

# N BARYONS

## ( $S = 0, I = 1/2$ )

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

**p**

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

$$\text{Mass } m = 938.27200 \pm 0.00004 \text{ MeV [a]}$$

$$= 1.00727646688 \pm 0.00000000013 \text{ u}$$

$$|m_p - m_{\bar{p}}|/m_p < 5 \times 10^{-7} \text{ [b]}$$

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

$$|q_p + q_{\bar{p}}|/e < 5 \times 10^{-7} \text{ [b]}$$

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

$$\text{Magnetic moment } \mu = 2.792847337 \pm 0.000000029 \mu_N$$

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

$$\text{Electric dipole moment } d = (-4 \pm 6) \times 10^{-23} \text{ e cm}$$

$$\text{Electric polarizability } \bar{\alpha} = (12.1 \pm 0.9) \times 10^{-4} \text{ fm}^3$$

$$\text{Magnetic polarizability } \bar{\beta} = (2.1 \pm 0.9) \times 10^{-4} \text{ fm}^3$$

$$\text{Mean life } \tau > 1.6 \times 10^{25} \text{ years (independent of mode)}$$

$$> 10^{31} \text{ to } 10^{33} \text{ years [d] (mode dependent)}$$

Below, for  $N$  decays,  $p$  and  $n$  distinguish proton and neutron partial lifetimes. See also the "Note on Nucleon Decay" in our 1994 edition (Phys. Rev. **D50**, 1673) for a short review.

The "partial mean life" limits tabulated here are the limits on  $\tau/B_i$ , where  $\tau$  is the total mean life and  $B_i$  is the branching fraction for the mode in question.

<b>p 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%	296
$n \rightarrow \nu \eta$	$> 158$	90%	310
$N \rightarrow e^+ \rho$	$> 217 (n), > 75 (p)$	90%	153
$N \rightarrow \mu^+ \rho$	$> 228 (n), > 110 (p)$	90%	119
$N \rightarrow \nu \rho$	$> 19 (n), > 162 (p)$	90%	153
$p \rightarrow e^+ \omega$	$> 107$	90%	142

$p \rightarrow \mu^+ \omega$	> 117	90%	104
$n \rightarrow \nu \omega$	> 108	90%	144
$N \rightarrow e^+ K$	> 17 ( <i>n</i> ), > 150 ( <i>p</i> )	90%	337
$p \rightarrow e^+ K_S^0$	> 76	90%	337
$p \rightarrow e^+ K_L^0$	> 44	90%	337
$N \rightarrow \mu^+ K$	> 26 ( <i>n</i> ), > 120 ( <i>p</i> )	90%	326
$p \rightarrow \mu^+ K_S^0$	> 64	90%	326
$p \rightarrow \mu^+ K_L^0$	> 44	90%	326
$N \rightarrow \nu K$	> 86 ( <i>n</i> ), > 670 ( <i>p</i> )	90%	339
$p \rightarrow e^+ K^*(892)^0$	> 84	90%	45
$N \rightarrow \nu K^*(892)$	> 78 ( <i>n</i> ), > 51 ( <i>p</i> )	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%	154
$n \rightarrow \mu^- \rho^+$	> 7	90%	120
$n \rightarrow e^- K^+$	> 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%	464
$p \rightarrow \mu^+ \mu^+ \mu^-$	> 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%	—
$nn \rightarrow \nu_e \bar{\nu}_e$	> 0.000012	90%	—
$nn \rightarrow \nu_\mu \bar{\nu}_\mu$	> 0.000006	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%	296
$\bar{p} \rightarrow e^- K_S^0$	> 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
$\bar{p} \rightarrow e^- \rho$	$> 200$	90%	153
$\bar{p} \rightarrow e^- \omega$	$> 200$	90%	142
$\bar{p} \rightarrow e^- K^*(892)^0$	$> 1 \times 10^3$	90%	141

**n**

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

Mass  $m = 939.56533 \pm 0.00004$  MeV [a]  
 $= 1.00866491578 \pm 0.00000000055$  u

$m_n - m_p = 1.2933318 \pm 0.0000005$  MeV  
 $= 0.0013884489 \pm 0.0000000006$  u

Mean life  $\tau = 886.7 \pm 1.9$  s (S = 1.2)  
 $c\tau = 2.658 \times 10^8$  km

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

Electric dipole moment  $d < 0.63 \times 10^{-25}$  e cm, CL = 90%

Electric polarizability  $\alpha = (0.98_{-0.23}^{+0.19}) \times 10^{-3}$  fm<sup>3</sup> (S = 1.1)

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

Mean  $n\bar{n}$ -oscillation time  $> 8.6 \times 10^7$  s, CL = 90% (free  $n$ )  
 $> 1.2 \times 10^8$  s, CL = 90% [e] (bound  $n$ )

**Decay parameters [f]**

$p e^- \bar{\nu}_e$   $g_A/g_V = -1.2670 \pm 0.0035$  (S = 1.9)

"  $A = -0.1162 \pm 0.0013$  (S = 1.8)

"  $B = 0.983 \pm 0.004$

"  $a = -0.102 \pm 0.005$

"  $\phi_{AV} = (180.07 \pm 0.18)^\circ$  [g]

"  $D = (-0.5 \pm 1.4) \times 10^{-3}$

<b>n DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$\frac{p}{\text{MeV}/c}$
$p e^- \bar{\nu}_e$	100 %		1.19
<b>Charge conservation (Q) violating mode</b>			
$p \nu_e \bar{\nu}_e$	Q $< 8 \times 10^{-27}$	68%	1.29

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

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

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

<b><math>N(1440)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	60–70 %	397
$N\pi\pi$	30–40 %	342
$\Delta\pi$	20–30 %	143
$N\rho$	<8 %	†
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	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 1530 ( $\approx 1520$ ) MeV  
 Breit-Wigner full width = 110 to 135 ( $\approx 120$ ) 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  
 $-2\text{Im}(\text{pole position}) = 110 \text{ to } 120$  ( $\approx 115$ ) MeV

