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PROPOSAL

To study rare meson systems produced in $K^{\pm}p$ collisions at 18 and 32 GeV/c using the RF separated beam and the Omega spectrometer at the SPS

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It is known that mesons composed mainly of strange quarks (e.g. the ϕ meson) are produced much more copiously by incident K mesons than by pions. It is proposed to exploit the RF beam and the Omega spectrometer to study the spectrum and the production mechanisms of such objects. Several thousand events per microbarn are expected. It is hard to see how such sensitivity could be achieved by other means.

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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

$$\begin{aligned} K^{\pm}p &\rightarrow K^{\mp}K^{\pm}K^{\pm}p \\ &\rightarrow \bar{p}p\ K^{\pm}p \\ &\rightarrow \Lambda\bar{p}p \text{ or } \bar{\Lambda}pp \\ \text{and}\quad K^{-}p &\rightarrow K^{+}K^{-}\Lambda \end{aligned}$$

In each case the trigger would be provided by the kaon or baryon of opposite charge to the beam particle (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 single fast π^{o}. 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. For example at 6 GeV/c the cross section for $K^{-}p \rightarrow \phi\Lambda$ is 50 times higher than the cross section for $\pi^{-}p \rightarrow \phi n$.1) 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 (32 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 enter the Č counters.

(ii) Properties of the f'

So far only about 200 f's have been reported [3] 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 $K^+p \rightarrow K^+pK^+K^-$ at 10 GeV/c is $(4 \pm 1)\mu b$ and in $K^-p \rightarrow \Lambda K^+K^-$ at 6 GeV/c is about 4 μb for seen Λ decays [2]. Thus some thousands of events should be obtained in ten days at the SPS, even allowing for the fall of the cross section with increasing primary momentum (see table 2).

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

These could be studied in 3-body reaction $Kp \rightarrow Kp\phi$, Kpf' etc. and in 2-body reactions $K^-p \rightarrow \Lambda\phi$, $\Lambda f'$ ... In the latter the polarization of the Λ would provide valuable information for amplitude analyses, and comparisons could be made with similar processes $K^-p \rightarrow \Lambda\rho$, $\Lambda\omega$, Λf^0 ... 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 values of the momentum transfer in excess of 1 $(GeV/c)^2$. Duality provides relationships between the couplings of different mesons on a given trajectory which could be checked [4].

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

$K^-p \rightarrow K\bar{K}\Lambda$ could go via K exchange (the d.m. elements for $K^-p \rightarrow \Lambda\phi$ at 4 GeV/c show strong unnatural parity exchange [5]. With the anticipated statistics this should provide one of the most promising ways of making a partial wave analysis of $K\bar{K} \rightarrow K\bar{K}$ up to high masses.

(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 in these channels. The studies of final states involving a fast π^o would make use of the forward π^o detector$^{6)}$. They are not discussed in detail in this proposal but calculations show that they are feasible.

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

$$\begin{aligned} Kp &\rightarrow Kp\bar{p}p \\ &\rightarrow \bar{p}\Lambda p \quad \text{and} \quad \bar{\Lambda}pp \end{aligned}$$

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. The spin parity structures of $\pi\pi\pi$ and $K\pi\pi$ are known to be similar$^{7)}$. It will be interesting to examine this for the 3K system.

Specific topics to be studied include:

(i) Variation of production cross-sections with energy

This will require runs at two widely spaced momenta, say 18 and 32 GeV/c (the reason for choosing the lower momentum is discussed later: there are bubble chamber data at 16 and 32 GeV/c for comparison). 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 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

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

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

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 $K^\pm p \to Q^\pm p$.$^{15)}$ All of these points would be studied and should give valuable information about the characteristics of the Regge pole trajectories involved.

2. OMEGA LAYOUT

Work is in progress at CERN to define the Omega system for use with the SPS; we are collaborating in this work. For the purpose of this proposal we have assumed the hybrid configuration considered for 1976 (see figure 1) and this is described below. Clearly the system which is built will be influenced both by the results of development work now taking place and by the needs of experiments accepted for the early years of the SPS, and cannot be specified by any single user.

The gamma-ray counters described in section 2.3 are a specific requirement of this proposal which we could provide. They should prove a useful general facility.

2.1 Chambers

The existing optical spark chamber - TV camera system would be retained. A 'lever-arm' of drift chambers (DC3 and DC4 in figure 1) will be added to improve the accuracy of the measurement of fast forward particles. A high precision co-ordinate is then needed at the hydrogen target. The TV readout has a two track resolution of ∿ 10 mm which would give problems when there are two or more fast tracks. High precision drift chambers or MWPC's will be used to measure the incident beam particle position and direction. This will give a well measured vertex position for events with a seen slow track. A high resolution, high precision chamber (DC1) after the target will provide an equivalent set of co-ordinates for events with no slow tracks but ambiguity problems may remain in associating points to tracks. It appears possible to solve this problem by adding a second high resolution high precision chamber (DC2). Recent tests suggest that drift chambers will have the required accuracy 11) (± 0.1 mm) and two-track resolution 12) (< 2 mm).

2.2 Čerenkov Counters

The trigger for this proposal is on forward going particles and is required to accept kaons, protons or antiprotons and reject pions from low momenta up to close to the incident beam momentum (see section 2.4 below). This can be accomplished at 18 GeV/c by running with two atmospheric pressure threshold Čerenkov counters. The first, containing neopentane, gives thresholds of 2.3 GeV/c for pions and 8.2 GeV/c for kaons, so can be used to accept kaons and reject pions between these limits. Above 8 GeV/c the particles must pass through a second Čerenkov counter. The second, containing methane, gives thresholds of 4.7 GeV/c and 16.7 GeV/c, and can be used to reject the high momentum pions without loss of kaons. (Pulse height discrimination can be used to avoid any loss of kaons that are just above threshold.)

A large aperture Čerenkov counter (Č1 in figure 1) already exists and has been used successfully at Omega. It is currently suggested that a second, longer, atmospheric pressure counter (Č2) should be built for use with the SPS. The combination of these two is sufficient for this proposal with no very stringent requirements on the new counter. However, at 18 GeV/c we should like to use a shortened version of $\check{C}_2$ displaced from the Omega axis as shown in figure 1. For 18 GeV/c running we would also need the largest possible acceptance in the vertical plane (∿ ± 1500 mm at the mirror plane) which could present some complications with a beam height of 2060 mm at Omega.

For 32 GeV/c running we would raise the thresholds in the counters. Methane in the first counter (threshold $\pi(K) = 4.7$ (16.7) GeV/c) would be followed by hydrogen in the second (threshold $\pi(K) = 8.5$ (30) GeV/c). Pions below 4.7 GeV/c can be suppressed using a coincidence matrix between scintillation counter hodoscopes (see section 2.4). This also reduces the acceptance for wanted particles.

An alternative possibility would be the construction of a third threshold Čerenkov counter. A thin counter (1500 mm in the incident particle direction) similar to that described by Badier et al.[8)] for the North Area Spectrometer could be placed immediately after the Omega magnet. This could fulfil the function of Č1 for 18 GeV/c running leaving it free for use as the higher threshold counter instead of modifying Č2. For 32 GeV/c running the thin counter could be used to reject pions down to 2.3 GeV/c without loss of kaons of the same momenta.

2.3 Gamma-ray Counters

In order to help in distinguishing slow Λs from slow Σ^os and to signal events with slow neutral pions we are proposing to add γ-ray detectors above and below the hydrogen target in between the geometry II modules and at the side of these modules as indicated in figure 2. The counters would consist of lead-scintillator sandwiches of about 6 radiation lengths and would be of modular construction to give some positional information. They would be used to flag γ-rays. The counters would all be 1 m long in the beam direction. Those above the target would be 18 cm wide and 15 cm from the beam while those at the side would be 120 cm high and 70 cm from the beam. With a 30 cm target about 40% of the γ-rays from Σ^o decays would be detected and in about 60% of the cases at least one γ-ray from the decay of a slow π^0. We are studying the possibility that shower products from the counters above and below the target could give background in the spark chambers. This could lead to a change in the geometry described above.

It would be an advantage to have some form of detection for charged particles not detected by the geometry II chambers above and below the hydrogen target. A cylindrical MWPC would be ideal if it could be provided.

2.4 The Trigger

The trigger would be on forward going particles, other than pions, which have opposite charge to that of this incident beam. It would consist of the following items:-

(i) A hydrogen interaction determined by MWPC before and after the target and/or by scintillation counters surrounding the target.

(ii) A coincidence between hodoscopes on either side of the Čerenkov counter $\check{C}_1$ indicating a particle of opposite sign to that of the incoming beam. A coincidence matrix will be used to reject low momentum pions.

(iii) No count in the second Čerenkov counter $\check{C}_2$ if the particle passes through it. Otherwise no count in the Čerenkov counter $\check{C}_1$. (Kaons above the threshold for $\check{C}_1$ pass through $\check{C}_2$.) This will require a hodoscope behind $\check{C}_2$.

(iv) If needed to tighten the trigger a topology requirement from MWPCs which will exist at Omega to reject high multiplicity events. A test run showed that about 30% of the events had 6 or more prongs.

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

3. PERFORMANCE OF THE APPARATUS

3.1 Acceptance

The geometrical acceptance of the apparatus for the produced mesons has been studied using a Monte Carlo program, for $K^-p \rightarrow K^+K^-\Lambda(\Sigma^0)$, $K^-p \rightarrow \bar{p}p\Lambda(\Sigma^0)$ and $K^\pm p \rightarrow K^\mp K^\pm K^\pm p$ at 18 GeV/c and 32 GeV/c where the triggering particle passes through one or both Cerenkov counters. Figure 3 shows the acceptance for the K^+K^- system and the $\bar{p}p$ system as a function of their invariant mass for $|t| = 0.2$ $(\text{GeV/c})^2$. The acceptance is only at 32 GeV/c but the cross sections may be too small in these channels for detailed analyses at this momentum.

