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THE OBSERVATION OF THE SECOND HEAVY STABLE $\tilde{H}(S = -2)$-DIBARYON

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We have succeeded in observing a second event which is unambiguously interpreted as the creation and weak decay of the heavy stable $\tilde{H}(S = -2)$ dibaryon. Its mass, equal to $M_{\tilde{H}} = (2384.9 \pm 31.0)$ MeV/c^2, is in good agreement with the mass of the first dibaryon, (2408.9 ± 11.2) MeV/c^2, recently observed.

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

Наблюдение второго тяжелого стабильного дибариона $\tilde{H}(S = -2)$

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Обнаружено второе событие, которое однозначно интерпретируется как рождение и слабый распад тяжелого стабильного $\tilde{H}(S = -2)$ дибариона. Масса его, равная (2384.9 ± 31.0) МэВ/c^2, находится в хорошем согласии с массой первого дибариона, найденного ранее, (2408.9 ± 11.2) МэВ/c^2.

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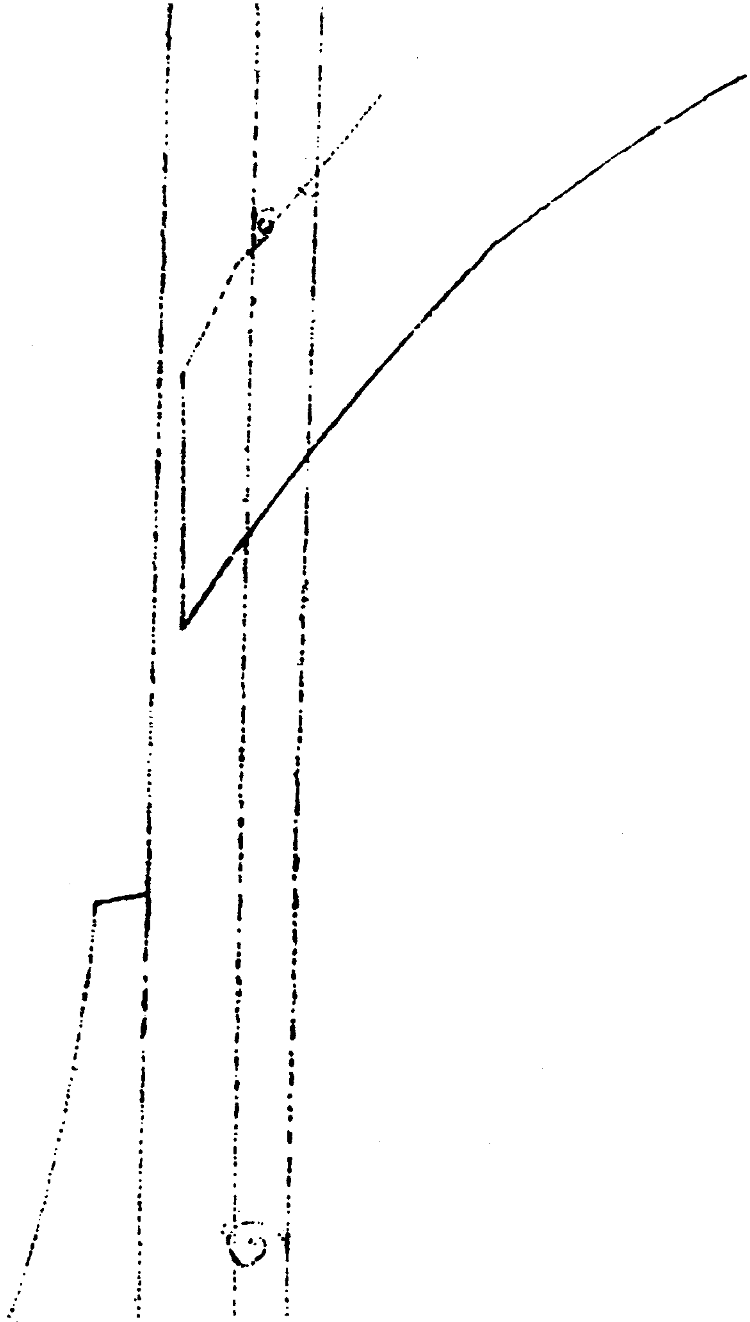
The search for stable dibaryons is in progress. On a photograph of the JINR 2m propane bubble chamber, exposed to 10 GeV/c proton beam on the 30th of December 1991, we have found an event, which as a result of the four-vertex, four-constraint fully exclusive kinematical fit, $(4V\text{—}4C)$, has been unambiguously interpreted as the creation and weak decay of the second heavy stable $\tilde{H}(S = -2)$-dibaryon.

