Decays of 1^{-+} Charmoniumlike Hybrid

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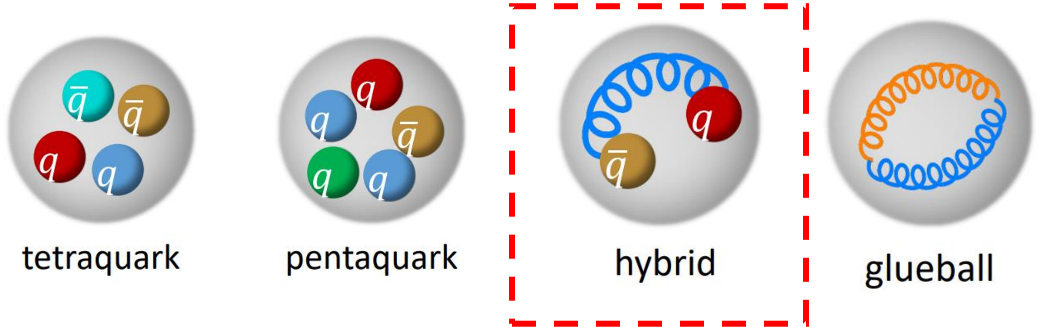
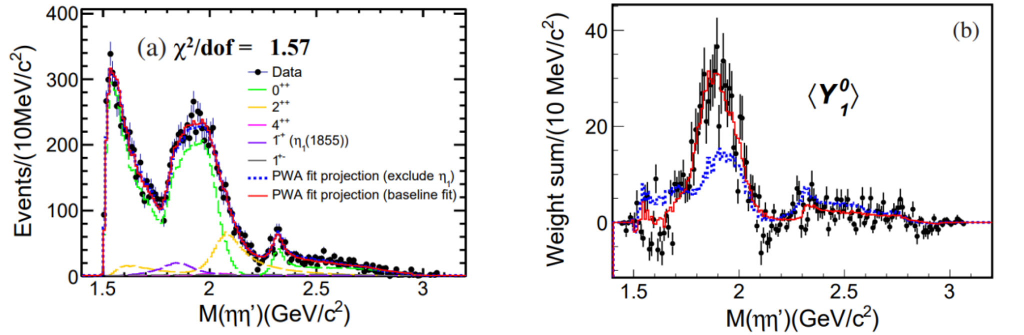
Outline

- Motivation
- Lattice methodology
- Lattice results
- Experimental prediction
- Summary

Introduction

- **1. Exotic hadrons:**
  - tetraquark / pentaquark states and hadronic molecule.
  - Glueball
  - hybrids ($q\bar{q}g$).
- **2. Experimental candidates for hybrids**
  - Isovector 1^{-+} states:
    - $\pi_1(1400)$ / $\pi_1(1600)$, $\Gamma_{tot} \sim 240 MeV$
    - $\pi_1(2105)$
  - Isoscalar 1^{-+} states: $\eta_1(1855)$.
  - charmoniumlike 1^{-+} counterpart $\eta_{c1}(c\bar{c}g)$ of $\eta_1(1855)$. **Exists?**
- **3. Insights of the masses of hybrids predicted by Lattice QCD**
- $m_{\pi_1} \sim 1.8 - 2.0\ GeV$, $m_{\eta_1} \sim 2.0 - 2.3\ GeV$,
- $m_{\eta_{c1}} \sim 4.2 - 4.4\ GeV$.





$\eta_1(1855)$ from $J/\psi \to \gamma\eta_1 \to \gamma\eta\eta'$

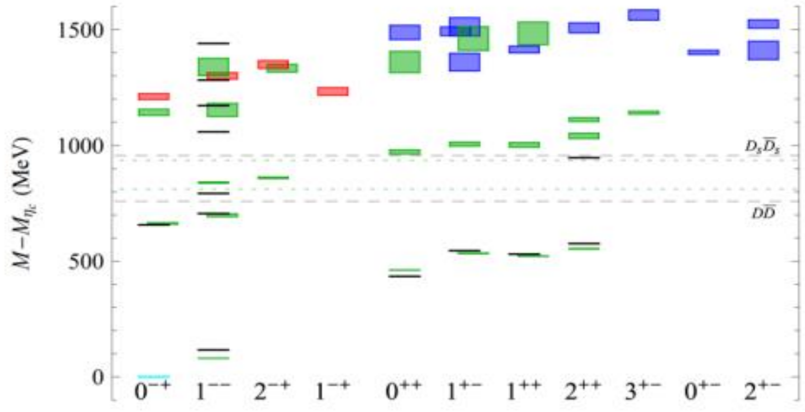
BESIII : PRD.107,079901 (2023)

BESIII : PRL.130,159901 (2023)

Spectrum of charmoniumlike 1^{-+}

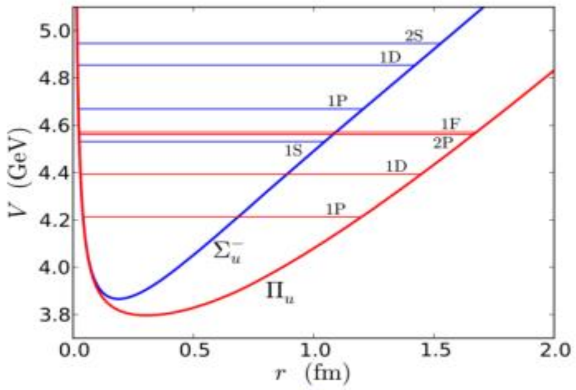
- **Super-multiplet $((0,1,2)^{-+}, 1^{--})$ observed around 4.2 GeV**
- **Consistent with the phenomenological expectation.**
- **Non-consistence appears in the spectrum of excited states**
  - **Flux-tube: $\Delta m(2P-1P) \sim 0.38$ GeV**
  - **QLQCD: $\Delta m(2P-1P) \sim 1.2-1.3$ GeV**

