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 $m = 938.27231 \pm 0.00028$ MeV [a]
$= 1.007276470 \pm 0.000000012$ u
$\left|\frac{q_{\overline{p}}}{m_{\overline{p}}}\right| / (\frac{q_p}{m_p}) = 1.0000000015 \pm 0.0000000011$
$\left|q_p + q_{\overline{p}}\right| / e < 2 \times 10^{-5}$
$\left|q_p + q_e\right| / e < 1.0 \times 10^{-21}$ [b]
Magnetic moment $\mu = 2.79284739 \pm 0.00000006\ \mu_N$
Electric dipole moment $d = (-4 \pm 6) \times 10^{-23}\ e$ cm
Electric polarizability $\overline{\alpha} = (12.1 \pm 0.9) \times 10^{-4}$ fm^3
Magnetic polarizability $\overline{\beta} = (2.1 \pm 0.9) \times 10^{-4}$ fm^3
Mean life $\tau > 1.6 \times 10^{25}$ years (independent of mode)
$=> 10^{31} - 5 \times 10^{32}$ years [c] (mode dependent)

Below, for N decays, p and n distinguish proton and neutron partial lifetimes. See also 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.

***p* DECAY MODES**	Partial mean life (10^{30} years)	Confidence level	p (MeV/c)
Antilepton + meson			
$N \to e^+ \pi$	> 130 (n), > 550 (p)	90%	459
$N \to \mu^+ \pi$	> 100 (n), > 270 (p)	90%	453
$N \to \nu \pi$	> 100 (n), > 25 (p)	90%	459
$p \to e^+ \eta$	> 140	90%	309
$p \to \mu^+ \eta$	> 69	90%	296
$n \to \nu \eta$	> 54	90%	310
$N \to e^+ \rho$	> 58 (n), > 75 (p)	90%	153
$N \to \mu^+ \rho$	> 23 (n), > 110 (p)	90%	119
$N \to \nu \rho$	> 19 (n), > 27 (p)	90%	153
$p \to e^+ \omega$	> 45	90%	142

$p \to \mu^+ \omega$	> 57	90%	104
$n \to \nu \omega$	> 43	90%	144
$N \to e^+ K$	> 1.3 (n), > 150 (p)	90%	337
$p \to e^+ K^0_S$	> 76	90%	337
$p \to e^+ K^0_L$	> 44	90%	337
$N \to \mu^+ K$	> 1.1 (n), > 120 (p)	90%	326
$p \to \mu^+ K^0_S$	> 64	90%	326
$p \to \mu^+ K^0_L$	> 44	90%	326
$N \to \nu K$	> 86 (n), > 100 (p)	90%	339
$p \to e^+ K^*(892)^0$	> 52	90%	45
$N \to \nu K^*(892)$	> 22 (n), > 20 (p)	90%	45

Antilepton + mesons

$p \to e^+ \pi^+ \pi^-$	> 21	90%	448
$p \to e^+ \pi^0 \pi^0$	> 38	90%	449
$n \to e^+ \pi^- \pi^0$	> 32	90%	449
$p \to \mu^+ \pi^+ \pi^-$	> 17	90%	425
$p \to \mu^+ \pi^0 \pi^0$	> 33	90%	427
$n \to \mu^+ \pi^- \pi^0$	> 33	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
$p \to e^- \pi^+ K^+$	> 20	90%	320
$p \to \mu^- \pi^+ K^+$	> 5	90%	279

Antilepton + photon(s)

$p \to e^+ \gamma$	> 460	90%	469
$p \to \mu^+ \gamma$	> 380	90%	463
$n \to \nu \gamma$	> 24	90%	470
$p \to e^+ \gamma \gamma$	> 100	90%	469

