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AGS #771 Collaboration

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STUDY OF $K^+K_S\pi^-$ Final State Produced by π^- and $\bar{p}$ Beams

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ABSTRACT

We observe the production of D and E mesons in the reactions $\pi^-p \to K^+K_S\pi^-n$ at 8 GeV/c and $\bar{p}p \to K^+K_S\pi^- + X$ at 6.5 GeV/c. A qualitative study of the Dalitz plot indicates that, unlike the D mesons, the E mesons observed in the π^-p induced reaction have different decay characteristics from those observed in the $\bar{p}p$ induced reaction.

Introduction

The main interest in studying the final state $K\bar{K}\pi$ is to clarify the status of the E(iota) meson which has been considered a strong glueball candidate after its observation in ψ radiative decays. Originally the E was observed in $\bar{p}p$ annihilations at rest, specifically in $\bar{p}p \rightarrow K\bar{K}\pi\pi\pi$.[2] The mass and width were found to be m_E = 1425 ± 7 MeV and Γ_E = 80 ± 10 MeV and its $J^{PC} = 0^{-+}$. More recently a state with similar mass and width (m_E = 1426 ± 6 MeV and Γ_E = 40 ± 15 MeV) was observed in the reaction $\pi^- p \rightarrow K\bar{K}\pi n$ at 4.0 GeV/c by Dionisi et al.[3] The spin-parity analysis gave $J^{PC} = 1^{++}$ and mostly a K^*K decay mode. Reanalysis of the $\bar{p}p$ data at rest by Baillon confirmed the original $J^{PC} = 0^{-+}$ with branching ratios 50% K^*K and 50% $\delta\pi$. Interest in this state increased substantially with the observation of a state in the decay $\psi \rightarrow \gamma KK\pi$ with mass 1440 ± 10 and width 60 ± 10.[4,5] A spin-parity analysis of that data found $J^{PC} = 0^{-+}$.[3] Although very similar in mass and width the different J^{PC} points to the conclusion that these may in fact be two distinct states. A particularly striking difference between the $\pi^- p$ data and the other experiments is the absence in the others of the D meson, with J^{PC} well established as 1^{++}.

In order to clarify this situation, an experiment (#771) was approved to run on the MPS spectrometer at BNL with different hadronic beams and study the $K^+K_S\pi^-$ final state. This experiment is a collaboration between BNL, Florida State University, Indiana University and Southern Massachusetts University.[1] In this report we will present some preliminary results based on a partial portion of the data accumulated to date.

Experimental Set-up

The experiment has a beam spectrometer with 3 Cerenkov counters to identify π, K and p and two electrostatic separators to separate the beams. So far data have been collected with a π^- beam at 8 GeV/c and a $\bar{p}$ beam at 6.5 GeV/c. A run with a K^- beam at 6.0 GeV/c is planned for next year. The layout of the rest of the experiment is shown in Fig. 1. The MPS magnet was powered to 5 Kgauss and filled with 3 proportional wire chambers (P1, P2, P3) and 7 drift chamber modules. Details of the drift chamber module construction are give in reference 6. The π^- data were collected with a 30 cm liquid-hydrogen target and the $\bar{p}$ data with a 60 cm target. Surrounding the target was a target box (TB) consisting of 4 planes (top, bottom, right and left) of Pb and plastic scintillator, 30 cm-wide and 80 cm-long. Downstream of the MPS was a high pressure Cerenkov counter (C1) with $\gamma_{threshold} \approx 10$ and two large area plastic scintillator hodoscopes H_1, H_2. Hodoscope H_1 matched the C1 acceptance and cells; hodoscope H_2 had finer strips (6.25 cm-wide) and was used in coincidence with P2 and P3 to select positive particles in the momentum range 1.5 to 5 GeV/c.

The trigger for both beams required a coincidence between two random-access memories (RAM1 and RAM2).[7] The inputs to RAM1 were P2, P3, H2 to select positive particles between 1.5 and 5 GeV/c. The inputs to RAM2 were P2, P3, $H1 \cdot \bar{C}1$ to ensure that the momentum selected particles went through C1 and that π^+'s accepted by RAM1 are rejected. In addition, for the $\bar{p}$ beam, we required that the number of hits on P1 be 2 or greater and on P2 be 4 or greater. For the π^- beam we had stricter trigger requirements: number of hits on P1 equal to 2, number of hits on P2 equal to 4 and no signal from the target box (to select neutron events). The trigger rates were 1/110K for π's and 1/4.5K for $\bar{p}$'s.

