First observation of a negative-parity doubly charmed baryon on lattice

---

Jing-Yu Yi (义景宇)
Hunan University (湖南大学)

Collaborators: Ze-Rui Liang (梁泽锐), Liuming Liu (刘柳明), De-Liang Yao (姚德良)

第五届强子与重味物理理论与实验联合研讨会 | March 29, 2026

Doubly charmed baryons

Observation of doubly charmed baryons

- SELEX M. Mattson and others, Phys. Rev. Lett. 89, 112001 (2002).
- FOCUS S. P. Ratti, Nucl. Phys. B Proc. Suppl. 115, 33 (2003).
- Belle R. Chistov and others, Phys. Rev. Lett. 97, 162001 (2006).
- BABAR B. Aubert and others, Phys. Rev. D 74, 011103 (2006).
- LHCb R. Aaij and others, Phys. Rev. Lett. 119, 112001 (2017).

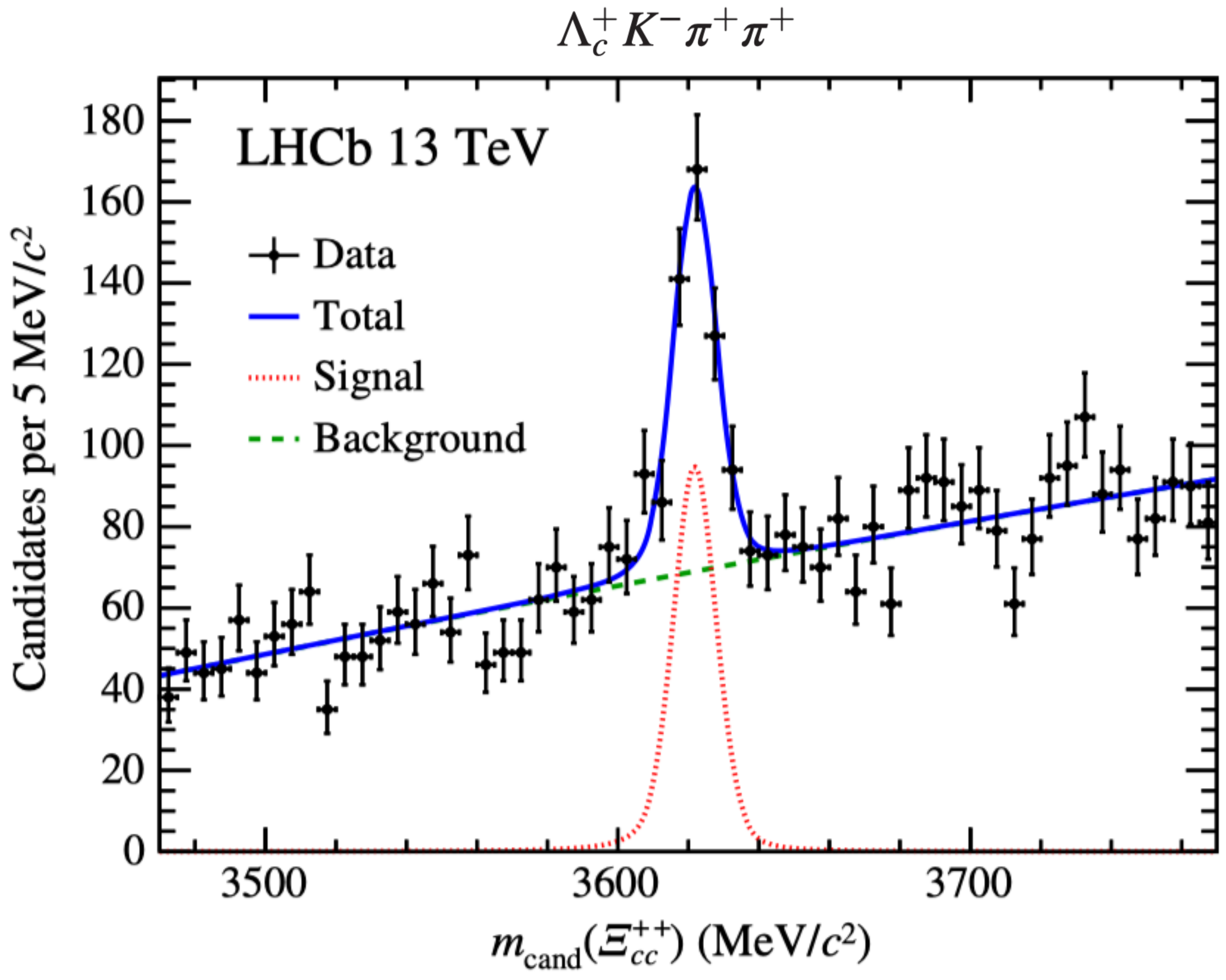
$$m_{\Xi_{cc}^{++}} = 3621.40 \pm 0.72(\text{stat.}) \pm 0.27(\text{syst.}) \pm 0.14(\Lambda_c^+)\ \text{MeV}/c^2$$

Observations in other decay channels

- $\Xi_{cc}^{++} \to \Xi_c^+\pi^+$ R. Aaij and others, Phys. Rev. Lett. **121**, 162002 (2018).
- $\Xi_{cc}^{++} \to \Xi_c^{\prime +}\pi^+$ R. Aaij and others, JHEP **05**, 038 (2022).
- $\Xi_{cc}^{++} \to \Xi_c^0\pi^+\pi^+$ R. Aaij and others, arXiv:2504.05063 [hep-ex] (2025).

More precise measurements

- Mass: R. Aaij and others, JHEP 02, 049 (2020)
- Lifetime: R. Aaij and others, Phys. Rev. Lett. **121**, 052002 (2018).
- Production cross section: R. Aaij and others, Chin. Phys. C **44**, 022001 (2020).



R. Aaij and others, Phys. Rev. Lett. 119, 112001 (2017)

Recent searches for Ξ_{cc}^+ and Ω_{cc}^+ at LHCb

- R. Aaij and others, JHEP **12**, 107 (2021).
- R. Aaij and others, Sci. China Phys. Mech. Astron. **64**, 101062 (2021).

Doubly charmed baryons

Lattice QCD calculations

Mass

- L. Liu, H.-W. Lin, K. Orginos, and A. Walker-Loud, Phys. Rev. D 81, 094505 (2010).
- Z. S. Brown, W. Detmold, S. Meinel, and K. Orginos, Phys. Rev. D 90, 094507 (2014).
- C. Alexandrou and C. Kallidonis, Phys. Rev. D **96**, 034511 (2017).
- S. Mondal, M. Padmanath, and N. Mathur, EPJ Web Conf. **175**, 05021 (2018).
- K. U. Can, H. Bahtiyar, G. Erkol, P. Gubler, M. Oka, and T. T. Takahashi, JPS Conf. Proc. **26**, 022028 (2019).
- N. Mathur and M. Padmanath, Phys. Rev. D 99, 031501 (2019).
- M. Padmanath, Heavy Baryon Spectroscopy from Lattice QCD (2019).
- H. Bahtiyar, K. U. Can, G. Erkol, P. Gubler, M. Oka, and T. T. Takahashi, Phys. Rev. D **102**, 054513 (2020).
- C. Alexandrou, S. Bacchio, G. Christou, and J. Finkenrath, Phys. Rev. D **108**, 094510 (2023).

Other properties (electromagnetic form factors, radiative transitions, …)

- K. U. Can, G. Erkol, B. Isildak, M. Oka, and T. T. Takahashi, Phys. Lett. B **726**, 703 (2013).
- K. U. Can, G. Erkol, B. Isildak, M. Oka, and T. T. Takahashi, JHEP **05**, 125 (2014).
- K. U. Can, Int. J. Mod. Phys. A **36**, 2130013 (2021).
- H. Bahtiyar, Phys. Rev. D **108**, 034504 (2023).
- H. Bahtiyar, K. U. Can, G. Erkol, M. Oka, and T. T. Takahashi, Phys. Rev. D **98**, 114505 (2018).
- G. Aarts, C. Allton, M. N. Anwar, R. Bignell, T. J. Burns, B. Jäger, and J.-I. Skullerud, Eur. Phys. J. A **60**, 59 (2024).

