$\Theta(1540)^+$

$I(J^P) = 0(?^?)$

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$\Theta(1540)^+$ MASS

The note below, from the 2006 Review, lists 10 papers on searches for the $\Theta(1540)$ with negative results. Since then, there have been six more such papers (four of them from the CLAS experiment): AKTAS 06B, DEVITA 06, KUBAROVSKY 06, LINK 06C, MCKINNON 06, and NICCOLAI 06. Two other papers, MIWA 06 and PANZARASA 06, did find a peak at about the right mass, but only at the 2.5-to-2.7 standard deviation level. We will summarize all these results in a table in the 2008 Review.

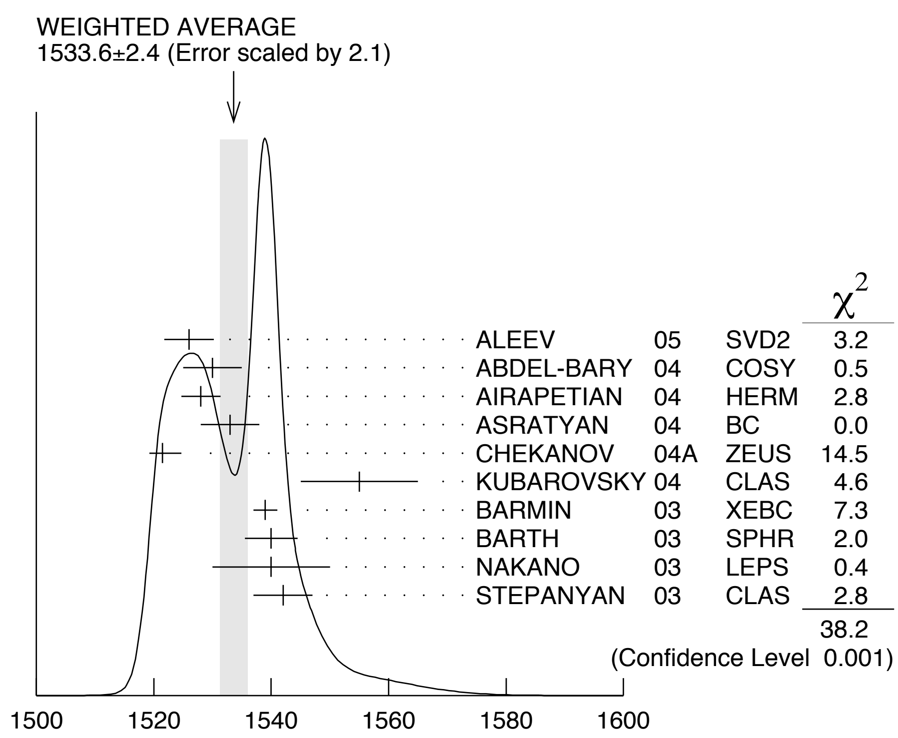
Since our 2004 edition, there have been several new claimed sightings of the $\Theta(1540)^+$ (see entries below marked with bars to the right), but there have also been several searches with negative results:

- ANTIPOV 04 (SPHINX Collab.) in $pN \to (nK^+, pK^0_S$, or $pK^0_L)\ \overline{K}^0 N$ in proton–carbon reactions at 70 GeV/c.
- BAI 04G (BES Collab.) in J/ψ and $\psi(2S)$ decays.
- SCHAEL 04 (ALEPH Collab.) in Z decays.
- ABT 04A (HERA-B Collab.) in p nucleus reactions at midrapidity and $\sqrt{s}$=41.6 GeV.
- LONGO 04 (HyperCP Collab.) in interactions of a high-energy beam of π^+, K^+, p, and charged hyperons with tungsten.
- ADAMOVICH 05 (WA89 Collab.) in Σ^- nucleus $\to K^0_S pX$ at 340 GeV/c.
- BATTAGLIERI 05 (CLAS Collab.) in $\gamma p \to K^0_S K^+ n$ with far greater statistics than BARTH 03 for the same reaction.
- WANG 05A (BELLE Collab.) in $B^+ \to \Theta^{++}\overline{p} \to K^+ p\overline{p}$ and $B^0 \to \Theta^+\overline{p} \to K^0_S p\overline{p}$.
- AUBERT,B 05D (BABAR Collab.) in $e^+e^- \to pK^0_S X$ at the $\Upsilon(4S)$.
- MIZUK 06 (BELLE Collab.) in secondary interactions of low-energy kaons in $KN \to \Theta(1540)^+ X$, $\Theta(1540)^+ \to pK^0_S$ and in $K^+ n \to \Theta(1540)^+ \to pK^0_S$.

