Quark mass dependence of charmed mesons

R. Molina, F. Gil, A. Giachino, and Pan-Pan Shi

Table of contents

Motivation: Heavy quark symmetry and exotic states

Heavy quark spin and flavor symmetries

- Heavy quark symmetries arises when $m_Q >> \Lambda_{QCD}$. $Q\bar{q}$ system, $\Delta p \simeq \Lambda_{QCD} \longrightarrow \Delta v = \frac{\Delta p}{m_Q} \to 0$ in the limit $m_Q \to \infty$. The heavy quark behaves as a static source.
- The heavy quark interacts with gluons through the chromoelectric charge. Spin dependent interactions, $\mu^c \propto 1/m_Q$. Heavy Quark Spin Symmetry (HQSS) and Heavy Quark Flavor Symmetry (HQFS) Isgur, Nathan and Wise, Mark B.PLB89, PLB90, PRL91, Manohar, Aneesh V. and Wise, Mark B., "Heavy Quark Physics"
- SU(2) spin symmetry, heavy hadrons organize into doublets with approximately similar mass and it is possible to work in this basis

$$|S_H, L, J\rangle \quad \text{HQSS basis} \tag{1}$$

- Doublets

$$(D, D^*) \quad (\eta_c, J/\psi) \quad (D_s, D_s^*) \cdots \tag{2}$$

$Q\bar{q}$-like systems

´ $D_{(s)}$ mesons, $j_l = L \pm \frac{1}{2}$

- $L = 0 : J^P = 0^-, 1^-$ (D, D^*), (D_s, D_s^*)
- $L = 1$: Two Doublets:
  - $j_l^P = \frac{1}{2}^+$. $J^P = (0,1)^+$. $D^*(2300)$, $D_1(2420)$?
  - $j_l^P = \frac{3}{2}^+$. $J^P = (1,2)^+$. $D_1(2430)$, $D_2^*(2460)$?
  - $j_l^P = \frac{1}{2}^+$. $J^P = (0,1)^+$. $D_{s0}(2317)$, $D_{s1}(2460)$?
  - $j_l^P = \frac{3}{2}^+$. $J^P = (1,2)^+$. $D_{s1}(2536)$, $D_{s2}^*(2573)$?
- However, there are some puzzles:
  - Exp. masses and widths of the $D_{s0}(2317)$ and $D_{s1}(2460)$ not compatible with $q\bar{q}$ expectations. Role of the DK, D^*K channel.
  - Masses of the D_s counterparts are expected to be 100 higher since $m_s/m_d \simeq 20$. Godfrey, Isgur, Kokoski, PRD79,85 However,

$$B(D_{s0}(2317))_{DK} \simeq B(D_{s1}(2460))_{D^*K} \simeq 40 \text{ MeV} \qquad (3)$$

  - Measurement of the $D_0^*(2300)$ mass varies from $2300 - 2400$ MeV. Possible two pole structure related to $D\pi$, $D_s\bar{K}$ channels. Not confirmed yet by LQCD (see C. Thomas talk on Monday).

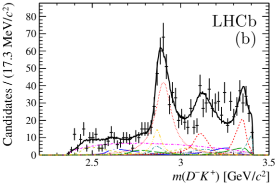
Kolomeitsev and Lutz, PLB04, Albaladejo, Fernandez-Soler, Nieves, Guo

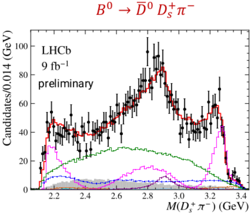
Flavor exotic tetraquarks

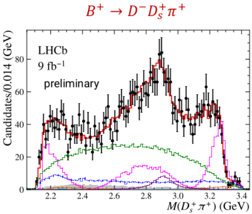
LHCb (2020, 2022)

T_{cs} states $J^P = 0^+, 1^-$ decaying to $D\bar{K}$, and $T_{c\bar{s}}(2900)$ (0^+), decaying to $D_s^+\pi^-$ and $D_s^+\pi^+$, $\sim cs\bar{q}\bar{q}, c\bar{s}qq, q = u, d$.

$$T_{cs,0}(2866) : M = 2866 \pm 7, \quad \Gamma = 57.2 \pm 12.9\,\mathrm{MeV},$$
$$T_{cs,1}(2900) : M = 2904 \pm 5, \quad \Gamma = 110.3 \pm 11.5\,\mathrm{MeV}$$
$$T_{c\bar{s}}(2900) : M = 2908 \pm 11\ \mathrm{MeV}, \quad \Gamma = 136 \pm 23\ \mathrm{MeV}$$







