全国第十三届重味物理和CP破坏研讨会

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Study of scalar charmed mesons in a chiral framework

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In collaboration with Ulf G. Meissner and De-Liang Yao, arXiv: 1507.03123

Outline:

1. Background & Introduction

2. ChPT amplitudes and Unitarizaiton

3. Results and Discussions

4. Summary

1. Background

$D^*_{s0}(2317)$: a hot topic at *B*-Factory

HEP 1,542 records found 1 - 25 jump to record: 1

1. **The BaBar detector**
(1868) BaBar Collaboration (Bernard Aubert (Annecy, LAPP) *et al.*). Apr 2001. 119 pp.
Published in **Nucl.Instrum.Meth. A479 (2002) 1-116**
SLAC-PUB-8569, BABAR-PUB-01-08
DOI: 10.1016/S0168-9002(01)02012-5
e-Print: hep-ex/0105044 | PDF
Detailed record - Cited by 1868 records 1000+

Top 2 @BaBar

2. **Observation of a narrow meson decaying to $D_s^+ \pi^0$ at a mass of 2.32-GeV/c^2**
(712) BaBar Collaboration (B. Aubert (Annecy, LAPP) *et al.*). Apr 2003. 7 pp.
Published in **Phys.Rev.Lett. 90 (2003) 242001**
SLAC-PUB-9711, BABAR-PUB-03-011
DOI: 10.1103/PhysRevLett.90.242001
e-Print: hep-ex/0304021 | PDF
Detailed record - Cited by 712 records 500+

3. **Observation of CP violation in the B^0 meson system**

5. **Measurements of the meson - photon transition form-factors of light pseudoscalar mesons at large momentum transfer**
(519) CLEO Collaboration (J. Gronberg (UC, Santa Barbara) *et al.*). Jul 1997. 30 pp.
Published in **Phys.Rev. D57 (1998) 33-54**
SLAC-PUB-9838, CLNS-97-1477, CLEO-97-7
DOI: 10.1103/PhysRevD.57.33
e-Print: hep-ex/9707031 | PDF
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
KEK scanned document ; ADS Abstract Service; Cornell U., LNS Server; Phys. Rev. D Server; SLAC Document Server
Data: INSPIRE | HepData
Detailed record - Cited by 519 records 500+

6. **Observation of a narrow resonance of mass 2.46-GeV/c**2 decaying to D*+(s) pi0 and confirmation of the D*(sJ)(2317) state**
(496) CLEO Collaboration (D. Besson (Kansas U.) *et al.*). May 2003. 16 pp.
Published in **Phys.Rev. D68 (2003) 032002, Phys.Rev. D75 (2007) 119908**
CLNS-03-1826, CLEO-03-09, CLNS03-1826
DOI: 10.1103/PhysRevD.75.119908, 10.1103/PhysRevD.68.032002
e-Print: hep-ex/0305100 | PDF
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
ADS Abstract Service; Phys. Rev. D Server
Detailed record - Cited by 496 records 250+

Top 6 @CLEO

7. **Observation of B Meson Semileptonic Decays to Noncharmed Final States**
(400) CLEO Collaboration (R. Fulton *et al.*). Nov 1989. 14 pp.
Published in **Phys.Rev.Lett. 64 (1990) 16-20**
CLNS-89/951, CLEO-89-14
DOI: 10.1103/PhysRevLett.64.16
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
CERN Document Server ; Phys. Rev. Lett. Server
Detailed record - Cited by 400 records 250+

References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
ADS Abstract Service; Phys. Rev. Lett. Server
Detailed record - Cited by 319 records 250+

9. **Observation of double c anti-c production in e+ e- annihilation at s**(1/2) approximately 10.6-GeV**
(319) Belle Collaboration (K. Abe *et al.*). May 2002. 7 pp.
Published in **Phys.Rev.Lett. 89 (2002) 142001**
BELLE-PREPRINT-2002-13, KEK-PREPRINT-2002-27
DOI: 10.1103/PhysRevLett.89.142001
e-Print: hep-ex/0205104 | PDF
Detailed record - Cited by 319 records 250+

10. **Observation of the D(sJ)(2317) and D(sJ)(2457) in B decays**
(298) Belle Collaboration (P. Krokovny (Novosibirsk, IYF) *et al.*). Aug 2003. 6 pp.
Published in **Phys.Rev.Lett. 91 (2003) 262002**
DOI: 10.1103/PhysRevLett.91.262002
e-Print: hep-ex/0308019 | PDF
Detailed record - Cited by 298 records 250+

Top 10 @Belle

11. **Evidence for X(3872) ---> gamma J / psi and the sub-threshold decay X(3872) ---> omega J / psi**
(295) Belle Collaboration (K. Abe *et al.*). May 2005. 10 pp.
BELLE-CONF-0540, LP-2005-175
Contributed to 22nd International Symposium on Lepton-Photon Conference: C05-06-30 Proceedings
505037 | PDF
ted by 295 records 250+

Continuing efforts from LHCb, Belle-II, PANDA,…

and also Lattice QCD

Theoretical interpretations

- $c\bar{s}$ state: Y.B.Dai, et al., PRD2003 ; S.Narison, PLB2005;

  E. van Beveren, et al., PRL 2003; ……
- Hadronic molecular state: T.Barnes, et al., PRD2003; F.K.Guo, et al., PLB2006; M.Cleven, et al., EPJA2011; D.LYao, et al., 1502.05981;……
- Four-quark state: H.Y.Cheng, et al., PRD 2003; K. Terasaki, PRD2003; L.Maiani et.al., PRD2005; M.Bracco, et al., PLB2005;……
- Mixing of molecular and four-quark states:

  T. Browder, et al., PLB2004;……
- ……

$D^*_{s0}(2317)$

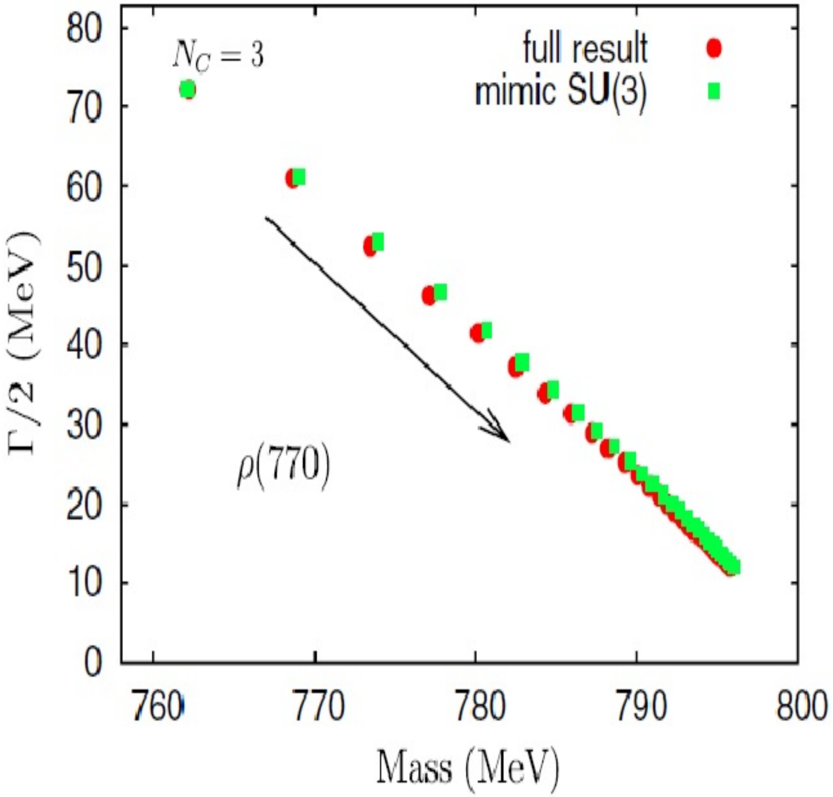
- chiral symmetry & heavy-quark symmetry
- a striking fact: below DK threshold (bound state)
- Nonperturbative effects: unitarity in D K scattering
- Coarse lattice study: scattering length with vayring m_π
- **We fill the gap to address the Nc trajectories for $D^*_{s0}(2317)$**

$f_0(500)/\sigma$

- chiral symmetry
- an extremely broad resonance
- Nonperturbative effects: unitarity in $\pi\pi$ scattering
- Theoretical prediction of pole trajectories with varying m_π
- Pole trajectories with Nc