Doubly charmed baryons

Chiral perturbation theory

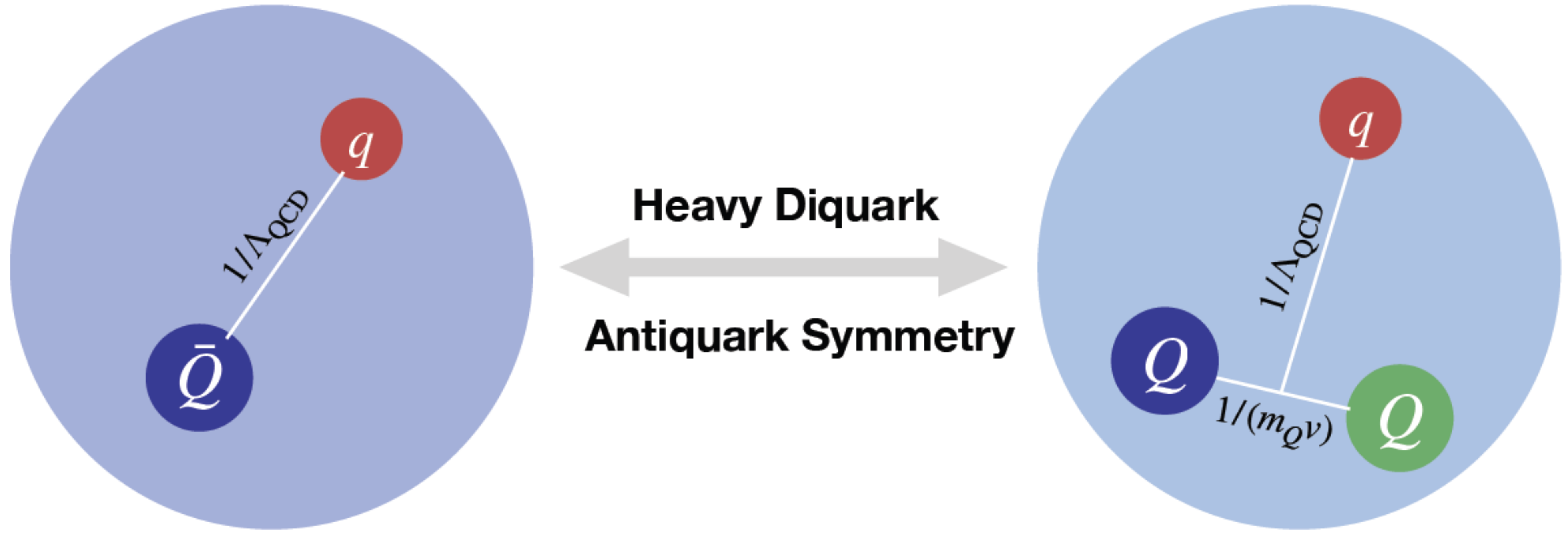
- Z.-H. Guo, Phys. Rev. D 96, 074004 (2017).
- Z.-F. Sun and M. J. Vicente Vacas, Phys. Rev. D 93, 094002 (2016).
- A. N. Hiller Blin, Z.-F. Sun, and M. J. Vicente Vacas, Phys. Rev. D 98, 054025 (2018).
- M.-J. Yan, X.-H. Liu, S. Gonzàlez-Solís, F.-K. Guo, C. Hanhart, U.-G. Meißner, and B.-S. Zou, Phys. Rev. D 98, 091502 (2018).
- M.-Z. Liu, Y. Xiao, and L.-S. Geng, Phys. Rev. D 98, 014040 (2018).
- D.-L. Yao, Phys. Rev. D 97, 034012 (2018).
- L. Meng and S.-L. Zhu, Phys. Rev. D 100, 014006 (2019).

Heavy diquark-antiquark (HDA) symmetry

- M. J. Savage and M. B. Wise, Phys. Lett. B 248, 177 (1990).
- M.-J. Yan, X.-H. Liu, S. Gonzàlez-Solís, F.-K. Guo, C. Hanhart, U.-G. Meißner, and B.-S. Zou, Phys. Rev. D 98, 091502 (2018).
- L. Meng and S.-L. Zhu, Phys. Rev. D 100, 014006 (2019).
- Z.-R. Liang, P.-C. Qiu, and D.-L. Yao, JHEP 07, 124 (2023).
- ……

Baryon chiral perturbation theory (BChPT)

$$\begin{aligned}
\mathcal{L}_{\psi\phi}^{(1)} &= \bar{\psi}\left(i\not{D} - m\right)\psi + \frac{g}{2}\bar{\psi}\not{u}\gamma_5\psi \ , \\
\mathcal{L}_{\psi\phi}^{(2)} &= b_1\bar{\psi}\left\langle\chi_+\right\rangle\psi + b_2\bar{\psi}\widetilde{\chi}_+\psi + b_3\bar{\psi}u^2\psi + b_4\bar{\psi}\left\langle u^2\right\rangle\psi + \frac{b_5}{m^2}\bar{\psi}\left(\{u^\mu, u^\nu\}D_{\mu\nu} + H.c.\right)\psi \\
&\quad + \frac{b_6}{m^2}\bar{\psi}\left(\left\langle u^\mu u^\nu\right\rangle D_{\mu\nu} + H.c.\right)\psi + ib_7\bar{\psi}\left[u^\mu, u^\nu\right]\sigma_{\mu\nu}\psi \ , \\
\mathcal{L}_{\psi\phi}^{(3)} &= ic_{11}\bar{\psi}\left[u_\mu, h^{\mu\nu}\right]\gamma_\nu\psi + \frac{c_{12}}{m^2}\bar{\psi}\left(i\left[u^\mu, h^{\nu\rho}\right]\gamma_\mu D_{\nu\rho} + H.c.\right)\psi + \frac{c_{13}}{m}\bar{\psi}\left(i\left\{u^\mu, h^{\nu\rho}\right\}\right. \\
&\quad \left.\times\sigma_{\mu\nu}D_\rho + H.c.\right)\psi + \frac{c_{14}}{m}\bar{\psi}\left(i\sigma_{\mu\nu}\left\langle u^\mu h^{\nu\rho}\right\rangle D_\rho + H.c.\right)\psi + c_{15}\bar{\psi}\left\{u^\mu, \widetilde{\chi}_+\right\}\gamma_5\gamma_\mu\psi \\
&\quad + c_{16}\bar{\psi}u^\mu\gamma_5\gamma_\mu\left\langle\chi_+\right\rangle\psi + c_{17}\bar{\psi}\gamma_5\gamma_\mu\left\langle u^\mu\widetilde{\chi}_+\right\rangle\psi + ic_{18}\bar{\psi}\gamma_5\gamma_\mu\left[D^\mu, \widetilde{\chi}_-\right]\psi \\
&\quad + ic_{19}\bar{\psi}\gamma_5\gamma_\mu\left\langle\left[D^\mu, \chi_-\right]\right\rangle\psi + c_{20}\bar{\psi}\left[\widetilde{\chi}_-, u^\mu\right]\gamma_\mu\psi \ .
\end{aligned}$$



Doubly charmed baryons

(S,I)	Processes	Connected(C)/ Disconnected(D)	(S,I)	Relation to $D\phi$ scattering	
$(-2,\frac{1}{2})$	$\Omega_{cc}\bar{K}\to\Omega_{cc}\bar{K}$	C	$(2,\frac{1}{2})$	$D_sK\to D_sK$	
$(-1,1)$	$\Omega_{cc}\pi\to\Omega_{cc}\pi$	C	$(1,1)$	$D_s\pi\to D_s\pi$	
	$\Xi_{cc}\bar{K}\to\Xi_{cc}\bar{K}$			$DK\to DK$	
	$\Omega_{cc}\pi\to\Xi_{cc}\bar{K}$			$D_s\pi\to DK$	
$(-1,0)$	$\Xi_{cc}\bar{K}\to\Xi_{cc}\bar{K}$	D	$(1,0)$	$DK\to DK$	2317
	$\Omega_{cc}\eta\to\Omega_{cc}\eta$			$D_s\eta\to D_s\eta$	
	$\Xi_{cc}\bar{K}\to\Omega_{cc}\eta$			$DK\to D_s\eta$	
$(1,0)$	$\Xi_{cc}K\to\Xi_{cc}K$	C	$(-1,0)$	$D\bar{K}\to D\bar{K}$	
$(1,1)$	$\Xi_{cc}K\to\Xi_{cc}K$	C	$(-1,1)$	$D\bar{K}\to D\bar{K}$	
$(0,\frac{1}{2})$	$\Xi_{cc}\pi\to\Xi_{cc}\pi$	D	$(0,\frac{1}{2})$	$D\pi\to D\pi$	Two-pole
	$\Xi_{cc}\eta\to\Xi_{cc}\eta$			$D\eta\to D\eta$	
	$\Omega_{cc}K\to\Omega_{cc}K$			$D_s\bar{K}\to D_s\bar{K}$	
	$\Xi_{cc}\pi\to\Xi_{cc}\eta$			$D\pi\to D\eta$	
	$\Xi_{cc}\pi\to\Omega_{cc}K$			$D\pi\to D_s\bar{K}$	
	$\Xi_{cc}\eta\to\Omega_{cc}K$			$D\eta\to D_s\bar{K}$	
$(0,\frac{3}{2})$	$\Xi_{cc}\pi\to\Xi_{cc}\pi$	C	$(0,\frac{3}{2})$	$D\pi\to D\pi$	

Doubly charmed baryons

(S, I)	Processes	Connected(C)/ Disconnected(D)	(S, I)	Relation to $D\phi$ scattering	
$(-2, \frac{1}{2})$	$\Omega_{cc}\bar{K} \to \Omega_{cc}\bar{K}$	C	$(2, \frac{1}{2})$	$D_sK \to D_sK$	
$(-1, 1)$	$\Omega_{cc}\pi \to \Omega_{cc}\pi$ $\Xi_{cc}\bar{K} \to \Xi_{cc}\bar{K}$ $\Omega_{cc}\pi \to \Xi_{cc}\bar{K}$	C	$(1, 1)$	$D_s\pi \to D_s\pi$ $DK \to DK$ $D_s\pi \to DK$	
$(-1, 0)$	$\Xi_{cc}\bar{K} \to \Xi_{cc}\bar{K}$ $\Omega_{cc}\eta \to \Omega_{cc}\eta$ $\Xi_{cc}\bar{K} \to \Omega_{cc}\eta$	D	$(1, 0)$	$DK \to DK$ $D_s\eta \to D_s\eta$ $DK \to D_s\eta$	2317
$(1, 0)$	$\Xi_{cc}K \to \Xi_{cc}K$	C	$(-1, 0)$	$D\bar{K} \to D\bar{K}$	
$(1, 1)$	$\Xi_{cc}K \to \Xi_{cc}K$	C	$(-1, 1)$	$D\bar{K} \to D\bar{K}$	
$(0, \frac{1}{2})$	$\Xi_{cc}\pi \to \Xi_{cc}\pi$ $\Xi_{cc}\eta \to \Xi_{cc}\eta$ $\Omega_{cc}K \to \Omega_{cc}K$ $\Xi_{cc}\pi \to \Xi_{cc}\eta$ $\Xi_{cc}\pi \to \Omega_{cc}K$ $\Xi_{cc}\eta \to \Omega_{cc}K$	D	$(0, \frac{1}{2})$	$D\pi \to D\pi$ $D\eta \to D\eta$ $D_s\bar{K} \to D_s\bar{K}$ $D\pi \to D\eta$ $D\pi \to D_s\bar{K}$ $D\eta \to D_s\bar{K}$	Two-pole
$(0, \frac{3}{2})$	$\Xi_{cc}\pi \to \Xi_{cc}\pi$	C	$(0, \frac{3}{2})$	$D\pi \to D\pi$	

