Decays of 1^{-+} Charmoniumlike Hybrid

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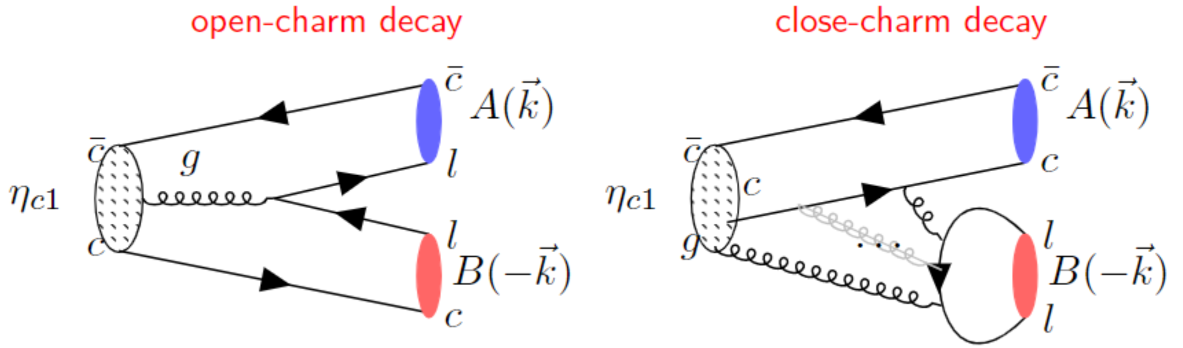
η_{c1} decay



open-charm decay: $D\bar{D}_1(S\text{-wave})$, $D\bar{D}^*(P\text{-wave})$, $D^*\bar{D}^*(P\text{-wave})$.
close-charm decay: $\chi_{c1}\eta(S\text{-wave})$, $\eta_c\eta'(P\text{-wave})$, $J/\psi\omega(P\text{-wave})$.

Methodology: McNeile & Michael method

(C. McNeile, C.Michael, and P. Pennanen. 2002).

$$|\eta_{c1}\rangle = \begin{pmatrix}1\\0\end{pmatrix} \quad |AB\rangle = \begin{pmatrix}0\\1\end{pmatrix}$$

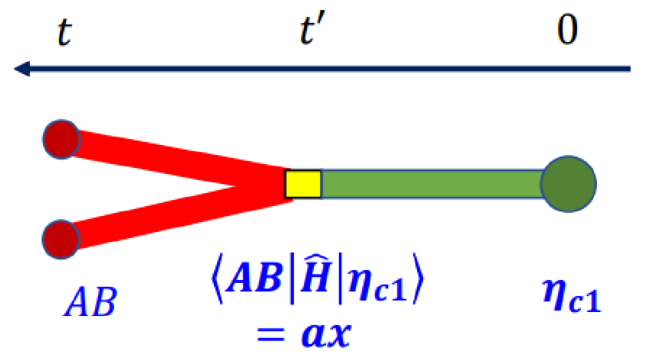
$$\hat{H} = \begin{pmatrix} m_{\eta_{c1}} & x \\ x & E_{AB}\end{pmatrix}$$

$$\Rightarrow$$

$$\hat{T}(a) = e^{-a\hat{H}} = e^{-a\bar{E}}\begin{pmatrix} e^{-a\Delta/2} & ax \\ ax & e^{a\Delta/2}\end{pmatrix}$$

$$\bar{E} = \frac{m_{\eta_{c1}} + E_{AB}}{2}, \qquad \Delta = m_{\eta_{c1}} - E_{AB}$$

$$\langle\Omega|\mathcal{O}_{AB}|\eta_{c1}\rangle \approx 0 \qquad \langle\Omega|\mathcal{O}_{\eta_{c1}}|AB\rangle \approx 0$$



