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PHYSICS I
ELECTRONICS EXPERIMENTS COMMITTEE

PROPOSAL:

To study the boson mass spectrum, in the mass region 2.0 - 3.0 GeV, with final decay products $\bar{p}\bar{p}\pi^-$, $K^+K^-\pi^-$ and $\pi^+\pi^-\pi^- + n\pi^0$ $(n \geqslant 0)$, using the CERN-ETH-IC spark chamber equipment triggered with a proton time of flight missing mass trigger.

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TO : ELECTRONICS EXPERIMENT COMMITTEE.

PROPOSAL: TO STUDY THE BOSON MASS SPECTRUM, IN THE MASS REGION 2.0 - 3.0 GeV, WITH FINAL DECAY PRODUCTS $p\bar{p}\pi^-$, $K^+K^-\pi^-$ AND $\pi^+\pi^-\pi^- + n\pi^0$ ($n \geq 0$), USING THE CERN-ETH-IC SPARK CHAMBER EQUIPMENT TRIGGERED WITH A PROTON TIME OF FLIGHT MISSING MASS TRIGGER.

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Summary

The object of the experiment is twofold :

a) to explore the feasibility of a trigger system based on the time of flight of the recoil proton from the reaction $\pi^- p \rightarrow px^-$ after the proton has crossed the optical spark chambers. This triggering system should be then useful for experiments with the Ω project.

b) to explore the boson spectrum in the mass region of 2.0 - 3.0 GeV by studying the mass spectrum of x^- in the reaction $\pi^- p \rightarrow px^-$ where x^- can decay via the systems: $\bar{p}p\pi^-$, $K^+K^-\pi^-$, or $\pi^+\pi^-\pi^- + n\pi^o$. $(n \geq 0)$.

Viz the reactions to be studied are:

$\pi^- p \rightarrow p(\bar{p}p\pi^-)^-$ (1)

$\rightarrow p(K^+K^-\pi^-)^-$ (2)

$\rightarrow p(\pi^+\pi^-\pi^-)^-$ (3)

$\rightarrow p(\pi^+\pi^-\pi^-\pi^o)^-$ (4)

$\rightarrow p(\pi^+\pi^-\pi^-x^o)^-$ (5)

This to be done by using an incident π^- beam of 8 GeV/c and triggering on the recoiling protons having small scattering angles with momenta between 0.5 and 1.3 GeV/c in the laboratory system.
The expected numbers of events from 4 days running time are of the order of 2500 for reaction 1, 2000 for reaction 2, 13000 for reaction 3, 40000 for reaction 4 and 45000 for reaction 5. Reactions 3 - 5 are heavily biased but can be used to a) establish the G parities of any possible peaks and b) study their decay modes.

1. Apparatus and triggering

Figure (1) shows a diagram of the CERN-ETH-IC spark chamber apparatus along with the proposed trigger system. Since this apparatus is open in the forward direction with respect to the incident beam, we have tried to see whether it is possible to detect protons coming from the target in the forward direction with a time of flight trigger. That this is possible can be seen from figure (1) where the trajectories are traced of protons leaving the target with momenta 0.5 to 1.3 GeV/c and passing out of the spark chamber assembly in the central region. The locus of these protons after a flight time of 20 nanosec. is also shown. We may approximate this locus with a straight line and determine the arrival times of protons and pions at this locus. The distributions of arrival times, figures (2a) and (2b) show that if we accept only those particles arriving within a time gate of (20 ± 4) nanosec., then only protons will be accepted. The kinematics of the reaction $\pi^- p \rightarrow px^-$ at 8 GeV/c is shown in figure (3) and the outlined area gives the region of mass x^- which can be studied with such a trigger, in this example 2.3 to 3 GeV.

Since we are interested in triggering on reactions (1) and (2), we have placed in front of the target a Charpak chamber (C) triggering on ≥ 4 charged particles. An anticoincidence counter (A) is also placed around the sides of the target to exclude events emitting charged secondaries which would not be measurable in the spark chambers. These guard counters reject a large fraction of the reactions $\pi^- p \rightarrow p\pi^+\pi^-\pi^- + n\pi^o$ where $n \geq 0$.
The complete trigger condition is given by $S_1 S_2 \bar{S}_3 \bar{A} S_4 C$. The request $S_1 S_2 \bar{S}_3$ gives the condition necessary for one beam particle interaction. The scintillators S_4 are placed at the locus of protons described above, and consist of two scintillators in coincidence: 200 x 50 x 2 cm (time of flight measure) and 200 x 50 x 1 cm (in front of the first one to reduce spurious coincidences).

2. Mass spectrum

In order to get some quantitative estimates we have used the 8 GeV/c π^+p bubble chamber data of the ABCLV collaboration⁄. Figure (4) shows the form of the $p\bar{p}\pi^+$ and $\bar{p}p$ mass spectra for those protons hitting the locus counter after a flight time from the target of (20 ± 4) nanosec.

3. Triggering rates:

The percentages of events triggering the apparatus for the reactions 1 to 5 for an incident momentum of 8 GeV/c are given in table 1. Here DX is the distance of the centre of the hydrogen target to the first spark chamber plate and 2DY, 2DZ is the separation of the guard counters.

Table 1

p_i = 8 GeV/c	DX = 15 cm.		DY = 15 cm.		DZ = 15 cm.
FINAL STATE	°/o Hitting Locus	°/o Pass guard counters	$\sigma(\mu b)$	$\sigma_{trigger}$ (μb)	No./100K triggers
1. $p\bar{p}p\pi^+$	0.9	87	20	0.16	2.500 (50)*
2. $pK^+K^-\pi^+$	0.26	67	70	0.12	1.850 (200)*
3. $p(3\pi)^+$	0.22	20	2000	0.88	13.250 (1000)*
4. $p(3\pi)^+\pi^o$	0.8	16	2000	2.50	37.400 (2000)*
5. $p(3\pi)^+n\pi^o$	1.6	7.7	2500	3.00	45.000 (3000)*
	Total		6590	6.66	100.000

⁄ We wish to thank Dr. Morrison and the ABCLV collaboration for the loan of this data.

* No. of event in mass region $2.3 < Mx < 3.0$ from an 8 GeV/c hydrogen bubble chamber exposure of 100 000 pictures.

