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THE NARROW LOW-MASS DIBARYONS AND THE POSSIBLE EXISTENCE OF A NEW STABLE BARYON

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The possible existence of a new stable baryon R (J = 1/2, I = 3/2, 1025 MeV) and its connection with the narrow low-mass dibaryons are discussed. Proposed is an experiment which can put in evidence the existence of an exotic baryon, R, as well as decide the isospin assignment for low-mass dibaryons (test for I = 2 assignment).

The investigation has been performed at the Laboratory of Nuclear Problems, JINR and the Nuclear Physics Institute, Leningrad (Gatchina).

Узкие дибарионы с низкой массой и возможность существования нового стабильного бариона

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Обсуждается возможность существования нового стабильного бариона R (J = 1/2, I = 3/2, M = 1025 МэВ) и его связь с узкими дибарионами с низкой массой. Предлагается эксперимент для выяснения возможности существования экзотического бариона R, а также для установления изоспина дибарионов с низкой массой (тест на изоспин I = 2).

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In a recent paper [1] a new mass formula has been proposed for multibaryons, as well as for baryons, which seems to be in good agreement with experimental observations. The model also predicts a new stable baryon state (a nucleon-like baryon) R - of mass $\simeq$ 1025 MeV, spin J = 1/2 but isospin I = 3/2.

An indirect indication of the existence of this new baryon state is provided by the cusp-like structure observed at $\sqrt{s} \simeq 2043$ MeV = $2 \cdot M_R$ in the $pp \to \pi^+ d$ reaction [1] (the threshold for $pp \to RR$ reaction). As was point out in ref. [2] in order to describe the invariant mass

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spectra $-m_{2p}$ from $p^4He \to nppd$ experiment /3/ in the framework of the OPE mechanism it is necessary that the off-shell $\pi^+ d \to pp$ amplitude has a structure at its threshold (or lower) energy which is not far from the $\pi d \to RN$ subthreshold branch point.

Some years ago the possible existence of a new nucleon state in one unitary multiplet with Σ (1475) was discussed in ref. /4/. The predicted mass of this nucleon state was in the range between 1100 (or even below the πN threshold) and 1390 MeV.

In the present work we shall discuss some consequences of the R existence, its connection with dibaryons and we shall propose some experimental tests for obtaining evidence of this new baryon state as well as decide the isospin assignment for low mass dibaryons.

First, if such stable state does exist, it has to contribute as a pole in the πN dispersion relation. Taking into account the present uncertainty in the real part of the πN forward scattering amplitude /5,6/ we estimate that this new pole can give contribution if $g^2_{\pi NR} \lesssim 0.03\, g^2_{\pi NN}$. The smallness of the πNR coupling constant is not unexpected because R cannot be a normal SU(6) state but rather an exotic one (a hybrid, for example).

Because the R is stable under the strong interaction ($M_R < M_N + M_\pi$) it can have electromagnetic as well as weak decay modes: $R^+ \to \gamma p$, $R^0 \to \gamma n$ with possible $\tau \sim 10^{-20}$ s, and $R \to Ne\nu$ with longer lifetimes.

One consequence of the existence of R is its connection with low-mass and narrow dibaryon resonances.

In the last few years there is a surprisingly large number of papers which claim to have found narrow dibaryon states. Below the NΔ threshold these states are grouped around the following mass values: 1905±5, 1935±10, 1965±10, 2015±10 and 2035±10 MeV.

The "errors" shown above in fact reflect the dimension of the mass "island" within which different authors claim to have observed the narrow structure in the pp invariant mass. Following A.M.Baldin and A.B.Kaidalov, these very narrow dibaryon resonances can be states with I = 2 decaying into pp or ppγ via electromagnetic interactions /7/.

The NR threshold is $\sqrt{s}$ = 1965 MeV and a natural hypotheses is to consider $B_2(1965)$ and the lower states as possible NR bound states, i.e., a deuteron like structures. With such a hypothesis, the I = 2 assignment /7/ for these dibaryons is readily understood. Another consequence of this hypothesis is the stability of these dibaryons. At least, the $B_2(1935)$ and if it indeed exists - $B_2(1905)$ should be stable under strong interaction and so electromagnetic as well as weak decay modes should be observed.

