Overview of PDG Activities

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(for the Unstable Baryons)

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Baryons@PDG

2010 edition	2012 edition	2014 edition	2016 edition
Charles Wohl	Charles Wohl	Mike Pennington	Mike Pennington ❋
Ron Workman	Eberhard Klempt	Charles Wohl ❋	Volker Burkert
	Ron Workman	Volker Burkert	Eberhard Klempt
		Eberhard Klempt	Lothar Tiator
		Lothar Tiator	Ron Workman
		Ron Workman	

Notable changes in the 2012 edition

Notation $L_{2I,\ 2J}$ changed to N, Δ J^P

Baryon Summary Table

This short table gives the name, the quantum numbers (where known), and the status of baryons in the Review. Only the baryons with 3- or 4-star status are included in the main Baryon Summary Table. Due to insufficient data or uncertain interpretation, the other entries in the short table are not established baryons. The names with masses are of baryons that decay strongly. For N, Δ, and Ξ resonances, the πN partial wave is indicated by the symbol $L_{2I,2J}$, where L is the orbital angular momentum (S, P, D, ...), I is the isospin, and J is the total angular momentum. For Λ and Σ resonances, the $\overline{K}N$ partial wave is labeled $L_{I,2J}$. The nucleon is a pole in the P_{11} wave, and similar comments apply to the Λ and Σ.

2010

p	P_{11}	****	$\Delta(1232)$	P_{33}	****	Σ^+	P_{11}	****	Ξ^0	P_{11}	****	Λ_c^+		****
n	P_{11}	****	$\Delta(1600)$	P_{33}	***	Σ^0	P_{11}	****	Ξ^-	P_{11}	****	$\Lambda_c(2595)^+$		***
$N(1440)$	P_{11}	****	$\Delta(1620)$	S_{31}	****	Σ^-	P_{11}	****	$\Xi(1530)$	P_{13}	****	$\Lambda_c(2625)^+$		***
$N(1520)$	D_{13}	****	$\Delta(1700)$	D_{33}	****	$\Sigma(1385)$	P_{13}	****	$\Xi(1620)$		*	$\Lambda_c(2765)^+$		*
$N(1535)$	S_{11}	****	$\Delta(1750)$	P_{31}	*	$\Sigma(1480)$		*	$\Xi(1690)$		***	$\Lambda_c(2880)^+$		***
$N(1650)$	S_{11}	****	$\Delta(1900)$	S_{31}	**	$\Sigma(1560)$		**	$\Xi(1820)$	D_{13}	***	$\Lambda_c(2940)^+$		***
$N(1675)$	D_{15}	****	$\Delta(1905)$	F_{35}	****	$\Sigma(1580)$	D_{13}	*	$\Xi(1950)$		***	$\Sigma_c(2455)$		****
$N(1680)$	F_{15}	****	$\Delta(1910)$	P_{31}	****	$\Sigma(1620)$	S_{11}	**	$\Xi(2030)$		***	$\Sigma_c(2520)$		***

became

2012

p	$1/2^+$	****	$\Delta(1232)$	$3/2^+$	****	Σ^+	$1/2^+$	****	Ξ^0	$1/2^+$	****	Λ_c^+	$1/2^+$	****
n	$1/2^+$	****	$\Delta(1600)$	$3/2^+$	***	Σ^0	$1/2^+$	****	Ξ^-	$1/2^+$	****	$\Lambda_c(2595)^+$	$1/2^-$	***
$N(1440)$	$1/2^+$	****	$\Delta(1620)$	$1/2^-$	****	Σ^-	$1/2^+$	****	$\Xi(1530)$	$3/2^+$	****	$\Lambda_c(2625)^+$	$3/2^-$	***
$N(1520)$	$3/2^-$	****	$\Delta(1700)$	$3/2^-$	****	$\Sigma(1385)$	$3/2^+$	****	$\Xi(1620)$		*	$\Lambda_c(2765)^+$		*
$N(1535)$	$1/2^-$	****	$\Delta(1750)$	$1/2^+$	*	$\Sigma(1480)$		*	$\Xi(1690)$		***	$\Lambda_c(2880)^+$	$5/2^+$	***
$N(1650)$	$1/2^-$	****	$\Delta(1900)$	$1/2^-$	**	$\Sigma(1560)$		**	$\Xi(1820)$	$3/2^-$	***	$\Lambda_c(2940)^+$		***
$N(1675)$	$5/2^-$	****	$\Delta(1905)$	$5/2^+$	****	$\Sigma(1580)$	$3/2^-$	*	$\Xi(1950)$		***	$\Sigma_c(2455)$	$1/2^+$	****
$N(1680)$	$5/2^+$	****	$\Delta(1910)$	$1/2^+$	****	$\Sigma(1620)$	$1/2^-$	**	$\Xi(2030)$	$\geq \frac{5}{2}?$	***	$\Sigma_c(2520)$	$3/2^+$	***

