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THE DISCOVERY OF RESONANCES IN MULTIBARYON SYSTEMS.

Part 1.

The Hypercharge Selection Rule Governs the Hadronic Resonance Formation. Multibaryon Resonances are Ultra-High Density Superstrange Objects

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The Hypercharge Selection Rule Governs the Hadronic Resonance Formation. Multibaryon Resonances are Ultra-High Density Superstrange Objects

Шахбазян Б.А. **E1 - 11774**

Обнаружение резонансов в многобарионных системах. Часть 1. Правило отбора по гиперзаряду управляет процессами образования адронных резонансов. Многобарионные резонансы - сверхплотные, сверхстранные объекты

Исследуются свойства многобарионных резонансов, обнаруженных в столкновениях нейтронов со средним импульсом 7 ГэВ/с и π^--мезонов с импульсом 4 ГэВ/с с ядрами углерода в пропановой пузырьковой камере. Показано, что, благодаря найденному ранее правилу отбора по гиперзаряду ($Y \leq 1$), многобарионные резонансы являются сверхплотными, сверхстранными объектами. Высказывается гипотеза о том, что вплоть до некоторых значений плотностей ядра галактик и квазары могут представлять собой гигантские многобарионные или даже многогиперонные резонансы.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна 1978

Shahbazian B.A. **E1 - 11774**

The Discovery of Resonances in Multibaryon Systems. Part 1. The Hypercharge Selection Rule Governs the Hadronic Resonance Formation. Multibaryon Resonances are Ultra-High Density Superstrange Objects

The properties of multibaryon resonances discovered in the collisions of fast neutrons and negative pions with carbon nuclei at 7.0 and 4.0 GeV/c momenta, respectively, in the JINR propane bubble chamber have been investigated. It has been shown that due to the hypercharge selection rule ($Y \leq 1$) found earlier multibaryon resonances are ultra-high density superstrange objects. The hypothesis has been brought up: the central regions of galaxies and quasars up to certain densities are huge multibaryon or even multihyperon resonances.

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

Communication of the Joint Institute for Nuclear Research. Dubna 1978

The examination of the problem of multibaryon resonances and interactions (1956–1962) has led us to the question on the role played by the quantum numbers of hypercharge Y, baryon number B and strangeness S in strong interactions of hadrons. This question has entailed another one : whether these quantum numbers are of equal rights or possibly one of them plays a dominant role at least in one of the aspects of strong interactions. Then some of its characteristics could be degenerated over one or both of the remaining quantum numbers.

The program of research on the problem in question was formulated at the High Energy Laboratory, JINR, and its realization was started in 1962. We performed a search and investigation of these specific entities studying various final states formed in the collisions of 4.0 GeV/c negative pions and $\langle p_n \rangle = 7.0$ GeV/c neutrons with carbon nuclei in a propane bubble chamber.

Up to now the effective mass spectra of seventeen multi-baryon systems have been studied (Table 1), and only in three of them $\Lambda\Lambda$, Λp, $\Lambda\Lambda p$ we succeeded in finding resonance-like peaks.

Table 1

Y	Systems investigated			
0	$\Lambda\Lambda$			
1	Λp	$\Lambda\Lambda p$	$K^0\bar{K}^0 p$	
2	$\Lambda 2p$	Kp	$2p$	$\Lambda K^0 p$
3	$\Lambda 3p$	$K^0 2p$	$3p$	
4	$\Lambda 4p$	$K^0 3p$	$4p$	
5		$K^0 4p$	$5p$	
6			$6p$	

The results obtained earlier[1a-11], when studying the effective mass spectra of nine systems, have been now confirmed on seventeen effective mass spectra (Table 1) : resonance-like peaks reveal themselves in the effective mass spectra of only $Y \leqslant 1$ systems. But all $B = 0$ and $B = 1$ resonances known up to now satisfy this condition. These facts lead to the hyper-charge selection rule[1f-1j] : " The hypercharge of hadronic resonances cannot exceed one ".