<b><math>N(1520)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	50–60 %	456
$N\pi\pi$	40–50 %	410
$\Delta\pi$	15–25 %	228
$N\rho$	15–25 %	†
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	<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 = 1520 to 1555 ( $\approx 1535$ ) MeV  
 Breit-Wigner full width = 100 to 250 ( $\approx 150$ ) MeV  
 $p_{\text{beam}} = 0.76 \text{ GeV}/c$        $4\pi\lambda^2 = 22.5 \text{ mb}$   
 Re(pole position) = 1495 to 1515 ( $\approx 1505$ ) 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 %	467
$N\eta$	30–55 %	182
$N\pi\pi$	1–10 %	422
$\Delta\pi$	<1 %	242
$N\rho$	<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 = 1640 to 1680 ( $\approx 1650$ ) MeV  
 Breit-Wigner full width = 145 to 190 ( $\approx 150$ ) MeV  
 $p_{\text{beam}} = 0.96 \text{ GeV}/c$        $4\pi\lambda^2 = 16.4 \text{ mb}$   
 Re(pole position) = 1640 to 1680 ( $\approx 1660$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 150 \text{ to } 170$  ( $\approx 160$ ) MeV

<b><math>N(1650)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	55–90 %	547
$N\eta$	3–10 %	346
$\Lambda K$	3–11 %	161
$N\pi\pi$	10–20 %	511
$\Delta\pi$	1–7 %	344
$N\rho$	4–12 %	†

$N(\pi\pi)_{S\text{-wave}}^{I=0}$	<4 %	—
$N(1440)\pi$	<5 %	147
$p\gamma$	0.04–0.18 %	558
$p\gamma$ , helicity=1/2	0.04–0.18 %	558
$n\gamma$	0.003–0.17 %	557
$n\gamma$ , helicity=1/2	0.003–0.17 %	557

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

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

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

<b><math>N(1675)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	40–50 %	563
$\Lambda K$	<1 %	209
$N\pi\pi$	50–60 %	529
$\Delta\pi$	50–60 %	364
$N\rho$	< 1–3 %	†
$p\gamma$	0.004–0.023 %	575
$p\gamma$ , helicity=1/2	0.0–0.015 %	575
$p\gamma$ , helicity=3/2	0.0–0.011 %	575
$n\gamma$	0.02–0.12 %	574
$n\gamma$ , helicity=1/2	0.006–0.046 %	574
$n\gamma$ , helicity=3/2	0.01–0.08 %	574

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

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

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

<b><math>N(1680)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	60–70 %	567
$N\pi\pi$	30–40 %	532
$\Delta\pi$	5–15 %	369
$N\rho$	3–15 %	†
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	5–20 %	—

$p\gamma$	0.21–0.32 %	578
$p\gamma$ , helicity=1/2	0.001–0.011 %	578
$p\gamma$ , helicity=3/2	0.20–0.32 %	578
$n\gamma$	0.021–0.046 %	577
$n\gamma$ , helicity=1/2	0.004–0.029 %	577
$n\gamma$ , helicity=3/2	0.01–0.024 %	577

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

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

Breit-Wigner mass = 1650 to 1750 ( $\approx 1700$ ) MeV

Breit-Wigner full width = 50 to 150 ( $\approx 100$ ) MeV

$$p_{\text{beam}} = 1.05 \text{ GeV}/c \quad 4\pi\chi^2 = 14.5 \text{ mb}$$

Re(pole position) = 1630 to 1730 ( $\approx 1680$ ) MeV

–2Im(pole position) = 50 to 150 ( $\approx 100$ ) MeV

<b><math>N(1700)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$N\pi$	5–15 %	580
$\Lambda K$	<3 %	250
$N\pi\pi$	85–95 %	547
$N\rho$	<35 %	†
$p\gamma$	0.01–0.05 %	591
$p\gamma$ , helicity=1/2	0.0–0.024 %	591
$p\gamma$ , helicity=3/2	0.002–0.026 %	591
$n\gamma$	0.01–0.13 %	590
$n\gamma$ , helicity=1/2	0.0–0.09 %	590
$n\gamma$ , helicity=3/2	0.01–0.05 %	590

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

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

Breit-Wigner mass = 1680 to 1740 ( $\approx 1710$ ) MeV

Breit-Wigner full width = 50 to 250 ( $\approx 100$ ) MeV

$$p_{\text{beam}} = 1.07 \text{ GeV}/c \quad 4\pi\chi^2 = 14.2 \text{ mb}$$

Re(pole position) = 1670 to 1770 ( $\approx 1720$ ) MeV

–2Im(pole position) = 80 to 380 ( $\approx 230$ ) MeV

<b><math>N(1710)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$\rho$ (MeV/c)
$N\pi$	10–20 %	587
$\Lambda K$	5–25 %	264
$N\pi\pi$	40–90 %	554
$\Delta\pi$	15–40 %	393
$N\rho$	5–25 %	48



$N(\pi\pi)_{S\text{-wave}}^{I=0}$	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

**$N(1720) P_{13}$**

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

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

<b><math>N(1720)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	10–20 %	594
$\Lambda K$	1–15 %	278
$N\pi\pi$	>70 %	561
$N\rho$	70–85 %	104
$p\gamma$	0.003–0.10 %	604
$p\gamma$ , helicity=1/2	0.003–0.08 %	604
$p\gamma$ , helicity=3/2	0.001–0.03 %	604
$n\gamma$	0.002–0.39 %	603
$n\gamma$ , helicity=1/2	0.0–0.002 %	603
$n\gamma$ , helicity=3/2	0.001–0.39 %	603

**$N(2190) G_{17}$**

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

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

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

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

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

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

<b><math>N(2220)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	10–20 %	905

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

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

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

<b><math>N(2250)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	5–15 %	923

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

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

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

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

# Δ BARYONS

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

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

### Δ(1232) P<sub>33</sub>

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

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

Breit-Wigner full width (mixed charges) = 115 to 125 ( $\approx 120$ ) 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

−2Im(pole position) = 98 to 102 ( $\approx 100$ ) MeV

Δ(1232) DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	>99 %	227
$N\gamma$	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

