ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

Лаборатория высоких энергий

Wang Yung-chang, V.I. Veksler, Du Yuan -cai, E.N. Kladnitskaya, A.A. Kuznetsov,
Nguyen Dinh-Tu, E.S. Sokolova, M.I. Soloviev, V.N. Penev, A. Mihul

D-965

A STUDY OF ΛK° AND $K^{\circ}\tilde{K}^{\circ}$ PAIR PRODUCTION IN $\pi^{-}P$ INTERACTIONS AT THE π^{-}-MESON MOMENTUM OF 7-8 BEV/C

ЖЭТФ, 1962, т43, вып 3, с815-822.

Дубна 1962 год

Wang Yung-chang, V.I. Veksler, Du Yuan -cai, E.N. Kladnitskaya, A.A. Kuznetsov,
Nguyen Dinh-Tu, E.S. Sokolova, M.I. Soloviev, V.N. Penev, A. Mihul*

A STUDY OF ΛK^0 AND $K^0\bar{K}^0$ PAIR PRODUCTION IN $\pi^- P$ INTERACTIONS AT THE π^--MESON MOMENTUM OF 7-8 BEV/C

* On leave from the Institute of Atomic Physics, Bucharest.

Abstract

ΛK° and $K^{\circ}\tilde{K}^{\circ}$ pair production in $\pi^{-}P$ - interactions is studied at the negative pion momentum of 7-8 BeV/c. The c.m.s angular and momentum characteristics of Λ and K° particles from ΛK° and $K^{\circ}\tilde{K}^{\circ}$ pairs, as well as those of $\pi^{\mp}$-mesons which accompany the ΛK° pairs are given. Besides, the data on Q for ΛK° and $K^{\circ}\tilde{K}^{\circ}$ pairs are presented.

1. Introduction

This note describes some results on the study of ΛK° and $K^{\circ}\tilde{K}^{\circ}$ pairs produced in $\pi^{-}P$-interactions,the momentum of negative pion being 7-8 BeV/c.

The present work has been performed with a 24-litre propane bubble chamber/1/.

It is a continuation of investigations of strange particle production reported earlier/2,3,4/.

The experimental set-up, beam characteristics, scanning technique, the analysis of the photographs, the introduction of different corrections, as well as the selection of $\pi^{-}P$- events in the propane have been described in papers/2,5/.

In order to find pairs, we have scanned 60.000 photographs.

After the identification and the measurements of the V° were made, all the events were classified as follows:

$\Lambda+K^{\circ}$	$K^{\circ}+\tilde{K}^{\circ}$	$(\Lambda\approx K^{\circ})+K^{\circ}$	$\Lambda+K^{\circ}+\tilde{K}^{\circ}$
52	37	16	2

16 events fit equally well the kinematics of the Λ and K° decay, but we considered them to be Λ particles since, according to out estimates, 80% of all non-identified events are Λ 's.

2. Experimental Results

a) The momentum distributions of Λ and K° from ΛK° pairs in the c.m.s. are shown in Fig. 1a, b, and of $K^{\circ}(\tilde{K}^{\circ})$ from $K^{\circ}\tilde{K}^{\circ}$ pair in Fig. 2 .There were taken into account the corrections for the probability of Λ and K° detecting in the fiducial volume of the chamber.

The momentum spectrum of Λ from ΛK° pairs is similar to that of the Λ from/3/. A group of Λ particles having a large momentum in the c.m.s. can be clearly seen*.

The momentum distributions of K° mesons from ΛK° and from $K^{\circ}\tilde{K}^{\circ}$ pairs are alike.

---

* It is not ruled out that some Λ -particles in this group are due to the interactions occuring inside a carbon nucleus. At present we are completing the analysis of πC - interactions which is likely to help us in solving this problem.

The average value of the momentum of K° mesons from ΛK° pairs was found to be (702 ± 54) MeV/c and of K° - mesons from $K^\circ\tilde{K}^\circ$ pair was (604 ± 55) MeV/c.

b) Figs. 3 and 4 show the c.m.s. angular distributions of Λ and K° from ΛK° pairs and K° from $K^\circ\tilde{K}^\circ$ pairs. There were taken into account the corrections for the probability of particle recording in the fiducial volume of the chamber. It follows from these results that

1) in the c.m.s. most of Λ particles are flying backward and form a sharp peak in the region of $\cos\theta^*_\Lambda = (-1.0 - -0.8)$. In these cases the baryon follows the direction of its initial motion. Another group of Λ particles is distributed isotropically.

2) The K° from ΛK° pairs, besides the isotropic part, have a peak forward in the c.m.s.

Such a character of the angular distributions has already been pointed out for single Λ and K° /2,7,8/.

3) In the angular distribution of K° mesons from $K^\circ\tilde{K}^\circ$ pairs in the c.m.s. of $\pi^- P$ interactions a maximum in the region of $\cos\theta^*_K = (+0.6 - +1.0)$. can also be seen above the isotropic part.

c) In Fig. 5 a, b is plotted the distribution of angles between Λ and K° in the $\pi^- P$ c.m.s. as well as of the angles between K° and $\tilde{K}^\circ$ from pair events. Note, that most of the Λ's and the K° from ΛK° pairs are flying in opposite directions, while for $K^\circ\tilde{K}^\circ$ pairs - the distribution is isotropic;

d) The c.m.s. momentum and angular distributions of $\pi^\pm$ mesons which accompany the ΛK° pairs are shown in Figs. 6 and 7. Fast π^- mesons are absent in the c.m.s. momentum distribution of π^- mesons which are produced together with strange particles. This is the difference between this momentum distribution and that of the usual multiple production (not involving strange particles).

The momentum spectra of π^- and π^+ mesons produced together with ΛK° pairs are identical.

The comparison of these spectra by Smirnov-Kolmogorov's method/6/ yields the coincidence probability of 0.95.

The angular distributions of $\pi^\mp$-mesons accompanying the production of ΛK° pairs are anisotropic and almost symmetrical. Here π-mesons are likely to be emitted forward more rarely than in the usual multiple production of π mesons.

e) In Figs. 8,9,10 are presented the distributions of the Q -values for ΛK° and $K^\circ\tilde{K}^\circ$ pairs,

$$Q = \sqrt{2[E_{\Lambda(K)}E_K - P_{\Lambda(K)}P_K \cos\theta_{\Lambda(K),K}] + m^2_{\Lambda(K)} + m^2_K} - m_{\Lambda(K)} - m_K$$

where $m_{\Lambda(K)}, m_K$ are the masses of $\Lambda(K^\circ)$ and K° particles; $\theta_{\Lambda(K),K}$ is the angle between $\Lambda(K^\circ)$ and K°, $P_{\Lambda(K)}$, P_K are the momenta and $E_{\Lambda(K)}$, E_K are the energies. The experimental results are compared with those calculated by the Monte-Carlo method (Fig. 8,10). In the calculations the experimental momentum spectra of Λ and K° particles and the spectrum of the angle between them was used. The law of energy conservation was also taken into account.

