Resonance parameters of the vector charmonium-like state G(3900)

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第十届手征有效场论研讨会

南京, 南京师范大学 2025.10.18

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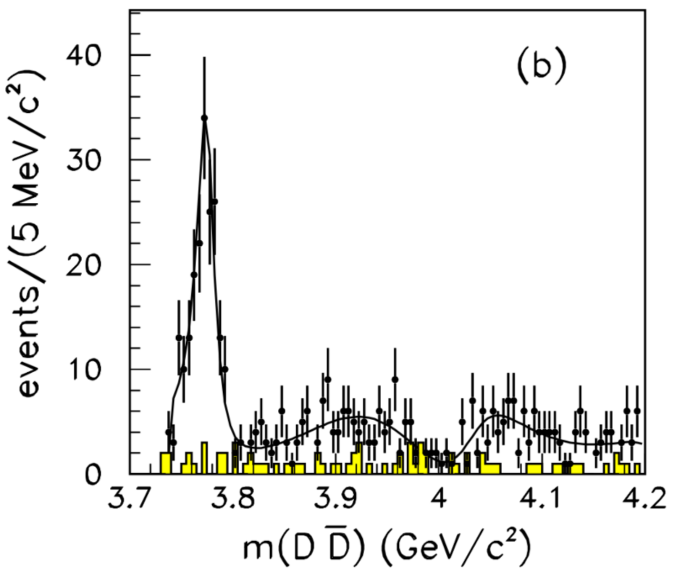
Phys. Rev. D 112 (2025), 016015

Background

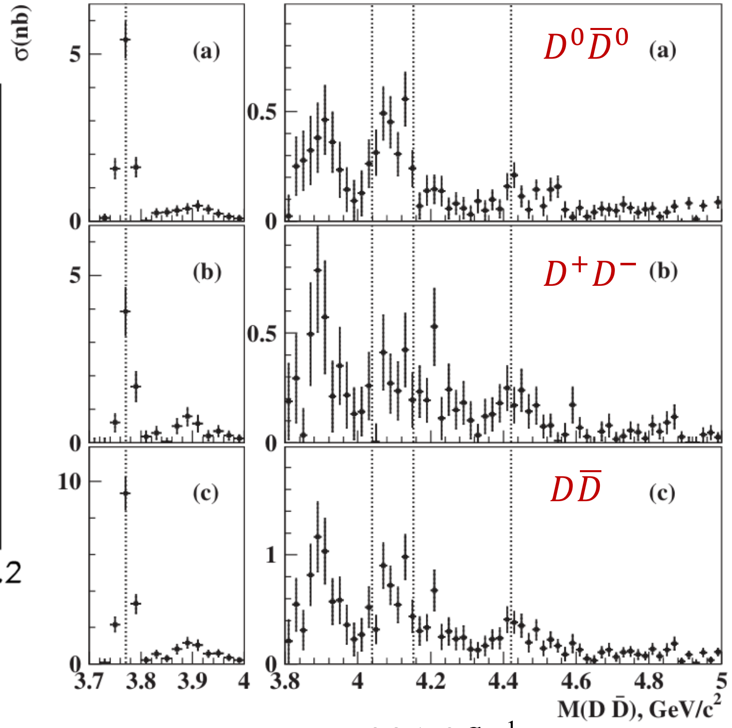
- The observation of G(3900)

[*BABAR*, PRD 76 (2007), 111105(R)]



