

# 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  $m = 1.00727646688 \pm 0.00000000013$  u

Mass  $m = 938.27203 \pm 0.00008$  MeV [a]

$$|m_p - m_{\bar{p}}|/m_p < 2 \times 10^{-9}, \text{ CL} = 90\% \text{ [b]}$$

$$|\frac{q_{\bar{p}}}{m_{\bar{p}}}|/(\frac{q_p}{m_p}) = 0.99999999991 \pm 0.00000000009$$

$$|q_p + q_{\bar{p}}|/e < 2 \times 10^{-9}, \text{ CL} = 90\% \text{ [b]}$$

$$|q_p + q_e|/e < 1.0 \times 10^{-21} \text{ [c]}$$

Magnetic moment  $\mu = 2.792847351 \pm 0.0000000028$   $\mu_N$

$$(\mu_p + \mu_{\bar{p}}) / \mu_p = (-2.6 \pm 2.9) \times 10^{-3}$$

Electric dipole moment  $d < 0.54 \times 10^{-23}$  e cm

Electric polarizability  $\alpha = (12.0 \pm 0.6) \times 10^{-4}$  fm<sup>3</sup>

Magnetic polarizability  $\beta = (1.9 \pm 0.5) \times 10^{-4}$  fm<sup>3</sup>

Charge radius =  $0.875 \pm 0.007$  fm

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

Mean life  $\tau > 10^{31}$  to  $10^{33}$  years [d] (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><math>p</math> DECAY MODES</b>	Partial mean life ( $10^{30}$ years)	Confidence level	$p$ (MeV/c)
<b>Antilepton + meson</b>			
$N \rightarrow e^+ \pi$	> 158 ( $n$ ), > 1600 ( $p$ )	90%	459
$N \rightarrow \mu^+ \pi$	> 100 ( $n$ ), > 473 ( $p$ )	90%	453
$N \rightarrow \nu \pi$	> 112 ( $n$ ), > 25 ( $p$ )	90%	459
$p \rightarrow e^+ \eta$	> 313	90%	309
$p \rightarrow \mu^+ \eta$	> 126	90%	297
$n \rightarrow \nu \eta$	> 158	90%	310
$N \rightarrow e^+ \rho$	> 217 ( $n$ ), > 75 ( $p$ )	90%	149
$N \rightarrow \mu^+ \rho$	> 228 ( $n$ ), > 110 ( $p$ )	90%	113
$N \rightarrow \nu \rho$	> 19 ( $n$ ), > 162 ( $p$ )	90%	149
$p \rightarrow e^+ \omega$	> 107	90%	143
$p \rightarrow \mu^+ \omega$	> 117	90%	105
$n \rightarrow \nu \omega$	> 108	90%	144
$N \rightarrow e^+ K$	> 17 ( $n$ ), > 150 ( $p$ )	90%	339
$p \rightarrow e^+ K_S^0$	> 120	90%	337
$p \rightarrow e^+ K_L^0$	> 51	90%	337
$N \rightarrow \mu^+ K$	> 26 ( $n$ ), > 120 ( $p$ )	90%	329
$p \rightarrow \mu^+ K_S^0$	> 150	90%	326
$p \rightarrow \mu^+ K_L^0$	> 83	90%	326
$N \rightarrow \nu K$	> 86 ( $n$ ), > 670 ( $p$ )	90%	339
$n \rightarrow \nu K_S^0$	> 51	90%	338
$p \rightarrow e^+ K^*(892)^0$	> 84	90%	45
$N \rightarrow \nu K^*(892)$	> 78 ( $n$ ), > 51 ( $p$ )	90%	45
<b>Antilepton + mesons</b>			
$p \rightarrow e^+ \pi^+ \pi^-$	> 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%	114
$n \rightarrow e^- K^+$	> 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
$n \rightarrow \nu \gamma$	> 28	90%	470
$p \rightarrow e^+ \gamma \gamma$	> 100	90%	469
$n \rightarrow \nu \gamma \gamma$	> 219	90%	470

### Three (or more) leptons

$p \rightarrow e^+ e^+ e^-$	> 793	90%	469
$p \rightarrow e^+ \mu^+ \mu^-$	> 359	90%	457
$p \rightarrow e^+ \nu \nu$	> 17	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
$p \rightarrow \mu^+ \nu \nu$	> 21	90%	463
$p \rightarrow e^- \mu^+ \mu^+$	> 6	90%	457
$n \rightarrow 3\nu$	> 0.0005	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.

$pp \rightarrow \pi^+ \pi^+$	$> 0.7$	90%	—
$pn \rightarrow \pi^+ \pi^0$	$> 2$	90%	—
$nn \rightarrow \pi^+ \pi^-$	$> 0.7$	90%	—
$nn \rightarrow \pi^0 \pi^0$	$> 3.4$	90%	—
$pp \rightarrow e^+ e^+$	$> 5.8$	90%	—
$pp \rightarrow e^+ \mu^+$	$> 3.6$	90%	—
$pp \rightarrow \mu^+ \mu^+$	$> 1.7$	90%	—
$pn \rightarrow e^+ \bar{\nu}$	$> 2.8$	90%	—
$pn \rightarrow \mu^+ \bar{\nu}$	$> 1.6$	90%	—
$nn \rightarrow \nu_e \bar{\nu}_e$	$> 0.000049$	90%	—
$pn \rightarrow$ invisible	$> 2.1 \times 10^{-5}$	90%	—
$pp \rightarrow$ invisible	$> 0.00005$	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



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

Mass  $m = 1.0086649156 \pm 0.0000000006$  u

Mass  $m = 939.56536 \pm 0.00008$  MeV [a]

$m_n - m_p = 1.2933317 \pm 0.0000005$  MeV  
 $= 0.0013884487 \pm 0.0000000006$  u

Mean life  $\tau = 885.7 \pm 0.8$  s

$c\tau = 2.655 \times 10^8$  km

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

Electric dipole moment  $d < 0.29 \times 10^{-25}$  e cm, CL = 90%

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

Electric polarizability  $\alpha = (11.6 \pm 1.5) \times 10^{-4} \text{ fm}^3$

Magnetic polarizability  $\beta = (3.7 \pm 2.0) \times 10^{-4} \text{ fm}^3$

Charge  $q = (-0.4 \pm 1.1) \times 10^{-21} e$

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

Mean  $n\bar{n}$ -oscillation time  $> 1.3 \times 10^8 \text{ s}$ , CL = 90% [e] (bound  $n$ )

### Decay parameters [f]

$p e^- \bar{\nu}_e$   $\lambda \equiv g_A / g_V = -1.2695 \pm 0.0029$  ( $S = 2.0$ )

"  $A = -0.1173 \pm 0.0013$  ( $S = 2.3$ )

"  $B = 0.9807 \pm 0.0030$

"  $C = -0.2377 \pm 0.0026$

"  $a = -0.103 \pm 0.004$

"  $\phi_{AV} = (180.06 \pm 0.07)^\circ$  [g]

"  $D = (-4 \pm 6) \times 10^{-4}$

$n$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$P$ (MeV/c)
$p e^- \bar{\nu}_e$	100	%	1
$p e^- \bar{\nu}_e \gamma$	[h] $(3.13 \pm 0.35) \times 10^{-3}$		1
<b>Charge conservation (Q) violating mode</b>			
$p \nu_e \bar{\nu}_e$	$Q < 8$	$\times 10^{-27}$	68% 1

**$N(1440) P_{11}$**

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

Breit-Wigner mass = 1420 to 1470 ( $\approx 1440$ ) MeV

Breit-Wigner full width = 200 to 450 ( $\approx 300$ ) MeV

$p_{\text{beam}} = 0.61 \text{ GeV}/c$   $4\pi\chi^2 = 31.0 \text{ mb}$

Re(pole position) = 1350 to 1380 ( $\approx 1365$ ) MeV

$-2\text{Im}(\text{pole position}) = 160$  to  $220$  ( $\approx 190$ ) MeV

<b>N(1440) DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	0.55 to 0.75	398
$N\pi\pi$	30–40 %	347
$\Delta\pi$	20–30 %	147
$N\rho$	<8 %	†
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	5–10 %	–
$p\gamma$	0.035–0.048 %	414
$p\gamma$ , helicity=1/2	0.035–0.048 %	414
$n\gamma$	0.009–0.032 %	413
$n\gamma$ , helicity=1/2	0.009–0.032 %	413

**N(1520)  $D_{13}$** 

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

Breit-Wigner mass = 1515 to 1525 ( $\approx 1520$ ) MeV  
 Breit-Wigner full width = 100 to 125 ( $\approx 115$ ) MeV  
 $p_{\text{beam}} = 0.74 \text{ GeV}/c$        $4\pi\lambda^2 = 23.5 \text{ mb}$   
 Re(pole position) = 1505 to 1515 ( $\approx 1510$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 105 \text{ to } 120$  ( $\approx 110$ ) MeV

<b>N(1520) DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	0.55 to 0.65	457
$N\eta$	$(2.3 \pm 0.4) \times 10^{-3}$	154
$N\pi\pi$	40–50 %	414
$\Delta\pi$	15–25 %	230
$N\rho$	15–25 %	†
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	<8 %	–
$p\gamma$	0.46–0.56 %	470
$p\gamma$ , helicity=1/2	0.001–0.034 %	470
$p\gamma$ , helicity=3/2	0.44–0.53 %	470
$n\gamma$	0.30–0.53 %	470
$n\gamma$ , helicity=1/2	0.04–0.10 %	470
$n\gamma$ , helicity=3/2	0.25–0.45 %	470