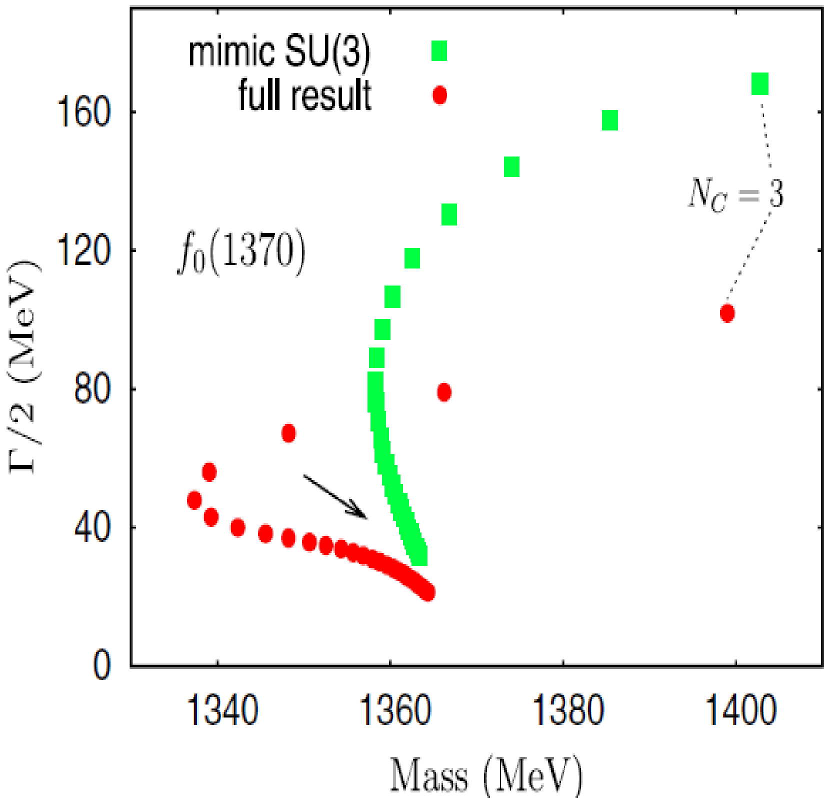
Why focusing on the Nc trajectory ?

A standard $\bar{q}q$ resonance: ρ(770)



M -> Const, Γ -> 1/Nc

Scalar resonance (unwilling to fall down to real axis)



ZHG, Oller, Ruiz de Elvira, PRD2011, 2012

Our focus:

Scalar Charmed states from $D_{(s)} + \pi(K,\eta,\eta')$ scattering

& their Nc and m_π dependences

2. Theoretical framework

LO ChPT with heavy-light mesons

$$\mathcal{L}^{(1)}_{D\phi} = \mathcal{D}_\mu D \mathcal{D}^\mu D^\dagger - \overline{M}^2_D D D^\dagger$$

NLO ChPT with heavy-light mesons [F.K.Guo,et al.,PLB08]

$$\mathcal{L}^{(2)}_{D\phi} = D\left(-h_0\langle\chi_+\rangle - h_1\chi_+ + h_2\langle u_\mu u^\mu\rangle - h_3 u_\mu u^\mu\right) D^\dagger + \mathcal{D}_\mu D\left(h_4\langle u_\mu u^\nu\rangle - h_5\{u^\mu, u^\nu\}\right)\mathcal{D}_\nu D^\dagger \,,$$

with $u_\mu = i\left(u^\dagger \partial_\mu u - u\,\partial_\mu u^\dagger\right)$ $\quad u = \exp\left(\frac{i\phi}{\sqrt{2}F_0}\right)$ $\quad \chi_\pm = u^\dagger \chi u^\dagger \pm u\chi u$

It is essential to generalize to U(3) case to study the Nc behaviors:

$$\phi = \begin{pmatrix} \frac{\sqrt{3}\pi^0 + \eta_8}{\sqrt{6}} & \pi^+ & K^+ \\ \pi^- & \frac{-\sqrt{3}\pi^0 + \eta_8}{\sqrt{6}} & K^0 \\ K^- & \bar{K}^0 & \frac{-2\eta_8}{\sqrt{6}} \end{pmatrix} \longrightarrow \begin{pmatrix} \frac{\sqrt{3}\pi^0 + \eta_8 + \sqrt{2}\eta_0}{\sqrt{6}} & \pi^+ & K^+ \\ \pi^- & \frac{-\sqrt{3}\pi^0 + \eta_8 + \sqrt{2}\eta_0}{\sqrt{6}} & K^0 \\ K^- & \bar{K}^0 & \frac{-2\eta_8 + \sqrt{2}\eta_0}{\sqrt{6}} \end{pmatrix}$$

Possible new operators with singlet η_0 can appear, but they are much less relevant in the present analysis.

Chiral Lagrangian for pseudo-Goldstone with $U_A(1)$ anomaly

$$\mathcal{L}_\chi = \frac{F^2}{4}\langle u_\mu u^\mu \rangle + \frac{F^2}{4}\langle \chi_+ \rangle + \boxed{\frac{F^2}{3} M_0^2 \ln^2 \det u}$$

Leads to a massive η_0

Why to include the singlet η_0 when discussing large Nc?

- Nc=3 : $U_A(1)$ anomaly is violated at quantum level and it is responsible for the massive η_0

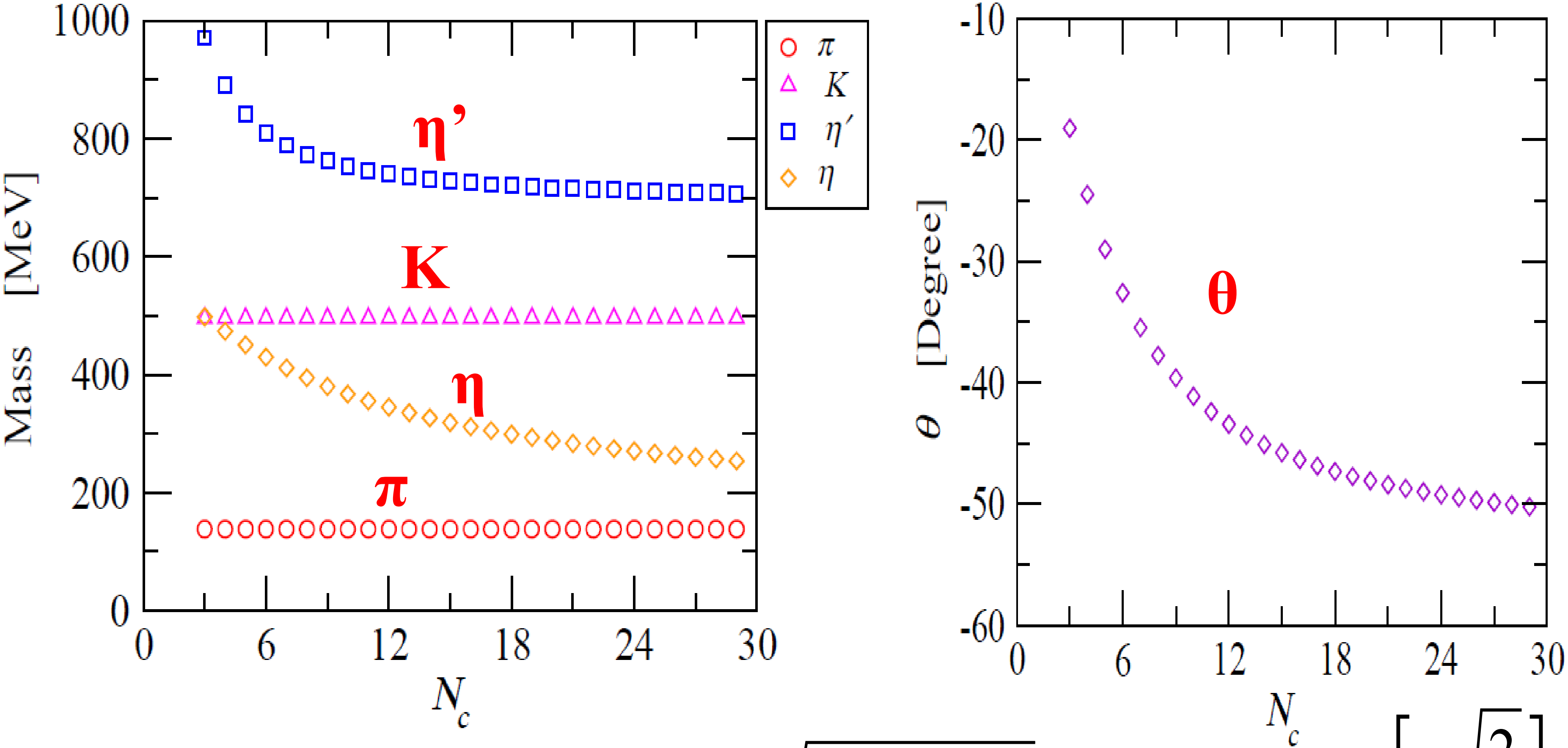
- Large Nc: $U_A(1)$ anomaly is 1/Nc suppressed, i.e. the mass of η_0 approaches to zero in the chiral limit.

As a result, pseudo-Goldstone nonet, π, K, η_8, η_0, will appear.

