EXISTENCE OF A Y_1* RESONANCE AT 1616 MeV *

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An enhancement at 1616 ±8 MeV is observed in the $\Lambda\pi^\pm$ mass spectrum from the reaction $K^-n\rightarrow\Lambda\pi^-\pi^-\pi^+$ at a beam momentum of 3.9 GeV/c. This is interpreted as a resonance of width 66 ±16 MeV and isospin one. A similar enhancement is also observed in other final states.

An analysis of 50 000 pictures obtained from an exposure of the Brookhaven National Laboratory 80-in. deuterium bubble chamber to a separated beam of K^- mesons at 3.9 BeV/c has yielded a sample of 548 events fitting the reaction[1]

$$K^-d\rightarrow p_s\Lambda\pi_a^-\pi_b^-\pi^+. \qquad (1)$$

Here p_S denotes a spectator proton of momentum less than 230 MeV/c. These spectators will be ignored in the following analysis, since the reaction of interest is that of K^- incident on a neutron.[2]

The insert to Fig. 1 shows the distribution in the square of the hyperon missing mass $(\mathrm{mm})_H^2$ for this 548 event sample. The hyperon missing mass is calculated using the unfitted quantities for the visible charged tracks at the production vertex, namely $K^-n\rightarrow\pi^-\pi^-\pi^+(\mathrm{mm})_H$. A clear peak in this spectrum is seen at the Λ mass (1.24 GeV^2) with the position of the Σ^0 (1.42 GeV^2) indicated. In order to reduce any possible contamination due to the Σ^0-Λ ambiguity, only the 458 events with $(\mathrm{mm})_H^2<1.4$ GeV^2 are included in the subsequent analysis of Reaction (1).

In Fig. 1 we plot the three $\Lambda\pi$ effective-mass combinations from Reaction (1). Strong Y_1*(1385), probably some Y_1*(1765) and Y_1*(1910) formation is evident and, in addition, there is an enhancement of more than 4.5 standard deviations significance at about 1616 MeV. To ensure that this enhancement is not due to misidentification of the events, the following fits were also tried, with less stringent acceptance criteria,[3] for the events satisfying Reaction (1):

$$K^-d\rightarrow p_s\Lambda\pi^0\pi^-\pi^-\pi^+ \qquad (2)$$

and

$$K^-d\rightarrow p_s\Sigma^0\pi^-\pi^-\pi^+. \qquad (3)$$
$$\quad\ \ \lfloor\!\rightarrow\Lambda\gamma$$

Of the original 458 events, only 36 fit Reaction (2) and, therefore, this ambiguity does not pose a serious problem. However, 347 events did fit Reaction (3) when the less stringent acceptance criteria were used. In view of this, we carried out the following analysis for the events (called "fake Σ^0" events) which fitted both Reactions (1)

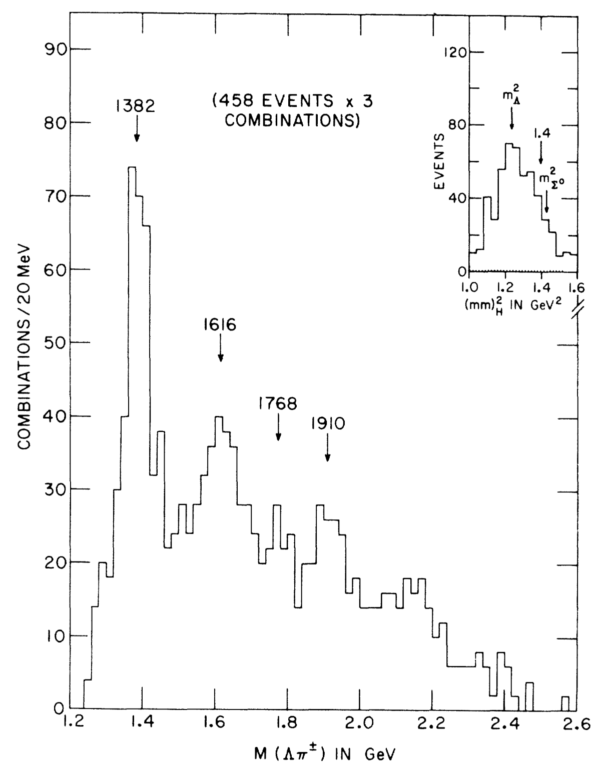

FIG. 1. Effective-mass distribution of the three $\Lambda\pi$ combinations for events of Reaction (1). The insert is the distribution of the square of the hyperon missing mass, $(\mathrm{mm})_H^2$, from the reaction $K^-n\rightarrow\pi^+\pi^-\pi^-(\mathrm{mm})_H$; events with visible spectator are shaded. The number of events in the insert is larger than that in the figure, as explained in the text.

