Pentaquark Searches at *BABAR*

Xin Chen

Physics Department, University of Wisconsin-Madison, Madison, WI 53706, USA
(representing the BABAR collaboration)

Abstract. A review of the pentaquark searches in data collected with the BABAR detetcor at the SLAC PEP-II asymmetric B factory is presented. There are inclusive searches for $\Theta_5(1540)^+$, $\Xi_5(1860)^{--}$, $\Xi_5(1860)^0$ and some other strange pentaquark states, a search for $\Theta_5(1540)^+$ in interactions of beam halo and hadrons with the inner-most detector material, inclusive and exclusive searches for the anti-charmed peentaquark Θ_c^0 claimed by H1 collaboration, and a search for the Θ^{*++} state. All of these searches have yielded negative results.

Keywords: pentaquark, baryon, BABAR
PACS: 13.60.Rj,13.66.Bc,14.20.Lq,14.65.-q,13.85.Rm

INTRODUCTION

Recently several experimental groups have reported observations of a new, manifestly exotic (B=1, S=1) baryon resonance $\Theta(1540)^+$ [1]. Also, the NA49 experiment reported evidence for an additional narrow exotic (B=1, Q=S=-2) state $\Xi(1862)^{--}$, as well as a corresponding $\Xi(1862)^0$ state [2]. Several theoretical models predict that the lowest mass states containing u, d and s quarks should occupy a spin-1/2 antidecuplet and octet [5]-[7]. More recently the H1 collaboration reported a narrow exotic charmed (B=1, C=-1) resonance $\Theta_c(3099)^0$ [3]. These results have prompted a surge of pentaquark searches in experimental data of many kinds, mostly with negative results [4]. BABAR has seached for all the reported pentaquark states both inclusively and exclusively, but no eveidence for their existence is seen. The BABAR detector is decribe in [8].

INCLUSIVE AND EXCLUSIVE SEARCHES

In search of $\Theta_5^+(1540)$, we look into the decay $\Theta_5^+ \to pK_s^0, K_s^0 \to \pi^+\pi^-$ [9]. After selection cuts were made to select a good sample of proton and K_s^0 candidates, the invariant mass of pK_s^0 is investigated but no excess is observed near 1540 Mev/c^2, whereas a prominent signal of $\Lambda_c(2285)^+$ decay is visible. There is good agreement on the resolution of Λ_c^+ between Monte Carlo (MC) simulation and data and we expect Θ_5^+ resolution to be about 2 MeV. The pK_s^0 decay mode is also possible for the predicted Σ_5^+ state. However, there is no sign of it either. The search result is quantified by setting an upper limit on the Θ_5^+ production. The Θ_5^+ signal is modeled by a P-wave Breit-Wigner convoluted with the resolution function. Background is modeled by a polynomial times a threhsold factor. Assuming $\mathscr{B}(\Theta_5^+ \to pK_s^0) = 1/4$, the upper limit of Θ_5^+ production at 95% confidence level (CL) is 171fb (363fb) in cross section, or 5×10^{-5}/event

(11×10^{-5}/event) in event rate, for decay width Γ=1 MeV/c^2 (Γ=8 MeV/c^2).

The pK_s^0 mass distribution is also investigated in the electro- and hadro-productions [11]. Such processes are mainly due to beam halo electrons and positrons, and to hadrons produced in the primary e^+e^- collisions, interacting with the detector material. The pK_s^0 vertex distribution reproduces the detector structure geometry very well and indeed we have many events from interactions in the detector materials such as the beam pipe and SVT. However, the pK_s^0 invariant mass distribution does not reveal any structure around 1540 MeV/c^2.