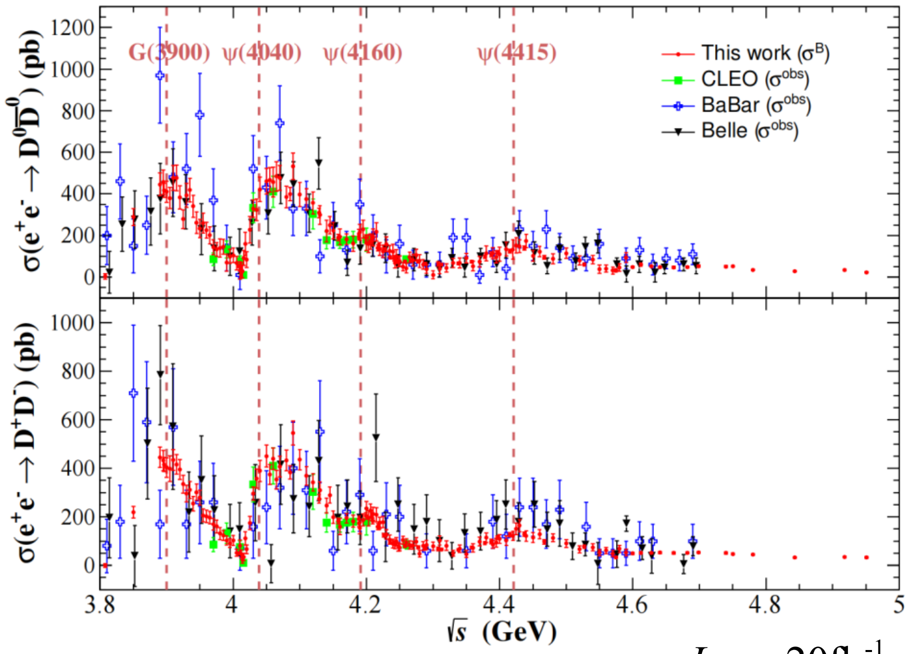
$L_{\text{int}} = 384\text{fb}^{-1}$

[Belle, PRD 77 (2008), 111103(R)]



$L_{\text{int}} = 921.9\text{fb}^{-1}$

[BESIII, PRL 133 (2024), 081901]



$L_{\text{int}} = 20\text{fb}^{-1}$

- $M(G(3900)) = 3943 \pm 17_{stat} \pm 12_{syst}$ MeV, $\sigma = 52 \pm 8_{stat} \pm 7_{syst}$ MeV

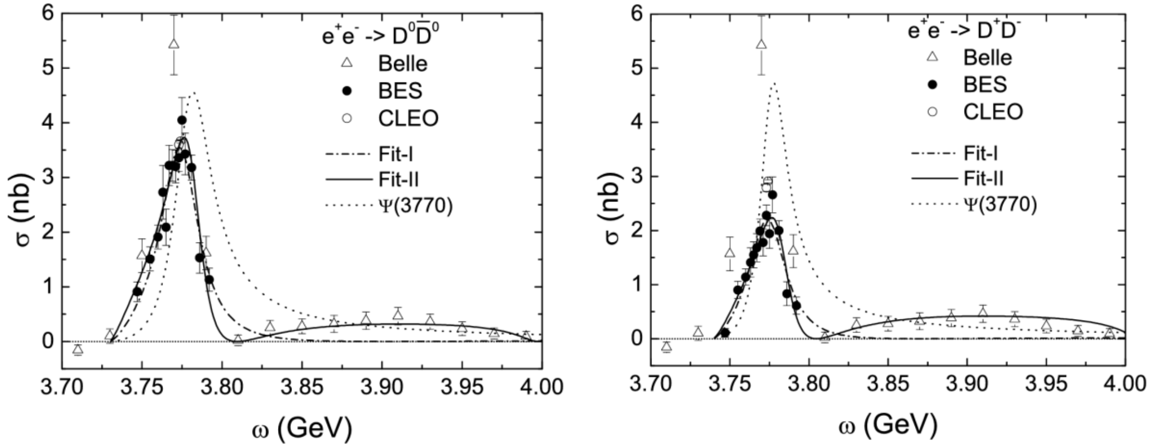
- Discovered in $e^+e^- \to D\bar{D}$
- Close to $D\bar{D}^*$ threshold
- $M(G(3900)) = 3872.5 \pm 14.2_{stat} \pm 3.0_{syst}$ MeV, $\Gamma = 179.7 \pm 14.1_{stat} \pm 7.0_{syst}$MeV
- Statistical significance >20 σ