- **The internal stucture of these hybrids reflected by the BS wave functions seems different from the flux-tube picture.**

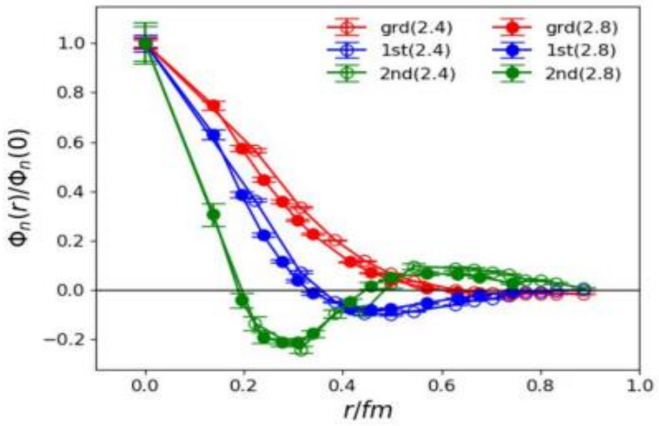


$m_{\eta_{c1}} \approx 4.23$ **GeV** $(N_f = 2+1)$

L. Liu [HSC Collab.], JHEP 07 (2012) 126



E. Braaten et al., Phys. Rev. D 90 (2014) 014044



#node	$m(1^{--})$ (GeV)	$m(0^{-+})$ (GeV)	$m(1^{-+})$ (GeV)	$m(2^{-+})$ (GeV)
0	3.109(5)	3.010(4)	-	-
0	3.703(82)	3.672(76)	-	-
0	4.591(69)	4.551(63)	4.309(2)	4.419(3)
1	5.460(31)	5.393(28)	5.693(12)	5.779(12)
2	8.226(99)	8.286(109)	7.661(31)	7.708(29)

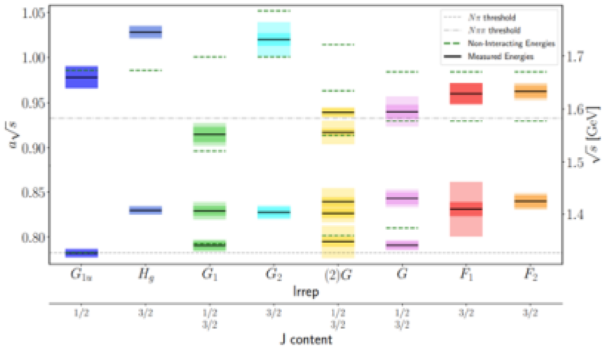
Y. Ma et al., Chin. Phys. C 45 (2021) 093111

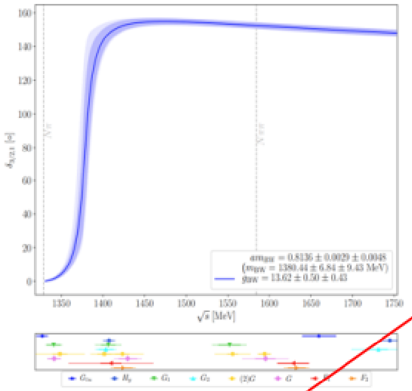
Lattice methodology: M&M method (C. McNeile & C. Michael, PLB 556 (2003) 177)

$N\pi$ scattering and the Δ resonance

G. Silvi et al., PRD103 (2021) 094508 (arXiv:2101.00689) and references therein

$N_s^3 \times N_t$	$24^3 \times 48$
β	3.31
$am_{u,d}$	-0.09530
am_s	-0.040
a [fm]	0.1163(4)
L [fm]	2.791(9)
m_π [MeV]	255.4(1.6)
$m_\pi L$	3.61(2)
N_{config}	600
N_{meas}	9600





K-matrix rescaled: $K = \rho^{1/2}\widehat{K}\rho^{1/2}$

K relates to the phase shift: $K^{Jl} = \tan\delta_{Jl}$

$m_\Delta = (1378.3 \pm 6.6 \pm 9.0)$ MeV

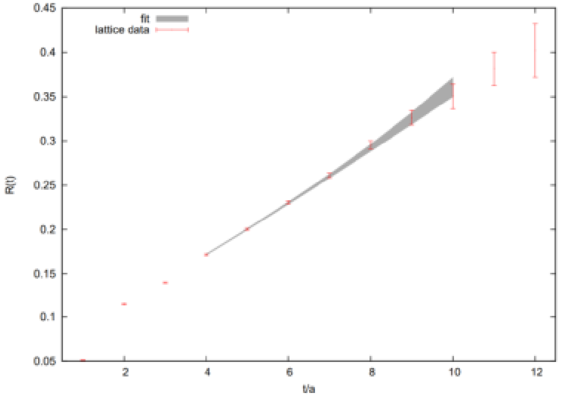
$\Gamma_\Delta = (\ \ 16.4 \pm 1.0 \pm 1.4)$ MeV

Breit Wigner: $\widehat{K}^{(3/2,1)} = \frac{\sqrt{s}\Gamma(s)}{(m_{BW}^2 - s)\rho}$