Inclusive searches for $\Xi_5^{--} \to \Xi^-\pi^-$ and $\Xi_5^0 \to \Xi^-\pi^+$, with $\Xi^- \to \Lambda^0\pi^-, \Lambda^0 \to p\pi^-$, are carried out in the primary e^+e^- collisions. The $\Xi^-\pi^-$ ($\Xi^-\pi^+$) invariant mass spectrum shows no structure for Ξ_5^{--} (Ξ_5^0) around 1862 MeV/c^2. However, clear signals of $\Xi^{*0}(1532)$ and $\Xi_c^0(2470)$ are seen in the $\Xi^-\pi^+$ spectrum. The expected resolution near 1862 MeV/c^2 is about 8 MeV/c^2. Using similar methods, the upper limit on Ξ_5^{--} production at 95% CL is found to be 22fb (34fb) in cross section, or 0.74×10^{-5}/event (1.1×10^{-5}/event) in event rate, for decay with hypothesis Γ=1 MeV/c^2 (Γ=18 MeV/c^2), assuming $\mathscr{B}(\Xi_5^{--} \to \Xi^-\pi^-) = 1/2$. The obtained upper limit on Θ_5^+ and Ξ_5^{--} in event rate (events per $e^+e^- \to q\overline{q}$, where $q = u,d,s,c$) are found to be 8-15 and 4-6 times lower than expected for conventional baryons of similar masses, depending on the decay width hypothesis.

There are also seaches for the strange pentaquarks Ξ_5^0 and N_5^0 decaying into $\Lambda^0K_s^0$. Clear signal is found for Ξ_c^0, but no strucure shows up around 1862 MeV/c^2. Similarly, Ω^- is seen in the Λ^0K^- spectrum in search for possible Ξ_5^-, and Λ_c^+ is seen in the Λ^0K^+ spectrum in search for N_5^+. Both of them yield negetive result. Mass combinations of Σ^0K^-, Σ^0K^+ and $\Sigma^0K_s^0$ are also investigated in search for Ξ_5^-, Ξ_5^+/N_5^+ and Ξ_5^0, respectively, but none of these has pentaquark evidence either.

A search for the anti-charmed pentaquark Θ_c^0 with quark content $uudd\bar{c}$ is performed at BABAR inclusively in the decay mode $\Theta_c^0 \to pD^{*-}, D^{*-} \to \overline{D}^0\pi^-$ ($\overline{D}^0 \to K^+\pi^-$ or $K^+\pi^-\pi^-\pi^+$). However, there is no narrow structure around 3099 MeV/c^2 as claimed by H1. It is shown that the resolution of Θ_c^0 is about 3 MeV/c^2 from MC. It's useful to note that H1 has reconstructed about 3,500 D^{*-} (using $\overline{D}^0 \to K^+\pi^-$), 550 of which appear in the mass plot. With a signal yield 51$\pm$11, the observed Θ_c^0 account for 1/70 of their D^{*-} production. In contrast, BABAR reconstructes 750,000 D^{*-}, 128,000 of which has a qualified proton, but no Θ_c^0 signal is found.

In addition to the inclusive search for Θ_c^0, there is exclusive search for it in the decays $B^0 \to D^{(*)-}p\overline{p}\pi^+$, where $D^{*-} \to \overline{D}^0\pi^-$ ($\overline{D}^0 \to K^+\pi^-$, $K^+\pi^-\pi^-\pi^+, K^+\pi^-\pi^0$), and $D^- \to K^+\pi^-\pi^-$. After a number of selection criteria required on the B^0 sample, pD^{*-} or pD^- mass distributions are visited and there is no Θ_c^0 signal found. However, there is a threshold enhancement effect seen in the $p\overline{p}$ mass distribution which is previously reported by BES [12].

A search for the strange pentaquark Θ^{*++}, with a quark content $uuud\bar{s}$, is done in the decay $B^+ \to p\overline{p}K^+$ [10]. There is 566$\pm$29 signal events found in the signal region and some charmonium states such as J/ψ, η_c, χ_c and $\psi(2S)$ are observed. The $p\overline{p}$ threshold enhancement effect is also seen. However, the Θ^{*++} is not seen and an upper limit on $\mathscr{B}(B^+ \to \Theta^{*++}\overline{p}) \times \mathscr{B}(\Theta^{*++} \to pK^+)$ is set in a range of Θ^{*++} masses, which is on the order of 10^{-7} at 90% CL and comparable to the limit set by BELLE [13] in the same decay mode.

