Fishing for Narrow Dibaryons in \( pd \rightarrow pX \) Reaction

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Abstract. An analysis of new experimental data, obtained at Linear Accelerator of INR, is carried out with the aim of searching for supernarrow dibaryons in the reactions \( pd \rightarrow p + X \) and \( pd \rightarrow p + pX_1 \). Dibaryons with masses 1904\( \pm \)2, 1926\( \pm \)2, and 1942\( \pm \)2 MeV have been observed in missing mass \( M_X \) spectra. In missing mass \( M_{X_1} \) spectra, the resonancelike states \( X_1 = \gamma + n \) at \( M_{X_1} = 966 \pm 2, 986 \pm 2, \) and 1003\( \pm \)2 MeV have been found. The analysis of the data obtained leads to the conclusion that the observed dibaryons are supernarrow dibaryons, the decay of which into two nucleons is forbidden by the Pauli exclusion principle.

In Ref. [1–3] the study of the reaction \( pd \rightarrow pX \) was performed with the aim of searching for supernarrow dibaryons (SND), the decay of which into two nucleons is forbidden by the Pauli exclusion principle [4–6]. Such dibaryons with the mass \( M < 2m_N + m_\pi \) can decay into two nucleons, mainly emitting a photon. The experiment was carried out at 305 MeV using the two-arm spectrometer TAMS. As was shown in Ref. [2,3], the nucleons and the deuteron from the decay of SND into \( \gamma NN \) and \( \gamma d \) have to be emitted in a narrow angle cone with respect to the direction of motion of the dibaryon. On the other hand, if a dibaryon decays mainly into two nucleons, then the expected angular cone of emitted nucleons must be more than 50\( ^\circ \). Therefore, a detection of the scattered proton in coincidence with the proton (or the deuteron) from the decay of particle \( X \) at correlated angles allowed to suppress essentially the contribution of the background processes and to increase the relative contribution of a possible SND production. As a result, two narrow peaks in missing mass spectra have been observed at \( M =1905 \) and 1924 MeV. The analysis of the angular distributions of the protons from the decay of particle \( X \) showed that the peak found at 1905 MeV most likely corresponds to a SND with isotopic spin equal to 1. In Ref. [3] arguments were presented for the resonance at \( M =1924 \) MeV is a SND, too.

In the present paper we give the results of an analysis of new experimental data
of $pd \to p + X$ and $pd \to p + pX_1$ reactions at 305 MeV. Experiment was performed using the spectrometer TAMS, the properties of which were described elsewhere [3]. CD$_2$ and C$^{12}$ were used as targets. In this experiment, the scattered proton was detected in the left arm of the spectrometer TAMS at the angle $\theta_L = 70^\circ$. The second charged particle (either $p$ or $d$ from the decay of $X$ state) was detected in the right arm by three telescopes located at $\theta_R = 34^\circ$, 36$^\circ$, and 38$^\circ$.

As follows from the present experiment, the main contribution into resonances observed here is given by processes where the second charged particle is a proton. The experimental missing mass $M_X$ spectra obtained with the CD$_2$ target are shown in Figs. 1(a-c), where (a), (b), and (c) correspond to a detection of the proton from the decay of $X$ states in the right arm detector at $\theta_R = 34^\circ$, 36$^\circ$, and 38$^\circ$, respectively.

Three peaks at $M_X = 1904 \pm 2$, 1926$\pm$2, and 1942$\pm$2 MeV are observed in these spectra. The first two of them confirmed the values of the dibaryon mass obtained by us earlier [1–3] and the resonance at 1942 MeV is a new one. It is expected [3,6] that isoscalar SNDs contribute mainly into $\gamma d$ channel and isovector SNDs do into $\gamma NN$ one. As the main decay of the found dibaryons is observed into $pX_1$ channel, it is possible to assume that $X_1 = \gamma + n$ and all these states are isovector SNDs. The calculations for the SNDs $D(T = 1, J^P = 1^{\pm})$ showed that the biggest contribution of such dibaryons must be at $\theta_R = 34^\circ$ and 36$^\circ$. The contribution to spectrum at 38$^\circ$ is expected to be several times smaller. These predictions are in agreement with our experimental data. If the observed states are usual $NN$-

