Search for Low Mass Exotic mesonic structures. Part I: experimental results

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Recently, several papers discussed on the existence of a low mass new structure at a mass close to M=214.3 MeV. It was suggested that the Σ^+ disintegration: $\Sigma^+ \to pP^0$, $P^0 \to \mu^-\mu^+$ proceeds through an intermediate particle P^0 having such mass. The present work intends to look at other new or available data, in order to observe the eventual existence of small narrow peaks or shoulders in very low mesonic masses. Indeed narrow structures were already extracted from various data in dibaryons, baryons and mesons (at larger masses that those studied here).

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I. INTRODUCTION

The Σ^+ disintegration: $\Sigma^+ \to pP^0$, $P^0 \to \mu^-\mu^+$ was studied at Fermilab by H. Park *et al.* [1]. The data were taken by the HyperCP (E871) Collaboration. The authors observed a narrow range of dimuon masses, and supposed that the decay may proceed via a neutral intermediate state P_0, with a mass M=214.3 MeV $\pm$ 0.5 MeV.

Several theoretical works were done assuming the existence of this new particle. He, Tandean, and Valencia performed a standard-model interpretation of the data [2]. Later on the same authors demonstrate that the new particle could be a pseudoscalar or axial-vector, but not scalar nor vector [3]. They also suggested that the particle could be a very light pseudoscaler Higgs [4]. Deshpande *et al.* [5] assume a fundamental spin zero boson, which couple to quarks with flavor changing transition $s \to d\mu^+\mu^-$. They estimate the scalar and pseudoscalar coupling constants and evaluate several branching ratios. Geng and Hsiao [6] found that the P^0 cannot be scalar but pseudoscalar, and determine that the decay width should be as small as $\approx 10^{-7}$MeV. Gorbunav and Rubakov [7] discuss possible sgoldstino interpretation of this possible particle.

The experimental observation was based on three events. We anticipate that this low counting is due to their observation in a weak disintegration channel. In order to eventually strengthen this result by a direct observation, we look at already existing data and try to observe a possible signature of (a) small peak(s), or (a) small shoulder(s), (at a mass not far from the mass of P^0). Such mass(es) can be observed, either in the invariant masses of two muons, $M_{\mu\mu}$, or in missing masses of different reactions, studied with incident leptons as well as with incident hadrons. However the signal, if any, is expected to be small. The spectra are therefore presented in the semi-log scale. The signals will be superposed to a relatively large tail of one pion missing mass. Therefore the signal, if any, can only be observed in precise data, with large statistics, good resolution and small binning. Moreover, the mass range studied must be small. Such data are scarce and concern reactions studied at rather low incident energies, with good resolution. When we found a hint for a small effect, we read out and reanalyzed the data. Several such structures were selected and presented below.

II. SELECTED DATA SHOWING SMALL STRUCTURES IN THE MASS RANGE ABOVE THE PION MASS

A. The missing mass of the pp→ppX reaction

The pp→ppX reaction was studied at Saturne (SPES3 beam line), at T_p=1520, 1805, and 2100 MeV [8]. The missing mass displays a broad structure, in the mass range 280≤M≤580 MeV, unstable for different kinematical conditions and slightly oscillating [9], previously called the ABC effect; it was analysed as being due to a superposition of four narrow mesonic states: M=310 MeV, 350 MeV, 430 MeV, and 495 MeV [9]. Above the η mass, narrow mesonic structures were extracted at the following masses: M=550, 588, 608, 647, 681, 700, 715, and 750 MeV [10].

Since the widths of the missing mass peaks increase for increasing spectrometer angles, we keep only the three lowest angle spectra at T_p=1520 MeV, add them, and show the resulting spectra in Fig. 1(a). The high counting rate allows to extract a clear peak at M_X=216.5 MeV.

The reaction pp→pp$\pi^0\pi^0$ was studied close to threshold at Celsius [11]. The missing mass data, after integration over two channels, are shown in Fig. 1(b). The two π^0 phase space starts at $M_X \approx$240 MeV. The events in the range 170 $\leq M_X \leq$ 240 MeV, are mostly physical as the background contribution is estimated to less than 10 events/channel. These data are fitted with a π^0 peak and two small structures, having the same shape as the π^0 peak, are extracted at M_X=182 and 220 MeV.

The pp→ppX reaction was also studied at Jülich COSY-TOF [12]. Both protons in the final state were detected in order to study the η production. The data were read and shown in Fig. 1(c). Since they are given in the original work as a function of the missing mass squared with constant binning (ΔM_X=0.002 GeV^2), they are plotted versus M_X as given, up to 210 MeV (empty circles), and for larger missing mass they are integrated over two channels (full circles). The peak corresponding to π^0 missing mass is fitted by a gaussian, at M_X=135 MeV (σ=67 MeV), and the data at larger missing mass are fitted with a polynomial. Two structures can be extracted, the first one at M=197 MeV, not valid statistically, and the second at M=224 MeV. They are very narrow, therefore, if fitted by only one structure, which includes both narrow structures, they result in a broad gaussian centered at M=214 MeV (dashed curve in Fig 1(c))

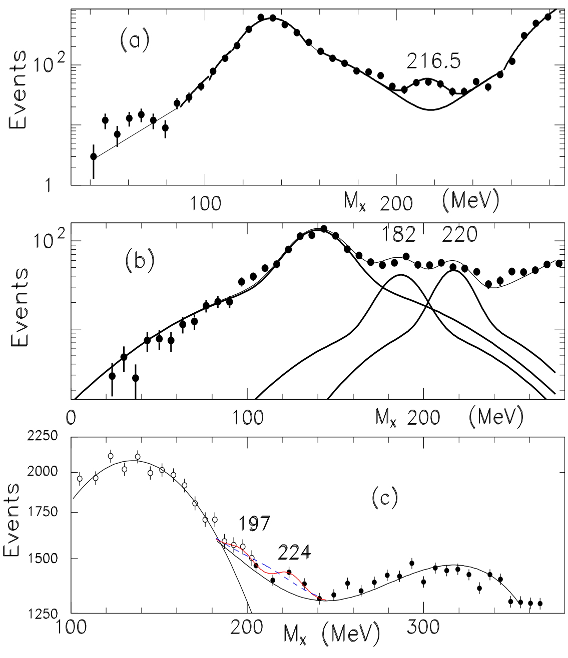

FIG. 1: Insert (a): missing mass of the pp→ppX reaction measured at Saturne (SPES3 beam line) at T_p=1520 MeV. Three spectra measured at θ_{pp}=0^0, 2^0, and 5^0, are added. Insert (b): same reaction measured at Celsius [11]. Insert (c): Missing mass of the pp→ppX reaction studied at Jülich COSY-TOF [12].