### Δ(1600) P<sub>33</sub>

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

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

−2Im(pole position) = 200 to 400 ( $\approx 300$ ) MeV

Δ(1600) DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	10–25 %	512
$N\pi\pi$	75–90 %	473
$\Delta\pi$	40–70 %	301
$N\rho$	<25 %	†
$N(1440)\pi$	10–35 %	74
$N\gamma$	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 = 1615 to 1675 ( $\approx 1620$ ) MeV  
 Breit-Wigner full width = 120 to 180 ( $\approx 150$ ) MeV  
 $p_{\text{beam}} = 0.91 \text{ GeV}/c$        $4\pi\lambda^2 = 17.7 \text{ mb}$   
 Re(pole position) = 1580 to 1620 ( $\approx 1600$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 100 \text{ to } 130$  ( $\approx 115$ ) MeV

<b><math>\Delta(1620)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	20–30 %	526
$N\pi\pi$	70–80 %	488
$\Delta\pi$	30–60 %	318
$N\rho$	7–25 %	†
$N\gamma$	0.004–0.044 %	538
$N\gamma$ , helicity=1/2	0.004–0.044 %	538

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

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

Breit-Wigner mass = 1670 to 1770 ( $\approx 1700$ ) MeV  
 Breit-Wigner full width = 200 to 400 ( $\approx 300$ ) MeV  
 $p_{\text{beam}} = 1.05 \text{ GeV}/c$        $4\pi\lambda^2 = 14.5 \text{ mb}$   
 Re(pole position) = 1620 to 1700 ( $\approx 1660$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 150 \text{ to } 250$  ( $\approx 200$ ) MeV

<b><math>\Delta(1700)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	10–20 %	580
$N\pi\pi$	80–90 %	547
$\Delta\pi$	30–60 %	385
$N\rho$	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 = 1870 to 1920 ( $\approx 1905$ ) MeV  
 Breit-Wigner full width = 280 to 440 ( $\approx 350$ ) MeV  
 $p_{\text{beam}} = 1.45 \text{ GeV}/c$        $4\pi\lambda^2 = 9.62 \text{ mb}$   
 Re(pole position) = 1800 to 1860 ( $\approx 1830$ ) MeV  
 $-2\text{Im}(\text{pole position}) = 230 \text{ to } 330$  ( $\approx 280$ ) MeV

$\Delta(1905)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	5–15 %	713
$N\pi\pi$	85–95 %	687
$\Delta\pi$	<25 %	542
$N\rho$	>60 %	421
$N\gamma$	0.01–0.03 %	721
$N\gamma$ , helicity=1/2	0.0–0.1 %	721
$N\gamma$ , helicity=3/2	0.004–0.03 %	721

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

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

Breit-Wigner mass = 1870 to 1920 ( $\approx 1910$ ) MeV

Breit-Wigner full width = 190 to 270 ( $\approx 250$ ) MeV

$$p_{\text{beam}} = 1.46 \text{ GeV}/c \quad 4\pi\lambda^2 = 9.54 \text{ mb}$$

Re(pole position) = 1830 to 1880 ( $\approx 1855$ ) MeV

–2Im(pole position) = 200 to 500 ( $\approx 350$ ) MeV

$\Delta(1910)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	15–30 %	716
$N\gamma$	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

$$p_{\text{beam}} = 1.48 \text{ GeV}/c \quad 4\pi\lambda^2 = 9.37 \text{ mb}$$

Re(pole position) = 1850 to 1950 ( $\approx 1900$ ) MeV

–2Im(pole position) = 200 to 400 ( $\approx 300$ ) MeV

$\Delta(1920)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	5–20 %	722

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

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

Breit-Wigner mass = 1920 to 1970 ( $\approx 1930$ ) MeV

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

$$p_{\text{beam}} = 1.50 \text{ GeV}/c \quad 4\pi\lambda^2 = 9.21 \text{ mb}$$

Re(pole position) = 1840 to 1940 ( $\approx 1890$ ) MeV

–2Im(pole position) = 200 to 300 ( $\approx 250$ ) MeV

$\Delta(1930)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	10–20 %	729
$N\gamma$	0.0–0.02 %	737
$N\gamma$ , helicity=1/2	0.0–0.01 %	737
$N\gamma$ , helicity=3/2	0.0–0.01 %	737

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

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

Breit-Wigner mass = 1940 to 1960 ( $\approx 1950$ ) MeV

Breit-Wigner full width = 290 to 350 ( $\approx 300$ ) MeV

$$p_{\text{beam}} = 1.54 \text{ GeV}/c \quad 4\pi\chi^2 = 8.91 \text{ mb}$$

Re(pole position) = 1880 to 1890 ( $\approx 1885$ ) MeV

–2Im(pole position) = 210 to 270 ( $\approx 240$ ) MeV

$\Delta(1950)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\pi$	35–40 %	741
$N\pi\pi$		716
$\Delta\pi$	20–30 %	574
$N\rho$	<10 %	469
$N\gamma$	0.08–0.13 %	749
$N\gamma$ , helicity=1/2	0.03–0.055 %	749
$N\gamma$ , helicity=3/2	0.05–0.075 %	749

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

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

Breit-Wigner mass = 2300 to 2500 ( $\approx 2420$ ) MeV

Breit-Wigner full width = 300 to 500 ( $\approx 400$ ) MeV

$$p_{\text{beam}} = 2.64 \text{ GeV}/c \quad 4\pi\chi^2 = 4.68 \text{ mb}$$

Re(pole position) = 2260 to 2400 ( $\approx 2330$ ) MeV

–2Im(pole position) = 350 to 750 ( $\approx 550$ ) MeV

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

# Λ BARYONS

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

$$\Lambda^0 = uds$$

**Λ**

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

Mass  $m = 1115.683 \pm 0.006$  MeV

$$(m_\Lambda - m_{\bar{\Lambda}}) / m_\Lambda = (-0.1 \pm 1.1) \times 10^{-5} \quad (S = 1.6)$$

$$\text{Mean life } \tau = (2.632 \pm 0.020) \times 10^{-10} \text{ s} \quad (S = 1.6)$$

$$c\tau = 7.89 \text{ cm}$$

Magnetic moment  $\mu = -0.613 \pm 0.004 \mu_N$

Electric dipole moment  $d < 1.5 \times 10^{-16} \text{ e cm}$ , CL = 95%

### Decay parameters

$p\pi^-$	$\alpha_- = 0.642 \pm 0.013$
"	$\phi_- = (-6.5 \pm 3.5)^\circ$
"	$\gamma_- = 0.76 [h]$
"	$\Delta_- = (8 \pm 4)^\circ [h]$
$n\pi^0$	$\alpha_0 = +0.65 \pm 0.05$
$p e^- \bar{\nu}_e$	$g_A/g_V = -0.718 \pm 0.015 [f]$

