

N BARYONS

($S = 0, I = 1/2$)

$p, N^+ = uud; \quad n, N^0 = udd$

p

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

Mass $m = 1.0072764665789 \pm 0.0000000000083 \text{ u}$

Mass $m = 938.27208943 \pm 0.00000029 \text{ MeV}$ [a]

$|m_p - m_{\bar{p}}|/m_p < 7 \times 10^{-10}, \text{ CL} = 90\%$ [b]

$|\frac{q_{\bar{p}}}{m_{\bar{p}}}|/(\frac{q_p}{m_p}) = 1.000000000003 \pm 0.000000000016$

$|q_p + q_{\bar{p}}|/e < 7 \times 10^{-10}, \text{ CL} = 90\%$ [b]

$|q_p + q_e|/e < 1 \times 10^{-21}$ [c]

Magnetic moment $\mu = 2.7928473446 \pm 0.0000000008 \mu_N$

$(\mu_p + \mu_{\bar{p}}) / \mu_p = (0.002 \pm 0.004) \times 10^{-6}$

Electric dipole moment $d < 0.021 \times 10^{-23} \text{ e cm}$

Electric polarizability $\alpha = (11.5 \pm 0.4) \times 10^{-4} \text{ fm}^3 \quad (S = 1.1)$

Magnetic polarizability $\beta = (2.31 \pm 0.29) \times 10^{-4} \text{ fm}^3 \quad (S = 1.1)$

p SPIN POLARIZABILITY $\gamma_{E1E1} = (-3.0 \pm 0.7) \times 10^{-4} \text{ fm}^4$

p SPIN POLARIZABILITY $\gamma_{M1M1} = (3.7 \pm 0.5) \times 10^{-4} \text{ fm}^4$

p SPIN POLARIZABILITY $\gamma_{E1M2} = (-1.2 \pm 1.0) \times 10^{-4} \text{ fm}^4$

p SPIN POLARIZABILITY $\gamma_{M1E2} = (2.0 \pm 0.8) \times 10^{-4} \text{ fm}^4$

Charge radius, μp Lamb shift = $0.84075 \pm 0.00064 \text{ fm}$ [d]

Charge radius = $0.8407 \pm 0.0006 \text{ fm}$ [d]

Magnetic radius = $0.851 \pm 0.026 \text{ fm}$ [e]

Mean life $\tau > 9 \times 10^{29} \text{ years}, \text{ CL} = 90\%$ ($p \rightarrow$ invisible mode)

See the "Note on Nucleon Decay" in our 1994 edition (*Phys. Rev.* **D50**, 1173) for a short review.

The "partial mean life" limits tabulated here are the limits on τ/B_i , where τ is the total mean life and B_i is the branching fraction for the mode in question. For N decays, p and n indicate proton and neutron partial lifetimes.

p DECAY MODES	Partial mean life (10^{30} years)	Confidence level	p (MeV/c)
Antilepton + meson			
$N \rightarrow e^+ \pi$	$> 5300 (n), > 24000 (p)$	90%	459
$N \rightarrow \mu^+ \pi$	$> 3500 (n), > 16000 (p)$	90%	453
$N \rightarrow \nu \pi$	$> 1100 (n), > 390 (p)$	90%	459
$p \rightarrow e^+ \eta$	> 10000	90%	309

$p \rightarrow \mu^+ \eta$	> 4700	90%	297
$n \rightarrow \nu \eta$	> 158	90%	310
$N \rightarrow e^+ \rho$	> 217 (n), > 720 (p)	90%	149
$N \rightarrow \mu^+ \rho$	> 228 (n), > 570 (p)	90%	113
$N \rightarrow \nu \rho$	> 19 (n), > 162 (p)	90%	149
$p \rightarrow e^+ \omega$	> 1600	90%	143
$p \rightarrow \mu^+ \omega$	> 2800	90%	105
$n \rightarrow \nu \omega$	> 108	90%	144
$N \rightarrow e^+ K$	> 17 (n), > 1000 (p)	90%	339
$N \rightarrow \mu^+ K$	> 26 (n), > 4500 (p)	90%	329
$N \rightarrow \nu K$	> 86 (n), > 5900 (p)	90%	339
$n \rightarrow \nu K_S^0$	> 1560	90%	338
$p \rightarrow e^+ K^*(892)^0$	> 84	90%	45
$N \rightarrow \nu K^*(892)$	> 78 (n), > 51 (p)	90%	45

Antilepton + mesons

$p \rightarrow e^+ \pi^+ \pi^-$	> 82	90%	448
$p \rightarrow e^+ \pi^0 \pi^0$	> 147	90%	449
$n \rightarrow e^+ \pi^- \pi^0$	> 52	90%	449
$p \rightarrow \mu^+ \pi^+ \pi^-$	> 133	90%	425
$p \rightarrow \mu^+ \pi^0 \pi^0$	> 101	90%	427
$n \rightarrow \mu^+ \pi^- \pi^0$	> 74	90%	427
$n \rightarrow e^+ K^0 \pi^-$	> 18	90%	319