R. Aaij et al. (LHCb Collaboration), PRL20, PRD20, PRD23

Flavour exotic states

Molina, Branz, Oset, PRD10 HGF-Interaction of vector mesons

C, S	Channels	$I[J^P]$	$\sqrt{s}$	$\Gamma_A(\Lambda = 1400)$	$\Gamma_B(\Lambda = 1200)$	State	$\sqrt{s}_{exp}$	Γ_{exp}
$1, -1$	$D^* \bar{K}^*$	$0[0^+]$	2848	23	59	$X_0(2866)$ or $T_{cs}(2900)$	2866	57
		$0[1^+]$	2839	3	3			
		$0[2^+]$	2733	11	36			
$1, 1$	$D^* K^*$, $D_s^* \omega$	$0[0^+]$	2683	20	71			
	$D_s^* \phi$	$0[1^+]$	2707	4×10^{-3}	4×10^{-3}			
		$0[2^+]$	2572	7	23	$D_{s2}(2573)$	2572	20
$1, 1$	$D^* K^*$, $D_s^* \rho$	$1[0^+]$	Cusp structure around $D_s^* \rho$, $D^* K^*$			new $T_{c\bar{s}}(2900)$	2908	136
$1, 1$		$1[1^+]$	Cusp structure around $D_s^* \rho$, $D^* K^*$					
$1, 1$		$1[2^+]$	2786	8	11			
$2, 0$	$D^* D^*$	$0[1^+]$	3969	0	0			
$2, 1$	$D^* D_s^*$	$1/2[1^+]$	4101	0	0			

Updates: Dai, Molina, Oset, PRD22, $B_{D^* D^*} \simeq 5$ MeV. Cusp at the $D^* D_s^*$ threshold. $T_{cs}/T_{c\bar{s}}$, Molina, Oset, PLB20, PRD23

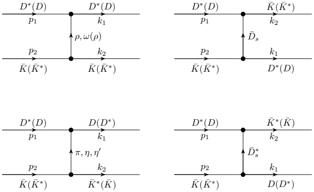
Sign of a new resonance below the $D^* D^*$ threshold from LQCD

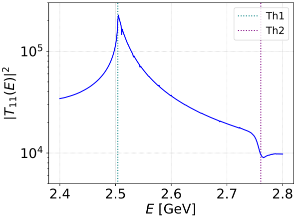
Whyte, Wilson, Thomas, 2405.15741 (2024)

Flavour exotic states

New prediction of states in the coupled-channel system $D^*\bar{K} - D\bar{K}^*$

	single channel		coupled channel	
Pole [MeV]	$2482.35 - 0.04i$	$2760.18 - 7.27i$	$2486.46 - 0.04i$	$2761.27 - 5.22i$
RS	$(-)$	$(+)$	$(-,+)$	$(-,+)$
Channel	Coupling g_i [GeV]			
$D^*\bar{K}(S)$	$0.00 - 4.10i$	—	$0.00 + 3.96i$	$0.05 - 0.42i$
$D^*\bar{K}(D)$	$0.00 - 0.00i$	—	$0.00 - 0.00i$	$0.26 - 0.09i$
$D\bar{K}^*(S)$	—	$1.89 - 0.52i$	$-0.09 + 2.24i$	$1.94 - 0.92i$
$D\bar{K}^*(D)$	—	$-0.00 - 0.00i$	$0.12 + 0.20i$	$-0.01 - 0.01i$





Quark mass dependence of exotic states

HHChPT

Heavy meson field: $P_l^{(*)} = (D^{(*)0}, D^{(*)+}, D_s^{(*)})$

$$H_l^{(Q)} = \frac{(1+\not{v})}{2}(P_{l\mu}^{*(Q)}\gamma^\mu - P_l^{(Q)}\gamma_5) \ . \tag{4}$$

They transforms as a doublet under heavy quark spin symmetry and like an anti-triplet under $SU(3)_V$ flavour symmetry,

$$H_l^{(Q)} \to S_Q(H^{(Q)}U^\dagger)_l, \quad \bar{H}_l^{(Q)} \to (U\bar{H}^{(Q)})_l S_Q^\dagger \tag{5}$$

At leading order, the chiral lagrangian reads (Jenkins, NPB94),

$$\mathcal{L}^0 = -i\,\mathrm{Tr}\bar{H}_v(v\cdot\partial)H_v + i\,\mathrm{Tr}\bar{H}_v H_v(v\cdot V) + 2g\,\mathrm{Tr}\bar{H}_v H_v(S_{lv}\cdot A) \tag{6}$$

with $g^2 = 0.55$. Relevant lagrangian for one-calculation,

$$\mathcal{L}_v^{\not{s}} = \sigma\,\mathrm{Tr}M_\xi\mathrm{Tr}\bar{H}_v H_v + a\,\mathrm{Tr}\bar{H}_v H_v M_\xi + b\,\mathrm{Tr}\bar{H}_v H_v M_\xi M_\xi + c\,\mathrm{Tr}M_\xi\mathrm{Tr}\bar{H}_v H_v M_\xi + d\,\mathrm{Tr}M_\xi M_\xi\mathrm{Tr}\bar{H}_v H_v$$
$$- \frac{\Delta}{8}\mathrm{Tr}\bar{H}_v\sigma^{\mu\nu}H_v\sigma_{\mu\nu} - \frac{\Delta^{(a)}}{8}\mathrm{Tr}\bar{H}_v\sigma^{\mu\nu}H_v\sigma_{\mu\nu}M_\xi - \frac{\Delta^{(\sigma)}}{8}\mathrm{Tr}M_\xi\mathrm{Tr}\bar{H}_v\sigma^{\mu\nu}H_v\sigma_{\mu\nu} \ , \tag{7}$$