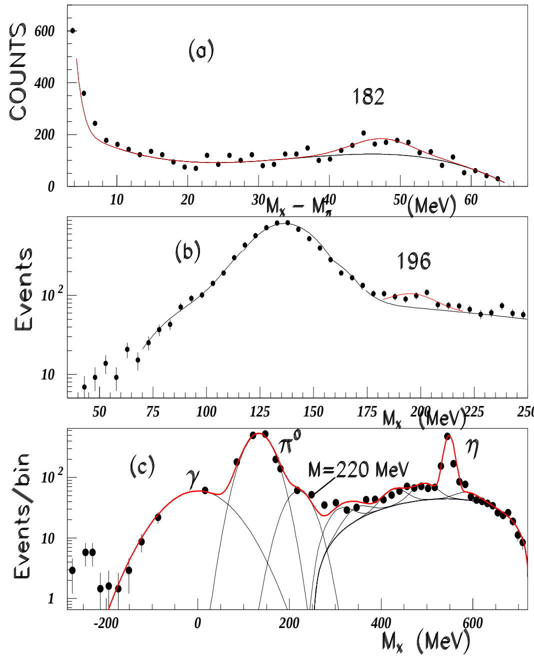

FIG. 2: Insert (a): π^0 electroproduction at threshold, measured at MAMI [13]. The missing mass spectra is integrated over 4 channels. Insert (b): missing mass of the p($\vec{e},e'\vec{p}$)π^0 reaction studied at JLAB Hall A at θ_{cm}=90^0 [14]. Insert (c): missing mass of the p(e,e'p)X reaction measured at JLAB Hall C [15].

B. The missing mass of the ep→e'pX reaction

The π^0 electroproduction at threshold for Q^2=0.05 GeV^2 was measured at MAMI [13]. The missing mass spectrum, up to M_X=200 MeV is given in Fig. 3(b) of [13], after background subtraction. The data are read, integrated over 4 channels and reported in Fig. 2(a). A peak at M_X=182 MeV is clearly observed. Indeed, the resolution in these data is as good as FWHM=2.2 MeV, as given in the π^0 peak (removed here to enhance the mass range discussed). The increase of the number of events between 48$\leq M_X$ - M_π $\leq$56 MeV is physical. The contribution from two pion production, cannot be large at a so low mass value as M=180 MeV.

The Roper resonance was studied at JLAB Hall A using the p($\vec{e},e'\vec{p}$)π^0 reaction [14]. Two missing mass spectra were given at θ_{cm}=90^0 and θ_{cm}=-90^0. No shoulder is observed in this last spectra. The values of the spectra at θ_{cm}=90^0 are read and shifted in order to put the π^0 peak at his right mass, namely at M_X=135 MeV. Fig. 2(b) shows this spectrum fitted with a gaussian and two polynomials. A small enhancement is observed at M_X=196 MeV.

The π^0 electroproduction on the proton was studied in Hall C at JLAB [15], in the region of the Δ(1232) resonance via the p(e,e'p)π^0 reaction. The authors give in

Fig. 1 of Ref. [15] an example of missing mass distribution for the reaction p(e,e'p)X. These data are read and reported in Fig. 2(c). The widths of all π^0 and η peaks are related to their masses (proportional to 1/M). These widths define the width of the small peak extracted at M=220 MeV. Several other peaks are introduced, following the results of the pp→ppX reaction studied at SPES3 (Saturne) [9]. After introduction of an arbitrary two-pion phase space, a contribution of the p(e,e'p)γ reaction is observed around M_X=0. More detailed data from

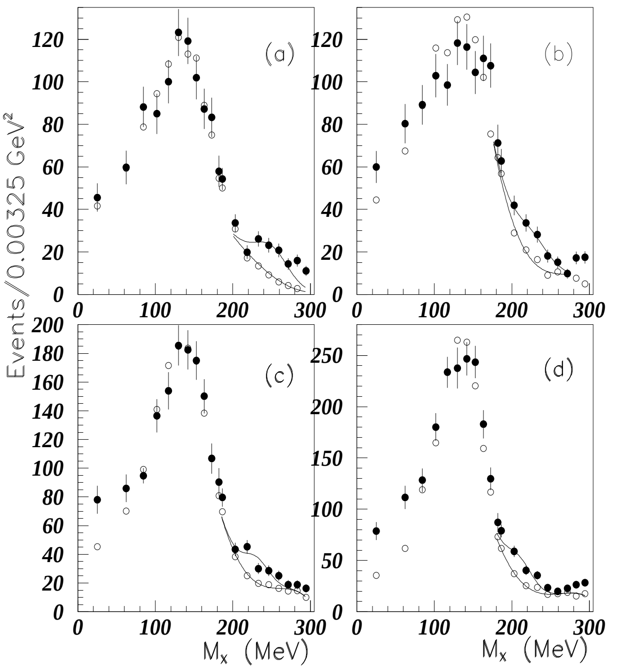

FIG. 3: The missing mass of the p(e,e'p)X reaction [16] studied at JLAB Hall C at Q^2=4.0 GeV^2. The empty circles correspond to Monte-Carlo simulations; the full circles correspond to data. Inserts (a), (b), (c), and (d) correspond respectively to p_p^0=2 GeV and θ_p^0=23^0, p_p^0=2 GeV and θ_p^0=20^0, p_p^0=2.2 GeV and θ_p^0=17^0, and p_p^0=2.45 GeV and θ_p^0=17^0.