Λ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$p\pi^-$	(63.9 ± 0.5) %	101
$n\pi^0$	(35.8 ± 0.5) %	104
$n\gamma$	(1.75 ± 0.15) × 10 <sup>-3</sup>	162
$p\pi^- \gamma$	[i] (8.4 ± 1.4) × 10 <sup>-4</sup>	101
$p e^- \bar{\nu}_e$	(8.32 ± 0.14) × 10 <sup>-4</sup>	163
$p\mu^- \bar{\nu}_\mu$	(1.57 ± 0.35) × 10 <sup>-4</sup>	131

**Λ(1405) S<sub>01</sub>**

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

Mass  $m = 1406 \pm 4$  MeV

Full width  $\Gamma = 50.0 \pm 2.0$  MeV

Below  $\bar{K}N$  threshold

Λ(1405) DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Sigma \pi$	100 %	152

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

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

Mass  $m = 1519.5 \pm 1.0$  MeV [1]

Full width  $\Gamma = 15.6 \pm 1.0$  MeV [1]

$p_{\text{beam}} = 0.39$  GeV/c       $4\pi\lambda^2 = 82.8$  mb

$\Lambda(1520)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	$45 \pm 1\%$	244
$\Sigma\pi$	$42 \pm 1\%$	267
$\Lambda\pi\pi$	$10 \pm 1\%$	252
$\Sigma\pi\pi$	$0.9 \pm 0.1\%$	152
$\Lambda\gamma$	$0.8 \pm 0.2\%$	351

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

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

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

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

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

$\Lambda(1600)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	15–30 %	343
$\Sigma\pi$	10–60 %	336

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

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

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

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

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

$\Lambda(1670)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	15–25 %	414
$\Sigma\pi$	20–60 %	393
$\Lambda\eta$	15–35 %	64



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

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

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

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

<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 %	409
$\Lambda\pi\pi$	$\sim 25$ %	415
$\Sigma\pi\pi$	$\sim 20$ %	350

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

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

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

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

<b><math>\Lambda(1800)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	25–40 %	528
$\Sigma\pi$	seen	493
$\Sigma(1385)\pi$	seen	345
$N\bar{K}^*(892)$	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

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

<b><math>\Lambda(1810)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	20–50 %	537
$\Sigma\pi$	10–40 %	501
$\Sigma(1385)\pi$	seen	356
$N\bar{K}^*(892)$	30–60 %	†

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

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

Mass  $m = 1815$  to  $1825$  ( $\approx 1820$ ) MeV

Full 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 %	508
$\Sigma(1385)\pi$	5–10 %	362

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

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

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 %	515
$\Sigma(1385)\pi$	>15 %	371

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

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

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 %	559
$\Sigma(1385)\pi$	seen	420
$N\bar{K}^*(892)$	seen	233

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

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

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
$\Sigma\pi$	$\sim 5$ %	704
$\Lambda\eta$	$< 3$ %	617
$\Xi K$	$< 3$ %	483
$\Lambda\omega$	$< 8$ %	443
$N\bar{K}^*(892)$	10–20 %	514

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

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

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	589
$N\bar{K}^*(892)$	10–60 %	524

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

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

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

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

Σ <sup>+</sup> DECAY MODES	Fraction (Γ <sub><i>i</i></sub> /Γ)	Confidence level	<i>p</i> (MeV/c)
$p\pi^0$	(51.57±0.30) %		189
$n\pi^+$	(48.31±0.30) %		185
$p\gamma$	( 1.23±0.05) × 10 <sup>-3</sup>		225
$n\pi^+\gamma$	[ <i>i</i> ] ( 4.5 ±0.5 ) × 10 <sup>-4</sup>		185
$\Lambda e^+\nu_e$	( 2.0 ±0.5 ) × 10 <sup>-5</sup>		71

### ΔS = ΔQ (SQ) violating modes or ΔS = 1 weak neutral current (S1) modes

$ne^+\nu_e$	SQ	< 5	× 10 <sup>-6</sup>	90%	224
$n\mu^+\nu_\mu$	SQ	< 3.0	× 10 <sup>-5</sup>	90%	202
$pe^+e^-$	S1	< 7	× 10 <sup>-6</sup>		225



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

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
$\Lambda e^+ e^-$	[k] $5 \times 10^{-3}$		74



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

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)

**Decay parameters**

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

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

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

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

$$\Sigma(1385)^+ \text{ mass } m = 1382.8 \pm 0.4 \text{ MeV} \quad (S = 2.0)$$

$$\Sigma(1385)^0 \text{ mass } m = 1383.7 \pm 1.0 \text{ MeV} \quad (S = 1.4)$$

$$\Sigma(1385)^- \text{ mass } m = 1387.2 \pm 0.5 \text{ MeV} \quad (S = 2.2)$$

$$\Sigma(1385)^+ \text{ full width } \Gamma = 35.8 \pm 0.8 \text{ MeV}$$

$$\Sigma(1385)^0 \text{ full width } \Gamma = 36 \pm 5 \text{ MeV}$$

$$\Sigma(1385)^- \text{ full width } \Gamma = 39.4 \pm 2.1 \text{ MeV} \quad (S = 1.7)$$

Below  $\bar{K}N$  threshold

<b><math>\Sigma(1385)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda\pi$	88±2 %	208
$\Sigma\pi$	12±2 %	127

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

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

$$\text{Mass } m = 1630 \text{ to } 1690 (\approx 1660) \text{ MeV}$$

$$\text{Full width } \Gamma = 40 \text{ to } 200 (\approx 100) \text{ MeV}$$

$$p_{\text{beam}} = 0.72 \text{ GeV}/c \quad 4\pi\lambda^2 = 29.9 \text{ mb}$$

<b><math>\Sigma(1660)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	10–30 %	405
$\Lambda\pi$	seen	439
$\Sigma\pi$	seen	385

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

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

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

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

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

<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 %	447
$\Sigma\pi$	30–60 %	393

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

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

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

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

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

$\Sigma(1750)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$N\bar{K}$	10–40 %	486
$\Lambda\pi$	seen	507
$\Sigma\pi$	<8 %	455
$\Sigma\eta$	15–55 %	81

