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

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

p

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

Mass $m = 1.00727646688 \pm 0.00000000013$ u
Mass $m = 938.27200 \pm 0.00004$ MeV [a]
$|m_p - m_{\overline{p}}|/m_p < 6 \times 10^{-8}$, CL = 90% [b]
$|\frac{q_{\overline{p}}}{m_{\overline{p}}}|/(\frac{q_p}{m_p}) = 0.99999999991 \pm 0.00000000009$
$|q_p + q_{\overline{p}}|/e < 6 \times 10^{-8}$, CL = 90% [b]
$|q_p + q_e|/e < 1.0 \times 10^{-21}$ [c]
Magnetic moment $\mu = 2.792847337 \pm 0.000000029\ \mu_N$
$(\mu_p + \mu_{\overline{p}}) / \mu_p = (-2.6 \pm 2.9) \times 10^{-3}$
Electric dipole moment $d = (-4 \pm 6) \times 10^{-23}$ $e$cm
Electric polarizability $\overline{\alpha} = (12.0 \pm 0.7) \times 10^{-4}$ fm^3
Magnetic polarizability $\overline{\beta} = (1.6 \pm 0.6) \times 10^{-4}$ fm^3
Charge radius = 0.870 ± 0.008 fm
Mean life $\tau > 1.6 \times 10^{25}$ years (independent of mode)
$> 10^{31}$ to 10^{33} years [d] (mode dependent)

See the "Note on Nucleon Decay" in our 1994 edition (Phys. Rev. **D50**, 1673) 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			
$N \to e^+\pi$	> 158 (n), > 1600 (p)	90%	459
$N \to \mu^+\pi$	> 100 (n), > 473 (p)	90%	453
$N \to \nu\pi$	> 112 (n), > 25 (p)	90%	459
$p \to e^+\eta$	> 313	90%	309
$p \to \mu^+\eta$	> 126	90%	296
$n \to \nu\eta$	> 158	90%	310
$N \to e^+\rho$	> 217 (n), > 75 (p)	90%	153
$N \to \mu^+\rho$	> 228 (n), > 110 (p)	90%	119
$N \to \nu\rho$	> 19 (n), > 162 (p)	90%	153
$p \to e^+\omega$	> 107	90%	142

$p \to \mu^+ \omega$	> 117	90%	104
$n \to \nu \omega$	> 108	90%	144
$N \to e^+ K$	> 17 (n), > 150 (p)	90%	337
$p \to e^+ K^0_S$	> 120	90%	337
$p \to e^+ K^0_L$	> 51	90%	337
$N \to \mu^+ K$	> 26 (n), > 120 (p)	90%	326
$p \to \mu^+ K^0_S$	> 150	90%	326
$p \to \mu^+ K^0_L$	> 83	90%	326
$N \to \nu K$	> 86 (n), > 670 (p)	90%	339
$n \to \nu K^0_S$	> 51	90%	–
$p \to e^+ K^*(892)^0$	> 84	90%	45
$N \to \nu K^*(892)$	> 78 (n), > 51 (p)	90%	45

Antilepton + mesons

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

Lepton + meson

$n \to e^- \pi^+$	> 65	90%	459
$n \to \mu^- \pi^+$	> 49	90%	453
$n \to e^- \rho^+$	> 62	90%	154
$n \to \mu^- \rho^+$	> 7	90%	120
$n \to e^- K^+$	> 32	90%	340
$n \to \mu^- K^+$	> 57	90%	330

Lepton + mesons

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

Antilepton + photon(s)

$p \to e^+ \gamma$	> 670	90%	469
$p \to \mu^+ \gamma$	> 478	90%	463
$n \to \nu \gamma$	> 28	90%	470
$p \to e^+ \gamma \gamma$	> 100	90%	469
$n \to \nu \gamma \gamma$	> 219	90%	470

Three (or more) leptons

$p \to e^+ e^+ e^-$	> 793	90%	469
$p \to e^+ \mu^+ \mu^-$	> 359	90%	457
$p \to e^+ \nu \nu$	> 17	90%	469
$n \to e^+ e^- \nu$	> 257	90%	470
$n \to \mu^+ e^- \nu$	> 83	90%	464
$n \to \mu^+ \mu^- \nu$	> 79	90%	458
$p \to \mu^+ e^+ e^-$	> 529	90%	464
$p \to \mu^+ \mu^+ \mu^-$	> 675	90%	439
$p \to \mu^+ \nu \nu$	> 21	90%	463
$p \to e^- \mu^+ \mu^+$	> 6	90%	457
$n \to 3\nu$	> 0.0005	90%	470
$n \to 5\nu$	—		–