This is a necessary condition for the existence of hadronic resonances. Let us stress that we mean the resonances the masses of which are far enough from the sum of masses of their decay products. It is obvious that due to this rule all di- and multi-baryon ($B > 2$) resonances must be of negative strangeness. The narrowness of these resonances means that they are single hadrons. This requires the geometrical volume of all hadrons, including multibaryon resonances, to be a universal constant. This means that at the same time multibaryon resonances ($B > 1$) are ultra-high density, strange ,or superstrange ($|S| > 1$) objects.

This hypercharge selection rule originates from the present experimental situation on multibaryon resonances and cannot be denied by the claims for discovery of diproton or other $Y = B = 2$ resonances periodically made by some authors. The data on this subject reported up to 1971 are collected in review[2]. The most recent results appeared in 1977[3]. All these claims refer to wide (100-300 MeV/c^2) bumps or sometimes even humps which are at least by an order of magnitude wider than the narrow peaks observed in the mentioned $Y \leqslant 1$ effective mass spectra. The inadequacy of the nonrelativistic models[4] as well as the inherent incompleteness of the phase shift analyses at high energies [5], used to suggest the existence of $S = 0$, $Y = 2$ dibaryon resonances, makes us , together with S. Minami[6], adopt the presence of significant peaks in effective mass spectra as the most reliable sign of resonance. Moreover, as an experimental indication of a genuine multibaryon resonance, i.e., of <u>a single multibaryon hadron state</u>, narrow significant peaks must be adopted which are sufficiently distant from the thresholds of the corresponding effective mass spectra. The above bumps and humps may be due either to kinematical effects or to hypothetical deeply- or quasi-bound dibaryon states in which each baryon preserves its individuality just as atoms do in molecules. Such dibaryon states, if they do exist at all, must be highly unstable and have no connection with genuine dibaryon resonances.

No indication of pp or np as well as other $Y > 1$ resonances have been found in a series of experiments/1,7-9/.

Thus, no violation of the hypercharge selection rule for the formation of hadron $Y \leq 1$ resonances has been observed up to now.

Instead of this, a number of experiments performed using various methods/10-18/ confirm the existence of Λp resonances at least.

The naive quark model has deprived multibaryon resonances ($B > 2$) of all rights of existence. Only since 1977 R.L. Jaffe /19/ and J.J. de Swart with their colleagues/20/ have shown that these systems not only may but also must exist, the masses of $\Lambda\Lambda$, Λp and $\Lambda\Lambda p$ resonance systems predicted being very close to those we measured as early as 1968 and 1970/1d,e/. They have been observed in the inclusive Λp, $\Lambda\Lambda$, $\Lambda\Lambda p$ effective mass spectra obtained in $n^{12}C$ and $\pi^{-12}C$ interactions at $\langle p_n \rangle = 7.0$ GeV/c and $p_{\pi^-} = 4.0$ GeV/c. Several J^P assignments are compatible with the Λp resonance in our experiment.

Table 2

Resonance	J^P	ℓ	M(MeV/c²)	(MeV/c²)	χ^2/n_D
Λp	1^+	0	2256.40±1.33	15.06±2.68	1.20
	2^+	1	2256.50±0.90	10.77±1.20	1.13
	3^+	2	2255.70±1.35	6.73±0.90	1.12
$\Lambda\Lambda$			2365.3±9.6	47.2±15.1	
$\Lambda\Lambda p$			3568.3±10.0	< 60	

The significance of these peaks has been considered earlier.

