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THE PRODUCTION OF $K^0\bar{K}^0$ PAIRS BY 10 GeV/c NEGATIVE PIONS ON PROTONS

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SUMMARY

On 83,000 photographs from an exposure of the 81 cm Saclay hydrogen bubble chamber to a 10 GeV/c π^- beam of the CERN proton synchrotron 63 events have been found showing a beam interaction in a fiducial region of the chamber and the decay of two neutral kaons from this interaction. The cms distributions of all produced particles are given. It was found that nucleons are emitted strongly backwards in the cms while both kaons show a pronounced forward emission. Pions are emitted with small momenta nearly isotropically. None of the known kaon or nucleon isobars is strongly produced, whereas a peaking of the $(K_1^0 K_1^0)$ Q-value is observed at ~ 50 MeV. The transverse and total cms momenta increase with the mass of particles produced.

INTRODUCTION

The production of strange particles in π^--proton interactions at high energy ($P_\pi > \sim$ 5 GeV/c) was first studied in the bubble chamber experiments at Dubna(1) and at CERN(2). These studies were based essentially on events with only one strange particle decay visible in the chamber. The analysis of such

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events cannot give us complete information on the process of $K^0\bar{K}$ pair production in high energy inelastic collisions. It is mainly due to the fact that in general we are not able to identify a single kaon as coming from a $K\bar{K}^0$ pair and not from a kaon-hyperon associated production. Nevertheless the analysis of events with a single kaon identified - being therefore a mixture of $K\bar{K}$ amd KY production events - has already given some characteristics of $K\bar{K}$ production by high energy π^- on protons.

The general result of these studies [1][2][3] was that the production of kaons does not differ very much from the statistical process if one considers their momentum or energy distribution in the $\pi - p$ cm system but their angular distribution is peaked forward. The kaon distribution in the $\pi - p$ cm system can be described as "a statistical cloud shifted in the forward direction".

A more detailed analysis of the production of kaon-antikaon pairs can be made with the events in which both kaons are recorded and identified inside the chamber. Such events were studied at the incoming pion momenta of 7 GeV/c[4], 6 - 11 - 18 GeV/c[5] and 10 GeV/c[6]. In [6] the preliminary results on the $K\bar{K}^0$ production by 10 GeV/c π^- on protons were given. Since then the sample of events has been increased and additional analysis has been performed. The results obtained are given in the present paper.

THE EXPERIMENTAL PROCEDURE

To study the associated production of strange particles in π^--p interactions the 81 cm Saclay hydrogen bubble chamber was exposed to a π^- beam from the CERN proton synchrotron. The beam momentum was measured to be (10.0 ± 0.6) GeV/c. About 83,000 photographs with an average of 10.5 tracks per picture were obtained. The μ^- and K^- admixtures were estimated to be $\sim$14 o/o and $<$ 1 o/o respectively.

The photographs were scanned twice for $V^{\pm}$ and V^0 decays associated with interactions in a fiducial region of the chamber. Several thousand V decays were found, among them 325 events in which the decay of both strange particles produced was observed in the chamber. The efficiency of scanning for "$2V^0$" events was found to be $>$ 99 o/o. For $V^{\pm}$ events the scanning efficiency depends generally on the momentum of the decaying particle (as described in work on kaon-hyperon events [7]).

The events were measured using the CERN Iep measuring machines. Each measurement was followed by calculations done with the IBM 709 "GAP" programme[8], which carried out the geometrical reconstruction of tracks and the fit of strange particle decays to a number of hypotheses.

This procedure allowed the identification of strange particles using the χ^2 value. For ambiguous events, i.e. those with more than one acceptable hypothesis, mean gap length measurements[9] have generally given a unique identification. Seven "$2V^0$" events which still could not be identified have been assumed to be of the $(K^0 + \Lambda^0)$ type using the argument that K^0 decay should be isotropic in its own rest system.

For all 63 $K\bar{K}$ events a systematic search for protons in the jets was performed. It was possible to distinguish protons from π^+ - mesons up to 2.0 GeV/c particle momentum using mean gap length measurements. In several more cases a more energetic proton was identified on the basis of missing mass considerations, so 26 events were found to have an identified proton. In those 11 $K\bar{K}$ events in which not all positive particles could be identified there remains only one track that could be a proton. In 26 events all positive particles were identified as pions ("neutron" events).

The kinematic parameters of all the events were computed using the Special Analysis Programme (SAP)[10] for the IBM 709 computer.

Finally, after cutting off the events in the outermost parts of the chamber where the escape probability for strange particles is large, we were left with a sample of 289 "$2V^{\mp}$" events having the average weight equal to ~ 1.5 (not counting events with K^-).

THE EXPERIMENTAL RESULTS

a) Cross-sections

Out of 289 "two strange particle" events accepted for analysis, 76 events were identified as $K\bar{K}$ production process. They belong to one of the classes given in Table I and Table II. Due to the high beam momentum the average momentum and its measurement error was high for secondary tracks, so it was not possible to separate uniquely by missing mass calculation events with more than one neutral particle emitted. The classes listed in the Tables I and II correspond therefore to the identification of charged particles. The estimation of the number of π^0's is given in Table IV.

TABLE I

Identification	Number of events observed	Number of events corrected for decays outside the chamber	for the invisible decays*)	for K_2^0 unobserved **)
$K_1^0+K_1^0+p+\pi^-+ \ldots$	12	22.60	51.0	204.0
$K_1^0+K_1^0+p+\pi^++2\pi^-+ \ldots$	14	20.14	45.6	182.4
$K_1^0+K_1^0+p$+pions	26	42.74	96.6	386.4
$K_1^0+K_1^0+n+ \ldots$	10	16.40	37.1	148.4
$K_1^0+K_1^0+n+\pi^-+\pi^++ \ldots$	10	14.16	32.0	128.0
$K_1^0+K_1^0+n+2\pi^-+2\pi^++ \ldots$	6	7.84	17.7	70.8
$K_1^0+K_1^0+n$+pions	26	38.40	86.8	347.2
$K_1^0+K_1^0+(\pi^+/p)+\pi^-+ \ldots$	9	12.38	28.0	112.0
$K_1^0+K_1^0+(\pi^+/p)+\pi^++2\pi^-+ \ldots$	2	2.97	6.7	26.8
$K_1^0+K_1^0+(\pi^+/p)$+pions	11	15.35	34.7	138.8
Total $K^0\bar{K}^0$	63	96.49	218.1	872.4

*) The ratio of $\dfrac{K_1^0 \quad \pi^++\pi^-}{K_1^0 \quad \text{all pions}}$ = 0.665 was taken (J.L. Brown et al. Phys. Rev. 130, 769 (1963))

**) It was assumed that the ratio $\dfrac{K_1^0}{K_1^0} = 1$

This is, of course, a simplifying hypothesis without any theoretical background. In the case of YK^0 production we know that the K^0 is a particle of strangeness + 1 and therefore will be half of the time K_1^0 and halfof the time K_2^0. In the case of pair production there could be very well a mechanism by which pairs of $2K_1^0$ are preferred to pairs K_1^0 K_2^0 or vice versa.