Lepton + meson

$n \rightarrow e^- \pi^+$	> 65	90%	459
$n \rightarrow \mu^- \pi^+$	> 49	90%	453
$n \rightarrow e^- \rho^+$	> 62	90%	150
$n \rightarrow \mu^- \rho^+$	> 7	90%	115
$n \rightarrow e^- K^+$	> 32	90%	340
$n \rightarrow \mu^- K^+$	> 57	90%	330

Lepton + mesons

$p \rightarrow e^- \pi^+ \pi^+$	> 30	90%	448
$n \rightarrow e^- \pi^+ \pi^0$	> 29	90%	449
$p \rightarrow \mu^- \pi^+ \pi^+$	> 17	90%	425
$n \rightarrow \mu^- \pi^+ \pi^0$	> 34	90%	427
$p \rightarrow e^- \pi^+ K^+$	> 75	90%	320
$p \rightarrow \mu^- \pi^+ K^+$	> 245	90%	279

Antilepton + photon(s)

$p \rightarrow e^+ \gamma$	> 670	90%	469
$p \rightarrow \mu^+ \gamma$	> 478	90%	463
$n \rightarrow \nu \gamma$	> 550	90%	470
$p \rightarrow e^+ \gamma \gamma$	> 100	90%	469
$n \rightarrow \nu \gamma \gamma$	> 219	90%	470

Antilepton + single massless

$p \rightarrow e^+ X$	> 790	90%	—
$p \rightarrow \mu^+ X$	> 410	90%	—

Three (or more) leptons

$p \rightarrow e^+ e^+ e^-$	> 34000	90%	469
$p \rightarrow e^+ \mu^+ \mu^-$	> 9200	90%	457
$p \rightarrow e^+ \nu \nu$	> 170	90%	469
$n \rightarrow e^+ e^- \nu$	> 257	90%	470
$n \rightarrow \mu^+ e^- \nu$	> 83	90%	464
$n \rightarrow \mu^+ \mu^- \nu$	> 79	90%	458
$p \rightarrow \mu^+ e^+ e^-$	> 23000	90%	463
$p \rightarrow \mu^- e^+ e^+$	> 19000	90%	463
$p \rightarrow \mu^+ \mu^+ \mu^-$	> 10000	90%	439
$p \rightarrow \mu^+ \nu \nu$	> 220	90%	463
$p \rightarrow e^- \mu^+ \mu^+$	> 11000	90%	457
$n \rightarrow 3\nu$	> 5×10^{-4}	90%	470

Inclusive modes

$N \rightarrow e^+$ anything	> 0.6 (n, p)	90%	—
$N \rightarrow \mu^+$ anything	> 12 (n, p)	90%	—
$N \rightarrow e^+ \pi^0$ anything	> 0.6 (n, p)	90%	—

$\Delta B = 2$ dinucleon modes

The following are lifetime limits per iron nucleus.

$pp \rightarrow \pi^+ \pi^+$	> 72.2	90%	—
$pn \rightarrow \pi^+ \pi^0$	> 170	90%	—
$nn \rightarrow \pi^+ \pi^-$	> 0.7	90%	—
$nn \rightarrow \pi^0 \pi^0$	> 404	90%	—
$pp \rightarrow K^+ K^+$	> 170	90%	—
$pp \rightarrow e^+ e^+$	> 5.8	90%	—
$pp \rightarrow e^+ \mu^+$	> 3.6	90%	—
$pp \rightarrow \mu^+ \mu^+$	> 1.7	90%	—
$pn \rightarrow e^+ \bar{\nu}$	> 260	90%	—
$pn \rightarrow \mu^+ \bar{\nu}$	> 200	90%	—
$pn \rightarrow \tau^+ \bar{\nu}_\tau$	> 29	90%	—
$nn \rightarrow$ invisible	> 1.4	90%	—
$nn \rightarrow \nu_e \bar{\nu}_e$	> 1.4	90%	—
$nn \rightarrow \nu_\mu \bar{\nu}_\mu$	> 1.4	90%	—
$pn \rightarrow$ invisible	> 0.06	90%	—
$pp \rightarrow$ invisible	> 0.11	90%	—

\bar{p} DECAY MODES

\bar{p} DECAY MODES	Partial mean life (years)	Confidence level	p (MeV/c)
$\bar{p} \rightarrow e^- \gamma$	$> 7 \times 10^5$	90%	469
$\bar{p} \rightarrow \mu^- \gamma$	$> 5 \times 10^4$	90%	463
$\bar{p} \rightarrow e^- \pi^0$	$> 4 \times 10^5$	90%	459
$\bar{p} \rightarrow \mu^- \pi^0$	$> 5 \times 10^4$	90%	453
$\bar{p} \rightarrow e^- \eta$	$> 2 \times 10^4$	90%	309
$\bar{p} \rightarrow \mu^- \eta$	$> 8 \times 10^3$	90%	297
$\bar{p} \rightarrow e^- K_S^0$	> 900	90%	337
$\bar{p} \rightarrow \mu^- K_S^0$	$> 4 \times 10^3$	90%	326
$\bar{p} \rightarrow e^- K_L^0$	$> 9 \times 10^3$	90%	337
$\bar{p} \rightarrow \mu^- K_L^0$	$> 7 \times 10^3$	90%	326
$\bar{p} \rightarrow e^- \gamma \gamma$	$> 2 \times 10^4$	90%	469
$\bar{p} \rightarrow \mu^- \gamma \gamma$	$> 2 \times 10^4$	90%	463
$\bar{p} \rightarrow e^- \omega$	> 200	90%	143

n

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

Mass $m = 1.0086649161 \pm 0.0000000004$ u

Mass $m = 939.5654219 \pm 0.0000005$ MeV [a]

