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LETTER OF INTENT

To study rare meson systems produced in $K^{\pm}p$ collisions at 16 and 32 GeV/c using the RF separated beam and the Omega spectrometer at the SPS

D.C. Colley, J.D. Dowell*, J. Garvey, R.J. Homer, M. Jobes
G.T. Jones, I.R. Kenyon, T. McMahon, P. Watkins and J. Wilson

Physics Department, University of Birmingham

* Contact man

1. Introduction

The RF beams planned for the Omega spectrometer at the SPS will have usable $K^{\pm}$ intensities of $\sim 2 \times 10^5$ per pulse at momenta from 10-30 GeV/c. These beams will permit investigation of $K^{\pm}$ induced reactions of the level of 10^3 events per microbarn per day, and so will open up the possibility of studying with very high statistics processes occurring with cross sections of a few microbarns or less. We propose to exploit this possibility to study reactions containing $K\bar{K}$ or $B\bar{B}$ pairs in the final state by using the $\check{C}$ counters downstream of Omega to trigger on a forward going K or $p(\bar{p})$ of opposite charge to the incident $K^{\pm}$.

The most common reactions that could be studied are

$$K^{\pm}p \rightarrow K^{\mp}\ K\bar{K}p$$
$$\rightarrow \bar{p}p\ K^{\pm}p$$
$$\rightarrow \Lambda\bar{p}p \quad \text{or} \quad \bar{\Lambda}pp$$
$$\text{and} \qquad K^{-}p \rightarrow K^{+}K^{-}\Lambda$$

In each case the trigger would be provided by the first final state particle listed (for the $\Lambda(\bar{\Lambda})$ by the $p(\bar{p})$ from the $\Lambda(\bar{\Lambda})$ decay). By using the downstream γ-detector planned for SPS experiments in Omega it will also be possible to study reactions containing the final state particles listed plus a a single fast π^0. These reactions should provide valuable information on diffractive processes as well as on unusual meson and baryon states.

It is known that particles containing mainly strange quarks (e.g. ϕ, f' ...) are produced much more abundantly by kaons than by pions. The possibility thus exists of searching for new particles of this type, of studying the properties of those already known and of investigating production mechanisms with statistics totally unattainable by other means. The states listed are also rich in exotic systems, and being free from pions will not suffer from overlap by the very strong and wide Δ that is a problem in many pion induced reactions.

Some specific points of interest are as follows:

1.1 Properties of Meson States

(i) Search for resonances in the series $\phi(1^-)$, $f'(2^+?)$ ...

The next in this series should be a 3^- state at about 2 GeV. Its detection and the determination of its J^P should be well within the scope of the proposed experiment. At a high beam momentum (30 GeV/C) it may also be possible to detect even higher mass states, since even though these would have high Q-values their decay products (presumed to include $K\bar{K}$) would still go forward in the lab. and should trigger the $\check{C}$ counters.

(ii) Properties of the f'

So far only about 150 f's have been reported and though the indications are that $J^P = 2^+$, this is not clearly established. There are also conflicting results on the width. The cross-section for f' production in $K^+p \to K^+pK^+K^-$ at 10 GeV/c is (4 ±1) μb and in $K^-p \to \Lambda K^+K^-$ at 6 GeV/c is about 4 μb for seen Λ decays.[1)] Thus some thousands of events should be obtained in a few days at the SPS.

(iii) Production mechanisms for ϕ, f' ...

These could be studied in 3-body reaction $Kp \to Kp\phi$, Kpf' etc. and in 2-body reactions $K^-p \to \Lambda\phi$, $\Lambda f'$ ... In the latter the polarization of the Λ would provide valuable information for amplitude analyses, and comparisons could be made with similar processes $K^-p \to \Lambda\rho$, $\Lambda\omega$, Λf^o .... The narrow width of the ϕ will mean that it will be very little affected by background so it should be possible to do a clean analysis to high values of the momentum transfer.

(iv) $K\bar{K}$ scattering

$K^-p \to K\bar{K}\Lambda$ could go via K exchange (the d.m. elements for $K^-p \to \Lambda\phi$ at 4 GeV/c show strong unnatural parity exchange). With the anticipated statistics a partial-wave analysis of $K\bar{K} \to K\bar{K}$ should be possible out to large values of t.

(v) Rare decays of resonances

Mesons which decay to $K\bar{K}\pi$ will be looked for. Decays to $p\bar{p}$, $p\bar{\Lambda}$ (or $\bar{\Lambda}p$) etc. would be observed for high mass states. These could include daughter states since low spins would be more likely.

