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THE OBSERVATION OF THE HEAVY STABLE POSITIVELY CHARGED $\tilde{H}^+$ (S= −2) DIBARYON

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We have succeeded in observing an event which is unambiguously interpreted as the weak decay of the heavy stable positively charged $\tilde{H}^+$ ($S= -2$) dibaryon. Its mass, equal to $M_{\tilde{H}^+} = (2377.5 \pm 9.5)$ MeV/c^2 is in fair agreement with the masses of the two heavy stable ($S= -2$) neutral dibaryons, (2408.9 ± 11.2) and (2384.9 ± 31.0) MeV/c^2, recently found.

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

Наблюдение тяжелого стабильного, положительно заряженного $\tilde{H}^+$ ($S= -2$) дибариона

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Нам удалось обнаружить событие, которое однозначно интерпретируется как слабый распад тяжелого стабильного, положительно заряженного $\tilde{H}^+$($S= -2$) дибариона. Масса его, равная $M_{\tilde{H}^+} = (2377{,}5 \pm 9{,}5)$ МэВ/c^2, находится в хорошем согласии с массами двух недавно найденных тяжелых стабильных ($S= -2$) нейтральных дибарионов, (2408,9 ± 11,2) и (2384,9 ± 31,0) МэВ/c^2.

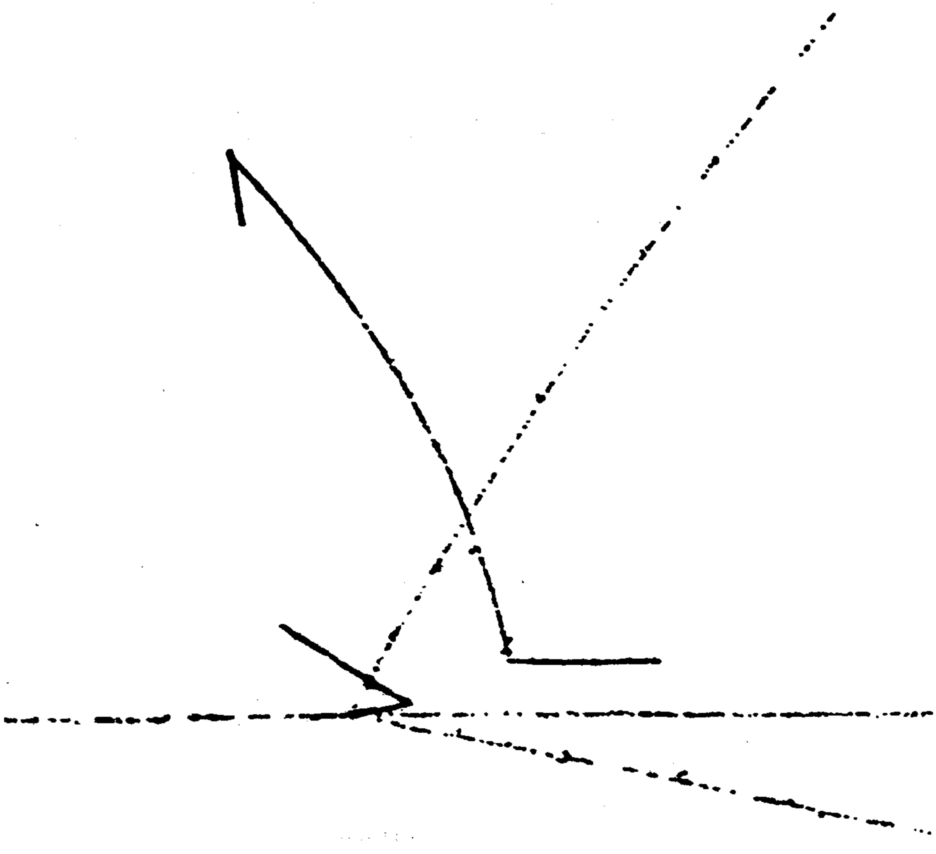
Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Recently we have reported [1,2,3] on two events, found on photographs of the JINR 2m propane bubble chamber exposed to 10 GeV/c proton beam of the Synchrophasotron, which were interpreted as the production and weak decays of the heavy neutral stable $\tilde{H}$ ($S= -2$) dibaryons of masses (2408.9 ± 11.2) and (2384.9 ± 31.0) MeV/c^2, coinciding with each other within the limits of errors. Moreover, the masses of these two events are very close to the lowest state of $S= -2$ dibaryons, $I = 1$, $J^{\pi} = 0^+$, {f} = {10*} stable with respect to strong decays of a mass 2370 MeV/c^2, predicted by the Callan — Klebanov — Kunz — Mulders soliton Skyrme-like model [4].

