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M.P. Combes, Y. Le Bornec, E. Loireleux, B. Tatischeff and N. Willis

Institut de Physique Nucléaire, Orsay, B.P. n° 1, 91406 Orsay Cedex, France

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Institut de Physique Nucléaire, Orsay, B.P. n° 1,
91406 Orsay Cedex, France

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Institut de Physique Nucléaire, Orsay, B.P. n° 1, 91406
Orsay Cedex, France

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Abstract

The experimental situation concerning the hunting of narrow non strange dibaryons is presented and discussed. These have not been firmly observed, up to now, in isospin T = 0 and T = 2 channels, contrary to the situation in T = 1 channel where the existence of such dibaryons is now experimentally well established.

Résumé

Nous présentons et discutons la situation expérimentale concernant la recherche de dibaryons étroits non étranges. Ceux-ci n'ont pas été observés avec certitude dans les cas d'isospin T = 0 ou T = 2. Dans le cas où T = 1, la mise en évidence de dibaryons étroits est claire.

Introduction

There is presently a rather good understanding of the measured data in Intermediate Energy Nuclear Physics, especially when few body systems are involved[1]. This overall situation leaves however some discrepancies or difficulties not yet clàrified. It is not the room here to discuss these problems, let us just recall the short part of NN potential, described by phenomenological interactions[2] instead of particle exchanges. When the interaction distances are smaller than 0.5 fm or when the transfer momenta are larger than 1 GeV/c, it is well founded to think about precursor quark deconfinement. The main question then is to be able to disentangle these possible effects from complicated graphs of baryons and mesons in interaction.

The best signatures of such deconfinement should be, experimental evidences for exotic mesons[3] as glueballs, hybrids or diquonias, as baryonia, evidences for stable heavy exotic baryons[4] ($qqqq\bar{Q}$), or evidences for narrow dibaryons since these are not present in conventional nuclear physics. By narrow dibaryons we mean dibaryons with FWHM less than 20 MeV in order to avoid possible Δ-N interaction states. In order to avoid possible cusp effects we want also dibaryon invariant masses different from masses of two nucleons plus one, two or three pions. The discussion will be confined to non strange resonances.

Experimental results

There have been a lot of experimental data devoted to the study of narrow structures in two proton (two proton plus pion(s)) invariant masses or to the study of missing mass spectra of two baryons. These data have been discussed in review articles[5]. Only those which are recent, precise and published will be presented here.

B = 2, T = 0 dibaryons

The finding of isoscalar dibaryons would be important for several reasons. The isospin will forbid any explanation in terms of ΔN interaction. A recent theoretical study of Goldman et al.[6] has shown that "*a six quark state with* $IJ^P = 03^+$ *is bound relative to* Δ-Δ *threshold in any QCD model* *that incorporates confinement and the hyperfine color magnetic interaction".*

The experimental situation is rather poor since it is not easy to extract the $np \to pp\pi^-$ ($T = 0$) cross section from $dp \to ppp\pi^-$ measurement[7]. The only data in a pure $T = 0$ channel have been provided by our measurements of missing mass spectra in $dd \to dX$ experiment studied[8] at Saturne some years ago (see Fig. 1). No clear structure has been extracted from these data, with a production upper limit of $d\sigma/dt \leq 0.03$ pb/MeV².

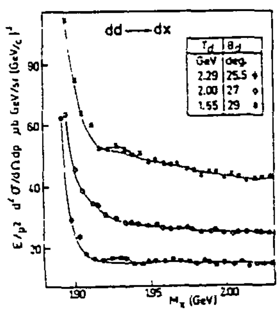


Fig. 1 : Missing mass spectra for isoscalar dibaryon search (Saturne data, Ref. 8).

B = 2, T = 1 dibaryons

The most precise missing mass spectra have been obtained by us at Saturne using $p\,^3He \to dX$ reactions at different angles and incident energies[9]. The last and most precise data are shown in Fig. 2. The statistical errors here are included into full circles. The curves correspond to polynomial only and polynomial + gaussian fits. The experimental situation appears clearly from this figure : the peak over background ratio is small (see the enhancement in vertical scale). Very precise measurements are needed. In the data shown, $\Delta\sigma/\sigma = \pm\ 0.7$ %. This explains why in our previous measurements we have not been able to observe some structures in some cases. Fig. 3 shows our old results (full squares) and those corresponding to Fig. 2 (full circles). The values obtained for masses (FWHM) of the observed narrow structures, and the corresponding number of standard deviations (SD) are (in MeV) :

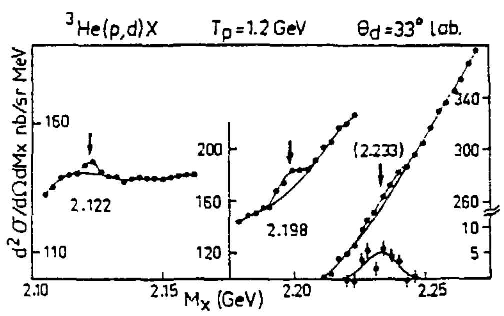


Fig. 2 : Missing mass spectra at T_p = 1.2 GeV, θd = 33°, binned into 3 MeV intervals (Saturne data, Ref. 9).