The dependence of the acceptance on the decay angles θ and ϕ in the Gottfried-Jackson system is shown in figure 5 for a $K\bar{K}$ mass of 1.5 GeV/c^2 and two t values at 18 GeV/c. There is a loss of events at one end of the θ angular distribution caused by low momentum particles not reaching the rear hodoscopes. The shape of the hole varies with t. It has, however, been shown possible to perform spin-parity analyses with considerably worse acceptance$^{9)}$.

The acceptance for slow Λs has been studied using the simulation program SIMEGA with subsequent analysis by the pattern recognition and geometry program ROMEO. Both prongs from the charged Λ decay are found about 25% of the time and about 80% of the time one of the two prongs is seen. Assuming that a polarization analysis will be possible only for fully seen Λs only one sixth of the events would yield this information. There are no strong biases of the Λ decay relative to its production plane.

Figure 6 shows the total acceptance for three-kaon events produced with an e^{6t} t-dependence at 18 GeV/c and 32 GeV/c. In figure 7 we show the Dalitz plot for the three kaons having a mass of 3.5 GeV/c^2 for an incident momentum of 32 GeV/c assuming isotropic distributions in the decay angles. The acceptance is uniform and high. The acceptance remains uniform for lower masses and for the lower momentum.

To describe the decay of the three-kaon system of fixed mass at a given t it is necessary to specify another angle γ in addition to the angles θ and ϕ and the Dalitz plot coordinates M_{12}^2 and M_{13}^2. If we define θ and ϕ as the angles of the odd kaon (the trigger particle) in the C of M system of the three kaons in the Gottfried-Jackson frame then γ describes the direction of one of the other kaons in this system$^{10)}$ (see figure 8). Since this particle is limited only by the overall geometrical acceptance of the Omega the biases in the angle γ are much smaller than in the θ, ϕ angles which refer to the trigger particle and are therefore limited by the Čerenkov counter acceptance. For these angles the acceptance is very similar to the case for the two body decay at a similar Q-value. The acceptance is very good at 32 GeV/c and since for the diffractive channel the cross section should not be strongly s-dependent this would be the best momentum at which to attempt a complete angular analysis.

3.2 Resolution

In order to estimate the momentum resolution of the hybrid system we have used the curves presented by Sonderegger 13) for the arrangement shown in figure 1. These assume a point accuracy for 6-plane drift chamber module of ± 0.15 mm which seems feasible in view of figures mentioned in 2.1. Multiple scattering limits the momentum resolution to about ± 0.35%. For the optical chambers alone measurement error begins to dominate above 5 GeV/c while for tracks which pass through one or both of the downstream drift chamber modules this limit is reached for momenta of 20 GeV/c and 30 GeV/c respectively.

For events having a K^+K^- pair passing through the whole system the corresponding effective mass resolution for a K^+K^- mass of 2.0 GeV/c^2 is ± 7 MeV/c^2 at 18 GeV/c and ± 9 MeV/c^2 at 32 GeV/c.

The missing mass resolution has been calculated using a Monte-Carlo method for the reactions $K^-p \rightarrow K^+K^-\Lambda(\Sigma^o)$ and $K^-p \rightarrow \bar{p}p\Lambda(\Sigma^o)$ assuming an isotropic decay of the K^+K^- or $\bar{p}p$ system. Figure 9 shows the situation at 18 GeV/c and 32 GeV/c for the $K^+K^-\Lambda$ reaction. The curves for $\bar{p}p\Lambda$ are similar.

In the above calculations we have assumed the momentum of the incident beam particle will be measured to ± 0.1%.

3.3 Particle Identification

Since the reactions leading to K^+K^- or $\bar{p}p$ with a recoil Λ or Σ^o have cross sections about two orders of magnitude lower than reactions which produce $K^-\pi^+$ with a recoil neutron, N^{*o} or Δ^o it is important that the efficiencies of the Čerenkov counters for detecting pions should be high. At most an inefficiency of 1 or 2 parts in 10^4 can be tolerated to keep the contamination from misidentified $K\pi$ events at a reasonable level (∿ 1%). The existing counter C_1 produces on average about 18 photo-electrons for $\beta = 1$ when filled with isobutane and easily satisfies this requirement but problems can arise with pions which interact before the Čerenkov. Care must also be taken with the electronics to avoid dead time effects. Furthermore a hodoscope behind the Čerenkov must be used to check that a particle emerged in the correct position.

The problem of confusing $\pi^+\pi^-$ pairs with K^+K^- pairs is much less severe since their cross section is only 4 times higher and the contamination should therefore be negligible.

The thresholds of the counters have been chosen to distinguish $K^+K^-\Lambda$ from $p\bar{p}\Lambda$. If the triggering particle is a kaon above threshold in C_1 it is identified directly. If the trigger kaon is below threshold in C_1 then the second kaon is above threshold and passes through the counter. In all cases protons and antiprotons will be below threshold and would only count by producing interactions or δ-rays. Therefore the amount of contamination of K^+K^- by $\bar{p}p$ should be less than 1% while the contamination of $\bar{p}p$ by K^+K^- could be a few % (due to Čerenkov inefficiency for Ks near threshold) if no requirement is imposed from kinematics.

For the three body channel there will be the problem of confusing $K^\pm p \rightarrow K^\mp K^\pm K^\pm p$ with $K^\pm p \rightarrow K^\pm \bar{p}pp$. All three kaons can have momenta below the kaon threshold of both counters meaning that the reactions can only be resolved by kinematics. This is discussed in the next section.

The inefficiency of the Čerenkov counter can also give triggers on pions from $K^\pm\pi^+\pi^- p$. If both pions are above threshold in C_1 the rate will be negligible. The relatively high cross-sections for these reactions (∿ 30 – 40 times the $K\,K\bar{K}$ cross-sections[2)]) places a similar but less severe requirement on the Cerenkov performance to that discussed above for $K\pi$ events.

For the final states $\bar{\Lambda}pp$ and $\Lambda\bar{p}p$ it is the decay baryon from the $\bar{\Lambda}$ or Λ which triggers. The observation of a V^o vertex will make these processes easily identified. If the Λ or $\bar{\Lambda}$ decay vertex is inside the target then the fast proton or antiproton from its decay will share most of the energy with the accompanying fast antiproton or proton produced in the reaction and the processes should be identifiable provided the pion track from the Λ or $\bar{\Lambda}$ decay is seen to allow the Λ or $\bar{\Lambda}$ to be reconstructed.

3.4 Background Considerations

The backgrounds arising from pion misidentification have been discussed in the last section. The main problem in the $K^+K^-\Lambda(\Sigma^0)$ and $\bar{p}p\Lambda(\Sigma^0)$ channels is the Λ-Σ^0 ambiguity. For the 25% of the cases where both Λ prongs are seen a 4-constraint fit will limit the number of falsely fitted Σ^0 events to about 4% of the Σ^0s by transverse momentum balance. Because of the lower cross section for Σ^0s the contamination of Λ events from misfitted Σ^0s will be at the 1% level. Events with seen Λ decays failing the Λ hypothesis will be fitted to the Σ^0 reaction as 1-constraint fits. From the expected missing mass resolution we expect a fairly clean sample of Σ^0 events will be obtained this way. However 40% of the Σ^0 events will have a detected γ-ray which should yield a well-identified Σ^0 sample.

Figure 10 shows curves of missing mass to the K^+K^- for Λ, Σ^0 and Y^*_{1385} events at 18 GeV/c in which the Σ^0 and Y^* are each assumed to have one fifth of the cross section for Λ events[14].

If the Λ decays neutrally or if neither prong is observed then the missing mass resolution will not allow an adequate separation of Σ^0 and Λ to be made from missing mass alone. The γ-detectors will not help since γ-rays will be produced from the neutral Λ decay as well as from the $\Sigma^0 \rightarrow \Lambda\gamma$ decay. However in the 80% of the cases where one of the prongs from the Λ decay is seen a detected γ-ray can only come from the Σ^0. The hatched area on figure 10 shows the fraction of Σ^0 missing events with a detected γ-ray. It should be possible to use this identified sample of Σ^0s to correct the missing mass spectrum and obtain the number of Λ events at each value of K^+K^- mass and four-momentum transfer t. The resolution should be good enough to prevent backgrounds from events with an additional π^0 from being serious for $K^+K^-\Lambda$ but $\Lambda\pi^0$ below the Y^*_{1385} could cause difficulty in extracting $K^+K^-\Sigma^0$. For the $\bar{p}p$ channel the arguments are identical.

Because of the worse missing mass resolution at 32 GeV/c we have assumed that the separation of Λ and Σ^0 events will only be reliable at 18 GeV/c. It will nevertheless be possible to study the K^+K^- and $\bar{p}p$ mass spectra and angular distributions at 32 GeV/c provided the cross sections are high enough.

For the $K^{\mp}K^{\pm}K^{\pm}p$ and $K^{\pm}\bar{p}pp$ channels we have already mentioned that there will be many cases where the three forward particles cannot be uniquely identified by the Čerenkovs. There will be no difficulty in separating the two reactions in cases where the slow recoil proton is observed ($|t| > 0.06$ $(\text{GeV/c})^2$) by energy balance in the 4-C fit. When the slow proton is not observed there should still be a reasonable chance of separating the reactions using missing mass, information from the γ-detector and events where the kaons are identified by the Čerenkovs, at least to the extent of allowing $\frac{d\sigma}{dt}$ to be examined down to lower values of t.

