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LIGHT MESON SPECTROSCOPY

THE D(1285) [f_1 (1285)] and E/iota(1420) [f_1 (1420), η (1440)]

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ABSTRACT

The $K^+K^o\pi^-$ state has been has been produced by π^-, K^- and $\bar{p}$ beams at beam momenta of about 8 GeV/c. The π^- and $\bar{p}$ beam data show peaks at 1285 and 1420 MeV identified as the D(1285) and E/iota(1420). The K^- beam data does not show any $K^+K^o\pi^-$ peaks. A partial wave analysis of the π^- beam data show evidence of $J^{PG} = 1^{++}$ resonance at 1285 MeV together with a small 0^{-+} peak. The 1420 MeV peak is mainly a 0^{-+} resonance with a small amount of 1^{++}. There is an indication of a 1^{+-} state at 1420 MeV. Also observed is a peak at a mass of 1512 MeV.

We have obtained a very large amount of data using the Brookhaven National Laboratory Multi-Particle Spectrometer (MPS). The reactions studied are

$\pi^- + p \longrightarrow K^+ + K^o_s + \pi^- + n$	at 8 GeV/c	Reaction (1)
$K^- + p \longrightarrow K^+ + K^o_s + \pi^- + X$	at 8 GeV/c	Reaction (2)
$\bar{p} + p \longrightarrow K^+ + K^o_s + \pi^- + X$	at 6.6 and 8 GeV/c	Reaction (3)

where X is one or more particles.

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The Particle Data Group has renamed these resonances, the D(1285) to f_1 (1285), the E(1420) to f_1 (1420) and the iota to η (1440). Since the new names imply particular spin parity states and our data show more partial waves resonating than the new names imply, I will use the old notation. The states in our data that are not in the PDG tables are the 1285 MeV 0^{-+} and 1420 MeV 1^{+-}.

The E resonance has been around for a long time. It was first observed in 1967 in a $\bar{p}$ experiment at rest [ref. 1] and the spin parity was determined to be 0^{-+}. A second experiment observed the E peak with a π^+ beam and determined the spin parity to be 1^{++} [ref. 2]. Figure 1a and 1b show the KKπ mass plots for these two experiments. By now many more experiments have observed both the D and E peaks with the spin parity being either 0^{-+} or 1^{++}. The interest in the E peak increased when e^+e^- collider experiments observed the J/ψ decay into a γ plus a peak around 1460 MeV decaying into KKπ [ref. 3]. Figure 1c shows a mass plot where the peak is clearly observed. Since the mass was higher than 1420 MeV, the peak was called the iota and the spin parity was determined to be 0^{-+}. All of these experiments had data samples of less than 1000 events in the 1420 MeV peak and some less than 100 events, so we decided to perform an experiment to produce about 10,000 E/iota events with π^-, K^- and $\bar{p}$ beams. The aim is to perform a complete partial wave analysis. The production of the iota revived the interest that this object may be a glueball.

Figure 2 shows the MPS with the various trigger and detection components. Reference 4 gives details of this experiment and Table I has the summary of the data taken over 5 years. The 1987 data has not yet been processed and this paper will report on the preliminary results of the 1983 to 1986 data.

Figure 3 shows the $K^+K^o\pi^-$ mass plot for reaction (1). There are about 30,000 events and the D(1285) and E/iota(1420) peaks are clearly observed. In addition a four sigma peak is also visible at 1510 MeV. The solid line is a fit to three Breit-Wigner resonances and a polynomial background.

DISCLAIMER

TABLE I

SUMMARY OF DATA TAKEN
FLUX AND NUMBER OF EVENTS

Year	BEAM 8 GeV/c		
	π^-	K^-	$\bar{p}$
1983	150×10^9 14,000 Events	NONE	30×10^9* 12,000 Events
1985	120×10^9 12,000 Events	8.5×10^9 1,000 Events	NONE
1986	260×10^9 20,000 Events	9.5×10^9 1,200 Events	NONE
1987	NONE	30×10^9 4,000 Events	45×10^9 ?????