**N(1535)  $S_{11}$** 

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

Breit-Wigner mass = 1525 to 1545 ( $\approx 1535$ ) MeV  
 Breit-Wigner full width = 125 to 175 ( $\approx 150$ ) MeV  
 $p_{\text{beam}} = 0.76 \text{ GeV}/c$        $4\pi\lambda^2 = 22.5 \text{ mb}$   
 Re(pole position) = 1490 to 1530 ( $\approx 1510$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 90 \text{ to } 250$  ( $\approx 170$ ) MeV

<b><math>N(1535)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	35–55 %	468
$N\eta$	45–60 %	186
$N\pi\pi$	1–10 %	426
$\Delta\pi$	<1 %	244
$N\rho$	<4 %	†
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	<3 %	–
$N(1440)\pi$	<7 %	†
$p\gamma$	0.15–0.35 %	481
$p\gamma$ , helicity=1/2	0.15–0.35 %	481
$n\gamma$	0.004–0.29 %	480
$n\gamma$ , helicity=1/2	0.004–0.29 %	480

### **$N(1650)$ $S_{11}$**

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

Breit-Wigner mass = 1645 to 1670 ( $\approx 1655$ ) MeV  
 Breit-Wigner full width = 145 to 185 ( $\approx 165$ ) MeV  
 $p_{\text{beam}} = 0.97$  GeV/c       $4\pi\lambda^2 = 16.2$  mb  
 Re(pole position) = 1640 to 1670 ( $\approx 1655$ ) MeV  
 –2Im(pole position) = 150 to 180 ( $\approx 165$ ) MeV

<b><math>N(1650)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	0.60 to 0.95	551
$N\eta$	3–10 %	354
$\Lambda K$	3–11 %	179
$N\pi\pi$	10–20 %	517
$\Delta\pi$	1–7 %	349
$N\rho$	4–12 %	†
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	<4 %	–
$N(1440)\pi$	<5 %	156
$p\gamma$	0.04–0.18 %	562
$p\gamma$ , helicity=1/2	0.04–0.18 %	562
$n\gamma$	0.003–0.17 %	561
$n\gamma$ , helicity=1/2	0.003–0.17 %	561

### **$N(1675)$ $D_{15}$**

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

Breit-Wigner mass = 1670 to 1680 ( $\approx 1675$ ) MeV  
 Breit-Wigner full width = 130 to 165 ( $\approx 150$ ) MeV  
 $p_{\text{beam}} = 1.01$  GeV/c       $4\pi\lambda^2 = 15.4$  mb  
 Re(pole position) = 1655 to 1665 ( $\approx 1660$ ) MeV  
 –2Im(pole position) = 125 to 150 ( $\approx 135$ ) MeV

<b><math>N(1675)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	0.35 to 0.45	564
$N\eta$	(0.0 $\pm$ 1.0) %	376
$\Lambda K$	<1 %	216
$N\pi\pi$	50–60 %	532
$\Delta\pi$	50–60 %	366
$N\rho$	< 1–3 %	†
$p\gamma$	0.004–0.023 %	575
$p\gamma$ , helicity=1/2	0.0–0.015 %	575
$p\gamma$ , helicity=3/2	0.0–0.011 %	575
$n\gamma$	0.02–0.12 %	574
$n\gamma$ , helicity=1/2	0.006–0.046 %	574
$n\gamma$ , helicity=3/2	0.01–0.08 %	574

 **$N(1680) F_{15}$** 

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

Breit-Wigner mass = 1680 to 1690 ( $\approx$  1685) MeV

Breit-Wigner full width = 120 to 140 ( $\approx$  130) MeV

$$p_{\text{beam}} = 1.02 \text{ GeV}/c \quad 4\pi\lambda^2 = 15.0 \text{ mb}$$

Re(pole position) = 1665 to 1680 ( $\approx$  1675) MeV

–2Im(pole position) = 110 to 135 ( $\approx$  120) MeV

<b><math>N(1680)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	0.65 to 0.70	571
$N\eta$	(0.0 $\pm$ 1.0) %	386
$N\pi\pi$	30–40 %	539
$\Delta\pi$	5–15 %	374
$N\rho$	3–15 %	†
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	5–20 %	–
$p\gamma$	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

 **$N(1700) D_{13}$** 

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



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

<b><math>N(1700)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	5–15 %	581
$N\eta$	$(0.0\pm 1.0)$ %	402
$\Lambda K$	<3 %	255
$N\pi\pi$	85–95 %	550
$N\rho$	<35 %	†
$p\gamma$	0.01–0.05 %	591
$p\gamma$ , helicity=1/2	0.0–0.024 %	591
$p\gamma$ , helicity=3/2	0.002–0.026 %	591
$n\gamma$	0.01–0.13 %	590
$n\gamma$ , helicity=1/2	0.0–0.09 %	590
$n\gamma$ , helicity=3/2	0.01–0.05 %	590

**$N(1710) P_{11}$**

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

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

<b>N(1710) DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	10–20 %	588
$N\eta$	( $6.2\pm 1.0$ ) %	412
$N\omega$	( $13.0\pm 2.0$ ) %	†
$\Lambda K$	5–25 %	269
$N\pi\pi$	40–90 %	557
$\Delta\pi$	15–40 %	394
$N\rho$	5–25 %	†
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	10–40 %	–
$p\gamma$	0.002–0.05%	598
$p\gamma$ , helicity=1/2	0.002–0.05%	598
$n\gamma$	0.0–0.02%	597
$n\gamma$ , helicity=1/2	0.0–0.02%	597

**N(1720) P<sub>13</sub>**

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

Breit-Wigner mass = 1700 to 1750 ( $\approx 1720$ ) MeV  
 Breit-Wigner full width = 150 to 300 ( $\approx 200$ ) MeV  
 $p_{\text{beam}} = 1.09$  GeV/c       $4\pi\lambda^2 = 13.9$  mb  
 Re(pole position) = 1660 to 1690 ( $\approx 1675$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 115$  to 275 MeV

<b>N(1720) DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	10–20 %	594
$N\eta$	( $4.0\pm 1.0$ ) %	422
$\Lambda K$	1–15 %	283
$N\pi\pi$	>70 %	564
$N\rho$	70–85 %	73
$p\gamma$	0.003–0.10 %	604
$p\gamma$ , helicity=1/2	0.003–0.08 %	604
$p\gamma$ , helicity=3/2	0.001–0.03 %	604
$n\gamma$	0.002–0.39 %	603
$n\gamma$ , helicity=1/2	0.0–0.002 %	603
$n\gamma$ , helicity=3/2	0.001–0.39 %	603

**N(2190) G<sub>17</sub>**

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

Breit-Wigner mass = 2100 to 2200 ( $\approx 2190$ ) MeV  
 Breit-Wigner full width = 300 to 700 ( $\approx 500$ ) MeV  
 $p_{\text{beam}} = 2.07$  GeV/c       $4\pi\lambda^2 = 6.21$  mb  
 Re(pole position) = 2050 to 2100 ( $\approx 2075$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 400$  to 520 ( $\approx 450$ ) MeV

<b>N(2190) DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	10–20 %	888
$N\eta$	$(0.0\pm 1.0)$ %	791

**N(2220)  $H_{19}$** 

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

Breit-Wigner mass = 2200 to 2300 ( $\approx 2250$ ) MeV  
 Breit-Wigner full width = 350 to 500 ( $\approx 400$ ) MeV  
 $p_{\text{beam}} = 2.21$  GeV/c       $4\pi\lambda^2 = 5.74$  mb  
 Re(pole position) = 2130 to 2200 ( $\approx 2170$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 400$  to 560 ( $\approx 480$ ) MeV

<b>N(2220) DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	10–20 %	924

**N(2250)  $G_{19}$** 

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

Breit-Wigner mass = 2200 to 2350 ( $\approx 2275$ ) MeV  
 Breit-Wigner full width = 230 to 800 ( $\approx 500$ ) MeV  
 $p_{\text{beam}} = 2.27$  GeV/c       $4\pi\lambda^2 = 5.56$  mb  
 Re(pole position) = 2150 to 2250 ( $\approx 2200$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 350$  to 550 ( $\approx 450$ ) MeV

<b>N(2250) DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	5–15 %	938

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

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

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

<b>N(2600) DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	5–10 %	1126

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

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

## $\Delta(1232) P_{33}$

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

Breit-Wigner mass (mixed charges) = 1231 to 1233 ( $\approx 1232$ ) MeV

Breit-Wigner full width (mixed charges) = 116 to 120 ( $\approx 118$ ) MeV

$$p_{\text{beam}} = 0.30 \text{ GeV}/c \quad 4\pi\lambda^2 = 94.8 \text{ mb}$$

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

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

$\Delta(1232)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	100 %	229
$N\gamma$	0.52–0.60 %	259
$N\gamma$ , helicity=1/2	0.11–0.13 %	259
$N\gamma$ , helicity=3/2	0.41–0.47 %	259