In ref.[7] are shown the momentum spectra of γ as well as the effective mass distribution of $pp\gamma$ from $\pi^{-12}C$ interactions at p_π = 40 GeV/c. In the γ spectrum there are two peaks - one at $\simeq$ 25 MeV/c and another asymmetrical one at $\simeq$ 70 MeV/c. The $pp\gamma$ mass distribution shows a clear peak at M $\simeq$ 1936 MeV. The authors of this ref.[7] claim that the peak observed at $\simeq$ 25 MeV/c in the γ spectrum is due to the electromagnetic decays $B_2(1936) \to pp\gamma$ ($E_\gamma \simeq$ $\simeq$ 28.8 MeV) and $B_2(1965) \to pp\gamma$ (E_γ = 44.5 MeV). The peak at 70 MeV/c is clearly due to the π^0 decay.

Here we can reformulate the hypothesis and say that $B_2(1965)$ is indeed a I = 2 dibaryon state but represents a deuteron-like state of nucleon on R. The other dibaryon state can be a I = 1 or I = 2 state, and the decay scheme of these dibaryons can be as shown in Fig.1.

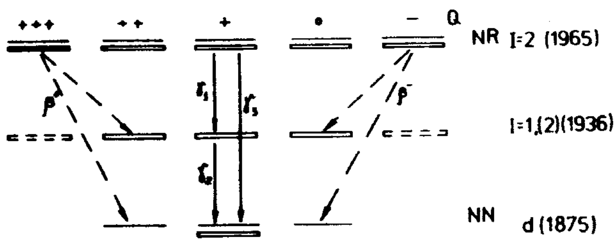


Fig.1

The γ spectrum in our hypothesis should show lines at $E_{\gamma 1} \simeq 30$, $E_{\gamma 2} \simeq 60$ MeV, $E_{\gamma 3}$ = 90 MeV (easily induced in the π^0 decay line) as well as E_γ = 85 MeV from the direct $R^0_+ \to \gamma N$ decay. These lines do not contradict the spectrum shown in ref.[7].

Here we also must notice that the deuteron-like hypotheses for B_2 (1965) fits the "rotational mass formula"[8,9] $M = M_0 + M_1 J(J+1)$. In ref.[10] on empirical relation is given between M_0 and M_1 established for strange and non-strange dibaryons: $M_0 / M_1 = 185.5 - 3.8 M_1$. Using this equation we can find the first two trajectories for the narrow low-mass dibaryons including the deuteron as well

J = 1	J = 2	J = 3
1875 (deuteron)	1931	2015
1905	1965	2048

Therefore, the most probable assignment for B_2 (1965) is J = 2, I = 2 and for B_2 (1935) J = 2 and I = 1 or I = 2.

In order to test this hypothesis as well as the existence of the new stable baryon state R (1025) we propose a simple and efficient experiment, i.e., the study of the inclusive π^- production in proton-proton collisions: $pp \to \pi^- + X$. Here X can be pR^{++} as well as a dibaryon resonance with I = 2 (B_2^{+++}). It is necessary to examine the momentum spectra of π^- in those regions where the phase space distribution for π^- from $pp \to \pi^-\pi^+ pp$ is already zero. For example, at $T_p \simeq 1$ GeV, the π^- momentum spectra from $\pi^+\pi^-$ production ($\theta_\pi = 0^0$) is ended at $p_\pi \simeq$ $\simeq 0.5$ GeV/c. If R exists, the reaction $pp \to \pi^- pR^{++}$ will extend the phase space available for π^- up to $p_\pi \simeq 0.62$ GeV/c. In Fig.2 shown are the pion momentum spectra for different R production in pp interaction. The calculations were done in a simple OPE model similar to $pp \to \pi NN$ calculations /11/. In Fig.3 shown are, as an example, the diagrams used for $pp \to \pi^- pR^{++}$ calculations. The coupling constant at the R vertex was taken to be $g^2_{\pi NR} = 0.03\, g^2_{\pi NN}$ given as an upper bound from the dispersion relations. For the R^{++} production the maximum cross section in the π^- momentum spectrum is $\simeq 0.04$ μb in the region between 0.5 and 0.6 GeV/c.

In Fig.4 shown is the energy dependence for the total cross section of $pp \to \pi^- pR^{++}$ reaction. At $T_p \simeq 1$ GeV the cross sections is $\sigma \simeq 20$ μb.