1.2 Diffractive-type processes

There is evidence of a strong diffractive component in the reactions

$$K^{\pm}p \rightarrow K^{\pm}K^{+}K^{-}p$$

Diffractive production can also occur in

$$Kp \rightarrow Kp\bar{p}p$$
$$\rightarrow \bar{p}\Lambda p \text{ and } \bar{\Lambda}pp$$

plus similar reactions with a π^{o}. Important information about the nature of diffractive processes should be provided by comparison with the more abundant reactions $Kp \rightarrow K\pi\pi p$ and $\pi p \rightarrow \pi\pi\pi p$. A full spin-parity analysis of the 3-body states will be carried out using the Illinois partial wave program. The $KK\bar{K}$ and $K\bar{K}\bar{K}$ systems are constrained by the requirements of Bose symmetry and reliable information on phases should be obtainable from study of overlapping resonance bands e.g. $K_1(K_2\bar{K})$ and $K_2(K_1\bar{K})$ etc.

Specific topics to be studied include:

(i) Variation of production cross-sections with energy

This will require runs at two widely spaced momenta, say 16 and 32 GeV (these values are chosen to facilitate comparison with bubble chamber data at these energies). At 32 GeV/c the non-diffractive channels may be unobservable but this requires investigation also.

(ii) Dependence of t-distributions on beam momentum and on the mass of the produced system.

(iii) Relationship between diffractive enhancements and threshold phenomena

It appears that in $\pi\pi\pi$ and $K\pi\pi$ systems diffractive enhancements occur at thresholds e.g. $\rho\pi$, $f\pi$ in the former and $K^{*}_{890}\pi$, $K^{*}_{1420}\pi$ in the latter.

This apparent relationship could be checked for $K\phi$, Kf' and any higher mass states detected.

(iv) Search for unusual decays of diffractive states

Decays to $KKK\pi$ and to $\bar{\Lambda}p$ or $\Lambda\bar{p}$ would be looked for.

(v) Comparison of $K^{\pm}$ induced reactions

On a Regge pole picture K^{+} induced diffractive processes are expected to proceed via $P + (f + \omega)$ exchange and K^{-} by $P + (f - \omega)$. $(f + \omega)$ is real and $(f - \omega)$ imaginary. The P amplitude is also imaginary, so the intensities for the two processes are

$$|K^{+}p|^{2} = |P|^{2} + |f + \omega|^{2}$$

$$|K^{-}p|^{2} = |P|^{2} + |f - \omega|^{2} - 2\,P.(f - \omega)$$

The $|P|^{2}$ term should be essentially energy independent whereas $|f \pm \omega|^{2}$ should go as $1/s$ and the interference term $P(f - \omega)$ as $1/\sqrt{s}$ Thus the reactions will have different s dependences. They will also have different t dependences, with cross-over phenomena similar to those in $K^{\pm}p$ elastic scattering and $K^{\pm}p \rightarrow Q^{\pm}p$. All of these points would be studied and should give valuable information about the characteristics of the Regge pole trajectories involved.

2. Trigger, Rates and Running Time

The trigger would be on forward going particles, other than pions, which have the opposite charge to that of the incident beams.

With isobutane the existing Sacaly counter (C_1) has a threshold for pions at 2.8 GeV/c and for kaons at 10 GeV/c. Therefore below 10 GeV/c kaons and protons would be indistinguishabe at the trigger level and would only be resolved by kinematic analysis. The proposed second Cerenkov counter (C_2) operated with a kaon threshold of about 20 GeV/c would allow kaons and protons to be distinguished between 10 and 20 GeV/c. For incident momenta above 20 GeV/c the thresholds of both counters would have to be raised in proportion to the incident momentum.

The trigger would consist of the following items:-

(i) A hydrogen interaction determined by MWPC before and after the target.

(ii) A coincidence between hodoscopes on either side of the existing atmospheric pressure Cerenkov counter C_1 indicating a particle of opposite sign to that of the incoming beam.

(iii) No count in the second Cerenkov counter C_2 if the particle passes through it. Otherwise no count in the Cerenkov counter C_1. (Kaons above the threshold for C_1 pass through C_2.)

(iv) If required to tighten the trigger, a topology requirement determined from the MWPC which will exist in Omega to select ≤ 3 forward going prongs. (Figure 1 shows how the topological cross sections for K^+p vary with incident momentum.)

Fast protons (antiprotons) and kaons would trigger the system.