Data

The data for experiment 771 was taken during April and May 1983. We collected 150 hours with a π^- beam at 8 GeV/c, 10^6 π's/pulse and 1200 pulses/hour, 200 hours with a $\bar{p}$ beam at 6.5 GeV/c, 10^5 $\bar{p}$'s/pulse. The total accumulated flux was 180 nb^{-1} (1.5×10^6 triggers) for π's and 40 nb^{-1} (4×10^6 triggers) for $\bar{p}$'s, with a typical overall acceptance of a few percent. Data processing was done on a 7600 CDC at BNL, a VAX-780 at Indiana University and a CYBER-175 at Florida State University.

Event Selection

The $K^+K_S\pi^-$ events are selected with the following requirements:

1) A positive track with $p > 1.5$ GeV/c going through C1 and producing no light is assumed to be a K^+.
2) The K^+ and π^- tracks form a primary vertex with the beam inside the liquid hydrogen target.
3) A K_S vertex should have $\pi^+\pi^-$ effective mass between .48 and .52 GeV, points to the primary vertex and is at least 2 cm downstream from it. In the π^- data the K_S vertex must be downstream of P1.
4) For $\bar{p}$ induced events if there is more than one π^- track, only the one with higher momentum is used to calculate a $K^+K_S\pi^-$ mass ($\approx$20% of the events have more than one π^- track).

The data to be presented here correspond to 40% of the π^- data and 30% of the $\bar{p}$ data taken during the last run. Figures 2a,b,c give the $K^+K_S\pi^-$ spectra for both beams (without and with n selection in the π^- case) and show clearly the presence of resonant states in the D (1.280

MeV) and E(1420 MeV) regions. Figures 3a,b,c show the missing mass spectrum from π^- data and the K_S mass for both beams. These figures show that the backgrounds are small, the resolution is good (FWHM = 6.5 MeV for K_S) and there is no noticeable systematic mass shift. Fits to the $K\bar{K}\pi$ mass spectra with two simple Breit-Wigner functions and polynomial backgrounds give:

For π beam:

M_D = 1285 ± 2 MeV, Γ_D = 22 ± 2 MeV, n_D = 500 ± 30 events

M_E = 1421 ± 2 MeV, Γ_E = 60 ± 10 MeV and n_E = 800 ± 80 events

For $\bar{p}$ beam:

M_D = 1282 ± 2 MeV, Γ_D = 27 ± 8 MeV and n_D = 400 ± 40 events

M_E = 1416 ± 5 MeV, Γ_E = 80 ± 30 MeV and n_E = 530 ± 100 events

The masses and widths for both states are compatible with being the same states with either π or $\bar{p}$ beams; the values are in good agreement with the ones in the Particle Data Group tables. The t-distributions for D and E are quite shallow, in the π case $\approx e^{1.5t}$ and in the $\bar{p}$ case compatible with being flat. In the latter case, it indicates that they are produced mainly by annihilations in flight. It is noteworthy to point out that, unlike $\bar{p}p$ annihilations at rest in which only the E is observed, both D and E mesons are produced.

In Figures 4 and 5 we show the Dalitz plots [$m^2(K_S\pi^-)$ vs. $m^2(K^+\pi^-)$] for 4 mass regions of $K^+K_S\pi^-$. Note that the D region (1.26 - 1.30 GeV) is very similar for both $\bar{p}$ and π^- data when one takes into account the relatively larger background in the $\bar{p}$ data. The accumulation of events towards the upper edge of the Dalitz plot is what one expects if the D decays tend to favor low $K\bar{K}$ mass. The region between D and E (1.30 - 1.38 GeV) shows no significant structure. The E region (1.38 - 1.46 GeV) shows K^* bands in both $\bar{p}$ and π data, although much more noticeably in the latter. However, the K^* overlap region, corresponding to low $K\bar{K}$ mass is markedly different in both sets: the π data shows an accumulation of events while the $\bar{p}$ data seems to be depleted. The region above the E shows very noticeable K^* bands in the π data but not in the $\bar{p}$ data. This indicates that part of the K^* bands seen in the π data in the E region is attributable to the background.