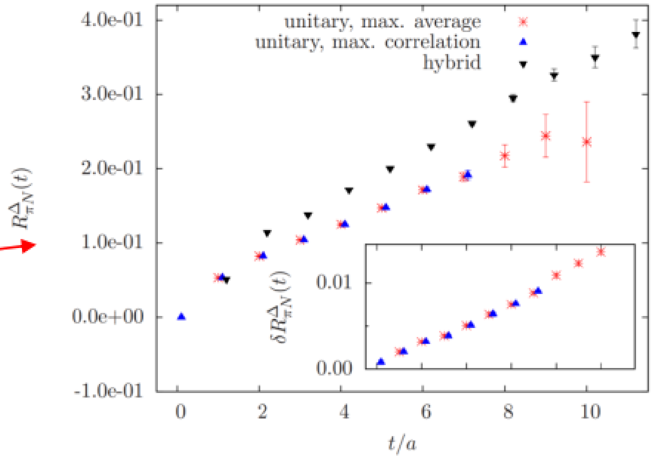
$$\Gamma(s) = \frac{g_{BW}^2}{6\pi}\frac{k^3}{s}$$

$$\Gamma_{\rm EFT}^{\rm LO} = \frac{g_{\Delta\text{-}\pi N}^2}{48\pi}\frac{E_N + m_N}{E_N + E_\pi}\frac{k^3}{m_N^2}$$

Collaboration	m_π [MeV]	Methodology	m_Δ [MeV]	$g_{\Delta\text{-}\pi N}$
Verduci 2014 [38]	266(3)	Distillation, Lüscher	$1396(19)_{\rm BW}$	19.90(83)
Alexandrou et al. 2013 [37]	360	Michael, McNeile	1535(25)	27.0(0.6)(1.5)
Alexandrou et al. 2016 [39]	180	Michael, McNeile	1350(50)	23.7(0.7)(1.1)
Andersen et al. 2018 [41]	280	Stoch. distillation, Lüscher	$1344(20)_{\rm BW}$	37.1(9.2)
Our result	255.4(1.6)	Smeared sources, Lüscher	$1380(7)(9)_{\rm BW}$, $1378(7)(9)_{\rm pole}$	23.8(2.7)(0.9)
Physical value [5]	139.5704(2)	phenomenology, K-matrix	$1232(1)_{\rm BW}$, $1210(1)_{\rm pole}$	29.4(3) [79], 28.6(3) [80]



C. Alexandrou et al.,
Phys. Rev. D 88 (2013) 031501



C. Alexandrou et al.,
Phys. Rev. D 93 (2016) 114515

Flux tube model

- A vibrational string along the $Q\bar{Q}$ axis.
- The picture is originated from the lattice QCD formulation.

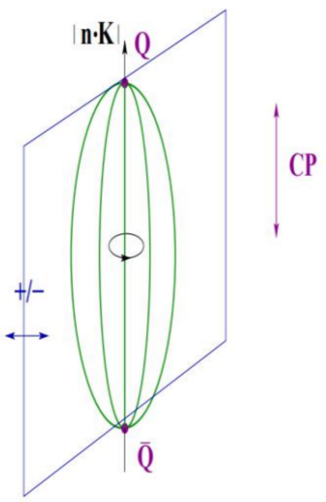


Figure 1: Quarkonium hybrid symmetries.

In analogy with di-atomic molecule:

Λ_η^ϵ ——cylinder symmetry along the $Q\bar{Q}$ axis

$|\vec{n}\cdot K| = 0, 1, 2, \cdots \Rightarrow \Lambda = \Sigma, \Pi, \Delta, \cdots$

η: CP of the flux tube, $CP = +, \ -\ \ (g, u)$

ϵ: reflection symmetry with respect to the plane including the $Q\bar{Q}$ axis

Spin of the meson : $J = L + S$

$L = L_{Q\bar{Q}} + K$

$L_{Q\bar{Q}}^2 = L^2 - 2\Lambda^2 + K^2 + \cdots$

PC of the meson :

$P = \epsilon(-1)^{L+\Lambda+1}, C = \eta\epsilon(-1)^{L+\Lambda+S}$

K. Juge et al., Phys. Rev. Lett. 82, 4400 (1999)

$$H = -\frac{1}{2\mu}\frac{\partial^2}{\partial r^2} + \frac{L(L+1)-\Lambda^2}{2\mu r^2} + E^1(r)$$

$$E^1(r) = -\frac{4\alpha_s}{3r} + c + br + \frac{\pi}{r}\left(1 - e^{-fb^{1/2}r}\right)$$

TABLE I. Some low-lying meson hybrids.

Flavor	J^{PC} or J^P	Mass (GeV) for $f=1$	$\frac{dm}{df}$ (GeV)	Δm [a] (GeV)	m [b] (GeV)
$I=1$	$2^{\pm\mp},1^{\pm\mp},0^{\pm\mp},1^{\pm\pm}$	1.67	0.08	0.19	~1.9
$I=\frac{1}{2}$	$2^{\pm},1^{\pm},0^{\pm},1^{\pm}$	1.80	0.10	0.17	~2.0
$I=0$ $\left[\frac{u\bar{u}+d\bar{d}}{\sqrt{2}}\right]$	$2^{\pm\mp},1^{\pm\mp},0^{\pm\mp},1^{\pm\pm}$	1.67	0.08	0.19	~1.9
$I=0$ $(s\bar{s})$	$2^{\pm\mp},1^{\pm\mp},0^{\pm\mp},1^{\pm\pm}$	1.91	0.12	0.14	~2.1
$c\bar{c}$	$2^{\pm\mp},1^{\pm\mp},0^{\pm\mp},1^{\pm\pm}$	4.19	0.18	0.06	~4.3
$b\bar{b}$	$2^{\pm\mp},1^{\pm\mp},0^{\pm\mp},1^{\pm\pm}$	10.79	0.28	0.02	~10.8

[a] Contribution to the mass from nonadiabatic effects, taken from Ref. 14.
[b] A "best guess" based on the previous columns.