Simulation in lattice QCD

Operators

↓

Energy levels

↓

Phase shift

↓

Scattering analysis

Two-particle operators for S-wave scattering $J^P = (1/2)^- \longrightarrow G_1^-$

Spectrum of two-particle system

Solve generalized eigenvalue problem (GEVP) and extract energy levels

$$C_{ij}(t) = \sum_{t_{src}} \left\langle \mathcal{O}_i \left(t + t_{src}\right) \mathcal{O}_j^\dagger \left(t_{src}\right) \right\rangle \qquad C(t) v^n(t) = \lambda^n(t) C\left(t_0\right) v^n(t)$$

M. Luscher and U. Wolff, Nucl. Phys. B 339, 222 (1990).

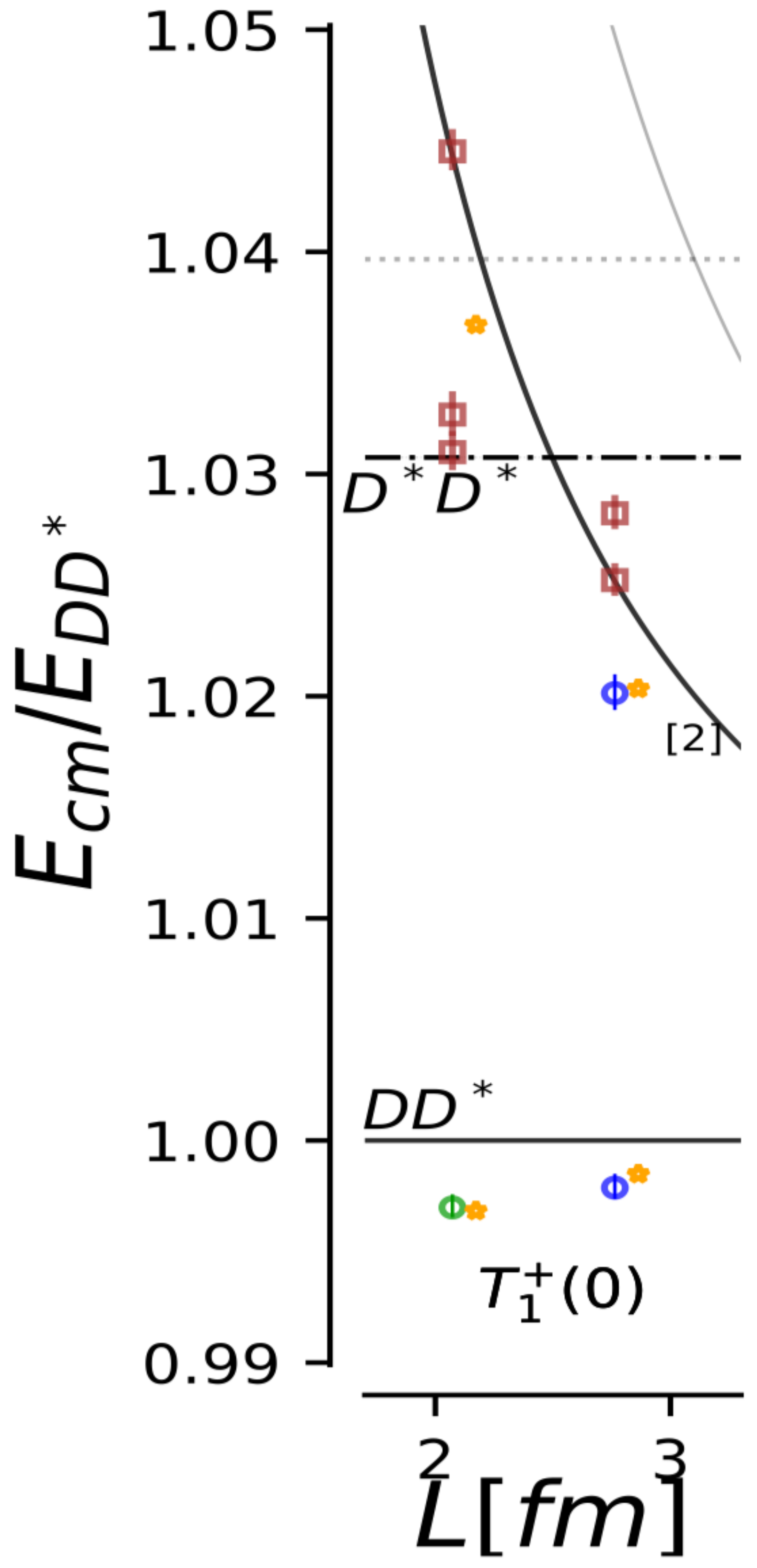
Luscher's formula for two-body scattering M. Luscher, Nucl. Phys. B 354, 531 (1991).

$$\det[\mathbf{1} + i\rho \cdot \mathbf{t} \cdot (1 + i\mathbf{M})] = 0$$

For single-channel S-wave scattering

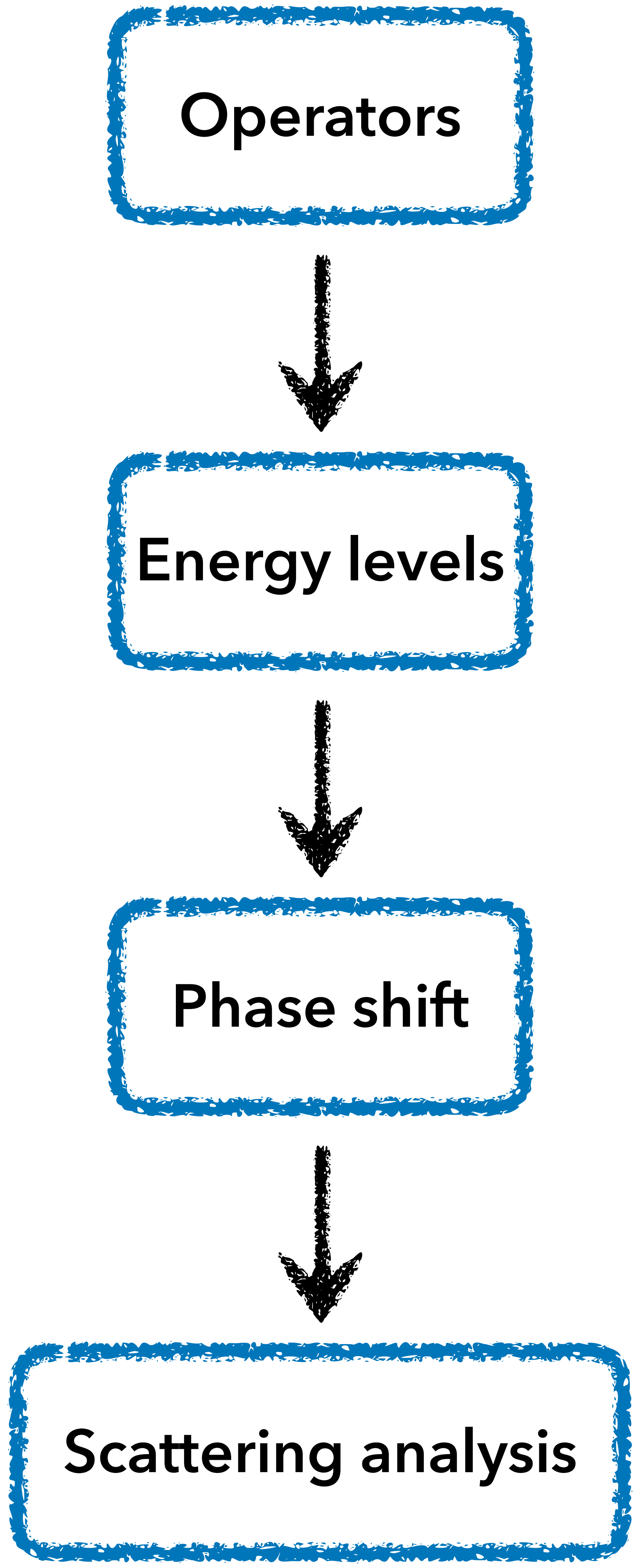
$$p \cot \delta_0(p) = \frac{2}{L\sqrt{\pi}} \mathcal{Z}_{00}\left(1; q^2\right)$$

