MASS SPECTRA OF EXCITED BARYONS IN A MEAN-FIELD APPROACH

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CONTENTS

MOTIVATION

p	$1/2^+$	****
n	$1/2^+$	****
$N(1440)$	$1/2^+$	****
$N(1520)$	$3/2^-$	****
$N(1535)$	$1/2^-$	****
$N(1650)$	$1/2^-$	****
$N(1675)$	$5/2^-$	****
$N(1680)$	$5/2^+$	****
$N(1700)$	$3/2^-$	***
$N(1710)$	$1/2^+$	****
$N(1720)$	$3/2^+$	****
$N(1860)$	$5/2^+$	**
$N(1875)$	$3/2^-$	***
$N(1880)$	$1/2^+$	**
$N(1895)$	$1/2^-$	**
$N(1900)$	$3/2^+$	***
$N(1990)$	$7/2^+$	**
$N(2000)$	$5/2^+$	**
$N(2040)$	$3/2^+$	*
$N(2060)$	$5/2^-$	**
$N(2100)$	$1/2^+$	*
$N(2120)$	$3/2^-$	**

$\Delta(1232)$	$3/2^+$	****
$\Delta(1600)$	$3/2^+$	***
$\Delta(1620)$	$1/2^-$	****
$\Delta(1700)$	$3/2^-$	****
$\Delta(1750)$	$1/2^+$	*
$\Delta(1900)$	$1/2^-$	**
$\Delta(1905)$	$5/2^+$	****
$\Delta(1910)$	$1/2^+$	****
$\Delta(1920)$	$3/2^+$	***
$\Delta(1930)$	$5/2^-$	***
$\Delta(1940)$	$3/2^-$	**
$\Delta(1950)$	$7/2^+$	****
$\Delta(2000)$	$5/2^+$	**
$\Delta(2150)$	$1/2^-$	*
$\Delta(2200)$	$7/2^-$	*

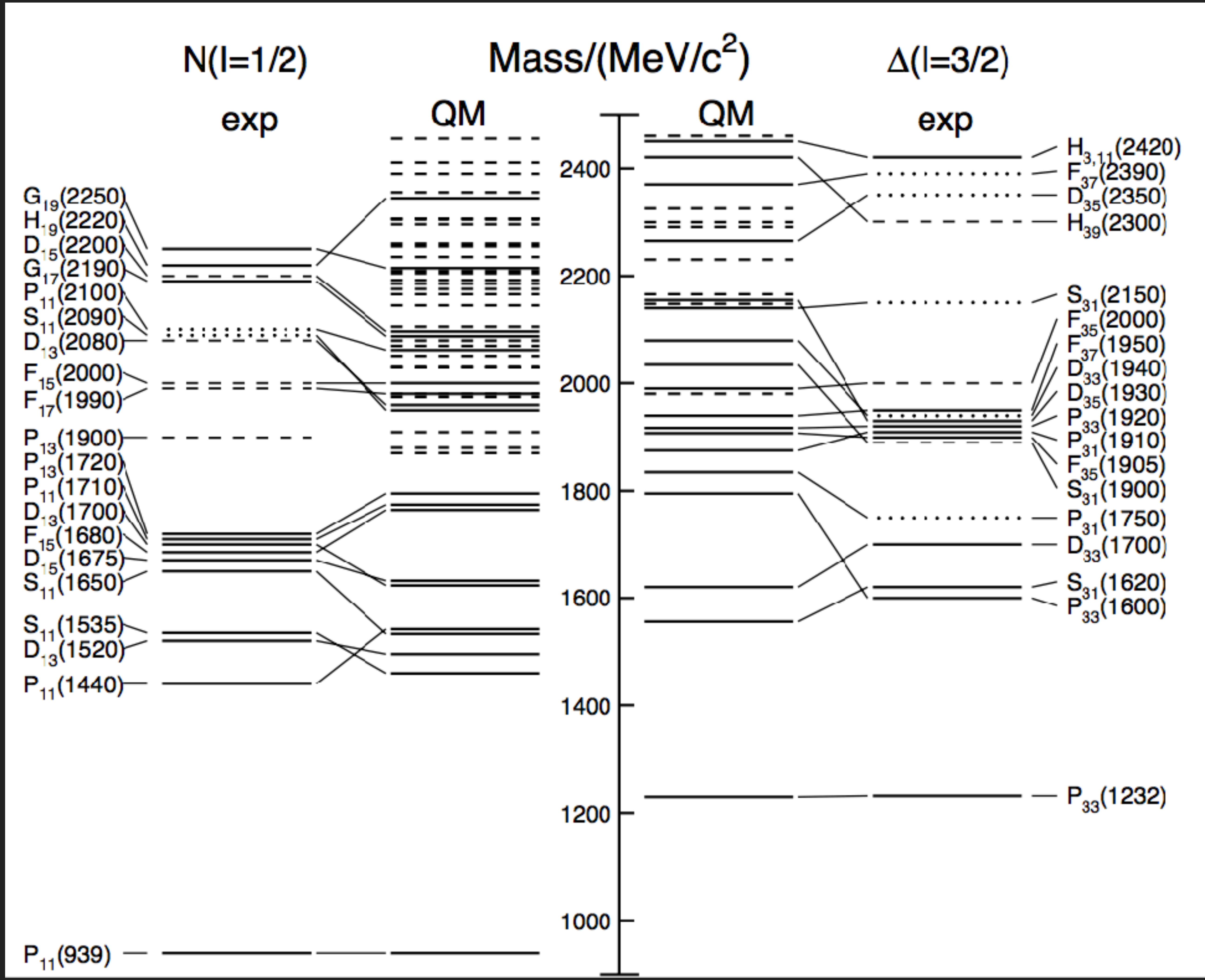
Λ	$1/2^+$	****
$\Lambda(1405)$	$1/2^-$	****
$\Lambda(1520)$	$3/2^-$	****
$\Lambda(1600)$	$1/2^+$	***
$\Lambda(1670)$	$1/2^-$	****
$\Lambda(1690)$	$3/2^-$	****
$\Lambda(1710)$	$1/2^+$	*
$\Lambda(1800)$	$1/2^-$	***
$\Lambda(1810)$	$1/2^+$	***
$\Lambda(1820)$	$5/2^+$	****
$\Lambda(1830)$	$5/2^-$	****
$\Lambda(1890)$	$3/2^+$	****
$\Lambda(2000)$		*
$\Lambda(2020)$	$7/2^+$	*
$\Lambda(2050)$	$3/2^-$	*
$\Lambda(2100)$	$7/2^-$	****
$\Lambda(2110)$	$5/2^+$	***