(a,b,c,d,σ) Respect HQSS $\mathcal{O}(1)$; $(\Delta, \Delta^{(\sigma)}, \Delta^{(a)})$ $\mathcal{O}(1/m_Q)$; $\frac{m_B^* - m_B}{m_D^* - m_D} \sim \frac{m_D}{m_B}$

Quark mass dependence of the $D(D^*)$ mesons

Heavy Hadron Chiral Perturbation Theory (HHχPT)

E. Jenkins, NPB412 (1994); Gil-Domínguez, Molina PLB (2023)

$$\frac{1}{4}(D+3D^*) = m_H + \alpha_a - \sum_{X=\pi,K,\eta} \beta_a^{(X)} \frac{M_X^3}{16\pi f^2} + \sum_{X=\pi,K,\eta} \left(\gamma_a^{(X)} - \lambda_a^{(X)}\alpha_a\right) \frac{M_X^2}{16\pi^2 f^2} \log\left(M_X^2/\mu^2\right) + c_a$$

$$(D^* - D) = \Delta + \sum_{X=\pi,K,\eta} \left(\gamma_a^{(X)} - \lambda_a^{(X)}\Delta\right) \frac{M_X^2}{16\pi^2 f^2} \log\left(M_X^2/\mu^2\right) + \delta c_a$$

$\mu = 770$ MeV; $g^2 = 0.55$ MeV (Decay of the D^* meson)

$$\left.\begin{aligned} \frac{1}{4}(D+3D^*) &= m_H + f(\sigma,a,b,c,d) \\ (D^*-D) &= \Delta + g(\Delta^{(\sigma)}, \Delta^{(a)}) \end{aligned}\right\}$$

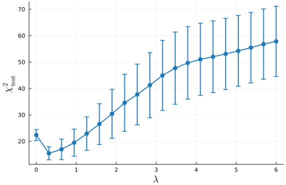
9 parameters, but different collaborations/scale settings, $7 + 2\times 7 = 21$ parameters, ~ 80 data points

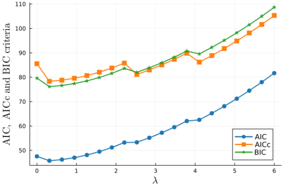
ETMC, PACS, HSC, CLS, RQCD, S.Prelovsek, MILC

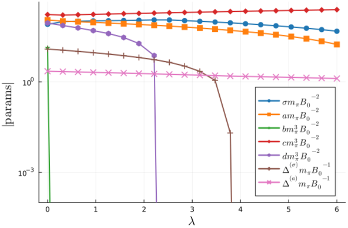
$D(D^*$ quark mass dependence

LASSO + information criteria;

$$\chi_P^2 = \chi^2 + \lambda \sum_i^n |p_i|; \quad \text{Data} = \text{Training}\,(70\%) + \text{Test}\,(30\%) \qquad (8)$$







Some of the parameters are not relevant

Plots for ETMC data analysis

$D(D^*)$ quark mass dependence

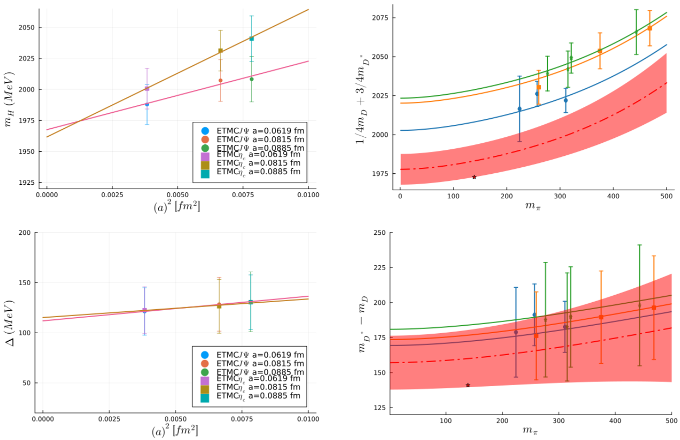


Figure 1: Extrapolation to the physical point of the ETMC data.
$m_H = m'_H + r_H a^2$, $\Delta = \Delta' + r_\Delta a^2$.

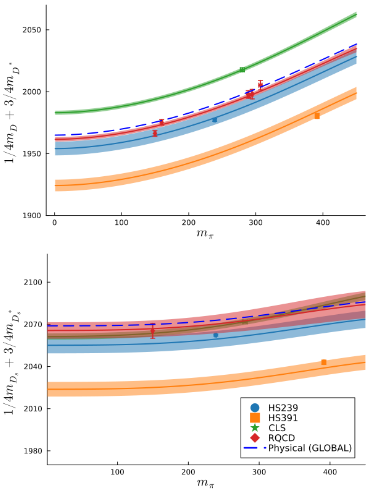
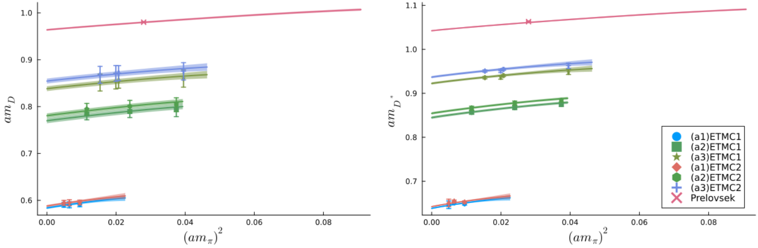


Figure 2: Results of the D, D^*, D_s and D_s^* meson masses for the global analysis of some collaborations.

