**Title**

PRODUCTION ANGULAR DISTRIBUTIONS OF Y*,(1385) IN nN INTERACTIONS FROM 1.8 TO 4.2 GeV/c

**Authors**

Abolins, Marts A.
Dahl, Orin I.
Danburg, Jerome
et al.

**Publication Date**

1968-07-08

UCRL-18288 Rev.

cy. 2

# PERIPHERAL PRODUCTION IN THE SINGLE-MESON-EXCHANGE FORBIDDEN REACTION $\pi^- p \to Y^{*-} K^+$ AT 2 TO 4 GeV/c

Maris A. Abolins, Orin I. Dahl, Jerome Danburg,
Donald Davies, Paul Hoch, Donald H. Miller,
Robert Rader, and Janos Kirz

December 1968

LAWRENCE RADIATION LABORATORY
UNIVERSITY of CALIFORNIA BERKELEY

UCRL-18288 Rev.

cy. 2

## DISCLAIMER

Submitted to Physical Review Letters

UCRL-18288 Rev.
Preprint

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

# PERIPHERAL PRODUCTION IN THE SINGLE-MESON-EXCHANGE FORBIDDEN REACTION $\pi^- p \to Y^{*-} K^+$ AT 2 TO 4 GeV/c

Maris A. Abolins, Orin I. Dahl, Jerome Danburg, Donald Davies,
Paul Hoch, Donald H. Miller, Robert Rader, and Janos Kirz

December 1968

# PERIPHERAL PRODUCTION IN THE SINGLE-MESON-EXCHANGE FORBIDDEN REACTION $\pi^- p \to Y^{*-}K^+$ AT 2 TO 4 GeV/c[*]

Maris A. Abolins,[†] Orin I. Dahl, Jerome Danburg, Donald Davies,
Paul Hoch, Donald H. Miller, and Robert Rader

Lawrence Radiation Laboratory
University of California, Berkeley, California

and

Janos Kirz

State University of New York
Stony Brook, New York

December 1968

## ABSTRACT

Data are presented showing that the $Y_1^*(1385)$ production angular distribution in the reaction $\pi^- p \to Y^{*-}K^+$ and in its charge-symmetric counterpart $\pi^+ n(p_{sp}) \to Y^{*+}K^0(p_{sp})$ is characterized by peripheral and antiperipheral peaking. Explanation for the latter is sought in terms of baryon exchange, and to this end comparisons with other $\pi N \to Y^*K$ reactions are made. The peripheral peak cannot arise through the exchange of any known meson. Alternative explanations are considered.

The one-particle exchange model, when modified by absorption, has been quite successful in predicting the production angular distributions and decay correlations in a large class of high-energy two-body processes. In particular, the characteristic forward-peaked production distribution can be understood in terms of meson exchange, and backward peaking is at least qualitatively explained in terms of baryon exchange.

For the reactions

$$\pi^- p \rightarrow Y^{*-} K^+ \qquad (1a)$$

and

$$\pi^+ n(p_{sp}) \rightarrow (p_{sp})\, Y^{*+} K^0 \qquad (1b)$$

from 1.8 to 4.2 GeV/c, we present data on the production angular distributions, which are characterized by both forward and backward peaking throughout this energy range. At the same energies, we have also studied the reactions

$$\pi^- p \rightarrow Y^{*0} K^0, \qquad (2a)$$

$$\pi^+ n\,(p_{sp}) \rightarrow (p_{sp})\, Y^{*0} K^+, \qquad (2b)$$

and

$$\pi^+ p\,(n_{sp}) \rightarrow (n_{sp})\, Y^{*+} K^+, \qquad (3)$$

where both meson and baryon exchange are allowed.[1] There is no known meson whose exchange could produce the forward peak in reaction (1), and it appears that simple u-channel or s-channel effects cannot account for this peaking.

