

# 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  $m = 1.00727646688 \pm 0.00000000009$  u

Mass  $m = 938.272081 \pm 0.000006$  MeV [a]

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

$|\frac{q_{\bar{p}}}{m_{\bar{p}}}|/(\frac{q_p}{m_p}) = 1.00000000000 \pm 0.00000000007$

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

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

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

$(\mu_p + \mu_{\bar{p}}) / \mu_p = (0.3 \pm 0.8) \times 10^{-6}$

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

Electric polarizability  $\alpha = (11.2 \pm 0.4) \times 10^{-4}$  fm<sup>3</sup>

Magnetic polarizability  $\beta = (2.5 \pm 0.4) \times 10^{-4}$  fm<sup>3</sup> ( $S = 1.2$ )

Charge radius,  $\mu p$  Lamb shift =  $0.84087 \pm 0.00039$  fm [d]

Charge radius,  $e p$  CODATA value =  $0.8751 \pm 0.0061$  fm [d]

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

Mean life  $\tau > 2.1 \times 10^{29}$  years, CL = 90% [f] ( $p \rightarrow$  invisible mode)

Mean life  $\tau > 10^{31}$  to  $10^{33}$  years [f] (mode dependent)

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  $\tau/B_i$ , where  $\tau$  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.

<b>p DECAY MODES</b>	Partial mean life ( $10^{30}$ years)	Confidence level	$p$ (MeV/c)
<b>Antilepton + meson</b>			
$N \rightarrow e^+ \pi$	$> 5300$ ( $n$ ), $> 16000$ ( $p$ )	90%	459
$N \rightarrow \mu^+ \pi$	$> 3500$ ( $n$ ), $> 7700$ ( $p$ )	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
$N \rightarrow \mu^+ K$	$> 26 (n), > 1600 (p)$	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

$p \rightarrow e^+ e^+ e^-$	> 793	90%	469
$p \rightarrow e^+ \mu^+ \mu^-$	> 359	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
$p \rightarrow \mu^+ e^+ e^-$	> 529	90%	463
$p \rightarrow \mu^+ \mu^+ \mu^-$	> 675	90%	439
$p \rightarrow \mu^+ \nu \nu$	> 220	90%	463
$p \rightarrow e^- \mu^+ \mu^+$	> 6	90%	457
$n \rightarrow 3\nu$	> $5 \times 10^{-4}$	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%	—
$nn \rightarrow \nu_e \bar{\nu}_e$	> 1.4	90%	—
$nn \rightarrow \nu_\mu \bar{\nu}_\mu$	> 1.4	90%	—
$pn \rightarrow$ invisible	> $2.1 \times 10^{-5}$	90%	—
$pp \rightarrow$ invisible	> $5 \times 10^{-5}$	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  $m = 1.0086649159 \pm 0.0000000005$  u

Mass  $m = 939.565413 \pm 0.000006$  MeV [a]

$(m_n - m_{\bar{n}}) / m_n = (9 \pm 6) \times 10^{-5}$

$m_n - m_p = 1.2933321 \pm 0.0000005$  MeV  
 $= 0.00138844919(45)$  u

Mean life  $\tau = 879.4 \pm 0.6$  s (S = 1.6)

$c\tau = 2.6362 \times 10^8$  km

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

Electric dipole moment  $d < 0.30 \times 10^{-25}$  e cm, CL = 90%

Mean-square charge radius  $\langle r_n^2 \rangle = -0.1161 \pm 0.0022$   
 $\text{fm}^2$  (S = 1.3)

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

Electric polarizability  $\alpha = (11.8 \pm 1.1) \times 10^{-4}$  fm<sup>3</sup>

Magnetic polarizability  $\beta = (3.7 \pm 1.2) \times 10^{-4}$  fm<sup>3</sup>

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  $> 2.7 \times 10^8$  s, CL = 90% [g] (bound  $n$ )

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

### $pe^- \nu_e$ decay parameters [i]

$\lambda \equiv g_A / g_V = -1.2732 \pm 0.0023$  (S = 2.4)

$A = -0.1187 \pm 0.0010$  (S = 2.6)

$B = 0.9807 \pm 0.0030$

$C = -0.2377 \pm 0.0026$

$a = -0.1059 \pm 0.0028$

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

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

$R = 0.004 \pm 0.013$  [k]

<b><i>n</i> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$\rho$ (MeV/c)
$p e^- \bar{\nu}_e$	100 %		1
$p e^- \bar{\nu}_e \gamma$	[1] $(9.2 \pm 0.7) \times 10^{-3}$		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
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**$N(1440) 1/2^+$**

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

Re(pole position) = 1360 to 1380 ( $\approx 1370$ ) MeV

$-2\text{Im}(\text{pole position}) = 160$  to  $190$  ( $\approx 175$ ) MeV

Breit-Wigner mass = 1410 to 1470 ( $\approx 1440$ ) MeV

Breit-Wigner full width = 250 to 450 ( $\approx 350$ ) MeV

<b><math>N(1440)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (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 ( $\approx 1510$ ) MeV

$-2\text{Im}(\text{pole position}) = 105$  to  $120$  ( $\approx 110$ ) MeV

Breit-Wigner mass = 1510 to 1520 ( $\approx 1515$ ) MeV

Breit-Wigner full width = 100 to 120 ( $\approx 110$ ) MeV

<b><math>N(1520)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (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
$N\sigma$	$< 2$ %	–

$p\gamma$	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  
 $-2\text{Im}(\text{pole position}) = 110$  to 150 ( $\approx 130$ ) MeV  
 Breit-Wigner mass = 1515 to 1545 ( $\approx 1530$ ) MeV  
 Breit-Wigner full width = 125 to 175 ( $\approx 150$ ) MeV

<b><math>N(1535)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$N\pi$	32–52 %	464
$N\eta$	30–55 %	176
$N\pi\pi$	3–14 %	422
$\Delta(1232)\pi$ , <i>D</i> -wave	1–4 %	240
$N\sigma$	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) = 1640 to 1670 ( $\approx 1655$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 100$  to 170 ( $\approx 135$ ) MeV  
 Breit-Wigner mass = 1635 to 1665 ( $\approx 1650$ ) MeV  
 Breit-Wigner full width = 100 to 150 ( $\approx 125$ ) MeV

<b><math>N(1650)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$N\pi$	50–70 %	547
$N\eta$	15–35 %	348
$\Lambda K$	5–15 %	169
$N\pi\pi$	8–36 %	514
$\Delta(1232)\pi$ , <i>D</i> -wave	6–18 %	345
$N\sigma$	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) = 1655 to 1665 ( $\approx 1660$ ) MeV $-2\text{Im}(\text{pole position}) = 125$  to  $150$  ( $\approx 135$ ) MeVBreit-Wigner mass = 1665 to 1680 ( $\approx 1675$ ) MeVBreit-Wigner full width = 130 to 160 ( $\approx 145$ ) MeV

<b><math>N(1675)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	38–42 %	564
$N\eta$	< 1 %	376
$N\pi\pi$	25–45 %	532
$\Delta(1232)\pi$ , <i>D</i> -wave	23–37 %	366
$N\sigma$	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) = 1665 to 1680 ( $\approx 1675$ ) MeV $-2\text{Im}(\text{pole position}) = 110$  to  $135$  ( $\approx 120$ ) MeVBreit-Wigner mass = 1680 to 1690 ( $\approx 1685$ ) MeVBreit-Wigner full width = 115 to 130 ( $\approx 120$ ) MeV

<b><math>N(1680)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	60–70 %	571
$N\eta$	<1 %	386
$N\pi\pi$	20–40 %	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
$N\sigma$	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 ( $\approx 1700$ ) MeV $-2\text{Im}(\text{pole position}) = 100$  to 300 ( $\approx 200$ ) MeVBreit-Wigner mass = 1650 to 1800 ( $\approx 1720$ ) MeVBreit-Wigner full width = 100 to 300 ( $\approx 200$ ) MeV

<b><math>N(1700)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	7–17 %	594
$N\eta$	seen	422
$N\omega$	10–34 %	†
$N\pi\pi$	60–90 %	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
$N(1440)\pi$	3–11 %	225
$N(1520)\pi$	<4 %	145
$N\rho$ , <i>S</i> =3/2, <i>S</i> -wave	32–44 %	74
$N\sigma$	2–14 %	–
$p\gamma$	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) = 1680 to 1720 ( $\approx 1700$ ) MeV $-2\text{Im}(\text{pole position}) = 80$  to 160 ( $\approx 120$ ) MeVBreit-Wigner mass = 1680 to 1740 ( $\approx 1710$ ) MeVBreit-Wigner full width = 80 to 200 ( $\approx 140$ ) MeV

<b><math>N(1710)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	5–20 %	588
$N\eta$	10–50 %	412
$N\omega$	1–5 %	†
$\Lambda K$	5–25 %	269
$\Sigma K$	seen	138



$N\pi\pi$	seen	557
$\Delta(1232)\pi$ , $P$ -wave	3–9 %	394
$N(1535)\pi$	9–21 %	113
$N\rho$ , $S=1/2$ , $P$ -wave	11–23 %	†
$p\gamma$ , 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 1690 ( $\approx 1675$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 150$  to 400 ( $\approx 250$ ) MeV  
 Breit-Wigner mass = 1680 to 1750 ( $\approx 1720$ ) MeV  
 Breit-Wigner full width = 150 to 400 ( $\approx 250$ ) MeV

<b><math>N(1720)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$N\pi$	8–14 %	594
$N\eta$	1–5 %	422
$N\omega$	12–40 %	†
$\Lambda K$	4–5 %	283
$N\pi\pi$	50–90 %	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

 **$N(1875) 3/2^-$** 

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

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

<b>N(1875) DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	3–11 %	695
$N\eta$	<1 %	559
$N\omega$	15–25 %	371
$\Lambda K$	seen	454
$\Sigma K$	seen	384
$N\pi\pi$		670
$\Delta(1232)\pi$	10–35 %	520
$\Delta(1232)\pi$ , <i>S</i> -wave	7–21 %	520
$\Delta(1232)\pi$ , <i>D</i> -wave	2–12 %	520
$N\rho$ , <i>S</i> =3/2, <i>S</i> -wave	seen	379
$N\sigma$	30–60 %	–
$N(1440)\pi$	2–8 %	365
$N(1520)\pi$	<2 %	301
$p\gamma$	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<sup>+</sup>**

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

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

<b>N(1880) DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	3–9 %	698
$N\eta$	5–55 %	563
$N\omega$	12–28 %	377
$\Lambda K$	12–28 %	459
$\Sigma K$	10–24 %	389
$N\pi\pi$	30–80 %	673
$\Delta(1232)\pi$	18–42 %	524
$N\sigma$	10–40 %	539
$N(1535)\pi$	4–12 %	293
$N a_0(980)$	1–5 %	†
$\Lambda K^*(892)$	0.5–1 %	†

$p\gamma$ , helicity=1/2	seen	706
$n\gamma$ , helicity=1/2	0.002–0.63 %	705

 **$N(1895) 1/2^-$** 

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

Re(pole position) = 1890 to 1930 ( $\approx 1910$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 80$  to 140 ( $\approx 110$ ) MeV  
 Breit-Wigner mass = 1870 to 1920 ( $\approx 1895$ ) MeV  
 Breit-Wigner full width = 80 to 200 ( $\approx 120$ ) MeV

<b><math>N(1895)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	2–18 %	707
$N\eta$	15–40 %	575
$N\eta'$	10–40 %	†
$N\omega$	16–40 %	395
$\Lambda K$	13–23 %	473
$\Sigma K$	6–20 %	405
$\Delta(1232)\pi$ , $D$ -wave	3–11 %	535
$N\rho$ , $S=1/2$ , $S$ -wave	seen	403
$N\rho$ , $S=3/2$ , $D$ -wave	3–12 %	403
$\Lambda K^*(892)$	4–9 %	†
$N\sigma$	seen	–
$N(1440)\pi$	1–4 %	382
$p\gamma$ , 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 ( $\approx 1920$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 100$  to 200 ( $\approx 150$ ) MeV  
 Breit-Wigner mass = 1890 to 1950 ( $\approx 1920$ ) MeV  
 Breit-Wigner full width = 100 to 320 ( $\approx 200$ ) MeV

<b><math>N(1900)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	1–20 %	723
$N\eta$	2–14 %	595
$N\eta'$	4–8 %	151
$N\omega$	7–13 %	424
$\Lambda K$	2–20 %	495
$\Sigma K$	3–7 %	431
$N\pi\pi$	40–80 %	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
$\Lambda K^*(892)$	< 0.2 %	†
$N\sigma$	1–7 %	–
$N(1520)\pi$	7–23 %	341
$N(1535)\pi$	4–10 %	328
$p\gamma$	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

### **$N(2060) 5/2^-$**

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

Re(pole position) = 2020 to 2130 ( $\approx 2070$ ) MeV

–2Im(pole position) = 350 to 430 ( $\approx 400$ ) MeV

Breit-Wigner mass = 2030 to 2200 ( $\approx 2100$ ) MeV

Breit-Wigner full width = 300 to 450 ( $\approx 400$ ) MeV

<b><math>N(2060)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	7–12 %	834
$N\eta$	2–6 %	729
$N\omega$	1–7 %	600
$\Lambda K$	seen	644
$\Sigma K$	1–5 %	593
$N\pi\pi$	7–19 %	814
$\Delta(1232)\pi$ , <i>D</i> -wave	4–10 %	680
$N\rho$ , <i>S</i> =1/2, <i>P</i> -wave	seen	605
$\Lambda K^*(892)$	0.3–1.3 %	307
$N\sigma$	3–9 %	–
$N(1440)\pi$	4–14 %	544
$N(1520)\pi$ , <i>P</i> -wave	9–21 %	490
$N(1680)\pi$ , <i>S</i> -wave	8–22 %	353
$p\gamma$	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 ( $\approx 2100$ ) MeV $-2\text{Im}(\text{pole position}) = 240$  to  $340$  ( $\approx 300$ ) MeVBreit-Wigner mass = 2050 to 2150 ( $\approx 2100$ ) MeVBreit-Wigner full width = 200 to 320 ( $\approx 260$ ) MeV

<b><math>N(2100)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	8–18 %	834
$N\eta$	seen	729
$N\eta'$	5–11 %	451
$N\omega$	10–25 %	600
$\Lambda K$	seen	644
$N\pi\pi$	20–40 %	814
$\Delta(1232)\pi$ , $P$ -wave	6–14 %	680
$N\rho$ , $S=1/2$ , $P$ -wave	seen	605
$\Lambda K^*(892)$	3–11 %	307
$N\sigma$	14–26 %	–
$N(1535)\pi$	26–34 %	478
$N\gamma$ , helicity=1/2	0.001–0.012 %	840

 **$N(2120) 3/2^-$** 

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

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

<b><math>N(2120)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	5–15 %	846
$N\eta'$	2–6 %	474
$N\omega$	4–20 %	617
$N\pi\pi$	50–95 %	827
$\Delta(1232)\pi$	40–90 %	693
$\Delta(1232)\pi$ , $S$ -wave	30–70 %	693
$\Delta(1232)\pi$ , $D$ -wave	8–32 %	693
$\Lambda K^*(892)$	< 0.2 %	339
$N\sigma$	7–15 %	–
$N(1535)\pi$	7–23 %	494

$p\gamma$	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) = 2050 to 2150 ( $\approx 2100$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 300$  to 500 ( $\approx 400$ ) MeV  
 Breit-Wigner mass = 2140 to 2220 ( $\approx 2180$ ) MeV  
 Breit-Wigner full width = 300 to 500 ( $\approx 400$ ) MeV