Table 1 lists some cross sections for individual channels of the type which could give triggers. We estimate that the triggering cross section would be in the range 0.2 to 0.4 mb based on these numbers and existing knowledge of Omega triggers. Improved knowledge in the 10 - 14 GeV/c region will be available from present and proposed experiments on Omega at the PS and from tests we intend to perform. The triggering cross section is expected to be similar at 32 GeV/c.

In order to estimate triggering rates and running time we make the following assumptions:-

Triggering cross section	400 μb
Total beam flux	$\leq 5 \times 10^5$ per burst
Kaon flux	10^5 per burst
Beam spill	1 sec
Repetition time	10 sec
Useful hours per day	20
Plumbicon dead time	15 msec
Hydrogen target	60 cm

Under these conditions we have 0.25 events/μb/burst. The triggering

Thus we have for 7,000 bursts in one day 28,000 triggers per day or

700 events/μb/day

In a two-week run one would therefore have 10,000 events/μb.

We would wish to run at two momenta say 16 GeV/c and 32 GeV/c for both K^+ and K^- with about 10 days at each giving a total of 40 days data taking. Allowing for 10 days testing in addition this would be about 3 present PS periods. It is considered valuable to propose an extensive physics programme of this kind rather than to run at a single momentum with one type of incident particle for a shorter period.

3. Computing

The total number of triggers recorded would be in the region of 10 million, about a factor of 3 higher than a typical present day Omega experiment. If every event were analysed through the pattern recognition and geometry program this would require about 400 hours of CDC 7600 time. It is however expected that some form of fast filtering would be used to reduce this number, but nevertheless when Monte Carlo and physics analysis computing is added the amount of time required would come to several hundred hours.

4. Acceptances and biases for the meson states

Figure 2 shows the approximate layout considered for Omega at the SPS using the existing optical chambers with the addition of a drift chamber lever arm.

Except at very high masses of the meson system the particles have small angles in the laboratory and the acceptance is high. Figure 3 is an estimate of the global acceptance as a function of mass for K^+K^- pairs produced isotropically in their own centre of mass system for incident momenta of 16 and 32 GeV/c.

The principal bias comes from the low energy cut-off which must be above the pion threshold of C_1 and is given in practice by the fact that particles of lower energy are swept out of the Cerenkov acceptance by the Omega field. The cut is in the region of 3-4 GeV/c for the full Omega field of 1.8 T. The effect of the bias on K^+K^- events is to reduce the acceptance for one end of the $\cos\theta^*$ range for the decay of a resonance in its centre of mass system. Figure 4 gives an estimate of the angular acceptance for a resonance of mass 1.5 GeV/c^2 produced at 16 GeV/c.

Figure 5 shows a scatter plot of events from the reaction $K^+p \rightarrow K^+K^+K^-p$ at 10 GeV/c[2)] for masses of the three kaon system below 2.1 GeV/c^2 and $|t| < 0.8$ (GeV/c)^2. The distribution is almost identical for each kaon. We have scaled the events to 16 and 32 GeV/c and find that for masses below 2.2(GeV/c)^2 respectively 75% and 95% of the events are accepted by the trigger system.

5. Detection of slow Λs

We have performed Monte Carlo simulations to find the acceptance for slow Λs. Preliminary results show that for a typical case 25% of those decaying via the charged mode would have both tracks recognized by the pattern recognition program ROMEO.

For events where the Λ is not detected the missing mass resolution would not be sufficient to distinguish Λs and Σ^0s so we are considering adding γ detection above and below the hydrogen target at the sides of the geometry II chambers which would allow the γ-ray from Σ^0 decay to be detected in about one quarter of the cases. Since the Σ^0 are expected to have a considerably lower cross section than Λ^0 this would probably allow an adequate separation to be made.

6. Resolution

At 16 GeV/c the optical chambers alone would have just sufficient accuracy for our purposes with an error on a 1.5 GeV/c^2 K^+K^- effective mass of ± 12 MeV/c^2 and a missing mass error on the recoil particle of

± 200 MeV/c^2. The situation would be improved by the lever arm with high resolution chambers near the target to give ± 6 MeV/c^2 and ± 70 MeV/c^2. At 32 GeV/c the corresponding figures would be 10 MeV/c^2 and 150 MeV/c^2.

7. Additions required by this experiment

It may be necessary to add further hodoscope counters near the Cerenkovs and provide the necessary associated logic if these do not by that time exist. Provision of gamma ray detection (lead scintillator sandwiches) close to the target may also be desirable as discussed above. The cost would be in the region of a few hundred thousand Swiss francs.

