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INTRODUCTION

The studies of narrow structures in Nuclear Physics at excitation energies, typically of several hundreds of MeV, have been actively carried out since the last five to ten years. Such studies correspond to different topics presenting all some common features :

When observed, they correspond to new physics, usually not taken into account in conventional theories of baryons and mesons in interaction.

The signatures, if any, will correspond to narrow and small effects, difficult to extract from a large physical background. It is therefore very important to get as careful and precise experiments as possible, with unquestionable data, and then to answer the question concerning the origin of the observed structures. Among the different topics which predict such manifestations :

a) The physics of dibaryons [1] has been intensively studied, experimentally and theoretically. Such narrow structures have been extracted from many data. But also in many cases, they have not been observed.

b) The small and narrow increase of inclusive pion production with 350 MeV incident protons, observed in some laboratories [2] has been interpreted as being the signature of a $\Delta\Delta$ state in nuclei decaying by two pion emission [3], or through a Δ ball corresponding to a Δ localized inside the nuclei [4].

c) It has been argued [5] that deeply bound π^- states can be produced in heavy nuclei like ^{208}Pb and are expected to have narrow widths due to the repulsive nature of π^- neutron interaction. A reaction like (n,p) or (d,2p) produce a π^- (in a 1 s state) inside the nucleus. In the same way, the possibility to have eta meson nucleus bound states has been estimated [6] theoretically and found possible. Again transfer or knock-out reactions have to be used in order to produce low momenta - eventually recoiless - η inside nuclei [7].

d) Auerbach suggested that narrow anti-nucleonic states should exist in nuclei [8], being a consequence of the Dirac description of p nucleus scattering. There, large energy ($\approx$ 1 GeV) transfers, but low momenta are expected.

Nearly all amongst these topics, have been motivated by theoretical works, and some measurements have been already undertaken. Since the reactions are mainly the same, namely either knock-out or transfer reactions, one should be careful when associating a structure to a specific topic a) $\rightarrow$ d). For exemple, in the reaction A + C $\rightarrow$ pp + X where the two proton missing masses are studied, one has to pay attention to the fact that a structure in Mpp can reflect a resonance in X. Therefore it is advised to have Bx = 0 (meson) or Bx = 1(without narrow structure). It is of course essential to compare results from different experiments.

For these reactions, narrow enhancements may occur for energies corresponding to the opening of a new channel with meson production (threshold effects) and special care must be brought against that. When inclusive experiments are done, special effort has to be also devoted to explain how a narrow structure can be observed when Fermi momenta should spread the momenta and energies inside nuclei.

Among these various topics, the topic of dibaryon physics is particularly interesting since if narrow structures are observed, they can be related to precursor partial quark deconfinement. That possibility stimulated the large number of data corresponding to such studies. We will therefore restrict this review to recent data [1].

ANALYZING POWERS IN NUCLEON-NUCLEON ELASTIC SCATTERING

Very precise measurements of the analyzing power in elastic proton proton scattering, have been recently performed [9] using Saturne polarized proton beams. SPES3 detection was used and a rotating wheel with 16 different thicknesses of an energy degrader, to get data for incident proton energy bins $\approx$ 2.6 MeV.

a) The first measurements have been accomplished for 14 different incident energies ranging from 558 to 725 MeV. The detection of the recoil proton by use of a backward telescope allows to reduce the background to a ratio close to 10^{-3}. The mean value of the extracted proton beam energy shift : 12 MeV, is smaller than the range in energy corresponding to each measurement : 32 MeV. It results in a large overlap allowing relative adjustments between data corresponding to different energies (different beam polarizations). The depolarization resonance $\gamma G = 3$ occurs in the region of Tp = 630 MeV. In that energy domain, the polarization of the beam was reduced up to 15% but thanks to our relative adjustments, this has no consequence on the final data. Due to the different thicknesses of the absorbing wheel, the straggling in energy varied from 1 to 5 MeV. The data which correspond to the forward angle $\theta_{lab} = 19.1°$ (corrected for very small angular variations, are displayed in fig. 1 [9]. There is no room for any structure like those found [10] in the KEK experiment : ($\Gamma_{1/2} \approx 14$ MeV, $\Delta A \approx 2.5\%$). Our limits are lower than 0.2 % for a resonance having about the same width but of course much worse for any broad resonance $\Gamma > 40$ MeV close to Tp $\approx$ 645 MeV (Mpp $\approx$ 2174 MeV) which corresponds to the maximum of the analyzing power (and also $M_N + M\Delta$).