and (3), and for a sample of 83 events (called "real Σ^0" events) which fitted Reaction (3) but not Reaction (1). Because the spins and parities of the Σ^0 and Λ are the same, and because parity is conserved in electromagnetic interactions, the decay $\Sigma^0 \rightarrow \Lambda\gamma$ must have an isotropic angular distribution of the Λ in the Σ^0 center of mass. For both the "fake Σ^0" and "real Σ^0" events, we calculated the angle α between the Λ momentum, in the center of mass of the "Σ^0", and $\hat{n}$, the normal to the production plane:

$$\hat{n} = (\vec{P}_{K^-} \times \vec{P}_{``\Sigma^0"}) / |\vec{P}_{K^-} \times \vec{P}_{``\Sigma^0"}|.$$

For true Σ^0 events there should be equal numbers of events with $|\cos\alpha| < 0.5$ and with $|\cos\alpha| > 0.5$. As shown in the Fig. 2 insert, the distribution for the "real Σ^0" events is consistent with isotropy, suggesting that this sample does contain a high proportion of true Σ^0 events. The "fake Σ^0" events with $|\cos\alpha| > 0.5$ together with the "fake Σ^0" events with $|\cos\alpha| < 0.5$ are shown in Fig. 2. In the region of the enhancement at 1616 MeV as well as in the region of the $Y_1^*(1385)$ the distribution is clearly not isotropic. Moreover, in the 1616 region the observed structure is associated only with those events for which $|\cos\alpha| < 0.5$. Hence the enhancement at 1616 does not come from true Σ^0 events misidentified as Λ events but comes from true Λ events.

To examine whether the $\Lambda\pi^\pm$ enhancement at 1616 MeV is due to a reflection of other resonances we note that only $\rho(765)$ and $Y_1^*(1385)$ resonances are formed strongly in Reaction (1) and we present the $\Lambda\pi^\pm$ mass spectrum in Fig. 3 with the following selections:

(a) If one $\Lambda\pi$ combination is in the $Y_1^*(1385)$ region (1390 ± 40 MeV) we plot only that particular combination and no other. If more than one is in this Y_1^* region we weight them appropriately.

(b) If the $\pi_{a(b)}^-\pi^+$ system forms a peripheral ρ (with mass 760 ± 60 MeV and $\Delta_{K^- \rightarrow \rho}^2 < 1.2$ GeV^2), we do not plot the $\Lambda\pi^+$ or $\Lambda\pi_{a(b)}^-$ combination.

It is clear that the enhancement at ~1616 MeV is not a reflection of these other resonances. The curve in Fig. 3 is a fit to four Breit-Wig-

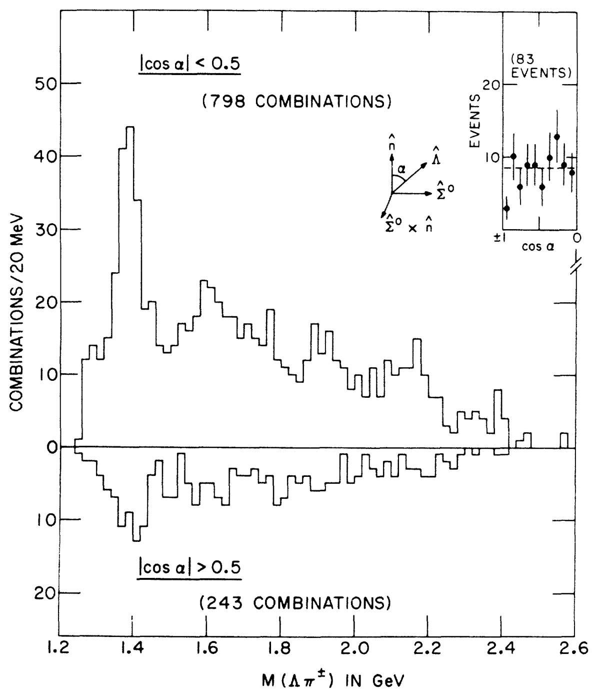

FIG. 2. Effective-mass distribution of the three $\Lambda\pi$ combinations for the "fake Σ^0" events for values of $|\cos\alpha| < 0.5$ and > 0.5. The definitions of $\cos\alpha$ and the terms "fake Σ^0" events and "real Σ^0" events are given in the text. The distribution of $\cos\alpha$ for the "real Σ^0" events is shown in the insert.