The data used in this report come from two separate experiments:

(a) Approximately 890 000 pictures of $\pi^- p$ interactions between 1.5 and 4.2 GeV/c in the 72-inch bubble chamber, in which more than 50 000 strange-particle events were found. A comprehensive report on this experiment, known as $\pi 63$, has been published.[2]

(b) An exposure known as $\pi$66A, consisting of more than 400 000 pictures of $\pi^+ d$ interactions between 2.8 and 4.2 GeV/c in the 72-inch chamber, yielding about 17 000 events with visible decays of neutral strange particles.

We have also used preliminary data from a lower-momentum run, π66B, for reaction (3) near 2 GeV/c.

Because of the rapid decrease of cross section with energy, particularly for reaction (1), it was found convenient to group the data into three beam-momentum intervals. The data of the two experiments were compared to check for consistency and then were combined. For angular distributions, a fiducial volume cut was made. The events were given weights (which averaged 1.1) according to their detection probabilities. For this report, we have examined only $\Lambda K\pi$ (not $\Sigma K\pi$) final states. Further details of the exposures are given in Table I.

The data-analysis methods for π63 have already been described.[2] The π66 events were measured on both the Spiral Reader and Franckenstein measuring machines. Ambiguous Franckenstein-measured events that might be resolvable on the basis of track ionization information were examined on the scanning table; the Spiral Reader automatically obtained such information. We feel that the remaining ambiguities do not affect the conclusions of this report; however, the cross sections for π66, which are presented in Table I, are preliminary.

The $\Lambda\pi$ mass spectra in Fig. 1 indicate the presence of $Y_1^*(1385)$. The $Y^*$ production angular distributions (Fig. 2) were obtained by dividing the events into six intervals in $\Lambda\pi$ production cosine, and, for each interval, calculating the number of $Y^*$ events present. The fraction of each resonance and of phase space was obtained by using the maximum-likelihood fitting program MURTLEBERT,[3] which properly takes into account the effects of $K^*(890)$ production competing with reactions (1) and (2). It was assumed that the resonances could be described by simple Breit-Wigner matrix elements with isotropic decay distributions, and that the various contributing processes were noninterfering. These assumptions seem to be justified by the absence of obviously important interference effects in the Dalitz plots, and by the generally good fits we get to the mass projections over the entire momentum region for the three reactions.[4]

It is, of course, impossible to rule out some small but perhaps important interference effects or other deficiencies in the model just described. As a check on the method, the angular distributions were also obtained in a more conventional manner: by making a mass cut to select the $Y^*(1385)$, eliminating events in the $K^*(890)$ band, and subtracting, as background, regions adjacent in $\Lambda\pi$ mass. The qualitative agreement with the maximum-likelihood results was quite good.

Figure 2 contains the essential results of this report. The dominant features of reactions (2) and (3), and the backward peaks in reaction (1), appear consistent with the allowed t- and u-channel exchanges.[5]

The statistically significant peripheral peak in reaction (1) persists through the whole momentum region. The cross section in the forward direction is estimated to be about 7 μb/sr at 2 GeV/c and about 2μb/sr at the higher momenta. Although the background is also peripherally peaked, the peaking is stronger in the $Y^*$ region. The shaded events ($\cos\theta > 2/3$) in Fig. 1 show that there is a definite $Y^*$ signal in the forward direction. The forward peak cannot be attributed to the exchange of any single known meson, since the t-channel quantum numbers require a particle with $I = 3/2$, $S = 1$ [for example, in reaction (1a), a $K^+\pi^+$ resonance].

If the reactions were dominated by a single s-channel resonant amplitude, parity conservation would require forward-backward symmetry in the production distribution in reaction (2) as well as in (1). The absence of a backward peak in reaction (2) at 2 GeV/c, where the statistics are best, means that at least two significant interfering amplitudes must be invoked to explain the forward peak as an s-channel effect. The persistence of the forward peak in reaction (1) as the energy varies argues against a fairly simple s-channel effect.

