Search for events consisting of six quarks in the final state

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A search has been made for events corresponding to the reaction $PP \to \Lambda\Lambda K^+K^+$ by bombarding a liquid-hydrogen filled chamber (ZhVK-205, Institute of Theoretical and Experimental Physics) with a pencil beam of 7.8-GeV/c protons. No events corresponding to this reaction were found in the experiment. The upper limit found on the cross section for this production reaction is 460 nb.

Exotic hadrons consisting of four, six, or more quarks have been predicted by various models (bag models). Jaffe[1] worked from the model of De Grand *et al.*[2] to point out the possible existence of a dibaryon with the quantum numbers $I = J = 0$ $(S = -2)$, $J^P = 0^+$ and a mass $M_H = 2150$ MeV (the H baryon), stable with respect to the strong decay $H \to 2\Lambda$.

The same model predicts the existence of a dibaryon octet with $J^P = I^+$ containing a dibaryon with $I = 0$ (the H^* baryon) with a mass of 2336 MeV, which probably is a $\Sigma\Sigma$ bound state with a mass of 2335 MeV which decays into $\Lambda\Lambda$ and $N\,\Xi$.

Similar predictions were made in papers by De Swart[3] and Simonov.[4]

So far, experimental searches for exotic H baryons have not yielded positive results.

Carrole *et al.*[5] studied the missing-mass spectrum in the reaction $PP \to K^+K^+X$ in the mass interval $2.0 < M_1 < 2.5$ GeV/c and established upper limits on the cross section for the production of H baryons: $\sigma < 30$–130 nb.

Shahbazian and Timonina[6] discovered an excess of events with a mass $M_{\Lambda\Lambda} = 2370$ MeV/c^2 in the mass spectrum of the $\Lambda\Lambda$ system. This excess was apparently due to a negative scattering length $\alpha_{\Lambda\Lambda}$.

An important source of information on the H baryons might be studies of the reaction

$$PP \to K^+K^+\Lambda\Lambda. \qquad (1)$$

Pole diagrams for the production of a H resonance in reaction (1) can be represented by the diagrams in Fig. 1.

The production of the same resonance, with the quark structure of the hadrons being taken into account, can be represented by the simple quark diagram in Fig. 2.

The processes described by the diagrams in Figs. 1 and 2 stem from baryon exchange. The cross sections for such reactions constitute a small fraction of the total partial cross section for reaction (1). The cross section for reaction (1) is dominated by diagrams with one-pion exchange (Fig. 3).

We have undertaken a search for H baryons in a study of the reaction

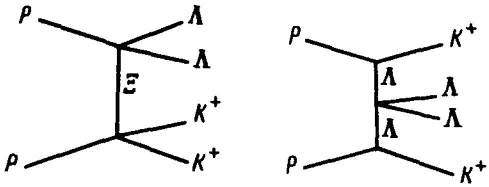

FIG. 1.

$$PP \to \Lambda\Lambda K^+K^+ + n\pi^0 \quad (n=0, 1 \ldots)$$

by means of the two-meter chamber of the Institute of Theoretical and Experimental Physics, exposed to a proton beam with a momentum of 7.8 GeV/c. To increase the rate of acquisition of the statistical base, we bombarded the chamber with a "pencil" beam, with a diameter $\sim$0.6 cm, containing $\sim$120 protons. This beam is described in detail in Ref. 7.

The results reported here are based on an analysis of 37 000 photographs (the sensitivity of this experiment was 10 events/μb).

The photographs were examined for events with the topology

$$2^* + 2V \ (31 \text{ events}) \text{and} 4^* + 2V \ (1 \text{ event}). \qquad (2)$$

An evaluation of the ionization of the secondary particles made it possible to distinguish between protons and π^+ mesons with momenta <1200 MeV/c and K^+ mesons with momenta <700 MeV/c.

Table I shows the results of the identification of the reaction channels in this topology of events for all 32 cases. It can be seen from this table that in only four cases of the topology $2^* + 2V$ were there possible candidates for the production of a pair of Λ hyperons. The results of a complete kinematic analysis of the observed V decays show that none of these four events contained an event with two Λ hyperons.

The final analysis of these studies shows that not a single event of reaction (1) was observed in this study.

On the basis of this conclusion we can set an upper limit on the cross section for the search for events of reaction (1). In our experiment, this upper limit is 460 nb at a 90% confidence level.

It is logical to suggest that this limiting value of the cross section refers to the process described by the diagram in Fig. 3, which is more probable than any of the other processes which contribute to reaction (1).

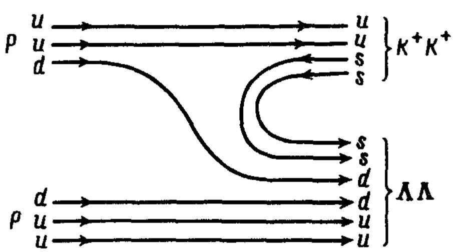

FIG. 2.

TABLE I

Total number of photographs	Number of events found in an examination with the topology $PP \to 2V + X$		Number of events after an additional selection on the basis of ionization, referred to the reaction				Number of events surviving the measurement and studied by the "geometry" and "kinematics" programs for the reaction			A*	B**	C*** nb
	$PP \to 2V + X$		$PP \to K^0 + V + X$		$PP \to \Lambda^0 + V + X$		$PP \to K^0 + \Lambda^0 + X$		$PP \to \Lambda + \Lambda + X$			
	$PP \to 2^* + 2V$	$PP \to 4^* + 2V$	$PP \to K^0 + V + 2^*$	$PP \to K^0 + V + 4^*$	$PP \to \Lambda^0 + V + 2^*$	$PP \to \Lambda^0 + V + 4^*$	$PP \to K^0 + \Lambda + 2^*$	$PP \to \Lambda^0 + K^0 + 4^*$				
37000	31	1	27	1	4	0	4	0	0	2.3	4.6	460

*A is the upper limit on the confidence interval for the number of events at a 90% confidence level, referred to reaction (1).

**B is the upper limit on the number of events, corrected for the detection efficiency.

***C is the upper limit on the cross section according to a search for events corresponding to reaction (1) at a 90% confidence level.

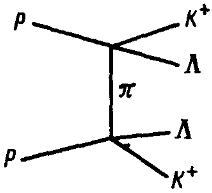

FIG. 3.

It should also be noted that the literature reveals no data from research on processes associated with reaction (1). This situation can be explained quite simply on the basis of the difficulties in organizing a master for detecting events of the topology given above.

On the other hand, a study of rare processes through the use of ordinary and conventional detection methods would hardly lead to the expected results. New and important progress on this question may result from an experiment with a hydrogen chamber bombarded by a neutron beam, with a load $\sim 10^3$ particles per frame, in which one could observe the production reaction

$$nP \rightarrow \Lambda\Lambda K^0 K^+ . \tag{3}$$

The topology of the search for events described by reaction (3) refers to simple cases for a selection of these events during examination because of the high efficiency at which the three V events are detected in a large hydrogen chamber. When a total of about 400 000 photographs are exposed, it will be possible to lower the cross section for the study of rare processes to a limit of a few nanobarns.

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Translated by Dave Parsons