Assuming that each charge combination of the $K\bar{K}$ system has the same probability, that is $N_{K^0\bar{K}^0} = N_{\bar{K}^0K^+} = N_{K^0K^-} = N_{K^+K^-}$, it is possible to evaluate the total cross-section for $K\bar{K}$ pair production.

By taking $\sigma_{K\bar{K}} = 4\,\sigma_{K^0\bar{K}^0}$ we have found

$$\sigma_{K\bar{K}} = 1.97 \pm 0.24 \text{ mb.}$$

The number of other $K\bar{K}$ combinations observed in the analysed material is given in Table II.

TABLE II

Identification	Number of events			
	observed	corrected for the decay probability	corrected for the invisible decay of K^0	corrected for K_2^0
$K^+\bar{K}^0$	6	400	500	1200
K^-K^0	6	450	600	1360
K^+K^-	1	1650	1650	1650

It is clear that a number of 1200 deduced from a number of 6 is quite uncertain. The numbers are just to show that the hypothesis of equal probability for all types of pairs is not in violent contradiction with the observations.

In Table III the cross-section obtained is compared with the results of other experiments on π^--p interactions.

TABLE III

Beam momentum GeV/c	Cross-section (mb)	Reference
4.7	0.57	11)
7÷8	1.6 ± 0.4	1)
10	1.97 ± 0.25	present work
16	2.21 ± 0.25	2)

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b) CM System distributions

The further analysis of $K\bar{K}$ production is based on $K_1^o K_1^o$ events. That is the only combination for which the statistics were rich enough.

In Fig. 1 the $P_\perp - P_L^*$ plot with its different projections gives us information on the K^o-mesons' distribution in the cm system.

The main characteristics of this distribution are:

1. Limited transverse momenta. All kaons but one fall in the region below 1 GeV/c;
2. Strong forward-backward asymmetry in the cm system with both kaons going mostly forward;
3. The absence of very fast kaons, i.e. kaons with momentum close to the kinematic limit.

Similar plots given in Figs. 2 and 3 characterise the cms distribution of pions. Both negative and positive pions seem to have similar distributions at least within the limits of the statistical uncertainty, which, especially for π^+, is rather large (39 identified π^+ and 11 π^+ or p). Looking at Figs. 2 and 3 the general features of the distributions are found to be similar to kaons. However: -

1. The transverse momentum distribution is still more strongly limited to low values;
2. The forward-backward asymmetry is less marked than for kaons. Nevertheless the angular distributions show peaks in forward and backward directions;
3. The cms momenta of π mesons are on average smaller than for K^o mesons.

The properties of the proton emission are shown in Fig. 4. There is no bias due to proton identification by ionisation, since also all non-identified positive tracks were taken as protons. In the plot they are drawn differently. There is a remarkable difference between the cm system distribution of protons and those of lighter particles - pions and kaons. It is noticeable that: -

1. The average transverse momentum is larger, but the protons on the $P_\perp - P_L^*$ plot are still collimated around the time of flight of the primary particle;

2. There is a pronounced asymmetry in the angular distribution with about 50 o/o of protons emitted with cos θ^* less than -0.9.
3. The cm system momentum distribution extends to the kinematic limit with more than 50 o/o of particles having momentum larger than 1 GeV/c. For pions and even for kaons there were only a few particles with such a momentum.

In the present experiment it was not possible to get direct information on the neutron emission. However, some information can be obtained by studying the distributions of the missing cm system momenta. In Fig. 5 such distributions are shown for the interactions without a proton among the charged secondaries (i.e. there must be a neutron). This figure then represents the momenta of a system containing a neutron and neutral pions. One can expect, however, by analogy to the charged pions, that the neutral ones are also emitted predominantly with rather low momenta. Therefore the missing momentum distribution reflects mainly the behaviour of the neutron emission. It can be seen in Fig. 5 that the neutron distribution resembles very much that of protons.

In order to get some information on the neutral pion production the missing momentum distribution for the events with an identified proton were plottted in Fig. 6. The missing momenta represent here the momenta of systems containing one or more pions. Some of the events have a missing cm momentum close to zero. They are mainly interactions without any neutral pion emitted. In spite of a large spread of the beam momentum ($\pm$ 0.6 GeV/c) it was possible using the missing mass calculation to perform a separation of the events with a visible proton into three classes: with no π^o, one π^o and $\geqslant$2 neutral pions. The results are given in Table IV. There is no contradiction between this statement and the one made before presenting Table I. Here we consider a restricted number of events (protons identified) in which the identification of π^o's is less difficult. The separation is rather statistical and not based on absolute certainty for each individual event.

TABLE IV

Directly observed particles	No. of π^0's	Number of events observed	Corrected for escape probability of kaons
$pK^0K^0\pi^-$	0	4	8.3
	1	5	9.1
	≥ 2	3	5.0
$pK^0K^0\pi^+\pi^-\pi^-$	0	4	6.9
	1	8	8.8
	≥ 2	2	3.5

From Fig. 6 we can conclude that the distribution of the neutral pions is very similar to those of charged ones.

It was of some interest to look at the distribution of the K_1^0 K_1^0 system. It is shown in Fig. 7. It can be seen that the system as a whole is emitted strongly forward. The distributions of Fig. 7 are in fact very similar to those of protons - or rather to their mirror reflection on the $P_L^* = 0$ $(\cos \Theta^* = 0)$ plane.

c) The invariant mass distribution

The distributions of the invariant mass for all two and three particle combinations have been studied. There was no indication for any of the known isobars. In particular there was no indication for the (3,3) pion-nucleon isobar (N_{1238}^*) and for either of the K^* resonances. It is interesting to notice that for K^0 mesons produced together with hyperons (6)(7) there was strong evidence for production of the 888 MeV K^*. In the invariant mass distribution of K^0-$\pi^{\mp}$ systems from interactions with $K^0\bar{K}^0$ production no excess of events in the expected regions has been observed. Therefore the upper limit for K^* production cross-section is rather low.

The only irregularity that was observed in the invariant mass distribution was the excess of events with small Q-value for the $K_1^oK_1^o$ systems[6] (Fig. 8). A similar effect has also been observed in other works [4][5][12][13]. In order to study the significance of this effect a "background" distribution should be calculated (i.e. "phase space"). Unfortunately the normal phase space calculations seem to have very little meaning for high energy interactions. This is because these processes show strong non-statistical structure and in addition the total number of particles involved could not be precisely determined because of missing neutrals.