## $\Delta(1600) P_{33}$

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

Breit-Wigner mass = 1550 to 1700 ( $\approx 1600$ ) MeV

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

$$p_{\text{beam}} = 0.87 \text{ GeV}/c \quad 4\pi\lambda^2 = 18.6 \text{ mb}$$

Re(pole position) = 1500 to 1700 ( $\approx 1600$ ) MeV

$-2\text{Im}(\text{pole position}) = 200$  to  $400$  ( $\approx 300$ ) MeV

<b><math>\Delta(1600)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	10–25 %	513
$N\pi\pi$	75–90 %	477
$\Delta\pi$	40–70 %	303
$N\rho$	<25 %	†
$N(1440)\pi$	10–35 %	82
$N\gamma$	0.001–0.02 %	525
$N\gamma$ , helicity=1/2	0.0–0.02 %	525
$N\gamma$ , helicity=3/2	0.001–0.005 %	525

### $\Delta(1620) S_{31}$

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

Breit-Wigner mass = 1600 to 1660 ( $\approx 1630$ ) MeV  
 Breit-Wigner full width = 135 to 150 ( $\approx 145$ ) MeV  
 $p_{\text{beam}} = 0.93 \text{ GeV}/c$        $4\pi\chi^2 = 17.2 \text{ mb}$   
 Re(pole position) = 1590 to 1610 ( $\approx 1600$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 115 \text{ to } 120$  ( $\approx 118$ ) MeV

<b><math>\Delta(1620)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	20–30 %	534
$N\pi\pi$	70–80 %	499
$\Delta\pi$	30–60 %	328
$N\rho$	7–25 %	†
$N\gamma$	0.004–0.044 %	545
$N\gamma$ , helicity=1/2	0.004–0.044 %	545

### $\Delta(1700) D_{33}$

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

Breit-Wigner mass = 1670 to 1750 ( $\approx 1700$ ) MeV  
 Breit-Wigner full width = 200 to 400 ( $\approx 300$ ) MeV  
 $p_{\text{beam}} = 1.05 \text{ GeV}/c$        $4\pi\chi^2 = 14.5 \text{ mb}$   
 Re(pole position) = 1620 to 1680 ( $\approx 1650$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 160 \text{ to } 240$  ( $\approx 200$ ) MeV

<b><math>\Delta(1700)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	10–20 %	581
$N\pi\pi$	80–90 %	550
$\Delta\pi$	30–60 %	386
$N\rho$	30–55 %	†
$N\gamma$	0.12–0.26 %	591
$N\gamma$ , helicity=1/2	0.08–0.16 %	591
$N\gamma$ , helicity=3/2	0.025–0.12 %	591

**$\Delta(1905) F_{35}$**

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

Breit-Wigner mass = 1865 to 1915 ( $\approx 1890$ ) MeV  
 Breit-Wigner full width = 270 to 400 ( $\approx 330$ ) MeV  
 $p_{\text{beam}} = 1.42 \text{ GeV}/c$        $4\pi\lambda^2 = 9.89 \text{ mb}$   
 Re(pole position) = 1825 to 1835 ( $\approx 1830$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 265 \text{ to } 300$  ( $\approx 280$ ) MeV

<b><math>\Delta(1905)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	0.09 to 0.15	704
$N\pi\pi$	85–95 %	680
$\Delta\pi$	<25 %	531
$N\rho$	>60 %	397
$N\gamma$	0.01–0.03 %	712
$N\gamma$ , helicity=1/2	0.0–0.1 %	712
$N\gamma$ , helicity=3/2	0.004–0.03 %	712

**$\Delta(1910) P_{31}$**

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

Breit-Wigner mass = 1870 to 1920 ( $\approx 1910$ ) MeV  
 Breit-Wigner full width = 190 to 270 ( $\approx 250$ ) MeV  
 $p_{\text{beam}} = 1.46 \text{ GeV}/c$        $4\pi\lambda^2 = 9.54 \text{ mb}$   
 Re(pole position) = 1830 to 1880 ( $\approx 1855$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 200 \text{ to } 500$  ( $\approx 350$ ) MeV

<b><math>\Delta(1910)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	15–30 %	717
$N\gamma$	0.0–0.2 %	725
$N\gamma$ , helicity=1/2	0.0–0.2 %	725

 **$\Delta(1920) P_{33}$** 

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

Breit-Wigner mass = 1900 to 1970 ( $\approx 1920$ ) MeV  
 Breit-Wigner full width = 150 to 300 ( $\approx 200$ ) MeV  
 $p_{\text{beam}} = 1.48$  GeV/c       $4\pi\chi^2 = 9.37$  mb  
 Re(pole position) = 1850 to 1950 ( $\approx 1900$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 200$  to 400 ( $\approx 300$ ) MeV

<b><math>\Delta(1920)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	5–20 %	723
$\Sigma K$	( $2.10 \pm 0.30$ ) %	431

 **$\Delta(1930) D_{35}$** 

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

Breit-Wigner mass = 1900 to 2020 ( $\approx 1960$ ) MeV  
 Breit-Wigner full width = 220 to 500 ( $\approx 360$ ) MeV  
 $p_{\text{beam}} = 1.56$  GeV/c       $4\pi\chi^2 = 8.76$  mb  
 Re(pole position) = 1840 to 1960 ( $\approx 1900$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 175$  to 360 ( $\approx 270$ ) MeV

<b><math>\Delta(1930)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	0.05 to 0.15	748
$N\gamma$	0.0–0.02 %	755
$N\gamma$ , helicity=1/2	0.0–0.01 %	755
$N\gamma$ , helicity=3/2	0.0–0.01 %	755

 **$\Delta(1950) F_{37}$** 

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

Breit-Wigner mass = 1915 to 1950 ( $\approx 1930$ ) MeV  
 Breit-Wigner full width = 235 to 335 ( $\approx 285$ ) MeV  
 $p_{\text{beam}} = 1.50$  GeV/c       $4\pi\chi^2 = 9.21$  mb  
 Re(pole position) = 1870 to 1890 ( $\approx 1880$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 220$  to 260 ( $\approx 240$ ) MeV

<b><math>\Delta(1950)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	0.35 to 0.45	729
$N\pi\pi$		706
$\Delta\pi$	20–30 %	560
$N\rho$	<10 %	442
$N\gamma$	0.08–0.13 %	737
$N\gamma$ , helicity=1/2	0.03–0.055 %	737
$N\gamma$ , helicity=3/2	0.05–0.075 %	737

### $\Delta(2420) H_{3,11}$

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

Breit-Wigner mass = 2300 to 2500 ( $\approx 2420$ ) MeV  
 Breit-Wigner full width = 300 to 500 ( $\approx 400$ ) MeV  
 $p_{\text{beam}} = 2.64$  GeV/c       $4\pi\chi^2 = 4.68$  mb  
 Re(pole position) = 2260 to 2400 ( $\approx 2330$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 350$  to 750 ( $\approx 550$ ) MeV

<b><math>\Delta(2420)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	5–15 %	1023

## $\Lambda$ 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  $\tau = (2.631 \pm 0.020) \times 10^{-10}$  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

$p\pi^-$	$\alpha_- = 0.642 \pm 0.013$
"	$\phi_- = (-6.5 \pm 3.5)^\circ$
"	$\gamma_- = 0.76$ [i]
"	$\Delta_- = (8 \pm 4)^\circ$ [i]
$n\pi^0$	$\alpha_0 = 0.65 \pm 0.04$
$p e^- \bar{\nu}_e$	$g_A/g_V = -0.718 \pm 0.015$ [f]

$\Lambda$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (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
$p\pi^- \gamma$	[j] $(8.4 \pm 1.4) \times 10^{-4}$	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

### $\Lambda(1405) S_{01}$

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

Mass  $m = 1406 \pm 4$  MeV  
 Full width  $\Gamma = 50 \pm 2$  MeV  
 Below  $\bar{K}N$  threshold

$\Lambda(1405)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Sigma \pi$	100 %	157

### $\Lambda(1520) D_{03}$

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

Mass  $m = 1519.5 \pm 1.0$  MeV [k]  
 Full width  $\Gamma = 15.6 \pm 1.0$  MeV [k]  
 $p_{\text{beam}} = 0.39$  GeV/c       $4\pi\lambda^2 = 82.8$  mb

$\Lambda(1520)$ DECAY MODES	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

 **$\Lambda(1600) P_{01}$** 

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

Mass  $m = 1560$  to  $1700$  ( $\approx 1600$ ) MeV

Full width  $\Gamma = 50$  to  $250$  ( $\approx 150$ ) MeV

$$p_{\text{beam}} = 0.58 \text{ GeV}/c \quad 4\pi\lambda^2 = 41.6 \text{ mb}$$

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

 **$\Lambda(1670) S_{01}$** 

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

Mass  $m = 1660$  to  $1680$  ( $\approx 1670$ ) MeV

Full width  $\Gamma = 25$  to  $50$  ( $\approx 35$ ) MeV

$$p_{\text{beam}} = 0.74 \text{ GeV}/c \quad 4\pi\lambda^2 = 28.5 \text{ mb}$$

$\Lambda(1670)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	20–30 %	414
$\Sigma\pi$	25–55 %	394
$\Lambda\eta$	10–25 %	69

 **$\Lambda(1690) D_{03}$** 

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

Mass  $m = 1685$  to  $1695$  ( $\approx 1690$ ) MeV

Full width  $\Gamma = 50$  to  $70$  ( $\approx 60$ ) MeV

$$p_{\text{beam}} = 0.78 \text{ GeV}/c \quad 4\pi\lambda^2 = 26.1 \text{ mb}$$

$\Lambda(1690)$ DECAY MODES	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