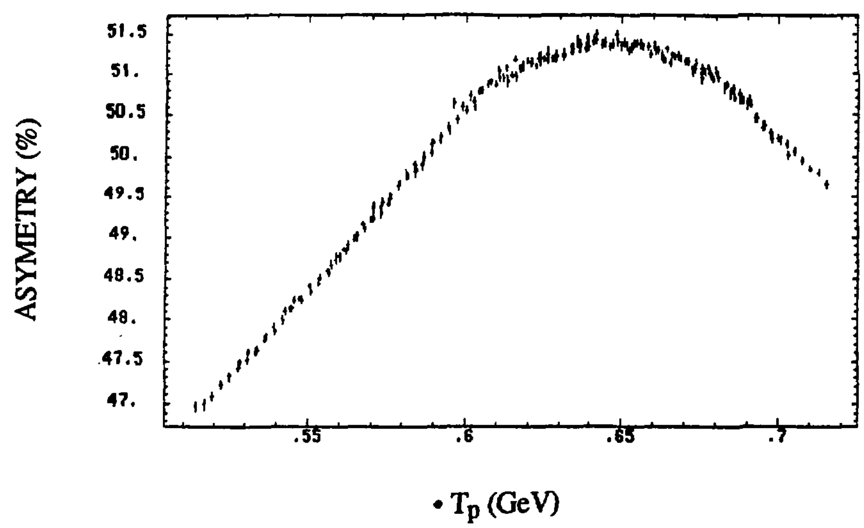

Fig. 1 : Asymetry versus incident proton kinetic energy in GeV for elastic pp scattering.

These data contradict the KEK results where structures have been observed at Mpp ($\Gamma_{1/2}$) = 2160 (14) and 2192 (13) MeV. The discrepancy may be induced by the $\gamma G=3$ depolarization resonance occuring in that region as already mentioned, and perhaps, not completely corrected at KEK. The KEK results have been analyzed recently [39]. Nagata et al. introduced a Breit-Wigner term in order to describe the narrow structure at 2.16 GeV. They performed a PSA of the other data to determine background partial wave amplitudes. They found $^3P_2$, $^3F_3$ and $^3H_5$ as possible candidates for the 2.16 GeV structure. The structure however should be still there for Saturne experimental conditions ($\theta_{CM} \approx 43°5$ for $\sqrt{s}$ = 2.16GeV). Although the angles (and angular acceptances) are somewhat different in both experiments, the differences are too small ($\Delta\theta_L \approx 2.4°$) to explain the discrepancy. We have rather to conclude that up to now no narrow structure has been observed in NN elastic scattering. Notice that analyzing powers can be more precise than cross sections to pick out small effects because of the interference terms, but it is also possible that additionnal amplitudes will give rise to the same analyzing powers than the background alone.

b) A second set of measurements with a thicker wheel, has been performed recently around Tp = 2.1 GeV, where an increase in analyzing power has been predicted by Lehar [11], from a twofold motivation. On one hand the extraction of amplitudes at three energies predicts a crossing of a phase φa through zero and that annulation should manifest itseft by an increase of the analyzing power. On the other hand a display of the world data, shows a maximum for that energy ($\sqrt{s} \approx 2.73$ GeV) although it relies really on few data only.

The analyzing power measurements, performed at Saturne, do not show any increase. The data correspond to a fixed backward angle $\theta_{lab.} = 56°$. Each extracted energy allows the measurements in a range $\Delta Tp = 52$ MeV, with 3.25 MeV bins. The total range $2.034 < Tp < 2.321$ GeV corresponds to $2.709 < \sqrt{s} < 2.807$ GeV. The statistical precision obtained is not as precise as it was in the set of measurements around Tp = 630 MeV since the $pp \rightarrow NN\pi$ cross sections dominates here. The data are only preliminary. The limit for a narrow relative increase of the asymetry around Tp = 2.15 GeV, is approximately equal or smaller than 2%.