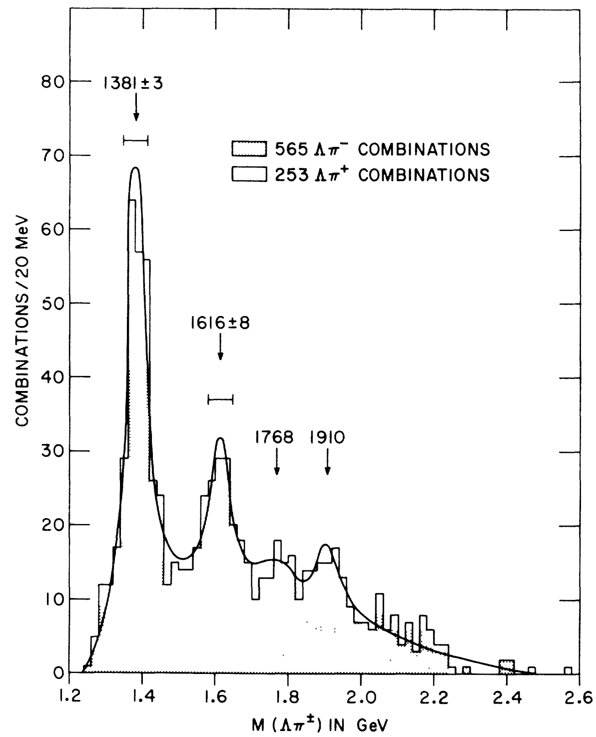

FIG. 3. Effective-mass distribution of the $\Lambda\pi$ combinations from Reaction (1) events after the reflections of the $Y^*(1385)$ and $\rho^0(760)$ have been removed as explained in the text. The smooth curve is a fit to four Breit-Wigner resonances, at the values indicated, and an estimated smooth background.

ner resonances with an estimated smooth background.[4] This fit yields a mass $M = 1616 \pm 8$ MeV and width $\Gamma = 66 \pm 16$ MeV for this enhancement and a mass $M = 1381 \pm 3$ MeV and width $\Gamma = 63 \pm 8$ for the $Y_1^*(1385)$, in agreement with accepted values.[5] The contribution of these two resonances to the fit are 12 ± 2 and $34 \pm 3\%$, respectively. The experimental resolution (~10 MeV) does not significantly increase their fitted widths.

Evidence for a peak at about 1600 MeV in the $\Lambda\pi$ mass spectrum is also found in the reactions $K^-d \to p_S\Lambda\pi^-\pi^-\pi^+$MM and $K^-d \to p_S\Lambda\pi^-$MM (not shown). MM denotes a missing mass greater than the π^0 mass. However, the reflections and contaminations in these channels are less well understood and no further analysis will be attempted here. Production of ρ^- dominates the final state $\Lambda\pi^-\pi^0$ where there is little evidence for any Y^*.

The width of 66 ± 16 MeV implies a strong decay of the $Y_1^*(1616)$ into $\Lambda\pi$ and hence requires an isospin of one. Presence of a large background (60 %) beneath the peak prevents a meaningful analysis of the spin and parity.

We have searched for other decay modes of the $Y_1^*(1616)^\pm$ in the final states $Y_1^*(1616)^\pm\pi^\mp\pi^-$ in the same data sample, and obtained the following decay rates normalized to make the $\Lambda\pi$ mode unity:

$$Y_1^*(1616)^\pm \to \Lambda\pi^\pm, \quad 1.0 \pm 0.16;$$
$$\to [Y^*(1385)\pi]^\pm, \quad 0.2 \pm 0.1;$$
$$Y_1^*(1616)^+ \to \bar{K}^0 p, \quad 0.0 \pm 0.1.$$

In summary, we have observed a new $I = 1$ hyperon resonance at a mass of 1616 ± 8 MeV with a width of 66 ± 16 MeV. The mass and width values for this $Y_1^*(1616)$ rule out the possible association with the $Y_1^*(1695 \pm 8)$ with a width of 108 ± 20 MeV. In view of the large $\Lambda\pi$ branching ratio, as well as the mass discrepancy, the possibility of its being the $Y_1^*(1660)$ is also eliminated.

Data on the $\bar{K}N$ formation experiments at around 620 MeV/c[6] (corresponding to a mass of ~1610 MeV) are insufficient at this time to shed any light on this new $I = 1$ hyperon resonance.

We would like to thank the crews of the Brookhaven National Laboratory alternating-gradient synchrotron and the 80-in. bubble chamber, and especially our scanning and measuring personnel for their help. We also wish to thank Dr. George Kalbfleisch for his interesting comments. Finally, we would like to express our gratitude to Dr. Ralph P. Shutt for his interest and encouragement.