Production angular distributions calculated for baryon exchange with absorption show, in some cases, a significant tail extending to $\cos\theta = +1$.[6] Although one hesitates to take such a model seriously so far from the backward region, it is conceivable that a combination of u-channel exchanges interfering in a suitable fashion, perhaps with an s-channel resonant amplitude, could generate a forward as well as a backward peak. A rapid change in relative phase with u would be required to give destructive interference in the backward direction but constructive interference in the forward direction.

We have not completed a study of the contributions of two-meson-exchange diagrams to reaction (1). In the simple quark model, the effect we observe may be associated with double quark scattering.[7]

The absence of forward peaking in the two-body processes $\pi^- p \to \Sigma^- K^+$ and $K^- p \to \Sigma^- \pi^+$ has been cited as weak evidence against the existence of the particular meson needed to mediate these reactions.[8] The results presented here indicate that such arguments against a $K^{*++}$ resonance are not necessarily conclusive. A similar "forbidden" forward peak has recently been observed in $K^- p \to K^+ \Xi^{*-}$ reactions.[9]

We thank Dr. Luis Alvarez and the many physicists, programmers, and scanners in Berkeley Physics Group A who have contributed to this work.

## FOOTNOTES AND REFERENCES

[*] Work supported by U. S. Atomic Energy Commission.

[†] Present address: Michigan State University, East Lansing, Michigan 48823

1. Reactions (1b), (2b), and (3) were observed in $\pi^+d$ interactions, where one of the target baryons was assumed to be a spectator (as indicated in the parentheses). Only events with spectator momentum less than 300 MeV/c were accepted.
2. O. I. Dahl, L. M. Hardy, R. I. Hess, J. Kirz, and D. H. Miller, Phys. Rev. 163, 1377 (1967); O. I. Dahl, L. M. Hardy, R. I. Hess, J. Kirz, D. H. Miller, and J. A. Schwartz, Phys. Rev. 163, 1430 (1967).
3. J. Friedman, Lawrence Radiation Laboratory Alvarez Programming Group Note P-156, 1966 (unpublished).
4. Reaction (1) constituted about 30% of the $\Lambda K\pi$ events at 2 GeV/c, and about 5% at the higher momenta; $K^*$ production was about 40% throughout. Reaction (2) was somewhat more copious and less obscured by $K^*$ production. The large background makes the extraction of reliable decay-correlation information from our data most difficult.
5. In the 2-GeV/c interval, the appearance of the backward peaks in reactions (1) and (3) and the absence of this peak in (2) (where $I = 0$ exchange is forbidden) suggest that $I = 0$ baryon exchange may play a

dominant role. The peripheral peaking in reaction (2a) has been analyzed in Ref. 2 in terms of $K^*$ exchange by use of the "$K^*$-photon analogy" (i. e., the SU(3)-generalized $\rho$-photon analogy) of Stodolsky and Sakurai. The model predicts decay correlations in reasonable agreement with the data, but the predicted zero in the production angular distribution at $\cos\theta = \pm 1$ was not clearly observed. The relative cross sections in the forward peaks in reactions (2) and (3) are consistent with $K^*$ exchange. Preliminary decay-correlation analysis of reaction (3) indicates rough agreement with the predictions of the Stodolsky-Sakurai model.

6. J. T. Donohue, thesis, University of Illinois, 1967.
7. Nathan W. Dean, Processes Requiring Double Scattering in the Quark Model, CERN Preprint TH. 881, February 29, 1968.
8. G. Goldhaber, in *Proceedings of the Thirteenth International Conference on High-Energy Physics, Berkeley, 1966* (University of California Press, Berkeley, California, 1967), p. 138.
9. P. M. Dauber, J. P. Berge, J. R. Hubbard, D. W. Merrill, and R. A. Muller, Lawrence Radiation Laboratory Report UCRL-18388, Nov. 1968 (submitted to Phys. Rev.).