In general, these experiments with negative results have many more events than do the experiments with positive results. Some, but not all, involve reactions or energies different from those giving positive results.

Furthermore, the $\Theta(1540)^+$ finds no support from the claimed observations of other pentaquarks, the $\Phi(1860)$ and the $\Theta_c(3100)$; for each of these, there are several non-sightings against a single claim of sighting. (See the Listings following the $\Theta(1540)^+$.) We have reduced the status of the $\Theta(1540)^+$ to no stars.

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
1533.6± 2.4 OUR AVERAGE		Error includes scale factor of 2.1. See the ideogram below.			
1526 ± 3 ±3		[1] ALEEV	05	SVD2	p nucleus $\rightarrow$ $pK^0_S X$
1530 ± 5		[2] ABDEL-BARY	04	COSY	$pp \rightarrow \Sigma^+ K^0 p$
1528.0± 2.6±2.1	59	[3] AIRAPETIAN	04	HERM	$\gamma^* d \rightarrow pK^0_S X$
1533 ± 5	27	[4] ASRATYAN	04	BC	ν, $\overline{\nu}$ in p,d,Ne, BEBC, 15-ft
$1521.5 \pm 1.5^{+2.8}_{-1.7}$	221	[5] CHEKANOV	04A	ZEUS	$\gamma^* p \rightarrow p/\overline{p} K^0_S X$
1555 ±10	41	[6] KUBAROVSKY	04	CLAS	$\gamma p \rightarrow \pi^+ K^- K^+ n$
1539 ± 2	29	[7] BARMIN	03	XEBC	K^+Xe $\rightarrow K^0 p$ Xe$'$
1540 ± 4 ±2	63	[8] BARTH	03	SPHR	$\gamma p \rightarrow nK^+ K^0_S$
1540 ±10	19	[9] NAKANO	03	LEPS	$\gamma\ ^{12}$C $\rightarrow K^+ K^- n$ X
1542 ± 5	43	[10] STEPANYAN	03	CLAS	$\gamma d \rightarrow K^+ K^- pn$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1559 ± 3		[11] GIBBS	04		K^+d total cross section



$\Theta(1540)^+$ mass (MeV)

$\Theta(1540)^+$ WIDTH

Given the systematic uncertainties of the estimates of CAHN 04 and GIBBS 04, we think it more reasonable to give the common value for the width and error rather than average the two values.

VALUE (MeV)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
0.9 ±0.3 OUR ESTIMATE						
0.9 ±0.3			[12] CAHN	04		$K^+ n \to K^0 p$ in xenon
0.9 ±0.3			GIBBS	04	PWA	$K^+ d$ total cross section
• • • We do not use the following data for averages, fits, limits, etc. • • •						
< 0.64	90		[13] MIZUK	06	BELL	$K^+ n \to K^0_S p$
<24			ALEEV	05	SVD2	p nucleus $\to p K^0_S X$
17 ±9 ±3			AIRAPETIAN	04	HERM	$\gamma^* d \to p K^0_S X$
<20			ASRATYAN	04	BC	ν, $\overline{\nu}$ in p,d,Ne, BEBC and 15-ft
8 ±4		221	CHEKANOV	04A	ZEUS	$\gamma^* p \to p/\overline{p} K^0_S X$
<26			KUBAROVSKY	04	CLAS	$\gamma p \to \pi^+ K^- K^+ n$
< 1			[14] SIBIRTSEV	04		$K^+ d \to K^0 p p$ reanalysis
$\lesssim$ 1			[15] ARNDT	03	DPWA	$K^+ N$ partial-wave reanalysis
< 9	90		BARMIN	03	XEBC	$K^+ \mathrm{Xe} \to K^0 p \mathrm{Xe}'$
<25	90		BARTH	03	SPHR	$\gamma p \to n K^+ K^0_S$
<25	90		NAKANO	03	LEPS	$\gamma\, {}^{12}\mathrm{C} \to K^+ K^- n X$
<21			STEPANYAN	03	CLAS	$\gamma d \to K^+ K^- p n$