4. TRIGGER RATES AND RUNNING TIME

We have carried out a test in order to estimate the triggering rate using 12 GeV/c K^- and a 30 cm long hydrogen target. The K^- induced reaction is a more critical test because the outgoing protons are more numerous than the antiprotons in the corresponding K^+ induced reaction. The low pressure Čerenkov counter contained isobutane (effective pion threshold = 3.0 GeV/c). A cylindrical scintillation counter surrounding the target and an end counter with a 2 cm diameter hole were used to indicate an interaction, and hodoscopes on either side of the Čerenkov counter defined the triggering particle with a coincidence matrix. The observed triggering cross section was 750 ± 30 μb. However, only two thirds of the analysed events had a triggering particle whose momentum was above the threshold momentum for pions. The other one third either had no charged particle in Omega which would have passed through the counter (∿ 20%) or a trigger particle (probably a pion) below 3 GeV/c (∿ 10%). About 30% of the good triggers had 6 or more prongs. Only 5% of the triggers were due to interactions in the spark chamber plates.

For the proposed experiment at 18 GeV/c we shall have a lower pion threshold (2.3 GeV/c) using neopentane. We would therefore expect to reduce the number of pion induced triggers since a smaller fraction of the pions will be below threshold. Assuming we can reduce the number of false triggers and high multiplicity event triggers we hope to be able to achieve a trigger cross section of 400 μb.

For incident K^+ the situation will be better because one triggers from a $\bar{p}$ or a K^-. At 32 GeV/c we assume the same triggering cross sections as at 18 GeV/c. In table 1 we list some cross sections for individual processes of the type which can trigger the system from which relative yields can be estimated.

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	2×10^5 per burst
Beam spill	1 sec
Repetition time	10 sec
Useful hours per day	20
Plumbicon dead time	15 msec
Hydrogen target	30 cm

Under these conditions we have 0.25 events/μb/burst. The triggering cross section therefore gives 100 events per burst which saturates the data taking rate giving an actual event rate with dead time of 40 triggers per burst.

Thus we have for 7,000 bursts in one day 280,000 triggers per day or

$$\boxed{\text{700 events/μb/day}}$$

We would wish to run at two momenta, 18 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. Estimated event rates are given in Table 2.

5. DATA ANALYSIS AND COMPUTING REQUIREMENTS

Some development of the pattern recognition programs will be necessary to handle the data from drift and optical chambers. The changes should be relatively straight-forward for incident charged particles where the incident trajectory is accurately measured since this will give important constraints on the vertex position.

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. Since the SPS programs are not yet written it is difficult to be more precise.

We would expect to do the bulk of the computing on the Rutherford Laboratory's IBM 360/195 computer (say 750 hours spread over 3 years) but would wish to analyse about 10% of the data at CERN. We have working facilities at Birmingham using the IBM 370/145 for the display and recovery of events from the optical spark chambers which fail the pattern recognition and geometry programs.

6. COST, MANPOWER AND TIMESCALE

We would expect to provide the γ-detectors mentioned in section 2.3 at a cost estimated to be in the region of SF 350,000. Appendix 1 gives a breakdown of this cost and an estimate of the manpower involved in manufacturing the lead-sandwiches and light guides. We would hope to construct a test counter at the Rutherford Laboratory (1/30th of the total device) within the next six months. If necessary the final counters could be assembled by an outside manufacturer.

We may wish to add additional hodoscope counters behind C_2 costing SF 200,000 if these are not otherwise provided. These would be straightforward scintillatoion counters of standard design.

Miscellaneous electronic equipment could amount to a further SF 100,000 bringing the total cost to SF 650,000.

We are prepared to contribute 1 man year to the central hardware effort involved in the preparation of Omega for the SPS and 1 man year to the central software effort. We would need to have 3 people resident at CERN for about a year including the data taking period of the experiment with the other members commuting as required.

We expect to be ready to start the experiment as soon as the SPS beams are available, provided the Omega is equipped with the lever arm drift chambers and the second Čerenkov counter. Even if the RF separators are not ready we consider it useful to take some data with unseparated K^- for test purposes.

7. OTHER REMARKS

The addition of a third Čerenkov counter (1.5 m thick) in front of the present one would improve the acceptance especially for high mass events, and a cylindrical MWPC surrounding the target to detect charged particles not seen by the chambers would be a useful feature.

As described the experiment is limited by the data taking rate of the Omega spark chamber system. Rates a few times higher would be achieved if Omega were equipped with automatic wire chambers.

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10. Addendum to the proposal to study rare decays of mesons using the Omega spectrometer. Bari, Bonn, CERN, Daresbury, Glasgow, Liverpool, Milan, Purdue, Vienna Collaboration. CERN/EEC 74-11 (1974).

11. A. Breskin et al. "Further results on the operation of high accuracy drift chambers", Nuclear Instr. Methods (1974).

12. M. Atkinson, F. Sauli, G. Schultz "Double track separation in drift chambers", OM/SPS/57 Development note 1974.

    The measurements referred to in 11) and 12) were made on a 50 cm^2 chamber outside a magnetic field but are expected to be valid inside the field for a chamber of this size.

13. P. Sonderegger, "Status report on the plans for Omega at the SPS; talk given to an SPS open meeting on March 26th 1974 (unpublished).

14. The cross-section ratios between Λ, Σ^o and Y^*_{1385} production are based on low energy data (see references 1, 2 and 3) and may not extrapolate to 18 GeV/c.

15. For a review of diffractive phenomena see D.W.G.S. Leith, Proceedings of the XVIth International Conference on High Energy Physics, Vol. 3, 321 (1972).

TABLE 1

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

TABLE 2

Reaction		Estimated cross-section (*) (μb)		Events expected in 10 day run (x 10^3)	
		18 GeV/c	32 GeV/c	18 GeV/c	32 GeV/c
$K^+p \rightarrow K^-K^+K^+p$	†	27.5	22.0	192	154
$\rightarrow \bar{p}pK^+p$	†	2.3	1.8	16	13
$\rightarrow \bar{\Lambda}pp$	†	3.2	2.5	22	17
$K^-p \rightarrow K^+K^-K^-p$	†	25.7	20.5	180	143
$\rightarrow p\bar{p}K^-p$	†	4.8	3.8	34	27
$\rightarrow p\bar{p}\Lambda$	§	1.9	0.6	13	4.2
$\rightarrow K^+K^-\Lambda$	§	2.6	0.8	18	5.6
$\rightarrow K^+K^-\Sigma^o$	§	0.5	0.2	3.5	1.4

* The reactions labelled † are assumed to be diffractive with $\sigma \propto p_{lab}^{-0.4}$; for the reactions labelled § it is assumed that $\sigma \propto p_{lab}^{-2.0}$ which is consistent with existing data.

Money from [illegible]

APPENDIX 1

Details of the γ-counters

We envisage about 30 identical counters each having an area of 10 x 100 cm^2 consisting of 6 layers of 6 layers of scintillator and lead. A timing measurement would be used to determine the position along a counter. The cost would be approximately the following:-

			SF
Phototube, base, discriminator delay box cables and sockets	2,500 x 30	=	75,000
ADCs, TDCs and pattern units			70,000
High voltage supplies, resistor units, racks			25,000
Scintillator and Lead			50,000
Light guides (including labour)			70,000
Mounting etc.			60,000
			350,000

Approximately 2,000 man hours are estimated for constructing the counters.

FIGURE CAPTIONS

Figure 1. The layout of the hybrid optical spark chamber and drift chamber system foreseen for Omega at the SPS. Also shown are the threshold Cerenkov counters C_1 (already existing) and C_2.

Figure 2. Possible arrangement of gamma ray counters around the Geometry II chambers.

Figure 3. Total acceptance as a function of mass for a K^+K^- pair and a $\bar{p}p$ pair decaying isotropically in their centre of mass system at 18 GeV/c and 32 GeV/c with $t = - 0.2\ (\text{GeV/c})^2$.

Figure 4. t-dependence of the acceptance for various masses of the K^+K^- and $\bar{p}p$ systems.

Figure 5. 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 18 GeV/c decaying isotropically in the Gottfried-Jackson system for $t = t_{min}$ and $t = - 0.2\ (\text{GeV/c})^2$.

Figure 6. Total acceptance for three-kaon events produced with an e^{6t} t dependence at 18 GeV/c and 32 GeV/c.

Figure 7. Dalitz plot for the three kaon system having a mass of 3.5 GeV/c^2 produced at 32 GeV/c. The percentage acceptance on the folded plot is given.

Figure 8. Description of the angular coordinates used to specify the three-kaon system.

Figure 9. Missing mass to the K^+K^- pair in the reaction $K^-p \rightarrow K^-K^+\Lambda$ at 18 GeV/c and 32 GeV/c.

Figure 10. Missing mass to the K^+K^- pair in the reactions $K^-p \rightarrow K^-K^+\Lambda$ and $K^-p \rightarrow K^-K^+\Sigma^0$ at 18 GeV/c where the Σ^0 cross section is taken to be one fifth of the Λ^0 cross section. The hatched area shows the fraction of Σ^0 events in which a γ-ray will be detected.