 **$\Lambda(1800) S_{01}$** 

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

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

$$p_{\text{beam}} = 1.01 \text{ GeV}/c \quad 4\pi\lambda^2 = 17.5 \text{ mb}$$

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

 **$\Lambda(1810) P_{01}$** 

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

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

$$p_{\text{beam}} = 1.04 \text{ GeV}/c \quad 4\pi\lambda^2 = 17.0 \text{ mb}$$

$\Lambda(1810)$ 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 %	†

 **$\Lambda(1820) F_{05}$** 

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

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

$$p_{\text{beam}} = 1.06 \text{ GeV}/c \quad 4\pi\lambda^2 = 16.5 \text{ mb}$$

$\Lambda(1820)$ 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

### $\Lambda(1830) D_{05}$

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

Mass  $m = 1810$  to  $1830$  ( $\approx 1830$ ) MeV

Full width  $\Gamma = 60$  to  $110$  ( $\approx 95$ ) MeV

$$p_{\text{beam}} = 1.08 \text{ GeV}/c \quad 4\pi\lambda^2 = 16.0 \text{ mb}$$

$\Lambda(1830)$ 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

### $\Lambda(1890) P_{03}$

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

Mass  $m = 1850$  to  $1910$  ( $\approx 1890$ ) MeV

Full width  $\Gamma = 60$  to  $200$  ( $\approx 100$ ) MeV

$$p_{\text{beam}} = 1.21 \text{ GeV}/c \quad 4\pi\lambda^2 = 13.6 \text{ mb}$$

$\Lambda(1890)$ DECAY MODES	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

### $\Lambda(2100) G_{07}$

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

Mass  $m = 2090$  to  $2110$  ( $\approx 2100$ ) MeV

Full width  $\Gamma = 100$  to  $250$  ( $\approx 200$ ) MeV

$$p_{\text{beam}} = 1.68 \text{ GeV}/c \quad 4\pi\lambda^2 = 8.68 \text{ mb}$$

$\Lambda(2100)$ DECAY MODES	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

### $\Lambda(2110) F_{05}$

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

Mass  $m = 2090$  to  $2140$  ( $\approx 2110$ ) MeV

Full width  $\Gamma = 150$  to  $250$  ( $\approx 200$ ) MeV

$$p_{\text{beam}} = 1.70 \text{ GeV}/c \quad 4\pi\lambda^2 = 8.53 \text{ mb}$$

$\Lambda(2110)$ DECAY MODES	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

### $\Lambda(2350) H_{09}$

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

Mass  $m = 2340$  to  $2370$  ( $\approx 2350$ ) MeV

Full width  $\Gamma = 100$  to  $250$  ( $\approx 150$ ) MeV

$$p_{\text{beam}} = 2.29 \text{ GeV}/c \quad 4\pi\lambda^2 = 5.85 \text{ mb}$$

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

# Σ BARYONS ( $S = -1, I = 1$ )

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

Σ<sup>+</sup>

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

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

$(\tau_{\Sigma^+} - \tau_{\Sigma^-}) / \tau_{\Sigma^+} = (-0.6 \pm 1.2) \times 10^{-3}$

Magnetic moment  $\mu = 2.458 \pm 0.010 \mu_N$  ( $S = 2.1$ )

$\Gamma(\Sigma^+ \rightarrow n\ell^+\nu) / \Gamma(\Sigma^- \rightarrow n\ell^-\bar{\nu}) < 0.043$

### Decay parameters

$p\pi^0$        $\alpha_0 = -0.980^{+0.017}_{-0.015}$

"       $\phi_0 = (36 \pm 34)^\circ$

"       $\gamma_0 = 0.16$  [i]

"       $\Delta_0 = (187 \pm 6)^\circ$  [i]

$n\pi^+$        $\alpha_+ = 0.068 \pm 0.013$

"       $\phi_+ = (167 \pm 20)^\circ$  ( $S = 1.1$ )

"       $\gamma_+ = -0.97$  [i]

"       $\Delta_+ = (-73^{+133}_{-10})^\circ$  [i]

$p\gamma$        $\alpha_\gamma = -0.76 \pm 0.08$

$\Sigma^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$\rho$ (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
$n\pi^+\gamma$	[j] $(4.5 \pm 0.5) \times 10^{-4}$		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	$(9 \pm 9)$	$\times 10^{-8}$		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  $|\mu_{\Sigma\Lambda}| = 1.61 \pm 0.08 \mu_N$

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

$n\pi^-$	$\alpha_- = -0.068 \pm 0.008$
"	$\phi_- = (10 \pm 15)^\circ$
"	$\gamma_- = 0.98$ [i]
"	$\Delta_- = (249_{-120}^{+12})^\circ$ [i]
$ne^- \bar{\nu}_e$	$g_A/g_V = 0.340 \pm 0.017$ [f]
"	$f_2(0)/f_1(0) = 0.97 \pm 0.14$
"	$D = 0.11 \pm 0.10$
$\Lambda e^- \bar{\nu}_e$	$g_V/g_A = 0.01 \pm 0.10$ [f] (S = 1.5)
"	$g_{WM}/g_A = 2.4 \pm 1.7$ [f]

$\Sigma^-$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$n\pi^-$	$(99.848 \pm 0.005) \%$	193
$n\pi^- \gamma$	[j] $(4.6 \pm 0.6) \times 10^{-4}$	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

 **$\Sigma(1385) P_{13}$** 

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

- $\Sigma(1385)^+$  mass  $m = 1382.8 \pm 0.4$  MeV (S = 2.0)  
 $\Sigma(1385)^0$  mass  $m = 1383.7 \pm 1.0$  MeV (S = 1.4)  
 $\Sigma(1385)^-$  mass  $m = 1387.2 \pm 0.5$  MeV (S = 2.2)  
 $\Sigma(1385)^+$  full width  $\Gamma = 35.8 \pm 0.8$  MeV  
 $\Sigma(1385)^0$  full width  $\Gamma = 36 \pm 5$  MeV  
 $\Sigma(1385)^-$  full width  $\Gamma = 39.4 \pm 2.1$  MeV (S = 1.7)  
 Below  $\bar{K}N$  threshold

$\Sigma(1385)$ 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
$\Lambda\gamma$	$(1.3 \pm 0.4) \%$		241
$\Sigma^- \gamma$	$< 2.4 \times 10^{-4}$	90%	173

 **$\Sigma(1660) P_{11}$** 

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

- Mass  $m = 1630$  to  $1690$  ( $\approx 1660$ ) MeV  
 Full width  $\Gamma = 40$  to  $200$  ( $\approx 100$ ) MeV  
 $p_{\text{beam}} = 0.72$  GeV/c  $4\pi\lambda^2 = 29.9$  mb



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

**$\Sigma(1670) D_{13}$**

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

Mass  $m = 1665$  to  $1685$  ( $\approx 1670$ ) MeV

Full width  $\Gamma = 40$  to  $80$  ( $\approx 60$ ) MeV

$$p_{\text{beam}} = 0.74 \text{ GeV}/c \quad 4\pi\lambda^2 = 28.5 \text{ mb}$$

<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

**$\Sigma(1750) S_{11}$**

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

Mass  $m = 1730$  to  $1800$  ( $\approx 1750$ ) MeV

Full width  $\Gamma = 60$  to  $160$  ( $\approx 90$ ) MeV

$$p_{\text{beam}} = 0.91 \text{ GeV}/c \quad 4\pi\lambda^2 = 20.7 \text{ mb}$$

<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

**$\Sigma(1775) D_{15}$**

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

Mass  $m = 1770$  to  $1780$  ( $\approx 1775$ ) MeV

Full width  $\Gamma = 105$  to  $135$  ( $\approx 120$ ) MeV

$$p_{\text{beam}} = 0.96 \text{ GeV}/c \quad 4\pi\lambda^2 = 19.0 \text{ mb}$$

$\Sigma(1775)$ DECAY MODES	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
$\Lambda(1520)\pi$	17–23%	201

 **$\Sigma(1915) F_{15}$** 

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

Mass  $m = 1900$  to  $1935$  ( $\approx 1915$ ) MeV

Full width  $\Gamma = 80$  to  $160$  ( $\approx 120$ ) MeV

$$p_{\text{beam}} = 1.26 \text{ GeV}/c \quad 4\pi\lambda^2 = 12.8 \text{ mb}$$

$\Sigma(1915)$ 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

 **$\Sigma(1940) D_{13}$** 

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

Mass  $m = 1900$  to  $1950$  ( $\approx 1940$ ) MeV

Full width  $\Gamma = 150$  to  $300$  ( $\approx 220$ ) MeV

$$p_{\text{beam}} = 1.32 \text{ GeV}/c \quad 4\pi\lambda^2 = 12.1 \text{ mb}$$

$\Sigma(1940)$ 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

 **$\Sigma(2030) F_{17}$** 

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

Mass  $m = 2025$  to  $2040$  ( $\approx 2030$ ) MeV

Full width  $\Gamma = 150$  to  $200$  ( $\approx 180$ ) MeV

$$p_{\text{beam}} = 1.52 \text{ GeV}/c \quad 4\pi\lambda^2 = 9.93 \text{ mb}$$

$\Sigma(2030)$ 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

$$p_{\text{beam}} = 2.04 \text{ GeV}/c \quad 4\pi\lambda^2 = 6.76 \text{ mb}$$

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

**$\Xi$  BARYONS**  
 **$(S = -2, I = 1/2)$**

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

**$\Xi^0$**

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

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

Mass  $m = 1314.86 \pm 0.20$  MeV

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

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

$$c\tau = 8.71 \text{ cm}$$

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

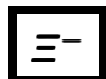
### Decay parameters

$\Lambda\pi^0$	$\alpha = -0.411 \pm 0.022$ (S = 2.1)
"	$\phi = (21 \pm 12)^\circ$
"	$\gamma = 0.85$ [i]
"	$\Delta = (218_{-19}^{+12})^\circ$ [i]
$\Lambda\gamma$	$\alpha = -0.73 \pm 0.17$
$\Lambda e^+ e^-$	$\alpha = -0.8 \pm 0.2$
$\Sigma^0\gamma$	$\alpha = -0.63 \pm 0.09$
$\Sigma^+ e^- \bar{\nu}_e$	$g_1(0)/f_1(0) = 1.21 \pm 0.05$
$\Sigma^+ e^- \bar{\nu}_e$	$f_2(0)/f_1(0) = 2.0 \pm 1.3$