* The beam momentum for this run was at 6.6 GeV/c

Below are the values of each peak:

Mass (MeV)	Width (MeV)	Number of Events
1285 ± 1	22 ± 2	4750 ± 100
1419 ± 1	66 ± 2	8800 ± 200
1512 ± 4	35 ± 15	600 ± 200

Figure 4 shows the mass plots of reaction (1) for three 4-vector momentum transfer (-t) regions. The D(1285) peak is clearly observed in all three (-t) regions. The strength of the D/iota(1420) changes with (-t) and becomes more pronounced at higher values of (-t). A partial wave analysis was performed where only spin 0 and 1 states were considered and each state was assumed to decay via either K^*K or $\delta\pi$. The $K^* - K\pi$ and the $\delta - K^+K^o$. The fits were done in 20 MeV mass bins and each mass fit was independent of the other mass bins. What is computed here are the intensities for each spin(J), parity(P) and G-parity(G) of the waves. For I=0 states, the G-parity and C-parity are equal, i.e. G=C. Figure 5 shows the intensities of various spin 0 and 1 waves. At the D region the 1^{++} is resonant and there is also a small peak in the 0^{-+} wave. The 0^{-+} wave was also observed by Ando et al [Ref. 5] where the D(1285) $\rightarrow \delta + \pi$, and $\delta \rightarrow \eta + \pi$. The strongest wave at the 1420 mass region is the 0^{-+}. In addition the 1^{++} and 1^{-+} also show small peaks. The peak in 1^{++} is mostly at low values of (-t), i.e. -t < 0.2 $(\mathrm{GeV/c})^2$.

Figure 6a shows the mass plot for reaction (3) [ref. 6]. This data was obtained in 1983 and did not have the time-of-flight counter that separated the proton from the K^+ and hence the data has much more background. The D(1285) and E/iota(1420) peaks are clearly visible. The solid line is the experimental acceptance. Figure 6b shows the 0^{-+} and 1^{++} waves. The data is consistant with a resonant 0^{-+} wave.

The data of reaction (2) is very preliminary. Figure 7a shows the $K^+K^o\pi^-$ mass plot produced by a K^- beam. There are about 1500 events in this plot and neither the E nor the D is seen. Figure 7b shows the $K^o\pi^-$ mass plot where the K^* is clearly observed. The absence of both the D and E are curious, but we need to wait until the 1987 data reduction is complete.

CONCLUSION: We have observed both the D and E/iota resonances. The partial wave analysis of the E/iota shows a resonant 0^{-+} wave with small peaks of 1^{++} and 1^{+-} waves. The D is mostly 1^{++} with a small peak of 0^{-+} wave. So far we cannot determine if there is any glueball component in the E/iota peak.