the same experiment [16], are reported in several spectra where structures can be extracted in the same missing mass range. The measurements were performed for two values of the four momentum transfer squared between the initial and the final electron, namely at Q^2=2.8 GeV^2 and Q^2=4 GeV^2. The measurements were performed for a few values of P_p^0 and a few values of θ_p^0. Four spectra are shown in Fig. 3 for Q^2=4 GeV^2. Fig. 4 shows another selection of spectra corresponding to Q^2=2.8 GeV^2. In both figures empty circles correspond to Monte-Carlo simulations [16] and full circles correspond to data. In the missing mass range studied here an excess of counts can be seen between data and the simulation which were fitted by a polynomial. The quantitative informations are given in Table I. The discrepancy between data and simulation for $M_X \leq 60$ MeV has been attributed to the Bethe-Heitler process (ep→e'p'γ reaction).

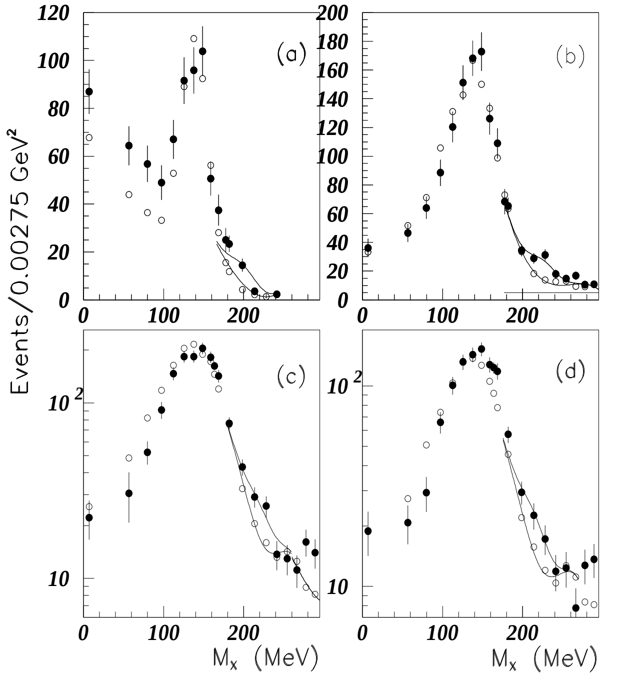

FIG. 4: The missing mass of the p(e,e'p)X reaction [16] studied at JLAB Hall C at Q^2=2.8 GeV^2. The empty circles correspond to Monte-Carlo simulations; the full circles correspond to data. Inserts (a), (b), (c), and (d) correspond respectively to p_p^0=1.9 GeV and θ_p^0=33^0, p_p^0=1.55 GeV and θ_p^0=23^0, p_p^0=1.7 GeV and θ_p^0=19^0, and p_p^0=1.7 GeV and θ_p^0=23^0.

C. Discussion

We have looked at some existing data, in order to find evidence for the existence of a new boson. All spectra shown here, display a structure, but at slightly different masses. However, there is an indication of a possible regrouping around several mass values. The statistics is too low for giving an evidence if the results privilege one unstable mass or a few better defined masses. We increase therefore the number of spectra studied, as those shown in Figs 3 and 4. These spectra are not shown here. The corresponding quantitative informations are summarized in Table I. They favor a regrouping into several values; the same conclusion is favored by the existence of more than one peak in the same spectrum, as in Fig. 1(b). In summary these narrow structures masses (see Fig. 5), are tentatively observed at:
M=181±2 MeV (5 events),
M=198±2 MeV (5 events),
M=215±5 MeV (12 events),
M=227.5±2.5 MeV (5 events),
M=235±1 MeV (3 events).

We notice that the range exhibiting the largest number of experimental mass structures, namely M=215 MeV, agrees with the value extracted at Fermilab: M=214.3 MeV [1]. There is also an addition-

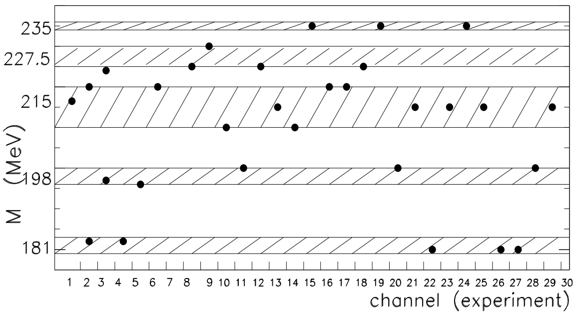

FIG. 5: Masses of the weakly excited structures extracted from several experiments (see text and table I).

nal but qualitative evidence in favour of a structure at M≈214 MeV. The pd→pdη reaction was studied at CELSIUS [17]. Their fig. 4 (lower frame) shows a scatterplot of $M_{\gamma\gamma}$ versus M_{pd}, where a careful observation indicates a lightly dark range around $M_{\gamma\gamma}$ ≈214 MeV.

III. SELECTED DATA SHOWING SMALL STRUCTURES IN THE MASS RANGE BELOW THE PION MASS

A. The missing mass of the pp→ppX reaction

The natural question, following the previous result, is to look, in already published data, at (a) possible structure(s) below the mass of the pion (M=135 MeV). All the data reanalyzed below, are read and their mass recalibrated, when necessary, to adjust the pion peak at M=135 MeV. The pion missing mass peak is described by a gaussian and the structure(s) at lower mass(es) is (are) described by a gaussian with the same width as the one given for π^0. The observed structures are small, therefore a semi-log scale is used. Also the mass(es) extracted is (are) not always stable since the corresponding statistics is not reach. A small background is arbitrarily drawn. If it will be modified, the results will not change much, since we are in the xesemi-log scale.

