Краткие сообщения ОИЯИ № 2[48]-91 *JINR Rapid Communications No.2[48]-91*
УДК 539.12

MULTIQUARK STABLE AND METASTABLE STATES

B.A.Shahbazian, T.A.Volokhovskaya, A.S.Martynov

In the stable state sector a candidate for the predicted A(I=1/2, Y=−1, B=2, S=−3)-dibaryon was observed in p-propane collisions at 10 GeV/c. Kinematical four-vertex, ten- and nine-constraint fits performed were successful in both cases. In the first one the dibaryon mass was fixed at the predicted values. In the second case the fitted mass values coincide with the predicted ones within the limits of errors. In the metastable state sector the $\Lambda p\pi$-resonance found in $n^{12}C$-collisions at 7 GeV/c has been confirmed in $p^{12}C$-interactions at 10 GeV/c.

The investigation has been performed at the Laboratory of High Energies, JINR.

Мультикварковые стабильные и метастабильные состояния

Б.А.Шахбазян, Т.А.Волоховская, А.С.Мартынов

На фотографиях 2м пропановой камеры, облученной протонами 10 ГэВ/с, найдено событие, интерпретируемое как внутриядерная конверсия предсказанного стабильного дибариона A (I = 1/2, Y = −1, B = 2, S = −3) в 3Λ-гиперон. Многовершинный кинематический анализ привел к значению массы, близкой к предсказанным значениям.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

A number of theoretical models accounted in a series of papers predict the existence of multiquark states or hadrons of quark contents $Q^m\bar{Q}^n$, m + n ≥ 4. Some of them turn out to be stable againts strong decays ($\tau \gtrsim 10^{-10}$ s), the others being metastable (resonances, $\tau \sim 10^{-22}$ — 10^{-23} s). The most important are, of course, the stable dibaryons /1-3/ of S = −2, −3, −4, −5, −6. Here we confine ourselves to the experimental situation in the search for the H(I = 0, Y = 0, B = 2, S = −2) and A(I=1/2, Y = −1, B = 2, S = −3)-dibaryons.

Hunting the Stable States

The experiment headed by Kycia [4] on the search for the H in the reaction $p+p \to H+K^{+}+K^{+}$ leaved open the question on its existence. Seven experiments on hunting the H are today in preparation.

The eighth experiment (Dubna) is using the propane bubble chamber technique. The peculiarities of this method permit us:

1. To detect not only the H, but the A dibaryon too, via
   a) the detection of their weak decays;
   b) the detection of the intranuclear conversion of the H- and A-dibaryons into Λ -hyperons.
2. To detect furthermore multiquark metastable hadrons (resonances) in invariant mass spectra the life-time of which differs from that of the stable states by thirteen orders of magnitude. Below these statements will be demonstrated.

Two candidates for the weak decay mode $H \to p + \Sigma^{-}$, $\Sigma^{-} \to n + \pi^{-}$ have been observed on 2m propane bubble chamber photographs at 10 GeV/c. The details of the analysis and identification can be found in [5, 6]. Here we wish to mention that for the fast [5] event (8 GeV/c) one has $M_H = (2174.60 \pm 13.10)$ MeV/c^2 and the time of flight $\tau = 0.689 \cdot 10^{-10}$ s, whereas for the slow one [6] (1.091 GeV/c) one has $M_H = (2218 \pm 12)$ MeV/c^2 and $1.37 \cdot 10^{-10}$ s, respectively. The average mass and the time of flight are respectively $M_H = (2197 \pm 9)$ MeV/c^2 and $\tau = 1.03 \cdot 10^{-10}$ s. A formal estimate of the H-production effective cross section in $p^{12}C$ or $p^{1}H$ collisions at 10 GeV/c is 40 nb. The new estimates of the M_H exceed the $M_{\Lambda p \pi}$ threshold. Therefore we are also searching for the H-decay via a supplementary weak decay mode $H \to \Lambda + p + \pi^{-}$.

Another means to detect a stable dibaryon provided by the propane bubble chamber method is the use of the strong intranuclear conversion reactions (Dubna) [7]. Two events found in $n^{12}C$ (7 GeV/c) and $p^{12}C$ (10 GeV/c) exposures have been well fitted by the reaction $H + p \to \Lambda + \Lambda + p$ [5, 7, 8].