Inclusive modes

$N \to e^+$ anything	> 0.6 (n, p)	90%	–
$N \to \mu^+$ anything	> 12 (n, p)	90%	–
$N \to \nu$ anything	—		–
$N \to e^+ \pi^0$ anything	> 0.6 (n, p)	90%	–
$N \to$ 2 bodies, ν-free	—		–

$\Delta B = 2$ dinucleon modes

The following are lifetime limits per iron nucleus.

$pp \to \pi^+ \pi^+$	> 0.7	90%	–
$pn \to \pi^+ \pi^0$	> 2	90%	–
$nn \to \pi^+ \pi^-$	> 0.7	90%	–
$nn \to \pi^0 \pi^0$	> 3.4	90%	–
$pp \to e^+ e^+$	> 5.8	90%	–
$pp \to e^+ \mu^+$	> 3.6	90%	–
$pp \to \mu^+ \mu^+$	> 1.7	90%	–
$pn \to e^+ \overline{\nu}$	> 2.8	90%	–
$pn \to \mu^+ \overline{\nu}$	> 1.6	90%	–
$nn \to \nu_e \overline{\nu}_e$	> 0.000012	90%	–
$nn \to \nu_\mu \overline{\nu}_\mu$	> 0.000006	90%	–
$pp \to$ neutrinos	> 0.00000055	90%	–

$\overline{p}$ DECAY MODES

$\overline{p}$ DECAY MODES	Partial mean life (years)	Confidence level	p (MeV/c)
$\overline{p} \rightarrow e^- \gamma$	$> 7 \times 10^5$	90%	469
$\overline{p} \rightarrow \mu^- \gamma$	$> 5 \times 10^4$	90%	463
$\overline{p} \rightarrow e^- \pi^0$	$> 4 \times 10^5$	90%	459
$\overline{p} \rightarrow \mu^- \pi^0$	$> 5 \times 10^4$	90%	453
$\overline{p} \rightarrow e^- \eta$	$> 2 \times 10^4$	90%	309
$\overline{p} \rightarrow \mu^- \eta$	$> 8 \times 10^3$	90%	296
$\overline{p} \rightarrow e^- K^0_S$	> 900	90%	337
$\overline{p} \rightarrow \mu^- K^0_S$	$> 4 \times 10^3$	90%	326
$\overline{p} \rightarrow e^- K^0_L$	$> 9 \times 10^3$	90%	337
$\overline{p} \rightarrow \mu^- K^0_L$	$> 7 \times 10^3$	90%	326
$\overline{p} \rightarrow e^- \gamma\gamma$	$> 2 \times 10^4$	90%	469
$\overline{p} \rightarrow \mu^- \gamma\gamma$	$> 2 \times 10^4$	90%	463
$\overline{p} \rightarrow e^- \rho$	—		153
$\overline{p} \rightarrow e^- \omega$	> 200	90%	142
$\overline{p} \rightarrow e^- K^*(892)^0$	—		141

n

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

Mass $m = 1.0086649158 \pm 0.0000000006$ u
Mass $m = 939.56533 \pm 0.00004$ MeV [a]
$m_n - m_p = 1.2933318 \pm 0.0000005$ MeV
$= 0.0013884489 \pm 0.0000000006$ u
Mean life $\tau = 885.7 \pm 0.8$ s
$c\tau = 2.655 \times 10^8$ km
Magnetic moment $\mu = -1.9130427 \pm 0.0000005\ \mu_N$
Electric dipole moment $d < 0.63 \times 10^{-25}\ e$cm, CL = 90%
Mean-square charge radius $\langle r_n^2 \rangle = -0.1161 \pm 0.0022$ fm^2 (S = 1.3)
Electric polarizability $\alpha = (9.8^{+1.9}_{-2.3}) \times 10^{-4}$ fm^3 (S = 1.1)
Charge $q = (-0.4 \pm 1.1) \times 10^{-21}\ e$
Mean $n\overline{n}$-oscillation time $> 8.6 \times 10^7$ s, CL = 90% (free n)
$> 1.2 \times 10^8$ s, CL = 90% [e] (bound n)