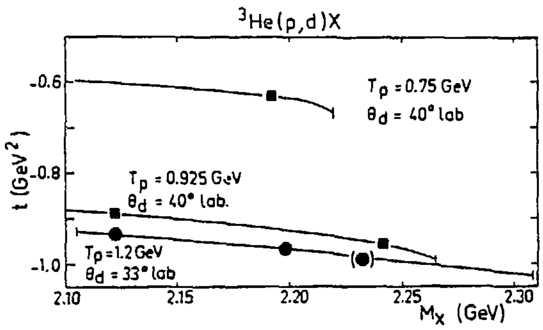


Fig. 3 : Masses of the narrow structures observed in different experimental conditions. The lines correspond to the missing mass range studied (Saturne data, Ref. 9).

masses *FWHM* *S.D.*

- 1969 ± 2(9 ± 2) S.D. = 3. However no structure has been observed in a precise spectrum of p^{3}He → dX at T_p = 750 MeV and θ_d = 40°.
- 2122 ± 1(5 ± 1) S.D. = 3.8
- 2198 ± 1(8 ± 1) S.D. = 7.7
- 2233 ± 2(13 ± 3) S.D. = 3.7

Below the pion threshold (M < 2015 MeV = 2 M_N + M_π) the experimental situation is very confused. There is a lot of structures, observed in two proton invariant masses using bubble chamber slides, by many groups (the references are quoted in Ref. 5), with usually poor statistics. The salient feature is the spread of masses making any conclusion premature. Above the pion threshold the masses concentrate around fixed values as will be seen later (Fig. 6). The last published result is from LAMPF where the analyzing power data from the same reaction p^{3}He → dX at T_p = 800 MeV, θ_d = 22° show peaks for the same masses (see Fig. 4). Moreover by using a rotational like mass formula, we have predicted that other dibaryons should exist[11] (see later). Peaks indeed have been observed also at the predicted masses in the analyzing power.

B = 2, T = 2 dibaryons

There have been many experiments in this channel, since if such dibaryon exist with a mass lower than 2 M_N + M_π, it will be bound by strong and electromagnetic interactions, consequently will be very narrow and could be detected (as is the pion). These experiments are summarized in Ref. 5.

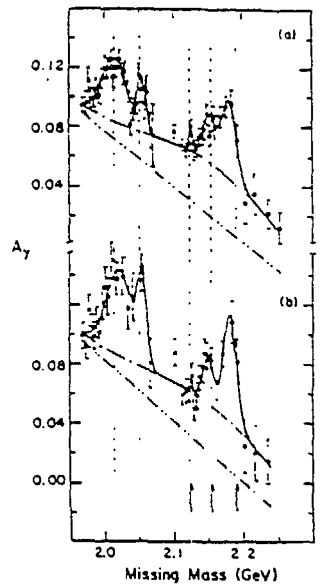


Fig. 4 : Analyzing power from $p^3He \to dX$ reaction before (a) and after (b) empty target subtraction. (Data from Lampf, Ref. 10). The arrows correspond to masses where structures have been observed at Saturne, and dotted lines correspond to predictions from Ref. 11.

Very small upper limits for $(\pi^-)^Z n^N$ bound states ($1 \leq Z \leq 2$; $2 \leq N \leq 6$) have been found by de Boer et al.[12] at SIN from $1.5 \cdot 10^{-1}$ to $6.1 \cdot 10^{-7}$ nb/sr (MeV/c)). Recently, by studying $\pi^{\pm} d \to \pi^{\mp} X$ reactions at Lampf, Ashery et al.[13] have observed weakly excited with only small confidence level structures, close to 2002 MeV. These structures seem to disappear in more recent and unpublished data[13]. The same states have been looked for at Saturne using $\vec{p}p \to \pi^- X$ reaction, and the data at 1.45 GeV incident proton beam just completed[14]. No structure has been observed -see Fig. 5 -with an upper limit of $d\sigma/d\Omega \cong 8$ nb/sr. Another experiment performed at Triumf had looked for 15-30 MeV photons from radiative capture of π^- in atomic orbital around deuterium[15]. Although this experiment has been forecast as being feasible theoretically[16] (production of atomic πNN states and signature of nuclear bound πNN system through γ detection), the upper limit of the branching ratio measured at Triumf $(1 - 6) \times 10^{-4}$ rules out the most probable calcu-