Fig. 6 shows the missing mass spectra studied at Saturne (SPES3 beam line) in the useful range, at T_p=1520 MeV, and at four different spectrometer angles. A small peak is easily extracted at forward angles. When the spectrometer angle increases, the excitation of this exotic structure increases also relatively to the π^0 excitation, but the resolution spoils and the peak although still extracted, is no more clearly separated from the π^0 peak. Fig. 7 shows another selection of four missing mass spectra. Here again the experimental results are well fitted with introduction of a second peak at a mass close to M≈65 MeV. Table II gives the quantitative informations. σ describes the width of the peaks and R is the ratio of the exotic structure excitation relative to the π^0 excitation.

TABLE I: Masses (in MeV) and number of standard deviations (S.D.) of the narrow peaks extracted around M≈215 MeV, from the p(e,e'p)X reaction studied at JLAB Hall C [16] for Q^2=4 GeV^2 (Fig. 3) and Q^2=2.8 GeV^2 (Fig. 4). The width of the peak is given by σ (in MeV). p_p^0 is in GeV, and θ is in degrees.

Fig.	insert	set in [16]	Q^2	p_p^0	θ_p^0	M	σ	S.D.
Fig. 3	(a)	10	4.0	2	23	250	22	9.5
	(b)	11	4.0	2	20	225	22	4.9
	(c)	21	4.0	2.2	17	230	17	5.2
	(d)	5	4.0	2.45	17	210	17	6.3
Fig. 4	(a)	14	2.8	1.9	33	200	17	1.9
	(b)	19	2.8	1.55	23	225	17	4.0
	(c)	34	2.8	1.7	19	215	17	3.0
	(d)	36	2.8	1.7	23	210	17	2.9
		12	4.0	2	17	235	22	5.1
		14	4.0	1.8	17	220	22	2.6
		15	4.0	1.8	20	220	17	4.9
		16	4.0	1.8	23	225	17	1.5
		19	4.0	2.2	23	235	17	5.3
		20	4.0	2.2	20	200	17	5.9
		4	4.0	2.45	14	215	17	3.5
		6	4.0	2.45	20	180	17	3.7
		9	2.8	1.9	23	215	17	3.8
		10	2.8	1.9	25	210	17	3.75
		13	2.8	1.9	31	235	17	1.9
		18	2.8	1.55	25	215	17	3.5
		28	2.8	2.15	23	180	17	11
		29	2.8	2.15	21	180	17	8.6
		30	2.8	2.15	19	200	17	3.4
		33	2.8	1.7	17	215	17	2.8

Fig. 8 shows a selection of missing mass peaks from Celsius in inserts (a), (b), and (c). Insert (a) shows the data from the pp→pp$\pi^+\pi^-$ reaction studied at Celsius [18] at T_p=775 MeV. The σ of the peaks equals 20 MeV, and R=17 10^{-2}. Insert (b) shows the data from the pp→pp$\gamma\gamma$ reaction studied at Celsius [19] at T_p=1360 MeV. Here σ=16 MeV and R=6.6 10^{-2}. Insert (c) shows the data of the pp→ppX reaction studied at Celsius [11] at T_p=650 MeV. Here σ=17 MeV and R=8.3 10^{-2} for the ratio of the "60"/"135" peaks and R=20 10^{-2} for the ratio of the "100"/"135" peaks. In all these spectra a peak at M≈65 MeV is observed, and also another one is extracted at M=100 MeV. Table II gives the quantitative informations. Several spectra from COSY-Julich are reported in fig. 9. They are all integreated by two channels in order to increase the precision. The effect in the spoiling of the resolution is observed, going from insert (a) to insert (c). Table III gives the quantitative informations. Insert (a) shows the data from the pd→^{3}Heπ^0 reaction measured

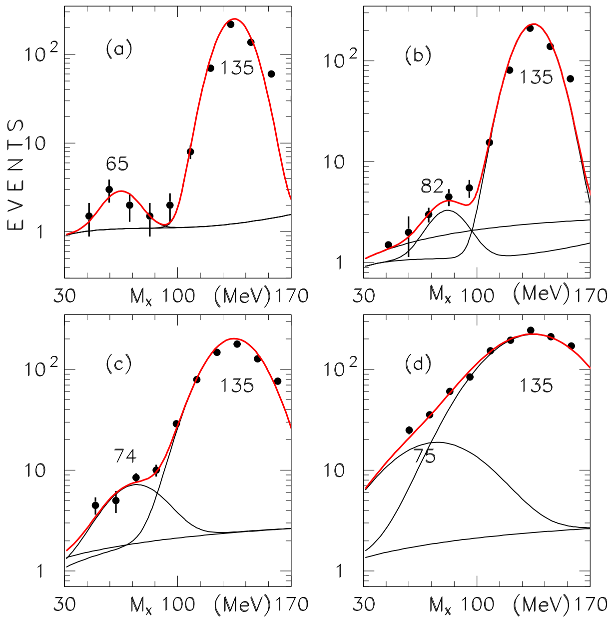

FIG. 6: Missing mass spectra for pp→ppX measured at Saturne (SPES3 beam line) at T_p=1520 MeV. Inserts (a), (b), (c), and (d) correspond respectively to the following spectrometer angles: $\theta_{spec.}=0^0$, 2^0, 5^0, and 9^0.