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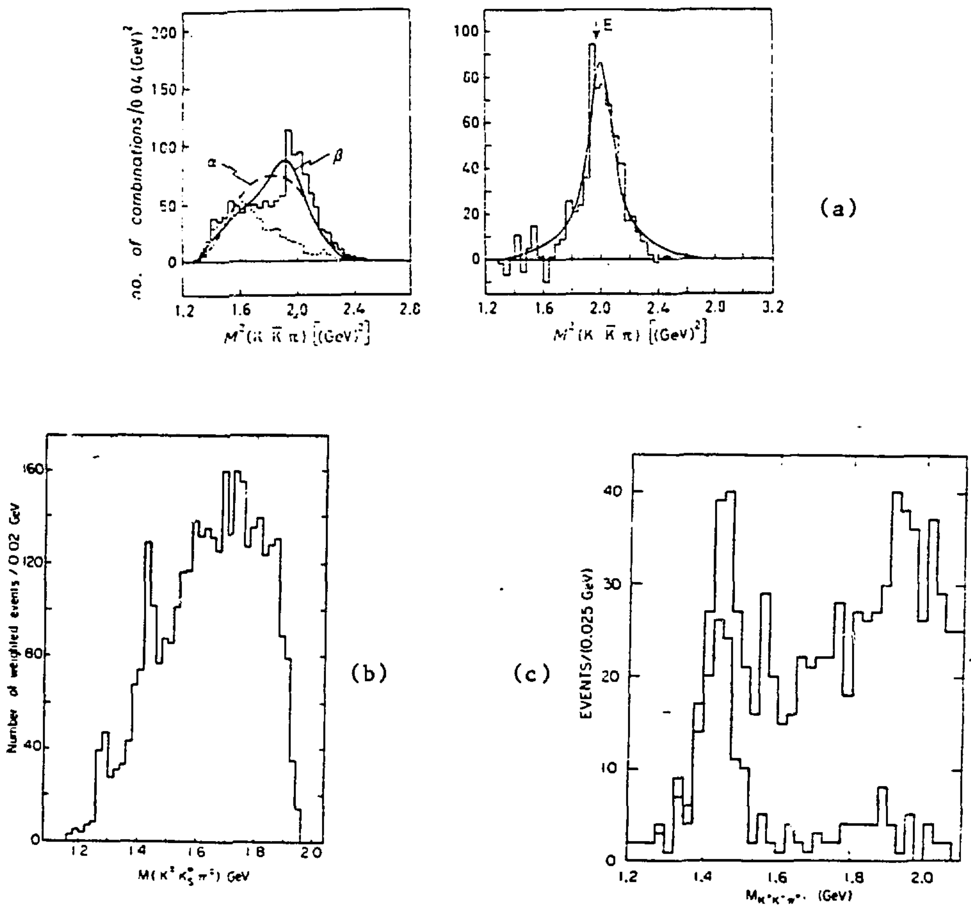


Figure 1. $KK\bar{\pi}$ mass distributions. a) $\bar{p}p \rightarrow (KK\pi)^0\pi^+\pi^-$ at rest, (ref. 1), b) $\pi^-p \rightarrow (KK\pi)^0 n$ at 3.9 GeV/c, (ref. 2); c) $J/\psi \rightarrow K^+K^-\pi^0\gamma$ (ref. 3).

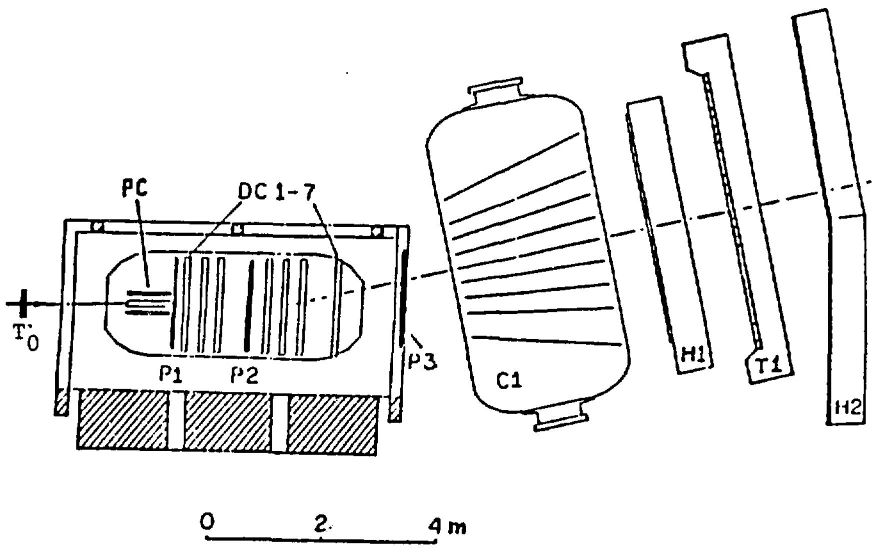


Figure 2. BNL-MPS. P1, P2 and P3 are PWC's used in the trigger. T_0 and T_1 are time-of-flight counters. DC's are 49 planes of drift chambers. C_1 is a high pressure Cherenkov counter that veto's pions. H_1 and H_2 are scintillator hodoscopes. Magnetic field is 0.5 Tesla.