Table I. Exposure size and $Y^*$ production cross section (approximate).

| Momentum interval (GeV/c) | Experiment | Exposure size (events/μb) | $\pi^+ n(p) \to (p)\Lambda K^0 \pi^+$ $[\pi^- p \to \Lambda K^+ \pi^-]$ | | $\pi^+ n(p) \to (p)\Lambda K^+ \pi^0$ $[\pi^- p \to \Lambda K^0 \pi^0]$ | | $\pi^+ p(n) \to (n)\Lambda K^+ \pi^+$ | |
|---|---|---|---|---|---|---|---|---|
| | | | (events per μb)[a] | $\sigma(Y^*K)$ (μb) | (events per μb)[a] | $\sigma(Y^*K)$ (μb) | (events per μb)[a] | $\sigma(Y^*K)$ (μb) |
| 1.9 - 2.4 | π66B | ≈6 | | | | | ≈2 | ≈90 |
| 1.8 - 2.2 | π63 | 12.5 ± 0.7 | ≈8 | 42.8 ± 4.0 | ≈3 | 61.6 ± 10.0 | | |
| 2.8 - 3.2 | π66A | ≈11 | ≈5 | ≈6 | ≈5 | ≈25 | ≈5 | ≈31 |
| 2.9 - 3.3 | π63 | 12.8 ± 0.5 | ≈8 | 5.0 ± 1.0 | ≈2 | 28.9 ± 7.0 | | |
| 3.8 - 4.2 | π66A | ≈4 | ≈2 | ≈7 | ≈2 | ≈23 | ≈2 | ≈28 |
| 3.8 - 4.2 | π63 | 5.6 ± 0.4 | ≈3 | 1.9 ± 1.9 | ≈1 | 13.0 ± 5.4 | | |

a. These columns apply to the events represented in Fig. 1. The values given take into account neutral decays of Λ and $K^0$, and the cuts on the c.m. energy made in π66 for the maximum-likelihood fits.