The final results

Due to $m_{\eta_{c1}} = 4.329(36)$ from our lattice

Mode (AB)	$\hat{k}$(IE)	r_1 $(\times 10^{-3})$	g_{AB}	g_{AB} (ave.)	Γ_{AB} (MeV)
$D_1\bar{D}$	(0,0,0)(L16)	4.95(5)	4.27(5)	4.6(6)	258(133)
	(0,0,0)(L24)	3.10(26)	4.92(41)		
$D^*\bar{D}$	(1,1,1)(L16)	1.11(3)	8.35(21)	8.3(7)	88(18)
	(2,2,0)(L24)	0.78(7)	8.34(74)		
$D^*\bar{D}^*$	(1,1,1)(L16)	1.00(3)	3.44(12)	4.6(1.8)	150(118)
	(1,1,0)(L16)	1.15(4)	3.79(12)		
	(2,0,0)(L24)	1.05(9)	5.06(42)		
	(1,1,1)(L24)	0.67(7)	6.31(58)		
$\chi_{c1}\eta_{(2)}$	(0,0,0)(L16)	2.04(26)	1.31(2)	1.35(45)	–
	(0,0,0)(L24)	1.18(38)	1.39(45)		
$\eta_c\eta_{(2)}$	(1,1,1)(L16)	0.20(6)	0.62(18)	0.55(22)	–
	(2,2,0)(L24)	0.10(3)	0.47(12)		

$$\overline{|\mathcal{M}(\eta_{c1} \to AP)|^2} = \frac{1}{3} g_{AP}^2 m_{\eta_{c1}} \left(3 + \frac{k_{\rm ex}^2}{m_A^2}\right),$$

$$\overline{|\mathcal{M}(\eta_{c1} \to PP)|^2} = \frac{4}{3} g_{PP}^2 k_{\rm ex}^2,$$

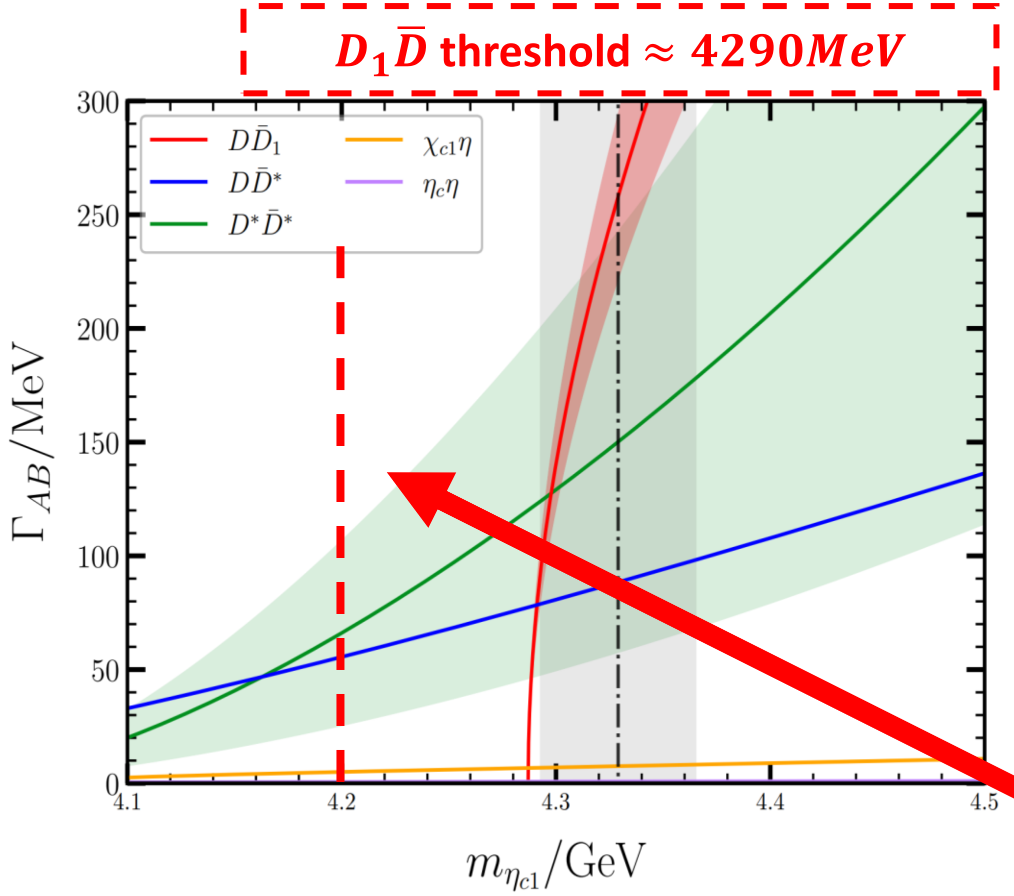
$$\overline{|\mathcal{M}(\eta_{c1} \to VP)|^2} = \frac{2}{3} g_{VP}^2 k_{\rm ex}^2,$$

