# A SIGNAL OF A NARROW $\pi$NN-RESONANCE IN $pp \to pp\pi^-\pi^+$ AND IN THE PIONIC DOUBLE CHARGE EXCHANGE* **

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We report on the current status of the search for the $\pi$NN resonance $d'$ with $I(J^P) = 0(0^-)$ and $M = 2.06$ GeV in the $2\pi$ production in pp collisions as well as in the pionic double charge exchange.

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## 1. Introduction

Recently the existence of a narrow, NN-decoupled $\pi$NN resonance, called $d'$, has been proposed [1, 2] to explain the peculiar resonance-like behavior of the pionic double charge exchange (DCX) reaction $(\pi^+, \pi^-)$ on nuclei at pion energies below the $\Delta$ resonance. From the analysis of these DCX data the parameters of $d'$ have been deduced to be $m \approx 2.06$ GeV, $\Gamma_{NN\pi} \approx 0.5$ MeV and $I(J^P) =$ even $(0^-)$. From the small width it was concluded that this resonance is NN-decoupled, hence the isospin should be even. A major critique on this interpretation was that the DCX reaction takes place on nuclei, where subtle, not yet understood medium effects cannot be excluded unambiguously as a possible alternative reason. To meet this critique, we have carried out a series of different and alternative experiments:

1. Extension of our systematic DCX studies to closed-shell and to light nuclei, in particular to non-analog transitions, where conventional mechanisms are expected to give particularly small cross sections;
2. Investigation of the $2\pi$ production in pp collisions according to $pp \rightarrow d'\pi^+ \rightarrow pp\pi^-\pi^+$, where the NN-decoupled resonance $d'$ could be produced hadronically in an elementary reaction. The $d'$ contribution there has been estimated [3, 4] to be in the order of (3 - 10)% of the conventional $2\pi$ cross section near the $d'$ threshold, which is expected to be around $T_p \approx 710$ MeV. In case of $I = 0$ the $d'$ should show up only in the invariant-mass spectrum $M_{pp\pi^-}$, whereas in case of $I = 2$ the resonance would appear both in $M_{pp\pi^-}$ and in $M_{pp\pi^+}$;
3. Study of the reaction $\gamma + d \rightarrow d' \rightarrow \pi^0 pn$, the photoproduction on the deuteron, which has the advantage of being a resonance reaction on a simple system [5]. At resonance energy $E_\gamma \approx 200$ MeV we expect a resonance cross section of $\sigma_{d'} \leq 1\,\mu$b. This has to be compared with the corresponding $1\pi$-production cross sections at this energy. The quasifree or incoherent photoproduction of neutral pions, $d(\gamma, \pi^0)np$ has a much smaller cross section ($\approx 20\,\mu$b) than the production of charged pions ($\approx 120\,\mu$b - $160\,\mu$b). A further background reaction in the $\pi^0$-channel is the coherent $\pi^0$-photoproduction with a predicted cross section of $40\,\mu$b. The total cross section for background reactions in the $\pi^0$-channel is therefore $\sigma_{tot}(\gamma, \pi^0) \approx 60\,\mu$b, which is a factor of 20 larger than the expected cross section for $d'$-formation. However, a coincident detection of $\pi^0$ and n in the experiment will eliminate the background from the coherent $\pi^0$-photoproduction. Based on these considerations first measurements have been carried out very recently with the TAPS-setup at MAMI. The data analysis just started, hence no results are available yet.

Here we report on latest results concerning the DCX and the $2\pi$ production in pp collisions.

## 2. DCX

The DCX measurements have been carried out with the LEPS spectrometer at PSI. Fig. 1 shows our results on $^{16}O$ and $^{40}Ca$ for the forward angle cross section, together with the LAMPF-data at higher energies. In both cases the broad structure due to the excitation of the $\Delta$-resonance is accompanied by a narrow, very pronounced one at low energies, which is very well accounted for by the $d'$ hypothesis (dark shaded areas in Fig. 1). This structure is also observed in our most recent measurements on $^{7}Li$, which constitutes the lightest nucleus, where the DCX can proceed to a quasi-binary final state with $^{7}B_{g.s.}$ being already proton instable. Inasmuch as the $\alpha$-core can be considered as a spectator, this measurement constitutes already the observation of the $d'$ signature in a 3N-system. In summary, the peculiar structures observed in the DCX even on the lightest nuclei are consistent with the formation [1, 2] or production [6] of $d'$ in the course of the DCX process.

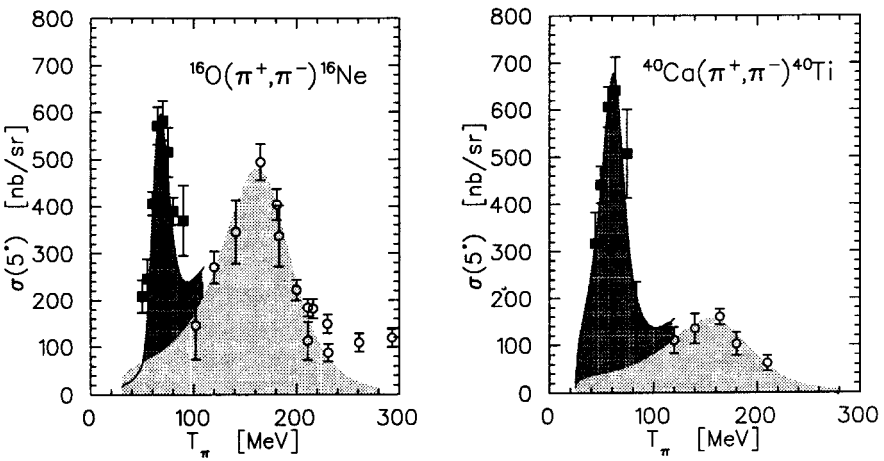


Fig. 1. Energy excitation functions for the DCX reaction on $^{16}O$ and $^{40}Ca$. The data points marked by black squares have been obtained by the LEPS collaboration.

