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M E M O R A N D U M

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TO STUDY RARE DECAYS OF MESONS USING THE OMEGA SPECTROMETER

REQUEST: 7 days running time in a π^- beam of 10^5 π^-/burst at 12 GeV/c.

APPARATUS: OMEGA plus the present low pressure Čerenkov counter and hodoscope system.

SENSITIVITY: 3,000 events/μb.

NUMBER OF EVENTS: 2×10^6.

(*) Subject to approval by I.N.F.N.

(**) Subject to approval by D.N.P.L.

1. SUMMARY

1.1 Proposed Experiment

It is proposed to use the Omega Spectrometer to obtain 2×10^6 good events of final states involving a K^- or $\bar{p}$. The experiment consists of using a negative incident pion beam and triggering on a forward K^- or $\bar{p}$ with the Cerenkov low pressure counter and its associated scintillator hadoscope. The doubling of the present Čerenkov would enable the flagging of K^+ or p. This will yield a high statistics sample of mesons decaying into $K\bar{K}$, $K\bar{K}\pi$, $\bar{p}p$ and $p\bar{p}\pi$ decay modes[1]. As an example, the reaction $\pi^- p \to pK^+K^-\pi^-$ should yield 10^5 events which is to be compared to the best bubble chamber experiment which has $\sim 10^3$ events. For this particular reaction this corresponds to 3000 events/μb.

The reactions $\pi^- p \to pK^+K^-\pi^-$ and $\pi^- p \to pp\bar{p}\pi^-$, are particularly interesting since even if the slow proton is not seen it is possible to kinematically fit the event. There are however many other reactions which will contain interesting physics on both strange and non-strange mesons. A partial list is:

K^- forward	$\bar{p}$ forward
$\pi^- p \to pK^-K^o$	$\pi^- p \to p\bar{p}p\pi^-$ $(p\ \overline{\Delta^{++}p})$
$pK^-K_1^o\pi^o$	$p\bar{p}p\pi^-\pi^o$
$pK^-K^+\pi^-$	$n\bar{p}p$
$pK^-K^+\pi^-\pi^o$	$n\bar{p}p\pi^+\pi^-$ $(\Delta^{--}\bar{p}p\pi^+,\ \Delta^{++-}\bar{p}n\pi^-)$
$pK^-K^o\pi^+\pi^-$ $(\Delta^{++}K^-K^o\pi^-)$	$p\bar{\Lambda}nK^-$
nK^-K^+	
$nK^+K^-\pi^+\pi^-$	

All the equipment for this experiment is available as part of current experiments and we ask for a <u>total of 7 days running</u>. The proposed experiment utilises Omega in an efficient way and takes advantage of its unique capabilities.

a) The trigger has good acceptance $\sim 40\%$.

b) The trigger cross section saturates the data acquisition system.

c) The final statistics will be a factor of 100 times more than current bubble chamber experiments.

1.2 Requirements

- The Omega Spectrometer
- Low Pressure Čerenkov counter plus scintillation hadoscopes
- Beam giving 10^5 π^-/burst
- Running time 7 days
- Beam momentum 12 GeV/c.

In addition, we shall use either the M.W.P.C. interaction trigger or a scintillator around the target to ensure that the interaction occured in the target. In the latter case this would be a larger version of the one used successfully for this purpose in the slow proton experiment.

1.3 Experimental plan

We would first do some preliminary testing on the reaction

$$\pi^- \text{ incident} \Rightarrow K^- \text{ or } \bar{p} \text{ forward}$$

using the low pressure Čerenkov counter. We would also at that time use either the M.W.P.C. interaction trigger or the installed scintillator (TS) by the target to see that it reduces the background and correctly gives only target interactions. The data obtained would then be put through Geometry and Kinematics to check that the final states of interest can be abstracted.

The following time scale seems feasible:

Up to Dec. 1973	-	Testing with the lower pressure C. Design and build scintillator, if interaction trigger runs into problems.
April-May 1974	-	Testing of the final configuration with the doubled low pressure Čerenkov.
Summer 1974	-	The actual experiment of 7 days.

2. PHYSICS INTEREST

2.1 Problems in Meson Spectroscopy

Our current knowledge of mesons is still very meagre. An examination of the Particle Data Group tables[(2)] shows that we know of ∿ 20 meson states many of which have not been studied well. Some outstanding problems are:

a) Do mesons exist at M > 1.8 GeV ?

b) Determination of the $I^G J^{PC}$ of known states such as the D.E.f', δ, B, etc.

c) Accurate determination of branching ratios of known states.

d) Exploration of the diffractive states and search for other decay modes.

e) Search for exotics[(3)] and any new phenomena which could appear as we push the cross section sensitivity down.