The striking difference between the π and $\bar{p}$ data in the E region can be best illustrated by plotting the $K^+K_S\pi^-$ spectrum requiring that the K^+K_S effective mass be less than 1.05 GeV (Figures 6a,b). The π data shows very clearly the D and E mesons with very little background while in the $\bar{p}$ data the E meson is noticeably less pronounced. Fitting the $K^+K_S\pi^-$ mass spectra obtained from selecting low mass $K^+{}_S$ (< 1.05 GeV) events while fixing the mass and widths of D and E mesons to values obtained from fitting the full mass spectra we find that for the π data 83 $\pm$ 5% of the D events and 67 $\pm$ 5% of the E events have $m(K^+K_S) < 1.05$ while for the $\bar{p}$ data the corresponding numbers are 74 $\pm$ 5% and 38 $\pm$ 4%. The difference for the E events is well beyond any statistical fluctuations. A detailed partial wave analysis of these data is in progress. It would be premature to present any results at this time; however, from the examination of the Dalitz plots it is already evident that the E meson decay in π^- induced reactions are different from those in $\bar{p}$ induced reactions.

Conclusions

We have observed the D and E mesons in the reactions $\pi^- p \rightarrow K^+K_S\pi^- n$ at 8 GeV/c and $\bar{p}p \rightarrow K^+K_S\pi^- + X$ at 6.5 GeV/c. The measured masses and widths are compatible with each other in both reactions, the average values are m_D = 1285 $\pm$ 2 MeV, Γ_D = 22 $\pm$ 2 MeV, M_E = 1420 $\pm$ 3 MeV and Γ_E = 70 $\pm$ 15 MeV. The slope of the t distribution is the same for D and E and is quite shallow in the π^- induced reaction, $d\sigma/dt \approx e^{1.5t}$. In the $\bar{p}$ induced reaction both D and E show very little t dependence consistent with being produced by annihilations in flight. A qualitative examination of the Dalitz plots show no significant difference in the decays of D meson produced by π or $\bar{p}$ beams. However, in the case of the E meson, those produced by a π^- beam favor in their decays lower $K\bar{K}$ masses compared to those produced by a $\bar{p}$ beam. This may imply that we are dealing with two or more distinct states but a definite statement will have to wait until the partial wave analysis is completed.

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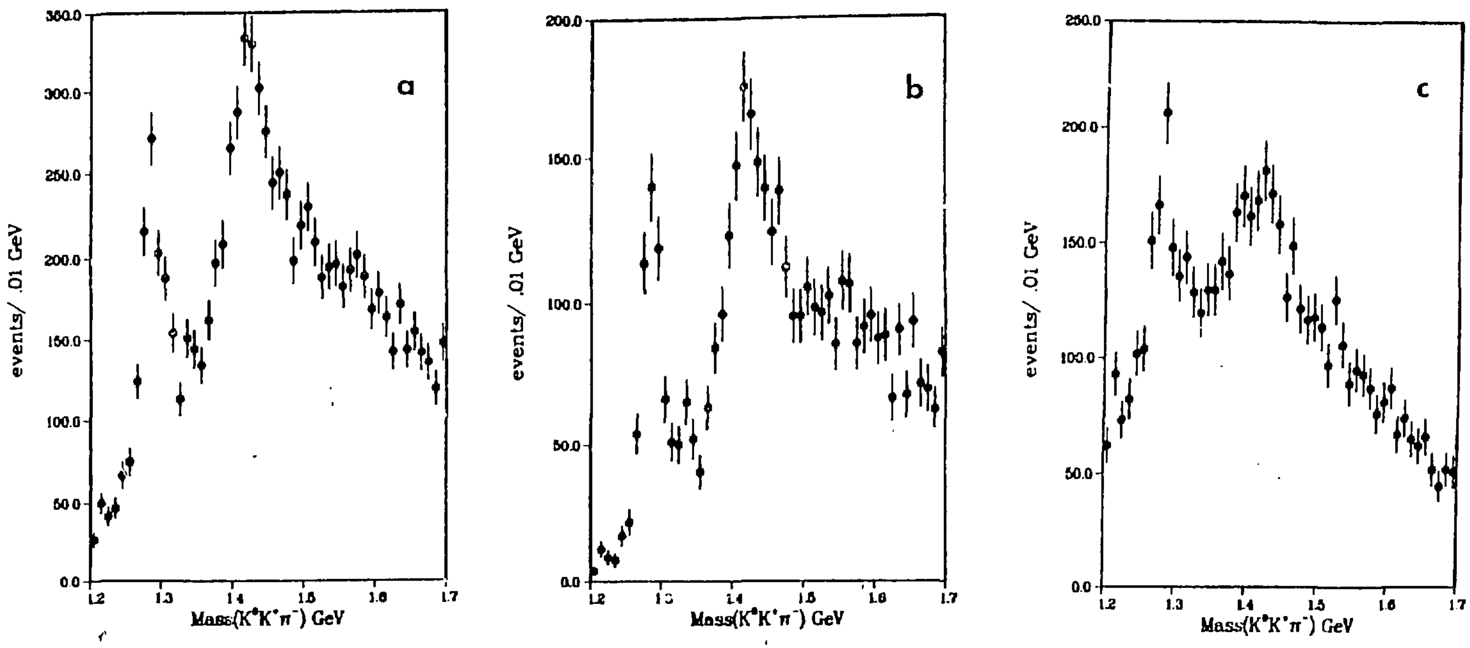