These data are in conflict with the analysis performed by Lehar and colleagues. It is clear that new measurements on the Saturne NN beam line, will be useful.

THE $p(\vec{d},pp)X$ REACTION

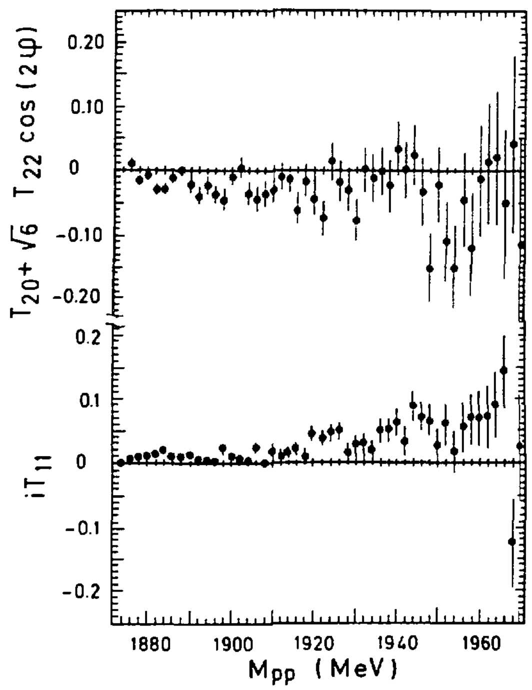

Fig. 2 : Tensor and vector analyzing powers for $p(\vec{d},pp)X$ reaction at T_d = 2.1 GeV, θ = 17°.

Using Saturne polarized deuteron beams and SPES3 facility, the analyzing powers of $p(\vec{d},pp)X$ reaction have been measured at T_d = 2.1 GeV, θ = 17° and T_d = 1.722 GeV, θ = 0°. Both protons were detected and identified at the same angle. Since they have each a momentum larger than 600MeV/c, the main mechanism involved is the charge exchange, with $X = (n\pi^{\circ}, p\pi^{-}$ or $\Delta^{\circ})$. The resolution F.W.H.M. is close to 1 MeV. The data presented in fig. 2 and 3 are binned into 2 MeV intervals. Fig. 2 displays the tensor analyzing power $T_{20} + \sqrt{6}.T_{22}\ \cos(2\varphi)$ and the vector analyzing power iT_{11} at Td = 2.1 GeV. There is a small bump in iT_{11} at M_{pp} = 1945 MeV, very poorly defined since it corresponds to S.D. = 1.15 only. An oscillatory pattern centered around 1.946 GeV is observed in the tensor analyzing power. The tensor analyzing power for the same data, plotted versus the missing mass M_x does not present such an oscillation. To get the corresponding number of standard deviations (S.D.), we define "a background" as a nearly flat curve extrapolating data for smaller Mpp.