Background

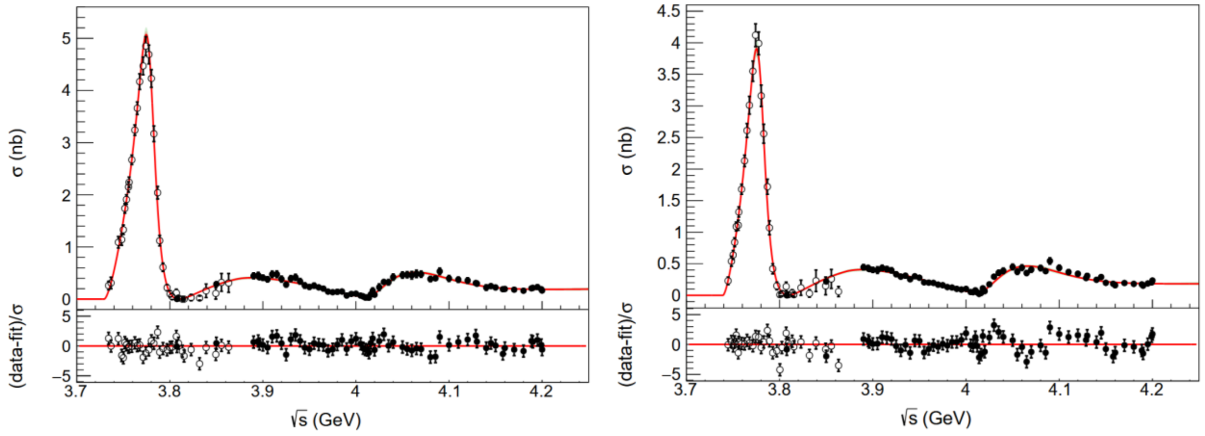
● Studies of G(3900)

◆ Threshold enhancement

[Xu Cao et al. arXiv (2014), 1410.1375]



[N. Hüsken et al. PRD 109 (2024), 114010]



◆ Couple-channel T-matrix

◆ Distortion of $\psi(3770)$ tail induced by the $D\bar{D}^*$ threshold

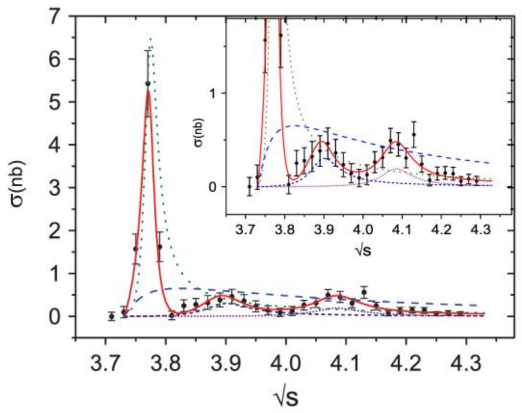
◆ Couple-channel K-matrix

◆ No additional bare pole near 3900 MeV is needed

Background

◆ P-wave $D\bar{D}^*$ molecular resonance

[Yuan-Jiang Zhang et al. PRD 81 (2010), 034011]

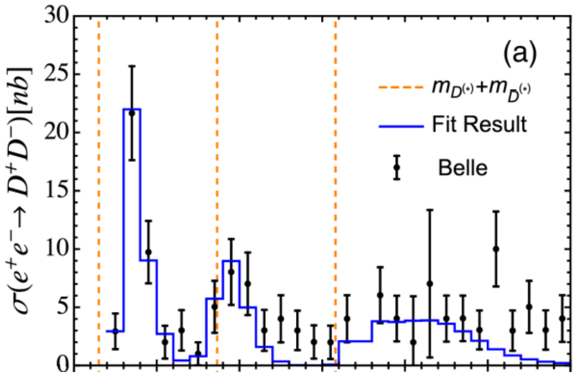


◆ Effective Lagrangian approach

◆ Extract $D^* \to D$ transition form factor

◆ $M(G(3900)) = 3894^{+11}_{-11}$ MeV
$\Gamma(G(3900)) = 89.9^{+12.6}_{-12.6}$ MeV