Figure 2.

a) $K_S K^{\mp} \pi^-$ mass spectrum for 40% of the π^- data.

b) Same as (a) after selecting for neutron events (.4 < MM^2 ($K^+ K^\circ \pi^-$) < 1.2 GeV^2).

c) $K_S K^+ \pi^+$ mass spectrum for 30% of the $\bar{p}$ data.

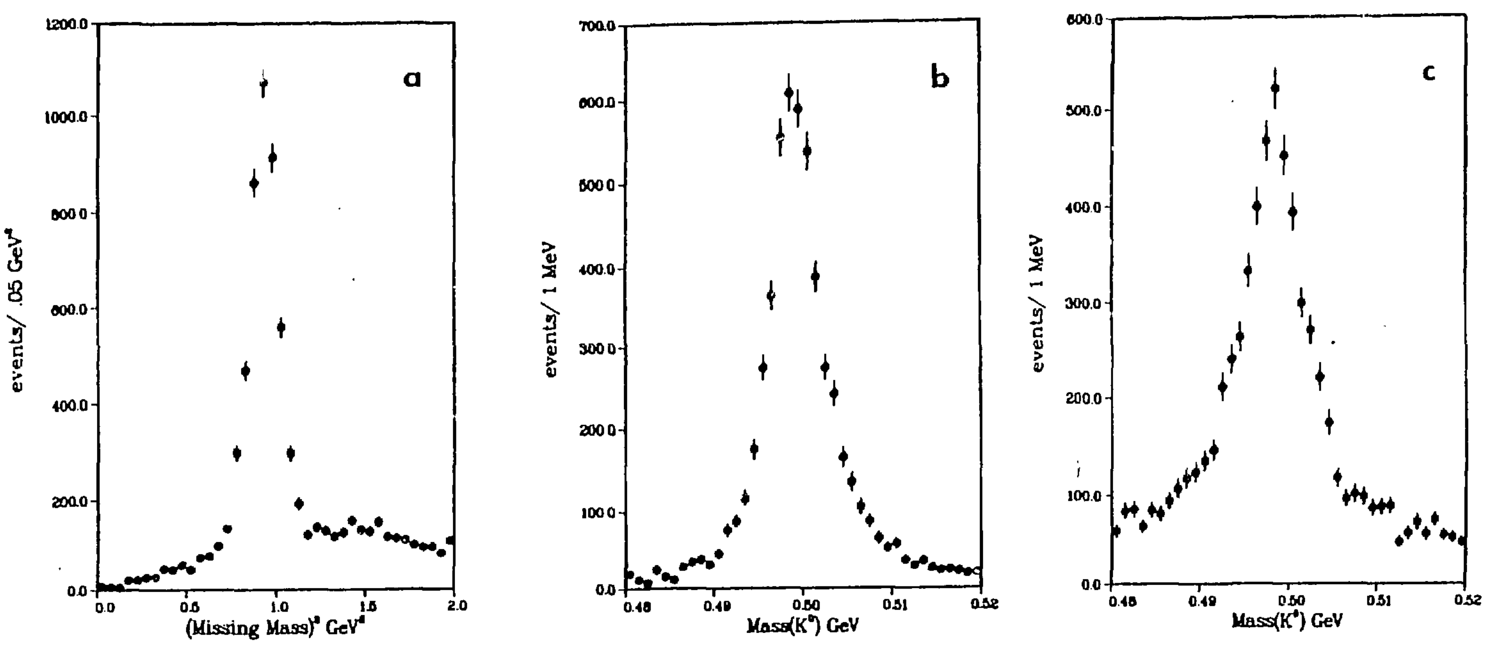

Figure 3.

a) MM^2 ($K^+K_S\pi^-$) for π^- data.
b) $\pi^+\pi^-$ effective mass for K° decays in π^- data.
c) Same as (b) for $\bar{p}$ data.