$\Xi^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$P$ (MeV/c)
$\Lambda\pi^0$	$(99.525 \pm 0.012) \%$		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
$\Sigma^+ e^- \bar{\nu}_e$	$(2.53 \pm 0.08) \times 10^{-4}$		120
$\Sigma^+ \mu^- \bar{\nu}_\mu$	$(4.6_{-1.4}^{+1.8}) \times 10^{-6}$		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

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

$c\tau = 4.91$  cm

Magnetic moment  $\mu = -0.6507 \pm 0.0025 \mu_N$

### Decay parameters

$\Lambda\pi^-$	$\alpha = -0.458 \pm 0.012$ (S = 1.8)
$[\alpha(\Xi^-)\alpha_-(\Lambda) - \alpha(\Xi^+)\alpha_+(\bar{\Lambda})] / [\text{sum}]$	$= (0 \pm 7) \times 10^{-4}$
"	$\phi = (-2.1 \pm 0.8)^\circ$
"	$\gamma = 0.89$ [i]
"	$\Delta = (175.9 \pm 1.5)^\circ$ [i]
$\Lambda e^- \bar{\nu}_e$	$g_A/g_V = -0.25 \pm 0.05$ [f]

$\Xi^-$ 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
$\Lambda \mu^- \bar{\nu}_\mu$	$(3.5^{+3.5}_{-2.2}) \times 10^{-4}$		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 ( $S_2$ ) modes**

$n\pi^-$	$S_2$	$< 1.9$	$\times 10^{-5}$	90%	304
$ne^- \bar{\nu}_e$	$S_2$	$< 3.2$	$\times 10^{-3}$	90%	327
$n\mu^- \bar{\nu}_\mu$	$S_2$	$< 1.5$	%	90%	314
$p\pi^- \pi^-$	$S_2$	$< 4$	$\times 10^{-4}$	90%	223
$p\pi^- e^- \bar{\nu}_e$	$S_2$	$< 4$	$\times 10^{-4}$	90%	305
$p\pi^- \mu^- \bar{\nu}_\mu$	$S_2$	$< 4$	$\times 10^{-4}$	90%	251
$p\mu^- \mu^-$	$L$	$< 4$	$\times 10^{-8}$	90%	272

**$\Xi(1530) P_{13}$**

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

$\Xi(1530)^0$  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

$\Xi(1530)$ DECAY MODES	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 [ $k$ ]

Full width  $\Gamma < 30$  MeV

$\Xi(1690)$ DECAY MODES	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

### $\Xi(1820) D_{13}$

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

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

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

$\Xi(1820)$ DECAY MODES	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 [k]

Full width  $\Gamma = 60 \pm 20$  MeV [k]

$\Xi(1950)$ DECAY MODES	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 [k]

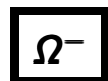
Full width  $\Gamma = 20^{+15}_{-5}$  MeV [k]

$\Xi(2030)$ DECAY MODES	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

### ( $S = -3, I = 0$ )

$\Omega^- = sss$



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

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

$$c\tau = 2.461$$
 cm

$$(\tau_{\Omega^-} - \tau_{\bar{\Omega}^+}) / \tau_{\Omega^-} = -0.002 \pm 0.040$$

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

#### Decay parameters

$$\Lambda K^- \quad \alpha = 0.0180 \pm 0.0024$$

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

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

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

$\Omega^-$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\Lambda K^-$	$(67.8 \pm 0.7) \%$		211
$\Xi^0 \pi^-$	$(23.6 \pm 0.7) \%$		294
$\Xi^- \pi^0$	$(8.6 \pm 0.4) \%$		289
$\Xi^- \pi^+ \pi^-$	$(4.3^{+3.4}_{-1.3}) \times 10^{-4}$		189
$\Xi(1530)^0 \pi^-$	$(6.4^{+5.1}_{-2.0}) \times 10^{-4}$		17
$\Xi^0 e^- \bar{\nu}_e$	$(5.6 \pm 2.8) \times 10^{-3}$		319
$\Xi^- \gamma$	$< 4.6 \times 10^{-4}$	90%	314
<b><math>\Delta S = 2</math> forbidden (<math>S_2</math>) modes</b>			
$\Lambda \pi^-$	$S_2 < 2.9 \times 10^{-6}$	90%	449

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

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

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 ( $C = +1$ )

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

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

**$\Lambda_c^+$**

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

$J$  is not well measured;  $\frac{1}{2}$  is the quark-model prediction.

Mass  $m = 2286.46 \pm 0.14$  MeV

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

$c\tau = 59.9$   $\mu$ m



### Decay asymmetry parameters

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

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

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

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

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

Nearly all branching fractions of the  $\Lambda_c^+$  are measured relative to the  $pK^-\pi^+$  mode, but there are no model-independent measurements of this branching fraction. We explain how we arrive at our value of  $B(\Lambda_c^+ \rightarrow pK^-\pi^+)$  in a Note at the beginning of the branching-ratio measurements in the Listings. When this branching fraction is eventually well determined, all the other branching fractions will slide up or down proportionally as the true value differs from the value we use here.

$\Lambda_c^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
<b>Hadronic modes with a <math>p</math>: <math>S = -1</math> final states</b>			
$p\bar{K}^0$	( 2.3 $\pm$ 0.6 ) %		873
$pK^-\pi^+$	[ <i>m</i> ] ( 5.0 $\pm$ 1.3 ) %		823
$p\bar{K}^*(892)^0$	[ <i>n</i> ] ( 1.6 $\pm$ 0.5 ) %		685
$\Delta(1232)^{++}K^-$	( 8.6 $\pm$ 3.0 ) $\times 10^{-3}$		710
$\Lambda(1520)\pi^+$	[ <i>n</i> ] ( 1.8 $\pm$ 0.6 ) %		627
$pK^-\pi^+$ nonresonant	( 2.8 $\pm$ 0.8 ) %		823
$p\bar{K}^0\pi^0$	( 3.3 $\pm$ 1.0 ) %		823
$p\bar{K}^0\eta$	( 1.2 $\pm$ 0.4 ) %		568
$p\bar{K}^0\pi^+\pi^-$	( 2.6 $\pm$ 0.7 ) %		754
$pK^-\pi^+\pi^0$	( 3.4 $\pm$ 1.0 ) %		759
$pK^*(892)^-\pi^+$	[ <i>n</i> ] ( 1.1 $\pm$ 0.5 ) %		580
$p(K^-\pi^+)_{\text{nonresonant}}\pi^0$	( 3.6 $\pm$ 1.2 ) %		759
$\Delta(1232)\bar{K}^*(892)$	seen		419
$pK^-\pi^+\pi^+\pi^-$	( 1.1 $\pm$ 0.8 ) $\times 10^{-3}$		671
$pK^-\pi^+\pi^0\pi^0$	( 8 $\pm$ 4 ) $\times 10^{-3}$		678
<b>Hadronic modes with a <math>p</math>: <math>S = 0</math> final states</b>			
$p\pi^+\pi^-$	( 3.5 $\pm$ 2.0 ) $\times 10^{-3}$		927
$pf_0(980)$	[ <i>n</i> ] ( 2.8 $\pm$ 1.9 ) $\times 10^{-3}$		622
$p\pi^+\pi^+\pi^-\pi^-$	( 1.8 $\pm$ 1.2 ) $\times 10^{-3}$		852
$pK^+K^-$	( 7.7 $\pm$ 3.5 ) $\times 10^{-4}$		616
$p\phi$	[ <i>n</i> ] ( 8.2 $\pm$ 2.7 ) $\times 10^{-4}$		590
$pK^+K^-$ non- $\phi$	( 3.5 $\pm$ 1.7 ) $\times 10^{-4}$		616

