

Properties of low-mass baryons

| | | | | | Marie and the second | | | | |
|-----------|---|--------------------------------------|-----------------------------|-----------------------------------|----------------------|---------------------------------|---------------------------------|---|---------------------|
| Name | Symbol | Spin (parity) | T Isospin | T ₃ Isospin projection | Hyper charge | Mass [MeV] | τ Lifetime | Main decay | Branching ratio [%] |
| | (p | 1/2+ | 1/2 | 1/2 | 1 | 938.3 | ∞ | | |
| Nucleon | $N \begin{cases} n \end{cases}$ | 1/2 ⁺ 1/2 ⁺ | 1/2 | $-\frac{1}{2}$ | 1 | 939.6 | 15 min | $pe^-\bar{v}_e$ | 100 |
| Hyperons | | | | | | | | | |
| Lambda 10 | 1/2+ | 0 | 0 | 0 | 1116 | $2.6 \times 10^{-10} \text{ s}$ | $p\pi^-$ | 64.2 | |
| | | | | | | | $n\pi^0$ | 35.8 | |
| | $(\Sigma^+$ | 1/2+ | 1 | 1 | 0 | 1189 | $0.8 \times 10^{-10} \text{ s}$ | $p\pi^{0}$, $n\pi^{+}$ | 51.6, 48.4 |
| Sigma | $\Sigma \begin{cases} \Sigma^+ \\ \Sigma^0 \\ \Sigma^- \end{cases}$ | 1/2+ | 1 | 0 | 0 | 1192 | $5.8 \times 10^{-20} \text{ s}$ | $\Lambda\gamma$ | 100 |
| | Σ^- | 1/2 + 1/2 + 1/2 + | 1 | -1 | 0 | 1197 | 1.5×10^{-10} s | $n\pi^-$ | 100 |
| | _ (\(\varepsilon^{\alpha}\) | 1/2+ | $\frac{1}{2}$ | $\frac{1}{2}$ | - 1 | 1315 | 2.9×10^{-10} s | $\Lambda\pi^0$ | 100 |
| Xi | $\mathcal{\Xi}\left\{egin{array}{l} \mathcal{\Xi}^{0} \\ \mathcal{\Xi}^{-} \end{array} ight.$ | 1/2 ⁺ 1/2 ⁺ | $\frac{1}{2}$ $\frac{1}{2}$ | $-\frac{1}{2}$ | - 1 | 1321 | $1.6 \times 10^{-10} \text{ s}$ | $\Lambda\pi^-$ | 100 |
| Omega | Ω- | 3/2+ | 0 | 0 | - 2 | 1672 | $0.8 \times 10^{-10} \text{ s}$ | $\Lambda K^-, \Xi^0 \pi^-$ $\Xi^- \pi^0$ | 68.6, 23.6 8 |
| | | | | | | | | | |

$$|p\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix}, |n\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix} \qquad |\Sigma^{+}\rangle = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}, |\Sigma^{0}\rangle = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}, |\Sigma^{-}\rangle = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} \rightarrow I = 1$$

$$\rightarrow I = \frac{1}{2}$$

Low Mass baryons - II

| Properties | of | low-mass | baryons |
|------------|----|----------|---------|
|------------|----|----------|---------|

