Charmed baryon spectroscopy section

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Status at KEK

- Section-by-section plan but no words
- List of references by topic
- Two volunteers to help with editing but not writing (Pat Burchat, Ruslan Chistov)

What’s new

- Not much
- I now have SVN commit access and have started (ab)using it.
  - Section list + paper jottings imported into repository (messy but no longer blank)
  - Draft of some words for intro section

As of last night...

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Jolanta Brodzicka (Belle)
Svjetlana Fajfer (theory)

Text here.

16.2 D-mixing and CP violation

Editors:
Brian Meadows (BABAR)
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16.3 Charmed meson spectroscopy

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16.4 Charmed baryon spectroscopy and decays

Editors:
Matthew Charles (BABAR)
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16.4.1 Spectroscopy

16.4.1.1 Introduction

Overview The spectroscopy of charmed baryons is beautiful and intricate. With three quarks there are numerous degrees of freedom, giving rise to many more states than in the charmed meson sector. At the same time, the large difference in mass between the charm quark and the light quarks provides a natural way to classify and understand these states: Heavy Quark Effective Theory (HQET). The spectrum of known singly charmed states can be thought of in three broad regimes: the ground states, which are a vindication of the constituent quark model; the low-lying excited states, which are described well by HQET; and higher excited states, where the situation is murkier.

The naming convention for charmed baryons is to take a light baryon, replace one or more s quarks with c quarks, and add a c subscript for every quark replaced. Isospin is unchanged. For example, Λ denotes a sud baryon with isospin zero and so Λ_c^+ denotes a cud baryon with isospin zero. Likewise, Ξ_c^0 denotes a csd baryon and Xi_{cc}^+ denotes a ccd baryon.

Diagram goes here

Fig. 5. The $SU(3)$ multiplets containing the ground state baryons.

Diagram goes here

Fig. 6. The $SU(4)$ multiplets containing the ground state baryons.

Quark model for ground states In the constituent quark model, baryons composed of u, d, s, c quarks can be classified into $SU(4)$ multiplets according to the symmetry of their flavor, spin, and spatial wavefunctions. All states in a given $SU(4)$ multiplet have the same angular momentum J, and parity P, but can have different quark flavours. For excited states with multiple units of orbital angular momentum the number of possible multiplets becomes large, but for the ground states the picture is much simpler. This framework is not exact—different states with the same conserved quantum numbers will mix, and baryons are not pure three-quark objects—but it works remarkably well for the ground states.

A baryon is a fermion and therefore must have a wavefunction that is overall antisymmetric under quark interchange[1]. Baryons are color singlets, and so have an antisymmetric color wavefunction. In the ground state, the spatial wavefunction is symmetric. Therefore, the product of the spin and flavor wavefunctions must also be symmetric for ground-state baryons. There are two ways this can be accomplished: both wavefunctions can be fully symmetric, or both can have mixed symmetry with the product being symmetric.

In concrete terms, we can consider a singly charmed baryon to consist of a heavy c quark and a light diquark with spin-parity j^p. Assuming isospin symmetry and letting q denote a u or d quark, there are four possibilities for the flavour content of the diquark:

- qq with isospin 0 (flavour antisymmetric);
- qq with isospin 1 (flavour symmetric);
- sq with isospin 1/2 (either);
- ss with isospin 0 (flavour symmetric).

These correspond to the Λ_c, Σ_c, Ξ_c, and Ω_c states, respectively. The diquark is a boson and its spatial and color wavefunctions are symmetric, so it may be either flavor-symmetric and spin-symmetric ($j^p = 1^+$) or flavor-antisymmetric and spin-antisymmetric ($j^p = 0^+$). Combining the diquark with the charm quark gives rise to the possible states set out in Table 1 and illustrated in Fig. 5. Those with $J^P = 1/2^+$ are all members of the same multiplet as the proton, and those with $J^P = 3/2^+$ are all members of the same multiplet as the Δ and Ω (Fig. 6).

The constituent quark model predicts relations between the masses of these states as well as their existence

[1] Strictly, it only needs to be symmetric under interchange of equal-mass quarks, but in order to build the model we assume $SU(4)$ is a good symmetry.

