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OBSERVATION OF A NARROW HYPERON STATE OF MASS 3.17 GeV

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ABSTRACT

We present evidence for a narrow Y^* with a mass of 3.17 GeV and a width ≤ 20 MeV decaying to $\Sigma K \bar{K} +$ pions, $\Lambda K \bar{K} +$ pions and $\Xi K +$ pions. The data come from two high statistics K^-p bubble chamber experiments with a sensitivity of ~ 100 ev/ μ b at 8.25 GeV/c and ~ 45 ev/ μ b at 6.5 GeV/c.

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We present evidence for a narrow Y^* state from two independent K^-p bubble chamber experiments at 8.25^(*) and 6.5 GeV/c. In the following text results of these two experiments are discussed separately.

(a) 8.25 GeV/c Experiment (Birmingham-CERN-Glasgow-Michigan State-Paris LPNHE Collaboration)

In a high statistics K^-p experiment in the CERN 2m HBC at 8.25 GeV/c we have made a systematic search for quasi two-body processes of the type

$$K^- + p \rightarrow \pi + Y^* \quad (1)$$

for the channels in which we have more than one strange particle in the final state. The present statistics are $\sim 100 \text{ ev}/\mu\text{b}$.

The interest of this search comes from the fact that recent predictions have been made concerning the existence of five-quark baryon systems $qqqq\bar{q}$, sufficiently narrow to be easily detected in mass spectra [2,3]. These models predict multiparticle decays and for states containing three strange quarks sss , a dominant decay into three strange particles is foreseen. This should be a signature of these states in contrast to "normal" hyperons ($qq\bar{s}$) where one would expect that single strange particle decays should be dominant. A review of the experimental situation concerning multiquark states can be found in ref. [4].

We present here the results on the observation of a narrow state at a mass of 3.17 GeV with a width of 20 MeV consistent with the experimental resolution. The effect has been observed in the mass spectrum of the system R^+ recoiling against a π^- for the kinematically constrained events that come from the reaction

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

where R decays into five or six particles (six or seven-body final states). The events are also required to contain more than one strange particle, i.e. Ξ signature or three strange particles coming from the production vertex. At least one neutral strange particle decay must be observed.

(*) The result of the 8.25 GeV/c experiment has been previously presented at the 1979 EPS Geneva Conference [1].

When more than one hypothesis remains after ionization consistency checks, we have retained the fit corresponding to the highest constraint class, and within the same constraint class the one with the highest probability.

Fig. 1(a) shows the mass spectrum of the system R^+ , and a three-standard deviation effect is present at a mass of 3.17 GeV. This can be better seen in fig. 1(b), where the same spectrum is shown for the mass region 3.00 - 3.30 GeV.

In fig. 2 we give the π^- angular distribution in the total c.m. system for the signal region 3.16 - 3.18 GeV (fig. 2(b)), and for side regions 3.00 - 3.16 GeV (fig. 2(a)) and 3.18 - 3.30 GeV (fig. 2(c)). Compared with the distributions for the control regions, the one in the 3.16 - 3.18 GeV region is richer in events with the π^- backward in the c.m. system. Selecting events with the π^- in the backward hemisphere, we obtain the mass spectrum shown in fig. 3(a), where now the peak is more prominent. The number of events above the background is the same as that in the total sample, but the background is down by a factor of two. Fig. 3(b) shows the same distribution plotted in 5 MeV bins and the width of the peak is consistent with the calculated resolution. A maximum likelihood fit to the spectrum of fig. 3(a) gives 22 events in the peak with a statistical significance of ~ 5.5 standard deviations; the level of significance is independent of the parametrization assumed for the background and the mass interval used. The mass of the peak has been fitted to be (3170 ± 5) MeV and we shall refer to it as $R(3170)$. We do not see any signal for the three-body decay of the $R(3170)$, even though the background is comparable to that observed for five and six-body decays. In the four-body decay, no effect is visible, but here the background is five times larger.