$$E = \sqrt{m_1^2 + p^2} + \sqrt{m_2^2 + p^2} \qquad q = \frac{pL}{2\pi}$$



M. Padmanath and S. Prelovsek, Phys. Rev. Lett. 129, 032002 (2022).

Simulation in lattice QCD



Operators

Energy levels

Phase shift

Scattering analysis

Effective range expansion

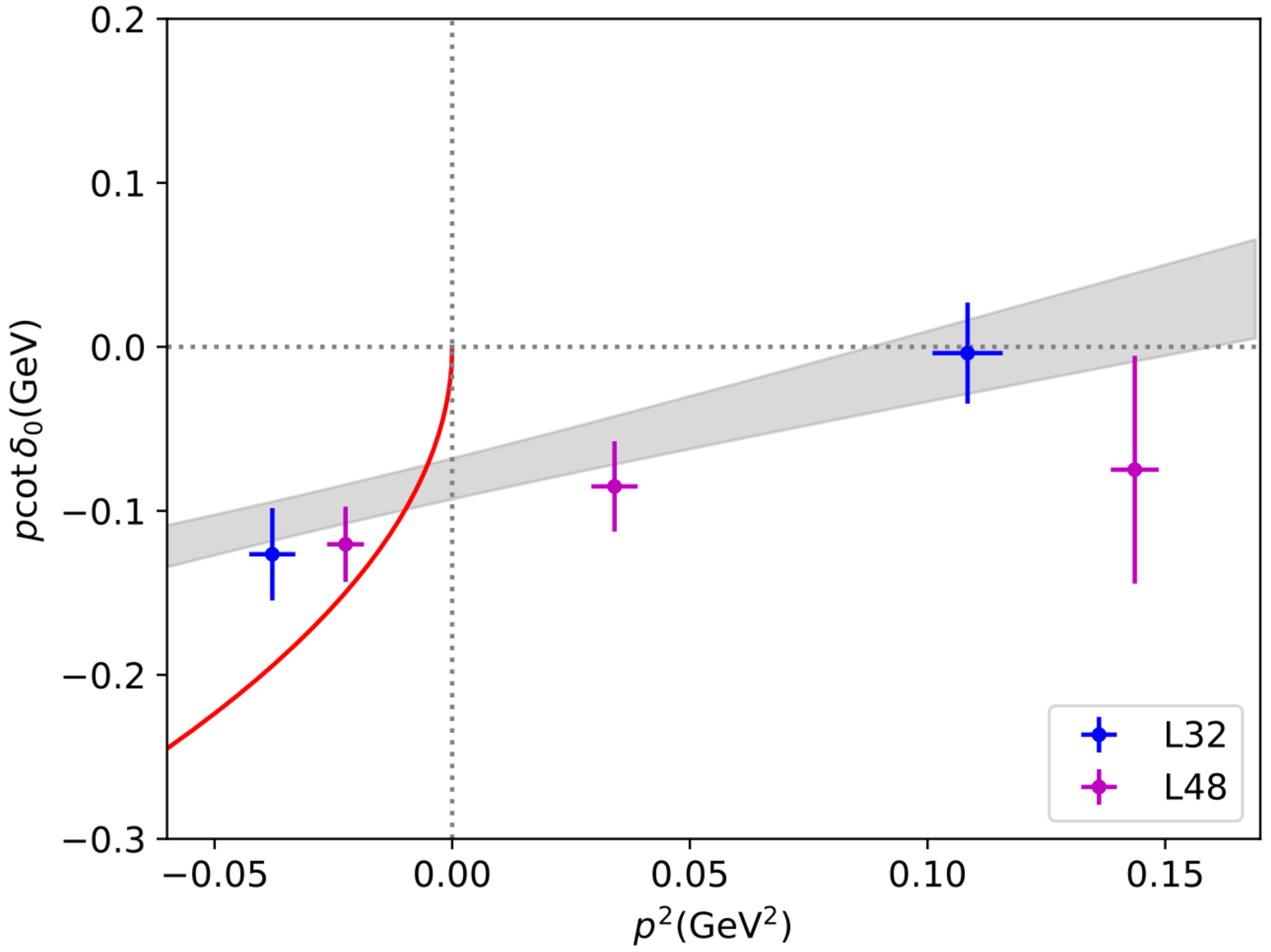
$$p\cot\delta_0 = \frac{1}{a_0} + \frac{1}{2}r_0 p^2 + \mathcal{O}(p^4)$$

Scattering amplitude

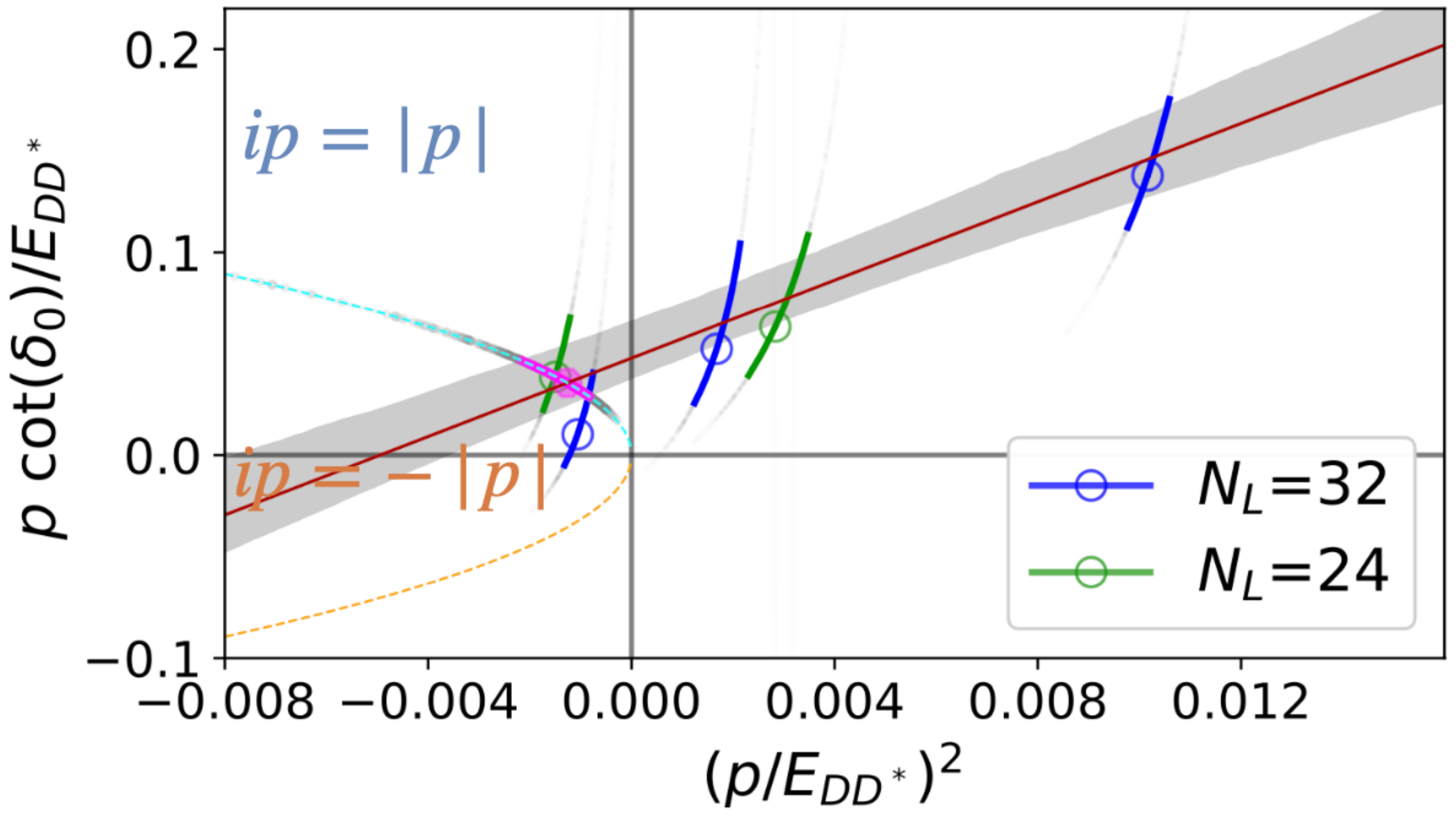
$$t_l^{(J)} \sim \frac{1}{p\cot\delta_l^{(J)} - ip}$$

For partial wave l and total angular momentum J

- L. Liu, K. Orginos, F.-K. Guo, C. Hanhart, and U.-G. Meissner, Phys. Rev. D 87, 014508 (2013).
- Y. Lyu, S. Aoki, T. Doi, T. Hatsuda, Y. Ikeda, and J. Meng, arXiv:2302.04505 [hep-lat] (2023).
- H. Xing, J. Liang, L. Liu, P. Sun, and Y.-B. Yang, arXiv:2210.08555 [hep-lat] (2022).
- M. Padmanath and S. Prelovsek, Phys. Rev. Lett. 129, 032002 (2022).
- ……