In the present study the "background" curve was approximated by Monte-Carlo calculations. The Q-value distribution was constructed for 1,000 $K^o\bar{K}^o$ pairs. The technique was to take the two K^o's that formed a "Monte-Carlo pair" at random from two different events from the sample of all analysed K^o's.

The comparison of the experimental distribution with the calculated Monte-Carlo curve shows that the observed excess of $K_1^o\bar{K}_1^o$ pairs with small Q-value is a two standard deviation effect. This means that the probability of obtaining the deviation from the Monte-Carlo distribution at least as big as the observed one is 5 o/o. Therefore, the evidence found in the present work is not entirely conclusive as such. However, taking into account that such an accumulation of low Q-values of the $K_1^oK_1^o$ system has been found in several other experiments [4][5][12][13] it is very likely that the effect found in the present work is real. Two interpretations of this effect can be given. One of them is to assume the existence of a new resonance with a Q-value of about 50 MeV. It would be, of course, a resonant state completely different from the ϕ^o resonance in the $K_1^oK_2^o$ system[14][15][16][17]. There is another argument that favours the resonant state hypothesis. It is based on the fact that no indication on the existence of the K^* has been found among $K_1^oK_1^o$ events, whereas in the $K^o\Lambda^o$ events it is produced abundantly[6][7]. It seems therefore that there is some mechanism competing with the creation of the K^* state. Such a mechanism might be a $K_1^oK_1^o$ resonance decaying outside the interaction region.

Another interpretation of the excess of the small Q-value events was given by Z. Koba and R. Sosnowski(17). The $K_1^o K_1^o$ pair is a symmetric system. The corrections due to this fact will raise the background curve in the region of small Q-values.

Conclusions

1. The results on cm system distributions obtained in the present experiment can be briefly summarised in the following way:

Nucleons have a tendency to keep their original line of flight and therefore are strongly peaked backwards. On the other hand, the $K^o\bar{K}^o$ system is emitted forwards with almost equally strong collimation. The distributions of pions are charge independent and nearly symmetric with a small forward excess in P_L^*.

In terms of the one meson exchange model, the process of $K^o\bar{K}^o$ production would be described rather as a pion and not as a kaon exchange.

2. The average value of the transverse momentum increases with the mass of the particles, as was already reported by us(6) and confirmed in another experiment(3). We find that also the total cms momentum is a function of particle mass. The experimental values are given in Table V.

TABLE V

Particle	$\bar{P}_\perp$	$\bar{P^*}$
$\pi^\pm$	0.30	0.44
K^o	0.39	0.69
P	0.38 0.37	0.96* (1.15)**

The $\bar{P^*}$ - m dependence can be well approximated by a linear function $\bar{P^*} = am + b$ with a slope equal to 0.84. If we take all the π^+/p tracks as protons the slope equals 0.66.

* Taking all π^+/p tracks as protons

** Taking only protons identified by MGL measurements ($P \leqslant 2$ GeV/c)

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The purely statistical model of production predicts also (at this small cms energy) that heavier particles have on average larger p^*. The calculations for the process (10 GeV/c) $\pi^- + p \rightarrow N + K + \bar{K} + n\pi$ gave the "slope" a = 0.30, almost independent of the multiplicity of pions.

A stronger P^* mass dependence can be expected if the observed particles are the products of decay of some heavier "intermediate states". If one performs the calculations according to the statistical model with known isobars one gets:

a) For $\pi^- + p \rightarrow N^* + (K\bar{K})^* + n\pi$ $\quad$ a $\approx$ 0.3

b) For $\pi^- + p \rightarrow N^* + K + \bar{K} + n\pi$ $\quad$ a $\approx$ 0.35

In fact we do observe some evidence for the production of $(K\bar{K})^*$ resonant state, while N^* production, if any, is rather weak.

We think that in order to explain the larger experimental value of "a" it is necessary to assume that the observed particles are produced via some heavier "intermediate states". This problem will be discussed in a forthcoming paper.

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FIGURE CAPTIONS

Fig. 1 $P_\perp - P_L^*$ plot for kaons from the reactions $\pi^- + p \rightarrow K_1^0 + K_1^0 + N + n\pi$. Histograms are given for P_L^*, P^*, $P_\perp$ and $\cos\theta^*$. Broken lines give uncorrected numbers of events. Solid lines include corrections for detection probability.

Fig. 2 $P_\perp - P_L^*$ plot and histograms for negative pions produced together with a pair of K_1^0.

Fig. 3 $P_\perp - P_L^*$ plot and histograms for positive pions produced together with a pair of K_1^0 (identified π^+ are given by full dots, π^+/p by empty circles).

Fig. 4 $P_\perp - P_L^*$ plot and histograms for protons from the reaction $\pi^- + p \rightarrow K_1^0 + K_1^0 + p + n\pi$ (identified protons are given by full dots, π^+/p tracks by empty circles.)

Fig. 5 $P_\perp - P_L^*$ plot and histograms for "missing particles" for events without identified proton. This represents the characteristics of particles whose properties were calculated without fit to fulfil energy and momentum conservation at the production point. Events with no possible proton are given by full dots, those with a π^+/p track by empty circles.

Fig. 6 $P_\perp - P_L^*$ plot and histograms for "missing particles" for events with an identified proton (full dots) or with a π^+/p track (empty circles).

Fig. 7 $P_\perp - P_L^*$ plot and histograms for system formed by both K_1^0 produced in the reaction $\pi^- + p \rightarrow K_1^0 + K_1^0 + N + n\pi$.

Fig. 8 Ideogram (in intervals of 25 MeV) for the Q-value of the $K_1^0 K_1^0$ system. The lines represent the background as calculated by a Monte Carlo method (upper line is normalised to total area of histogram, lower lines to the part $Q > 50$ MeV).

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REFERENCES

1. M.I. Soloviev, Proceedings of the 1960 International Conference on High Energy Physics at Rochester, p. 388

2. J. Bartke, R. Budde, W.A. Cooper, H. Filthuth, Y. Goldschmidt-Clermont, G.R. Macleod, A. de Marco, A. Minguzzi-Ranzi, L. Montanet, D.R.O. Morrison, S. Nillson, Ch. Peyrou, R. Sosnowski, A. Bigi, R. Carrara, C. Franzinetti, I. Manelli, G. Brauti, M. Ceschia, L. Chersovani - ibid., p. 402 and Nuovo Cimento 24, 876 (1962)

3. T. Ferbel, H. Taft, Nuovo Cimento, 28, 1214 (1963)

4. V.A. Belyakov, Wang Yung-Chang, V.I. Veksler, N.M. Viryasov, Du Yuan-cai, Kim Hi In, E.N. Kladnitskaya, A.A. Kuznetsov, A. Mikhul, Nguyen Dinh-Tu, V.N. Penev, E.S. Sokolova, M.I. Soloviev - Proceedings of the 1962 International Conference on High Energy Physics at CERN, p. 261 and p. 336

5. H.H. Bingham, M. Bloch, D. Drijard, A. Minguzzi-Ranzi, M. Nicolić - ibid. p. 240 (see also Nuovo Cimento 29, 339 (1963)).