For the following it is important to clear up possible mechanisms of creation of these resonances. It has been already shown/11/ that adopting the Fermi gas model of the ^{12}C nucleus, the 2256 MeV/c² Λp resonance may be produced in the final state elastic scattering $\Lambda p \longrightarrow \Lambda p$. Though the effective cross section of its formation via this channel $\sigma_f(2256) = 5.3(2J_{\Lambda p}+1)$

mb/11/ can attain rather high values depending on the resonance spin $J_{\Lambda p}$, its production cross section via $n^{12}C$ interactions at $\langle p_n \rangle = 7.0$ GeV/c is only $\sigma_{pt}(2256) = (85.3 \pm 20.0)$ μb.

The 2365 MeV/c^2 $\Lambda\Lambda$-resonance in the frame of the same model may arise in final state inelastic hyperon-nucleon interactions : $\Lambda N \rightarrow \Lambda\Lambda K^{\pm}(m\pi)$, $\Sigma N \rightarrow \Lambda\Lambda K^{\pm}(m\pi)$, $\Xi N \rightarrow \Lambda\Lambda(m\pi)$, $m = 0, 1, 2, \ldots$, the lowest threshold momentum for incident lambdas being 2.6 GeV/c. The production of this resonance via $n^{12}C$ interactions at $\langle p_n \rangle = 7.0$ GeV/c proceeds with an effective cross section of $\sigma_{pt}(2365) = (24.2 \pm 7.0)$ μb.

Finally, the $\Lambda\Lambda p$ production effective cross section in $n^{12}C$ collisions at $\langle p_n \rangle = 7.0$ GeV/c is estimated to be $\sigma_{pt}(3568) = (16.1 \pm 5.2)$ μb. Thus, we can state that the Λp, $\Lambda\Lambda$ dibaryon and $\Lambda\Lambda p$ tribaryon resonance production effective cross sections via $n^{12}C$ collisions at $\langle p_n \rangle = 7.0$ GeV/c differ by less than one order of magnitude .

The Fermi gas model of nuclei cannot ensure the creation of multibaryon resonances with sensible probabilities. Hence a new mechanism should be suggested.

A relativistic particle (or a nucleus) at $cp \approx (8-10)$GeV/n penetrating at small impact parameters into a nucleus, even into a light one like ^{12}C, may produce a rather high compression of nuclear matter in a time interval about an order of magnitude shorter than the mean lifetime of a $\Gamma \sim 10$ MeV/c^2 wide multibaryon resonance. The compressed nuclear matter may become a source of secondary particles/21/. If the relativistic nuclear fluid dynamics/22/ were applicable to our case, then the maximal compression would achieve $n/n_0 = 14-18$, where n_0 is the normal nuclear matter density. This would be far enough for a partial hyperonization of the compressed nuclear matter providing thus a small number of dilambda states. Moreover, this possible mechanism could ensure di- and multibaryon, especially multihyperon, resonance formation. If multibaryon resonances could be formed via only two possible mechanisms : nuclear matter compression and final state hyperon-nucleon resonant interaction, then the possible three-baryon $\Lambda\Lambda p$ resonance would be formed only via the first one, predominantly in central collisions, whereas the Λp and $\Lambda\Lambda$ resonances could be formed via both mechanisms.

The occurrence of a definite mechanism for dibaryon resonance production should depend on the magnitude of the impact parameter occurred in the collision act.

The above remarkable proximity of the di- and tribaryon resonance production effective cross sections proves an important role of the compression mechanism. Most probably, multibaryon resonances ($B > 2$) can be created practically only via this mechanism.

Multibaryon resonances formed via the compression mechanism in light nuclei survive the ultra-high density short lifetime environment and decay if fast enough in free space or if slow in a rather rarefied nuclear matter without substantial rescattering of resonance decay products. Thus, multibaryon resonances produced in light nuclei are detectable. In the extreme case of very light nuclei such as deuteron or helium, this mechanism should be very improbable. Perhaps, this reason could explain the absence of the 2256 MeV/c^2 peak in the Λp spectra from the K^-d experiments/10-14/. In the controversial extreme case of heavy nuclei such as Br or Pt, the ultra-high density states could exist during the time intervals comparable to multibaryon mean lifetimes. On the other hand, in this case the dimensions of the compressed nuclear matter volume should be larger than in light (^{12}C) nuclei. These reasons result in heavy rescattering of resonance decay products smearing out the peaks in the Λp and $\Lambda\Lambda$ spectra from the heavy liquid bubble chamber experiment/23-25/ and the $\Lambda\Lambda$ peak from the K^-Pt experiment/26/.

