Spectroscopy and Strong Decays of Baryons

Bao N. Tran

A Thesis

in

The Department

of

Physics

Presented in Partial Fulfillmemt of the Requirements
for the Degree of Doctor of Philosophy at
Concordia University
Montréal, Québec, Canada

March 1989

ISBN 0-315-49073-X

ABSTRACT

Spectroscopy and Strong Decays of Baryons

Bao N. Tran, Ph.D.
Concordia University, 1989

A quark model, suggested by quantum chromodynamics, is used to calculate the entire spectrum of baryons, containing u, d, s, c, b quarks. A short-range Coulomb potential is used, together with a long-range linear potential, modified by a harmonic-oscillator potential. This combination leads to a good description of the masses of both positive and negative-parity baryons, based on the five quark masses and four additional parameters related to the chosen potential.

The Quark pair creation model by A. Le Yaouanc et al. is then used to study the decay processes N, $\Delta \longrightarrow N\pi$ and Λ, $\Sigma \longrightarrow N\bar{K}$. The pair creation strength γ is replaced by k^{γ}. Beside the meson radius, this is the only parameter of the model. The result is in good agreement with the experimental data and confirms the assignment of baryons in the mass calculation.

Acknowledgement

I would like to express my gratitude to professor C.S. Kalman for his guidance and advice during the period of preparation of this thesis. I also wish to thank Dr. Mariana Frank and professor S.K. Misra for their advice and support.

Thanks also to the Concordia University, the Physics Department, the Natural Sciences and Engineering Research Council of Canada, the Fonds pour la Formation de Chercheurs et l'Aide à la Recherche, The O'Brien Foundation for the financial assistances.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

The field of particle physics has made substantial progress during the past two decades. Earlier, in the 1950s, theorists were confronted by a wide range of experimental data, produced by the accelerators. The newly found "elementary particles" kept piling up, exposing the need for a new layer of structure to explain them. Experimental confirmation occured when around 1968, deep inelastic electron-nucleon scattering experiments at Stanford Linear Accelerator revealed point-like particles inside nucleons.

The idea of quarks as new "elementary" particles was introduced in 1964 independently by Murray Gell-Mann[(1)] and George Zweig[(2)]. At first, this was looked at skeptically and this was why Zweig's work was not published. They showed that the properties of the particles could be accounted for in terms of the simple motions and interactions of just three different kinds of fractionally charged spin $\frac{1}{2}$ quarks. Later discoveries of new kinds of particles led to the introduction of more quarks to describe them. Today it is considered that six different kinds of quarks are needed to complete the picture of high energy physics.

The theory describing the strong interaction between quarks is known as Quantum Chromodynamics (QCD). While this seems to be the right theory to describe the strong interaction, most of the calculations in QCD are very arduous and may be impossible. For this reason, the quark model with a phenomenological potential, despite its lack of theoretical background, is still the popular choice in the attempts to account for the baryon and meson spectra and decays.

In this work, the spectrum and the strong decays of baryons are studied using the quark model. In chapter one and two, the quark model and the theory of the strong interaction or QCD are reviewed. In chapter three, a nonrelativistic quark model and an explicit potential are used to calculate the masses of the ground-state baryons as well as excited baryons. The strong decays of baryons are examined in chapter four. Chapter five is devoted to presenting and discussing the results of the mass and decay calculations presented in chapters three and four respectively.

Chapter One

QUARKS AND HADRONS

In this chapter, the experimental evidence for the existence of quarks inside nucleons is reviewed. The properties of quarks and their antiparticles, and how they are combined to form baryons and mesons, collectively known as hadrons, are also examined.

1.1 Evidence of quarks inside nucleons

Consider a particle A, of unit charge and momentum $\vec{P}$, which comprises of n particles of charges e_i and effective momentum $\vec{p}_i$. If $f_i(x)$ describes the probability of the particle (quark) i inside A having momentum $x = p_i/P$ then

$$\sum_{i=1}^{n} \int_0^1 x\, f_i(x)\, dx = 1 \qquad (1.1)$$

The structure function of A is defined by

$$F(x) = \sum_{i=1}^{n} e_i^2\, x\, f_i(x) \qquad (1.2)$$

The charges are included in order to consider experimental results arising from electromagnetic interaction.

If A is an elementary particle, then the structure function $F_A(x)$ is described by figure 1.1a. If it is comprised of three quarks, each quark will occupy one-third of the momentum and $F_A(x)$ is described by figure 1.1b. The interactions between quarks will redistribute the

Figure 1.1 The structure function corresponding to different assumed compositions of the nucleon.

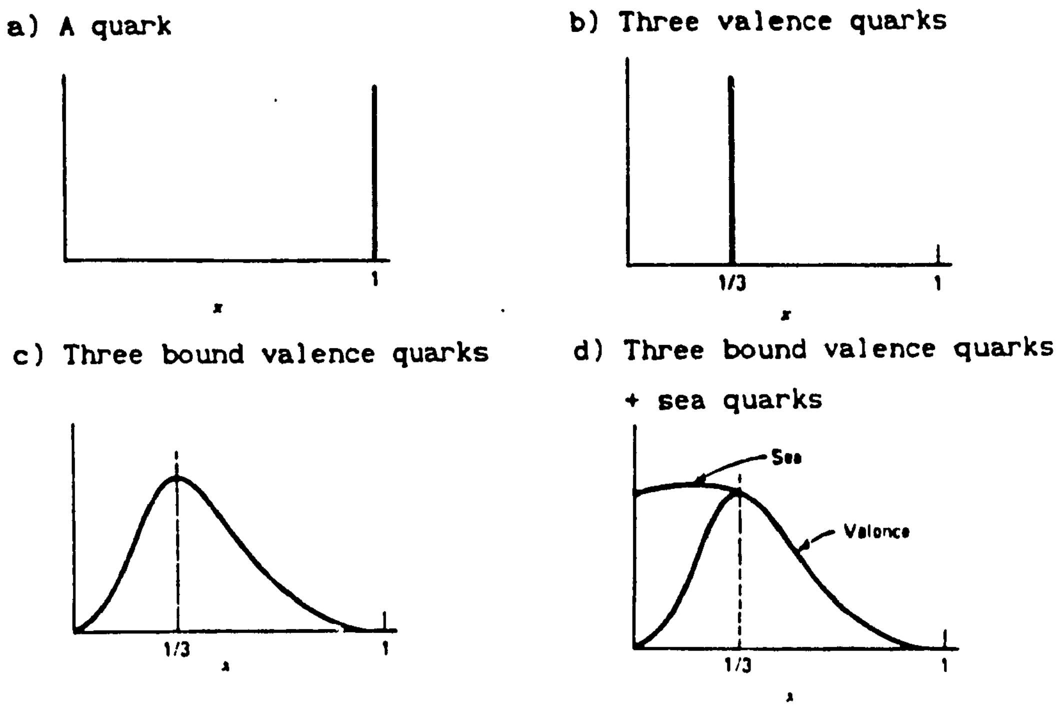
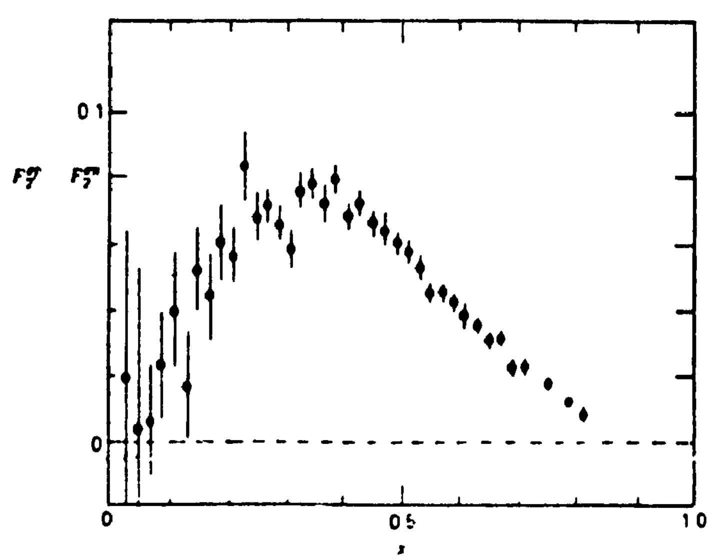


Figure 1.2 The difference $F_p(x) - F_n(x)$ as a function of x. Da.a are from the Stanford Linear Accelerator[3].



momenta among themselves and the sharply peaked curve in figure 1.1b becomes that in figure 1.1c.

The experimental values of $F_p(x) - F_n(x)$ (Figure 1.2) show that there are indeed three quarks, called valence quarks, inside nucleons. The reason why $F_p(x) - F_n(x)$ is considered, instead of $F_p(x)$ and $F_n(x)$ separately, is that besides the valence quarks, there are also many quark - antiquark pairs, called sea quarks, created and then annihilated, which makes the structure functions $F_p(x)$ and $F_n(x)$ look like figure 1.1d. Usually, just the valence quarks are considered and referred to simply as quarks, because the sea quarks do not contribute to the quark properties, such as spin, flavor etc.

1.2 The internal quantum numbers of quarks

Quarks are fermions with spin $\frac{1}{2}$. To every quark, there is, of course, an antiquark. Baryons consist of three quarks and mesons contain one quark and one antiquark. To have a baryon number B = 1 for baryons and B = 0 for mesons, one can ascribe a baryon number $B = \frac{1}{3}$ to a quark. In order to account for the other quantum numbers of hadrons, it is necessary to ascribe to quark isospin and all additive quantum numbers such as strangeness s, charm c, b, t quantum numbers and any similar quantum number of new quarks should they be discovered. There are six types or flavors of quarks:

a) Two types of ordinary quarks called up and down, symbolized by letters u and d.

b) Strange quarks referred as s-quarks.

c) Charm quarks referred as c-quarks.

d) Bottom or beauty and top quarks called b-quarks and t-quarks.

Quarks and their quantum numbers are described in table 1.1. Five types of quark are now confirmed by experiments and the sixth quark, t-quark, is believed to exist.

In order to obtain the isospin of hadrons, one considers the u, d ordinary quarks to form an isospin doublet ($I = \frac{1}{2}$); u with $I_3 = +\frac{1}{2}$, d with $I_3 = -\frac{1}{2}$. The other flavors are assumed to be isospin singlets ($I = 0$). Thus all isospin properties come from u and d quarks contained in hadrons. s, c, b and t quarks are the carrier of s, c, b and t quantum numbers respectively.

The generalized Gell-Mann-Nishijima relation relates the electric charge to these quantum numbers:

$$Q/e = I_3 + \frac{1}{2}(B + s + c + b + t) \tag{1.3}$$

One can define the hypercharge by

$$Y = s + B - \frac{1}{3}(c - b + t) \tag{1.4}$$

and inserting eq.(1.4) in eq.(1.3) one arrives at

$$Q/e = I_3 + \frac{1}{2}Y + \frac{2}{3}c + \frac{1}{3}b + \frac{2}{3}t \tag{1.5}$$

These equations give rise to the quantum numbers in table 1.1

It is surprising to encounter fractional charges, but any combination of three quarks or quark and antiquark yields hadrons having values of electric charge.

Table 1.1

Quantum numbers of six quarks and six antiquarks

quark	J^P	B	Q/e	I	I_3	Y	c	s	t	b
u	$\frac{1}{2}^+$	$\frac{1}{3}$	$\frac{2}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{3}$	0	0	0	0
d	$\frac{1}{2}^+$	$\frac{1}{3}$	$-\frac{1}{3}$	$\frac{1}{2}$	$-\frac{1}{2}$	$\frac{1}{3}$	0	0	0	0
c	$\frac{1}{2}^+$	$\frac{1}{3}$	$\frac{2}{3}$	0	0	0	1	0	0	0
s	$\frac{1}{2}^+$	$\frac{1}{3}$	$-\frac{1}{3}$	0	0	$-\frac{2}{3}$	0	-1	0	0
t	$\frac{1}{2}^+$	$\frac{1}{3}$	$\frac{2}{3}$	0	0	0	0	0	1	0
b	$\frac{1}{2}^+$	$\frac{1}{3}$	$-\frac{1}{3}$	0	0	0	0	0	0	-1
$\bar{u}$	$\frac{1}{2}^-$	$-\frac{1}{3}$	$-\frac{2}{3}$	$\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{3}$	0	0	0	0
$\bar{d}$	$\frac{1}{2}^-$	$-\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$-\frac{1}{3}$	0	0	0	0
$\bar{c}$	$\frac{1}{2}^-$	$-\frac{1}{3}$	$-\frac{2}{3}$	0	0	0	-1	0	0	0
$\bar{s}$	$\frac{1}{2}^-$	$-\frac{1}{3}$	$\frac{1}{3}$	0	0	$\frac{2}{3}$	0	1	0	0
$\bar{t}$	$\frac{1}{2}^-$	$-\frac{1}{3}$	$-\frac{2}{3}$	0	0	0	0	0	-1	0
$\bar{b}$	$\frac{1}{2}^-$	$-\frac{1}{3}$	$\frac{1}{3}$	0	0	0	0	0	0	1

1.3 SU(3) Group

The set of unitary 3 x 3 matrices with det U = 1 form the group SU(3). This group has $3^2 - 1$ generators, which can be taken as

$$\lambda_1 = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \qquad \lambda_2 = \begin{bmatrix} 0 & -i & 0 \\ i & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \qquad \lambda_3 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$\lambda_4 = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix} \qquad \lambda_5 = \begin{bmatrix} 0 & 0 & -i \\ 0 & 0 & 0 \\ i & 0 & 0 \end{bmatrix} \qquad \lambda_6 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

$$\lambda_7 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & -i \\ 0 & i & 0 \end{bmatrix} \qquad \lambda_8 = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -2 \end{bmatrix} \qquad (1.6)$$

These matrices satisfy the commutative relation

$$\left[\frac{1}{2} \lambda_i , \frac{1}{2} \lambda_j \right] = i \sum_k f_{ijk} \left(\frac{1}{2} \lambda_k \right) \qquad (1.7)$$

where the structure constants f_{ijk} are antisymmetric under interchange of any two indices. The nonvanishing values of f_{ijk} are

$$f_{123} = 1, \qquad f_{458} = f_{678} = \frac{\sqrt{3}}{2} ,$$

$$f_{147} = f_{165} = f_{246} = f_{257} = f_{345} = f_{376} = \frac{1}{2} . \qquad (1.8)$$

Three quarks, u, d, s, form the fundamental representation of SU(3) flavor group. This basic multiplet is given in figure 1.3. The generators λ_1 and λ_2 are actually the enlargement of the Pauli matrices σ_1 and σ_2 of the SU(2) isospin group. Then the operator F_3 ($F_i = \frac{1}{2}\lambda_i$, i=1,8) is the isospin operator and the hypercharge operator is

$$Y = \frac{2}{\sqrt{3}} F_8 \tag{1.9}$$

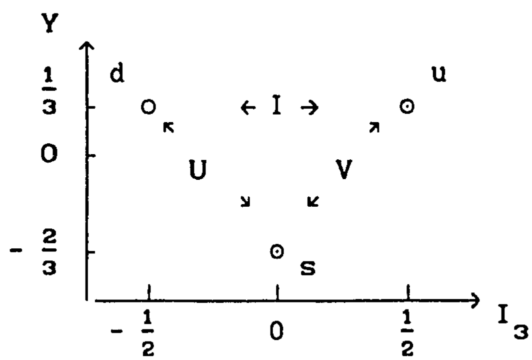
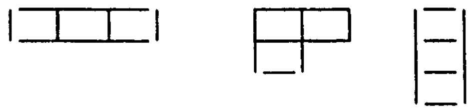


Figure 1.3 SU(3) triplet with I, U, V doublets.

Similarly, $\lambda_{4,5}$ and $\lambda_{6,7}$ are part of SU(2) subgroups called V-spin and U-spin respectively. The "step-up" and "step-down" operator of I, V, U-spin are $(F_1 \pm iF_2)$, $(F_4 \pm iF_5)$, $(F_6 \pm iF_7)$ respectively (Figure 1.3).

1.4 Baryons: three-quark states

For simplicity, we consider u, d, s quarks or the SU(3) flavor group discussed in the previous section. Including the SU(2) spin group, one obtains the SU(6) spin-flavor group. The possible Young diagrams consisting of three boxes (three quarks) are (see appendix A about the Young Tableau technique):



	S	M	A	
SU(6):	56	70	20	(1.10)
SU(3):	10	8	1	(1.11)
SU(2):	4	2		(1.12)

where S, M and A stand for symmetry, mixed symmetry and antisymmetry respectively. The dimensionalities corresponding to each representation and group are given. There is no antisymmetric SU(2) tableau with three boxes because SU(2) spin has only two degrees of freedom: up and down. Combining three quarks gives

$$6 \otimes 6 \otimes 6 = 56 \oplus 70 \oplus 70 \oplus 20 \tag{1.13}$$

for SU(6) and

$$\begin{aligned}(3,2) \otimes (3,2) \otimes (3,2) &= (3 \otimes 3 \otimes 3 \;,\; 2 \otimes 2 \otimes 2) \\ &= (10 \oplus 8 \oplus 8 \oplus 1 \;,\; 4 \oplus 2 \oplus 2) \\ &= (10,4) \oplus (10,2) \oplus (10,2) \oplus \\ &\quad (8,4) \oplus (8,2) \oplus (8,2) \oplus \\ &\quad (8,4) \oplus (8,2) \oplus (8,2) \oplus \\ &\quad (1,4) \oplus (1,2) \oplus (1,2)\end{aligned} \tag{1.14}$$

for SU(3) x SU(2). The notation (SU(3) , SU(2)) has been used to denote a multiplet. Using the symmetry properties of the products of table 1.2 one arrives at the relations between eq. (1.13) and eq. (1.14).

$$56 \supset (10,4) \oplus (8,2) \tag{1.15}$$

$$70 \supset (10,2) \oplus (1,2) \oplus (8,4) \oplus (8,2) \tag{1.16}$$

$$20 \supset (1,4) \oplus (8,2) \tag{1.17}$$

The lowest mass baryons fit neatly into the symmetric spin $\frac{3}{2}$ decouplet (10,4) and the spin $\frac{1}{2}$ octet (8,2) (see figure 1.4).

Table 1.2

Symmetry property of the product of two factors

Factors	Product
SS or AA	S
SA	A
SM or AM	M
MM	S, A or M

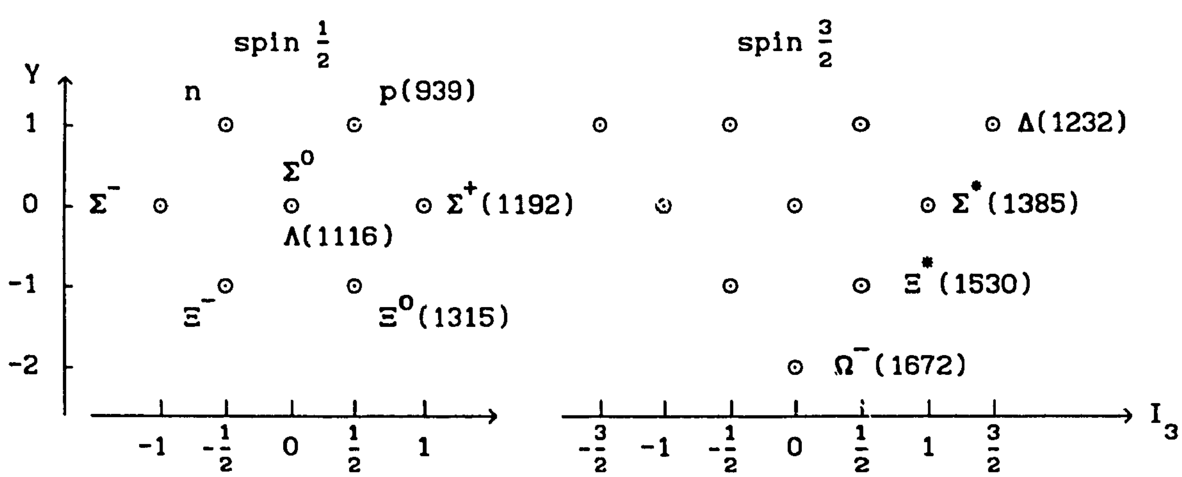


Figure 1.4 Ground state baryons. (The masses are in MeV)

1.5 Mesons: quark-antiquark states

Combining a quark and an antiquark gives

$$SU(6):\ 6 \otimes \bar{6} = 35 \oplus 1 \tag{1.18}$$

$$\begin{aligned} SU(3) \times SU(2):\ (3,2) \otimes (\bar{3},\bar{2}) &= (3 \otimes \bar{3} \ , \ 2 \otimes \bar{2}) \\ &= (8 \oplus 1 \ , \ 3 \oplus 1) \\ &= (8,3) \oplus (8,1) \oplus (1,3) \oplus (1,1) \end{aligned} \tag{1.19}$$

The relations between eq.(1.18) and eq.(1.19) are given by

$$1 \supset (1,1) \tag{1.20}$$

$$35 \supset (8,3) \oplus (8,1) \oplus (1,3) \tag{1.21}$$

We have an octet and a singlet for each spin 0 and spin 1. Hence the octet and the singlet can mix with each other and so are usually called a nonet. Experimentally there is more mixing between the vector meson octet and singlet than in the case of the pseudoscalar mesons. This may occur because, as can be seen from eqs (1.20) and (1.21), the vector meson octet and singlet belong to the same multiplet, while those of the pseudoscalar mesons belong to different multiplets. Figure 1.5 shows the quark content of the meson octet and singlet, where A, B and the flavor singlet C are given by:

$$A = \sqrt{\tfrac{1}{2}} \left[u\bar{u} - d\bar{d} \right] \tag{1.22}$$

$$B = \sqrt{\tfrac{1}{6}} \left[u\bar{u} + d\bar{d} - 2s\bar{s} \right] \tag{1.23}$$

$$C = \sqrt{\tfrac{1}{3}} \left[u\bar{u} + d\bar{d} + s\bar{s} \right] \tag{1.24}$$

The observed nonets are given in table 1.3.

The quarks and antiquarks inside hadrons interact with each other through the strong interaction. The theory of the strong interaction is known as Quantum Chromodynamics (QCD), which is the subject to be discussed in the next chapter.

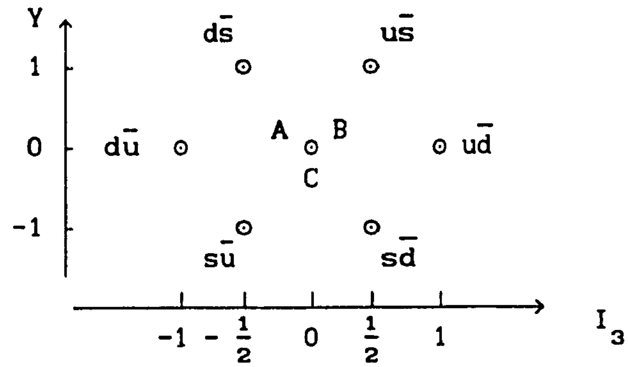


Figure 1.5 The quark content of the meson nonet

Table 1.3 The SU(3) meson nonets

$q\bar{q}$ Orbital ang. mom.	$q\bar{q}$ spin	J^{PC}	observed nonet I=1	I=$\frac{1}{2}$	I=0	Typical mass (MeV)
0	0	0^{-+}	π	K	η, η'	500
0	1	1^{--}	ρ	K^*	ω, ϕ	800
1	0	1^{+-}	B	Q_2	H, ?	1250
1	1	2^{++}	A_2	K^*	f, f'	1400
1	1	1^{++}	A_1	Q_1	D, ?	1300
1	1	0^{++}	δ	κ	ε, S^*	1150

Chapter Two

QUANTUM CHROMODYNAMICS

2.1 Color

The low-lying baryon states are symmetric with respect to the interchange of quark flavors and spin indices. Consider, for example, the Δ^{++} and Ω^- particles. For the $J_3 = \frac{3}{2}$ state, it is easily seen that the spin wavefunction is symmetric, and the flavors of three quarks are the same. The spin-flavor wavefunctions

$$| \Delta^{++}, J_3 = \frac{3}{2} > = | u\uparrow u\uparrow u\uparrow >$$

and

$$| \Omega^-, J_3 = \frac{3}{2} > = | s\uparrow s\uparrow s\uparrow >$$

are obviously symmetric. Furthermore, Δ^{++} and Ω^- are the ground-state baryons which have zero orbital angular momentum. This means the total spin-flavor-space wavefunctions of these particles are symmetric under the interchange of the quarks. This contradicts the theorem on the connection between spin and statistics, since quarks have spin $\frac{1}{2}$ and should obey Fermi-Dirac statistics. To explain this, a new quantum number is introduced: color. There are three colors called red, blue, green. To satisfy the spin-statistics relation, the color wavefunctions are then assumed to be antisymmetric. In fact, until now all observed hadrons are colorless and it is believed that all physical observables are color singlets. This is known as the confinement postulate.

There are a number of experimental confirmations of the colors hypothesis. First the ratio [3,6]:

$$R = \frac{\sigma(e^+e^- \longrightarrow \text{hadrons})}{\sigma(e^+e^- \longrightarrow \mu^+\mu^-)} = n \sum_q \frac{Q^2}{e^2} \tag{2.1}$$

where n is the number of colors. If n = 3 then

$$\begin{aligned} R &= 3\left[\left(\frac{2}{3}\right)^2 + \left(\frac{1}{3}\right)^2 + \left(\frac{1}{3}\right)^2 \right] = 2 \quad \text{for u, d, s,} \\ &= 2 + 3\left(\frac{2}{3}\right)^2 = \frac{10}{3} \quad \text{for u, d, s, c,} \\ &= \frac{10}{3} + 3\left(\frac{1}{3}\right)^2 = \frac{11}{3} \quad \text{for u, d, s, c, b.} \end{aligned} \tag{2.2}$$

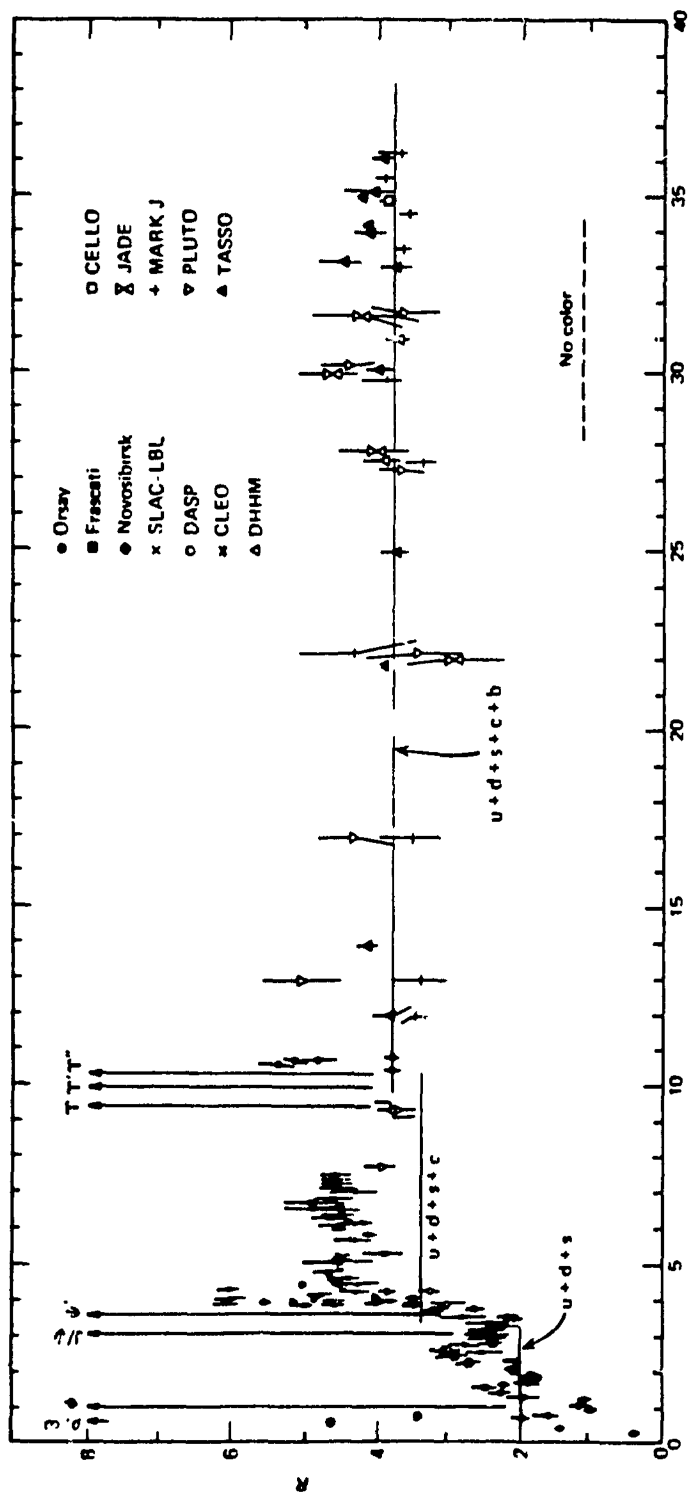
The measured value of R shown in figure 2.1 confirms that there are three colors. Another place where color can be seen is the transition of a meson to a nonhadronic state. One example is the two-photon decay of neutral mesons. For the pion one has[6]:

$$\Gamma(\pi^o \longrightarrow 2\gamma) = \frac{m_\pi^3}{32\pi F_\pi^2}\left(\frac{\alpha}{\pi}\right)^2\left(\frac{n}{3}\right)^2 = 7.87\left(\frac{n}{3}\right)^2 \text{eV.} \tag{2.3}$$

Where $F = 0.96m_\pi$ is the pion decay constant and n is the number of colors. For n = 3, eq.(2.3) is in exellent agreement with the experimental value:

$$\Gamma(\pi^o \longrightarrow 2\gamma) = 7.95 \pm .55 \text{ eV.} \tag{2.4}$$

Figure 2.1 R-ratio as a function of the total e^-e^+ energy. (The sharp peaks correspond to the production of narrow 1^- resonances just below or near the flavor thresholds.



2.2 Gluons

The field quanta of Quantum Chromodynamics (QCD), the theory of strong interaction, are called gluons. Quarks interact with each other by exchanging gluons. The role of colors in QCD is the same as that of electric charge in QED. The gluon is colored. In fact it is bicolored: color-anticolored. This combination gives (see appendix A).

$$3 \otimes \bar{3} = 8 \oplus 1 \tag{2.5}$$

Unlike SU(3) flavor symmetry, the symmetry of SU(3) color is expected to be exact. The color octet and singlet are ($G\bar{B}$, $R\bar{B}$, $R\bar{G}$, $B\bar{G}$, $B\bar{R}$, $G\bar{R}$, A, B) and C respectively, in which

$$A = \sqrt{\frac{1}{2}} \left[R\bar{R} - G\bar{G} \right] \tag{2.6}$$

$$B = \sqrt{\frac{1}{6}} \left[R\bar{R} + G\bar{G} - 2B\bar{B} \right] \tag{2.7}$$

$$C = \sqrt{\frac{1}{3}} \left[R\bar{R} + G\bar{G} + B\bar{B} \right] \tag{2.8}$$

The singlet C does not carry color so it cannot play the role of a gluon. We thus have eight gluons mediating between color charges.

2.3 The QCD Lagrangian

The Lagrangian of a free quark is given by

$$\mathcal{L}_0 = \bar{q} \left[i \gamma^{\mu} \partial_{\mu} - m \right] q \tag{2.9}$$

Consider the transformation

$$q(x) \longrightarrow U\, q(x) = e^{i\alpha_a(x)\, T_a} q(x) \tag{2.10}$$

where α_a are the group parameters, $T_a = \lambda_a/2$ (see section 1.3) and U is an arbitrary 3x3 unitary matrix. The summation over a = 1, 2, ...,8 is implied. Because all the generators do not commute with each other, the group $\{ U \}$ is nonabelian.

Now consider the local gauge invariance of the Lagrangian. It is sufficient to consider the infinitesimal transformation

$$q(x) \longrightarrow \left[1 + i\alpha_a(x)\, T_a \right] q(x) \;, \tag{2.11}$$

$$\partial_{\mu} q(x) \longrightarrow \left[1 + i\alpha_a(x)\, T_a \right] \partial_{\mu} q(x) + i\, T_a q(x)\, \partial_{\mu}\alpha_a(x) \;. \tag{2.12}$$

The last term of eq.(2.12) destroys the gauge invariance of the Lagrangian. The gauge invariance can be restored by adding to the Lagrangian the gauge fields G^a_{μ}, a = 1, 2, ..,8, which transform as

$$G^a_{\mu} \longrightarrow G^a_{\mu} - \frac{1}{g}\, \partial_{\mu}\alpha_a - f_{abc}\,\alpha_b\, G^c_{\mu} \;, \tag{2.13}$$

where f_{abc} is the structure constant of the SU(3) color group, and replacing ∂_{μ} by the covariant derivative

$$D_\mu = \partial_\mu + i\, g\, T_a G^a_\mu \quad , \tag{2.14}$$

where g is the color charge. Adding the gauge invariant kinetic term of the gluons to the Lagrangian one arrives at the complete Lagrangian of QCD

$$\mathcal{L} = \bar{q} \left[i\, \gamma^\mu \partial_\mu - m \right] q - g \left[\bar{q}\, \gamma^\mu T_a\, q \right] G^a_\mu - \frac{1}{4} G^a_{\mu\nu} G^{\mu\nu}_a \quad , \tag{2.15}$$

where the field strength $G^a_{\mu\nu}$ is given by

$$G^a_{\mu\nu} = \partial_\mu G^a_\nu - \partial_\nu G^a_\mu - g\, f_{abc} G^b_\mu\, G^c_\nu \; . \tag{2.16}$$

This Lagrangian is invariant under the local gauge transformation. Thus QCD is a nonabelian gauge invariance theory. The local gauge invariance requires the gluons to be massless like the photon in QED. Indeed, adding the mass term $\frac{1}{2} m_g^2\, G^a_\mu\, G^\mu_a$ to the Lagrangian will destroy the gauge invariance.

Writing the Lagrangian in a symbolic form

$$\mathcal{L} = \text{" } q\bar{q} \text{ "} + \text{" } G^2 \text{ "} + g \text{ " } \bar{q}qG \text{ "} + g \text{ " } G^3 \text{ "} + g^2 \text{ " } G^4 \text{ "} \quad , \tag{2.17}$$

it is seen that the first three terms have equivalents in QED. They describe the propagation of quarks, of gluons and the interaction between quarks and gluons. The last two terms represent the fact that gluons themselves carry (color) charges and can interact with each other.

2.4 The coupling constant

The existence of the coupling of gluons to each other leads to the effect of charge antiscreening which is in contrast with that in QED. In fact the loop corrections yield[3]

$$\alpha_s(q^2) = \frac{12\pi}{\left(33 - 2n_f\right)\ln\left(\dfrac{q^2}{\Lambda^2}\right)} \qquad (2.18)$$

Where $\alpha_s = g^2/4\pi$ is the coupling constant, q is the momentum transfered, n_f is the number of flavors and Λ is a normalization point. Λ is a free parameter determined by experiments and has a value about 0.1-0.5 GeV.

For q^2 much larger than Λ^2, the coupling is small. This is known as "asymptotic freedom". In this region, perturbation theory is applicable. For q^2 of the order of Λ^2, quarks and gluons interact strongly with each other. This is the case of quarks and gluons inside of hadrons. One may think of Λ as the boundary between the quasi-free quarks and the strongly bound hadrons.

At small distances, QCD suggests a Coulomb-type potential $-\alpha_S/r$ between quarks and antiquarks. At large distances, one expects a confining potential. The exact form of the confining potential is unknown, however lattice gauge theory[7] and string models[8] lead one to expect a linear confining potential. This idea is used to develop a model with an explicit potential for baryons in the next chapter.

CHAPTER THREE

BARYON MASSES IN A QUARK MODEL

In this chapter a quark model of baryons is presented. Only eight parameters are used to describe both the positive and negative-parity baryons containing u, d, s, c and b quarks. The model is developed within the framework introduced by De Rújula, Georgi and Glashow[9]. A combination of a linear confining potential plus Coulombic-type short-distance potential plus one-gluon-exchange forces provides a good fit to meson mass spectra[10]. For baryons, the situation is much less clear. One might assume, as seen at the end of the previous chapter, the potential between two quarks in baryons has the form

$$V(r_{ij}) \quad = \quad - C_F\alpha_S/r_{ij} + ar_{ij} \, , \tag{3.1}$$

where r_{ij} is the separation between quark i and j, C_F is the color factor of baryons taken to be 2/3 as suggested by QCD and a is a constant describing the string tension. In an earlier more primitive version of the model used here, it was shown by Kalman, Tran and Hall[11] that the potential between two quarks in a baryon is indeed of the form of eq.(3.1). Another possibility is that suggested by a branched string emanating from some central point in between the three quarks. It is probably not necessary to give special consideration to such models, since it has been shown in an appropriate treatment of lattice gauge theory[12] that a sum of linear two-body forces may have the same effect as such a three-body force. A number of other potentials have been suggested; the harmonic-oscillator potential by Mitra[13], the Martin potential $V(r) = A + Br^{\alpha}$ by Bhaduri, Cohler and Nogami[14] and by

Ono and Schoberl[15], the logarithmic potential by Gromes and Stamatescu[16] and also by Bhaduri and Racz[17]. Gromes and Stamatescu[16,18] made a general study of baryons using a harmonic - oscillator basis by writing

$$V'(r_{ij}) = \frac{1}{2}\ \mu\omega^2\ r_{ij}^2 + [V(r_{ij}) - \frac{1}{2}\ \mu\omega^2\ r_{ij}^2]$$
$$= V_0(r_{ij}) + U(r_{ij}) \tag{3.2}$$

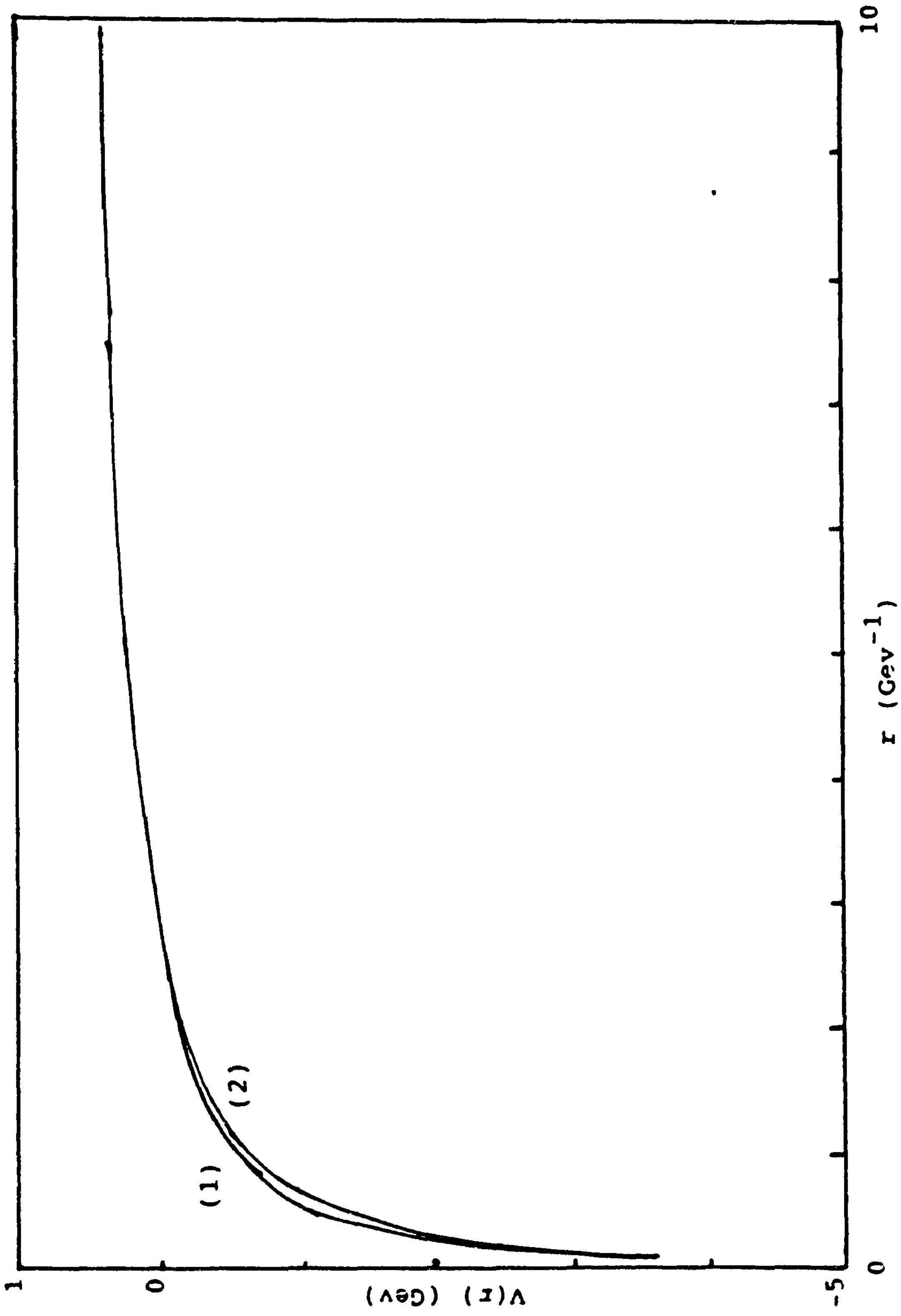
where μ is the reduced mass and $V(r_{ij})$ is the potential. $U(r_{ij})$ is treated perturbatively. Such a treatment takes advantage of the fact that the harmonic-oscillator potential is the only potential which can be solved exactly for any number of particles[19]. Barbour and Ponting[20] reexamined the problem using a stochastic variational method. These papers describe non-stranged baryons with some success. Isgur and Karl[21] used an unspecified $U(r_{ij})$ in a highly successfully calculation of the excited positive-parity baryons. In this model different parameter sets have to be applied to analyze the positive and negative-parity baryons. Kalman[22] in a similar approach was able to describe a broad spectrum of baryons containing c, b quarks in addition to u, d and s quarks with a single set of parameters.

In our model the combination of Coulomb and linear potential given by eq.(3.1) is modified by a harmonic-oscillator potential. This combination behaves in a manner similar to a combination of a Coulomb and a logarithmic potential at short and medium range. As illustration, Figure 3.1 shows the potential used in this model for the situation where the coefficient of the harmonic-oscillator term corresponds to the

Figure 3.1 The graphs of the potentials

(1): $V(r) = -0.667/r + 0.08r - 0.004r^2$ and

(2): $V(r) = -0.667/r + 0.19\ \ln(r)$



ground state of the ρ oscillator (this coefficient varies with states, which will be explained in section 3.2) and a combination of a Coulomb and logarithmic potential, which is the form of the potential used by Gromes and Stamatescu[16]. It should be noted that as pointed out by Gromes and Stamatescu, the logarithmic potential only describes the interaction at medium range and the potential may have a different form at long range. Furthermore, the energy of the states corresponds to the short and medium range behavior of the chosen potential.

In this model a single set of parameters is used for all baryon states. The mixings between the ground-state and the first-excited positive-parity baryons as well as the mixings between the first and the second-excited negative-parity baryons are taken into account. The importance of this interband mixing was shown by Isgur and Karl[23].