$\Theta(1540)^+$ DECAY MODES

$N K$ is the only strong decay mode allowed for a strangeness S=+1 resonance of this mass.

	Mode	Fraction (Γ_i/Γ)
Γ_1	$K N$	100%

$\Theta(1540)^+$ FOOTNOTES

[1] ALEEV 05 estimates 50 events over a background of 78, and claims a statistical significance of 5.6 standard deviations.

[2] ABDEL-BARY 04 finds a peak with a statistical significance of 4–to–6 standard deviations, depending on background assumptions. The width is consistent with resolution.

[3] AIRAPETIAN 04, in $e^+ d$ at 27.6 GeV, finds 59 ± 16 events (3.7 σ) in the peak.

[4] ASRATYAN 04 analyzes old BEBC and 15-ft bubble-chamber data and estimates a peak of 27 $K^0 p$ events (mostly from ν, $\overline{\nu}$ in Ne) above a background of 8 events and claims a statistical significance of 6.7 standard deviations.

[5] CHEKANOV 04A, in $e^\pm p$ at c.m. energies near 300 GeV and $Q^2 > 20$ GeV^2, finds 221 ± 48 events (4.6 σ) in the peak.

[6] KUBAROVSKY 04 estimates a peak of 41 $K^+ n$ events and claims a statistical significance of 7.8 ± 1.0 standard deviations.

[7] BARMIN 03 estimates a peak of 29 $K^0 p$ events above a background of 44 events and claims a statistical significance of 4.4 standard deviations.

[8] BARTH 03 estimates a peak of 63 $\pm$ 13 $K^+ n$ events and claims a significance of 4.8 standard deviations.

[9] NAKANO 03 estimates a peak of 19.0 $\pm$ 2.8 $K^+ n$ events above a background of 17.0 $\pm$ 2.8 events and claims a significance of $4.6^{+1.2}_{-1.0}$ standard deviations.

[10] STEPANYAN 03 estimates a peak of 43 $K^+ n$ events above a background of 54 events and claims a statistical significance of 5.2 $\pm$ 0.5 standard deviations.

[11] GIBBS 04 analyses K^+d total-cross-section data with corrections for K^+ double scattering and for the neutron Fermi momentum. Evidence is found for a state at 1559 $\pm$ 3 MeV if it is in the P_{01} wave, or at 1547 $\pm$ 2 MeV if in the S_{01} wave (errors are statistical only).

[12] CAHN 04 uses the integrated $K^+ n \rightarrow K^0 p$ cross section estimated from the DIANA experiment in xenon (BARMIN 03); some assumptions are needed. Other of their estimates, based on measured $K^+ d$ cross sections, give upper limits in the 1–4 MeV range.

[13] MIZUK 06 finds no evidence for the $\Theta(1540)^+$ – see the list of negative results with the $\Theta(1540)^+$ masses above.

[14] SIBIRTSEV 04 introduces a test resonance at 1540 MeV in the P_{01} KN partial wave in an analysis of $K^+ d \rightarrow K^0 p p$ data. The analysis uses the Julich model and takes into account Fermi motion in the deuteron.