Decay parameters [f]

$p\,e^-\,\overline{\nu}_e$	$\lambda \equiv g_A\ /\ g_V = -1.2670 \pm 0.0030$	(S = 1.6)
"	$A = -0.1162 \pm 0.0013$	(S = 1.8)
"	$B = 0.983 \pm 0.004$	
"	$a = -0.102 \pm 0.005$	
"	$\phi_{AV} = (180.08 \pm 0.10)^\circ$ [g]	
"	$D = (-0.6 \pm 1.0) \times 10^{-3}$	

n DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$p\,e^-\,\overline{\nu}_e$	100 %		1.19
Charge conservation (Q) violating mode			
$p\,\nu_e\,\overline{\nu}_e$	Q $<$ 8×10^{-27}	68%	1.29

$N(1440)\ P_{11}$

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

Breit-Wigner mass = 1430 to 1470 ($\approx$ 1440) MeV
Breit-Wigner full width = 250 to 450 ($\approx$ 350) MeV
p_{beam} = 0.61 GeV/c $\quad 4\pi\lambda\!\!\!^{-2}$ = 31.0 mb
Re(pole position) = 1345 to 1385 ($\approx$ 1365) MeV
-2Im(pole position) = 160 to 260 ($\approx$ 210) MeV

***N*(1440) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	60–70 %	397
$N\pi\pi$	30–40 %	342
$\Delta\pi$	20–30 %	143
$N\rho$	<8 %	†
$N(\pi\pi)^{I=0}_{S\text{-wave}}$	5–10 %	–
$p\gamma$	0.035–0.048 %	414
$p\gamma$, helicity=1/2	0.035–0.048 %	414
$n\gamma$	0.009–0.032 %	413
$n\gamma$, helicity=1/2	0.009–0.032 %	413

$N(1520)\ D_{13}$

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

Breit-Wigner mass = 1515 to 1530 ($\approx$ 1520) MeV
Breit-Wigner full width = 110 to 135 ($\approx$ 120) MeV
p_{beam} = 0.74 GeV/c $\quad 4\pi\lambda\!\!\!^{-2}$ = 23.5 mb
Re(pole position) = 1505 to 1515 ($\approx$ 1510) MeV
-2Im(pole position) = 110 to 120 ($\approx$ 115) MeV

***N*(1520) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	50–60 %	456
$N\eta$	(0.0 $\pm$ 1.0) %	149
$N\pi\pi$	40–50 %	410
$\Delta\pi$	15–25 %	228
$N\rho$	15–25 %	†
$N(\pi\pi)^{I=0}_{S\text{-wave}}$	<8 %	–
$p\gamma$	0.46–0.56 %	470
$p\gamma$, helicity=1/2	0.001–0.034 %	470
$p\gamma$, helicity=3/2	0.44–0.53 %	470
$n\gamma$	0.30–0.53 %	470
$n\gamma$, helicity=1/2	0.04–0.10 %	470
$n\gamma$, helicity=3/2	0.25–0.45 %	470

$N(1535)$ S_{11}

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

Breit-Wigner mass = 1520 to 1555 ($\approx$ 1535) MeV
Breit-Wigner full width = 100 to 200 ($\approx$ 150) MeV
p_{beam} = 0.76 GeV/c $\quad 4\pi\lambda\!\!\!^{-2}$ = 22.5 mb
Re(pole position) = 1495 to 1515 ($\approx$ 1505) MeV
-2Im(pole position) = 90 to 250 ($\approx$ 170) MeV

***N*(1535) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	35–55 %	467
$N\eta$	30–55 %	182
$N\pi\pi$	1–10 %	422
$\Delta\pi$	<1 %	242
$N\rho$	<4 %	†
$N(\pi\pi)^{I=0}_{S\text{-wave}}$	<3 %	–
$N(1440)\pi$	<7 %	†
$p\gamma$	0.15–0.35 %	481
$p\gamma$, helicity=1/2	0.15–0.35 %	481
$n\gamma$	0.004–0.29 %	480
$n\gamma$, helicity=1/2	0.004–0.29 %	480