Global analysis



Fit	$\frac{\sigma m_\pi}{B_0{}^2}\cdot 10^{-4}$	$\frac{a m_\pi}{B_0{}^2}\cdot 10^{-4}$	$\frac{b m_\pi^3}{B_0{}^2}\cdot 10^{-10}$	$\frac{c m_\pi^3}{B_0{}^2}\cdot 10^{-10}$	$\frac{d m_\pi^3}{B_0{}^2}\cdot 10^{-10}$	$\frac{\Delta^{(\sigma)} m_\pi}{B_0}\cdot 10^{-5}$	$\frac{\Delta^{(a)} m_\pi}{B_0}\cdot 10^{-5}$
$\text{ETMC}_{(\text{I})}$	0.89 ± 0.08	2.08 ± 0.13	-0.55 ± 0.21	6.51 ± 0.20	3.39 ± 0.18	5.78 ± 3.43	-2.16 ± 2.27
$\text{ETMC}_{(\text{II})}$	1.02 ± 0.01	2.02 ± 1.18	-	6.16 ± 0.24	3.24 ± 0.27	5.88 ± 3.85	-2.17 ± 2.24
$\text{MILC}_{(\text{I})}$	3 ± 22	3 ± 18	7 ± 108	2 ± 55	1.56 ± 7.08	4 ± 255	36 ± 478
$\text{MILC}_{(\text{II})}$	1.74 ± 0.40	2.40 ± 0.73	-	5.61 ± 1.66	-	-	-
$\text{PACS}_{(\text{I})}$	0.90 ± 0.24	2.62 ± 0.20	-2.38 ± 1.81	7.03 ± 1.24	3.53 ± 0.74	3.60 ± 0.16	-0.76 ± 0.44
$\text{PACS}_{(\text{II})}$	1.22 ± 0.02	2.36 ± 0.03	-	5.40 ± 0.03	4.50 ± 0.03	3.59 ± 0.16	-0.75 ± 0.44
$\text{GLOBAL}_{(\text{I})}$	1.84 ± 0.01	2.54 ± 0.02	0.57 ± 0.05	4.47 ± 0.04	2.34 ± 0.03	2.70 ± 0.21	-1.43 ± 0.47
$\text{GLOBAL}_{(\text{II})}$	1.17 ± 0.01	2.58 ± 0.02	-	4.89 ± 0.05	2.27 ± 0.03	2.56 ± 0.20	-1.47 ± 0.46

Table 1: (I) "before LASSO" and (II) "after LASSO".

Quark mass dependence of $D_{s0}(2317)$ and $D_{s1}(2460)$

Predictions: Cleven, Guo, Hanhart, Meissner (2011); Liu, Orginos, Guo, Meissner, (2013); Previous analyses of LQCD data: Martínez Torres, Oset, Prelovsek, A. Ramos (2015), Yao, Du, Guo, and Meißner, (2015); Albaladejo, Fernandez-Soler, Nieves, Ortega, (2018). LQCD data:

Col.	a(fm)	L(fm)	m_π(MeV)	m_{D_s}(MeV)
	0.12			
HSC	$a_t^{-1} = 6079$ MeV	3.8	239	1967
(2021)	$a_t^{-1} = 5667$ MeV	$1.9 - 2.9$	391	1951
RQCD (2017)	0.071	4.5	150	1977
PACS-CS (2014)	0.0907	2.9	156	1809
Prelovsek et al.	0.1239	2.0	266	1657

Table 2: Charm quark mass settings, m_{D_s}. $m_{D_s}^{phys} = 1968.35 \pm 0.07$ MeV.

Formalism in the finite volume

Infinite volume (Two-meson loop)

$$G = G^{co}(E) = \int_{q<q_{max}} \frac{d^3q}{(2\pi)^3} \frac{\omega_1+\omega_2}{2\omega_1\omega_2} \frac{2M_i}{E^2-(\omega_1+\omega_2)^2+i\epsilon}$$

where $\omega_i = \sqrt{m_i^2 + |\vec{q}_i\,|^2}$.

Finite volume (Doring, Meißner, Oset, Rusetsky (2011))

$$\vec{q}_i = \frac{2\pi}{L}\vec{n}_i; \qquad T \longrightarrow \tilde{T}; \qquad G(E) \longrightarrow \tilde{G}(E)\ ,$$

$$\tilde{G}(E) = \frac{1}{L^3}\sum_{\vec{q}_i} I(E,\vec{q}_i); \qquad I(E,\vec{q}_i) = \frac{\omega_1(\vec{q}_i)+\omega_2(\vec{q}_i)}{2\omega_1(\vec{q}_i)\omega_2(\vec{q}_i)} \frac{1}{(E)^2-(\omega_1(\vec{q}_i)+\omega_2(\vec{q}_i))^2}$$

$$\tilde{G} = G^{DR} + \lim_{q_{max}\to\infty}\left(\frac{1}{L^3}\sum_{q<q_{max}} I(E,\vec{q}) - \int_{q<q_{max}} \frac{d^3q}{(2\pi^3)} I(E,\vec{q})\right)$$

$$\equiv G^{DR} + \lim_{q_{max}\to\infty} \Delta G\ ,$$

Martinez Torres, Dai, Koren, Jido and Oset (2012)