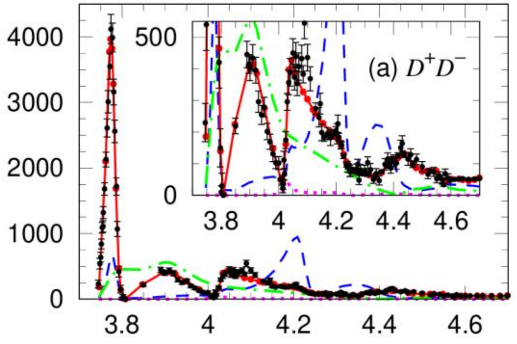
[Meng-Lin Du et al. PRD 94 (2016), 096006]



◆ Under HQSS, LSE approch

◆ $M(G(3900)) = 3879$ MeV
$\Gamma(G(3900)) = 64$ MeV

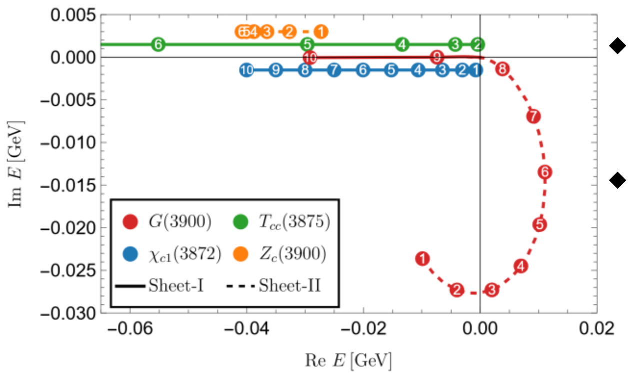
[S. X. Nakamura et al. arXiv (2023), 2312.17658]



◆ Global fitting (10 two-body, 9 three-body, 1 four-body final states)

◆ $M(G(3900)) = 3896^{+1.4}_{-1.4}$ MeV
$\Gamma(G(3900)) = 70.0^{+3.9}_{-3.9}$ MeV

[Zi-Yang Lin et al. PRL 133 (2024), 241903]



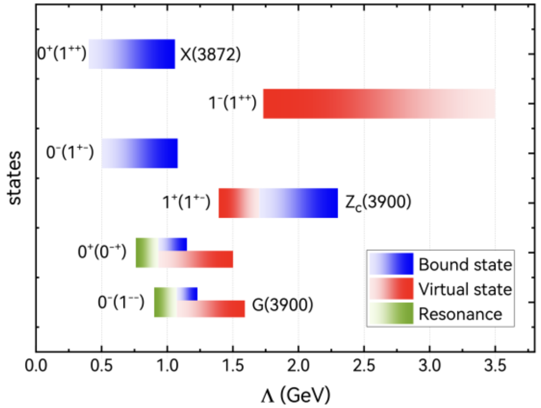
◆ OBE: $\rho, \omega, \sigma, \pi, \eta$
HM: $X(3872), Z_c(3900), T_{cc}(3875)$

◆ $M(G(3900)) = 3869.2^{+6.7}_{-6.7}$ MeV
$\Gamma(G(3900)) = 29.0^{+5.2}_{-5.2}$ MeV

Background

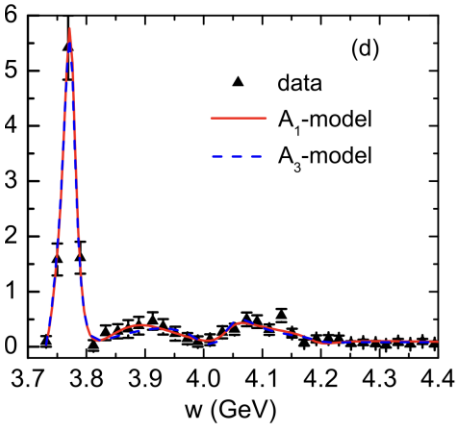
◆ Other structures

[Xiao-Xiao Chen et al. PRD 111 (2025), 114008]



- ◆ qBSE + OBE
- ◆ Pole trajectory of G(3900) with energy scale
- ◆ Genuine state: bound, resonance, or virtual (scale-dependent)

[Yin Huang et al. arXiv (2025),2509.06353]