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

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

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%	474
$\Sigma(1385)\pi$	8–12%	324
$\Lambda(1520)\pi$	17–23%	198

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

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

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	622
$\Sigma\pi$	seen	577
$\Sigma(1385)\pi$	<5 %	440

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

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

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	639
$\Sigma\pi$	seen	594
$\Sigma(1385)\pi$	seen	460
$\Lambda(1520)\pi$	seen	354
$\Delta(1232)\bar{K}$	seen	410
$N\bar{K}^*(892)$	seen	320

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

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

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 %	412
$\Sigma(1385)\pi$	5–15 %	529
$\Lambda(1520)\pi$	10–20 %	430
$\Delta(1232)\bar{K}$	10–20 %	498
$N\bar{K}^*(892)$	<5 %	438



**$\Sigma(2250)$**

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

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

# Ξ 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  $m = 1314.83 \pm 0.20$  MeV

$m_{\Xi^-} - m_{\Xi^0} = 6.48 \pm 0.24$  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**

$\Lambda\pi^0 \quad \alpha = -0.411 \pm 0.022 \quad (S = 2.1)$

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

"  $\gamma = 0.85 [h]$

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

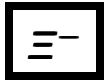
$\Lambda\gamma \quad \alpha = 0.4 \pm 0.4$

$\Sigma^0\gamma \quad \alpha = 0.20 \pm 0.32$

$\Xi^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$\Lambda\pi^0$	$(99.51 \pm 0.05) \%$	S=1.2	135
$\Lambda\gamma$	$(1.18 \pm 0.30) \times 10^{-3}$	S=2.0	184
$\Sigma^0\gamma$	$(3.5 \pm 0.4) \times 10^{-3}$		117
$\Sigma^+ e^- \bar{\nu}_e$	$(2.7 \pm 0.4) \times 10^{-4}$		120
$\Sigma^+ \mu^- \bar{\nu}_\mu$	$< 1.1 \times 10^{-3}$	CL=90%	64

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

$\Sigma^- e^+ \nu_e$	SQ	$< 9 \times 10^{-4}$	CL=90%	112
$\Sigma^- \mu^+ \nu_\mu$	SQ	$< 9 \times 10^{-4}$	CL=90%	49
$p\pi^-$	S2	$< 4 \times 10^{-5}$	CL=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  $m = 1321.31 \pm 0.13$  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**

$\Lambda\pi^- \quad \alpha = -0.456 \pm 0.014 \quad (S = 1.8)$

"  $\phi = (4 \pm 4)^\circ$

"  $\gamma = 0.89 [h]$

"  $\Delta = (188 \pm 8)^\circ [h]$

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

$\Xi^-$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$P$ (MeV/c)
$\Lambda\pi^-$	$(99.887 \pm 0.035) \%$		139
$\Sigma^- \gamma$	$(1.27 \pm 0.23) \times 10^{-4}$		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
$\Sigma^0 e^- \bar{\nu}_e$	$(8.7 \pm 1.7) \times 10^{-5}$		122
$\Sigma^0 \mu^- \bar{\nu}_\mu$	$< 8 \times 10^{-4}$	90%	70
$\Xi^0 e^- \bar{\nu}_e$	$< 2.3 \times 10^{-3}$	90%	6

**$\Delta S = 2$  forbidden ( $S_2$ ) modes**

$n\pi^-$	$S_2$	$< 1.9$	$\times 10^{-5}$	90%	303
$ne^- \bar{\nu}_e$	$S_2$	$< 3.2$	$\times 10^{-3}$	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%	304
$p\pi^- \mu^- \bar{\nu}_\mu$	$S_2$	$< 4$	$\times 10^{-4}$	90%	250
$p\mu^- \mu^-$	$L$	$< 4$	$\times 10^{-4}$	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 %		152
$\Xi \gamma$	<4 %	90%	200

**$\Xi(1690)$**

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

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

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	51
$\Xi \pi$	seen	—
$\Xi^- \pi^+ \pi^-$	possibly seen	214

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

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

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

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

$\Xi(1820)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda \bar{K}$	large	400
$\Sigma \bar{K}$	small	320
$\Xi \pi$	small	413
$\Xi(1530) \pi$	small	234

**$\Xi(1950)$**

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

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

<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	518

**$\Xi(2030)$**

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

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

<b><math>\Xi(2030)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda \bar{K}$	$\sim 20\%$	589
$\Sigma \bar{K}$	$\sim 80\%$	533
$\Xi \pi$	small	573
$\Xi(1530)\pi$	small	421
$\Lambda \bar{K} \pi$	small	501
$\Sigma \bar{K} \pi$	small	430

# Ω BARYONS (S = -3, I = 0)

$$\Omega^- = sss$$

**Ω<sup>-</sup>**

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

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

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

$$\Lambda K^- \quad \alpha = -0.026 \pm 0.023$$

$$\frac{1}{2}[\alpha(\Lambda K^-) + \alpha(\bar{\Lambda} K^+)] = -0.004 \pm 0.040$$

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

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

Ω <sup>-</sup> DECAY MODES	Fraction (Γ <sub>i</sub> /Γ)	Confidence level	<sup>p</sup> (MeV/c)
ΛK <sup>-</sup>	(67.8±0.7) %		211
Ξ <sup>0</sup> π <sup>-</sup>	(23.6±0.7) %		294
Ξ <sup>-</sup> π <sup>0</sup>	( 8.6±0.4) %		290
Ξ <sup>-</sup> π <sup>+</sup> π <sup>-</sup>	( 4.3 <sup>+3.4</sup> <sub>-1.3</sub> ) × 10 <sup>-4</sup>		190
Ξ(1530) <sup>0</sup> π <sup>-</sup>	( 6.4 <sup>+5.1</sup> <sub>-2.0</sub> ) × 10 <sup>-4</sup>		17
Ξ <sup>0</sup> e <sup>-</sup> $\bar{\nu}_e$	( 5.6±2.8) × 10 <sup>-3</sup>		319
Ξ <sup>-</sup> γ	< 4.6 × 10 <sup>-4</sup>	90%	314
<b>ΔS = 2 forbidden (S2) modes</b>			
Λπ <sup>-</sup>	S2 < 1.9 × 10 <sup>-4</sup>	90%	449