Until now no true relativistic potential model exists. The approach taken by many model builders is to adopt relativistic kinematics[24,25]. This is an interesting half-way house, but there are no objective criteria to show that such models are more realistic. A recent study of the unequal-mass quarkonium spectra by Kalman and D'Souza[26], using only a few undetermined parameters and a non-relativistic approach, yields results which are extremely close to experimental data and which are similar to those obtained by Godfrey and Isgur[27] in a model based on relativistic kinematics.

3.1. The Harmonic-Oscillator model

Because the present model employs the harmonic-oscillator wavefunctions basis and also is an extension of the harmonic-oscillator potential model, it is useful to go over this model. The model employs a Hamiltonian of the form

$$H = \sum_i m_i + H_0 , \tag{3.3}$$

where m_i are the quark masses and

$$H_0 = \sum_i \frac{P_i^2}{2m_i} + \sum_{i<j} \frac{1}{2} k r_{ij}^2 - \frac{(\sum P_i)^2}{2\sum_i m_i} . \tag{3.4}$$

In terms of Jacobi relative coordinates

$$\vec{\rho} = \frac{1}{\sqrt{2}} (\vec{r}_1 - \vec{r}_2) \tag{3.5a}$$

$$\vec{\lambda} = \frac{1}{\sqrt{6}} (\vec{r}_1 + \vec{r}_2 - 2\vec{r}_3) \tag{3.5b}$$

eq.(3.4) decouples into a description of two independent harmonic -oscillators with the same spring constant k.

$$H_0 = \frac{P_\rho^2}{2m_\rho} + \frac{P_\lambda^2}{2m_\lambda} + \frac{3}{2} k(\rho^2 + \lambda^2) . \tag{3.6}$$

This particular decomposition is valid provided that at least two of the quark masses are equal. The masses of u and d quarks are taken to be the same, since the difference between them is just of the order of the hadron electromagnetic interaction. Baryons containing three different quark masses can still be included, but require a different decomposition than the one provided by the Jacobi coordinates introduced in eq.(3.5). In this work the convention will be used that in all cases the two quarks comprising the ρ oscillator are the ones with the same masses. Hence the reduced masses of m_ρ and m_λ of the ρ and λ oscillator respectively, have the form;

$$m_\rho = m_1 , \tag{3.7a}$$

$$m_\lambda = \frac{3m_1 m_3}{2m_1 + m_3} , \tag{3.7b}$$

where for the various hadrons.

$$m_1 = m_u;\ N,\ \Delta,\ \Lambda,\ \Lambda_c,\ \Lambda_b,\ \Sigma,\ \Sigma_c,\ \Sigma_b, \tag{3.8a}$$

$$= m_s;\ \Xi,\ \Omega, \tag{3.8b}$$

$$= m_c;\Xi_c,\ \Omega_c, \tag{3.8c}$$

$$= m_b;\ \Xi_b,\ \Omega_b, \tag{3.8d}$$

$$m_3 = m_u;\ N,\ \Delta,\ \Xi,\ \Xi_c,\ \Xi_b, \tag{3.8e}$$

$$= m_s;\ \Lambda,\ \Sigma,\ \Omega, \tag{3.8f}$$

$$= m_c;\ \Lambda_c,\ \Sigma_c,\ \Omega_c, \tag{3 8g}$$

$$= m_b;\ \Lambda_b,\ \Sigma_b,\ \Omega_b. \tag{3.8h}$$

It will be convenient to use the notation

$$x_1 = m_u/m_s,\quad x_2 = m_u/m_c,\quad x_3 = m_u/m_b \tag{3.9}$$

and

$$\omega_j^2 = 3k/m_j,\quad \alpha_j^4 = 3km_j,\qquad j = \rho,\lambda\ . \tag{3.10}$$

The eigenfunction of the Hamiltonian for the ground state is the wavefunction

$$\Psi_{00}^{s} = \psi_{000}\phi_{000} \tag{3.11}$$

and the eigenfunctions of the hamiltonian for the N = 1 band can be chosen as

$$\Psi_{11}^{\lambda} = \psi_{000}\phi_{111} , \tag{3.12a}$$

$$\Psi^{\rho}_{11} = \psi_{111}\phi_{000} \, . \tag{3.12b}$$

For baryons with equal quark masses, the eigenfunctions for N = 2 can be chosen as

$$\Psi^{S'}_{00} = \frac{1}{\sqrt{2}} (\psi_{000}\phi_{200} + \psi_{200}\phi_{000}) \, , \tag{3.13a}$$

$$\Psi^{\rho}_{00} = \frac{1}{\sqrt{3}}(\psi_{110}\phi_{110} - \psi_{111}\phi_{11-1} - \psi_{11-1}\phi_{111}) \, , \tag{3.13b}$$

$$\Psi^{\lambda}_{00} = \frac{1}{\sqrt{2}} (\psi_{200}\phi_{000} - \psi_{000}\phi_{200}) \, , \tag{3.13c}$$

$$\Psi^{A}_{11} = \frac{1}{\sqrt{2}} (\psi_{111}\phi_{110} - \psi_{110}\phi_{111}) \, , \tag{3.13d}$$

$$\Psi^{S}_{22} = \frac{1}{\sqrt{2}} (\psi_{000}\phi_{222} + \psi_{222}\phi_{000}) \, , \tag{3.13e}$$

$$\Psi^{\rho}_{22} = \psi_{111}\phi_{111}, \tag{3.13f}$$

$$\Psi^{\lambda}_{22} = \frac{1}{\sqrt{2}} (\psi_{222}\phi_{000} - \psi_{000}\phi_{222}) \tag{3.13g}$$

and for N = 3 as

$$\Psi^{S}_{33} = -\frac{1}{2} (\psi_{000}\phi_{333} - \sqrt{3}\psi_{222}\phi_{111}) \, , \tag{3.14a}$$

$$\Psi^{A}_{33} = \frac{1}{2} (\psi_{333}\phi_{000} - \sqrt{3}\psi_{111}\phi_{222}) \, , \tag{3.14b}$$

$$\Psi^{\rho}_{33} = \frac{1}{2} (\sqrt{3}\psi_{333}\phi_{000} + \psi_{111}\phi_{222}) \, , \tag{3.14c}$$

$$\Psi^{\lambda}_{33} = \frac{1}{2} (\sqrt{3}\psi_{000}\phi_{333} + \psi_{222}\phi_{111}) \, , \tag{3.14d}$$

$$\Psi^{\rho}_{22} = \frac{1}{\sqrt{3}} (\psi_{111}\phi_{221} - \sqrt{2}\psi_{110}\phi_{222}) \, , \tag{3.14e}$$

$$\Psi^{\lambda}_{22} = \frac{1}{\sqrt{3}} (\psi_{221}\phi_{111} - \sqrt{2}\psi_{222}\phi_{110}) \, , \tag{3.14f}$$

$$\Psi^{S}_{11} = \frac{1}{\sqrt{60}}(5\psi_{200}\phi_{111} - \sqrt{15}\psi_{000}\phi_{311} - 2\sqrt{3}\psi_{222}\phi_{11-1} + \sqrt{6}\psi_{221}\phi_{110} - \sqrt{2}\psi_{220}\phi_{111}) , \tag{3.14g}$$

$$\Psi^{A}_{11} = \frac{1}{\sqrt{60}}(- 5\psi_{111}\phi_{200} + \sqrt{15}\psi_{311}\phi_{000} + 2\sqrt{3}\psi_{11-1}\phi_{222} - \sqrt{6}\psi_{110}\phi_{221} + \sqrt{2}\psi_{111}\phi_{220}) , \tag{3.14h}$$

$$\Psi^{\lambda}_{11} = \frac{1}{\sqrt{30}}(\frac{5}{2}\psi_{200}\phi_{111} - \frac{\sqrt{15}}{2}\psi_{000}\phi_{311} + 2\sqrt{3}\psi_{222}\phi_{11-1} - \sqrt{6}\psi_{221}\phi_{110} + \sqrt{2}\psi_{220}\phi_{111}) , \tag{3.14i}$$

$$\Psi^{\rho}_{11} = \frac{1}{\sqrt{30}}(\frac{5}{2}\psi_{111}\phi_{200} - \frac{\sqrt{15}}{2}\psi_{311}\phi_{000} + 2\sqrt{3}\psi_{11-1}\phi_{222} - \sqrt{6}\psi_{110}\phi_{221} + \sqrt{2}\psi_{111}\phi_{220}) , \tag{3.14j}$$

$$\Psi^{\lambda'}_{11} = \frac{1}{\sqrt{8}}(\sqrt{3}\psi_{200}\phi_{111} + \sqrt{5}\psi_{000}\phi_{311}) , \tag{3.14k}$$

$$\Psi^{\rho'}_{11} = \frac{1}{\sqrt{8}}(\sqrt{3}\psi_{111}\phi_{200} + \sqrt{5}\psi_{311}\phi_{000}) . \tag{3.14l}$$

For states containing quarks with two distinct masses, the eigenstates with N = 2, 3 are quite distinct from those shown in eqs.(3.13) and (3.14) since the degeneracy between the ρ and λ normal modes has been broken (see eq.(3.10)). The eigenfunctions used in our model for the corresponding baryons for N=2 have the form

$$\Psi^{\lambda\lambda}_{00} = \psi_{000}\phi_{200} , \tag{3.15a}$$

$$\Psi^{\rho\lambda}_{00} = \frac{1}{\sqrt{3}}(\psi_{110}\phi_{110} - \psi_{111}\phi_{11-1} - \psi_{11-1}\phi_{111}) , \tag{3.15b}$$

$$\Psi^{\rho\rho}_{00} = \psi_{200}\phi_{000} , \tag{3.15c}$$

$$\Psi^{\rho\lambda}_{11} = \frac{1}{\sqrt{2}}(\psi_{111}\phi_{110} - \psi_{110}\phi_{111}) , \tag{3.15d}$$

$$\Psi_{22}^{\rho\rho} = \psi_{222}\phi_{000} \ , \tag{3.15e}$$

$$\Psi_{22}^{\rho\lambda} = \psi_{111}\phi_{111} \ , \tag{3.15f}$$

$$\Psi_{22}^{\lambda\lambda} = \psi_{000}\phi_{222} \tag{3.15g}$$

and for N = 3

$$\Psi_{33}^{\rho\rho\rho} = \psi_{333}\phi_{000} \ , \tag{3.16a}$$

$$\Psi_{33}^{\rho\rho\lambda} = \psi_{222}\phi_{111} \ , \tag{3.16b}$$

$$\Psi_{33}^{\rho\lambda\lambda} = \psi_{111}\phi_{222} \ , \tag{3.16c}$$

$$\Psi_{33}^{\lambda\lambda\lambda} = \psi_{000}\phi_{333} \ , \tag{3.16d}$$

$$\Psi_{22}^{\rho\rho\lambda} = \frac{1}{\sqrt{3}} (\psi_{221}\phi_{111} - \sqrt{2}\psi_{222}\phi_{110}) \ , \tag{3.16e}$$

$$\Psi_{22}^{\rho\lambda\lambda} = \frac{1}{\sqrt{3}} (\psi_{111}\phi_{221} - \sqrt{2}\psi_{110}\phi_{222}) \ , \tag{3.16f}$$

$$\Psi_{11}^{\rho\rho\rho} = \psi_{311}\phi_{000} \ , \tag{3.16g}$$

$$\Psi_{11}^{\rho\rho\lambda} = \frac{1}{\sqrt{10}}(\sqrt{6}\psi_{222}\phi_{11-1} - \sqrt{3}\psi_{221}\phi_{110} + \psi_{220}\phi_{111}) \ , \tag{3.16h}$$

$$\Psi_{11}^{\rho\lambda\lambda} = \frac{1}{\sqrt{10}}(\sqrt{6}\psi_{11-1}\phi_{222} - \sqrt{3}\psi_{110}\phi_{221} + \psi_{111}\phi_{220}) \ , \tag{3.16i}$$

$$\Psi_{11}^{\lambda\lambda\lambda} = \psi_{000}\phi_{311} \ , \tag{3.16j}$$

$$\Psi_{11}^{\rho\rho\lambda'} = \psi_{200}\phi_{111} \ , \tag{3.16k}$$

$$\Psi_{11}^{\rho\lambda\lambda'} = \psi_{111}\phi_{200} \ , \tag{3.16l}$$

in which $\psi_{n\ell m}$, $\phi_{n\ell m}$ are the eigenfunctions of the ρ and λ oscillators respectively.

The eigenvalue corresponding to $\psi_{n\ell m}\phi_{n'\ell'm'}$ is given by

$$E_0 = (n + \tfrac{3}{2})\omega_\rho + (n' + \tfrac{3}{2})\omega_\lambda \ . \tag{3.17}$$

3.2 The Model

The model used in this work employs a Hamiltonian of the form

$$H = \sum_i \left[m_i + \frac{P_i^2}{2m_i} \right] + \sum_{i<j} V(r_{ij}) - \frac{(\sum_i P_i)^2}{2\sum_i m_i} + H_{hyp.} , \qquad (3.18)$$

where

$$V(r_{ij}) = - 2\alpha_s/3r_{ij} + ar_{ij} \qquad (3.19)$$

and

$$H_{hyp.} = \sum_{i<j} H^{ij}_{hyp.}, \qquad (3.20)$$

where

$$H^{ij}_{hyp.} = \frac{2\alpha_s}{3m_i m_j} \left\{ \frac{8\pi}{3} \vec{S}_i . \vec{S}_j \, \delta^3(\vec{r}_{ij}) + \frac{1}{r^3_{ij}} \left[\frac{3(\vec{S}_i . \vec{r}_{ij})(\vec{S}_j . \vec{r}_{ij})}{r^2_{ij}} - \vec{S}_i . \vec{S}_j \right] \right\} . \qquad (3.21)$$

Following Gromes and Stamatescu[16,18] the Hamiltonian is rewritten as

$$H = H_0 + \sum_{i<j} \left[V(r_{ij}) - \tfrac{1}{2} bkr^2_{ij} \right] + H_{hyp.}$$

$$= H_0 + \sum_{i<j} U(r_{ij}) + H_{hyp.}, \qquad (3.22)$$

where H_0 is given by eq.(3.4). In this model the potential is modified by attaching a coefficient b to the harmonic-oscillator term (see eq.(3.2)) We now turn off the hyperfine interaction. The variational method is employed to determine α_ρ and α_λ. In the case of three equal quark masses we can make use of the resulting symmetry and it follows that

$$\langle\alpha| \sum_{i<j} U_{ij} |\beta\rangle = 3\langle\alpha|U_{12}|\beta\rangle \ , \tag{3.23}$$

which considerably simplifies the calculation. In the case of two distinct quark masses, we still have symmetry between quark 1 and 2. Hence

$$\langle\alpha| \sum_{i<j} U_{ij} |\beta\rangle = \langle\alpha|U_{12}|\beta\rangle + 2\langle\alpha|U_{13}|\beta\rangle \tag{3.24}$$

The changing of the variables

$$\begin{bmatrix} \vec{\rho} \\ \vec{\lambda} \end{bmatrix} = \begin{bmatrix} t/2\sqrt{2} & -\sqrt{\frac{3}{2}} \\ t\sqrt{\frac{3}{8}}\left[\frac{\alpha_\rho}{\alpha_\lambda}\right]^2 & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} \vec{r}_{13} \\ \vec{x} \end{bmatrix} \tag{3.25}$$

where

$$t = \frac{4}{1 + 3\left[\frac{\alpha_\rho}{\alpha_\lambda}\right]^2} \tag{3.26}$$

is used to calculate $\langle\alpha|U_{13}|\beta\rangle$ (see appendix c).

These are also applied to the calculation of the hyperfine interactions later. The variational process is applied separately to the ρ and λ oscillators and to different orbital angular momentum sectors as follows: To determine α_ρ, a basis of $\{ \psi_{n\ell m}\phi_{\ell\ell m} \}$, $n = 2i+\ell$, $i=0,1$ ≡ $\{\Phi_i\}$ is used. We diagonalize the two by two matrix $\{ \langle \Phi_i|H|\Phi_j \rangle \}$, $i, j = 0,1$ and minimize the eigenvalues. In this process the coefficient b is attached to the harmonic-oscillator term in H_0 (see eq.(3.4)). There are two reasons for doing this. First the matrix element may have no minimum eigenvalues when b is large. Secondly, we find that by doing this, the mixing due to the U-term is small and so as far as the potential is concerned, we achieve almost the same effect as taking into account the mixing by the potential in a large basis. That is, the eigenfunctions of the potential used are well approximated by the hamonic-oscillator wavefunctions. α_λ is determined similarly by using the basis $\{ \psi_{\ell\ell m}\phi_{n\ell m} \}$, $n = 2i+\ell$, $i = 0,1 \equiv \{\Phi_i\}$. Here we use these wavefunctions instead of eqs.(3.11)-(3.16) for the reason of simplicity and because we are interested in the two lowest radially excited states in each sector. In the model by Gromes and Stamatescu[16] α_ρ and α_λ are determined by minimizing each state separately.

If b>1.0, as occurs here, the potential will become unconfining at some point. At first sight, this seems to be an unphysical potential. However, as mentioned earlier, the energy of the states corresponds to the short and medium range behavior of the potential and the potential used is valid only in these ranges. We take the same view as Gromes and Stamatescu[16] that the potential may be different than that used in this work at long range. Examining figure 3.1 it is clear that in the regions of interest to this model, the potential used is confining. For excited states, the potential will be more confining than in the ground state due to the lower values of α_ρ and α_λ.

Eqs.(3.11) - (3.16) are now used to construct the baryon wavefunctions. The construction of the complete baryon wavefunctions and the treatment of the hyperfine interaction is given in appendices B and C respectively. As seen in chapter 1, the color wavefunction is antisymmetric and can be neglected in the complete baryon wavefunctions. The space-spin-flavor wavefunctions are constructed to be symmetric under interchange of quark indices. The U-term (eq.(3.22)) and the hyperfine interaction are treated as perturbations. The mixings by these terms within each band and between different bands are taken into account. The resulted baryon spectra and the mixings between different states are given in tables 5.1 - 5.14 and also in tables 5.15 - 5.18.

The vast amount of experimental data in baryon spectrum and the complicated three-body problem of baryons would justify the study of the spectroscopy alone. Although most of the works on the baryon spectrum have successfully accounted for many important properties of baryons such as their masses, spin etc., there is a serious drawback in comparing the spectrum with the experimental data without studying their decays. For most of the resonances, it is difficult to assign predicted baryons to experimentally known particles. This difficulty is compounded by the many resonances given by the model which are left unaccounted for. This problem is dealt with in the next chapter, in which the strong decays of baryons are studied.

CHAPTER FOUR

STRONG DECAYS OF BARYONS

In order to be useful in accounting for the spectroscopy, a decay model must have the following properties: (i) It should be consistent with the model of the mass calculation. A change of some features of the mass calculation in the decay model may compromise the purpose. (ii) The result of the decay calculation should be mainly determined by that of the mass calculation. For instance, if there are too many parameters in the decay model it is difficult to relate the results obtained, to the particles considered in the model, used in the mass calculation.

Generally, there are two types of strong decay models: The meson emission model which treats the emitted meson as a point - like particle and the pair creation model which takes into account the quark components and the size of the meson. The main advantage of the former model is simplicity. One may also use relativistic kinematics for the meson, while considering the quark components of the meson restricted to a nonrelativistic approximation. In this work the quark pair creation model by A. le Yaouanc et al. is utilized. It seems to be the natural choice for a mass calculation using a nonrelativistic quark model and this model takes into account the quark components and the size of the particles involved, which is more realistic than the meson emission model. On the other hand, this model is still a simple model, lacking a fully developed theoretical background. One should keep this in mind during the process of studying the decays.

4.1 The Quark Pair Creation model by A. Le Yaouanc et al.[28]

The decay A $\longrightarrow$ B + M where A and B are baryons and M is a meson is shown in fig. 4.1. During the process a quark-antiquark pair is created and combines with the initial quarks of the baryon A to form the final baryon B and the meson M. The initial quarks remain unaffected during the process. The notation J_x, ℓ_x, S_x, I_x (x = A, B, M, P) is used to denote the total spin, orbital angular momentum, spin and isospin of A, B, M and the pair P.

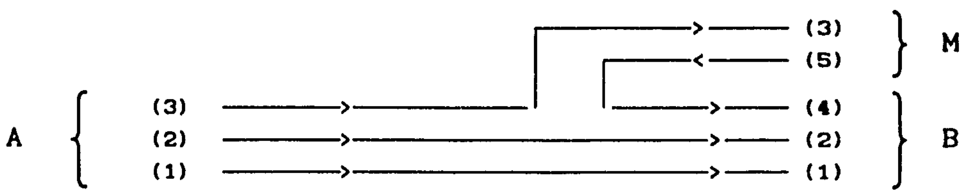


Figure 4.1 The decay A $\longrightarrow$ B + M.

The $q\bar{q}$ pair has the quantum numbers of the vacuum. It is a color singlet and flavor singlet. It has zero momentum and zero total angular momentum. The pair must also be of positive parity for parity conservation. A fermion-antifermion pair has $P = (-1)^{\ell+1}$, $C = (-1)^{\ell+s}$ so the pair must be in a $^3P_0$ state.

The partial decay amplitude $M(\ell, j)$ is expressed in terms of the spatial, spin and isospin reduced matrix elements by

$$M(\ell, j) = \mathfrak{J}^{(I_A,\ I_B I_M)} \sum_{\ell_1, \ell_f, s} \mathcal{L}^{(\ell_A,\ \ell_B \ell_M)}_{\ell_1 \ell_f, \ell} \ \mathcal{G}^{(s_A,\ s_B s_M)}_{s}$$

$$\times \left[(2\ell_1+1)(2s+1)(2J_A+1) \right]^{\frac{1}{2}} \left\{ \begin{matrix} \ell_A & s_A & J_A \\ \ell_P & s_P & 0 \\ \ell_1 & s & J_A \end{matrix} \right\}$$

$$\times \left[(2\ell_f+1)(2s+1)(2J_B+1)(2J_M+1) \right]^{\frac{1}{2}} \left\{ \begin{matrix} \ell_B & s_B & J_B \\ \ell_M & s_M & J_M \\ \ell_f & s & j \end{matrix} \right\}$$

$$\times (-1)^{\ell+\ell_f+s+J_A} \left[(2\ell_1+1)(2j+1) \right]^{\frac{1}{2}} \left\{ \begin{matrix} \ell_f & \ell & \ell_1 \\ J_A & s & j \end{matrix} \right\} \tag{4.1}$$

Where ℓ is the orbital angular momentum between B and M and

$$\left. \begin{aligned} \vec{\ell}_f &= \vec{\ell}_B + \vec{\ell}_M , \\ \vec{\ell}_1 &= \vec{\ell}_f + \vec{\ell} = \vec{\ell}_A + \vec{\ell}_P , \\ \vec{j} &= \vec{j}_B + \vec{j}_M , \\ \vec{s} &= \vec{s}_B + \vec{s}_M = \vec{s}_A + \vec{s}_P . \end{aligned} \right\} \tag{4.2}$$

The reduced spatial matrix element $\mathcal{L}^{(\ell_A, \ell_B \ell_M)}_{\ell_1 \ell_f, \ell}$ is defined from the spatial integral

$$I^{(\ell_A,\ \ell_B \ell_M)}_{m_A m_P,\ m_B m_M} = 3\gamma \int d\vec{k}_1 d\vec{k}_2 d\vec{k}_3 d\vec{k}_4 d\vec{k}_5 \ \psi^{m_B *}_{B}(\vec{k}_1, \vec{k}_2, \vec{k}_4)$$

$$\times \delta(\vec{k}_1+\vec{k}_2+\vec{k}_4+\vec{k}_M) \ \psi^{m_M *}_{M}(\vec{k}_3, \vec{k}_5) \ \delta(\vec{k}_3+\vec{k}_5-\vec{k}_M)$$

$$\times Y^{m_P}_{1}(\vec{k}_4-\vec{k}_5) \ \psi^{m_A}_{A}(\vec{k}_1, \vec{k}_2, \vec{k}_3) \ \delta(\vec{k}_1+\vec{k}_2+\vec{k}_3) \tag{4.3}$$

by

$$I^{(\ell_A,\ \ell_B\ell_M)}_{m_Am_P,\ m_Bm_M} = \sum_{\ell_1,\ell_f,\ell} \mathcal{E}^{(\ell_A,\ \ell_B\ell_M)}_{\ell_1\ell_f,\ell}(k_M) \sum_{m_1,m_f,m} \langle \ell_A m_A \ell_P m_P | \ell_1 m_1 \rangle$$

$$\times \langle \ell_B m_B \ell_M m_M | \ell_f m_f \rangle \langle \ell m \ell_f m_f | \ell_1 m_1 \rangle \, Y^m_\ell(\hat{k}_M)$$

(4.4)

and the reduced matrix elements $\mathcal{G}^{(S_A,S_BS_M)}_S$ and $\mathfrak{F}^{(I_A,I_BI_M)}$ are defined by

$$\mathcal{G}^{(S_A,S_BS_M)}_S = \left[(2s_B+1)(2s_M+1)(2s_A+1)(2s_P+1) \right]^{\frac{1}{2}} \begin{Bmatrix} s_{12} & \frac{1}{2} & s_B \\ \frac{1}{2} & \frac{1}{2} & s_M \\ s_A & s_P & s \end{Bmatrix}$$

(4.5)

and

$$\mathfrak{F}^{(I_A,I_BI_M)} = (-1)^{I_{12}+I_M+I_A+\frac{1}{2}} \left[\frac{1}{2}\,(2I_M+1)(2I_B+1) \right]^{\frac{1}{2}}$$

$$\times \begin{Bmatrix} I_{12} & I_B & \frac{1}{2} \\ I_M & \frac{1}{2} & I_A \end{Bmatrix} \tag{4.6}$$

in which the subscript 12 denotes the diquark (q_1q_2). The eq.(4.6) comes about because $\vec{I}_P = 0$ and

$$\vec{I}_A + \vec{I}_P = \vec{I}_A = \vec{I}_B + \vec{I}_M \tag{4.7}$$

If B and M are in the ground state, as in our case, $\ell_B = \ell_M = 0$. Eqs. (4.1) and (4.4) reduce to

$$M(\ell, j) = \mathfrak{J}^{(I_A, \; I_B I_M)} \; \mathcal{E}^{(\ell_A, \; 0\,0\,)}_{\ell\,0,\ell} \; \mathcal{G}^{(s_A, \; s_B s_M)}_{s}$$

$$\times \; (-1)^{\ell_A + J_A + s + 1} \left[\frac{1}{3} \, (2\ell+1)(2s+1) \right]^{\frac{1}{2}}$$

$$\times \begin{Bmatrix} \ell_A & s_A & J_A \\ s & \ell & 1 \end{Bmatrix} \tag{4.8}$$

$$I^{(\ell_A, \; 0\,0\,)}_{m_A m_P, \; 00} = \sum_{\ell} \mathcal{E}^{(\ell_A, \; 00\,)}_{\ell\,0\;,\ell} (k_M) \; \langle \ell_A m_A \ell_P m_P | \ell \; 0 \rangle \; Y^0_1 \; (\hat{k}_M) \; , \tag{4.9}$$

where $\hat{k}_M$ is taken as the axis of quantization. The partial decay width is given by

$$\Gamma(\ell, j) = 2\pi \, \frac{E_B E_M k_M}{m_A} \; |M(\ell, j)|^2 \; . \tag{4.10}$$

From eq.(4.2), $\ell = \ell_A + 1, \; \ell_A, \; \ell_A - 1$. Because the ground state baryon and meson have the parity +1 and -1 respectively, the conservation of parity gives

$$(-1)^{\ell_A} = (-1)^{\ell+1} \; . \tag{4.11}$$

This excludes the value $\ell = \ell_A$. Furthermore, in the examined processes N, $\Delta \longrightarrow N\,\pi$ and Λ, $\Sigma \longrightarrow N\,\bar{K}$. π and $\bar{K}$ have spin zero so

$$\vec{s} = \vec{s}_B + \vec{s}_M = \vec{s}_N = \frac{1}{2} \; . \tag{4.12}$$

Conservation of total angular momentum gives

$$\vec{J}_A = \vec{\ell}_A + \vec{s}_A = \vec{j} + \vec{\ell} = \vec{s} + \vec{\ell} \; . \tag{4.13}$$

From this we have $\ell = \ell_A+1$ for the case $J_A > \ell_A$ and $\ell = \ell_A-1$ for the case $J_A < \ell_A$. In summary, we have only one value of ℓ and J in each decay. In this case, the partial decay width (4.10) can be taken as the total width of the channel.

4.2 The model

In the QPC model by A. Le Yaouanc et al. the pair creation is the same for all processes. In this work, we allow the creation strength to be dependent on momentum and replace γ in eq.(4.3) by k_M^{γ}. To have the correct unit of the widths, a coefficient a = 1 Gev^{-1} is understood to be attached to k_M. The constant 3 (see eq.(4.3)) in the processes N, $\Delta \longrightarrow N\,\pi$ is removed in Λ, $\Sigma \longrightarrow N\,\bar{K}$, because in the former any of the first three initial quarks can combine with the antiquark to form the meson, but in the latter the strange quark has to combine with the antiquark. The wavefunction of the ground state meson is given by

$$\psi_M(\vec{k}_1,\vec{k}_2) = \left[\frac{1}{\pi\alpha_M^2} \right]^{\frac{3}{4}} \exp\left[- \frac{1}{8\alpha_M^2} (\vec{k}_1 - \vec{k}_2)^2 \right] \tag{4.14}$$

In the mass calculation, the wavefunctions are expressed in r-representation. The transformation to k-representation of the Harmonic-oscillator wavefunctions is given by

$$\phi_{n\ell}(k) = (-i)^{\ell} \frac{(-1)^n}{\alpha^3} R_{n\ell}\left[\frac{k}{\alpha^2} \right] , \tag{4.15}$$

where $R_{n\ell}$ is the radial part of the wavefunctions. Due to the variation process, in the mass calculation, α has different values in different orbital angular momentum sectors. The relevant values are α = 0.29, 0.25, 0.23 and 0.22 Gev for $\ell_{\rho,\lambda}$ = 0, 1, 2 and 3 respectively, in the N and Δ sectors. In the Λ and Σ sectors, α_λ = 0.32, 0.28, 0.26, 0.25 Gev for ℓ_λ = 0, 1, 2, 3 respectively.

The wavefunction of the ground-state nucleon is given by (Table 5.1)

$$|N \tfrac{1}{2}^+ > = -.9715 \ |N \ ^2S_S \tfrac{1}{2}^+> + .1592 \ | \ N \ ^2S_S{}' \tfrac{1}{2}^+> - .1725 \ |N \ ^2S_M \tfrac{1}{2}^+> + .0333 \ | \ N \ ^4D_M \tfrac{1}{2}^+> + .0011 \ |N \ ^2P_A \tfrac{1}{2}^+> \tag{4.16}$$

Because the mixings with the last two states are small one can set

$$|N \tfrac{1}{2}^+ > \simeq -.9715 \ |N \ ^2S_S \tfrac{1}{2}^+> + .1592 \ | \ N \ ^2S_S{}' \tfrac{1}{2}^+> - .1725 \ |N \ ^2S_M \tfrac{1}{2}^+> \tag{4.17}$$

This considerably reduces the amount of work.

The spatial integral of eq. (4.3) can be calculated by using the variables

$$\left.\begin{aligned} \vec{k}_\rho &= \frac{1}{\sqrt{2}} (\vec{k}_1 - \vec{k}_2) \\ \vec{k}_\lambda &= \frac{1}{\sqrt{6}} (\vec{k}_1 + \vec{k}_2 - 2\vec{k}_3) \end{aligned}\right\} \tag{4.18}$$

Eq. (4.3) becomes

$$I^{(\ell_A, \ell_B \ell_M)}_{m_A m_P, m_B m_M} = 3\gamma\ \delta(\vec{K}_M+\vec{K}_B) \int d\vec{K}_\rho d\vec{K}_\lambda\ \psi^{m}_{A}{}^{A}(\vec{K}_\rho, \vec{K}_\lambda)\ \psi^{m}_{B}{}^{B\,*}(\vec{K}_\rho, \vec{K}_\lambda + \sqrt{\tfrac{2}{3}}\ \vec{K}_M)$$

$$\times\ \psi^{m}_{M}{}^{M\,*}(-\frac{2\sqrt{2}}{\sqrt{3}}\ \vec{K}_\lambda - \vec{K}_M)\ Y^{m}_{1}{}^{P}(\ \frac{2\sqrt{2}}{\sqrt{3}}\ \vec{K}_\lambda + ?\vec{?}_M) \tag{4.19}$$

The integration of $d\vec{K}_\rho$ gives 0 or 1 by the normalization. For the integration of $\vec{K}_\lambda$, we have the term

$$\exp\left[-\frac{1}{2\alpha_A^2}\vec{K}_\lambda^2\right]\exp\left[-\frac{1}{2\alpha_B^2}\left(\vec{K}_\lambda + \sqrt{\tfrac{2}{3}}\ \vec{K}_M\right)\right]\exp\left[-\frac{1}{8\alpha_M^2}\left(\frac{2\sqrt{2}}{\sqrt{3}}\ \vec{K}_\lambda + 2\vec{K}_M\right)\right] \tag{4.20}$$

in which the three exponential terms belong to the wavefunctions of A, B and M respectively. The integration can be carried out by changing the variable

$$\vec{K}_\lambda = \vec{K}'_\lambda - \frac{\sqrt{\tfrac{2}{3}}\ B + \frac{\sqrt{3}}{2\sqrt{2}}\ C}{A + B + C}\ \vec{K}_M\ , \tag{4.21}$$

where

$$A = \frac{1}{2\alpha_A^2}\ ,\quad B = \frac{1}{2\alpha_B^2}\ ,\quad C = \frac{1}{3\alpha_M^2}\ . \tag{4.22}$$

The exponential term (4.20), then becomes

$$\exp\left(-\beta_M^2\ k_M^2\right)\exp\left(-\beta_\lambda^2\ k_\lambda'^2\right) \tag{4.23}$$

where

$$\beta_M^2 = \frac{\frac{1}{24}\ BC + \frac{2}{3}\ AB + \frac{3}{8}\ AC}{A + B + C}\ ,\qquad \beta_\lambda^2 = A + B + C \tag{4.24}$$

The calculated decay widths of baryons are given in tables 5.15-5.18. The discussion of these results and those of baryon spectra is given in the next chapter.

CHAPTER FIVE

RESULTS AND DISCUSSIONS

This chapter is devoted to fitting to the experimental data, discussion of the results and comparing them with the experimental data and with other works.

5.1 The mass calculation

N, Δ, Λ, Σ sector (Table 5.1-5.4 also Table 5.15-5.18) The calculation of the baryon masses depends on the quark masses, α_s, a, b and an overall constant C. Fitting the S=0 and S= -1 strangeness sector results in $m_u = m_d = 0.23$ Gev, x_1 =0.38, $\alpha_s = 1.0$, a = 0.08 Gev^2, b = 1.68 and C = - 0.6 Gev. In the papers by Gromes and Stamatescu[18] and Barbour and Ponting[20] they have, in the corresponding parts, m_u = 0.3 Gev, α_s = 0.5, a = 0.05 Gev^2, C = -0.32 Gev and m_u = 1.12 Gev, α_s = 1.01, a = 0.042 Gev^2, C = -0.67 Gev respectively.

In this sector, the fitting shows a quantatively good description of the spectrum. The predicted masses of most states are close or contained within the experimental ranges. The ones which are somewhat problematic are $\Lambda\ \frac{5}{2}^+$(1.930 Gev), $\Lambda\ \frac{3}{2}^+$(2.087 Gev), $\Lambda\ \frac{5}{2}^-$(1.972 Gev), $\Lambda\ \frac{3}{2}^-$(1.865 Gev) which are a little bit high compared to the experimental values of (1.815-1.825 Gev), (1.850-1.910 Gev), (1.810-1.830 Gev), (1.685-1.695 Gev) respectively and $\Sigma\ \frac{7}{2}^+$(2.266 Gev), $\Sigma\ \frac{5}{2}^-$(1.880 Gev) which are also high compared to the experimental values of (2.025-2.040 Gev), (1.770-1.780 Gev) respectively.

Ξ and Ω sector (Table 5.9, 5.12) No new parameters are used to perform calculations in this sector. Hence while there is not much experimental data available, the predictions for this sector are encouraging. The prediction of $\Xi\ \frac{3}{2}^+$(1.446 Gev) is a little bit low compared to 1.530 Gev of the experimental data, but the prediction of $\Xi\ \frac{1}{2}^+$(1.349 Gev) is very close to the experimental value of 1.317 Gev. The prediction of $\Xi\ \frac{3}{2}^-$ at 1.910 Gev is a little bit high compared to the experimental value of 1.820 Gev. For the Ω, the prediction of $\Omega\ \frac{3}{2}^+$(1.620 Gev) is close to the experimental value of 1.672 Gev. The recent report of a Ω resonance at 2.252 ± 0.009 Gev seems to be in agreement with the predictions here. The leading candidates are $\Omega\ \frac{7}{2}^+$(2.263 Gev), $\Omega\ \frac{5}{2}^+$(2.268 Gev), $\Omega\ \frac{3}{2}^+$(2.265 Gev), $\Omega\ \frac{1}{2}^+$(2.259 Gev), $\Omega\ \frac{5}{2}^-$(2.250 Gev), $\Omega\ \frac{3}{2}^-$(2.251 Gev) and $\Omega\ \frac{1}{2}^-$(2.250 Gev).

c and b sector. The calculation of baryons containing c and b quarks requires in addition $x_2 = m_u/m_c$ and $x_3 = m_u/m_b$. Fitting $\Lambda_c\ \frac{1}{2}^+$ at 2.282 Gev and $\Lambda_b\ \frac{1}{2}^+$ at 5.425 Gev yields $x_2 = 0.1237$ and $x_3 = 0.0455$. The prediction of $\Sigma_c\ \frac{1}{2}^+$(2.515 Gev) is close to the experimental value of 2.453 Gev. If $\Lambda_b\ \frac{1}{2}^+$ is at 5.425 Gev, as presently claimed, our prediction is $\Sigma_b\ \frac{1}{2}^+$ would have a mass around 5.675 Gev as in table 5.8.

Until now, accommodating the negative-parity baryons into the same framework with the positive-parity baryons seems to be a problem for many models using a non-relativistic approach. Isgur and Karl[21,23,32] successfully described the negative-parity and positive-parity baryons but with a high price of using different parameter sets. Forsyth[31] obtained good results but a new parameter has to be introduced for the

$(56,1^-)$ multiplet. In term of a universal parameter set Barbour and Ponting[20] had some success with the positive-parity section but the negative-parity section is not as good.

So far, the only successful description of both positive and negative-parity baryons is the work by Capstick and Isgur[25] using the relativized quark model. In this model relativistic kinematics are used and some other terms are put in by hand to describe the momentum dependence of the interaction.

The model used by Barbour and Ponting[20] is similar to the model here. Compared to this work, the results obtained here are a considerable improvement. Their results show a rather high value for the $(56',0^+)_{N=2}$ state and rather low values for the first-excited negative-parity states. This problem is considerably improved in the results obtained here. Of course it can be said that the reason is that there is one more parameter in this model but it should be remembered that the work here covers much larger ground than that of Barbour and Ponting and also that this problem seem to persist even in the relativized model, where a large number of parameters are used. Similarly, the model here is able to accommodate the $(56,1^-)_{N=3}$states which have to be lowered by introducing a new parameter S_{56}=200 Mev in Forsyth[31]. The high values of these states are also found in the relativized model[25]. Finally one point that should be stressed is that the model here uses less parameters than used by Forsyth and by Capstick and Isgur in their models. Not counting the masses of the c and b quarks, the model here uses six parameters, as compared to thirteen in the relativized quark model. Forsyth's model only considers the non-strange section and employs nine parameters compared to five employed to calculate the non-strange sector in this model.

5.2 The decay calculation

In the N and Δ sectors we seem to have consistent experimental data by Cutkosky and Hoehler[29]. Because there are some discrepancies between them, we quote both of them for comparison with the experimental data. In the Λ and Σ sectors, because we do not have such a consistent set of experimental data, we list the values given in the Baryon summary tables. The value of α_M is determined by fitting Δ(1232) yielding α_M = 0.194 Gev. γ, by a fit to Cutkosky's data, is determined to have the value $\gamma = -1.11$. The results are listed in table 5.15-5.18. The negative value of γ is interesting. This may be due to two factors which are not taken into account by the overlap of the wavefunctions. (i). Based on QCD the amplitude of the pair creation is proportional to $\alpha_s(Q^2)$ and so is smaller with higher momentum. (ii). Consider, for instance, the decay $N' \longrightarrow N\pi$. What is wanted in this process is only one $u\bar{u}$ or $d\bar{d}$ pair created. At low $E_{N'} - E_N = E$, only one $u\bar{u}$ or $d\bar{d}$ pair can be created. At higher E, two pairs may be created, giving rise to, for instance, the process $N' \longrightarrow N\pi\pi$, or for example a single $s\bar{s}$ is created and then we may have $N' \longrightarrow \Lambda K$ etc. This means the higher momentum, the lower the chance of creating only one $u\bar{u}$ or $d\bar{d}$ pair. It is interesting to note that this factor has about the same strength as the factor $E_M k_M$ in the phase factor and their effects cancel each other. In the mass calculation, a constant value α_s is used and so the parameters used here should be considered as effective values, which have taken into account the variation of α_s. For this reason, it is more likely that the negative value of γ is due to the second factor.

Two major analyses on the decays of baryons have been done by Koniuk and Isgur[30] and by Forsyth and Cutkosky[31]. In the following, a detailed comparison of the results with the experimental data and with these two works is presented. The work by Koniuk and Isgur does not cover the N = 3 band baryons, so in this region we compare only with the results by Forsyth and Cutkosky. On the other hand, Forsyth and Cutkosky's calculations do not cover the Λ and Σ sectors, so there, we will compare with Koniuk and Isgur's alone. The N = 3 band in the Λ and Σ sectors has not been considered before this paper.

N sector (Table 5.15). The outstanding problems of the predicted widths in this sector are the widths of $N\frac{5}{2}^+$ (1.670 - 1.690) Gev and $N\frac{7}{2}^-$ (2.120 - 2.230) Gev. They are too high compared to the experimental data, however the main objective of the decay calculation here is to assign predicted baryons to experimentally known particles and the results here confirm that these resonances are the most likely to be seen of all those particles with the same value of J^P. The widths of 0.074 Gev and 0.078 Gev of $N\frac{3}{2}^+$ (1.690 - 1.800) Gev and $N\frac{1}{2}^+$ (1.680 - 1.740) Gev are also somewhat high compared to the experimental data of (.018 - .037) Gev and (.010 - .029) Gev respectively. The value of .020 Gev of $N\frac{1}{2}^-$ (1.620 - 1.680) Gev is low compared to the experimental value of (.061 - .143) Gev. Beside these, all the other results are in agreement or close to the experimental data.

About the unseen resonances in the $J^P = \frac{3}{2}^+$ sector, there are some differences between the results here and those of Koniuk and Isgur[30] and Forsyth and Cutkosky[31]. Three resonances are predicted to be seen and the last is predicted to be weakly coupled by the results here. Koniuk and Isgur predict that the second resonance should be seen but the next two are weakly coupled and the last is decoupled. In Forsyth and Cutkosky, the second resonance is predicted to be seen and the rest are predicted to be weakly coupled. Unanimous agreement is achieved for the only unseen resonance in the $J^P = \frac{1}{2}^+$ section: $N\frac{1}{2}^+$ (2.096 Gev) is predicted to be weakly coupled. It should be clear that all the predicted masses are from the model here and may not be in agreement with the other two.