6. A. Bigi, S. Brandt, R. Carrara, W.A. Cooper, A. de Marco, G.R. Macleod, Ch. Peyrou, R. Sosnowski, A. Wroblewski - ibid. p. 247

7. A. Bigi, S. Brandt, W.A. Cooper, A. de Marco, Ch. Peyrou, R. Sosnowski, A. Wroblewski - Nuovo Cimento - to be published

8. A. Kernan, R. Böck, W.G. Moorhead - Internal CERN - DD report (1961)

9. C. Dilworth, D.R.O. Morrison, G. Membriani - Nuovo Cimento - to be published

10. S. Brandt - CERN Internal Note DD/EXP/62/25 and S. Brandt - Dissertation, Bonn University (1963)

11. L. Bertanza, B.B. Culwick, K.W. Lai, I.S. Mitra, N.P. Samios, A.M. Thorndike, S.S. Yamamoto, R.M. Lea, Phys. Rev. 130, 786 (1963)

12. G. Alexander, O.I. Dahl, L. Jacobs, G.R. Kalbfleisch, D.H. Miller, A. Rittenberg, J. Schwartz, G.A. Smith, Phys. Rev. Letters 9, 460 (1962).

13. A.R. Erwin, G.A. Hoyer, R.A. March, W.D. Walker, T.P. Wangler, Phys. Rev. Letters 9, 34 (1962)

14. L. Bertanza, V. Brisson, P.L. Connolly, E.L. Hart, I.S. Mitra, G.C. Moneti, R.R. Rau, N.P. Samios, I.O. Skillicorn, S.S. Yamamoto, M. Goldberg, L. Gray, J. Leitner, S. Lichtman, J. Westgard, Phys. Rev. Letters 9, 180 (1962)

PS/4105/dac

15. P.L. Connolly, E.L. Hart, K.W. Lai, G. London, G.C. Moneti, R.R. Rau, N.P. Samios, I.O. Skillicorn, S.S. Yamamoto, M. Goldberg, M. Gundzik, J. Leitner, S. Lichtman, Phys. Rev. Letters 10, 371 (1963).

16. P. Schlein, W.E. Slater, L.T. Smith, D.H. Stork, H.K. Ticho, Phys. Rev. Letters 10, 368 (1963).

17. Z. Koba, R. Sosnowski - to be published.

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$P_\perp - P_L^*$ PLOT FOR K^0

