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ON A MANIFESTATION OF DIBARYON RESONANCES IN THE STRUCTURE OF PROTON-PROTON TOTAL CROSS-SECTION AT LOW ENERGIES

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Abstract

Arkhipov A.A. On a Manifestation of Dibaryon Resonances in the Structure of Proton-Proton Total Cross-Section at Low Energies: IHEP Preprint 2001-44. – Protvino, 2001. – p. 6, figs. 3, tables 1, refs.: 12.

A manifestation of narrow diproton resonances in the early discovered global structure of proton-proton total cross section (see [8,9]) at low energies is discussed. It is also discussed the existence of new particle with the mass $1.833\,MeV$ predicted early.

Аннотация

Архипов А.А. Проявление дибарионных резонансов в полных сечениях протон-протонного рассеяния при низких энергиях: Препринт ИФВЭ 2001-44. – Протвино, 2001. – 6 с., 3 рис., 1 табл., библиогр.: 12.

В работе обсуждается проявление дипротонных резонансов в обнаруженной нами ранее [8,9] глобальной структуре полных протон-протонных сечений. Также обсуждается предсказанное нами ранее существование новой частицы с массой $1.833\,MeV$.

Introduction

We are all know an incessant interest to the physics of dibaryons and this session at the Conference is an additional confirmation of that [1,2,3]. It is well known fact that diprotons have experimentally been observed as a narrow structures in the distributions over invariant mass of proton-proton system in the processes of proton-nucleus interaction [4,5,6]. The physical origin of these narrow structures is high interest because it has fundamental importance which is related to the nature of fundamental nucleon-nucleon forces and not only to this one. However the experimental and theoretical understanding of the dibaryon physics is far from desired.

From experimental point of view it would be well done to obtain a strong statement concerning the observation of narrow dibaryons regardless of their origin. However at present time there are many experiments where we can find quite an opposite results: some authors state that they have observed such narrow dibaryons [4,5,6] but the others make the contrary conclusion. It is usually supposed that the main reason for these disagreements is the weakness of dibaryons signatures compared to the physical background of a given process under experimental study. In that case there are needed the experiments with a high precision. Of course we can always explain a contradiction between the different experiments by a poor energy resolution and statistics or by kinematically unfavourable conditions and all somethings like that. Therefore it would be desirable to have the measurements with one and the same positive signals coming from different kinds of experiments.

Certainly it's bad that at present time there is no theory which can explain the existence of the dibaryons and describe them.

I will adress here a nontrivial physical phenomenon related to a manifestation of diproton resonances in the proton-proton total cross sections at low energies. We faced with the phenomenon in our study of global structure for the nucleon-nucleon total cross section.

Mabe it should be emphasized a common experimental point of view that the total cross section is not a suitable characteristic to study the resonance physics. Nevertheless we will show that the existing experimental data set on proton-proton total cross sections allowed us to find a clear signatures for diproton resonances. Let me remind you what was the beginning on.

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1. Global structure of proton-proton(antiproton) total cross sections

Recently a simple theoretical formula describing the global structure of pp and $p\bar{p}$ total cross-sections in the whole range of energies available up today has been derived. The fit to the experimental data with the formula was made, and it was shown that there is a very good correspondence of the theoretical formula to the existing experimental data obtained at the accelerators [7,8].