Σ^+	$1/2^+$	****
Σ^0	$1/2^+$	****
Σ^-	$1/2^+$	****
$\Sigma(1385)$	$3/2^+$	****
$\Sigma(1480)$		*
$\Sigma(1560)$		**
$\Sigma(1580)$	$3/2^-$	*
$\Sigma(1620)$	$1/2^-$	*
$\Sigma(1660)$	$1/2^+$	***
$\Sigma(1670)$	$3/2^-$	****
$\Sigma(1690)$		**
$\Sigma(1730)$	$3/2^+$	*
$\Sigma(1750)$	$1/2^-$	***
$\Sigma(1770)$	$1/2^+$	*
$\Sigma(1775)$	$5/2^-$	****
$\Sigma(1840)$	$3/2^+$	*
$\Sigma(1880)$	$1/2^+$	**
$\Sigma(1900)$	$1/2^-$	*
$\Sigma(1915)$	$5/2^+$	****
$\Sigma(1940)$	$3/2^+$	*
$\Sigma(1940)$	$3/2^-$	***
$\Sigma(2000)$	$1/2^-$	*
$\Sigma(2030)$	$7/2^+$	****
$\Sigma(2070)$	$5/2^+$	*
$\Sigma(2080)$	$3/2^+$	**
$\Sigma(2100)$	$7/2^-$	*
$\Sigma(2250)$		***

Ξ^0	$1/2^+$	****
Ξ^-	$1/2^+$	****
$\Xi(1530)$	$3/2^+$	****
$\Xi(1620)$		*
$\Xi(1690)$		***
$\Xi(1820)$	$3/2^-$	***
$\Xi(1950)$		***
$\Xi(2030)$	$\geq \frac{5}{2}?$	***
$\Xi(2120)$		*
$\Xi(2250)$		**
$\Xi(2370)$		**
$\Xi(2500)$		*
Ω^-	$3/2^+$	****
$\Omega(2250)^-$		***
$\Omega(2380)^-$		**
$\Omega(2470)^-$		**

[http://pdg.lbl.gov/2017/tables/rpp2017-qtab-baryons.pdf]

MOTIVATION



[S. Capstick and W. Roberts, Phys. Rev. D49, 4570 (1994), D57, 4301 (1998), D58, 074011 (1998)

S. Capstick, Phys. Rev. D46, 2864 (1992)

U. Löring et al, Eur. Phys. J. A 10, 309 (2001)

http://pdg.lbl.gov/2008/reviews/rpp2008-rev-quark-model.pdf]

MOTIVATION

- Many of the baryons are known below 2 GeV
- Quark model is not enough to describe their mass spectra
- Solitonic model, e.g. Skryme model, do not contain explicit quarks
- Chiral quark soliton model(CQSM) is a bridge between the 2 models
- Quarks are bound by the mesonic mean-field at large N_c

[D. Diakonov, V. Petrov, and A. Vladimirov, Phys. Rev. D88, 074030 (2013)]

EFFECTIVE CHIRAL ACTION

$$\mathcal{L}_e = \bar{\psi}\left[i\gamma^\mu\partial_\mu - \hat{m} - MU^{\gamma_5}\right]\psi \qquad U^{\gamma_5} = e^{i\gamma_5\tau^a\pi^a} \qquad \hat{m} = \mathrm{diag}\left(m_u,\, m_d,\, m_s\right)$$