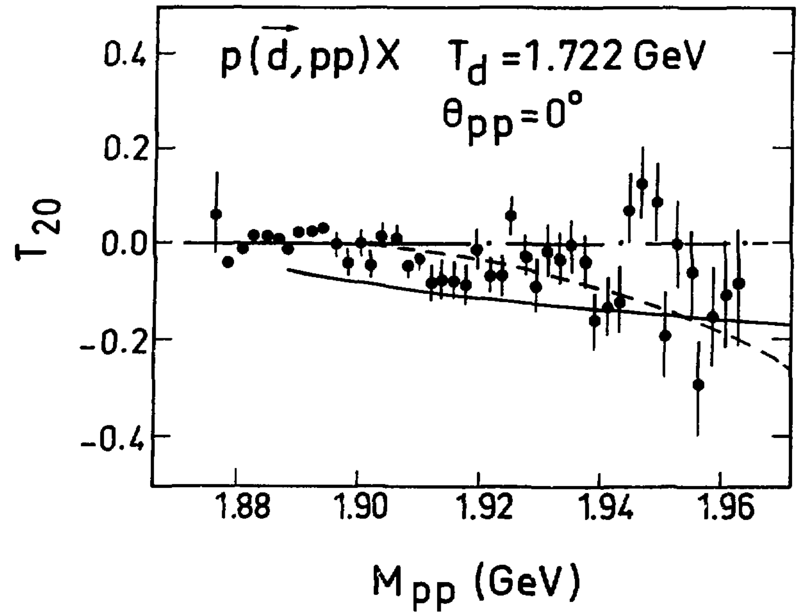

Fig. 3 : Tensor analyzing power for p(d⃗,pp)X reaction at Td = 1.722 GeV, $\theta = 0°$. The theoretical curve are from Lykasov [26]. Full (dashed) curve is the result of T_{20} calculation within spectator mechanism, when FSI and Glauber screening effect are (are not) taken into account.

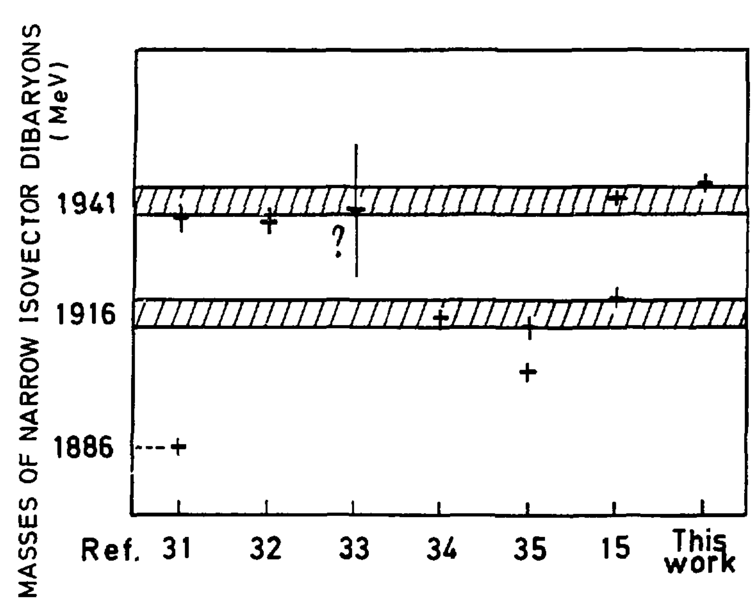

Fig. 4 : Masses of isovector narrow structures observed recently, in the range $1876 < M_{pp} < 1955$ MeV.

Since the effect is an oscillation, the number of S.D. depenses very little on the assumption concerning "the background", allowing the assumption that the background is obtained without unprecision. We obtain then S.D.= 2.45 for the tensor analyzing power (maximum value).

The measurement has been repeated in new conditions with 1.722 GeV polarized deuterons, the protons being detected at 0° [12]. Fig. 3 displays the results for T_{20} versus Mpp. We observe an oscillation centered at 1945 GeV but with opposite sign. The corresponding number of S.D. is 3.86. In order to strengthen the oscillation versus background, both results have been mixed (with sign inversion). We obtain then S.D. = 4.7. In the Mpp range studied in this experiment, the observation of different narrow dibaryons have been reported [1] - see fig. 4 - although always with poor statistics. They concentrate around 1916 MeV and 1941 MeV. In the data presented here, there is no signal around 1915 MeV. Since the large statistics at small Mpp is mainly due to small transfer momenta, we cannot conclude that our data bring a strong argument against a narrow structure at this mass.

Around 1939 MeV, three different studies reported to have observed narrow dibaryons. Troyan studied np $\rightarrow pp\pi^-$ and $\rightarrow pp\pi^-\pi^0$ and reported [31] the existence of a resonance at 1937 MeV with 3.7 S.D. A study of the ratio of elastic to inelastic proton scattering [32] has been done at Dubna and the authors, in spite of a small statistical precision, concluded to the presence of a narrow signal at 1936MeV. Glogolev studied dp $\rightarrow$ ppn and $\rightarrow p\pi^+nn$ and reported [33] the observation of a peak in Mpp at 1939 ± 15 MeV ($\Gamma_{1/2}$ = 27 ± 13 MeV) with 2.2 S.D.