A 10 GeV/c beam proton produced a two-prong star and a V^0-particle, which after covering a range of 6.87 cm in propane, weakly decays into a slow proton of black track that stops in propane after rescattering, and a relativistic negative particle of minimum ionization doubly kinked track (Figure). The first part of this track between the V^0-vertex and the first kink, 6.65 cm long, is formed by a negative charged particle of a momentum certainly over 1.0 GeV/c and thus cannot be visually identified in propane. Instead, the second and third parts of this track with momenta coinciding within the half an error,



The production and weak decay of the heavy stable $\widetilde{H}(S = -2)$-dibaryon parts of this track with momenta coinciding within the half an error, are due to the same uniquelly identified negative pion, recoiled against a ^{12}C nucleus.

One of the prongs of the star is due to a slow positively charged particle of a black track, emitted in the backward hemisphere. After travelling in propane a range of 1.3 cm this particle obviously suffers weak decay, the positively charged light decay particle being emitted also in the backward hemisphere. Its momentum, averaged over six measurements is equal to (231.1 ± 4.9) MeV/c. The apperance of the corresponding track excludes the positron hypothesis, whereas the closeness of the measured momentum to the rest system momentum, $p_{\mathrm{r.s.}} = 236$ MeV/c, for the $K^+ \to \mu^+ + \nu$ decay mode, rejects the alternative decay mode $K^+ \to \pi^+ + \pi^0$, because in this case $p_{\mathrm{r.s.}} = 205$ MeV/c. So, these facts suggest that the black track is formed by a stopping positive kaon of (136.5 ± 3.7) Mev/c momentum, suffering $K^+ \to \mu^+ + \nu$ weak decay.

The second prong of the star is formed by a fast relativistic positively charged particle of minimum ionization and a momentum of several GeV/c. Therefore it has been identified only in kinematical analysis.

The multivertex kinematical analysis we have started with two-vertex, four-constraint fits. Hypotheses on combinations of sequences of two-body weak decays, rescattering on a neutron or a ^{12}C nucleus, as a whole, as well as reactions, able to imitate the observed event have

Table 1. The results of the ($2V$—$4C$) kinematical fits of the hypotheses on the possible reactions able to imitate the observed event. $\chi^2(2V—4C)$ are averaged over six measurements

№	Possible imitating reactions		$\chi^2(2V—4C)$
1.	$\Lambda \to p + \pi^-$;	$\pi^- + n \to \pi^- + n$	450.20
2.		$\pi^- + {}^{12}\mathrm{C} \to \pi^- + {}^{12}\mathrm{C}$	454.72
3.	$\Xi^0 \to p + \pi^-$;	$\pi^- + n \to \pi^- + n$	220.61
4.		$\pi^- + {}^{12}\mathrm{C} \to \pi^- + {}^{12}\mathrm{C}$	212.91
5.	$\Lambda + n \to p + \Sigma^-$;	$\Sigma^- \to n + \pi^-$	401.40
6.	$\bar{K}^0 + n \to p + K^-$;	$K^- \to \pi^- + \pi^0$	no fit
7.		$K^- \to \mu^- + \nu$	no fit
8.	$\bar{K}^0 + n \to p + K^-$;	$K^- + n \to \pi^- + \Lambda$	no fit
9.		$K^- + n \to \pi^- + \Sigma^0$	no fit