Formalism in the finite volume

- **Bethe-Salpeter** equation in finite volume, **One-channel case**

$$\tilde{T}^{-1} = V^{-1} - \tilde{G}$$

- Energy levels in the box in the presence of interaction V correspond to the condition

$$\boxed{\det(I - V\tilde{G}) = 0}$$

- One-channel-amplitude in infinite volume T

$$T = (\tilde{G}(E_i) - G(E_i))^{-1}.$$

- Phase shift and scattering parameters:

$$\tan\delta = -k/(8\pi E \Delta G); \quad p\cot\delta = \frac{1}{a} + \frac{1}{2} r_0 p^2 \ .$$

(Similar to the Lüscher condition (1986) but relativistic.)

Boosts

Doering, Meißner, Oset, Rusetsky (2012)

$\vec{q}_1, \vec{q}_2 = \vec{P} - \vec{q}_1$, $s \equiv W^2 = (P^0)^2 - \vec{P}^2$, and $\vec{q}^*$ the momenta in the CM frame

$$\int \frac{d^3\vec{q}^{\,*}}{(2\pi)^3} I(|\vec{q}^{\,*}|) \to \tilde{G}(P) = \frac{1}{L^3}\frac{\sqrt{s}}{P^0}\sum_{\vec{n}} I(|\vec{q}^{\,*}(\vec{q})|).$$

$\vec{q}^{\,*}_{1,2} = \vec{q}_{1,2} + \left[\left(\frac{\sqrt{s}}{P^0} - 1\right)\frac{\vec{q}_{1,2}\cdot\vec{P}}{|\vec{P}|^2} - \frac{q^{*0}_{1,2}}{P^0}\right]\vec{P}$; with $\vec{q} = \frac{2\pi}{L}(n_x, n_y, n_z)$, $\vec{P} = \frac{2\pi}{L}(N_x, N_y, N_z)$.

$$\tilde{T}_{lm,l'm'} = V_l \delta_{ll'}\delta_{mm'} + \sum_{l''m''} V_l \tilde{G}_{lm,l''m''}\tilde{T}_{l''m'',lm}$$

$$\boxed{\det(\delta_{ll'}\delta_{mm'} - V_l \tilde{G}_{lm,l'm'}) = 0}$$

Irreducible representations for asymmetric boxes and boost $\vec{P} = \frac{2\pi}{L}(0, 0, 1)$,

$$\mathrm{I = L = 0 \longrightarrow A^+ : -1 + V_0 G_{00,00} = 0}$$

$$\mathrm{I = L = 1 \longrightarrow A_2^- : -1 + V_1 G_{10,10} = 0; E^- : -1 + V_1 G_{11,11} = 0}$$

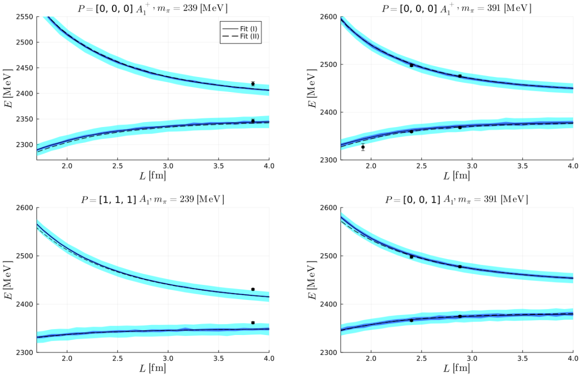
Quark mass dependence of $D_{s0}(2317)$ and $D_{s1}(2460)$

Potential $V(s)$ (consistent with HQSS)

$$V(s) = V_{DK}(s) + V_{\rm ex}(s); \quad V_{DK} = -\frac{s-u}{2f^2}; \quad \text{Fit I}: V_{\rm ex} = 0;$$

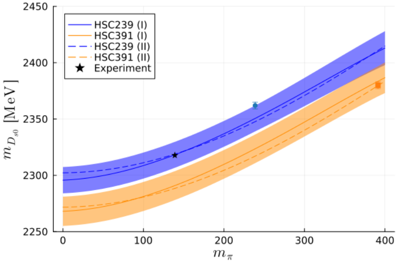
$$\text{Fit II}: V_{\rm ex} = \frac{V_{c\bar{s}}^2}{s - m_{c\bar{s}}^2}; V_{c\bar{s}}(s) = -\frac{c}{f}\sqrt{M_D m_{c\bar{s}}}\frac{s + m_K^2 - M_D^2}{\sqrt{s}}$$

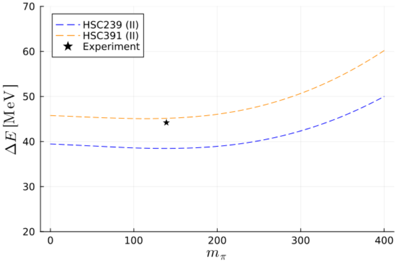
Fitting parameters: $a = a_1 + a_2 m_\pi^2$ (subtraction constant), m_{cs}, c.