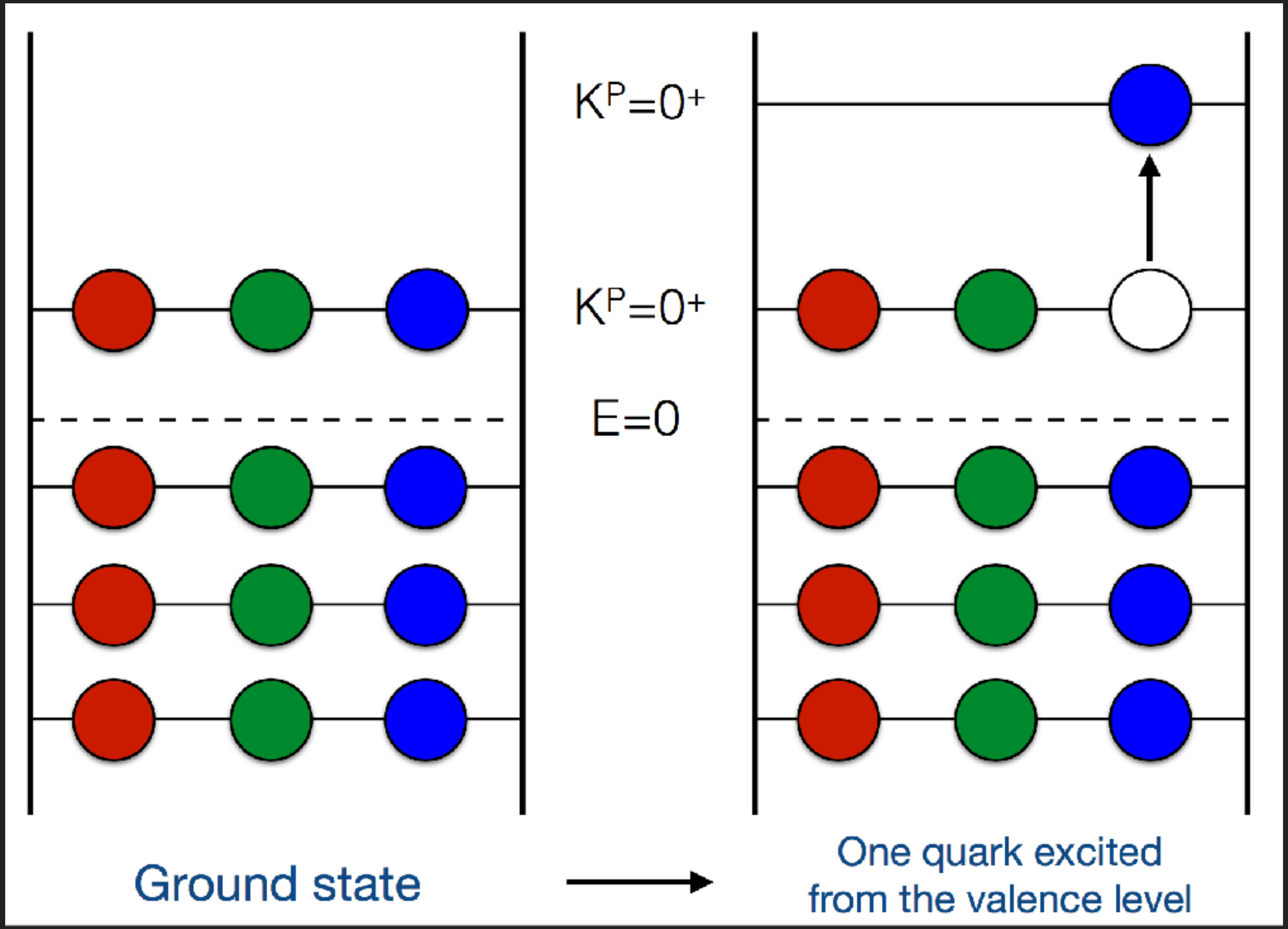
$$\Rightarrow \quad \mathcal{S}_e = -N_c Trln\left[\partial_\tau + h(U)\right] \qquad h(U) = -i\gamma^0\gamma^k\partial_k + \gamma^0\hat{m} + \gamma^0 MU^{\gamma_5}$$

$$\Rightarrow \quad \mathcal{S}_e = -N_c Trln\left[\partial_\tau + h(U) + i\Omega + \delta m\right]$$

$$\Pi(x'-x) = \langle 0\left| J(x')J^\dagger(x)\right| 0\rangle$$
$$\sim \exp\left[-\mathcal{S}_e\left(\Omega^0,\, \delta m^0\right) - \mathcal{S}_e\left(\Omega^1,\, \delta m^0\right) - \mathcal{S}_e\left(\Omega^0,\, \delta m^1\right) - \mathcal{S}_e\left(\Omega^1,\, \delta m^1\right) - \mathcal{S}_e\left(\Omega^2,\, \delta m^0\right)\right]$$

$$J(x) = \frac{1}{N_c!}\epsilon^{\beta_1\cdots\beta_{N_c}}\Gamma^{\{f\}}_{JJ_3,TT_3}\psi_{\beta_1 f_1}(x)\cdots\psi_{\beta_{N_c} f_{N_c}}(x)$$ [B. L. Ioffe, Nucl. Phys. B188, 317 (1981)]

MASS SPLITTING



MASS SPLITTING

- Center energy of the multiplets

$$\mathcal{H}_K = \frac{1}{2I_2}\Sigma_{a=4}^{7}(\tilde{T}_a)^2 + \frac{(\tilde{T} - \tilde{a}_K\hat{K})^2}{2I_1}$$

Quantization conditions :

$$\tilde{T} + \tilde{J} = \hat{K},\ \tilde{Y} = \frac{N_c}{3}$$

$$\mathcal{E}_K = \frac{C_2(SU(3)) - \tilde{T}(\tilde{T}+1) - \frac{3}{4}\tilde{Y}^2}{2I_2} + \frac{1}{2I_1}\left[\tilde{a}_K J(J+1) + (1-\tilde{a}_K)\tilde{T}(\tilde{T}+1) - \tilde{a}_K(1-\tilde{a}_K)K(K+1)\right]$$