As far as the unseen resonances in the N = 3 band region is concerned, there is a good agreement between the results here and those by Forsyth and Cutkosky[31] with the following exceptions: The resonances which are predicted to be seen by this work and predicted to be weakly coupled or decoupled by Forsyth and Cutkosky are $N\frac{7}{2}^-$(2.290 Gev), $N\frac{3}{2}^-$ (2.245 Gev). In the opposite case, the resonances predicted to be seen by Forsyth and Cutkosky and predicted to be weakly coupled or decoupled here, are $N\frac{5}{2}^-$ (2.252 Gev), $N\frac{5}{2}^-$ (2.357 Gev), $N\frac{3}{2}^-$ (2.314 Gev), $N\frac{3}{2}^-$ (2.391 Gev).

Δ sector (Table 5.16). The results obtained here show an excellent agreement with the experimental data in this sector. All the predicted widths are contained within the experimental ranges, except for the cases of $\Delta\frac{1}{2}^-$ (1.600 - 1.650) Gev and $\Delta\frac{1}{2}^-$ (1.850 - 2.000) Gev. The predicted values of 0.019 Gev and 0.040 Gev are a little bit lower and higher than the experimental values of (.026 - .045) Gev and (.008 - .029) Gev respectively.

The weakly coupled resonance, $\Delta\frac{3}{2}^{+}$ (2.017 Gev) here is in agreement with Forsyth and Cutkosky[31], while predicted to be decoupled according to Koniuk and Isgur[30]. Again, there is an excellent agreement between the results obtained here and in Forsyth and Cutkosky in terms of the unseen resonances of the N = 3 band. The only exception is $\Delta\frac{3}{2}^{-}$ (2.304 Gev) predicted to be seen here and predicted to be decoupled by Forsyth and Cutkosky[31].

Λ sector (Table 5.17). The predicted widths of .001 Gev and .088 Gev for $\Lambda\frac{5}{2}^{+}$ (1.815 - 1.825) Gev and $\Lambda\frac{5}{2}^{+}$ (2.090 - 2.140) Gev are low and high compared to the experimental values of (0.039 - 0.059) Gev and (0.008 - 0.063) Gev respectively. These are the only two nondecoupled resonances in this J^P sector. The width of the only nondecoupled resonance in the $J^P = \frac{3}{2}^{+}$ sector $\Lambda\frac{3}{2}^{+}$ (1.850 - 1.910) Gev is in good agreement with the experimental data. The predicted width of .104 Gev for $\Lambda\frac{1}{2}^{+}$ (1.560 - 1.700) Gev is a little high compared to the experimental value of (0.008 - 0.075) Gev . The widths of 0.050 Gev and 0.079 Gev for $\Lambda\frac{1}{2}^{+}$ (1.750 - 1.850) Gev and $\Lambda\frac{7}{2}^{-}$ (2.090 - 2.110) Gev are contained within the experimental ranges of (0.010 - 0.125) Gev and (0.025 - 0.088) Gev respectively. There is a problem with the resonance $\Lambda\frac{5}{2}^{-}$ (1.810 - 1.830) Gev. The result here shows no coupled resonance with mass around this range. It should be noted that experimentally this resonance decays mainly through the $\Sigma\pi$ channel and this may be the reason for the situation here. The predicted values of 0.030 Gev and 0.002 Gev for $\Lambda^{3-}_{\frac{}{2}}$ (1.520 Gev) and $\Lambda^{3-}_{\frac{}{2}}$ (1.685 - 1.695) Gev are high and low compared to the experimental values of 0.007 Gev and (0.010 - 0.021) Gev respectively. The predicted width of 0.009 Gev for $\Lambda^{1-}_{\frac{}{2}}$ (1.660 - 1.690) Gev is in agreement with the experiment data, while the prediction of 0.001 Gev for $\Lambda^{1-}_{\frac{}{2}}$ (1.720 - 1.850) Gev is low, compared to the experimental value of (0.050 - 0.160) Gev.

Also, many unseen resonances are decoupled from or weakly coupled to the $N\bar{K}$ channel, in agreement with the results by Koniuk and Isgur[30]. The only exception for the N = 0, 1, 2 bands is $\Lambda^{1+}_{\frac{}{2}}$ (2.076) Gev, which is unseen experimentally and which we predict to be decoupled, but has an observable width according to Koniuk and Isgur[30].

This work is the first to cover the N = 3 band in this sector. A striking feature, in this region, is that among a vast amount of resonances, given by the mass calculation, few of them are coupled to the $N\bar{K}$ channel. They are $\Lambda^{7-}_{\frac{}{2}}$ (2.193 Gev), $\Lambda^{3-}_{\frac{}{2}}$ (1.865 Gev), $\Lambda^{3-}_{\frac{}{2}}$ (2.412 Gev), $\Lambda^{1-}_{\frac{}{2}}$ (1.895 Gev) whose existences are already confirmed by the experimental data and $\Lambda^{7-}_{\frac{}{2}}$ (2.414 Gev), $\Lambda^{5-}_{\frac{}{2}}$ (2.193 Gev), $\Lambda^{5-}_{\frac{}{2}}$ (2.413 Gev) expected to be seen.

Σ sector (Table 5.18). In this sector, the results obtained here are in good agreement with the experimental data. The discrepancy occurs in the case of $\Sigma^{5+}_{\frac{}{2}}$ (1.900 - 1.935) Gev with a width of (0.004 - 0.024) Gev while predicted to be decoupled by the model here. Like the case of

Λ^{5-}_{2} (1.810 - 1.830) Gev, the $N\bar{K}$ channel occupies a small fraction of the total width of this resonance.

About the unseen resonances, we also have an agreement between the results obtained here and Koniuk and Isgur's that many resonances are decoupled from or weakly coupled to the $N\bar{K}$ channel in the N = 0, 1, 2 band region. The resonances which are predicted to be decoupled, or weakly coupled, by this model and predicted to be seen by Koniuk and Isgur(30) are Σ^{7+}_{2} (1.939 Gev), Σ^{3+}_{2} (1.945 Gev), Σ^{1+}_{2} (2.140 Gev). In the opposite case, the resonances, predicted to be seen by this model and predicted to be weakly coupled or decoupled by Koniuk and Isgur(30), are Σ^{3+}_{2} (2.259 Gev) and Σ^{1+}_{2} (2.251 Gev).

Again, the result obtained here is the only one for the N = 3 band region. Like the case of Λ, all the resonances in this region are found to be weakly coupled to or decoupled from the $N\bar{K}$ channel with the exceptions of only Σ^{9-}_{2} (2.298 Gev) and Σ^{3-}_{2} (2.296 Gev).

In summary, the results obtained show a generally good agreement with the experimental data. A large number of resonances are essentially decoupled from the studied channels, a result first noted by Koniuk and Isgur(30). Koniuk and Isgur's calculations do not include the N = 3 band and Forsyth and Cutkosky(31) do not cover the Λ and Σ sectors. This is the only calculation that considers the N = 3 band Λ and Σ baryons. Koniuk and Isgur have suppressed the dependence of the amplitudes on the structure of the wavefunctions, which has an important effect on the decay amplitudes, and replaced two constants in the forward and recoil terms by four independent constants. Similarly, Forsyth and Cutkosky allow these two constants to be different, in different spin and orbital states of the q_1q_2 pair. In effect, they used eight parameters, in addition to the baryon and meson radii. In this work, beside the meson radius, the constant γ in the pair creation term, is the only parameter of the decay model.

CONCLUSION

For the mass calculation, it should be kept in mind that the model employs only one parameter set for the whole spectrum . Of course, it is not expected that the parameters reflect the true values but rather the "effective" ones. In addition to the constituent quark masses, the values of α_s and a should be regarded as the effective values which include any relativistic effects, the variation of α_s with energy etc. Even though good results are obtained by adding a harmonic-oscillator potential, its role has yet to be clarified. It is unclear whether this potential really corresponds to what happens inside baryons or simply reflects the closeness with a logarithmic potential discussed earlier.

As far as the decay widths are concerned, despite the generally good agreement with the experimental data, the failure of some of the states mentioned in the previous section does not allow us to be sure about the values of the resulted widths. The main purpose of this part is to establish the baryon spectrum, namely identifying the resonances with the experimental data. We are confident that with the results obtained, this goal is indeed achieved, despite the fact that only the nonrelativistic quark model and the simple QPC model are used.

Since the predicted spectra is in good agreement with the experimental data and confirmed by the decay widths, it seems clear that the baryon spectrum can be presented very well, within a non-relativistic scheme. We believe this is the most consistent quark model[33] to-date, describing the baryon spectroscopy in the sense that a single set of parameters is used, for the whole spectra and then subjecting all of their properties namely the masses, radii and their wavefunction structures to a strict test by a decay model, which has only two parameters (or three parameters if the coefficient $a = 1\ \mathrm{Gev}^{-1}$ is included (see section 4.2)).

Table 5.1 The masses and the components of N

State	Mass	Components				
$N\ {}^4D_M\ \frac{7}{2}^+$	2.006	1.0				
$N\ {}^2D_S\ \frac{5}{2}^+$	1.781	-.8942	.4476	.0006		
$N\ {}^2D_M\ \frac{5}{2}^+$	1.996	-.4395	-.8777	-.1912		
$N\ {}^4D_M\ \frac{5}{2}^+$	2.042	-.0850	-.1712	.9816		
$N\ {}^4S_M\ \frac{3}{2}^+$	1.780	.0881	-.8874	.4524	-.0097	.0008
$N\ {}^2D_S\ \frac{3}{2}^+$	1.915	.9368	.1820	.1693	-.2434	.0379
$N\ {}^2D_M\ \frac{3}{2}^+$	1.995	.3270	-.3447	-.7296	.4717	-.1393
$N\ {}^4D_M\ \frac{3}{2}^+$	2.018	-.0799	-.2449	-.4821	-.7772	.3116
$N\ {}^2P_A\ \frac{3}{2}^+$	2.093	.0371	.0236	.0445	.3377	.9392
$N\ {}^2S_S\ \frac{1}{2}^+$	.958	-.9715	.1592	-.1725	.0333	.0011
$N\ {}^2S_S'\ \frac{1}{2}^+$	1.458	-.1243	-.9726	-.1961	.0079	.0005
$N\ {}^2S_M\ \frac{1}{2}^+$	1.805	-.2017	-.1680	.9559	-.1307	-.0175
$N\ {}^4D_M\ \frac{1}{2}^+$	1.973	.0059	-.0196	.1320	.9396	.3150
$N\ {}^2P_A\ \frac{1}{2}^+$	2.096	.0045	-.0037	.0259	.3144	-.9489
$N\ {}^4F_M\ \frac{9}{2}^-$	2.258	1.0				
$N\ {}^4F_M\ \frac{7}{2}^-$	2.123	.0160	.0003	.8448	-.5348	-.0023
$N\ {}^2F_A\ \frac{7}{2}^-$	2.270	-.9643	-.0445	-.1264	-.2285	-.0006
$N\ {}^2F_M\ \frac{7}{2}^-$	2.290	.2601	.0162	-.5199	-.8134	-.0117

State	Mass	Components				
N $^2F_S\ \frac{7}{2}^-$	2.359	-.0456	.9477	.0037	.0065	-.3157
N $^4D_M\ \frac{7}{2}^-$	2.373	.0125	-.3155	.0032	.0094	-.9488
N $^4P_M\ \frac{5}{2}^-$	1.648	.9909	-.0326	-.0101	-.0126	.0476
		-.0197	-.0069	.0658	.0985	
N $^4F_M\ \frac{5}{2}^-$	2.105	-.0935	.0401	-.0026	.1387	-.1275
		.0109	-.0012	.0927	.9723	
N $^2F_A\ \frac{5}{2}^-$	2.124	-.0542	.0439	-.0032	-.8365	.5126
		-.0033	.0011	.0424	.1755	
N $^2F_M\ \frac{5}{2}^-$	2.253	.0111	.7998	-.1565	-.1074	-.2518
		-.0474	.0129	.4990	-.0971	
N $^2F_S\ \frac{5}{2}^-$	2.290	-.0167	-.5279	-.0838	-.3957	-.6219
		-.0306	.0157	.4094	-.0438	
N $^4D_M\ \frac{5}{2}^-$	2.297	.0755	.2767	.2269	-.3343	-.5160
		.1198	-.0453	-.6857	.0405	
N $^2D_M\ \frac{5}{2}^-$	2.357	-.0048	-.0053	.4203	.0263	.0404
		.5170	-.7076	.2287	-.0260	
N $^4P'_M\ \frac{5}{2}^-$	2.366	.0001	.0206	.7966	.0176	.0196
		.0250	.5632	.2147	-.0187	
N $^4P''_M\ \frac{5}{2}^-$	2.392	.0163	-.0119	-.3249	.0050	.0160
		.8450	.4239	-.0057	-.0058	
N $^2P_M\ \frac{3}{2}^-$	1.470	-.8977	.0637	-.0006	-.0115	.0012
		-.0043	.0004	.0961	.4100	.0212
		.1102				

State	Mass	Components										
$N\ {}^4P_M\ \frac{3}{2}^-$	1.680	-.0590	-.9809	-.0212	-.0290	-.0290	-.0752	-.0115	-.0117	.0227	-.1567	.0361
$N\ {}^4F_M\ \frac{3}{2}^-$	1.841	.4344	-.0043	.0124	.0190	.0005	.0137	.0001	.2184	.8589	-.0035	.1585
$N\ {}^4D_M\ \frac{3}{2}^-$	1.973	.0315	.0188	-.0016	-.0063	.0001	.0500	.0011	.0582	-.2107	.0371	.9731
$N\ {}^2D_M\ \frac{3}{2}^-$	2.158	.0075	-.1657	-.0438	-.0236	-.0072	.1093	-.0083	.1088	-.0196	.9712	-.0506
$N\ {}^4P_M'\ \frac{3}{2}^-$	2.245	-.0080	-.0150	.8994	-.0377	-.0028	-.1425	-.0783	.3899	-.0984	.0050	-.0357
$N\ {}^2P_A\ \frac{3}{2}^-$	2.271	.0095	-.0069	.3908	.0418	.0187	-.0804	-.0407	-.8784	.1963	.1336	.0949
$N\ {}^2P_M'\ \frac{3}{2}^-$	2.314	.0198	.0624	-.1739	-.1267	.0818	-.9615	-.0663	.0289	-.0035	.1066	.0400
$N\ {}^2P_S\ \frac{3}{2}^-$	2.343	-.0146	-.0421	.0062	.6958	.7114	-.0362	.0585	.0493	-.0206	.0141	-.0004

State	Mass	Components				
N $^4P''_M \frac{3}{2}^-$	2.392	-.0107	.0058	.0032	.6822	-.6920
		-.1566	.1708	.0272	-.0148	.0288
		.0066				
N $^2P''_M \frac{3}{2}^-$	2.413	.0035	-.0087	.0750	-.1713	.0841
		-.0505	.9772	-.0105	.0040	.0137
		.0015				
N $^2P_M \frac{1}{2}^-$	1.469	-.8996	.0366	.0202	.0284	-.0024
		.0954	.4057	-.0475	.1102	
N $^4P_M \frac{1}{2}^-$	1.613	-.0080	.9849	.0551	.0583	-.0347
		-.0664	-.1077	.0524	.0585	
N $^4D_M \frac{1}{2}^-$	1.842	.4295	.1008	-.0195	-.0429	-.0020
		.2099	.8486	.0318	.1949	
N $^4P'_M \frac{1}{2}^-$	1.968	-.0102	.0654	.0021	.1654	-.0131
		-.0644	.2385	.0459	-.9513	
N $^2P_A \frac{1}{2}^-$	2.057	-.0496	-.0690	-.0209	.0708	.0185
		-.2023	.0326	.9691	.0764	
N $^2P'_M \frac{1}{2}^-$	2.274	.0560	-.0805	.1487	.9306	-.1808
		-.1605	.0355	-.1126	.1729	
N $^2P_S \frac{1}{2}^-$	2.276	-.0057	.0157	.1025	.1839	-.0370
		.9309	-.2085	.1973	-.0719	
N $^4P''_M \frac{1}{2}^-$	2.393	-.0167	.0488	-.9646	.1954	.1474
		.0716	-.0308	-.0209	.0198	
N $^2P''_M \frac{1}{2}^-$	2.417	.0119	.0159	.1805	.1536	.9708
		-.0041	.0048	-.0263	.0149	

Table 5.2 The masses and the components of Δ

State	Mass	Components			
$\Delta\ ^4D_S\ \frac{7}{2}^+$	1.943	1.0			
$\Delta\ ^4D_S\ \frac{5}{2}^+$	1.956	-.9961	-.0886		
$\Delta\ ^2D_M\ \frac{5}{2}^+$	2.016	-.0886	.9961		
$\Delta\ ^4S_S\ \frac{3}{2}^+$	1.215	.9738	.2184	-.0529	.0346
$\Delta\ ^4S_S'\ \frac{3}{2}^+$	1.788	.2102	-.9707	-.1031	.0537
$\Delta\ ^4D_S\ \frac{3}{2}^+$	1.950	-.0784	.0936	-.9869	.1056
$\Delta\ ^2D_M\ \frac{3}{2}^+$	2.018	.0370	-.0350	-.1125	-.9924
$\Delta\ ^2S_M\ \frac{1}{2}^+$	1.919	-.8813	-.4726		
$\Delta\ ^4D_S\ \frac{1}{2}^+$	1.937	-.4726	.8813		
$\Delta\ ^4F_S\ \frac{9}{2}^-$	2.297	1.0			
$\Delta\ ^4F_S\ \frac{7}{2}^-$	2.262	.0800	.9968		
$\Delta\ ^2F_M\ \frac{7}{2}^-$	2.315	-.9968	.0800		
$\Delta\ ^4F_S\ \frac{5}{2}^-$	2.020	.0169	-.0094	-.0088	.9998
$\Delta\ ^2F_M\ \frac{5}{2}^-$	2.262	-.1437	.9895	.0064	.0118
$\Delta\ ^2D_M\ \frac{5}{2}^-$	2.307	-.9862	-.1440	.0804	.0161
$\Delta\ ^4P_S\ \frac{5}{2}^-$	2.366	-.0806	-.0052	-.9967	-.0074

State	Mass	Components					
$\Delta\ ^2P_M\ \frac{3}{2}^-$	1.653	.9888	-.0002	.0190	.0667	.1099	-.0736
$\Delta\ ^2D_M\ \frac{3}{2}^-$	2.020	-.0152	.0315	.9990	-.0081	-.0219	.0134
$\Delta\ ^4P_S\ \frac{3}{2}^-$	2.116	.1112	-.0023	-.0197	-.1001	-.9858	-.0741
$\Delta\ ^2P'_M\ \frac{3}{2}^-$	2.284	-.0248	-.0429	.0083	-.6536	.1195	-.7456
$\Delta\ ^2P''_M\ \frac{3}{2}^-$	2.304	.0953	.0491	-.0141	-.7471	.0376	.6548
$\Delta\ ^4F_S\ \frac{3}{2}^-$	2.366	.0048	-.9974	.0305	-.0087	-.0017	.0649

$\Delta\ ^2P_M\ \frac{1}{2}^-$	1.655	.9895	-.0626	.0677	.1112
$\Delta\ ^4P_S\ \frac{1}{2}^-$	2.020	-.0526	-.9954	-.0280	-.0751
$\Delta\ ^2P'_M\ \frac{1}{2}^-$	2.117	.1216	.0706	-.0935	-.9856
$\Delta\ ^2P''_M\ \frac{1}{2}^-$	2.295	.0575	.0172	-.9929	.1025

Table 5.3 The masses and the components of Λ

State	Mass	Components				
$\Lambda\ ^4D_{\rho\lambda}\ \frac{7}{2}^+$	2.213	1.0				
$\Lambda\ ^2D_{\lambda\lambda}\ \frac{5}{2}^+$	1.930	.0921	-.0850	.9920	.0069	.0126
$\Lambda\ ^2D_{\rho\lambda}\ \frac{5}{2}^+$	2.089	-.9943	.0441	.0958	.0059	.0166
$\Lambda\ ^2D_{\rho\rho}\ \frac{5}{2}^+$	2.186	-.0501	-.9747	-.0790	-.1726	.1073
$\Lambda\ ^4D_{\rho\lambda}\ \frac{5}{2}^+$	2.242	.0077	.1892	.0199	-.9640	.1854
$\Lambda\ ^4P_{\rho\lambda}\ \frac{5}{2}^+$	2.278	-.0198	-.0715	.0095	-.2018	-.9766
$\Lambda\ ^2D_{\lambda\lambda}\ \frac{3}{2}^+$	1.929	.0882	.9905	-.0900	-.0160	-.0033
		-.0521	.0016			
$\Lambda\ ^2D_{\rho\rho}\ \frac{3}{2}^+$	2.087	-.9851	.0882	.0503	-.0354	.1129
		-.0725	.0059			
$\Lambda\ ^2D_{\rho\lambda}\ \frac{3}{2}^+$	2.145	-.1188	-.0451	-.5498	.2806	-.7607
		-.1478	-.0492			
$\Lambda\ ^4D_{\rho\lambda}\ \frac{3}{2}^+$	2.189	.0500	-.0885	-.7220	-.0487	.5716
		-.3721	.0297			
$\Lambda\ ^4S_{\rho\lambda}\ \frac{3}{2}^+$	2.213	-.0182	.0316	-.0004	.8401	.2801
		.2818	-.3675			
$\Lambda\ ^4P_{\rho\lambda}\ \frac{3}{2}^+$	2.266	-.0686	.0125	-.3885	-.1740	.0420
		.8523	.2928			
$\Lambda\ ^2P_{\rho\lambda}\ \frac{3}{2}^+$	2.281	-.0134	-.0071	-.1225	-.4259	-.0404
		.1609	-.8808			

State	Mass	Components				
$\Lambda\ {}^2S\ \frac{1}{2}^+$	1.134	.9540	.0434	-.2912	-.0367	.0440
		.0005	.0013			
$\Lambda\ {}^2S_{\lambda\lambda}\ \frac{1}{2}^+$	1.622	.1101	.8642	.4905	.0116	.0162
		.0003	.0008			
$\Lambda\ {}^2S_{\rho\rho}\ \frac{1}{2}^+$	1.788	.2666	-.4961	.8168	-.1243	.0111
		.0003	.0008			
$\Lambda\ {}^2S_{\rho\lambda}\ \frac{1}{2}^+$	2.076	-.0763	.0664	-.0847	-.9648	.2239
		.0138	.0394			
$\Lambda\ {}^4D_{\rho\lambda}\ \frac{1}{2}^+$	2.186	.0274	.0251	-.0151	-.2229	-.8913
		-.1288	-.3711			
$\Lambda\ {}^4P_{\rho\lambda}\ \frac{1}{2}^+$	2.282	.0134	.0073	-.0034	-.0513	-.3912
		.2764	.8762			
$\Lambda\ {}^2P_{\rho\lambda}\ \frac{1}{2}^+$	2.303	-.0004	-.0002	.0001	.0012	.0103
		-.9523	.3050			
$\Lambda\ {}^4F_{\rho\rho\rho}\ \frac{9}{2}^-$	2.111	-.9988	-.0482			
$\Lambda\ {}^4F_{\rho\lambda\lambda}\ \frac{9}{2}^-$	2.569	-.0482	.9988			
$\Lambda\ {}^4F_{\rho\rho\rho}\ \frac{7}{2}^-$	2.095	.0264	-.0024	-.9956	.0379	-.0727
		-.0370	.0002			
$\Lambda\ {}^4F_{\rho\lambda\lambda}\ \frac{7}{2}^-$	2.128	.9978	.0562	.0264	.0163	.0112
		-.0096	.0025			
$\Lambda\ {}^2F_{\rho\rho\rho}\ \frac{7}{2}^-$	2.193	-.0207	-.0032	.0389	.6677	.1754
		-.7221	.0000			
$\Lambda\ {}^2F_{\rho\rho\lambda}\ \frac{7}{2}^-$	2.414	-.0086	.0113	-.0612	.3723	.7619
		.5261	-.0162			

State	Mass	Components				
$\Lambda\ ^2F_{\rho\lambda\lambda}\ \frac{7}{2}^-$	2.594	.0558	-.9851	.0052	.0271	-.0174
		.0239	-.1579			
$\Lambda\ ^2F_{\lambda\lambda\lambda}\ \frac{7}{2}^-$	2.621	-.0062	.1569	-.0007	-.0197	-.0006
		-.0190	-.9872			
$\Lambda\ ^4D_{\rho\lambda\lambda}\ \frac{7}{2}^-$	2.830	-.0030	.0419	.0529	.6425	-.6190
		.4465	-.0144			
$\Lambda\ ^4P_{\rho}\ \frac{5}{2}^-$	1.654	.9201	-.0088	.0050	.0140	-.0030
		.0035	-.0013	.0004	.0011	.0000
		.0815	.0446	.3801		
$\Lambda\ ^4F_{\rho\rho\rho}\ \frac{5}{2}^-$	1.972	.3742	-.0072	.0002	.0213	-.0009
		.0011	-.0001	-.0004	.0002	.0000
		.0851	-.0156	-.9230		
$\Lambda\ ^4F_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.094	.0124	-.0495	.0033	-.9915	.0383
		-.0723	-.0369	-.0004	.0000	.0001
		.0784	-.0034	-.0103		
$\Lambda\ ^2F_{\rho\rho\rho}\ \frac{5}{2}^-$	2.119	.0182	-.9601	-.0494	.0268	.0228
		.0157	-.0135	.0023	.0000	.0002
		-.2714	.0096	-.0097		
$\Lambda\ ^2F_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.129	.1067	.2682	.0196	-.0863	-.0024
		-.0072	-.0036	.0002	.0011	-.0001
		-.9514	.0346	-.0492		
$\Lambda\ ^2F_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.193	-.0006	.0284	.0049	.0388	.6675
		.1754	-.7220	-.0003	.0001	.0001
		.0044	.0047	.0004		

State	Mass	Components				
$\Lambda\ {}^2F_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	2.413	-.0005	.0132	-.0179	-.0615	.3697
		.7621	.5241	.0542	.0002	-.0040
		.0012	.0274	-.0017		
$\Lambda\ {}^4D_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.521	-.0018	-.0026	.0448	.0003	.0024
		.0008	.0028	-.0302	.9714	.2310
		.0014	.0097	-.0006		
$\Lambda\ {}^2D_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.577	-.0065	-.0483	.9146	.0069	.0483
		-.0135	.0466	-.2682	-.1142	.2644
		.0050	.0388	-.0020		
$\Lambda\ {}^2D_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.595	-.0048	-.0168	.3416	.0036	-.0267
		-.0259	-.0292	.9028	.0688	-.2397
		.0044	.0597	-.0026		
$\Lambda\ {}^4P_{\rho\rho\rho}\ \frac{5}{2}^-$	2.624	.0014	.0106	-.1875	-.0015	-.0228
		.0029	-.0214	.3256	-.1962	.9051
		-.0009	-.0059	.0003		
$\Lambda\ {}^4P_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.823	.0168	.0031	-.0339	.0497	.6111
		-.5773	.4250	.0497	.0038	.0011
		-.0136	-.3256	.0108		
$\Lambda\ {}^4P'_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.891	.0351	-.0037	.0727	-.0173	-.1971
		.2211	-.1354	.0283	.0097	-.0081
		-.0303	-.9405	.0275		
$\Lambda\ {}^4P_{\rho}\ \frac{3}{2}^-$	1.547	-.0097	.8597	-.3520	.0056	-.0007
		-.0011	.0001	.0000	.0047	-.0012
		-.0092	.0567	.0775	-.2447	.1177
		-.0397	.2286			

State	Mass	Components				
$\Lambda\ ^2P_\lambda\ \frac{3}{2}^-$	1.612	-.0767	-.2783	-.8822	.0147	.0017
		.0001	.0004	.0000	.0188	-.0055
		-.0233	-.0099	-.0185	.0773	-.0767
		-.2663	-.2324			
$\Lambda\ ^2P_\rho\ \frac{3}{2}^-$	1.743	.9872	-.0057	-.0742	-.0063	.0039
		-.0006	-.0049	.0004	.0237	.0509
		.1204	-.0325	-.0018	.0075	-.0019
		-.0124	-.0303			
$\Lambda\ ^4F_{\rho\rho\rho}\ \frac{3}{2}^-$	1.865	.0105	-.0002	.2318	-.0094	-.0031
		-.0013	.0000	.0000	-.0168	.0008
		-.0594	-.2462	.2146	-.0625	-.0276
		-.9015	.1352			
$\Lambda\ ^4F_{\rho\lambda\lambda}\ \frac{3}{2}^-$	1.976	-.1233	-.0088	-.0109	.0013	.0014
		-.0008	-.0012	.0002	-.0125	.0309
		.9885	-.0435	.0121	-.0035	.0006
		-.0473	.0458			
$\Lambda\ ^4D_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.053	-.0132	-.1256	-.1525	.0144	.0088
		.0011	.0001	-.0001	-.0610	-.0013
		-.0510	-.8076	-.0700	.0124	.0538
		.2393	.4867			
$\Lambda\ ^2D_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.103	.0088	-.0147	.0137	.9970	.0449
		-.0032	-.0003	.0003	.0261	-.0003
		-.0007	.0350	.0033	-.0020	.0012
		-.0104	.0373			

State	Mass	Components				
$\Lambda\ {}^2D_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.166	-.0027	-.1503	-.0434	-.0485	.0024
		.0017	.0028	-.0004	.8535	-.0317
		-.0017	.2244	-.0179	.0109	.0015
		-.0271	.4383			
$\Lambda\ {}^4P_{\rho\rho\rho}\ \frac{3}{2}^-$	2.198	-.0393	.2396	.0992	.0314	-.0125
		-.0001	.0023	.0001	.5141	-.0211
		.0171	-.4777	.0328	-.0091	.0078
		.0540	-.6578			
$\Lambda\ {}^4P_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.412	.0046	-.1771	.0070	.0016	-.0662
		-.0047	.0010	.0029	.0054	-.0039
		.0011	-.0150	-.0854	-.8950	-.3889
		.0537	-.0392			
$\Lambda\ {}^4P'_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.521	.0067	.0018	-.0006	.0047	-.0950
		.0592	.9636	.2398	-.0051	-.0352
		.0031	.0005	.0022	.0091	-.0025
		.0002	.0024			
$\Lambda\ {}^2P_{\rho\rho\rho}\ \frac{3}{2}^-$	2.552	.0046	.0155	-.0063	.0433	-.9605
		.1395	-.1431	.1504	-.0047	-.0285
		.0019	.0008	.0511	.0814	-.0432
		.0121	.0230			
$\Lambda\ {}^2P_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.599	-.0010	-.0027	.0033	-.0077	.2219
		.7503	-.1724	.5954	.0004	-.0119
		.0005	.0001	-.0439	-.0251	.0251
		-.0116	-.0076			

State	Mass	Components				
$\Lambda\ ^2P'_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.634	.0047	.0018	.0017	.0045	-.0460
		.6388	.1408	-.7512	-.0041	-.0673
		.0036	.0002	-.0301	-.0036	.0087
		-.0080	-.0011			
$\Lambda\ ^2P_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.728	.0016	.0635	.0503	.0048	-.0696
		-.0529	-.0039	.0061	-.0002	-.0485
		.0046	-.0041	-.9398	-.0268	.2257
		-.2186	-.0251			
$\Lambda\ ^2P'_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.889	.0473	.0015	-.0011	-.0017	.0368
		-.0557	-.0378	.0307	-.0368	-.9927
		.0361	.0004	.0433	.0099	-.0276
		.0085	.0029			
$\Lambda\ ^2P_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	2.997	-.0017	.2275	.0245	.0005	.0641
		.0109	.0006	.0008	.0008	.0208
		-.0004	-.0316	-.2079	.3474	-.8781
		-.0199	.0810			
$\Lambda\ ^4P_{\rho}\ \frac{1}{2}^-$	1.525	-.2021	.7279	.5127	.0011	.0275
		-.0104	-.0746	.0237	.0642	-.1932
		.1246	.1525	.2815		
$\Lambda\ ^2P_{\lambda}\ \frac{1}{2}^-$	1.604	.6533	.4622	-.4579	.0008	.0245
		.0297	.2728	.0803	.0566	-.1556
		.0500	-.1561	.1149		
$\Lambda\ ^2P_{\rho}\ \frac{1}{2}^-$	1.658	.6303	-.2801	.6609	-.0010	.1199
		.0218	.1997	.0194	-.0297	.0868
		-.0247	.1526	.0081		

State	Mass	Components				
$\Lambda\ {}^4D_{\rho\lambda\lambda}\ \frac{1}{2}^-$	1.859	.1314	.0383	-.2354	-.0018	-.0600
		.0041	-.2665	.2552	-.1981	.0373
		.0344	.8596	-.0725		
$\Lambda\ {}^4P_{\rho\rho\rho}\ \frac{1}{2}^-$	1.929	-.3135	.0205	-.0166	-.0012	-.0739
		.0186	.8937	.0888	-.0649	.0222
		.0067	.2612	-.1250		
$\Lambda\ {}^4P_{\rho\lambda\lambda}\ \frac{1}{2}^-$	2.038	-.0200	-.0585	-.1575	-.0012	.4963
		-.0102	.0722	-.7438	-.0660	-.0040
		.0479	.2498	.3123		
$\Lambda\ {}^4P'_{\rho\lambda\lambda}\ \frac{1}{2}^-$	2.087	-.0595	.1624	.0163	.0021	.7658
		-.0261	-.0422	.2292	.0288	-.0131
		-.0298	-.0608	-.5681		
$\Lambda\ {}^2P_{\rho\rho\rho}\ \frac{1}{2}^-$	2.209	-.1197	-.2443	-.0833	-.0008	.3759
		-.0143	.0499	.5591	-.0302	.0014
		-.0113	-.0674	.6759		
$\Lambda\ {}^2P_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.413	.0102	.1779	-.0259	-.0107	.0150
		-.0080	.0010	.0157	.0843	.8975
		.3870	-.0511	.0447		
$\Lambda\ {}^2P'_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.589	.0023	-.0013	-.0034	.9960	-.0022
		-.0639	.0032	-.0004	.0551	.0154
		-.0194	.0152	.0043		
$\Lambda\ {}^2P_{\rho\lambda\lambda}\ \frac{1}{2}^-$	2.723	.0016	-.0599	-.0464	-.0697	.0004
		-.1511	.0123	.0043	.9321	.0273
		-.2214	.2175	.0244		

State	Mass	Components				
$\Lambda\ ^2P'_{\rho\lambda\lambda}\ \frac{1}{2}^-$	2.883	.0333	-.0103	.0031	-.0528	-.0295
		-.9817	.0267	.0007	-.1314	-.0410
		.1046	-.0268	-.0111		
$\Lambda\ ^2P_{\lambda\lambda\lambda}\ \frac{1}{2}^-$	2.995	0040	.2265	.0114	-.0155	-.0016
		-.0808	.0009	-.0317	-.2146	.3475
		-.8756	-.0202	.0824		

Table 5.4 The masses and the components of Σ

State	Mass	Components				
$\Sigma\ ^4D_{\lambda\lambda}\ \frac{7}{2}^+$	1.939	.0278	.9996			
$\Sigma\ ^4D_{\rho\rho}\ \frac{7}{2}^+$	2.266	-.9996	.0278			
$\Sigma\ ^2D_{\lambda\lambda}\ \frac{5}{2}^+$	1.905	-.0616	-.9954	.0706	-.0173	-.0029
$\Sigma\ ^2D_{\rho\rho}\ \frac{5}{2}^+$	1.962	-.0015	.0166	-.0138	-.9989	-.0409
$\Sigma\ ^2D_{\rho\lambda}\ \frac{5}{2}^+$	2.211	-.0862	.0760	.9933	-.0122	-.0019
$\Sigma\ ^4D_{\rho\rho}\ \frac{5}{2}^+$	2.267	.9568	-.0525	.0866	.0077	-.2724
$\Sigma\ ^4D_{\lambda\lambda}\ \frac{5}{2}^+$	2.281	.2707	-.0170	.0261	-.0404	.9613
$\Sigma\ ^4S\ \frac{3}{2}^+$	1.395	-.9760	-.1162	-.1747	.0362	.0176
		.0077	-.0393	-.0141	.0003	
$\Sigma\ ^4S_{\rho\rho}\ \frac{3}{2}^+$	1.887	.1865	-.2140	-.9373	-.1978	-.0077
		-.0027	-.0298	.0292	-.0055	
$\Sigma\ ^4S_{\lambda\lambda}\ \frac{3}{2}^+$	1.905	.0264	.0774	.0189	.0127	.0049
		-.0613	-.9919	.0724	.0003	
$\Sigma\ ^4D_{\rho\rho}\ \frac{3}{2}^+$	1.945	.0883	-.2404	-.1302	.9569	.0209
		-.0097	-.0072	-.0172	.0317	
$\Sigma\ ^4D_{\lambda\lambda}\ \frac{3}{2}^+$	2.013	-.0575	.9354	-.2701	.2035	.0419
		.0223	.0690	.0171	.0072	
$\Sigma\ ^2D_{\lambda\lambda}\ \frac{3}{2}^+$	2.211	-.0197	-.0195	.0255	.0177	.0028
		-.0865	.0765	.9924	.0029	
$\Sigma\ ^2D_{\rho\rho}\ \frac{3}{2}^+$	2.259	-.0186	.0329	-.0096	.0003	-.6872
		-.4774	.0250	-.0426	.5440	

State	Mass	Components				
$\Sigma\ ^2D_{\rho\lambda}\ \frac{3}{2}^+$	2.269	.0057	-.0128	.0052	-.0113	-.0979
		.7993	-.0454	.0716	.5866	
$\Sigma\ ^2P_{\rho\lambda}\ \frac{3}{2}^+$	2.281	-.0096	.0178	-.0051	.0442	-.7181
		.3484	-.0211	.0353	-.5991	
$\Sigma\ ^2S\ \frac{1}{2}^+$	1.279	-.9960	.0667	-.0117	.0495	.0293
		-.0106	-.0006			
$\Sigma\ ^2S_{\lambda\lambda}\ \frac{1}{2}^+$	1.710	-.0530	-.8715	-.4866	-.0196	.0225
		-.0013	-.0006			
$\Sigma\ ^2S_{\rho\rho}\ \frac{1}{2}^+$	1.920	-.0193	.0826	-.1926	.0373	-.9755
		.0283	.0441			
$\Sigma\ ^2S_{\rho\lambda}\ \frac{1}{2}^+$	1.971	-.0541	-.4705	.8442	-.1349	-.2108
		-.0203	.0101			
$\Sigma\ ^4D_{\rho\rho}\ \frac{1}{2}^+$	2.140	-.0411	.0886	-.1149	-.9851	-.0093
		-.0821	-.0066			
$\Sigma\ ^4D_{\lambda\lambda}\ \frac{1}{2}^+$	2.251	-.0123	-.0037	.0101	-.0760	.0430
		.8537	.5132			
$\Sigma\ ^2P_{\rho\lambda}\ \frac{1}{2}^+$	2.278	.0079	.0036	-.0074	.0376	.0269
		-.5130	.8571			
$\Sigma\ ^4F_{\lambda\lambda\lambda}\ \frac{9}{2}^-$	2.298	-.6545	.7561			
$\Sigma\ ^4F_{\rho\rho\lambda}\ \frac{9}{2}^-$	2.756	-.7561	-.6545			
$\Sigma\ ^4F_{\lambda\lambda\lambda}\ \frac{7}{2}^-$	2.109	-.0022	.0062	.9976	-.0464	.0462
		.0223	-.0001			

State	Mass	Components				
$\Sigma\ {}^4F_{\rho\rho\lambda}\ \frac{7}{2}^-$	2.249	.0167	-.0197	-.0319	-.8054	-.3470
		.4787	.0003			
$\Sigma\ {}^2F_{\rho\rho\rho}\ \frac{7}{2}^-$	2.305	-.6588	.7517	-.0062	-.0171	-.0200
		.0103	-.0028			
$\Sigma\ {}^2F_{\rho\rho\lambda}\ \frac{7}{2}^-$	2.482	.0217	.0069	.0465	-.0640	-.7540
		-.6517	-.0065			
$\Sigma\ {}^2F_{\rho\lambda\lambda}\ \frac{7}{2}^-$	2.528	-.0031	.0009	.0003	-.0009	-.0044
		-.0050	1.0000			
$\Sigma\ {}^2F_{\lambda\lambda\lambda}\ \frac{7}{2}^-$	2.770	.7516	.6587	-.0024	.0171	.0003
		.0297	.0019			
$\Sigma\ {}^4D_{\rho\rho\lambda}\ \frac{7}{2}^-$	2.869	-.0159	-.0231	.0400	.5869	-.5554
		.5871	.0009			
$\Sigma\ {}^4P_{\lambda}\ \frac{5}{2}^-$	1.880	-.9833	-.0016	.0264	-.0031	-.0318
		-.0159	.0126	-.0120	.0061	-.0008
		.0937	-.1403	.0481		
$\Sigma\ {}^4F_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	2.109	-.0028	.0034	-.0098	.9975	-.0464
		.0161	.0222	.0001	.0001	.0000
		-.0088	-.0025	.0016		
$\Sigma\ {}^4F_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.235	.0784	.0433	-.0562	.0176	.2591
		.1057	-.1473	.0102	-.0049	.0002
		.8963	.0510	.2871		
$\Sigma\ {}^2F_{\rho\rho\rho}\ \frac{5}{2}^-$	2.251	-.0654	.0098	-.0095	.0274	.7616
		.3295	-.4550	-.0034	.0022	.0000
		-.3069	-.0223	-.0672		

State	Mass	Components				
$\Sigma\ {}^2F_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.302	-.0226	.6548	-.7513	-.0104	-.0240
		-.0296	.0142	-.0028	.0089	.0042
		-.0632	-.0210	.0023		
$\Sigma\ {}^2F_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.482	.0048	-.0339	-.0111	.0464	-.0638
		-.7535	-.6513	.0204	.0034	.0005
		.0019	.0018	-.0074		
$\Sigma\ {}^2F_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	2.517	.0052	.0059	-.002[illegible]	.0008	-.0016
		-.0111	-.0121	-.6765	-.7170	-.1663
		.0066	-.0085	-.0106		
$\Sigma\ {}^4D_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.527	-.0154	.0080	-.0024	-.0008	.0010
		.0073	.0100	.73[illegible]8	-.6598	-.1495
		-.0226	.0133	.[illegible]349		
$\Sigma\ {}^2D_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.619	.0039	-.0038	-.0062	.0000	.0003
		.0003	.0005	.0030	.2234	-.9746
		.0035	-.0131	-.0059		
$\Sigma\ {}^2D_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.712	.1254	.0643	.0623	.0010	.0115
		.0021	-.0037	.0315	-.0135	.0118
		.1571	-.8989	-.3769		
$\Sigma\ {}^4P_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	2.747	-.0617	.4281	.3431	.0043	-.0215
		.0326	-.0536	.0206	-.0077	-.0059
		.2051	.3800	-.7098		
$\Sigma\ {}^4P_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.772	.0474	.6166	.5558	.0020	-.0126
		-.0286	-.0140	-.0173	.0147	-.0041
		-.1493	-.1523	.5113		