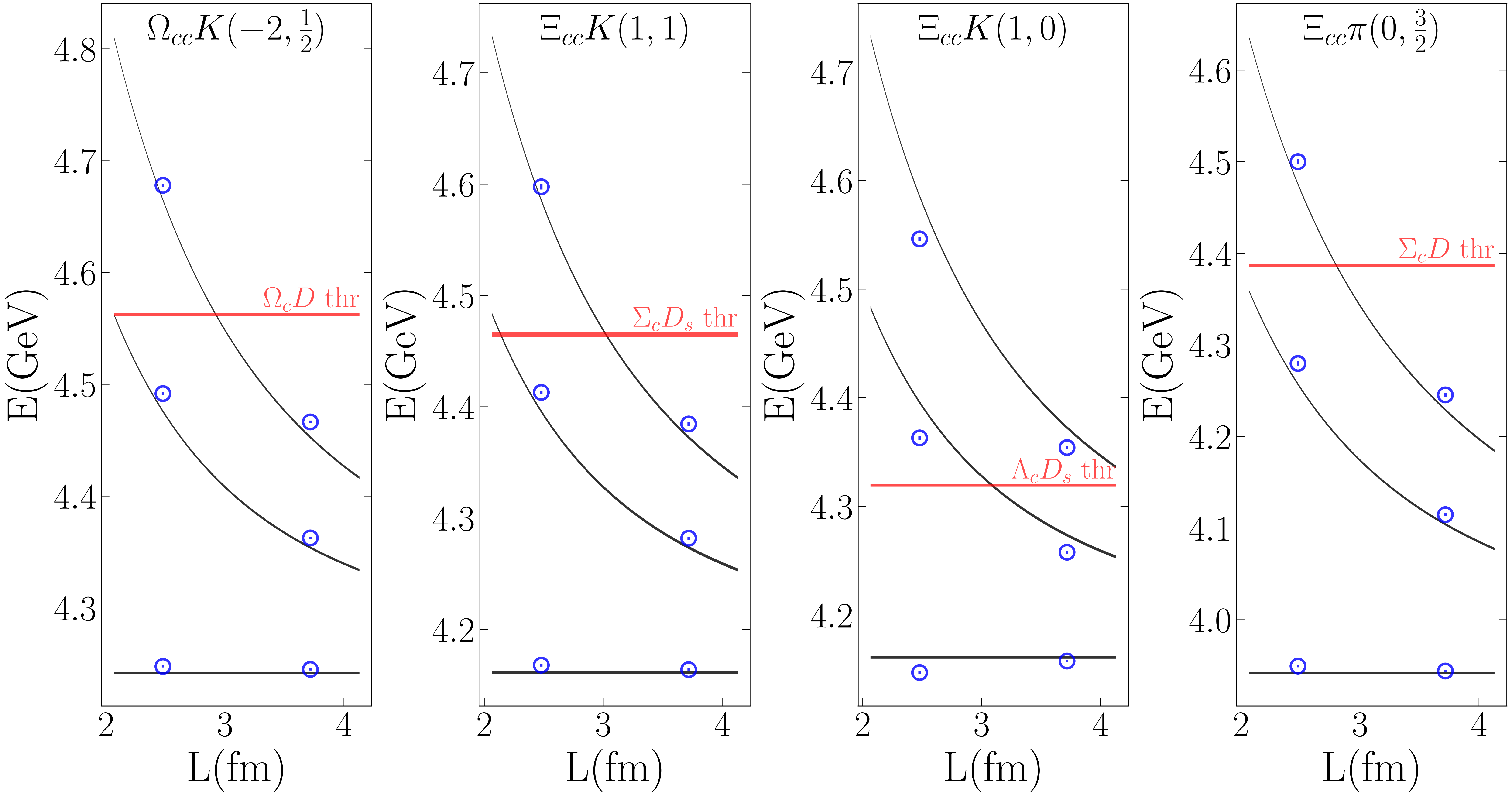


H. Xing, J. Liang, L. Liu, P. Sun, and Y.-B. Yang, arXiv:2210.08555 [hep-lat] (2022).



M. Padmanath and S. Prelovsek, Phys. Rev. Lett. 129, 032002 (2022).

Single-channel results



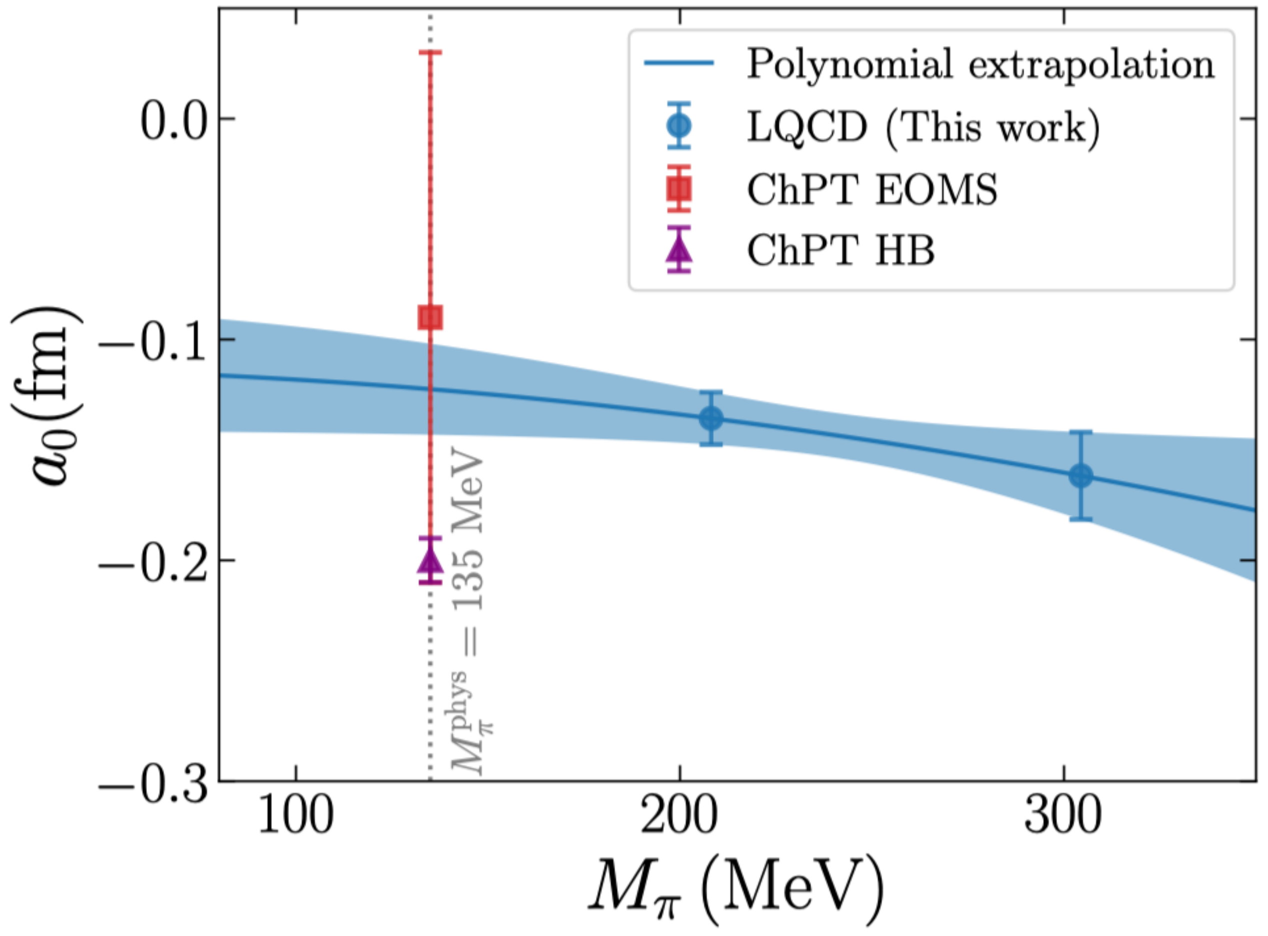
J.-Y. Yi, Z.-R. Liang, L. Liu & DLY, JHEP03(2026)

Results for four single channels

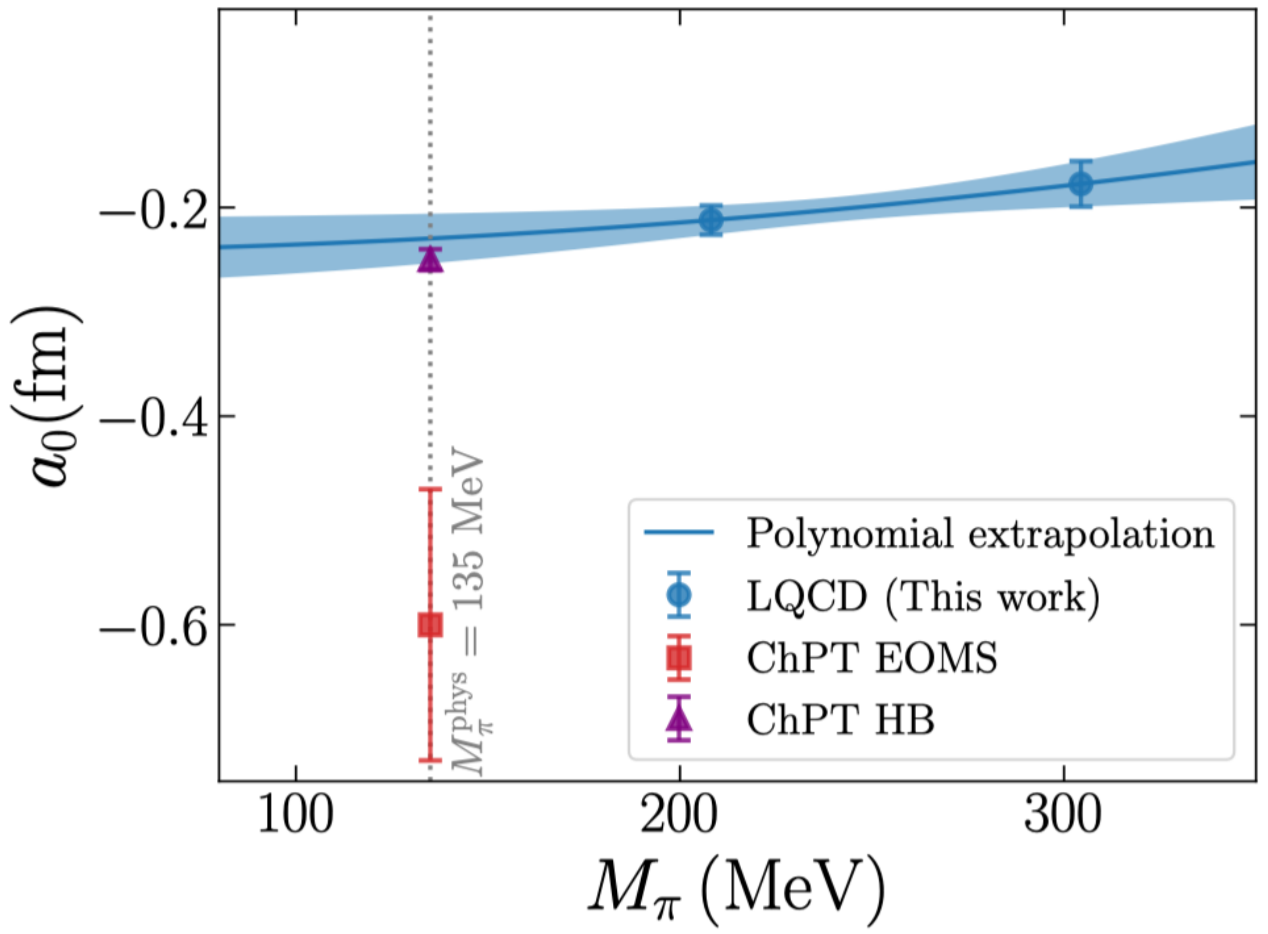
- Pion mass ~ 300 and 210 MeV.
- Lattice spacing a = 0.07746.
- A possible virtual state in $(S, I) = (1{,}0)$ channel.