<b><math>N(2190)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$N\pi$	10–20 %	882
$N\eta$	1–3 %	785
$N\omega$	8–20 %	667
$\Delta(1232)\pi$ , $D$ -wave	19–31 %	734
$N\rho$ , $S=3/2$ , $D$ -wave	seen	672
$\Lambda K^*(892)$	0.2–0.8 %	423
$N\sigma$	3–9 %	–
$p\gamma$	0.014–0.077 %	888
$n\gamma$	<0.04 %	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 ( $\approx 2170$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 360$  to 480 ( $\approx 400$ ) MeV  
 Breit-Wigner mass = 2200 to 2300 ( $\approx 2250$ ) MeV  
 Breit-Wigner full width = 350 to 500 ( $\approx 400$ ) MeV

<b><math>N(2220)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$N\pi$	15–30 %	924

 **$N(2250) 9/2^-$** 

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

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

<b>N(2250) DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	0.05 to 0.15 ( $\approx 0.10$ )	941

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

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

Breit-Wigner mass = 2550 to 2750 ( $\approx 2600$ ) MeV

Breit-Wigner full width = 500 to 800 ( $\approx 650$ ) MeV

<b>N(2600) DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	3–8 %	1126

**$\Delta$  BARYONS**  
**( $S=0, I=3/2$ )**

$$\Delta^{++} = uuu, \quad \Delta^+ = uud, \quad \Delta^0 = udd, \quad \Delta^- = ddd$$

**$\Delta(1232) 3/2^+$**

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

Re(pole position) = 1209 to 1211 ( $\approx 1210$ ) MeV

$-2\text{Im}(\text{pole position}) = 98$  to  $102$  ( $\approx 100$ ) MeV

Breit-Wigner mass (mixed charges) = 1230 to 1234 ( $\approx 1232$ ) MeV

Breit-Wigner full width (mixed charges) = 114 to 120 ( $\approx 117$ ) MeV

<b><math>\Delta(1232)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	99.4 %	229
$N\gamma$	0.55–0.65 %	259
$N\gamma$ , helicity=1/2	0.11–0.13 %	259
$N\gamma$ , helicity=3/2	0.44–0.52 %	259
$pe^+e^-$	$(4.2 \pm 0.7) \times 10^{-5}$	259

**$\Delta(1600) 3/2^+$**

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

Re(pole position) = 1460 to 1560 ( $\approx 1510$ ) MeV

$-2\text{Im}(\text{pole position}) = 200$  to  $340$  ( $\approx 270$ ) MeV

Breit-Wigner mass = 1500 to 1640 ( $\approx 1570$ ) MeV

Breit-Wigner full width = 200 to 300 ( $\approx 250$ ) MeV

<b><math>\Delta(1600)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	8–24 %	492
$N\pi\pi$	75–90 %	454
$\Delta(1232)\pi$	73–83 %	276
$\Delta(1232)\pi$ , <i>P</i> -wave	72–82 %	276
$\Delta(1232)\pi$ , <i>F</i> -wave	<2 %	276
$N(1440)\pi$ , <i>P</i> -wave	15–25 %	†
$N\gamma$	0.001–0.035 %	505
$N\gamma$ , helicity=1/2	0.0–0.02 %	505
$N\gamma$ , helicity=3/2	0.001–0.015 %	505

 **$\Delta(1620)$   $1/2^-$** 

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

Re(pole position) = 1590 to 1610 ( $\approx 1600$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 100$  to 140 ( $\approx 120$ ) MeV  
 Breit-Wigner mass = 1590 to 1630 ( $\approx 1610$ ) MeV  
 Breit-Wigner full width = 110 to 150 ( $\approx 130$ ) MeV

<b><math>\Delta(1620)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	25–35 %	520
$N\pi\pi$	55–80 %	484
$\Delta(1232)\pi$ , <i>D</i> -wave	52–72 %	311
$N\rho$ , <i>S</i> =1/2, <i>S</i> -wave	seen	†
$N\rho$ , <i>S</i> =3/2, <i>D</i> -wave	seen	†
$N(1440)\pi$	3–9 %	98
$N\gamma$ , helicity=1/2	0.03–0.10 %	532

 **$\Delta(1700)$   $3/2^-$** 

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

Re(pole position) = 1640 to 1690 ( $\approx 1665$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 200$  to 300 ( $\approx 250$ ) MeV  
 Breit-Wigner mass = 1690 to 1730 ( $\approx 1710$ ) MeV  
 Breit-Wigner full width = 220 to 380 ( $\approx 300$ ) MeV

<b><math>\Delta(1700)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	10–20 %	588
$N\pi\pi$	10–55 %	557
$\Delta(1232)\pi$	10–50 %	394
$\Delta(1232)\pi$ , <i>S</i> -wave	5–35 %	394
$\Delta(1232)\pi$ , <i>D</i> -wave	4–16 %	394



$N\rho$ , $S=3/2$ , $S$ -wave	seen	†
$N(1520)\pi$ , $P$ -wave	1–5 %	133
$N(1535)\pi$	0.5–1.5 %	113
$\Delta(1232)\eta$	3–7 %	†
$N\gamma$	0.22–0.60 %	598
$N\gamma$ , helicity=1/2	0.12–0.30 %	598
$N\gamma$ , helicity=3/2	0.10–0.30 %	598

 **$\Delta(1900) 1/2^-$** 

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

Re(pole position) = 1830 to 1900 ( $\approx 1865$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 180$  to 300 ( $\approx 240$ ) MeV  
 Breit-Wigner mass = 1840 to 1920 ( $\approx 1860$ ) MeV  
 Breit-Wigner full width = 180 to 320 ( $\approx 250$ ) MeV

<b><math>\Delta(1900)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	4–12 %	685
$\Sigma K$	seen	367
$N\pi\pi$	45–85 %	660
$\Delta(1232)\pi$ , $D$ -wave	30–70 %	509
$N\rho$ , $S=1/2$ , $S$ -wave	8–16 %	360
$N\rho$ , $S=3/2$ , $D$ -wave	18–28 %	360
$N(1440)\pi$	8–32 %	353
$N(1520)\pi$	2–10 %	288
$\Delta(1232)\eta$	0–2 %	251
$N\gamma$ , helicity=1/2	0.06–0.43 %	693

 **$\Delta(1905) 5/2^+$** 

$$I(J^P) = \frac{3}{2}(\frac{5}{2}^+)$$

Re(pole position) = 1770 to 1830 ( $\approx 1800$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 260$  to 340 ( $\approx 300$ ) MeV  
 Breit-Wigner mass = 1855 to 1910 ( $\approx 1880$ ) MeV  
 Breit-Wigner full width = 270 to 400 ( $\approx 330$ ) MeV

<b><math>\Delta(1905)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	9–15 %	698
$N\pi\pi$		673
$\Delta(1232)\pi$	80–100 %	524
$\Delta(1232)\pi$ , $P$ -wave	23–43 %	524
$\Delta(1232)\pi$ , $F$ -wave	56–72 %	524
$N\rho$ , $S=3/2$ , $P$ -wave	seen	385

$N(1535)\pi$	< 1 %	293
$N(1680)\pi$ , $P$ -wave	5–15 %	133
$\Delta(1232)\eta$	2–6 %	282
$N\gamma$	0.012–0.036 %	706
$N\gamma$ , helicity=1/2	0.002–0.006 %	706
$N\gamma$ , helicity=3/2	0.01–0.03 %	706

 **$\Delta(1910) 1/2^+$** 

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

Re(pole position) = 1830 to 1890 ( $\approx 1860$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 200$  to  $400$  ( $\approx 300$ ) MeV  
 Breit-Wigner mass = 1850 to 1950 ( $\approx 1900$ ) MeV  
 Breit-Wigner full width = 200 to 400 ( $\approx 300$ ) MeV

<b><math>\Delta(1910)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$N\pi$	15–30 %	710
$\Sigma K$	4–14 %	410
$N\pi\pi$		686
$\Delta(1232)\pi$	34–66 %	539
$N(1440)\pi$	3–9 %	386
$\Delta(1232)\eta$	5–13 %	310
$N\gamma$ , helicity=1/2	0.0–0.02 %	718

 **$\Delta(1920) 3/2^+$** 

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

Re(pole position) = 1850 to 1950 ( $\approx 1900$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 200$  to  $400$  ( $\approx 300$ ) MeV  
 Breit-Wigner mass = 1870 to 1970 ( $\approx 1920$ ) MeV  
 Breit-Wigner full width = 240 to 360 ( $\approx 300$ ) MeV

<b><math>\Delta(1920)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$N\pi$	5–20 %	723
$\Sigma K$	2–6 %	431
$N\pi\pi$		699
$\Delta(1232)\pi$	50–90 %	553
$\Delta(1232)\pi$ , $P$ -wave	8–28 %	553
$\Delta(1232)\pi$ , $F$ -wave	44–72 %	553

$N(1440)\pi$ , $P$ -wave	<4 %	403
$N(1520)\pi$ , $S$ -wave	<5 %	341
$N(1535)\pi$	<2 %	328
$N_{a_0}(980)$	seen	41
$\Delta(1232)\eta$	5–17 %	336

 **$\Delta(1930) 5/2^-$** 

$$I(J^P) = \frac{3}{2}(\frac{5}{2}^-)$$

Re(pole position) = 1840 to 1920 ( $\approx 1880$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 230$  to  $330$  ( $\approx 280$ ) MeV  
 Breit-Wigner mass = 1900 to 2000 ( $\approx 1950$ ) MeV  
 Breit-Wigner full width = 200 to 400 ( $\approx 300$ ) MeV

<b><math>\Delta(1930)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$N\pi$	5–15 %	742
$N\gamma$	0.0–0.01 %	749
$N\gamma$ , helicity=1/2	0.0–0.005 %	749
$N\gamma$ , helicity=3/2	0.0–0.004 %	749

 **$\Delta(1950) 7/2^+$** 

$$I(J^P) = \frac{3}{2}(\frac{7}{2}^+)$$

Re(pole position) = 1870 to 1890 ( $\approx 1880$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 220$  to  $260$  ( $\approx 240$ ) MeV  
 Breit-Wigner mass = 1915 to 1950 ( $\approx 1930$ ) MeV  
 Breit-Wigner full width = 235 to 335 ( $\approx 285$ ) MeV

<b><math>\Delta(1950)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$N\pi$	35–45 %	729
$\Sigma K$	0.3–0.5 %	441
$N\pi\pi$		706
$\Delta(1232)\pi$ , $F$ -wave	1–9 %	560
$N(1680)\pi$ , $P$ -wave	3–9 %	191
$\Delta(1232)\eta$	< 0.6 %	349

 **$\Delta(2200) 7/2^-$** 

$$I(J^P) = \frac{3}{2}(\frac{7}{2}^-)$$

Re(pole position) = 2050 to 2150 ( $\approx 2100$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 260$  to  $420$  ( $\approx 340$ ) MeV  
 Breit-Wigner mass = 2150 to 2250 ( $\approx 2200$ ) MeV  
 Breit-Wigner full width = 200 to 500 ( $\approx 350$ ) MeV

$\Delta(2200)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	2–8 %	894
$\Sigma K$	1–7 %	672
$\Delta\pi$ , $D$ -wave	40–100 %	747
$\Delta\pi$ , $G$ -wave	5–25 %	747
$\Delta\eta$ , $D$ -wave	seen	614

### $\Delta(2420) 11/2^+$

$$I(J^P) = \frac{3}{2}(\frac{11}{2}^+)$$

Re(pole position) = 2300 to 2500 ( $\approx 2400$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 350$  to 550 ( $\approx 450$ ) MeV  
 Breit-Wigner mass = 2300 to 2600 ( $\approx 2450$ ) MeV  
 Breit-Wigner full width = 300 to 700 ( $\approx 500$ ) MeV

$\Delta(2420)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	5–10 %	1040

## $\Lambda$ BARYONS

### $(S = -1, I = 0)$

$$\Lambda^0 = uds$$

### $\Lambda$

$$I(J^P) = 0(\frac{1}{2}^+)$$

Mass  $m = 1115.683 \pm 0.006$  MeV  
 $(m_\Lambda - m_{\bar{\Lambda}}) / m_\Lambda = (-0.1 \pm 1.1) \times 10^{-5}$  ( $S = 1.6$ )  
 Mean life  $\tau = (2.632 \pm 0.020) \times 10^{-10}$  s ( $S = 1.6$ )  
 $(\tau_\Lambda - \tau_{\bar{\Lambda}}) / \tau_\Lambda = -0.001 \pm 0.009$   
 $c\tau = 7.89$  cm  
 Magnetic moment  $\mu = -0.613 \pm 0.004 \mu_N$   
 Electric dipole moment  $d < 1.5 \times 10^{-16}$  ecm, CL = 95%

#### Decay parameters

$p\pi^-$        $\alpha_- = 0.750 \pm 0.010$   
 $\bar{p}\pi^+$        $\alpha_+ = -0.758 \pm 0.012$   
 $\bar{\alpha}_0$  FOR  $\bar{\Lambda} \rightarrow \bar{n}\pi^0 = -0.692 \pm 0.017$   
 $p\pi^-$        $\phi_- = (-6.5 \pm 3.5)^\circ$   
 "       $\gamma_- = 0.76 [n]$   
 "       $\Delta_- = (8 \pm 4)^\circ [n]$

$$\begin{aligned} \bar{\alpha}_0 / \alpha_+ \text{ in } \bar{\Lambda} \rightarrow \bar{n}\pi^0, \bar{\Lambda} \rightarrow \bar{p}\pi^+ &= 0.913 \pm 0.030 \\ n\pi^0 &\quad \alpha_0 = 0.75 \pm 0.05 \\ p e^- \bar{\nu}_e &\quad g_A/g_V = -0.718 \pm 0.015 [i] \end{aligned}$$

<b><math>\Lambda</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$p\pi^-$	(63.9 $\pm$ 0.5 ) %		101
$n\pi^0$	(35.8 $\pm$ 0.5 ) %		104
$n\gamma$	( 1.75 $\pm$ 0.15) $\times 10^{-3}$		162
$p\pi^- \gamma$	[o] ( 8.4 $\pm$ 1.4 ) $\times 10^{-4}$		101
$p e^- \bar{\nu}_e$	( 8.32 $\pm$ 0.14) $\times 10^{-4}$		163
$p\mu^- \bar{\nu}_\mu$	( 1.57 $\pm$ 0.35) $\times 10^{-4}$		131

**Lepton (L) and/or Baryon (B) number violating decay modes**

$\pi^+ e^-$	L,B	< 6	$\times 10^{-7}$	90%	549
$\pi^+ \mu^-$	L,B	< 6	$\times 10^{-7}$	90%	544
$\pi^- e^+$	L,B	< 4	$\times 10^{-7}$	90%	549
$\pi^- \mu^+$	L,B	< 6	$\times 10^{-7}$	90%	544
$K^+ e^-$	L,B	< 2	$\times 10^{-6}$	90%	449
$K^+ \mu^-$	L,B	< 3	$\times 10^{-6}$	90%	441
$K^- e^+$	L,B	< 2	$\times 10^{-6}$	90%	449
$K^- \mu^+$	L,B	< 3	$\times 10^{-6}$	90%	441
$K_S^0 \nu$	L,B	< 2	$\times 10^{-5}$	90%	447
$\bar{p}\pi^+$	B	< 9	$\times 10^{-7}$	90%	101

**$\Lambda(1405) 1/2^-$**

$$I(J^P) = 0(\frac{1}{2}^-)$$

Mass  $m = 1405.1^{+1.3}_{-1.0}$  MeV  
 Full width  $\Gamma = 50.5 \pm 2.0$  MeV  
 Below  $\bar{K}N$  threshold

<b><math>\Lambda(1405)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Sigma \pi$	100 %	155

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

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

Mass  $m = 1519.5 \pm 1.0$  MeV [p]  
 Full width  $\Gamma = 15.6 \pm 1.0$  MeV [p]