A comparison of these curves points to the deviation of the experimental distribution of Q for ΛK° from the curve calculated by the Monte-Carlo method in the Q -value region of $(100 - 200)$ MeV*.

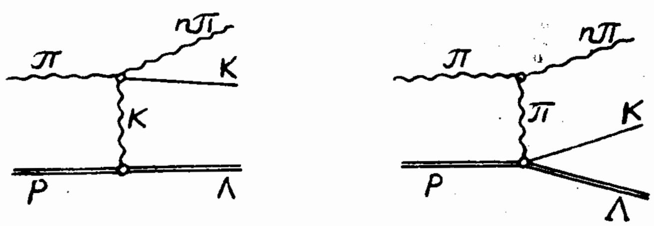
---

* It may be, that the distribution over Q for ΛK° -pairs has a 'fine structure'. However, the amount of the statistical material does not allow to be quite sure of this.

The distribution of Q for $K^0\tilde{K}^0$ has the maximum in the interval of (50 – 150) MeV.

3. Discussion

By studying the ΛK^0 and $K^0\tilde{K}^0$ pairs and comparing the characteristics of their production with those of 'single' Λ and K^0 particles (the statistics for 'single' Λ and K^0 is richer) it is possible to get a more detailed picture concerning the production mechanism of strange particles. The angular and momentum distribution of Λ hyperons from ΛK^0 pairs are similar to those of 'single' Λ particles* (Fig. 11, 12). Out of all ΛK^0 pairs there are (55 ± 9) % of events when Λ hyperons are flying backward, while K^0 mesons are flying forward; (33 ± 7) % of the events when both particles are flying backward, and the remaining (12 ± 4) % are the events in which Λ and K^0 are flying forward, or it may be that Λ hyperons are flying forward, while K^0 mesons - backward. Such a nature of the angular distribution of Λ and K^0 from ΛK^0 pairs in the $\pi^- P$ c.m.s. is likely to point out the possibility of an essential contribution of the peripheral diagrams



a) b)

One can expect that the K^0 produced in the upper vertex of the diagram a) will fly predominantly forward in the c.m.s., and Λ hyperons - backward, whereas in the diagram b) K^0 and Λ will fly backward**.

Good agreement of the curve for the Q -values of the ΛK^0 system obtained on the basis of the diagram b) with the experimental data indicates the presence of the contribution from this diagram.

In making calculations*** for the interaction of the π^- meson with the proton in the lower vertex we used the experimental energy dependence of the cross section /10/ for the virtual reaction

$$\pi^- + P \to \Lambda + K^0 \qquad (1)$$

The theoretical curve agrees well with the experimental distribution (Fig. 9). The peak in the distribution over Q at 100-200 MeV can be accounted for the presence of the maximum in the cross section of reaction (1) for the negative pion momentum of ~ 1.1 MeV/c.

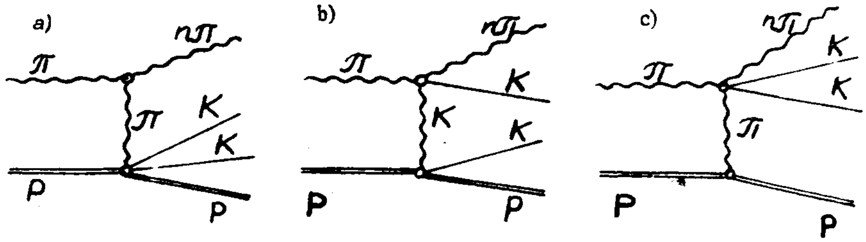
---

* 'Single' Λ hyperons consist of Λ particles from ΛK^0 pairs (K^0 particle was not detected in the chamber) and from ΛK^+ pairs. 'Single' K^0 mesons are $K^0(\tilde{K}^0)$ mesons from $K^0\Lambda$ and $K^0\tilde{K}^0$ pairs (the second particle was not detected in the chamber) as well as from K^0K^-, $\tilde{K}^0K^+$ pairs.

** We do not discuss here some other possible diagrams, for instance, those describing the production of π -mesons not only in the upper vertex, but in the lower one.

*** This calculation has been made by I.Patera whom we are very indebted to.

A comparison between the angular distributions of K° mesons from $K^\circ\tilde{K}^\circ$ pairs and that of the 'single' K° -mesons is given in Fig.13. As is seen, within the statistical errors they coincide. A half of all the observed $K^\circ\tilde{K}^\circ$ pairs - (47 ± 12) % are such that the particles are flying in opposite directions. In other cases either both K° mesons are flying backward (25 ± 7) % or both-forward (28 ± 8)%. The angular distribution obtained does not make it possible to prefer any peripheral diagram to some possible ones.



For a complete analysis of the $K^\circ\tilde{K}^\circ$ pair production in $\pi^- P$ interaction it is very important to consider the nucleon behaviour in this interaction. There were analysed 34 'stars' which generate the $K^\circ\tilde{K}^\circ$ pair and it was established that only in the six of them there are slow protons which can be with certainty identified. If the number of slow neutrons is assumed to be the same, it turns out that in most events of the $K^\circ\tilde{K}^\circ$ pair production (≈ 65 %) fast nucleons in the lab.system are also produced. This is likely to point out that the process of $K^\circ\tilde{K}^\circ$ pair production is not in the main, peripheral. The comparison of our angular distribution of the K° from $K^\circ\tilde{K}^\circ$ pairs with the data obtained by a CERN group who use a 1 m propane bubble chamber/11/ shows that these distributions within the statistical error coincide (Fig. 14). .