State	Mass	Components				
$\Sigma\ ^4P'_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.869	-.0073	.0192	.0292	.0403	.5868
		-.5542	.5856	-.0019	-.0003	-.0001
		.0058	.0262	-.0453		
$\Sigma\ ^4P_{\lambda}\ \frac{3}{2}^-$	1.631	.0211	-.1919	.9130	-.0005	.0077
		-.0056	.0005	.0000	-.0094	.0028
		.0001	.0167	-.0380	.0375	.0196
		.3305	.1277			
$\Sigma\ ^2P_{\lambda}\ \frac{3}{2}^-$	1.813	-.0789	.8879	.0665	.0129	-.0234
		.0123	-.0019	.0001	.0173	-.0135
		.0076	.1796	.0173	.0078	.1828
		.3542	-.0901			
$\Sigma\ ^2P_{\rho}\ \frac{3}{2}^-$	1.901	.9762	.1006	.0109	.0031	-.0206
		-.0154	.0246	-.0029	-.0874	.1571
		-.0296	.0010	.0162	.0047	.0230
		-.0391	.0034			
$\Sigma\ ^4F_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	1.926	-.0712	.2875	.3706	.0069	-.0079
		.0070	-.0021	.0002	-.0072	-.0134
		-.0012	.0118	.2656	-.0224	.0406
		-.8368	.0384			
$\Sigma\ ^4F_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.095	.0215	-.1617	.0406	-.0076	.0084
		-.0014	.0013	.0000	.0299	.0044
		.0108	.8594	-.0417	-.1365	-.1447
		-.0642	-.4320			

State	Mass	Components				
$\Sigma\ ^4D_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.223	.0089	.0281	.1345	.0039	-.0010
		.0019	.0012	.0000	.0431	.0005
		.0166	-.4765	-.0178	-.2897	-.1398
		.0197	-.8048			
$\Sigma\ ^2D_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.262	-.0808	.0050	-.0032	-.0426	.0529
		.0161	-.0226	-.0001	-.9496	-.0625
		-.2806	.0079	-.0037	-.0140	-.0107
		.0123	-.0556			
$\Sigma\ ^2D_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.296	.0180	.0301	.0003	-.6506	.7553
		.0030	.0101	.0040	.0664	.0150
		.0064	-.0070	.0061	.0012	.0096
		-.0020	.0028			
$\Sigma\ ^4P_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	2.513	-.0345	.0047	-.0006	.0043	-.0013
		-.6244	.7553	.1750	-.0460	.0175
		.0644	.0001	-.0160	.0110	.0251
		-.0073	-.0099			
$\Sigma\ ^4P_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.534	.0003	-.0057	.0001	.0099	-.0027
		.7768	.6125	.1376	-.0017	-.0116
		.0010	.0001	.0223	-.0176	-.0337
		.0099	.0145			
$\Sigma\ ^4P'_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.618	-.0155	-.0004	.0001	.0043	.0064
		-.0003	.2204	-.9739	-.0138	.0413
		.0251	-.0001	-.0035	.0039	.0039
		-.0012	-.0020			

State	Mass	Components				
$\Sigma\ ^2P_{\rho\rho\rho}\ \frac{3}{2}^-$	2.648	-.0121	-.0312	.0395	.0127	.0106
		.0535	-.0006	.0095	-.0056	.0428
		.0218	-.0190	-.5410	.6680	.3770
		-.1769	-.2814			
$\Sigma\ ^2P_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.720	-.1132	.0433	.0142	-.1449	-.1224
		.0441	-.0497	.0345	-.1921	.6906
		.5292	-.0028	-.2758	-.2436	-.0270
		-.0566	.1019			
$\Sigma\ ^2P'_{\rho\rho\lambda}\ \frac{3}{2}^-$	2 726	-.0608	-.1117	-.0413	.1100	.0904
		.0098	-.0183	.0191	-.0570	.4034
		.1338	.0087	.7115	.4483	.0770
		.1508	-.2031			
$\Sigma\ ^2P_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.750	.0266	-.0284	-.0047	-.7141	-.6104
		.0018	.0036	-.0125	-.0234	-.2152
		.1158	-.0018	.1637	.1549	-.0100
		.0338	-.0589			
$\Sigma\ ^2P'_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.774	-.0953	.0058	.0071	-.1755	-.1707
		-.0222	.0413	.0086	.1998	.5283
		-.7768	-.0005	-.0573	-.0509	.0100
		-.0117	.0126			
$\Sigma\ ^2P_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	3.004	-.0070	.1949	.0365	.0225	.0221
		-.0233	-.0007	.0004	.0010	.0429
		-.0036	-.0349	-.1398	.4022	-.8790
		-.0134	.0442			

State	Mass	Components				
$\Sigma\ ^4P_\lambda\ \frac{1}{2}^-$	1.629	-.0789	-.1996	.9099	.0087	.0328
		-.0087	.0026	.0128	-.0384	.0384
		.0184	.3232	.1299		
$\Sigma\ ^2P_\lambda\ \frac{1}{2}^-$	1.804	-.3553	-.8115	-.0912	.0197	.0677
		-.0488	.0389	-.1797	-.0138	-.0029
		-.1656	-.3609	.0893		
$\Sigma\ ^2P_\rho\ \frac{1}{2}^-$	1.872	-.9080	.3788	-.0087	.0081	.0800
		-.1156	.0536	.0301	.0209	.0156
		.0838	.0239	-.0108		
$\Sigma\ ^4D_{\rho\rho\lambda}\ \frac{1}{2}^-$	1.926	.1008	.2778	.3711	-.0101	.0388
		.0189	.0068	.0107	.2659	-.0229
		.0380	-.8359	.0390		
$\Sigma\ ^4P_{\lambda\lambda\lambda}\ \frac{1}{2}^-$	2.093	.0649	.1609	-.0457	-.0038	.1247
		.0106	.0440	-.8479	.0408	.1372
		.1436	.0724	.4301		
$\Sigma\ ^4P_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.216	.0834	-.0189	-.1111	-.0102	.7013
		.0313	.2319	.4098	.0027	.1847
		.0780	.0164	.4746		
$\Sigma\ ^4P'_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.228	-.0534	-.0225	-.0807	.0138	-.6187
		-.0401	-.1883	.2794	.0219	.2226
		.1176	-.0408	.6530		
$\Sigma\ ^2P_{\rho\rho\rho}\ \frac{1}{2}^-$	2.520	.0224	.0102	-.0010	.9939	.0330
		-.0346	-.0498	.0000	-.0393	.0276
		.0605	-.0177	-.0243		

State	Mass	Components				
$\Sigma\ ^2P_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.645	.0417	-.0343	.0382	-.0839	.0235
		-.2111	-.0709	-.0188	-.5237	.6419
		.3825	-.1725	-.2753		
$\Sigma\ ^2P'_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.701	-.1177	.0274	.0158	.0278	-.0593
		.9475	.0674	-.0074	-.2390	.1293
		-.0259	-.0609	-.0179		
$\Sigma\ ^2P_{\rho\lambda\lambda}\ \frac{1}{2}^-$	2.718	-.0007	.1039	.0288	-.0365	.1679
		-.0574	-.4857	-.0060	-.6365	-.4917
		-.0806	-.1322	.2211		
$\Sigma\ ^2P'_{\rho\lambda\lambda}\ \frac{1}{2}^-$	2.755	-.0511	-.0604	-.0335	-.0344	.2507
		.1424	-.8102	.0042	.4100	.2587
		.0060	.0867	-.0965		
$\Sigma\ ^2P_{\lambda\lambda\lambda}\ \frac{1}{2}^-$	3.008	.0169	.1943	.0367	.0315	-.0024
		-.1185	.0034	-.0348	-.1379	.3964
		-.8752	-.0131	.0446		

Table 5.5 The masses and the components of Λ_c

State	Mass	Components				
$\Lambda_c\,^4D_{\rho\lambda}\,\frac{7}{2}^+$	3.340	1.0				
$\Lambda_c\,^2D_{\lambda\lambda}\,\frac{5}{2}^+$	3.139	-.5286	.0461	-.8476	-.0017	-.0039
$\Lambda_c\,^2D_{\rho\lambda}\,\frac{5}{2}^+$	3.174	-.8487	-.0121	.5286	.0023	.0090
$\Lambda_c\,^2D_{\rho\rho}\,\frac{5}{2}^+$	3.327	-.0127	-.9326	-.0428	-.3263	.1479
$\Lambda_c\,^4D_{\rho\lambda}\,\frac{5}{2}^+$	3.368	.0052	.3517	.0167	-.9117	.2115
$\Lambda_c\,^4P_{\rho\lambda}\,\frac{5}{2}^+$	3.414	.0066	.0660	-.0054	.2495	.9661
$\Lambda_c\,^2D_{\lambda\lambda}\,\frac{3}{2}^+$	3.139	.5266	.8482	-.0505	-.0032	-.0188
		-.0167	.0007			
$\Lambda_c\,^2D_{\rho\rho}\,\frac{3}{2}^+$	3.174	-.8489	.5260	-.0134	-.0132	.0297
		-.0381	.0023			
$\Lambda_c\,^2D_{\rho\lambda}\,\frac{3}{2}^+$	3.261	-.0382	-.0178	-.3741	.2910	-.8768
		-.0522	-.0452			
$\Lambda_c\,^4D_{\rho\lambda}\,\frac{3}{2}^+$	3.326	-.0094	.0510	.8113	-.1721	-.4264
		.3565	.0236			
$\Lambda_c\,^4S_{\rho\lambda}\,\frac{3}{2}^+$	3.338	.0083	-.0283	-.1201	-.8226	-.2145
		-.3974	.3227			
$\Lambda_c\,^4P_{\rho\lambda}\,\frac{3}{2}^+$	3.409	.0195	-.0064	.3449	.1021	-.0408
		-.7461	-.5584			
$\Lambda_c\,^2P_{\rho\lambda}\,\frac{3}{2}^+$	3.416	.0110	.0023	.2562	.4455	.0221
		-.3923	.7625			

State	Mass	Components				
$\Lambda_c\,^2S\ \frac{1}{2}^+$	2.282	.9464	.0589	-.3167	-.0152	.0187
		.0003	.0006			
$\Lambda_c\,^2S_{\lambda\lambda}\ \frac{1}{2}^+$	2.759	-.0673	-.9253	-.3731	-.0083	-.0061
		-.0002	-.0003			
$\Lambda_c\,^2S_{\rho\rho}\ \frac{1}{2}^+$	2.991	-.3136	.3735	-.8710	.0573	-.0121
		-.0006	-.0010			
$\Lambda_c\,^2S_{\rho\lambda}\ \frac{1}{2}^+$	3.228	.0373	-.0258	.0419	.9368	-.3357
		-.0389	-.0673			
$\Lambda_c\,^4D_{\rho\lambda}\ \frac{1}{2}^+$	3.315	-.0083	-.0114	.0080	.3373	.8474
		.2048	.3550			
$\Lambda_c\,^4P_{\rho\lambda}\ \frac{1}{2}^+$	3.412	.0058	0030	-.0011	-.0719	-.4108
		.4510	.7891			
$\Lambda_c\,^2P_{\rho\lambda}\ \frac{1}{2}^+$	3.439	.0000	.0000	.0000	-.0002	-.0015
		.8679	-.4968			
$\Lambda_c\,^4F_{\rho\rho\rho}\ \frac{9}{2}^-$	3.345	-.9988	-.0487			
$\Lambda_c\,^4F_{\rho\lambda\lambda}\ \frac{9}{2}^-$	3.659	-.0487	.9988			
$\Lambda_c\,^4F_{\rho\rho\rho}\ \frac{7}{2}^-$	3.315	-.0008	-.0003	.2501	-.6034	-.0860
		.7523	.0002			
$\Lambda_c\,^4F_{\rho\lambda\lambda}\ \frac{7}{2}^-$	3.342	-.1288	-.0101	-.9578	-.1440	-.0896
		.1926	.0002			
$\Lambda_c\,^2F_{\rho\rho\rho}\ \frac{7}{2}^-$	3.356	.9903	.0512	-.1249	-.0162	-.0062
		.0288	.0021			
$\Lambda_c\,^2F_{\rho\rho\lambda}\ \frac{7}{2}^-$	3.518	.0090	-.0399	.0478	-.4115	-.7971
		-.4371	.0166			

State	Mass	Components				
$\Lambda_c\, ^2F_{\rho\lambda\lambda}\ \frac{7}{2}^-$	3.682	.0513	-.9802	.0028	.0360	.0115
		.0290	-.1854			
$\Lambda_c\, ^2F_{\lambda\lambda\lambda}\ \frac{7}{2}^-$	3.717	.0074	-.1839	.0007	.0229	.0077
		.0187	.9824			
$\Lambda_c\, ^4D_{\rho\lambda\lambda}\ \frac{7}{2}^-$	3.935	.0018	-.0335	-.0458	-.6661	.5908
		-.4516	.0132			
$\Lambda_c\, ^4P_{\rho}\ \frac{5}{2}^-$	2.864	.9643	-.0115	.0033	.0146	-.0015
		.0028	-.0003	.0005	.0006	-.0001
		.1167	.0492	.2320		
$\Lambda_c\, ^4F_{\rho\rho\rho}\ \frac{5}{2}^-$	3.154	.2441	-.0078	-.0017	.0111	-.0009
		-.0015	.0001	-.0007	-.0001	.0002
		-.0854	-.0369	-.9652		
$\Lambda_c\, ^4F_{\rho\lambda\lambda}\ \frac{5}{2}^-$	3.315	-.0025	.0003	.0003	.2510	-.6031
		-.0861	.7518	-.0007	.0000	.0000
		-.0237	-.0026	.0052		
$\Lambda_c\, ^2F_{\rho\rho\rho}\ \frac{5}{2}^-$	3.338	.0522	-.2749	-.0132	.6044	.1034
		.0637	-.1343	.0026	.0004	-.0005
		-.7176	.0376	.0843		
$\Lambda_c\, ^2F_{\rho\rho\lambda}\ \frac{5}{2}^-$	3.345	.0731	.0384	.0101	-.7250	-.0995
		-.0633	.1343	-.0004	.0004	.0000
		-.6558	.0319	.0668		
$\Lambda_c\, ^2F_{\rho\lambda\lambda}\ \frac{5}{2}^-$	3.352	.0253	.9592	.0490	.2032	.0292
		.0124	-.0490	-.0012	.0004	.0006
		-.1784	.0114	.0162		

State	Mass	Components				
$\Lambda_c\,{}^2F_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	3.517	.0020	-.0136	.0634	.0484	-.4069
		-.7962	-.4343	-.0614	.0005	.0080
		-.0048	-.0392	.0046		
$\Lambda_c\,{}^4D_{\rho\lambda\lambda}\ \frac{5}{2}^-$	3.659	-.0034	-.0234	.4496	.0018	.0350
		.0205	.0297	-.1983	.7702	.4016
		.0038	.0299	-.0028		
$\Lambda_c\,{}^2D_{\rho\rho\lambda}\ \frac{5}{2}^-$	3.669	-.0055	-.0414	.8178	.0034	.0525
		.0244	.0438	-.1566	-.5431	.0326
		.0065	.0602	-.0052		
$\Lambda_c\,{}^2D_{\rho\lambda\lambda}\ \frac{5}{2}^-$	3.689	-.0044	-.0141	.3019	.0013	-.0280
		-.0228	-.0244	.8999	.1828	-.2443
		.0053	.0607	-.0049		
$\Lambda_c\,{}^4P_{\rho\rho\rho}\ \frac{5}{2}^-$	3.720	.0014	.0075	-.1504	-.0009	-.0235
		-.0071	-.0191	.3465	-.2799	.8819
		-.0014	-.0149	.0012		
$\Lambda_c\,{}^4P_{\rho\lambda\lambda}\ \frac{5}{2}^-$	3.922	.0275	.0007	.0156	.0363	.5428
		-.4491	.3689	.0487	.0036	-.0067
		-.0262	-.6009	.0328		
$\Lambda_c\,{}^4P'_{\rho\lambda\lambda}\ \frac{5}{2}^-$	3.959	.0325	-.0032	.0913	-.0276	-.3863
		.3837	-.2607	.0094	.0044	-.0131
		-.0306	-.7890	.0404		
$\Lambda_c\,{}^4P_{\rho}\ \frac{3}{2}^-$	2.669	-.0043	.8953	-.1257	.0020	.0018
		.0002	.0000	.0000	.0019	-.0002
		-.0022	.0336	.0943	-.2563	.1206
		-.0185	.3032			

State	Mass	Components				
$\Lambda_c\,{}^2P_\lambda\ \frac{3}{2}^-$	2.843	.1462	.0526	.9473	-.0177	.0011
		.0004	-.0003	.0001	-.0172	.0083
		.0163	.0502	.0036	-.0262	.0574
		.1774	.1988			
$\Lambda_c\,{}^2P_\rho\ \frac{3}{2}^-$	2.924	.9852	.0010	-.1361	-.0059	.0022
		-.0007	-.0022	.0007	.0413	.0495
		.0492	-.0416	.0023	.0040	-.0067
		-.0329	-.0371			
$\Lambda_c\,{}^4F_{\rho\rho\rho}\ \frac{3}{2}^-$	3.086	-.0045	-.0683	.1566	-.0072	-.0034
		-.0009	.0001	-.0001	-.0298	-.0054
		-.1296	-.2100	.2253	-.0323	-.0458
		-.9117	.1544			
$\Lambda_c\,{}^4F_{\rho\lambda\lambda}\ \frac{3}{2}^-$	3.179	-.0580	-.0624	-.0186	.0027	.0026
		-.0012	-.0008	.0008	.1181	.0491
		.9647	-.0849	.0177	-.0089	-.0026
		-.0857	.1742			
$\Lambda_c\,{}^4D_{\rho\lambda\lambda}\ \frac{3}{2}^-$	3.199	.0102	-.2879	-.1786	.0113	.0073
		.0010	.0001	-.0003	-.0346	-.0091
		-.1755	-.3476	-.0974	-.0292	.0245
		.2119	.8223			
$\Lambda_c\,{}^2D_{\rho\rho\lambda}\ \frac{3}{2}^-$	3.339	-.0154	.0631	.0111	-.9047	-.0417
		.0026	-.0001	.0008	-.1776	.0067
		.0258	-.3493	-.0025	.0123	.0204
		.0633	-.1288			

State	Mass	Components				
$\Lambda_c\,{}^2D_{\rho\lambda\lambda}\,\frac{3}{2}^-$	3.348	.0126	-.1377	-.0678	-.4226	-.0236
		.0009	.0008	-.0001	.4003	-.0190
		-.0549	.7300	-.0051	-.0307	-.0531
		-.1201	.2872			
$\Lambda_c\,{}^4P_{\rho\rho\rho}\,\frac{3}{2}^-$	3.395	.0413	-.0702	-.0580	-.0095	.0016
		-.0026	-.0023	.0013	-.8878	.0483
		.1087	.4047	-.0065	-.0272	-.0353
		-.0608	.1348			
$\Lambda_c\,{}^4P_{\rho\lambda\lambda}\,\frac{3}{2}^-$	3.528	-.0001	.1378	-.0297	-.0086	.1040
		.0114	-.0008	-.0043	-.0119	.0066
		-.0009	.0506	.1583	.8766	.4018
		-.0212	.1051			
$\Lambda_c\,{}^4P'_{\rho\lambda\lambda}\,\frac{3}{2}^-$	3.642	.0050	.0245	-.0024	.0448	-.9208
		.2074	.1668	.2496	-.0066	-.0426
		.0046	-.0008	.0403	.1073	-.0267
		.0118	.0216			
$\Lambda_c\,{}^2P_{\rho\rho\rho}\,\frac{3}{2}^-$	3.662	-.0009	.0076	-.0005	.0120	-.2654
		-.0990	-.9054	-.3136	.0004	-.0050
		-.0002	-.0008	.0143	.0317	-.0121
		.0046	.0065			
$\Lambda_c\,{}^2P_{\rho\rho\lambda}\,\frac{3}{2}^-$	3.694	-.0018	-.0100	.0006	-.0093	.2414
		.7190	-.3428	.5514	.0016	.0098
		-.0009	.0013	-.0246	-.0399	.0239
		-.0083	-.0083			

State	Mass	Components				
$\Lambda_c\,{}^2P'_{\rho\rho\lambda}\,\frac{3}{2}^-$	3.732	.0052	-.0028	.0001	.0022	-.0158
		.6529	.1856	-.7297	-.0060	-.0779
		.0068	.0011	-.0136	-.0116	.0112
		-.0048	-.0023			
$\Lambda_c\,{}^2P_{\rho\lambda\lambda}\,\frac{3}{2}^-$	3.877	-.0015	-.0731	-.0332	-.0029	.0500
		.0273	.0014	-.0036	.0012	.0448
		-.0074	.0006	.9198	-.0287	-.2836
		.2460	.0190			
$\Lambda_c\,{}^2P'_{\rho\lambda\lambda}\,\frac{3}{2}^-$	3.949	.0484	-.0008	-.0015	-.0013	.0488
		-.0513	-.0208	.0536	-.0431	-.9910
		.0582	.0018	.0393	.0042	-.0203
		.0090	.0019			
$\Lambda_c\,{}^2P_{\lambda\lambda\lambda}\,\frac{3}{2}^-$	4.061	.0015	-.2262	-.0376	.0000	-.0713
		-.0213	-.0002	-.0004	-.0017	-.0117
		.0005	.0368	.2348	-.3826	.8550
		.0163	-.0867			
$\Lambda_c\,{}^4P_{\rho}\,\frac{1}{2}^-$	2.653	-.0681	.8486	.2948	-.0004	.0160
		-.0038	-.0096	.0422	.0916	-.2379
		.1286	.0292	.3221		
$\Lambda_c\,{}^2P_{\lambda}\,\frac{1}{2}^-$	2.811	.7995	.2053	-.5080	-.0002	.0241
		.0390	.1837	.0450	.0307	-.0776
		.0041	-.1201	.0351		
$\Lambda_c\,{}^2P_{\rho}\,\frac{1}{2}^-$	2.387	.5429	-.2149	.7696	-.0008	.1281
		.0231	.1043	.0788	-.0338	.0789
		.0028	.1585	.0158		

State	Mass	Components				
$\Lambda_c\,{}^4D_{\rho\lambda\lambda}\,\frac{1}{2}^-$	3.061	-.1266	-.0610	.1592	.0008	.1189
		.0157	.5514	-.1853	.1790	-.0101
		-.0406	-.7523	.0491		
$\Lambda_c\,{}^4P_{\rho\rho\rho}\,\frac{1}{2}^-$	3.144	-.1763	.1036	-.0806	-.0017	.0446
		.0327	.7769	.1526	-.1264	.0166
		.0256	.4963	-.2421		
$\Lambda_c\,{}^4P_{\rho\lambda\lambda}\,\frac{1}{2}^-$	3.192	-.0308	-.2667	-.1264	-.0017	.1156
		.0054	.1579	-.3520	-.1010	-.0385
		.0325	.2492	.8216		
$\Lambda_c\,{}^4P'_{\rho\lambda\lambda}\,\frac{1}{2}^-$	3.268	.0008	-.1270	.0484	-.0007	-.8087
		.0335	.1325	.4647	.0057	-.0070
		-.0232	-.1027	.2859		
$\Lambda_c\,{}^2P_{\rho\rho\rho}\,\frac{1}{2}^-$	3.398	.1084	.1182	.0932	-.0038	-.5448
		.0311	.0499	-.7665	.0090	.0617
		.0660	.1141	-.2380		
$\Lambda_c\,{}^2P_{\rho\rho\lambda}\,\frac{1}{2}^-$	3.531	.0043	-.1421	.0520	.0277	-.0331
		.0105	-.0016	-.0613	-.1594	-.8803
		-.3982	.0190	-.1101		
$\Lambda_c\,{}^2P'_{\rho\rho\lambda}\,\frac{1}{2}^-$	3.683	.0027	.0078	-.0012	.9975	-.0033
		-.0521	.0046	-.0021	.0244	.0329
		-.0181	.0088	.0061		
$\Lambda_c\,{}^2P_{\rho\lambda\lambda}\,\frac{1}{2}^-$	3.876	-.0027	.0704	.0267	.0352	.0029
		.1321	-.0203	.0002	-.9141	.0288
		.2796	-.2455	-.0179		

State	Mass	Components				
$\Lambda_c\ ^2P'_{\rho\lambda\lambda}\ \frac{1}{2}^-$	3.940	-.0393	.0056	-.0035	.0463	.0364
		.9853	-.0482	.0031	.1128	.0284
		-.0860	.0274	.0091		
$\Lambda_c\ ^2P_{\lambda\lambda\lambda}\ \frac{1}{2}^-$	4.058	.0043	.2249	.0204	-.0276	-.0044
		-.0581	.0020	-.0366	-.2384	.3845
		-.8548	-.0161	.0886		

Table 5.6 The masses and the components of Σ_c

State	Mass	Components				
$\Sigma_c\,{}^4D_{\lambda\lambda}\,\frac{7}{2}^+$	3.149	.0617	.9981			
$\Sigma_c\,{}^4D_{\rho\rho}\,\frac{7}{2}^+$	3.364	-.9981	.0617			
$\Sigma_c\,{}^2D_{\lambda\lambda}\,\frac{5}{2}^+$	3.137	-.0837	-.9850	.0414	-.1448	-.0108
$\Sigma_c\,{}^2D_{\rho\rho}\,\frac{5}{2}^+$	3.165	.0123	.1442	-.0138	-.9867	-.0725
$\Sigma_c\,{}^2D_{\rho\lambda}\,\frac{5}{2}^+$	3.343	-.1047	.0517	.9931	-.0076	-.0003
$\Sigma_c\,{}^4D_{\rho\rho}\,\frac{5}{2}^+$	3.364	.9554	-.0766	.1048	.0187	-.2645
$\Sigma_c\,{}^4D_{\lambda\lambda}\,\frac{5}{2}^+$	3.370	.2627	-.0213	.0286	-.0709	.9616
$\Sigma_c\,{}^4S\,\frac{3}{2}^+$	2.556	-.9820	-.0828	-.1622	.0334	.0083
		.0031	-.0347	-.0062	.0001	
$\Sigma_c\,{}^4S_{\rho\rho}\,\frac{3}{2}^+$	3.002	-.1755	.2377	.9542	.0444	.0024
		-.0004	-.0145	-.0087	.0005	
$\Sigma_c\,{}^4S_{\lambda\lambda}\,\frac{3}{2}^+$	3.136	.0477	.0050	-.0225	.3461	.0223
		-.0801	-.9322	.0376	.0055	
$\Sigma_c\,{}^4D_{\rho\rho}\,\frac{3}{2}^+$	3.156	-.0302	.1060	.0065	-.9297	-.0574
		-.0276	-.3443	.0274	-.0161	
$\Sigma_c\,{}^4D_{\lambda\lambda}\,\frac{3}{2}^+$	3.216	.0379	-.9614	.2500	-.0909	-.0344
		-.0185	-.0428	-.0132	-.0015	
$\Sigma_c\,{}^2D_{\lambda\lambda}\,\frac{3}{2}^+$	3.343	.0088	.0126	-.0108	-.0119	.0020
		.1051	-.0527	-.9928	-.0010	
$\Sigma_c\,{}^2D_{\rho\rho}\,\frac{3}{2}^+$	3.362	.0090	-.0296	.0095	-.0406	.6590
		.7408	-.0600	.0831	-.0613	

State	Mass	Components				
$\Sigma_c\ ^2D_{\rho\lambda}\ \frac{3}{2}^+$	3.368	.0015	-.0098	.0030	-.0478	.7422
		-.6577	.0531	-.0705	-.0795	
$\Sigma_c\ ^2P_{\rho\lambda}\ \frac{3}{2}^+$	3.406	-.0002	.0025	-.0010	.0234	-.0988
		.0068	-.0001	.0013	-.9948	
$\Sigma_c\ ^2S\ \frac{1}{2}^+$	2.515	-.9960	-.0625	-.0440	.0226	.0391
		-.0053	-.0003			
$\Sigma_c\ ^2S_{\lambda\lambda}\ \frac{1}{2}^+$	2.931	.0734	-.9373	-.3401	-.0208	.0026
		-.0003	.0000			
$\Sigma_c\ ^2S_{\rho\rho}\ \frac{1}{2}^+$	3.138	.0372	-.0163	.0614	-.0133	.9968
		-.0166	-.0243			
$\Sigma_c\ ^2S_{\rho\lambda}\ \frac{1}{2}^+$	3.197	.0251	.3373	-.9310	.1205	.0639
		.0189	-.0015			
$\Sigma_c\ ^4D_{\rho\rho}\ \frac{1}{2}^+$	3.265	.0214	-.0597	.1086	.9908	.0056
		.0483	.0016			
$\Sigma_c\ ^4D_{\lambda\lambda}\ \frac{1}{2}^+$	3.359	-.0060	-.0043	.0129	-.0507	.0179
		.9923	.1105			
$\Sigma_c\ ^2P_{\rho\lambda}\ \frac{1}{2}^+$	3.406	.0013	.0006	-.0015	.0039	.0225
		-.1108	.9936			
$\Sigma_c\ ^4F_{\lambda\lambda\lambda}\ \frac{9}{2}^-$	3.429	-.6636	.7481			
$\Sigma_c\ ^4F_{\rho\rho\lambda}\ \frac{9}{2}^-$	3.878	-.7481	-.6636			
$\Sigma_c\ ^4F_{\lambda\lambda\lambda}\ \frac{7}{2}^-$	3.345	.0000	-.0010	-.9899	.1216	-.0100
		-.0729	-.0001			

State	Mass	Components				
$\Sigma_c\,{}^4F_{\rho\rho\lambda}\,\frac{7}{2}^-$	3.399	-.0438	.0542	.1289	.7808	.3503
		-.4963	-.0014			
$\Sigma_c\,{}^2F_{\rho\rho\rho}\,\frac{7}{2}^-$	3.435	-.6688	.7402	-.0093	-.0512	-.0304
		.0354	-.0048			
$\Sigma_c\,{}^2F_{\rho\rho\lambda}\,\frac{7}{2}^-$	3.579	.0087	.0024	.0473	-.0502	-.7821
		-.6192	-.0014			
$\Sigma_c\,{}^2F_{\rho\lambda\lambda}\,\frac{7}{2}^-$	3.668	.0065	-.0006	-.0001	-.0001	.0002
		.0020	-1.0000			
$\Sigma_c\,{}^2F_{\lambda\lambda\lambda}\,\frac{7}{2}^-$	3.886	-.7420	-.6699	.0006	-.0123	.0076
		-.0215	-.0044			
$\Sigma_c\,{}^4D_{\rho\rho\lambda}\,\frac{7}{2}^-$	3.986	-.0144	-.0204	.0356	.6086	-.5143
		.6027	.0010			
$\Sigma_c\,{}^4P_{\lambda}\,\frac{5}{2}^-$	3.002	.9739	.0064	-.0285	.0003	.0335
		.0115	-.0110	.0134	-.0070	.0003
		-.1654	.1463	-.0181		
$\Sigma_c\,{}^4F_{\lambda\lambda\lambda}\,\frac{5}{2}^-$	3.331	-.1459	-.0281	.0426	.0784	-.0828
		-.0257	.0442	-.0117	.0059	.0000
		-.9378	-.0871	-.2709		
$\Sigma_c\,{}^4F_{\rho\rho\lambda}\,\frac{5}{2}^-$	3.345	.0175	.0034	-.0065	.9872	-.1122
		.0134	.0677	.0009	-.0006	.0000
		.0846	.0081	.0234		
$\Sigma_c\,{}^2F_{\rho\rho\rho}\,\frac{5}{2}^-$	3.399	.0512	-.0641	.0789	-.1249	-.7745
		-.3470	.4931	-.0009	-.0017	-.0002
		.0878	.0175	-.0043		

State	Mass	Components				
$\Sigma_c\ {}^2F_{\rho\rho\lambda}\ \frac{5}{2}^-$	3.433	.0262	-.6631	.7389	.0153	.0790
		.0469	-.0542	.0046	-.0079	-.0022
		.0406	.0167	-.0085		
$\Sigma_c\ {}^2F_{\rho\lambda\lambda}\ \frac{5}{2}^-$	3.579	-.0038	.0135	.0038	-.0473	.0503
		.7821	.6192	-.0037	-.0003	.0000
		-.0014	-.0013	.0042		
$\Sigma_c\ {}^2F_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	3.660	-.0005	.0071	-.0013	.0001	.0002
		-.0004	-.0024	-.4087	-.8612	-.3020
		-.0008	-.0013	.0010		
$\Sigma_c\ {}^4D_{\rho\rho\lambda}\ \frac{5}{2}^-$	3.670	.0209	-.0072	.0010	.0003	.0008
		.0007	-.0057	-.9113	.3802	.1488
		.0233	-.0163	-.0391		
$\Sigma_c\ {}^2D_{\rho\rho\lambda}\ \frac{5}{2}^-$	3.714	.0043	-.0037	-.0028	.0000	.0001
		.0002	-.0001	-.0128	.3362	-.9416
		.0045	-.0061	-.0081		
$\Sigma_c\ {}^2D_{\rho\lambda\lambda}\ \frac{5}{2}^-$	3.836	.1550	.0462	.0403	.0001	.0020
		.0084	-.0097	.0341	-.0166	.0039
		.1704	-.8879	-.3914		
$\Sigma_c\ {}^4P_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	3.878	.0120	-.6903	-.6041	-.0008	.0268
		-.0296	.0512	-.0073	-.0015	.0024
		-.0792	-.2173	.3173		
$\Sigma_c\ {}^4P_{\rho\rho\lambda}\ \frac{5}{2}^-$	3.909	.0427	.2763	.2796	.0022	.0370
		-.0602	.0589	-.0279	.0170	-.0009
		-.2013	-.3649	.8127		

State	Mass	Components				
$\Sigma_c\,{}^4P'_{\rho\rho\lambda}\ \frac{5}{2}^-$	3.987	-.0117	.0132	.0199	.0356	.6072
		-.5101	.5981	-.0004	-.0012	.0000
		.0190	.0366	-.0985		
$\Sigma_c\,{}^4P_{\lambda}\ \frac{3}{2}^-$	2.845	.0201	-.3373	.9066	-.0028	.0111
		-.0070	.0005	.0000	-.0072	.0043
		-.0001	.0410	-.0474	.0233	-.0020
		.1942	.1467			
$\Sigma_c\,{}^2P_{\lambda}\ \frac{3}{2}^-$	2.969	-.0730	.8903	.3120	.0120	-.0293
		.0168	-.0022	.0000	.0133	-.0163
		.0018	.1572	.0981	.0307	.1905
		.1546	-.0862			
$\Sigma_c\,{}^2P_{\rho}\ \frac{3}{2}^-$	3.008	.9699	.0763	.0053	.0052	-.0207
		-.0170	.0269	-.0009	-.1592	.1618
		-.0074	.0061	.0041	.0041	.0167
		.0027	-.0062			
$\Sigma_c\,{}^4F_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	3.106	-.0058	.0774	.2342	.0017	-.0024
		.0044	-.0004	.0000	-.0097	-.0019
		-.0048	-.1107	.2656	-.0019	-.0129
		-.9226	.0696			
$\Sigma_c\,{}^4F_{\rho\rho\lambda}\ \frac{3}{2}^-$	3.274	-.0102	.1172	-.0889	.0067	-.0104
		.0031	-.0011	.0000	-.0300	-.0038
		-.0104	-.4955	.0409	.2543	.2014
		.1147	.7820			

State	Mass	Components				
$\Sigma_c\,{}^4D_{\rho\rho\lambda}\,\frac{3}{2}^-$	3.340	-.1397	-.0009	-.0006	-.0187	.0277
		.0163	-.0238	-.0004	-.9466	-.0967
		-.2676	.0027	-.0012	-.0097	-.0078
		.0089	-.0361			
$\Sigma_c\,{}^2D_{\rho\rho\lambda}\,\frac{3}{2}^-$	3.375	-.0006	-.0597	-.1211	-.0103	.0115
		-.0008	-.0003	.0000	-.0164	.0001
		-.0059	.8450	.0259	.1546	.0402
		-.0941	.4819			
$\Sigma_c\,{}^2D_{\rho\lambda\lambda}\,\frac{3}{2}^-$	3.427	.0200	.0322	.0013	-.6601	.7490
		.0069	.0086	.0021	.0320	.0116
		-.0047	-.0149	.0109	.0039	.0120
		.0040	-.0025			
$\Sigma_c\,{}^4P_{\lambda\lambda\lambda}\,\frac{3}{2}^-$	3.656	.0431	-.0077	.0003	-.0014	.0006
		.5583	-.7805	-.2626	.0459	-.0241
		-.0719	.0000	.0082	-.0060	-.0157
		.0050	.0040			
$\Sigma_c\,{}^4P_{\rho\rho\lambda}\,\frac{3}{2}^-$	3.673	.0027	-.0110	.0002	.0140	-.0013
		.8260	.5212	.2118	.0022	-.0057
		-.0043	.0000	.0126	-.0103	-.0240
		.0073	.0068			
$\Sigma_c\,{}^4P'_{\rho\rho\lambda}\,\frac{3}{2}^-$	3.714	.0149	.0003	.0000	-.0039	-.0028
		-.0308	-.3340	.9413	.0148	-.0189
		-.0266	.0000	-.0005	.0004	.0005
		-.0002	-.0002			

State	Mass	Components				
$\Sigma_c\,{}^2P_{\rho\rho\rho}\,\frac{3}{2}^-$	3.819	.0172	.1420	.0067	-.0464	-.0353
		-.0289	.0045	-.0020	.0132	-.0852
		-.0293	-.0102	.0773	-.7780	-.4869
		.0710	.3370			
$\Sigma_c\,{}^2P_{\rho\rho\lambda}\,\frac{3}{2}^-$	3.840	.1628	-.0163	-.0014	.0636	.0517
		-.0454	.0636	-.0148	.1987	-.8126
		-.5011	.0012	.0290	.0823	.0236
		.0044	-.0324			
$\Sigma_c\,{}^2P'_{\rho\rho\lambda}\,\frac{3}{2}^-$	3.864	.0111	.1013	.0367	-.2751	-.2319
		.0221	.0008	-.0018	-.0136	-.1262
		.0716	-.0091	-.8690	-.1020	.1247
		-.2280	.0623			
$\Sigma_c\,{}^2P_{\rho\lambda\lambda}\,\frac{3}{2}^-$	3.876	-.0081	.0602	.0127	.6883	.6077
		-.0010	-.0060	.0030	.0065	.0916
		-.0419	-.0027	-.3435	-.1138	.0433
		-.0872	.0496			
$\Sigma_c\,{}^2P'_{\rho\lambda\lambda}\,\frac{3}{2}^-$	3.922	.0666	-.0097	-.0041	.0871	.0956
		.0268	-.0457	-.0002	-.1840	-.5200
		.8145	.0003	.0802	.0316	-.0214
		.0192	-.0082			
$\Sigma_c\,{}^2P_{\lambda\lambda\lambda}\,\frac{3}{2}^-$	4.074	.0050	-.1699	-.0415	-.0158	-.0184
		.0123	.0002	-.0001	-.0013	-.0269
		.0082	.0379	.1687	-.5228	.8152
		.0085	-.0054			

State		Mass	Components				
$\Sigma_c\,{}^4P_\lambda$	$\frac{1}{2}^-$	2.844	-.0690	-.3401	.9031	.0107	.0243
			-.0126	.0015	.0394	-.0485	.0236
			-.0024	.1922	.1473		
$\Sigma_c\,{}^2P_\lambda$	$\frac{1}{2}^-$	2.966	.2824	.8445	.3203	-.0261	-.0528
			.0512	-.0113	.1555	.0965	.0281
			.1809	.1567	-.0819		
$\Sigma_c\,{}^2P_\rho$	$\frac{1}{2}^-$	3.001	.9308	-.2904	-.0323	-.0110	-.1612
			.1233	-.0255	-.0287	-.0199	-.0144
			-.0623	-.0164	.0253		
$\Sigma_c\,{}^4D_{\rho\rho\lambda}$	$\frac{1}{2}^-$	3.106	-.0206	-.0770	-.2337	.0067	-.0324
			-.0052	-.0156	.1114	-.2661	.0016
			.0130	.9216	-.0705		
$\Sigma_c\,{}^4P_{\lambda\lambda\lambda}$	$\frac{1}{2}^-$	3.273	-.0377	-.1166	.0904	.0063	-.1210
			-.0118	-.0408	.4921	-.0408	-.2523
			-.1995	-.1199	-.7738		
$\Sigma_c\,{}^4P_{\rho\rho\lambda}$	$\frac{1}{2}^-$	3.326	.1573	-.0109	-.0017	-.0168	.9355
			.0819	.2689	.0369	-.0057	-.0359
			-.0302	.0247	-.1287		
$\Sigma_c\,{}^4P'_{\rho\rho\lambda}$	$\frac{1}{2}^-$	3.375	.0011	-.0602	-.1214	.0009	.0372
			-.0021	.0145	.8461	.0257	.1539
			.0396	-.0933	.4791		
$\Sigma_c\,{}^2P_{\rho\rho\rho}$	$\frac{1}{2}^-$	3.669	-.0275	-.0189	.0006	-.9958	-.0316
			.0239	.0531	-.0001	.0226	-.0170
			-.0419	.0131	.0111		

State	Mass	Components				
$\Sigma_c\ ^2P_{\rho\rho\lambda}\ \frac{1}{2}^-$	3.816	.0703	-.1305	-.0078	-.0513	.0461
		-.4392	-.0767	.0097	-.0371	.6860
		.4538	-.0559	-.3055		
$\Sigma_c\ ^2P'_{\rho\rho\lambda}\ \frac{1}{2}^-$	3.835	-.1247	-.0595	.0013	.0217	-.1156
		.8415	.2201	.0030	-.0968	.3816
		.1783	-.0459	-.1473		
$\Sigma_c\ ^2P_{\rho\lambda\lambda}\ \frac{1}{2}^-$	3.858	.0163	.1036	.0339	-.0510	.1193
		.0615	-.4071	-.0089	-.8485	-.1114
		.1183	-.2245	.0686		
$\Sigma_c\ ^2P'_{\rho\lambda\lambda}\ \frac{1}{2}^-$	3.904	-.0281	-.0524	-.0189	-.0327	.2185
		.2540	-.8376	.0028	.3931	.1045
		-.0714	.0966	-.0366		
$\Sigma_c\ ^2P_{\lambda\lambda\lambda}\ \frac{1}{2}^-$	4.075	-.0129	-.1706	-.0417	-.0171	.0031
		.0735	-.0169	.0379	.1706	-.5196
		.8139	.0089	-.0060		