<b><math>\Lambda(1520)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	(45 $\pm$ 1 ) %	243
$\Sigma \pi$	(42 $\pm$ 1 ) %	268
$\Lambda \pi \pi$	(10 $\pm$ 1 ) %	259

$\Sigma \pi \pi$	( 0.9 $\pm$ 0.1 ) %	169
$\Lambda \gamma$	( 0.85 $\pm$ 0.15 ) %	350

 **$\Lambda(1600) 1/2^+$** 

$$I(J^P) = 0(\frac{1}{2}^+)$$

Mass  $m = 1560$  to  $1700$  ( $\approx 1600$ ) MeVFull width  $\Gamma = 50$  to  $250$  ( $\approx 150$ ) MeV

<b><math>\Lambda(1600)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N \bar{K}$	15–30 %	343
$\Sigma \pi$	10–60 %	338

 **$\Lambda(1670) 1/2^-$** 

$$I(J^P) = 0(\frac{1}{2}^-)$$

Mass  $m = 1660$  to  $1680$  ( $\approx 1670$ ) MeVFull width  $\Gamma = 25$  to  $50$  ( $\approx 35$ ) MeV

<b><math>\Lambda(1670)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N \bar{K}$	20–30 %	414
$\Sigma \pi$	25–55 %	394
$\Lambda \eta$	10–25 %	69
$N \bar{K}^*(892)$ , $S=3/2$ , $D$ -wave	( $5 \pm 4$ ) %	†

 **$\Lambda(1690) 3/2^-$** 

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

Mass  $m = 1685$  to  $1695$  ( $\approx 1690$ ) MeVFull width  $\Gamma = 50$  to  $70$  ( $\approx 60$ ) MeV

<b><math>\Lambda(1690)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N \bar{K}$	20–30 %	433
$\Sigma \pi$	20–40 %	410
$\Lambda \pi \pi$	$\sim 25$ %	419
$\Sigma \pi \pi$	$\sim 20$ %	358

 **$\Lambda(1800) 1/2^-$** 

$$I(J^P) = 0(\frac{1}{2}^-)$$

Mass  $m = 1720$  to  $1850$  ( $\approx 1800$ ) MeVFull width  $\Gamma = 200$  to  $400$  ( $\approx 300$ ) MeV

$\Lambda(1800)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	25–40 %	528
$\Sigma\pi$	seen	494
$\Sigma(1385)\pi$	seen	349
$\Lambda\eta$	$(6\pm 5)$ %	326
$N\bar{K}^*(892)$	seen	†

 **$\Lambda(1810) 1/2^+$** 

$$I(J^P) = 0(\frac{1}{2}^+)$$

Mass  $m = 1750$  to  $1850$  ( $\approx 1810$ ) MeVFull width  $\Gamma = 50$  to  $250$  ( $\approx 150$ ) MeV

$\Lambda(1810)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	20–50 %	537
$\Sigma\pi$	10–40 %	501
$\Sigma(1385)\pi$	seen	357
$N\bar{K}^*(892)$	30–60 %	†

 **$\Lambda(1820) 5/2^+$** 

$$I(J^P) = 0(\frac{5}{2}^+)$$

Mass  $m = 1815$  to  $1825$  ( $\approx 1820$ ) MeVFull width  $\Gamma = 70$  to  $90$  ( $\approx 80$ ) MeV

$\Lambda(1820)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	55–65 %	545
$\Sigma\pi$	8–14 %	509
$\Sigma(1385)\pi$	5–10 %	366
$N\bar{K}^*(892)$ , $S=3/2$ , $P$ -wave	$(3.0\pm 1.0)$ %	†

 **$\Lambda(1830) 5/2^-$** 

$$I(J^P) = 0(\frac{5}{2}^-)$$

Mass  $m = 1810$  to  $1830$  ( $\approx 1830$ ) MeVFull width  $\Gamma = 60$  to  $110$  ( $\approx 95$ ) MeV

$\Lambda(1830)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	3–10 %	553
$\Sigma\pi$	35–75 %	516

$\Sigma(1385)\pi$	>15 %	374
$\Sigma(1385)\pi$ , <i>D</i> -wave	(52±6) %	374

 **$\Lambda(1890) 3/2^+$** 

$$I(J^P) = 0(\frac{3}{2}^+)$$

Mass  $m = 1850$  to  $1910$  ( $\approx 1890$ ) MeVFull width  $\Gamma = 60$  to  $200$  ( $\approx 100$ ) MeV

<b><math>\Lambda(1890)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	20–35 %	599
$\Sigma\pi$	3–10 %	560
$\Sigma(1385)\pi$	seen	423
$N\bar{K}^*(892)$	seen	236

 **$\Lambda(2100) 7/2^-$** 

$$I(J^P) = 0(\frac{7}{2}^-)$$

Mass  $m = 2090$  to  $2110$  ( $\approx 2100$ ) MeVFull width  $\Gamma = 100$  to  $250$  ( $\approx 200$ ) MeV

<b><math>\Lambda(2100)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	25–35 %	751
$\Sigma\pi$	$\sim 5$ %	705
$\Lambda\eta$	<3 %	617
$\Xi K$	<3 %	491
$\Lambda\omega$	<8 %	443
$N\bar{K}^*(892)$	10–20 %	515

 **$\Lambda(2110) 5/2^+$** 

$$I(J^P) = 0(\frac{5}{2}^+)$$

Mass  $m = 2090$  to  $2140$  ( $\approx 2110$ ) MeVFull width  $\Gamma = 150$  to  $250$  ( $\approx 200$ ) MeV

<b><math>\Lambda(2110)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	5–25 %	757
$\Sigma\pi$	10–40 %	711
$\Lambda\omega$	seen	455
$\Sigma(1385)\pi$	seen	591
$N\bar{K}^*(892)$	10–60 %	525



**$\Lambda(2350) 9/2^+$**

$$I(J^P) = 0(\frac{9}{2}^+)$$

Mass  $m = 2340$  to  $2370$  ( $\approx 2350$ ) MeV  
 Full width  $\Gamma = 100$  to  $250$  ( $\approx 150$ ) MeV

<b><math>\Lambda(2350)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	$\sim 12\%$	915
$\Sigma\pi$	$\sim 10\%$	867

## **$\Sigma$ BARYONS** **( $S = -1, I = 1$ )**

$$\Sigma^+ = uus, \quad \Sigma^0 = uds, \quad \Sigma^- = dds$$

**$\Sigma^+$**

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

Mass  $m = 1189.37 \pm 0.07$  MeV ( $S = 2.2$ )  
 Mean life  $\tau = (0.8018 \pm 0.0026) \times 10^{-10}$  s  
 $c\tau = 2.404$  cm  
 $(\tau_{\Sigma^+} - \tau_{\Sigma^-}) / \tau_{\Sigma^+} = -0.0006 \pm 0.0012$   
 Magnetic moment  $\mu = 2.458 \pm 0.010 \mu_N$  ( $S = 2.1$ )  
 $(\mu_{\Sigma^+} + \mu_{\Sigma^-}) / \mu_{\Sigma^+} = 0.014 \pm 0.015$   
 $\Gamma(\Sigma^+ \rightarrow nl^+\nu) / \Gamma(\Sigma^- \rightarrow nl^-\bar{\nu}) < 0.043$

### Decay parameters

$p\pi^0$	$\alpha_0 = -0.980^{+0.017}_{-0.015}$
"	$\phi_0 = (36 \pm 34)^\circ$
"	$\gamma_0 = 0.16 [n]$
"	$\Delta_0 = (187 \pm 6)^\circ [n]$
$n\pi^+$	$\alpha_+ = 0.068 \pm 0.013$
"	$\phi_+ = (167 \pm 20)^\circ$ ( $S = 1.1$ )
"	$\gamma_+ = -0.97 [n]$
"	$\Delta_+ = (-73^{+133}_{-10})^\circ [n]$
$p\gamma$	$\alpha_\gamma = -0.76 \pm 0.08$

<b><math>\Sigma^+</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$p\pi^0$	$(51.57 \pm 0.30)\%$		189
$n\pi^+$	$(48.31 \pm 0.30)\%$		185
$p\gamma$	$(1.23 \pm 0.05) \times 10^{-3}$		225

$n\pi^+\gamma$	[o]	$(4.5 \pm 0.5) \times 10^{-4}$	185
$\Lambda e^+\nu_e$		$(2.0 \pm 0.5) \times 10^{-5}$	71

**$\Delta S = \Delta Q$  (SQ) violating modes or  
 $\Delta S = 1$  weak neutral current (S1) modes**

$ne^+\nu_e$	SQ	$< 5 \times 10^{-6}$	90%	224
$n\mu^+\nu_\mu$	SQ	$< 3.0 \times 10^{-5}$	90%	202
$pe^+e^-$	S1	$< 7 \times 10^{-6}$		225
$p\mu^+\mu^-$	S1	$(2.4^{+1.7}_{-1.3}) \times 10^{-8}$		121

**$\Sigma^0$**

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

Mass  $m = 1192.642 \pm 0.024$  MeV  
 $m_{\Sigma^-} - m_{\Sigma^0} = 4.807 \pm 0.035$  MeV (S = 1.1)  
 $m_{\Sigma^0} - m_\Lambda = 76.959 \pm 0.023$  MeV  
 Mean life  $\tau = (7.4 \pm 0.7) \times 10^{-20}$  s  
 $c\tau = 2.22 \times 10^{-11}$  m  
 Transition magnetic moment  $|\mu_{\Sigma\Lambda}| = 1.61 \pm 0.08 \mu_N$

<b><math>\Sigma^0</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$\rho$ (MeV/c)
$\Lambda\gamma$	100 %		74
$\Lambda\gamma\gamma$	$< 3$ %	90%	74
$\Lambda e^+e^-$	[q] $5 \times 10^{-3}$		74

**$\Sigma^-$**

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

Mass  $m = 1197.449 \pm 0.030$  MeV (S = 1.2)  
 $m_{\Sigma^-} - m_{\Sigma^+} = 8.08 \pm 0.08$  MeV (S = 1.9)  
 $m_{\Sigma^-} - m_\Lambda = 81.766 \pm 0.030$  MeV (S = 1.2)  
 Mean life  $\tau = (1.479 \pm 0.011) \times 10^{-10}$  s (S = 1.3)  
 $c\tau = 4.434$  cm  
 Magnetic moment  $\mu = -1.160 \pm 0.025 \mu_N$  (S = 1.7)  
 $\Sigma^-$  charge radius =  $0.78 \pm 0.10$  fm

**Decay parameters**

$n\pi^-$	$\alpha_- = -0.068 \pm 0.008$
"	$\phi_- = (10 \pm 15)^\circ$
"	$\gamma_- = 0.98$ [n]
"	$\Delta_- = (249^{+12}_{-120})^\circ$ [n]
$ne^-\bar{\nu}_e$	$g_A/g_V = 0.340 \pm 0.017$ [i]
"	$f_2(0)/f_1(0) = 0.97 \pm 0.14$

$$\begin{array}{ll}
 " & D = 0.11 \pm 0.10 \\
 \Lambda e^- \bar{\nu}_e & g_V/g_A = 0.01 \pm 0.10 [i] \quad (S = 1.5) \\
 " & g_{WM}/g_A = 2.4 \pm 1.7 [i]
 \end{array}$$

$\Sigma^-$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$n\pi^-$	$(99.848 \pm 0.005) \%$	193
$n\pi^- \gamma$	$[o] (4.6 \pm 0.6) \times 10^{-4}$	193
$ne^- \bar{\nu}_e$	$(1.017 \pm 0.034) \times 10^{-3}$	230
$n\mu^- \bar{\nu}_\mu$	$(4.5 \pm 0.4) \times 10^{-4}$	210
$\Lambda e^- \bar{\nu}_e$	$(5.73 \pm 0.27) \times 10^{-5}$	79

### $\Sigma(1385) 3/2^+$

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

$$\begin{array}{l}
 \Sigma(1385)^+ \text{mass } m = 1382.80 \pm 0.35 \text{ MeV} \quad (S = 1.9) \\
 \Sigma(1385)^0 \text{mass } m = 1383.7 \pm 1.0 \text{ MeV} \quad (S = 1.4) \\
 \Sigma(1385)^- \text{mass } m = 1387.2 \pm 0.5 \text{ MeV} \quad (S = 2.2) \\
 \Sigma(1385)^+ \text{full width } \Gamma = 36.0 \pm 0.7 \text{ MeV} \\
 \Sigma(1385)^0 \text{full width } \Gamma = 36 \pm 5 \text{ MeV} \\
 \Sigma(1385)^- \text{full width } \Gamma = 39.4 \pm 2.1 \text{ MeV} \quad (S = 1.7) \\
 \text{Below } \bar{K}N \text{ threshold}
 \end{array}$$

$\Sigma(1385)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\Lambda\pi$	$(87.0 \pm 1.5) \%$		208
$\Sigma\pi$	$(11.7 \pm 1.5) \%$		129
$\Lambda\gamma$	$(1.25^{+0.13}_{-0.12}) \%$		241
$\Sigma^+ \gamma$	$(7.0 \pm 1.7) \times 10^{-3}$		180
$\Sigma^- \gamma$	$< 2.4 \times 10^{-4}$	90%	173

### $\Sigma(1660) 1/2^+$

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

$$\begin{array}{l}
 \text{Mass } m = 1630 \text{ to } 1690 (\approx 1660) \text{ MeV} \\
 \text{Full width } \Gamma = 40 \text{ to } 200 (\approx 100) \text{ MeV}
 \end{array}$$

$\Sigma(1660)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	10–30 %	405
$\Lambda\pi$	seen	440
$\Sigma\pi$	seen	387

**$\Sigma(1670) 3/2^-$** 

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

Mass  $m = 1665$  to  $1685$  ( $\approx 1670$ ) MeVFull width  $\Gamma = 40$  to  $80$  ( $\approx 60$ ) MeV

<b><math>\Sigma(1670)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	7–13 %	414
$\Lambda\pi$	5–15 %	448
$\Sigma\pi$	30–60 %	394

 **$\Sigma(1750) 1/2^-$** 

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

Mass  $m = 1730$  to  $1800$  ( $\approx 1750$ ) MeVFull width  $\Gamma = 60$  to  $160$  ( $\approx 90$ ) MeV

<b><math>\Sigma(1750)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	10–40 %	486
$\Lambda\pi$	seen	507
$\Sigma\pi$	<8 %	456
$\Sigma\eta$	15–55 %	98
$N\bar{K}^*(892)$ , $S=1/2$	( $8\pm 4$ ) %	†

 **$\Sigma(1775) 5/2^-$** 

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

Mass  $m = 1770$  to  $1780$  ( $\approx 1775$ ) MeVFull width  $\Gamma = 105$  to  $135$  ( $\approx 120$ ) MeV

<b><math>\Sigma(1775)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	37–43%	508
$\Lambda\pi$	14–20%	525
$\Sigma\pi$	2–5%	475
$\Sigma(1385)\pi$	8–12%	327
$\Lambda(1520)\pi$ , $P$ -wave	17–23%	201

 **$\Sigma(1915) 5/2^+$** 

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

Mass  $m = 1900$  to  $1935$  ( $\approx 1915$ ) MeVFull width  $\Gamma = 80$  to  $160$  ( $\approx 120$ ) MeV

$\Sigma(1915)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	5–15 %	618
$\Lambda\pi$	seen	623
$\Sigma\pi$	seen	577
$\Sigma(1385)\pi$	<5 %	443

 **$\Sigma(1940) 3/2^-$** 

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

Mass  $m = 1900$  to  $1950$  ( $\approx 1940$ ) MeV  
 Full width  $\Gamma = 150$  to  $300$  ( $\approx 220$ ) MeV

$\Sigma(1940)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	<20 %	637
$\Lambda\pi$	seen	640
$\Sigma\pi$	seen	595
$\Sigma(1385)\pi$	seen	463
$\Lambda(1520)\pi$	seen	355
$\Delta(1232)\bar{K}$	seen	410
$N\bar{K}^*(892)$	seen	322

 **$\Sigma(2030) 7/2^+$** 

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

Mass  $m = 2025$  to  $2040$  ( $\approx 2030$ ) MeV  
 Full width  $\Gamma = 150$  to  $200$  ( $\approx 180$ ) MeV

$\Sigma(2030)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	17–23 %	702
$\Lambda\pi$	17–23 %	700
$\Sigma\pi$	5–10 %	657
$\Xi K$	<2 %	422
$\Sigma(1385)\pi$	5–15 %	532
$\Lambda(1520)\pi$	10–20 %	430
$\Delta(1232)\bar{K}$	10–20 %	498
$N\bar{K}^*(892)$	<5 %	439

 **$\Sigma(2250)$** 

$$I(J^P) = 1(?^?)$$

Mass  $m = 2210$  to  $2280$  ( $\approx 2250$ ) MeV  
 Full width  $\Gamma = 60$  to  $150$  ( $\approx 100$ ) MeV

$\Sigma(2250)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	<10 %	851
$\Lambda\pi$	seen	842
$\Sigma\pi$	seen	803

## $\Xi$ BARYONS

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

$\Xi^0 = uss, \Xi^- = dss$

 $\Xi^0$ 

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

$P$  is not yet measured; + is the quark model prediction.