[15] ARNDT 03 introduces a test resonance in various partial waves in a reanalysis of $K^+ N$ elastic-scattering data and finds that a width of more than an MeV or so would greatly increase the χ^2 of the fit.

$\Theta(1540)^+$ REFERENCES

AKTAS	06B	PL B639 202	A. Aktas *et al.*	(HERA H1 Collab.)
DEVITA	06	PR D74 032001	R. De Vita *et al.*	(JLab CLAS Collab.)
KUBAROVSKY	06	PRL 97 102001	V. Kubarovsky *et al.*	(JLab CLAS Collab.)
LINK	06C	PL B639 604	J.M. Link *et al.*	(FNAL FOCUS Collab.)
MCKINNON	06	PRL 96 212001	B. McKinnon *et al.*	(JLab CLAS Collab.)
MIWA	06	PL B635 72	K. Miwa *et al.*	(KEK E522 Collab.)
MIZUK	06	PL B632 173	R. Mizuk *et al.*	(BELLE Collab.)
NICCOLAI	06	PRL 97 032001	S. Niccolai *et al.*	(JLab CLAS Collab.)
PANZARASA	06	NP A779 116	A. Panzarasa *et al.*	(CERN OBELIX Collab.)
ADAMOVICH	05	PR C72 055201	M.I Adamovich *et al.*	(CERN WA89 Collab.)
ALEEV	05	PAN 68 974	A.N. Aleev *et al.*	(IHEP SVD-2 Collab.)
		Translated from YAF 68 1012.		
AUBERT,B	05D	PRL 95 042002	B. Aubert *et al.*	(BABAR Collab.)
BATTAGLIERI	05	PRL 96 042001	M. Battaglieri *et al.*	(JLab CLAS Collab.)
Submited to PRL.				
WANG	05A	PL B617 141	M.-Z. Wang *et al.*	(BELLE Collab.)
ABDEL-BARY	04	PL B595 127	M. Abdel-Bary *et al.*	(COSY-TOF Collab.)
ABT	04A	PRL 93 212003	I. Abt *et al.*	(HERA B Collab.)
AIRAPETIAN	04	PL B585 213	A. Airapetian *et al.*	(HERA HERMES Collab.)
ANTIPOV	04	EPJ A21 455	Yu.M. Antipov *et al.*	(IHEP SPHINX Collab.)
ASRATYAN	04	PAN 67 682	A.E. Asratyan, A. Dolgolenko, M. Kubantsev	(ITEP)
		Translated from YAF 67 704.		
BAI	04G	PR D70 012004	J.Z. Bai *et al.*	(BES Collab.)
CAHN	04	PR D69 011501R	R.N. Cahn, G.H. Trilling	(LBNL)
CHEKANOV	04A	PL B591 7	S. Chekanov *et al.*	(HERA ZEUS Collab.)
GIBBS	04	PR C70 045208	W.R. Gibbs	(NMSU)
KUBAROVSKY	04	PRL 92 032001	V. Kubarovsky *et al.*	(Jefferson Lab CLAS Collab.)
LONGO	04	PR D70 111101R	M.J. Longo *et al.*	(FNAL HyperCP Collab.)
SCHAEL	04	PL B599 1	S. Schael *et al.*	(ALEPH Collab.)
SIBIRTSEV	04	PL B599 230	A. Sibirtsev *et al.*	(JULI, ADLD, BONN)
ARNDT	03	PR C68 042201R	R.A. Arndt, I.I. Strakovsky, R.L. Workman	(GWU)
BARMIN	03	PAN 66 1715	V.V. Barmin *et al.*	(ITEP DIANA Collab.)
		Translated from YAF 66 1763.		
BARTH	03	PL B572 127	J. Barth *et al.*	(Bonn SAPHIR Collab.)
NAKANO	03	PRL 91 012002	T. Nakano *et al.*	(SPring-8 LEPS Collab.)
STEPANYAN	03	PRL 91 252001	S. Stepanyan *et al.*	(Jefferson Lab CLAS Collab.)