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

$\Lambda\pi^+$	( 1.07 ± 0.28 ) %	864
$\Lambda\pi^+\pi^0$	( 3.6 ± 1.3 ) %	844
$\Lambda\rho^+$	< 5 %	CL=95% 635
$\Lambda\pi^+\pi^+\pi^-$	( 2.6 ± 0.7 ) %	807
$\Sigma(1385)^+\pi^+\pi^-, \Sigma^{*+} \rightarrow$ $\Lambda\pi^+$	( 7 ± 4 ) × 10 <sup>-3</sup>	688
$\Sigma(1385)^-\pi^+\pi^+, \Sigma^{*-} \rightarrow$ $\Lambda\pi^-$	( 5.5 ± 1.7 ) × 10 <sup>-3</sup>	688
$\Lambda\pi^+\rho^0$	( 1.1 ± 0.5 ) %	523
$\Sigma(1385)^+\rho^0, \Sigma^{*+} \rightarrow \Lambda\pi^+$	( 3.7 ± 3.1 ) × 10 <sup>-3</sup>	363
$\Lambda\pi^+\pi^+\pi^-$ nonresonant	< 8 × 10 <sup>-3</sup>	CL=90% 807
$\Lambda\pi^+\pi^+\pi^-\pi^0$ total	( 1.8 ± 0.8 ) %	757
$\Lambda\pi^+\eta$	[n] ( 1.8 ± 0.6 ) %	691
$\Sigma(1385)^+\eta$	[n] ( 8.5 ± 3.3 ) × 10 <sup>-3</sup>	570
$\Lambda\pi^+\omega$	[n] ( 1.2 ± 0.5 ) %	517
$\Lambda\pi^+\pi^+\pi^-\pi^0$ , no $\eta$ or $\omega$	< 7 × 10 <sup>-3</sup>	CL=90% 757
$\Lambda K^+\bar{K}^0$	( 4.7 ± 1.5 ) × 10 <sup>-3</sup>	S=1.2 443
$\Xi(1690)^0 K^+, \Xi^{*0} \rightarrow \Lambda\bar{K}^0$	( 1.3 ± 0.5 ) × 10 <sup>-3</sup>	286
$\Sigma^0\pi^+$	( 1.05 ± 0.28 ) %	825
$\Sigma^+\pi^0$	( 1.00 ± 0.34 ) %	827
$\Sigma^+\eta$	( 5.5 ± 2.3 ) × 10 <sup>-3</sup>	713
$\Sigma^+\pi^+\pi^-$	( 3.6 ± 1.0 ) %	804
$\Sigma^+\rho^0$	< 1.4 %	CL=95% 575
$\Sigma^-\pi^+\pi^+$	( 1.9 ± 0.8 ) %	799
$\Sigma^0\pi^+\pi^0$	( 1.8 ± 0.8 ) %	803
$\Sigma^0\pi^+\pi^+\pi^-$	( 8.3 ± 3.1 ) × 10 <sup>-3</sup>	763
$\Sigma^+\pi^+\pi^-\pi^0$	—	767
$\Sigma^+\omega$	[n] ( 2.7 ± 1.0 ) %	569
$\Sigma^+K^+K^-$	( 2.8 ± 0.8 ) × 10 <sup>-3</sup>	349
$\Sigma^+\phi$	[n] ( 3.2 ± 1.0 ) × 10 <sup>-3</sup>	295
$\Xi(1690)^0 K^+, \Xi^{*0} \rightarrow$ $\Sigma^+K^-$	( 8.2 ± 3.1 ) × 10 <sup>-4</sup>	286
$\Sigma^+K^+K^-$ nonresonant	< 7 × 10 <sup>-4</sup>	CL=90% 349
$\Xi^0 K^+$	( 3.9 ± 1.4 ) × 10 <sup>-3</sup>	653
$\Xi^- K^+\pi^+$	( 5.1 ± 1.4 ) × 10 <sup>-3</sup>	565
$\Xi(1530)^0 K^+$	[n] ( 2.6 ± 1.0 ) × 10 <sup>-3</sup>	473

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

$\Lambda K^+$	( 5.0 ± 1.6 ) × 10 <sup>-4</sup>	781
$\Lambda K^+\pi^+\pi^-$	< 4 × 10 <sup>-4</sup>	CL=90% 637
$\Sigma^0 K^+$	( 4.2 ± 1.3 ) × 10 <sup>-4</sup>	735

$\Sigma^0 K^+ \pi^+ \pi^-$	< 2.1	$\times 10^{-4}$	CL=90%	574
$\Sigma^+ K^+ \pi^-$	( 1.7 $\pm$ 0.7 )	$\times 10^{-3}$		670
$\Sigma^+ K^*(892)^0$	[n] ( 2.8 $\pm$ 1.1 )	$\times 10^{-3}$		470
$\Sigma^- K^+ \pi^+$	< 1.0	$\times 10^{-3}$	CL=90%	664

### Doubly Cabibbo-suppressed modes

$p K^+ \pi^-$	< 2.3	$\times 10^{-4}$	CL=90%	823
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### Semileptonic modes

$\Lambda \ell^+ \nu_\ell$	[o] ( 2.0 $\pm$ 0.6 ) %			871
$\Lambda e^+ \nu_e$	( 2.1 $\pm$ 0.6 ) %			871
$\Lambda \mu^+ \nu_\mu$	( 2.0 $\pm$ 0.7 ) %			867

### Inclusive modes

$e^+$ anything	( 4.5 $\pm$ 1.7 ) %			—
$p e^+$ anything	( 1.8 $\pm$ 0.9 ) %			—
$p$ anything	( 50 $\pm$ 16 ) %			—
$p$ anything (no $\Lambda$ )	( 12 $\pm$ 19 ) %			—
$n$ anything	( 50 $\pm$ 16 ) %			—
$n$ anything (no $\Lambda$ )	( 29 $\pm$ 17 ) %			—
$\Lambda$ anything	( 35 $\pm$ 11 ) %		S=1.4	—
$\Sigma^\pm$ anything	[p] ( 10 $\pm$ 5 ) %			—
3prongs	( 24 $\pm$ 8 ) %			—

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

$p \mu^+ \mu^-$	C1	< 3.4	$\times 10^{-4}$	CL=90%	937
$\Sigma^- \mu^+ \mu^+$	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  $\Sigma_c(2455)$ .

$$\text{Mass } m = 2595.4 \pm 0.6 \text{ MeV} \quad (S = 1.1)$$

$$m - m_{\Lambda_c^+} = 308.9 \pm 0.6 \text{ MeV} \quad (S = 1.1)$$

$$\text{Full width } \Gamma = 3.6_{-1.3}^{+2.0} \text{ MeV}$$

$\Lambda_c^+ \pi \pi$  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)
$\Lambda_c^+ \pi^+ \pi^-$	[q] $\approx 67\%$	124
$\Sigma_c(2455)^{++} \pi^-$	$24 \pm 7\%$	28
$\Sigma_c(2455)^0 \pi^+$	$24 \pm 7\%$	28
$\Lambda_c^+ \pi^+ \pi^-$ 3-body	$18 \pm 10\%$	124
$\Lambda_c^+ \pi^0$	[r] not seen	261
$\Lambda_c^+ \gamma$	not seen	291

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

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

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

$$\text{Mass } m = 2628.1 \pm 0.6 \text{ MeV} \quad (S = 1.5)$$

$$m - m_{\Lambda_c^+} = 341.7 \pm 0.6 \text{ MeV} \quad (S = 1.6)$$

$$\text{Full width } \Gamma < 1.9 \text{ MeV, CL} = 90\%$$

$\Lambda_c^+ \pi \pi$  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)
$\Lambda_c^+ \pi^+ \pi^-$	[q] $\approx 67\%$		184
$\Sigma_c(2455)^{++} \pi^-$	$< 5$	90%	102
$\Sigma_c(2455)^0 \pi^+$	$< 5$	90%	102
$\Lambda_c^+ \pi^+ \pi^-$ 3-body	large		184
$\Lambda_c^+ \pi^0$	[r] not seen		293
$\Lambda_c^+ \gamma$	not seen		319

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

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

There is some good evidence that indeed  $J^P = 5/2^+$

$$\text{Mass } m = 2881.53 \pm 0.35 \text{ MeV}$$

$$m - m_{\Lambda_c^+} = 595.1 \pm 0.4 \text{ MeV}$$

$$\text{Full width } \Gamma = 5.8 \pm 1.1 \text{ MeV}$$

$\Lambda_c(2880)^+$ DECAY MODES	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
$pD^0$	seen	316

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

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

$$\text{Mass } m = 2939.3^{+1.4}_{-1.5} \text{ MeV}$$

$$\text{Full width } \Gamma = 17^{+8}_{-6} \text{ MeV}$$

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

**$\Sigma_c(2455)$**

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

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

$$\Sigma_c(2455)^{++} \text{ mass } m = 2454.02 \pm 0.18 \text{ MeV}$$

$$\Sigma_c(2455)^+ \text{ mass } m = 2452.9 \pm 0.4 \text{ MeV}$$

$$\Sigma_c(2455)^0 \text{ mass } m = 2453.76 \pm 0.18 \text{ MeV}$$

$$m_{\Sigma_c^{++}} - m_{\Lambda_c^+} = 167.56 \pm 0.11 \text{ MeV}$$

$$m_{\Sigma_c^+} - m_{\Lambda_c^+} = 166.4 \pm 0.4 \text{ MeV}$$

$$m_{\Sigma_c^0} - m_{\Lambda_c^+} = 167.30 \pm 0.11 \text{ MeV}$$

$$m_{\Sigma_c^{++}} - m_{\Sigma_c^0} = 0.27 \pm 0.11 \text{ MeV} \quad (S = 1.1)$$

$$m_{\Sigma_c^+} - m_{\Sigma_c^0} = -0.9 \pm 0.4 \text{ MeV}$$

$$\Sigma_c(2455)^{++} \text{ full width } \Gamma = 2.23 \pm 0.30 \text{ MeV}$$

$$\Sigma_c(2455)^+ \text{ full width } \Gamma < 4.6 \text{ MeV, CL} = 90\%$$

$$\Sigma_c(2455)^0 \text{ full width } \Gamma = 2.2 \pm 0.4 \text{ MeV} \quad (S = 1.4)$$