In order to extract an oscillation, the assumption here has been done that the physics of mesons and nucleons in interaction will give rise to a continuous curve. Such calculation has been performed by Lykasov [26].The theoretical results are plotted on fig. 3 where full (dashed) curve corresponds to spectator mechanism with (without) FSI and Glauber screening effect. The Paris deuteron wave function has been used. The calculated values decrease slowly without any oscillation.

THE $^2H(p,n)X^{++}$ REACTION

It has been studied at IUCF using T_p = 200 MeV proton beam. Neutrons were detected at 0° with a flight path of ≈ 50m allowing a very good missing mass resolution : $\Delta M_x \approx 0.2$ MeV. The useful experimental range is $20 < T_N < 160$ MeV since for larger neutron energies the spectrum displays peaks from C (CD_2 target was used). This range corresponds to ≈ $2.0 > M_x > 1.91$ GeV. The preliminary data [13] are shown in fig. 5. They do not display any structure and the authors concluded that "for missing masses near 2 GeV/c^2 and particle intrinsic widths $\lesssim$ 500 keV, we expect the 0° $^2H(p,n)X^{++}$ cross section limits to be of order 0.1 - 1 µb/sr".

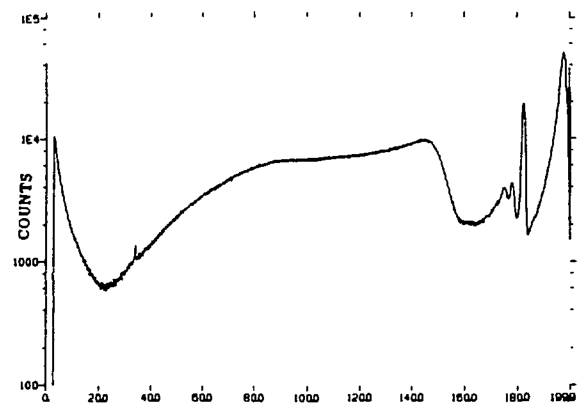

Figure 2. The neutron time spectrum of Fig. 1(a) converted to a neutron energy spectrum. The peak at $E_n \simeq 34$ MeV arises from pulse selection feedthrough. The rise at low E_n corresponds to background events uncorrelated with the cyclotron rf signal.

Fig. 5 : CD_2 (p,n)X^{++}, 0°. Data from Indiana [13].

DIBARYON SEARCHES FROM PHOTONUCLEAR REACTIONS

Since the measurements performed at Bonn, where the $\gamma d \rightarrow pp\pi^-$ reactions were studied with observation of a narrow enhancement in two proton mass distribution at Mpp = 2014 ± 2 MeV [14], many works have been devoted to such studies, using γd as input channel. In the range of masses below $2M_N + M_\pi$, deuteron photodesintegration cross sections using // and ⊥ polarized photons from Kharkov electron linear accelerator, have been studied (1904 < $\sqrt{s}$ < 1973 MeV). When photons are polarized orthogonally to the scattering plane, the differential cross sections of $\gamma d \rightarrow pn$ exhibit a narrow structure at $\sqrt{s}$ = 1919.5 MeV [15].

For masses above $2M_N + M_\pi$, no structure has been observed in cross sections :

- neither at INS (Tokyo), in the total cross section of the $\gamma d \rightarrow \pi^- pp$ reaction studied [16] in the range 2222 < $\sqrt{s}$ < 2582 MeV,

- nor in $M_{\pi pp}$ mass distribution studied at Bonn [17] in $\gamma d \rightarrow pp\pi^-$ reaction (2.16 < $\sqrt{s}$ < 2.32 GeV), and at Saclay [18] 2.19 < $\sqrt{s}$ < 2.293 GeV).