[t'Hooft, NPB'74; Witten, NPB'79; Coleman, Witten, PRL'80]

$$\mathcal{L}_\chi = \frac{F^2}{4}\langle u_\mu u^\mu \rangle + \frac{F^2}{4}\langle \chi_+ \rangle + \frac{F^2}{3} M_0^2 \ln^2 \det u$$ -> Leading order η-η' mixing

$$M_0^2 \to 1/Nc, \quad m_\pi^2, m_K^2 \to Const.$$



$$Nc \to \infty: \quad m_\eta \to m_\pi, \quad m_{\eta'} \to \sqrt{2m_K^2 - m_\pi^2}, \quad ,\theta \to \text{Arcsin}\left[-\sqrt{\frac{2}{3}}\right]$$

$D_{(s)}$ and light pseudoscalar meson scattering amplitudes

$$\mathcal{V}^{(S,I)}_{D_1\phi_1\to D_2\phi_2}(s,t,u)=\frac{1}{F^2}\left[\frac{C_{\rm LO}}{4}(s-u)-4C_0h_0+2C_1h_1-2C_{24}H_{24}(s,t,u)+2C_{35}H_{35}(s,t,u)\right]$$

(S,I)	Channels	$C_{\rm LO}$	C_0	C_1	C_{24}	C_{35}
$(-1,0)$	$D\bar{K}\to D\bar{K}$	-1	M_K^2	M_K^2	1	-1
$(-1,1)$	$D\bar{K}\to D\bar{K}$	1	M_K^2	$-M_K^2$	1	1
$(2,\frac{1}{2})$	$D_sK\to D_sK$	1	M_K^2	$-M_K^2$	1	1
$(0,\frac{3}{2})$	$D\pi\to D\pi$	1	M_π^2	$-M_\pi^2$	1	1
$(1,1)$	$D_s\pi\to D_s\pi$	0	M_π^2	0	1	0
	$DK\to DK$	0	M_K^2	0	1	0
	$DK\to D_s\pi$	1	0	$-(M_K^2+M_\pi^2)/2$	0	1
$(1,0)$	$DK\to DK$	-2	M_K^2	$-2M_K^2$	1	2
	$DK\to D_s\eta$	$-\sqrt{3}c_\theta$	0	$C_1^{1,0\ DK\to D_s\eta}$	0	$C_{35}^{1,0\ DK\to D_s\eta}$
	$D_s\eta\to D_s\eta$	0	$C_0^{1,0\ D_s\eta\to D_s\eta}$	$C_1^{1,0\ D_s\eta\to D_s\eta}$	1	$C_{35}^{1,0\ D_s\eta\to D_s\eta}$
	$DK\to D_s\eta'$	$-\sqrt{3}s_\theta$	0	$C_1^{1,0\ DK\eta\to D_s\eta'}$	0	$C_{35}^{1,0\ DK\eta\to D_s\eta'}$
	$D_s\eta\to D_s\eta'$	0	$C_0^{1,0\ D_s\eta\to D_s\eta'}$	$C_1^{1,0\ D_s\eta\to D_s\eta'}$	0	$C_{35}^{1,0\ D_s\eta\to D_s\eta'}$
	$D_s\eta'\to D_s\eta'$	0	$C_0^{1,0\ D_s\eta'\to D_s\eta'}$	$C_1^{1,0\ D_s\eta'\to D_s\eta'}$	1	$C_{35}^{1,0\ D_s\eta'\to D_s\eta'}$
$(0,\frac{1}{2})$	$D\pi\to D\pi$	-2	M_π^2	$-M_\pi^2$	1	1
	$D\eta\to D\eta$	0	$C_0^{0,\frac{1}{2}\ D\eta\to D\eta}$	$C_1^{0,\frac{1}{2}\ D\eta\to D\eta}$	1	$C_{35}^{0,\frac{1}{2}\ D\eta\to D\eta}$
	$D_s\bar{K}\to D_s\bar{K}$	-1	M_K^2	$-M_K^2$	1	1
	$D\eta\to D\pi$	0	0	$M_\pi^2(\sqrt{2}s_\theta-c_\theta)$	0	$c_\theta-\sqrt{2}s_\theta$
	$D_s\bar{K}\to D\pi$	$-\frac{\sqrt{6}}{2}$	0	$-\sqrt{6}(M_K^2+M_\pi^2)/4$	0	$\frac{\sqrt{6}}{2}$
	$D_s\bar{K}\to D\eta$	$-\frac{\sqrt{6}}{2}c_\theta$	0	$C_1^{0,\frac{1}{2}\ D_sK\to D\eta}$	0	$C_{35}^{0,\frac{1}{2}\ D_sK\to D\eta}$
	$D\eta'\to D\pi$	0	0	$-M_\pi^2(\sqrt{2}c_\theta+s_\theta)$	0	$s_\theta+\sqrt{2}c_\theta$
	$D\eta\to D\eta'$	0	$C_0^{0,\frac{1}{2}\ D\eta\to D\eta'}$	$C_1^{0,\frac{1}{2}\ D\eta\to D\eta'}$	0	$C_{35}^{0,\frac{1}{2}\ D\eta\to D\eta'}$
	$D_s\bar{K}\to D\eta'$	$-\frac{\sqrt{6}}{2}s_\theta$	0	$C_1^{0,\frac{1}{2}\ D_sK\to D\eta'}$	0	$C_{35}^{0,\frac{1}{2}\ D_sK\to D\eta'}$
	$D\eta'\to D\eta'$	0	$C_0^{0,\frac{1}{2}\ D\eta'\to D\eta'}$	$C_1^{0,\frac{1}{2}\ D\eta'\to D\eta'}$	1	$C_{35}^{0,\frac{1}{2}\ D\eta'\to D\eta'}$

$$H_{24}(s,t,u) = 2h_2 p_2\cdot p_4 + h_4(p_1\cdot p_2 p_3\cdot p_4 + p_1\cdot p_4 p_2\cdot p_3)\,,$$
$$H_{35}(s,t,u) = h_3 p_2\cdot p_4 + h_5(p_1\cdot p_2 p_3\cdot p_4 + p_1\cdot p_4 p_2\cdot p_3)\,,$$

$$C_1^{1,0\ DK\to D_s\eta} = \frac{-M_K^2(5c_\theta + 4\sqrt{2}s_\theta) + 3M_\pi^2 c_\theta}{2\sqrt{3}}\,,$$
$$C_{35}^{1,0\ DK\to D_s\eta} = \frac{c_\theta + 2\sqrt{2}s_\theta}{\sqrt{3}}\,,$$

$$C_0^{1,0\ D_s\eta\to D_s\eta} = \frac{c_\theta^2(4m_K^2 - m_\pi^2) + 4\sqrt{2}c_\theta s_\theta(m_K^2 - m_\pi^2) + s_\theta^2(2m_K^2 + m_\pi^2)}{3}\,,$$
$$C_1^{1,0\ D_s\eta\to D_s\eta} = \frac{2(m_\pi^2 - 2m_K^2)(\sqrt{2}c_\theta + s_\theta)^2}{3}\,,$$
$$C_{35}^{1,0\ D_s\eta\to D_s\eta} = \frac{2(\sqrt{2}c_\theta + s_\theta)^2}{3}\,,$$

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Partial wave projection

$$\mathcal{V}_\ell^{(S,I)}(s)_{D_1\phi_1\to D_2\phi_2} = \frac{1}{2}\int_{-1}^{1} \mathrm{d}\cos\theta\, P_\ell(\cos\theta)\, \mathcal{V}^{(S,I)}_{D_1\phi_1\to D_2\phi_2}(s, t(s,\cos\theta))$$

Unitarization

$$T(s) = \frac{1}{1-\mathcal{V}_\ell^{(S,I)}\cdot g(s)}\cdot \mathcal{V}_\ell^{(S,I)}\,, \qquad g(s) = \mathrm{diag}\{g(s)_{i=D_i\phi_i}\}$$

$$g(s)_i = i\int \frac{\mathrm{d}^4 q}{(2\pi)^4}\frac{1}{(q^2-M_{D_i}^2+i\epsilon)((P-q)^2-M_{\phi_i}^2+i\epsilon)}$$

$$16\pi^2 g(s) = \boxed{a_{SL}(\mu)} + \log\frac{m_b^2}{\mu^2} - x_+\log\frac{x_+-1}{x_+} - x_-\log\frac{x_--1}{x_-}$$