Table 5.7 The masses and the components of Λ_b

State	Mass	Components				
$\Lambda_b\,{}^4D_{\rho\lambda}\,\frac{7}{2}^+$	6.501	1.0				
$\Lambda_b\,{}^2D_{\lambda\lambda}\,\frac{5}{2}^+$	6.274	.3812	-.0154	.9244	.0008	.0017
$\Lambda_b\,{}^2D_{\rho\lambda}\,\frac{5}{2}^+$	6.318	-.9245	-.0003	.3812	.0007	.0029
$\Lambda_b\,{}^2D_{\rho\rho}\,\frac{5}{2}^+$	6.495	.0048	.8884	.0128	.4267	-.1687
$\Lambda_b\,{}^4D_{\rho\lambda}\,\frac{5}{2}^+$	6.529	.0027	.4541	.0069	-.8703	.1907
$\Lambda_b\,{}^4P_{\rho\lambda}\,\frac{5}{2}^+$	6.579	.0024	.0655	-.0019	.2461	.9670
$\Lambda_b\,{}^2D_{\lambda\lambda}\,\frac{3}{2}^+$	6.274	.3809	.9244	-.0167	-.0018	-.0053
		-.0071	.0003			
$\Lambda_b\,{}^2D_{\rho\rho}\,\frac{3}{2}^+$	6.318	-.9244	.3809	-.0002	-.0044	.0127
		-.0121	.0007			
$\Lambda_b\,{}^2D_{\rho\lambda}\,\frac{3}{2}^+$	6.417	.0152	.0042	.3112	-.2817	.9062
		.0280	.0402			
$\Lambda_b\,{}^4D_{\rho\lambda}\,\frac{3}{2}^+$	6.492	-.0013	.0127	.7622	-.4376	-.4093
		.2205	.1061			
$\Lambda_b\,{}^4S_{\rho\lambda}\,\frac{3}{2}^+$	6.501	-.0031	.0138	.3697	.7307	.0976
		.4890	-.2839			
$\Lambda_b\,{}^4P_{\rho\lambda}\,\frac{3}{2}^+$	6.577	-.0057	.0025	-.2496	.0155	.0384
		.5990	.7597			
$\Lambda_b\,{}^2P_{\rho\lambda}\,\frac{3}{2}^+$	6.581	.0061	-.0001	.3506	.4416	.0096
		-.5938	.5739			

State	Mass	Components						
$\Lambda_b\,{}^2S\ \frac{1}{2}^+$	5.425	.9458	.0712	-.3168	-.0059	.0073	.0001	.0002
$\Lambda_b\,{}^2S_{\lambda\lambda}\ \frac{1}{2}^+$	5.885	-.0572	-.9239	-.3784	-.0026	-.0020	-.0001	-.0001
$\Lambda_b\,{}^2S_{\rho\rho}\ \frac{1}{2}^+$	6.132	-.3194	.3759	-.8697	.0186	-.0048	-.0002	-.0004
$\Lambda_b\,{}^2S_{\rho\lambda}\ \frac{1}{2}^+$	6.403	.0138	-.0081	.0132	.9177	-.3850	-.0528	-.0802
$\Lambda_b\,{}^4D_{\rho\lambda}\ \frac{1}{2}^+$	6.479	.0028	.0039	-.0029	-.3892	-.8257	-.2244	-.3411
$\Lambda_b\,{}^4P_{\rho\lambda}\ \frac{1}{2}^+$	6.574	-.0023	-.0010	.0003	.0779	.4121	-.4977	-.7592
$\Lambda_b\,{}^2P_{\rho\lambda}\ \frac{1}{2}^+$	6.604	.0000	.0000	.0000	-.0001	-.0006	.8362	-.5485
$\Lambda_b\,{}^4F_{\rho\rho\rho}\ \frac{9}{2}^-$	6.464	-.9994	-.0343					
$\Lambda_b\,{}^4F_{\rho\lambda\lambda}\ \frac{9}{2}^-$	6.809	-.0343	.9994					
$\Lambda_b\,{}^4F_{\rho\rho\rho}\ \frac{7}{2}^-$	6.458	-.1062	-.0036	-.6074	.4643	.0252	-.6353	-.0002
$\Lambda_b\,{}^4F_{\rho\lambda\lambda}\ \frac{7}{2}^-$	6.466	-.3456	-.0138	-.7188	-.3462	-.0638	.4896	.0000
$\Lambda_b\,{}^2F_{\rho\rho\rho}\ \frac{7}{2}^-$	6.472	.9317	.0318	-.3360	-.0742	-.0183	.1104	.0011

State	Mass	Components				
$\Lambda_b\,{}^2F_{\rho\rho\lambda}\ \frac{7}{2}^-$	6.664	.0046	-.0490	.0248	-.4469	-.8066
		-.3828	.0152			
$\Lambda_b\,{}^2F_{\rho\lambda\lambda}\ \frac{7}{2}^-$	6.829	.0342	-.9816	.0009	.0379	.0223
		.0276	-.1803			
$\Lambda_b\,{}^2F_{\lambda\lambda\lambda}\ \frac{7}{2}^-$	6.868	-.0052	.1790	-.0004	-.0220	-.0097
		-.0160	-.9834			
$\Lambda_b\,{}^4D_{\rho\lambda\lambda}\ \frac{7}{2}^-$	7.101	-.0009	.0274	.0285	.6764	-.5864
		.4439	-.0116			
$\Lambda_b\,{}^4P_{\rho}\ \frac{5}{2}^-$	5.983	.9273	-.0117	.0018	.0137	-.0005
		.0018	.0000	.0004	.0002	-.0001
		.0909	.0423	.3601		
$\Lambda_b\,{}^4F_{\rho\rho\rho}\ \frac{5}{2}^-$	6.254	-.3642	.0110	.0010	-.0132	.0006
		.0007	.0000	.0003	.0000	-.0001
		.0218	.0211	.9307		
$\Lambda_b\,{}^4F_{\rho\lambda\lambda}\ \frac{5}{2}^-$	6.457	-.0067	.2835	.0092	-.6580	.3722
		.0122	-.5079	-.0004	.0000	.0002
		.2989	-.0095	-.0223		
$\Lambda_b\,{}^2F_{\rho\rho\rho}\ \frac{5}{2}^-$	6.462	.0301	-.4232	-.0147	.2362	.4036
		.0541	-.5604	.0017	.0001	-.0005
		-.5317	.0213	.0318		
$\Lambda_b\,{}^2F_{\rho\rho\lambda}\ \frac{5}{2}^-$	6.468	-.0722	-.3052	-.0149	.4714	.1467
		.0317	-.2101	.0003	-.0002	-.0001
		.7813	-.0293	-.0357		

State	Mass	Components				
$\Lambda_b\,{}^2F_{\rho\lambda\lambda}\ \frac{5}{2}^-$	6.470	-.0091	-.8037	-.0266	-.5360	-.1346
		-.0319	.1978	-.0001	-.0001	-.0004
		.0875	-.0056	-.0035		
$\Lambda_b\,{}^2F_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	6.662	-.0019	.0069	-.0769	-.0251	.4423
		.8051	.3801	.0578	-.0006	-.0082
		.0041	.0408	-.0030		
$\Lambda_b\,{}^4D_{\rho\lambda\lambda}\ \frac{5}{2}^-$	6.814	.0042	.0309	-.8814	-.0012	-.0636
		-.0451	-.0471	.2487	-.2068	-.3233
		-.0051	-.0685	.0038		
$\Lambda_b\,{}^2D_{\rho\rho\lambda}\ \frac{5}{2}^-$	6.831	.0024	.0133	-.3966	-.0006	-.0096
		-.0040	-.0069	-.2564	.7858	.3961
		-.0030	-.0477	.0025		
$\Lambda_b\,{}^2D_{\rho\lambda\lambda}\ \frac{5}{2}^-$	6.843	-.0023	-.0059	.1855	.0001	-.0304
		-.0205	-.0227	.8703	.4372	-.1139
		.0028	.0454	-.0024		
$\Lambda_b\,{}^4P_{\rho\rho\rho}\ \frac{5}{2}^-$	6.873	-.0009	-.0041	.1243	.0004	.0204
		.0083	.0148	-.3312	.3855	-.8516
		.0010	.0169	-.0008		
$\Lambda_b\,{}^4P_{\rho\lambda\lambda}\ \frac{5}{2}^-$	7.079	-.0281	.0004	-.0504	-.0166	-.4158
		.3143	-.2736	-.0428	-.0025	.0125
		.0272	.8039	-.0300		
$\Lambda_b\,{}^4P'_{\rho\lambda\lambda}\ \frac{5}{2}^-$	7.113	.0192	-.0018	.0797	-.0232	-.5339
		.4953	-.3498	-.0049	.0017	-.0113
		-.0183	-.5823	.0207		

State		Mass	Components				
$\Lambda_b\,{}^4P_\rho$	$\frac{3}{2}^-$	5.828	-.0082	.8935	-.1333	.0021	.0031
			.0007	.0000	.0000	.0028	-.0002
			-.0023	.0284	.1005	-.2564	.1190
			-.0462	.3015			
$\Lambda_b\,{}^2P_\lambda$	$\frac{3}{2}^-$	5.973	-.1449	-.0773	-.8955	.0171	-.0019
			-.0006	.0001	-.0001	.0192	-.0065
			-.0217	-.0534	.0386	.0286	-.0613
			-.3562	-.1849			
$\Lambda_b\,{}^2P_\rho$	$\frac{3}{2}^-$	6.058	.9870	-.0025	-.1185	-.0070	.0009
			-.0005	-.0008	.0006	.0162	.0387
			.0217	-.0444	.0139	.0017	-.0080
			-.0810	-.0263			
$\Lambda_b\,{}^4F_{\rho\rho\rho}$	$\frac{3}{2}^-$	6.202	-.0271	-.0582	.3478	-.0125	-.0021
			-.0003	.0001	-.0002	-.0364	-.0095
			-.2395	-.0927	.2117	-.0167	-.0244
			-.8637	.1254			
$\Lambda_b\,{}^4F_{\rho\lambda\lambda}$	$\frac{3}{2}^-$	6.257	.0347	.0209	-.0666	.0022	-.0007
			.0008	.0003	-.0007	-.0679	-.0373
			-.9665	.0286	-.0563	.0040	.0070
			.2179	-.0471			
$\Lambda_b\,{}^4D_{\rho\lambda\lambda}$	$\frac{3}{2}^-$	6.338	-.0051	-.2987	-.1734	.0076	.0038
			.0005	.0000	-.0001	-.0243	-.0005
			-.0182	-.3731	-.0606	-.0236	.0211
			.1050	.8514			

State	Mass	Components				
$\Lambda_b\,{}^2D_{\rho\rho\lambda}\ \frac{3}{2}^-$	6.460	-.0139	.0285	-.0068	-.9781	-.0331
		.0014	.0001	.0007	-.0921	.0017
		.0075	-.1686	.0006	.0009	.0044
		.0210	-.0616			
$\Lambda_b\,{}^2D_{\rho\lambda\lambda}\ \frac{3}{2}^-$	6.477	.0209	-.1356	-.0634	-.2035	-.0102
		.0001	.0003	-.0003	.5000	- 0169
		-.0388	.7672	-.0193	-.0115	-.0348
		-.0667	.2985			
$\Lambda_b\,{}^4P_{\rho\rho\rho}\ \frac{3}{2}^-$	6.519	.0261	-.0723	-.0633	-.0133	-.0002
		-.0016	-.0007	.0011	-.8562	.0341
		.0621	.4761	-.0152	-.0112	-.0257
		-.0347	.1511			
$\Lambda_b\,{}^4P_{\rho\lambda\lambda}\ \frac{3}{2}^-$	6.692	.0002	.1406	-.0260	-.0071	.1270
		.0147	-.0007	-.0052	-.0053	.0065
		-.0010	.0305	.1644	.8655	.4234
		.0005	.0819			
$\Lambda_b\,{}^4P'_{\rho\lambda\lambda}\ \frac{3}{2}^-$	6.793	-.0031	-.0300	.0016	-.0326	.9358
		-.2127	-.0794	-.2246	.0039	.0431
		-.0028	.0010	-.0419	-.1265	.0112
		-.0098	-.0190			
$\Lambda_b\,{}^2P_{\rho\rho\rho}\ \frac{3}{2}^-$	6.828	-.0007	-.0098	.0003	-.0077	.2463
		.2881	.7678	.5141	.0011	.0212
		-.0010	.0007	-.0157	-.0380	.0113
		-.0042	-.0061			

State	Mass	Components				
$\Lambda_b\,{}^2P_{\rho\rho\lambda}\ \frac{3}{2}^-$	6.849	-.0010	-.0109	.0002	-.0055	.1922
		.6771	-.5858	.3987	.0009	.0083
		-.0005	.0010	-.0194	-.0403	.0173
		-.0054	-.0067			
$\Lambda_b\,{}^2P'_{\rho\rho\lambda}\ \frac{3}{2}^-$	6.884	-.0039	.0045	.0001	-.0008	.0064
		-.6403	-.2467	.7230	.0043	.0764
		-.0045	-.0009	.0106	.0158	-.0107
		.0032	.0027			
$\Lambda_b\,{}^2P_{\rho\lambda\lambda}\ \frac{3}{2}^-$	7.053	.0006	.0566	.0280	.0017	-.0487
		-.0231	-.0004	.0021	-.0002	-.0291
		.0052	-.0064	-.9049	.0035	.3479
		-.2277	-.0218			
$\Lambda_b\,{}^2P'_{\rho\lambda\lambda}\ \frac{3}{2}^-$	7.094	.0384	-.0004	-.0012	-.0008	.0508
		-.0459	-.0110	.0602	-.0342	-.9932
		.0418	.0018	.0242	.0027	-.0133
		.0053	.0012			
$\Lambda_b\,{}^2P_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	7.226	-.0011	.2327	.0364	-.0001	.0650
		.0224	.0000	.0002	.0016	.0068
		.0003	-.0332	-.2951	.4048	-.8233
		-.0416	.0900			
$\Lambda_b\,{}^4P_{\rho}\ \frac{1}{2}^-$	5.817	.0797	-.8497	-.2844	.0012	-.0134
		.0039	.0242	-.0379	-.0860	.2396
		-.1287	-.0539	-.3229		

State	Mass	Components				
$\Lambda_b\,{}^2P_\lambda\ \frac{1}{2}^-$	5.929	-.7690	-.2100	.4670	.0003	-.0204
		-.0338	-.2991	-.0412	-.0527	.0726
		-.0055	.2117	-.0309		
$\Lambda_b\,{}^2P_\rho\ \frac{1}{2}^-$	6.012	.5177	-.1931	.7262	-.0006	.1179
		.0213	.1755	.0799	-.0723	.0726
		.0089	.3242	.0109		
$\Lambda_b\,{}^4D_{\rho\lambda\lambda}\ \frac{1}{2}^-$	6.172	.2213	.0775	-.3014	-.0004	-.0938
		-.0106	-.6002	.1069	-.1536	-.0116
		.0254	.6698	-.0271		
$\Lambda_b\,{}^4P_{\rho\rho\rho}\ \frac{1}{2}^-$	6.259	.2694	-.0711	.2291	.0010	.0363
		-.0189	-.7163	-.0362	.1456	.0068
		-.0233	-.5717	.0715		
$\Lambda_b\,{}^4P_{\rho\lambda\lambda}\ \frac{1}{2}^-$	6.330	.0058	-.2755	-.1222	-.0008	.1706
		-.0030	.0145	-.4030	-.0518	-.0323
		.0260	.0966	.8388		
$\Lambda_b\,{}^4P'_{\rho\lambda\lambda}\ \frac{1}{2}^-$	6.397	.0082	-.1452	.0509	-.0004	-.8091
		.0255	.0639	.4396	-.0031	-.0017
		-.0122	-.0753	.3432		
$\Lambda_b\,{}^2P_{\rho\rho\rho}\ \frac{1}{2}^-$	6.529	-.1076	-.1026	-.0993	.0026	.5388
		-.0247	-.0121	.7872	-.0242	-.0288
		-.0429	-.0539	.2262		
$\Lambda_b\,{}^2P_{\rho\rho\lambda}\ \frac{1}{2}^-$	6.694	.0042	-.1456	.0446	.0375	-.0178
		.0072	-.0025	-.0362	-.1659	-.8729
		-.4205	-.0040	-.0854		

State	Mass	Components				
$\Lambda_b\,{}^2P'_{\rho\rho\lambda}\,\frac{1}{2}^-$	6.836	.0019	.0114	-.0012	.9976	-.0023
		-.0447	.0027	-.0016	.0202	.0432
		-.0147	.0060	.0067		
$\Lambda_b\,{}^2P_{\rho\lambda\lambda}\,\frac{1}{2}^-$	7.052	.0008	.0540	.0239	.0270	-.0005
		.0583	-.0140	-.0061	-.9045	.0013
		.3488	-.2280	-.0215		
$\Lambda_b\,{}^2P'_{\rho\lambda\lambda}\,\frac{1}{2}^-$	7.085	.0328	-.0077	.0025	-.0420	-.0310
		-.9948	.0350	-.0038	-.0438	-.0235
		.0514	-.0097	-.0062		
$\Lambda_b\,{}^2P_{\lambda\lambda\lambda}\,\frac{1}{2}^-$	7.223	.0033	.2318	.0215	-.0286	-.0042
		-.0394	-.0005	-.0332	-.2976	.4069
		-.8235	-.0410	.0915		

Table 5.8 The masses and the components of Σ_b

State	Mass	Components				
$\Sigma_b\ {}^4D_{\lambda\lambda}\ \frac{7}{2}^+$	6.278	.0626	.9980			
$\Sigma_b\ {}^4D_{\rho\rho}\ \frac{7}{2}^+$	6.512	-.9980	.0626			
$\Sigma_b\ {}^2D_{\lambda\lambda}\ \frac{5}{2}^+$	6.274	-.0686	-.9538	.0133	-.2915	-.0193
$\Sigma_b\ {}^2D_{\rho\rho}\ \frac{5}{2}^+$	6.292	.0220	.2913	-.0065	-.9541	-.0660
$\Sigma_b\ {}^2D_{\rho\lambda}\ \frac{5}{2}^+$	6.506	-.1710	.0268	.9849	-.0030	.0063
$\Sigma_b\ {}^4D_{\rho\rho}\ \frac{5}{2}^+$	6.512	.9499	-.0663	.1684	.0180	-.2542
$\Sigma_b\ {}^4D_{\lambda\lambda}\ \frac{5}{2}^+$	6.515	.2516	-.0168	.0377	-.0663	.9647
$\Sigma_b\ {}^4S\ \frac{3}{2}^+$	5.690	-.9822	-.0805	-.1632	.0322	.0035
		.0008	-.0327	-.0024	.0001	
$\Sigma_b\ {}^4S_{\rho\rho}\ \frac{3}{2}^+$	6.117	-.1774	.2604	.9485	.0282	.0013
		-.0007	-.0174	-.0027	.0001	
$\Sigma_b\ {}^4S_{\lambda\lambda}\ \frac{3}{2}^+$	6.270	.0503	-.0124	-.0194	.5855	.0364
		-.0577	-.8059	.0099	.0033	
$\Sigma_b\ {}^4D_{\rho\rho}\ \frac{3}{2}^+$	6.288	-.0106	.0427	-.0004	-.8061	-.0524
		-.0435	-.5861	.0121	-.0048	
$\Sigma_b\ {}^4D_{\lambda\lambda}\ \frac{3}{2}^+$	6.350	.0331	-.9611	.2708	-.0378	-.0130
		-.0066	-.0173	-.0046	-.0002	
$\Sigma_b\ {}^2D_{\lambda\lambda}\ \frac{3}{2}^+$	6.506	.0036	.0032	-.0032	-.0052	.0166
		.1726	-.0273	-.9844	-.0005	

State	Mass	Components				
$\Sigma_b\,^2D_{\rho\rho}\,\frac{3}{2}^+$	6.511	.0032	−.0107	.0039	−.0420	.6440
		.7481	−.0531	.1437	−.0175	
$\Sigma_b\,^2D_{\rho\lambda}\,\frac{3}{2}^+$	6.514	−.0005	−.0039	.0015	−.0484	.7616
		−.6367	.0435	−.0998	−.0214	
$\Sigma_b\,^2P_{\rho\lambda}\,\frac{3}{2}^+$	6.571	.0001	.0003	−.0001	.0076	−.0272
		.0005	.0002	.0001	−.9996	
$\Sigma_b\,^2S\,\frac{1}{2}^+$	5.675	−.9893	−.1236	−.0645	.0088	.0421
		−.0021	−.0001			
$\Sigma_b\,^2S_{\lambda\lambda}\,\frac{1}{2}^+$	6.088	−.1370	.9423	.3051	.0089	.0123
		−.0001	−.0001			
$\Sigma_b\,^2S_{\rho\rho}\,\frac{1}{2}^+$	6.270	.0429	−.0113	.0143	−.0027	.9989
		−.0057	−.0085			
$\Sigma_b\,^2S_{\rho\lambda}\,\frac{1}{2}^+$	6.342	−.0241	−.3104	.9496	−.0332	−.0162
		−.0068	.0001			
$\Sigma_b\,^4D_{\rho\rho}\,\frac{1}{2}^+$	6.426	.0092	−.0177	.0296	.9991	.0019
		.0241	.0003			
$\Sigma_b\,^4D_{\lambda\lambda}\,\frac{1}{2}^+$	6.509	.0022	.0019	−.0057	.0243	−.0059
		−.9991	−.0343			
$\Sigma_b\,^2P_{\rho\lambda}\,\frac{1}{2}^+$	6.571	−.0003	−.0001	.0002	−.0005	−.0083
		.0343	−.9994			
$\Sigma_b\,^4F_{\lambda\lambda\lambda}\,\frac{9}{2}^-$	6.577	−.6892	.7246			
$\Sigma_b\,^4F_{\rho\rho\lambda}\,\frac{9}{2}^-$	7.033	−.7246	−.6892			

State	Mass	Components				
$\Sigma_b\,{}^4F_{\lambda\lambda\lambda}\,\frac{7}{2}^-$	6.465	.0001	.0001	.9984	-.0448	.0215
		.0268	.0000			
$\Sigma_b\,{}^4F_{\rho\rho\lambda}\,\frac{7}{2}^-$	6.556	.0680	-.0775	-.0421	-.7688	-.3205
		.5421	.0016			
$\Sigma_b\,{}^2F_{\rho\rho\rho}\,\frac{7}{2}^-$	6.582	-.6925	.7140	-.0043	-.0766	-.0350
		.0592	-.0044			
$\Sigma_b\,{}^2F_{\rho\rho\lambda}\,\frac{7}{2}^-$	6.715	-.0011	-.0021	-.0290	.0945	.7934
		.6006	.0001			
$\Sigma_b\,{}^2F_{\rho\lambda\lambda}\,\frac{7}{2}^-$	6.838	.0071	.0005	.0000	-.0003	-.0008
		.0013	-1.0000			
$\Sigma_b\,{}^2F_{\lambda\lambda\lambda}\,\frac{7}{2}^-$	7.039	.7181	.6956	.0000	.0095	-.0107
		.0165	.0055			
$\Sigma_b\,{}^4D_{\rho\rho\lambda}\,\frac{7}{2}^-$	7.152	-.0120	-.0180	.0235	.6262	-.5158
		.5838	.0009			
$\Sigma_b\,{}^4P_{\lambda}\,\frac{5}{2}^-$	6.155	.9680	.0080	-.0268	-.0001	.0318
		.0088	-.0102	.0128	-.0067	.0000
		-.1994	.1422	-.0288		
$\Sigma_b\,{}^4F_{\lambda\lambda\lambda}\,\frac{5}{2}^-$	6.465	-.0063	-.0012	.0013	.9973	-.0471
		.0207	.0280	-.0005	.0002	.0000
		-.0410	-.0043	-.0116		
$\Sigma_b\,{}^4F_{\rho\rho\lambda}\,\frac{5}{2}^-$	6.476	-.1816	-.0285	.0423	-.0467	-.0628
		-.0242	.0348	-.0116	.0059	.0001
		-.9375	-.1019	-.2591		

State	Mass	Components				
$\Sigma_b\ {}^2F_{\rho\rho\rho}\ \frac{5}{2}^-$	6.556	-.0510	.1025	-.1166	.0410	.7598
		.3165	-.5362	.0013	.0018	.0002
		-.0794	-.0185	.0069		
$\Sigma_b\ {}^2F_{\rho\rho\lambda}\ \frac{5}{2}^-$	6.581	-.0249	.6842	-.7099	-.0069	-.1193
		-.0543	.0916	-.0045	.0066	.0011
		-.0354	-.0132	.0075		
$\Sigma_b\ {}^2F_{\rho\lambda\lambda}\ \frac{5}{2}^-$	6.715	-.0042	.0018	.0033	-.0290	.0945
		.7934	.6006	-.0003	-.0001	.0000
		-.0032	-.0016	.0044		
$\Sigma_b\ {}^2F_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	6.830	-.0038	.0072	.0000	.0000	.0001
		.0004	-.0008	-.2417	-.8618	-.4457
		-.0042	.0021	.0071		
$\Sigma_b\ {}^4D_{\rho\rho\lambda}\ \frac{5}{2}^-$	6.842	.0197	-.0058	-.0004	.0000	.0011
		.0032	-.0043	-.9682	.1933	.1502
		.0216	-.0156	-.0386		
$\Sigma_b\ {}^2D_{\rho\rho\lambda}\ \frac{5}{2}^-$	6.868	-.0056	.0048	.0019	.0000	-.0001
		-.0004	.0003	.0426	-.4682	.8825
		-.0062	.0058	.0119		
$\Sigma_b\ {}^2D_{\rho\lambda\lambda}\ \frac{5}{2}^-$	7.007	.1501	.0782	.0686	-.0003	-.0051
		.0156	-.0172	.0357	-.0180	.0023
		.1901	-.8454	-.4623		
$\Sigma_b\ {}^4P_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	7.034	-.0157	.7001	.6653	-.0002	-.0192
		.0255	-.0348	-.0003	.0059	-.0013
		.0298	.2047	-.1480		

State	Mass	Components				
$\Sigma_b\,{}^4P_{\rho\rho\lambda}\ \frac{5}{2}^-$	7.082	.0575	.1547	.1798	.0025	.0595
		-.0741	.0795	-.0270	.0155	-.0008
		-.1847	-.4582	.8247		
$\Sigma_b\,{}^4P'_{\rho\rho\lambda}\ \frac{5}{2}^-$	7.153	.0149	-.0099	-.0153	-.0234	-.6233
		.5099	-.5774	-.0004	.0016	-.0001
		-.0232	-.0456	.1201		
$\Sigma_b\,{}^4P_{\lambda}\ \frac{3}{2}^-$	5.970	.0082	-.2475	.8854	-.0019	.0073
		-.0047	.0002	.0000	-.0025	.0022
		.0004	.0427	-.0790	.0242	.0110
		.3614	.1236			
$\Sigma_b\,{}^2P_{\lambda}\ \frac{3}{2}^-$	6.126	-.0640	.9171	.1903	.0115	-.0314
		.0177	-.0019	.0000	.0128	-.0155
		.0014	.1427	.0888	.0193	.1859
		.2000	-.1171			
$\Sigma_b\,{}^2P_{\rho}\ \frac{3}{2}^-$	6.156	.9653	.0633	.0016	.0058	-.0189
		-.0162	.0255	.0000	-.1937	.1558
		-.0224	.0079	- 0008	.0017	.0133
		.0170	-.0088			
$\Sigma_b\,{}^4F_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	6.214	-.0079	-.0961	-.3996	-.0015	.0030
		-.0038	-.0001	.0000	.0064	-.0009
		.0030	.0360	-.2442	-.0036	-.0076
		.8756	-.0571			

State	Mass	Components				
$\Sigma_b\,{}^4F_{\rho\rho\lambda}\,\frac{3}{2}^-$	6.419	.0044	-.1308	.0733	-.0069	.0112
		-.0045	.0006	.0000	.0157	.0027
		.0053	.5634	-.0598	-.2342	-.1984
		-.0722	-.7461			
$\Sigma_b\,{}^4D_{\rho\rho\lambda}\,\frac{3}{2}^-$	6.479	.1757	.0024	.0006	.0178	-.0261
		-.0158	.0232	.0007	.9421	.1110
		.2592	-.0025	-.0012	.0050	.0047
		-.0045	.0182			
$\Sigma_b\,{}^2D_{\rho\rho\lambda}\,\frac{3}{2}^-$	6.503	.0007	.0437	.1114	.0052	-.0063
		.0007	.0001	.0000	.0084	.0000
		.0029	-.8110	-.0193	-.1724	-.0716
		.0470	-.5389			
$\Sigma_b\,{}^2D_{\rho\lambda\lambda}\,\frac{3}{2}^-$	6.575	-.0202	-.0312	-.0009	.6858	-.7259
		-.0068	-.0074	-.0010	-.0293	-.0099
		.0051	.0096	-.0115	-.0043	-.0124
		-.0039	.0006			
$\Sigma_b\,{}^4P_{\lambda\lambda\lambda}\,\frac{3}{2}^-$	6.827	.0404	-.0075	-.0003	-.0017	.0002
		.4560	-.7972	-.3834	.0430	-.0257
		-.0720	.0005	.0059	-.0034	-.0099
		.0028	.0018			
$\Sigma_b\,{}^4P_{\rho\rho\lambda}\,\frac{3}{2}^-$	6.841	.0087	-.0137	-.0005	.0142	.0012
		.8830	.3716	.2841	.0091	-.0074
		-.0164	.0009	.0116	-.0073	-.0195
		.0054	.0040			

State	Mass	Components				
$\Sigma_b\ {}^4P'_{\rho\rho\lambda}\ \frac{3}{2}^-$	6.868	.0162	.0011	.0001	-.0054	-.0021
		-.0871	-.4671	.8788	.0176	-.0164
		-.0334	-.0001	-.0011	.0008	.0018
		-.0005	-.0005			
$\Sigma_b\ {}^2P_{\rho\rho\rho}\ \frac{3}{2}^-$	6.982	-.0070	-.1603	-.0101	.0476	.0377
		.0172	-.0021	.0005	-.0050	.0394
		.0089	.0081	.0278	.7596	.5215
		-.0295	-.3432			
$\Sigma_b\ {}^2P_{\rho\rho\lambda}\ \frac{3}{2}^-$	7.006	-.1549	.0079	.0007	-.0797	-.0689
		.0482	-.0702	.0092	-.2109	.7854
		.5429	-.0005	-.0162	-.0303	-.0072
		-.0033	.0121			
$\Sigma_b\ {}^2P'_{\rho\rho\lambda}\ \frac{3}{2}^-$	7.030	.0158	-.0056	.0058	-.7077	-.6653
		.0119	.0098	-.0019	.0009	-.1470
		.0279	-.0016	-.1633	.0424	.0566
		-.0427	-.0145			
$\Sigma_b\ {}^2P_{\rho\lambda\lambda}\ \frac{3}{2}^-$	7.049	-.0040	-.0944	-.0304	-.1271	- 1299
		-.0199	.0054	-.0004	.0169	.0559
		-.0741	.0101	.9095	.1096	-.2364
		.2247	-.0456			
$\Sigma_b\ {}^2P'_{\rho\lambda\lambda}\ \frac{3}{2}^-$	7.097	-.0800	.0103	.0033	-.0573	-.0710
		-.0253	.0430	-.0016	.1630	.5645
		-.7903	-.0006	-.1013	-.0285	.0360
		-.0235	.0068			

State	Mass	Components				
$\Sigma_b\,{}^2P_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	7.242	.0038	-.1716	-.0365	-.0102	-.0153
		.0064	-.0001	.0000	-.0014	-.0176
		.0102	.0330	.2383	-.5673	.7665
		.0341	.0031			
$\Sigma_b\,{}^4P_{\lambda}\ \frac{1}{2}^-$	5.970	-.0262	-.2481	.8849	.0070	.0081
		-.0064	-.0010	.0425	-.0795	.0242
		.0109	.3612	.1237		
$\Sigma_b\,{}^2P_{\lambda}\ \frac{1}{2}^-$	6.124	.2018	.8972	.1930	-.0268	-.0419
		.0431	-.0065	.1410	.0903	.0187
		.1816	.1959	-.1143		
$\Sigma_b\,{}^2P_{\rho}\ \frac{1}{2}^-$	6.157	.9472	-.2004	-.0057	-.0130	-.1995
		.1244	-.0340	-.0249	.0015	-.0052
		-.0417	-.0526	.0279		
$\Sigma_b\,{}^4D_{\rho\rho\lambda}\ \frac{1}{2}^-$	6.214	.0232	-.0980	-.3992	.0052	-.0206
		.0022	-.0101	.0360	-.2441	-.0038
		-.0080	.8750	-.0570		
$\Sigma_b\,{}^4P_{\lambda\lambda\lambda}\ \frac{1}{2}^-$	6.419	.0154	.1307	-.0737	-.0071	.0544
		.0079	.0183	-.5626	.0602	.2339
		.1979	.0734	.7446		
$\Sigma_b\,{}^4P_{\rho\rho\lambda}\ \frac{1}{2}^-$	6.475	.1937	-.0118	-.0020	-.0166	.9393
		.0966	.2566	.0138	.0027	-.0169
		-.0167	.0136	-.0597		

State	Mass	Components				
$\Sigma_b\,{}^4P'_{\rho\rho\lambda}\,\frac{1}{2}^-$	6.503	-.0024	.0441	.1114	-.0009	-.0239
		.0006	-.0082	-.8114	-.0193	-.1721
		-.0713	.0468	-.5379		
$\Sigma_b\,{}^2P_{\rho\rho\rho}\,\frac{1}{2}^-$	6.842	-.0264	-.0222	-.0009	-.9965	-.0297
		.0192	.0537	.0014	.0199	-.0118
		-.0322	.0092	.0063		
$\Sigma_b\,{}^2P_{\rho\rho\lambda}\,\frac{1}{2}^-$	6.981	-.0271	.1587	.0105	.0294	-.0174
		.1731	.0241	-.0081	-.0412	-.7477
		-.5154	.0255	.3394		
$\Sigma_b\,{}^2P'_{\rho\rho\lambda}\,\frac{1}{2}^-$	7.008	-.1404	-.0312	.0011	.0375	-.1498
		.9056	.3173	.0007	-.0588	.1476
		.0760	-.0205	-.0569		
$\Sigma_b\,{}^2P_{\rho\lambda\lambda}\,\frac{1}{2}^-$	7.039	.0058	.0775	.0269	-.0522	.1238
		.1289	-.4693	-.0094	-.8053	-.0651
		.2088	-.2022	.0325		
$\Sigma_b\,{}^2P'_{\rho\lambda\lambda}\,\frac{1}{2}^-$	7.081	-.0420	-.0486	-.0151	-.0257	.1819
		.3224	-.7793	.0039	.4578	.0964
		-.1385	.1083	-.0281		
$\Sigma_b\,{}^2P_{\lambda\lambda\lambda}\,\frac{1}{2}^-$	7.242	-.0102	-.1722	-.0367	-.0093	.0039
		.0474	-.0264	.0330	.2415	-.5656
		.7651	.0347	.0028		

Table 5.9 The masses and the components of Ξ

State	Mass	Components				
$\Xi\ {}^4D_{\lambda\lambda}\ \frac{7}{2}^+$	1.925	.0115	.9999			
$\Xi\ {}^4D_{\rho\rho}\ \frac{7}{2}^+$	2.449	-.9999	.0115			
$\Xi\ {}^2D_{\lambda\lambda}\ \frac{5}{2}^+$	1.852	-.0288	-.9970	.0671	.0276	-.0010
$\Xi\ {}^2D_{\rho\rho}\ \frac{5}{2}^+$	1.943	-.0025	-.0283	-.0113	-.9994	-.0181
$\Xi\ {}^2D_{\rho\lambda}\ \frac{5}{2}^+$	2.283	.0159	-.0672	-.9975	.0130	.0051
$\Xi\ {}^4D_{\rho\rho}\ \frac{5}{2}^+$	2.450	-.9548	.0261	-.0155	-.0035	.2955
$\Xi\ {}^4D_{\lambda\lambda}\ \frac{5}{2}^+$	2.463	.2953	-.0093	.0100	-.0179	.9552
$\Xi\ {}^4S\ \frac{3}{2}^+$	1.446	-.9407	-.1123	-.3183	.0136	.0174
		.0084	-.0231	-.0122	.0000	
$\Xi\ {}^4S_{\rho\rho}\ \frac{3}{2}^+$	1.851	-.0049	-.1670	.0094	.0853	-.0030
		.0273	.9793	-.0709	.0023	
$\Xi\ {}^4S_{\lambda\lambda}\ \frac{3}{2}^+$	1.898	.1194	-.9319	.0012	.2882	-.0088
		-.0130	-.1839	-.0098	.0087	
$\Xi\ {}^4D_{\rho\rho}\ \frac{3}{2}^+$	1.932	.0497	-.2945	-.0877	-.9489	-.0168
		.0016	.0348	.0179	-.0302	
$\Xi\ {}^4D_{\lambda\lambda}\ \frac{3}{2}^+$	2.103	-.3108	-.0610	.9413	-.0865	.0111
		.0070	-.0190	-.0752	-.0054	
$\Xi\ {}^2D_{\lambda\lambda}\ \frac{3}{2}^+$	2.285	.0350	.0218	-.0695	-.0193	-.0123
		.0144	-.0661	-.9942	-.0038	
$\Xi\ {}^2D_{\rho\rho}\ \frac{3}{2}^+$	2.321	.0025	-.0001	-.0026	.0310	.0648
		.0026	.0000	.0028	-.9974	

State	Mass	Components				
$\Xi\ ^2D_{\rho\lambda}\ \frac{3}{2}^+$	2.446	-.0228	.0116	.0069	.0069	-.6519
		-.7563	.0201	-.0053	-.0442	
$\Xi\ ^2P_{\rho\lambda}\ \frac{3}{2}^+$	2.459	-.0094	.0043	.0034	.0135	-.7550
		.6533	-.0195	.0196	-.0469	
$\Xi\ ^2S\ \frac{1}{2}^+$	1.349	.9960	.0692	.0259	-.0479	-.0093
		.0118	.0003			
$\Xi\ ^2S_{\lambda\lambda}\ \frac{1}{2}^+$	1.723	.0584	-.5193	-.8523	.0081	-.0183
		.0051	.0006			
$\Xi\ ^2S_{\rho\rho}\ \frac{1}{2}^+$	1.905	-.0275	.4278	-.2431	.0881	-.8647
		.0142	.0372			
$\Xi\ ^2S_{\rho\lambda}\ \frac{1}{2}^+$	1.932	.0283	-.7271	.4546	-.1178	-.4994
		.0022	.0228			
$\Xi\ ^4D_{\rho\rho}\ \frac{1}{2}^+$	2.233	.0533	-.1172	.0843	.9875	.0177
		.0297	.0004			
$\Xi\ ^4D_{\lambda\lambda}\ \frac{1}{2}^+$	2.321	.0013	-.0011	.0004	.0039	-.0447
		-.0960	-.9944			
$\Xi\ ^2P_{\rho\lambda}\ \frac{1}{2}^+$	2.441	-.0133	.0007	.0041	-.0295	.0088
		.9948	-.0966			
$\Xi\ ^4F_{\lambda\lambda\lambda}\ \frac{9}{2}^-$	2.447	-.3210	.9471			
$\Xi\ ^4F_{\rho\rho\lambda}\ \frac{9}{2}^-$	2.797	-.9471	-.3210			
$\Xi\ ^4F_{\lambda\lambda\lambda}\ \frac{7}{2}^-$	2.024	.0008	-.0089	-.9992	.0329	-.0229
		-.0003	.0000			

State	Mass	Components				
$\Xi\ ^4F_{\rho\rho\lambda}\ \frac{7}{2}^-$	2.379	.0042	-.0222	.0232	.9129	.3100
		-.2634	.0053			
$\Xi\ ^2F_{\rho\rho\rho}\ \frac{7}{2}^-$	2.454	-.3302	.9425	-.0076	.0251	-.0097
		-.0088	.0439			
$\Xi\ ^2F_{\rho\rho\lambda}\ \frac{7}{2}^-$	2.503	-.0167	.0405	-.0002	.0061	.0004
		-.0025	-.9990			
$\Xi\ ^2F_{\rho\lambda\lambda}\ \frac{7}{2}^-$	2.755	-.0759	-.0091	-.0257	-.1678	.8754
		.4461	-.0009			
$\Xi\ ^2F_{\lambda\lambda\lambda}\ \frac{7}{2}^-$	2.802	-.1835	-.0698	.0206	.3642	-.3699
		.8316	.0002			
$\Xi\ ^4D_{\rho\rho\lambda}\ \frac{7}{2}^-$	2.807	.9226	.3235	.0000	.0635	-.0064
		.2001	-.0024			
$\Xi\ ^4P_{\lambda}\ \frac{5}{2}^-$	2.005	-.9887	.0047	.0114	-.0057	-.0113
		-.0085	.0054	-.0048	.0026	-.0009
		-.0404	-.0850	.1148		
$\Xi\ ^4F_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	2.024	.0045	-.0013	.0139	-.9991	.0329
		-.0227	-.0003	-.0001	-.0001	.0000
		.0027	.0052	-.0058		
$\Xi\ ^4F_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.378	-.0004	.0030	-.0236	-.0223	-.8927
		-.3026	.2568	.0155	.0030	.0004
		-.1435	.0315	-.1509		
$\Xi\ ^2F_{\rho\rho\rho}\ \frac{5}{2}^-$	2.389	-.0602	-.0250	.0787	.0080	.1841
		.0691	-.0565	-.0136	.0064	.0018
		-.7415	.2390	-.5835		

State	Mass	Components				
$\Xi\ ^2F_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.450	-.0033	.3224	-.9361	-.0122	.0439
		-.0128	-.0155	.0415	.0554	.0048
		-.1047	-.0369	-.0085		
$\Xi\ ^2F_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.486	.0045	.0219	-.0550	-.0011	-.0114
		-.0045	.0049	-.9185	-.3859	-.0222
		.0056	-.0516	-.0246		
$\Xi\ ^2F_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	2.500	-.0002	.0113	-.0298	-.0005	.0048
		.0003	-.0023	.3870	-.9186	-.0486
		-.0398	.0151	.0348		
$\Xi\ ^4D_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.540	.1340	-.0387	.0653	-.0065	-.0215
		-.0010	.0062	-.0219	.0358	-.0019
		-.6429	-.3353	.6695		
$\Xi\ ^2D_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.565	.0274	-.0014	.0378	-.0005	.0307
		-.0026	-.0051	.0627	-.0065	-.0132
		.0444	-.9042	-.4161		
$\Xi\ ^2D_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.752	-.0001	-.0211	-.0089	.0008	.0053
		-.0296	-.0163	.0009	.0535	-.9976
		.0007	.0135	.0017		
$\Xi\ ^4P_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	2.755	.0021	-.1258	-.0167	.0253	.1655
		-.8687	-.4469	-.0028	-.0020	.0368
		-.0032	.0078	.0033		
$\Xi\ ^4P_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.801	.0085	.5361	.1937	.0204	.3117
		-.3645	.6665	.0011	.0021	-.0112
		-.0097	.0106	.0098		

State	Mass	Components				
$\Xi\ {}^4P'_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.804	-.0065	-.7679	-.2629	.0065	.2000
		-.1203	.5352	-.0004	-.0028	.0143
		.0050	-.0006	-.0114		
$\Xi\ {}^4P_{\lambda}\ \frac{3}{2}^-$	1.526	-.0045	-.0666	-.7667	-.0024	-.0023
		.0009	.0000	.0000	.0035	.0006
		-.0012	.1892	.0105	-.0183	.0114
		-.5968	-.1229			
$\Xi\ {}^2P_{\lambda}\ \frac{3}{2}^-$	1.910	-.0756	.7591	-.4086	.0031	-.0080
		.0054	-.0008	.0002	.0157	-.0066
		.0081	.1156	-.0275	-.0031	.0661
		.4816	-.0151			
$\Xi\ {}^2P_{\rho}\ \frac{3}{2}^-$	2.030	-.2333	.0850	.3194	.0010	.0014
		.0017	-.0024	.0008	-.0035	-.0243
		.0330	.8981	.0544	-.0805	-.0045
		-.1150	-.0733			
$\Xi\ {}^4F_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	2.039	-.9584	-.0821	-.0435	.0026	.0084
		.0064	-.0105	.0035	-.0405	-.0951
		.0930	-.2303	-.0070	.0123	-.0068
		-.0034	.0071			
$\Xi\ {}^4F_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.095	.0015	-.6126	-.3530	-.0065	.0063
		-.0007	.0000	.0000	.0101	-.0004
		-.0054	.2808	-.1214	.1580	-.1101
		.6071	-.0252			