Many of these problems have been reviewed recently by one of us[(4)]. One general conclusion is that one needs experiments which are sensitive to cross sections <1 μb. Extrapolation of known cross sections indicates that if high mass mesons exist, they are produced with a cross section <1 μb. Such experiments would also answer items b) and c) since production cross sections are tens of microbarns.

Final states involving kaons and antiprotons have been poorly studied at the present time[(5)]. As examples, since 1969 less than 100 events have been published of f' production[(6)], the D and E mesons known for many years still lack definitive J^P assignments, branching ratios of the g into these modes is badly determined.

Because of different detection efficiency of each reaction the sensitivity of the experiment will vary between 100 → 3000 events/μb. This will clearly give the sensitivity to answer some of the problems discussed above and it will also allow us to probe into regions where new effects may occur.

2.2 Relation to current Omega experiments

This experiment is a natural extension of those currently approved for Omega. Both the recoil neutron experiment and slow proton experiment[7] will accumulate relatively high statistics on meson states. This data will be dominated by the decays of mesons into pions since the trigger is on the nucleon, so that the rarer decays will occur only in their natural fraction.

The proposed experiment will give comparable statistics in the rarer channels involving kaons and antiprotons and is clearly a desirable and an important thing to do to complete this phase of the Omega activity.

3. DESCRIPTION OF THE EXPERIMENT

3.1 Trigger

A plan view of the proposed experiment is shown in fig. 1. The low pressure Cerenkov is placed at the downstream end of Omega sandwiched between its scintillation counter hodoscope which records when a particle has passed through the Cerenkov. This allows the selection of a particle which can be a negative kaon or an antiproton. The other half of the Cerenkov will be used to flag K^+ and p.

This gives the reactions

$$\pi^- p \to K^- + \text{anything}$$

$$\pi^- p \to \bar{p} + \text{anything}$$

with the secondaries from "anything" being observed in the spectrometer.

It seems clear from the initial tests under less than ideal conditions that some extra requirement may be needed to ensure that the interaction occurs in the target and to reduce background interactions.

Two solutions have been thought of as additions to the main requirements of a K^- or $\bar{p}$ forward:

a) To use the available multiwire chambers to detect that a beam particle has not interacted in the target. This system is being implemented at the present time as part of the Omega facility and may prove to be sufficient for our purpose.

b) To put scintillator counters close to and around the target and demand another secondary particle in addition to the forward particle. Since nearly all the interactions of interest have other charged secondaries this should not introduce a significant loss of events.

3.2 Rates

Published cross sections[8] are rather poor simply because kaons are difficult to detect. It appears that the cross section for a π^- giving a final state involving a K^- is $\sim$ 500 b. A detailed analysis of one final state which has a cross section of 50 μb viz

$$\pi^+ p \rightarrow pK^+K^-\pi^+$$

yields a 40% acceptance for a forward K^-.

So a best conservative estimate gives

Trigger cross section	= 200 μb (≡ 500 μb x 40% for K^-)
Target length	= 60 cm
Beam Flux	= 10^5 π^-/burst
Rate $\pi^- p \rightarrow K^-$ + anything	= 40/burst
BACKGROUND RATE	= 20/burst

(one could tolerate a background rate as high as this but hopefully one could reduce it).

7 days	= 168 hours (at 66% efficiency)
Total rate	= 60/burst
Actual rate with dead time	= 20/burst
Total good events	= 2×10^6

To this rate we have to add the reactions producing $\bar{p}$'s which are of the order a factor 10 down in cross section.

4. TECHNICAL FEASIBILITY

4.1 Preliminary Test

During a recent Omega run some preliminary tests were done to study the feasibility of this experiment. The results are not completely accurate because of fluctuating conditions and the necessity of not interfering with the running of the other experiments.

Rates were taken using the low pressure Čerenkov and the fast $\bar{\Lambda}$ trigger[9] of the Glasgow-Saclay Collaboration for

π^- incident $K^+(p)$ out

π^+ incident $K^-\bar{p}$ out

π^- incident $K^-\bar{p}$ out

The results were all quite similar with a true hydrogen rate of

(30 $\rightarrow$ 60 triggers 10^5 incident π's (no dead time))

in agreement with the cross section being in the range 500 $\rightarrow$ 1000 μb.