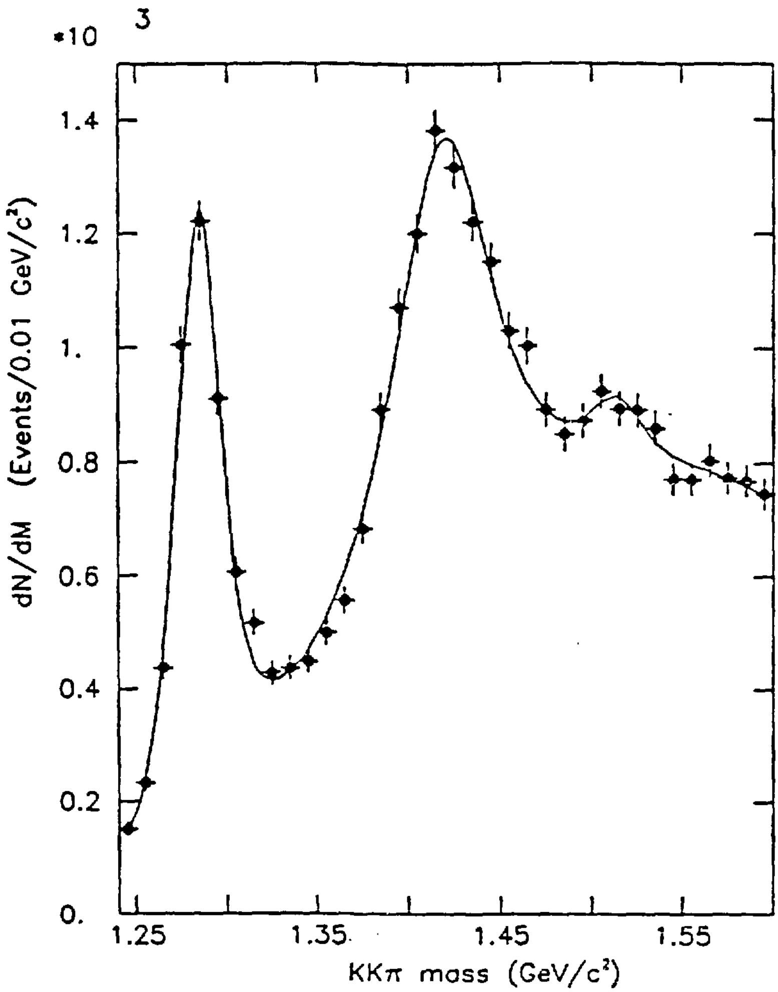
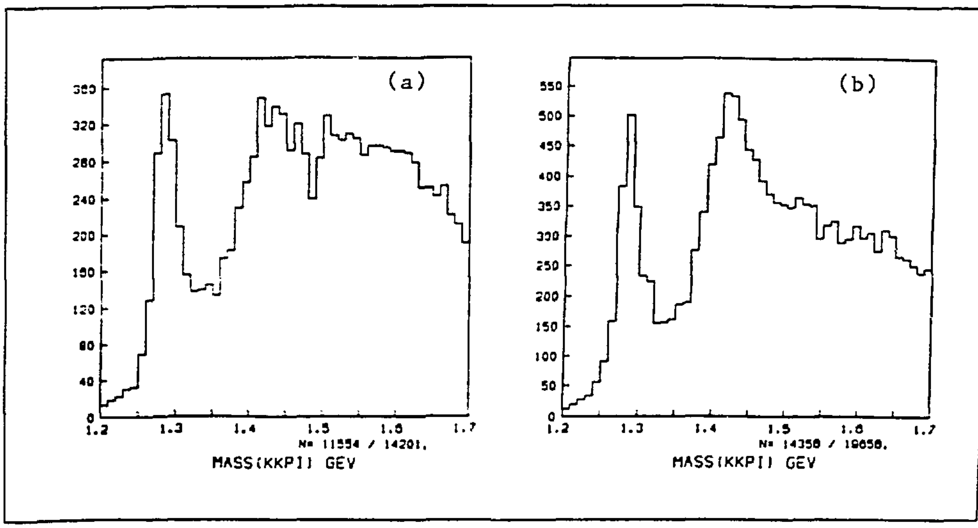