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[1]Events with a neutral V and three outgoing tracks with no visible spectator or with a spectator proton of less than 6 cm were measured. These were analyzed with the Brookhaven National Laboratory QLOD system of programs, the selection on competing hypotheses being made from a fit to the measured ionization and the usual χ^2 value from the kinematic fit. Events for which no measurements, or insufficient measurements, of ionization were available were examined at the scanning table.

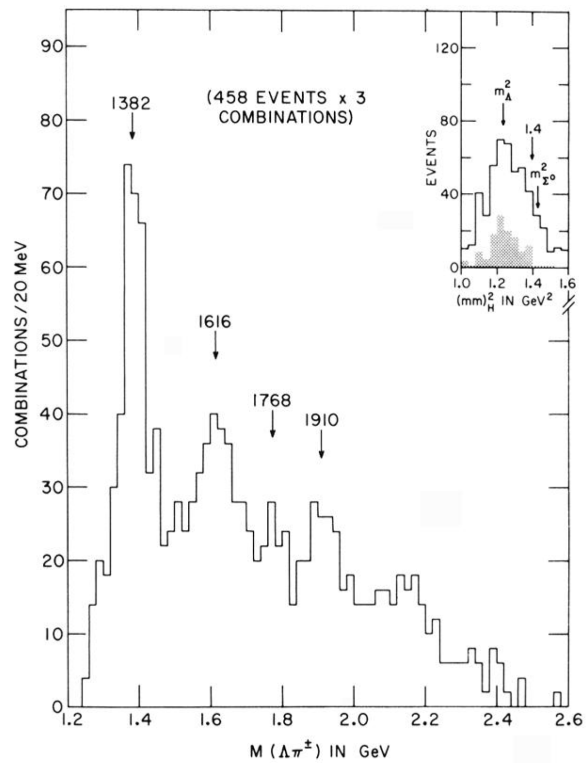
[2]About 30 % of the spectator protons had sufficient momentum to cause a visible track. The unseen spectators in the remaining events were constrained to have a momentum of 0 ± 50 MeV for the purpose of the fitting program. When the momentum distribution after fitting was added to that of the visible spectators, good agreement was achieved with the Hulthén wave function.

[3]The less stringent acceptance criteria used for the refitting described in this paragraph were that all hypotheses with χ^2 probabilities >0.001 % were accepted (in the original fitting procedure this figure was 2.5 %), and all competing fits were ignored.

[4]The fit determines the masses, widths, and proportion of the resonances. However, in this case the masses and widths of $Y^*(1768)$ and $Y^*(1910)$ were held fixed at the accepted values. This fit achieved a probability of 10 %; yet when the $Y^*(1616)$ was constrained to the mass and width of the $Y^*(1660)$ or $Y^*(1695)$, probabilities of 2×10^{-5} or 10^{-6} were obtained. This confirms the clear difference between this enhancement and other previously discovered resonances nearby.

[5]For a compilation of experimental results see, for example, A. H. Rosenfeld et al., Rev. Mod. Phys. 40, 77 (1968).

[6]J. Meyer, in Proceedings of the International Conference on Elementary Particles, Heidelberg, Germany, 1967 (North-Holland Publishing Company, Amsterdam, The Netherlands, 1968), p. 117.



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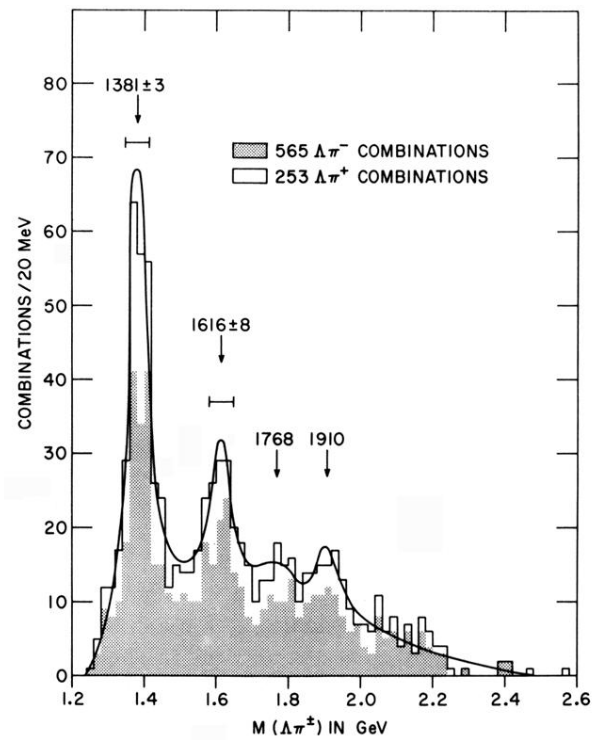

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