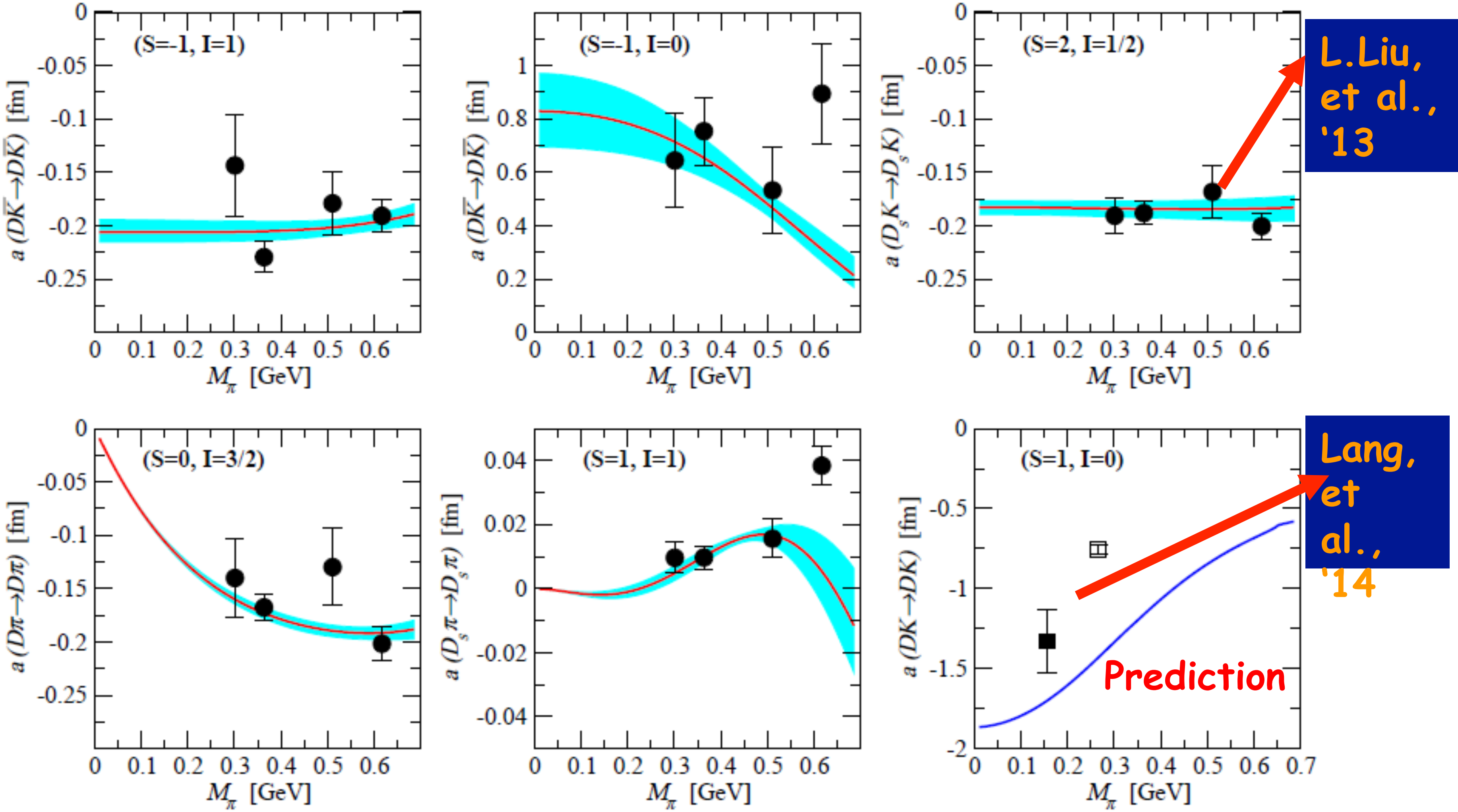
$$\mathrm{Im}\, g(s)_i = \frac{\sqrt{[s-(M_{\phi_i}+M_{D_i})^2][s-(M_{\phi_i}-M_{D_i})^2]}}{8\pi\sqrt{s}}$$

Results and Discussions

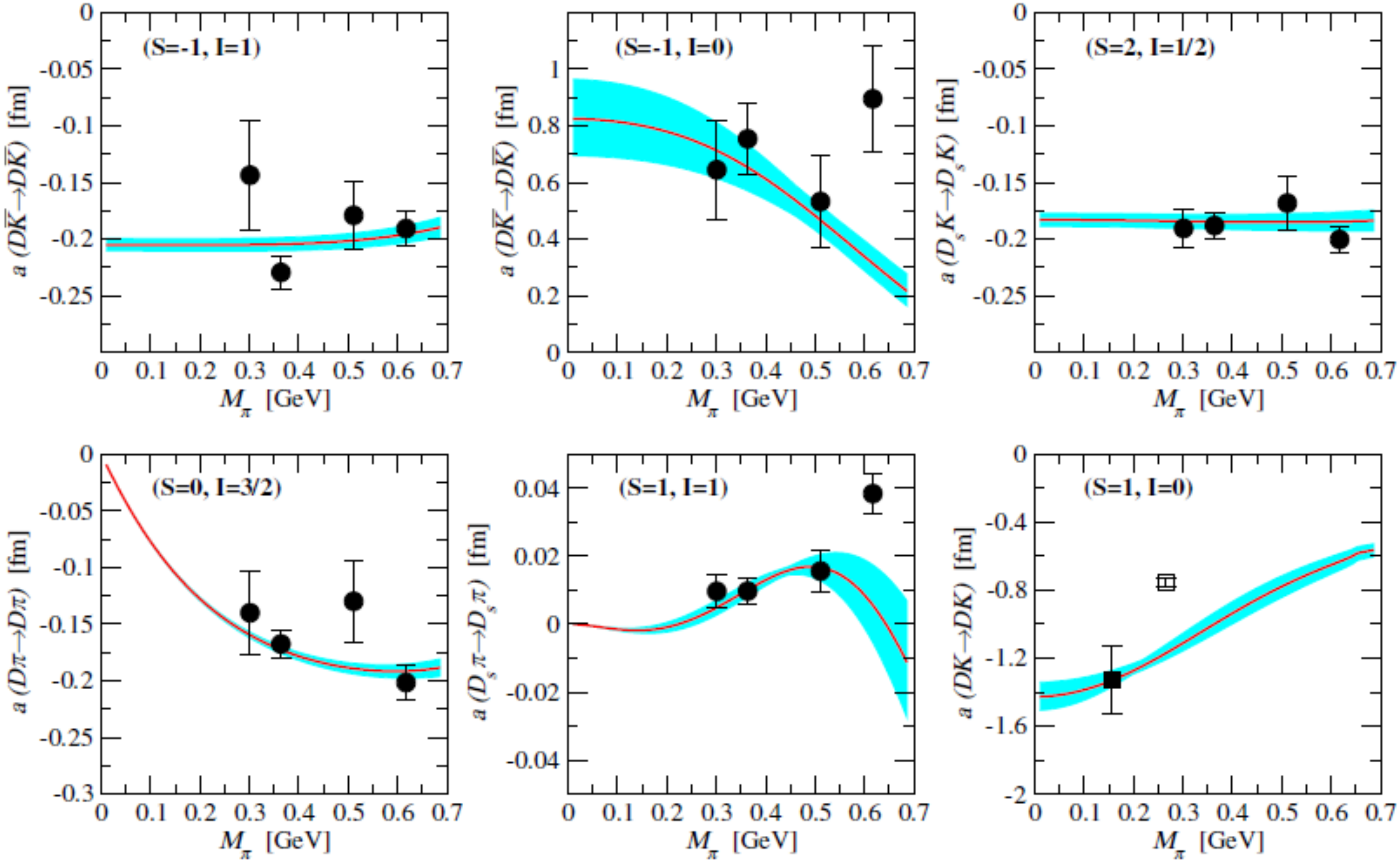
$$D\left(-h_0\langle\chi_+\rangle - h_1\chi_+\right)D^\dagger$$

h_0 h_1 determined by masses of D and Ds

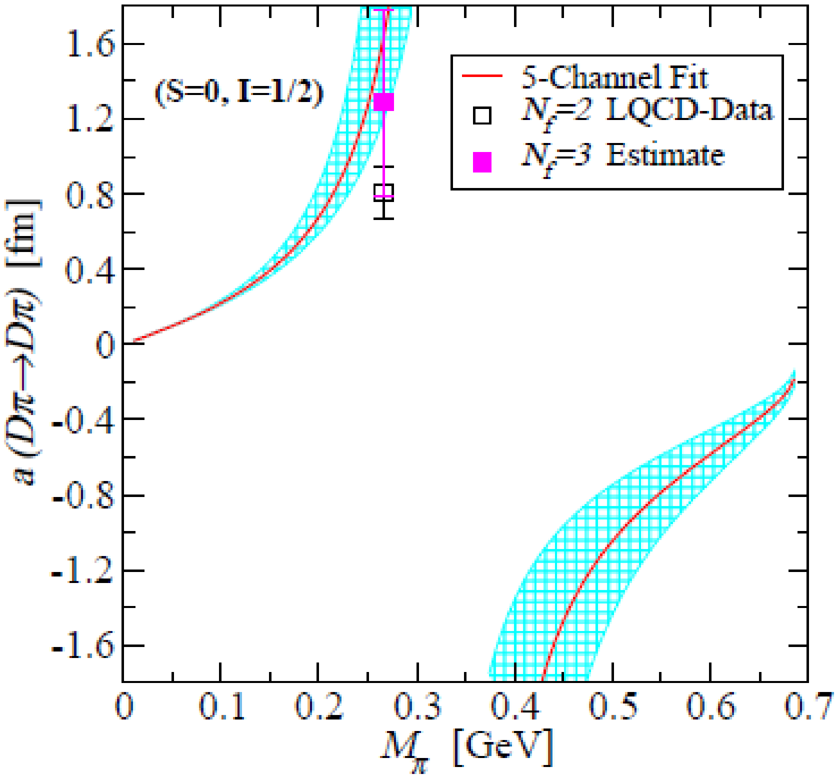
Five-channel fit (5c): 4 LECs and 1 common a_{SL}