$$C_2(SU(3)) = \frac{1}{3}\left[p^2 + q^2 + pq + 3(p+q)\right]$$

MASS SPLITTING

- Splitting inside a multiplet

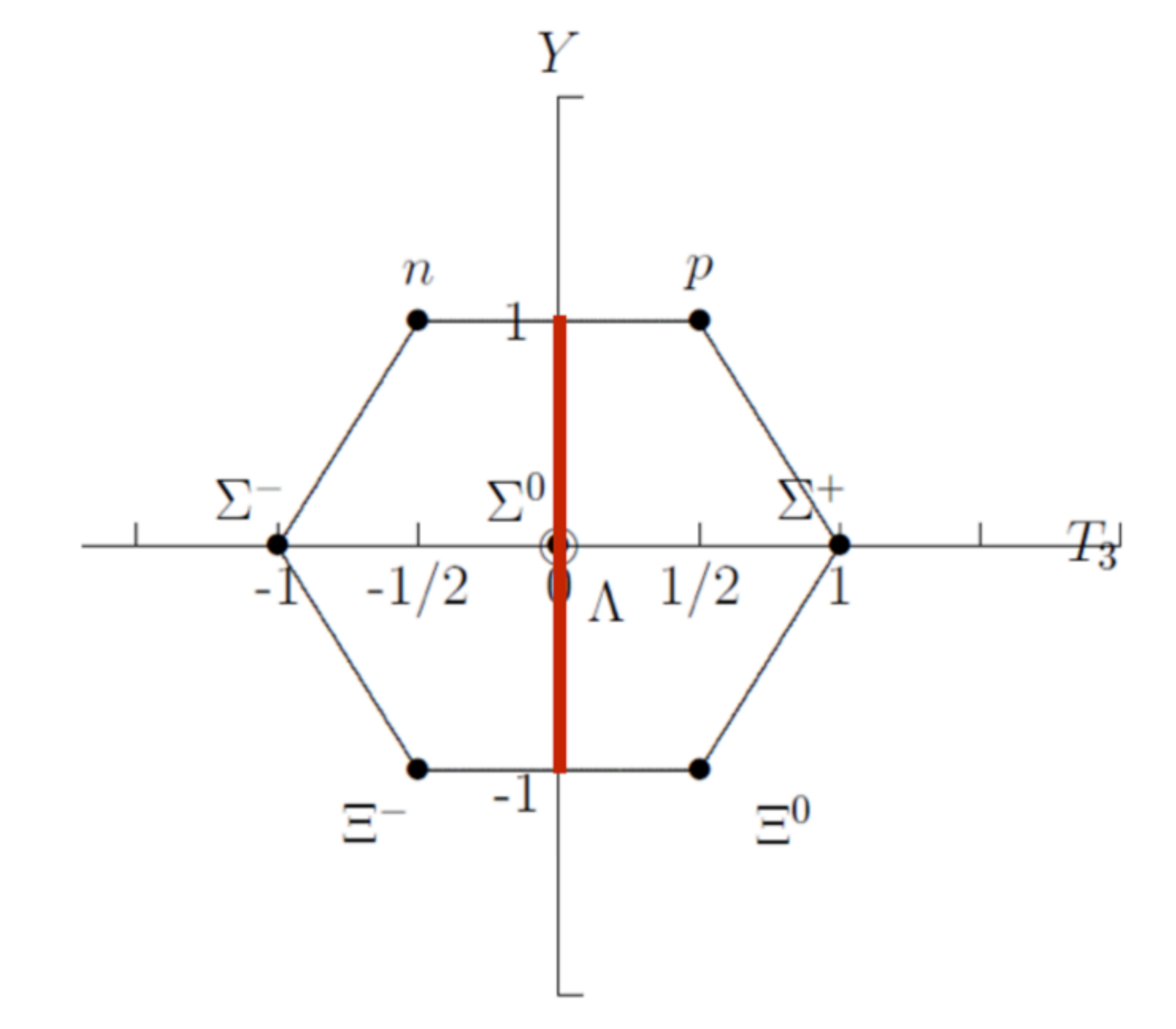
$$\mathcal{H}_{br} = \alpha \mathcal{D}^{(8)}_{88}(R) + \beta \hat{Y} - \frac{\gamma}{\sqrt{3}} \sum_{i=1}^{3} \mathcal{D}^{(8)}_{8i}(R) \tilde{T}_i - \frac{\delta}{\sqrt{3}} \sum_{i=1}^{3} \mathcal{D}^{(8)}_{8i}(R) \hat{K}_i$$

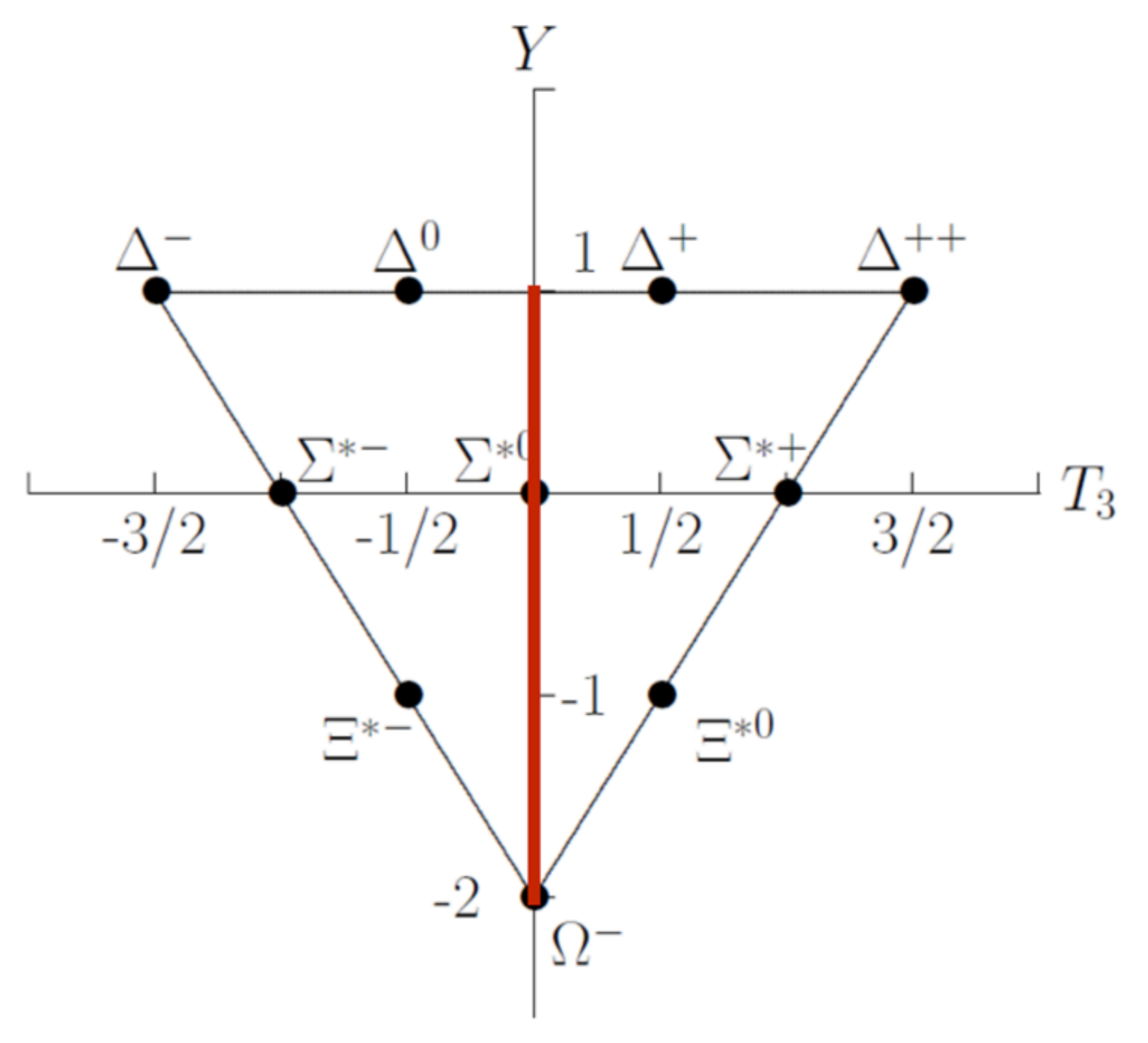
$$\alpha = -\frac{2}{3}\frac{m_s}{m_u + m_d}\sigma + m_s \frac{K_2}{I_2} \qquad \beta = -m_s \frac{K_2}{I_2} \qquad \gamma = 2m_s \left(\frac{K_1}{I_1} - \frac{K_2}{I_2}\right) \qquad \delta = 2m_s \left(d_K - \frac{K_1}{I_1}\tilde{a}_K\right)$$