Thus for a 20 cm H_2 target and 2 x 10^5 π's/pulse we can expect ~ 1 event/machine pulse or ~ 35 000 triggers/day machine time. From table 1 it can be seen that the enrichment of reactions 1 and 2 is a factor of about 50 and 10 respectively and reactions 3 to 5 a factor 15 over that from a 100 000 picture bubble chamber exposure.

4.a) Measureability:

Taking as origin of the interactions a point 15 cm outside the first spark chamber and tracing each track of an event through the spark chamber system, we find that the guard counters around the target can be placed so that events with particles not hitting the guard counters are all well measured. Plots of the momentum errors on tracks and the errors on missing mass for reaction (1) are shown in figures 5 and 6.

b) Separation of channels

The fraction of the events triggering the locus counter which do not trigger the guard counters are : (Table 1)

$\pi^+ p \rightarrow p\bar{p}p\pi^+$	87 %	(1)
$\rightarrow pK^+K^-\pi^+$	67 %	(2)
$\rightarrow p\pi^+\pi^-\pi^+$	20 %	(3)
$\rightarrow p\pi^+\pi^-\pi^+\pi^o$	16 %	(4)
$\rightarrow p\pi^+\pi^-\pi^+(\pi^o\pi^o---)$	7.7%	(5)

The possibility of separating events into channels 1 to 5 by a kinematical fitting program (GRIND) has been tested by generating events with the correct experimental errors. The 4 constraint channels 1, 2, and 3 are uniquely identified. Channel 4 has 10 % of the events

M_x is the missing mass opposite the recoil proton.

$\theta_f P_f$ are scattering angle and momentum of proton in the lab. system.

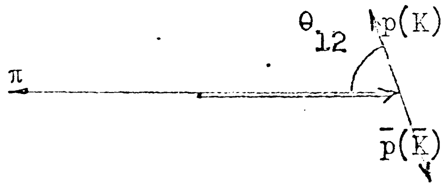
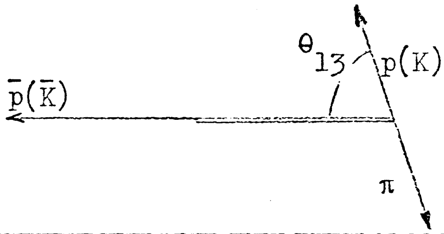
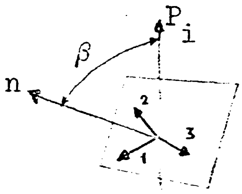
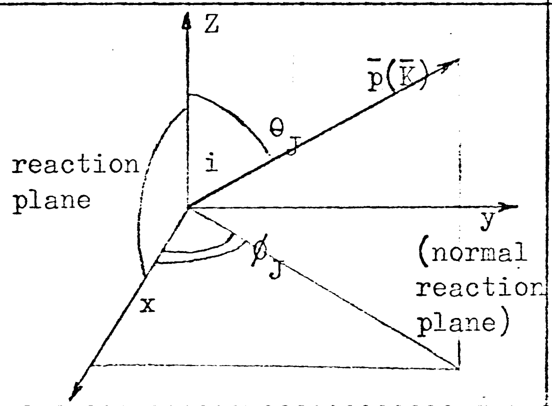
One sees that the error on the missing mass is typically of the order $\pm$ 10 MeV over the whole mass spectrum. Measurement of the time of flight of the proton from the target to the locus counter to $\pm$ 0.5 nanosec will also give an accuracy on the recoil proton momentum similar to that obtained from the measurement of its curvature in the magnetic field and will also enable the mass of the particle crossing the locus to be determined.

5. Possibility of J^P determination

Although we know that the bias for reactions (1) and (2) is not high, it is interesting to look how some characteristic angular distributions are modified by the guard counter.

The characteristic angles chosen are sketched in table 2. Fig. 8, a, b, c, d, e show how these originally isotropic angular distributions are modified for the reaction (1).
Fig. 9a, b, c, d, e show the same angles for reaction 2.
It can be seen that they are never distributed too far from isotropy, and will thus allow the study of angular decay distributions and the determination of the J^P quantum numbers of possible detected bosons either in $\bar{p}p\pi$ ($K\bar{K}\pi$) or $\bar{p}p$ ($\bar{K}K$) states.

Table 2

	Symbol		Comments
3	θ_{12}		Proportional to $M^2_{p(K)\pi}$
Body	θ_{13}		Proportional to $M^2_{p(K)\bar{p}(\bar{K})}$
decay	β		Angle between normal decay plane and incident
2 Body decay	θ_J ϕ_J		Jackson angles in $p\bar{p}(K\bar{K})$ system

8. Conclusions

This proposal investigates the possibility of studying boson resonances with a mass resolution of $\pm$ 10 MeV in the reactions (1), (2), (3), (4) and (5) at 8 GeV/c with a missing mass trigger to select masses, in the region between 2.0 and 3 GeV. The possibility of obtaining at the same time separate mass spectra of the states $p\bar{p}\pi$, $p\bar{p}$, $K\bar{K}\pi$, $K\bar{K}$, $(3\pi)^-$, $(3\pi)^-\pi^0$, $(3\pi)^-n\pi^0$ with high statistics and a missing mass resolution of $\pm$ 10 MeV is certainly useful for deriving information about G-parity, partial decay modes, branching ratios and J^P quantum numbers of bosons detected in the states $p\bar{p}\pi$, $p\bar{p}$, $K\bar{K}\pi$, $K\bar{K}$.

The experiment should be useful to check the proposed trigger on the missing mass and improve it in view of further development for the Ω project.

In conclusion we would like to request some 2 weeks of parasite machine time to test the triggering system with the aim of having a 1 week run at 8 GeV/c yielding $\sim$ 100 000 good events.

9. Alternative run at 6 GeV/c.

In addition to the run at 8 GeV/c we looked into the characteristics of an exposure at a π^- primary momentum of 6 GeV/c. This is of interest for the following reasons:-

a) Determination of the cross section of reaction 1) which is unknown at 6 GeV/c incoming momentum.

b) If the cross section does not drop too much, this incident momentum is more favourable for selection of reaction 1) with respect to reactions 2), 3), 4) and 5).
In table 3 the percentages of events triggering the apparatus are given, assuming for reaction 1) a σ = 10 μb and a guard counter configuration chosen to optimise the selection of reaction 1) without too much bias.

