Systematic Study of Spectrum of Heavy-light mesons

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Nanjing, Apr. 27, 2008

Outline

- Mass loaded flux tube model
- Spectrum of heavy-light mesons
- Some new observations
- Conclusions and discussions

Mass loaded flux tube model

Hadron spectrum, higher orbital excitation, challenge!

♠ Idea

Alexander Selem and Frank Wilczek, hep-ph/0602128

Two masses m_1 and m_2 are connected by a relativistic string with constant tension T rotaing with angular momentum L.

For heavy-light systems, the energy E is

$$E - M = \sqrt{\frac{\sigma L}{2}} + 2^{\frac{1}{4}} \kappa L^{-\frac{1}{4}} \mu^{\frac{3}{2}}, \tag{1}$$

M: heavy quark mass

μ: $m_u = m_d$, m_s, light quark mass

L: orbital angular momentum

$T = \frac{\sigma}{2\pi}$: string tension

$\kappa = \frac{2}{3}\frac{\pi^{\frac{1}{2}}}{\sigma^{\frac{1}{4}}}$

♠ Problems

- Spin-Orbit forces were ignored!

- Heavy-light systems were not analyzed!

♠ Improvements

Spin-Orbit forces

A. De. Rujula, H. Georgi and S. L. Glashow, Phys. Rev. **D12**, 147 (1977)

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

T. Barnes, F. E. Close, P. R. Page and E. Swanson, Phys. Rev. **D 55**, 4157 (1997)

- Spin-Orbital correction is dominant
- Spin-triplet and spin-singlet hyperfine splitting relation!
- experimental data of D and D_s mesons!

Spectrum of heavy-light mesons

Hong-Yun Shan and Ailin Zhang, in preparation

$$E - M = \sqrt{\frac{\sigma L}{2}} + 2^{\frac{1}{4}} \kappa L^{-\frac{1}{4}} \mu^{\frac{3}{2}} + aL \cdot S \qquad (2)$$

a: fitted constant, S: Spin

States	J^P	$n^{2S+1}L_J$	GI	PE	BR	our paper
D^0	0^-	1^1S_0	1.88	1.868	?	-
$D^\star(2007)^0$	1^-	1^3S_1	2.04	2.005	?	-
$D_0^\star(2400)^0$	0^+	1^3P_0	2.40	2.377	?	2.370
$D_1(2420)^0$	1^+	1^3P_1	2.49	2.417	?	2.408
$D_1(2430)^0$	1^+	1^1P_1	2.44	2.49	?	2.446
$D_2^\star(2460)^0$	2^+	1^3P_2	2.50	2.46	?	2.484
?	1^-	1^3D_1	2.82	2.775	?	2.623
?	2^-	1^3D_2	?	2.795	?	2.699
?	2^-	1^1D_2	?	2.799	?	2.737
?	3^-	1^3D_3	2.83	2.833	?	2.775

Tab. 1: Spectrum of charmed mesons(GeV).

States	J^P	$n^{2S+1}L_J$	GI	PE	BR	our paper
$D_s^{\pm}(1969)$	0^-	1^1S_0	1.98	1.965	?	-
$D_s^{\star\pm}(2112)^0$	1^-	1^3S_1	2.13	2.113	?	-
$D_{s0}^{\star}(2317)^{\pm}$	0^+	1^3P_0	2.48	2.487	?	2.441
$D_{s1}(2536)^{\pm}$	1^+	1^3P_1	2.57	2.535	?	2.517
$D_{s1}(2460)^{\pm}$	1^+	1^1P_1	2.53	2.605	?	2.555
$D_{s2}(2573)^{\pm}$	2^+	1^3P_2	2.59	2.581	?	2.593
$D_{sJ}(2700)$	1^-	1^3D_1	2.90	2.900	?	2.714
?	2^-	1^3D_2	?	2.913	?	2.790
?	2^-	1^1D_2	?	2.925	?	2.828
$D_{sJ}(2860)$	3^-	1^3D_3	2.92	2.953	?	2.866

Tab. 2: Spectrum of charmed strange mesons(GeV).