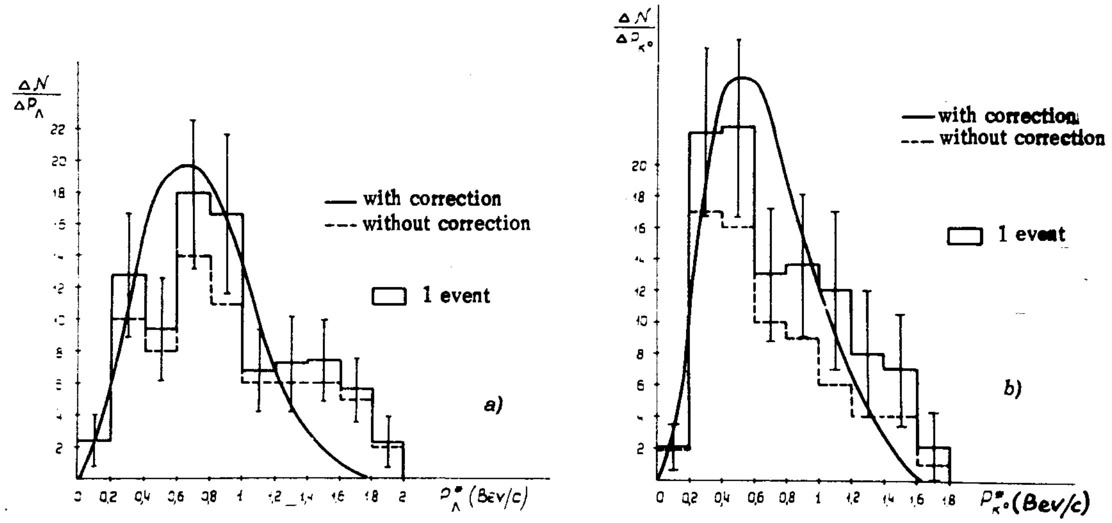
Fig.15. shows the angular distribution of the $K^\circ(\tilde{K}^\circ)$ in the c.m.s. of the $K^\circ\tilde{K}^\circ$ pair. This distribution points to the fact that in the $K^\circ\tilde{K}^\circ$ pair production besides the S -wave, the states with higher relative orbital moments are present. As far as we detect only the K°_1 , there can arise the states with even ℓ only/12/. As has been already shown, in the distribution over Q for the $K^\circ\tilde{K}^\circ$ pairs a maximum is observed in the region 50-150 MeV , (see Fig. 10) the angular distribution of the $K^\circ(\tilde{K}^\circ)$ in the c.m.s. of the $K^\circ\tilde{K}^\circ$ pair conserves the anisotropy in this interval. If the anisotropy is conserved as the statistics increases, this will indicate that the system is in the resonant state and has the angular moment equal to 2*. The possibility of such a resonance was pointed out in/13/.

The authors express their deep gratitude to A.V. Nikitin, N.M. Viryasov, Kim Hi In, V.A. Belyakov, I. Brana, T.Hofmokl, Tshen Lin-yen for the help in performing the experiment and for useful discussions, as well as a group of assistants who made measurements. We are also thankful to the workers of the Theoretical Physics Laboratory V.I. Ogievetsky, I. Patera, B. Arbusov, R. Faustov for numerous discussions of experimental data, and to the workers of the Computing Bureau Ye.P. Zhydkov, K.Danilova, G.I. Tentukova, V. Khlaponina, L. Shustrova and others for making the calculations. One of the authors (M.A.) is very grateful to Academician H.Hulubei for valuable discussions.

Received by Publishing Department
on April 10, 1962.

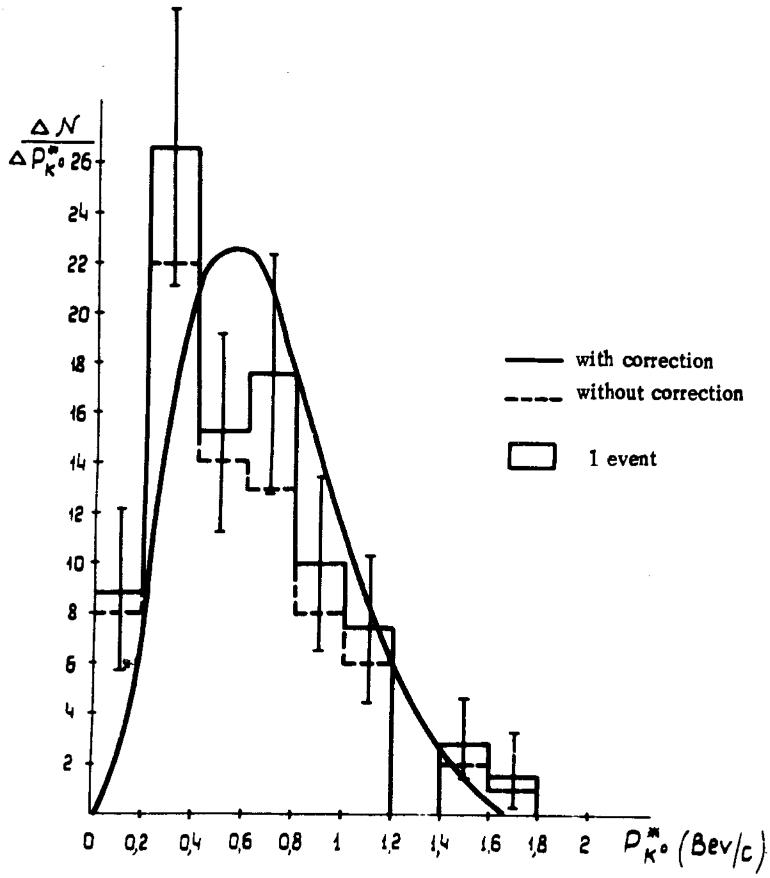
---

* We wish to thank V.I. Ogievetski who drew our attention to this fact.