- Excited baryon masses are given by the matrix elements

$$M_B = \langle B \,| M_{cl} + \Delta\mathcal{E}_{0K} + \mathcal{H}_K + \mathcal{H}_{br} |\, B \rangle$$

MODEL-INDEPENDENT CALCULATION





MODEL-INDEPENDENT CALCULATION

- Center energy of the multiplets

8	$J=\frac{1}{2}$	$J=\frac{3}{2}$	$J=\frac{5}{2}$
K=0	$\frac{3}{8\,\mathrm{MI1}}+\frac{3}{4\,\mathrm{MI2}}$		
K=1	$\frac{a(1)^2}{\mathrm{MI1}}-\frac{a(1)}{\mathrm{MI1}}+\frac{3}{8\,\mathrm{MI1}}+\frac{3}{4\,\mathrm{MI2}}$	$\frac{a(1)^2}{\mathrm{MI1}}+\frac{a(1)}{2\,\mathrm{MI1}}+\frac{3}{8\,\mathrm{MI1}}+\frac{3}{4\,\mathrm{MI2}}$	
K=2		$\frac{3\,a(2)^2}{\mathrm{MI1}}-\frac{3\,a(2)}{2\,\mathrm{MI1}}+\frac{3}{8\,\mathrm{MI1}}+\frac{3}{4\,\mathrm{MI2}}$	$\frac{3\,a(2)^2}{\mathrm{MI1}}+\frac{a(2)}{\mathrm{MI1}}+\frac{3}{8\,\mathrm{MI1}}+\frac{3}{4\,\mathrm{MI2}}$

10	$J=\frac{1}{2}$	$J=\frac{3}{2}$	$J=\frac{5}{2}$	$J=\frac{7}{2}$
K=0		$\frac{15}{8\,\mathrm{MI1}}+\frac{3}{4\,\mathrm{MI2}}$		
K=1	$\frac{a(1)^2}{\mathrm{MI1}}-\frac{5\,a(1)}{2\,\mathrm{MI1}}+\frac{15}{8\,\mathrm{MI1}}+\frac{3}{4\,\mathrm{MI2}}$	$\frac{a(1)^2}{\mathrm{MI1}}-\frac{a(1)}{\mathrm{MI1}}+\frac{15}{8\,\mathrm{MI1}}+\frac{3}{4\,\mathrm{MI2}}$	$\frac{a(1)^2}{\mathrm{MI1}}+\frac{3\,a(1)}{2\,\mathrm{MI1}}+\frac{15}{8\,\mathrm{MI1}}+\frac{3}{4\,\mathrm{MI2}}$	
K=2	$\frac{3\,a(2)^2}{\mathrm{MI1}}-\frac{9\,a(2)}{2\,\mathrm{MI1}}+\frac{15}{8\,\mathrm{MI1}}+\frac{3}{4\,\mathrm{MI2}}$	$\frac{3\,a(2)^2}{\mathrm{MI1}}-\frac{3\,a(2)}{\mathrm{MI1}}+\frac{15}{8\,\mathrm{MI1}}+\frac{3}{4\,\mathrm{MI2}}$	$\frac{3\,a(2)^2}{\mathrm{MI1}}-\frac{a(2)}{2\,\mathrm{MI1}}+\frac{15}{8\,\mathrm{MI1}}+\frac{3}{4\,\mathrm{MI2}}$	$\frac{3\,a(2)^2}{\mathrm{MI1}}+\frac{3\,a(2)}{\mathrm{MI1}}+\frac{15}{8\,\mathrm{MI1}}+\frac{3}{4\,\mathrm{MI2}}$

$\overline{10}$	$J=\frac{1}{2}$	$J=\frac{3}{2}$	$J=\frac{5}{2}$
K=0	$\frac{3}{8\,\mathrm{MI1}}+\frac{9}{4\,\mathrm{MI2}}$		
K=1	$\frac{a(1)^2}{\mathrm{MI1}}-\frac{a(1)}{\mathrm{MI1}}+\frac{3}{8\,\mathrm{MI1}}+\frac{9}{4\,\mathrm{MI2}}$	$\frac{a(1)^2}{\mathrm{MI1}}+\frac{a(1)}{2\,\mathrm{MI1}}+\frac{3}{8\,\mathrm{MI1}}+\frac{9}{4\,\mathrm{MI2}}$	
K=2		$\frac{3\,a(2)^2}{\mathrm{MI1}}-\frac{3\,a(2)}{2\,\mathrm{MI1}}+\frac{3}{8\,\mathrm{MI1}}+\frac{9}{4\,\mathrm{MI2}}$	$\frac{3\,a(2)^2}{\mathrm{MI1}}+\frac{a(2)}{\mathrm{MI1}}+\frac{3}{8\,\mathrm{MI1}}+\frac{9}{4\,\mathrm{MI2}}$