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

$\Sigma_c(2455)$ DECAY MODES	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.

$$\Sigma_c(2520)^{++} \text{ mass } m = 2518.4 \pm 0.6 \text{ MeV} \quad (S = 1.4)$$

$$\Sigma_c(2520)^+ \text{ mass } m = 2517.5 \pm 2.3 \text{ MeV}$$

$$\Sigma_c(2520)^0 \text{ mass } m = 2518.0 \pm 0.5 \text{ MeV}$$

$$m_{\Sigma_c(2520)^{++}} - m_{\Lambda_c^+} = 231.9 \pm 0.6 \text{ MeV} \quad (S = 1.5)$$

$$m_{\Sigma_c(2520)^+} - m_{\Lambda_c^+} = 231.0 \pm 2.3 \text{ MeV}$$

$$m_{\Sigma_c(2520)^0} - m_{\Lambda_c^+} = 231.6 \pm 0.5 \text{ MeV} \quad (S = 1.1)$$

$$m_{\Sigma_c(2520)^{++}} - m_{\Sigma_c(2520)^0} = 0.3 \pm 0.6 \text{ MeV} \quad (S = 1.2)$$

$$\Sigma_c(2520)^{++} \text{ full width } \Gamma = 14.9 \pm 1.9 \text{ MeV}$$

$$\Sigma_c(2520)^+ \text{ full width } \Gamma < 17 \text{ MeV, CL} = 90\%$$

$$\Sigma_c(2520)^0 \text{ full width } \Gamma = 16.1 \pm 2.1 \text{ MeV}$$

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

$\Sigma_c(2520)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_c^+ \pi$	$\approx 100\%$	180

### $\Sigma_c(2800)$

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

$$\Sigma_c(2800)^{++} \text{ mass } m = 2801_{-6}^{+4} \text{ MeV}$$

$$\Sigma_c(2800)^+ \text{ mass } m = 2792_{-5}^{+14} \text{ MeV}$$

$$\Sigma_c(2800)^0 \text{ mass } m = 2802_{-7}^{+4} \text{ MeV}$$

$$m_{\Sigma_c(2800)^{++}} - m_{\Lambda_c^+} = 514_{-6}^{+4} \text{ MeV}$$

$$m_{\Sigma_c(2800)^+} - m_{\Lambda_c^+} = 505_{-5}^{+14} \text{ MeV}$$

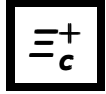
$$m_{\Sigma_c(2800)^0} - m_{\Lambda_c^+} = 515_{-7}^{+4} \text{ MeV}$$

$$\Sigma_c(2800)^{++} \text{ full width } \Gamma = 75_{-17}^{+22} \text{ MeV}$$

$$\Sigma_c(2800)^+ \text{ full width } \Gamma = 62_{-40}^{+60} \text{ MeV}$$

$$\Sigma_c(2800)^0 \text{ full width } \Gamma = 61_{-18}^{+28} \text{ MeV}$$

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



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

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

Mass  $m = 2467.9 \pm 0.4$  MeV

Mean life  $\tau = (442 \pm 26) \times 10^{-15}$  s ( $S = 1.3$ )

$c\tau = 132$   $\mu$ m

$\Xi_c^+$ 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  $\Xi^- \pi^+ \pi^+$ .**

**Cabibbo-favored ( $S = -2$ ) decays**

$p K_S^0 K_S^0$	[s]	$0.087 \pm 0.022$		767
$\Lambda \bar{K}^0 \pi^+$		—		852
$\Sigma(1385)^+ \bar{K}^0$	[n,s]	$1.0 \pm 0.5$		746
$\Lambda K^- \pi^+ \pi^+$	[s]	$0.323 \pm 0.033$		787
$\Lambda \bar{K}^*(892)^0 \pi^+$	[n,s]	$< 0.2$	90%	608
$\Sigma(1385)^+ K^- \pi^+$	[n,s]	$< 0.3$	90%	678
$\Sigma^+ K^- \pi^+$	[s]	$0.94 \pm 0.11$		811
$\Sigma^+ \bar{K}^*(892)^0$	[n,s]	$0.81 \pm 0.15$		658
$\Sigma^0 K^- \pi^+ \pi^+$	[s]	$0.29 \pm 0.16$		735
$\Xi^0 \pi^+$	[s]	$0.55 \pm 0.16$		877
$\Xi^- \pi^+ \pi^+$	[s]	DEFINED AS 1		851
$\Xi(1530)^0 \pi^+$	[n,s]	$< 0.1$	90%	750
$\Xi^0 \pi^+ \pi^0$	[s]	$2.34 \pm 0.68$		856
$\Xi^0 \pi^+ \pi^+ \pi^-$	[s]	$1.74 \pm 0.50$		818
$\Xi^0 e^+ \nu_e$	[s]	$2.3 \begin{smallmatrix} +0.7 \\ -0.9 \end{smallmatrix}$		884
$\Omega^- K^+ \pi^+$	[s]	$0.07 \pm 0.04$		399

**Cabibbo-suppressed decays**

$p K^- \pi^+$	[s]	$0.21 \pm 0.03$		944
$p \bar{K}^*(892)^0$	[n,s]	$0.12 \pm 0.02$		828
$\Sigma^+ K^+ K^-$	[s]	$0.15 \pm 0.07$		580
$\Sigma^+ \phi$	[n,s]	$< 0.11$	90%	549
$\Xi(1690)^0 K^+, \Xi(1690)^0 \rightarrow \Sigma^+ K^-$	[s]	$< 0.05$	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  $m = 2471.0 \pm 0.4$  MeV

$$m_{\Xi_c^0} - m_{\Xi_c^+} = 3.1 \pm 0.5 \text{ MeV}$$

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

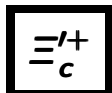
$$c\tau = 33.6 \text{ } \mu\text{m}$$

### Decay asymmetry parameters

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

No absolute branching fractions have been measured. Several measurements of ratios of fractions may be found in the Listings that follow.

$\Xi_c^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$pK^- K^- \pi^+$	seen	676
$pK^- \bar{K}^*(892)^0$	seen	413
$pK^- K^- \pi^+$ no $\bar{K}^*(892)^0$	seen	676
$\Lambda K_S^0$	seen	906
$\Lambda \bar{K}^0 \pi^+ \pi^-$	seen	787
$\Lambda K^- \pi^+ \pi^+ \pi^-$	seen	703
$\Xi^- \pi^+$	seen	875
$\Xi^- \pi^+ \pi^+ \pi^-$	seen	816
$\Omega^- K^+$	seen	523
$\Xi^- e^+ \nu_e$	seen	882
$\Xi^- \ell^+$ anything	seen	—



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

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

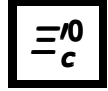
Mass  $m = 2575.7 \pm 3.1$  MeV

$$m_{\Xi_c^{'+}} - m_{\Xi_c^+} = 107.8 \pm 3.0 \text{ MeV}$$



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

$\Xi_c^{'+}$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$\Xi_c^+ \gamma$	seen	106



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

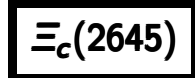
$J^P$  has not been measured;  $\frac{1}{2}^+$  is the quark-model prediction.

Mass  $m = 2578.0 \pm 2.9$  MeV

$$m_{\Xi_c^{'0}} - m_{\Xi_c^0} = 107.0 \pm 2.9 \text{ MeV}$$

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

$\Xi_c^{'0}$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$\Xi_c^0 \gamma$	seen	105



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

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

$\Xi_c(2645)^+$  mass  $m = 2646.6 \pm 1.4$  MeV (S = 1.6)

$\Xi_c(2645)^0$  mass  $m = 2646.1 \pm 1.2$  MeV

$$m_{\Xi_c(2645)^+} - m_{\Xi_c^0} = 175.6 \pm 1.4 \text{ MeV} \quad (S = 1.7)$$

$$m_{\Xi_c(2645)^0} - m_{\Xi_c^+} = 178.2 \pm 1.1 \text{ MeV}$$

$\Xi_c(2645)^+$  full width  $\Gamma < 3.1$  MeV, CL = 90%

$\Xi_c(2645)^0$  full width  $\Gamma < 5.5$  MeV, CL = 90%

$\Xi_c \pi$  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	107

### $\Xi_c(2790)$

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

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

$$\begin{aligned} \Xi_c(2790)^+ \text{ mass} &= 2789.2 \pm 3.2 \text{ MeV} \\ \Xi_c(2790)^0 \text{ mass} &= 2791.9 \pm 3.3 \text{ MeV} \\ m_{\Xi_c(2790)^+} - m_{\Xi_c^0} &= 318.2 \pm 3.2 \text{ MeV} \\ m_{\Xi_c(2790)^0} - m_{\Xi_c^+} &= 324.0 \pm 3.3 \text{ MeV} \\ \Xi_c(2790)^+ \text{ width} &< 15 \text{ MeV, CL} = 90\% \\ \Xi_c(2790)^0 \text{ width} &< 12 \text{ MeV, CL} = 90\% \end{aligned}$$

$\Xi_c(2790)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi_c^+ \pi^-$	seen	159