This method permitted us to identify an event as a candidate for the A-dibaryon. But first, a few words on A-dibaryon. First of all it can exist in a neutral and negative charge states, weakly decaying into a Ξ^{-} and a nucleon: $A^{-}(s^3\,u^1\,d^2) \to \Xi^{-}+n$, $A^{\circ}\ (s^3\,u^2\,d^1) \to \Xi^{-}+p$ or $\Xi^{\circ}+n$. The stability condition is $M_A < M_{\Omega^-} + M_N$. In [2] the mass $M_{Aj} = M_{\Omega^-} + M_N + E_{Bj}$ was computed in two models: (i) the spherical Bag Model (SBM, j =1) and (ii) the potential model (P.M., j = 2). According to [2] $\langle E_{B1} \rangle = -140.0$ MeV/c^2, $M_{A1} = 2472.7$ MeV/c^2; $E_{B2} = -244.5$ MeV/c^2, $M_{A2} = 2366.2$ MeV/c^2. Note that for the H computed

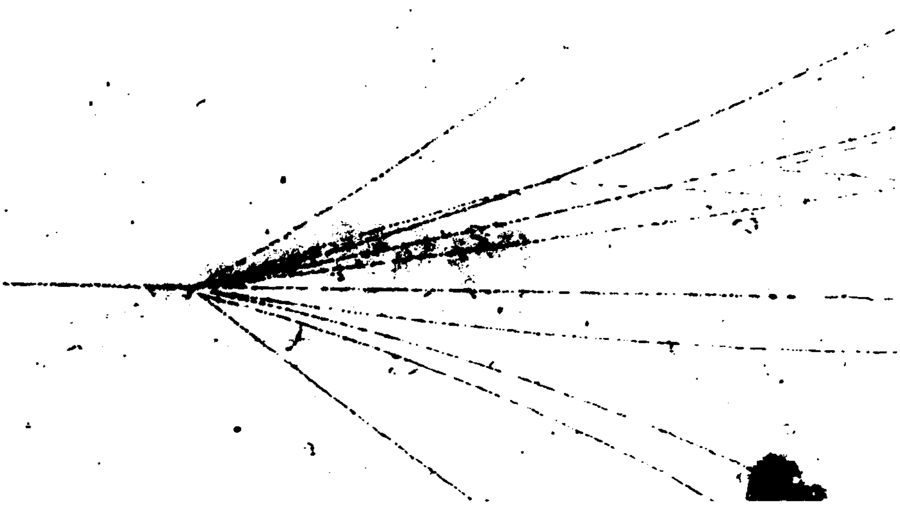

Fig.1

in this models one has $|E_{Bj}(A)| > |E_{Bj}(H)|$. As a result of triple scan of 180 K photographs an event has been found which can be interpreted as due to intranuclear conversion of an A-dibaryon.

A 10 GeV/c beam proton produces a six-prong star and three lambdas (Fig.1).

The most "dangerous" background able to imitate this event is the possible creation af all the three lambdas in an intranuclear cascade process. Unfortunately a precise and refined estimate of its probability today is impossible because of the absence of suitable algorithms. Instead, the pessimistic, crude but for sure overestimated background of this sort is $8.85 \cdot 10^{-2}$ events on 180 K photographs. Here we have supposed that the most energetic lambda is created in $p^{12}C$ collisions with $0.1\sigma^{tot}(p^{12}C) = 0.5$ mb cross section, the two slower lambdas being created in π N intranuclear collisions with $0.1\sigma^{tot}(\pi N) = 0.1$ mb cross section at $n = 1.3 \cdot 10^{38}$ cm^{-3} nucleon density on $r = 1.5R_{^{12}C} = 4.12$ fm path length each. The coefficient 0.1 accounts for the momentum and angular distributions of lambdas. It should be noted that out of six prongs only one could be visually identified as due to a positive pion. Other five particles could not be definitely identified.

Only four of a series of intranuclear conversion reactions fitted successfully the event observed (Tables 1 and 2).

The highest confidence suggests the four-vertex, ten- and nine-constraint fits. Indeed in these cases one has seven unmeasured parame-

Table 1. The results of the fits at M_A from the two models

Reactions	mV-nC	S.B.M. x_n^2	S.B.M. C.L. (%)	P.M. x_n^2	P.M. C.L. (%)
$A^- + n \to \Lambda + \Lambda + \Lambda + \pi^-$	4V-10C	9.38	50.00	20.15	3.0
$A^o + p \to \Lambda + \Lambda + \Lambda + \pi^+$	4V-10C	10.50	40.0	16.30	9.0
		11.44	32.0	—	—

Table 2. The results of the fit at M_A as a free parameter

Reactions	nV-nC	x_n^2	C.L. (%)	Fitted M_A (MeV/c^2)
$A^- + n \to \Lambda + \Lambda + \Lambda + \pi^-$	4V-9C	9.19	42.0	2492.1 ± 48.4
$A^o + p \to \Lambda + \Lambda + \Lambda + \pi^+$	4V-9C	9.19	42.0	2437.5 ± 27.6
		9.19	42.0	2510.9 ± 21.5
$A^- + p \to \Lambda + \Lambda + p + K^-$	3V-6C	3.16	79.0	2433.0 ± 27.2
		7.19	30.0	2292.9 ± 25.9
$A^o + n \to \Lambda + \Lambda + p + K^-$	3V-6C	3.16	79.0	2429.6 ± 27.2
		7.19	30.0	2290.0 ± 26.0

ters: the momenta of the three lambdas and the mass, momentum, dip and azimuthal angles of the A-dibaryon.