Table 3

P_i = 6 GeV/c		DX = 15 cm.		DY = 7.5 cm.	DZ = 7.5 cm.
Final state	°/o Hitting Locus	°/o pass guard counter	$\sigma(\mu b)$	σ trigger (μb)	No./100 K triggers.
1. $p\bar{p}p\pi^-$	0.9	77.0	10	0.07	7 000
2. $pK^+K^-\pi^-$	0.26	28.7	80	0.07	7.000
3. $p(3\pi)^-$	0.22	9.2	2000	0.4	43.000
4. $p(3\pi)^-\pi^0$	0.8	2.1	2000	0.3	32.000
5. $p(3\pi)^-\ n\pi^0$	1.6	0.7	1200	0.1	11.000
			5290	0.94	100.000

This statistic should be sufficient for a study of the mass system $\bar{p}p\pi^-$ from 2.0 to 2.5 GeV.
The data acquisition rate in this case is 1 ev. each 7 bursts.

Fig. 1 Experimental set up

trigger $S_1 S_2 \bar{S}_3 \bar{A} S_4 C$

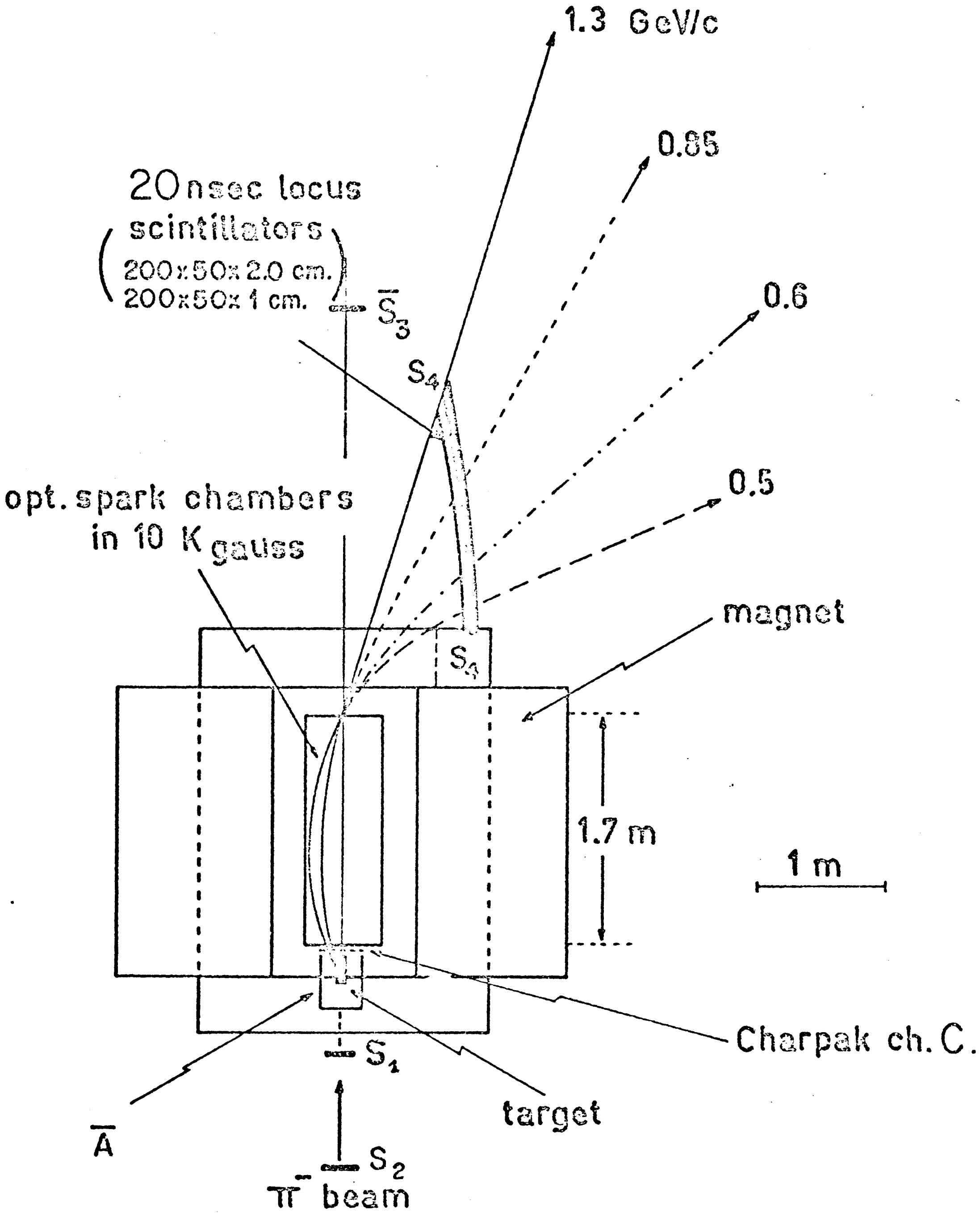
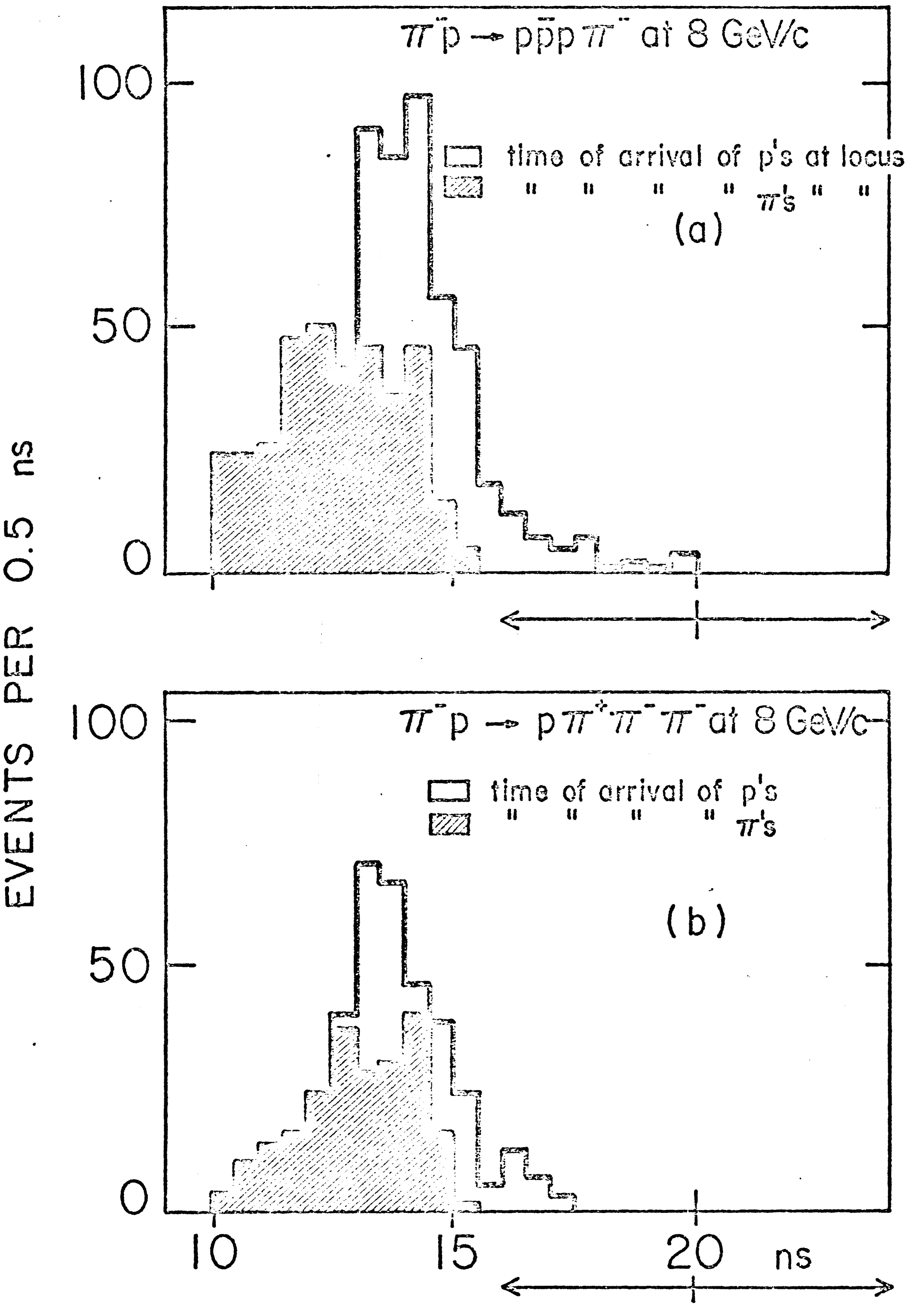