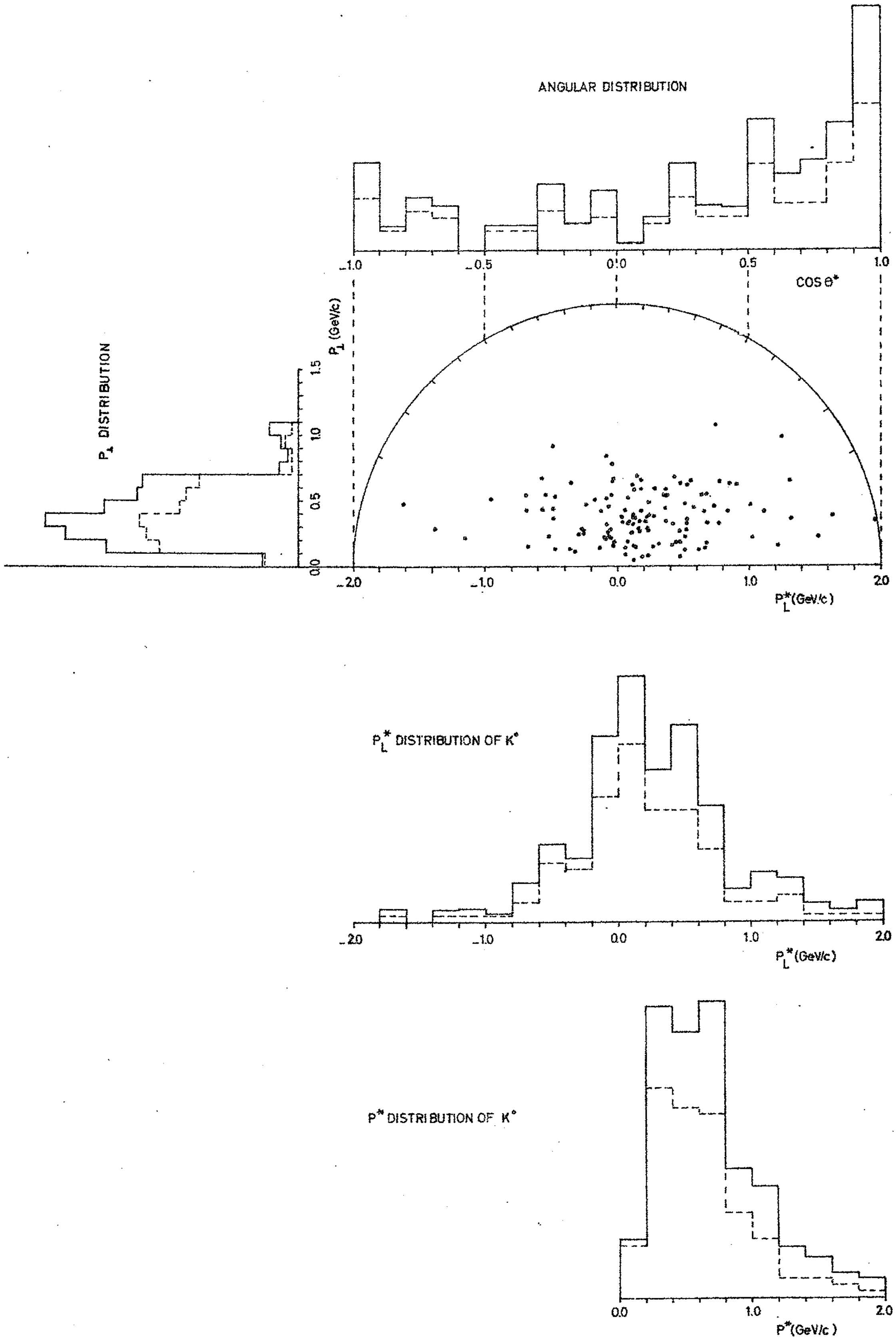

Fig.1

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NEGATIVE PIONS

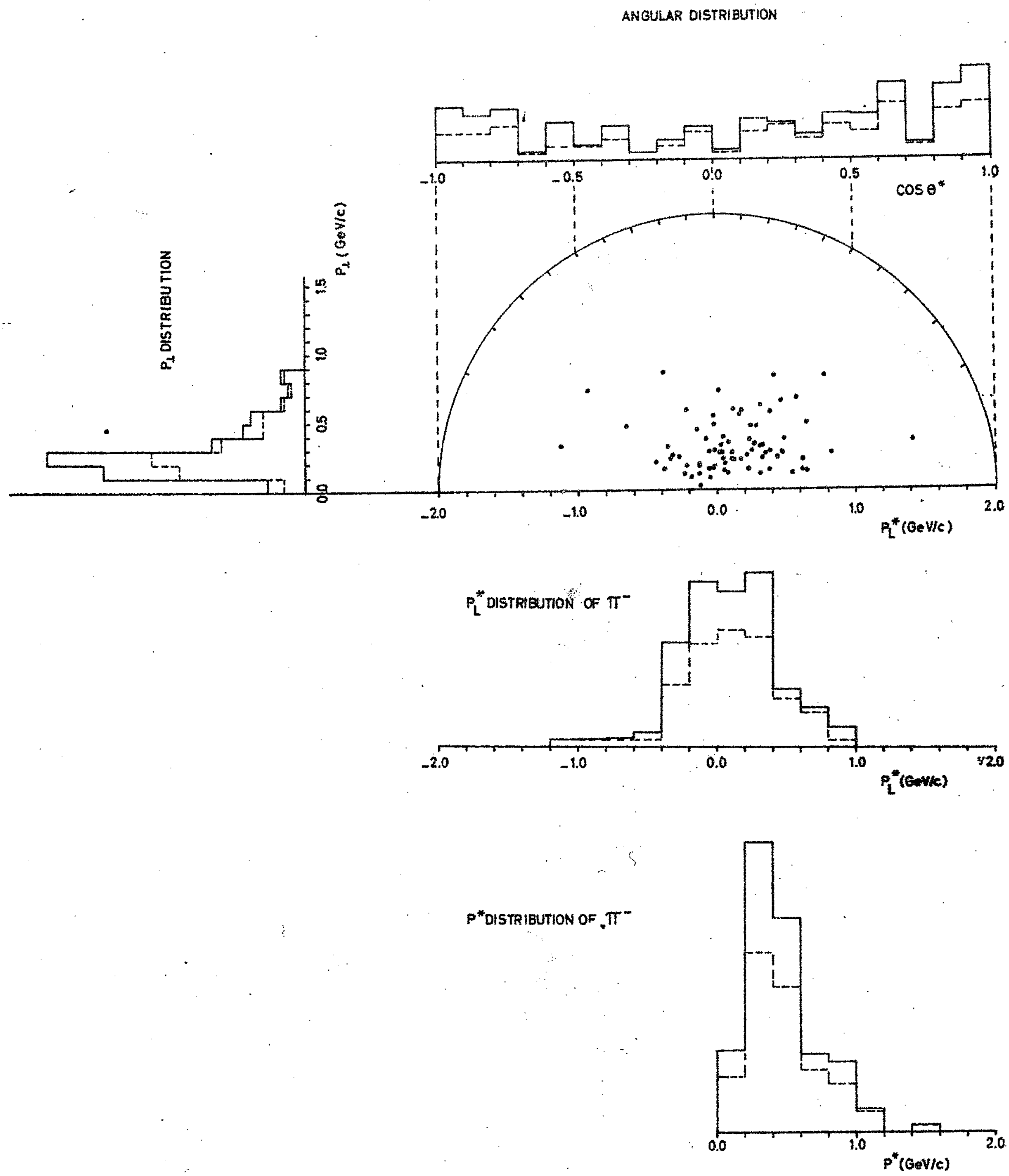

Fig. 2

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PS/4105/dec

POSITIVE PIONS