$(m_n - m_{\bar{n}}) / m_n = (9 \pm 5) \times 10^{-5}$

$m_n - m_p = 1.2933325 \pm 0.0000004$ MeV
 $= 0.0013884495 \pm 0.0000000004$ u

Mean life $\tau = 878.3 \pm 0.4$ s (S = 1.8)

$c\tau = 2.6332 \times 10^8$ km

Magnetic moment $\mu = -1.9130428 \pm 0.0000005 \mu_N$

Electric dipole moment $d < 0.18 \times 10^{-25}$ e cm, CL = 90%

Mean-square charge radius $\langle r_n^2 \rangle = -0.1155 \pm 0.0017$ fm²

Magnetic radius $\sqrt{\langle r_M^2 \rangle} = 0.864_{-0.008}^{+0.009}$ fm

Electric polarizability $\alpha = (11.8 \pm 1.1) \times 10^{-4}$ fm³

Magnetic polarizability $\beta = (3.7 \pm 1.2) \times 10^{-4}$ fm³

Charge $q = (-0.2 \pm 0.8) \times 10^{-21}$ e

Mean $n\bar{n}$ -oscillation time $> 8.6 \times 10^7$ s, CL = 90% (free n)

Mean $n\bar{n}$ -oscillation time $> 4.7 \times 10^8$ s, CL = 90% [f] (bound n)

Mean nn' -oscillation time > 448 s, CL = 90% [g]

$pe^- \nu_e$ decay parameters [h]

$\lambda \equiv g_A / g_V = -1.2753 \pm 0.0013$ (S = 2.7)

$A = -0.11958 \pm 0.00021$ (S = 1.2)

$B = 0.9807 \pm 0.0030$

$$C = -0.2377 \pm 0.0026$$

$$a = -0.1044 \pm 0.0007$$

$$\phi_{AV} = (180.017 \pm 0.026)^\circ [i]$$

$$D = (-1.2 \pm 2.0) \times 10^{-4} [j]$$

$$R = 0.004 \pm 0.013 [j]$$

Fierz interference term $b = 0.017 \pm 0.020$

See the proton listings for many other neutron decay modes.

<i>n</i> DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$p e^- \bar{\nu}_e$	100 %		1
$p e^- \bar{\nu}_e \gamma$	[k] $(9.2 \pm 0.7) \times 10^{-3}$		1
hydrogen-atom $\bar{\nu}_e$	< 2.7 $\times 10^{-3}$	95%	1.19
Charge conservation (Q) violating mode			
$p \nu_e \bar{\nu}_e$	Q < 8 $\times 10^{-27}$	68%	1

$N(1440) 1/2^+$

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

Re(pole position) = 1360 to 1380 (≈ 1370) MeV
 $-2\text{Im}(\text{pole position}) = 180$ to 205 (≈ 190) MeV
 Breit-Wigner mass = 1410 to 1470 (≈ 1440) MeV
 Breit-Wigner full width = 250 to 450 (≈ 350) MeV

$N(1440)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	55–75 %	398
$N\eta$	< 1 %	†
$N\pi\pi$	17–50 %	347
$\Delta(1232)\pi$	6–27 %	147
$N\rho$	(18±6) %	†
$N\rho, S=1/2$	(9±4) %	†
$N\rho, S=3/2$	(9±4) %	†
$N\sigma$	11–23 %	–
$p\gamma, \text{helicity}=1/2$	0.035–0.048 %	414
$n\gamma, \text{helicity}=1/2$	0.02–0.04 %	413

$N(1520) 3/2^-$

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$$

Re(pole position) = 1505 to 1515 (≈ 1510) MeV
 $-2\text{Im}(\text{pole position}) = 105$ to 120 (≈ 110) MeV
 Breit-Wigner mass = 1510 to 1520 (≈ 1515) MeV
 Breit-Wigner full width = 100 to 120 (≈ 110) MeV