- ◆ Transverse momentum analysis of $e^+e^- \to D\bar{D}$
- ◆ Jacobian peak = direct evidence of G(3900)
- ◆ Not a $D\bar{D}^*$ molecule → other structure

Background

◆ Other structures

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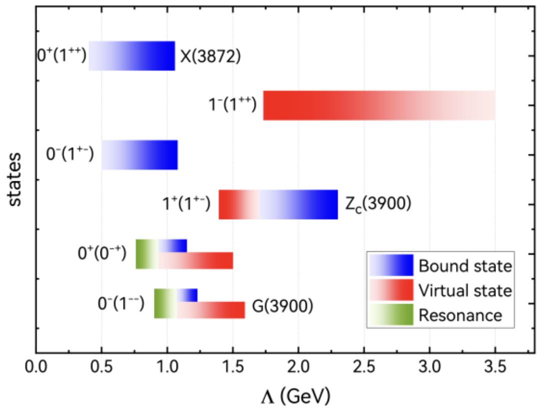

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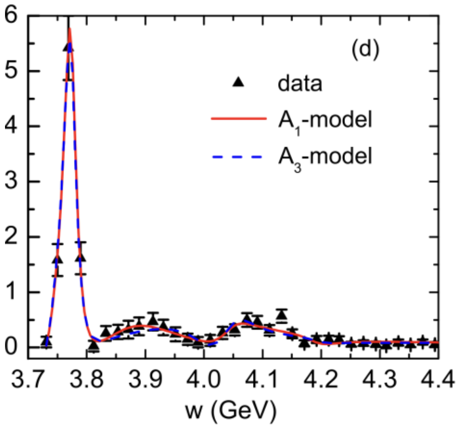

- Transverse momentum analysis of $e^+e^- \to D\overline{D}$
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◆ Motivation

- **Recently precise measurement of $e^+e^- \to D^{(*)}\overline{D}^{(*)}$ reported by BESIII**
- **Perform a global analysis under HQS and SU(3) symmetry**
- **Exploring whether G(3900) is dynamically generated or a renormalized bare state**

Formalism

1

- Molecular framework

Transformation

hadron basis → SU(3) basis

$$\begin{pmatrix} |D^{(*)+}D^{(*)-}\rangle \\ |D^{(*)0}\bar{D}^{(*)0}\rangle \\ |D_s^{(*)+}D_s^{(*)-}\rangle \end{pmatrix} \qquad \begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{-1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{-2}{\sqrt{6}} & 0 \end{pmatrix} \otimes 1_{4\times 4} \qquad \begin{pmatrix} |D^{(*)}\bar{D}^{(*)}\rangle^{0} \\ |D^{(*)}\bar{D}^{(*)}\rangle^{8} \\ |D^{(*)}\bar{D}^{(*)}\rangle^{1} \end{pmatrix}$$

- Heavy-light decomposition

$$|l([s_{l_1}s_{Q_1}]_{j_1}[s_{l_2}s_{Q_2}]_{j_2})_s\rangle_J$$

$$= \sum_{s_l,s_Q,s_q} (-1)^{l+s_Q+s_q+J}\,\hat{s}_q\hat{s}_Q\hat{j}_1\hat{j}_2\hat{s}\hat{s}_l \begin{Bmatrix} s_{l_1} & s_{Q_1} & j_1 \\ s_{l_2} & s_{Q_2} & j_2 \\ s_q & s_Q & s \end{Bmatrix} \times \begin{Bmatrix} l & s_q & s_l \\ s_Q & J & s \end{Bmatrix} |s_Q \otimes s_l\rangle_J$$

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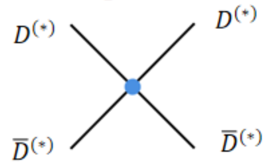
- Potential

◆ Charm meson pairs



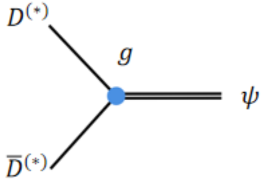
◆ Coupling betweencharm meson pairs

$$C_1^i \equiv {}^i\langle 0\otimes 1|H_{CT}|0\otimes 1\rangle^j \delta^{ij}$$
$$C_2^i \equiv {}^i\langle 1\otimes 0|H_{CT}|1\otimes 0\rangle^j \delta^{ij}$$
$$C_3^i \equiv {}^i\langle 1\otimes 1|H_{CT}|1\otimes 1\rangle^j \delta^{ij}$$
$$C_4^i \equiv {}^i\langle 1\otimes 2|H_{CT}|1\otimes 2\rangle^j \delta^{ij}$$