$$\overline{|\mathcal{M}(\eta_{c1} \to D^*\bar{D}^*)|^2} = \frac{4}{3} g^2 k_{\rm ex}^2 \frac{m_{\eta_{c1}}^2}{m_{D^*}^2}.$$

$$\Gamma_{AB} = \frac{1}{8\pi} \frac{k_{\rm ex}}{m_{\eta_{c1}}^2} \overline{|\mathcal{M}(\eta_{c1} \to AB)|^2}$$

- $D_1\,\bar{D}$ dominates.
- $D^*\bar{D}$ and $D^*\bar{D}^*$ are important.

This observation is in striking contrast to the expectation of the flux-tube model.



The $m_{\eta_{c1}}$-dependence of partial decay widths

$$\left|D^*\bar{D}^*\right\rangle^{(I=0)}_{(C=+)} = \frac{1}{\sqrt{2}}\left(\left|D^{*+}D^{*-}\right\rangle + \left|D^{0*}\bar{D}^{0*}\right\rangle\right)^{(S=1)}_{(L=1)}$$

$L + S = \text{even}$

- For $m_{\eta_{c1}} = 4329(36)$ MeV, we have

$$\Gamma_{D_1\bar{D}} = 258(133)\ \text{MeV}$$
$$\Gamma_{D^*\bar{D}^*} = 150(118)\ \text{MeV}$$
$$\Gamma_{D\bar{D}^*} = 88(18)\ \text{MeV}$$

$$\Gamma_{\chi_{c1}\eta} = \sin^2\theta \cdot 44(29)\ \text{MeV}$$
$$\Gamma_{\eta_c\eta'} = \cos^2\theta \cdot 0.93(77)\ \text{MeV}$$

- Given the mass above, η_{c1} seems too wide to be identified easily in experiments.

- However, $\Gamma_{\eta_{c1}}$ is very sensitive to $m_{\eta_{c1}}$.
- If $m_{\eta_{c1}} \sim 4.2$ GeV, then $\Gamma_{\eta_{c1}} \sim 100$ MeV. The dominant decay channels are $D^*\bar{D}$ and $D^*\bar{D}^*$.
- Especially for $D^*\bar{D}^*$, the measurement of the polarization of D^* and $\bar{D}^*$ will help distinguish a 1^{-+} states from 1^{--} states.

- We suggest LHCb, BelleII and BESIII to search for η_{c1} in $D^*\bar{D}$ and $D^*\bar{D}^*$ systems !

Possible production in experiments

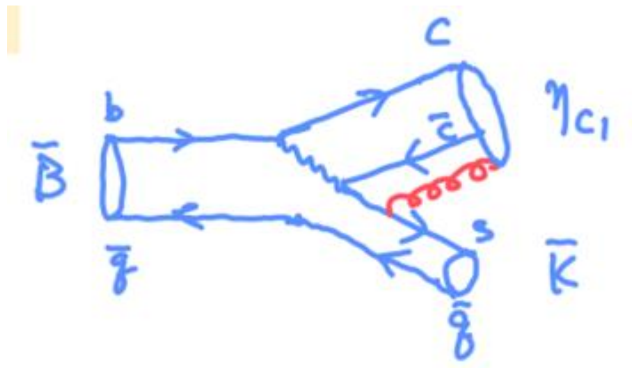
1) η_{c1} production on e^+e^- collider experiments: (BESⅢ)

$$e^+e^- \to \psi(nS) \to \gamma\eta_{c1}$$

2) η_{c1} production from B meson weak decay

$$B \to \eta_{c1}\bar{K}$$

(LHCb and Belle):



Summary

- ✓We give the first Lattice QCD prediction of the partial decay widths of the charmoniumlike η_{c1}.
- ✓Disfavor the results of the Flux-tube model.
- ✓We provide the theoretical information for the experimental search for charmoniumlike hybrid η_{c1}.

Thank You