Fortunately, the propane bubble chamber technique makes it possible to search for all the three charge triplet components simultaneously, via weak decay modes

$$\tilde{H}^+ \to p + \Lambda, \qquad \Lambda \to p + \pi^- \tag{1}$$
$$p + \Lambda + \pi^0, \qquad \Lambda \to p + \pi^- \tag{2}$$
$$p + \Lambda + \pi^+ + \pi^-, \qquad \Lambda \to p + \pi^- \tag{3}$$
$$p + p + K^-, \tag{4}$$ etc.
$$\tilde{H} \to p + \Sigma^-, \qquad \Sigma^- \to n + \pi^- \tag{5}$$
$$\tilde{H}^- \to p + \Lambda + \pi^- + \pi^-, \qquad \Lambda \to P + \pi^- \tag{6}$$ etc.

Therefore we have started with the search for the charged heavy stable dibaryons in the sample of events, compatible with the topologies (1) — (4).



The $\tilde{H}^+$ dibaryon suffering weak decay $\tilde{H}^+ \to p + \Lambda + \pi^0$, $\Lambda \to p + \pi^-$

On the 10th of January 1992 a noteworthy event was found in this sample (Figure). A beam proton produces a four-prong star of a total electric charge $Q = +4$. The most intriguing in this star is the black kinked track. The appearance of its first part, 1.14 cm long, situated between the star and the kink — vertices, suggests that it is due to a very slow heavily ionizing positively charged massive particle, suffering violent scattering in propane. The second part is certainly due to a slow proton, $p_p = (261.5 \pm 5.7)$ MeV/c, which stops in propane. A slow V^0-particle is clearly seen near the star. The black track of the positively charged decay particle is due to a slow proton of $p_p = (259.7 \pm 5.8)$ MeV/c momentum, which stops in propane. The second decay track is due to a slow negative pion of $p_{\pi^-} = -(100.8 \pm 2.2)$ MeV/c, which also stops in propane, is captured by a carbon nucleus, which de-excitates, evaporating two short-range protons. Thus, the V^0 can be due to the weak decay of a lambda-hyperon only. Indeed, the invariant mass of the (p, π^-) pair is (1114.5 ± 1.5) MeV/c^2. The hypothesis on emission of this lambda from the primary interaction vertex fails to fit the event with $\chi^2(1\,\mathrm{V} - 3\,\mathrm{C}) = 50.4$. This negative result is due to a large noncoplanarity angle, $\eta = (0.36312 \pm 0.03254)$ radians, formed by the supposed line of flight, connecting the interaction and decay vertices, with the decay plane. Contrary to this, the hypothesis on emission of the lambda hyperon from the kink-vertex fits well the event with $\chi^2(1\mathrm{V} - 3\mathrm{C}) = 2.92$, C.L.= 40.5%, $p_\Lambda = (263.4 \pm 6.1)$ MeV/c. The proton and negative pion transversal momenta $p_p = (97.4 \pm 4.5)$ and $p_{\pi^-} = -(98.2 \pm 5.0)$ MeV/c coincide within the limits of errors.