During the preliminary test a high target empty rate was observed. A subsequent analysis of the events revealed that this was almost entirely due to beam particles either not interacting in the target (or suffering a small deflection) and subsequently interacting in the spark chamber plates. This background can be reduced by the addition in the trigger of the M.W.P.C. interaction trigger or a scintillator to define that a target interaction has occurred.

4.2 The reaction $\pi^- p \rightarrow pK^-K^+\pi^-$

The reactions

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

are one of the few reactions of this type which have been analysed in bubble chamber experiments. A sample of real events from a 13 GeV/c bubble chamber experiment[10] has been used to study the proposed experiment. A sophisticated programme was used which simulates Ω[11]. A vertex point was generated for each real event within the Ω hydrogen target. Starting with the fitted four vectors each track was followed in the non-uniform field of Ω and in all cases decays of the kaons were taken into account.

The Č was positioned to accept negative particles and events were accepted if the K^- passed through the Cerenkov.

Out of a total of 747 $\pi^+p \rightarrow K^+K^-\pi^+p$ bubble chamber events, 282 events had a K^- pass through the Čerenkov (= 38%).

The mass spectra for the total sample and for the events giving a trigger are shown in fig. 2. The efficiency of the trigger slowly drops off, as expected, at high mass values but is not concentrated at any particular mass.

In order to have a feeling of we might have a chance to do a spin parity analysis on the three-body systems we determined the detection efficiency at a function of the Dalitz plot angles for the reaction $\pi^+p \rightarrow K^+K^-\pi^+p$ at 13 GeV/c. These efficiencies, plotted in fig. 3, show that, although corrections will have to be made, nowhere is the efficiency zero. We thus feel the possibility for a J^P determination is encouraging.

4.3 Analysis of the final data

There will be some difficulties associated with the analysis of the final data as is always true for strange particle final states. The final states produced fall into several broad categories.

a) This category is for reactions which have only charged particles in the final states e.g.:

$\pi^-p \rightarrow pK^+K^-\pi^-$

$\pi^-p \rightarrow pp\bar{p}\pi^-$

This is the best category yielding high statistics and minimum biases. Even if the proton does not leave the target a 1C fit is possible.

b) This category is for the reactions where a visible V decay occurs e.g.:

$$\pi^- p \rightarrow pK^- K_1^o \quad (A_2,\ g^-\ \text{for example})$$

$$\rightarrow pK^- K_1^o \pi^+ \pi^-$$

This will reduce the effective events/μb by a factor of 3. However, since bubble chamber experiments have the same problem, the increase in data by a factor of 100 is still correct.

c) This category is for events with a missing neutral (in general a π^o) e.g.:

$$\pi^- p \rightarrow pK^- K^+ \pi^- \pi^o$$

$$\rightarrow pK^- K_1^o \pi^o$$

$$\rightarrow nK^+ K^-$$

$$\rightarrow nK_1^o \pi^+ K^-$$ (non diffractive production of K^o and E^o for example(12))

$$\rightarrow nK^+ K^- \pi^+ \pi^-$$

$$\rightarrow n\bar{p}p$$

$$\rightarrow n\bar{p}p\pi^+ \pi^-$$

These reactions demand that one sees all charged particles and/or all V decays.

REFERENCES

1. The present proposal is an extension of the existing experiment S 115 (PH.I/COM-71/5 and DNPL/SCP 71) which has as far operated only with a positive beam.

2. Review of ModernPhysics. 45 (1973) 51.

3. J. Rosner, Phys. Rev. Letters 21, 950 (1968) 1422;
H.J. Lipkin, Nucl. Phys. B9 (1969) 349;
P.G.O. Freund, R. Waltz and J.L. Rosner, Nucl. Phys. 13 (1969) 237;
H.J. Lipkin, Phys. Letters 32B (1970) 301;
H.J. Lipkin, NAL-TNY-70 (1972)

4. The current status of Meson Spectroscopy, D.H. Miller, CERN/D.Ph.II/PHYS 73-22.

5. Some experiments such as the CERN-Munich group have looked at a few single channels e.g. $\pi^- p \rightarrow p \bar{p} n$, Phys. Lett. 39B (1972) 563.