MODEL-INDEPENDENT CALCULATION

- Splitting inside a octet

N	$J=\frac{1}{2}$	$J=\frac{3}{2}$	$J=\frac{5}{2}$
K=0	$\frac{3\alpha}{10}+\beta-\frac{\gamma}{20}$		
K=1	$\frac{3\alpha}{10}+\beta-\frac{\gamma}{20}-\frac{\delta}{15}$	$\frac{3\alpha}{10}+\beta-\frac{\gamma}{20}+\frac{\delta}{30}$	
K=2		$\frac{3\alpha}{10}+\beta-\frac{\gamma}{20}-\frac{\delta}{10}$	$\frac{3\alpha}{10}+\beta-\frac{\gamma}{20}+\frac{\delta}{15}$

Λ	$J=\frac{1}{2}$	$J=\frac{3}{2}$	$J=\frac{5}{2}$
K=0	$\frac{\alpha}{10}+\frac{3\gamma}{20}$		
K=1	$\frac{\alpha}{10}+\frac{3\gamma}{20}+\frac{\delta}{5}$	$\frac{\alpha}{10}+\frac{3\gamma}{20}-\frac{\delta}{10}$	
K=2		$\frac{\alpha}{10}+\frac{3\gamma}{20}+\frac{3\delta}{10}$	$\frac{\alpha}{10}+\frac{3\gamma}{20}-\frac{\delta}{5}$

Σ	$J=\frac{1}{2}$	$J=\frac{3}{2}$	$J=\frac{5}{2}$
K=0	$-\frac{\alpha}{10}-\frac{3\gamma}{20}$		
K=1	$-\frac{\alpha}{10}-\frac{3\gamma}{20}-\frac{\delta}{5}$	$-\frac{\alpha}{10}-\frac{3\gamma}{20}+\frac{\delta}{10}$	
K=2		$-\frac{\alpha}{10}-\frac{3\gamma}{20}-\frac{3\delta}{10}$	$-\frac{\alpha}{10}-\frac{3\gamma}{20}+\frac{\delta}{5}$

Ξ	$J=\frac{1}{2}$	$J=\frac{3}{2}$	$J=\frac{5}{2}$
K=0	$-\frac{\alpha}{5}-\beta+\frac{\gamma}{5}$		
K=1	$-\frac{\alpha}{5}-\beta+\frac{\gamma}{5}+\frac{4\delta}{15}$	$-\frac{\alpha}{5}-\beta+\frac{\gamma}{5}-\frac{2\delta}{15}$	
K=2		$-\frac{\alpha}{5}-\beta+\frac{\gamma}{5}+\frac{2\delta}{5}$	$-\frac{\alpha}{5}-\beta+\frac{\gamma}{5}-\frac{4\delta}{15}$

MODEL-INDEPENDENT CALCULATION

- Splitting inside a decuplet

Δ	$J=\frac{1}{2}$	$J=\frac{3}{2}$	$J=\frac{5}{2}$	$J=\frac{7}{2}$
K=0		$\frac{\alpha}{8}+\beta-\frac{5\gamma}{16}$		
K=1	$\frac{\alpha}{8}+\beta-\frac{5\gamma}{16}-\frac{5\delta}{24}$	$\frac{\alpha}{8}+\beta-\frac{5\gamma}{16}-\frac{\delta}{12}$	$\frac{\alpha}{8}+\beta-\frac{5\gamma}{16}+\frac{\delta}{8}$	
K=2	$\frac{\alpha}{8}+\beta-\frac{5\gamma}{16}-\frac{3\delta}{8}$	$\frac{\alpha}{8}+\beta-\frac{5\gamma}{16}-\frac{\delta}{4}$	$\frac{\alpha}{8}+\beta-\frac{5\gamma}{16}-\frac{\delta}{24}$	$\frac{\alpha}{8}+\beta-\frac{5\gamma}{16}+\frac{\delta}{4}$

Σ^*	$J=\frac{1}{2}$	$J=\frac{3}{2}$	$J=\frac{5}{2}$	$J=\frac{7}{2}$
K=0		0		
K=1	0	0	0	
K=2	0	0	0	0

Ξ^*	$J=\frac{1}{2}$	$J=\frac{3}{2}$	$J=\frac{5}{2}$	$J=\frac{7}{2}$
K=0		$-\frac{\alpha}{8}-\beta+\frac{5\gamma}{16}$		
K=1	$-\frac{\alpha}{8}-\beta+\frac{5\gamma}{16}+\frac{5\delta}{24}$	$-\frac{\alpha}{8}-\beta+\frac{5\gamma}{16}+\frac{\delta}{12}$	$-\frac{\alpha}{8}-\beta+\frac{5\gamma}{16}-\frac{\delta}{8}$	
K=2	$-\frac{\alpha}{8}-\beta+\frac{5\gamma}{16}+\frac{3\delta}{8}$	$-\frac{\alpha}{8}-\beta+\frac{5\gamma}{16}+\frac{\delta}{4}$	$-\frac{\alpha}{8}-\beta+\frac{5\gamma}{16}+\frac{\delta}{24}$	$-\frac{\alpha}{8}-\beta+\frac{5\gamma}{16}-\frac{\delta}{4}$

Ω	$J=\frac{1}{2}$	$J=\frac{3}{2}$	$J=\frac{5}{2}$	$J=\frac{7}{2}$
K=0		$-\frac{\alpha}{4}-2\beta+\frac{5\gamma}{8}$		
K=1	$-\frac{\alpha}{4}-2\beta+\frac{5\gamma}{8}+\frac{5\delta}{12}$	$-\frac{\alpha}{4}-2\beta+\frac{5\gamma}{8}+\frac{\delta}{6}$	$-\frac{\alpha}{4}-2\beta+\frac{5\gamma}{8}-\frac{\delta}{4}$	
K=2	$-\frac{\alpha}{4}-2\beta+\frac{5\gamma}{8}+\frac{3\delta}{4}$	$-\frac{\alpha}{4}-2\beta+\frac{5\gamma}{8}+\frac{\delta}{2}$	$-\frac{\alpha}{4}-2\beta+\frac{5\gamma}{8}+\frac{\delta}{12}$	$-\frac{\alpha}{4}-2\beta+\frac{5\gamma}{8}-\frac{\delta}{2}$

