Resonance	Mass (GeV)	Width, $\Gamma$ (GeV)
$Y^{*+}$	1.385	0.05
$Y^{*-}$	1.385	0.05
$Y^{*0}$	1.385	0.05
$\rho^+$	0.750	0.150
$\rho^-$	0.750	0.150
$\rho^0$	0.765	0.120
$\omega$	0.782	0.035

Table V. Maximum-likelihood solution for final-state contributions for each process for  $K^- p \rightarrow \Lambda \pi^+ \pi^0 \pi^-$ .

Reaction	Percent
$K^- p \rightarrow \Lambda \omega$	$21.5 \pm 1.4$
$K^- p \rightarrow Y^{*+} \rho^-$	$12.0 \pm 2.2$
$K^- p \rightarrow Y^{*0} \rho^0$	$5.0 \pm 1.9$
$K^- p \rightarrow Y^{*-} \rho^+$	$10.7 \pm 2.1$
$K^- p \rightarrow Y^{*+} \pi^0 \pi^-$	$6.4 \pm 2.3$
$K^- p \rightarrow Y^{*0} \pi^+ \pi^-$	$8.5 \pm 2.2$
$K^- p \rightarrow Y^{*-} \pi^+ \pi^0$	$4.7 \pm 2.3$
$K^- p \rightarrow \Lambda \pi^- \rho^+$	$0(-1.9) \pm 2.4$
$K^- p \rightarrow \Lambda \pi^0 \rho^0$	$3.8 \pm 2.1$
$K^- p \rightarrow \Lambda \pi^+ \rho^-$	$3.4 \pm 2.5$
"Phase space"	$25.8 \pm 4.8$

# REFERENCES

1. J. J. Murray, J. Button-Shafer, F. T. Shively, G. H. Trilling, J. A. Kadyk, A. Rittenberg, D. M. Siegel, J. S. Lindsey, and D. W. Merrill. A Separated 2.5- to 2.8-GeV/c  $K^-$  Beam at the Bevatron, Lawrence Radiation Laboratory Report UCRL-11426, July 1964.
2. Philippe Eberhard and Morris Pripstein, Phys. Rev. Letters 10, 35 (1963).
3. Robert P. Ely, Sun-Yiu Fung, G. Gidal, Yu-Li Pon, W. M. Powell, and H. S. White, Phys. Rev. Letters 7, 461 (1961). J. Button-Shafer, D. Huwe, and J. J. Murray, " $\Lambda \pi^+ \pi^-$  Final State in  $K^-$ -p Interactions at  $K^-$  Momenta of 1.22 and 1.51 GeV/c," in Proceedings of the 1962 International Conference on High Energy Physics at CERN (CERN, Geneva, 1962), p. 303.
4. L. Bertanza, V. Brisson, P. L. Connally, E. L. Hart, I. S. Mittra, G. C. Moneti, R. R. Rau, N. P. Samios, I. O. Skillicorn, S. S. Yamamoto, M. Goldberg, L. Gray, J. Leitner, S. Lichtman and J. Westgard, " $K^-$ -p Interactions at 2.24 GeV/c II: Production Properties," in Proceedings of the 1962 International Conference on High Energy Physics at CERN (CERN, Geneva, 1962), p. 284.
5. G. A. Smith, J. S. Lindsey, and J. J. Murray, Production of  $\Xi K(n)\pi$ ,  $\Lambda K \bar{K}(n)\pi$ , and  $\Lambda K \bar{K}$  Final States in  $K^-$ -p Interactions at 2.45 to 2.70 GeV/c, Lawrence Radiation Laboratory Report UCRL-11430, July 1964.

# FIGURE LEGENDS

Fig. 1. Two-particle invariant-mass distributions for  $\Lambda \pi^+ \pi^-$  events.

(Solid curve) likelihood fit; (dashed curve) phase space normalized to 576 events.

Fig. 2. Production angular distributions for

(a)  $Y_1^{*+}(1385)$ : (solid) no  $\rho$ ; (dashed) adjusted total distribution (see text)

(b)  $Y_1^{*-}(1385)$ : (solid) no  $\rho$ ; (dashed) adjusted total distribution (see text)

(c)  $\rho$ : (solid) all  $\rho$ ; (dashed) adjusted total distribution (see text).

Fig. 3. Two-particle and  $\pi^+ \pi^0 \pi^-$  invariant mass distributions for

$\Lambda \pi^+ \pi^0 \pi^-$  events: (solid curve) Monte Carlo representation of the likelihood fit ( $\omega$ -decay matrix element taken as a constant); (dashed curve) phase space normalized to 1508 events.