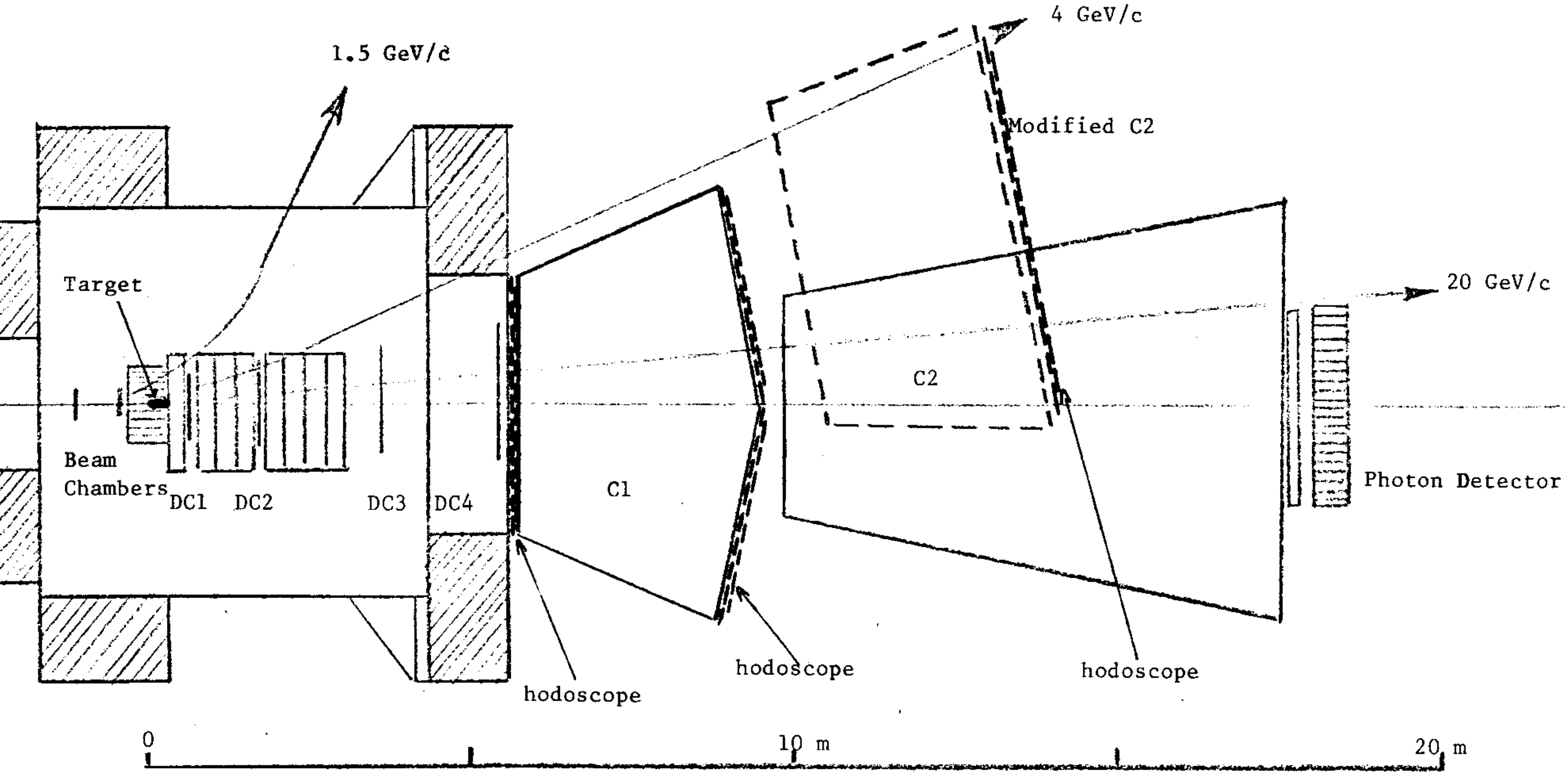

1.5 GeV/c
4 GeV/c
Modified C2
20 GeV/c
Target
Beam
Chambers
DC1
DC2
DC3
DC4
C1
C2
Photon Detector
hodoscope
hodoscope
hodoscope
0
10 m
20 m

FIGURE 1.

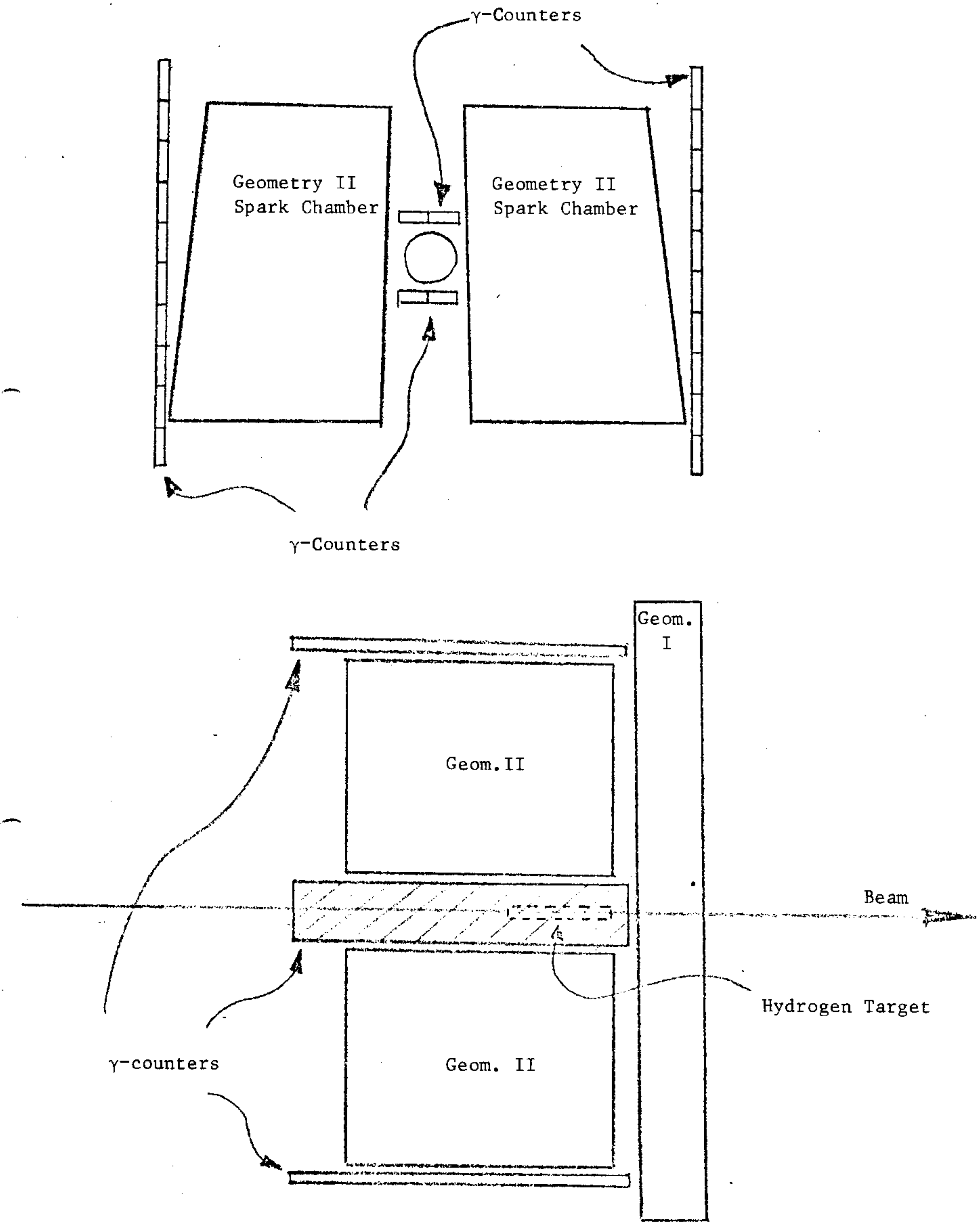

γ-Counters
Geometry II
Spark Chamber
Geometry II
Spark Chamber
γ-Counters
Geom.
I
Geom. II
Beam
Hydrogen Target
γ-counters
Geom. II

FIGURE 2.