Isgur & Paton, Phys. Rev. D 31 (1985) 2910

Hybrid in the Flux tube model

Flux-tube model has selection rule: (P. Page et al., Phys.Rev.D 59 (1999) 034016)

$$\langle AB|H_I|H\rangle \propto \int d^3\vec{r}(\phi_H(\vec{r})\cdots) \int_0^1 d\xi \cos(\xi\pi)\cdot \phi_A(\xi\vec{r})\cdot\phi_B((1-\xi)\vec{r})$$

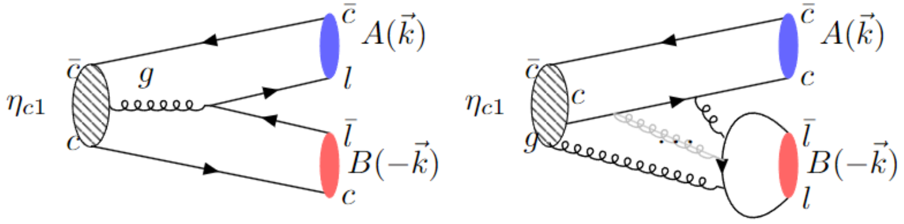
1) Modes of two S-wave mesons are suppressed, SP-modes are favored.

2) Modes of two identical mesons are prohibited.

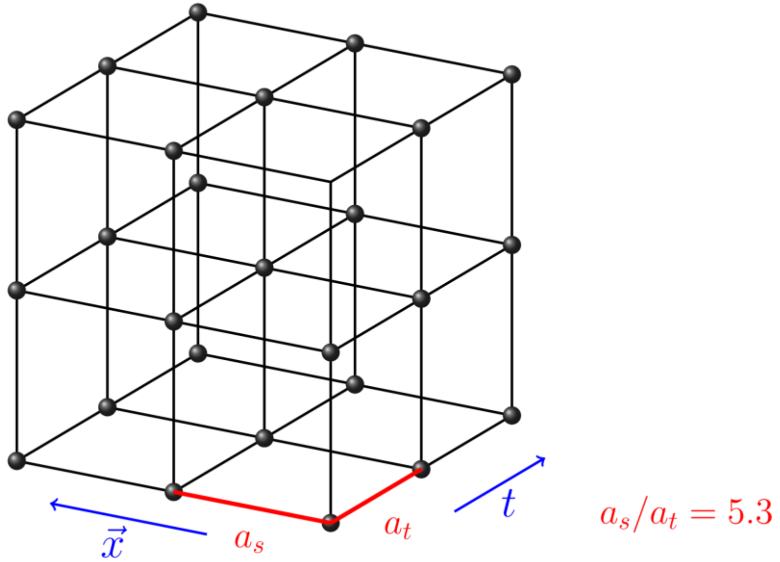
Open-charm and closed-charm decay modes

1） SP modes： $D_1\overline{D}$, $\chi_{c1}\eta(\eta')$

2） SS modes： $D^*\overline{D}$, $D^*\overline{D}^*$, $\eta_c\eta(\eta'), J/\psi\omega(\phi)$



Lattice setup



- Tadpole improved Symanzik's gauge action
  (C. Morningstar, PRD60(1999)034509)
- Anisotropic Lattice

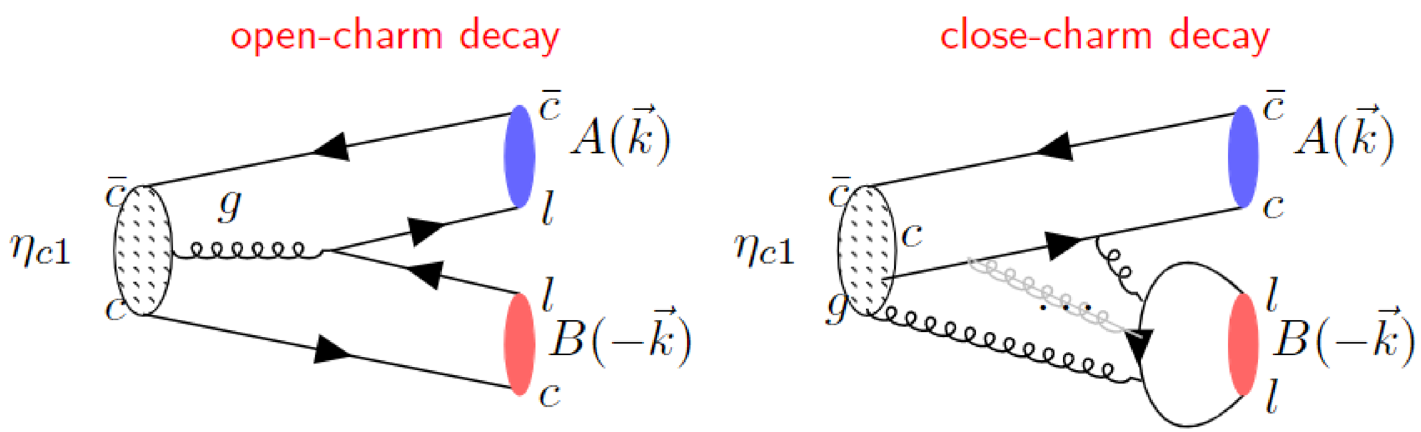
- $N_f = 2$ clover gauge ensembles with degenerate u, d quarks

IE	$N_s^3 \times N_t$	β	a_t^{-1}(GeV)	ξ	m_π(MeV)	N_V	N_{cfg}
L16	$16^3 \times 128$	2.0	6.894(51)	~ 5.3	~ 350	70	708
L24	$24^3 \times 192$	2.0	6.894(51)	~ 5.3	~ 350	160	171

See: Jiang et al, Phys.Rev.D 107 (2023) 094510

- **Distillation method**:
  (M.Peardon et al.(HSC.)(2009)PRD80,054506)
- disconnected diagrams are involved

η_{c1} decay modes



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: $\chi_{c1}\eta(S\text{-wave})$, $\eta_c\eta'(P\text{-wave})$, $J/\psi\omega(P\text{-wave})$.