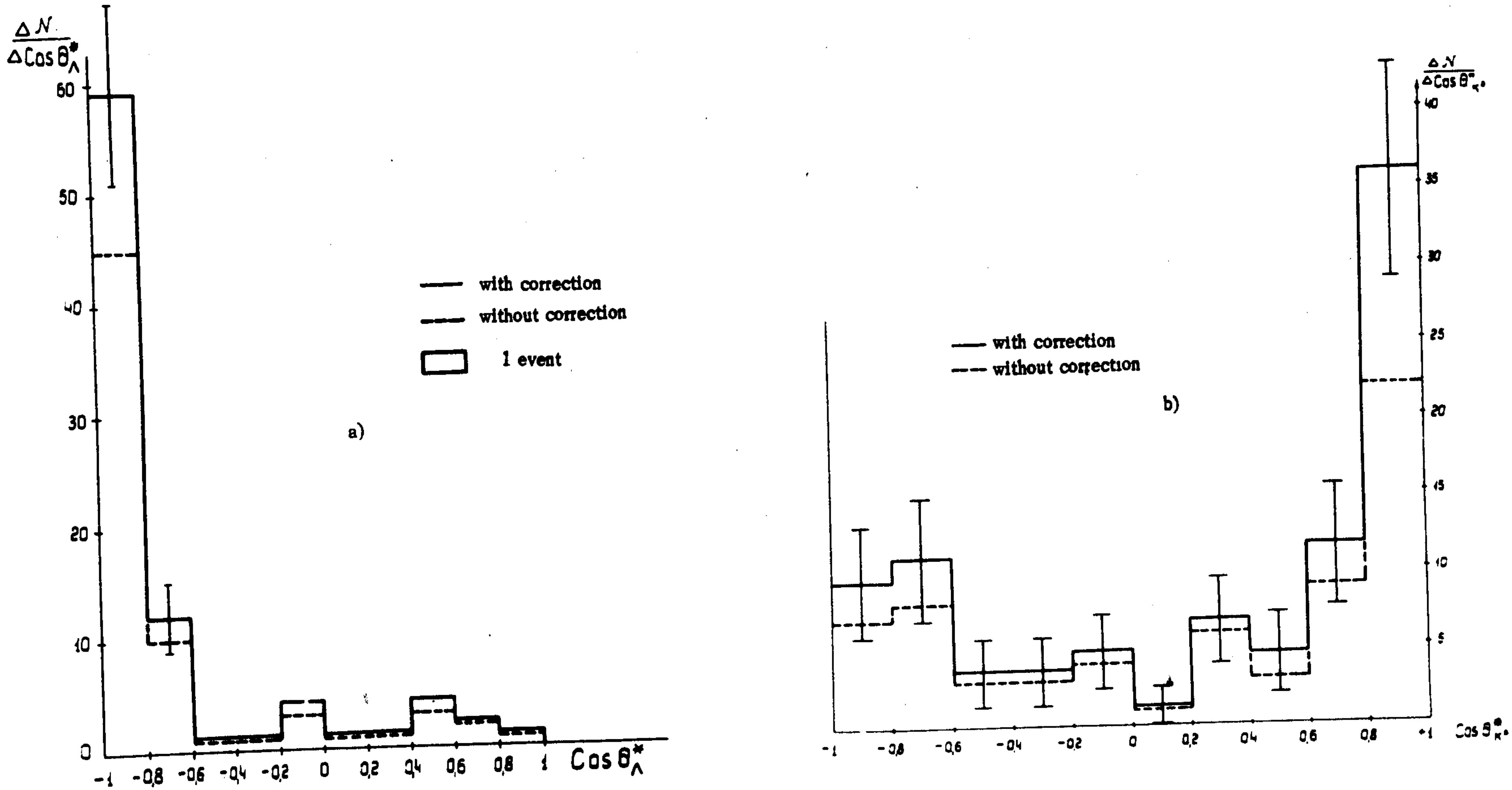
F i g. 1.

The momentum distribution in the $\pi^- p$ c.m.s. a) of Λ hyperons and b) of K^0 mesons from ΛK^0 pairs. The solid line shows the spectrum after introducing the correction for the recording probability of Λ and K^0 particles in the fiducial volume of the chamber. The smooth curve represents the result of the calculation according to the statistical model.



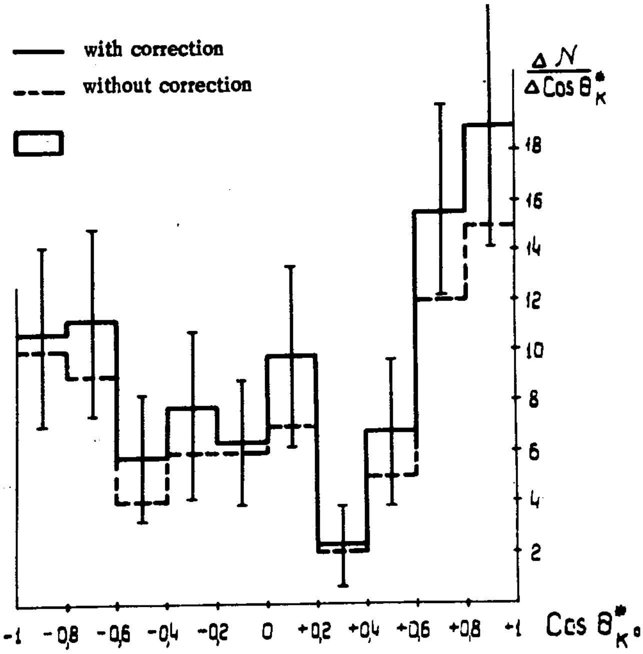
F i g. 2.

The momentum distribution in the $\pi^- P$ c.m.s. of K^0 mesons from $K^0\tilde{K}^0$ pairs. The smooth curve shown the result of the calculation by the statistical model.



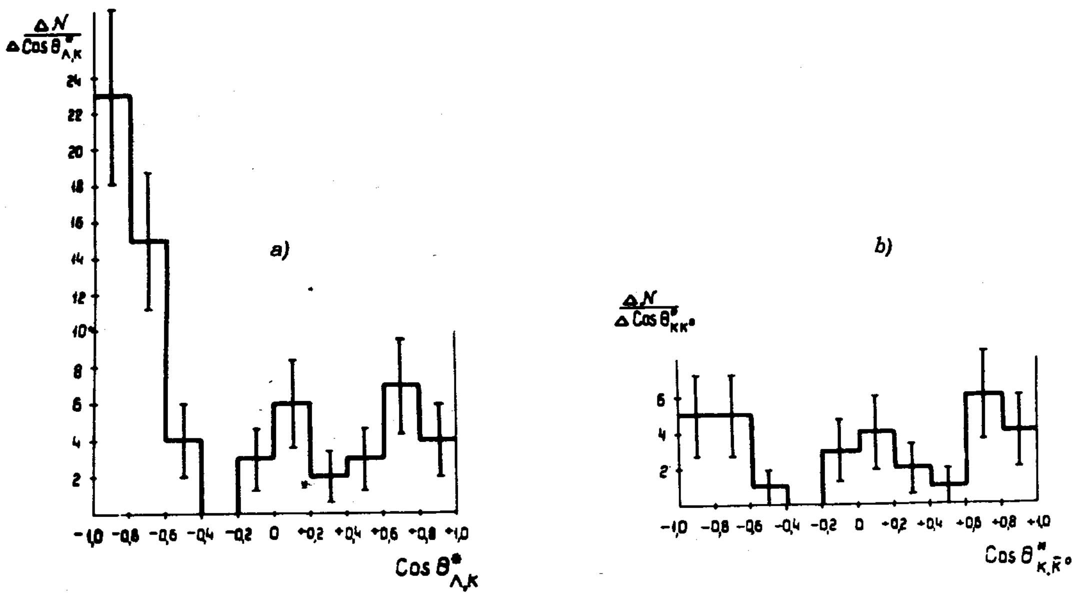
F i g. 3. a, b.