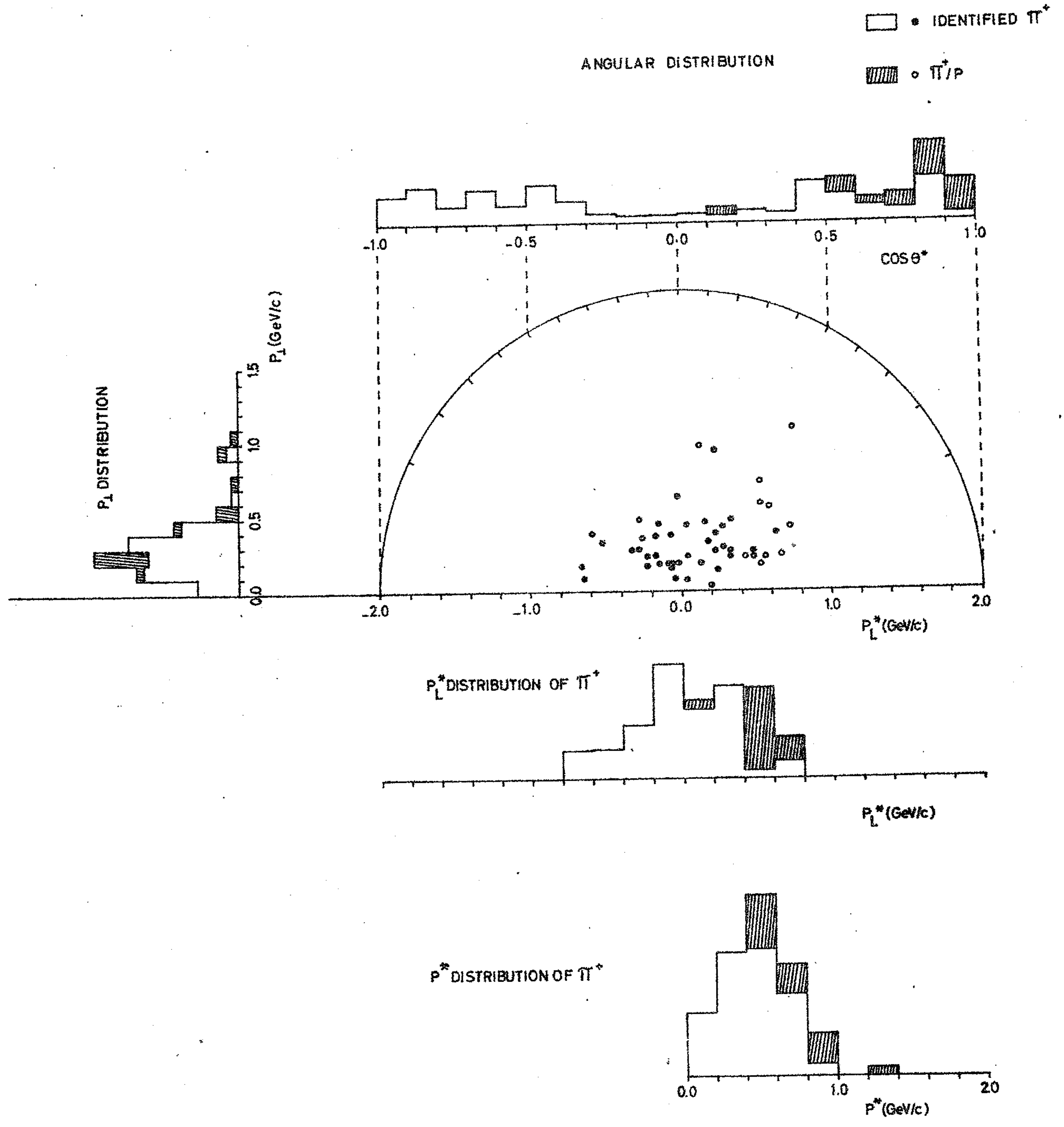

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Fig. 3

PROTONS

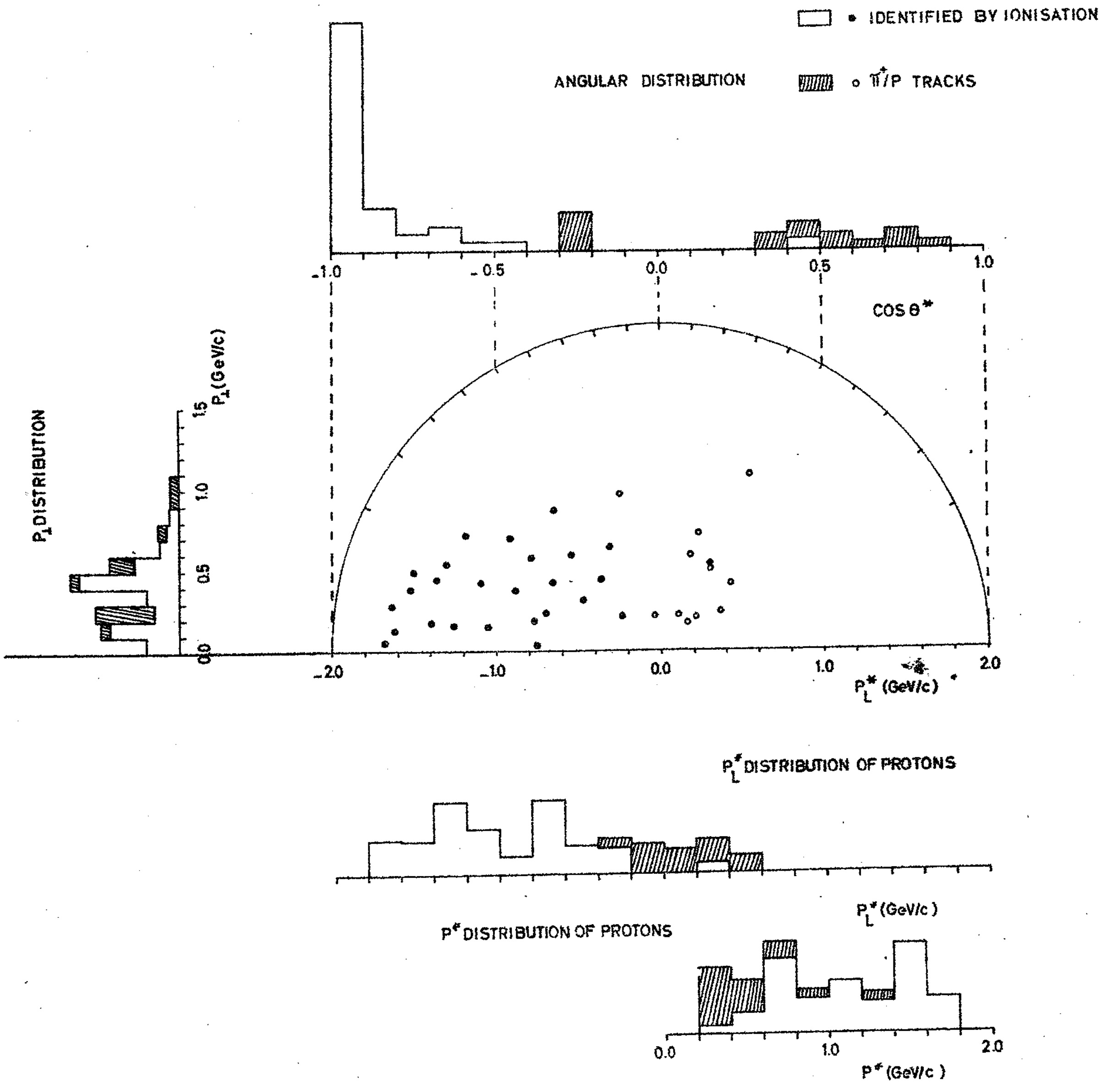

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Fig.4

MISSING "PARTICLES"