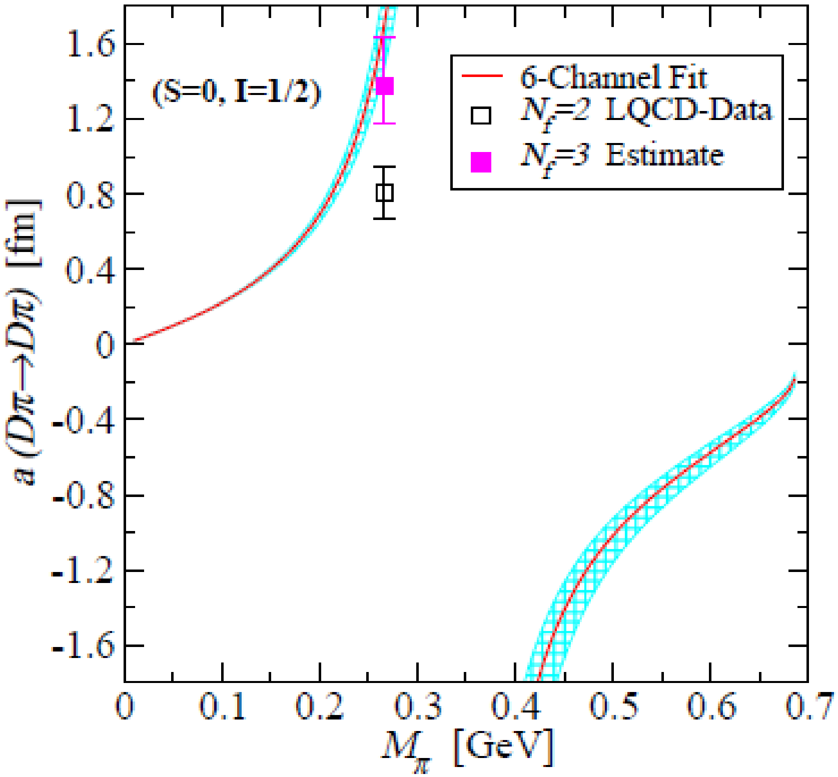


Six-channel fit (6c): 4 LECs and 1 common a_{SL}



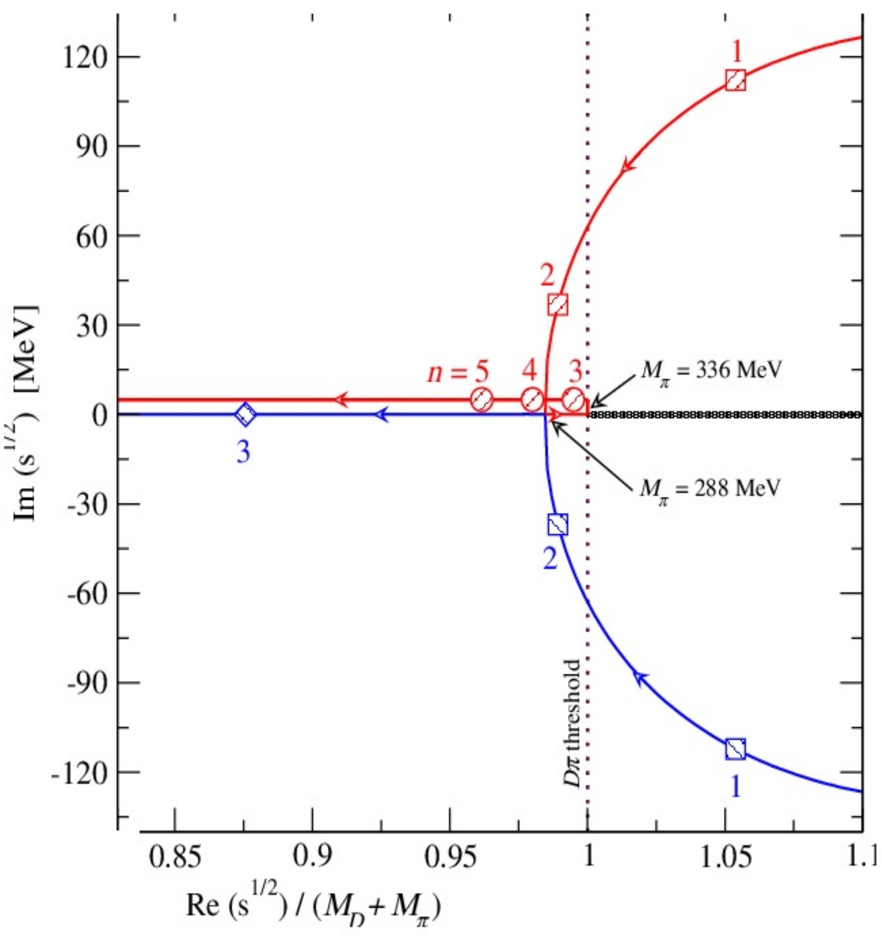
Prediciton of scattering lengths for (S,I)=(0,1/2) channel