Single-channel results

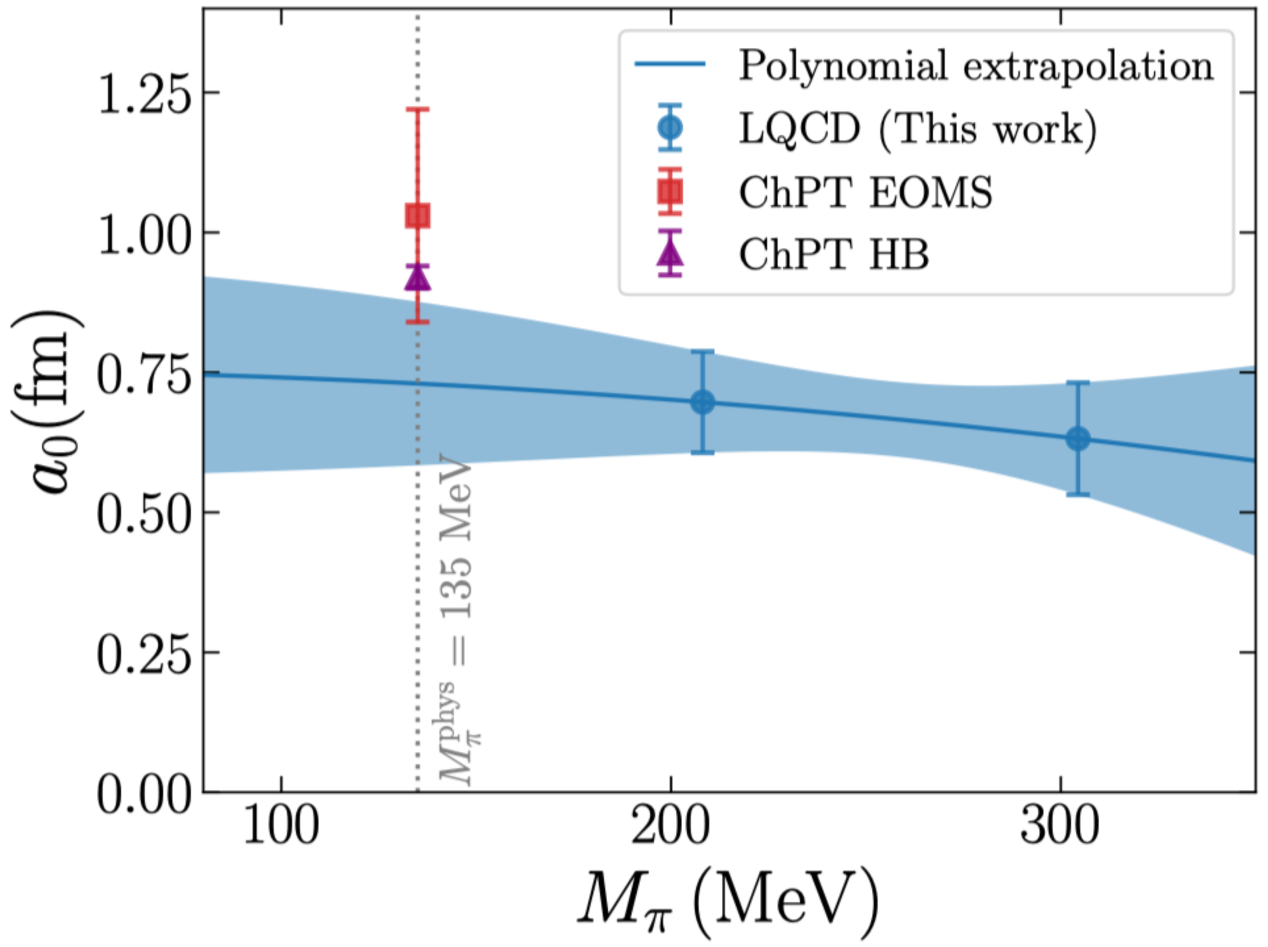
Extrapolation of S-wave scattering length a_0 to the physical pion mass



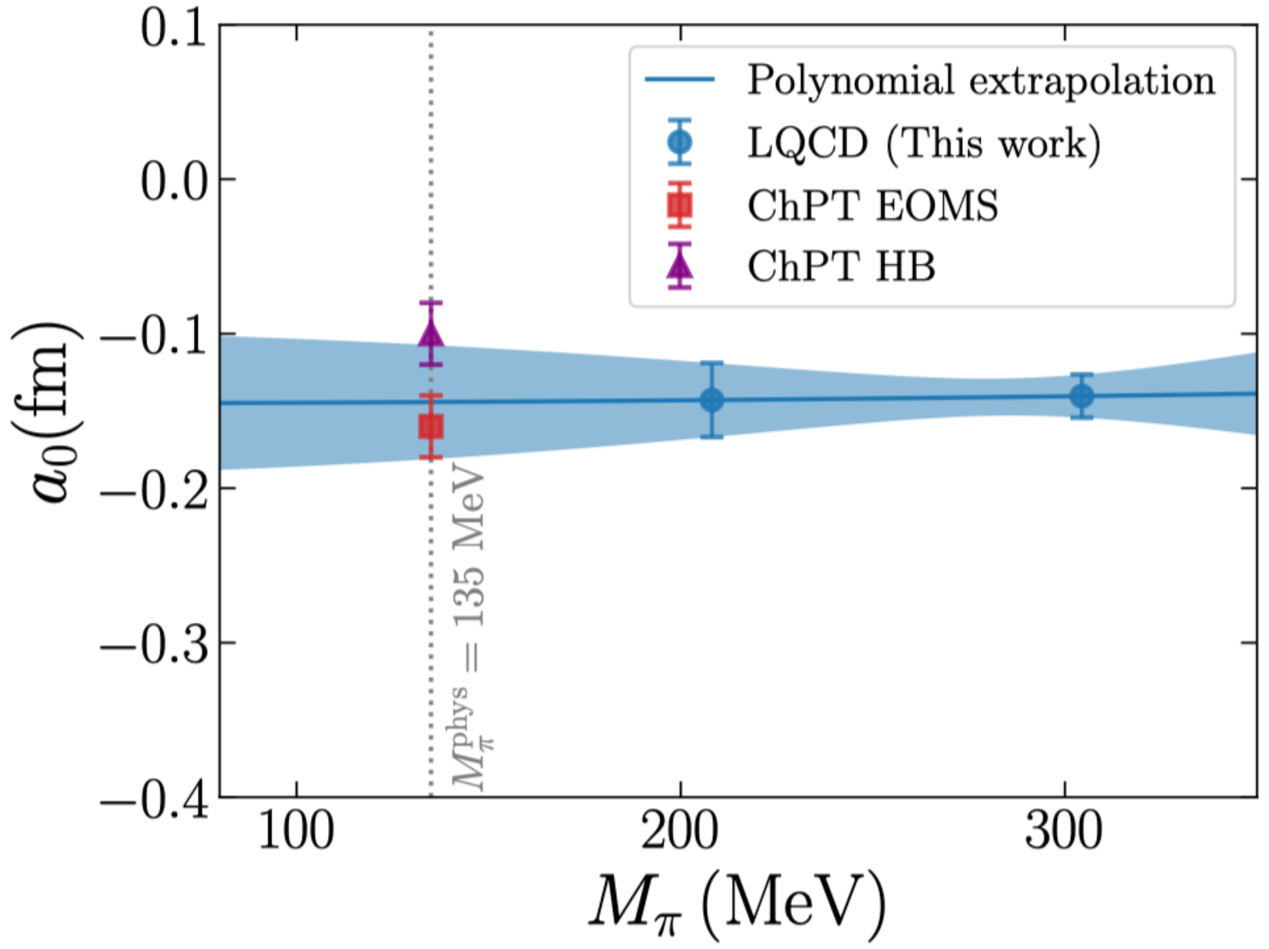
(a) $\Omega_{cc}\bar{K}^{(-2,\frac{1}{2})}$



(b) $\Xi_{cc}K(1,1)$



(c) $\Xi_{cc}K(1,0)$



(d) $\Xi_{cc}\pi(0,\frac{3}{2})$

(S,I)	Processes	Connected(C)/ Disconnected(D)	(S,I)	Relation to $D\phi$ scattering
✓ $(-2,\frac{1}{2})$	$\Omega_{cc}\bar{K}\to\Omega_{cc}\bar{K}$	C	$(2,\frac{1}{2})$	$D_sK\to D_sK$
$(-1,1)$	$\Omega_{cc}\pi\to\Omega_{cc}\pi$ $\Xi_{cc}\bar{K}\to\Xi_{cc}\bar{K}$ $\Omega_{cc}\pi\to\Xi_{cc}\bar{K}$	C	$(1,1)$	$D_s\pi\to D_s\pi$ $DK\to DK$ $D_s\pi\to DK$
$(-1,0)$	$\Xi_{cc}\bar{K}\to\Xi_{cc}\bar{K}$ $\Omega_{cc}\eta\to\Omega_{cc}\eta$ $\Xi_{cc}\bar{K}\to\Omega_{cc}\eta$	D	$(1,0)$	$DK\to DK$ $D_s\eta\to D_s\eta$ $DK\to D_s\eta$
✓ $(1,0)$	$\Xi_{cc}K\to\Xi_{cc}K$	C	$(-1,0)$	$D\bar{K}\to D\bar{K}$
✓ $(1,1)$	$\Xi_{cc}K\to\Xi_{cc}K$	C	$(-1,1)$	$D\bar{K}\to D\bar{K}$
$(0,\frac{1}{2})$	$\Xi_{cc}\pi\to\Xi_{cc}\pi$ $\Xi_{cc}\eta\to\Xi_{cc}\eta$ $\Omega_{cc}K\to\Omega_{cc}K$ $\Xi_{cc}\pi\to\Xi_{cc}\eta$ $\Xi_{cc}\pi\to\Omega_{cc}K$ $\Xi_{cc}\eta\to\Omega_{cc}K$	D	$(0,\frac{1}{2})$	$D\pi\to D\pi$ $D\eta\to D\eta$ $D_s\bar{K}\to D_s\bar{K}$ $D\pi\to D\eta$ $D\pi\to D_s\bar{K}$ $D\eta\to D_s\bar{K}$
✓ $(0,\frac{3}{2})$	$\Xi_{cc}\pi\to\Xi_{cc}\pi$	C	$(0,\frac{3}{2})$	$D\pi\to D\pi$

Lattice setup & operators

Lattice setup

Gauge configurations from CLQCD

	C48P14	F32P30	F48P30	F32P21	F48P21	H48P32
β	6.20	6.41				6.72
a(fm)	0.10530(18)	0.07746(18)				0.05187(26)
am_l	-0.2825	-0.2295	-0.2295	-0.2320	-0.2320	-0.1850
am_s	-0.2310	-0.2050	-0.2050	-0.2050	-0.2050	-0.1700
M_π(MeV)	135.5(1.6)	303.9(0.6)	304.9(0.4)	208.1(1.9)	207.4(0.7)	317.2(0.9)
$M_\pi L$	3.471(41)	3.8180(75)	5.7458(75)	2.614(24)	3.908(13)	4.003(11)
$L^3 \times T$	$48^3 \times 96$	$32^3 \times 96$	$48^3 \times 96$	$32^3 \times 64$	$48^3 \times 96$	$48^3 \times 144$
$N_{\text{cfgs.}}$	-	750	359	459	222	-

- Four pion masses (~140–320 MeV).
- Three lattice spacings (~ 0.05–0.11 fm).
- Six ensembles of gauge configurations with 2+1 dynamical quark flavors.
- tree-level Symanzik-improved gauge action.
- Shekholeslami-Wohlert fermion action with tree-level tadpole improvement.
- Distillation quark smearing.
- Charm quark mass determined by physical J/ψ.