Fig. 4. Production angular distributions for pseudo-two-particle final

states in the  $\Lambda \pi^+ \pi^0 \pi^-$  final state. (See text for selection criteria.)



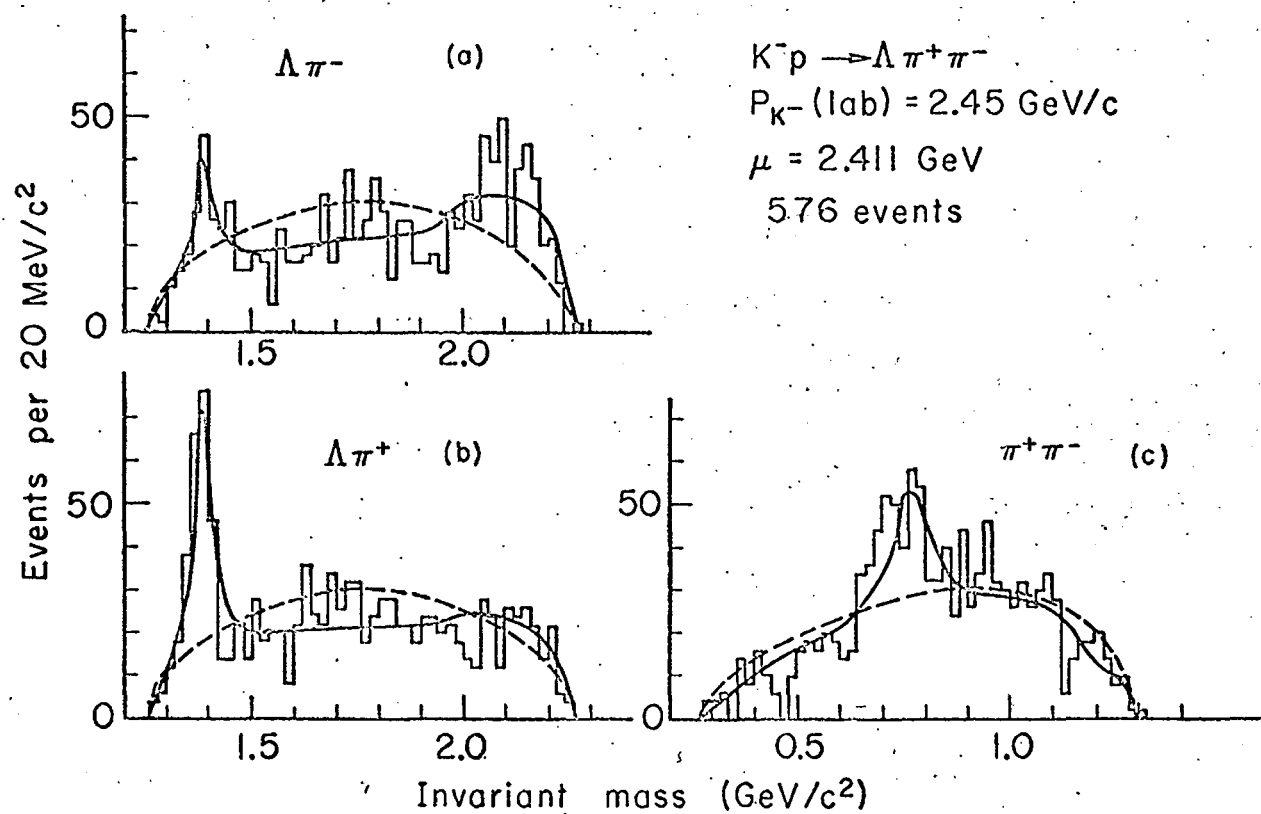


Fig. 1

MUB-3401

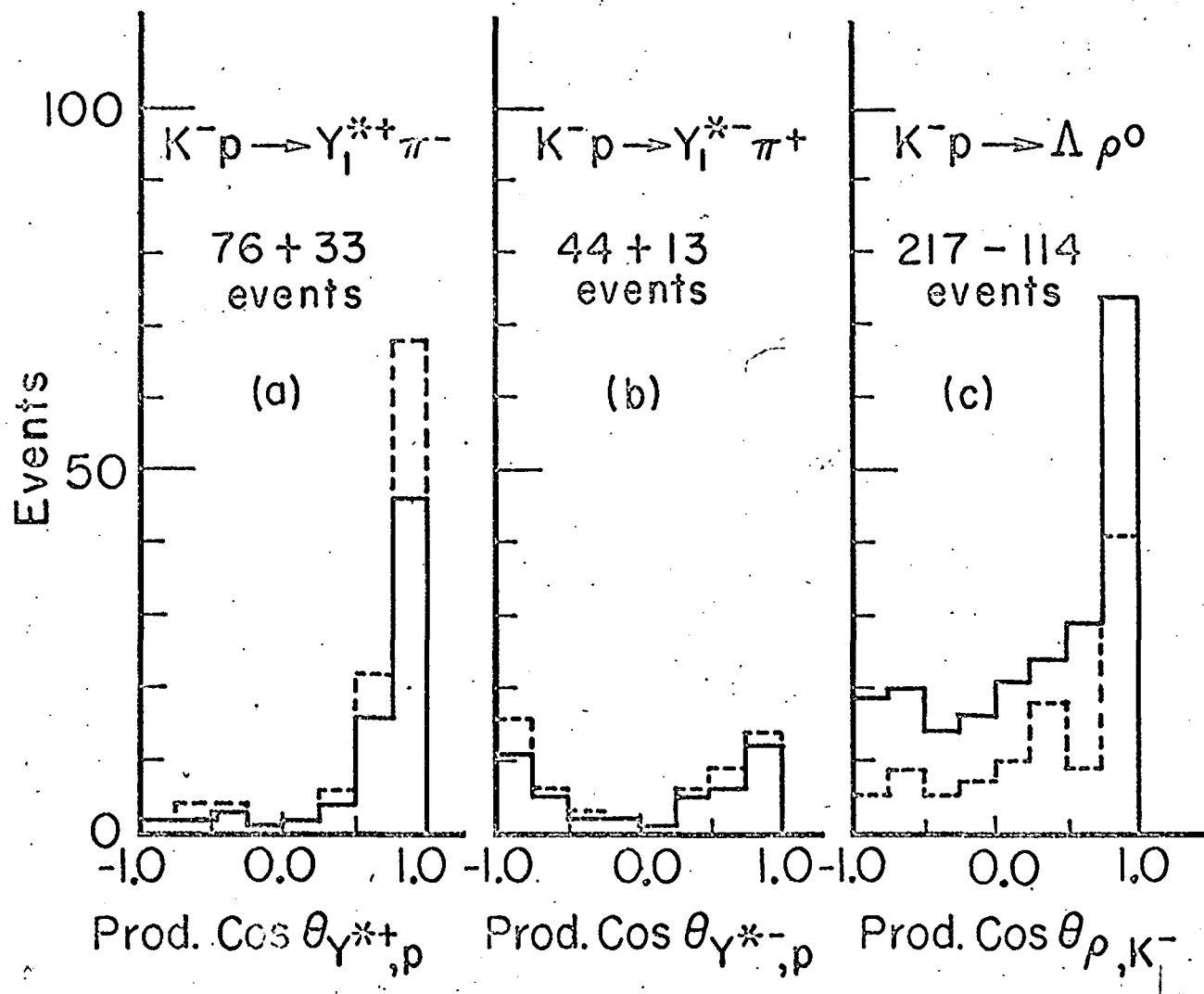
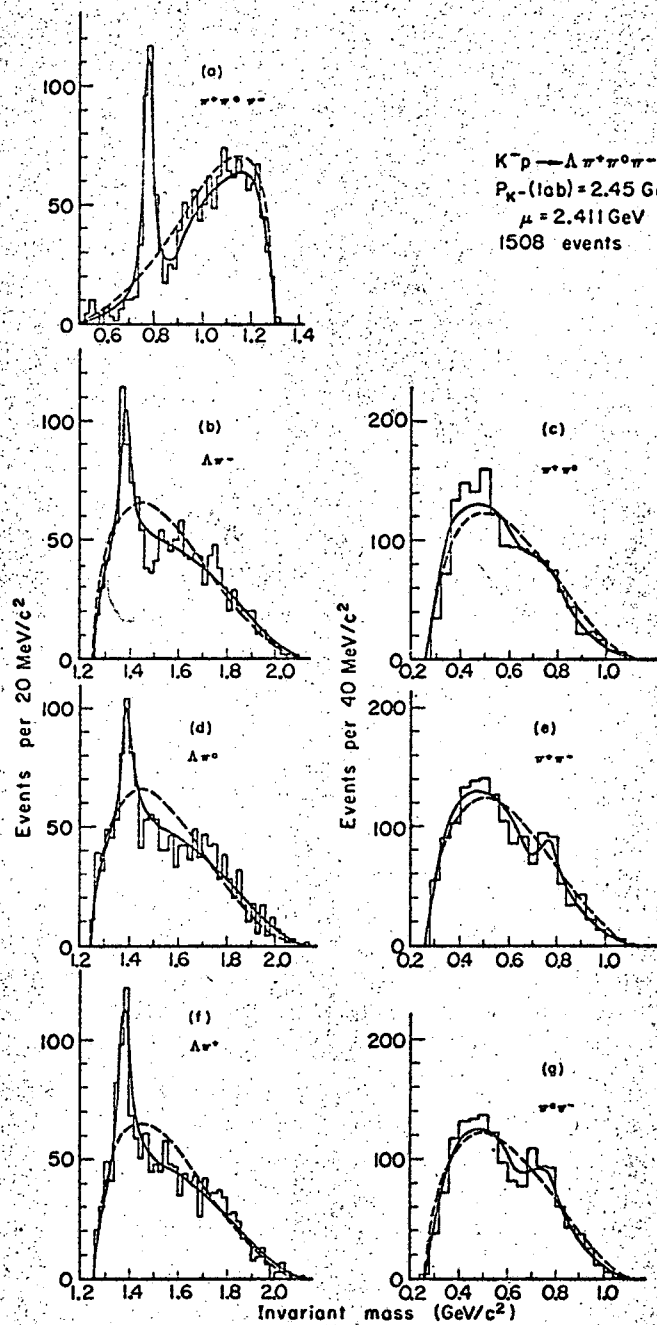