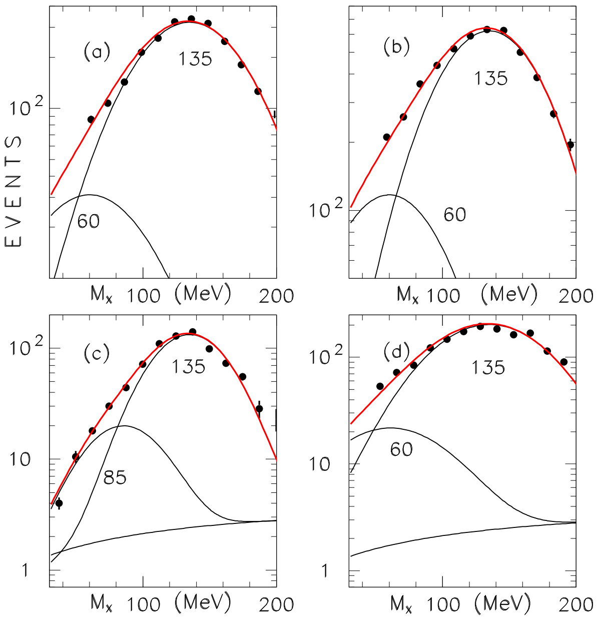

FIG. 7: Missing mass spectra for pp→ppX measured at Saturne (SPES3 beam line). Inserts (a), (b), (c), and (d) correspond respectively to the following kinematical conditions: T_p=1520 MeV, $\theta_{spec.}=13^0$; T_p=1520 MeV, $\theta_{spec.}=17^0$; T_p=1805 MeV, $\theta_{spec.}=9^0$; and T_p=1805 MeV, $\theta_{spec.}=13^0$.

TABLE II: Quantitative information on the small structure extracted from the missing mass spectra studied with pp→ppX reaction at Saturne (SPES3 beam line) [8]. The incident proton energies T_p and the mass M≈65 are in MeV. R is the ratio of the M≈65 MeV structure excitation over the π^0 excitation.

Fig.	T_p	θ_{pp}	σ	M≈65	R
Fig. 6(a)	1520	0	10.3	65	7.2 10^{-3}
Fig. 6(b)	1520	2	11.5	82	9.6 10^{-3}
Fig. 6(c)	1520	5	17	74	27 10^{-3}
Fig. 6(d)	1520	9	28	75	77 10^{-3}
Fig. 7(a)	1520	13	38	60	9.4 10^{-2}
Fig. 7(b)	1520	17	38	60	18.7 10^{-2}
Fig. 7(c)	1805	9	27	85	13.8 10^{-2}
Fig. 7(d)	1805	13	40	60	10.0 10^{-2}

TABLE III: Quantitative informations concerning figs. 8, 9, and 10.

Fig.	reaction	ref	lab.	M (R)	M (R)
Fig. 8(a)	pp→pp$\pi^+\pi^-$	[18]	Celsius		65 (0.17)
Fig. 8(b)	pp→pp$\gamma\gamma$	[19]	Celsius		65 (0.07)
Fig. 8(c)	pp→pp$\pi^0\pi^0$	[11]	Celsius	100 (0.2)	60 (0.08)
Fig. 8(d)	$p(\vec{e},e'\vec{p})\pi^0$	[14]	JLAB A	100 (0.09)	60 (0.01)
Fig. 9(a)	pd→^{3}Heπ^0	[20]	COSY	100 (0.1)	60 (0.02)
Fig. 9(b)	pd→Tπ^+	[21]	COSY		73
Fig. 9(c)	dp→^{3}Heη	[22]	COSY	97 (0.03)	61(0.25)
Fig. 10(a)	γp→pX	[23]	JLAB B	100 (0.33)	55 (0.06)
Fig. 10(b)	γp→pX	[23]	JLAB B	100 (0.13)	65 (0.04)
Fig. 10(c)	γp→pX	[23]	JLAB B		65 (0.09)
Fig. 10(d)	γp→pX	[23]	JLAB B		65 (0.10)

by the GEM detector at COSY [20] at T_p=328 MeV. Here σ=13 MeV and R=1.7 10^{-2} for the ratio of the "60"/"135" peaks and R=10.9 10^{-2} for the ratio of the "100"/"135" peaks. A large statistics missing mass spectra was obtained with the pd→^{3}Tπ^+ reaction studied at COSY [21] at T_p=328 MeV also. The authors said that "small background was subtracted for each angular bin". The data are read, integrated by two channels, and shown in fig. 9(b). A small peak at M=73.6 MeV is extracted. Insert (c) shows the missing mass spectra of the dp→^{3}Heη reaction at T_d=1780 MeV [22]. Here σ=29 MeV and R=25.2 10^{-2} for the ratio of the "61"/"135" peaks and R=2.8 10^{-2} for the ratio of the "97"/"135" peaks.

The missing mass of the $p(\vec{e},e'\vec{p})\pi^0$ reaction [14] studied at JLAB Hall A at $\theta_{cm}=90^0$ is read and reported in fig. 8(d). Two structures, at M=100 MeV and 60 MeV are extracted.

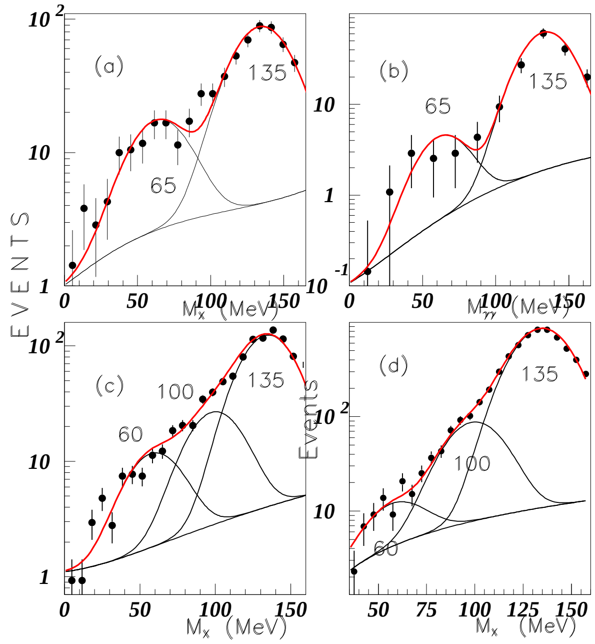

FIG. 8: Missing mass spectra for several different reactions measured at Celsius. (a) pp→pp$\pi^+\pi-$ [18], (b) pp→pp$\gamma\gamma$ [19], (c) pp→ppX [11]. Insert (d) shows the missing mass of the p($\vec{e}, e'\vec{p}$)π^0 reaction [14] studied at JLAB Hall A at θ_{cm}=90^0.