Thus there arized the problem of the identification of the very slow massive particle able to produce two baryons, a lambda hyperon and a proton, at least. It should be noted that the best measurement of its momentum for the proton hypothesis was performed with a relative error of 80%. There are measurements, also with large errors, ascribing negative charge to the particle, e.g. $p_{K^-} = -(101.7 \pm 98.6)$ MeV/c for the K^--hypothesis. Therefore we had to examine all possible imitating reactions induced by both positively and negatively charged particles.

(i) Of all very slow positively charged particles only the Σ^+ hyperon is able to create a lambda hyperon and a proton. The hypothesis on the reaction sequence $\Sigma^+ + n \to \Lambda + p$, $\Lambda \to p + \pi^-$ failed to fit the event with $\chi^2(2\mathrm{V} - 6\mathrm{C}) = 645.8$. Here one has only two unmeasurable parameters, the Λ and Σ^+ momenta. There were no (2V—4C) fits for the hypotheses on the reaction sequences $\Sigma^+ + n \to p + \Lambda + \pi^0$, $\Lambda \to p + \pi^-$ and $\Sigma^+ + (2n) \to p + \Lambda + n$, $\Lambda \to p + \pi^-$, $M(2n) = 2M_n$, as well.

(ii) No successful (2V—4C) fits of the reactions

$$K^- + (2p) \to p + \Lambda + \pi^0, \quad \Lambda \to p + \pi^-, \quad M(2p) = 2M_p$$

$$K^- + (2pn) \to p + \Lambda + N^0/\Delta^0, \quad \Lambda \to p + \pi^-, \quad M(2pn) = 2M_p + M_n$$

$$\Sigma^- + (2p) \to p + \Lambda + N^0/\Delta^0, \quad \Lambda \to p + \pi^-, \quad M(2p) + 2M_p$$

have been obtained. By N^0 and Δ^0 the neutron and all known neutral N- and Δ-baryons are meant.

(iii) The only alternative remains the hypothesis on weak decay modes of a positively charged stable dibaryon. The hypothesis on two-body weak decays $\tilde{H}^+ \to p + \Lambda$, $\Lambda \to p + \pi^-$ failed to fit the event with $\chi^2(2V\text{—}6C) = 95.9$.

Only the hypothesis on the three-body weak decay $\tilde{H}^+ \to p + \Lambda + \pi^0$, $\Lambda \to p + \pi^-$ fits well the event with $\chi^2(2V\text{—}3C) = 3.24$, C.L. = 35.6%. The best-fit parameters are: $M_{\tilde{H}^+} = (2377.5 \pm 9.5)$ MeV/c^2, $p_{\tilde{H}^+} = (50.0 \pm 40{,}6)$ MeV/c, $\mathrm{tg}\,\alpha_{\tilde{H}^+} = 0.47661 \pm 0.27837$, $\beta_{\tilde{H}^+} = (1.93508 \pm 0.12774)$ radians. Here $\alpha_{\tilde{H}^+}$ and $\beta_{\tilde{H}^+}$ are the dip and azimuthal angles, respectively. The large errors are due to the violent scattering of $\tilde{H}^+$ in propane.

Finally, one cannot exclude that the weak decay $\tilde{H}^+ \to p + \Lambda + \pi^0$ took place at rest. In this case one is deprived of the possibility of performing the kinematical fit except the (1V-3C) fit on $\Lambda \to p + \pi^-$ hypothesis. Then, using the fitted parameters of the lambda and four constraint equations, one can compute the mass of the $\tilde{H}^+$ dibaryon and the three components of the neutral pion momentum. The mass obtained in this way, $M_{\tilde{H}^+} = 2378.2$ MeV/c^2 is in excellent agreement with the above cited value.