N(1520) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	55–65 %	453
$N\eta$	0.07–0.09 %	142
$N\pi\pi$	25–35 %	410
$\Delta(1232)\pi$	22–34 %	225
$\Delta(1232)\pi$, <i>S</i> -wave	15–23 %	225
$\Delta(1232)\pi$, <i>D</i> -wave	7–11 %	225
$N\rho$	10–16 %	†
$N\rho$, $S=1/2$	0.2–0.4 %	†
$N\rho$, $S=3/2$, <i>S</i> -wave	10–16 %	†
$N\rho$, $S=3/2$, <i>D</i> -wave	<1 %	†
$N\sigma$	<10 %	–
$p\gamma$	0.31–0.52 %	467
$p\gamma$, helicity=1/2	0.01–0.02 %	467
$p\gamma$, helicity=3/2	0.30–0.50 %	467
$n\gamma$	0.30–0.53 %	466
$n\gamma$, helicity=1/2	0.04–0.10 %	466
$n\gamma$, helicity=3/2	0.25–0.45 %	466

N(1535) 1/2⁻

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^-)$$

Re(pole position) = 1500 to 1520 (\approx 1510) MeV

–2Im(pole position) = 80 to 130 (\approx 110) MeV

Breit-Wigner mass = 1515 to 1545 (\approx 1530) MeV

Breit-Wigner full width = 125 to 175 (\approx 150) MeV

N(1535) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	32–52 %	464
$N\eta$	30–55 %	176
$N\pi\pi$	4–31 %	422
$\Delta(1232)\pi$	1–4 %	240
$N\rho$	2–17 %	†
$N\rho$, $S=1/2$	2–16 %	†
$N\rho$, $S=3/2$	<1 %	†
$N\sigma$	2–10 %	–
$N(1440)\pi$	5–12 %	†
$p\gamma$, helicity=1/2	0.15–0.30 %	477
$n\gamma$, helicity=1/2	0.01–0.25 %	477

$N(1650) 1/2^-$

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^-)$$

Re(pole position) = 1650 to 1680 (≈ 1665) MeV $-2\text{Im}(\text{pole position}) = 100$ to 170 (≈ 135) MeVBreit-Wigner mass = 1635 to 1665 (≈ 1650) MeVBreit-Wigner full width = 100 to 150 (≈ 125) MeV

$N(1650)$ DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
$N\pi$	50–70 %	547
$N\eta$	15–35 %	348
ΛK	5–15 %	169
$N\pi\pi$	20–58 %	514
$\Delta(1232)\pi$	6–18 %	345
$N\rho$	12–22 %	†
$N\rho, S=1/2$	<4 %	†
$N\rho, S=3/2$	12–18 %	†
$N\sigma$	2–18 %	–
$N(1440)\pi$	6–26 %	150
$p\gamma$, helicity=1/2	0.04–0.20 %	558
$n\gamma$, helicity=1/2	0.003–0.17 %	557

 $N(1675) 5/2^-$

$$I(J^P) = \frac{1}{2}(\frac{5}{2}^-)$$

Re(pole position) = 1650 to 1660 (≈ 1655) MeV $-2\text{Im}(\text{pole position}) = 120$ to 150 (≈ 135) MeVBreit-Wigner mass = 1665 to 1680 (≈ 1675) MeVBreit-Wigner full width = 130 to 160 (≈ 145) MeV

$N(1675)$ DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
$N\pi$	38–42 %	564
$N\eta$	< 1 %	376
ΛK	<0.04 %	216
$N\pi\pi$	25–45 %	532
$\Delta(1232)\pi$	(19 \pm 4) %	366
$\Delta(1232)\pi$, <i>D</i> -wave	23–37 %	366
$N\rho$	0.1–0.9 %	†
$N\rho, S=1/2$	<0.2 %	†
$N\rho, S=3/2$, <i>D</i> -wave	0.1–0.7 %	†
$N\sigma$	3–7 %	–
$p\gamma$	0–0.02 %	575
$p\gamma$, helicity=1/2	0–0.01 %	575
$p\gamma$, helicity=3/2	0–0.01 %	575

$n\gamma$	0–0.15 %	574
$n\gamma$, helicity=1/2	0–0.05 %	574
$n\gamma$, helicity=3/2	0–0.10 %	574

$N(1680) 5/2^+$

$$I(J^P) = \frac{1}{2}(\frac{5}{2}^+)$$

Re(pole position) = 1660 to 1680 (≈ 1670) MeV
 $-2\text{Im}(\text{pole position}) = 110$ to 135 (≈ 120) MeV
 Breit-Wigner mass = 1680 to 1690 (≈ 1685) MeV
 Breit-Wigner full width = 115 to 130 (≈ 120) MeV

$N(1680)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	60–70 %	571
$N\eta$	<1 %	386
$N\pi\pi$	28–53 %	539
$\Delta(1232)\pi$	11–23 %	374
$\Delta(1232)\pi$, <i>P</i> -wave	4–10 %	374
$\Delta(1232)\pi$, <i>F</i> -wave	1–13 %	374
$N\rho$	8–11 %	†
$N\rho$, $S=3/2$, <i>P</i> -wave	6–8 %	†
$N\rho$, $S=3/2$, <i>F</i> -wave	2–3 %	†
$N\sigma$	9–19 %	–
$p\gamma$	0.21–0.32 %	581
$p\gamma$, helicity=1/2	0.001–0.011 %	581
$p\gamma$, helicity=3/2	0.20–0.32 %	581
$n\gamma$	0.021–0.046 %	581
$n\gamma$, helicity=1/2	0.004–0.029 %	581
$n\gamma$, helicity=3/2	0.01–0.024 %	581