| Symbol | Spin (parity) | T Isospin | T ₃ Isospin projection | Hyper charge | Mass [MeV] | τ Lifetime | Main decay | Branching ratio [%] |
|---|---|---|---|--|--|--|--|--|
| (p | 1/2+ | 1/2 | 1/2 | 1 | 938.3 | ∞ | - | |
| N n | 1/2+ | $\frac{1}{2}$ | $-\frac{1}{2}$ | 1 | 939.6 | 15 min | $pe^-\bar{v}_e$ | 100 |
| | | | | | | | | |
| Λ^0 | 1/2+ | 0 | 0 | 0 | 1116 | $2.6 \times 10^{-10} \text{ s}$ | $p\pi^ n\pi^0$ | 64.2 35.8 |
| (5+ | 1 /2 + | 1 | 1 | 0 | 1189 | 0.8×10^{-10} s | | 51.6, 48.4 |
| 5 50 | 1/2+ | 1 | 0 | | | | - Transaction | 100 |
| $\left(\sum_{\Sigma^{-}}\right)^{2}$ | 1/2+ | 1 | – 1 | 0 | 1197 | $1.5 \times 10^{-10} \text{ s}$ | $n\pi^-$ | 100 |
| (<i>Ξ</i> ° | | | $\frac{1}{2}$ | - 1 | 1315 | 2.9×10^{-10} s | $\Lambda\pi^0$ | 100 |
| $^{arnothing}\left\{ arnothing_{arnothing}^{-} ight.$ | 1/2+ | $\frac{1}{2}$ | $-\frac{1}{2}$ | - 1 | 1321 | $1.6 \times 10^{-10} \text{ s}$ | $\Lambda\pi^-$ | 100 |
| Ω^- | 3/2+ | 0 | 0 | - 2 | 1672 | $0.8 \times 10^{-10} \text{ s}$ | $\Lambda K^-, \Xi^0 \pi^-$ $\Xi^- \pi^0$ | 68.6, 23.6 8 |
| | $N \begin{cases} p \\ n \end{cases}$ Λ^{0} $\Sigma \begin{cases} \Sigma^{+} \\ \Sigma^{0} \\ \Sigma^{-} \end{cases}$ $\Xi \begin{cases} \Xi^{0} \\ \Xi^{-} \end{cases}$ | $ \begin{array}{ccc} & (parity) \\ & J^{(p)} \\ N \begin{cases} p & 1/2^+ \\ n & 1/2^+ \end{cases} $ $ \Lambda^0 & 1/2^+ \\ \Sigma \begin{cases} \Sigma^+ & 1/2^+ \\ \Sigma^0 & 1/2^+ \\ \Sigma^- & 1/2^+ \end{cases} $ $ \Xi \begin{cases} \Xi^0 & 1/2^+ \\ \Xi^- & 1/2^+ \end{cases} $ | $ \begin{array}{cccccccccccccccccccccccccccccccccccc$ | $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$ |

$$|p\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix}, |n\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix} |\Xi^0\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix}, |\Xi^-\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

 $\rightarrow I = \frac{1}{2}$

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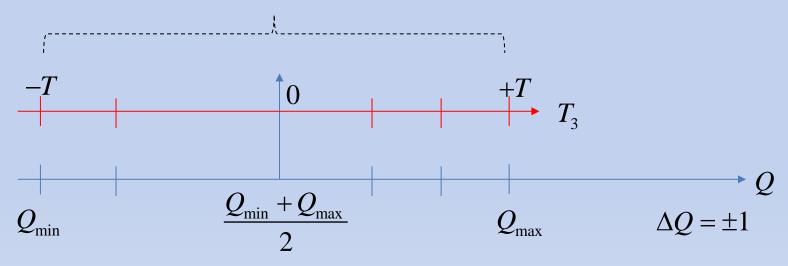
But different sets

→ Introduce Hypercharge

| Properties of the baryon resonances | | | | | | | | | |
|---|--|----------|---|-------|--------------------------------------|--------------------------|-------|----------------------------|------------------------------------|
| Symbol | J^{P} | Q | T | T_3 | Y Mass | Lifetime τ Γ | | Main decay channels | Resonant partial waves |
| | | | | | [MeV] | [s] | [MeV] | chamicis | partial waves |
| (\(\Delta + + \) | 3/2+ | 2 | | | | | | | |
| $N*$ Δ^+ | 3/2 ⁺ 3/2 ⁺ 3/2 ⁺ | 1 | | | 1232 ± 2 | 5.49×10^{-24} | 120 | $N\pi$ | $P_{33}\pi p$ |
| 1 | 3/2+ | 0 | | | 1232 1 2 | 3.47 × 10 | 120 | 1476 | 1 33 % |
| (<u></u> <u>/</u> | 3/2+ | - 1 | | | | | | | |
| N' SN'+ | 1/2+ | 1 | | | 1440 ± 40 | 3.13×10^{-24} | 210 | Νπ, Νππ | $P_{11} \pi p$ |
| N' N'' | 1/2+ | 0 | | | 1440 _ 40 | 3.13 × 10 | 210 | 1111, 11111 | 111 " P |
| 1* | $1/2^{-}$ | 0 | | | 1405 ± 5 | 1.65×10^{-23} | 40 | $\Sigma\pi$ | $S_{01} K^- p$ |
| $\sum_{n=0}^{\infty} \sum_{n=0}^{\infty}$ | 3/2+ | 1 | | | 1382.3 ± 0.4 | 1.50 10-25 | 25 | 4 5 | D W |
| $\sum^* \left\{ \begin{array}{l} \sum^{*0} \\ \sum^{*-1} \end{array} \right.$ | 3/2+ 3/2+ 3/2+ | 0 - 1 | | | 1382.0 ± 2.5 1387.4 ± 0.6 | 1.78×10^{-25} | 37 | $\Lambda\pi$, $\Sigma\pi$ | $P_{13} \mathrm{K}^{-} \mathrm{p}$ |
| Ξ* (Ξ*° | 3/2+ | 0 | | | 1531.8 ± 0.3 | 0.4. 10-23 | 7 | | D |
| Ξ^* $\left\{\Xi^{*-}\right\}$ | 3/2+ | - 1 | | | 1535.0 ± 0.6 | 9.4×10^{-23} | 7 | $\Xi\pi$ | P |