The angular distributions in the $\pi^- p$ c.m.s. a) of Λ hyperons, b) of K° mesons from ΛK° pairs. The solid line shows the spectrum after introducing the correction for the recording probability of Λ and K° particles in the fiducial volume of the chamber.



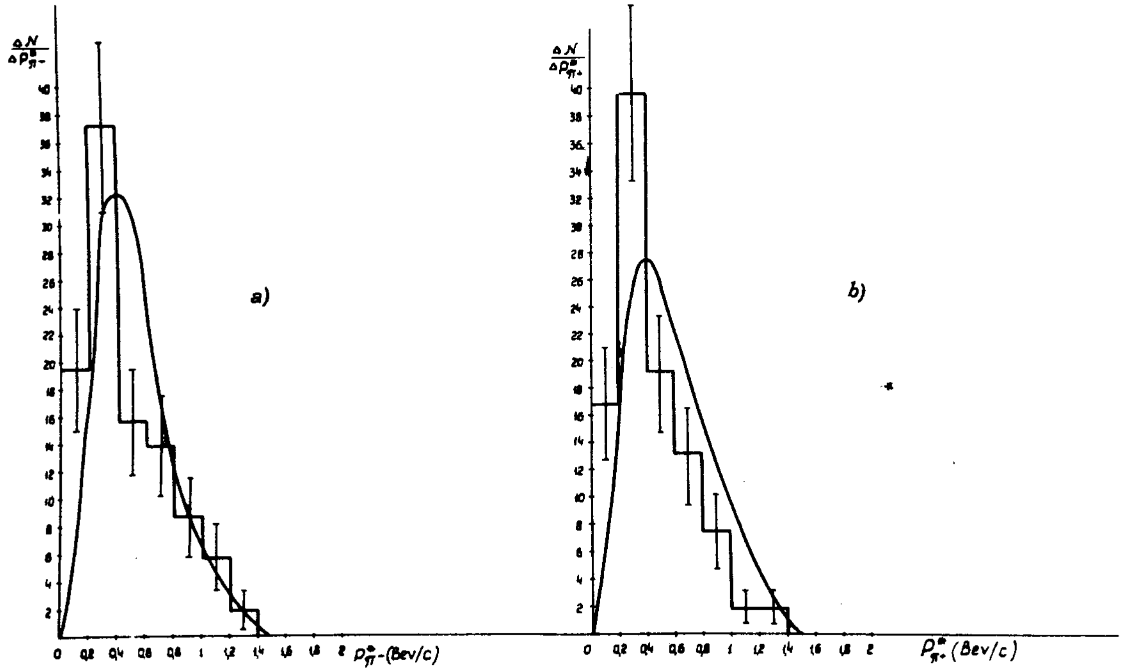
F i g. 4.

The angular distribution in the $\pi^- P$ c.m.s. of K° mesons from $K^\circ\tilde{K}^\circ$ pairs. The solid line repre-rents the spectrum after introducing the correction for the recording probability of K° and $\tilde{K}^\circ$ particles in the fiducial volume of the chamber.



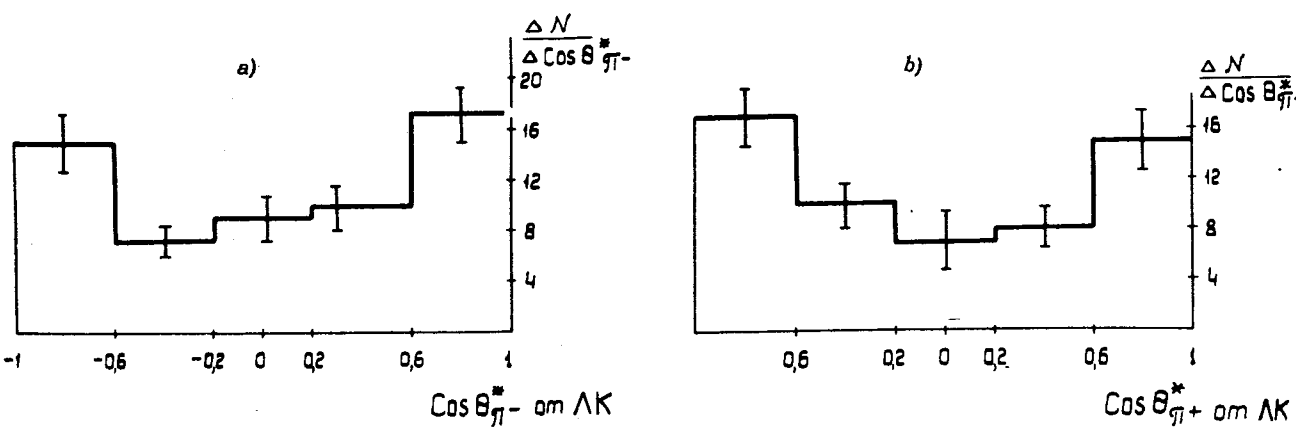
F i g. 5 a,b.

The distribution in the πP c.ms. a) of the angles between Λ and K° particles b) of the angles between K° and $\tilde{K}^\circ$ mesons from pair events.



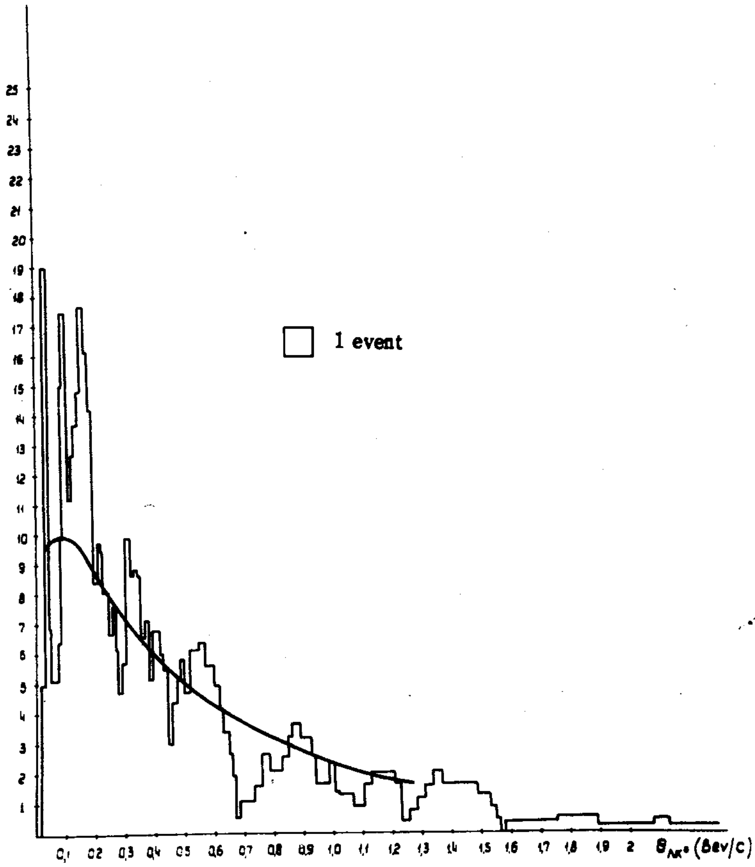
F i g. 6 a,b.