The compression mechanism must not seem to be extremely fantastic because if the quark confinement and infrared slavery principles are valid, both a multiquark and a three-quark systems should be confined to a bag of the same volume. This means that a multibaryon resonance should be an ultra-high density and a strange or superstrange ($|S|>1$) entity at the same time. And the multibaryon resonance formation via the compression mechanism reduces to the phase transition of the normal density nuclear matter into the ultra-high density superstrange multibaryon hadronic matter revealing itself as a multibaryon resonance.

Thus, we state the following :

1. The formation of all hadronic resonances, including the

multibaryon ones, is governed by the hypercharge selection rule: "The hypercharge of hadronic resonances cannot exceed one($Y \leqslant 1$)". This rule governs the above phase transition also.

2. The narrowness of the discovered Λp, $\Lambda\Lambda$ and $\Lambda\Lambda p$ resonances is a direct experimental demonstratior that they are single multibaryon hadron states. But hadron states require the geometrical volume of all hadrons, including the multibaryon resonances ($B > 1$), to be a universal oonstant. The quark confinement , asymptotic freedom and infrared slavery concepts are the manifestations of this fact.

Thus, at the same time multibaryon resonances are ultra-high density, superstrange objects or states of hadronic matter.

The formation of ultra-high density states needs huge external pressures. Ultra-high density states can be formed in Nature in the central regions of galaxies and quasi-stellar objects. Enormous gravitational forces ensure high external pressures which are enough to initiate and maintain phase transitions of the nuclear matter into multibaryon resonant states. Thus, it is very probable that the central regions of these celestial objects are formed of huge multibaryon or even multihyperon resonances, the quasi-stationary states of which are possible up to certain values of the matter density.

The conclusion suggests itself that the hypothetical ultra-high density states of the protostellar matter,brought up by V.A. Ambartsumian/27/in connection with his cosmogonic concepts are identical with the huge multibaryon, even multihyperon, resonances which must be strange or even superstrange and of ultra-high density due to the hypercharge selection rule ($Y \leqslant 1$).

In terrestrial conditions, high pressures and compressions of the nulear matter can be attained bombarding nuclei with relativistic particles and nuclei. The droplets of ultra-high density hadron matter, multibaryon or multihyperon resonances thus obtained, can live at most 10^{-21}-10^{-20}sec in the absence of corresponding external pressures. Thus, the most direct way to detect ultra-high density states in laboratory conditions is the detection of multibaryon resonances. Other ways seem to be hopeless.

Thus, in our experiment, apart from the discovery of multibaryon resonances, we have succeeded in the observation of ultra-high density superstrange states of hadronic matter.

In conclusion we note that the exciting program of study of multibaryon resonances and ultra-high density superstrange states requires machines, accelerating heavy ions up to tens of GeV/n or even higher energies, because both the hyperon production effective cross sections and the hyperonization via the compression of the nuclear matter increase with the energy of bombarding projectiles.