### $\Xi_c(2815)$

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

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

$$\begin{aligned} \Xi_c(2815)^+ \text{ mass } m &= 2816.5 \pm 1.2 \text{ MeV} \\ \Xi_c(2815)^0 \text{ mass } m &= 2818.2 \pm 2.1 \text{ MeV} \\ m_{\Xi_c(2815)^+} - m_{\Xi_c^+} &= 348.6 \pm 1.2 \text{ MeV} \\ m_{\Xi_c(2815)^0} - m_{\Xi_c^0} &= 347.2 \pm 2.1 \text{ MeV} \\ \Xi_c(2815)^+ \text{ full width } \Gamma &< 3.5 \text{ MeV, CL} = 90\% \\ \Xi_c(2815)^0 \text{ full width } \Gamma &< 6.5 \text{ MeV, CL} = 90\% \end{aligned}$$

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)
$\Xi_c^+ \pi^+ \pi^-$	seen	196
$\Xi_c^0 \pi^+ \pi^-$	seen	191

### $\Xi_c(2980)$

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

- $\Xi_c(2980)^+ m = 2974 \pm 5$  MeV (S = 2.3)
- $\Xi_c(2980)^0 m = 2974 \pm 4$  MeV
- $\Xi_c(2980)^+ \text{ width } \Gamma = 33 \pm 8$  MeV (S = 1.3)
- $\Xi_c(2980)^0 \text{ width } \Gamma = 31 \pm 11$  MeV

$\Xi_c(2980)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_c^+ \bar{K} \pi$	seen	244
$\Sigma_c(2455) \bar{K}$	seen	151
$\Lambda_c^+ \bar{K}$	not seen	421

### $\Xi_c(3080)$

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

- $\Xi_c(3080)^+ m = 3077.0 \pm 0.4$  MeV
- $\Xi_c(3080)^0 m = 3079.9 \pm 1.4$  MeV (S = 1.3)
- $\Xi_c(3080)^+ \text{ width } \Gamma = 5.8 \pm 1.0$  MeV
- $\Xi_c(3080)^0 \text{ width } \Gamma = 5.6 \pm 2.2$  MeV

$\Xi_c(3080)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_c^+ \bar{K} \pi$	seen	415
$\Sigma_c(2455) \bar{K}$	seen	342
$\Sigma_c(2455) \bar{K} + \Sigma_c(2520) \bar{K}$	seen	—
$\Lambda_c^+ \bar{K}$	not seen	536
$\Lambda_c^+ \bar{K} \pi^+ \pi^-$	not seen	143

### $\Omega_c^0$

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

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

- Mass  $m = 2697.5 \pm 2.6$  MeV (S = 1.2)
- Mean life  $\tau = (69 \pm 12) \times 10^{-15}$  s
- $c\tau = 21$   $\mu\text{m}$

No absolute branching fractions have been measured.

$\Omega_c^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Sigma^+ K^- K^- \pi^+$	seen	691
$\Xi^0 K^- \pi^+$	seen	903
$\Xi^- K^- \pi^+ \pi^+$	seen	832
$\Omega^- e^+ \nu_e$	seen	830
$\Omega^- \pi^+$	seen	822
$\Omega^- \pi^+ \pi^0$	seen	798
$\Omega^- \pi^- \pi^+ \pi^+$	seen	754

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

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

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

$$\text{Mass } m = 2768.3 \pm 3.0 \text{ MeV} \quad (S = 1.2)$$

$$m_{\Omega_c(2770)^0} - m_{\Omega_c^0} = 70.8 \pm 1.5 \text{ MeV}$$

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

## BOTTOM BARYONS ( $B = -1$ )

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

### $\Lambda_b^0$

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

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

$$\text{Mass } m = 5620.2 \pm 1.6 \text{ MeV}$$

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

$$\text{Mean life } \tau = (1.383^{+0.049}_{-0.048}) \times 10^{-12} \text{ s}$$

$$c\tau = 415 \mu\text{m}$$

These branching fractions are actually an average over weakly decaying  $b$ -baryons weighted by their production rates in  $Z$  decay (or high-energy  $p\bar{p}$ ), branching ratios, and detection efficiencies. They scale with the LEP  $b$ -baryon production fraction  $B(b \rightarrow b\text{-baryon})$  and are evaluated for our value  $B(b \rightarrow b\text{-baryon}) = (9.2 \pm 1.8)\%$ .

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.

$\Lambda_b^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$J/\psi(1S)\Lambda$	$(4.7 \pm 2.8) \times 10^{-4}$		1741
$\Lambda_c^+ \pi^-$	$(8.8 \pm 3.2) \times 10^{-3}$		2343
$\Lambda_c^+ a_1(1260)^-$	seen		2153
$\Lambda_c^+ \ell^- \bar{\nu}_\ell \text{ anything}$	[t] $(9.9 \pm 2.6) \%$		—
$\Lambda_c^+ \ell^- \bar{\nu}_\ell$	$(5.0^{+1.9}_{-1.4}) \%$		2345
$\Lambda_c^+ \pi^+ \pi^- \ell^- \bar{\nu}_\ell$	$(5.6 \pm 3.1) \%$		2335
$p h^-$	[u] $< 2.3 \times 10^{-5}$	90%	2730
$p \pi^-$	$< 5.0 \times 10^{-5}$	90%	2730
$p K^-$	$< 5.0 \times 10^{-5}$	90%	2709
$\Lambda \gamma$	$< 1.3 \times 10^{-3}$	90%	2699



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

$I, J, P$  need confirmation.

$$\text{Mass } m(\Sigma_b^+) = 5807.8 \pm 2.7 \text{ MeV}$$

$$\text{Mass } m(\Sigma_b^-) = 5815.2 \pm 2.0 \text{ MeV}$$

$\Sigma_b$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_b^0 \pi$	dominant	128



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

$I, J, P$  need confirmation.

$$\text{Mass } m(\Sigma_b^{*+}) = 5829.0 \pm 3.4 \text{ MeV}$$

$$\text{Mass } m(\Sigma_b^{*-}) = 5836.4 \pm 2.8 \text{ MeV}$$

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

$\Sigma_b^*$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_b^0 \pi$	dominant	156

$\Xi_b^0, \Xi_b^-$

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

$I, J, P$  need confirmation.

Mass  $m = 5792.4 \pm 3.0$  MeV

Mean life  $\tau = (1.42^{+0.28}_{-0.24}) \times 10^{-12}$  s

$\Xi_b$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor	$p$ (MeV/c)
$\Xi_b^- \rightarrow \Xi^- \ell^- \bar{\nu}_\ell X \times B(\bar{b} \rightarrow \Xi_b^-)$	$(3.9 \pm 1.2) \times 10^{-4}$	1.4	-
$\Xi_b^- \rightarrow J/\psi \Xi^- \times B(\bar{b} \rightarrow \Xi_b^-) / B(\bar{b} \rightarrow \Lambda_b)$	$(1.3 \pm 1.0) \times 10^{-4}$		-

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

Mean life  $\tau = (1.319^{+0.039}_{-0.038}) \times 10^{-12}$  s

These branching fractions are actually an average over weakly decaying  $b$ -baryons weighted by their production rates in  $Z$  decay (or high-energy  $p\bar{p}$ ), branching ratios, and detection efficiencies. They scale with the LEP  $b$ -baryon production fraction  $B(b \rightarrow b\text{-baryon})$  and are evaluated for our value  $B(b \rightarrow b\text{-baryon}) = (9.2 \pm 1.8)\%$ .

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	$(5.3^{+2.3}_{-2.0})\%$	-
$p \ell \bar{\nu}_\ell$ anything	$(5.1 \pm 1.4)\%$	-
$p$ anything	$(64 \pm 23)\%$	-
$\Lambda \ell^- \bar{\nu}_\ell$ anything	$(3.5 \pm 0.8)\%$	-
$\Lambda/\bar{\Lambda}$ anything	$(36 \pm 9)\%$	-
$\Xi^- \ell^- \bar{\nu}_\ell$ anything	$(6.0 \pm 1.8) \times 10^{-3}$	-

## NOTES

- [a] The masses of the  $p$  and  $n$  are most precisely known in  $u$  (unified atomic mass units). The conversion factor to MeV,  $1 u = 931.494043 \pm 0.000080$  MeV, is less well known than are the masses in  $u$ .
- [b] These two results 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 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.
- [e] 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.
- [f] 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.
- [g] Time-reversal invariance requires this to be  $0^\circ$  or  $180^\circ$ .
- [h] This limit is for  $\gamma$  energies between 35 and 100 keV.
- [i] 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.
- [j] See the Listings for the pion momentum range used in this measurement.
- [k] The error given here is only an educated guess. It is larger than the error on the weighted average of the published values.
- [l] A theoretical value using QED.
- [m] See the note on " $\Lambda_c^+$  Branching Fractions" in the  $\Lambda_c^+$  Particle Listings.
- [n] This branching fraction includes all the decay modes of the final-state resonance.
- [o] An  $\ell$  indicates an  $e$  or a  $\mu$  mode, not a sum over these modes.

- [*p*] The value is for the sum of the charge states or particle/antiparticle states indicated.
- [*q*] Assuming isospin conservation, so that the other third is  $\Lambda_c^+ \pi^0 \pi^0$ .
- [*r*] A test that the isospin is indeed 0, so that the particle is indeed a  $\Lambda_c^+$ .
- [*s*] No absolute branching fractions have been measured. The value here is the branching *ratio* relative to  $\Xi^- \pi^+ \pi^+$ .
- [*t*] Not a pure measurement. See note at head of  $\Lambda_b^0$  Decay Modes.
- [*u*] Here  $h^-$  means  $\pi^-$  or  $K^-$ .