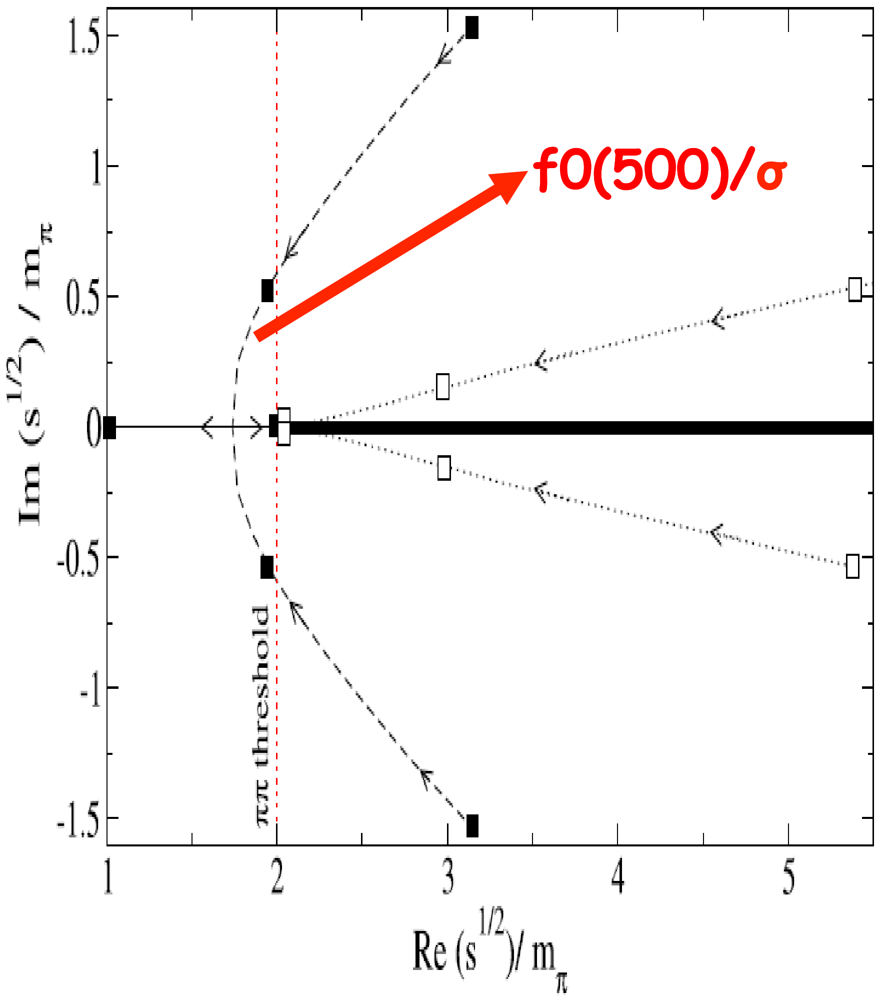




It clearly indicates that "exotics" things happen around m_π=0.3~0.4GeV

Pole trajectories with varying m_π





(S,I)=(0,1/2) channel

Hanhart, et al., PLB14

(S,I)	Channels	Fit-5C	Fit-6C
$(-1,0)$	$D\bar{K}\to D\bar{K}$	$1.27^{+0.49}_{-0.36}$	$1.26^{+0.46}_{-0.32}$
$(-1,1)$	$D\bar{K}\to D\bar{K}$	$-0.21^{+0.02}_{-0.01}$	$-0.21^{+0.01}_{-0.01}$
$(2,\frac{1}{2})$	$D_sK\to D_sK$	$-0.19^{+0.01}_{-0.01}$	$-0.19^{+0.01}_{-0.01}$
$(0,\frac{3}{2})$	$D\pi\to D\pi$	$-0.101^{+0.003}_{-0.003}$	$-0.101^{+0.001}_{-0.001}$
$(1,1)$	$D_s\pi\to D_s\pi$	$0.004^{+0.001}_{-0.001}$	$0.004^{+0.001}_{-0.001}$
	$DK\to DK$	$0.06^{+0.03}_{-0.03}+i\,0.17^{+0.02}_{-0.01}$	$0.06^{+0.03}_{-0.03}+i\,0.17^{+0.01}_{-0.01}$
$(1,0)$	$DK\to DK$	$-0.92^{+0.22}_{-0.40}$	$-0.89^{+0.06}_{-0.10}$
	$D_s\eta\to D_s\eta$	$-0.27^{+0.01}_{-0.01}+i\,0.03^{+0.01}_{-0.01}$	$-0.27^{+0.01}_{-0.01}+i\,0.03^{+0.01}_{-0.01}$
	$D_s\eta'\to D_s\eta'$	$-0.22^{+0.03}_{-0.01}+i\,0.01^{+0.01}_{-0.01}$	$-0.22^{+0.01}_{-0.01}+i\,0.01^{+0.01}_{-0.01}$
$(0,\frac{1}{2})$	$D\pi\to D\pi$	$0.35^{+0.04}_{-0.02}$	$0.35^{+0.01}_{-0.01}$
	$D\eta\to D\eta$	$0.02^{+0.06}_{-0.04}+i\,0.03^{+0.03}_{-0.01}$	$0.02^{+0.02}_{-0.02}+i\,0.03^{+0.01}_{-0.01}$
	$D_s\bar{K}\to D_s\bar{K}$	$-0.05^{+0.04}_{-0.06}+i\,0.35^{+0.07}_{-0.03}$	$-0.05^{+0.02}_{-0.02}+i\,0.35^{+0.04}_{-0.03}$
	$D\eta'\to D\eta'$	$0.16^{+0.64}_{-0.22}+i\,0.05^{+0.26}_{-0.03}$	$0.34^{+0.31}_{-0.14}+i\,0.04^{+0.12}_{-0.02}$

Scattering lengths at physical masses

(S, I)	RS	$\sqrt{s_{pole}}$ [MeV]	$\|\text{Residue}\|^{1/2}$ [GeV]	Ratios	
$(-1,0)$	II	2333^{+15}_{-36}	$7.45^{+3.56}_{-1.38}(D\bar{K})$		
$(0,\frac{3}{2})$	II	$2033^{+3}_{-3} - i\,251^{+3}_{-3}$	$6.64^{+0.04}_{-0.04}(D\pi)$		
$(1,1)$	II	$2466^{+32}_{-27} - i\,271^{+4}_{-5}$	$6.95^{+0.60}_{-0.37}(D_s\pi)$	$1.72^{+0.12}_{-0.15}(DK/D_s\pi)$	
	III	$2225^{+12}_{-9} - i\,178^{+19}_{-17}$	$7.35^{+0.19}_{-0.13}(D_s\pi)$	$0.80^{+0.04}_{-0.04}(DK/D_s\pi)$	
$(1,0)$	I	2321^{+6}_{-3}	$9.30^{+0.04}_{-0.12}(DK)$	$0.77^{+0.02}_{-0.02}(D_s\eta/DK)$	$0.43^{+0.15}_{-0.13}(D_s\eta'/DK)$
	II	2356^{+1}_{-1}	$2.85^{+0.08}_{-0.13}(DK)$	$0.69^{+0.01}_{-0.01}(D_s\eta/DK)$	$0.38^{+0.12}_{-0.11}(D_s\eta'/DK)$
$(0,\frac{1}{2})$	II	$2114^{+3}_{-3} - i\,111^{+8}_{-7}$	$9.66^{+0.15}_{-0.13}(D\pi)$	$0.31^{+0.03}_{-0.03}(D\eta/D\pi)$	$0.46^{+0.02}_{-0.02}(D_s\bar{K}/D\pi)$
				$0.49^{+0.08}_{-0.08}(D\eta'/D\pi)$	
	III	$2473^{+29}_{-22} - i\,140^{+8}_{-7}$	$5.36^{+0.40}_{-0.28}(D\pi)$	$1.09^{+0.06}_{-0.05}(D\eta/D\pi)$	$2.12^{+0.06}_{-0.08}(D_s\bar{K}/D\pi)$
				$1.12^{+0.18}_{-0.16}(D\eta'/D\pi)$	

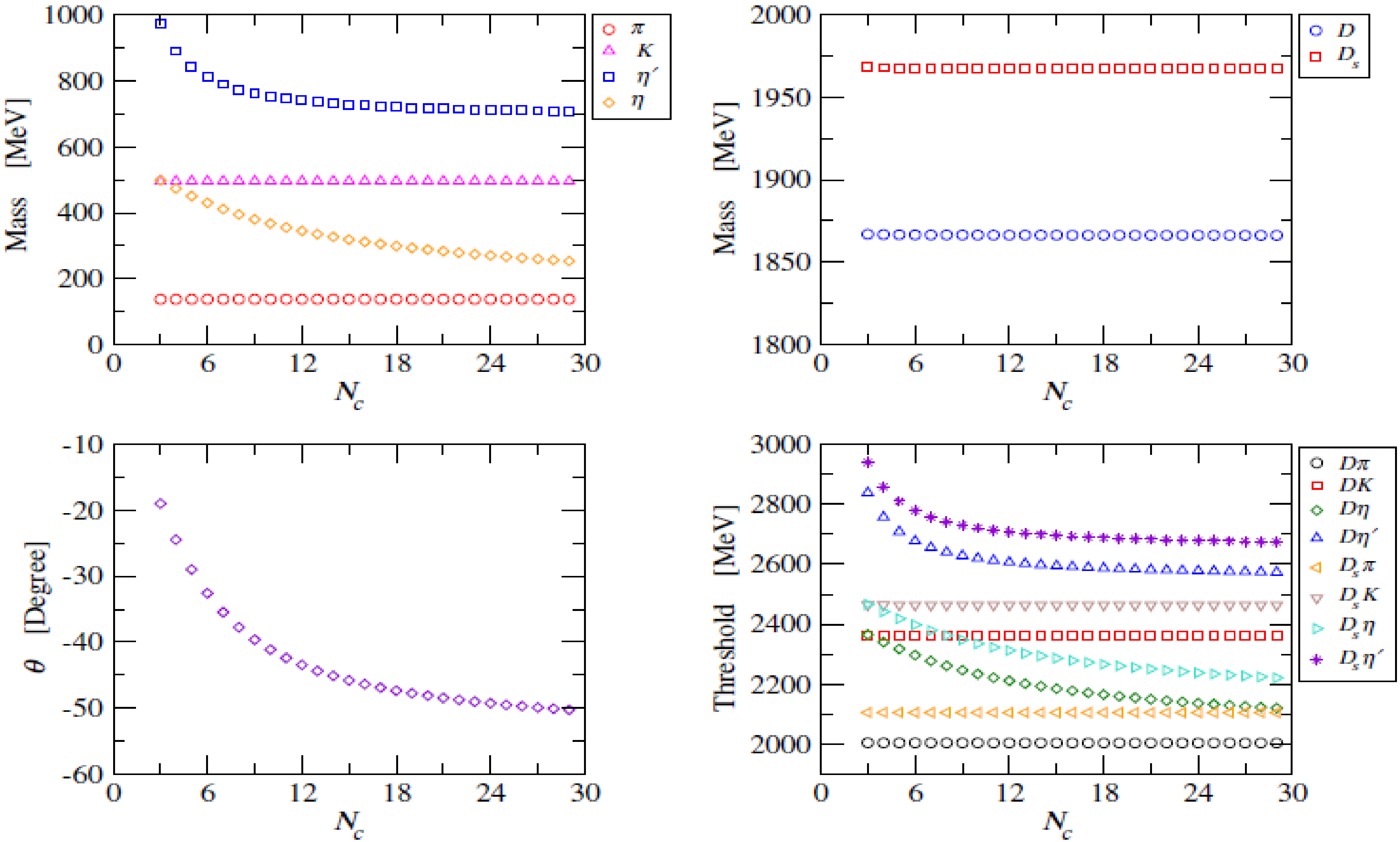
May explain the enhancement of the $D^0 K^+$ channel: 1506.00600