FIGURE 2



π⁻p → pp̄pπ⁻ at 8 GeV/c
time of arrival of p's at locus
" " " " π's " "
(a)
π⁻p → pπ⁺π⁻π⁻ at 8 GeV/c
time of arrival of p's
" " " " π's
(b)
EVENTS PER 0.5 ns
100
50
0
10
15
20
ns

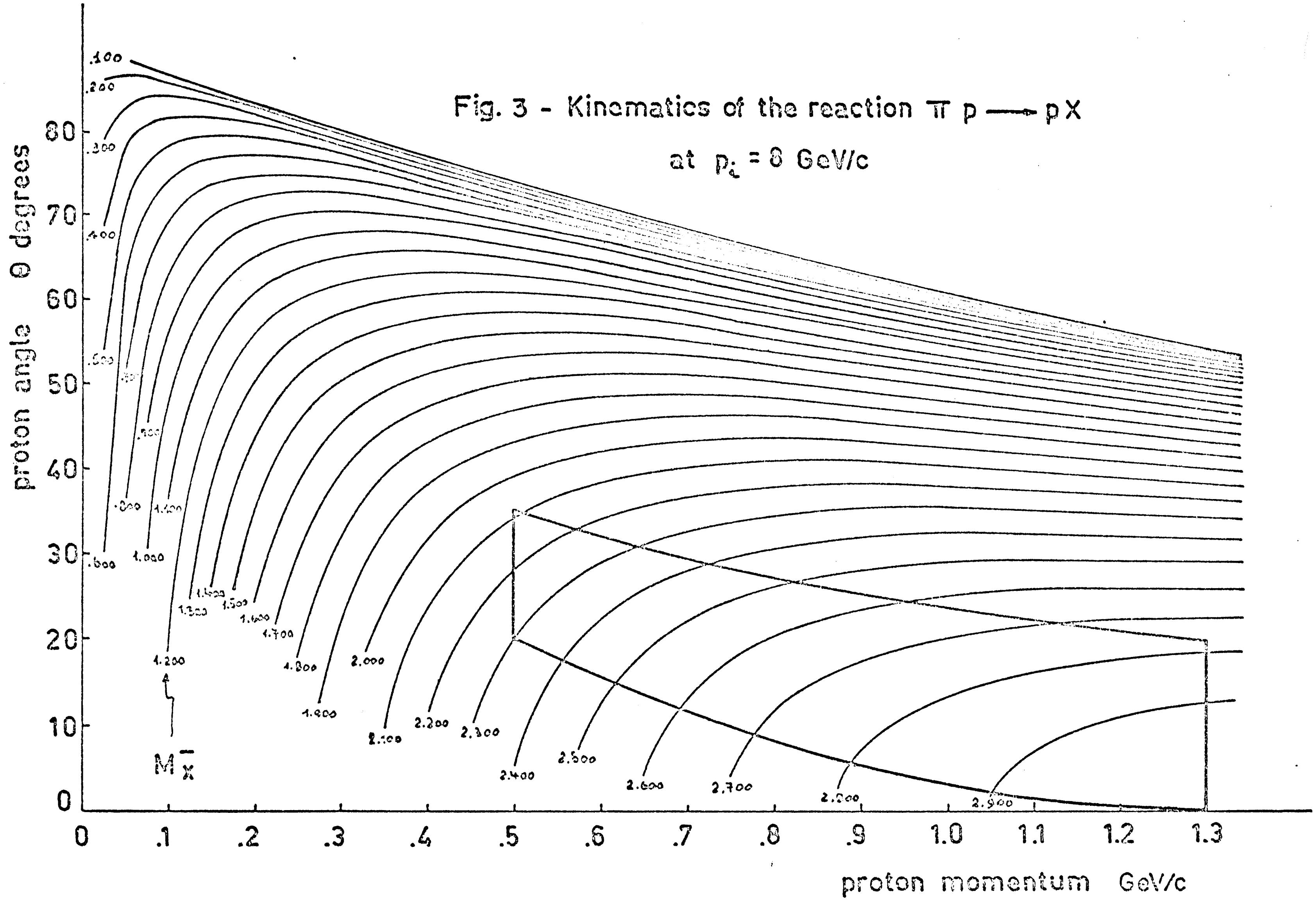
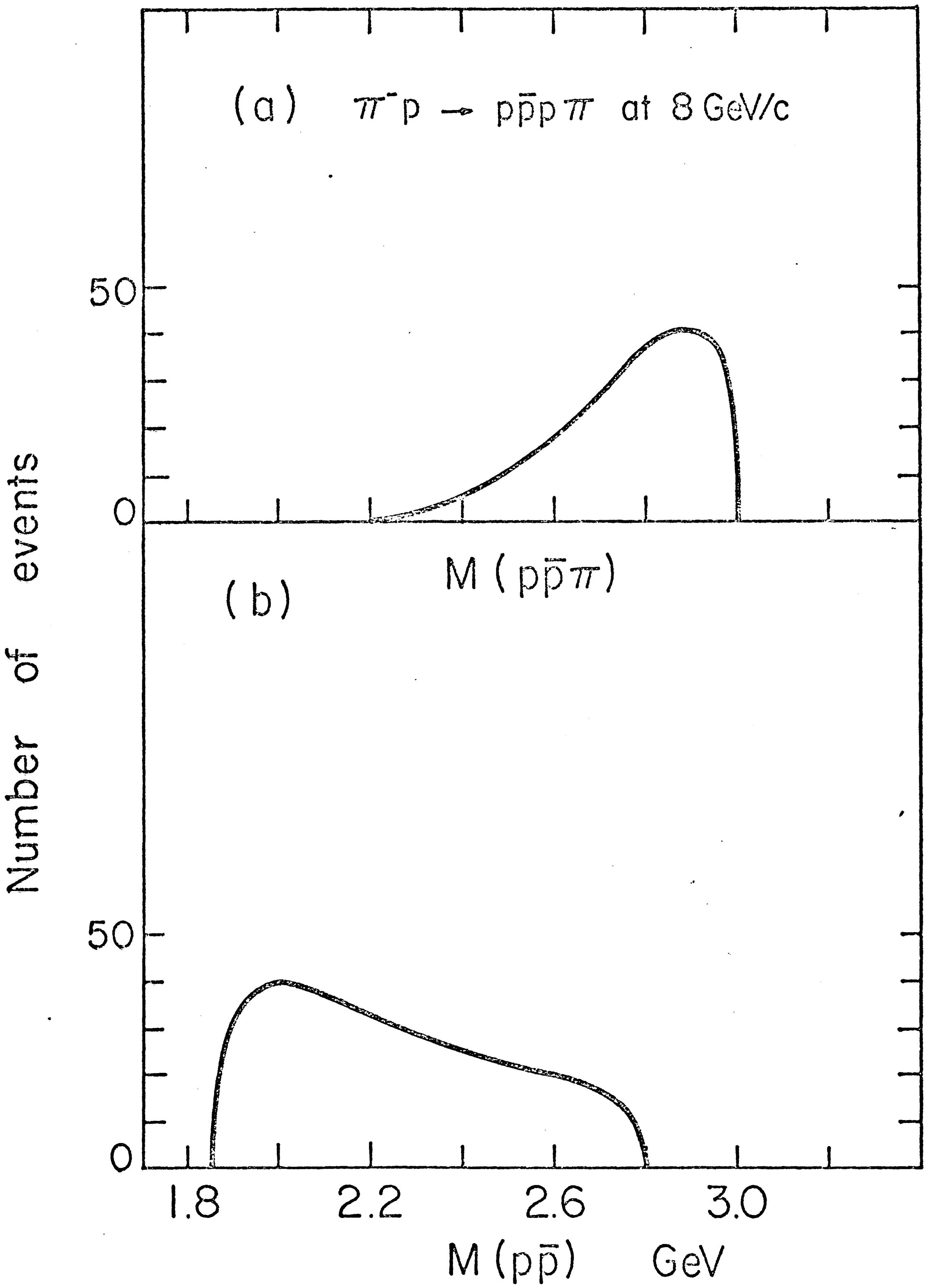