Mass  $m = 1314.86 \pm 0.20$  MeV

$m_{\Xi^-} - m_{\Xi^0} = 6.85 \pm 0.21$  MeV

Mean life  $\tau = (2.90 \pm 0.09) \times 10^{-10}$  s

$c\tau = 8.71$  cm

Magnetic moment  $\mu = -1.250 \pm 0.014 \mu_N$

### Decay parameters

$\Lambda\pi^0 \quad \alpha = -0.347 \pm 0.010$

"  $\phi = (21 \pm 12)^\circ$

"  $\gamma = 0.85 [n]$

"  $\Delta = (218_{-19}^{+12})^\circ [n]$

$\Lambda\gamma \quad \alpha = -0.70 \pm 0.07$

$\Lambda e^+ e^- \quad \alpha = -0.8 \pm 0.2$

$\Sigma^0\gamma \quad \alpha = -0.69 \pm 0.06$

$\Sigma^+ e^- \bar{\nu}_e \quad g_1(0)/f_1(0) = 1.22 \pm 0.05$

$\Sigma^+ e^- \bar{\nu}_e \quad f_2(0)/f_1(0) = 2.0 \pm 0.9$

$\Xi^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\Lambda\pi^0$	$(99.524 \pm 0.012) \%$		135
$\Lambda\gamma$	$(1.17 \pm 0.07) \times 10^{-3}$		184
$\Lambda e^+ e^-$	$(7.6 \pm 0.6) \times 10^{-6}$		184
$\Sigma^0\gamma$	$(3.33 \pm 0.10) \times 10^{-3}$		117
$\Sigma^+ e^- \bar{\nu}_e$	$(2.52 \pm 0.08) \times 10^{-4}$		120
$\Sigma^+ \mu^- \bar{\nu}_\mu$	$(2.33 \pm 0.35) \times 10^{-6}$		64

**$\Delta S = \Delta Q$  (SQ) violating modes or  
 $\Delta S = 2$  forbidden (S2) modes**

$\Sigma^- e^+ \nu_e$	SQ	< 9	$\times 10^{-4}$	90%	112
$\Sigma^- \mu^+ \nu_\mu$	SQ	< 9	$\times 10^{-4}$	90%	49
$p\pi^-$	S2	< 8	$\times 10^{-6}$	90%	299
$p e^- \bar{\nu}_e$	S2	< 1.3	$\times 10^{-3}$		323
$p\mu^- \bar{\nu}_\mu$	S2	< 1.3	$\times 10^{-3}$		309



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

$P$  is not yet measured; + is the quark model prediction.

Mass  $m = 1321.71 \pm 0.07$  MeV

$$(m_{\Xi^-} - m_{\Xi^+}) / m_{\Xi^-} = (-3 \pm 9) \times 10^{-5}$$

$$\text{Mean life } \tau = (1.639 \pm 0.015) \times 10^{-10} \text{ s}$$

$$c\tau = 4.91 \text{ cm}$$

$$(\tau_{\Xi^-} - \tau_{\Xi^+}) / \tau_{\Xi^-} = -0.01 \pm 0.07$$

$$\text{Magnetic moment } \mu = -0.6507 \pm 0.0025 \mu_N$$

$$(\mu_{\Xi^-} + \mu_{\Xi^+}) / |\mu_{\Xi^-}| = +0.01 \pm 0.05$$

**Decay parameters**

$$\Lambda\pi^- \quad \alpha = -0.392 \pm 0.008$$

$$[\alpha(\Xi^-)\alpha_-(\Lambda) - \alpha(\Xi^+)\alpha_+(\bar{\Lambda})] / [\text{sum}] = (0 \pm 7) \times 10^{-4}$$

$$" \quad \phi = (-2.1 \pm 0.8)^\circ$$

$$" \quad \gamma = 0.89 [n]$$

$$" \quad \Delta = (175.9 \pm 1.5)^\circ [n]$$

$$\Lambda e^- \bar{\nu}_e \quad g_A/g_V = -0.25 \pm 0.05 [i]$$

$\Xi^-$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$P$ (MeV/c)
$\Lambda\pi^-$	$(99.887 \pm 0.035) \%$		140
$\Sigma^- \gamma$	$(1.27 \pm 0.23) \times 10^{-4}$		118
$\Lambda e^- \bar{\nu}_e$	$(5.63 \pm 0.31) \times 10^{-4}$		190
$\Lambda\mu^- \bar{\nu}_\mu$	$(3.5 \begin{smallmatrix} +3.5 \\ -2.2 \end{smallmatrix}) \times 10^{-4}$		163
$\Sigma^0 e^- \bar{\nu}_e$	$(8.7 \pm 1.7) \times 10^{-5}$		123
$\Sigma^0 \mu^- \bar{\nu}_\mu$	< 8	$\times 10^{-4}$	90% 70
$\Xi^0 e^- \bar{\nu}_e$	< 2.3	$\times 10^{-3}$	90% 7

**$\Delta S = 2$  forbidden (S2) modes**

$n\pi^-$	S2	< 1.9	$\times 10^{-5}$	90%	304
$n e^- \bar{\nu}_e$	S2	< 3.2	$\times 10^{-3}$	90%	327
$n\mu^- \bar{\nu}_\mu$	S2	< 1.5	%	90%	314
$p\pi^- \pi^-$	S2	< 4	$\times 10^{-4}$	90%	223

$p\pi^-e^-\bar{\nu}_e$	S2	< 4	$\times 10^{-4}$	90%	305
$p\pi^-\mu^-\bar{\nu}_\mu$	S2	< 4	$\times 10^{-4}$	90%	251
$p\mu^-\mu^-$	L	< 4	$\times 10^{-8}$	90%	272

**$\Xi(1530) 3/2^+$**

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

$\Xi(1530)^0$  mass  $m = 1531.80 \pm 0.32$  MeV ( $S = 1.3$ )

$\Xi(1530)^-$  mass  $m = 1535.0 \pm 0.6$  MeV

$\Xi(1530)^0$  full width  $\Gamma = 9.1 \pm 0.5$  MeV

$\Xi(1530)^-$  full width  $\Gamma = 9.9^{+1.7}_{-1.9}$  MeV

<b><math>\Xi(1530)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\Xi\pi$	100 %		158
$\Xi\gamma$	<4 %	90%	202

**$\Xi(1690)$**

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

Mass  $m = 1690 \pm 10$  MeV [ $p$ ]

Full width  $\Gamma < 30$  MeV

<b><math>\Xi(1690)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda\bar{K}$	seen	240
$\Sigma\bar{K}$	seen	70
$\Xi\pi$	seen	311
$\Xi^-\pi^+\pi^-$	possibly seen	213

**$\Xi(1820) 3/2^-$**

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

Mass  $m = 1823 \pm 5$  MeV [ $p$ ]

Full width  $\Gamma = 24^{+15}_{-10}$  MeV [ $p$ ]

<b><math>\Xi(1820)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda\bar{K}$	large	402
$\Sigma\bar{K}$	small	324
$\Xi\pi$	small	421
$\Xi(1530)\pi$	small	237



**$\Xi(1950)$** 

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

Mass  $m = 1950 \pm 15$  MeV [ $\rho$ ]Full width  $\Gamma = 60 \pm 20$  MeV [ $\rho$ ]

<b><math>\Xi(1950)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda \bar{K}$	seen	522
$\Sigma \bar{K}$	possibly seen	460
$\Xi \pi$	seen	519

 **$\Xi(2030)$** 

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

Mass  $m = 2025 \pm 5$  MeV [ $\rho$ ]Full width  $\Gamma = 20^{+15}_{-5}$  MeV [ $\rho$ ]

<b><math>\Xi(2030)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda \bar{K}$	$\sim 20\%$	585
$\Sigma \bar{K}$	$\sim 80\%$	529
$\Xi \pi$	small	574
$\Xi(1530)\pi$	small	416
$\Lambda \bar{K} \pi$	small	499
$\Sigma \bar{K} \pi$	small	428

## $\Omega$ BARYONS ( $S = -3, I = 0$ )

$$\Omega^- = sss$$

 **$\Omega^-$** 

$$I(J^P) = 0(\frac{3}{2}^+)$$

$J^P = \frac{3}{2}^+$  is the quark-model prediction; and  $J = 3/2$  is fairly well established.

Mass  $m = 1672.45 \pm 0.29$  MeV

$$(m_{\Omega^-} - m_{\bar{\Omega}^+}) / m_{\Omega^-} = (-1 \pm 8) \times 10^{-5}$$

Mean life  $\tau = (0.821 \pm 0.011) \times 10^{-10}$  s

$$c\tau = 2.461 \text{ cm}$$

$$(\tau_{\Omega^-} - \tau_{\bar{\Omega}^+}) / \tau_{\Omega^-} = 0.00 \pm 0.05$$

Magnetic moment  $\mu = -2.02 \pm 0.05 \mu_N$

**Decay parameters**

$$\alpha(\Omega^-) \alpha_-(\Lambda) \text{ FOR } \Omega^- \rightarrow \Lambda K^- = 0.0115 \pm 0.0015$$

$$\Lambda K^- \quad \alpha = 0.0154 \pm 0.0020$$

$$\Lambda K^-, \bar{\Lambda} K^+ \quad (\alpha + \bar{\alpha})/(\alpha - \bar{\alpha}) = -0.02 \pm 0.13$$

$$\Xi^0 \pi^- \quad \alpha = 0.09 \pm 0.14$$

$$\Xi^- \pi^0 \quad \alpha = 0.05 \pm 0.21$$

$\Omega^-$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\Lambda K^-$	(67.8±0.7) %		211
$\Xi^0 \pi^-$	(23.6±0.7) %		294
$\Xi^- \pi^0$	( 8.6±0.4) %		289
$\Xi^- \pi^+ \pi^-$	( 3.7 <sup>+0.7</sup> <sub>-0.6</sub> ) × 10 <sup>-4</sup>		189
$\Xi(1530)^0 \pi^-$	< 7 × 10 <sup>-5</sup>	90%	17
$\Xi^0 e^- \bar{\nu}_e$	( 5.6±2.8) × 10 <sup>-3</sup>		319
$\Xi^- \gamma$	< 4.6 × 10 <sup>-4</sup>	90%	314
<b><math>\Delta S = 2</math> forbidden (<math>S_2</math>) modes</b>			
$\Lambda \pi^-$	$S_2$ < 2.9 × 10 <sup>-6</sup>	90%	449

**$\Omega(2012)^-$**

$$I(J^P) = 0(?^-)$$

Mass  $m = 2012.4 \pm 0.9$  MeV

Full width  $\Gamma = 6.4^{+3.0}_{-2.6}$  MeV

$\Omega(2012)^-$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi^0 K^-$	seen	403
$\Xi^- K^0$	seen	392

**$\Omega(2250)^-$**

$$I(J^P) = 0(?^?)$$

Mass  $m = 2252 \pm 9$  MeV

Full width  $\Gamma = 55 \pm 18$  MeV

$\Omega(2250)^-$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi^- \pi^+ K^-$	seen	532
$\Xi(1530)^0 K^-$	seen	437

# CHARMED BARYONS ( $C = +1$ )

$$\Lambda_c^+ = udc, \quad \Sigma_c^{++} = uuc, \quad \Sigma_c^+ = udc, \quad \Sigma_c^0 = ddc,$$

$$\Xi_c^+ = usc, \quad \Xi_c^0 = dsc, \quad \Omega_c^0 = ssc$$

$\Lambda_c^+$

$$I(J^P) = 0(\frac{1}{2}^+)$$

Mass  $m = 2286.46 \pm 0.14$  MeV

Mean life  $\tau = (200 \pm 6) \times 10^{-15}$  s ( $S = 1.6$ )

$$c\tau = 59.9 \mu\text{m}$$

### Decay asymmetry parameters

$$\Lambda\pi^+ \quad \alpha = -0.91 \pm 0.15$$

$$\Sigma^+\pi^0 \quad \alpha = -0.45 \pm 0.32$$

$$\Lambda\ell^+\nu_\ell \quad \alpha = -0.86 \pm 0.04$$

$$(\alpha + \bar{\alpha})/(\alpha - \bar{\alpha}) \text{ in } \Lambda_c^+ \rightarrow \Lambda\pi^+, \bar{\Lambda}_c^- \rightarrow \bar{\Lambda}\pi^- = -0.07 \pm 0.31$$

$$(\alpha + \bar{\alpha})/(\alpha - \bar{\alpha}) \text{ in } \Lambda_c^+ \rightarrow \Lambda e^+\nu_e, \bar{\Lambda}_c^- \rightarrow \bar{\Lambda}e^-\bar{\nu}_e = 0.00 \pm 0.04$$

$$A_{CP}(\Lambda X) \text{ in } \Lambda_c \rightarrow \Lambda X, \bar{\Lambda}_c \rightarrow \bar{\Lambda} X = (2 \pm 7)\%$$

$$\Delta A_{CP} = A_{CP}(\Lambda_c^+ \rightarrow pK^+K^-) - A_{CP}(\Lambda_c^+ \rightarrow p\pi^+\pi^-) = (0.3 \pm 1.1)\%$$

Branching fractions marked with a footnote, e.g. [a], have been corrected for decay modes not observed in the experiments. For example, the sub-mode fraction  $\Lambda_c^+ \rightarrow p\bar{K}^*(892)^0$  seen in  $\Lambda_c^+ \rightarrow pK^-\pi^+$  has been multiplied up to include  $\bar{K}^*(892)^0 \rightarrow \bar{K}^0\pi^0$  decays.