Moreover it turned out there is a very good correspondence of the theory to all existing cosmic ray experimental data as well. The predicted values for σ_{tot}^{pp} obtained from theoretical description of all existing accelerators data are completely compatible with the values obtained from cosmic ray experiments [9]. The global structure of proton-proton total cross section is shown in Fig. 1 extracted from paper [9].
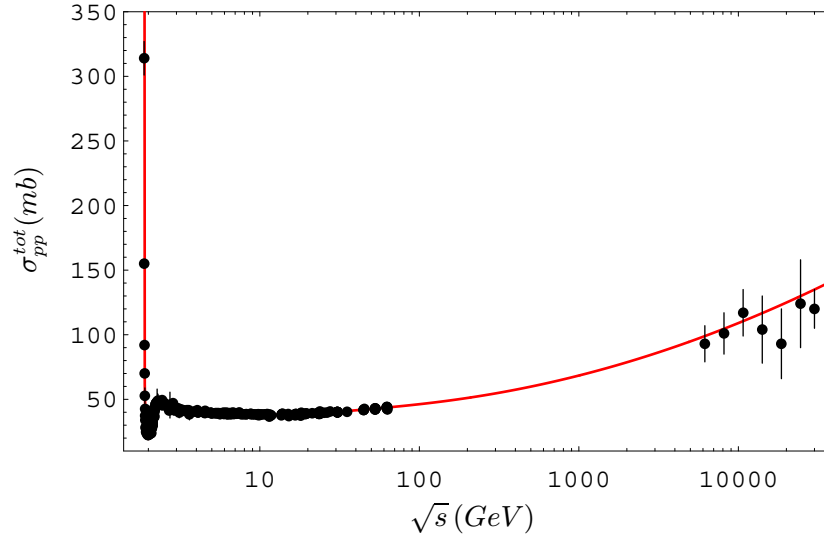

Fig. 1.   The proton-proton total cross-section versus $\sqrt{s}$ with the cosmic rays data points from Akeno Observatory and Fly's Eye Collaboration. Solid line corresponds to our theory predictions.

The theoretical formula describing the global structure of proton-proton total cross section is written below

$$\sigma_{pp}^{tot}(s) = \sigma_{asmpt}^{tot}(s)\left[1 + \left(\frac{c_1}{\sqrt{s-4m_N^2}R_0^3(s)} - \frac{c_2}{\sqrt{s-s_{thr}}R_0^3(s)}\right)(1+d(s)) + Resn(s)\right],$$

$$R_0^2(s) = \left[0.40874044\sigma_{asmpt}^{tot}(s)(mb) - B(s)\right](GeV^{-2}),$$

$$\sigma_{asmpt}^{tot}(s) = 42.0479 + 1.7548\ln^2(\sqrt{s}/20.74),$$

$$B(s) = 11.92 + 0.3036\ln^2(\sqrt{s}/20.74),$$

$$c_1 = (192.85 \pm 1.68)GeV^{-2}, \quad c_2 = (186.02 \pm 1.67)GeV^{-2},$$

$$s_{thr} = (3.5283 \pm 0.0052)GeV^2,$$

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$$d(s) = \sum_{k=1}^{8} \frac{d_k}{s^{k/2}}, \qquad Resn(s) = \sum_{i=1}^{N} \frac{C_R^i s_R^i \Gamma_R^{i\,2}}{\sqrt{s(s-4m_N^2)}[(s-s_R^i)^2 + s_R^i \Gamma_R^{i\,2}]}.$$

For the numerical values of the parameters $d_i (i = 1, ...8)$ see original paper [8]. It should be pointed out that the mathematical structure of the formula is very simple and physically transparent: the total cross section is represented in a factorized form. One factor describes high energy asymptotics of total cross section and it has the universal energy dependence predicted by the general theorems in local quantum field theory (Froissart theorem). The other factor is responsible for the behaviour of total cross section at low energies and it has a complicated resonance structure. However this factor has also the universal asymptotics at elastic threshold. It is a remarkable fact that the low energy asymptotics of total cross section at elastic threshold is dictated by high energy asymptotics of three-body (three-nucleon in that case) forces. The appearance of new threshold $s_{thr} = 3.5283\,GeV^2$ in the proton-proton channel, which is near the elastic threshold, is nontrivial fact too.

Some experimental information concerning the diproton resonances is collected in Table 1.

Table 1.   Diproton resonances.