$N(1700) 3/2^-$

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$$

Re(pole position) = 1650 to 1750 (≈ 1700) MeV
 $-2\text{Im}(\text{pole position}) = 100$ to 300 (≈ 200) MeV
 Breit-Wigner mass = 1650 to 1800 (≈ 1720) MeV
 Breit-Wigner full width = 100 to 300 (≈ 200) MeV

$N(1700)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	7–17 %	594
$N\eta$	1–2 %	422
$N\omega$	10–34 %	†
ΛK	1–2 %	283

$N\pi\pi$	>89 %	564
$\Delta(1232)\pi$	55–85 %	402
$\Delta(1232)\pi$, <i>S</i> -wave	50–80 %	402
$\Delta(1232)\pi$, <i>D</i> -wave	4–14 %	402
$N\rho$	(21 ± 9) %	75
$N\rho$, <i>S</i> =1/2	(5.0±3.0) %	75
$N\rho$, <i>S</i> =3/2 , <i>S</i> -wave	32–44 %	75
$N\rho$, <i>S</i> =3/2 , <i>D</i> -wave	(16 ± 8) %	75
$N\sigma$	2–14 %	–
$N(1440)\pi$	3–11 %	225
$N(1520)\pi$	<4 %	145
$N(1535)\pi$	< 1 %	126
$p\gamma$	0.01–0.05 %	604
$p\gamma$, helicity=1/2	0.0–0.024 %	604
$p\gamma$, helicity=3/2	0.002–0.026 %	604
$n\gamma$	0.01–0.13 %	603
$n\gamma$, helicity=1/2	0.0–0.09 %	603
$n\gamma$, helicity=3/2	0.01–0.05 %	603

$N(1710) 1/2^+$

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

Re(pole position) = 1650 to 1750 (\approx 1700) MeV

–2Im(pole position) = 80 to 160 (\approx 120) MeV

Breit-Wigner mass = 1680 to 1740 (\approx 1710) MeV

Breit-Wigner full width = 80 to 200 (\approx 140) MeV

$N(1710)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	5–20 %	588
$N\eta$	10–50 %	412
$N\omega$	1–5 %	†
ΛK	5–25 %	269
ΣK	seen	138
$N\pi\pi$	14–48 %	557
$\Delta(1232)\pi$	3–9 %	394
$N\rho$	(17 ± 4) %	†
$N\rho$, <i>S</i> =1/2	11–23 %	†
$N\rho$, <i>S</i> =3/2	(11.0± 3.0) %	†
$N\sigma$	<16 %	–
$N(1440)\pi$	(22 ± 12) %	215
$N(1520)\pi$	< 2 %	133
$N(1535)\pi$	9–21 %	113
$p\gamma$, helicity=1/2	0.002–0.08 %	598
$n\gamma$, helicity=1/2	0.0–0.02%	597

$N(1720) 3/2^+$

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$$

Re(pole position) = 1660 to 1710 (≈ 1680) MeV $-2\text{Im}(\text{pole position}) = 150$ to 300 (≈ 200) MeVBreit-Wigner mass = 1680 to 1750 (≈ 1720) MeVBreit-Wigner full width = 150 to 400 (≈ 250) MeV

$N(1720)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	8–14 %	594
$N\eta$	1–5 %	422
$N\omega$	12–40 %	†
ΛK	4–19 %	283
$N\pi\pi$	>50 %	564
$\Delta(1232)\pi$	47–89 %	402
$\Delta(1232)\pi$, P -wave	47–77 %	402
$\Delta(1232)\pi$, F -wave	<12 %	402
$N\rho$	(29 \pm 8) %	75
$N\rho$, $S=1/2$	1–2 %	75
$N\rho$, $S=3/2$, P -wave	(17 \pm 6) %	75
$N\sigma$	2–14 %	–
$N(1440)\pi$	<2 %	225
$N(1520)\pi$, S -wave	1–5 %	145
$N(1535)\pi$	(4.0 \pm 2.0) %	126
$p\gamma$	0.05–0.25 %	604
$p\gamma$, helicity=1/2	0.05–0.15 %	604
$p\gamma$, helicity=3/2	0.002–0.16 %	604
$n\gamma$	0.0–0.016 %	603
$n\gamma$, helicity=1/2	0.0–0.01 %	603
$n\gamma$, helicity=3/2	0.0–0.015 %	603

 $N(1875) 3/2^-$

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$$

was $N(2080)$ Re(pole position) = 1850 to 1950 (≈ 1900) MeV $-2\text{Im}(\text{pole position}) = 100$ to 220 (≈ 160) MeVBreit-Wigner mass = 1850 to 1920 (≈ 1875) MeVBreit-Wigner full width = 120 to 250 (≈ 200) MeV

$N(1875)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	3–11 %	695
$N\eta$	3–16 %	559