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

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

Mass  $m = 2252 \pm 9$  MeV

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

<b><math>\Omega(2250)^-</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Xi^- \pi^+ K^-$	seen	531
$\Xi(1530)^0 K^-$	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.

$$\text{Mass } m = 2284.9 \pm 0.6 \text{ MeV}$$

$$\text{Mean life } \tau = (0.206 \pm 0.012) \times 10^{-12} \text{ s}$$

$$c\tau = 61.8 \text{ } \mu\text{m}$$

### Decay asymmetry parameters

$$\Lambda\pi^+ \quad \alpha = -0.98 \pm 0.19$$

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

$$\Lambda\ell^+\nu_\ell \quad \alpha = -0.82^{+0.11}_{-0.07}$$

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> and one <math>\bar{K}</math></b>			
$p\bar{K}^0$	( 2.3 $\pm$ 0.6 ) %		872
$pK^-\pi^+$	[1] ( 5.0 $\pm$ 1.3 ) %		822
$p\bar{K}^*(892)^0$	[m] ( 1.6 $\pm$ 0.5 ) %		681
$\Delta(1232)^{++}K^-$	( 8.6 $\pm$ 3.0 ) $\times 10^{-3}$		709
$\Lambda(1520)\pi^+$	[m] ( 5.9 $\pm$ 2.1 ) $\times 10^{-3}$		626
$pK^-\pi^+$ nonresonant	( 2.8 $\pm$ 0.8 ) %		822
$p\bar{K}^0\pi^0$	( 3.3 $\pm$ 1.0 ) %		822
$p\bar{K}^0\eta$	( 1.2 $\pm$ 0.4 ) %		567



$\rho \bar{K}^0 \pi^+ \pi^-$	( 2.6 ± 0.7 ) %	753
$\rho K^- \pi^+ \pi^0$	( 3.4 ± 1.0 ) %	758
$\rho K^*(892)^- \pi^+$	[m] ( 1.1 ± 0.5 ) %	579
$\rho (K^- \pi^+)_{\text{nonresonant}} \pi^0$	( 3.6 ± 1.2 ) %	758
$\Delta(1232) \bar{K}^*(892)$	seen	416
$\rho K^- \pi^+ \pi^+ \pi^-$	( 1.1 ± 0.8 ) × 10 <sup>-3</sup>	670
$\rho K^- \pi^+ \pi^0 \pi^0$	( 8 ± 4 ) × 10 <sup>-3</sup>	676
$\rho K^- \pi^+ \pi^0 \pi^0 \pi^0$	( 5.0 ± 3.4 ) × 10 <sup>-3</sup>	573

### Hadronic modes with a $\rho$ and zero or two $K$ 's

$\rho \pi^+ \pi^-$	( 3.5 ± 2.0 ) × 10 <sup>-3</sup>	926
$\rho f_0(980)$	[m] ( 2.8 ± 1.9 ) × 10 <sup>-3</sup>	621
$\rho \pi^+ \pi^+ \pi^- \pi^-$	( 1.8 ± 1.2 ) × 10 <sup>-3</sup>	851
$\rho K^+ K^-$	( 2.3 ± 0.9 ) × 10 <sup>-3</sup>	615
$\rho \phi$	[m] ( 1.2 ± 0.5 ) × 10 <sup>-3</sup>	589

### Hadronic modes with a hyperon

$\Lambda \pi^+$	( 9.0 ± 2.8 ) × 10 <sup>-3</sup>	863
$\Lambda \pi^+ \pi^0$	( 3.6 ± 1.3 ) %	843
$\Lambda \rho^+$	< 5 %	CL=95% 638
$\Lambda \pi^+ \pi^+ \pi^-$	( 3.3 ± 1.0 ) %	806
$\Lambda \pi^+ \eta$	( 1.8 ± 0.6 ) %	690
$\Sigma(1385)^+ \eta$	[m] ( 8.5 ± 3.3 ) × 10 <sup>-3</sup>	569
$\Lambda K^+ \bar{K}^0$	( 6.0 ± 2.1 ) × 10 <sup>-3</sup>	441
$\Sigma^0 \pi^+$	( 9.9 ± 3.2 ) × 10 <sup>-3</sup>	824
$\Sigma^+ \pi^0$	( 1.00 ± 0.34 ) %	826
$\Sigma^+ \eta$	( 5.5 ± 2.3 ) × 10 <sup>-3</sup>	712
$\Sigma^+ \pi^+ \pi^-$	( 3.4 ± 1.0 ) %	803
$\Sigma^+ \rho^0$	< 1.4 %	CL=95% 578
$\Sigma^- \pi^+ \pi^+$	( 1.8 ± 0.8 ) %	798
$\Sigma^0 \pi^+ \pi^0$	( 1.8 ± 0.8 ) %	802
$\Sigma^0 \pi^+ \pi^+ \pi^-$	( 1.1 ± 0.4 ) %	762
$\Sigma^+ \pi^+ \pi^- \pi^0$	—	766
$\Sigma^+ \omega$	[m] ( 2.7 ± 1.0 ) %	568
$\Sigma^+ \pi^+ \pi^+ \pi^- \pi^-$	( 3.0 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 4.1 \\ 2.1 \end{smallmatrix}$ ) × 10 <sup>-3</sup>	707
$\Sigma^+ K^+ K^-$	( 3.5 ± 1.2 ) × 10 <sup>-3</sup>	346
$\Sigma^+ \phi$	[m] ( 3.5 ± 1.7 ) × 10 <sup>-3</sup>	292
$\Sigma^+ K^+ \pi^-$	( 7 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 6 \\ 4 \end{smallmatrix}$ ) × 10 <sup>-3</sup>	668
$\Xi^0 K^+$	( 3.9 ± 1.4 ) × 10 <sup>-3</sup>	652
$\Xi^- K^+ \pi^+$	( 4.9 ± 1.7 ) × 10 <sup>-3</sup>	564
$\Xi(1530)^0 K^+$	[m] ( 2.6 ± 1.0 ) × 10 <sup>-3</sup>	471

### Semileptonic modes

$\Lambda \ell^+ \nu_\ell$	[n] ( 2.0 ± 0.6 ) %	—
$\Lambda e^+ \nu_e$	( 2.1 ± 0.6 ) %	870
$\Lambda \mu^+ \nu_\mu$	( 2.0 ± 0.7 ) %	866

### Inclusive modes

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

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

$p \mu^+ \mu^-$	$C1$	< 3.4	$\times 10^{-4}$	CL=90%	936
$\Sigma^- \mu^+ \mu^+$	$L$	< 7.0	$\times 10^{-4}$	CL=90%	811

**$\Lambda_c(2593)^+$**

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

The spin-parity follows from the fact that  $\Sigma_c(2455)\pi$  decays, with little available phase space, are dominant.

$$\text{Mass } m = 2593.9 \pm 0.8 \text{ MeV}$$

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

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

$\Lambda_c^+ \pi \pi$  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.