CONCLUSIONS

In conclusion, BABAR has performed searches for the strange pentaquark states $\Theta_5(1540)^+$, $\Xi_5(1860)^{--}$, $\Xi_5(1860)^0$ and some other states in the $\overline{10} \oplus 8$ multiplet in several decay modes inclusively in the primary e^+e^- annihilations. Large signals of smoe known baryons are found but there are no exesses at the reported pentaquark masses. A search for $\Theta_5(1540)^+$ in electro- and hadro-productions within the inner part of the detedtor gives no evidence either. Inclusive search for the anti-charmed pentaquark Θ_c^0 shows no exess around the mass value claimed by H1. Exclusive search for Θ_c^0 and Θ^{*++} in B meson decays show no evidence for them either.

ACKNOWLEDGMENTS

The author is grateful for the excellent luminosity and machine conditions provided by our PEP-II colleagues, and for the substantial dedicated effort from the computing organizations that support BABAR. The collaborating institutions wish to thank SLAC for its support and kind hospitality. This work is supported by DOE and NSF (USA), NSERC (Canada), IHEP (China), CEA and CNRS-IN2P3 (France), BMBF and DFG (Germany), INFN (Italy), FOM (The Netherlands), NFR (Norway), MIST (Russia), and PPARC (United Kingdom). Individuals have received support from CONACyT (Mexico), A. P. Sloan Foundation,Research Corporation, and Alexander von Humboldt Foundation.

REFERENCES

1. LEPS Collaboration, T. Nakano et al., Phys. Rev. Lett. **91**, 012002 (2003); SAPHIR Collaboration, J. Barth et al., Phys. Lett. **B 572**, 127 (2003); CLAS Collaboration, V. Kubarovsky et al., Phys. Rev. Lett. **92**, 032001 (2004). Erratum; ibid, 049902; DIANA Collaboration, V.V. Barmin et al., Phys. Atom. Nucl. **66**, 1715 (2003); SVD Collaboration, A. Aleev et al., hep-ex/0401024 (2004); HERMES Collaboration, A. Airapetian et al., Phys. Lett. **B 585**, 213 (2004); COSY-TOF Collaboration, M. Abdel-Bary et al., Phys. Lett. **B 595**, 127 (2004);
2. NA49 Collaboration, C. Alt et al., Phys. Rev. Lett. **92**, 042003 (2004).
3. H1 Collaboration, A. Aktas et al., Phys. Lett. **B 588**, 17 (2004).
4. See, e.g. K. H. Hicks, Prog Part Nucl Phys **55**, 647 (2005), and reference therein.
5. D. Diakonov, V. Petrov and M.V. Polyakov, Z. Phys. **A 359**, 305 (1997).
6. M. Karliner and H. Lipkin, hep-ph/0402260 (2004).
7. R. Jaffe and F. Wilczek, Phys. Rev. Lett. **91**, 232003 (2003).
8. B. Aubert et al., BABAR Collaboration, Nucl. Instr. Meth. **A 479** (2002).
9. B. Aubert et al., BABAR Collaboration, Phys. Rev. Lett **95**, 042002 (2005).
10. B. Aubert et al., BABAR Collaboration, Phys. Rev. D **72**, 051101R (2005).
11. J. Coleman, A Search for Pentaquarks at BABAR, Ph.D. Thesis, University of Liverpool (May 2005); BABAR-THESIS-05/015.
12. BES Collaboration, J. Z. Bai et al., Phys. Rev. Lett **91**, 022001 (2003).
13. BELLE Collaboration, M. Z. Wang et al., Phys. Lett. **B 617**, 141 (2005).