MODEL-INDEPENDENT CALCULATION

Octet	(J,P)	N	Λ	Σ	Ξ	(K,P)
56,L=0	($\frac{1}{2}$,+)	939	1115	1192	1317	(0,+),Ground
	($\frac{1}{2}$,+)	1440	1600	1660	1690	(0,+)
	($\frac{1}{2}$,+)	1710	1810	1880	1950	(1,+)
70,L=1	($\frac{3}{2}$,−)	1520	1690	1670	1820	(1,−)
	($\frac{1}{2}$,−)	1535	1670	1560	1700	(1,−)
	($\frac{3}{2}$,−)	1700	1850	1940	2045	(2,−)
	($\frac{5}{2}$,−)	1675	1830	1775	1960	(2,−)
	($\frac{1}{2}$,−)	1650	1800	1620	1900	(0,−)
56,L=2	($\frac{5}{2}$,+)	1680	1820	1915	2030	(2,+)
	($\frac{3}{2}$,+)	1720	1890	1840	2035	(2,+)

Decuplet	(J,P)	Δ	Σ	Ξ	Ω	(K,P)
56,L=0	($\frac{3}{2}$,+)	1232	1385	1530	1672	(0,+),Ground
	($\frac{3}{2}$,+)	1600	1690	1780	1870	(0,+)
70,L=1	($\frac{1}{2}$,−)	1620	1750	1900	2050	(1,−)
	($\frac{3}{2}$,−)	1700	1808	1915	2023	(1,−)
56,L=2	($\frac{3}{2}$,+)	1920	2080	2240	2470	(2,+)
	($\frac{5}{2}$,+)	1905	2070	2250	2380	(2,+)
	($\frac{1}{2}$,+)	1910	2060	2210	2360	(1,+)
	($\frac{7}{2}$,+)	1950	2030	2120	2250	(2,+)
AntiDecuplet	(J,P)	Θ^+	$N_{\overline{10}}$	$\Sigma_{\overline{10}}$	$\Xi_{\overline{10}}$	(K,P)
	($\frac{1}{2}$,+)	1540	1670	1760	1862	Ground

V. Guzey, M. V. Polyakov, hep-ph/0512355 (2005)

MODEL-INDEPENDENT CALCULATION

- Center masses

Octet	(J,P)	$\frac{2N+\Lambda+3\Sigma+2\Xi}{8}$	$\frac{N+\Sigma+\Xi}{3}$	$\frac{\Lambda+\Sigma}{2}$	N+Ξ−Λ	(K,P)
56,L=0	$(\frac{1}{2},+)$	1150.38	1149.33	1153.5	1141	(0,+),Ground
	$(\frac{1}{2},+)$	1605.	1596.67	1630.	1530	(0,+)
	$(\frac{1}{2},+)$	1846.25	1846.67	1845.	1850	(1,+)
70,L=1	$(\frac{3}{2},-)$	1672.5	1670.	1680.	1650	(1,−)
	$(\frac{1}{2},-)$	1602.5	1598.33	1615.	1565	(1,−)
	$(\frac{3}{2},-)$	1895.	1895.	1895.	1895	(2,−)
	$(\frac{5}{2},-)$	1803.13	1803.33	1802.5	1805	(2,−)
	$(\frac{1}{2},-)$	1720.	1723.33	1710.	1750	(0,−)
56,L=2	$(\frac{5}{2},+)$	1873.13	1875.	1867.5	1890	(2,+)
	$(\frac{3}{2},+)$	1865.	1865.	1865.	1865	(2,+)

Decuplet	(J,P)	$\frac{4\Delta+3\Sigma+2\Xi+\Omega}{10}$	$\frac{\Delta+\Sigma+\Xi}{3}$	Σ	$\frac{2\Delta+\Sigma+\Omega}{4}$	(K,P)
56,L=0	$(\frac{3}{2},+)$	1381.5	1382.33	1385	1380.25	(0,+),Ground
	$(\frac{3}{2},+)$	1690.	1690.	1690	1690.	(0,+)
70,L=1	$(\frac{1}{2},-)$	1758.	1756.67	1750	1760.	(1,−)
	$(\frac{3}{2},-)$	1807.7	1807.67	1808	1807.75	(1,−)
56,L=2	$(\frac{3}{2},+)$	2087.	2080.	2080	2097.5	(2,+)
	$(\frac{5}{2},+)$	2071.	2075.	2070	2065.	(2,+)
	$(\frac{1}{2},+)$	2060.	2060.	2060	2060.	(1,+)
	$(\frac{7}{2},+)$	2038.	2033.33	2030	2045.	(2,+)
AntiDecuplet	(J,P)	$\frac{\Theta+2N_{10}+3\Sigma_{10}+4\Xi_{10}}{10}$	$\frac{N_{10}+\Xi_{10}}{2}$	Σ	$\frac{\Theta+2\Xi_{10}}{3}$	(K,P)
	$(\frac{1}{2},+)$	1760.8	1766.	1760.	1754.67	Ground

MODEL-INDEPENDENT CALCULATION

- Parameters (MeV)

α	β	γ
-255.03	-140.04	-101.08

[Ghil-Seok Yang, Hyun-Chul Kim, Prog. Theor. Phys. 128, 397 (2012)]

$K=1^-$	δ
$N(1520)$-$\Lambda(1690)$	6.23
$\Lambda(1690)$-$\Sigma(1670)$	-506.65
$\Sigma(1670)$-$\Xi(1820)$	-85.01

MODEL-INDEPENDENT CALCULATION

- Parameters (MeV)