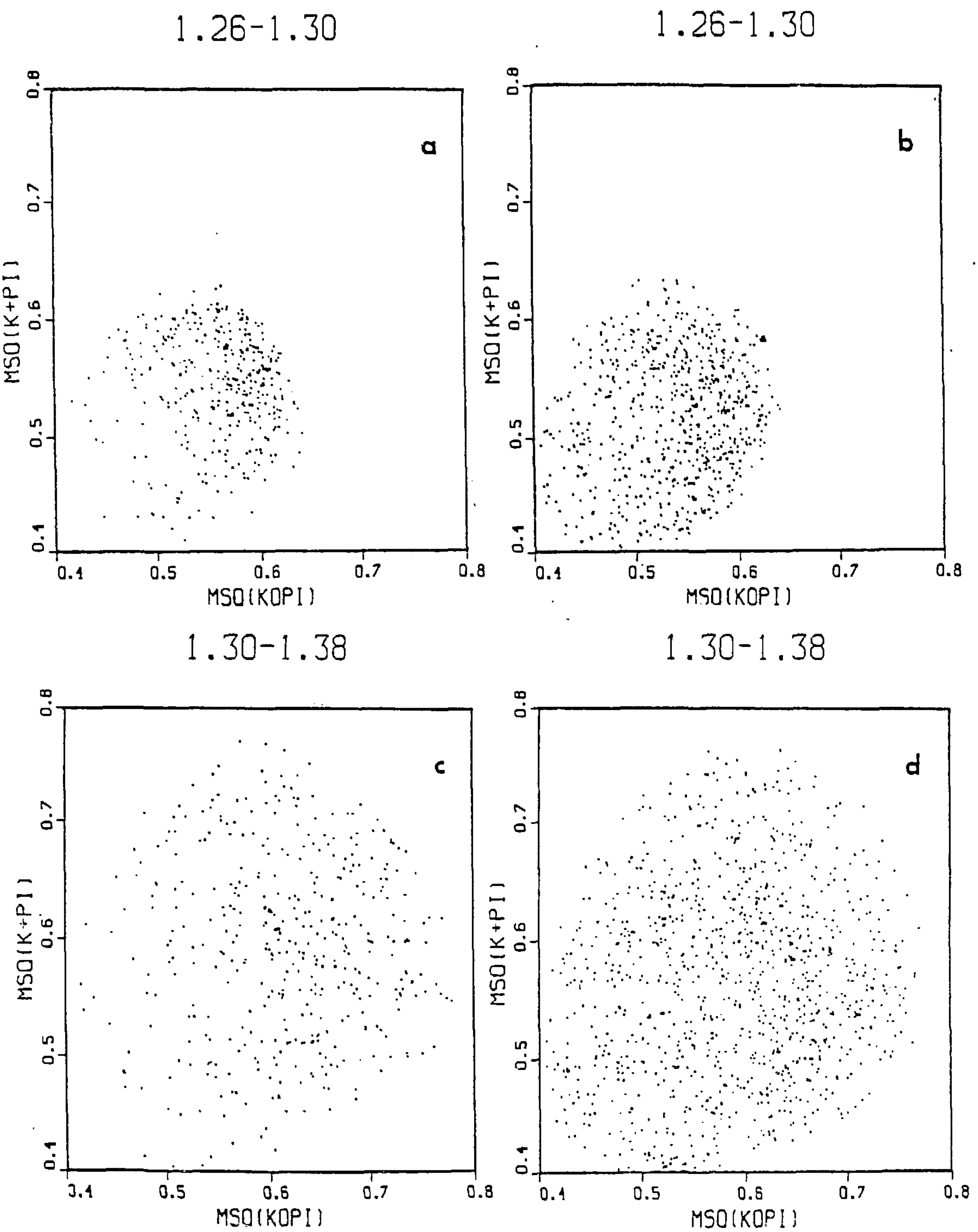

Figure 4. Dalitz plots of $K^+ K_S\pi^-$ events, x-axis is M^2 $(K^\circ\pi^-)$ y-axis is M^2 $(K^+\pi^-)$. (a) $1.28 < M(K^+K^\circ\pi^-) < 1.30$ GeV for π^- data; (b) Same as (a) for $\bar{p}$ data; (c) $1.30 < M(K^+K^\circ\pi^-) < 1.38$ GeV for π^- data; (d) Same as (c) for $\bar{p}$ data.