$\Lambda_c^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
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### Hadronic modes with a $p$ or $n$ : $S = -1$ final states

$pK_S^0$	( 1.59 ± 0.08 ) %	S=1.1	873
$pK^-\pi^+$	( 6.28 ± 0.32 ) %	S=1.4	823
$p\bar{K}^*(892)^0$	[r] ( 1.96 ± 0.27 ) %		685
$\Delta(1232)^{++}K^-$	( 1.08 ± 0.25 ) %		710
$\Lambda(1520)\pi^+$	[r] ( 2.2 ± 0.5 ) %		627
$pK^-\pi^+$ nonresonant	( 3.5 ± 0.4 ) %		823
$pK_S^0\pi^0$	( 1.97 ± 0.13 ) %	S=1.1	823
$nK_S^0\pi^+$	( 1.82 ± 0.25 ) %		821
$p\bar{K}^0\eta$	( 1.6 ± 0.4 ) %		568

$\rho K_S^0 \pi^+ \pi^-$	( 1.60 ± 0.12 ) %	S=1.1	754
$\rho K^- \pi^+ \pi^0$	( 4.46 ± 0.30 ) %	S=1.5	759
$\rho K^*(892)^- \pi^+$	[r] ( 1.4 ± 0.5 ) %		580
$\rho (K^- \pi^+)_{\text{nonresonant}} \pi^0$	( 4.6 ± 0.8 ) %		759
$\Delta(1232) \bar{K}^*(892)$	seen		419
$\rho K^- 2\pi^+ \pi^-$	( 1.4 ± 0.9 ) × 10 <sup>-3</sup>		671
$\rho K^- \pi^+ 2\pi^0$	( 1.0 ± 0.5 ) %		678

**Hadronic modes with a  $\rho$ : S = 0 final states**

$\rho \pi^0$	< 2.7 × 10 <sup>-4</sup>	CL=90%	945
$\rho \eta$	( 1.24 ± 0.30 ) × 10 <sup>-3</sup>		856
$\rho \omega(782)^0$	( 9 ± 4 ) × 10 <sup>-4</sup>		751
$\rho \pi^+ \pi^-$	( 4.61 ± 0.28 ) × 10 <sup>-3</sup>		927
$\rho f_0(980)$	[r] ( 3.5 ± 2.3 ) × 10 <sup>-3</sup>		614
$\rho 2\pi^+ 2\pi^-$	( 2.3 ± 1.4 ) × 10 <sup>-3</sup>		852
$\rho K^+ K^-$	( 1.06 ± 0.06 ) × 10 <sup>-3</sup>		616
$\rho \phi$	[r] ( 1.06 ± 0.14 ) × 10 <sup>-3</sup>		590
$\rho K^+ K^- \text{ non-}\phi$	( 5.3 ± 1.2 ) × 10 <sup>-4</sup>		616
$\rho \phi \pi^0$	( 10 ± 4 ) × 10 <sup>-5</sup>		460
$\rho K^+ K^- \pi^0 \text{ nonresonant}$	< 6.3 × 10 <sup>-5</sup>	CL=90%	494

**Hadronic modes with a hyperon: S = -1 final states**

$\Lambda \pi^+$	( 1.30 ± 0.07 ) %	S=1.1	864
$\Lambda \pi^+ \pi^0$	( 7.1 ± 0.4 ) %	S=1.1	844
$\Lambda \rho^+$	< 6 %	CL=95%	636
$\Lambda \pi^- 2\pi^+$	( 3.64 ± 0.29 ) %	S=1.4	807
$\Sigma(1385)^+ \pi^+ \pi^-, \Sigma^{*+} \rightarrow \Lambda \pi^+$	( 1.0 ± 0.5 ) %		688
$\Sigma(1385)^- 2\pi^+, \Sigma^{*-} \rightarrow \Lambda \pi^-$	( 7.6 ± 1.4 ) × 10 <sup>-3</sup>		688
$\Lambda \pi^+ \rho^0$	( 1.5 ± 0.6 ) %		524
$\Sigma(1385)^+ \rho^0, \Sigma^{*+} \rightarrow \Lambda \pi^+$	( 5 ± 4 ) × 10 <sup>-3</sup>		363
$\Lambda \pi^- 2\pi^+ \text{ nonresonant}$	< 1.1 %	CL=90%	807
$\Lambda \pi^- \pi^0 2\pi^+ \text{ total}$	( 2.3 ± 0.8 ) %		757
$\Lambda \pi^+ \eta$	[r] ( 2.2 ± 0.5 ) %		691
$\Sigma(1385)^+ \eta$	[r] ( 1.07 ± 0.32 ) %		570
$\Lambda \pi^+ \omega$	[r] ( 1.5 ± 0.5 ) %		517
$\Lambda \pi^- \pi^0 2\pi^+, \text{ no } \eta \text{ or } \omega$	< 8 × 10 <sup>-3</sup>	CL=90%	757
$\Lambda K^+ \bar{K}^0$	( 5.7 ± 1.1 ) × 10 <sup>-3</sup>	S=1.9	443
$\Xi(1690)^0 K^+, \Xi^{*0} \rightarrow \Lambda \bar{K}^0$	( 1.6 ± 0.5 ) × 10 <sup>-3</sup>		286
$\Sigma^0 \pi^+$	( 1.29 ± 0.07 ) %	S=1.1	825
$\Sigma^+ \pi^0$	( 1.25 ± 0.10 ) %		827
$\Sigma^+ \eta$	( 6.9 ± 2.3 ) × 10 <sup>-3</sup>		713
$\Sigma^+ \pi^+ \pi^-$	( 4.50 ± 0.25 ) %	S=1.3	804
$\Sigma^+ \rho^0$	< 1.7 %	CL=95%	575

$\Sigma^- 2\pi^+$	( 1.87 ± 0.18 ) %		799
$\Sigma^0 \pi^+ \pi^0$	( 3.5 ± 0.4 ) %		803
$\Sigma^+ \pi^0 \pi^0$	( 1.55 ± 0.15 ) %		806
$\Sigma^0 \pi^- 2\pi^+$	( 1.11 ± 0.30 ) %		763
$\Sigma^+ \pi^+ \pi^- \pi^0$	—		767
$\Sigma^+ \omega$	[r] ( 1.70 ± 0.21 ) %		569
$\Sigma^- \pi^0 2\pi^+$	( 2.1 ± 0.4 ) %		762
$\Sigma^+ K^+ K^-$	( 3.5 ± 0.4 ) × 10 <sup>-3</sup>	S=1.1	349
$\Sigma^+ \phi$	[r] ( 3.9 ± 0.6 ) × 10 <sup>-3</sup>	S=1.1	295
$\Xi(1690)^0 K^+, \Xi^{*0} \rightarrow$	( 1.02 ± 0.25 ) × 10 <sup>-3</sup>		286
$\Sigma^+ K^-$			
$\Sigma^+ K^+ K^-$ nonresonant	< 8 × 10 <sup>-4</sup>	CL=90%	349
$\Xi^0 K^+$	( 5.5 ± 0.7 ) × 10 <sup>-3</sup>		653
$\Xi^- K^+ \pi^+$	( 6.2 ± 0.6 ) × 10 <sup>-3</sup>	S=1.1	565
$\Xi(1530)^0 K^+$	( 4.3 ± 0.9 ) × 10 <sup>-3</sup>	S=1.1	473

### Hadronic modes with a hyperon: **S = 0** final states

$\Lambda K^+$	( 6.1 ± 1.2 ) × 10 <sup>-4</sup>		781
$\Lambda K^+ \pi^+ \pi^-$	< 5 × 10 <sup>-4</sup>	CL=90%	637
$\Sigma^0 K^+$	( 5.2 ± 0.8 ) × 10 <sup>-4</sup>		735
$\Sigma^0 K^+ \pi^+ \pi^-$	< 2.6 × 10 <sup>-4</sup>	CL=90%	574
$\Sigma^+ K^+ \pi^-$	( 2.1 ± 0.6 ) × 10 <sup>-3</sup>		670
$\Sigma^+ K^*(892)^0$	[r] ( 3.5 ± 1.0 ) × 10 <sup>-3</sup>		470
$\Sigma^- K^+ \pi^+$	< 1.2 × 10 <sup>-3</sup>	CL=90%	664

### Doubly Cabibbo-suppressed modes

$p K^+ \pi^-$	( 1.11 ± 0.18 ) × 10 <sup>-4</sup>		823
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### Semileptonic modes

$\Lambda e^+ \nu_e$	( 3.6 ± 0.4 ) %		871
$\Lambda \mu^+ \nu_\mu$	( 3.5 ± 0.5 ) %		867

### Inclusive modes

$e^+$ anything	( 3.95 ± 0.35 ) %		—
$p$ anything	( 50 ± 16 ) %		—
$n$ anything	( 50 ± 16 ) %		—
$\Lambda$ anything	( 38.2 $\begin{smallmatrix} + 2.9 \\ - 2.4 \end{smallmatrix}$ ) %		—
3prongs	( 24 ± 8 ) %		—

### $\Delta C = 1$ weak neutral current (**C1**) modes, or Lepton Family number (**LF**), or Lepton number (**L**), or Baryon number (**B**) violating modes

$p e^+ e^-$	<b>C1</b>	< 5.5 × 10 <sup>-6</sup>	CL=90%	951
$p \mu^+ \mu^-$ non-resonant	<b>C1</b>	< 7.7 × 10 <sup>-8</sup>	CL=90%	937
$p e^+ \mu^-$	<b>LF</b>	< 9.9 × 10 <sup>-6</sup>	CL=90%	947
$p e^- \mu^+$	<b>LF</b>	< 1.9 × 10 <sup>-5</sup>	CL=90%	947

$\bar{p}2e^+$	$L,B$	$< 2.7$	$\times 10^{-6}$	CL=90%	951
$\bar{p}2\mu^+$	$L,B$	$< 9.4$	$\times 10^{-6}$	CL=90%	937
$\bar{p}e^+\mu^+$	$L,B$	$< 1.6$	$\times 10^{-5}$	CL=90%	947
$\Sigma^-\mu^+\mu^+$	$L$	$< 7.0$	$\times 10^{-4}$	CL=90%	812

### $\Lambda_c(2595)^+$

$$I(J^P) = 0(\frac{1}{2}^-)$$

The spin-parity follows from the fact that  $\Sigma_c(2455)\pi$  decays, with little available phase space, are dominant. This assumes that  $J^P = 1/2^+$  for the  $\Sigma_c(2455)$ .

$$\begin{aligned} \text{Mass } m &= 2592.25 \pm 0.28 \text{ MeV} \\ m - m_{\Lambda_c^+} &= 305.79 \pm 0.24 \text{ MeV} \\ \text{Full width } \Gamma &= 2.6 \pm 0.6 \text{ MeV} \end{aligned}$$

$\Lambda_c^+\pi\pi$  and its submode  $\Sigma_c(2455)\pi$  — the latter just barely — are the only strong decays allowed to an excited  $\Lambda_c^+$  having this mass; and the submode seems to dominate.

$\Lambda_c(2595)^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_c^+\pi^+\pi^-$	[s] —	117
$\Sigma_c(2455)^{++}\pi^-$	$24 \pm 7\%$	†
$\Sigma_c(2455)^0\pi^+$	$24 \pm 7\%$	†
$\Lambda_c^+\pi^+\pi^-$ 3-body	$18 \pm 10\%$	117
$\Lambda_c^+\pi^0$	[t] not seen	258
$\Lambda_c^+\gamma$	not seen	288

### $\Lambda_c(2625)^+$

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

$J^P$  has not been measured;  $\frac{3}{2}^-$  is the quark-model prediction.

$$\begin{aligned} \text{Mass } m &= 2628.11 \pm 0.19 \text{ MeV} \quad (S = 1.1) \\ m - m_{\Lambda_c^+} &= 341.65 \pm 0.13 \text{ MeV} \quad (S = 1.1) \\ \text{Full width } \Gamma &< 0.97 \text{ MeV, CL} = 90\% \end{aligned}$$

$\Lambda_c^+\pi\pi$  and its submode  $\Sigma(2455)\pi$  are the only strong decays allowed to an excited  $\Lambda_c^+$  having this mass.

$\Lambda_c(2625)^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\Lambda_c^+\pi^+\pi^-$	$\approx 67\%$		184
$\Sigma_c(2455)^{++}\pi^-$	$< 5$	90%	102

$\Sigma_c(2455)^0 \pi^+$	<5	90%	102
$\Lambda_c^+ \pi^+ \pi^-$ 3-body	large		184
$\Lambda_c^+ \pi^0$	[t] not seen		293
$\Lambda_c^+ \gamma$	not seen		319

 **$\Lambda_c(2860)^+$** 

$$I(J^P) = 0(\frac{3}{2}^+)$$

$$\text{Mass } m = 2856.1^{+2.3}_{-6.0} \text{ MeV}$$

$$\text{Full width } \Gamma = 68^{+12}_{-22} \text{ MeV}$$

<b><math>\Lambda_c(2860)^+</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$D^0 p$	seen	259

 **$\Lambda_c(2880)^+$** 

$$I(J^P) = 0(\frac{5}{2}^+)$$

$$\text{Mass } m = 2881.63 \pm 0.24 \text{ MeV}$$

$$m - m_{\Lambda_c^+} = 595.17 \pm 0.28 \text{ MeV}$$

$$\text{Full width } \Gamma = 5.6^{+0.8}_{-0.6} \text{ MeV}$$

<b><math>\Lambda_c(2880)^+</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_c^+ \pi^+ \pi^-$	seen	471
$\Sigma_c(2455)^{0,++} \pi^\pm$	seen	376
$\Sigma_c(2520)^{0,++} \pi^\pm$	seen	317
$p D^0$	seen	316

 **$\Lambda_c(2940)^+$** 

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

$J^P = 3/2^-$  is favored, but is not certain

$$\text{Mass } m = 2939.6^{+1.3}_{-1.5} \text{ MeV}$$

$$\text{Full width } \Gamma = 20^{+6}_{-5} \text{ MeV}$$

<b><math>\Lambda_c(2940)^+</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$p D^0$	seen	420
$\Sigma_c(2455)^{0,++} \pi^\pm$	seen	—

**$\Sigma_c(2455)$** 

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

$$\begin{aligned}
\Sigma_c(2455)^{++} \text{ mass } m &= 2453.97 \pm 0.14 \text{ MeV} \\
\Sigma_c(2455)^+ \text{ mass } m &= 2452.9 \pm 0.4 \text{ MeV} \\
\Sigma_c(2455)^0 \text{ mass } m &= 2453.75 \pm 0.14 \text{ MeV} \\
m_{\Sigma_c^{++}} - m_{\Lambda_c^+} &= 167.510 \pm 0.017 \text{ MeV} \\
m_{\Sigma_c^+} - m_{\Lambda_c^+} &= 166.4 \pm 0.4 \text{ MeV} \\
m_{\Sigma_c^0} - m_{\Lambda_c^+} &= 167.290 \pm 0.017 \text{ MeV} \\
m_{\Sigma_c^{++}} - m_{\Sigma_c^0} &= 0.220 \pm 0.013 \text{ MeV} \\
m_{\Sigma_c^+} - m_{\Sigma_c^0} &= -0.9 \pm 0.4 \text{ MeV} \\
\Sigma_c(2455)^{++} \text{ full width } \Gamma &= 1.89^{+0.09}_{-0.18} \text{ MeV} \quad (S = 1.1) \\
\Sigma_c(2455)^+ \text{ full width } \Gamma &< 4.6 \text{ MeV, CL} = 90\% \\
\Sigma_c(2455)^0 \text{ full width } \Gamma &= 1.83^{+0.11}_{-0.19} \text{ MeV} \quad (S = 1.2)
\end{aligned}$$

$\Lambda_c^+ \pi$  is the only strong decay allowed to a  $\Sigma_c$  having this mass.

<b><math>\Sigma_c(2455)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_c^+ \pi$	$\approx 100\%$	94

 **$\Sigma_c(2520)$** 

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

$J^P$  has not been measured;  $\frac{3}{2}^+$  is the quark-model prediction.

$$\begin{aligned}
\Sigma_c(2520)^{++} \text{ mass } m &= 2518.41^{+0.21}_{-0.19} \text{ MeV} \quad (S = 1.1) \\
\Sigma_c(2520)^+ \text{ mass } m &= 2517.5 \pm 2.3 \text{ MeV} \\
\Sigma_c(2520)^0 \text{ mass } m &= 2518.48 \pm 0.20 \text{ MeV} \quad (S = 1.1) \\
m_{\Sigma_c(2520)^{++}} - m_{\Lambda_c^+} &= 231.95^{+0.17}_{-0.12} \text{ MeV} \quad (S = 1.3) \\
m_{\Sigma_c(2520)^+} - m_{\Lambda_c^+} &= 231.0 \pm 2.3 \text{ MeV} \\
m_{\Sigma_c(2520)^0} - m_{\Lambda_c^+} &= 232.02^{+0.15}_{-0.14} \text{ MeV} \quad (S = 1.3) \\
m_{\Sigma_c(2520)^{++}} - m_{\Sigma_c(2520)^0} &= 0.01 \pm 0.15 \text{ MeV} \\
\Sigma_c(2520)^{++} \text{ full width } \Gamma &= 14.78^{+0.30}_{-0.40} \text{ MeV} \\
\Sigma_c(2520)^+ \text{ full width } \Gamma &< 17 \text{ MeV, CL} = 90\% \\
\Sigma_c(2520)^0 \text{ full width } \Gamma &= 15.3^{+0.4}_{-0.5} \text{ MeV}
\end{aligned}$$

$\Lambda_c^+ \pi$  is the only strong decay allowed to a  $\Sigma_c$  having this mass.