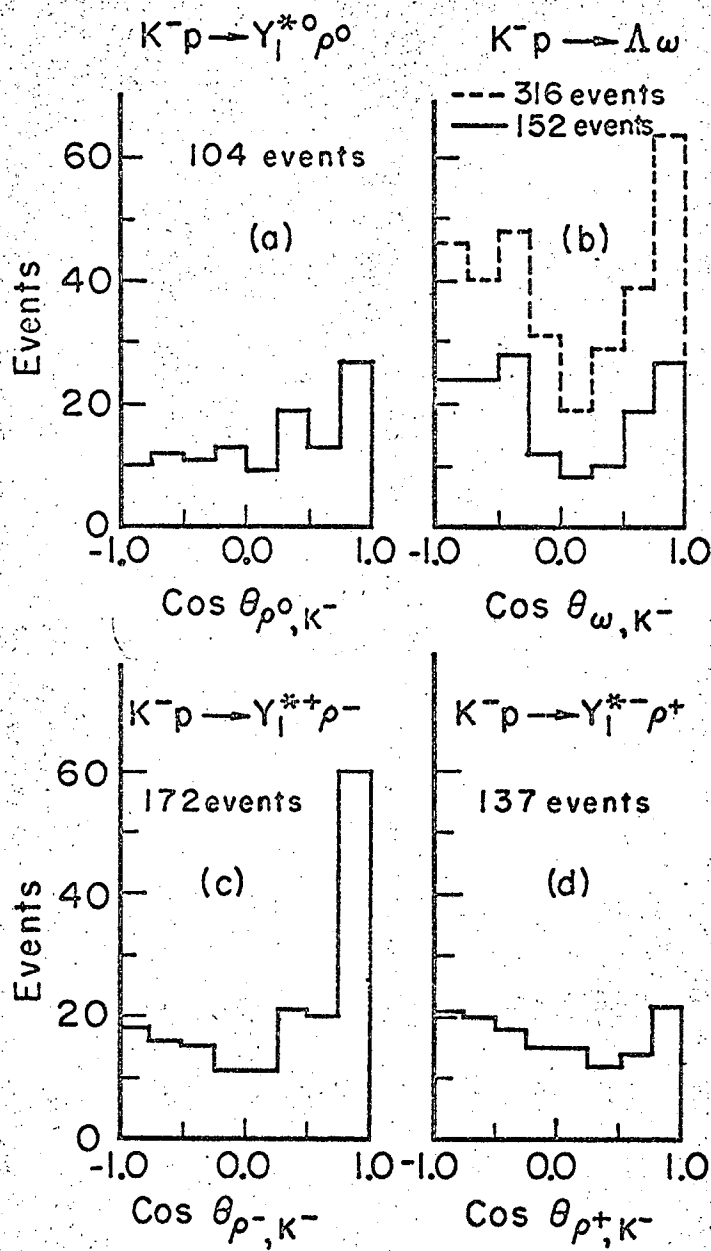
Fig. 2

MUB-3400



MUB-3402

Fig. 3



MUB-3399

Fig. 4

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.