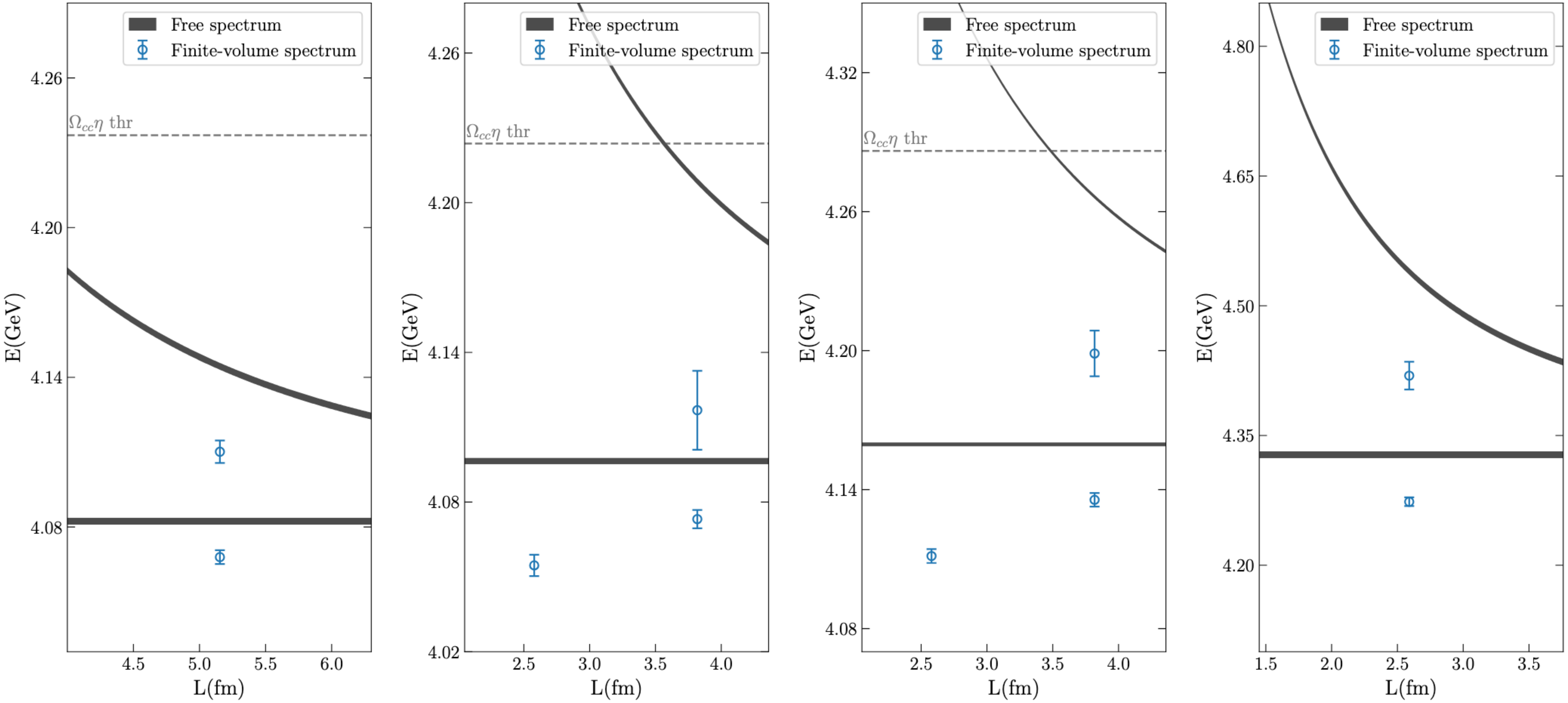
Operators

$$\mathcal{O}_p^{\Xi_{cc}\bar{K}} = \frac{1}{\sqrt{2}} \sum_{\alpha,\mathbf{p_1},\mathbf{p_2}} C_{\alpha,\mathbf{p_1},\mathbf{p_2}} \left(\mathcal{O}_{\Xi_{cc}^{++},\alpha}(\mathbf{p_1}) \mathcal{O}_{K^-}(\mathbf{p_2}) - \mathcal{O}_{\Xi_{cc}^{+},\alpha}(\mathbf{p_1}) \mathcal{O}_{\bar{K}^0}(\mathbf{p_2}) \right)$$

$$\mathcal{O}_{ccs}(x) = \epsilon^{ijk} P_- [c^{iT}(x) C \gamma_5 s^j(x)] c^k(x)$$

Preliminary results for $\Xi_{cc}\bar{K}\ (I = 0)$

Energy levels



(a) $M_\pi \approx 140$ MeV,
$a = 0.10530$ fm $(L = 48)$

(b) $M_\pi \approx 210$ MeV,
$a = 0.07746$ fm $(L = 32, 48)$

(c) $M_\pi \approx 300$ MeV,
$a = 0.07746$ fm $(L = 32, 48)$

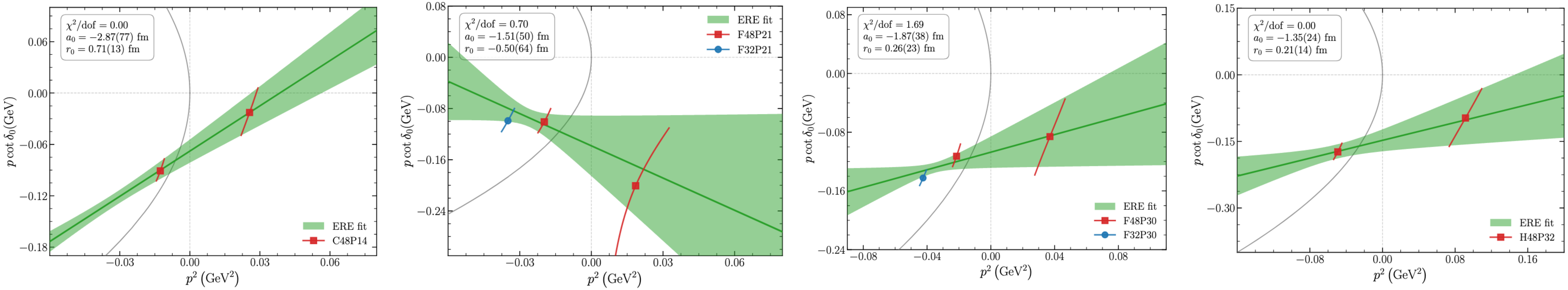
(d) $M_\pi \approx 320$ MeV,
$a = 0.05187$ fm $(L = 48)$

Preliminary results for $\Xi_{cc}\bar{K}$ $(I=0)$

Scattering analysis

$$p\cot\delta_0 = \frac{1}{a_0} + \frac{1}{2}r_0 p^2 + \mathcal{O}(p^4) \qquad t_l^{(J)} \sim \frac{1}{p\cot\delta_l^{(J)} - ip}$$

Ensemble Group	a_0 (fm)	r_0 (fm)	$p_B^2(\mathrm{GeV}^2)$	$E_B(\mathrm{MeV})$	χ^2/dof
$M_\pi \approx 140$ MeV, $a = 0.105$ fm $(L=48)$	$-2.87(77)$	$0.71(13)$	$-0.0064(23)$	$7.3(2.6)$	0.00
$M_\pi \approx 210$ MeV, $a = 0.077$ fm $(L=32,48)$	$-1.51(50)$	$-0.50(64)$	$-0.0131(38)$	$15.4(4.5)$	0.70
$M_\pi \approx 300$ MeV, $a = 0.077$ fm $(L=32,48)$	$-1.87(38)$	$0.26(23)$	$-0.0130(36)$	$14.4(4.0)$	1.69
$M_\pi \approx 320$ MeV, $a = 0.052$ fm $(L=48)$	$-1.35(24)$	$0.21(14)$	-0.0256(65)	$27.7(7.1)$	0.00