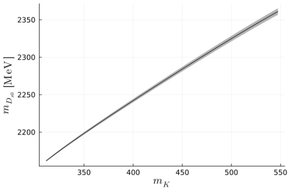
Quark mass dependence of $D_{s0}(2317)$ and $D_{s1}(2460)$

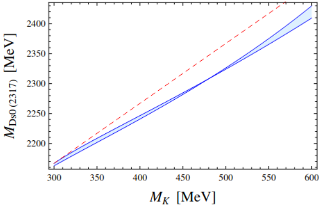
Pion and kaon mass dependence



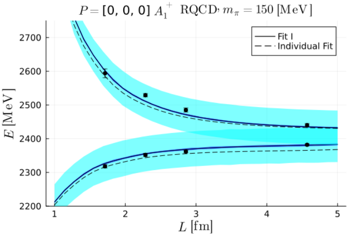


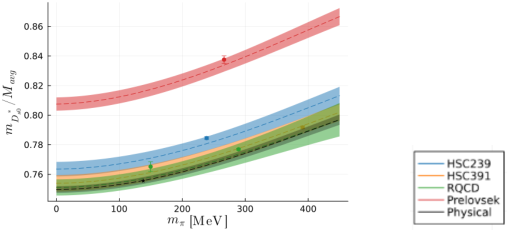
$m_\pi = 236$ MeV; $a_t^{-1} = 5.667$ GeV; $a_t M_{\eta_c} = 0.2412$, $M_{\eta_c} = 2986$ MeV; $m_\pi = 391$ MeV; $a_t^{-1} = 6.079$ GeV; $a_t M_{\eta_c} = 0.2735$; $M_{\eta_c} = 2963$ MeV; Similar trends than in Cleven, Guo, Hanhart, Meißner (2010)

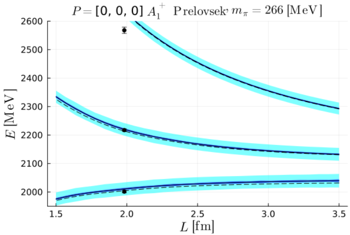


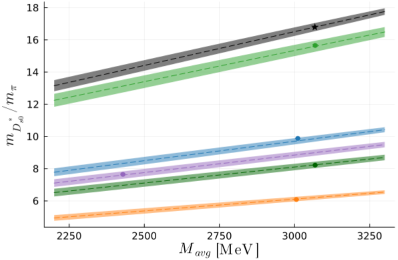


Quark mass dependence of $D_{s0}(2317)$ and $D_{s1}(2460)$

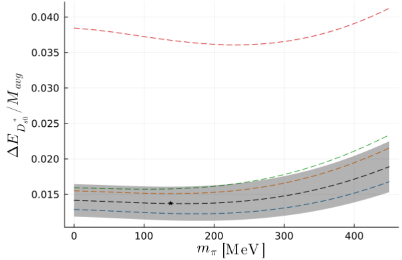


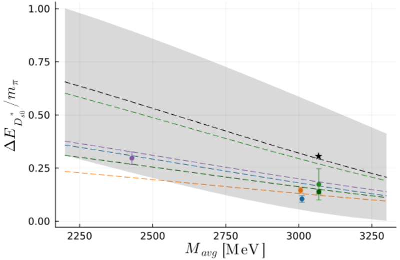


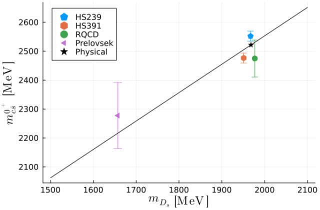




Quark mass dependence of $D_{s0}(2317)$ and $D_{s1}(2460)$







	c	$a_1^{0^+}$	$a_1^{1^+}$	$a_2[(m_\pi^0)^{-2}]$
Fit I	-	$-1.87(1)$	$-2.05(2)$	$-0.040(2)$
Fit II	$1.05(1)$	$-1.34(1)$	$-1.44(1)$	$-0.002(1)$

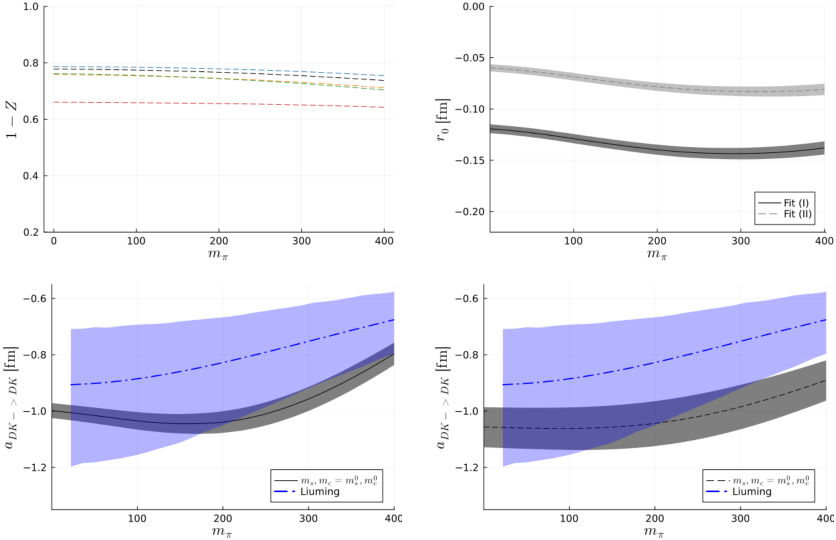
	$m_{c\bar{s}}^{0^+}$	$m_{c\bar{s}}^{1^+}$
HSC239	2552(26)	-
HSC391	2476(25)	-
RQCD	2475(25)	2553(25)
Prelovsek	2277(23)	2356(23)