$m_R(MeV)$	$\Gamma_R(MeV)$	$Reference$	$C_R(GeV^2)$
1937 ± 2	7 ± 2	[6]	0.058 ± 0.018
$1947(5) \pm 2.5$	8 ± 3.9	[4]	0.093 ± 0.028
1955 ± 2	9 ± 4	[6]	0.158 ± 0.024
1965 ± 2	6 ± 2	[6]	0.138 ± 0.009
1980 ± 2	9 ± 2	[6]	0.310 ± 0.051
1999 ± 2	9 ± 4	[6]	0.188 ± 0.070
2008 ± 3	4 ± 2	[6]	0.176 ± 0.050
$2027 \pm ?$	$10 - 12$		0.121 ± 0.018
2087 ± 3	12 ± 7	[6]	-0.069 ± 0.010
2106 ± 2	11 ± 5	[6]	-0.232 ± 0.025
$2127(9) \pm 5$	4 ± 2	[6]	-0.222 ± 0.056
$2180(72) \pm 5$	7 ± 3	[6]	0.131 ± 0.015
$2217 \pm ?$	$8 - 10$		0.112 ± 0.031
2238 ± 3	22 ± 8	[6]	0.221 ± 0.078
2282 ± 4	24 ± 9	[6]	0.098 ± 0.024

The positions of resonances and their widths, listed in Table 1, were fixed in our fit, and only relative contributions of the resonances C_R^i have been considered as free fit parameters. Fitted parameters C_R^i obtained by the fit are listed in Table 1 too. It should be remarked that the experimental data set on proton-proton total cross sections revealed the existence of two unknown resonances with the masses $\sim 2027\,MeV$ and $\sim 2217\,MeV$. These resonances were also included in our fit. Some known diproton resonances are not included in the list by the reason of our computer allowance. We plan to make a more extended analysis in the future.
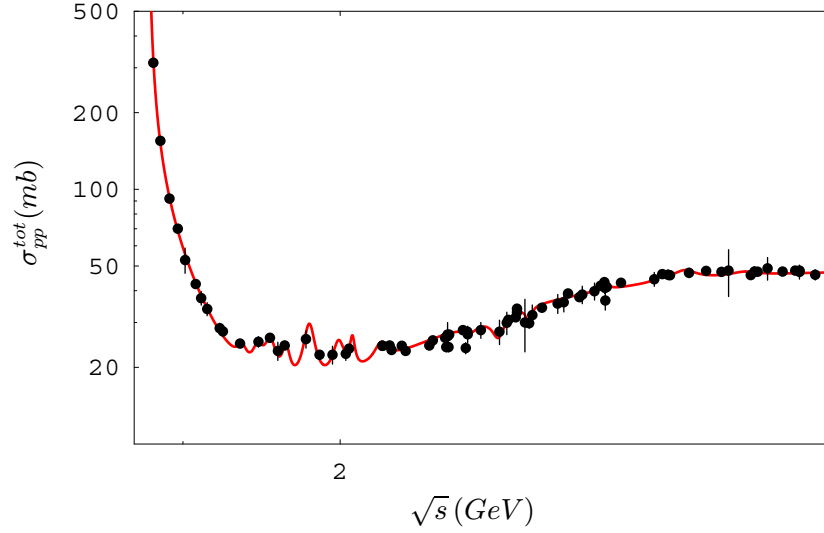
Fig. 2. The proton-proton total cross-section versus $\sqrt{s}$ at low energies. Solid line corresponds to our theory predictions.

