Possible observation of narrow two-proton resonances in hadron-nucleus interactions

S. A. Azimov, M. L. Allaberdin, S. O. Edgorov, Sh. V. Inogamov, E. A. Kosonovskiĭ, V. D. Lipin, S. L. Lutpullaev, K. T. Turdaliev, A. A. Yuldashev, and B. S. Yuldashev
Physicotechnical Institute, Academy of Sciences of the Uzbek SSR

(Submitted 4 May 1984; resubmitted 3 August 1984)
Pis'ma Zh. Eksp. Teor. Fiz. **40**, No. 7, 316–318 (10 October 1984)

Narrow structural features have been detected in the effective-mass spectrum of pairs of protons produced in $\pi^- {}^{12}C$ interactions at 4 and 40 GeV/c and in $p^{20}Ne$ collisions at 300 GeV/c. These structural features may be evidence of the existence of diproton resonances.

The possible existence of multibaryon resonances, particularly dibaryon resonances, has attracted intense interest for many years,[1] but particularly in recent years because of the formulation of several theoretical concepts according to which such resonances should exist in nature.[2] Dibaryon states have been sought in various experiments, and already there are indications of the possible observation of narrow resonances in the two-proton system and in the $\Lambda^0 p$ system.[3]

In this letter we report a search for two-proton resonances in $\pi^- {}^{12}C$ interactions at 4 and 40 GeV/c and in $p^{20}Ne$ collisions at 300 GeV/c. The experimental data were obtained from 55- and 200-cm bubble chambers filled with propane (C_3H_8), bombarded by π^- mesons at 4 and 40 GeV/c, respectively, and from a 30-inch bubble chamber filled with NeH_2, exposed to a proton beam at 300 GeV/c. The procedure used to analyze the data from the three experiments is described in detail in Ref. 4. The total number of $p^{20}Ne$ events analyzed in the present study was more than 18 000.

For the search for two-proton resonances we selected $\pi^- {}^{12}C$ and $p^{20}Ne$ interactions having at least two protons in the final state; the protons were identified on the basis of range and ionization. After the measurements, the proton momenta were restricted to the interval $220 \leqslant p \leqslant 400$ MeV/c. The introduction of this lower bound on the proton momenta makes it possible to essentially eliminate the contribution of so-called evaporation nucleons—products of the decay of excited fragments of the nucleus.[4] The upper bound on the proton momentum was set by the accuracy of the momentum measurements required in this experiment; the momenta of about 92% of the protons over the interval $220 \leqslant p \leqslant 400$ MeV/c were determined from the range in the bubble chambers. This circumstance made it possible to determine the effective masses of the proton pairs, $M(2p)$, within a mean square error $\sigma[M(2p)] \leqslant 3$ MeV over the mass interval $2m_p \leqslant M(2p) \leqslant 1970$ MeV, where m_p is the proton mass.

Figure 1, a and b, shows distributions in $M(2p)$ in the $\pi^- {}^{12}C$ and $p^{20}Ne$ interactions; the data for $\pi^- {}^{12}C$ at 4 and 40 GeV/c have been combined, since the distributions have identical shapes. We see that, regardless of the nature of the incident particle, regardless of its energy, and regardless of the nature of the target nucleus, there

 0021-3640/84/191109-03$01.00

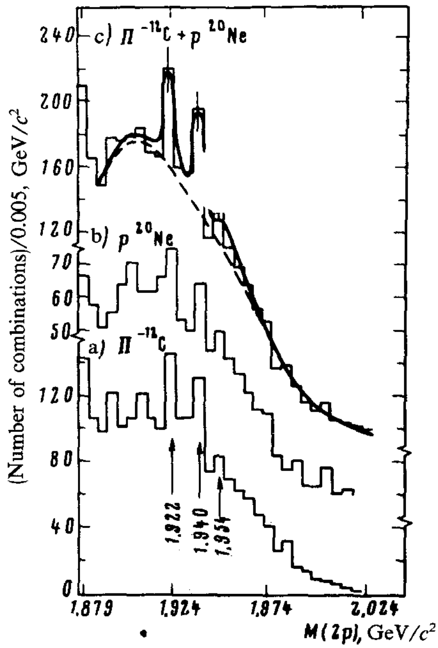

FIG. 1. Effective-mass spectra of pairs of protons with momenta $220 \leqslant p \leqslant 400$ MeV/c produced in π^{-12}C interactions at 4 and 40 GeV/c (a) and in p^{20}Ne collisions at 300 GeV/c (b). Figure 1c shows the overall spectrum in $M(2p)$. Dashed curve—Background distribution; solid curve—approximation of the experimental data by the sum of a background spectrum and three Breit-Wigner functions.

are statistically significant peaks in the distributions in the effective mass of pairs of protons with momenta in the interval $220 \leqslant p \leqslant 400$ MeV/c. These peaks occur at the following values of $M(2p)$: $\cong 2m_p$, $\cong 1924$, $\cong 1939$, and, possibly, $\cong 1950$ MeV. The first peak, at $M(2p) \cong 2m_p = 1877$ MeV, is known to be due to a final-state interaction of the protons, as discussed in detail in Ref. 5. The other three spikes are seen particularly clearly when the data for the three energies are combined (Fig. 1c).