Table 1. The status of the N and Δ resonances. Only those with an overall status of *** or **** are included in the main Baryon Summary Table.

2010

Particle	$L_{2I \cdot 2J}$	Overall status	Status as seen in — $N\pi$	$N\eta$	ΛK	ΣK	$\Delta\pi$	$N\rho$	$N\gamma$
$N(939)$	P_{11}	****							
$N(1440)$	P_{11}	****	****	*			***	*	***
$N(1520)$	D_{13}	****	****	***			****	****	****
$N(1535)$	S_{11}	****	****	****			*	**	***
$N(1650)$	S_{11}	****	****	*	***	**	***	**	***
$N(1675)$	D_{15}	****	****	*	*		****	*	****
$N(1680)$	F_{15}	****	****	*			****	****	****

Baryon status table changed to reflect the influence of γN reactions

became

2012

Particle	J^P	Status overall	πN	γN	Status as seen in — $N\eta$	$N\sigma$	$N\omega$	ΛK	ΣK	$N\rho$	$\Delta\pi$
N	$1/2^+$	****									
$N(1440)$	$1/2^+$	****	****	****		***				*	***
$N(1520)$	$3/2^-$	****	****	****	***					***	***
$N(1535)$	$1/2^-$	****	****	****	****					**	*
$N(1650)$	$1/2^-$	****	****	***	***			***	**	**	***
$N(1675)$	$5/2^-$	****	****	***	*			*		*	***
$N(1680)$	$5/2^+$	****	****	****	*	**				***	***

Changes in the 2014 edition

For the Note on N and Delta resonances:

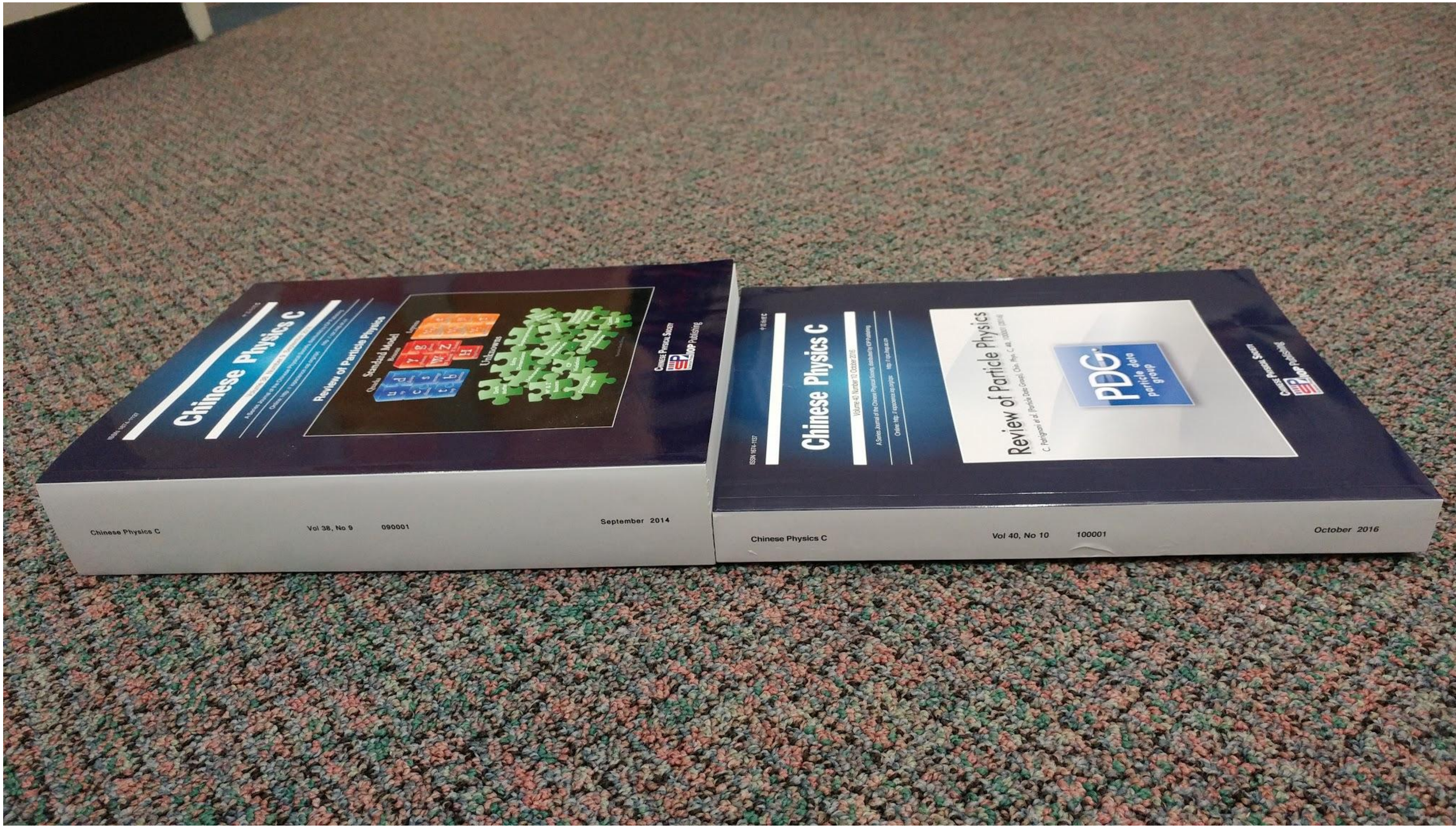
Added a short section on the electroproduction of mesons

Outlined the minimal error analysis required for new results

Changes in the 2016 edition

A brief review of the $\Lambda(1405)$ has been written to address the recent flurry of publications (theory/experiment) reporting a two-pole structure. [*Ulf-G. Meissner and Tetsuo Hyodo*]

Entries for the N and Delta resonances re-ordered to emphasize pole-related quantities over Breit-Wigner values.



2014 Edition

(too big)

2016 Edition

(no Listings)

$N(1440)\ 1/2^+$

$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$ Status: ∗∗∗∗

Most of the results published before 1975 were last included in our 1982 edition, Physics Letters **111B** 1 (1982). Some further obsolete results published before 1984 were last included in our 2006 edition, Journal of Physics (generic for all A,B,E,G) **G33** 1 (2006).

Listing in the PDG Review for the Roper as of 2014

N(1440) BREIT-WIGNER MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1410 to 1450 (≈ 1430) OUR ESTIMATE				
1515 ±15	SHKLYAR	13	DPWA	Multichannel
1430 ± 8	ANISOVICH	12A	DPWA	Multichannel
1485.0 ± 1.2	ARNDT	06	DPWA	$\pi N \to \pi N$, ηN
1440 ±30	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
1410 ±12	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1412 ± 2	SHRESTHA	12A	DPWA	Multichannel
1440 ±12	ANISOVICH	10	DPWA	Multichannel
1439 ±19	BATINIC	10	DPWA	$\pi N \to N\pi$, $N\eta$
1436 ±15	SARANTSEV	08	DPWA	Multichannel
1468.0 ± 4.5	ARNDT	04	DPWA	$\pi N \to \pi N$, ηN
1518 ± 5	PENNER	02C	DPWA	Multichannel
1479 ±80	VRANA	00	DPWA	Multichannel
1463 ± 7	ARNDT	96	IPWA	$\gamma N \to \pi N$
1467	ARNDT	95	DPWA	$\pi N \to N\pi$
1465	LI	93	IPWA	$\gamma N \to \pi N$
1462 ±10	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
1471	CUTKOSKY	90	IPWA	$\pi N \to \pi N$
1380	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
1390	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