Three leptons

$p \to e^+ e^+ e^-$	> 510	90%	469
$p \to e^+ \mu^+ \mu^-$	> 81	90%	457
$p \to e^+ \nu \nu$	> 11	90%	469
$n \to e^+ e^- \nu$	> 74	90%	470
$n \to \mu^+ e^- \nu$	> 47	90%	464
$n \to \mu^+ \mu^- \nu$	> 42	90%	458
$p \to \mu^+ e^+ e^-$	> 91	90%	464
$p \to \mu^+ \mu^+ \mu^-$	> 190	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

Inclusive modes

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

$\Delta B = 2$ 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%	–

$\overline{p}$ DECAY MODES

$\overline{p}$ DECAY MODES	Partial mean life (years)	Confidence level	p (MeV/c)
$\overline{p} \to e^- \gamma$	> 1848	95%	469
$\overline{p} \to e^- \pi^0$	> 554	95%	459
$\overline{p} \to e^- \eta$	> 171	95%	309
$\overline{p} \to e^- K^0_S$	> 29	95%	337
$\overline{p} \to e^- K^0_L$	> 9	95%	337

n

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

Mass $m = 939.56563 \pm 0.00028$ MeV [a]
$= 1.008664904 \pm 0.000000014$ u
$m_n - m_p = 1.293318 \pm 0.000009$ MeV
$= 0.001388434 \pm 0.000000009$ u
Mean life $\tau = 887.0 \pm 2.0$ s (S = 1.3)
$c\tau = 2.659 \times 10^8$ km
Magnetic moment $\mu = -1.9130428 \pm 0.0000005\ \mu_N$
Electric dipole moment $d < 1.1 \times 10^{-25}\ e$cm, CL = 95%
Electric polarizability $\alpha = (0.98^{+0.19}_{-0.23}) \times 10^{-3}$ fm^3 (S = 1.1)
Charge $q = (-0.4 \pm 1.1) \times 10^{-21}\ e$
Mean $n\overline{n}$-oscillation time $> 1.2 \times 10^8$ s, CL = 90% [d] (bound n)
$> 0.86 \times 10^8$ s, CL = 90% (free n)

Decay parameters [e]

$p e^- \overline{\nu}_e$	$g_A/g_V = -1.2601 \pm 0.0025$ (S = 1.1)
"	$A = -0.1139 \pm 0.0011$ (S = 1.3)
"	$B = 0.990 \pm 0.008$
"	$a = -0.102 \pm 0.005$
"	$\phi_{AV} = (180.07 \pm 0.18)^\circ$ [f]
"	$D = (-0.5 \pm 1.4) \times 10^{-3}$

***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 < 9×10^{-24}	90%	1.29

$N(1440)\ P_{11}$ $\quad I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

Mass $m = 1430$ to 1470 (≈ 1440) MeV
Full width $\Gamma = 250$ to 450 (≈ 350) MeV
$p_{\text{beam}} = 0.61$ GeV/c $\quad 4\pi\lambda\!\!\!^{-2} = 31.0$ mb

***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

$N(1520)\ D_{13}$ $\quad I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$

Mass $m = 1515$ to 1530 (≈ 1520) MeV
Full width $\Gamma = 110$ to 135 (≈ 120) MeV
$p_{\text{beam}} = 0.74$ GeV/c $\quad 4\pi\lambda\!\!\!^{-2} = 23.5$ mb

***N*(1520) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	50–60 %	456
$N\pi\pi$	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} $I(J^P) = \frac{1}{2}(\frac{1}{2}^-)$

Mass $m = 1520$ to 1555 (≈ 1535) MeV
Full width $\Gamma = 100$ to 250 (≈ 150) MeV
$p_{\text{beam}} = 0.76$ GeV/c $4\pi\lambda\!\!\!^{-2} = 22.5$ mb

$N(1535)$ 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 %	†
$p\gamma$	0.08–0.27 %	481
$p\gamma$, helicity=1/2	0.08–0.27 %	481
$n\gamma$	0.004–0.29 %	480
$n\gamma$, helicity=1/2	0.004–0.29 %	480