Figure 3. Uncorrected $K^+K^0\pi^-$ mass from $\pi^-p \to K\bar{K}\pi n$ at 8 GeV/c and $-t < 1.0\ (GeV/c)^2$. Fit is 3 Breit-Wigners plus polynomial background.



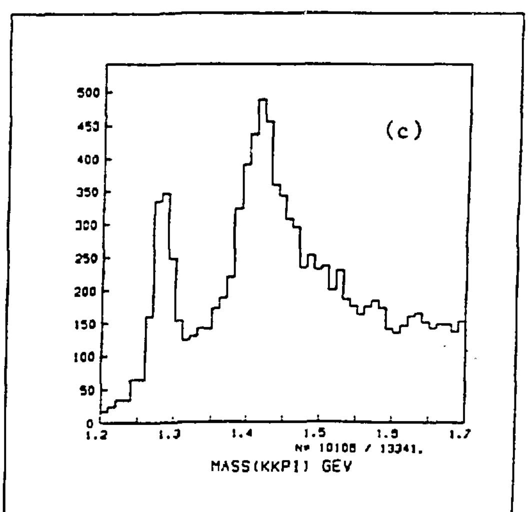


Figure_4. Uncorrected $K^+K^0\pi^-$ mass from $\pi^- p \to KK\pi n$ at 8 GeV/c. at 3 t ranges. a) $-t < 0.14 (GeV/c)^2$.

b) $0.14 < -t < 0.4\ (GeV/c)^2$.

c) $0.4 < -t < 1.0\ (GeV/c)^2$.