$m_{D_s} - m_{D_s^0} \simeq m_{c\bar{s}} - m_{c\bar{s}^0}$. Compatible with Albaladejo, Nieves, PRD18

Quark mass dependence of $D_{s0}(2317)$ and $D_{s1}(2460)$

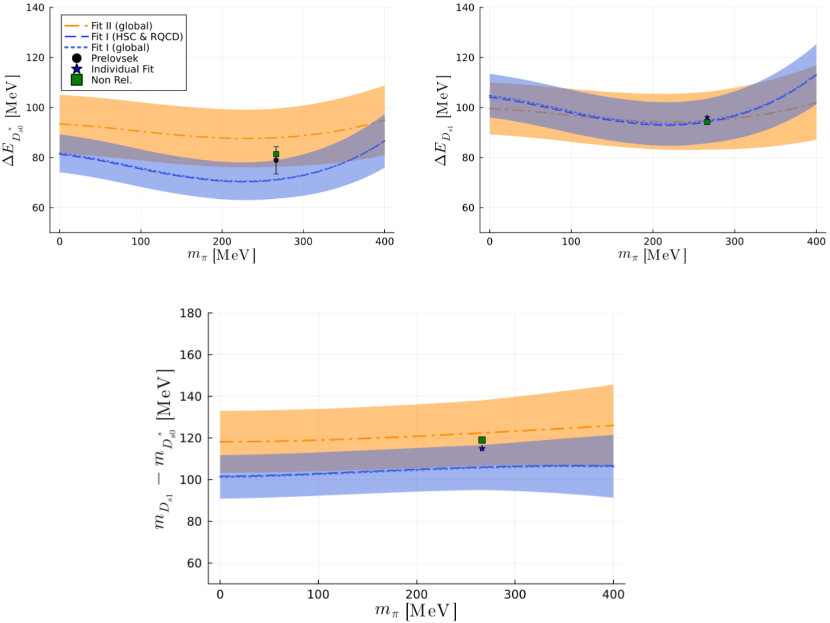
Compositeness and Scattering parameters

See also Dai,Song,Oset,PLB (2023)



Comparison with Liu, Orginos, Guo, Meissner (2013)

Quark mass dependence of $D_{s0}(2317)$ and $D_{s1}(2460)$



Decay width of the $D_{s0}^*(2317)$ to $D_s^+\pi^0$

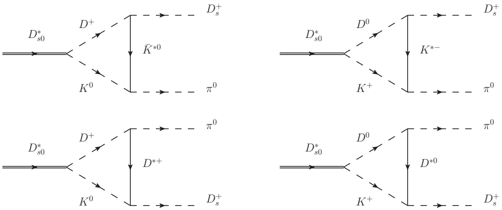


Figure 3: Feynman diagrams of the $D_s^{*0} \to D_s^+\pi^0$.

$\pi^0 - \eta$ mixing

$$\tilde{\pi}^0 = \pi^0 \cos\tilde{\epsilon} + \eta_8 \sin\tilde{\epsilon}$$

$$\tilde{\eta} = -\pi^0 \sin\tilde{\epsilon} + \eta_8 \cos\tilde{\epsilon}$$

with $\eta_8 = \frac{2\sqrt{2}}{3}\eta - \frac{1}{3}\eta'$

$$g_X = \frac{g_{DK}^{(I=0)}}{\sqrt{2}}$$

$$\Gamma_X = |\vec{p}_f| \frac{|t|^2}{8\pi m_X^2} \tag{9}$$

$$\boxed{\Gamma_{D_{s0}^*} = 128 \pm 40\ \mathrm{KeV}}$$

H. L. Fu et al., 120^{+18}_{-4} KeV, EPJA58(2022), M. Cleven,

$c\bar{s}$ state: $\Gamma = 7.83^{+1.97}_{-1.55}$ KeV

M. Han et al., CPC23

Results for the T_{cc}

Preliminary (including only vector meson exchange)