# FIGURE LEGENDS

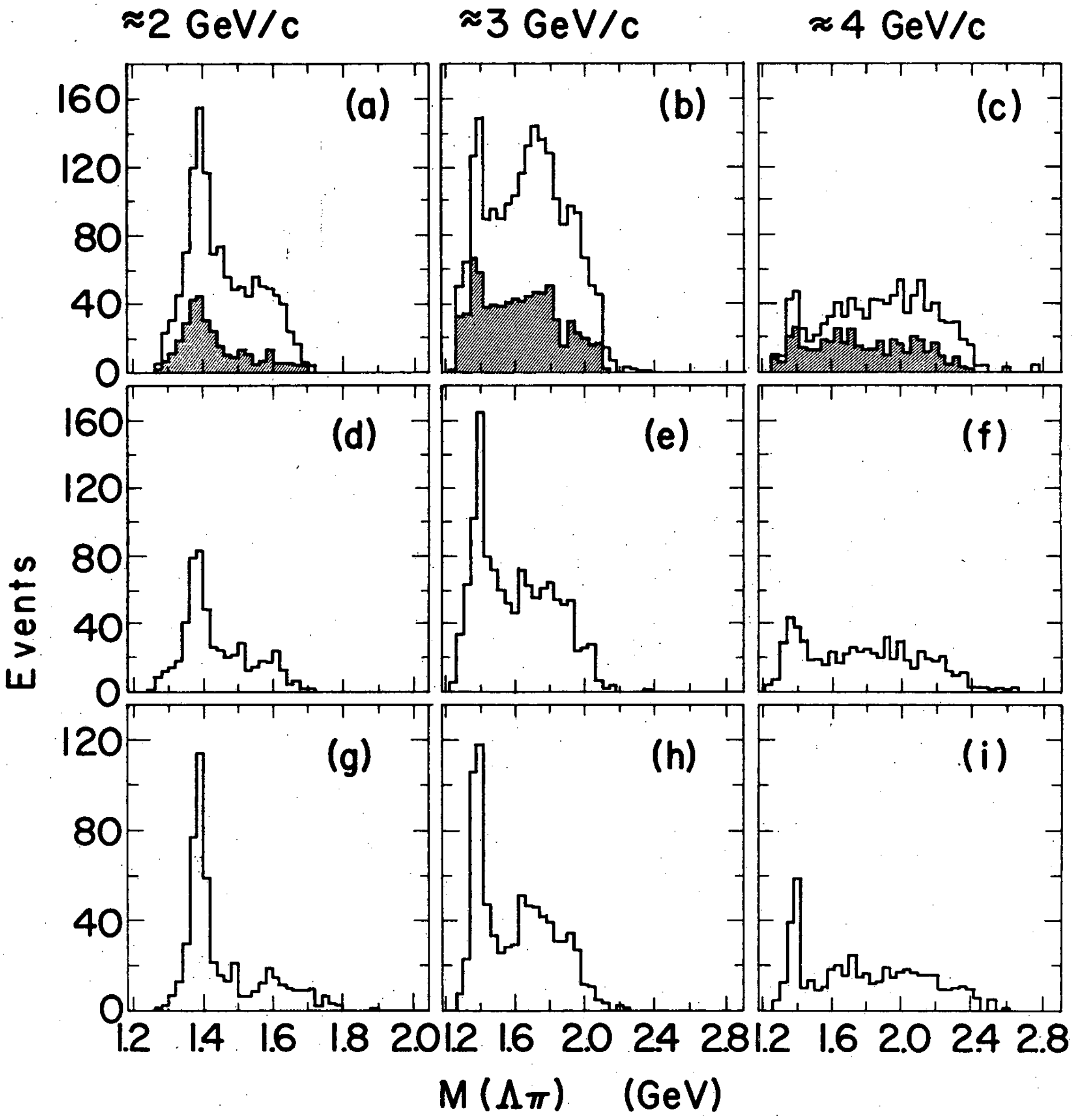
Fig. 1. Effective mass of $\Lambda\pi$ for (a-c) $\pi^- p \rightarrow \Lambda K^+ \pi^-$ and $\pi^+ n \rightarrow \Lambda K^0 \pi^+$; (d-f) $\pi^- p \rightarrow \Lambda K^0 \pi^0$ and $\pi^+ n \rightarrow \Lambda K^+ \pi^0$; and (g-i) $\pi^+ p \rightarrow \Lambda K^+ \pi^+$. The beam momentum interval in (a), (d), and (g) is 1.8 to 2.4 GeV/c; in (b), (e), and (h), 2.8 to 3.3 GeV/c; and in (c), (f), and (i) 3.8 to 4.2 GeV/c. In (a), (b), and (c), events with production cosine greater than 2/3 are shaded.

Fig. 2. $Y_1^*(1385)$ production angular distribution. The angle $\theta$ lies between the incident pion and the K in the final state.

(a-c): reaction (1), $\pi^- p \rightarrow Y^{*-} K^+$ and $\pi^+ n \rightarrow Y^{*+} K^0$;

