

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 $m = 1.007276466621 \pm 0.000000000053$ u

Mass $m = 938.27208816 \pm 0.00000029$ MeV [a]

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

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

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

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

Magnetic moment $\mu = 2.7928473446 \pm 0.00000000008 \mu_N$

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

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

Electric polarizability $\alpha = (11.2 \pm 0.4) \times 10^{-4}$ fm³

Magnetic polarizability $\beta = (2.5 \pm 0.4) \times 10^{-4}$ fm³ ($S = 1.2$)

Charge radius, μp Lamb shift = 0.84087 ± 0.00039 fm [d]

Charge radius = 0.8409 ± 0.0004 fm [d]

Magnetic radius = 0.851 ± 0.026 fm [e]

Mean life $\tau > 9 \times 10^{29}$ years, 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 |
| $n \rightarrow \nu K_S^0$ | > 260 | 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) |
|------------------------------------|------------------------------|------------------|----------------|
| $\bar{p} \rightarrow e^- \gamma$ | > 7×10^5 | 90% | 469 |
| $\bar{p} \rightarrow \mu^- \gamma$ | > 5×10^4 | 90% | 463 |
| $\bar{p} \rightarrow e^- \pi^0$ | > 4×10^5 | 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 $m = 1.0086649160 \pm 0.0000000005$ u

Mass $m = 939.5654205 \pm 0.0000005$ MeV [a]

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

$m_n - m_p = 1.2933324 \pm 0.0000005$ MeV
 $= 0.00138844919(45)$ u

Mean life $\tau = 878.4 \pm 0.5$ s (S = 1.8)

$c\tau = 2.6335 \times 10^8$ km

Magnetic moment $\mu = -1.9130427 \pm 0.0000005 \mu_N$

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]

$p e^- \nu_e$ decay parameters [h]

$\lambda \equiv g_A / g_V = -1.2754 \pm 0.0013$ (S = 2.7)

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

$B = 0.9807 \pm 0.0030$

$C = -0.2377 \pm 0.0026$

$a = -0.1049 \pm 0.0013$ (S = 1.8)

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

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

$R = 0.004 \pm 0.013$ [j]

Fierz interference term $b = 0.017 \pm 0.020$

| <i>n</i> DECAY MODES | Fraction (Γ_i/Γ) | Confidence level | ρ (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) MeVBreit-Wigner mass = 1410 to 1470 (≈ 1440) MeVBreit-Wigner full width = 250 to 450 (≈ 350) MeV

| $N(1440)$ DECAY MODES | Fraction (Γ_i/Γ) | ρ (MeV/c) |
|---|--------------------------------|----------------|
| $N\pi$ | 55–75 % | 398 |
| $N\eta$ | < 1 % | † |
| $N\pi\pi$ | 17–50 % | 347 |
| $\Delta(1232)\pi$, <i>P</i> -wave | 6–27 % | 147 |
| $N\sigma$ | 11–23 % | – |
| $p\gamma$, helicity=1/2 | 0.035–0.048 % | 414 |
| $n\gamma$, 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) MeVBreit-Wigner mass = 1510 to 1520 (≈ 1515) MeVBreit-Wigner full width = 100 to 120 (≈ 110) MeV

| $N(1520)$ DECAY MODES | Fraction (Γ_i/Γ) | ρ (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 % | † |
| $N\rho$, $S=3/2$, <i>S</i> -wave | 10–16 % | † |

| | | |
|--------------------------------|-------------|-----|
| $N\rho, S=1/2, D\text{-wave}$ | 0.2–0.4 % | † |
| $N\sigma$ | <10 % | – |
| $p\gamma$ | 0.31–0.52 % | 467 |
| $p\gamma, \text{helicity}=1/2$ | 0.01–0.02 % | 467 |
| $p\gamma, \text{helicity}=3/2$ | 0.30–0.50 % | 467 |
| $n\gamma$ | 0.30–0.53 % | 466 |
| $n\gamma, \text{helicity}=1/2$ | 0.04–0.10 % | 466 |
| $n\gamma, \text{helicity}=3/2$ | 0.25–0.45 % | 466 |