The momentum distributions of $\pi^{\mp}$ mesons from ΛK° pairs.
a) of π^{-} mesons from ΛK° pairs b) of π^{+} mesons from ΛK° pairs. A smooth curve represents the result of the calculation by the statistical model (with account of the isobars).



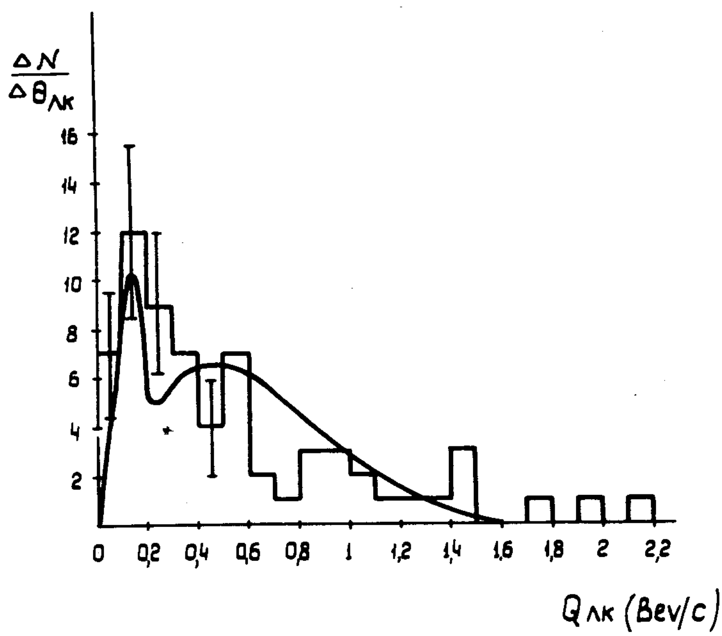
F i g. 7 a,b.

The angular distributions of $\pi^{\mp}$ mesons from ΛK° pairs. a) of π^{-} mesons,
b) of π^{+} mesons.



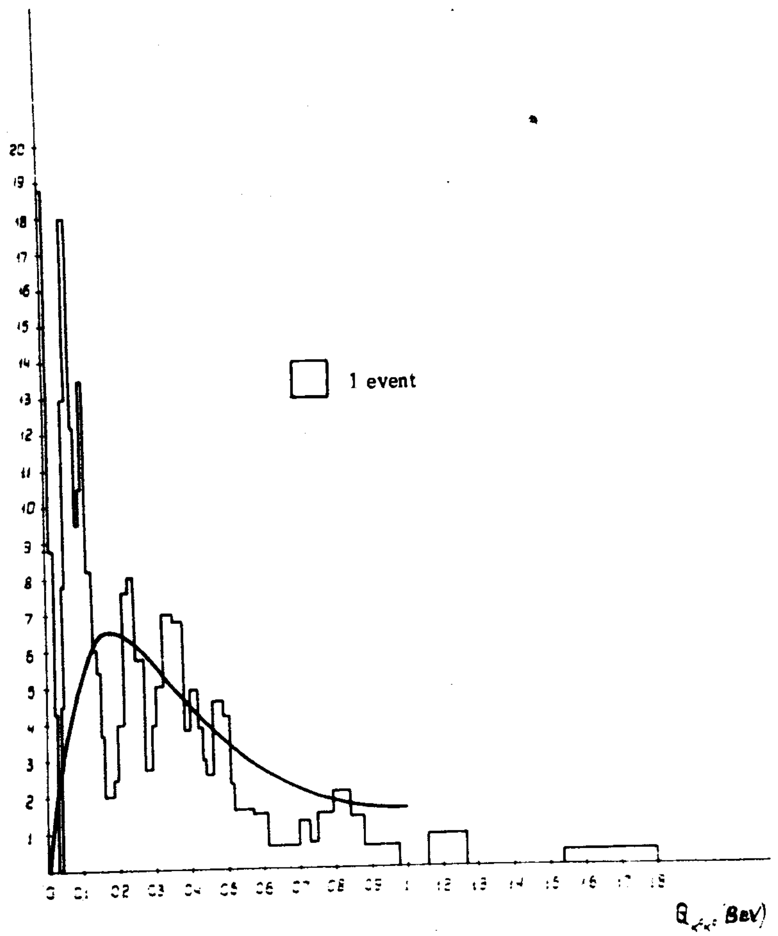
F i g. 8.

Histogram of the Q values for ΛK° pairs. The curve is the result of the caclulation by the Monte-Carlo method.



F i g. 9.

Histogram of the Q values ΛK° pairs. The theoretical curve obtained on the basis of the peripheral diagram is normalized to the histogram.



F i g. 10.

Histogram of the Q values for $K^{\circ}K^{\circ}$ pairs. The curve is the result of the calculation by the Monte-Carlo method.

