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THE 1660 MeV/c^2 AND Y_o^* RESONANCES

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We have studied interactions of 1.455 GeV/c K^- mesons with protons in the CERN 32 cm hydrogen bubble chamber and have looked for evidence of a resonance near 1660 MeV/c^2 decaying into two and three bodies. This resonance was first suggested by Alexander et al[1] among $(Y\pi)$ combinations produced by π-p interactions, and by preliminary analysis of the present data [2] on K^-p interactions. Evidence for its existence in several decay channels was given by Alvarez et al.[3]. More recently, Bastien[4] has studied the perturbations in the K^-p inelastic cross-sections very close to threshold (760 MeV/c incident K^-) and Smith[5] has discussed further πp data. The existence of this resonance is accordingly no longer in doubt, but the decay branching ratios are uncertain. The evidence from the above experiments is summarised in Table I. The effective mass plots on which the evidence of the present experiment is based are shown in Figs. 1$(\Sigma^o\pi^+)$, 2 $(\Sigma^-\pi^+)$, 3 $(\Sigma^+\pi^-)$, 4 $(\Lambda\pi)$, 5 $(\Sigma\pi\pi)$ and 6 $(\Lambda\pi\pi)$. Fig. 6 is not a straightforward mass plot for the following reason. The $(\Lambda\pi\pi)$ combinations in the $\pi^+\pi^-\pi^o$ reactions show stronger evidence in the positive state than in the neutral and negative. Since this channel is a mixture of the reactions $Y_1^+ + \pi^- + \pi^o$, $Y_1^- + \pi^+ + \pi^o$, $Y_1^o + \pi^+ + \pi^-$, $\Lambda^o + \omega$ and $\Lambda + \pi^+ + \pi^- + \pi^o$ in comparable strengths it is not possible to calculate the "phase space". Therefore in Fig. 6 the distribution of the difference between the population in the $(\Lambda\pi\pi)^+$ channel and the mean population of the $(\Lambda\pi\pi)^-$ and $(\Lambda\pi\pi)^o$ channels has been drawn. It is clear from the symmetry of the competing reactions that this gives an unbiassed estimate of the contribution of the Y_1^+ (1660). This estimate is a lower limit if the Y_1^- (1660) and Y_1^o (1660) are not negligible. The peak in the $\Sigma^o\pi^+$ mass in Fig. 1 is narrower than the resolution $\pm$ 18 MeV/c (or width) of the resonance and so is regarded as a fluctuation.

Considering the $\Sigma^{\pm}\pi^+\pi^-\pi^{\mp}$ reactions, a $(\Sigma\pi\pi)^+$ can result from either of two $\Sigma^+\pi^+\pi^-$ combinations or a unique $\Sigma^-\pi^+\pi^+$ combination. If the resolution were very poor, on the other hand, the two combinations are not

Table I

Channel		K^-p 1.455 GeV/c Present expt.	K^-p 1.51 GeV/c ref. 3)	π^-p ref. 5)	K^-p Threshold expt. ref. 4)
	Threebody production Two body decay				
positive	$\Lambda\pi^+$	.03 mb			
	$\Sigma^0\pi^+$	$\leq$16/234 ($\leq$.15 mb)	60/504		
	$\Sigma^+\pi^0$	Y^{0**} reflection (70/752)			
neutral	$\Sigma^-\pi^+$	12/341=.03 mb		crosses K^*	$\pi : \pi\pi : \pi\pi\pi = 1.4 : 1 : 1.6$
	$\Sigma^+\pi^-$	<10/520 (< .02 mb)		yes	
	$\Lambda^0\pi^0$	---		weak	
negative	$\Lambda^0\pi^-$	17/669=.02 mb		weak	
	$\Sigma^0\pi^-$	<24/234 (<0.2 mb)		crosses K^*	
	$\Sigma^-\pi^0$	Y_0^{**} reflection		yes	
	Four body production Three body decay				
positive	$(\Sigma\pi\pi)^+$	13/121 (.04 mb)	180/1058		
	$\Lambda^0\pi^+\pi^0$	49/709($\geq$ .17 mb)	90/1736		
neutral	$\Lambda^0\pi^+\pi^-$	(< .07 mb)	—		
negative	$(\Sigma\pi\pi)^-$	$\leq$12/121($\leq$.04 mb)			
	$\Lambda^0\pi^0\pi^-$	(< .04 mb)			

mutually exclusive and count as half an event each. In a practical case, some weighting between the two is appropriate but we have taken the "good resolution" case (as used, implicitly in ref. 3)). If the limits of the resonance are taken as 1.60 ÷ 1.72 only 10 o/o of events where one combination is "resonant" has also the other combination "resonance". The $(\Sigma\pi\pi)^-$ mass (Fig. 5) shows a depression at 1660 MeV/c^2 and a small peak each side. Only an upper limit can therefore be given.