Fig. 3 - Kinematics of the reaction $\pi p \longrightarrow pX$ at p_i = 8 GeV/c

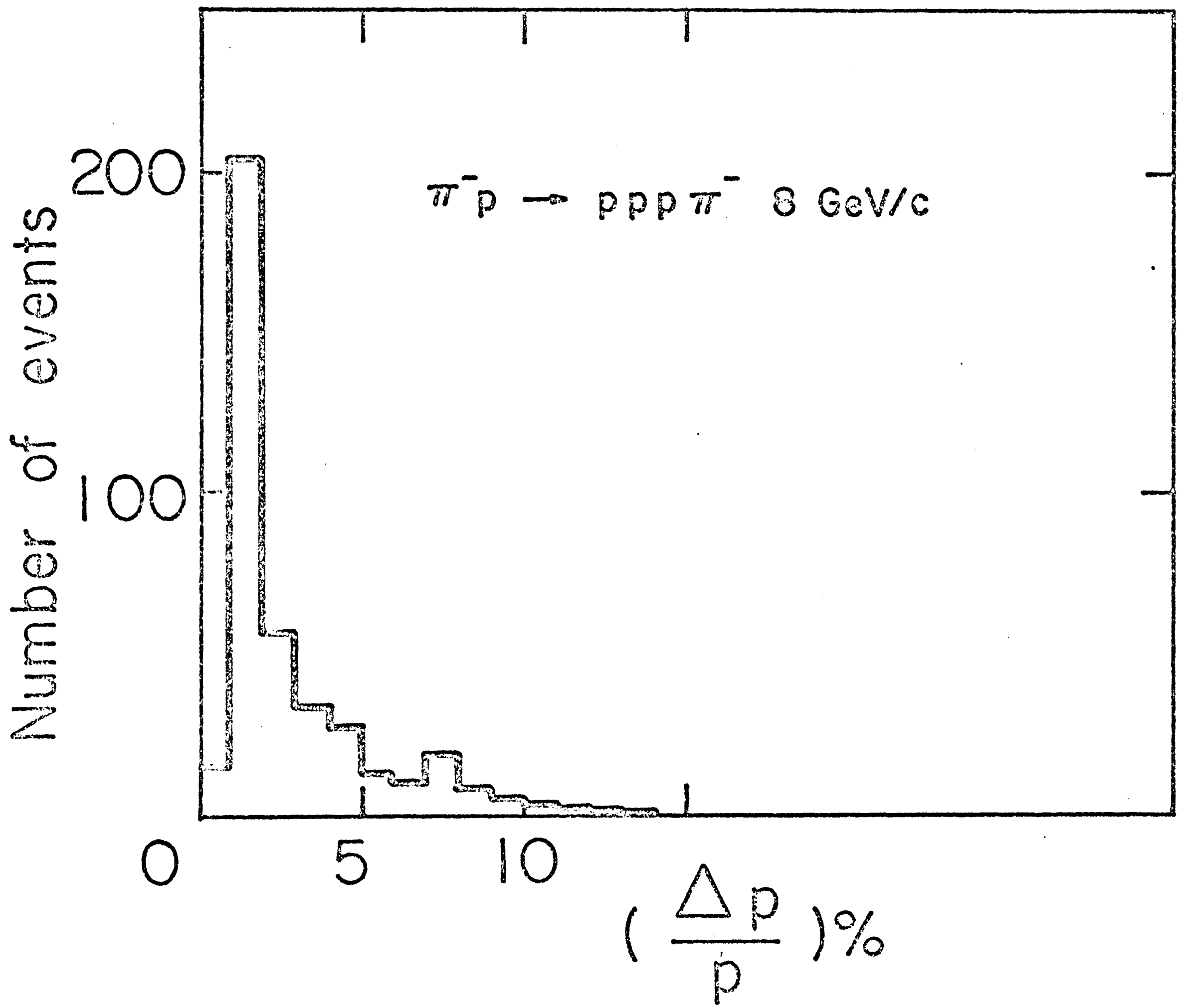
FIGURE 4



(a) $\pi^- p \rightarrow p\bar{p}p\pi$ at 8 GeV/c
50
0
M ($p\bar{p}\pi$)
(b)
50
0
1.8
2.2
2.6
3.0
M ($p\bar{p}$) GeV
Number of events

FIGURE 5

ERRORS ON PARTICLES OPPOSITE TRIGGERING PROTON.