$N(1650)$ S_{11} $I(J^P) = \frac{1}{2}(\frac{1}{2}^-)$

Mass $m = 1640$ to 1680 (≈ 1650) MeV
Full width $\Gamma = 145$ to 190 (≈ 150) MeV
$p_{\text{beam}} = 0.96$ GeV/c $4\pi\lambda\!\!\!^{-2} = 16.4$ mb

$N(1650)$ 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} $I(J^P) = \frac{1}{2}(\frac{5}{2}^-)$

Mass $m = 1670$ to 1685 (≈ 1675) MeV
Full width $\Gamma = 140$ to 180 (≈ 150) MeV
$p_{\text{beam}} = 1.01$ GeV/c $\quad 4\pi\lambda\!\!\!^{-2} = 15.4$ mb

***N*(1675) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	40–50 %	563
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} $I(J^P) = \frac{1}{2}(\frac{5}{2}^+)$

Mass $m = 1675$ to 1690 (≈ 1680) MeV
Full width $\Gamma = 120$ to 140 (≈ 130) MeV
$p_{\text{beam}} = 1.01$ GeV/c $\quad 4\pi\lambda\!\!\!^{-2} = 15.2$ mb

***N*(1680) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	60–70 %	567
$N\pi\pi$	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}

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

Mass m = 1650 to 1750 ($\approx$ 1700) MeV
Full width Γ = 50 to 150 ($\approx$ 100) MeV
p_{beam} = 1.05 GeV/c $4\pi\lambda\!\!\!^{-2}$ = 14.5 mb

***N*(1700) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	5–15 %	580
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}

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

Mass m = 1680 to 1740 ($\approx$ 1710) MeV
Full width Γ = 50 to 250 ($\approx$ 100) MeV
p_{beam} = 1.07 GeV/c $4\pi\lambda\!\!\!^{-2}$ = 14.2 mb

***N*(1710) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	10–20 %	587
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

$N(1720)\ P_{13}$ $I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$

Mass $m = 1650$ to 1750 (≈ 1720) MeV
Full width $\Gamma = 100$ to 200 (≈ 150) MeV
$p_{\text{beam}} = 1.09$ GeV/c $4\pi\lambda\!\!\!^{-2} = 13.9$ mb

***N*(1720) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	10–20 %	594
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

$N(2190)\ G_{17}$ $I(J^P) = \frac{1}{2}(\frac{7}{2}^-)$

Mass $m = 2100$ to 2200 (≈ 2190) MeV
Full width $\Gamma = 350$ to 550 (≈ 450) MeV
$p_{\text{beam}} = 2.07$ GeV/c $4\pi\lambda\!\!\!^{-2} = 6.21$ mb

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

$N(2220)\ H_{19}$ $I(J^P) = \frac{1}{2}(\frac{9}{2}^+)$

Mass $m = 2180$ to 2310 (≈ 2220) MeV
Full width $\Gamma = 320$ to 550 (≈ 400) MeV
$p_{\text{beam}} = 2.14$ GeV/c $4\pi\lambda\!\!\!^{-2} = 5.97$ mb

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

$N(2250)$ G_{19} $I(J^P) = \frac{1}{2}(\frac{9}{2}^-)$

Mass $m = 2170$ to 2310 (≈ 2250) MeV
Full width $\Gamma = 290$ to 470 (≈ 400) MeV
$p_{\text{beam}} = 2.21$ GeV/c $\quad 4\pi\lambda\!\!\!^{-2} = 5.74$ mb

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

$N(2600)$ $I_{1,11}$ $I(J^P) = \frac{1}{2}(\frac{11}{2}^-)$

Mass $m = 2550$ to 2750 (≈ 2600) MeV
Full width $\Gamma = 500$ to 800 (≈ 650) MeV
$p_{\text{beam}} = 3.12$ GeV/c $\quad 4\pi\lambda\!\!\!^{-2} = 3.86$ mb

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