Pole positions and their residues with physical masses

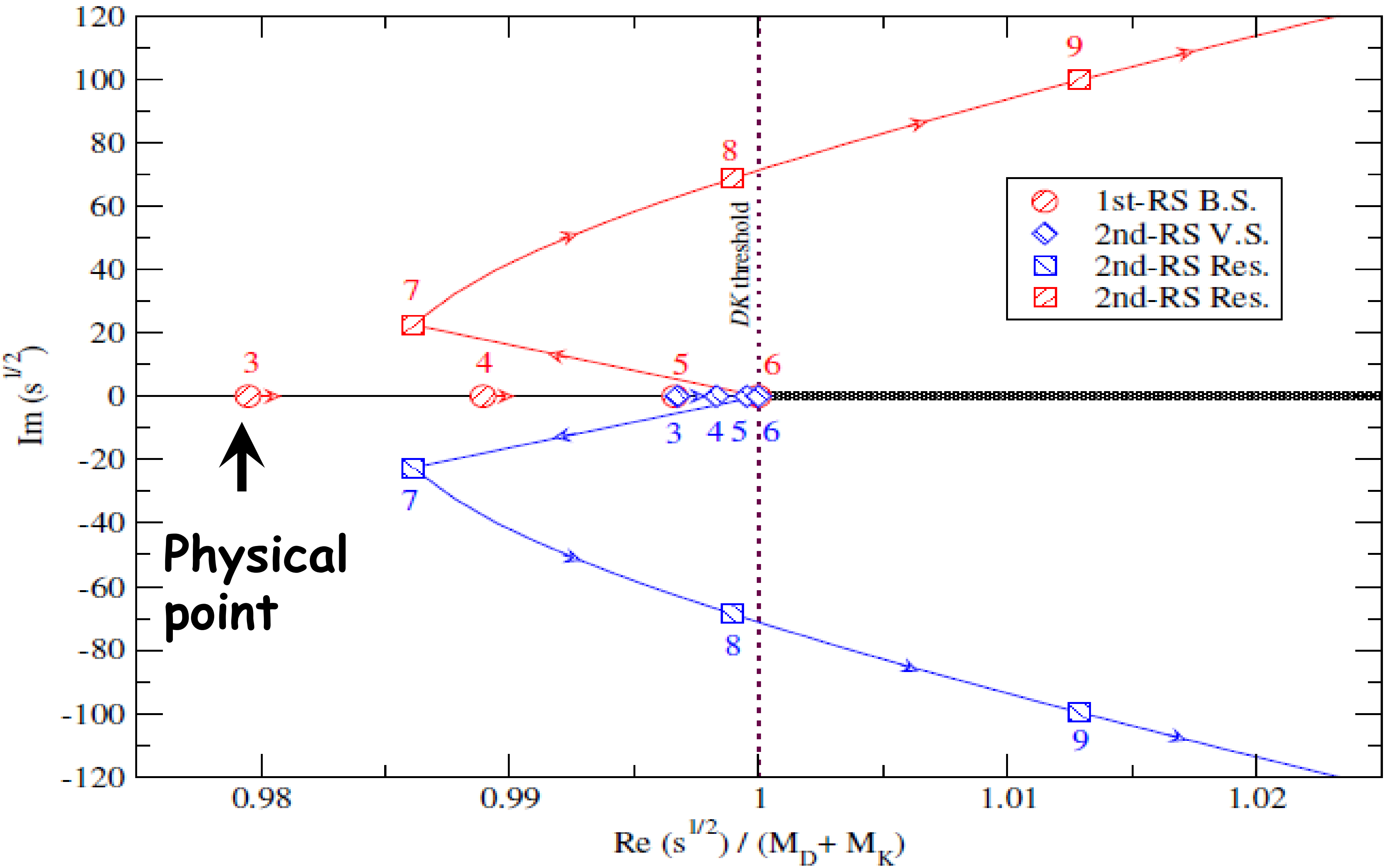
Nc trajectories

$$\bar{M}_D \to O(1), \quad m_\pi^2, m_K^2 \to O(1)$$

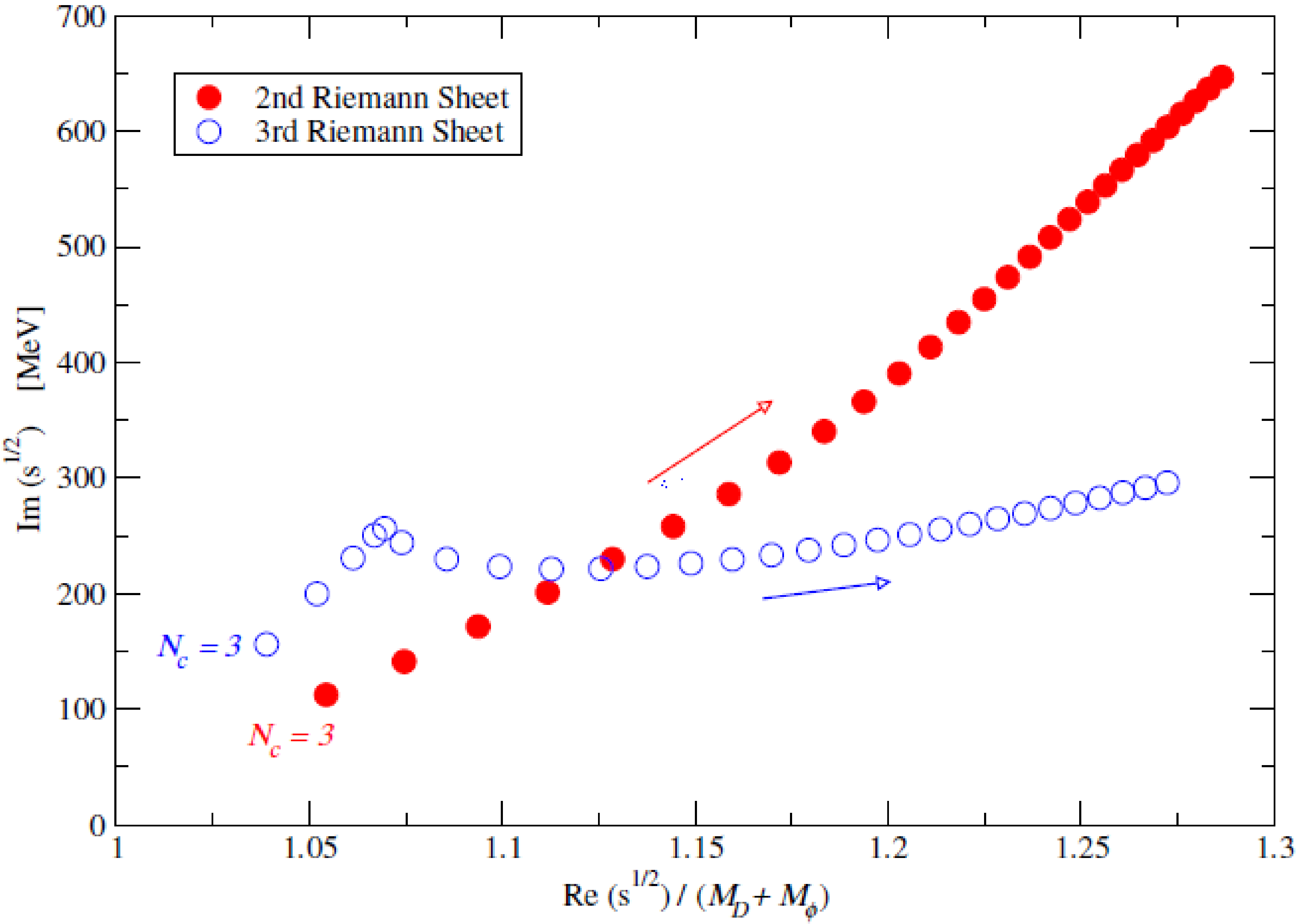
$$M_0^2 \to 1/N_C, \quad F \to \sqrt{N_C}, \quad h_{1,3,5} \to O(1), \quad h_{0,2,4} \to 1/N_C$$



Nc trajectories for $D^*_{s0}(2317)$



Nc trajectories for D^*_0 pole in (S,I)=(0,1/2) channel



Summary

- $D_{(s)}$ + $\pi(K,\eta,\eta')$ scattering amplitudes are calculated in U(3) chiral Lagrangian and then unitarized.

- The broad pole around 2.5 GeV with (S,I)=(1,1) may explain the newly observed enhancement in D^0K^+ channel

- Pole trajectories with varying m_π for the (S,I)=(0,1/2) channel are found to be quite similar as those from f0(500).