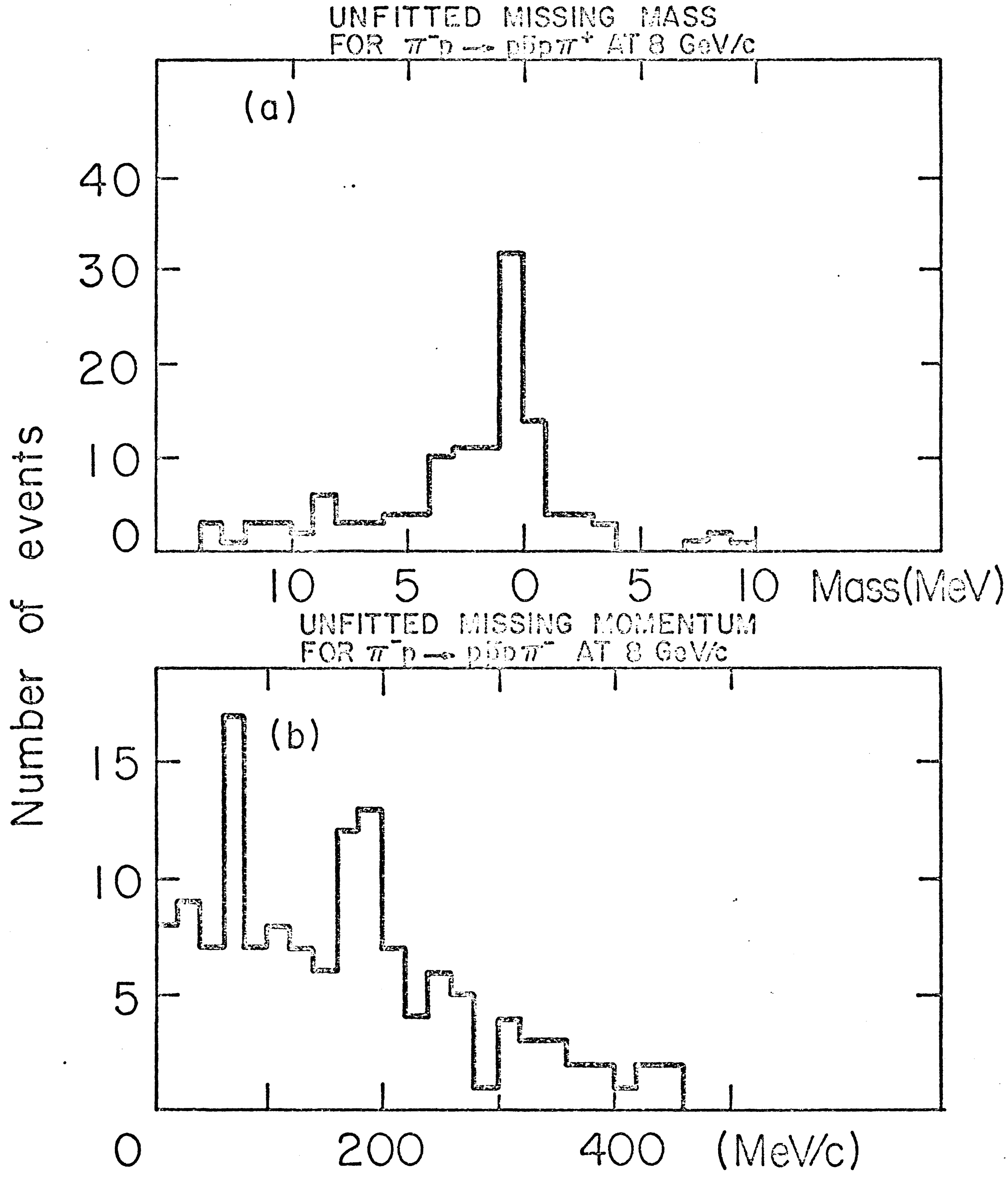
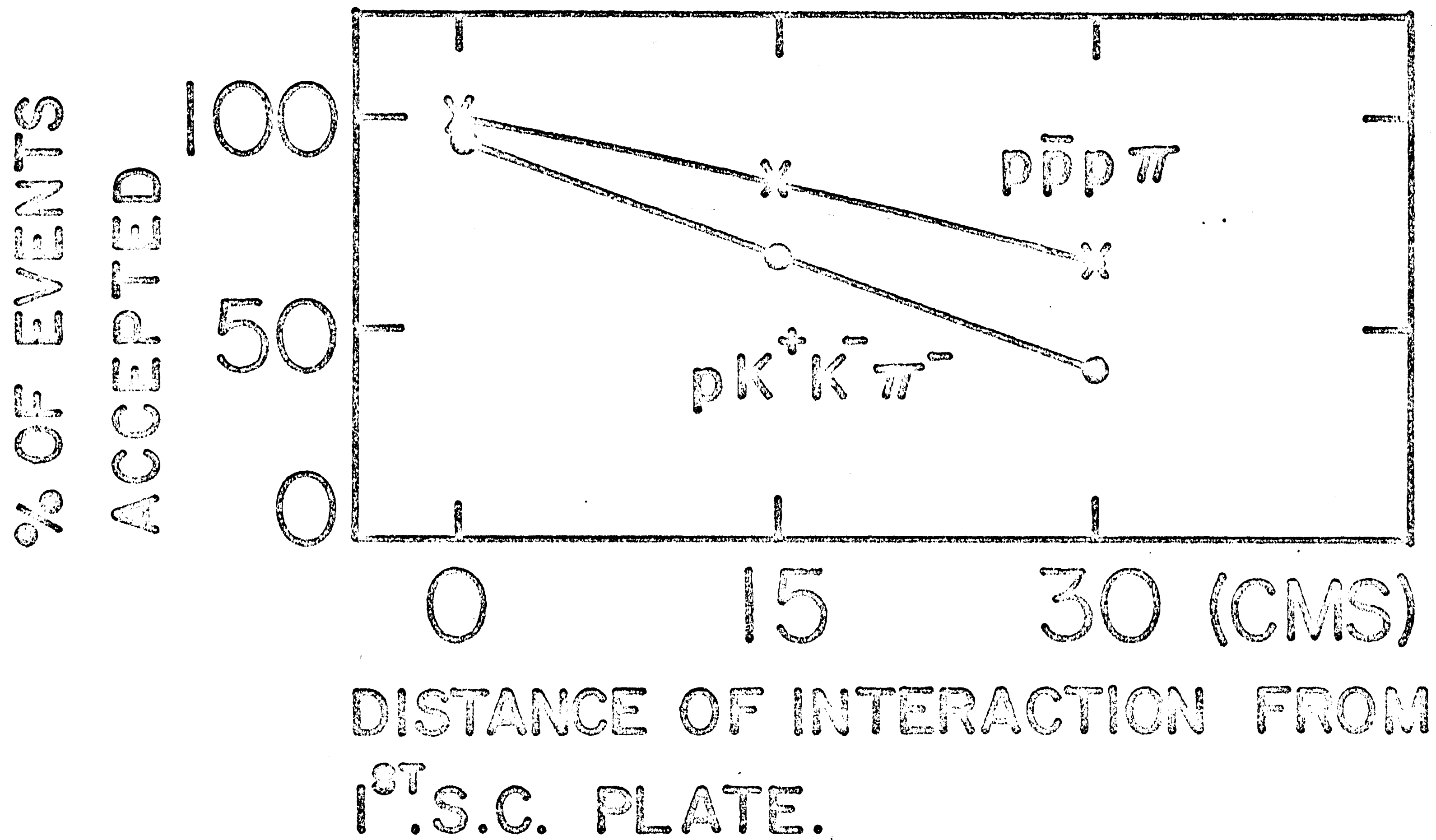

UNFITTED MISSING MASS
FOR $\pi^- p \rightarrow p\bar{p}p\pi^+$ AT 8 GeV/c
(a)
40
30
20
10
0
10
5
0
5
10
Mass(MeV)
Number of events
UNFITTED MISSING MOMENTUM
FOR $\pi^- p \rightarrow p\bar{p}p\pi^-$ AT 8 GeV/c
(b)
15
10
5
0
200
400
(MeV/c)