been tried (Table 1). Clearly all hypotheses on imitating processes have to be rejected. The estimated probability of the sequence of the reactions $n + n \to n + p + \pi^-$, $\pi^- + n \to \pi^- + n$ or $\pi^- + {}^{12}C \to \pi^- + {}^{12}C$ of the 10^{-5} order of magnitude on 10^5 K photographs [2,3] holds for this event also. Furthermore the track length of the ${}^{12}C$ nucleus recoiled as a whole in the reactions 1—4 of the Table 1 would have been 0.7 cm long, which would be quite reliably detected. Any of the lighter fragments of a ${}^{12}C$ nucleus would produce longer tracks. Thus we have independent proofs that the first kink of the V^0 negative track does not result in the above reactions. Again, as in [2] special attention had been paid to the hypotheses on $\Lambda\Sigma$ conversion on a neutron both at rest and Fermi-moving one. The hypothesis on $\Lambda\Sigma$ conversion on a neutron at rest (reaction 5, Table 1) fails to fit the event. The fit proceeded in two steps. In the first one the hypothesis on $\Lambda + n \to p + \Sigma^-$ conversion fails to fit the event with $\chi^2(1V\text{—}3C) = 400.00$, demonstrating thereby that the V^0 observed is not created in the above binary reaction and particularly that the neutral particle is not a Λ-hyperon. The second step hypothesis on a weak decay $\Sigma^- \to n + \pi^-$ fits well the event with $\chi^2(1V\text{—}1C) = 0.76$, C.L. = 38.3% proving threby that the negative kinked track of the V^0 is due to the weak decay of a Σ^--hyperon. The total hypothesis on the sequence of $\Lambda + n \to p + \Sigma^-$ conversion and $\Sigma^- \to n + \pi^-$ weak decay fails to fit the event observed with $\chi^2(2V\text{—}4C) = 401.40$, and have to be rejected. Again, as in [2] the (2V—3C) kinematical fits of the hypotheses on $\Lambda\Sigma$ conversion taking place on a Fermi-moving neutron of a momentum both parallel and antiparallel to the incident Λ momentum vector, proved to be unsuccessful.

We have considered also the same reaction, induced by a Λ, emitted this time from an unknown interaction vertex. Then the Λ-momentum three-vector is an unmeasurable parameter. Therefore both in the first and in the second steps one has (1V—1C)-fits. Again as in [2] the full two-step fit has failed with $\chi^2(2V\text{—}2C) = 101.1$ though the second step fit of the hypothesis on weak decay $\Sigma^- \to n + \pi^-$ once more was successful with $\chi^2(1V\text{—}1C) = 1.6 \cdot 10^{-3}$ C.L. = 96.8%, thereby again confirming that the the kinked track of the V^0 observed belongs to a Σ^--hyperon.

Thus the above analysis demonstrates that $\Lambda\Sigma$ conversion of a Λ, emitted both from the interaction vertex and from an unknown one on a neutron, both Fermi-moving and at rest, fails to imitate the event observed. Six reactions $\Lambda + n \to p + \Sigma^- + \pi^0$ with π^0 and n momenta parallel or antiparallel to the Λ momentum, or n at rest, failed to fit the event also.

Again, as in [2], within the frame of the OBE model, it has been demonstrated that the yield of imitating «V^0-particles», which could arise in sequences of reactions and weak decays, $n + n \to p + \Sigma^- + K^0 + m\pi^0$ $m = 0, 1, 2, ..., \Sigma^- \to n + \pi^-$ induced by a fast neutron, born in a primary proton- or secondary hadron- ^{12}C or ^{1}H nuclei interactions is $8 \cdot 10^{-7}$ on 100 K photographs. Therefore this possibility of imitating the event observed also should be rejected.

Of the exotic weak decay sequences (i) $\tilde{H} \to p + \Sigma^-$, $\Sigma^- \to n + \pi^-$ (ii) $A^0 \to p + \Xi^-$, $\Xi^- \to \Lambda + \pi^-$, only the first one fits successfully our event with $\chi^2(2V\text{—}3C) = 3.05$, C.L. = 38.42% and $M_{\tilde{H}} = (2385.8 \pm 31.0)$ MeV/c^2 (averaged over six measurements with s.d. of 31.0 MeV/c^2).

Thus, we have proved that the observed V^0-particle is due to the weak decay of a heavy stable $S = -2$ dibaryon $\tilde{H} \to p + \Sigma^-$, $\Sigma^- \to n + \pi^-$. Its mass, within the limits of errors coincides with the mass of the first one, observed earlier, (2408.9 ± 11.2) MeV/c^2, [2].