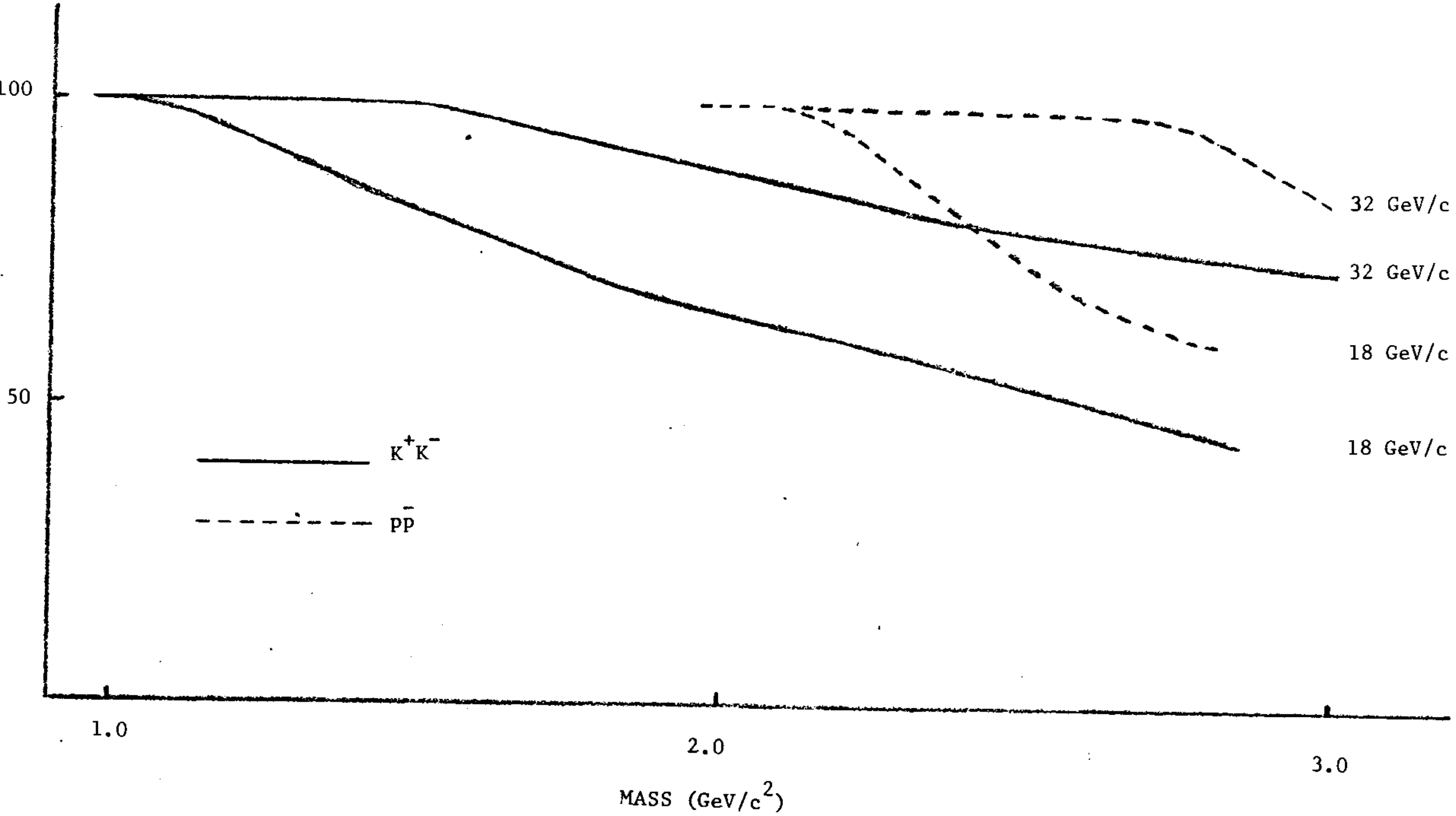

100
50
1.0
2.0
3.0
MASS (GeV/c^2)
K$^+$K$^-$
p$\bar{p}$
32 GeV/c
32 GeV/c
18 GeV/c
18 GeV/c

FIGURE 3.

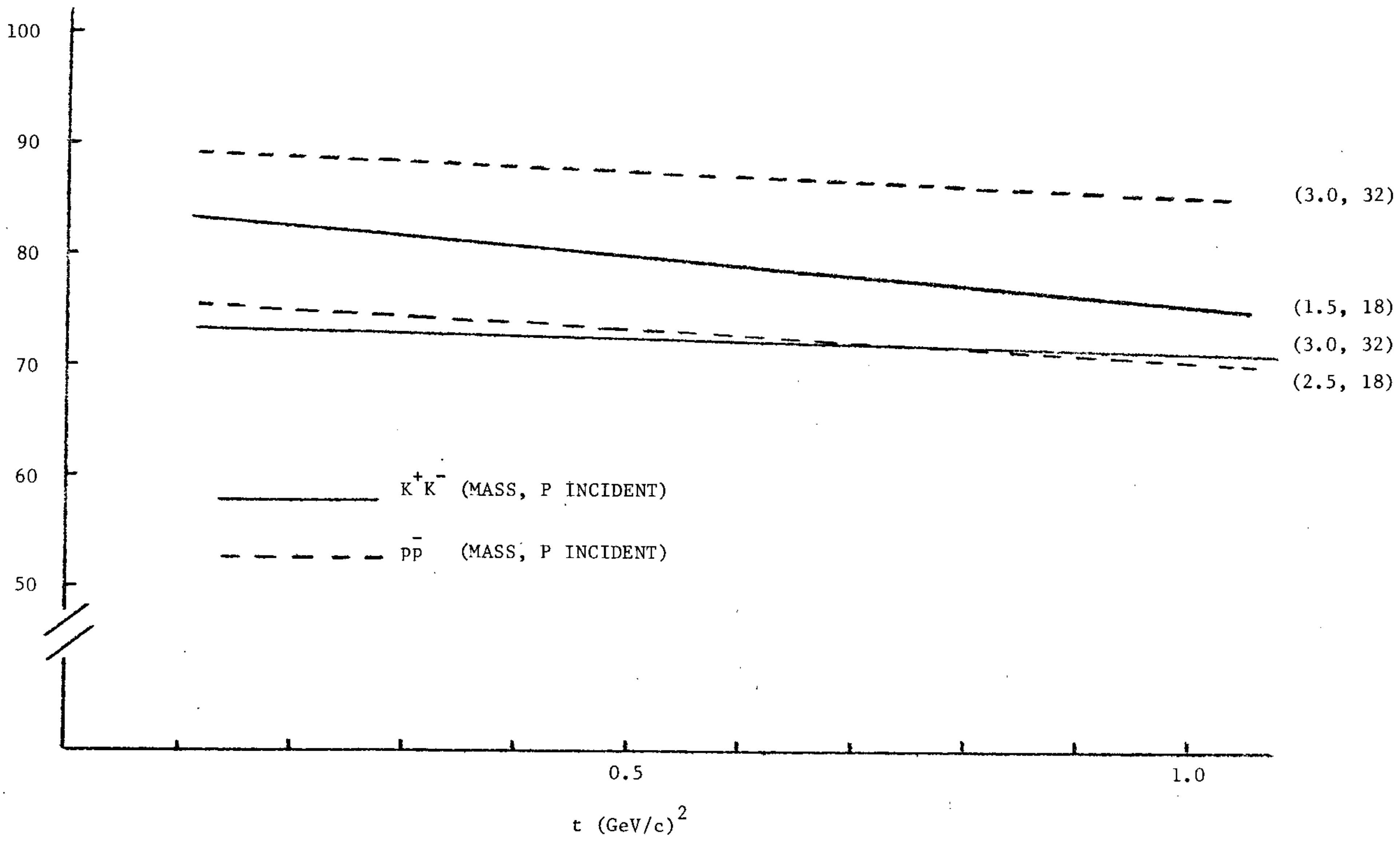

100
90
80
70
60
50
(3.0, 32)
(1.5, 18)
(3.0, 32)
(2.5, 18)
K^+K^- (MASS, P INCIDENT)
$p\bar{p}$ (MASS, P INCIDENT)
0.5
1.0
t $(GeV/c)^2$

FIGURE 4.