8. Conclusion

We intend to submit a full proposal to study the kind of physics outlined in this letter. Our requirements are such that we would be able to start the experiment as soon as the RF beam and the second Cerenkov counter are available. The operation of the lever arm though very desirable would not be essential for the 16 GeV/c part of the experiment but would be required at 32 GeV/c.

References

1) Compilation of $K^{\pm}$ cross sections, CERN/HERA 72-2 (1972).

2) Birmingham-Glasgow 10 GeV/c K^+p experiment in the 2 m hydrogen bubble chamber.

Figure Captions

Fig. 1 Topological cross sections for K^+p as a function of momentum.

Fig. 2 Possible layout for the Omega spectrometer at the SPS.

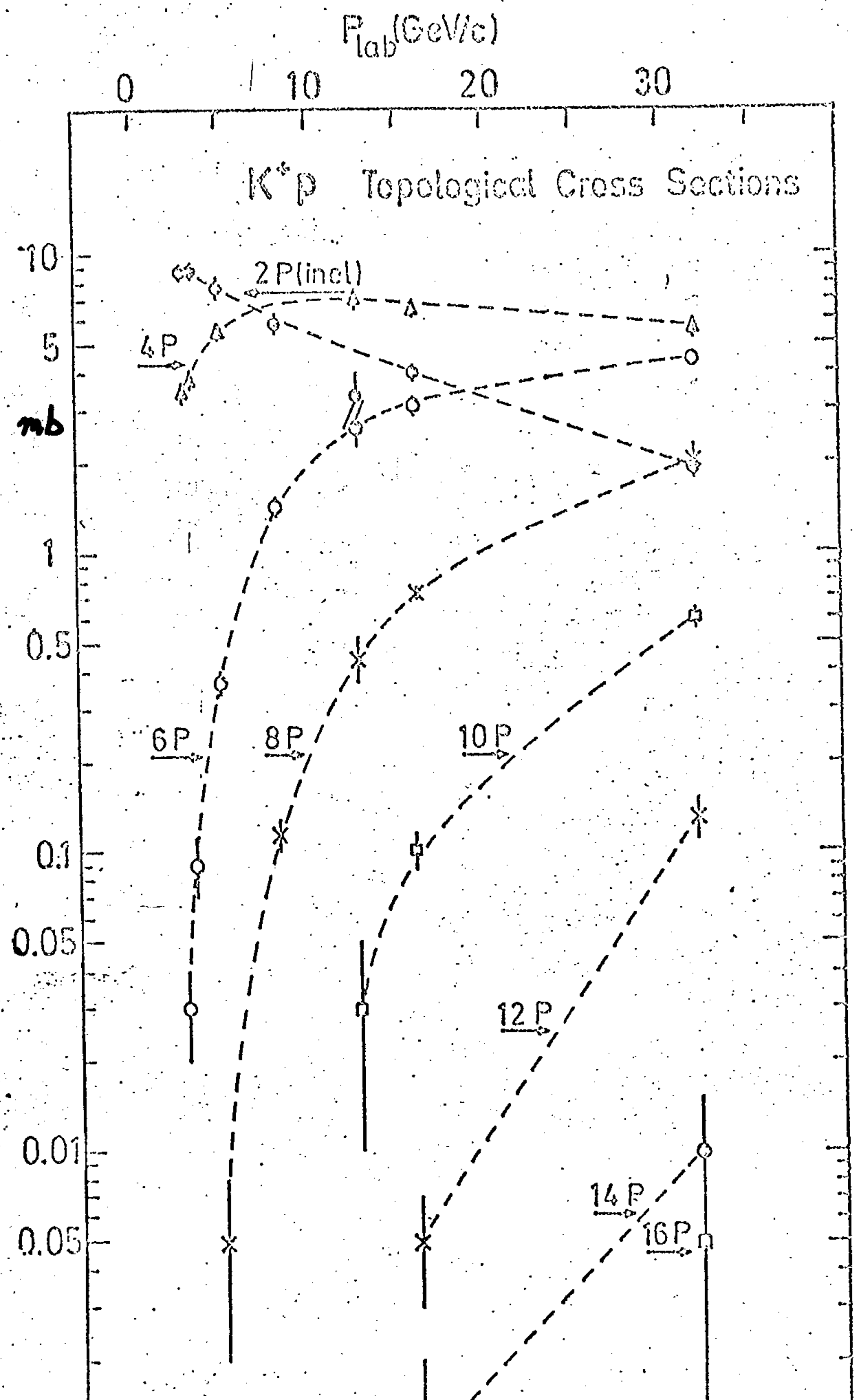
Fig. 3 Total acceptance as a function of mass for a K^+K^- system decaying isotropically in its centre of mass system at 16 and 32 GeV/c.