B. The missing mass of the γp→pX reaction

The missing mass of the γp→pX reaction was studied at JLAB in Hall B, in an experiment devoted to study the inclusive η photoproduction in nuclei [23] by the CLAS Collaboration. The data at low missing mass range are read and reported in fig. 10. We observe the good fit obtained with introduction of a structure at M=100 MeV in inserts (a) and (b) and a structure at M=65 MeV (M=55 MeV in insert (a)) in all inserts.

The mean values of the two low mass structures extracted from the various spectra shown, are M=62 MeV and M=100 MeV.

IV. CONCLUSION

Fig. 11 shows the various exotic masses shown in previous figs.. These masses are M=62 MeV, 80 MeV, 100 MeV, 181 MeV, 198 MeV, 215 MeV, 227.5 MeV, and 235 MeV, although the last one may be uncertain, since determined by only three data, and being located at the limit of the spectra. A few points, located around M=75 MeV, may be thought as being not resolved structures. Indeed when they are extracted none of the structures at M=100 or M=62 MeV is observed. However the symmetry of the masses reported in fig. 11, may be considered as an indication of their genuine existence.

We have selected some spectra showing these structures. In many other spectra, such extraction is not possible, either since their experimental resolution is worse, either since the dynamics of the experiment (reaction, incident energy ...) is less favourable. In figs. 6 and 7, and table II, six spectra obtained at the same incident energy and same reaction, show that R increases with the spectrometer angle (but the resolution spoils, as already indicated). Figs. 6 and 7 show that R increases with the incident energy (but again the resolution spoils in that case).

We suggest that the reason for which these narrow, weakly excited structures were not observed till now is due to the lack of experimental precision (resolution and statistics) of previous experiments.

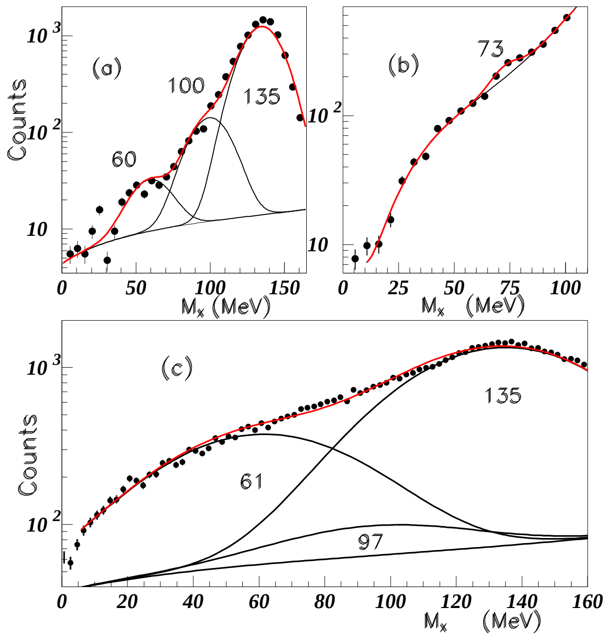

FIG. 9: Missing mass spectra for several different reactions measured at Cosy. (a) pd→^{3}Heπ^0 [20], (b) pd→Tπ^+ [21], (c) dp→^{3}Heη [22].

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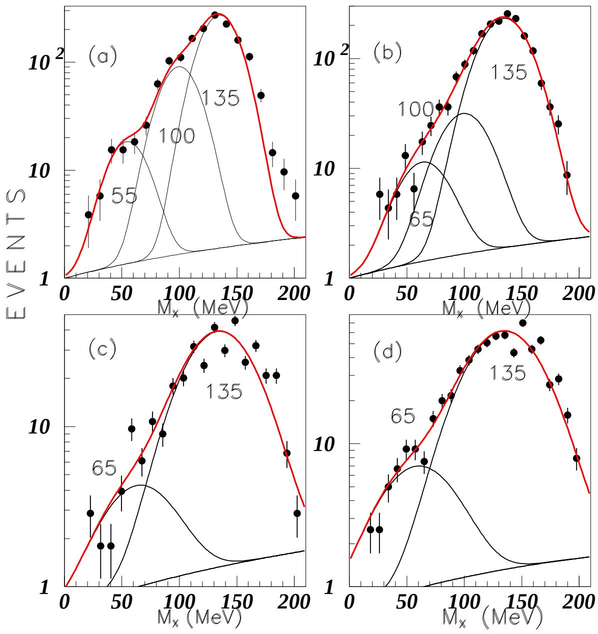

FIG. 10: Missing mass spectra for γp→pX measured at JLAB Hall B [23] CLAS Collaboration. Inserts (a),)b), (c), and (d) correspond respectively to the following kinematical conditions: 0.8≤E≤0.9 GeV and -0.75≤cos(T)≤-0.50, 0.8≤E≤0.9 GeV and -0.25≤cos(T)≤-0.00, 1.2≤E≤1.3 GeV and -0.50≤cos(T)≤-0.25, and 1.2≤E≤1.3 GeV and 0.50≤cos(T)≤0.75. E is the beam energy and T is the proton center-of-mass angle.