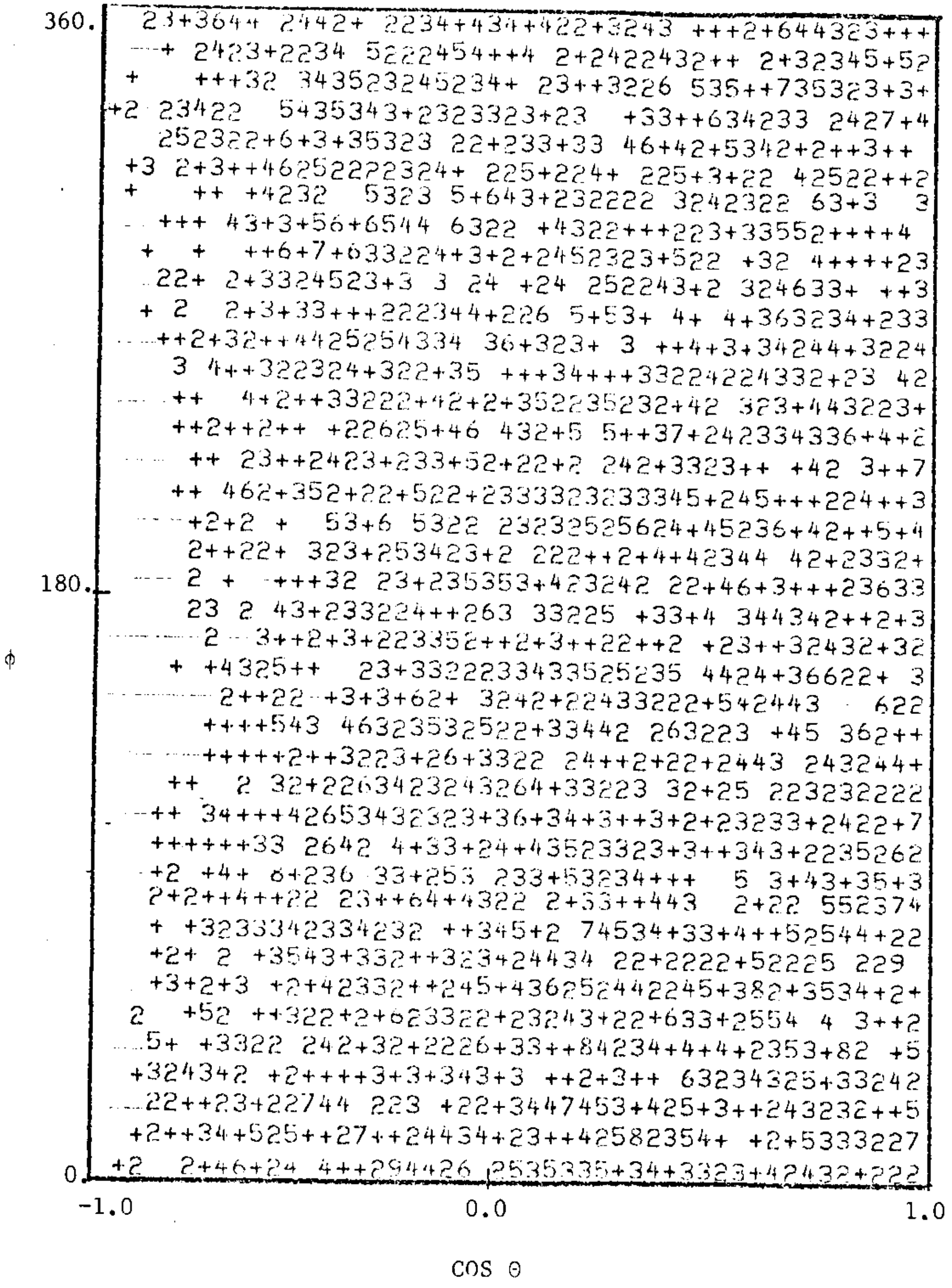


FIGURE 5a $t = t_{min}$

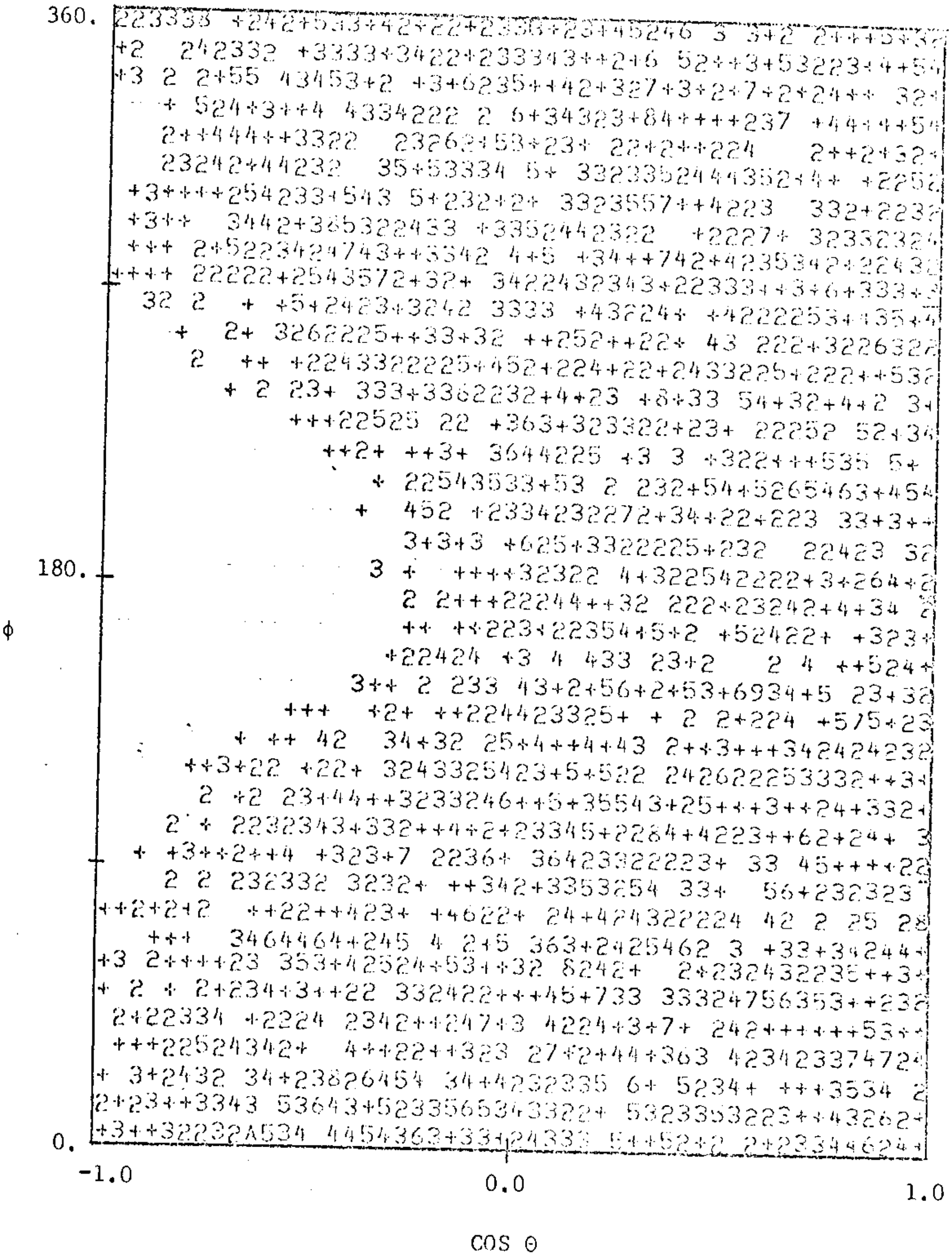
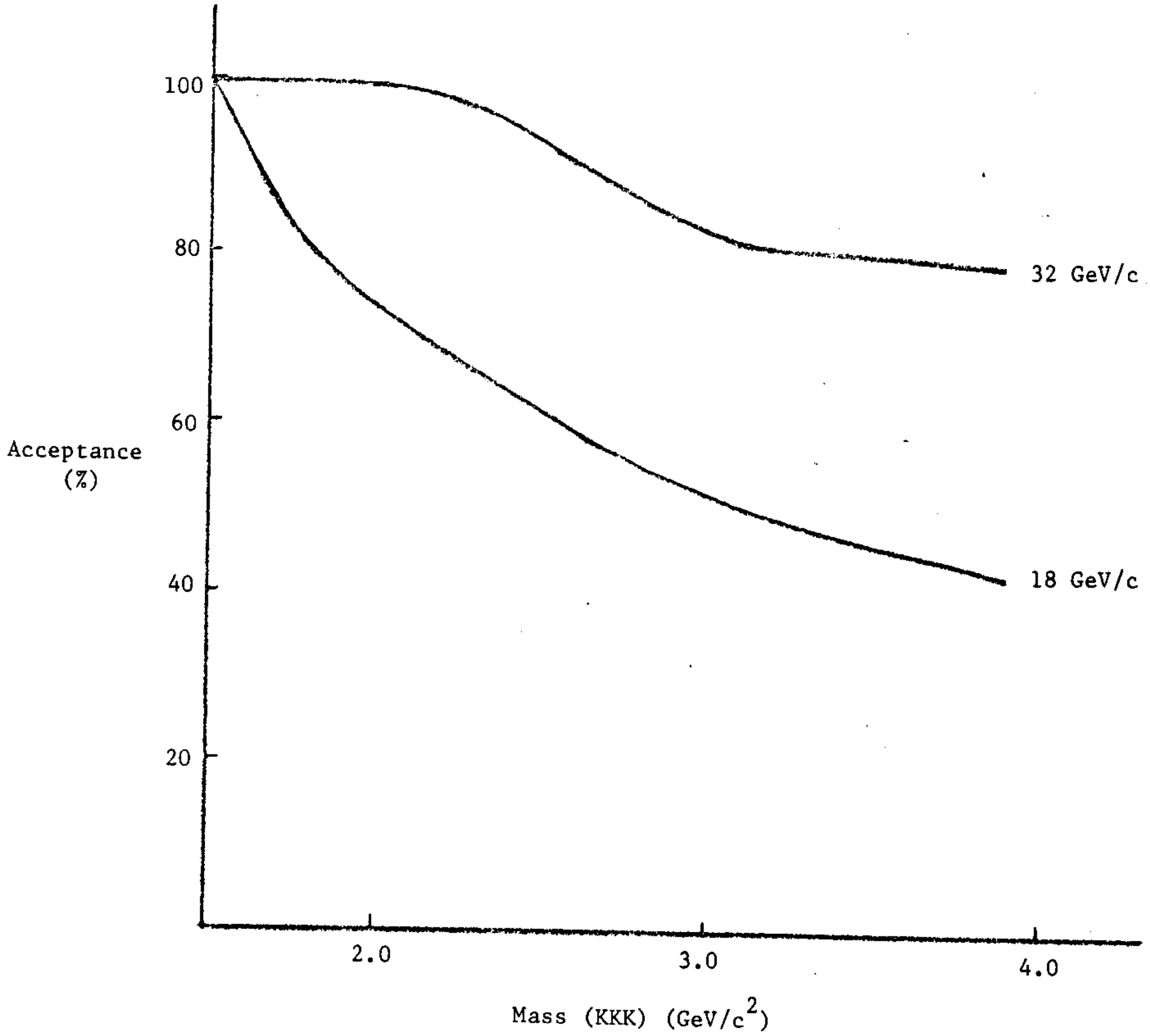


FIGURE 5b $t = -0.2\ (\mathrm{GeV}/c)^2$



100
80
60
40
20
Acceptance
(%)
32 GeV/c
18 GeV/c
2.0
3.0
4.0
Mass (KKK) (GeV/c^2)

FIGURE 6.