Careful studies have been made to check for spurious sources of the peak. Each event in the peak has been individually checked by physicists. All the events are consistent with a π^- for the recoil track; in addition, in 60% of the cases the track was unambiguously identified as a π^- by ionization. Furthermore we find that the 29 events in the peak are

distributed amongst the five laboratories in proportion to the film analysed. Different measuring and processing systems have been used at each laboratory.

The forward production of the R(3170) implies that the resonance is produced via $I = 3/2$ baryon exchange. If we assume: (a) that this production mechanism is the dominant one and (b) $I = 1$ for the R(3170), we can predict what we expect in the channels

$$K^- + p \rightarrow \pi^+ + R^- \quad (3)$$

and

$$K^- + p \rightarrow \pi^0 + R^0 \quad ; \quad (4)$$

namely, $\sigma(R^-) = 1/9 \sigma(R^+)$ and $\sigma(R^0) = 4/9 \sigma(R^+)$.

Indeed the R^- mass spectrum does not show any structure. For R^0 , the worse experimental resolution (in this case ~ 60 MeV) makes the comparison difficult. Nonetheless a fit to the mass spectrum taking into account the resolution gives $N(R^0) = (16 \pm 8)$ events. These results appear to be consistent with the above assumptions. Furthermore we note that $I = 3/2$ baryon exchange and $I = 2$ for the R(3170) predict $\sigma(R^-) = \sigma(R^+)$. The data appear to be inconsistent with this conjecture. In the above arguments no allowance has been made for undetected channels.

The observed decay modes of the R(3170) are given in table 1, in terms of the baryon present in the final states, together with those of the neighbouring control regions. It appears that Λ , Σ and Ξ all contribute to the resonance. We do not find evidence for possible sequential decays to known resonances or to other narrow objects.

The cross section for production of the R(3170) on the basis of the 22 observed events correcting for neutral decay losses and geometrical and processing inefficiencies is

$$\sigma(R^+) = 0.7 \pm 0.2 \text{ } \mu\text{b at } 8.25 \text{ GeV/c.} \quad (5)$$

This number has not been corrected for losses due to decays into five and six bodies with more than one unseen particle in the final state. In addition, only events with at least one V^0 are included in our data sample.

The decay rate into three strange particle final states should be compared with that for final states containing only one strange particle. In fact, for "normal" hyperons the latter dominates. We have studied the $(\Lambda\pi\pi)^+$, $(\Sigma^0\pi\pi)^+$, $(K^0\pi\pi)^+$ and $(K^0\pi\pi)^+$ systems recoiling against a π^- for constrained events applying the same production angular cuts. No structure at 3.17 GeV is seen and the following upper limits at the 95% confidence level can be given:

$$\sigma(R(3170) \rightarrow \Lambda\pi\pi) < 0.6 \text{ } \mu\text{b}, \quad m = 1-5 \quad (6)$$

$$\sigma(R(3170) \rightarrow K^0\pi\pi) < 1.3 \text{ } \mu\text{b}, \quad m = 1-5 \quad (7)$$

$$\sigma(R(3170) \rightarrow \Sigma^0\pi\pi) < 0.1 \text{ } \mu\text{b}, \quad m = 1, 3, 5 \quad (8)$$

$$\sigma(R(3170) \rightarrow K^0\pi\pi) < .7 \text{ } \mu\text{b}, \quad m = 1, 3, 5 \quad (9)$$

where again no correction for unobserved channels has been made.

On the basis of these numbers we conclude that the "normal" decay modes cannot be significantly larger than the multistrange modes. These characteristics together with its narrow width, make the R(3170) a plausible candidate for a hadron having a more complicated internal structure than that of a "normal" hadron.

(b) 6.5 GeV/c Experiment (Cambridge-Michigan State Collaboration)

In a high statistics K^-p experiment in the Argonne 12 ft HBC, we have also studied the aforementioned reactions. The statistics of this experiment correspond to ~ 45 events/ μb . Using similar criteria to those applied to the 8.25 GeV/c data, we show in fig. 4(a) the R^+ spectrum recoiling against a backwards π^- (as in fig. 2(a)). An enhancement is observed in the 3.16 - 3.18 GeV interval, precisely at the location of the 8.25 GeV/c resonance. The significance of this enhancement is ~ 4 standard deviations. As before, the signal is confined to the five and six-body decays, with no evidence for three or four-body decays. In this experiment the resolution is ~ 20 MeV, thus comparable to that from the 8.25 GeV/c experiment.