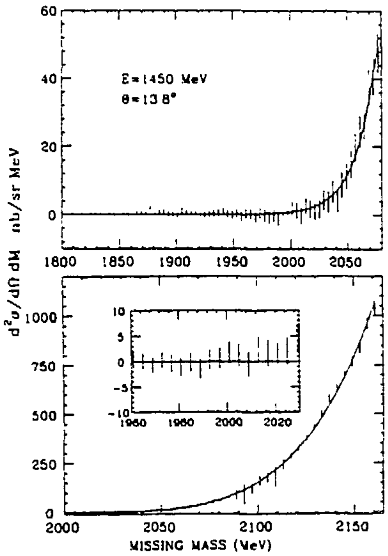


Fig. 5 : Differential cross section for pp → π^-X reaction (Saturne data, Ref. 14).

lated configurations ($J^\pi = 0^-$). It appears that the existence of isospin 2 dibaryons is not presently reliable. If these states exist with a mass larger than 2.015 GeV, among the different experiments quoted, only that from Saturne ($\vec{p}p \to \pi^- X$) will be able to observe an eventual bump in the missing mass spectra. Fig. 5 shows that this is not the case up to M_x = 2.15 GeV, with an upper limit for the production cross section (at $M_x \cong$ 2.15 GeV) of 70 nb/sr for a 3 σ deviation. There is no structure neither in the analyzing power data[14].

Discussion

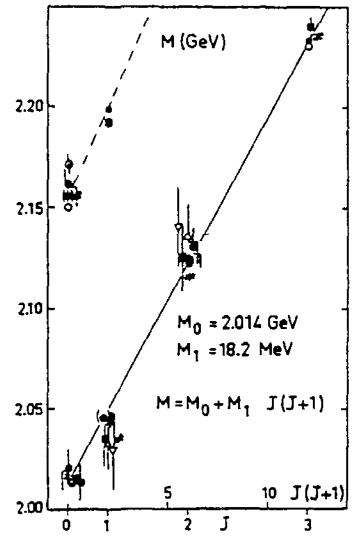
In the T = 1 sector, above π production threshold, the masses of all the narrow dibaryons found, as shown in Fig. 6 :

- concentrate around some defined values,
- can be displayed using a rotational like mass formula $M = M_0 + M_1\, J(J+1)$[11].

Such mass formula has been predicted within a quasi molecular model of two nucleons and a pion[17]. Since the structures appear at the same masses in missing mass experiments (as ours) as in two proton invariant mass experiments an explanation of this quasi molecular type can be ruled out.

This mass formula appears also from MIT bag model[18] of six quarks in a spherical bag with values for M_0 and M_1 close to those extracted from experiment (within 10 %). The cloudy bag model predict larger masses and widths than those observed experimentally[19]. Calculated masses and widths are much closer in a semiphenomenological diquark model[20] but after adjustment of some free parameters. Streched rotating bag model, with

Fig. 6 : Display of T = 1 dibaryons versus a J(J + 1) mass formula. The references of data are quoted in Ref. 5 and 9.



two coloured clusters of four and two quarks at both ends, predict[21] several dibaryons with low masses (in the same range where isovectorial dibaryons have been experimentally observed).

The different theoretical studies based on quark models give different predictions for properties of such narrow dibaryons. There is no calculation predicting them in the framework of conventional baryon-meson dynamic[22]. The experimental data are reasonably reliable, for isovectoriel dibaryons with masses larger than 2 M_N + M_π. In other channels (masses lower than 2 M_N + M_π in isospin T = 1 sector, but also T = 0 and T = 2 channels) the experimental results are up to now not conclusive. No firm candidate was observed.

When positively extracted from data, the structures correspond always to small peak over background ratio, requiring very precise measurements. Even then in some such data no structure could be extracted (see Ref. 5 and 9 for more complete discussion). At Saturne, the experiments have been performed using not too large incident energies (1-2 GeV). However the center of mass momenta transfered where usually larger than 1 GeV/c. It is clear that due to the form factor, any increase of energy corresponds to a decrease of cross sections (peak and background). These values of energy and transfered momenta are lower than what is usually considered to be necessary to observe quark degrees of freedom. However since there is no alternative explanation we can speculate on the assignement of the observed narrow structures to possible partial precursor quark deconfinement at intermediate energy nuclear physics.

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