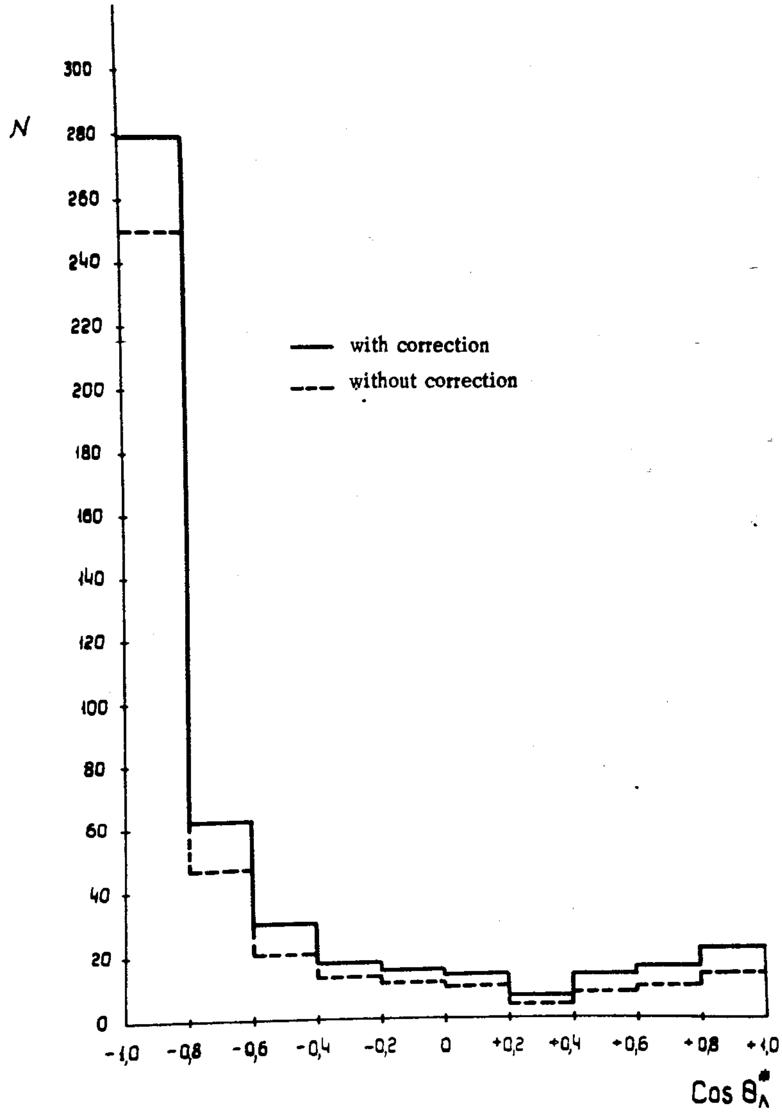


Fig. 11. The angular distribution (c.m.s.) of 'single' Λ hyperons produced in $\pi^- P$ interactions. In making the plot, we took into account the corrections for the recording probability in the working region of the chamber.

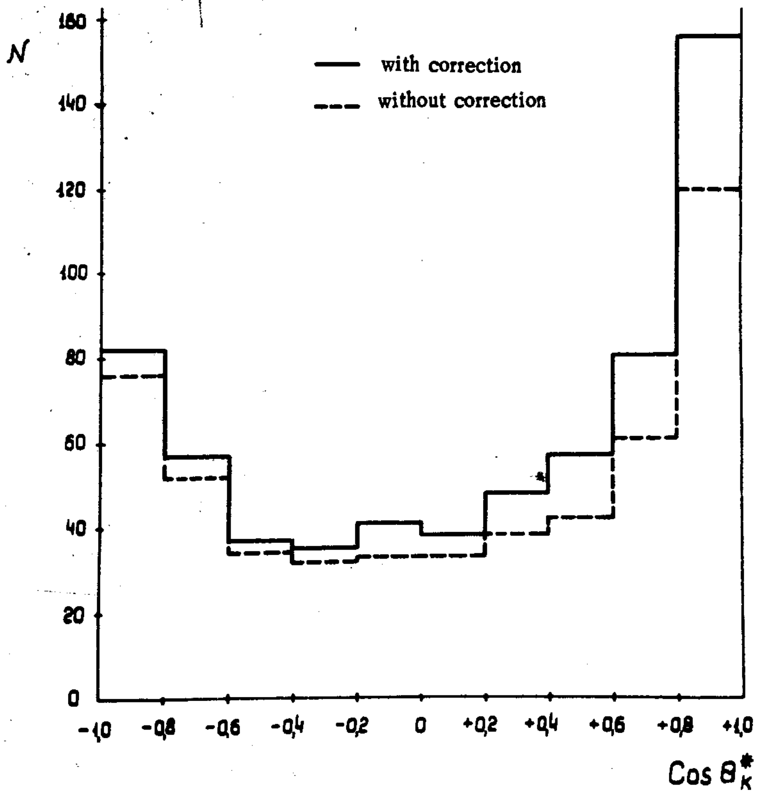


Fig. 12.

The angular distribution in the c.m.s. of 'single' K^0 mesons produced in $\pi^- P$-interactions. In making the plot, the correction was taken into account for the recording probability in the fiducial region of the chamber.

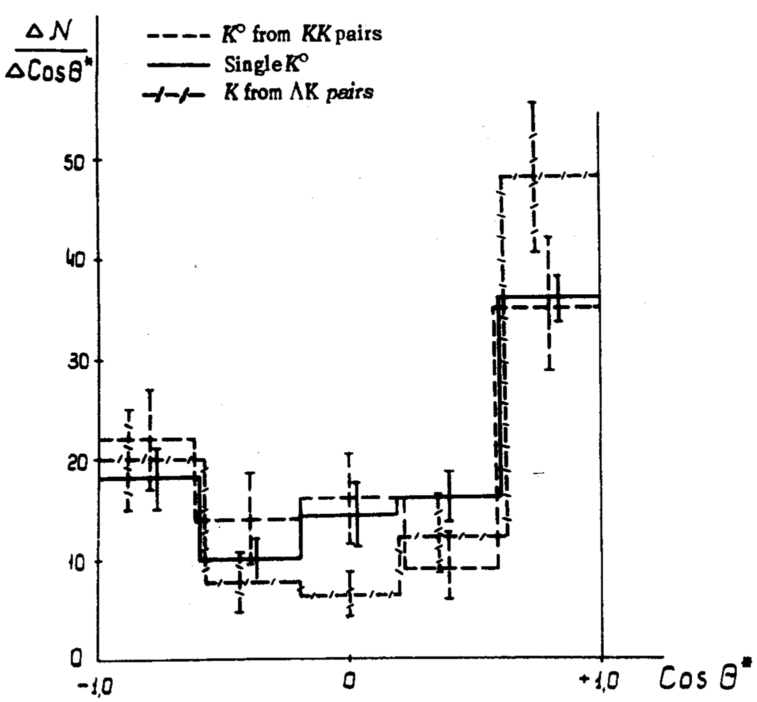


Fig. 13.

Comparison of the angular distributions in the c.m.s. of 'single' K^0 mesons (solid line), of K^0 mesons from $K^0\tilde{K}^0$ pairs (dotted line) and K^0 mesons from ΛK^0 pairs (dash-dot line). All the distributions are normalized to the same area.