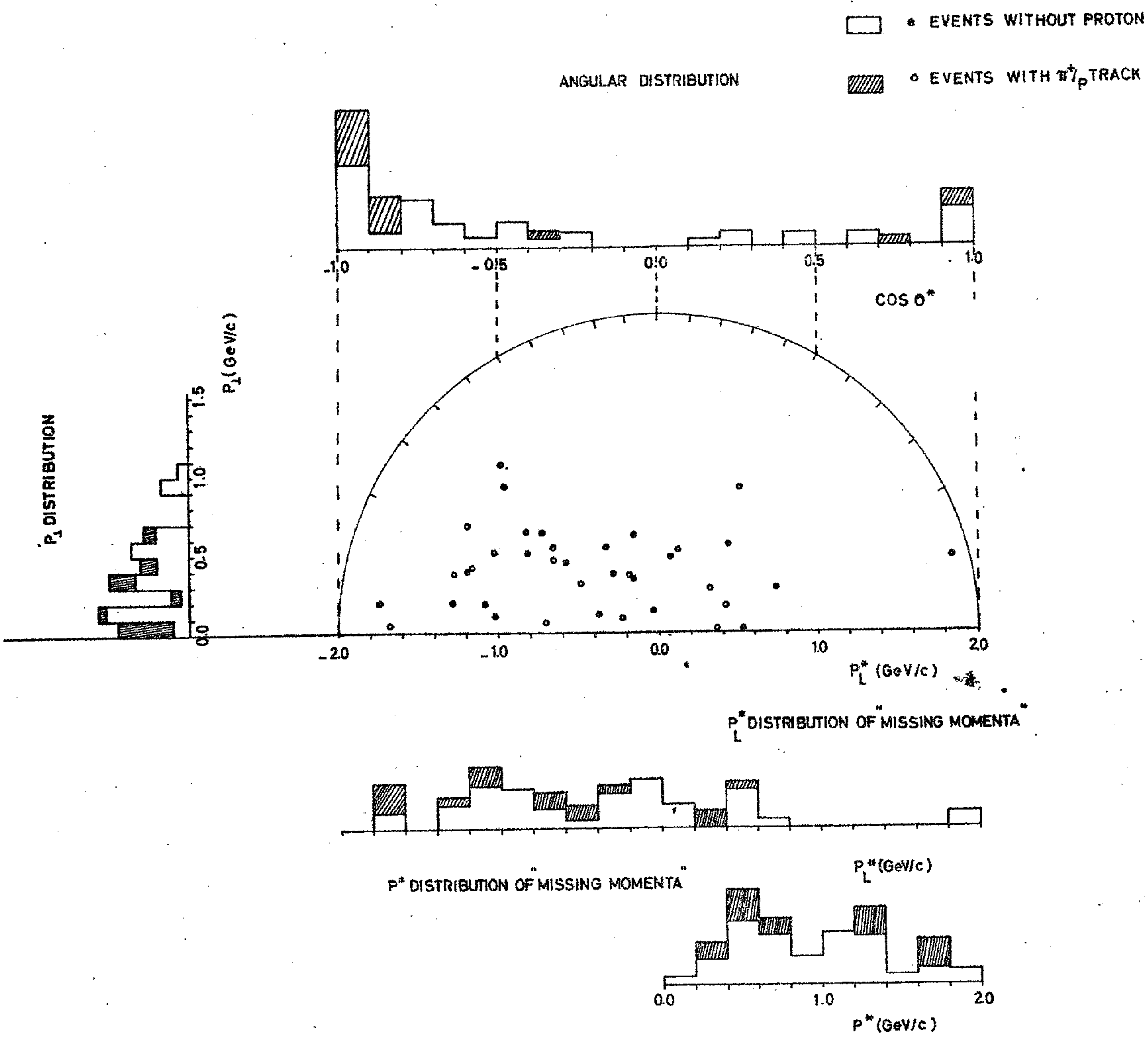

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Fig. 5

MISSING "PARTICLES"