![Figure 1](image.png)

**FIGURE 1.** The missing mass $M_X$ spectra for the reaction $pd \to p + X$; (a) $\theta_R = 34^\circ$, (b) $\theta_R = 36^\circ$, (c) $\theta_R = 38^\circ$.
coupled dibaryons decaying mainly into two nucleons then their contributions to the missing mass spectra in Fig.1(a), 1(b), and 1(c) would be nearly the same and would not exceed a few events. Hence, the peaks found most likely correspond to isovector SNDs.

The summary spectrum over angles $\theta_R = 34^\circ$ and $36^\circ$ is presented in Fig. 2a. This spectrum was interpolated by a second order polynomial (for the background) plus Gaussians (for the peaks). The numbers of standard deviations are 6.0, 7.0, and 6.3 SD for resonances at 1904, 1926, and 1942 MeV, respectively.

An additional information about the nature of the observed states is given by study of the missing mass $M_{X_1}$ spectra of the reaction $pd \rightarrow p + pX_1$. If the state found is a dibaryon decaying mainly into two nucleons then $X_1$ is a neutron and

**FIGURE 2.** The missing mass $M_X$ (a) and $M_{X_1}$ (b) for the sum of angles of $\theta_R = 34^\circ$ and $\theta_R = 36^\circ$. 
the mass \( M_{X_1} \) is equal to the neutron mass \( m_n \). If the value of \( M_{X_1} \), obtained from the experiment, differs essentially from \( m_n \) then \( X_1 = \gamma + n \) and we have the additional indication that the observed dibaryon is SND.

The simulation of mass spectra for the reaction \( pd \to p + pX_1 \), where \( pX_1 \) are decay products of SNDs with masses 1904, 1926, and 1942 MeV, gave peaks at \( M_{X_1} = 965, 987, \) and 1003 MeV, respectively. Fig. 2b demonstrates the missing mass \( M_{X_1} \) spectrum obtained from the experiment for the sum of the angles \( \theta_R = 34^\circ \) and \( 36^\circ \). As is seen from this figure, besides the peak at neutron mass, which caused by the process \( pd \to p + pn \), resonance-like behavior of the spectrum is observed at \( 966 \pm 2, 986 \pm 2, \) and 1003 \( \pm 2 \) MeV. These values of \( M_{X_1} \) coincide with the ones obtained from the simulation and differ essentially from the value of the neutron mass. Hence, for all states under study, \( X_1 = \gamma + n \) and the dibaryons found are really SNDs.

It should be noted that a resonance-like behavior of \( X_1 \) at \( M_{X_1} = 1003 \pm 2 \) MeV corresponds to the resonance found in [7] and attributed to an excited nucleon state \( N^* \). In this work, the authors brought out three such states with masses 1004, 1044, and 1094 MeV. Taking into account the found connection between the SNDs and the resonance-like states \( X_1 \), it is possible to assume that the peaks, observed in [7] are not the excited nucleons, but they are resonance-like states \( X_1 \) caused by possible existence and decay of SNDs with the masses 1942, 1982, and 2033 MeV, respectively.

The following conclusion can be made. As a result of the study of the reaction \( pd \to pX \) and \( pd \to p + pX_1 \) three narrow peaks at 1904, 1926, and 1942 MeV have been observed in the missing mass \( M_X \) spectra. The analysis of the angular distributions of the protons from decay of \( X \) states showed that the peaks found can be explained as a manifestation of the SNDs, the decay of which into two nucleons is forbidden by the Pauli exclusion principle. The observation of the resonance-like structures in the missing mass \( M_{X_1} \) spectra at 966, 986, and 1003 MeV is an additional confirmation that the dibaryons found are really SNDs.

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