In Fig.5 shown is the end of the spectrum for $T_p \simeq$ $\simeq 1$ GeV, $pp \to \pi^- + X$ at $\theta_\pi = 0^0$. Experimental points are taken from ref. /11/. The curves show the π^- spectrum from $pp \to \pi^+\pi^- pp$ (dashed line), the π^- spectrum from $pp \to \pi^- pR^{++}$ (dashed-dotted line), their sum (solid line) as well as the possible peak due to B_2^{+++} (1965) of the I = 2 hypothesis holds (dotted line). The arrow points to the momentum corresponding to the second dibaryon resonance (if I = 2). The peaks of B_2(1965) and B_2(1935) at the end of the π^- momentum spectrum should not depend on its stability under strong interaction and should exist only, if I = 2.

The situation is very similar to the inclusive reaction $pp \to \pi^+ + X$, where the bound up state - the deuteron, is seen at the end of the π^+ spectrum as a very narrow peak (see Fig.6).

In order to put in evidence this effect of the spectrum extension to $p_\pi \simeq 0.6$ GeV/c and eventually the peak due to I = 2 dibaryon resonances the experimental error must not exceed 0.01 μb.

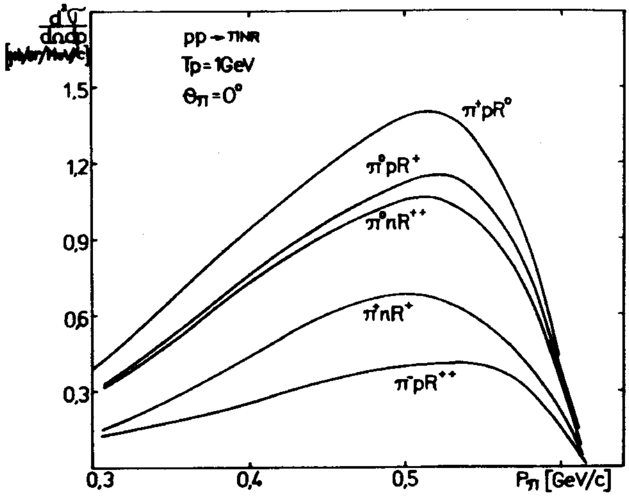
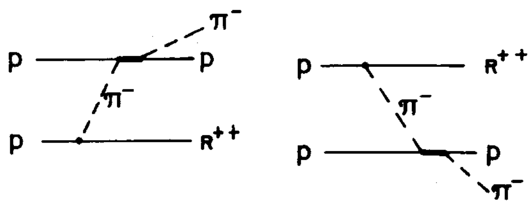