FIGURE 6

FIGURE 7



% OF EVENTS ACCEPTED
100
50
0
0
15
30 (CMS)
DISTANCE OF INTERACTION FROM 1ST S.C. PLATE.
$p\bar{p}p\pi$
$pK^+K^-\pi^-$

ANGULAR EFFICIENCY FOR THE REACTION $\pi^- p \rightarrow p\bar{p}p\pi^-$ 8 GeV/c

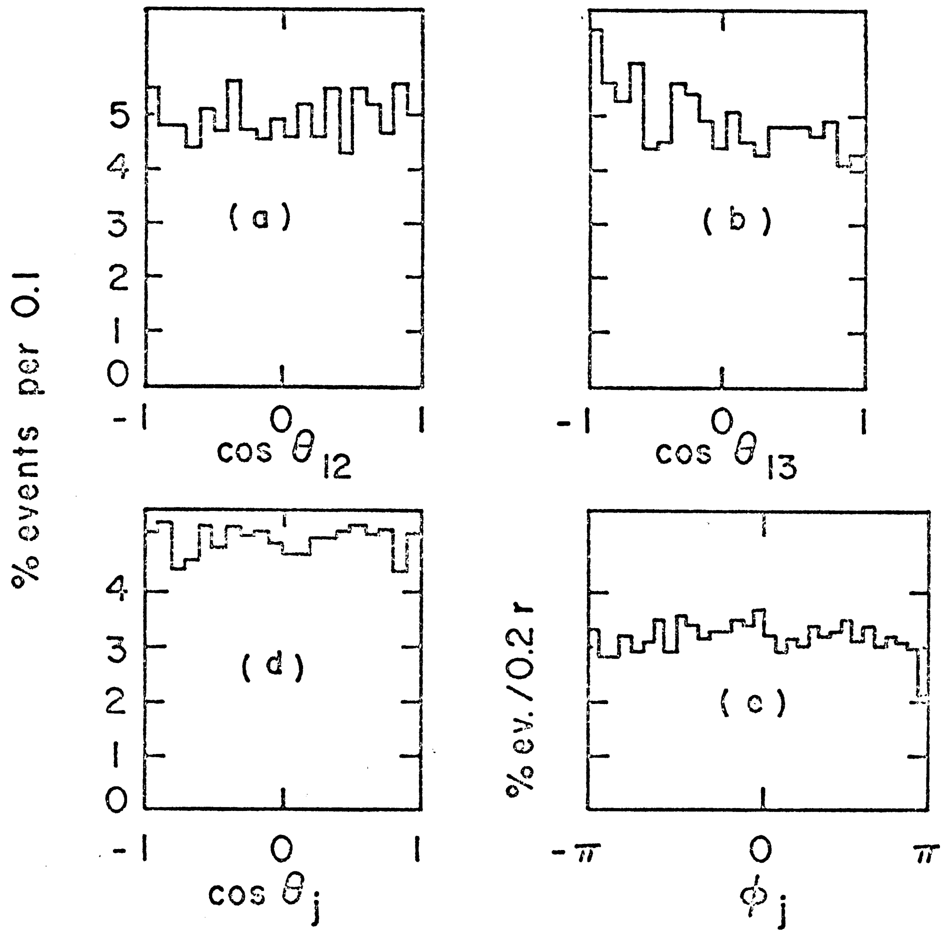


FIGURE 8

ANGULAR EFFICIENCY FOR THE REACTION $\pi^- p \rightarrow p K^+ K^- \pi^-$ 8 Gev/c

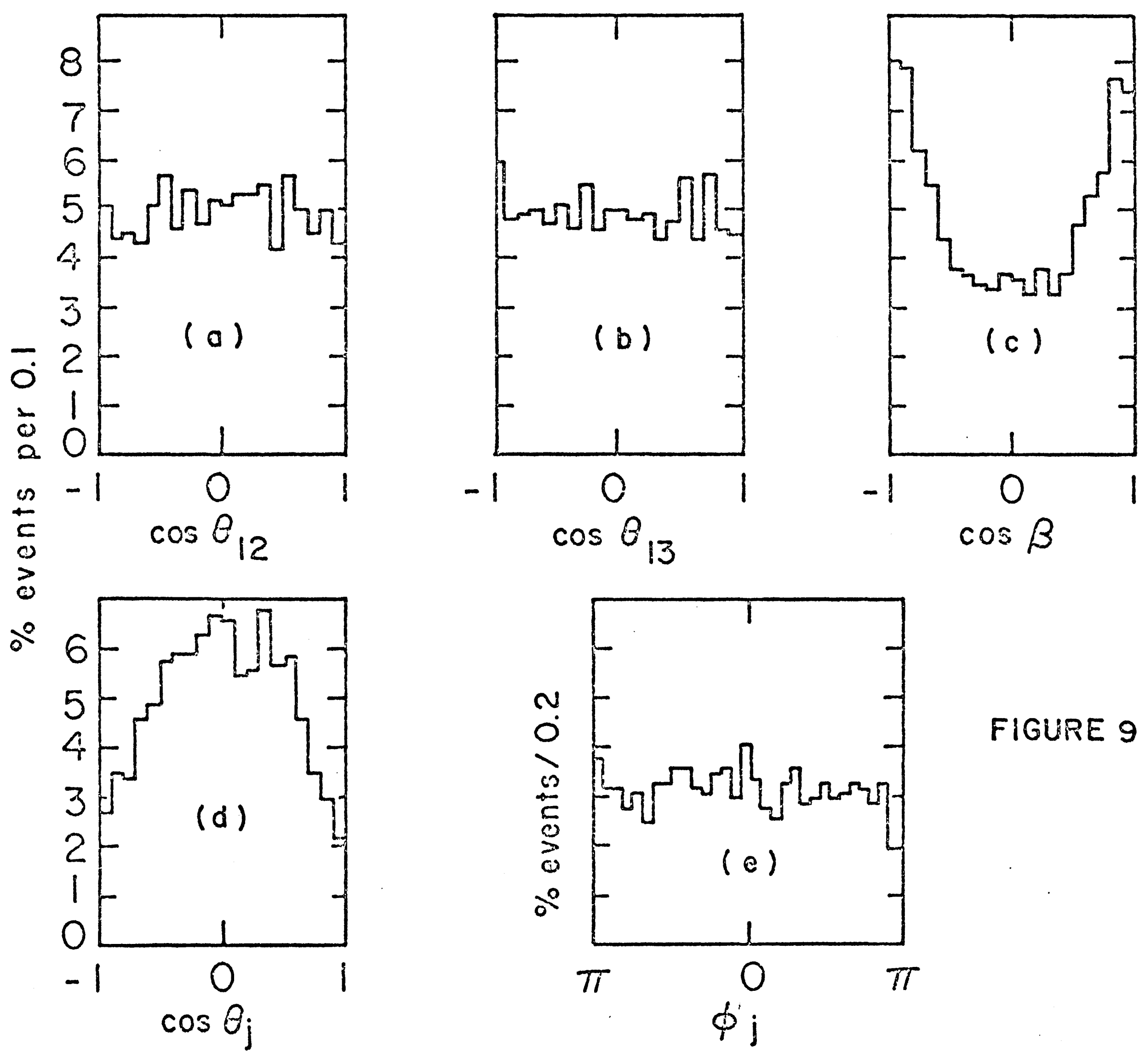


FIGURE 9