 $N(1535) 1/2^-$

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

Re(pole position) = 1500 to 1520 (≈ 1510) MeV
 $-2\text{Im}(\text{pole position}) = 80$ to 130 (≈ 110) MeV
 Breit-Wigner mass = 1515 to 1545 (≈ 1530) MeV
 Breit-Wigner full width = 125 to 175 (≈ 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 |
| $\Delta(1232)\pi, D\text{-wave}$ | 1–4 % | 240 |
| $N\rho$ | 2–17 % | † |
| $N\rho, S=1/2, S\text{-wave}$ | 2–16 % | † |
| $N\rho, S=3/2, D\text{-wave}$ | <1 % | † |
| $N\sigma$ | 2–10 % | – |
| $N(1440)\pi$ | 5–12 % | † |
| $p\gamma, \text{helicity}=1/2$ | 0.15–0.30 % | 477 |
| $n\gamma, \text{helicity}=1/2$ | 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) MeV
 Breit-Wigner mass = 1635 to 1665 (≈ 1650) MeV
 Breit-Wigner full width = 100 to 150 (≈ 125) MeV

| $N(1650)$ DECAY MODES | Fraction (Γ_i/Γ) | p (MeV/c) |
|---|--------------------------------|-------------|
| $N\pi$ | 50–70 % | 547 |
| $N\eta$ | 15–35 % | 348 |
| ΛK | 5–15 % | 169 |
| $N\pi\pi$ | 20–58 % | 514 |
| $\Delta(1232)\pi, D\text{-wave}$ | 6–18 % | 345 |

| | | |
|-------------------------------|--------------|-----|
| $N\rho$ | 12–22 % | † |
| $N\rho$, $S=1/2$, S -wave | <4 % | † |
| $N\rho$, $S=3/2$, D -wave | 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) MeV

Breit-Wigner mass = 1665 to 1680 (≈ 1675) MeV

Breit-Wigner full width = 130 to 160 (≈ 145) MeV

| $N(1675)$ DECAY MODES | Fraction (Γ_i/Γ) | p (MeV/c) |
|---|--------------------------------|-------------|
| $N\pi$ | 38–42 % | 564 |
| $N\eta$ | < 1 % | 376 |
| ΛK | <0.04 % | 216 |
| $N\pi\pi$ | 25–45 % | 532 |
| $\Delta(1232)\pi$, D -wave | 23–37 % | 366 |
| $N\rho$ | 0.1–0.9 % | † |
| $N\rho$, $S=1/2$ | <0.2 % | † |
| $N\rho$, $S=3/2$, D -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 |
| $\Delta(1232)\pi$, P -wave | 4–10 % | 374 |
| $\Delta(1232)\pi$, F -wave | 1–13 % | 374 |
| $N\rho$ | 8–11 % | † |
| $N\rho$, $S=3/2$, P -wave | 6–8 % | † |
| $N\rho$, $S=3/2$, F -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

–2Im(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 |
| $\Delta(1232)\pi$, S -wave | 50–80 % | 402 |
| $\Delta(1232)\pi$, D -wave | 4–14 % | 402 |
| $N\rho$, $S=3/2$, S -wave | 32–44 % | 74 |
| $N\sigma$ | 2–14 % | – |
| $N(1440)\pi$ | 3–11 % | 225 |
| $N(1520)\pi$ | <4 % | 145 |
| $p\gamma$ | 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 (≈ 1700) MeV $-2\text{Im}(\text{pole position}) = 80$ to 160 (≈ 120) MeVBreit-Wigner mass = 1680 to 1740 (≈ 1710) MeVBreit-Wigner full width = 80 to 200 (≈ 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 |
| $\Delta(1232)\pi$, P -wave | 3–9 % | 394 |
| $N\rho$, $S=1/2$, P -wave | 11–23 % | † |
| $N\sigma$ | <16 % | – |
| $N(1535)\pi$ | 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 |
| $N\rho$, $S=1/2$, P -wave | 1–2 % | 74 |
| $N\sigma$ | 2–14 % | – |
| $N(1440)\pi$ | <2 % | 225 |
| $N(1520)\pi$, S -wave | 1–5 % | 145 |

| | | |
|--------------------------|--------------|-----|
| $p\gamma$ | 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) MeV
 Breit-Wigner mass = 1850 to 1920 (≈ 1875) MeV
 Breit-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 |
| $\Lambda K^*(892)$ | <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 (≈ 1860) MeV $-2\text{Im}(\text{pole position}) = 180$ to 280 (≈ 230) MeVBreit-Wigner mass = 1830 to 1930 (≈ 1880) MeVBreit-Wigner full width = 200 to 400 (≈ 300) MeV

| $N(1880)$ DECAY MODES | Fraction (Γ_i/Γ) | ρ (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 |
| $N\rho, S=1/2, P\text{-wave}$ | 19–45 % | 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 % | † |
| $p\gamma, \text{helicity}=1/2$ | seen | 706 |
| $n\gamma, \text{helicity}=1/2$ | 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 $-2\text{Im}(\text{pole position}) = 80$ 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) | ρ (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 |
| $\Delta(1232)\pi, D\text{-wave}$ | 3–11 % | 535 |

| | | |
|--------------------------------|--------------|-----|
| $N\rho$ | 14–50 % | 403 |
| $N\rho, S=1/2, S\text{-wave}$ | <18 % | 403 |
| $N\rho, S=3/2, D\text{-wave}$ | 14–32 % | 403 |
| $N\sigma$ | <13 % | – |
| $N(1440)\pi$ | 2–12 % | 382 |
| $\Lambda K^*(892)$ | 4–9 % | † |
| $p\gamma, \text{helicity}=1/2$ | 0.01–0.06 % | 715 |
| $n\gamma, \text{helicity}=1/2$ | 0.003–0.05 % | 715 |