It is possible to identify the combined $(\Sigma^0\pi^+)$, $(\Lambda^0\pi^+)$ and $(\Lambda^0\pi^+\pi^0)$ resonant combinations by plotting the c.m.s. kinetic energy for the π^- in all Λ^0 2-prong events. This is shown in Fig. 7. In principle, all biases of identification and kinematic fitting are avoided by this means. The $\Lambda\omega$ reaction however places an upper limit of 270 MeV for T_π - which results in a broad hump in the region corresponding to 1660 MeV/c^2. If the ω events are subtracted some 60 events with mass 1660 rise above a background of 1100 events. This, and consideration of the individual mass plots give an estimate of

$$\sigma(Y_1^+(1660)) = 0.27 \text{ mb} \qquad \text{in reactions leading to } \Lambda^0$$

The branching ratios can be expressed as

$K^-p \rightarrow Y + \pi^-$	.29 mb		
$Y + \pi^0$	.03 mb	÷	.12 mb
$Y + \pi^+$	.02 mb	÷	.22 mb

We have looked for decays of the type $Y_1(1660) \rightarrow Y_1^*(1385) + \pi$ or $\rightarrow Y_0^*(1405/1520) + \pi$ by counting the number of candidates for such decays in the wings and in the central region of the resonance. If this decay really takes place there should be more candidates in the central region. However, the background of spurious candidates is so high that such decays would be detected only if they were dominant. We have not observed any effect.

The above results are consistent with a resonance which decays preferentially or exclusively into 3-body positive combinations, and a resonance which decays into 2-body combinations of all three charge states. They are not necessarily different resonances.

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Y_o^* (1405) and Y_o^{**} (1520)

Among the $\Sigma^{\pm}\pi^{\mp}\pi^{o}$ reactions the two I=0 resonances show clearly above a general background. By taking events falling in the mass bands $1{\cdot}405 \pm {\cdot}040$ GeV/c^2 and $1{\cdot}52 \pm {\cdot}04$ GeV/c^2 samples of about 50 o/o purity can be obtained. The angular distributions for these events cannot be interpreted directly but differences between the resonances and non-resonant background can reasonably be ascribed to the resonances. The production angular distributions for Y_o^*, Y_o^{**} and non-resonant are shown in Fig. 8a, c and d. The corresponding two body reaction is shown in Fig. 8b. It is striking that the $Y_o^* + \pi^o$ reaction closely resembles the $\Sigma\pi$ reaction whereas the Y_o^{**} and non resonant reactions show flatter distributions.

Acknowledgements

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References

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4) P.L. Bastien, UCRL 10779 (1963)

5) D.A. Smith, UCRL 10810 (1963)

Figure Captions

Fig. 1 The $(\Sigma^{o}\pi^{+})$ effective mass in the reaction $K^{-} + p \rightarrow \Sigma^{o} + \pi^{+} + \pi^{-}$

Fig. 2 The $(\Sigma^{-}\pi^{+})$ effective mass in the reaction $K^{-} + p \rightarrow \Sigma^{-} + \pi^{+} + \pi^{o}$

Fig. 3 The $(\Sigma^{+}\pi^{-})$ effective mass in the reaction $K^{-} + p \rightarrow \Sigma^{+} + \pi^{-} + \pi^{o}$

Fig. 4 The $(\Lambda^{o}\pi^{+})$ and $(\Lambda^{o}\pi^{-})$ effective masses in the reaction $K^{-} + p \rightarrow \Lambda^{o} + \pi^{+} + \pi^{-}$

Fig. 5 The $(\Sigma\pi\pi)^{+}$ and $(\Sigma\pi\pi)^{-}$ effective masses in the reactions $K^{-} + p \rightarrow \Sigma^{+} + \pi^{+} + \pi^{-} + \pi^{-}$ and $\rightarrow \Sigma^{-} + \pi^{+} + \pi^{+} + \pi^{-}$

Fig. 6 The difference between the $(\Lambda\pi^{+}\pi^{o})$ effective mass distribution and the mean of the $(\Lambda\pi^{-}\pi^{o})$ and $(\Lambda\pi^{+}\pi^{-})$ effective mass distribution in the region of the 1660 MeV/c^2 resonance for the reaction $K^{-} + p \rightarrow \Lambda^{o} + \pi^{+} + \pi^{-} + \pi^{o}$.