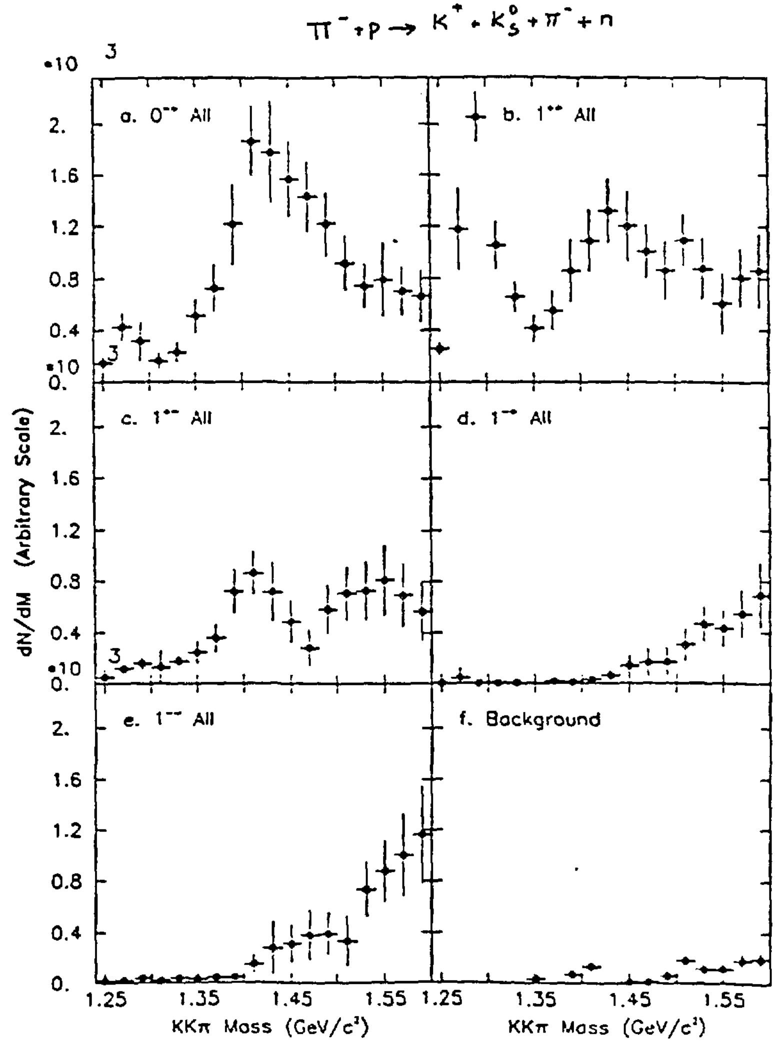


Figure 5. Intensities of J^{PC} Waves, $0.0 \leq -t < 1.0$
a. 0^{-+} b. 1^{++} c. 1^{+-} d. 1^{-+} e. 1^{--} f. Background

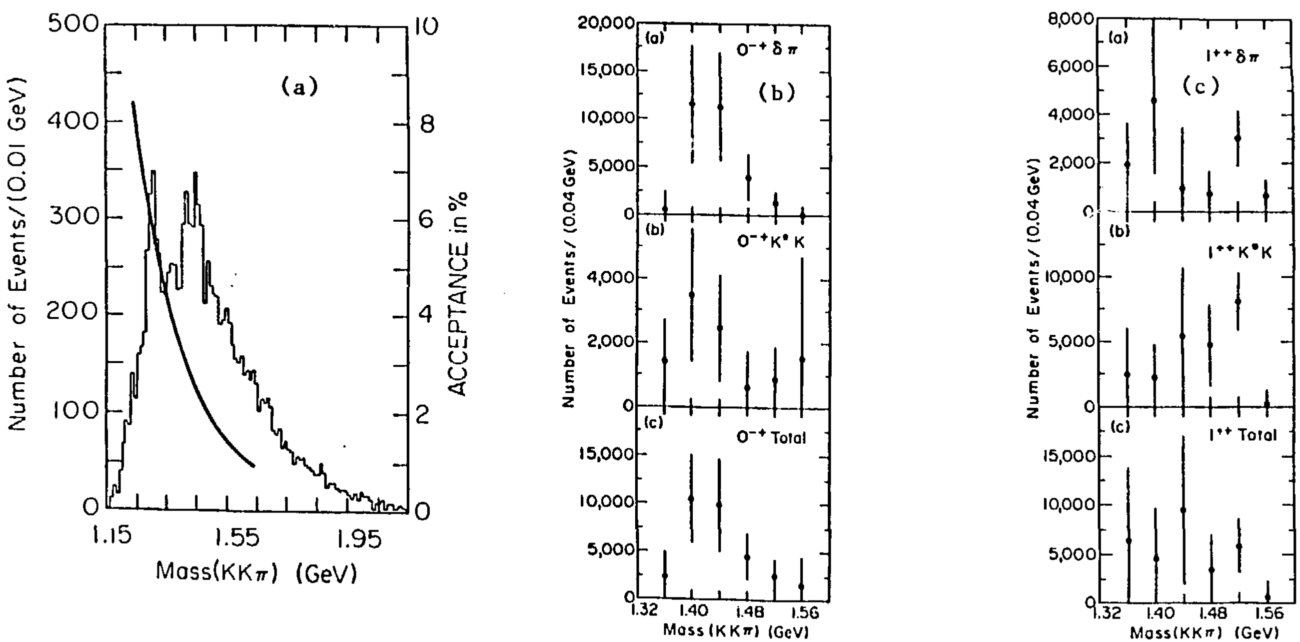


Figure 6. $\bar{p}p \rightarrow K^+K^0\pi^-$ X at 6.6 GeV/c. a) $K^+K^0\pi^-$ mass; smooth curve is acceptance. b) and c) Intensities of J^{PG} waves.