$N(1650)$ S_{11}

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

Breit-Wigner mass = 1640 to 1680 ($\approx$ 1650) MeV
Breit-Wigner full width = 145 to 190 ($\approx$ 150) MeV
p_{beam} = 0.96 GeV/c $\quad 4\pi\lambda\!\!\!^{-2}$ = 16.4 mb
Re(pole position) = 1640 to 1680 ($\approx$ 1660) MeV
-2Im(pole position) = 150 to 170 ($\approx$ 160) MeV

***N*(1650) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	55–90 %	547
$N\eta$	3–10 %	346
ΛK	3–11 %	161
$N\pi\pi$	10–20 %	511
$\Delta\pi$	1–7 %	344
$N\rho$	4–12 %	†
$N(\pi\pi)^{I=0}_{S\text{-wave}}$	<4 %	–
$N(1440)\pi$	<5 %	147
$p\gamma$	0.04–0.18 %	558
$p\gamma$, helicity=1/2	0.04–0.18 %	558
$n\gamma$	0.003–0.17 %	557
$n\gamma$, helicity=1/2	0.003–0.17 %	557

$N(1675)$ D_{15}

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

Breit-Wigner mass = 1670 to 1685 ($\approx$ 1675) MeV
Breit-Wigner full width = 140 to 180 ($\approx$ 150) MeV
$p_{\rm beam}$ = 1.01 GeV/c $\quad 4\pi\lambda\!\!\!^{-2}$ = 15.4 mb
Re(pole position) = 1655 to 1665 ($\approx$ 1660) MeV
-2Im(pole position) = 125 to 155 ($\approx$ 140) MeV

***N*(1675) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	40–50 %	563
$N\eta$	(0.0 $\pm$ 1.0) %	374
ΛK	<1 %	209
$N\pi\pi$	50–60 %	529
$\Delta\pi$	50–60 %	364
$N\rho$	< 1–3 %	†
$p\gamma$	0.004–0.023 %	575
$p\gamma$, helicity=1/2	0.0–0.015 %	575
$p\gamma$, helicity=3/2	0.0–0.011 %	575
$n\gamma$	0.02–0.12 %	574
$n\gamma$, helicity=1/2	0.006–0.046 %	574
$n\gamma$, helicity=3/2	0.01–0.08 %	574

$N(1680)$ F_{15}

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

Breit-Wigner mass = 1675 to 1690 ($\approx$ 1680) MeV
Breit-Wigner full width = 120 to 140 ($\approx$ 130) MeV
p_{beam} = 1.01 GeV/c $\quad 4\pi\lambda\!\!\!^{-2}$ = 15.2 mb
Re(pole position) = 1665 to 1675 ($\approx$ 1670) MeV
-2Im(pole position) = 105 to 135 ($\approx$ 120) MeV

***N*(1680) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	60–70 %	567
$N\eta$	(0.0 $\pm$ 1.0) %	379
$N\pi\pi$	30–40 %	532
$\Delta\pi$	5–15 %	369
$N\rho$	3–15 %	†
$N(\pi\pi)^{I=0}_{S\text{-wave}}$	5–20 %	–
$p\gamma$	0.21–0.32 %	578
$p\gamma$, helicity=1/2	0.001–0.011 %	578
$p\gamma$, helicity=3/2	0.20–0.32 %	578
$n\gamma$	0.021–0.046 %	577
$n\gamma$, helicity=1/2	0.004–0.029 %	577
$n\gamma$, helicity=3/2	0.01–0.024 %	577

$N(1700)$ D_{13}

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

Breit-Wigner mass = 1650 to 1750 ($\approx$ 1700) MeV
Breit-Wigner full width = 50 to 150 ($\approx$ 100) MeV
p_{beam} = 1.05 GeV/c $\quad 4\pi\lambda\!\!\!^{-2}$ = 14.5 mb
Re(pole position) = 1630 to 1730 ($\approx$ 1680) MeV
-2Im(pole position) = 50 to 150 ($\approx$ 100) MeV

***N*(1700) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	5–15 %	580
$N\eta$	(0.0 ± 1.0) %	400
ΛK	<3 %	250
$N\pi\pi$	85–95 %	547
$N\rho$	<35 %	†
$p\gamma$	0.01–0.05 %	591
$p\gamma$, helicity=1/2	0.0–0.024 %	591
$p\gamma$, helicity=3/2	0.002–0.026 %	591
$n\gamma$	0.01–0.13 %	590
$n\gamma$, helicity=1/2	0.0–0.09 %	590
$n\gamma$, helicity=3/2	0.01–0.05 %	590