In all the above graphs the "phase space" normalisation for the non-resonant reaction is by eye.

Fig. 7 The kinetic energy spectrum of π^{-} produced in events with Λ^{o} (i.e. $\Lambda\pi^{+}\pi^{-}$, $\Lambda\pi^{+}\pi^{-}\pi^{o}$ and $\Sigma^{o}\pi^{+}\pi^{-}$). The peak near ·4 GeV corresponds to Y_1^{*+} produced in $\Lambda\pi\pi$ events.

Fig. 8 Production angular distribution for the reactions:

a) $K^{-} + p \rightarrow Y_o^{*} + \pi^{o}$

b) $K^{-} + p \rightarrow \Sigma^{\pm} + \pi^{\mp}$

c) $K^{-} + p \rightarrow Y_o^{**} + \pi^{o}$

d) $K^{-} + p \rightarrow (\Sigma^{\pm}\pi^{\mp}) + \pi^{o}$ non resonant

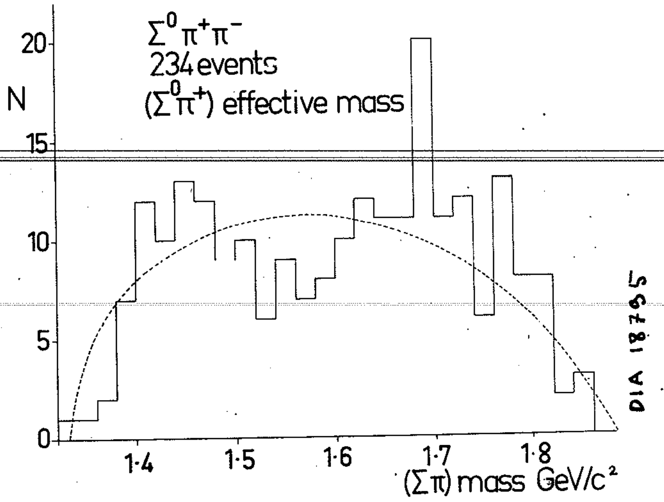

Fig. 1

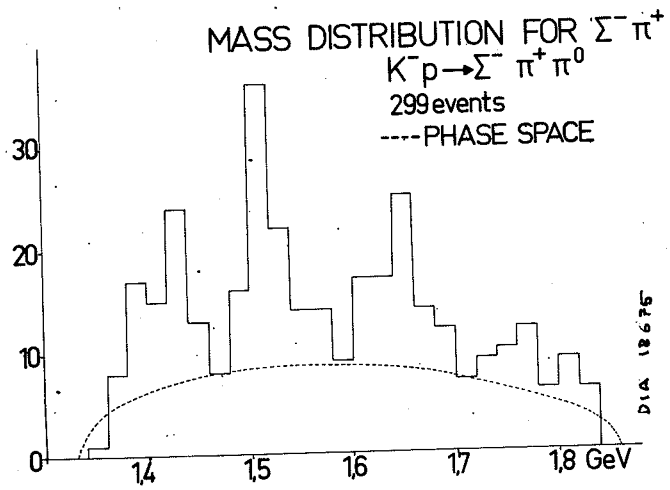