<b><math>\Sigma_c(2520)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_c^+ \pi$	$\approx 100\%$	179



**$\Sigma_c(2800)$**

$$I(J^P) = 1(?^?)$$

$$\begin{aligned} \Sigma_c(2800)^{++} \text{ mass } m &= 2801_{-6}^{+4} \text{ MeV} \\ \Sigma_c(2800)^+ \text{ mass } m &= 2792_{-5}^{+14} \text{ MeV} \\ \Sigma_c(2800)^0 \text{ mass } m &= 2806_{-7}^{+5} \text{ MeV} \quad (S = 1.3) \\ m_{\Sigma_c(2800)^{++}} - m_{\Lambda_c^+} &= 514_{-6}^{+4} \text{ MeV} \\ m_{\Sigma_c(2800)^+} - m_{\Lambda_c^+} &= 505_{-5}^{+14} \text{ MeV} \\ m_{\Sigma_c(2800)^0} - m_{\Lambda_c^+} &= 519_{-7}^{+5} \text{ MeV} \quad (S = 1.3) \\ \Sigma_c(2800)^{++} \text{ full width } \Gamma &= 75_{-17}^{+22} \text{ MeV} \\ \Sigma_c(2800)^+ \text{ full width } \Gamma &= 62_{-40}^{+60} \text{ MeV} \\ \Sigma_c(2800)^0 \text{ full width } \Gamma &= 72_{-15}^{+22} \text{ MeV} \end{aligned}$$

$\Sigma_c(2800)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_c^+ \pi$	seen	443

**$\Xi_c^+$**

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

$J^P$  has not been measured;  $\frac{1}{2}^+$  is the quark-model prediction.

$$\begin{aligned} \text{Mass } m &= 2467.93 \pm 0.18 \text{ MeV} \quad (S = 1.1) \\ \text{Mean life } \tau &= (442 \pm 26) \times 10^{-15} \text{ s} \quad (S = 1.3) \\ c\tau &= 132 \mu\text{m} \end{aligned}$$

Branching fractions marked with a footnote, e.g. [a], have been corrected for decay modes not observed in the experiments. For example, the sub-mode fraction  $\Xi_c^+ \rightarrow \Sigma^+ \bar{K}^*(892)^0$  seen in  $\Xi_c^+ \rightarrow \Sigma^+ K^- \pi^+$  has been multiplied up to include  $\bar{K}^*(892)^0 \rightarrow \bar{K}^0 \pi^0$  decays.

$\Xi_c^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$P$ (MeV/c)
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**No absolute branching fractions have been measured.  
The following are branching ratios relative to  $\Xi^- 2\pi^+$ .**

**Cabibbo-favored ( $S = -2$ ) decays — relative to  $\Xi^- 2\pi^+$**

$p 2K_S^0$	$0.087 \pm 0.021$		767
$\Lambda \bar{K}^0 \pi^+$	—		852
$\Sigma(1385)^+ \bar{K}^0$	[r] 1.0 $\pm 0.5$		746
$\Lambda K^- 2\pi^+$	$0.323 \pm 0.033$		787
$\Lambda \bar{K}^*(892)^0 \pi^+$	[r] $< 0.16$	90%	608
$\Sigma(1385)^+ K^- \pi^+$	[r] $< 0.23$	90%	678

$\Sigma^+ K^- \pi^+$		$0.94 \pm 0.10$		811
$\Sigma^+ \bar{K}^*(892)^0$	[r]	$0.81 \pm 0.15$		658
$\Sigma^0 K^- 2\pi^+$		$0.27 \pm 0.12$		735
$\Xi^0 \pi^+$		$0.55 \pm 0.16$		877
$\Xi^- 2\pi^+$		<b>DEFINED AS 1</b>		851
$\Xi(1530)^0 \pi^+$	[r]	$<0.10$	90%	750
$\Xi(1620)^0 \pi^+$		seen		—
$\Xi(1690)^0 \pi^+$		seen		644
$\Xi^0 \pi^+ \pi^0$		$2.3 \pm 0.7$		856
$\Xi^0 \pi^- 2\pi^+$		$1.7 \pm 0.5$		818
$\Xi^0 e^+ \nu_e$		$2.3 \begin{smallmatrix} +0.7 \\ -0.8 \end{smallmatrix}$		884
$\Omega^- K^+ \pi^+$		$0.07 \pm 0.04$		399

### Cabibbo-suppressed decays — relative to $\Xi^- 2\pi^+$

$\rho K^- \pi^+$		$0.21 \pm 0.04$		944
$\rho \bar{K}^*(892)^0$	[r]	$0.116 \pm 0.030$		828
$\Sigma^+ \pi^+ \pi^-$		$0.48 \pm 0.20$		922
$\Sigma^- 2\pi^+$		$0.18 \pm 0.09$		918
$\Sigma^+ K^+ K^-$		$0.15 \pm 0.06$		580
$\Sigma^+ \phi$	[r]	$<0.11$	90%	549
$\Xi(1690)^0 K^+, \Xi^0 \rightarrow \Sigma^+ K^-$		$<0.05$	90%	501



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

$J^P$  has not been measured;  $\frac{1}{2}^+$  is the quark-model prediction.

Mass  $m = 2470.91 \pm 0.25$  MeV

$$m_{\Xi_c^0} - m_{\Xi_c^+} = 2.98 \pm 0.22 \text{ MeV}$$

$$\text{Mean life } \tau = (112_{-10}^{+13}) \times 10^{-15} \text{ s}$$

$$c\tau = 33.6 \text{ } \mu\text{m}$$

### Decay asymmetry parameters

$$\Xi^- \pi^+ \quad \alpha = -0.6 \pm 0.4$$

$\Xi_c^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor	$\frac{p}{\text{MeV}/c}$
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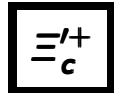
### Cabibbo-favored ( $S = -2$ ) decays

$\rho K^- K^- \pi^+$	$(4.8 \pm 1.2) \times 10^{-3}$	1.1	676
$\rho K^- \bar{K}^*(892)^0, \bar{K}^{*0} \rightarrow K^- \pi^+$	$(2.0 \pm 0.6) \times 10^{-3}$		413
$\rho K^- K^- \pi^+$ (no $\bar{K}^{*0}$ )	$(3.0 \pm 0.9) \times 10^{-3}$		676
$\Lambda K_S^0$	$(3.0 \pm 0.8) \times 10^{-3}$		906
$\Lambda K^- \pi^+$	$(1.45 \pm 0.33) \%$	1.1	856

$\Lambda \bar{K}^0 \pi^+ \pi^-$	seen		787
$\Lambda K^- \pi^+ \pi^+ \pi^-$	seen		703
$\Xi^- \pi^+$	$(1.43 \pm 0.32) \%$	1.1	875
$\Xi^- \pi^+ \pi^+ \pi^-$	$(4.8 \pm 2.3) \%$		816
$\Omega^- K^+$	$(4.2 \pm 1.0) \times 10^{-3}$		522
$\Xi^- e^+ \nu_e$	$(1.8 \pm 1.2) \%$		882

### Cabibbo-suppressed decays

$\Xi^- K^+$	$(3.9 \pm 1.2) \times 10^{-4}$		790
$\Lambda K^+ K^-$ (no $\phi$ )	$(4.1 \pm 1.4) \times 10^{-4}$		648
$\Lambda \phi$	$(4.9 \pm 1.5) \times 10^{-4}$		621



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

$J^P$  has not been measured;  $\frac{1}{2}^+$  is the quark-model prediction.

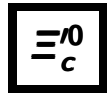
Mass  $m = 2578.4 \pm 0.5$  MeV

$$m_{\Xi_c^{'+}} - m_{\Xi_c^+} = 110.5 \pm 0.4 \text{ MeV}$$

$$m_{\Xi_c^{'+}} - m_{\Xi_c^{\prime 0}} = -0.8 \pm 0.6 \text{ MeV}$$

The  $\Xi_c^{'+} - \Xi_c^+$  mass difference is too small for any strong decay to occur.

$\Xi_c^{'+}$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi_c^+ \gamma$	seen	108



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

$J^P$  has not been measured;  $\frac{1}{2}^+$  is the quark-model prediction.

Mass  $m = 2579.2 \pm 0.5$  MeV

$$m_{\Xi_c^{\prime 0}} - m_{\Xi_c^0} = 108.3 \pm 0.4 \text{ MeV}$$

The  $\Xi_c^{\prime 0} - \Xi_c^0$  mass difference is too small for any strong decay to occur.

$\Xi_c^{\prime 0}$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi_c^0 \gamma$	seen	106

**$\Xi_c(2645)$** 

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

$J^P$  has not been measured;  $\frac{3}{2}^+$  is the quark-model prediction.

$$\Xi_c(2645)^+ \text{ mass } m = 2645.57 \pm 0.26 \text{ MeV}$$

$$\Xi_c(2645)^0 \text{ mass } m = 2646.38 \pm 0.21 \text{ MeV} \quad (S = 1.1)$$

$$m_{\Xi_c(2645)^+} - m_{\Xi_c^0} = 174.66 \pm 0.09 \text{ MeV}$$

$$m_{\Xi_c(2645)^0} - m_{\Xi_c^+} = 178.44 \pm 0.10 \text{ MeV}$$

$$m_{\Xi_c(2645)^+} - m_{\Xi_c(2645)^0} = -0.80 \pm 0.26 \text{ MeV}$$

$$\Xi_c(2645)^+ \text{ full width } \Gamma = 2.14 \pm 0.19 \text{ MeV} \quad (S = 1.1)$$

$$\Xi_c(2645)^0 \text{ full width } \Gamma = 2.35 \pm 0.22 \text{ MeV}$$

$\Xi_c \pi$  is the only strong decay allowed to a  $\Xi_c$  resonance having this mass.

 **$\Xi_c(2645)$  DECAY MODES**

	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi_c^0 \pi^+$	seen	102
$\Xi_c^+ \pi^-$	seen	106

 **$\Xi_c(2790)$** 

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

$J^P$  has not been measured;  $\frac{1}{2}^-$  is the quark-model prediction.

$$\Xi_c(2790)^+ \text{ mass } = 2792.4 \pm 0.5 \text{ MeV}$$

$$\Xi_c(2790)^0 \text{ mass } = 2794.1 \pm 0.5 \text{ MeV}$$

$$m_{\Xi_c(2790)^+} - m_{\Xi_c^0} = 213.20 \pm 0.22 \text{ MeV}$$

$$m_{\Xi_c(2790)^0} - m_{\Xi_c^+} = 215.70 \pm 0.22 \text{ MeV}$$

$$m_{\Xi_c(2790)^+} - m_{\Xi_c(2790)^0} = -1.7 \pm 0.7 \text{ MeV}$$

$$\Xi_c(2790)^+ \text{ width } = 8.9 \pm 1.0 \text{ MeV}$$

$$\Xi_c(2790)^0 \text{ width } = 10.0 \pm 1.1 \text{ MeV}$$

 **$\Xi_c(2790)$  DECAY MODES**

	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi_c^+ \pi^-$	seen	160

 **$\Xi_c(2815)$** 

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

$J^P$  has not been measured;  $\frac{3}{2}^-$  is the quark-model prediction.

$$\Xi_c(2815)^+ \text{ mass } m = 2816.73 \pm 0.21 \text{ MeV}$$

$$\Xi_c(2815)^0 \text{ mass } m = 2820.26 \pm 0.27 \text{ MeV}$$

$$m_{\Xi_c(2815)^+} - m_{\Xi_c^0} = 348.80 \pm 0.10 \text{ MeV}$$

$$m_{\Xi_c(2815)^0} - m_{\Xi_c^0} = 349.35 \pm 0.11 \text{ MeV}$$

$$m_{\Xi_c(2815)^+} - m_{\Xi_c(2815)^0} = -3.53 \pm 0.27 \text{ MeV}$$

$$\Xi_c(2815)^+ \text{ full width } \Gamma = 2.43 \pm 0.26 \text{ MeV}$$

$$\Xi_c(2815)^0 \text{ full width } \Gamma = 2.54 \pm 0.25 \text{ MeV}$$

The  $\Xi_c \pi \pi$  modes are consistent with being entirely via  $\Xi_c(2645)\pi$ .

$\Xi_c(2815)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi_c' \pi$	seen	188
$\Xi_c(2645)\pi$	seen	102

### $\Xi_c(2970)$

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

$$\Xi_c(2970)^+ m = 2969.4 \pm 0.8 \text{ MeV} \quad (S = 1.1)$$

$$\Xi_c(2970)^0 m = 2967.8^{+0.9}_{-0.7} \text{ MeV} \quad (S = 1.1)$$

$$m_{\Xi_c(2970)^+} - m_{\Xi_c^0} = 498.5 \pm 0.8 \text{ MeV} \quad (S = 1.1)$$

$$m_{\Xi_c(2970)^0} - m_{\Xi_c^+} = 499.9^{+0.8}_{-0.7} \text{ MeV} \quad (S = 1.1)$$

$$m_{\Xi_c(2970)^+} - m_{\Xi_c(2970)^0} = 1.5^{+1.1}_{-1.2} \text{ MeV} \quad (S = 1.1)$$

$$\Xi_c(2970)^+ \text{ width } \Gamma = 20.9^{+2.4}_{-3.5} \text{ MeV} \quad (S = 1.2)$$

$$\Xi_c(2970)^0 \text{ width } \Gamma = 28.1^{+3.4}_{-4.0} \text{ MeV} \quad (S = 1.5)$$

$\Xi_c(2970)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_c^+ \bar{K} \pi$	seen	231
$\Sigma_c(2455) \bar{K}$	seen	133
$\Lambda_c^+ \bar{K}$	not seen	414
$\Xi_c 2\pi$	seen	385
$\Xi_c' \pi$	seen	—
$\Xi_c(2645)\pi$	seen	277

### $\Xi_c(3055)$

$$I(J^P) = ??(??)$$

$$\text{Mass } m = 3055.9 \pm 0.4 \text{ MeV}$$

$$\text{Full width } \Gamma = 7.8 \pm 1.9 \text{ MeV}$$

$\Xi_c(3055)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Sigma^{++} K^-$	seen	—
$\Lambda D^+$	seen	316

**$\Xi_c(3080)$**

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

$$\begin{aligned} \Xi_c(3080)^+ m &= 3077.2 \pm 0.4 \text{ MeV} \\ \Xi_c(3080)^0 m &= 3079.9 \pm 1.4 \text{ MeV} \quad (S = 1.3) \\ \Xi_c(3080)^+ \text{ width } \Gamma &= 3.6 \pm 1.1 \text{ MeV} \quad (S = 1.5) \\ \Xi_c(3080)^0 \text{ width } \Gamma &= 5.6 \pm 2.2 \text{ MeV} \end{aligned}$$