- **The flavor wave functions of the open-charm modes**

$$|D\bar{D}'\rangle^{(I=0)}_{(C=+)} = \frac{1}{2}\left(|D^+D'^-\rangle + |D^0\bar{D}'^0\rangle\right) \pm \frac{1}{2}\left(|D^-D'^+\rangle + |\bar{D}^0D'^0\rangle\right)$$

$D' = D^*, D_1$,
"+" for $D\bar{D}^*$
"-" for $D\bar{D}_1$

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

$L + S = \text{even}$

Decay amplitudes in M&M method

Effective Lagrangian:

$$\mathcal{L}_{\mathrm{I}}^{\mathrm{cc}} \sim -\, g_{\chi\eta} m_{\eta_{c1}} H_\mu A^\mu \eta - i g_{\eta_c\eta} H_\mu \eta_c \overleftrightarrow{\partial}^{\mu} \eta + iH_\mu \left(g\psi_\nu \partial^\nu \omega^\mu + g'\omega_\nu \partial^\nu \psi^\mu + g_0 \psi_\nu \overleftrightarrow{\partial}^{\mu} \omega^\nu \right),$$

$$\mathcal{L}_{\mathrm{I}}^{\mathrm{oc}} \sim g_{D_1 D} m_{\eta_{c1}} H_\mu \frac{1}{2}\left(D_1^{\mu,\dagger} D + D^\dagger D_1^\mu \right) + g_{D^*\bar{D}^*} H^\mu \frac{i}{\sqrt{2}} \left(D^{\nu,\dagger} \partial_\nu D_\mu + \partial_\nu D_\mu^\dagger D^\nu \right) + \frac{g_{D^*\bar{D}}}{m_{\eta_{c1}}} \epsilon^{\mu\nu\rho\sigma} (\partial_\mu H_\nu) \frac{1}{2} \left[(\partial_\rho D_\sigma^\dagger) D - D^\dagger (\partial_\rho D_\sigma) \right].$$

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

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

$$\Rightarrow$$

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

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

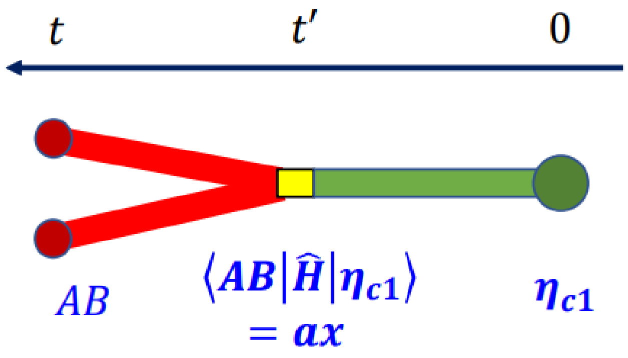
$$x_{AP}^{\lambda'\lambda} = g_{AP} m_{\eta_{c1}} \vec{\epsilon}_\lambda(\vec{0}) \cdot \vec{\epsilon}_{\lambda'}^{\,*}(\vec{k}),$$

$$x_{PP}^{\lambda} = 2 g_{PP} \vec{\epsilon}_\lambda(\vec{0}) \cdot \vec{k},$$

$$x_{VP}^{\lambda'\lambda} = g_{VP} \vec{\epsilon}_\lambda(\vec{0}) \cdot \left(\vec{\epsilon}_{\lambda'}^{\,*}(\vec{k}) \times \vec{k} \right),$$

$$x_{D^*\bar{D}^*}^{\lambda'\lambda''\lambda} = 2 g_{D^*\bar{D}^*} \vec{\epsilon}_\lambda(\vec{0}) \cdot \left(\vec{k} \times \left[\vec{\epsilon}_{\lambda'}^{\,*}(\vec{k}) \times \vec{\epsilon}_{\lambda''}^{\,*}(-\vec{k}) \right] \right),$$