Thus of sexteen energy-momenta component equations only ten remain independent if the mass M_A is fixed at predicted values and only nine independent equations if M_A is a free parameter. In this context both models fit the event observed though the Spherical Bag Model seems to be preferable (Table 1).

The same conclusion suggests the fit at M_A as a free parameter (the upper part of Table 2). Two versions of the second reactions in these cases are due to the second positively charged particle which is not identified.

But the three-vertex six constraint fits allow M_A values meeting the predictions of both models depending on combinations of lambdas and protons (the lower part of Table 2).

The search is in progress.

Hunting the Metastable States

Here we confine ourselves to the search for multiquark metastable states hunting peaks in $\Lambda p\pi$ invariant mass spectra.

Let us remaind that in $n^{12}C$ collisions at 7 GeV/c the $\Lambda p\pi$ invariant mass spectrum has revealed a strongly pronounced peak (Fig.2).

An appropriate analysis led to the following resonance parameters [9].

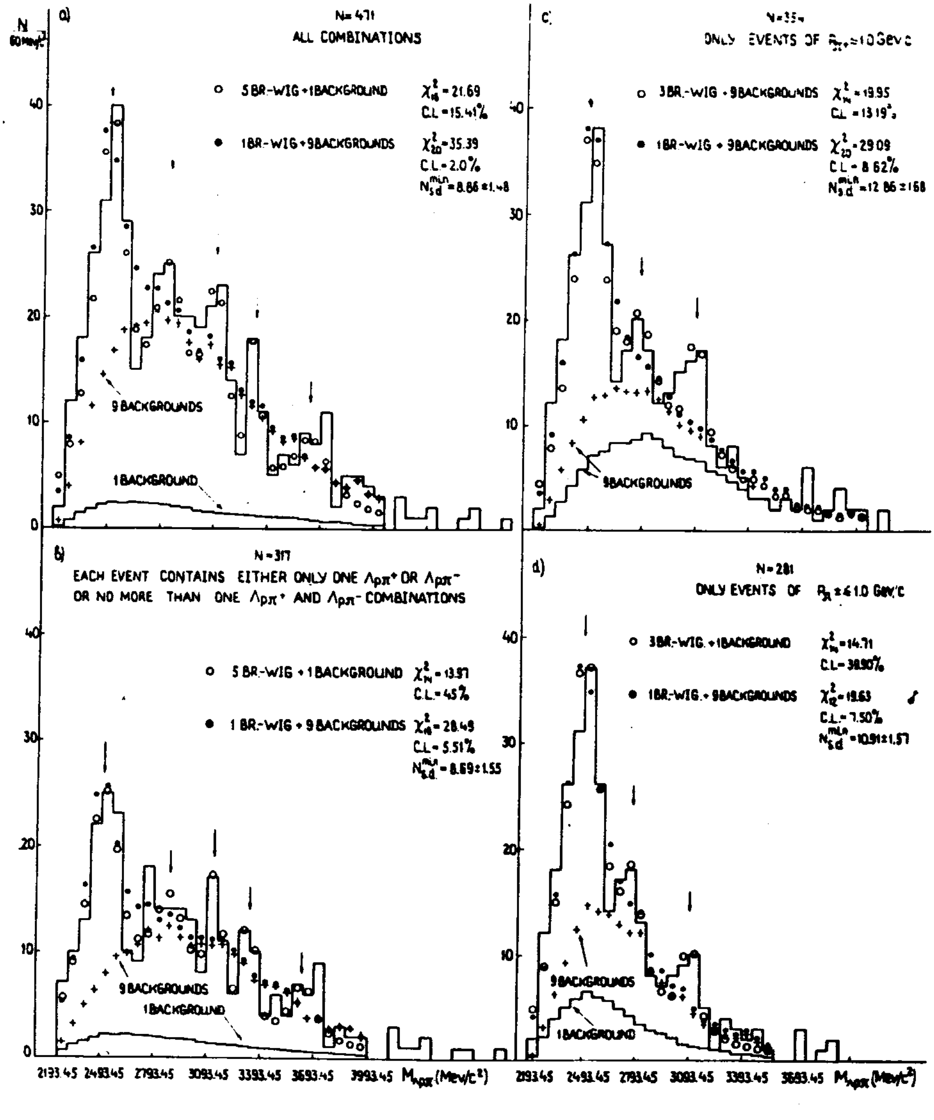

Fig.2

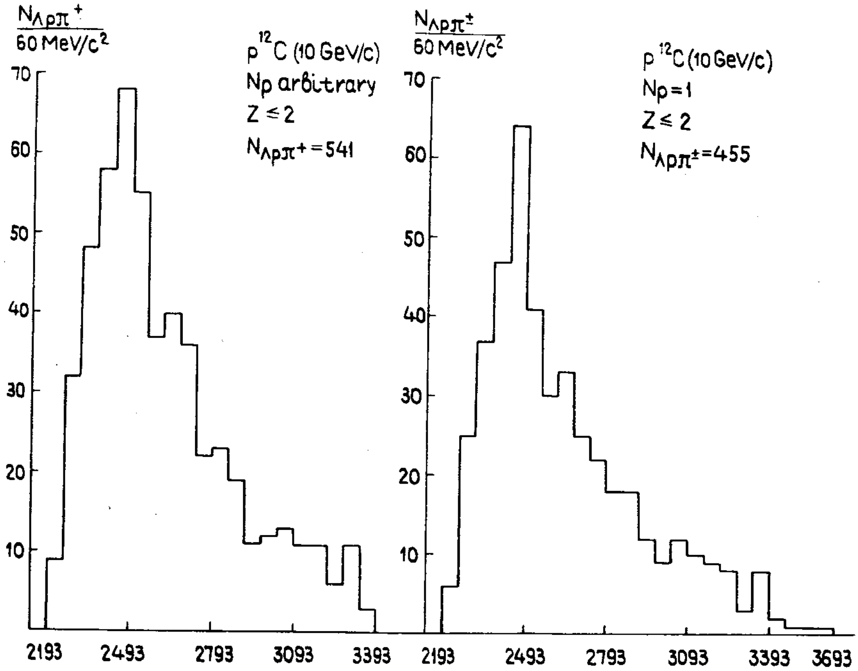

Fig.3

$M = (2495.2 \pm 8.7)$ MeV/c^2, $\Gamma = (204.7 \pm 5.6)$ MeV/c^2,

$\sigma_{prod} = (70.5 \pm 26.0)\,\mu$b.

The predicted $\Lambda p \pi$-resonance mass value is 2500 MeV/c^2 /10/. This peak has been confirmed in p^{12}C collisions at 10 GeV/c (Fig.3).