$N(1710)$ P_{11}

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

Breit-Wigner mass = 1680 to 1740 ($\approx$ 1710) MeV
Breit-Wigner full width = 50 to 250 ($\approx$ 100) MeV
p_{beam} = 1.07 GeV/c $\quad 4\pi\lambda\!\!\!^{-2}$ = 14.2 mb
Re(pole position) = 1670 to 1770 ($\approx$ 1720) MeV
-2Im(pole position) = 80 to 380 ($\approx$ 230) MeV

***N*(1710) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	10–20 %	587
$N\eta$	(6.0 ± 1.0) %	410
ΛK	5–25 %	264
$N\pi\pi$	40–90 %	554
$\Delta\pi$	15–40 %	393
$N\rho$	5–25 %	48
$N(\pi\pi)^{I=0}_{S\text{-wave}}$	10–40 %	–
$p\gamma$	0.002–0.05%	598
$p\gamma$, helicity=1/2	0.002–0.05%	598
$n\gamma$	0.0–0.02%	597
$n\gamma$, helicity=1/2	0.0–0.02%	597

$N(1720)\ P_{13}$

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

Breit-Wigner mass = 1650 to 1750 ($\approx$ 1720) MeV
Breit-Wigner full width = 100 to 200 ($\approx$ 150) MeV
$p_{\rm beam}$ = 1.09 GeV/c $\quad 4\pi\lambda\!\!\!^{-2}$ = 13.9 mb
Re(pole position) = 1650 to 1750 ($\approx$ 1700) MeV
-2Im(pole position) = 110 to 390 ($\approx$ 250) MeV

***N*(1720) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	10–20 %	594
$N\eta$	(4.0 $\pm$ 1.0) %	420
ΛK	1–15 %	278
$N\pi\pi$	>70 %	561
$N\rho$	70–85 %	104
$p\gamma$	0.003–0.10 %	604
$p\gamma$, helicity=1/2	0.003–0.08 %	604
$p\gamma$, helicity=3/2	0.001–0.03 %	604
$n\gamma$	0.002–0.39 %	603
$n\gamma$, helicity=1/2	0.0–0.002 %	603
$n\gamma$, helicity=3/2	0.001–0.39 %	603

$N(2190)\ G_{17}$

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

Breit-Wigner mass = 2100 to 2200 ($\approx$ 2190) MeV
Breit-Wigner full width = 350 to 550 ($\approx$ 450) MeV
$p_{\rm beam}$ = 2.07 GeV/c $\quad 4\pi\lambda\!\!\!^{-2}$ = 6.21 mb
Re(pole position) = 1950 to 2150 ($\approx$ 2050) MeV
-2Im(pole position) = 350 to 550 ($\approx$ 450) MeV

***N*(2190) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	10–20 %	888
$N\eta$	(0.0 $\pm$ 1.0) %	790

$N(2220)$ H_{19}

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

Breit-Wigner mass = 2180 to 2310 ($\approx$ 2220) MeV
Breit-Wigner full width = 320 to 550 ($\approx$ 400) MeV
p_{beam} = 2.14 GeV/c $4\pi\lambda\!\!\!^{-2}$ = 5.97 mb
Re(pole position) = 2100 to 2240 ($\approx$ 2170) MeV
-2Im(pole position) = 370 to 570 ($\approx$ 470) MeV

$N(2220)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	10–20 %	905

$N(2250)$ G_{19}

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

Breit-Wigner mass = 2170 to 2310 ($\approx$ 2250) MeV
Breit-Wigner full width = 290 to 470 ($\approx$ 400) MeV
p_{beam} = 2.21 GeV/c $4\pi\lambda\!\!\!^{-2}$ = 5.74 mb
Re(pole position) = 2080 to 2200 ($\approx$ 2140) MeV
-2Im(pole position) = 280 to 680 ($\approx$ 480) MeV

$N(2250)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	5–15 %	923

$N(2600)$ $I_{1,11}$

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

Breit-Wigner mass = 2550 to 2750 ($\approx$ 2600) MeV
Breit-Wigner full width = 500 to 800 ($\approx$ 650) MeV
p_{beam} = 3.12 GeV/c $4\pi\lambda\!\!\!^{-2}$ = 3.86 mb

$N(2600)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	5–10 %	1126