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

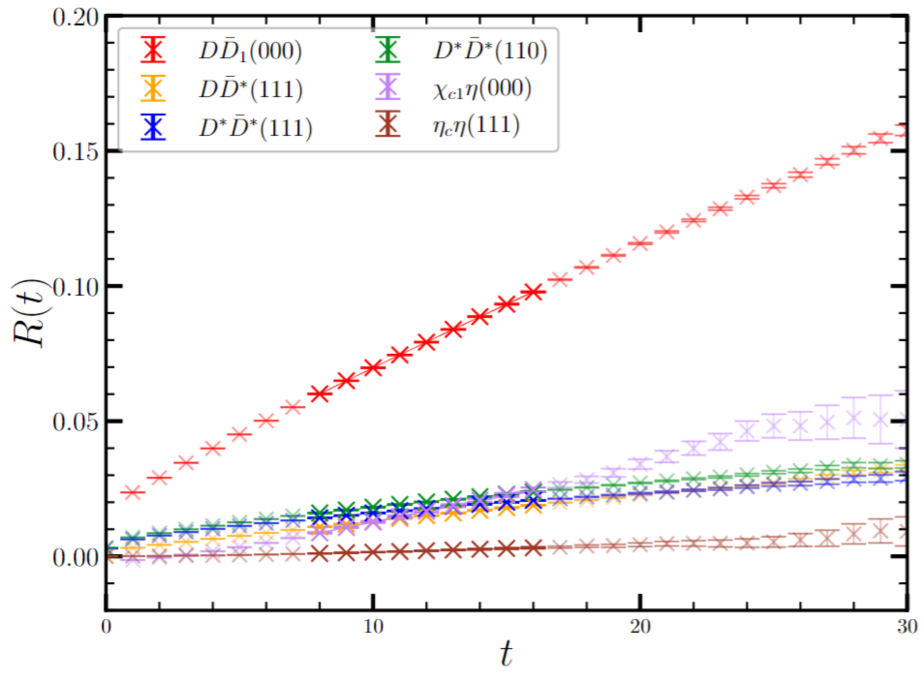


Lattice results

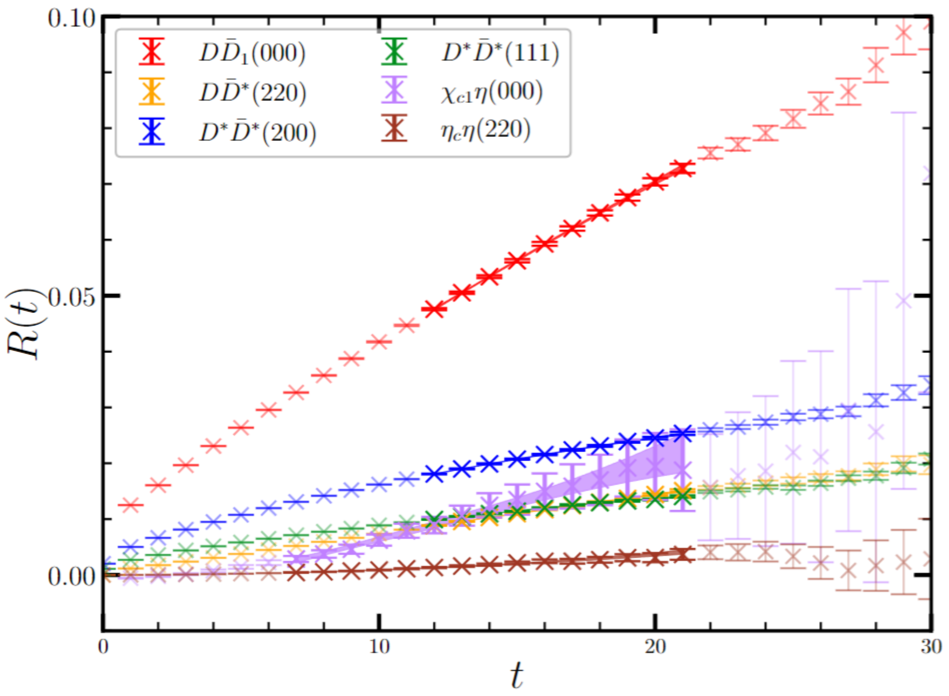
$$\mathcal{C}_{\eta_{c1},AB}(t) = \langle\Omega|\mathcal{O}_{AB}(t)\mathcal{O}^{+}_{\eta_{c1}}(0)|\Omega\rangle$$
$$= \langle\Omega|\mathcal{O}_{AB}(0)e^{-t\,a\hat{H}}\mathcal{O}^{+}_{\eta_{c1}}(0)|\Omega\rangle$$
$$\to -axt\; e^{-t\,a\bar{E}}\langle\Omega|\mathcal{O}_{AB}|AB\rangle\,\langle\eta_{c1}|\mathcal{O}^{+}_{\eta_{c1}}|\Omega\rangle$$

transition amplitude

$$\frac{\mathcal{C}_{\eta_{c1},AB}(t)}{\sqrt{\mathcal{C}_{\eta_{c1}}(t)\mathcal{C}_{A}(t)\mathcal{C}_{B}(t)}} \to -(ax)\,t\left(1+\frac{1}{24}(a\Delta\,t)^2\right)$$



L16



L24

Numerical results

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.

Numerical results

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

Mode (AB)	$\hat{k}$(IE)	r_1 $(\times 10^{-3})$	g_{AB}	g_{AB} (ave.)	Γ_{AB} (MeV)
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$$\overline{|\mathcal{M}(\eta_{c1} \to D^*\bar{D}^*)|^2} = \frac{4}{3} g^2 k_{\rm ex}^2 \frac{m_{\eta_{c1}}^2}{m_{D^*}^2}.$$

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

- $D_1\bar{D}$ dominates.
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This observation is in striking contrast to the expectation of the flux-tube model.

Results v.s. Flux-tube model

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(Isgur& Paton 1985)

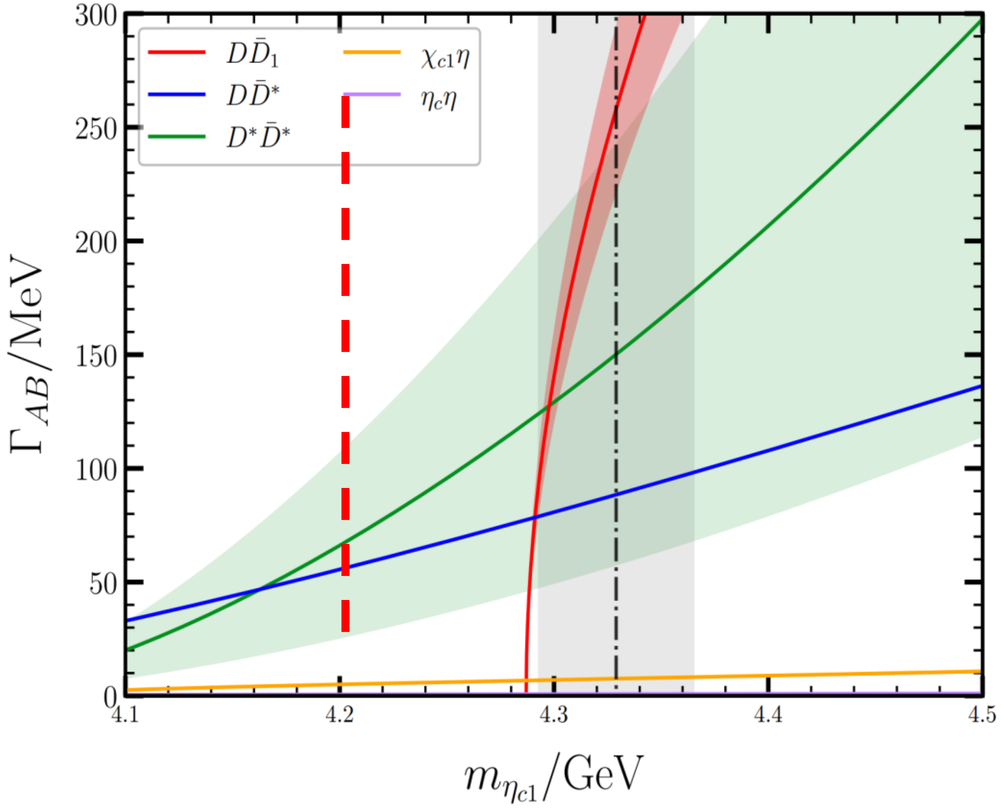
Flux tube model: light Isoscalar hybrid width ~150MeV