State	Mass	Components				
$\Xi\ {}^4D_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.366	-.0204	.0748	.0228	-.0094	.0267
		-.0184	-.0016	-.0007	-.0898	.0329
		-.0598	.0937	-.4163	.6496	.1943
		-.1477	.5621			
$\Xi\ {}^2D_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.425	.0549	.0037	.0179	.0385	-.1163
		-.0205	.0489	.0095	.7245	-.2613
		.6037	-.0072	-.1088	.0883	.0236
		-.0282	.0046			
$\Xi\ {}^2D_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.443	.0067	.0174	.0194	-.3066	.9228
		-.0692	.0601	.0051	.0988	.0074
		.0510	-.0129	-.1147	.0104	.0222
		-.0066	-.1373			
$\Xi\ {}^4P_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	2.460	-.0043	.0547	.1173	.0574	-.1602
		-.0051	-.0199	-.0030	-.0768	.0475
		-.0610	-.0544	-.5938	.2083	.0730
		-.0386	-.7323			
$\Xi\ {}^4P_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.489	.0100	.0027	.0050	-.0300	.0793
		.6994	-.6996	-.0373	.0913	-.0452
		-.0371	-.0005	-.0154	.0175	-.0170
		-.0070	.0022			
$\Xi\ {}^4P'_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.507	-.0044	-.0031	-.0041	.0036	-.0085
		-.7050	-.7033	-.0383	.0465	.0582
		.0066	.0003	.0161	-.0180	.0199
		.0048	.0074			

State	Mass	Components				
$\Xi\ ^2P_{\rho\rho\rho}\ \frac{3}{2}^-$	2.551	.1109	-.0088	-.0205	-.0213	.0229
		.0287	-.0767	.0012	-.6354	-.1601
		.6929	.0056	-.1721	-.1860	.0031
		.0103	.0751			
$\Xi\ ^2P_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.559	-.0421	-.0451	-.0301	.0054	-.0315
		.0118	.0229	-.0075	.1762	.1862
		-.1494	.0178	-.6050	-.6643	.0451
		-.0019	.3096			
$\Xi\ ^2P'_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.575	-.0605	-.0021	.0021	.0019	-.0185
		.0786	.0085	-.0504	.0630	.9216
		.3344	-.0041	.1113	.0910	.0158
		.0040	-.0332			
$\Xi\ ^2P_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.752	-.0005	-.0003	.0001	-.0220	-.0101
		.0036	-.0533	.9969	.0030	.0516
		.0070	-.0001	.0010	.0000	.0019
		.0002	-.0003			
$\Xi\ ^2P'_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.793	.0064	-.0067	-.0051	.9480	.3159
		.0045	-.0039	.0236	-.0062	.0032
		.0094	.0023	.0006	-.0075	.0234
		.0028	.0034			
$\Xi\ ^2P_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	2.978	.0031	-.1382	-.0147	-.0210	-.0146
		.0306	.0007	-.0012	-.0027	-.0298
		-.0014	.0093	.1482	-.0995	.9673
		.0758	-.0696			

State	Mass	Components				
$\Xi\ {}^4P_\lambda\ \frac{1}{2}^-$	1.526	.0159	-.0652	-.7675	-.0014	-.0115
		-.0022	.0032	.1897	.0106	-.0185
		.0115	-.5954	-.1234		
$\Xi\ {}^2P_\lambda\ \frac{1}{2}^-$	1.898	.3498	.7104	-.3717	-.0085	-.0459
		.0251	-.0491	.1247	-.0220	-.0107
		.0597	.4574	-.0259		
$\Xi\ {}^2P_\rho\ \frac{1}{2}^-$	1.989	.9113	-.2522	.2017	-.0034	.0604
		.0711	-.1214	.0882	.0281	-.0306
		-.0287	-.1739	-.0343		
$\Xi\ {}^4D_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.031	.1460	-.1247	-.3022	-.0008	.0332
		.0064	.0168	-.9207	-.0510	.0783
		.0002	.0955	.0693		
$\Xi\ {}^4P_{\lambda\lambda\lambda}\ \frac{1}{2}^-$	2.095	.0035	-.6173	-.3498	.0008	-.0350
		.0024	.0146	.2787	-.1204	.1571
		-.1109	.6044	-.0266		
$\Xi\ {}^4P_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.343	-.0702	-.0666	.0074	-.0082	-.5922
		.1785	-.4414	-.1031	.2155	-.4148
		-.1288	.0692	-.4033		
$\Xi\ {}^4P'_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.384	.0118	-.0415	-.0400	-.0387	.4667
		-.1242	.4097	-.0348	.3957	-.5090
		-.1511	.1353	-.3686		
$\Xi\ {}^2P_{\rho\rho\rho}\ \frac{1}{2}^-$	2.460	.0027	.0549	.1164	.0725	.0598
		-.1267	.0719	-.0545	-.5853	.1855
		.0803	-.0326	-.7523		

State	Mass	Components				
$\Xi\ {}^2P_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.483	.0066	-.0100	-.0170	.9886	.0183
		-.0946	-.0445	.0029	.0632	-.0584
		.0357	.0160	.0445		
$\Xi\ {}^2P'_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.530	-.1403	.0110	-.0368	.0075	.6298
		.4361	-.6024	.0047	-.1339	-.0947
		-.0348	.0290	-.0101		
$\Xi\ {}^2P_{\rho\lambda\lambda}\ \frac{1}{2}^-$	2.549	.0124	-.0473	-.0359	-.1020	.0536
		-.6982	-.3089	.0102	-.3455	-.4698
		.0734	.0167	.2329		
$\Xi\ {}^2P'_{\rho\lambda\lambda}\ \frac{1}{2}^-$	2.567	.0227	-.0218	-.0096	.0597	-.1404
		.4862	.3927	.0161	-.5228	-.5093
		-.0018	-.0172	.2278		
$\Xi\ {}^2P_{\lambda\lambda\lambda}\ \frac{1}{2}^-$	2.981	.0083	.1374	.0149	.0411	-.0075
		-.0891	-.0045	-.0095	-.1460	.0991
		-.9641	-.0754	.0693		

Table 5.10 The masses and the components of Ξ_c

State	Mass	Components				
$\Xi_c\ {}^4D_{\lambda\lambda}\ \frac{7}{2}^+$	3.864	.0071	1.0000			
$\Xi_c\ {}^4D_{\rho\rho}\ \frac{7}{2}^+$	4.552	-1.0000	.0071			
$\Xi_c\ {}^2D_{\lambda\lambda}\ \frac{5}{2}^+$	3.814	-.0117	-.9992	.0238	.0298	-.0002
$\Xi_c\ {}^2D_{\rho\rho}\ \frac{5}{2}^+$	3.873	-.0008	-.0299	-.0037	-.9995	-.0088
$\Xi_c\ {}^2D_{\rho\lambda}\ \frac{5}{2}^+$	4.417	.0055	-.0238	-.9997	.0043	.0036
$\Xi_c\ {}^4D_{\rho\rho}\ \frac{5}{2}^+$	4.553	-.9518	.0110	-.0044	-.0022	.3064
$\Xi_c\ {}^4D_{\lambda\lambda}\ \frac{5}{2}^+$	4.559	.3063	-.0039	.0051	-.0086	.9519
$\Xi_c\ {}^4S\ \frac{3}{2}^+$	3.309	.8678	.1003	.4867	-.0007	-.0067
		-.0033	.0063	.0028	.0000	
$\Xi_c\ {}^4S_{\rho\rho}\ \frac{3}{2}^+$	3.811	.0539	-.6317	.0245	.1202	-.0015
		.0080	.7632	-.0240	.0011	
$\Xi_c\ {}^4S_{\lambda\lambda}\ \frac{3}{2}^+$	3.818	.0756	-.7589	.0299	.0585	-.0013
		-.0088	-.6433	.0088	.0006	
$\Xi_c\ {}^4D_{\rho\rho}\ \frac{3}{2}^+$	3.868	.0158	-.1214	-.0073	-.9908	-.0080
		.0013	.0548	.0058	-.0101	
$\Xi_c\ {}^4D_{\lambda\lambda}\ \frac{3}{2}^+$	4.321	-.4859	-.0126	.8700	-.0139	.0216
		.0115	-.0043	-.0779	-.0013	
$\Xi_c\ {}^2D_{\lambda\lambda}\ \frac{3}{2}^+$	4.417	-.0398	-.0091	.0669	.0070	.0099
		-.0038	.0235	.9966	.0003	
$\Xi_c\ {}^2D_{\rho\rho}\ \frac{3}{2}^+$	4.442	-.0011	.0000	.0014	-.0099	-.0299
		-.0007	.0000	-.0001	.9995	

State	Mass	Components				
$\Xi_c\,{}^2D_{\rho\lambda}\,\frac{3}{2}^+$	4.551	-.0178	.0020	.0169	.0045	-.6801
		-.7323	.0081	.0019	-.0209	
$\Xi_c\,{}^2P_{\rho\lambda}\,\frac{3}{2}^+$	4.557	-.0067	.0007	.0063	.0063	-.7320
		.6807	-.0084	.0094	-.0214	
$\Xi_c\,{}^2S\,\frac{1}{2}^+$	3.292	-.8937	-.4353	-.1077	.0108	.0038
		-.0049	.0000			
$\Xi_c\,{}^2S_{\lambda\lambda}\,\frac{1}{2}^+$	3.731	.1486	-.0607	-.9864	.0196	-.0280
		.0024	.0003			
$\Xi_c\,{}^2S_{\rho\rho}\,\frac{1}{2}^+$	3.858	.0131	-.0118	-.0259	-.0083	.9994
		-.0033	-.0142			
$\Xi_c\,{}^2S_{\rho\lambda}\,\frac{1}{2}^+$	4.122	.4203	-.8943	.1168	-.0987	-.0139
		.0070	.0005			
$\Xi_c\,{}^4D_{\rho\rho}\,\frac{1}{2}^+$	4.377	.0485	-.0828	.0320	.9948	.0075
		.0106	-.0002			
$\Xi_c\,{}^4D_{\lambda\lambda}\,\frac{1}{2}^+$	4.442	.0004	-.0005	.0001	.0003	-.0143
		-.0437	-.9989			
$\Xi_c\,{}^2P_{\rho\lambda}\,\frac{1}{2}^+$	4.548	.0081	-.0051	-.0006	.0099	-.0028
		-.9989	.0438			
$\Xi_c\,{}^4F_{\lambda\lambda\lambda}\,\frac{9}{2}^-$	4.568	-.0855	.9963			
$\Xi_c\,{}^4F_{\rho\rho\lambda}\,\frac{9}{2}^-$	4.841	-.9963	-.0855			
$\Xi_c\,{}^4F_{\lambda\lambda\lambda}\,\frac{7}{2}^-$	3.897	.0000	.0036	.9995	.0219	-.0231
		-.0012	.0000			

State	Mass	Components				
$\Xi_c\,{}^4F_{\rho\rho\lambda}\,\frac{7}{2}^-$	4.544	.0028	-.0465	-.0168	.9755	.1937
		-.0917	.0100			
$\Xi_c\,{}^2F_{\rho\rho\rho}\,\frac{7}{2}^-$	4.573	-.0893	.9880	-.0046	.0457	-.0002
		-.0048	.1170			
$\Xi_c\,{}^2F_{\rho\rho\lambda}\,\frac{7}{2}^-$	4.589	-.0110	.1159	-.0007	.0152	.0016
		-.0016	-.9931			
$\Xi_c\,{}^2F_{\rho\lambda\lambda}\,\frac{7}{2}^-$	4.817	.0073	.0078	.0219	-.2094	.7784
		-.5913	-.0002			
$\Xi_c\,{}^2F_{\lambda\lambda\lambda}\,\frac{7}{2}^-$	4.844	.9923	.0891	-.0019	.0066	-.0567
		-.0637	-.0005			
$\Xi_c\,{}^4D_{\rho\rho\lambda}\,\frac{7}{2}^-$	4.857	-.0843	-.0137	-.0156	.0421	-.5940
		-.7987	.0003			
$\Xi_c\,{}^4P_{\lambda}\,\frac{5}{2}^-$	3.897	-.0005	.0000	-.0056	.9995	.0219
		-.0231	-.0012	.0000	.0000	.0000
		-.0005	-.0029	.0019		
$\Xi_c\,{}^4F_{\lambda\lambda\lambda}\,\frac{5}{2}^-$	4.130	.9628	-.0030	-.0021	.0012	.0021
		.0025	-.0019	.0012	-.0006	.0004
		.0899	.0920	-.2376		
$\Xi_c\,{}^4F_{\rho\rho\lambda}\,\frac{5}{2}^-$	4.439	.2168	.0005	-.0240	-.0028	.0093
		.0017	-.0012	-.0007	-.0033	-.0013
		.3037	-.3736	.8488		
$\Xi_c\,{}^2F_{\rho\rho\rho}\,\frac{5}{2}^-$	4.543	-.0001	-.0057	.0862	-.0163	.9706
		.1938	-.0913	-.0408	-.0051	.0001
		-.0226	.0427	.0181		

State	Mass	Components				
$\Xi_c\,{}^2F_{\rho\rho\lambda}\,\frac{5}{2}^-$	4.570	-.0595	.0728	-.7894	-.0071	.0999
		.0039	-.0080	-.0114	.0668	-.0017
		.2768	-.4335	-.2979		
$\Xi_c\,{}^2F_{\rho\lambda\lambda}\,\frac{5}{2}^-$	4.573	-.0803	-.0448	.5551	.0030	-.0233
		-.0021	.0055	-.3073	-.1203	-.0037
		.4632	-.4899	-.3456		
$\Xi_c\,{}^2F_{\lambda\lambda\lambda}\,\frac{5}{2}^-$	4.580	.0352	.0167	-.2030	-.0006	-.0316
		-.0068	.0022	-.8843	-.3228	.0000
		-.2035	.1266	.1122		
$\Xi_c\,{}^4D_{\rho\rho\lambda}\,\frac{5}{2}^-$	4.587	-.0057	.0055	-.0567	-.0006	.0158
		.0017	-.0015	.3446	-.9363	-.0018
		.0191	-.0193	-.0190		
$\Xi_c\,{}^2D_{\rho\rho\lambda}\,\frac{5}{2}^-$	4.606	.1215	-.0105	.0917	-.0017	.0052
		.0007	-.0011	.0557	.0128	-.0040
		-.7525	-.6369	-.0395		
$\Xi_c\,{}^2D_{\rho\lambda\lambda}\,\frac{5}{2}^-$	4.817	-.0034	-.0117	-.0119	.0218	-.2093
		.7779	-.5919	.0003	-.0001	-.0006
		.0036	-.0060	-.0034		
$\Xi_c\,{}^4P_{\lambda\lambda\lambda}\,\frac{5}{2}^-$	4.837	-.0002	-.0709	-.0071	-.0002	.0007
		-.0047	-.0039	.0003	.0019	-.9974
		.0007	.0055	.0006		
$\Xi_c\,{}^4P_{\rho\rho\lambda}\,\frac{5}{2}^-$	4.843	-.0042	-.9869	-.0858	-.0026	.0096
		-.0784	-.0852	-.0004	-.0006	.0715
		.0040	-.0017	-.0029		

State	Mass	Components				
$\Xi_c\,{}^4P'_{\rho\rho\lambda}\ \frac{5}{2}^-$	4.857	-.0004	-.1144	-.0193	.0154	-.0418
		.5921	.7962	.0007	-.0001	.0024
		.0003	-.0024	-.0011		
$\Xi_c\,{}^4P_{\lambda}\ \frac{3}{2}^-$	3.102	-.0001	-.1237	-.6038	-.0011	-.0004
		-.0003	.0000	.0000	.0003	.0006
		-.0001	.2825	-.0033	.0057	.0889
		-.7239	-.0914			
$\Xi_c\,{}^2P_{\lambda}\ \frac{3}{2}^-$	3.979	.0136	-.1778	.0104	.0004	.0009
		-.0008	.0000	.0000	-.0045	.0019
		-.0044	-.9234	-.0449	.0389	.0473
		-.3309	-.0106			
$\Xi_c\,{}^2P_{\rho}\ \frac{3}{2}^-$	4.050	-.0342	.6169	-.6600	.0005	-.0032
		.0022	-.0001	.0000	.0056	-.0030
		.0024	-.2512	.0385	.0241	-.0216
		.3409	.0281			
$\Xi_c\,{}^4F_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	4.148	.9622	.0066	-.0318	-.0020	-.0014
		-.0016	.0022	-.0017	.0881	.0977
		-.2343	.0044	-.0006	.0124	-.0038
		.0258	.0073			
$\Xi_c\,{}^4F_{\rho\rho\lambda}\ \frac{3}{2}^-$	4.211	.0260	.6843	.3960	.0026	-.0011
		-.0012	.0001	-.0001	.0022	.0024
		.0034	.0127	.0883	-.4073	.0986
		-.4362	.0195			

State	Mass	Components				
$\Xi_c\ {}^4D_{\rho\rho\lambda}\ \frac{3}{2}^-$	4.435	.0213	-.2732	-.1516	-.0001	-.0139
		.0021	.0009	.0004	.0310	-.0369
		.0699	-.0643	.5672	-.6901	-.1719
		.1448	-.2047			
$\Xi_c\ {}^2D_{\rho\rho\lambda}\ \frac{3}{2}^-$	4.453	.2206	.0196	.0078	.0003	-.0162
		.0012	.0141	.0050	.2704	-.3853
		.8494	.0023	-.0576	.0610	.0108
		-.0087	.0114			
$\Xi_c\ {}^2D_{\rho\lambda\lambda}\ \frac{3}{2}^-$	4.564	.0098	-.0440	-.0467	-.0746	.8805
		-.1455	.0868	-.0017	-.0279	.1276
		.0775	-.0028	-.3124	-.2367	.0633
		.0582	-.0458			
$\Xi_c\ {}^4P_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	4.572	.0012	.0988	.0954	-.0325	.4109
		-.0487	.0610	.0014	.0049	-.0461
		-.0076	.0039	.7147	.5102	-.1229
		-.1165	.0561			
$\Xi_c\ {}^4P_{\rho\rho\lambda}\ \frac{3}{2}^-$	4.577	-.0767	.0064	.0090	-.0103	.1596
		.2726	-.0962	.0146	.4632	-.6745
		-.4317	-.0021	-.0860	-.0250	.0114
		.0098	-.1432			
$\Xi_c\ {}^4P'_{\rho\rho\lambda}\ \frac{3}{2}^-$	4.582	.0285	-.0089	-.0079	-.0141	.1447
		.6283	-.7076	-.0057	-.1366	.1797
		.1325	.0012	.0264	-.0065	-.0207
		-.0086	.1124			

State	Mass	Components				
$\Xi_c\,^2P_{\rho\rho\rho}\,\frac{3}{2}^-$	4.587	.0018	.1050	.0833	.0060	-.0293
		-.0714	-.1764	-.0040	.0294	.1679
		.0625	-.0092	-.0287	.1848	.0643
		.0365	-.9335			
$\Xi_c\,^2P_{\rho\rho\lambda}\,\frac{3}{2}^-$	4.591	-.0170	-.0165	-.0123	.0018	-.0185
		-.7068	-.6680	.0016	.1155	-.1049
		-.0671	.0014	.0180	-.0219	.0004
		-.0056	.1531			
$\Xi_c\,^2P'_{\rho\rho\lambda}\,\frac{3}{2}^-$	4.619	-.1261	-.0127	.0004	.0040	-.0287
		.0479	.0346	-.0129	.8185	.5433
		.0183	-.0009	.0340	.0042	-.0039
		-.0126	.1128			
$\Xi_c\,^2P_{\rho\lambda\lambda}\,\frac{3}{2}^-$	4.837	.0003	-.0005	-.0004	.1771	.0158
		-.0007	.0017	-.9838	-.0021	-.0206
		-.0028	.0001	-.0002	-.0003	.0004
		.0002	.0005			
$\Xi_c\,^2P'_{\rho\lambda\lambda}\,\frac{3}{2}^-$	4.840	.0027	-.0033	-.0024	.9806	.0818
		.0010	-.0007	.1777	-.0023	.0046
		.0024	.0007	.0008	-.0016	.0069
		.0017	.0035			
$\Xi_c\,^2P_{\lambda\lambda\lambda}\,\frac{3}{2}^-$	4.954	-.0014	.0769	.0180	.0071	.0052
		-.0195	-.0002	.0006	.0017	.0138
		.0003	-.0022	-.2117	.0155	-.9624
		-.1400	-.0480			

State	Mass	Components				
$\Xi_c\,{}^4P_\lambda$ $\frac{1}{2}^-$	3.102	.0003	-.1237	-.6038	.0004	-.0008
		-.0018	.0004	.2825	-.0033	.0057
		.0889	-.7239	-.0914		
$\Xi_c\,{}^2P_\lambda$ $\frac{1}{2}^-$	3.978	.0529	.1847	-.0169	-.0012	-.0146
		.0067	-.0171	.9192	.0454	-.0394
		-.0474	.3337	.0097		
$\Xi_c\,{}^2P_\rho$ $\frac{1}{2}^-$	4.048	-.1474	-.6090	.6514	.0033	.0142
		-.0121	.0181	.2655	-.0376	-.0225
		.0201	-.3301	-.0247		
$\Xi_c\,{}^4D_{\rho\rho\lambda}$ $\frac{1}{2}^-$	4.118	.9475	-.0645	.1181	-.0010	.0956
		.0865	-.2410	-.0114	-.0026	-.0292
		.0111	-.0879	-.0230		
$\Xi_c\,{}^4P_{\lambda\lambda\lambda}$ $\frac{1}{2}^-$	4.211	-.0590	.6861	.3924	.0019	-.0064
		-.0040	-.0185	.0128	.0882	-.4066
		.0982	-.4337	.0206		
$\Xi_c\,{}^4P_{\rho\rho\lambda}$ $\frac{1}{2}^-$	4.425	-.1879	-.1483	-.0883	-.0029	-.3006
		.3220	-.7288	-.0419	.2570	-.3347
		-.0942	.0815	-.1199		
$\Xi_c\,{}^4P'_{\rho\rho\lambda}$ $\frac{1}{2}^-$	4.438	-.0998	.2311	.1236	.0016	-.1402
		.1678	-.4249	.0505	-.5098	.6058
		.1447	-.1198	.1682		
$\Xi_c\,{}^2P_{\rho\rho\rho}$ $\frac{1}{2}^-$	4.564	-.1069	-.0625	-.0801	.1801	.5606
		-.5456	-.4258	.0025	-.2098	-.2334
		.0431	.0554	.2218		

State	Mass	Components				
$\Xi_c\ {}^2P_{\rho\rho\lambda}\ \frac{1}{2}^-$	4.569	.0637	-.0720	-.0599	.0979	-.3648
		-.0759	.1235	-.0088	-.7037	-.4445
		.1468	.1164	-.3092		
$\Xi_c\ {}^2P'_{\rho\rho\lambda}\ \frac{1}{2}^-$	4.578	.0219	.0473	.0460	.9250	-.1409
		-.0945	.0060	-.0022	.1846	.1792
		.0108	-.0180	-.2100		
$\Xi_c\ {}^2P_{\rho\lambda\lambda}\ \frac{1}{2}^-$	4.585	-.0015	.0971	.0847	-.3134	-.0881
		-.5261	-.1796	-.0079	.1544	.2614
		.0288	.0028	-.6894		
$\Xi_c\ {}^2P'_{\rho\lambda\lambda}\ \frac{1}{2}^-$	4.604	.1138	-.0534	-.0143	-.0581	-.6367
		-.5192	-.0196	.0002	.1456	-.0021
		-.0304	-.0482	.5299		
$\Xi_c\ {}^2P_{\lambda\lambda\lambda}\ \frac{1}{2}^-$	4.955	.0042	.0767	.0180	.0267	-.0049
		-.0429	-.0009	-.0023	-.2110	.0156
		-.9616	-.1399	-.0476		

Table 5.11 The masses and the components of Ξ_b

State	Mass	Components				
$\Xi_b\,{}^4D_{\lambda\lambda}\ \frac{7}{2}^+$	9.890	.0052	1.0000			
$\Xi_b\,{}^4D_{\rho\rho}\ \frac{7}{2}^+$	10.619	-1.0000	.0052			
$\Xi_b\,{}^2D_{\lambda\lambda}\ \frac{5}{2}^+$	9.856	-.0068	-.9996	.0120	.0245	.0000
$\Xi_b\,{}^2D_{\rho\rho}\ \frac{5}{2}^+$	9.895	-.0003	-.0245	-.0019	-.9997	-.0058
$\Xi_b\,{}^2D_{\rho\lambda}\ \frac{5}{2}^+$	10.499	.0019	-.0119	-.9999	.0022	.0021
$\Xi_b\,{}^4D_{\rho\rho}\ \frac{5}{2}^+$	10.619	-.9502	.0064	-.0012	-.0017	.3115
$\Xi_b\,{}^4D_{\lambda\lambda}\ \frac{5}{2}^+$	10.622	.3115	-.0022	.0026	-.0056	.9502
$\Xi_b\,{}^4S\ \frac{3}{2}^+$	9.137	.8274	.0740	.5567	.0004	-.0028
		-.0014	.0017	.0008	.0000	
$\Xi_b\,{}^4S_{\rho\rho}\ \frac{3}{2}^+$	9.796	.0625	-.9965	.0394	.0331	-.0001
		.0000	.0219	-.0045	.0001	
$\Xi_b\,{}^4S_{\lambda\lambda}\ \frac{3}{2}^+$	9.856	.0034	-.0233	.0012	-.0476	.0000
		-.0068	-.9985	.0120	-.0002	
$\Xi_b\,{}^4D_{\rho\rho}\ \frac{3}{2}^+$	9.892	-.0042	.0319	.0013	.9983	.0054
		-.0006	-.0484	-.0034	.0049	
$\Xi_b\,{}^4D_{\lambda\lambda}\ \frac{3}{2}^+$	10.499	-.0206	.0040	.0315	-.0042	-.0028
		.0024	-.0120	-.9992	-.0013	
$\Xi_b\,{}^2D_{\lambda\lambda}\ \frac{3}{2}^+$	10.505	.0003	.0000	-.0005	-.0048	-.0129
		-.0002	.0000	-.0012	.9999	
$\Xi_b\,{}^2D_{\rho\rho}\ \frac{3}{2}^+$	10.603	-.5394	-.0024	.8034	-.0043	.2175
		.1225	-.0010	.0361	.0034	

State	Mass	Components				
$\Xi_b\,^2D_{\rho\lambda}\ \frac{3}{2}^+$	10.619	-.1294	-.0005	.1876	.0022	-.5709
		-.7887	.0052	.0082	-.0073	
$\Xi_b\,^2P_{\rho\lambda}\ \frac{3}{2}^+$	10.621	.0578	.0002	-.0834	-.0042	.7916
		-.6024	.0043	-.0076	.0100	
$\Xi_b\,^2S\ \frac{1}{2}^+$	9.133	-.8344	-.5451	-.0817	.0027	.0013
		-.0020	.0000			
$\Xi_b\,^2S_{\lambda\lambda}\ \frac{1}{2}^+$	9.745	-.0827	-.0227	.9962	-.0122	.0118
		-.0003	-.0001			
$\Xi_b\,^2S_{\rho\rho}\ \frac{1}{2}^+$	9.887	-.0033	.0009	.0117	.0044	-.9999
		.0012	.0068			
$\Xi_b\,^2S_{\rho\lambda}\ \frac{1}{2}^+$	10.455	-.3413	.5274	-.0069	.7780	.0049
		-.0076	-.0007			
$\Xi_b\,^4D_{\rho\rho}\ \frac{1}{2}^+$	10.481	-.4247	.6512	-.0282	-.6281	-.0011
		-.0166	-.0012			
$\Xi_b\,^4D_{\lambda\lambda}\ \frac{1}{2}^+$	10.505	.0009	-.0014	.0001	.0003	-.0069
		-.0184	-.9998			
$\Xi_b\,^2P_{\rho\lambda}\ \frac{1}{2}^+$	10.617	.0113	-.0137	.0004	.0045	-.0011
		-.9997	.0184			
$\Xi_b\,^4F_{\lambda\lambda\lambda}\ \frac{9}{2}^-$	10.625	.0526	.9986			
$\Xi_b\,^4F_{\rho\rho\lambda}\ \frac{9}{2}^-$	10.928	-.9986	.0526			
$\Xi_b\,^4F_{\lambda\lambda\lambda}\ \frac{7}{2}^-$	9.886	.0001	.0019	.9964	.0675	-.0515
		.0002	.0000			

State	Mass	Components				
$\Xi_b\,{}^4F_{\rho\rho\lambda}\,\frac{7}{2}^-$	10.621	.0071	.1320	.0652	-.9872	-.0287
		-.0522	-.0111			
$\Xi_b\,{}^2F_{\rho\rho\rho}\,\frac{7}{2}^-$	10.628	.0509	.9831	-.0107	.1295	-.0003
		.0065	.1184			
$\Xi_b\,{}^2F_{\rho\rho\lambda}\,\frac{7}{2}^-$	10.639	.0063	.1157	-.0020	.0265	.0000
		.0014	-.9929			
$\Xi_b\,{}^2F_{\rho\lambda\lambda}\,\frac{7}{2}^-$	10.908	-.0051	.0043	.0513	-.0412	.9399
		.3351	-.0002			
$\Xi_b\,{}^2F_{\lambda\lambda\lambda}\,\frac{7}{2}^-$	10.929	.9740	-.0503	.0036	.0091	.0792
		-.2062	.0002			
$\Xi_b\,{}^4D_{\rho\rho\lambda}\,\frac{7}{2}^-$	10.931	.2207	-.0125	-.0143	-.0400	-.3270
		.9179	.0002			
$\Xi_b\,{}^4P_{\lambda}\,\frac{5}{2}^-$	9.886	-.0005	-.0001	-.0030	.9964	.0675
		-.0515	.0002	-.0001	.0000	.0000
		-.0001	-.0026	.0010		
$\Xi_b\,{}^4F_{\lambda\lambda\lambda}\,\frac{5}{2}^-$	10.139	.8952	-.0011	-.0001	.0012	-.0001
		.0006	-.0006	.0004	-.0001	.0002
		.2352	.0885	-.3681		
$\Xi_b\,{}^4F_{\rho\rho\lambda}\,\frac{5}{2}^-$	10.420	.3037	-.0010	-.0088	-.0022	.0066
		.0004	-.0002	-.0015	-.0010	-.0005
		.2776	-.3966	.8205		
$\Xi_b\,{}^2F_{\rho\rho\rho}\,\frac{5}{2}^-$	10.551	-.1333	-.0001	-.0323	-.0041	.0289
		-.0021	.0018	-.0156	-.0018	-.0019
		.1637	-.8764	-.4303		

State	Mass	Components				
$\Xi_b\ {}^2F_{\rho\rho\lambda}\ \frac{5}{2}^-$	10.621	.0031	.0147	.2758	-.0621	.9518
		.0290	.0504	-.0970	-.0253	.0013
		-.0086	.0185	.0056		
$\Xi_b\ {}^2F_{\rho\lambda\lambda}\ \frac{5}{2}^-$	10.627	-.0065	.0493	.9434	.0219	-.2851
		-.0023	-.0146	-.1109	-.1073	.0052
		.0235	-.0323	-.0090		
$\Xi_b\ {}^2F_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	10.633	-.0038	.0089	.1650	-.0031	.0549
		.0019	.0032	.9108	.3733	-.0200
		.0097	-.0158	-.0061		
$\Xi_b\ {}^4D_{\rho\rho\lambda}\ \frac{5}{2}^-$	10.637	.0005	.0027	.0506	.0021	-.0293
		-.0002	-.0016	-.3853	.9196	-.0496
		.0009	.0016	.0015		
$\Xi_b\ {}^2D_{\rho\rho\lambda}\ \frac{5}{2}^-$	10.704	.2976	-.0014	.0150	-.0001	-.0086
		.0009	-.0020	.0041	.0017	-.0009
		-.9166	-.2551	.0769		
$\Xi_b\ {}^2D_{\rho\lambda\lambda}\ \frac{5}{2}^-$	10.908	-.0008	.0082	-.0067	.0513	-.0412
		.9397	.3354	.0006	.0000	.0000
		.0007	-.0022	-.0010		
$\Xi_b\ {}^4P_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	10.920	.0000	.0184	-.0005	.0000	-.0001
		-.0005	.0009	-.0003	.0537	.9984
		-.0003	-.0022	-.0002		
$\Xi_b\ {}^4P_{\rho\rho\lambda}\ \frac{5}{2}^-$	10.929	-.0024	-.9692	.0502	.0040	.0099
		.0887	-.2231	.0003	.0011	.0181
		.0022	-.0008	-.0010		

State	Mass	Components				
$\Xi_b\,{}^4P'_{\rho\rho\lambda}\ \frac{5}{2}^-$	10.931	.0011	-.2397	.0141	-.0142	-.0398
		-.3249	.9138	-.0004	.0002	.0034
		-.0010	.0003	.0006		
$\Xi_b\,{}^4P_{\lambda}\ \frac{3}{2}^-$	8.854	.0001	-.1646	-.5740	-.0005	-.0001
		-.0002	.0000	.0000	.0000	.0003
		.0000	.2969	.0122	.0226	.1247
		-.7259	-.1104			
$\Xi_b\,{}^2P_{\lambda}\ \frac{3}{2}^-$	10.003	-.0047	.1234	.0649	-.0003	-.0003
		.0004	.0000	.0000	.0011	-.0010
		.0026	.9413	.0339	-.0691	-.0695
		.2826	.0626			
$\Xi_b\,{}^2P_{\rho}\ \frac{3}{2}^-$	10.127	.0489	-.7796	.5417	-.0002	.0017
		-.0013	.0000	.0000	.0084	.0054
		-.0168	.1383	-.0728	.0916	.0925
		-.1502	-.1791			
$\Xi_b\,{}^4F_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	10.149	.8934	.0391	-.0308	-.0007	-.0002
		-.0004	.0003	-.0007	.2337	.0913
		-.3690	-.0025	.0031	-.0001	-.0063
		.0116	.0125			
$\Xi_b\,{}^4F_{\rho\rho\lambda}\ \frac{3}{2}^-$	10.269	.0101	.2942	.4346	.0007	-.0001
		-.0018	.0000	.0000	.0020	.0001
		.0074	.0035	.1756	-.7175	.1028
		-.4102	-.0024			

State	Mass	Components				
$\Xi_b\,{}^4D_{\rho\rho\lambda}\,\frac{3}{2}^-$	10.427	.3076	-.0033	-.0063	-.0006	-.0059
		.0022	.0041	.0021	.2710	-.4078
		.8158	-.0018	-.0005	.0051	-.0039
		.0045	-.0010			
$\Xi_b\,{}^2D_{\rho\rho\lambda}\,\frac{3}{2}^-$	10.493	.0036	.3011	.2501	.0010	.0143
		.0004	.0001	-.0001	-.0050	.0100
		.0092	.0626	-.7934	.2495	.1643
		-.2547	.2425			
$\Xi_b\,{}^2D_{\rho\lambda\lambda}\,\frac{3}{2}^-$	10.554	.1332	-.0128	-.0182	.0002	.0224
		-.0205	-.0060	-.0072	-.1582	.8730
		.4389	-.0024	-.0065	-.0213	.0050
		.0180	-.0076			
$\Xi_b\,{}^4P_{\lambda\lambda\lambda}\,\frac{3}{2}^-$	10.566	.0072	.2711	.3333	.0002	-.0213
		.0018	-.0006	-.0002	-.0146	.0270
		.0172	.0448	.5369	.6132	-.1152
		-.3243	.1703			
$\Xi_b\,{}^4P_{\rho\rho\lambda}\,\frac{3}{2}^-$	10.623	-.0037	.0064	.0037	.0523	.9846
		-.1321	.0944	-.0044	.0125	-.0212
		-.0063	.0005	.0232	.0120	.0006
		-.0023	-.0077			
$\Xi_b\,{}^4P'_{\rho\rho\lambda}\,\frac{3}{2}^-$	10.634	.0015	-.0038	-.0001	.0087	.1571
		.6298	-.7594	.0406	.0016	.0040
		.0040	-.0005	.0022	-.0026	-.0090
		-.0023	.0081			

State	Mass	Components				
$\Xi_b\ ^2P_{\rho\rho\rho}\ \frac{3}{2}^-$	10.640	.0036	-.0064	-.0009	.0023	.0416
		.7647	.6414	-.0350	-.0111	.0158
		.0053	-.0007	-.0002	- 0052	-.0119
		-.0027	.0138			
$\Xi_b\ ^2P_{\rho\rho\lambda}\ \frac{3}{2}^-$	10.675	-.0217	.3090	.0826	.0017	-.0085
		.0234	.0026	-.0004	.0765	.0209
		-.0062	.0280	-.0323	.1755	.2757
		.0625	-.8819			
$\Xi_b\ ^2P'_{\rho\rho\lambda}\ \frac{3}{2}^-$	10.713	.2941	.0248	-.0003	-.0009	.0072
		-.0040	-.0052	.0034	-.9168	-.2471
		.0702	.0029	-.0050	.0081	.0218
		.0111	-.0752			
$\Xi_b\ ^2P_{\rho\lambda\lambda}\ \frac{3}{2}^-$	10.920	.0001	.0000	.0000	.0220	-.0007
		-.0006	-.0537	-.9983	-.0012	-.0083
		-.0009	.0000	-.0001	.0000	-.0002
		.0000	-.0001			
$\Xi_b\ ^2P'_{\rho\lambda\lambda}\ \frac{3}{2}^-$	10.927	.0013	-.0016	-.0011	.9983	-.0530
		-.0003	.0013	.0220	-.0012	.0006
		.0005	.0003	-.0005	-.0007	.0001
		.0004	.0016			
$\Xi_b\ ^2P_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	10.996	-.0001	.0357	.0482	.0007	.0017
		-.0099	-.0001	.0002	-.0003	.0051
		-.0004	-.0025	-.2078	-.0423	-.9184
		-.1668	-.2829			

State		Mass	Components				
$\Xi_b\,{}^4P_\lambda$	$\frac{1}{2}^-$	8.854	-.0002	-.1646	-.5740	.0003	.0000
			-.0009	-.0001	.2969	.0122	.0226
			.1247	-.7259	-.1104		
$\Xi_b\,{}^2P_\lambda$	$\frac{1}{2}^-$	10.003	.0170	.1241	.0645	-.0005	-.0030
			.0032	-.0092	.9410	.0339	-.0693
			-.0696	.2827	.0625		
$\Xi_b\,{}^2P_\rho$	$\frac{1}{2}^-$	10.125	.4534	.6778	-.4671	-.0018	.1072
			.0447	-.1766	-.1289	.0638	-.0848
			-.0781	.1248	.1505		
$\Xi_b\,{}^4D_{\rho\rho\lambda}$	$\frac{1}{2}^-$	10.133	-.7717	.3862	-.2771	-.0005	-.2108
			-.0736	.3223	-.0550	.0349	-.0345
			-.0502	.0853	.0979		
$\Xi_b\,{}^4P_{\lambda\lambda\lambda}$	$\frac{1}{2}^-$	10.269	.0302	-.2949	-.4336	-.0026	.0066
			-.0010	.0273	-.0033	-.1754	.7170
			-.1025	.4098	.0019		
$\Xi_b\,{}^4P_{\rho\rho\lambda}$	$\frac{1}{2}^-$	10.414	.2999	.0106	.0207	.0024	.2835
			-.3889	.8229	.0057	.0039	-.0188
			.0115	-.0153	.0035		
$\Xi_b\,{}^4P'_{\rho\rho\lambda}$	$\frac{1}{2}^-$	10.492	.0113	-.3009	-.2491	.0005	-.0179
			.0349	.0277	-.0626	.7925	-.2500
			-.1641	.2539	-.2431		
$\Xi_b\,{}^2P_{\rho\rho\rho}$	$\frac{1}{2}^-$	10.550	.1321	.0316	.0462	-.0235	-.1645
			.8771	.4217	.0059	.0005	.0466
			-.0111	-.0456	.0179		

State	Mass	Components				
$\Xi_b\,{}^2P_{\rho\rho\lambda}\,\frac{1}{2}^-$	10.566	.0194	-.2690	-.3302	.0012	-.0437
		.0522	.0385	-.0445	-.5388	-.6110
		.1159	.3218	-.1719		
$\Xi_b\,{}^2P'_{\rho\rho\lambda}\,\frac{1}{2}^-$	10.632	-.0061	-.0112	-.0019	-.9991	.0152
		-.0186	-.0088	-.0012	-.0019	-.0100
		-.0204	-.0041	.0223		
$\Xi_b\,{}^2P_{\rho\lambda\lambda}\,\frac{1}{2}^-$	10.672	-.1009	-.2911	-.0868	.0332	.3313
		.0951	-.0313	-.0257	.0260	-.1736
		-.2586	-.0504	.8221		
$\Xi_b\,{}^2P'_{\rho\lambda\lambda}\,\frac{1}{2}^-$	10.701	.2822	-.1089	-.0074	.0003	-.8511
		-.2419	.0758	-.0117	.0200	-.0428
		-.0965	-.0412	.3263		
$\Xi_b\,{}^2P_{\lambda\lambda\lambda}\,\frac{1}{2}^-$	10.996	-.0004	-.0357	-.0482	-.0137	-.0009
		.0161	-.0012	.0025	.2077	.0422
		.9183	.1668	.2828		

Table 5.12 The masses and the components of Ω

State	Mass	Components			
$\Omega\ ^4D_S\ \frac{7}{2}^+$	2.263	1.0			
$\Omega\ ^4D_S\ \frac{5}{2}^+$	2.268	-.9996	-.0287		
$\Omega\ ^2D_M\ \frac{5}{2}^+$	2.344	-.0287	.9996		
$\Omega\ ^4S_S\ \frac{3}{2}^+$	1.620	.9947	.0982	-.0261	.0165
$\Omega\ ^4S_S'\ \frac{3}{2}^+$	2.020	-.0976	.9950	.0179	-.0097
$\Omega\ ^4D_S\ \frac{3}{2}^+$	2.265	-.0285	.0156	-.9984	.0464
$\Omega\ ^2D_M\ \frac{3}{2}^+$	2.344	.0161	-.0073	-.0470	-.9987
$\Omega\ ^2S_M\ \frac{1}{2}^+$	2.219	-.9977	-.0679		
$\Omega\ ^4D_S\ \frac{1}{2}^+$	2.259	-.0679	.9977		
$\Omega\ ^4F_S\ \frac{9}{2}^-$	2.575	1.0			
$\Omega\ ^4F_S\ \frac{7}{2}^-$	2.538	.0389	.9992		
$\Omega\ ^2F_M\ \frac{7}{2}^-$	2.582	-.9992	.0389		
$\Omega\ ^4F_S\ \frac{5}{2}^-$	2.250	.0048	-.0025	-.0028	1.0000
$\Omega\ ^2F_M\ \frac{5}{2}^-$	2.538	-.0651	.9979	.0010	.0029
$\Omega\ ^2D_M\ \frac{5}{2}^-$	2.579	-.9976	-.0651	.0235	.0047
$\Omega\ ^4P_S\ \frac{5}{2}^-$	2.663	-.0235	-.0005	-.9997	-.0027