Breit-Wigner values listed first

N(1440) BREIT-WIGNER WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
250 to 450 (≈ 350) OUR ESTIMATE				
605 ± 90	SHKLYAR	13	DPWA	Multichannel
365 ± 35	ANISOVICH	12A	DPWA	Multichannel
284 ± 18	ARNDT	06	DPWA	$\pi N \to \pi N$, ηN
340 ± 70	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
135 ± 10	HOEHLER	79	IPWA	$\pi N \to \pi N$

$N(1440)$ $1/2^+$

$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$ Status: ∗∗∗∗

Older and obsolete values are listed and referenced in the 2014 edition, Chinese Physics C **38** 070001 (2014).

Listing in the PDG Review for the Roper as of 2016

$N(1440)$ POLE POSITION

Pole values listed first

REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1369 ± 3	SOKHOYAN	15A	DPWA	Multichannel
1363 ± 2 ± 2	[1] SVARC	14	L+P	$\pi N \to \pi N$
1359	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
1385	HOEHLER	93	SPED	$\pi N \to \pi N$
1375 ± 30	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1386	SHKLYAR	13	DPWA	Multichannel
1370 ± 4	ANISOVICH	12A	DPWA	Multichannel
1370	SHRESTHA	12A	DPWA	Multichannel
1363 ± 11	BATINIC	10	DPWA	$\pi N \to N\pi, N\eta$
1383	VRANA	00	DPWA	Multichannel

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
189 ± 5	SOKHOYAN	15A	DPWA	Multichannel
180 ± 4 ± 5	[1] SVARC	14	L+P	$\pi N \to \pi N$
162	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
164	HOEHLER	93	SPED	$\pi N \to \pi N$
180 ± 40	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
277	SHKLYAR	13	DPWA	Multichannel
190 ± 7	ANISOVICH	12A	DPWA	Multichannel
214	SHRESTHA	12A	DPWA	Multichannel
151 ± 13	BATINIC	10	DPWA	$\pi N \to N\pi, N\eta$
316	VRANA	00	DPWA	Multichannel

$N(1440)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
40 to 52 (≈ 46) OUR ESTIMATE				
49 ± 3	SOKHOYAN	15A	DPWA	Multichannel
50 ± 1 ± 2	[1] SVARC	14	L+P	$\pi N \to \pi N$
38	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
40	HOEHLER	93	SPED	$\pi N \to \pi N$
52 ± 5	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
126	SHKLYAR	13	DPWA	Multichannel
48 ± 3	ANISOVICH	12A	DPWA	Multichannel

Re-ordering

2014

Breit-Wigner Mass
Breit-Wigner Width

Pole Position
Elastic Pole Residue $\pi N \rightarrow \pi N$
Inelastic Pole Residue $\pi N \rightarrow \pi \Delta$ etc

Decay Modes
Branching Ratios
Photon Decay Amplitudes

2016

Pole Position
Elastic Pole Residue
Inelastic Pole Residue

Breit-Wigner Mass
Breit-Wigner Width
Decay Modes
Branching Ratios
Photon Decay Amplitudes
(at the pole)
Photon Decay Amplitudes
(BW values)

Original Formalism

49.1. Resonance Formation

Resonant cross sections are generally described by the Breit-Wigner formula (Sec. 19 of this *Review*).

$$\sigma(E) = \frac{2J+1}{(2S_1+1)(2S_2+1)} \frac{4\pi}{k^2} \left[\frac{\Gamma^2/4}{(E-E_0)^2+\Gamma^2/4} \right] B_{in} B_{out}, \qquad (49.1)$$