$c\bar{c}$ Isoscalar hybrid width ~30MeV

1^{-+}	D^*D	P	.5	.1
	$D^{**}(2^+)D$	D	–	.5
	$D^{**}(1^+_L)D$	S	–	1.2
		D	–	2.5
	$D^{**}(1^+_H)D$	S	–	25
		D	–	0
	Γ		.5	29

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

Conclusion



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

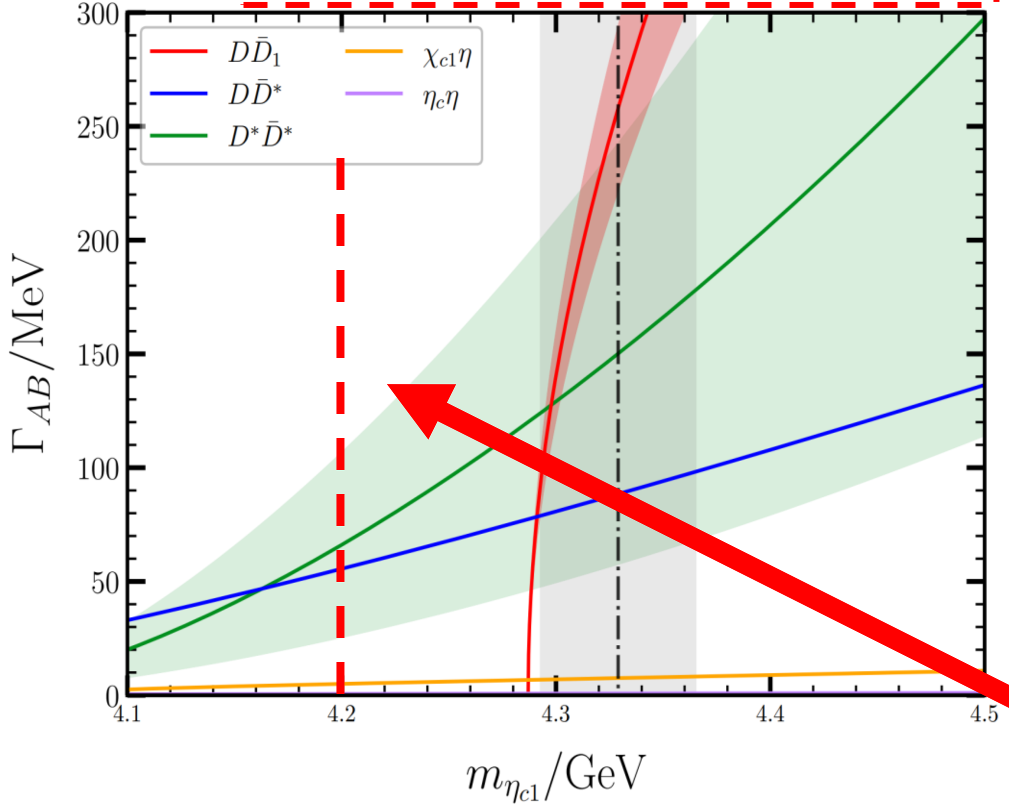
$$\Gamma_{D_1\bar{D}} = 258(133)\ \text{MeV}$$
$$\Gamma_{D^*\bar{D}^*} = 150(118)\ \text{MeV}$$
$$\Gamma_{D\bar{D}^*} = 88(18)\ \text{MeV}$$

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

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

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

$D_1\bar{D}$ threshold $\approx 4290 MeV$



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- **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

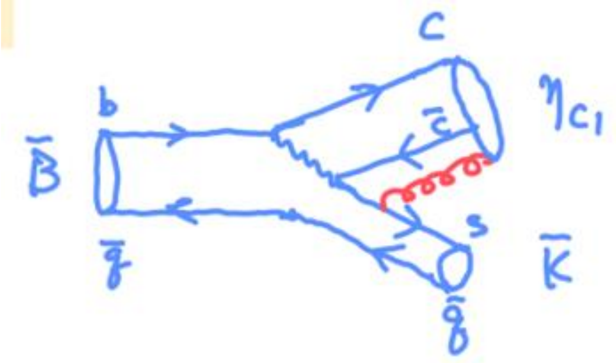
1) η_{c1} production on e^+e^- collider experiments: (BESIII)

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

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

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

(LHCb and Belle):