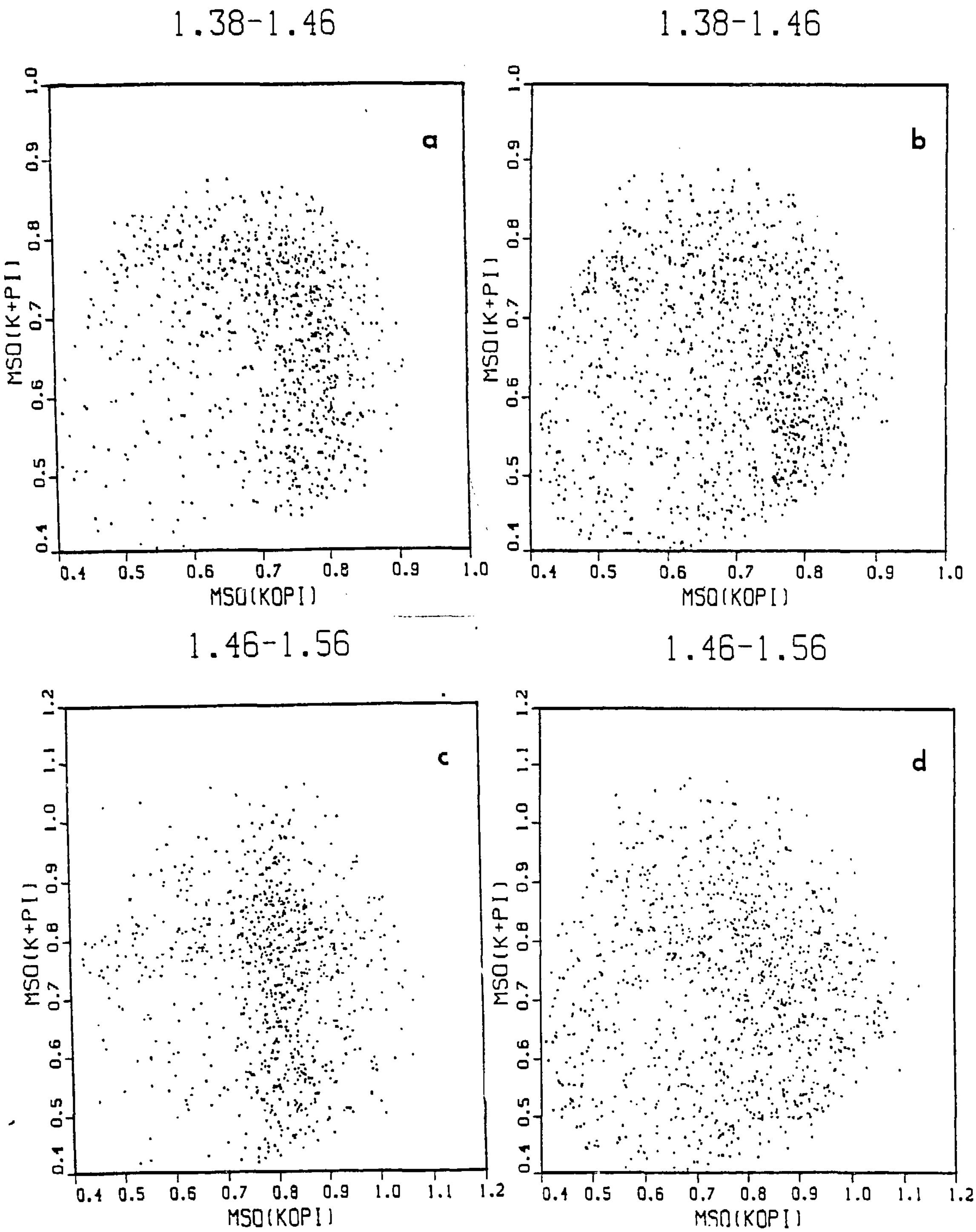

Figure 5. Dalitz plots of $K^+K_S\pi^-$ events, x-axis is M^2 ($K^\circ\pi^-$), y-axis is M^2 ($K^+\pi^-$). (a) 1.38 < M^2 ($K^+K^\circ\pi^-$) < 1.46 GeV for π^- data; (b) same as (a) for $\bar{p}$ data; (c) 1.46 < M ($K^+K_S\pi^-$) < 1.54 GeV for π^- data; (d) same as (c) for $\bar{p}$ data.

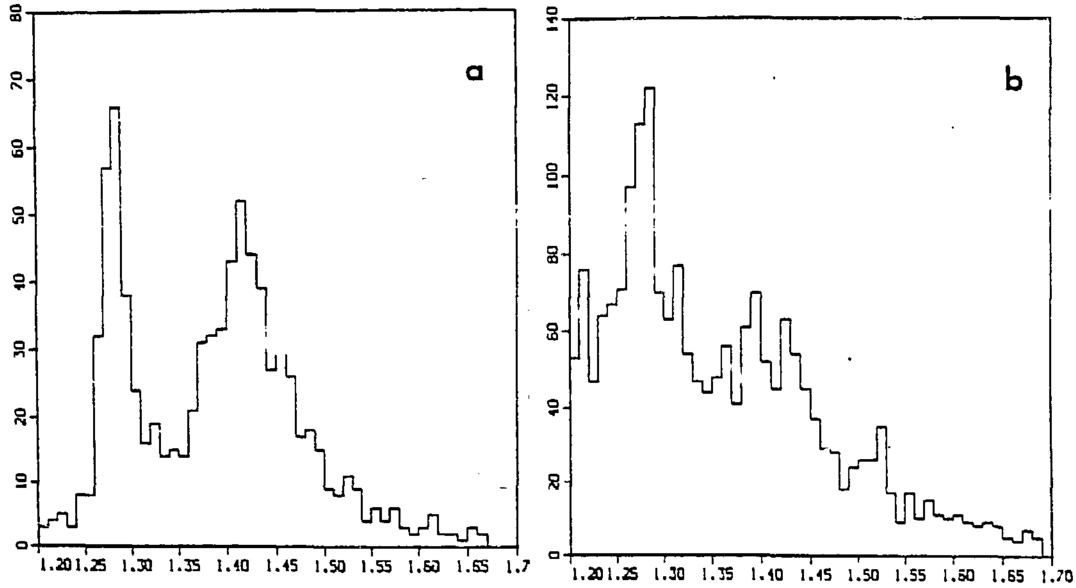

Figure 6. $K^+K_s\pi^-$ mass spectrum requiring M (K^+K_s) < 1.05 GeV.
a) π^- data; (b) $\bar{p}$ data.

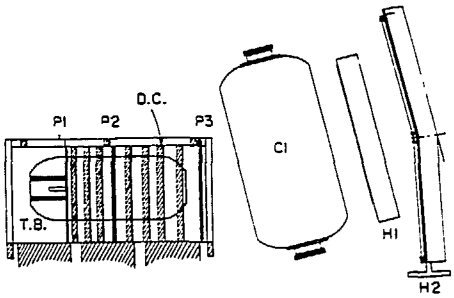

Figure 1. Schematic layout of apparatus. T.B. is target box; P1, P2, P3 are the multiwire proportional chambers; D.C. are the drift chamber modules; C1 is the high pressure Cerenkov, H1, H2 are plastic scintillator hodoscopes.