<b><math>\Xi_c(3080)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_c^+ \bar{K} \pi$	seen	415
$\Sigma_c(2455) \bar{K}$	seen	342
$\Sigma_c(2455)^{++} K^-$	seen	342
$\Sigma_c(2520)^{++} K^-$	seen	239
$\Sigma_c(2455) \bar{K} + \Sigma_c(2520) \bar{K}$	seen	—
$\Lambda_c^+ \bar{K}$	not seen	536
$\Lambda_c^+ \bar{K} \pi^+ \pi^-$	not seen	144
$\Lambda D^+$	seen	362

**$\Omega_c^0$**

$$I(J^P) = 0(\frac{1}{2}^+)$$

$J^P$  has not been measured;  $\frac{1}{2}^+$  is the quark-model prediction.

$$\begin{aligned} \text{Mass } m &= 2695.2 \pm 1.7 \text{ MeV} \quad (S = 1.3) \\ \text{Mean life } \tau &= (268 \pm 26) \times 10^{-15} \text{ s} \\ c\tau &= 80 \text{ } \mu\text{m} \end{aligned}$$

<b><math>\Omega_c^0</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
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**No absolute branching fractions have been measured.  
The following are branching *ratios* relative to  $\Omega^- \pi^+$ .**

**Cabibbo-favored ( $S = -3$ ) decays — relative to  $\Omega^- \pi^+$**

$\Omega^- \pi^+$	<b>DEFINED AS 1</b>		821
$\Omega^- \pi^+ \pi^0$	$1.80 \pm 0.33$		797
$\Omega^- \rho^+$	$>1.3$	90%	532
$\Omega^- \pi^- 2\pi^+$	$0.31 \pm 0.05$		753
$\Omega^- e^+ \nu_e$	$2.4 \pm 1.2$		829
$\Xi^0 \bar{K}^0$	$1.64 \pm 0.29$		950
$\Xi^0 K^- \pi^+$	$1.20 \pm 0.18$		901
$\Xi^0 \bar{K}^{*0}, \bar{K}^{*0} \rightarrow K^- \pi^+$	$0.68 \pm 0.16$		764
$\Xi^- \bar{K}^0 \pi^+$	$2.12 \pm 0.28$		895

$\Xi^- K^- 2\pi^+$	$0.63 \pm 0.09$		830
$\Xi(1530)^0 K^- \pi^+, \Xi^{*0} \rightarrow$	$0.21 \pm 0.06$		757
$\Xi^- \bar{K}^{*0} \pi^+$	$0.34 \pm 0.11$		653
$\Sigma^+ K^- K^- \pi^+$	$< 0.32$	90%	689
$\Lambda \bar{K}^0 \bar{K}^0$	$1.72 \pm 0.35$		837

### $\Omega_c(2770)^0$

$$I(J^P) = 0(\frac{3}{2}^+)$$

$J^P$  has not been measured;  $\frac{3}{2}^+$  is the quark-model prediction.

$$\text{Mass } m = 2765.9 \pm 2.0 \text{ MeV} \quad (S = 1.2)$$

$$m_{\Omega_c(2770)^0} - m_{\Omega_c^0} = 70.7^{+0.8}_{-0.9} \text{ MeV}$$

The  $\Omega_c(2770)^0 - \Omega_c^0$  mass difference is too small for any strong decay to occur.

$\Omega_c(2770)^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Omega_c^0 \gamma$	presumably 100%	70

### $\Omega_c(3000)^0$

$$I(J^P) = ?(?^?)$$

$$\text{Mass } m = 3000.41 \pm 0.22 \text{ MeV}$$

$$\text{Full width } \Gamma = 4.5 \pm 0.7 \text{ MeV}$$

$\Omega_c(3000)^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi_c^+ K^-$	seen	181

### $\Omega_c(3050)^0$

$$I(J^P) = ?(?^?)$$

$$\text{Mass } m = 3050.20 \pm 0.13 \text{ MeV}$$

$$\text{Full width } \Gamma < 1.2 \text{ MeV, CL} = 95\%$$

$\Omega_c(3050)^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi_c^+ K^-$	seen	278

### $\Omega_c(3065)^0$

$$I(J^P) = ?(?^?)$$

$$\text{Mass } m = 3065.46 \pm 0.28 \text{ MeV}$$

$$\text{Full width } \Gamma = 3.5 \pm 0.4 \text{ MeV}$$

$\Omega_c(3065)^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi_c^+ K^-$	seen	303

**$\Omega_c(3090)^0$**

$$I(J^P) = ?(??)$$

Mass  $m = 3090.0 \pm 0.5$  MeV

Full width  $\Gamma = 8.7 \pm 1.3$  MeV

$\Omega_c(3090)^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi_c^+ K^-$	seen	339

**$\Omega_c(3120)^0$**

$$I(J^P) = ?(??)$$

Mass  $m = 3119.1 \pm 1.0$  MeV

Full width  $\Gamma < 2.6$  MeV, CL = 95%

$\Omega_c(3120)^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi_c^+ K^-$	seen	379

## DOUBLY CHARMED BARYONS ( $C = +2$ )

$$\Xi_{cc}^{++} = ucc, \Xi_{cc}^+ = dcc, \Omega_{cc}^+ = scc$$

**$\Xi_{cc}^{++}$**

$$I(J^P) = ?(??)$$

Mass  $m = 3621.2 \pm 0.7$  MeV

Mean life  $\tau = (256 \pm 27) \times 10^{-15}$  s

$\Xi_{cc}^{++}$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_c^+ K^- \pi^+ \pi^+$	seen	880
$\Xi_c^+ \pi^+, \Xi_c^+ \rightarrow p K^- \pi^+$	seen	—



# BOTTOM BARYONS

## ( $B = -1$ )

$$\Lambda_b^0 = udb, \Xi_b^0 = usb, \Xi_b^- = dsb, \Omega_b^- = ssb$$

$\Lambda_b^0$

$$I(J^P) = 0(\frac{1}{2}^+)$$

$I(J^P)$  not yet measured;  $0(\frac{1}{2}^+)$  is the quark model prediction.

$$\text{Mass } m = 5619.60 \pm 0.17 \text{ MeV}$$

$$m_{\Lambda_b^0} - m_{B^0} = 339.2 \pm 1.4 \text{ MeV}$$

$$m_{\Lambda_b^0} - m_{B^+} = 339.72 \pm 0.28 \text{ MeV}$$

$$\text{Mean life } \tau = (1.471 \pm 0.009) \times 10^{-12} \text{ s}$$

$$c\tau = 441.0 \text{ } \mu\text{m}$$

$$A_{CP}(\Lambda_b \rightarrow p\pi^-) = -0.025 \pm 0.029 \quad (S = 1.2)$$

$$A_{CP}(\Lambda_b \rightarrow pK^-) = -0.025 \pm 0.022$$

$$\Delta A_{CP}(pK^-/\pi^-) \equiv A_{CP}(pK^-) - A_{CP}(p\pi^-) = 0.014 \pm 0.024$$

$$A_{CP}(\Lambda_b \rightarrow p\bar{K}^0\pi^-) = 0.22 \pm 0.13$$

$$\Delta A_{CP}(J/\psi p\pi^-/K^-) \equiv A_{CP}(J/\psi p\pi^-) - A_{CP}(J/\psi pK^-) \\ = (5.7 \pm 2.7) \times 10^{-2}$$

$$A_{CP}(\Lambda_b \rightarrow \Lambda K^+\pi^-) = -0.53 \pm 0.25$$

$$A_{CP}(\Lambda_b \rightarrow \Lambda K^+K^-) = -0.28 \pm 0.12$$

$$\Delta A_{CP}(\Lambda_b^0 \rightarrow pK^-\mu^+\mu^-) \equiv A_{CP}(pK^-\mu^+\mu^-) \\ - A_{CP}(pK^-J/\psi) = (-4 \pm 5) \times 10^{-2}$$

$$A_{FB}^\ell(\mu\mu) \text{ in } \Lambda_b \rightarrow \Lambda\mu^+\mu^- = -0.39 \pm 0.04$$

$$\Delta(A_{FB}^\ell(\mu\mu)) \text{ in } \Lambda_b \rightarrow \Lambda\mu^+\mu^- = -0.05 \pm 0.09$$

$$A_{FB}^h(p\pi) \text{ in } \Lambda_b \rightarrow \Lambda(p\pi)\mu^+\mu^- = -0.30 \pm 0.05$$

$$A_{FB}^{\ell h} \text{ in } \Lambda_b \rightarrow \Lambda\mu^+\mu^- = 0.25 \pm 0.04$$

The branching fractions  $B(b\text{-baryon} \rightarrow \Lambda\ell^-\bar{\nu}_\ell \text{ anything})$  and  $B(\Lambda_b^0 \rightarrow \Lambda_c^+\ell^-\bar{\nu}_\ell \text{ anything})$  are not pure measurements because the underlying measured products of these with  $B(b \rightarrow b\text{-baryon})$  were used to determine  $B(b \rightarrow b\text{-baryon})$ , as described in the note "Production and Decay of  $b$ -Flavored Hadrons."

For inclusive branching fractions, e.g.,  $\Lambda_b \rightarrow \bar{\Lambda}_c \text{ anything}$ , the values usually are multiplicities, not branching fractions. They can be greater than one.

$\Lambda_b^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$J/\psi(1S)\Lambda \times B(b \rightarrow \Lambda_b^0)$	$( 5.8 \pm 0.8 ) \times 10^{-5}$		1740
$pD^0\pi^-$	$( 6.3 \pm 0.7 ) \times 10^{-4}$		2370
$pD^0K^-$	$( 4.6 \pm 0.8 ) \times 10^{-5}$		2269
$pJ/\psi\pi^-$	$( 2.6 \begin{smallmatrix} +0.5 \\ -0.4 \end{smallmatrix} ) \times 10^{-5}$		1755
$p\pi^- J/\psi, J/\psi \rightarrow \mu^+\mu^-$	$( 1.6 \pm 0.8 ) \times 10^{-6}$		—
$pJ/\psi K^-$	$( 3.2 \begin{smallmatrix} +0.6 \\ -0.5 \end{smallmatrix} ) \times 10^{-4}$		1589
$P_c(4380)^+ K^-, P_c \rightarrow pJ/\psi$	[u] $( 2.7 \pm 1.4 ) \times 10^{-5}$		—
$P_c(4450)^+ K^-, P_c \rightarrow pJ/\psi$	[u] $( 1.3 \pm 0.4 ) \times 10^{-5}$		—
$\chi_{c1}(1P)pK^-$	$( 7.6 \begin{smallmatrix} +1.5 \\ -1.3 \end{smallmatrix} ) \times 10^{-5}$		1242
$\chi_{c2}(1P)pK^-$	$( 7.9 \begin{smallmatrix} +1.6 \\ -1.4 \end{smallmatrix} ) \times 10^{-5}$		1198
$pJ/\psi(1S)\pi^+\pi^-K^-$	$( 6.6 \begin{smallmatrix} +1.3 \\ -1.1 \end{smallmatrix} ) \times 10^{-5}$		1410
$p\psi(2S)K^-$	$( 6.6 \begin{smallmatrix} +1.2 \\ -1.0 \end{smallmatrix} ) \times 10^{-5}$		1063
$\psi(2S)p\pi^-$	$( 7.5 \begin{smallmatrix} +1.6 \\ -1.4 \end{smallmatrix} ) \times 10^{-6}$		1320
$p\bar{K}^0\pi^-$	$( 1.3 \pm 0.4 ) \times 10^{-5}$		2693
$pK^0K^-$	$< 3.5 \times 10^{-6}$	CL=90%	2639
$\Lambda_c^+\pi^-$	$( 4.9 \pm 0.4 ) \times 10^{-3}$	S=1.2	2342
$\Lambda_c^+K^-$	$( 3.59 \pm 0.30 ) \times 10^{-4}$	S=1.2	2314
$\Lambda_c^+ a_1(1260)^-$	seen		2153
$\Lambda_c^+ D^-$	$( 4.6 \pm 0.6 ) \times 10^{-4}$		1886
$\Lambda_c^+ D_s^-$	$( 1.10 \pm 0.10 ) \%$		1833
$\Lambda_c^+ \pi^+ \pi^- \pi^-$	$( 7.7 \pm 1.1 ) \times 10^{-3}$	S=1.1	2323
$\Lambda_c(2595)^+ \pi^-$	$( 3.4 \pm 1.5 ) \times 10^{-4}$		2210
$\Lambda_c(2595)^+ \rightarrow \Lambda_c^+ \pi^+ \pi^-$			
$\Lambda_c(2625)^+ \pi^-$	$( 3.3 \pm 1.3 ) \times 10^{-4}$		2193
$\Lambda_c(2625)^+ \rightarrow \Lambda_c^+ \pi^+ \pi^-$			
$\Sigma_c(2455)^0 \pi^+ \pi^-$ , $\Sigma_c^0 \rightarrow \Lambda_c^+ \pi^-$	$( 5.7 \pm 2.2 ) \times 10^{-4}$		2265
$\Sigma_c(2455)^{++} \pi^- \pi^-$ , $\Sigma_c^{++} \rightarrow \Lambda_c^+ \pi^+$	$( 3.2 \pm 1.6 ) \times 10^{-4}$		2265
$\Lambda_c^+ p\bar{p}\pi^-$	$( 2.65 \pm 0.29 ) \times 10^{-4}$		1805
$\Sigma_c(2455)^0 p\bar{p}$ , $\Sigma_c(2455)^0 \rightarrow \Lambda_c^+ \pi^-$	$( 2.4 \pm 0.5 ) \times 10^{-5}$		—

$\Sigma_c(2520)^0 p \bar{p}, \Sigma_c(2520)^0 \rightarrow \Lambda_c^+ \pi^-$	$(3.2 \pm 0.7) \times 10^{-5}$	—
$\Lambda_c^+ \ell^- \bar{\nu}_\ell$ anything	[v] $(10.4 \pm 2.2) \%$	—
$\Lambda_c^+ \ell^- \bar{\nu}_\ell$	$(6.2^{+1.4}_{-1.3}) \%$	2345
$\Lambda_c^+ \pi^+ \pi^- \ell^- \bar{\nu}_\ell$	$(5.6 \pm 3.1) \%$	2335
$\Lambda_c(2595)^+ \ell^- \bar{\nu}_\ell$	$(7.9^{+4.0}_{-3.5}) \times 10^{-3}$	2212
$\Lambda_c(2625)^+ \ell^- \bar{\nu}_\ell$	$(1.3^{+0.6}_{-0.5}) \%$	2195
$p h^-$	[x] $< 2.3 \times 10^{-5}$	CL=90% 2730
$p \pi^-$	$(4.3 \pm 0.8) \times 10^{-6}$	2730
$p K^-$	$(5.1 \pm 0.9) \times 10^{-6}$	2709
$p D_s^-$	$< 4.8 \times 10^{-4}$	CL=90% 2364
$p \mu^- \bar{\nu}_\mu$	$(4.1 \pm 1.0) \times 10^{-4}$	2730
$\Lambda \mu^+ \mu^-$	$(1.08 \pm 0.28) \times 10^{-6}$	2695
$p \pi^- \mu^+ \mu^-$	$(6.9 \pm 2.5) \times 10^{-8}$	2720
$\Lambda \gamma$	$< 1.3 \times 10^{-3}$	CL=90% 2699
$\Lambda \eta$	$(9^{+7}_{-5}) \times 10^{-6}$	2670
$\Lambda \eta'(958)$	$< 3.1 \times 10^{-6}$	CL=90% 2611
$\Lambda \pi^+ \pi^-$	$(4.7 \pm 1.9) \times 10^{-6}$	2692
$\Lambda K^+ \pi^-$	$(5.7 \pm 1.3) \times 10^{-6}$	2660
$\Lambda K^+ K^-$	$(1.62 \pm 0.23) \times 10^{-5}$	2605
$\Lambda \phi$	$(9.3 \pm 2.5) \times 10^{-6}$	2599
$p \pi^- \pi^+ \pi^-$	$(2.11 \pm 0.23) \times 10^{-5}$	2715
$p K^- K^+ \pi^-$	$(4.1 \pm 0.6) \times 10^{-6}$	2612
$p K^- \pi^+ \pi^-$	$(5.1 \pm 0.5) \times 10^{-5}$	2675
$p K^- K^+ K^-$	$(1.27 \pm 0.14) \times 10^{-5}$	2524