Fig. 2

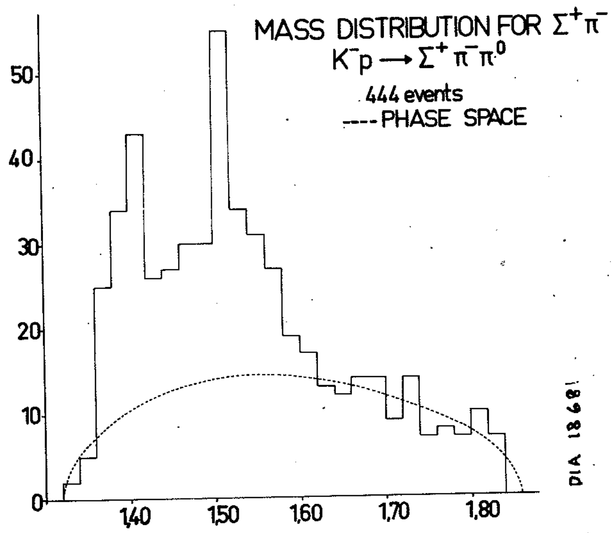

Fig. 3

SIS/R/6879

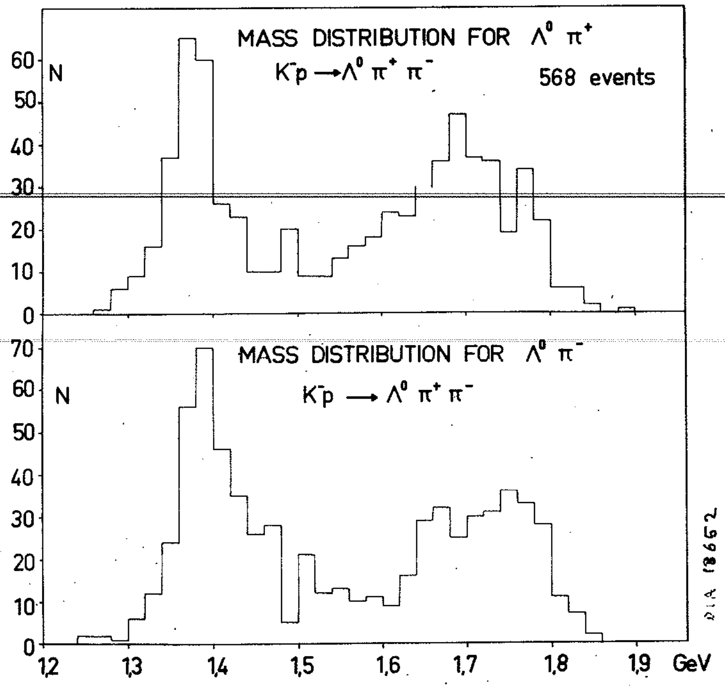
MASS DISTRIBUTION FOR $\Lambda^0 \pi^+$
$K^- p \to \Lambda^0 \pi^+ \pi^-$
568 events
N
MASS DISTRIBUTION FOR $\Lambda^0 \pi^-$
$K^- p \to \Lambda^0 \pi^+ \pi^-$
N
1,2 1,3 1,4 1,5 1,6 1,7 1,8 1,9 GeV
DIA 18662

Fig.4

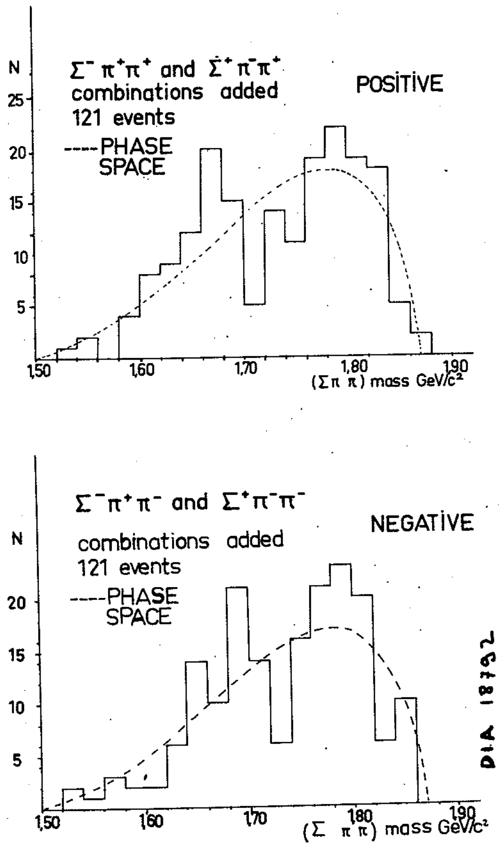
N
$\Sigma^- \pi^+ \pi^+$ and $\Sigma^+ \pi^- \pi^+$
combinations added
121 events
----PHASE SPACE
POSITIVE
1,50 1,60 1,70 1,80 1,90
$(\Sigma \pi \pi)$ mass GeV/c²
N
$\Sigma^- \pi^+ \pi^-$ and $\Sigma^+ \pi^- \pi^-$
combinations added
121 events
----PHASE SPACE
NEGATIVE
$(\Sigma \pi \pi)$ mass GeV/c²
DIA 18782