References

1. B.A. Shahbazian et al., a) Proc. of the 13th Int.Conf. on High Energy Physics, Berkeley, 1966; b) Letters to JETP, 1967, 5, p. 307; JINR, P1-3169, Dubna, 1967; c) Proc. of the 14th Int.Conf. on High Energy Physics, 173, Vienna, 1968; JINR, E1-4022, Dubna, 1968; d) High Energy Physics and Nuclear Structure, 524, Plennum Press, N.-Y.-L., Sept. 8-12, 1968; JINR, E1-4584, Dubna, 1969; JINR, Annual Report, 1969; e) Proc. of the 15th Int.Conf. on High Energy Physics, 187, Kiev, 1970; JINR, Annual Report, 1970; f) Proc. of the Int. Conf. on Elementary Particles, Amsterdam, 1971 (N.H. Amsterdam, 1972); JINR, E1-5935; 1971, Proc. of the 4th Int.Conf. on High Energy Physics and Nuclear Structure, Dubna, 57, 1971; Comm. JINR, P1-6439, Dubna, 1972; g) Proc. of the 16th Int. Conf., 855, Batavia, 1972; JINR, E1-6704, Dubna, 1972; h) Nucl.Phys., 1973, B53, 19; i) Lett. Nuovo Cim., 1973, v.2, p. 63; j) YECHAYA, 1973, v. 4, vyp. 3, p. 811; k) JINR, E1-7669, Dubna, 1974; l) Proc. of the 18th Int.Conf. on High Energy Physics, C-35, July, 1976; JINR, E1-10037, 1976;
2. G.A. Leksin, ITEP-854, 1971.
3. T, Kamae et al., Phys.Rev.Lett., v. 38, 468, 1977 ; I.P. Auer et al., Phys.Lett., v. 67B, 113, 1977.

4. T. Kamae et al., Phys.Rev.Lett., v. 38, 471, 1977 ;
T. Ueda, Phys.Lett., v. 74B, 123, 1978.
5. H. Hidaka et al., Phys.Lett., v. 70B, 479, 1977.
6. S. Minami, Phys.Lett., v. 74B, 120, 1978.
7. A. Abdivaliev et al., JINR, P-11614, P-11615, P-11616, Dubna, 1978.
8. A.V. Arefiev et al., Yad.Fiz., v. 27, 716, 1978.
9. Yu.D. Bayukov et al., ITEP-103, 1976.
10. Tai Ho Tan, Phys.Rev.Lett., 1969, v. 23, 395.
11. D.T. Cline et al., Phys.Rev.Lett., 1968, v. 20, 1452.
12. W. Sims et al., Phys.Rev., 1971, v. 3D, 1162.
13. D. Eastwood et al., Phys.Rev., 1971, v. 3, 2603.
14. O. Braun et al., Nucl.Phys., B124, 1977, № 1, 45.
15. J. Kadyk et al., Nucl.Phys., B27, 13, 1971.
16. G. Alexander et al., Phys.Rev., 1968, v. 173, 1452.
17. B. Sechi-Zorn et al., Phys.Rev., 1968, v. 175, 1735.
18. J.M. Hauptmann et al., Nucl.Phys., B125 (1977) 29-51.
19. R.L. Jaffe, Phys.Rev.Lett., v. 38, No 5, 195.
20. A.Th. Aerts, P.J.G. Mulders and J.J. de Swart, Phys.Rev., D17, 260, 1978.
21. G.F. Chapline et al., Phys.Rev., 8D, 4302, 1973;
B.A. Shahbazian, P.P. Temnikov, A.A. Timonina, Nuclotron and Relativistic Nuclear Physics, 85, Dubna, 8309, 1974;
JINR, P1-8153, Dubna, 1974.
22. A.A. Amsden et al., LA-UR-31, 1977. Phys.Rev.17C, 2080,1978.
23. P. Beilliere et al., IIHE-76.9.
24. P. Beilliere et al., Phys.Lett., 39B, 1972, 671.
25. C. Wilquet, Phys.Lett., 57B, 1975, 97.
26. J.G. Guy, J. Kadyk, RL-77-054/A.
27. V.A. Ambartsumian, Observatory, v. 75, 72, 1955.

Received by Publishing Department
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Издательский отдел Объединенного института ядерных исследований.
Заказ 25257. Тираж 620. Уч.-изд. листов 0,6.
Редактор Э.В.Ивашкевич. Подписано к печати 29.8.78 г.
Корректор В.А.Халякина.