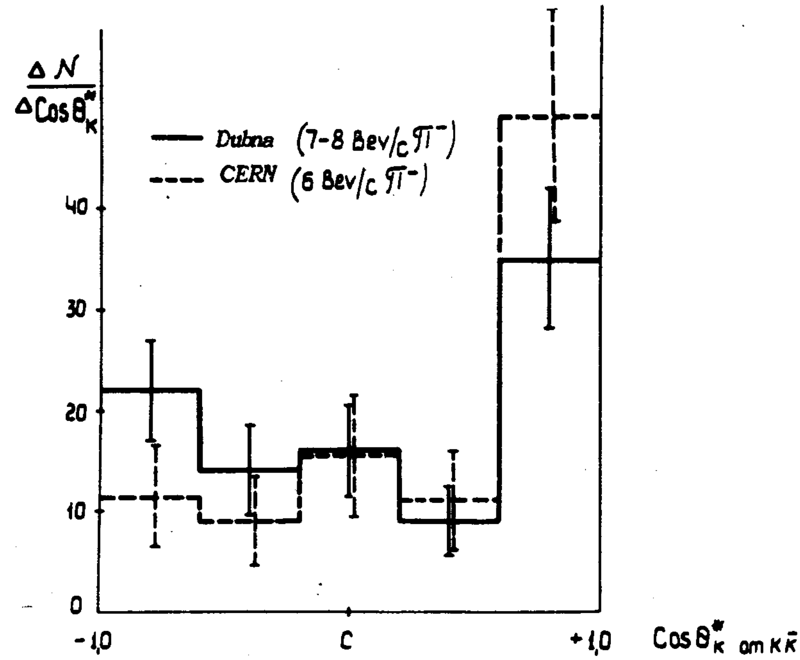


Fig. 14.

Comparison of the angular distributions of K° mesons from $K^{\circ}\tilde{K}^{\circ}$ pairs in the c.m.s. of $\pi^{-}P$ interactions. The solid line shows the experimental data obtained by us (7–8 BeV/c). The dotted line is from the CERN data (6 BeV/c).

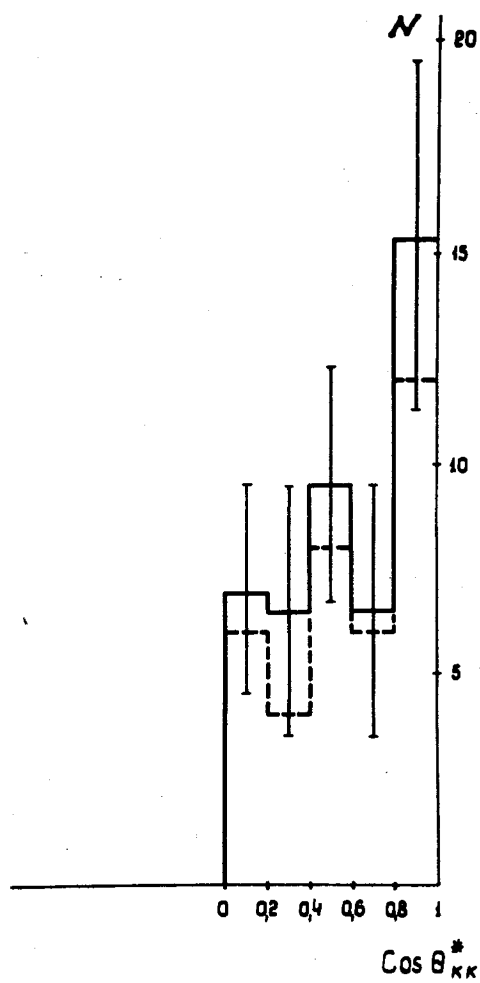


Fig. 15.

The angular distribution in the c.m.s. system $K^{\circ}\tilde{K}^{\circ}$ of $K^{\circ}(\tilde{K}^{\circ})$ mesons from $K^{\circ}\tilde{K}^{\circ}$ pairs.

References

1. Ван Ган-чан, М.И. Соловьев, Ю.Н. Шкобин. ПТЭ, 1, 41, 1959.
2. Ван Ган-чан, Ван Цу-цзен, В.И. Векслер, И. Врана, Дин Да-цао, В.Г. Иванов, Е.Н. Кладницкая, А.А. Кузнецов, Нгуен Дин Ты, А.В. Никитин, М.И. Соловьев, Чен Лин-янь. ЖЭТФ, 40, 464 /1961/.
3. В.И. Векслер, И. Врана, Е.Н. Кладницкая, А.А. Кузнецов, А.К. Михул, Э.К. Михул, Нгуен Дин Ты, В.Н. Пенев, М.И. Соловьев, Т. Хофмокль, Чен Лин-янь. Препринт Д-806.
4. Ван Ган-чан, Ван Цу-цзен, Н.М. Вирясов, Дин, Да-цао, Ким Хи Ин, Е.Н. Кладницкая, А.А. Кузнецов, А. Михул, Нгуен Дин Ты, А.В. Никитин, М.И.Соловьев. ЖЭТФ 40, 732 /1961/.
5. Ван Ган-чан, Ван Цу-цзен, Дин, Да- цао, В.Г. Иванов, Ю.В. Катышев, Е.Н. Кладницкая, Л.А. Кулюкина, Нгуен Дин Ты, А.В. Никитин, С.З. Отвиновский, М.И. Соловьев, Р. Сосновский, М.Д. Шафранов. ЖЭТФ 38, 426 /1960/.
6. М В. Дунин-Барковский, Н.В. Смирнов "Теория вероятности и математическая статистика в технике". Гостехиздат, 1955.
7. M.J. Soloviev. Proc. of the 1960 Ann. Intern. Conf. on High Energy Physics at Rochester p.388.
8. C.Peyrou Proc. of the 1960 Ann. Intern. Conf. on High Energy Physics at Rochester. p. 402
9. Н.Г. Биргер, Ван Ган-чан, Ван Цу-цзен, Дин Да-цао, Ю.В. Катышев, Е.Н. Кладницкая, Д.К. Копылова, В.Б. Любимов, Нгуен Дин Ты, А.В. Никитин, М.И. Подгорецкий, Ю.А. Смородин, М.И. Соловьев, З. Трка. ЖЭТФ 41, 1461 /1961/.
10. J.Steinberger. Proc. of the 1958 Ann Intern. Conf. on Sligh Energy Physics at CERN.
11. C.Peyrou The Aix-en- Provence Intern. Conf. on Elementary Particles. Sept. 1961.
12. В.И. Огиевецкий, М.И. Подгорецкий, Э.О. Оконов. Препринт ОИЯИ /to be publisched / ковано/.
13. .C.Frautschi, M.Gell-Mann F.Zachariasen. Preprint.