GI: S. Godfrey and N. Isgur, Phys. Rev. D32: 189(1985); Relativized quark model

PE: M.Di Pierro and E. Eichten, Phys. Rev. D64: 114004(2001); Chiral quark model

BR: E.van Beveren and G. Rupp, Coupled channels models

Higher orbital excitation?

Spin-orbit inversion? N. Isgur, Phys. Rev. D57: 4041(1998)

Some new observations

♠ $D_{sJ}(2700)$

K. Abe, et al., Belle Collaboration, hep-ex/0608031

$$B^+ \to \bar{D}^0 D_{sJ} \to \bar{D}^0 D^0 K^+$$

with $M = 2715 \pm 11^{+11}_{-14}$ and $\Gamma = 115 \pm 20^{36}_{-32}$ MeV

J. Brodzicka et al., Belle Collaboration, Phys. Rev. Lett. **100**, 092001(2008)

$$B^+ \to \bar{D}^0 D_{sJ} \to \bar{D}^0 D^0 K^+$$

with $M = 2708 \pm 9^{+11}_{-10}$ and $\Gamma = 108 \pm 23^{36}_{-31}$ MeV

$J^P = 1^-$, 2^3S_1

Possible explanations:

- $c\bar{s}$, mixture of 2^3S_1 and 1^3D_1; F.E. Close, C.E. Thomas, O. Lakhina and E.S. Swanson, Phys. Lett. B647: 159(2007)

- $1^-(1^3D_1)$, Bo Zhang, Xiang Liu, Wei-Zhen Deng and Shi-Lin Zhu, Eur. Phys. J. C50: 617(2007)

♠ $D_{SJ}(2860)$

B. Aubert, et al, BABAR Collaboration, Phys. Rev. Lett. **97**, 222001 (2006)

$$D_{sJ}(2860) \to D^0 K^+ \ , \ D^+ K_s^0$$

with $M = 2856.6 \pm 1.5(stat) \pm 5.0(syst)$ and $\Gamma = 48 \pm 7(stat) \pm 10(syst)$ MeV

Natural spin-parity: $J^P = 0^0, \ 1^-, \ \cdots$

Possible explanations:

- First radial excitation of the $D^{\star}_{s0}(2317)$; E. Beveren and G. Rupp, Phys. Rev. Lett. 97: 202001(2006)
- $c\bar{s}(2p)$; F.E. Close, C.E. Thomas, O. Lakhina and E.S. Swanson, Phys. Lett. B647: 159(2007)
- $0^+(2^3P_0)$ or $3^-(1^3D_3)$, unlikely $1^-(2^3S_1)$ and $1^-(1^3D_1)$, Bo Zhang, Xiang Liu, Wei-Zhen Deng and Shi-Lin Zhu, Eur. Phys. J. C50: 617(2007)

♠ $X(2690)$

B. Aubert, et al, BABAR Collaboration, Phys. Rev. Lett. **97**, 222001 (2006)

Broad enhancement: not possible to associate with any known reflection or background

$$X(2690) \to D^0 K^+ \ , \ D^+ K_s^0$$

with $M = 2688 \pm 4(stat) \pm 3(syst)$ and $\Gamma = 112 \pm 7(stat) \pm 36(syst)$ MeV

Conclusions:

* Mass loaded flux tube model, predictable
* $D^{\star}_{s0}(2317)^{\pm}$, $D_{s1}(2460)^{\pm}$? D_s mesons!
* $D_{sJ}(2700)$, $D_{sJ}(2860) \approx 1^3D_1$, 1^3D_3!

Discussions:

* Mesons and baryons with b quark?
* Spin-orbit inversion?
* mixing?
* Dynamics and decays?

Thank you!