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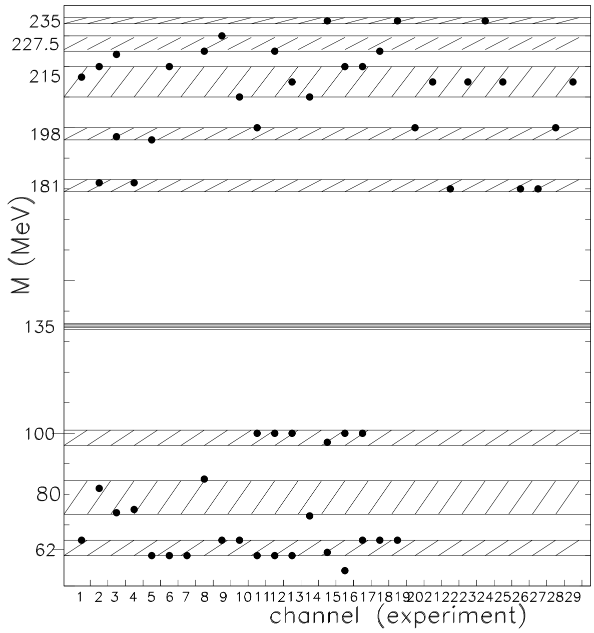

FIG. 11: Masses of the weakly excited structures extracted from several experiments.

Search for Low Mass Exotic mesonic structures. Part II: attempts to understand the experimental results

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Our previous paper, part I of the same study, shows the different experimental spectra used to conclude on the genuine existence of narrow, weakly excited mesonic structures, having masses below and a little above the pion (M=139.56 MeV) mass. This work [1] was instigated by the observation, in the Σ^+ disintegration: $\Sigma^+ \to pP^0$, $P^0 \to \mu^-\mu^+$ [2], of a narrow range of dimuon masses. The authors conclude on the existence of a neutral intermediate state P_0, with a mass M=214.3 MeV $\pm$ 0.5 MeV. We present here some attempts to understand the possible nature of the structures observed in part I.

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I. INTRODUCTION

In part I of the same study [1], several spectra were presented, showing narrow and weakly excited structures, having masses below and just above the pion mass (M=139.56 MeV). These data are mainly missing mass precise spectra of the pp→ppX reaction studied at SPES3 (Saturne). Different selected results from COSY, Celsius, MAMI, and JLAB Hall A, Hall B, and Hall C were also shown, which confirm the genuine existence of the structures. The statistical confidence was often large. In some cases, this confidence is not large, but several structures at the ≈ same masses were observed.

These masses are M=62 MeV, 80 MeV, 100 MeV, 181 MeV, 198 MeV, 215 MeV, 227.5 MeV, and 235 MeV, although the last one may be uncertain, since determined by only three data, and being located at the limit of the spectra. They are shown in Fig. 1. A few points, located around M=75 MeV, may be thought as being not resolved structures. Indeed when they are extracted none of the structures at M=100 or M=62 MeV is observed. However the symmetry of the masses reported in Fig. 1, may be considered as an indication of their genuine existence.

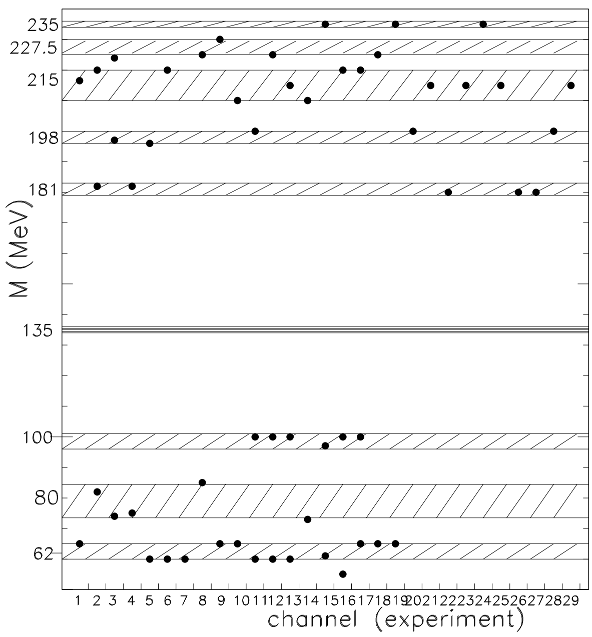

FIG. 1: Masses of the weakly excited structures extracted from several experiments.

II. DISCUSSION

A. Possible mass relation between mesons and baryons

Narrow structures in dibaryons [3], in baryons [4], and in mesons at larger masses [5] [6] were already previously observed . Mesonic structures appeared in the missing mass of the same reaction, pp→ppX but in different kinematical conditions from those discussed here. The sequence of the presently discussed low mass exotic mesons, reproduce fairly well the sequence of the low mass exotic baryons [4]. Indeed the three first narrow baryonic structure masses are M=1004 MeV, 1044 MeV, and 1094 MeV. We note that the first baryonic mass differences are: M=1004-939=65 MeV, 1044-939=105 MeV, and 1094-939=155 MeV. The two first values agree with the masses extracted in the present study (and the third one is to compare to the meson mass). Such property may indicate a relation between baryons and mesons. Already long time ago, the possibility to calculate the baryon spectrum, starting from the meson one was considered [7]. The shifts between adjacent masses, close to ΔM≈20 MeV or 40 MeV, compare favourably to the model [8] which suggests the existence of a "genuine" Goldstone Boson with a mass close to 20 MeV.

We observe mass differences close to ΔM≈35 MeV. The mass difference between the three lowest masses extracted before, is close to ΔM=17.5 MeV. A mass gap of

$$\Delta M = 35\ MeV = \frac{1}{2}\frac{m_e}{\alpha},$$

where m_e is the electron mass and α is the fine structure constant, was observed between several narrow hadronic exotic masses [3]. Such gaps for leptons, mesons, and baryons were discussed since long time [11] and recently discussed again [12].The mass difference observed here equals half this value. We notice that the first excited state of the light and stable nucleus ^{4}He, is close to ΔM≈20 MeV, not far from 17.5 MeV. The shift between both values could eventually be associated with residual interactions between several nucleons.