6. Two recent papers are: Nucl. Phys. 50B (1972) 1, and Phys. Lett. 41B (1972) 21.

7. These are experiments S112, S113 looking at $\pi^- p \rightarrow nX^0$ and $\pi^- p \rightarrow pX^-$.

8. One paper "II Nuovo Cimento" V9A, page 1, lists some cross sections at 11.2 GeV where a V is seen. These include 111 μb with a K^-. The reaction $\pi^{\pm} p \rightarrow pK^+K^-\pi^{\pm}$ is better known, e.g. NPB 32, 10 and has a cross section near 50 μb. An educated guess would then give ∿ 500 μb for all reactions leading to a K^- in the final state.

9. This is experiment S115 looking specifically at reactions of the type K^+ and π^+ incident with a K^- or $\bar{p}$ in the low pressure C.

10. A partial sample is published in NPB32, 10. Further measuring has increased this to 1200 events.

11. K. Knudson, TC simulation program.

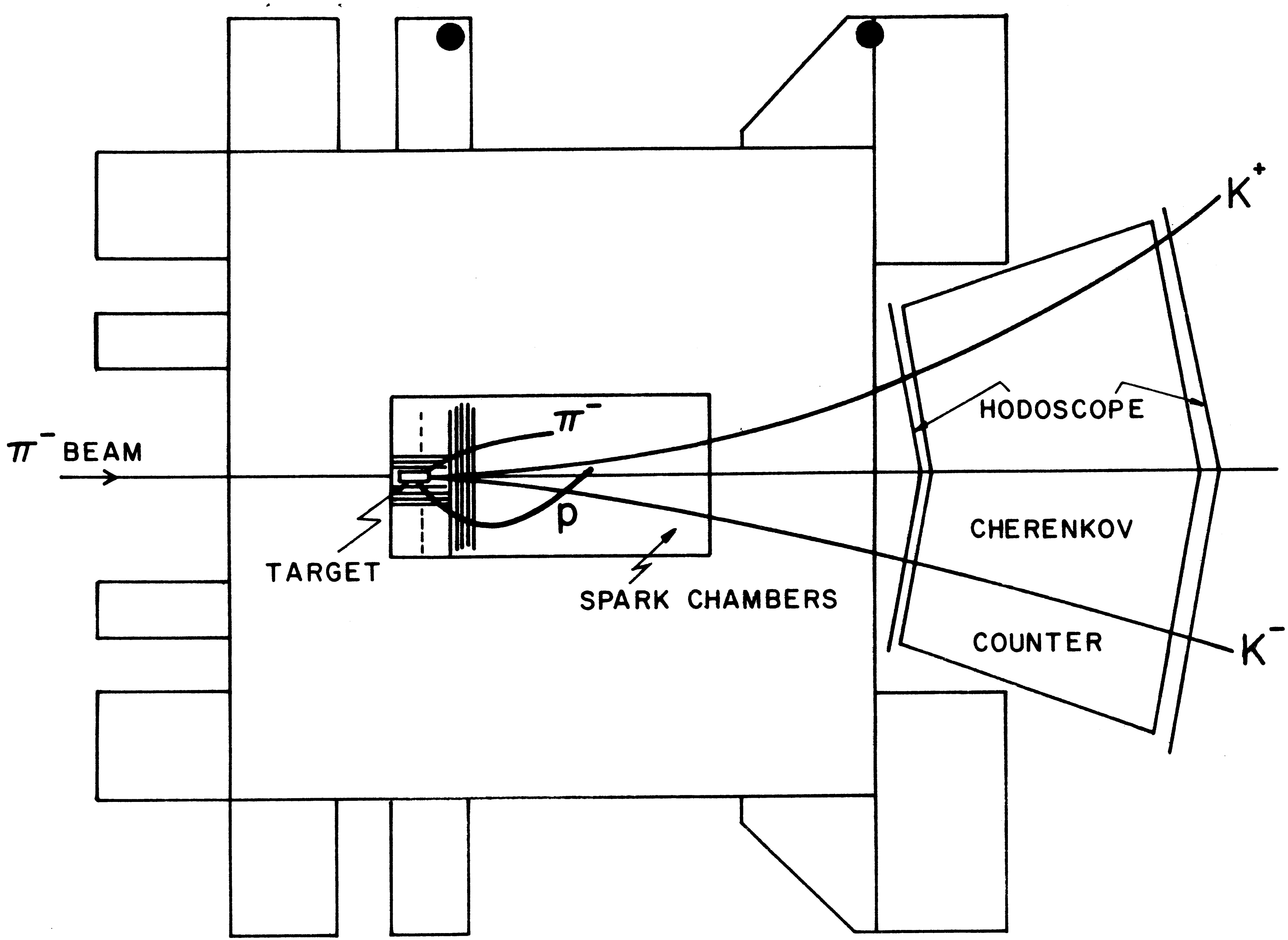
12. J. Fox, CALT 68-361 (1972).