Fig.2

Fig.3



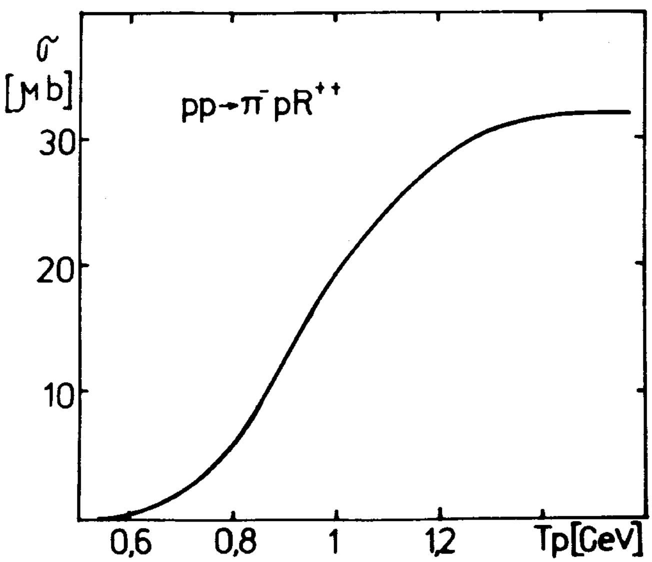


Fig.4

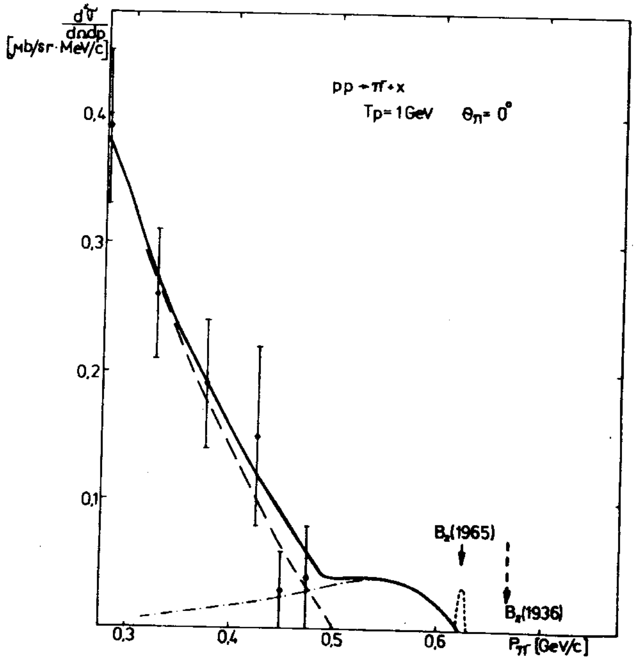

pp → π⁺ + x
Tp = 1 GeV θπ = 0°
B₂(1965)
B₂(1936)
0,4
0,3
0,2
0,1
0,3
0,4
0,5
0,6
Pπ [GeV/c]

Fig.5

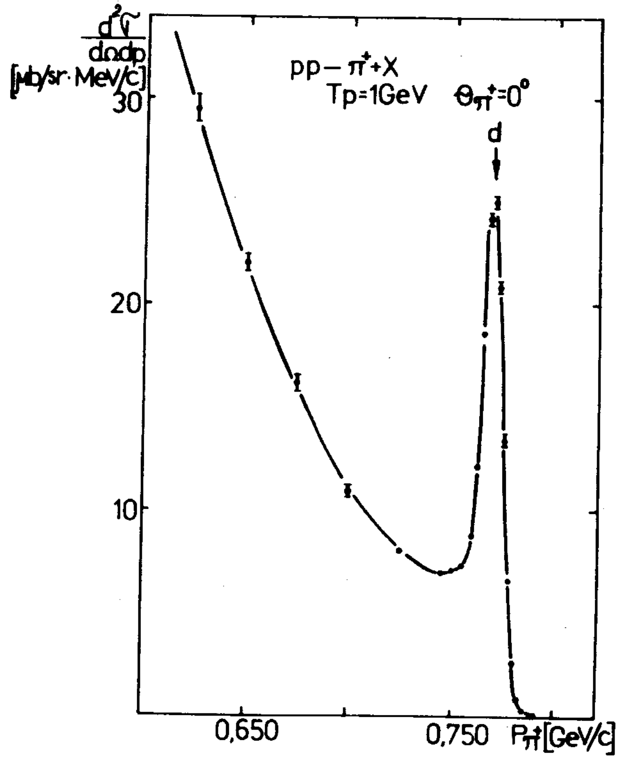

pp — π⁺ + X
Tp = 1GeV θπ⁺ = 0°
d
30
20
10
0,650
0,750
Pπ⁺ [GeV/c]

Fig.6

An interesting consequence of the R existence is the non-zero (otherwise very small) cross section for the elementary double charge exchange reactions $\pi^- p \to \pi^+ R^-$, $\pi^+ n \to \pi^- R^{++}$,which can be used for searching for the R. Inspecting the literature [13] we can see that no evidence exist for a R signal in a double charge exchange reaction on different nuclei. If R production is dominated by a one pole diagram we can expect that the R production cross section by pions should be lower by one or two orders of magnitude than the corresponding R production cross section in nucleon-nucleon interaction.

A direct evidence for R can be obtained from $np \to R^- + X$ at small angles. (The cross section is drastically reduced when θ is increased). In an experiment [13] a search was made for negatively charged stable objects arising from 590 MeV proton beryllium collisions. No signal was found for any lifetime bigger than 26 ns. The R could not be seen even if it existed because, on the one hand, the small proton energy and the large angle at which negative particles were looked for result in a very small cross section and, on the other hand, owing to the cut in the mass, i.e., the negatively stable particles were assumed to have the configuration $\pi^- n^N$ with $N \geq 2$.

Another reaction which can be used in order to put in evidence the existence of such an exotic stable baryon, as well as the possible I = 2 dibaryons, is the double π^- production below the 3π production $np \to \pi^- \pi^- X^{+++}$, where $X^{+++} = pR^{++}$ or B_2^{+++} . The optimum energy for such an experiment is $T_n = 930$ MeV.

A direct evidence for R state can also be obtained in "nucleon-nucleon charge exchange": $pp \to nR^{++}$ at low energy, i.e., up to one pion production. Neutron detection or/and positron detection should be an unambiguously indication of such an exotic R production.

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