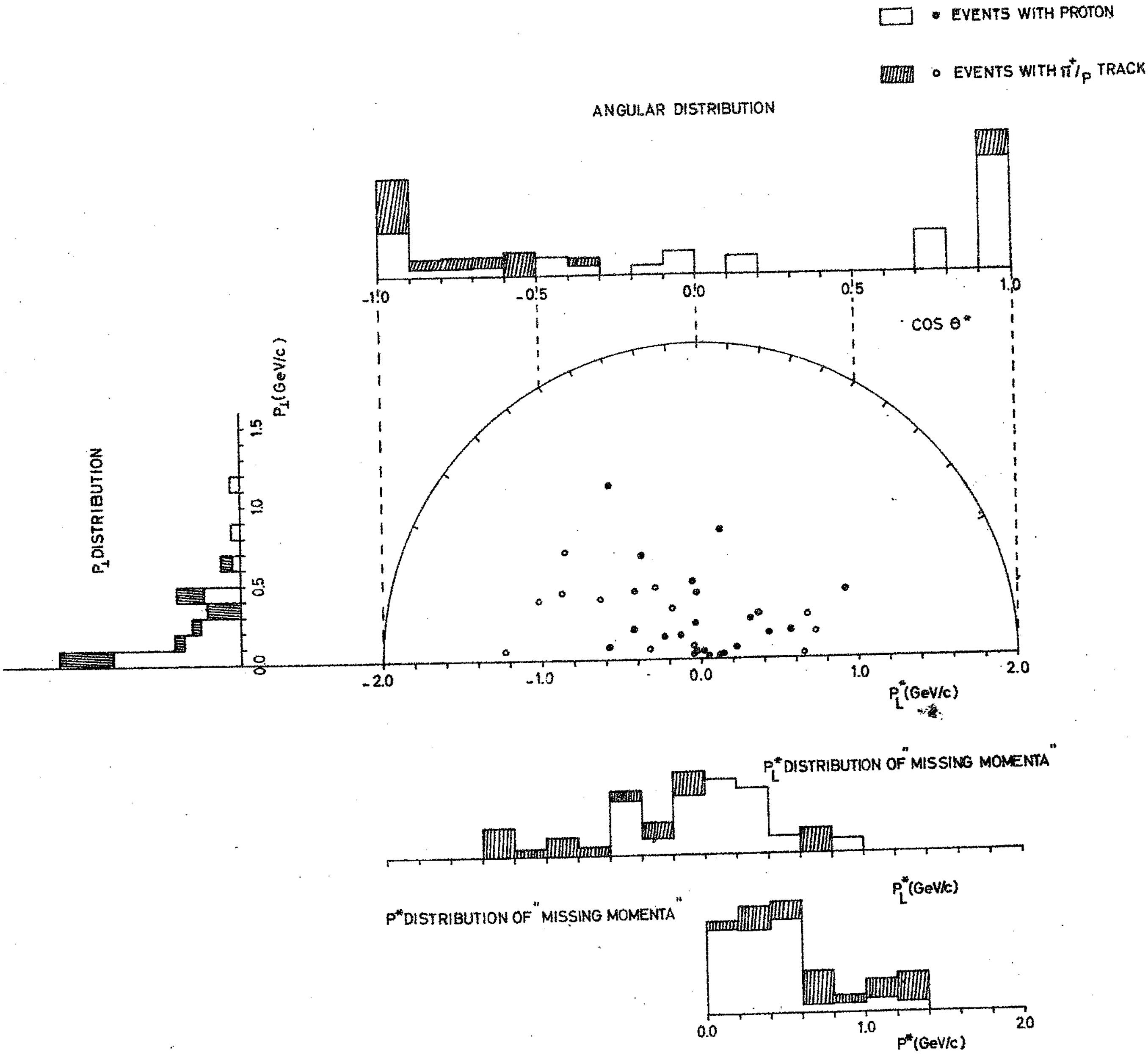

Fig.6

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K^0K^0 SYSTEMS

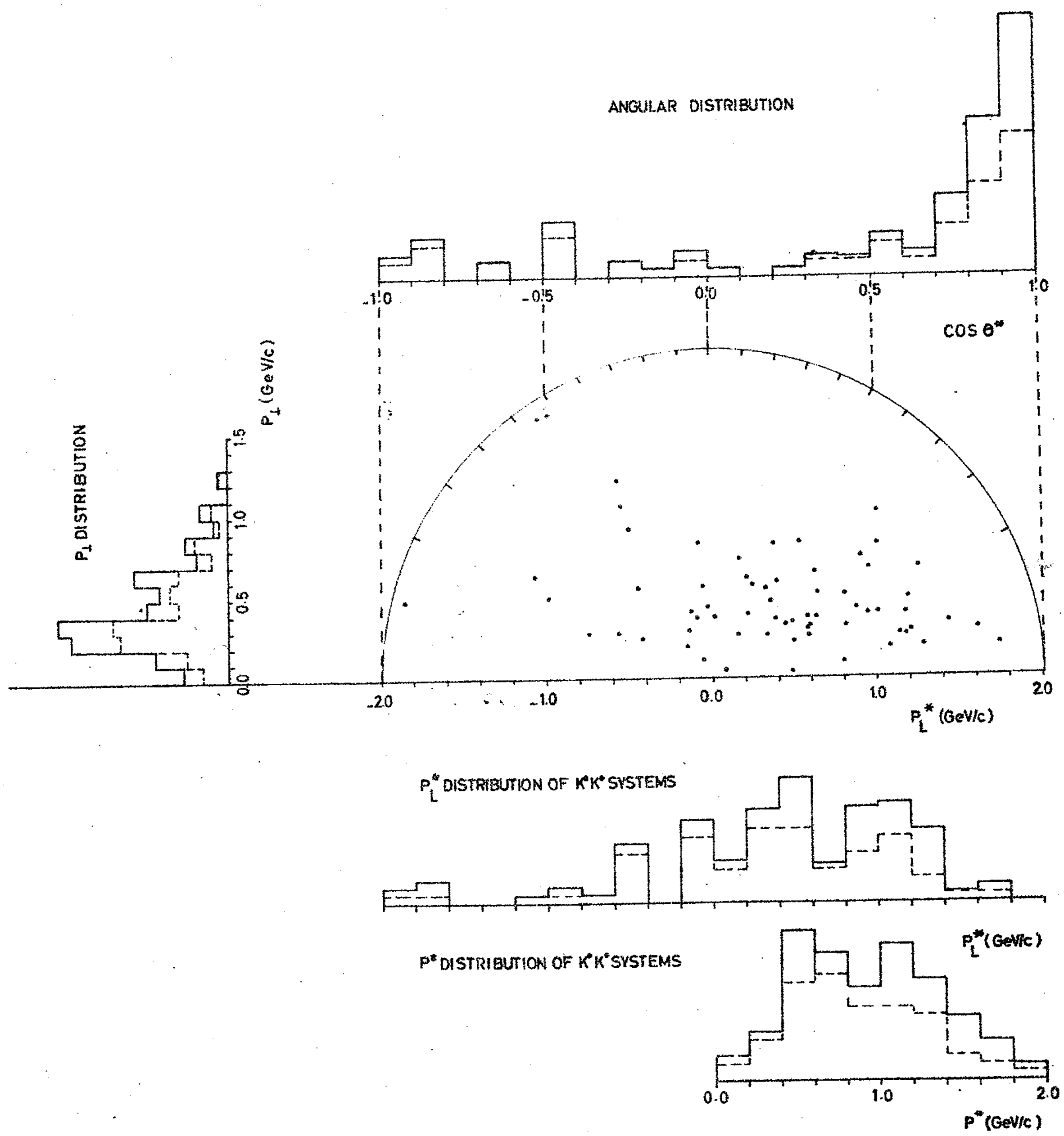

Fig.7

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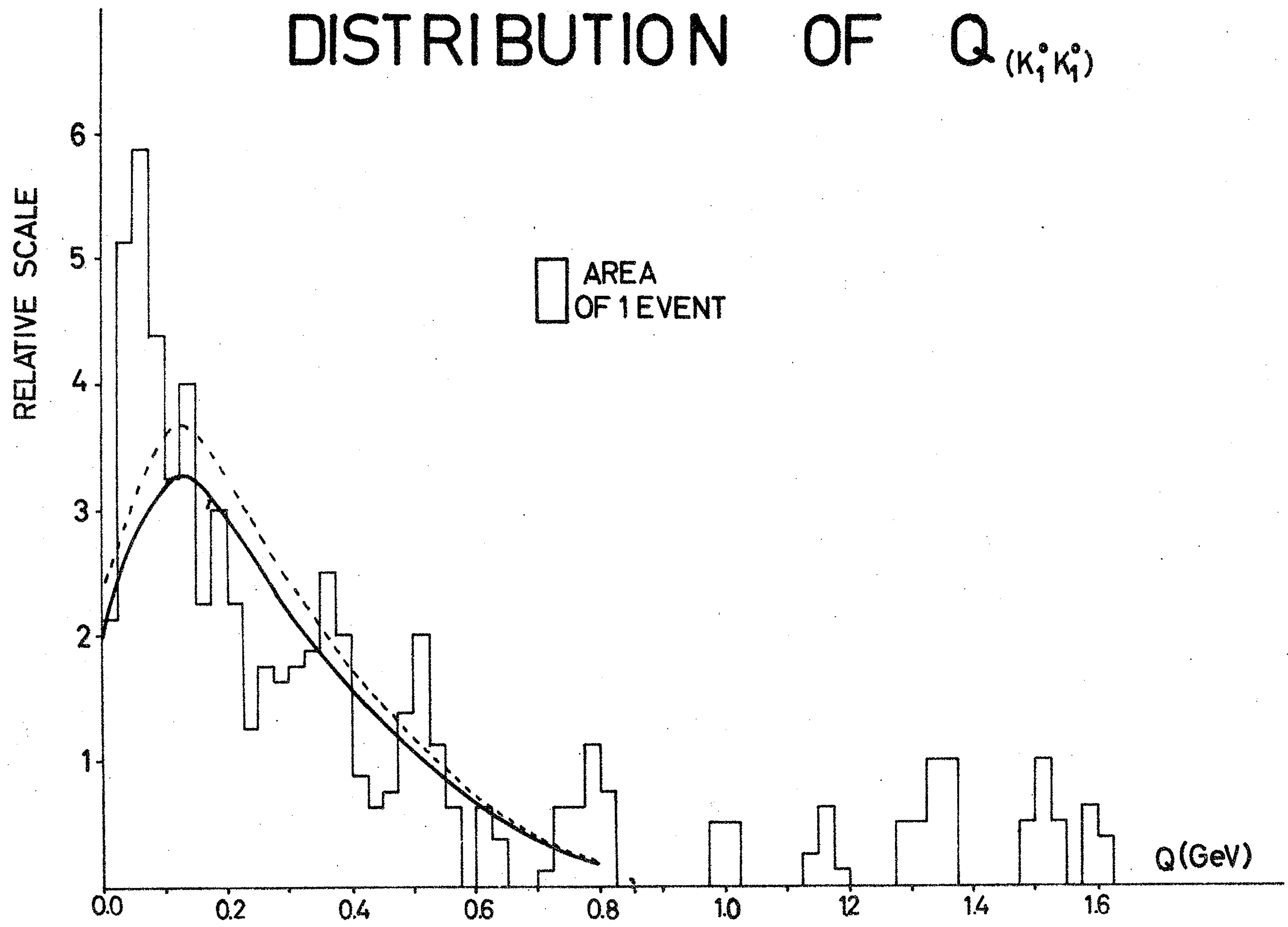
DISTRIBUTION OF Q (K°1 K°1)
RELATIVE SCALE
6
5
4
3
2
1
AREA
OF 1 EVENT
Q (GeV)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6

Fig. 8