State	Mass	Components					
$\Omega\ {}^2P_M\ \frac{3}{2}^-$	2.022	.9976	.0000	.0133	.0255	.0510	-.0363
$\Omega\ {}^2D_M\ \frac{3}{2}^-$	2.251	-.0128	.0104	.9998	-.0027	-.0064	.0038
$\Omega\ {}^4P_S\ \frac{3}{2}^-$	2.356	.0531	-.0002	-.0059	-.1157	-.9917	-.0176
$\Omega\ {}^2P_M'\ \frac{3}{2}^-$	2.569	-.0135	-.0152	.0015	-.6852	.0920	-.7222
$\Omega\ {}^2P_M''\ \frac{3}{2}^-$	2.576	-.0398	-.0155	.0037	.7187	-.0737	-.6901
$\Omega\ {}^4F_S\ \frac{3}{2}^-$	2.663	.0007	-.9997	.0103	-.0007	-.0001	.0217

$\Omega\ {}^2P_M\ \frac{1}{2}^-$	2.022	.9975	-.0428	.0256	.0511
$\Omega\ {}^4P_S\ \frac{1}{2}^-$	2.250	.0416	.9989	.0086	.0207
$\Omega\ {}^2P_M'\ \frac{1}{2}^-$	2.356	.0546	.0192	-.1152	-.9917
$\Omega\ {}^2P_M''\ \frac{1}{2}^-$	2.573	.0198	.0053	-.9930	.1166

Table 5.13 The masses and the components of Ω_c

State	Mass	Components			
$\Omega_c\,{}^4D_S\,\frac{7}{2}^+$	5.103	1.0			
$\Omega_c\,{}^4D_S\,\frac{5}{2}^+$	5.105	-1.0000	-.0072		
$\Omega_c\,{}^2D_M\,\frac{5}{2}^+$	5.219	-.0072	1.0000		
$\Omega_c\,{}^4S_S\,\frac{3}{2}^+$	4.364	.9939	.1101	-.0090	.0055
$\Omega_c\,{}^4S_S'\,\frac{3}{2}^+$	4.722	-.1101	.9939	.0028	-.0015
$\Omega_c\,{}^4D_S\,\frac{3}{2}^+$	5.104	-.0093	.0018	-.9999	.0129
$\Omega_c\,{}^2D_M\,\frac{3}{2}^+$	5.219	-.0055	.0009	.0129	.9999
$\Omega_c\,{}^2S_M\,\frac{1}{2}^+$	5.026	-1.0000	-.0043		
$\Omega_c\,{}^4D_S\,\frac{1}{2}^+$	5.101	-.0043	1.0000		
$\Omega_c\,{}^4F_S\,\frac{9}{2}^-$	5.446	1.0			
$\Omega_c\,{}^4F_S\,\frac{7}{2}^-$	5.376	.0090	1.0000		
$\Omega_c\,{}^2F_M\,\frac{7}{2}^-$	5.449	-1.0000	.0090		
$\Omega_c\,{}^4F_S\,\frac{5}{2}^-$	4.870	-.0001	.0001	-.0005	1.0000
$\Omega_c\,{}^2F_M\,\frac{5}{2}^-$	5.376	.0141	-.9999	-.0001	.0001
$\Omega_c\,{}^2D_M\,\frac{5}{2}^-$	5.448	.9999	.0141	-.0054	.0001
$\Omega_c\,{}^4P_S\,\frac{5}{2}^-$	5.586	-.0054	.0000	-1.0000	-.0005

State	Mass	Components					
$\Omega_c\,{}^2P_M\,\frac{3}{2}^-$	4.848	-.9925	-.0001	-.0549	-.0239	-.1060	.0132
$\Omega_c\,{}^2D_M\,\frac{3}{2}^-$	4.870	-.0544	.0018	.9985	-.0019	-.0067	.0007
$\Omega_c\,{}^4P_S\,\frac{3}{2}^-$	5.106	.1087	.0000	-.0010	-.1642	-.9804	-.0037
$\Omega_c\,{}^2P'_M\,\frac{3}{2}^-$	5.445	-.0125	-.0053	-.0001	-.1370	.0253	-.9902
$\Omega_c\,{}^2P''_M\,\frac{3}{2}^-$	5.450	.0079	.0008	-.0005	-.9766	.1639	.1392
$\Omega_c\,{}^4F_S\,\frac{3}{2}^-$	5.586	.0001	-1.0000	.0019	.0000	.0000	.0053
$\Omega_c\,{}^2P_M\,\frac{1}{2}^-$	4.848	-.9788	.1749	-.0233	-.1042		
$\Omega_c\,{}^4P_S\,\frac{1}{2}^-$	4.870	.1736	.9846	.0062	.0213		
$\Omega_c\,{}^2P'_M\,\frac{1}{2}^-$	5.106	.1088	.0031	-.1642	-.9804		
$\Omega_c\,{}^2P''_M\,\frac{1}{2}^-$	5.450	.0061	.0015	-.9861	.1658		

Table 5.14 The masses and the components of Ω_b

State	Mass	Components			
$\Omega_b\,{}^4D_S\,\frac{7}{2}^+$	13.541	1.0			
$\Omega_b\,{}^4D_S\,\frac{5}{2}^+$	13.542	-1.0000	-.0015		
$\Omega_b\,{}^2D_M\,\frac{5}{2}^+$	13.830	-.0015	1.0000		
$\Omega_b\,{}^4S_S\,\frac{3}{2}^+$	12.359	.9954	.0954	-.0030	.0017
$\Omega_b\,{}^4S_S'\,\frac{3}{2}^+$	12.856	-.0954	.9954	.0001	.0000
$\Omega_b\,{}^4D_S\,\frac{3}{2}^+$	13.541	-.0030	-.0002	-1.0000	.0028
$\Omega_b\,{}^2D_M\,\frac{3}{2}^+$	13.830	-.0017	-.0001	.0028	1.0000
$\Omega_b\,{}^2S_M\,\frac{1}{2}^+$	13.485	-1.0000	.0049		
$\Omega_b\,{}^4D_S\,\frac{1}{2}^+$	13.540	.0049	1.0000		
$\Omega_b\,{}^4F_S\,\frac{9}{2}^-$	14.050	1.0			
$\Omega_b\,{}^4F_S\,\frac{7}{2}^-$	13.895	.0022	1.0000		
$\Omega_b\,{}^2F_M\,\frac{7}{2}^-$	14.051	-1.0000	.0022		
$\Omega_b\,{}^4F_S\,\frac{5}{2}^-$	12.888	-.0004	.0002	-.0001	1.0000
$\Omega_b\,{}^2F_M\,\frac{5}{2}^-$	13.895	-.0035	1.0000	.0000	-.0002
$\Omega_b\,{}^2D_M\,\frac{5}{2}^-$	14.050	-1.0000	-.0035	.0011	-.0004
$\Omega_b\,{}^4P_S\,\frac{5}{2}^-$	14.419	-.0011	.0000	-1.0000	-.0001

State	Mass	Components					
$\Omega_b\,{}^2P_M\,\frac{3}{2}^-$	12.889	-.0018	-.0003	-1.0000	.0001	-.0001	.0003
$\Omega_b\,{}^2D_M\,\frac{3}{2}^-$	13.236	.9913	.0000	-.0018	.0287	.1284	-.0051
$\Omega_b\,{}^4P_S\,\frac{3}{2}^-$	13.512	-.1315	.0000	.0001	.2047	.9700	.0006
$\Omega_b\,{}^2P'_M\,\frac{3}{2}^-$	14.049	-.0052	-.0011	-.0002	-.0011	.0002	-1.0000
$\Omega_b\,{}^2P''_M\,\frac{3}{2}^-$	14.179	.0015	.0000	-.0002	-.9784	.2067	.0011
$\Omega_b\,{}^4F_S\,\frac{3}{2}^-$	14.419	.0000	1.0000	- 0003	.0000	.0000	-.0011

State	Mass	Components			
$\Omega_b\,{}^2P_M\,\frac{1}{2}^-$	12.888	.0058	-1.0000	-.0004	.0004
$\Omega_b\,{}^4P_S\,\frac{1}{2}^-$	13.236	.9913	.0058	.0287	.1284
$\Omega_b\,{}^2P'_M\,\frac{1}{2}^-$	13.512	.1315	.0004	-.2047	-.9700
$\Omega_b\,{}^2P''_M\,\frac{1}{2}^-$	14.179	.0015	.0005	-.9784	.2067

Table 5.15 The masses and widths of the $N\pi$ channel of nucleon

The experimental data are listed in the parentheses. In the width, the uppers and the lowers are by Cutkosky and Hoehler[29] respectively. The data of the resonances with the (*) are those with the * or ** status and are omitted from the summary table by the particle data group. All the values are given in Gev.

STATE	MASS		WIDTH	
$N\,^4D_M\,\frac{7}{2}^+$	2.005	(1.920 - 2.020)	.016	(.009 - .038)*
				(.005 - .027)
$N\,^2D_S\,\frac{5}{2}^+$	1.781	(1.670 - 1.690)	.555	(.063 - .087)
				(.076 - .091)
$N\,^2D_M\,\frac{5}{2}^+$	1.995	(2.000)	.001	- *
$N\,^4D_M\,\frac{5}{2}^+$	2.041		.004	(.002 - .007)
$N\,^4S_M\,\frac{3}{2}^+$	1.779	(1.690 - 1.800)	.074	(.003 - .027)
				(.018 - .037)
$N\,^2D_S\,\frac{3}{2}^+$	1.914		.021	
$N\,^2D_M\,\frac{3}{2}^+$	1.994		.086	
$N\,^4D_M\,\frac{3}{2}^+$	2.018		.101	
$N\,^2P_A\,\frac{3}{2}^+$	2.093		.003	
$N\,^2S_S\,\frac{1}{2}^+$	.958	(0.939)	below threshold	
$N\,^2S'_S\,\frac{1}{2}^+$	1.458	(1.400 - 1.480)	.068	(.173 - .295)
				(.058 - .081)
$N\,^2S_M\,\frac{1}{2}^+$	1.805	(1.680 - 1.740)	.078	(.010 - .029)
				(.008 - .022)

N $^{4}D_{M}\ \frac{1}{2}^{+}$	1.972	(2.030 - 2.070)	.012	(.014 - .054)*
				(.010 - .032)
N $^{2}P_{A}\ \frac{1}{2}^{+}$	2.096		.001	
N $^{4}F_{M}\ \frac{9}{2}^{-}$	2.257	(2.130 - 2.270)	.011	(.029 - .072)
				(.021 - .027)
N $^{4}F_{M}\ \frac{7}{2}^{-}$	2.123	(2.120 - 2.230)	.426	(.021 - .117)
				(.043 - .067)
N $^{2}F_{A}\ \frac{7}{2}^{-}$	2.270		.018	
N $^{2}F_{M}\ \frac{7}{2}^{-}$	2.290		.065	
N $^{2}F_{S}\ \frac{7}{2}^{-}$	2.359		small	
N $^{4}D_{M}\ \frac{7}{2}^{-}$	2.373		small	
N $^{4}P_{M}\ \frac{5}{2}^{-}$	1.647	(1.660 - 1.690)	.026	(.046 - .077)
				(.037 - .055)
N $^{4}F_{M}\ \frac{5}{2}^{-}$	2.105	(2.100-2.260)	.024	(.021 - .065)*
N $^{2}F_{A}\ \frac{5}{2}^{-}$	2.124		.156	(.013 - .032)
N $^{2}F_{M}\ \frac{5}{2}^{-}$	2.252		.005	
N $^{2}F_{S}\ \frac{5}{2}^{-}$	2.289		small	
N $^{4}D_{M}\ \frac{5}{2}^{-}$	2.297		.007	
N $^{2}D_{M}\ \frac{5}{2}^{-}$	2.357		small	
N $^{4}P'_{M}\ \frac{5}{2}^{-}$	2.365		small	
N $^{4}P''_{M}\ \frac{5}{2}^{-}$	2.392		small	
N $^{2}P_{M}\ \frac{3}{2}^{-}$	1.470	(1.510 - 1.530)	.120	(.058 - .082)
				(.055 - .069)
N $^{4}P_{M}\ \frac{3}{2}^{-}$	1.680	(1.670 - 1.730)	.001	(.003 - .021)
				(.004 - .015)
N $^{4}F_{M}\ \frac{3}{2}^{-}$	1.841		.044	

N $^4D_M \frac{3}{2}^-$	1.972	(1.980 - 2.140)	.027	(.014 - .084)*
				(.009 - .024)
N $^2D_M \frac{3}{2}^-$	2.158		.001	
N $^4P'_M \frac{3}{2}^-$	2.245		.015	
N $^2P_A \frac{3}{2}^-$	2.271		small	
N $^2P'_M \frac{3}{2}^-$	2.314		small	
N $^2P_S \frac{3}{2}^-$	2.342		small	
N $^4P''_M \frac{3}{2}^-$	2.391		small	
N $^2P''_M \frac{3}{2}^-$	2.413		small	
N $^2P_M \frac{1}{2}^-$	1.469	(1.520 - 1.560)	.056	(.064 - .192)
				(.034 - .059)
N $^4P_M \frac{1}{2}^-$	1.613	(1.620 - 1.680)	.020	(.061 - .143)
				(.091 - .130)
N $^4D_M \frac{1}{2}^-$	1.842	(1.860-2.260)	.049	(.025 - .117)*
N $^4P'_M \frac{1}{2}^-$	1.967		.014	(.003 - .018)
N $^2P_A \frac{1}{2}^-$	2.057		.006	
N $^2P'_M \frac{1}{2}^-$	2.274		small	
N $^2P_S \frac{1}{2}^-$	2.276		.001	
N $^4P''_M \frac{1}{2}^-$	2.392		small	
N $^2P''_M \frac{1}{2}^-$	2.417		small	

Table 5.16 The masses and widths of the Nπ channel of Δ (see table 5.15)

STATE	MASS		WIDTH	
$\Delta\ ^4D_S\ \frac{7}{2}^+$	1.943	(1.910 - 1.960)	.105	(.102 - .168)
				(.077 - .094)
$\Delta\ ^4D_S\ \frac{5}{2}^+$	1.956	(1.890 - 1.920)	.026	(.015 - .055)
				(.031 - .048)
$\Delta\ ^2D_M\ \frac{5}{2}^+$	2.016	(2.000)	.010	(.008 - .058)*
$\Delta\ ^4S_S\ \frac{3}{2}^+$	1.215	(1.230 - 1.234)	.120	(.115 - .125)
				(.111 - .121)
$\Delta\ ^4S'_S\ \frac{3}{2}^+$	1.788	(1.550 - 1.650)	.001	(.028 - .088)*
				(.027 - .070)
$\Delta\ ^4D_S\ \frac{3}{2}^+$	1.949	(1.860 - 2.160)	.073	(.030 - .100)
				(.014 - .054)
$\Delta\ ^2D_M\ \frac{3}{2}^+$	2.017		.006	
$\Delta\ ^2S_M\ \frac{1}{2}^+$	1.919	(1.850-1.950)	.042	(.028 - .061) (.041 - .099)
$\Delta\ ^4D_S\ \frac{1}{2}^+$	1.937		.086	
$\Delta\ ^4F_S\ \frac{9}{2}^-$	2.296	(2.200 - 2.400)	.022	(.007 - .030)*
				(.011 - .052)
$\Delta\ ^4F_S\ \frac{7}{2}^-$	2.262	(2.120 - 2.280)	.010	(.014 - .044)*
				(.009 - .035)
$\Delta\ ^2F_M\ \frac{7}{2}^-$	2.315		.004	
$\Delta\ ^4F_S\ \frac{5}{2}^-$	2.019	(1.890 - 1.960)	.033	(.026 - .068)
				(.001 - .018)

$\Delta\,{}^2F_M\ \frac{5}{2}^-$	2.261	(2.275-2.525)	.009	(.025 - .165)*
$\Delta\,{}^2D_M\ \frac{5}{2}^-$	2.307		.007	(.005 - .022)
$\Delta\,{}^4P_S\ \frac{5}{2}^-$	2.366		small	
$\Delta\,{}^2P_M\ \frac{3}{2}^-$	1.652	(1.630 - 1.740)	.023	(.018 - .054)
				(.026 - .071)
$\Delta\,{}^2D_M\ \frac{3}{2}^-$	2.020	(1.840 - 2.040)	.005	(.003 - .021)*
$\Delta\,{}^4P_S\ \frac{3}{2}^-$	2.115		.006	
$\Delta\,{}^2P'_M\ \frac{3}{2}^-$	2.283		.008	
$\Delta\,{}^2P''_M\ \frac{3}{2}^-$	2.304		.016	
$\Delta\,{}^4F_S\ \frac{3}{2}^-$	2.366		small	
$\Delta\,{}^2P_M\ \frac{1}{2}^-$	1.655	(1.600 - 1.650)	.019	(.026 - .045)
				(.035 - .064)
$\Delta\,{}^4P_S\ \frac{1}{2}^-$	2.020	(1.850 - 2.000)	.040	(.008 - .029)
				(.004 - .022)
$\Delta\,{}^2P'_M\ \frac{1}{2}^-$	2.117	(2.050 - 2.250)	.006	(.006 - .030)*
$\Delta\,{}^2P''_M\ \frac{1}{2}^-$	2.295		.001	

Table 5.17 The masses and widths of the N $\bar{K}$ channel of Λ

The experimental data are listed in the parentheses. The data are taken from the summary table where available. The data of the resonances with the (*) are those with the * or ** status and are omitted from the summary table by the particle data group. All the values are given in Gev.

STATE	MASS		WIDTH	
$\Lambda\ ^4D_{\rho\lambda}\ \frac{7}{2}^+$	2.213	(2.070 - 2.130)	small	(.003 - .011)*
$\Lambda\ ^2D_{\lambda\lambda}\ \frac{5}{2}^+$	1.930	(1.815 - 1.825)	.001	(.039 - .059)
$\Lambda\ ^2D_{\rho\lambda}\ \frac{5}{2}^+$	2.089	(2.090 - 2.140)	.088	(.008 - .063)
$\Lambda\ ^2D_{\rho\rho}\ \frac{5}{2}^+$	2.186		small	
$\Lambda\ ^4D_{\rho\lambda}\ \frac{5}{2}^+$	2.242		small	
$\Lambda\ ^4P_{\rho\lambda}\ \frac{5}{2}^+$	2.278		small	
$\Lambda\ ^2D_{\lambda\lambda}\ \frac{3}{2}^+$	1.929		small	
$\Lambda\ ^2D_{\rho\rho}\ \frac{3}{2}^+$	2.087	(1.850 - 1.910)	.066	(.012 - .070)
$\Lambda\ ^2D_{\rho\lambda}\ \frac{3}{2}^+$	2.145		small	
$\Lambda\ ^4D_{\rho\lambda}\ \frac{3}{2}^+$	2.189		small	
$\Lambda\ ^4S_{\rho\lambda}\ \frac{3}{2}^+$	2.213		small	
$\Lambda\ ^4P_{\rho\lambda}\ \frac{3}{2}^+$	2.266		small	
$\Lambda\ ^2P_{\rho\lambda}\ \frac{3}{2}^+$	2.281		small	
$\Lambda\ ^2S\ \frac{1}{2}^+$	1.134	(1.116)	below threshold	
$\Lambda\ ^2S_{\lambda\lambda}\ \frac{1}{2}^+$	1.622	(1.560 - 1.700)	.104	(.008 - .075)
$\Lambda\ ^2S_{\rho\rho}\ \frac{1}{2}^+$	1.788	(1.750 - 1.850)	.050	(.010 - .125)
$\Lambda\ ^2S_{\rho\lambda}\ \frac{1}{2}^+$	2.076		small	
$\Lambda\ ^4D_{\rho\lambda}\ \frac{1}{2}^+$	2.186		small	
$\Lambda\ ^4P_{\rho\lambda}\ \frac{1}{2}^+$	2.282		small	

$\Lambda\ ^2P_{\rho\lambda}\ \frac{1}{2}^+$	2.303		small	
$\Lambda\ ^4F_{\rho\rho\rho}\ \frac{9}{2}^-$	2.111		small	
$\Lambda\ ^4F_{\rho\lambda\lambda}\ \frac{9}{2}^-$	2.569		small	
$\Lambda\ ^4F_{\rho\rho\rho}\ \frac{7}{2}^-$	2.095		small	
$\Lambda^2F_{\rho\rho\rho}\ \frac{7}{2}^-$	2.193	(2.090 - 2.110)	.079	(.025 - .088)
$\Lambda\ ^2F_{\rho\rho\lambda}\ \frac{7}{2}^-$	2.414		.028	
$\Lambda\ ^2F_{\rho\lambda\lambda}\ \frac{7}{2}^-$	2.594		small	
$\Lambda\ ^2F_{\lambda\lambda\lambda}\ \frac{7}{2}^-$	2.621		small	
$\Lambda\ ^4D_{\rho\lambda\lambda}\ \frac{7}{2}^-$	2.830		.003	
$\Lambda\ ^4P_{\rho}\ \frac{5}{2}^-$	1.654		small	
$\Lambda\ ^4F_{\rho\rho\rho}\ \frac{5}{2}^-$	1.972	(1.810 - 1.830)	small	(.002 - .011)
$\Lambda\ ^4F_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.094		small	
$\Lambda\ ^2F_{\rho\rho\rho}\ \frac{5}{2}^-$	2.119		small	
$\Lambda\ ^2F_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.129		small	
$\Lambda\ ^2F_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.193		.056	
$\Lambda\ ^2F_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	2.413		.023	
$\Lambda\ ^4D_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.521		small	
$\Lambda\ ^2D_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.577		small	
$\Lambda\ ^2D_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.595		small	
$\Lambda\ ^4P_{\rho\rho\rho}\ \frac{5}{2}^-$	2.624		small	
$\Lambda\ ^4P_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.823		.002	
$\Lambda\ ^4P'_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.891		small	
$\Lambda\ ^4P_{\rho}\ \frac{3}{2}^-$	1.547	(1.520)	.030	(.007)
$\Lambda\ ^2P_{\lambda}\ \frac{3}{2}^-$	1.612		small	
$\Lambda\ ^2P_{\rho}\ \frac{3}{2}^-$	1.743		small	
$\Lambda\ ^4F_{\rho\rho\rho}\ \frac{3}{2}^-$	1.865	(1.685 - 1.695)	.002	(.010 - .021)

$\Lambda\ {}^4F_{\rho\lambda\lambda}\ \frac{3}{2}^-$	1.976		small	
$\Lambda\ {}^4D_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.053		.007	
$\Lambda\ {}^2D_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.103		small	
$\Lambda\ {}^2D_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.166		.001	
$\Lambda\ {}^4P_{\rho\rho\rho}\ \frac{3}{2}^-$	2.198		small	
$\Lambda\ {}^4P_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.412	(2.312 - 2.372)	.003	(.018 - .054)*
$\Lambda\ {}^4P'_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.521		small	
$\Lambda\ {}^2P_{\rho\rho\rho}\ \frac{3}{2}^-$	2.552		small	
$\Lambda\ {}^2P_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.599		small	
$\Lambda\ {}^2P'_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.634		small	
$\Lambda\ {}^2P_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.728		small	
$\Lambda\ {}^2P'_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.889		small	
$\Lambda\ {}^2P_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	2.997		.001	
$\Lambda\ {}^4P_{\rho}\ \frac{1}{2}^-$	1.525	(1.405)	below threshold	
$\Lambda\ {}^2P_{\lambda}\ \frac{1}{2}^-$	1.604		.006	
$\Lambda\ {}^2P_{\rho}\ \frac{1}{2}^-$	1.658	(1.660 - 1.680)	.009	(.004 - .013)
$\Lambda\ {}^4D_{\rho\lambda\lambda}\ \frac{1}{2}^-$	1.859	(1.720 - 1.850)	.001	(.050 - .160)
$\Lambda\ {}^4P_{\rho\rho\rho}\ \frac{1}{2}^-$	1.929		.001	
$\Lambda\ {}^4P_{\rho\lambda\lambda}\ \frac{1}{2}^-$	2.038		.003	
$\Lambda\ {}^4P'_{\rho\lambda\lambda}\ \frac{1}{2}^-$	2.087		.006	
$\Lambda\ {}^2P_{\rho\rho\rho}\ \frac{1}{2}^-$	2.209		small	
$\Lambda\ {}^2P_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.413		.003	
$\Lambda\ {}^2P'_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.589		small	
$\Lambda\ {}^2P_{\rho\lambda\lambda}\ \frac{1}{2}^-$	2.723		small	
$\Lambda\ {}^2P'_{\rho\lambda\lambda}\ \frac{1}{2}^-$	2.883		small	
$\Lambda\ {}^2P_{\lambda\lambda\lambda}\ \frac{1}{2}^-$	2.995		.001	

Table 5.18 The masses and widths of the N $\bar{K}$ channel of Σ (see table 5.17)

STATE	MASS		WIDTH	
$\Sigma\ ^4D_{\lambda\lambda}\ \frac{7}{2}^+$	1.939		small	
$\Sigma\ ^4D_{\rho\rho}\ \frac{7}{2}^+$	2.266	(2.025 - 2.040)	.033	(.026 - .046)
$\Sigma\ ^2D_{\lambda\lambda}\ \frac{5}{2}^+$	1.905		small	
$\Sigma\ ^2D_{\rho\rho}\ \frac{5}{2}^+$	1.962	(1.900 - 1.935)	small	(.004 - .024)
$\Sigma\ ^2D_{\rho\lambda}\ \frac{5}{2}^+$	2.211		small	
$\Sigma\ ^4D_{\rho\rho}\ \frac{5}{2}^+$	2.267	(2.060 - 2.080)	.010	(.014 - .036)•
$\Sigma\ ^4D_{\lambda\lambda}\ \frac{5}{2}^+$	2.281		.003	
$\Sigma\ ^4S_{s}\ \frac{3}{2}^+$	1.395	(1.385)	below threshold	
$\Sigma\ ^4S_{\rho\rho}\ \frac{3}{2}^+$	1.887	(1.830 - 1.850)	.007	(.026 - .065)•
$\Sigma\ ^4S_{\lambda\lambda}\ \frac{3}{2}^+$	1.905		small	
$\Sigma\ ^4D_{\rho\rho}\ \frac{3}{2}^+$	1.945		.001	
$\Sigma\ ^4D_{\lambda\lambda}\ \frac{3}{2}^+$	2.013	(1.725 - 2.125)	.003	(<055) •
$\Sigma\ ^2D_{\lambda\lambda}\ \frac{3}{2}^+$	2.211		small	
$\Sigma\ ^2D_{\rho\rho}\ \frac{3}{2}^+$	2.259		.017	
$\Sigma\ ^2D_{\rho\lambda}\ \frac{3}{2}^+$	2.269		.002	
$\Sigma\ ^2P_{\rho\lambda}\ \frac{3}{2}^+$	2.281		.006	
$\Sigma\ ^2S_{s}\ \frac{1}{2}^+$	1.279	(1.192)	below threshold	
$\Sigma\ ^2S_{\lambda\lambda}\ \frac{1}{2}^+$	1.710	(1.630 - 1.690)	.005	(.004 - .060)
$\Sigma\ ^2S_{\rho\rho}\ \frac{1}{2}^+$	1.920	(1.750 - 1.790)	small	(.006 - .015)•
$\Sigma\ ^2S_{\rho\lambda}\ \frac{1}{2}^+$	1.971	(1.930 - 1.990)	.001	(.003 - .008)•
$\Sigma\ ^4D_{\rho\rho}\ \frac{1}{2}^+$	2.140		.001	
$\Sigma\ ^4D_{\lambda\lambda}\ \frac{1}{2}^+$	2.251		.031	
$\Sigma\ ^2P_{\rho\lambda}\ \frac{1}{2}^+$	2.278		.0[illegible]	

$\Sigma\ ^4F_{\lambda\lambda\lambda}\ \frac{9}{2}^-$	2.298		.018	
$\Sigma\ ^4F_{\rho\rho\lambda}\ \frac{9}{2}^-$	2.756		.005	
$\Sigma\ ^4F_{\lambda\lambda\lambda}\ \frac{7}{2}^-$	2.109		small	
$\Sigma\ ^4F_{\rho\rho\lambda}\ \frac{7}{2}^-$	2.249		.002	
$\Sigma\ ^2F_{\rho\rho\rho}\ \frac{7}{2}^-$	2.305		.005	
$\Sigma\ ^2F_{\rho\rho\lambda}\ \frac{7}{2}^-$	2.482		.003	
$\Sigma\ ^2F_{\rho\lambda\lambda}\ \frac{7}{2}^-$	2.528		small	
$\Sigma\ ^2F_{\lambda\lambda\lambda}\ \frac{7}{2}^-$	2.770		.001	
$\Sigma\ ^4D_{\rho\rho\lambda}\ \frac{7}{2}^-$	2.869		small	
$\Sigma\ ^4P_{\lambda}\ \frac{5}{2}^-$	1.880	(1.770 - 1.780)	.069	(.039 - .058)
$\Sigma\ ^4F_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	2.109		small	
$\Sigma\ ^4F_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.235		.008	
$\Sigma\ ^2F_{\rho\rho\rho}\ \frac{5}{2}^-$	2.251		.004	
$\Sigma\ ^2F_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.302		.006	
$\Sigma\ ^2F_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.482		.002	
$\Sigma\ ^2F_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	2.517		small	
$\Sigma\ ^4D_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.527		small	
$\Sigma\ ^2D_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.619		small	
$\Sigma\ ^2D_{\rho\lambda\lambda}\ \frac{5}{2}^-$	2.712		.002	
$\Sigma\ ^4P_{\lambda\lambda\lambda}\ \frac{5}{2}^-$	2.747		.003	
$\Sigma\ ^4P_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.772		small	
$\Sigma\ ^4P'_{\rho\rho\lambda}\ \frac{5}{2}^-$	2.869		small	
$\Sigma\ ^4P_{\lambda}\ \frac{3}{2}^-$	1.631	(1.665 - 1.685)	.001	(.003 - .010)
$\Sigma\ ^2P_{\lambda}\ \frac{3}{2}^-$	1 913	(1.900-1.950)	.014	(<.060)
$\Sigma\ ^2P_{\rho}\ \frac{3}{2}^-$	1.901		.009	
$\Sigma\ ^4F_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	1.926		.002	

$\Sigma\ ^4F_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.095		small	
$\Sigma\ ^4D_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.223		.001	
$\Sigma\ ^2D_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.262		.002	
$\Sigma\ ^2D_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.296		.018	
$\Sigma\ ^4P_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	2.513		small	
$\Sigma\ ^4P_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.534		small	
$\Sigma\ ^4P'_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.618		small	
$\Sigma\ ^2P_{\rho\rho\rho}\ \frac{3}{2}^-$	2.648		.001	
$\Sigma\ ^2P_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.720		.002	
$\Sigma\ ^2P'_{\rho\rho\lambda}\ \frac{3}{2}^-$	2.726		.001	
$\Sigma\ ^2P_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.750		.005	
$\Sigma\ ^2P'_{\rho\lambda\lambda}\ \frac{3}{2}^-$	2.774		small	
$\Sigma\ ^2P_{\lambda\lambda\lambda}\ \frac{3}{2}^-$	3.004		small	
$\Sigma\ ^4P_{\lambda}\ \frac{1}{2}^-$	1.629	(1.603 - 1.613)	.002	(.002)*
$\Sigma\ ^2P_{\lambda}\ \frac{1}{2}^-$	1.804	(1.730 - 1.800)	.040	(.006 - .064)
$\Sigma\ ^2P_{\rho}\ \frac{1}{2}^-$	1.872	(1.755)	.056	(.051 - .103)*
$\Sigma\ ^4D_{\rho\rho\lambda}\ \frac{1}{2}^-$	1.926		.003	
$\Sigma\ ^4P_{\lambda\lambda\lambda}\ \frac{1}{2}^-$	2.093		.001	
$\Sigma\ ^4P_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.216		.009	
$\Sigma\ ^4P'_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.228		.003	
$\Sigma\ ^2P_{\rho\rho\rho}\ \frac{1}{2}^-$	2.520		small	
$\Sigma\ ^2P_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.645		small	
$\Sigma\ ^2P'_{\rho\rho\lambda}\ \frac{1}{2}^-$	2.701		.001	
$\Sigma\ ^2P_{\rho\lambda\lambda}\ \frac{1}{2}^-$	2.718		.003	
$\Sigma\ ^2P'_{\rho\lambda\lambda}\ \frac{1}{2}^-$	2.755		.002	
$\Sigma\ ^2P_{\lambda\lambda\lambda}\ \frac{1}{2}^-$	3.008		small	

REFERENCES

1. M.Gell-Mann, Phys. Lett 8, 214(1964).
2. G.Zweig CERN Reprint TH401, 412(1964).
3. F.Halzen and A.D.Martin, *Quarks and Leptons*, John Wiley & Son N.Y Chichester Brisbane Toronto Singapore (1984).
4. F.E.Close, *An introduction to Quarks and Partons*, Academic Press, London N.Y San-Francisco (1979).
5. D.B.Lichtenberg, *Unitary Symmetry and elementary particles*, Academic Press, N.Y (1978).
6. D.Flamm and F.Schöberl, *Introduction to the quark model of elementary particles*, Vol.1, Gordon and Breach, N.Y London Paris (1982).
7. K.G.Wilson, Phys. Rev. D10, 2445(1974); Phys. Rev. C23, 331(1976). J.Kogut and L.Susskind, Phys. Rev. D11, 395(1975).
8. K.Johnson and C.Thorn, Phys. D13, 1934(1976).
9. A. De Rújula, H.Georgi and S.L.Glashow, Phys. Rev. D12, 147 (1975).
10. E.Eichten, K.Gottfried, T.Kinoshita, K.D. Lane and T.M.Yan, Phys. Rev. D17, 3090(1978).
11. C.S. Kalman, B. Tran and R.L. Hall, Il Nuovo Cimento, 98A, 125(1987).
12. H.D.Dosch and V.F. Muller, Nucl. Phys. B116, 470(1976).
13. A.N.Mitra, Proc. Indian Natl. Sci. Acad., Part A, 47, 167(1981).
14. R.K.Bhaduri, L.E.Cohler and Y.Nogami, Il Nuovo Cimento, 95, 376(1981).
15. S.Ono and F.Schoberl, Phys. Lett. B118, 419(1982).
16. D.Gromes and I.O.Stamatescu, Z. Phys. C3, 43(1979).
17. B.K.Bhaduri and V.Racz, Phys. Rev. D22, 1161(1980).

18. D.Gromes and I.O.Stamatescu, Nucl. Phys. B122 213(1976).

19. R.L.Hall and B.Schwesinger, J. Math. Phys. (N.Y), 20, 2481(1979).

20. J.M.Barbour and D.K.Ponting, Z. Phys. C4, 119(1980).

21. N.Isgur and G.Karl, Phys. Rev. D19, 2653(1979).

22. C.S.Kalman, Il Nuovo Cimento Series 11, 94, 219(1986).

23. N.Isgur and G.Karl, Phys. Rev. D20, 1101(1979).

24. J.Franklin, Phys. Rev. D21, 241(1980); D.B. Lichtenberg: *Quark cluster potential model with relativistic kinematics*, Indiana University publication IUHET 88 (1983). Invited talk presented at the Indiana Unversity workshop on manifestation of hadron structure in Nuclear Physics, McCormick's Creek State Park, Oct. 19-21, 1983

25. S.Capstick and N.Isgur, Phys. Rev. D34, 2809(1986).

26. C.S.Kalman and I.D'Souza, Il Nuovo Cimento Series 11, 96, 286(1986).

27. S.Godfrey and N.Isgur, Phys. Rev. D32, 189(1985).

28. A.Le Yaounanc, L. Oliver, O. Pène and J.C.Raynal, Phys. Rev. D9, 1415(1974), Phys. Rev. D11, 1272(1975), Phys. Rev. D8, 2223(1975), *Hadron Transitions in the Quark Model*, Gordon and Breach Science, N.Y London Paris Montreux Tokyo Melbourne (1988).

29. Particle Data Group, Phys. Lett. B204(1988).

30. R.Koniuk and N.Isgur, Phys. Rev. D21, 1868(1980).

31. C.P. Forsyth and R.E. Cutkosky, Z. Phys. C18, 219(1983).

32. N.Isgur and G.Karl, Phys. Rev. D18,4187(1978).

33. C.S. Kalman and B. Tran, *Baryon Spectrum in a Potential Quark Model*, Concordia University publication CUQ/EPP 56, accepted for publication, Il Nuovo Cimento; *Strong Decays of Baryons*, Concordia University publication CUQ/EPP 60.

34. M.Weissbluth, *Atoms and Molecules*, Academic Press N.Y. (1978).

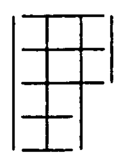
Appendix A

THE YOUNG TABLEAU TECHNIQUE

In this appendix, the details of the Young Tableaux technique for the SU(n) group[4,5] are studied. This is an elegant technique used to deduce the dimensions of the representations arising from the products of other representations of the group.

A.1 The Young Tableau

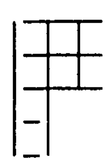
A Young tableau is a number of boxes arranged in rows and columns. For example



(A.1)

is a Young Tableau of four rows and three columns. In a tableau it is symmetric and antisymmetric with respect to permutations within each row and column respectively. Each tableau should be a proper one; that is no row is longer than any row above it and no column is longer than any on its left. A tableau is identified by n - 1 numbers $(p_1, p_2, \ldots, p_{n-1})$. Where p_i is the number of columns with i boxes. For example the tableau (A.1) is denoted by (0, 1, 0, 2, 0) in SU(6). The conjugate tableau of $(p_1, p_2, \ldots, p_{n-1})$ is $(p_{n-1}, \ldots, p_2, p_1)$. The conjugate tableau of (A.1) is

(0, 2, 0, 1, 0):



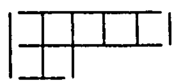
(A.2)

A.2 The dimensionality of a Young tableau

The dimensionality of a tableau has the form

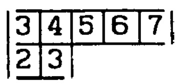
$$D = \frac{A}{B} \tag{A.3}$$

To calculate A, first put the number n in the box at the upper left corner of the tableau. Increasing the number by one from left to right in each row and decreasing by one from top to bottom in each column. A is the product of all these numbers. As an example, consider the tableau



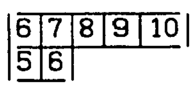
(A.4)

SU(3):



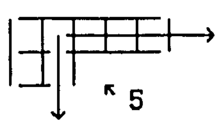
$$A = 3 \times 4 \times 5 \times 6 \times 7 \times 2 \times 3 \tag{A.5}$$

SU(6):



$$A = 6 \times 7 \times 8 \times 9 \times 10 \times 5 \times 6 \tag{A.6}$$

B depends only on the structure of the tableau and not on n of the SU(n). From a point in a box, draw two lines one to the right and one down. The number of the boxes cut by the lines is attached to that box. B is the product of all these numbers. For tableau (A.4)



$$B = 6 \times 5 \times 3 \times 2 \times 1 \times 2 \times 1 \tag{A.7}$$

So the dimensionality of (A.4) is

$$\text{SU(3)}: \quad D = \frac{A}{B} = \frac{3 \times 4 \times 5 \times 6 \times 7 \times 2 \times 3}{6 \times 5 \times 3 \times 2 \times 1 \times 2 \times 1} = 42 \tag{A.8}$$

$$\text{SU(6)}: \quad D = \frac{A}{B} = \frac{6 \times 7 \times 8 \times 9 \times 10 \times 5 \times 6}{6 \times 5 \times 3 \times 2 \times 1 \times 2 \times 1} = 2520 \tag{A.9}$$

A tableau has the same dimensionality as its conjugate.

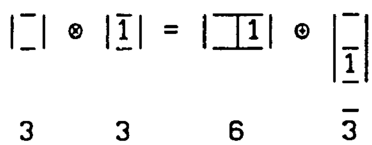
A.3 Product of the Young Tableaux

We wish now to obtain the product of two Young tableaux. To do this, first mark each box of the second tableau with the number of the row to which it belongs, then attach the boxes of the second tableau to the first in all possible ways subject to the following rules:

1. No tableau has a column with more than n boxes.

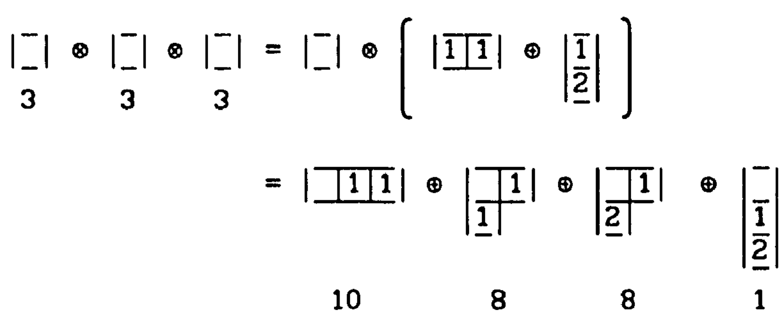
2. The numbers must not decrease going from left to right across a row and must increase from top to bottom in a column.

As examples, consider the combination of two quarks in SU(3):



(A.10)

The bar indicates the conjugate tableau. The last tableau in (A.10) identified by (0,1) is the conjugate of (1,0) which identifies the boxes on the left hand side. A quark is represented by a box and an antiquark by its conjugate. Combinations of three quarks and a quark and an antiquark give



(A.11)

and

$$\begin{array}{|c|}\hline \ \\ \hline\end{array} \otimes \begin{array}{|c|}\hline 1 \\ \hline 2 \\ \hline\end{array} = \begin{array}{|c|c|}\hline \ & 1 \\ \hline 2 & \multicolumn{1}{c}{} \\ \cline{1-1}\end{array} \oplus \begin{array}{|c|}\hline \ \\ \hline 1 \\ \hline 2 \\ \hline\end{array} \qquad \text{(A.12)}$$

$$3 \qquad \bar{3} \qquad 8 \qquad 1$$

APPENDIX B

THE COMPLETE BARYON WAVEFUNCTIONS

This appendix is devoted to the construction of the complete baryon wavefunctions. Only the highest states of total angular momentum and the highest m-states in each J-state are given. The lower states can be obtained, by the usual combination of orbital angular momentum and spin. Following Isgur and Karl[21], the construction of baryons containing quarks with equal masses, follow the SU(6) type and the ones with two distinct quark masses follows the uds type.