Summary

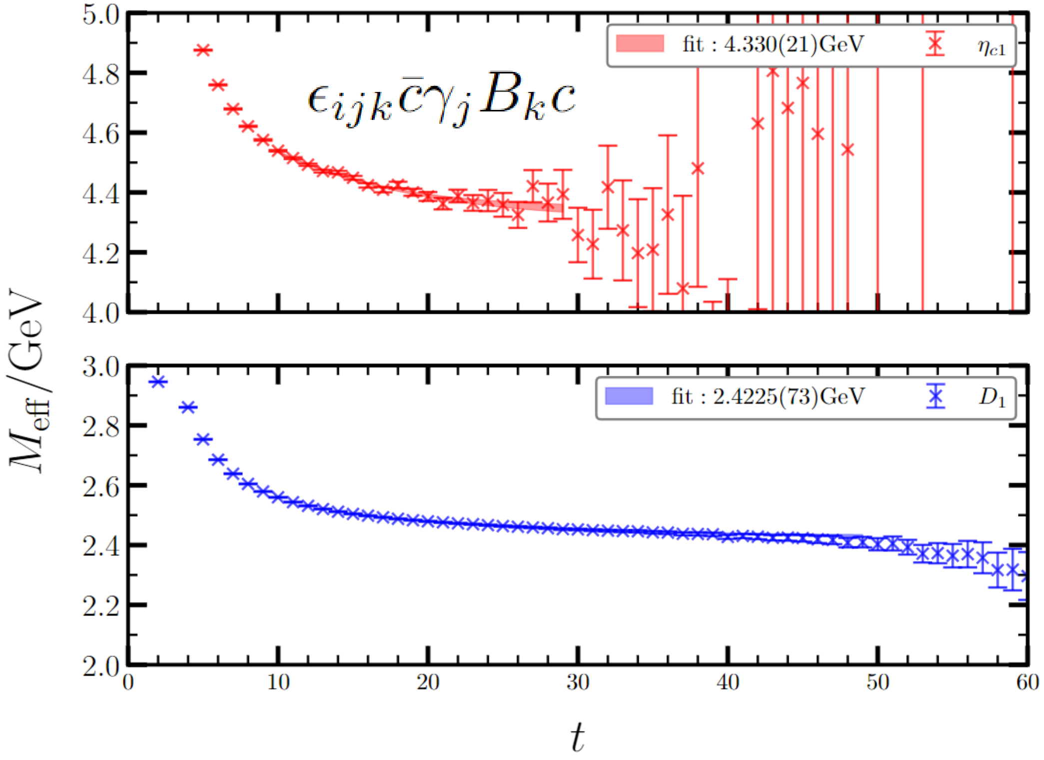
- ✓We give the first Lattice QCD prediction of the partial decay widths of the charmoniumlike η_{c1}.
- ✓Disfavor the results of the Flux-tube model (Disfavor the S-wave suppression).
- ✓We provide the theoretical information for the experimental search for charmoniumlike hybrid η_{c1}.

Thank You

Backup slides

Meson spectrum on our lattice

X	ω	$\eta_{(2)}$	η_c	J/ψ	χ_{c1}	D	D^*	D_1	η_{c1}
m_X(L16)(MeV)	857(10)	715(10)	2975.0(3)	3099.1(2)	3559.8(1.7)	1882(1)	2023(1)	2423(7)	4330(21)
m_X(L24)(MeV)	845(7)	705(21)	2976.3(4)	3099.4(4)	3560.4(6.4)	1881(1)	2019(1)	2430(10)	4328(68)
m_X(PDG)(MeV) [42]	782	547/958	2983	3097	3511	$\sim$ 1867	$\sim$ 2008	2420	-



Partial-wave operators

$$\mathcal{O}^{M}_{AB;JLSP}(\hat{k}) = \sum_{M_L,M_S,M_A,M_B} \langle L, M_L; S, M_S | JM \rangle \langle S_A M_A; S_B M_B | S, M_S \rangle$$
$$\times \sum_{R\in O_h} Y^{*}_{LM_L}(R\circ\vec{k})\mathcal{O}^{M_A}_{A}(R\circ\vec{k})\mathcal{O}^{M_B}_{B}(-R\circ\vec{k}),$$

Mode (AB)	E_{AB} (MeV)	$a_t\Delta$	r_0	r_1 $(\times 10^{-3})$	r_3 $(\times 10^{-7})$
L16	$(m_{\eta_{c1}} = 4330(21)$ MeV)				
$D\bar{D}_1(000)$	4304(7)	$\sim$ 0.004	0.02077(38)	4.95(5)	-5.1(1.3)
$D\bar{D}^*(111)$	4301(4)	$\sim$ 0.004	0.00210(19)	1.11(3)	-2.2(8)
$D^*\bar{D}^*(111)$	4405(10)	$\sim$ -0.011	0.00702(25)	1.00(3)	-4.3(9)
$D^*\bar{D}^*(110)$	4288(4)	$\sim$ 0.006	0.00702(25)	1.15(4)	-4.1(9)
$\chi_{c1}\eta_{(2)}(000)$	4262(8)	$\sim$ 0.010	-0.0076(18)	2.04(26)	-0.9(6.8)
$\eta_c\eta_{(2)}(111)$	4347(39)	$\sim$ -0.003	-0.00057(39)	0.20(6)	1.6(1.6)
L24	$(m_{\eta_{c1}} = 4328(68)$ MeV)				
$D\bar{D}_1(000)$	4310(10)	$\sim$ 0.003	0.0110(26)	3.10(26)	-3.3(3.5)
$D\bar{D}^*(220)$	4361(5)	$\sim$ -0.005	-0.00027(69)	0.78(7)	-1.07(97)
$D^*\bar{D}^*(200)$	4269(2)	$\sim$ 0.009	0.00598(87)	1.05(9)	-3.1(1.2)
$D^*\bar{D}^*(111)$	4216(3)	$\sim$ 0.016	0.00234(62)	0.67(7)	-2.50(83)
$\chi_{c1}\eta_{(2)}(000)$	4260(7)	$\sim$ 0.010	-0.0057(27)	1.18(38)	-3.0(9.0)
$\eta_c\eta_{(2)}(220)$	4304(25)	$\sim$ 0.004	-0.00037(17)	0.10(3)	2.49(77)

Fitting stability