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SEARCHES FOR CHARMED PENTAQUARKS AT CDF

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Recently the H1 Collaboration observed a narrow peak in $D^{*-}p$ invariant mass spectrum from what is believed to be an anti-charmed pentaquark baryon state with $(\bar{c}dudu)$ quark content, produced in deep inelastic scattering in ep collisions at HERA. This new state was tentatively named Θ_c^0 as being an anti-charmed analog of Θ^+ pentaquark discovered in 2003 by LEPS Collaboration. The upgraded CDF detector is sensitive to production of charmed pentaquark states in central rapidity region due to ability to trigger on displaced tracks from weakly decaying daughter hadrons. At this conference we report results of searches for anti-charmed pentaquark Θ_c^0 and its charged isospin partner Θ_c^+ in $p\bar{p}$ collisions at $\sqrt{s} = 1.96\,\mathrm{TeV}$ at Tevatron.

Keywords: spectroscopy; baryons; pentaquarks; charmed hadrons.

Searches for states, characterized by exotic quantum numbers, i.e. quantum numbers that cannot be obtained from minimal $(q\bar{q})$ or (qqq) configurations of standard mesons and baryons, have taken place since the introduction of QCD. Until recently, these searches yielded very little conclusive evidence for such states.

During 2003, however, the situation has changed dramatically. Many experiments using incident beams of real and quasi-real photons, kaons and neutrinos reported evidence for a narrow resonance decaying to nK^+ [1]. The state has an exotic quantum number, positive strangeness, and cannot exist in a simple three-quark model. A pentaquark interpretation was employed suggesting the quark content to be $(\bar{s}udud)$. Most remarkably the pentaquark state at this mass was predicted earlier in chiral soliton model of baryons [2]. Later followed observations of exotic S=-2 baryon state by NA49 [3] and anti-charmed baryon state by H1 experiment [4].

However all pentaquark observations are based on relatively small data samples. While the Θ^+ has been seen by several experiments, an independent confirmation of the $\Phi^{--,0}$ and Θ_c states has not been made. Definitely high statistics experiments are needed to establish pentaquark states unambiguously.

In this paper we describe searches for (anti)charmed pentaquark states using data produced in $p\bar{p}$ collision at $\sqrt{s} = 1.96$ TeV and recorded with the upgraded CDFII detector at Tevatron, Fermilab. The data sample comprised integrated lu-

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minosity of 240 pb^{-1}.

To expand its B-physics reach the CDF detector was instrumented with Silicon Vertex Trigger (SVT) which triggers on fully hadronic and semileptonic decays of heavy flavor hadrons. The trigger requires presence of two oppositely charged tracks each having $p_T > 2$ GeV/c and impact parameter with respect to the beam (d_0) to fall within the range $120\,\mu\text{m} < |d_0| < 1\,\text{mm}$. In addition a scalar sum of two tracks' transverse momenta is required to be greater than $5.5\,\text{GeV/c}^2$. This trigger efficiently selects very clean samples of D-mesons making CDF especially sensitive to pentaquarks decaying to D-mesons+proton in the final state. The H1 Collaboration found that the fraction of Θ_c^0 is roughly 1% of the total D^* production [4]. Assuming that the dominant production mechanism of Θ_c^0 in deep inelastic ep collisions is fragmentation of the c-quark produced in $\gamma^* p \to c\bar{c}$, the CDF should see $\sim 10^4$ per 100 pb^{-1} [5].

We searched for pentaquarks strongly decaying to $D^{*-}p$, D^-p, $\bar{D}^0p$ and D^0p with subsequent decays $D^{*-} \to \bar{D}^0\pi^-$, $D^- \to K^+\pi^-\pi^-$ and $\bar{D}^0 \to K^+\pi^-$. No kinematic cuts were applied to pentaquark candidates except the requirement that two oppositely charged tracks contributing to pentaquark candidate passed SVT trigger track matching. Vertex fit quality cuts, mass windows and vertex constraints were worked out on reference D^{**} signals having similar D-meson+track final states and similar decay kinematics. The proton identification procedure was based on combined likelihood ratio calculated from measurements of specific ionization and time-of-flight for allowed mass hypotheses (e, μ, π,K and p). A track was treated as proton if the corresponding likelihood ratio exceeded 40%.