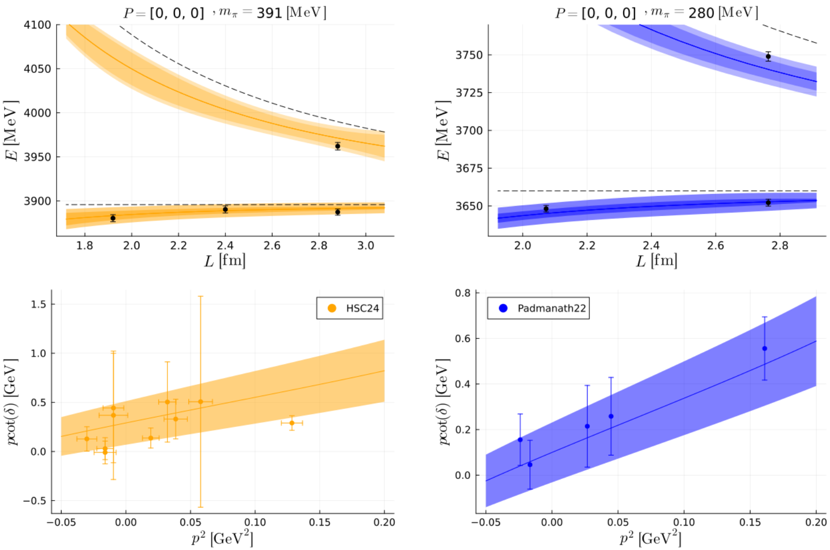
$$V^{\rho(I=0)}_{\lambda,\lambda'}(p,p') = -g^2 \frac{(p_1+p_3)_\mu (p_2+p_4)^\mu}{t-m_\rho^2} \epsilon_{\lambda,\nu}(p_1)\epsilon^{*\,\nu}_{\lambda'}(p_3) \qquad (10)$$

and $g = g_1 + g_2\, m_\pi^2$. Quark mass dependence of m_ρ, Molina, Elvira, JHEP20

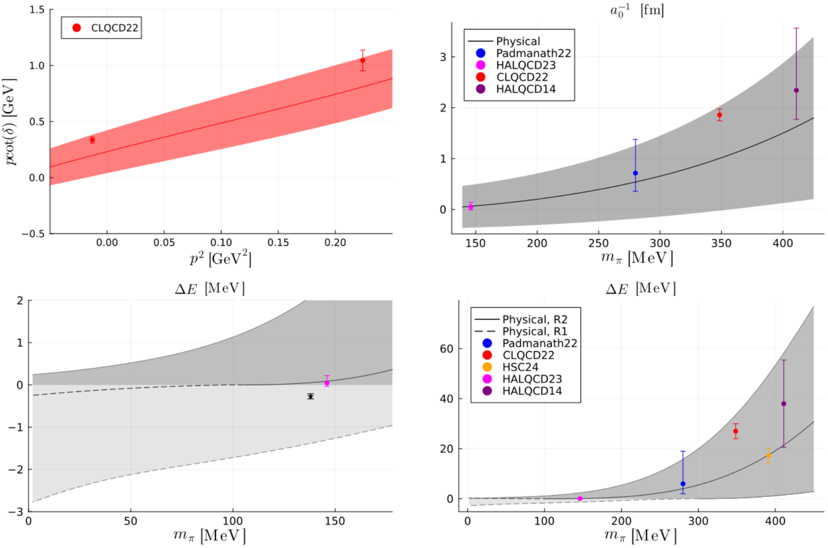
Col.	a	L	m_π
Padmanath22,Collins24	0.086	$2-3$	280
HSC24	0.120	$1.9-2.9$	391
CLQCD Chen22	0.152	2.4	349

Col.	a	m_π	a_0^{-1}
HALQCD23	0.0846	146	0.05
HALQCD14	0.0907	411	2.34

Results for the T_{cc}



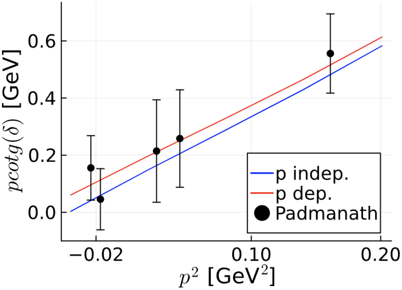
Results for the T_{cc}

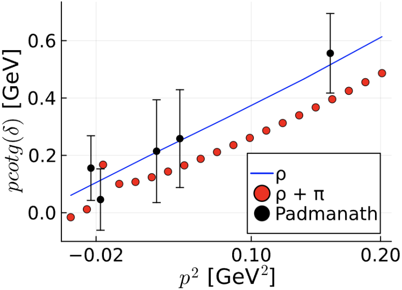


Results for the T_{cc}

Preliminary momentum dependent BS equation including $\pi + \rho$

$$V^{\pi(I=0)}_{\lambda,\lambda'}(p,p') = \frac{3}{4}\, g^2_{D^*D\pi}\, \frac{e^{u/\Lambda^2}}{u - m_\pi^2}\, (2p_4 - p_1)_\mu \epsilon_\lambda^{\ \mu}(p_1)\, (2p_2 - p_3)_\nu \epsilon^{*\ \nu}_{\lambda'}(p_3)$$





Conclusions

Conclusions

- The masses of the low-lying charmed mesons are well described by HHChPT, PLB 843, 137997 (2023)
- The combination of LQCD with EFT's is a usefool tool to extract the properties or esonances with high accuracy
- The study of the pion mass dependence of the $D_{s0}(2317)$ and $D_{s1}(2460)$ supports the DK and D^*K molecular picture ($1 - Z \simeq 0.7 - 0.8$), Phys.Rev.D 109, 096002 (2024)
- The results of the LQCD simulation for the T_{cc} are compatible with a virtual state that is transitioning into a bound state for a pion mass close to physical and with the vector meson exchange being dominant