Fig. 4 Scatter plot of the acceptance in the centre of mass decay angles for a K^+K^- system of mass 1.5 GeV/c^2 at 16 GeV/c, and $t=-0.2(\text{GeV}/c)^2$ decaying isotropically in the Gottfried-Jackson system.

Fig. 5 Scatter plot of laboratory momentum versus laboratory angle for kaons from the reaction $K^+p \rightarrow K^+K^+K^-p$ at 10 GeV/c.

TABLE 1

REACTION	cross-section (μb) (approx.)	p_{lab}(GeV/c)
$K^+p \to K^+K^+K^-p$	35	10
$\to K^+K^+K^-\pi^0p$	27	8
$\to ppK^-\bar{\Xi}^+$	0.7	12.5
$\to p\bar{\Lambda}p$ and $p\bar{\Sigma}^0p$	8	10
$\to p\bar{\Lambda}p\pi^0$ and $p\bar{\Sigma}^0p\pi^0$	30	10
$K^-p \to K^-K^-K^+p$	27	16
$\to K^-\bar{p}pp$	5	16
$\to \Lambda^0K^+K^-$	8	10
$\to \Lambda^0K^+K^-\pi^0$	4.5	2.5
$\to \Sigma^0K^+K^-$	7	5
$\to \Sigma^-K^+K^-\pi^+$	20	5
$\to \Sigma^-K^+\bar{K}^0$	12	6
$\to \Xi^-K^+$	5	5
$\to \Xi^-K^+\pi^0$	6.3	6
$\to \bar{p}\Lambda p$	6.1	10



P_{lab}(GeV/c)
0
10
20
30
K⁺p Topological Cross Sections
10
5
mb
1
0.5
0.1
0.05
0.01
0.05
2 P(incl)
4 P
6 P
8 P
10 P
12 P
14 P
16 P