$N\omega$	15–25 %	371
ΛK	1–2 %	454
ΣK	0.3–1.1 %	384
$N\pi\pi$	>56 %	670
$\Delta(1232)\pi$	4–44 %	520
$\Delta(1232)\pi$, S-wave	2–21 %	520
$\Delta(1232)\pi$, D-wave	2–23 %	520
$N\rho$, $S=3/2$, S-wave	36–56 %	379
$N\sigma$	16–60 %	–
$N(1440)\pi$	2–8 %	365
$N(1520)\pi$	<2 %	301
$N(1535)\pi$	(2.0±2.0) %	288
$\Lambda K^*(892)$	<0.2 %	†
$p\gamma$	0.001–0.025 %	703
$p\gamma$, helicity=1/2	0.001–0.021 %	703
$p\gamma$, helicity=3/2	<0.003 %	703
$n\gamma$	<0.040 %	702
$n\gamma$, helicity=1/2	<0.007 %	702
$n\gamma$, helicity=3/2	<0.033 %	702

N(1880) 1/2⁺

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

Re(pole position) = 1820 to 1900 (\approx 1860) MeV

– 2Im(pole position) = 180 to 280 (\approx 230) MeV

Breit-Wigner mass = 1830 to 1930 (\approx 1880) MeV

Breit-Wigner full width = 200 to 400 (\approx 300) MeV

N(1880) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	3–31 %	698
$N\eta$	1–55 %	563
$N\omega$	12–28 %	377
ΛK	1–3 %	459
ΣK	10–24 %	389
$N\pi\pi$	>32 %	673
$\Delta(1232)\pi$	5–42 %	524
$N\rho$	(28 ± 7) %	385
$N\rho$, $S=1/2$	19–45 %	385
$N\rho$, $S=3/2$	(8.0±3.0) %	385
$N\sigma$	8–40 %	539
$N(1535)\pi$	4–12 %	293
$N a_0(980)$	1–5 %	†
$\Lambda K^*(892)$	0.5–1.1 %	†
$p\gamma$, helicity=1/2	seen	706

$n\gamma$, helicity=1/2

0.002–0.63 %

705

 $N(1895) 1/2^-$

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^-)$$

was $N(2090)$ Re(pole position) = 1890 to 1930 (≈ 1910) MeV–2Im(pole position) = 80 to 140 (≈ 110) MeVBreit-Wigner mass = 1870 to 1920 (≈ 1895) MeVBreit-Wigner full width = 80 to 200 (≈ 120) MeV

$N(1895)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	2–18 %	707
$N\eta$	15–45 %	575
$N\eta'$	10–40 %	†
$N\omega$	16–40 %	395
ΛK	3–23 %	473
ΣK	6–20 %	405
$N\pi\pi$	17–74 %	683
$\Delta(1232)\pi$	3–11 %	535
$N\rho$	14–50 %	403
$N\rho, S=1/2$	<18 %	403
$N\rho, S=3/2$	14–32 %	403
$N\sigma$	<13 %	–
$N(1440)\pi$	2–12 %	382
$\Lambda K^*(892)$	4–9 %	†
$p\gamma$, helicity=1/2	0.01–0.06 %	715
$n\gamma$, helicity=1/2	0.003–0.05 %	715

 $N(1900) 3/2^+$

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$$

Re(pole position) = 1900 to 1940 (≈ 1920) MeV–2Im(pole position) = 90 to 160 (≈ 130) MeVBreit-Wigner mass = 1890 to 1950 (≈ 1920) MeVBreit-Wigner full width = 100 to 320 (≈ 200) MeV

$N(1900)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	1–20 %	723
$N\eta$	2–14 %	595
$N\eta'$	4–8 %	151
$N\omega$	7–13 %	424
ΛK	2–20 %	495

ΣK	3–7 %	431
$N\pi\pi$	>56 %	699
$\Delta(1232)\pi$	30–70 %	553
$\Delta(1232)\pi$, <i>P</i> -wave	9–25 %	553
$\Delta(1232)\pi$, <i>F</i> -wave	21–45 %	553
$N\rho$	(46 ± 13) %	432
$N\rho$, <i>S</i> =1/2	25–40 %	432
$N\rho$, <i>S</i> =3/2 , <i>P</i> -wave	(9.0 ± 3.0) %	432
$N\rho$, <i>S</i> =3/2 , <i>F</i> -wave	(30 ± 12) %	432
$N\sigma$	1–7 %	–
$N(1440)\pi$	(9 ± 6) %	403
$N(1520)\pi$, <i>S</i> -wave	7–23 %	341
$N(1535)\pi$	4–10 %	328
$\Lambda K^*(892)$	< 0.2 %	†
$p\gamma$	0.001–0.025 %	731
$p\gamma$, helicity=1/2	0.001–0.021 %	731
$p\gamma$, helicity=3/2	<0.003 %	731
$n\gamma$	<0.040 %	730
$n\gamma$, helicity=1/2	<0.007 %	730
$n\gamma$, helicity=3/2	<0.033 %	730