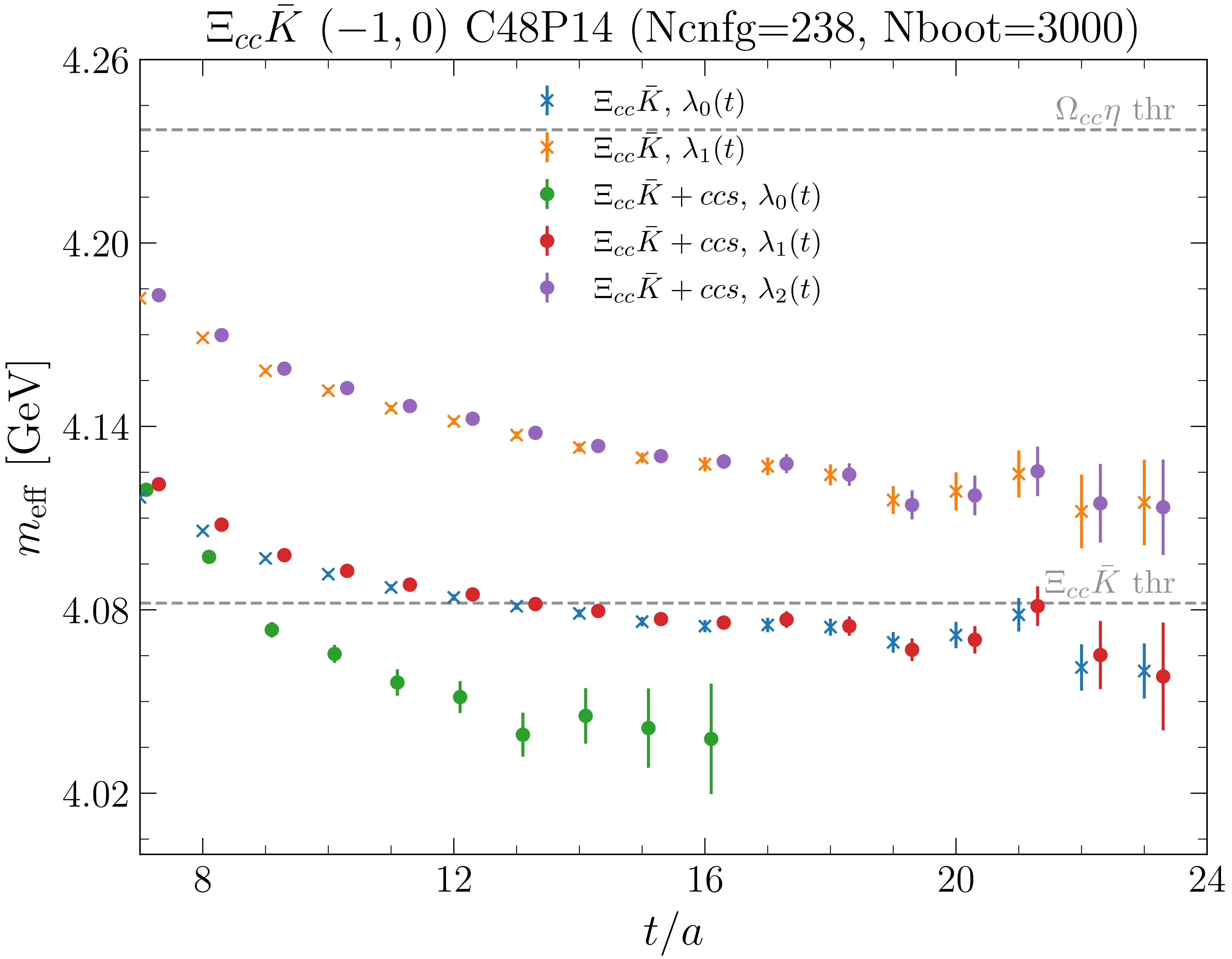
(a) $M_\pi \approx 140$ MeV, $a = 0.105$ fm $(L=48)$

(b) $M_\pi \approx 210$ MeV, $a = 0.077$ fm $(L=32,48)$

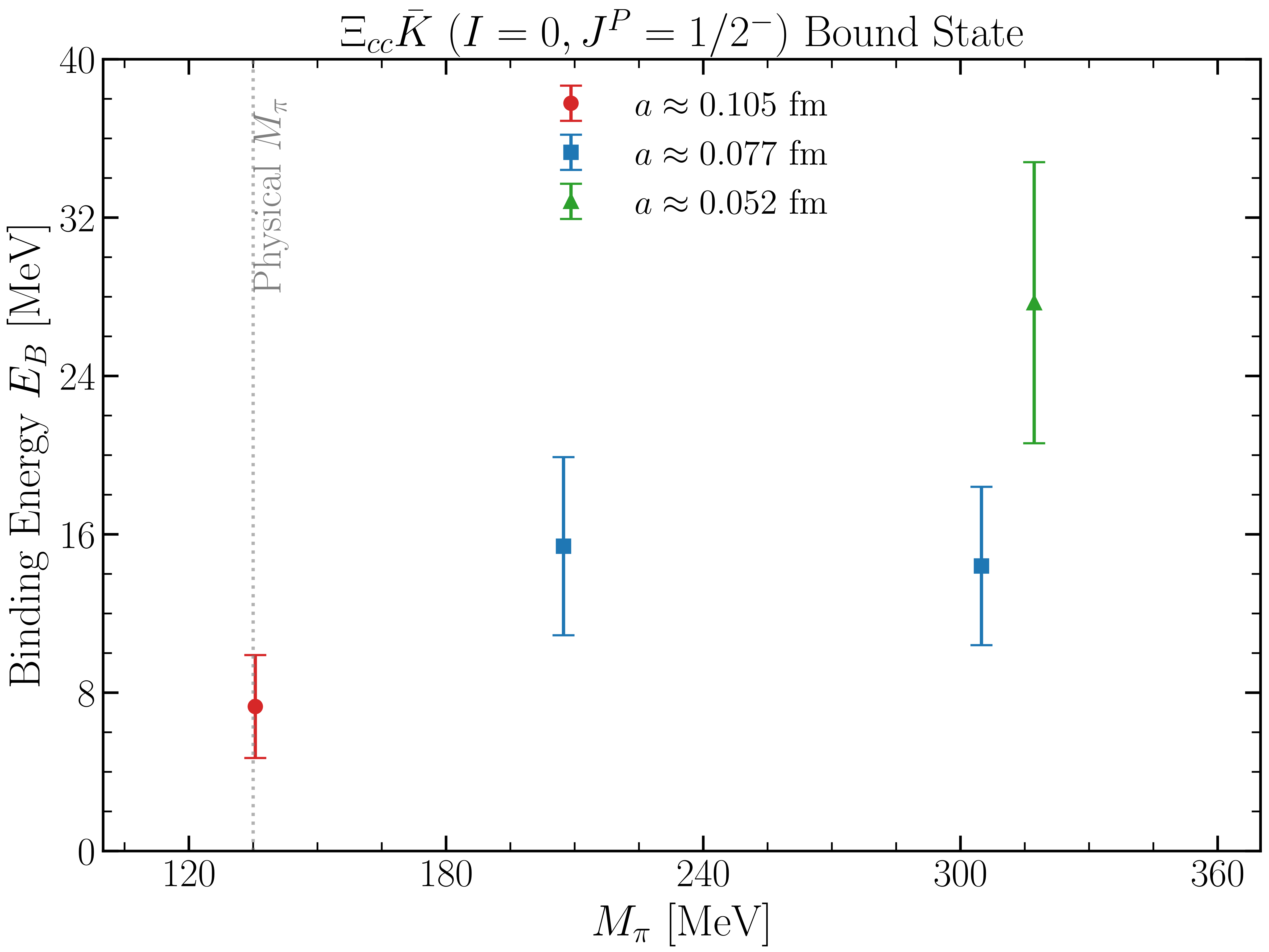
(c) $M_\pi \approx 300$ MeV, $a = 0.077$ fm $(L=32,48)$

(d) $M_\pi \approx 320$ MeV, $a = 0.052$ fm $(L=48)$

Preliminary results for $\Xi_{cc}\bar{K}$ $(I = 0)$



Mass ≈ 4075 MeV



Summary

(S,I)	Processes	Connected(C)/ Disconnected(D)	(S,I)	Relation to $D\phi$ scattering
✓ $(-2,\frac{1}{2})$	$\Omega_{cc}\bar{K}\to\Omega_{cc}\bar{K}$	C	$(2,\frac{1}{2})$	$D_sK\to D_sK$
$(-1,1)$	$\Omega_{cc}\pi\to\Omega_{cc}\pi$ $\Xi_{cc}\bar{K}\to\Xi_{cc}\bar{K}$ $\Omega_{cc}\pi\to\Xi_{cc}\bar{K}$	C	$(1,1)$	$D_s\pi\to D_s\pi$ $DK\to DK$ $D_s\pi\to DK$
✓ $(-1,0)$	$\Xi_{cc}\bar{K}\to\Xi_{cc}\bar{K}$ $\Omega_{cc}\eta\to\Omega_{cc}\eta$ $\Xi_{cc}\bar{K}\to\Omega_{cc}\eta$	D	$(1,0)$	$DK\to DK$ $D_s\eta\to D_s\eta$ $DK\to D_s\eta$
✓ $(1,0)$	$\Xi_{cc}K\to\Xi_{cc}K$	C	$(-1,0)$	$D\bar{K}\to D\bar{K}$
✓ $(1,1)$	$\Xi_{cc}K\to\Xi_{cc}K$	C	$(-1,1)$	$D\bar{K}\to D\bar{K}$
$(0,\frac{1}{2})$	$\Xi_{cc}\pi\to\Xi_{cc}\pi$ $\Xi_{cc}\eta\to\Xi_{cc}\eta$ $\Omega_{cc}K\to\Omega_{cc}K$ $\Xi_{cc}\pi\to\Xi_{cc}\eta$ $\Xi_{cc}\pi\to\Omega_{cc}K$ $\Xi_{cc}\eta\to\Omega_{cc}K$	D	$(0,\frac{1}{2})$	$D\pi\to D\pi$ $D\eta\to D\eta$ $D_s\bar{K}\to D_s\bar{K}$ $D\pi\to D\eta$ $D\pi\to D_s\bar{K}$ $D\eta\to D_s\bar{K}$
✓ $(0,\frac{3}{2})$	$\Xi_{cc}\pi\to\Xi_{cc}\pi$	C	$(0,\frac{3}{2})$	$D\pi\to D\pi$

- S-wave scattering lengths.
- A virtual state in $(S,I)=(1,0)$ channel.
- A bound state in $(S,I)=(-1,0)$ channel.
- Examination of the validity of HDA symmetry.
- Determination of LECs in BChPT.
- Better understanding of double-heavy baryon spectroscopy.

Thank you!