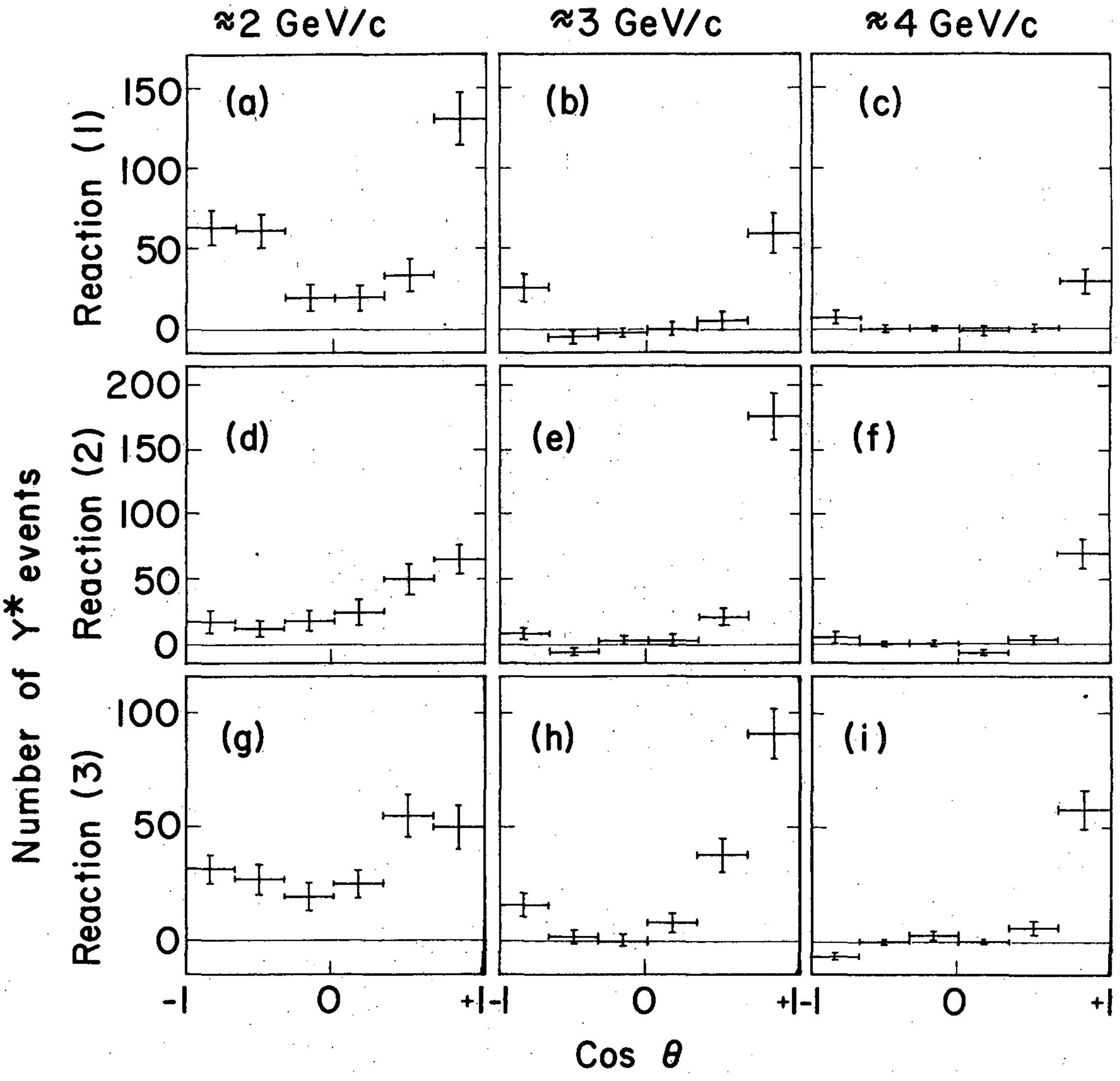
(d-f): reaction (2), $\pi^- p \rightarrow Y^{*0} K^0$ and $\pi^+ n \rightarrow Y^{*0} K^+$;

(g-i): reaction (3), $\pi^+ p \rightarrow Y^{*+} K^+$. The beam momentum interval in (a), (d), and (g) is 1.8 to 2.4 GeV/c; in (b), (e), and (h), 2.8 to 3.3 GeV/c; in (c), (f), and (i), 3.8 to 4.2 GeV/c. The errors shown are statistical only.



XBL687-3206

Fig. 1



XBL687-3205

Fig. 2

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