Fig.5

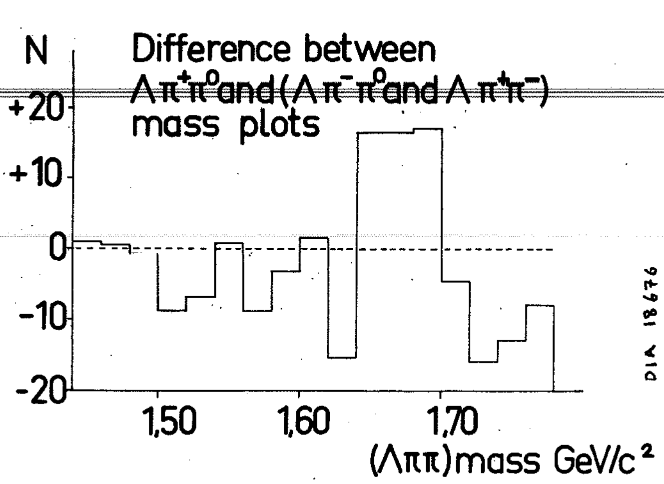
N
Difference between
Λπ⁺π⁰ and (Λπ⁻π⁰ and Λπ⁺π⁻)
mass plots
+20
+10
0
-10
-20
1,50
1,60
1,70
(Λππ) mass GeV/c²
DIA 18676

Fig.6

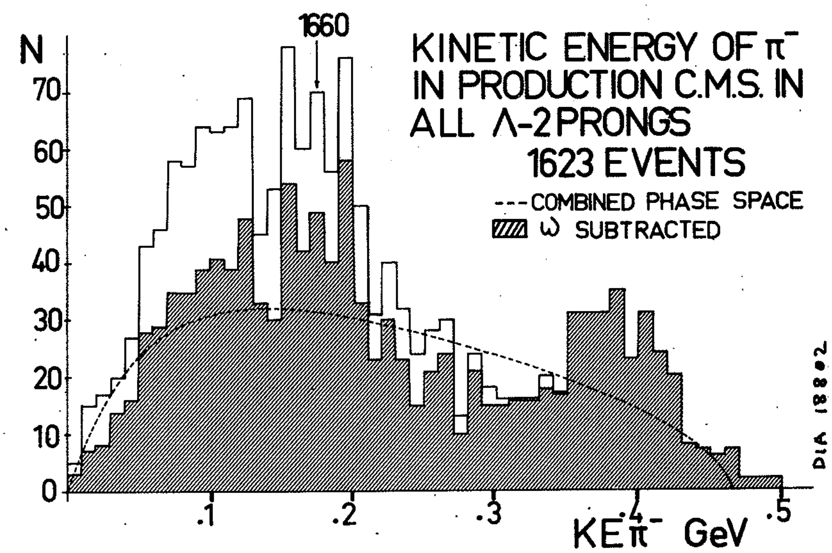
N
1660
KINETIC ENERGY OF π⁻
IN PRODUCTION C.M.S. IN
ALL Λ-2 PRONGS
1623 EVENTS
---COMBINED PHASE SPACE
ω SUBTRACTED
70
60
50
40
30
20
10
0
.1
.2
.3
.4
.5
KEπ⁻ GeV
DIA 18802

Fig.7

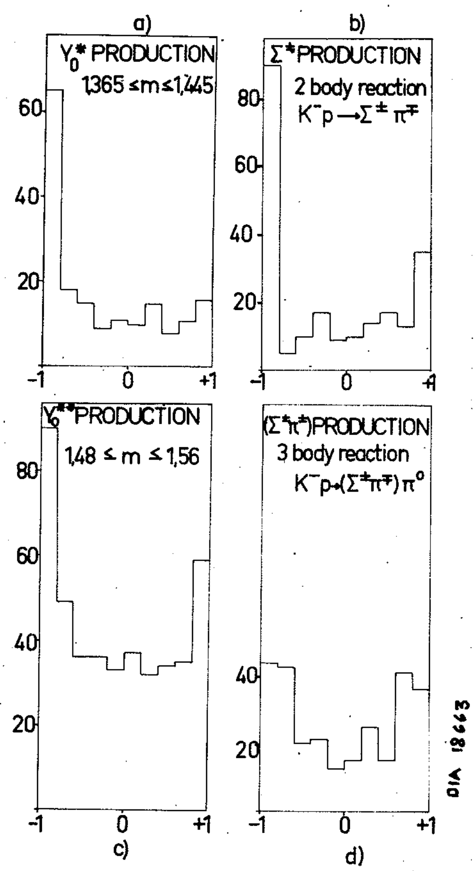
a)
Y_0^* PRODUCTION
1,365 ≤ m ≤ 1,445
b)
Σ^* PRODUCTION
2 body reaction
$K^- p \to \Sigma^\pm \pi^\mp$
Y_0^{**} PRODUCTION
1,48 ≤ m ≤ 1,56
($\Sigma^\pm \pi^\mp$) PRODUCTION
3 body reaction
$K^- p \to (\Sigma^\pm \pi^\mp) \pi^0$
c)
d)
DIA 18663

Fig.8