◆ Corresponding potential

$$V_{nn'}^i = {}^i_n\langle D^{(*)}\bar{D}^{(*)}|H_{CT}|D^{(*)}\bar{D}^{(*)}\rangle^j_{n'}\delta^{ij}$$

◆ Charm meson pairs with charmonia



◆ Coupling between charm meson pairs and charmonia

$$g_{1D}^0 \equiv {}^0\langle 1\otimes 2|H_{bare}|\langle 1\otimes 2\rangle_{1D}^0$$
$$g_{3S}^0 \equiv {}^0\langle 1\otimes 0|H_{bare}|\langle 1\otimes 0\rangle_{3S}^0$$
$$g_{2D}^0 \equiv {}^0\langle 1\otimes 2|H_{bare}|\langle 1\otimes 2\rangle_{2D}^0$$

Model II

Model I

◆ Corresponding potential

$$V_{c\bar{c}}^0 = {}^0_n\langle D^{(*)}\bar{D}^{(*)}|H_{bare}|j\rangle^0$$

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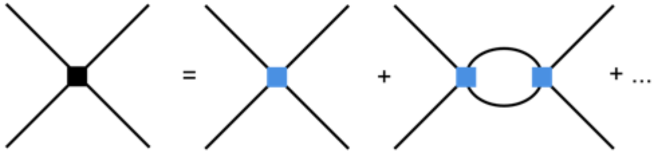
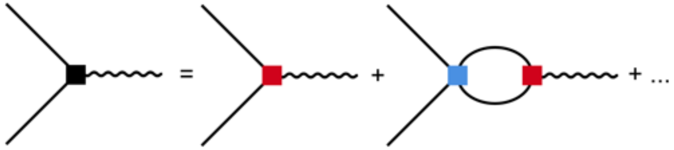
- The T-matrix and physical production amplitude

◆ T-matrix



$$T_{oo}(E) = \left[\left[\hat{V}_{oo}^{eff}(E)\right]^{-1} - G_{CT}(E)\right]^{-1}$$

◆ Production amplitude



$$\mathcal{U}_0(E) = \left(1_{12\times 12} - \hat{V}_{oo}^{eff}G_{CT}(E)\right)^{-1}\hat{F}_o^{eff}$$

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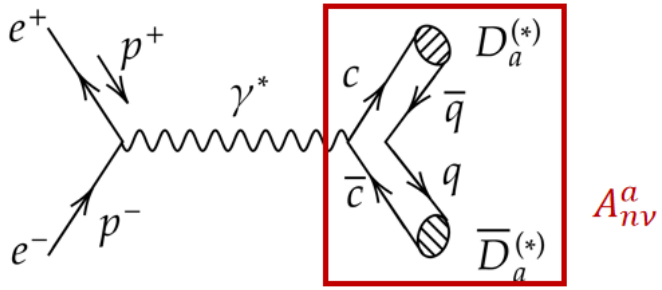
- The cross section for $e^+e^- \to D^{(*)}\bar{D}^{(*)}$