$\Lambda_c(2593)^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda_c^+ \pi^+ \pi^-$	[p] $\approx 67$ %	124
$\Sigma_c(2455)^{++} \pi^-$	$24 \pm 7$ %	17
$\Sigma_c(2455)^0 \pi^+$	$24 \pm 7$ %	23
$\Lambda_c^+ \pi^+ \pi^-$ 3-body	$18 \pm 10$ %	124
$\Lambda_c^+ \pi^0$	not seen	261
$\Lambda_c^+ \gamma$	not seen	290

## $\Lambda_c(2625)^+$

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

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

$$\text{Mass } m = 2626.6 \pm 0.8 \text{ MeV} \quad (S = 1.2)$$

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

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

$\Lambda_c^+ \pi \pi$  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)
$\Lambda_c^+ \pi^+ \pi^-$	[p] $\approx 67\%$		184
$\Sigma_c(2455)^{++} \pi^-$	<5	90%	100
$\Sigma_c(2455)^0 \pi^+$	<5	90%	101
$\Lambda_c^+ \pi^+ \pi^-$ 3-body	large		184
$\Lambda_c^+ \pi^0$	not seen		293
$\Lambda_c^+ \gamma$	not seen		319

## $\Sigma_c(2455)$

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

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

$$\Sigma_c(2455)^{++} \text{ mass } m = 2452.8 \pm 0.6 \text{ MeV}$$

$$\Sigma_c(2455)^+ \text{ mass } m = 2453.6 \pm 0.9 \text{ MeV}$$

$$\Sigma_c(2455)^0 \text{ mass } m = 2452.2 \pm 0.6 \text{ MeV}$$

$$m_{\Sigma_c^{++}} - m_{\Lambda_c^+} = 167.87 \pm 0.19 \text{ MeV}$$

$$m_{\Sigma_c^+} - m_{\Lambda_c^+} = 168.7 \pm 0.6 \text{ MeV}$$

$$m_{\Sigma_c^0} - m_{\Lambda_c^+} = 167.30 \pm 0.20 \text{ MeV}$$

$$m_{\Sigma_c^{++}} - m_{\Sigma_c^0} = 0.57 \pm 0.23 \text{ MeV}$$

$$m_{\Sigma_c^+} - m_{\Sigma_c^0} = 1.4 \pm 0.6 \text{ MeV}$$

$\Lambda_c^+ \pi$  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)
$\Lambda_c^+ \pi$	$\approx 100\%$	90

**$\Sigma_c(2520)$**

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

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

$$\Sigma_c(2520)^{++} \text{ mass } m = 2519.4 \pm 1.5 \text{ MeV}$$

$$\Sigma_c(2520)^0 \text{ mass } m = 2517.5 \pm 1.4 \text{ MeV}$$

$$m_{\Sigma_c(2520)^{++}} - m_{\Lambda_c^+} = 234.5 \pm 1.4 \text{ MeV}$$

$$m_{\Sigma_c(2520)^0} - m_{\Lambda_c^+} = 232.6 \pm 1.3 \text{ MeV}$$

$$m_{\Sigma_c(2520)^{++}} - m_{\Sigma_c(2520)^0} = 1.9 \pm 1.7 \text{ MeV}$$

$$\Sigma_c(2520)^{++} \text{ full width } \Gamma = 18 \pm 5 \text{ MeV}$$

$$\Sigma_c(2520)^0 \text{ full width } \Gamma = 13 \pm 5 \text{ MeV}$$

$\Lambda_c^+ \pi$  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

**$\Xi_c^+$**

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

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

$$\text{Mass } m = 2466.3 \pm 1.4 \text{ MeV}$$

$$\text{Mean life } \tau = (0.33^{+0.06}_{-0.04}) \times 10^{-12} \text{ s}$$

$$c\tau = 98 \text{ } \mu\text{m}$$

No absolute branching fractions have been measured. The following are branching *ratios* relative to  $\Xi^- \pi^+ \pi^+$ .

$\Xi_c^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\Lambda K^- \pi^+ \pi^+$	[q] $0.58 \pm 0.18$		785
$\Lambda \bar{K}^*(892)^0 \pi^+$	[m,q] $< 0.29$	90%	603
$\Sigma(1385)^+ K^- \pi^+$	[m,q] $< 0.41$	90%	677
$\Sigma^+ K^- \pi^+$	[q] $1.18 \pm 0.31$		809
$\Sigma^+ \bar{K}^*(892)^0$	[m,q] $0.92 \pm 0.30$		654
$\Sigma^0 K^- \pi^+ \pi^+$	[q] $0.49 \pm 0.26$		734

$\Xi^0 \pi^+$	[q] $0.55 \pm 0.16$	876
$\Xi^- \pi^+ \pi^+$	[q] $\Xi 1.0$	850
$\Xi(1530)^0 \pi^+$	[m,q] $< 0.2$	90% 749
$\Xi^0 \pi^+ \pi^0$	[q] $2.34 \pm 0.68$	855
$\Xi^0 \pi^+ \pi^+ \pi^-$	[q] $1.74 \pm 0.50$	817
$\Xi^0 e^+ \nu_e$	[q] $2.3 \begin{smallmatrix} +0.7 \\ -0.9 \end{smallmatrix}$	883
$p K^- \pi^+$	[q] $0.20 \pm 0.05$	—



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

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

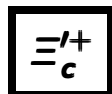
Mass  $m = 2471.8 \pm 1.4$  MeV

$m_{\Xi_c^0} - m_{\Xi_c^+} = 5.5 \pm 1.8$  MeV

Mean life  $\tau = (0.098 \begin{smallmatrix} +0.023 \\ -0.015 \end{smallmatrix}) \times 10^{-12}$  s