Our fitting curve is shown in Fig. 2. We also plotted in Fig. 3 the resonance structure for proton-proton total cross section at low energies without the experimental points but with dashed line corresponding the "background" where all resonances are switched off. As it is seen from this Figure there is a clear signature for the diproton resonances.
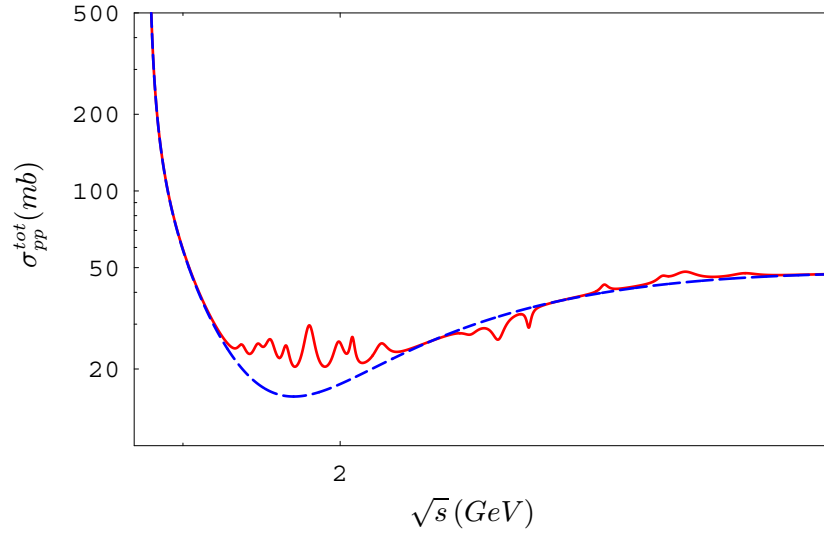

Fig. 3. The resonance structure for the proton-proton total cross-section versus $\sqrt{s}$ at low energies. Solid line is our theory predictions. Dashed line corresponds to the "background" where all resonances are switched off.

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2. Conclusion

- It appears the diproton resonances are confirmed by the data set for proton-proton total cross section at low energies from statistical point of view (good fit!).

- There is a big bag ("bol'shoi korob") with many dibaryon resonances. This korob-bag is not completely filled yet till now! How many dibaryon resonances are there?

- There are many questions???...There are no answers!!!...What is the physical nature and dynamical origin of dibaryon resonances? What are the quantum numbers: spin, isospin, and so on. A nontrivial fact in our fitting games is the observation that three resonances with the mass 2087, 2106, 2127 MeV have an odd parity.

- Without any doubt the physics of dibaryon resonances is very interesting, very exciting, very promising, very..., very... part of elementary particle and nuclear physics.

- From the global structure it follows that new threshold, which is near the elastic one, looks like a manifestation of a new unknown particle:

$$\sqrt{s_{thr}} = 2m_p + m_{\mathcal{L}}, \qquad m_{\mathcal{L}} = 1.833 \, MeV.$$

  We predicted the position of new threshold with a high accuracy.

- It seems $\mathcal{L}$-particle may have many faces. We could take a refreshing thought that $\mathcal{L}$-particle may be a bound state of photons–"photoball", or a bound state of electron-positron pairs embedded in continuum, or very deeply bounded system of pions. A very intriguing idea that $\mathcal{L}$-particle is a Higgs particle, which is well known theoretically but it is not observed experimentally, is admissible one as well. Is $\mathcal{L}$-particle a photonium, positronium, pionium, and so on x-onium?

- Could one make an experiment to search $\mathcal{L}$-particle? It is very probably that $\mathcal{L}$-particle has been observed in Darmstadt. We find in the abstract of paper [10]: "The most pronounced line appears at a sum energy of $\sim 810 \, keV$, corresponding to an invariant mass of $\sim 1.83 \, MeV/c^2$." This result was confirmed by the other group a year later [11]. Now we can understand an independence of Darmstadt effect on the content of beam and target nuclei because this is a manifestation of fundamental nucleon-nucleon dynamics. It's a pity, the present status of Darmstadt efect is not so stable. That is why, it would be very desirable to make new experiments to search $\mathcal{L}$-particle.

- Could one measure a missing mass spectra in one-particle $pp \to pX$ and in two-particle $pp \to ppX$ inclusive reactions with a high precision and with a high resolution in missing mass?
  Such measurements will shed more light on the questions surrounding the nature of diproton resonances.

- Surely, it is very important to perform systematic studies and precise calculations using quantum field theoretical methods. In this respect we hope that the discovery of quasicrystal structure of the vacuum in quantum field theory [12] will help us to understand the new sites of the fundamental dynamics.

Acknowledgments

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