However many studies have been performed using polarization degrees of freedom, ($\gamma d \rightarrow pn$ reactions) :

- no structure from INS [19] in the target asymmetry T(θ) studied in the range 2.155 < $\sqrt{s}$ < 2.480 GeV,

- using linearly polarized photons from Yerevan synchrotron, the polarization of the emitted proton has been measured at center of mass proton angles : 75°, 2.16 < $\sqrt{s}$ < 2.28 GeV [20] and 65°, 2.15 < $\sqrt{s}$ < 2.25 GeV [21]. There is a possible narrow structure close to $\sqrt{s} = 2.24$ GeV in Py (plane orthogonal to the scattering plane) but its definition is not precise enough.

- Polarized deuterons photodisintegration has been studied at Bonn at $T\gamma = 450$, 550 and 650 MeV [22]. The authors concluded that a second minimum of T at 550 ± 50 MeV around 90° could perhaps be an indication for a dibaryon resonance. This speculation is not strong enough.

- A few analysis have been performed in order to improve the agreement between theoretical description and different photonuclear data by introduction of dibaryon resonances as free parameters. Such approach has been used in the analysis of data from Yerevan synchrotron [23], $2.24 < \sqrt{s} < 2.55$ GeV, and especially for analysis of data from Kharkov accelerator [24], $2.11 < \sqrt{s} < 2.40$ GeV ($d\sigma/d\Omega$, Σ, P, T). The agreement is of course improved when additional free parameters are introduced, but this very indirect approach is not convincing enough.

CONCLUSION

Although we have restricted this review to recent data, it is clear that the number of experiments increase continously. The number of precise results increase, which is as a matter of fact more important.

There is no measurement amongst those presented, from where unambiguous dibaryons can be extracted. There is a possible evidence for a dibaryon close to 1940 MeV.

It is specially important that both precise analyzing power measurements in pp elastic scattering, performed at Saturne (SPES3) concluded to the absence of any narrow structure. If we remember that never any dibaryon has been observed in isospin 0 or 2 channels [25], one can been lead to speculate that they simply do not exist. However that would be incorrect since precise data exist in case of isovector channel where narrow dibaryons have been observed [1].

The answer to the first question set in the introduction, namely is there unquestionnable data showing dibaryons, must be no, for the recent data discussed here.

Some years ago, a semi-phenomenological di-quark model [27] has been able - after adjustement of a few free parameters - to get a good agreement between data and calculated masses and widths of some isovector dibaryonic resonances. Recently a work has been presented, within a modified MIT bag model where a di-quark cluster has been assumed [28]. A good agreement has been achieved for approximately half of the masses found in various experiments for isovector dibaryons (fig. 6). However it has been shown that the improvement of calculations, from spherical MIT [29] to cloudy bag model [30], enhanced by a few hundreds of MeV the masses of predicted dibaryons. We have therefore to consider with care the previous agreement between di-quark cluster model and data.

The answer to the second question set in the introduction concerning the origin of the observed structures remains still open.

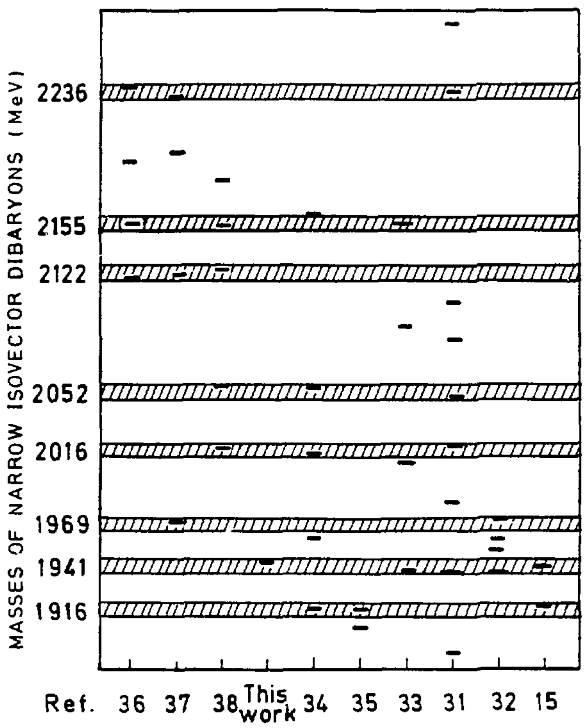

Fig. 6 : Masses of isovector narrow structures.

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