$c\tau = 29$   $\mu\text{m}$

$\Xi_c^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda \bar{K}^0$	seen	907
$\Lambda \bar{K}^0 \pi^+ \pi^-$	seen	788
$\Lambda K^- \pi^+ \pi^+ \pi^-$	seen	704
$\Xi^- \pi^+$	seen	876
$\Xi^- \pi^+ \pi^+ \pi^-$	seen	817
$p K^- \bar{K}^*(892)^0$	seen	408
$\Omega^- K^+$	seen	523
$\Xi^- e^+ \nu_e$	seen	883
$\Xi^- \ell^+$ 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  $m = 2574.1 \pm 3.3$  MeV

$m_{\Xi_c^{'+}} - m_{\Xi_c^+} = 107.8 \pm 3.0$  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	106



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

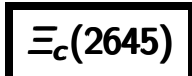
$J^P$  has not been measured;  $\frac{1}{2}^+$  is the quark-model prediction.

Mass  $m = 2578.8 \pm 3.2$  MeV

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

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)
$\Xi_c^{\prime 0} \gamma$	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  $m = 2647.4 \pm 2.0$  MeV ( $S = 1.2$ )

$\Xi_c(2645)^0$  mass  $m = 2644.5 \pm 1.8$  MeV

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

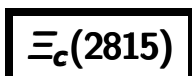
$m_{\Xi_c(2645)^0} - m_{\Xi_c^+} = 178.2 \pm 1.1$  MeV

$\Xi_c(2645)^+$  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	103
$\Xi_c^+ \pi^-$	seen	107



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

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

$\Xi_c(2815)^+$  mass  $m = 2814.9 \pm 1.8$  MeV

$\Xi_c(2815)^0$  mass  $m = 2819.0 \pm 2.5$  MeV

$m_{\Xi_c(2815)^+} - m_{\Xi_c^+} = 348.6 \pm 1.2$  MeV

$m_{\Xi_c(2815)^0} - m_{\Xi_c^0} = 347.2 \pm 2.1$  MeV

$\Xi_c(2815)^+$  full width  $\Gamma < 3.5$  MeV, CL = 90%

$\Xi_c(2815)^0$  full width  $\Gamma < 6.5$  MeV, CL = 90%

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	193



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

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

$$\text{Mass } m = 2704 \pm 4 \text{ MeV} \quad (S = 1.8)$$

$$\text{Mean life } \tau = (0.064 \pm 0.020) \times 10^{-12} \text{ s}$$

$$c\tau = 19 \mu\text{m}$$

$\Omega_c^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Sigma^+ K^- K^- \pi^+$	seen	697
$\Xi^- K^- \pi^+ \pi^+$	seen	838
$\Omega^- \pi^+$	seen	827
$\Omega^- \pi^- \pi^+ \pi^+$	seen	759

# BOTTOM BARYONS

## ( $B = -1$ )

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



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

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

$$\text{Mass } m = 5624 \pm 9 \text{ MeV} \quad (S = 1.8)$$

$$\text{Mean life } \tau = (1.229 \pm 0.080) \times 10^{-12} \text{ s}$$

$$c\tau = 368 \text{ } \mu\text{m}$$

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  $B(b \rightarrow b\text{-baryon}) = (11.6 \pm 2.0)\%$ .

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."

$\Lambda_b^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$P$ (MeV/c)
$J/\psi(1S)\Lambda$	$(4.7 \pm 2.8) \times 10^{-4}$		1744
$\Lambda_c^+ \pi^-$	seen		2345
$\Lambda_c^+ a_1(1260)^-$	seen		2156
$\Lambda_c^+ \ell^- \bar{\nu}_\ell \text{ anything}$	[r] $(7.9 \pm 1.9)\%$		—
$p\pi^-$	$< 5.0 \times 10^{-5}$	90%	2732
$pK^-$	$< 5.0 \times 10^{-5}$	90%	2711

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

$$\text{Mean life } \tau = (1.208 \pm 0.051) \times 10^{-12} \text{ s}$$

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  $B(b \rightarrow b\text{-baryon}) = (11.6 \pm 2.0)\%$ .



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."

<b><math>b</math>-baryon ADMIXTURE (<math>\Lambda_b, \Xi_b, \Sigma_b, \Omega_b</math>)</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$p \mu^- \bar{\nu}$ anything	$(4.2^{+1.8}_{-1.5})\%$	—
$p \ell \bar{\nu}_\ell$ anything	$(4.1 \pm 1.0)\%$	—
$p$ anything	$(51 \pm 17)\%$	—
$\Lambda \ell^- \bar{\nu}_\ell$ anything	$(2.7 \pm 0.8)\%$	—
$\Lambda/\bar{\Lambda}$ anything	$(28 \pm 7)\%$	—
$\Xi^- \ell^- \bar{\nu}_\ell$ anything	$(4.8 \pm 1.3) \times 10^{-3}$	—

## NOTES

- [a] The masses of the  $p$  and  $n$  are most precisely known in  $u$  (unified atomic mass units). The conversion factor to MeV,  $1 u = 931.494013 \pm 0.000037$  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 geochemical and independent of decay mode. 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] 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.
- [i] See the Listings for the pion momentum range used in this measurement.
- [j] The error given here is only an educated guess. It is larger than the error on the weighted average of the published values.
- [k] A theoretical value using QED.
- [l] See the "Note on  $\Lambda_c^+$  Branching Fractions" in the Branching Fractions of the  $\Lambda_c^+$  Particle Listings.
- [m] This branching fraction includes all the decay modes of the final-state resonance.
- [n] An  $\ell$  indicates an  $e$  or a  $\mu$  mode, not a sum over these modes.

- [o] The value is for the sum of the charge states or particle/antiparticle states indicated.
- [p] Assuming isospin conservation, so that the other third is  $\Lambda_c^+ \pi^0 \pi^0$ .
- [q] No absolute branching fractions have been measured. The following are branching *ratios* relative to  $\Xi^- \pi^+ \pi^+$ .
- [r] Not a pure measurement. See note at head of  $\Lambda_b^0$  Decay Modes.