The left-hand side $M_{\Lambda p\pi^+}$ spectrum is due to events of arbitrary proton number but of the total electric charge $Z \leq 2$. The right-hand side $M_{\Lambda p\pi^\pm}$ spectrum is due to events of only one proton and $Z \leq 2$. Both spectra reveal a strongly pronounced peak at the same position as in Fig.2, thus confirming the existence of the $\Lambda p\pi$ resonance.

Let us note that this result has been obtained on a total statistics of 4610 Λ out of 6585 V° events.

The collection of statistics is continued.

References

1. Faessler A., Straub U. — Annalen der Physik, 1990, 47, p.439.
2. Goldman T. et al. — Phys. Rev. Lett., 1987, 59, p.627.

3. Kopeliovich V.B. et al. — Phys. Lett. B, 1990, 242, p.145.
4. Carroll A.S. et al.— Phys. Rev. Lett., 1978, 41, p.777.
5. Shahbazian B.A. et al. — Z. Phys. C, 1988, 39, p.151.
6. Shahbazian B.A. et al. — Phys. Lett. B, 1990, 235, p.208, Errata, 1990, 238, p.452, 1990, 244, p.580.
7. Shahbazian B.A. et al. — Proceedings of the VIII Int. Seminar on High Energy Physics Problems, v. II, Dubna, 1986, JINR, D1,2-86-668, Dubna, 1986, p.84.
8. Shahbazian B.A. et al. — Proceedings of the IX Int. Seminar on High Energy Physics Problems, Dubna, 1988, JINR, D1,2-88-652, Dubna, 1988, p.337.
9. Shahbazian B.A. et al. — Proceedings of the Intern. Conference on Hyper-Nuclear and Kaon Physics, Heidelberg, Germany, 1982, p. 287.
10. Mulders P.J., Aerts A.Th.M., de Swart J.J. — Phys. Rev. D, 1980, 21, p. 2653.

Received on April 8, 1991.