Then a full exclusive multivertex kinematical analysis became of a special importance. The hypotheses on reactions of the beam protons with proton targets

$$p + p \to \tilde{H} + K_1^+ + K_2^+,\ \tilde{H} + K_1^+ + K_2^+ + \pi^0,\ H + K_1^+ + K^0 + \pi^+,$$

each channel followed by weak decay sequences $\tilde{H} \to p + \Sigma^-$, $\Sigma^- \to n + \pi^-$, $K_1^+ \to \mu^+ + \nu$ were tried. The corresponding ($4V$—$8C$)-, and ($4V$—$5C$)-fits proved to be unsuccessful. This negative result forced us to profit by our idea already successfully used in the analysis of the $H(2175)$-event [3,4]. It seems quite natural that the most favourable kinematical conditions for the formation of the stable $S = -2$ dibaryons by nonstrange projectiles arise in their collisions with dibaryonic targets. As real sources of such dibaryonic intranuclear fluctuons, D, light nuclei, the ^{12}C nucleus including, can serve. As far as the masses of such hypothetical dibaryonic fluctuons, excepting the deuteron, are unknown, one more unmeasured parameter, the fluctuon mass M_D, was introduced. Then one has twelve unmeasurable parameters: the mass of the $\tilde{H}$, the modulus of its momentum, nine momentum components of the

Table 2. The results of the successful (4V—4C) kinematical fits. The $\chi^2(4V—4C)$ and $M_{\tilde{H}}$ were averaged over six measurements. As the errors of the $M_{\tilde{H}}$ (MeV/c^2), the s.d. are cited. C.L. in %. $M_{\tilde{H}}$ and M_D — in MeV/c^2

The sucessfully fitted reactions	$\chi^2(4V—4C)$	C.L.	$M_{\tilde{H}}$	M_D
$p + D \to \tilde{H} + \binom{K^+}{p} + K^+ \binom{n}{K^0}$; $\tilde{H} \to p + \Sigma^-$, $\Sigma^- \to n+\pi^-$; $K^+ \to \mu^+ + \nu$	4.52	34.0	2384.9 ± 31.0	1700^{+176}_{-76}
	6.97	13.8	23749 ± 29.6	

three neutrals and the target-fluctuon mass M_D (Table 2). Of sixteen constraint equations only four are inpendent. Therefore (4V—4C) exclusive kinematical fits of only two hypothetical channels were performed. The not detected kaon of (930.1 ± 121.1) MeV/c momentum should be assumed to be either long-living k_L^0 or short-living component suffering $K_s^0 \to \pi^0 + \pi^0$ decay. It is worth to mention that the efficiency of the simultaneous detection of four e^+e^- pairs in our bubble chamber is $3.9 \cdot 10^{-3}$.

As it follows from Table 2, both channels fit our event, though the C.L. of the first channel 2.4 times exceeds that of the second one, and therefore is more preferable.

Rather large errors of the best-fit target mass M_D (Table 2) do not permit us to exclude a deuteron-mass M_d fluctuon target which could exist within the nucleus before the moment of the collision. Nevertheless, one has $M_D - M_d < 0$.

An analysis of the same kind, performed for the event $H(2175)$ [4] with (2V—2C)-fit led to $M_D = (1250\ ^{+500}_{-75})$ MeV/c^2, $M_{\tilde{H}} = (2172.7 \pm$ $\pm$ 15.2) MeV/c, i.e., again one has $M_D - M_d < 0$. Let us note, that in both cases the multiplicities of the charged secondaries are the lowest ones for the total electric charges of the events $Q = 2$ and in both of them there is no seen fragmentation of the ^{12}C nucleus.

As we believe these facts indicate that the above low mass superdense dibaryonic targets of $Q = 1$ electric charge and $Y = 2$ hypercharge were formed dynamically within the ^{12}C nucleus in the moment of the collision. And in both events the nucleus leave not the $Y = 2$ dibaryons