The peaks at the higher values of $M(2p)$ may be evidence of the existence of narrow dibaryon resonances with relatively small widths. We wish to emphasize that these peaks were observed in three independent experiments, carried out at different primary energies (4, 40, and 300 GeV) and in different types of interactions (π^{-12}C and p^{20}Ne). It can thus be concluded that the structural features observed in the effective-mass spectra of the pairs of protons are apparently attributable to the presence of diproton resonances, rather than to statistical fluctuations.

The dashed curve in Fig. 1c is the background distribution found by randomly mixing protons with momenta $220 \leqslant p \leqslant 400$ MeV/c from different events (π^{-12}C and p^{20}Ne, respectively), but with an identical number of final-state protons. The first two peaks in the $M(2p)$ spectrum exceed the background distribution by 4.1 and 4.5 statistical errors, respectively. The solid curve is an approximation of the resultant experimental distribution in $M(2p)$ by the function

$$\frac{dN}{dM(2p)} = \alpha\phi\,[M\,(2p)\,] + \sum_{i=1}^{3} \beta_i BW_i[M(2p)\,],$$

where $\phi\,[M(2p)]$ is the background distribution; $BW_i\,[M(2p)]$, $i = 1,2,3$, are the Breit-Wigner functions, in which the experimental errors in the determination of $M(2p)$ are taken into account; and α and β_i are the relative contributions of the background distribution and of the resonances. This approximation yields the following values for the mass M and the width Γ of the resonances (the value of χ^2 divided by the number of degrees of freedom is 1.2):

$M_1 = 1922 \pm 1.3$ MeV; $\Gamma_1 = 11 \pm 3.6$ MeV;
$M_2 = 1940 \pm 0.4$ MeV; $\Gamma_2 = 10 \pm 4.5$ MeV;
$M_3 = 1954 \pm 5$ MeV; $\Gamma_3 = 21 \pm 20$ MeV.

We have previously[6] pointed out the possible existence of a diproton resonance at the mass $M(2p) \cong 1922$ MeV.

It can thus be concluded from this analysis of experimental data that narrow diproton resonances with isospins $T = 1$ can be observed in collisions of pions and protons with light nuclei (^{12}C and ^{20}Ne). By way of example, we note that the total inclusive cross section for the production of these resonances in $p^{20}Ne$ interactions at 300 GeV/c is, with a probability of 90%, smaller than 4 mb, in comparison with the total inelastic cross section $\sigma_{in}(p^{20}Ne) = 356 \pm 13$ mb.

[1]G. A. Leksin, in: Problemy sovremennoĭ yadernoĭ fiziki (Current Problems in Nuclear Physics), Nauka, Moscow, 1972, p. 511; M. M. Makarov, Usp. Fiz. Nauk **136**, 185 (1982) [Sov. Phys. Usp. **25**, 83 (1982)].

[2]R. J. Jaffe, Phys. Rev. Lett. **38**, 195 (1977); V. A. Matveev and P. Sorba, Lett. Nuovo Cimento **20**, 425 (1977); M. Imachi *et al.*, Prog. Theor. Phys. **55**, 551 (1976); M. H. MacGregor, Phys. Rev. D **20**, 1616 (1979).

[3]I. P. Auer *et al.*, Phys. Rev. Lett. **41**, 1436 (1978); B. A. Shakhbazyan, Preprint E1-82-446, Joint Institute for Nuclear Research, Dubna, 1982, V. V. Glagolev *et al.*, Preprints E1-83-59, 1-83-556, R1-83-565, Joint Institute for Nuclear Research, Dubna, 1983; A. A. Baĭramov *et al.*, Preprint R1-83-207, Joint Institute for Nuclear Research, Dubna, 1983; K. Beshliu *et al.*, Report D1-83-815, Joint Institute for Nuclear Research, Dubna, 1983.

[4]S. A. Azimov *et al.*, Yad. Fiz. **23**, 987 (1976) [Sov. J.Nucl. Phys. **23**, 519 (1976)]; **22**, 1168 (1975) [Sov. J. Nucl. Phys. **22**, 608 (1975)]; Pis'ma Zh. Eksp. Teor. Fiz. **23**, 231 (1976) [JETP Lett. **23**, 208 (1976)]; Yad. Fiz. **32**, 1560 (1980) [Sov. J. Nucl. Phys. **32**, 808 (1980)];**39**, 662 (1984) [Sov. J. Nucl. Phys. **39**, 420 (1984)]; Nucl. Phys. **107**, 45 (1976).

[5]S. A. Azimov *et al.*, Pis'ma Zh. Eksp. Teor. Fiz. **36**, 349 (1982) [JETP Lett. **36**, 428 (1982)]; Yad. Fiz. **38**, 1461 (1983) [Sov. J. Nucl. Phys. **38**, 890 (1983)]; Phys. Rev. D **29**, 1304 (1984).

[6]S. A. Azimov *et al.*, Yad Fiz. **19**, 317 (1974) [Sov. J. Nucl. Phys. **19**, 156 (1974)].

Translated by Dave Parsons
Edited by S. J. Amoretty