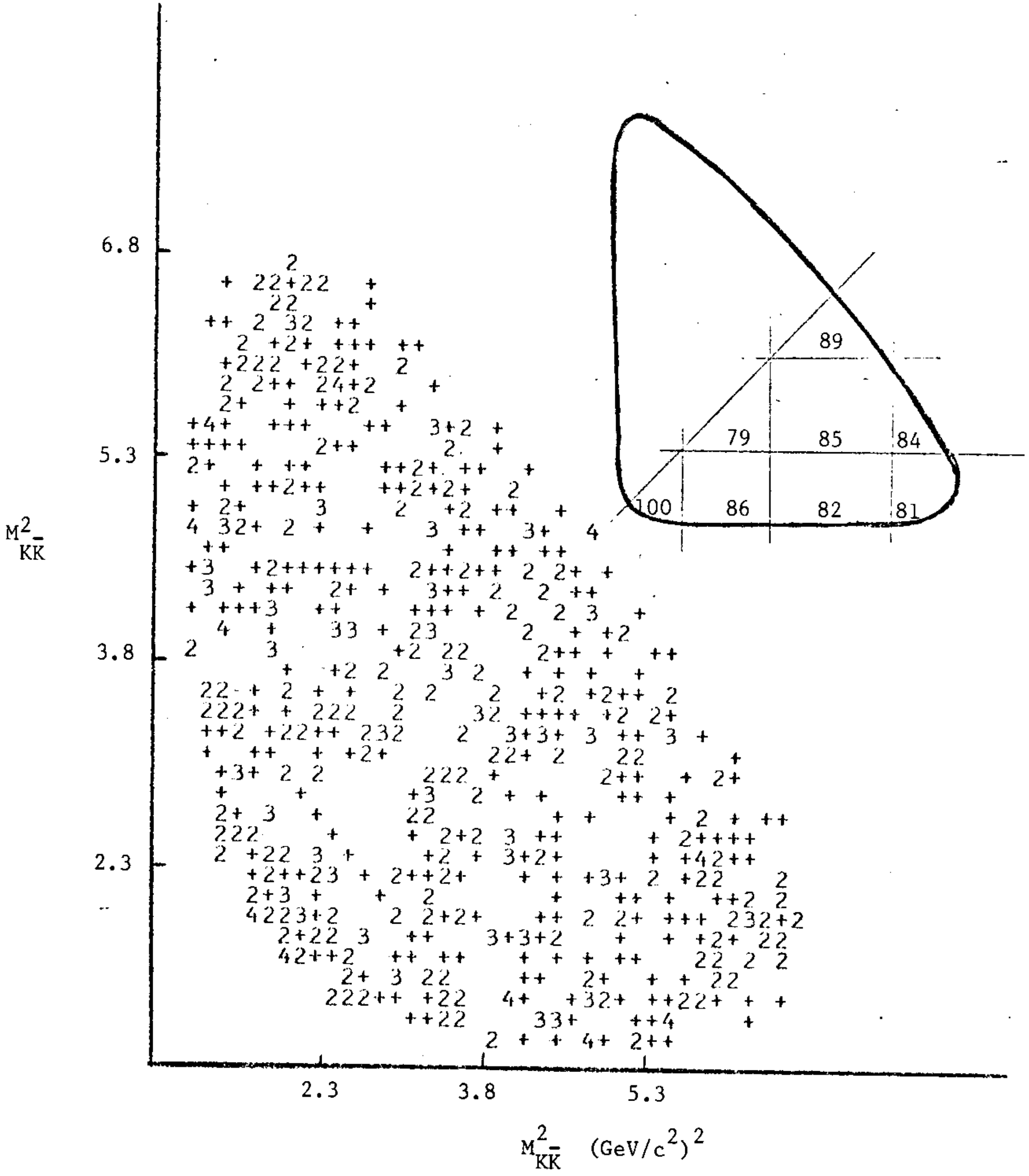

6.8
5.3
3.8
2.3
$M^2_{K\bar{K}}$
2.3
3.8
5.3
$M^2_{K\bar{K}}$ $(GeV/c^2)^2$
89
79
85
84
100
86
82
81

FIGURE 7.

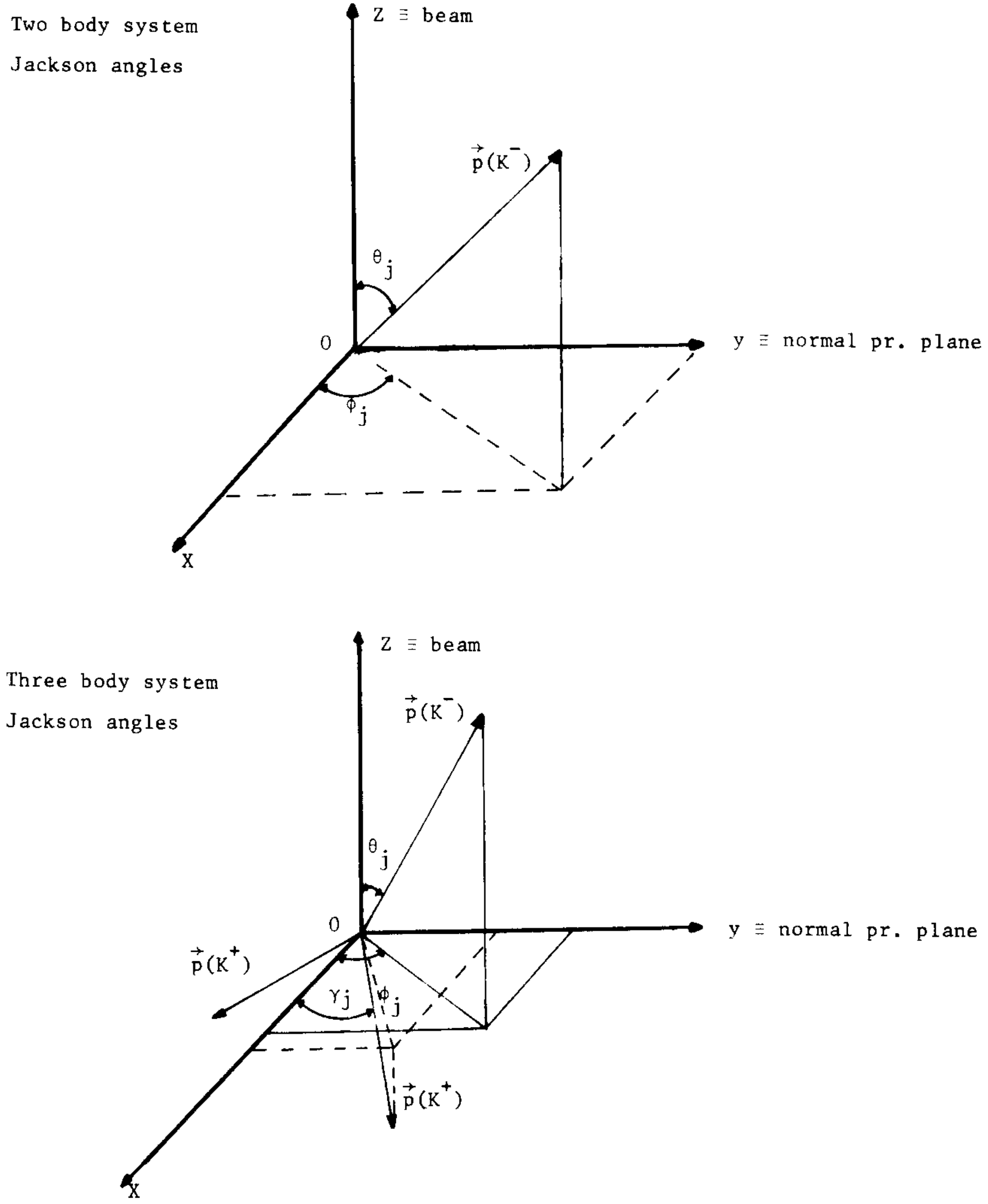

Two body system
Jackson angles
Z ≡ beam
$\vec{p}(K^-)$
θ_j
0
y ≡ normal pr. plane
ϕ_j
X
Three body system
Jackson angles
Z ≡ beam
$\vec{p}(K^-)$
θ_j
0
y ≡ normal pr. plane
$\vec{p}(K^+)$
γ_j
ϕ_j
$\vec{p}(K^+)$
X

FIGURE 8.