$N(1440)$ BRANCHING RATIOS

Retained in Listings

$\Gamma(N\pi)/\Gamma_{total}$ **Γ_1/Γ**

Available only in past editions

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to N(1440) \to \Delta(1232)\pi$, P-wave **$(\Gamma_1\Gamma_5)^{1/2}/\Gamma$**

VALUE	DOCUMENT ID	TECN	COMMENT

Note on N and Δ Resonances (2012)

Branching ratios of a pole can be defined by

$$BR_{\text{pole}}(\text{channel } b) = \frac{|Res(\pi N \to b)|^2}{|Res(\pi N \to N\pi)| \cdot (\Gamma_{\text{pole}}/2)}. \qquad (6)$$

This information is, however, not given in the literature.

Listings now include related quantity

$N(1440)$ INELASTIC POLE RESIDUE

The "normalized residue" is the residue divided by $\Gamma_{pole}/2$.

Normalized residue in $N\pi \to N(1440) \to \Delta\pi$, P-wave

MODULUS (%)	PHASE (°)	DOCUMENT ID		TECN	COMMENT
27±2	38 ± 5	SOKHOYAN	15A	DPWA	Multichannel
• • • We do not use the following data for averages, fits, limits, etc. • • •					
27±2	40 ± 5	ANISOVICH	12A	DPWA	Multichannel

Photon-decay Amplitudes listed in BW and pole forms

$$A_h^{\mathrm{BW}} = C\sqrt{\frac{q_r}{k_r}\frac{\pi(2J+1)M_r\Gamma_r^2}{m_N\Gamma_{\pi,r}}}\,\tilde{\mathcal{A}}_\alpha^h.$$

evaluated at resonance energy

For details and examples see:

Workman, Tiator, Sarantsev,
Phys. Rev. C87 (2013) 068201

evaluated at the pole

$$A_h^{\mathrm{pole}} = C\sqrt{\frac{q_p}{k_p}\frac{2\pi(2J+1)W_p}{m_N\mathrm{Res}_{\pi N}}}\,\mathrm{Res}\,\mathcal{A}_\alpha^h,$$

$\Lambda(1520)\ 3/2^-$

$I(J^P) = 0(\frac{3}{2}^-)$ Status: ∗∗∗∗

Discovered by FERRO-LUZZI 62; the elaboration in WATSON 63 is the classic paper on the Breit-Wigner analysis of a multichannel resonance.

The measurements of the mass, width, and elasticity published before 1975 are now obsolete and have been omitted. They were last listed in our 1982 edition Physics Letters **111B** 1 (1982).

Production and formation experiments agree quite well, so they are listed together here.

$\Lambda(1520)$ POLE POSITION

REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
$1517\ ^{+4}_{-4}$	[1] KAMANO	15	DPWA	Multichannel
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1518	ZHANG	13A	DPWA	Multichannel
1518.8	QIANG	10	SPEC	$ep \to e' K^+ X$ (fit to X)

[1] From the preferred solution A in KAMANO 15.

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
$16\ ^{+10}_{-8}$	[1] KAMANO	15	DPWA	Multichannel
• • • We do not use the following data for averages, fits, limits, etc. • • •				
16	ZHANG	13A	DPWA	Multichannel
17.2	QIANG	10	SPEC	$ep \to e' K^+ X$ (fit to X)

[1] From the preferred solution A in KAMANO 15.

$\Lambda(1520)$ POLE RESIDUES

The normalized residue is the residue divided by $\Gamma_{pole}/2$.

Normalized residue in $N\overline{K} \to \Lambda(1520) \to N\overline{K}$

MODULUS	PHASE (°)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.431	−11	[1] KAMANO	15	DPWA	Multichannel

[1] From the preferred solution A in KAMANO 15.

Normalized residue in $N\overline{K} \to \Lambda(1520) \to \Sigma\pi$

MODULUS	PHASE (°)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.435	−10	[1] KAMANO	15	DPWA	Multichannel

[1] From the preferred solution A in KAMANO 15.

The new ordering is being extended to the hyperons.

More on Branching Ratios

and

Star-Rating Issues

from

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