### $\Lambda_b(5912)^0$

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

Mass  $m = 5912.20 \pm 0.21$  MeV

Full width  $\Gamma < 0.66$  MeV, CL = 90%

$\Lambda_b(5912)^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_b^0 \pi^+ \pi^-$	seen	86

### $\Lambda_b(5920)^0$

$$J^P = \frac{3}{2}^-$$

Mass  $m = 5919.92 \pm 0.19$  MeV (S = 1.1)

Full width  $\Gamma < 0.63$  MeV, CL = 90%

$\Lambda_b(5920)^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$\Lambda_b^0 \pi^+ \pi^-$	seen	108

$\Sigma_b$

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

$I, J, P$  need confirmation.

$$\text{Mass } m(\Sigma_b^+) = 5810.56 \pm 0.25 \text{ MeV}$$

$$\text{Mass } m(\Sigma_b^-) = 5815.64 \pm 0.27 \text{ MeV}$$

$$m_{\Sigma_b^+} - m_{\Sigma_b^-} = -5.06 \pm 0.18 \text{ MeV}$$

$$\Gamma(\Sigma_b^+) = 5.0 \pm 0.5 \text{ MeV}$$

$$\Gamma(\Sigma_b^-) = 5.3 \pm 0.5 \text{ MeV}$$

$\Sigma_b$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$\Lambda_b^0 \pi$	dominant	133

$\Sigma_b^*$

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

$I, J, P$  need confirmation.

$$\text{Mass } m(\Sigma_b^{*+}) = 5830.32 \pm 0.27 \text{ MeV}$$

$$\text{Mass } m(\Sigma_b^{*-}) = 5834.74 \pm 0.30 \text{ MeV}$$

$$m_{\Sigma_b^{*+}} - m_{\Sigma_b^{*-}} = -4.37 \pm 0.33 \text{ MeV} \quad (S = 1.6)$$

$$m_{\Sigma_b^{*+}} - m_{\Sigma_b^+} = 19.73 \pm 0.18$$

$$m_{\Sigma_b^{*-}} - m_{\Sigma_b^-} = 19.09 \pm 0.22$$

$$\Gamma(\Sigma_b^{*+}) = 9.4 \pm 0.5 \text{ MeV}$$

$$\Gamma(\Sigma_b^{*-}) = 10.4 \pm 0.8 \text{ MeV} \quad (S = 1.3)$$

$$m_{\Sigma_b^*} - m_{\Sigma_b} = 21.2 \pm 2.0 \text{ MeV}$$

$\Sigma_b^*$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$\Lambda_b^0 \pi$	dominant	159

$\Sigma_b(6097)^+$

$$J^P = ??$$

$$\text{Mass } m = 6095.8 \pm 1.7 \text{ MeV}$$

$$\text{Full width } \Gamma = 31 \pm 6 \text{ MeV}$$

$\Sigma_b(6097)^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$\Lambda_b \pi^+ \times B(b \rightarrow \Sigma_b(6097)^+)$	seen	—

$\Sigma_b(6097)^-$ 

$$J^P = ??$$

 Mass  $m = 6098.0 \pm 1.8$  MeV

 Full width  $\Gamma = 29 \pm 4$  MeV

$\Sigma_b(6097)^-$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_b \pi^- \times B(b \rightarrow \Sigma_b(6097)^-)$	seen	—

 $\Xi_b^0, \Xi_b^-$ 

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

 $I, J, P$  need confirmation.

$$m(\Xi_b^-) = 5797.0 \pm 0.9 \text{ MeV} \quad (S = 1.8)$$

$$m(\Xi_b^0) = 5791.9 \pm 0.5 \text{ MeV}$$

$$m_{\Xi_b^-} - m_{\Lambda_b^0} = 177.5 \pm 0.5 \text{ MeV} \quad (S = 1.6)$$

$$m_{\Xi_b^0} - m_{\Lambda_b^0} = 172.5 \pm 0.4 \text{ MeV}$$

$$m_{\Xi_b^-} - m_{\Xi_b^0} = 5.9 \pm 0.6 \text{ MeV}$$

$$\text{Mean life } \tau_{\Xi_b^-} = (1.572 \pm 0.040) \times 10^{-12} \text{ s}$$

$$\text{Mean life } \tau_{\Xi_b^0} = (1.480 \pm 0.030) \times 10^{-12} \text{ s}$$

$\Xi_b$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$\Xi^- \ell^- \bar{\nu}_\ell X \times B(\bar{b} \rightarrow \Xi_b)$	$(3.9 \pm 1.2) \times 10^{-4}$	S=1.4	—
$J/\psi \Xi^- \times B(b \rightarrow \Xi_b^-)$	$(1.02^{+0.26}_{-0.21}) \times 10^{-5}$		1782
$J/\psi \Lambda K^- \times B(b \rightarrow \Xi_b^-)$	$(2.5 \pm 0.4) \times 10^{-6}$		1631
$\rho D^0 K^- \times B(\bar{b} \rightarrow \Xi_b)$	$(1.8 \pm 0.6) \times 10^{-6}$		2374
$\rho \bar{K}^0 \pi^- \times B(\bar{b} \rightarrow \Xi_b)/B(\bar{b} \rightarrow B^0)$	$< 1.6 \times 10^{-6}$	CL=90%	2783
$\rho K^0 K^- \times B(\bar{b} \rightarrow \Xi_b)/B(\bar{b} \rightarrow B^0)$	$< 1.1 \times 10^{-6}$	CL=90%	2730
$\rho K^- K^- \times B(\bar{b} \rightarrow \Xi_b)$	$(3.6 \pm 0.8) \times 10^{-8}$		2731
$\Lambda \pi^+ \pi^- \times B(b \rightarrow \Xi_b^0)/B(b \rightarrow \Lambda_b^0)$	$< 1.7 \times 10^{-6}$	CL=90%	2781
$\Lambda K^- \pi^+ \times B(b \rightarrow \Xi_b^0)/B(b \rightarrow \Lambda_b^0)$	$< 8 \times 10^{-7}$	CL=90%	2751
$\Lambda K^+ K^- \times B(b \rightarrow \Xi_b^0)/B(b \rightarrow \Lambda_b^0)$	$< 3 \times 10^{-7}$	CL=90%	2698
$\Lambda_c^+ K^- \times B(\bar{b} \rightarrow \Xi_b)$	$(6 \pm 4) \times 10^{-7}$		2416
$\Lambda_b^0 \pi^- \times B(b \rightarrow \Xi_b^-)/B(b \rightarrow \Lambda_b^0)$	$(5.7 \pm 2.0) \times 10^{-4}$		99

$pK^- \pi^+ \pi^- \times B(b \rightarrow \Xi_b^0)/B(b \rightarrow \Lambda_b^0)$	$(1.9 \pm 0.4) \times 10^{-6}$	2766
$pK^- K^- \pi^+ \times B(b \rightarrow \Xi_b^0)/B(b \rightarrow \Lambda_b^0)$	$(1.73 \pm 0.32) \times 10^{-6}$	2704
$pK^- K^+ K^- \times B(b \rightarrow \Xi_b^0)/B(b \rightarrow \Lambda_b^0)$	$(1.8 \pm 1.0) \times 10^{-7}$	2620

**$\Xi_b'(5935)^-$**

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

Mass  $m = 5935.02 \pm 0.05$  MeV

$$m_{\Xi_b'(5935)^-} - m_{\Xi_b^0} - m_{\pi^-} = 3.653 \pm 0.019 \text{ MeV}$$

Full width  $\Gamma < 0.08$  MeV, CL = 95%

<b><math>\Xi_b'(5935)^-</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi_b^0 \pi^- \times B(\bar{b} \rightarrow \Xi_b'(5935)^-)/B(\bar{b} \rightarrow \Xi_b^0)$	$(11.8 \pm 1.8) \%$	31

**$\Xi_b(5945)^0$**

$$J^P = \frac{3}{2}^+$$

Mass  $m = 5952.3 \pm 0.9$  MeV

Full width  $\Gamma = 0.90 \pm 0.18$  MeV

<b><math>\Xi_b(5945)^0</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi_b^- \pi^+$	seen	78

**$\Xi_b(5955)^-$**

$$J^P = \frac{3}{2}^+$$

Mass  $m = 5955.33 \pm 0.13$  MeV

$$m_{\Xi_b(5955)^-} - m_{\Xi_b^0} - m_{\pi^-} = 23.96 \pm 0.13 \text{ MeV}$$

Full width  $\Gamma = 1.65 \pm 0.33$  MeV

<b><math>\Xi_b(5955)^-</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi_b^0 \pi^- \times B(\bar{b} \rightarrow \Xi_b^*(5955)^-)/B(\bar{b} \rightarrow \Xi_b^0)$	$(20.7 \pm 3.5) \%$	84

**$\Xi_b(6227)$**

$$J^P = ??$$

Mass  $m = 6226.9 \pm 2.0$  MeV

Full width  $\Gamma = 18 \pm 6$  MeV

$\Xi_b(6227)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor	$\rho$ (MeV/c)
$\Lambda_b^0 K^- \times B(b \rightarrow \Xi_b(6227))/B(b \rightarrow \Lambda_b^0)$	$(3.20 \pm 0.35) \times 10^{-3}$		336
$\Xi_b^0 \pi^- \times B(b \rightarrow \Xi_b(6227))/B(b \rightarrow \Xi_b^0)$	$(2.8 \pm 1.1) \%$	1.8	398

## $\Omega_b^-$

$I(J^P) = 0(\frac{1}{2}^+)$   
 $I, J, P$  need confirmation.

Mass  $m = 6046.1 \pm 1.7$  MeV

$m_{\Omega_b^-} - m_{\Lambda_b^0} = 426.4 \pm 2.2$  MeV

$m_{\Omega_b^-} - m_{\Xi_b^-} = 247.3 \pm 3.2$  MeV

Mean life  $\tau = (1.64_{-0.17}^{+0.18}) \times 10^{-12}$  s

$\tau(\Omega_b^-)/\tau(\Xi_b^-)$  mean life ratio =  $1.11 \pm 0.16$

$\Omega_b^-$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$\rho$ (MeV/c)
$J/\psi \Omega_b^- \times B(b \rightarrow \Omega_b^-)$	$(2.9_{-0.8}^{+1.1}) \times 10^{-6}$		1806
$p K^- K^- \times B(\bar{b} \rightarrow \Omega_b^-)$	$< 2.5 \times 10^{-9}$	90%	2866
$p \pi^- \pi^- \times B(\bar{b} \rightarrow \Omega_b^-)$	$< 1.5 \times 10^{-8}$	90%	2943
$p K^- \pi^- \times B(\bar{b} \rightarrow \Omega_b^-)$	$< 7 \times 10^{-9}$	90%	2915

## $b$ -baryon ADMIXTURE ( $\Lambda_b, \Xi_b, \Sigma_b, \Omega_b$ )

These branching fractions are actually an average over weakly decaying  $b$ -baryons weighted by their production rates at the LHC, LEP, and Tevatron, branching ratios, and detection efficiencies. They scale with the  $b$ -baryon production fraction  $B(b \rightarrow b\text{-baryon})$ .

The branching fractions  $B(b\text{-baryon} \rightarrow \Lambda \ell^- \bar{\nu}_\ell \text{ anything})$  and  $B(\Lambda_b^0 \rightarrow \Lambda_c^+ \ell^- \bar{\nu}_\ell \text{ anything})$  are not pure measurements because the underlying measured products of these with  $B(b \rightarrow b\text{-baryon})$  were used to determine  $B(b \rightarrow b\text{-baryon})$ , as described in the note "Production and Decay of  $b$ -Flavored Hadrons."

For inclusive branching fractions, *e.g.*,  $B \rightarrow D^\pm \text{ anything}$ , the values usually are multiplicities, not branching fractions. They can be greater than one.

***b*-baryon ADMIXTURE DECAY MODES**

$(\Lambda_b, \Xi_b, \Sigma_b, \Omega_b)$	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$p\mu^-\bar{\nu}$ anything	$(5.6^+_{-2.2} \text{ } 1.9) \%$	—
$p\ell\bar{\nu}_\ell$ anything	$(5.4 \pm 1.2) \%$	—
$p$ anything	$(67 \pm 21) \%$	—
$\Lambda\ell^-\bar{\nu}_\ell$ anything	$(3.6 \pm 0.6) \%$	—
$\Lambda\ell^+\nu_\ell$ anything	$(3.0 \pm 0.8) \%$	—
$\Lambda$ anything	$(38 \pm 7) \%$	—
$\Xi^-\ell^-\bar{\nu}_\ell$ anything	$(6.3 \pm 1.6) \times 10^{-3}$	—

## EXOTIC BARYONS

### $P_c(4380)^+$

Mass  $m = 4380 \pm 30$  MeV  
 Full width  $\Gamma = 205 \pm 90$  MeV

$P_c(4380)^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$J/\psi p$	seen	741

### $P_c(4450)^+$

Mass  $m = 4449.8 \pm 3.0$  MeV  
 Full width  $\Gamma = 39 \pm 20$  MeV

$P_c(4450)^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$J/\psi p$	seen	820



## NOTES

- [a] The masses of the  $p$  and  $n$  are most precisely known in  $u$  (unified atomic mass units). The conversion factor to MeV,  $1 u = 931.494061(21)$  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  $\mu p$  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] The first limit is for  $p \rightarrow$  anything or "disappearance" modes of a bound proton. The second entry, a rough range of limits, assumes the dominant decay modes are among those investigated. For antiprotons the best limit, inferred from the observation of cosmic ray  $\bar{p}$ 's is  $\tau_{\bar{p}} > 10^7$  yr, the cosmic-ray storage time, but this limit depends on a number of assumptions. The best direct observation of stored antiprotons gives  $\tau_{\bar{p}}/B(\bar{p} \rightarrow e^- \gamma) > 7 \times 10^5$  yr.
- [g] 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.
- [h] 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).
- [i] 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  $\phi_{AV}$  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.
- [j] Time-reversal invariance requires this to be  $0^\circ$  or  $180^\circ$ .
- [k] This coefficient is zero if time invariance is not violated.
- [l] This limit is for  $\gamma$  energies between 0.4 and 782 keV.
- [n] The decay parameters  $\gamma$  and  $\Delta$  are calculated from  $\alpha$  and  $\phi$  using

$$\gamma = \sqrt{1-\alpha^2} \cos\phi, \quad \tan\Delta = -\frac{1}{\alpha} \sqrt{1-\alpha^2} \sin\phi.$$

See the "Note on Baryon Decay Parameters" in the neutron Particle Listings.

- [o] See the Listings for the pion momentum range used in this measurement.
- [p] The error given here is only an educated guess. It is larger than the error on the weighted average of the published values.
- [q] A theoretical value using QED.
- [r] This branching fraction includes all the decay modes of the final-state resonance.
- [s] See AALTONEN 11H, Fig. 8, for the calculated ratio of  $\Lambda_c^+ \pi^0 \pi^0$  and  $\Lambda_c^+ \pi^+ \pi^-$  partial widths as a function of the  $\Lambda_c(2595)^+ - \Lambda_c^+$  mass difference. At our value of the mass difference, the ratio is about 4.
- [t] A test that the isospin is indeed 0, so that the particle is indeed a  $\Lambda_c^+$ .
- [u]  $P_c^+$  is a pentaquark-charmonium state.
- [v] Not a pure measurement. See note at head of  $\Lambda_b^0$  Decay Modes.
- [x] Here  $h^-$  means  $\pi^-$  or  $K^-$ .