The spin wavefunctions used have the form

$$\chi_+^\rho = \frac{1}{\sqrt{2}}(\uparrow\downarrow\uparrow - \downarrow\uparrow\uparrow) \tag{B.1}$$

$$\chi_-^\rho = \frac{1}{\sqrt{2}}(\uparrow\downarrow\downarrow - \downarrow\uparrow\downarrow) \tag{B.2}$$

$$\chi_+^\lambda = \frac{1}{\sqrt{6}}(2\uparrow\uparrow\downarrow - \uparrow\downarrow\uparrow - \downarrow\uparrow\uparrow) \tag{B.3}$$

$$\chi_-^\lambda = \frac{1}{\sqrt{6}}(\uparrow\downarrow\downarrow + \downarrow\uparrow\downarrow - 2\downarrow\downarrow\uparrow) \tag{B.4}$$

$$\chi_{3/2}^S = \uparrow\uparrow\uparrow, \text{ etc.} \tag{B.5}$$

and the flavor wavefunctions

$$\phi_p^\rho = \frac{1}{\sqrt{2}} (udu - duu) \tag{B.6}$$

$$\phi_n^\rho = \frac{1}{\sqrt{2}} (udd - dud) \tag{B.7}$$

$$\phi_p^\lambda = \frac{1}{\sqrt{6}} (2uud - udu - duu) \tag{B.8}$$

$$\phi_n^\lambda = \frac{1}{\sqrt{6}} (udd + dud - 2ddu) \tag{B.9}$$

$$\phi_{\Delta}^{S} = uuu, \text{ etc.} \tag{B.10}$$

$$\phi_{\Lambda} = \frac{1}{\sqrt{2}} (ud - du)s \tag{B.11}$$

$$\phi_{\Sigma} = \frac{1}{\sqrt{2}} (ud + du)s \tag{B.12}$$

The flavor wavefunctions of the other particles are similar.

Each state in SU(6) type is presented in the form $A^{S}\ell_{s'} J^{P}$ in which A is the name of the particle and s, ℓ, s', J, P represent spin, orbital angular momentum, spatial symmetry, total angular momentum and parity respectively. In the uds type, the spatial symmetry is replaced by the excitation mode. The wavefunctions of the nucleons are given by

N = 0:

$$N^{2}S_{S}\,\frac{1}{2}^{+} = \frac{1}{\sqrt{2}} (\chi_{+}^{\rho}\phi^{\rho} + \chi_{+}^{\lambda}\phi^{\lambda})\Psi_{00}^{S} \tag{B.13}$$

N = 1:

$$N^{2}P_{M}\,\frac{3}{2}^{-} = \frac{1}{2}\left[(\chi_{+}^{\rho}\phi^{\rho} - \chi_{+}^{\lambda}\phi^{\lambda})\Psi_{11}^{\lambda} + (\chi_{+}^{\rho}\phi^{\lambda} + \chi_{+}^{\lambda}\phi^{\rho})\Psi_{11}^{\rho}\right], \tag{B.14}$$

$$N^{4}P_{M}\,\frac{5}{2}^{-} = \frac{1}{\sqrt{2}} (\phi^{\rho}\Psi_{11}^{\rho} + \phi^{\lambda}\Psi_{11}^{\lambda})\,\chi_{3/2}^{S}, \tag{B.15}$$

N = 2:

$$N^{4}D_{M}\,\frac{7}{2}^{+} = \frac{1}{\sqrt{2}} (\phi^{\rho}\Psi_{22}^{\rho} + \phi^{\lambda}\Psi_{22}^{\lambda})\,\chi_{3/2}^{S}, \tag{B.16}$$

$$N^{2}D_{S}\,\frac{5}{2}^{+} = \frac{1}{\sqrt{2}} (\chi_{+}^{\rho}\phi^{\rho} + \chi_{+}^{\lambda}\phi^{\lambda})\Psi_{22}^{S}, \tag{B.17}$$

$$N^{2}D_{M}\,\frac{5}{2}^{+} = \frac{1}{2}\left[(\chi_{+}^{\rho}\phi^{\rho} - \chi_{+}^{\lambda}\phi^{\lambda})\Psi_{22}^{\lambda} + (\chi_{+}^{\rho}\phi^{\lambda} + \chi_{+}^{\lambda}\phi^{\rho})\Psi_{22}^{\rho}\right], \tag{B.18}$$

$$N^{4}S_{M}\,\frac{3}{2}^{+} = \frac{1}{\sqrt{2}} (\phi^{\rho}\Psi_{00}^{\rho} + \phi^{\lambda}\Psi_{00}^{\lambda})\,\chi_{3/2}^{S}, \tag{B.19}$$

$$N^{2}P_{A}\,\frac{3}{2}^{+} = \frac{1}{\sqrt{2}} (\chi_{+}^{\rho}\phi^{\lambda} - \chi_{+}^{\lambda}\phi^{\rho})\Psi_{11}^{A}, \tag{B.20}$$

$$N^2S'_S\ \tfrac{1}{2}^+ = \frac{1}{\sqrt{2}}\,(\chi_+^\rho\phi^\rho + \chi_+^\lambda\phi^\lambda)\Psi_{00}^{S'}\,, \tag{B.21}$$

$$N^2S_M\ \tfrac{1}{2}^+ = \frac{1}{2}\left[\,(\chi_+^\rho\phi^\rho - \chi_+^\lambda\phi^\lambda)\Psi_{00}^\lambda + (\chi_+^\rho\phi^\lambda + \chi_+^\lambda\phi^\rho)\Psi_{00}^\rho\right], \tag{B.22}$$

N = 3:

$$N^2P_S\ \tfrac{3}{2}^- = \frac{1}{\sqrt{2}}\,(\chi_+^\rho\phi^\rho + \chi_+^\lambda\phi^\lambda)\Psi_{11}^S\,, \tag{B.23}$$

$$N^2P'_M\ \tfrac{3}{2}^- = \frac{1}{2}\left[\,(\chi_+^\rho\phi^\rho - \chi_+^\lambda\phi^\lambda)\Psi_{11}^\lambda + (\chi_+^\rho\phi^\lambda + \chi_+^\lambda\phi^\rho)\Psi_{11}^\rho\right], \tag{B.24}$$

$$N^2P''_M\ \tfrac{3}{2}^- = \frac{1}{2}\left[\,(\chi_+^\rho\phi^\rho - \chi_+^\lambda\phi^\lambda)\Psi_{11}^{\lambda'} + (\chi_+^\rho\phi^\lambda + \chi_+^\lambda\phi^\rho)\Psi_{11}^{\rho'}\right], \tag{B.25}$$

$$N^2P_A\ \tfrac{3}{2}^- = \frac{1}{\sqrt{2}}\,(\chi_+^\rho\phi^\lambda - \chi_+^\lambda\phi^\rho)\Psi_{11}^A\,, \tag{B.26}$$

$$N^4P_M\ \tfrac{5}{2}^- = \frac{1}{\sqrt{2}}\,(\phi^\rho\Psi_{11}^\rho + \phi^\lambda\Psi_{11}^\lambda)\,\chi_{3/2}^S\,, \tag{B.27}$$

$$N^4P'_M\ \tfrac{5}{2}^- = \frac{1}{\sqrt{2}}\,(\phi^\rho\Psi_{11}^{\rho'} + \phi^\lambda\Psi_{11}^{\lambda'})\,\chi_{3/2}^S\,, \tag{B.28}$$

$$N^2D_M\ \tfrac{5}{2}^- = \frac{1}{2}\left[\,(\chi_+^\rho\phi^\rho - \chi_+^\lambda\phi^\lambda)\Psi_{22}^\lambda + (\chi_+^\rho\phi^\lambda + \chi_+^\lambda\phi^\rho)\Psi_{22}^\rho\right], \tag{B.29}$$

$$N^4D_M\ \tfrac{7}{2}^- = \frac{1}{\sqrt{2}}\,(\phi^\rho\Psi_{22}^\rho + \phi^\lambda\Psi_{22}^\lambda)\,\chi_{3/2}^S\,, \tag{B.30}$$

$$N^2F_S\ \tfrac{7}{2}^- = \frac{1}{\sqrt{2}}\,(\chi_+^\rho\phi^\rho + \chi_+^\lambda\phi^\lambda)\Psi_{33}^S\,, \tag{B.31}$$

$$N^2F_M\ \tfrac{7}{2}^- = \frac{1}{2}\left[\,(\chi_+^\rho\phi^\rho - \chi_+^\lambda\phi^\lambda)\Psi_{33}^\lambda + (\chi_+^\rho\phi^\lambda + \chi_+^\lambda\phi^\rho)\Psi_{33}^\rho\right], \tag{B.32}$$

$$N^4F_M\ \tfrac{9}{2}^- = \frac{1}{\sqrt{2}}\,(\phi^\rho\Psi_{33}^\rho + \phi^\lambda\Psi_{33}^\lambda)\,\chi_{3/2}^S\,, \tag{B.33}$$

$$N^2F_A\ \tfrac{7}{2}^- = \frac{1}{\sqrt{2}}\,(\chi_+^\rho\phi^\lambda - \chi_+^\lambda\phi^\rho)\Psi_{33}^A\,. \tag{B.34}$$

For the Δ we have;

N = 0:

$$\Delta^4S_S\ \tfrac{3}{2}^+ = \chi_{3/2}^S\phi^S\Psi_{00}^S \tag{B.35}$$

N = 1:

$$\Delta^2P_M\ \tfrac{3}{2}^- = \frac{1}{\sqrt{2}}\ (\chi_+^\rho\Psi_{11}^\rho + \chi_+^\lambda\Psi_{11}^\lambda)\ \phi^S\ , \tag{B.36}$$

N = 2:

$$\Delta^4D_S\ \tfrac{7}{2}^+ = \chi_{3/2}^S\phi^S\Psi_{22}^S\ , \tag{B.37}$$

$$\Delta^2D_M\ \tfrac{5}{2}^+ = \frac{1}{\sqrt{2}}\ (\chi_+^\rho\Psi_{22}^\rho + \chi_+^\lambda\Psi_{22}^\lambda)\ \phi^S\ , \tag{B.38}$$

$$\Delta^4S_S'\ \tfrac{3}{2}^+ = \chi_{3/2}^S\phi^S\Psi_{00}^{S'}\ , \tag{B.39}$$

$$\Delta^2S_M\ \tfrac{1}{2}^+ = \frac{1}{\sqrt{2}}\ (\chi_+^\rho\Psi_{00}^\rho + \chi_+^\lambda\Psi_{00}^\lambda)\ \phi^S\ , \tag{B.40}$$

N = 3:

$$\Delta^2P_M'\ \tfrac{3}{2}^- = \frac{1}{\sqrt{2}}\ (\chi_+^\rho\Psi_{11}^\rho + \chi_+^\lambda\Psi_{11}^\lambda)\ \phi^S\ , \tag{B.41}$$

$$\Delta^2P_M''\ \tfrac{3}{2}^- = \frac{1}{\sqrt{2}}\ (\chi_+^\rho\Psi_{11}^{\rho'} + \chi_+^\lambda\Psi_{11}^{\lambda'})\ \phi^S\ , \tag{B.42}$$

$$\Delta^4P_S\ \tfrac{5}{2}^- = \chi_{3/2}^S\phi^S\Psi_{11}^S\ , \tag{B.43}$$

$$\Delta^4D_M\ \tfrac{5}{2}^- = \frac{1}{\sqrt{2}}\ (\chi_+^\rho\Psi_{22}^\rho + \chi_+^\lambda\Psi_{22}^\lambda)\ \phi^S\ , \tag{B.44}$$

$$\Delta^2F_M\ \tfrac{7}{2}^- = \frac{1}{\sqrt{2}}\ (\chi_+^\rho\Psi_{33}^\rho + \chi_+^\lambda\Psi_{33}^\lambda)\ \phi^S\ , \tag{B.45}$$

$$\Delta^4F_S\ \tfrac{9}{2}^- = \chi_{3/2}^S\phi^S\Psi_{33}^S\ . \tag{B.46}$$

For the Λ we have;

N = 0:

$$\Lambda^2S\ \tfrac{1}{2}^+ = \phi_\lambda\ \chi_+^\rho\ \Psi_{00} \tag{B.47}$$

N = 1:

$$\Lambda^4P_\rho\ \tfrac{5}{2}^- = \phi\ \ \chi^S\ \ \Psi^\rho\ , \tag{B.48}$$

$$\Lambda^4P_\lambda\ \tfrac{3}{2}^- = \phi_\lambda\ \chi_+^\rho\ \Psi_{11}^\lambda\ , \tag{B.49}$$

$$\Lambda^4 P_\rho \, \tfrac{3}{2}^- = \phi_\lambda \, \chi_+^\lambda \, \Psi_{11}^\rho \,, \tag{B.50}$$

N = 2:

$$\Lambda^4 D_{\rho\lambda} \, \tfrac{7}{2}^+ = \phi_\lambda \, \chi_{3/2}^S \Psi_{22}^{\rho\lambda} \,, \tag{B.51}$$

$$\Lambda^4 P_{\rho\lambda} \, \tfrac{5}{2}^+ = \phi_\lambda \, \chi_{3/2}^S \Psi_{11}^{\rho\lambda} \,, \tag{B.52}$$

$$\Lambda^2 D_{\rho\rho} \, \tfrac{5}{2}^+ = \phi_\lambda \, \chi_+^\rho \, \Psi_{22}^{\rho\rho} \,, \tag{B.53}$$

$$\Lambda^2 D_{\lambda\lambda} \, \tfrac{5}{2}^+ = \phi_\lambda \, \chi_+^\rho \, \Psi_{22}^{\lambda\lambda} \,, \tag{B.54}$$

$$\Lambda^2 D_{\rho\lambda} \, \tfrac{5}{2}^+ = \phi_\lambda \, \chi_+^\lambda \, \Psi_{22}^{\rho\lambda} \,, \tag{B.55}$$

$$\Lambda^4 S_{\rho\lambda} \, \tfrac{3}{2}^+ = \phi_\lambda \, \chi_{3/2}^S \Psi_{00}^{\rho\lambda} \,, \tag{B.56}$$

$$\Lambda^2 P_{\rho\lambda} \, \tfrac{3}{2}^+ = \phi_\lambda \, \chi_+^\lambda \, \Psi_{11}^{\rho\lambda} \,, \tag{B.57}$$

$$\Lambda^2 S_{\rho\lambda} \, \tfrac{3}{2}^+ = \phi_\lambda \, \chi_+^\lambda \, \Psi_{00}^{\rho\lambda} \,, \tag{B.58}$$

$$\Lambda^2 S_{\lambda\lambda} \, \tfrac{1}{2}^+ = \phi_\lambda \, \chi_+^\rho \, \Psi_{00}^{\lambda\lambda} \,, \tag{B.59}$$

$$\Lambda^2 S_{\rho\rho} \, \tfrac{1}{2}^+ = \phi_\lambda \, \chi_+^\rho \, \Psi_{00}^{\rho\rho} \,, \tag{B.60}$$

N = 3:

$$\Lambda^2 P_{\lambda\lambda\lambda} \, \tfrac{3}{2}^- = \phi_\lambda \, \chi_+^\rho \, \Psi_{11}^{\lambda\lambda\lambda} \,, \tag{B.61}$$

$$\Lambda^2 P_{\rho\lambda\lambda} \, \tfrac{3}{2}^- = \phi_\lambda \, \chi_+^\lambda \, \Psi_{11}^{\rho\lambda\lambda} \,, \tag{B.62}$$

$$\Lambda^2 P'_{\rho\lambda\lambda} \, \tfrac{3}{2}^- = \phi_\lambda \, \chi_+^\lambda \, \Psi_{11}^{\rho\lambda\lambda'} \,, \tag{B.63}$$

$$\Lambda^2 P_{\rho\rho\lambda} \, \tfrac{3}{2}^- = \phi_\lambda \, \chi_+^\lambda \, \Psi_{11}^{\rho\rho\lambda} \,, \tag{B.64}$$

$$\Lambda^2 P'_{\rho\rho\lambda} \, \tfrac{3}{2}^- = \phi_\lambda \, \chi_+^\rho \, \Psi_{11}^{\rho\rho\lambda'} \,, \tag{B.65}$$

$$\Lambda^2 P_{\rho\rho\rho} \, \tfrac{3}{2}^- = \phi_\lambda \, \chi_+^\lambda \, \Psi_{11}^{\rho\rho\rho} \,, \tag{B.66}$$

$$\Lambda^4P_{\rho\lambda\lambda}\ \frac{5}{2}^- = \phi_\lambda\ \chi^S_{3/2}\Psi^{\rho\lambda\lambda}_{11}\ , \qquad (B.67)$$

$$\Lambda^4P'_{\rho\lambda\lambda}\ \frac{5}{2}^- = \phi_\lambda\ \chi^S_{3/2}\Psi^{\rho\lambda\lambda'}_{11}\ , \qquad (B.68)$$

$$\Lambda^4P_{\rho\rho\rho}\ \frac{5}{2}^- = \phi_\lambda\ \chi^S_{3/2}\Psi^{\rho\rho\rho}_{11}\ , \qquad (B.69)$$

$$\Lambda^2D_{\rho\lambda\lambda}\ \frac{5}{2}^- = \phi_\lambda\ \chi^\lambda_+\ \Psi^{\rho\lambda\lambda}_{22}\ , \qquad (B.70)$$

$$\Lambda^2D_{\rho\rho\lambda}\ \frac{5}{2}^- = \phi_\lambda\ \chi^\rho_+\ \Psi^{\rho\rho\lambda}_{22}\ , \qquad (B.71)$$

$$\Lambda^4D_{\rho\lambda\lambda}\ \frac{5}{2}^- = \phi_\lambda\ \chi^S_{3/2}\Psi^{\rho\lambda\lambda}_{22}\ , \qquad (B.72)$$

$$\Lambda^2F_{\lambda\lambda\lambda}\ \frac{7}{2}^- = \phi_\lambda\ \chi^\rho_+\ \Psi^{\lambda\lambda\lambda}_{33}\ , \qquad (B.73)$$

$$\Lambda^2F_{\rho\lambda\lambda}\ \frac{7}{2}^- = \phi_\lambda\ \chi^\lambda_+\ \Psi^{\rho\lambda\lambda}_{33}\ , \qquad (B.74)$$

$$\Lambda^2F_{\rho\rho\lambda}\ \frac{7}{2}^- = \phi_\lambda\ \chi^\rho_+\ \Psi^{\rho\rho\lambda}_{33}\ , \qquad (B.75)$$

$$\Lambda^2F_{\rho\rho\rho}\ \frac{7}{2}^- = \phi_\lambda\ \chi^\lambda_+\ \Psi^{\rho\rho\rho}_{33}\ , \qquad (B.76)$$

$$\Lambda^4F_{\rho\lambda\lambda}\ \frac{9}{2}^- = \phi_\lambda\ \chi^S_{3/2}\Psi^{\rho\lambda\lambda}_{33}\ , \qquad (B.77)$$

$$\Lambda^4F_{\rho\rho\rho}\ \frac{9}{2}^- = \phi_\lambda\ \chi^S_{3/2}\Psi^{\rho\rho\rho}_{33} \qquad (B.78)$$

and for Σ

N = 0:

$$\Sigma^2S\ \frac{1}{2}^+ = \phi_\Sigma\ \chi^\lambda_+\ \Psi_{00} \qquad (B.79)$$

N = 1:

$$\Sigma^4P_\lambda\ \frac{5}{2}^- = \phi_\Sigma\ \chi^S_{3/2}\Psi^\lambda_{11}\ , \qquad (B.80)$$

$$\Sigma^4P_\lambda\ \frac{3}{2}^- = \phi_\Sigma\ \chi^\lambda_+\ \Psi^\lambda_{11}\ , \qquad (B.81)$$

$$\Sigma^4P_\rho\ \frac{3}{2}^- = \phi_\Sigma\ \chi^\rho_+\ \Psi^\rho_{11}\ , \qquad (B.82)$$

N = 2:

$$\Sigma^4D_{\rho\rho}\ \tfrac{7}{2}^+ = \phi_\Sigma\ \chi^S_{3/2}\Psi^{\rho\rho}_{22}\ , \tag{B.83}$$

$$\Sigma^4D_{\lambda\lambda}\ \tfrac{7}{2}^+ = \phi_\Sigma\ \chi^S_{3/2}\Psi^{\lambda\lambda}_{22}\ , \tag{B.84}$$

$$\Sigma^2D_{\rho\rho}\ \tfrac{5}{2}^+ = \phi_\Sigma\ \chi^\lambda_+\ \Psi^{\rho\rho}_{22}\ , \tag{B.85}$$

$$\Sigma^2D_{\lambda\lambda}\ \tfrac{5}{2}^+ = \phi_\Sigma\ \chi^\lambda_+\ \Psi^{\lambda\lambda}_{22}\ , \tag{B.86}$$

$$\Sigma^2D_{\rho\lambda}\ \tfrac{5}{2}^+ = \phi_\Sigma\ \chi^\rho_+\ \Psi^{\rho\lambda}_{22}\ , \tag{B.87}$$

$$\Sigma^4S_{\rho\rho}\ \tfrac{3}{2}^+ = \phi_\Sigma\ \chi^S_{3/2}\Psi^{\rho\rho}_{00}\ , \tag{B.88}$$

$$\Sigma^4S_{\lambda\lambda}\ \tfrac{3}{2}^+ = \phi_\Sigma\ \chi^S_{3/2}\Psi^{\lambda\lambda}_{00}\ , \tag{B.89}$$

$$\Sigma^2P_{\rho\lambda}\ \tfrac{3}{2}^+ = \phi_\Sigma\ \chi^\rho_+\ \Psi^{\rho\lambda}_{11}\ , \tag{B.90}$$

$$\Sigma^2S_{\rho\rho}\ \tfrac{3}{2}^+ = \phi_\Sigma\ \chi^\lambda_+\ \Psi^{\rho\rho}_{00}\ , \tag{B.91}$$

$$\Sigma^2S_{\lambda\lambda}\ \tfrac{1}{2}^+ = \phi_\Sigma\ \chi^\lambda_+\ \Psi^{\lambda\lambda}_{00}\ , \tag{B.92}$$

$$\Sigma^2S_{\rho\lambda}\ \tfrac{1}{2}^+ = \phi_\Sigma\ \chi^\rho_+\ \Psi^{\rho\lambda}_{00}\ . \tag{B.93}$$

N = 3:

$$\Sigma^2P_{\lambda\lambda\lambda}\ \tfrac{3}{2}^- = \phi_\Sigma\ \chi^\lambda_+\ \Psi^{\lambda\lambda\lambda}_{11}\ , \tag{B.94}$$

$$\Sigma^2P_{\rho\lambda\lambda}\ \tfrac{3}{2}^- = \phi_\Sigma\ \chi^\rho_+\ \Psi^{\rho\lambda\lambda}_{11}\ , \tag{B.95}$$

$$\Sigma^2P'_{\rho\lambda\lambda}\ \tfrac{3}{2}^- = \phi_\Sigma\ \chi^\rho_+\ \Psi^{\rho\lambda\lambda'}_{11}\ , \tag{B.96}$$

$$\Sigma^2P_{\rho\rho\lambda}\ \tfrac{3}{2}^- = \phi_\Sigma\ \chi^\lambda_+\ \Psi^{\rho\rho\lambda}_{11}\ , \tag{B.97}$$

$$\Sigma^2P'_{\rho\rho\lambda}\ \tfrac{3}{2}^- = \phi_\Sigma\ \chi^\lambda_+\ \Psi^{\rho\rho\lambda'}_{11}\ , \tag{B.98}$$

$$\Sigma^2P_{\rho\rho\rho}\ \tfrac{3}{2}^- = \phi_\Sigma\ \chi^\rho_+\ \Psi^{\rho\rho\rho}_{11}\ , \tag{B.99}$$

$$\Sigma^4P_{\rho\rho\lambda}\ \tfrac{5}{2}^- = \phi_\Sigma\, \chi^S_{3/2} \Psi^{\rho\rho\lambda}_{11} \ , \tag{B.100}$$

$$\Sigma^4P'_{\rho\rho\lambda}\ \tfrac{5}{2}^- = \phi_\Sigma\, \chi^S_{3/2} \Psi^{\rho\rho\lambda'}_{11} \ , \tag{B.101}$$

$$\Sigma^4P_{\lambda\lambda\lambda}\ \tfrac{5}{2}^- = \phi_\Sigma\, \chi^S_{3/2} \Psi^{\lambda\lambda\lambda}_{11} \ , \tag{B.102}$$

$$\Sigma^2D_{\rho\lambda\lambda}\ \tfrac{5}{2}^- = \phi_\Sigma\, \chi^\rho_+\, \Psi^{\rho\lambda\lambda}_{22} \ , \tag{B.103}$$

$$\Sigma^2D_{\rho\rho\lambda}\ \tfrac{5}{2}^- = \phi_\Sigma\, \chi^\lambda_+\, \Psi^{\rho\rho\lambda}_{22} \ , \tag{B.104}$$

$$\Sigma^4D_{\rho\rho\lambda}\ \tfrac{5}{2}^- = \phi_\Sigma\, \chi^S_{3/2} \Psi^{\rho\rho\lambda}_{22} \ , \tag{B.105}$$

$$\Sigma^2F_{\lambda\lambda\lambda}\ \tfrac{7}{2}^- = \phi_\Sigma\, \chi^\lambda_+\, \Psi^{\lambda\lambda\lambda}_{33} \ , \tag{B.106}$$

$$\Sigma^2F_{\rho\lambda\lambda}\ \tfrac{7}{2}^- = \phi_\Sigma\, \chi^\rho_+\, \Psi^{\rho\lambda\lambda}_{33} \ , \tag{B.107}$$

$$\Sigma^2F_{\rho\rho\lambda}\ \tfrac{7}{2}^- = \phi_\Sigma\, \chi^\lambda_+\, \Psi^{\rho\rho\lambda}_{33} \ , \tag{B.108}$$

$$\Sigma^2F_{\rho\rho\rho}\ \tfrac{7}{2}^- = \phi_\Sigma\, \chi^\rho_+\, \Psi^{\rho\rho\rho}_{33} \ , \tag{B.109}$$

$$\Sigma^4F_{\rho\rho\lambda}\ \tfrac{9}{2}^- = \phi_\Sigma\, \chi^S_{3/2} \Psi^{\rho\rho\lambda}_{33} \ , \tag{B.110}$$

$$\Sigma^4F_{\lambda\lambda\lambda}\ \tfrac{9}{2}^- = \phi_\Sigma\, \chi^S_{3/2} \Psi^{\lambda\lambda\lambda}_{33} \ . \tag{B.111}$$

The wavefunctions of the other particles are constructed similarly.

APPENDIX C

HYPERFINE INTERACTION

In this appendix, the hyperfine interaction is considered in detail. This interaction has the form

$$H_{hyp.} = \sum_{i<j} H^{ij}_{hyp.} , \tag{C.1a}$$

where

$$H^{ij}_{hyp.} = \frac{2\alpha_s}{3m_i m_j} \left\{ \frac{8\pi}{3} \vec{S}_i.\vec{S}_j \, \delta^3(\vec{r}_{ij}) + \frac{1}{r^3_{ij}} \left[\frac{3(\vec{S}_i.\vec{r}_{ij})(\vec{S}_j.\vec{r}_{ij})}{r^2_{ij}} - \vec{S}_i.\vec{S}_j \right] \right\} . \tag{C.1b}$$

The first term is called the contact term and the second is the tensor term. It is clear from eq. (C.1b), that the contact term is independent of the total angular momentum. Moreover, it vanishes for any element involving states with $\ell \neq 0$. The hyperfine interaction is treated as a perturbation. As already mentioned for the baryons containing quarks with equal masses we have

$$H_{hyp.} = \sum_{i<j} H^{ij}_{hyp.} = 3H^{12}_{hyp.} \tag{C.2}$$

and for the baryons containing two distinct masses

$$H_{hyp} = \sum_{i<j} H^{ij}_{hyp.}$$

$$= H^{12}_{hyp.} + 2H^{23}_{hyp.} \tag{C.3}$$

The calculation of the 12-component of the contact term is straight forward. The 23-component is also easily calculated by replacing

$$\delta^3(\overrightarrow{r_{23}}) = \left[\frac{2}{3} \right]^{3/2} \delta^3(\overrightarrow{\lambda} - \frac{1}{\sqrt{3}} \overrightarrow{\rho}) \quad . \tag{C.4}$$

The tensor term is calculated by using[34]

$$< j_1 j_2 j_m \mid \frac{1}{r_{ij}^3} \left[\frac{3(\vec{S}_i . \overrightarrow{r_{ij}})(\vec{S}_j . \overrightarrow{r_{ij}})}{r_{ij}^2} - \vec{S}_i . \vec{S}_j \right] \mid j'_1 j'_2 j'_m > =$$

$$(-1)^{j+j_2+j'_1} \delta_{jj'} \delta_{mm'} \begin{Bmatrix} j'_1 & j'_2 & j \\ j_2 & j_1 & k \end{Bmatrix}$$

$$\times < j_1 \| \sqrt{\frac{3}{2}} \frac{1}{r_{ij}^3} (3\cos^2\theta - 1) \| j'_1 >$$

$$\times < j_2 \| \frac{1}{\sqrt{6}} (3S_{i0}S_{j0} - \vec{S}_i . \vec{S}_j) \| j'_2 > , \tag{C.5}$$

where $\{ \quad \}$ is the 6j symbol and $< \| \quad \| >$ is the reduced matrix defined by

$$<jm \mid T_0^k \mid j'm'> = (-1)^{j-m} \begin{pmatrix} j & k & j' \\ -m & 0 & m' \end{pmatrix} < j \| T^k \| j' > , \tag{C.6}$$

where $(..)$ is the 3j symbol. The tensor operator has rank k = 2. Therefore it cannot connect either two $S = \frac{1}{2}$ states or 0 and 0 or 0 and 1 of orbital angular momentum states.

In the following, we calculate the spin part of the hyperfine interaction. From

$$\vec{S}_1 . \vec{S}_2 = \frac{1}{2} \left[\left(\vec{S}_1 + \vec{S}_2 \right)^2 - \vec{S}_1^2 - \vec{S}_2^2 \right] , \tag{C.7}$$

we have

$$< \chi_m^S \mid \vec{S}_1 . \vec{S}_2 \mid \chi_m^S > = \frac{1}{2} \left(1 \times 2 - \frac{1}{2} \times \frac{3}{2} - \frac{1}{2} \times \frac{3}{2} \right) = \frac{1}{4} . \tag{C.8a}$$

Similarly

$$< \chi_{\pm}^{\rho} | \vec{S}_1 . \vec{S}_2 | \chi_{\pm}^{\rho} > = - \frac{3}{4} , \tag{C.8b}$$

$$< \chi_{\pm}^{\rho} | \vec{S}_1 . \vec{S}_3 | \chi_{\pm}^{\rho} > = 0 , \tag{C.8c}$$

$$< \chi_{\pm}^{\lambda} | \vec{S}_1 . \vec{S}_2 | \chi_{\pm}^{\lambda} > = \frac{1}{4} , \tag{C.8d}$$

$$< \chi_{\pm}^{\lambda} | \vec{S}_1 . \vec{S}_3 | \chi_{\pm}^{\lambda} > = - \frac{1}{2} , \tag{C.8e}$$

$$< \chi_{\pm}^{\lambda} | \vec{S}_1 . \vec{S}_2 | \chi_{\pm}^{\rho} > = 0 , \tag{C.8f}$$

$$< \chi_{\pm}^{\lambda} | \vec{S}_1 . \vec{S}_3 | \chi_{\pm}^{\rho} > = - \frac{\sqrt{3}}{4} , \tag{C.8g}$$

$$< \chi_{\pm}^{\lambda} | \vec{S}_2 . \vec{S}_3 | \chi_{\pm}^{\rho} > = \frac{\sqrt{3}}{4} , \tag{C.8h}$$

$$< \chi^{\rho,\lambda} | \vec{S}_1 . \vec{S}_2 | \chi^{s} > = 0 . \tag{C.8i}$$

Other elements can be deduced by using the symmetry properties of χ^s, χ^ρ, χ^λ. From eqs. (C.6) and (C.8), the expectation values of $\frac{1}{\sqrt{6}} (3S_{i0}S_{j0} - \vec{S}_i . \vec{S}_j) \equiv S^0_{ij}$ are given by

$$< \chi^{s}_{3/2} \| S^0_{ij} \| \chi^{s}_{3/2} > = \sqrt{\frac{5}{6}} , \quad i<j, \ i,j = 1, 2, 3, \tag{C.9a}$$

$$< \chi^{\rho}_{1/2} \| S^0_{12} \| \chi^{s}_{1/2} > = 0 , \tag{C.9b}$$

$$< \chi^{\rho}_{1/2} \| S^0_{13} \| \chi^{s}_{1/2} > = - \frac{\sqrt{10}}{4} , \tag{C.9c}$$

$$< \chi^{\lambda}_{1/2} \| S^0_{12} \| \chi^{s}_{1/2} > = - \sqrt{\frac{5}{6}} , \tag{C.9d}$$

$$< \chi^{\lambda}_{1/2} \| S^0_{13} \| \chi^{s}_{1/2} > = \frac{\sqrt{5}}{2\sqrt{6}} . \tag{C.9e}$$

These are all needed for the spin part of the tensor terms. As an example, we will calculate the hyperfine interaction energy of the state

$$| \Lambda\, {}^4D_{\rho\lambda}\, \tfrac{7}{2}^{+} > \; = \; \phi_\lambda\, \chi^{S}\, \psi^{\rho\lambda}_{22} \; , \qquad \text{(C.10)}$$

where

$$\psi^{\rho\lambda}_{22} = \psi_{111}\varphi_{111}$$

$$= \frac{\alpha_\rho^{5/2}\, \alpha_\lambda^{5/2}}{\pi^{3/2}}\; \lambda_+\, \rho_+\, \exp\left[-\tfrac{1}{2}\alpha_\rho^2\rho^2 - \tfrac{1}{2}\alpha_\lambda^2\lambda^2 \right] , \qquad \text{(C.11)}$$

where $r_+ = r_1 + ir_2$. From eqs. (C.1b), (C.3), (C.4), (3.5), (3.9).

$$H_{cont.} = \sum_{i<j} H^{ij}_{cont.} = \sum_{i<j} \frac{2\alpha_s}{3m_i m_j}\, \frac{8\pi}{3}\, \vec{S}_i.\vec{S}_j\, \delta^3(\vec{r}_{ij})$$

$$= \frac{8\pi\, \alpha_s}{9\sqrt{2}\, m_u^2} \left[\vec{S}_1.\vec{S}_2\, \delta^3(\vec{\rho}) + 4\sqrt{2}\, x_1\, \vec{S}_2.\vec{S}_3\, \delta^3(\vec{r}_{23}) \right]$$

$$= \frac{8\pi\, \alpha_s}{9\sqrt{2}\, m_u^2} \left[\vec{S}_1.\vec{S}_2\, \delta^3(\vec{\rho}) + \frac{16x_1}{3\sqrt{3}}\, \vec{S}_2.\vec{S}_3\, \delta^3(\vec{\lambda} - \tfrac{1}{\sqrt{3}}\rho) \right] . \qquad \text{(C.12)}$$

From eq. (C.8)

$$<\Lambda\, {}^4D_{\rho\lambda}\, \tfrac{7}{2}^{+} | H_{cont.} | \Lambda\, {}^4D_{\rho\lambda}\, \tfrac{7}{2}^{+}> \; = \; <\phi_\lambda\, \chi^{S}\, \psi^{\rho\lambda}_{22} | H_{cont.} | \phi_\lambda\, \chi^{S}\, \psi^{\rho\lambda}_{22}>$$

$$= \frac{8\pi\, \alpha_s}{9\sqrt{2}\, m_u^2}\, \frac{1}{4} \left[< \psi^{\rho\lambda}_{22} \,|\delta^3(\vec{\rho}) + \frac{16x_1}{3\sqrt{3}}\, \delta^3(\vec{\lambda} - \tfrac{1}{\sqrt{3}}\rho) |\, \psi^{\rho\lambda}_{22} > \right]$$

$$= \frac{2\tau\, \alpha_s}{9\sqrt{2}\, m_u^2}\, \frac{16x_1}{3\sqrt{3}} \int \left(\frac{8}{3} \right)^2 \frac{\alpha_\rho^5\, \alpha_\lambda^5}{\pi}\, \rho^2\lambda^2 \exp\left[-\alpha_\rho^2\rho^2 - \alpha_\lambda^2\lambda^2 \right]$$

$$\times \sin^2(\theta_\rho)\, \sin^2(\theta_\lambda) \left(\frac{3}{8\pi} \right)^2 \delta^3(\vec{\lambda} - \tfrac{1}{\sqrt{3}}\rho)\, d^3\rho\, d^3\lambda$$

$$= \frac{2\pi\ \alpha_s}{9\sqrt{2}\ m_u^2} \ \frac{16x_1}{3\sqrt{3}} \ \frac{2\ \alpha_\rho^5\ \alpha_\lambda^5}{\pi^2} \int \frac{\rho^3}{3} \exp\left[-\left(\alpha_\rho^2 + \frac{\alpha_\lambda^2}{3} \right) \rho^2 \right] d\rho$$

$$\times \int \sin^5\theta \ d\theta$$

$$= \frac{1}{8}\, x_1\, r^2\, t^{7/2}\, \delta\ , \tag{C.13}$$

where t is given by eq.(3.26) and

$$r = \frac{\alpha_\rho}{\alpha_\lambda}\ , \qquad \delta = \frac{4\ \alpha_s\ \alpha_\rho^3}{3\sqrt{2\pi}\ m_u^2} \ . \tag{C.14}$$

For the tensor term, from eqs.(C.1) and (C.5)

$$\langle \Lambda\ {}^4D_{\rho\lambda}\ \tfrac{7}{2}^+ | H_{tens.} | \Lambda\ {}^4D_{\rho\lambda}\ \tfrac{7}{2}^+ \rangle \ = \ \langle \phi_\lambda\ \chi^S\ \psi_{22}^{\rho\lambda} | H_{tens.} | \phi_\lambda\ \chi^S\ \psi_{22}^{\rho\lambda} \rangle$$

$$= \ \langle \phi_\lambda\ \chi^S\ \psi_{22}^{\rho\lambda} | \sum H_{tens.}^{ij} | \phi_\lambda\ \chi^S\ \psi_{22}^{\rho\lambda} \rangle$$

$$= \ \frac{2\alpha_s}{3m_u^2}\ (-1)^{7/2\ +\ 3/2\ +\ 2} \begin{Bmatrix} 2 & \frac{3}{2} & \frac{7}{2} \\ \frac{3}{2} & 2 & 2 \end{Bmatrix} \times$$

$$\Big[\langle \chi^S_{3/2} \| S^0_{12} \| \chi^S_{3/2} \rangle \langle \psi^{\rho\lambda}_{22} \| R^0_{12} \| \psi^{\rho\lambda}_{22} \rangle \ +$$

$$2x_1 \langle \chi^S_{3/2} \| S^0_{13} \| \chi^S_{3/2} \rangle \langle \psi^{\rho\lambda}_{22} \| R^0_{13} \| \psi^{\rho\lambda}_{22} \rangle \Big] ,$$

where

$$S^0_{ij} = \frac{1}{\sqrt{6}}\ (3S_{i0}S_{j0} \ - \ \vec{S}_i . \vec{S}_j\ ) \tag{C.15}$$

and

$$R^0_{ij} = \left(\frac{3}{2} \right)^{1/2} \frac{1}{r^3_{ij}} \left(3\cos^2\theta \ - 1 \right) . \tag{C.16}$$

From eqs. (C.6) and (C.9a), we have

$$\mathbb{T} \equiv \langle \Lambda\, {}^4D_{\rho\lambda}\, \tfrac{7}{2}^+ | H_{tens.} | \Lambda\, {}^4D_{\rho\lambda}\, \tfrac{7}{2}^+ \rangle$$

$$= \frac{2\alpha_s}{3m_u^2} \frac{1}{5\sqrt{14}} \sqrt{\frac{5}{6}} \frac{(-1)^{2-2}}{\begin{pmatrix} 2 & 2 & 2 \\ -2 & 2 & 0 \end{pmatrix}} \times$$

$$\left[\langle \psi^{\rho\lambda}_{22} | R^0_{12} | \psi^{\rho\lambda}_{22} \rangle + 2x_1 \langle \psi^{\rho\lambda}_{22} | R^0_{13} | \psi^{\rho\lambda}_{22} \rangle \right]$$

$$= \frac{2\alpha_s}{3m_u^2} \frac{1}{2\sqrt{6}} \left[\langle \psi^{\rho\lambda}_{22} | R^0_{12} | \psi^{\rho\lambda}_{22} \rangle + 2x_1 \langle \psi^{\rho\lambda}_{22} | R^0_{13} | \psi^{\rho\lambda}_{22} \rangle \right]$$

$$\equiv \frac{2\alpha_s}{3m_u^2} \frac{1}{2\sqrt{6}} \left[\mathbb{R}_{12} + 2x_1 \mathbb{R}_{13} \right] \qquad (C.17)$$

$\mathbb{R}_{12}$ and $\mathbb{R}_{13}$ are calculated as followed:

$$\mathbb{R}_{12} = \frac{1}{2\sqrt{2}} \langle \psi_{111}\varphi_{111} | \frac{1}{\rho^3} \left[3\cos^2\theta_\rho - 1 \right] | \psi_{111}\varphi_{111} \rangle$$

$$= \frac{1}{2\sqrt{2}} \langle \psi_{111} | \frac{1}{\rho^3} \left[3\cos^2\theta_\rho - 1 \right] | \psi_{111} \rangle$$

$$= \frac{1}{2\sqrt{2}} \frac{8}{3} \frac{\alpha_\rho^5}{\sqrt{\pi}} \int \rho^2 \exp\left[-\alpha_\rho^2 \rho^2\right] \frac{3}{8\pi} \sin^2\theta_\rho \frac{1}{\rho^3} \left[3\cos^2\theta_\rho - 1\right] d^3\rho$$

$$= -\frac{2\sqrt{2}}{15}\ \frac{\alpha_\rho^{\ 3}}{\sqrt{\pi}}\ , \qquad \text{(C.18)}$$

$$\mathbb{R}_{13} = \ < \psi_{111}\varphi_{111} \mid \frac{1}{r_{13}^{\ 3}} \left[3\cos^2\theta_{r_{13}} - 1 \right] \mid \psi_{111}\varphi_{111} > .$$

Using eqs. (3.25), (3.26), (C.11), (C.14) and $\vec{p} = \frac{1}{\sqrt{2}}\ \vec{r}_{13}$, one arrives at

$$\mathbb{R}_{13} = \frac{\alpha_\rho^5\ \alpha_\lambda^5}{\pi^3} \int \Bigg[\frac{\sqrt{3}}{4}\ t^2r^2p^2\ e^{-2i\varphi_p}\ \sin^2\theta_p - \frac{\sqrt{3}}{2}\ x^2\ e^{-2i\varphi_x}\ \sin^2\theta_x$$

$$+ \frac{t}{2\sqrt{2}} \left[1 - 3r^2 \right] p\ x\ \sin\theta_p\ \sin\theta_x \Bigg] \Big[\ldots \Big]^*$$

$$\times\ \frac{1}{p^3} \left[3\cos^2\theta_p \ - 1 \right] d^3p\ d^3x$$

$$= \frac{\alpha_\rho^5\ \alpha_\lambda^5}{\pi^3} \int \Bigg[\frac{3}{16}\ t^4r^4p^4\ \sin^4\theta_p \ + \ \frac{3}{4}\ x^4\sin^4\theta_x \ +$$

$$\frac{t^2}{8} \left[1 - 3r^2 \right] p^2x^2\ \sin^2\theta_p\ \sin^2\theta_x \Bigg]\ \times$$

$$\frac{1}{p^3} \left[3\cos^2\theta_p \ - 1 \right] d^3p\ d^3x$$

$$= -\ \frac{\alpha_\rho^{\ 3}}{\sqrt{\pi}} \left[\frac{\sqrt{2}}{35}\ t^{7/2}\ r^6 + \ \frac{\sqrt{2}}{120}\ t^{7/2} \left[1 - 3r^2 \right]^2 \right] . \qquad \text{(C.19)}$$

The same techniques here are also used to calculate the U term of the potential (see eq.(3.24)).