Each Isospin symmetric state from a representation of the of total isospin I=T the states in a representation have different T_3 but also different charge Q.

$$2T + 1$$
 States separated by $\Delta T = \pm 1$

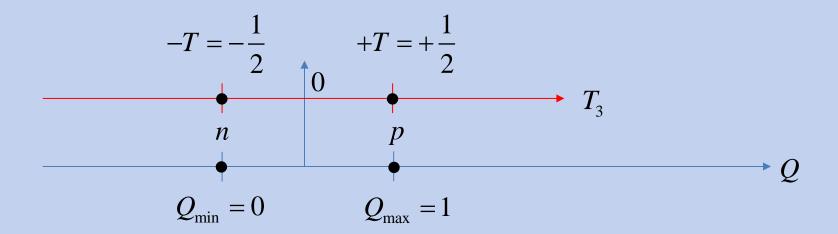


Determination of Isospin $2T = Q_{\text{max}} - Q_{\text{min}}$

When T3 increases by 1 so does Q $T_3 = Q + [$ State independent constant] Introduce Hypercharge common to all states in this set $Q = \frac{1}{2}Y + T_3$

$$\rightarrow$$
 $Q_{\text{max}} = \frac{1}{2}Y + T$, $Q_{\text{min}} = \frac{1}{2}Y - T$ \rightarrow $Y = Q_{\text{max}} + Q_{\text{min}}$

Example I: proton (p) and Neutron (n):



$$2T = Q_{\text{max}} - Q_{\text{min}} \qquad \to T = \frac{1}{2}$$

$$\rightarrow T = \frac{1}{2}$$

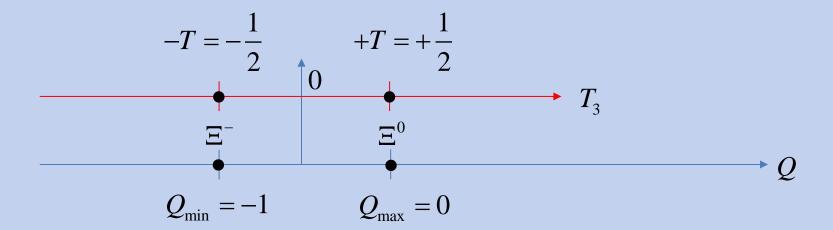
$$Q = \frac{1}{2}Y + T_3$$

$$Q = \frac{1}{2}Y + T_3$$
 $Y = Q_{\text{max}} + Q_{\text{min}} = 1$

$$p \rightarrow T = \frac{1}{2}, T_3 = +\frac{1}{2}, Y = 1$$

$$n \rightarrow T = \frac{1}{2}, T_3 = -\frac{1}{2}, Y = 1$$

Example I: Xi (Ξ) states:



Determination of Isospin $2T = Q_{\text{max}} - Q_{\text{min}} \rightarrow T = \frac{1}{2}$

$$2T = Q_{\text{max}} - Q_{\text{min}}$$

$$\rightarrow T = \frac{1}{2}$$

$$Q = \frac{1}{2}Y + T$$

Introduce Hypercharge
$$Q = \frac{1}{2}Y + T_3$$
 $Y = Q_{\text{max}} + Q_{\text{min}} = -1$

$$\Xi^{-} \rightarrow T = \frac{1}{2}, T_3 = +\frac{1}{2}, Y = -1$$

$$\Xi^0 \rightarrow T = \frac{1}{2}, T_3 = -\frac{1}{2}, Y = -1$$

Example III: Delta ∆ resonance :

$$-T = -\frac{3}{2}$$

$$+T = +\frac{3}{2}$$

$$\Delta^{-} \qquad \Delta^{0} \qquad \Delta^{+} \qquad \Delta^{++}$$

$$Q_{\min} = -1$$

$$Q_{\max} = 2$$

Determination of Isospin
$$2T = Q_{\text{max}} - Q_{\text{min}} \longrightarrow T = \frac{3}{2}$$

$$2T = Q_{\text{max}} - Q_{\text{min}}$$

$$\rightarrow T = \frac{3}{2}$$

$$Q = \frac{1}{2}Y + T_3$$

Introduce Hypercharge
$$Q = \frac{1}{2}Y + T_3$$
 $Y = Q_{\text{max}} + Q_{\text{min}} = 1$

$$\Delta^{++} \rightarrow T = \frac{3}{2}, \quad T_3 = +\frac{3}{2}, \quad Y = 1$$
 $\Delta^0 \rightarrow T = \frac{3}{2}, \quad T_3 = -\frac{1}{2}, \quad Y = 1$
 $\Delta^+ \rightarrow T = \frac{3}{2}, \quad T_3 = +\frac{1}{2}, \quad Y = 1$
 $\Delta^- \rightarrow T = \frac{3}{2}, \quad T_3 = -\frac{3}{2}, \quad Y = 1$

$$\Delta^0 \to T = \frac{3}{2}, T_3 = -\frac{1}{2}, Y =$$

$$\Delta^+ \rightarrow T = \frac{3}{2}, \quad T_3 = +\frac{1}{2}, \quad Y = 1$$

$$\Delta^{-} \rightarrow T = \frac{3}{2}, T_{3} = -\frac{3}{2}, Y = 1$$

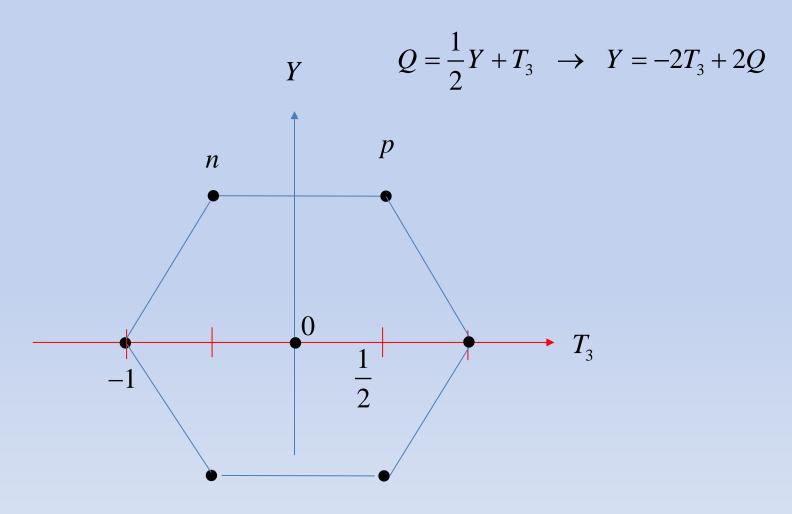
Example IV: Quantum number of a nuclei composed of Z number of (p) and N (n)

Only T3 and Y is well determined

$$T_3 = \sum_{i=p,n} T_3(i) = \frac{1}{2}(Z-N)$$

From
$$Q = \frac{1}{2}Y + T_3$$
 $\rightarrow Z = \frac{1}{2}Y + T_3$ $\rightarrow Y = Z + N$

□ plot of T3 and Y



prediction of particle before observation