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|-----------------------------------|
| $N(1900) 3/2^+$ |
|-----------------------------------|

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

Re(pole position) = 1900 to 1940 (≈ 1920) MeV

–2Im(pole position) = 90 to 160 (≈ 130) MeV

Breit-Wigner mass = 1890 to 1950 (≈ 1920) MeV

Breit-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 |
| $\Delta(1232)\pi, P\text{-wave}$ | 9–25 % | 553 |
| $\Delta(1232)\pi, F\text{-wave}$ | 21–45 % | 553 |
| $N\rho, S=1/2$ | 25–40 % | 432 |
| $N\sigma$ | 1–7 % | – |
| $N(1520)\pi$ | 7–23 % | 341 |
| $N(1535)\pi$ | 4–10 % | 328 |
| $\Lambda K^*(892)$ | < 0.2 % | † |
| $p\gamma$ | 0.001–0.025 % | 731 |
| $p\gamma, \text{helicity}=1/2$ | 0.001–0.021 % | 731 |
| $p\gamma, \text{helicity}=3/2$ | <0.003 % | 731 |
| $n\gamma$ | <0.040 % | 730 |
| $n\gamma, \text{helicity}=1/2$ | <0.007 % | 730 |
| $n\gamma, \text{helicity}=3/2$ | <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 $-2\text{Im}(\text{pole position}) = 350$ to 430 (≈ 400) MeVBreit-Wigner mass = 2030 to 2200 (≈ 2100) MeVBreit-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 |
| $\Delta(1232)\pi$, D -wave | 4–10 % | 680 |
| $N\rho$ | 5–33 % | 605 |
| $N\rho$, $S=1/2$, P -wave | <10 % | 605 |
| $N\rho$, $S=3/2$, D -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 % | 307 |
| $p\gamma$ | 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) MeVBreit-Wigner mass = 2050 to 2150 (≈ 2100) MeVBreit-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 |
| $\Delta(1232)\pi$, P -wave | 6–14 % | 680 |
| $N\rho$, $S=1/2$, P -wave | 35–70 | 605 |
| $N\sigma$ | 14–35 % | – |
| $N(1535)\pi$ | 26–34 % | 478 |
| $\Lambda K^*(892)$ | 3–11 % | 307 |
| $p\gamma$, 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–2Im(pole position) = 200 to 360 (≈ 280) MeVBreit-Wigner mass = 2060 to 2160 (≈ 2120) MeVBreit-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 |
| $N\rho$, $S=3/2$, S -wave | < 3 % | 622 |
| $N\sigma$ | 4–15 % | – |
| $N(1535)\pi$ | 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 |

$N(2190) 7/2^-$

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

Re(pole position) = 1950 to 2150 (≈ 2050) MeV
 $-2\text{Im}(\text{pole position}) = 300$ to 500 (≈ 400) MeV
 Breit-Wigner mass = 2140 to 2220 (≈ 2180) MeV
 Breit-Wigner full width = 300 to 500 (≈ 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 |
| $\Delta(1232)\pi$, D -wave | 19–31 % | 734 |
| $N\rho$, $S=3/2$, D -wave | <11 % | 672 |
| $N\sigma$ | 3–9 % | – |
| $\Lambda K^*(892)$ | 0.2–0.8 % | 423 |
| $p\gamma$ | <0.08 % | 888 |
| $p\gamma$, helicity=1/2 | <0.06 % | 888 |
| $p\gamma$, helicity=3/2 | <0.02 % | 888 |
| $n\gamma$ | <0.04 % | 888 |
| $n\gamma$, helicity=1/2 | <0.01 % | 888 |
| $n\gamma$, 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 |

 $N(2250) 9/2^-$

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

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 |

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|---|
| $N(2600)$ $11/2^-$ |
|---|

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

Breit-Wigner mass = 2550 to 2750 (≈ 2600) MeV

Breit-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, $1 \text{ u} = 931.494061(21) \text{ MeV}$, 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 $>12 \text{ s}$ (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.