PENTAQUARKS

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See pp. 1019–1022 of the 2006 *Review* [1] for the evidence for the $\Theta(1540)$, $\Phi(1860)$, and $\Theta_c(3100)$, and for the early unsuccessful attempts to confirm them. The table below lists papers published since then giving results of further unsuccessful searches. There are experiments at high energies and low; in new reactions and old; there are experiments—some by the same groups that claimed the original discoveries—with orders-of-magnitude greater statistics than before; there are experiments that find 100,000 $\Lambda(1520)$s in $\bar{K}N$, but no hint of a $\Theta(1540)$ in KN. Many of the experiments search over large ranges of mass. The limits on production of a pentaquark given in the last column of the table are at 90 or 95% confidence level; the cross-section limits are in some cases now fractions of a nanobarn. The limits often involve assumptions about the width of the pentaquark, its production angular distribution, or other matters. There is not room (or reason) to give here all the details—for which, see the papers.

There are two or three recent experiments that find weak evidence for signals near the nominal masses, but there is simply no point in tabulating them in view of the overwhelming evidence that the claimed pentaquarks do not exist. The only advance in particle physics thought worthy of mention in the American Institute of Physics "Physics News in 2003" was a false alarm. The whole story—the discoveries themselves, the tidal wave of papers by theorists and phenomenologists that followed, and the eventual "undiscovery" —is a curious episode in the history of science.

Table 1: Unsuccessful searches for pentaquarks. There are ten more unsuccessful searches for the $\Theta(1540)$, nine for the $\Phi(1860)$, and three for the $\Theta_c(3100)$ listed in our 2006 edition [1].

Experiment	Reaction	Energy, etc.	Limits, etc.
Searches for the $\Theta(1540)^+$			
BABAR [2]	$B^0 \to (pK^0_S)\bar{p}$	$\sqrt{s}$ 10.58 GeV	$< 2 \times 10^{-7}$ per B^0
CLAS [3]	$\gamma p \to (nK^+/pK^0_S)K^0$	E_γ 1.6–3.8 GeV	$\sigma < 0.7$ nb, 100k $\Lambda(1520)$
CLAS [4]	$\gamma d \to (nK^+)pK^-$	E_γ 0.8–3.6 GeV	$\sigma < 0.3$ nb
CLAS [5]	$\gamma d \to (nK^+)\Lambda$	E_γ 0.8–3.6 GeV	$\sigma <$ 5–25 nb
COSY-ANKE [6]	$pp \to (pK^0_S)\Lambda\pi^+$	p_p 3.65 GeV/c	$\sigma < 58$ nb
COSY-TOF [7]	$pp \to (pK^0_S)\Sigma^+$	p_p 3.059 GeV/c	$\sigma < 150$ nb
DELPHI [8]	$Z \to (pK^0_S)X$	$\sqrt{s}$ 91.2 GeV	$< 5.1 \times 10^{-4}$ per Z
FOCUS [9]	$\gamma A \to (pK^0_S)X$	$\bar{E}_\gamma$ 180 GeV	400k $\Sigma(1385)^+$
HERA-H1 [10]	$ep \to (p/\bar{p}K^0_S)eX$	$5 < Q^2 < 100$ GeV^2	$\sigma <$ 30–90 pb
KEK-E522 [11]	$\pi^- p \to K^-(X)$	p_π 1.9 GeV/c	$\sigma < 3.9$ nb
L3 [12]	$\gamma^*\gamma^* \to (p/\bar{p}K^0_S)X$	$E_{\gamma\gamma} > 5$ GeV	$\sigma < 1.8$ nb
NOMAD [13]	$\nu_\mu N \to (pK^0_S)X$		< 2.13x10^{-3} per evt
Searches for a pK^+ state			
CLAS [14]	$\gamma p \to (pK^+)K^-$	E_γ 1.8–3.8 GeV	$\sigma < 0.15$ nb
DELPHI [8]	$Z \to (pK^+)X$	$\sqrt{s}$ 91.2 GeV	$< 1.6 \times 10^{-3}$ per Z
JLAB-HALL-A [15]	$ep \to eK^-(X)$	E_e 5 GeV	$< 5\%$ of $\Lambda(1520)$
Searches for the $\Phi(1860)$			
CDF [16]	$\bar{p}p \to (\Xi^-\pi^\pm)X$	$\sqrt{s}$ 1.96 TeV	1.9k $\Xi(1530)^0$
DELPHI [8]	$Z \to (\Xi^-\pi^-)X$	$\sqrt{s}$ 91.2 GeV	$< 2.9 \times 10^{-4}$ per Z
FOCUS [17]	$\gamma N \to (\Xi^-\pi^-)X$	$\bar{E}_\gamma$ 180 GeV	65k $\Xi(1530)^0$
HERA-H1 [18]	$ep \to (\Xi^-\pi^\pm)eX$	$2 < Q^2 < 100$ GeV^2	163 $\Xi(1530)^0$
SERP-EXCHARM [19]	$nC \to (\Xi^-\pi^\pm)X$	$\bar{E}_n$ 51 GeV	1.5k $\Xi(1530)^0$
Searches for the $\Theta_c(3100)$			
BABAR [20]	$e^+e^- \to (pD^{*-})X$	$\sqrt{s}$ 10.58 GeV	125k evts
CHORUS [21]	$\bar{\nu}_\mu A \to \mu^+ X$	$\bar{E}_\nu$ 18 GeV	2262 evts
DELPHI [8]	$Z \to (pD^{*-})X$	$\sqrt{s}$ 91.2 GeV	$< 8.8 \times 10^{-4}$ per Z

References

1. W.-M Yao *et al.*, J. Phys. **G33**, 1 (2006).
2. B. Aubert *et al.*, Phys. Rev. **D76**, 092004 (2007).
3. R. De Vita *et al.*, Phys. Rev. **D74**, 032001 (2006).
4. B. McKinnon *et al.*, Phys. Rev. Lett. **96**, 212001 (2006).
5. S. Niccolai *et al.*, Phys. Rev. Lett. **97**, 032001 (2006).
6. M. Nekipelov *et al.*, J. Phys. **G34**, 627 (2007).
7. M. Abdel-Bary *et al.*, Phys. Lett. **B649**, 252 (2007).
8. J. Abdallah *et al.*, Phys. Lett. **B653**, 151 (2007).
9. J.M. Link *et al.*, Phys. Lett. **B639**, 604 (2006).
10. A. Aktas *et al.*, Phys. Lett. **B639**, 202 (2006).
11. K. Miwa *et al.*, Phys. Lett. **B635**, 72 (2006).
12. P. Achard *et al.*, Eur. Phys. J. **C49**, 395 (2007).
13. O. Samoylov *et al.*, Eur. Phys. J. **C49**, 499 (2007).
14. V. Kubarovsky *et al.*, Phys. Rev. Lett. **97**, 102001 (2006).
15. Y. Qiang *et al.*, Phys. Rev. **C75**, 055208 (2007).
16. A. Abulencia *et al.*, Phys. Rev. **D75**, 032003 (2007).
17. J.M. Link *et al.*, Phys. Lett. **B661**, 14 (2008).
18. A. Aktas *et al.*, Eur. Phys. J. **C52**, 507 (2007).
19. A.N. Aleev *et al.*, Sov. J. Nucl. Phys. **70**, 1527 (2007).
20. B. Aubert *et al.*, Phys. Rev. **D73**, 091101 (2006).
21. G. De Lellis *et al.*, Nucl. Phys. **B763**, 268 (2007).