$N(2060) 5/2^-$

$$I(J^P) = \frac{1}{2}(\frac{5}{2}^-)$$

was $N(2200)$

Re(pole position) = 2020 to 2130 (≈ 2070) MeV
 – 2Im(pole position) = 350 to 430 (≈ 400) MeV
 Breit-Wigner mass = 2030 to 2200 (≈ 2100) MeV
 Breit-Wigner full width = 300 to 450 (≈ 400) MeV

$N(2060)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	7–12 %	834
$N\eta$	2–38 %	729
$N\omega$	1–7 %	600
ΛK	10–20 %	644
ΣK	1–5 %	593
$N\pi\pi$	12–52 %	814
$\Delta(1232)\pi$	(12.0 ± 3.0) %	680
$\Delta(1232)\pi$, <i>D</i> -wave	4–10 %	680
$N\rho$	5–33 %	605
$N\rho$, <i>S</i> =3/2 , <i>D</i> -wave	5–23 %	605
$N\sigma$	3–9 %	–
$N(1440)\pi$	4–14 %	544

$N(1520)\pi$, P -wave	9–21 %	490
$N(1680)\pi$, S -wave	8–22 %	353
$\Lambda K^*(892)$	0.3–1.3 %	306
$p\gamma$	0.03–0.19 %	840
$p\gamma$, helicity=1/2	0.02–0.08 %	840
$p\gamma$, helicity=3/2	0.01–0.10 %	840
$n\gamma$	0.003–0.07 %	840
$n\gamma$, helicity=1/2	0.001–0.02 %	840
$n\gamma$, helicity=3/2	0.002–0.05 %	840

$N(2100) 1/2^+$

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

Re(pole position) = 2050 to 2150 (≈ 2100) MeV
 $-2\text{Im}(\text{pole position}) = 240$ to 340 (≈ 300) MeV
 Breit-Wigner mass = 2050 to 2150 (≈ 2100) MeV
 Breit-Wigner full width = 200 to 320 (≈ 260) MeV

$N(2100)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	8–32 %	834
$N\eta$	5–45 %	729
$N\eta'$	5–11 %	451
$N\omega$	10–25 %	600
ΛK	<1.0 %	644
$N\pi\pi$	>55 %	814
$\Delta(1232)\pi$	6–14 %	680
$N\rho$	(17 \pm 6) %	605
$N\rho$, $S=1/2$	35–70 %	605
$N\rho$, $S=3/2$	(5.0 \pm 3.0) %	605
$N\sigma$	14–35 %	–
$N(1535)\pi$	26–34 %	478
$N(1520)\pi$, D -wave	< 2 %	490
$\Lambda K^*(892)$	3–11 %	306
$p\gamma$, helicity=1/2	0.001–0.13 %	840
$n\gamma$, helicity=1/2	0.004–0.09 %	840

$N(2120) 3/2^-$

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$$

Re(pole position) = 2050 to 2150 (≈ 2100) MeV
 $-2\text{Im}(\text{pole position}) = 200$ to 360 (≈ 280) MeV
 Breit-Wigner mass = 2060 to 2160 (≈ 2120) MeV
 Breit-Wigner full width = 260 to 360 (≈ 300) MeV

N(2120) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	5–15 %	846
$N\eta$	1–5 %	743
$N\eta'$	2–6 %	474
$N\omega$	4–20 %	617
ΛK	6–11 %	660
$N\pi\pi$	>27 %	827
$\Delta(1232)\pi$	>23 %	693
$\Delta(1232)\pi$, S -wave	15–70 %	693
$\Delta(1232)\pi$, D -wave	8–45 %	693
$N\rho$	(28 \pm 6) %	622
$N\rho$, $S=1/2$	(4.0 \pm 2.0) %	622
$N\rho$, $S=3/2$, S -wave	< 3 %	622
$N\rho$, $S=3/2$, D -wave	(5.0 \pm 3.0) %	622
$N\sigma$	4–15 %	–
$N(1440)\pi$	(6 \pm 6) %	559
$N(1520)\pi$, P -wave	(10 \pm 5) %	505
$N(1535)\pi$	7–23 %	494
$\Lambda K^*(892)$	< 0.2 %	339
$p\gamma$	0.16–2.1 %	852
$p\gamma$, helicity=1/2	0.07–0.80 %	852
$p\gamma$, helicity=3/2	0.09–1.3 %	852
$n\gamma$	0.04–0.72 %	852
$n\gamma$, helicity=1/2	0.04–0.60 %	852
$n\gamma$, helicity=3/2	0.001–0.12 %	852

N(2190) 7/2⁻

$$I(J^P) = \frac{1}{2}(7_2^-)$$

Re(pole position) = 1950 to 2150 (\approx 2050) MeV

–2Im(pole position) = 300 to 500 (\approx 400) MeV

Breit-Wigner mass = 2140 to 2220 (\approx 2180) MeV

Breit-Wigner full width = 300 to 500 (\approx 400) MeV

N(2190) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	10–20 %	882
$N\eta$	1–5 %	785
$N\omega$	8–20 %	667
ΛK	0.2–0.8 %	705
$N\pi\pi$	22–51 %	864
$\Delta\pi$	(4.0 \pm 2.0) %	734
$\Delta(1232)\pi$, D -wave	19–31 %	734