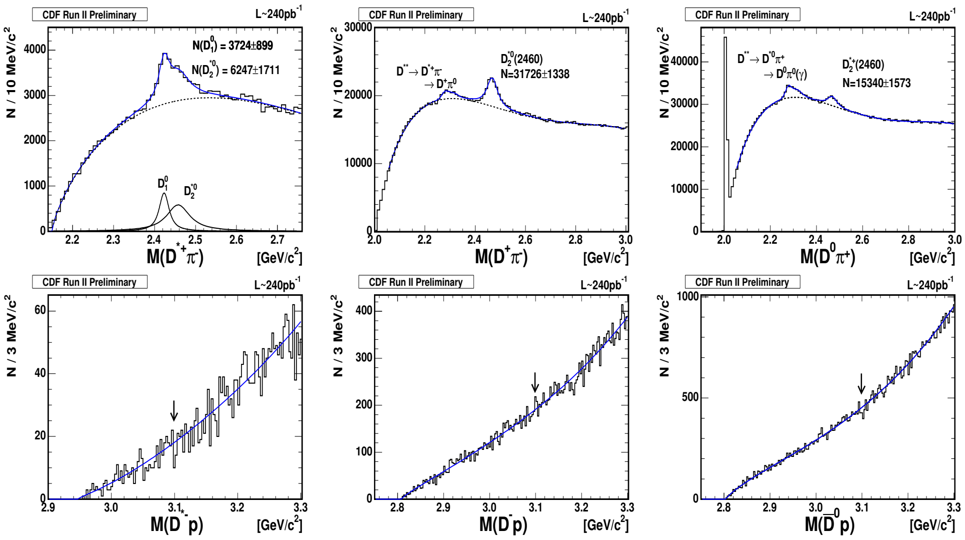

Fig. 1. Top row: reference D^{**} signals, from left to right, $D^{*+}\pi^-$, $D^+\pi^-$ and $D^0\pi^+$. Bottom row: from left to right, $D^{*-}p$, D^-p and $\bar{D}^0p$ invariant mass spectra

The reference D^{**} signals are shown in the top row of histograms in Figure 1. High statistics signals from $D_2^{*0} \to D^{*+}\pi^-$, $D_1^0 \to D^{*+}\pi^-$, $D_2^{*0} \to D^+\pi^-$ and $D_2^{*+} \to D^-\pi^+$ decays can be seen in corresponding invariant mass spectra. Feed-downs from D^{**} decays involving lost neutrals are present as broad lower mass bumps in $D^+\pi^-$ and $D^0\pi^+$ spectra with the latter dominated by huge $D^{*+} \to D^0\pi^+$ signal at the threshold. The invariant mass spectra of $D^{*-}p$, D^-p and $\bar{D}^0p$ are shown in the lower row of Figure 1. Arrows mark position of the Θ_c pentaquark. The expected detector mass resolution at $3.099\,\mathrm{GeV/c^2}$ is $2.4\,\mathrm{MeV/c^2}$ for $D^{*-}p$ mode and $\sim 3\,\mathrm{MeV/c^2}$ for D^-p and $\bar{D}^0p$ modes. Apparently no narrow peaks are seen. The superimposed curves show the results of unbinned maximum likelihood fits using background function consisted of polynomials multiplied by exponential threshold factors. Table 1 summarizes event yields in reference modes and upper limits on charmed pentaquark event yields at 90%.

Table 1. Event yields in reference D^{**} decay modes and upper limits on event yields in Θ_c decay modes

Reference modes		Pentaquark modes	
Channel	Yield	Channel	Yield
$\mathrm{N(D_2^{*0}) \to D^{*+}\pi^-}$	6247 ± 1711	$\mathrm{\Theta_c^0 \to D^{*-}p}$	< 21 @ 90 % CL
$\mathrm{N(D_1^0) \to D^{*+}\pi^-}$	3724 ± 899		
$\mathrm{N(D_2^{*0}) \to D^+\pi^-}$	31726 ± 1338	$\mathrm{\Theta_c^0 \to D^-p}$	< 80 @ 90 % CL
$\mathrm{N(D_2^{*+}) \to D^0\pi^+}$	15340 ± 1573	$\mathrm{\Theta_c^+ \to \bar{D}^0p}$	< 87 @ 90 % CL
		$\mathrm{\Theta_c^+ \to D^0p}$	< 97 @ 90 % CL

Using high statistics samples of D^{*+}, D^+ and D^0 mesons produced in $p\bar{p}$ interactions at $\sqrt{s}$=1.96 TeV and reconstructed with the detector having excellent momentum resolution and adequate particle identification system we performed a sensitive search for narrow pentaquark states decaying to $D^{*-}p$, D^-p, $\bar{D}^0p$ and D^0p. No signal found in either channel. The analysis technique was tested by demonstrating the ability to reconstruct signals from standard narrow D^{**} resonances having similar decay kinematics. The absence of pentaquark signals suggests that, if existent, charmed pentaquarks are not produced in the process of quark fragmentation or such production is severely suppressed.

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