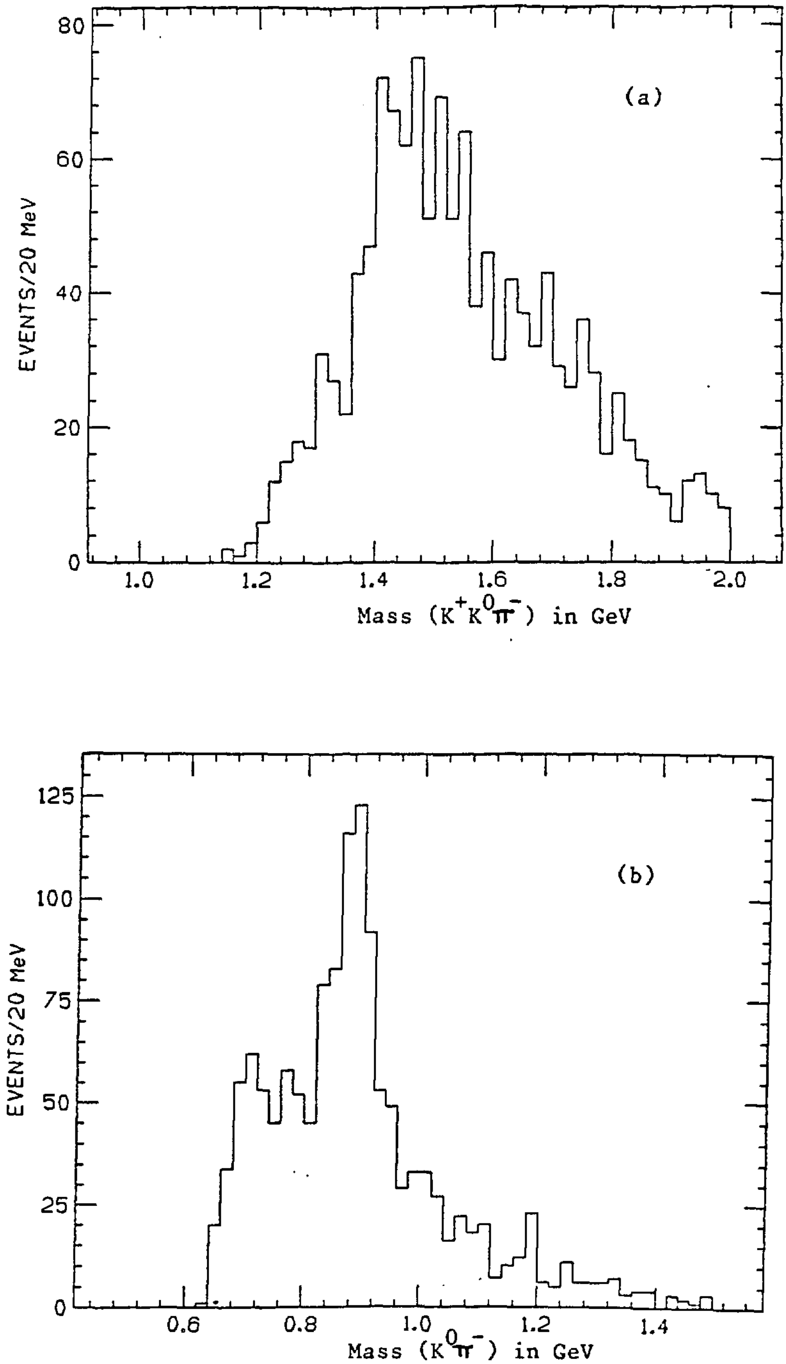


Figure 7. $K^-p \rightarrow K^+K^0\pi^-$ X at 8 GeV/c and $-t < 1.0$ (GeV/c)^2