POSSIBLE LAYOUT FOR 1976

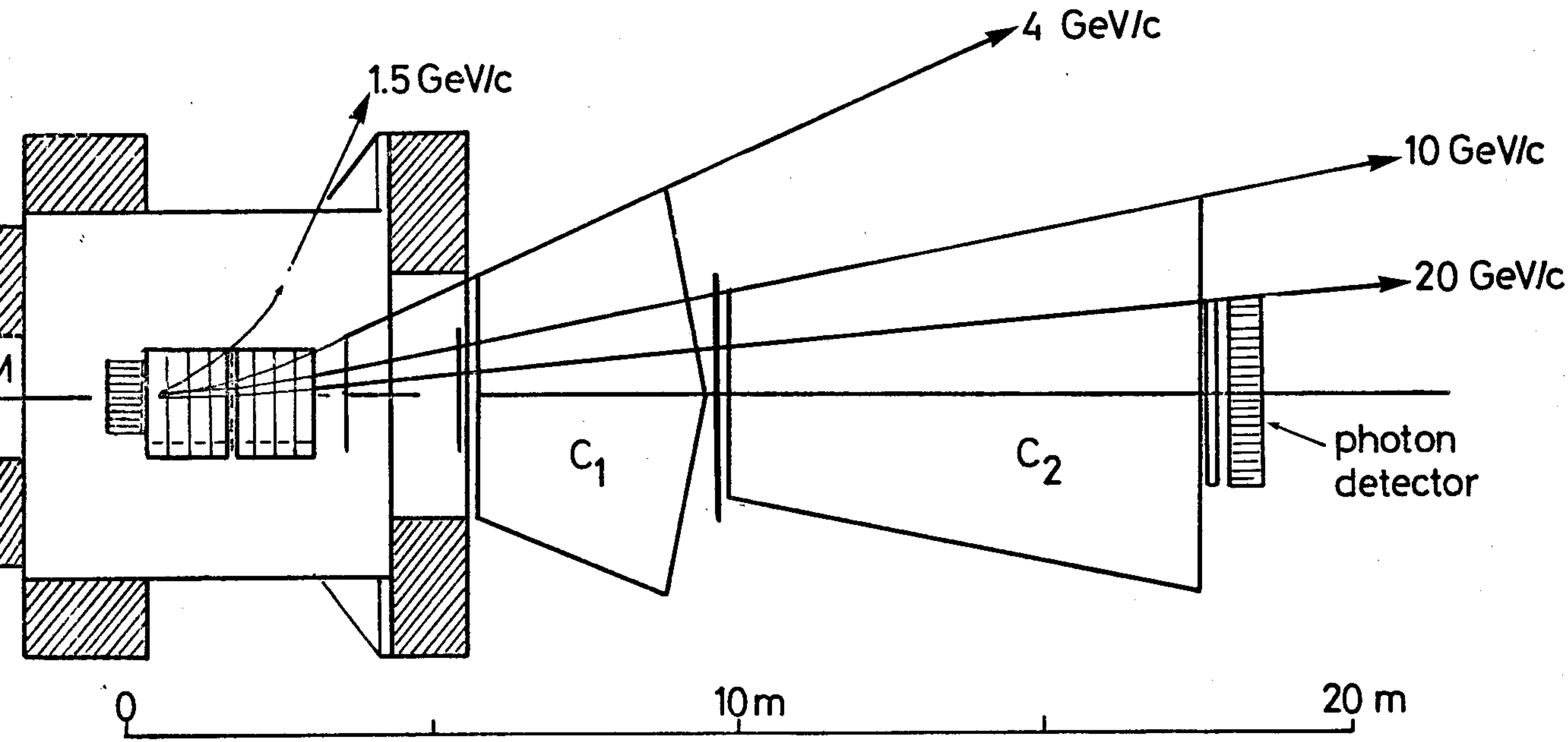


Fig. 2

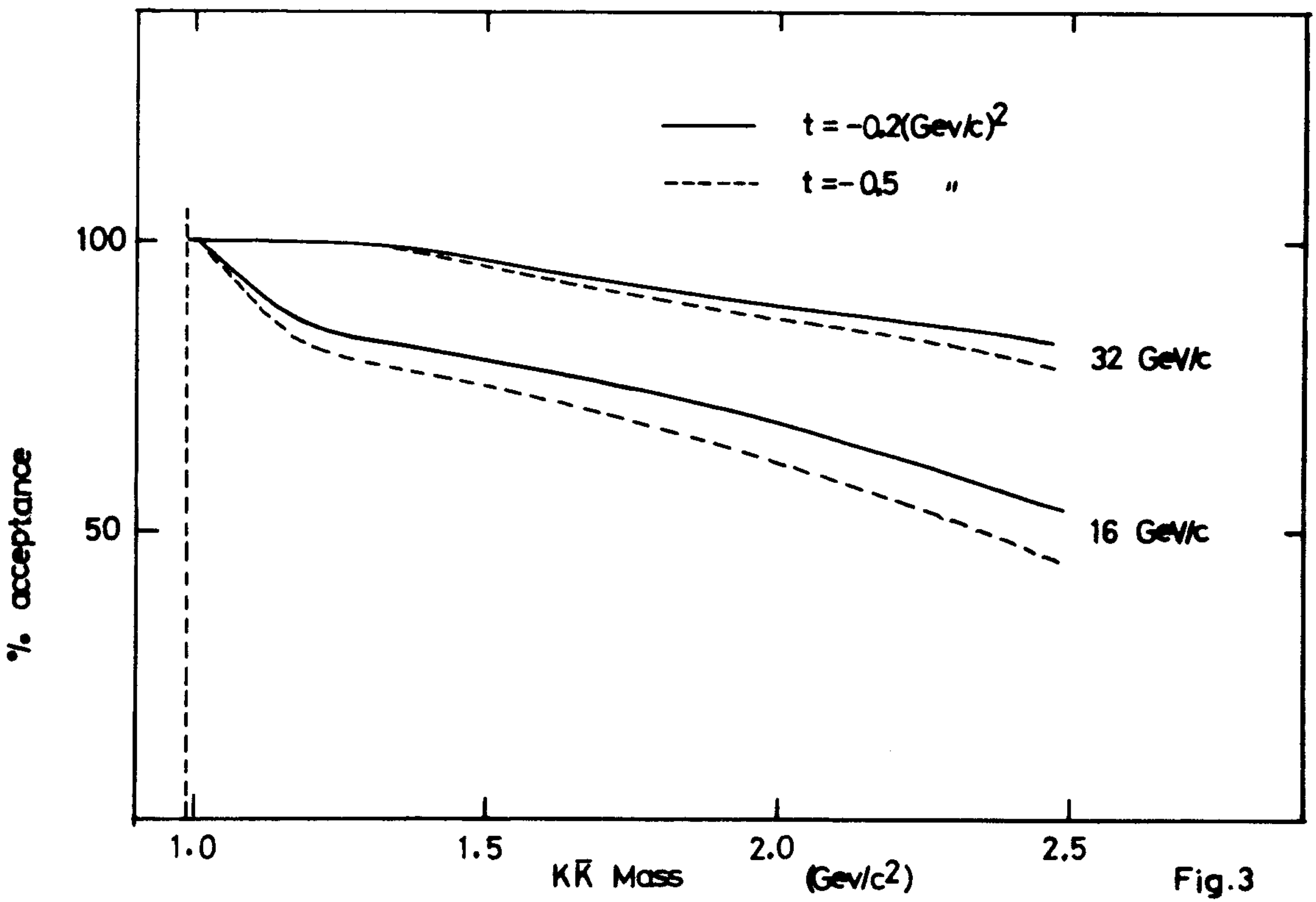

t = -0.2(Gev/c)^2
t = -0.5 "
100
50
% acceptance
32 GeV/c
16 GeV/c
1.0
1.5
2.0
2.5
KK̄ Mass (Gev/c^2)