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Table 1. Summary of the ground state singly charmed baryons. S denotes a wavefunction that is fully symmetric under interchange of any two quarks; M_S and M_A denote mixed overall symmetry with interchange of the two light quarks being symmetric or asymmetric, respectively; and A would denote a fully asymmetric wavefunction.

Baryon	Diquark	Diquark I	Diquark j^p	Baryon flavor symmetry	Baryon spin symmetry	Baryon J^P
Λ_c	qq	0	0^+	M_A	M_A	$1/2^+$
Σ_c	qq	1	1^+	M_S	M_S	$1/2^+$
Σ_c^*	qq	1	1^+	S	S	$3/2^+$
Ξ_c	sq	1/2	0^+	M_A	M_A	$1/2^+$
Ξ_c'	sq	1/2	1^+	M_S	M_S	$1/2^+$
Ξ_c^*	sq	1/2	1^+	S	S	$3/2^+$
Ω_c	ss	0	1^+	M_S	M_S	$1/2^+$
Ω_c^*	ss	0	1^+	S	S	$3/2^+$

and quantum numbers. These were expressed for the light baryons as Gell-Mann-Okubo sum rules (see Gell-Mann (1962); Okubo (1962)):

$$(m_N + m_\Xi)/2 = (3m_\Lambda + m_\Sigma)/4,$$
$$m_{\Sigma^*} - m_\Delta = m_{\Xi^*} - m_{\Sigma^*} = m_\Omega - m_{\Xi^*}.$$

Generalize to charmed baryons. (Use Gasiorowicz-Rosner instead?)

Mention lovely agreement of Ω_c^* with prediction.

Phenomenological predictions for higher states Text goes here, needs theory input!

16.4.1.2 Λ_c, Σ_c families

Experimental results and interpretation

- BABAR: Λ_c^+ ground state mass
- BABAR: $\Lambda_c(2880)^+$ and $\Lambda_c(2940)^+$ mass, width
- Belle: Spin/parity of $\Lambda_c(2880)^+$; mass and width of $\Lambda_c(2880)^+$ and $\Lambda_c(2940)^+$
- BABAR: Σ_c resonances in $B^- \to \Lambda_c^+ \bar{p} \pi^-$
- Belle: Properties of $\Sigma_c(2800)$

16.4.1.3 Ξ_c family

Experimental results and interpretation

- Belle: Masses of Ξ_c^0, Ξ_c^+
- BABAR: Mass, spin of $\Xi_c'^0$
- Belle: $\Xi_c(2980)$, $\Xi_c(3077)$; search for Ξ_{cc}
- Belle: $\Xi_c(2645)$, $\Xi_c(2815)$, $\Xi_c(2980)$ masses, width of $\Xi_c(2980)$
- BABAR: $\Xi_c(2980)$, $\Xi_c(3055)$, $\Xi_c(3077)$, $\Xi_c(3123)$ properties
- BABAR: Possible $\Xi_c(2930)$ in B c+ c K

16.4.1.4 Ω_c family

Experimental results and interpretation

- BABAR: Ω_c^{*0} mass
- Belle: Masses of Ω_c^0, Ω_c^{*0}

16.4.1.5 Searches for Ξ_{cc}

Experimental results and interpretation

- BABAR: Search for Ξ_{cc}

16.4.1.6 Conclusions

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16.4.2 Weak decays

16.4.2.1 Introduction

16.4.2.2 Results and discussion

Λ_c^+

- Belle: Weak decay BRs of Λ_c
- BABAR: Weak decay BRs of Λ_c

Ξ_c^0 and Ξ_c^+

- BABAR: Weak decay BRs of Ξ_c^0
- Belle: Weak decay BRs of Ξ_c^0, Ξ_c^+

Ω_c^0

- BABAR: Weak decay BRs of Ω_c

16.4.2.3 Comments on absolute branching fractions

16.4.3 Applications to light baryon spectroscopy

16.4.3.1 Introduction

16.4.3.2 Spin of the Ω^-

- BABAR: Spin of Ω