Ground	$8, J=\frac{1}{2}$	$10, J=\frac{3}{2}$	$\overline{10}, J=\frac{1}{2}$
$8, J=\frac{1}{2}$	0	$-\frac{3}{2\,MI1}$	$-\frac{3}{2\,MI2}$
$10, J=\frac{3}{2}$	$\frac{3}{2\,MI1}$	0	$\frac{3}{2\,MI1}-\frac{3}{2\,MI2}$
$\overline{10}, J=\frac{1}{2}$	$\frac{3}{2\,MI2}$	$\frac{3}{2\,MI2}-\frac{3}{2\,MI1}$	0

K=0	$8, J=\frac{1}{2}$	$10, J=\frac{3}{2}$
$8, J=\frac{1}{2}$	0	$-\frac{3}{2\,MI1}$
$10, J=\frac{3}{2}$	$\frac{3}{2\,MI1}$	0

K=1	$8, J=\frac{1}{2}$	$8, J=\frac{3}{2}$	$10, J=\frac{1}{2}$	$10, J=\frac{3}{2}$
$8, J=\frac{1}{2}$	0	$-\frac{3\,a(1)}{2\,MI1}$	$\frac{3\,a(1)}{2\,MI1}-\frac{3}{2\,MI1}$	$-\frac{3}{2\,MI1}$
$8, J=\frac{3}{2}$	$\frac{3\,a(1)}{2\,MI1}$	0	$\frac{3\,a(1)}{MI1}-\frac{3}{2\,MI1}$	$\frac{3\,a(1)}{2\,MI1}-\frac{3}{2\,MI1}$
$10, J=\frac{1}{2}$	$\frac{3}{2\,MI1}-\frac{3\,a(1)}{2\,MI1}$	$\frac{3}{2\,MI1}-\frac{3\,a(1)}{MI1}$	0	$-\frac{3\,a(1)}{2\,MI1}$
$10, J=\frac{3}{2}$	$\frac{3}{2\,MI1}$	$\frac{3}{2\,MI1}-\frac{3\,a(1)}{2\,MI1}$	$\frac{3\,a(1)}{2\,MI1}$	0

Ground	$8, J=\frac{1}{2}$	$10, J=\frac{3}{2}$	$\overline{10}, J=\frac{1}{2}$
$8, J=\frac{1}{2}$	0.	−231.125	−610.425
$10, J=\frac{3}{2}$	231.125	0.	−379.3
$\overline{10}, J=\frac{1}{2}$	610.425	379.3	0.

$K=0^{+}$	$8, J=\frac{1}{2}$	$10, J=\frac{3}{2}$
$8, J=\frac{1}{2}$	0.	−85.
$10, J=\frac{3}{2}$	85.	0

$K=1^{-}$	$8, J=\frac{1}{2}$	$8, J=\frac{3}{2}$	$10, J=\frac{1}{2}$	$10, J=\frac{3}{2}$
$8, J=\frac{1}{2}$	0.	−57.5	−135.	−192.7
$8, J=\frac{3}{2}$	57.5	0.	−77.5	−135.2
$10, J=\frac{1}{2}$	135.	77.5	0	−57.7
$10, J=\frac{3}{2}$	192.7	135.2	57.7	0.

MODEL-INDEPENDENT CALCULATION

- Parameters (MeV)

K=2	$8, J=\frac{3}{2}$	$8, J=\frac{5}{2}$	$10, J=\frac{3}{2}$	$10, J=\frac{5}{2}$	$10, J=\frac{7}{2}$
$8, J=\frac{3}{2}$	0	$-\frac{5\,a(2)}{2\,MI1}$	$\frac{3\,a(2)}{2\,MI1}-\frac{3}{2\,MI1}$	$-\frac{a(2)}{MI1}-\frac{3}{2\,MI1}$	$-\frac{9\,a(2)}{2\,MI1}-\frac{3}{2\,MI1}$
$8, J=\frac{5}{2}$	$\frac{5\,a(2)}{2\,MI1}$	0	$\frac{4\,a(2)}{MI1}-\frac{3}{2\,MI1}$	$\frac{3\,a(2)}{2\,MI1}-\frac{3}{2\,MI1}$	$-\frac{2\,a(2)}{MI1}-\frac{3}{2\,MI1}$
$10, J=\frac{3}{2}$	$\frac{3}{2\,MI1}-\frac{3\,a(2)}{2\,MI1}$	$\frac{3}{2\,MI1}-\frac{4\,a(2)}{MI1}$	0	$-\frac{5\,a(2)}{2\,MI1}$	$-\frac{6\,a(2)}{MI1}$
$10, J=\frac{5}{2}$	$\frac{a(2)}{MI1}+\frac{3}{2\,MI1}$	$\frac{3}{2\,MI1}-\frac{3\,a(2)}{2\,MI1}$	$\frac{5\,a(2)}{2\,MI1}$	0	$-\frac{7\,a(2)}{2\,MI1}$
$10, J=\frac{7}{2}$	$\frac{9\,a(2)}{2\,MI1}+\frac{3}{2\,MI1}$	$\frac{2\,a(2)}{MI1}+\frac{3}{2\,MI1}$	$\frac{6\,a(2)}{MI1}$	$\frac{7\,a(2)}{2\,MI1}$	0

$K=2^+$	$8, J=\frac{3}{2}$	$8, J=\frac{5}{2}$	$10, J=\frac{3}{2}$	$10, J=\frac{5}{2}$	$10, J=\frac{7}{2}$
$8, J=\frac{3}{2}$	0.	−8.125	−222.	−206.	−173.
$8, J=\frac{5}{2}$	8.125	0.	−213.875	−197.875	−164.875
$10, J=\frac{3}{2}$	222.	213.875	0.	16.	49.
$10, J=\frac{5}{2}$	206.	197.875	−16.	0.	33.
$10, J=\frac{7}{2}$	173.	164.875	−49.	−33.	0.

SUMMARY

- We saw that how to mass spectra are determined in CQSM
- We extract parameters from the experimental data
- All parameters depend on grand spin K but some parameters have representation dependence also
- After parameters are determined, We will calculate all parameters and masses in model-dependent way

Thank you for listening!!!