FIGURE CAPTIONS

Fig. 1 Experimental set-up shows OMEGA, the low pressure Čerenkov counter and scintillator hodoscope.

Fig. 2 The mass spectrum of $K^+K^-\pi^+$ accepted by the trigger using real events from the reaction $\pi^+p \rightarrow K^+K^-\pi^+p$ at 13 GeV/c.

Fig. 3 The acceptance of the trigger regarding Dalitz plot helicity angles for real events from the reaction $\pi^+p \rightarrow K^+K^-\pi^+p$ at 13 GeV/c.



Experimental set - up

Fig. 1

$\pi^+ p \rightarrow K^+ K^- \pi^+ p$ at 13 GeV/c

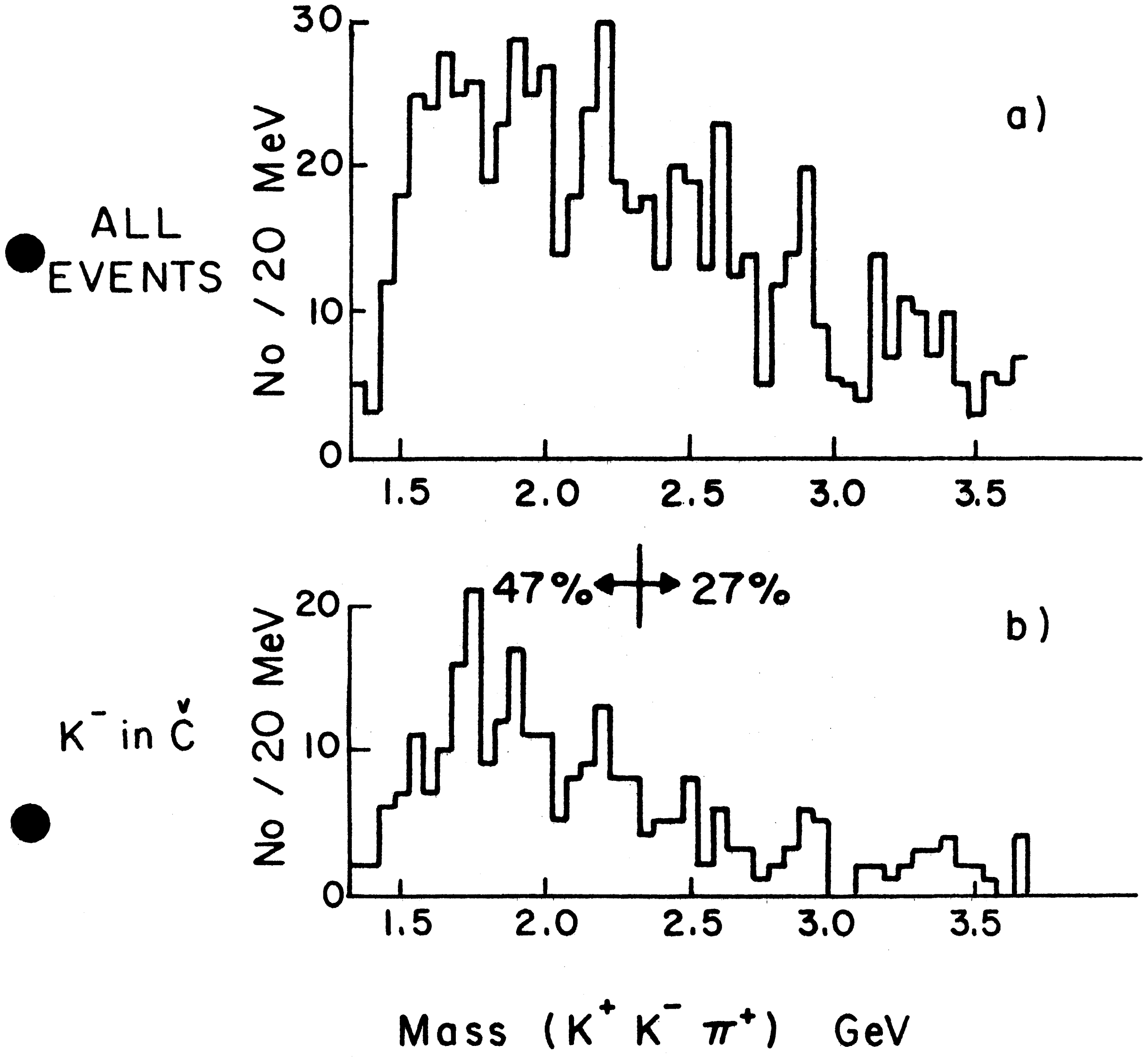


Fig. 2

$\pi^+ p \rightarrow K^+K^-\pi^+ p$ at 13 GeV/c

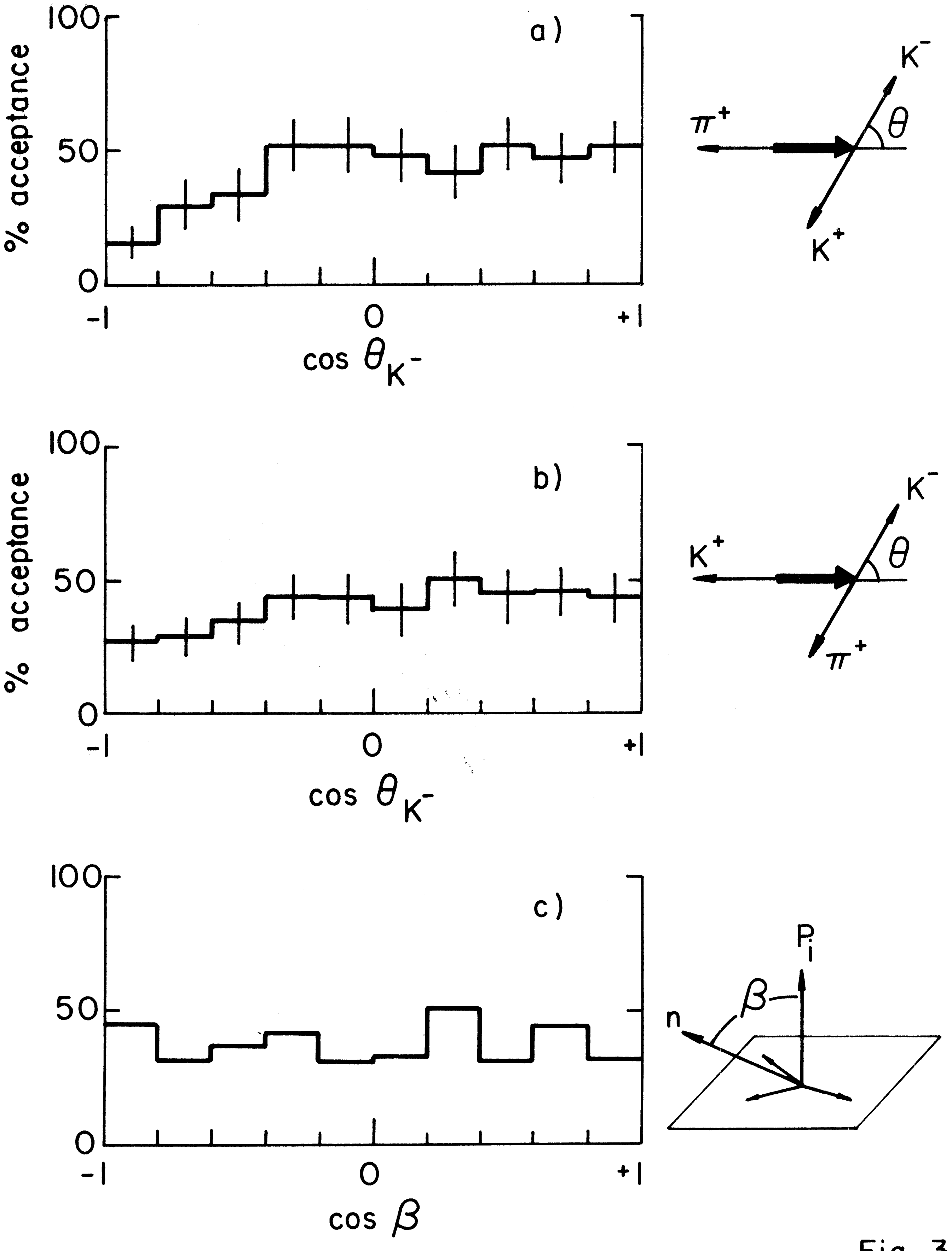


Fig. 3