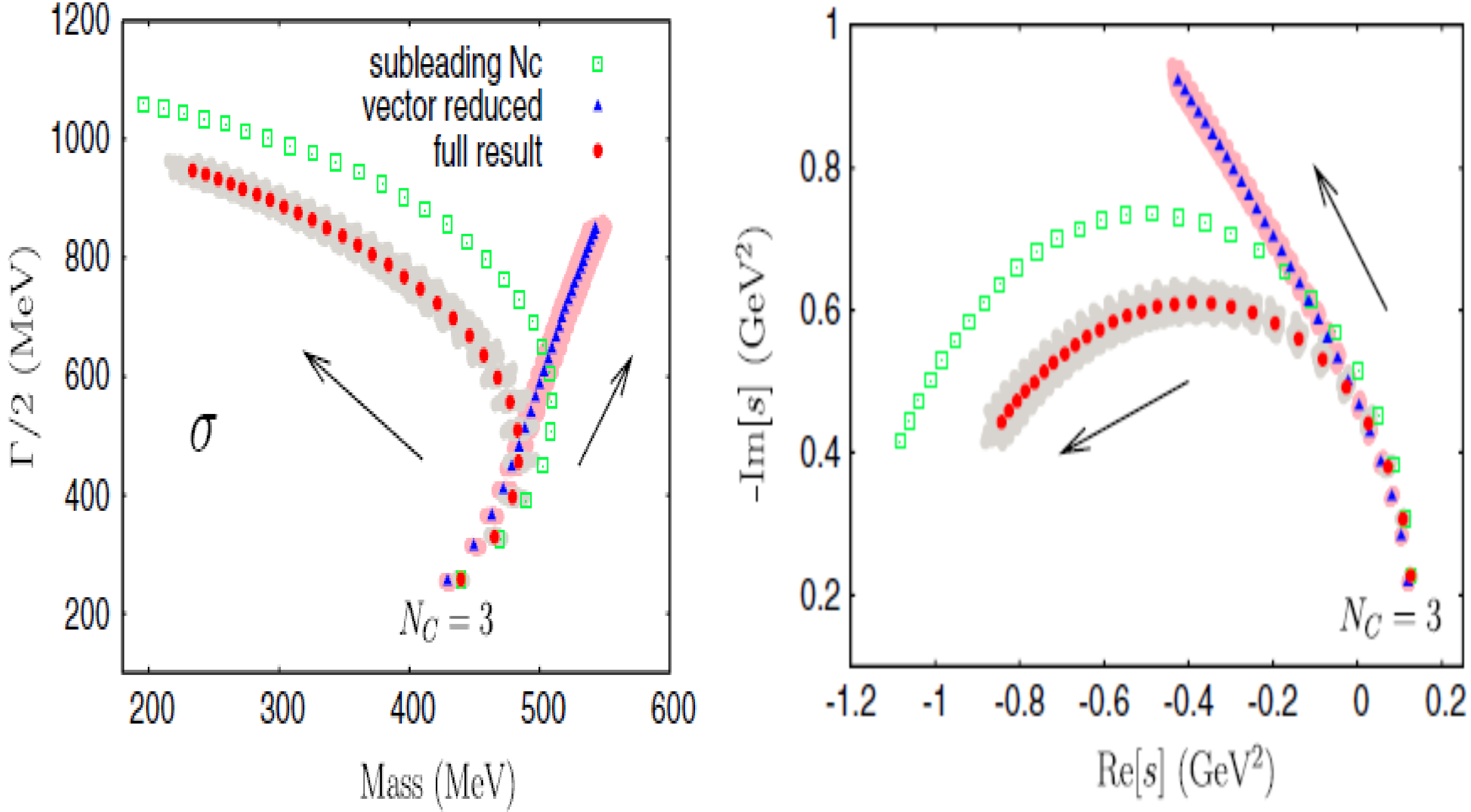
- Pole trajectories with varying Nc for $D^*_{s0}(2317)$ and the (S,I)=(0,1/2) channel are given.

They do not tend to fall down to the real axis for large values of Nc, indicating their marginal effects at large Nc.

谢谢大家！

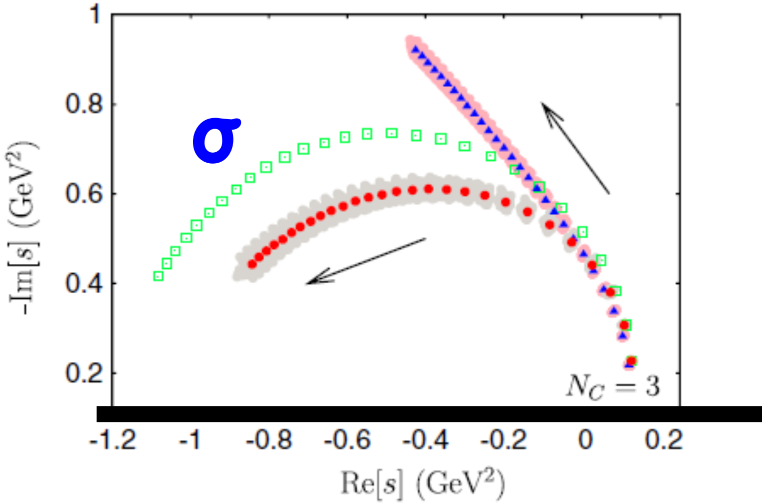
Even more exotic case: f0 (500)/σ

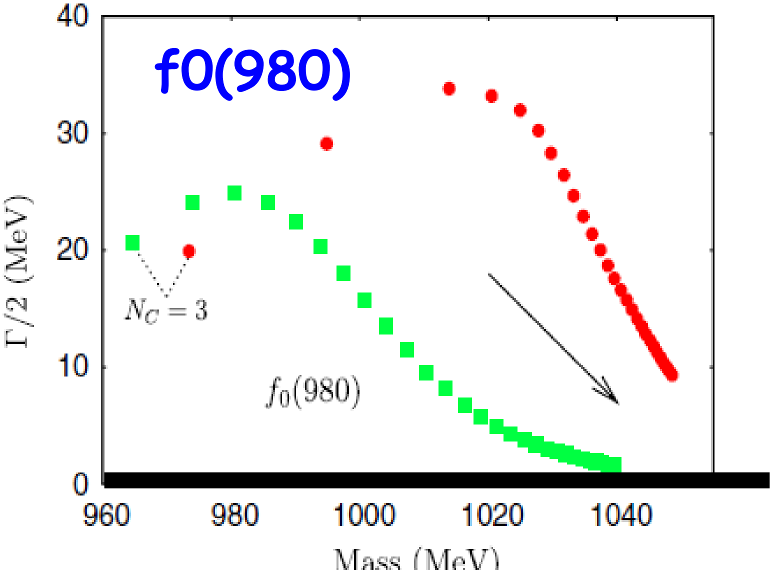
ZHG,Oller,Ruiz de Elvira, PRD2011,2012

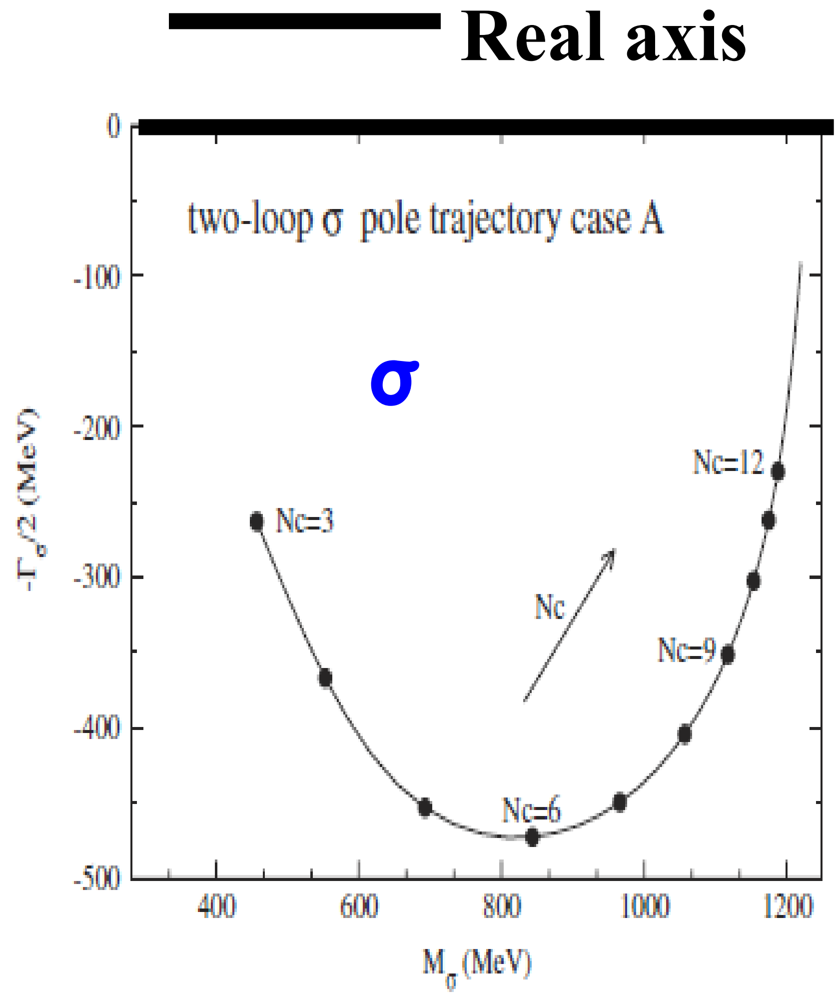


Similar behaviors are found from [Dai,Wang,Zheng,CTP'12]

Controversial behaviors: f0 (500)/σ







ZHG,Oller,Ruiz de Elvira, PRD2011,2012

Pelaez, et al., '11