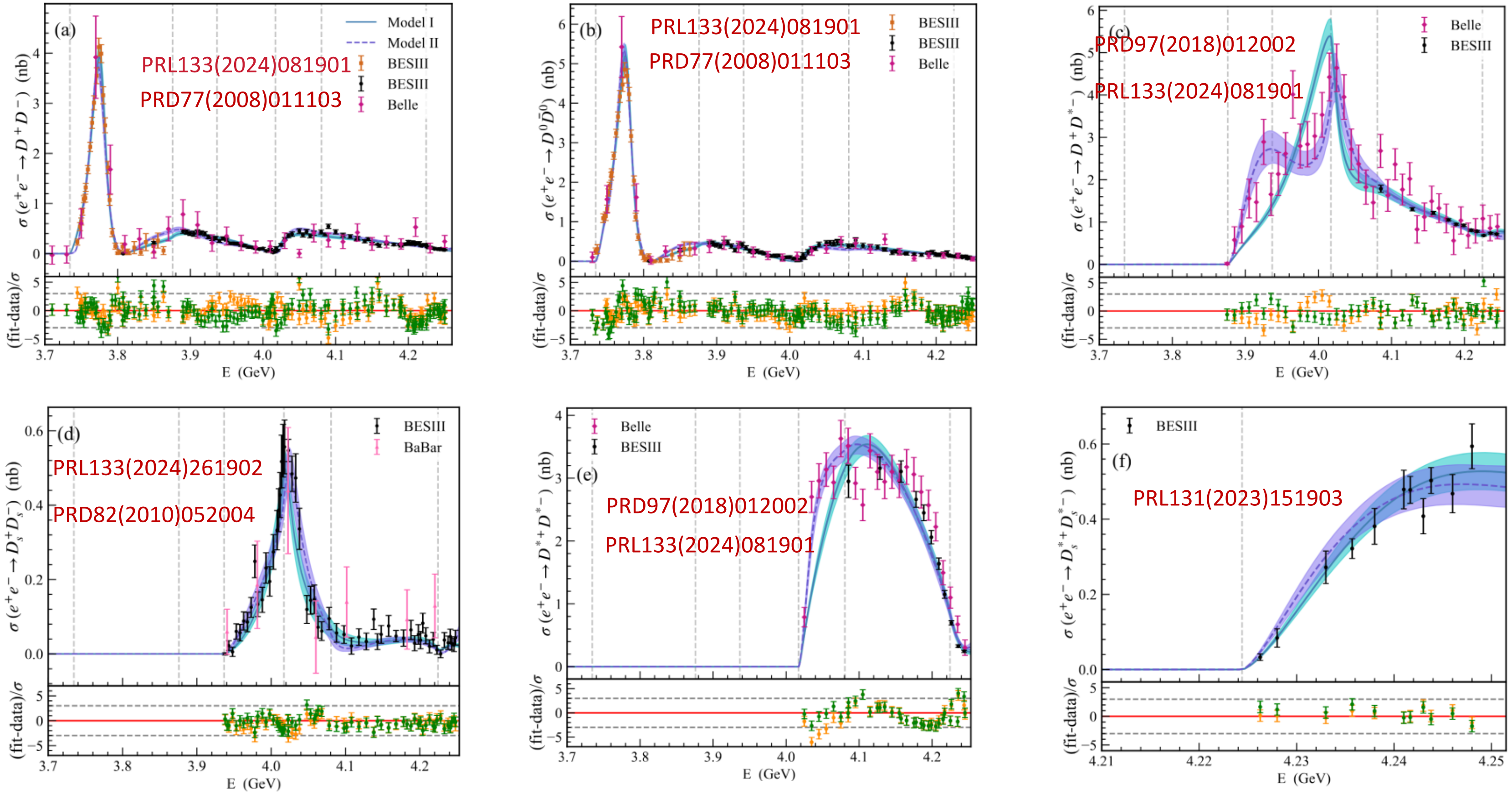
$$\mathcal{M}_n^a = \bar{v}(p_+)(-ie\gamma_\mu)u(p_-)\frac{-ig^{\mu\nu}}{s+i\varepsilon^+}A_{n\nu}^a$$

[S. U. Chung, PRD 48 (1993), 1225]

[B. S. Zou et al. EPJA 16 (2003), 537-547]

Results

- The line shapes in comparison with the experimental data



- Blue line (Model I), purple line (Model II)
- Residuals: Orange (Model I), in Green (Model II)
- $\chi^2/d.o.f = 2.17$ for Model I, $\chi^2/d.o.f = 2.66$ for Model II