B. Regge-like trajectories

In order to support the hadronic nature of these low mass mesonic structures, we study the Regge-like trajectories of all narrow exotic mesonic structure masses extracted [5] [6] and those of the present work

$$n = a + bM^2. \tag{1}$$

This is shown in Fig. 2 where filled circles correspond to experimental structure masses and empty squares to not observed masses. These masses follow three straight lines, the two inflexion points corresponding to one and two pion masses. We name them Regge-like trajectories, since the ordinate "n" is arbitrary (as "a") and corresponds to an unknown quantum number and not to the spin. The slopes "b" of the straight lines are much larger than the slope of "classical" (PDG) mesons slope [14] which is close to 0.9 GeV^{-2} when determined in the range ρ(770)≤m≤f$_6$(2510) [14]. Namely their values, for the three straight lines from small to larger mesonic masses, are: 390, 149.7, and 32.5 GeV^{-2}. We notice that these four slopes, including the PDG meson slope vary continuously. This is shown in Fig. 3 where the slope is reported versus the mean mesonic mass range (MM).

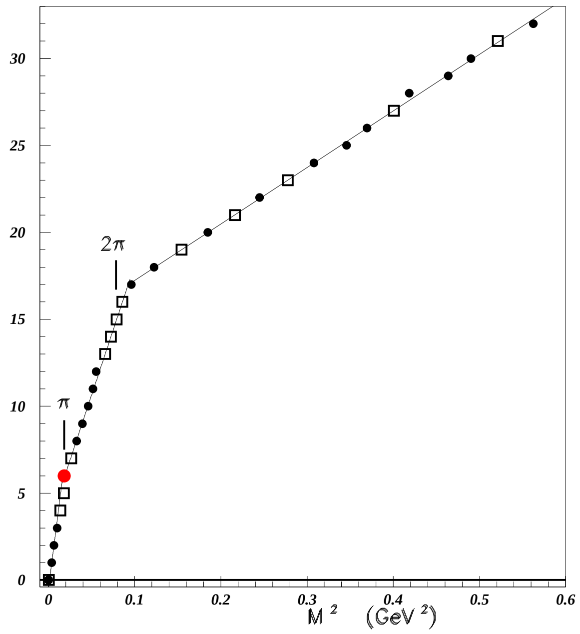

FIG. 2: Regge-like trajectory of all narrow structure mesonic masses observed in this work and in [5, 6]. Solid circles (empty squares) represent observed(expected) resonances.

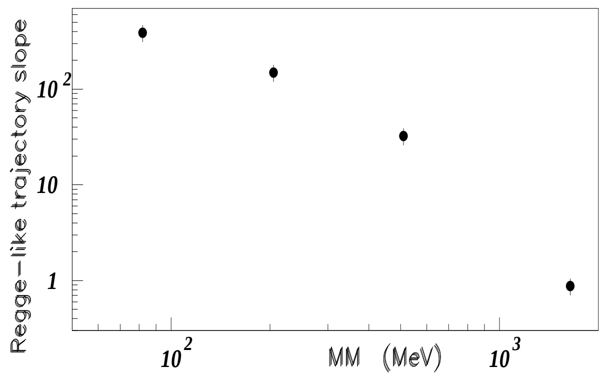

FIG. 3: Slopes of the Regge-like trajectories versus the mean mesonic mass of each straight line range.

C. Kaluza-Klein mass formula

It has been shown that the Kaluza-Klein formula [15] predicts rather well the masses of the narrow exotic baryons experimentally observed [16] and also predicts although a little less well, the masses of the narrow dibaryons experimentally observed. We use the same relation for one particle:

$$m_n^2 = m_0^2 + n^2/R^2$$

where R^{-1}=41.481 MeV is the fundamental scale parameter and "n" the sequence of integer numbers. This second term describes the contribution to the mass of the extra dimensions. If we choose - arbitrarily - m_0=63.3 MeV, adjusted to obtain m=m_{π}^{+} for n=3, we get the calculated masses shown in Fig. 4. These values compare quite well with several experimental masses of narrow low mass mesonic structures. For instance, up tp M=190 MeV, the number of calculated states and their masses are well reproduced.

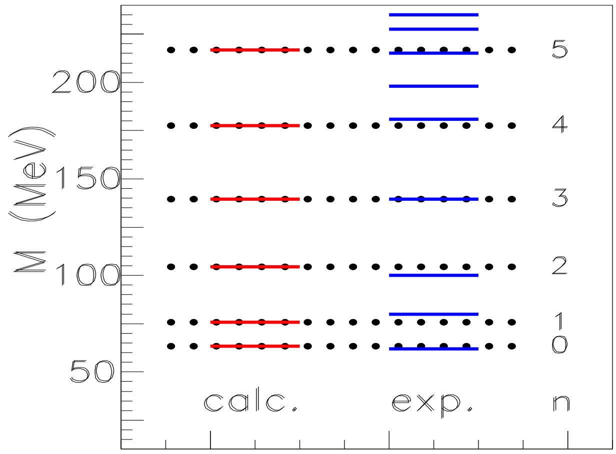

FIG. 4: Narrow meson low masses calculated using the Kaluza Klein formula (n=0,1,2,3,4,5).

D. What kind of particles ?

The possibility to explain the 511 KeV γ ray line observed by the INTEGRAL satellite from the "galactic bulge", was discussed in relation with spin 0 or 1 boson particles, candidates to dark matter [9]. Indeed as said by the author of ref.[10], "It has long been understood that weakly interacting particles with masses smaller than a few GeV (but larger than ≈1 MeV) are expected to be overproduced in the early universe relative to the dark matter abundance". The author of ref.[9] applied his calculations to dark matter particle of mass either M=1 MeV, 10 MeV, 100 MeV or 1 GeV. Although the range of masses fits the masses observed in this work, we have no argument to identify them to eventual dark matter particle(s).

III. CONCLUSION

We have discussed the nature of the structures discussed in the previous part I of this study [1]. Their hadronic nature is supported by the Regge-like trajectory shown in Fig. 2. The masses of narrow exotic mesons, baryons, and dibaryons, observed before, were attributed to quark clusters [3–5, 13]. For a review, see also [17]. We suggest that the structures shown here are also due to quark clusters as the previous ones. Since their masses are lower than the mass of two pions, they can only disintegrate through electromagnetic or weak interactions.

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