Table 3. The best-fit parameters, averaged over six measurements (s.d. are cited as errors) obtained in (4V—4C)-fit of the $p + D \rightarrow \tilde{H} + K^+ + K^+_{stop} + n$, $\tilde{H} \rightarrow p + \Sigma^-$, $\Sigma^- \rightarrow n + \pi^-$, $K^+ \rightarrow \mu^+ + \nu$ channel to the event observed, $M_D = (1700^{+176}_{-76})$ MeV/c^2, $M_{\tilde{H}} = (2384.9 \pm 31.0)$ MeV/c^2

	p (MeV/c)	tg α	β (rad)
p_{in}	9497.6 ± 396.3	0.00603 ± 0.00102	1.60933 ± 0.00056
K^+	4739.5 ± 410.4	0.02508 ± 0.00306	1.62039 ± 0.00144
K^+_{stop}	136.4 ± 3.7	−0.20090 ± 0.09871	3.38749 ± 0.01790
μ^+	242.9 ± 2.9	0.30689 ± 0.01586	4.62467 ± 0.00904
ν	247.2 ± 2.9	−0.43238 ± 0.05979	2.07284 ± 0.019178
n	2326.5 ± 220.6	0.08575 ± 0.01783	1.66042 ± 0.01101
$\tilde{H}$	2501.7 ± 137.4	−0.09258 ± 0.01081	1.48843 ± 0.00275
p	484.5 ± 9.9	−0.11483 ± 0.04517	1.02283 ± 0.01970
Σ^-	2080.2 ± 137.1	−0.08491 ± 0.01179	1.59296 ± 0.00338
n	1881.4 ± 147.1	−0.16490 ± 0.01480	1.63075 ± 0.00811
π^-	262.3 ± 17.1	0.56448 ± 0.01588	1.28461 ± 0.00665

formed, but the H- and $\tilde{H}$-dibaryons of hypercharge $Y = 0$. These facts satisfy well the empirical hypercharge selection rule: «The hypercharge of free hadrons (multiquark and multibaryon ones including) cannot exceed unity: $Y < 1$» (see [4] and our earlier articles cited therein).

The analysis performed suggests that in $p^{12}C$ collisions at 10 GeV/c resulting in both light (of masses less than two lambda masses) and heavy (of masses close to two sigma hyperon masses) stable dibaryons, nonstrange QGP dynamically is formed which immediately suffers a phase transiton into a stable dibaryon and two kaons of positive strangeness and all the three hadrons of hypercharges 0 and 1 leave the nucleus. Thus the stable dibaryons serve as a signature of the QGP formation in a nucleus. This analysis in full scale is feasible only for the events of the simplest topology, i.e. events not obscured by cascade or fragmentation processes.

The best-fit parameters for the first of the channels (Table 2) in Table 3 are presented. For the Σ^--momentum treated as an unmeasurable parameter the (4V—3C)-fit led to the best-fit parameters which coincide with those of Table 3 within the limits of errors.

The time of flight of this heavy stable dibaryon is $2.18 \cdot 10^{-10}$ s. Thus we have observed a second event of the formation and the weak decay of the heavy stable dibaryon $\tilde{H}(S = -2)$, the mass of which (2384.9 ± 31.0) MeV/c^2 within the limits of the errors coincides with the mass of the first one, (2408.9 ± 11.2) MeV/c^2 [2].

The effective cross section of the $\tilde{H}$ production in $p^{12}C$ interactions at the 10 GeV/c momentum was estimated as (200 ± 180) nb, using these two events and the number of photographs, scanned up to the present.

The masses of these two events are very close to the lowest state $I = 1$, $J^{\pi} = 0^+$, $\{f\} = \{10*\}$ mass of $\approx$ 2370 MeV/c^2 predicted within the frames of the Callan-Klebanov-Kunz-Mulders soliton Skyrme-like model [5].

Fortunately the bubble chamber technique makes it possible to search for all the three charge components simultaneously via weak decay modes: $\tilde{H}^+ \to p + \Lambda$ or $p + \Lambda + \pi^+ + \pi^-$ etc., $\Lambda \to p + \pi^-$; $\tilde{H} \to p + \Sigma^-$, $\Sigma^- \to n + \pi^-$; $\tilde{H}^- \to p + \Lambda + \pi^-$, etc., $\Lambda \to p + \pi^-$.

The search for these hadrons is in progress.

We succeeded in observing a weak decay of the positively charged heavy dibaryon into a proton, lambda and neutral pion, the mass of which is in fair agreement with the masses of the above considered neutral dibaryons. The details in a forthcoming paper will be given.

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