Results

- The dynamical parameters

Parameters	Model I	Model II
g^0_{1D} [GeV^{-1}]	0.66 ± 0.04	-12.93 ± 0.26
g^0_{3S} [GeV^{-1}]	-14.66 ± 0.37	-14.11 ± 0.96
g^0_{2D} [GeV^{-1}]	-17.09 ± 0.23	–
m^0_{1D} [GeV]	3.807 ± 0.001	3.804 ± 0.001
m^0_{3S} [GeV]	4.229 ± 0.002	4.253 ± 0.005
m^0_{2D} [GeV]	3.692 ± 0.003	–

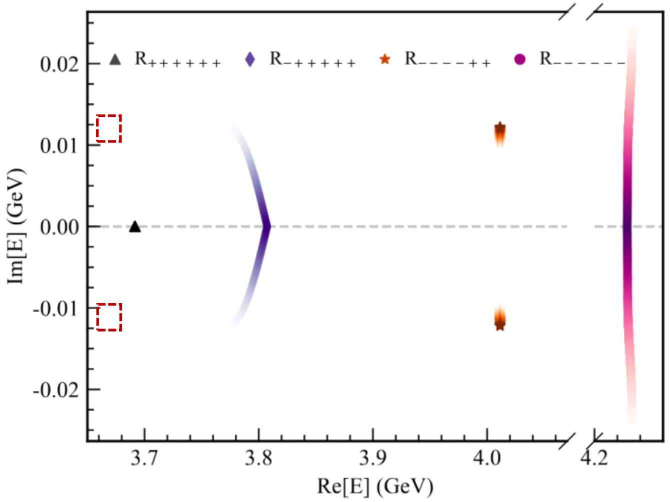
unphysical parameter

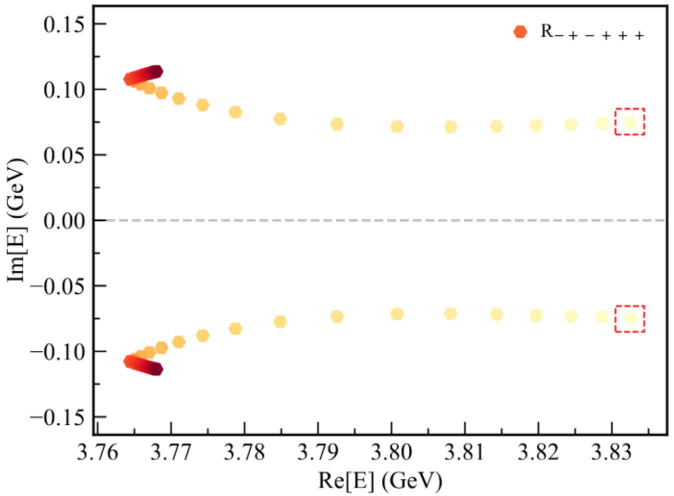
- The pole positions

Riemann sheets	Model I	Model II
$(+,+,+,+,+,+)$	3.691.60	–
$(-,+,+,+,+,+)$	–	$3743.07 \pm 7.36i$ [7]
	$3778.42 \pm 11.81i$ [12]	$3775.29 \pm 14.31i$ [14]
$(-,+,-,+,+,+)$	$3832.52 \pm 74.53i$	– G(3900)
$(-,-,+,+,+,+)$	–	$3883.91 \pm 46.53i$ [47]
$(-,-,-,-,+,+)$	$4011.05 \pm 10.13i$ [16]	$4019.42 \pm 17.40i$ [17]
$(-,-,-,-,-,-)$	$4232.78 \pm 23.96i$ [24]	$4278.21 \pm 21.59i$ [22]

● bare states ● dynamically generated states

- The trajectory of poles in Model I





Summary

● A couple channel analysis of the $e^+e^- \to D^{(*)}\overline{D}^{(*)}$ processes in HQSS and SU(3) within the energy region [3.7, 4.25] GeV.

● Pole position of G(3900), $3832.57^{+0.91}_{-0.79} - 74.53^{+0.68}_{-2.15}i$ MeV for Model I, $3883.91^{+0.38}_{-0.46} - 46.53^{+1.22}_{-1.22}i$ MeV for Model II.

● G(3900) is a dynamically generated state, instead of a renormalized charmonium.

Thanks for your attention!