Fig.3

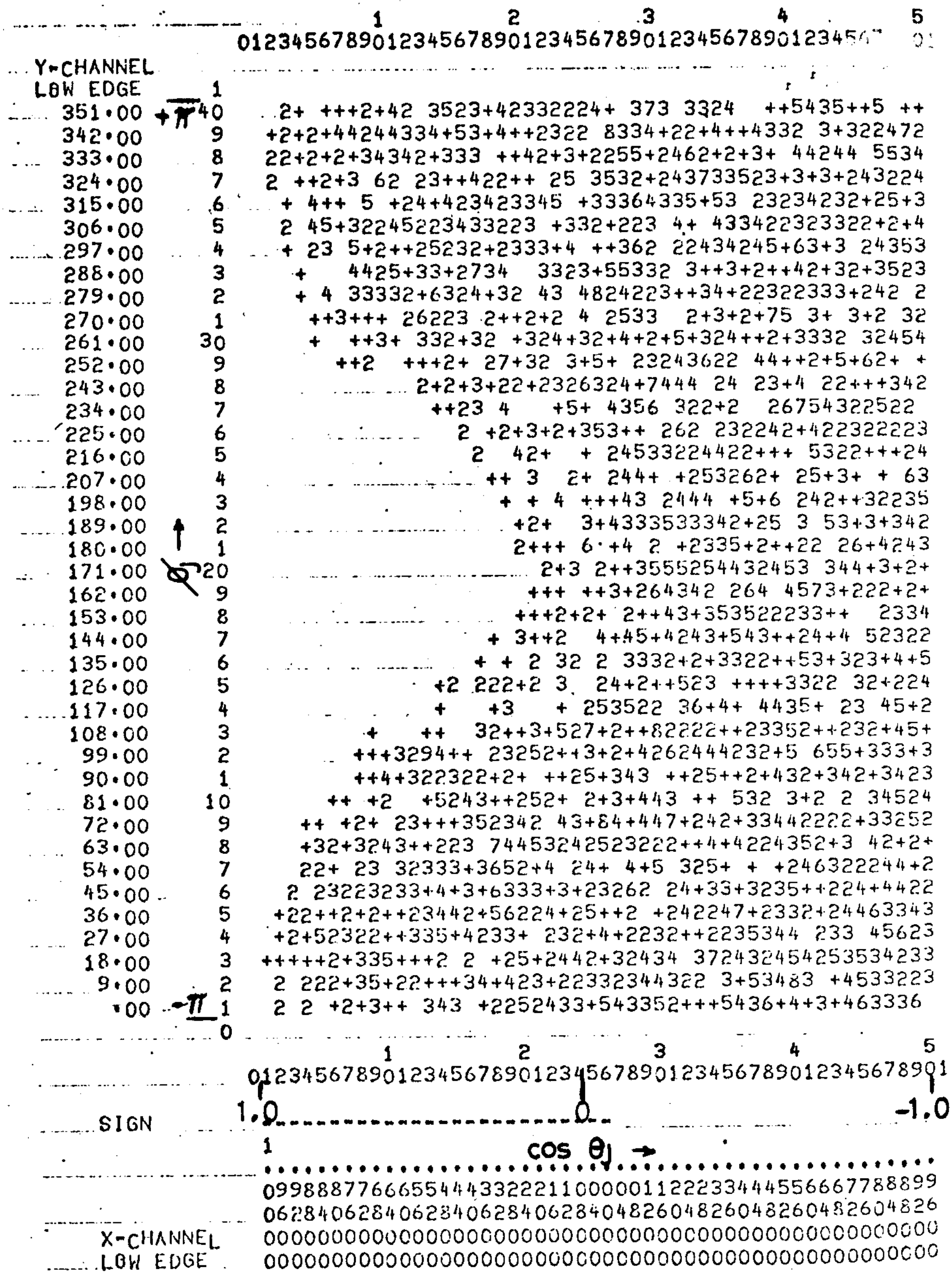
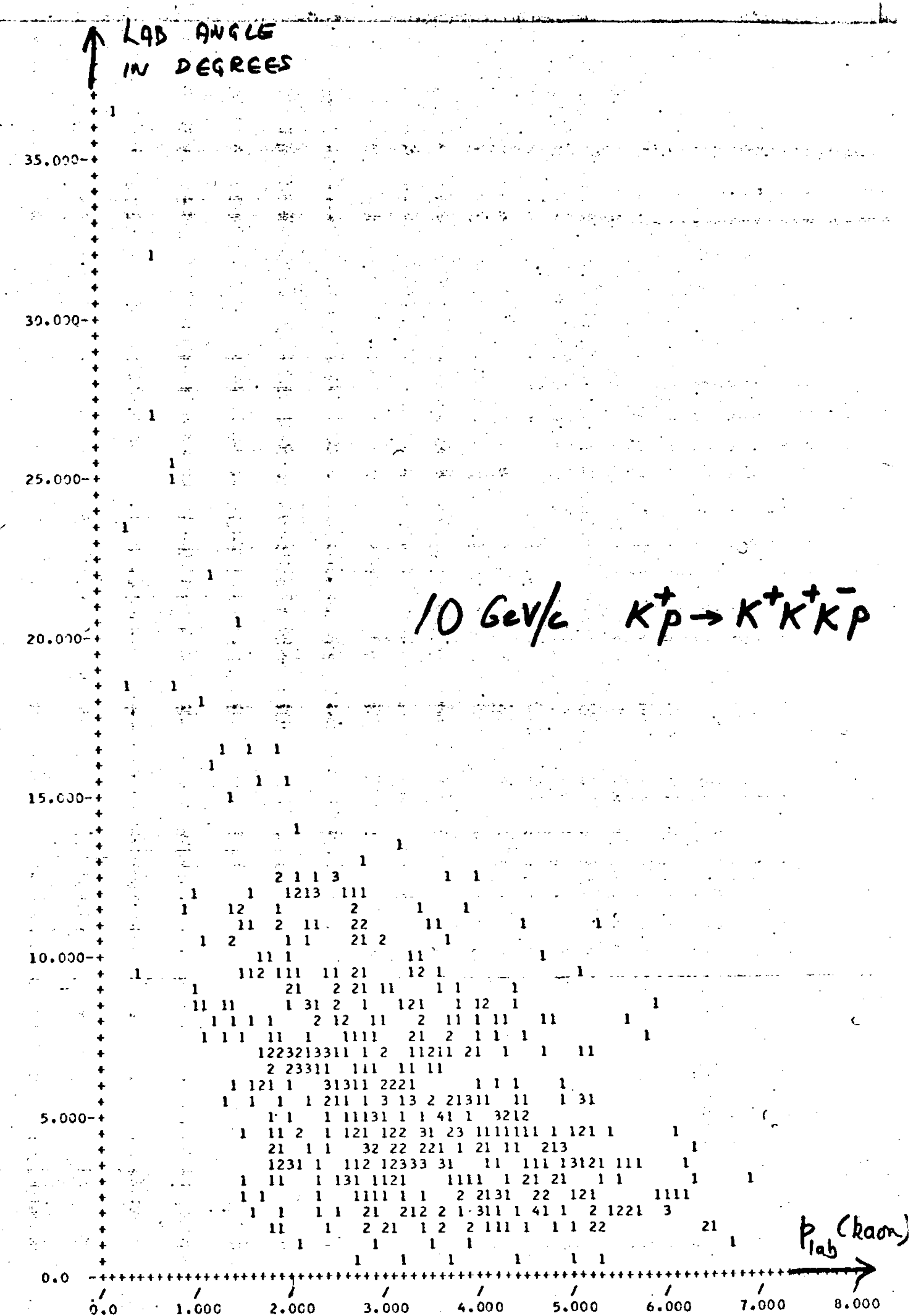


Fig. 4


LAB ANGLE IN DEGREES
35.000
30.000
25.000
20.000
15.000
10.000
5.000
0.0
0.0
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000
10 GeV/c K+p → K+K+K−p
Plab (kaon)