We show in table 2 the number of events observed in the R region and neighbouring control regions in terms of Λ , Σ and Ξ baryon content (as in table 1). Again, we see that the Λ , Σ and Ξ all contribute to the R(3170). Making corrections as before, we find

$$\sigma(R^+) = 1.0 \pm 0.3 \mu\text{b at } 6.5 \text{ GeV/c.} \quad (10)$$

(c) Conclusions

We show in fig. 4(b) the combined R^+ spectrum from the two experiments. The significance of the R(3170) enhancement is $\gtrsim 6.5 \sigma$. We emphasize the effect is seen in two independent experiments. The mass and width are $(3170 \pm 5) \text{ MeV}$ and $\leq 20 \text{ MeV}$ respectively. The R(3170) is produced via $I = 3/2$ baryon exchange and $I = 1$ is favoured. The dominance of multistrange decay modes and the narrow width suggest the existence of a new type of hadron.

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REFERENCES

- [1] Birmingham-CERN-Glasgow-Michigan State-Paris LPNHE Collaboration,
M. Baubillier et al., Submitted to the 1979 EPS Geneva Conf.,
CERN/EP 79-64.
- [2] H. Högaasen and P. Sorba, Nucl. Phys. B145 (1978) 119.
- [3] M. De Crombrugghe, H. Högaasen and P. Sorba, Nucl. Phys. B,
(in press).
- [4] H. Högaasen and P. Sorba, CERN report, TH 2586 (1978); a complete
bibliography on states with more than three quarks can be found
in this paper.

TABLE 1

Decay modes of the R^+ system in the R(3170) and side mass regions in terms of the baryon present in the final state.

8.25 GeV/c

Mass region GeV	3.00 - 3.16	3.16 - 3.18	3.18 - 3.30	3.16 - 3.18 bkg removed ^(a)
Λ	8	8	25	6.1
Σ	5	11	15	9.8
Ξ	25	9	40	5.2
p	1	1	2	0.8
Total	39	29	82	22

TABLE 2

Decay modes of the R^+ system in the R(3170) and side mass regions in terms of the baryon present in the final state.

6.5 GeV/c

Mass region GeV	3.00 - 3.16	3.16 - 3.18	3.18 - 3.30	3.16 - 3.18 bkg removed ^(a)
Λ	12	8	34	5.1
Σ	7	4	11	2.9
Ξ	21	8	25	5.1
Total	40	20	70	13

(a) The sum of the side mass regions normalized to the background in the R(3170) region has been subtracted from the observed number of events.

FIGURE CAPTIONS

- Fig. 1 (a) Mass spectrum of the R^+ system recoiling against a π^- (8.25 GeV/c). For the definition of R^+ see text.
- (b) Mass region 3.00 - 3.30 GeV on an expanded scale. The continuous line is the result of a polynomial fit to the spectrum.
- Fig. 2 Production angular distribution of the recoil π^- in the centre of mass system for the mass regions (8.25 GeV/c data):
(a) 3.00 - 3.16 GeV, (b) 3.16 - 3.18 GeV and (c) 3.18 - 3.30 GeV.
- Fig. 3 (a) Mass spectrum of R^+ for events in which $\cos\theta^*(\pi^-, \text{beam}) < 0$. The continuous line is the result of a maximum likelihood fit to the background (8.25 GeV/c).
- (b) Mass spectrum for R^+ for the same events as (a) in 5 MeV bins. The continuous line is obtained by adding a resolution function centered at 3.17 GeV to a smooth background.
- Fig. 4 (a) Same as fig. 3(a), for 6.5 GeV/c.
- (b) Combined data from both experiments (figs 3(a) and 4(a)).

Fig. 1

Fig. 2

Fig. 3

Fig. 4