Our attempts to perform exclusive multivertex kinematical analysis of the production (both on a proton and multibaryon targets) and the weak decay of the $\tilde{H}^+$, were not successful. We ascribe this failure to the obscuring effect of the nuclear cascade process. In the recent article [3] we arrived at the conclusion, that both the heavy ($M_{\tilde{H}} \sim 2M_\Sigma$) and light

($M_H < 2M_\Lambda$) dibaryons with the accompanying two kaons of $S = +1$ strangeness have appeared as a result of the phase transition of the nonstrange quark-gluon plasma (QGP) formed in the moment of the collision of 10 GeV/c protons with carbon nuclei. Thus the stable dibaryons serve as signatures of the QGP.

This new mechanism of the stable dibaryon formation fits well our empirical hypercharge selection rule: «The hypercharge of free hadrons (the exotic ones including) cannot exceed unity: $Y \leq 1$» ([5] and the earlier papers cited therein).

Now, it should be noted, that the quite unsufficient precision of the contemporary methods of the time interval measurement ($\Delta t = 9.11^{-11}$ s) do not permit one to discriminate the creation of the H ($\sim 10^{-22}$ s) against the substantial background of K^+-mesons produced together with hyperons or antikaons in nuclear cascade processes ($\sim 10^{-22}$ sec). This circumstance depreciates the tagging by the $K^- \to K^+$ strangeness exchange ($\Delta S = +2$) process, used in the experiments [6,7]. Therefore the reliable identification of the weak decay of the stable dibaryons H, $\tilde{H}^+$, $\tilde{H}$, $\tilde{H}^-$ — turns into a problem of paramount importance. The urgency of this statement becomes quite evident for the production of dibaryons via phase transition mechanism, for the realization of which the collisions of relativistic ions with nuclei are best suited. But the backgrounds of any kinds, the K^+ mesons including, due to nuclear cascade and fragmentation processes are the highest possible ones in this case, as well. Therefore we are doomed to scrupulous multivertex kinematical analysis of a candidate for stable dibaryon weak decay observed, like the one, developed in [1,2,3] and this article. And the more dense is the material of the detector used (propane, fibre scintillators, nuclear emulsions), the more imperative is the necessity of such an analysis, irrespective of the projectile used.

Thus we have succeeded in observing an event of weak decay of a heavy stable positively charged dibaryon, $\tilde{H}^+ \to p + \Lambda + \pi^0$, $\Lambda \to P + \pi^-$, of a mass $M_{\tilde{H}^+} = (2377.5 \pm 9.5)$ MeV/c^2. This value within the limits of errors coincides with the masses of two neutral heavy dibaryons (2408.9 ± 11.2) [2] and (2384.9 ± 31.0) MeV/c^2 [3], observed earlier. For the present, at the cited errors one cannot speak of electromagnetic mass splitting. The mass, averaged over the three events, is (2390.4 ± 17.2) MeV/c^2, i.e. $\sim 2M_\Sigma$. The formally estimated effective cross section of the $\tilde{H}^+$ production in p^{12}C collisions at

10 GeV/c is 100 nb. The time of flight before the weak decay of the $\tilde{H}^+$ is $1.8 \cdot 10^{-9}$ s.

Of all $\tilde{H}^+$ weak decay modes (1)—(4) the simplest topology belongs to the mode (4). Note, that within the limits of errors $M_{\tilde{H}^+} = M_{K^-} + 2M_p$. Then the laboratory proton and K^--meson momenta are $p_p = M_p (\beta\gamma)_{\tilde{H}^+}$ and $p_{K^-} = M_{K^-} (\beta\gamma)_{\tilde{H}^+}$. The weak decay via this mode would look out as a narrow trident with the radius of curvature of the K^- trajectory in a magnetic field equal to $R_{K^-} = (M_{K^-}/M_p) R_p$.

Perhaps this decay mode is best suited for the counter experiments with live targets. But even in this case for an unambiguous identification of the $\tilde{H}^+$ one needs for either (1V—3C) or (2V—4C) kinematical analysis, depending on coordinates (the K^- momentum) of the K^- decay vertex. The search for H, $\tilde{H}^+$, $\tilde{H}$, $\tilde{H}^-$-dibaryons is in progress.

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