## 3. $2\pi$ production in pp collisions

A cleaner way to produce the $d'$ hadronically without the complication of a nuclear medium is the reaction $pp \to d'\pi^+ \to pp\pi^-\pi^+$ with the advantage of having four charged particles in the exit channel.

Here we report on the first exclusive measurement of the reaction $pp \to pp\pi^-\pi^+$ at $T_p = 750$ MeV [7] using a $H_2$ cluster jet target. All previous measurements of this reaction in this energy region have been inclusive and/or difference measurements on $CH_2$ and C targets. The experiment was carried out at the CELSIUS storage ring using the detector setup of the WASA/PROMICE collaboration [8]. For the data presented here only events registered in the forward detector, a segmented plastic scintillation calorimeter covering the angular range $4° \leq \theta \leq 21°$ have been used. Since the present setup contains no magnetic field, the delayed pulse technique has been used for $\pi^+/\pi^-$ discrimination. Whereas $\pi^-$ undergoes hadronic absorption when stopped in matter, $\pi^+$ particles undergo weak decays leading to delayed pulses in the scintillator by the succeeding $\pi^+ \to \mu^+\nu_\mu$ and $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$ decays. Naturally, this allows only for a positive $\pi^+$ identification, here, with an efficiency of about 60%. The trigger was set to at least 3-prong events in the forward detector, thus suppressing events from single pion production. A dominant source of background in these events comes from low-energy electrons/positrons, which result from conversion of $\pi^0$ decay photons. By requiring the kinematic limits for $2\pi$ production in the missing mass of the two protons and by requiring a delayed pulse for $\pi^+$ identification this background could be removed completely. For the

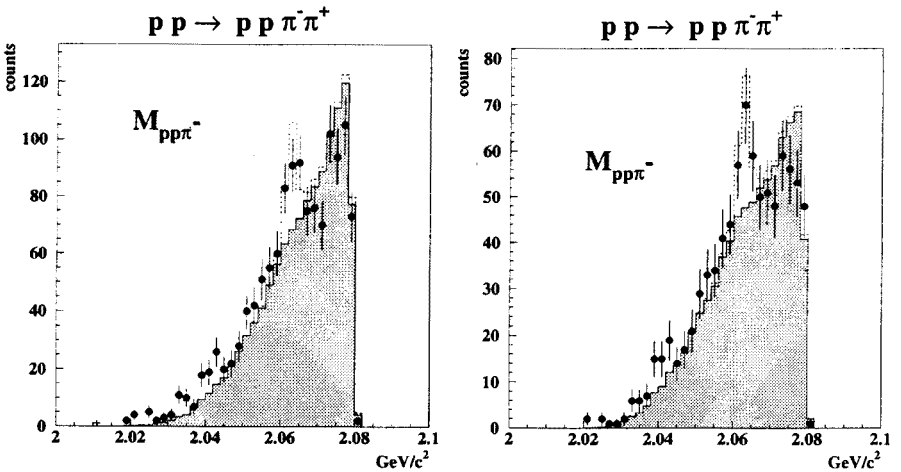


Fig. 2. Invariant-mass spectrum $M_{pp\pi^-}$ of the reaction $pp \to pp\pi^-\pi^+$ at $T_p = 750$ MeV with (right) and without (left) constraints on the missing-mass spectrum $MM(pp\pi^+)$. The solid histograms show the MC simulations of the conventional $2\pi$ production process, the dashed ones show the result with inclusion of the $d'$ production process.

final $2\pi$ production events selected we demand two identified protons and one identified $\pi^+$ particle. The thus selected events are kinematically complete. The missing-mass spectrum of these identified $pp\pi^+$ events peaks as expected right at the mass of the unidentified $\pi^-$ particle.

Using the momentum and energy information of the identified $\pi^+$ from these selected $pp\pi^+$ events together with the corresponding information of the beam, we obtain the $M_{pp\pi^-}$ spectrum as shown on the top of Fig. 2.

If in addition we require the missing mass of the registered $pp\pi^+$ event, i.e. the mass of the unobserved $\pi^-$, to be in the range of 130 MeV – 150 MeV, then we obtain the $M_{pp\pi^-}$ spectrum as shown at the bottom of Fig. 2. On top of a smooth distribution we observe in both cases a narrow irregularity around 2.063 GeV with a statistical significance of about $4\sigma$ relative to the Monte-Carlo (MC) simulations for the conventional $2\pi$ production (shaded histogram in Fig. 2). For these simulations a pure phase space distribution of the conventional $2\pi$ production process has been assumed. Since the experimental resolution is $\Delta M_{pp\pi^-} \approx 3\,\mathrm{MeV}$ (FWHM), this observed irregularity fits very well both in energy and width to the conclusions from DCX experiments. The observed signal from $d'$ would mean that there are more states in the dibaryon system than just the meson-dominated NN ground state, the deuteron and the virtual $^1S_0$ level. Further measurements to increase the statistics are in progress.

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