$N\rho$	$(8 \pm 7) \%$	672
$N\rho, S=3/2, D\text{-wave}$	$<11 \%$	672
$N\sigma$	$3\text{--}9 \%$	–
$\Lambda K^*(892)$	$0.2\text{--}0.8 \%$	423
$p\gamma$	$<0.08 \%$	888
$p\gamma, \text{helicity}=1/2$	$<0.06 \%$	888
$p\gamma, \text{helicity}=3/2$	$<0.02 \%$	888
$n\gamma$	$<0.04 \%$	888
$n\gamma, \text{helicity}=1/2$	$<0.01 \%$	888
$n\gamma, \text{helicity}=3/2$	$<0.03 \%$	888

$N(2220) 9/2^+$

$$I(J^P) = \frac{1}{2}(\frac{9}{2}^+)$$

Re(pole position) = 2130 to 2200 (≈ 2150) MeV
 $-2\text{Im}(\text{pole position}) = 360$ to 480 (≈ 400) MeV
 Breit-Wigner mass = 2200 to 2300 (≈ 2250) MeV
 Breit-Wigner full width = 350 to 500 (≈ 400) MeV

$N(2220)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	15–30 %	924
$\Delta\pi$	$(15\pm 10) \%$	780
$\Delta\pi, F\text{-wave}$	$(15\pm 10) \%$	780
$N\rho$	$(10\pm 10) \%$	727
$N\rho, S=3/2, F\text{-wave}$	$(10\pm 10) \%$	727
$N\sigma$	$(5\pm 5) \%$	–

$N(2250) 9/2^-$

$$I(J^P) = \frac{1}{2}(\frac{9}{2}^-)$$

Re(pole position) = 2100 to 2200 (≈ 2150) MeV
 $-2\text{Im}(\text{pole position}) = 350$ to 500 (≈ 420) MeV
 Breit-Wigner mass = 2250 to 2320 (≈ 2280) MeV
 Breit-Wigner full width = 300 to 600 (≈ 500) MeV

$N(2250)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	5–15 %	941
$N\eta$	$<5 \%$	852
ΛK	1–3 %	777
$\Delta\pi$	$(10\pm 7) \%$	800
$\Delta\pi, G\text{-wave}$	$(10\pm 7) \%$	800
$N\rho$	$(11\pm 7) \%$	750
$N\rho, S=1/2$	$(5\pm 5) \%$	750
$N\rho, S=3/2, G\text{-wave}$	$(6\pm 4) \%$	750

$N(2600) 11/2^-$

$$I(J^P) = \frac{1}{2}(\frac{11}{2}^-)$$

Breit-Wigner mass = 2550 to 2750 (≈ 2600) MeVBreit-Wigner full width = 500 to 800 (≈ 650) MeV

$N(2600)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	3–8 %	1126

NOTES

- [a] The masses of the p and n are most precisely known in u (unified atomic mass units). The conversion factor to MeV, $1 u = 931.494 103 72(29)$ MeV, is less well known than are the masses in u .
- [b] The $|m_p - m_{\bar{p}}|/m_p$ and $|q_p + q_{\bar{p}}|/e$ are not independent, and both use the more precise measurement of $|q_{\bar{p}}/m_{\bar{p}}|/(q_p/m_p)$.
- [c] The limit is from neutrality-of-matter experiments; it assumes $q_n = q_p + q_e$. See also the charge of the neutron.
- [d] The μp and $e p$ values for the charge radius are much too different to average them. The disagreement is not yet understood.
- [e] There is a lot of disagreement about the value of the proton magnetic charge radius. See the Listings.
- [f] There is some controversy about whether nuclear physics and model dependence complicate the analysis for bound neutrons (from which the best limit comes). The first limit here is from reactor experiments with free neutrons.
- [g] Lee and Yang in 1956 proposed the existence of a mirror world in an attempt to restore global parity symmetry—thus a search for oscillations between the two worlds. Oscillations between the worlds would be maximal when the magnetic fields B and B' were equal. The limit for any B' in the range 0 to $12.5 \mu\text{T}$ is >12 s (95% CL).
- [h] The parameters g_A , g_V , and g_{WM} for semileptonic modes are defined by $\bar{B}_f[\gamma_\lambda(g_V + g_A\gamma_5) + i(g_{WM}/m_{B_i}) \sigma_{\lambda\nu} q^\nu]B_i$, and ϕ_{AV} is defined by $g_A/g_V = |g_A/g_V|e^{i\phi_{AV}}$. See the “Note on Baryon Decay Parameters” in the neutron Particle Listings.
- [i] Time-reversal invariance requires this to be 0° or 180° .
- [j] This coefficient is zero if time invariance is not violated.
- [k] This limit is for γ energies between 0.4 and 782 keV.