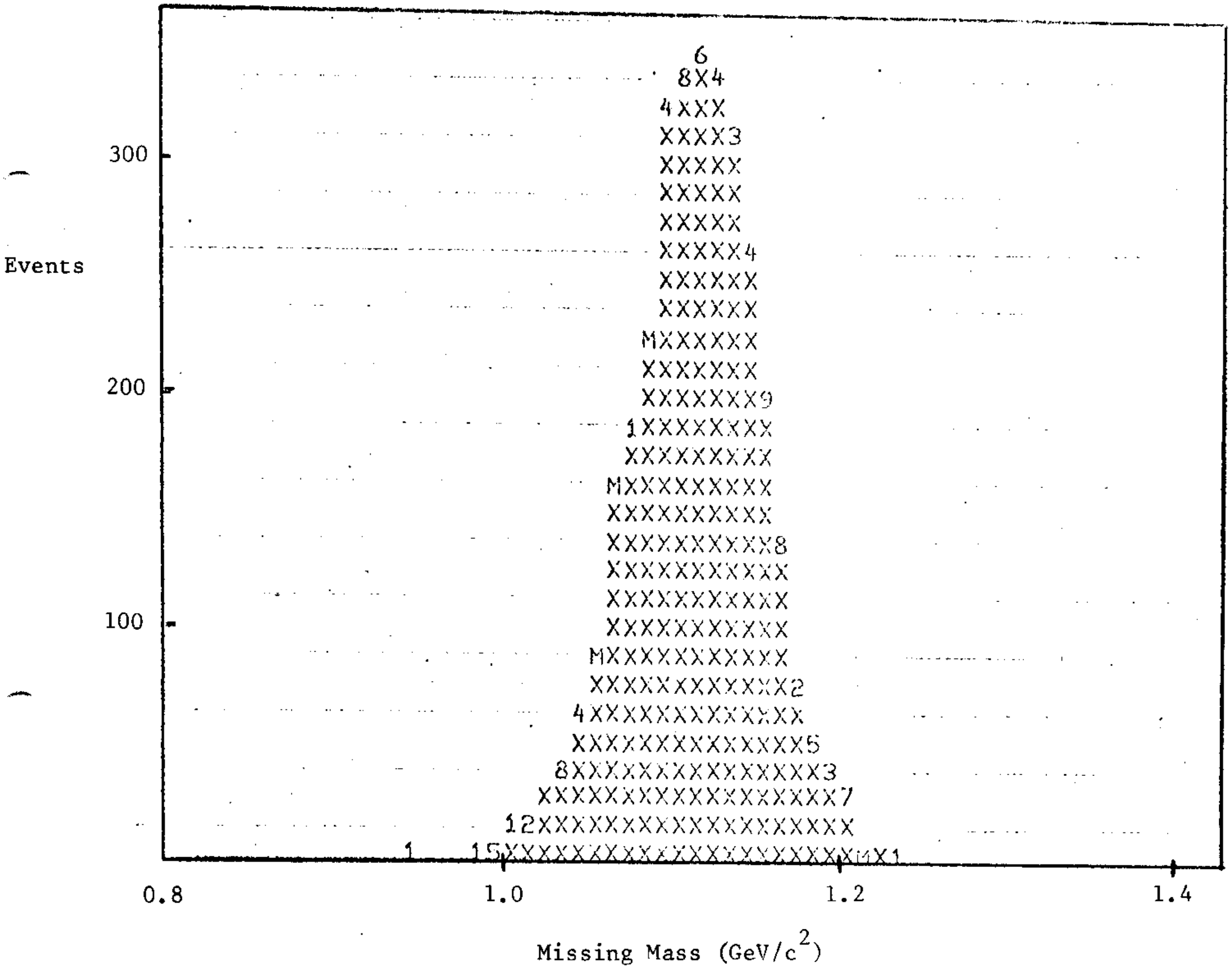


FIGURE 9a (18 GeV/c)

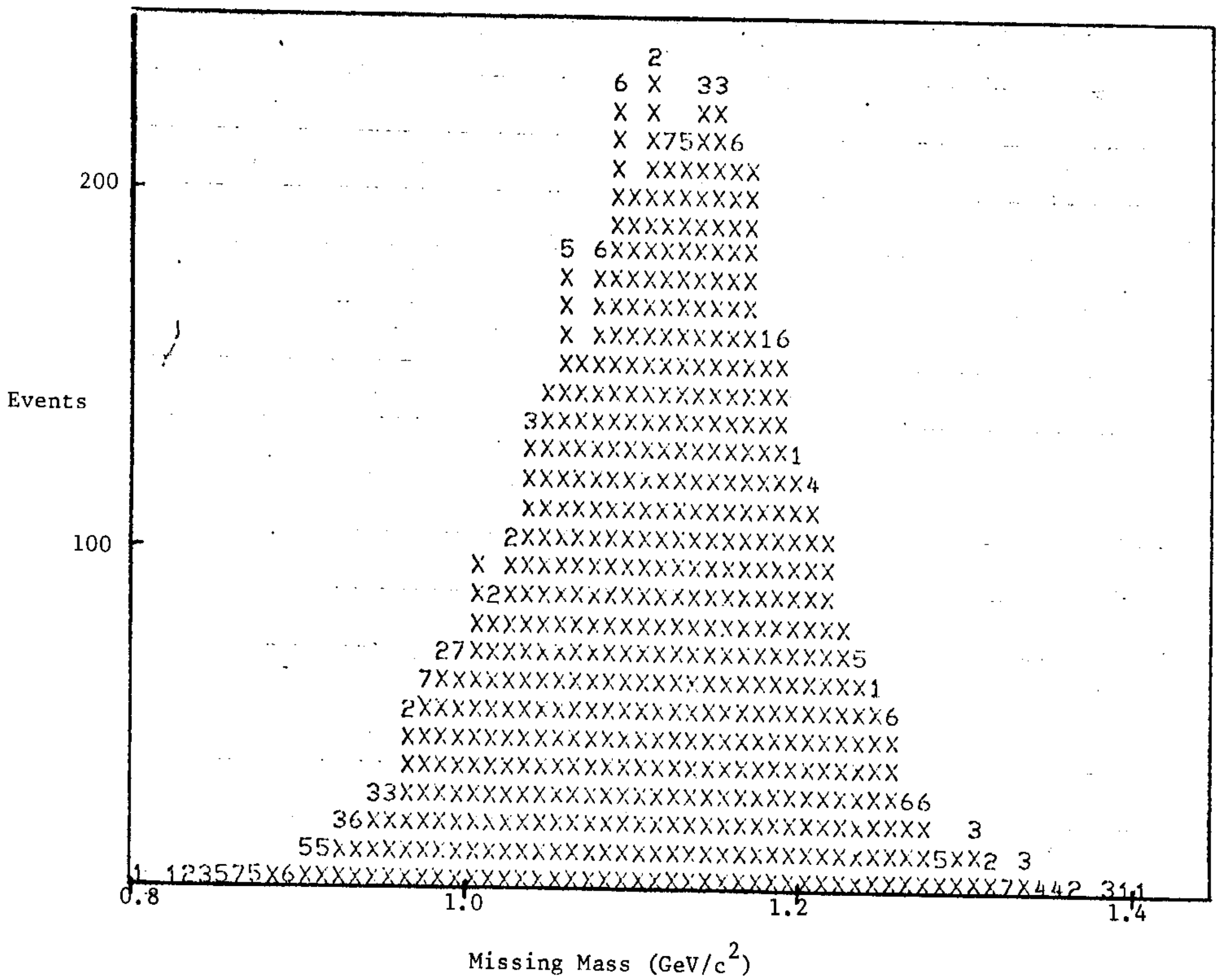


FIGURE 9b (32 GeV/c)

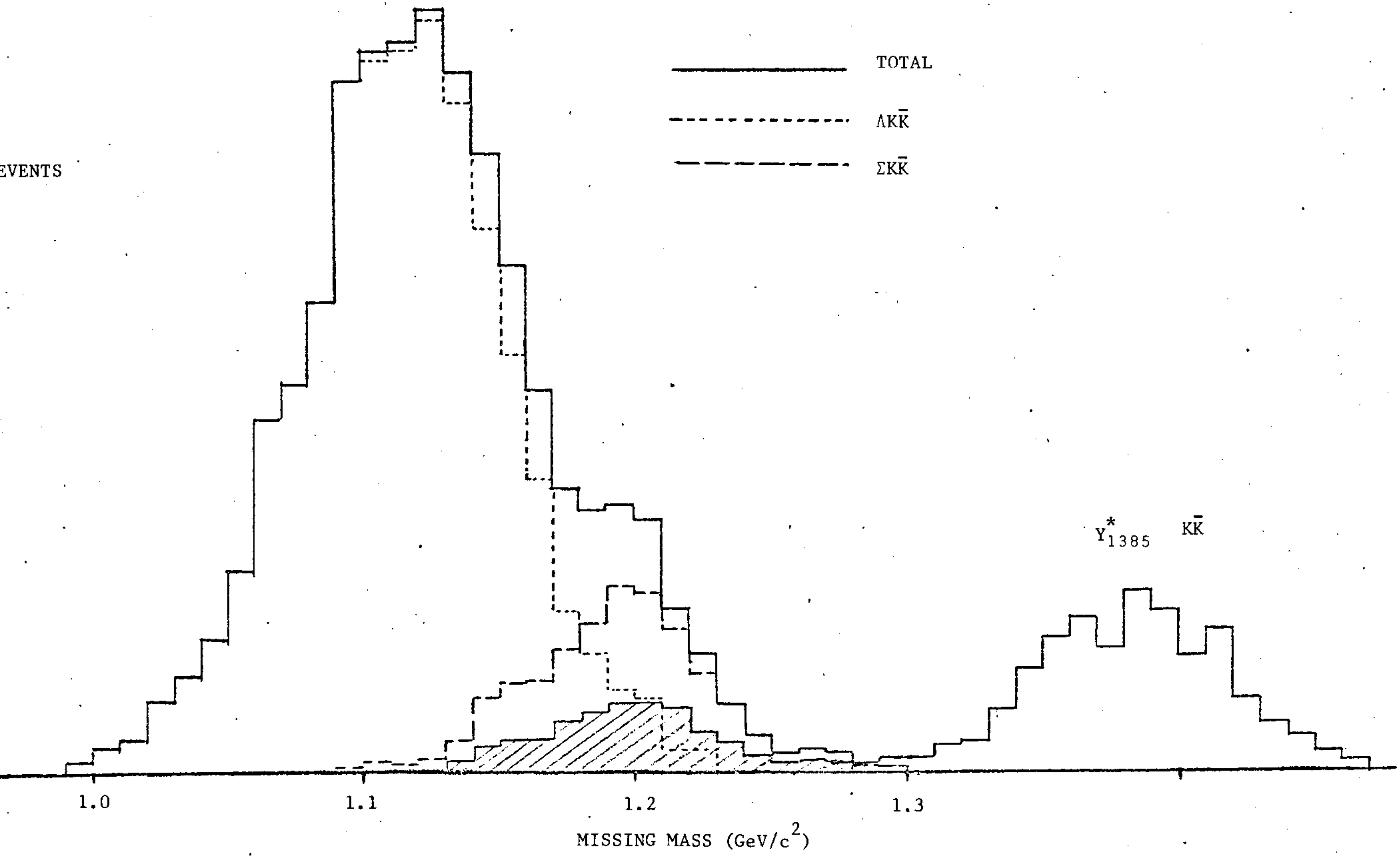

EVENTS
TOTAL
$\Lambda K\bar{K}$
$\Sigma K\bar{K}$
Y^*_{1385} $K\bar{K}$
1.0
1.1
1.2
1.3
MISSING MASS (GeV/c^2)

FIGURE 10.